# ILC Asia Status

J. Gao

ACFA-AsiaHEP

Jan. 31, 2015, Dong guan, China

# Contents

- Japan
- China
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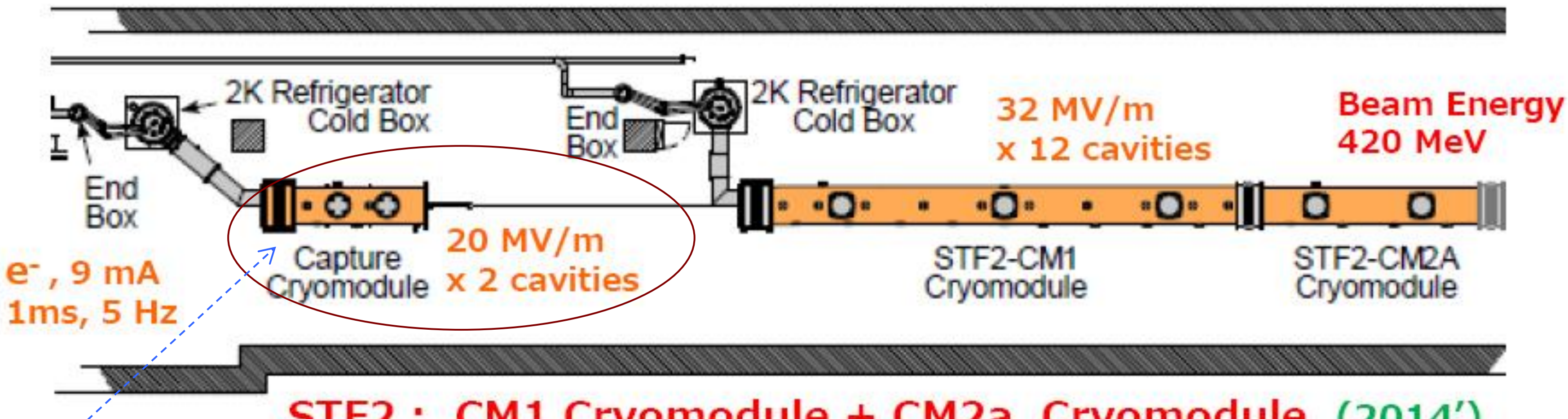
- India

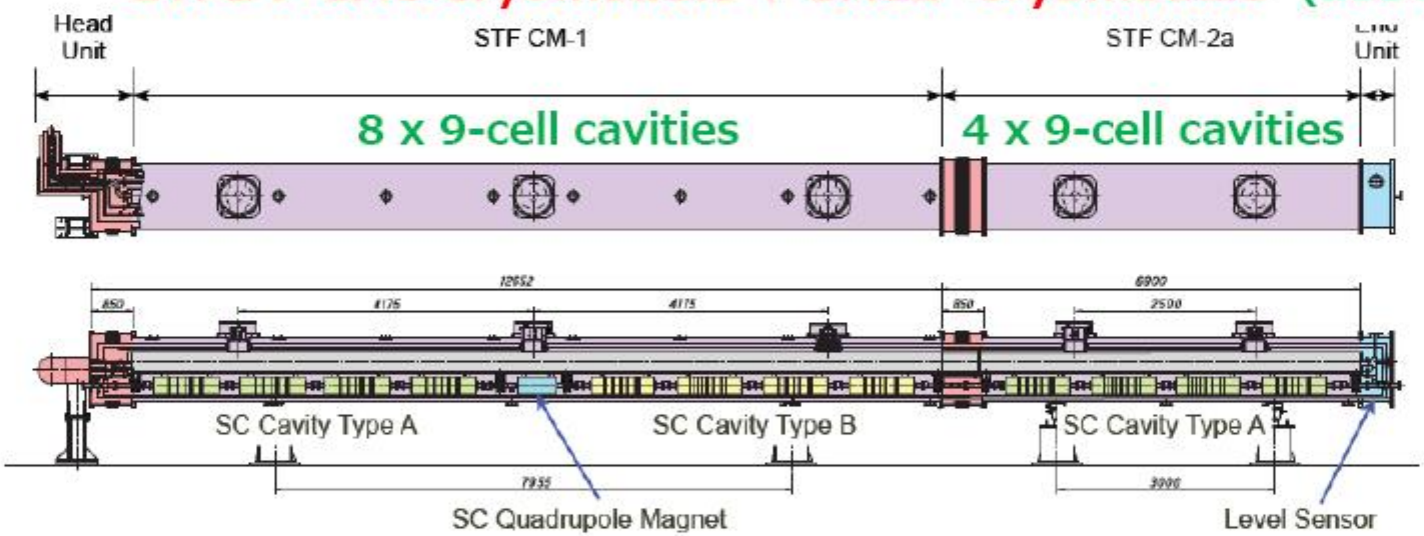
# Progress in Japan to prepare for ILC

- **SRF and Accelerator Technology**
  - KEK STF2 Cryomodule Assembly completed with CM1 (8 cavity string) + CM2a (4 cavity string)
  - The Cool-down and Low power RF test has been successfully carried out in October – November in 2014
  - Beam acceleration to be realized, after RF power transmission (wave guide) system facilitated in 2015.

# Progress in STF2 CM Assembly at KEK



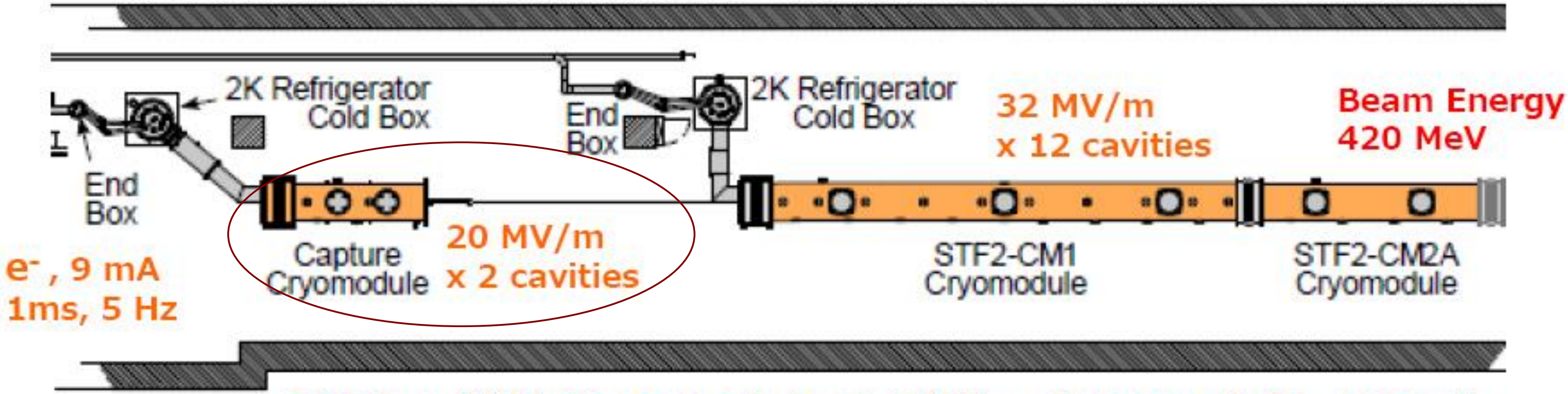

## STF2 : CM1 Cryomodule + CM2a Cryomodule (2014')



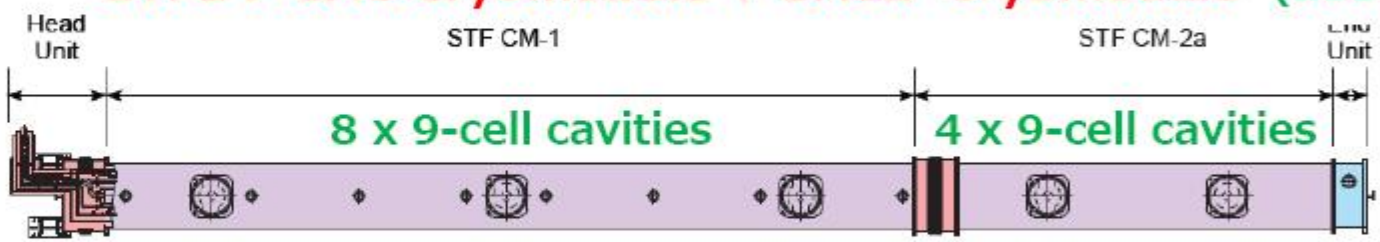

up to ~ 420MeV

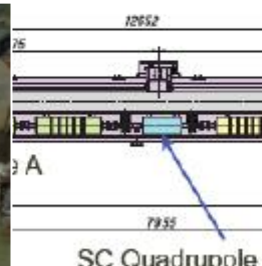
# Progress in STF2 CM Assembly at KEK

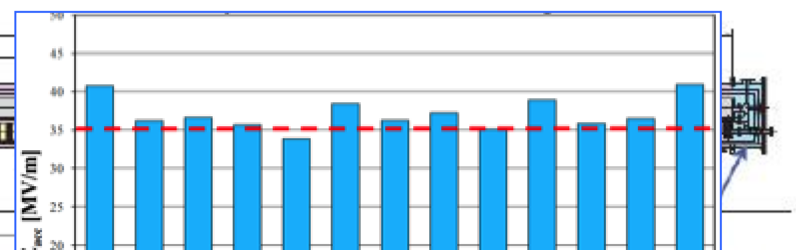
Beam Acceleration
To be in 2015




**STF2 : CM1 Cryomodule + CM2a Cryomodule (2014')**




p to ~ 420Me

Individual vertical test result for Cm1 + CM2a]
Gradient achieved at STF2: > ~ 35 MV/m
Progress: > 90 %, to reach 35 MV/m.

# Progress in Cavity low-power-test at STF2 CMs, October – November, 2014

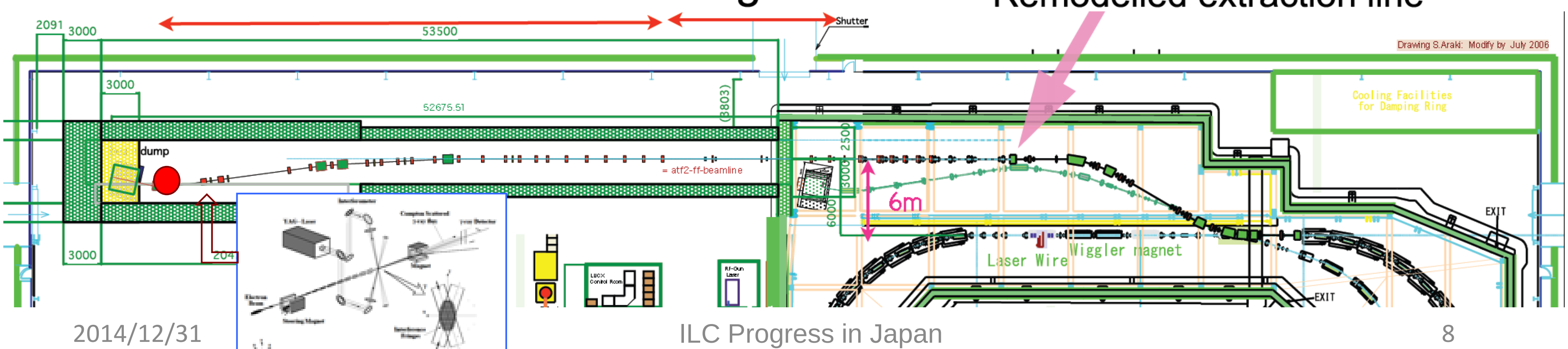
# Progress in Japan to prepare for ILC

- **Nano-beam Technology**
  - ATF2 Collaboration has realized a vertical beam size of 44 nm, as a record, at the ATF2 final focus point, and is closing the major R&D goal of 37 nm (another ~ 20 % to the primary goal).
  - The tuning time for reaching a level of 50 nm has been also getting much shorter, less than 20 hours even after a long shut-down of the machine.
  - The nano-beam technology required for the ILC is being well demonstrated, keeping the forward looking progress.

