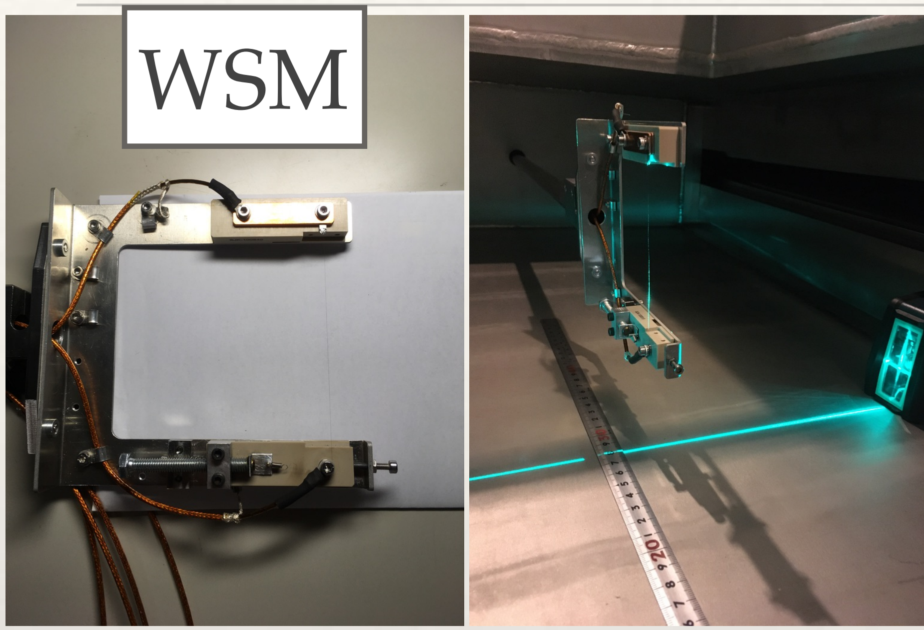
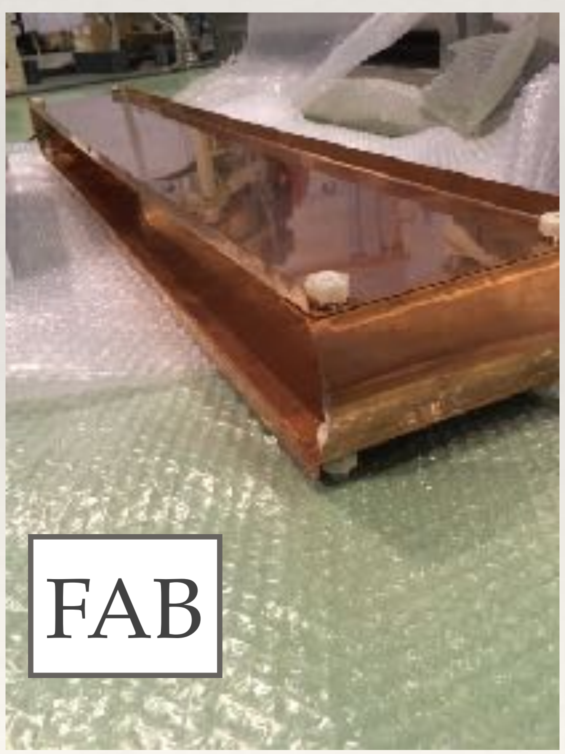
21 July 2022

BPM & WSM Analysis

E. Yamakawa

Layout at KURNS





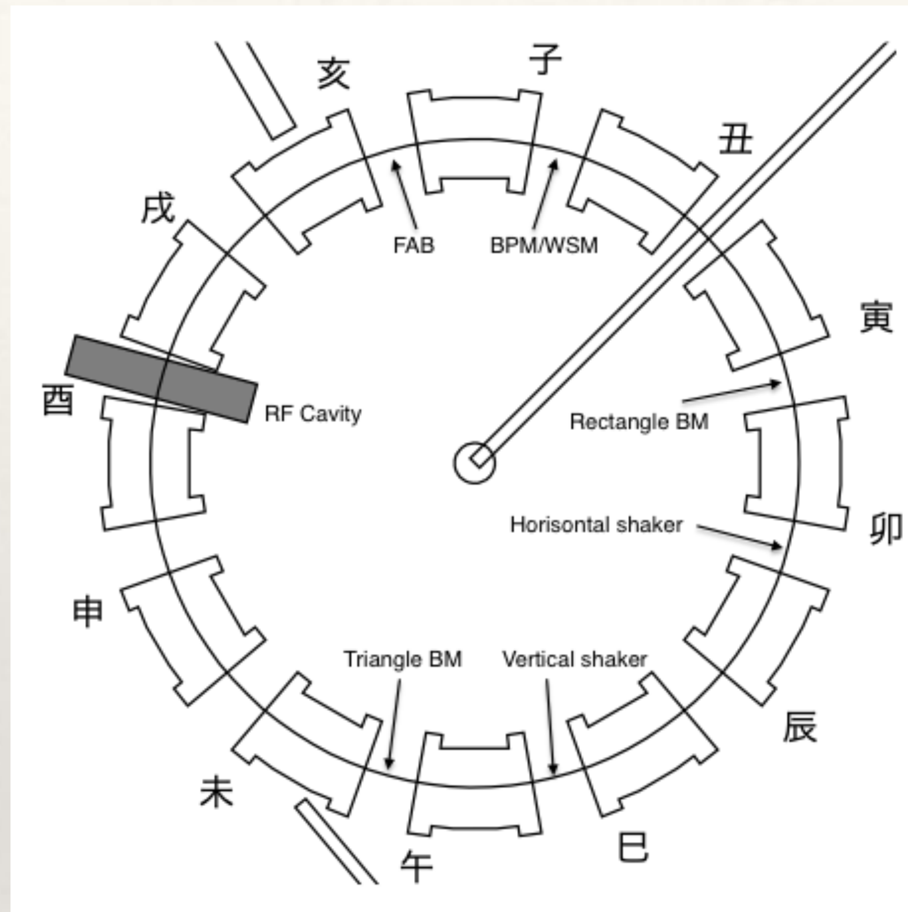
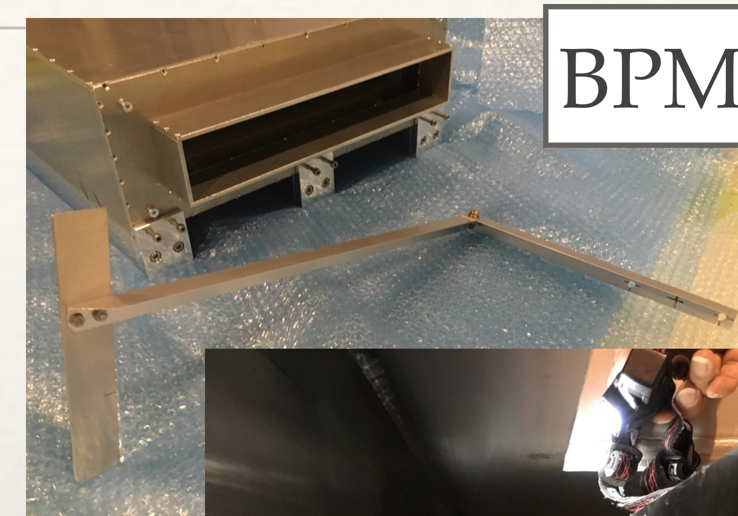


Figure 4: The illustration of beam monitors installed in the KURNS main ring.



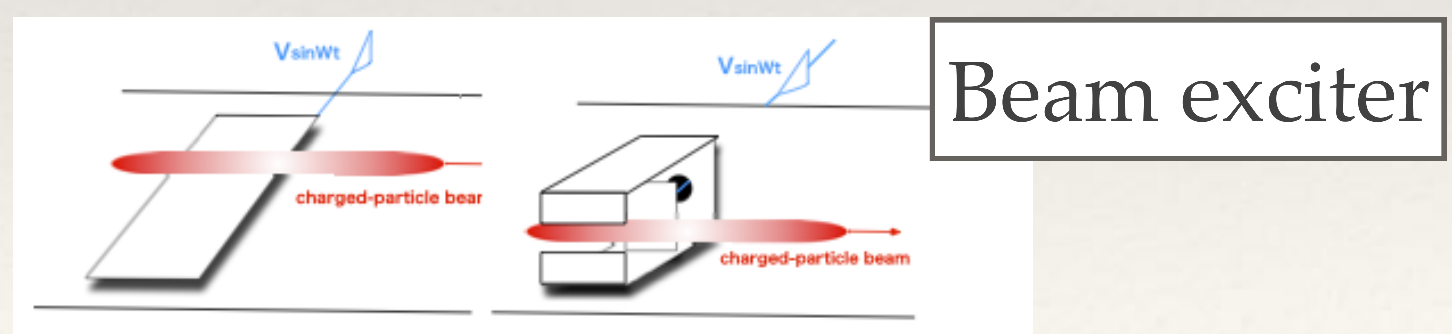


Figure 12: Left: the shaker to excite the vertical betatron oscillation. Right: the shaker to excite the horizontal betatron oscillation.

BPM Position Measurements

- Beam positions were computed by BPM waveform signals and pre-measured BPM parameters.
- The angle of horizontal beam orbit was measured by the scraper to estimate beam position at horizontal BPM.
  - Beam acceleration was stopped at certain energy (FT energy).
  - Push the scraper inward to interrupt the beam at FT energy.

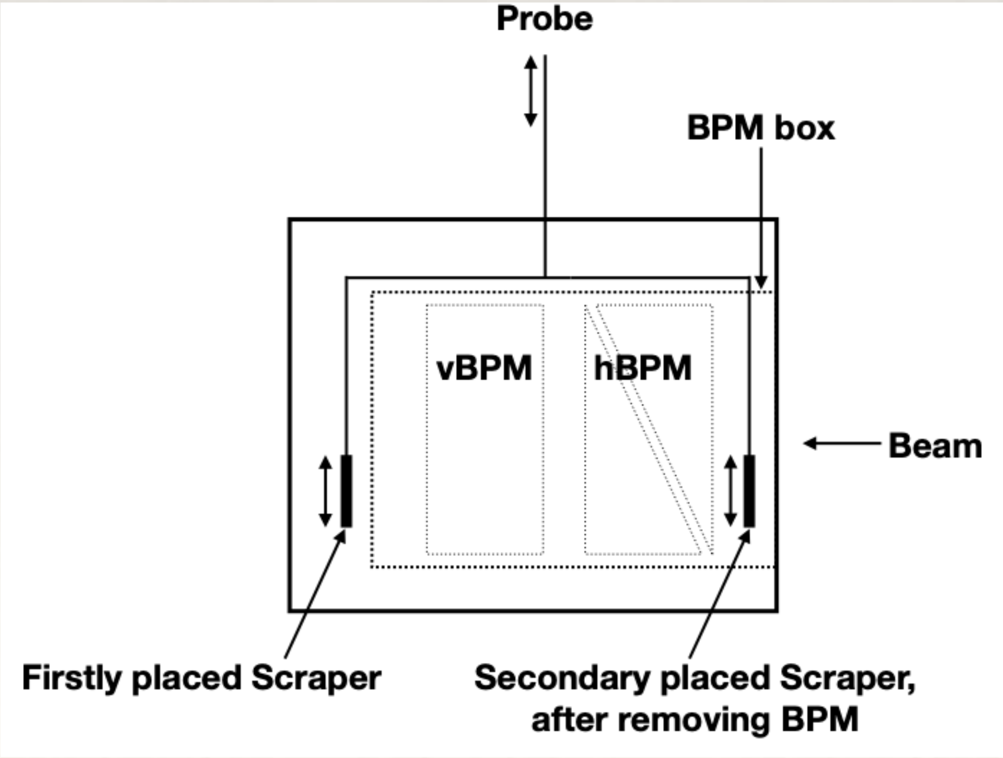
The measured beam position (y) is computed as

$$y = \frac{1}{K}\frac{E1 - E2}{E1 + E2} + \delta$$

where K the position sensitivity, δ the offset and E the electrode signal.

