

# First Measurement of Centroid slice Energy Spread using TDS Amplitude Scan

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# Outline

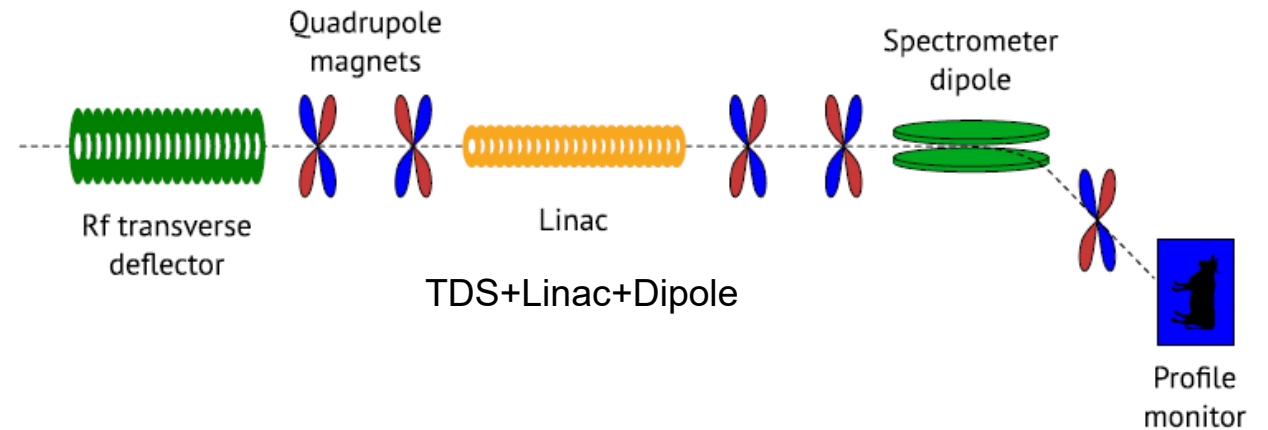
- Overview of the PSI paper E. Prat, et al, Phys. Rev. Accel. Beams 23, 090701, 2020
- Our measurement method and procedure
- Analyzed results from 2 cases
  - standard focusing at reference screen
  - strong focusing in bending axis

# Paper E. Prat, et al, Phys. Rev. Accel. Beams 23, 090701, 2020

- slice energy spread measurement
- Use of Transverse deflecting structure (TDS) and dipole magnet
- Uncorrelated contribution to measured beam size at monitor (standard approach)
- Energy spread reconstruction
- Scheme at PSI
- Additional energy contribution from TDS
  - if beam size in TDS is significantly large enough
- Energy spread further improved by this reconstruction (new approach)
  - scan V with TDS and scan E with Linac
  - Centroid E spread is independent of energy

$$\sigma_M^2 = \sigma_R^2 + \frac{m_e c^2 \beta \epsilon_n}{E} + \frac{D^2 \sigma_E^2}{E^2}$$

measured beam size      monitor resolution      resolution contribution from betatron      Dispersion  $D$



$$\sigma_E^2 = \sigma_{E0}^2 + e^2 k^2 V^2 \cos^2(\phi) \frac{m_e c^2 \beta_T \epsilon_{nT}}{E_T}$$

