Beam Studies for eRHIC

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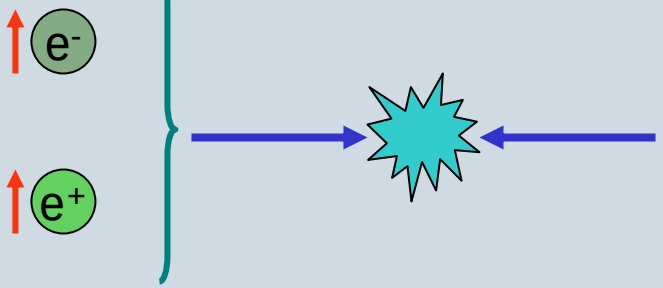
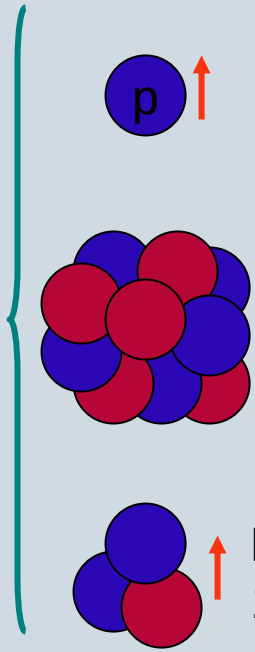
eRHIC Scope

Electron accelerator

RHIC



Polarized leptons
5-10 Gev



Polarized protons
50-250 Gev

Heavy ions (Au)
100 Gev/u

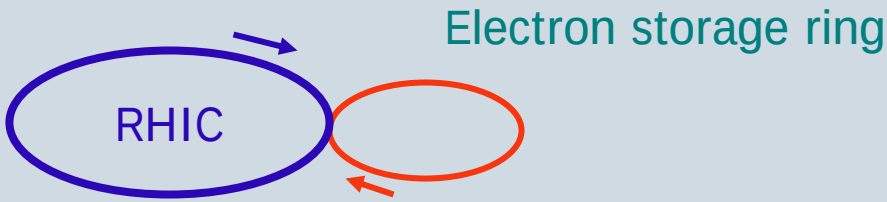
Polarized light ions (He^3)
167 Gev/u

70% beam polarization goal

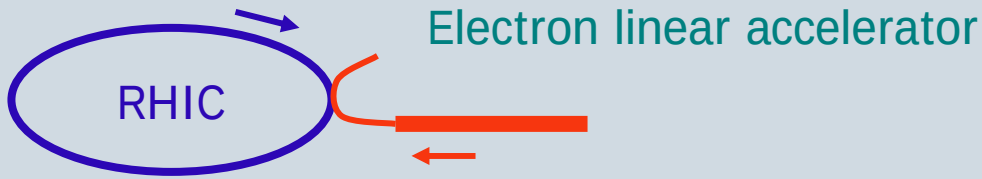
Center mass energy range: 30-100 Gev

How eRHIC can be realized?

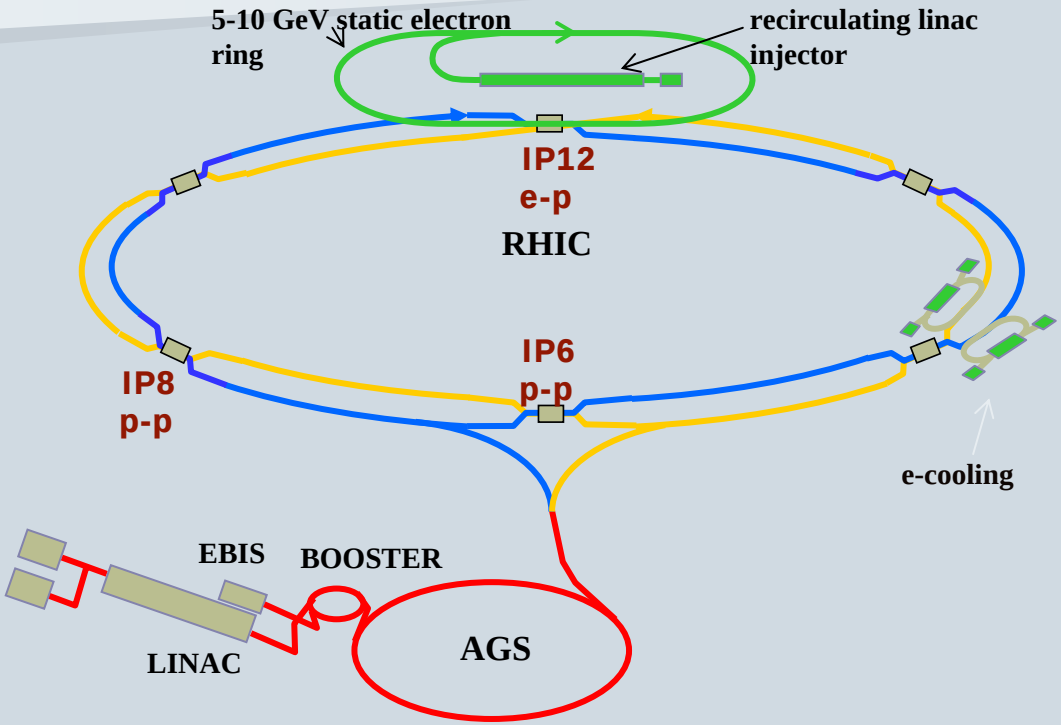
- Two main design options:
  - Ring-ring:



  - Linac-ring:



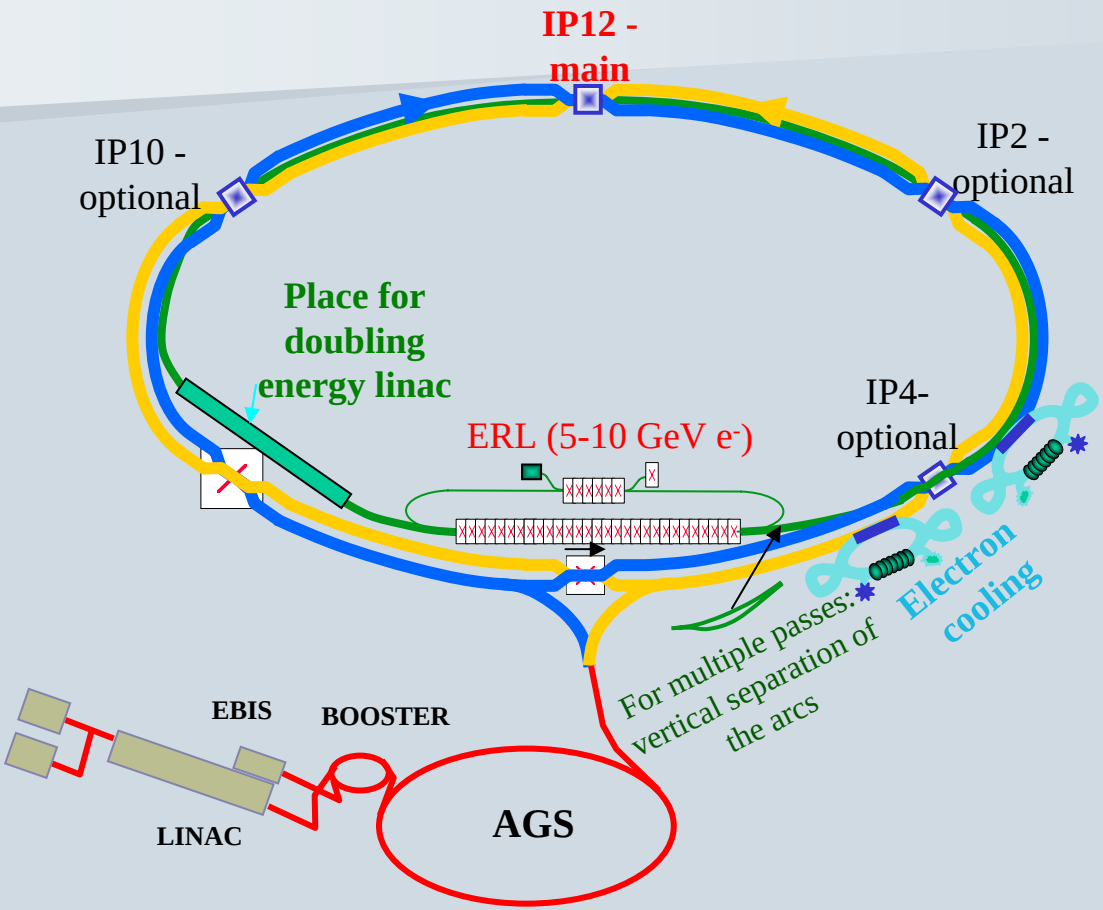
Ring-ring design option



- 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.
  (Parallel mode : Ion-ion collisions in IP6 and IP8 at the same time are possible.)
- Longitudinal polarization produced by local spin rotators in interaction regions.
- ZDR design luminosities (for high energy setup):
  - e-p: 4.4 10^{32} $cm^{-2}s^{-1}$
  - e-Au: 4.4 10^{30} $cm^{-2}s^{-1}$
  - e-He^3: 3.1 10^{32} $cm^{-2}s^{-1}$

