

Simulation on slice momentum spread measurement with TDS and HEDA2

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Introduction

- The slice momentum measurement has been simulated in three scenarios
 - 250 pC
 - 250 pC with EMSY1 50 um slit
 - 10 pC
- Simulation tools:
 - Astra for the linear beamline: with 2D/3D space charge
 - SpaceChargeOptimizer for optics design: with SC
 - 4D/6D transfer matrix for the dispersion section: No SC

Introduction

- Resolution of momentum measurement

$$\delta p \geq \frac{\sqrt{\beta_x \varepsilon_x}}{D}$$

D: dispersion function
 β_x : beta function
 ε_x : geometric emittance

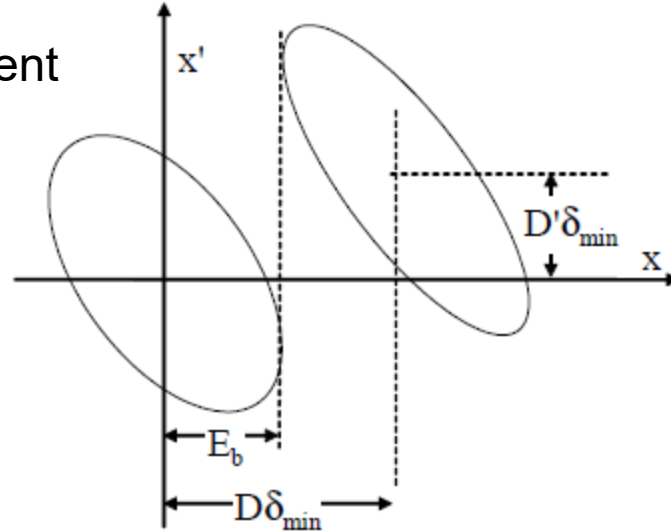


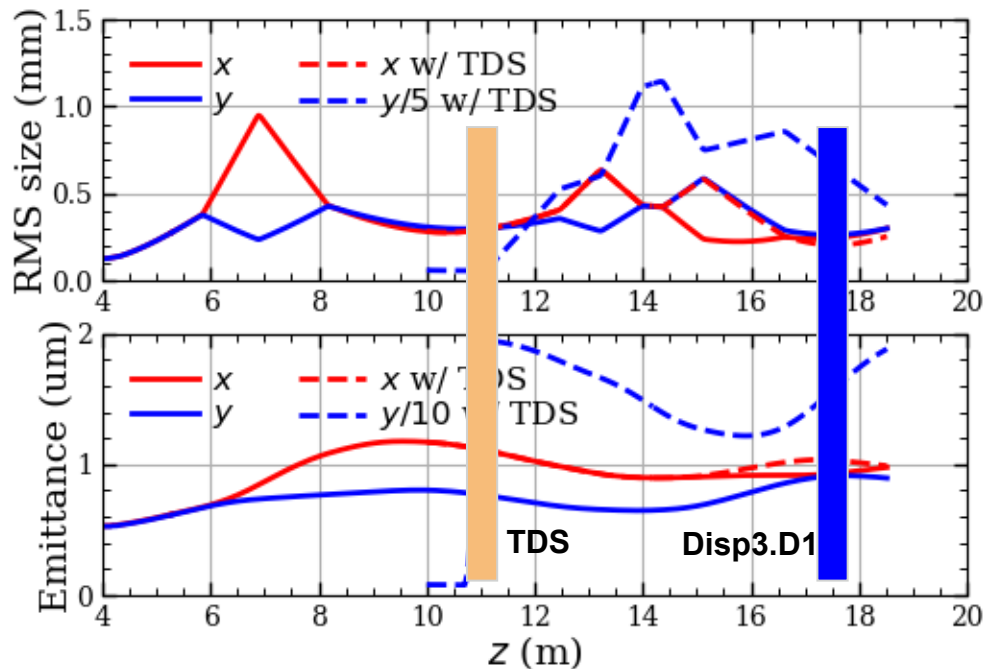
Fig. 5.14. Energy resolution in phase space

- → to maximize the resolution, the beam size (affected by space charge and emittance) should be small and the dispersion should be large

