Asia ILC Activity Report

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IHEP

LCB Meeting, August 7, 2016

Chicago, USA

Contents

- Japan
- China
- Korea
- India

ILC Progress at KEK/Japan

during a period of Feb. ~ Aug. 2016

ILC R&D Progress, in Japan/KEK

January ~ July, 2016

SRF Technology:

- **STF2 SRF Accelerator Construction at KEK**
  - Completion of RF distribution system installation for STF2 Cryomodules (CMs)
    - Cavity gradient: 34.9 MV/m with best 8 cavities (of 12 cavities, CM1 + CM2a)
  - Cool-down and RF power test to be realized in October, 2016.
- **SRF Cavity R&D cooperation in Asia**
  - A 9-cell cavity developed by IHEP processed and vertically tested at KEK, in 2016.
- **"Marx" Modulator (Solid State, RF Power Supply) R&D at KEK**
  - A prototype development in progress in cooperation with Japanese industry

Nano-beam Technology:

- **ATF2, FF beam-size and the stability**
  - A beam size of 41 nm (preliminary) achieved with FONT feed-back ON.
  - Non-linear magnetic field effect being studied.

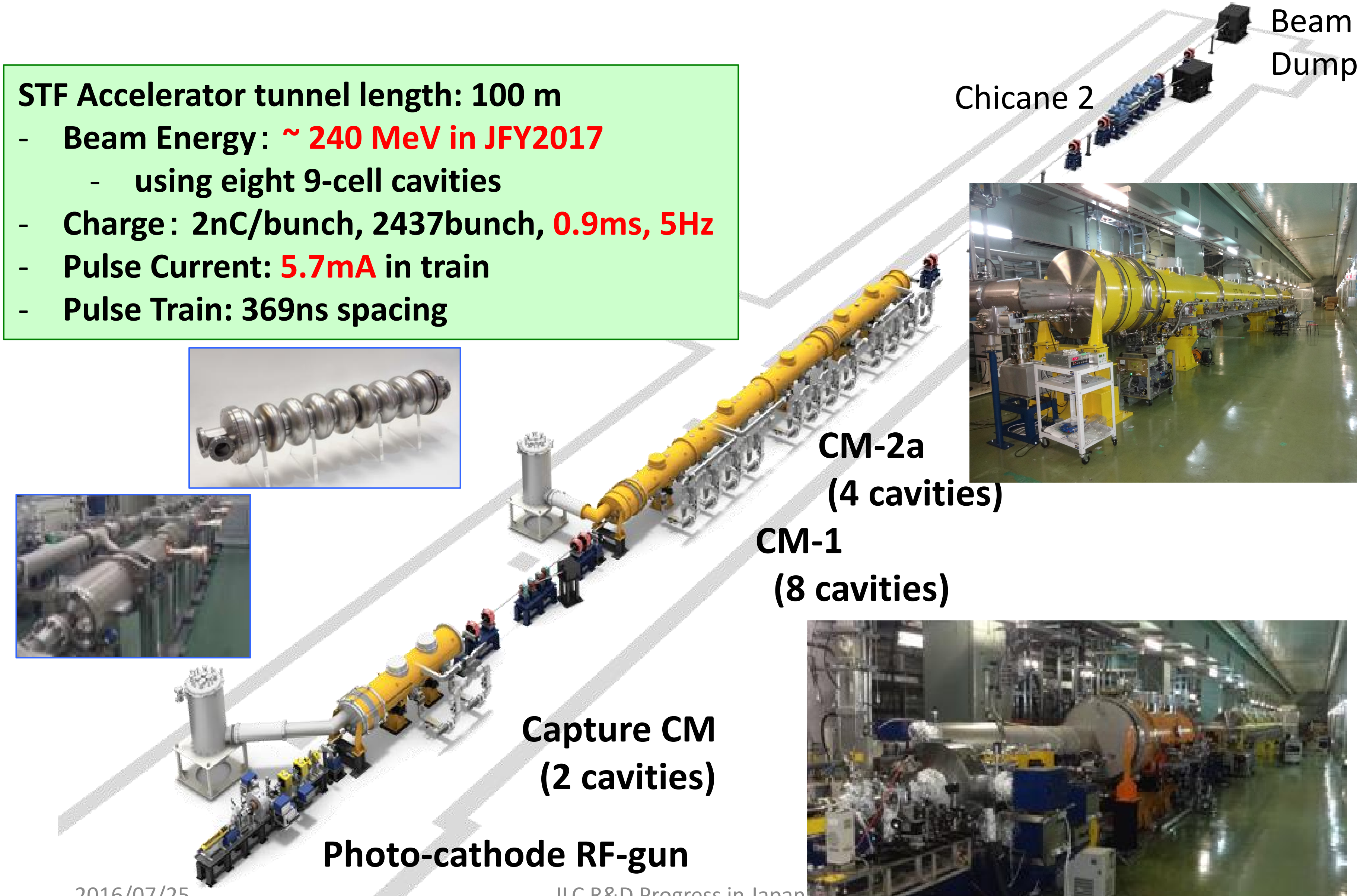
KEK-ILC Action Plan:

- **SRF Cost Reduction R&D plan proposed**
  - SRF cost reduction R&D proposed in close communication b/w Fermilab and KEK

KEK-STF SRF Accelerator Plan

STF Accelerator tunnel length: 100 m

- **Beam Energy : ~ 240 MeV in JFY2017**
  - **using eight 9-cell cavities**
- **Charge : 2nC/bunch, 2437bunch, 0.9ms, 5Hz**
- **Pulse Current: 5.7mA in train**
- **Pulse Train: 369ns spacing**

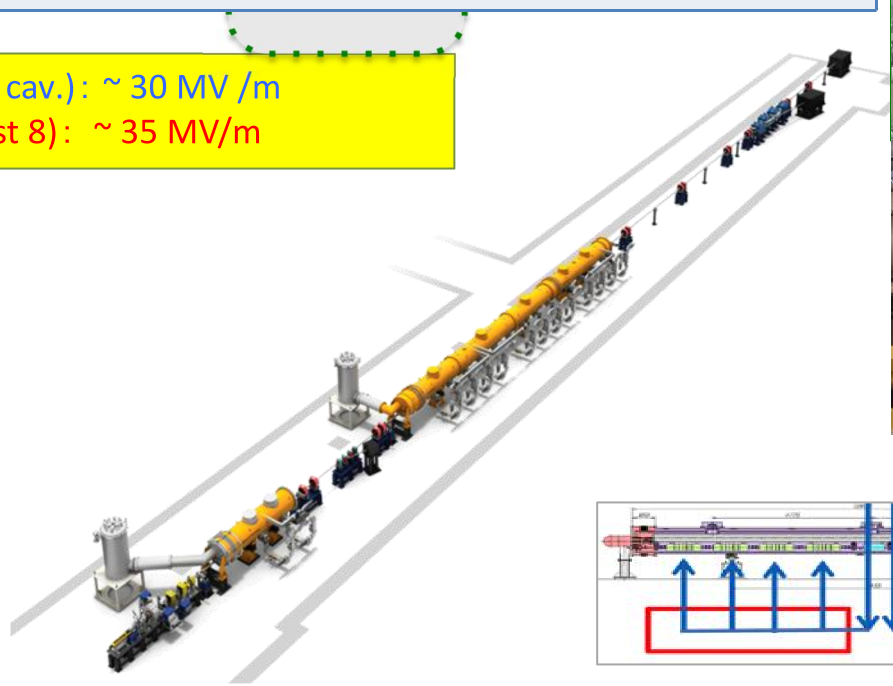


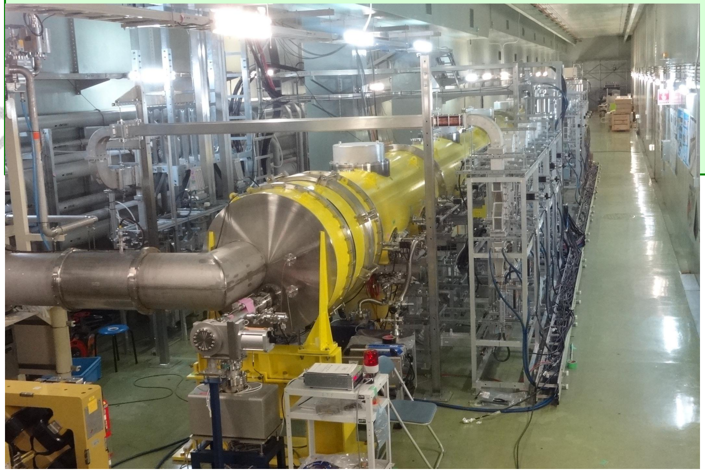
KEK-STF: Cavity/CM Performance, and RF-Power/Control and Beam Test Preparation

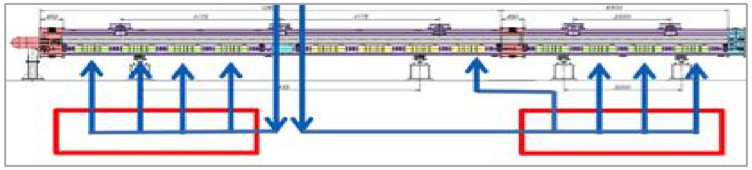
SRF cavity Gradient (MV/m) before/after CM Assembly												
Module	CM1a				CM1b				CM2a			
Cav. #	1	2	3	4	5	6	7	8	9	10	11	12
V. Test (CW)	37	36	38	36	37	35	39	36	12	36	32	32
in CM (pulse)	**39**	**37**	**35**	**36**	**26**	**16**	**26**	**32**	**18**	**34**	**33**	**32**
	Gradient stable				Degraded				Gradient stable			

FY14: CM1+CM2a (8+4) assembly
FY15: Cavity individually tested in CM
RF power system in preparation
FY16: **8-cavity** string to be RF tested
FY17: Beam Acceleration anticipated
（to reach ＞250 MeV)

*G (av. of 12 cav.) : ~ 30 MV /m
G (av. of best 8) : ~ 35 MV/m

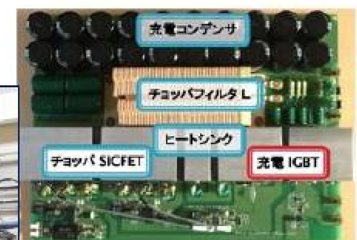






Marx Modulator Development at KEK

- A prototype "Marx" modulator being developed at KEK in cooperation with a company in Japan, base on preliminary effort between SLAC and KEK.
  - It features "parallel charging and series discharging" by using SiC devices (instead of Si) to cost-effectively generate RF high-voltage,



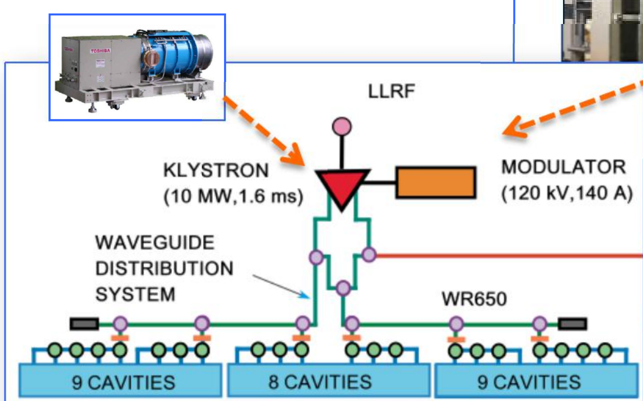
High voltage device
From 1.2kV to 12 kV

- Make smaller
- Lower cost

Low loss device
Switching loss 1/3, diode loss ½

Low electric power loss

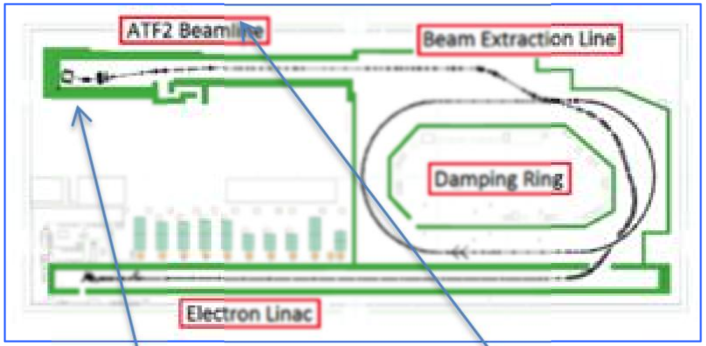
- Low operation cost

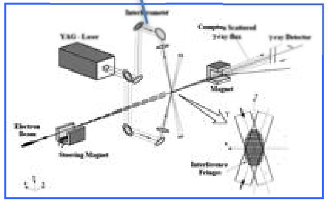


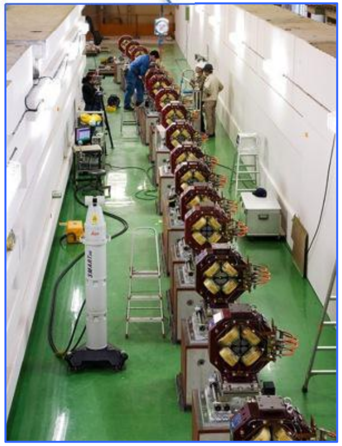
MARX modulator (20 Marx modules are used.)