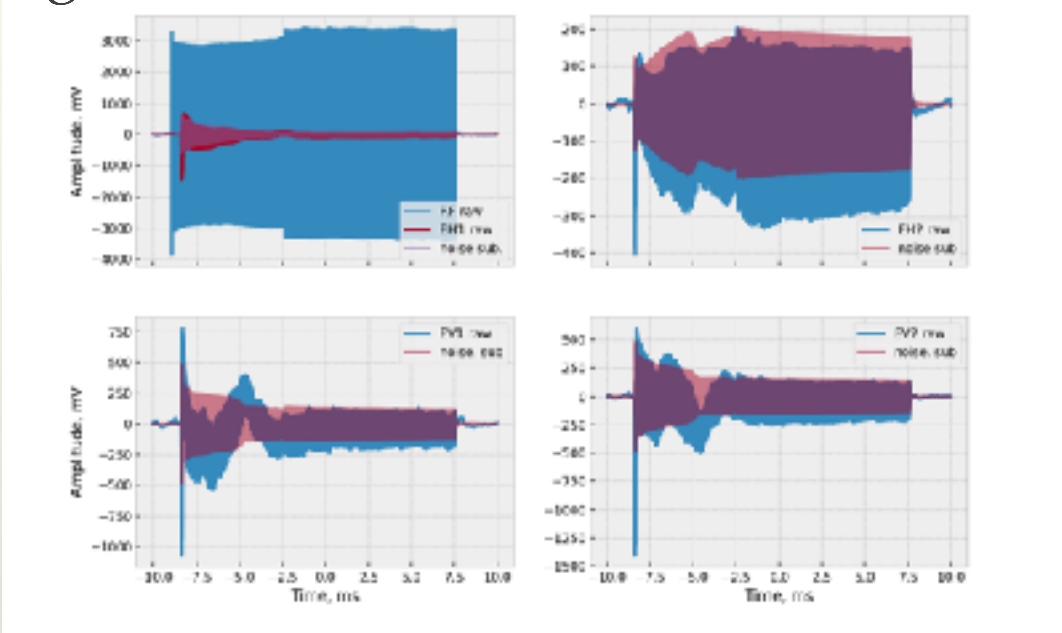
	Horizontal
Position sensitivity [1/mm]	-0.00513 ± 8.46E-6
Offset	0.0172 ± 8.01E-4
	Vertical
Position sensitivity [1/mm]	0.0341 ± 1.70E-4
Offset	-0.0445 ± 2.51E-3

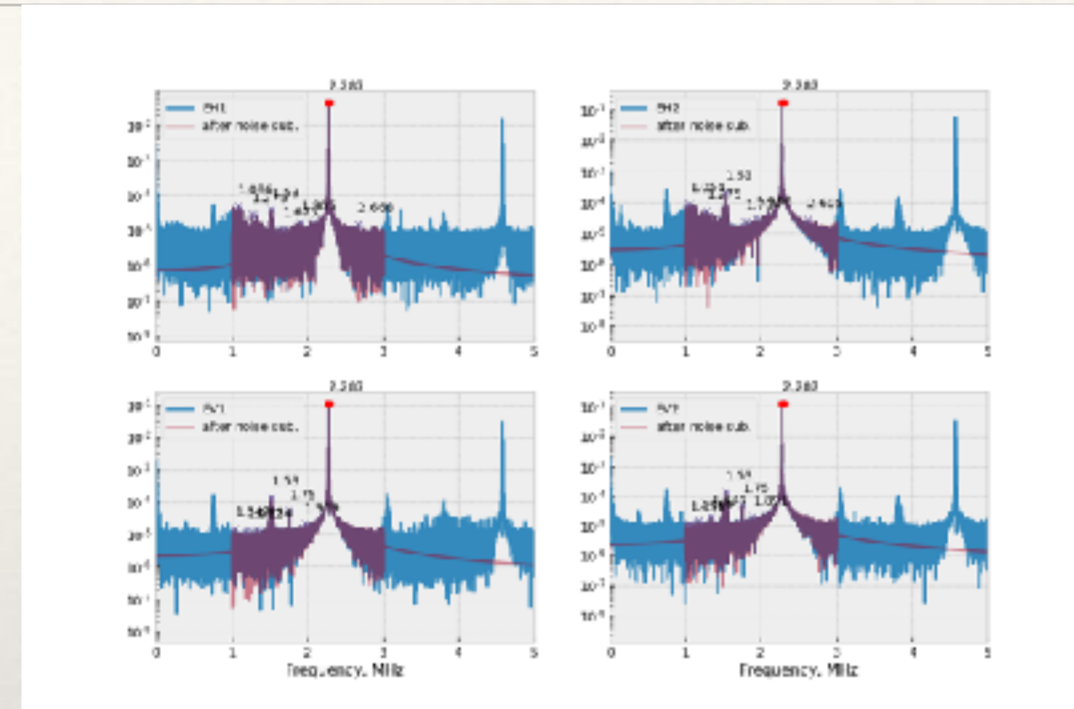
Table 2: BPM calibration parameters.

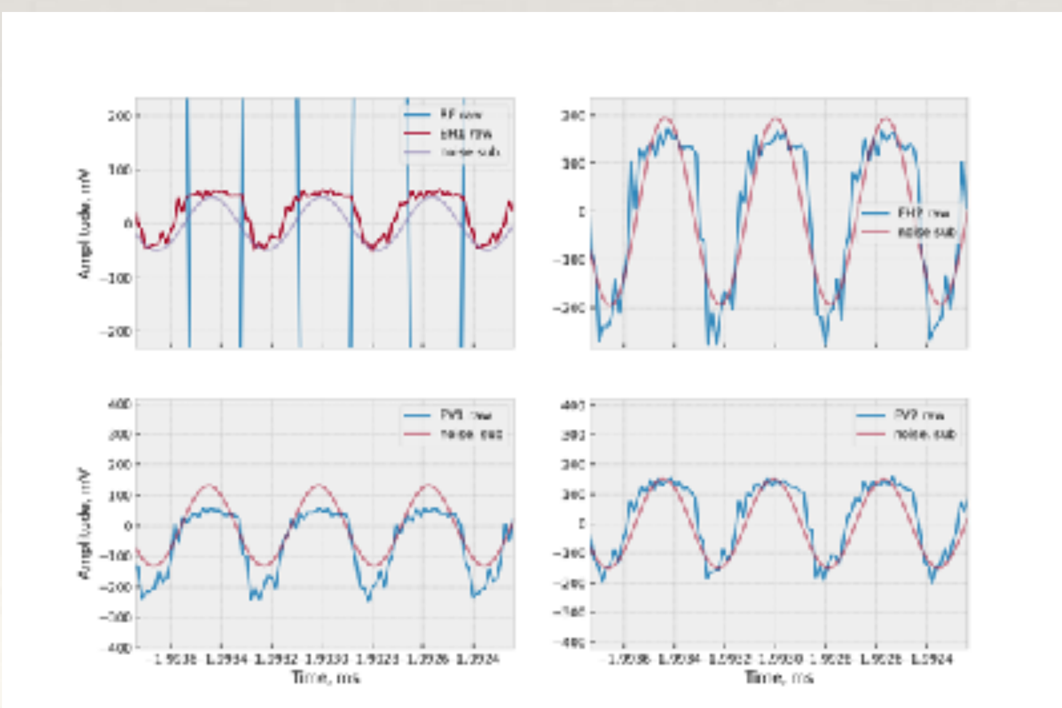


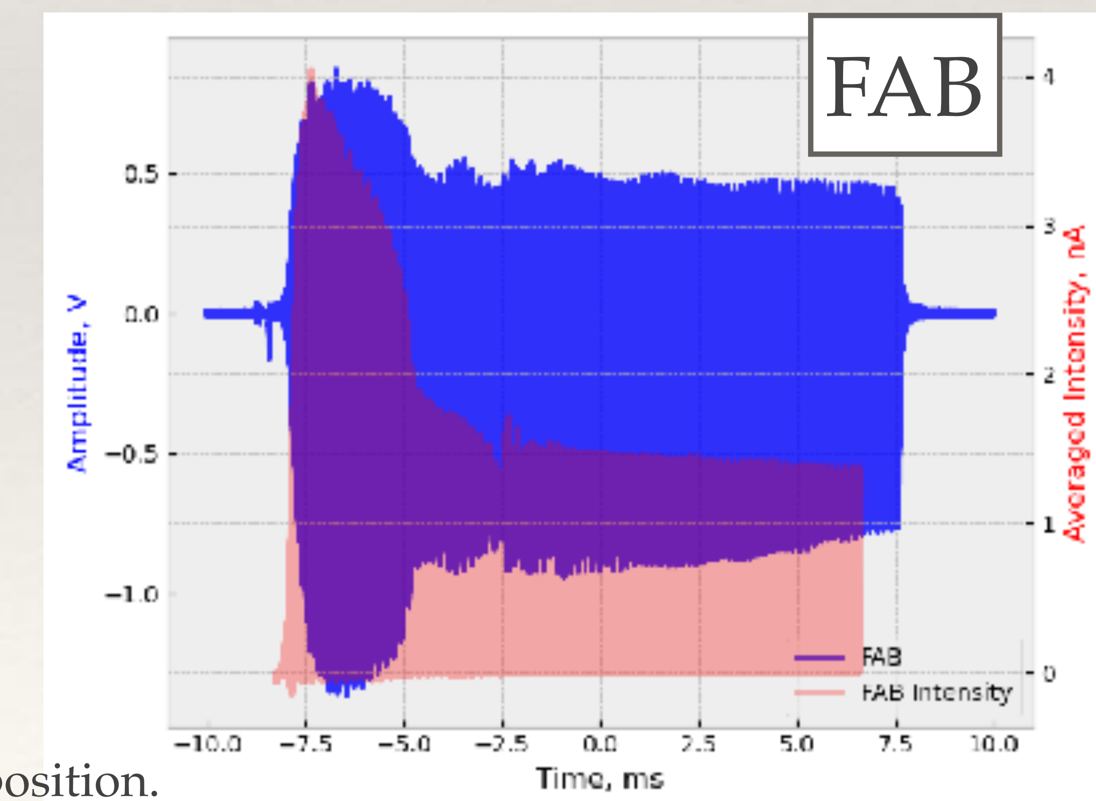
BPM Position Measurements

Signal subtraction : 1MHz<f, f<3MHz



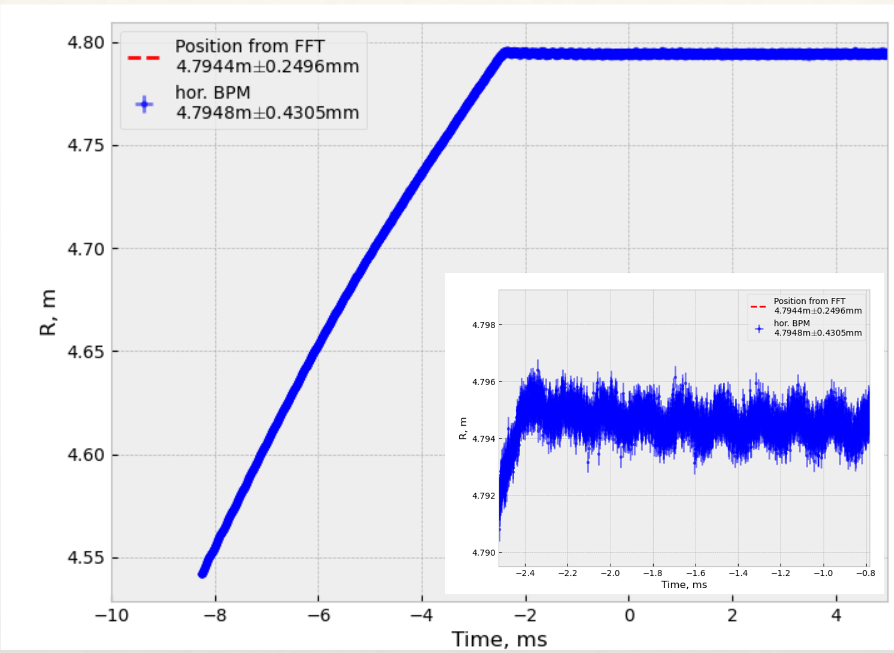




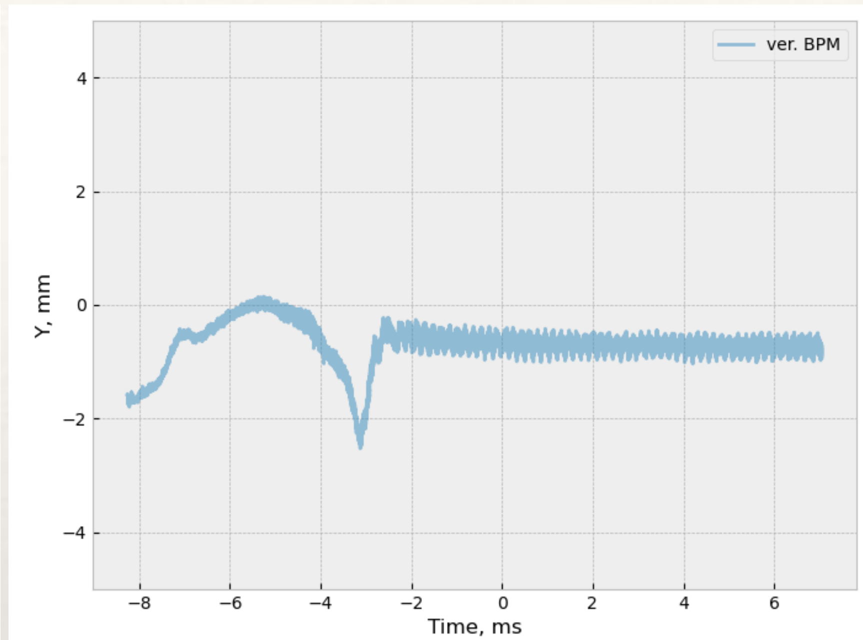


Peak to peak signal of one RF period is used to compute beam position.

