Low-Emittance Tuning at CesrTA
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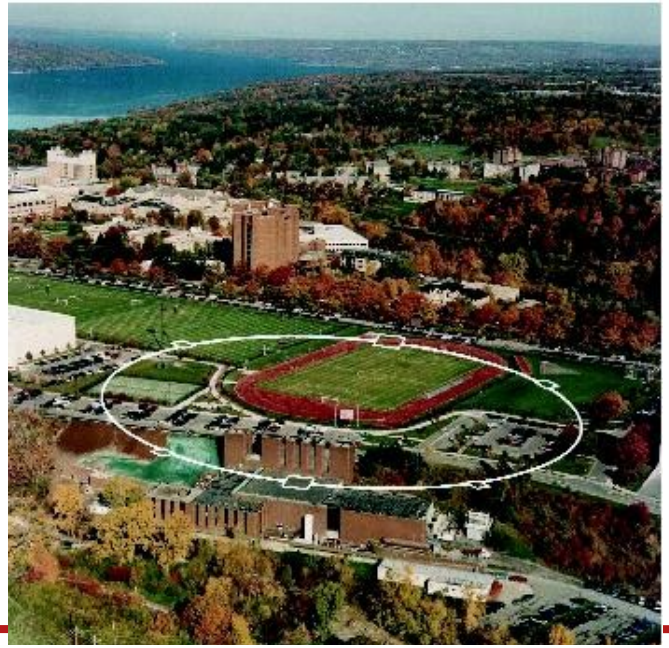
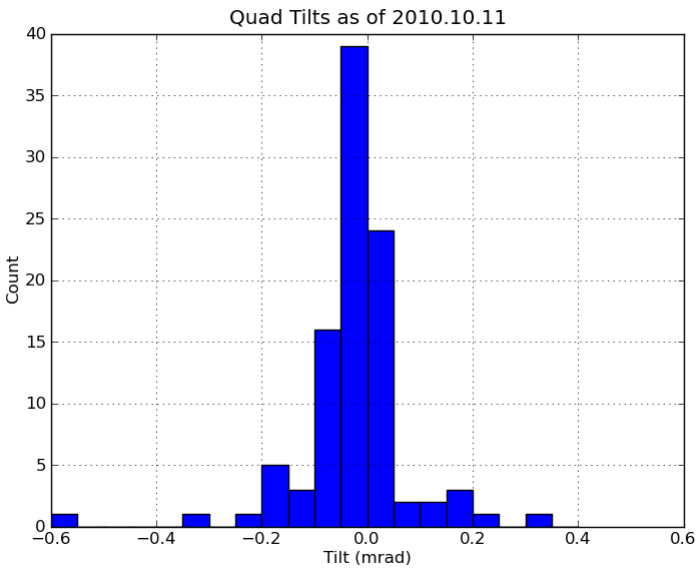
On Behalf of D. Rubin, D. Sagan, et al.

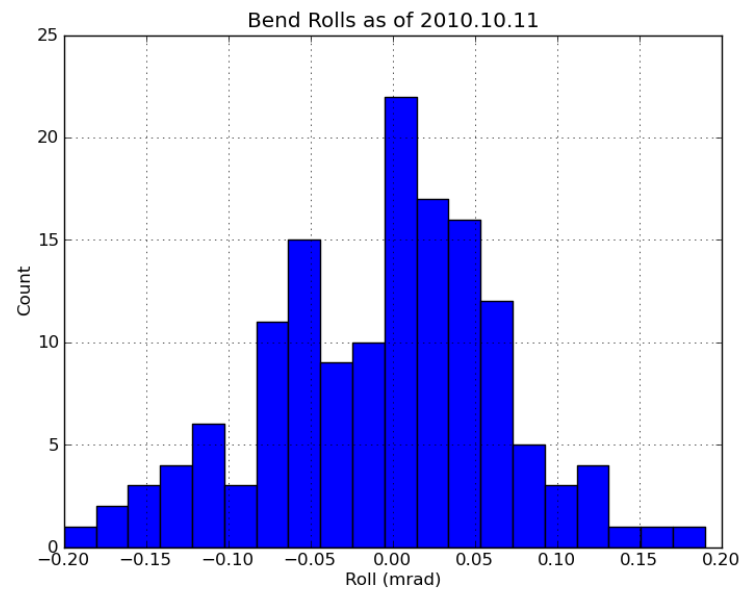


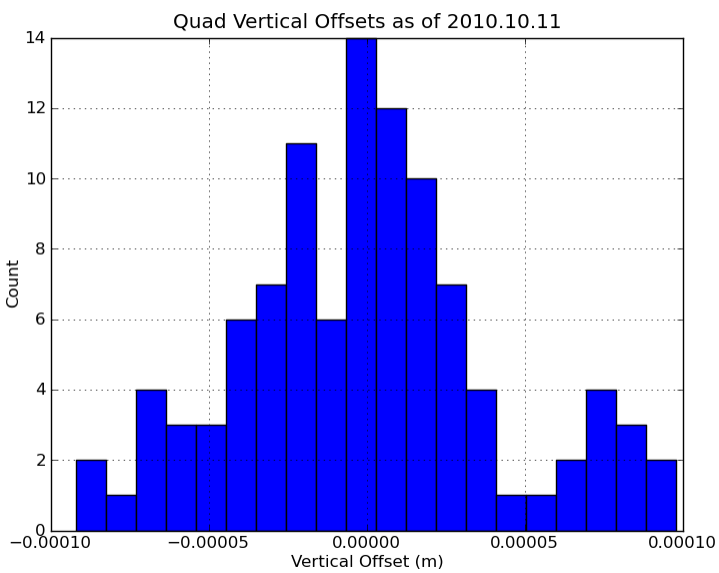
Overview

- Survey/alignment
- BPM Electrode Gain Map / BPM Tilt Calibration
- X-ray Beam Size Monitor
- LET Procedure, Results
- Sextupole Optimizations / Tune Scans
- Beamsize vs. Closed Coupling, η_y, β_y Bumps
- Conclusions

