Beam Dynamics of the JLEIC Ion Collider Ring

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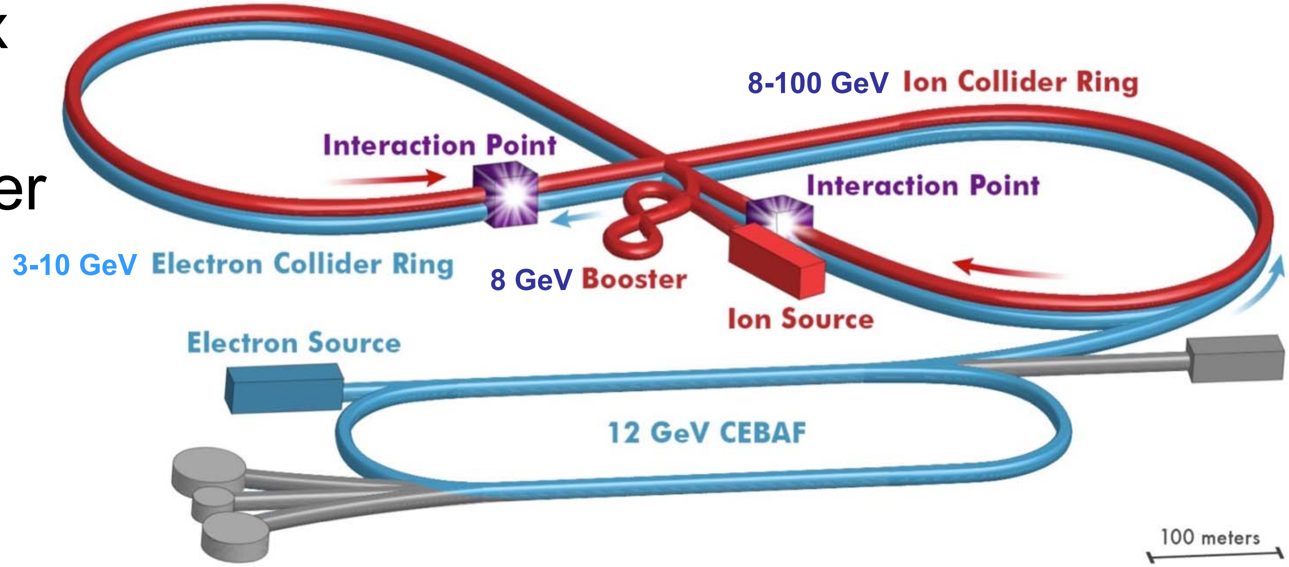
Outline

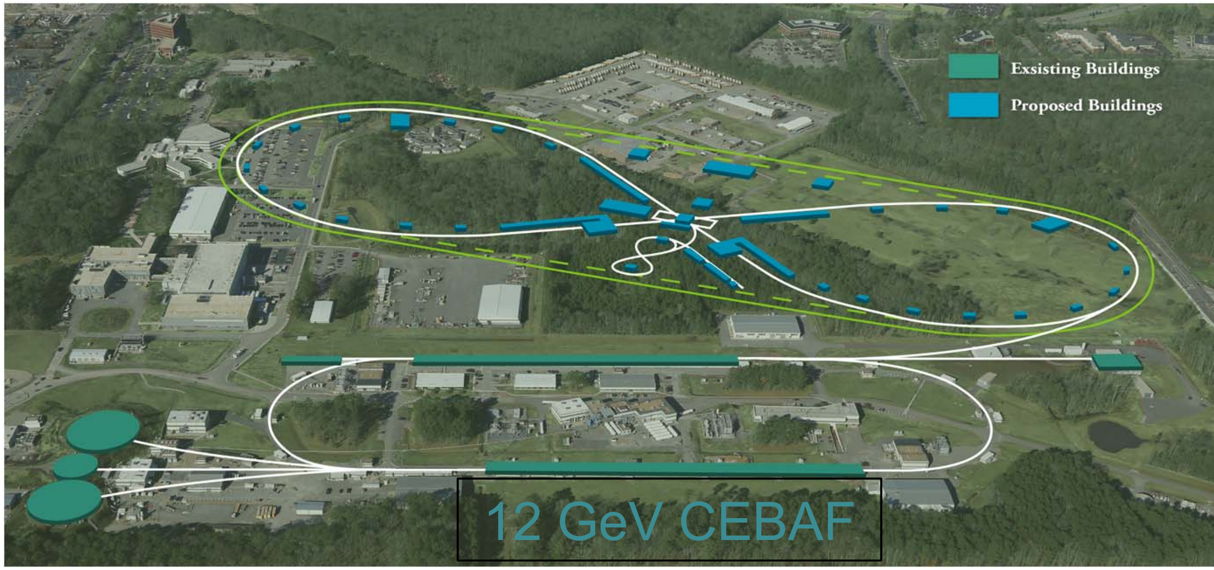
- Introduce to the JLEIC (Jefferson Lab Electron Ion Collider)
- IR (Interaction Region) requirement and challenges
- Summary

JLEIC Layout

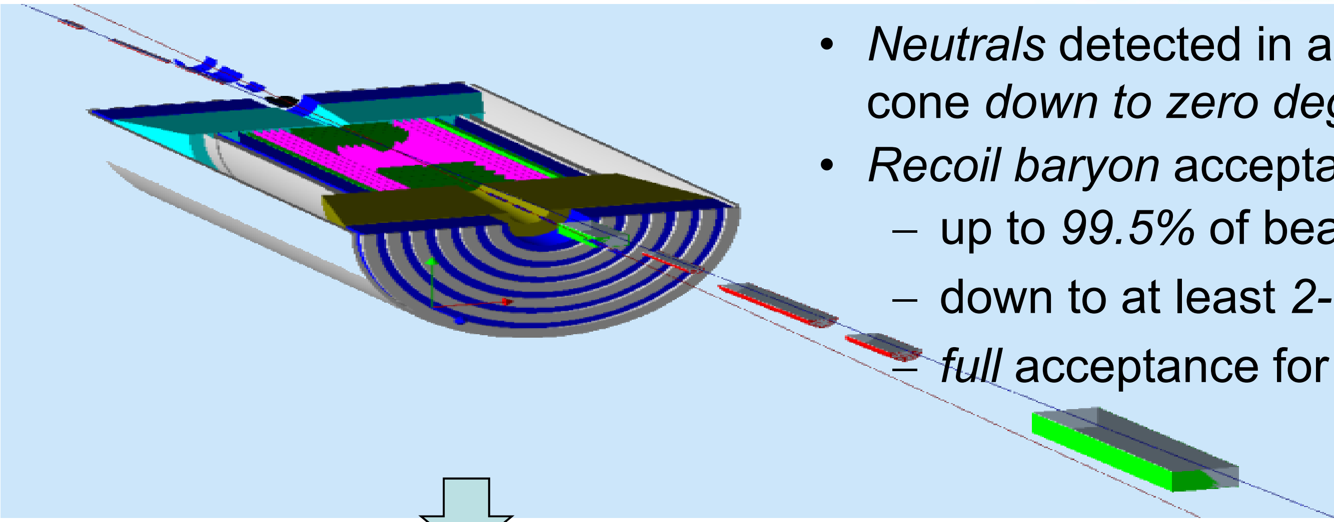
- Electron complex
  - CEBAF
  - Electron collider ring
- Ion complex
  - Ion source
  - SRF linac
  - Booster
  - Ion collider ring



