

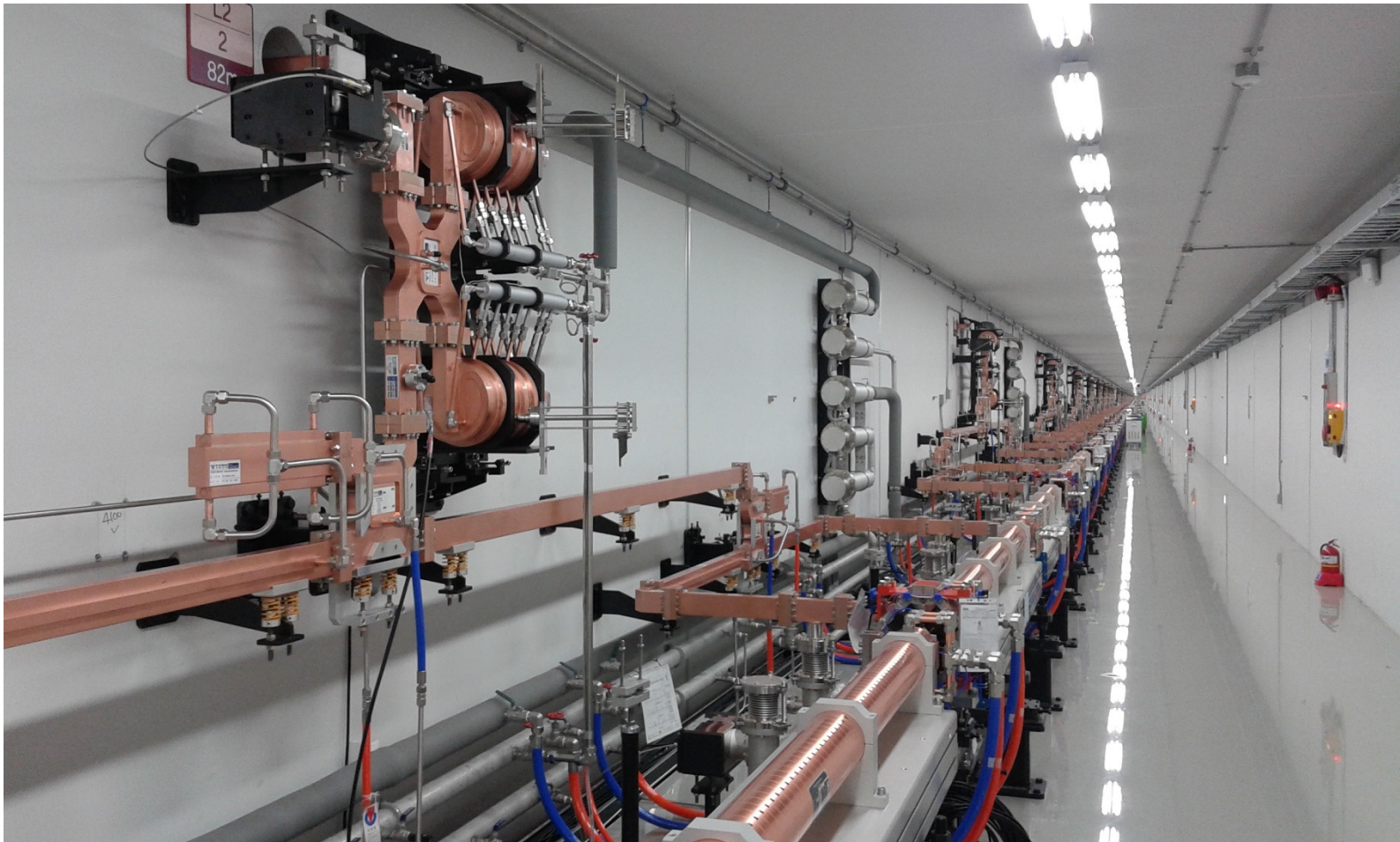
Diagnostic System of PAL-XFEL



2016. 5. 11

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

PAL-XFEL Linac

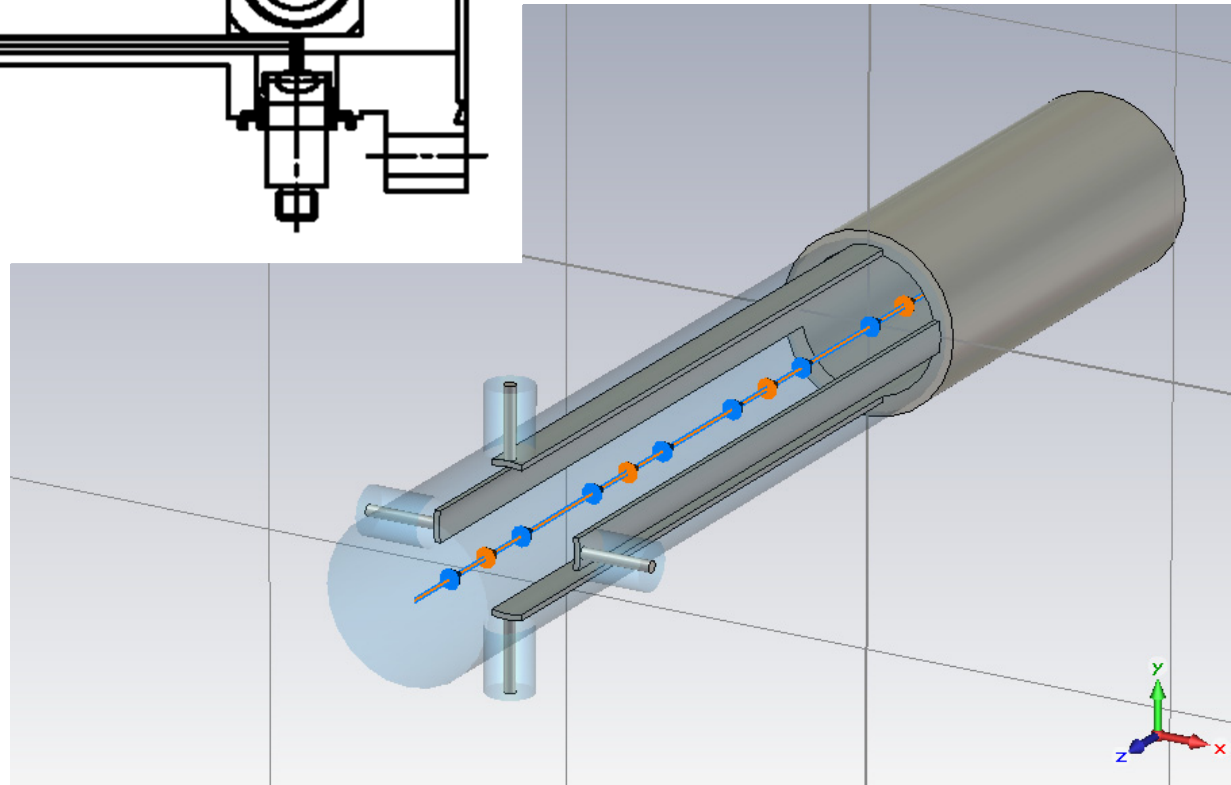
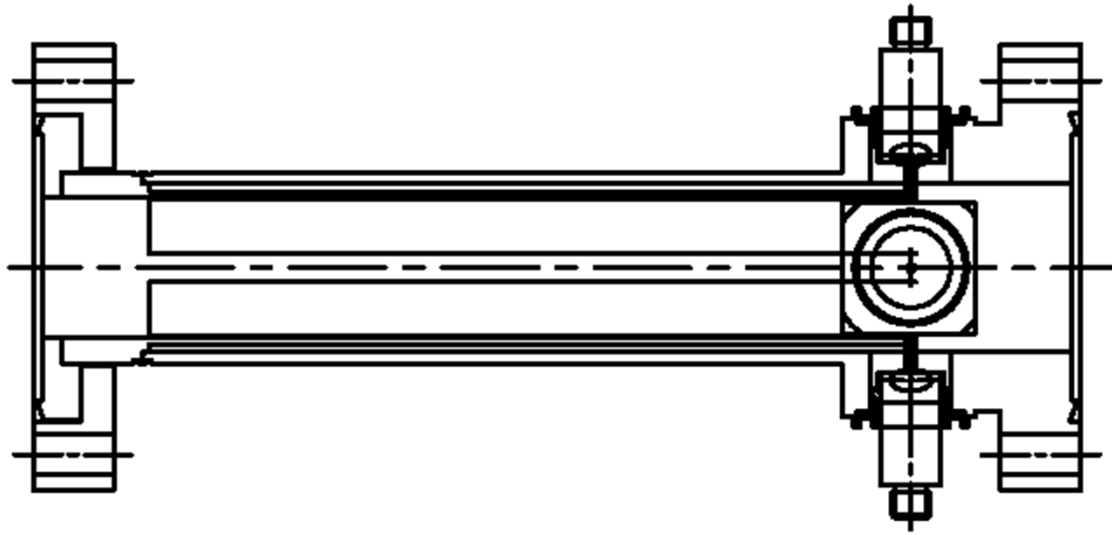


PAL-XFEL Diagnostics

Parameter	Instruments	Number	Resolution
Beam Position & Beam Energy	Stripline BPM	160	< 5 μm
	Cavity BPM	49	< 1 μm
Beam Charge	Turbo ICT	10	< 1 pC
Beam Size	Screen Monitor	54	< 10 μm
	Wire Scanner	9	< 10 μm
Bunch Length	Coherent Radiation Monitor	4	-
	Transverse Deflecting Cavity	3	< 10 fs
Beam Arrival Time	Beam Arrival Time Monitor	10	< 30 fs
Beam Loss	Beam Loss Monitor	26	-

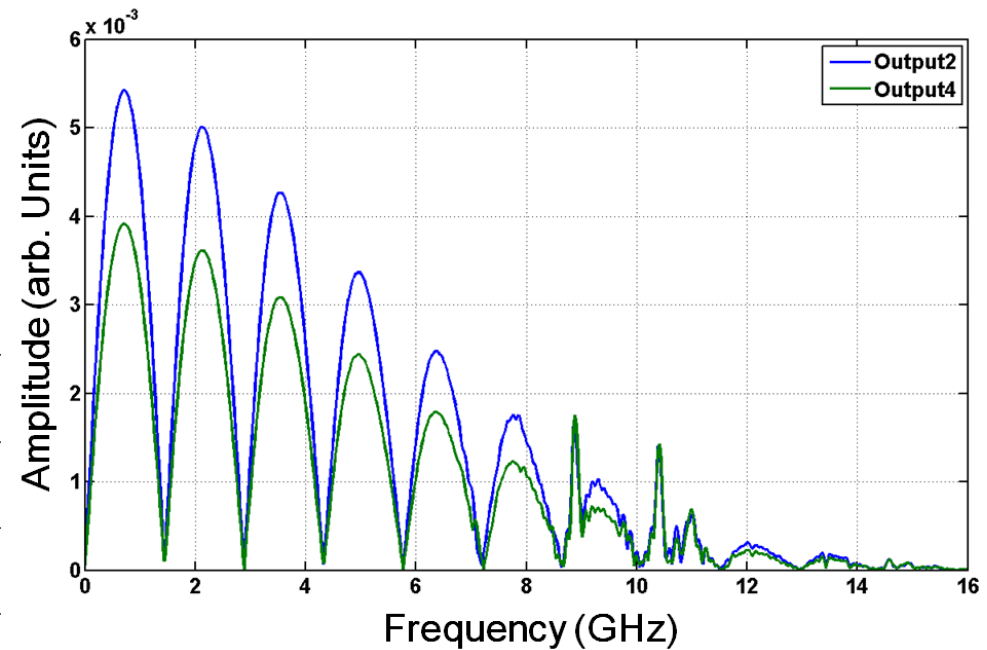
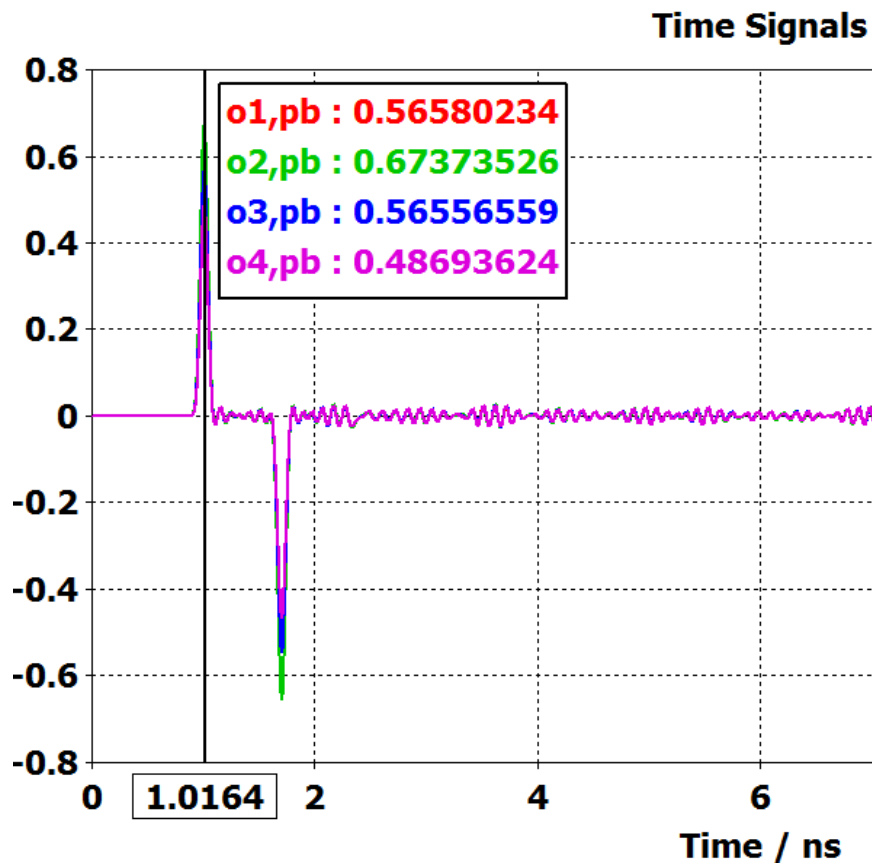
Beam Position Monitor

