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बी एआरसी न्यूज़लैटर
BARC NEWSLETTER

Homi Bhabha Birth Centenary Year
30 October 2008-30 October 2009

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In the Next Issue

Mobile-based Tele-ECG for Rural Health Care

Telemedicine is a boon to patients in rural areas, who can have access to medical care, without the need to visit hospitals in far-flung areas. Cardiology merits special attention as routine monitoring is essential to control the growing incidence of heart disease. The Electronics Division, BARC, has developed a hand-held battery-operated Tele-ECG unit with mobile connectivity to an expert. The details of this development are described in this article.

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BARC NEWSLETTER

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डॉ. श्रीकुमार बॅनर्जी

निदेशक, भापअ केंद्र का भारत के 60 वें गणतंत्र दिवस एवं नव वर्ष के अवसर पर संदेश

" प्रिय साथियों,
मेरे लिए यह अत्यंत प्रसन्नता का अवसर है कि मैं अपने देश के 60 वें गणतंत्र दिवस समारोह में आप सभी का हार्दिक स्वागत कर रहा हूँ। अपने राष्ट्रीय ध्वज के प्रति सामूहिक रूप से आदर प्रकट करने की दृष्टि से प्रतिवर्ष इस शुभ प्रभात पर गणतंत्र दिवस को मनाने के लिए हम एकत्रित होते हैं । इस अवसर पर मैं, आप में से प्रत्येक को तथा आपके परिवारजनों को नववर्ष की शुभकामनाएं देता हूँ।

गणतंत्र दिवस के अवसर पर हमारा कर्तव्य है कि हम अपने सैन्य बलों के उन सदस्यों के प्रति अपनी आदरांजलि प्रस्तुत करें जो हमारे देश की सुरक्षा में संलग्न हैं । 26 नवंबर 2008 को मुंबई शहर एवं पूरे देश को अत्यंत आघात लगा जब इस शहर के कुछ भाग पर आतंकी हमला किया गया । हमारे सैन्य बलों के कमांडोज द्वारा प्रदर्शित बहादुरी से उनके प्रति हमारा विश्वास और मजबूत हुआ है । हम इस अवसर पर उनके प्रति अपनी श्रद्धांजलि अर्पित करते हैं जिन्होंने आतंकियों की कायरतापूर्ण कार्रवाई का सामना करते हुए अपने जीवन का बलिदान दिया।

जैसाकि आप जानते हैं, वर्ष 1950 में इसी दिन भारत एक सार्वभौम गणतंत्र के रूप में अस्तित्व में आया । 1950 में यह ऐतिहासिक क्षण हम भारतवासियों के उस स्वप्निल निश्चय की पूर्ति के रूप में सामने आया जो उन्होंने 26 जनवरी 1930 को "स्वराज" से कम कुछ भी नहीं के रूप में लिया था।

जबकि गणतंत्र दिवस हमारे जीवन में एक ऐतिहासिक दिवस है, यह हमारे लिए आत्मविश्लेषण करने का भी दिन है ।

भापअ केंद्र विश्व के सबसे बड़े अनुसंधान एवं विकास केंद्रों में से एक है जहां एक ही छत के नीचे नाभिकीय विज्ञान एवं प्रौद्योगिकी की विविध गतिविधियाँ उत्कृष्टतापूर्वक संचालित की जा रही हैं।

नाभिकीय विज्ञान एवं प्रौद्योगिकी के क्षेत्र में किए गए विकासात्मक प्रयासों तथा विद्युत उत्पादन, कृषि, खाद्य संरक्षण, स्वास्थ्य देखभाल एवं राष्ट्रीय सुरक्षा के लिए उनके अनुप्रयोग की दृष्टि से पिछला वर्ष हमारे लिए एक और सफल वर्ष रहा है । इस संबंध में अभी हाल ही में विकसित की गई विभिन्न प्रणालियों एवं प्रौद्योगिकियों में से कुछ का विवरण मैं उदाहरणार्थ यहां दे रहा हूँ ।

अनुसंधान रिएक्टर

अप्सरा, सायरस तथा ध्रुवा, सभी तीनों रिएक्टर उच्च स्तरीय संरक्षा तथा आइसोटोप उत्पादन, अनुसंधान, पदार्थ परीक्षण एवं मानव संसाधन विकास हेतु उपलब्धता सहित संतोषजनक रूप से प्रचालित किए गए ।

अप्सरा रिएक्टर की पावर 02 मेगावाट तक बढ़ाने तथा 6.5 ई13 का अधिकतम न्यूट्रॉन प्रवाह प्राप्त करने के लिए उसे अपग्रेड किया जा रहा है । रिएक्टर क्रोड की मूलभूत डिजाइन एवं विभिन्न रिएक्टर प्रणालियों का कार्य पूरा कर लिया गया है । अपग्रेड किए हुए रिएक्टर द्वारा न्यूट्रॉन बीम अनुसंधान , रेडियो आइसोटोप उत्पादन, न्यूट्रॉन संसूचकों का अशांकन एवं परीक्षण, पदार्थ परीक्षण एवं बल्क शील्डिंग प्रयोगों के लिए सुविधाएं प्रदान की जाएंगी ।

7 अप्रैल 2008 को प्रथम क्रांतिकता प्राप्त भारी पानी रिएक्टरों के लिए क्रांतिक सुविधा का औपचारिक उद्घाटन 30 अक्तूबर 2008 को माननीय प्रधानमंत्री द्वारा किया गया । प्राथमिक शटडाउन प्रणाली, वास्तविक विद्युत एवं न्यूट्रॉन प्रवाह अनुमानों की रिएक्टिविटी जांच हेतु भौतिकी प्रयोगों को पूरा किया गया ।

एक उच्च प्रवाह वाले अनुसंधान रिएक्टर की संकल्पनात्मक डिजाइन का कार्य पूरा किया गया । यह रिएक्टर उच्च विशिष्ट सक्रियता वाले रेडियो आइसोटोपों की बड़ी आवश्यकताओं को पूरा करने के लिए अभिकल्पित किया गया है । इसके द्वारा विज्ञान के अग्रणी क्षेत्रों में मूलभूत अनुसंधान एवं नाभिकीय ईंधन और रिएक्टर सामग्री के विकास एवं परीक्षण हेतु विस्तारित सुविधाएं उपलब्ध कराई जायेंगी। इस रिएक्टर की क्रोड में एक बाह्य न्यूट्रॉन स्रोत को समाविष्ट करने से संबंधित व्यवहार्यता अध्ययन चल रहे हैं ताकि रिएक्टर को एक त्वरक चालित उपक्रांतिक रिएक्टर प्रणाली के रूप में प्रचालित किया जा सके ।

एएचडब्ल्यूआर कार्यक्रम

एएचडब्ल्यूआर ईंधन का औसत निर्गत बर्न-अप 38 GWD/t तक और बढ़ाने के लिए संतुलनकारी क्लस्टर डिजाइन का परिष्करण किया गया । विभिन्न ईंधन एवं पुनर्संसाधन आवश्यकताओं को पूरा करने के लिए प्रारंभिक ईंधन लोडिंग के दो विकल्पों पर लगभग 7 पूर्ण विद्युत वर्षों तक कार्य किया गया । क्रोड अभिलक्षणों, जैसे कि सक्रियता गुणांक, शटडाउन आवश्यकताओं और संरक्षा एवं नियंत्रण प्रविधियों युक्त सक्रियता पर उपरोक्त मामलों में विभिन्न पूर्ण विद्युत दिवसों पर कार्य किया गया ।

एएचडब्ल्यूआर के डिजाइन में अपने प्रकार की पहली विभिन्न संरक्षा विशेषताएं हैं जिनके समुचित मूल्यांकन की आवश्कयता है । पैसिव कंटेन्मेंट आइसोलेशन सिस्टम के कार्य निष्पादन के अध्ययन के लिए प्रयोग किए गए । क्षय ऊष्मा के निष्कासन हेतु पृथक्करण संघारित्र के कार्य निष्पादन के मूल्यांकन के लिए इंटिग्रल टेस्ट लूप (आईटीएल) में कार्य निष्पादन आंकड़ों का सृजन किया गया । तप्त शटडाउन पैसिव वाल्व का भी सफलतापूर्वक परीक्षण किया गया ।

आरएण्डडी सेंटर, तारापुर में समेकित परीक्षण सुविधा (आईटीएफटी) की स्थापना की जा रही है । इसके दो उद्देश्य है-ताप एवं स्थिरता मार्जिन की स्थापना तथा एएचडब्ल्यूआर ईंधन मशीन का परीक्षण ।

एचटीआर कार्यक्रम

संहत उच्च ताप रिएक्टर (सीएचटीआर) तथा 5 मेगावाट (th) वाले नाभिकीय पॉवर पैक के अभिकल्पन एवं विश्लेषण का कार्य प्रगति पर है । 100 kW (th) सीएचटीआर की संरक्षा तथा नियंत्रण सक्रियता संबंधी आवश्यकता का विस्तृत विश्लेषण तथा ईंधन में ज्वलनीय अवशोषक एवं क्रोड लाइफ के इष्टतमीकरण का कार्य पूरा कर लिया गया ।

लेड-बिस्मथ यूटेक्टिक का शीतलक के रूप में प्रयोग करते हुए एक द्रव धातु लूप की स्थापना तथा कमीशनन किया गया है । इस सुविधा का उद्देश्य थर्मल हायड्रालिक एवं करोसन डाटा प्राप्त करना है ।

रिएक्टर इंजीनियरी में अनुसंधान एवं विकास

220 मेगावाट वाले पीएचडब्ल्यूआर के सेवाकालीन निरीक्षण के लिए " टूल डिलिवरी सिस्टम" के अभिकल्पन का कार्य पूरा हो गया है । इस विकास कार्य से निरीक्षण के समय, मैन-रेम में कमी आयगी तथा इससे किसी आईएसआई कैंपेन के लिए लचीली निरीक्षण अनुसूची में सुविधा होगी ।

540 मेगावाट पीएचडब्ल्यूआर के लिए शीतलक चैनलों के सेवाकालीन निरीक्षण हेतु एक एडवांस्ड ड्राईव मशीन (एडीएम) की रूपरेखा बनाई गई है । इस मशीन को चैनल में निरीक्षण टूल्स की डिलिवरी के लिए दूर से प्रचालित किया जाएगा तथा इसमें एक स्प्लिट प्लग

एसेंबली की आवश्यकता होगी जिससे इन्स्पेक्शन हेड को चैनल डायमीटर के समकक्ष डायमीटर पैसेज में सहायता मिलेगी। रैखिक स्थिरता विधि एवं एक उत्कृष्ट अनुमान संरक्षा कोड का उपयोग करके 700 मेगावाट वाले पीएचडब्ल्यूआर के समानांतर क्वथन चैनलों की स्थिरता का विश्लेषण किया गया ।

एक सहमति पत्र के अंतर्गत एनटीपीसी के औरिया साइट पर गैस टरबाइन पर संस्थापित एक ऑनलाइन कंपन नैदानिकी प्रणाली का कमीशनन किया गया । कोयना में एक ऑनलाइन डाटा अर्जन प्रणाली का स्थापन तथा कमीशनन कार्य किया गया ताकि भूंकप के दौरान उपस्कर एवं सिविल संरचना से भूंकपीय अनुक्रिया संबंधी विवरण प्राप्त किया जा सके।

ईंधन पुनर्संसाधन एवं अपशिष्ट प्रबंधन गतिविधियां

कार्प सुविधा, कलपाक्कम को एक स्वचालित भुक्त ईंधन भरण सुविधा, पुनर्चक्रित निवेश के लिए पृथक सह निष्कर्षण एवं विभाजनीकरण व्यवस्था एवं अन्य उन्नत विशेषतओं के द्वारा पुनर्संज्जित किया गया है ताकि संयंत्र का सुचारू रूप से प्रचालन सुनिश्चित किया जा सके । सामरिक सामग्री की आपूर्ति बढ़ाने के लिए संयंत्र को दोबारा शुरू किया गया है ।

कलपाक्कम में डब्ल्यूआईपी-3ए का निर्माण कार्य पूरा हो गया है तथा विभिन्न प्रणालियों के परीक्षण एवं कमीशनन का कार्य प्रगति पर है । इस संयंत्र का अभिकल्पन जूल तापित सिरेमिक मेल्टर के प्रयोग द्वारा साइट पर उत्पादित एचएलडब्ल्यू के काचीकरण एवं विभिन्न द्रव अपशिष्ट धाराओं की कंडीशनिंग के लिए किया गया है ।

1975 मूल के प्रिफ्री संयंत्र में विभिन्न उपस्करों यथा वाष्पित्र एवं विलायित्र की विफलता के बावजूद प्रचालन सुरक्षित रूप से जारी रहा।

एक बार में ईंधन बंडलों की गैंग चॉपिंग के लिए अद्यतन भुक्त ईंधन चॉपर का सफलतापूर्वक विकास किया गया और तारापुर में स्थापित पहली इकाई कमीशनाधीन है ।

आईएलडब्ल्यू के उपचार के लिए पूर्व में प्लूटोनियम संयंत्र, ट्रांबे में प्रयोग की जाने वाली मोबाइल ट्रिक्स यूनिट की रिकंडीशनिंग की गई है तथा उसे तारापुर साइट पर स्थानांतरित किया गया है । ट्रिक्स द्वारा स्वदेश में विकसित रिसार्सिनॉल फार्मल्डीहाइड कंन्डेसेट रेजिन का उपयोग किया जाता है । आज की तारीख तक तारापुर में 50 घन मीटर से अधिक अपशिष्ट का संसाधन किया गया है ।

रेडियोलॉजिकल प्रयोगशालाओं से प्राप्त तीन अल्फा संदूषित ग्लोव बाक्सों को सुरक्षित प्रकार से स्वस्थाने संपुटित किया गया है तथा उन्हें सालिड वेस्ट ट्रांजिट फैसिलिटी, आरएसएमएस, ट्रांबे में स्थानांतरित किया गया । इसके परिणामस्वरूप आरएलजी में बहुमूल्य फ्लोर स्पेस प्राप्त हुआ है ।

दूरस्थ प्रचालनों के लिए चेटे एनक्लोजर्स हेतु 8 किलो पेलोड धारिता वाले आर्टीकुलेटेड मैनिपुलेटर की एक प्रोटोटाइप यूनिट का सफलतापूर्वक विकास किया गया ।

एचएलडब्ल्यू से ^{90}Y और ^{106}Ru की रिकवरी के लिए प्रक्रियाओं का विकास किया गया तथा प्राप्त आइसोटोपों की आपूर्ति उपयोग हेतु रेडियो भेषज प्रभाग को की गई है । पुराने प्लूटोनियम स्क्रैप से सामरिक सामग्री ^{241}Am की रिकवरी की जा रही है ।

द्रुत रिएक्टरों के लिए ईंधन

भापअ केंद्र, कलपाक्कम में निर्माणाधीन एफबीटीआर एवं पीएफबीआर सहित द्रुत रिएक्टर कार्यक्रम के लिए नाभिकीय ईंधन की आपूर्ति हेतु उत्तरदायी है । एफबीटाआर मिश्रित कार्बाइड ईंधन के संविरचन के लिए पिछली वर्ष आरएमडी में कमीशन की गई नयी लाइन अब पूरी तरह से प्रचालनरत हो गई है और इस लाइन में सफलतापूर्वक मिश्रित कार्बाइड ईंधन के अनेक बैचों का सफलतापूर्वक संसाधन किया गया । पिछले सप्ताह हमने इस लाइन में निर्मित MK । कार्बाइड ईंधन पिनों को इंगांपअ केंद्र को डिस्पैच किया ।

प्रगत ईंधन संविरचन सुविधा, तारापुर में संविरचित पीएफबीआर प्रयोगात्मक मॉक्स ईंधन पिनों को एफबीटीआर के केंद्र में भारित किया गया और अब यह 80000 MWd/T से भी अधिक बर्न-अप तक पहुंच गई है ।

श्रेडिंग, निक्षालन एवं संहनन से जुड़े प्लूटोनियम संदूषित पीवीसी/नियोप्रीन अपशिष्ट हेतु एक प्रयोगशाला स्तरीय अल्फा अपशिष्ट उपचार सुविधा को आरएमडी में कमीशन किया गया एवं इसका प्रारंभिक शीत परीक्षण जारी है । तारापुर स्थित हमारी सुविधा में पीएफबीआर प्रथम क्रोड हेतु मॉक्स ईंधन पिनों का विनिर्माण किया जा रहा है एवं स्वीकार्य गुणवत्ता ईंधन की उच्च प्राप्ति हेतु संविरचन प्राचलों को इष्टतमीकृत किया गया । Nd - Yag लेसर का प्रयोग करते हुए D-9 क्लैड नलियों के एंड प्लग वेल्डिंग को सफलतापूर्वक निदर्शित किया गया एवं क्लोशर वेल्ड के निरीक्षण हेतु एक पराध्वनिक तकनीक विकसित की गयी ।

भापअ केंद्र, उच्च अभिजनन अनुपात वाले प्रगत तीव्र अभिजनक रिएक्टरों हेतु धात्विक ईंधन पर आरएण्डडी से भी जुड़ा है । धात्विक ईंधन के कास्टिंग हेतु इंजेक्शन कास्टिंग सिस्टम, ग्लव बॉक्स के अंदर संस्थापनाधीन है तथा डीमौल्डिंग एवं स्लग शियरिंग मशीन का प्रचालन परीक्षण चल रहा है ।

भावी तीव्र अभिजनक रिएक्टरों (एफबीआर) हेतु धात्विक ईंधन का 2-D ताप - यांत्रिक विश्लेषण किया जा चुका है । अभिलक्षणात्मक उच्च अभिजनक अनुपात एवं कुशल विद्युत उत्पादन वाले ईंधन में ईंधन स्लग एवं क्लैडिंग पदार्थ तथा सेमी-सर्क्युलर ग्रूव क्षेत्र में हीलियम गैस के बीच Zr परत सहित T91 मिश्रधातु में 15% Pu क्लैडित U-Pu बाइनरी मिश्रधातु होती है ।

स्वास्थ्य, संरक्षा एवं पर्यावरण

भापअ केंद्र संरोधन मॉडल (बीएआरसीओएम), जो 540 मेगावाट पीएचडब्ल्यूआर का एक 1:4 आकार का प्रीस्ट्रेस्ड कंक्रीट इनर कंटेनमेंट है का निर्माण भापअ केंद्र, तारापुर परियोजना स्थल पर किया गया ताकि इसकी परम भार क्षमता एवं विभिन्न विफलता मोडों का मूल्यांकन किया जा सके । 69 विनिर्दिष्ट सेंसर स्थानों पर मॉडल की अनुक्रिया का प्रयोग अभिगृहीत डिजाइन आधार एवं गंभीर दुर्घटना परिस्थितियों हेतु संरोधन विश्लेषण कंप्यूटर कोड का बेंचमार्क किया जा सके ।

एएचडब्ल्यूआर के पीएचटी प्रणाली के बेस एवं वेल्ड पदार्थ हेतु उनकी 450°C पर 1300 घंटे एवं 400°C पर 8000 घंटों तक तापीय एजिंग एवं 300°C पर 100 वर्षों का अनुकारण करने के पश्चात त्वरित एजिंग एवं संक्षारण अध्ययन पूरे किए जा चुके हैं । परिणामों से पता चला है कि संवेदीकरण की सीमा स्वीकार्य मान 5% की तुलना में बहुत कम है ।

आईआईटी, रूड़की में पीएचडब्ल्यूआर में स्माल ब्रेक लोका की गंभीर दुर्घटना की स्थिति के दौरान दाब नली बैलूनिंग लक्षण अनुकारण, चैनल हीट-अप अनुप्रयोगों को 20, 40 एवं 60 bar के विविध दाबों पर किया गया । दाब नली के अवनमन प्रयोगों को भी विभिन्न ऊष्मन दरों पर किया गया । प्रयोगात्मक डाटा का उपयोग दाब नली क्रीप (पीटीक्रीप) क्रोड पूर्वानुमान हेतु किया गया ।

भापअ केंद्र में विकसित रिस्क मॉनिटर साफ्टवेयर टूल को संबंधित पीएसए मॉडलों सहित पायलट प्रयोग हेतु विभिन्न नाभिकीय ऊर्जा परियोजनाओं में नियोजित किया गया । इसका अनुप्रयोग सिगनिफिकेंट ईवेंट रिपोर्टों से एकत्रित केएपीएस 1 एवं 2 प्रचालन इवेन्ट्स पर किया गया है ।

इंटरफियरिंग ^{133}Xe की उपस्थिति में क्षेत्र मॉनीटरन हेतु ट्रिशियम मॉनीटर का विकास किया गया जिसका प्रयोग एनपीसीआईएल से विशिष्ट अनुरोध पर टीएपीएस#4 में किया गया । इस प्रणाली के निष्पादन के मूल्यांकन करने हेतु लगातार तीन महीनों तक रिएक्टर स्थल पर क्षेत्र परीक्षण किया गया ।

