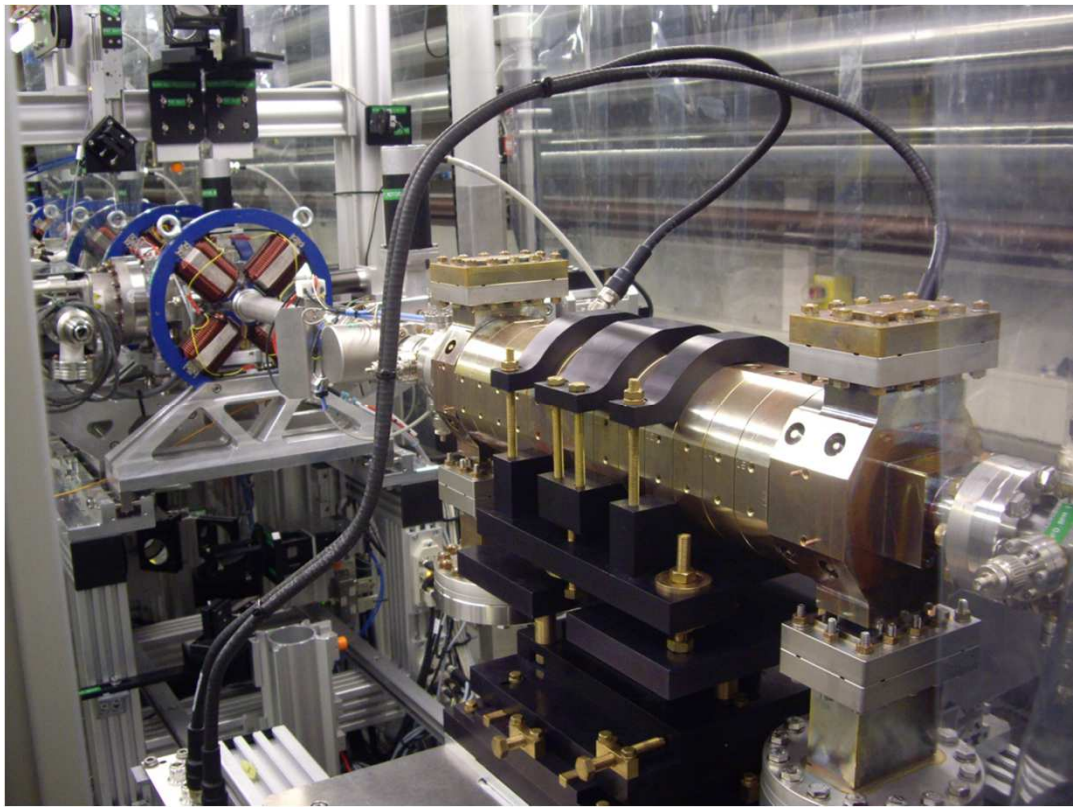
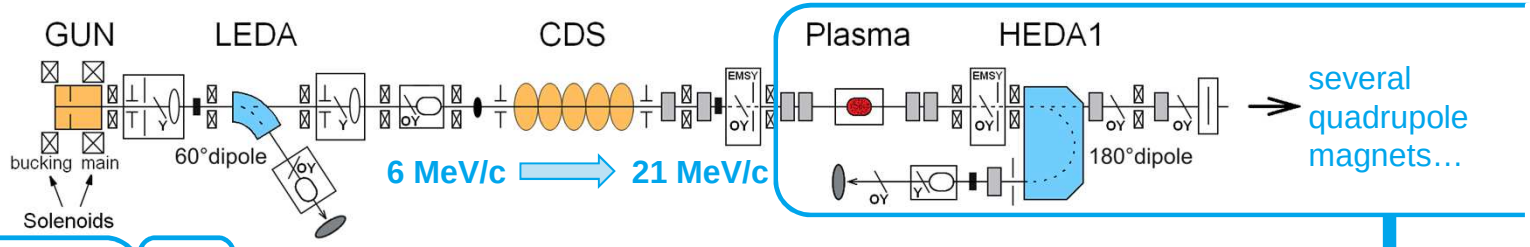
PITZ Quadrupoles in ASTRA

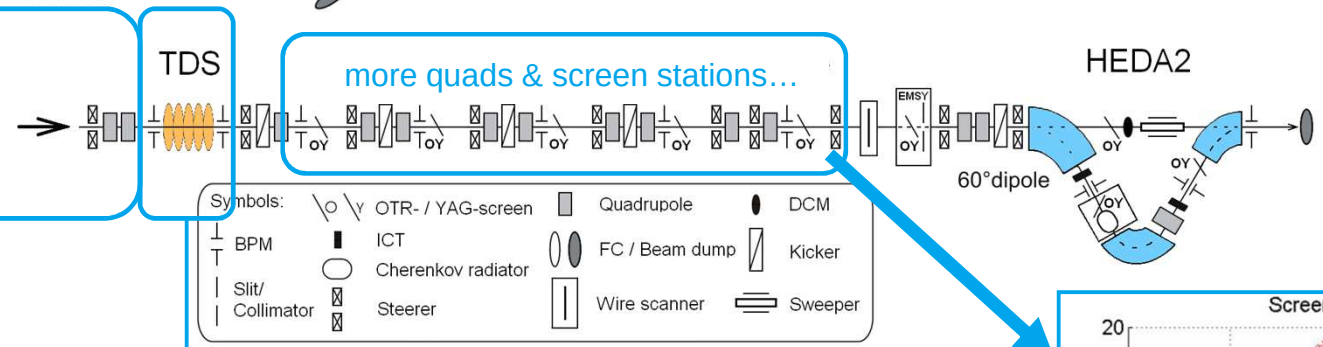
- Motivation: SLEM, quad scan
- Different quad models
- Errors
- SLEM program for this run