Stripline BPM Design

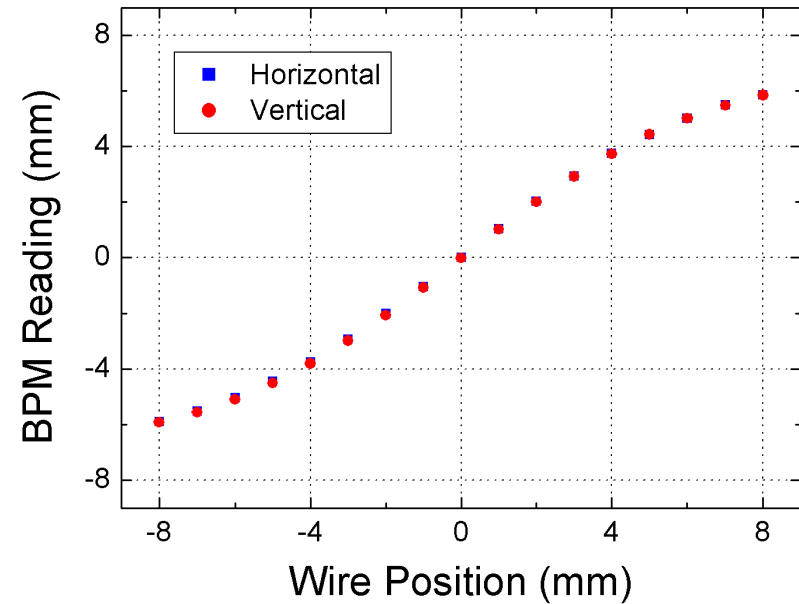


CST Simulation

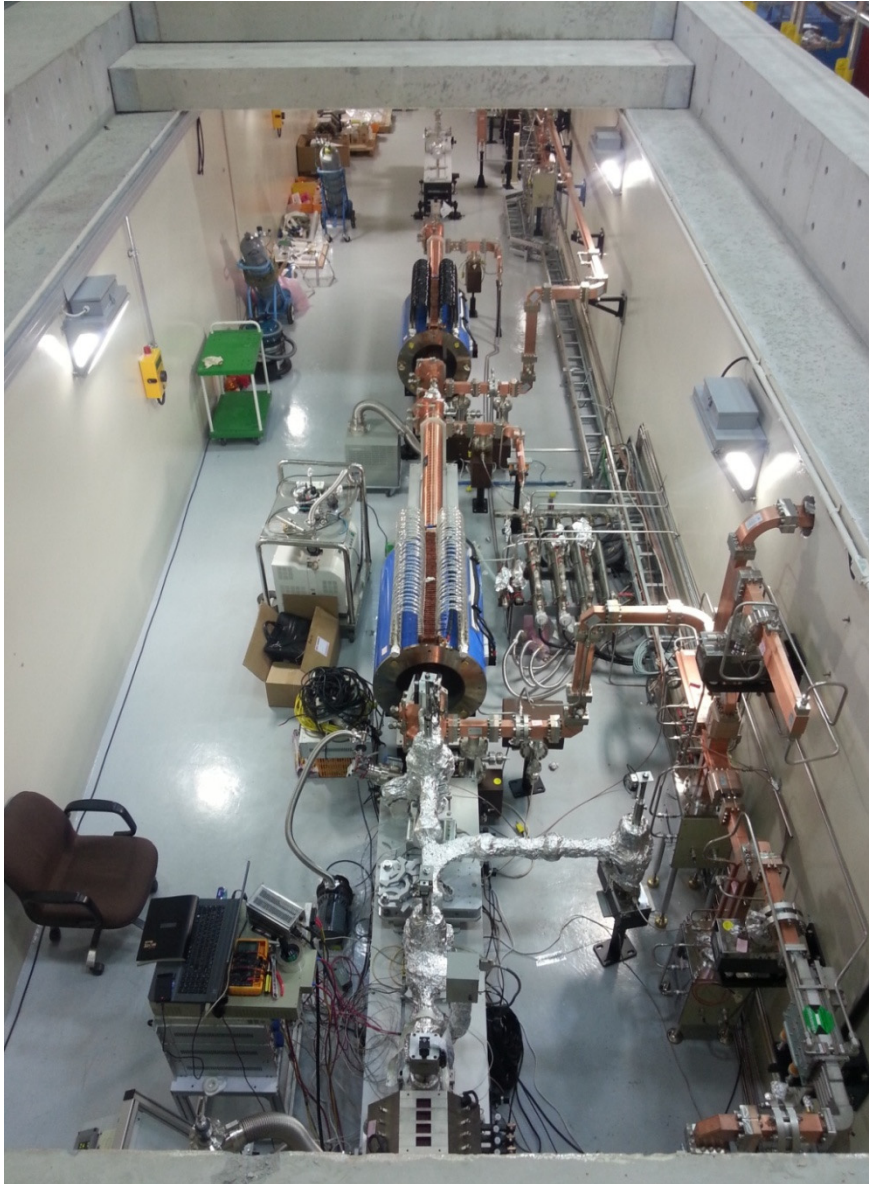
Simulation Results



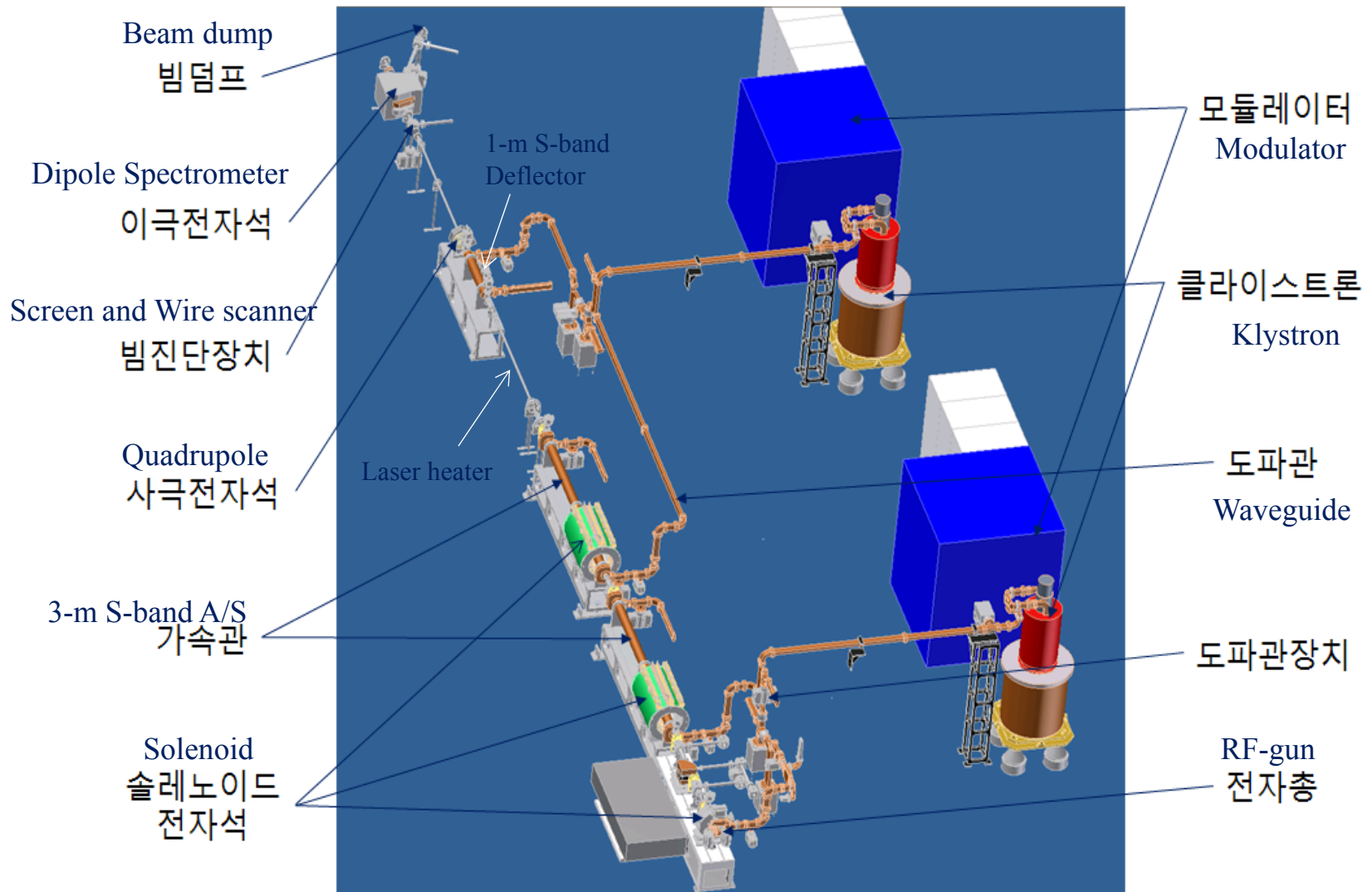
Wire Test Stand



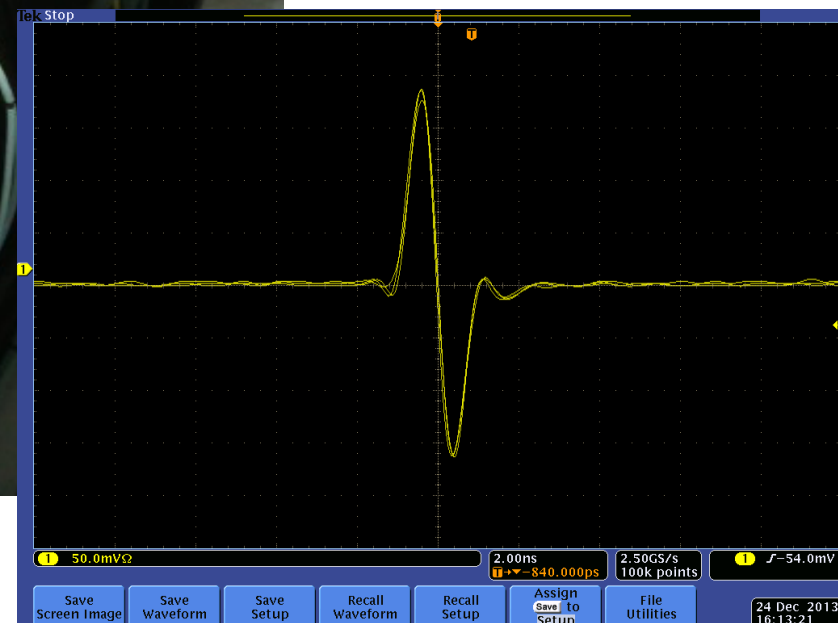
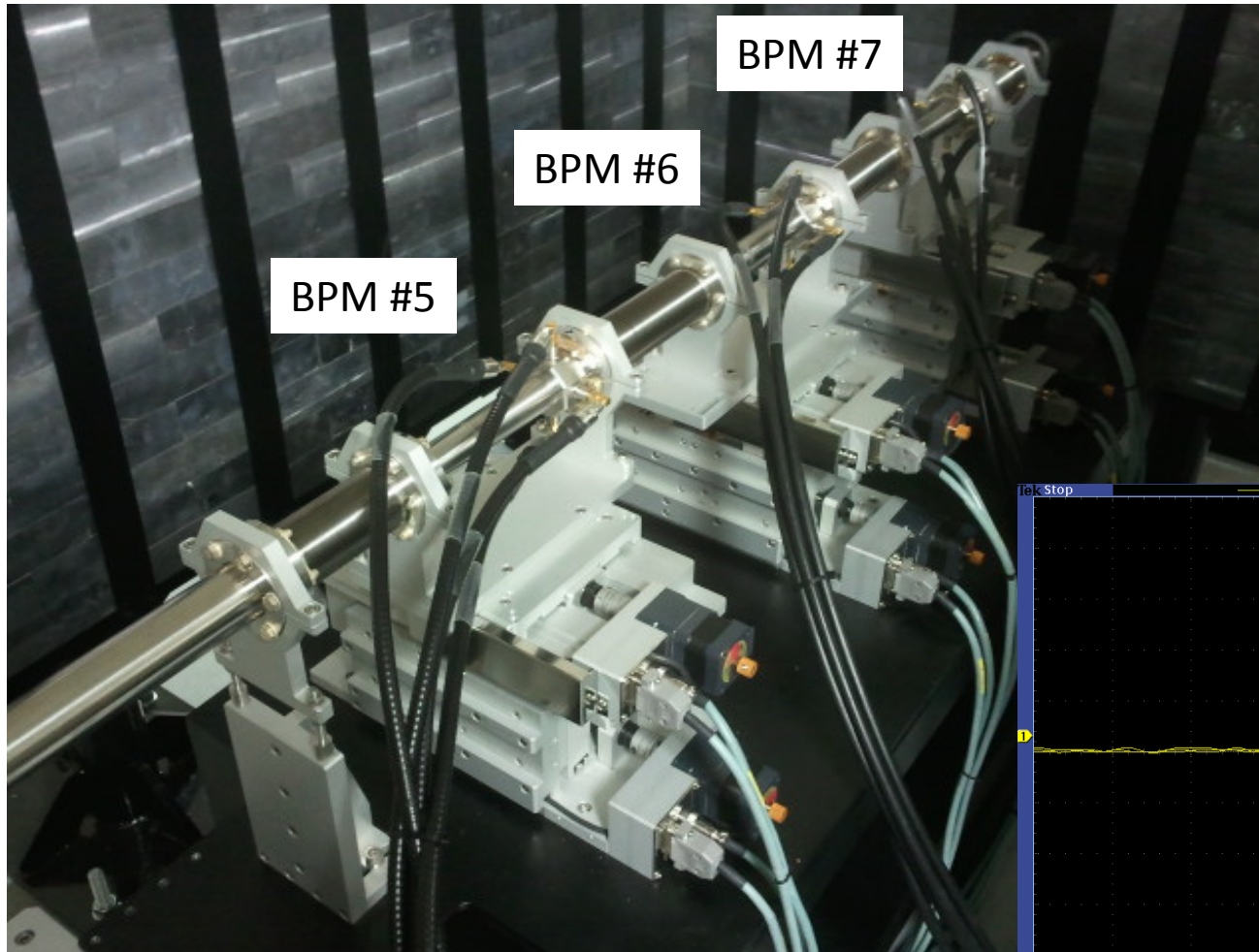
Injector Test Facility (ITF)



ITF Layout



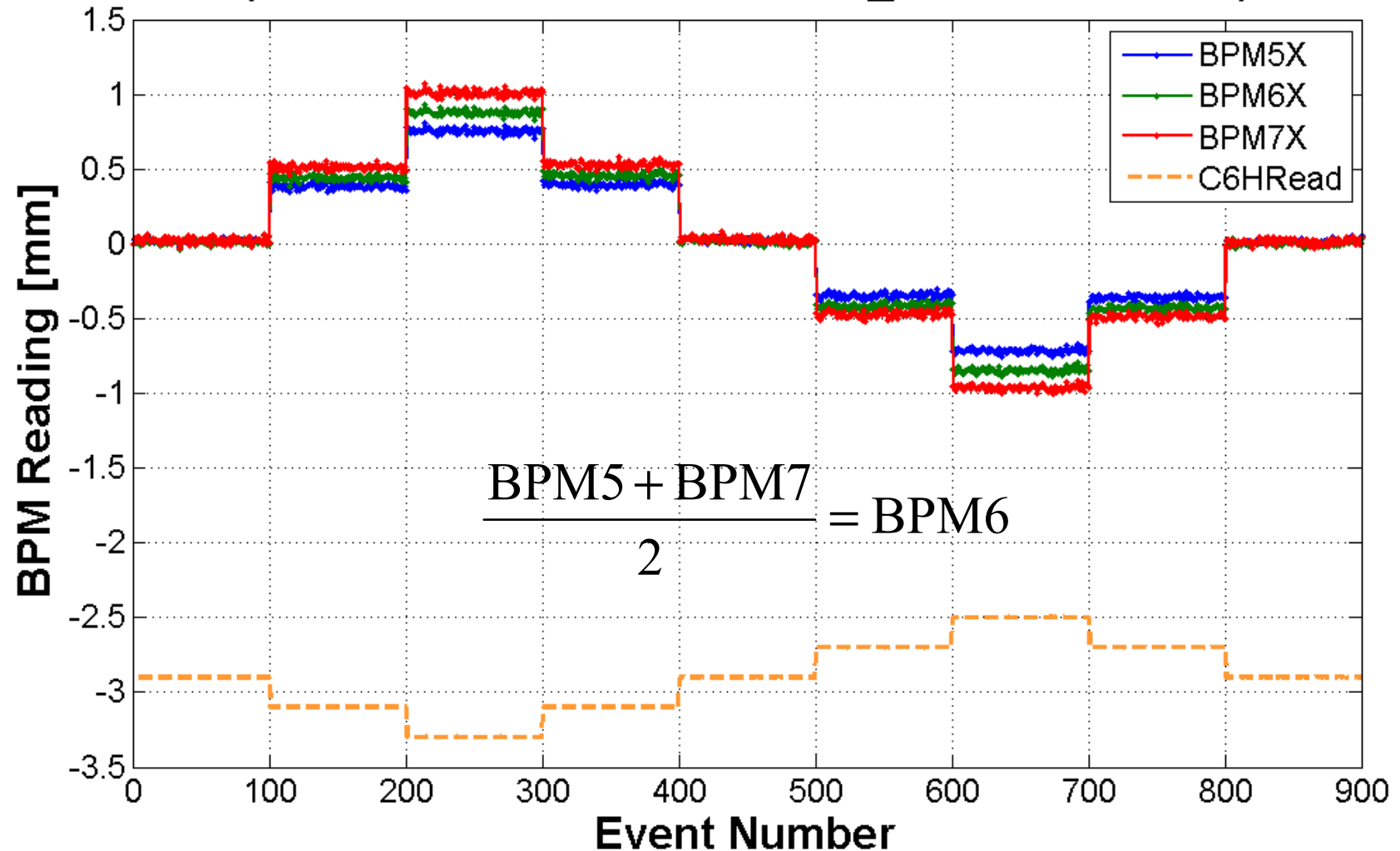
BPM Test Stand in ITF



Stripline BPM Signal

Corrector Current & BPMs

BPM Response To C6HRead
(BPMTestwithCM62013Dec31_181446Data.mat)



BPM Resolution

Libera Units

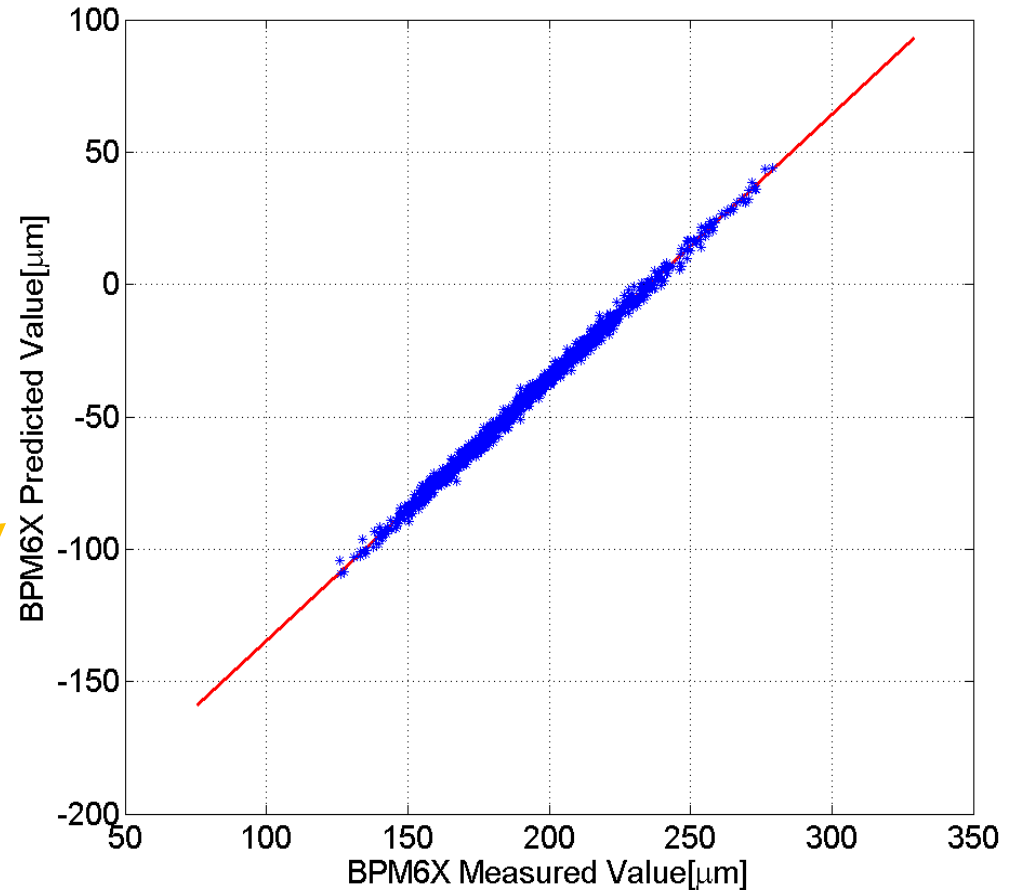
Libera Single Pass E (New unit)

- Sampling frequency 155 MHz
- VIRTEX 5
- Phase alignment feature
- Event receiver (EVRX)
- Measuring resolution ~ 1.2 μm