to be reconstructed      contribution from TDS voltage      beam size at TDS

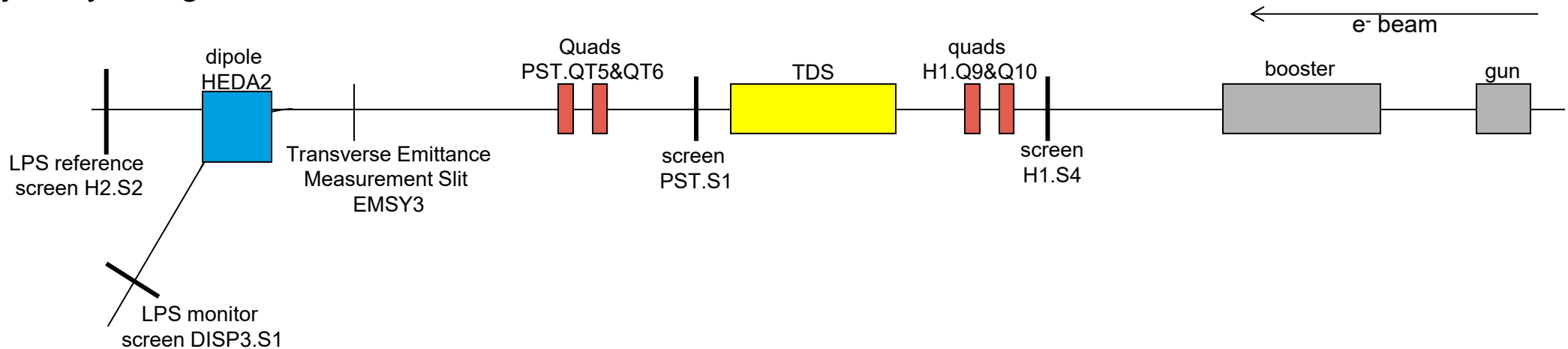
# Method Applied to PITZ

- The paper also mentions that position TDS+Linac+Dipole can be changed to Linac+TDS+Dipole

- The relation becomes

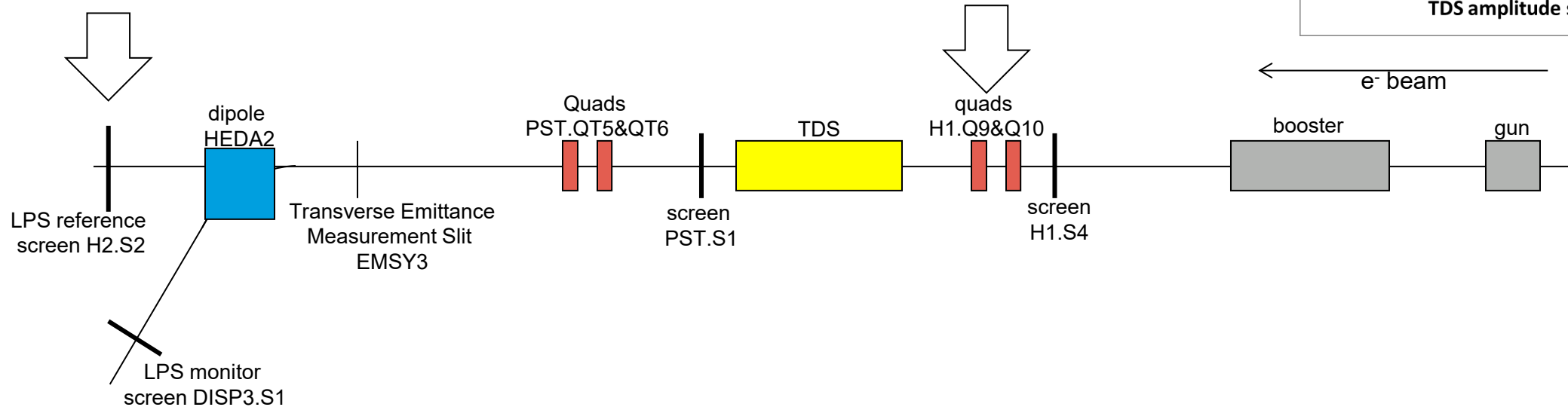
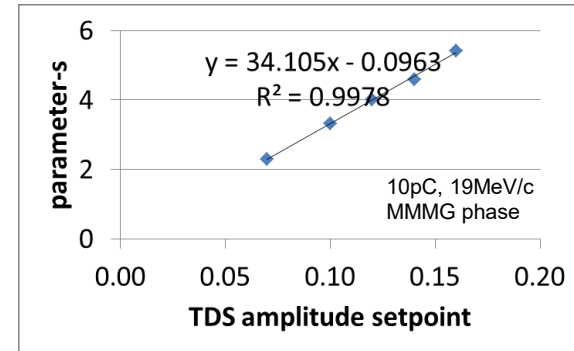
$$\sigma_M^2 = \sigma_R^2 + \frac{m_e c^2 \beta \epsilon_n}{E} + \frac{D^2 \sigma_{E0}^2}{E^2} + \frac{D^2 e^2 k^2 V^2 \cos^2(\phi) m_e c^2 \beta_T \epsilon_{nT}}{E^3}$$

- Scan V with TDS (and scan E with Linac) to grab longitudinal phase space profile (LPS), measure emittance before bending
- Analyze by fitting the relation as a function of V and/or E