The e-ring design development led by MIT-Bates.
Technology similar to used at B-factories.
Presently main design option.

Linac-ring design



Design being developed at BNL
(ZDR: V.Litvinenko et al.)

- Electron beam is transported to collision point(s) directly from **superconducting energy recovery linac (ERL).**
- No beam-beam limitation for electron beam (the beam is used once!).
- No prohibited energy areas for the polarization.
- No spin rotators needed.
- e-p luminosity $>10^{33}$ cm^{-2}s^{-1} possible
- But no straightforward way to get polarized positrons

Luminosity for different options

- **Linac-Ring:**

$$L = \gamma_i \, f_c \, N_i \, \frac{\xi_i \, Z_i}{\beta_i^* \, r_i}$$

No electron beam-beam limit on ion current.

Luminosity is defined by ion beam parameters.

IR design allows for round beams at the collision point.

- **Ring-ring:**

$$L = f_c \, \frac{\pi \gamma_i \gamma_e}{r_i r_e} \, \xi_{xi} \, \xi_{ye} \, \sigma'_{xi} \, \sigma'_{ye} \, k_e \, \frac{(1+K)^2}{K}$$

Limitation from IR design (septum magnet aperture) leads to elliptical beam (vertical to horizontal beam size ratio: K=1/2 and emittance ratio k_e~0.18) and the limit on σ'_{xi}

Electron beam-beam limit (ξ_e < 0.08) prevents proton intensity more than 1e11 p/bunch

Possible eRHIC operation modes

- Parallel mode: e-ion and ion-ion collisions at the same time.

  So far considered as the main operation scenario for eRHIC design.

  Limitation: luminosity pie is divided between e-ion and ion-ion experiments, since beam-beam limit

- Dedicated mode: e-ion collision only.

  Higher luminosity (no luminosity sharing).

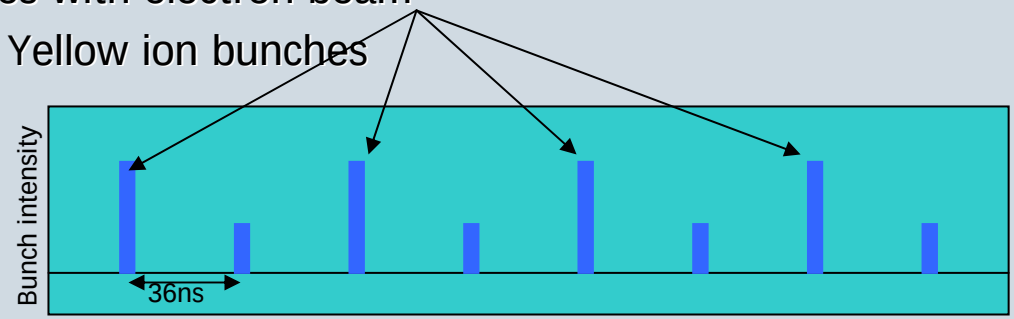
  Linac-ring option gets greater benefits since it can use increased proton (ion) bunch intensities and reduced emittances for luminosity gains.

- Shared ring mode: e-ion and ion-ion collisions at the same time but involving different sets of proton bunches.

  Parallel e-ion and ion-ion operation but with advantages of dedicated mode!

Shared Blue ring mode

- Blue ring: 360 bunches
  - Half of the bunches collides with electron beam
  - Another half collides with Yellow ion bunches



- Yellow ring: 180 bunches
- Electron bunches in 180 bunch mode distance.