Survey and Alignment







Parameter	σ
Quad tilt	120 μrad
Quad vert. offset	41 μm
Bend roll	73 μrad

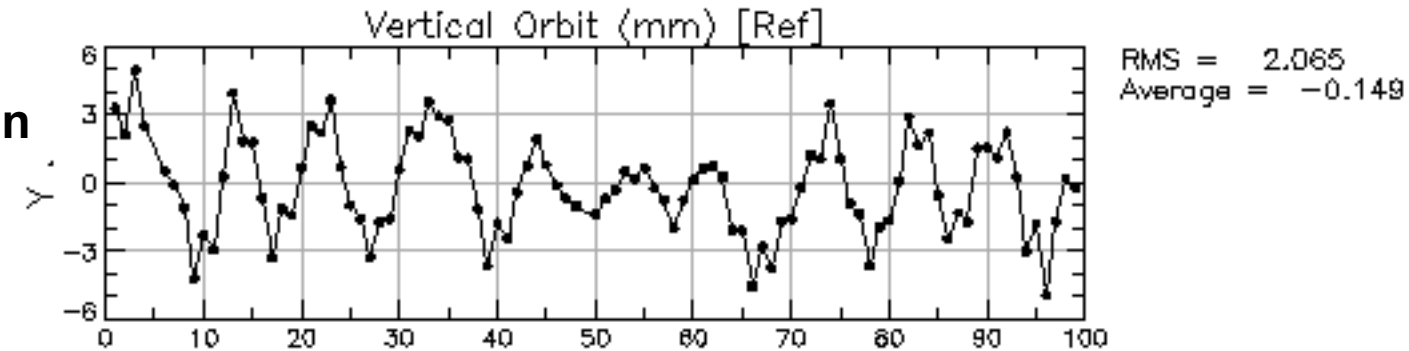
Zero-Corrector Orbit

Measure vertical orbit with all vertical correctors off:

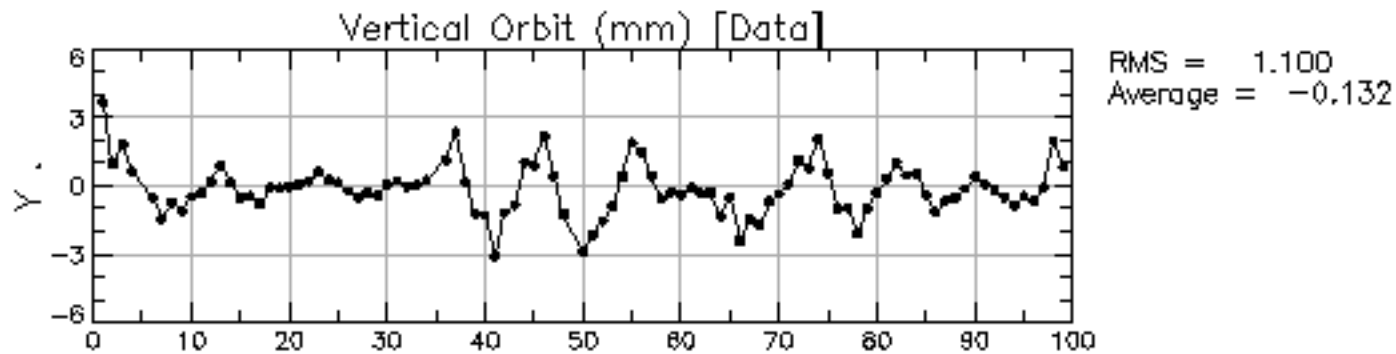
- Before and after major magnet alignment effort in August down period

Top: Zero vert–corrector, July 2010
Bottom: Zero vert–corrector, September 2010

Before August down

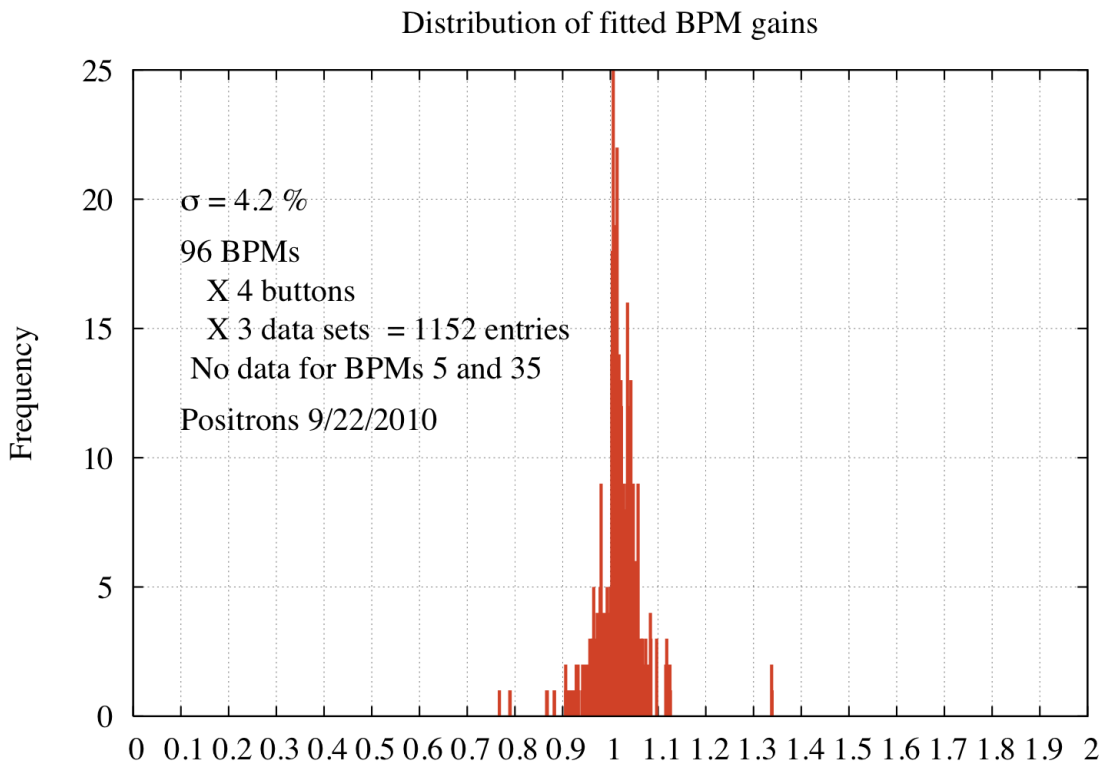


After August down



BPM Electrode Gain Mapping

- Acquire turn-by-turn (TBT) data for 1024 turns
- Fit gains using a relation accurate to second-order*
- Fast data acquisition and analysis

