eRHIC collider at BNL

V.Ptitsyn
C-AD, BNL

eRHIC

Zeroth-Order Design Report

BNL: L. Ahrens, D. Anderson, M. Bai, J. Beebe-Wang, I. Ben-Zvi, M. Blaskiewicz, J.M. Brennan, R. Calaga, X. Chang, E.D. Courant, A. Deshpande, A. Fedotov, W. Fischer, H. Hahn, J. Kewisch, V. Litvinenko, W.W. MacKay, C. Montag, S. Ozaki, B. Parker, S. Peggs, T. Roser, A. Ruggiero, B. Surrow, S. Tepikian, D. Trbojevic, V. Yakimenko, S.Y. Zhang
MIT-Bates: W. Franklin, W. Graves, R. Milner, C. Tschalaer, J. van der Laan, D. Wang, F. Wang, A. Zolfaghari and T. Zwart
BINP: A.V. Otboev, Yu.M. Shatunov
DESY: D.P. Barber

Editors: M. Farkhondeh (MIT-Bates) and V. Ptitsyn (BNL)

- Detailed document (265 pages) reporting studies on the accelerator and the interaction region of this future collider.
- The work performed jointly by BNL and MIT-Bates, with close collaboration with scientists from BINP (Novosibirsk) and DESY (Hamburg).
- Goals:
  - to develop an initial design for eRHIC
  - to investigate most important accelerator physics issues
  - to evaluate the luminosities that could be achieved in such a collider

The present efforts are towards conceptual design development.

