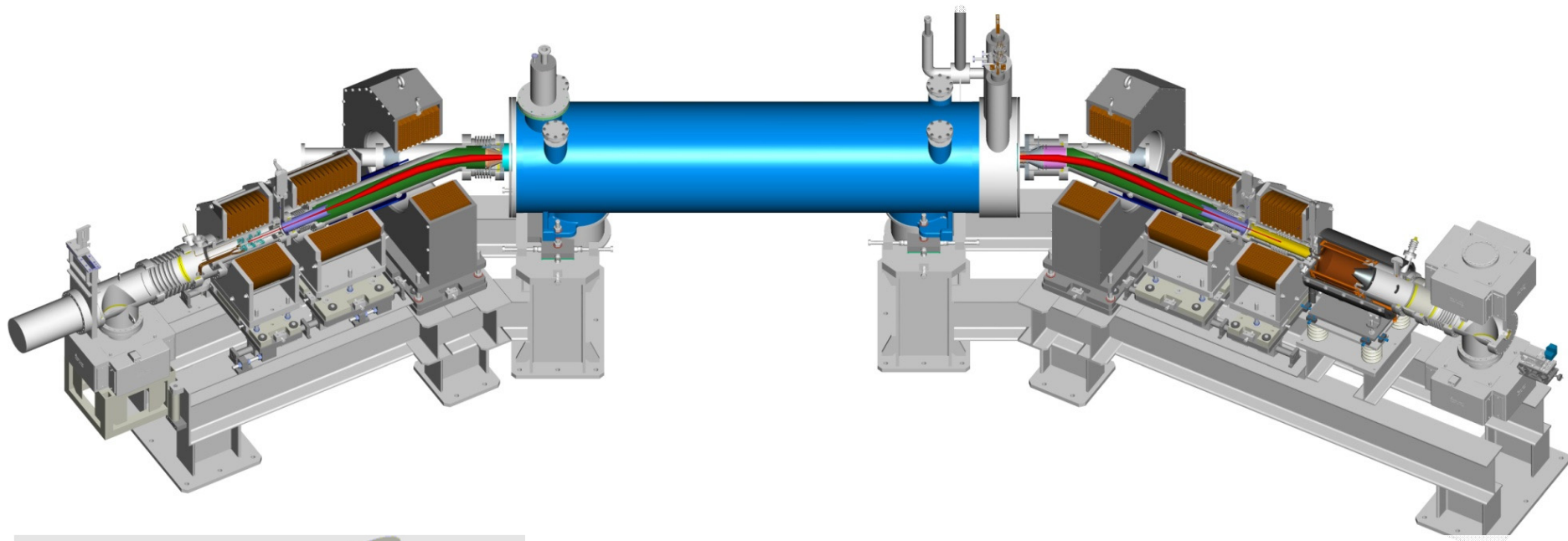


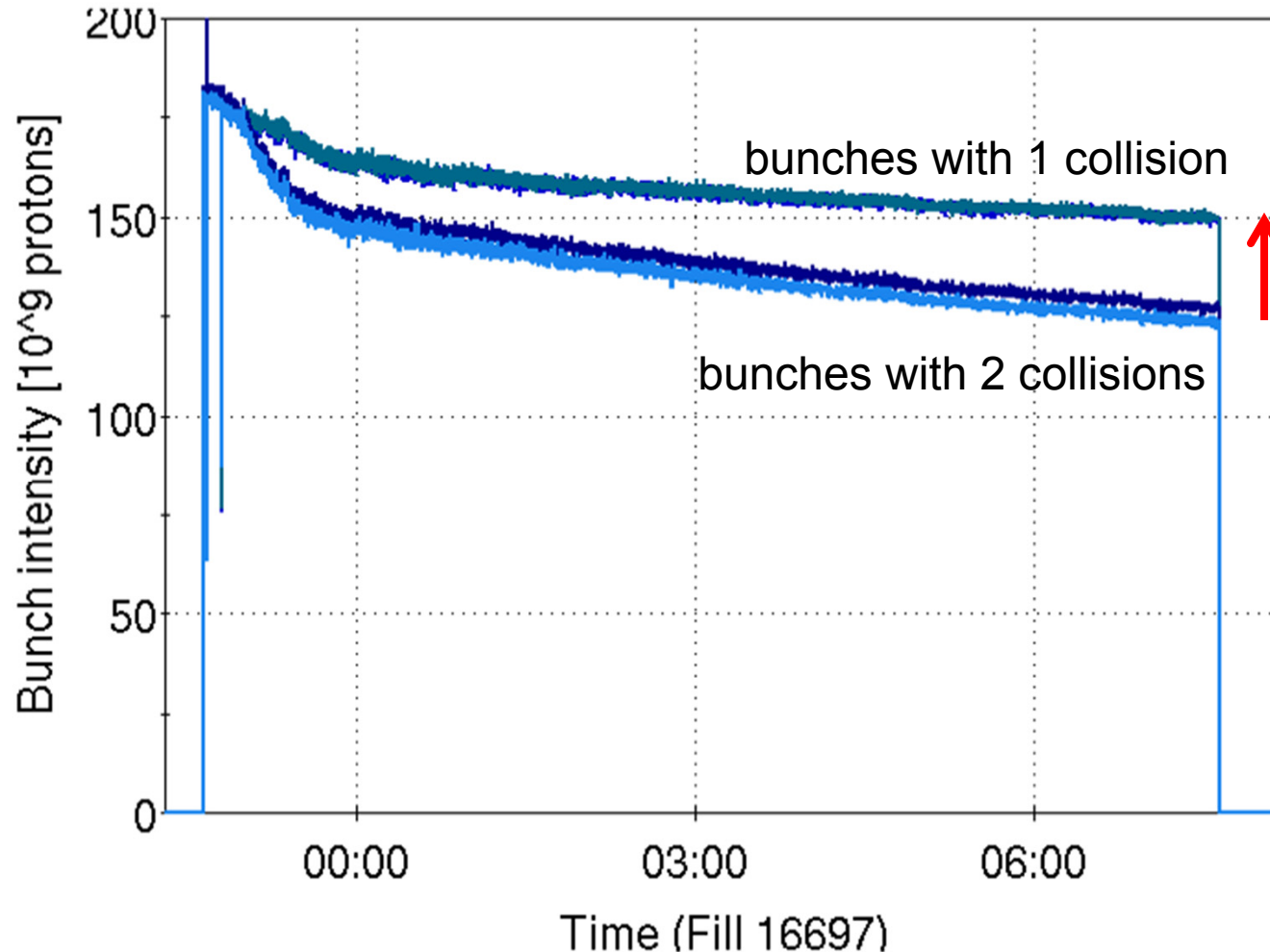
Construction progress of the RHIC electron lenses

W. Fischer , Z. Altinbas, M. Anerella, E. Beebe, D. Bruno, W.C. Dawson,
D.M. Gassner, X. Gu, R.C. Gupta, K. Hamdi, J. Hock, L.T. Hoff, A.K. Jain,
R. Lambiase, Y. Luo, M. Mapes, A. Marone, T.A. Miller, M. Minty, C. Montag,
M. Okamura, A.I. Pikin, S.R. Plate, D. Raparia, Y. Than, C. Theisen,
P. Thieberger, J. Tuozzolo, P. Wanderer, S.M. White, W. Zhang



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

Bunch intensity in 2012 polarized proton physics store



Goal:

