# IP Beam Size Tuning

- Glen White, on behalf of IP tuning task group (SLAC, LAL, CERN, KEK, Tokyo, IHEP, LAPP, STFC...)
- 7th ATF2 Collaboration Meeting, Dec 2008

- Summary of work and objectives
- Summary of simulation-based studies
- Plans

# Objectives

- Formulate and test in simulation the procedure for achieving the goal vertical waist size at IP.
- Include as much realism as possible, starting with expected beam conditions after installation and alignment.
  - Standardise error conditions for cross-code comparisons (use common initial seeds).
  - Include measurements where possible
- Compare multiple methods accross different codes
- Produce production code (flight-simulator based), simulation tested and ready for beam operations early in 2009.

# Collaboration

- Strong collaboration across many labs/institutes.
- First informal group meeting, August at LAL.
- Webex meetings every ~3 weeks since- talks and minutes on ATF2 Indico site.
- Software and simulation details (common error set etc) shared on SLAC ATF2 Flight Simulator wiki pages.
- Common simulation seeds stored on SLAC ATF2 ftp server
  - Common accelerator description through AML
  - AML Parsers available and under development in Lucretia, PLACET, SAD, XSIF.

# Simulation Studies

- Define realistic starting conditions (100 seeds)
  - Standard installation errors + EXT BBA, disp corr, coupling corr, FFS BBA
- Study performance of IP tuning on 100 seeds including dynamic errors.
- Check h/w limits not exceeded at any point.
- Study effect of dynamic errors on tuned machine.

# Standard Error List

Co-ordinate system used here is right-handed. Roll = rotation in x-y plane, pitch= rotation in y-z p

The reference ground motion model for ATF based on measured GM spectra on the DR floor is in t
(also available as a standalone Matlab routine- to be provided here shortly).

| Error Parameter | Error magnitude |
|---|---|
| x/y/z Post-Survey | 200 um |
| Roll Post-Survey | 300 urad |
| BPM - Magnet field center alignment (initial install) (x & y) | 30 um |
| BPM - Magnet alignment (post-BBA, if BBA not simulated) (x & y) | 10 um |
| Relative Magnetic field strength (dB/B) (systematic) | 1e-4 |
| Relative Magnetic field strength (dB/B) (random) | 1e-4 |
| Magnet mover step-size (x & y / roll) | 300 nm / 600 nrad |
| Magnet mover LVDT-based trim tolerance (x & y / roll) | 1 um / 2 urad |
| C/S - band BPM nominal resolution (x & y) | 100 nm |
| Stripline BPM nominal resolution (x & y) | 10 um |
| IP BPM nominal resolution (x & y) | 2 nm |
| IP Carbon wirescanner vertical beam size resolution | 2 um |
| IP BSM (Shintake Monitor) vertical beam size resolution | use attached data |
| EXT magnet power-supply resolution | 11-bit |
| FFS magnet power-suppy resolution | 20-bit |
| Pulse - pulse random magnetic component jitter | 10 nm |
| Pulse - pulse relative energy jitter (dE/E) | 1e-4 |
| Pulse - pulse ring extraction jitter (x, x', y, y') | 0.1 sigma |
| Corrector magnet pulse-pulse relative field jitter | 1e-4 |

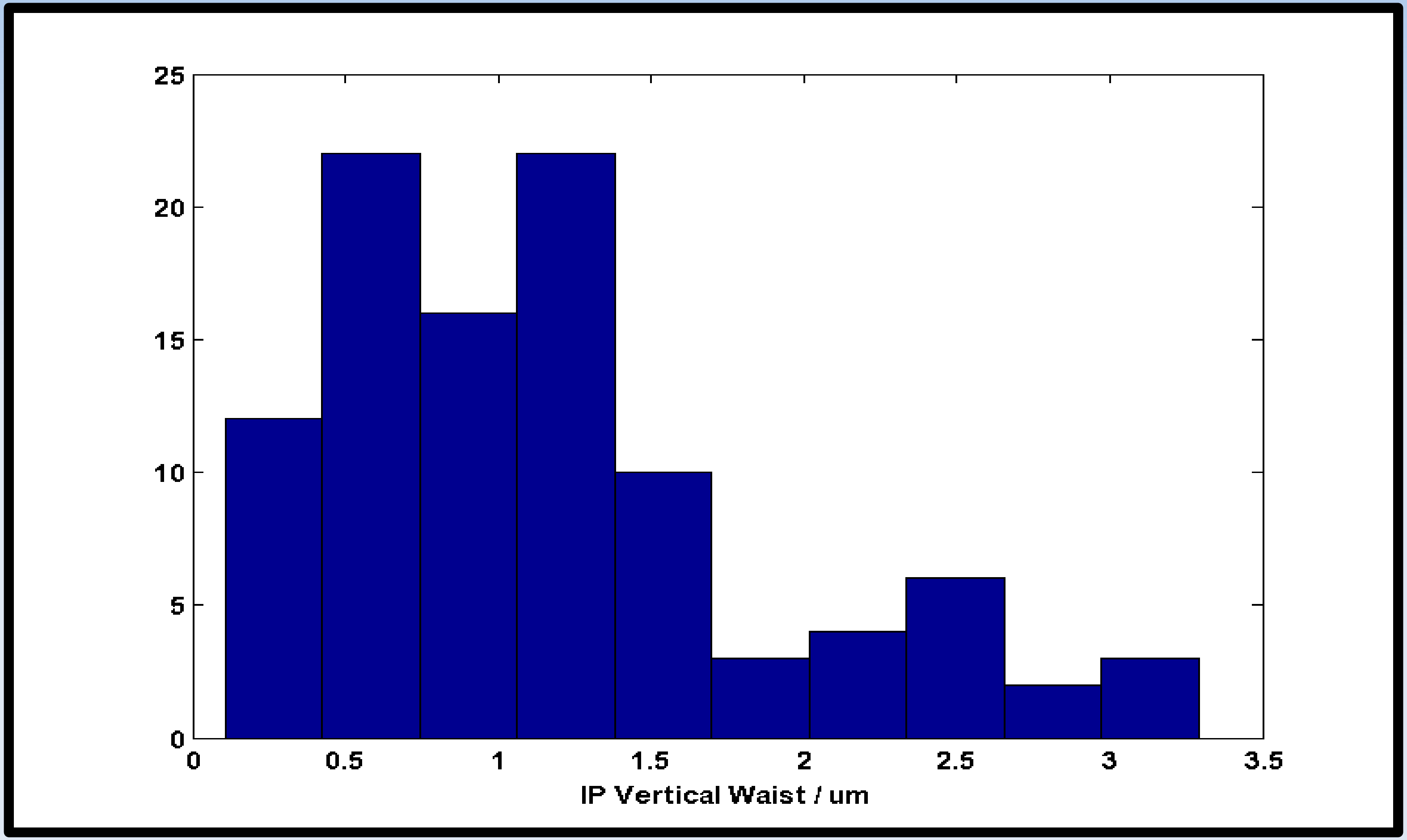
Done

- Error list on wiki
- Also GM- ATF fitted Model
- Also include measured multipoles for final doublet, sextupoles and FFS bends.
- Also, detailed SM resolution simulation

