Collider aspects of the polarized beams at RHIC, RHICII and eRHIC

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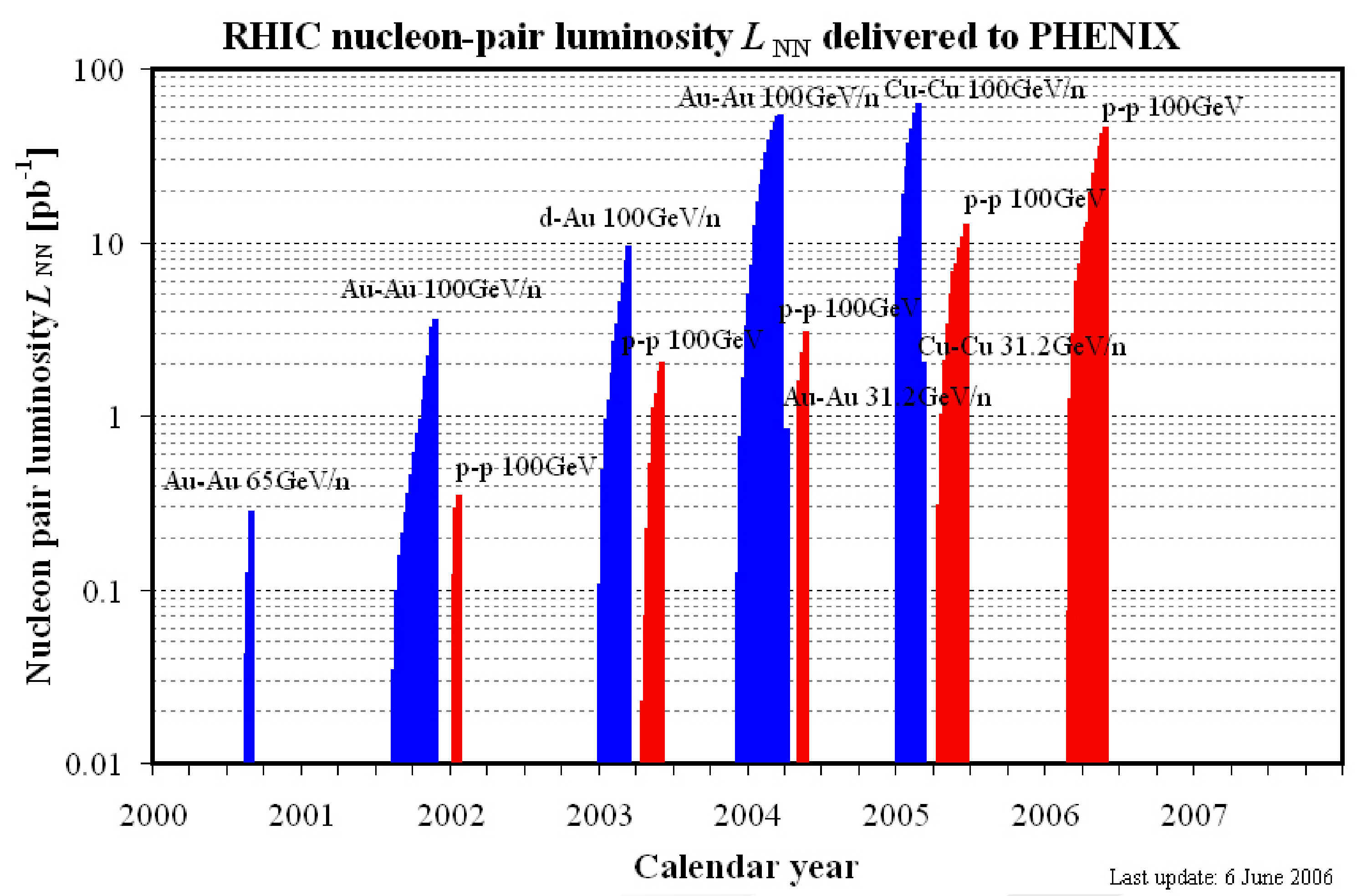
RHIC Luminosity History