# Our First Measurement Try with 10pC, 19MeV/c beam

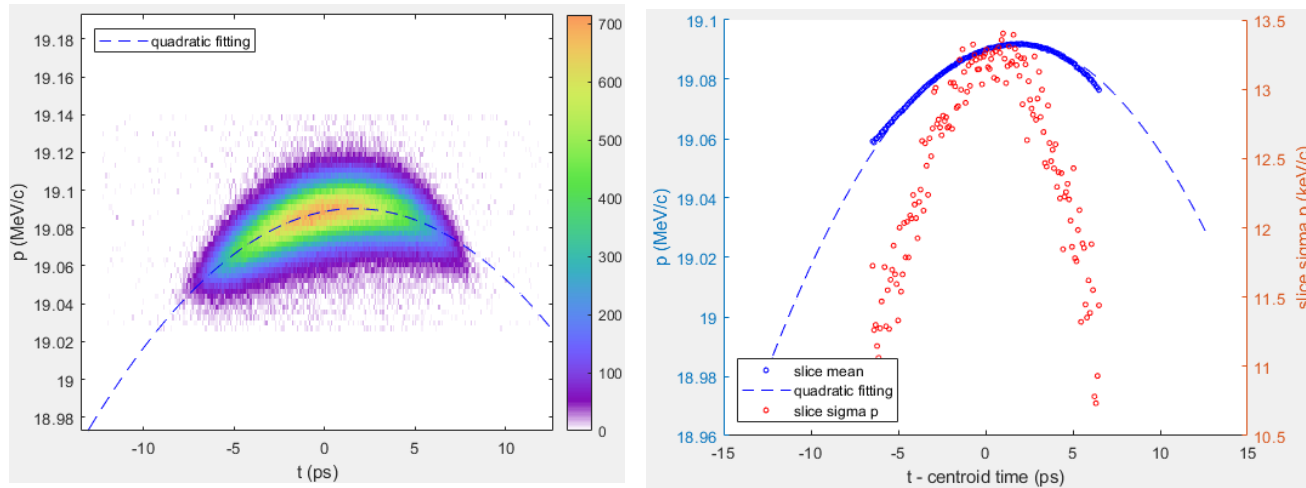
- Use solenoid to briefly focus beam at screen H1.S4 (before TDS)
- Use quads H1.Q9&Q10 (steering free) to focus beam at LPS reference screen H2.S2
- Measure transverse phase space at EMSY3
- Scan TDS amplitude setpoint (proportional to parameter  $s$  or voltage  $V$ ) to grab LPS



# Longitudinal Phase Space Measurement Case #1

standard focusing at reference screen

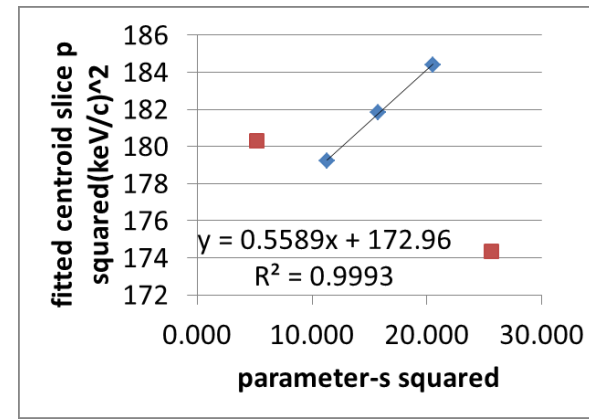
@Gun and Booster MMMG phase



resolution\_t (ps) = 0.6731  
 mean\_p (MeV/c) = 19.0905  
 rmsbunchlength (ps) = 3.2464  
 chirp\_P\_t (MeV/c/ps) = 0.0019  
 secondorder(MeV/c/ps^2) = -5.4035e-04  
 uncorr\_E\_spread (keV) = 14.2999

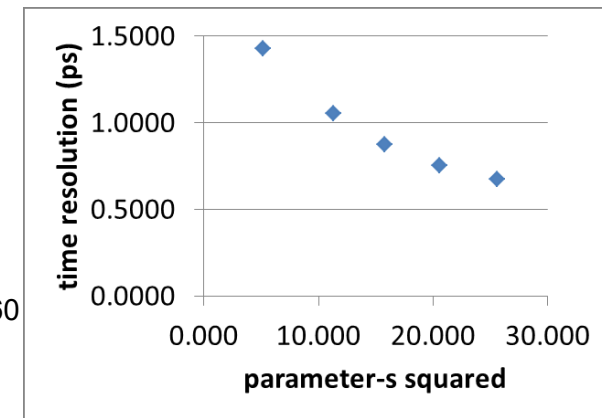
mean slice sigma p (keV/c) = 12.7178  
 centroid slice sigma p (keV/c) = 13.1919  
 fitted centroid 0.5ps-slice mean p (MeV/c) = 19.0899  
 fitted centroid 0.5ps-slice sigma p (keV/c) = 13.2047  
 fitted centroid 3pixel-slice mean p (MeV/c) = 19.0880  
 fitted centroid 3pixel-slice sigma p (keV/c) = 13.3391