# Simulation Steps

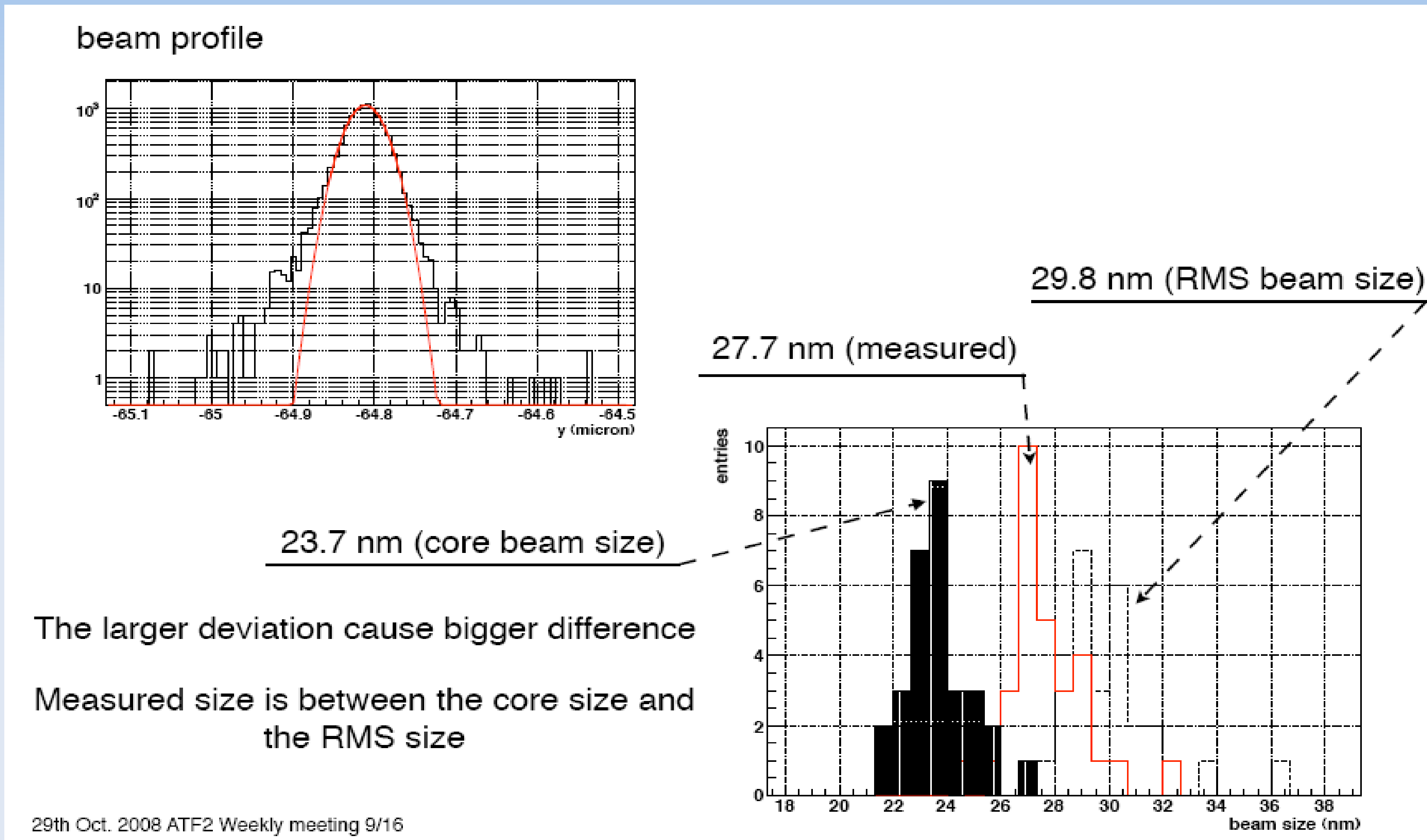
- Use EXT correctors + BPMs (EXT FB) to get orbit through EXT.
- Use FFS FB to get beam through FFS.
- Correct Dy/Dy' in EXT using skew-quad sum knob.
- Correct coupling in EXT using coupling correction system.
- Use FFS FB for launch into FFS.
- FFS Quad BPM alignment using quad shunting with movers.
- FFS Quad mover-based BBA.
- FFS Sext BPM alignment using Sext movers and IP BPM.
- Sextupole mover tuning knobs to get final spot size
  - Vertical IP dispersion and Waist
  - <x'y> coupling
  - Higher order terms collectively through Sext rolls + dK.
- Also use EXT skew-quads to tune other coupling terms.
- No attempt to model EXT BBA yet (assume 10um RMS bpm-magnet center offset)
- No attempt to model any lattice matching (Ring - EXT)

# Beamsize After EXT Tuning and Steering/BBA etc



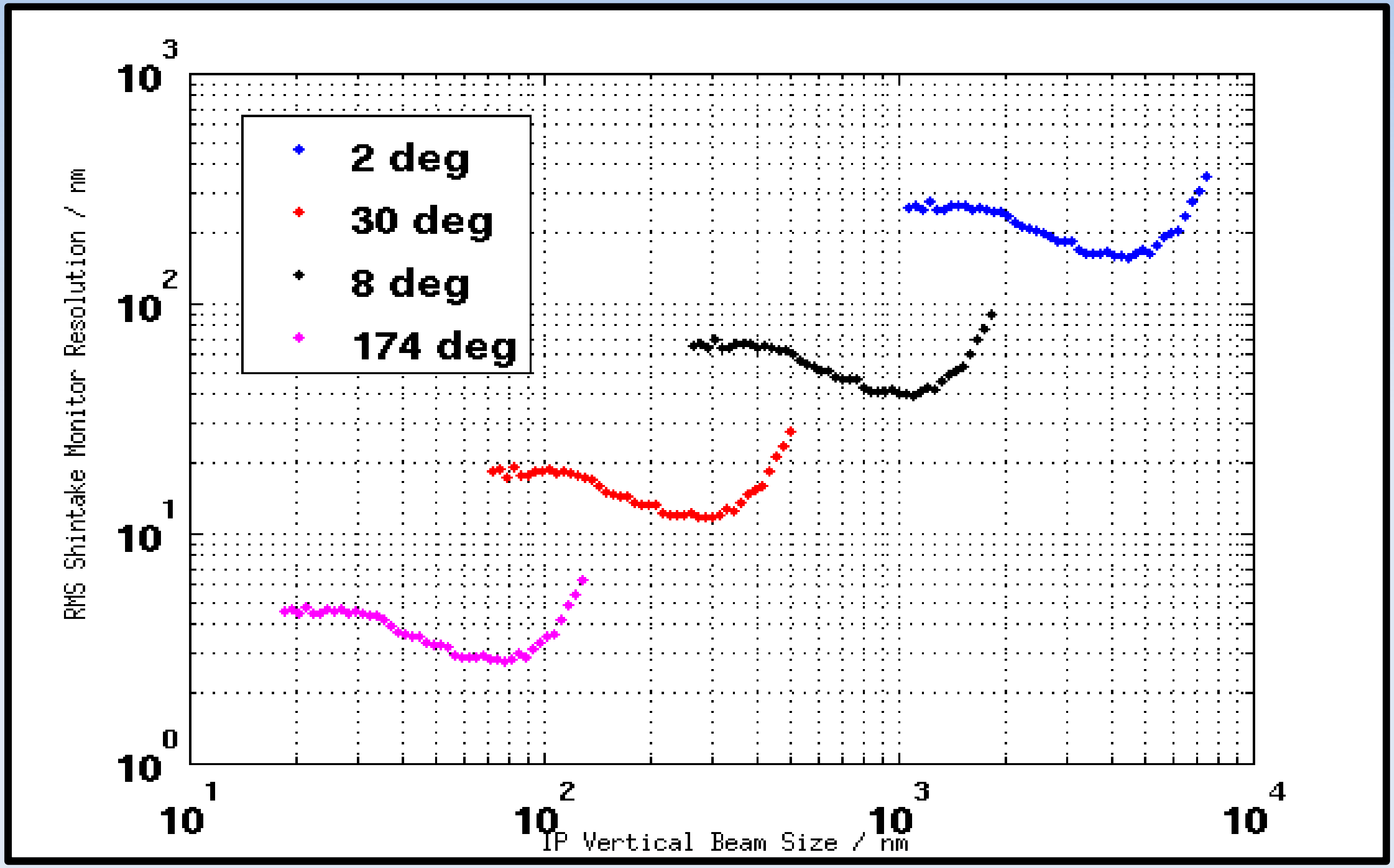

- IP waist size before sextupole FFS tuning knobs applied (100 seeds).

# Beamsize Measurement with BSM



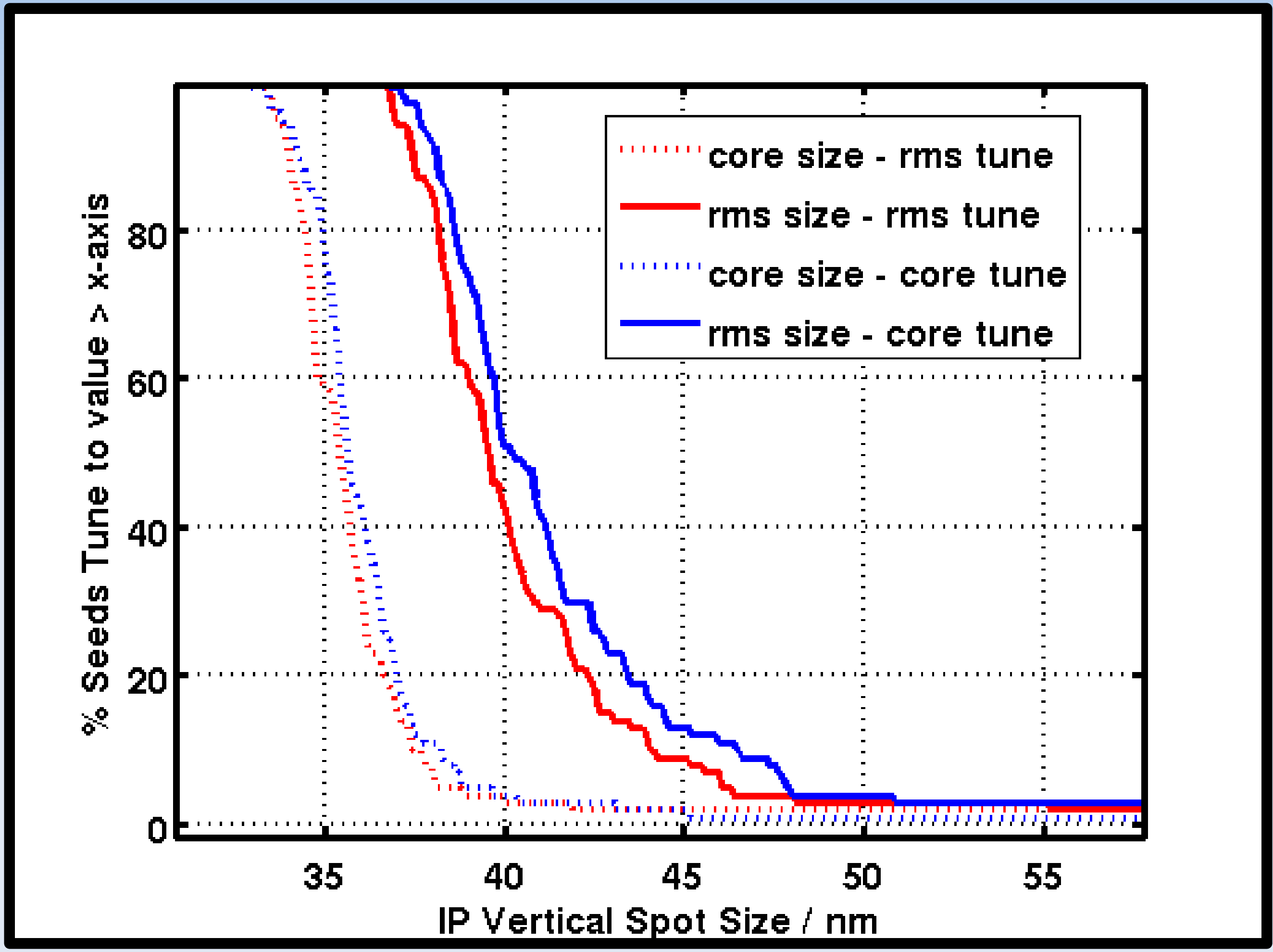

- IP beam size not gaussian, Shintake monitor measures somewhere between RMS and core in this case.