इलेक्ट्रोस्टैटिक कलेक्शन सिद्धांत पर आधारित स्वदेश में ही विकसित रेडान मानिटरिंग सिस्टम्स को तुरमदीह स्थित भूगर्भीय यूरेनियम खानों के विभिन्न स्थानों पर स्थापित किया गया एवं केबल नेटवर्क के माध्यम से नेटवर्क किया गया ताकि ग्राउंड लोकेशन पर एक केंद्रीय स्थल पर रेडान सांद्रण डिस्प्ले किया जा सके ।

CaF_2 चूर्ण आधारित वर्तमान पर्यावरणीय मॉनीटरन हेतु प्रयुक्त ताप संदीप्तिशील मात्रामिति तकनीक को एक स्वचालित $CaSO_4$:Dy आधारित प्रणाली से प्रतिस्थापित किया गया, जिसके कारण संसाधन समय तीन के गुणांक तक कम हो गया है जिससे पर्यावरणीय मानिटरन की बढ़ती हुई मांग को पूरा किया जा सके ।

एक नया चार एलिमेंट वाला Al_2O_3:C आधारित प्रकाश प्रेरित संदीप्तिशील (ओएसएल) फास्फर बैज का डिजाइन किया गया है एवं इसका परीक्षण 20 KeV से 3 MeV रेंज में फोटॉन ऊर्जा के विकिरण किरणपुंजों एवं 300 KeV से 3 MeV रेंज की ऊर्जा में बीटा विकिरण में किया गया । इस नये ओएसएल मात्रामापी बैज को टीएलडी कार्मिक मॉनीटरन प्रणाली आधारित वर्तमान में प्रयुक्त $CaSO_4$:Dy के स्थान पर एक प्रभावशील विकल्प के रूप में नियोजित किया जा रहा है ।

इंटेंसिटी मॉडुलेटेड रेडियोथेरेपी (आईएमआरटी) फैंतम का स्वदेशी विकास कर पीडी हिंदुजा अस्पताल में उसका डोज सत्यापन किया गया । प्राप्त परिणाम वाणिज्यिक आईएमआरटी फैंतम के प्रयोग से प्राप्त परिणामों के 2% के अंदर थे ।

चर्म कैंसर के उपचार हेतु भापअ केंद्र द्वारा विकसित P-32 पैच ब्रैकीथेरेपी स्रोतों पर गैफक्रोमिक फिल्म स्टैक का प्रयोग करते हुए मात्रामिति अध्ययन किया गया । गैफक्रोमिक फिल्मों तथा ताप संदीप्तिशील मात्रामापियों का प्रयोग करते हुए स्टीरियोटैक्टिक रेडियोसर्जरी पद्धतियों पर आधारित गामा नाइफ के दौरान डोज प्रोफाइल एवं डोज वितरण के मापन हेतु एक ऊतक समतुल्य हेड एण्ड नेक फैंतम का डिजाइन किया गया ।

रासायनिक कैर्सिनोजन 4 - नाइट्रोक्विनोलिन 1 - ऑक्साइड (4-NQO) द्वारा प्रेरित जीनोटाक्सिसिटी पर ब्युटाइलेटेड हाइड्राक्सी टोलवीन (बीएचटी) खाद्य परिरक्षक के प्रभाव के अध्ययन करने हेतु प्रयोग किए गए ।

आईईआरएमओएन के अंतर्गत श्रीनगर (J&K), उधमपुर, जम्मु, नाल, सूरतगढ़, उत्तरलाई, जेसलमेर एवं जोधपुर स्थित भारत के उत्तरी पश्चिम क्षेत्र में सौर ऊर्जित मॉनीटरन केंद्रों को स्थापित किया गया । इससे देश भर में 45 स्थानों को सम्मिलित करते हुए स्थापित की गई केंद्रों की कुल संख्या 80 तक हो गई है ।

TATA-207 मॉडल का प्रयोग करते हुए एक चलती फिरती विकिरणात्मक संघात मूल्यांकन प्रयोगशाला (M-RIAL) वाहन का डिजाइन किया गया । यह वाहन वायु गुणवत्ता मापन एवं मौसम से संबंधित तथा ग्लोबल पोजीशनिंग सिस्टम हेतु गामा, अल्फा एवं बीटा गणना को मॉनीटर करने की विकिरण मॉनीटरन प्रणाली से लैस है ।

पदार्थ विकास

एडीएसएस एवं इंडियन टीबीएम (आईटीईआर) हेतु कार्यक्रमों में मुख्य मुद्दों में से एक है उच्च प्रवाह दर पर पिघले हुए लेड-बिस्मथ एवं लेड-लिथियम यूटेक्टिक का होना । मोल्टेन यूटेक्टिकों हेतु स्वगृहे विकसित घूर्णी चुंबकों पर इलेक्ट्रो मैग्नेटिक इंडक्शन पंप का परीक्षण जांच परस्थितियों के अंतर्गत पिछले चार महीनों से सतत चलाकर किया जा रहा है ।

20, 200 एवं 700 ppb घुलित ऑक्सीजन स्तरों पर रिएक्टर अनुकारित परिस्थितियों में DCPD तकनीक द्वारा संवेदीकृत SS 304L हेतु पुन: परिचालन जांच सुविधा में SCC भंजन वृद्धि दर का मापन किया गया । इस सुविधा का प्रयोग प्रगत रिएक्टरों जैसे कि एएचडब्ल्यूआर हेतु प्रयोग में लाए जाने वाले पदार्थों एवं शीत/गर्म परिस्थितियों में स्टेनलेस स्टील के लिए भंजन वृद्ध दरों को जनरेट करने के लिए भी किया जाएगा ।

भापअ केंद्र द्वारा आईपीआर में संलयन अनुसंधान हेतु आवश्यक अतिचालक चुंबकों के विभिन्न अभिविन्यास के लिए केबल इन कांड्यूट कंडक्टर का विकास एवं संविरचन प्रारंभ किया गया । इस संबंध में, 50 मीटर लंबी 30 KA हाइब्रिड CICC, 0.8 मिमी व्यास तथा 504 Nb-Ti Sc युक्त तारों वाले एक 60 मीटर केबल का संविरचन किया गया ।

एएचडब्ल्यूआर की दाब नलियों हेतु एक इष्टतमीकृत पदार्थ के विकास के प्रति एक शमन डाइलैटोमेट्री द्वारा 1300 ppm ऑक्सीजन सहित Zr-2.5Nb हेतु सतत शीतलन परिवर्तन चित्र स्थापित किए गए । इस सीसीटी चित्र के आधार पर ताप यांत्रिक संसाधन प्राचलों को अंतिम रूप दिया जाएगा ।

8.5 EFPY प्रचालन के पश्चात केएपीएस-2, एस-7शीतलक वाहकों से प्राप्त टाइट फिट Zr-2.5Nb इ 0.5 cu गार्टर स्प्रिंगों का परीक्षण किया गया । परीक्षण से स्प्रिंगों की उत्कृष्ट कार्य निष्पादन की पुष्टि हुई जिससे रिएक्टरों में 30 वर्षों के लिए उनका सुरक्षित प्रचालन सुनिश्चित हो गया ।

स्थानीय रूप से उपलब्ध कच्चे माल से लैंथेनम फासफेट के तापीय स्प्रे ग्रेड चूर्ण के संश्लेषण हेतु एक प्रक्रिया विकसित की गयी । एक DC तापीय प्लाज्मा रिएक्टर का प्रयोग करते हुए चूर्ण की तापीय एवं रासायनिक स्थिरता का अध्ययन प्लाज्मा स्पेराइडाइजेशन प्रयोग द्वारा किया गया । स्टेनलेस स्टील सहित अनेक सबस्ट्रेटों में $LaPO_4$ का चिपका हुआ लेपन प्राप्त किया गया जिसकी निक्षेप कुशलता काफी अच्छी रही ।

जल गतिकी के पूर्वानुमान हेतु दो चरण वाले सीएफडी एवं समष्टि तुला मॉडलों के सफलतापूर्वक विकास के माध्यम से बृहत क्षमता का पंप मिक्स मिक्सर स्थिरक (पीएमएमएस) का डिजाइन किया गया एवं अपकेंद्री पृथक्कारक के साथ युग्मन हेतु भारी पानी बोर्ड को परिक्षेपित फेस की गुणवत्ता के साथ 50 m^3 प्रति घंटा द्वि-इंपैलर पंप-मिक्स मिक्सर का डिजाइन दिया गया ।

अनुकारित पीएचडब्ल्यूआर उच्च स्तरीय अपशिष्ट के साथ-साथ पीएफबीआर उच्च स्तरीय अपशिष्ट माइनर एक्टिनाइडों के पार्टिशन हेतु मिक्सर स्थिरक प्रचालन सफलतापूर्वक किए गए ।

इलेक्ट्रानिकी एवं यंत्रीकरण

द्रुत, निम्न ध्वनि, निम्न शक्ति प्री एम्प्लीफायर हाइब्रिड माइक्रो सरकिटों (एचएमसी) विकसित किए गए एवं इन एचएमसी में से 3000 का प्रयोग टीआईएफआर में विकासाधीन आईएनओ (भारत आधारित न्यूट्रिनों वेधशाला) हेतु प्रोटोटाइप डिटेक्टरों में किया गया ।

ईंधन छड़ों के β- ऊष्मा उपचार को क्वालिफाई करने हेतु यूरेनियम ईंधन छड़ों में ध्वनि वेग प्रोफाइलिंग के लिए पराध्वनिक प्रणाली का विकास एवं स्थापन किया गया ।

यूएसबी मल्टी चैनल एनालाइजर में एमसीएस (मल्टी चैनल स्केलिंग) कार्य की प्रौद्योगिकी का हस्तांतरण मैसर्स न्यूक्लियोनिक्स, हैदराबाद को किया गया ।

भारतीय डीप स्पेस नेटवर्क (आईडीएसएन-32)

परिशुद्ध आईडीएसएन-32 (32 मीटर भारतीय डीप स्पेस एन्टिना सिस्टम) का प्रयोग इसरो के चंद्र अभियान वाहन चंद्रयान-। के साथ संचार के लिए किया जाता है । भापअ केंद्र द्वारा 15 मि. डिग्री के अंदर एक दिशा केंद्रित परिशुद्धता सहित अजीमथ एवं एलिवेशन ऐन्टिना में 380 टन ऐन्टिना को संचालित करने के लिए एन्टिना कंट्रोल सर्वो सिस्टम (एसीएसएस) का डिजाइन किया गया एवं बैंगलूर के निकट बयलालू में सफलतापुर्वक कमीशन किया गया । आईडीएसएन-32 दिनांक 22 अक्तूबर 2008 को 1330 बजे पृथ्वी से टेकऑफ से लेकर चंद्रयान-। की चंद्रमा तक की यात्रा को सफलतापूर्वक ट्रैक करता रहा है ।

आईओसीएल की पाइपलाइन के दिल्ली पानीपत सेक्शन में 14" तेल पाइपलाइन के निरीक्षण हेतु आईओसीएल के साथ समझौता ज्ञापन के अंतर्गत भापअ केंद्र द्वारा डिजाइन किया गया कैलिपर एण्ड इन्स्ट्रूमेंटेड पीआईजी का पहला वाणिज्यिक परीक्षण किया गया । संक्षारण त्रुटियों को दर्शाने के अलावा दिल्ली पानीपत क्षेत्र में गैर कानूनी टैपिंग को सही डिटेक्ट करने में सहायता मिली है । डिग साइट सत्यापन द्वारा इसकी पुष्टि की गई ।

आईओसीएल को पहले सपुर्द की गयी 12" पीआईजी विनिर्माण हेतु प्रौद्योगिकी को ईसीआईएल, हैदराबाद को हस्तांतरित किया जा रहा है जो आईओसीएल से प्राप्त आदेश का कार्य पालन कर रहे हैं ।

कुडनकुलम नाभिकीय विद्युत परियोजना (केके-एनपीपी) स्थित 220kV गैस रोधित प्रणाली स्विचयार्ड की उच्च वोल्टता जांच

भापअ केंद्र द्वारा विकसित एई सिस्टम का प्रयोग करते हुए कुडनकुलम में एनपीसीआईएल के सहयोग से रूस निर्मित 220kV गैस रोधित स्विचयार्ड (जीआईएस) की ध्वानिक उत्सर्जन आधारित उच्च वोल्टता परीक्षण किया गया । Y-फेस में अर्थ स्विचों में से एक में त्रुटि देखी गई जिसे तुरंत सुधारा गया ।

नाभिकीय पुन:संसाधन संयंत्रों हेतु स्वचालित सीधा ईंधन अंतरण प्रणाली

वर्तमान में भंडारण कुंड से भुक्त शेष ईंधन गुच्छों को प्रशिक्षित एवं कुशल कार्मिकों द्वारा संचालित जटिल प्रक्रिया द्वारा पुन: संसाधन संयंत्र में हस्तांतरित किया जाता था । इस प्रचालन से फर्श पर संदूषित जल फैलने के कारण मैन-रैम खपत होता था । भापअ केंद्र द्वारा भूजलीय सुरंग के माध्यम से स्थानांतरण प्रचालन करने के लिए उच्च विश्वसनीय एवं सुदूर हस्तनीय स्वचालन प्रणाली का डिजाइन किया गया जिससे चार्जिंग कास्क के हस्तन से बचा जा सके । निदर्शन के प्रयोजन हेतु एक वर्किंग मॉडल का भी विकास किया गया।

हल्का पानी रिएक्टर (एलडब्ल्यूआर) हेतु प्रशिक्षण अनुकारक

भापअ केंद्र द्वारा डिजाइन किया गया एलडब्ल्यूआर हेतु प्रशिक्षण अनुकारक, जो रिएक्टर प्रचालकों को प्रशिक्षण देने एवं योग्य बनाने के लिए था, का प्रचालकों द्वारा पिछले एक वर्ष के दौरान विस्तृत रूप से प्रयोग किया गया । अनुकारक की सहायता से नियंत्रण प्रक्रिया दस्तावेजीकरण में अनेक विसंगतियों को पहचाना गया । नियंत्रण प्रक्रिया दस्तावेजीकरण में परिवर्तन के पश्चात नवंबर 2008 में मॉडलों का अंतिम रूप से सुधार किया गया ।

भौतिक विज्ञान

उच्च शक्ति त्वरक विकास कायर्क्रम के अंतर्गत आरएफक्यू का एक ताम्र मॉडल का विकास किया गया एवं भापअ केंद्र के डिजाइन एवं विनिर्माण केंद्र में निर्वात ब्रेजिंग प्रक्रिया के अंतर्गत इसे दो चरणों में मशीनित एवं निर्वात ब्रेज किया गया । ट्यूनरों से 350 MHz डिजाइन मान को अनुनाद आवृत्ति (आरएफ) से सुधारा गया । देश में ही विकसित आरएफ युग्मक का प्रयोग आरएफक्यू को विद्युत भरण के लिए किया गया ।

निम्न ऊर्जा उच्च तीव्रता प्रोटान त्वरक (LEHIPA) के विभिन्न घटकों (जैसे कि RFQ, DIL क्लिस्ट्रान आदि) के शीतलन हेतु निम्न चालकता जल प्रणाली के विभिन्न सह प्रणालियों का डिजाइन पूरा किया गया ।

INO सहयोग के अंतर्गत भापअ केंद्र एवं टीआईएफआर द्वारा संयुक्त रूप से डिजाइन किये गये एवं पुणे में एक विपणक द्वारा सविरचन 20 गोलाइयों वाल वाटर कूल्ड कॉपर काइलों सहित एक 35 टन ICAL प्रोटोटाइप चुंबक को VECC में समुच्चायित किया गया ।

भापअ केंद्र एवं टीआईएफआर द्वारा संयुक्त रूप से स्थापित पेलेट्रान त्वरक सुविधा ने प्रगतिशील वर्धन क्षमता के साथ दो दशकों का सफलतापूर्वक त्वरक प्रछालन पूरी कर ली है ।

तप्त घूर्णी नाभिक में जायन्ट डाइपोल रेसोनैन्स (GDR) नाभिकीय भौतिकी का 28 Si एवं +132 Sn से जुड़ी नाभिकीय अभिक्रिया में उच्च ऊर्जा गामा स्पेक्ट्रा के मुंबई लिनक सुविधा से मापन किये जाने पर GDR चौडाई की स्पिन निर्भरता प्राप्त की गई । प्रयोगात्मक परिजनों से तप्त घूर्णी नाभिक में विस्तार की गति को समझने हेतु सुस्थापित तापीय माडल की विफलता प्रकट हुई ।

भापअ केंद्र का GANIL के साथ चल रहे सहयोग के अंतर्गत GANIL स्थित स्पाइनल त्वरक को 6 He के साथ एवं भापअ केंद्र-टीआईएफआर पेलेट्रान त्वरक मुंबई में 6 एवं 7 Li के द्वारा प्रयोग किए गए । GANIL में 65 Cu टार्गेट पर 6 He किरणपुंज का प्रयोग करते हुए भापअ केंद्र के वैज्ञानिकों द्वारा हाल ही में मापी गई अंतरण अभिक्रिया से 6He सिगार आकार के न होते हुए प्रबल द्वि-न्यूट्रान के रूप में प्रकट हुआ जिसे अंतर्राष्ट्रीय समुदाय द्वारा अत्यंत सराहा गया ।

सर्न में CMS सहयोग के अंतर्गत, डबल गैप रेसिस्टिव प्लेट चैम्बर्स (RPC) का समुच्चयन एवं परीक्षण नाभिकीय भौतिकी प्रभाग के RPL प्रयोगशाला में किया गया । जुलाई 2008 में सीएमएस, सर्न को सुपुर्द दस ऐसे डिटेक्टरों को उनकी कार्यकुशलता के लिए सर्न के ISR प्रयोगशाला में होडोस्कोप में कॉस्मिक म्यूआनों के लिए मूल्यांकन किया गया ।

किरणपुंज प्रौद्योगिकी विकास

कार्गो स्कैनिंग हेतु बीएआरसी-ईसीआईएल लिनाक को समेकित किया गया है । 200 Hz की बारंबारता दर पर 30mA, 7μs पल्स पर एक 10 MeV इलेक्ट्रान किरणपुंज का उत्पादन एवं अभिगमन कर अभिलक्षणन हेतु 2 mm एक्स-रे टार्गेट पर सफलतापूर्वक फोकस किया गया ।

नवीन उच्च शक्ति SF_6 स्पार्क गैप एवं प्रीपल्स स्विच को समायोजित करते हुए काली-5000 पल्स पावर स्स्टिम को उन्नयित किया गया । यह सुविधा 12.5 GW की शक्ति स्तर पर प्रचालन हेतु कमीशनन के स्तर पर है ।

आइसोटोप वरणात्मक पदार्थ संसाधन, ट्रेस विश्लेषण एवं अन्य स्पेक्ट्रोस्कोपी अनुप्रयोगों हेतु पहली बार एक निम्न शक्ति डायोड - पंप्ड ठोस रंजक अवस्था लेसर (DPSSL) पंप्ड लेसर का स्वदेशी विकास किया गया । 2 ये 6 KHz की आवृत्ति पर इसकी जांच की गई जिससे रोडामाइन 6G रंजक के ट्यूनिंग रेंज के शिखर पर 4% कुशलता पर ~ 3GHz लाइन विड्थ का ट्यूनेबल आउटपुट उत्पन्न किया गया ।

निर्लवणीकरण गतिविधियां

कलपाक्म में नाभिकीय निर्लवणीकरण परियोजना के मल्टी-स्टेज फ्लैश (MSF) वाष्पन संयंत्र का दिनांक 30 अक्तूबर 2008 को माननीय प्रधानमंत्री द्वारा उद्घाटन किया गया । संयंत्र को शीघ्र ही पूर्ण स्तरीय उत्पादन में लाया जाएगा । भापअ केंद्र द्वारा तटीय सेवा हेतु भारतीय शिपिंग रजिस्ट्रार (IRS) के नियमों एवं विनियमों के अनुसार एक बार्ज माउंटेड निर्लवणीकरण संयंत्र का डिजाइन एवं निर्माण किया गया और इसका भी उद्घाटन माननीय प्रधानमंत्री द्वारा उसी दिन किया गया । संयंत्र द्वारा समुद्री जल से 50000 लीटर प्रति दिन सुरक्षित पेयजल का उत्पादन किया जा सकता है ।

डिजाइन डाटा जनरेट करने के लिये हाल ही में इलेक्ट्रो-डाइलिसिस आयनीकरण (ईडीआई) यूनिट (5000 लीटर प्रति दिन क्षमता) का कमीशनन एवं प्रचालन किया गया । विभिन्न आवश्यकताओं को पूरा करने हेतु इसके द्वारा परा-शुद्ध जल (चालकता < 0.1 माइक्रो -सीमन्स प्रति से.मी.) उत्पादन किया जाता है ।

