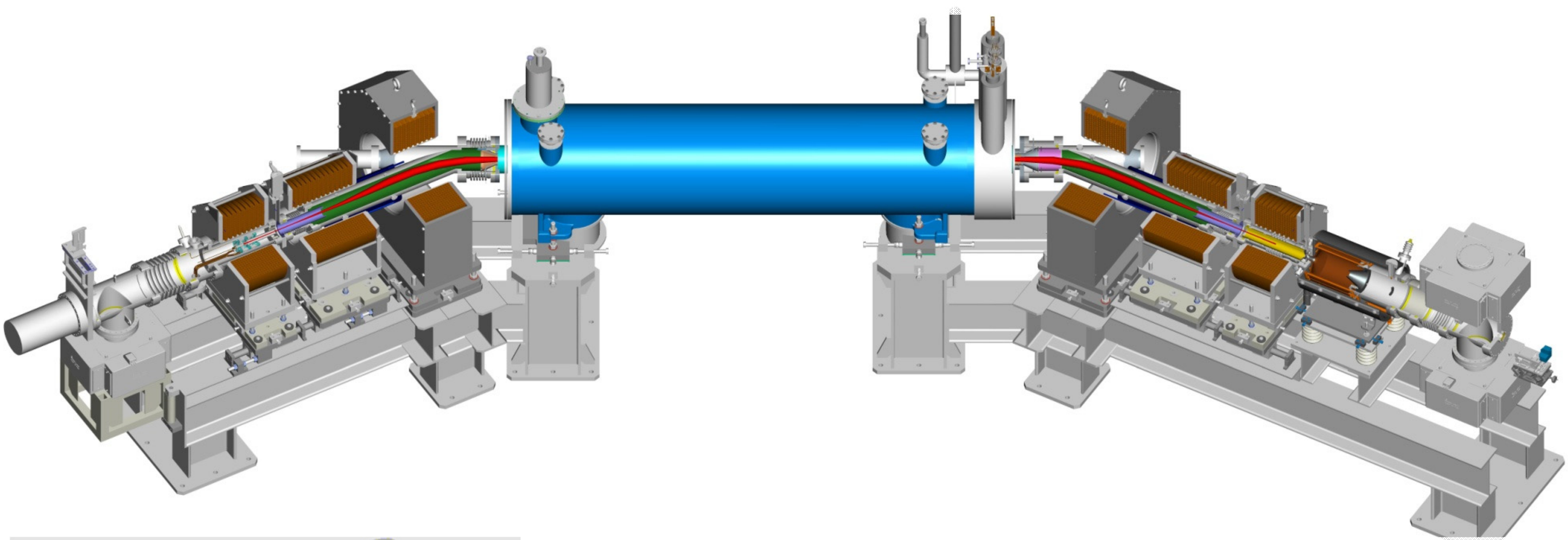
Construction progress of the RHIC electron lenses

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



BROOKHAVEN NATIONAL LABORATORY

23 May 2012
IPAC 2012,
New Orleans, Louisiana

Outline

1. Motivation: Head-on beam-beam effect in RHIC

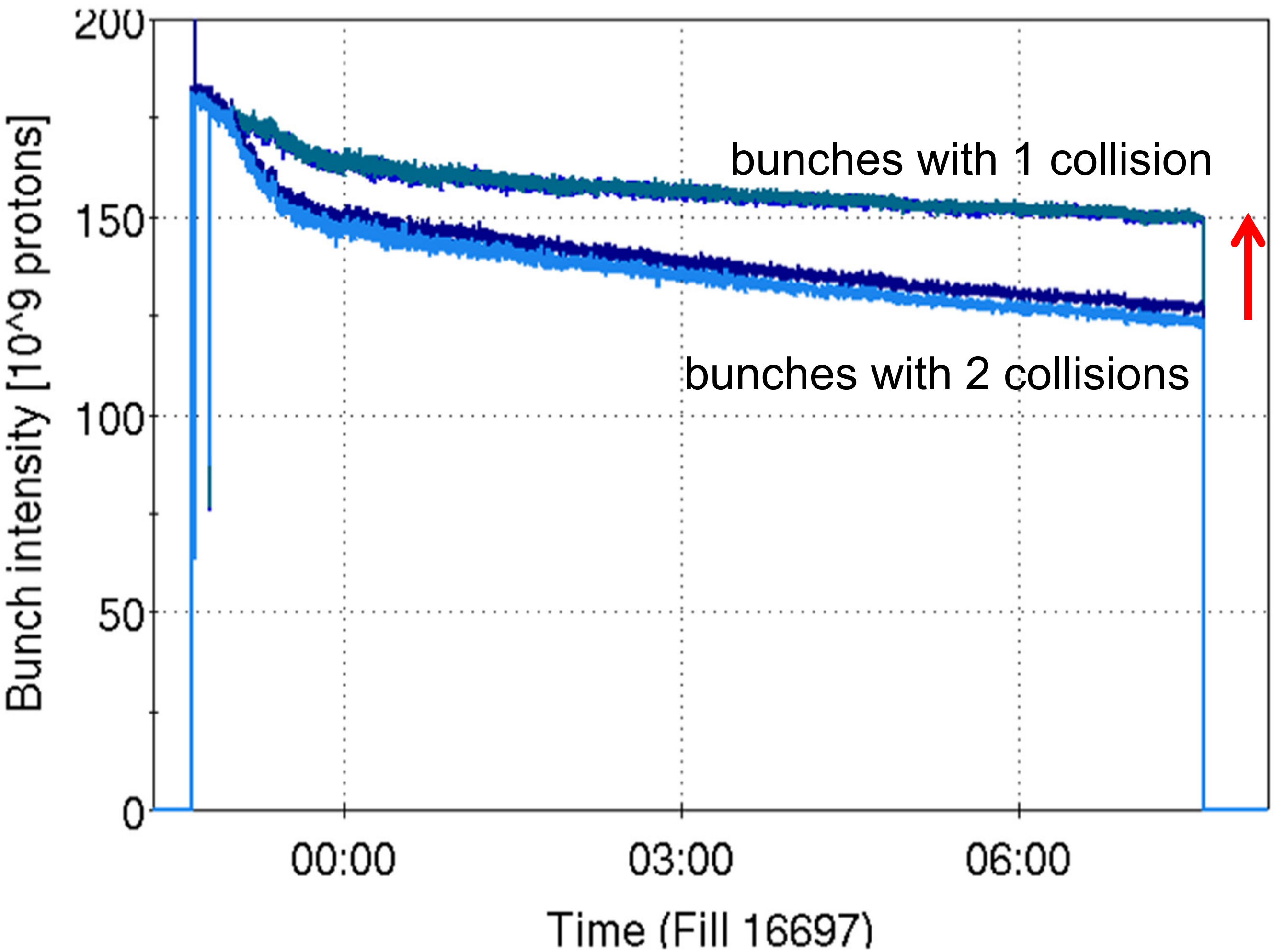
2. Compensation overview

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

4. Test bench

Motivation

Bunch intensity in 2012 polarized proton physics store



Goal:

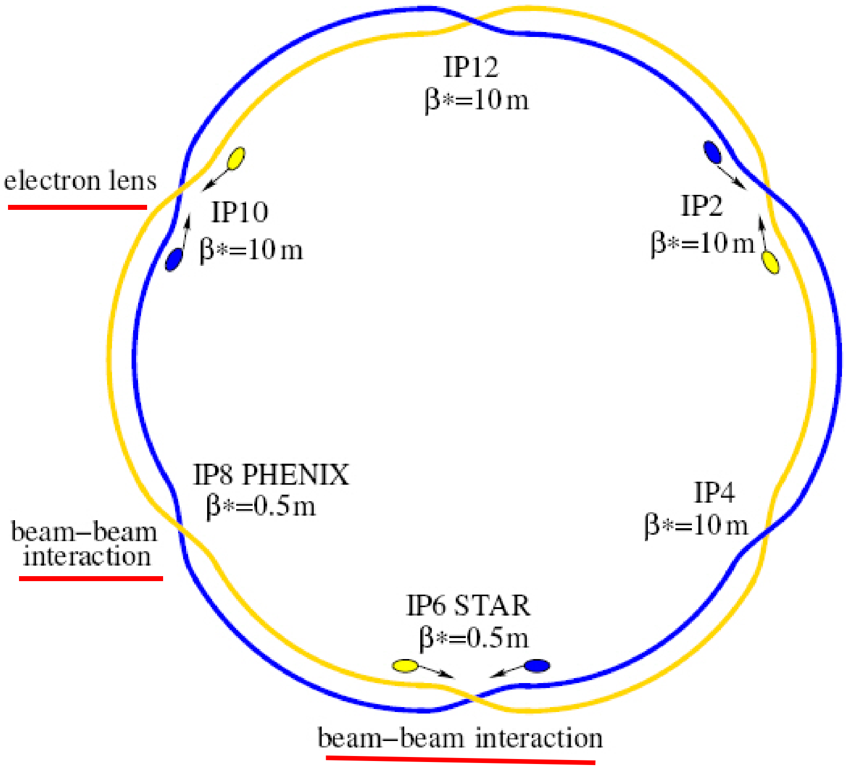
Compensate for 1 of 2 beam-beam interactions with electron lenses