BPM Position Measurements



Horizontal position displacement



Vertical position displacement

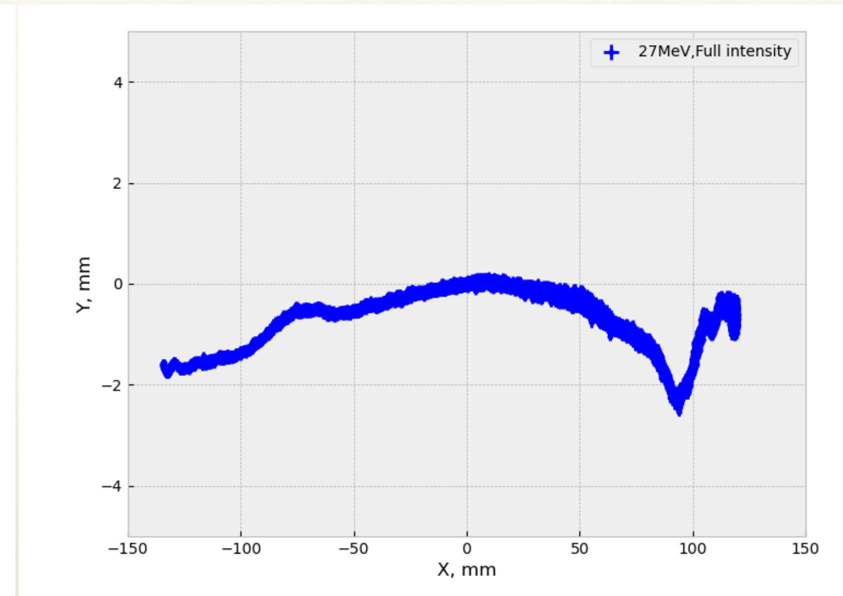
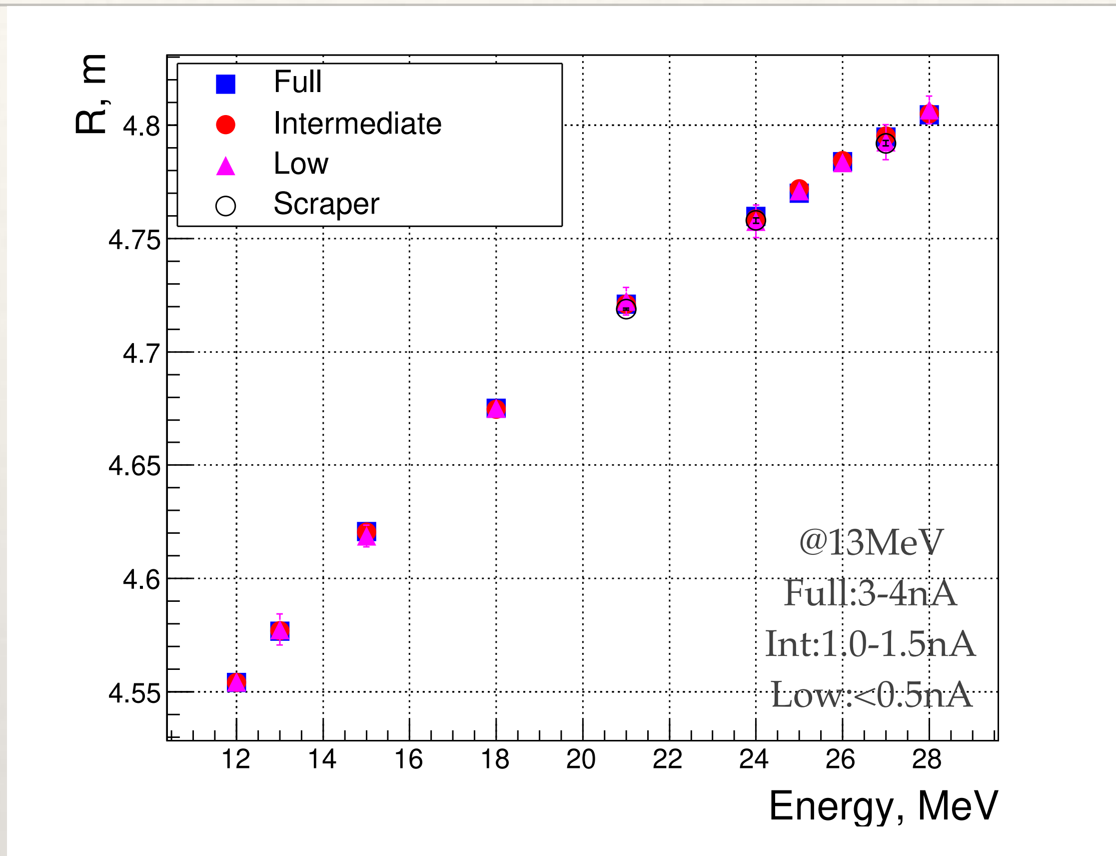
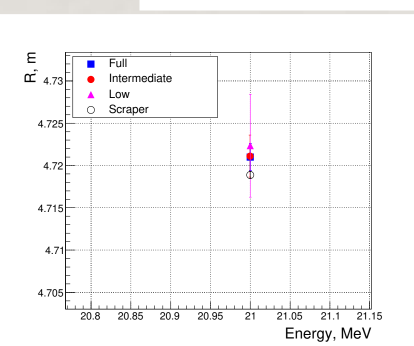


Figure 9: The horizontal and vertical beam positions.
3.7nA at around 13MeV

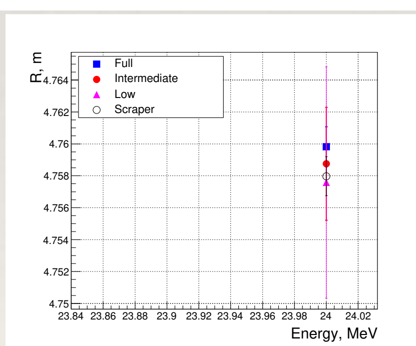
- Synchrotron oscillation has been seen when the synchronous phase was jumped (20deg -> 0deg).
- FFT is applied within two synchronous periods at FT energy, which is used to compute beam positions.
- Beam position movements has been measured over the full range of BPM.

BPM Position Measurements

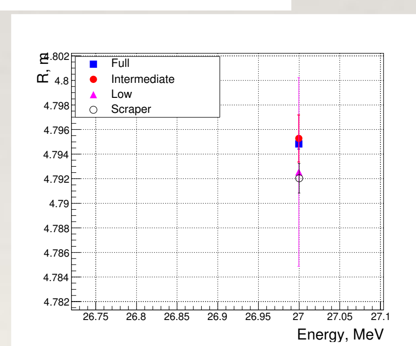




(a) 21 MeV



(b) 24 MeV

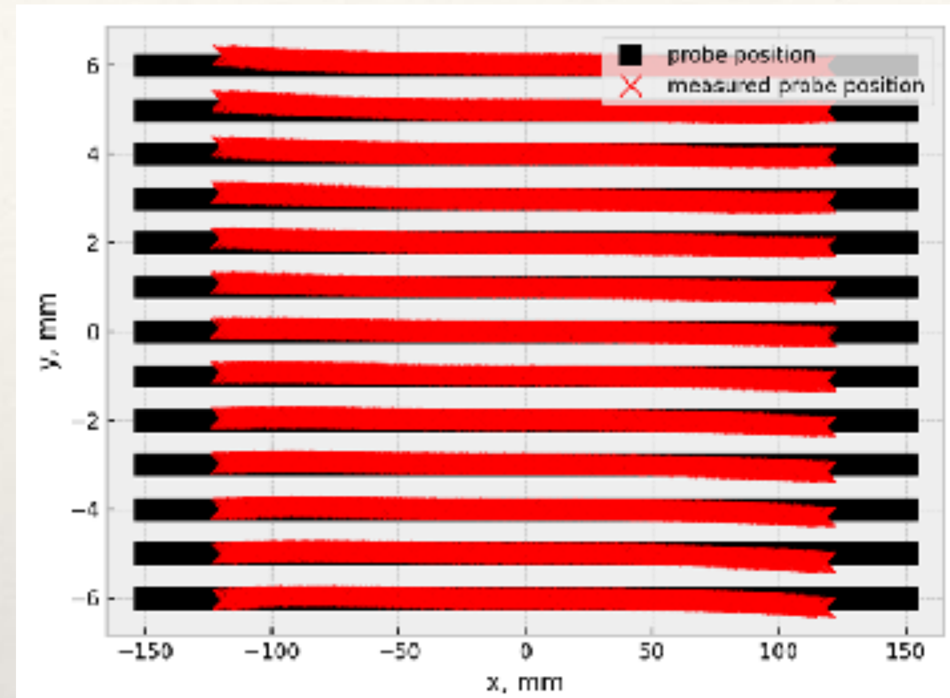


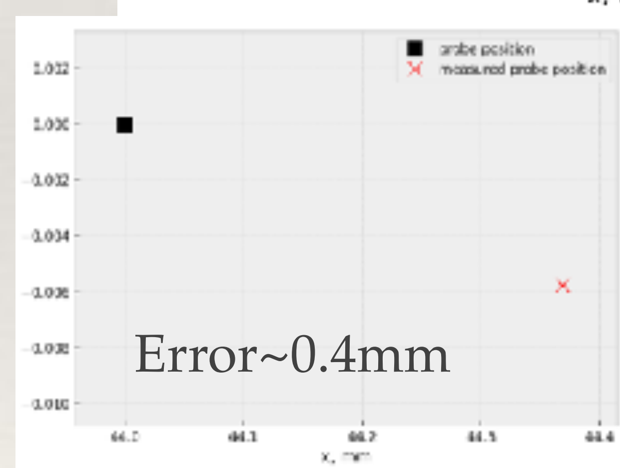
(c) 27 MeV

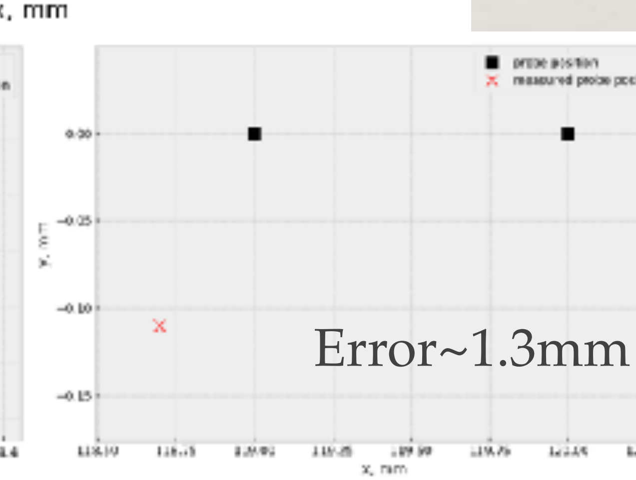
Figure 10: The horizontal beam positions with different flat top energies.

FT energy	21 MeV	24 MeV	27 MeV
BPM	4.7210±1.5995E-3	4.7598±1.2548E-3	4.7948±0.4305E-3
Scraper	4.7189±0.3882E-3	4.7580±1.223E-3	4.7920±1.199E-3

Pre-measurement at Lab.







- **Pre-measured BPM features have been changed.**
- **S/N ratio**
- **2D error map will help to improve position accuracy for FETS-FFA.**

BPM Position Measurements

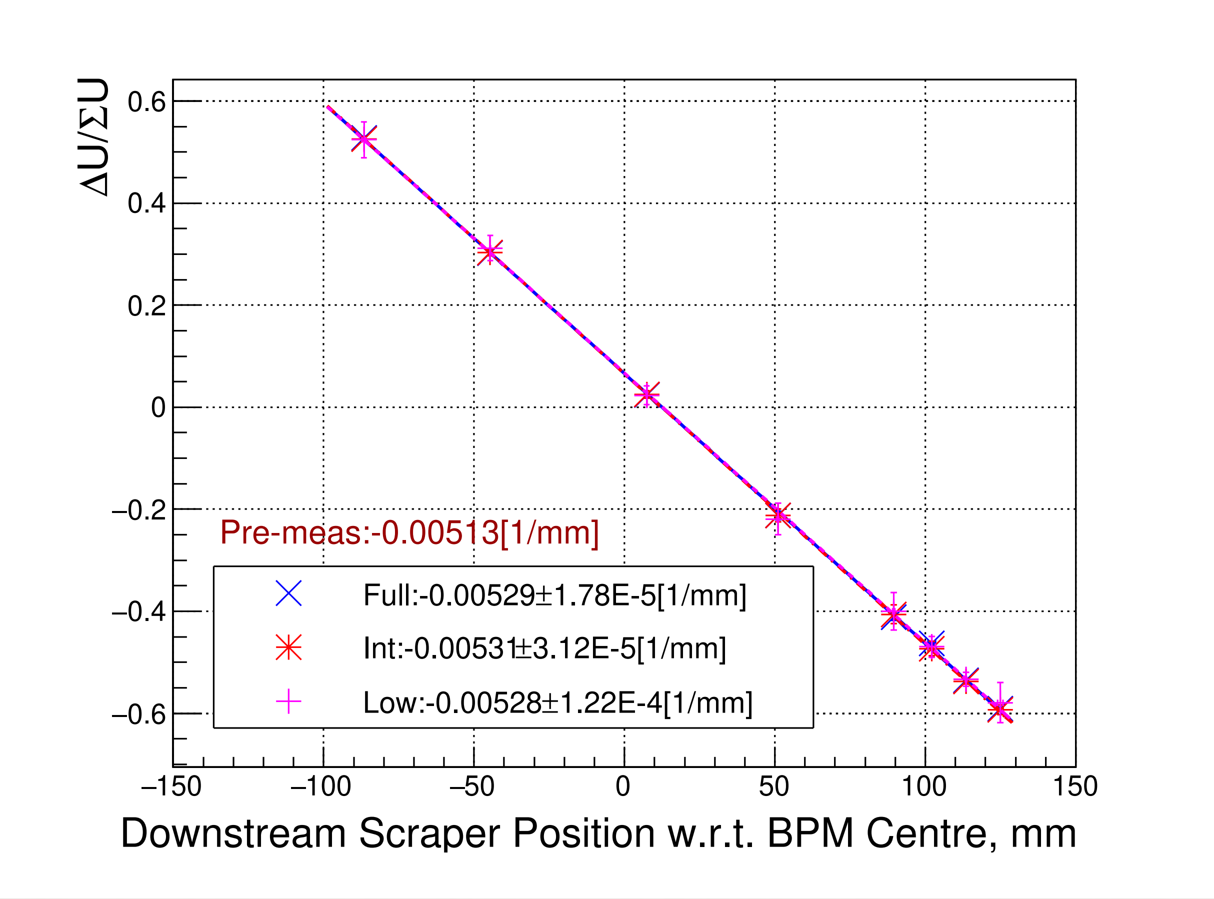
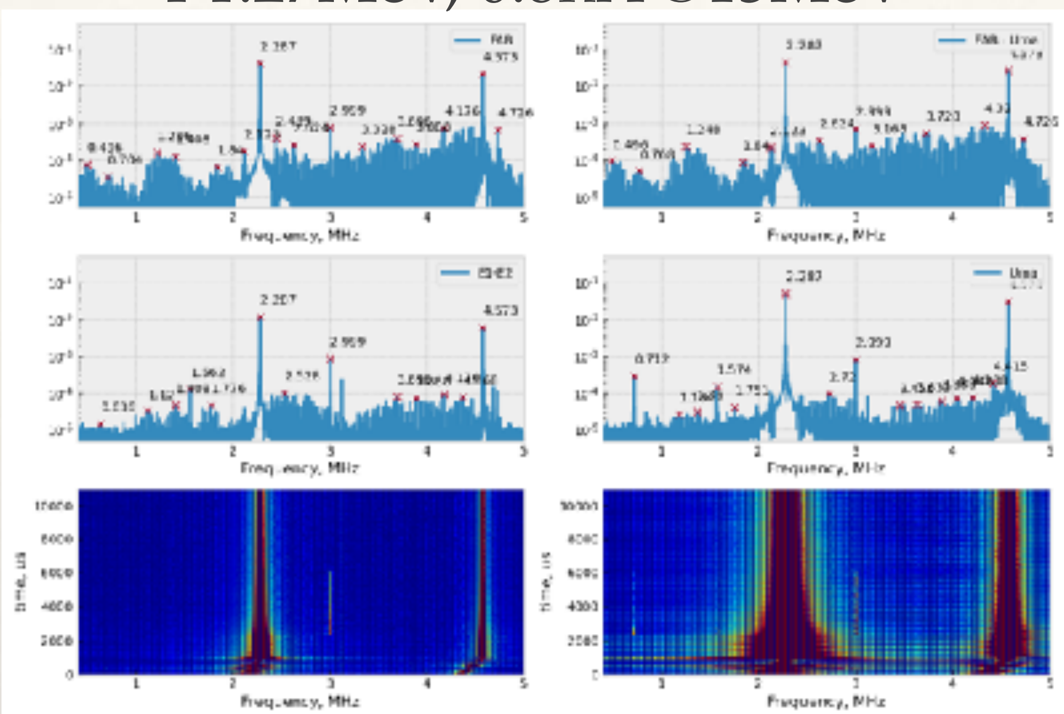


Figure 11: The horizontal position sensitivity measured by BPM with KURNS beam.