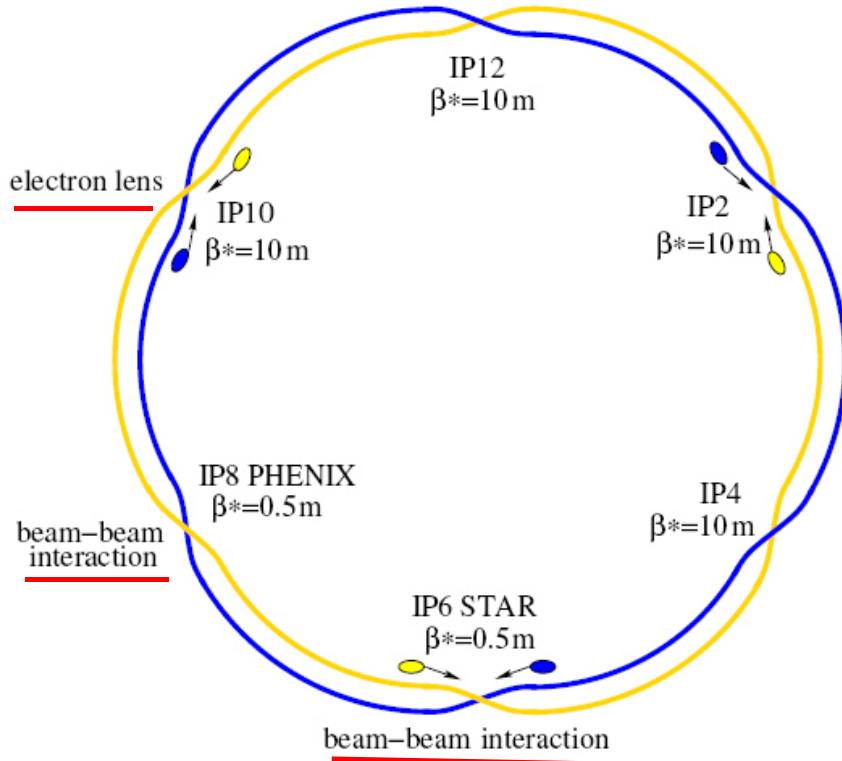
Compensate for
1 of 2 beam-beam
interactions with
electron lenses

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

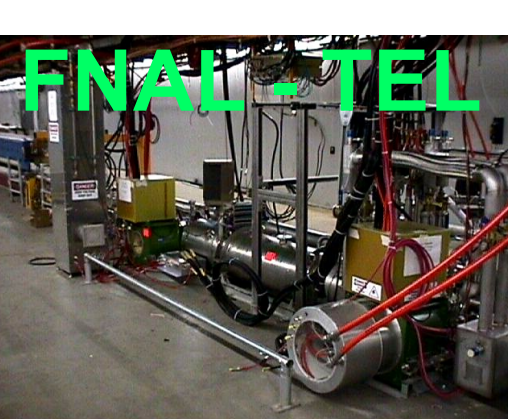


Basic idea:

- 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



Wolfram Fischer

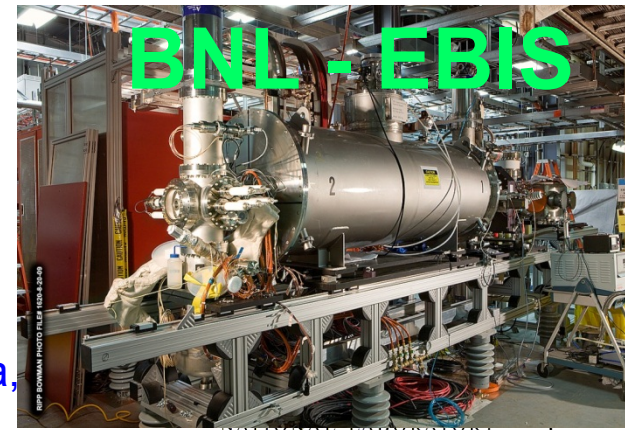
Built on experience with

Tevatron electron lenses

V. Shiltsev, A. Burov, A. Valishev,
G. Stancari, X.-L. Zhang, ...

BNL Electron Beam Ion Source

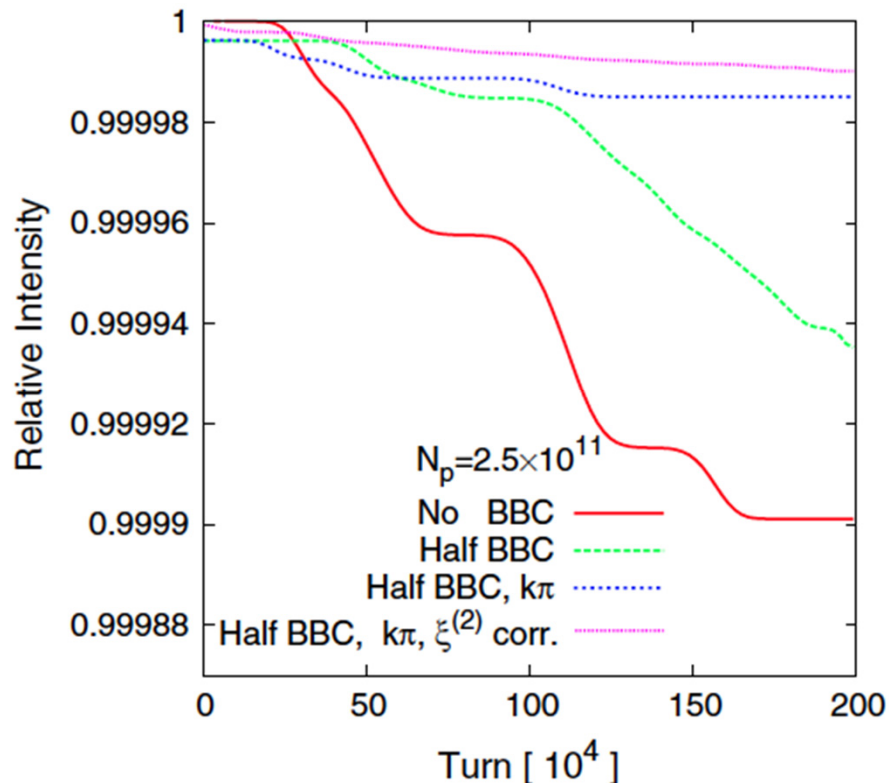
(EBIS) J. Alessi, E. Beebe, M. Okamura,
A. Pikin, D. Raparia, ...



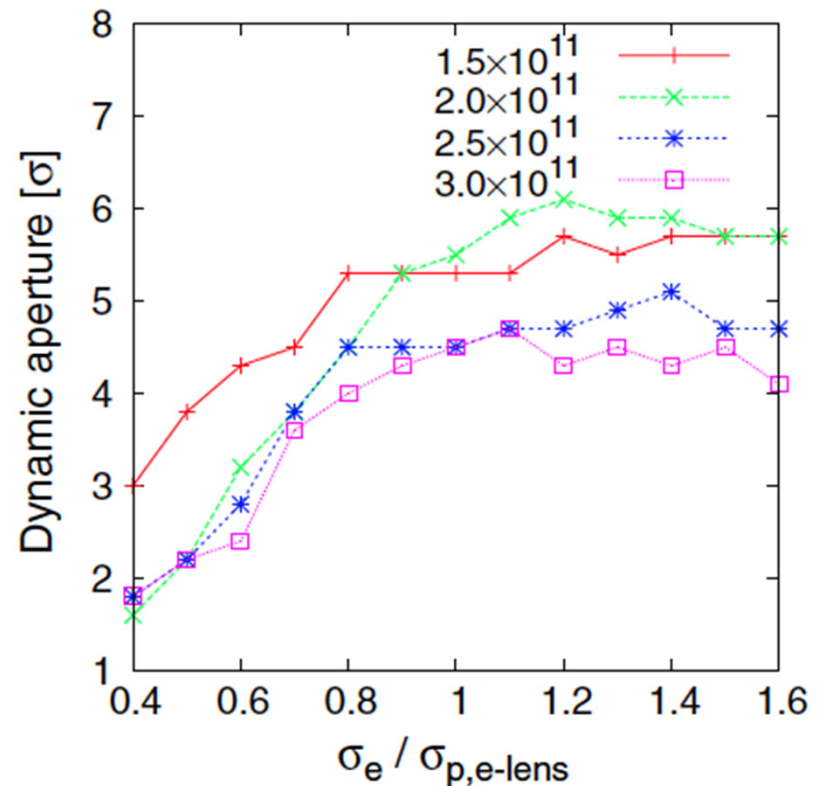
Compensation and tolerances extensively studied in simulations

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. Schoeffler 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”
- THPPR032: X. Gu et al.
“The clearing electrode for the scattering electrons in the e-lens”

