

# Extending Collaboration with Indian Institutions

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Fermilab



# International Collaboration Activities

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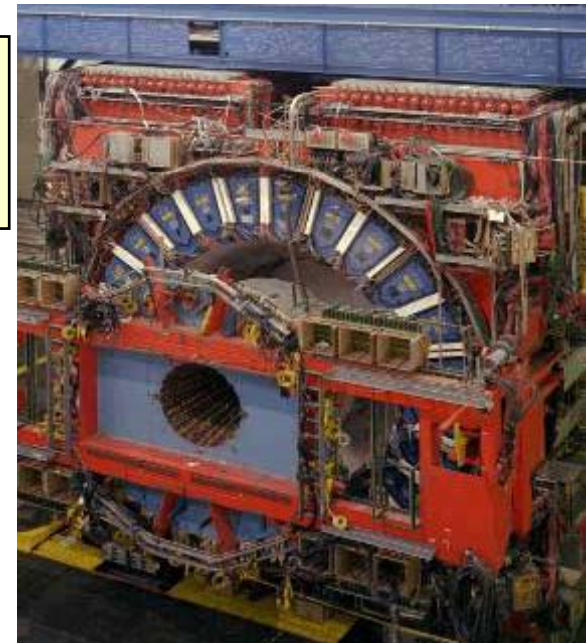
- Fermilab has a long tradition of National and International Collaboration.
- Recently US collaboration has help build the LHC, CMS and ATLAS detector at CERN.
  - Fermilab has a lead role in these activates.
- Fermilab is collaborating on the International Linear Collider through the GDE and also established direct bilateral collaborations with international laboratories.
  - DESY (Germany), KEK (Japan), INFN (Italy)
  - TRIUMF (Canada)
  - RRCAT (India), BARC (India), IUAC (India)



# International Collaboration



CDF  
11 Countries



D0  
18 Countries



MINOS  
6 Countries

CMS  
36 Countries





# How did it start...

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- It all started with a cup of coffee and three friends talking about the future of HEP, Fermilab and Indian collaboration.
  - D0 → CMS
- Prof. V. S. Ramamurthy and Dr. Anil Kakodkar: Get our scientists excited about the science and show that there is a mutual benefit to both sides.





# Strong Management Support





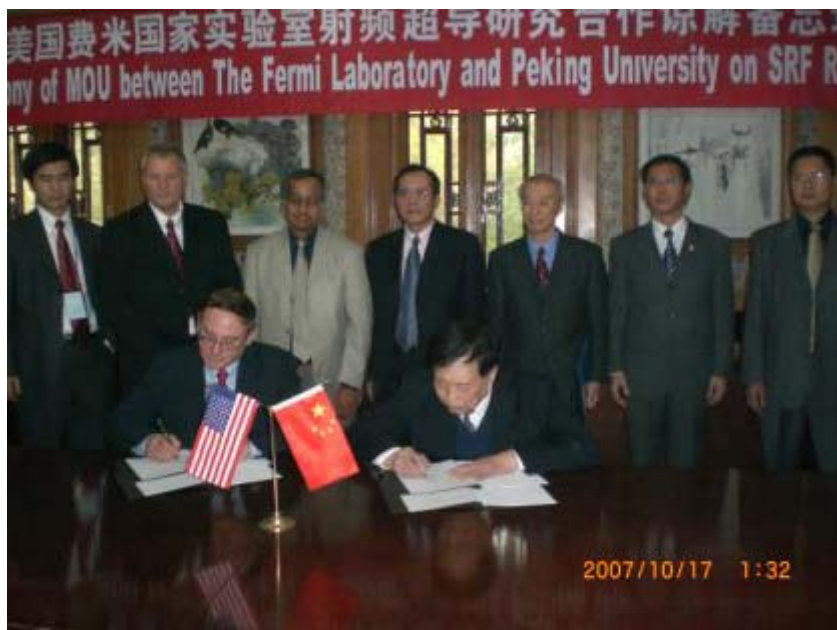
# International Accelerator Development

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- Several countries (India, China and Korea) have proposed to build large accelerators for domestic programs that uses SRF technology.
  - High Intensity Proton Accelerator
  - Next generation light source
  - Radioactive Ion Beam Facility
- CERN has proposed an upgrade of LHC using a superconducting Linac
- DESY is building a XFEL
- KEK and US programs have light sources and proton accelerators that uses SRF technology.