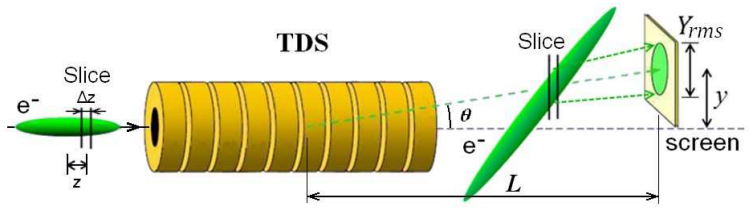


Holger Huck
29.06.2017, PITZ RC/PPS

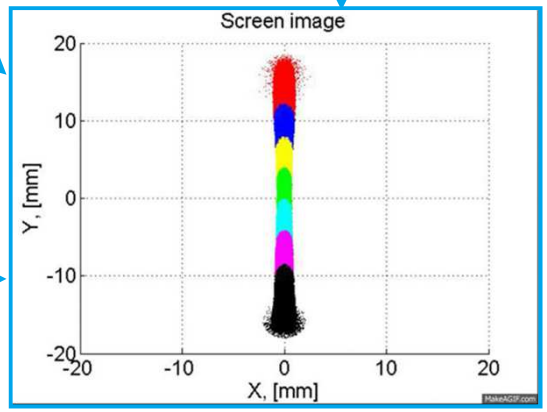
Slice Emittance Measurement Setup @ PITZ







deflecting cavity: bunch length mapped to vertical axis



applying quad-scan technique to TDS-separated longitudinal slices of the bunch =

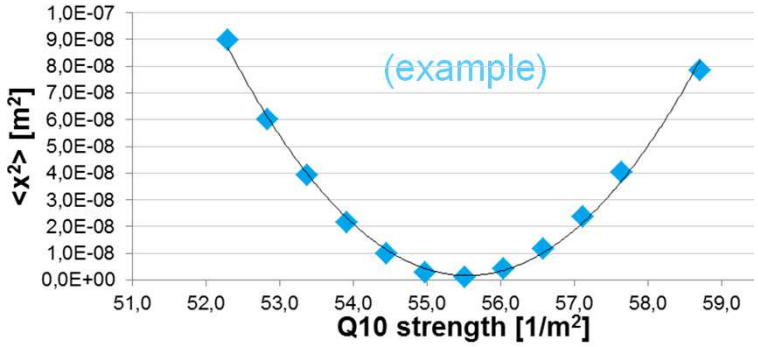
horizontal slice emittance measurement!

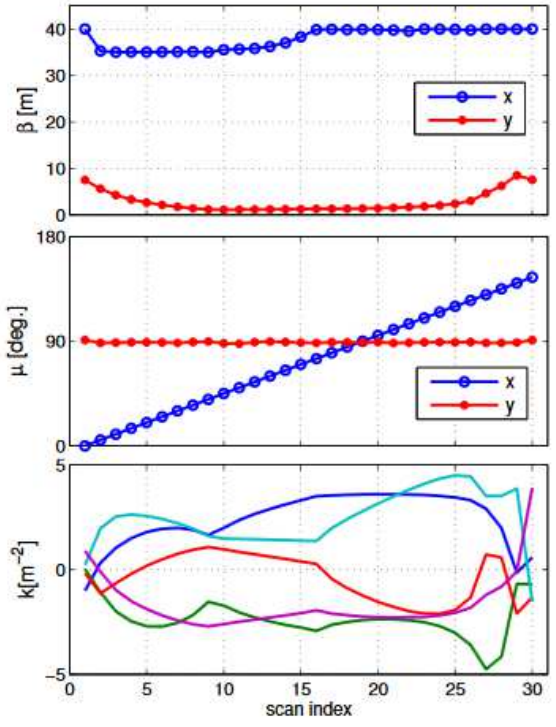
Emittance Measurement by Quadrupole Scan

- Idea:
  - Backtracking the measured beam size <x²> through a known beam transport matrix.
  - Measure <x²> for different matrices but the same starting distribution x_0, x_0', then fit a parabola.
- General approach (linear matrix optics): $x = R_{11}x_0 + R_{12}x_0'$

$$\rightarrow \quad \langle x^2 \rangle = R_{11}^2 \langle x_0^2 \rangle + 2R_{11}R_{12}\langle x_0 x_0' \rangle + R_{12}^2 \langle x_0'^2 \rangle$$

  - With at least 3 measurements, the unknown moments of the starting distribution can be obtained by a parabola fit (…and a matrix formalism can replace fit)

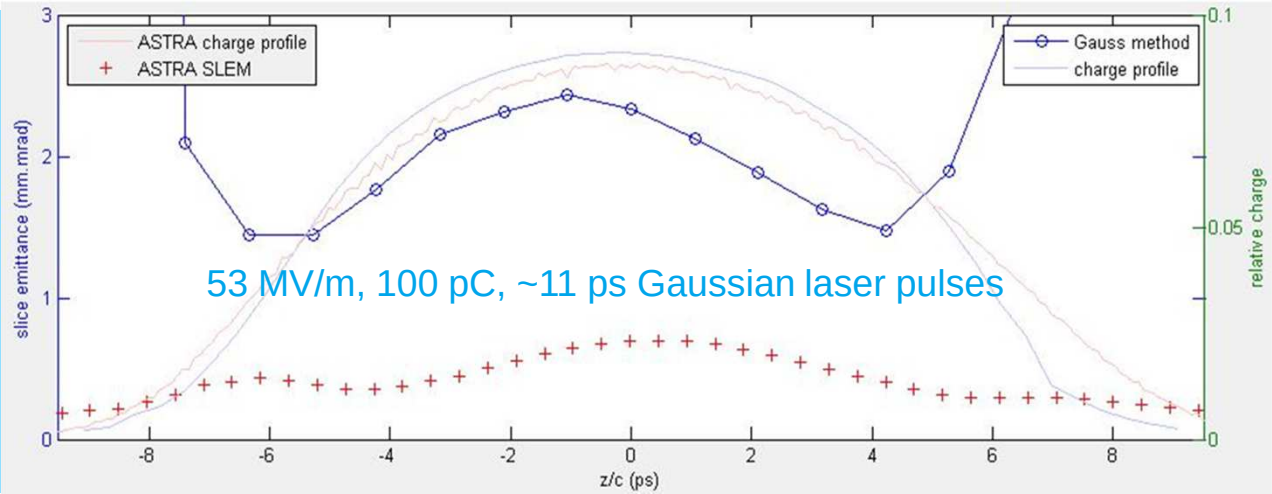




- Better approach: keep beam size constant, scan phase advance (ref.: E. Prat, FEL'13, TUOCN06)
- Main problem at PITZ: Space charge at 20 MeV!

