



中国科学院高能物理研究所  
Institute of High Energy Physics  
Chinese Academy of Sciences



# IHEP 1.3 GHz SRF Technology R&D Progress

Jie Gao, IHEP

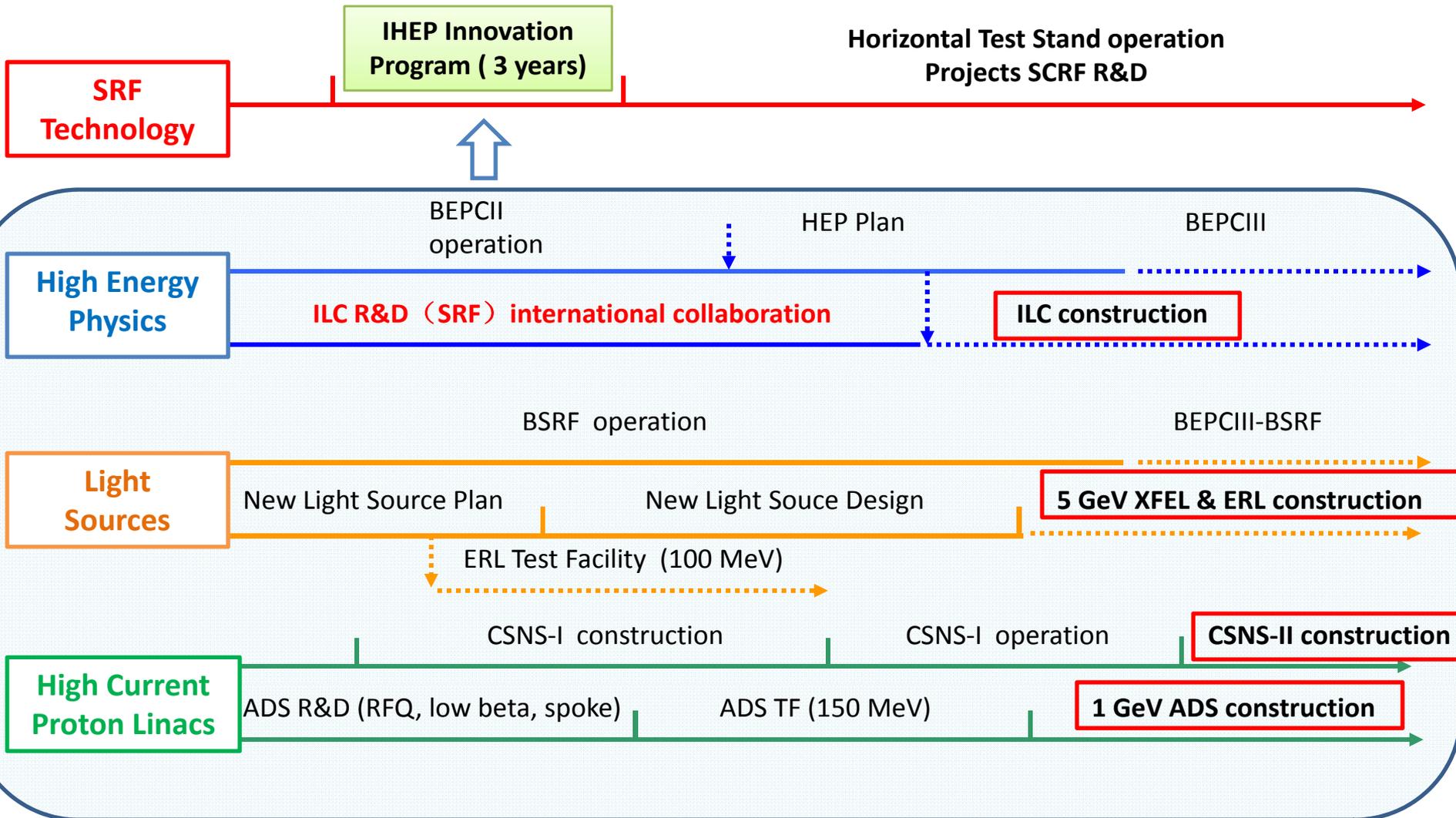
IPAC10, Kyoto, 27 May 2010

# Content

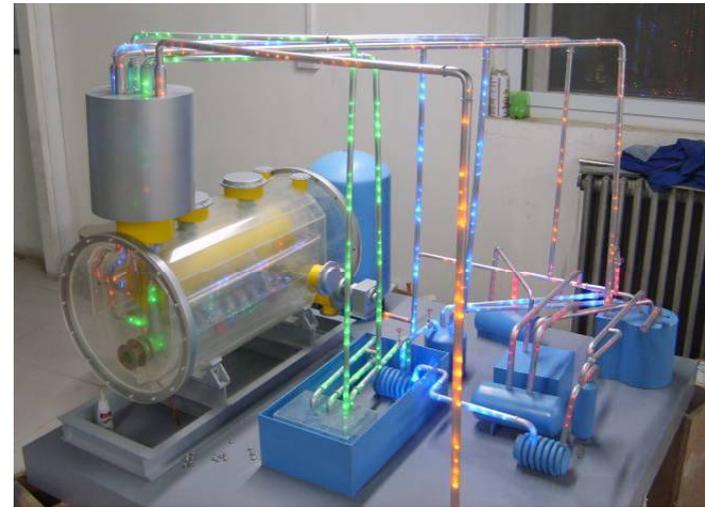
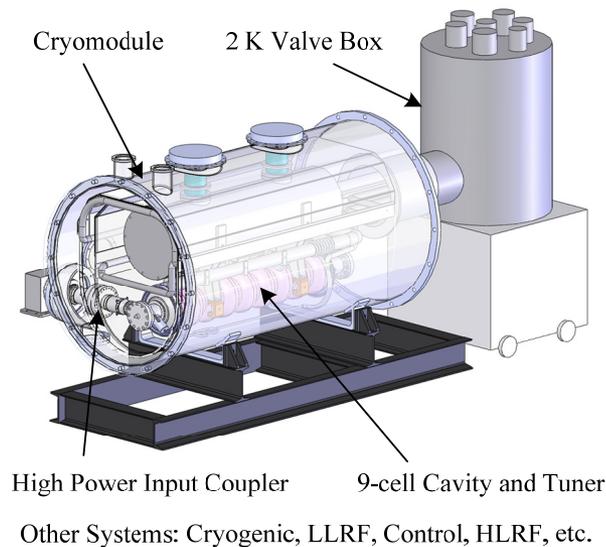
- **Program Overview**
- **1.3 GHz 9-cell cavity and SRF facilities**
- **1.3 GHz high power input coupler**
- **Tuner and LLRF**
- **Cryomodule and cryogenics**
- **Summary**

# IHEP Route Map (accelerator-based)

2008 2010 2012 2014 2016 2018 2020



# 1.3 GHz SCRF Accelerating Unit and Horizontal Test Stand Project



1. Cavity Package and Horizontal Test (J. Gao, J.Y. Zhai)
  2. Cryomodule and Cryogenics (S.P. Li)
  3. High Power Input Coupler (W.M. Pan)
  4. LLRF and Tuner (Y. Sun)
  5. SCRF Lab and Facilities (J.P. Dai)
- project leader: J. Gao
  - approved: July. 2008
  - time: 2009-2011 (3 years)
  - budget: 1.8 M USD (12.5 M CNY)
  - project team: 30 members

# Superconducting Accelerating Unit Project

## Aims:

- Provide key technologies of the next generation accelerators for IHEP
- Make China's contribution to the ILC SCRF TDP and SCRF community