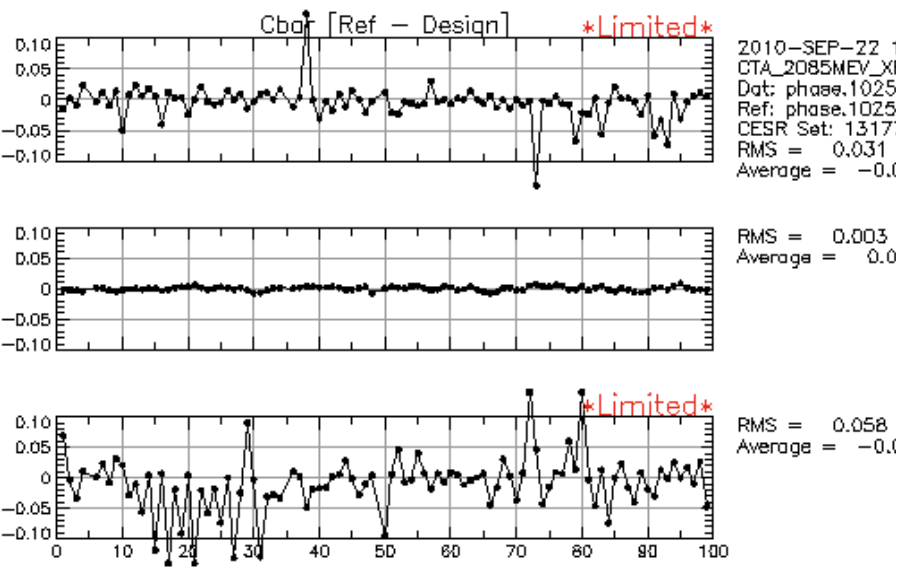


D. Rubin et al., PRST-AB 13, 092802 (2010)

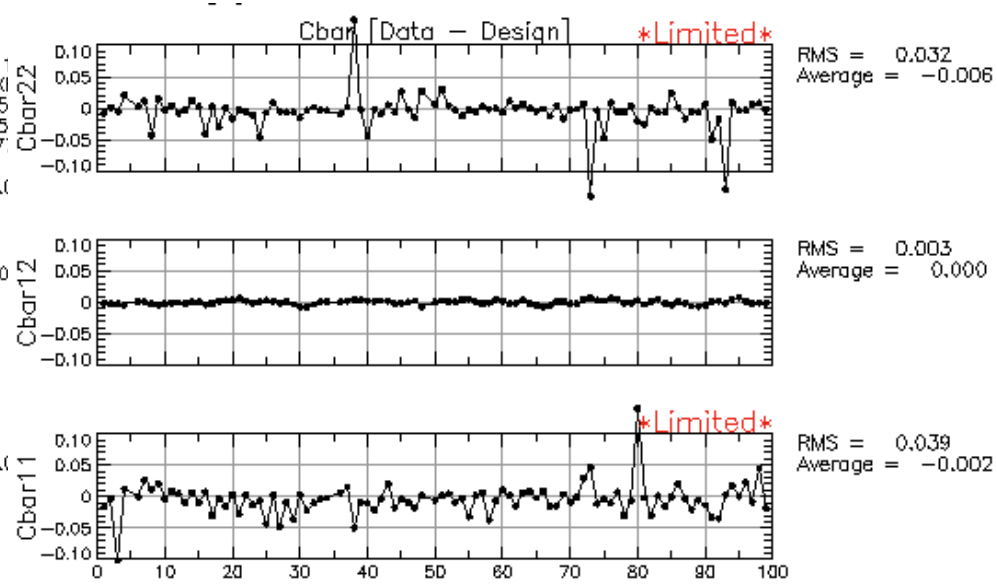
Effects on Coupling Matrix

Coupling matrix before and after BPM electrode gain calibrations

Before Gain Calibration



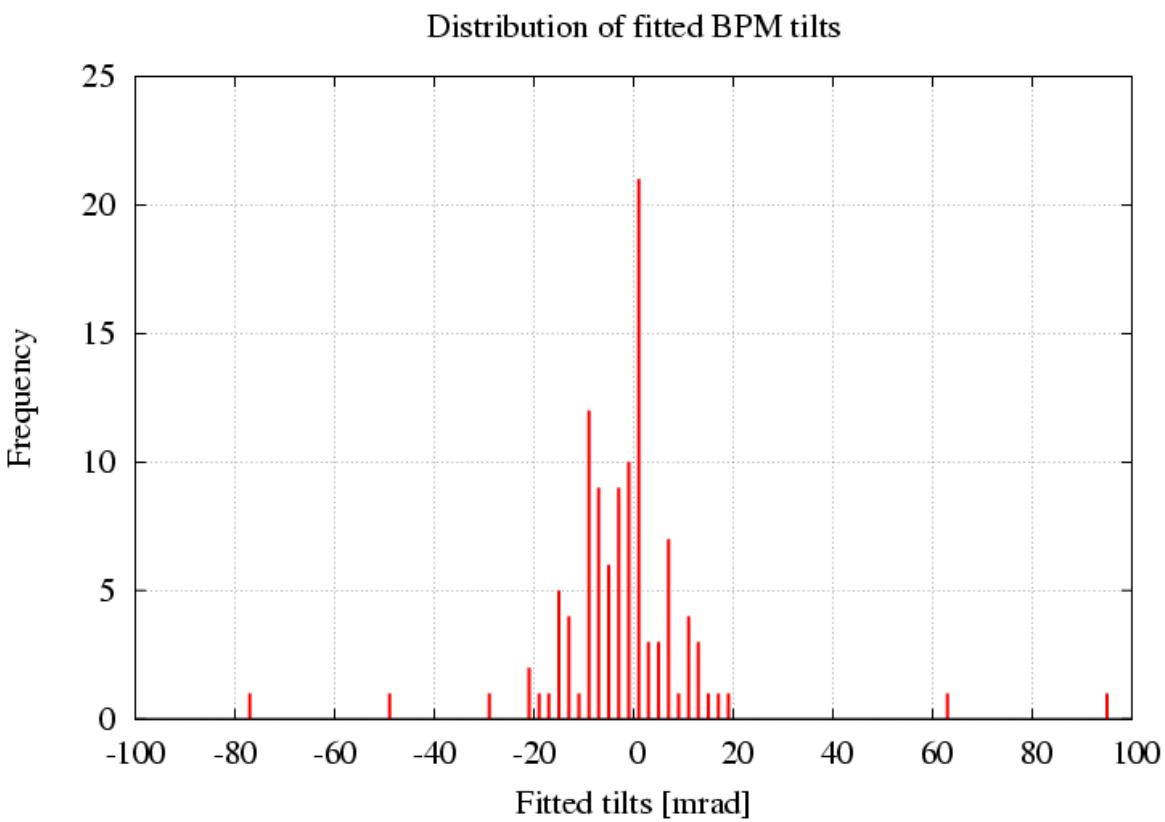
After Gain Calibration



Cbar11 significantly improved after gain calibration

BPM Tilt Calibration

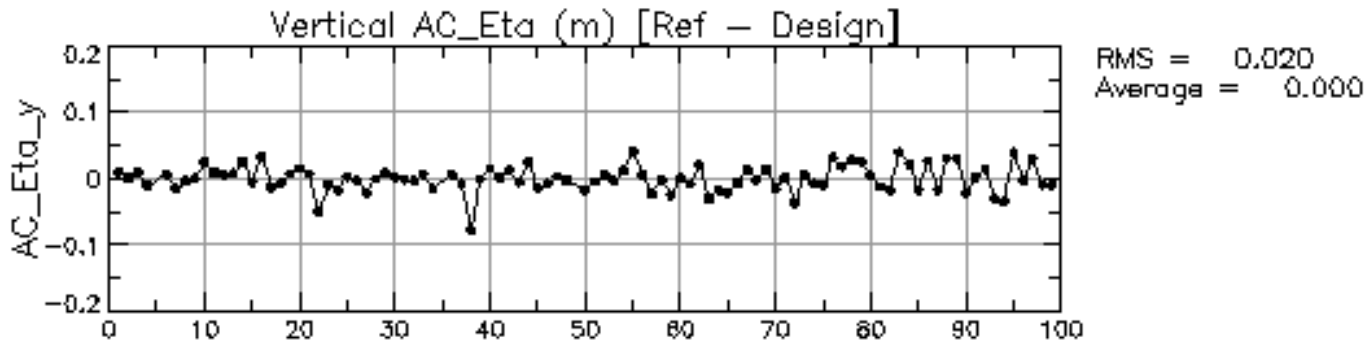
- Calibrate gains, correct Cbar12 coupling
  - Cbar12 = “out-of-phase” coupling; independent of BPM tilt
- Now coupling matrix elements Cbar22,Cbar11 are proportional to BPM tilt (plus error terms)