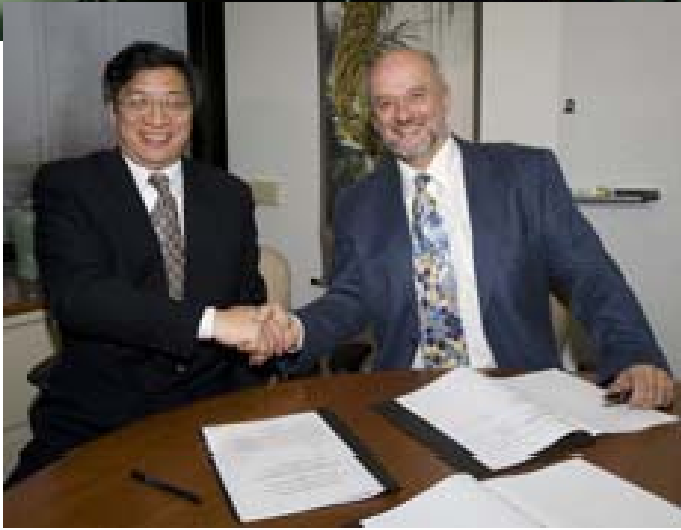


# Start of Talks with China



PKU

IHEP





# India HEP Collaboration in world

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- Indian scientists have been collaborating at CERN for decades.
- Its participation and contribution to LHC has given India an Associate Member State status with CERN.
- India has build accelerator and detector components for LHC/CMS.
- India also participates in experiments at KEK and DESY.





# Indo-US Science and Technology

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- Sharing a Common Vision for the New Millennium



- Indo-US Science and Technology Forum is established on March 21, 2000 to facilitate and promote the interaction, in India and the United States, of government, academia, and industry in science and technology.
- There are several other agreements in place for S&T collaboration and new agreements are being discussed.

<http://www.indousstf.org/>



## 20 Years of Indo-US HEP Collaboration

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- Indian Scientists have collaborated in a High Energy Physics Experiments from early 80's at Fermilab and other US laboratories.
- At Fermilab the collaboration started with Fixed Target Experiment and has now extended to D0 and Accelerator.
- Argonne National Laboratory has collaborated with India on Superconducting cavity development.
- Six Institutes from India collaborates on the STAR experiment at BNL.
- Many US laboratories have worked with Indian laboratories
- Indians are on staff of every US laboratories, universities and major US industries.



# Indo-US Collaboration History

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- Since the start of the discussion in Dec. 02 with Prof. Ramamurthy we have been making progress.
- Interaction Meeting on Linear Collider and Neutrino Physics was held in New Delhi, Nov. 03. (Attended by 19 US and 70 Indian scientists) Followed by visits to CAT & TIFR. (A detailed report was submitted to FNAL/DOE)
- Indo-US working group was established by Prof. Ramamurthy and Prof. Witherell, Director of Fermilab.
- Working group met at Fermilab in Aug. 04 and a program of collaboration was discussed. All US and 2 Indian members participated. Also present were several Indian scientists working at Fermilab.