# SM Resolution



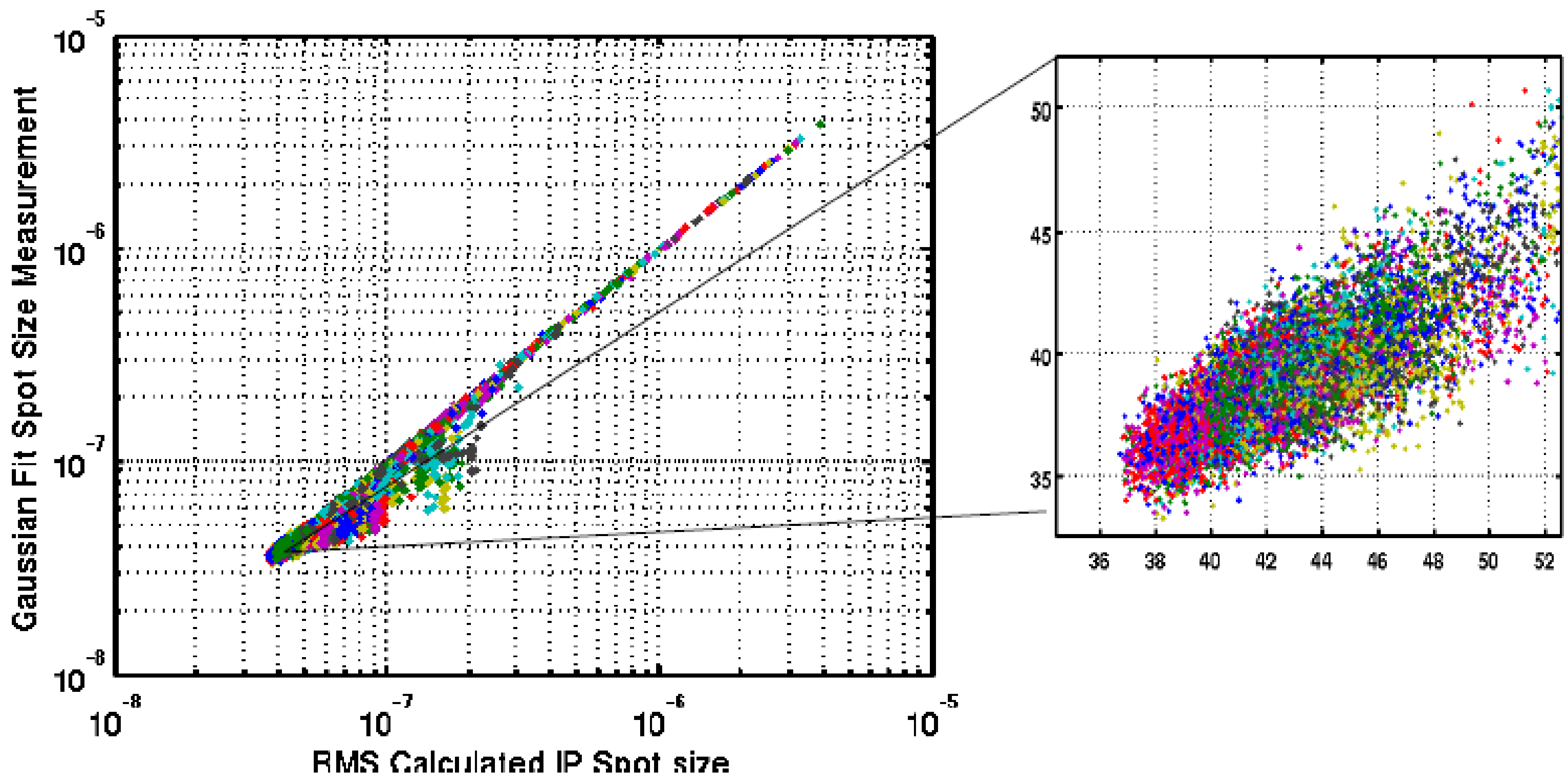

- Include simulated resolution capabilities of SM as function of beamsize for different laser crossing angles.

# RMS vs. Core fit Results



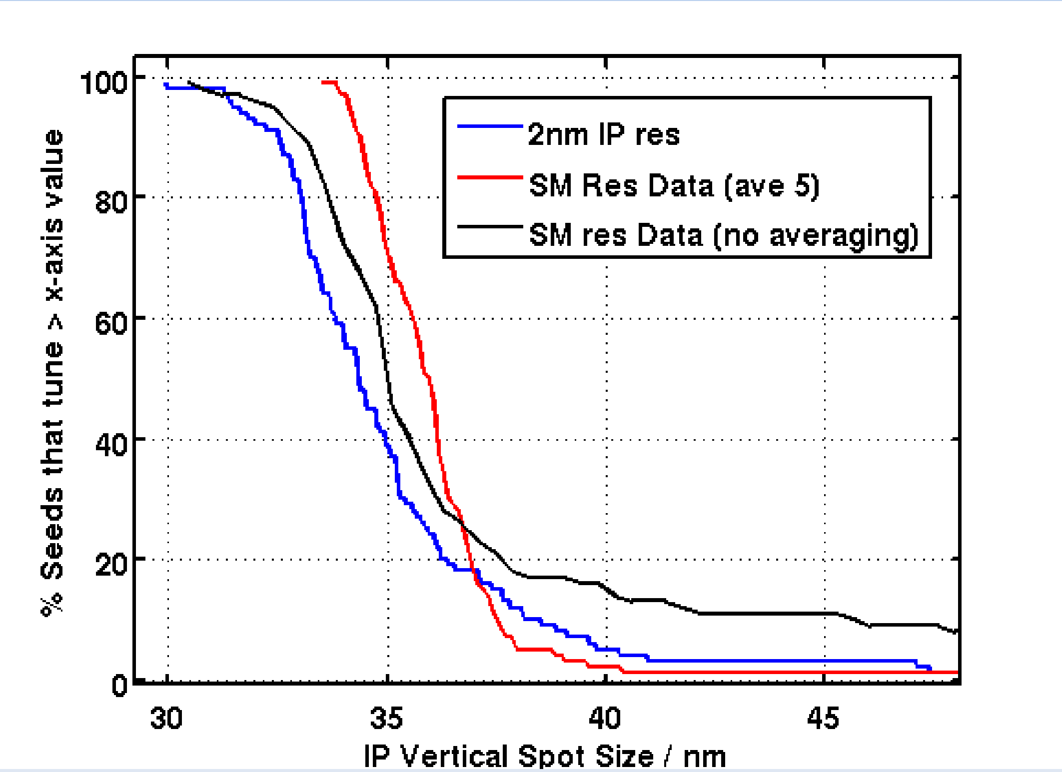

- Simulation results measuring core or rms IP size.