## Goals:

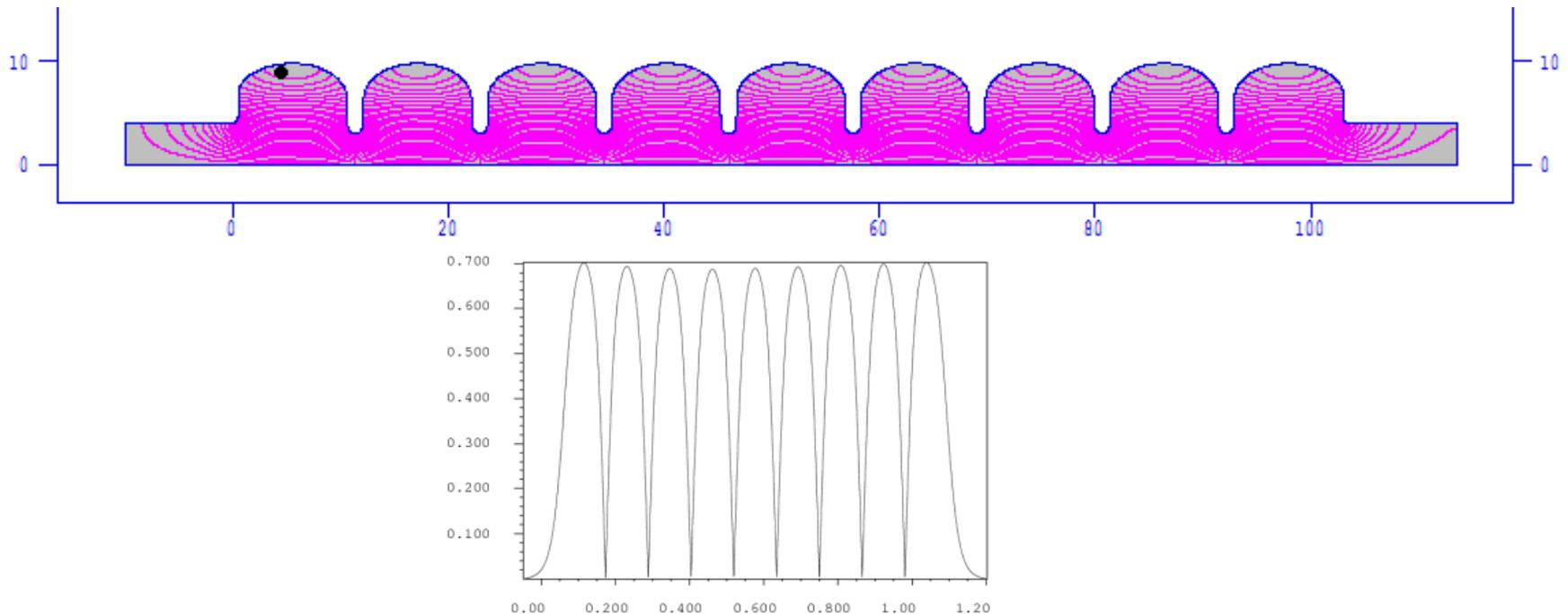
1. accelerating gradient of 20 - 31.5 MV / m for the cavity horizontal test
2. 300 kW (5 Hz, 1.5 ms pulse, SW) power through the high power input coupler during the horizontal test
3. LLRF phase stability 0.1 degree, amplitude stability 0.1 %
4. lab and facility capability for the 9-cell cavity processing (except EP), pretuning, vertical test and horizontal test, and enough for the BEPCII spare cavity and cryostat usage

# Content

- **Program Overview**
- **1.3 GHz 9-cell cavity and SRF facilities**
  - IHEP-01 fabrication and surface treatment
  - IHEP-02 design
- **1.3 GHz high power input coupler**
- **Tuner and LLRF**
- **Cryomodule and cryogenics**

# Low loss large grain 9-cell cavity

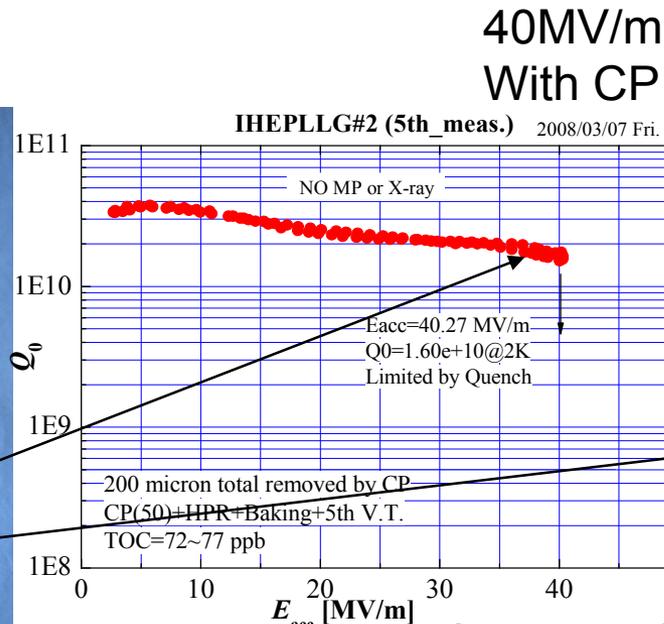
- **inner cell** similar to the original Low Loss shape (iris 60, beam tube 80)
- **end cell** design without HOM consideration
- **end plates and end stiffening rings** to strengthen the end cell



# 1.3GHz low loss large grain single-cell cavity experiences



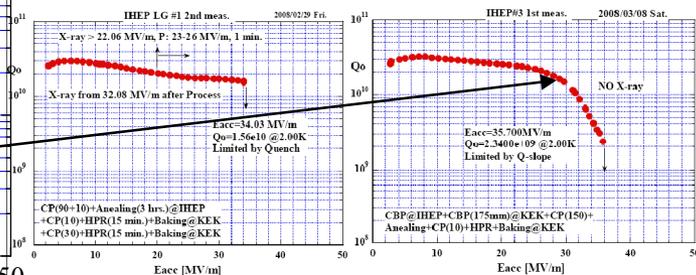
IHEP made



Large grain

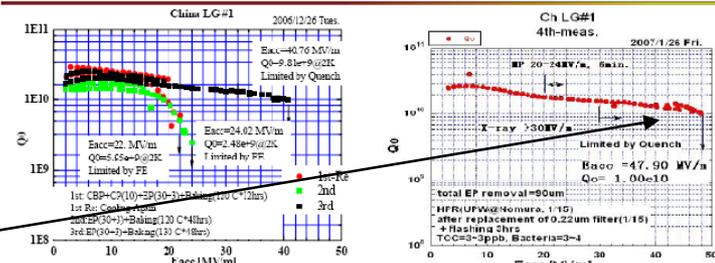
## Comparison between NingXia large grain and fine grain cavities

IHEP#3 has achieved 35.7MV/m but heavy Q-slope appeared even after baking (120°C 48hr). Q-slope in chemical polished cavity is not always removed by baking. It will be recovered by EP+ Baking. Unfortunately his schedule is too tight to confirm it.



Fine grain

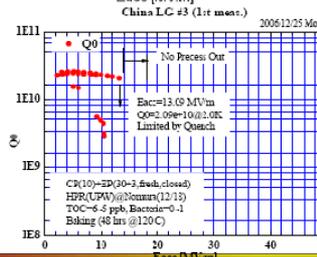
## Results of Cryogenic Vertical Tests- China LG #1



Large grain



- 1 China LG #1 would be removed 30 micron per step by EP and the relationship of Eacc,max and thickness removed by EP was expected to achieve by serials of tests.
- 2 In the first two test, FE was very strong with large X-ray and limited maximum Eacc.
- 3 In the third test, the gradient once reached to 40.76 MV/m and the quality factor is almost 1.0 E 10.
- 4 For the 2nd and 3rd test, the cavity has been baked for 48 hours and no evidence of a strong degradation of the quality factor is seen in these tests.
- 5 China LG #3 was tested vertically only once. In the test, FE is very strong and the cavity is limited by quench. The roughness of the inner surface is very large without CBP. More EP and vertical tests would be continued.