रसायन विज्ञान

2.8 - 6 माइक्रान रीजन में ट्यूनेबल 400 nm - मिड - IR प्रोब पर दृश्य पंप का प्रयोग करते हुये 200 fs टाइम रेसोल्यूशन सहित एक फेम्टोसेंकड (fs) ट्रान्सियंट अवशोषण वर्णक्रममापी का कमीशनन किया गया । डिफरैंस फ्रीक्वेंसी जनरेशन प्रणाली (DFG) के साथ संबद्ध स्वदेश में विकसित ऑप्टिकल पैरामैट्रिक ऐम्प्लिफायर (OPA) से प्रोब आईआर किरणपुंज उत्पन्न किया जाता है ।

अभिनव कार्बन नैनो पदार्थों के डिजाइन पर परिकलनात्मक जांच करने पर यह निदर्शित हुआ कि हाइड्रोजन के प्रति कार्बन नैनो पदार्थों को कार्बन नैनो-सर्फेस में वांचित वक्र देकर इसे बढ़ाया जा सकता है तथा क्षार धातु परमाणुओं के डोपिंग के माध्यम से भी एक आवेशित पृष्ठ के निर्माण द्वारा भी इसे किया जा सकता है। उपयुक्त क्षार धातु डोपित कार्बनिक अणुओं में 10 wt% हाइड्रोजन अवचूषण क्षमता पायी गयी।

एक सोनो - रासायनिक संश्लेषण सुविधा स्थापित की गयी है जिसमें वांछित कण आकार के साथ नैनो पदार्थों का संश्लेषण किया जा सकेगा । हाल ही में इस संश्लेषण मार्ग का प्रयोग प्रकाशिकी पदार्थ आधारित अनेक विरल-मृदा बनाने में किया गया है ।

विकिरण औषधि एवं आइसोटोप

स्केलिटल मैटास्टासिस के कारण हड्डियों के दर्द से ग्रसित रोगियों के लिये वर्तमान में प्रयुक्त ^{153}Sm-EDTMP के वैकल्पिक एजेंट ^{177}Lu के एम्स, नई दिल्ली के सहयोग से मूल्यांकन किया जा रहा है । आशा है कि कुछ ही समय में अस्पतालों को रेडियोभेषजों की नियमित आपूर्ति ब्रिट के माध्यम से विपणन द्वारा की जायेगी ।

न्यूरो एण्डोक्रिन कैंसर के उपचार हेतु ^{177}Lu-DOTATATE एक विभव एजेंट है वर्तमान में उसका प्रयोग मानव रेगियों पर एम्स, नई दिल्ली के सहयोग से किया जा रहा है । इस एजेंट की उपचारात्मक डोज़ (28 nos) अब तक 14 रोगियों को दी जा चुकी है तथा इसके प्रारंभिक परिणाम उत्साहवर्धक रहे हैं ।

सेंटीनल नोड इमेजिंग एजेंट के रूप में इसके मूल्यांकन हेतु (^{99}mTc-HSA) नैनोकोलाइड का निर्माण किया गया था । इस निर्माण के चिकित्सा पूर्व मूल्यांकन टाटा मेमोरियल अस्पताल के सहयोग से किए जा रहे हैं । अब रेडियोभेषज समिति द्वारा चिकित्सीय प्रयोगों हेतु इस उत्पाद को अनुमोदित कर दिया गया है ।

^{32}P रेडियोसक्रिय पैचेस हेतु एक नवीन तकनीक का विकास मोल्ड ब्रैकीथेरेपी में उपयोग हेतु किया गया है । इस प्रकार के दस कस्टम आकार वाले पैचेज़ (रेडियो सक्रियता की ~37MBq/cm^2 वाले) की आपूर्ति, एआईआईएमएस, नई दिल्ली को की गई ताकि ऊपरी त्वचा कैंसर के रोगियों के उपचार हेतु इसकी चिकित्सीय क्षमता का मूल्यांकन किया जा सके । इसके प्रारंभिक परिणाम अति उत्साहवर्धक रहे और कुछ रोगी पूरी तरह रोगमुक्त हो गये ।

जैविकी

पोटैशियम की कमी को संवेद करने वाली व अभिक्रिया करने वाली सैल्युलर सिगनलिंग प्रणाली का मूल्यांकन नाइट्रोजन फिक्सिंग सायनोबैक्टिीरियम एनाबेना में किया गया ।

HrcA हार्मोडाइमर द्वारा संघात प्रतिसंवेदी आण्विक संरक्षिताओं के नकारात्मक नियमनीकरण का एनाबेना में निदर्शन किया गया ।

सतही लीगैंड्स के बंध द्वारा समुद्री जल से यूरेनियम की पर्याप्त मात्रा का सायनोकोकस इलोंगेट्स का मैरिन कायनोबैक्टिीरियल स्ट्रेन देखा गया ।

तनुकृत क्षारीय घोलों से फॉस्फेट के रूप में 90% से अधिक यूरेनियम को तीव्र रूप से जेव अवक्षेपण करने वाला एक आनुवांशिक रूप से इंजीनियरीकृत ई. कोलै स्ट्रेन देखा गया ।

परिकलनात्मक सुविधा

भापअ केंद्र के प्रयोक्ताओं को रिलीज किया गया 9 - टेराफ्लॉप सुपर कंप्यूटर अनुपम - अजेय द्वारा 80% उपयोगिता प्राप्त की गयी । 47 मेगा पिक्सल रेसोल्यूशन सहित एक 6x6 टाइटल्ड डिस्प्ले दृश्य प्रणाली, 19 हाई-एन्ड सर्वोरों की शक्ति वाले बैकअप का

विकास किया गया ताकि वैज्ञानिक परिणामों का दृश्य सुविधाजनक हो ।एनआईसी-दिल्ली, भापअ केंद्र एवं वीएसएससी-तिरुवनंथपुरम संकाय के माध्यम से 3D मॉडलिंग हेतु एक 3D CADCAM सॉफ्टवेयर "Collab CAD" का विकास किया गया ।

कार्यक्रम एवं संसाधन समाकलित प्रणाली (परिणय) अब लोकप्रिय हो रहा है और इस केंद्र की विभिन्न गतिविधियों को जोड़ने हेतु व्यापक रूप से कार्यरत है ।

वर्ष 2007-2008 के लिए इस केंद्र के अधिकारियों द्वारा गोपनीय रिपोर्टों के प्रस्तुतीकरण हेतु कंप्यूटर प्रभाग द्वारा ऑनलाइन गोपनीय रिपोर्ट (ओसीआर) प्रणाली का अभिकल्पन किया गया जो सफलतापूर्वक सेवाएं प्रदान कर रहा है । इस वर्ष के दौरान उपभोक्ताओं से प्राप्त फीडबैक के अनुसार इस प्रणाली में अन्य सुधार किए जायेंगे ।

नाभिकीय कृषि एवं खाद्य किरणन

कृषि के क्षेत्र में दो नये ट्रांबे फसल किस्म टीजी-39 (ट्रांबे-बीकानेर मुंगफली) एक मिठाई श्रेणी की मुंगफली को राजस्थान में खेती के लिये अधिसूचित किया गया एवं टीजी-51 एक शीघ्र बढ़ने वाली मुंगफली किस्म को पश्चिम बंगाल, उड़ीसा, बिहार एवं उत्तरी पुर्व राज्यों के लिये अधिसूचित किया गया । इसके साथ कृषि मंत्रालय, भारत सरकार द्वारा वाणिज्यिक खेती के लिये अधिसूचित ट्रांबे फसल किस्मों की कुल संख्या 37 हो गयी है ।

वर्ष 2008 में 19 नये निसर्गऋण बायोगैस संयंत्रों को स्थापित किया गया जिससे इन संयंत्रों की कुल संख्या 37 हो गयी है ।

प्रौद्योगिकी हस्तांतरण

इस साल विभिन्न सात प्रौद्योगिकियों का हस्तांतरण 26 पार्टियों को किया गया और 17 समझौता ज्ञापन हस्ताक्षरित किए गए । तीन अंतराष्ट्रीय पेटेंट्स फाइल किए गए हैं और एक राष्ट्रीय पेटेंट दिया गया है । महाराष्ट्र में तीन नयी आकृतियां स्थापित की गई हैं, इस तरह भारत में कुल आठ आकृतियां कार्यरत हैं ।

- महाराष्ट्र के सभी तीन निसर्गऋण संयंत्र आकृति नोडों में सफलतापूर्वक चल रहे हैं । इन आकृतियों में बायोगैस निर्मित बिजली का प्रयोग इन आकृतियों में किया जा रहा है ।
- फोल्डेबल सोलार ड्रायर, घरेलू जल शुद्धीकरण यंत्र एवं मृदा कार्बनिक कार्बन टेस्टिंग किट सहित निदर्शन प्रयोग विभिन्न ग्रामों एवं खेतों में किए जा रहे हैं ।
- इन आकृति नोडों के चारों ओर 100 से अधिक क्षेत्रों में दूसरी बार भापअ केंद्र की नवीन बीज किस्में देखी गयी हैं ।

राष्ट्रीय सुरक्षा

यह आप सभी को अच्छी तरह मालूम है कि बीएआरसी, देश की अनेक राष्ट्रीय सुरक्षा परियोजनाओं के संचालन में संलग्न है । राष्ट्रीय सुरक्षा से संबंधित कार्यों में संलग्न हमारे बहुत से साथियों की समर्पित सेवा के द्वारा ही हम राष्ट्र के साथ किए गए अपने वादे को पूरा करने में समर्थ हुए हैं ।

इन क्षेत्रों में हमने अपने लिए दीर्घ अवधि और लघु अवधि वाले सुपरिभाषित लक्ष्यों का निर्धारण किया है । यह हमारे लिए आत्म निरीक्षण का समय है, क्योंकि हम इस वर्ष को अपने संस्थापक डॉ. होमी भाभा की जन्म शताब्दी वर्ष के रूप में मना रहे हैं । पिछली शताब्दी के उत्तरार्द्ध की अवधि के दौरान हमारे केंद्र द्वारा देश को नाभिकीय प्रौद्योगिकी के क्षेत्र में एक आत्मनिर्भर देश बनाने और हमारी आवश्यकताओं से संबंधित मांगों को पूरा करने के लिए प्रौद्योगिकी का एक मजबूत आधार बनाया गया है । जैसाकि आप सबको मालूम है, प्रत्येक वैज्ञानिक, इंजीनियर, तकनीकी एवं प्रशासनिक स्टाफ द्वारा इस केंद्र के कार्यों में दिया गया छोटा से छोटा योगदान हमारे

समग्र लक्ष्य को पूरा करने की दिशा में बढ़ाया गया एक कदम होगा । हमारे लिए अपने दिन-प्रतिदिन के कार्यों में इस तथ्य को याद रखना बहुत महत्वपूर्ण है । चूंकि हमारा प्रत्येक कार्य आपस में जुड़ा हुआ है, अत: हमारी इस महान संस्था का कार्य निष्पादन आवश्यक रूप से विभिन्न प्रभागों और वर्गों के कार्यों के बीच होने वाले आपसी कार्यों पर निर्भर करता है ।

अब हमारे लिए यह समय आ गया है कि अपने दीर्घ अवधि वाले उद्देश्यों को सामने रखते हुए लघु अवधि वाले लक्ष्यों को एक समयबद्ध आधार पर तेजी के साथ पूरा करें । वर्तमान परिदृश्य में हमारे लिए राष्ट्रीय सुरक्षा का महत्व सबसे बड़ी चिंता का विषय है और मैं अपने सभी साथियों से यह आग्रह करता हूं कि वे अपने छोटे-छोटे आपसी मतभेदों और व्यक्तिगत कारणों को भूलते हुए कम से कम अवधि में अपनी संस्था के लक्ष्यों को सामूहिक रूप से प्राप्त करने हेतु मजबूती के साथ जुड़ें । इसके द्वारा ही हम अपनी संस्था और अपने राष्ट्र के प्रति गौरव भाव जागृत कर सकेंगे ।

अपने केंद्र एवं इसकी विभिन्न संस्थापनाओं का भौतिक संरक्षण हमारे लिए अत्यंत महत्वपूर्ण है । मुझे विश्वास है कि मेरे सभी साथी वर्तमान में सुरक्षा के प्रति बढ़ी हुई चिंताओं को समझेंगे । हमारे संस्थान का प्रभावी सुरक्षा बंदोबस्त बनाये रखने के लिए बीएआरसी सीक्योरिटी और सीआईएसएफ के कार्मिकों द्वारा प्रशंसनीय कार्य किया जा रहा है । मैं बीएआरसी की फायर सर्विस के कर्मचारियों की भी हार्दिक सराहना करता हूं जो हमारे केंद्र की विभिन्न स्थापनाओं की लगातार चौकशी के कार्य में लगे हुए हैं । मैं इस केंद्र के सभी अधिकारियों और स्टाफ को भी बधाई देता हूं जो उच्च सुरक्षा व्यवस्था बनाये रखने में सुरक्षा कर्मचारियों को अपने कर्तव्यों के निर्वहन में सहयोग कर रहे हैं । अंतत: मैं इस केंद्र में अपने सभी साथियों से अनुरोध करूंगा कि वे वर्तमान परिस्थिति में हमेशा सतर्क और जागरूक रहें ।

भू-दृश्य एवं स्वच्छता अनुरक्षण

इस स्थल के सुंदरीकरण में हमारे भूदृश्य एवं स्वच्छता अनुरक्षण अनुभाग के कार्मिकों द्वारा दिए गए प्रशंसनीय योगदान की झलक दिखाई देती है ।

निष्कर्ष

निष्कर्ष रूप में मैं इस बात को रेखांकित करना चाहूंगा कि हमारे सामने अनेक चुनौतियां हैं। मुझे विश्वास है कि भापअ केंद्र में हम अपने सभी वैज्ञानिकों, तकनीशियनों और प्रशासकों के एक जुट प्रयासों से बीएआरसी की परंपरा के अनुरूप भावी चुनौतियों का सामना करने में सफल होंगे ।

मित्रों, अंत में इस शुभ दिवस पर आइए, हम यह दृढ़ संकल्प करें कि अपनी जनता के कल्याण के लिए हम नाभिकीय विज्ञान एवं प्रौद्योगिकी के अग्रणी क्षेत्रों में उत्कृष्टता को बनाए रखने हेतु पूर्ण समर्पण की भावना से कार्य करेंगे ।

जयहिंद !"

बीएआरसी न्यूज़लैटर
BARC NEWSLETTER

Message on the occassions of the 60th Republic Day of India and the New Year from

Dr. Srikumar Banerjee

Director, BARC

"Dear colleagues,

It is indeed a matter of great pleasure for me to extend a warm welcome to you all to celebrate the 60th Republic Day of our country. As a mark of our collective salutation to our national flag, every year we assemble on this auspicious morning to celebrate the Republic day. Let me also take this opportunity to extend my greetings and best wishes for the New Year to each one of you and your family.

On the occasion of Republic Day, it is our duty to salute the members of Armed Forces who have been providing the security of this country. On November 26, 2008, the city of Mumbai and the country were shocked by the terrorist attacks on some parts of the city. The gallantry shown by the commandos of our Armed Forces has reinforced our confidence in them. We also take the opportunity of paying our homage to those who sacrificed their lives for tackling the cowardly act of the terrorists.

As you are aware, on this date in the year 1950, the Sovereign Democratic Republic of India came into being. On this historic moment in 1950, the dream of having nothing less than 'Swaraj' that was resolved on 26th January, 1930 by we Indians was realized.

While the Republic Day is a historic day in our life, it is also the day for some introspection on our part.

BARC is one of the world's largest R&D centres, where we pursue excellence in nuclear science and technology, covering a very wide spectrum of activities under a common umbrella. The last year has been yet another successful year in our developmental efforts in nuclear science and technology and its applications in power generation, agriculture, food preservation, health care and national security. Among the various systems and technologies developed recently, I would make a mention of only a few as illustrative examples.

Research Reactors

All the three research reactors APSARA, CIRUS and DHRUVA were operated satisfactorily with high level of safety and availability for the purpose of isotope production, research, material testing and human resource development.

The APSARA reactor is being upgraded to raise its power to 2 MW and achieve a maximum neutron flux of 6.5 E13. The basic designs of the reactor core and various reactor systems havebeen completed. The upgraded reactor will provide facilities to carry out neutron beam research,radioisotope production, calibration and testing of neutron detectors, material testing and bulk shielding experiments.

The Critical Facility for Heavy Water Reactors, which attained its first criticality on April 7, 2008, was formally inaugurated on October 30, 2008 by the Honourable Prime Minister. Physics experiments for reactivity worth checking of primary shutdown system, actual power and neutron flux estimations have been completed.

The conceptual design of a high flux Research Reactor has been completed. This reactor is designed to meet the large requirements of high specific activity radioisotopes. It will also provide enhanced facilities for basic research in frontier areas of Science and for development and testing of nuclear fuel and reactor materials. Feasibility study for incorporation of an external neutron source in the core of this reactor is underway, so as to operate the reactor as an Accelerator Driven Sub-critical reactor system.

AHWR Programme

In order to further increase the average exit burn-up of AHWR fuel up to 38 GWD/t , the equilibrium cluster design was modified. Two options of initial fuel loadings have been followed for nearly 7 Full Power Years to obtain various fueling and reprocessing requirements. The core characteristics such as reactivity coefficients, shut-down requirements and reactivity worth of safety and control devices have been worked out at different full power days for the above cases.

The AHWR design contains several first-of-a-kind passive safety features, which needs to be evaluated properly. Experiments was conducted to study the performance of Passive Containment Isolation System. Performance data was generated in an Integral Test Loop (ITL) for validation of Isolation Condenser's performance for decay heat removal. Hot shut down passive valve has also been tested successfully.

The Integral Test Facility at Tarapur (ITFT) is being set up at the R&D Centre, Tarapur with the dual objectives of establishing thermal and stability margins and testing of the AHWR fueling machine.

HTR programme

Design and analytical work on Compact High Temperature Reactor (CHTR) as well as on 5 MW(th) Nuclear Power Pack are in progress. A detailed analysis of the safety and control reactivity requirement of the 100 kW(th) CHTR, along with optimisation of burnable absorber in the fuel and core life has been completed.

A liquid metal loop employing lead-bismuth eutectic as coolant has been installed and commissioned. The facility is aimed at generating thermal hydraulic and corrosion data.

R&D in Reactor Engineering

Design of "Tool Delivery System" required for In-Service Inspection for 220MWe PHWR has been completed. This development would lead to reduction in inspection time, man-rem consumption and will also facilitate flexible inspection schedule for any ISI campaign.

For the 540 MWe PHWRs, an Advanced Drive Machine (ADM) has been conceptualized for In-Service Inspection (ISI) of coolant channels. This machine, to be remotely operated for delivery of inspection tools into the

channel, requires a split plug assembly, which enables the passage of inspection head with a diameter close to channel diameter. This innovative plug has been designed successfully.

Stability of parallel boiling channels of 700 MWe PHWR was analyzed using linear stability method and a best estimate safety code.

An online vibration diagnostics system installed on Gas Turbine at NTPC's Auriaya site under an MoU was commissioned. An online data acquisition system has been installed and commissioned in Koyna to acquire seismic response from equipment and civil structure during earthquakes.

Fuel Reprocessing & Waste Management Activities

KARP facility at Kalpakkam has been successfully refurbished with a provision of automated spent fuel charging facility, separate co-extraction and partitioning for recycle feed and several other improved features to ensure smooth operation of the plant. The plant has been restarted to augment supply of strategic material.

The erection of WIP-3A plant at Kalpakkam has been completed and testing and commissioning of various systems is in progress. The plant is designed to vitrify the HLW generated at site using joule heated ceramic melter and for conditioning of various liquid waste streams.

The PREFRE plant, of 1975 origin, continued to operate safely despite failure of several equipment like evaporator and dissolver.

State-of-the-art spent fuel chopper for gang chopping of fuel bundles in one stroke has been successfully developed and the first unit installed at Tarapur is under commissioning.

The mobile TRIX unit used earlier at Plutonium Plant, Trombay for treatment of ILW has been re-conditioned and shifted to Tarapur site. TRIX uses indigenously developed resorcinol formaldehyde condensate resin. As on date, more than 50 M^3 of waste at Tarapur has been processed.

Three numbers of alpha contaminated glove boxes from radiological laboratories have been *in-situ* encapsulated safely and shifted to Alpha Solid Waste Transit Facility at RSMS, Trombay. This has resulted in release of precious floor space at RLG.

A prototype unit of Articulated Manipulator with 8 Kg payload capacity for small enclosures for remote operations has been successfully developed.

Processes have been developed for the recovery of ^{90}Y and ^{106}Ru from HLW and the isotopes have been supplied for use in Radio Pharmaceuticals Division. Strategic material ^{241}Am is being recovered from old plutonium scrap.

Fuel for Fast Reactors

BARC has the responsibility of supplying nuclear fuels for the Fast Reactor Programme including FBTR and PFBR

(under construction) at Kalpakkam. The new line for fabricating FBTR Mixed carbide fuel commissioned at RMD last year is now fully operational and several batches of mixed carbide fuel have been processed successfully in this line. Last week, we have dispatched MK I Carbide fuel pins to IGCAR manufactured in this line.