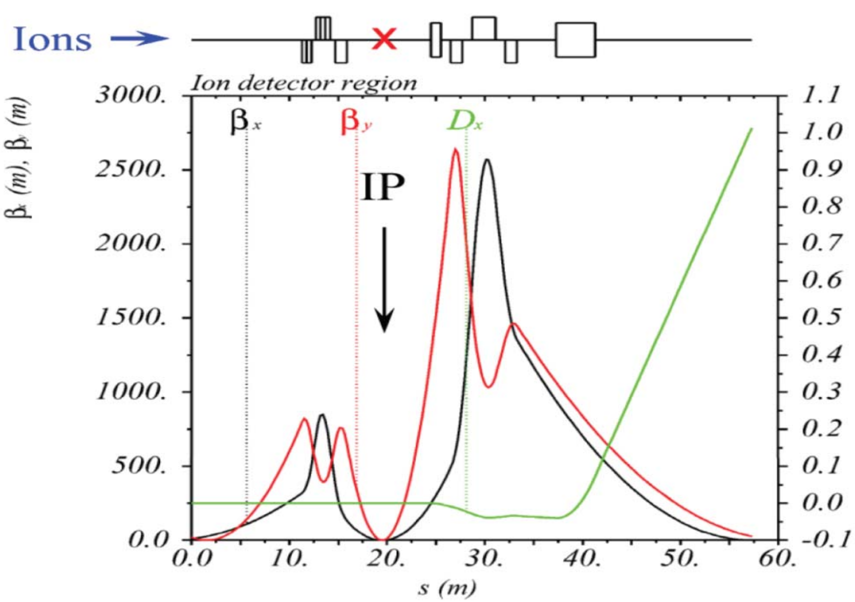
arXiv:1504.07961



IR Requirement and Challenges

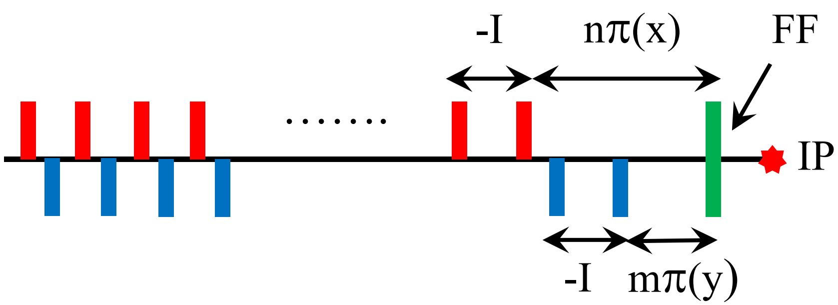


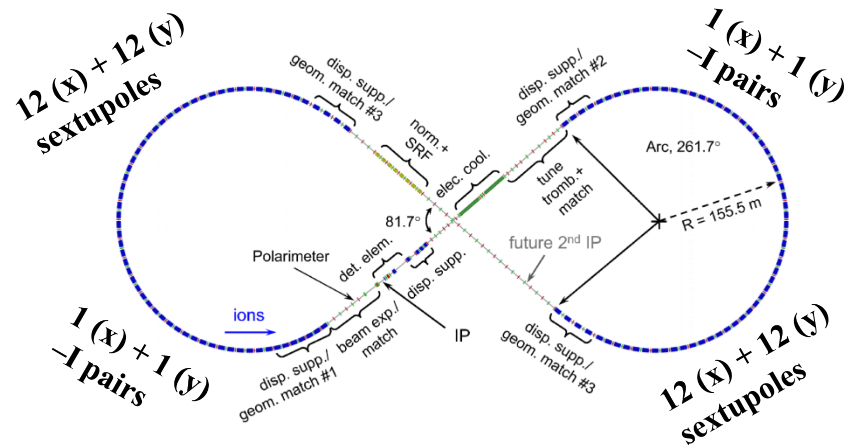
- *Neutrals* detected in a 25 mrad (total) cone *down to zero degrees*
- *Recoil baryon* acceptance:
  - up to *99.5%* of beam energy for *all angles*
  - down to at least *2-3 mrad* for *all momenta*
  - *full* acceptance for x > 0.005



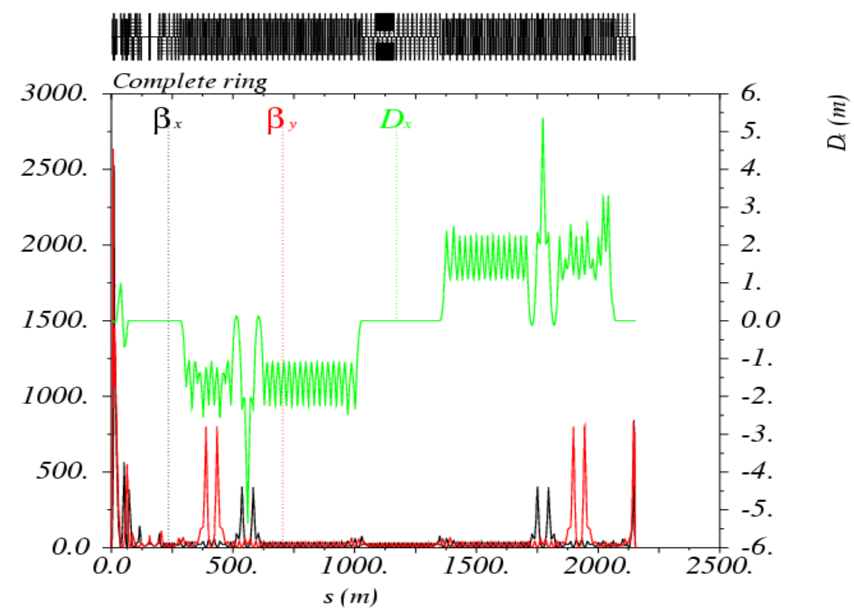
- Challenges:
  - Chromaticity issue
  - Detector solenoid issue
  - Misalignment issue
  - Magnet quality
  - Beta squeeze