RHIC electron lenses

Compensation overview

GS1 warm solenoid

SC main solenoid

$B = 6\text{ T}$, $I = 440\text{ A}$
+ 16 more magnets

CSB = GSB

CS2 = GS2

CS1 = GS1

GS2 warm solenoid

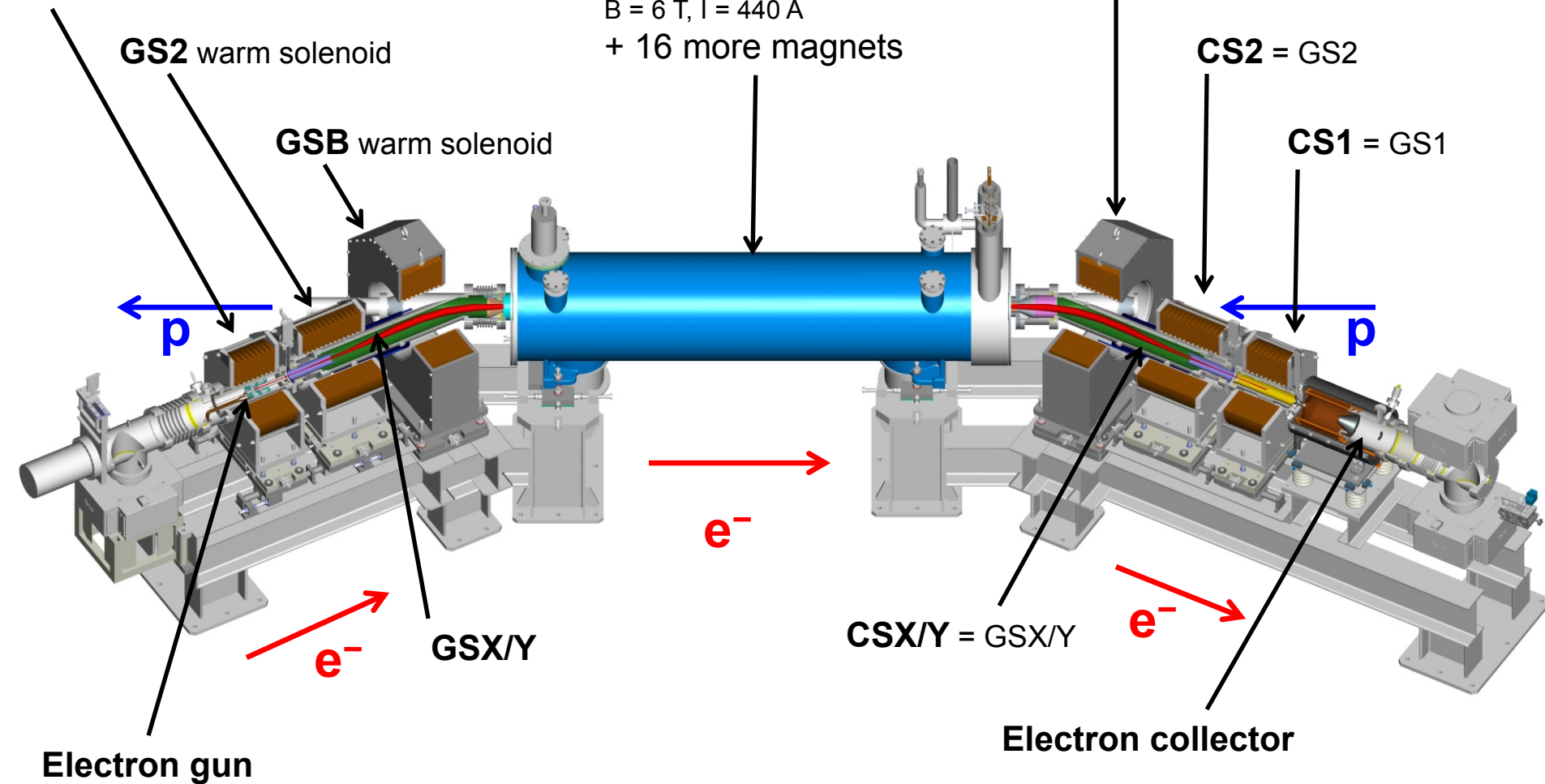
GSB warm solenoid

GSX/Y

CSX/Y = GSX/Y

Electron gun

Electron collector



RHIC electron lenses

Gun

Designed for: current density, profile

3 modes:

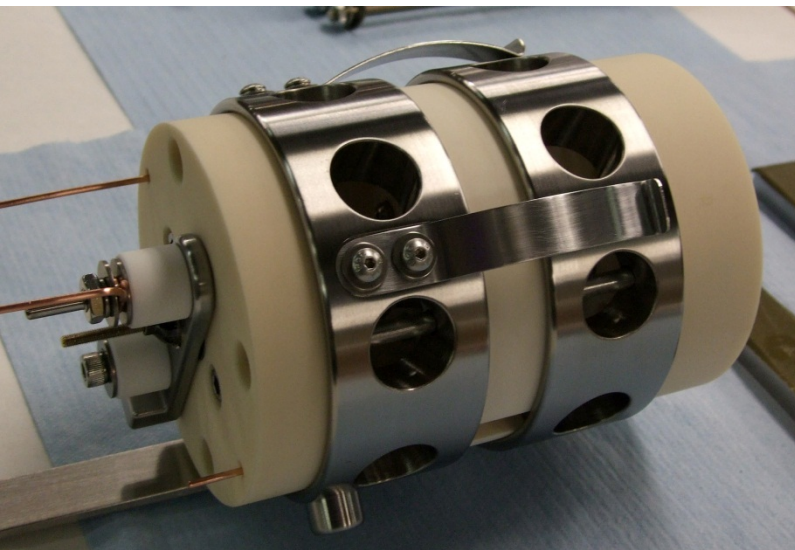
- DC (full compensation)

- 100 Hz (positioning)

- 78 kHz (single bunch compensation)

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

Cathodes: LaB_6 and IrCe (from Budker),
4.1 mm radius, Gaussian profile (2.8σ)



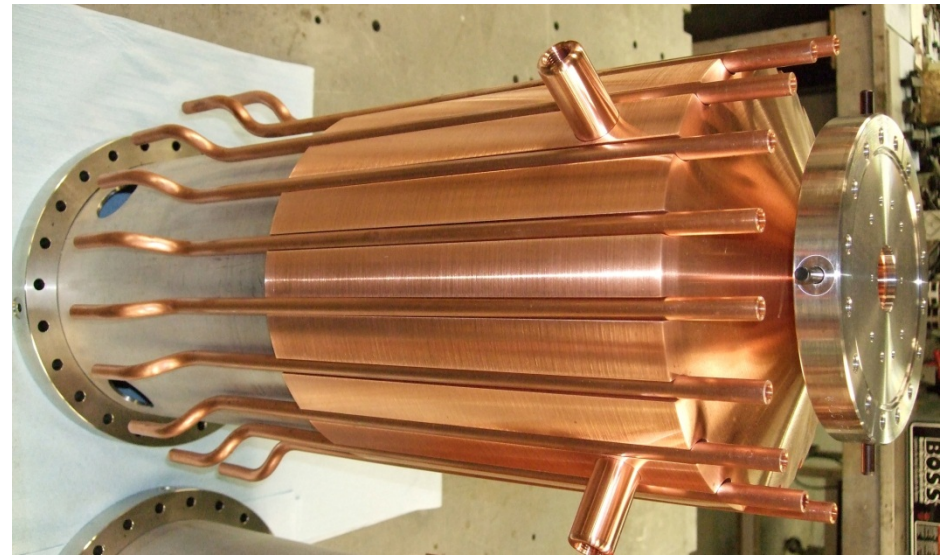
Gun and collector (A. Pikin)

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)

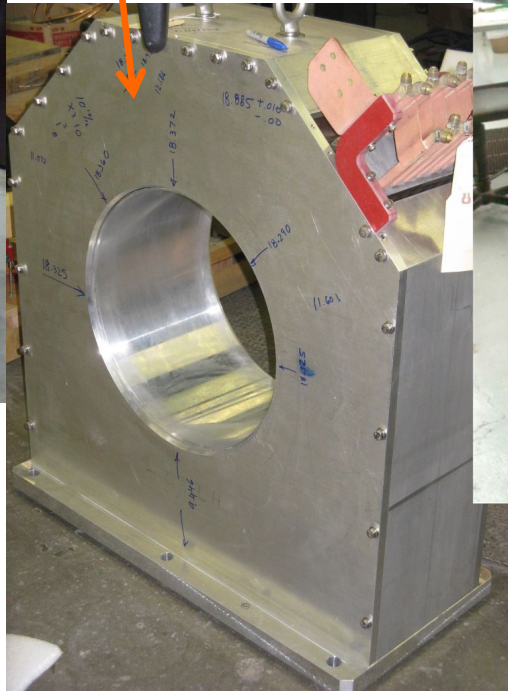
$B = 0.8 \text{ T}$, $I = 1200 \text{ A}$, $P = 58 \text{ kW}$