H. Wiedmann, Particle accelerator physics, third edition. 2007

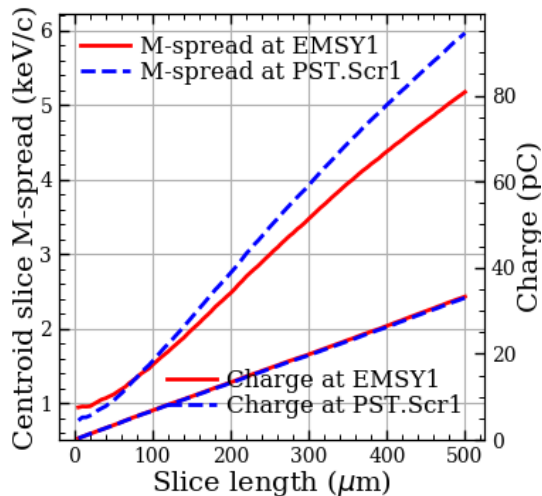
250 pC beam transport with TDS

- Photo injector setup
 - BSA 1 mm, 6 ps FWHM Gaussian
 - Gun @ MMMG -> 6.3 MeV/c
 - Booster @ MMMG -> 19 MeV/c
 - Solenoid current @ 364 A -> optimized for best emittance at EMSY1
- Three triplets used for focusing the beam
 - Small beam size in TDS (10.99 m)
 - Small beam size after HEDA2 (> 17.14 m) and at the reference position of Disp3.Scr1

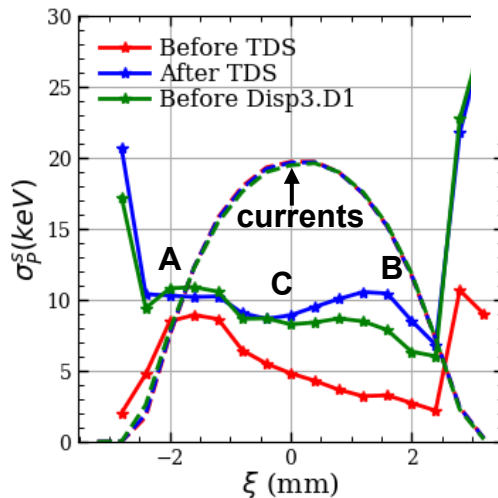


250 pC beam transport with TDS

- Slice momentum spread vs slice length

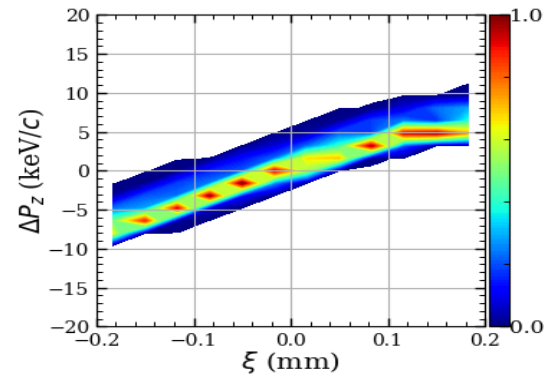


Due to the energy chirp, the thinner the slice, the smaller the momentum spread is;
The momentum spread has increased from EMSY1 to PST.Scr1



Here, slice length of 400 μm makes 10 slices inside the FWHM region

A and B: at half maximum;
C: centroid slice



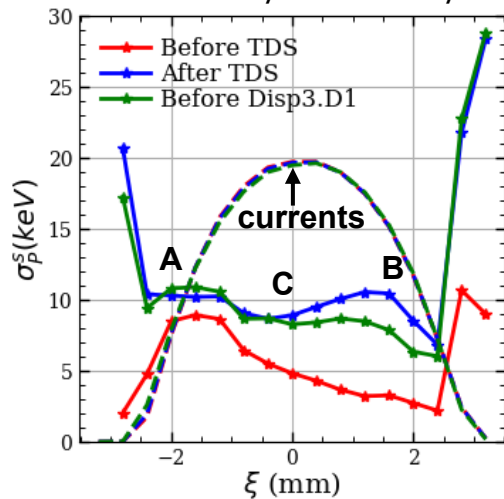
LPS around bunch center

250 pC beam transport with TDS

- Using 4D transfer matrix, one gets the horizontal beam size at the Disp3.Scr1

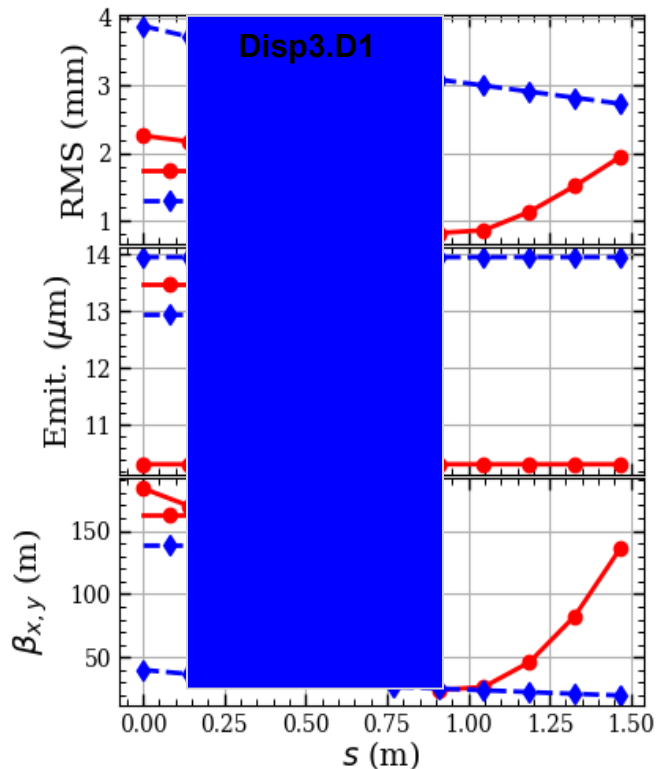
$$\delta p_{\min} = \frac{0.195 \text{ [mm]}}{0.9057 \text{ [m]}}$$