Motivation: First Slice Emittance Measurements

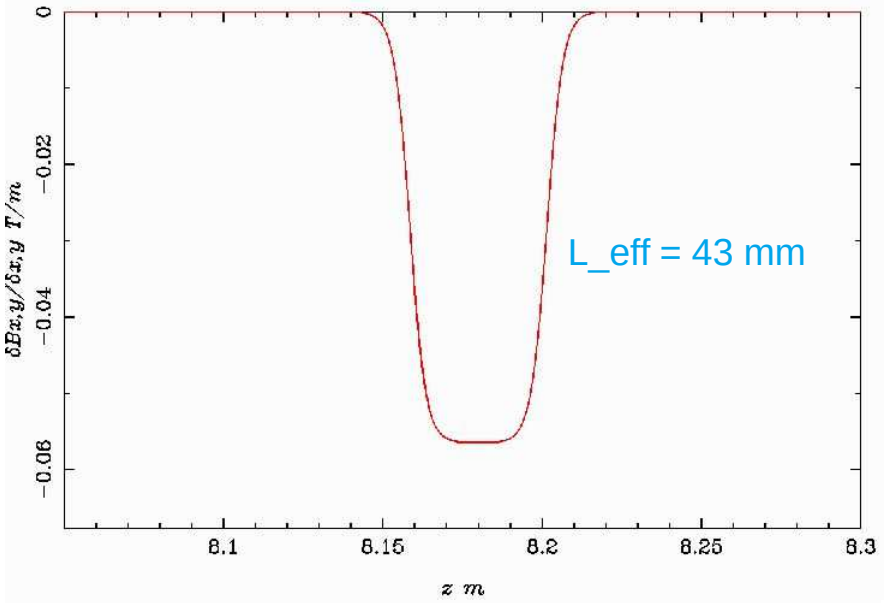
- First try (right): measured slice emittance ~3x higher than in ASTRA…
  - Only **single-quad scan**, different beam sizes for different slices and for different quad strengths ->
  - -> Systematic errors by varying intensity and by slice mixing

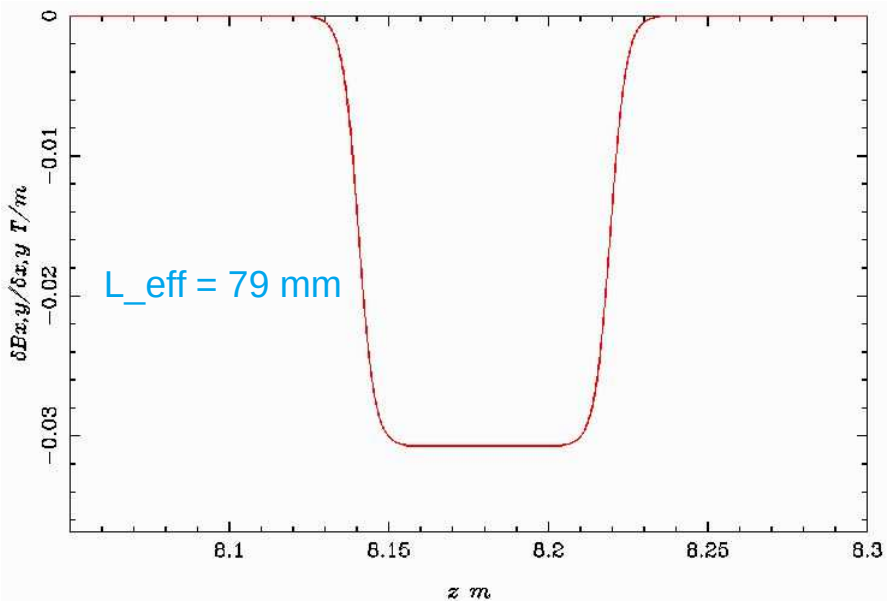


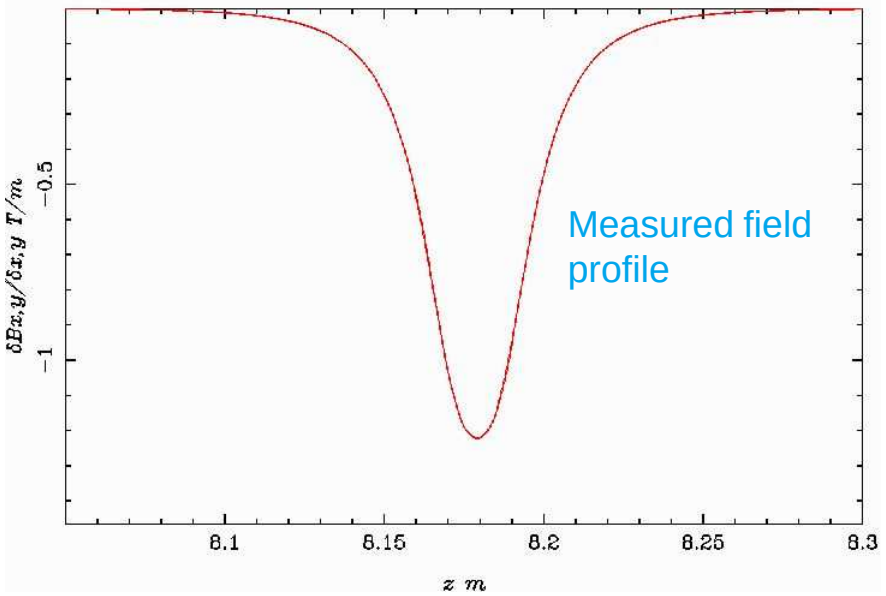
- Next try: **Multi-quad scan**
  - 10 pC to almost eliminate space charge effects
  - Took measured projected emittance and Twiss parameters at EMSY2 as input for MADX matching
- Results: worse than single-quad scan, reconstruction impossible (imaginery)
- Measured beam sizes were way off (>50%) the linear matrix prediction!
  - Explanation? Quad currents were fine!

