Construction progress of the RHIC electron lenses


23 May 2012
IPAC 2012,
New Orleans, Louisiana
1. Motivation: Head-on beam-beam effect in RHIC

2. Compensation overview

3. Components
   - Gun and collector
   - Warm magnets
   - Super-conducting magnets
   - Instrumentation

4. Test bench
**Motivation**

Bunch intensity in 2012 polarized proton physics store

**Goal:**

Compensate for 1 of 2 beam-beam interactions with electron lenses

Then increase bunch intensity \( \Rightarrow up to 2 \times luminosity \)

Need new polarized proton source – under construction, A. Zelenski

\[ L \propto N_b^2 \]
Partial head-on beam-beam compensation overview

Basic idea:
• 2 beam-beam collisions with **positively** charged beam
• Add collision with a **negatively** charged beam – with matched intensity and same amplitude dependence

Compensation of nonlinear effects:
• e-beam current and shape
  => reduces tune spread
• $\Delta \psi_{x,y} = k\pi$ between p-p and p-e collision
  => reduces resonance driving terms

Built on experience with

**Tevatron electron lenses**
V. Shiltsev, A. Burov, A. Valishev, G. Stancari, X.-L. Zhang, …

**BNL Electron Beam Ion Source (EBIS)**
J. Alessi, E. Beebe, M. Okamura, A. Pikin, D. Raparia, …
Compensation and tolerances extensively studied in simulations
Y. Luo et al. – PRST-AB 15, 051004 (2012)

Losses with and w/o BBC

Effect of e-beam size
RHIC electron lenses

Related IPAC 2012 presentations

- MOPPC024: V. Schoeffer et al.
  “RHIC polarized proton operation in Run-12”

- MOPPC025: S.M. White, W. Fischer, Y. Luo
  “Simulations of coherent beam-beam effects with head-on compensation”

- TUPPC114: C. Montag, W. Fischer, A. Oeftiger
  “Ion bunch length effects on the beam-beam interaction and its compensation in a high-luminosity ring-ring Electron-ion collider”

- WEOBA01: C. Montag et al.
  “Beam Experiments towards High-intensity Proton Beams in RHIC”

- WEPPD084: X. Gu et al.
  “The e-lens test bench for RHIC beam-beam compensation”

- THPPPR032: X. Gu et al.
  “The clearing electrode for the scattering electrons in the e-lens”
RHIC electron lenses

Compensation overview

**GS1** warm solenoid

**GS2** warm solenoid

**GSB** warm solenoid

**SC main solenoid**
B = 6 T, I = 440 A
+ 16 more magnets

**CSB = GSB**

**CS2 = GS2**

**CS1 = GS1**

**Electron gun**

**e−**

**Electron collector**

**e−**

**CSX/Y = GSX/Y**

**e−**

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RHIC electron lenses

**Gun**
*Designed for: current density, profile*

3 modes:
- DC (full compensation)
- 100 Hz (positioning)
- 78 kHz (single bunch compensation)

\[ V_{\text{max}} = 10 \text{ kV}, I_{\text{max}} = 1 \text{ A}, P = 1 \times 10^{-6} \text{ AV}^{-3/2} \]

Cathodes: LaB₆ and IrCe (from Budker), 4.1 mm radius, Gaussian profile (2.8 σ)

**Collector**
*Designed for: Reliability*

Water cooled,
can take 5x nominal load

\[ \rho_P < 50 \text{ W/cm}^2, T < 125^\circ \text{ C} \]
RHIC electron lenses

Warm magnets (A. Pikin, X. Gu)

4 types: GS1, GS2, GSB, GSX/Y

**Designed for:** 0.3 T min transport field, power consumption (total < 0.5 MW)

**GS1** (gun, collector)
- $B = 0.8$ T, $I = 1200$ A, $P = 58$ kW

**GS2**
- $B = 0.5$ T, $I = 730$ A, $P = 25$ kW

**GSB** (bend)
- $B = 0.3$ T, $I = 770$ A, $P = 45$ kW

**PS in assembly**
- (1 each for GS1-CS1, GS2-CS2, GSB-CSB)
RHIC electron lenses  Superconducting magnets (R. Gupta)

**Designed for:** solenoid field strength (6T), field straightness (±50 μm)

Stabilizes e-beam

Magnetic compression (need 310 μm rms beam size)

\[ \sigma_{\text{main}} = \sigma_{\text{gun}} \sqrt{\frac{B_{\text{gun}}}{B_{\text{main}}}} \]

Maximize overlap of p- and e-beams
RHIC electron lenses

Superconducting magnets (R. Gupta)

**Designed for:** solenoid field strength (6T), field straightness (±50 μm)

Stabilizes e-beam

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\[ \sigma_{\text{main}} = \sigma_{\text{gun}} \sqrt{\frac{B_{\text{gun}}}{B_{\text{main}}}} \]

Maximize overlap of p- and e-beams

17 magnets total

0.3 T with reduced \( B_{\text{main}} \)

fringe field solenoid

anti-fringe field solenoid

main solenoid

main “trim” solenoid

correctors

To correct for straightness 5 hor + 5 ver

maintain field quality with reduced \( B_{\text{main}} \)
RHIC electron lenses

winding at BNL
22 layers, ~25000 turns

Superconducting magnets

shell with correctors

1st solenoid tested cold:

<table>
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<th>quench no</th>
<th>current [A]</th>
<th>field [T]</th>
<th>location</th>
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<td>340</td>
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Ground fault developed in layer 1, decided to disable layers 1&2

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RHIC electron lenses

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2nd solenoid being prepared for cold test

Ground fault developed in layer 1, decided to disable layers 1&2

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**Designed for:**
- e-beam position
- e-current and losses **halo monitor**
- Drift tubes
  - ion extraction with DC e-beam
- e-beam profiles **pin-hole detector, YAG screen**
- Overlap of p- and e-beam
Beam overlap monitor (P. Thieberger):

- $p$-$e$ beam interaction creates bremsstrahlung (photons) and backscattered electrons.
- Backscattered electrons can be detected near gun (above e-beam).
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Test bench

- Collector
- Instrument holder
  - Pin hole detector
  - YAG screen
  - Halo monitor

More details: X. Gu et al., WEPP094
RHIC electron lenses

Test bench goals

1. Measure gun perveance (I vs. U)
2. Verify transverse Gaussian profile
3. Gun operation in all modes (100 Hz, 78 kHz, DC)
4. Measure collector temperature and pressure with highest load
5. Commissioning of pin hole detector and YAG screen
6. Prototype of machine protection system
7. Test of software controls

More details: X. Gu et al., WEPP044
RHIC electron lenses

Infrastructure

Racks with equipment fill trailer and part of existing service building

33 m
RHIC electron lenses

Infrastructure

Racks with equipment

33 m
RHIC electron lenses

Infrastructure

Racks with equipment

33 m
RHIC electron lenses

Summary

- Partial head-on beam-beam compensation in RHIC:
  - 5 keV electron beam to reduce beam-beam induced tune spread and resonance driving terms
  - Aim for 2x increase in luminosity

- 2 electron lenses under construction
  - 1st superconducting solenoid reached 5.6 T (modified after ground fault), 2nd being prepared for cold test
  - Received almost all warm magnets and power supplied
  - Some instrumentation and vacuum chamber still to be manufactured

- Test bench set up to verify performance of:
  - Gun, collector, GS1, part of instrumentation, software

- Plan for installation in summer of 2012