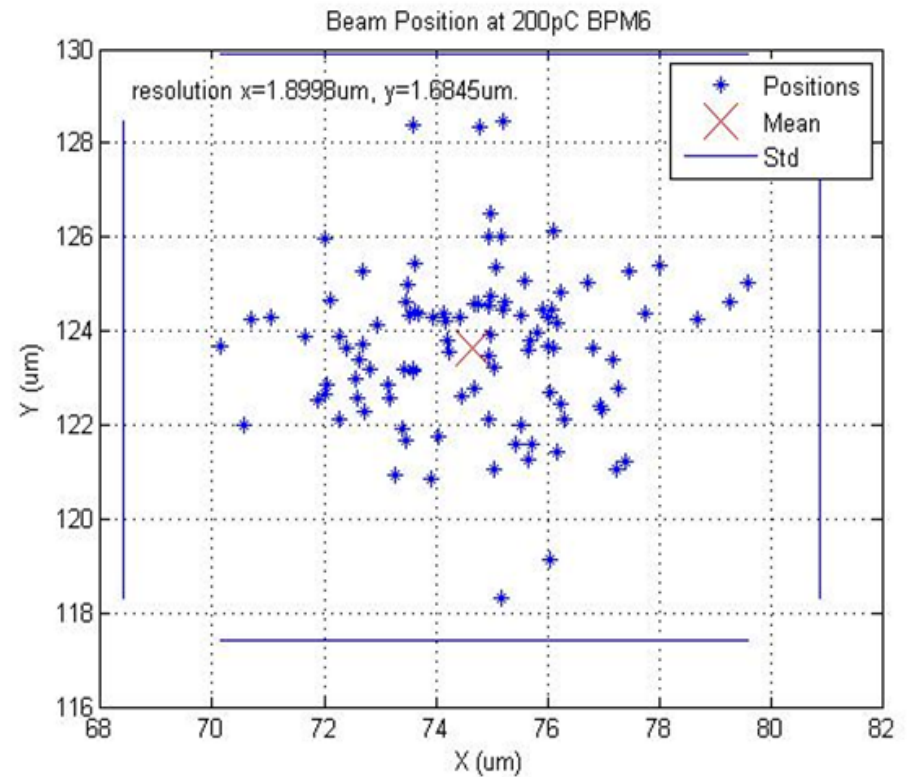
www.i-tech.si

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



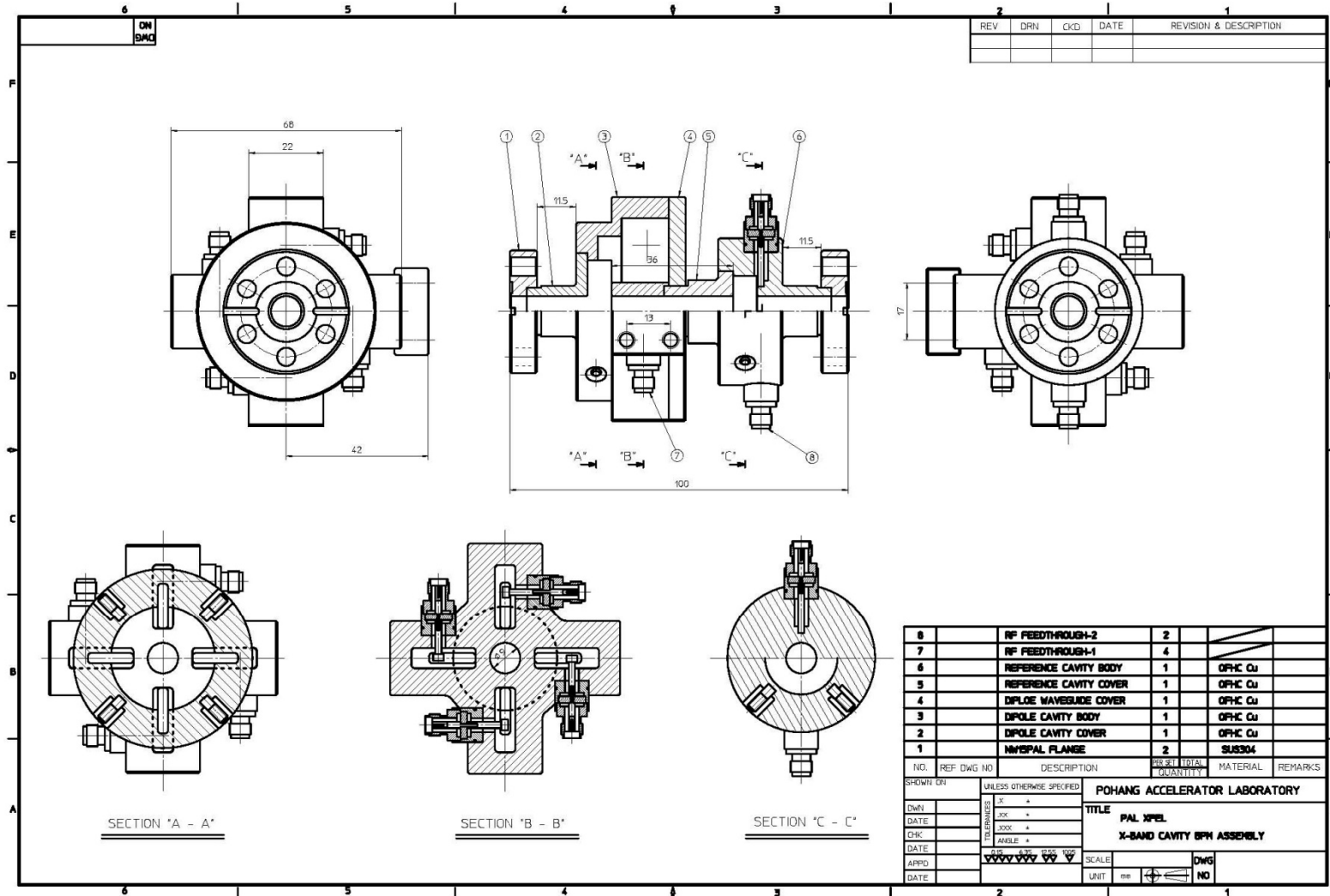
Resolution : 1.5 μm @ 200 pC

uTCA Electronics from SLAC

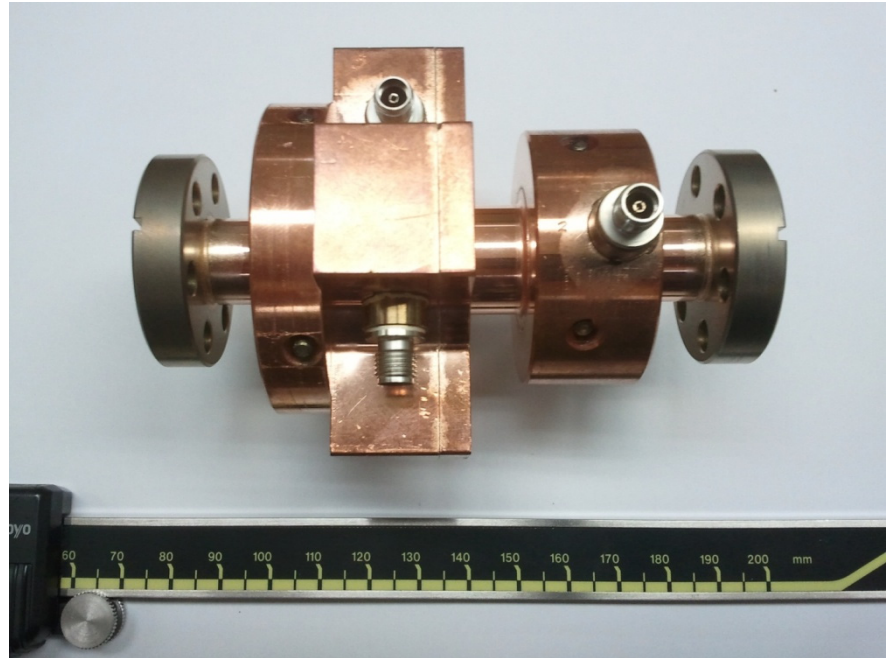
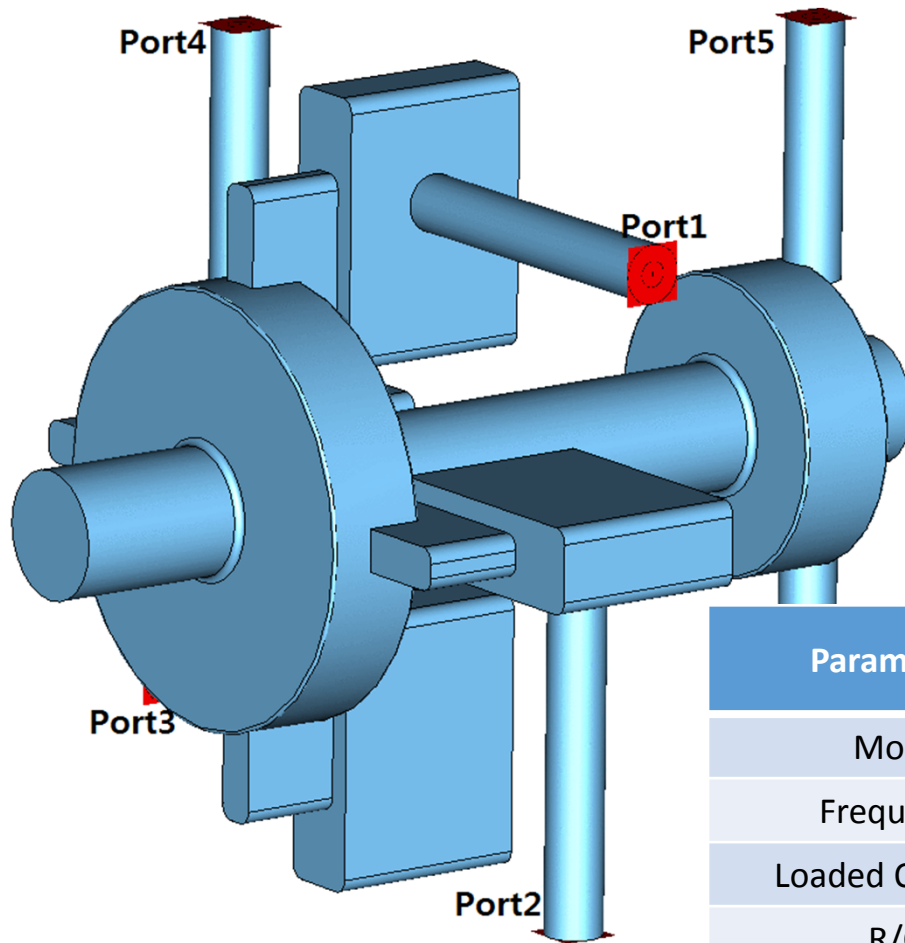


Cavity Beam Position Monitor

Cavity BPM Design

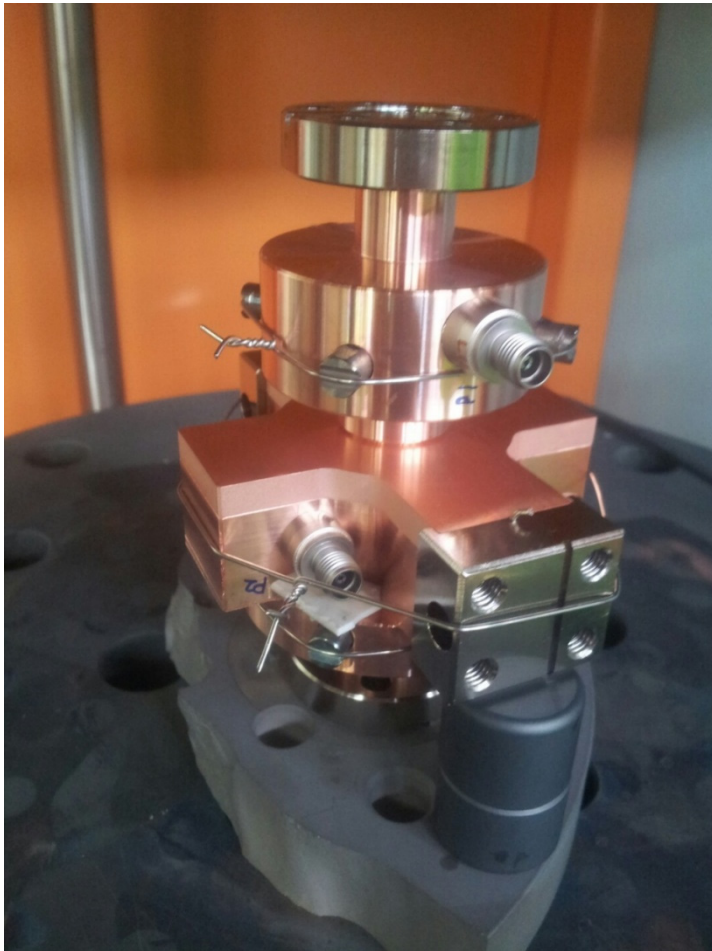


X-Band Cavity BPM

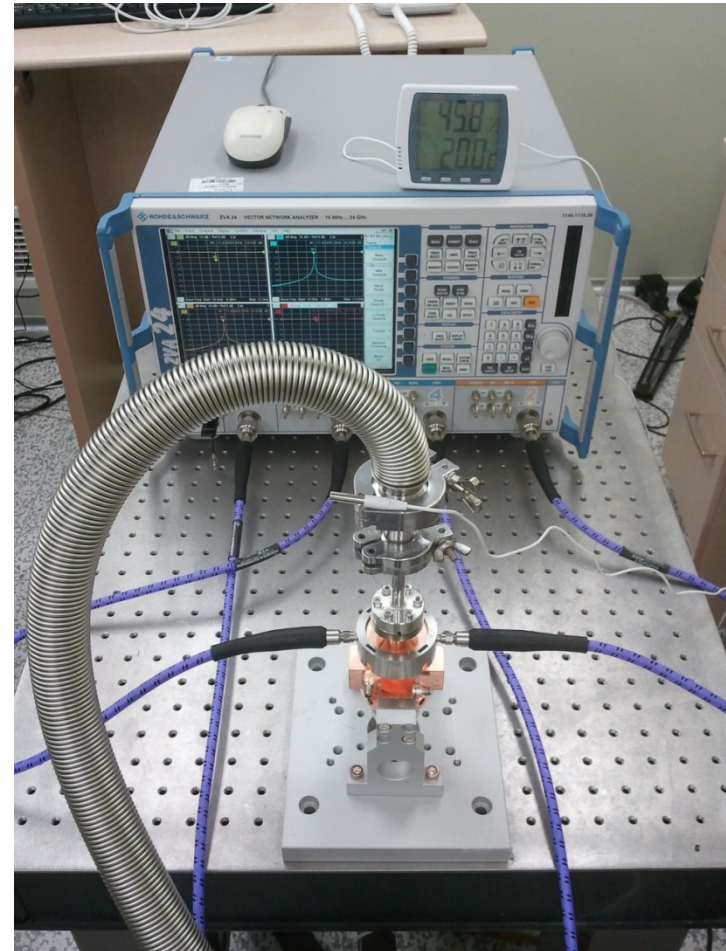


Parameters	XY Cavity (Dipole Cavity)	Reference Cavity (Monopole Cavity)
Mode	TM110	TM010
Frequency	11.424 GHz	11.424 GHz
Loaded Q Factor	2000 – 3000	2000 – 3000
R/Q	> 2 Ohms/mm	> 12 Ohms
Induced Voltage	> 5 mV/pC·mm	> 20 mV/pC
X/Y Cross Talk Level	< -20 dB	-

Brazing & Tuning

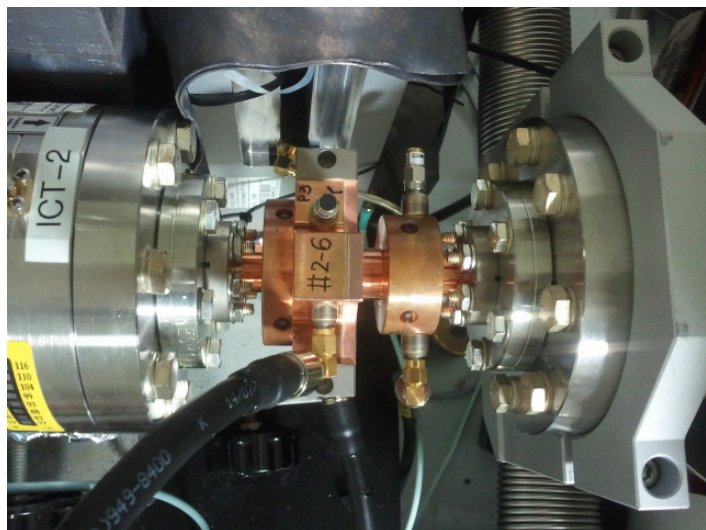
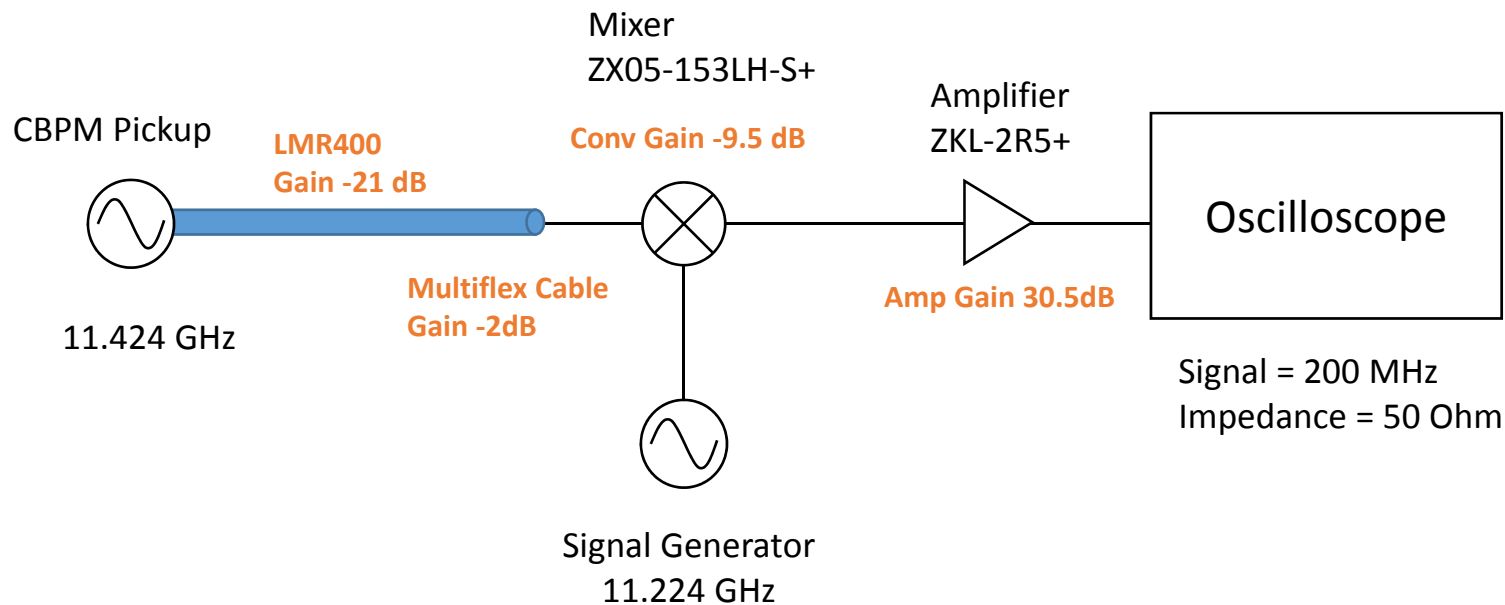