Chromaticity Compensation

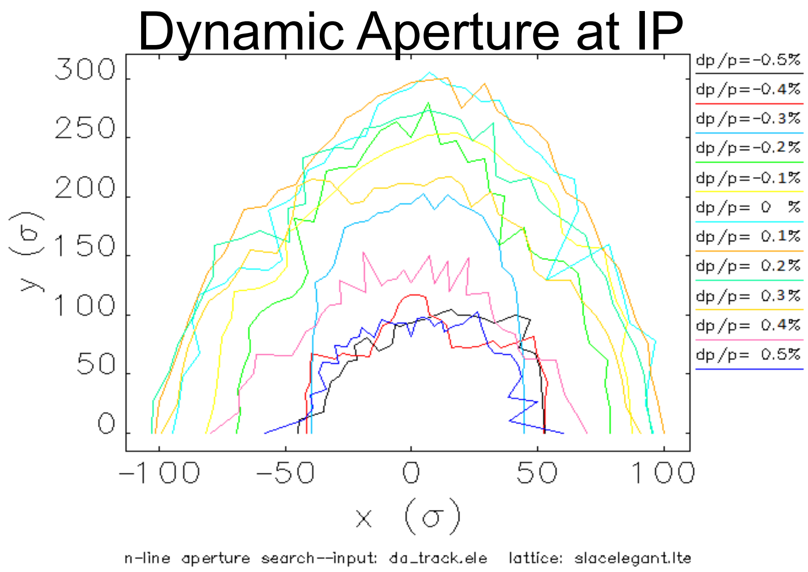


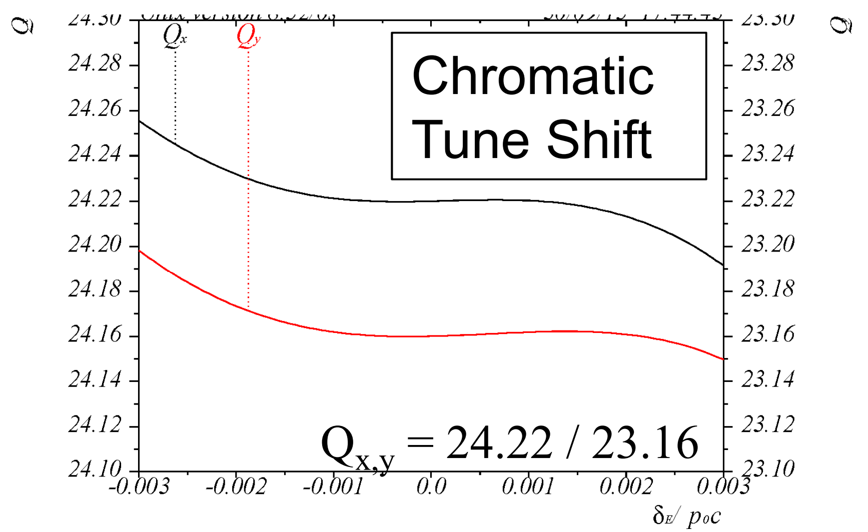


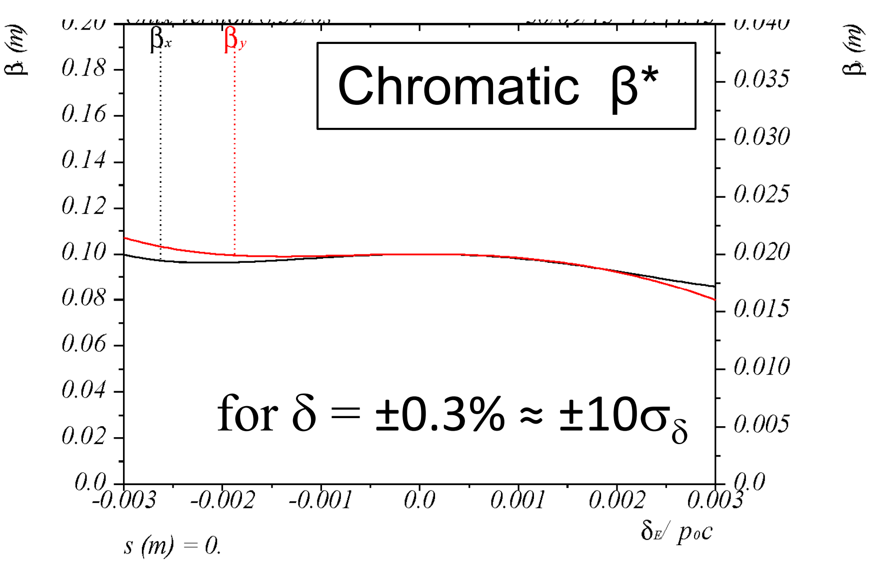
- Two non-interleaved –I sextupole pairs (X & Y) to compensate $\Delta\beta/\beta(\delta)$.
- The remaining linear chromaticity is canceled using two-family sextupoles in arc section