The PFBR experimental MOX Fuel pins fabricated at Advanced Fuel Fabrication Facility, Tarapur loaded in the centre of FBTR core has now reached a burn up exceeding 80,000 MWd/T.

A lab scale alpha waste treatment facility for Plutonium contaminated PVC/Neoprene waste involving shredding, leaching and compaction has been commissioned in RMD and is undergoing initial cold trials.

The manufacture of MOX fuel pins for PFBR first core is continuing at our facility in Tarapur and the fabrication parameters have been optimized to get a high yield of acceptable quality fuel. End plug welding of D-9 clad tubes using Nd – Yag laser has been successfully demonstrated and an ultrasonic technique has been developed for inspection of the closure weld.

BARC is also involved in R&D on metallic fuel for the advanced fast breeder reactors with high breeding ratio. The injection casting system for casting of metallic fuel is under installation inside a glove box and a demoulding and slug shearing machine is undergoing trial operations.

2-D thermo-mechanical analysis of metallic fuel for future Fast Breeder Reactors (FBRs) has been carried out. The fuel, with characteristic high breeding ratio and efficient power production, consists of U-Pu binary alloy containing 15 % Pu cladded in T91 alloy with Zr layer between the fuel slug and cladding material and helium gas in semicircular groove region.

Health, Safety & Environment

The BARC Containment Model (BARCOM), which is a 1:4 size pre-stressed concrete inner containment of 540 MWe PHWR has been built at BARC Tarapur project site to assess its ultimate load capacity and various failure modes. The model response at 69 specified sensor locations will be used, to benchmark the containment analysis computer codes for the postulated design basis and severe accidents scenarios.

Accelerated ageing and corrosion studies have been completed for base and weld material of the PHT system of AHWR after thermally aging them for 1300 hours at 450°C and for 8000 hours at 400°C, simulating 100 years at 300°C. The results indicated that the degree of sensitization is very small as compared to the acceptable value of 5%.

Channel heat up experiments, simulating pressure tube ballooning phenomena during severe accident phase of Small Break LOCA in a PHWR were conducted at different pressures of 20, 40 and 60 bar at IIT Roorkee. Pressure tube sagging experiments were also carried out at different heating rates. The experimental data was used for validating the Pressure Tube Creep (PTCREEP) code predictions.

A Risk Monitor Software Tool developed in BARC, is deployed at various nuclear power project sites for pilot use with their respective PSA models. It has been used in analyzing KAPS 1 & 2 operational events, collected from Significant Event Reports.

Tritium monitor for area monitoring in the presence of interfering ^{133}Xe was developed for use in TAPS#4 on a specific request from NPCIL. This system was field tested at reactor site continuously for three months, to evaluate its performance.

Indigenously developed Radon Monitoring systems, based on the electrostatic collection principle, have been installed in various locations of the underground Uranium mines at Turamdih and networked through a cable network so as to display the radon concentrations at a central over ground location.

The existing CaF_2 powder based thermo-luminescent dosimetry technique used for environmental monitoring, has been replaced by an automated $CaSO_4$:Dy based system, thereby reducing the processing time by a factor of 3, to meet the increasing demand of environmental monitoring.

A new four element Al_2O_3:C based Optically Stimulated Luminescence (OSL) phosphor badge has been designed for testing in radiation beams of photon energies, in the range of 20 keV to 3 MeV and beta radiation in the energy range 300 keV to 3 MeV. This new OSL dosimeter badge is being planned as a potential replacement for the present $CaSO_4$:Dy based TLD personnel monitoring system.

Intensity Modulated Radio Therapy (IMRT) phantom has been indigenously developed and the dose verification was carried out at the P.D.Hinduja Hospital. The results obtained were within 2% of those obtained using commercial IMRT phantom.

Dosimetry studies, using Gafchromic film stack were carried out on P-32 patch brachytherapy sources developed by BARC for the treatment of skin cancer. A tissue equivalent head and neck phantom was designed for the measurement of dose profile and dose distribution during Gamma Knife based stereotactic radiosurgery procedures, using gafchromic films and thermo-luminescent dosimeters.

Experiments were carried out to study the effect of food preservative Butylated Hydroxy Toluene (BHT) on genotoxicity induced by the chemical carcinogen 4-Nitroquinoline 1-oxide (4-NQO).

Under IERMON, solar powered monitoring stations were established across the north-western sector of India at Srinagar (J&K), Udhampur, Jammu, Nal, Suratgarh, Uttarlai, Jaisalmer and Jodhpur. This brings the total number of stations installed to 80, covering 45 locations across the country.

A Mobile Radiological Impact Assessment Laboratory (M-RIAL) vehicle using TATA-207 model has been designed. The vehicle is equipped with radiation monitoring systems to monitor gamma, alpha and beta counting for air quality measurements and a meteorological as well as Global Positioning System.

Materials Development

One of the key issues in the ADSS and Indian TBM (for ITER) programmes is the circulation of molten lead-bismuth and lead-lithium eutectic at high flow rates. The Electro Magnetic Induction Pump on rotating magnets developed in-house for the molten eutectics are being tested by constantly running them for the last four months under test conditions. These units are compact in size, have an efficiency better than those based on MHD pumps.

The SCC crack growth rate has been measured in the recirculation test facility for sensitized SS 304L by DCPD technique in the reactor simulated conditions at 20, 200 and 700 ppb dissolved oxygen levels. This facility will also be used for generating crack growth rates for the materials that would be used for advanced reactors e.g., AHWR and for stainless steels in cold/warm worked conditions.BARC has initiated development and fabrication of cable in conduit conductor for various configurations for superconducting magnets required for fusion research at IPR. In this connection, 50 m long 30 KA hybrid CICC, a 60 Mtr cable containing 504 Nb–Ti Sc wires of 0.8 mm dia have been fabricated.

Towards the development of an optimized material for pressure tubes of AHWR, continuous cooling transformation diagrams were established for Zr-2.5Nb with 1300 ppm of oxygen by quenching dilatometry. The thermo-mechanical processing parameters will be finalized based on this CCT diagram.

Tight fit Zr-2.5Nb – 0.5cu garter springs received from KAPS-2, S-7 coolant channel after 8.5 EFPY of operation were examined. The examination confirmed the excellent performance of the springs ensuring their safe operation for 30 years in a reactor.

A process for synthesis of thermal spray grade powder of lanthanum phosphate has been developed from locally available raw material. Thermal and chemical stability of the powder was studied by plasma spheroidization experiments using a DC thermal plasma reactor. Adherent coatings of $LaPO_4$ on various substrates including stainless steel could be obtained with reasonably good deposition efficiency.

Large capacity Pump Mix Mixer Settler (PMMS) has been designed by successful development of two phase CFD and population balance models for predicting the hydrodynamics and the quality of the dispersed phase and a design of 50 m3 per hour dual impeller pump-mix mixer has been given to Heavy Water Board for coupling with the centrifugal separator.

Mixer settler runs were successfully carried out on simulated PHWR high level waste as well as PFBR high level waste for the partitioning of minor actinides.

Electronics & Instrumentation

Fast, low noise, low power, preamplifier Hybrid Micro Circuits (HMCs) were developed and 3000 of these HMCs were used, in the prototype detector for INO (India based Neutrino Observatory) being developed at TIFR.
Ultrasonic system for sound velocity profiling in uranium fuel rods was developed and installed to qualify b-heat treatment of fuel rods.

The technology of MCS (Multi-Channel Scaling) function in USB Multi Channel Analyser has been transferred to M/s. Nucleonicx, Hyderabad.

Indian Deep Space Network (IDSN-32)

The precision IDSN-32 (32 meter Indian Deep Space Antenna System) is used for communication with ISRO's

Moon mission vehicle "Chandrayaan-I". The Antenna Control Servo System (ACSS) to steer the 380 ton antenna in azimuth and elevation axes with a directional pointing accuracy within 15 milli-degrees was designed by BARC and successfully commissioned at Bayalalu near Bengaluru. The IDSN-32 has been successfully tracking the Chandrayaan-I's journey to the moon following its take off from earth at 13: 30hrs on 22nd October, 2008. The Caliper & Instrumented PIG designed by BARC under an MoU with IOCL, for inspection of 14" oil pipeline has taken its first commercial trial in Delhi – Panipath section of IOCL pipeline. Besides revealing the corrosion defects, it has helped to precisely detect an illegal tapping in the Delhi-Panipath section. The diagnosis was confirmed by dig site verification.

The technology for manufacturing 12" PIG delivered earlier to IOCL is being transferred to ECIL, Hyderabad who are executing an order from IOCL.

High Voltage Testing of 220kV Gas Insulated System switchyard at Kudankulam Nuclear Power Project (KK-NPP), was done.

Acoustic Emission based high voltage tests of Russian make 220 KV Gas Insulated Switchyard (GIS) were carried out at Kudankulam site jointly with NPCIL, using AE system developed by BARC. A fault was detected in one of the earth switches in the Y-Phase, which was subsequently rectified.

Automated Direct Fuel Transfer System for Nuclear Reprocessing Plants

Presently, spent fuel bundles from storage pool are transferred to the reprocessing plant through complex manual operations performed by trained and skilled personnel. The operation also results in spillage of contaminated water on the floor contributing to man-rem consumption. BARC has designed a highly reliable and remotely maintainable automation system to carry out the transfer operation through an underwater tunnel, eliminating handling of charging cask. For demonstration purpose, a working model has also been developed.

Training Simulator for Light Water Reactor (LWR)

Training simulator for LWR designed by BARC for imparting training and qualifying the reactor operators was extensively used by the operators during the last one year. The simulator helped in uncovering several anomalies in the control system documentation. The final corrections of the models were carried out in November, 2008 after the changes in the control system documentation.

Physical Science

As part of the high power accelerator development programme, a copper model of RFQ was machined and vacuum brazed in two-steps of vacuum brazing procedure at the Centre for Design & Manufacture, BARC. The Resonant Frequency (RF) could be corrected to design value of 350 MHz with tuners. The RF coupler developed indigenously was used to feed the power to the RFQ.

Design of various sub systems of low conductivity water system for cooling the various components (such as RFQ, DTL, Klystrons etc.) of Low Energy High Intensity Proton Accelerator (LEHIPA) has been completed.

As part of the INO collaboration, a 35 ton ICAL prototype magnet along with the 20 turns of water-cooled copper coils designed jointly by BARC and TIFR and fabricated by a vendor in Pune has been assembled in VECC.

The Pelletron Accelerator facility set up jointly by BARC and TIFR has completed two decades of successful accelerator operation with progressively increased efficiency.

A current issue in nuclear physics is the study of Giant Dipole Resonance (GDR) in hot rotating nuclei. A measurement from the Mumbai Linac facility of high energy gamma spectra in a nuclear reaction involving 28 Si and + 132 Sn has yielded the spin dependence of the GDR width. The experimental findings revealed the failure of a well-established thermal model for understanding the width evolution in hot rotating nuclei.

Under the ongoing collaboration of BARC with GANIL, experiments have been performed with 6He using the SPIRAL Accelerator at GANIL and with 6 & 7 Li using the BARC-TIFR Pelletron Accelerator in Mumbai. Recent measurement by BARC scientists, of transfer reactions using 6He beam on 65Cu target at GANIL, revealed dominant di-neutron rather than the cigar shape of 6He were highly lauded by the international community.

As part of CMS collaboration at CERN, double gap Resistive Plate Chambers (RPC) were assembled and tested in RPC Lab at the Nuclear Physics Division. Ten such detectors delivered to CMS at CERN in July, 2008 were further evaluated for their efficiency with cosmic muons in the hodoscope in the ISR Lab at CERN.

Beam Technology Development

The BARC-ECIL Linac for cargo scanning has been integrated. A 10 MeV, electron beam at 30mA, 7μs pulse at a repetition rate of 200Hz, has been produced, transported and successfully focused on the 2mm X-ray target for characterisation.

The KALI-5000 pulse power system has been upgraded by incorporating a new high power SF_6 spark-gap and a prepulse switch. This facility is in commissioning stages for operation at a power level of 12.5 GW.

For isotope selective material processing, trace analysis and other spectroscopic applications, a low-power Diode-Pumped Solid-State Laser (DPSSL) pumped dye laser has been developed for the first time indigenously. It was tested over a frequency of 2 to 6 kHz, producing a tunable output with a line width of ~3 GHz at 4% efficiency at the peak of the tuning range of Rhodamine 6G dye.

Desalination Activities

The Multi-Stage Flash (MSF) Evaporation plant of Nuclear Desalination Project at Kalpakkam was inaugurated by the Hon'ble Prime Minister on October 30, 2008. The plant will be brought up to full scale production shortly. A barge mounted Desalination Plant designed and built by BARC in accordance with the rules and regulations of Indian Registrar of Shipping (IRS) for coastal service was also inaugurated by the Hon'ble Prime Minister on the same day. The plant can produce 50,000 litres/day of safe drinking water from seawater.

The Electro-Dialysis Ionization (EDI) unit (5000 litres/day capacity) was recently commissioned and operated

to generate design data. It produces ultra-pure water (<0.1 micro-siemens/cm conductivity) to meet various requirements.

Chemical Science

A femtosecond transient absorption Spectrometer with 200 fs time resolution utilizing visible pump at 400 nm - mid-IR probe tunable in 2.8 – 6 micron region has been successfully commissioned. The probe IR beam is generated from an indigenously developed Optical Parametric Amplifier (OPA) combined with Difference Frequency Generation system (DFG).

Computational investigations on the design of novel carbon nanomaterials, demonstrated that, the affinity of the carbon nanomaterials towards hydrogen can be enhanced significantly by introducing desired curvature into the carbon nano-surface as well as by creating a charged surface through doping of alkali metal atoms. Suitable alkali metal doped organic molecules are shown to have a hydrogen adsorption capacity of 10 wt %.

A sono-chemical synthesis facility has been set up, which facilitates synthesis of nanomaterials with desired particle size. Recently this synthesis route has been used to prepare a number of rare-earth based optical materials.

Radiation Medicine & Isotope Applications

^{177}Lu which would be an alternative agent of the currently used ^{153}Sm-EDTMP for the treatment of patients suffering from bone pain due to skeletal metastasis, is undergoing clinical evaluation in collaboration with AIIMS, New Delhi. The radiopharmaceutical is expected to be marketed through BRIT for regular supply to hospitals within a short time.

^{177}Lu-DOTATATE, a potential agent for treatment of neuro-endocrine cancers is currently undergoing clinical trials in human patients, in collaboration with AIIMS, New Delhi. Therapeutic doses (28 nos) of this agent have been administered in 14 patients till date and the preliminary results are encouraging.

^{99m}Tc-Human Serum Albumin (^{99m}Tc-HSA) nanocolloid was prepared for its evaluation as a sentinel node imaging agent. Pre-clinical evaluation of the preparation was carried out in collaboration with Tata Memorial Hospital, Mumbai. The product has now been approved for clinical trials by the Radiopharmaceuticals Committee.

A new technique for the preparation of ^{32}P radioactive patches was developed for use in mould brachytherapy. Ten numbers of such custom-shaped patches (containing ~37 MBq/cm^2 of radioactivity) were supplied to AIIMS, New Delhi for evaluating their clinical efficacy for treatment of superficial skin cancers in patients. The initial results are very promising and the first few patients were found to be completely free of disease.

Biology

The cellular signaling system which senses and responds to potassium deficiency was elucidated in the nitrogen-fixing cyanobacterium *Anabaena.*

Negative regulation of heat-shock responsive molecular chaperones by the HrcA homodimer was demonstrated *in Anabaena.*

A marine cyanobacterial strain of *Synechococcus* elongates was shown to sequester significant amounts of uranium from sea water, by binding to surface ligands.

A genetically engineered *E.coli* strain was shown to rapidly bioprecipitate >90% uranium, as phosphate, from dilute alkaline solutions.

Computing Facility

The 9-TeraFLOP Supercomputer ANUPAM-AJEYA, released to BARC users attained 80% of its utilization. To facilitate visualization of results, a 6 x 6 tiled display visualization system with 47 mega pixel resolution, backed-up by a power of 19 high-end servers has been developed. The 3D CAD/CAM software "CollabCAD" has been developed for 3D modeling work, through a consortium of NIC-Delhi, BARC and VSSC-Thiruvananthapuram.

The Program And Resource Integration System (PARINAY) is becoming popular and is being extensively used for linking various activities of this Centre.

The Online Confidential Report (OCR) system designed by the Computer Division, has been successfully put in service for submission of CRs, by the officers of this centre for the year 2007-08. Based on the user feedback received during the year, the system will be further improved.

Nuclear Agriculture & Food Irradiation

In the field of agriculture, two new Trombay crop varieties, TG-39 (Trombay-Bikaner groundnut) a confectionary grade groundnut was notified for cultivation in Rajasthan and TG-51 an early maturing groundnut variety was notified for West Bengal, Orissa, Bihar and north-eastern States. With this, the total number of Trombay crop varieties released and notified by the Ministry of Agriculture, Government of India for commercial cultivation has reached 37.

19 new Nisargruna Biogas plants were established in 2008, taking the total number of plants to 37.

Technology Transfer

Seven different technologies have been transferred to 26 parties and 17 MoUs have been signed this year. Three international patents have been filed and one national patent was granted. Three new AKRUTIs have been set up in Maharashtra, making a total of eight AKRUTIs functional in India.

- All the three NISARGRUNA plants in AKRUTI nodes of Maharashtra are running successfully. Electricity generated using biogas has been utilized in these AKRUTIs.
- Demonstration experiments with Foldable Solar Dryer, Domestic Water Purifier and Soil Organic Carbon Testing Kit are carried out in different villages and fields.
- New seed varieties of BARC have been sown for the second time in more than 100 locations around

these AKRUTI nodes through KRUTIKs amongst the villagers and farmers in the surrounding villages.

National Security

You are all aware that BARC is involved in a number of strategic projects of our country. Many of our colleagues are engaged in activities related to national security. It is through their dedicated service we are in a position to keep our promises to the nation. In these strategic areas, we have some well defined goals – both short term and long term. Many of you may not be even aware how the individual contributions every one of you are making, are helping us in fulfilling our goal in the strategic area. It is important for us to remember that our day-to-day work and our individual contributions are all linked and the overall performance of this great institution is essentially a product of the synergy between the activities of individuals, different Divisions and Groups.

The time has come for us to make faster strides attending the short-term goals in a time bound manner, keeping our long-term visions alive. The importance of national security in the present scenario is of the greatest concern and I urge all my colleagues to forget minor differences and small issues and forge together to collectively achieve our institutional goals in the shortest possible time. By this, we can make our institution and our country proud of us. It is through our work we can prove our courage and commitment to our country.

Physical protection of our Centre and its various installations is of paramount importance. I am sure, all my colleagues will understand that the concern of security has further increased in the present time. BARC security and CISF personnel have been performing a commendable task of providing the physical protection to our establishment. I would like to appreciate the BARC Fire Service personnel for maintaining a constant vigil on the various establishments of our Centre. I also compliment all officers and staff of our Centre for extending their cooperation with the security personnel in discharging their duties effectively for implementing the higher level of security procedures. Finally, I urge all my colleagues in our Centre to remain vigilant and alert in the present environment.

Landscape & Cosmetic maintenance

The contribution made by the personnel of our Landscape & Cosmetics Maintenance Section is aptly demonstrated by the beautiful ambience of this venue.

Conclusion

While concluding my address, I would like to emphasize that we have plenty of challenges ahead. With the synergistic effort of all of us in BARC – scientists, technicians and administrators, I am sure we will be able to rise to the occasion to meet the future challenges in a manner consistent with the traditions of BARC.

Friends, finally on this very special day, let us firmly resolve and rededicate ourselves to continue our pursuit of excellence, in the frontier areas of nuclear science and technology, for the betterment of the lives of our people.

*** Jai Hind *"**

STUDY OF QUARK GLUON PLASMA: JOURNEY FROM RHIC TO LHC

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Introduction

Since the discovery of quarks in the 1960s, the core questions in Nuclear and Particle Physics have undergone dramatic changes. The nucleus had long been viewed as a densely packed assembly of neutrons and protons, bound together by a strong force, mediated by pions and other mesons. It is now well understood that the fundamental constituents are the point-like quarks (and anti-quarks) bound together through interactions mediated by gluons (See Box A for more details). Quantum Chromodynamics (QCD), the current theory of strong interactions, is a field theory of quarks and gluons. It forbids the appearance of free quarks or gluons, but their existence proves their fundamental role in the nature of matter. At extremely high energy densities, QCD predicts a new form of matter, consisting of an extended volume of interacting quarks, anti-quarks and gluons, what is known as quark gluon plasma (QGP). It is in this context, that in the hot Big Bang scenario, the early Universe in a few micro seconds after its formation existed, in the form of quark gluon plasma. Physicists from around the world have now demonstrated that by colliding two ultra-relativistic heavy ions (like Au or Pb atoms), it is possible to compress and heat the nuclei to such an extent that their individual protons and neutrons will overlap, creating a region of enormously high energy density, where a relatively large number of free quarks and gluons can exist for a brief time.