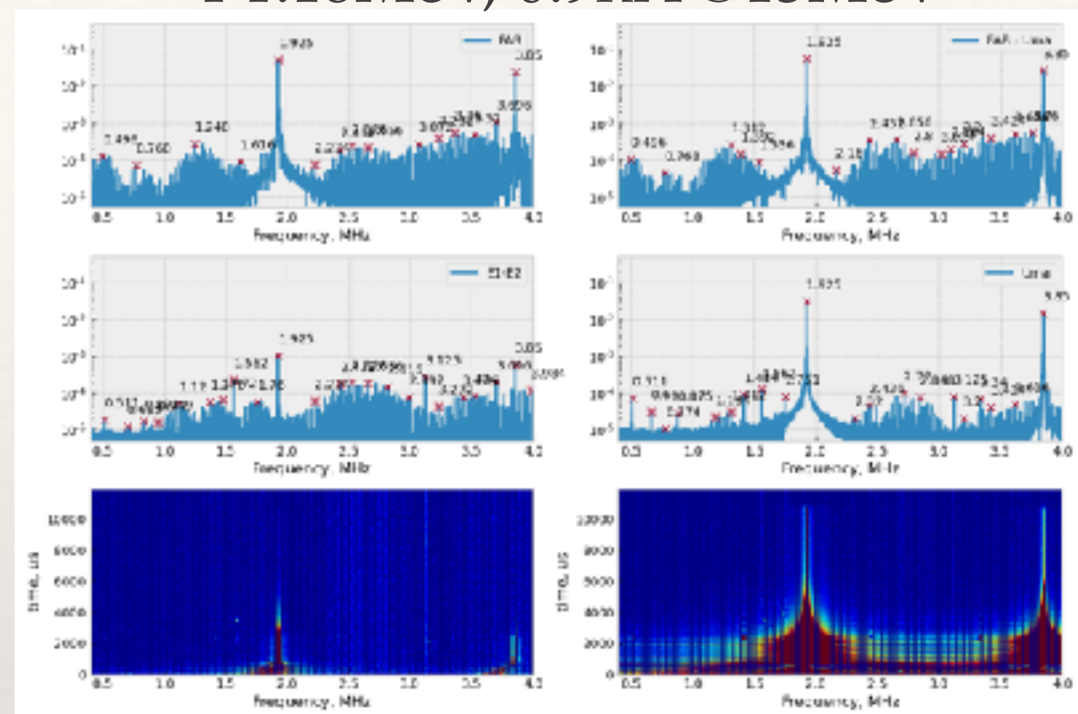
- **Position sensitivity for each beam intensity is different from the one measured at ISIS Lab., but they are consistent each other.**
- **Worth for considering to install a beam scraper close to BPM for FETS-FFA. The beam-based position sensitivity and offsets could be useful to adjust variable capacitances and improve position accuracy.**