# KEK-ATF2: BDS Test for ILC

- Modeling of ILC BDS
- – Same Optics:
- – Int’l Collab.
- ~25 Lab. , > 100 Collaborators

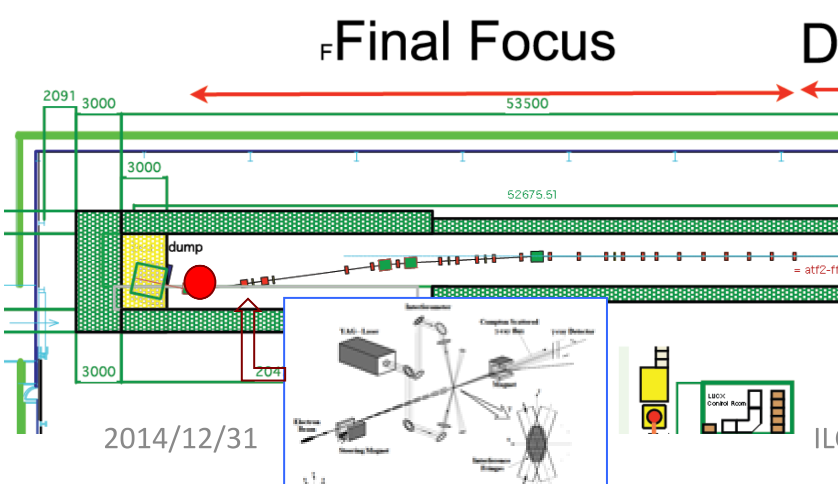
- Goal:
  FF Beam Size: 37 nm
- – (ILC で5.9 nm に相当)



# KEK-ATF2: BDS, FF Test for ILC

- Modeling of ILC - BDS
  - Same Optics:
  - Int'l Collab.
- ~25 Lab. , > 100 Collaborators

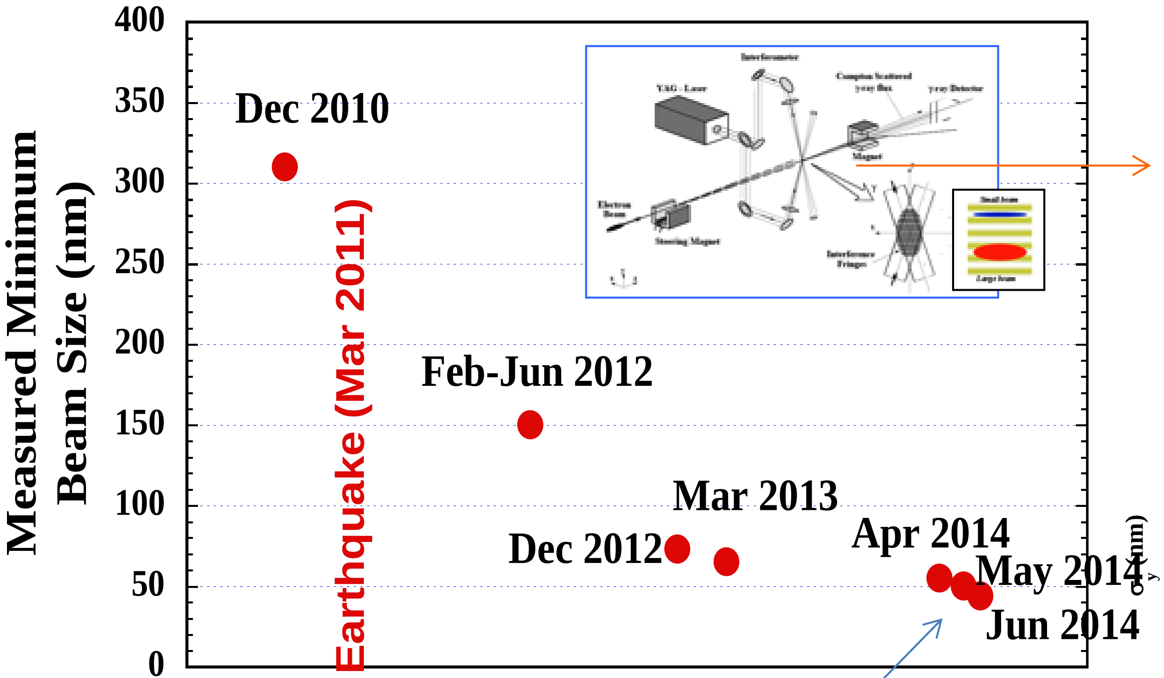
- Goal:
  FF Beam Size: 37 nm
  - (corresponding to 5.9 nm at ILC

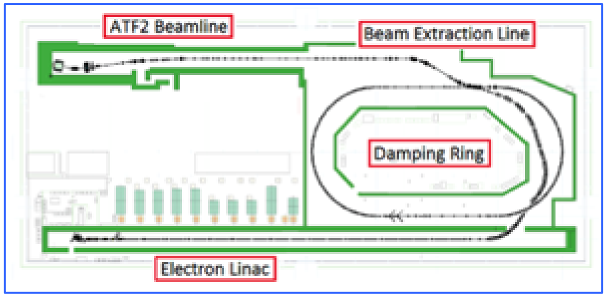


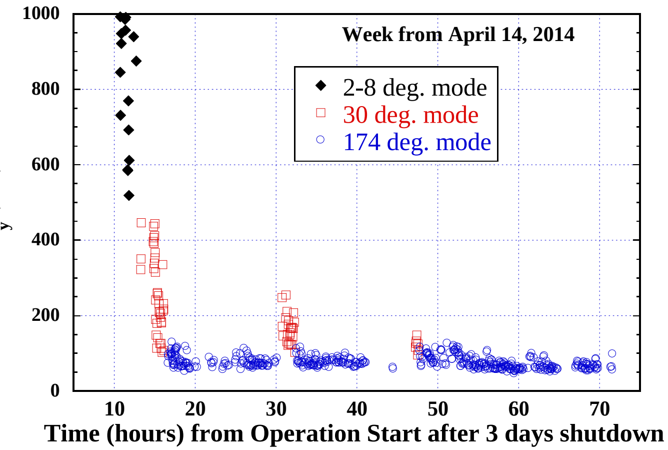

| Parameter | ILC | ATF2 |
|---|---|---|
| **Beam Energy [GeV]** | **250** | **1.3** |
| **Energy Spread ($e^+/e^-$) [%]** | **0.07/0.12** | **0.06~0.08** |
| Final quad – IP distance ($L^*$) (SiD/ILD detector) [m] | 3.5/4.5 | 1.0 |
| Vertical beta function at IP ($\beta^*_y$) [mm] | 0.48 | 0.1 |
| **Vertical emittance [pm]** | **0.07** | **12** |
| **Vertical beam size at IP ($s^*_y$) [nm]** | **5.9** | **37** |
| **$L^*/\beta^*_y$ (~natural vertical chromaticity, SiD/ILD detector)** | **7300/9400** | **10000** |

IPAC2014, K. Kubo
ICHEp2014, S. Kuroda

# Progress in Beam Size at ATF2




Beam Size 44 nm observed,
(Goal : **37** nm
corresponding to **6** nm at ILC)

Quick tuning to reach ~ 50 nm after long shut-down, less than 20 hours

# MEXT's Organization for Studying ILC

## based on SCJ's Recommendation

SCJ

Science Council, Japan

Recommendation in 2013 →

MEXT

Ministry of Education, Science, … Technology.

ILC Taskforce
formed in 2013

Academic Experts Committee
formed in 2014

Particle & Nuclear **Phys.** Working Group
formed in 2014

**TDR** Validation Working Group
formed in 2014

ILC project is being officially investigated by MEXT (Japanese Government), since June 2014

# ILC Project Overview anticipated

| Years | TDR baseline Scenario |
|---|---|
| 1 - 2 | Pre-preparation for 2yrs (for technical effort continuity) |
| 3 - 6 | Preparation (4 yrs) |
| 7 - 15 | Construction (9 yrs) |
| (12 -) | (start installation) |
| 16 - | Beam Commissioning start |
| 17 – | Operation at 250 ~ 500 GeV (550 GeV) |
| TBD | Toward 500 GeV HL upgrade |
| TBD | Toward 1 TeV upgrade |

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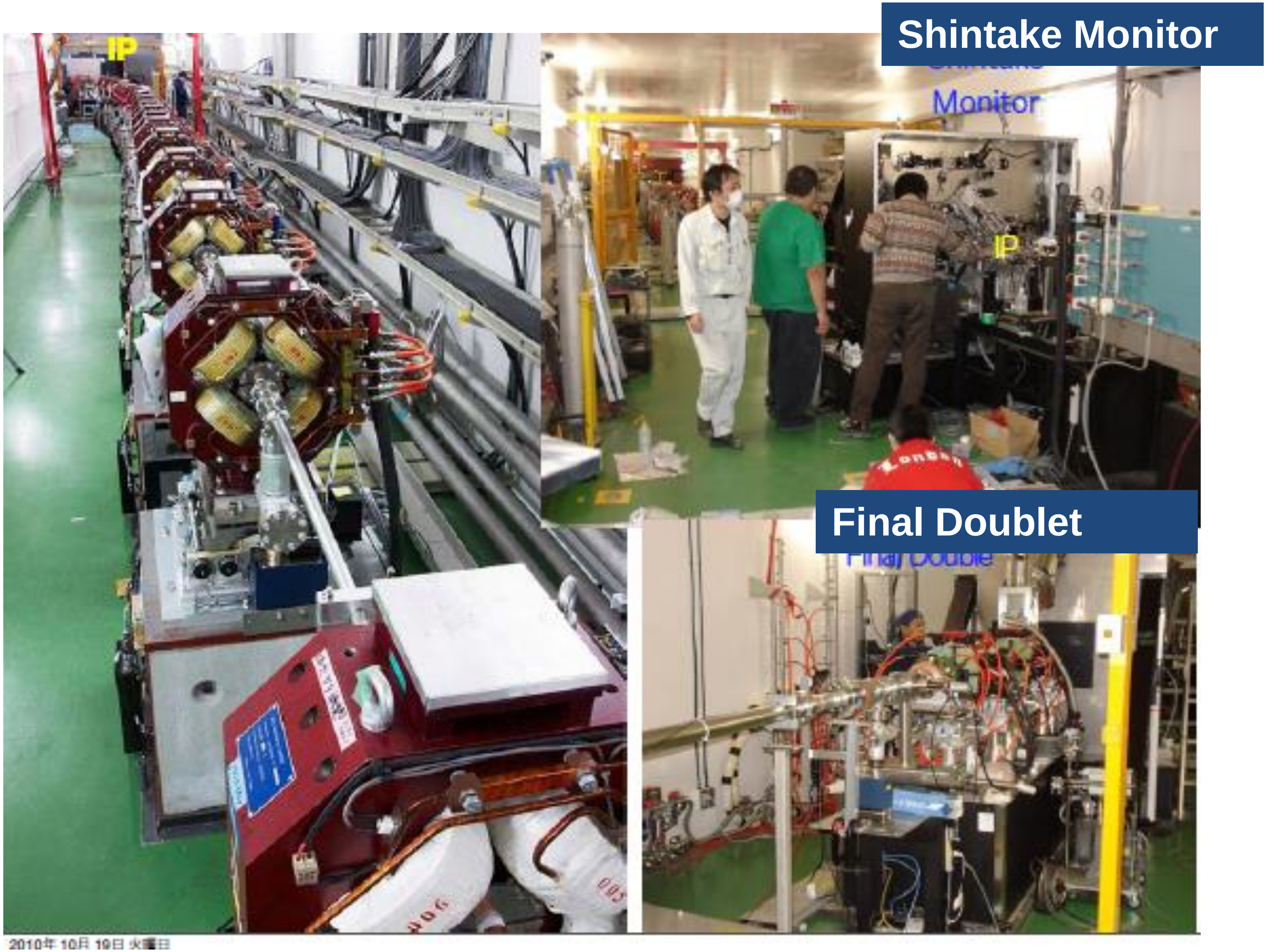
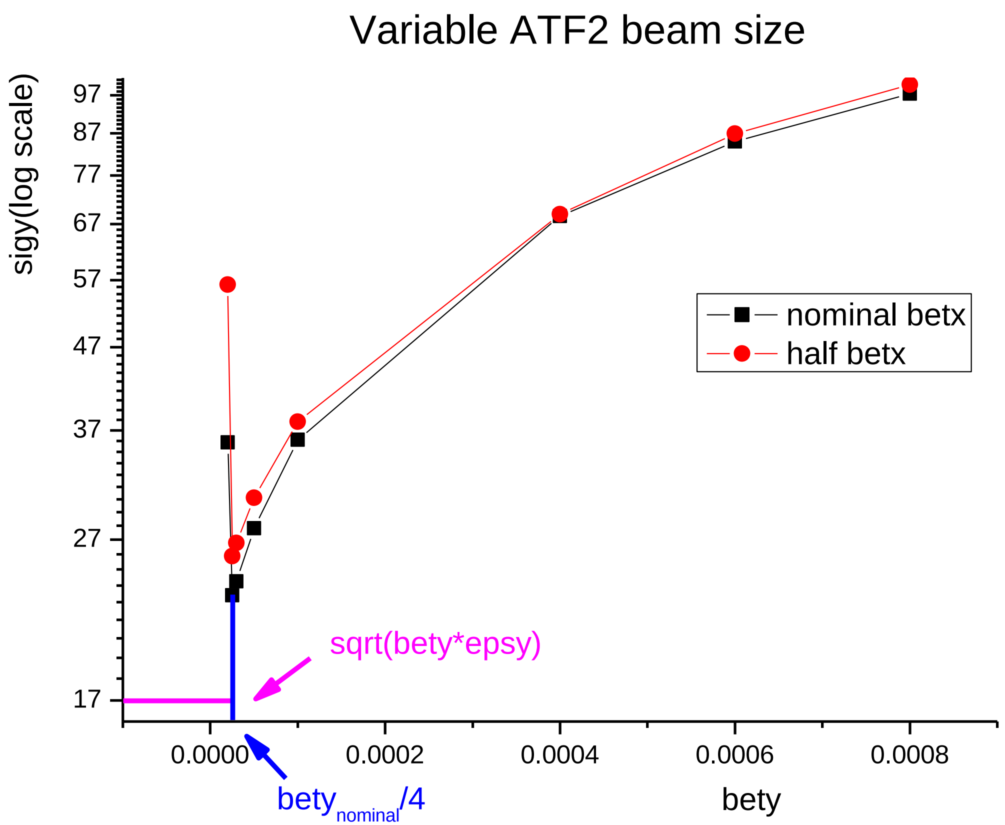
# IHEP in ATF2 collaboration since 2005: hardwares, beam dynamics and experiments and in continue…



**We propose a Ultra-low beta by reducing the IP vertical beta to a quarter**

*~ S.Bai et. al, ELAN-Document-2008-002.pdf*

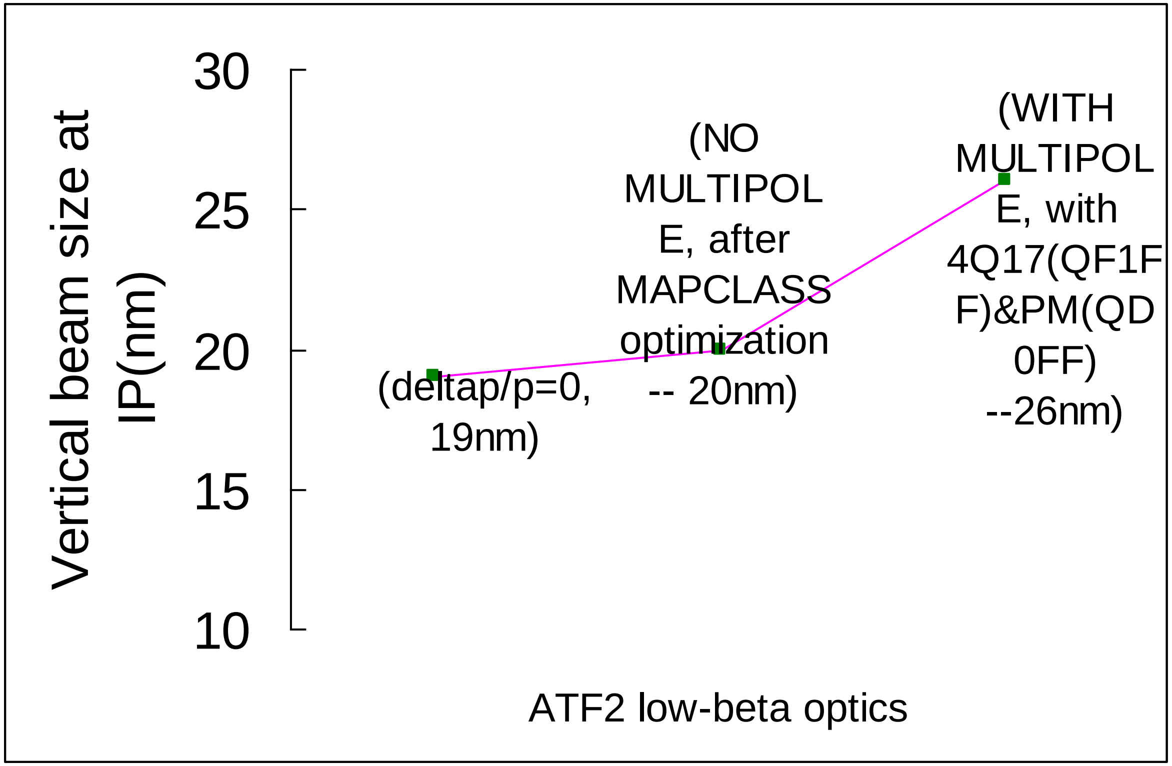



- The linear vertical beam size at IP is ~ 19nm, while tracking can increase to ***23nm*** by cancelling the aberrations to second order.