GSB (bend)

$B = 0.3 \text{ T}$, $I = 770 \text{ A}$, $P = 45 \text{ kW}$

GS2

$B = 0.5 \text{ T}$, $I = 730 \text{ A}$, $P = 25 \text{ kW}$



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 ($\pm 50 \mu\text{m}$)

Stabilizes e-beam

Magnetic compression (need $310 \mu\text{m}$ rms beam size)

$$\sigma_{main} = \sigma_{gun} \sqrt{\frac{B_{gun}}{B_{main}}}$$

Maximize overlap
of p- and e-beams

RHIC electron lenses Superconducting magnets (R. Gupta)

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Magnetic compression (need $310 \mu\text{m}$ rms beam size)

$$\sigma_{main} = \sigma_{gun} \sqrt{\frac{B_{gun}}{B_{main}}}$$

Maximize overlap
of p- and e-beams

17 magnets total

0.3 T with reduced B_{main}

fringe field solenoid

anti-fringe field solenoid

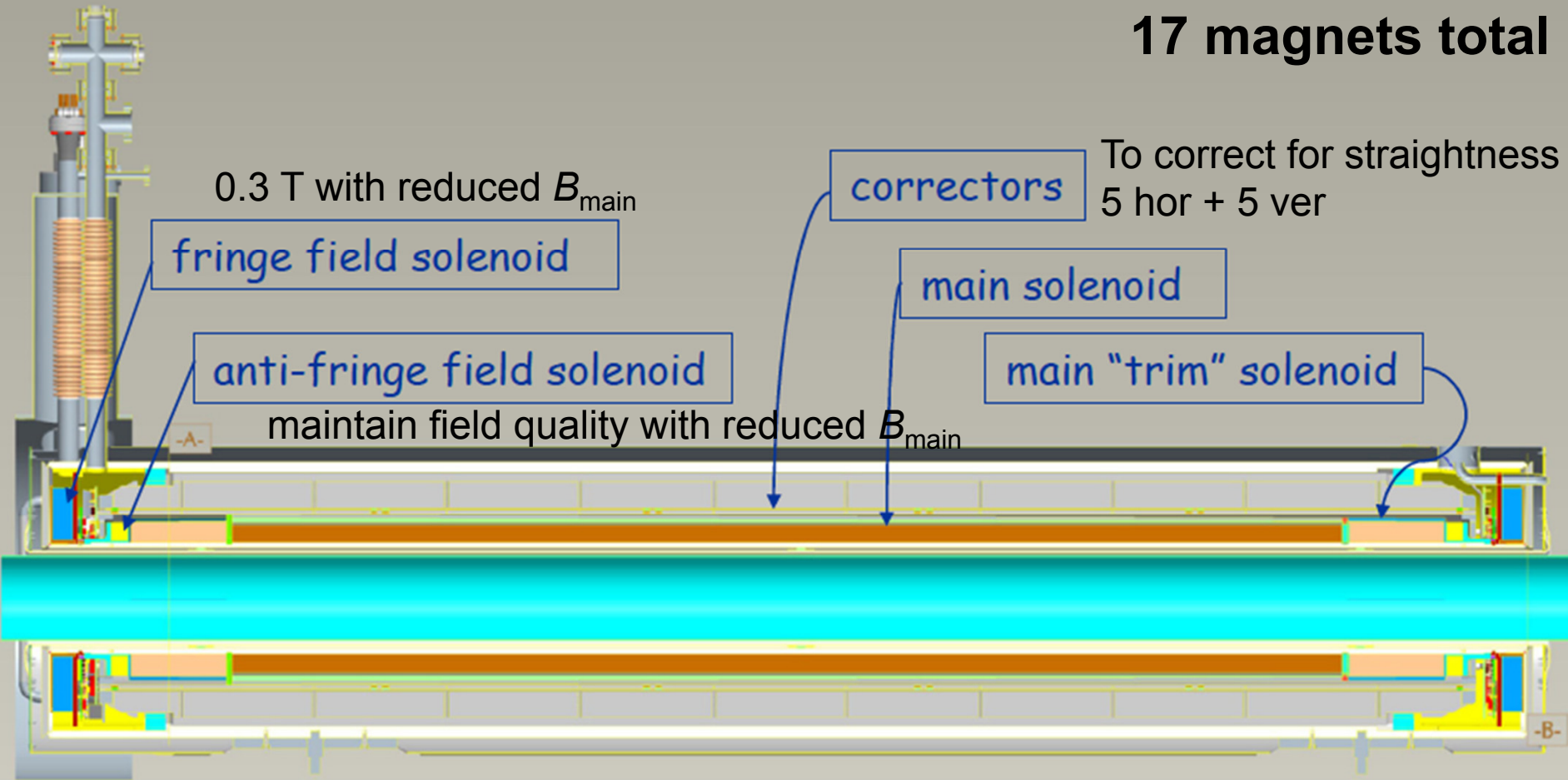
maintain field quality with reduced B_{main}

correctors

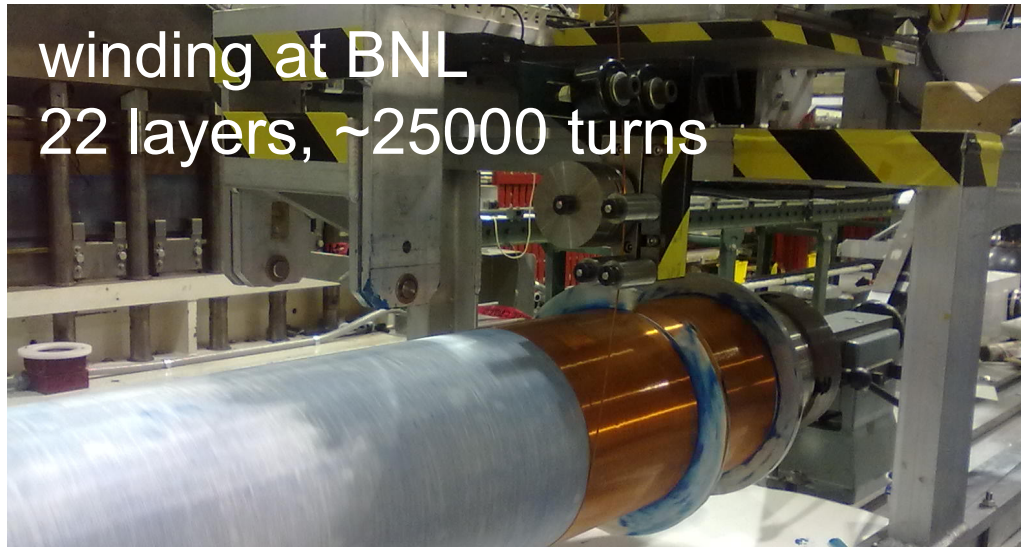
To correct for straightness
5 hor + 5 ver