BPM Hori. Tune Measurements

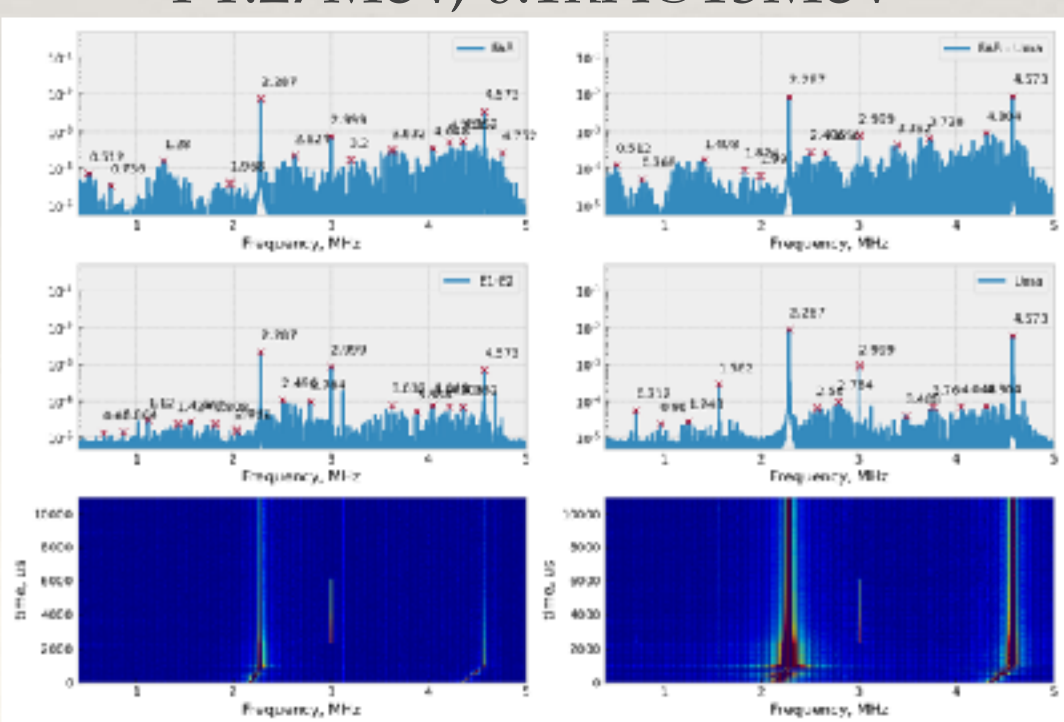
FT:27MeV, 0.8nA @13MeV Fd=2.999MHz



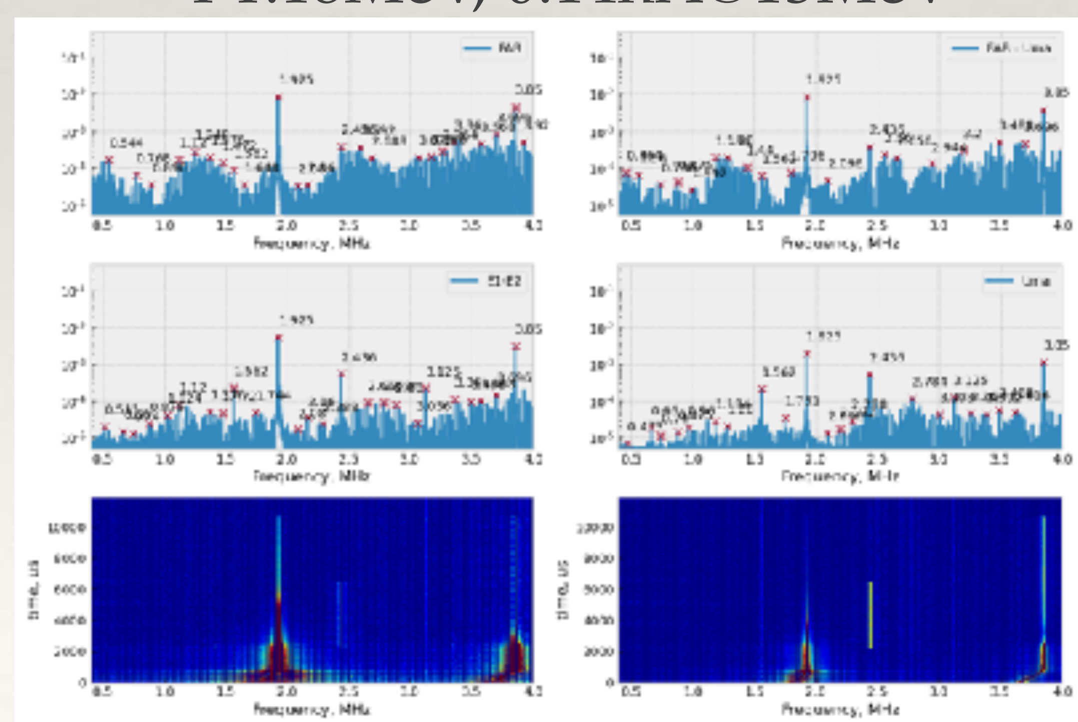
FT:18MeV, 0.9nA @13MeV Fd=2.436MHz



FT:27MeV, 0.1nA@13MeV

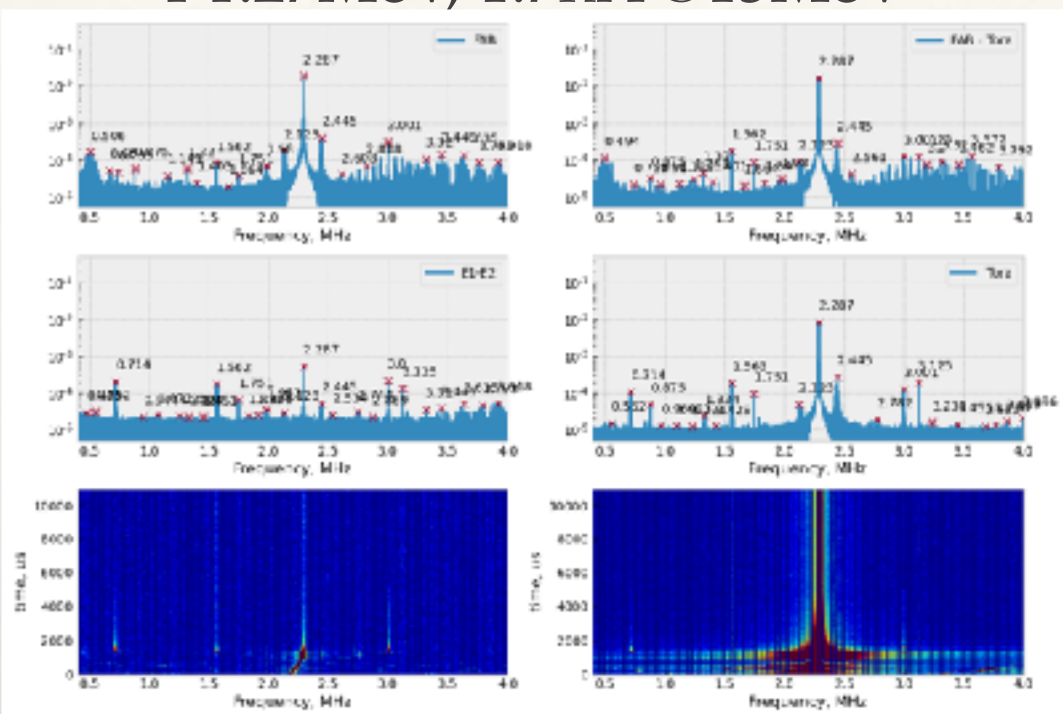


FT:18MeV, 0.14nA@13MeV

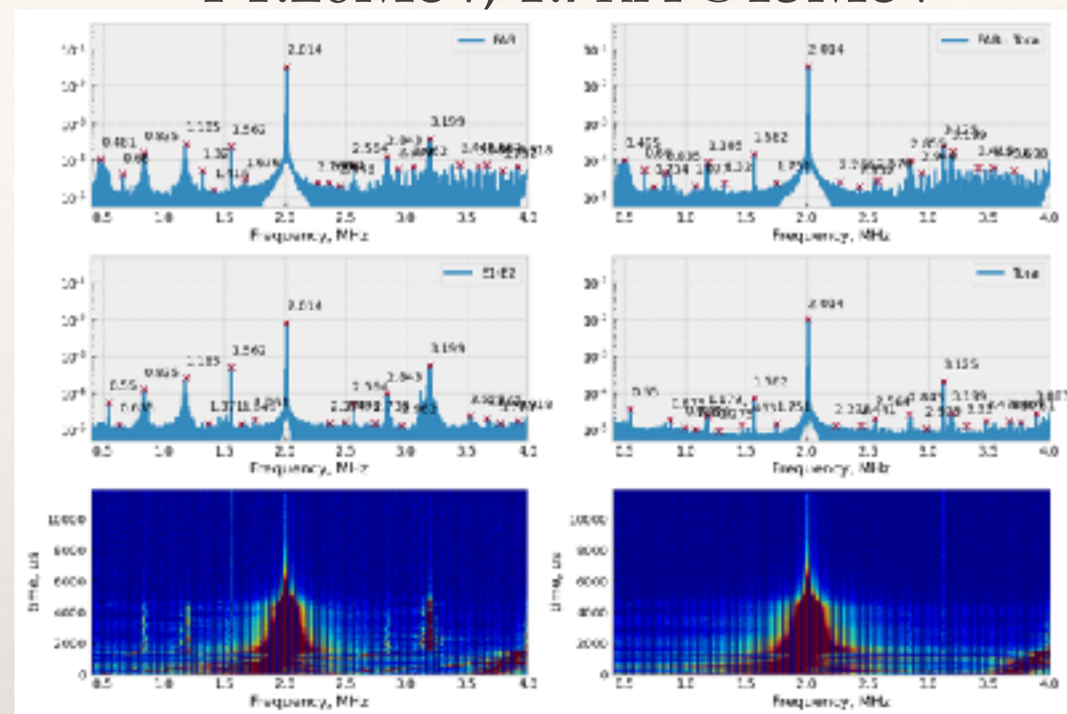


BPM Vert. Tune Measurements

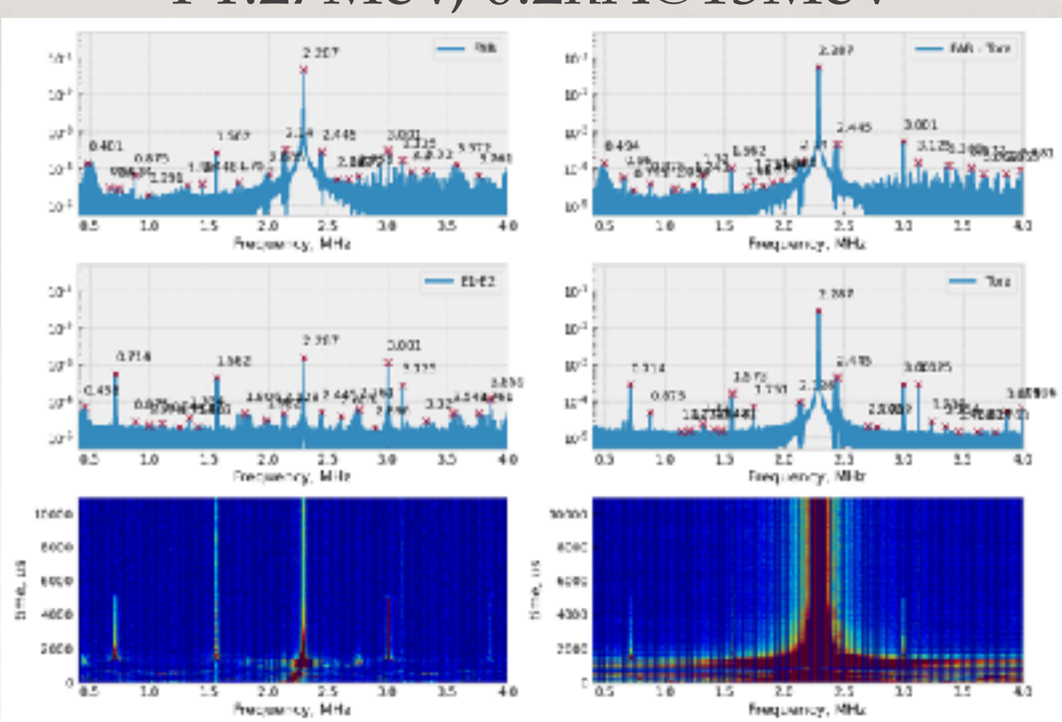
FT:27MeV, 1.7nA @13MeV Fd=3.001MHz



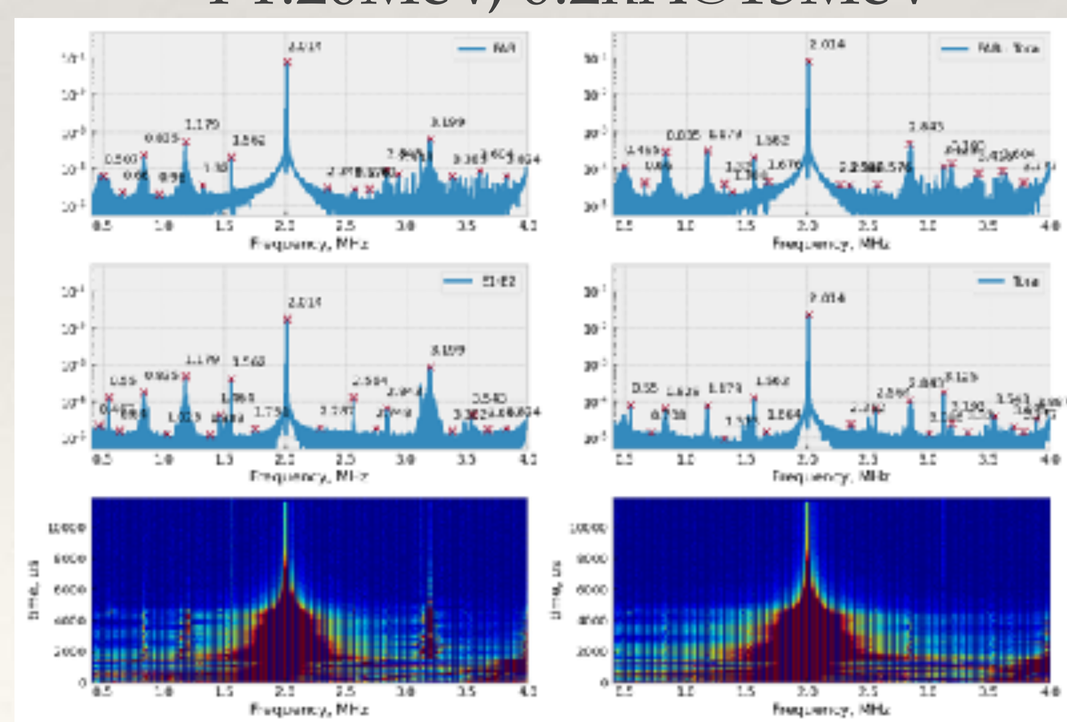
FT:20MeV, 1.7nA @13MeV Fd=2.564MHz



FT:27MeV, 0.2nA@13MeV



FT:20MeV, 0.2nA@13MeV



BPM Summary

- Capacitive pickup type of BPM measured the beam position displacements in horizontal and vertical within a few mm accuracy when the beam intensity was about 4 nA at about 13 MeV in KURNS FFA. This is consistent to the case when the beam intensity was about 10 times lower.
- The vertical BPM measured betatron tune over the range of BPM aperture. The horizontal BPM measured betatron tune when the beam was at around centre of BPM aperture. But it was difficult to detect the tune when the beam was at around the edge of BPM aperture. This can be improved by better S/N ratio and stronger beam exciter (stronger horizontal kick).
- For FETS-FFA:
    - Mechanical BPM design (double the length) including a destructive beam scraper, as well as the way to measure BPM features (error-map, beam-based measurements etc), is worth for considering to achieve the position accuracy within 1mm.
    - Electronics and DAQ system need to be developed to achieve the position resolution within a few 100um.

WSM Measurements

- The ϕ30um CNT wire was installed on the WSM.
- The frame was grounded to vacuum chamber.

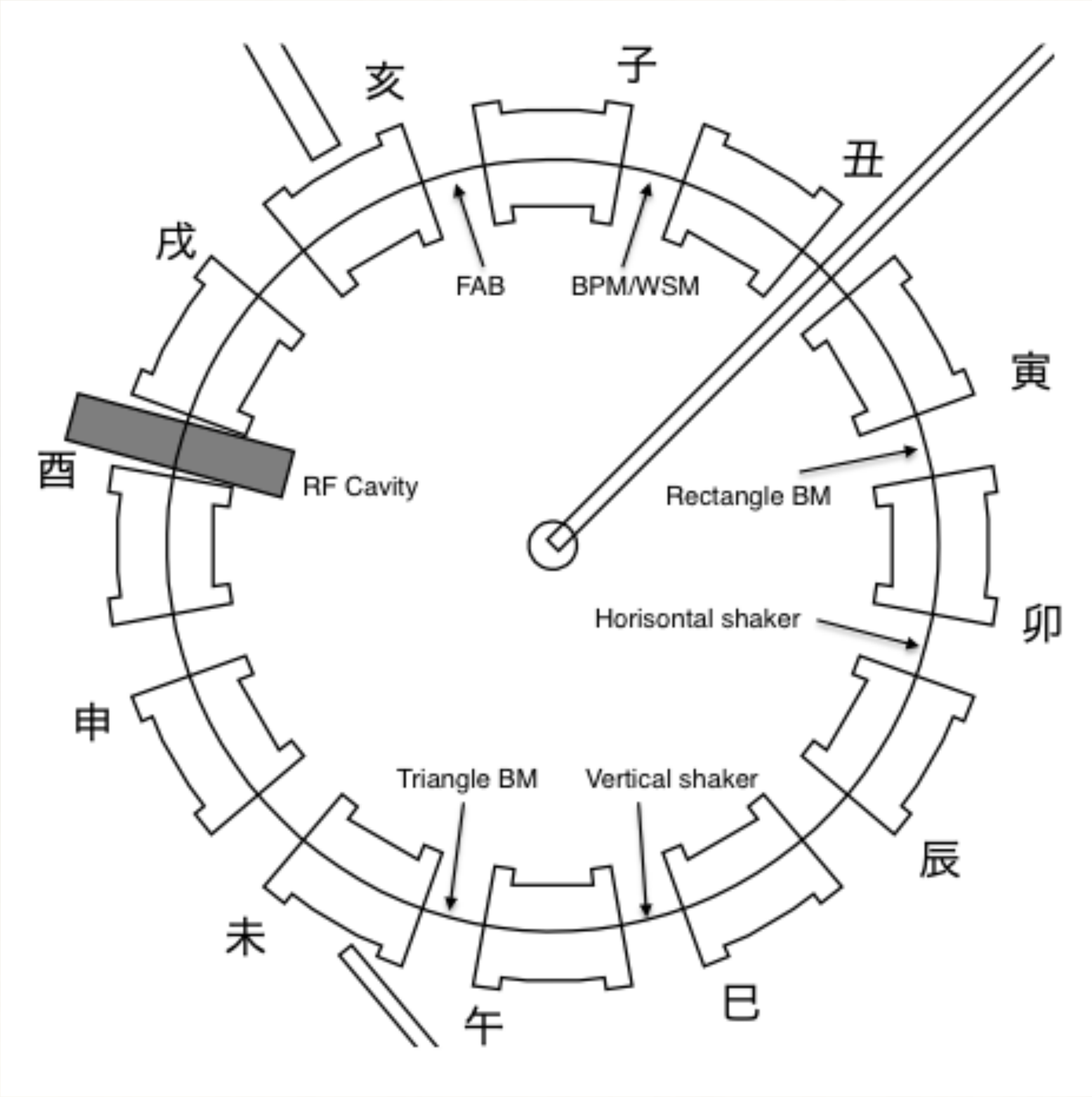


Figure 4: The illustration of beam monitors installed in the KURNS main ring.

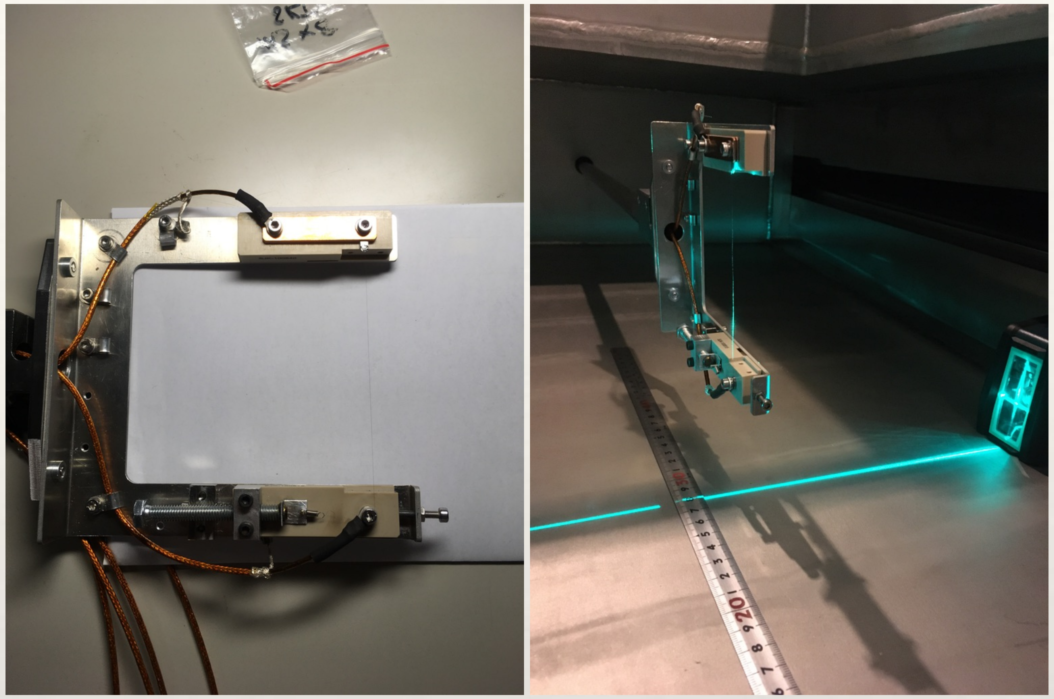
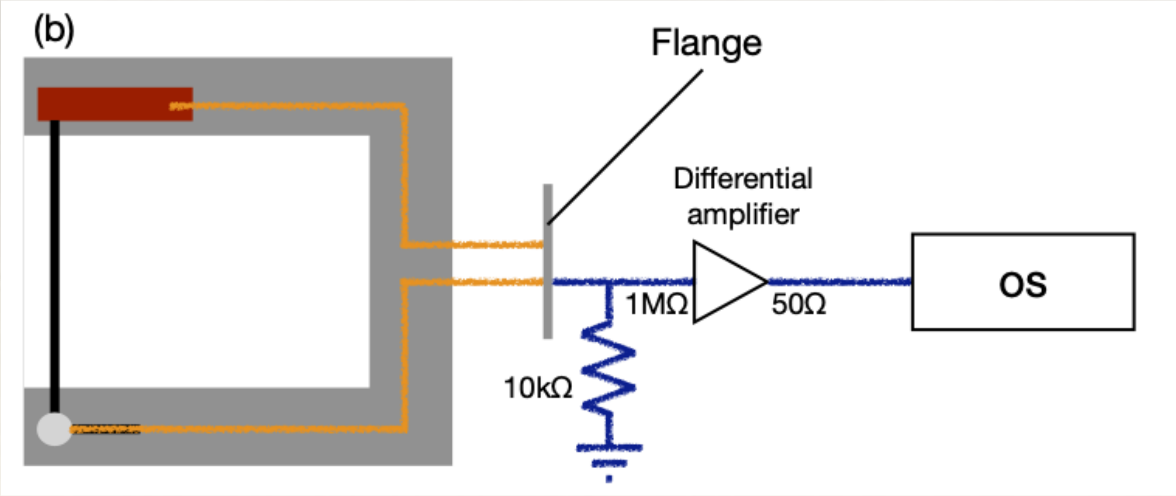
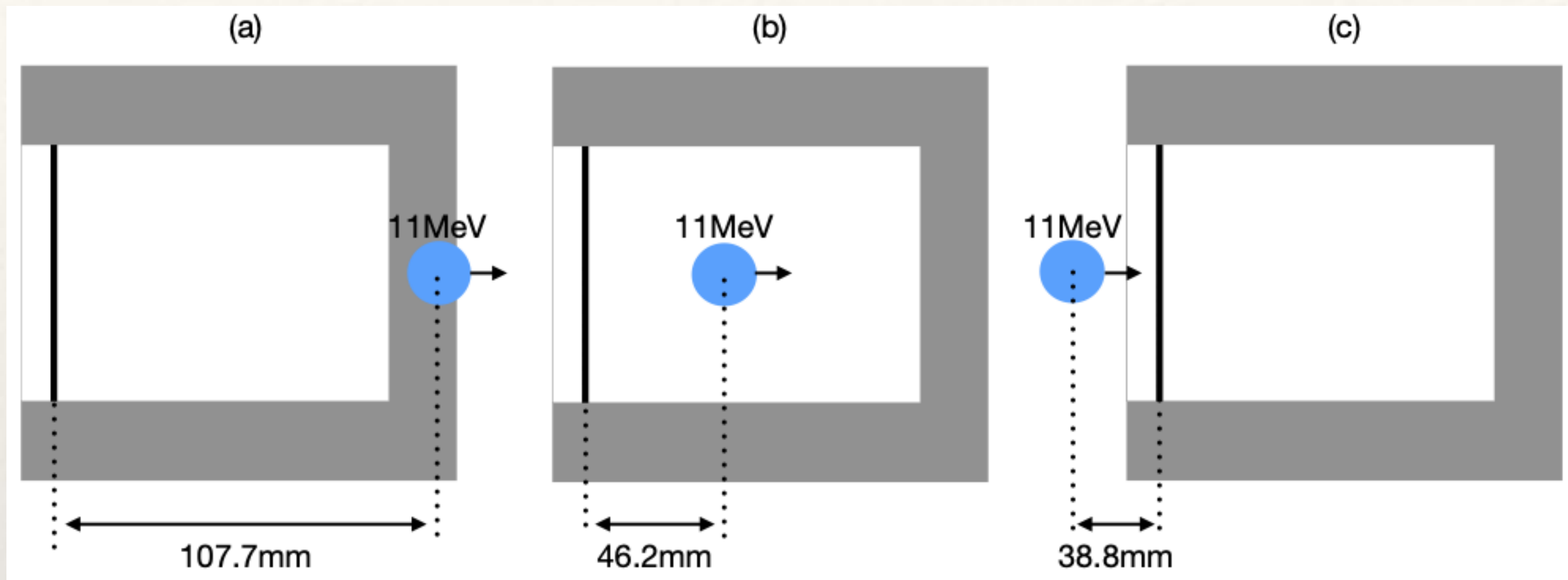
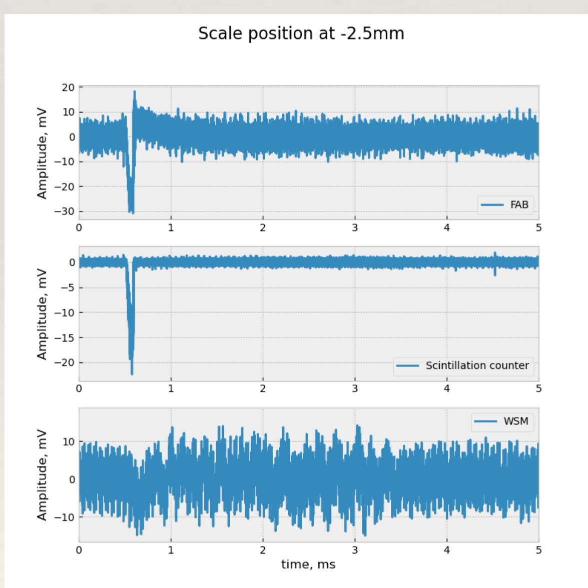