*Now the ATF2 is on road and close to reaching 37nm at IP, the newest* ***45nm !***

*NEXT STEP: ATF2 from nominal to low-beta !*

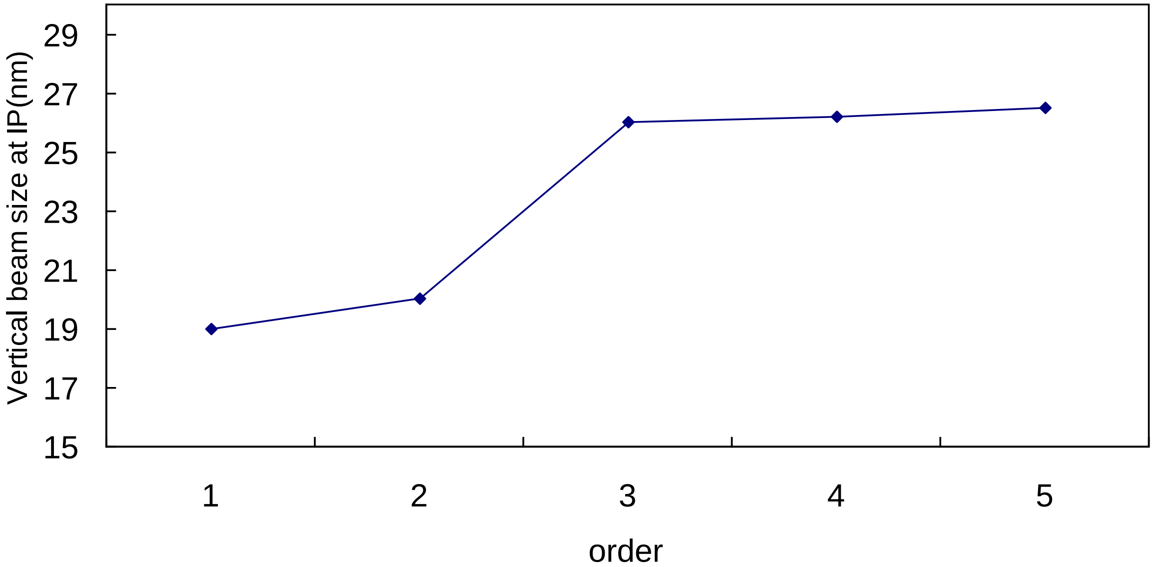
## The vertical beam size at IP of ATF2 can be reduced to ~ *20nm*




- Since the magnets are not perfect, which is with multipole, the vetical beam size will increase to ***80nm(rms).***
- QF1FF magnet is replaced by a 4Q17 from PEP-II in Nov 2012 and CERN has designed a permanent QD0FF which has better quality.

With the better quality Final Doublet magnets, the ATF2 vertical beam size at IP can reduce to ***26nm.***

# ATF2 will run with low-beta optics from 2015




- MAPCLASS order analysis reveals the dominant is from the Octupole chromatic aberration.

*What can we do to beat the vertical beam size at IP amoung third order ?*

Octupole magnets could be inserted for optimization

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

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

# Study of alternative ILC final focus optical configurations

Dou Wang (IHEP), Yiwei Wang (IHEP), Philip Bambade (LAL), Jie Gao (IHEP)

International Workshop on Future Linear Colliders 2014 (LCWS14)

Vinca Institute of Nuclear Sciences, Belgrade, Serbia. *6- 10 October 2014*

Reduced bunch length enables:

1) less beamstrahlung with the same luminosity,
2) or higher luminosity with equal amount beamstrahlung.

The approach is to use flatter beams

Using exactly the same magnets as ILC nominal design, only refitting them, but requiring a short bunch length (150 or 200 microns), which is the price to pay...

# Alternative optical parameters for ILC FFS with five sextupoles

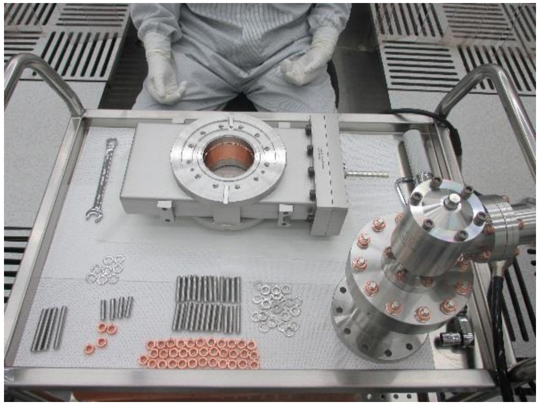
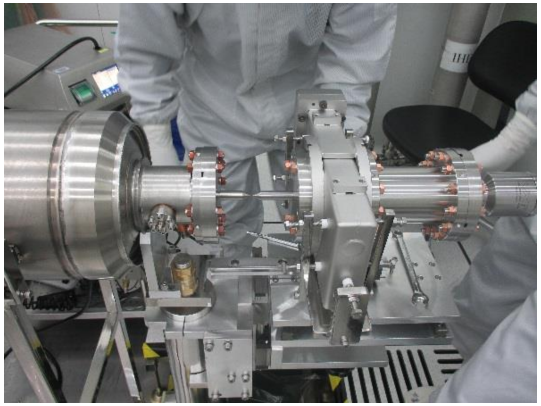
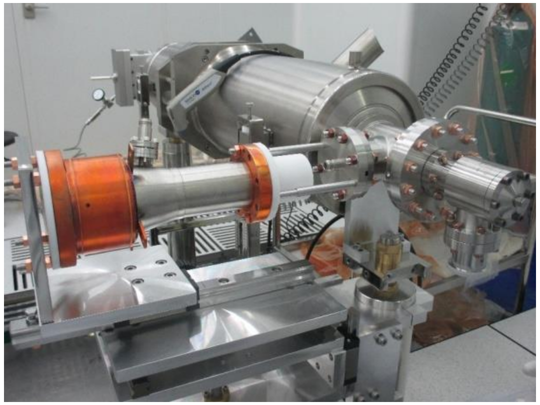
| | ILC nominal | ILC-low BS | ILC-high Lum |
|---|---|---|---|
| E/beam (GeV) | 250 | 250 | 250 |
| Ne ($\times 10^{10}$) | 2 | 2 | 2 |
| $\sigma_z$ (um) | 300 | 150 | 150 |
| $\beta^*_{x/y}$ (mm) | 15/0.4 | 45/0.2 | 20/0.2 |
| Ay | 0.75 | 0.75 | 0.75 |
| $\sigma^*_{x/y}$ by MAPCLASS (nm) | 594/7.89 | 994/4.10 | 750/4.6 |
| $\sigma^*_x \times \sigma^*_y$ (nm$^2$) | 4687 | 4075 | 3450 |
| Luminosity from guineapig++ ($\times 10^{34}$ m$^{-2}$) | 1.126 | 1.143 | 1.40 |
| Beamstrahlung energy spread from guineapig++ (%) | 2.8 | 1.8 | 2.8 |

We can get higher luminosity while keeping similar beamstrahlung level as nominal design when $\beta x^*$ is smaller than 45 mm, or we can get same luminosity as nominal design with much weaker beamstrahlung effect if we just choose 45 mm $\beta x^*$.

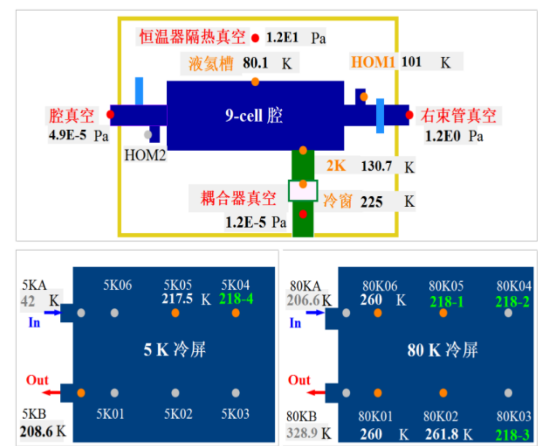
# New FFS optics with real beam distribution and coherent waist shift

| | ILC nominal (theoretical) | ILC nominal (real) | ILC-low BS (real) | ILC-high Lum (real) |
|---|---|---|---|---|
| E/beam (GeV) | 250 | 250 | 250 | 250 |
| Repetition rate (Hz) | 5 | 5 | 5 | 5 |
| Bunch number/pulse | 2625 | 2625 | 2625 | 2625 |
| Ne ($\times 10^{10}$) | 2 | 2 | 2 | 2 |
| $\sigma_z$ (um) | 300 | 300 | 150 | 150 |
| $\beta^*_{x/y}$ (mm) | 15/0.4 | 15/0.4 | 45/0.2 | 20/0.2 |
| Luminosity by single collision ($\times 10^{34}$ $m^{-2}$) | 1.8 | 1.40 | 1.42 | 1.82 |
| Luminosity by single collision (inc. vertical waist shift) ($\times 10^{34}$ $m^{-2}$) | | 1.69 | 1.72 | 2.21 |
| Total luminosity (inc. vertical waist shift) ($\times 10^{34}$ $cm^{-2}s^{-1}$) | 2.4 | 2.22 | 2.25 | 2.9 |

# IHEP 1.3GHz 9-cell cavity assembly

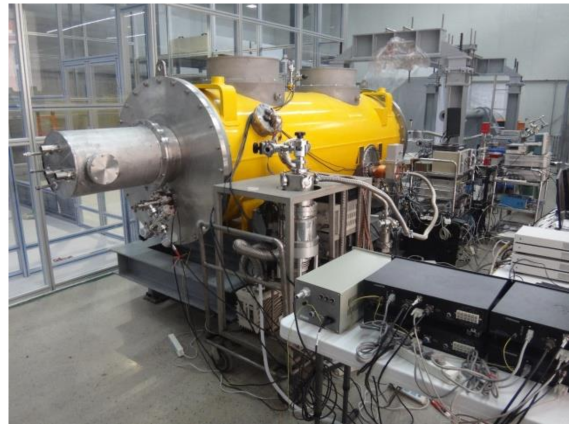





# 1.3 GHz accelerating unit assembly and cold tested at 80K



# IHEP SRF Key Technology Experience


1.3 GHz 9-cell cavity
vertical test 20 MV/m, $Q_0$=1.4E10



1.3 GHz test cryomodule
horizontal test soon

12 m 1.3 GHz cryomodule
for Euro-XFEL

650 MHz β=0.82 5-cell cavity
vertical test soon

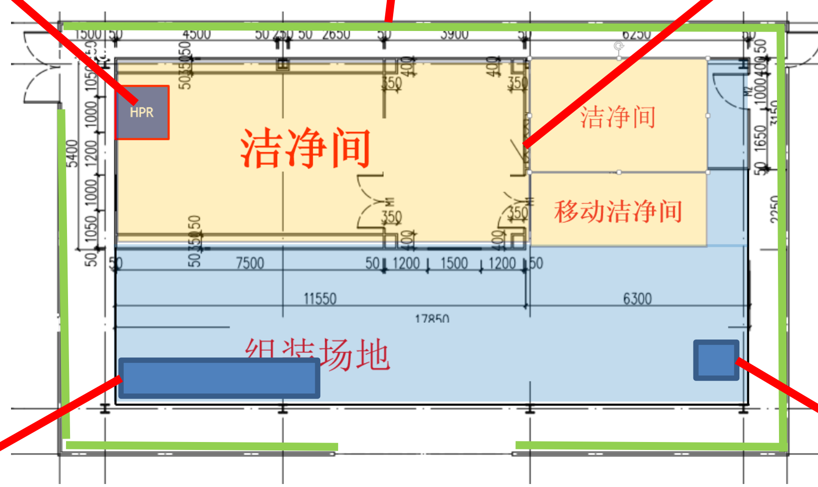
500 MHz coupler
420 kW CW TW

HOM absorber
ferrite 6kW

500 MHz cavity module
horizontal tested

# New SC lab at IHEP (assembly)





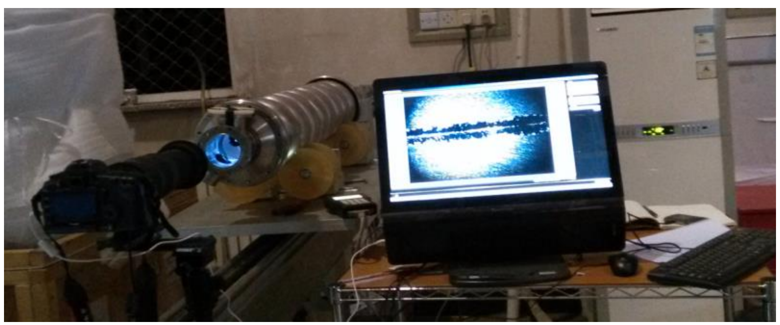
# IHEP 1000W refrigerator and helium recovery system installed and in operation