Progress in KEK-ATF2, 2016

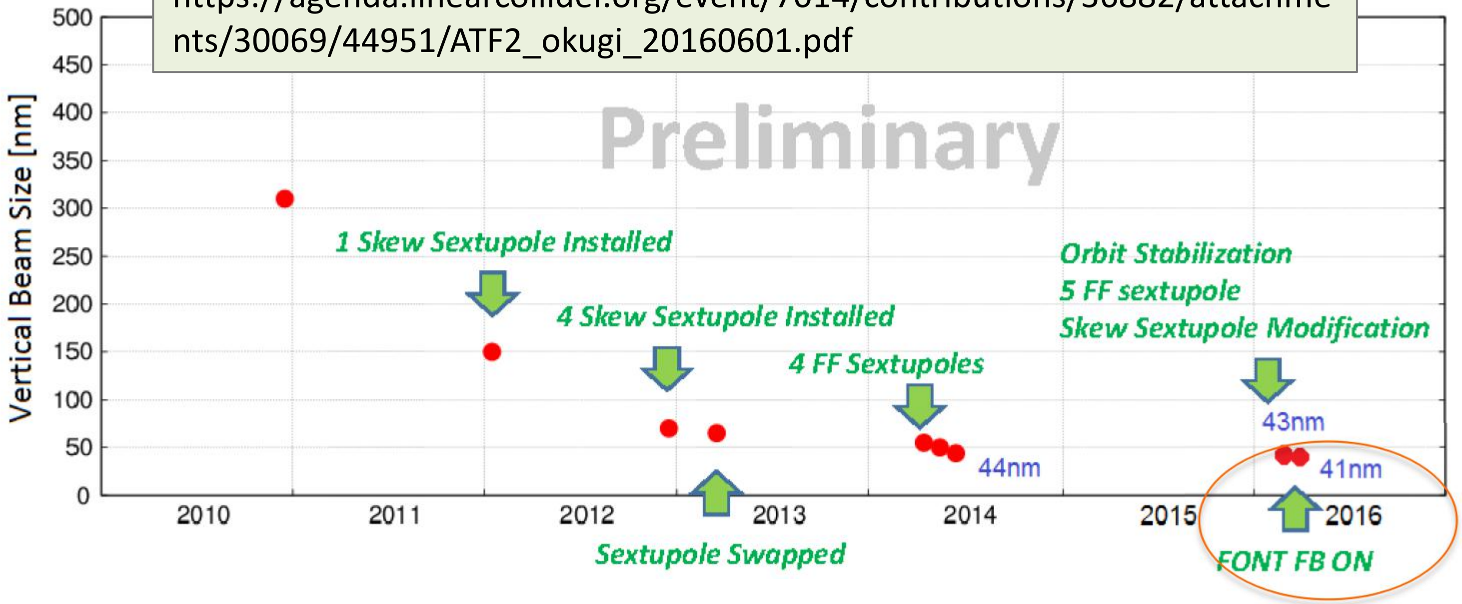
- **Int'l Collaboration for "Nano-beam" Research**
  - ~25 Lab. , and > 100 Collaborators
- **Modeling of ILC - BDS**
  - Same Optics: as ILC-BDS
- **Goal**
  - FF Beam Size: 37 nm (→ 5.9 nm at ILC)
- **Progress**
  - 41 nm (preliminary) reached with FONT FB ON
  - Non-linear magnetic field effect being studied.







https://agenda.linearcollider.org/event/7014/contributions/36882/attachments/30069/44951/ATF2_okugi_20160601.pdf



T. Okugi, ECFA-LCW, Santander June, 2016

KEK-ILC Action Plan Issued, 2016

https://www.kek.jp/en/NewsRoom/Release/20160106140000/

Topics

KEK issues action plan for the International Linear Collider

January 6, 2016

Japan's High Energy Accelerator Research Organization (KEK) issued an KEK-ILC action plan for how KEK should start its preparation toward the International Linear Collider when the Ministry of Education, Culture, Sports, Science and Technology (MEXT), decides to initiate negotiations with foreign countries.

KEK has been promoting the development of linear collider accelerator technology for a long time and has greatly contributed to the publication of the ILC Technical Design Report (TDR). KEK considers the promotion of the ILC project to be a strategic part of organization's future, described in the KEK Roadmap published in May 2013. Its activities are currently centered around three facilities: the Superconducting RF Test Facility (STF), the Accelerator Test Facility (ATF), and the Cavity Fabrication Facility (CFF). In addition to the efforts in the technical development,, KEK established the Planning Office for the ILC in February 2014, to promote the ILC project and the technical development activities at KEK.

KEK ILC Action Plan

- plan the technical actions, organization, human resources and training to realize formal approval of the ILC project
- ensure a smooth start of the construction phase through the preparation phase from the current status

	Pre-preparation Phase	Main Preparation Phase			
	Present	P1	P2	P3	P4
ADI	Establish main parameters	Verify parameters w/ simulations			
SRF	Accelerate beam with SRF cavity string and cryomodule	Demonstrate mass-production technology and stability Demonstrate Hub-lab functioning and global sharing			
Nanobeam	Achieve the ILC beam-size goal	Demonstrate the nanobeam size and stabilize the beam position			
Positron source	Demonstrate technological feasibility	Demonstrate both the undulator and e-driven e+ sources			
CFS	Pre-survey and basic design	Geology survey, engineering design, specification, and drawings			
Common technical support	Support engineering and safety	Common engineering supports (network, radiation safety, etc.)			
Administration	Project planning and promotion Preparation for the ILC pre-lab	General affairs, finance, international relations, public relations Establishing the ILC pre-lab and managing the ILC preparation			

ILC Cost-Reduction R&D Proposal

focusing on SRF in 2~3 years

The R&D proposal addresses the International Linear Collider (ILC) cost reduction feasibility, followed by industrialization R&D during the “main preparation” phase.

A-1. Nb material preparation
- with optimum RRR and clean processing for sheeting/piping

A-2. SRF cavity fabrication for high-G and high-Q
- with a new surface process provided by Fermilab

A-3. Power input coupler fabrication
- using new ceramic requiring no coating

A-4. Cavity chemical treatment
- vertical EP and easier handling w/ safer solution

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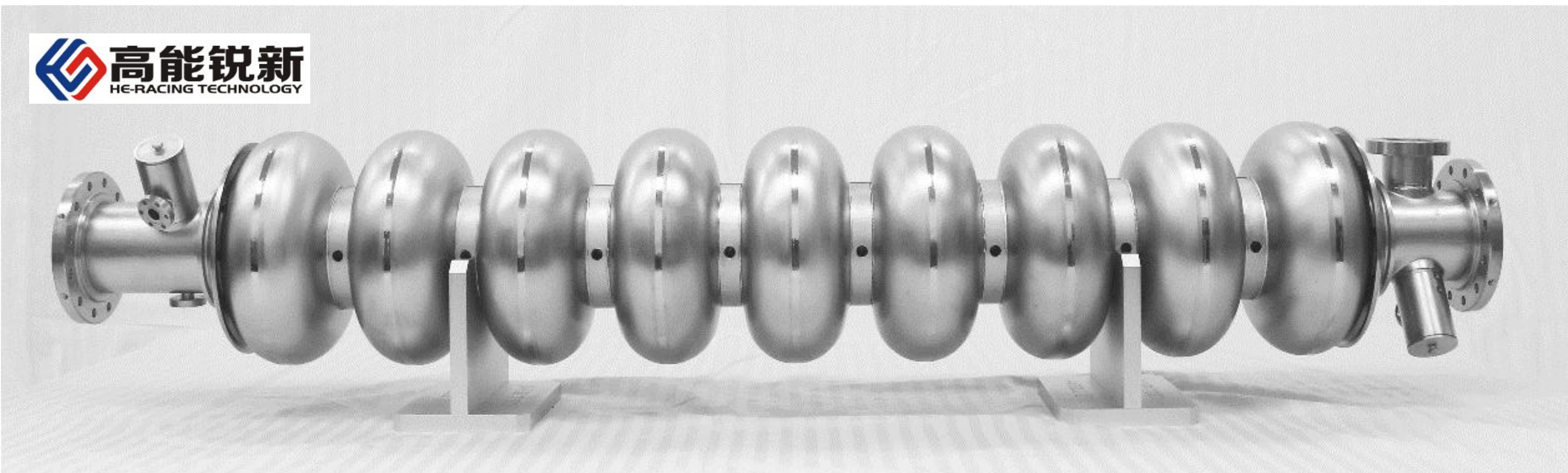
IHEP TESLA Cavity Industrialization

(July 28, 2016)



- Joint effort of IHEP ILC Group and HE-Racing Technology Corporation (IHEP workshop) for ILC cavity technology transfer and industrialization study.
- First 1.3 GHz TESLA 9-cell cavity (HERT001) has been completed on July 28th, 2016 and passed vacuum test.
- Expect to surface-process by EP and test at KEK in Autumn.

HE-Racing Technology (HERT)

- Rich experience in accelerator components manufacture:
  - S-band and C-band accelerator tubes, SLED, RFQ, magnets …
  - SRF cavities (spoke and elliptical) and high power input couplers
- Cavity fabrication facilities:

Press Machine

CNC Turning Center

Vertical Machining Center

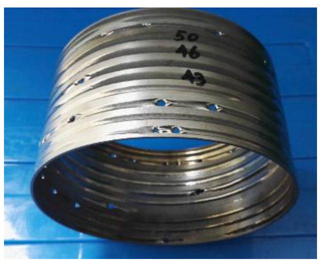
CMM Machine

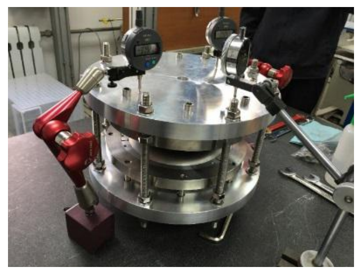
Vacuum Furnace

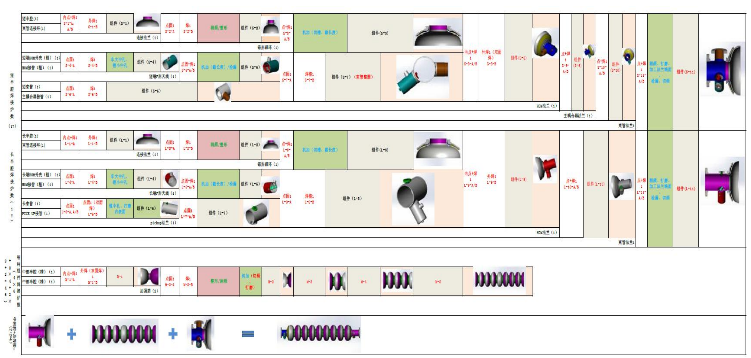
EBW Machine

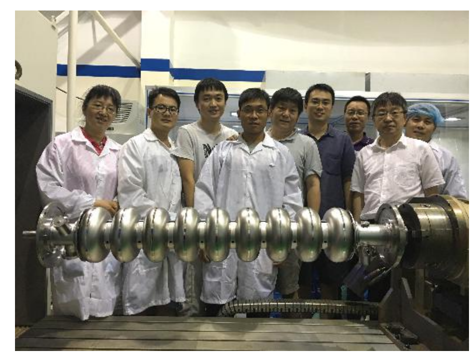
Cavity Fabrication

- Optimized manufacturing process, welding parameters and structures
- Accurate frequency, shape and length control; careful surface cleaning
- More cavities to further improve the welding quality, simplify the manufacturing process, and reduce cost for mass-production



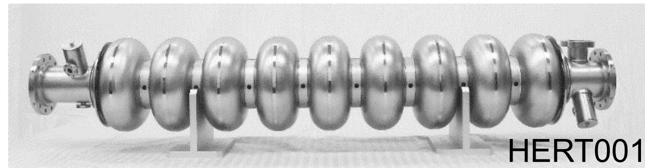




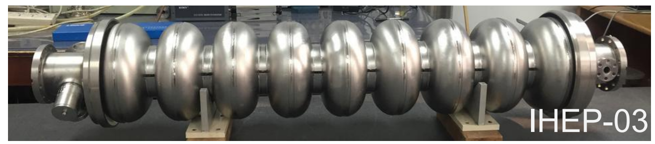


IHEP 1.3 GHz Cavity R&D

2016 9-cell **TESLA**, fine grain cavity with HOM, by High-Energy Racing

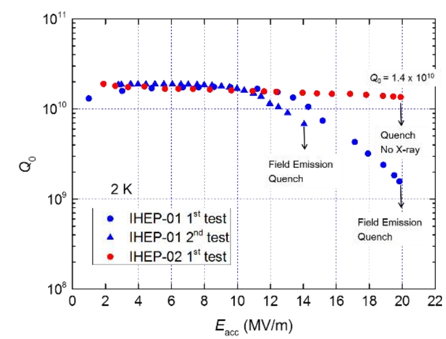


2014 9-cell **TESLA-like**, fine grain cavity with HOM, 16.8 MV/m by EP



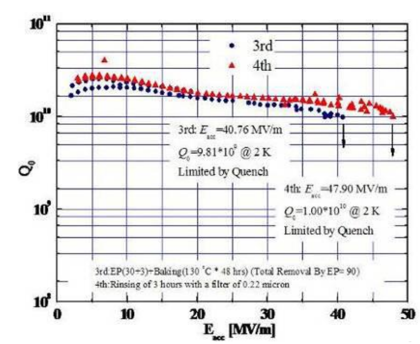
2012 9-cell **Low Loss**, large grain cavity with HOM, 20 MV/m by EP

