E-lens Related Beam Dynamics Studies

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(2012 APEX Workshop, Nov.19-20, BNL)

Outline

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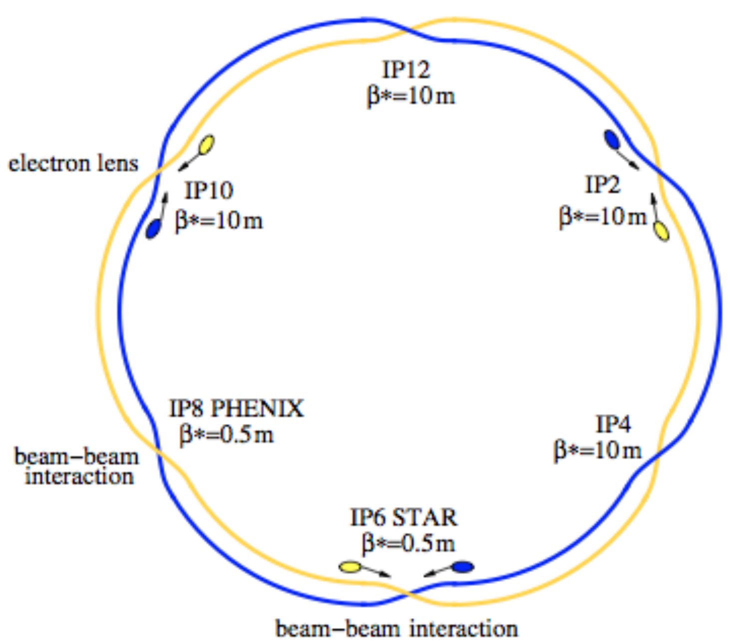
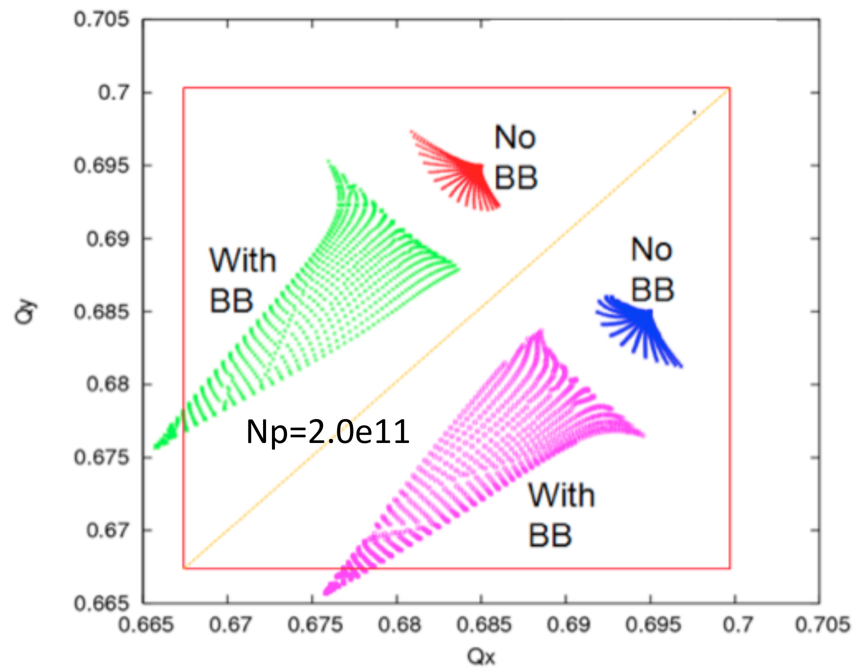
2. Critical Beam Parameters
3. APEX Proposals
4. Summary