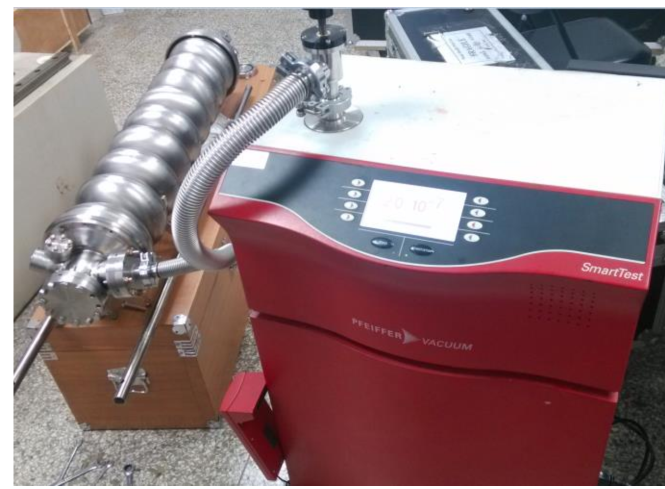


| | OK / NOT OK |
|---|---|
| Test 1 : Cold Box Liquefaction with LN2 | OK |
| Test 2 : Cold Box Refrigeration with LN2 1000W @ 4,5K | OK |
| Test 3 : Cold Box Liquefaction/Refrigeration with LN2 350W @ 4,5K | OK |

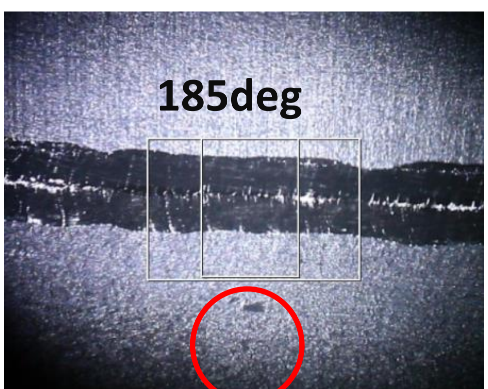
Test results

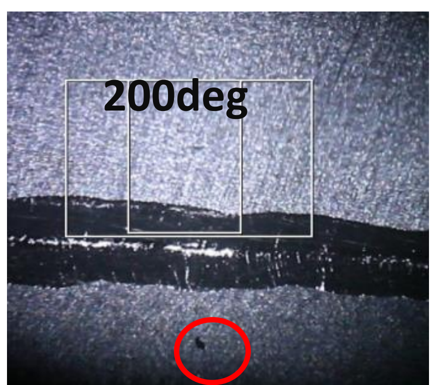
# IHEP03 (KEK Tesla-like) completed (Dec. 2014)



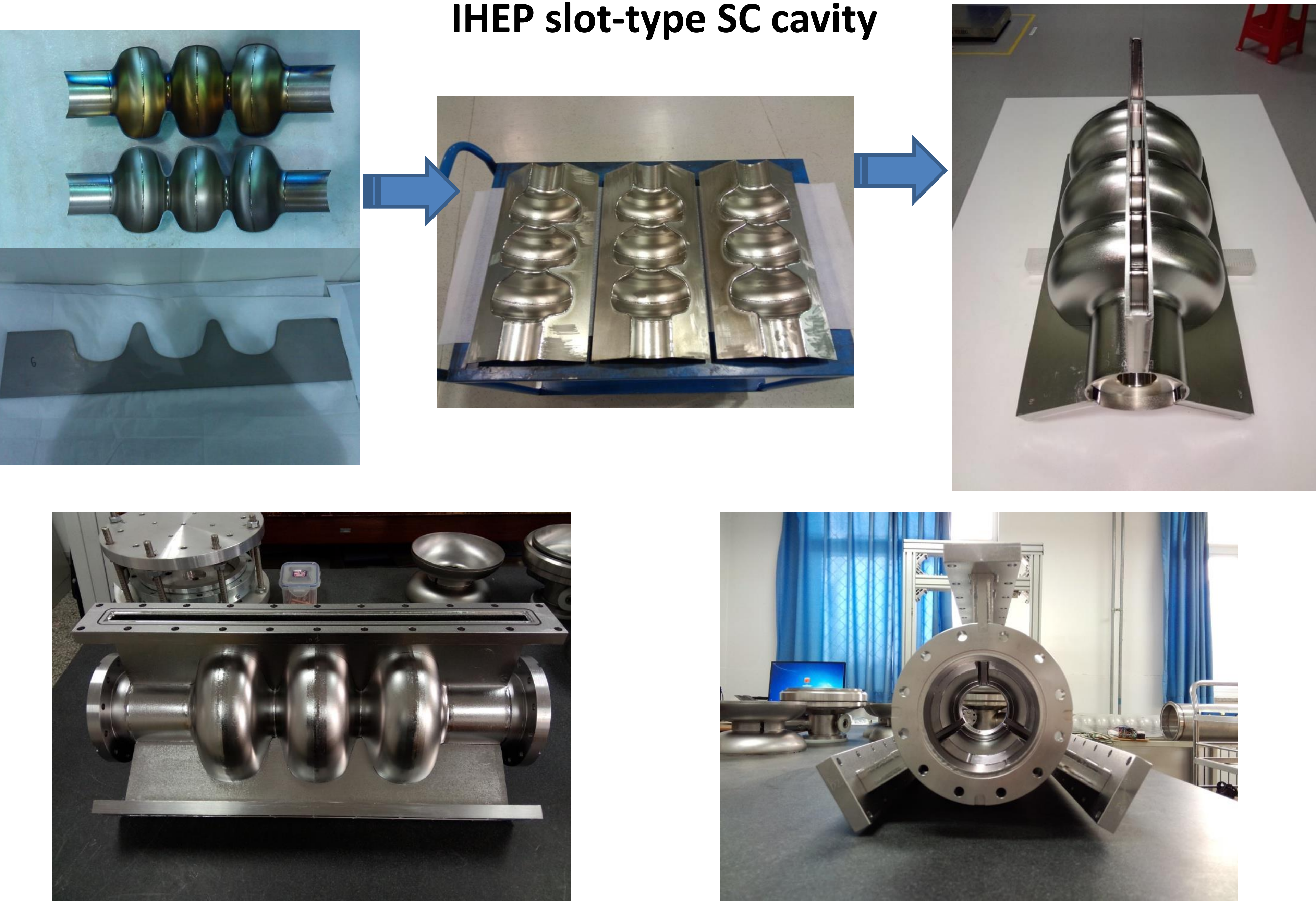



Vacuum tested
1*10e-11， OK!

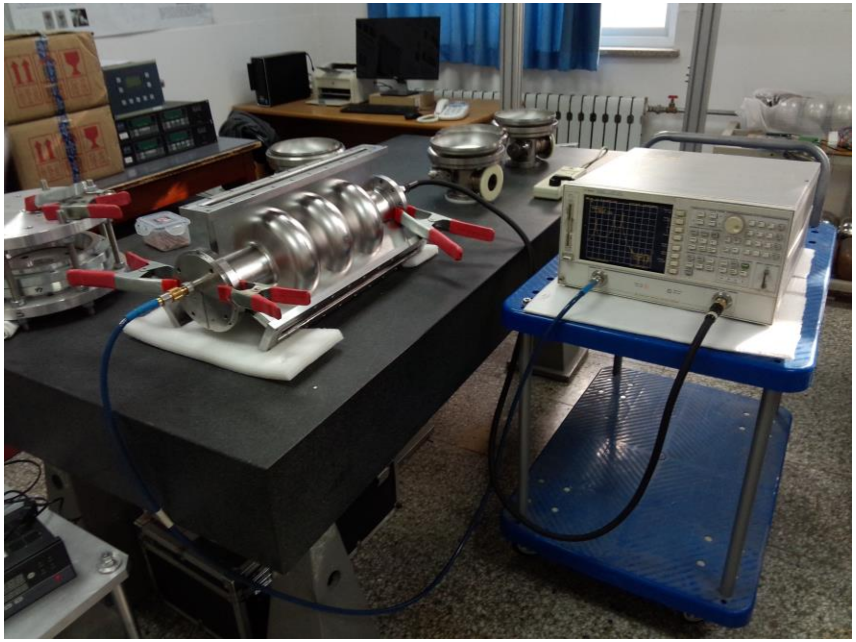


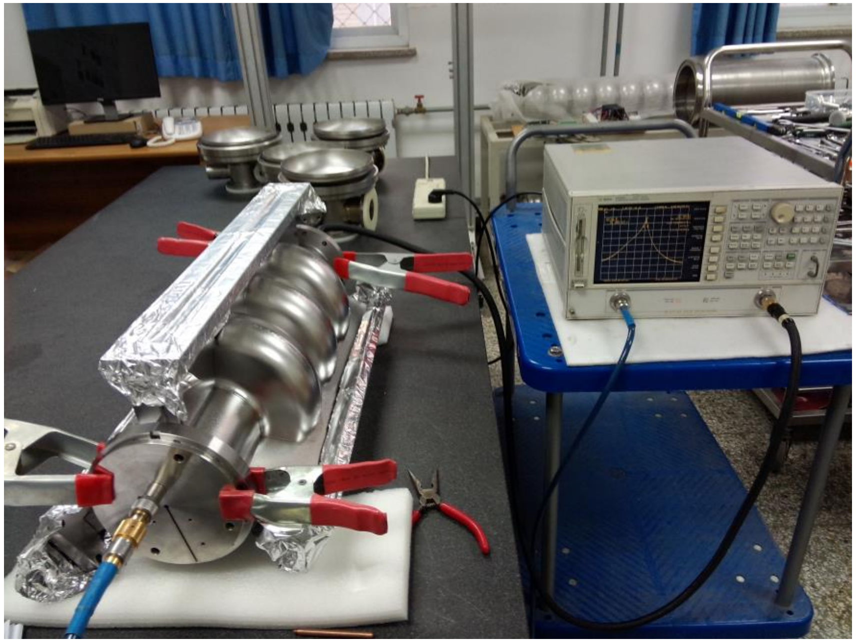
# IHEP slot-type SC cavity



# HOM measurements on the slot-type SC cavity



Waveguide open



Waveguide closed

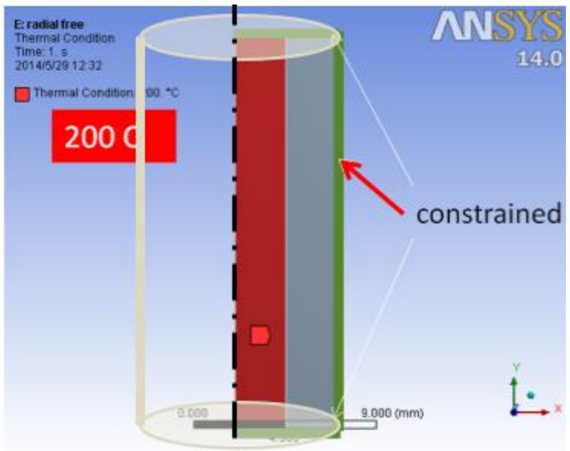
# IHEP-KEK ILC  Positron Source Collaboration

Dr. S. Jin has visited twice in 2015 to KEK on ILC conventional positron source  target study

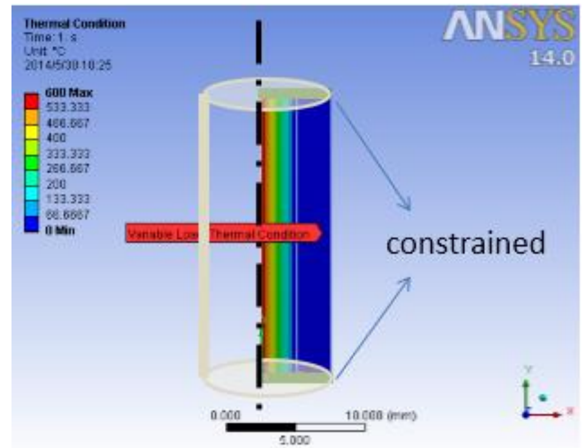
2014/5/25-2014/5/31


At POSIPOL2014
2014/8/24-2014/9/2

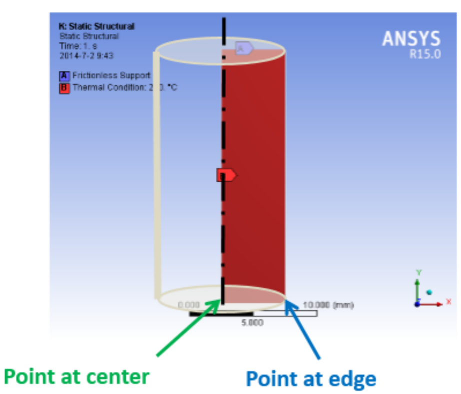
# ILC positron source : target heat analysis by ANSYS