Brazing

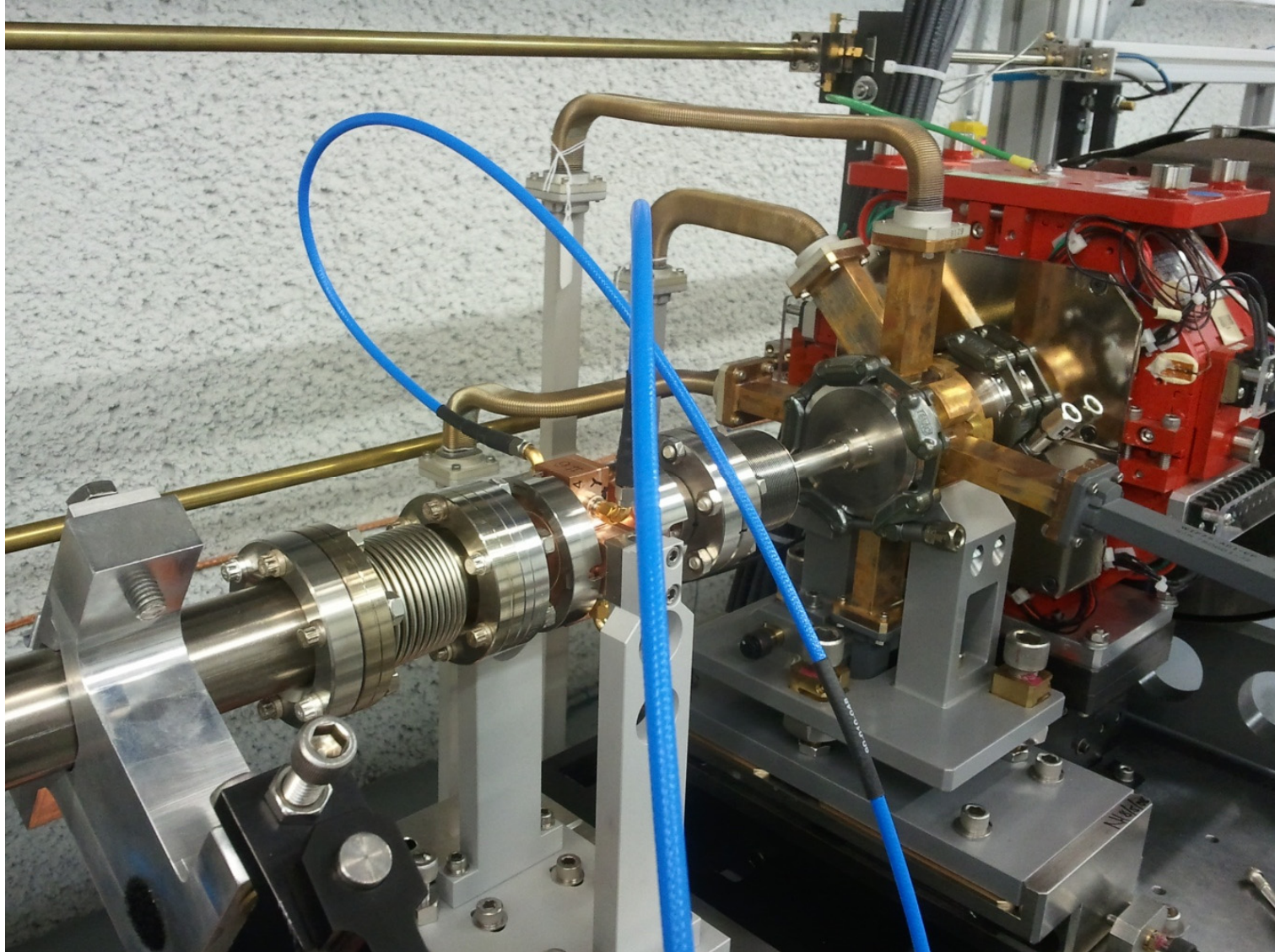


Cavity BPM Tuning

ITF Measurement Setup



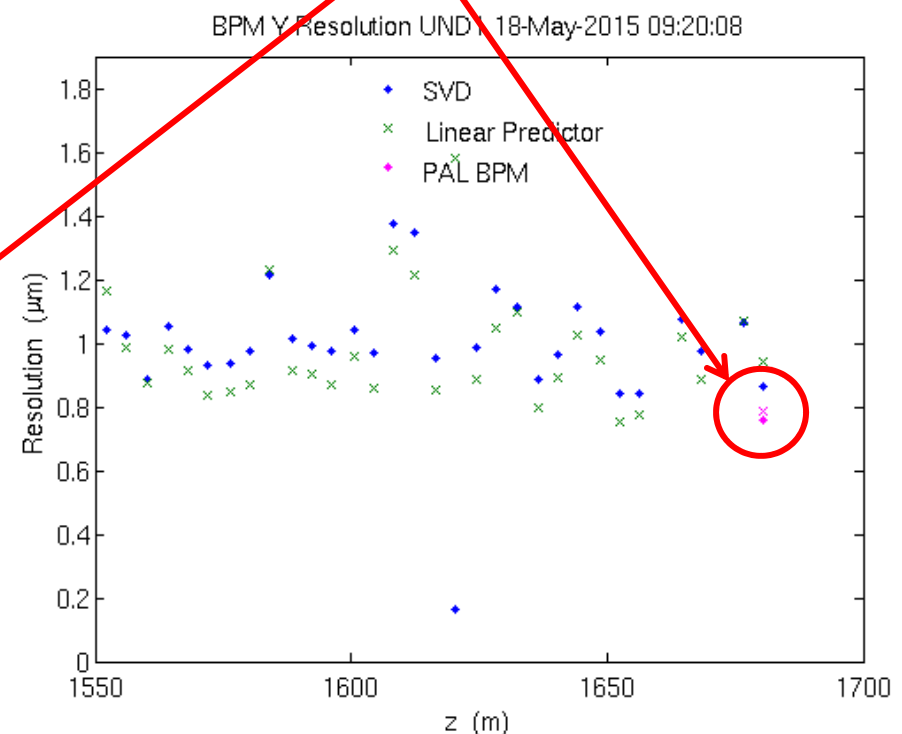
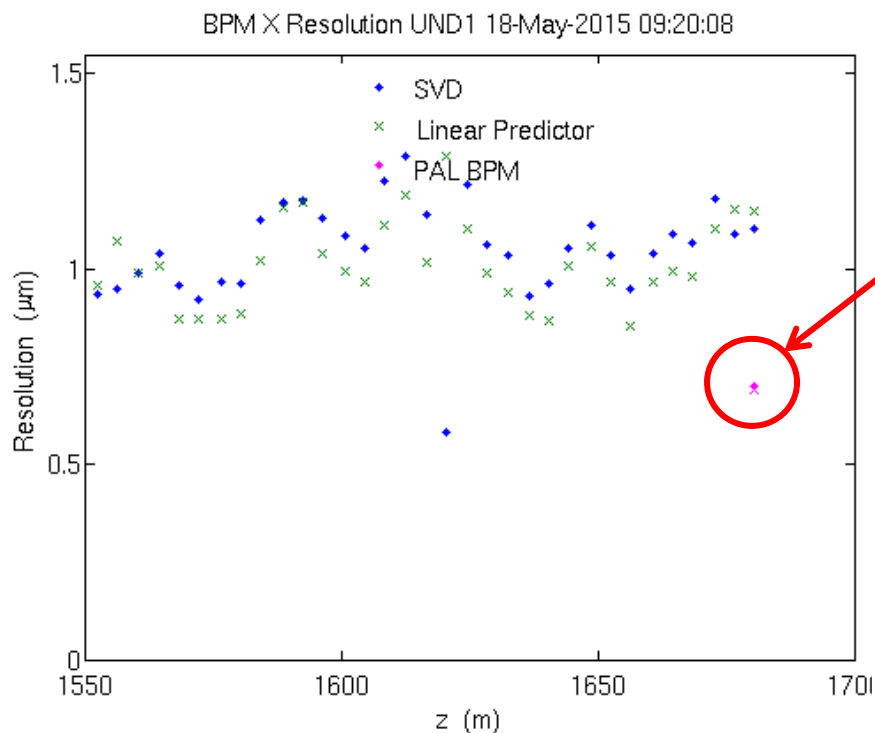
PAL Cavity BPM in LCLS



LCLS Resolution Test Result

- Measured Resolution: 700 nm (x), 800 nm (y) @ 25 pC

PAL-XFEL Cavity BPM

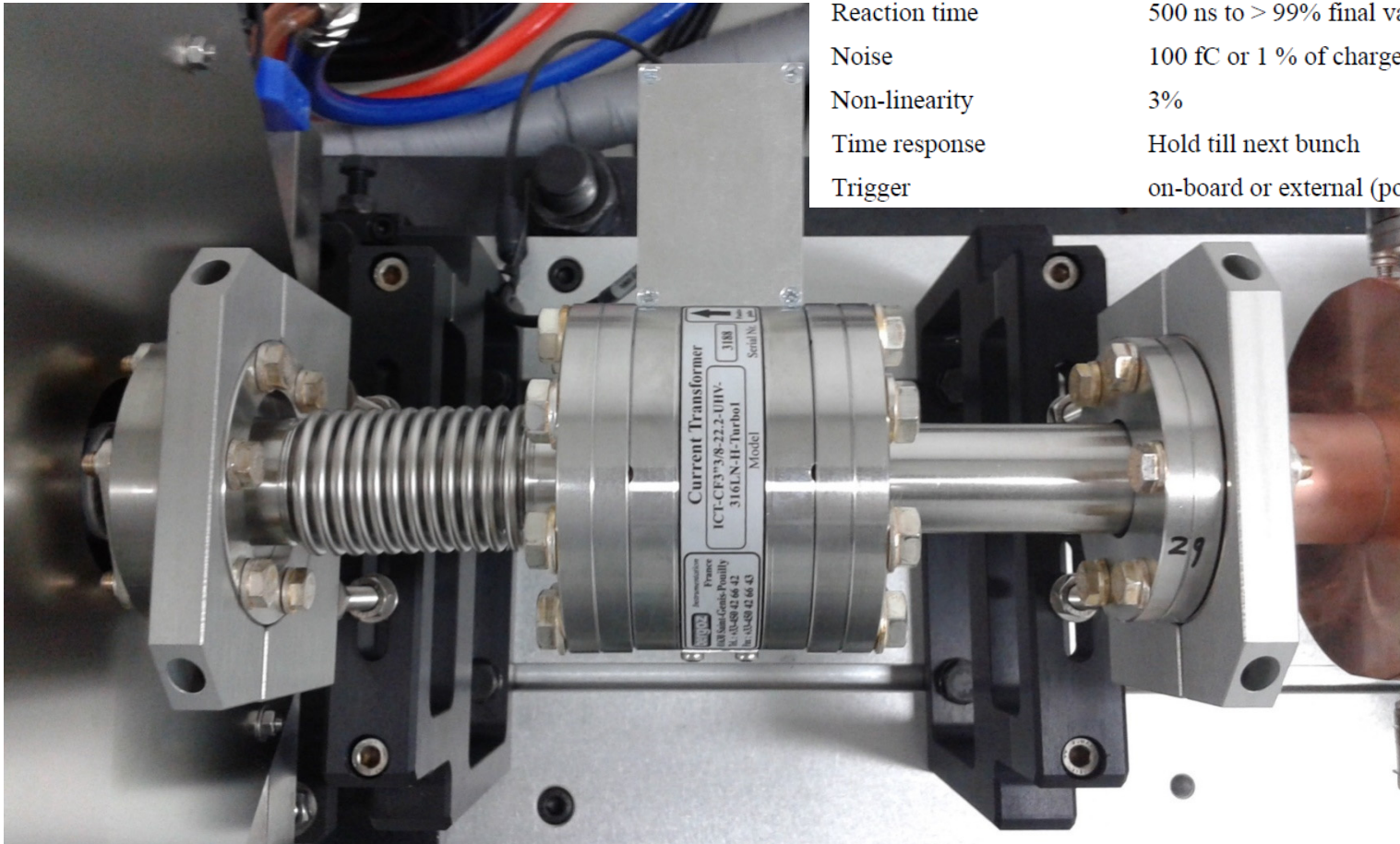


Beam Charge Monitor

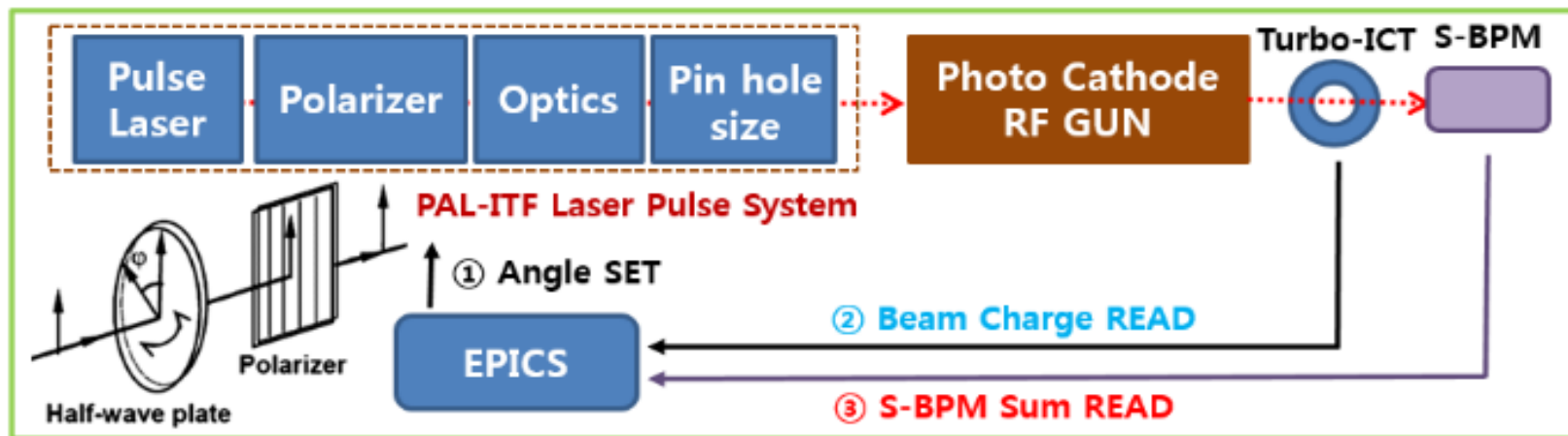
Turbo-ICT

Charge measurement:

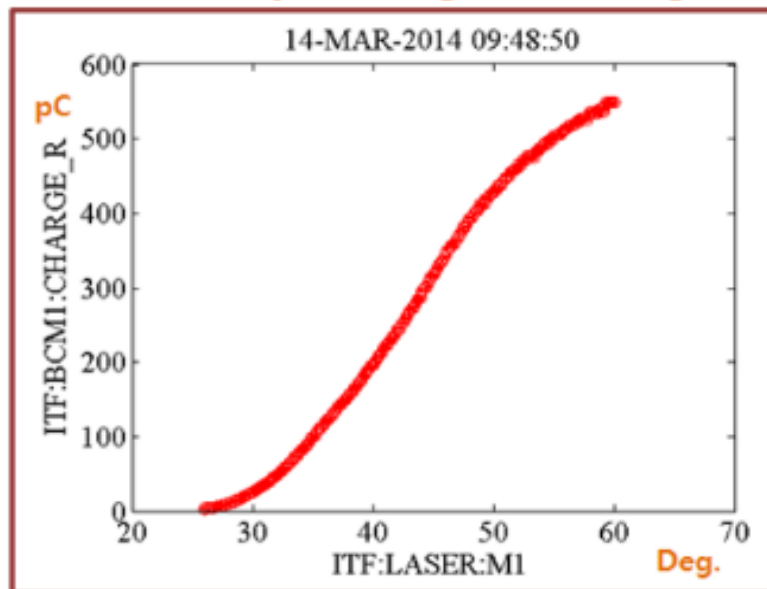
BCM-RF mode	S&H
Input charge	200 pC max (more without front-end amplifier)
Measurement single range	100 fC – 200 pC
Bunch repetition rate	Single bunch – 2 MHz
Output voltage	0 / 5V, log of the beam charge
Reaction time	500 ns to > 99% final value
Noise	100 fC or 1 % of charge
Non-linearity	3%
Time response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



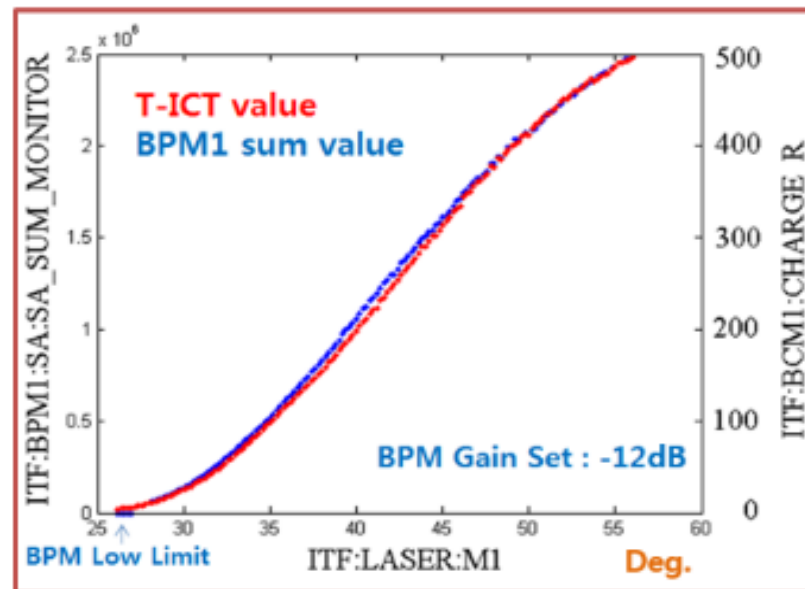
Beam Charge Monitor



Half-wave plate Angle vs. Charge

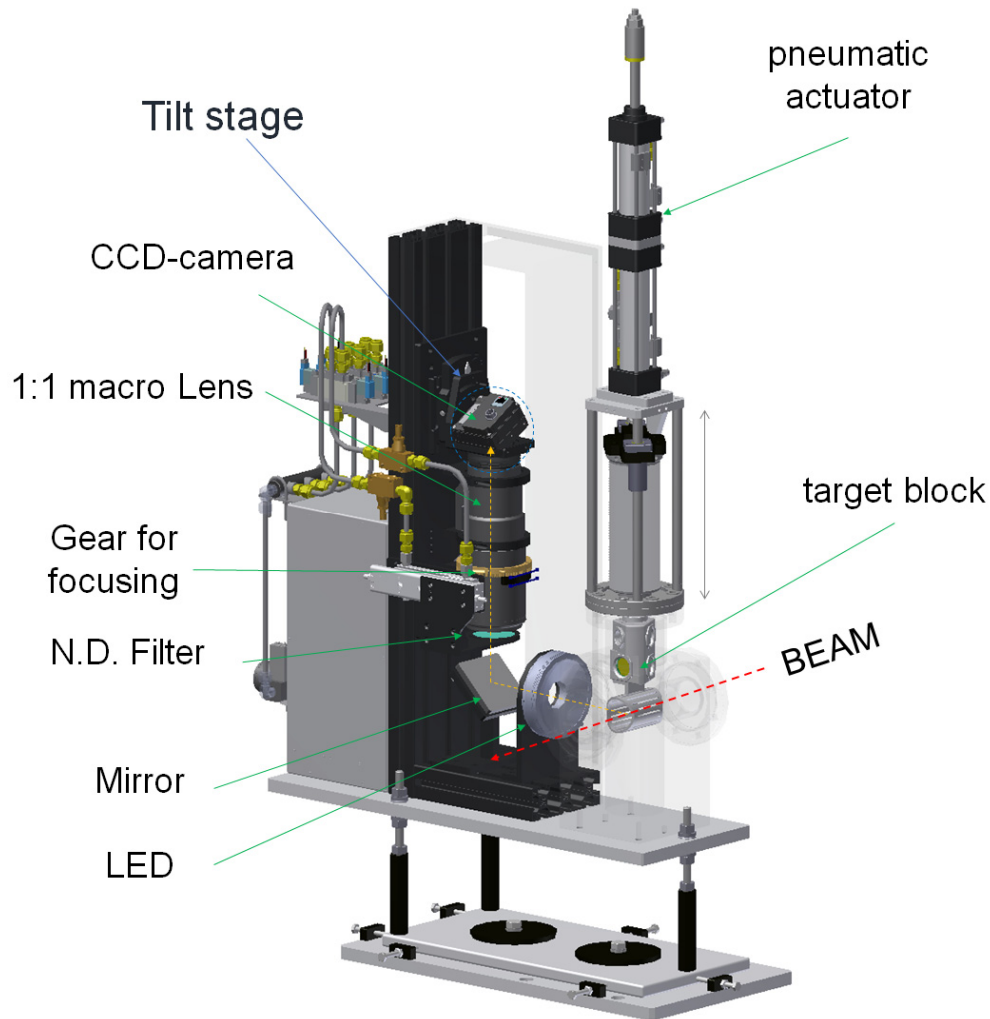


T-ICT value vs. S-BPM sum



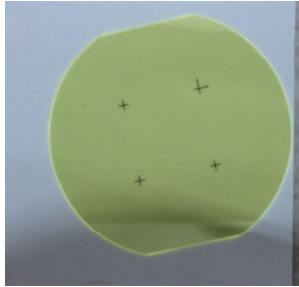
Transverse Profile

Screen Monitor

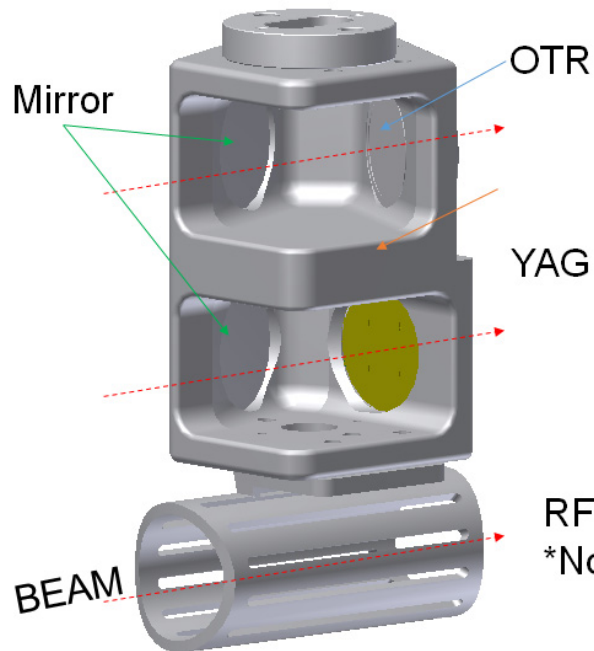


- 3-position pneumatic actuator
- RF shield for reducing the wake field
- Scintillator (YAG:Ce)
- OTR Target (Al-foil)
- LED backlight lamp
- Neutral density filter
- DSLR lens (Magnification : x1)
- DC motor for remote focusing
- Tilt stage for Scheimflug's geometry
- GigE camera