main solenoid

main "trim" solenoid



RHIC electron lenses



Superconducting magnets



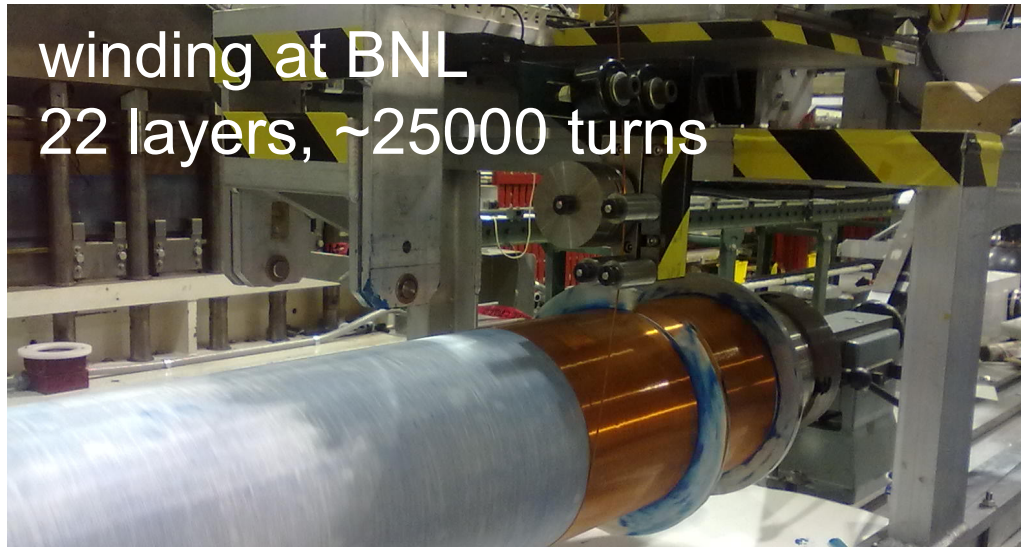
1st solenoid tested cold:

quench no	current [A]	field [T]	location
1	340	4.64	layer 1
2	366	5.00	layer 1
3	380	5.18	layer 1
4	389	5.30	layer 1
5	408	5.56	layer 1



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

RHIC electron lenses



winding at BNL
22 layers, ~25000 turns

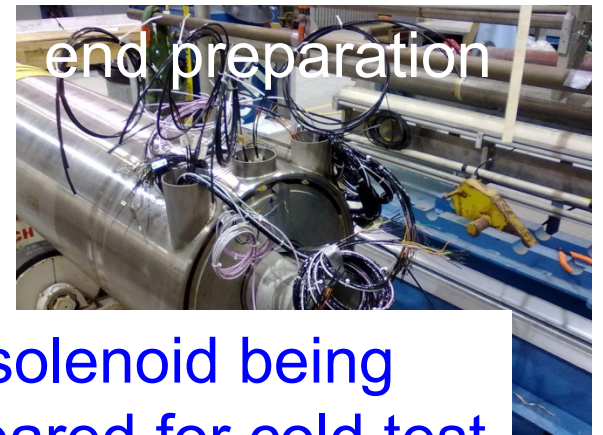
Superconducting magnets



shell with correctors

1st solenoid tested cold:

quench no	current [A]	field [T]	location
1	340	4.64	layer 1
2	366	5.00	layer 1
3	380	5.18	layer 1
4	389	5.30	layer 1
5	408	5.56	layer 1



end preparation

2nd solenoid being
prepared for cold test

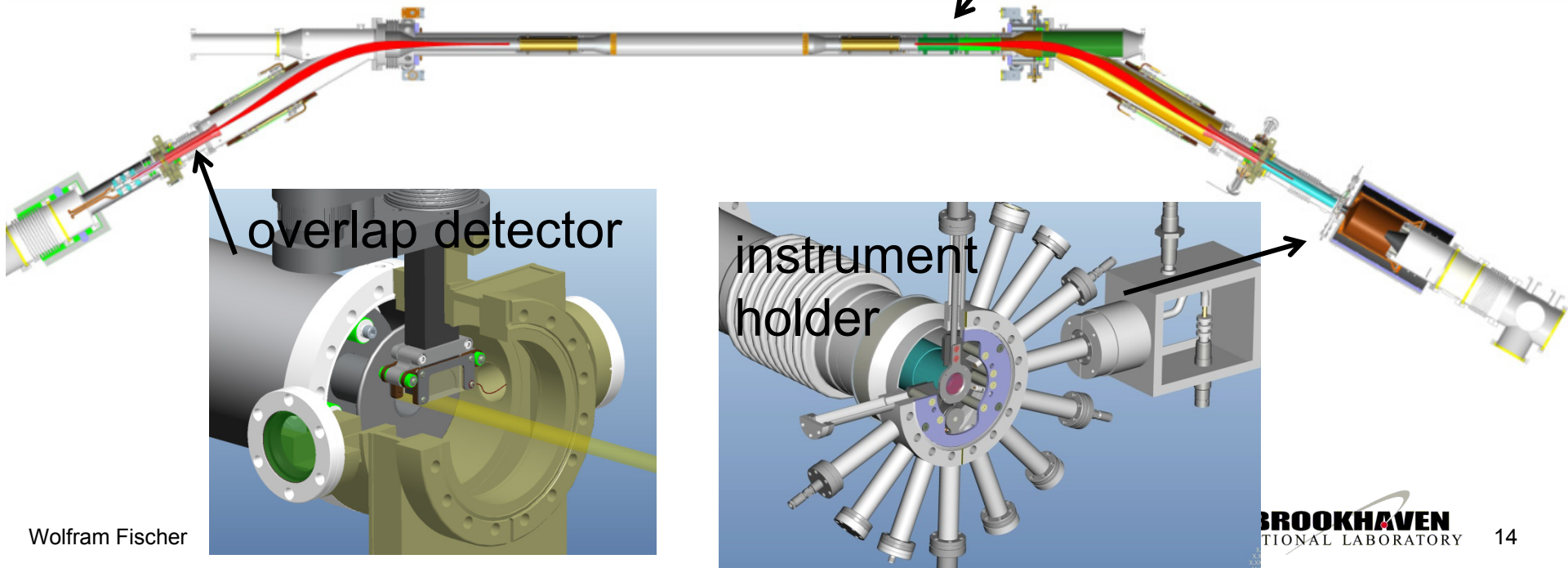
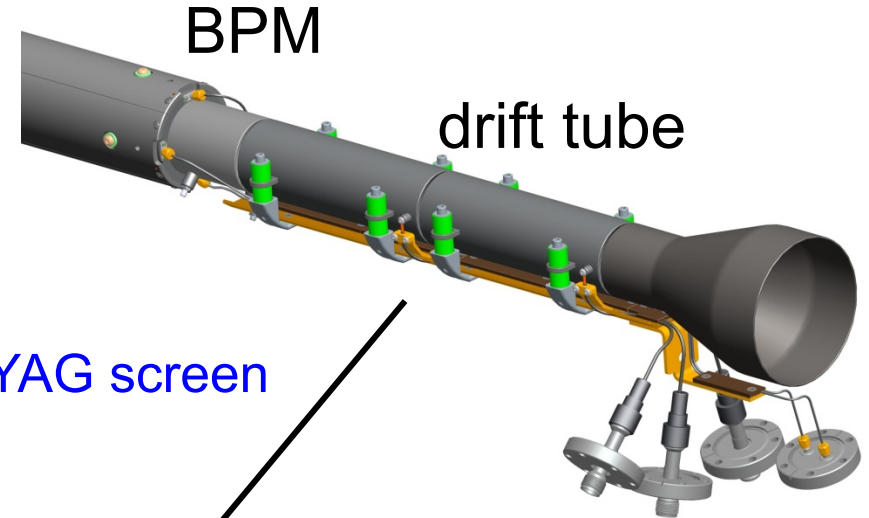
← Ground fault developed in layer 1,
decided to disable layers 1&2