Figure 17: The WSM frame with $\phi 30$ μm CNT wire.

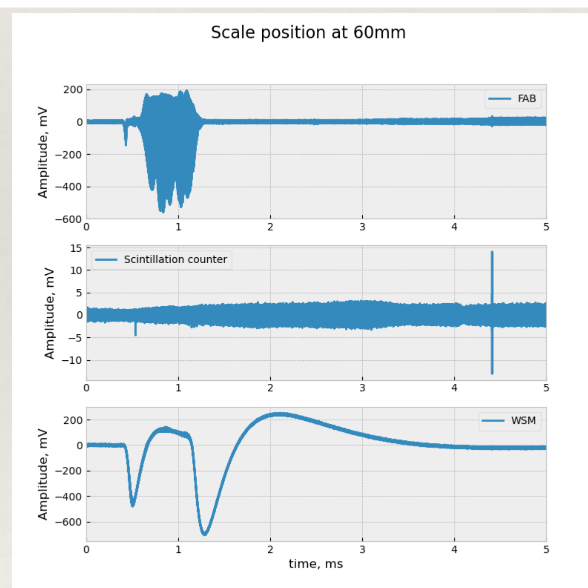


WSM Measurements

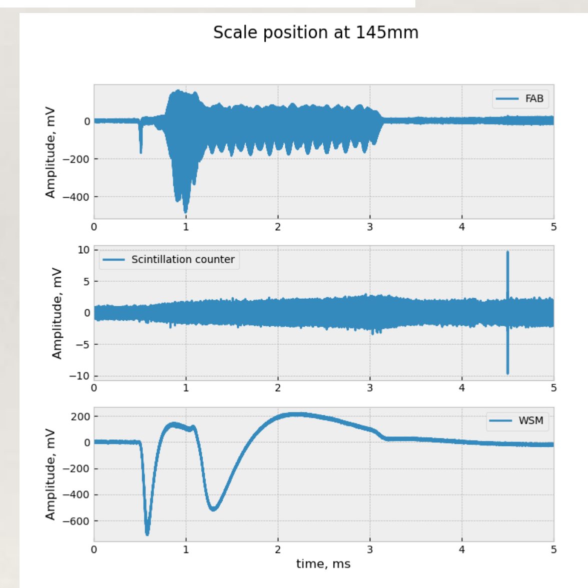




(a) The 11 MeV injection beam hit the WSM frame.



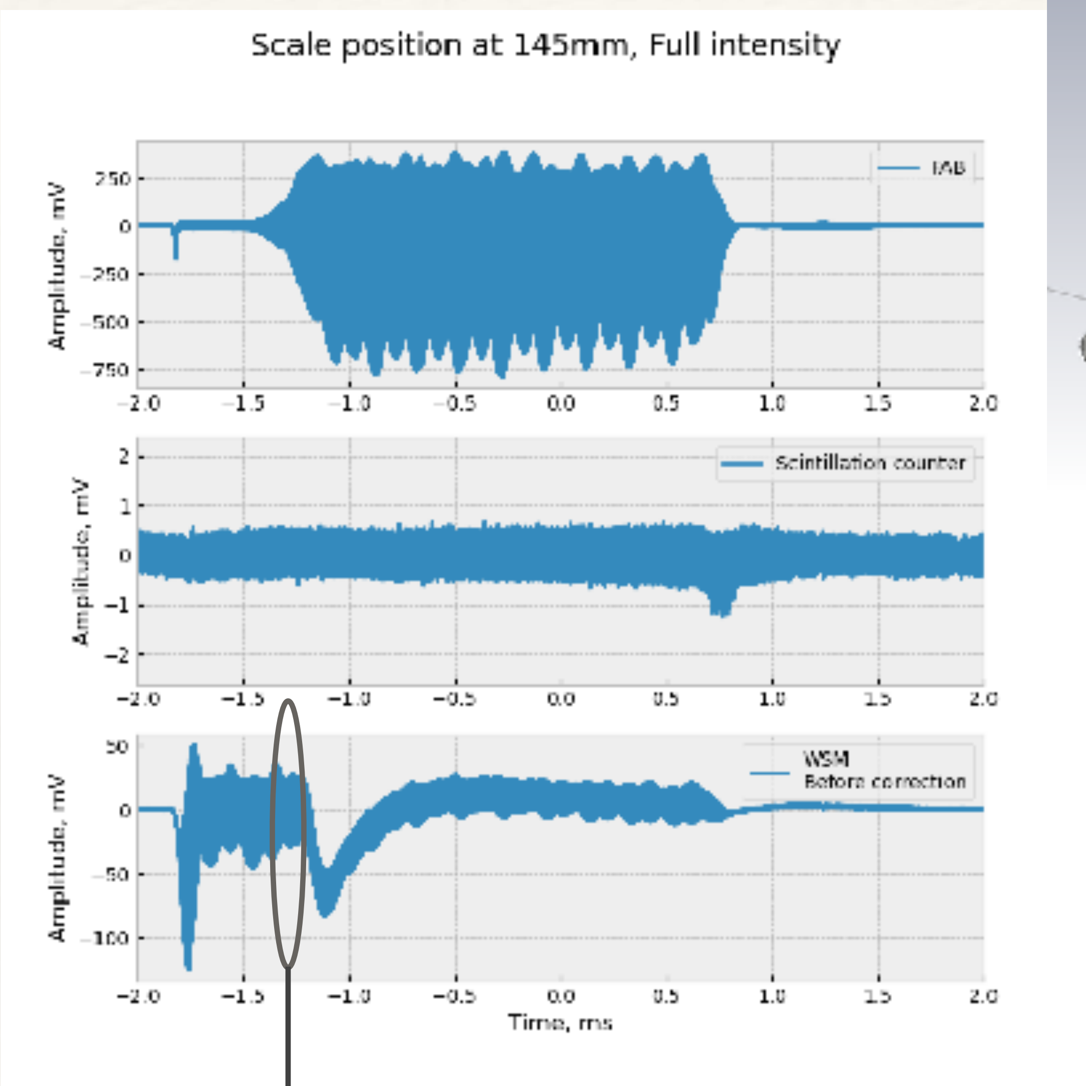
(b) The 11 MeV injection beam was between CNT wire and frame.

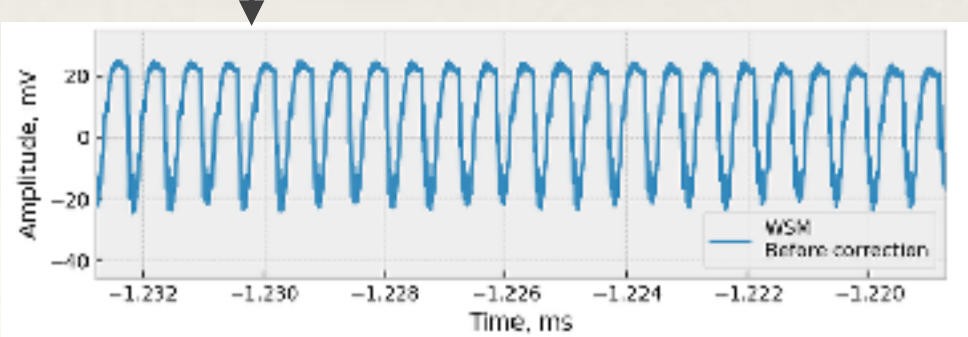


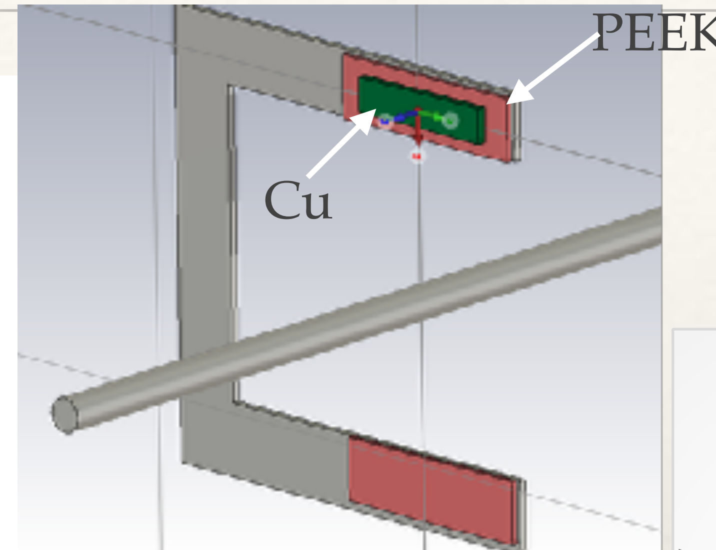
(c) The 11 MeV injection beam was inward from CNT wire.

* Shunt impedance was not used.