2010 9-cell low-loss, large grain cavity without HOM, 20 MV/m by CP



2008 single cell low-loss large and fine cavity, max. 40 MV/m by CP

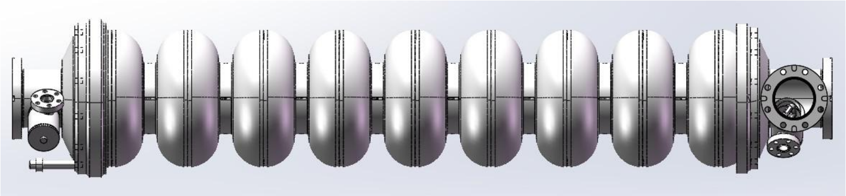
2006 single cell ICHIRO large grain cavity, max. 48 MV/m by EP

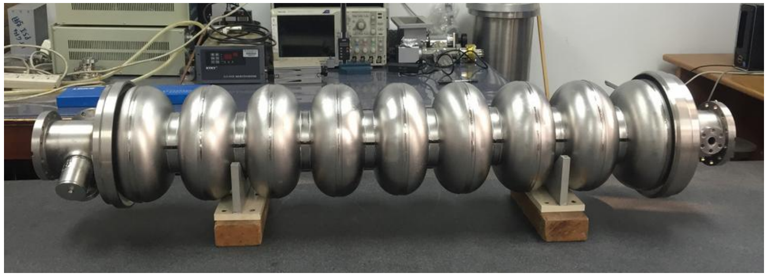


IHEP03@KEK（2016.02.22~2016.04.30）

(IHEP-KEK ILC 1.3GHz TESLA-like 9cell Cavity Collaboration)

1. Frequency and field flatness measurement
2. Inspection of inner surface by Kyoto-camera
3. Local grinding around defect area
4. Pre-EP (5 um) &EP-I (100 um)
5. Annealing
6. Inspection of inner surface by Kyoto-camera
7. Pretuning
8. EP-II (10 um), HPR
9. Clean room assembly, baking
10. Set-up of VT system with T-map
11. Vertical Test
12. Frequency and Field flatness measurement
13. Inspection of inner surface by Kyoto-camera after VT

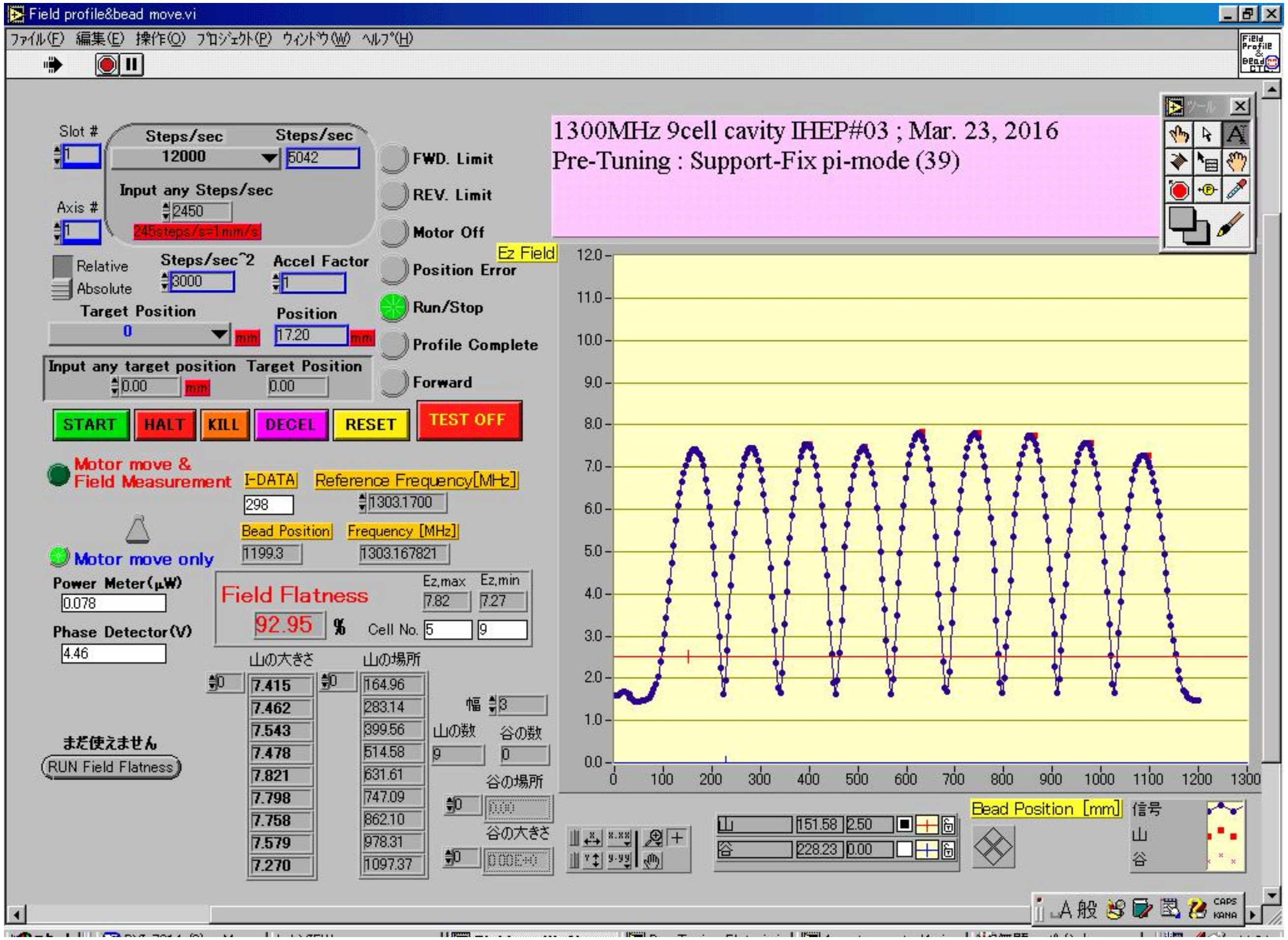




EP Preparations

Ultrasonic cleaning

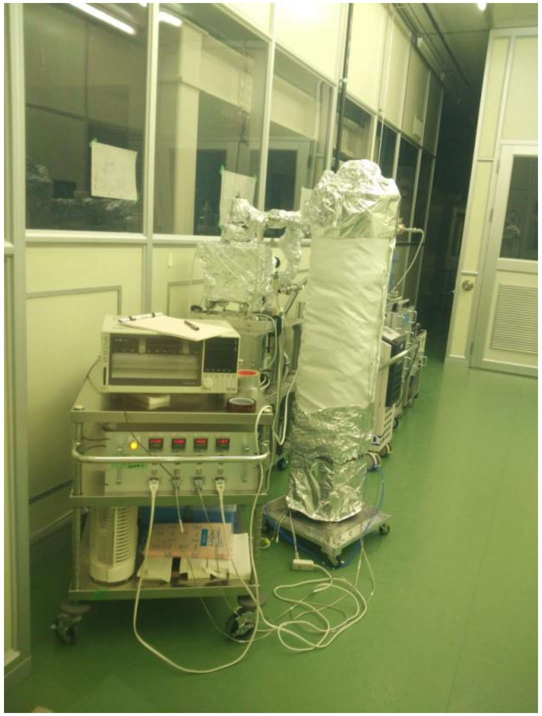
π-mode Field Flatness after pre-tuning



π-mode (1303.167MHz) Field Flatness = 92.95%

Cavity assembly, Baking

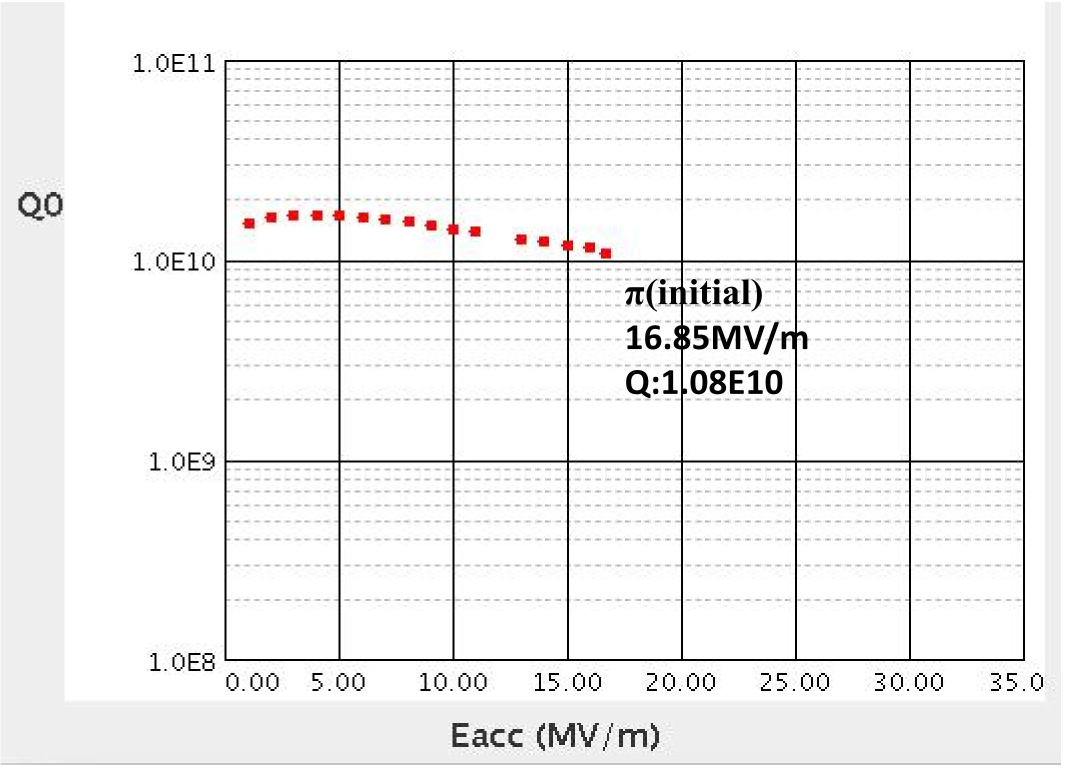
leak test



Baking(48h)

IHEP-03 Vertical Test Result

CBP(80 μm@IHEP), Pre-EP(5 μm),EP-I(100 μm), Annealing(750 ℃,3h)
EP-II(20 μm), HPR(1.5h+3.5h),baking(140 ℃,48h)