Then increase bunch intensity
⇒up to 2 × luminosity

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

$$L \propto N_b^2$$

Partial head-on beam-beam compensation overview

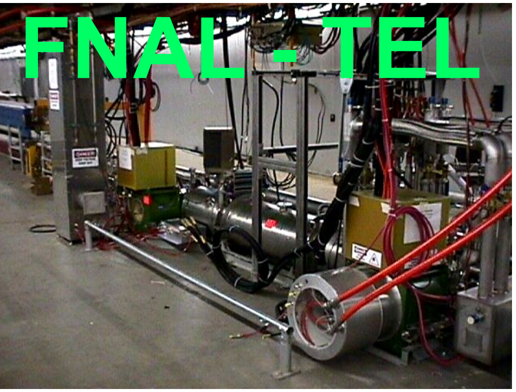


Basic idea:

- 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:

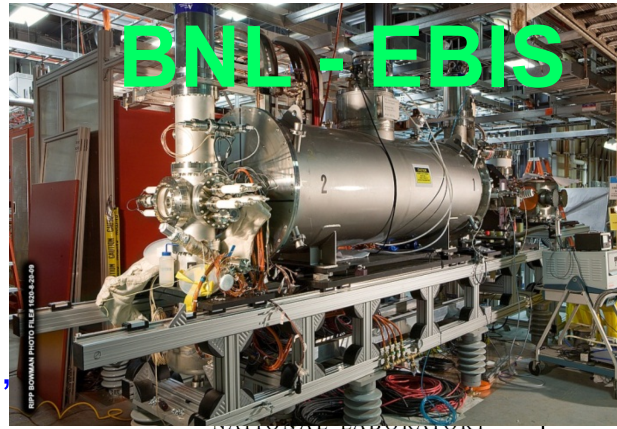
- e-beam current and shape
  => reduces tune spread
- $\Delta\psi_{x,y}$ = $k\pi$ between p-p and p-e collision
  => reduces resonance driving terms



Built on experience with

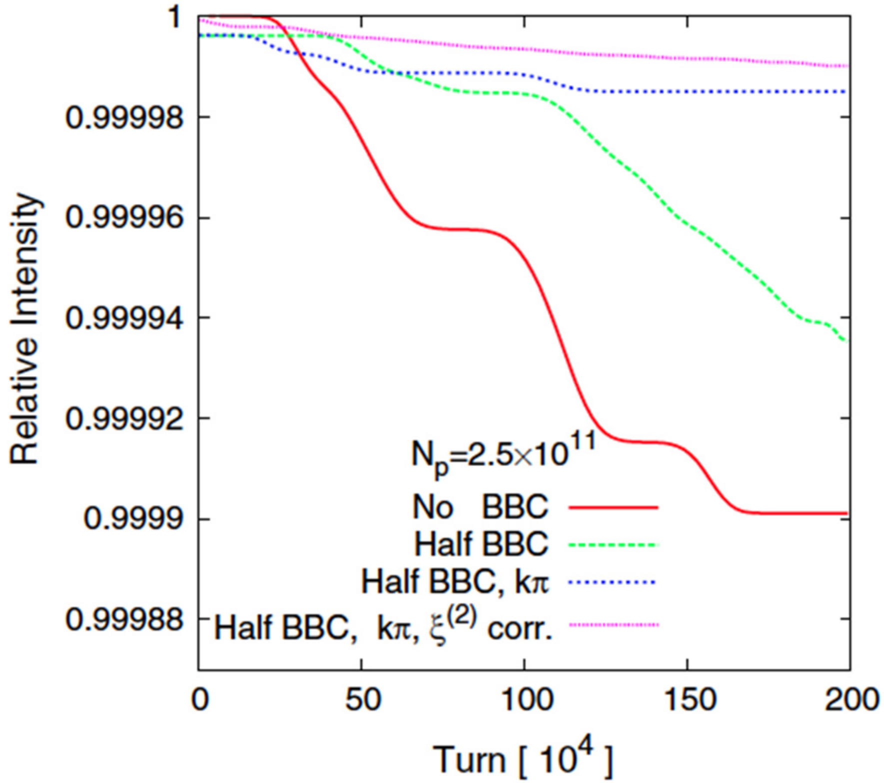
Tevatron electron lenses
V. Shiltsev, A. Burov, A. Valishev, G. Stancari, X.-L. Zhang, …

BNL Electron Beam Ion Source (EBIS) J. Alessi, E. Beebe, M. Okamura, **A. Pikin**, D. Raparia, …

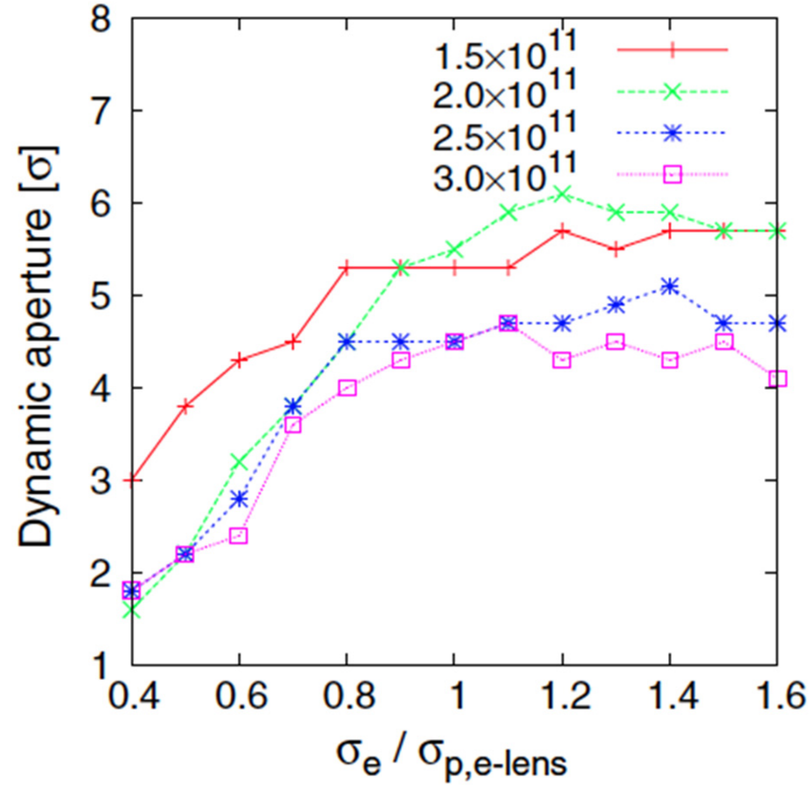


Compensation and tolerances extensively studied in simulations
Y. Luo et al. – PRST-AB 15, 051004 (2012)

Losses with and w/o BBC



Effect of e-beam size



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"