→ 3.9 keV/c@19MeV/c



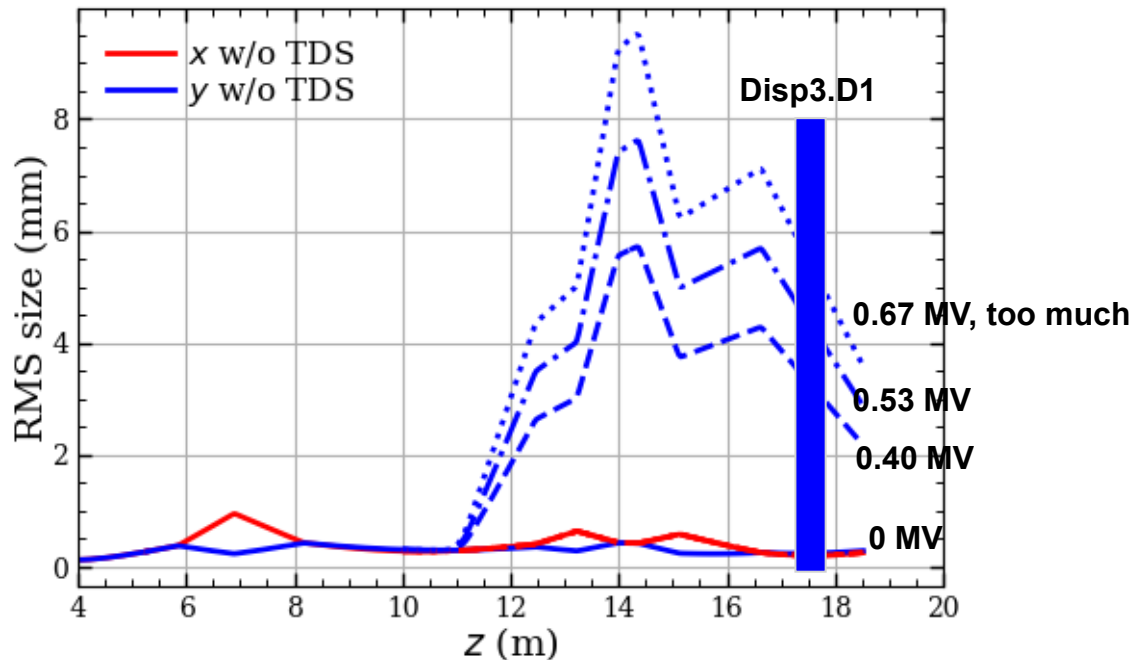
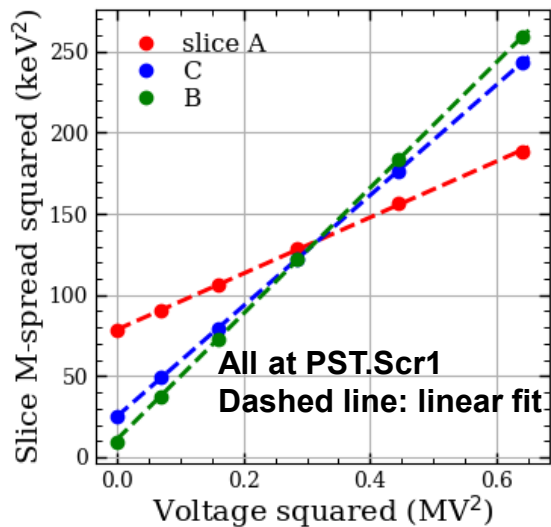
A and B: at half maximum; C: centroid slice