Each collision acts like a microscopic pressure cooker, producing temperatures and pressures more extreme than those that exist even now in the cores of the hottest stars. As an illustrative example, the red, green and blue circles (See Fig. 1) are quarks, connected by black lines representing gluons. In the beginning, quarks and gluons are held tightly inside the protons and neutrons in the nucleus of an atom. As the pressure and temperature rise, new particles called mesons (made of a quark and anti-quark) are produced. Finally, the conditions are just right for the phase transition to take place (from a hadron phase to QGP) and the quark gluon plasma is produced.

Once the QGP is produced in a collision, it will quickly cool, expand and collapse into hadrons. The QGP cannot can be detected directly, as its life time is too brief, but by the distinct characteristics of the particles that shower out from the collision.

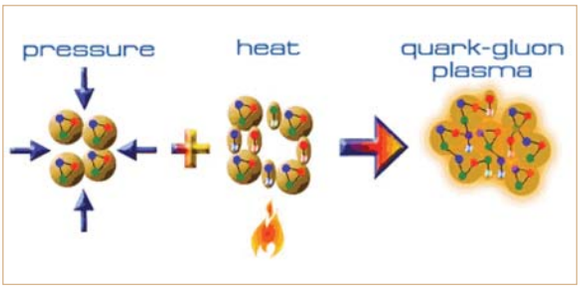
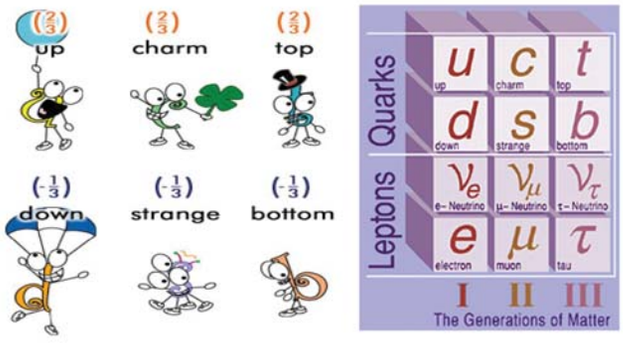


Fig. 1 : Formation of the Quark Gluon Plasma

Early Big Bang Scenario

The quark gluon plasma is thought to have existed in the first micro seconds of the formation of the universe. Fig. 2 shows the timeline of how the Universe is thought to have evolved as it cooled, following the Big Bang. Starting from the bottom left, one can track the Universe as it evolved from 0.000000001 second



Box A: Matter is built from two types of fundamental fermions called quarks and leptons. Quarks come in six flavors: up (u), down (d), charm©, bottom(b) and top (t) carrying fractional electric charge of 2/3 or –1/3. The proton contains two up and one down quarks (uud) where as a neutron is made up of one up and two down quarks (udd). Similarly, there are six leptons, electron (e), muon (μ), tau (τ) and their corresponding neutrinos (ν). They all fall into three families or generations. Protons and neutrons are classified as baryons which contain three quarks where as mesons like pion (π) contain a quark and anti-quark pair. Both baryons and mesons are known as hadrons that participate in strong interactions through gluon exchange.

till today. The purple band in the top panel is the realm where QGP can exist at very high temperatures above 10^{12} deg Kelvin. As the Universe expanded and cooled, the QGP coalesced into protons and neutrons (hadronization), then nuclei (nucleosynthesis) and then into atoms. Finally, the atoms came together to form molecules and bulk matter.

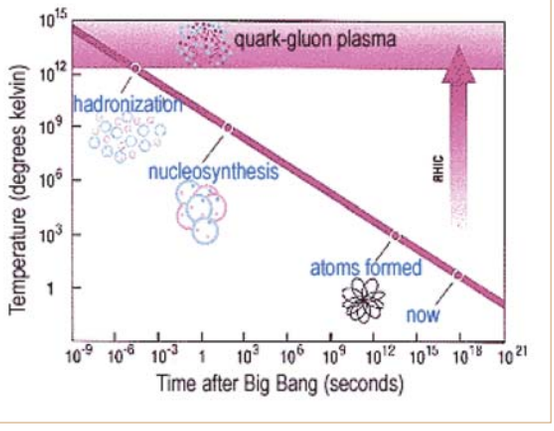
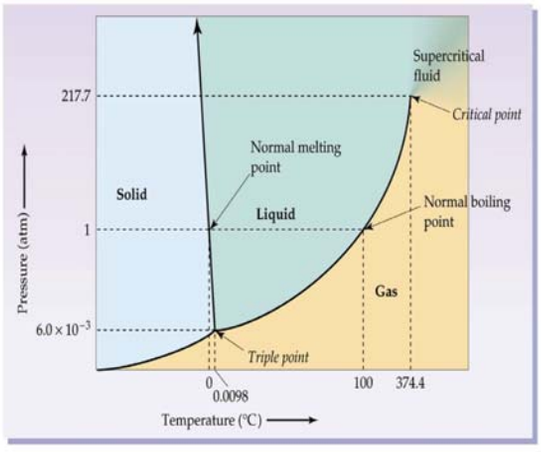


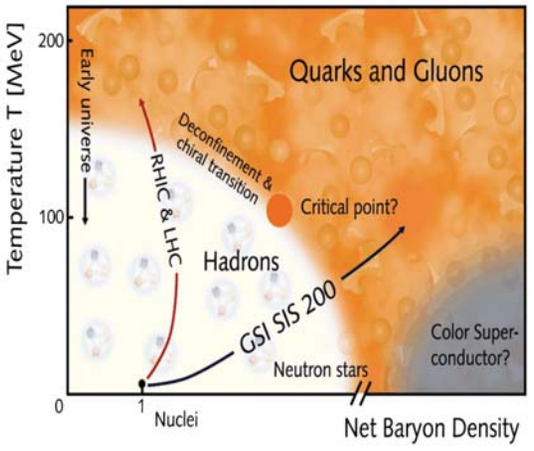
Fig. 2: Timeline of the formation of the Universe

Relativistic heavy ion collisions, recreate on a small scale, a mini-universe in the laboratory. Physicists expect to gain a new understanding of the relationship between the most fundamental constituents of matter and the complex array of particles and nuclei that make up the world around us.

The RHIC era begins

Interest in the study of relativistic heavy ion collisions began with several fixed target experiments, prior to the period when heavy ion colliders became available. Several pioneering fixed target experiments were carried out with CERN Super Proton Synchrotron (SPS), which provided 160 GeV per nucleon beam of sulphur and lead nuclei. In particular, the measurements of J / Ψ meson – the bound state of charmed quark and its anti-quark ($c\bar{c}$) indicated that, the nucleus-nucleus collisions at high energy are very different from a simple superposition of nucleon-nucleon interactions. The suppression of J / Ψ production was a strong





Box B: The diagram on the left shows, in pressure-temperature space, the lines of equilibrium or phase boundaries between the three phases of solid, liquid and gas for a simple system like water. The phase boundary between liquid and gas does not continue indefinitely. Instead, it terminates at a point on the phase diagram called the critical end point. This reflects the fact that, at extremely high temperatures and pressures, the liquid and gaseous phases become indistinguishable in what is known as a supercritical fluid. In water, the critical point occurs at around T_c=647 K, p_c =22 MPa, and $\tilde{n}_c$=356 kg/m^3. Below this critical point, the transition from liquid to gas phase is of first order in nature where as it becomes second order beyond T_c. The well known phenomena of critical opalescence in case of liquid gas phase transition is a result of fluctuations at all length scales due to a second order phase transition.

The diagram on the right shows a similar phase diagram for QCD matter in temperature and baryon density space showing the transition from the normal hadronic matter to a new state of matter comprising of quarks and gluons. The black dot around unity baryon density and low temeparature corresponds to the normal world of hadronic matter where quarks and gluons are confined to the size of the hadrons. When temperature or density becomes very high, strongly interacting quarks and gluons become free and transform themselves into a new deconfined phase of matter. Here baryon density refers to the excess of quark density over the anti-quarks. The quark gluon plasma state of early Universe corresponds to a plasma at high temperature and zero baryon density meaning the plasma has equal number of quarks and anti-quarks. On the otherhand, the quark matter that exists at the core of the neutron star is a plasma at low temperature and very high density comprising of more quarks and gluons. In between these two extreme limits, quark gluon plasma at different baryon density can be created in the laboratory by colliding two heavy ions at different bombarding energies. The plasma which is expected to be formed at the Large Hadron Collider (LHC) will mimic the plasma of very early universe having high temperature and low baryon density. The programs of SPS at CERN, RHIC at BNL and Facility for Anti-proton Ion Research (FAIR) at GSI, Darmstadt probe the QGP region at finite baryon density and temperature. For the baryon rich matter, the transition from the hadron phase to QGP phase is expected to be of first order, whereas, for zero density scenario (like in early universe), the transition is of second order (or a smooth cross over for finite quark mass). Therefore, as in liquid gas scenario, there exists a QCD critical endpoint where the first order line ends.

indicator, that the heavy ion collisions might be leading to the formation of a QGP, although the produced energy density was not enough for a detailed study of this new state of matter. It was believed that definitive observation of the elusive QGP would be found at higher collision energies with the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory, USA and Large Hadron Collider (LHC) at CERN, Switzerland.

With RHIC and LHC, it is possible to achieve temperatures and baryon densities similar to those existing at the beginning of the early universe (For details see Box B).

The RHIC, the first heavy ion collider of the world (located and operated by the Brookhaven National Laboratory, (USA), became operational in the year 2000, provides protons and heavy ion beams for the international community of more than 1000 scientists, who are participating in four of the major detector experiments: PHENIX, STAR, PHOBOS and BRAHMS. RHIC is an Intersecting Storage Ring (ISR) particle accelerator. Two independent rings (arbitrarily denoted as "blue" and "yellow" rings allow a virtually free choice of colliding projectiles (see Fig. 3). The maximum energy of beam particle ranges from 250 GeV for protons to 100 GeV / u for Au ions.

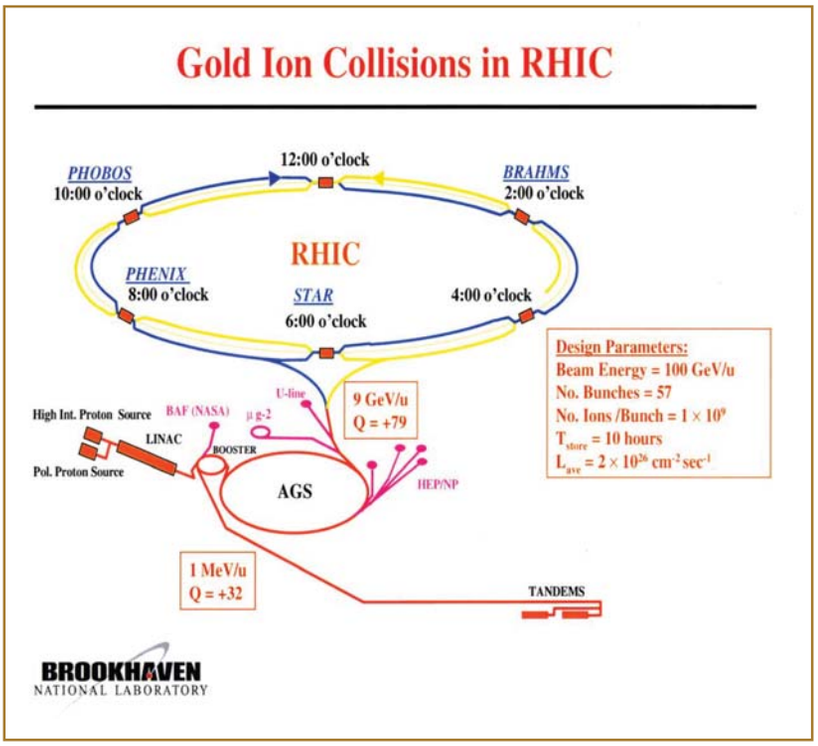


Fig. 3: **The RHIC double storage ring is itself hexagonally shaped and 3834 m long in circumference, in which stored particles are deflected by superconducting niobium-titanium magnets. The six interaction points are at the middle of the six straight sections, where the two rings cross, allowing the particles to collide. The interaction points are enumerated by clock positions, with the injection point at 6 'o' clock. The machine can accelerate gold nuclei up to momenta of 100 GeV/c per nucleon in each beam, protons up to 250 GeV/c, and smaller mass nuclei up to intermediate momenta depnding on their mass-to-charge ratio. The centre of mass energy in these collisions is more than an order of magnitude higher than the previous highest energy heavy ion reactions at the CERN-SPS fixed target facility. The nominal design luminosity of 2.96×10^{26} cm^{-2} s^{-1} for gold at full energy was already achieved during first two physics running periods. A unique characteristic of RHIC is its capability to produce polarized protons. RHIC holds the record of highest energy polarized protons. Polarized protons are injected into RHIC and their spin directions are preserved through the energy ramp with the aid of Siberian Snakes (a chain of solenoids and quadrupoles).**

PHENIX (Pioneering High Energy Nuclear Interaction Experiment) is one of the largest detectors among the four experiments, which has been collecting data since 2000. The PHENIX collaboration is made up of over 430 scientists and engineers from all over the globe including India (BARC and BHU). PHENIX (see Fig. 4) consists of a collection of detectors , each of which performs a specific task, in the measurement of particles produced in the heavy ion collisions. The detectors are grouped into two central arms, which are capable of measuring hadrons (pions, protons, kaons, deuterons etc), photons and electrons and two muon arms which focus on the measurement of muon particles. There are also additional event characterization detectors, that provide additional information about a collision and a set of three huge magnets that bend the trajectories of the charged particles. The Nuclear Physics Division of BARC had contributed to the fabrication of PHENIX muon arm detectors along with LANL, USA as well as in the PHENIX software development (PISA and PISORP) for Physics simulations.

STAR is another big detector system which is based on a Time Projection Chamber (TPC) inside a solenoidal magnet, that provides exceptional charged particle tracking and particle identification. The BRAHMS experiment has two movable, small acceptance spectrometer arms, which can measure pions, kaons and protons up to very large rapidity. The PHOBOS experiment covers nearly full solid angle and has excellent global event characterization capability. The later two experiments have completed their data accumulation and have been discontinued since 2006.

Each RHIC collision produces several thousands of particles which are detected by various detectors. Fig. 5 shows the particle trajectories reconstructed by STAR (left) and PHENIX (right) detectors. The centrality of collisions can be measured in terms of number of particles (mostly pions), emitted into a given interval of solid angle.

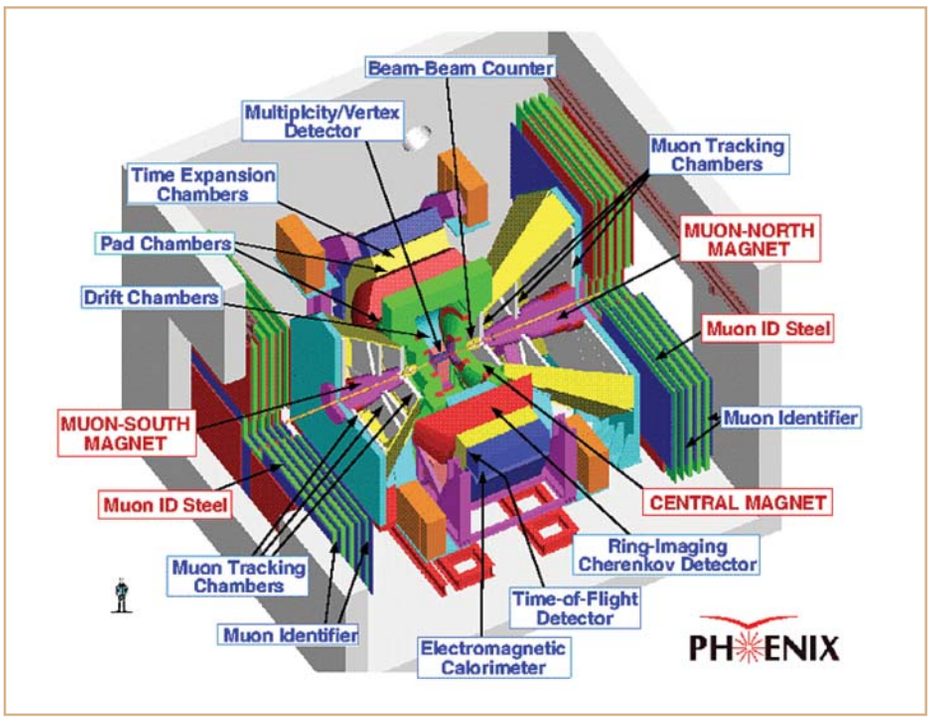


Fig. 4 : Various components of the PHENIX detector system

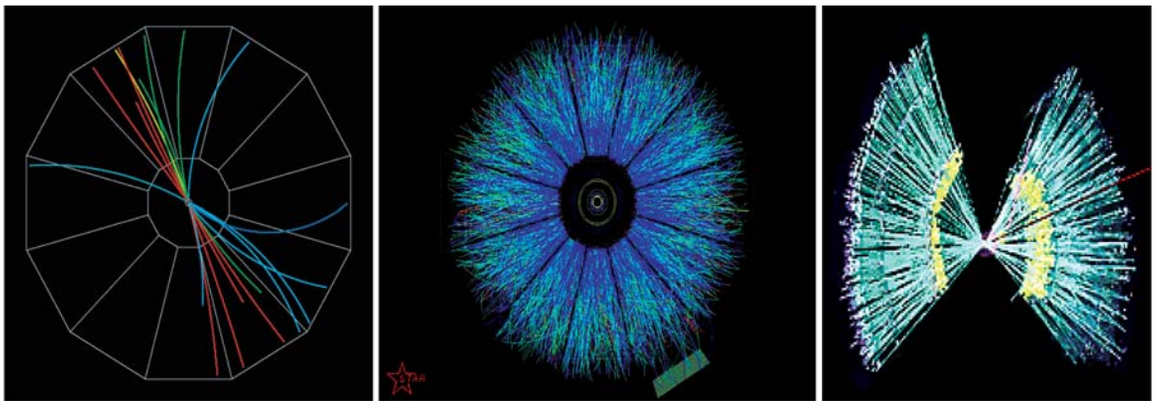


Fig. 5: Reconstructed particle trajectories in STAR and PHENIX detector. The quark gluon plasma cools, expand and collapse into hadrons mostly comprising of charged and neutral pions. These charge particle trajectories are tracked in various detectors. Knowing the curvature of the trajectories and the magnetic field, the momentum of each particle can be reconstructed. In case of p+p collisions (left figure), the number of particles produced are less leading to a few particle trajectories which are relatively easier to reconstruct. For Au+Au collsions, more than 5000 charged particles per collision are produced. Due to increase in track density, the trajectory reconstruction becomes difficult which requires sophisticated tracking algorithm like Kalman filter and other pattern recognition programme are used. The middle and right figures show the reconstructed tracks in Au+Au collisions recorded by STAR and PHENIX detector.

RHIC Discoveries

(a) Global Characteristics

A key question for the RHIC experiments is whether the energy density created in the collisions is sufficient to initiate a QGP phase transition. Experimental measurements suggest an initial energy density more than 15 GeV / fm^3 at time t=0.2 fm / c decreasing to 5.4 GeV / fm^3 by time t=1 fm / c (1 fm = 10^{-13} cm and time in second is estimated by dividing by the velocity of light c). The rest energy density of a lone proton is of the order of 1 GeV / fm^3. Theoretical QCD calculations predict the critical energy density in the range of 1-2 GeV / fm^3 corresponding to a temperature in the range of 170 to 180 MeV for T_c (T_c about 10^{12} K). Such temperatures are sustained for only a few times 10^{-23} s. Due to rapid expansion, the QGP cools down and undergoes phase transition (hadronization). The temperature at the freeze out point has been inferred, by measuring the relative abundances of the different meson and baryon species, produced as the QGP condenses into the final state hadrons. The measurements at RHIC are consistent with a temperature of about 176 MeV at the chemical freeze out.

The experiments have also measured the charged particle multiplicity as a function of collision energy and centrality (impact parameter). The growth of multiplicity with increasing collision energy, is less than what is expected from a simple picture of soft coherent production combined with hard mini jet production, that increases quickly with increasing energy. This observation has given rise to a new model known as Color Glass Condensate (CGC). The CGC which incorporates gluon saturation gives an alternative description of the multiplicity dependence on

collision energy and has been quite successful in describing the data. As described by QCD, this condensate is present in all strongly interacting particles, but it shows itself only in very high energy collisions. The CGC is a very dense superposition of gluons similar to Bose condensate. It has properties similar to glasses—that exhibits slow evolution as compared to the natural time scales of constituent interactions. The CGC is a relatively new idea describing the initial conditions for the QGP produced in high energy collisions.