Luminosity and polarization projections to 2008 for 100 GeV energy beam

Fiscal year		2002A	2003A	2004A	2005A	2006E	2007E	2008E
No of bunches	…	55	55	56	106	111	111	111
Ions/bunch, initial	10^{11}	0.7	0.7	0.7	0.9	1.4	1.8	2.0
Average beam current/ring	mA	48	48	52	119	187	243	280
β^*	m	3	1	1	1	1	1	0.9
Peak luminosity	10^{30} cm^{-2}s^{-1}	2	6	6	10	30	61	90
Average store luminosity	10^{30} cm^{-2}s^{-1}	1.5	3	4	6	20	41	60
Time in store	%	30	41	41	56	46	58	60
Maximum luminosity/week	pb^{-1}	0.2	0.6	0.9	1.9	7.0	14.3	21.9
Minimum luminosity/week	pb^{-1}						7.0	7.0
Maximum integrated luminosity	pb^{-1}	0.5	1.6	3	13	41	123	180
Minimum integrated luminosity	pb^{-1}						63	63
AGS polarization at extraction	%	35	45	50	55	65	70	75
RHIC store polarization, average	%	15	35	46	47	65	65	70
Maximum LP^4/week	nb^{-1}	0	9	40	90	945	2550	5250
Minimum LP^4/week	nb^{-1}						1250	1250

AGS polarization gain (65%->70% (75%)):
both betatron tunes placed in the spin tune gap that dual snakes provide

RHIC

Luminosity improvement factors for next 100 GeV runs

Goal: doubling, then tripling the luminosity, by bunch intensity increase and increased time in store

- Nonlinear chromaticity correction
- 10Hz IR orbit feedback
- 2/3 resonance compensation
- New working point test ~(0.92;0.93)

} Beam lifetime in the store

- Additional NEG pipes (100m)
- 9.3Mhz RF cavity system for the injection (should allow for smaller longitudinal emittance)

Possible problem to watch: slow emittance growth due to electron cloud

RHIC

Polarization preservation

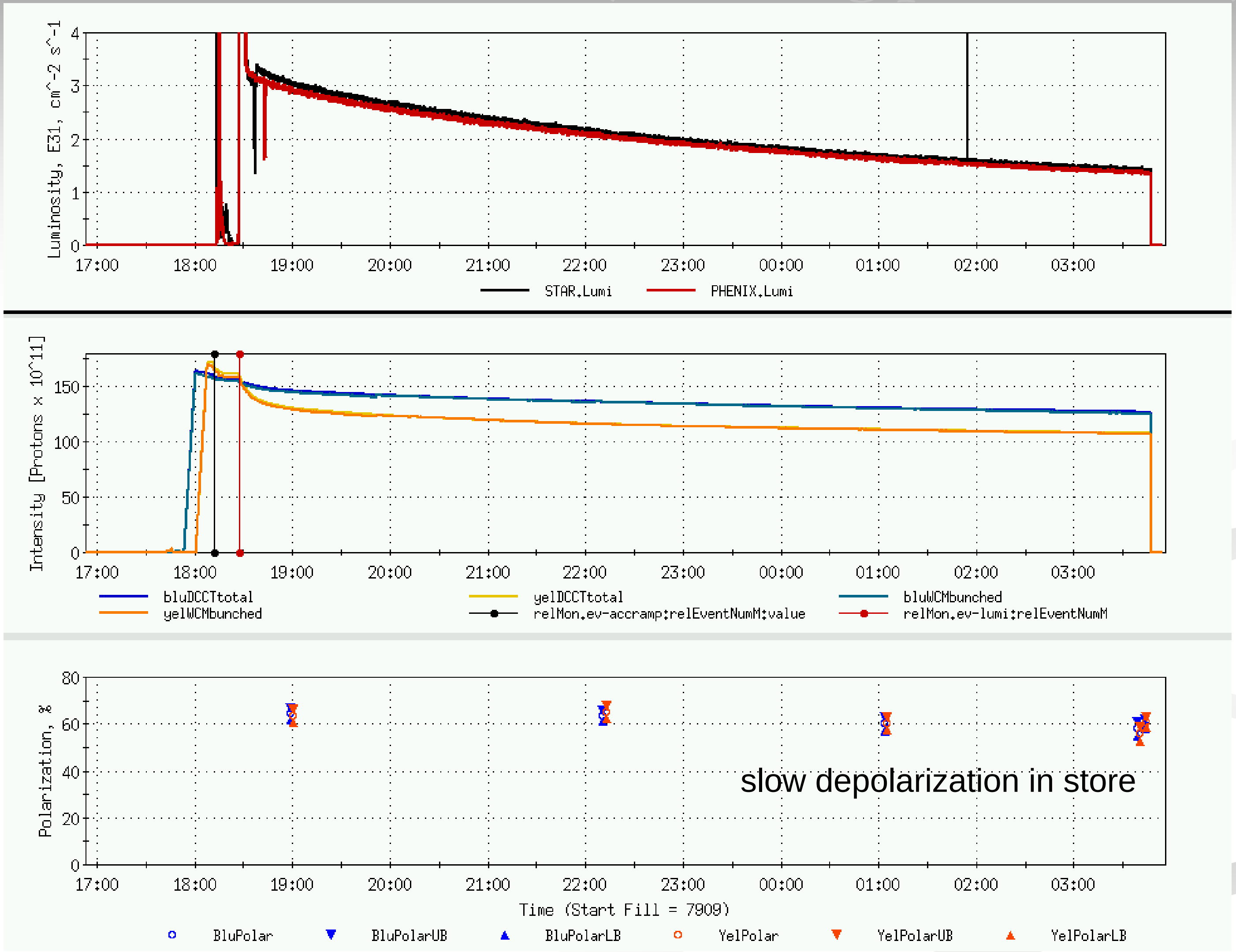
Polarization transmission in RHIC close to 100% (i.e. no polarization loss during the acceleration).

