



2016. 10. 24

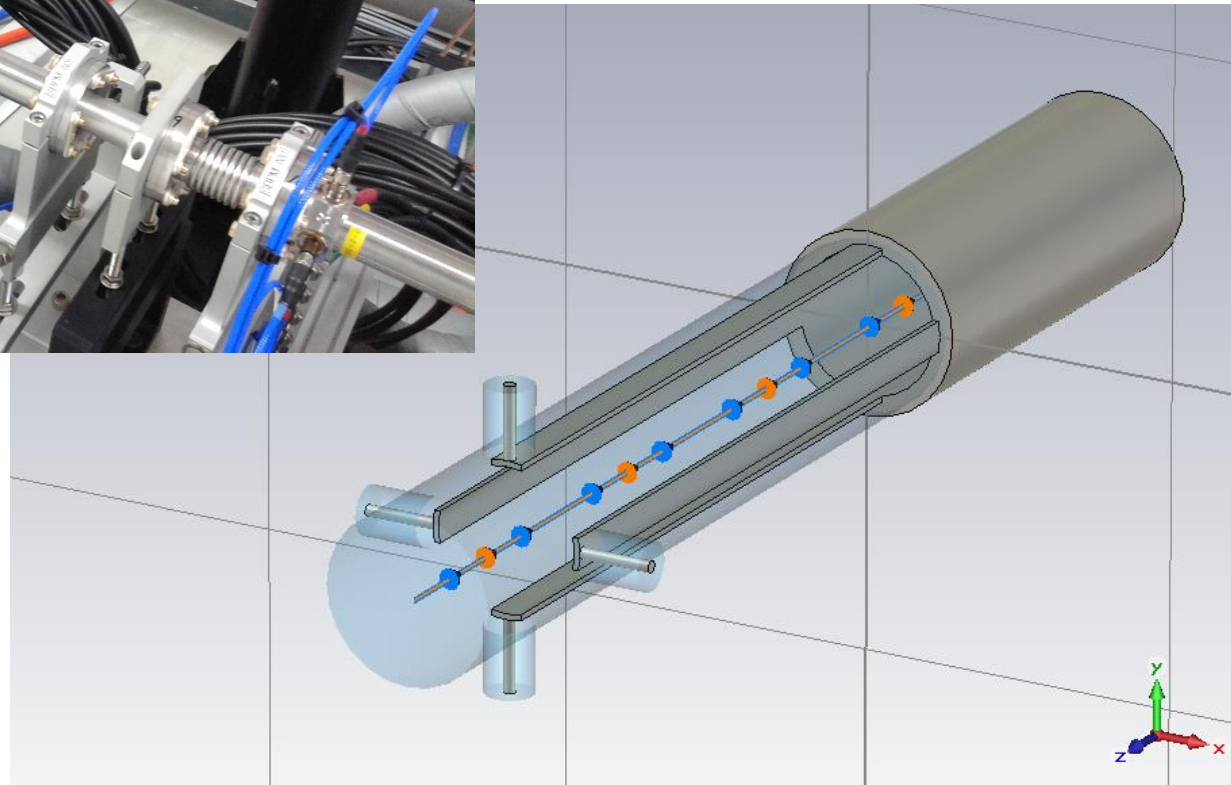
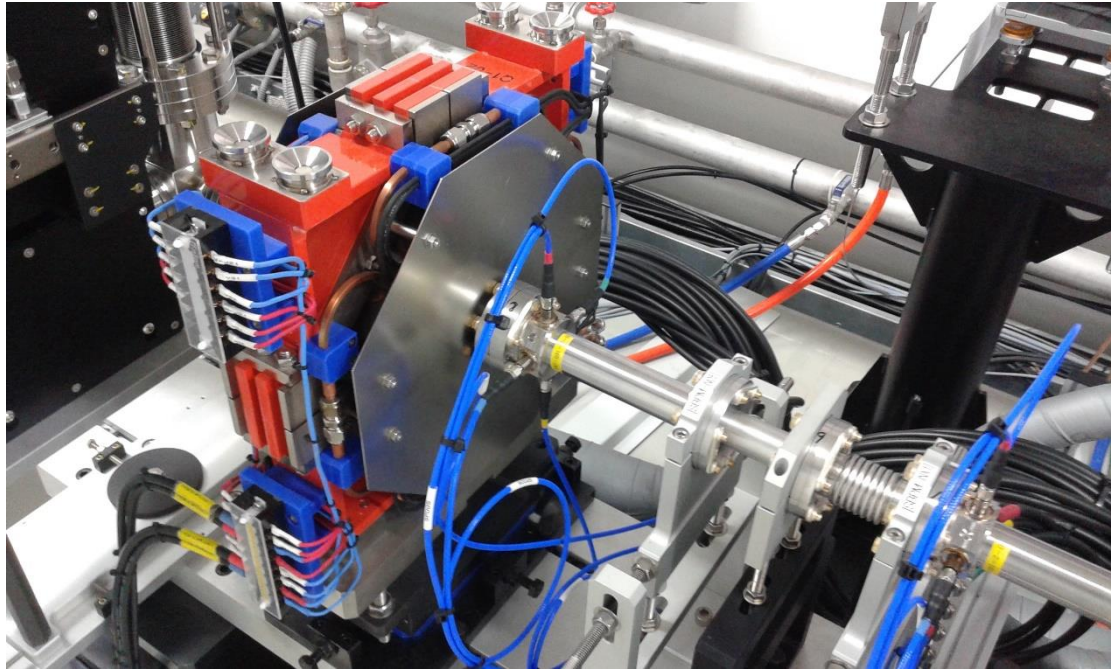
Changbum Kim on behalf of instrument & control group  
Pohang Accelerator Laboratory

# Contents

- Linac Diagnostics
  - Stripline BPM
  - Screen Monitor & Wire Scanner
  - Transverse Deflector & Coherent Radiation Monitor
  - ...
- Undulator Diagnostics
  - Cavity BPM
  - Beam Loss Monitor
  - ...

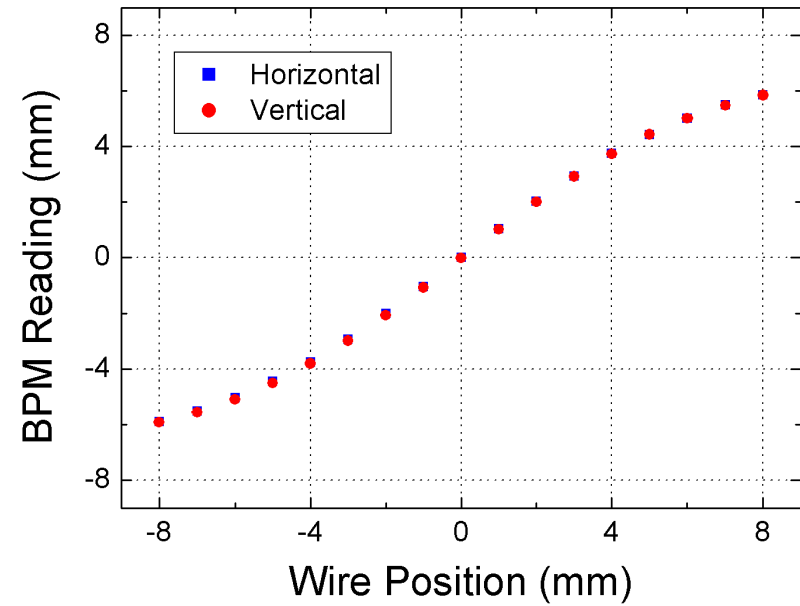
# Linac Diagnostics

# Stripline BPM Design

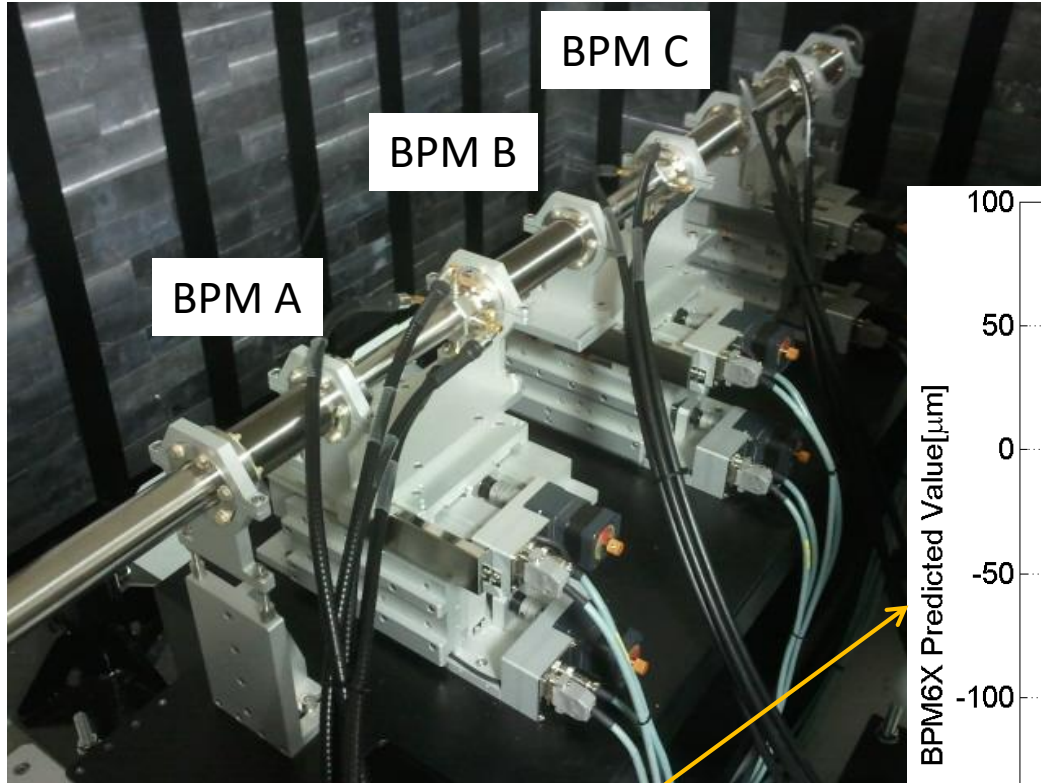


CST Simulation

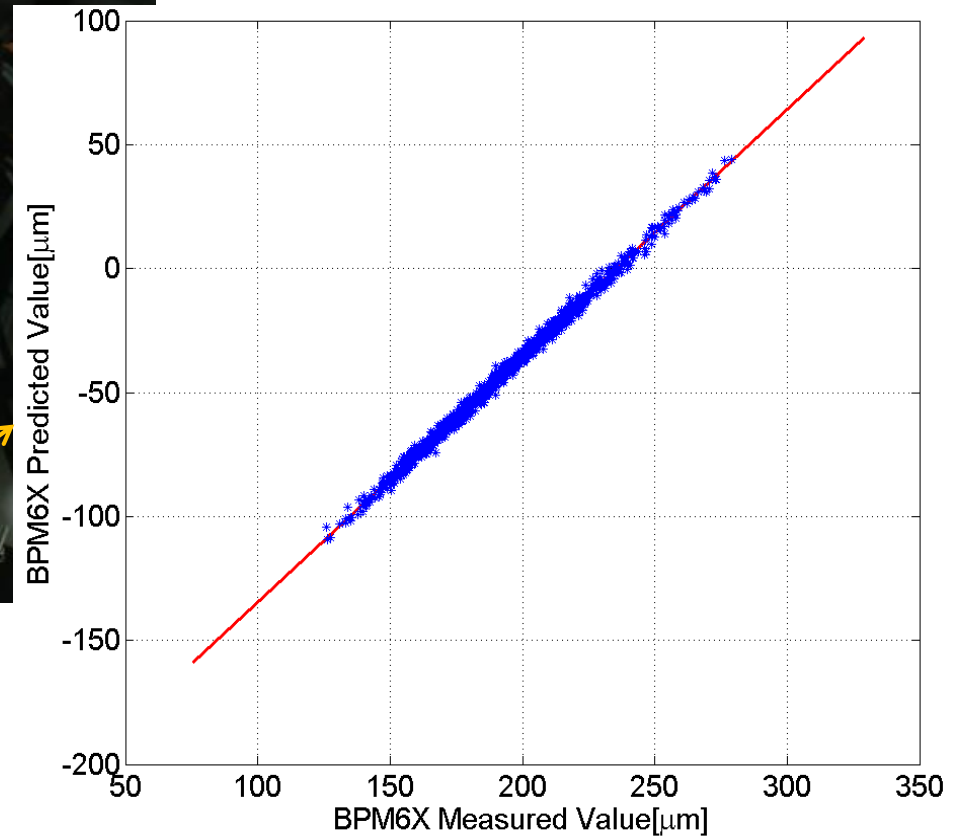
# Wire Test Stand



# BPM Test Stand

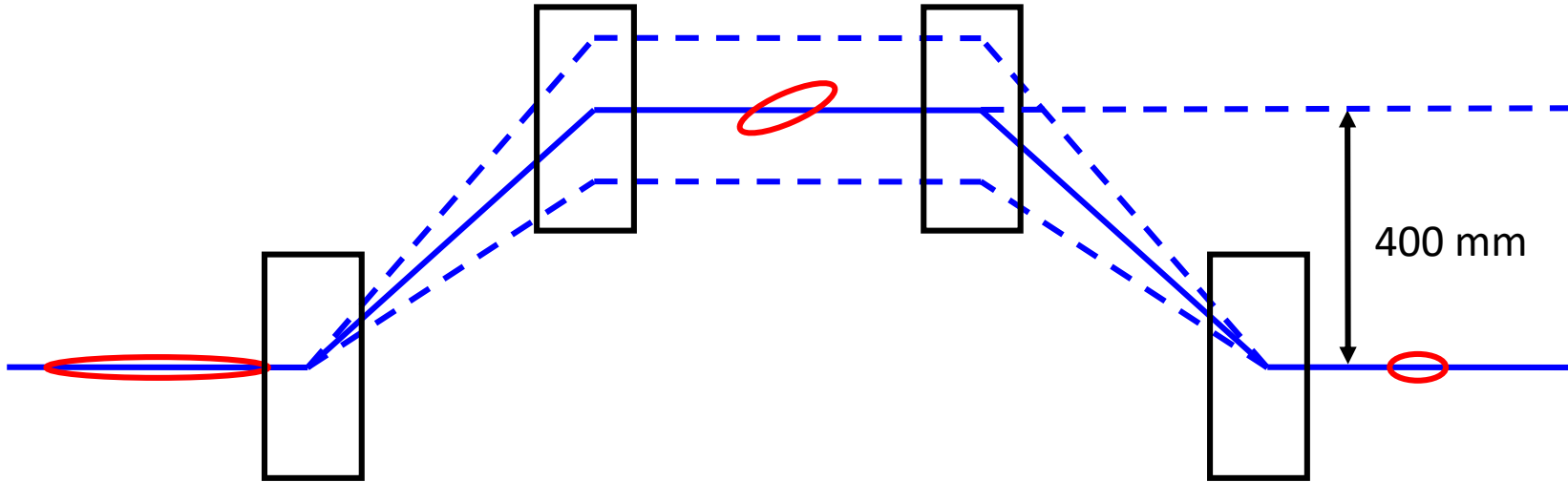


$$\text{BPM B} = \frac{\text{BPM A} + \text{BPM C}}{2}$$



Resolution : 1.5 μm @ 200 pC

# Bunch Compressor



- Requirement
  - Wide dynamic range
  - High resolution
  - Energy measurement & energy feedback

# FLASH Bunch Compressor BPM

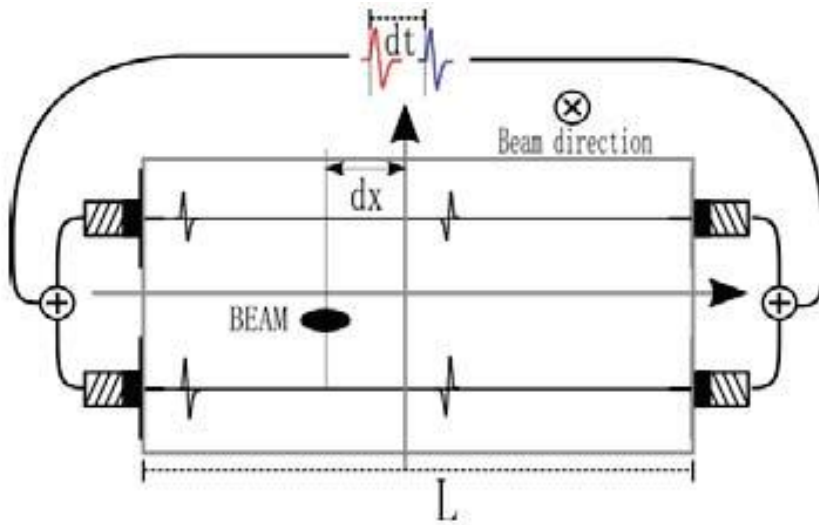


Figure 1: Time of flight principle.

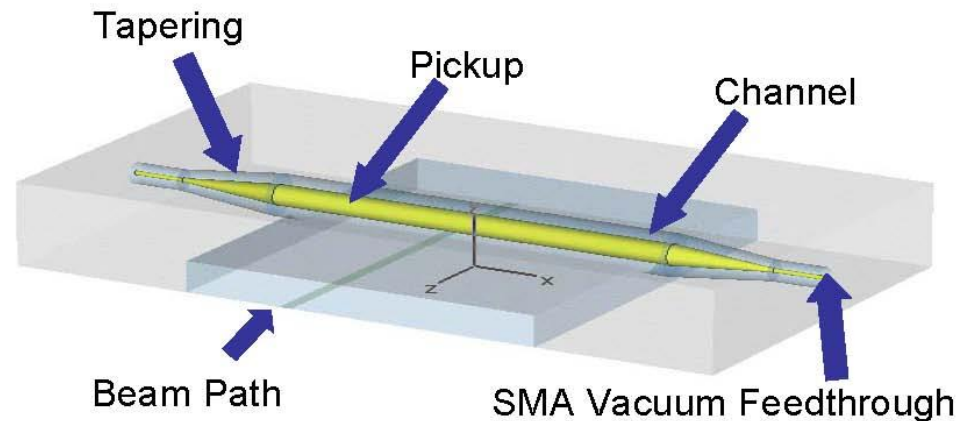


Figure 5.5.1 3-D transparent representation of the upper-half of the chicane BPM pickup (not-to-scale). The beam (green) travels under the pickup (yellow).