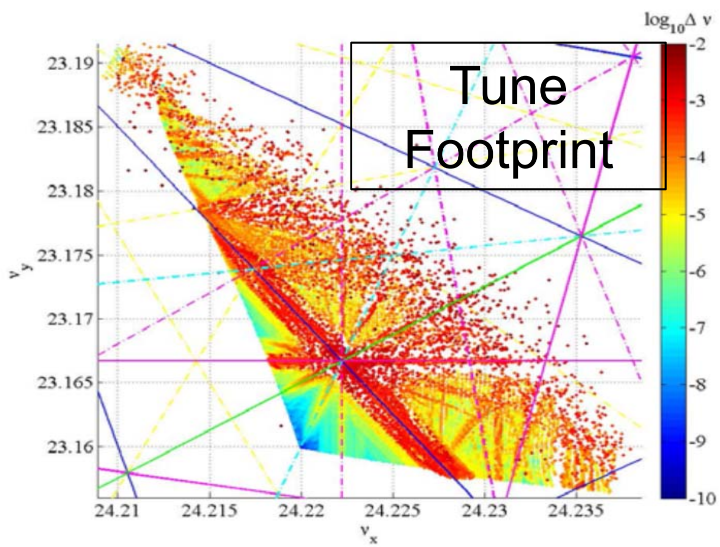


Dynamic Aperture & Chromatic Tune Shift

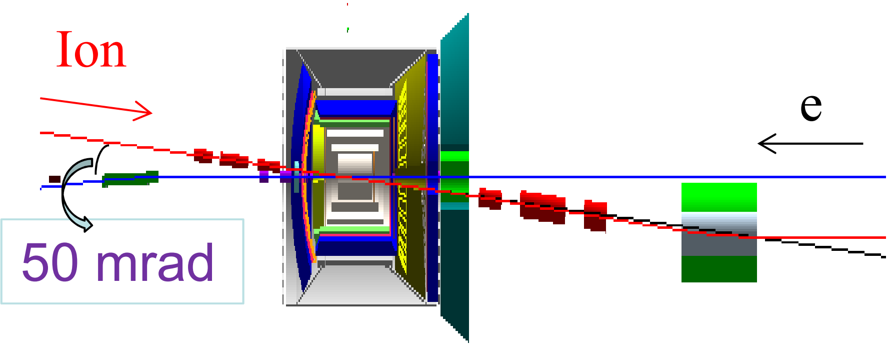








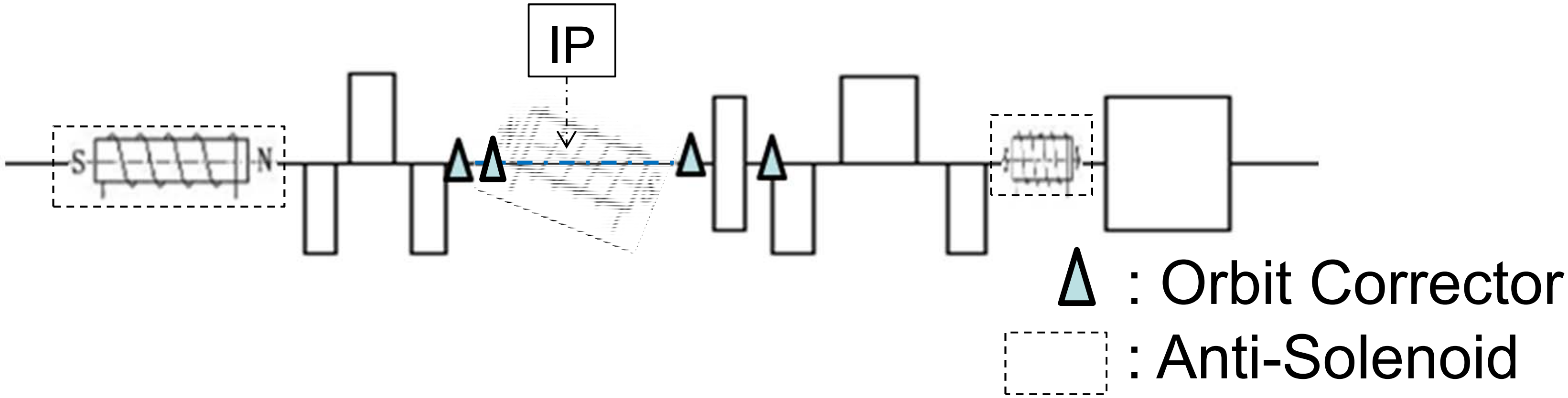
Detector Solenoid Issues



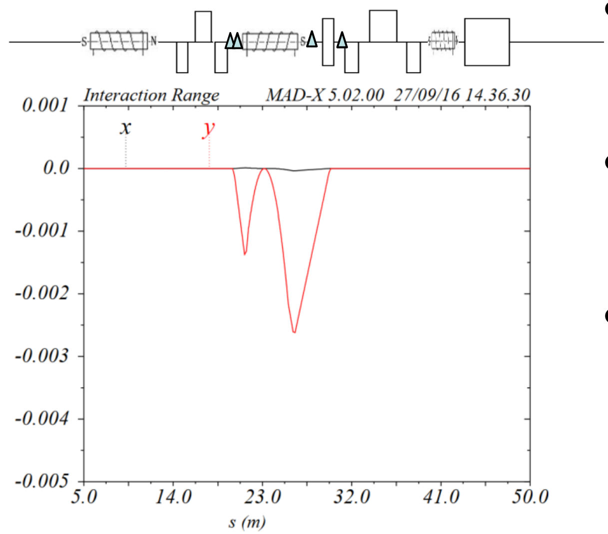
JLEIC Detector solenoid

Length	4 m
Strength	< 3 T
Crossing Angle	50 mrad

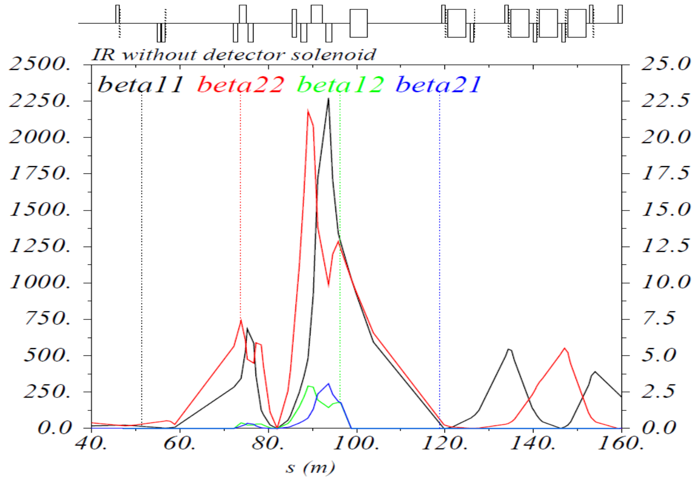
- Detector Solenoid causes Coherent orbit distortion & Coupling effects, etc.
- A solution: Solenoid + Quads(normal+skew) + Anti-Solenoid

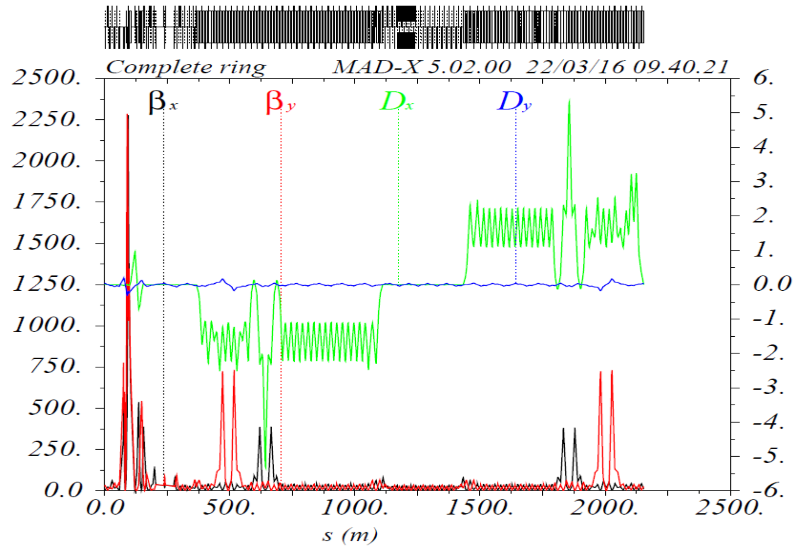


Coherent Orbit & Decoupling



- Two correctors on each side of the IP are used to make orbit correction.
- The coupling effects are controlled locally.
- After re-matching, a vertical dispersion of < 0.2 m was left, which can be ignored.