- **>> ASTRA simulations with different quad models!**

Quad models

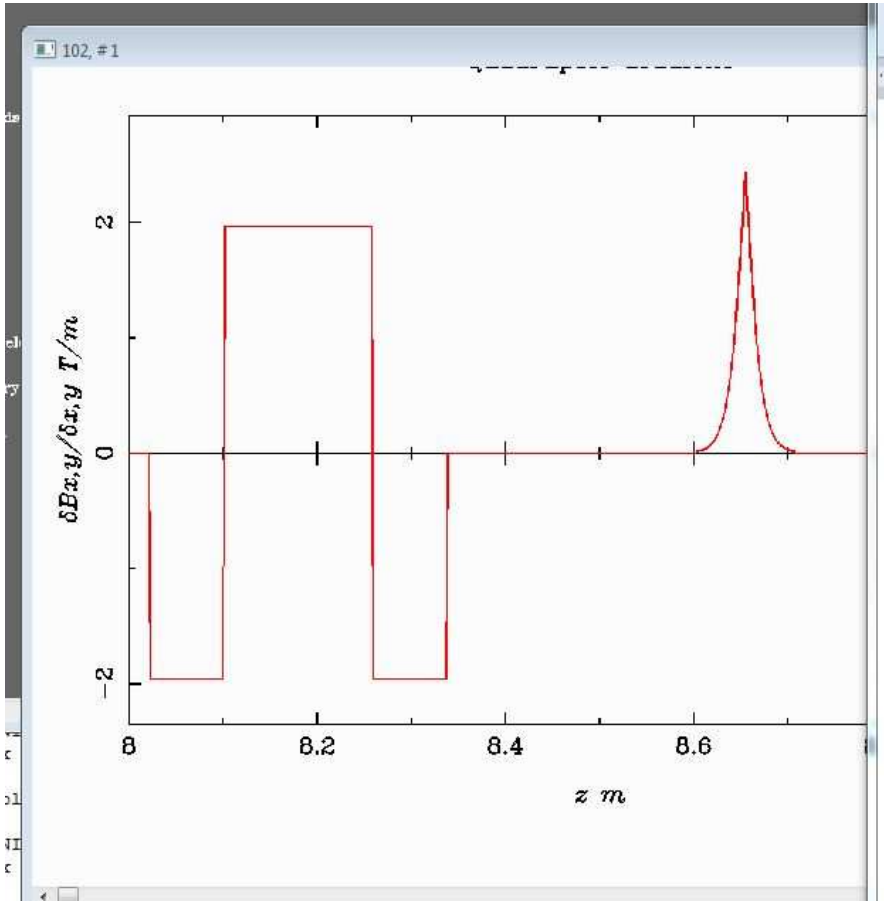






- Area (B*dz) is the same for all models (B scaled according)
- Standard model: 43-mm hard edge linear matrix, with B=B_max of field profile data)
- Field profile data taken from Danfysik calibration sheets for individual magnets
- 79 mm was suggested/calculated by A. Matveenko (analytical formula)