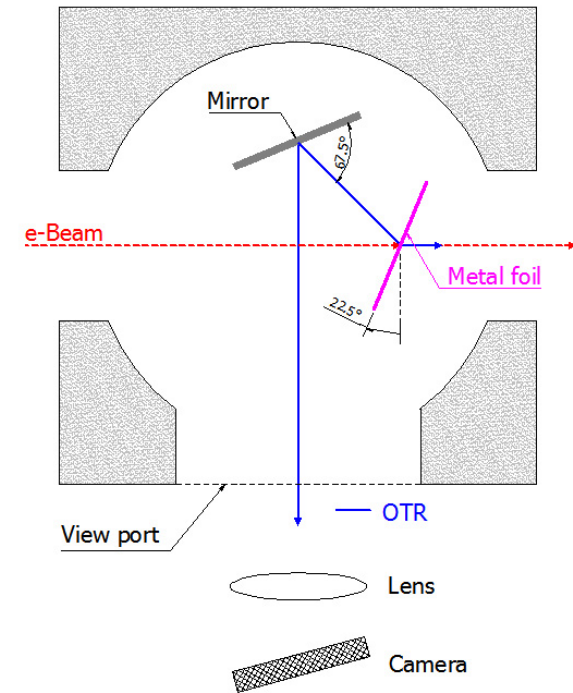
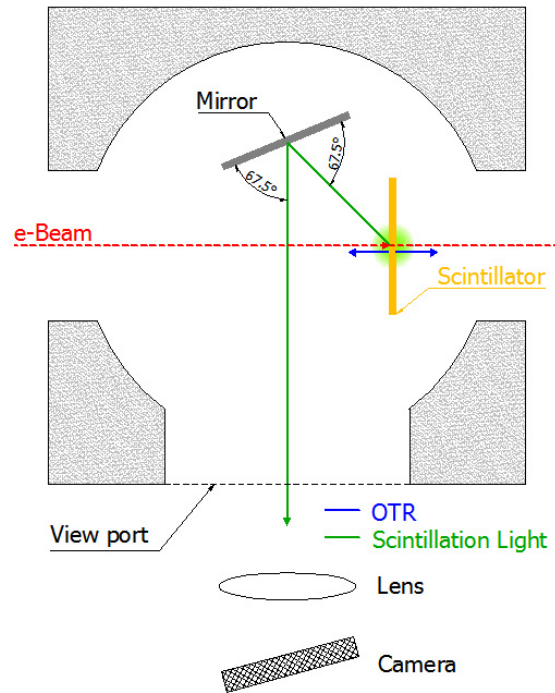
Target Holder



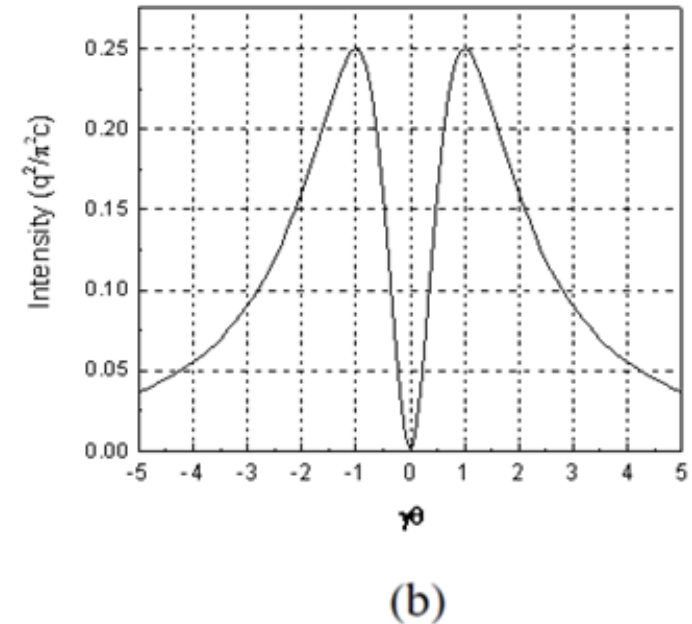
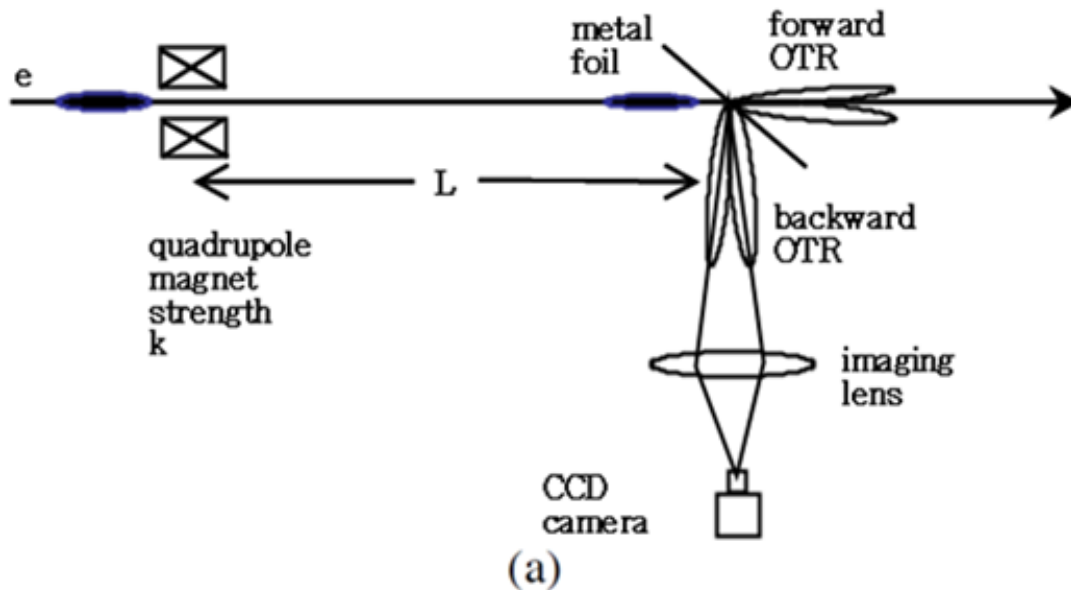
YAG:Ce with patterning
for size calibration



RF shield
*Nominal operation



Optical Transition Radiation



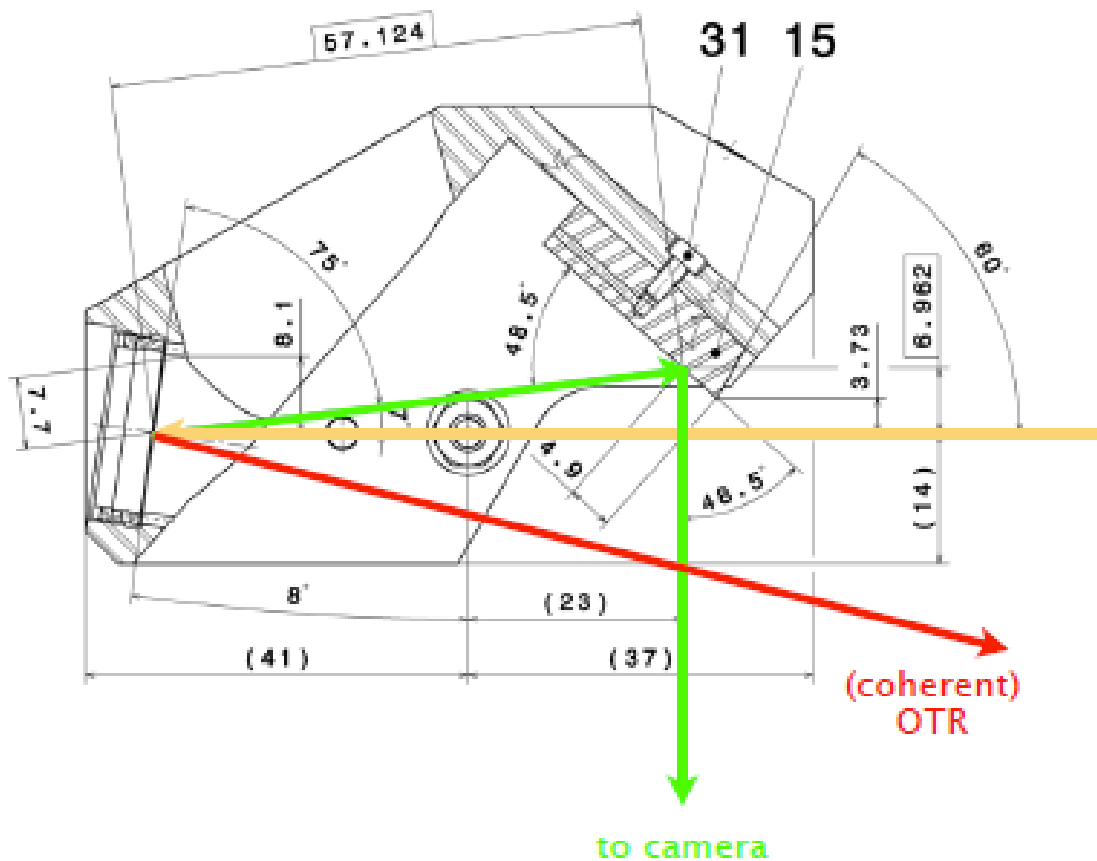
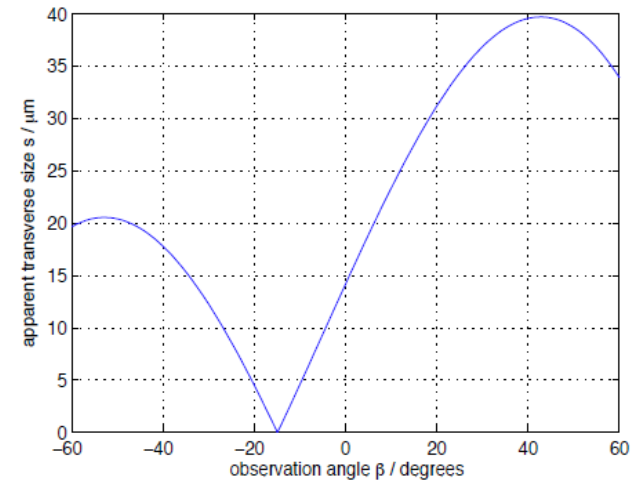
OTR measurement setup and angular profile

$$\text{Radiation power} \propto \left(\sum_{j=1}^N E_j e^{i\phi_j} \right)^2 = \sum_{j=1}^N E_j^2 + \sum_{\substack{j=1 \\ j \neq k}}^N \sum_{k=1}^N E_j E_k^* e^{i(\phi_j - \phi_k)}$$

Coherent OTR can make a saturated beam image.

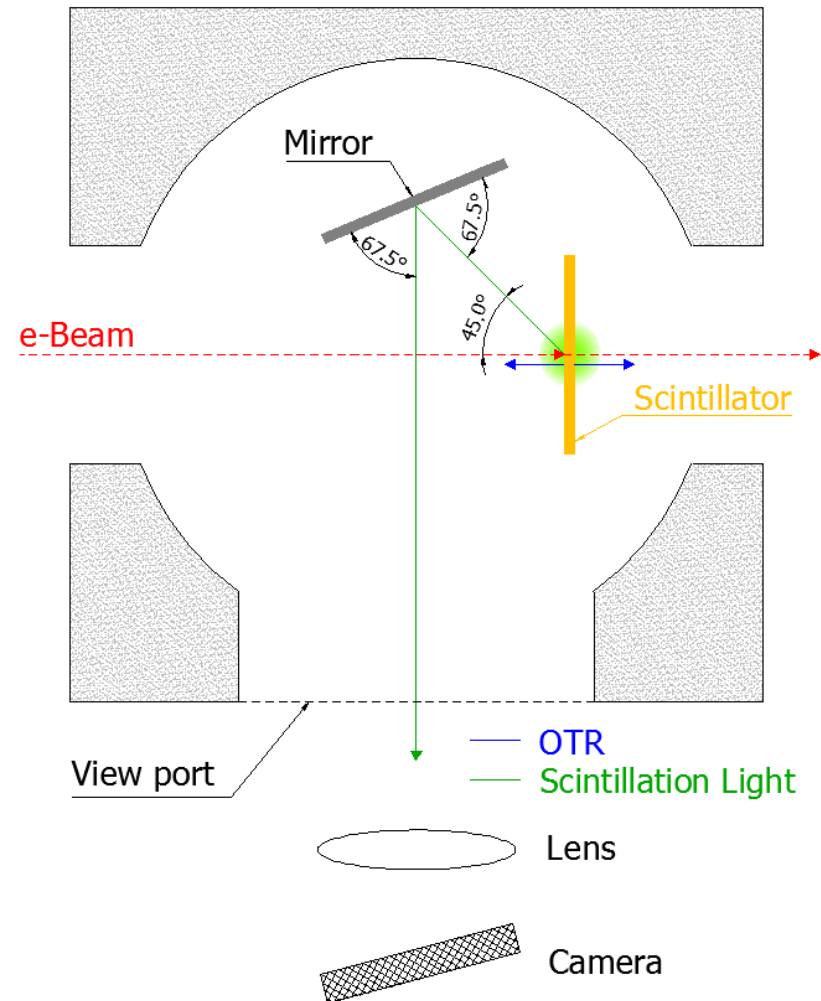
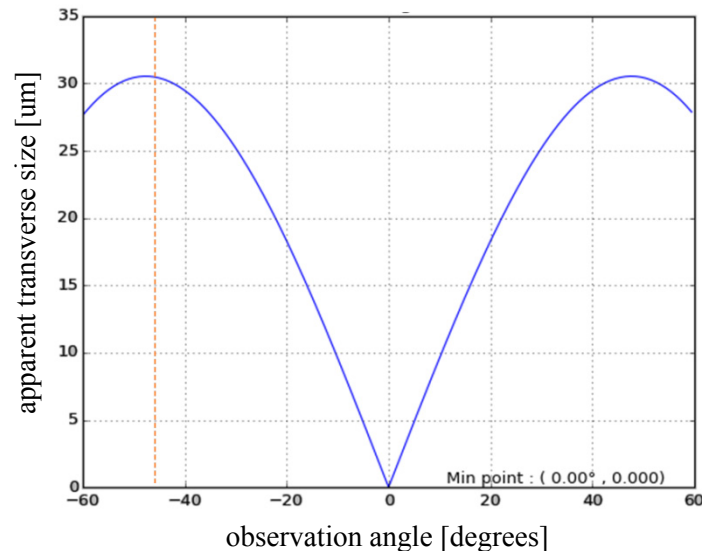
SwissFEL Screen Monitor

Observed Beam Size

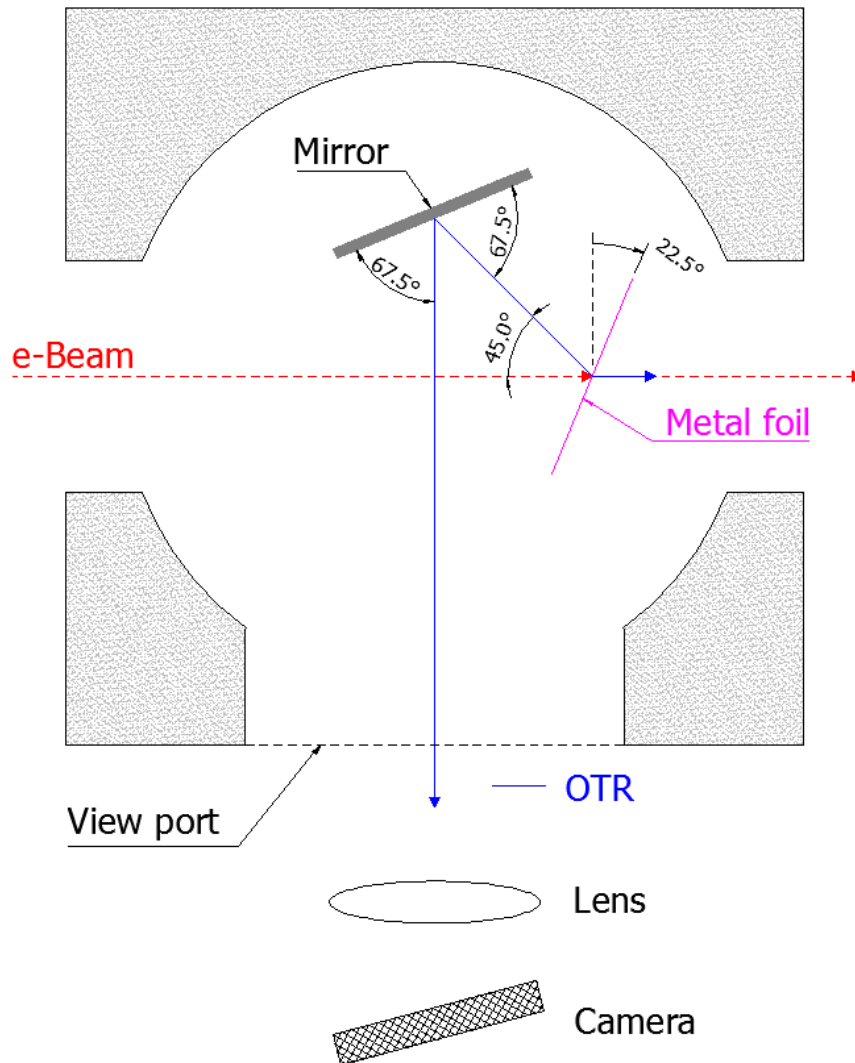


Scintillator Target

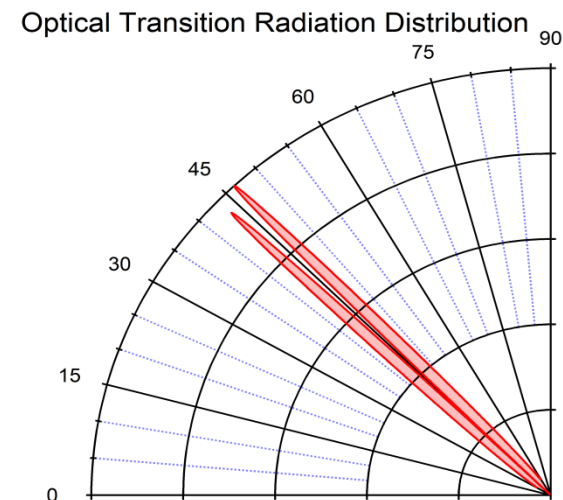
- YAG:Ce scintillator
- Thickness : 100 or 30 μm
- Observation geometry of 45°
with respect to the beam axis
 $\Rightarrow$ Minimized holder size