# It's a long Road

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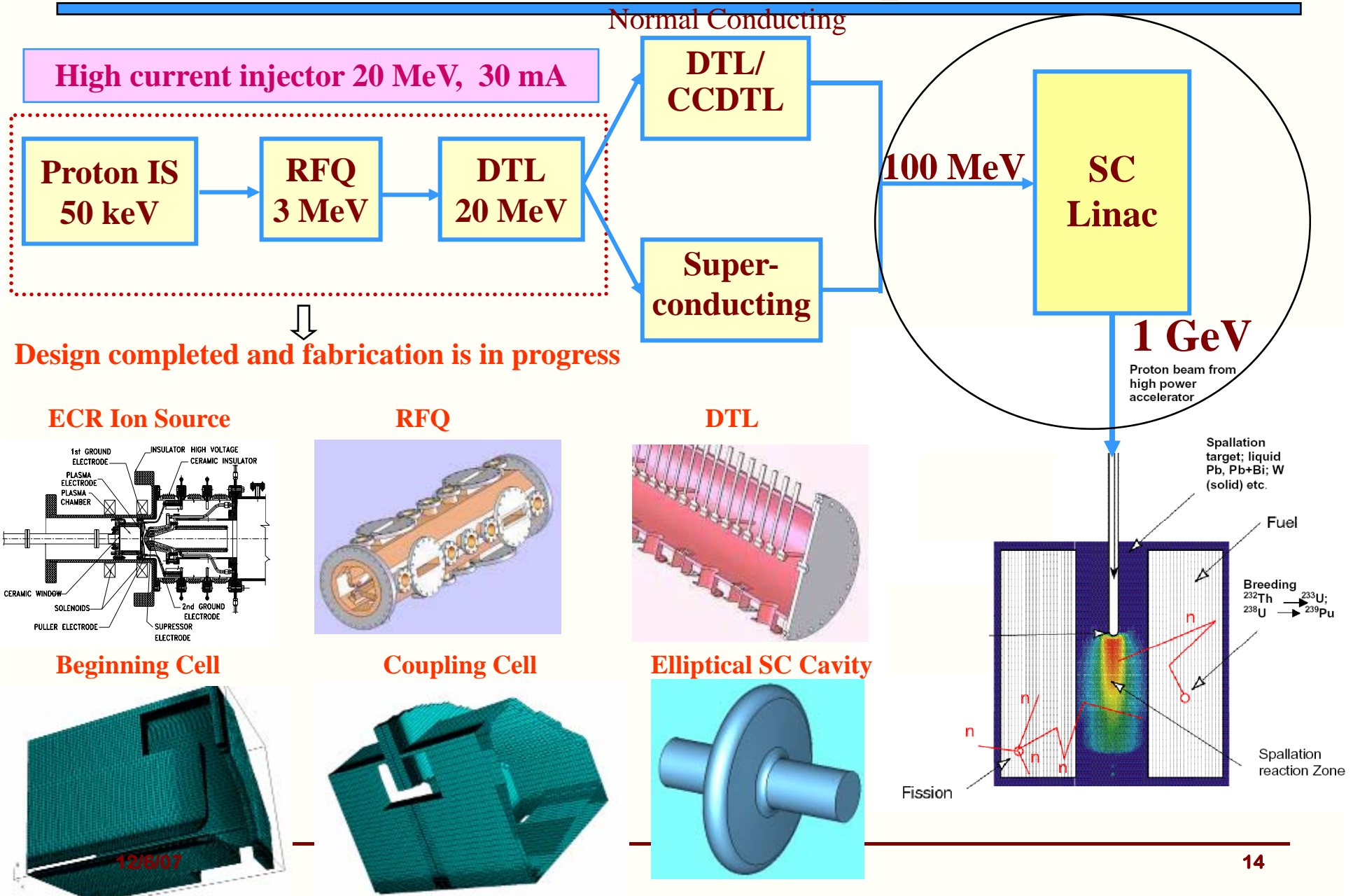
- 2004-2005 Several Visits
  - Fermilab Director Pier Oddone on India Collaboration
    - [http://www.fnal.gov/pub/today/archive\\_2006/today06-03-07.html](http://www.fnal.gov/pub/today/archive_2006/today06-03-07.html)
    - [http://www.fnal.gov/pub/today/archive\\_2006/today06-03-14.html](http://www.fnal.gov/pub/today/archive_2006/today06-03-14.html)
  - SLAC Director Jonathan Dofran on India Collaboration
    - <http://today.slac.stanford.edu/a/2006/03-06.htm>
  - Robin Staffin's Visit to India on ILC Collaboration
    - [http://www.linearcollider.org/newsline/readmore\\_20061214\\_feature1.html](http://www.linearcollider.org/newsline/readmore_20061214_feature1.html)
  - Barry Barish on India Collaboration
    - <http://www.linearcollider.org/newsline/archive/2006/20060316.html>
    - <http://www.linearcollider.org/cms/?pid=1000235>
  - Indian Media on our collaboration (Negative)
    - <http://www.indianexpress.com/story/1911.html>
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# Developing Collaboration With India