Model 1-stationary




Model 2-stationary



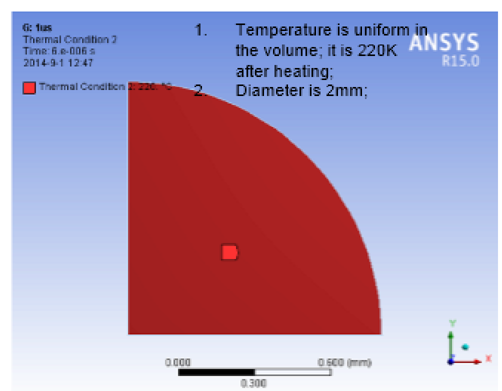

1.Still a cylinder model is used;

2. Axial constrained and radial free; and temperature is linearly increased from 0C to 200C.

3. We check two heating time: 100ns and 1us.

4. For each case, the point at the center and the point at the edge are calculated.

Model 3- transition

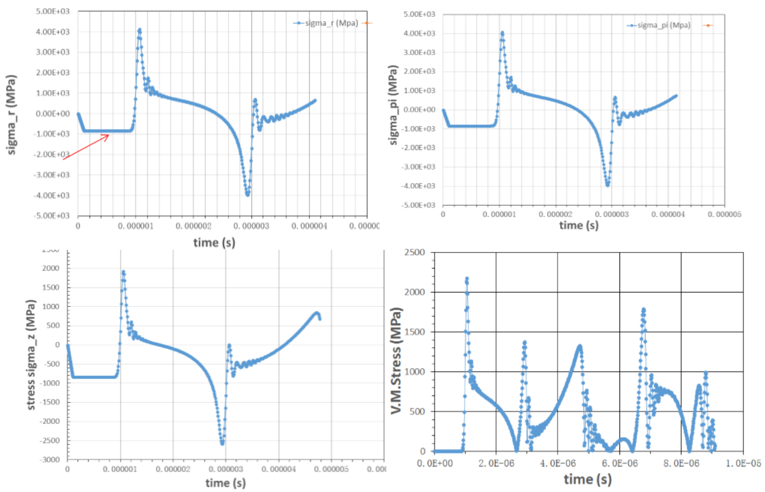



- Two cases are simulated
  - Heating time is 100ns;
  - Heating time is 1us;
- Two points are analyzed:
  - At the center;
  - At the boundary;

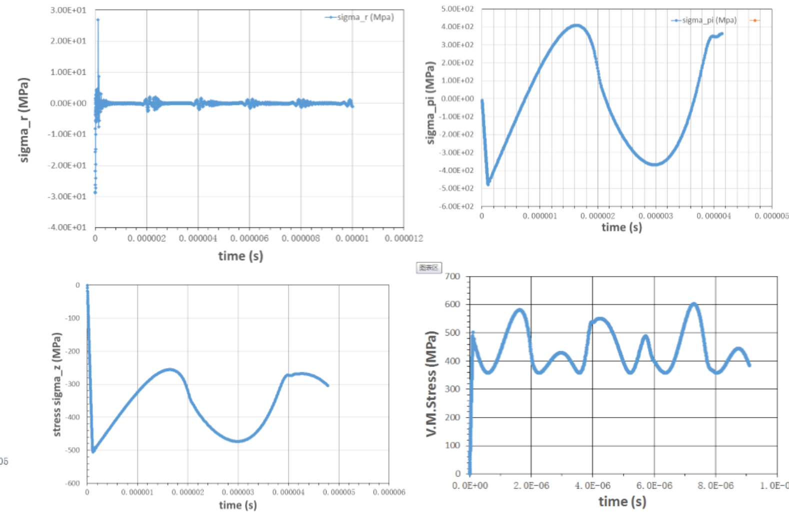
Model 4- transition

# Simulation results (model 3)

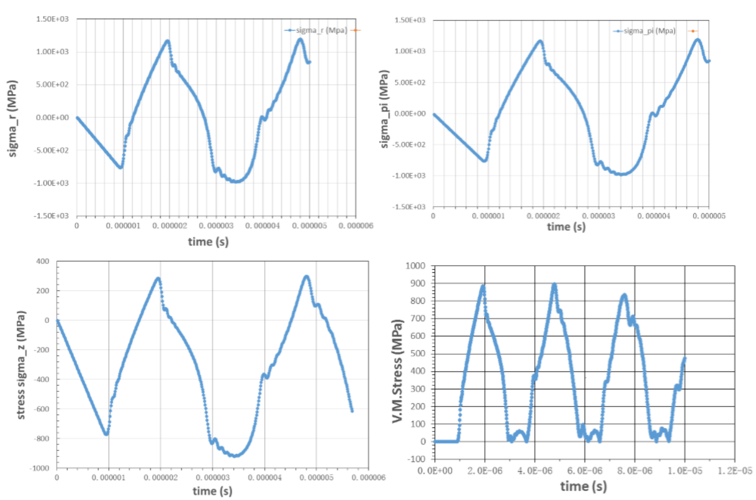
Heating time:100ns; the point at Center



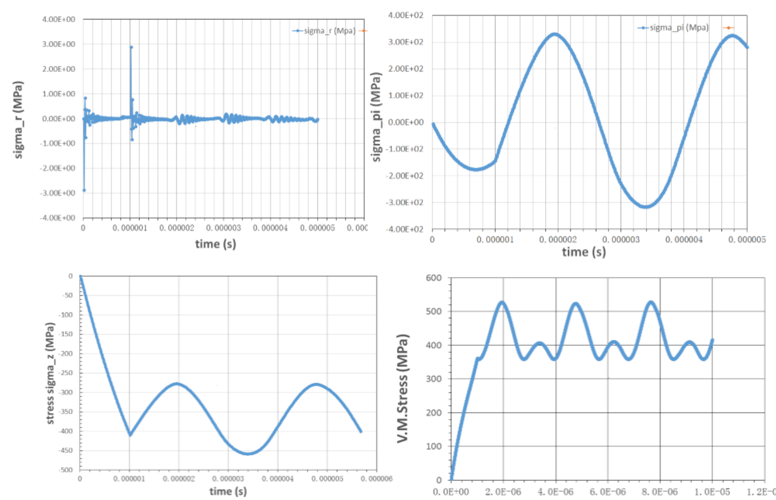

Heating time:100ns;the point at edge




Heating time:1us;the point at center




Heating time:1us;the point at edge




For Model 3, the temperature at the center and on the edge

# Talks at LCWS2014 and POSITOL2014

**Progress on Stress Analysis of Positron Source Target by AWB Simulation**

S. Jin[1], P. Sievers[2], T. Omori[3], J.Gao[1]

[1] *IHEP;* [2]*CERN;* [3]*KEK;*

LCWS2014, , Belgrade, Serbia, 6-10 October, 2014.

1

LCWS2014 Talk

9th International Workshop on Polarized Positrons, Gamma-rays and X-rays

POSIPOL 2014

**Basic Study on Vibration of Positron Source Target with ANSYS**

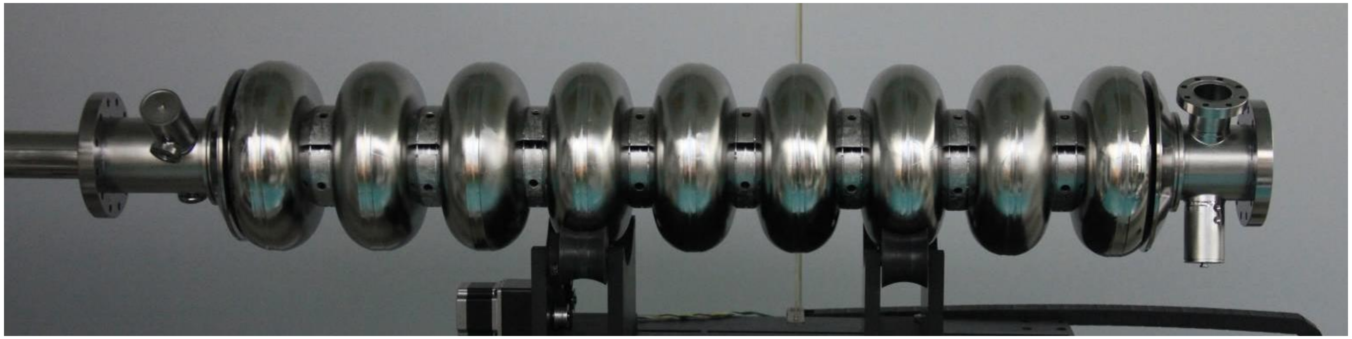
Posipol 2014, 27-29 August, 2014, Ichinoseki, Japan.

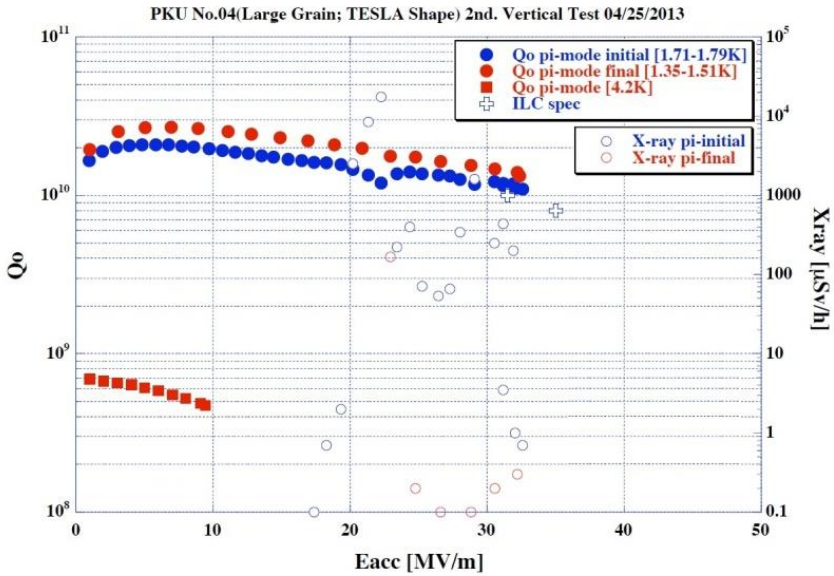
Song JIN /IHEP

1

POSIPOL2014 Talk

# TESLA type SRF cavity fabricated at PKU

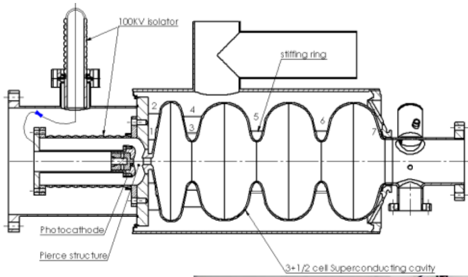





- Forth 9-cell TESLA type cavity was fabricated in 2013
- Vertical test was performed at KEK
- $Q_0$ is $>1\times10^{10}$ at 32.6MV/m

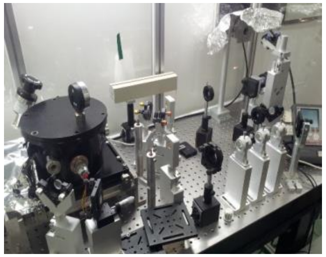
- Reached the reqiurement for the ILC

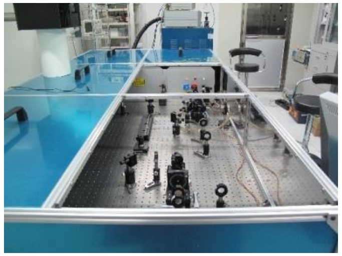
# DC-SRF photo-injector and beam line



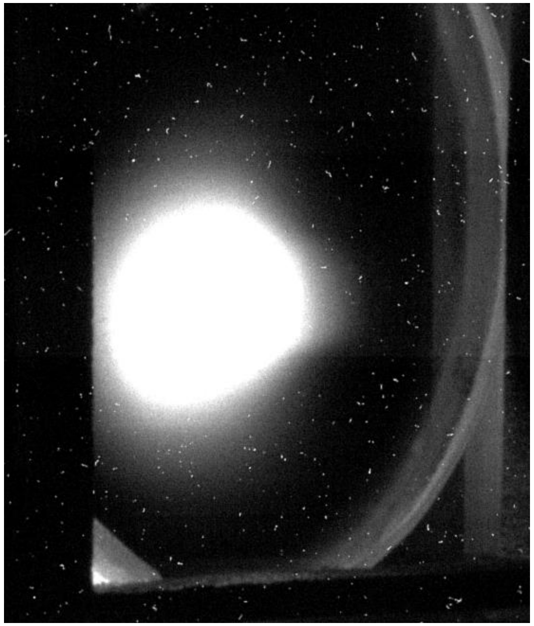

# Auxiliary facilities for DC-SRF injector

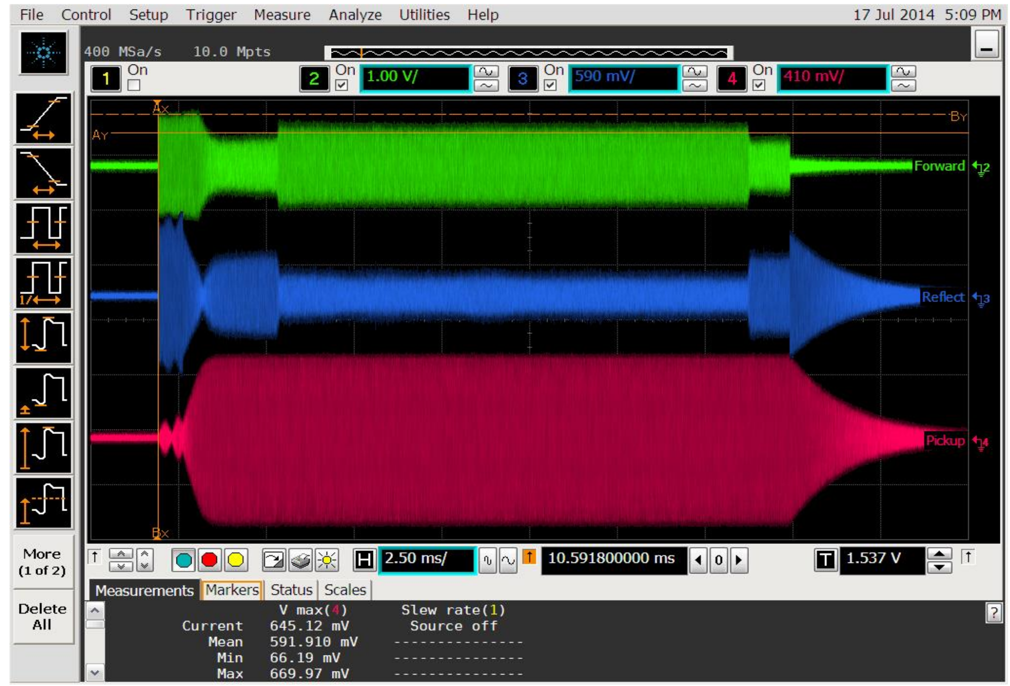
2K system,
LLRF control,
20kW solid state
RF amplifier,
and drive laser





# Stable operation of DC-SRF injector






A stable beam current has been obtained for long-term operation in 2014. The electron beam energy is higher than 3MeV, duty factor is 7%, the average beam current is 0.55mA in macro pulse and the beam emmittance is about 3.0mm.mrad. The electron beam has been used for the preliminary experiment to generate THz radiation and will be used for other applications such as ultrafast electron diffraction.