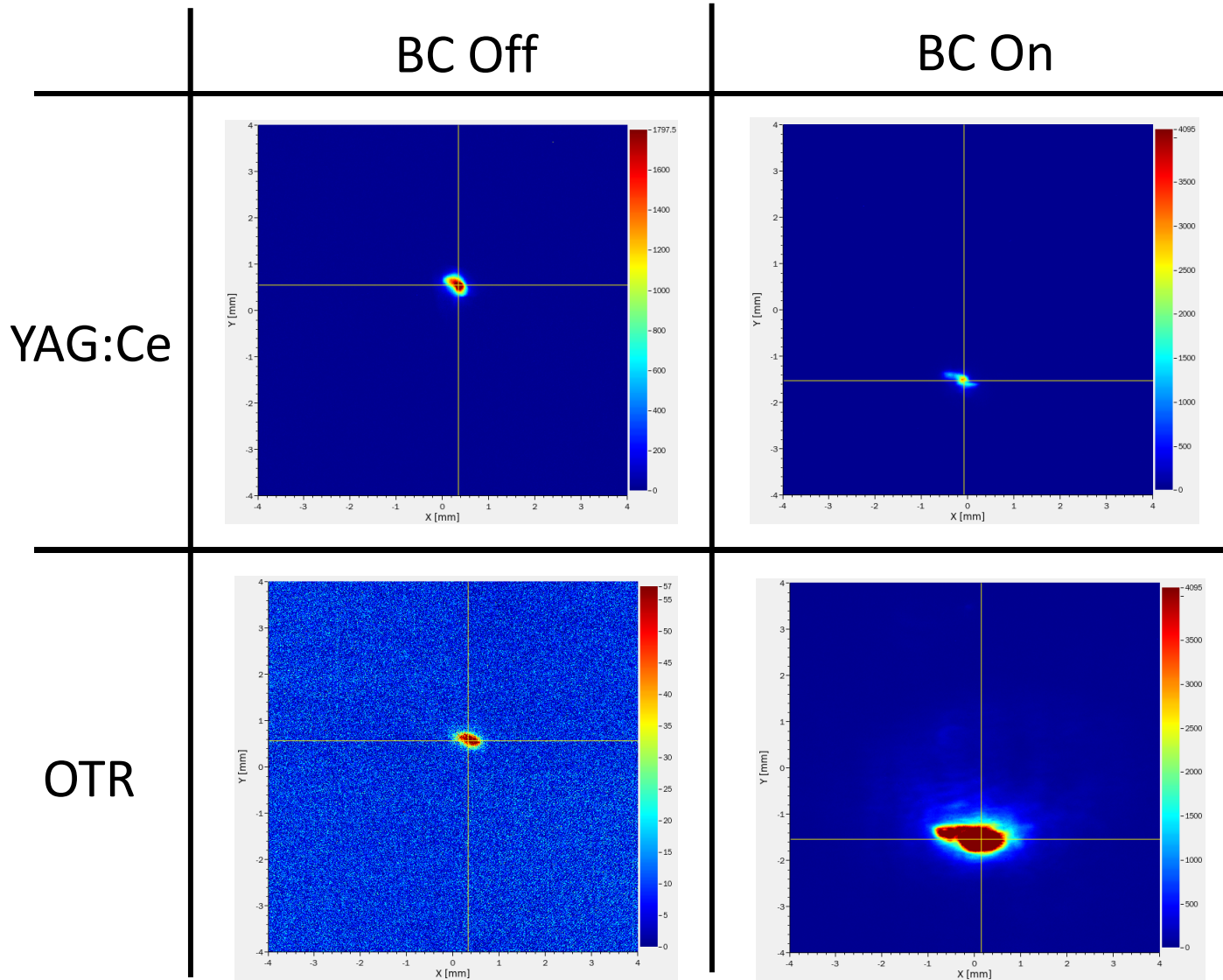
OTR Target



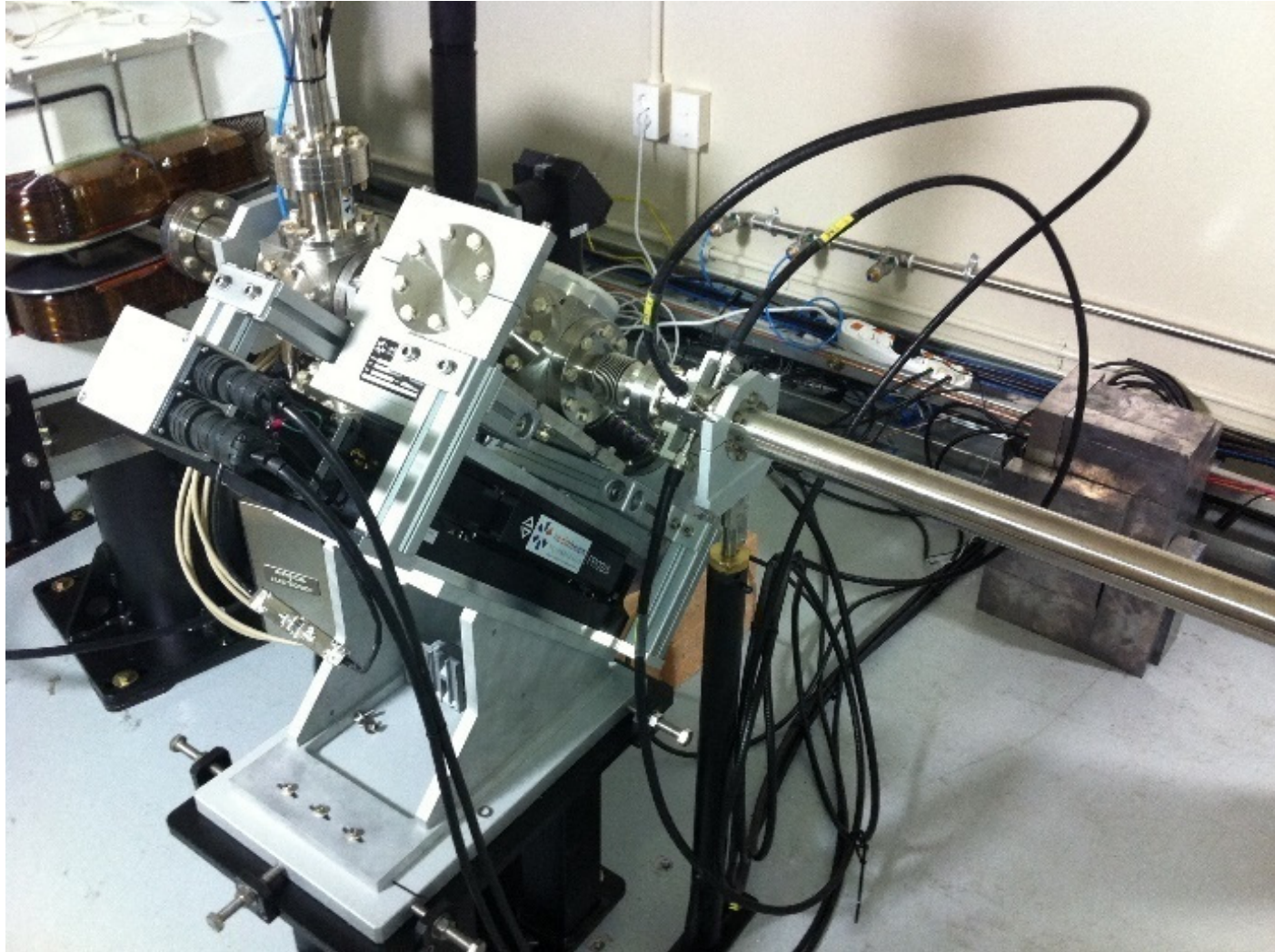
- OTR imaging with Al foil
- thickness : 1 μm
- Target rotation: 22.5°



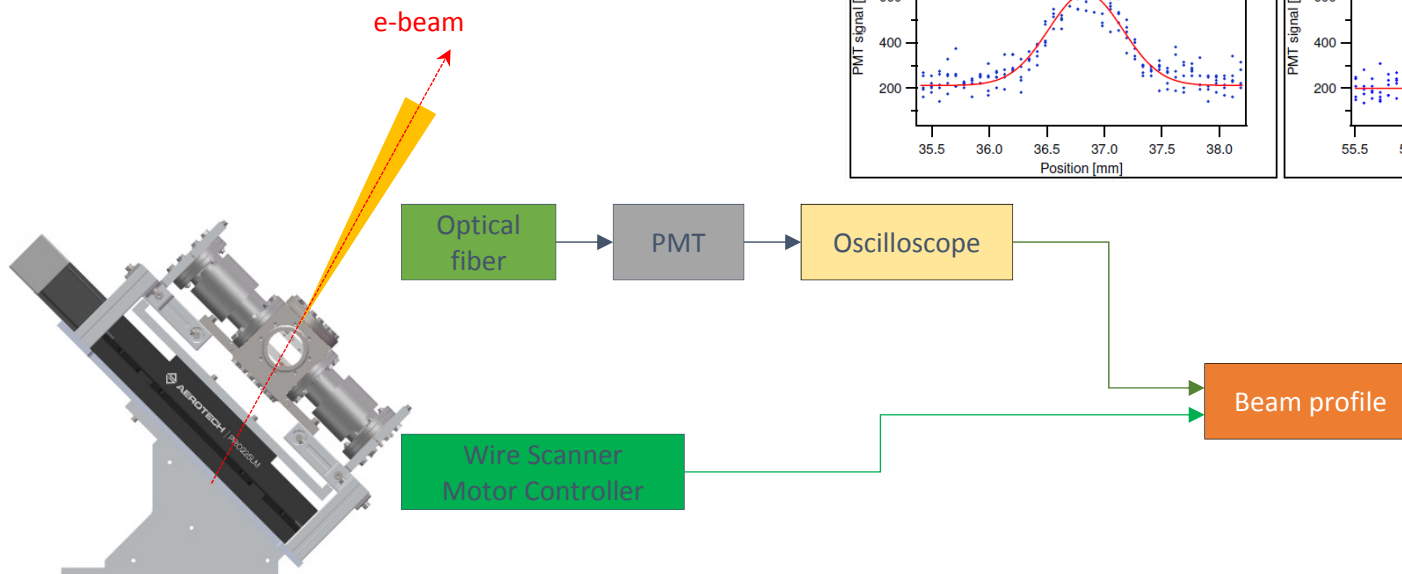
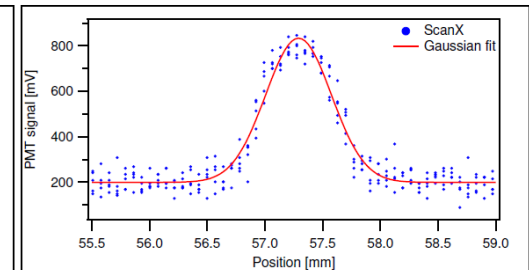
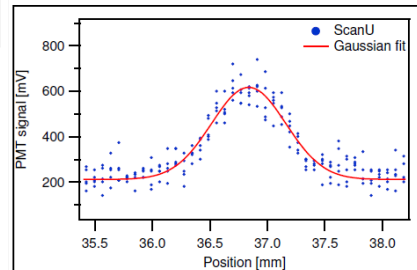
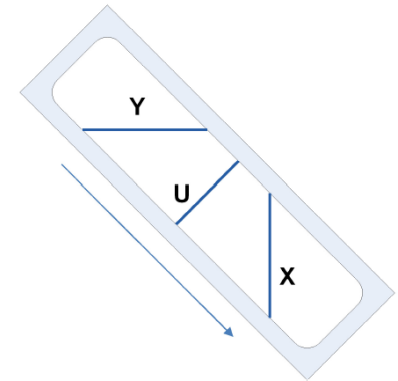
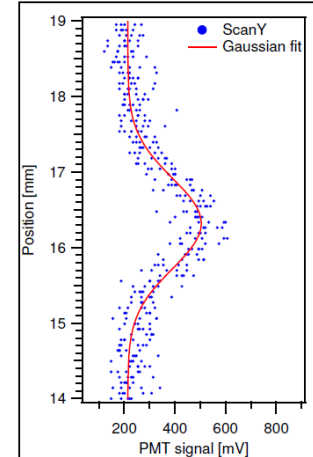
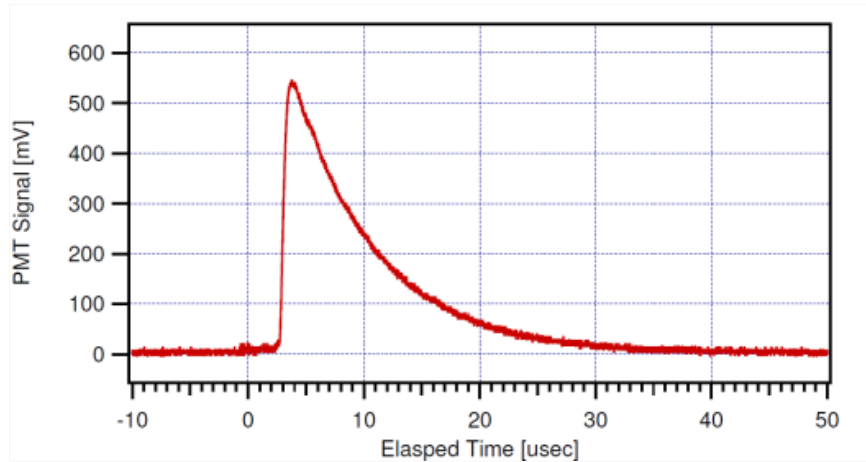
COTR Measurement Results



ITF Wire Scanner



ITF Wire Scanner Test Result

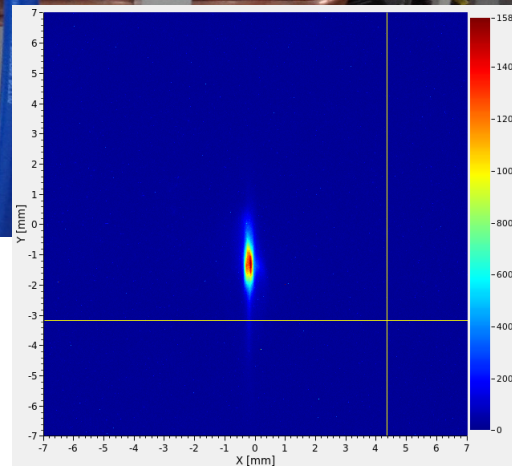
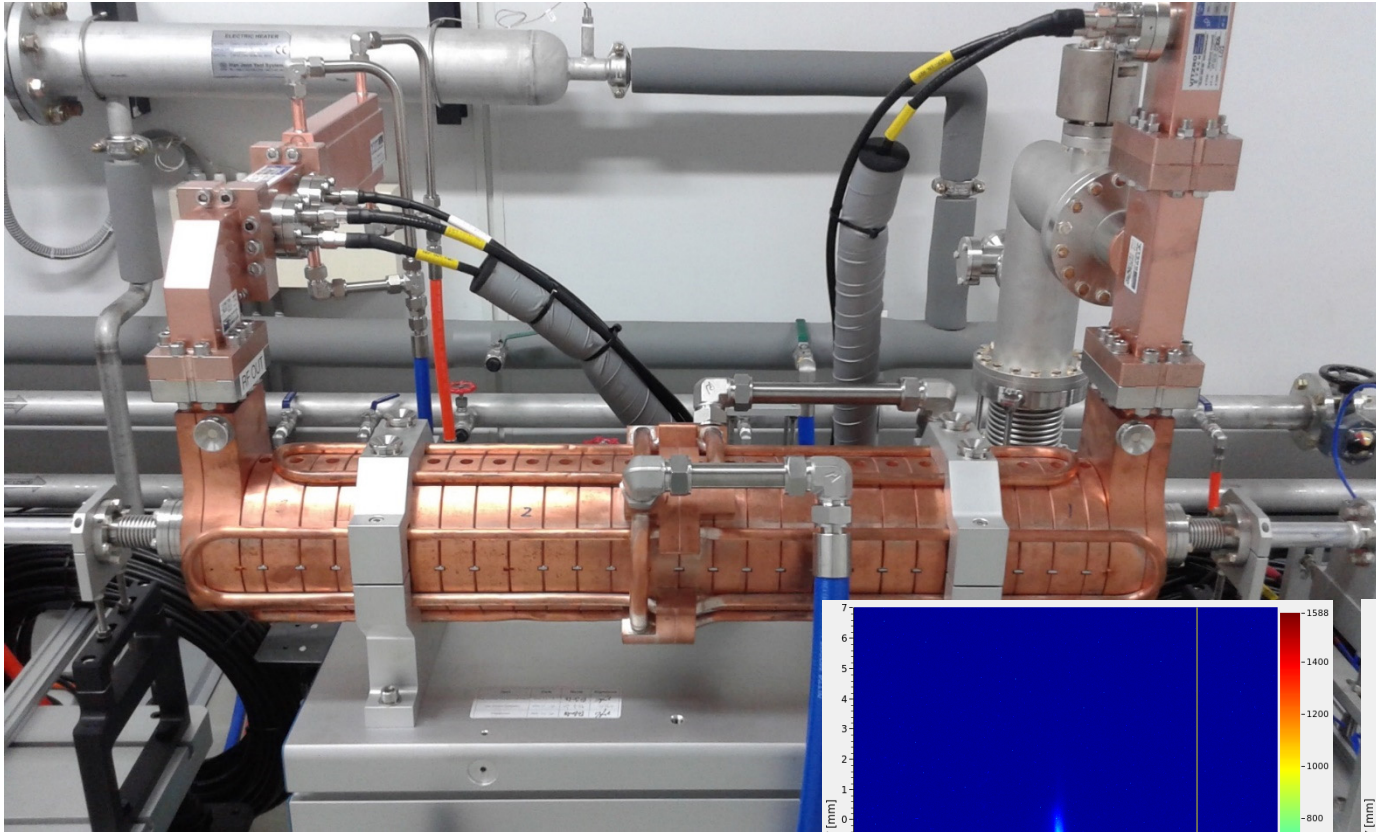




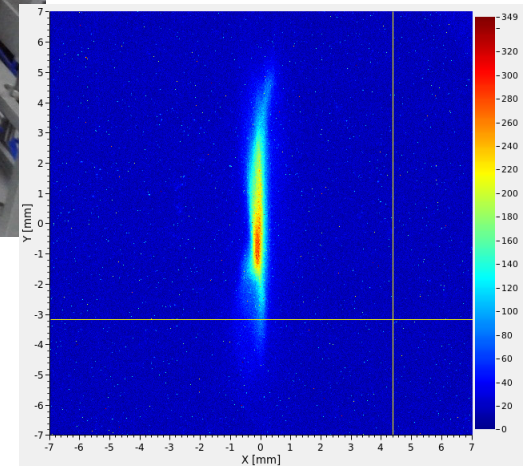
PAL-XFEL
Screen Monitor
and Wire Scanner

Longitudinal Profile

Transverse Deflecting Cavity

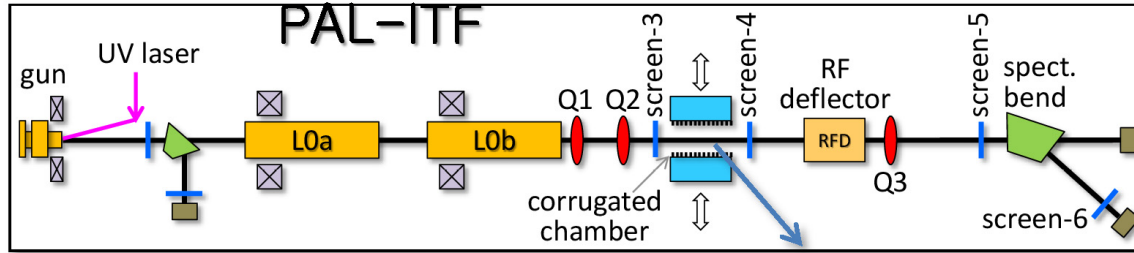


Deflector Off



Deflector On

Wakefield Dechirper Chamber – Simulation & Measurement

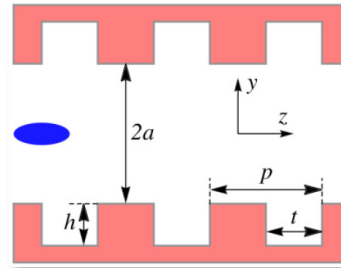


PAL POHANG ACCELERATOR
LABORATORY

SLAC

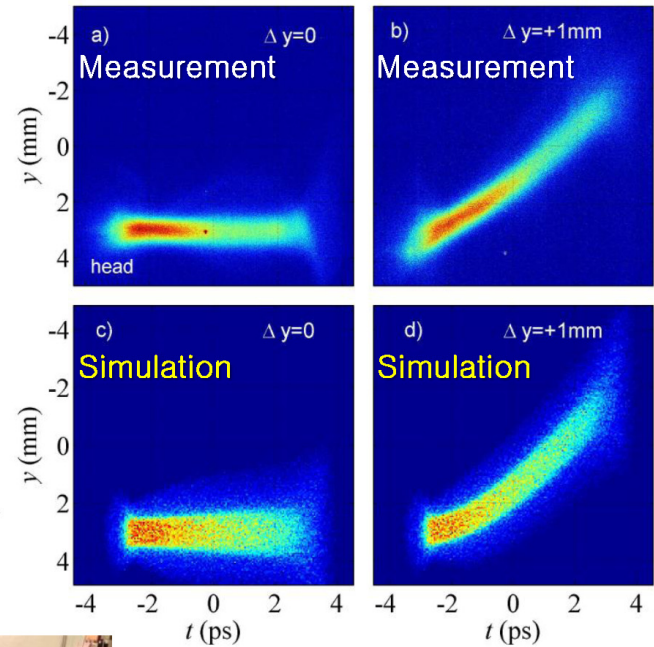


Time-resolved chirp meas. & sims.