DESY. Simulation on slice momentum spread measurement



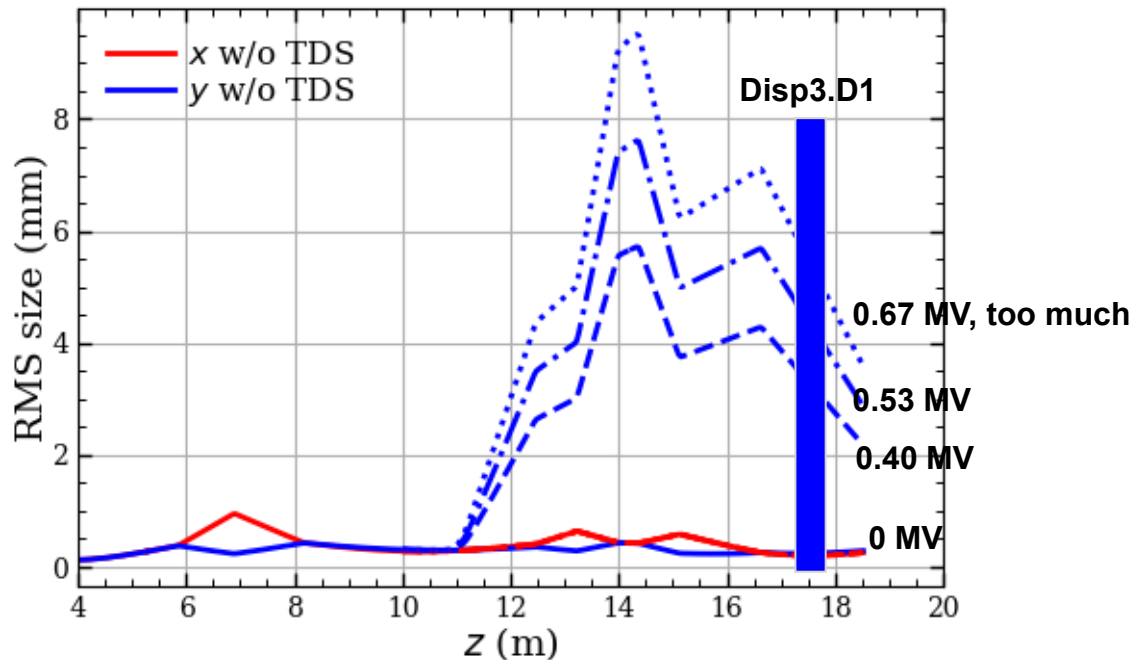
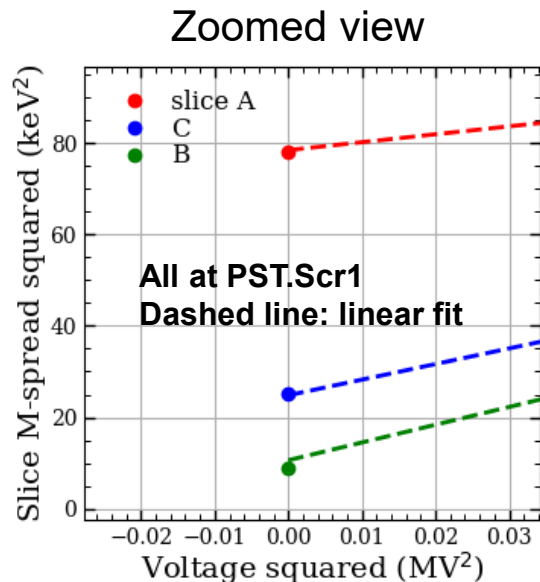
250 pC beam transport with TDS

- Scan of the TDS voltage



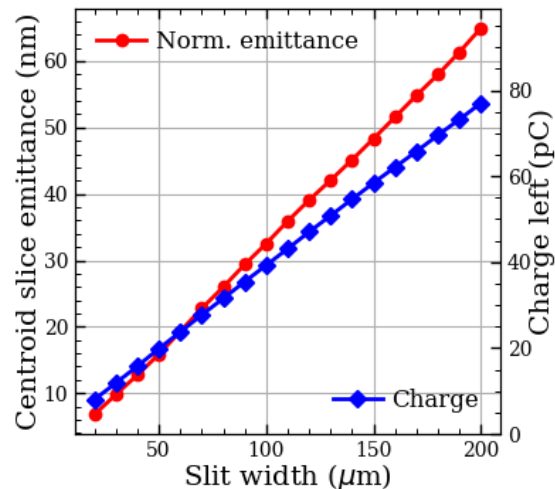
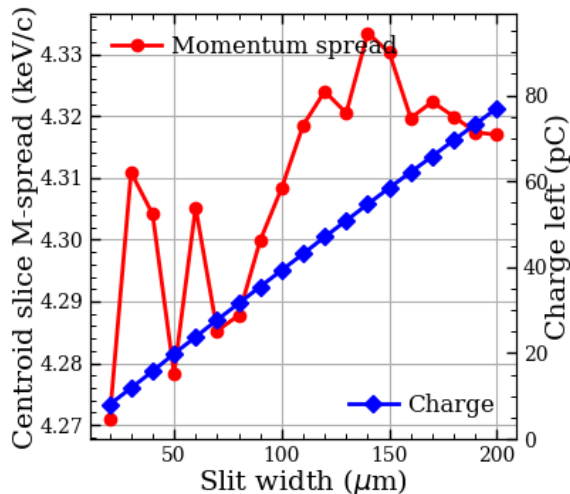
250 pC beam transport with TDS