Introduction to RHIC E-lens Project

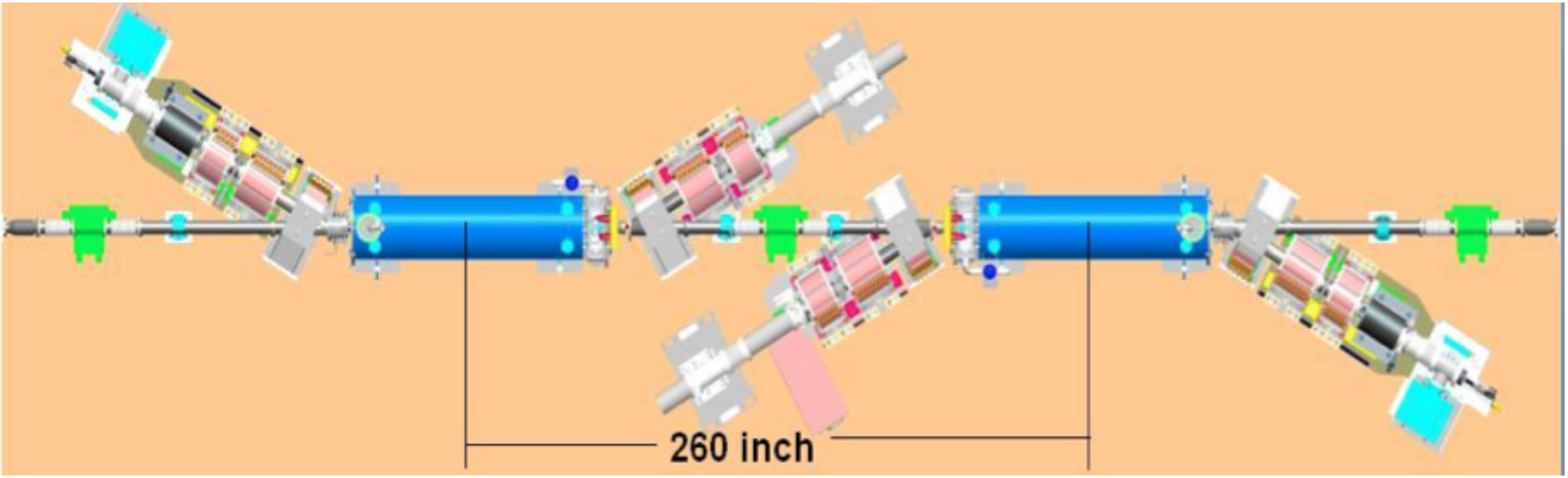
- To compensate the large beam-beam tune spread and nonlinear beam-beam resonance driving terms in the polarized proton operation, we planned to install head-on beam-beam compensation with electron lenses (e-lenses).
- Electron beams in the interaction region should have the same transverse profile as the proton bunches. Interaction region is surrounded by super-conducting solenoid.
- Currently half head-on beam-beam compensation is considered. Half compensation compensate half total beam-beam parameter. The goal is to double current luminosity with higher proton bunch intensity.