(b) Flow observables

One of the most dramatic discoveries at RHIC is that, the medium displays a high degree of collectivity often referred to as flow. Since nuclear matter reaches a high degree of compression at the beginning, large interactions between the constituents of the medium can translate this density gradient into outward pressure, which causes the medium to explode at relativistic speeds. Experiments can probe this outward pressure with great precision by characterizing noncentral (non zero impact parameter) nuclear collisions. In these reactions, the nuclear overlap region is not circular in the transverse plane, instead it is elliptically shaped. Experimentally the azimuthal angular distribution (Φ) of particles is measured relative to the reaction plane angle Ψ_R for each nucleus-nucleus collision and then a Fourier decomposition is performed. The second component v_2 of the Fourier decomposition is referred to as elliptic flow. Evidence that the medium is composed of deconfined, thermalized and collectively flowing quarks, comes from detailed measurement of v_2 coefficients, for a wide variety of hadrons. Baryons which contain three valence quarks show yields that are strongly enhanced relative to those of mesons containing a valence quark and anti quark. This observation warrants a new scaling law, based on both hydrodynamics and quark recombination which suggests that, the elliptic flow parameters of mesons and baryons are related to the elliptic flow parameter of quarks assuming quarks and anti quarks exhibit the same collective flow. Fig. 6 shows the plot of v_2 as a function of transverse kinetic energy which are scaled by the number of valence quarks. It shows that the relatively complicated dependence of v_2 on centrality, transverse momentum, particle type and quark number can be scaled to a single function, indicating that, the flow pattern is originally developed in the quark level. The observation of flow indicates that the RHIC collisions produce matter that interacts strongly with itself. There might be some disagreement about the

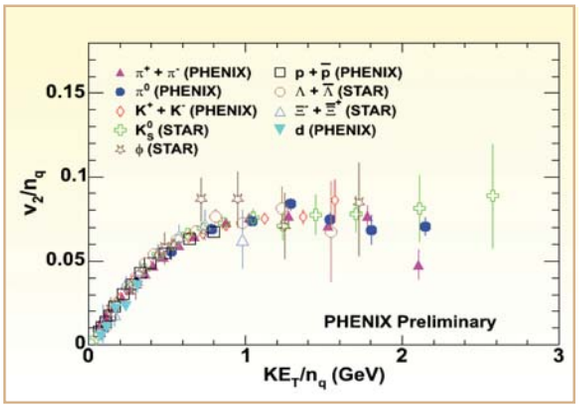
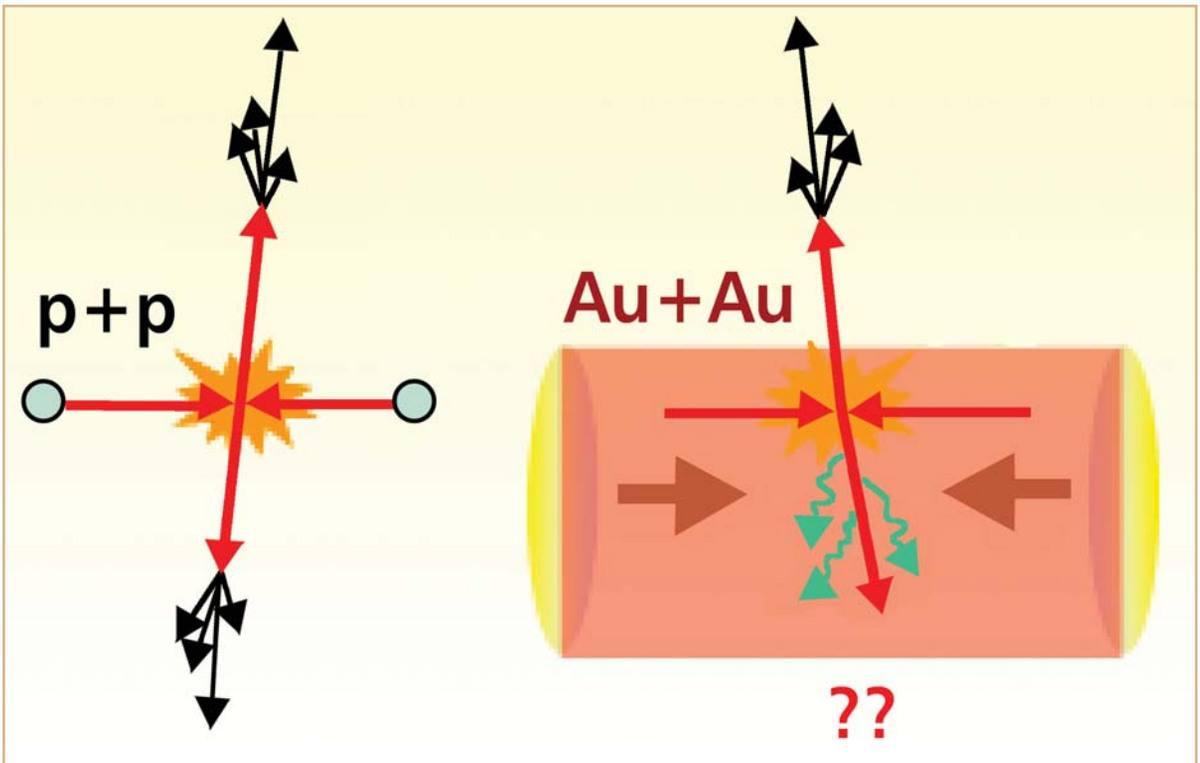


Fig. 6: $v_2/\varepsilon n_q$ vs KE_T / n_q for several identified particle species obtained in minimum bias Au+au collisions at RHIC. The dashed dot line represents a fit to the data

specific mechanism that produces such strong anisotropic flow, but there is a general agreement that the effect is largely due to very strong interactions between the system constituents and that the flow must occur relatively early in the collision, when the relevant constituents are quarks and gluons. Since the flow data can be explained on the basis of ideal hydrodynamics, which refers to a medium that behaves like a strongly interacting ideal fluid, with nearly zero viscosity and perfect heat conductivity.

(c) Jet quenching

Another striking early observation at RHIC is a phenomena called jet quenching (see Box C) which is considered a powerful probe of the hot and dense matter, created in the collisions. In a hard scattering,



Box C: **During the collision of two energetic protons (diagram on the left) , a quark and anti-quark pair is created at the point marked by a star. The quark and anti-quark fly off in opposite directions (shows by the arrows). Since quarks cannot move too far, it hadronizes into a bunch of light mesons (mostly pions). The group of energetic hadrons are emitted in a narrow angle which are known as jets. In case of p+p collisions, two back-to-back jets are seen experimentally. However, the Au+Au collisions lead to the formation of a dense medium, comprising of strongly interacting quarks and gluons (see the diagram on the right). As contrast to p+p collision, while the near side jet can escape, then far side jet gets quenched (loses energy) while moving through this dense medium. Thus, the jet suppression in case of heavy ion collisions indicates the formation of new state of dense matter which is not found in case of p+p collision.**

the partons fly off in opposite direction giving rise to narrowly collimated sprays of hadrons called jets. The STAR and PHENIX experiments have been analyzed using the highest P_T hadron as the trigger particle, to define azimuthal angle f=0 and by plotting Df of other hadrons (associated particles) in the same event. In proton-proton interactions, this analysis results in a sharp peak centered at Df=0, owing to other hadrons fragmenting from the same parton as the trigger particle and a wider peak near Df=p owing to hadrons fragmenting from the opposite parton as seen from Fig. 7. On the other hand, the result from Au+Au collision shows complete disappearance of the opposite side peak. This disappearance can be explained if the energetic parton loses energy while propagating through the dense medium. The demonstration that suppression effects were absent in d+Au collisions, provided crucial evidence that the quenching observed in Au+Au collisions was due to parton propagation in a dense thermal environment,

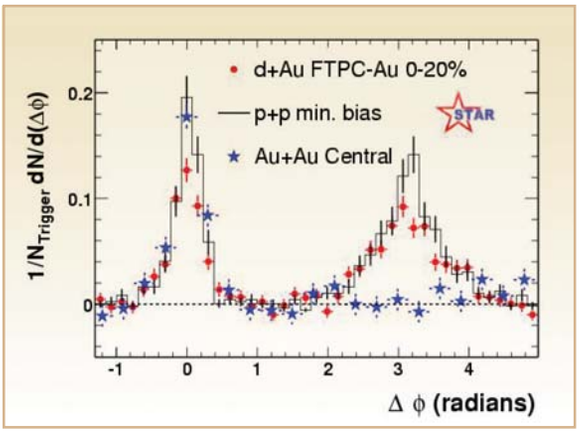


Fig. 7: d+Au collisions

which is opaque to the high P_T partons. PHENIX and STAR have also measured the yield of D and B mesons, by measuring non-photonic electrons. The D and B mesons come from the fragmentation of charm and beauty quarks. The yields from the Au+Au collisions as compared to p+p data show significant suppression. This suppression of heavy partons (like charm and beauty) came as a surprise, as it was expected that light quarks and gluons fragmenting into pions and other light mesons would suffer significant energy loss, due to gluon radiation as compared to heavy quarks. The more massive charm quark should suffer a dead cone effect suppressing a forward emission of gluons. The strong suppression of heavy meson production has led to a reassessment of alternative scenarios of parton energy loss.

(d) Anomalous J/ψ suppression

The study of charmonium production – a bound state of charm quark and anti-quark has drawn special attention to QGP research. In 1986, Satz and Matsui proposed, that the formation of a quark gluon plasma would destroy the charmonium bound state, by a process analogous to Debye screening of the electro-magnetic field, due to electric charges. Measurements at SPS energy showed the suppression of charmonium production as compared to their production in the absence of quark gluon plasma. However, this observation could not be taken as strong evidence of formation of quark gluon plasma, as alternate explanations like absorption of charmonium in the nuclear medium could explain the above suppression. Thus, the SPS data remained inconclusive. This study took an interesting turn again with RHIC measurements, where charmonium suppression is found similar to SPS measurements in spite of a temperature difference of a factor of two. This observation has now led to new interpretation, to produce charmonium either through statistical production at the phase boundary or through coalescence of the charm quarks in the plasma. The additional re-generation can compensate the suppression. Since, Pb+Pb collision at LHC will lead to a very high initial temperature as compared to RHIC, charmonium enhancement seems to be more probable rather than suppression. If observed, this will be a stronger fingerprint of a high energy quark gluon plasma in which charm quarks are effectively de-confined. The data from LHC will be decisive in settling this issue. Moreover, the abundant production of Υ(1s, 2s, 3s) states at LHC will open up a unique opportunity to study the threshold dissociation behaviour of the whole bottomonium family. The Υ is expected to survive up to $4T_c$ and therefore, direct suppression of the $b\bar{b}$ ground state would be indicative of medium temperature around 1 GeV at the LHC.

Large Hadron Collider

Most of the activities at CERN are currently directed towards building a new collider, the Large Hadron Collider (LHC) and experiments for it. The LHC represents a large-scale, worldwide scientific cooperation project. Physics experiments are expected to start by the end of 2008. The LHC tunnel is located 100 metres underground, in the region covering Switzerland and France. It uses the 27 km circumference circular tunnel, previously occupied by LEP which was closed down in November 2000. CERN's existing PS / SPS accelerator complexes will

be used to pre-accelerate protons and heavy ions which will then be injected into the LHC. Six experiments (CMS, ATLAS, LHCb, TOTEM, LHC-forward and ALICE) are currently being built (Fig. 8) and will be running on the collider; each of them will study particle collisions from a different point of view and with different technologies. Construction for these experiments required an extraordinary engineering effort. This accelerator will generate vast quantities of computer data, which CERN will stream to laboratories around the world for distributed processing using the GRID technology. CMS (Compact Muon Solenoid) is designed as a general-purpose detector, capable of studying many aspects of proton collisions at 14 TeV, the center of mass energy of the LHC particle accelerator. It contains subsystems which are designed to measure the energy and momentum of photons, electrons, muons and other products of the collisions. The innermost layer is a silicon-based tracker. Surrounding it is a scintillating crystal electromagnetic calorimeter, which is itself surrounded with a sampling calorimeter for hadrons. The tracker and the calorimetry are compact enough to fit inside the CMS solenoid which generates a powerful magnetic field of 4 T. Outside the magnet are the large muon detectors, which are inside the return yoke of the magnet. ALICE (A Large Ion Collider Experiment) is another big scale dedicated heavy ion experiment, optimized to study heavy ion collisions. Pb-Pb nuclei collisions will be studied at a centre of mass energy of 5.5 TeV per nucleon. The resulting temperature being enough to generate a quark-gluon plasma at temperature much higher than RHIC energy. ATLAS (A Toroidal LHC ApparatuS) is the biggest detector which has been designed to observe phenomena that involve highly massive particles, which were not observable using earlier lower-energy accelerators and might shed light on new theories of Particle Physics beyond the Standard Model. The LHCb (standing for Large Hadron Collider beauty where "beauty" refers to the bottom quark) experiment is constructed for b-Physics experiment, particularly aimed at measuring the parameters of CP Violation in the interactions of b-hadrons (heavy particles containing a bottom quark). TOTEM (Total Cross Section, Elastic Scattering and Diffraction Dissociation) is another small detector experiment which is ready to measure total cross section, elastic scattering and diffractive processes. LHCf (Large Hadron Collider forward) is a special

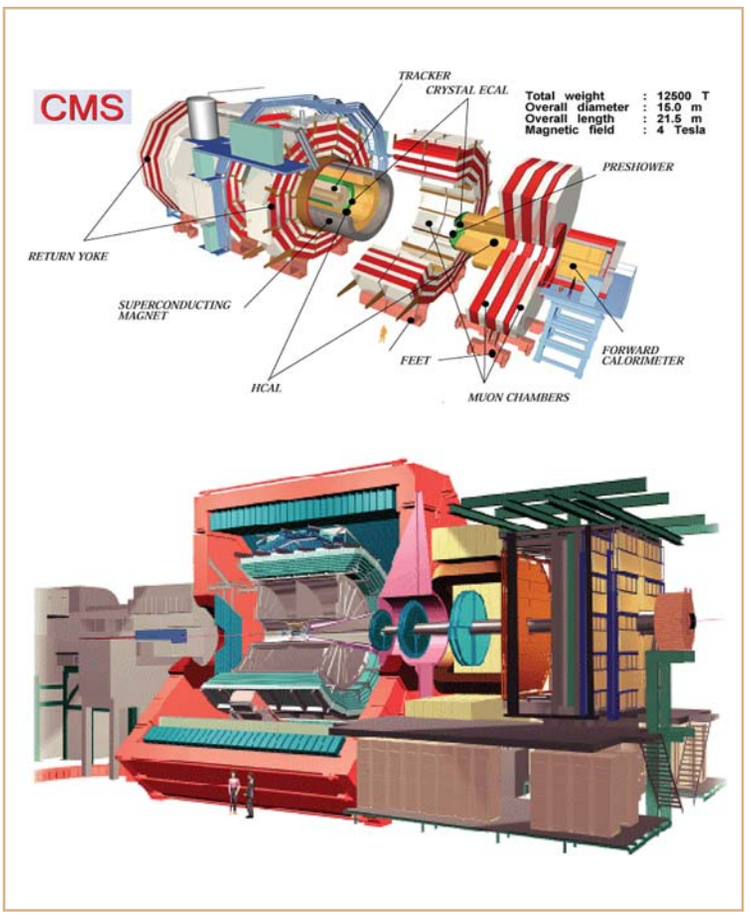


Fig. 8: The CMS (left) and ALICE (right) detectors

purpose LHC experiment for astroparticle (cosmic ray) Physics. It is to study the particles generated in the forward region of collisions, those almost directly in line with the colliding proton beams.

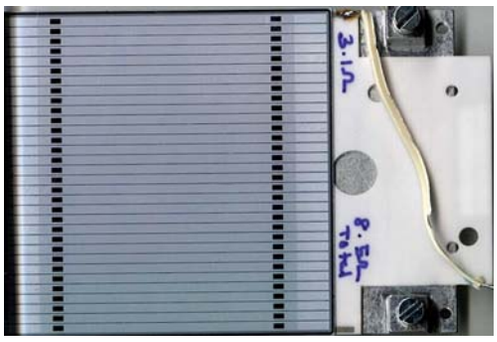
Heavy Ion Programme at LHC

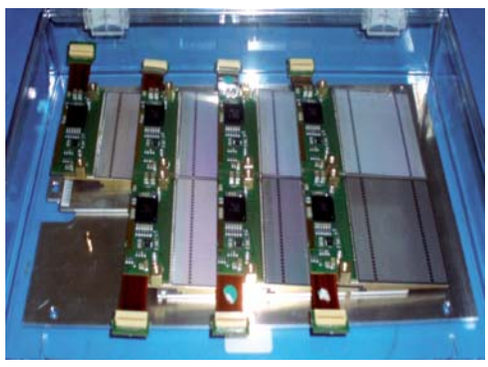
Three experiments, ALICE, CMS and ATLAS will collect data both for p+p at 14 TeV per nucleon and Pb+Pb at 5.5 TeV per nuceon. ALICE is a detector system dedicated to heavy ion physics. The requirements include large coverage to low transverse momentum, excellent particle identification and specialized detectors for specific channels of interest. ATLAS and CMS are detectors designed primarily for discovering the Higgs boson, supersymmetric particles and other new Physics. Both detectors have excellent calorimetry with large coverage and inner silicon detectors for charged particle tracking. Thus, experiments at LHC are well equipped and despite only one month of heavy ion running per year, the large rate capabilities of these detectors make the programme very promising.

BARC participation in CMS programme

The Nuclear Physics Division of BARC is participating in CMS experiment, particularly on CMS heavy ion programme. Analysis of simulated data shows, that the CMS detector is a powerful tool for studying charged particle multiplicity (event by event basis), azimuthal asymmetry of particle production, quarkonia and heavy quark production, jets, photons, Z^0 and diffractive physics at ultra peripheral collisions. The cross section of many hard probes such as flavorless mesons with hidden charm and bottom (J/ψ and Υ) as well as those with open flavor (D and B mesons), energetic photons, electro weak gause boson (W and Z^0) and high P_T jets of the order of magnitude larger at LHC energies as compared to RHIC. Partons with high transverse momentum are predicted to suffer radiative and collisional energy loss in the plasma suppressing the yield of jets as compared to a p+p collision. The measured quarkonia yields depend on the high energy density partonic matter created in the collision. The abundance of variety of these hard probes at the LHC makes study of partonic energy loss, possible.

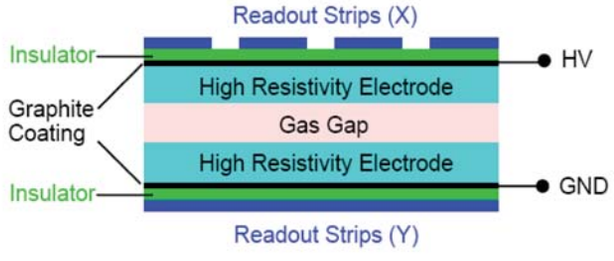
Detector Micromodule

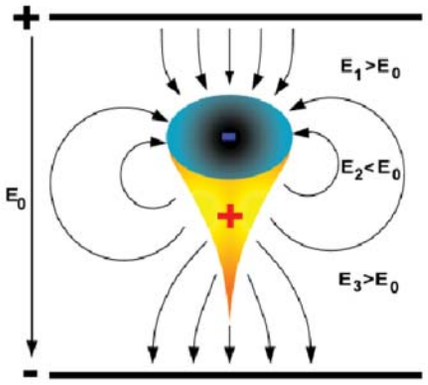




Box D: **The diagram on the left shows the 32 strip silicon sensors fabricated at BEL, Bengaluru in collaboration with BARC. The diagram on the right shows a micromodule assembly. The detector has a geometry of 63 mm x 63 mm and it incorporates 32 P^+strips with a width of 1.78 mm with a pitch of 1.9 m. These sensors have low leakage currents of the order of 10nA / cm^2 per strip and high breakdown voltage of >500 V.**

The participation of BARC in CMS programme includes both physics and hardware contributions. The Electronics Division in collaboration with BEL has supplied about 1000 silicon strip detectors (see Box D) which will be used in CMS pre-shower detector in the forward EM calorimeter. These silicon sensors will be providing crucial information to distinguish whether the particle is a neutral pion or a high energy gamma radiation. NPD is also involved in fabrication and assembly of Resistive Plate Chambers (RPC), a new type of detector (see Box E) which will be used to detect the passage of a muon. Initially, ten RPCs have been supplied to CMS which were assembled and tested at NPD RPC lab. BARC is also committed to supply another 80 RPCs as part of the CMS detector upgrade programme. As part of the CMS Physics programme, we are looking into three important signals: (i) Upsilon production in Ultra Peripheral Collisions (UPC) (ii) Z^0 production in central Pb+Pb collisions and (iii) B meson production through B to j /ψ decays. The upsilon in UPC will probe the gluon distribution function where as Z^0 production will be sensitive to quark distribution functions. Both these signals are important to study the nuclear shadowing effect by comparing the Pb+Pb yield with p+p data. The B meson production will be sensitive to the properties of the QGP medium. The p_T distribution of B meson will indicate how the b-quark





Box E: **The Resitive Plate Chambers (RPC) are gaseous parallel plate avalanche detectors (a new type of detector) which are being used in high energy experiments to trigger the passage of a charged particle like muon. In avalanche mode, it can have detection efficiency above 98% and time resolution down to pico second range. Advantages as compared to other detectors are the robustness, simplicity of construction and it can cover a large area. These detectors are expected to work for several years in radiation environment. The diagram at the left shows a schematic picture of a RPC geometry which consists of two electrode plates (made of backelite or glass) with a high volume resistivity between 10^7 and 10^{12} ohm-cm and separated by a small gas gap of the order of a few mm. The gas could be a mixture of $C_2H_2F_4$/i-C_4H_{10}/SF_6 (85:5:10). The voltage applied is of the order of a few kV creating a uniform electric field about 100 kV/cm. When a charged particle (a muon for example) passes through the gas gap, the gas atoms are ionized along its path. The free electrons undergo further multiplications leading to a Townsend avalanche. Finally, the electrons are drifted towards the anode and ions reach the cathode. The charges in the resistive electrodes cause the high voltage and thus the electric field in gas gap to drop locally around the initial avalanche which induces voltage in the read out strips. Due to high resistivity of the electrodes, the avalanche region is highly localized and the rest of the counter area remains sensitive to the particles.**

loses energy in the medium. Specific parts of the data analysis will be carried out at BARC. This involves setting up of analysis software and high speed connectivity for grid computing. Presently key Physics analysis problems are carried out through simulations. A Tier-2 grid computing centre is currently being established at TIFR which will have a very high speed ink to CERN. The Tier-3 centre at BARC would be linked to TIFR via high speed links.