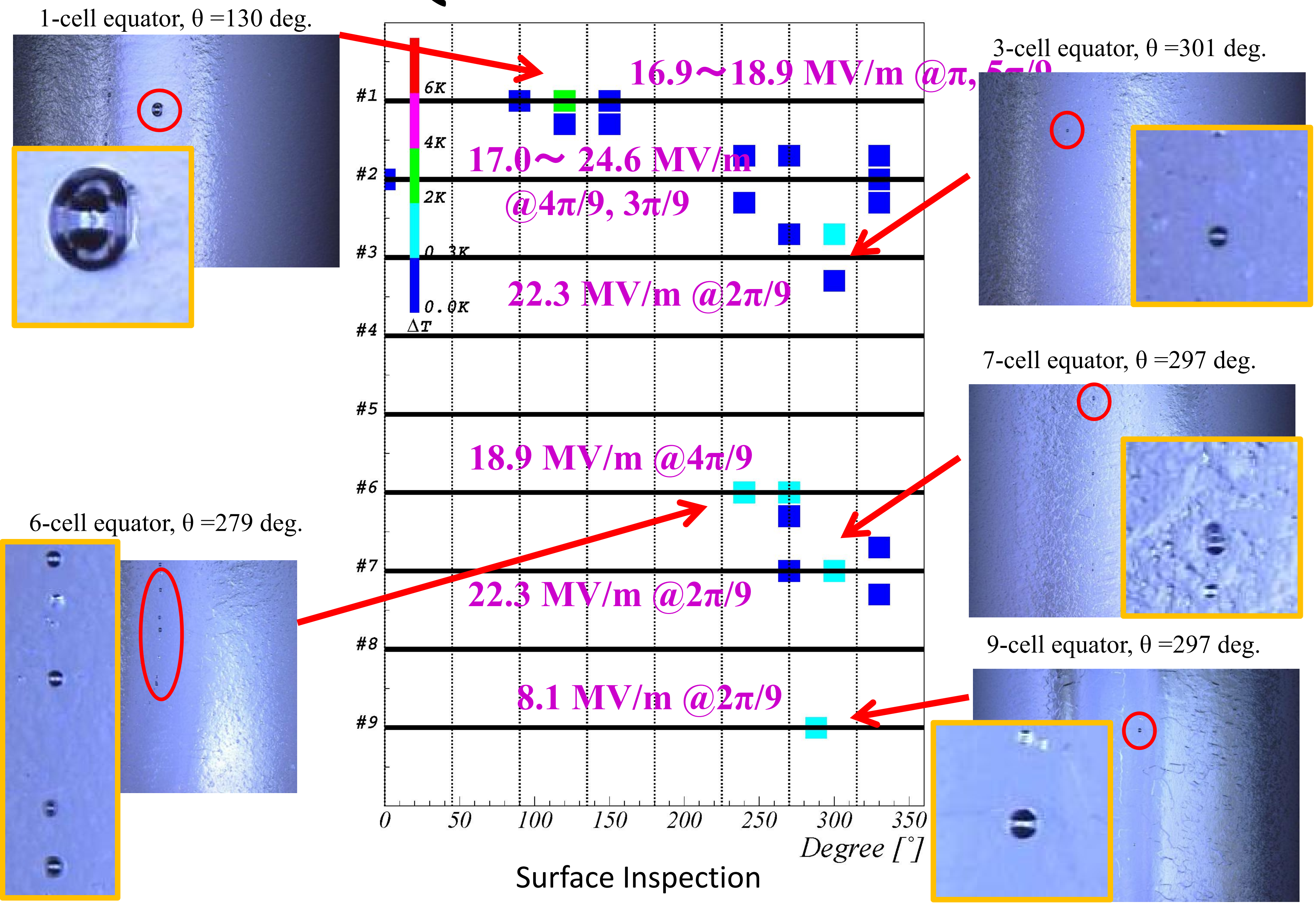


Cell Gradient by Passband Modes Test

MV / m	Cell 1& 9	Cell 2 & 8	Cell 3 & 7	Cell 4 & 6	Cell 5	Quench Location/Comments
π(initial)	16.85	16.85	16.85	16.85	16.85	**Heat @ 1-cell equator 120°** X-Ray
π(final)	16.64	16.64	16.64	16.64	16.64	**Heat @ 1-cell equator 120°** X-Ray
2 π / 9	8.10	19.44	22.28	14.90	---	**Heat @ 3&7-cell equator** X-Ray
5 π / 9	18.85	12.82	22.24	3.77	23.94	**Heat @ 1-cell equator 120°** X-Ray
4 π / 9	13.00	17.03	7.41	18.85	---	**Heat @ 6-cell equator 240°~270°** X-Ray
3 π / 9	12.32	24.64	12.32	12.32	>24.64	**Heat @ 2-cell equator 300°** X-Ray
$E_{acc, max}$	**18.85**	**24.64**	**22.28**	**18.95**	**24.64**	**Ave. $E_{acc,max}$=21.54**

Cell3 >22MV/m, Cell4 >19MV/m, Cell8>24.6MV/m,Cell9 >16.85MV/m

Quench location



Surface Inspection

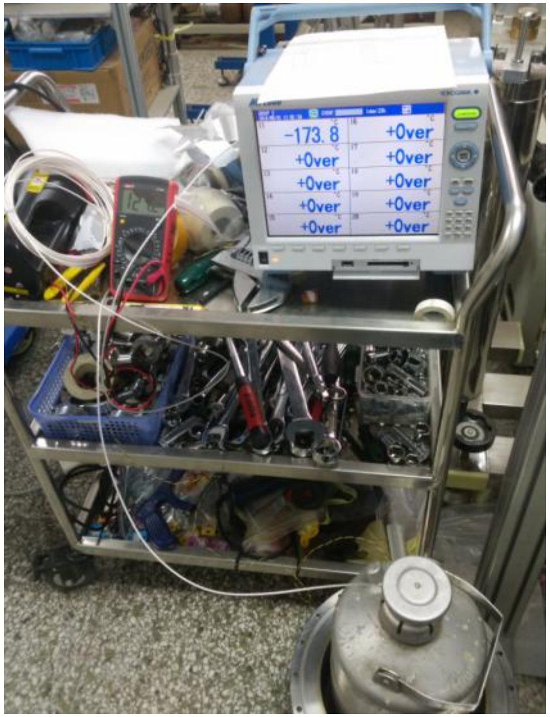
Acknowledgement

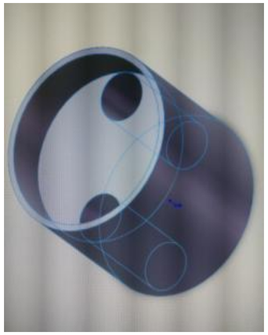
Eiji Kako, Kensei Umemori, Mineyuki Asano, Motoaki Sawabe, Kouichi Nakamura, Fumihiko Tukada, Jun Sakai, Taisuke Yanagimachi, Shinichi Imada, Hiroki Yamada……

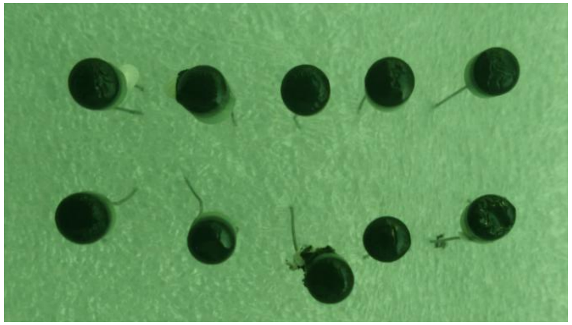
IHEP T-mapping System

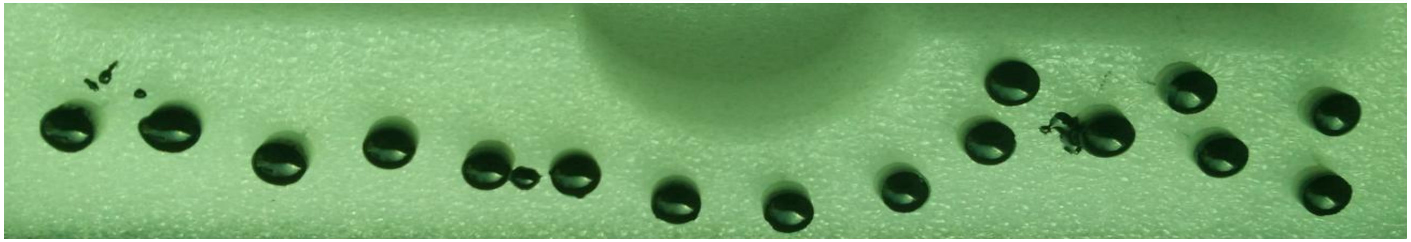
- T-mapping is the most common diagnostic tool for SRF cavities
- We will develop a fixed T-mapping systems
- With Carbon Resistor (200 AB sensor at first step)
- Sampling time: < 100ms
- Data logger: Not determined
- Labview

T-mapping : Resistors





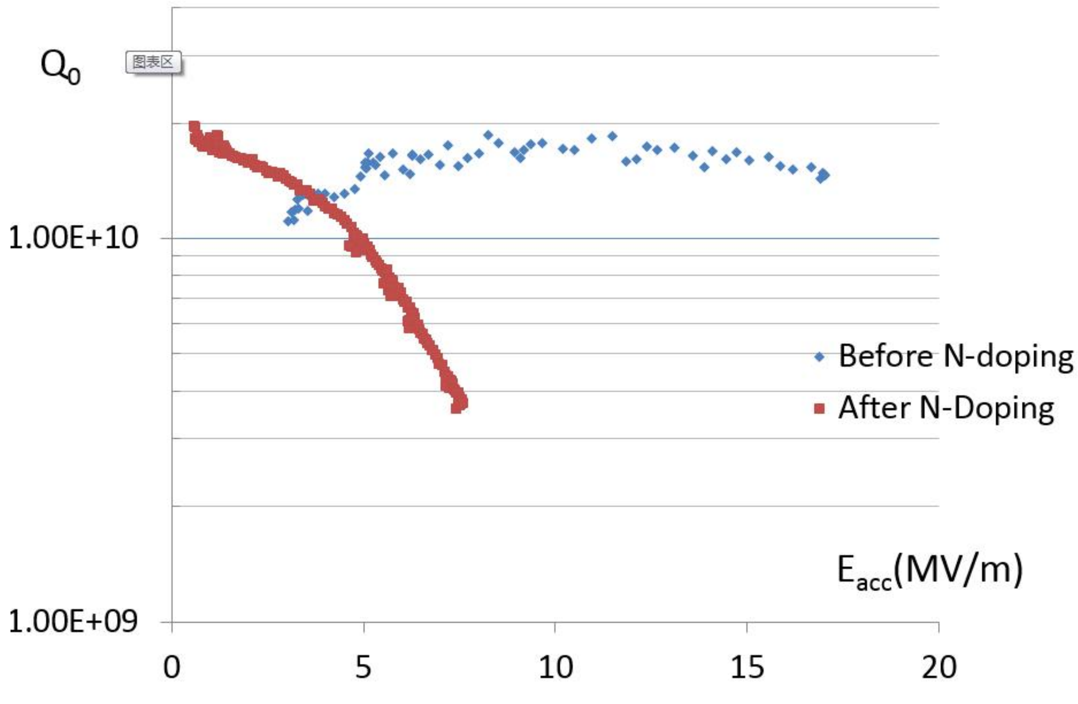




Temperature sensor

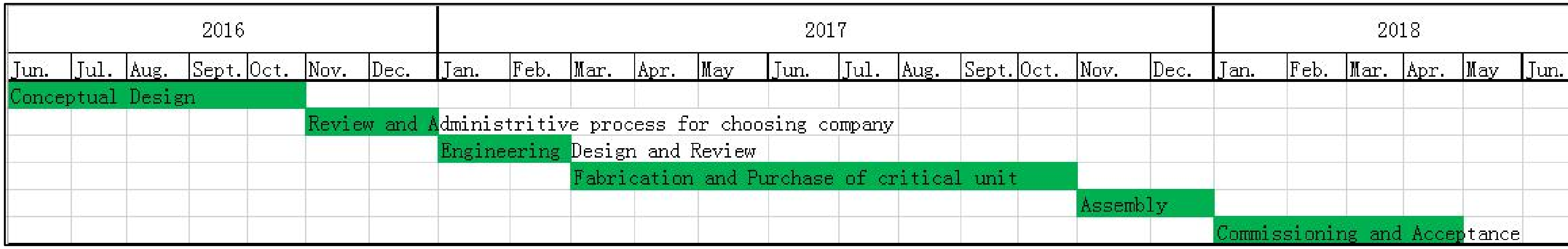
Vertical test of 1.3GHz cavity N-doped

- 1.3 GHz single-cell cavities were N-doped after Nb sample experiments.
- Several vertical tests were finished, but Q Value didn't increase. Key reason: **NO EP**, just received BCP. Other reasons are also under research.