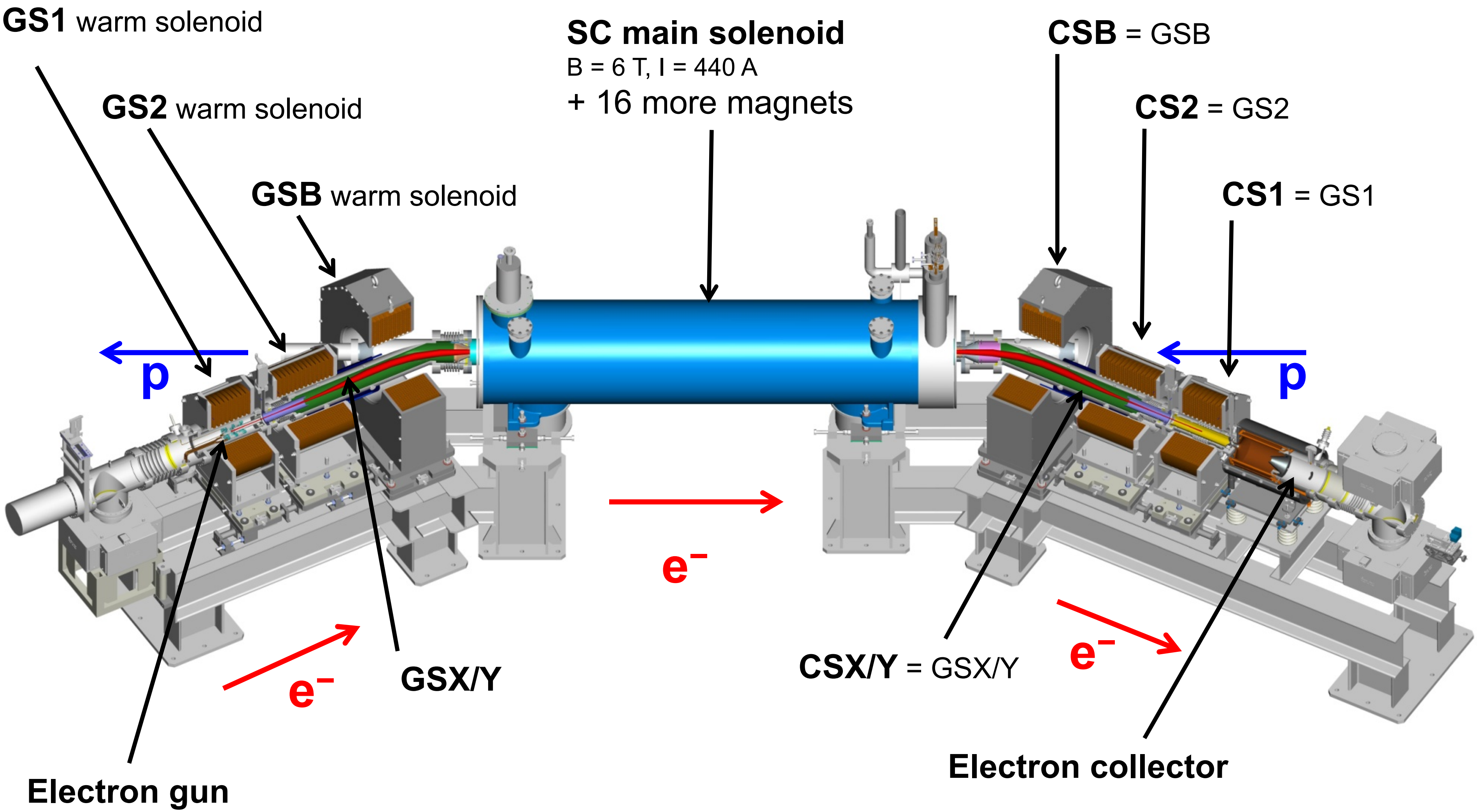
- WEOBA01: C. Montag et al.
  "Beam Experiments towards High-intensity Proton Beams in RHIC"

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

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

RHIC electron lenses

Compensation overview



RHIC electron lenses

Gun and collector (A. Pikin)

Gun

Designed for: current density, profile

3 modes:

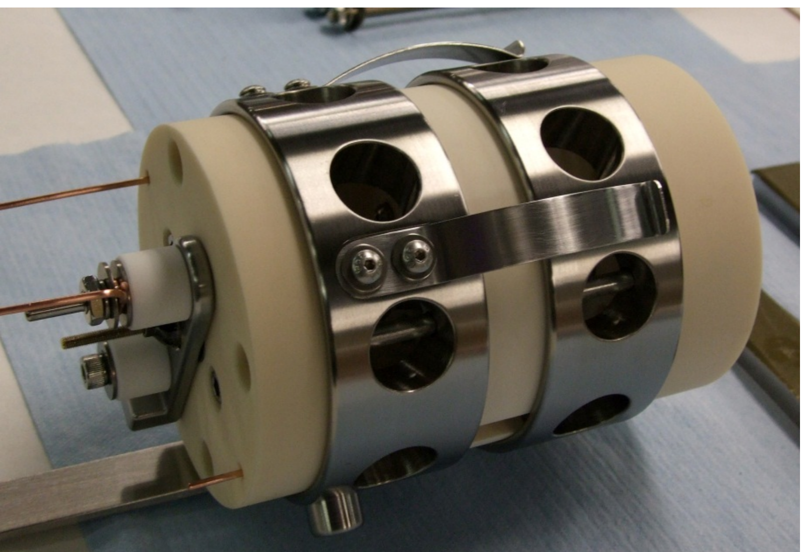
DC (full compensation)

100 Hz (positioning)

78 kHz (single bunch compensation)

V_{max} = 10 kV, I_{max} = 1 A, P = 1×10^{-6} $AV^{-3/2}$

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

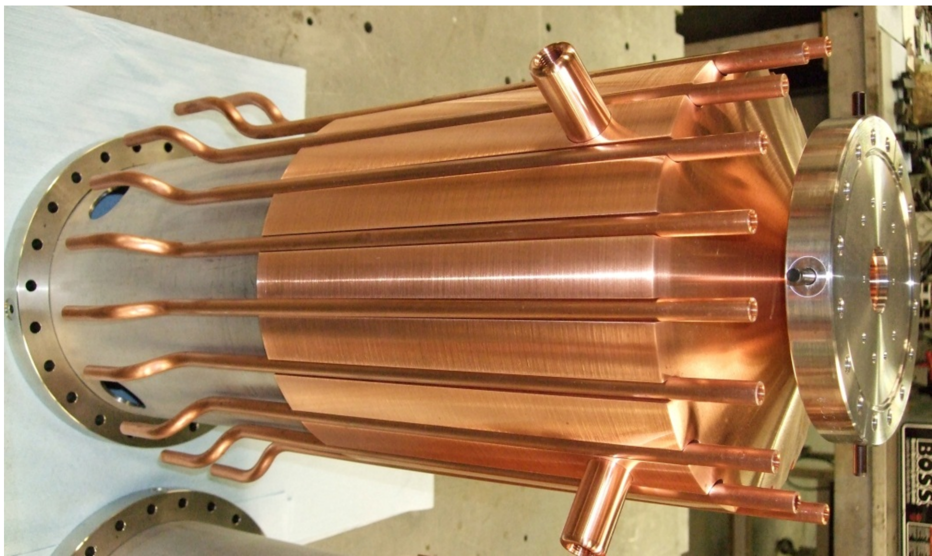


Collector

Designed for: Reliability

Water cooled,
can take 5x nominal load

ρ_P < 50 W/cm^2, T < 125° C



Warm magnets (A. Pikin, X. Gu)

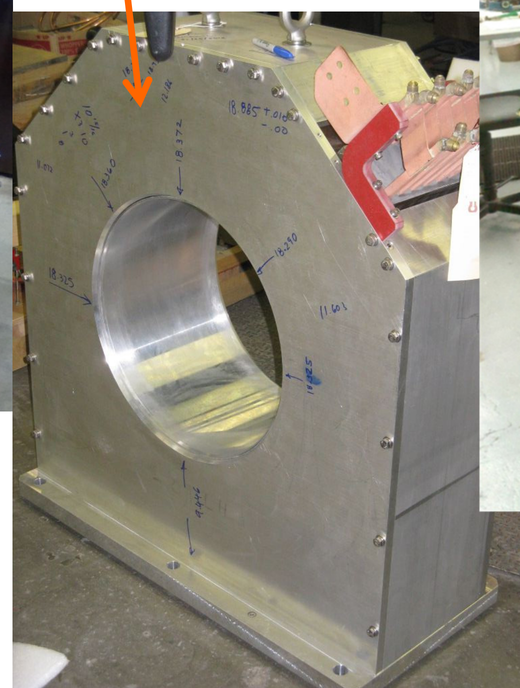
4 types: GS1, GS2, GSB, GSX/Y

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

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

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



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)