# Scheme for Accelerator Development for ADS



# Indus-II



Indus-2 Ring in the Tunnel



RF Cavities installed in Indus-2 Ring



12/6/07 Long Straight Section LS-6 Assembly



Transport Line-3 Joining on to Indus-2

# LHC Contributions



7080 Nos. Magnet Positioning System Jacks



MCS (1146 Units) & MCDO (616 Units)



Magnetic measurements teams- ~100 Man-years



5500 Nos. Quench Heater Power supplies( QHPS)



1435 Nos. Local Protection Units



A part of DAE's contributions installed in LHC Tunnel at CERN

12/6/07



# IUAC Linac Booster



**8 QWRs and superconducting solenoid in Linac module 1**

# Major Facilities Available at CDM, BARC



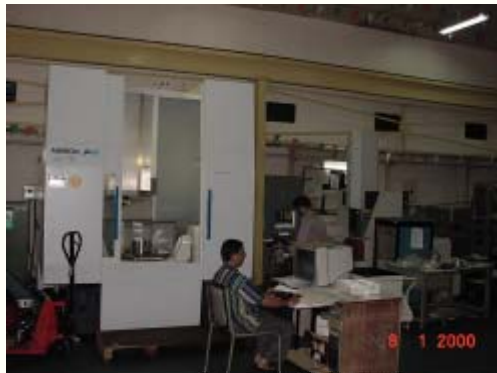
UPMC-850 CARAT S-ACCURATE CNC  
Range X: 850 mm Y: 1150 mm Z: 600 mm



LENGTH: 510 mm , ACCURACY: 0.004 mm



CNC Universal Boring And Milling Machine  
Table Area : 900X530 mm, Accuracy: 0.010 mm



CNC 5 AXES BORING & MILLING MACHINE  
Table Area: 600X600 mm, Positional Accuracy:0.01 mm



CNC VERTICAL BORING & MILLING CENTRE ,  
Table Area:900X720 mm, Accuracy :0.005mm



CNC Wire-Cut EDM Machine Super Cut 734  
X: 250 mm, Y : 350, U&V : 73, Accuracy :0.010 mm



CNC, Ultra Precision Mount Bed Lathe, Length : 400 mm  
Accuracy : 0.002 mm



3 Axis Coordinate Measuring Machine



NIKON MEASUROSCOPE  
MAGNIFICATION 1000 X

# Proposed SRF Infrastructure at RRCAT

- **RRCAT has proposed to build significant infrastructure to Fabricate, Process and Test SRF cavities**
  - **1200 sq meter building**
  - **Cavity Fabrication infrastructure including Electron Beam Welding Machine**
  - **Material Qualification Facility ( Eddy Current Scanner, RRR, Surface Characterization, SIMS, Photo Emission Analyzer and SEM)**
  - **Vacuum Annealing Furnace up to 1400°C**
  - **Clean Room (Processing and Assembly)**
  - **Chemical Processing (EP, BCP, Mechanical Polishing)**
  - **High Pressure Rinse and Ultra Pure Water System**
  - **He liquefire 35 l/hr to be upgraded to 100 l/hr (LHe storage dewar ~ 5000 liter)**
  - **Vertical and Horizontal test facility for Cavity**
  - **Underground tunnel to build ~50 MeV Linac**
  - **Computing (ANSYS) and CAD Facilities (NX-4)**