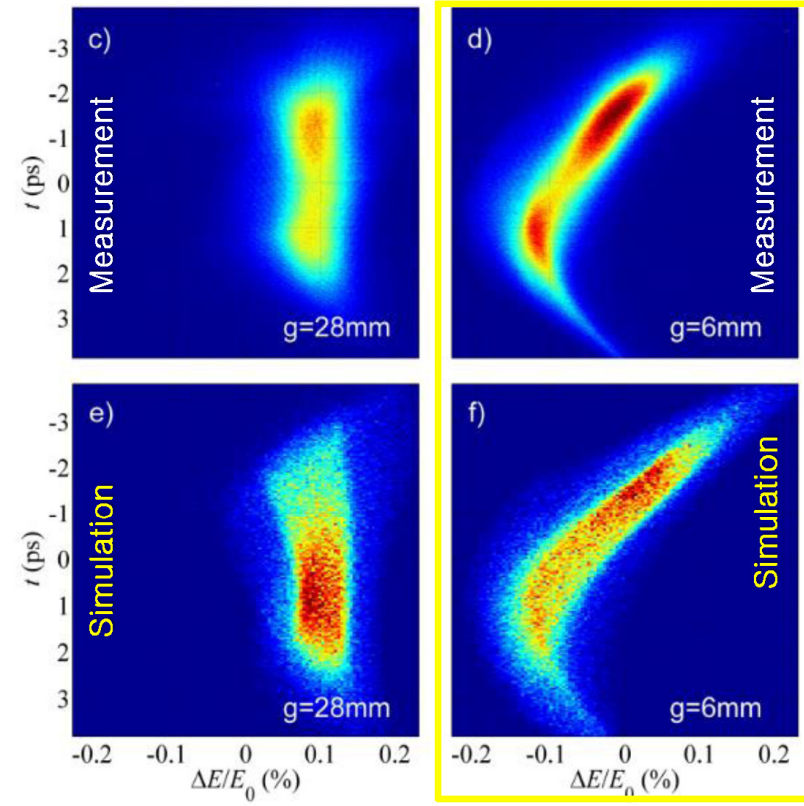
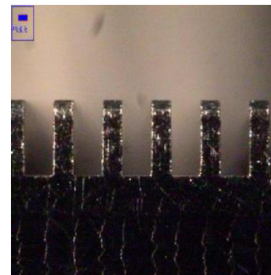
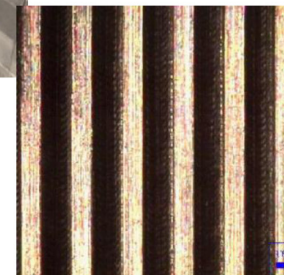


corrugated chamber

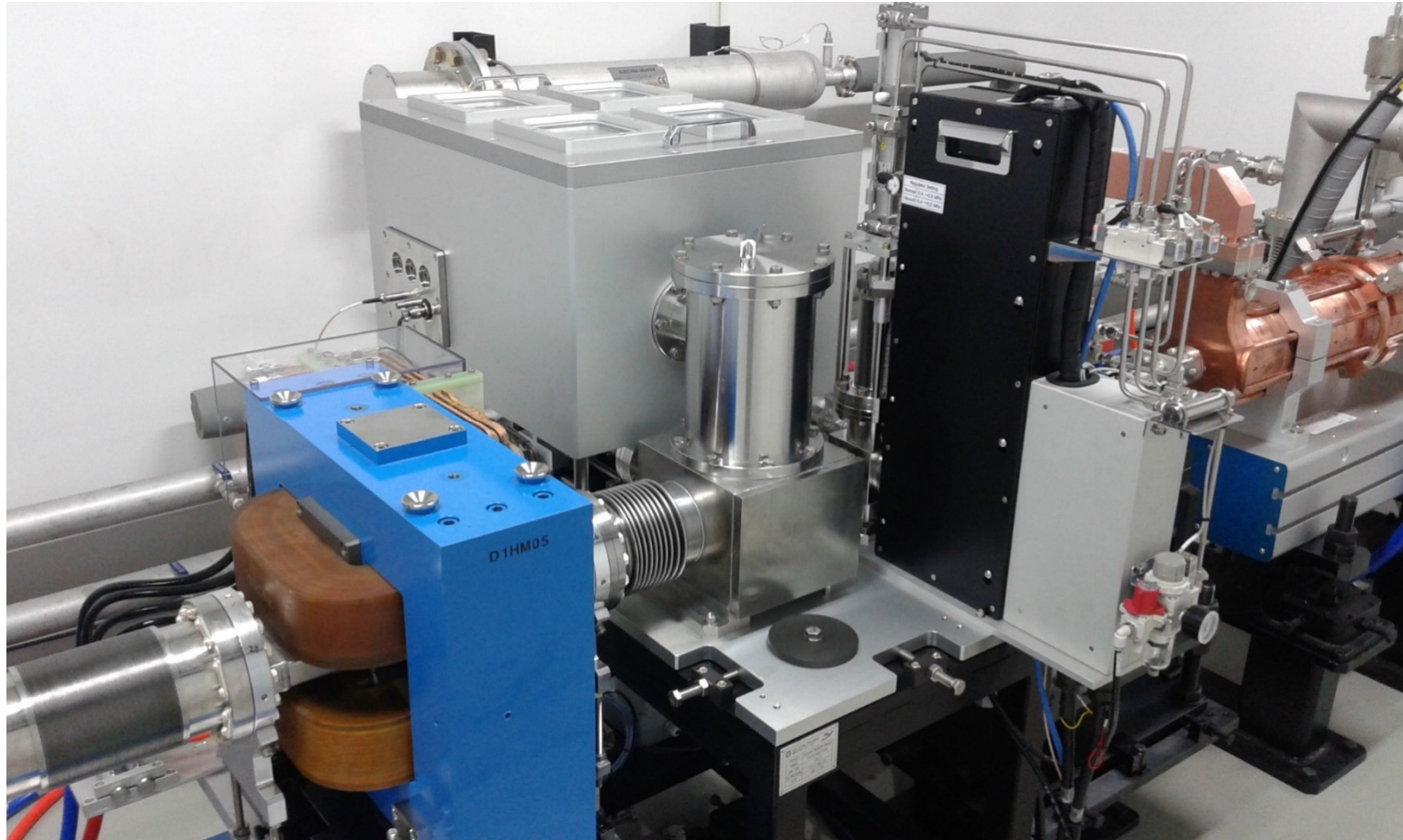
Time-resolved T-wake meas. & sims.



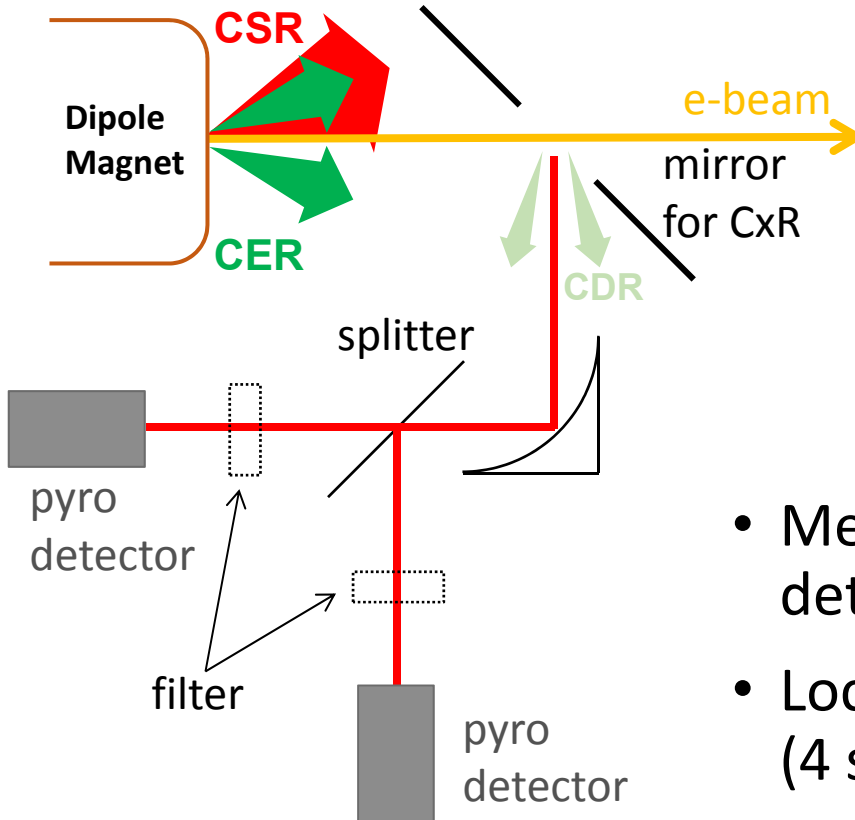
P. Emma *et al.*,
Phys. Rev. Lett. **112**, 034801



Coherent Radiation Monitor



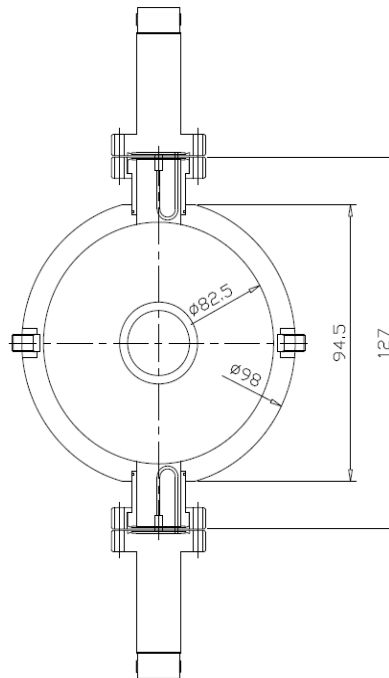
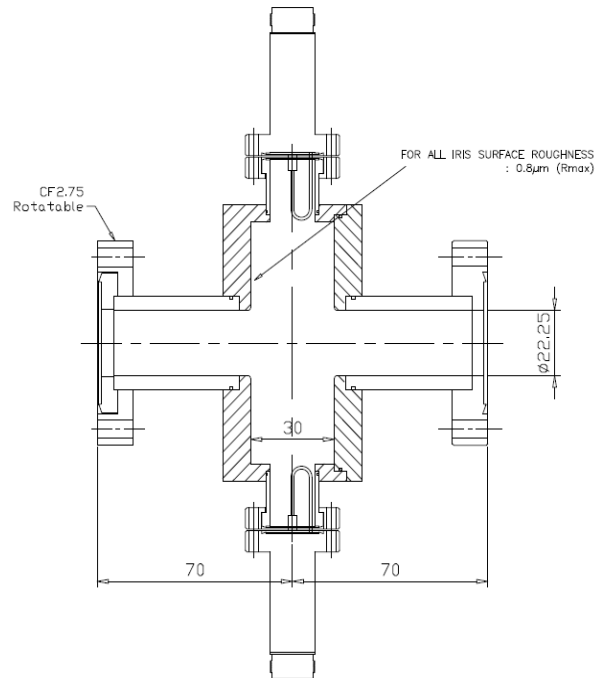
Coherent Radiation Monitor



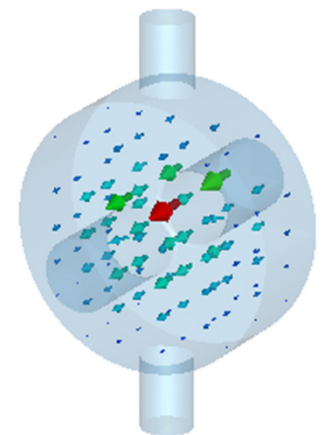
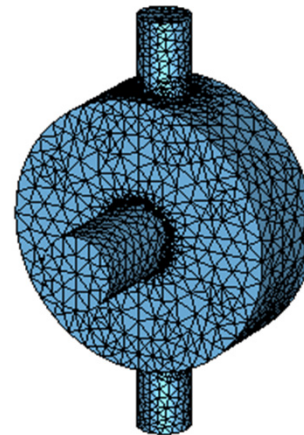
- Measure CxR intensity with pyro-detectors
- Located after bunch compressors (4 sets)
- Calibration with the deflector
- Bunch length monitor & feedback

Beam Arrival Monitor

Beam Arrival Monitor

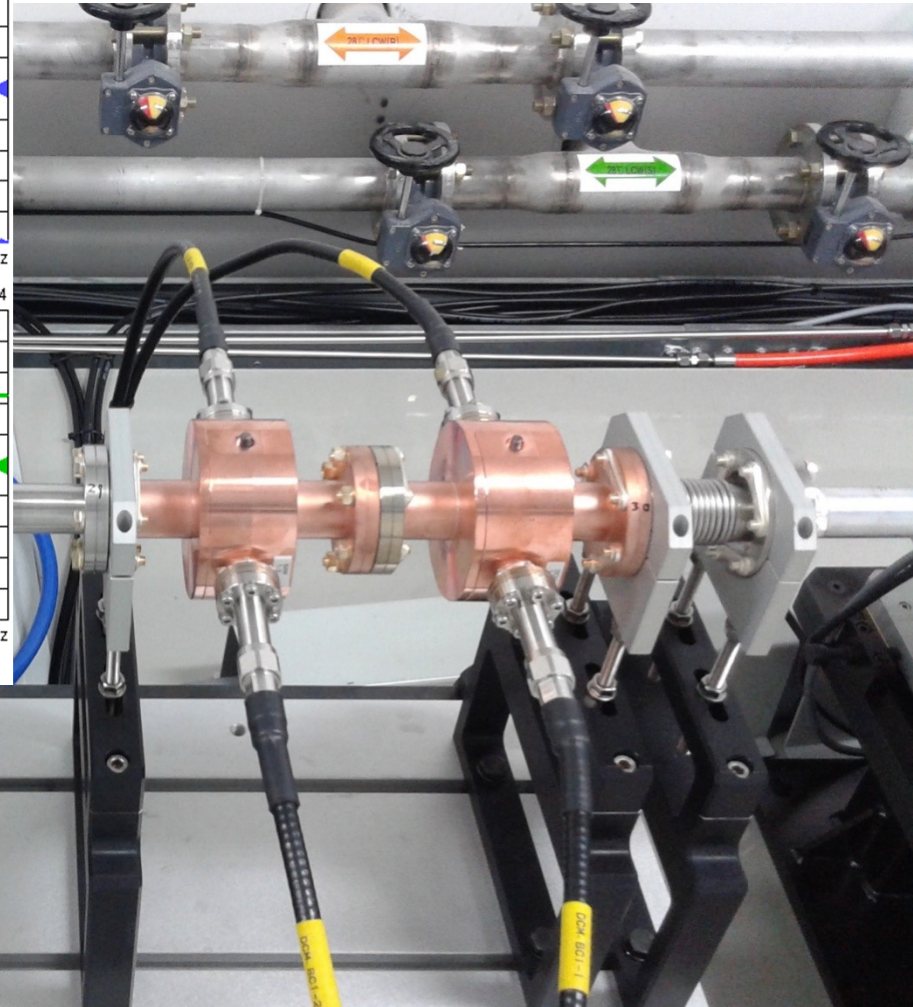
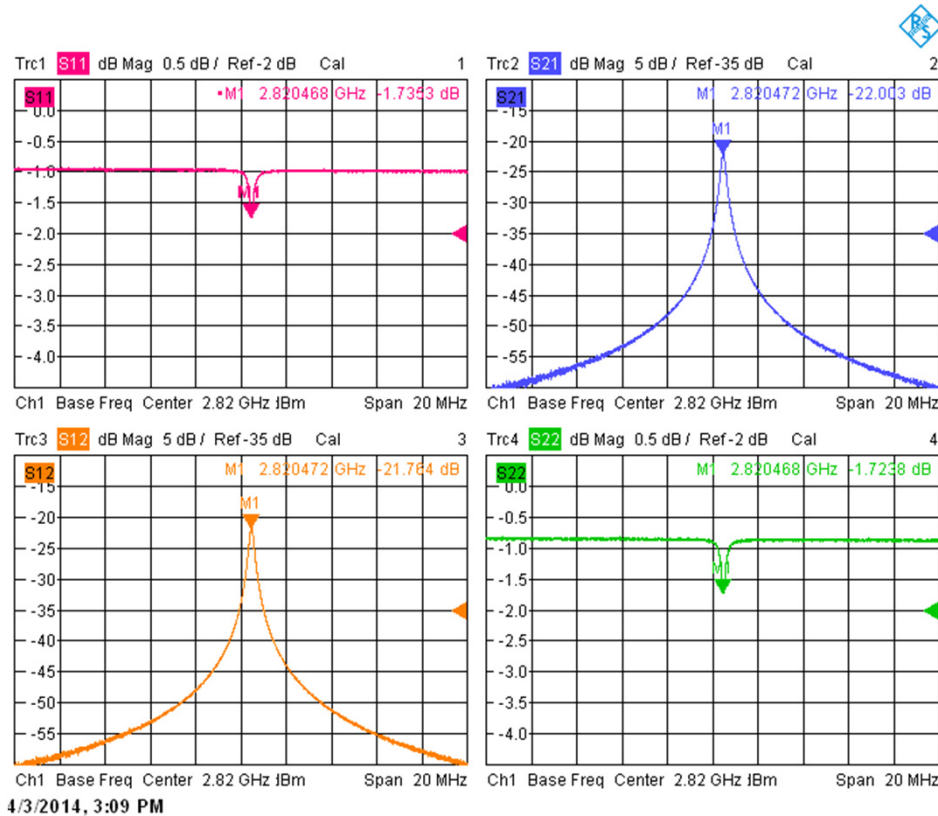


CST simulation
Cavity type BAM w/o Pickup



$Q_0 \sim 14000$ @ $\sigma = 5.8 \times 10^7$ (Cu)
 $f_{RF} = 2826.25$ MHz
 (* $f_{LO} = 2856$ MHz, $f_{IF} = 29.75$ MHz)