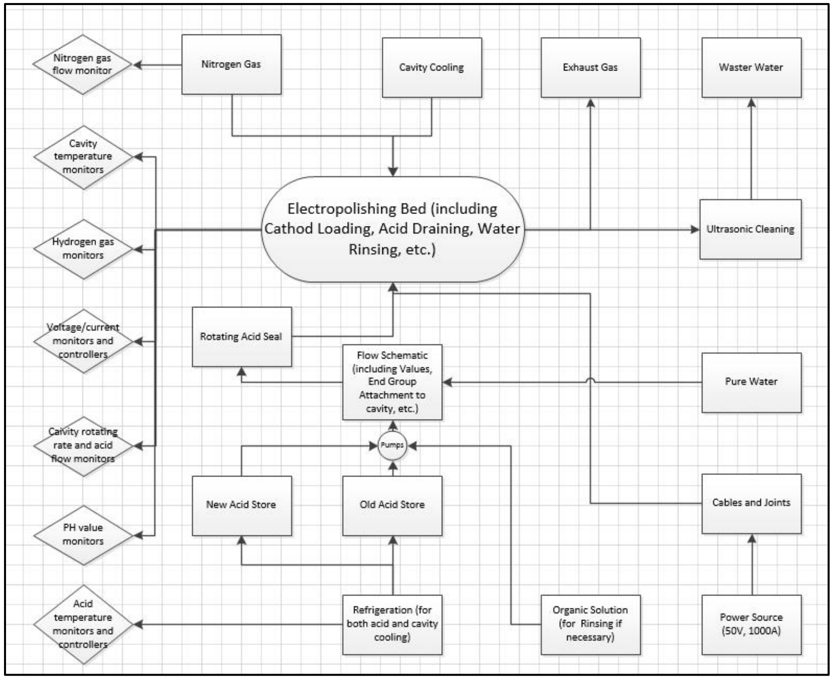
Magnetic shielding around cavity

IHEP EP Schedule



Key Time Points:

- Oct. 2016: Finish the Conceptual Design
- Dec. 2016: Finish Review and Administrative process for choosing company
- Feb. 2017: Finish Engineering Design and Review
- Oct. 2017: Finish Critical Units fabrication or Purchase
- Dec. 2017: Finish Assembly
- Apr. 2018: Finish Commissioning and Acceptance

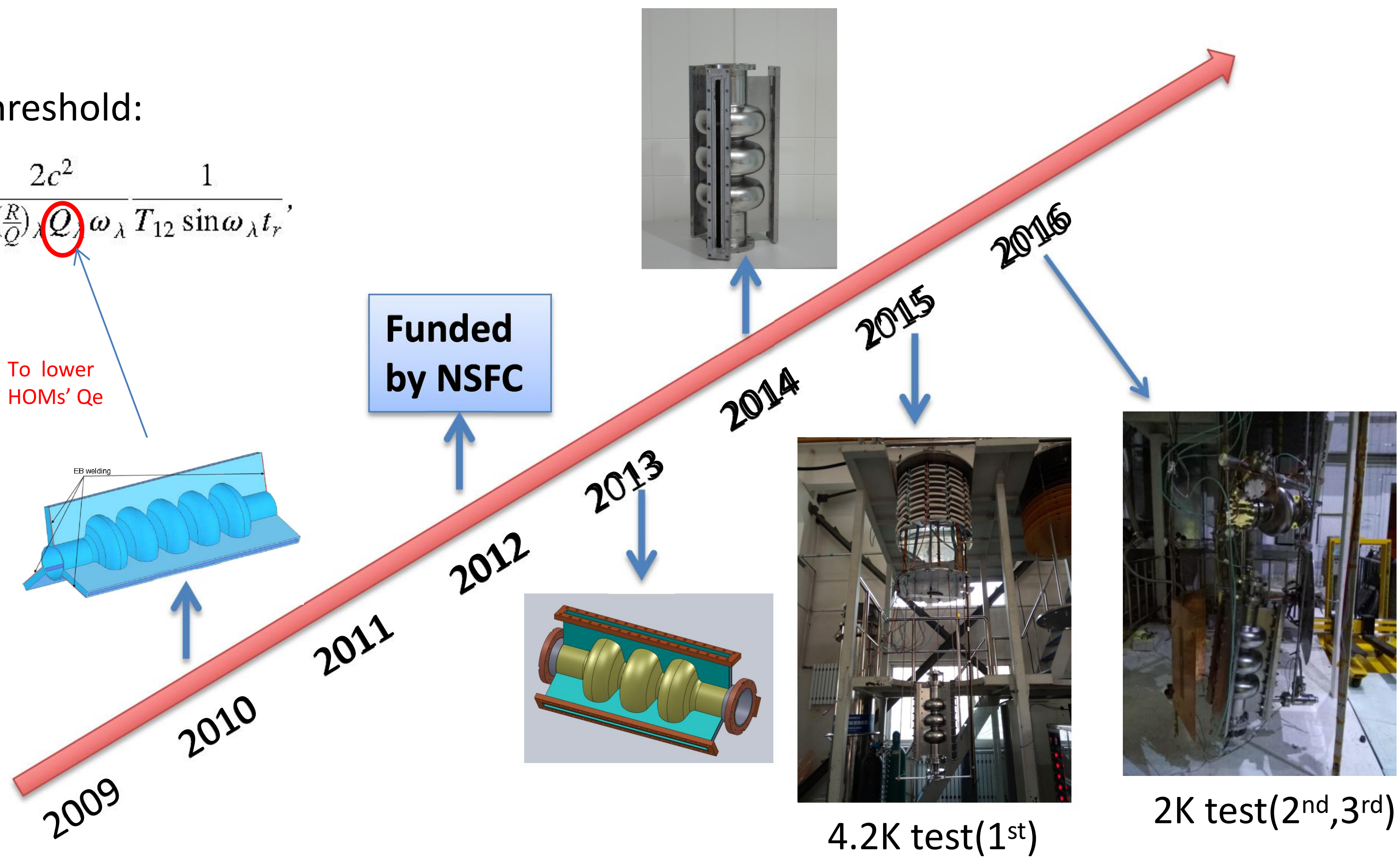


Layout of Critical Units for Electropolishing facility

Slotted cavity development time line

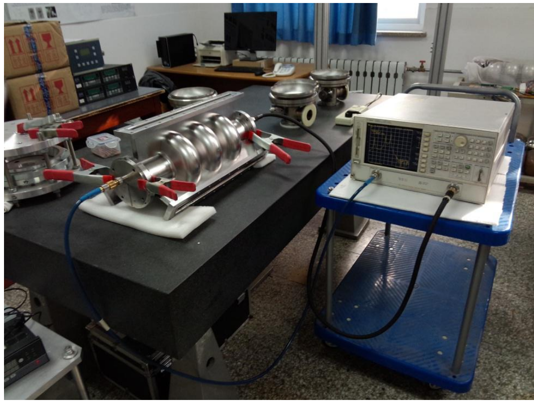
BBU threshold:

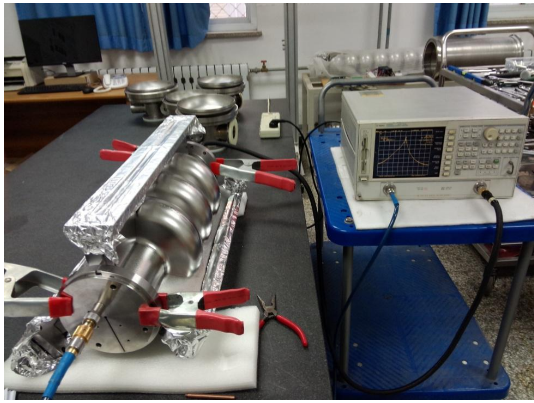
$$I_{\mathrm{th}} = -\frac{2c^2}{e(\frac{R}{Q})_\lambda Q_\lambda \omega_\lambda} \frac{1}{T_{12}\sin\omega_\lambda t_r},$$



Slotted Cavity HOMs' Damping Comparison

Measured Value				Calculated Value	
F (GHz, with covers)	Q_L (with covers)	Q_L ($\approx Q_e$, without covers)	F (GHz, without covers)	Q_e (without covers)	F (GHz)
1.524	560	x	x	5.2	1.525
1.5312	714	x	x	-	-
1.5926	624	x	x	-	-
1.5979	606	100	1.599	2.17	1.599(TE_{111})
1.677	1037	x	x	5.74	1.676
1.68	995	x	x	-	-
1.713	94	x	x	-	-
1.7526	1192	x	x	-	-
1.7492	1280	x	x	20.4/8.8	1.754/1.747
1.794	1312	x	x	-	-
1.8405	2047	344	1.842	446	1.855(TM_{110})
1.9	445	x	x	-	-
1.973	714	x	x	15.9	1.973
2.052	470	x	x	5.43	2.043
2.086	615	x	x	15.2	2.093
2.184	531	172	2.173	14.2	2.175
2.1985	321	x	x	-	-
2.254	1450	x	x	20.7	2.252
2.324	1990	2136	2.324	185961	2.326 *
2.365	1224	x	x	-	-
2.4	1071	630	2.4	-	-
2.437	800	667	2.437	105.1	2.439 *





*Notes on TABLE III: Many HOMs disappeared in the network analyzer when opening the waveguide port as the Q_L of these mode decreased below 10 or so. These modes are depicted by "x". Since there are several calculated modes around the measured frequency or the frequency shift between measured frequency and calculated frequency is large, we use "-" to depict. * depicts quadruple mode.

Vertical test

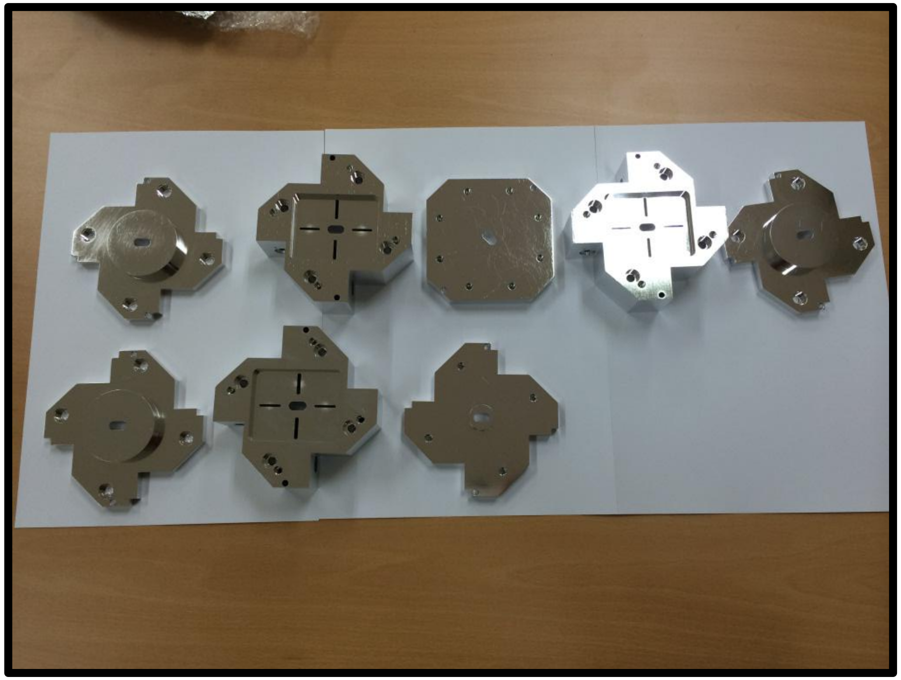
- First test： 4.2K vertical test, limited by power, the accelerating gradient of the cavity reached 2.4MV/m ($Q_0=1.4\times10^8$).
- Second & third test： 2K vertical test, the Q_0 of slotted cavity were limited by the coupler flange (stainless steel). Maximum Q_0 is 1×10^8. π mode gradient is 1.4MV/m. Maximum B_{pk} of 2/3π mode(with a lower field in beam pipe) is 24.5mT. It is equal to the B_{pk} of π mode with a gradient of 4.3MV/m.
- A longer Nb beam pipe is needed to increase Q_0. Next step, we will add the beam pipe length.