# Fermilab-Indian Institution Collaboration

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- Fermilab and Indian Institutions have **Singed an Addendum MOU** “Fermilab, RRCAT, BARC, IUAC and VECC Collaboration on ILC Main Linac SRF Accelerator Technology R&D”
  - Focus is on ILC
  - Indian Institutions Infrastructure development
- **Indian Accelerator Program**
  - High Intensity Proton Accelerators (SNS, ADS)
  - Radioactive Ion Beam
  - Related SRF infrastructure development
- **Collaboration on High Intensity Proton Accelerator is under discussion**
  - Fermilab Proton Accelerator R&D (Project-X, HINS)



# Scope of work CY07-09

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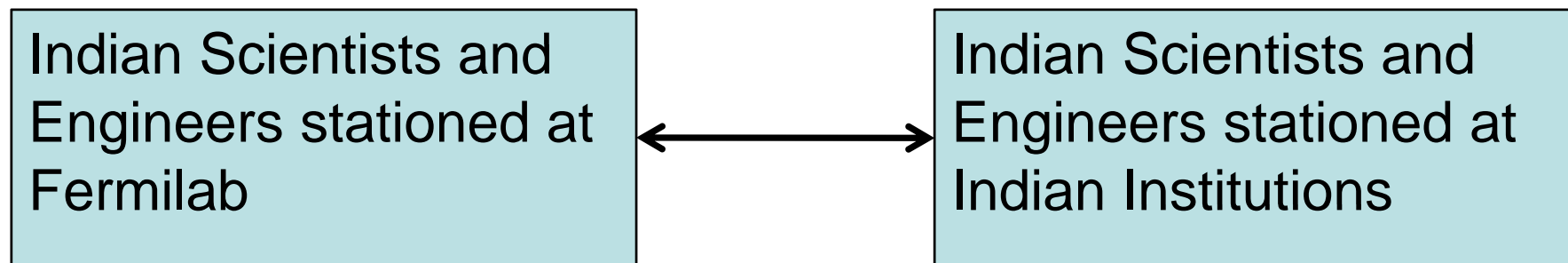
- Develop Cavity Fabrication tooling
- Fabrication of 1-Cell TESLA Shape cavity
- Fabrication of 9-Cell ILC Cavity (TESLA Shape)
- Fabrication of an ILC Tuner
- Collaboration on the design of the ILC Cavity and Cryomodule
  - Design for manufacturing
- Design and construction of components for ILCTA@Fermilab



# Not Just talk

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- The real collaborative work started in summer of 07 with two Indian Scientists Jishnu and Pitamber visiting Fermilab for 3 months.
- This visit was followed by visit of Avinash and Prashant for 3 months (**Talk to follow**)
- With a short winter break we (Fermilab and SLAC) will have more visits.
  - At least two people stationed at Fermilab
  - Fermilab staff will also visit Indian Institutions