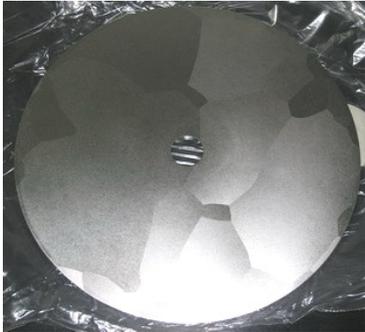


47MV/m  
With EP

KEK (Saito)-IHEP (Gao) joint effort

# Large Grain Niobium

- disks from Ningxia OTIC (72 pieces, Sept.- Nov., 2008)
- **ultrasonic and eddy current scanning** tests
- **mechanical behavior** sample test at **room temp. and 4K**



宁夏东方钨业股份有限公司产品质量证书

地址: 宁夏石嘴山市 105 信箱 邮政编码: 753000  
电话: 0952-2098640 传真: 0952-2098639

产品名称: 大晶粒钨片 用户名称: 中科院高能物理研究所  
产品批号: ENT-21 产品重量: 28.95kg  
产品规格:  $\Phi 270 \times 2.8\text{mm}$  日期: 2008-9-23  
数量: 21 片

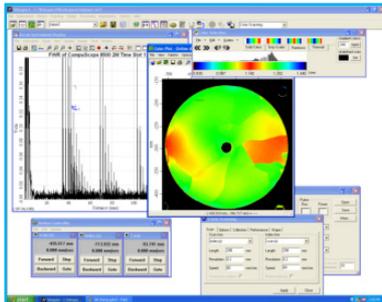
化学成分:

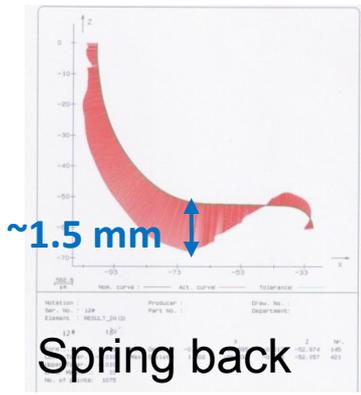
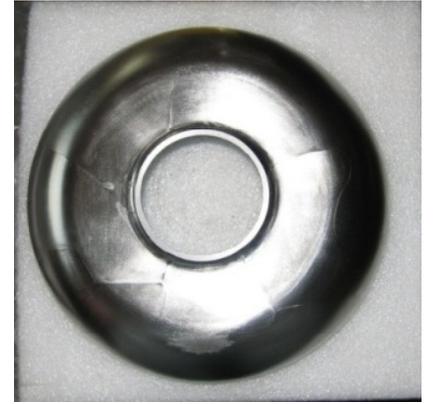
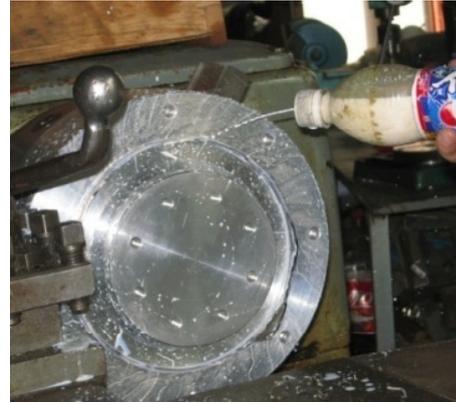
元素	分析值 (ppm, wt)	元素	分析值 (ppm, wt)
C	5	Fe	<5
O	5	Si	<10
N	6	Ni	<5
H	2	Ti	<5
V	10	Ta	<180
Mo	10		

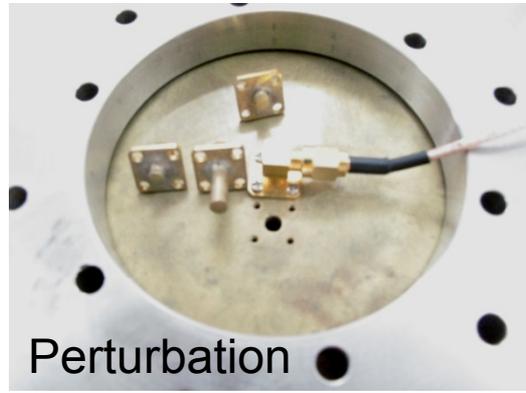
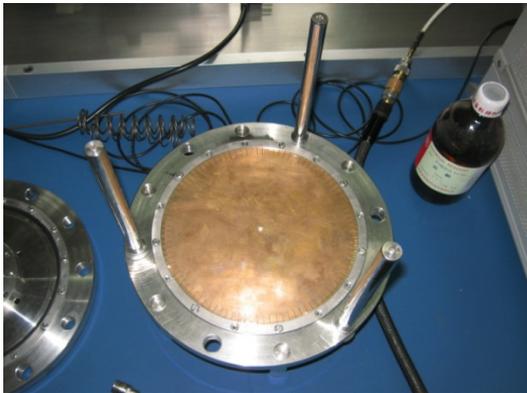
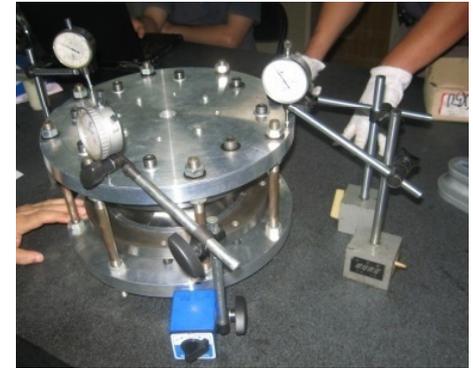
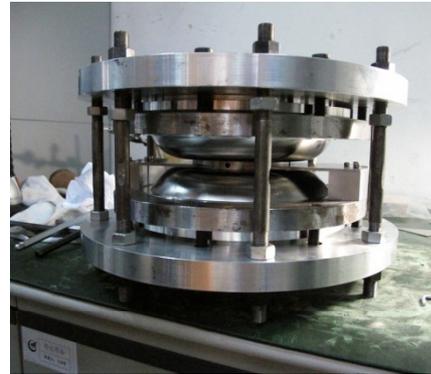
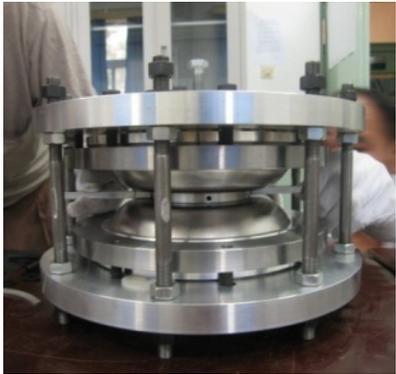
性能:

延伸率 (%)	HV10N	RRR
>40	55.3 / 53.5 / 51.7	430

填报人: 牟东 审核人: [Signature]  
评判结果: [Stamp] 评判时间: 2008.9.22 评判人: [Signature]