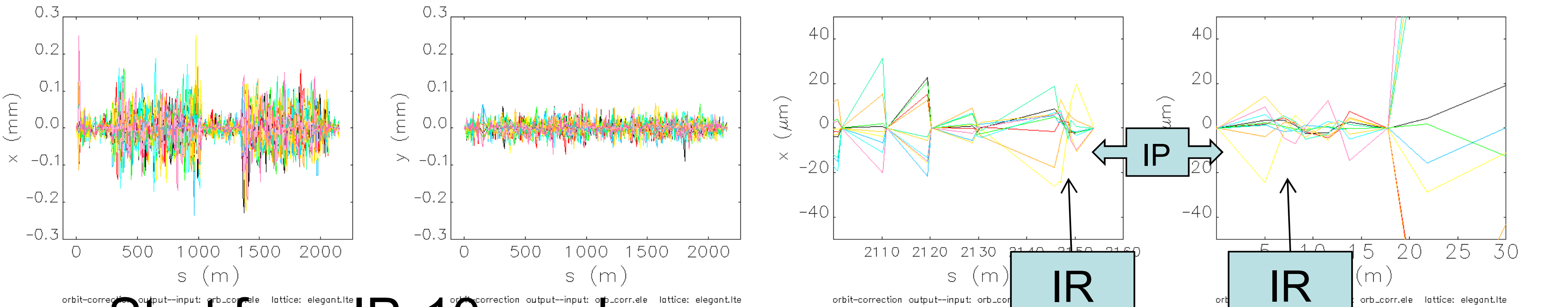
Error Issue

– Assume conservative errors, σ of Gaussian distribution

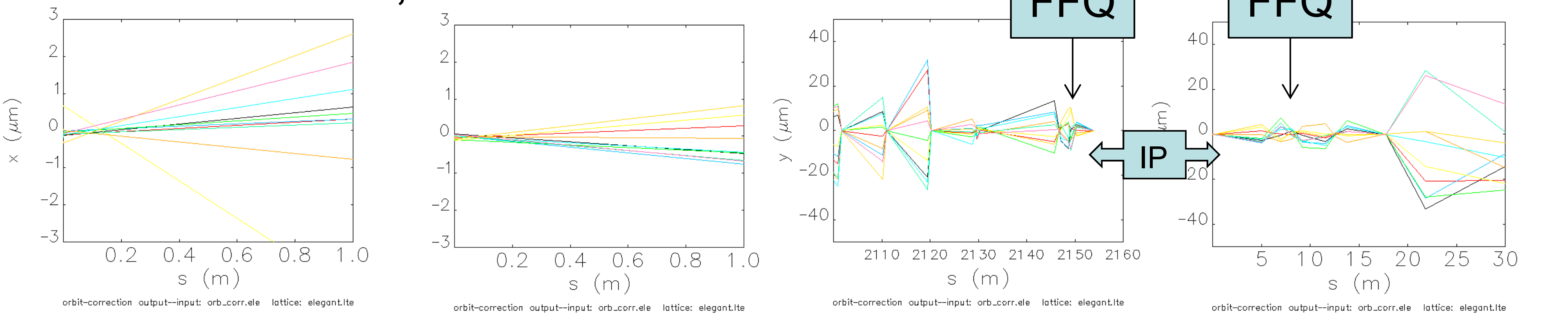
	Dipole	Quadrupole	Sextupole	BPM (noise)
x displacement(mm)	0.3	0.3, FFQ0.03	0.3	0.05
y displacement(mm)	0.3	0.3, FFQ0.03	0.3	0.05
x-y rotation(mrad)	0.3	0.3, FFQ0.05	0.3	-
s displacement(mm)	0.3	0.3, FFQ0.03	0.3	-
Strength error(%)	0.1	0.2, FFQ0.03	0.2	-

- Corrections: Orbit Correction, Twiss @ IP, Tune correction, Beta-beat correction, Chromaticity correction, Decoupling.