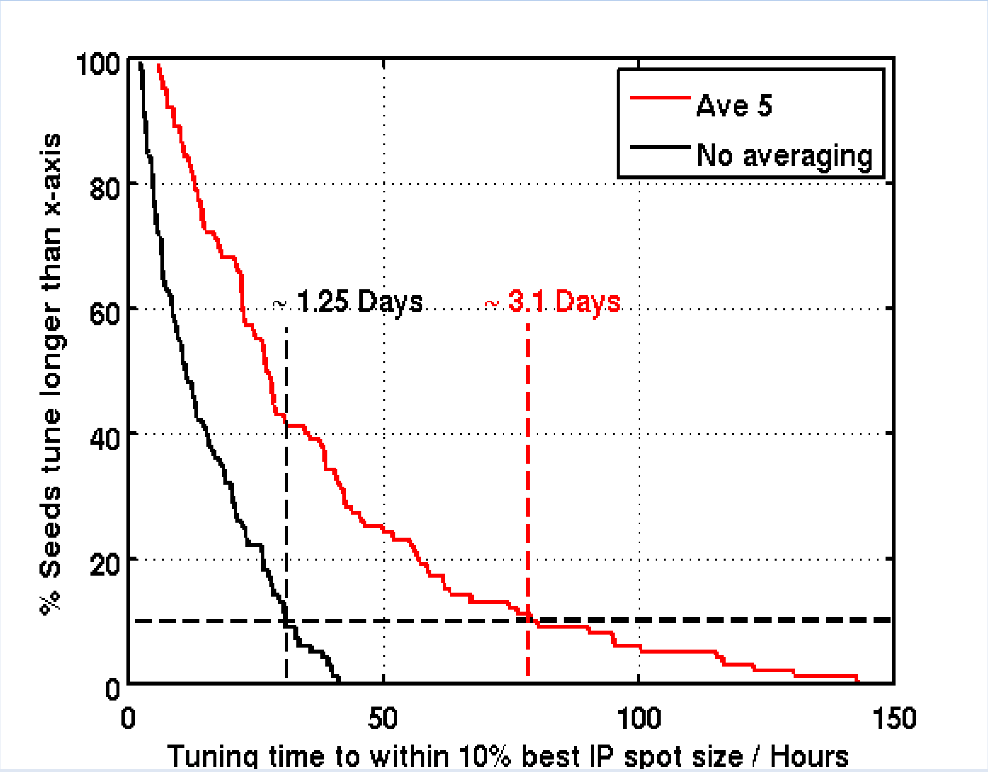
# RMS/Core IP Size Correlation




- RMS vs. Core fit IP beamsize, for 100 seeds all tuning steps.
- Possible to predict core from rms near goal size, ambiguous further out.

# Results with SM Resolution Data



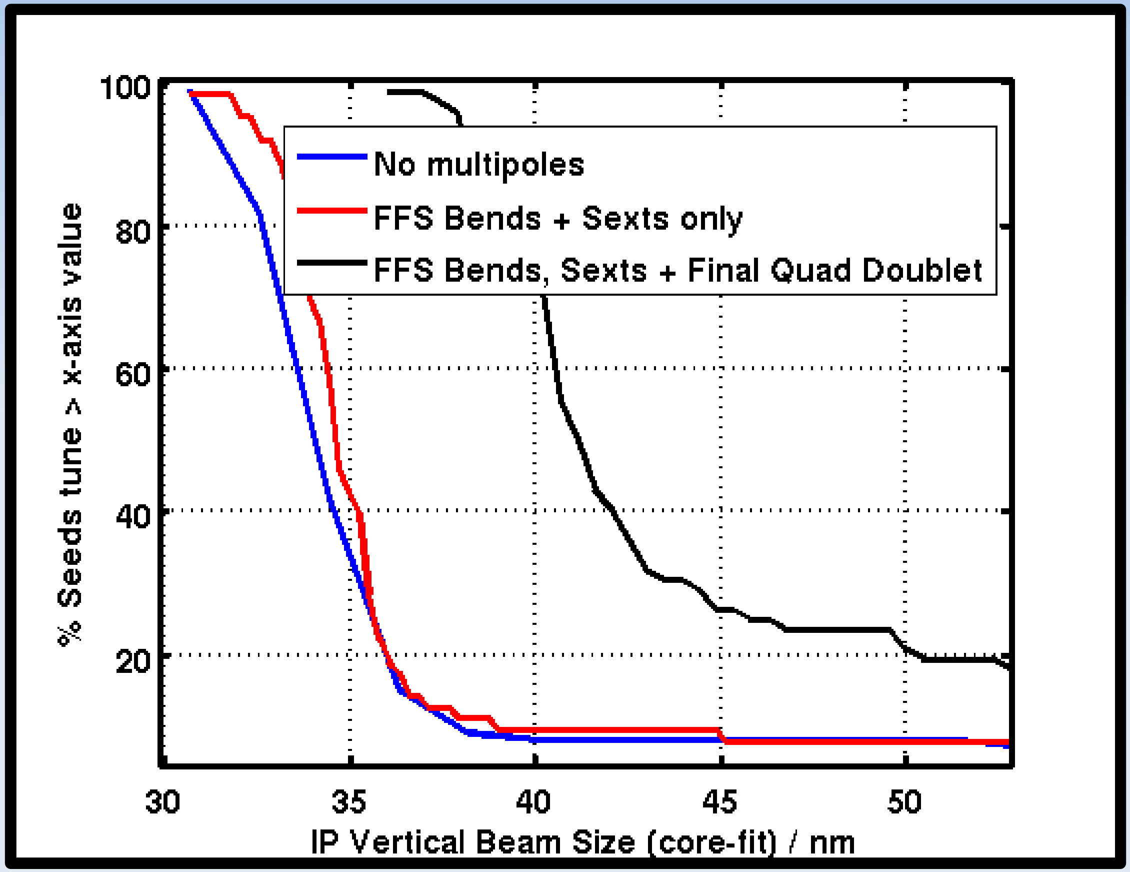

- Performance with SM resolution data.

# Multipole Measurements

| Magnet Name | Sextupole/ quad | Octupole/quad | 10pole/quad | 12pole/quad | 20pole/quad |
|---|---|---|---|---|---|
| Tolerance (tightest)* | <0.03 | <0.025 | <~0.01 | <0.05 | <0.12 |
| QD0 at 132.2 amps | **0.0255** | 0.0052 | 0.007 | 0.036 | 0.0027 |
| QF1 at 77.5 amps | **0.0274** | 0.0058 | 0.0128 | **0.036** | 0.0027 |

- Measured multipoles exist for final focus bends, sextupoles and final doublet quads.
- All have minimal effect on beam size and tuning process other than those highlighted above.

# Simulation Results with Multipoles




- Measured multipoles of final doublet have major impact on beam size (mainly due to sextupole component).
- Need to rematch optics for these conditions before tuning.

# MAPCLASS Rematching

**Settings found reach 38nm**

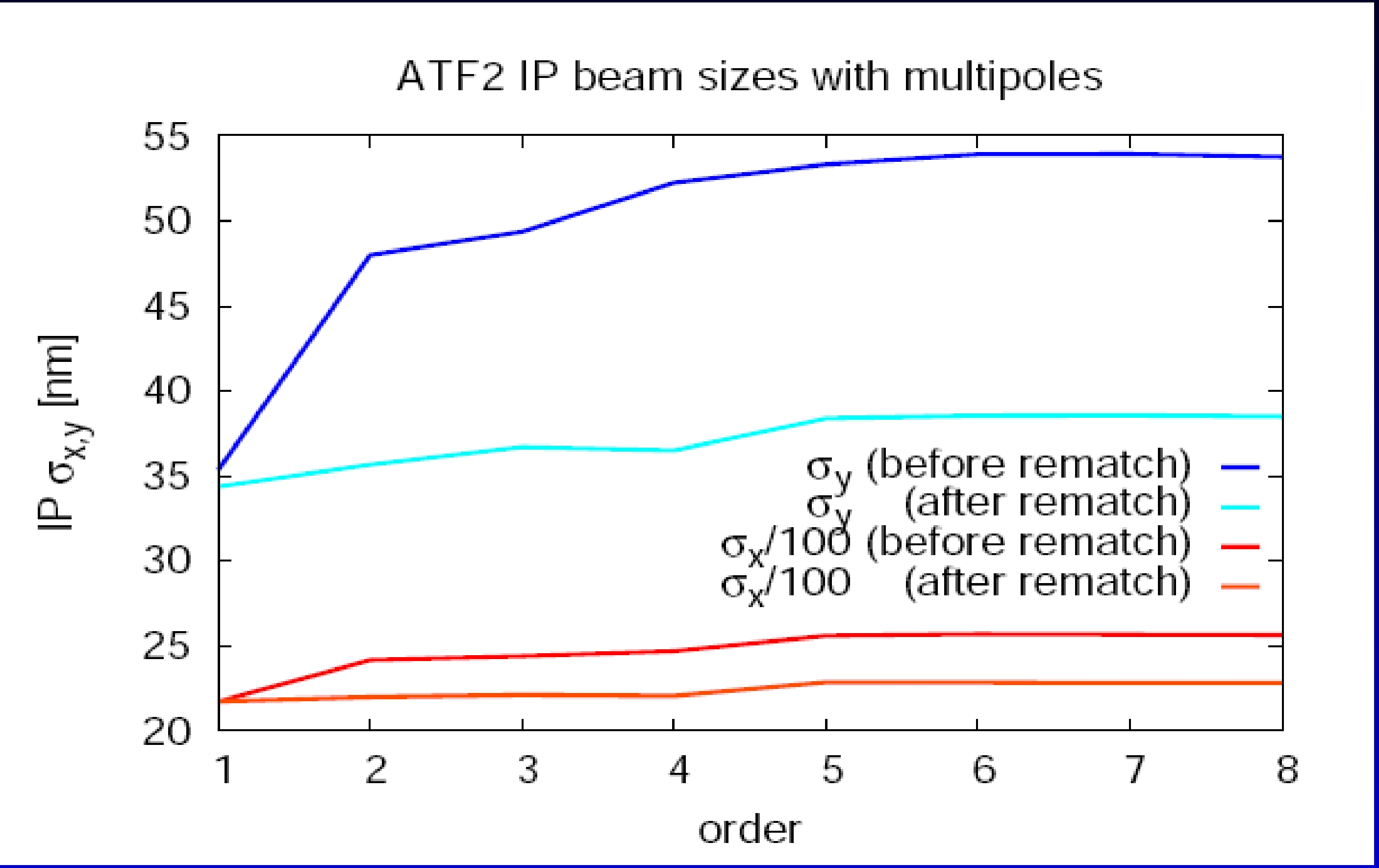
```
klsf6ff  =         8.564015604
klsf5ff  =       -0.8108457023 !
klsd4ff  =         14.92233907
klsf1ff  =        -2.549000405
klsd0ff  =         4.367344565
sf1tilt  =  -0.000651444947 !
sd0tilt  =   -0.001280764859 !

klqf5ff  =        0.3760683487
klqd4ff  =       -0.2968406921
klqf3ff  =        0.5531909983 !
klqd2bff =        -0.198360278
klqd2aff =        -0.289811683
klqf1ff  =        0.7417848785
klqd0ff  =        -1.363966125
```