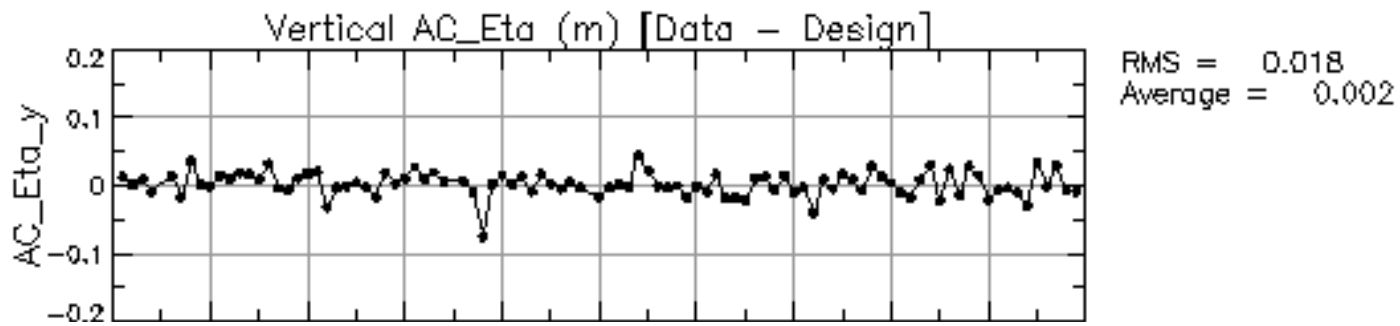
σ ~ 10mrad

Effects of Calibrations on η_y

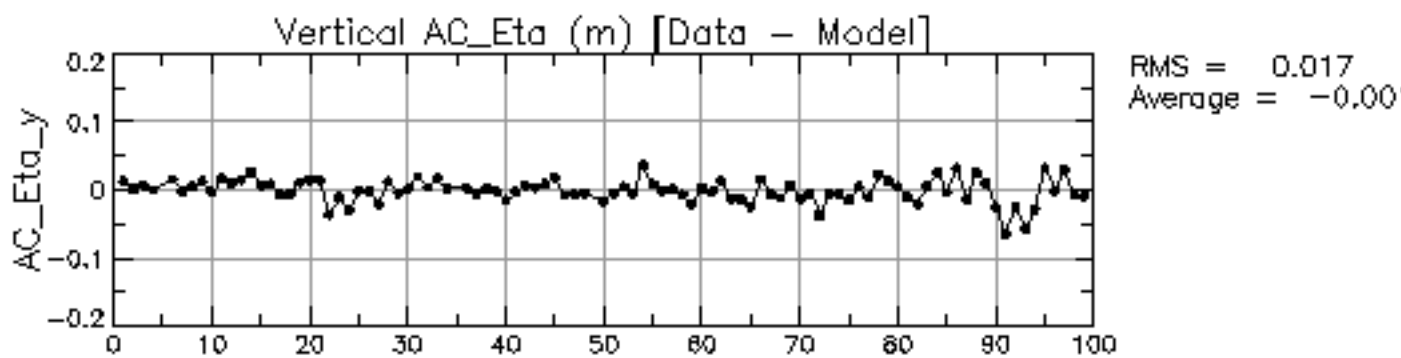
Measured dispersion



Measured dispersion with BPM gain corrections

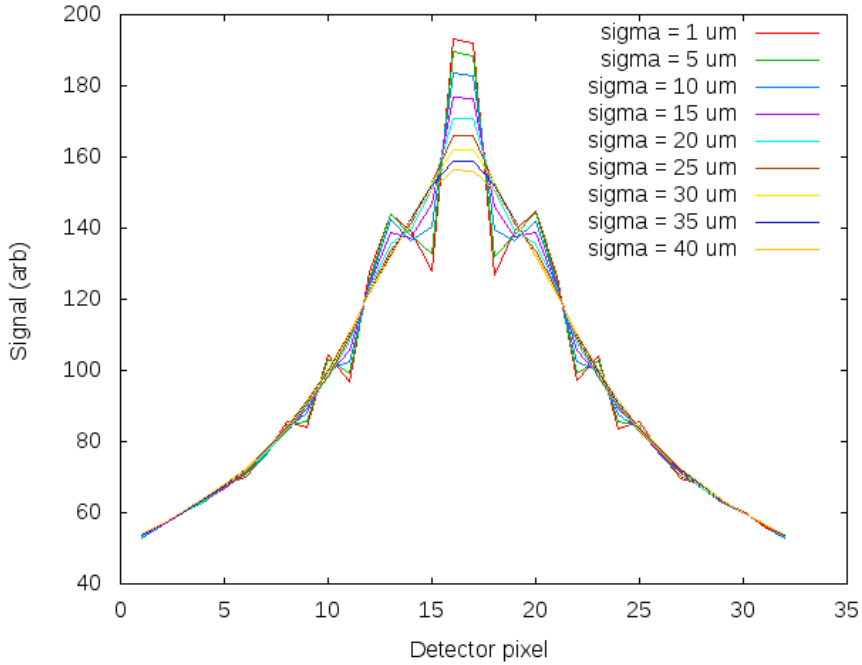


Measured dispersion with gain corrections and fitted BPM tilts

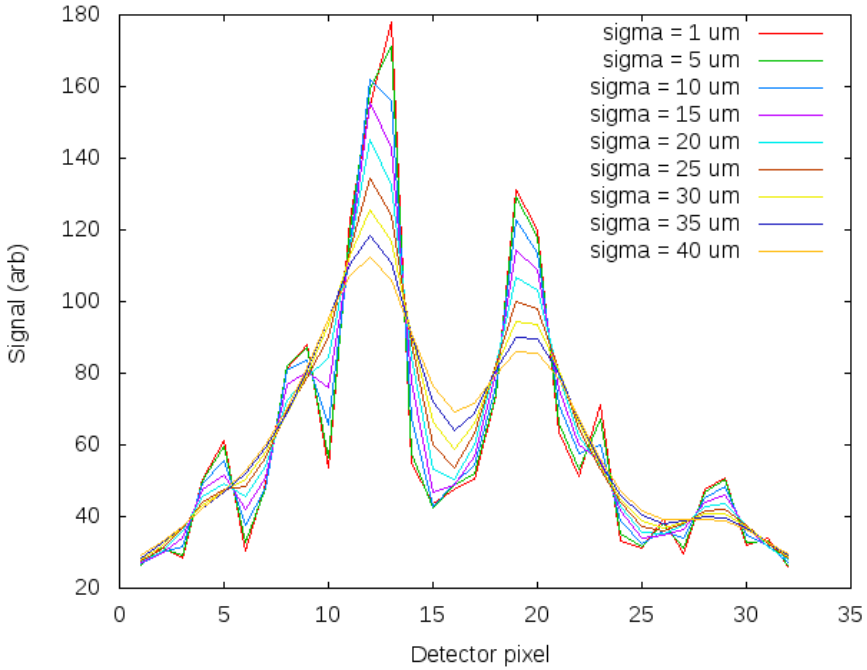


X-Ray Beam Size Monitor

- xBSM detectors are operational for both positrons and electrons
- Both capable of bunch-by-bunch, turn-by-turn readout
- Resolution: ~ 16 microns with pinhole optic
  < 10 microns with FZP
  < 10 microns with Coded Aperture
- Capable of varying βy at xBSM source: 4m ➡ 30m