Closed Orbit Distortion after Correction



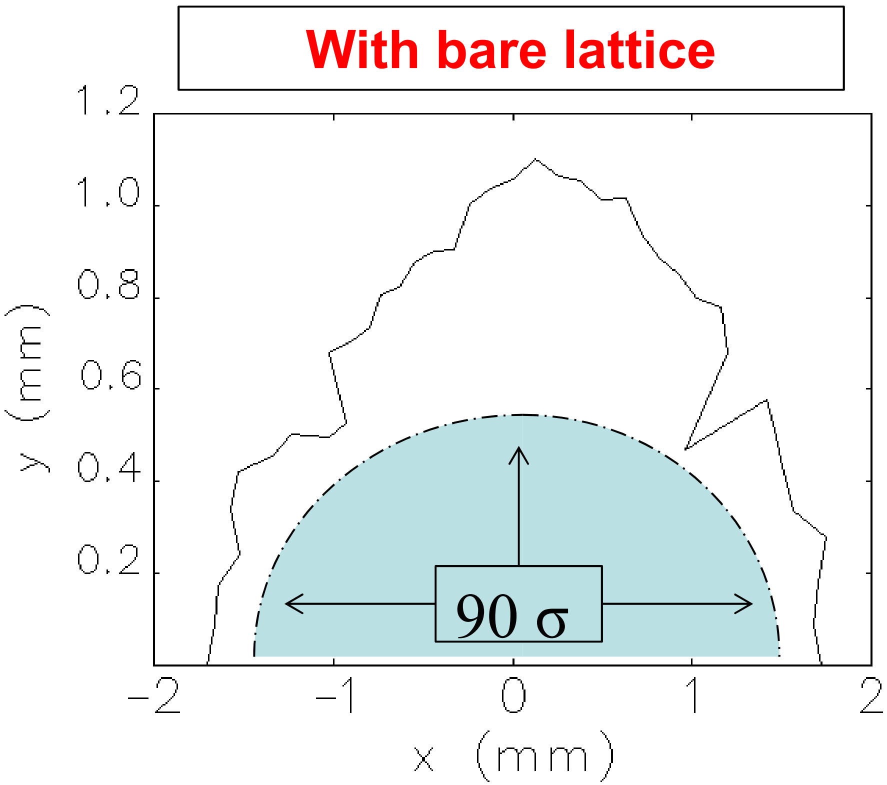
- Start from IP, 10 seeds

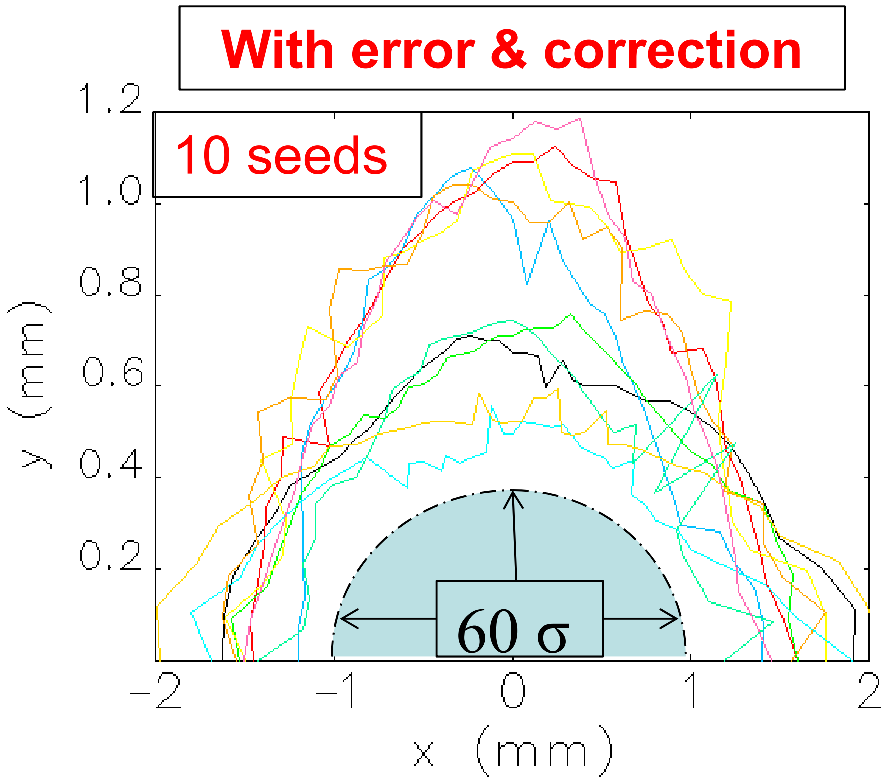


	ex/ey(nor. mm-mrad)	Δx/Δy @ IP	Δx/Δy @ FFQ
Case 1, strong cooling	0.35/0.07	< 1 σ	< 0.01 σ
Case 2, large emittance	1.2/1.2	< 0.6 σ	< 0.006 σ

- Δx/Δy @ IP didn't include local orbit correction

Dynamic Aperture after Correction



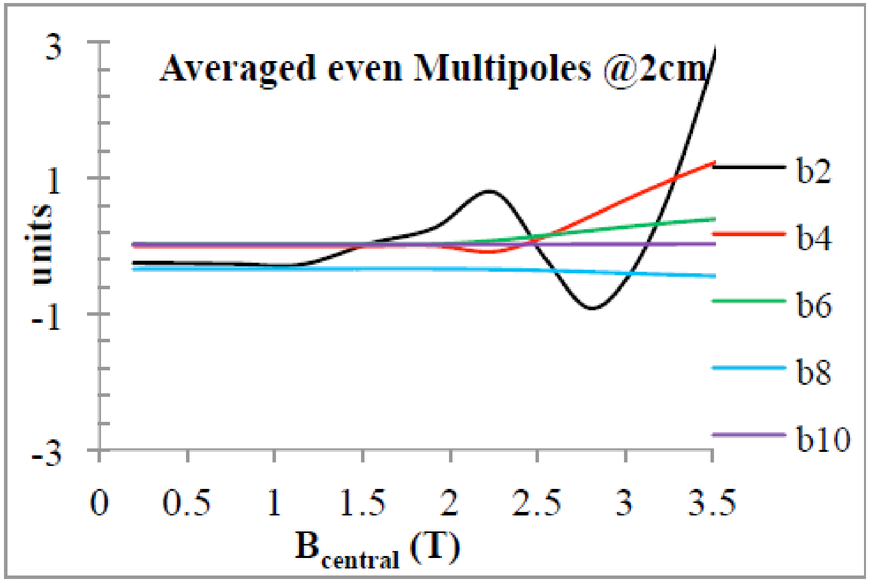


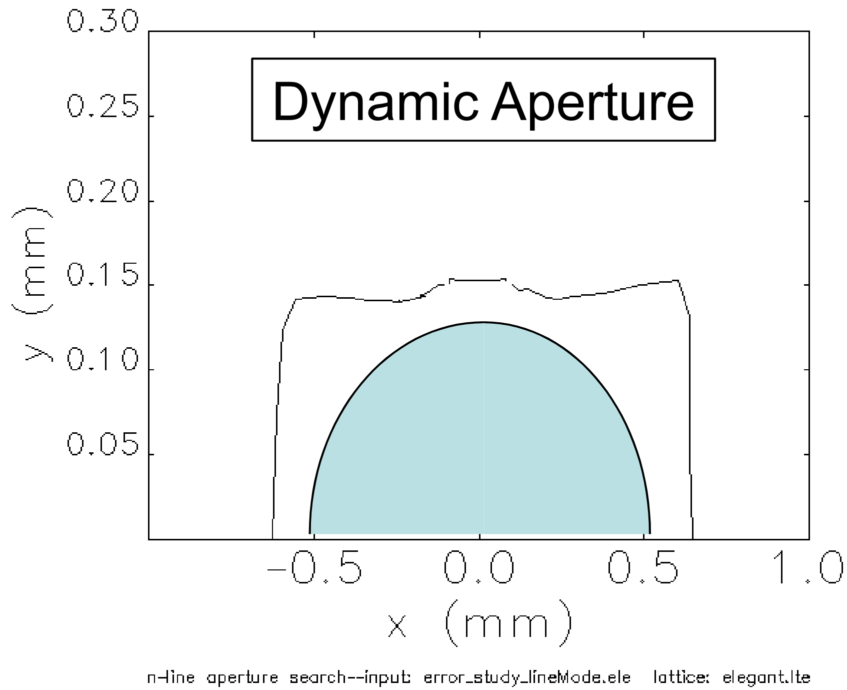
100 GeV proton	ex/ey(nor. mm-mrad)	DA origin	DA with error
Case 1, strong cooling	0.35/0.07	~ 90 σ	~ 60 σ
Case 2, large emittance	1.2/1.2	~ 48 σ	~ 32 σ

Much Larger than 10 σ of required DA

Magnet Quality (arc dipole)