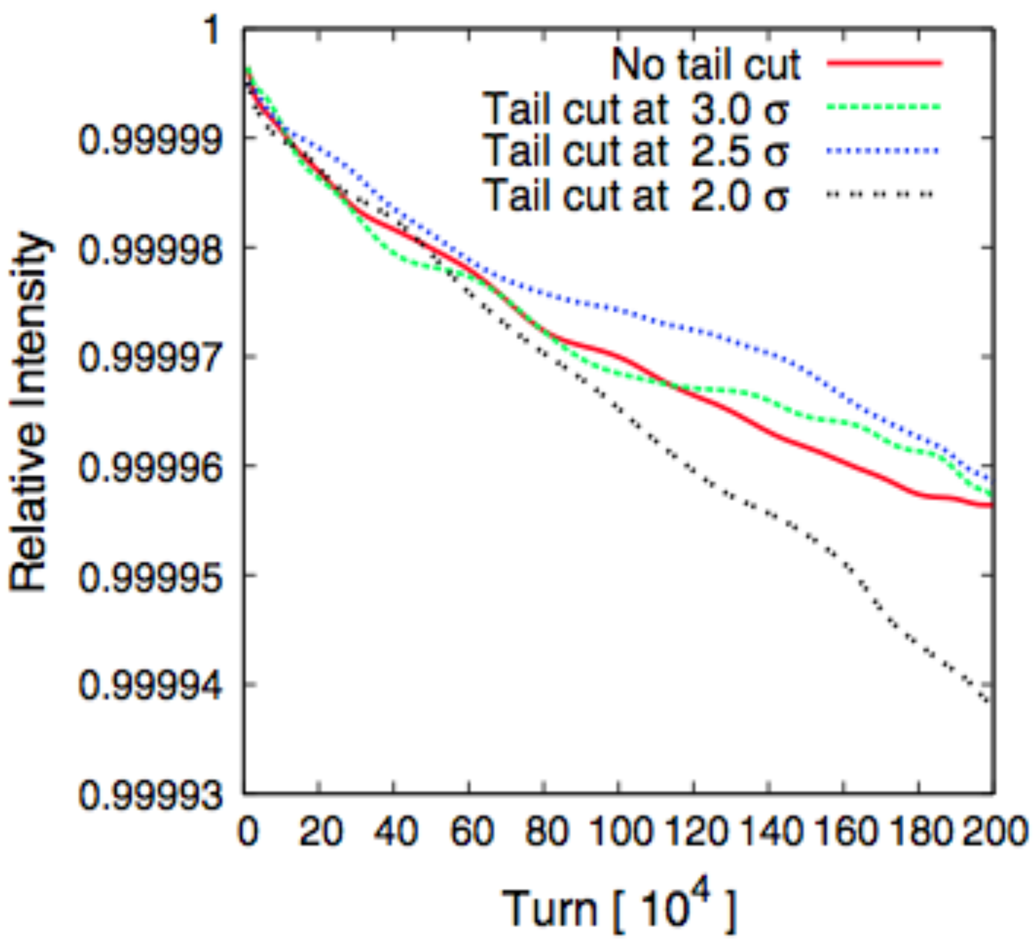


RHIC E-lens System and Its Installation

- E-lens system includes: electron gun, transfer line, main solenoid, transfer line, electron collector. The length of effective interaction region is 2.1 meter, the working magnetic field of main solenoid is 3-5 T.
- Two e-lenses are needed, one for each ring. They are located on either side of IP10. The distance from e-lens center to IP10 is 3.3 meter. The Blue ring e-lens is on the south of IP10.
- E-lens solenoids are being fabricated at SMD. One e-lens solenoid is scheduled for delivery in December. Another one will be EBIS spare solenoid which will be operated at 1 T.m so that the proton beam and spin dynamics are not negatively effected.