Main factors for the polarization preservation:

- **Optimal Snake current setting.** To avoid the deviation of spin tune from ½ and corresponding shift in the position of high order spin resonances)
- **Betatron tune control.** To avoid the depolarization caused by ¾ and 7/10 high order spin resonances.
  - Tune+decoupling feedback system was applied succesfully on the machine setup stage of Run-6.
- **Vertical orbit control.** To minimize the strength of ¾ spin resonance
  - Whole machine vertical realignment was done before the run 6.
  - Reliability of BPM system.
  - orbit rms <0.5mm

RHIC

Golden Store #7909 (including polarization)



250 Gev polarized protons

- Luminosity: increased by factor 2.5 due to transverse emittance reduction, $L \sim 2.2\ 10^{32}\ cm^{-2}\ s^{-1}$

- Polarization:

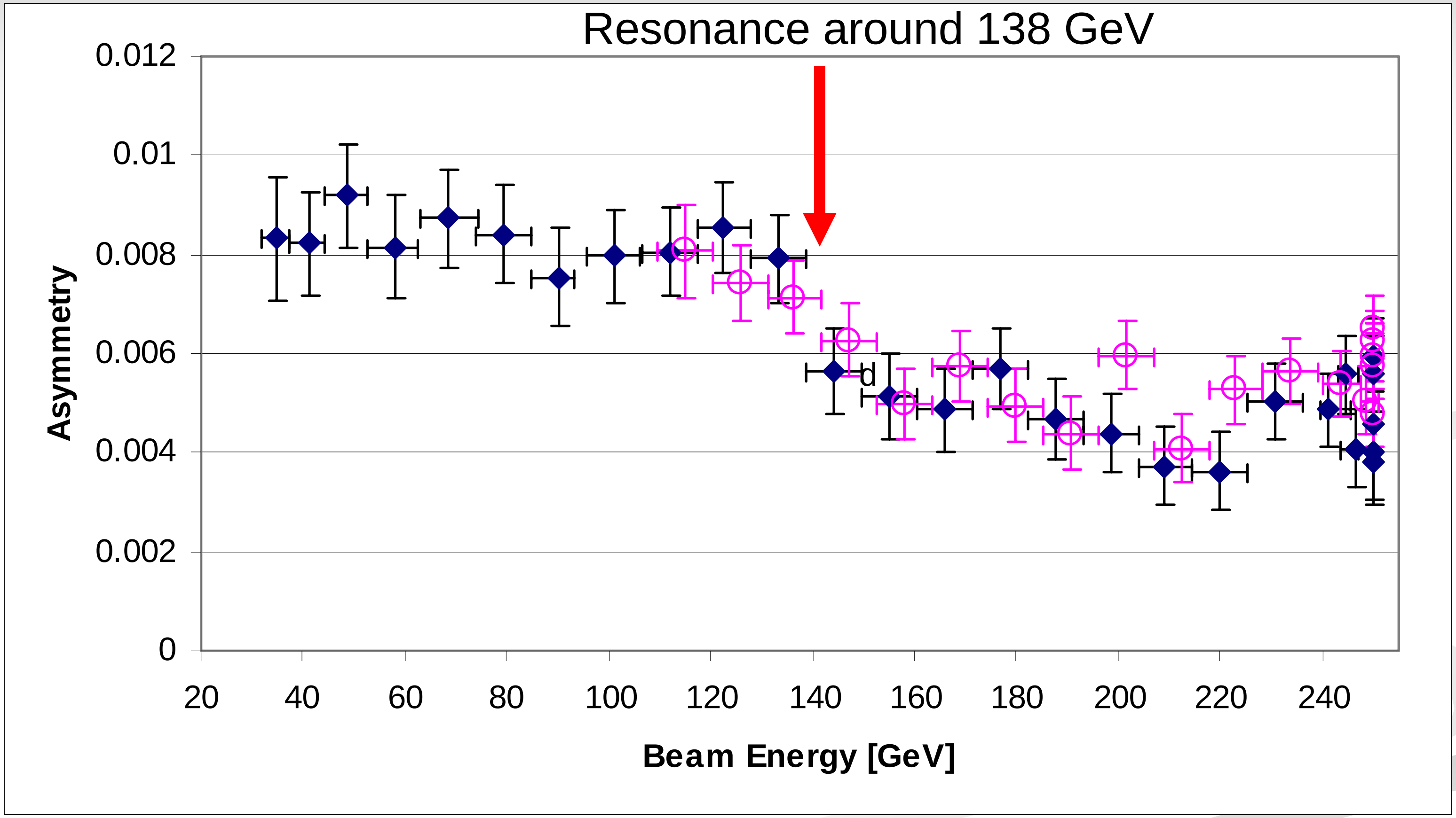
  stronger depolarizing resonances, tighter requirements for vertical beam orbit control:

  - Orbit rms < 0.3mm
  - Beam-based alignment (BPM relative to quad center)
  - Vertical ring realignment (how often?)

RHIC