Simulated data of a superferric dipole from Texas A&M University

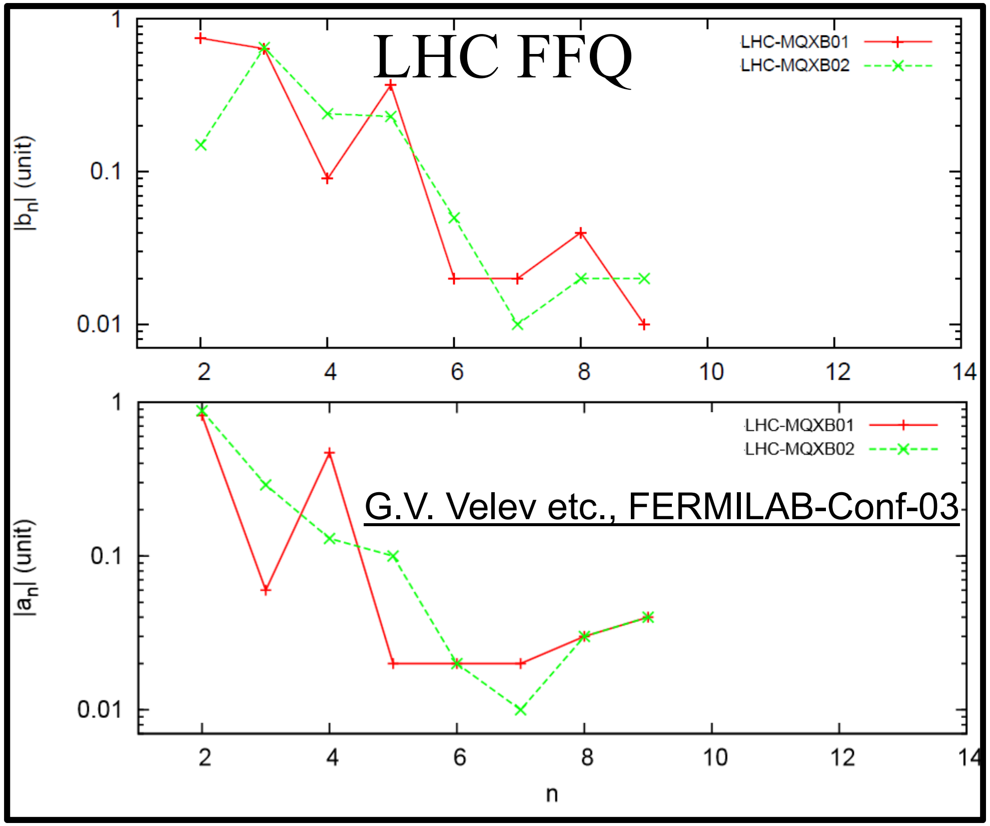


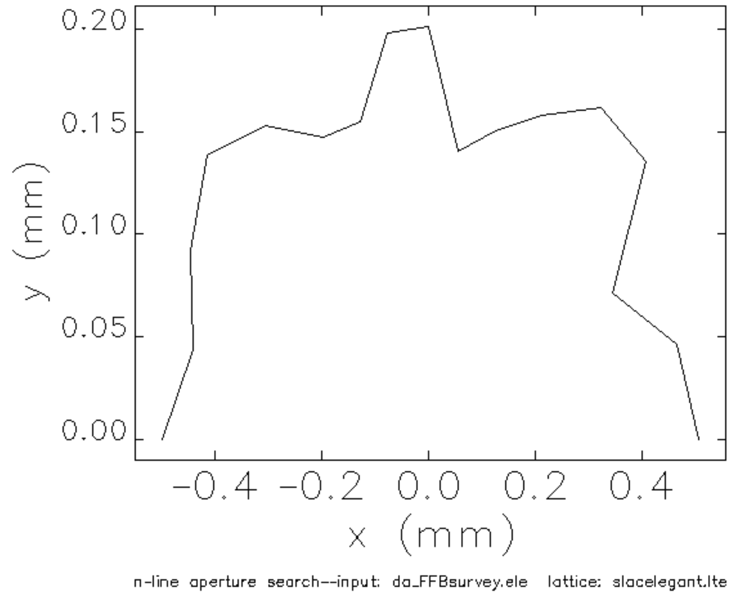


100 GeV, Proton	ex/ey(nor. mm-mrad)	DA right figure
Case 1, strong cooling	0.35/0.07	~ 30 σ
Case 2, large emittance	1.2/1.2	~ 16 σ

>10 σ of required DA

Magnet Quality (FFQ: Bottom-up approach)



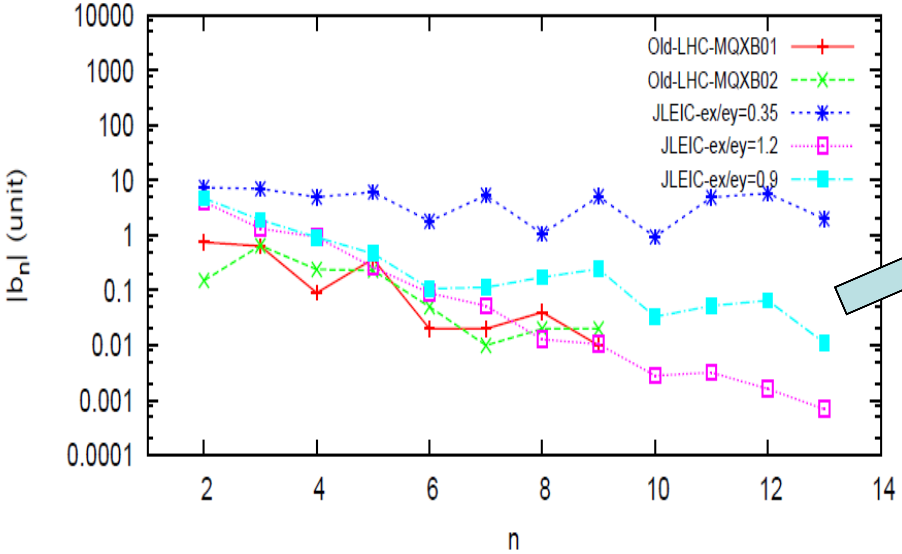


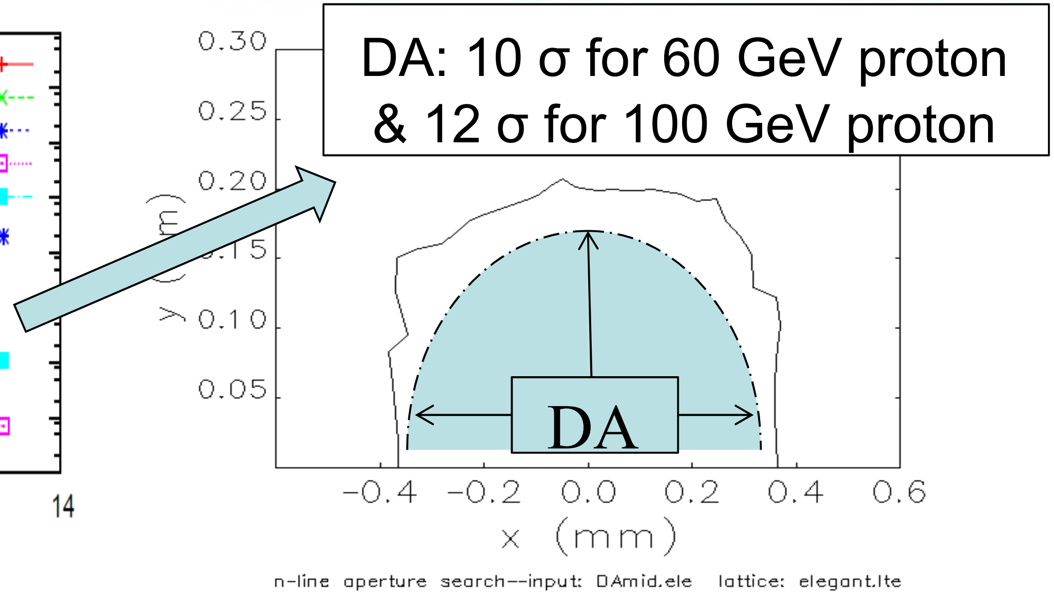
	ex/ey(nor.)	DA
Case 1	0.35/0.07	~ 16 σ
Case 2	1.2/1.2	~ 10 σ