ASTRA bug or feature…

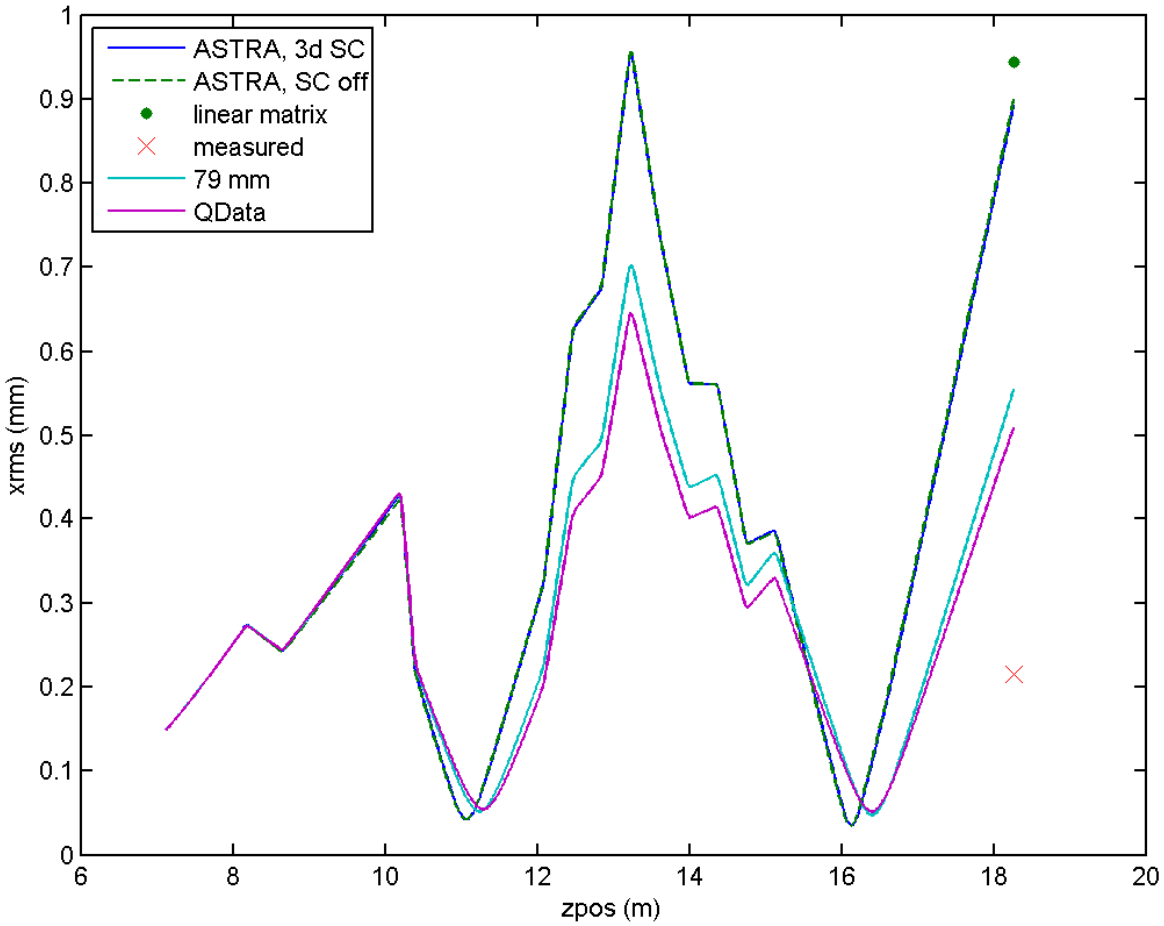



```
&QUADRUPOLE
Lquad=TRUE
Q_pos(1)=8.1800
Q_grad(1)=1.962643467
Q_length(1)=0.0790
Q_bore(1)=0.0001
Q_type(1)='../../../AstraPortal/Q1cutM.data'
Q_noscale(1)=TRUE
Q_pos(2)=8.6550
Q_grad(2)=-2.437197193
Q_type(2)='../../../AstraPortal/Q1cutM.data'
Q_noscale(2)=TRUE
Q_pos(3)=10.2080
Q_grad(3)=0.336537207
Q_type(3)='../../../AstraPortal/Q9.data'
Q_noscale(3)=TRUE
Q_pos(4)=10.3880
Q_grad(4)=0.675420113
Q_type(4)='../../../AstraPortal/Q10.data'
Q_noscale(4)=TRUE
Q_pos(5)=12.0880
Q_grad(5)=-1.958436100
Q_type(5)='../../../AstraPortal/QM1.data'
Q_noscale(5)=TRUE
Q_pos(6)=12.4680
```

- When „tr“ keyword appears before „data“ keyword in the Q_Type string, ASTRA creates a triplet!
- Hard to find out, since no proper warning and default soft edge model with 0 length looks not so different from real profile…

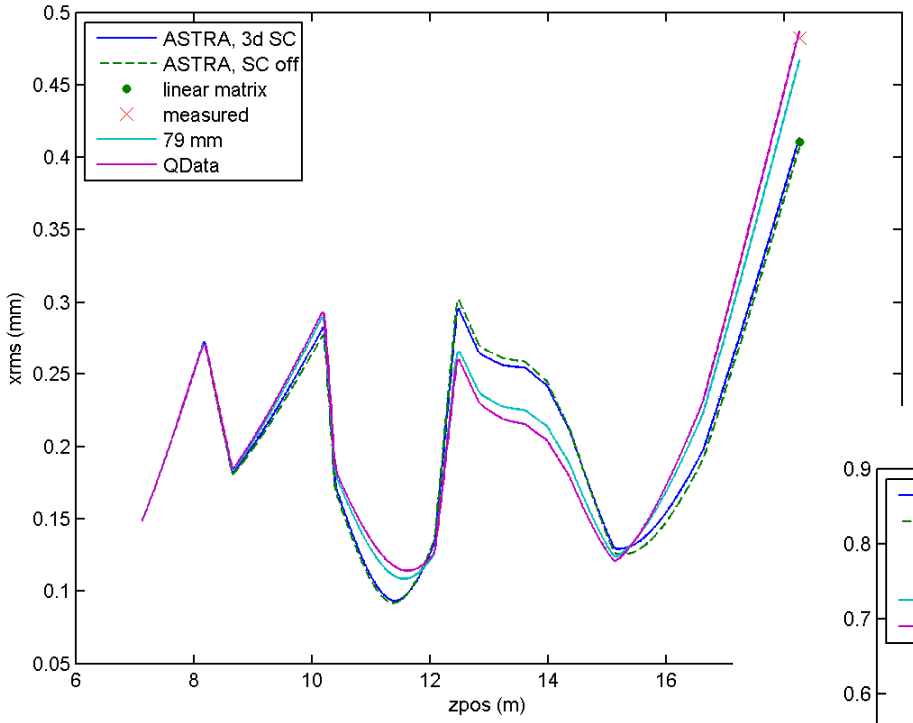
Results for matching solution #1

- 10 pC, simulating 14 quads between EMSY2 and High2.Scr2
- Twiss-matched starting distribution at EMSY2 (using *ps_viewer.m*)
- Blue & green curves use 43-mm model