250 GeV polarization ramp measurement

M.Bai



RHIC II polarized proton parameters

polarized p^+ on polarized p^+		RHIC	RHICII
beam energy	GeV	— 250 —	
number of bunches	...	— 112 —	
bunch intensity, initial	10^{11}	— 2.0 —	
β-function at IP	m	1.0	0.5
peak luminosity	$10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	220	**500**
average store luminosity	$10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	150	500
average store polarization	%	70	70
Total beam-beam parameter		**0.017**	**0.02**

- Main luminosity gain (x2) is from reducing β* by factor 2.
  Modified Interaction Regions (added doublets?)
- Pre-cooling at the low energy (injection).
  Minimum emittance value is defined by beam-beam limit.
  Moderate luminosity gain ~20%
- Cooling at store can be done for protons up to 100 GeV
  Increased average luminosity.

RHIC

Other possible luminosity improvements

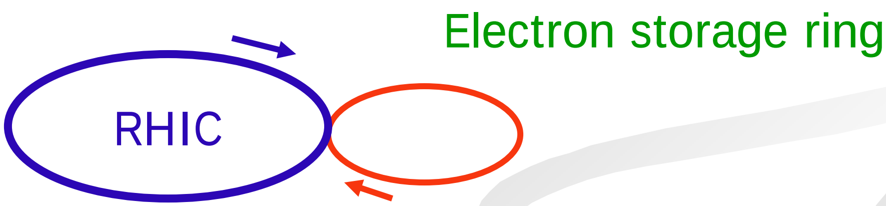
- Beam-beam compensation by electron beam lens

- Increase of number of bunches (upgrade of the injection system): 111 -> 166 (-> 330?)