Summary

Relativistic heavy ion Physics has witnessed several paradigm shifts during the past decade, driven largely by experimental discoveries. The original expectation that the quark gluon plasma would be a simple state of matter characterized by largely perturbative interactions and transport processes, has fallen by the way side. It has been replaced with the understanding that the quark gluon plasma, accessible at RHIC, is a state of matter characterized by strong interactions among its constituents and by novel properties, such as a very low viscosity and large stopping power. Questions of immediate interest are the fundamental properties of QGP at the expected higher initial temperatures at the LHC- Will it remained strongly coupled ? Will it exhibit perfect flow ?. However, the RHIC experience has taught us that the very nature of important questions, changes in response to experimental data and it would be wise to anticipate that the same would hold true for heavy ion Physics at LHC energies. A compelling programme of more detailed investigations at RHIC is already underway, based on a series of detector upgrades to PHENIX and STAR, together with ongoing and future substantial increases in RHIC luminosity. The simultaneous progress on multiple energy frontiers at RHIC (PHENIX and STAR experiments), at the LHC (ALICE, CMS and ATLAS experiments) and at GSI / FAIR are certain to lead to new insights and a deeper understanding of the fluid nature of the quark gluon plasma.

Figure shows assembly and testing infrastructure at NPD-BARC. The lab has an associated storage area and is backed by a robust workshop for handling all the relevant mechanical jobs. The HV, LV, 4 channel gas mixing unit, 8 channel gas flow system and gas recovery unit are fully operational. The cosmic ray stand can handle eight RPCs of RE*/3 type at a time. Scintillators of the relevant sizes are under fabrication at BARC, Centre for Design and Manufacture and accordingly the cosmic hodoscope would be set up to study the chamber.

FIRST SERC SCHOOL ON MICRO MACHINING: A REPORT

Micro machining is gaining importance with the emergence of micro electronics and nano technology. Machining in 100 micron domain needs new set of precision machines, micro tools, machining techniques and optimization of parameters which are quite different from that of conventional machining. DST identified 'Micro Machining' as thrust area and 'First Micro Machining School' was organized by BARC and IIT(B) Mumbai during 2-7, June, 2008. Subsequently, IIT Kanpur and CMTI, Bengaluru will conduct such schools. The initiative has been taken to familiarize the researchers, academicians, students and entrepreneurs with micro machining concepts and culture and also to induce them to establish the necessary infrastructure and to develop human resources to meet the challenges in the upcoming field.

The School was inaugurated by Dr. R. B. Grover, Director, HBNI and Prof. Ashok Mishra, Director, IIT (B) Mumbai presided over the function. Dr. R.B. Grover highlighted the various activities initiated by BARC in these areas. He mentioned that BARC has established an advanced Micro Machining, Nano Finishing and Metrology Lab and concurrently collaborating with various national labs and educational institutes including IIT (B) Mumbai, IIT Kanpur, IIT Delhi, CSIO Chandigarh and BEL, Bengaluru. He further mentioned that various critical micro components and MEMS Pressure Sensors have been developed. He said that HBNI would be keen to participate in such schools in the future too.

Prof. Mishra has emphasized the need for accelerating the activities in this area to meet futuristic challenges. He appreciated the work being done in these areas jointly by BARC and IIT (B) Mumbai.

Dr. V.K. Suri, Member, National Advisory Committee brought out the relevance and importance of these fields for nuclear, space, defence and other strategic areas. Prof. Suhas Joshi, IIT (B) Mumbai made the

On the dais from left to right: Prof. S.K. Maiti, Dr. R.B. Grover, Prof. Ashok Mishra, Mr. Kulkarni, Dr. V.K. Suri and a section of the participants seen on the right side

introductory remarks and the vote of thanks was proposed by Dr. R. Balasubramaniam, BARC as organizing committee member.

Other dignitaries present during the occasion are Prof. S.K. Maiti, Head, Mechanical Engineering Department from IIT(B) Mumbai, Mr. Manjeet Singh, AD, DMAG, Mr. A.K. Singal, Head, CTD, Mr. Trilok Singh, Head, CrTD and Mr. M.M. Sharma, Head, C&IS from BARC, Dr. Dev and Dr. Lodha from RRCAT.

The course was offered to 40 selected participants from academia, research institutes and industries from various parts of the country. Regular lectures covering various topics in micro and nano machining like basics of manufacturing science, metrology, applications, research work being carried out in these areas of manufacturing, etc., were delivered by faculty from HBNI, BARC, IITs, ISRO, ARAI and from industries. Hands-on lab sections to manufacture real life micro machined components using various micro machining techniques viz. μ-turning, μ-milling, μ-drilling, μ-EDM, μ-ECM, μ-WEDM, PCM and excimer laser micro machining were conducted by Mr. Tarun Dewangan and his team from BARC and Prof. Ramesh Singh and his students from IIT(B). Visits were organized to BARC and L & T, Mumbai.

The school was a grand success with active participation from all over the country. It provided a platform for interaction and exposure to the participants for pursuing manufacturing research and technology realization.

Photograph of SERC School participants during their visit to BARC

SIXTEENTH NATIONAL SYMPOSIUM ON ENVIRONMENT : CONFERENCE REPORT

The Health, Safety and Environment Group of BARC, Mumbai in collaboration with Narora Atomic Power Station, Narora organized the 16th National Symposium on Environment at the Department of Environmental Sciences and Engineering, Guru Jambheswar University of Science and Technology, Hisar, Haryana during July 16 – 18, 2008 with the focal theme **"Ground Water Resources: Conservation and Management".** The symposium was organized by the Department of Environmental Science and Engineering, Guru Jambheswar University of Science and Technology, Hisar and was sponsored by the Board of Research in Nuclear Sciences, DAE. There were ten invited talks from experts across the country besides 100 contributed papers. There were 40 registered delegates from DAE and 50 delegates from different universities and institutes across the country in this three-day symposium.

In his inaugural address, Mr. V.P. Raja, Principal Adviser, DAE, Mumbai stressed upon ground water resources, its conservation and management in detail. He described his experiences in ground water resource management problems especially with reference to Maharashtra State. Dr. D.D.S. Sandhu, the Vice-Chancellor of the Guru Jambheswar Univerisity of Science and Technology, Hisar in his welcome address expressed serious concern over ground water resources, its scarcity and problems faced by the general population. He complemented the organizers for selecting the Guru Jambheswar University of Science and Technology, as the venue for holding the Sixteenth National Symposium on Environment and the topic of current interest as focal theme. The conference proceedings was released during the inaugural session. The proceedings were published by Vayu Education of India, New Delhi in the form of a book comprising all the invited talks and contributed papers.

The contributed papers accepted for the presentation were grouped into 6 groups comprising ground water for sustainable development - problems, perspectives and challenges, monitoring and modeling of pollutants and their transport, waste management, environmental radioactivity, environmental awareness and biodiversity. Of these, 37 papers were selected for oral presentation and remaining were presented as posters.

In the ten technical sessions, invited talks followed by oral presentations were made. The oral presentations covered topics of ground water resources, pollutant transport, air pollution, natural radioactivity levels in environment, bio-remediation processes for treatment of waste. Experts reviewed poster presentations and the prizes are awarded to six Best Posters.

In her invited talk Dr. Gabriele Voigt, invitee from IAEA and Director of IAEA laboratories provided in detail, the activities going on in IAEA. Dr. D. Muralidharan of National Geophysical Research Institute, Hyderabad in his invited talk, reviewed the current sustainable water development programmes in India, including

important problems, perspectives and challenges in the national water policy, surface water resources, ground water resources etc. in detail. He also covered surface water resources, ground water resources, drinking water resources as well as water supply management in detail in his presentation.

In his talk Dr. R.S. Antil of Department of Soil Sciences, CCS Haryana Agricultural University, Hisar reviewed ground water contamination problems due to the excessive application of fertilizers, pesticides and from sewage water. He also reviewed the occurrence and distribution, sources of ground water contamination, fertilizer production and its application.

Dr. P.C. Verma of Health Physics Division BARC Mumbai, in his invited talk, reviewed the impact assessment of nuclear power plants using 25 years of environmental radioactivity monitoring data collected at Tarapur, Maharashtra.

Mr. R. Bhattacharya of Atomic Energy Regulatory Board, Mumbai briefly presented the environmental monitoring programme, instrumental procedures used and the results obtained, in his invited talk. He reviewed the environmental awareness, legislation and regulation policies adopted in Indian nuclear power programme. Brief account of environmental legislation in India, Water Act, Air Act, Environmental Protection Act was also presented by him.

In his invited talk Mr. D.K. Goyal of the Nuclear Power Corporation of India Ltd., outlined the supply and demand of energy, Indian power system, major energy options, nuclear power and besides the environmental impact assessment studies of nuclear power plants, environmental monitoring schedule and the radiation dose received by the general population.

Dr. R.P. Narwal of Department of Soil Sciences, CCS, Haryana Agricultural University, Hisar reviewed the influence of sewage water and industrial effluents on soil and plant health in detail in his presentation. Sewage water and industrial effluents generated in various cities in India, composition of sewage sludge, its effect on soil characteristics, effects of sewage water and industrial effluents on plants were discussed in detail in the presentation.

In her invited talk on ecological engineering – principles and applications, Dr. Anubha Kausik of Department of Environmental Sciences and Engineering, Guru Jambheswar University, spoke on how the ecosystem could be engineered to find solutions to various environmental problems.

Mr. V.D. Puranik, of the Environmental Assessment Division, BARC, Mumbai, presented in detail the environmental surveillance of front-end fuel cycle facilities of Indian nuclear energy programme in his invited talk.

In the concluding secession, chaired by the Vice Chancellor of the Guru Jambheswar University of Science and Technology the speakers emphasized the importance of ground water modeling, resources and management. The deliberations had also outlined few action plans to act upon the ground water resources, conservation and management. The proceedings of the symposium were well covered by the local media and helped in creating awareness among general public.

67TH AND 68TH BRNS-IANCAS NATIONAL WORKSHOPS ON RADIOCHEMISTRY AND APPLICATIONS OF RADIOISOTOPES : A REPORT

The 67th BRNS-IANCAS National Workshop on Radiochemistry and Applications of Radioisotopes was held at the Department of Physics, Dr. Babasaheb Ambedkar Marathwada University (Dr.BAMU), Aurangabad, Maharashtra during 11-18 August, 2008. The Fifty delegates included faculty and research students from different Science departments of the Dr. BAM University and its affiliated colleges in and around Aurangabad, Andur, Omerga, Beed, Nanded, Ashti and Pune participated in this workshop.

The workshop was formally inaugurated by Dr. Tulsi Mukherjee, Director, Chemistry Group of BARC in a function presided over by Prof. A.G. Khan, Director, Board of College and University Development, Dr. BAM University. Prof. Behere welcomed the resource persons, delegates and guests and Prof. K.M. Jadhav, Head, Physics Department who was also the Convener of the workshop, briefed about the various scientific activities perused by the Physics department. Prof. Jadhav added that Dr. BAMU is one of the Indian universities which offered M.Sc. in Nuclear Physics and he hoped that the workshop would definitely strengthen the association between university and BARC, for further research activities. The workshop course coordinator Mr. S. Jeyakumar, RACD, BARC briefed the audience about the course contents of the workshop.

Dr. V.K. Manchanda, Head, RCD, BARC and President, IANCAS emphasized the various activities of IANCAS to promote Nuclear Science in general and Radiochemistry in particular. He spoke on the world

At the Inauguration of the 67th BRNS-IANCAS Workshop: (L-R): Dr. Tulsi Mukherjee, Director, Chemistry Group, BARC, Prof. A.G. Khan (Dr. BAMU); Dr. V.K. Manchanda, Head, RCD, BARC and Prof. K.M. Jadhav (Dr. BAMU)

At the Valedictory function of the 67th workshop: Dr. S. K. Aggarwal, Head, FCD, BARC addressing the gathering.

scenario of nuclear energy including the Indian status where he justified the option of using nuclear energy for sustainable development of India.

Dr. Mukherjee, in his inaugural address, appreciated the painstaking efforts of IANCAS to conduct such workshops at national level to popularize the subject of Radiochemistry and applications of radioisotopes for the welfare of mankind. Dr. Mukherjee provided the details of various programmes through which the students and faculty members can join BARC for coordinated research programmes.

While presiding over the function, Prof. A.G. Khan said that he and his university were privileged to have this workshop during this Golden Jubilee year of Dr. BAM University. He expressed his concern at the non-preference of science education by the present generation and therefore, he highlighted the necessity of promoting basic Science education and research. He thanked IANCAS and requested them to arrange more such scientific interactions between the scientists and teachers.

Prof. Manchanda gave a key-note address on DAE and its programmes. Prof. R.G. Kulkarni, a well known Nuclear Physicist, gave a special talk on Marvels in Nuclear Science-an overview. Moreover, four half day workshops consisting of a lecture on the radioactivity and applications of radioisotopes for the welfare of mankind, two demo experiments using GM counter and NaI(Tl) gamma spectrometer and an interaction session with students and teachers were conducted by Dr. B.S. Tomar, Mr. M.Y. Ali, Dr. R.N. Acharya, Dr. A.U. Bhanu and Mr. P.S. Shankaran in two colleges and two schools. One of the school workshops was conducted in Marathi and all half-day workshops received appreciation from both teachers and students. Eighteen posters on Facts and Figures on Radioactivity prepared by IANCAS, were exhibited at the

Physics Department.

The Workshop concluded on 18th August, 2008 and Prof. (Dr). S.K. Aggarwal, Head, Fuel Chemistry Division, BARC was the Chief Guest at the Valedictory function. On behalf of IANCAS, he presented a GM-counter and a NaI(Tl) Gamma spectrometer to Prof. Nagnath Kotapalle, Hon'ble Vice Chancellor, Dr. BAM University, who presided over the function. Dr. Aggarwal, in his Valedictory address, pointed out that all kinds of energy needed to be reviewed with equal importance and depleted resources of fossil fuels made us realize the immediate demand of nuclear energy production. He suggested that Nuclear Chemistry should be a part of the university curriculum which would be helpful in promoting R&D inputs from universities to DAE. The Vice chancellor expressed his sincere thanks for conducting the workshop at Dr. BAMU and presenting two pieces of equipment to the university. In his speech, he added that his university staff and students understood the vast spectrum of radiochemistry and the immense contribution of this subject in the development of Science and Technology. Mr. S. Jeyakumar, summarized and replied to the feedback received from the delegates and he also thanked all the officials of BRNS, DAE, who contributed to the grand success of the workshop. Prof. K.M. Jadhav, the convener of the workshop proposed vote of thanks.

The 68th Workshop on Radiochemistry and Applications of Radioisotopes was held at the Department of Chemistry, Manipur University, Imphal during September 22-30, 2008. 15 lectures were delivered by expert speakers and 6 experiments based on application of radioisotopes were also demonstrated during the workshop. For the first time awards were given to the participants for the Best Three Questions asked during the workshop.

50 participants including the Faculty and research scholars from the host institutes as well as from the universities and colleges from the other north-east states like Nagaland and Assam participated in the Workshop. The presence of participants from different subject backgrounds like Chemistry, Physics, Life Sciences, Agricultural Sciences and Environmental Sciences made this workshop a multidisciplinary one.

The workshop was inaugurated on Sept. 22nd by Prof. Ambubha Singh, Vice-Chancellor, Manipur University, a former BARC Scientist from the 11th Batch of BARC Training School and the function was graced by the Chief guest Prof. V. C. Sahni, Director, Raja Ramanna Centre for Advanced Technology, Indore & Director Physics Group, BARC. Prof. Manihar Singh, Chairman, Workshop Organizing Committee and former Head, Department of Chemistry, MU, Imphal welcomed the guests. He lauded the efforts of IANCAS and BARC in educating the public by providing detailed information through organizing these workshops.

In his inaugural speech, Prof. Ambubha Singh focused on the role of Nuclear Scientists in harnessing the beneficial uses of Nuclear Energy and thanked IANCAS for choosing this venue to organize the workshop. He pointed out that this workshop would be an eye-opener for the people from this region and asked the participants to take a serious note to initiate the collaboration programmes with the Nuclear Scientists.

Prof. V. C. Sahni gave an elaborate lecture on the information and facility available at Raja Ramanna Centre for Advanced Technology, Indore. Prof. Sahni also gave an invitation to the participants to send their students for a short term training course at RRCAT, Indore and make use of the facilities in their research work.

Dr. V. K. Manchanda, President, IANCAS & Head RCD gave an overview of the IANCAS activities and the workshops held at various educational institutes since its (IANCAS) formation. He explained that the purpose of conducting workshops in academic institutes was

At the Inauguration of the 68th workshop (L-R): Dr.V.K. Manchanda, Head, Radiochemistry, BARC, President, IANCAS, Dr. R.K. Hemakumar Singh, M.K. Saxena, Prof. Ambubha Singh, Vice-Chancellor, Manipur Univ., Dr. V.C. Sahni, Prof. Manihar Singh, Dept. of Chemistry.

to expose the teaching community and the research scholars to Radiochemistry and to motivate them to this field of exciting science. While delivering the keynote address on "DAE at a Glance" ("The Atomic Energy Programme in India") Prof. Manchanda gave the present scenario of Indian research and power reactors and discussed about the future plans.

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Dr. M. K. Saxena, coordinator of the workshop and Jt. Secretary, IANCAS explained the contents of the programme for the entire period of the workshop. He also stressed the importance of conducting the 68th BRNS-IANCAS National Workshop on Radiochemistry and Applications of Radioisotopes at the Department of Chemistry, Manipur University, Imphal being the far north-eastern state of the country.

Prof. R. K. Hemakumar Singh, Convenor, Workshop Organizing Committee and Head, Department of Chemistry, MU welcomed all the guests including the resource persons and the participants from the north-eastern states. He also lauded the efforts taken by IANCAS and BARC in conducting this 68th BRNS-IANCAS National Workshop on Radiochemistry and Applications of Radioisotopes at the Department of Chemistry, Manipur University, Imphal under elaborate security measures.

A school workshop was conducted in the Manipur University premises where 30 students from 11th and 12th Standards from Herbert School, Imphal participated.

Dr. V. Venugopal, Director, RC&I Group, BARC, on 29th Sept, 2008 presented an interactive

At the Valedictory of the 68th workshop:(L-R) Dr. V. Venugopal, Director, RC & I Group, BARC handing over the counting equipment to the university. Seen are Prof. R.K. Hemakumar Singh, Prof. H.N.K. Sarma, Pro-Vice Chancellor and Prof. Manihar Singh

and intensive question-answer session on Application of Radioisotope in Health and Industry, organized by the UGC in Manipur University campus which was telecast on National Television Channel during the UGC curriculum. In his valedictory address, Dr. Venugopal gave a detailed account of the common people's perception of Nuclear Energy and compared nuclear energy with other forms of energy for the production of electricity. He traced back the green and white revolutions and encouraged universities to contribute in nation building programmes. He handed over the two instruments.