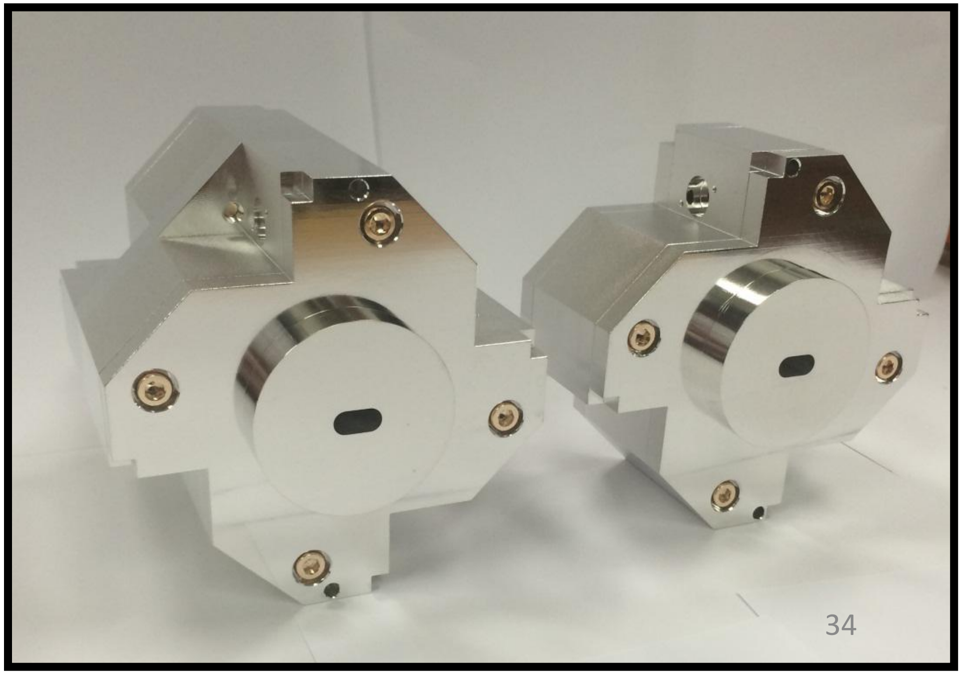
Contents

- Japan
- China
- Korea
- India

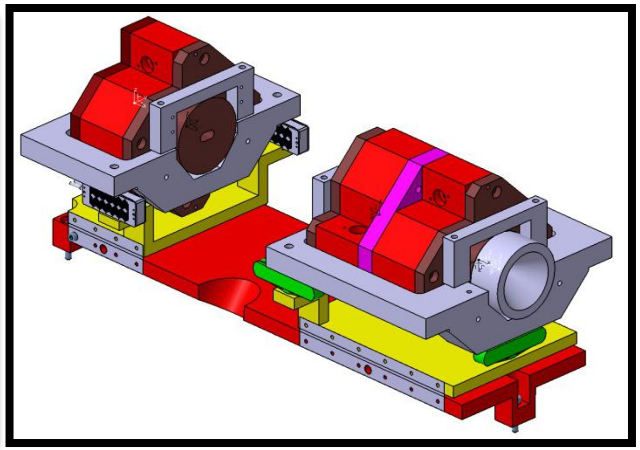
Fabrication of Low-Q IP-BPM

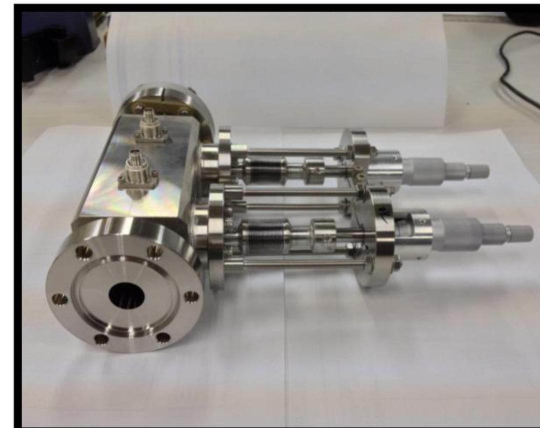
- **Made by Aluminum** (2kg for double block)
  - Precise surface machining within 4um.
  - IPBPM A & B are fabricated together in same block.
  - IPBPM C was fabricated to single block.

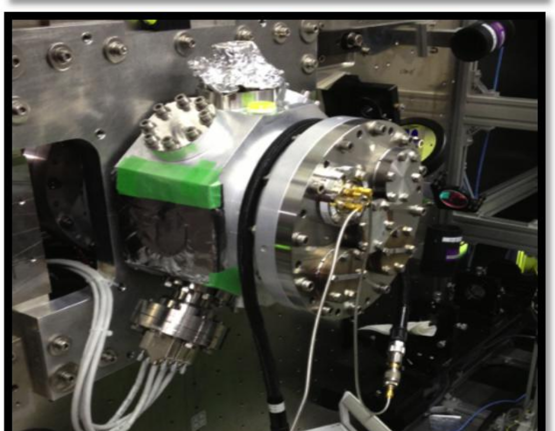


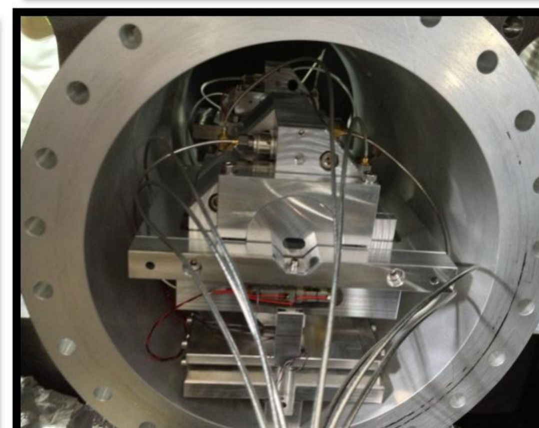


Installation of IP-BPM system









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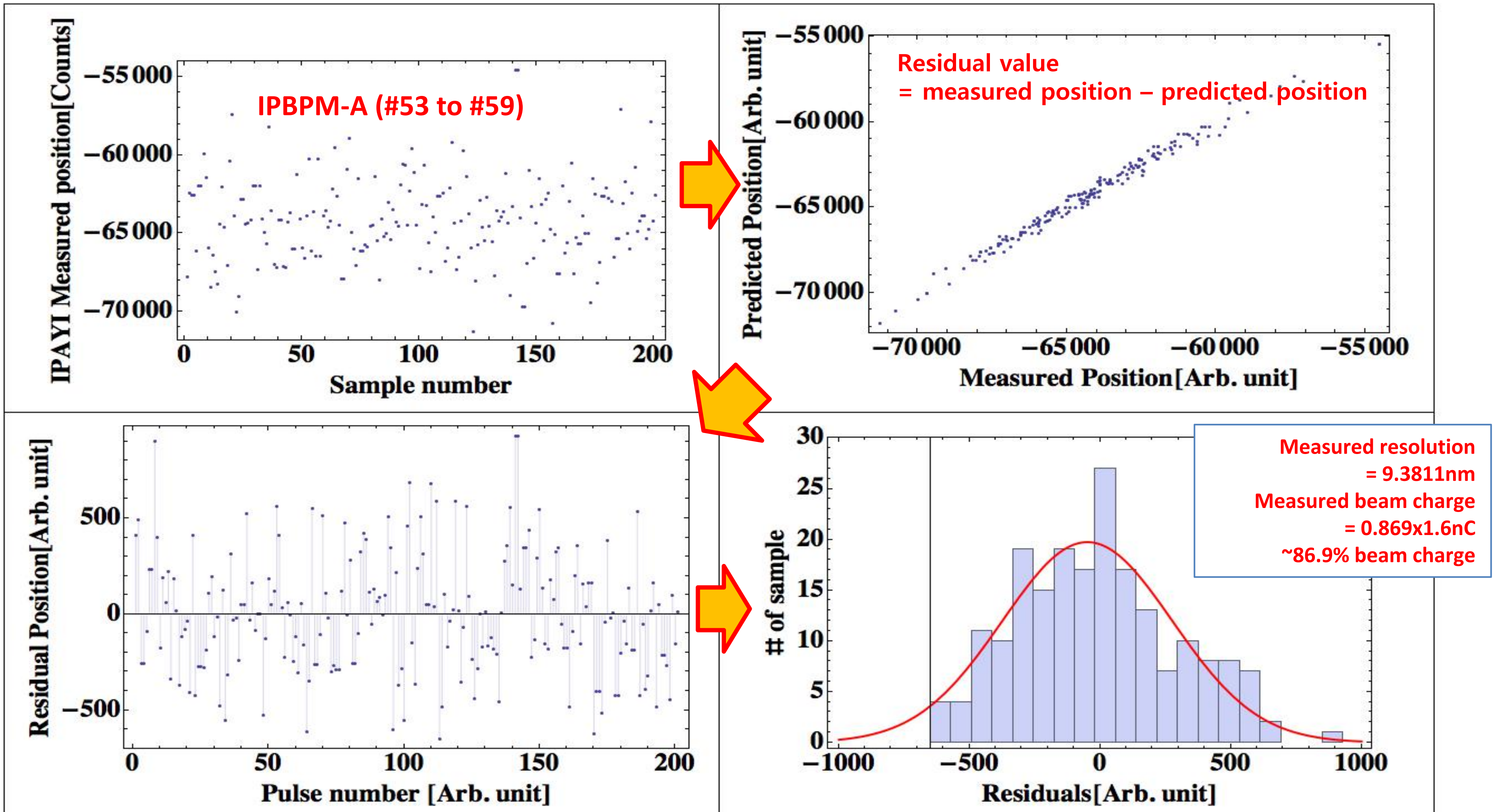
IP-BPM resolution test in KEK-ATF2 (Mar. 2016): position resolution of 8nm



$$\text{Norm. Resolution} = \text{Geo. factor} \times \frac{\text{RMS of residual}}{\text{Calibration factor}} \times \frac{\text{Measured charge}}{\text{Nominal charge}} = \mathbf{8.1586nm}$$

Current Accelerator Activities in Korea (2016)

PLS-II
(3.0-GeV Light Source)

10-GeV PAL-XFEL

Rare Isotope
Science Project

Synchrotron for
Carbon Therapy

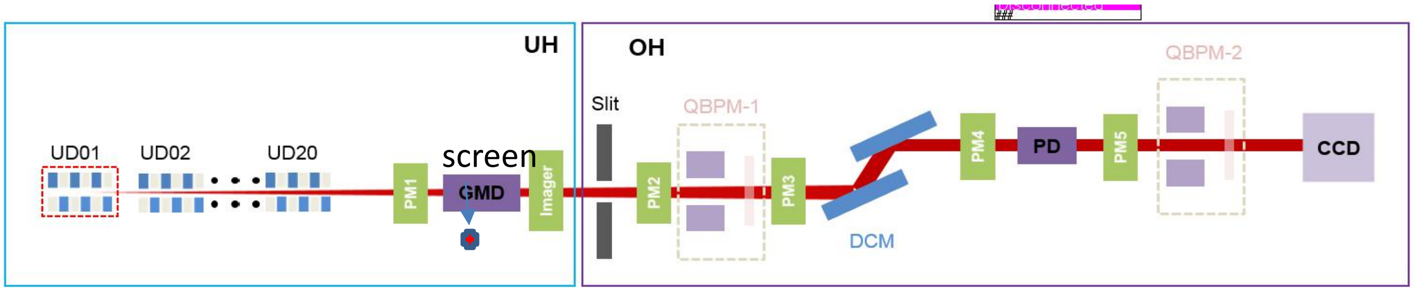
KOMAC,100-MeV
Proton Linac

Status of Accelerator R&D in Korea

- **PAL-XFEL (10 GeV): Commissioning is under progress smoothly. SASE Lasing was achieved officially on June 27. 2016**
- **Construction of RISP (Rare Isotope Science Project) & KHIMA (Carbon Therapy) Project are on-going as planned.**
- **PLS-II (3.0 GeV light source) and KOMAC (100 MeV proton linac) are in users' service.**