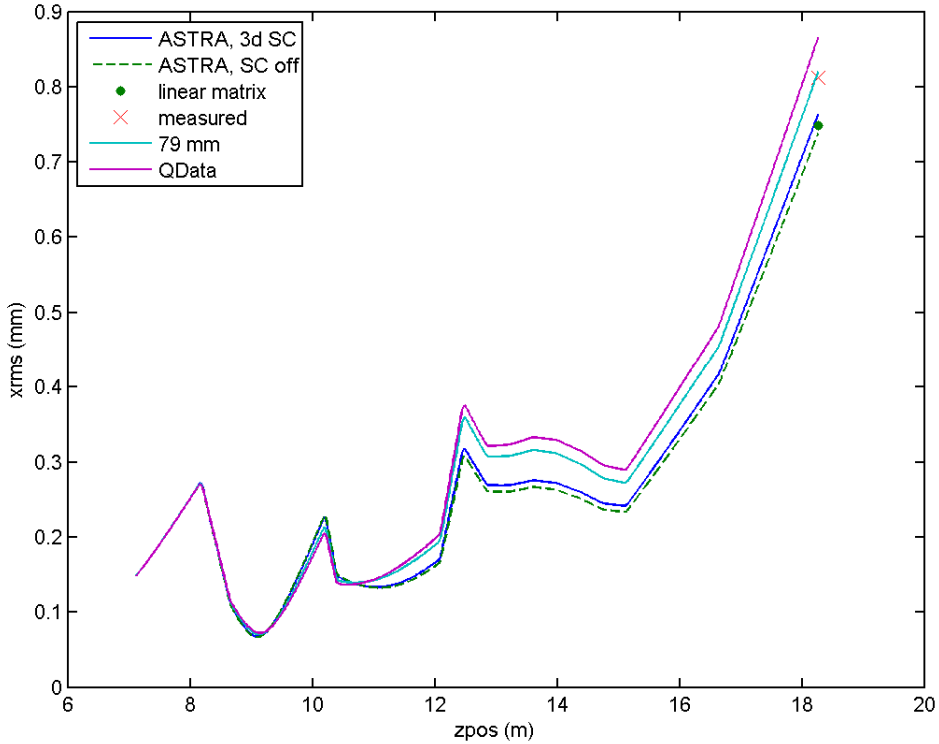


- 5% discrepancy between hard and soft edge model
- Almost no SC effect
- 79mm model close to real profile! (+5%)
- 43mm model ~100% off!
- Measurement still 50% lower than Qdata (=real profile)
- Major source of discrepancies: early and tiny waist (~50 µm)

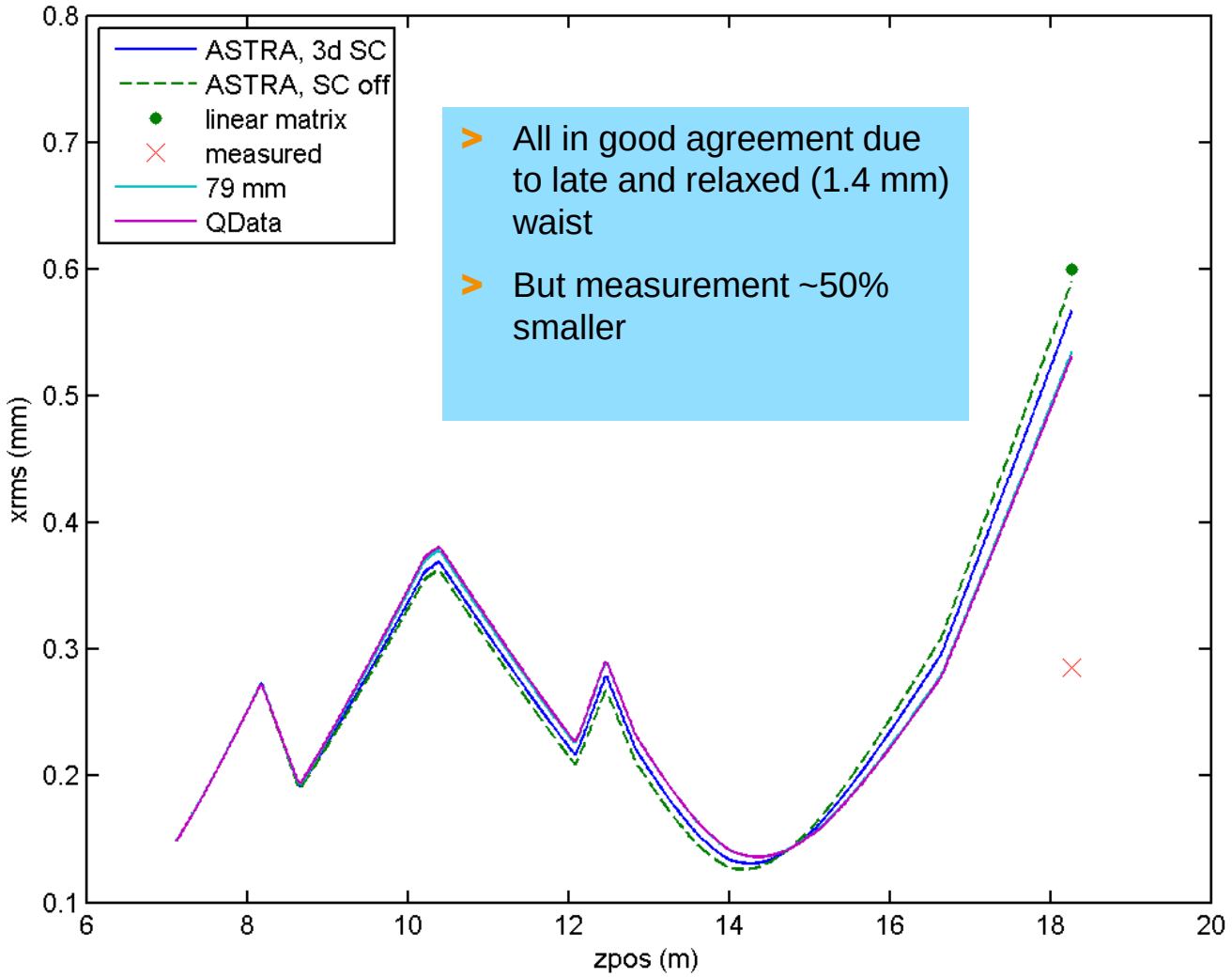
#2, #3



- Smaller errors, larger waists
- Very good agreement between Qdata and measurement!
- 43mm is 10-15% off