RHIC electron lenses

Instrumentation

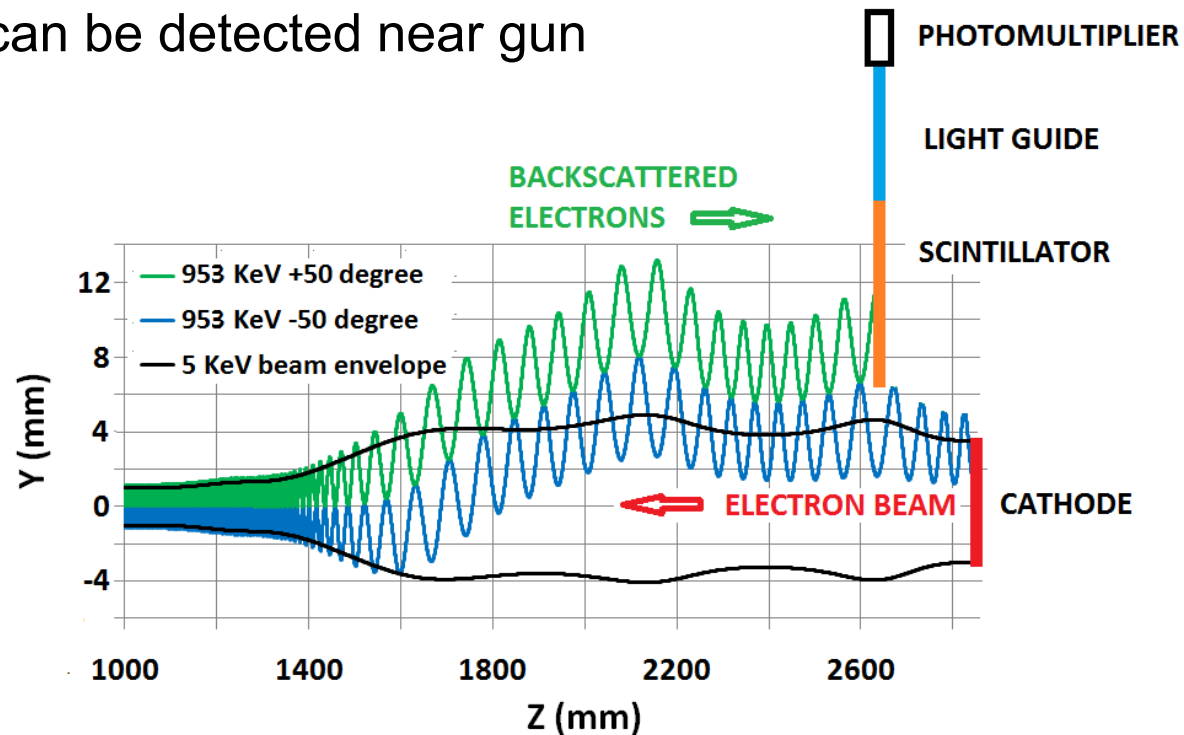
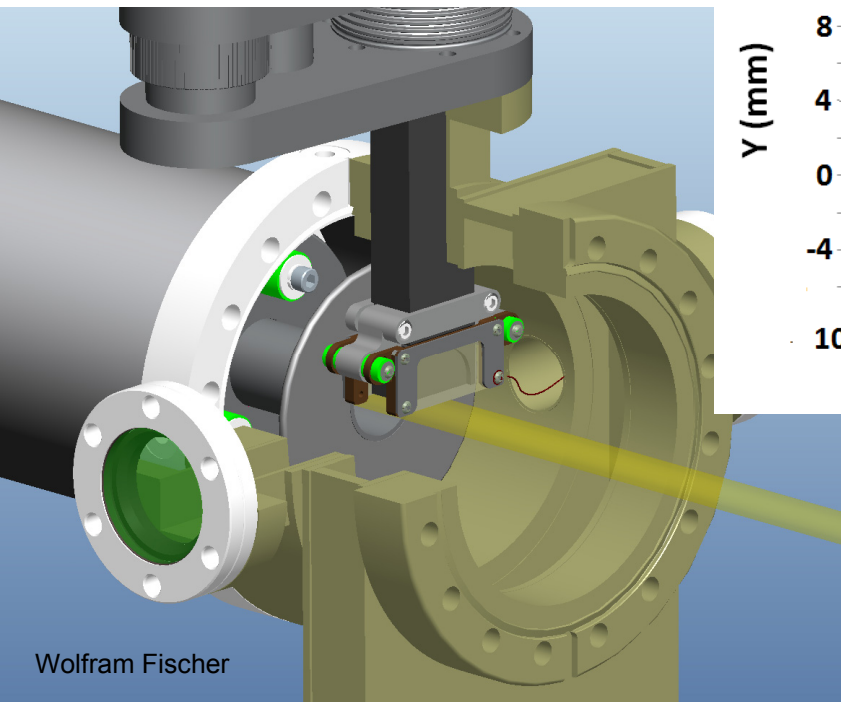
Designed for:

- 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



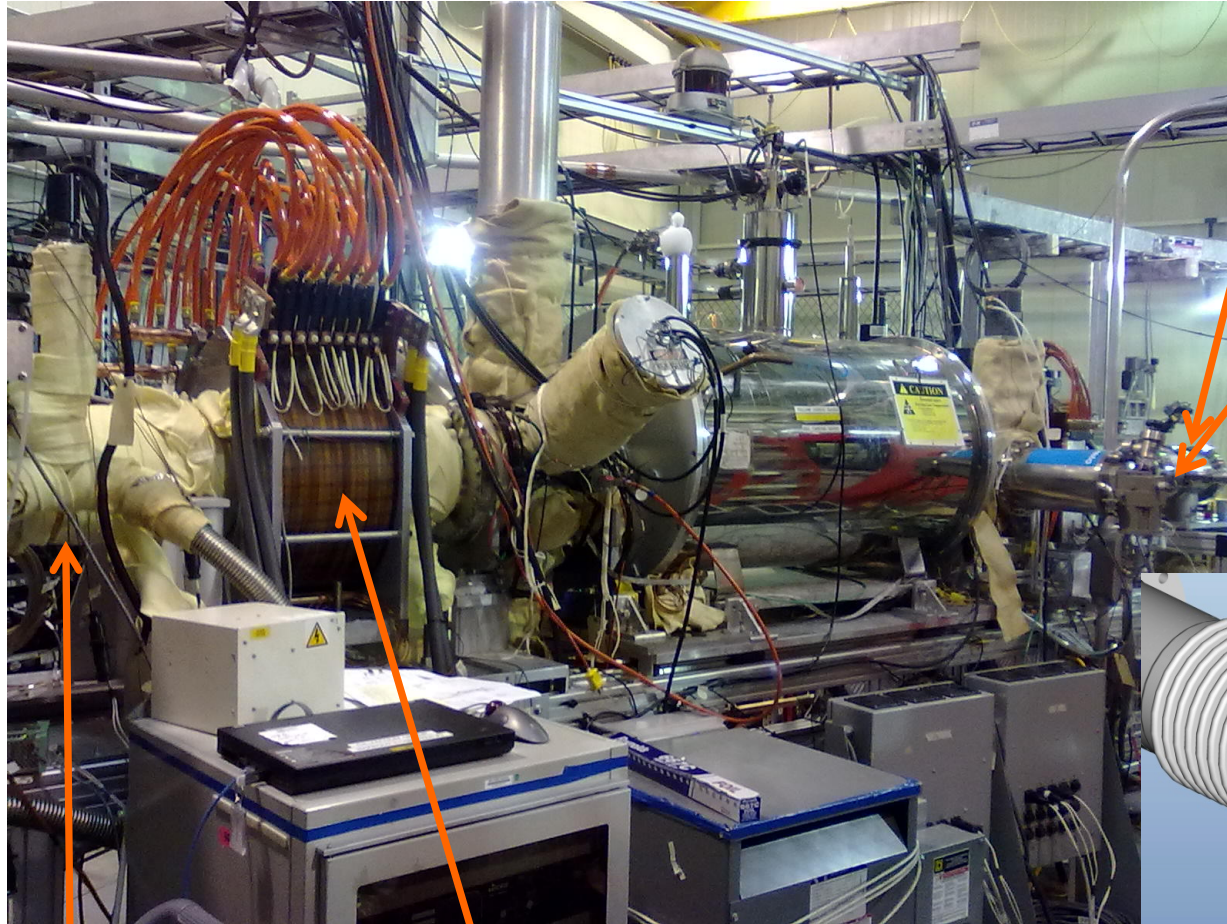
Beam overlap monitor (P. Thieberger):