# SACLA Bunch Compressor BPM

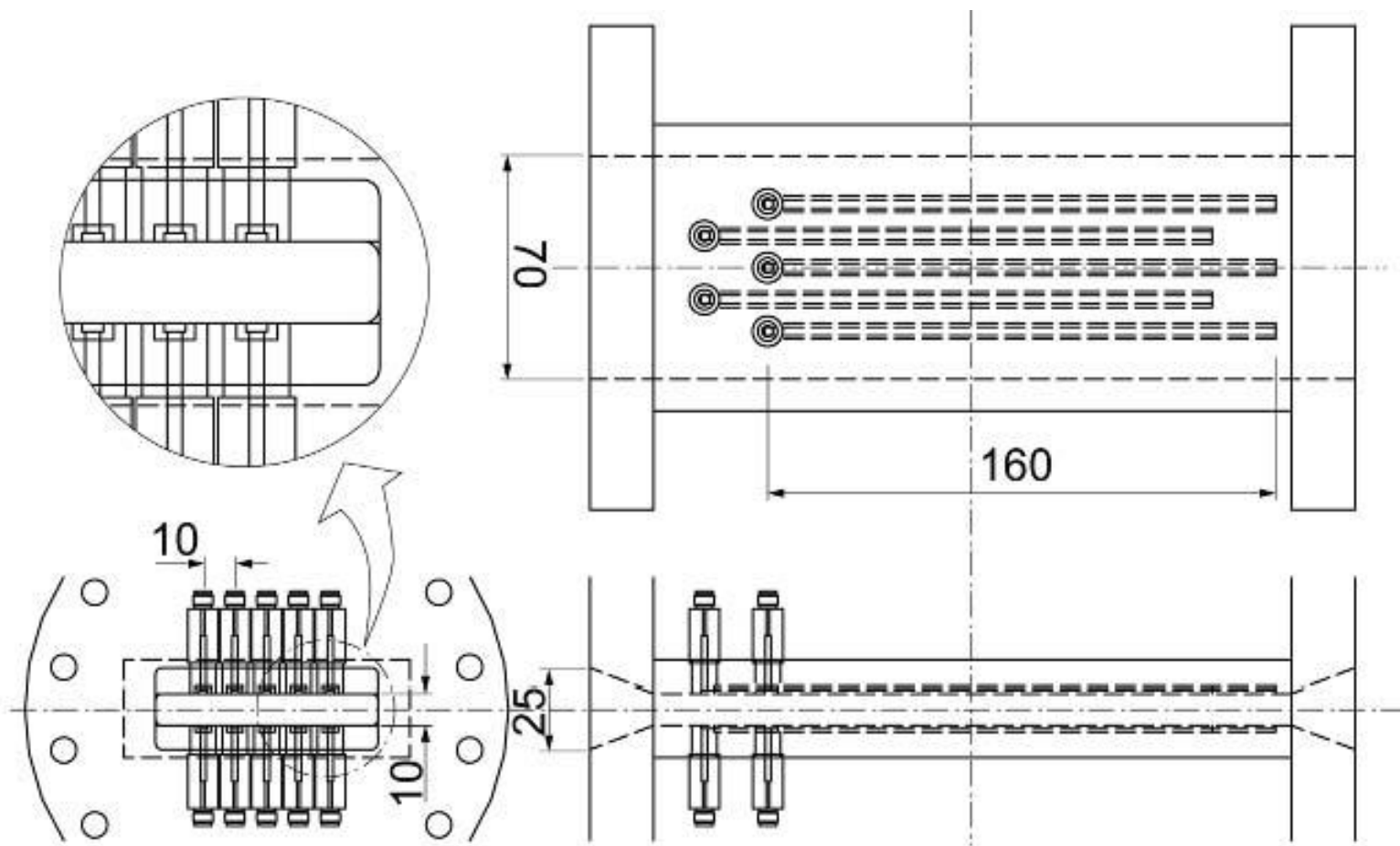
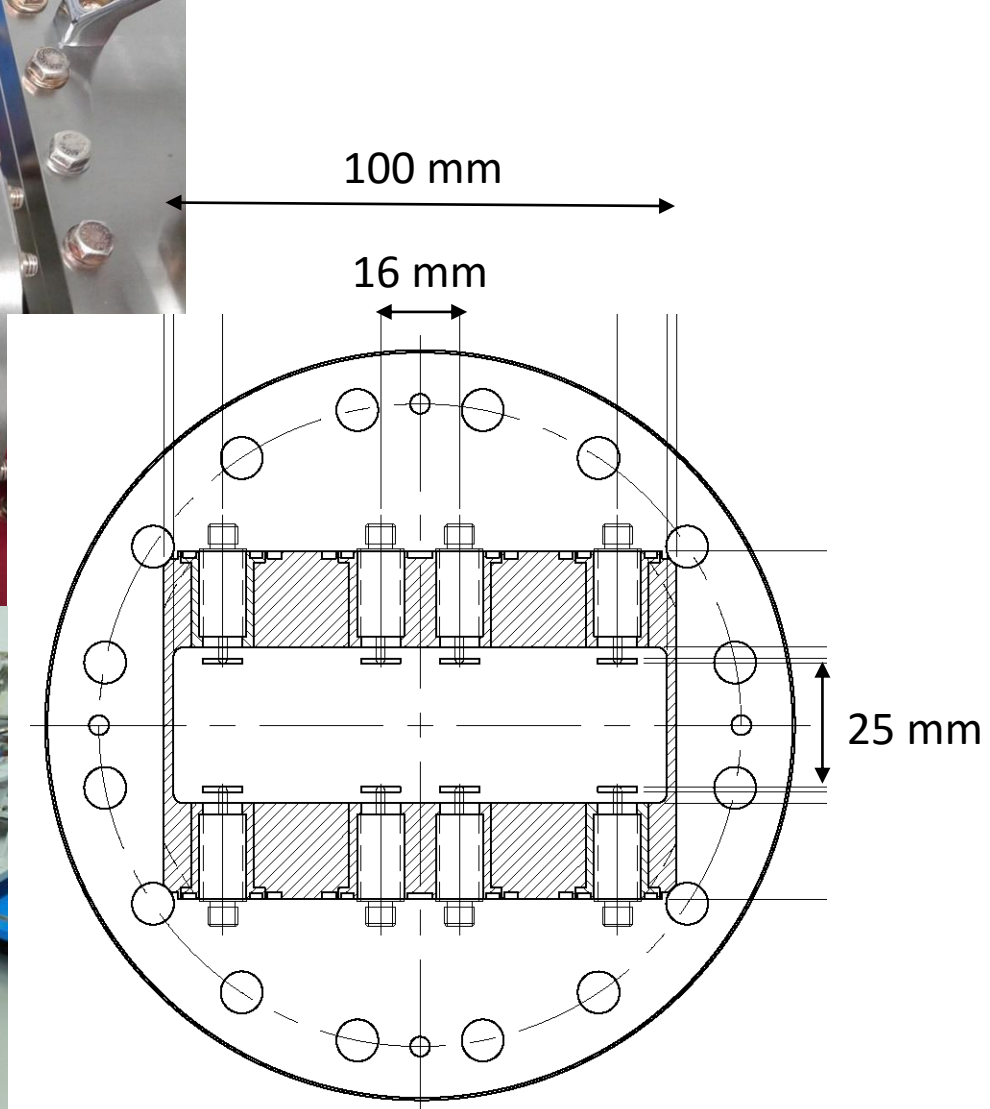
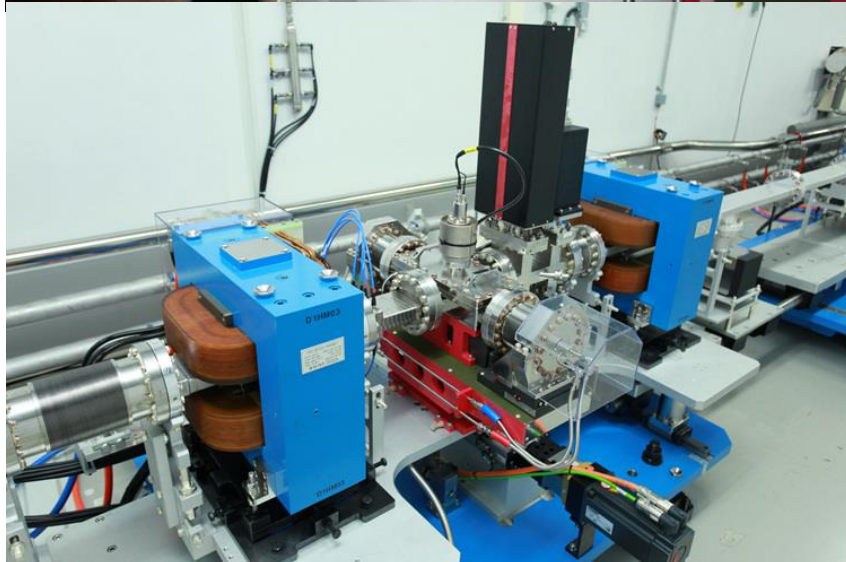
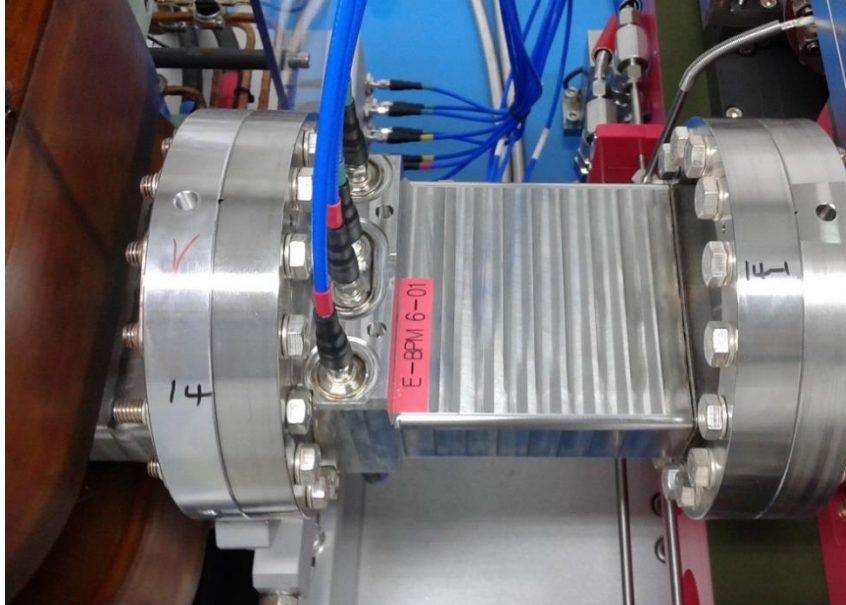
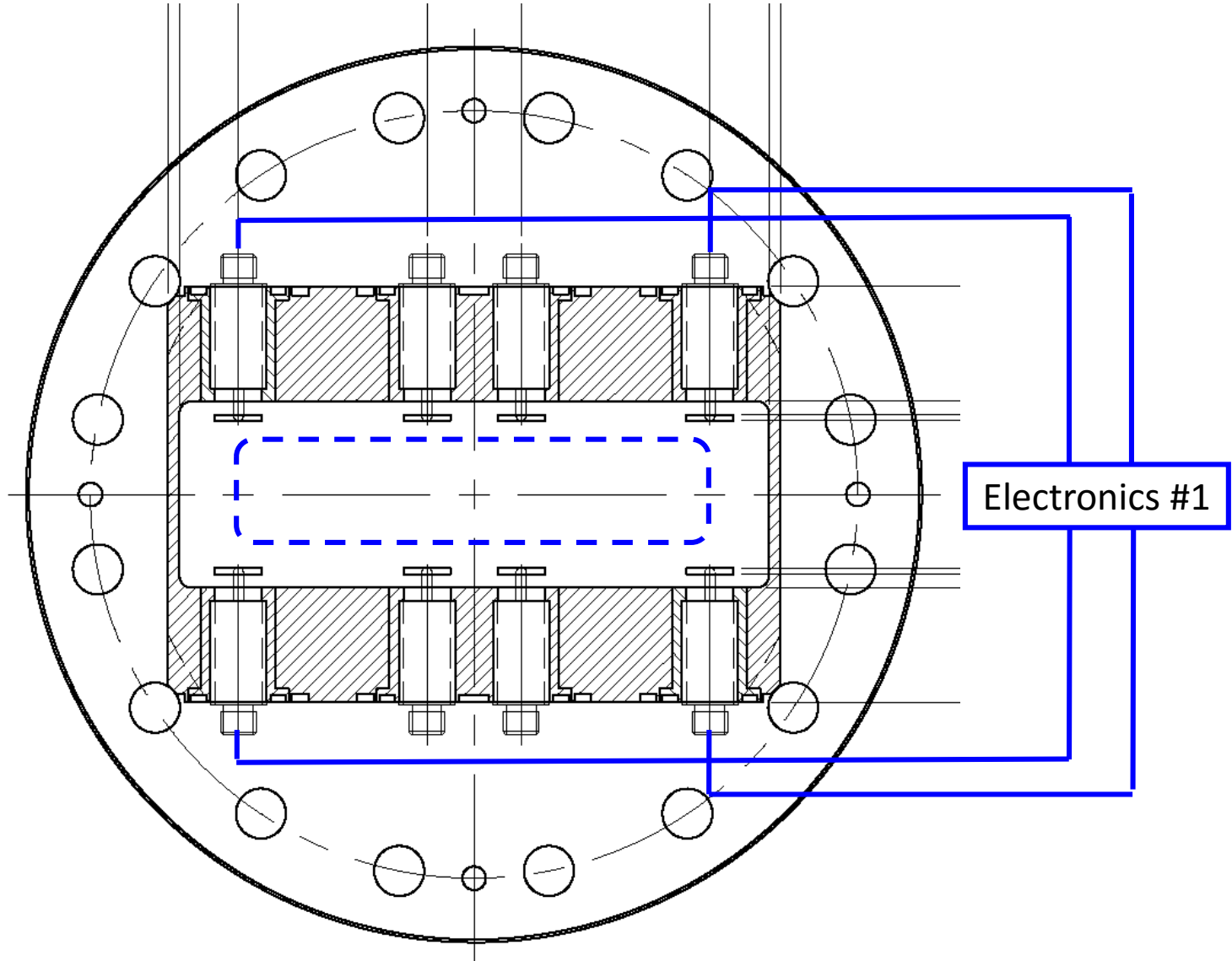


Figure 1: Schematic drawing of the multi-stripline BPM.

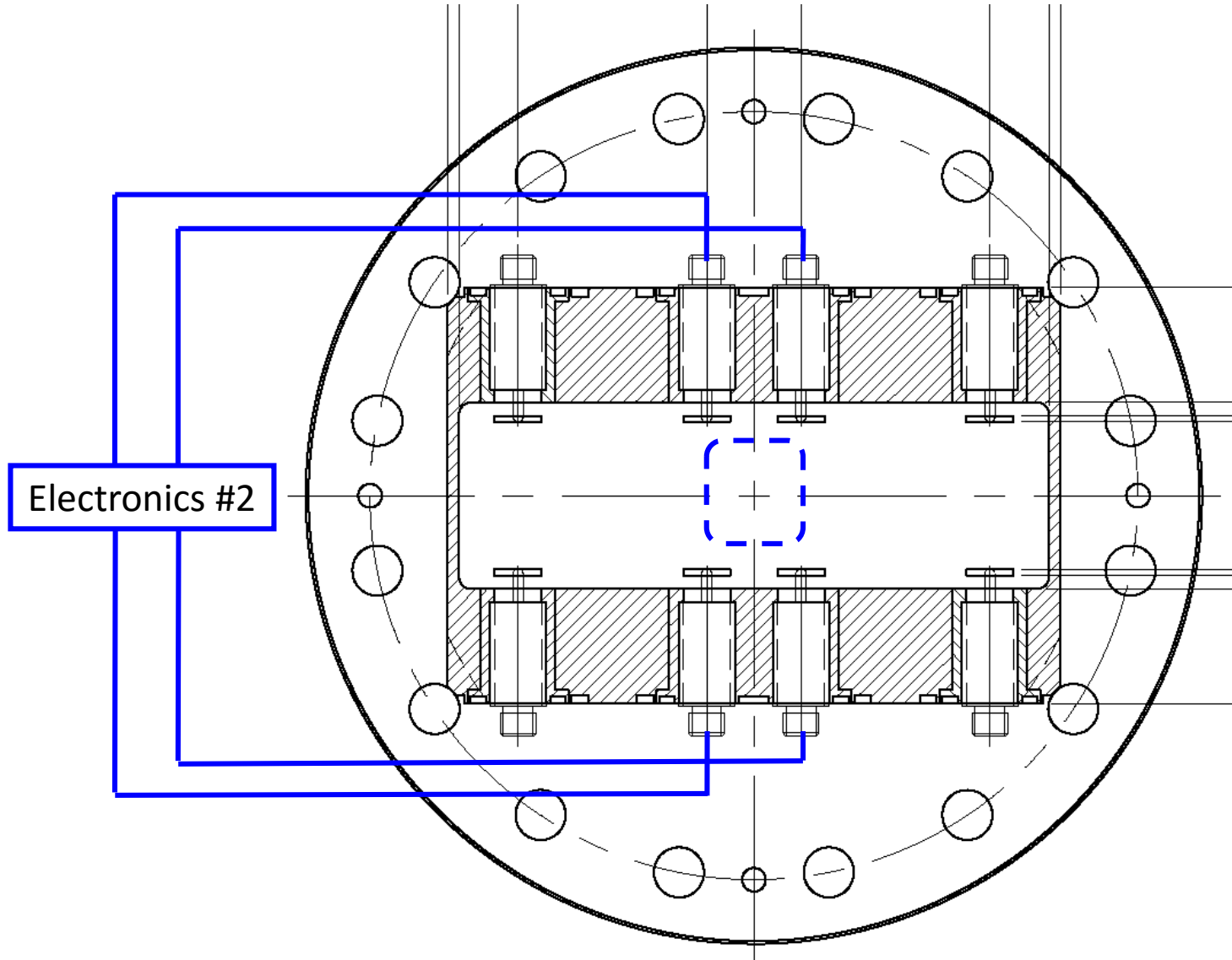
# PAL-XFEL Bunch Compressor BPM



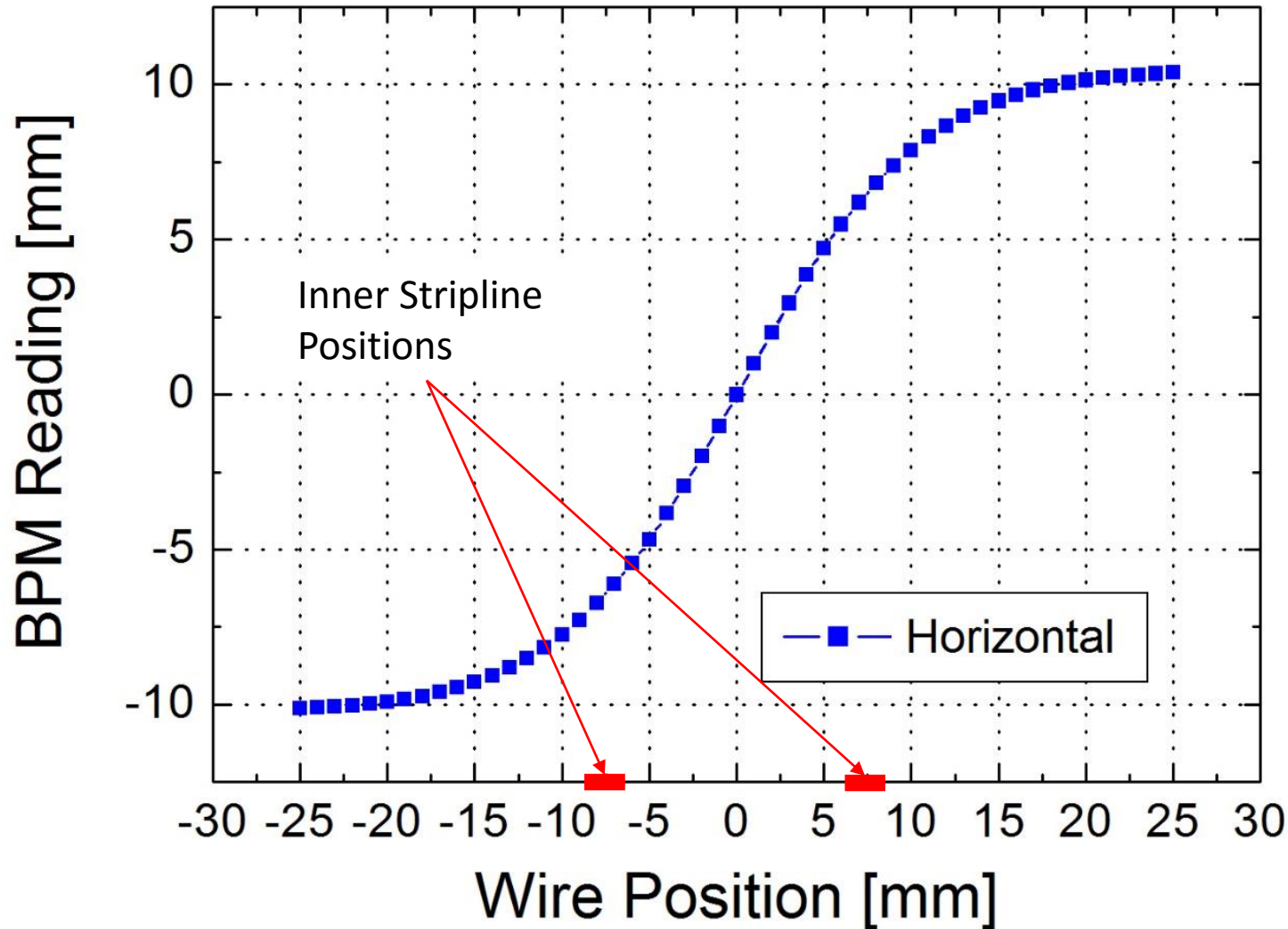
# BC BPM (Outer Stripline)