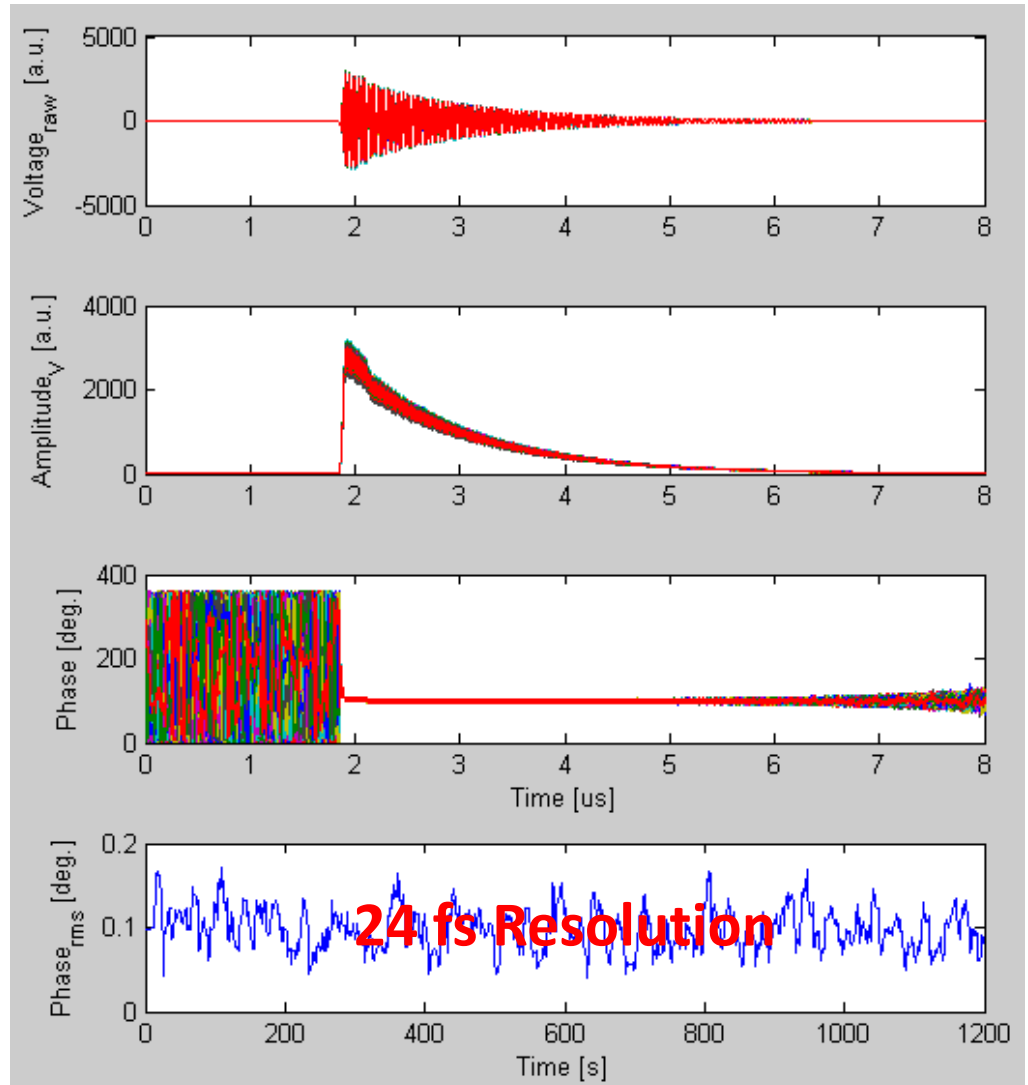
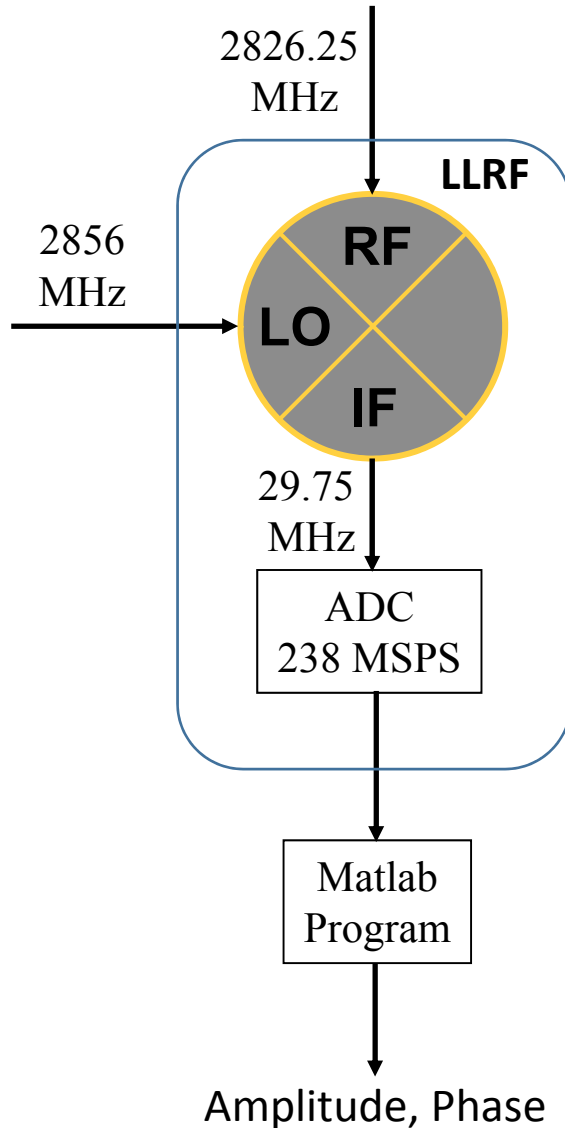
Beam Arrival Monitor Pickup



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

Beam Arrival Monitor Signal

Using LLRF @ ITF (10Hz, 200 pC, total 20 min)

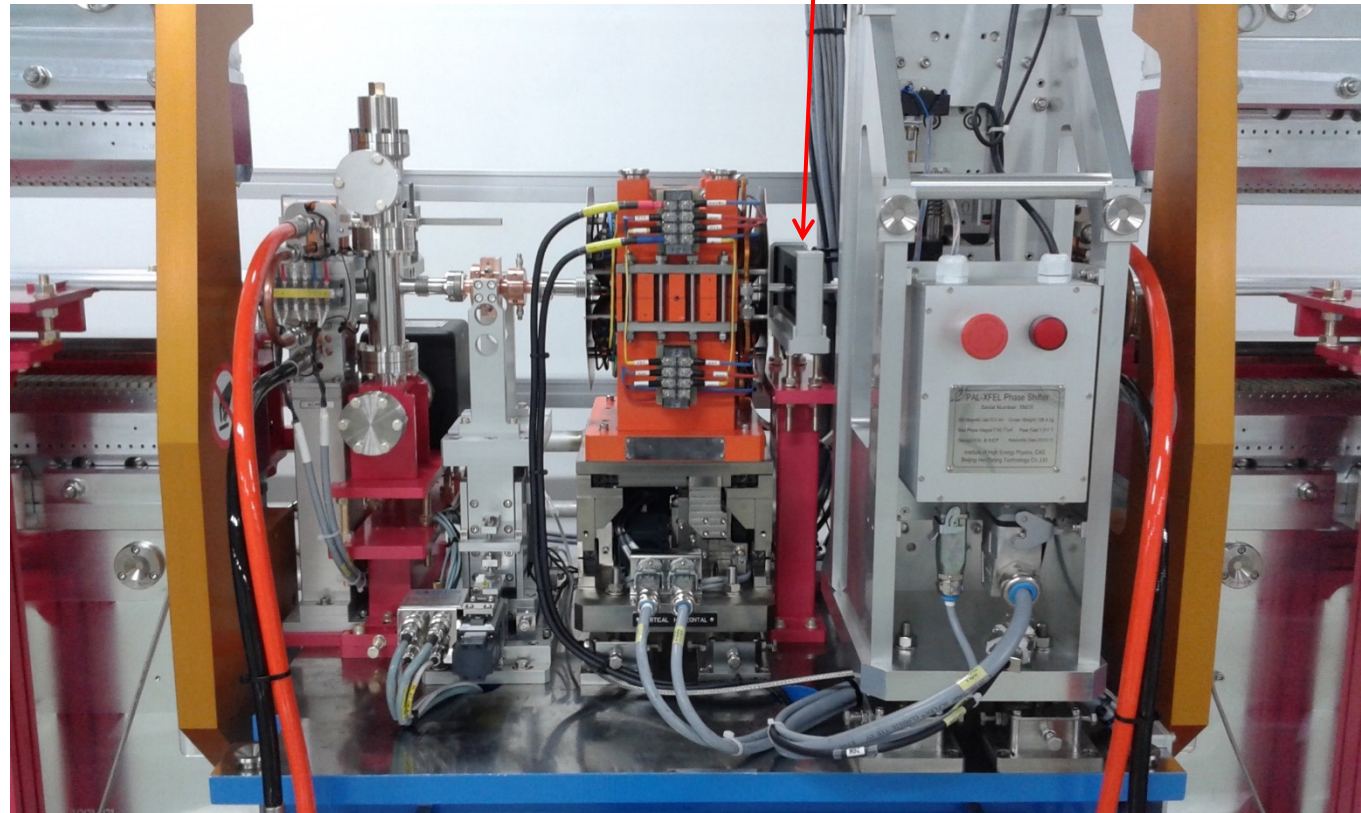


Beam Loss Monitor

Beam Loss Monitor

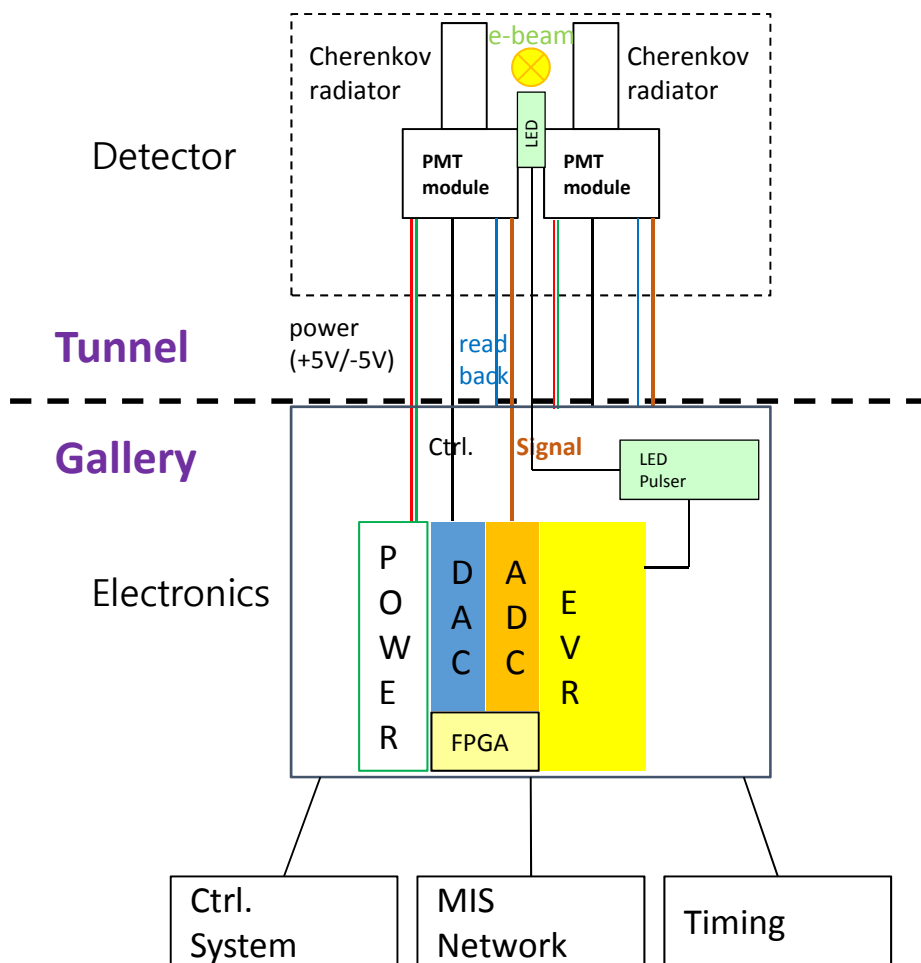
- Located in undulator intersection
- 1 detector per 1 undulator
- Cherenkov radiator (PMMA or fused-silica) with PMT
- Protect undulator magnets

Beam Loss Monitor

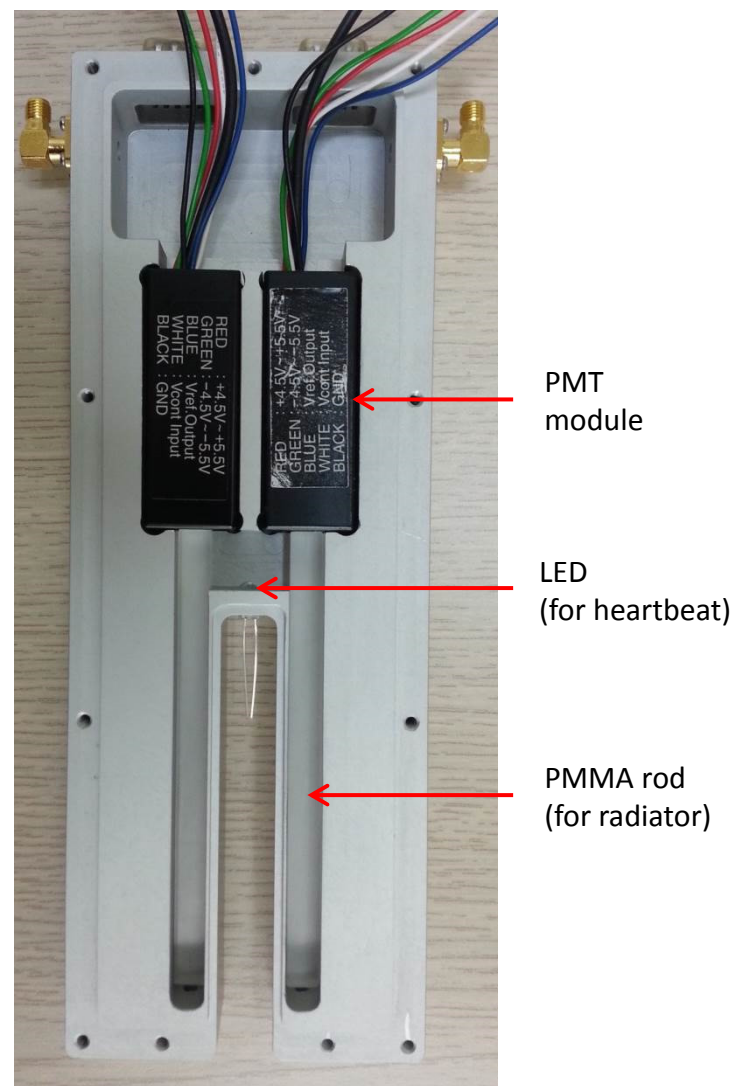


Beam Loss Monitor

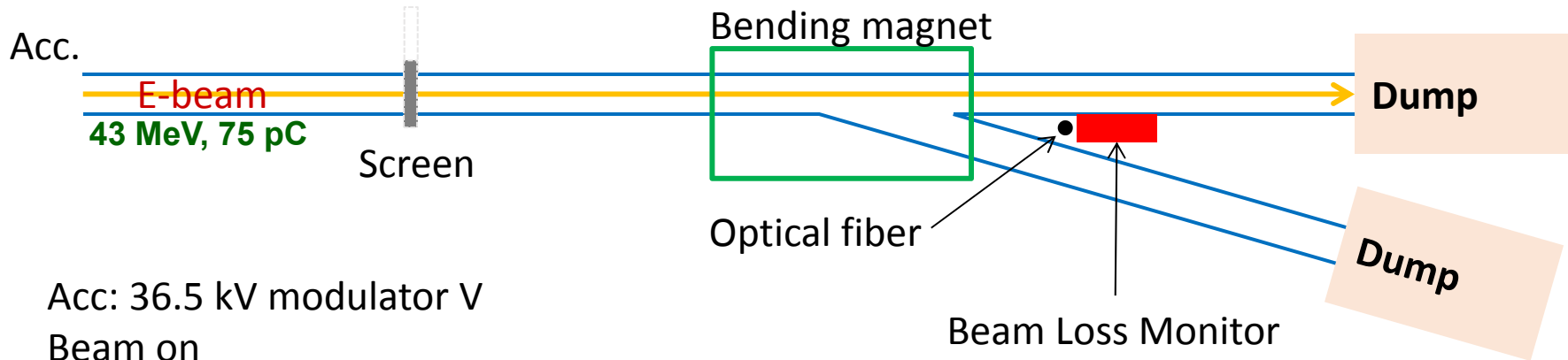
Conceptual Design



Proto-type Detector



BLM Head vs. Optical Cable



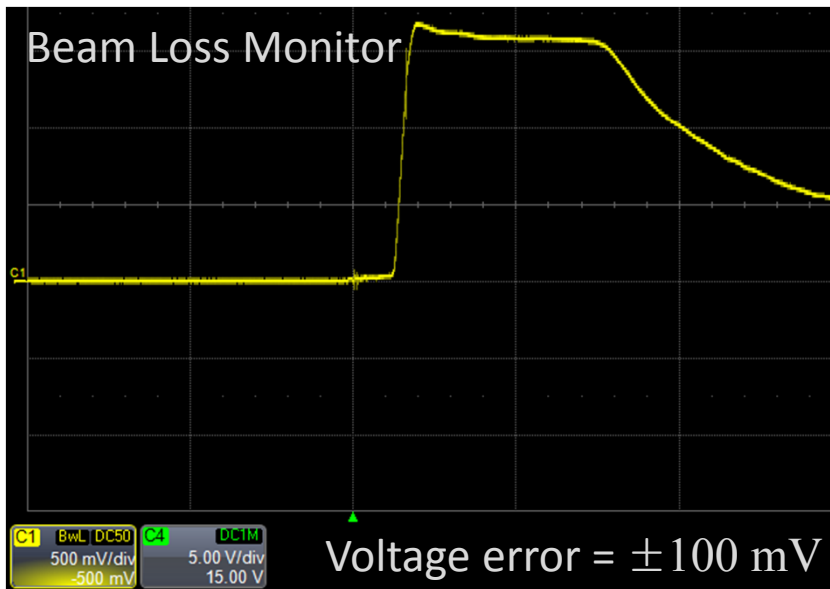
Acc: 36.5 kV modulator V

Beam on

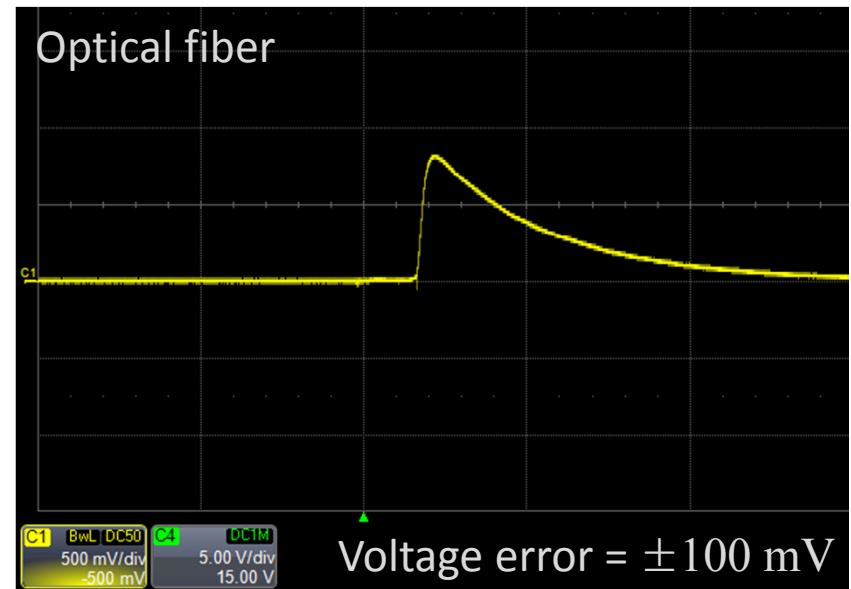
Screen on

Bending off

PMT ctrl. V = 0.6 V



PMT ctrl. V = 0.6 V



Summary

Parameter	Instruments	Number	Resolution
Beam Position & Beam Energy	Stripline BPM	160	< 5 μm
	Cavity BPM	49	< 1 μm
Beam Charge	Turbo ICT	10	< 1 pC
Beam Size	Screen Monitor	54	< 10 μm
	Wire Scanner	9	< 10 μm
Bunch Length	Coherent Radiation Monitor	4	-
	Transverse Deflecting Cavity	3	< 10 fs
Beam Arrival Time	Beam Arrival Time Monitor	10	< 30 fs
Beam Loss	Beam Loss Monitor	26	-

Thank you for your
attention