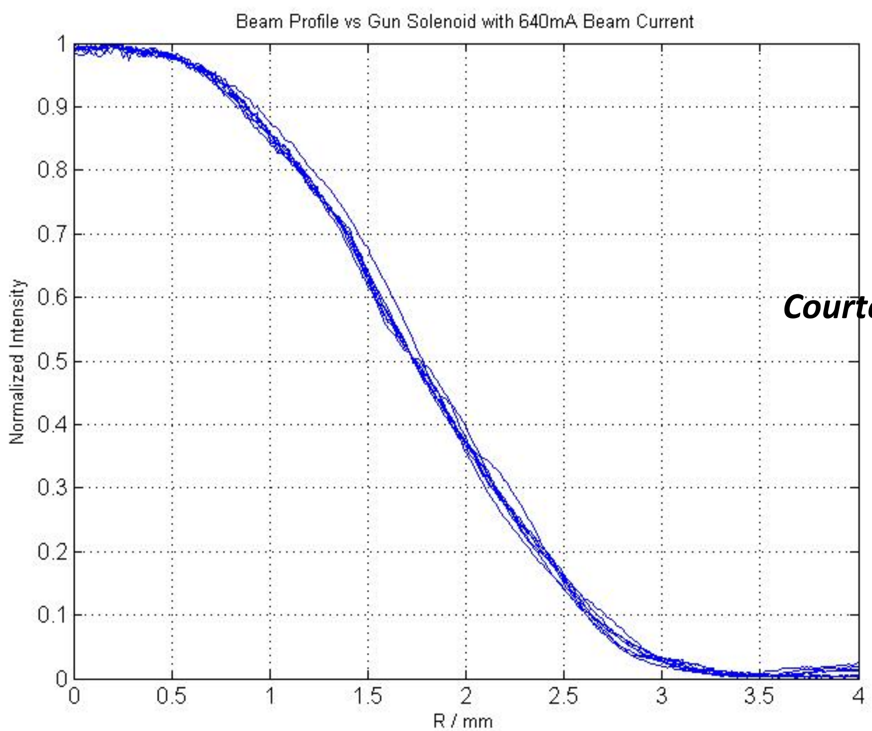
Transverse Gaussian Profile



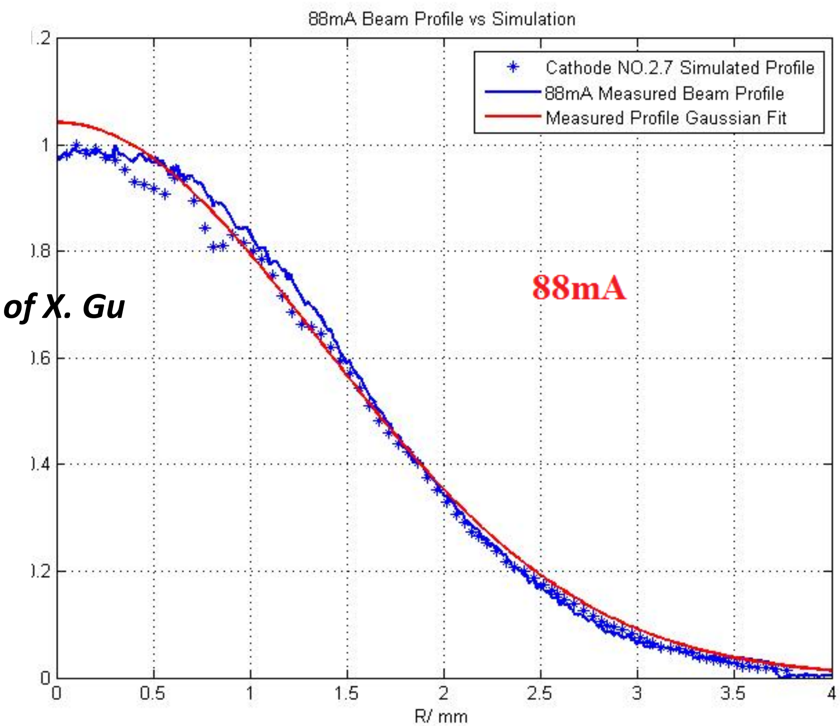
Simulation: beam loss rate vs. Gaussian tail cutoff.

- For best beam-beam compensation, the electron beam should have the same transverse Gaussian distribution as the proton bunch. With beta=9 m at the e-lenses, the rms proton beam size is 0.29 mm.
- From simulation, the electron beam has a Gaussian distribution cutoff at 2.8 sigma with current e-gun design. The Gaussian tail cutoff is determined by the electric field distribution on the cathode.
- Simulation shows that Gaussian tail cutoff. 2.8 sigma Gaussian tail cutoff is acceptable.