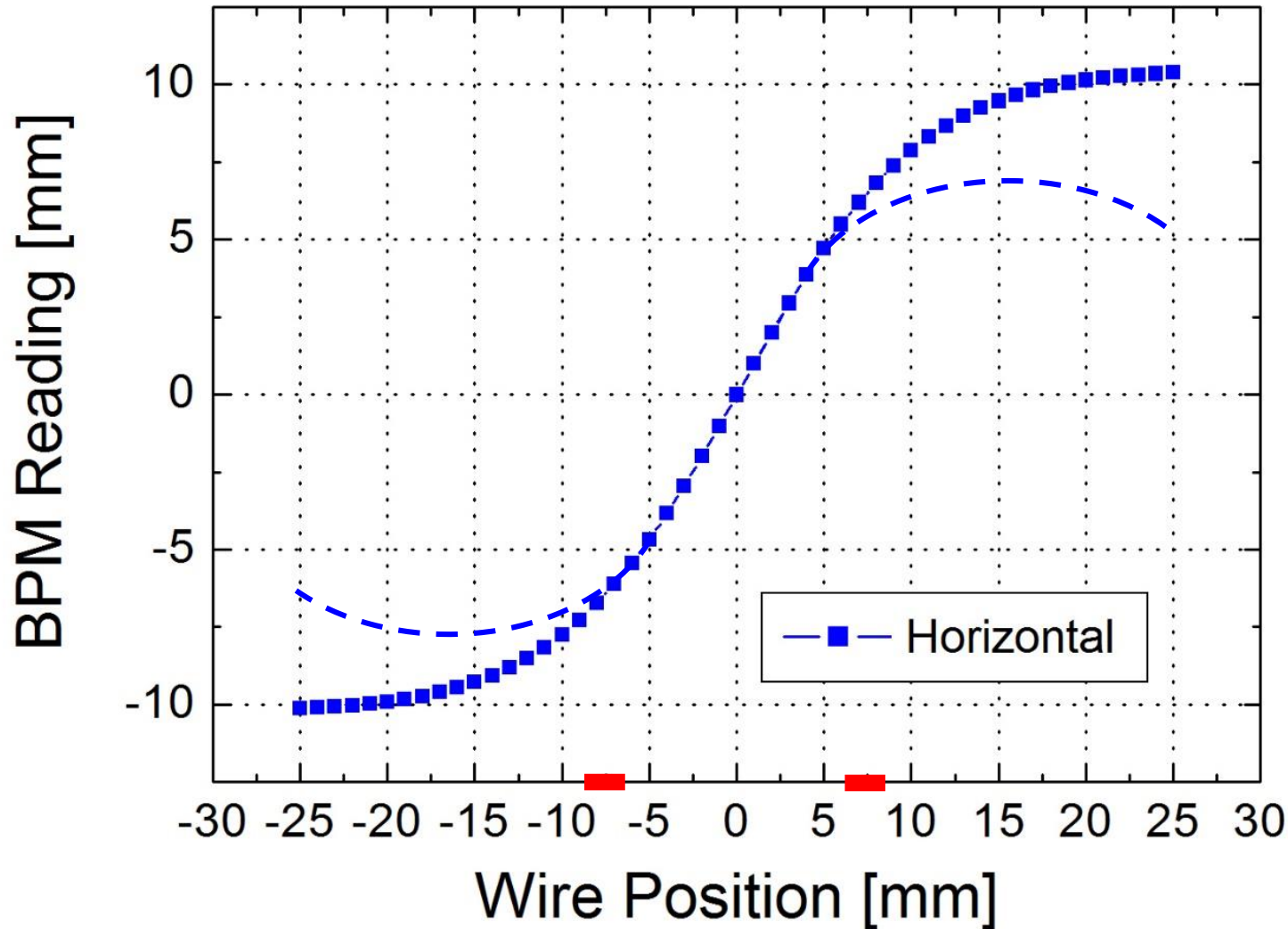
# BC BPM (Inner Stripline)



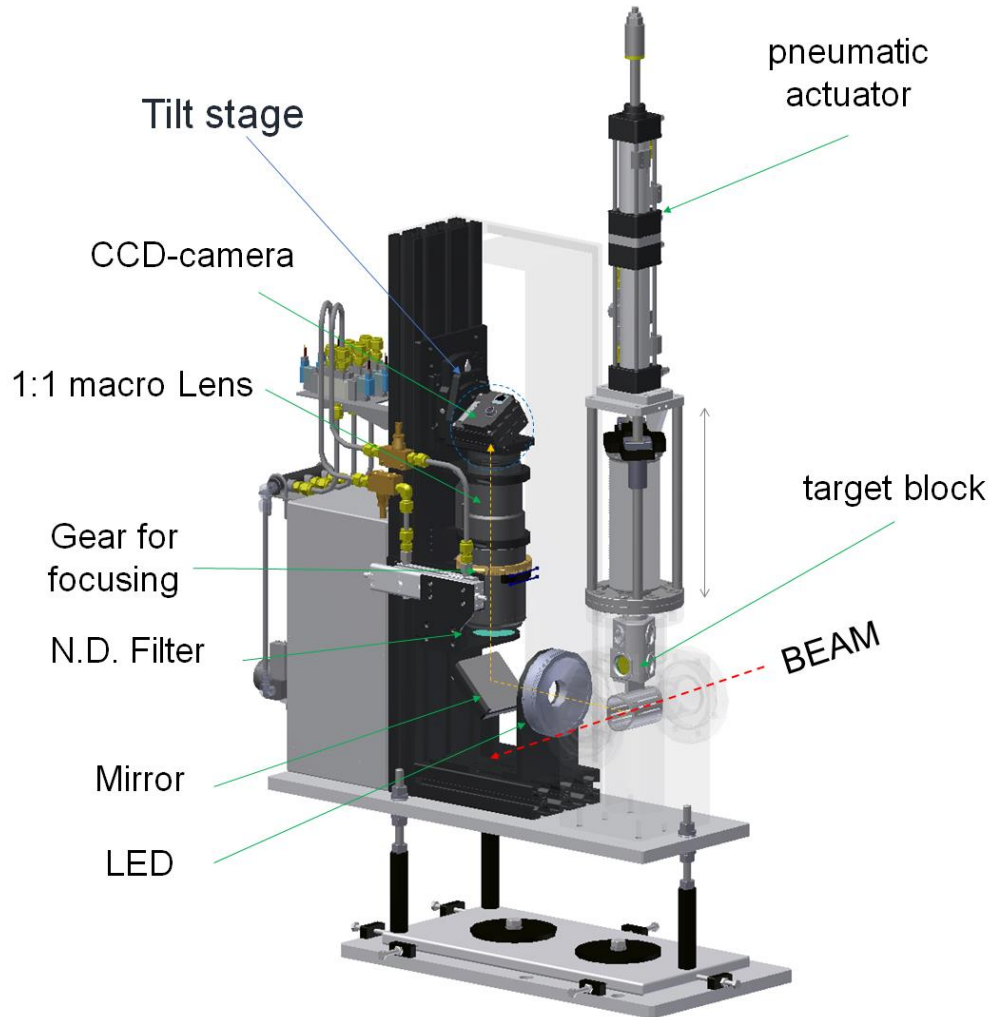
# Wire Test Result (Inner Stripline)



# Wire Test Result (Inner Stripline)

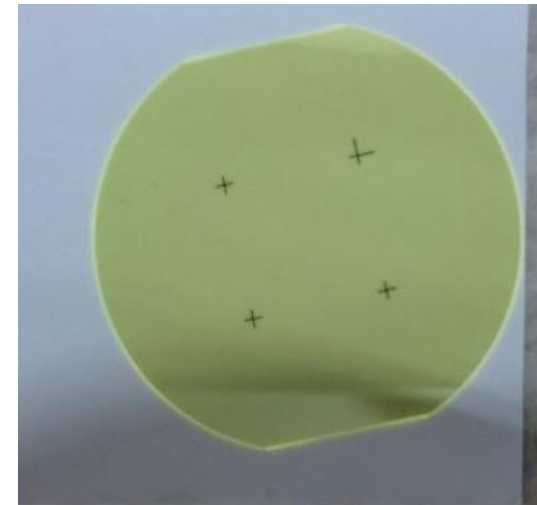
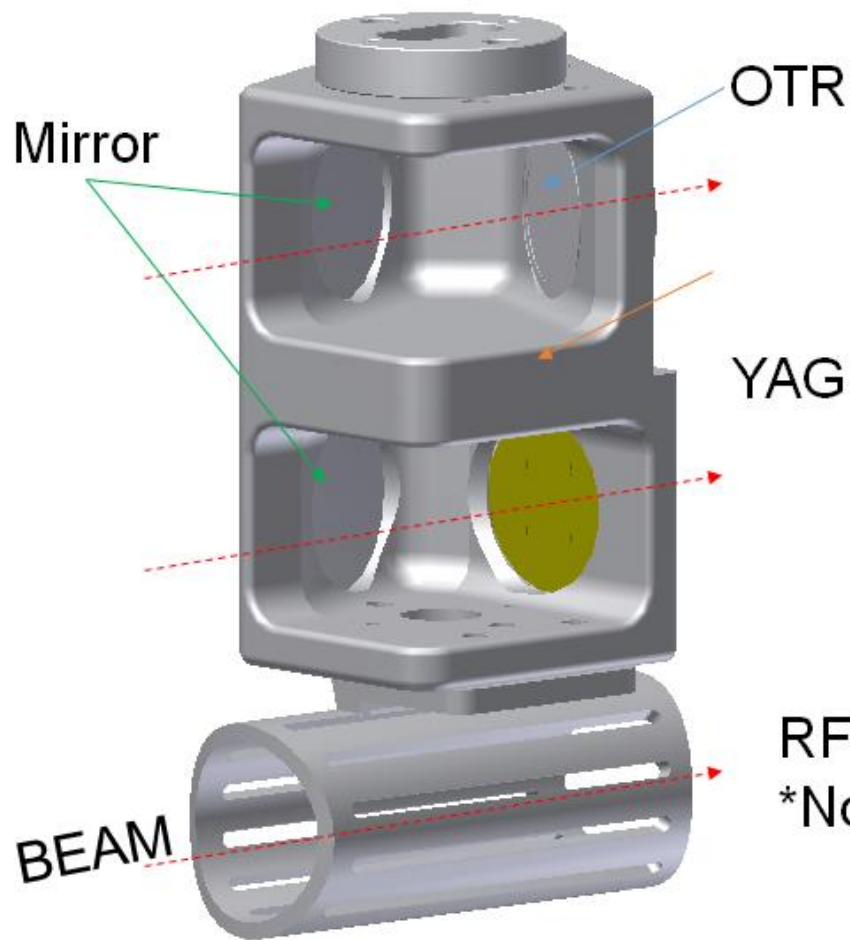


# Screen Monitor



- 3-position pneumatic actuator
- RF shield for reducing the wake field
- Scintillator (YAG:Ce)
- OTR Target (Al-foil)
- LED backlight lamp
- Neutral density filter
- DSLR lens (Magnification : x1)
- DC motor for remote focusing
- Tilt stage for Scheimflug's geometry
- GigE camera

# Target Holder

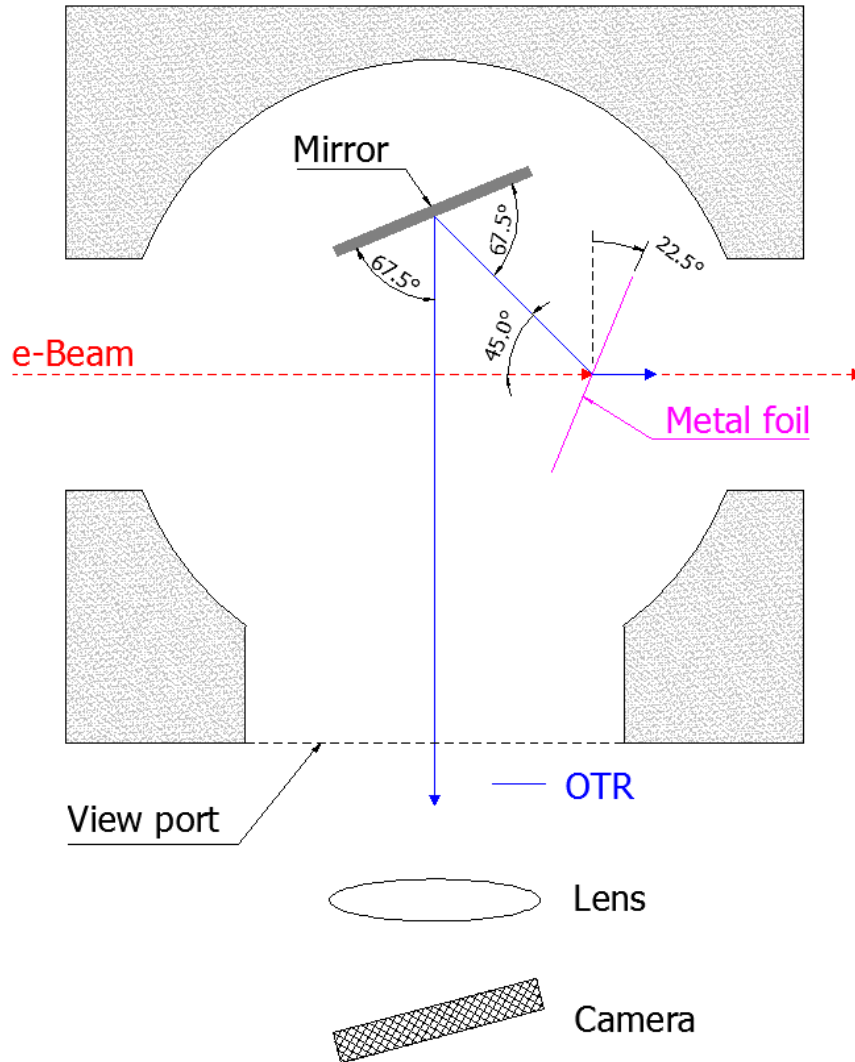


YAG:Ce with patterning  
for size calibration  
(Measured resolution  
= 8  $\mu\text{m}$  X 6.5  $\mu\text{m}$ )

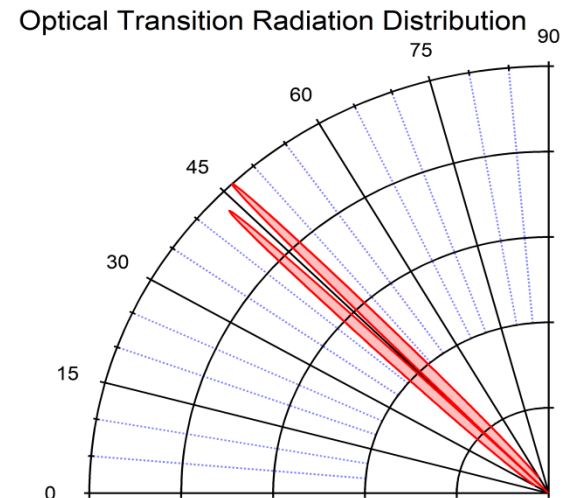
RF shield  
\*Nominal operation



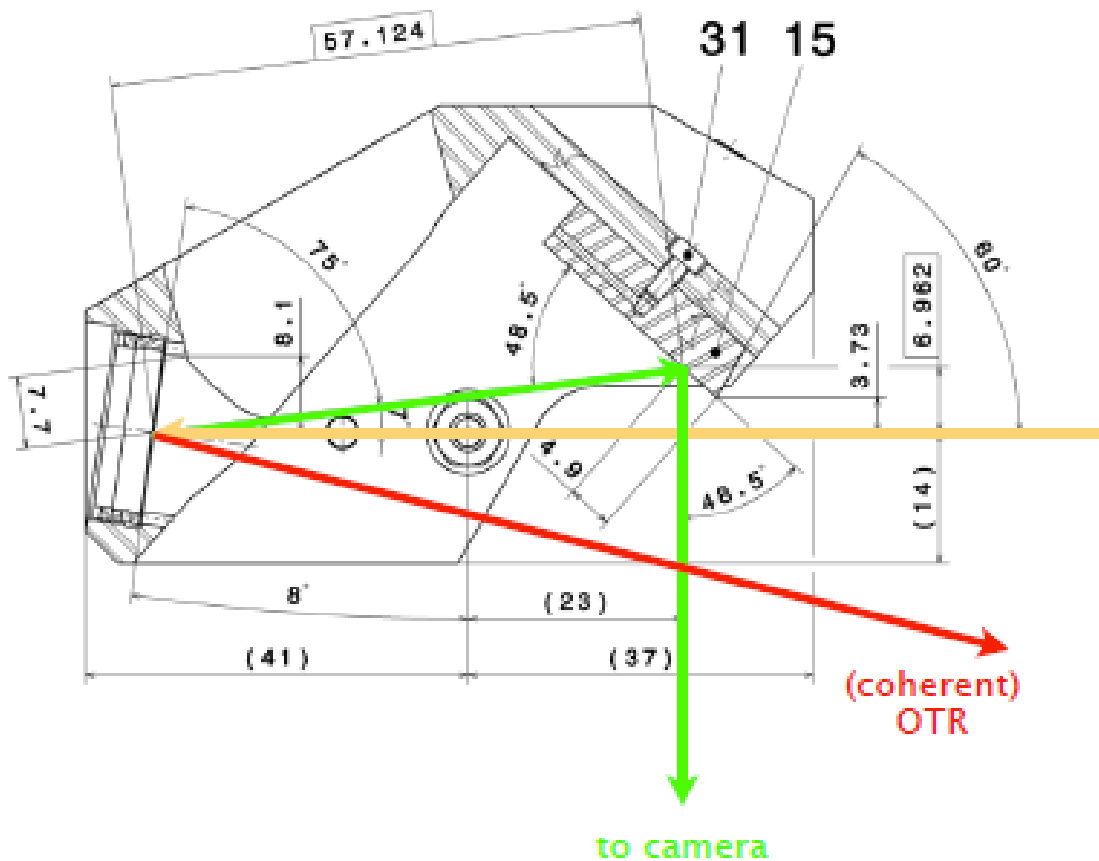
# OTR Target



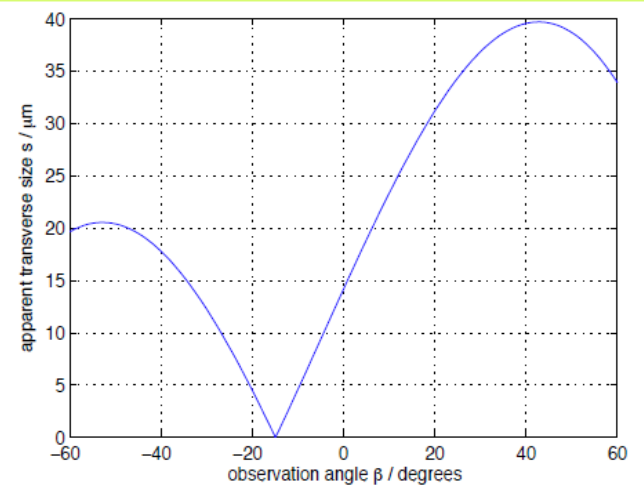
- OTR imaging with Al foil - thickness : 1  $\mu\text{m}$
- Target rotation: 22.5  $^{\circ}$