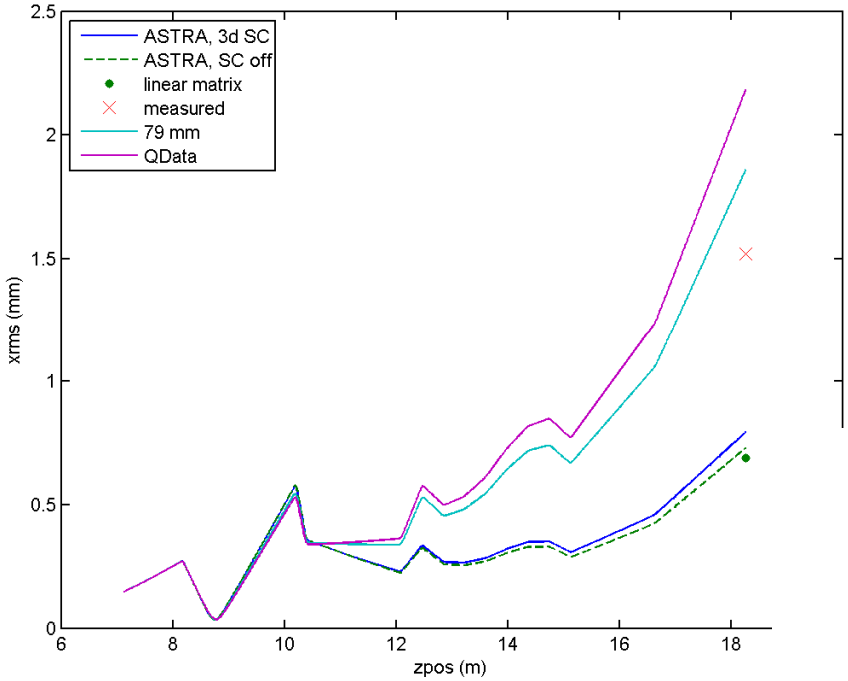


#5

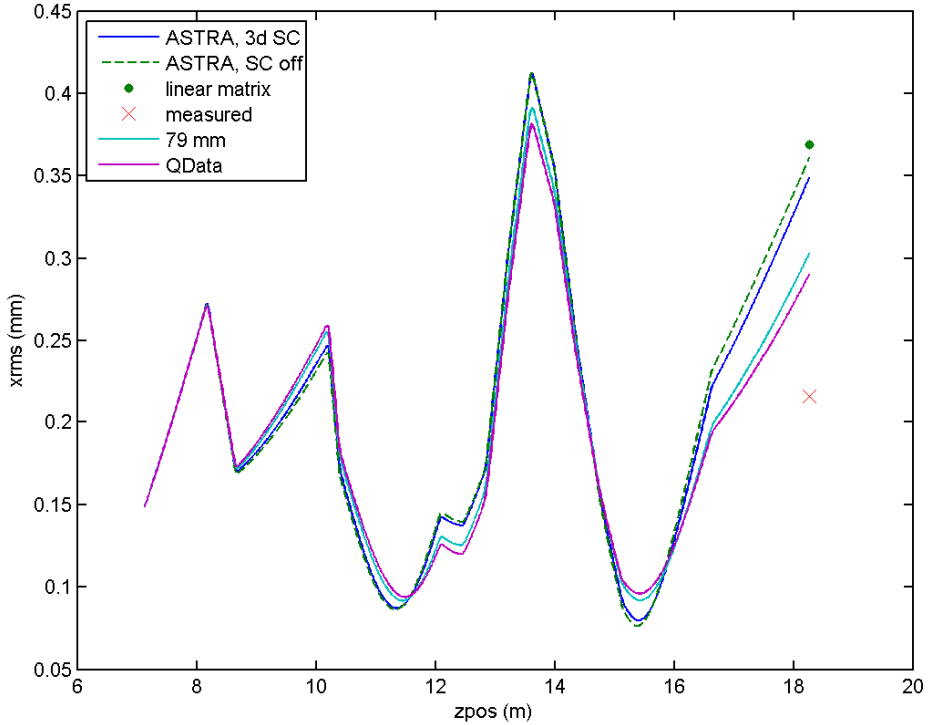


- All in good agreement due to late and relaxed (1.4 mm) waist
- But measurement ~50% smaller