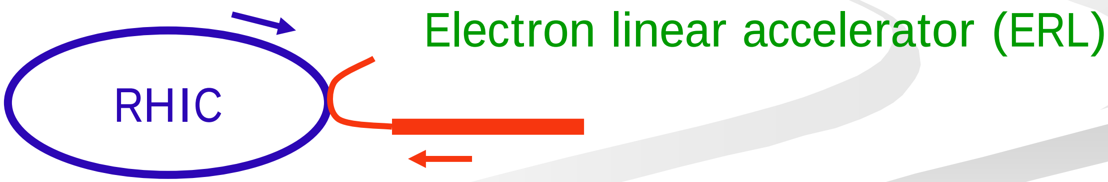
Planned for eRHIC

How eRHIC can be realized?

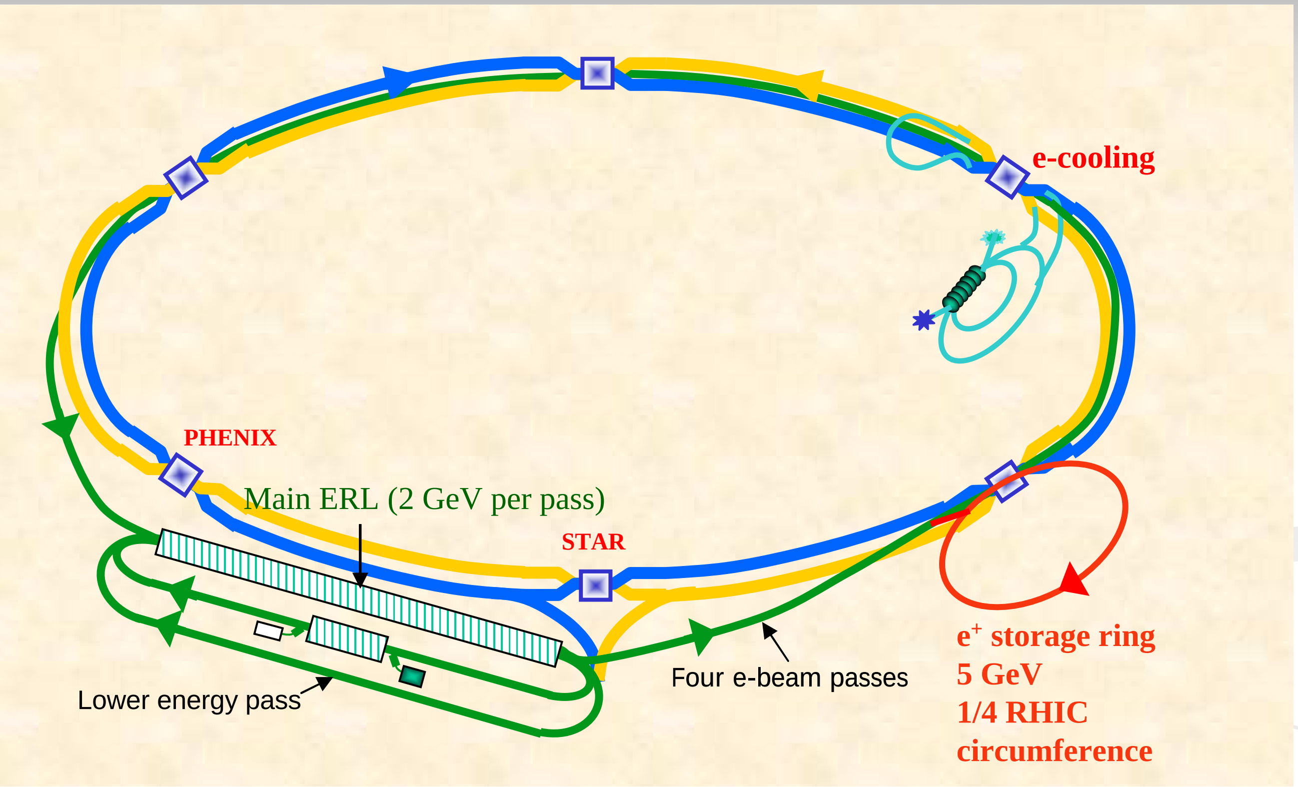
- Two design options:
  - Ring-ring:

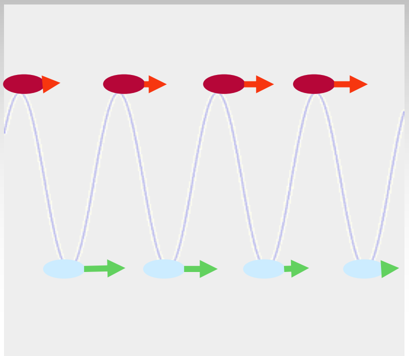


  - Linac-ring:



The design based on Energy Recovery Linac (ERL)





Energy recovery:

decelerate bunches in the same linac; the energy taken from decelerated bunches can be reused for acceleration of new bunches

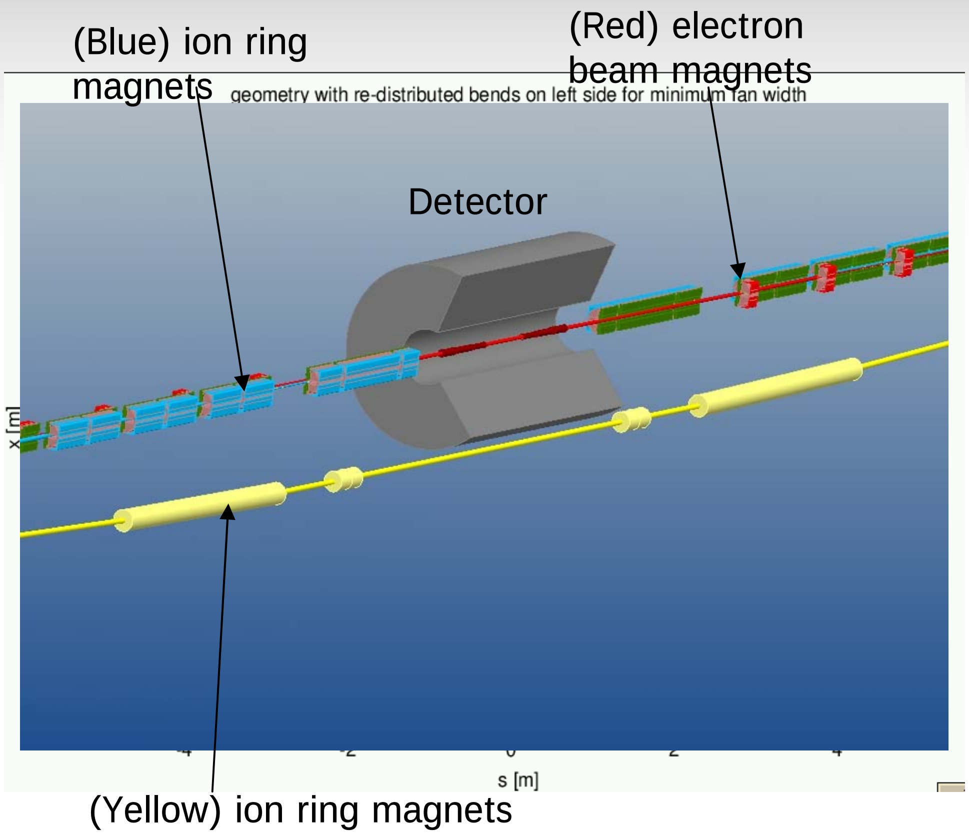
Electron energy range: 3-10 GeV (possible upgrade option to 20 GeV)
Proton energy range: 50-250 GeV
Au ion energy range: 50-100 Gev/n

Peak luminosity:
2.6 10^{33} $cm^{-2}s^{-1}$

eRHIC beam parameter for e-p collisions

	High energy setup		Low energy setup	
	p	e	p	e
Energy, GeV	250	10	50	3
Number of bunches	**166**		166	
Bunch spacing, ns	71	71	71	71
Bunch intensity, 10^{11}	2	1.2	2.0	1.2
Beam current, mA	420	**260**	420	260
Normalized 95% emittance, π μm	**6**	115	6	115
Rms emittance, nm	3.8	1.0	19	3.3
beta*, x/y, cm	26	100	26	150
Beam-beam parameters, x/y	0.015	2.3	0.015	2.3
Rms bunch length, cm	20	1	20	1
Polarization, %	70	80	70	80
Peak Luminosity, 1.e33 $cm^{-2}s^{-1}$	2.6		0.53	
Aver.Luminosity, 1.e33 $cm^{-2}s^{-1}$	0.87		0.18	
Luminosity integral /week, pb^{-1}	530		105	