# SwissFEL Screen Monitor

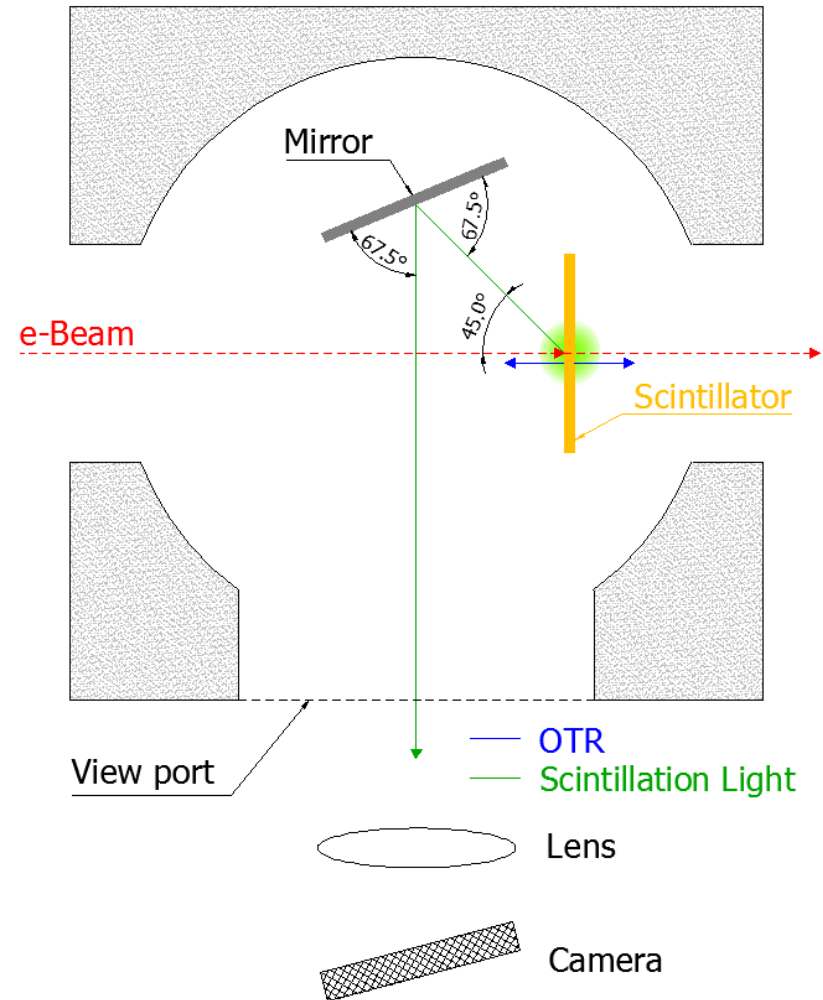
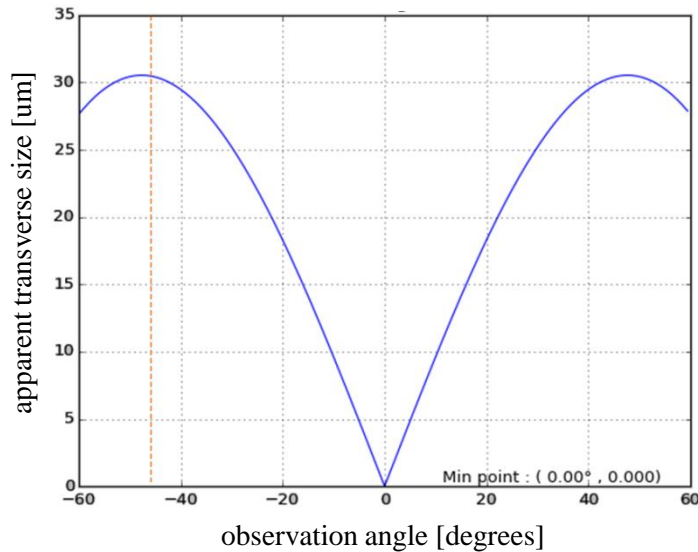


Observed Beam Size

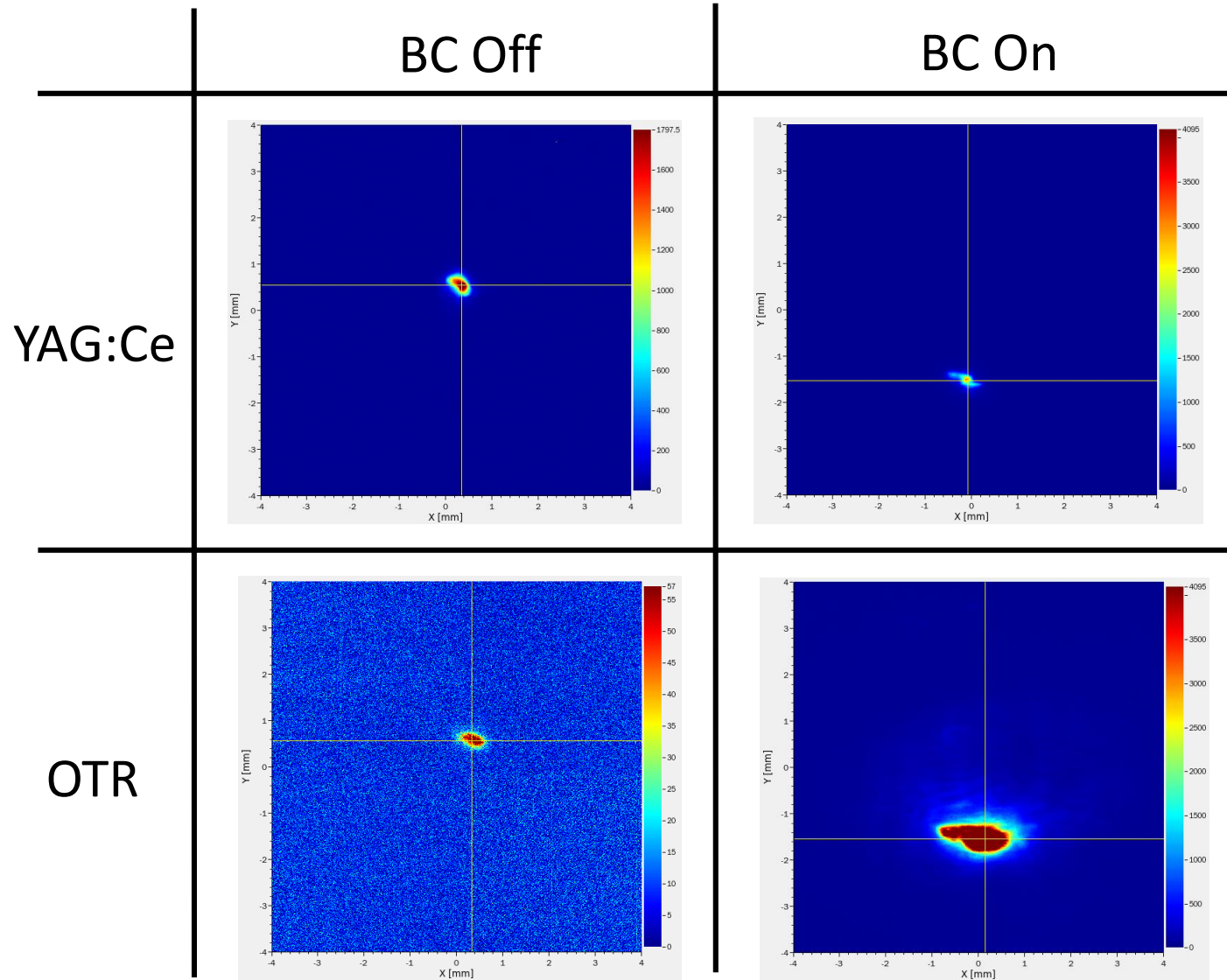


# Scintillator Target

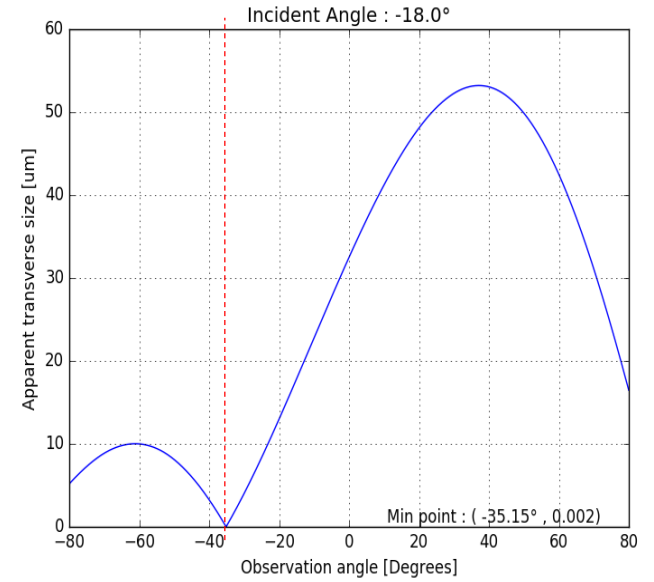
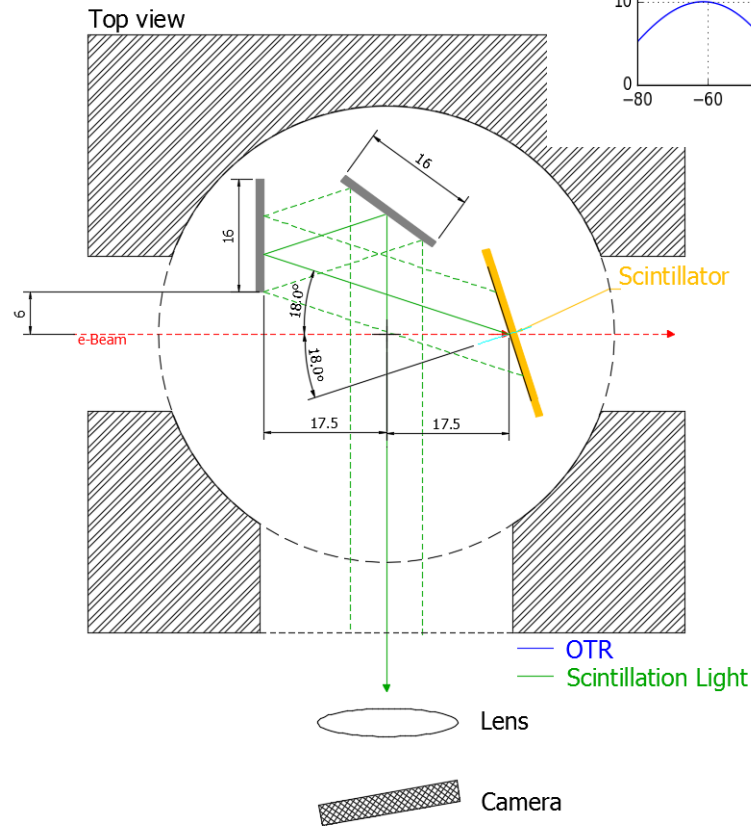
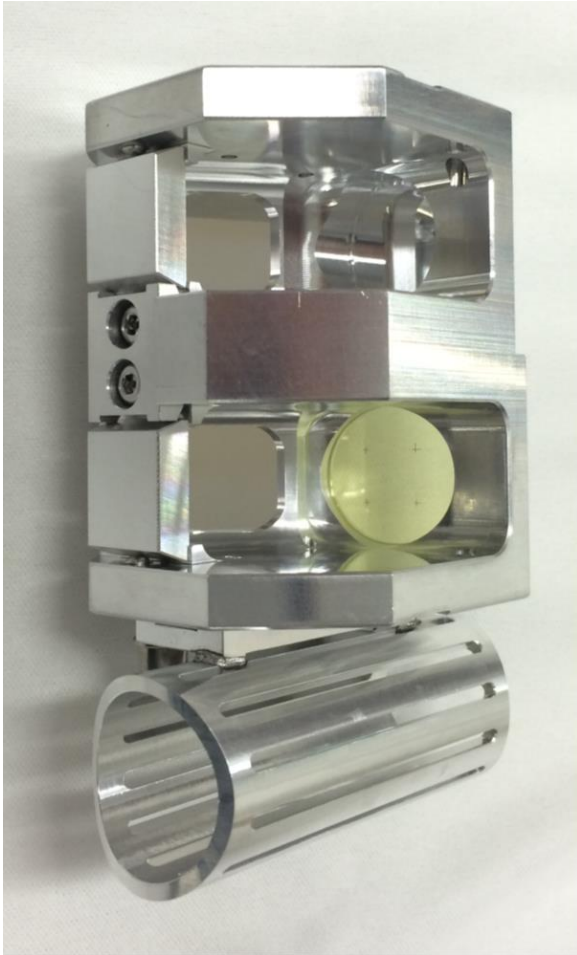
- YAG:Ce scintillator
  - Thickness : 100 or 30  $\mu\text{m}$
- Observation geometry of  $45^\circ$  with respect to the beam axis
  - $\Rightarrow$  Minimized holder size



# COTR Measurement Results

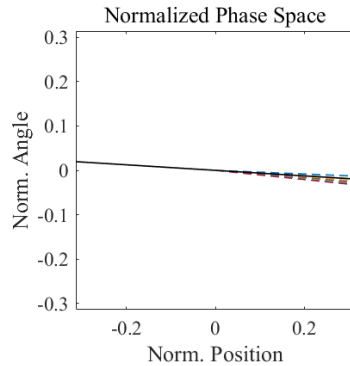
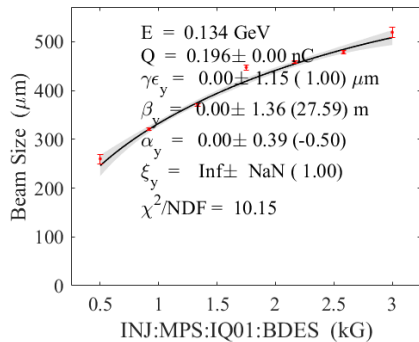
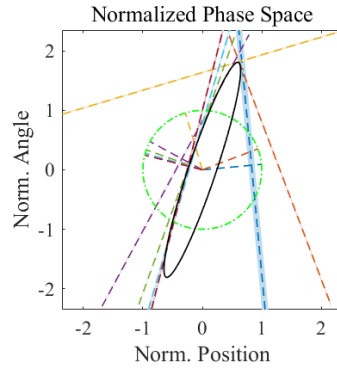
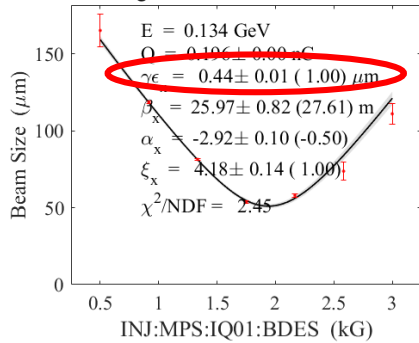


# New Target Holder

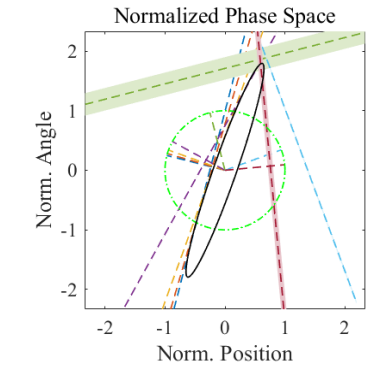
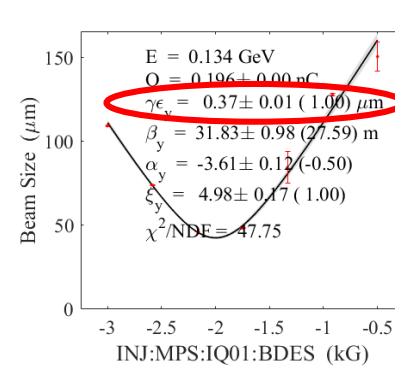
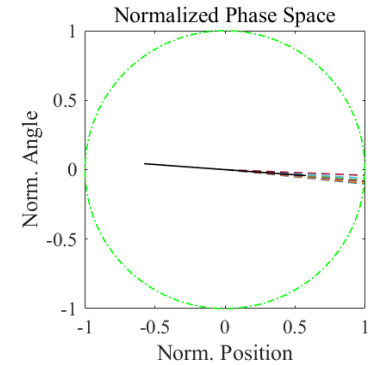
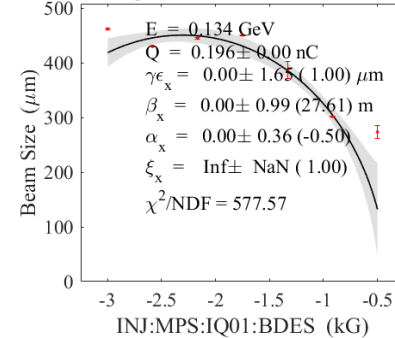


# Emittance Measurement

Emittance Scan on INJ:SCM03  
26-Aug-2016 16:57:01 RMS cut area



Emittance Scan on INJ:SCM03  
26-Aug-2016 16:53:15 RMS cut area



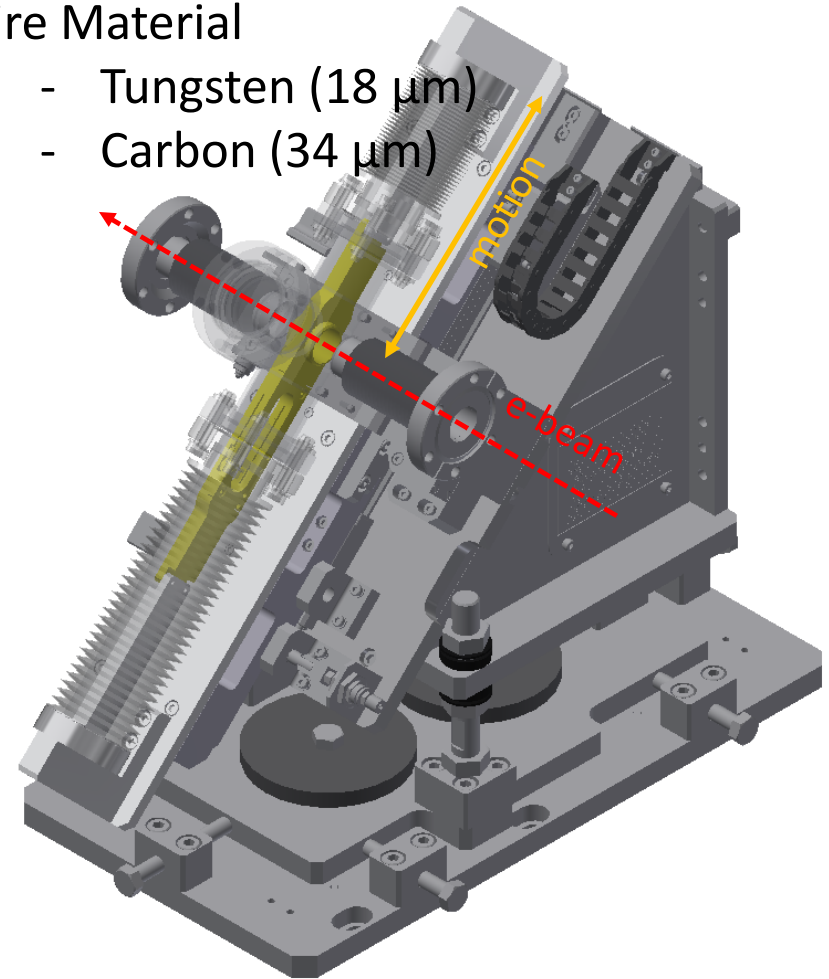
Gun Emittance  
Horizontal: 0.44 mm-mrad  
Vertical: 0.37 mm-mrad