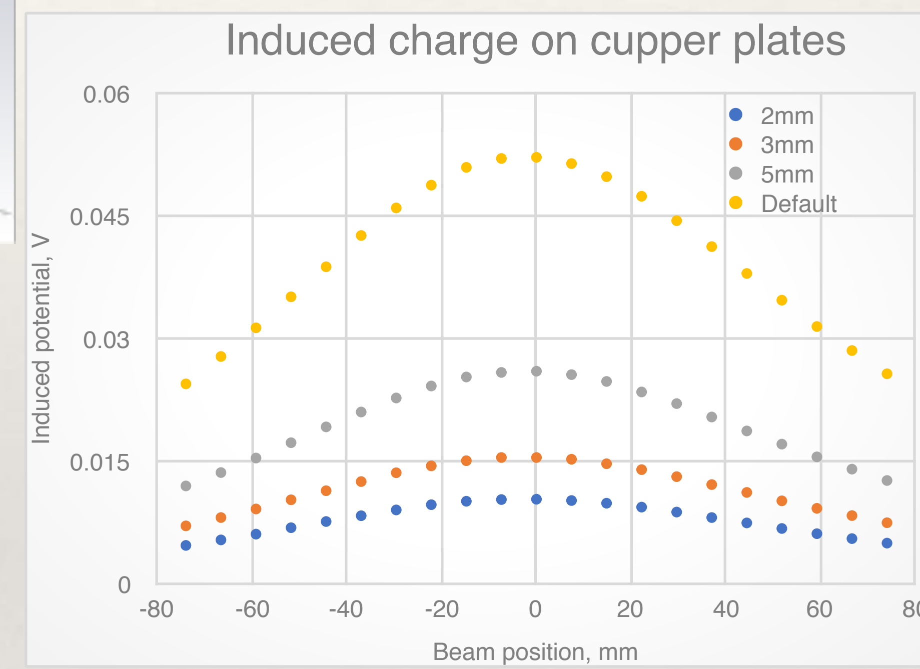
WSM Measurements





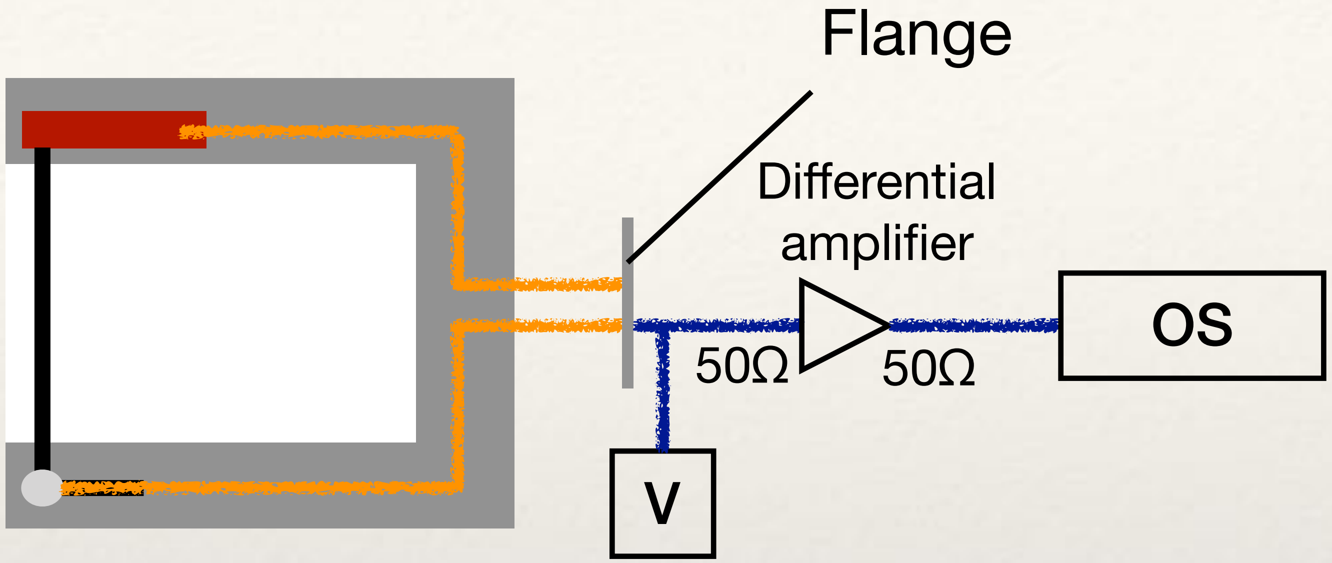


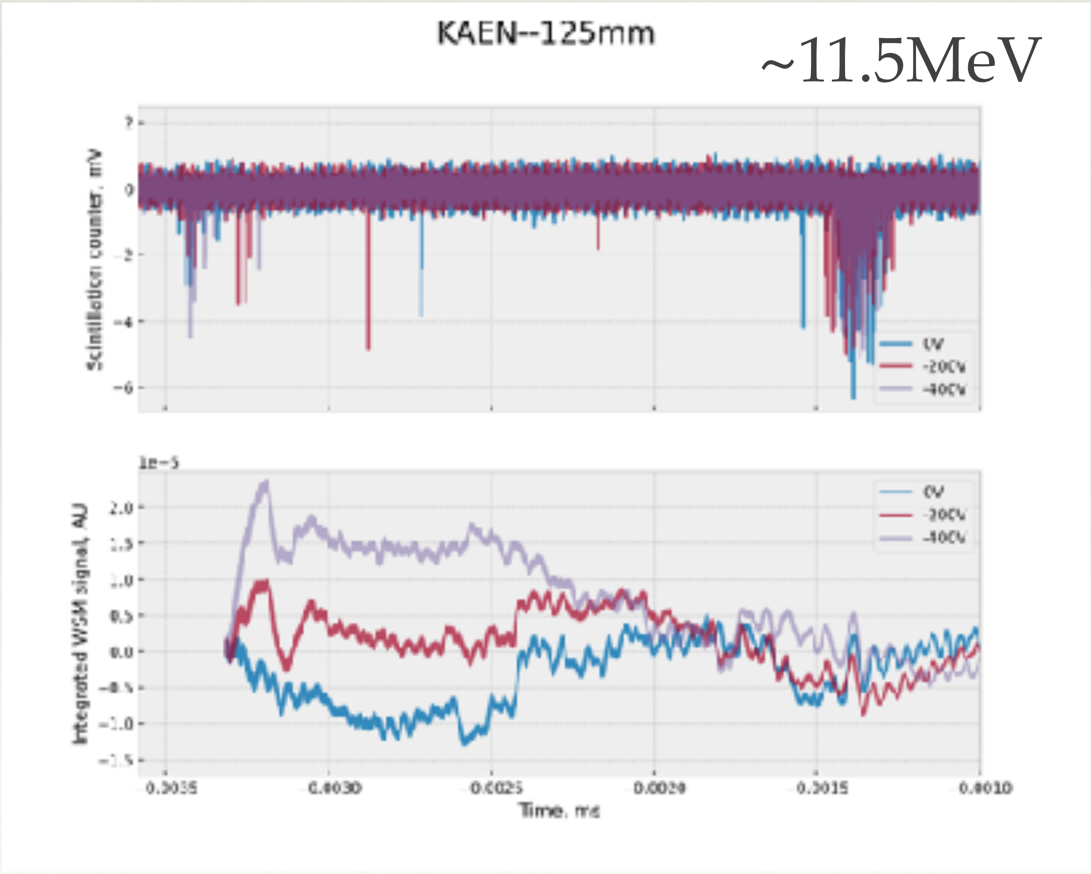
1V is applied on the probe, which position is moved in horizontal. Induced charge on copper plate is computed by CST.

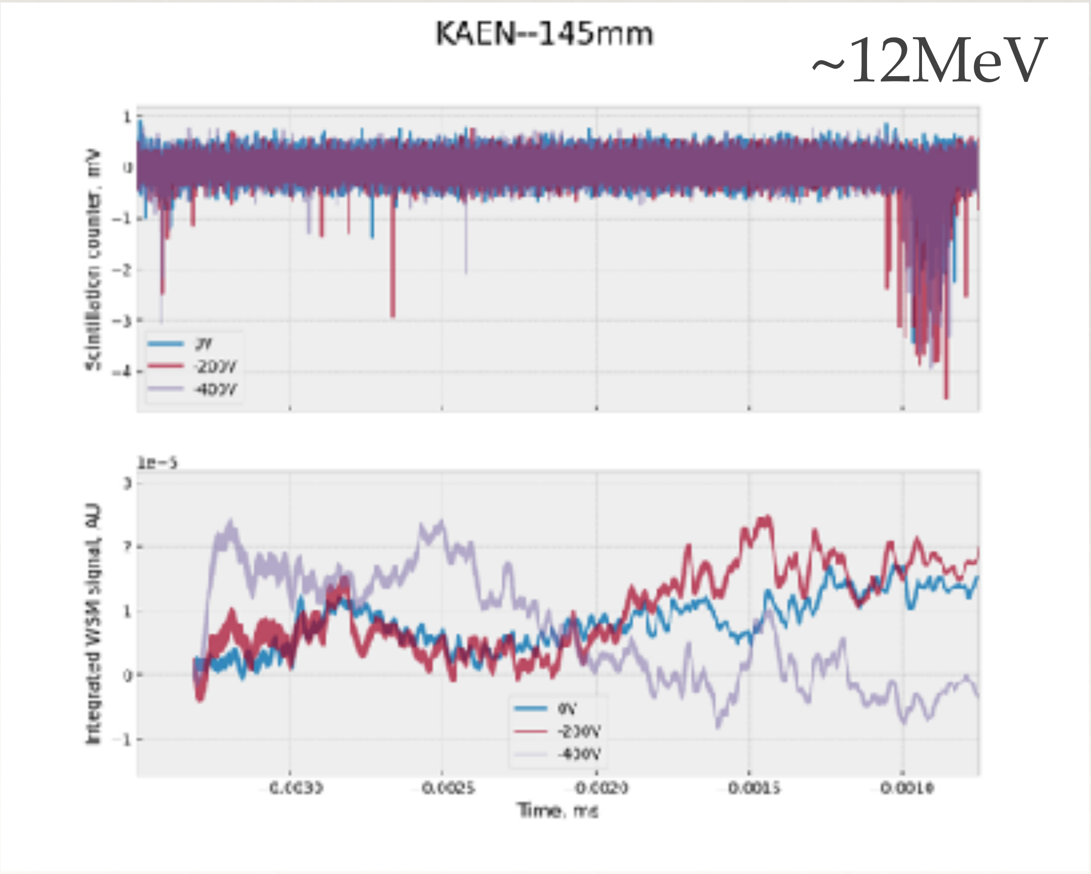


- The WSM picked up beam induced charge via metallic structures.
- The thinner PEEK block increases the capacitance between metallic plates and grounded frame, minimising induced pickup signals.