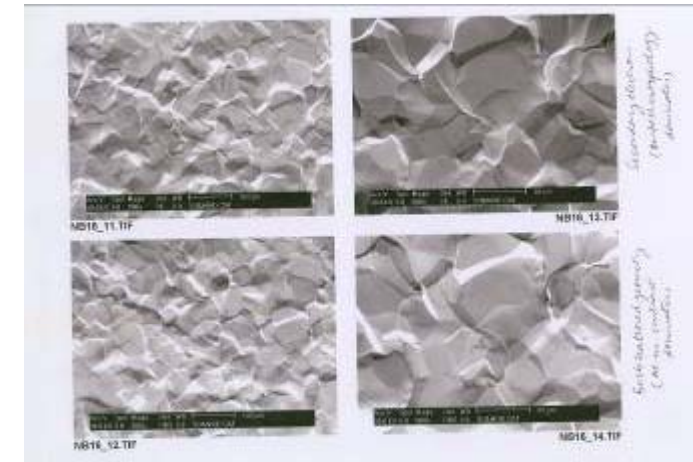
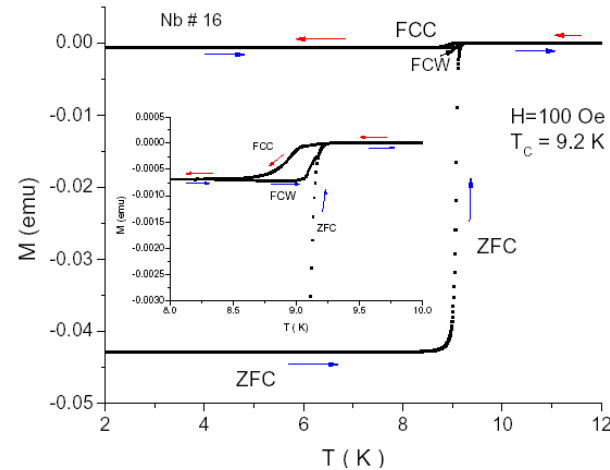




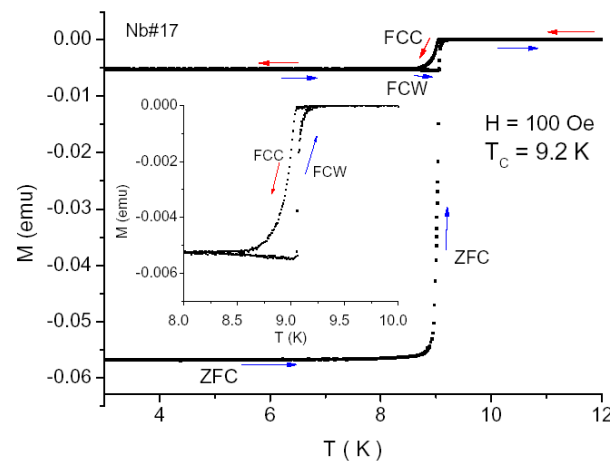
# Material R&D at RRCAT

Results on BCP Samples of Nb from Fermilab. (Large Grain Nb from Jlab also studied)

Sample # 16  
Avg grain size  
~ 30-35 Micron



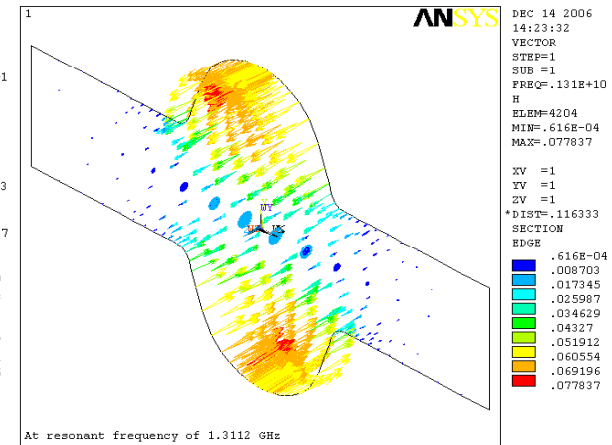
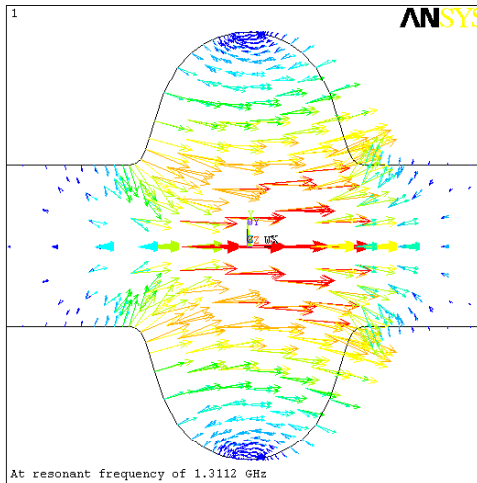
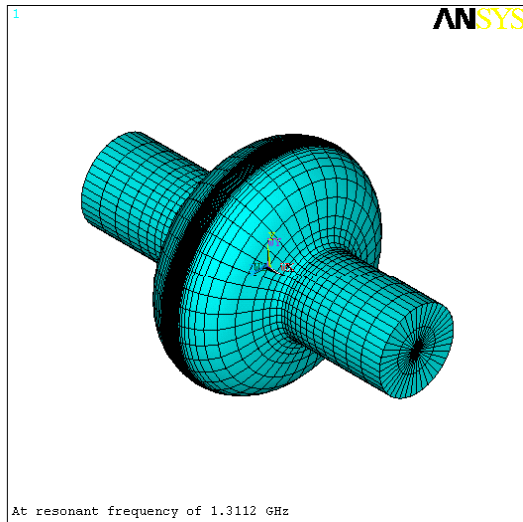
Sample # 17  
Avg grain size  
~ 40-45 micron