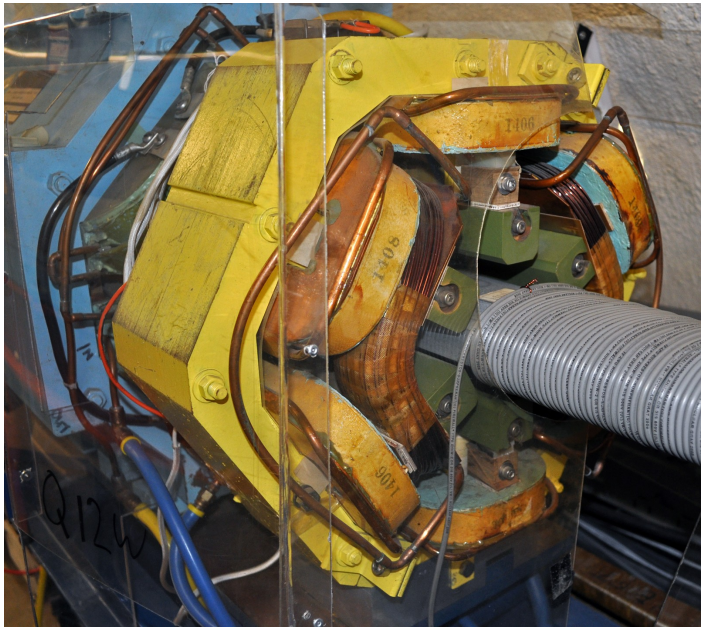
FZP (simulated)

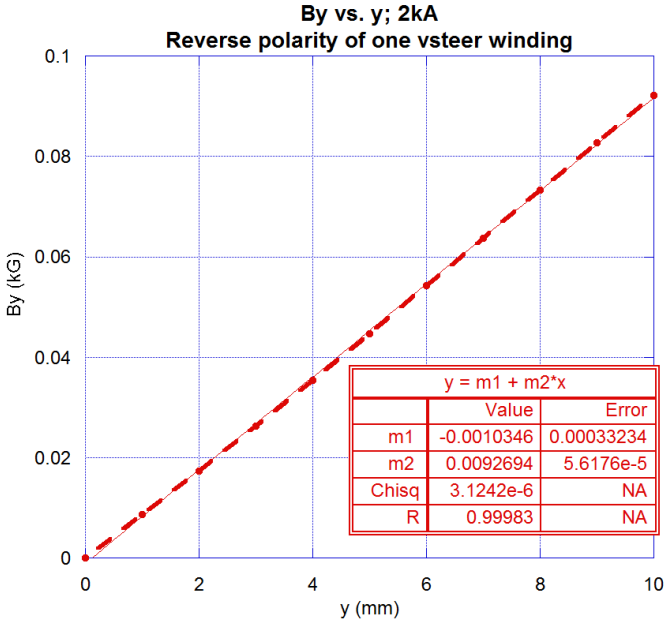


Coded Aperture (simulated)

Skew Quad Trims on Sextupoles

- Vertical steering trim coils already exist on all sextupoles
  - Only trims on sextupoles near vertical-focusing quadrupoles are normally powered as steerings
- Reversing polarity on one coil creates a skew-quad-like field
- Power 12 sextupole trims (6 through each arc wiggler triplet) as skew quadrupoles to fine-tune coupling through wigglers
- Increased total number of skew quadrupoles in CESR from 15 to 27





Low-Emittance Tuning Procedure

Standard Low-Emittance Tuning Procedure:

- Measure / correct orbit to reference for xBSM horizontal orbit bump
  - Horizontal orbit bump required to mimic CHESS pretzel orbit and get light down xBSM beamline
- Measure betatron phase and coupling using resonant excitation; correct
- Next, measure:
  - Orbit (remeasure)
  - Betatron phase and coupling (remeasure)
  - Dispersion (using resonant excitation)
- Correct all three simultaneously using:
  - all 57 vertical steering correctors
  - all 27 skew quadrupoles

LET Procedure - Results

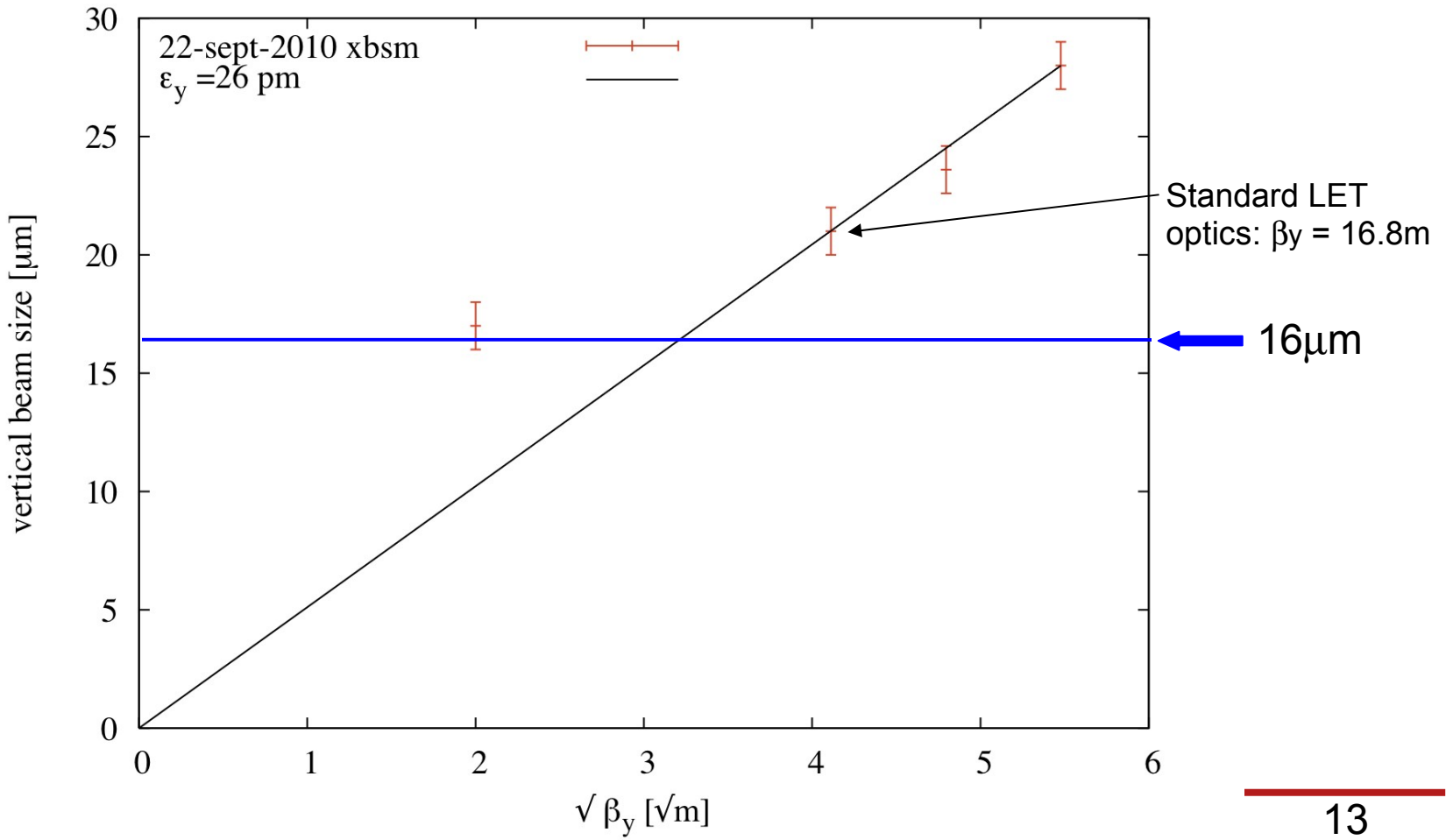
- Typical correction levels:
  - Cbar12 reduced to < 0.5% (RMS)
    - Contribution to ε_y is negligible
  - Vertical dispersion reduced to ~1.5cm (RMS)
- For standard optics (β_y = 16.8m at source) and using 16μm pinhole optic, typical beamsize is **~18μm**
  - corresponds to $\boldsymbol{\varepsilon_y}$ **~ 20 pm**
  - CesrTA Phase I emittance target met
  - Very close to resolution limit of pinhole optic
- η_y is typically ~several mm at xBSM source point
  - Typically adds ~10μm in quadrature to σ_y:

$$\sigma_y = \sqrt{\beta_y \epsilon_y + \left(\eta_y \frac{\sigma_E}{E}\right)^2}$$

Beamsize vs. β

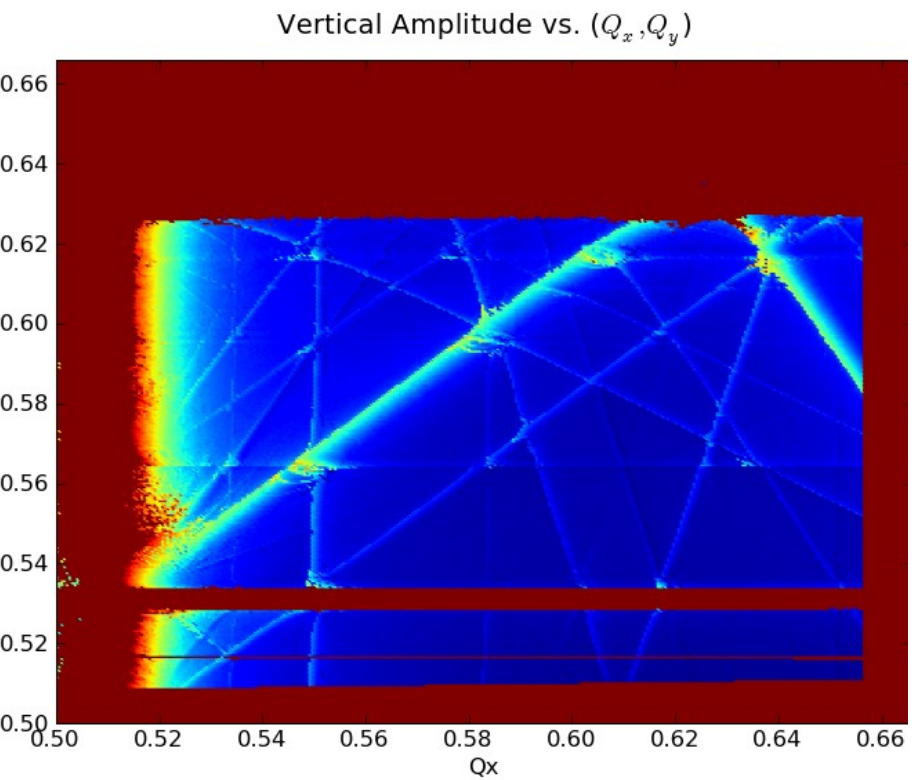
-Fully-automated analysis for FZP, coded aperture is under development