Interaction region design



- Yellow ion ring makes 3m vertical excursion.
- Design incorporates both normal and superconducting magnets.
- Fast beam separation. Besides the interaction point no electron-ion collisions allowed.
- Synchrotron radiation emitted by electrons does not hit surfaces of cold magnets

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RHIC

IR design schemes

	Distance to nearest magnet from IP	Beam separation	Magnets used	Hor/Ver beam size ratio
Ring-ring, l*=1m	1m	Combined field quadrupoles	Warm and cold	0.5
Ring-ring, l*=3m	3m	Detector integrated dipole	Warm and cold	0.5
Linac-ring	>3m	Detector integrated dipole	Warm	1

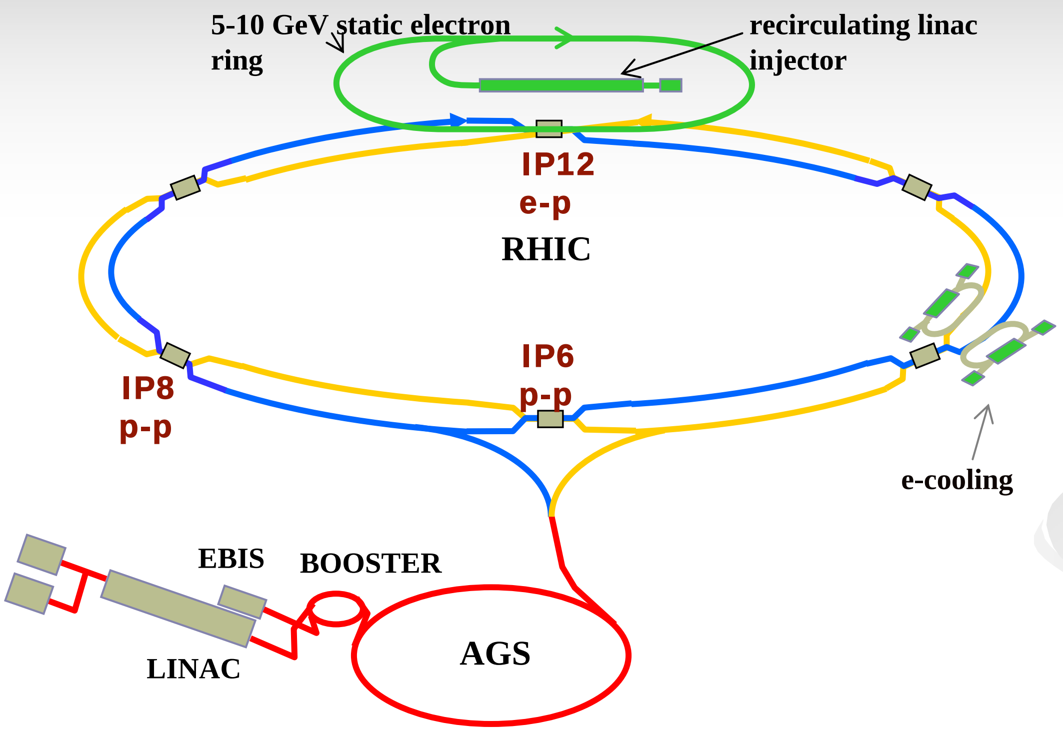
- No crossing angle at the IP
- Linac-ring: larger electron beta*; relaxed aperture limits ; allows round beam collision geometry (the luminosity gain by the factor 2.5).
- Detector integrated dipole: dipole field superimposed on detector solenoid.