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

Maximize overlap of p- and e-beams

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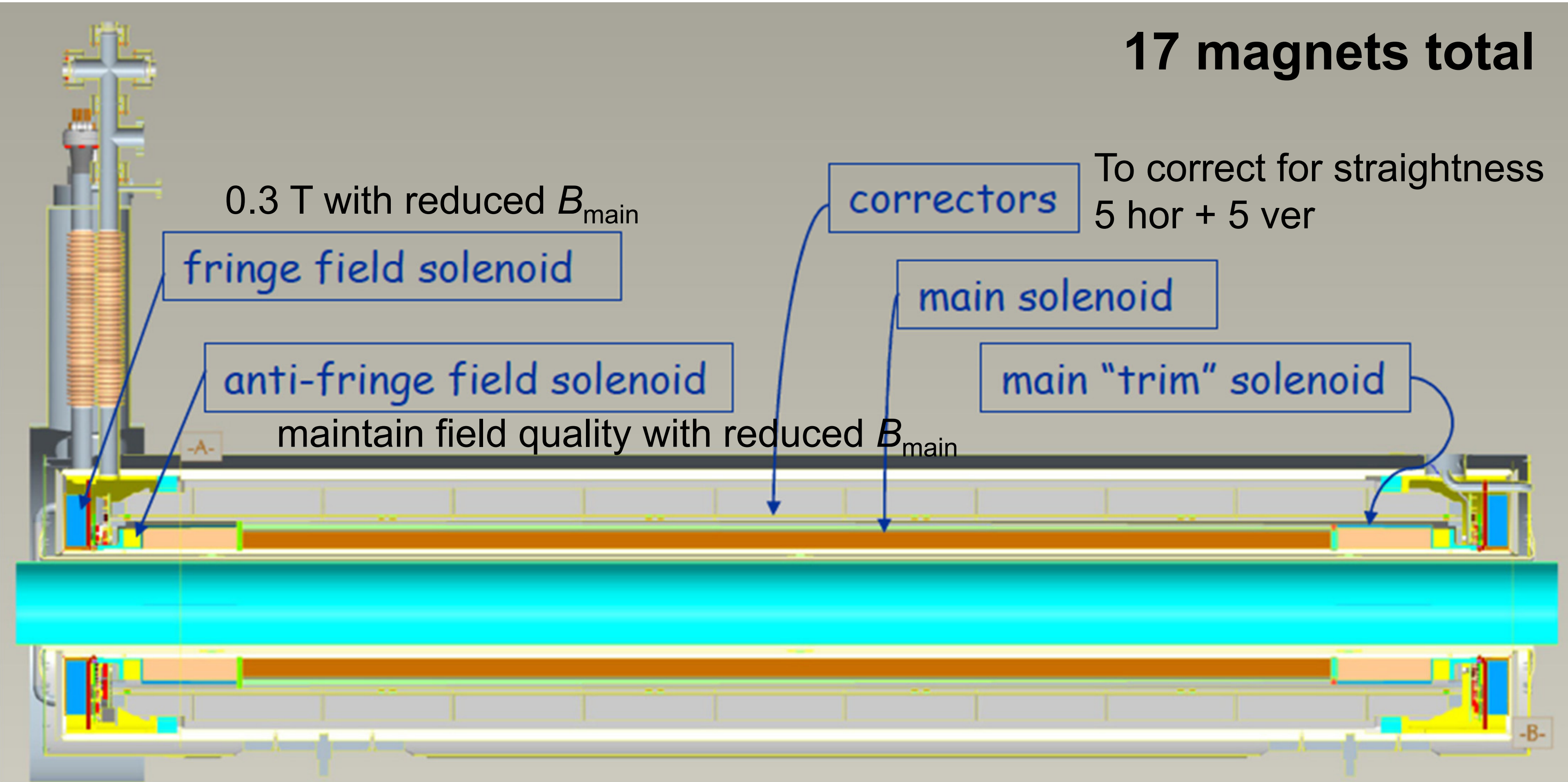
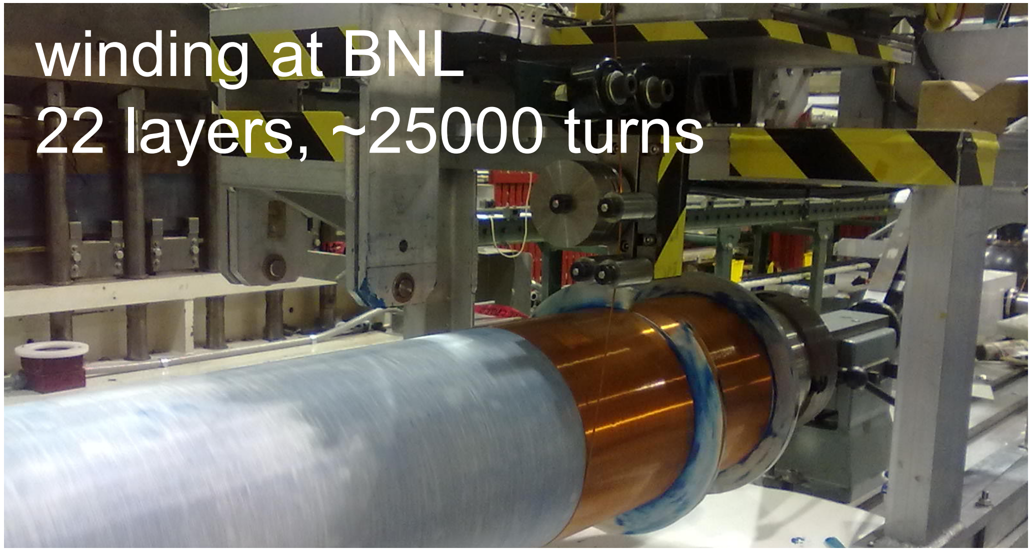
17 magnets total



RHIC electron lenses **Superconducting magnets**



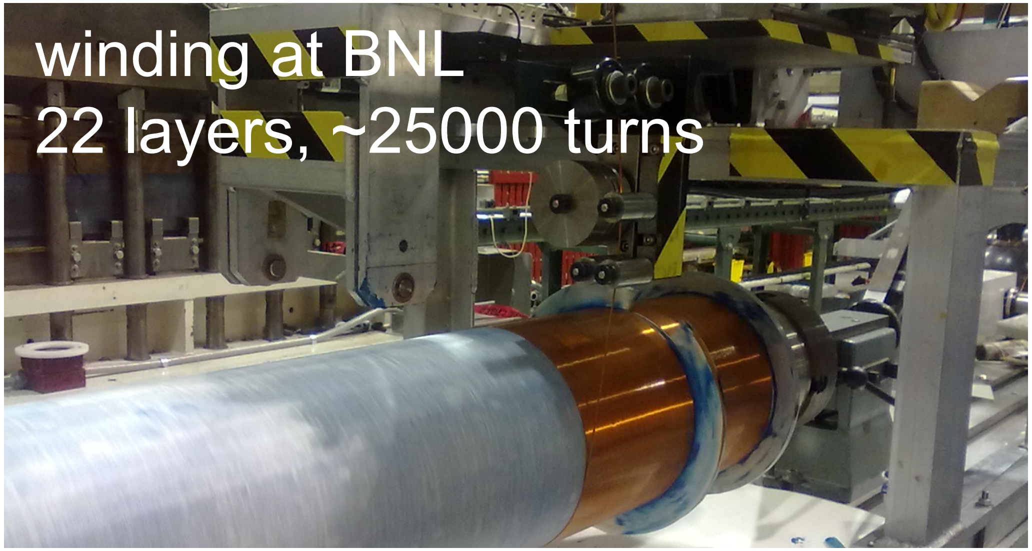
1^{st} solenoid tested cold:

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

Wolfram Fischer

RHIC electron lenses — **Superconducting magnets**



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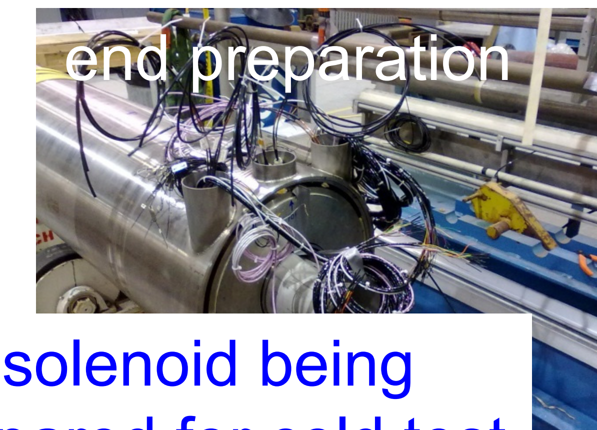
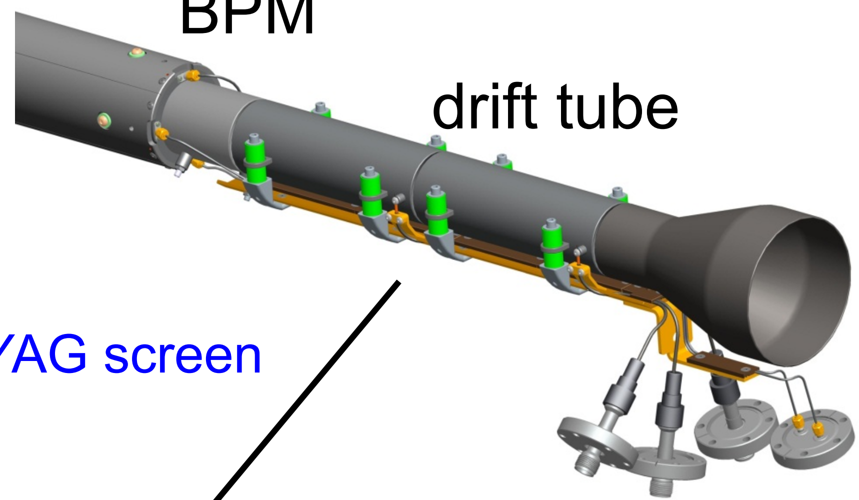