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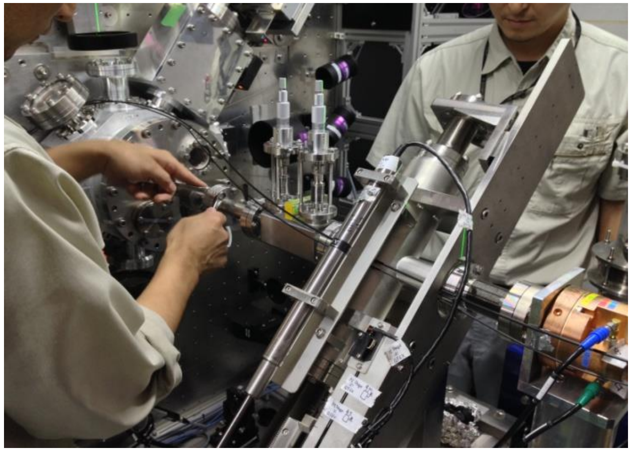
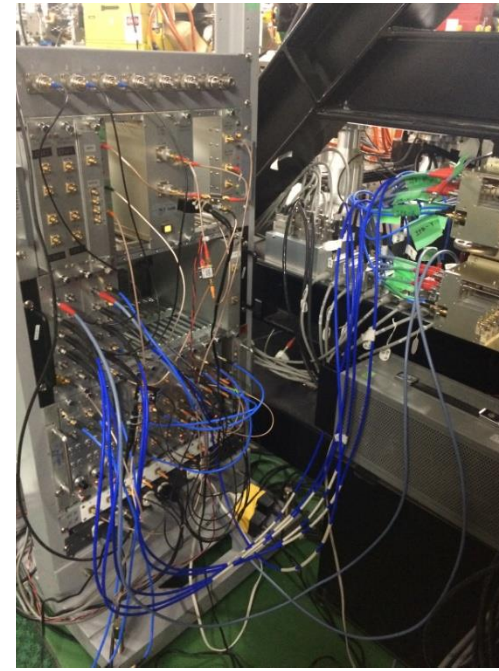
# IPBPM status

# R&D of IP-BPM

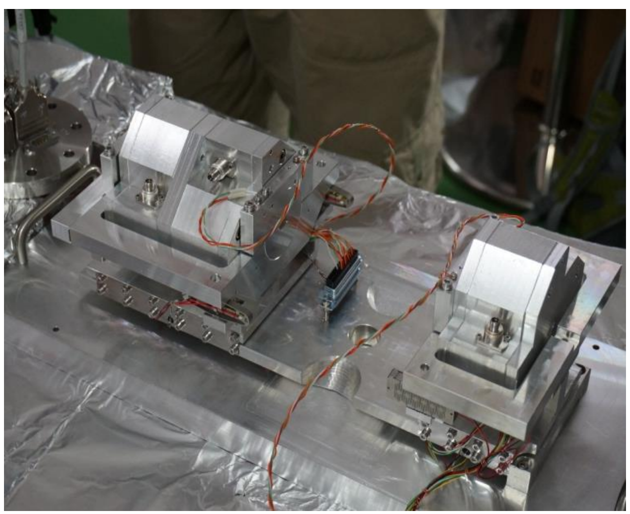


Ref. BPM install

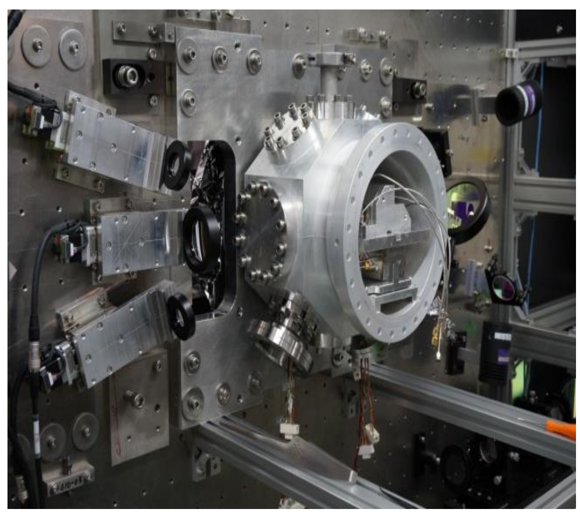
Sep. : fabrication at KNU
Nov. : Installation at KEK-ATF



IPBPM electronics
with variable
attenuators



IPBPM alignment
on base plate

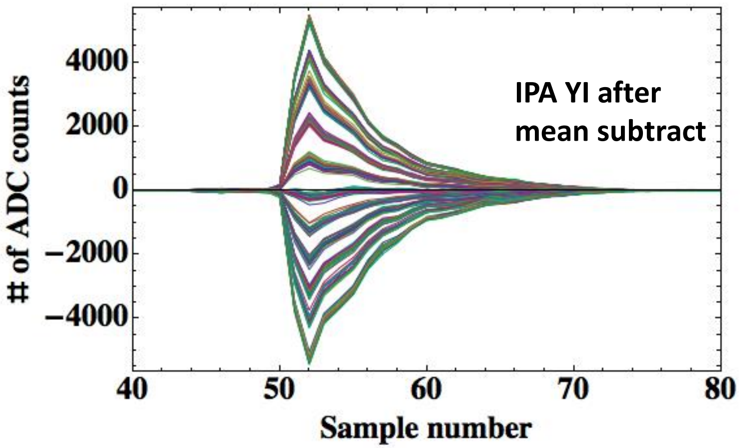


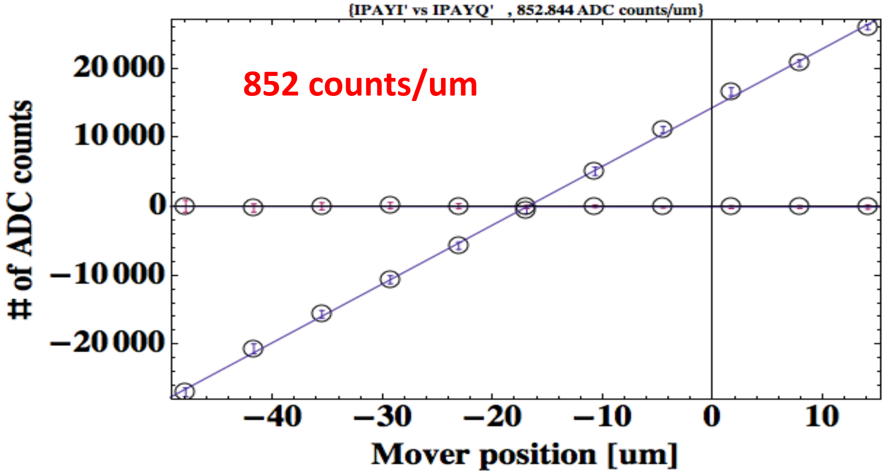
IPBPM installation
Inside IP-chamber

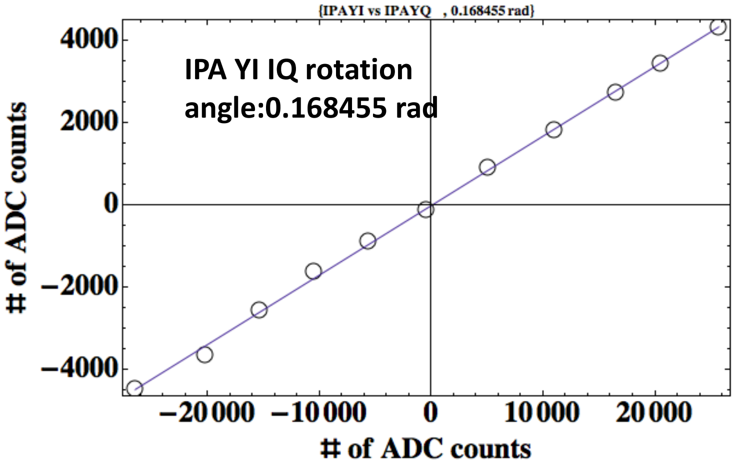
# IPBPM calibration

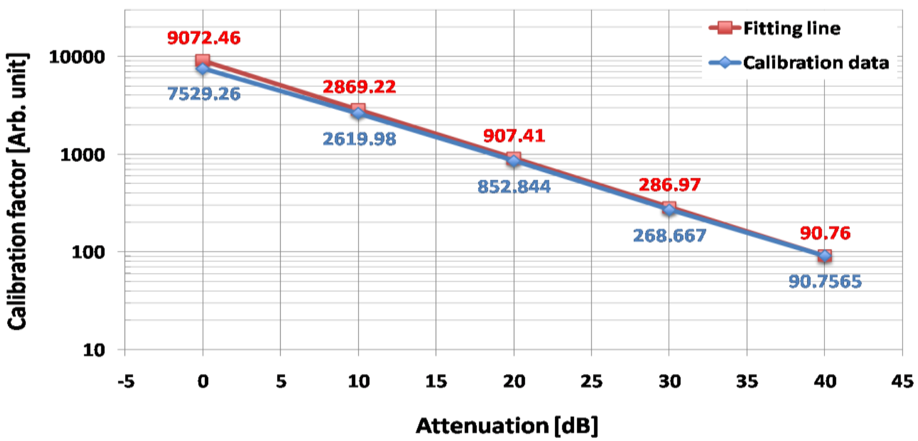
## Nov. : beam testing at KEK-ATF

- IPA 20dB calibration case.



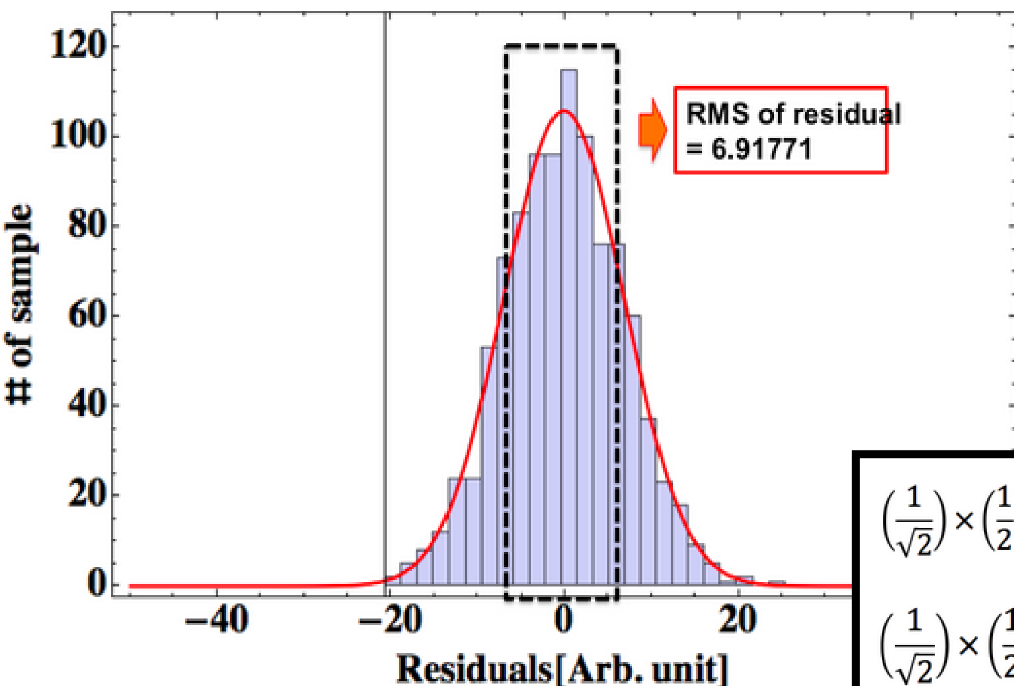



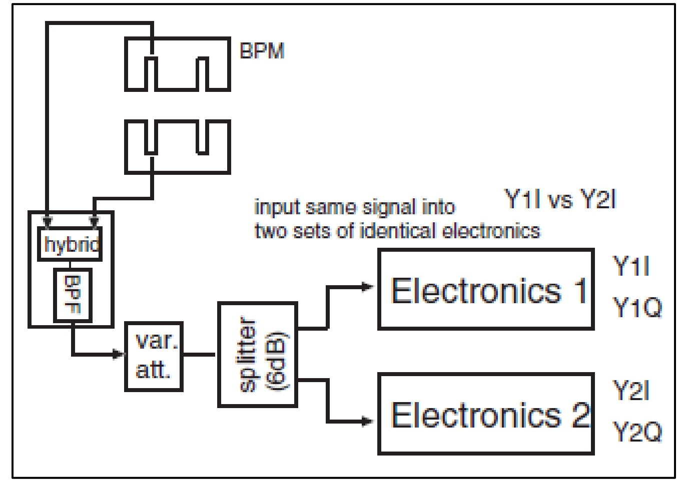

- The integrated calibration factor from 40dB to 0dB shows good ratio to around 3.162 times for every 10B attenuation case.