V.Ptitsyn

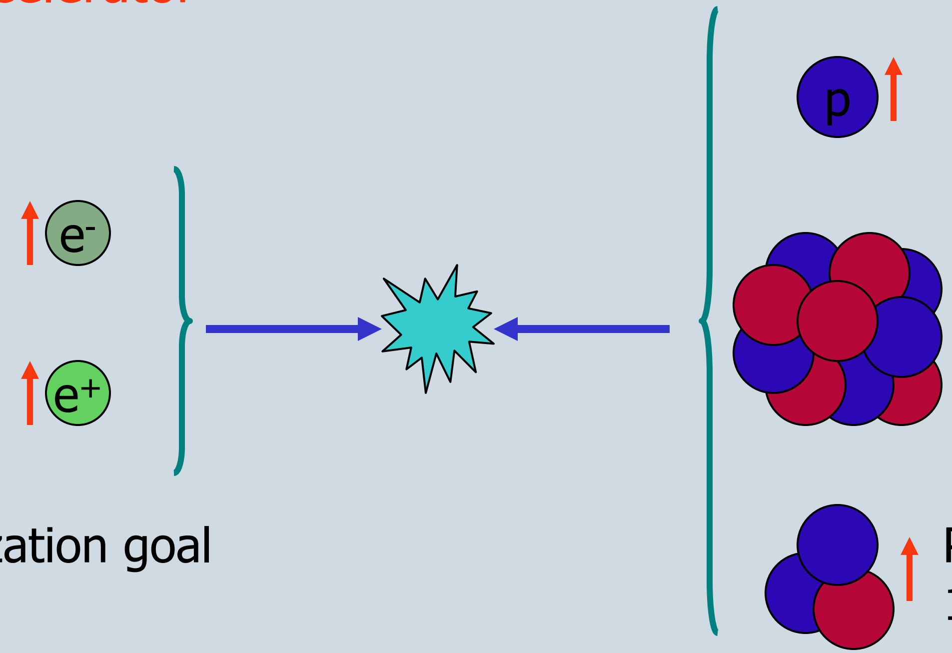
eRHIC Scope

Electron accelerator

Polarized leptons
5-10 Gev

70% beam polarization goal

RHIC



Polarized protons
50-250 Gev

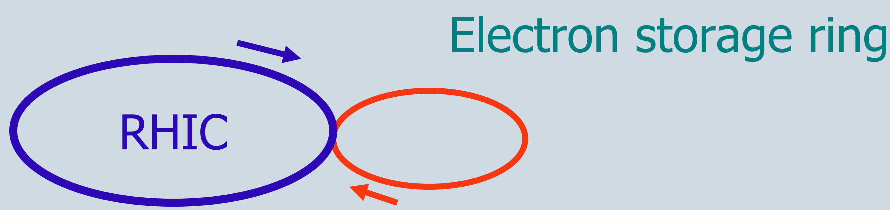
Heavy ions (Au)
100 Gev/u

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

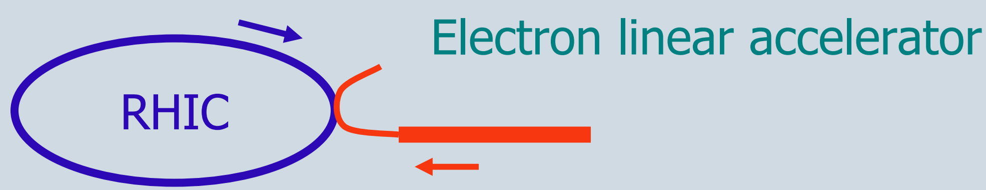
Center mass energy range: 30-100 Gev

How eRHIC can be realized?

- Two main design options:
  - Ring-ring:

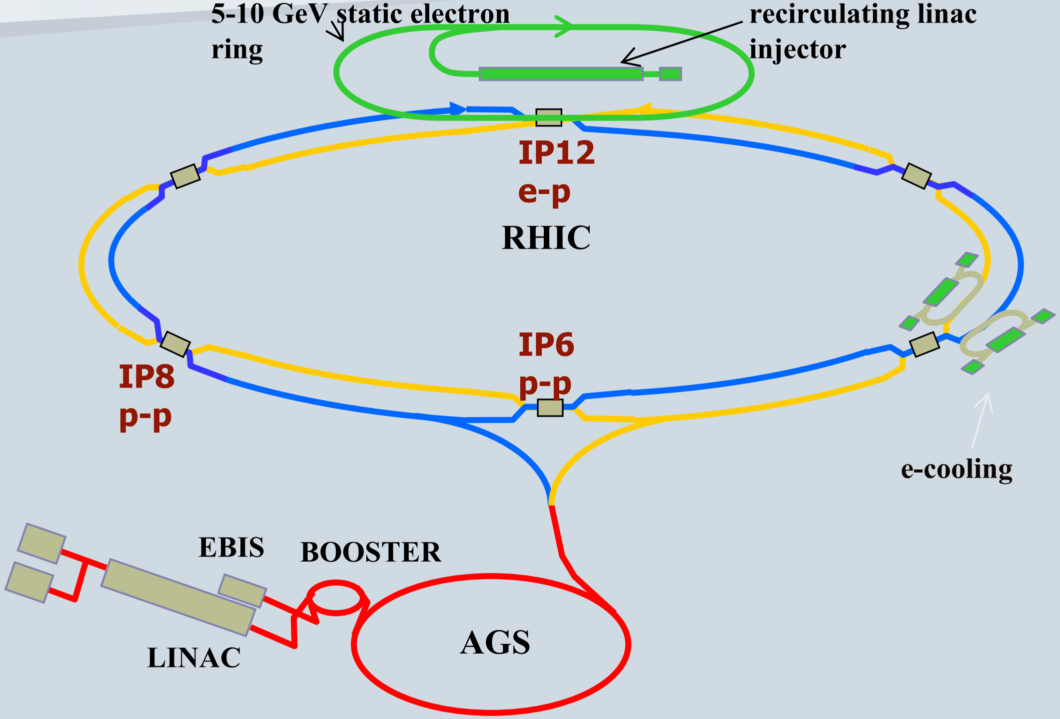


  - Linac-ring:



V.Ptitsyn

Ring-ring design option

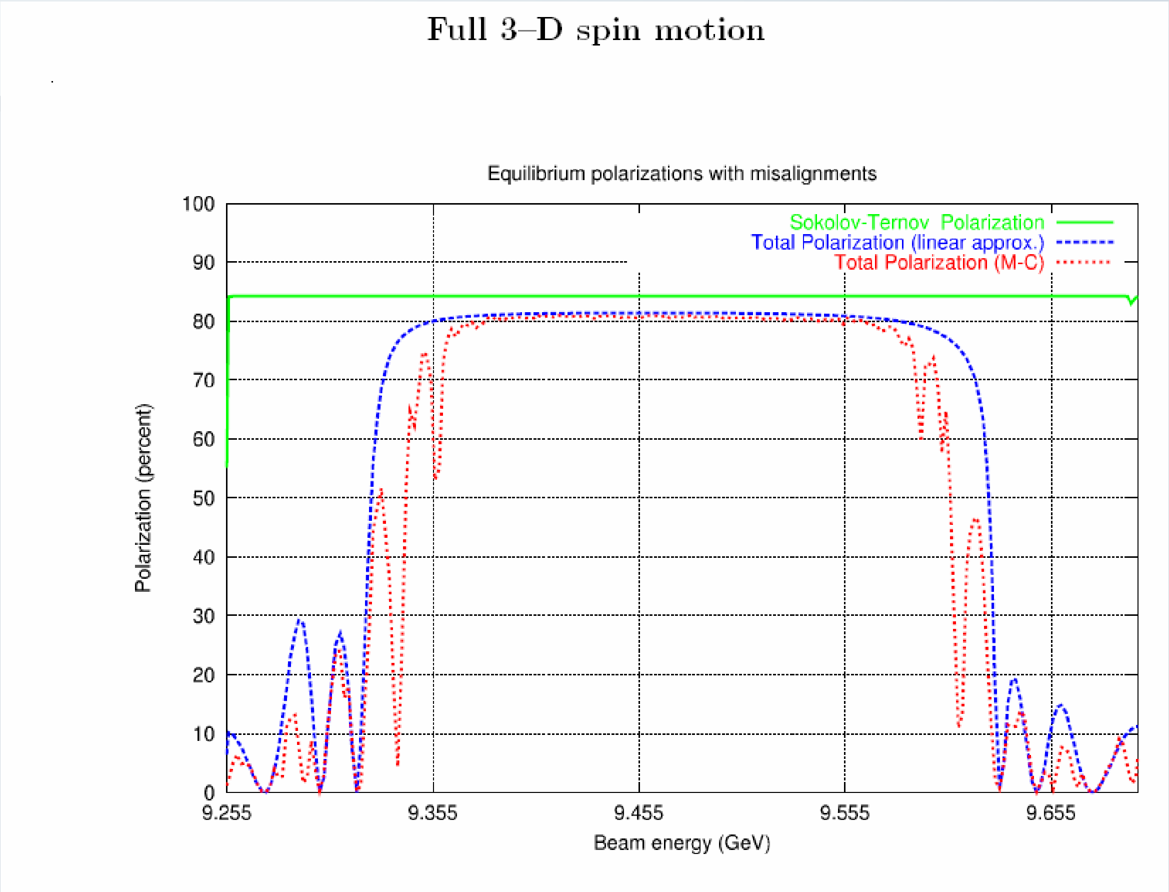


- The electron ring of 1/3 of the RHIC ion ring circumference
- Full energy injection using polarized electron source and 10 GeV energy linac.
- e-ion collisions in one interaction point.
  (Parallel mode : Ion-ion collisions in IP6 and IP8 at the same time are possible.)
- Longitudinal polarization 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.