# Wire Scanner



## Wire Material

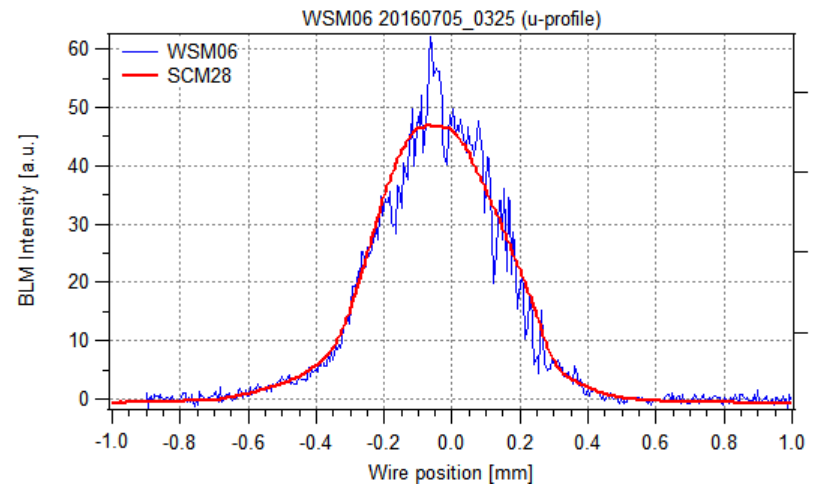
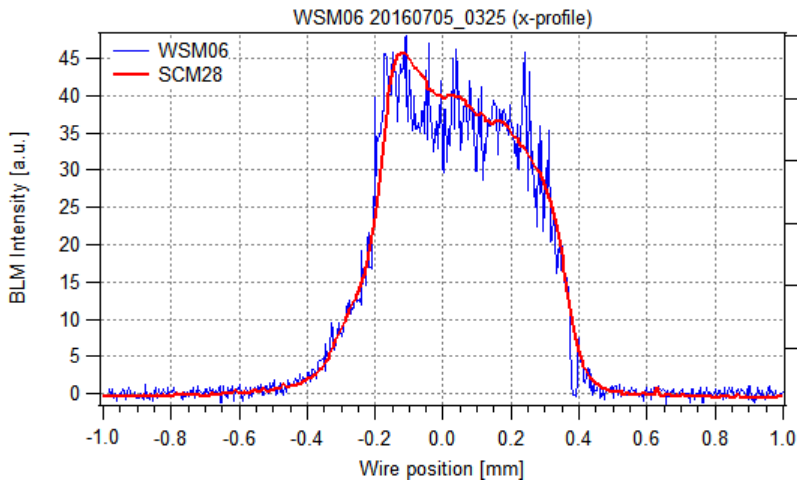
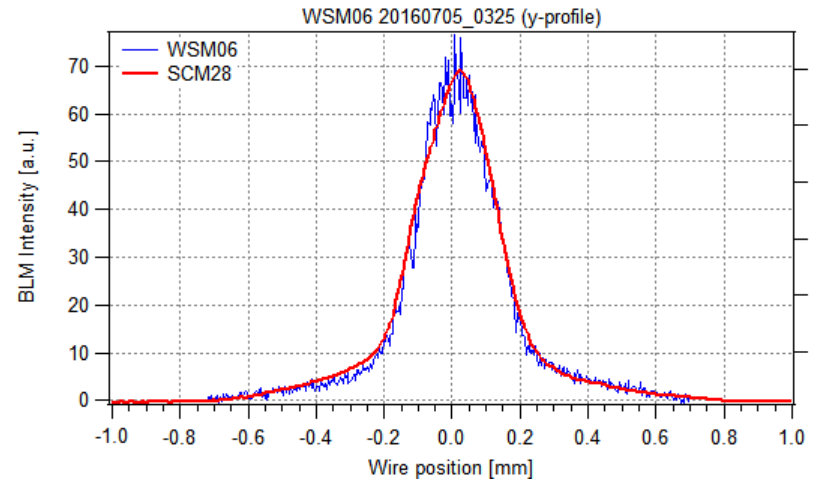
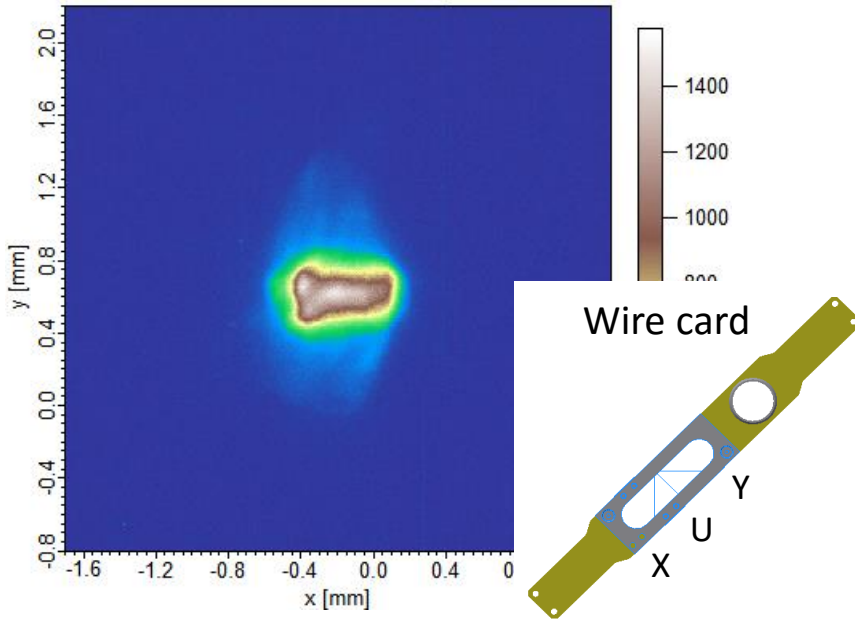
- Tungsten ( $18\ \mu\text{m}$ )
- Carbon ( $34\ \mu\text{m}$ )



Screen Monitor  
and Wire Scanner

# Screen & Wire scanner profile

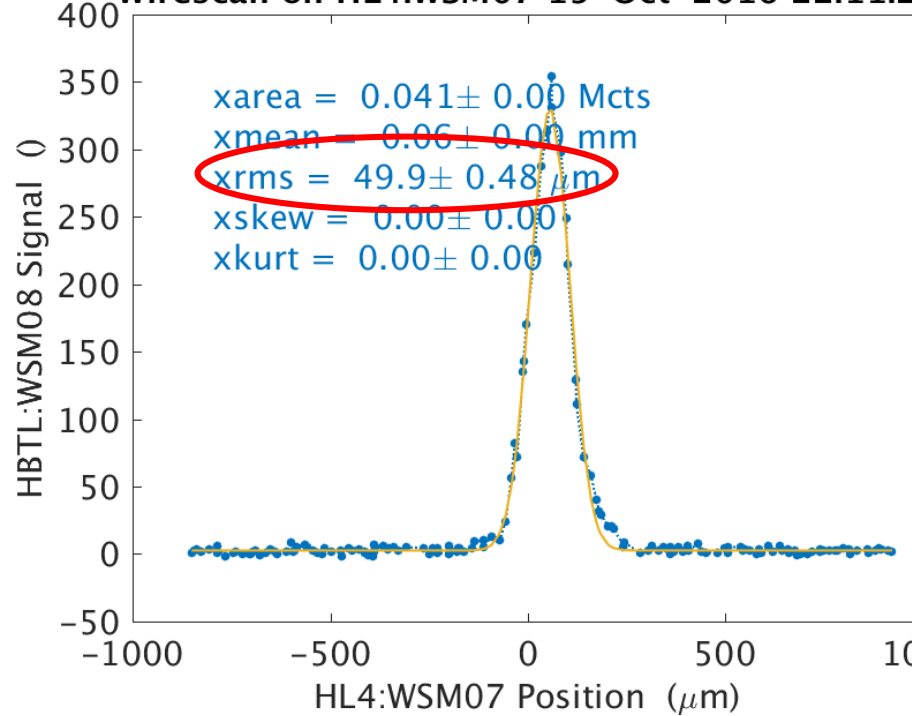
HL4:SCM28 20160701\_0312





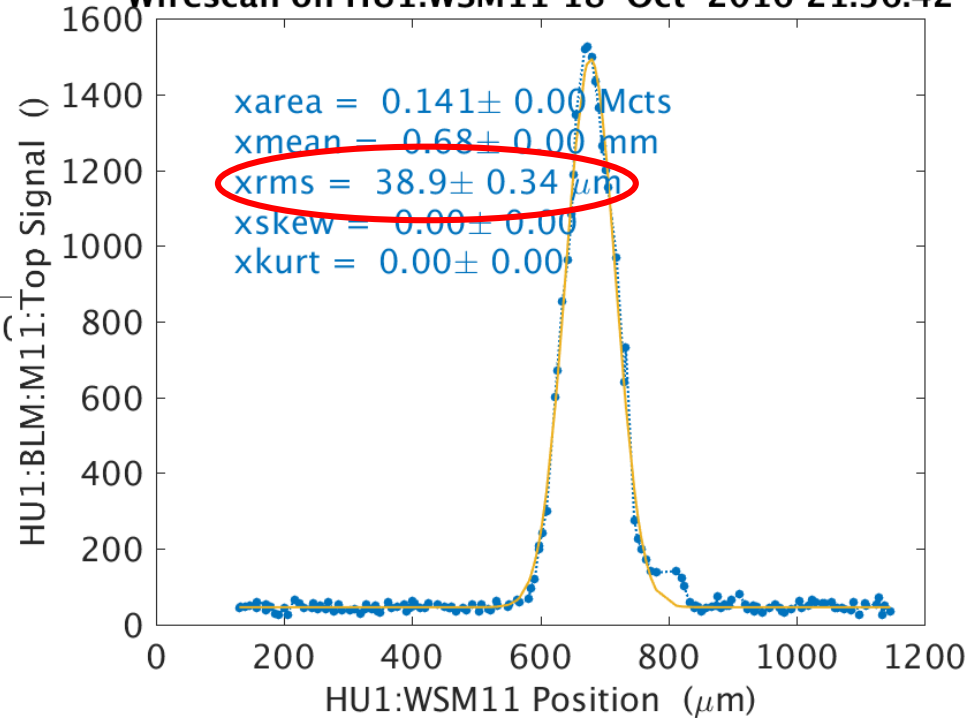
# Beam Size Measurement

Wirescan on HL4:WSM07 15-Oct-2016 22:11:26



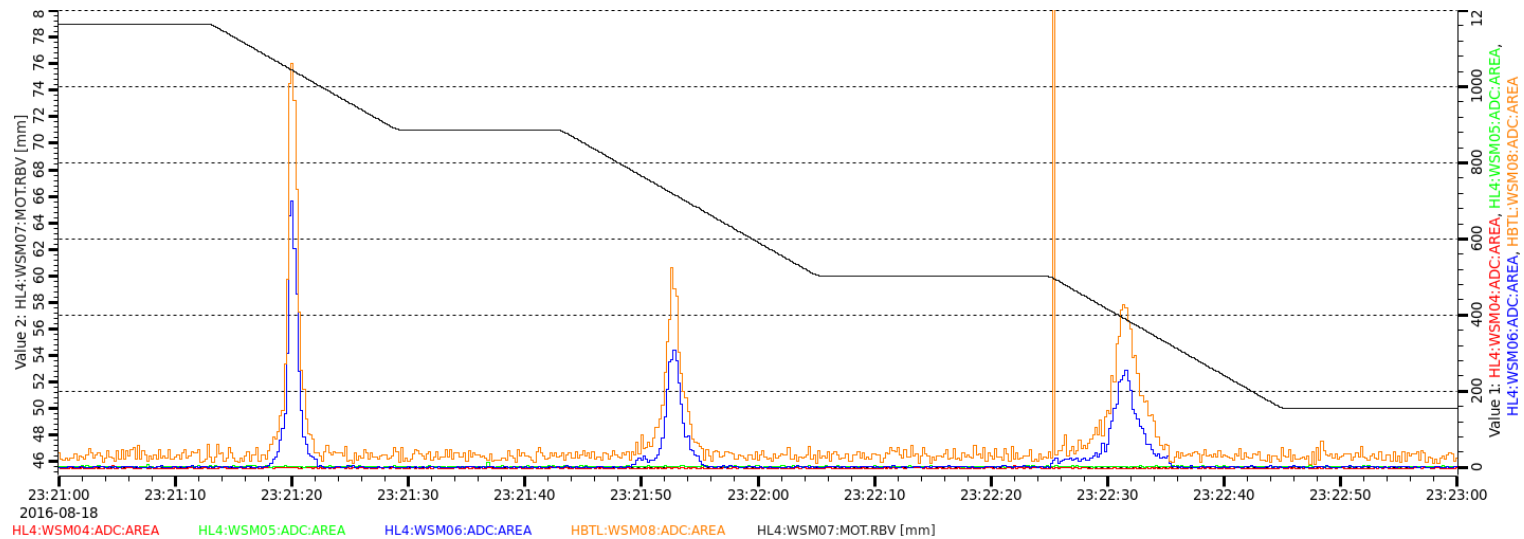
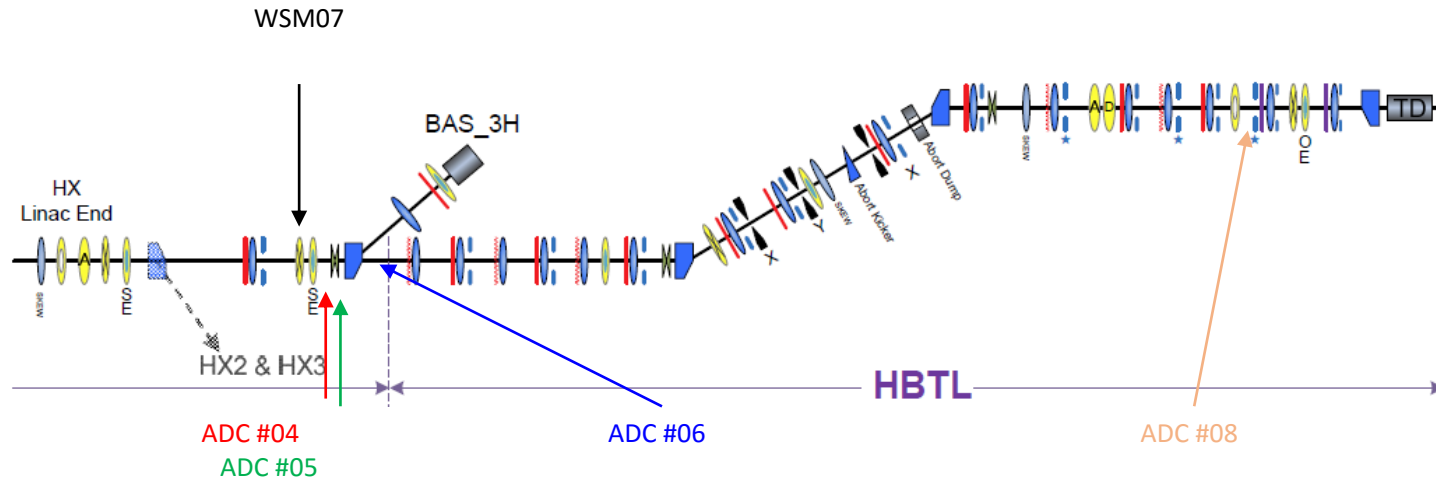
@ Linac End

Wirescan on HU1:WSM11 18-Oct-2016 21:36:42

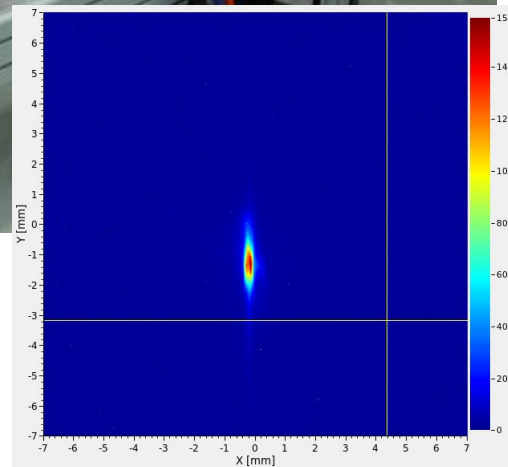
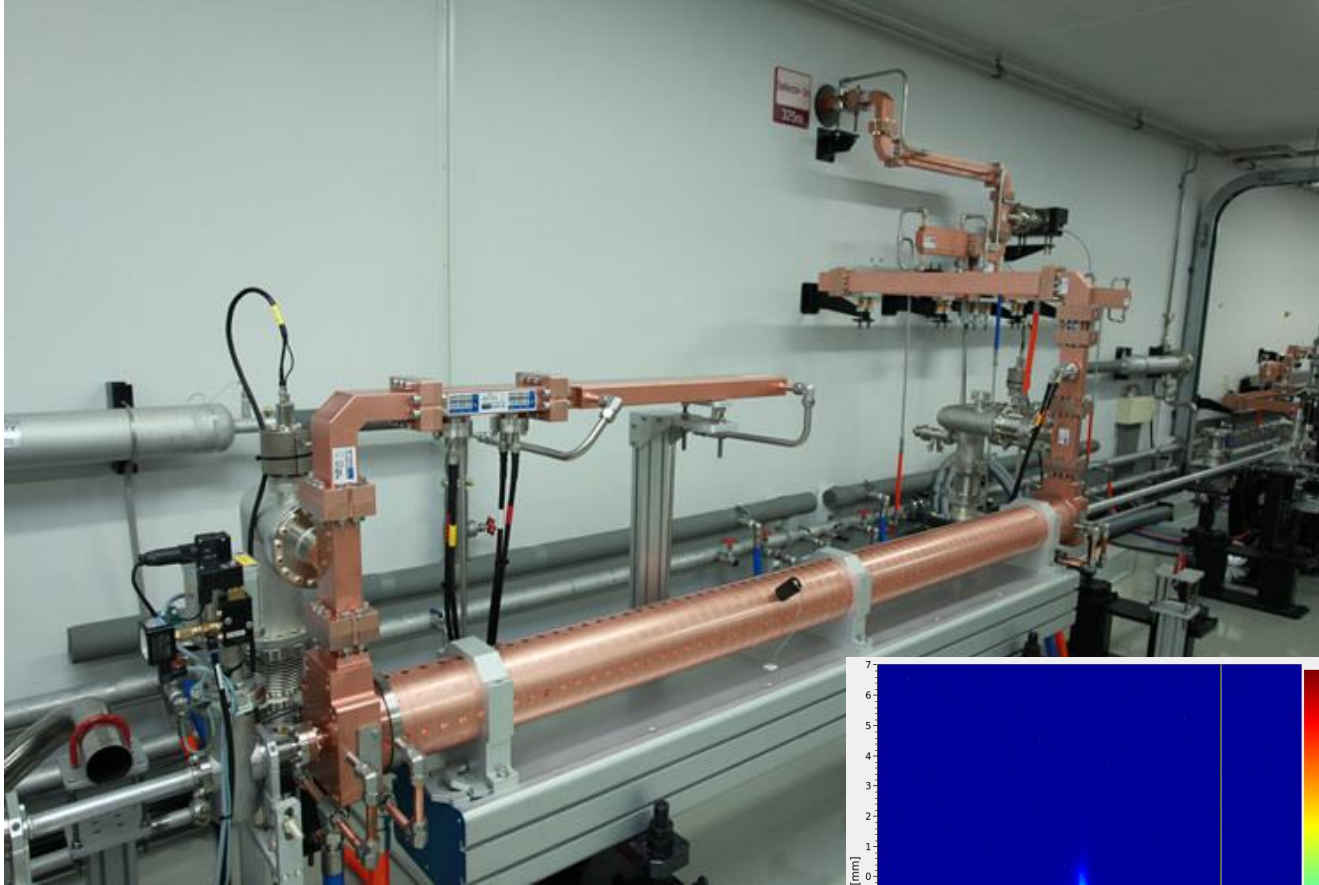