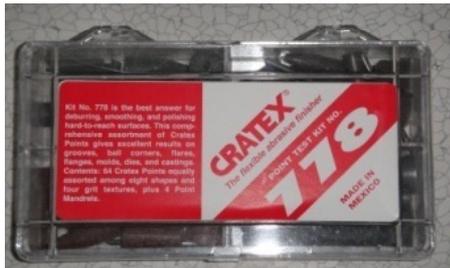




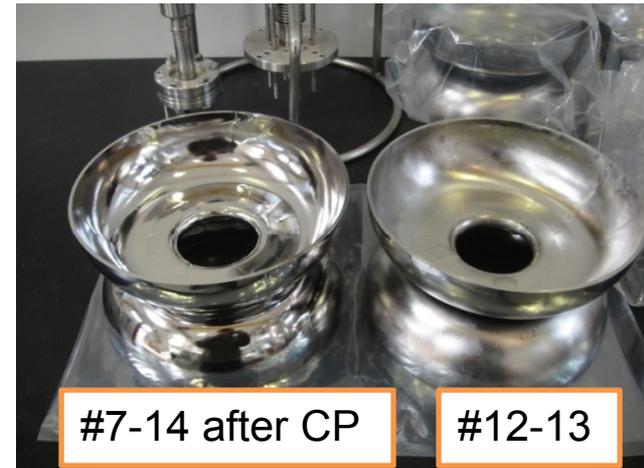


# Dumbbell Grinding

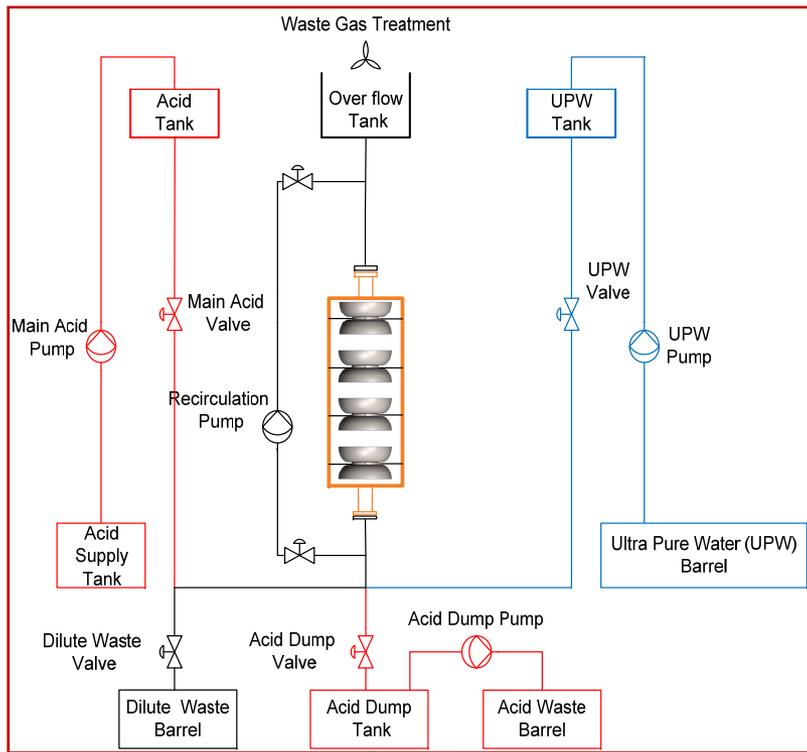
We inspected and carefully grinded most of the defects on the inner surface of the dumbbells, especially totally removed one layer of the iris EBW area.



**CRATEX**  
rubberized SiC



# Dumbbell CP and Transportation



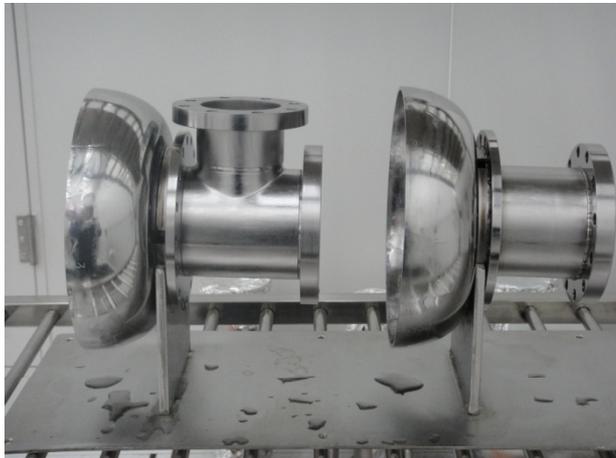
EBW

Rinse in Class 10 Clean Room and Dry

Fill in with Argon gas

# Cavity Components and Spares

Due to the special properties of the large grain material, several mechanical and RF problems were found and successfully solved during the fabrication and EBW of half cells and dumbbells. **The dumbbells were reshaped and trimmed** to have the right length and frequency.