TDS amplitude setpoint scan & centroid slice momentum spread reconstruction



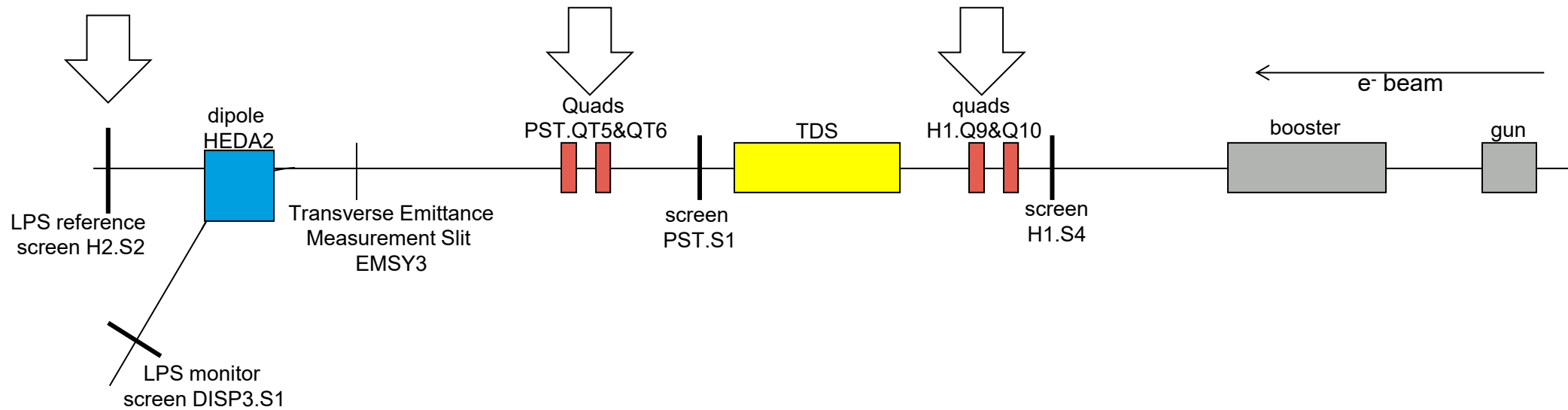
alpha (emsy x-stat) = 1.92567  
 beta(m) (emsy x-stat) = 13.44067  
 emittance(um) (emsy x-stat) = 0.90933  
 beta (m) at d3s1 = 2.17569  
 beta (m) at reference screen = 6.30956  
 estimated x-rms at reference screen = 0.39160  
 monitor resolution(keV/c/pixel) = 2.78414  
 screen scale (mm/pixel) = 0.13187  
 scale(MeV/c/m) = 21.11307  
 Disp (m) = 0.90555  
 p(MeV/c) = 19.11895  
 fitting term = 172.96319  
 corrected centroid slice p spread(keV/c) = 11.90164  
 centroid slice p spread(keV/c) before correction = 13.19190

- Reconstruction removes errors from
- Monitor screen resolution
  - Beam x-size at screen (main contribution due to focusing of beam at monitor screen)
  - TDS energy contribution (found low effect from the fitting)



# strong focusing in bending axis

- Also use quads PST.QT5&QT5 (steering free) to focus beam at LPS reference screen H2.S2