# Resolution limit of electronics

# 0.5 nm

**RMS of residual for IPA resolution limit calculation (RMS = 6.91771 counts) :**




$$\left(\frac{1}{\sqrt{2}}\right)\times\left(\frac{1}{2}\right)\times\left(\frac{average\ charge}{nominal\ charge}\right)\times\left(\frac{RMS\ of\ residual}{Calibration\ factor}\right)$$

$$\left(\frac{1}{\sqrt{2}}\right)\times\left(\frac{1}{2}\right)\times\left(\frac{0.5\times 1.6\ nC}{1.0\times 1.6\ nC}\right)\times\left(\frac{6.91771\ counts}{2330.59\ counts/um}\right)=0.5247nm$$

**RMS/(Calibration factor)= 6.91771 counts/(2330.59 counts/um)= 0.0029682um = 2.9682nm**

**The rms of the actual residual signal should be larger than the intrinsic noise by factor Sqrt(2).**

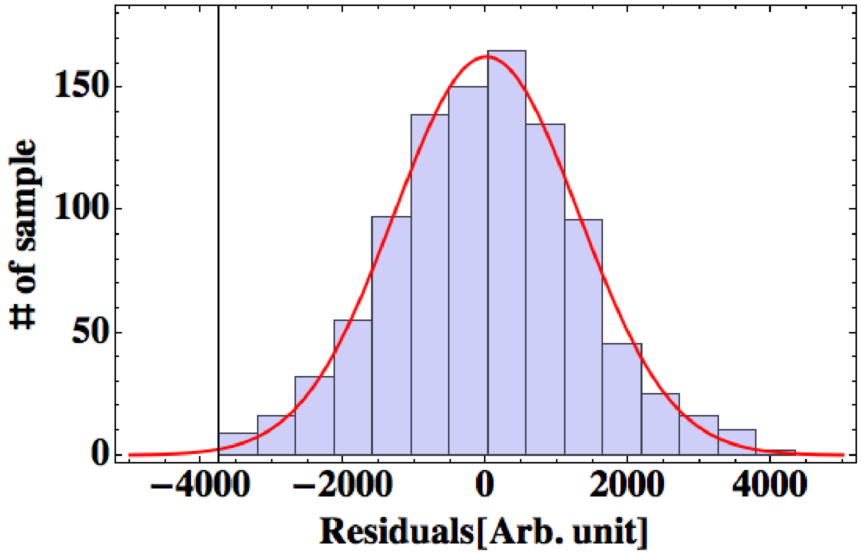
**Also the 6dB splitter used to divide the BPM signal reduced the signal by a factor of 2 as compare with the original configuration.**

**The beam intensity was 0.5x1.6nC, half of nominal beam charge.**

**Then the electronics limit resolution for nominal beam charge was 0.5247nm.**

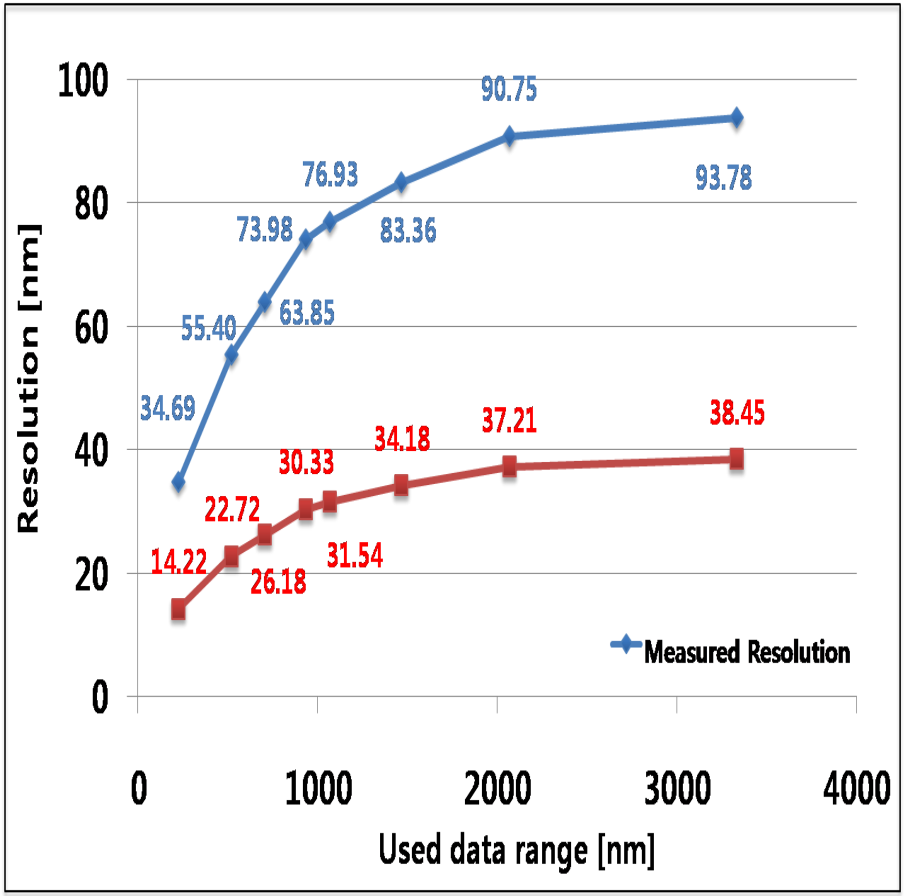
# Measured IPBPM resolution

RMS of residual for IPA resolution calculation
(RMS = 1293.91counts) :




RMS/(Calibration factor)= 1293counts/(7529counts/um)= 171nm
Geometrical factor x RMS/cal = 93.7811nm
Measured charge/norm charge x Geo X RMS/cal = 38.4503 nm
The dynamics range = 3.3um

The resolution data under the 0dB attenuation.



# Accelerator Status in Korea

# Current Accelerator Activities in Korea (2013)


PLS-II (3.0-GeV Light Source)

10-GeV PAL-XFEL

RAON, Rare Isotope Acc. / IBS

SC Cyclotron for Carbon Therapy

KOMAC,100-MeV Proton Linac

# Status of Accelerator R&D in Korea

(1) Buildings for PAL-XFEL (10 GeV) are completed. Installation will be started in Jan. 2015, and commissioning will scheduled to start in Jan. 2016.

(2) A new RISP Project Director is being appointed, and an architect is selected for site and building design.

(3) The KHIMA project, a carbon therapy facility is under construction, and it is scheduled to be completed in March 2017.

(4) PLS-II (3.0 GeV light source) and KOMAC (100 MeV proton linac) are in users' service.

# PAL-XFEL on Dec.12, 2014

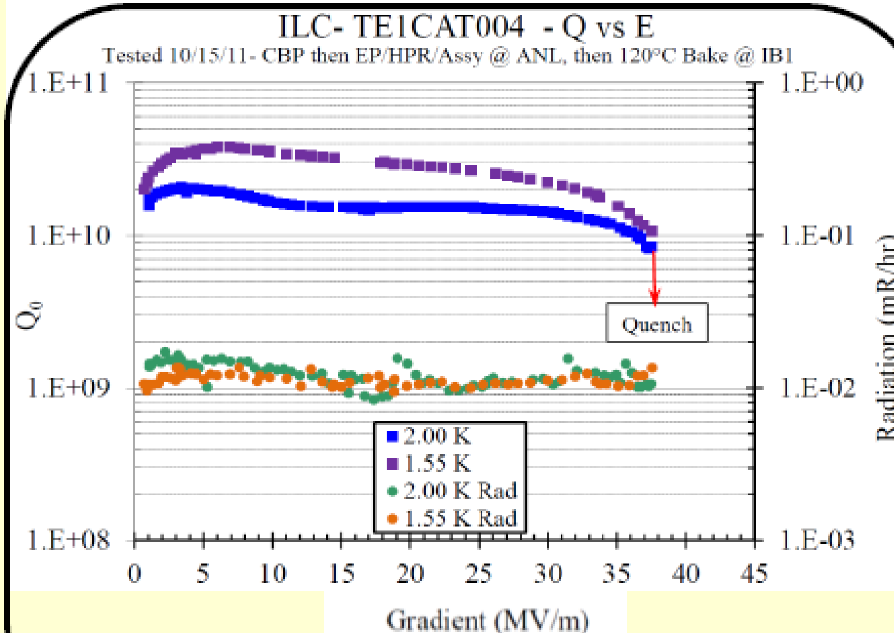
# Contents

- Japan
- China
- Korea
- India

# SRF ACTIVITY IN INDIA

- Four numbers of single-cell 1.3 GHz cavities fabricated at RRCAT / IUAC and tested at Fermilab.

1.3 GHz Nb Single Cell Niobium Cavity developed in India (RRCAT / IUAC)



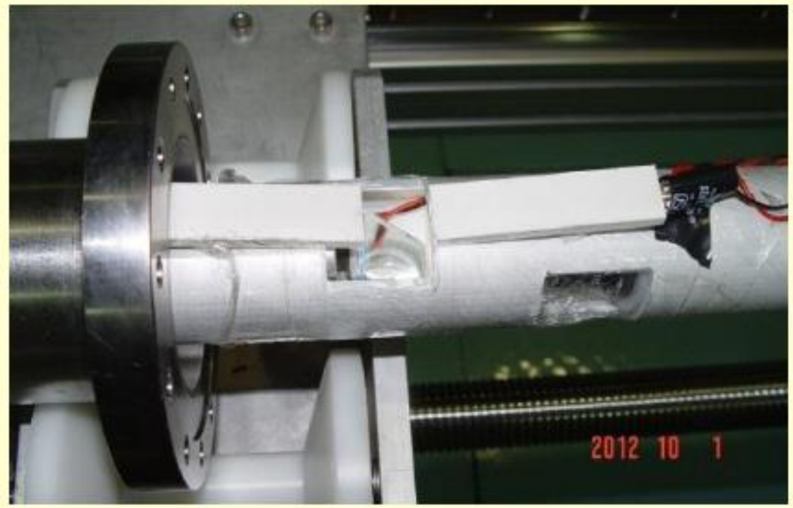

(October (2011)

Acceleration gradient of 37.5 MV/m with Q > $10^{10}$ at 2K

## RRCAT & IUAC have also developed a 1.3 GHz TESLA-type 5-Cell Niobium Cavity.

Essentially to understand multi-cell cavity fabtication

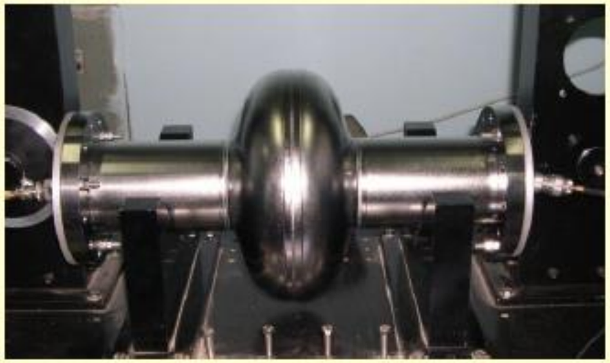
- An optical inspection bench has been developed to carry out internal inspection of multi-cell SCRF cavities.
- It consist of an optical imaging system and a cavity support bench. This is equipped with imaging software and provision for video recording.




Optical inspection bench for multi-cell SCRF cavities

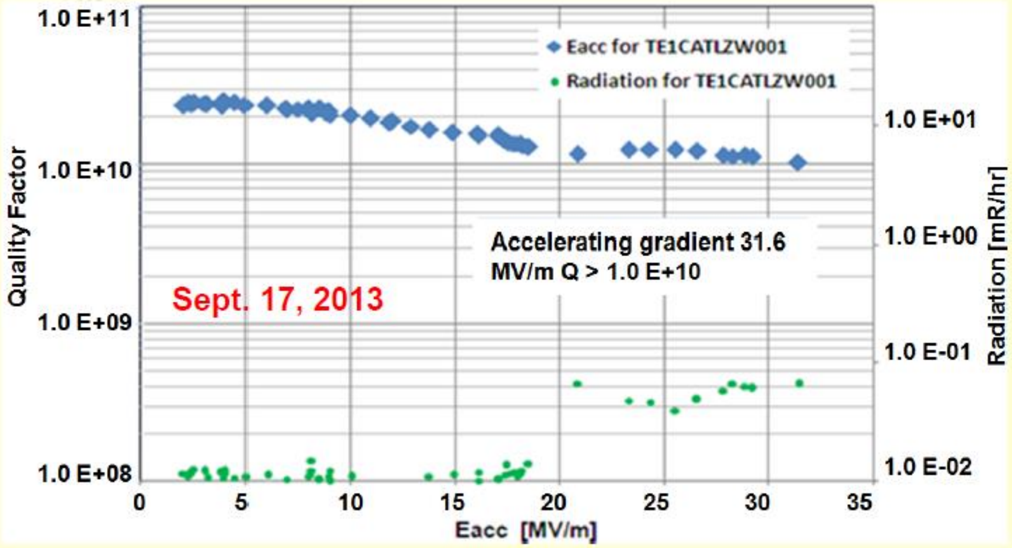
- RRCAT has made a technological innovation of fabricating superconducting cavities using laser welding.

10 kW fibre coupled Nd:YAG laser



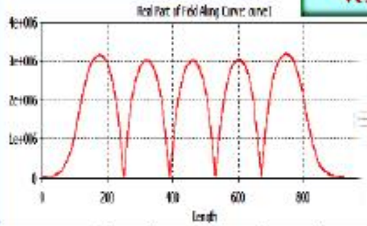
World's first laser-welded single-cell 1.3 GHz niobium cavity

**International patent applied**

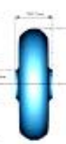


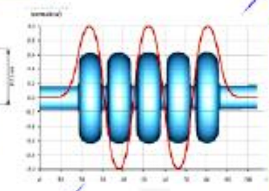
# Design of 650 MHz cavities at beta = 0.61

**Accelerating mode**



**Field flatness: Very good!**





**Data: Generated by VECC**

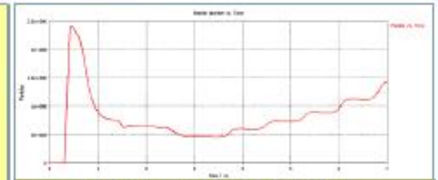
**Results: Very good!**

kc = 1.24% (Riris=48 mm.)