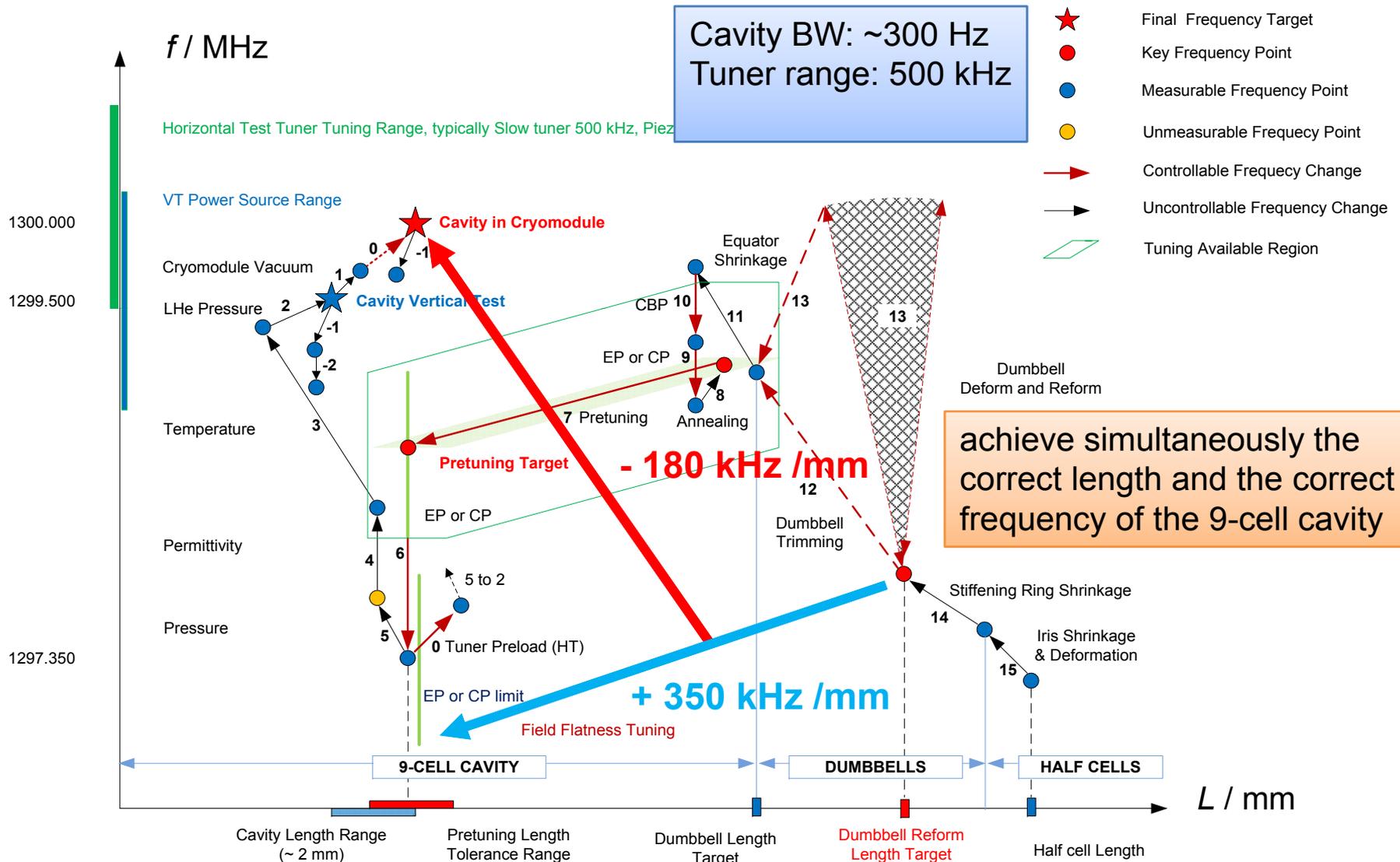


# **IHEP01 was fabricated on April 15, 2010!**

**-The first 1.3GHz low loss type large grain 9cell cavity in China**

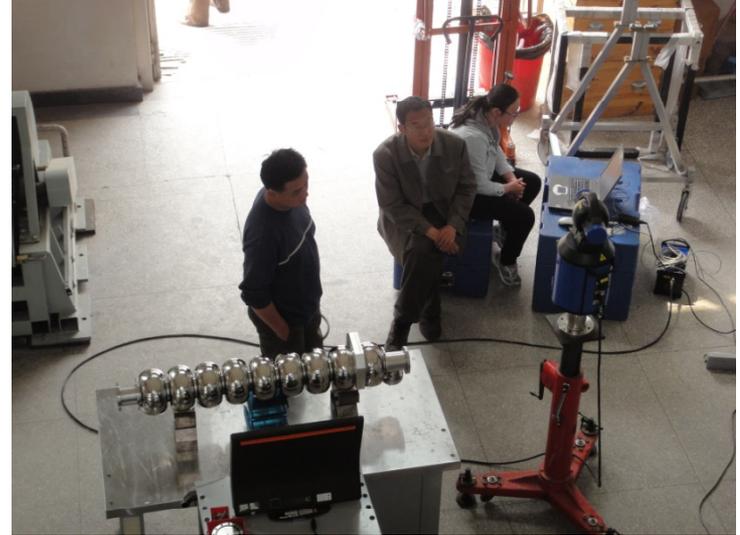


# Cavity Frequency Control

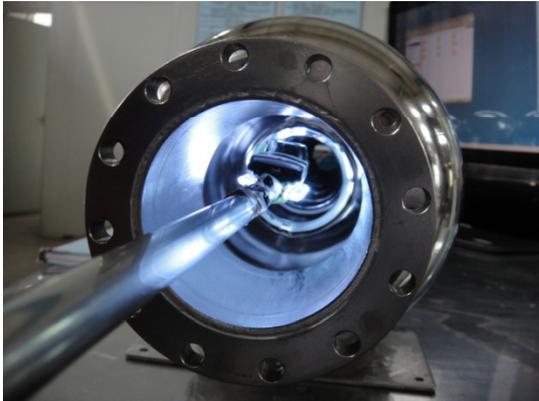


# Vacuum and dimension check

- The total length (flange to flange) is **1252.85 mm** and the concentricity of the 9 cells is **0.86 mm**. The designed value are **1247.4 mm** and **0.8 mm** respectively. During pretuning, we will only squeeze the cells to make the cavity frequency down and the cavity shorter as planned.



# Optical Inspection



Many sputters were found in the equator area of cell#2 to cell#8. We are still investigating the reason of sputtering. The EBW vendor is expected to be qualified because they made the IHEP 40 MV/m single cell CP cavity.

# CBP



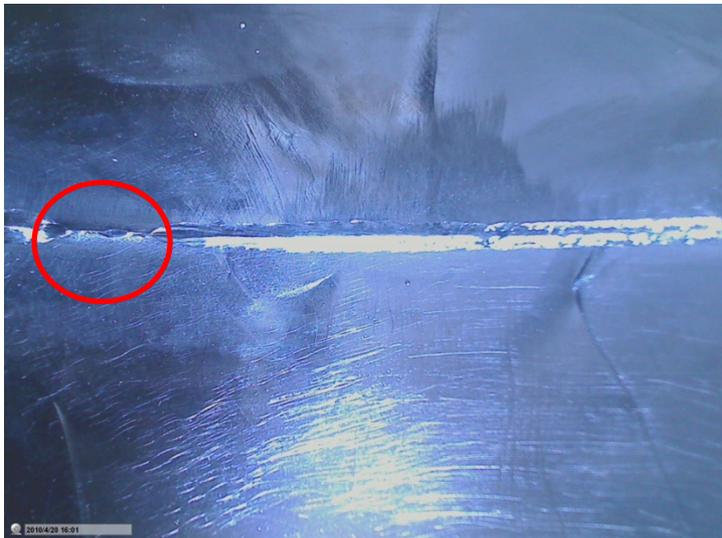
Due to the EBW problem, we made 12 times CBP on this cavity with different abrasives ( $\text{SiC}$ ,  $\text{Al}_2\text{O}_3$ ), bonders (ceramic and plastic), stone shapes and filling amount. The rotation speed around the cavity axis was 100 - 150 rpm, and 100 rpm around the machine axis. It took about 62 hours to totally remove **190  $\mu\text{m}$**  of the equator wall thickness.



**Cell#3 90° before CBP**



**Cell#3 90° after CBP**



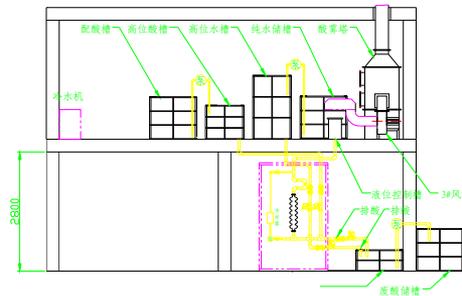
**Cell#9 90° before CBP**



**Cell#9 90° after CBP**

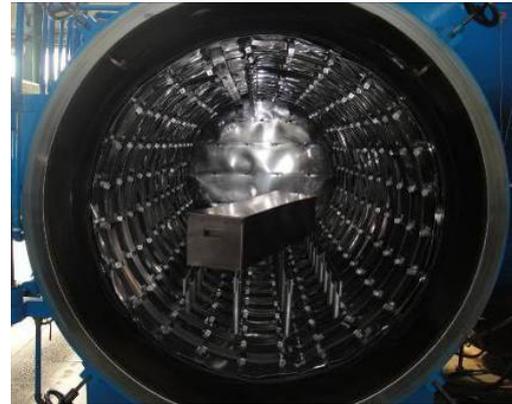
# BCP

- The circulating acid is cooled by a heat exchanger. The storage acid and the spray water are chilled below 10 °C. We made 4 times CP and each time took 25 minutes. For the second and fourth CP, we **reversed the cavity to make the etching more uniformly**. During CP, the **acid temperature at the cavity exit was 13 - 15 °C**. The measured etching amount of the equator wall thickness was **114 μm**.