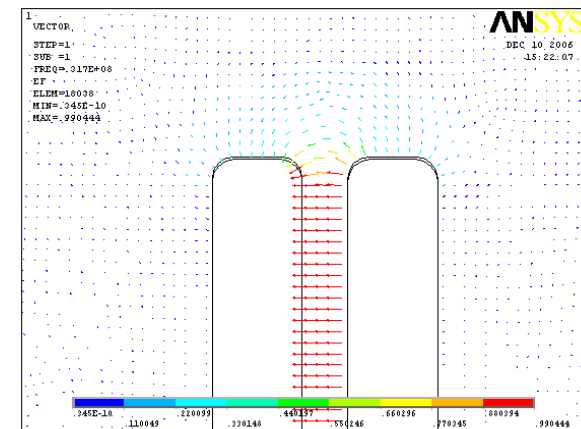
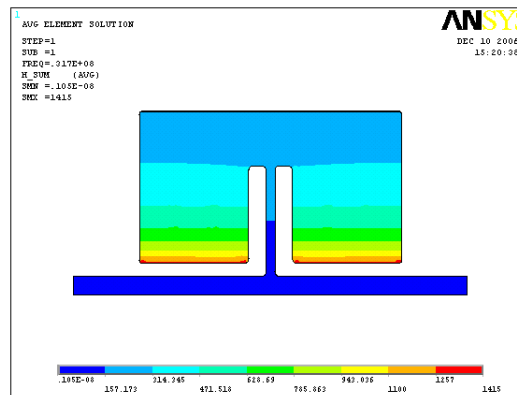
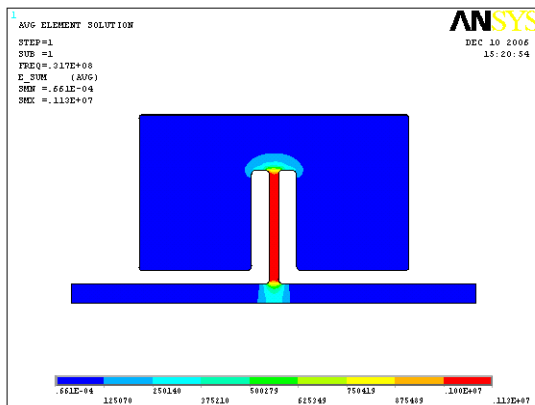


# RRCAT: Cavity RF Simulation

## 1.3 GHz Cavity



## 31.6 MHz Indus-1 Cavity







# Cavity Tooling

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**Subject:** Cavity tooling drgs - proposal