#4, #6

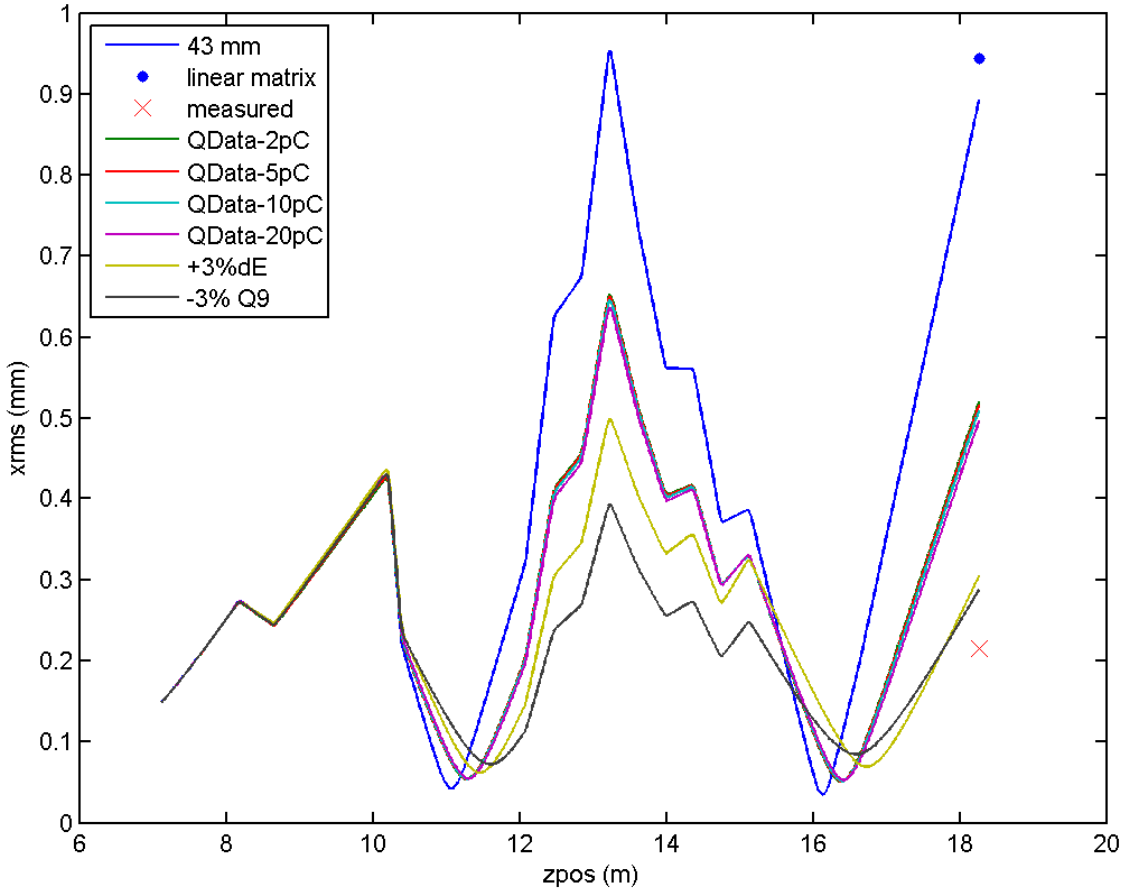


- Qdata is always closer to measurement than 43-mm model
- But still some ~40% difference to measurement...



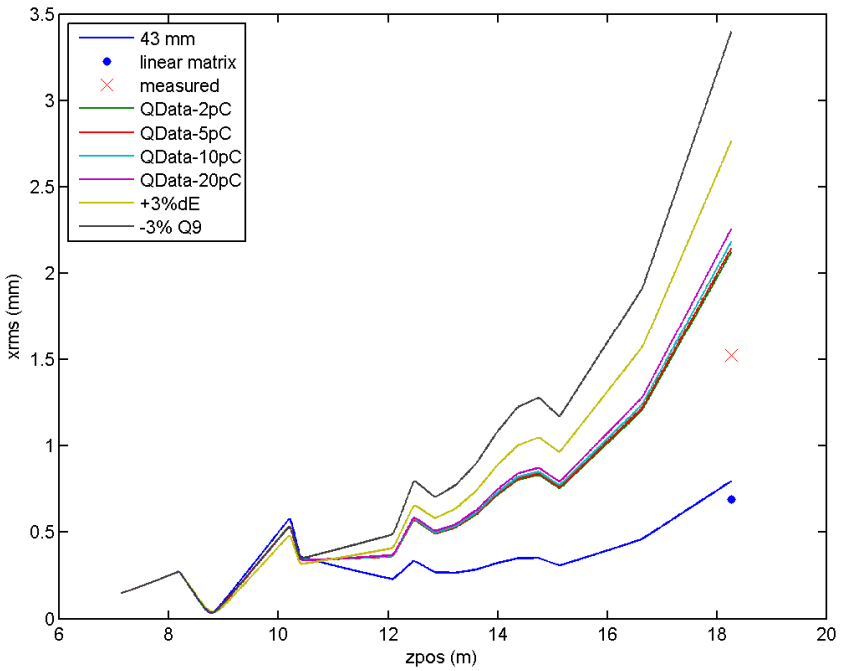
Error sources…

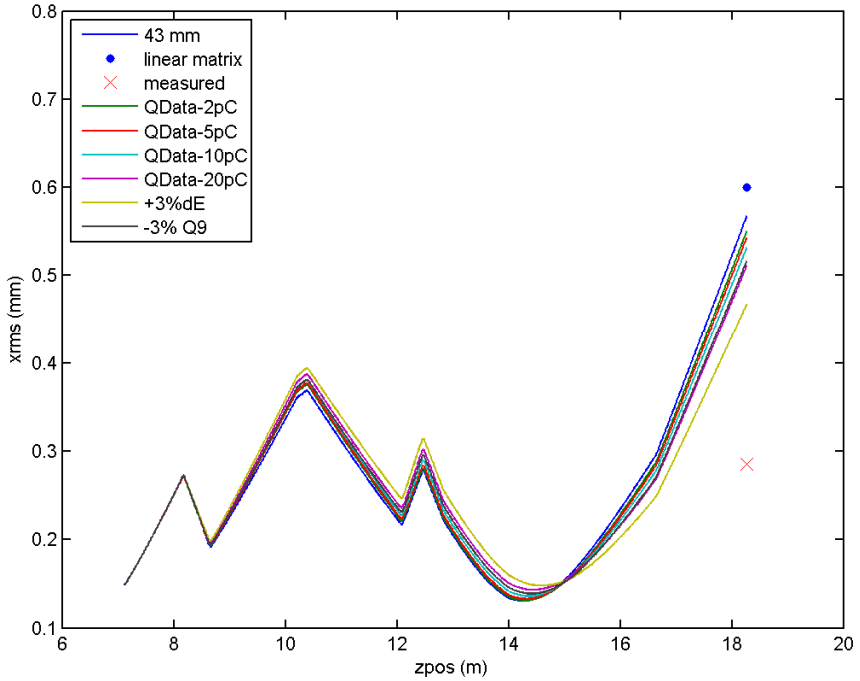
- Can we explain the remaining discrepancies to measurement?
- Below are the effects of 3% energy offset and 3% single-quad gradient error:



Error sources…

> Not so nice for #4 and #5...:





Summary

- 43-mm model can give major errors compared to the measured field profile
- 79-mm model results seem very close to field profile
- Real field profile simulations are closer to measurements, but sometimes still large errors
- Remaining errors probably can be explained of combination of ~1% errors in 14 quad gradients

- Better use **less** quads!
- Avoid sharp waists / high divergences
- Find more robust optics, that are **insensitive** to small quad gradient errors!