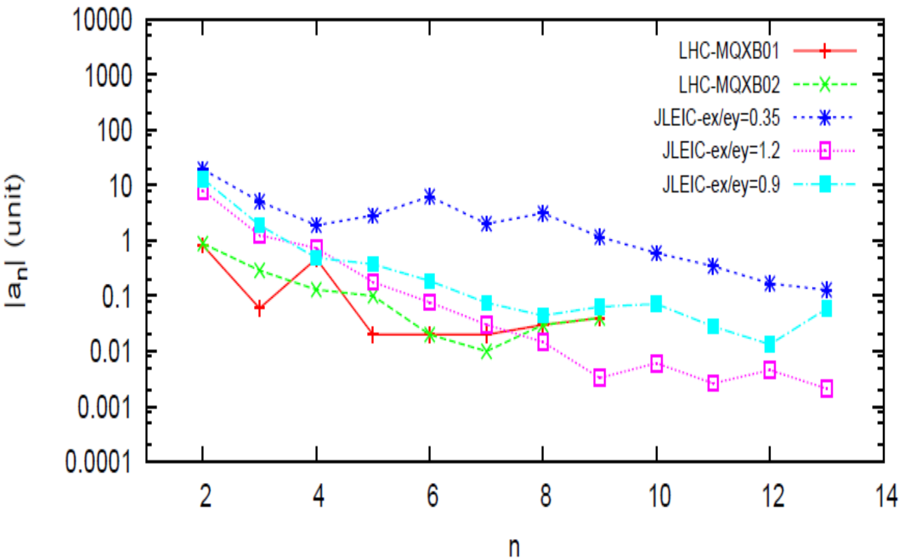
>10 σ of required DA

- Bottom-up approach by using LHC FFQ measured data
- DA results are OK for 100 GeV proton case.

Magnet Quality (FFQ: Top-down estimation)

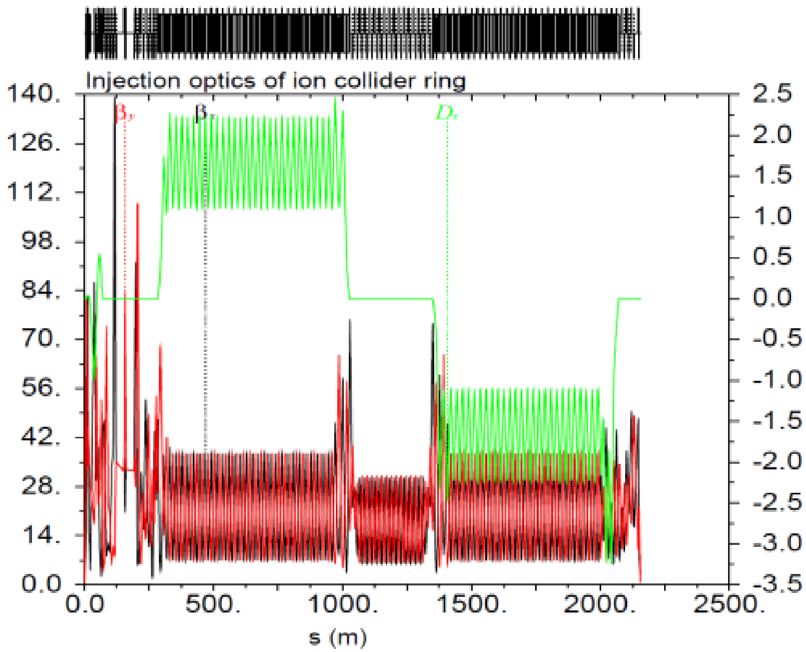


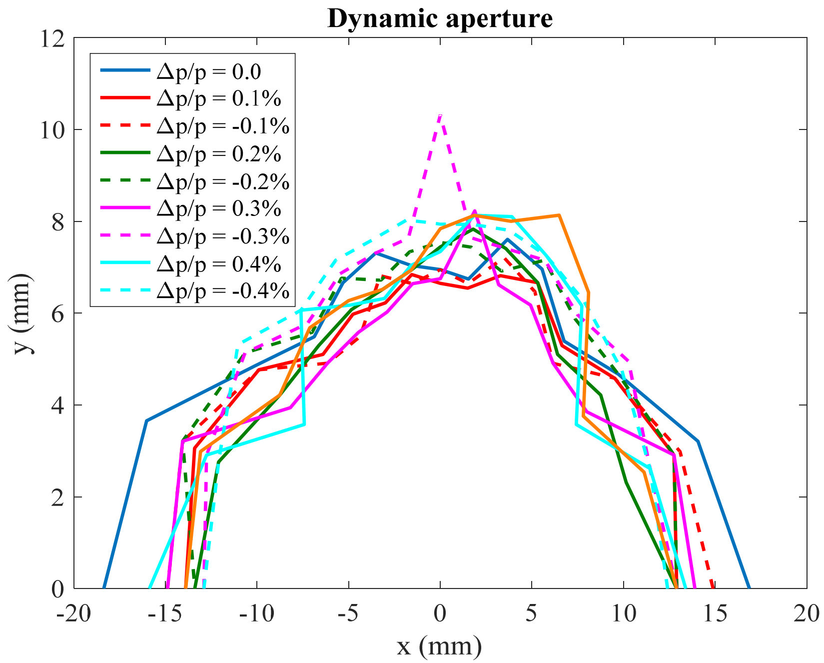




- Larger beam emittance with weak cooling results in the tighter limit multipole
- Survey with 0.9/0.9 mm-mrad of emittance gives a balance between multipole field of IR triplet and dynamic aperture.

Beam Squeeze





- A factor of 32 is difference between the geometric emittances at 8 and 100 GeV. β* at IP is enlarged in lattice design for 8-GeV proton injection.
- Dynamic aperture is good with magnet multipole components.

Summary

- IR design gives follow challenges: Chromaticity issue, Detector solenoid issue, Misalignment issue, Magnet quality, Beta squeeze, etc.
- For Chromaticity Compensation, a non-interleaved –I pairs scheme is selected, and dynamic aperture is 90 σ with bare lattice and strong cooling.
- Other issues has been also studied. Required dynamic aperture of 10 σ is achieved. The most limit to the dynamic aperture is multipole field components of IR triplets. IR triplets with LHC measured data is good for any cooling schemes. If cooling is better, we can release the magnet quality requirement.

Thank you