Rogelio Tomás García Optimizing ATF2 with multipoles

- Rogelio re-matched optics with multipoles using mapclass

# MADX Tracking with Rematched Optics

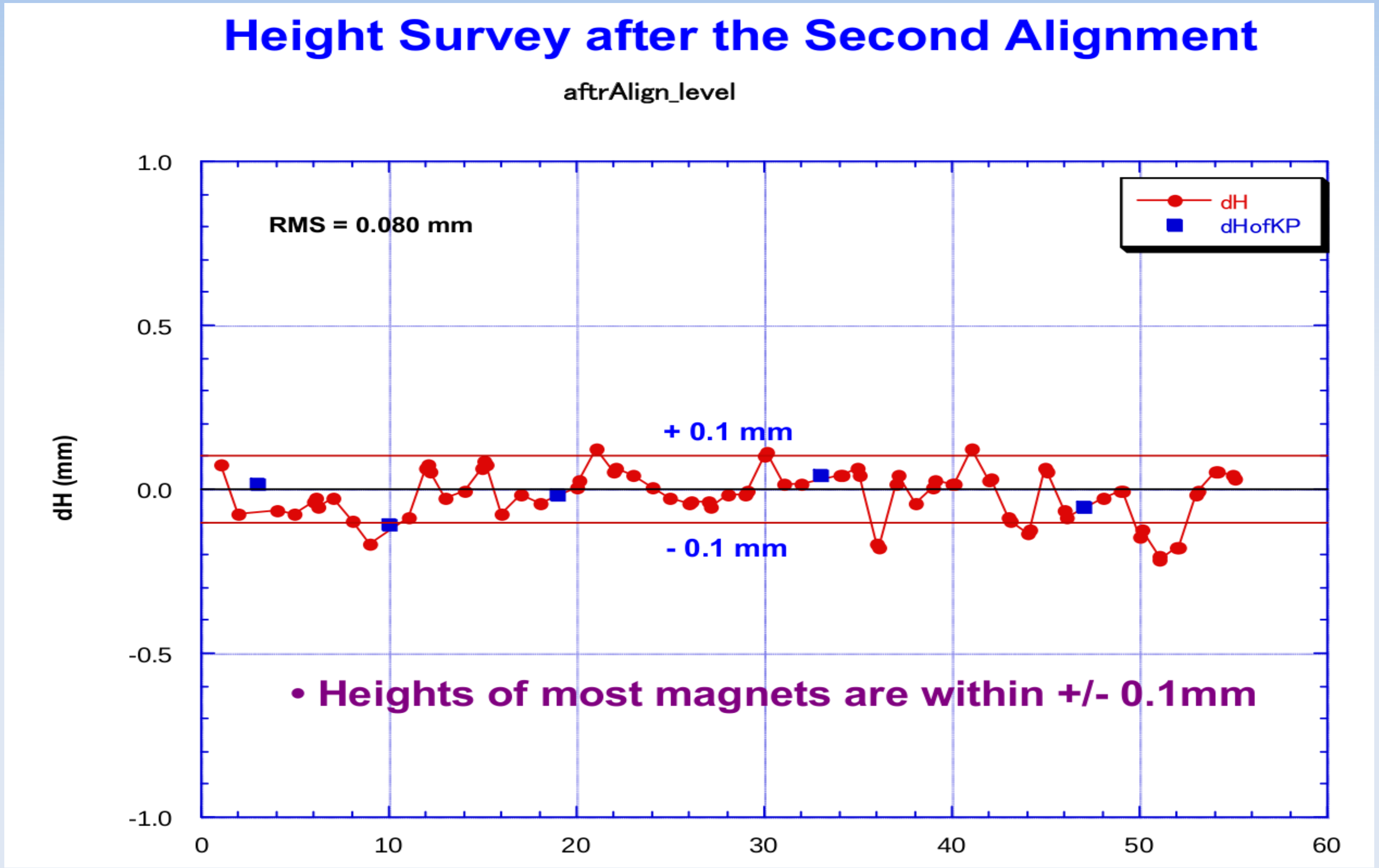
## IP $\sigma$ before and after rematching




Dodecapolar component remains in both planes.

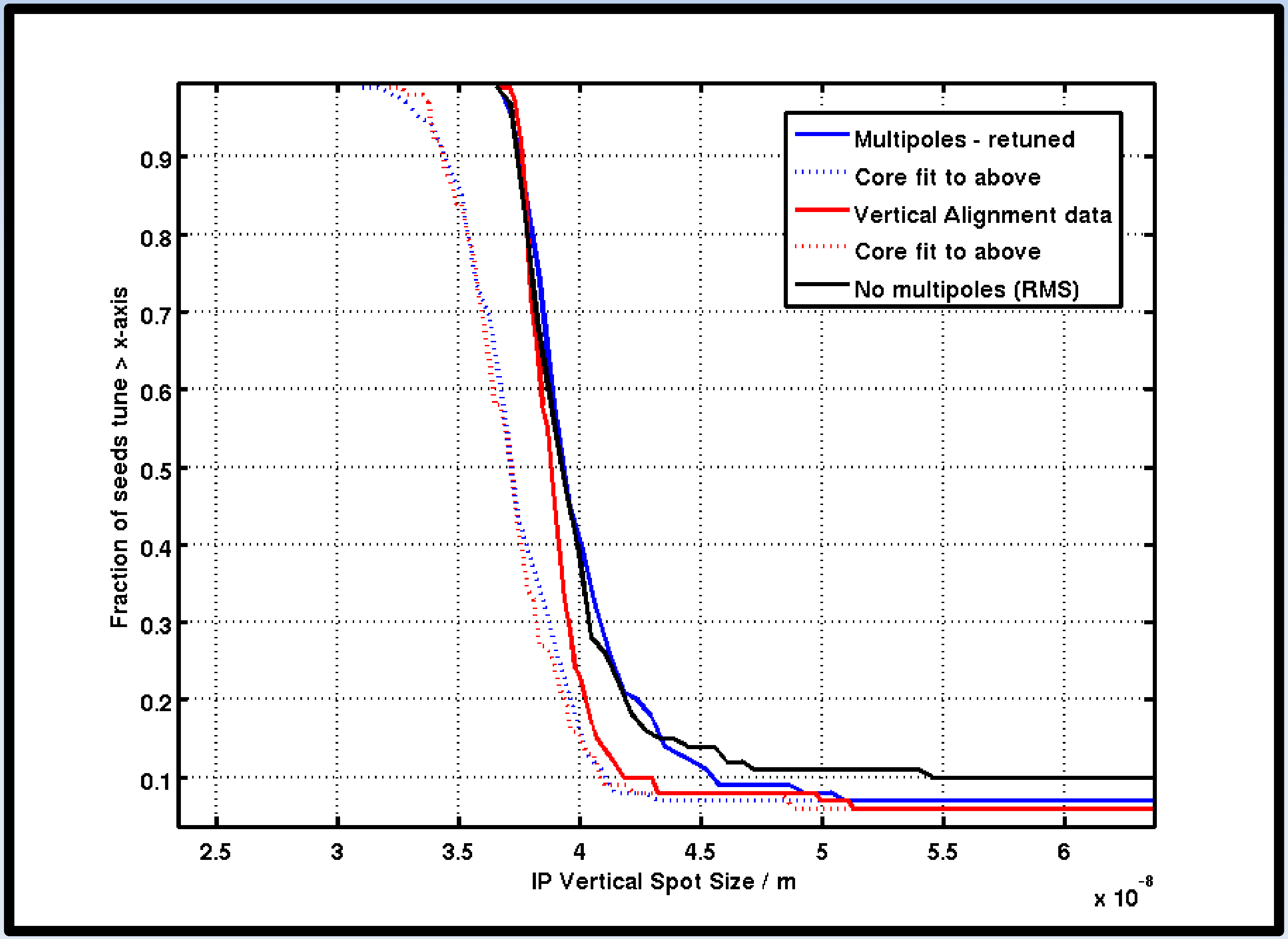
Do we need a dodecapole? octupole?