V.Ptitsyn

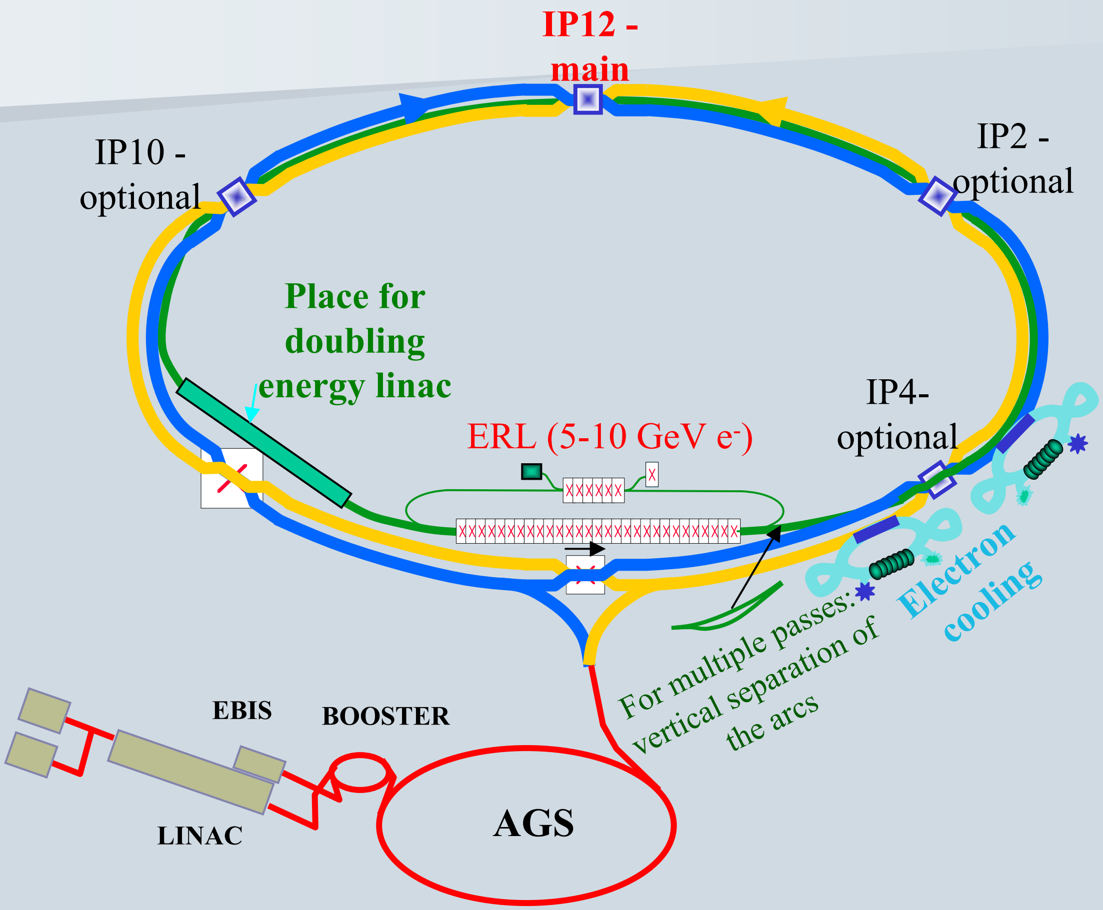
Electron polarization



D.Barber

- First results for high order calculation of electron polarization indicate wide enough energy range without strong depolarization resonances.
- Open issues:
  - Compensation of depolarization from detector solenoid
  - Possible depolarization from beam-beam effects