PAL-XFEL Tunnel

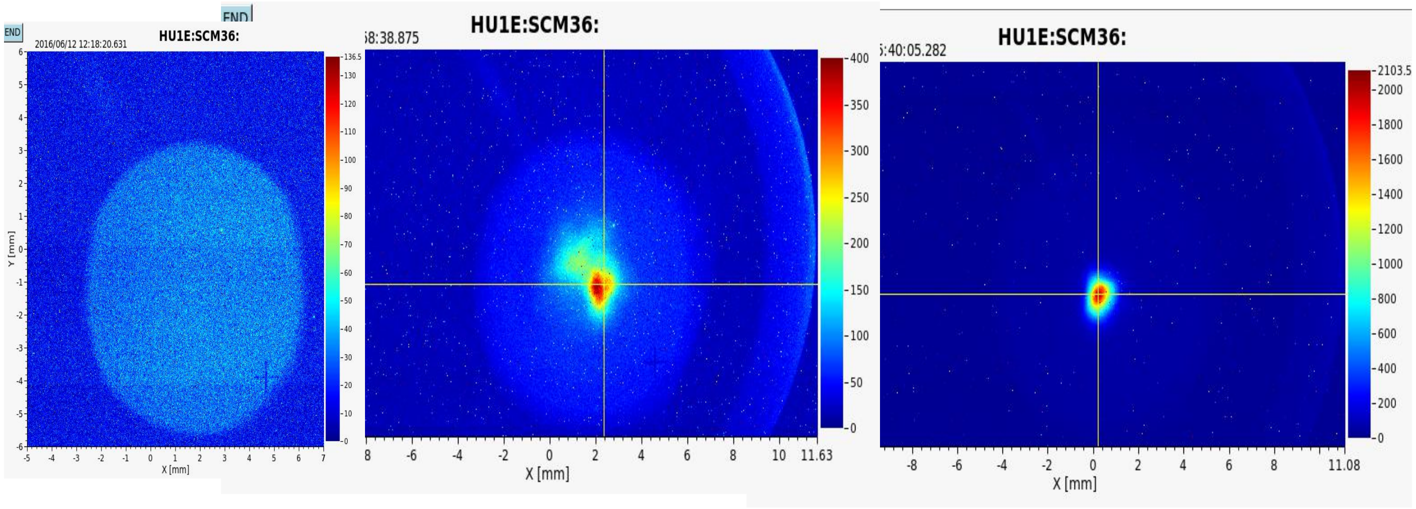
First Lasing at 0.5 nm on 14 June, 2016



Spontaneous Radiation

SASE Radiation

SASE Radiation

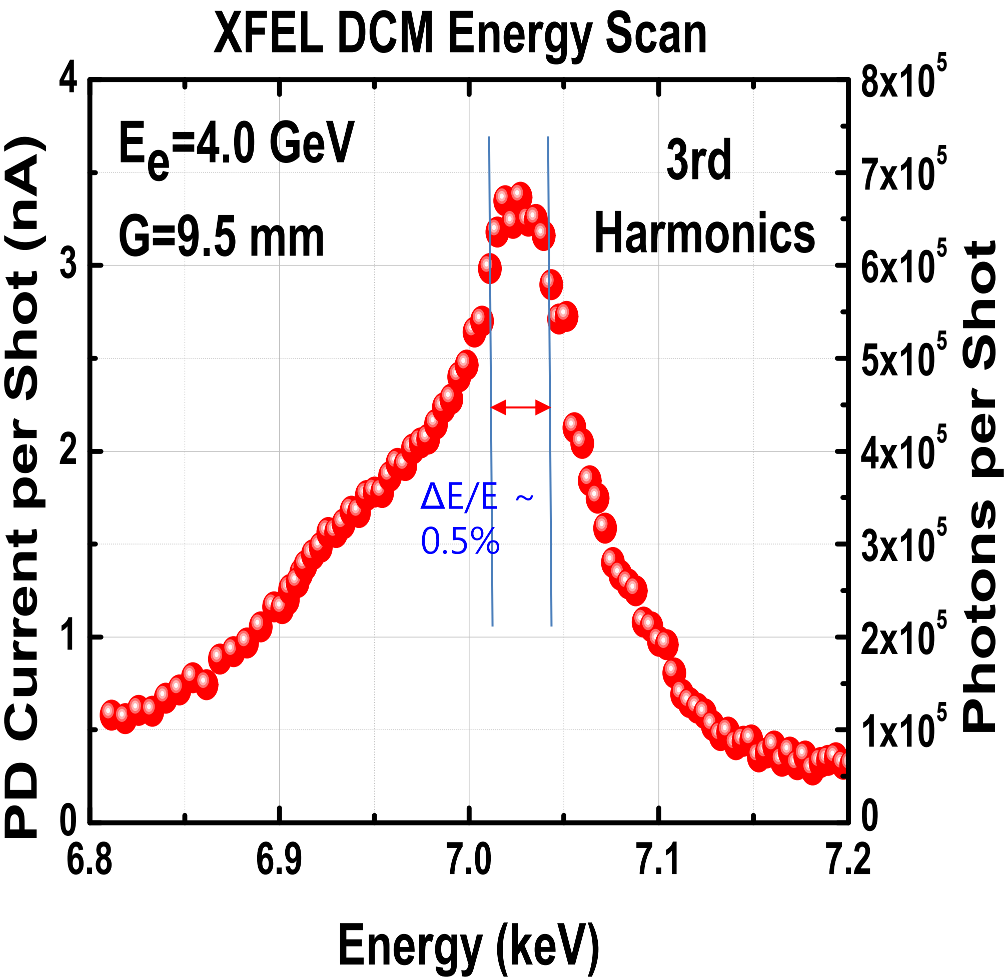


June 12, 2016

14 June 2016

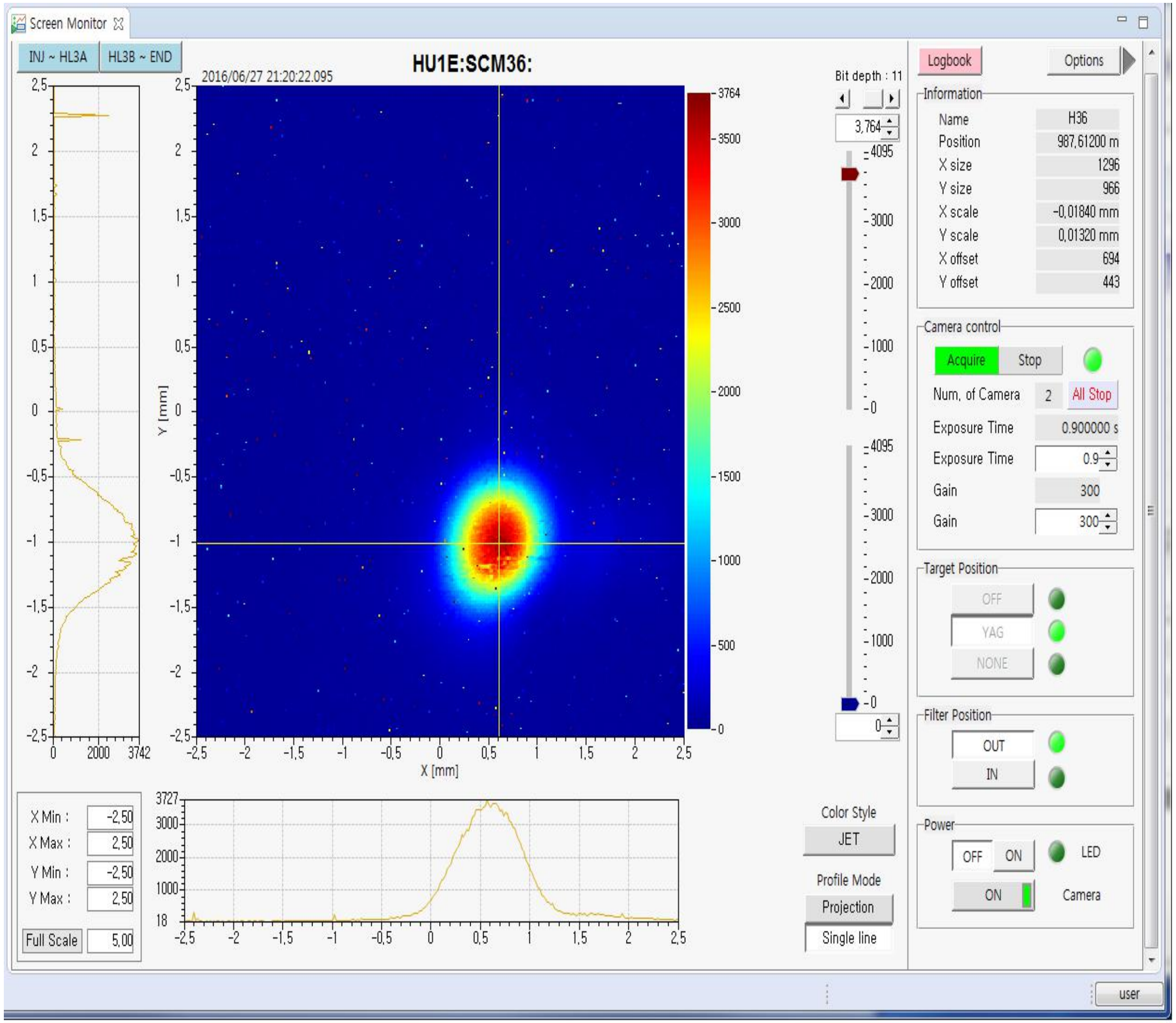
16 June 2016

DCM Energy Scan



- Scan method: 100 shots/point

The brightest 0.5-nm FEL
(Achieved on June 27. 2016)



Contents

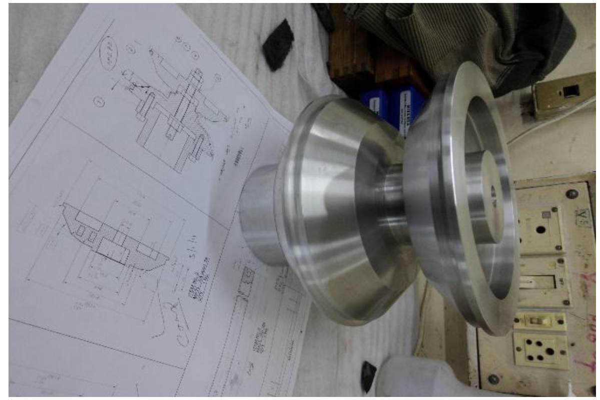
- Japan
- China
- Korea
- India

Development for SCRF Cavity at RRCAT

Raja Ramanna Centre for Advanced Technology

Machining facility

Machined half cells of five- cell SCRF cavity



Dumbell Machining fixture development

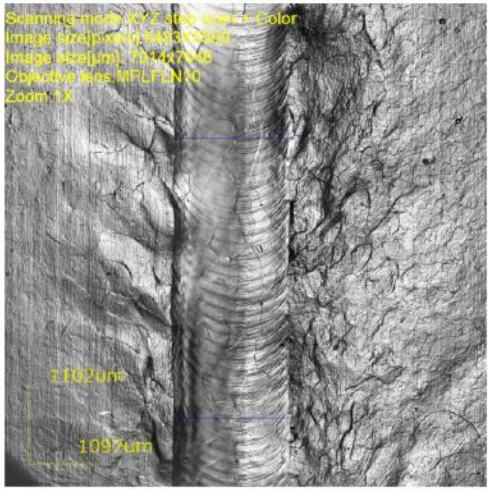
Machining of dumbells on precision lathe

Inspection of machined components

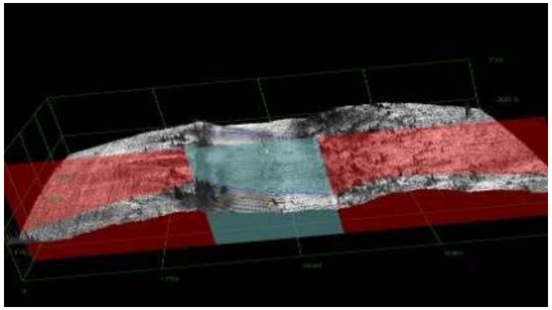
SCRF Cavity Inspection Facility

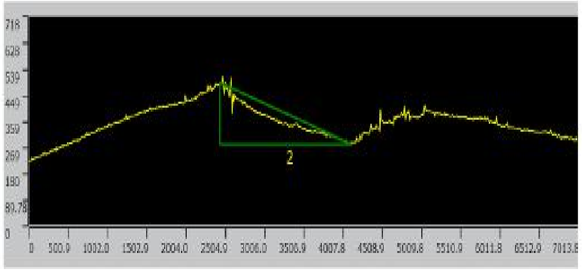
Laser Scanning Confocal Microscope

Imaging Method	3-D Laser Scanning Confocal system
Z - Resolution (Depth)	1 nm
Z - Measurement repeatability	12 nm
X-Y Resolution	0.12 µm



Confocal image of replica





No.	Result	Width[µm]	Height[µm]	Length[µm]
1		1806.831	252.657	1824.410
2		1689.145	212.954	1702.516

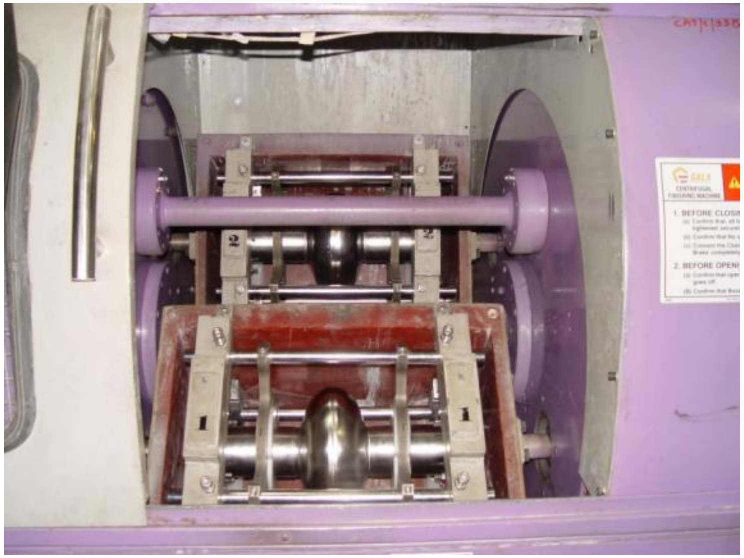
Measurement of bead profile

Cavity Processing Facility

Centrifugal Barrel Polishing (single Cell)

Main features of CBP machine

- Turret and Barrel rotate in opposite direction
- Turret speed – 0 – 200 rpm (variable)
- Barrel speed – 0 – 200 rpm (variable)
- Barrel size – 320 X 320 X 500 mm