- Scan of the TDS voltage



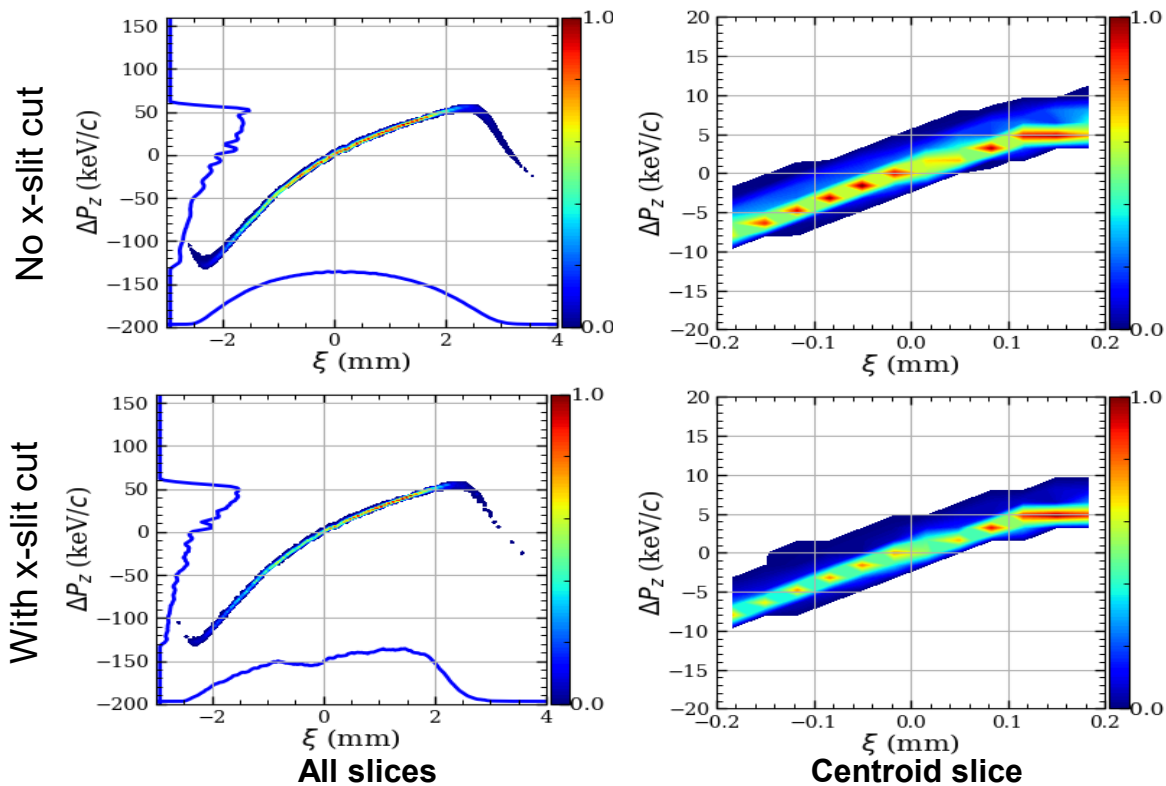
Cut the beam with 50 μm slit at EMSY1

- The resolution of the momentum measurement is limited by the horizontal emittance and space charge of the beam
- By cutting the beam, only the very center part with a small emittance and charge is left



Cut the beam with 50 μm slit at EMSY1

- Effect of the cut on long. Phase space (e-beam at EMSY1)



Cut the beam with 50 μm slit at EMSY1

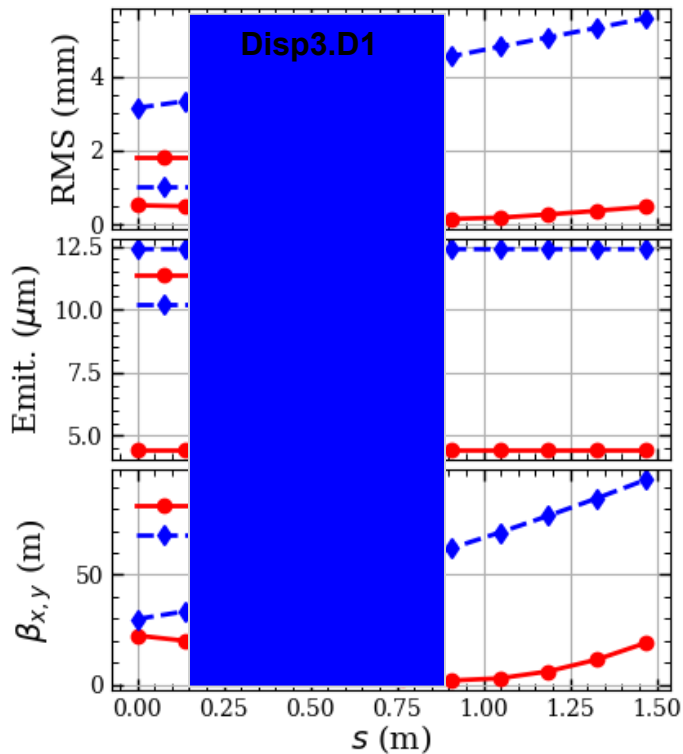
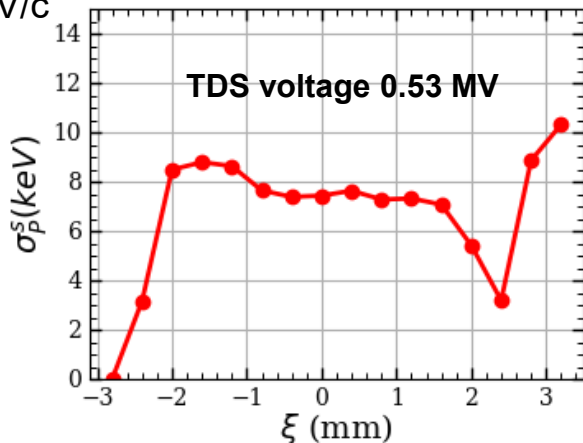
Resolution of momentum measurement