@ Undulator Start

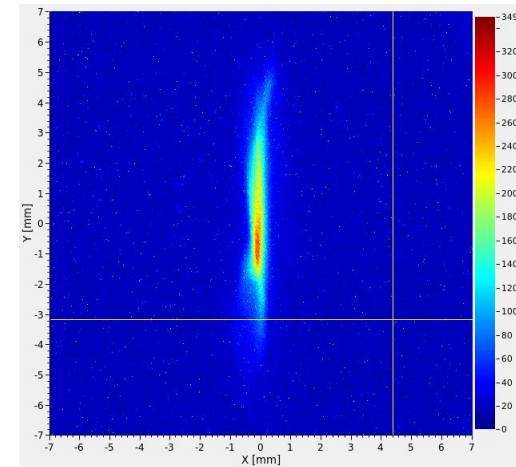
# Wire & Detector Positions



# Transverse Deflecting Cavity



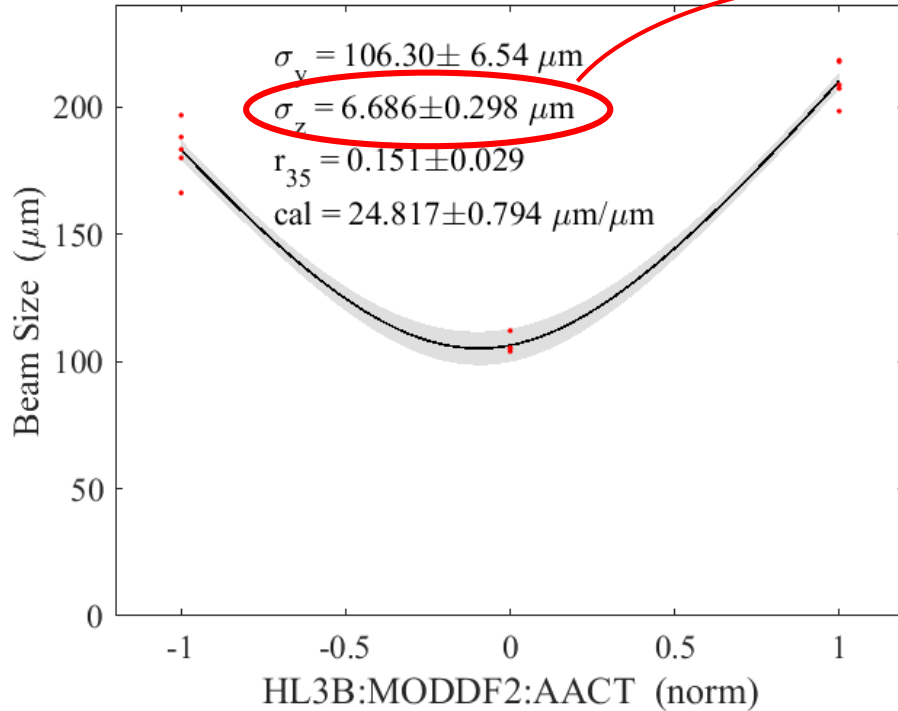
Deflector Off



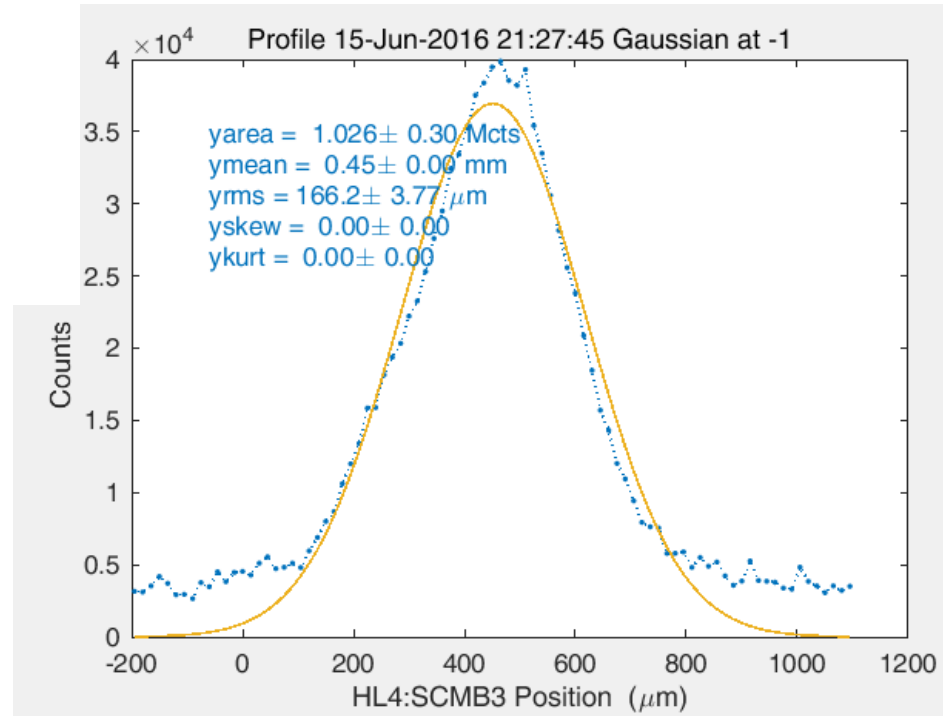
Deflector On

# Bunch Length Measurement

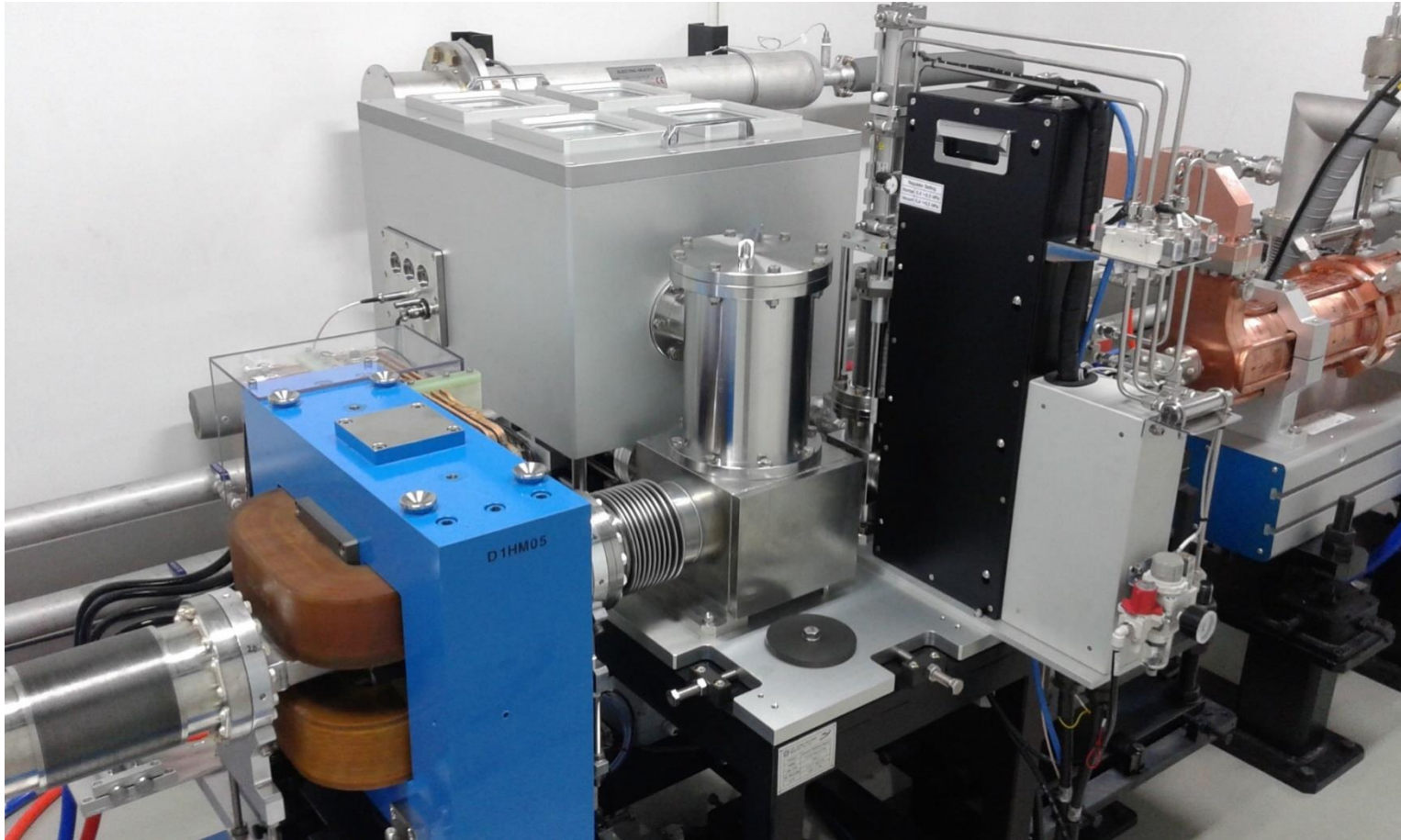
TCAV bunch length on HL4:SCMB3 15-Jun-2016 21:27:45 Gauss



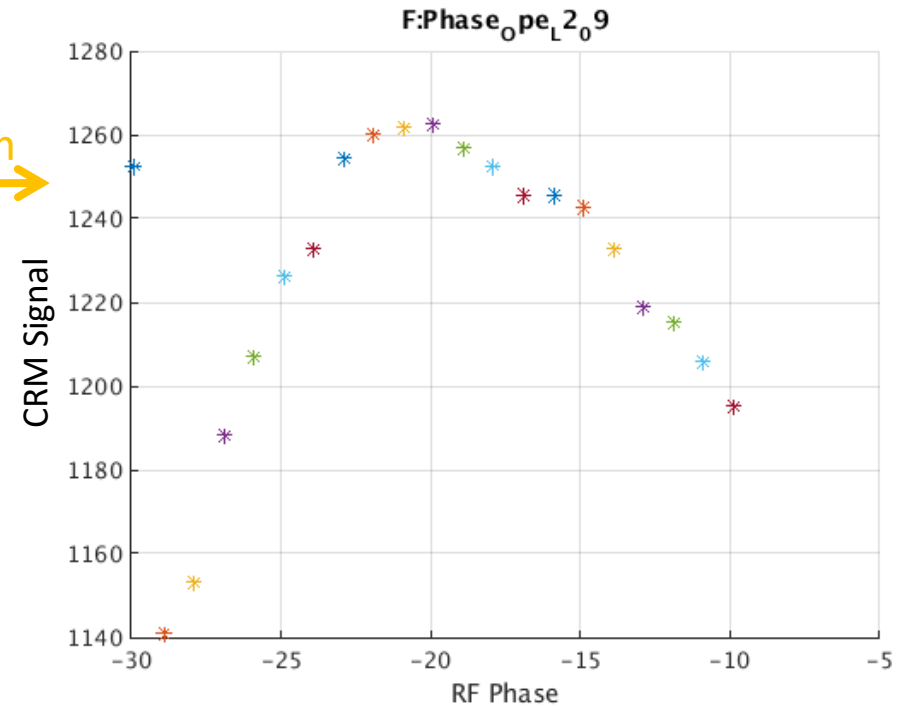
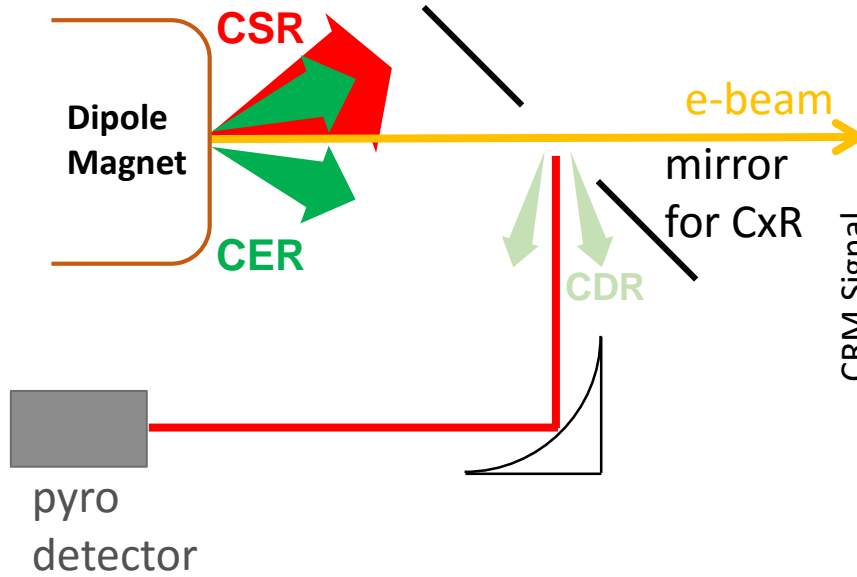
Bunch length  
 $6.7 \mu\text{m} = 22 \text{ fs}$   
 $(170 \text{ pC} \rightarrow 3.07 \text{ kA})$



# Coherent Radiation Monitor



# Coherent Radiation Monitor

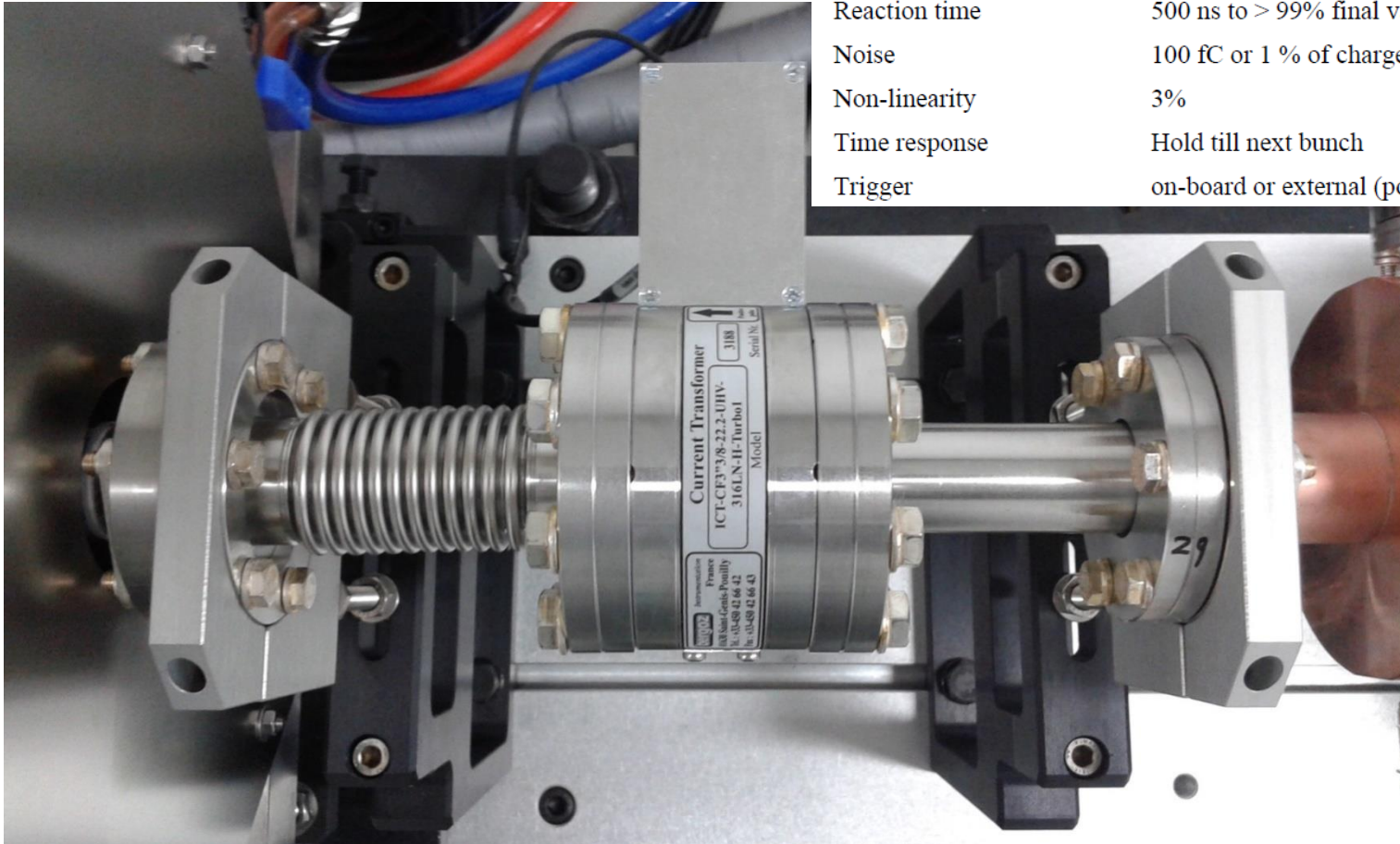


- Measurement of coherent radiation intensity
- Located after bunch compressors
- Calibration with the transverse deflecting cavity
- Bunch length monitor & feedback

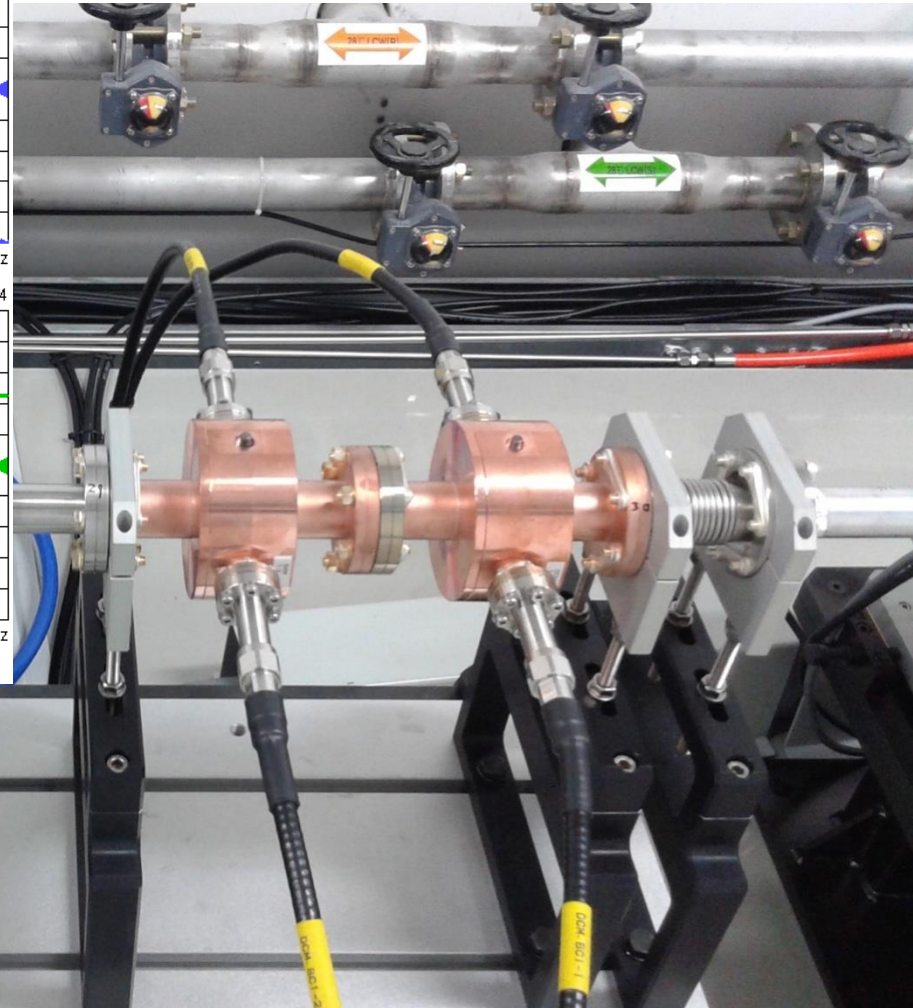
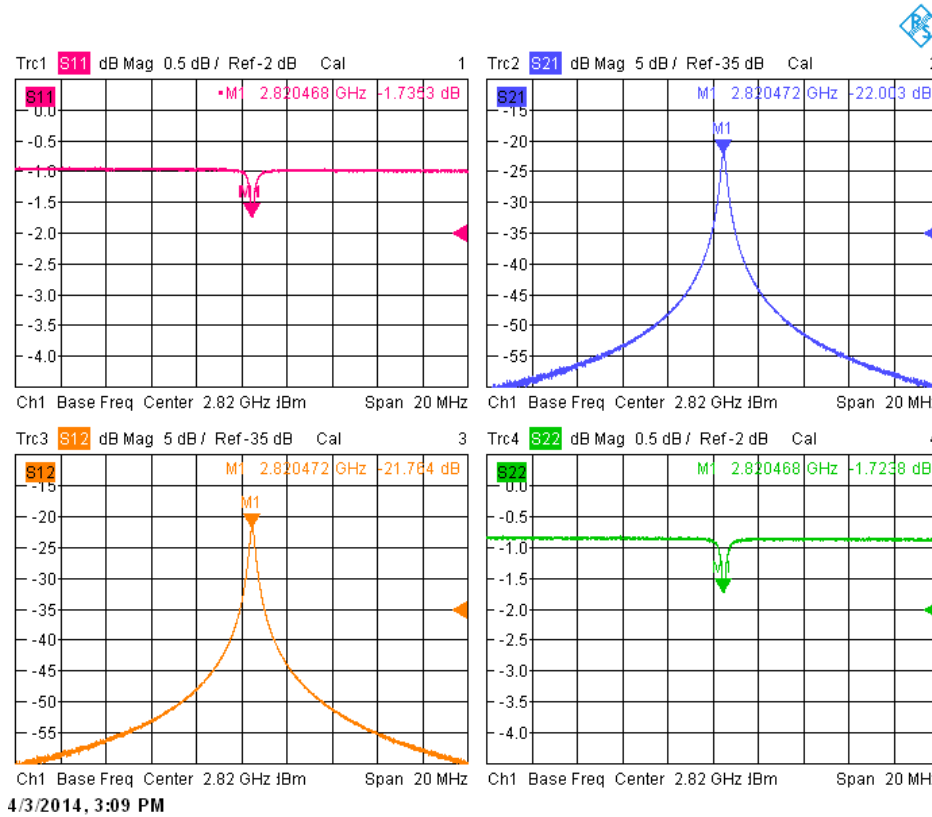
# Turbo-ICT