Results of Electron Profile Measurement

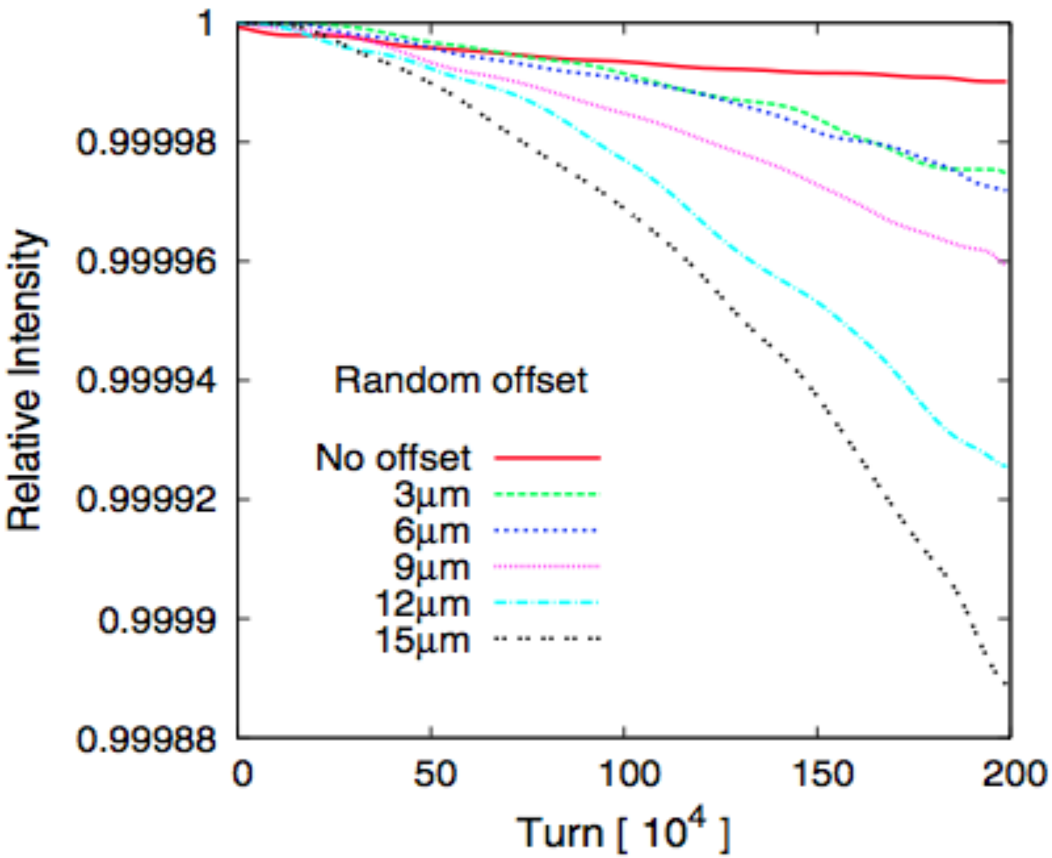


Courtesy of X. Gu



- Actual electron profile was measured on test bench with YAG screen +camera and pin pole +wire scan.
- It will be difficult to measure the electron profile on line during operation.
- The electron beam size at the e-lenses will be controlled on line by the ratio of magnetic fields of gun and main solenoids.

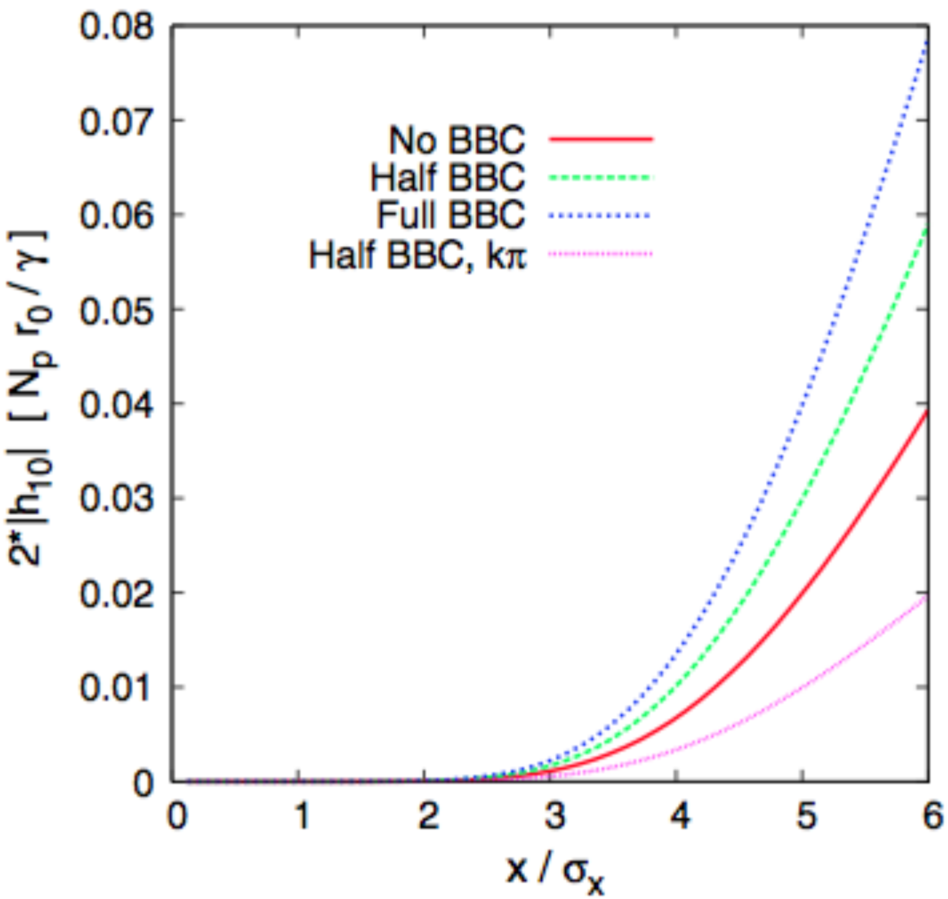
Over-lapping of e-p beams



Simulation: beam loss rate vs. random e-p offset.