# Vertical Survey Data



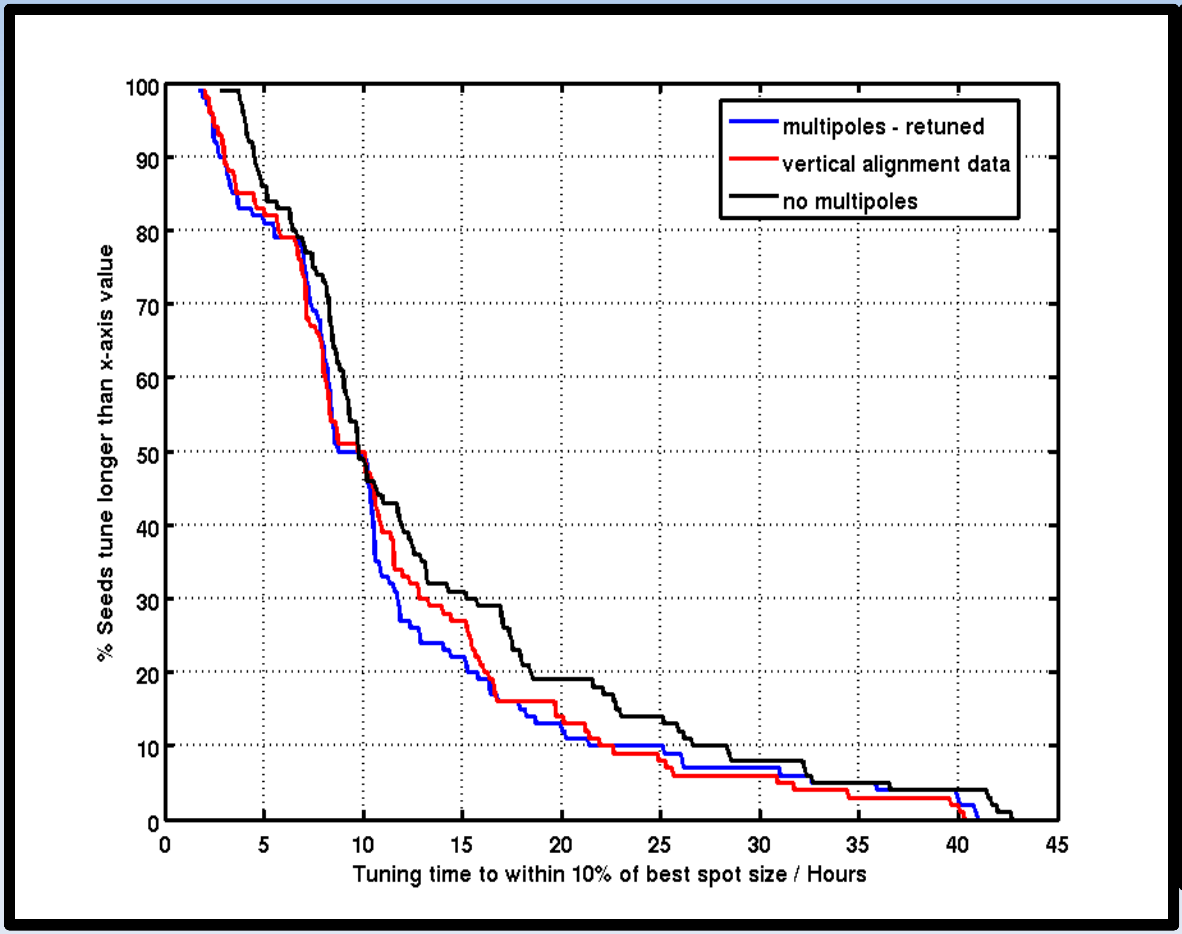

- Use vertical alignment data from Sugahara-san.

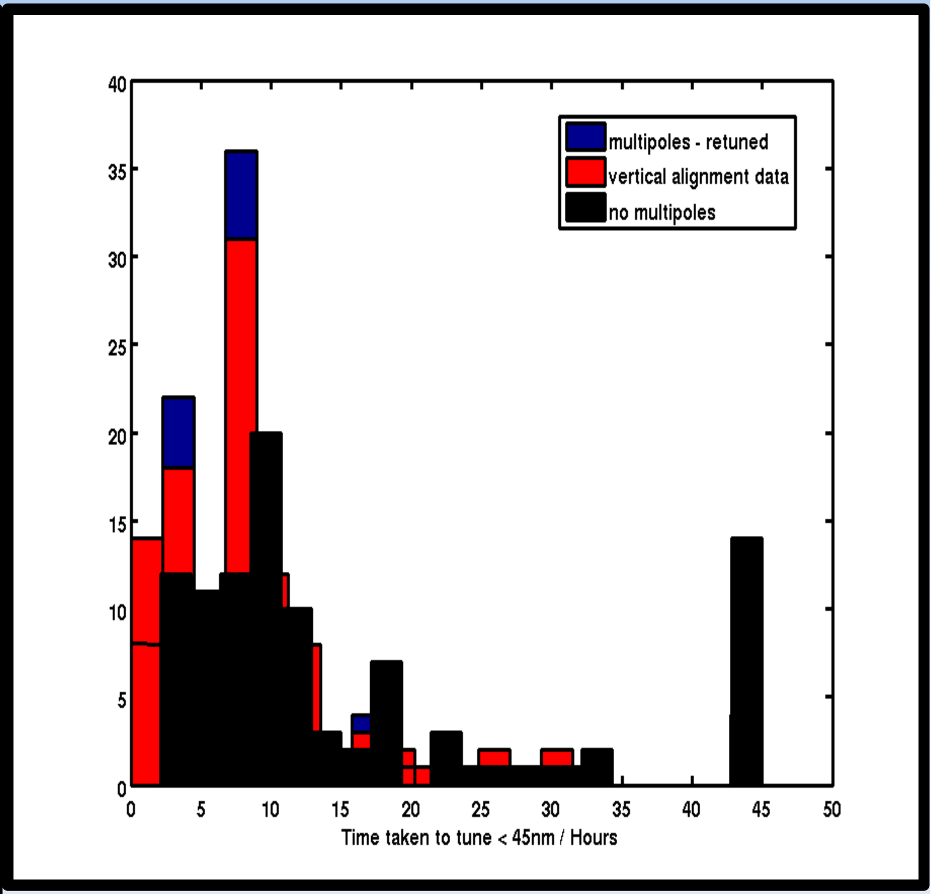
# Tuning Results




- MAPCLASS rematching improves performance even over case where no multipoles were added.
- Better vertical alignment has noticable effects in tail of tuning distribution
- 90% seeds tune < 41-42nm
- 50% seeds tune <37-39nm