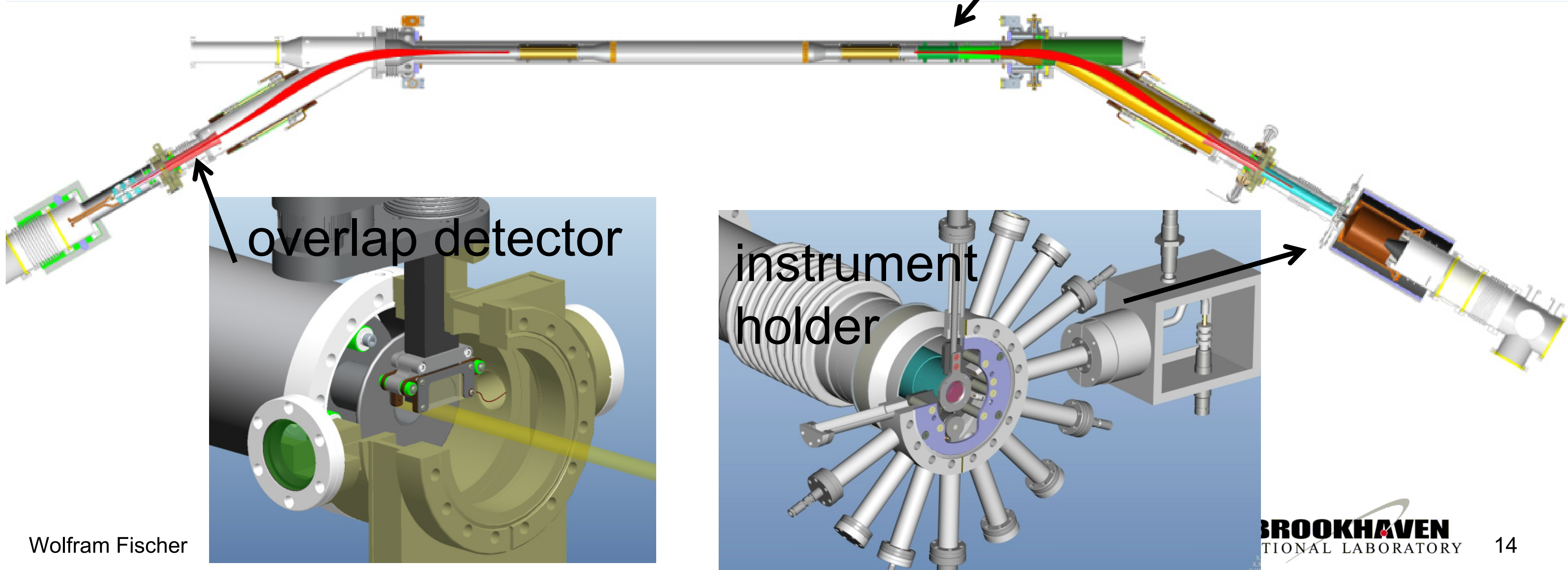
2nd solenoid being prepared for cold test

Instrumentation

Designed for:

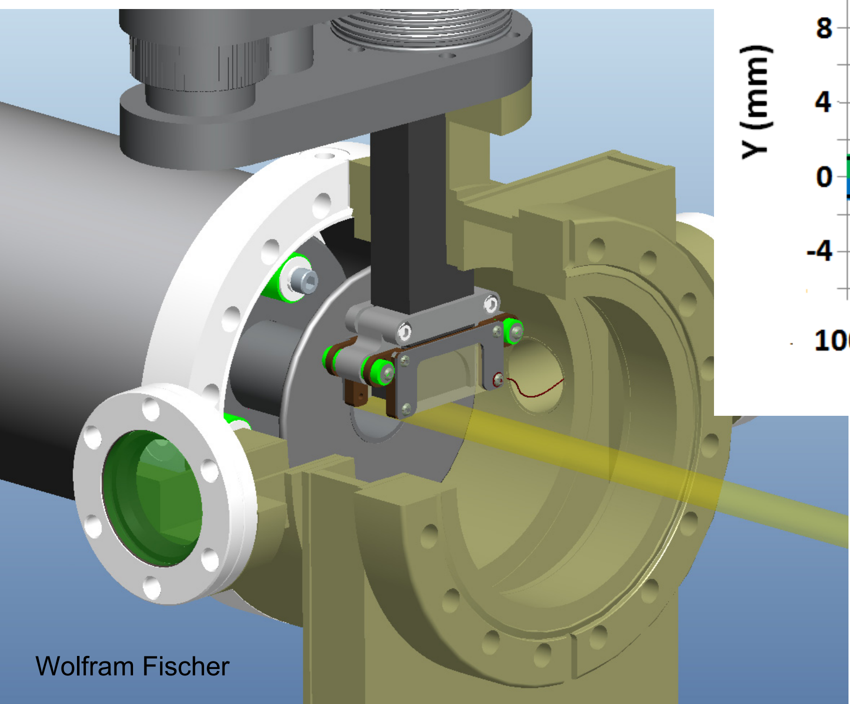
- e-beam position
- e-current and losses halo monitor
- Drift tubes
  ion extraction with DC e-beam
- e-beam profiles pin-hole detector, YAG screen
- Overlap of p- and e-beam

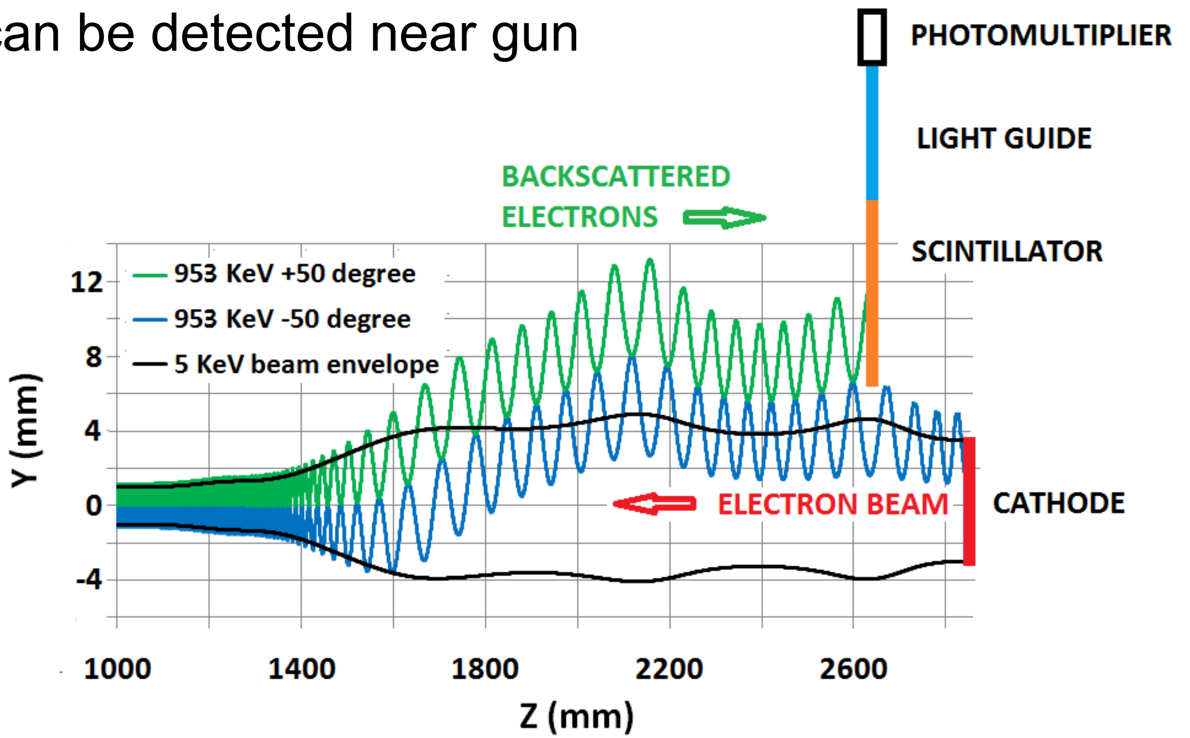




Beam overlap monitor (P. Thieberger):