R&D issues

- Linac-ring:
  - High current polarized electron source (for polarized beams!)
  - Energy recovery technology for high energy and high current beams
  - Beam-beam effects

- Ion ring:
  - Beam cooling techniques development (electron, stochastic).
  - Increasing total current (ions per bunch and number of bunches).
  - Polarized He^3 production (EBIS) and acceleration

Ring-ring design option

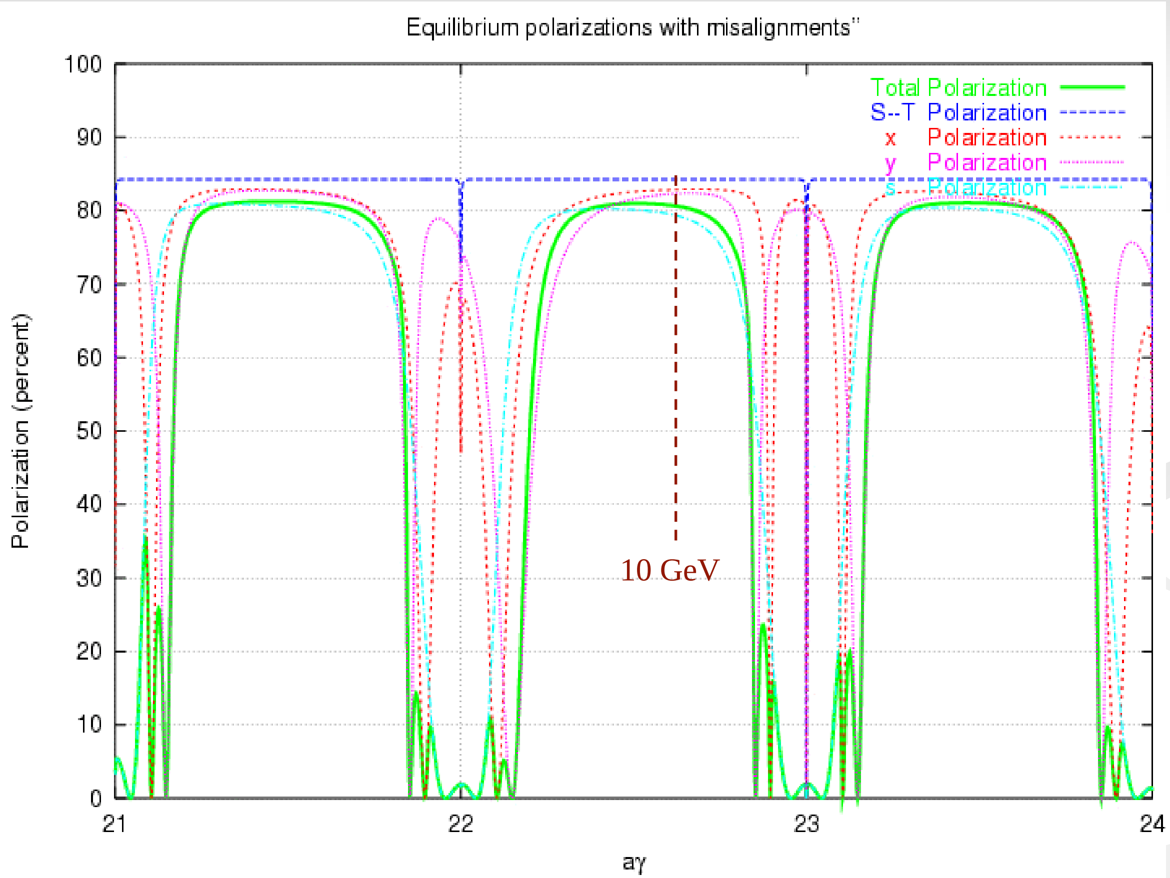


- The electron ring of 1/3 of the RHIC ion ring circumference
- Full energy injection using polarized electron source and 10 GeV energy linac.
- e-ion collisions in one interaction point.
- Longitudinal polarization produced by local spin rotators in interaction regions.
- Aver Luminosity, 1-2 10^{32} $cm^{-2}s^{-1}$

The e-ring design development led by MIT-Bates

Electron polarization

D.Barber



- Beam polarization can not be achieved in certain energy areas. (Spin resonance zones)
- Requirements for good vertical alignment and precise vertical orbit control:

  $y_{co\ rms} < 150\ \mu m$

- Positrons: self-polarized in the ring :

  $\tau_{pol} = 20min$ at 10 GeV

RHIC