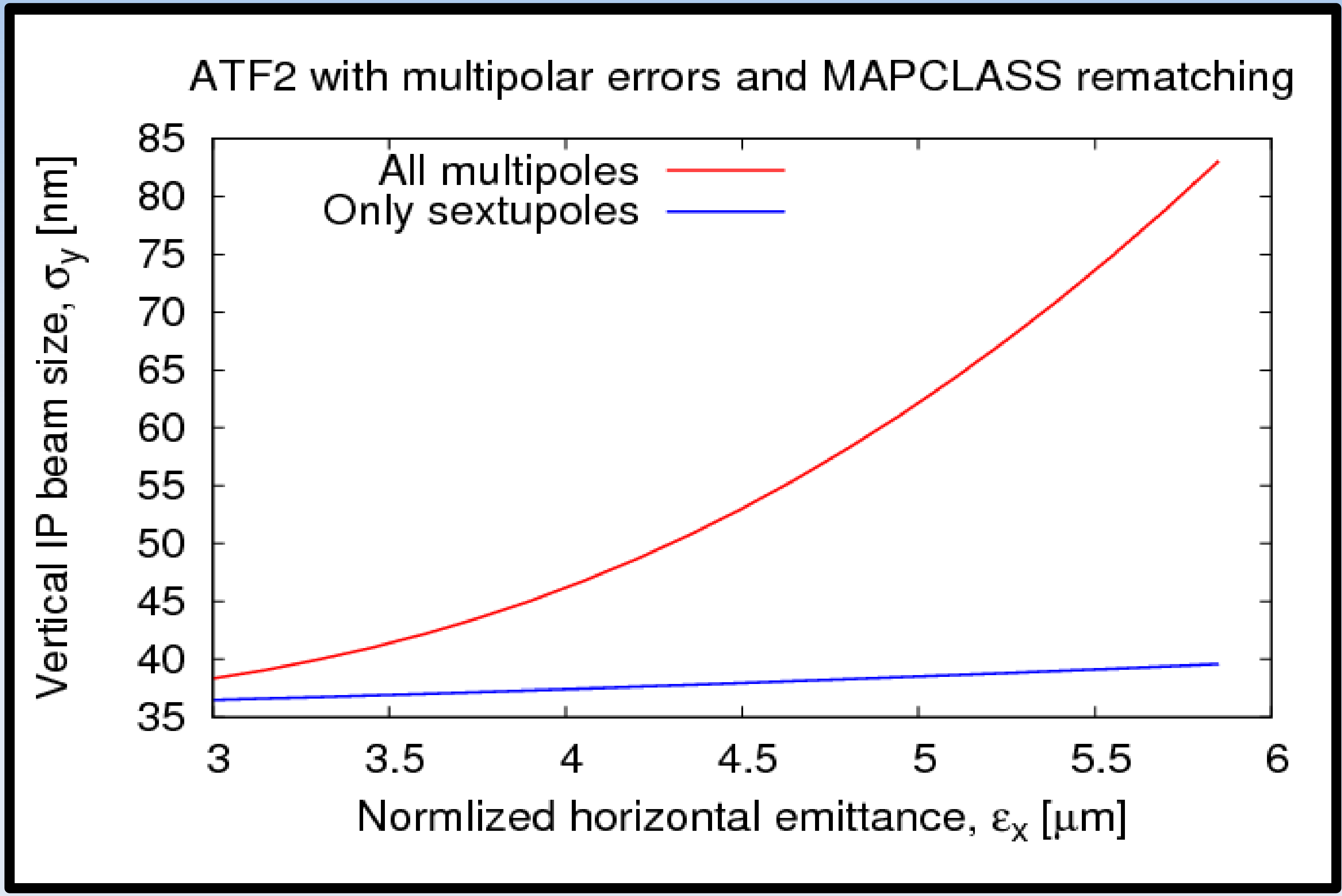
# Tuning Time



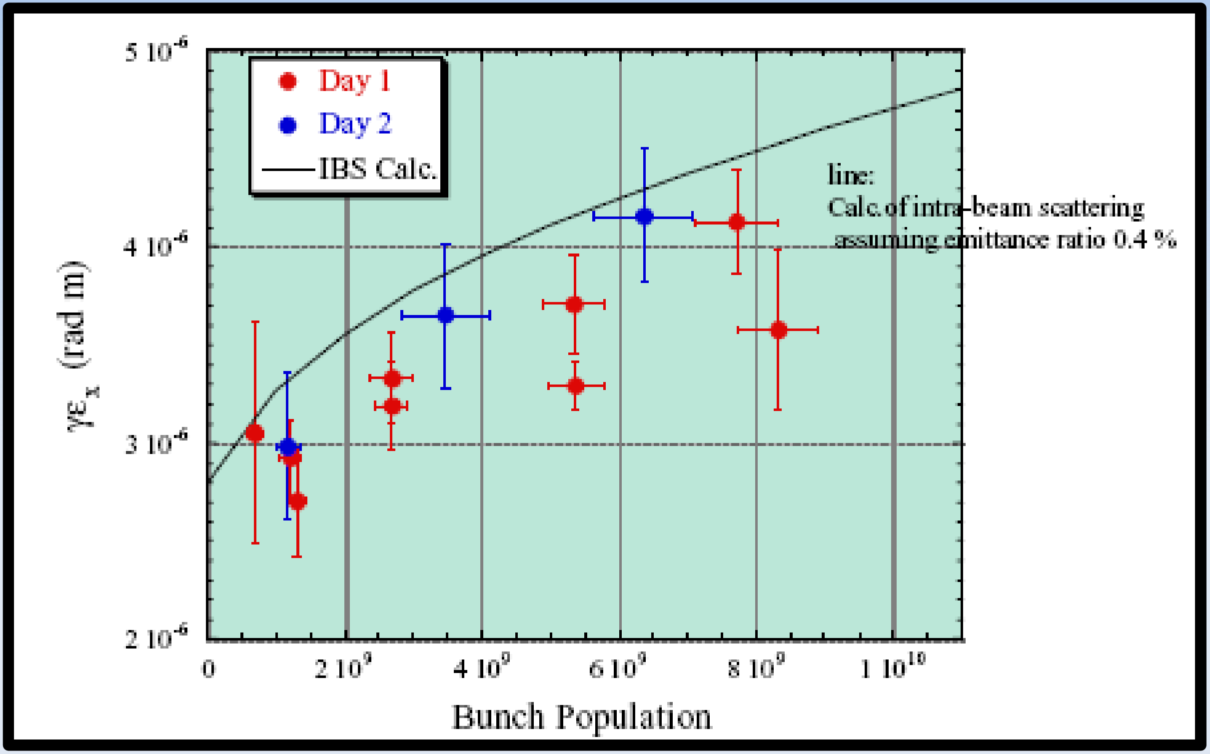

- 90% Seeds tune < 1 day
- All results similar- < 45nm results noticeably better after MAPCLASS rematching

# Effect of Horizontal Emittance



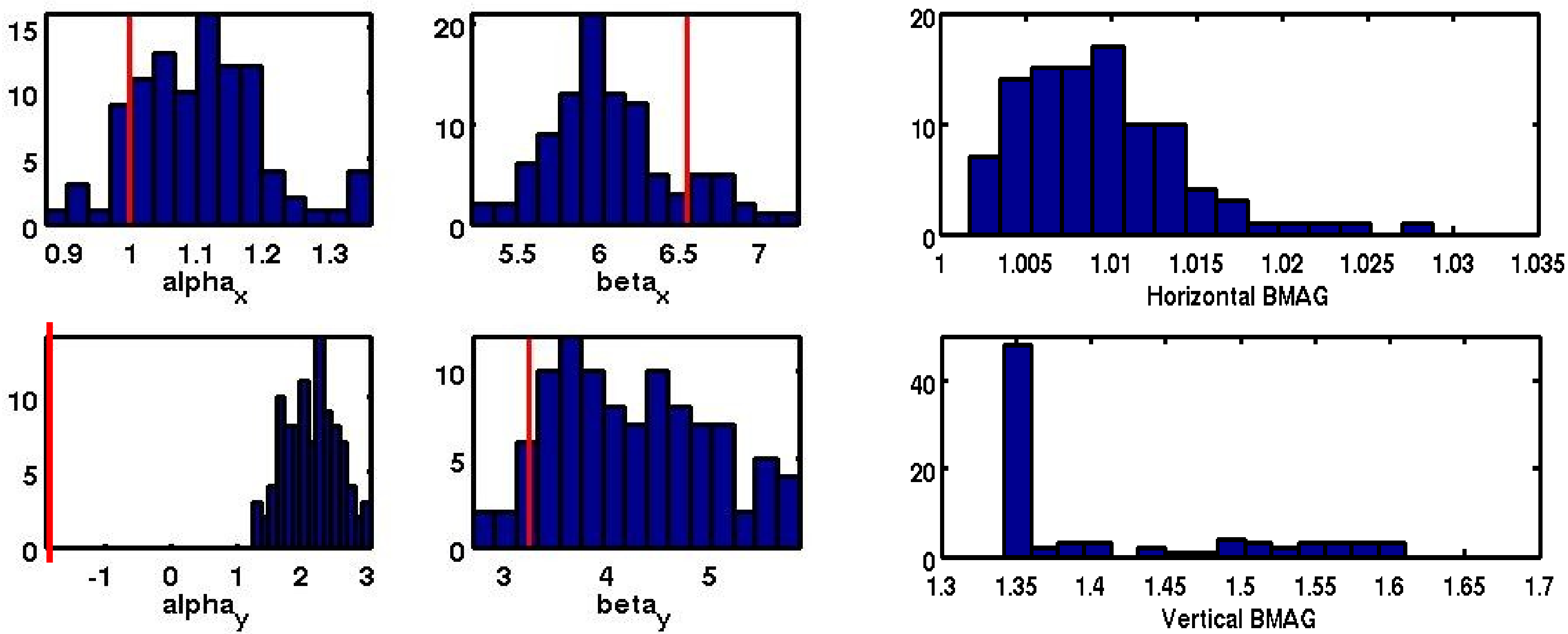

- 12-pole in QF1FF causes vertical beamsize growth at IP with higher horizontal emittances.

# Horizontal Emittance at ATF



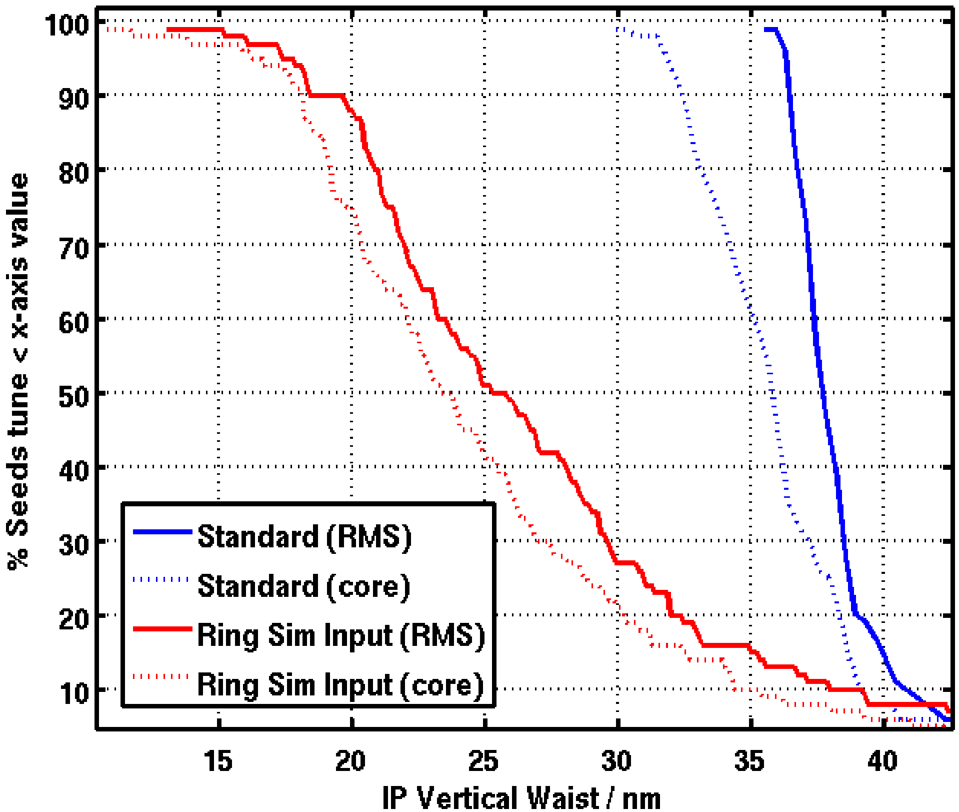

- Only get simulated 3e-6 emittance at low charge. 1E10 charge implies min RMS y size of ~60nm.
- Get large RMS sigma_y due to high tail-population (will be measured by shintake monitor?).
- Need dodecopole magnet for tuning?