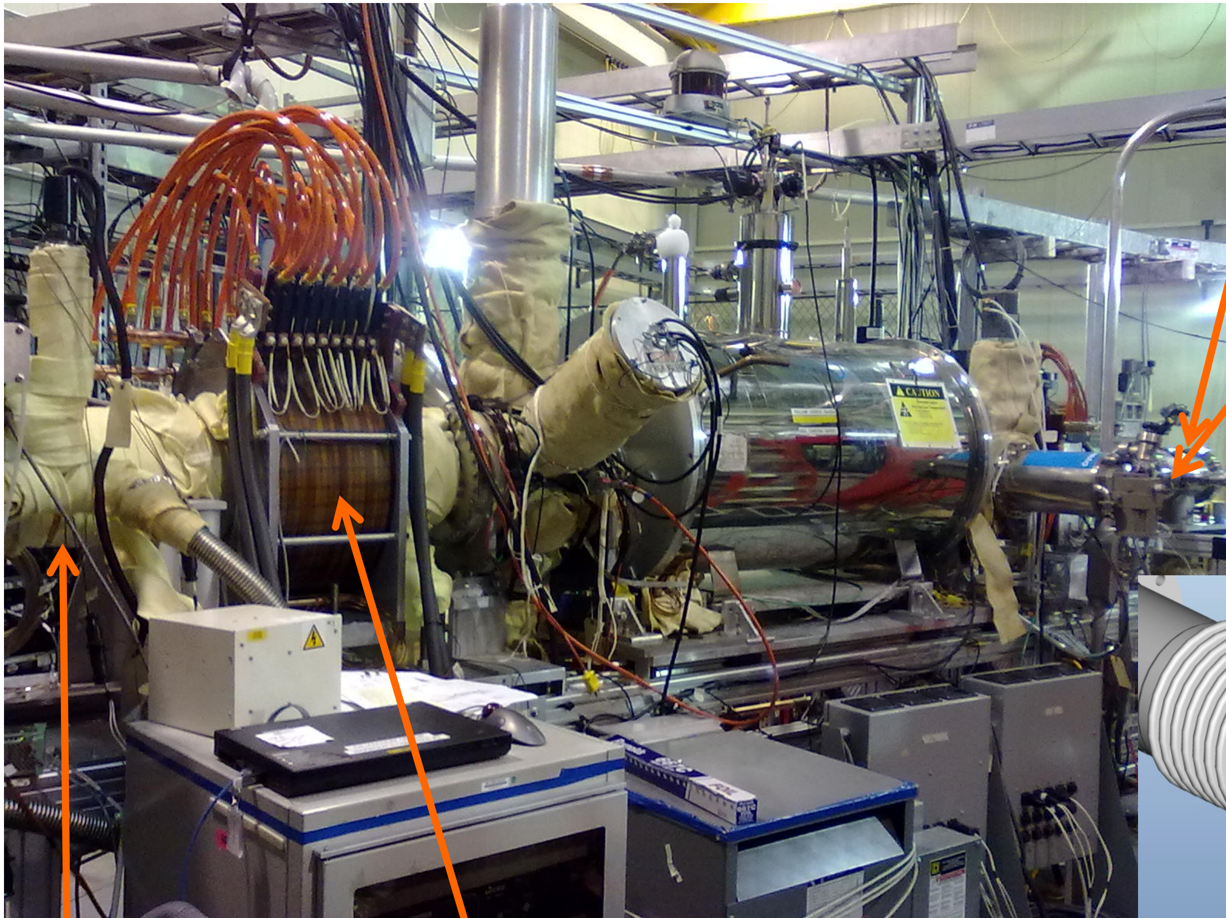
- p-e beam interaction creates bremsstrahlung (photons) and backscattered electrons
- Backscattered electrons can be detected near gun (above e-beam)