**From:** Jishnu Dwivedi <jishnu@fnal.gov>

**Date:** Sat, 21 Jul 2007 14:06:32 -0500

**To:** Don Mitchell <dmitchel@fnal.gov>, "Michael H. Foley" <foleymh@fnal.gov>

**CC:** "C. S. Mishra" <mishra@fnal.gov>

Dear Don and Mike,

Please find attached to this folder a set of 40 drawings, for cavity tooling. The drawings have been modified, by my colleagues in India, in following ways -

1. The drawings are put on ISO template,
2. Dimensional and geometric tolerances have been proposed,

I request you to go through the drawings and make your comments, before we discuss these drawings with Jefferson Lab.

-Jishnu





# T5CM

## Design for Manufacturing Cavity to Cryomodule

Date: 13 August 2007

Compiled by Jishnu Dwivedi & Don Mitchell

Some preliminary areas for work on T5CM by Indian Team -

	Description	Details and drawings	Loads Requirements
1.	Bellow flange and seal redesign to fit in the tighter space, design of assembly procedure. Possibly Al diamond seal can be used which is already qualified for low particle generation.		
2.	Metal part of the cold support needs optimization. It seems too thick now, checking of design basis and redesign.		
3.	Shrinkage calculations for the cool-down of cryo-components and movement of cavities in 3 dimensions.		
4.	ASME calculations of Helium vessel, Cryostat and other components		
5.	Cavity needle bearing (flat cage based) support redesign for lesser number of parts and faster assembly		
6.	Study of Helium vessels and possibility of stainless steel design		Which stainless steel is to be used?
7.	Verification of T4CM "Cavity_Master_Spread_Sheets"		
8.	Study of cryo-module configuration		



# ASME Calculation

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**Subject:** ASME Calculation

**From:** Jishnu Dwivedi <jishnu@cat.ernet.in>

**Date:** Tue, 30 Oct 2007 17:52:17 +0530 (IST)

**To:** don <dmitchel@fnal.gov>

**CC:** pankajk@cat.ernet.in, abhay@cat.ernet.in, rss <rssandha@cat.ernet.in>, bapna@cat.ernet.in, Fermi-avinash <avinash@fnal.gov>, Shekhar <mishra@fnal.gov>, vcsahni <vcsahni@cat.ernet.in>, vcs-barc <vcsahni@barc.gov.in>

Dear Don,

I am attaching a part calculation of Helium Pressure Vessel of 1.3 GHz ILC Cavities, done to validate its design as per B & PV Code of ASME. The work is done by my colleague Mr. Pankaj Kumar. We would like to take-up the ASME calculations for the Cryostat vessel, as soon as its final drawings are available to us. I request you to send us PDF drawings of the cryostat vessel as we would have to rely on this method of drawing exchange till we sort out the problem with EDMS. I request your comments on the calculations and request you to send us the cryostat drawings in PDF format.

Best regards,

-Jishnu

## **11. Conclusion**

**The part no. 1 and part no. 2 of the He Vessel are safe in 0.4 MPa (4 bar) internal pressure as well as 0.1MPa (1 bar) external pressure as per ASME B & PV Code Sec. VIII div 1.**



# HINS-Project-X Development

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- IUAC is fabricating 2 spoke cavities for HINS.
- During his visit Pitamber Singh studied the design of Proton Driver → HINS.
- He is the lead accelerator physicist for the Indian ADS Program.
- HINS design team gave him a set of drawings (cavity, coupler, tuners etc.) for study and evaluation with engineering at BARC.
- They have evaluated them and are ready to fabricate parts.
  - We have requested them to focus on 1.3 GHz components till we get some guidance on Project-X



# Looking Ahead

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- India will play a major role in ILC.
  - US is interested building ILC at Fermilab.
- We would like to develop even closer ties with Indian High Intensity Proton Accelerator program (1-2 GeV Linac).
  - This would help the development Fermilab Project-X R&D and proposed construction.