- Using 4D transfer matrix, one gets the horizontal beam size at the Disp3.Scr1

$$\delta p_{\min} = \frac{0.04755 \text{ [mm]}}{0.9057 \text{ [m]}}$$

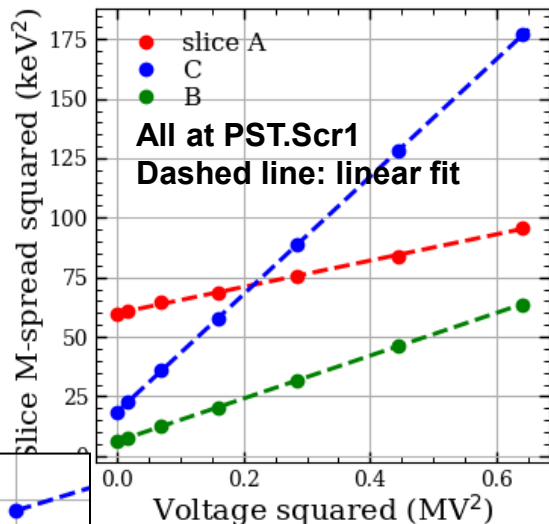
$\rightarrow 1 \text{ keV}/c @ 19 \text{ MeV}/c$

- The centroid slice momentum spread $\sim 7.5 \text{ keV}/c$

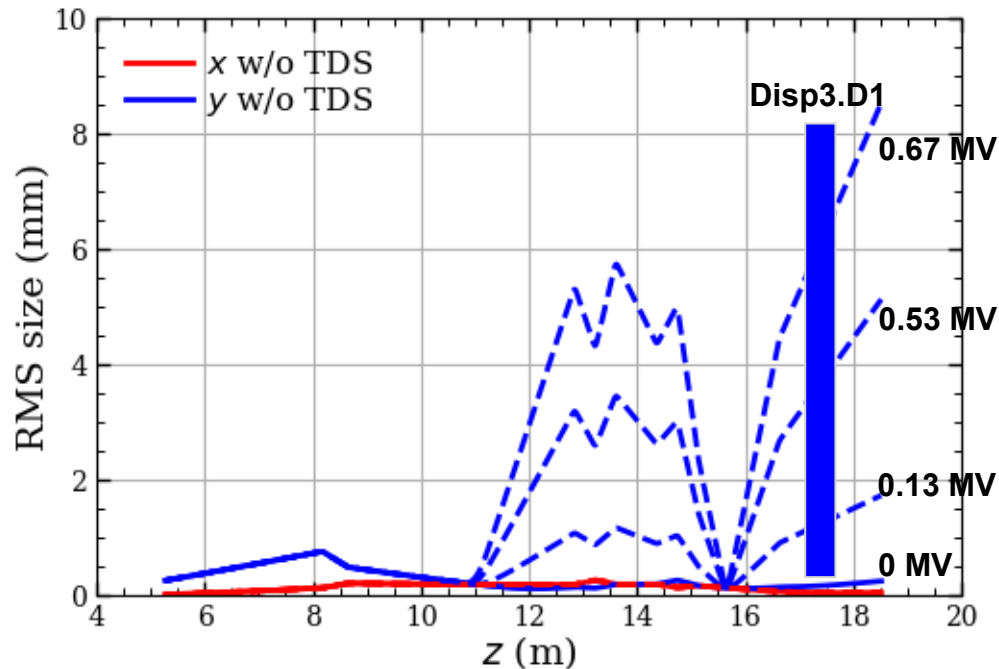
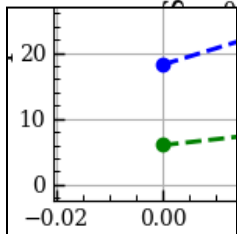