- Overlapping of the electron and proton beams in the e-lens plays a crucial role in the head-on beam-beam compensation.
- A transverse offset of electron beam with respect to the proton beam center will cause losses of beam-beam tune spread compensation and beam-beam resonance driving term cancellation.
- Two kinds of transverse offsets: static and random. The random offset is mainly determined by the stability of the power supply of the bending magnets and its tolerance is only 9 microns.

Phase Advances Between IP8 and E-lens

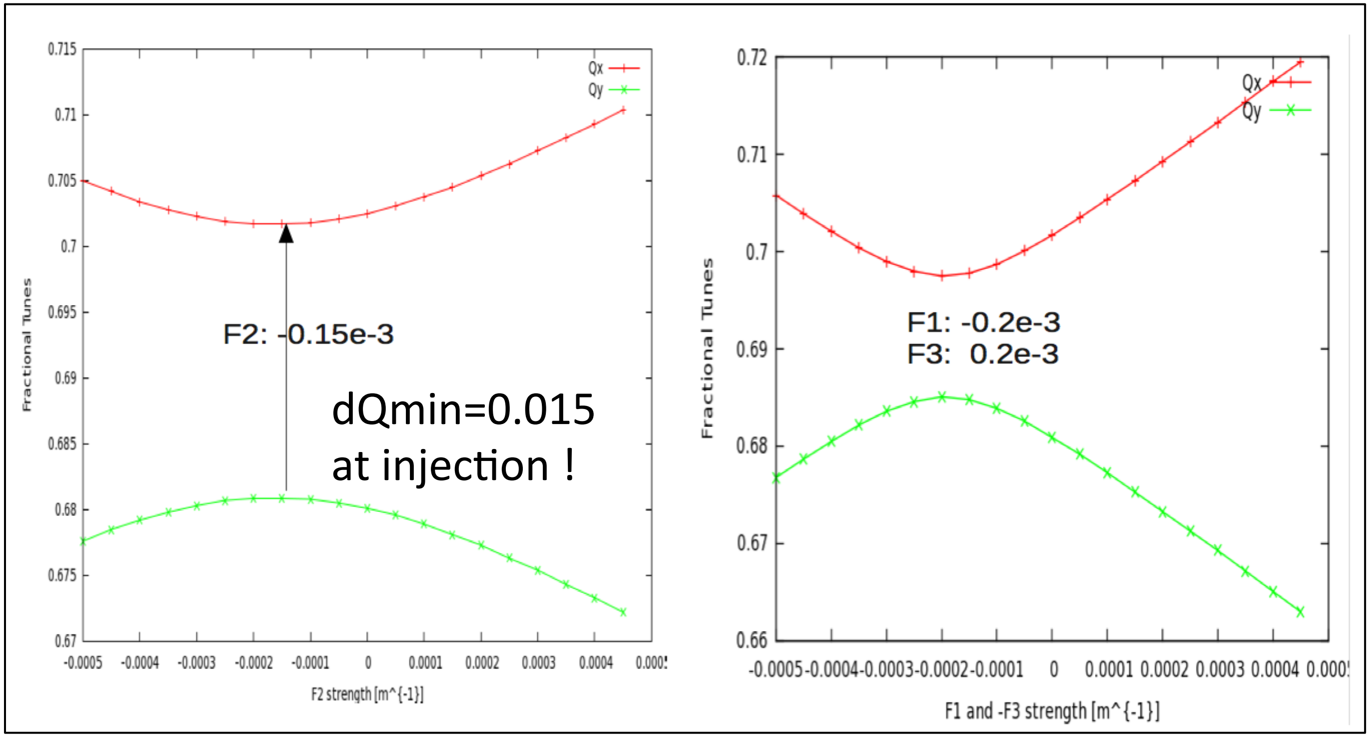


Simulation: BB RDT h10 under different conditions.