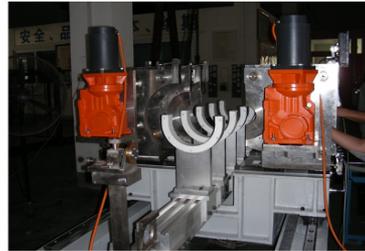
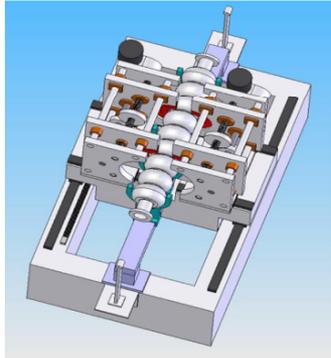
With reference to Fermilab BCP design

# Low Pressure Rinsing and Annealing



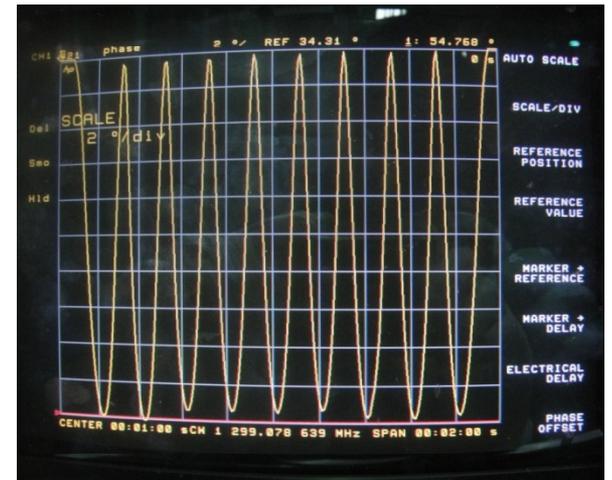
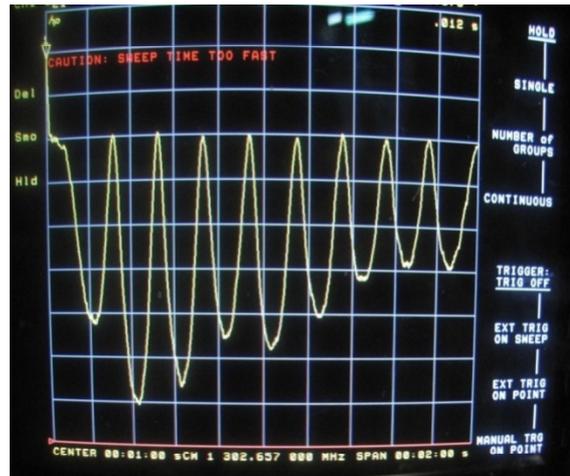
750°C  
3 hours  
 $10^{-3}$  Pa  
Ningxia

# Pretuning



Specification of the pretuning machine:

- Longitudinal precision:  $2 \mu\text{m}$
- Maximum force: 10 kN (1000 kgf)
- Maximum movement: 6 mm
- Minimum movement:  $2 \mu\text{m}$

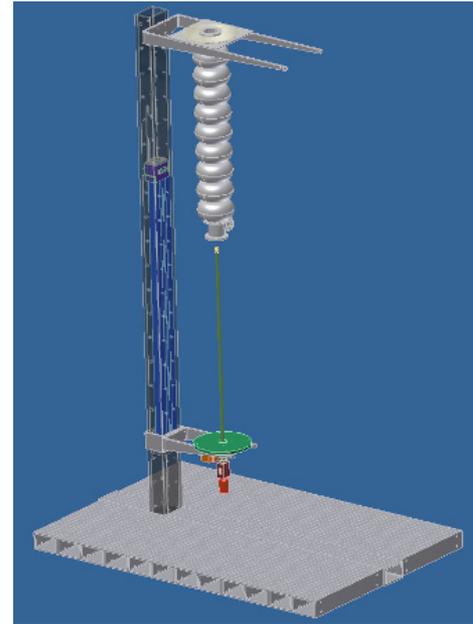


**Cavity field flatness as delivered (70%) and after pre-tuning (97.6 %)**

# Other facilities



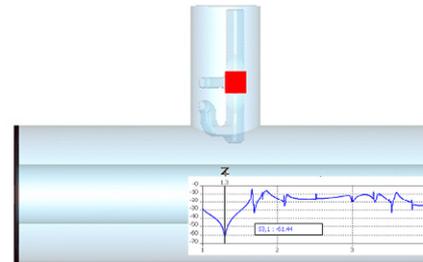
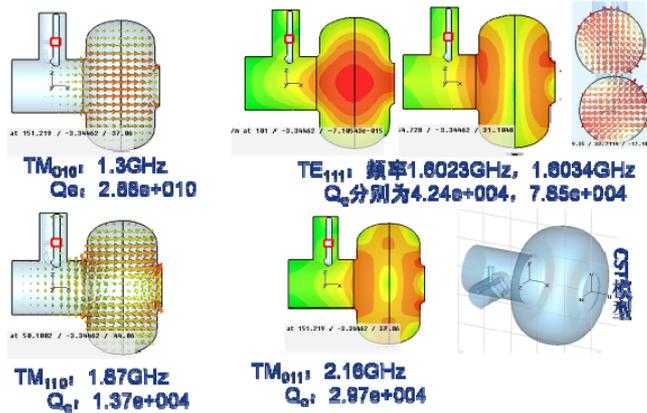
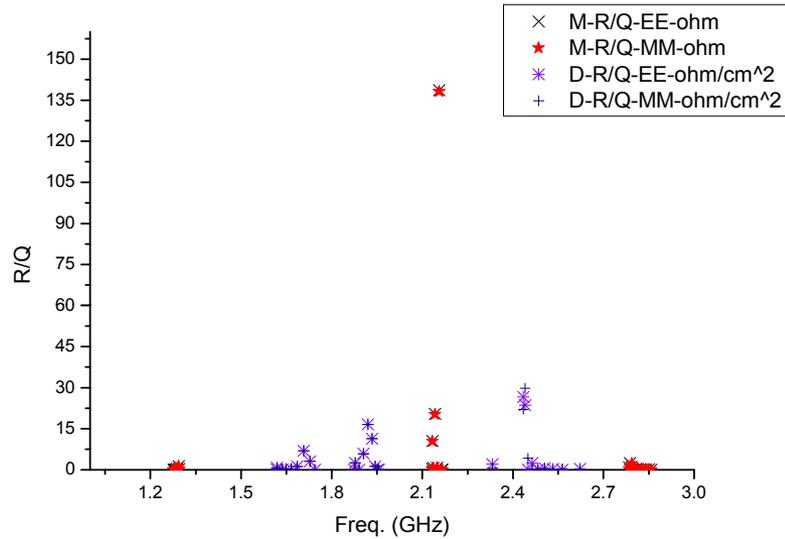
Ultrasonic cleaner for the 9-cell cavity



HPR for the 9-cell cavity

**The cavity will be sealed and shipped to KEK and test after HPR at STF at the end of June. T-mapping, optical inspection and replica can be applied to identify the defects.**

# IHEP-02 9-cell Cavity Design

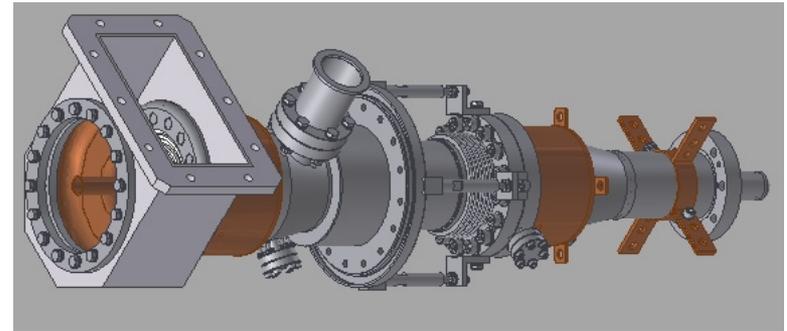
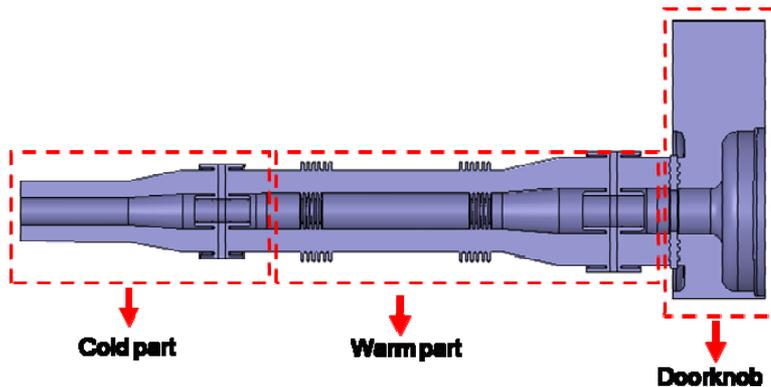