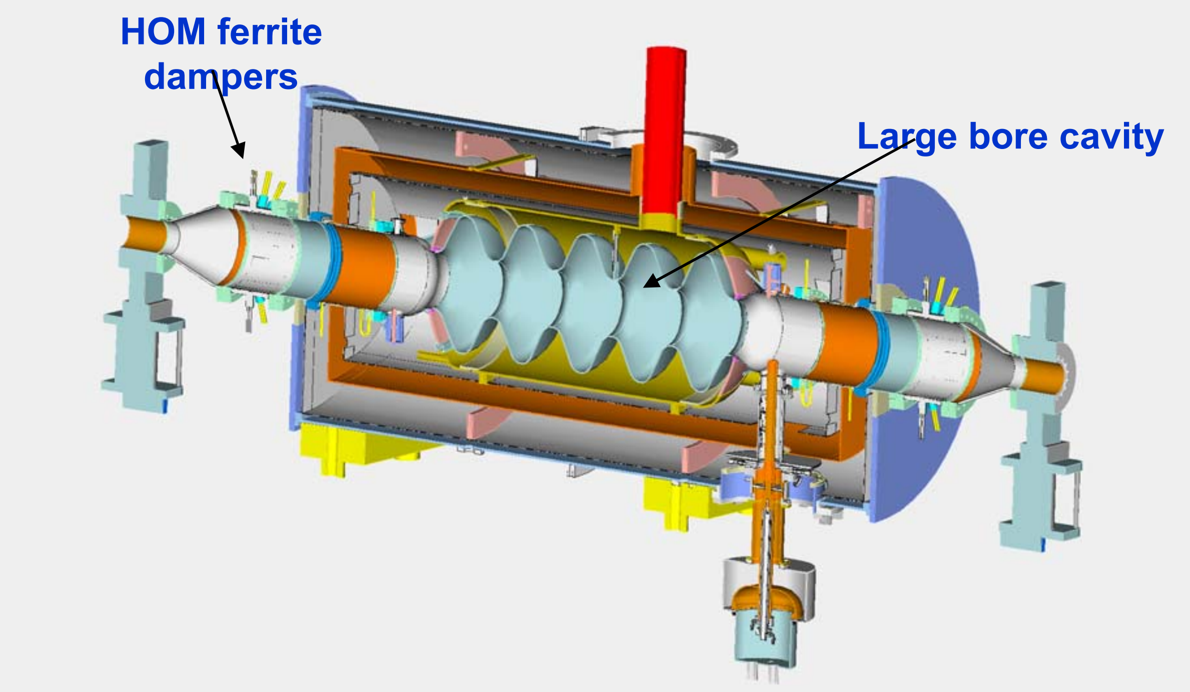
Linac-ring design



- 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

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

Superconducting RF Cavity



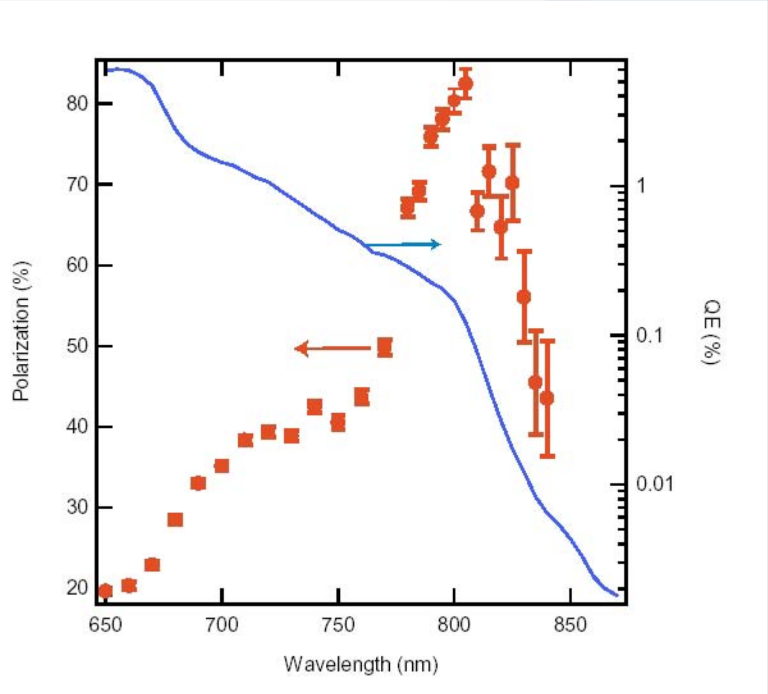
703.75 MHz 5-cell cavity
designed in BNL
for e-cooling and eRHIC

Cryostat assembly and cold testing in Sept.2006

State-of-the-art cavity engineering design to minimize and damp High Order modes of electromagnetic field.

Electron Polarized Source

Photoemission from strained GaAs cathode



High polarization ->Low QE

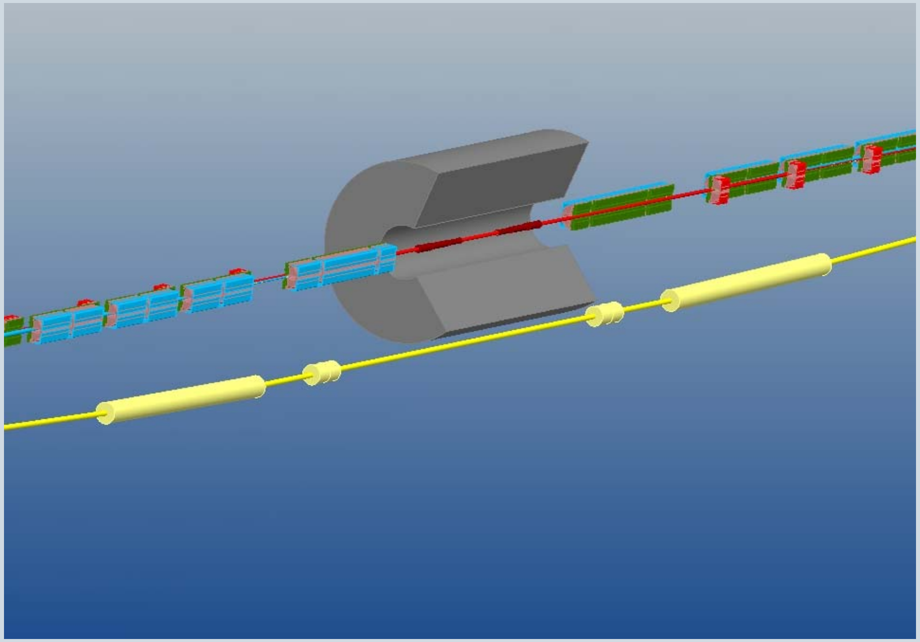
- Present polarized CW sources:
  - Mainz: <100 μA
  - JLab(CEBAF):
    - 100 μA in routine operation
    - 200 μA (occasionally)
    - 1-2 mA (clear idea, plans for tests)
- eRHIC linac-ring requires several hundred mAs to go above 1.e33 luminosity

Major R&D is needed for the polarized electron source.