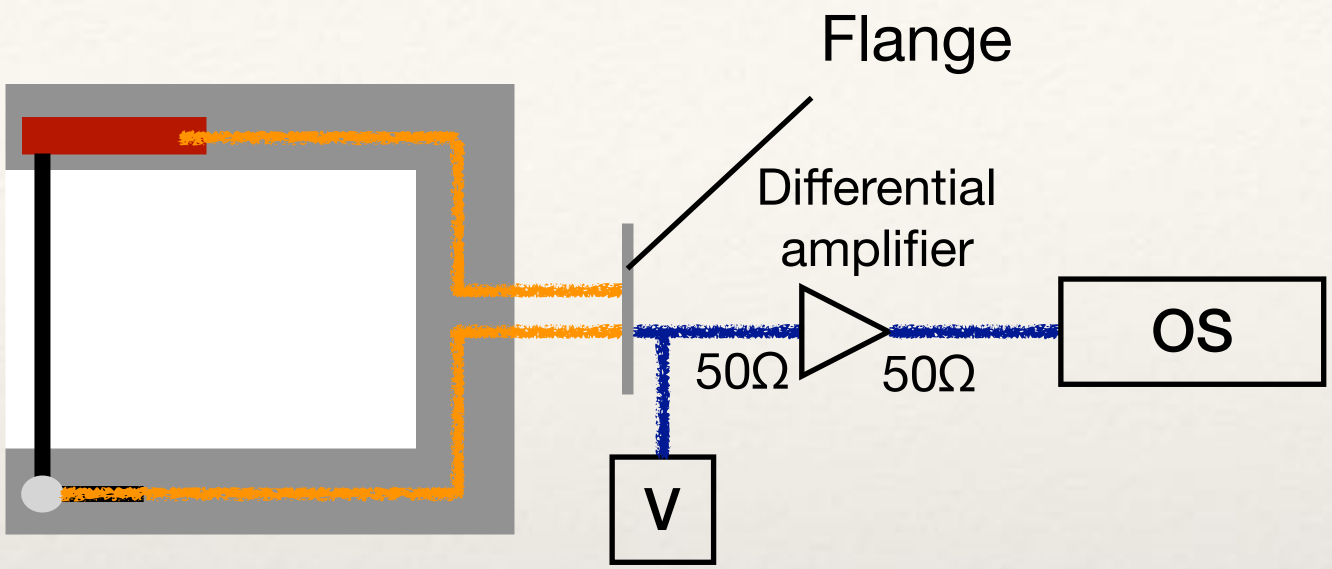
50Ω KAEN amplifier
Bias voltage on wire

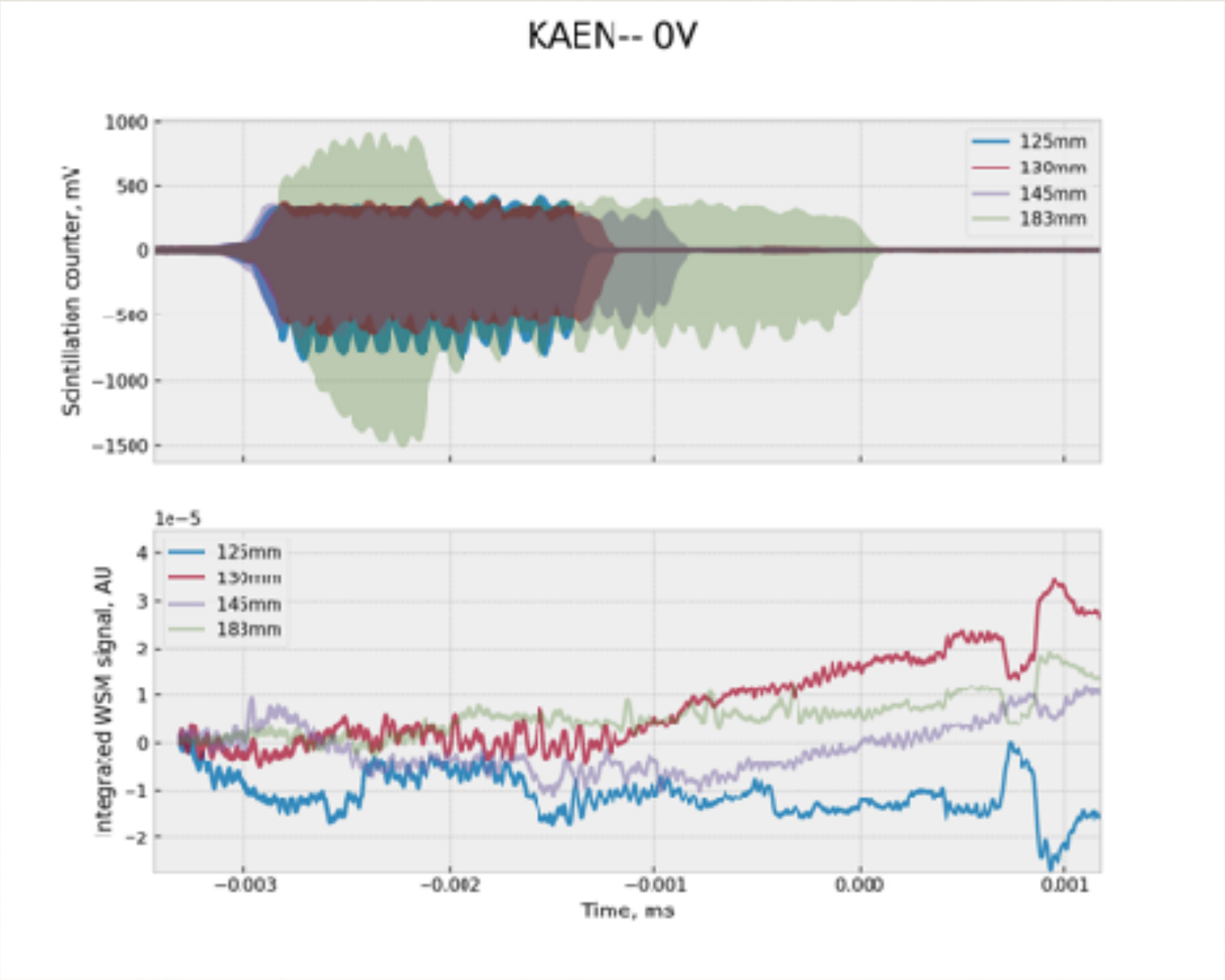


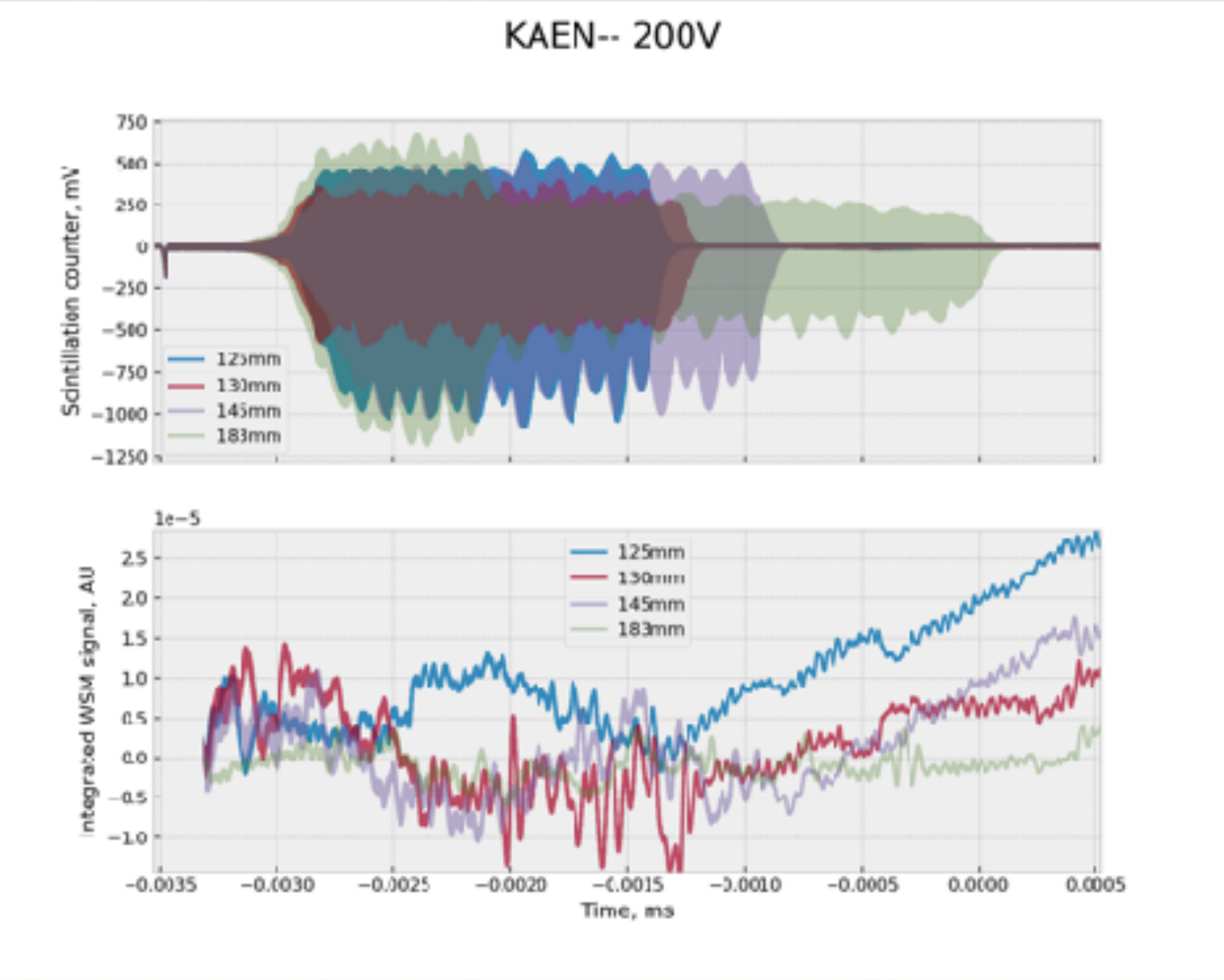




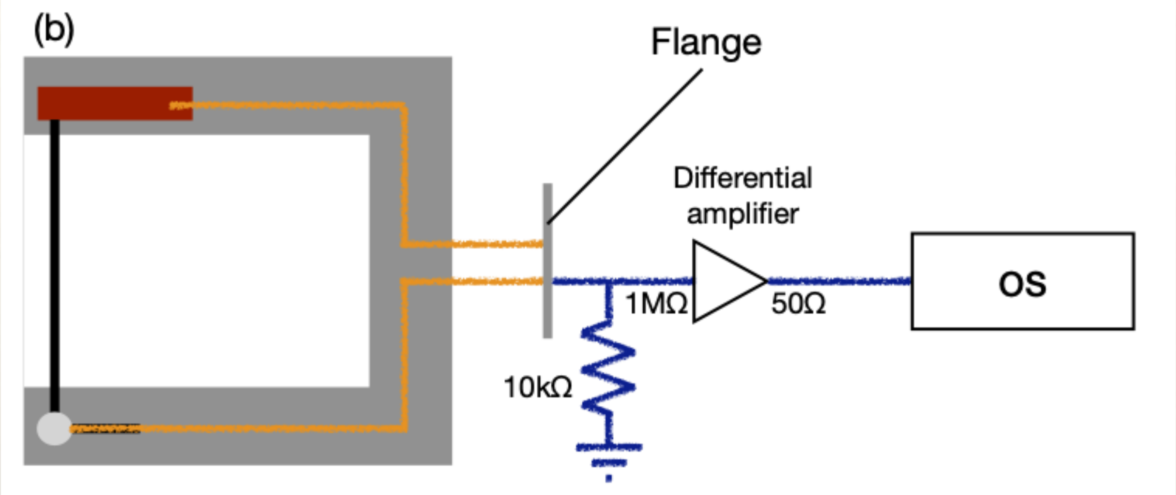
50Ω KAEN amplifier
Position Dependency







10kΩ Shunt + NF amplifier
Dependency on Wire Positions

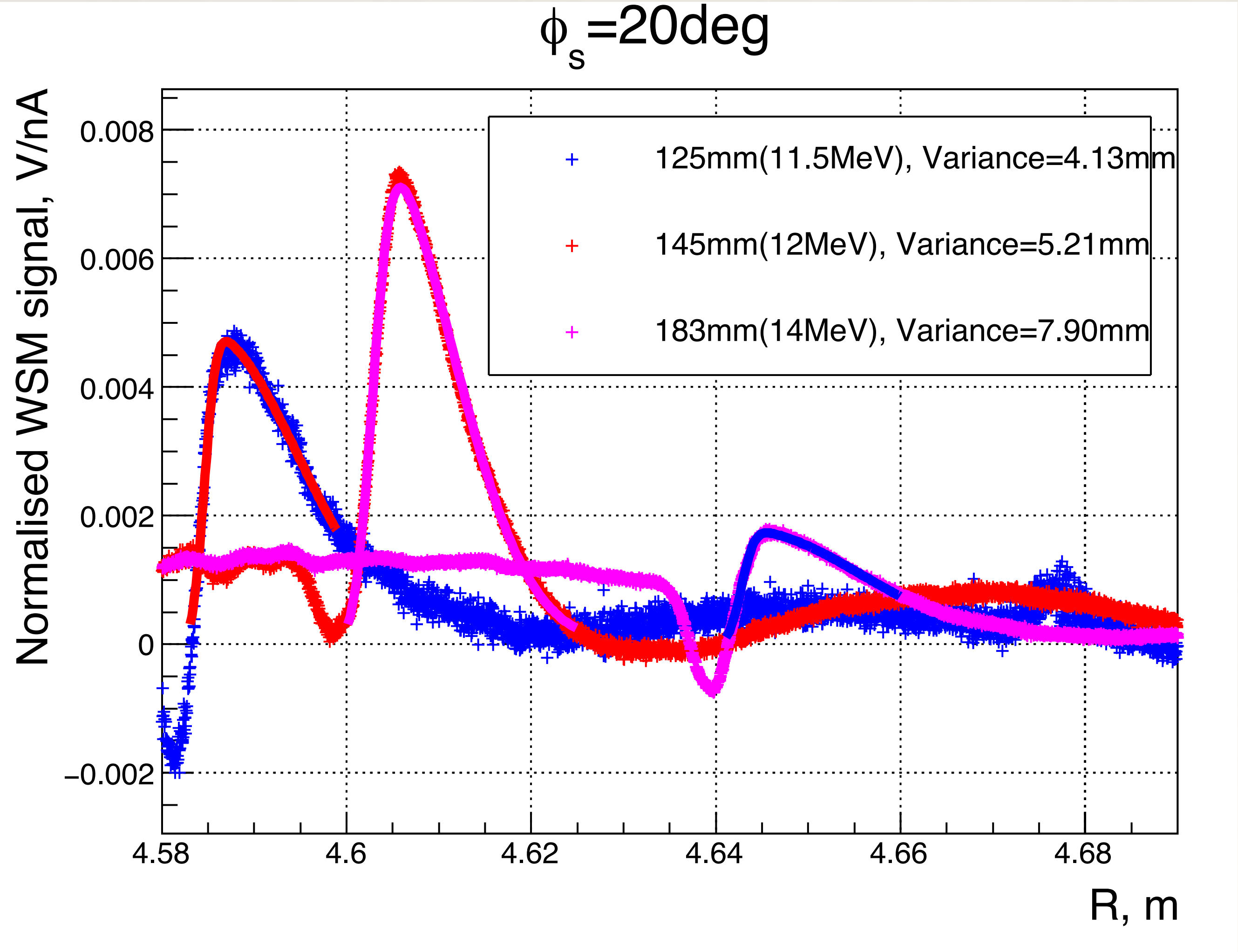


$$V(t+dt) = V(t+dt) - V(t)\exp(-dt/\tau)$$

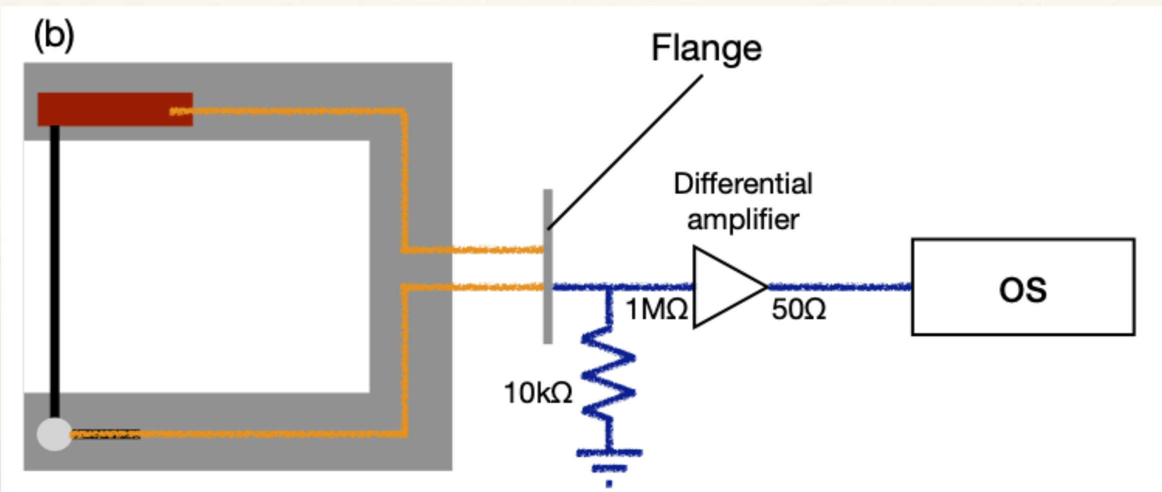
$$\frac{2}{\omega\sqrt{2\pi}} e^{-\frac{(x-\xi)^2}{2\omega^2}} \int_{-\infty}^{\alpha\left(\frac{2-\xi}{\omega}\right)} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} dt,$$

ξ : location, ω : scale, α : shape

https://en.wikipedia.org/wiki/Skew_normal_distribution



10kΩ Shunt + NF amplifier
Dependency on Acceleration Speeds



$$V(t+dt) = V(t+dt) - V(t)\exp(-dt/\tau)$$

$$\frac{2}{\omega\sqrt{2\pi}}e^{-\frac{(x-\xi)^2}{2\omega^2}}\int_{-\infty}^{\alpha(\frac{2-\xi}{\omega})}\frac{1}{\sqrt{2\pi}}e^{-\frac{t^2}{2}}dt,$$

ξ : location, ω : scale, α : shape

https://en.wikipedia.org/wiki/Skew_normal_distribution

Effect of injection error?