RHIC electron lenses

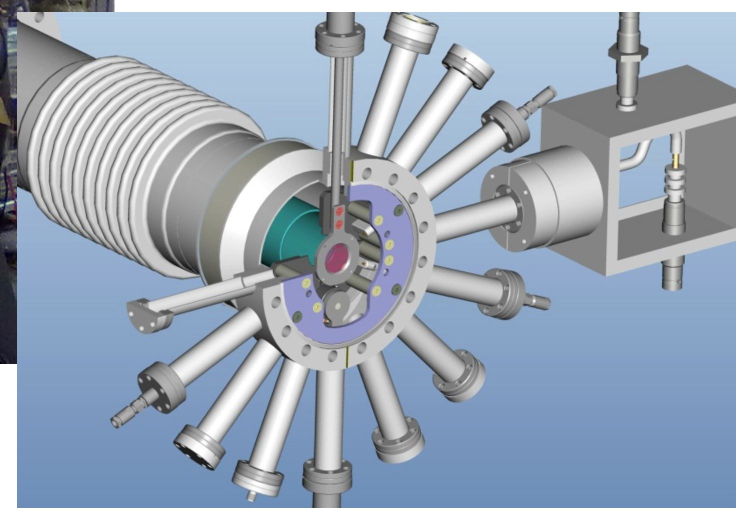
Test bench



collector

instrument holder

- pin hole detector
- YAG screen
- halo monitor



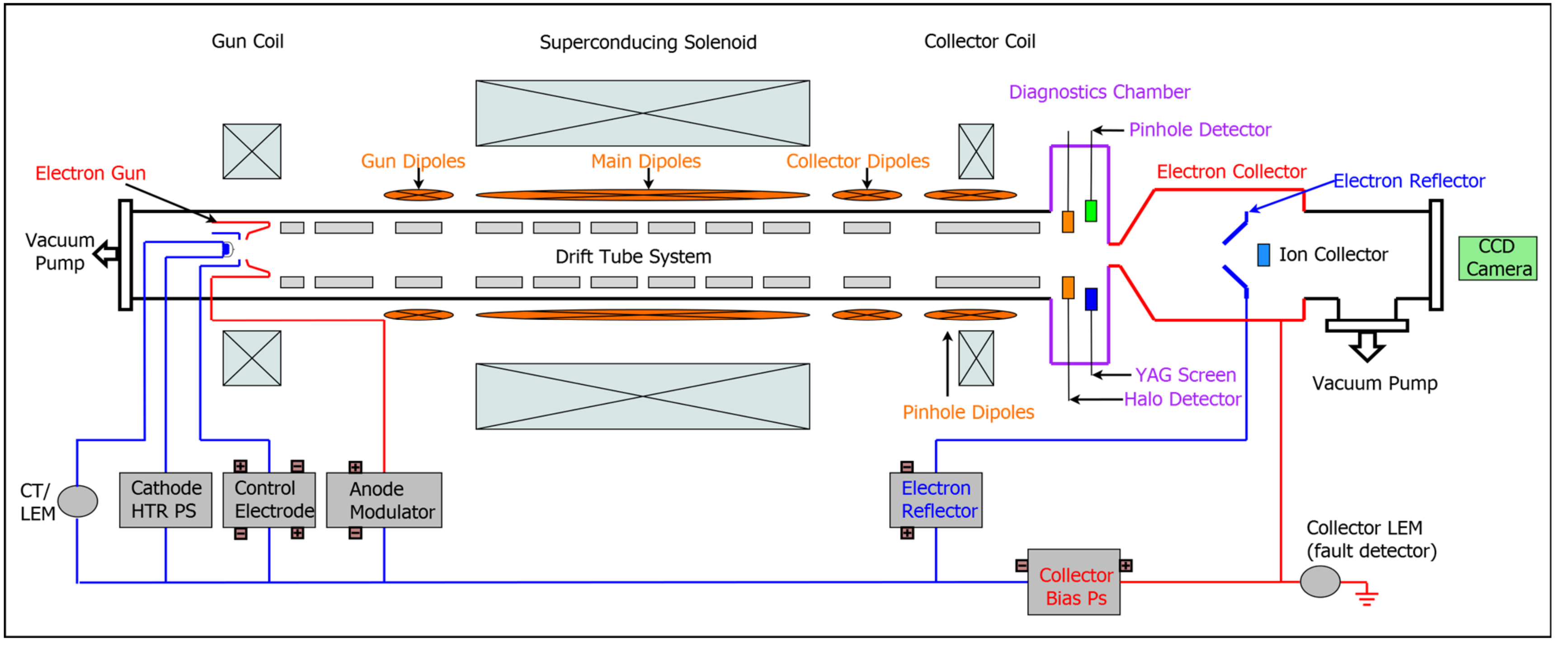
e-gun

GS1 solenoid

More details: X. Gu et al., WEPP094

Test bench goals

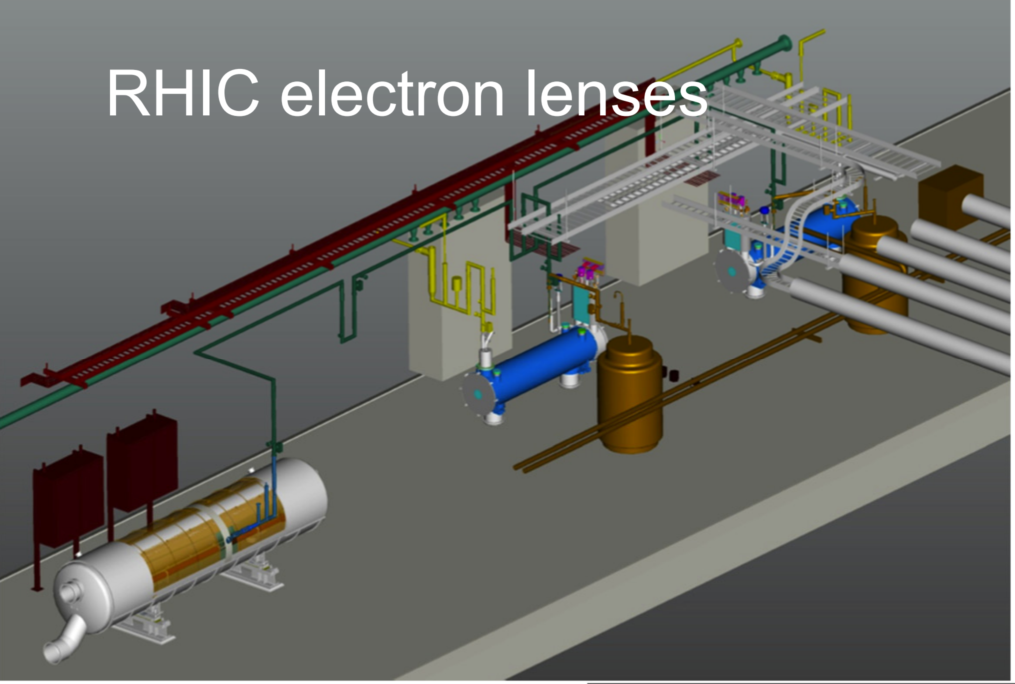
1. Measure gun perveance (I vs. U)
2. Verify transverse Gaussian profile
3. Gun operation in all modes (100 Hz, 78 kHz, DC)
4. Measure collector temperature and pressure with highest load
5. Commissioning of pin hole detector and YAG screen
6. Prototype of machine protection system
7. Test of software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