-Measurement of beam size vs β at xBSM source agrees with independently-measured resolution for pinhole optic **~ 16μm**

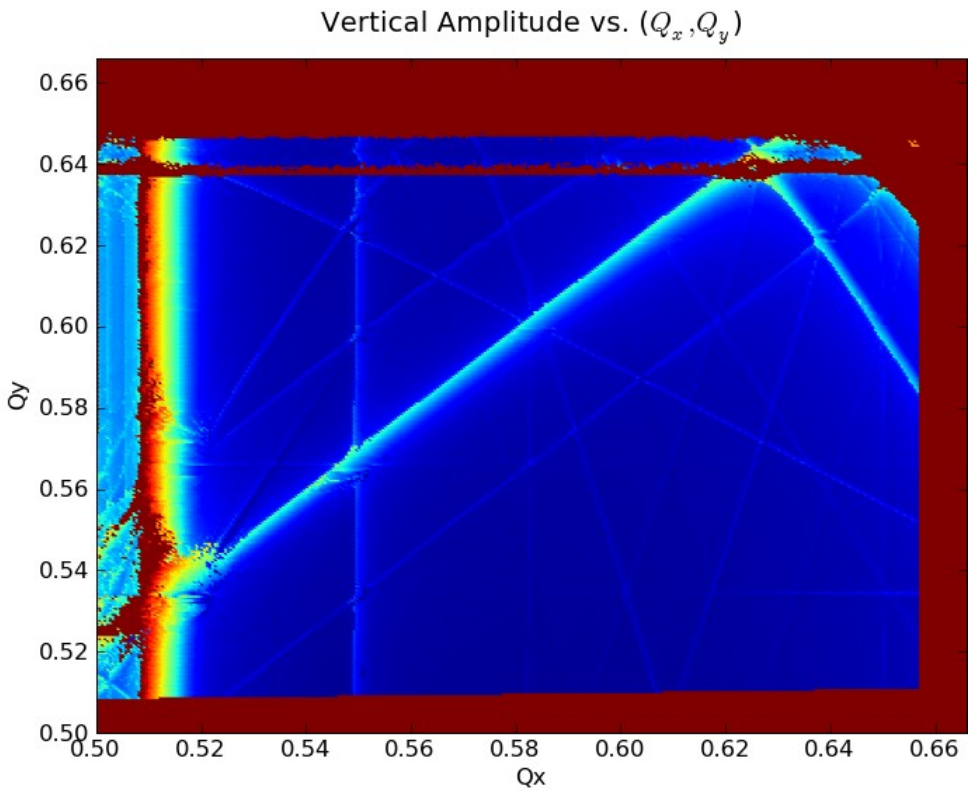


Sextupole Optimizations

Optimize sextupole distribution to reduce resonance-driving terms, etc.



2-family



Optimized

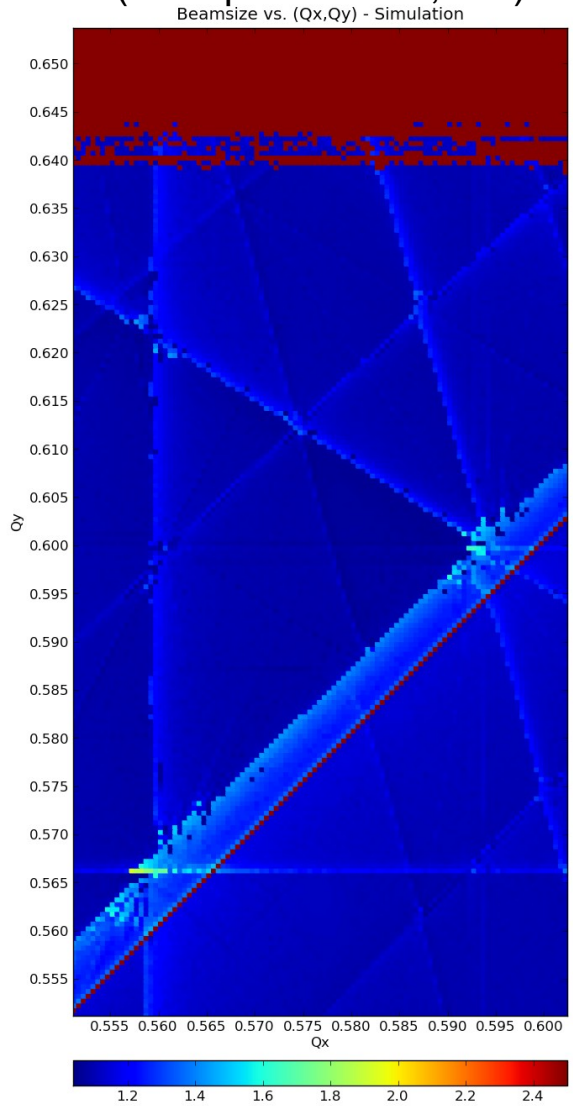
Tune Scan Measurement

- Automated measurement of beam size using xBSM
- Stitch together 8 individual tune scan measurements