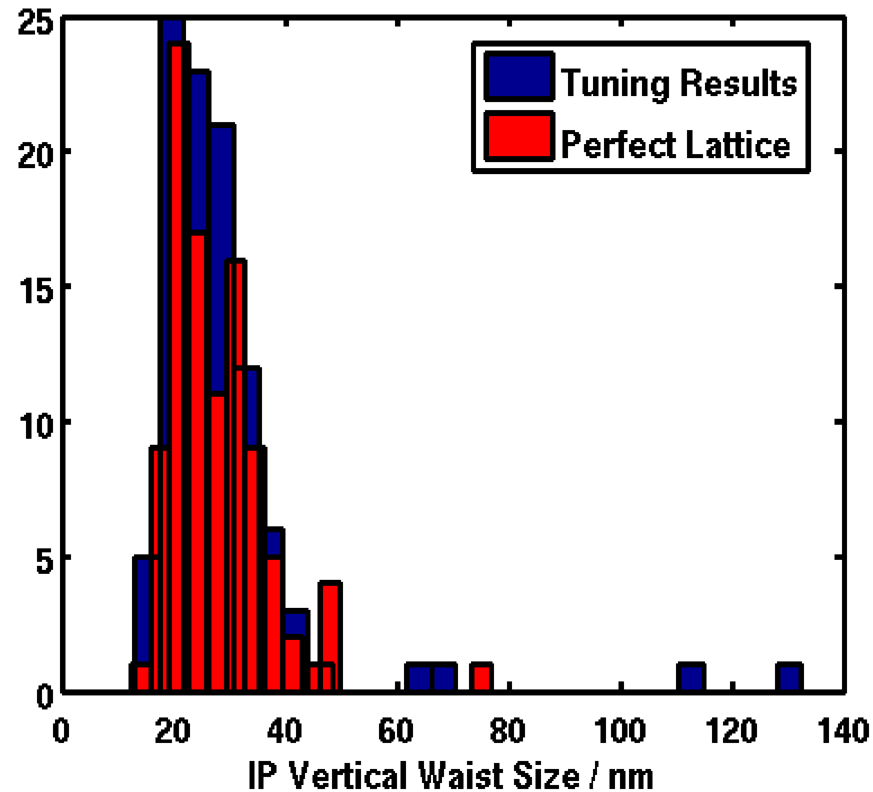
# Input Parameters from Ring Extraction point




- Input match conditions used from Kubo DR simulation input (100 seeds), red line shows design model parameters.

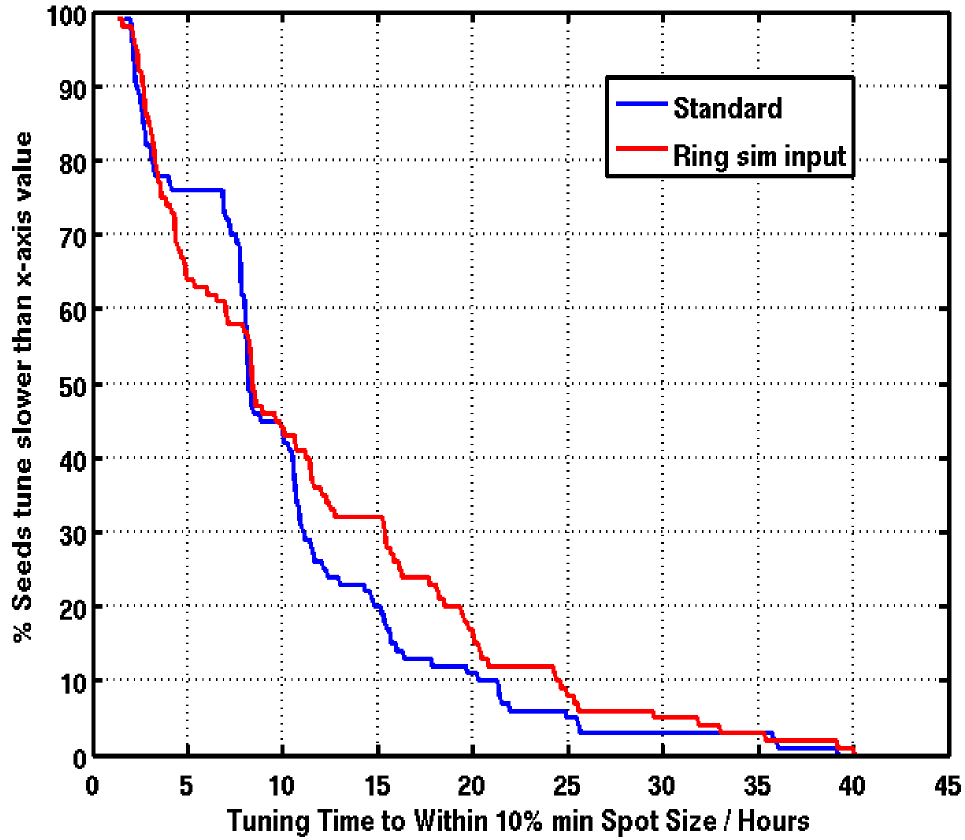
# Tuning Simulation Results

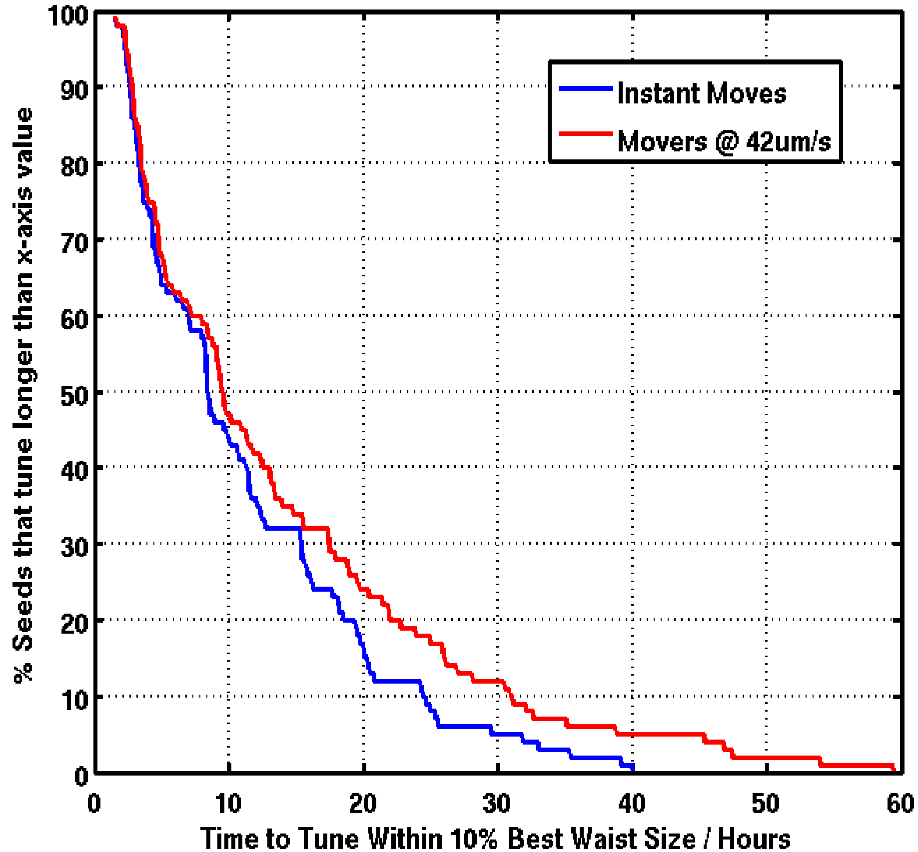



- Vertical waist size at Shintake IP compared with last simulation (left)
- IP vertical size in comparison with best achievable given input emittances (right)

# Tuning Time




- Comparison of tuning time with previous simulation (left)
- Effect of adding finite mover speed (right)

# Summary

- A lot of work from many people summarised here, more on wiki and Indico.
  - PAC paper abstract submitted
- Need to complete comparison studies (Lucretia [vs. MADX]? vs. PLACET)
  - Possible through AML parsers we now have.
- Then write control system tuning software
  - Liase with Shintake group for BSM readout.
- Simulation studies done also provide useful starting conditions for dynamic studies.