Cut the beam with 50 um slit at EMSY1

- Transport of the beam with various TDS voltages until HEDA2

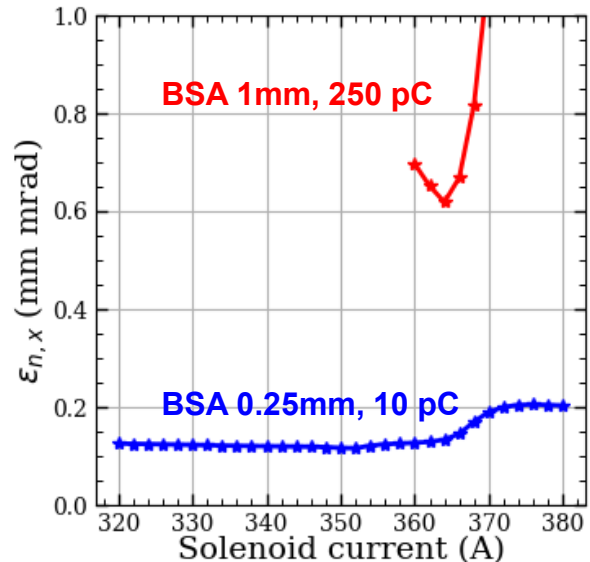


Zoomed view



10 pC beam transport with TDS

- The resolution of the momentum measurement is limited by the horizontal emittance of the beam
- With a smaller BSA size and a lower charge of 10 pC, the beam emittance is reduced to 0.12 μm



10 pC beam transport with TDS

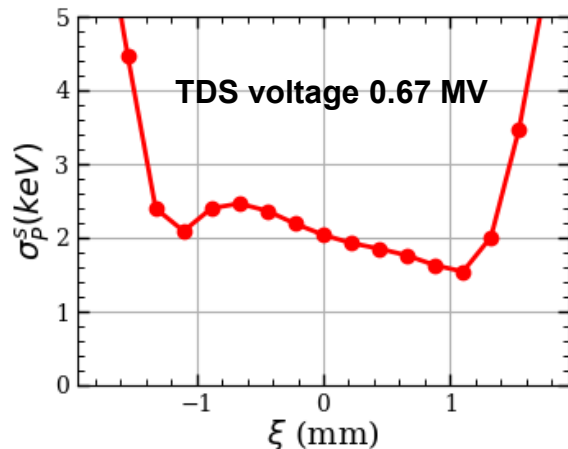
Resolution of momentum measurement

- Using 4D transfer matrix, one gets the horizontal beam size at the Disp3.Scr1

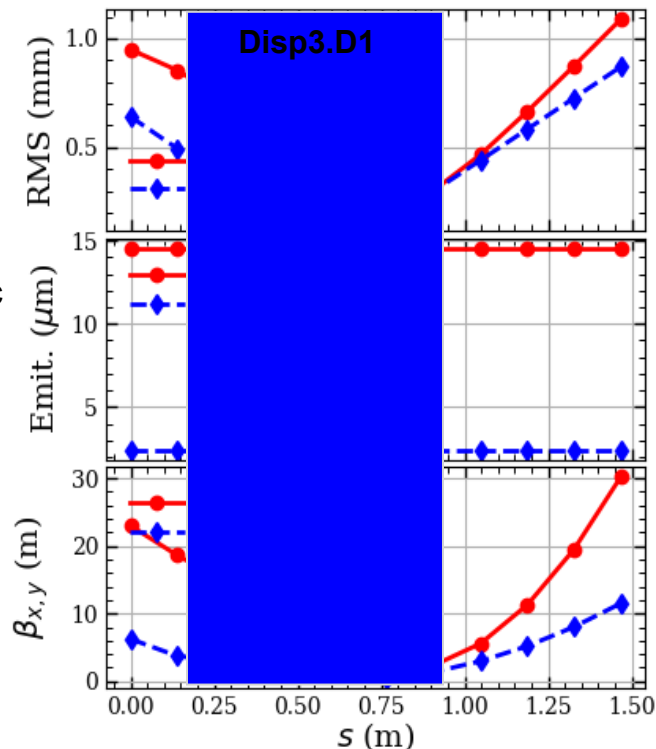
$$\delta p_{\min} = \frac{0.109 \text{ [mm]}}{0.9057 \text{ [m]}}$$