Possible path (V.Litvinenko, M.Farkhondeh) :
•increased laser spot on the cathode,
•Free Electron Laser to provide sufficient laser power

Interaction region design

C.Montag, B.Parker, S.Tepikian, T.Zwart, D.Wang



- Design incorporates both warm and cold magnets.
- Provides fast beam separation. No parasitic collisions.
- Yellow ion ring makes 3m vertical excursion.
- Accommodates spin rotators and electron polarimeter.
- Put a limit on horizontal β^* for protons, because of aperture limitation in septum magnet, thus affecting achievable luminosity.
- Background produced by synchrotron radiation hitting septum magnet should not be problem (with HERA-like absorber used)

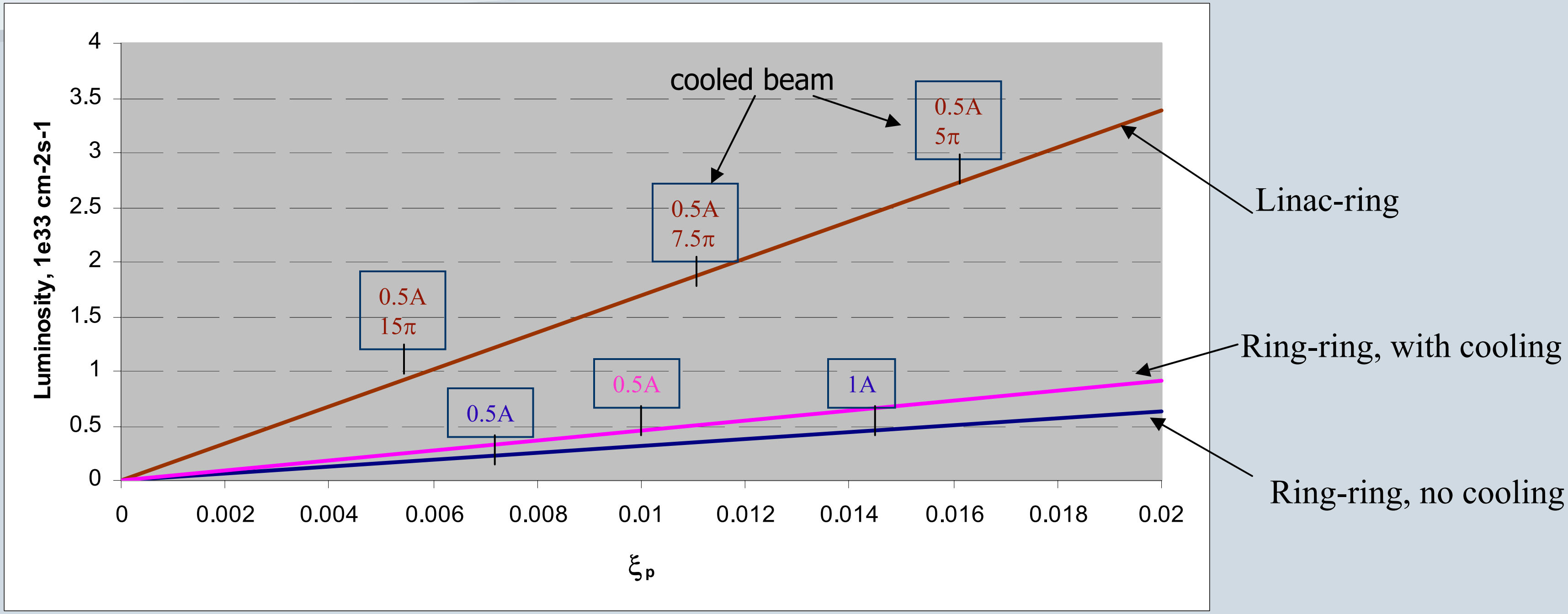
IR design schemes

	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	5m	Detector integrated dipole	warm	1

- l*=3m is preferable for ring-ring, compared to l*=1m, due to larger detector acceptance. But at the cost of the factor 2 luminosity reduction.
- Detector integrated dipole: dipole field superimposed on detector solenoid.