## Charge measurement:

BCM-RF mode	S&H
Input charge	200 pC max (more without front-end amplifier)
Measurement single range	100 fC – 200 pC
Bunch repetition rate	Single bunch – 2 MHz
Output voltage	0 / 5V, log of the beam charge
Reaction time	500 ns to > 99% final value
Noise	100 fC or 1 % of charge
Non-linearity	3%
Time response	Hold till next bunch
Trigger	on-board or external (pos. edge, > 2.4V, > 30 ns width)



# Beam Arrival Monitor Pickup

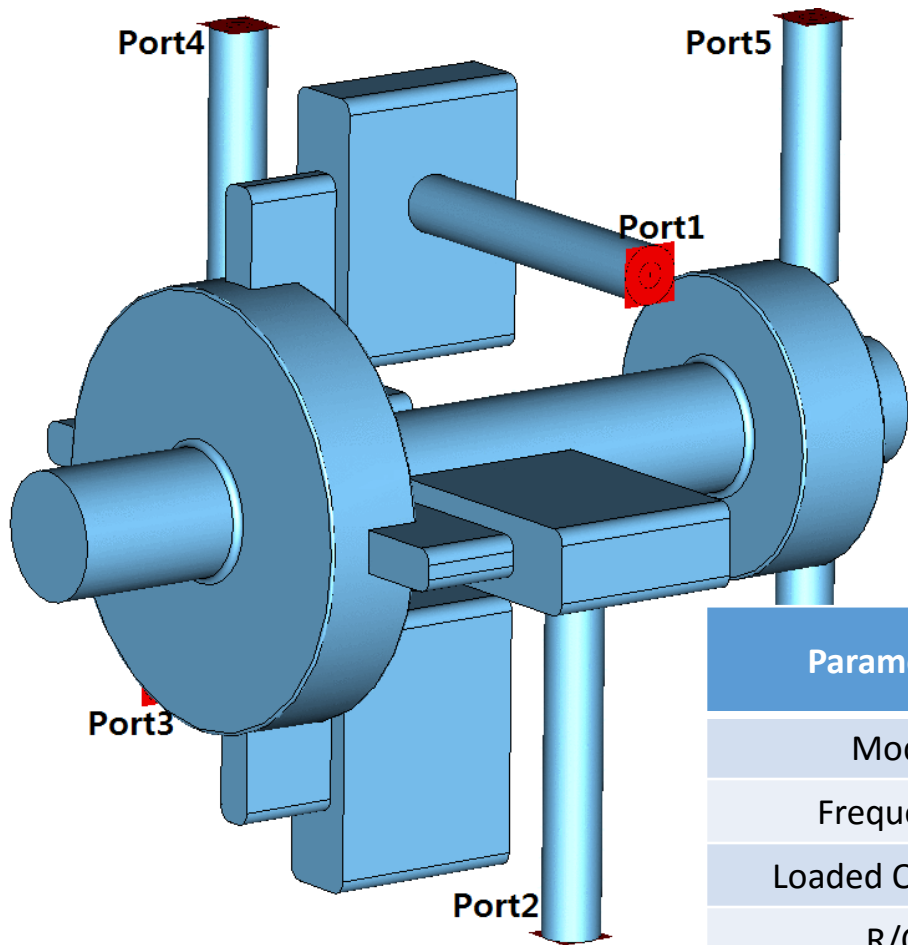


Parameter	Value	Unit
Operating Frequency	2,823	MHz
Coupling Coefficient	0.1	
Quality Factor	10,000	

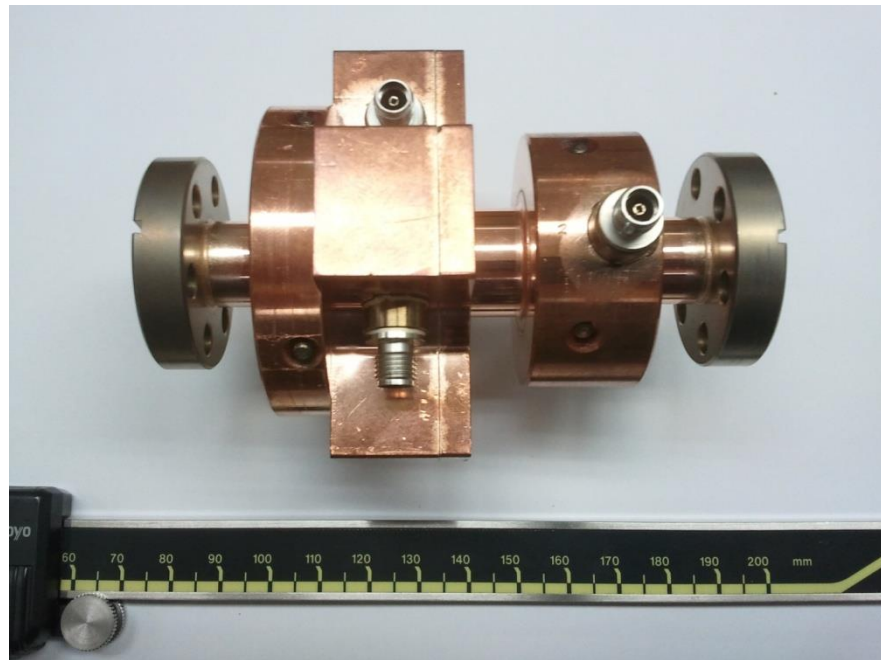


# Undulator Diagnostics

# X-Band Cavity BPM

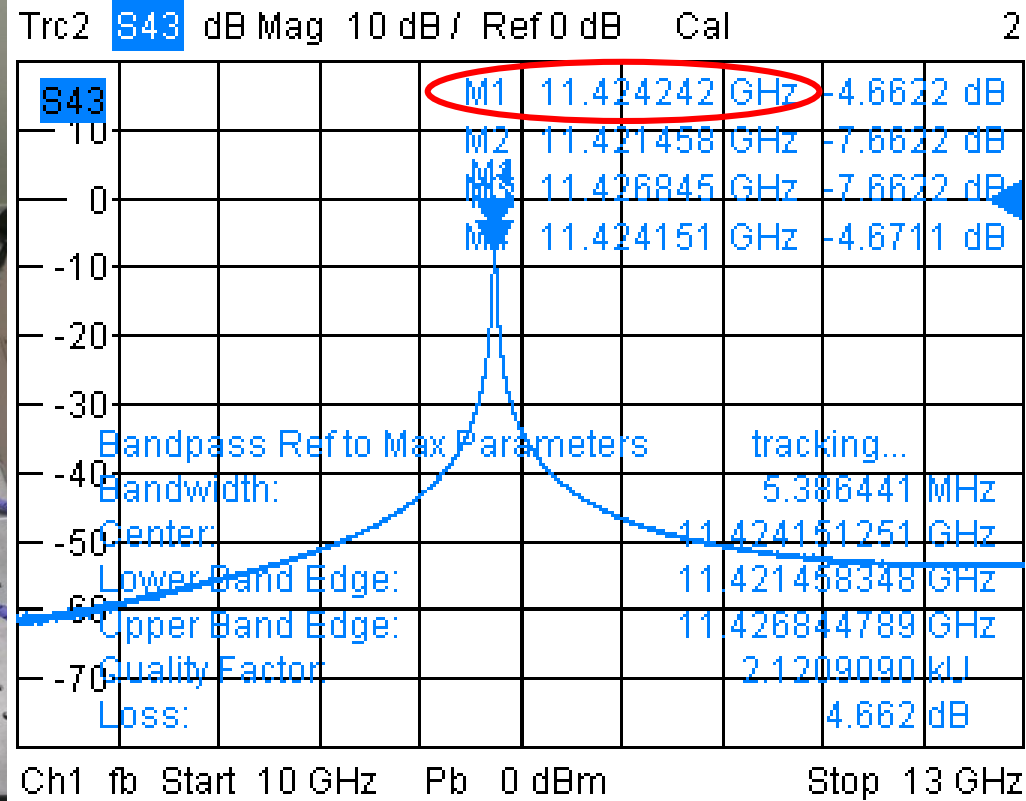
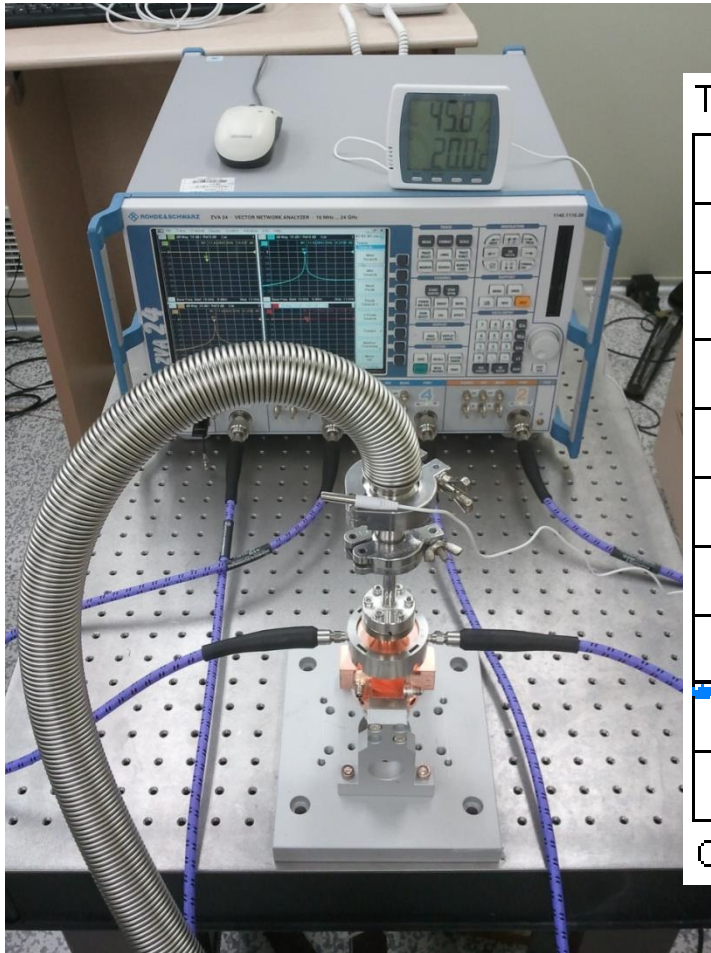


CST Simulation



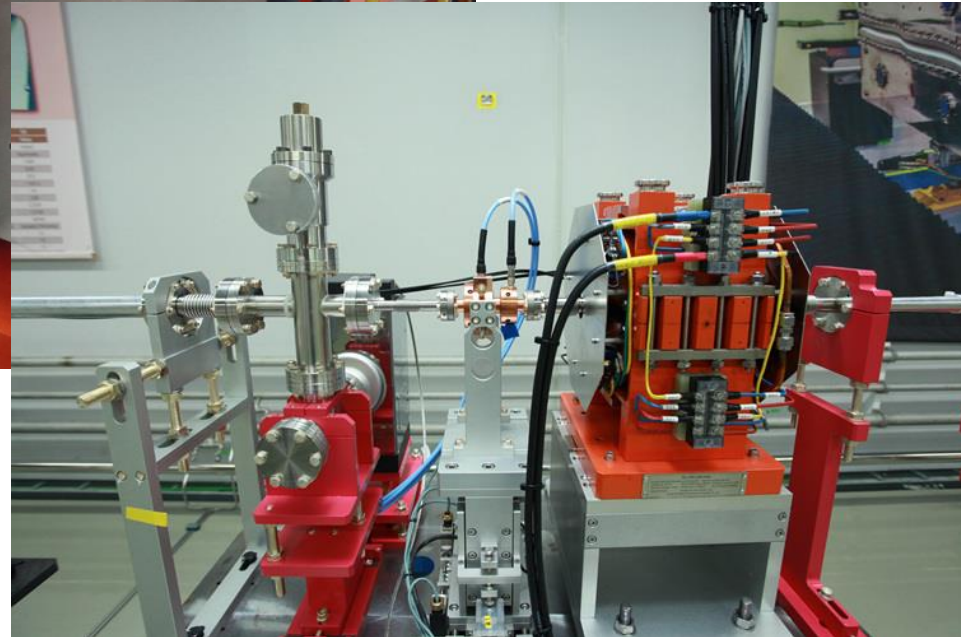
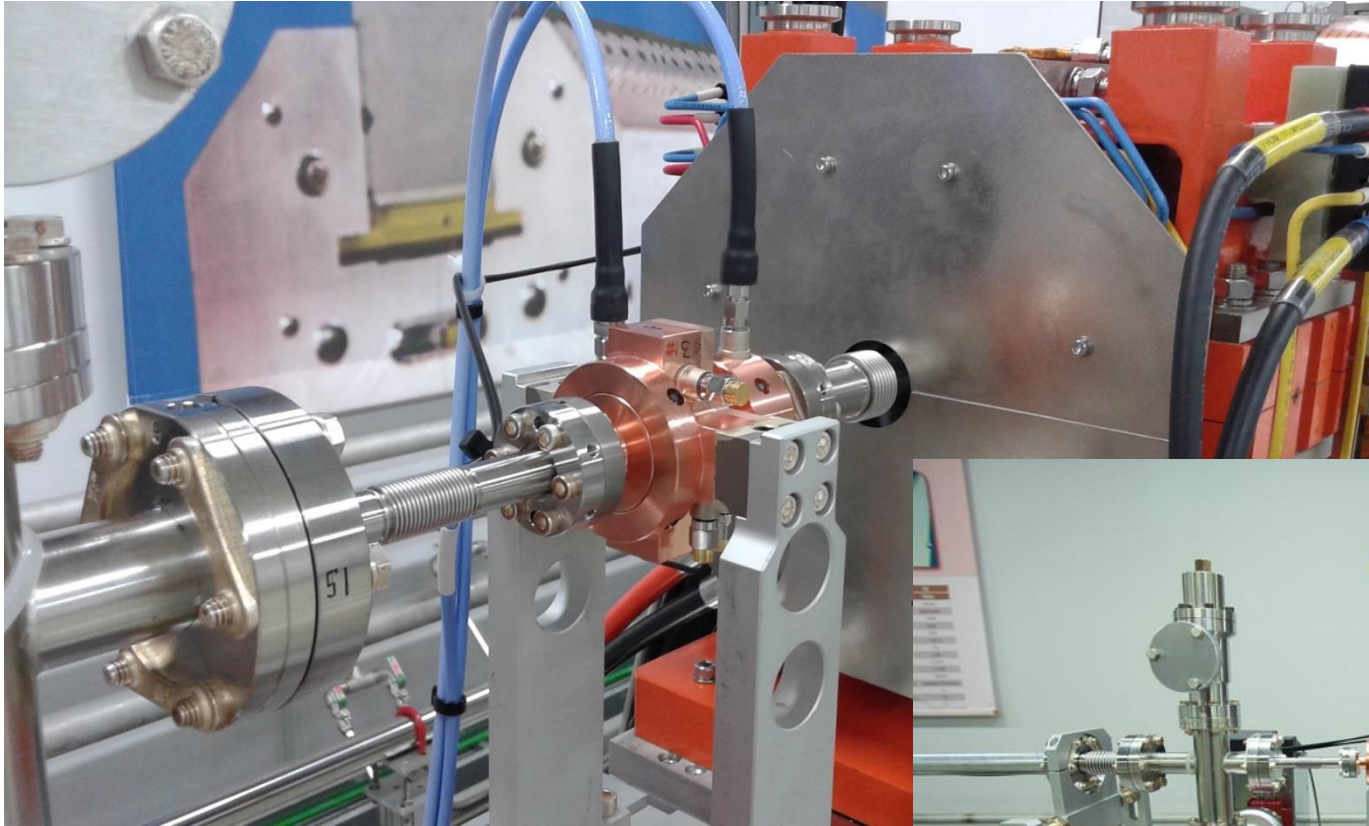
Parameters	XY Cavity (Dipole Cavity)	Reference Cavity (Monopole Cavity)
Mode	TM <sub>110</sub>	TM <sub>010</sub>
Frequency	11.424 GHz	11.424 GHz
Loaded Q Factor	2000 – 3000	2000 – 3000
R/Q	> 2 Ohms/mm	> 12 Ohms
Induced Voltage	> 5 mV/pC·mm	> 20 mV/pC
X/Y Cross Talk Level	< -20 dB	-