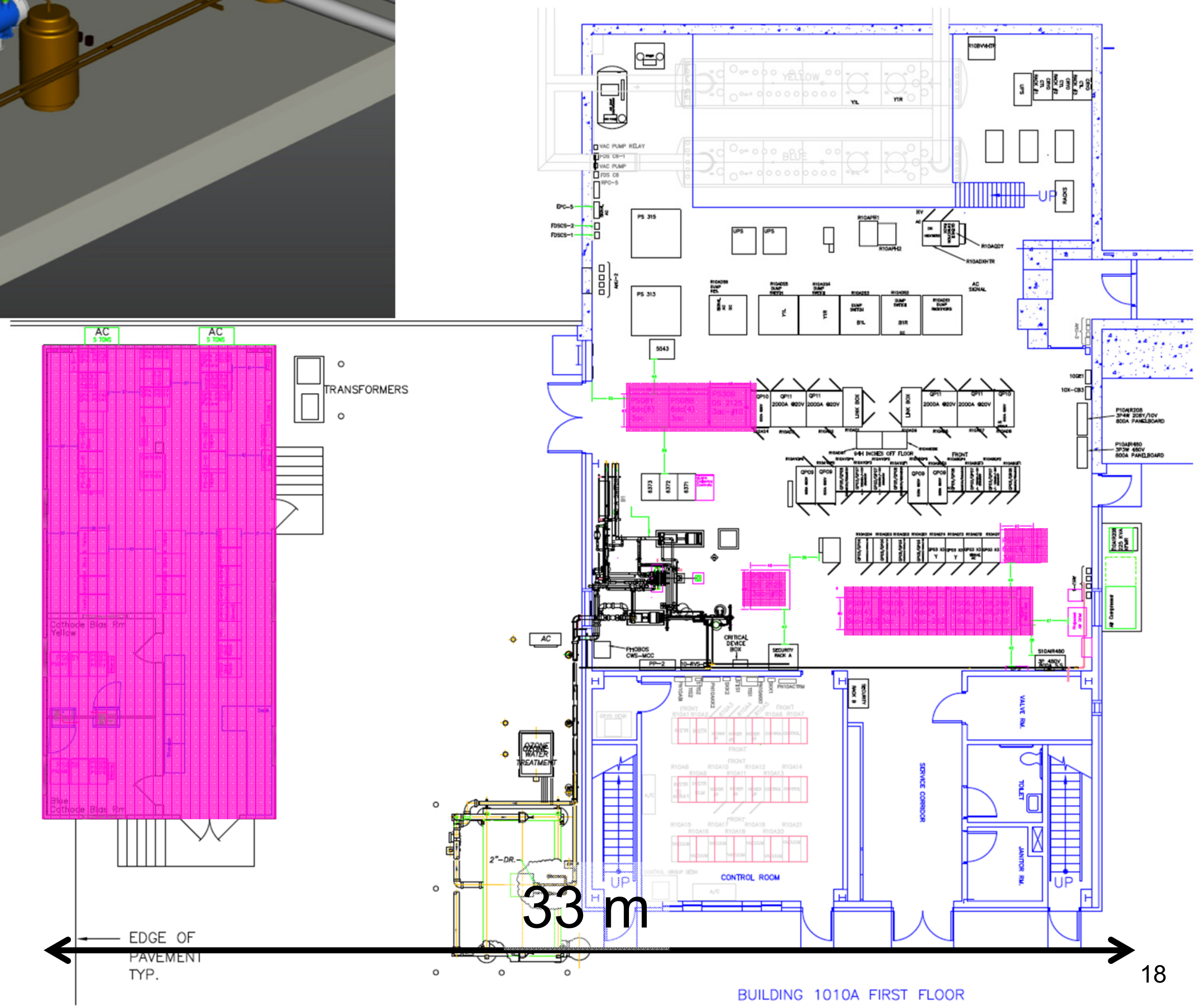
More details: X. Gu et al., WEPP044

RHIC electron lenses

Infrastructure

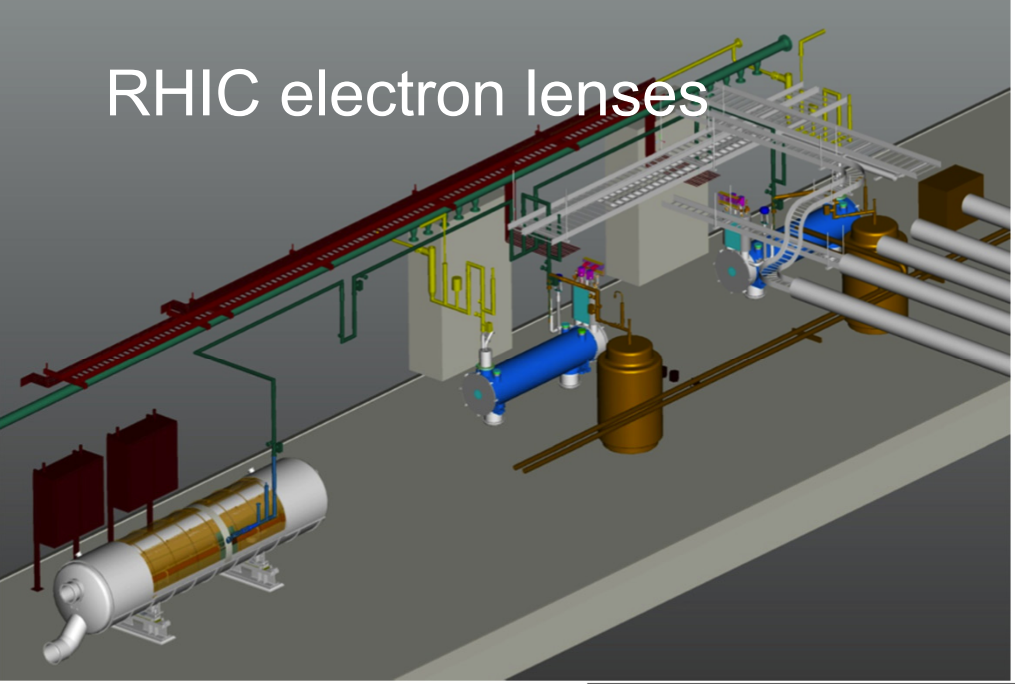


Racks with equipment fill trailer and part of existing service building

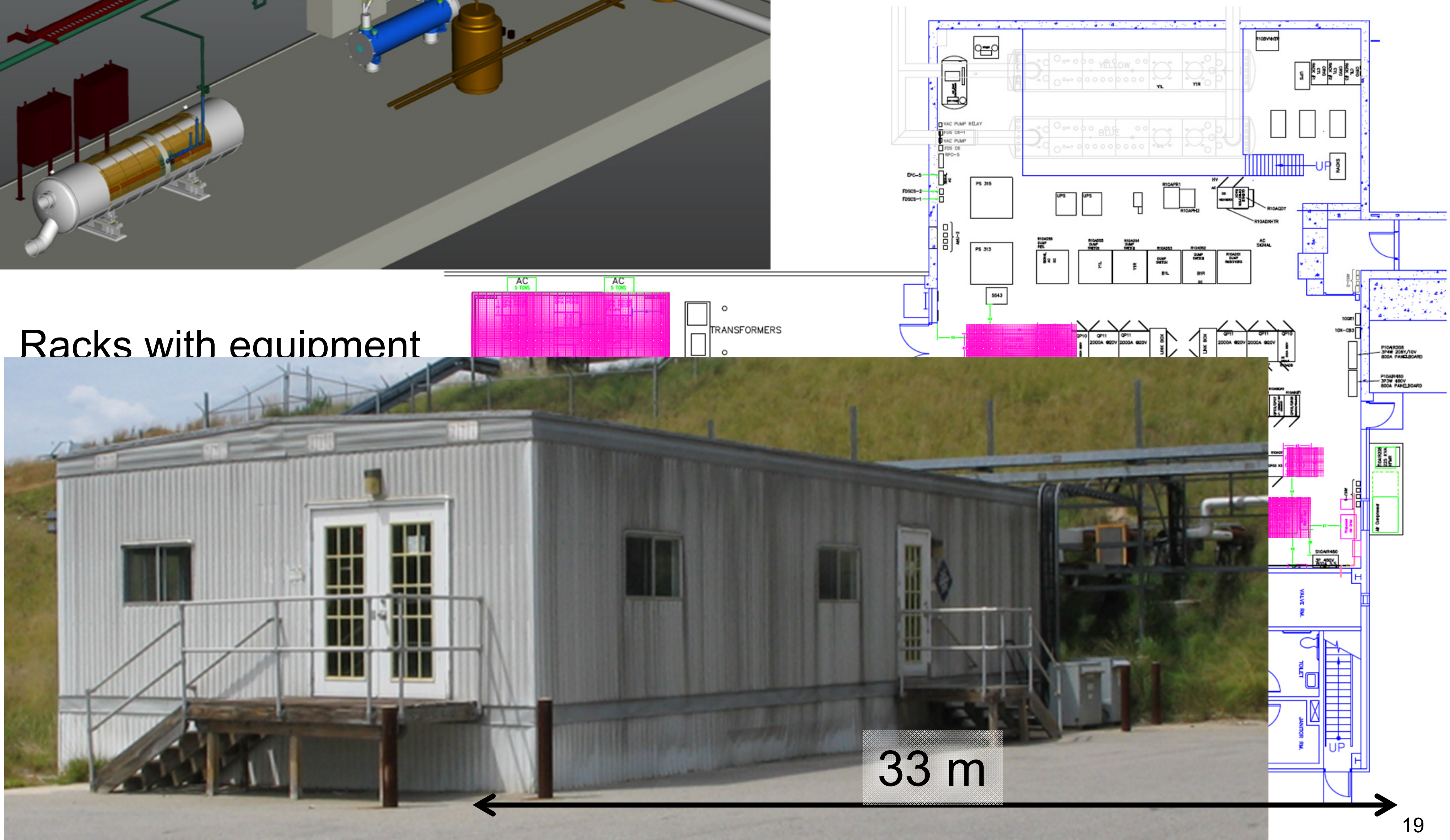


Infrastructure

RHIC electron lenses

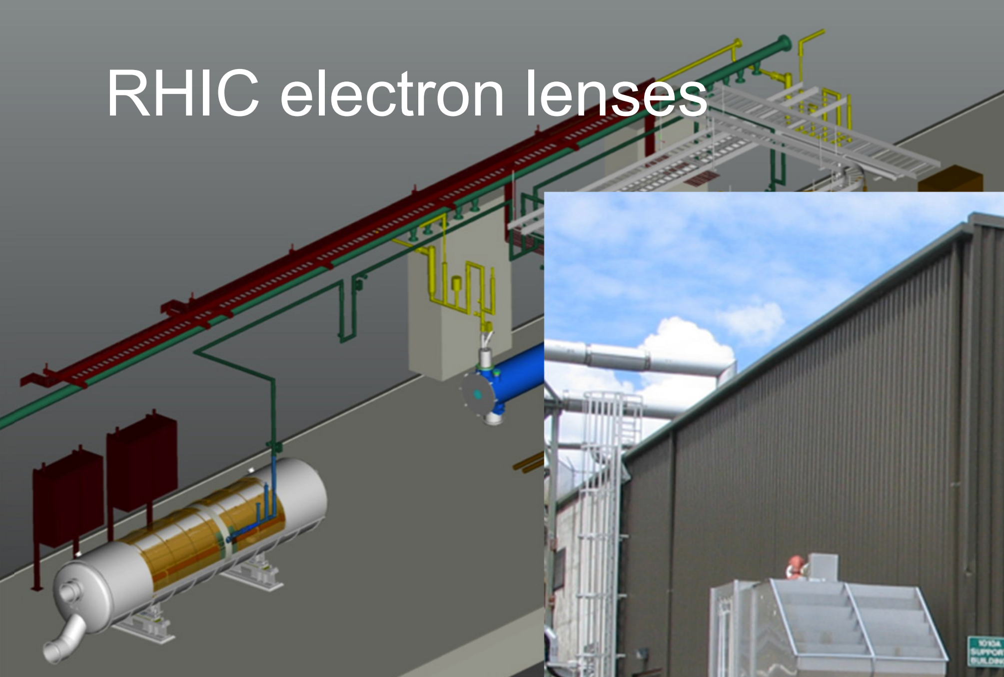


Racks with equipment

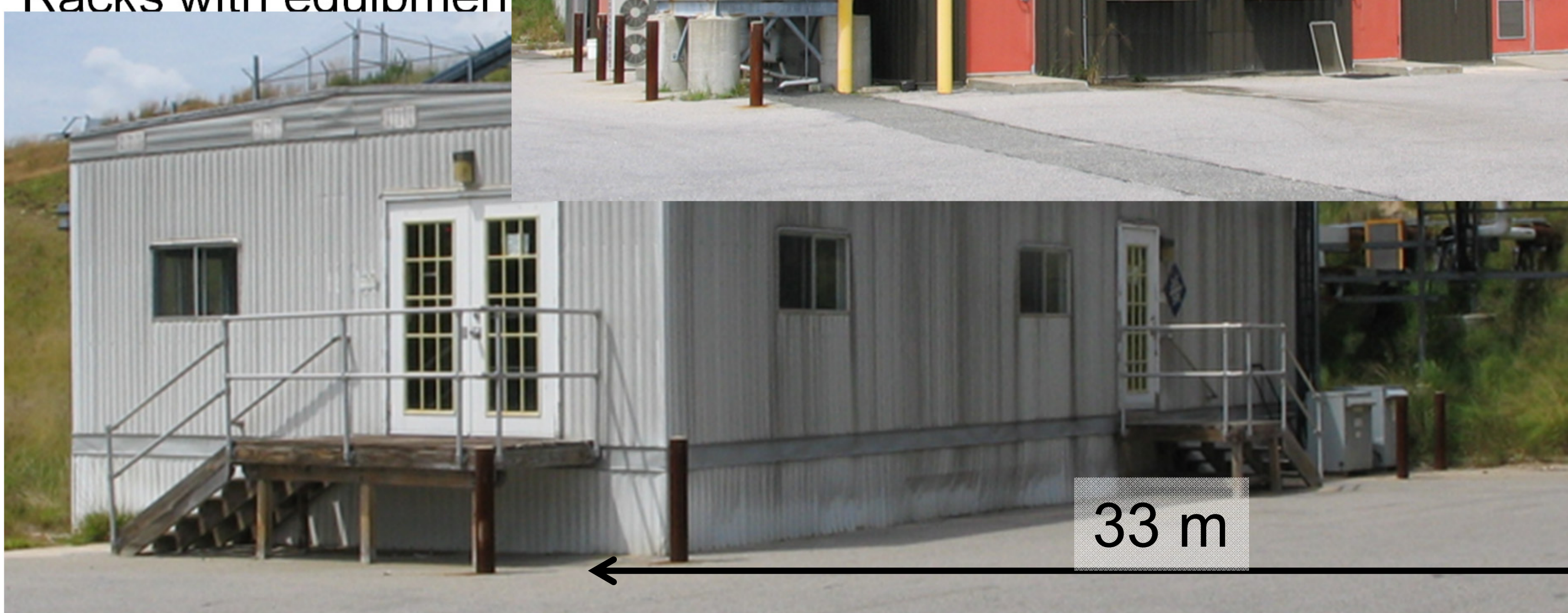


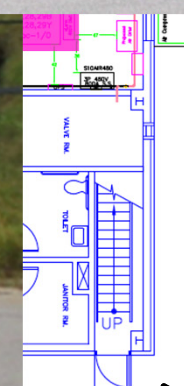
RHIC electron lenses

Infrastructure



Racks with equipmen





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Summary

- Partial head-on beam-beam compensation in RHIC:
  - 5 keV electron beam to reduce beam-beam induced tune spread an resonance driving terms
  - aim for 2x increase in luminosity
- 2 electron lenses under construction
  - 1st superconducing 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