- We would like that e-lenses not only compensate the beam-beam tune spread but also the beam-beam resonance driving terms.
- For half head-on beam-beam compensation, we adjust the betatron phase advances between IP8 and the center of e-lenses to be k*PI so that the beam-beam resonance driving terms from IP8 and e-lens cancel each other.
- Good news: 0.1 Degree accuracy in measurement of phase advances was achieved in last year's APEX.
- To create k*PI phase advances, the new integer tunes for the Blue lattice are (27,29), while for the Yellow they are (29,30).

APEX Proposal:
Effects of E-Lens Solenoids

- To minimize the influences of two e-lenses on the proton beam and spin dynamics, we power the two solenoids with opposite polarities. If there is only one solenoid available, from simulation, the coupling and polarization will be affected.
- We propose a dedicated or parasitic experiment to measure the effects of one or two solenoids on orbit , tune, coupling, polarization at injection and at store.

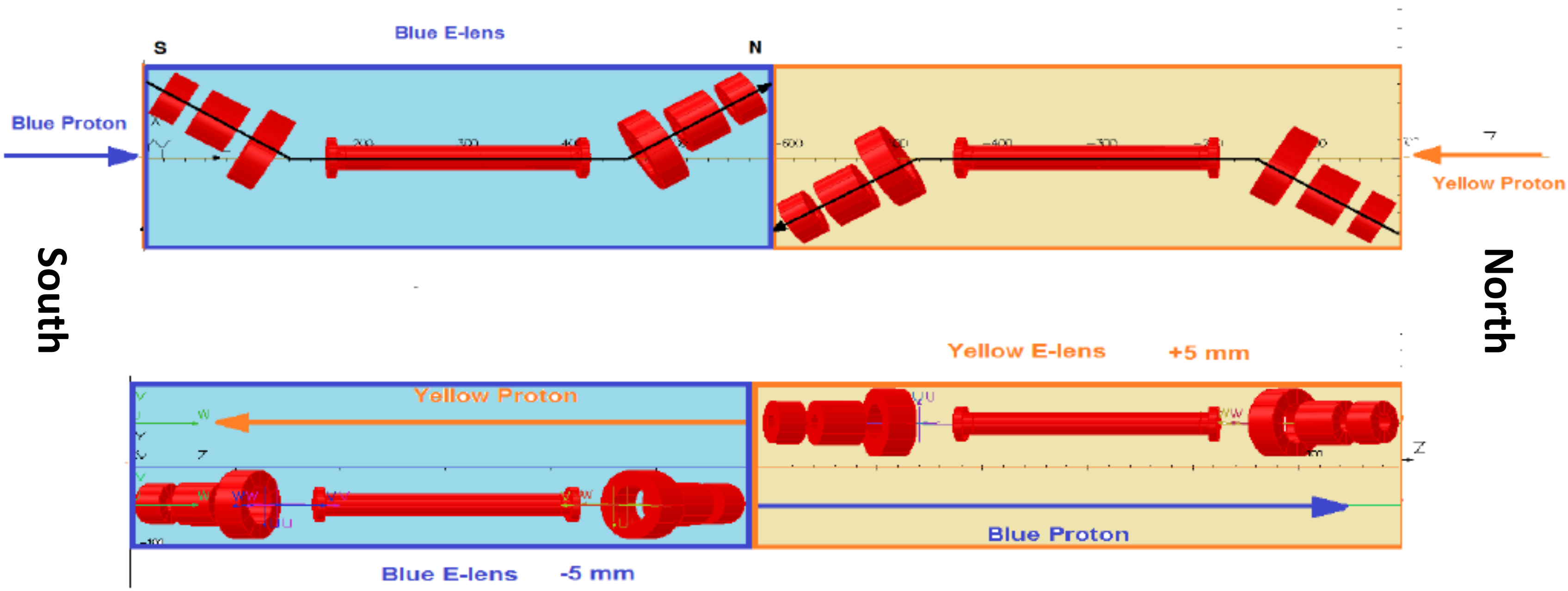


Blue skewQ polarities and decoupling families have to be re-defined with integer tunes (27,29).

Left plot shows coupling correction with only EBIS solenoid 10 T.m at injection.