# Content

- **Program Overview**
- **1.3 GHz 9-cell cavity and SRF facilities**
- **1.3 GHz high power input coupler**
- **Tuner and LLRF**
- **Cryomodule and cryogenics**

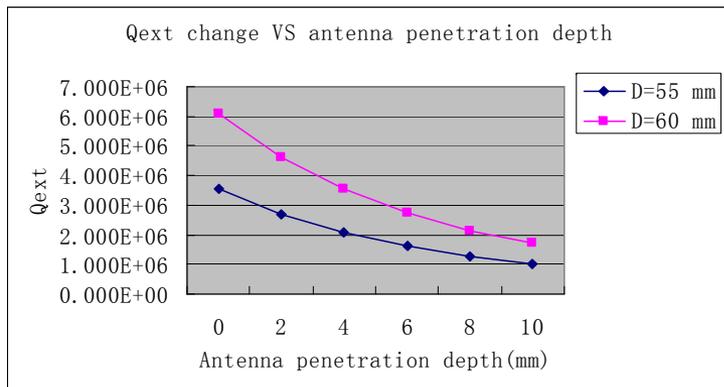
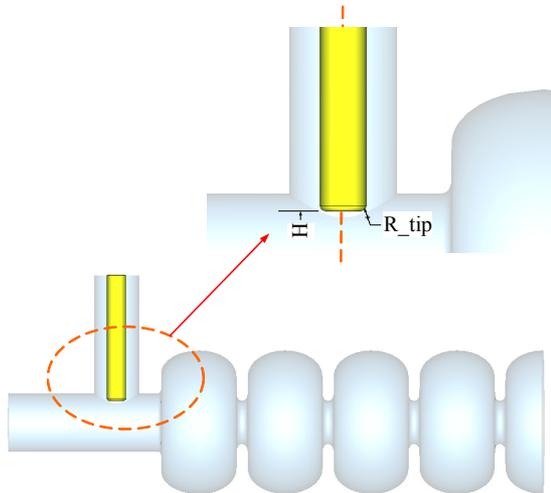
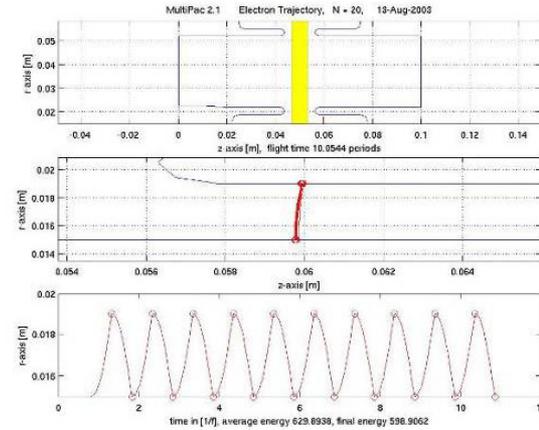
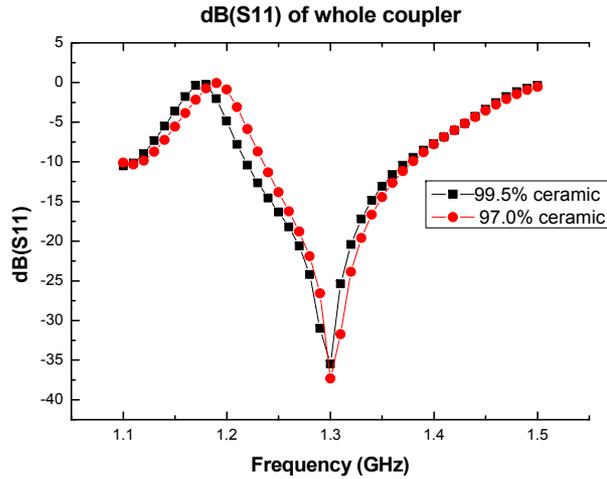
# High Power Input Coupler

Frequency	1.3 GHz
Power	Test: 1MW, 1.5ms,5Hz (average:7.5 kW) Oper:300kW,1.5ms,5Hz (average:2.25 kW)
Two Tristan windows	safe operation clean cavity assembly for high gradients
2 K heat load	0.06 W
5 K heat load	1 W
80 K heat load	8 W
$Q_e$	Fixed: $2 \times 10^6$



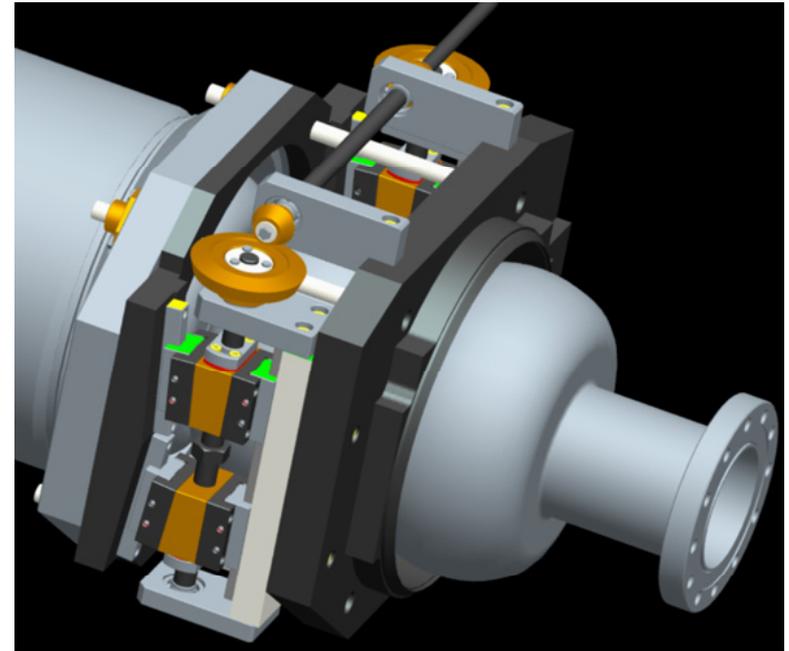
**Two input couplers are under fabrication  
To be test at the end of this year**

# RF Simulation and Design

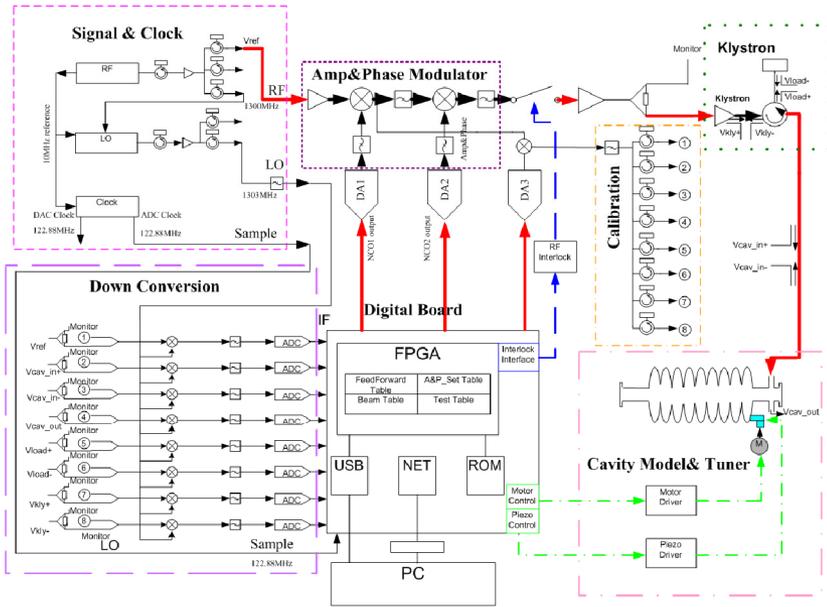


# Tuner

- The STF type tuner will be developed at IHEP. The mechanical simulation and design have been made for the fabrication of a prototype tuner.
- The tuner will be set **in the middle of the cavity Ti helium vessel**.
- A special **motor** to drive the tuner will be installed **inside the cryomodule**.