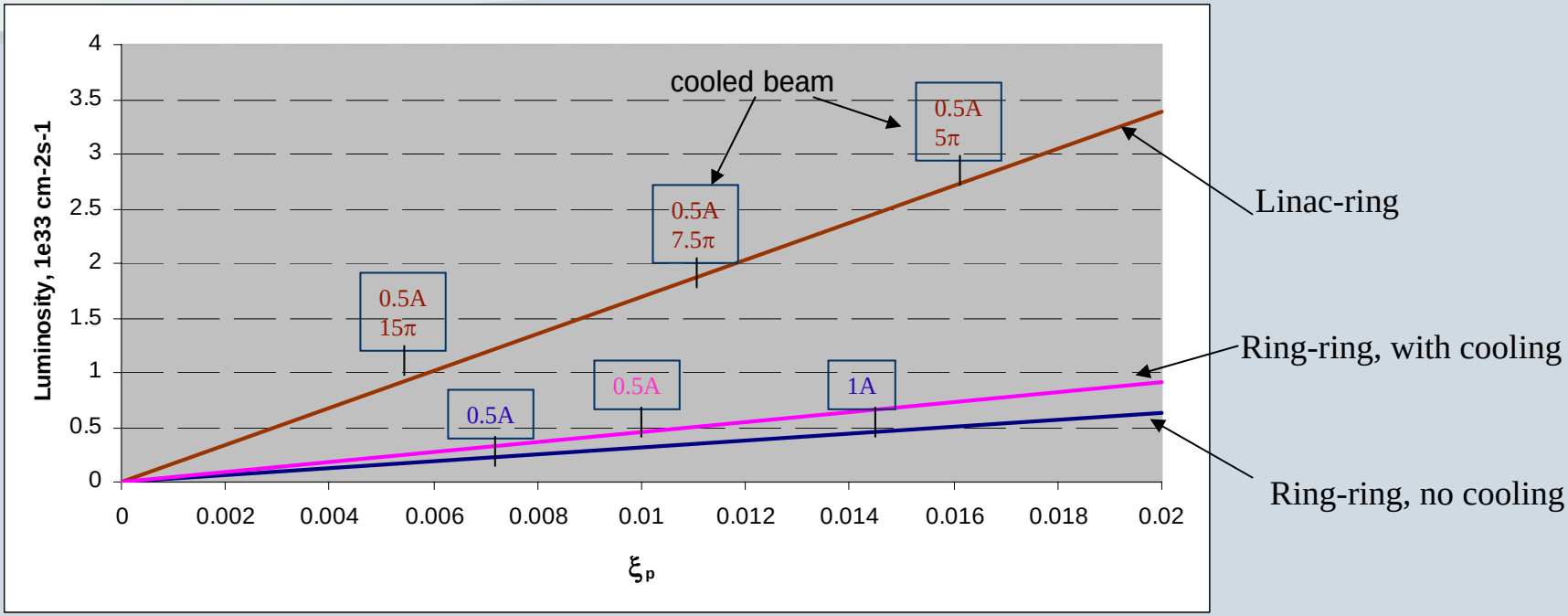
- A variant for smaller number of bunches:

  120 in Blue; 60 in Yellow; 60 bunch mode distance in electron machine

- Issue: working point must accommodate beam-beam tune shifts and spreads both from e-p and p-p collisions.