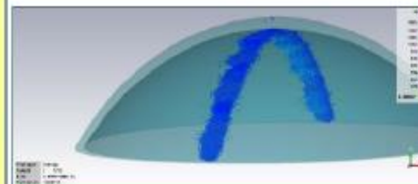
|  | $\frac{A}{B}$ mm./mm. | $\frac{a}{b}$ mm./mm. | Equator radius D/2 mm. | Iris radius $R_{iris}$ mm. | Half-cell L/2 (inner) mm. | $\frac{R}{Q}$ Ω | G=Q.$R_s$ Ω | $E_{acc}$ MV/m | $\frac{E_p}{E_{acc}}$ | $\frac{B_p}{E_{acc}}$ | $f_{\pi-mode}$ MHz | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VECC Design1 Result | $\frac{54}{58}$ | $\frac{11.99}{27}$ | 198.175 | 48 | 70.335 | 290 | 197 | 16.95 | 3.34 | 4.90 | 650.000 | 2D SUPERFISH 3D CST MWS $\left(\frac{a}{b}\right)_{end}=\frac{20.66}{46.54}$ $\left(\frac{A}{B}\right)_{end}=\frac{45.94}{49.35}$ α=3.6 deg Energy=118.8 J Mesh size=0.05 |
| VECC Design2 Result | $\frac{54}{58}$ | $\frac{13.60}{30.82}$ | 197.4 | 48 | 70.335 | 296 | 200 | 17.00 | 3.00 | 4.84 | 649.99869 | 2D SUPERFISH 3D CST MWS $\left(\frac{a}{b}\right)_{end}=\frac{10.67}{24.02}$ $\left(\frac{A}{B}\right)_{end}=\frac{54}{58}$ α =2.4 deg (mid) =4.5 deg (end) Energy=118.8 J Mesh size=0.05 |

**Multipacting simulation results for 650MHz, β=0.61 SCRF Cavity using 3D CST Particle Studio**

- 30 mm. of equator region has been simulated.
- Mesh: min 0.37 mm., max 0.74mm.
- Multipacting has been found between 5.8 MV/m to 11.5 MV/m
- Multipacting rate is very high in the region of 6.8 MV/m.
- At 11.6 MV/m, increase in partcle due to multipacting is very low.



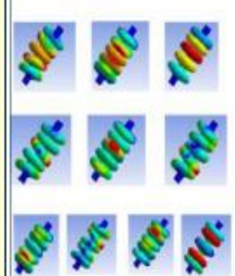
Particle vs. time(ns) at 5.8 MV/m



Particles after 7ns at 5.8 MV/m

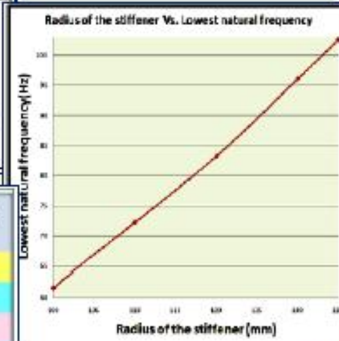
- Structural analysis carried out using ANSYS 3D code.
- Stresses are within the allowable limit.
- Mechanical modal analysis : (without stiffener) shows frequency within 100 Hz (NOT desirable!)

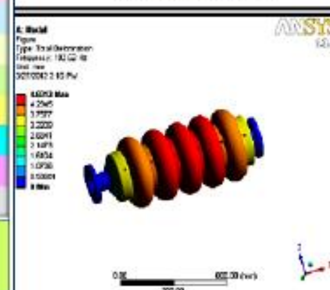
  (with stiffener) shows frequency >100 MHz



| Mode | Frequency [Hz] |
|---|---|
| 1. | 3.0625 |
| 2. | 5.9953 |
| 3. | 8.6136 |
| 4. | 10.776 |
| 5. | 11.161 |
| 6. | 24.688 |
| 7. | 26.005 |
| 8. | 27.449 |
| 9. | 28.538 |
| 10. | 57.485 |

Mechanical modal analysis (without stiffener)

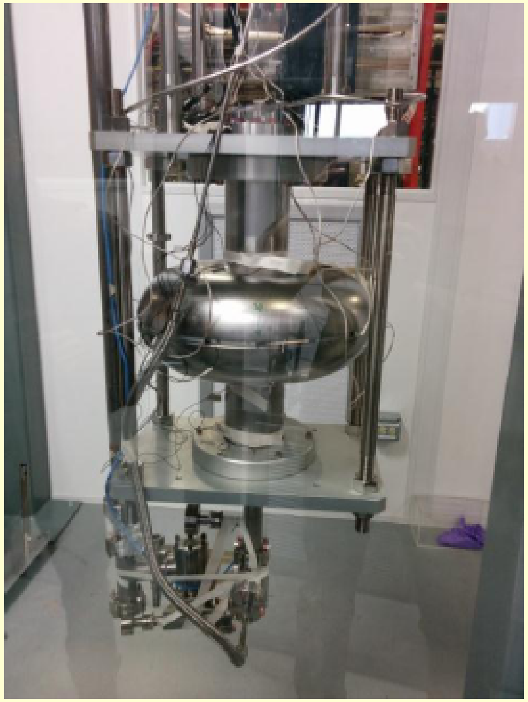


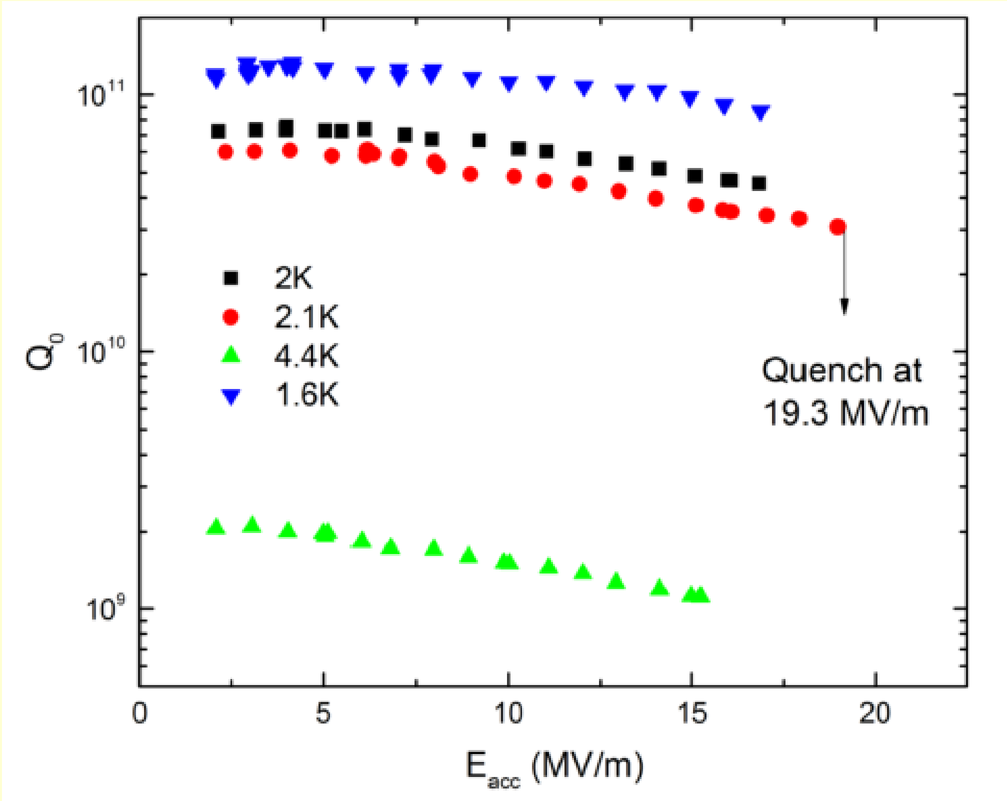




|  | Modal Frequencies [Hz] |  |
|---|---|---|
|  | Both End Fixed | One End Free |
| 650 MHz Cavity β=0.6 | 51.952 | 24.705 |
|  | 101.72 | 73.351 |
|  | 146.16 | 119.15 |
|  | 182.75 | 158.05 |
|  | 189.39 | 186.75 |
|  | 419.78 | 353.67 |
|  | 442.33 | 421.16 |
|  | 467.10 | 444.88 |
|  | 485.8 | 469.09 |
|  | 975.59 | 486.47 |

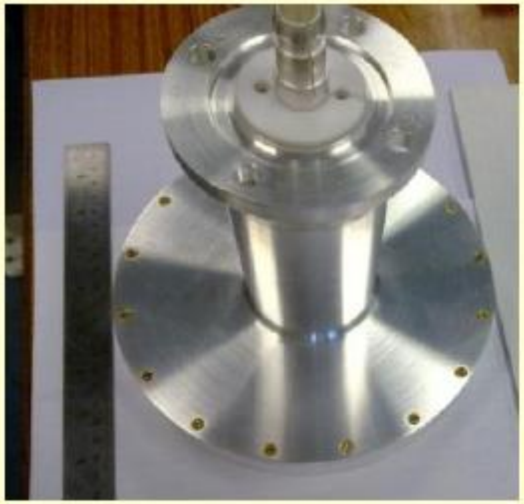
**Mechanical modal analysis (with stiffener)**

- First 650 MHz single-cell niobium cavity fabricated by RRCAT and IUAC was processed and tested at Fermilab during Dec-2013 and January 2014.
- The single-cell cavity reached $E_{acc}$ of 19.3 MV/m and $Q_o$ of of $7x10^{10}$ at 2K. This performance exceeds the design parameters.

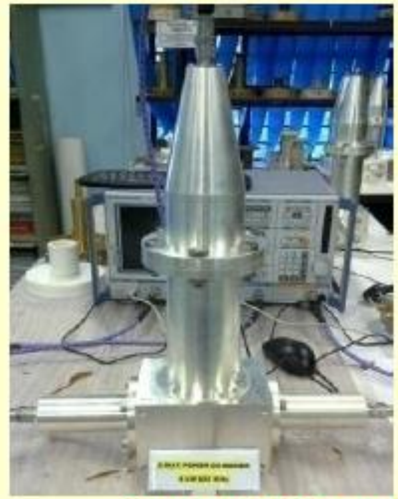




# Development of 650 MHz RF Components

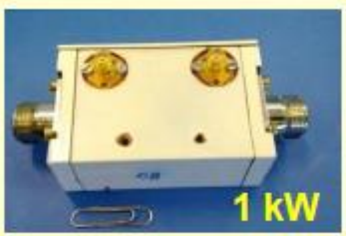


16-way 4 and 8 kW Power combiner



2-way 8 kW and 18kW Power combiners

Output port: 3-1/8” EIA



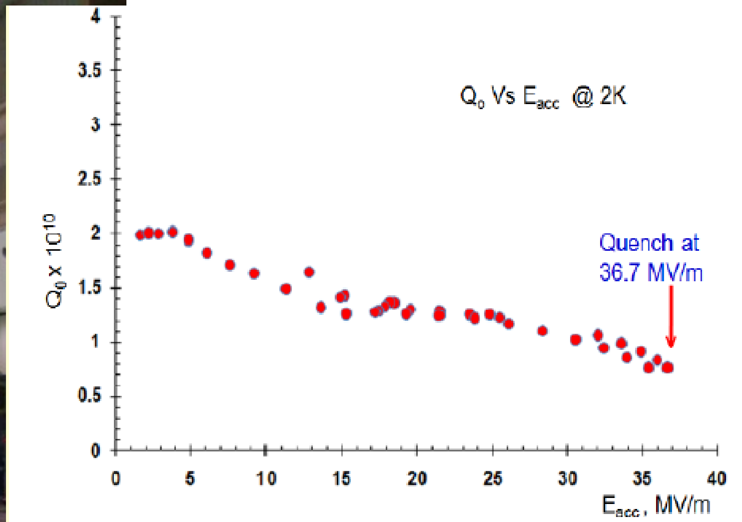



Wide-Band Directional Couplers


Coaxial Transitions 3-1/8” EIA to 1-5/8” EIA

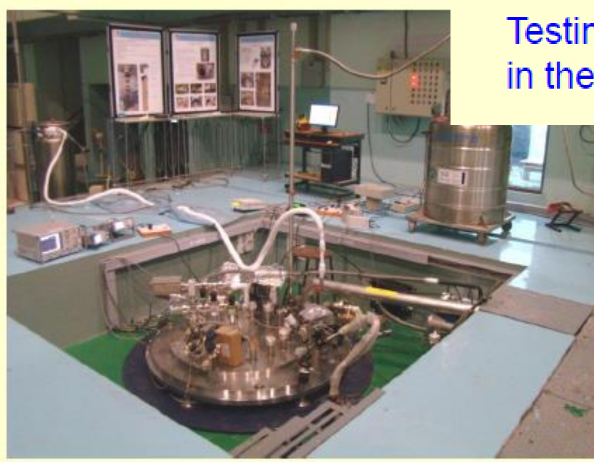
1-5/8” EIA to N Type

# SCRF Cavity Processing and Assembly Hall




Testing of single-cell 1.3 GHz SCRF cavity in the VTS facility at RRCAT

Installation of cryostat in pit



Transfer of liquid helium in the VTS cryostat

# Conclusions

- Asia countries are progressing in post ILC TDR phase, in ILC parameter optimization, AFT2, SCRF, positron source, facility development, etc.

- Continuous efforts should be kept towards the goal.

# Acknowledgement

Thanks goes to A. Yamamoto, E.S. Kim, W. Namkung, T. Datta and K.X. Liu for their kind providing useful information in preparing this talk.