Luminosity with e-cooling

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

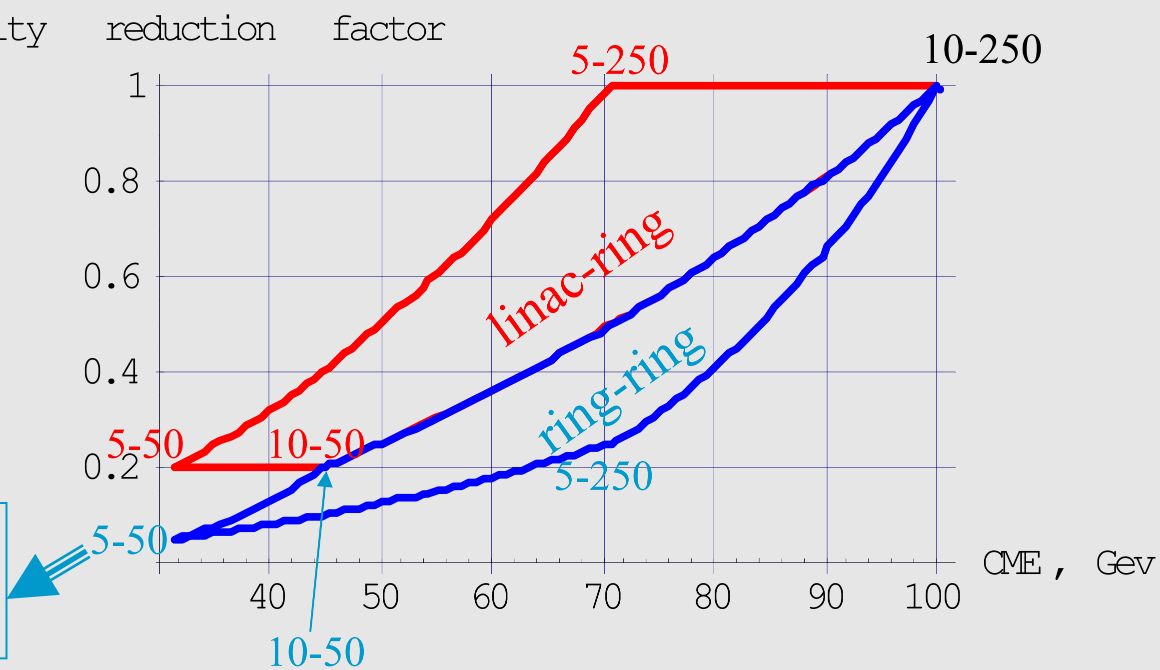


Markers show electron current and (for linac-ring) normalized proton emittance.
In dedicated mode (only e-p collision): maximum ξ_p~0.016-0.018;

Transverse cooling can be used to improve luminosity or to ease requirements on electron source current in linac-ring option.
For proton beam only e-cooling at the injection energy is possible at reasonable time (~1h)

V.Ptitsyn

Luminosity dependence on CME with cooling



Luminosity reduction factor at 5-50 mode for ring-ring : 0.05.
Required norm.emittance ~3π mm*mrad

- For ring-ring the cooling improves luminosities for low energy proton modes. The optimal curve is: **10-250-> 10-50 -> 5-50**
- For linac-ring operation in proton beam-beam limit the cooling can be used to reduce requirements on electron current.

The optimal curve is: **10-250-> 5-250 -> 5-50**

Major R&D issues

- Ring-ring:
  - The accommodation of synchrotron radiation power load on vacuum chamber. (To go beyond 5.e32 $cm^{-2}s^{-1}$ luminosity).
- Linac-ring:
  - High current polarized electron source
  - Energy recovery technology for high energy and high current beams
- 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

Summary

- Two design options for eRHIC are under development:
  ring-ring and linac-ring
  - Zero-degree design has been produced (ZDR, 2004).
  - Present development is towards more detailed conceptual design report.

- Ring-ring design is at present level of accelerator technology, but e-p luminosity of 1.e33 $cm^{-2}s^{-1}$ is difficult to achieve.

- At similar level of electron beam intensities the linac-ring design provides higher luminosity, but requires considerable R&D for polarized electron source.