# Cavity BPM Tuning



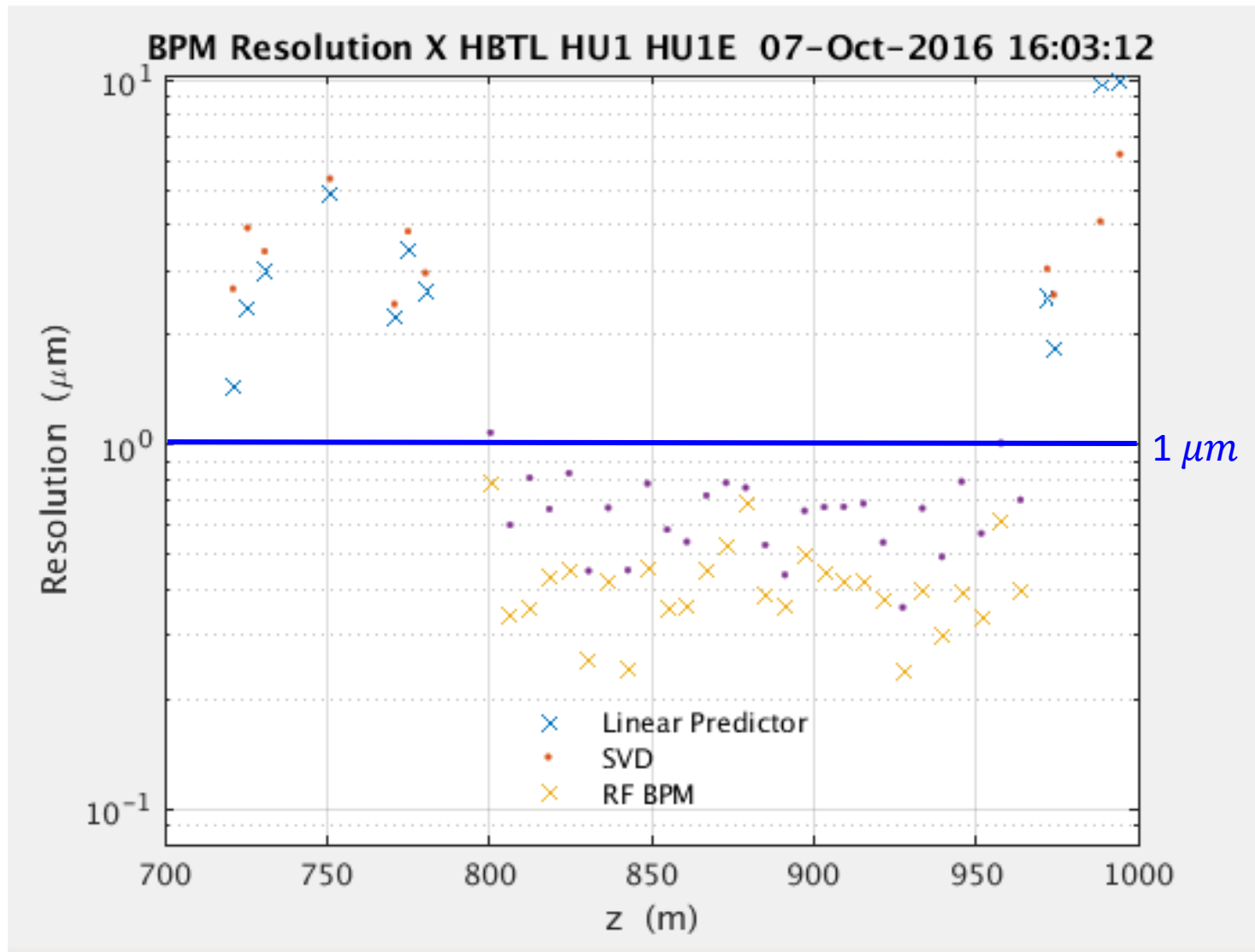
Cavity BPM Tuning

# Installed Cavity BPM

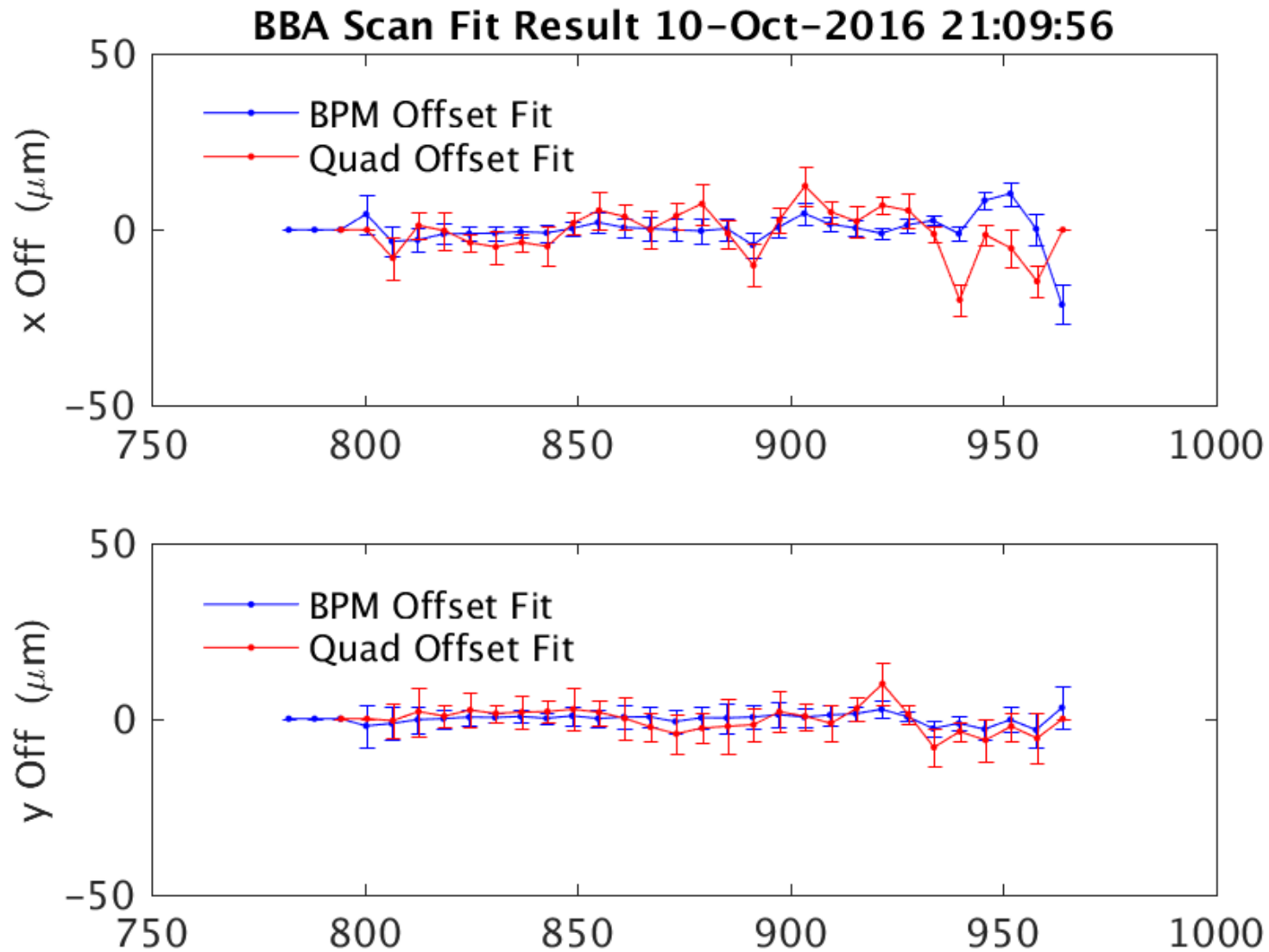


XY translators for all cavity BPMs

# Cavity BPM Resolution



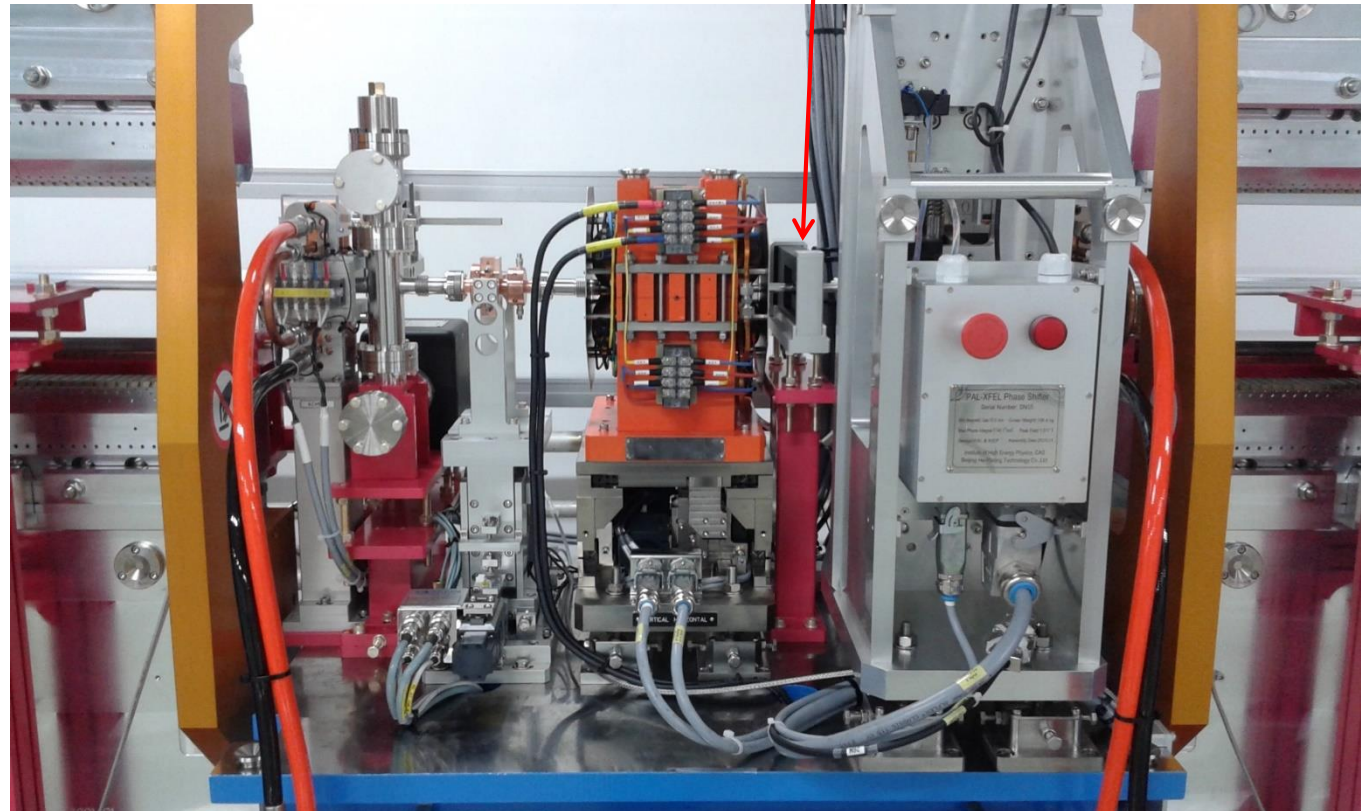
# Undulator BBA Result



# Beam Loss Monitor

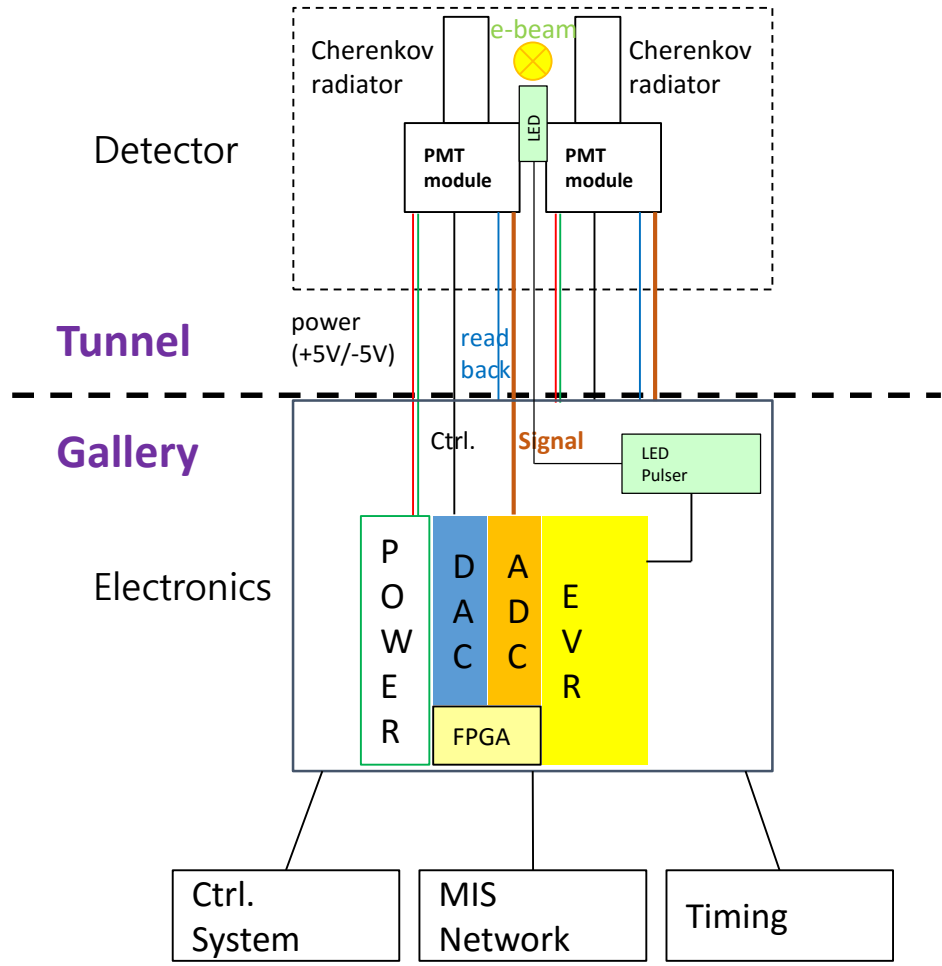
- Cherenkov radiator (acrylic) with Photon Multiplier Tube
- 1 beam loss monitor per 1 undulator
- To protect undulator magnets

Beam Loss Monitor

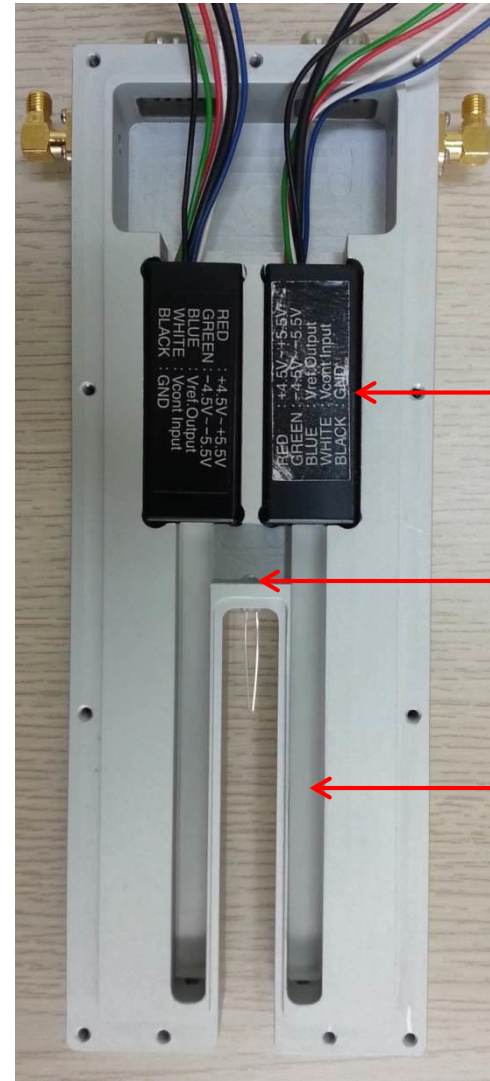


# Beam Loss Monitor

## System Layout



## Detector Head



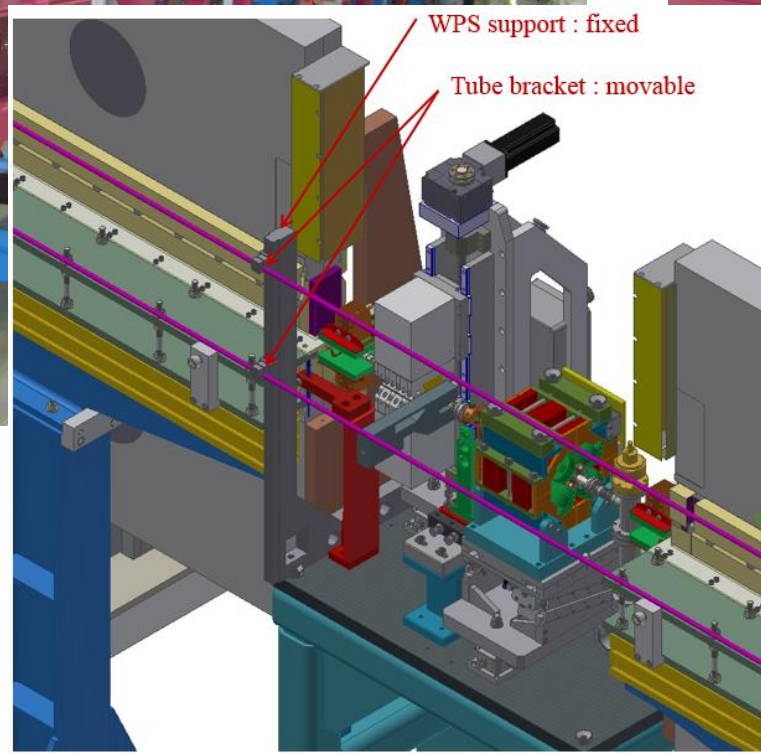
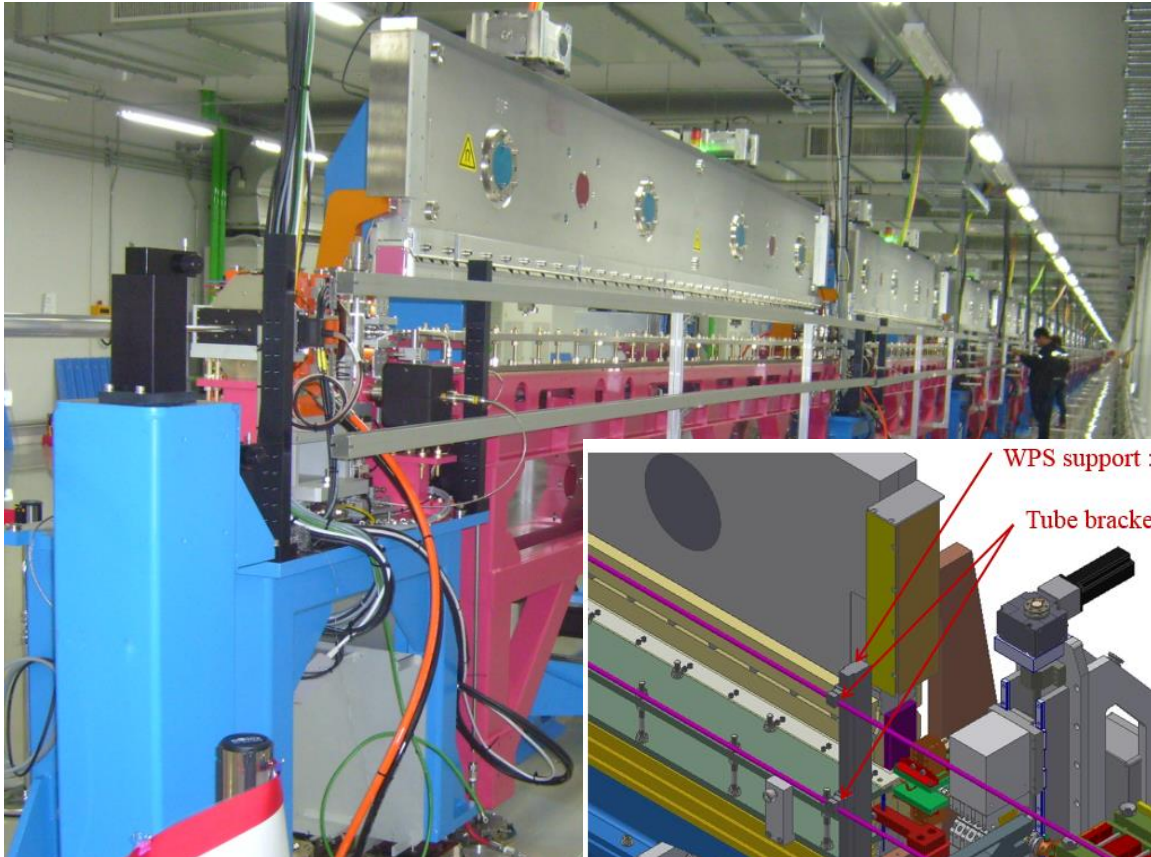
PMT module

LED (for heartbeat)

PMMA rod (for radiator)



# Wire Position Sensor



# Diagnostic Systems for PAL-XFEL

Parameter	Instruments	Number	Resolution
Beam Position & Beam Energy	Stripline BPM	160	< 7 $\mu\text{m}$
	Cavity BPM	49	< 1 $\mu\text{m}$
Beam Charge	Turbo ICT	10	< 1 pC
Beam Size	Screen Monitor	54	< 10 $\mu\text{m}$
	Wire Scanner	9	< 10 $\mu\text{m}$
Bunch Length	Transverse Deflecting Cavity	3	< 20 fs
	Coherent Radiation Monitor	4	-
Beam Arrival Time	Beam Arrival Time Monitor	10	< 30 fs
Beam Loss	Beam Loss Monitor	26	-

**Thank you  
for your attention**