→ 2.3 keV/c@19MeV/c

- The centroid slice momentum spread ~ 2 keV/c

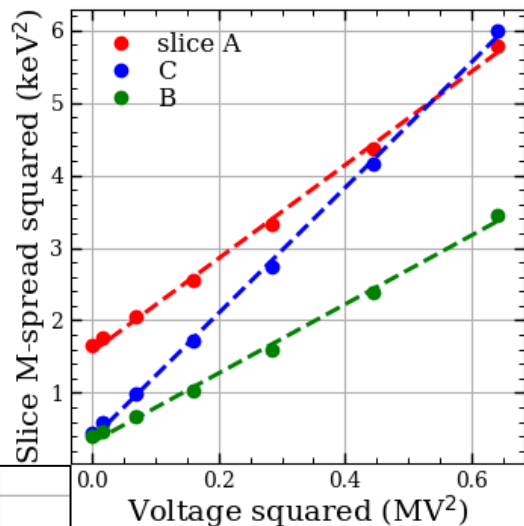


x-rms increased a lot after the bending magnet; might be improved

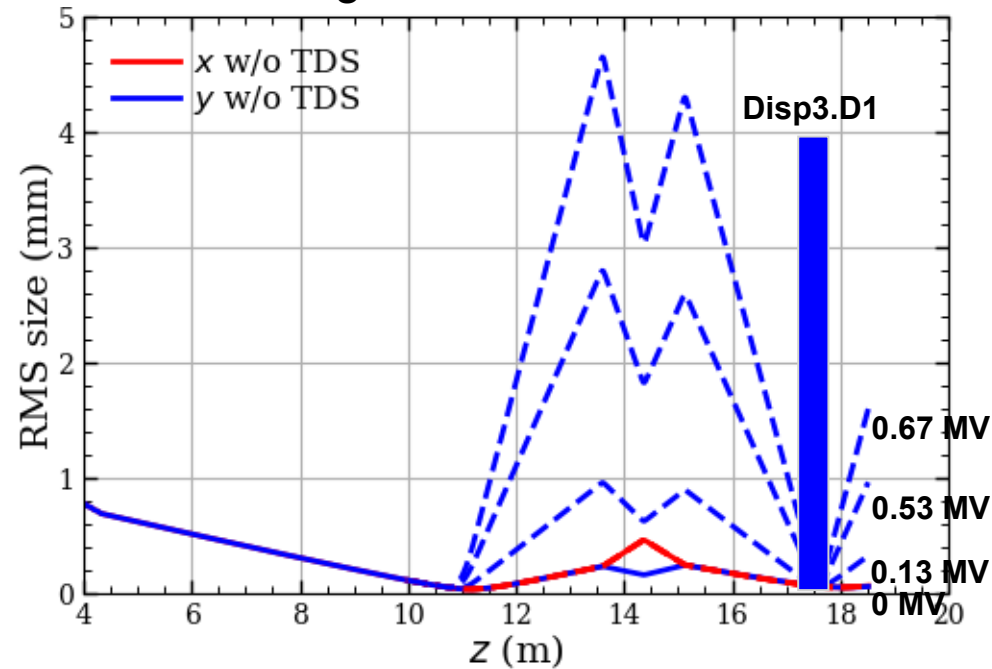
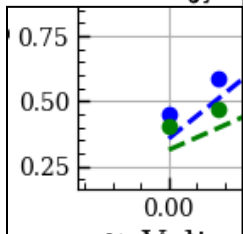


10 pC beam transport with TDS

- Transport of the beam with various TDS voltages until HEDA2

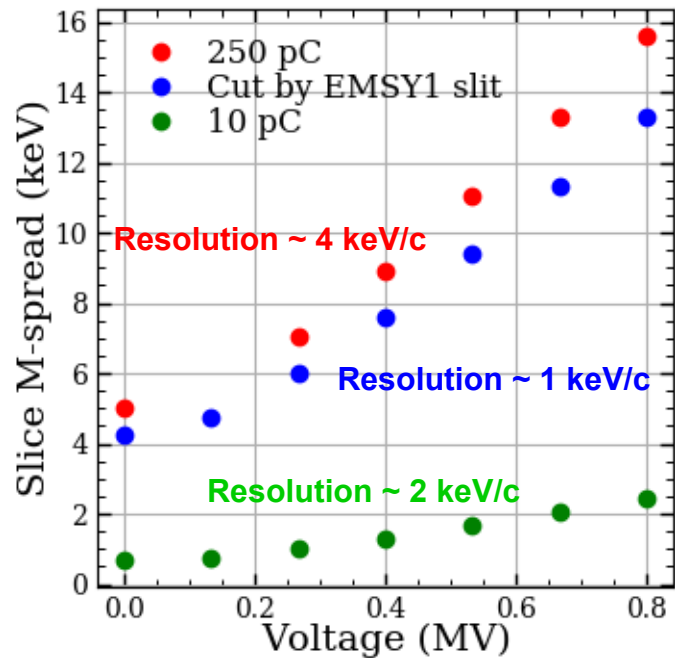


Zoomed view



Summary

- Using the EMSY1 slit to cut the 250 pC bunch seems the best for slice momentum spread measurement
- Monitor resolution
 - Bin2x2: 0.13187 mm/pixel
 - ~ 2.8 keV/c/pixel



Summary

- The asymmetry of the beam emittance with the EMSY1 slit makes the focusing more difficult