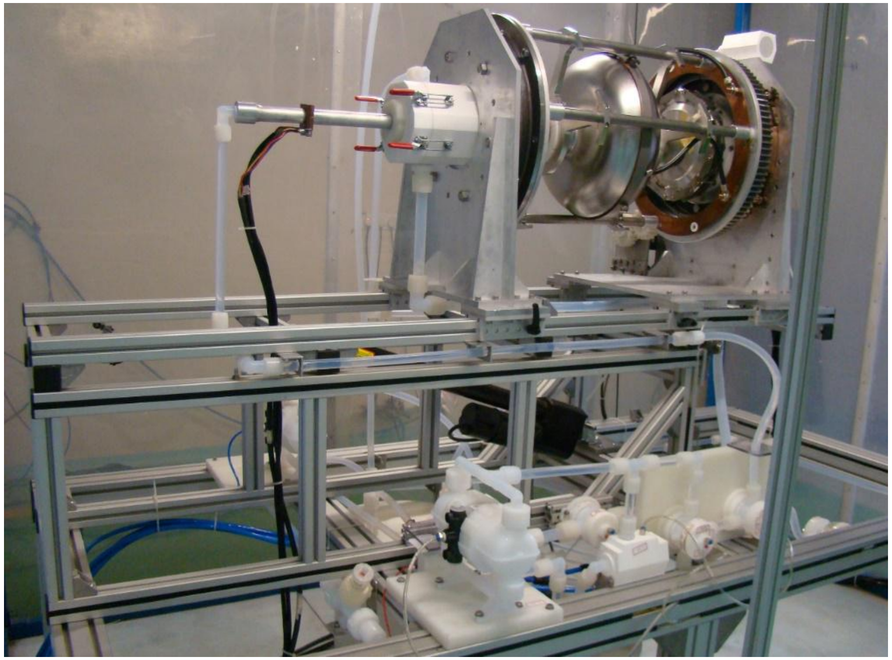


Barrel Polishing Machine

Cavity Processing Facility

Electro-polishing setup for 1.3 GHz & 650 MHz Cavities

EP bench for 1.3 GHz Cavities



EP bench for 650 MHz Cavities

Cavity Processing Facility

High Pressure Rinsing Setup

Ultra Pure Water Plant

Low Temperature Baking & Pilot Cleanroom Facilities

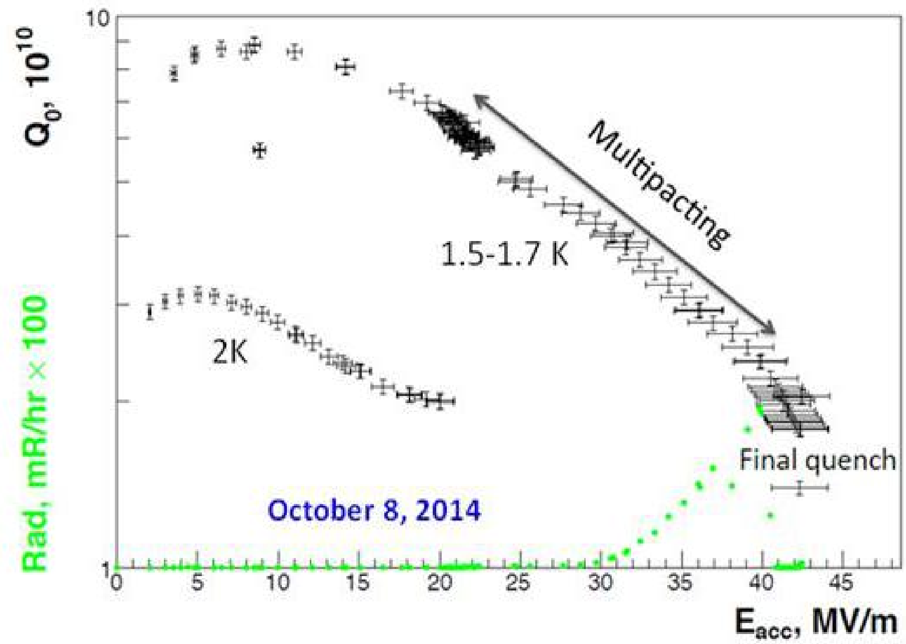
Low temperature baking facility for 650 MHz

Pilot clean room facility

EBW Machine Installed at RRCAT, INDORE

Development of 1.3 GHz Five-cell cavity

A five-cell 1.3 GHz SCRF cavity was Fabricated with IUAC. The cavity was sent to Fermilab for processing under IIFC. The cavity was tested in October 2014.

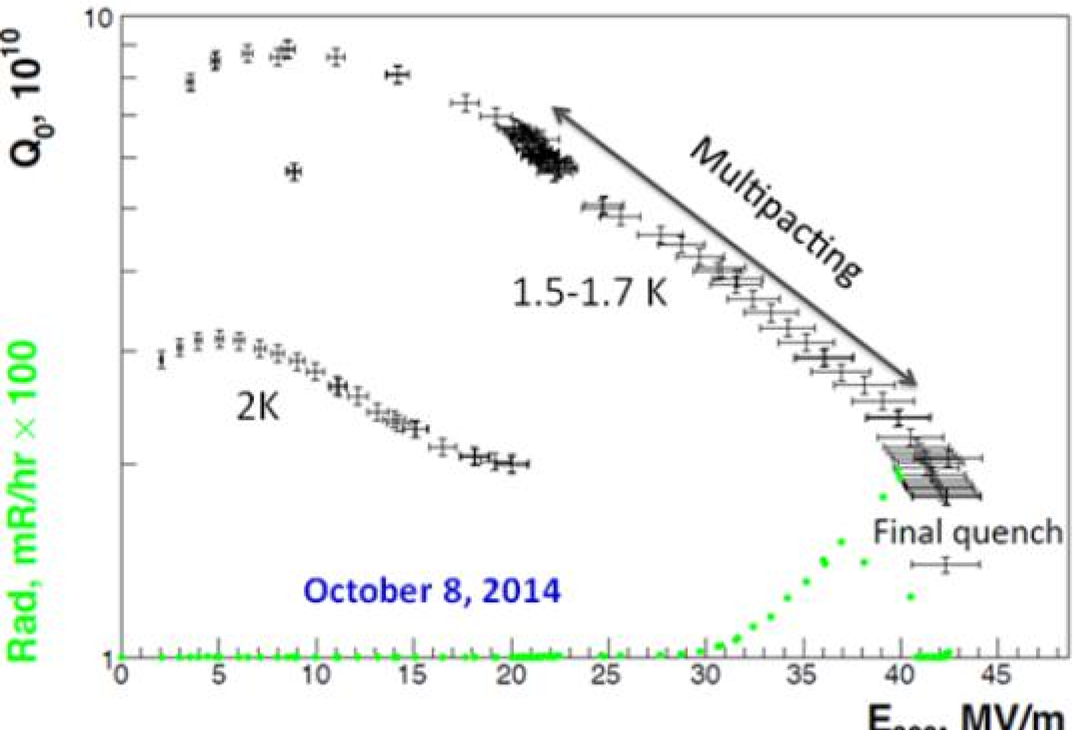


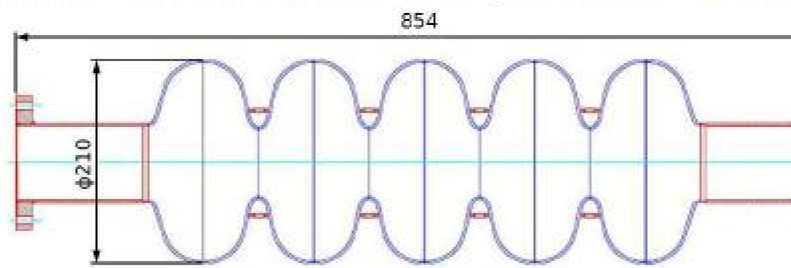
The cavity achieved the accelerating gradient (Eacc) of 20.3 MV/m at 2 K and 42 MV/m at 1.5-1.7 K with Q_0 of 2 x 10^{10}

1.3 GHz 5-Cell Cavity

Two halves of the 5-Cell Cavity.

First multi-cell niobium cavity built in India





1.3 GHz 5-Cell Cavity.

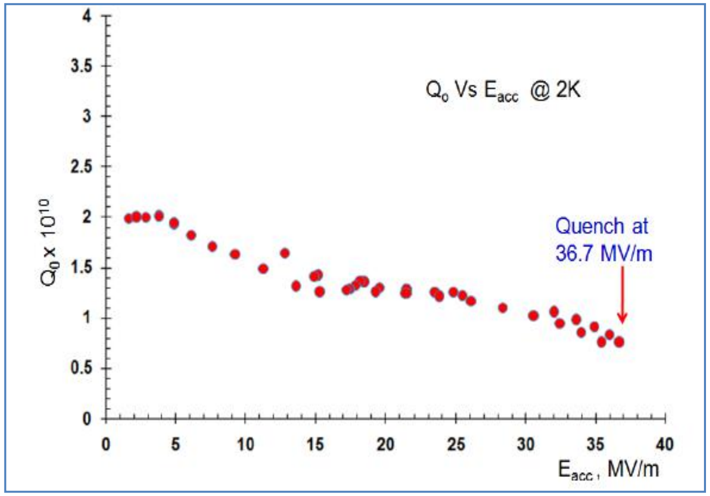
Result of the cold test performed at Fermilab. The cavity reached 20.3 MV/m @ 2 K, and 42 MV/m @ 1.5-1.7 K.

2K Vertical Test Stand Facility

Cryostat & Cavity Insert Assembly

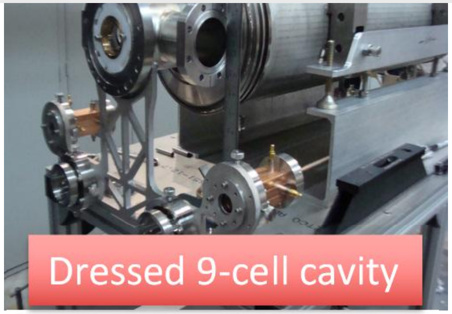
Transfer of liquid helium

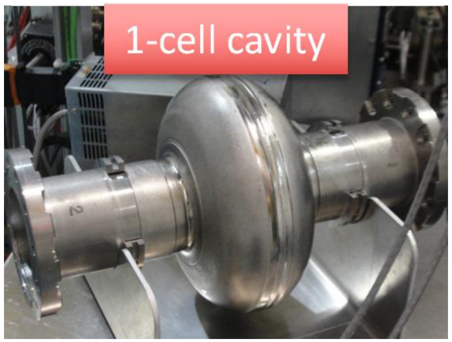
RF testing in progress

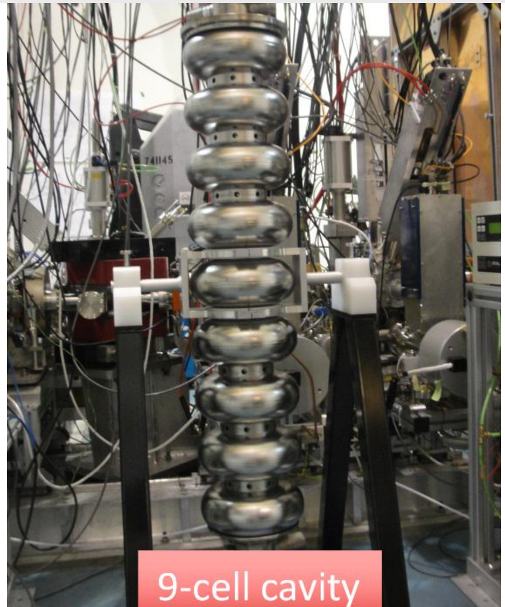


The 2K cryostat & electronics was developed in collaboration with Fermilab under IIFC

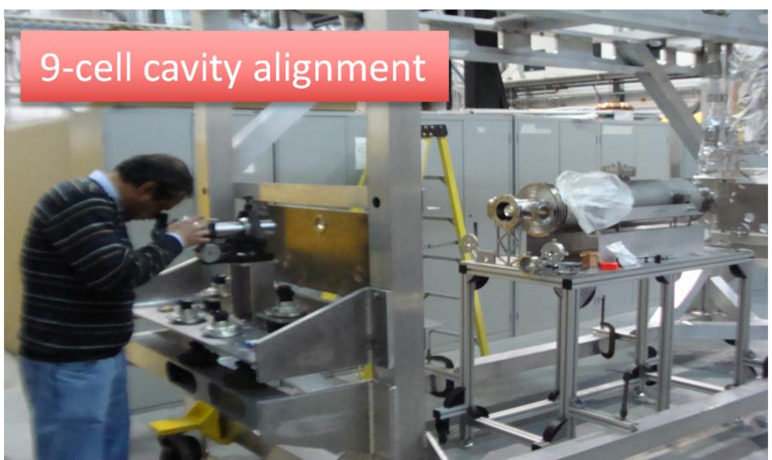
Niobium Cavity development at TRIUMF


Dressed 9-cell cavity


1-cell cavity


9-cell cavity


1-cell cavity cold tests


9-cell cavity alignment


9-cell cavity inspection

Cavities for VECC will come from TRIUMF

Conclusions

Asian countries continue to work and collaborate on
ILC related tecnologies in 2016

- Japan: KEK continue to work on SCRF and Nanobeam technology for ILC with 41nm achieved at ATF2
- China: IHEP continue its effort on 1.3GHz SCRF technologies with great progress with the first IHEP Factory made 1.3GHz 9cell TESLA cavity completed and collaborate actively with KEK on ILC SCRF and positron source. Financial support for ILC ATF2 and positron source collaboration with ILC has been quaranteed in the nex five years.
- Korea: Korea University collaborate actively on ATF2 BPM and home accelerator projects goes well with PAL-XFEL SASE laseing on June 27, 2016.
- India: BARC progresses well on 1.3GHz SC technology and laboratory deveoplments.

Thanks go to Profs. S. Michizono, A. Yamamoto, W. Namkung, E.S. Kim and D. Datta for their providing progress information fron their countries.