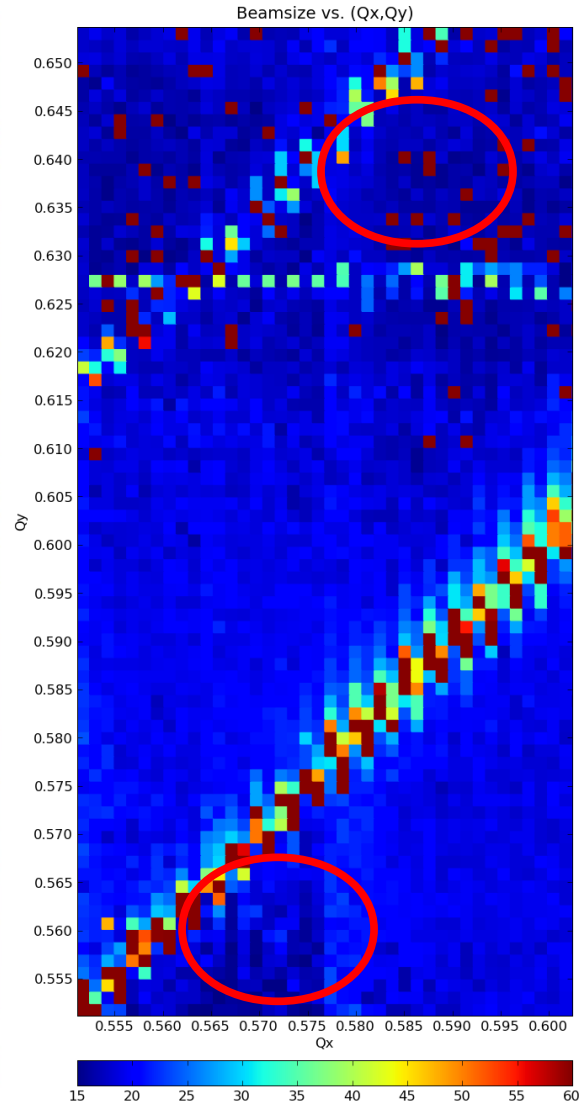
Tune scans cover region (0.550,0.550) to (0.605,650)

Regions with smallest measured beamsize circled in RED

Simulation
(with quad offsets, tilts)



Data

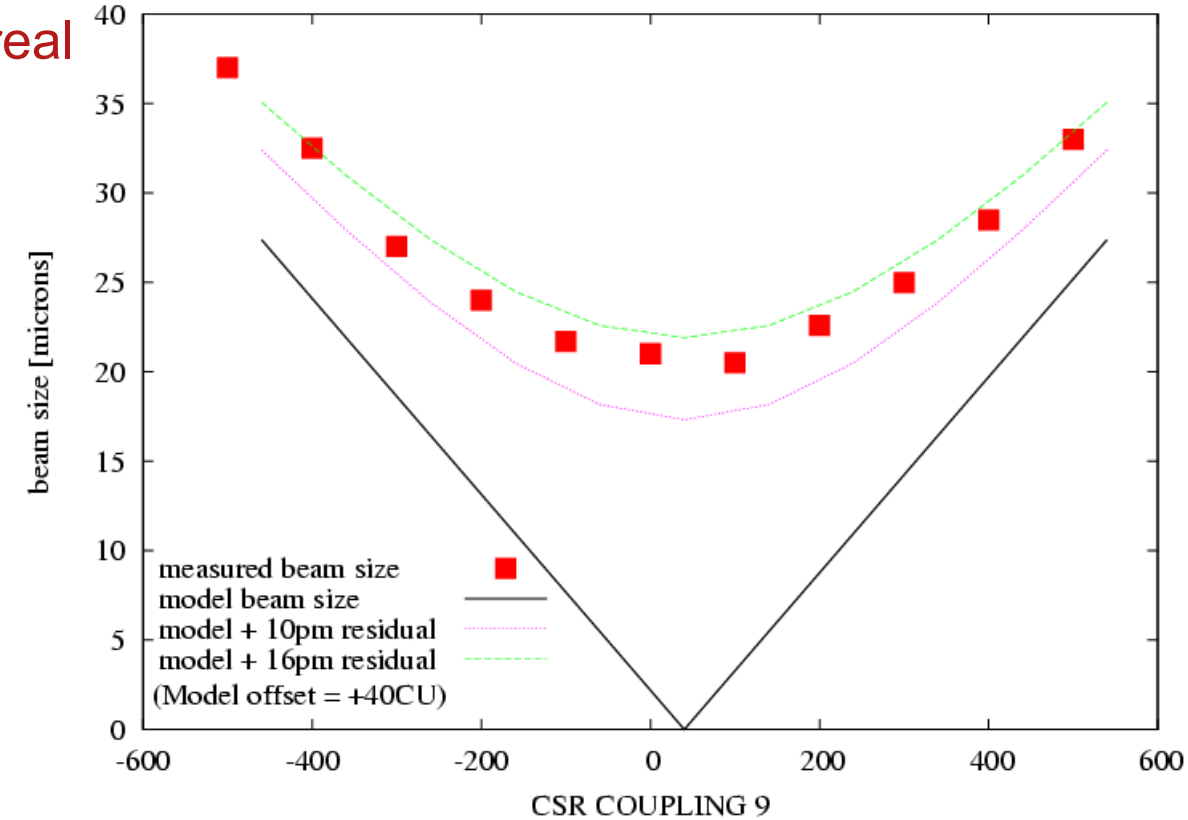


LET - Final Result

- Combining everything we've learned...
  - Improved magnet alignment
  - Time in BPM system
  - New sextupole distribution
  - New working point based on tune scan results
  - Increased β_y at xBSM source (16.8m --> 30m)
  - Full LET optimization procedure
  - Vary the closed-η_y bump at xBSM source
- ...we observed xBSM measurements consistent with **ε_y < 15pm**
  - **VERY PRELIMINARY** ➡ no chance to check repeatability
  - Need to verify in next CesrTA run!

Beamsize vs. coupling 9

- In "sub-15pm" corrected optics, vary a closed coupling bump through one triplet of wigglers
  - To first order, bump does not affect optics at xBSM source point
- Measure beam size response
  - serves as cross-check for beam size measurements
- Suggests beamsize is real
- Minimum not at 0CU



Contributions to Uncertainty

- Uncertainty in ε_y measurement: **+2.5/-4.5 pm**
- Considered contributions to uncertainty from:
  - β_y at source
  - η_y at source (unidirectional for uncertainty in ε_y)
  - Uncertainty in longitudinal location of source point
    - Including Twiss parameter propagation with s
  - Scatter in individual beam size measurements

Conclusions

- Need to confirm these results in the next CesrTA run (December)
  - Reproduce result
  - Further characterize contributions to emittance reduction:
    - Optimized sextupole distribution
    - New working point
    - Large β_y at source
  - Lifetime
  - IBS...
- Several new techniques under development:
  - Normal-mode corrections - A. Wolski
  - “2Qx” phase measurement - D. Sagan, Y. Yanay
- To be done:
  - High-chromaticity sextupole distribution for multibunch operation
  - Further increase β_y at xBSM source (40m or higher)

Acknowledgments

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