Luminosity versus proton beam-beam parameter

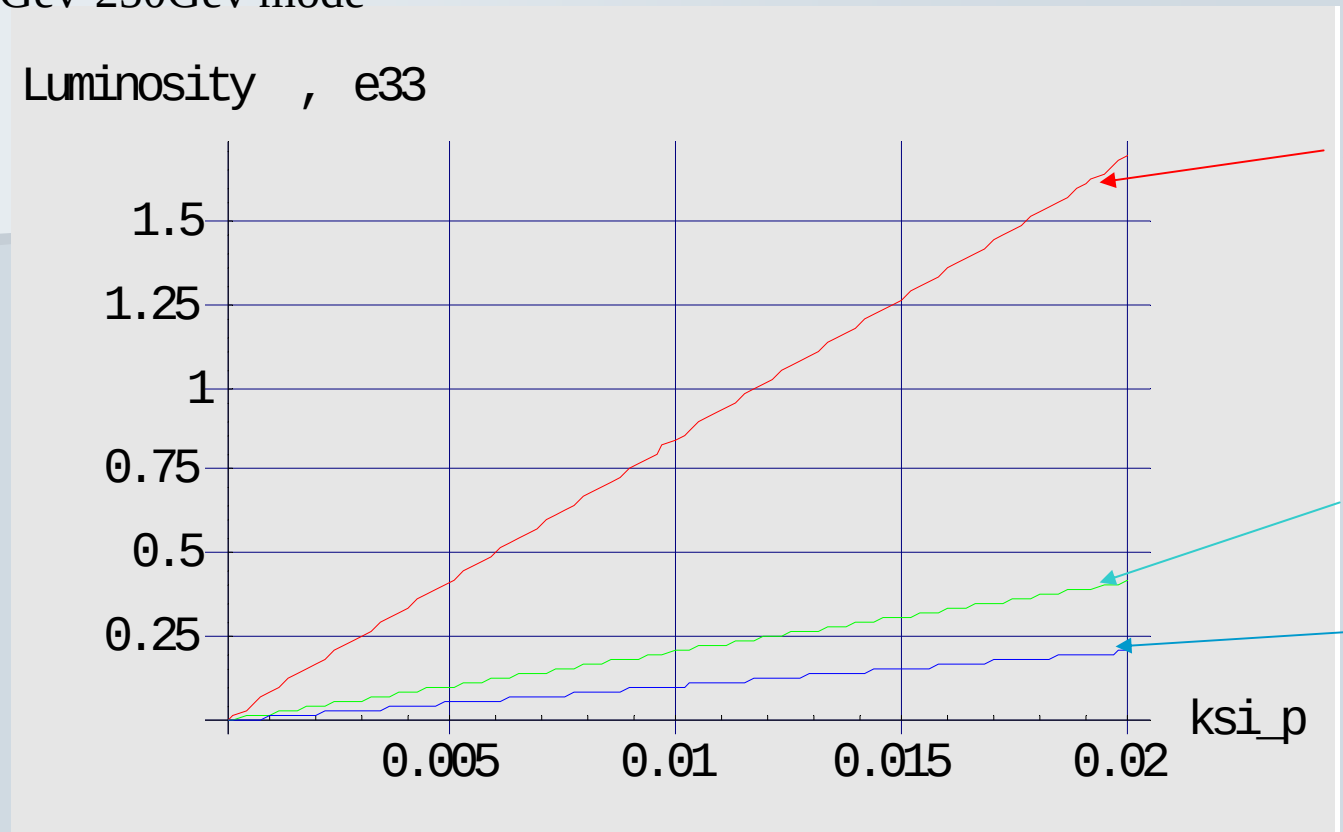
Calculations for 360 bunch mode and 250 Gev(p) x 10 Gev(e) setup; 1e11 p/bunch



Markers show electron current and (for linac-ring) normalized proton emittance.
In dedicated mode (only e-p collision): maximum ξ_p~0.016-0.018;
In parallel mode without cooling: maximum ξ_p~0.0065

Transverse cooling can be used to improve luminosity or to ease requirements on electron source current in linac-ring option. BUT, only in dedicated mode!

e-p luminosity for 112 bunches and 15pi proton emittance
10Gev-250Gev mode



	Ksi_p	Ne per bunch, 1e11	Total electron current, A	Luminosity, 1e33
Linac-ring	0.0049	1	0.150	0.41
	0.012	2.46	0.37	1.01
Ring-ring l*=3m design	0.0065	1	0.150	0.07
	0.013	2	0.300	0.14

Beam studies for eRHIC

- Beam-beam limits

  Goal: better understanding achievable luminosity in dedicated mode.

  RHIC operation provides knowledge on beam-beam limits with 2,3,4 collision points. No data yet on beam-beam limit with 1 collision that corresponds to eRHIC dedicated mode.

  High per bunch intensity (3.e11 p/bunch) can be used to investigate beam-beam limit in 1 collision mode.

- Increasing number of bunches.

  335 is ultimate goal for eRHIC. Presently 112 has been achieved.

  - **Identifying limits on number of bunches from present injection system** (112 bunches-> 168 bunches?)
  - **Parasitic beam-beam compensation scheme.**
  - **Crossing angle schemes to avoid head-on parasitic collisions.**

Beam studies for eRHIC

- Total beam current and bunch intensity increase.

  Goal: explore machine limits

  - Studies of cryogenic load due to vacuum pipe heating
  - Continue studies on electron cloud related effect and pressure rise.

- For shared ring mode:

  Studies on injection and coexistence of two sets of bunches with very different bunch intensities and/or emittances.