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



RHIC electron lenses

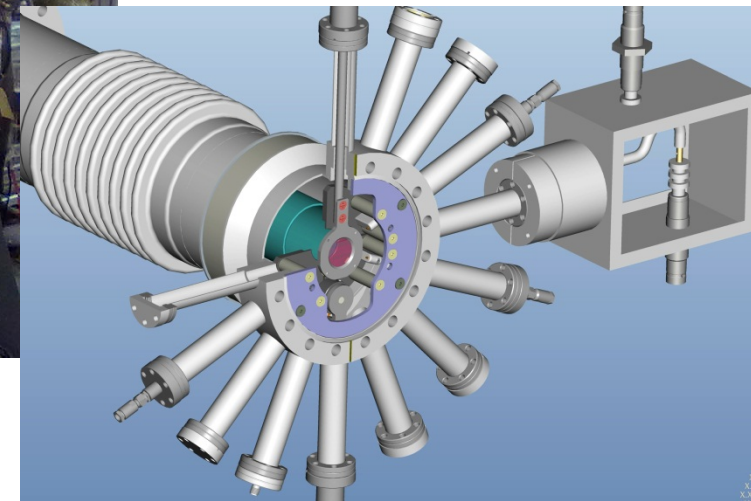
Test bench



collector

instrument holder

- pin hole detector
- YAG screen
- halo monitor



e-gun

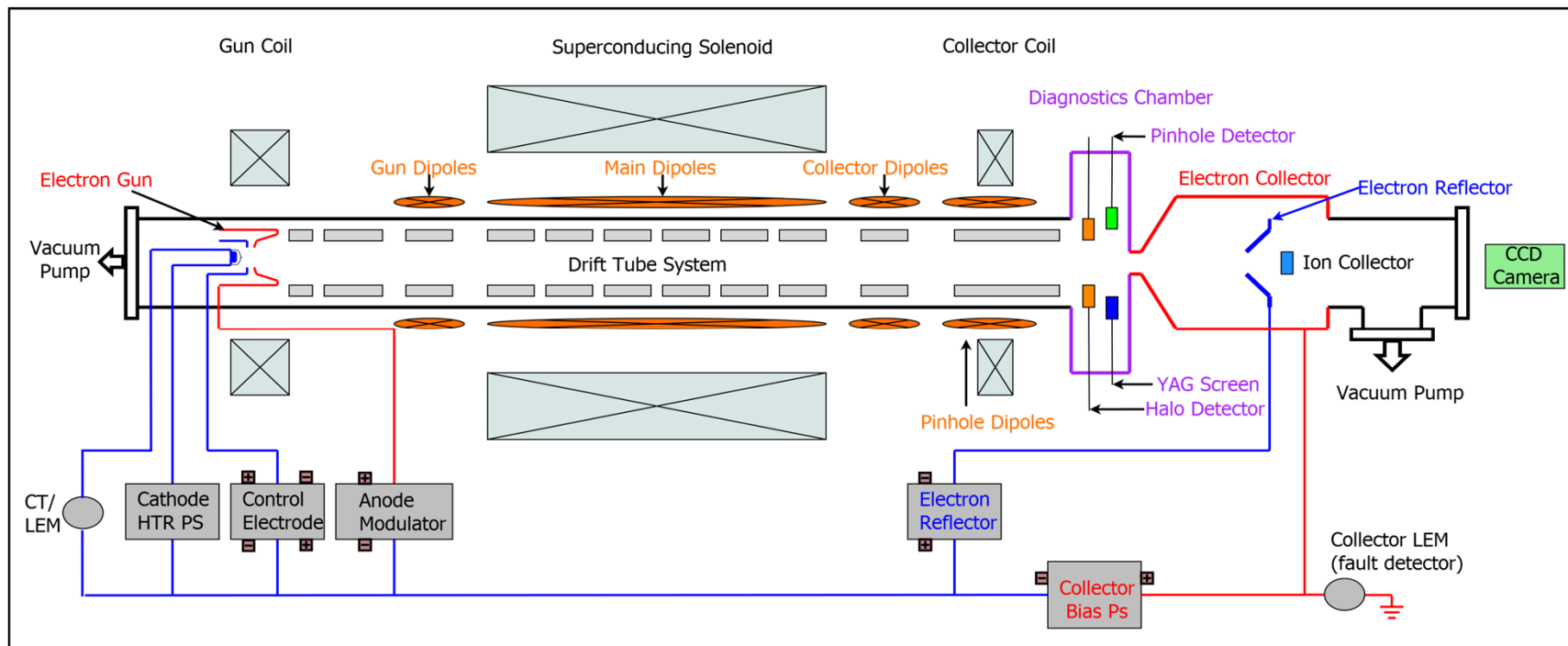
GS1 solenoid

More details: X. Gu et al., WEPP094

RHIC electron lenses

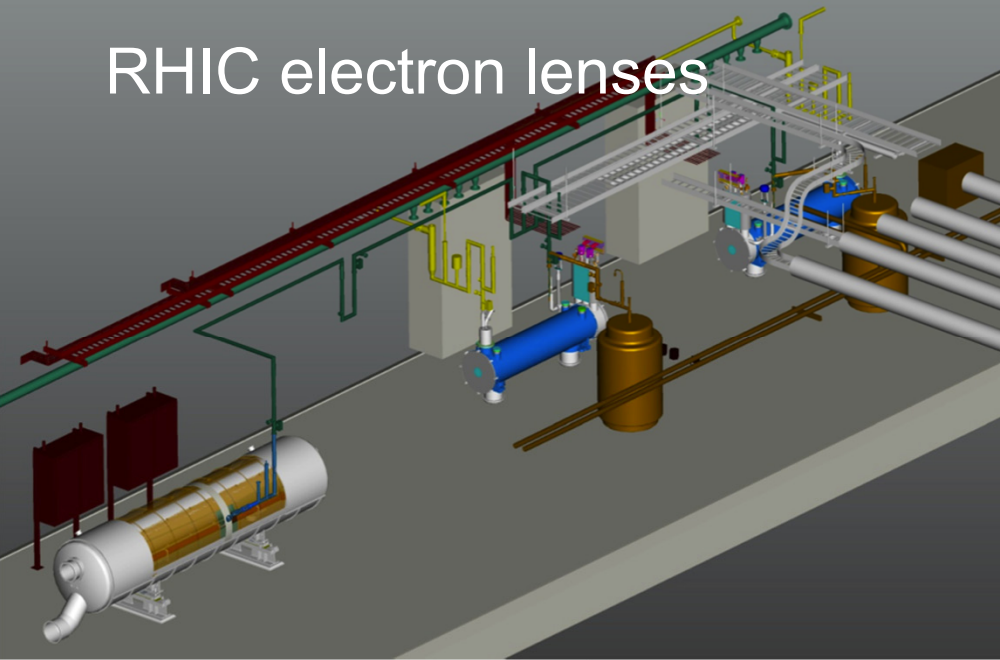
Test bench goals

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



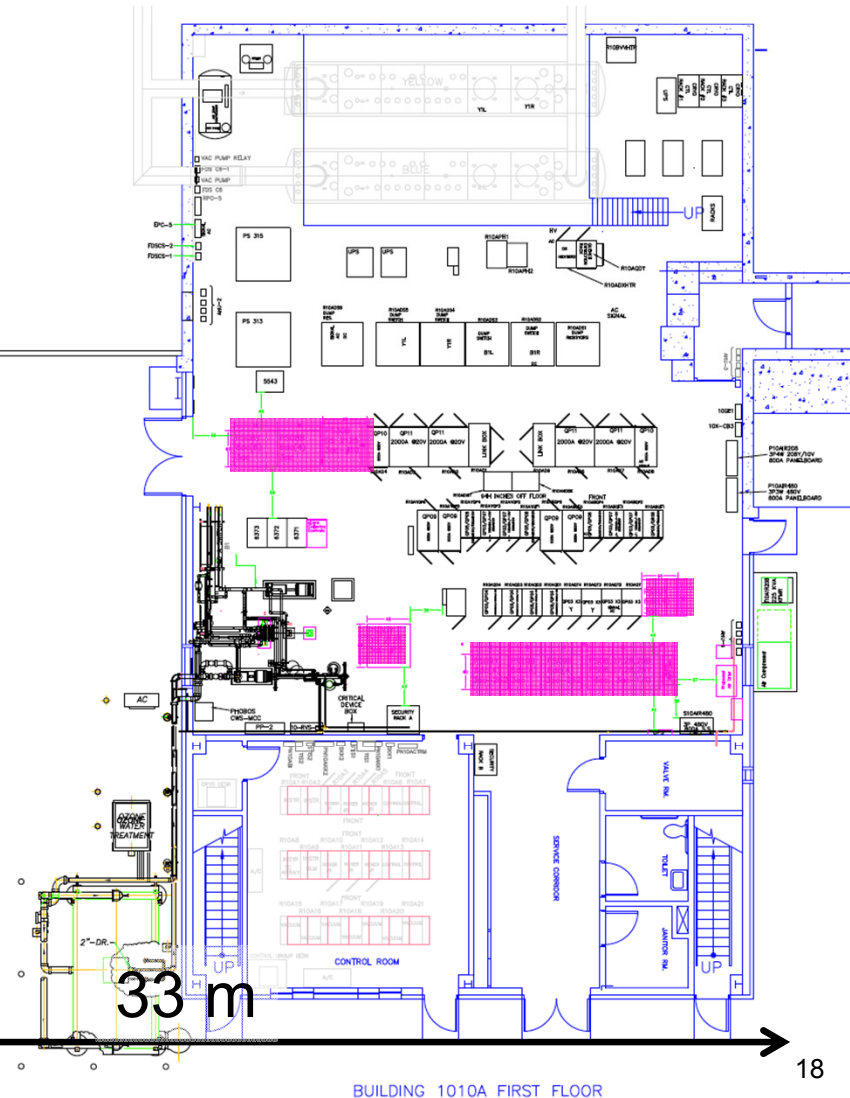
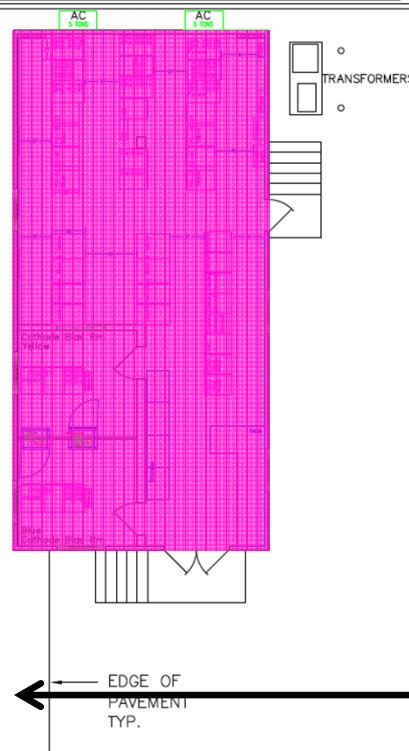
More details: X. Gu et al., WEPP044

RHIC electron lenses



Infrastructure

Racks with equipment fill trailer and part of existing service building



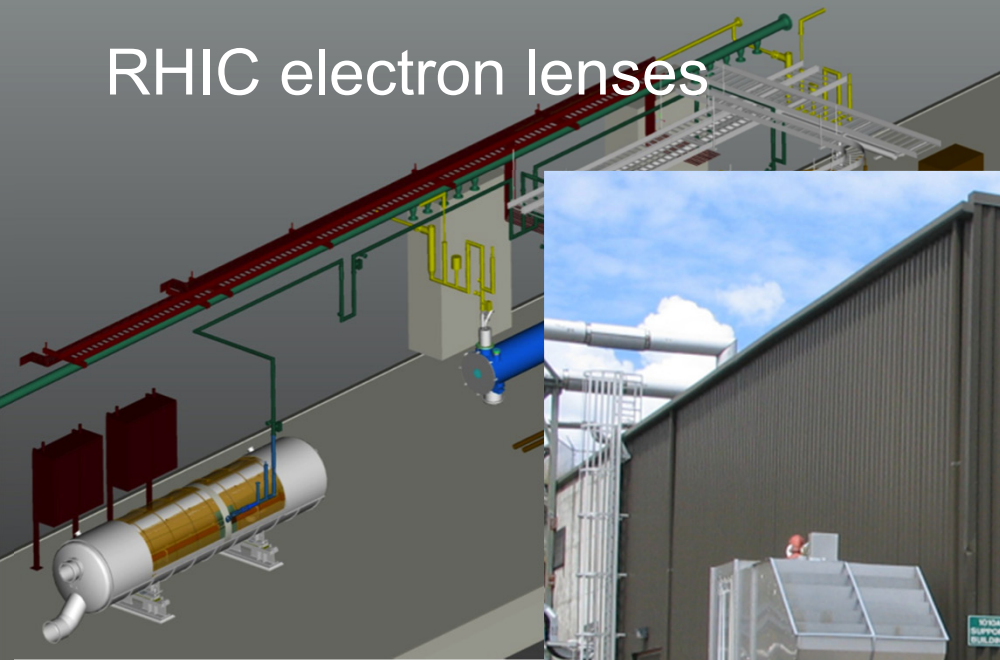
RHIC electron lenses

The image is a composite. The top portion is a detailed architectural floor plan of a building. A pink rectangular area is highlighted on the plan, corresponding to a specific section of the building. The plan includes various rooms, corridors, and structural elements, with labels such as 'PS 315', 'PS 313', '5543', 'OP11', 'OP12', 'OP13', 'OP14', 'OP15', 'OP16', 'OP17', 'OP18', 'OP19', 'OP20', 'OP21', 