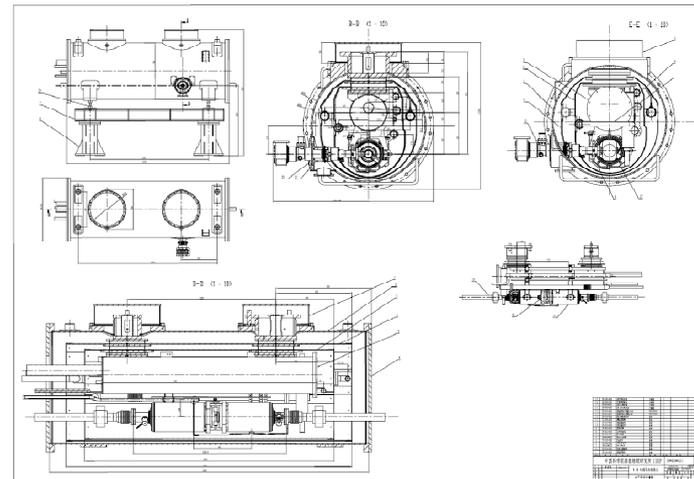
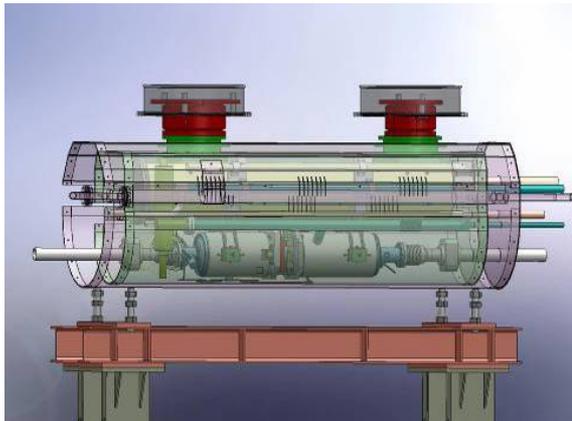
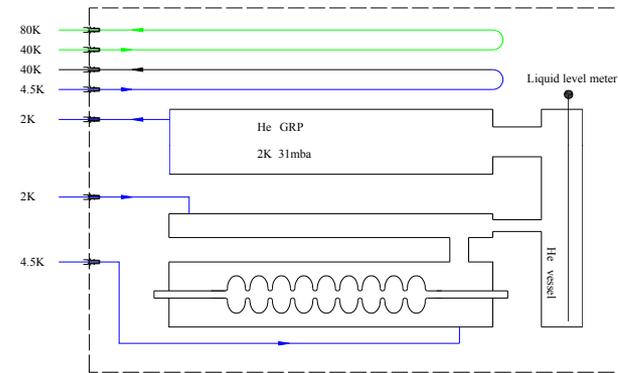
# LLRF



**The LLRF loops based on FPGA is under test**

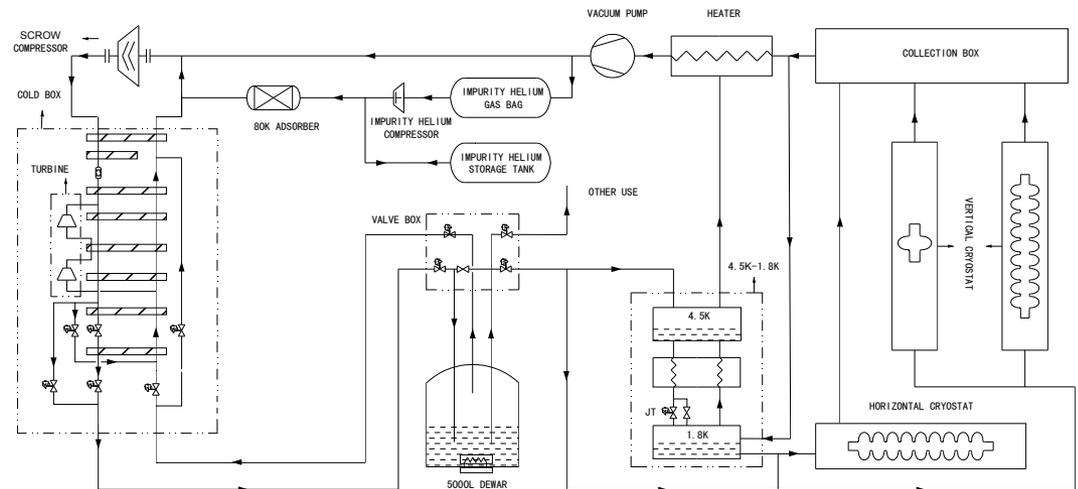
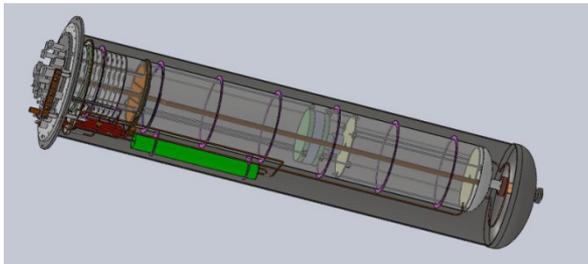
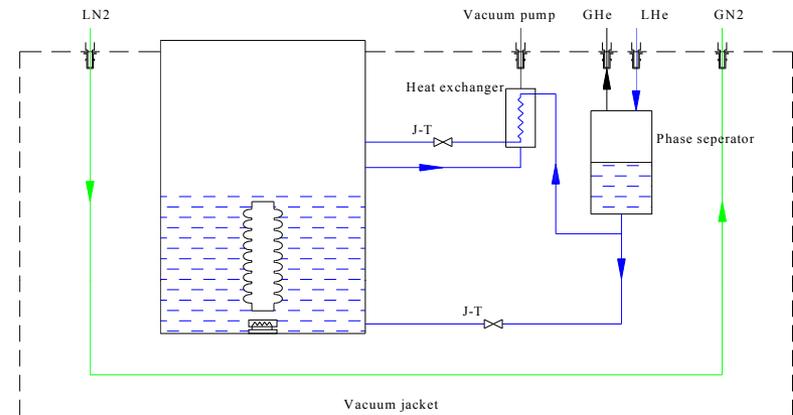
# Cryomodule

Based on Euro-XFEL **PXFEL-1** experience, but shorter  
Beam test interfaces added  
Finish fabrication early next year



# Cryogenics System

- For vertical and horizontal test
- Vertical test Dewar and 2 K system design finished
- 500 W @ 4.2 K Cryogenic system under discussion



# Summary

1. IHEP 1.3GHz SC SRF technology has progressed greatly in last several years started from 1.3GHz single cell cavity till 9cell one with the main aim of high gradient for ILC, but also for ERL technology.
2. The 1.3GHz SC accelerator unit related technologies are also under development such as high power coupler, tuner, LLRF, cryostat, etc.
3. 1.3GHz surface treatment technology has been established and used in IHEP made 1.3GHz single and 9 cell cavities.
4. Cold station for IHEP 1.3GHz 9 cell cavity vertical and horizontal test stand is till under planning.
5. The IHEP02 with helium vessel and high power and HOM couplers is started.
6. International collaboration in the main frame of ILC (especially with KEK) is very important and necessary for IHEP 1.3GHz SC SRF to progress smoothly and successfully.

**Thank you for your attention!**