Special security arrangements were made during this workshop. The valedictory function was graced by Prof. H. N. K. Sarma, Pro-Vice Chancellor, MU and Dr. V. Venugopal, Director, RC& I Group being the Guest of Honour from BARC. Prof. Manihar Singh, Chairman, Workshop Organising Committee thanked the authorities of IANCAS, especially Dr. V. K. Manchanda, President IANCAS for agreeing to hold this workshop in his Department. Prof. H. N. K. Sarma, Pro-VC, MU congratulated Prof. R. K. Hemakumar Singh in convincing IANCAS and BARC to hold this workshop in the university premises and to gather scientists at this place.

Dr. A. C. Deb, practical coordinator of the workshop, presented a formal vote of thanks to the authorities of BARC for conducting the workshop in this security threatened region and the university for making all the arrangements for the success of the workshop.

भा.प.अ. केंद्र के वैज्ञानिकों को सम्मान
BARC SCIENTISTS HONOURED

इंडियन सोसाइटी फॉर इलैक्ट्रोअनालिटिकल कैमिस्ट्री द्वारा मुन्नार, केरल में फरवरी 23-25, 2008 के दौरान आयोजित डीएम-ई एल ऐ एन टी ई - 2008 में ईंधन रसायन प्रभाग के तीन शोध-पत्रों को पुरस्कार दिया गया।

Three papers presented at the Discussion Meet organized by the Indian Society for Electro-analytical Chemistry on Electro Analytical Techniques and thier Applications (DM-ELANTE-2008) held at Munnar, Kerala from Feb. 23-28, 2008 were awarded prizes.

जे.वी. कामत, एन. गोपीनाथ, एच.एस. शर्मा तथा ए.के.अग्रवाल द्वारा लिखित स्टडीज़ ऑन स्क्वेअर वेव ऍनोडिक स्ट्रिप्पिंग वोल्टामीटरी फॉर ट्रेस लेवेल्स ऑफ गेलियम एम्पलोइंग बिसमथ फिल्म इलेक्ट्रोड नामक पहले शोध-पत्र को द्वितीय पुरस्कार से सम्मानित किया गया।

The first paper entitled "Studies on Square Wave Anodic Stripping Voltammetry for Trace Levels of Gallium Employing Bismuth Film Electrode" by J.V. Kamat, N.Gopinath, H.S. Sharma and S.K. Aggarwal was awarded Second Prize.

राजेश वी. पई, रतीकांता मिश्रा, एस.के. मुखर्जी, वी. वेणुगोपाल द्वारा लिखित "स्टडीज़ ऑन इलेक्ट्रिकल प्रोपरटीज़ ऑफ पीज़डटीज़ कंटेंनिंग वेरीयिंग एमौंटस ऑफ रेयर अर्थस (सीई, पीआर एंड एनडी) बई इम्पेंडंस स्पेक्ट्रोसकोपी" नामक द्वितीय शोध-पत्र को द्वितीय पुस्कार से सम्मानित किया गया।

The second paper entitled "Studies on Electrical Properties of PZTs Containing Varying Amounts of Rare Earths (Ce, Pr and Nd) by Impedance Spectroscopy" by Rajesh V. Pai, R. Mishra, S.K. Mukerjee and V. Venugopal was awarded the Second Prize.

पी.सी. पान्डे, जी. सिंग, एच.एस. शर्मा एवं एस.के. अगरवाल द्वारा लिखित "स्टडीज़ ऑन इलेक्ट्रोपोलिमेराइज़ेशन ऑफ इन्डोल एन्ड सबस्टिट्यूटिड इन्डोल इन एसिटोनाइट्राईल" नामक तीसरे शोध-पत्र को तृतीय पुस्कार से सम्मानित किया गया।

The third paper entitled "Studies on Electropolymerization of Indole and substituted Indole in Acetonitrile" by P.C. Pandey, G. Singh, Dept. of Applied Chemistry Institute of Technology BHU, Varanasi, H.S. Sharma and S.K. Aggarwal was awarded the Third Prize.


Dr. Ms. J.V. Kamat

डॉ. जे.वी. कामत ने मुंबई विश्वविद्यालय से एम.एस.सी की उपाधि प्राप्त की । इन्होंने भाभा परमाणु अनुसंधान केंद्र में वर्ष 1982 से कार्यभार संभालने के पश्चात् मुंबई विश्वविद्यालय से रसायन विज्ञान में पीएच.डी प्राप्त की। इलेक्ट्रोएनालिटिकल केमिस्ट्री ऑफ एक्टिनाइडस इनके अनुसंधान का मुख्य क्षेत्र है। आप नाभिकीय ईंधन साइकल में इलेक्ट्रोएनालिटिकल के विभिन्न अनुप्रयोगों के विकास में व्यस्त हैं। आप इन्डियन सोसाइटी फॉर इलेक्ट्रोएनालिटिकल केमिस्ट्री (आइएसईएसी) के कोषाध्यक्ष भी हैं।

Dr. J.V. Kamat obtained her M. Sc. Degree from Mumbai University. She joined BARC in 1982. After joining, she obtained her Ph. D. (Chemistry) from Mumbai University. Her main field of research is electroanalytical chemistry of actinides. She is involved in developing and employing various Electroanalytical Techniques for different applications in the nuclear fuel cycle. She is the Treasurer of the Indian Society for ElectroAnalytical Chemistry (ISEAC).

श्री. एन. गोपीनाथ ने वर्ष 1973 में श्री वेंकटेश्वरा विश्वविद्यालय, तिरुपति से एम.एस.सी की उपाधि प्राप्त की। इन्होंने वर्ष 1977 में भाभा परमाणु अनुसंधान केंद्र के रेडियोकेमिस्ट्री प्रभाग में कार्यभार संभाला। इस समय ये भाभा परमाणु अनुसंधान केंद्र के ईंधन रसायन प्रभाग में कार्यरत हैं। भाभा परमाणु अनुसंधान केंद्र में कार्यभार संभालने के पश्चात यह नाभिकीय ईंधन सामग्री की गुणवता


N. Gopinath

के क्षेत्र में सक्रिय रूप से व्यस्त हैं तथा नाभिकीय ईंधन सामग्री के निर्धारण हेतु नये इलेक्ट्रोएनालिटिकल कार्यविधि का विकास किया। नाभिकीय ईंधन सामग्री के इलेक्ट्रोएनालिटिकल रसायन क्षेत्र में इनके कई अनुसंधान शोध-पत्र हैं। इस समय आप एनालिटिकल उद्देश्यों हेतु नेनों सामग्री के विशेष गुणों के शोषण का अध्ययन करने में व्यस्त हैं। आप इन्डियन सोसाइटी फॉर इलेक्ट्रोएनालिटिकल केमिस्ट्री (आइएसईएसी) के सचिव हैं ।

Mr. N. Gopinath received M.Sc. degree from Sri Venkateswara University, Tirupati in 1973. He joined the Radiochemistry Division, BARC in 1977. Presently he is working in the Fuel Chemistry Division, BARC. Since he joined BARC, he has been actively involved in the field of quality assurance of nuclear fuel materials and has developed new electroanalytical methodologies for determination of nuclear fuel materials. He has authored a good number of research papers in the field of electroanalytical chemistry of nuclear materials. Presently he is involved in studies on exploitation of the significant electrocatalytic properties of nanomaterials for analytical purposes. He is the Secretary of the Indian Society for ElectroAnalytical Chemistry (ISEAC).


Dr. H.S. Sharma

डॉ. एच.एस.शर्मा ने वर्ष 1978 में इलाहाबाद विश्वविद्यालय से डी.फिल करके भाभा परमाणु अनुसंधान केंद्र के रेडियोकेमिस्ट्री प्रभाग में कार्यभार संभाला तथा इस समय ये भाभा परमाणु अनुसंधान केंद्र के ईंधन रसायन प्रभाग के इलेक्ट्रोकेमिस्ट्री अनुभाग की अध्यक्षता कर रहे हैं। नाभिकीय ईंधन सामग्री का सही एवं यथार्थ निर्धारण हेतु विश्लेशनात्मक क्रिया-पद्धति तथा पोलिमर्स एवं नेनो-स्केल सामग्री संचालन का इलेक्ट्रोकेमिकल संयोग तथा स्पेक्ट्रोसकोपिक एवं माइक्रोसकोपिक तकनीकों के उपयोग का चरित्रांकन इनकी अधिकांश रुचि में शामिल है। नाभिकीय ईंधन सामग्री में यू एवं पीयू का सही एवं यथार्थ निर्धारण हेतु कौलोमीट्रिक विकास में इनका विशेष योगदान है। इन्होंने इलेक्ट्रोकेमिकल अनुसंधान में वोल्टामीट्रिक एवं इलेक्ट्रकेमिकल क्वुआर्ट्ज् क्रिस्टल माइक्रोबेलंस तकनीकों का परिचय दिया। डॉ शर्मा ने "पोहांग यूनिवर्सिटी ऑफ साइंस एंड टेक्नालोजी साउथ कोरिया में "अतिथि विद्वान" की हेसियत से इलेक्ट्रोकेमिकल सिन्थिसिज़ एवं फ्लोरीन आधारित पोलिमर्स के चरित्रांकन पर काम किया । नेनो -स्केल निक्षेप के पीबी एवं जीए के विभिन्न कार्यद्रव पर सिलेन प्रतिस्थापित पोलिफ्लोरीन के कार्यसंचालन हेतु इलेक्ट्रोकेमिकल संयोग के लिए अर्जित दक्षता को एफसीडी में विस्तृत किया गया। डॉ शर्मा विभिन्न भारतीय विश्वविद्यालयों में पीएच.डी शोधों का मूल्यांकन हेतु परीक्षक मंडल में कार्यरत हैं तथा सीसीएस यूनिवर्सिटी, मेरठ में अनुसंधान निर्देशक भी हैं। डॉ शर्मा इन्सटिट्यूट ऑफ मिनरल्ज़ एंड मेटीरियल्ज़ टेक्नॉलोजी, भुवनेश्वर में डीएसडी समीक्षक, डीआरडीओ एवं डीएई-बीआरएनएस अनुसंधान प्रस्ताव के एक विशेषज्ञ की हेसियत से काम कर रहे हैं तथा बीआरएनएस परियोजना के प्रमुख सहयोगकर्ता हैं। हाल में ही डॉ शर्मा को इलेक्ट्रोकेमिकल रिसर्च में उत्कृष्ट योगदान देने के लिए इन्डियन केमिकल सोसाइटी के द्वारा "प्रोफैसर एस.एस. सन्धू पुरस्कार" से सम्मानित किया गया ।

Dr. H.S. Sharma joined the Radiochemistry Division, BARC in 1978, after completing D.Phil. from University of Allahabad and is presently Head, Electrochemistry Section, Fuel Chemistry Division, BARC. His major fields of interest include development of analytical methodologies for precise and accurate determination of actinides in nuclear fuel materials and electrochemical synthesis of conducting polymers and nano-scale materials and their characterization employing spectroscopic and microscopic techniques. He has contributed significantly to the development of coulometric method for precise and accurate determination of U and Pu in nuclear fuel materials. He has introduced voltammetric and Electrochemical Quartz Crystal Microbalance techniques in electrochemical research. Dr. Sharma worked as a "Visiting Scholar" at Pohang University of Science and Technology, South Korea on electrochemical synthesis and characterization of fluorene based conducting

polymers. The expertise gained is being extended in FCD, for the electrochemical synthesis of silane substituted polyfluorene conducting polymers and nano-scale deposits of Pb and Ga at different substrates. Dr. Sharma is serving on the board of examiners for evaluating Ph.D. thesis at different Indian universities and is a research guide of CCS University, Meerut. Dr. Sharma is serving as an expert for evaluating/reviewing DST, DRDO and DAE-BRNS research proposals and is a Principal collaborator to BRNS project at Institute of Minerals & Materials Technology, Bhuvaneshwar. Dr. Sharma has been recently awarded, "Prof. S. S. Sandhu Award " (2007 -08) by the Indian Chemical Society for his outstanding contributions in Electrochemical Research.

Dr. S.K. Aggarwal

डॉ. एस.के. अग्रवाल, जुलाई 2005 से भाभा परमाणु अनुसंधान केंद्र के ईंधन रसायन विज्ञान प्रभाग की अध्यक्षता कर रहे हैं तथा होमी भाभा नैशनल इन्सटिट्यूट में रसायन विज्ञान के प्रोफैसर हैं। इन्होंने वर्ष 1972 में भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र के 16वें वर्ग से स्नातकता प्राप्त करके होमी भाभा पुरस्कार प्राप्त किया। मुंबई विश्वविद्यालय से पीएच.डी की डिग्री प्राप्त करके इन्होंने वर्जीनिया विश्वविद्यालय, यूएसए से पोस्ट - डोक्टोरल प्रशिक्षण प्राप्त किया। डॉ. अग्रवाल को वर्ष 1996 में इन्डियन सोसाइटी फॉर मॉस स्पेक्ट्रोमीटरी च्आइएसएमएएसछ के द्वारा एमिनन्ट मॉस स्पेक्ट्रोमीटरिस्ट पुरस्कार से सम्मानित किया गया तथा हाल में ही इन्हें डीएई 2006 का स्पेशल कंट्रिब्यूशन अवार्ड भी प्रदान किया गया। आप एटोमिक मॉस स्पेक्ट्रोमीटरी एवं अल्फा स्पेक्ट्रोमीटरी क्षेत्र के विषेशज्ञ हैं तथा विभिन्न स्पेक्ट्रोमीटरिक तकनीकों में रुचि रखते हैं। इनकी अन्य रुचियों के क्षेत्र में लेज़र बेस्ड एनालिटिकल टेक्नीक्स, इलेक्ट्रोकेमिस्ट्री, एक्सरे स्पेक्ट्रोस्कोपी एवं सेपरेशन टेक्नीक्स जैसे सोलवंट एक्सट्रेक्शन आदि शामिल हैं। अंतर्राष्ट्रीय पत्रिकाओं में आपके 100 से अधिक प्रकाशन हैं तथा मुंबई विश्वविद्यालय एवं एचबीएनआइ के मान्यता प्राप्त पीएचडी निर्देशक भी हैं।

Dr. S.K. Aggarwal is Head, Fuel Chemistry Division, BARC since July 2005 and is a Professor of Chemistry at the Homi Bhabha National Institute (HBNI). He joined the 16th Batch of BARC Training School in 1972 and received the Homi Bhabha Award. He did his Ph.D. from Mumbai University and did his Post-Doctoral training at the University of Virginia, USA. Dr. Aggarwal was honoured with the Eminent Mass Spectrometrist Award by the Indian Society for Mass Spectrometry (ISMAS) in 1996 and was recently conferred with the DAE Special Contributions award 2006. He is a specialist in the field of atomic mass spectrometry and alpha spectrometry and is interested in various mass spectrometric techniques. His other areas of interest include laser-based analytical techniques, Electrochemistry, X-ray spectroscopy and Separation techniques like HPLC, solvent extraction etc. He has more than 100 publications in reputed international journals and is a recognized Ph.D. Guide of the Mumbai University and of HBNI.

Rajesh Pai

श्री. राजेश वी पई ने कोचीन यूनिवर्सिटी ऑफ साइन्स एन्ड टेक्नालोजी से एप्लाइड केमिस्ट्री में एम.एस.सी पूर्ण करने के उपरान्त वर्ष 1997 में भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र के 40 वें बैच से स्नातकता प्राप्त करके ईंधन रसायन प्रभाग में कार्यारंभ किया। इन्होंने विभिन्न तकनीकों से मिश्रित ऑक्साइडस के नेनो -साइज़ चूर्ण का चरित्रांकन एवं संयोजन का अनुभव प्राप्त किया है। मुख्यत: आप नाभिकीय पदार्थों हेतु सोल-जेल प्रकिया के विकास तथा उच्च स्तरीय सिरामिक्स तकनीक से जुड़े हैं। आप प्रतिबाधा स्पेकट्रोस्कोपी द्वारा विभिन्न फैरोइलैक्ट्रिक एवं पीज़ोइलैक्ट्रिक पदार्थ के इलेकट्रिकल चरित्रांकन में व्यस्त हैं।

Mr. Rajesh V. Pai joined the Fuel Chemistry Division, BARC after graduating from the 40th batch of Training School in the year 1997, after completing his M.Sc. (Applied Chemistry) from Cochin University of Science & Technology. He gained experience in synthesis and characterization of nano-size powders of mixed oxides by various techniques. He is mainly associated with the development of sol-gel process for nuclear materials and high technology ceramics. He is also engaged in the electrical characterization of various ferroelectric and

piezoelectric materials by Impedance Spectroscopy.


Dr. Ratikanta Mishra

डॉ. रतीकांता मिश्रा ने उत्कल विश्वविद्यालय से एम.एससी पूर्ण करने के उपरान्त भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र के 36वें बैच से स्नातकता प्राप्त करके वर्ष 1992 में भाभा परमाणु अनुसंधान केंद्र में कार्यारंभ किया। वर्ष 1999 में मुंबई विश्वविद्यालय से पीएचडी के पश्चात यूनिवर्सिटी ऑफ म्यूनिख, जर्मनी में पोस्टडाक्टरल रिसर्च किया। इस समय आप भाभा परमाणु अनुसंधान केंद्र के रसायन प्रभाग में कार्यरत हैं। केमिकल थरमॉडीनामिक्स एन्ड ट्रॉन्सपोर्ट प्रोपरटीज़ ऑफ ऑक्ज़ाइडस, एलॉइज एन्ड इन्टरमेटालिक कम्पौउंड आदि इनकी रुचि के क्षेत्र मे हैं ।

Dr. Ratikanta Mishra joined BARC in 1992, after completing M.Sc. from Utkal University and graduating from the 36th Batch of the BARC training School. He completed his Ph.D. from the University of Mumbai in 1999 and did his Post Doctoral research at the University of Munich, Germany. He is presently working in the Chemistry Division, BARC. His field of interest is Chemical thermodynamics & transport properties of oxides, alloys and intermetallic compounds.


Dr. S.K. Mukerjee

डॉ. एस.के. मुखर्जी ने नागपुर विश्वविद्यालय से रसायन विज्ञान में एम.एससी समाप्त करके परमाणु ऊर्जा प्रभाग में कार्यारंभ किया। इन्होंने वर्ष 1993 में मुंबई विश्वविद्यालय से पीएच.डी की डिग्री प्राप्त की। इस समय आप भाभा परमाणु अनुसंधान केंद्र के ईंधन रसायन विज्ञान प्रभाग में प्रोसस रसायन अनुभाग के अध्यक्ष हैं तथा मुंबई विश्वविद्यालय एवं होमी भाभा नैशनल इन्सटिट्यूट के भी मान्यता प्राप्त निर्देशक हैं । नाभिकीय तकनीक के अनुप्रयोग हेतु सिरामिक्स पदार्थों के विकास में इनकी रुचि है। इन्होंने प्रगतिशील ईंधन निर्माण हेतु नाभिकीय पदार्थों के सोल-ज्यल प्रक्रिया का विस्तृत रुप से अध्यन किया है।

Dr. S.K. Mukerjee joined the Department of Atomic Energy after completing his M.Sc. (Chemistry) from Nagpur University. He obtained his Ph.D. degree from Mumbai University in the year 1993. Currently he is heading the Process Chemistry Section of Fuel Chemistry Division, BARC and is a recognized Ph.D. Guide of Mumbai University and of Homi Bhabha National Institute. His area of interest involves the development of ceramic materials for applications in Nuclear Technology. He has extensively studied sol gel processing of nuclear materials for advanced fuel fabrication.


Dr. V. Venugopal

डॉ. वी. वेणुगोपाल भाभा परमाणु अनुसंधान केंद्र के रेडियो केमिस्ट्री एन्ड आइसोटोप ग्रुप के निदेशक हैं। ये पीयू आधारित ईंधन के उच्च ताप ऊष्मागतिक एवं रसायन गुणवत्ता नियंत्रण क्षेत्र के विशेषज्ञ हैं। इन्होंने न्युकिलयर रिसर्च सेंटर, ज्यूलिच में रॉकेट जेट नूज़ल एन्ड टरबाइन ब्लेड हेतु निकल - बेस्ड बइनरी सुपर एलोइज़ तथा उच्च ताप में प्रबल धातु हेलाइड वेपर लेंम्प के विकास हेतु काम किया । उष्मीय विज्ञान एवं ठोस अवस्था रसायन के क्षेत्र में उत्कृष्ट योगदान के लिए आपको एनईटीज़डएससीएच-आइएससीएएस पुरस्कार से सम्मानित किया गया।

Dr. V. Venugopal is the Director, Radiochemistry & Isotope Group, BARC. He is a specialist in the field of high temperature thermodynamics and chemical quality control of Pu-based fuels. He has worked at the Nuclear Research Centre, Julich on the development of Nickel-based binary super alloys required for Rocket Jet Nozzle and turbine blades and also on the development of high intensity metal halide vapour lamps at high temperature. He has been honoured with NETZSCH-ITAS and ISCAS for his outstanding contributions in the field of thermal science and solid state chemistry respectively.

Portrait sketched by Dr. Homi J. Bhabha

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