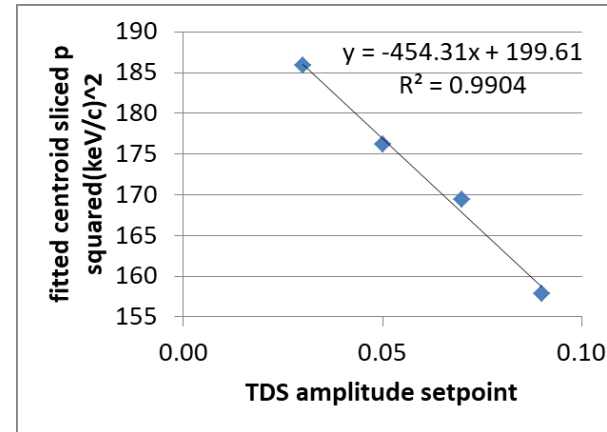
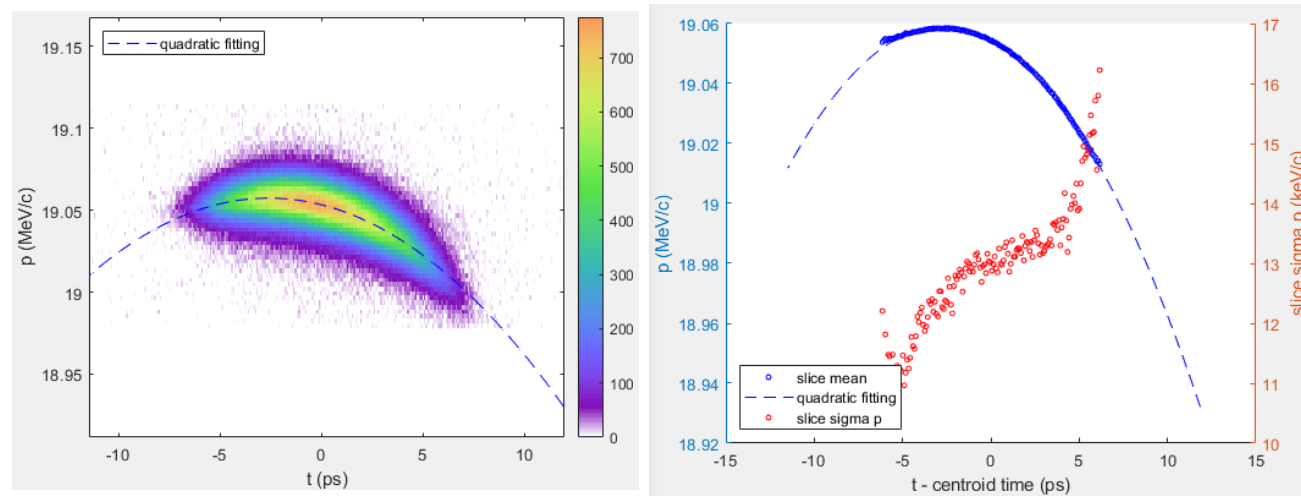


# Longitudinal Phase Space Measurement Case #2

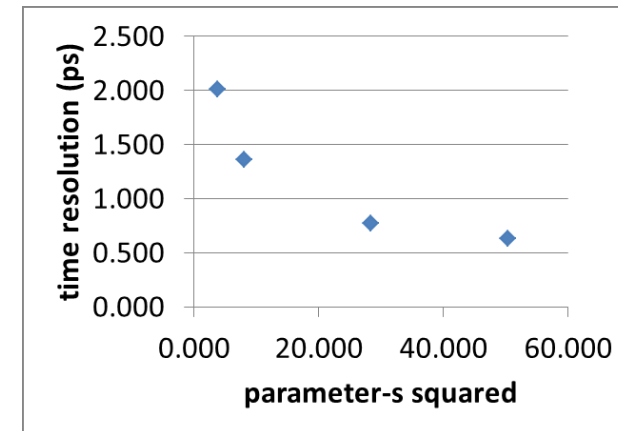
strong focusing in bending axis

@Gun MMMG and Booster MMMG phase+4

TDS amplitude setpoint scan & centroid slice momentum spread reconstruction



Negative slope sacrificed time resolution



resolution\_t (ps) = 0.7664  
 mean\_p (MeV/c) = 19.0549  
 rmsbunchlength (ps) = 3.0767  
 chirp\_P\_t (MeV/c/ps) = -0.0033  
 secondorder(MeV/c/ps^2) = -6.0516e-04  
 uncorr\_E\_spread (keV) = 14.4579

mean slice sigma p (keV/c) = 12.9415  
 centroid slice sigma p (keV/c) = 13.0144  
 fitted centroid 0.5ps-slice mean p (MeV/c) = 19.0545  
 fitted centroid 0.5ps-slice sigma p (keV/c) = 13.0182  
 fitted centroid 3pixel-slice mean p (MeV/c) = 19.0525  
 fitted centroid 3pixel-slice sigma p (keV/c) = 13.1509



# Next

- Use new range of TDS amplitude scan
- Scan both TDS and Booster amplitude
- Use slit at EMSY3 (vertical slit to cut beam horizontally)