'OP22', 'OP23', 'OP24', 'OP25', 'OP26', 'OP27', 'OP28', 'OP29', 'OP30', 'OP31', 'OP32', 'OP33', 'OP34', 'OP35', 'OP36', 'OP37', 'OP38', 'OP39', 'OP40', 'OP41', 'OP42', 'OP43', 'OP44', 'OP45', 'OP46', 'OP47', 'OP48', 'OP49', 'OP50', 'OP51', 'OP52', 'OP53', 'OP54', 'OP55', 'OP56', 'OP57', 'OP58', 'OP59', 'OP60', 'OP61', 'OP62', 'OP63', 'OP64', 'OP65', 'OP66', 'OP67', 'OP68', 'OP69', 'OP70', 'OP71', 'OP72', 'OP73', 'OP74', 'OP75', 'OP76', 'OP77', 'OP78', 'OP79', 'OP80', 'OP81', 'OP82', 'OP83', 'OP84', 'OP85', 'OP86', 'OP87', 'OP88', 'OP89', 'OP90', 'OP91', 'OP92', 'OP93', 'OP94', 'OP95', 'OP96', 'OP97', 'OP98', 'OP99', 'OP100'. The bottom portion is a photograph of a building exterior, showing a large, open structure with a metal roof and a concrete floor. A large '33 m' label is overlaid on the photograph, indicating the length of the building. The photograph shows a building with a metal roof and a concrete floor, with a large '33 m' label overlaid on the image.

33 m

33 m

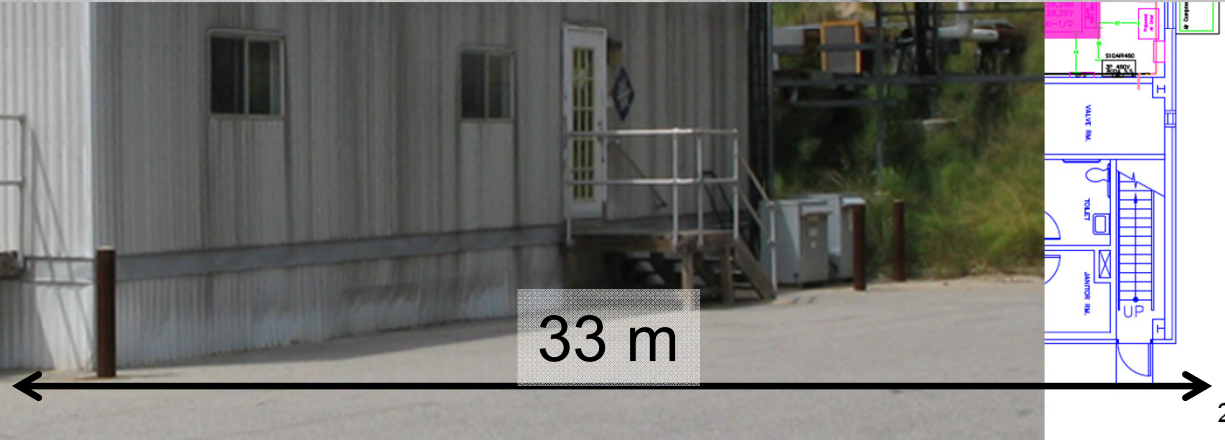
RHIC electron lenses



Infrastructure



Racks with equipment



- 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