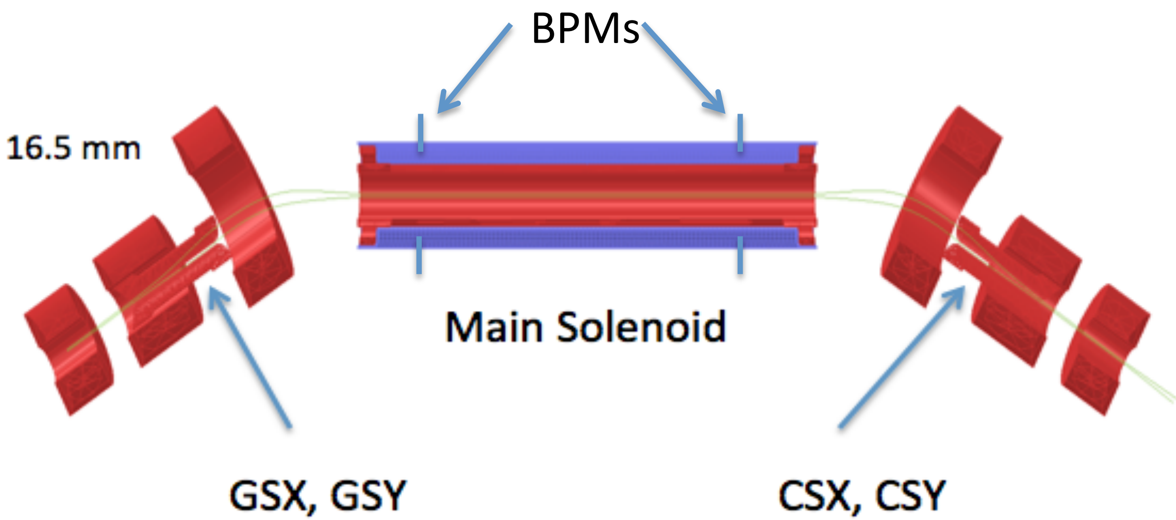
APEX Proposal:
Control of Proton Parameters at E-lens

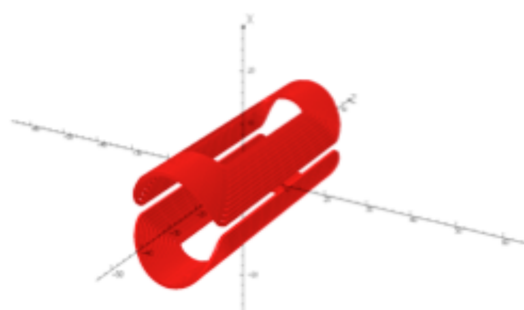
- Orbit: The two proton beams are vertically separated in the e-lenses. The proton beams should have (y,y')=(+/-5mm, 0) in the solenoids. We need to precisely measure and control the proton beam's orbit in the solenoids.
- Phase advances: k*PI between IP8 and the e-lens. We need to precisely measure and be able to adjust them on line.
- We propose one or two dedicated sessions to measure and adjust proton beam orbit at e-lenses and phase advances between IP8 and the center of e-lenses.



APEX Proposal:
Control of Electron Beam Parameters

- BPMs: two critical BPMs with distance 1.5 m inside the solenoids are designed to measure the position and angle of electron and proton beams.
- Correctors: on both sides of main solenoid, there are two X/Y steering coils to adjust the electron beam's position in the e-lenses. Inside the main solenoids, two sets of long coils are used to change the X/Y angles of the electron beams.
- We propose dedicated or parasitic beam time to measure the electron beam's position and to test our ability to change the position and angle of electron beam in the main solenoid.





One corrector

Who Are We

- Proton optics measurement team:
  M. Bai, C. Liu, S. Tepikian, Y. Luo
- Phase advance measurement and adjustment:
  M. Bai, C. Liu, P. Thieberger,
  S. Tepikian, C. Montag, A. Marusic, Y. Luo
- Proton & electron orbit, proton coupling team:
  X. Gu, A. Marusic, Y. Luo
- Effect of solenoid on proton polarization team:
  M. Bai, V. Ranjbar
- Supporting team:
  X. Gu, D. Gassner, A. Marusic, S. Nemesure, W. Fischer

Summary

1. We reviewed critical beam parameters for head-on beam-beam compensation.
2. We proposed several APEX items to measure the proton and electron beam parameters and to adjust them on line.
3. The detailed beam experiment plan for each topic will be worked out soon.