High Luminosity Electron-Hadron Collider eRHIC

V. PTITSYN

ON BEHALF OF ERHIC DESIGN TEAM:

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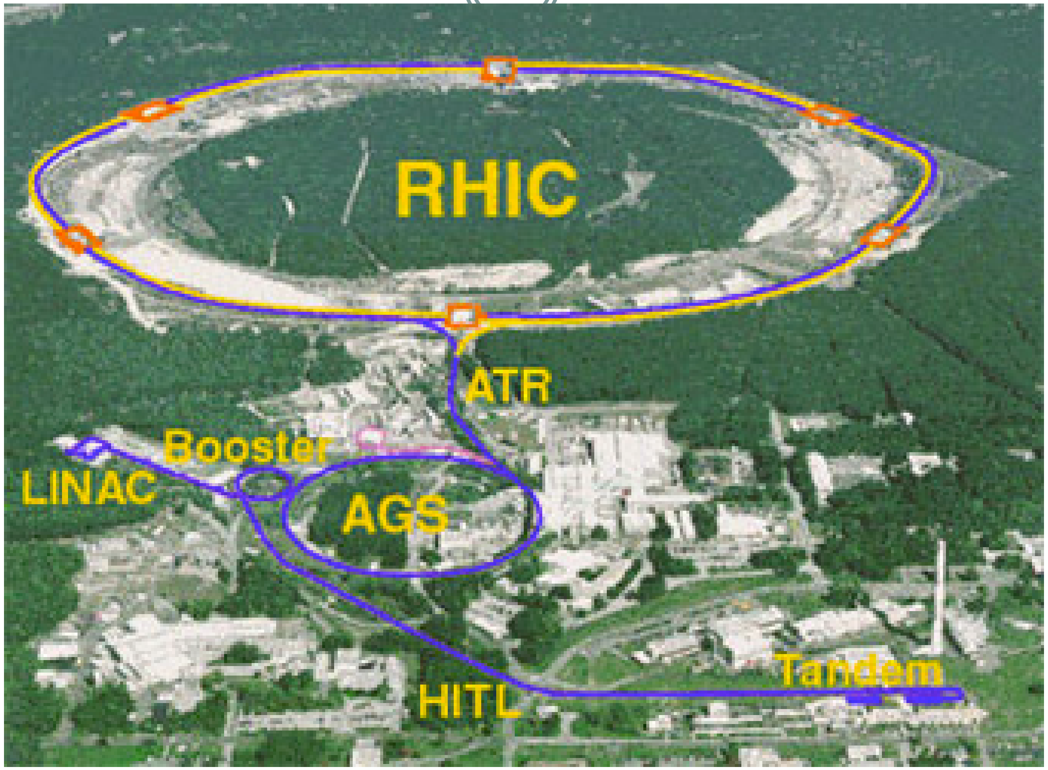
BROOKHAVEN NATIONAL LABORATORY

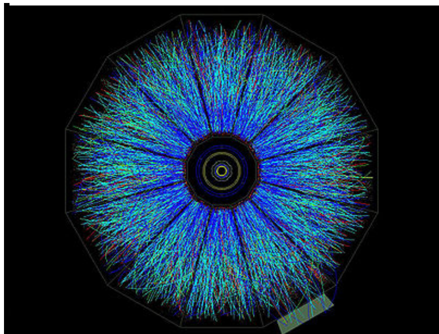
Office of Nuclear Physics — Exploring Nuclear Matter - Quarks to Stars

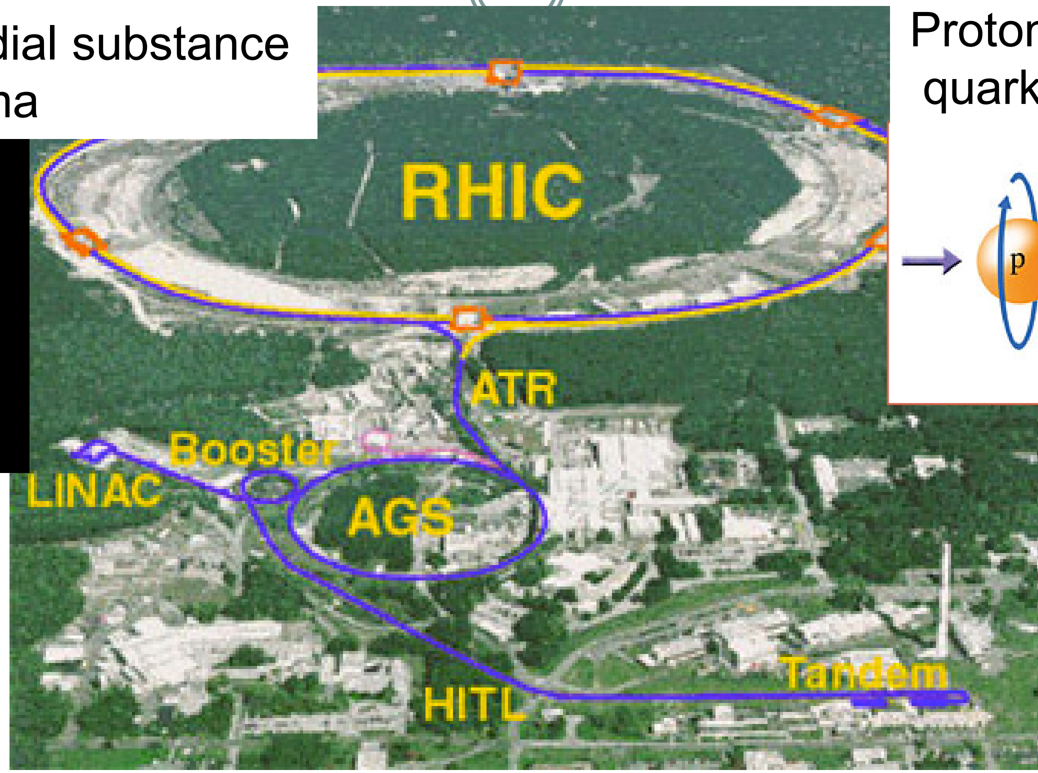
From RHIC to eRHIC



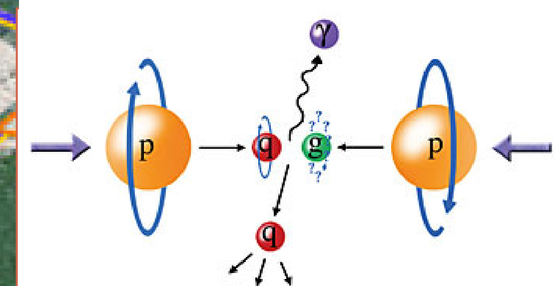
From RHIC to eRHIC

Superfluid primordial substance quark-gluon plasma





Proton spin: gluon spin, quark and antiquark



From RHIC to eRHIC

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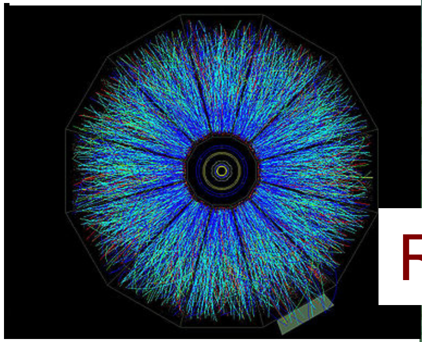
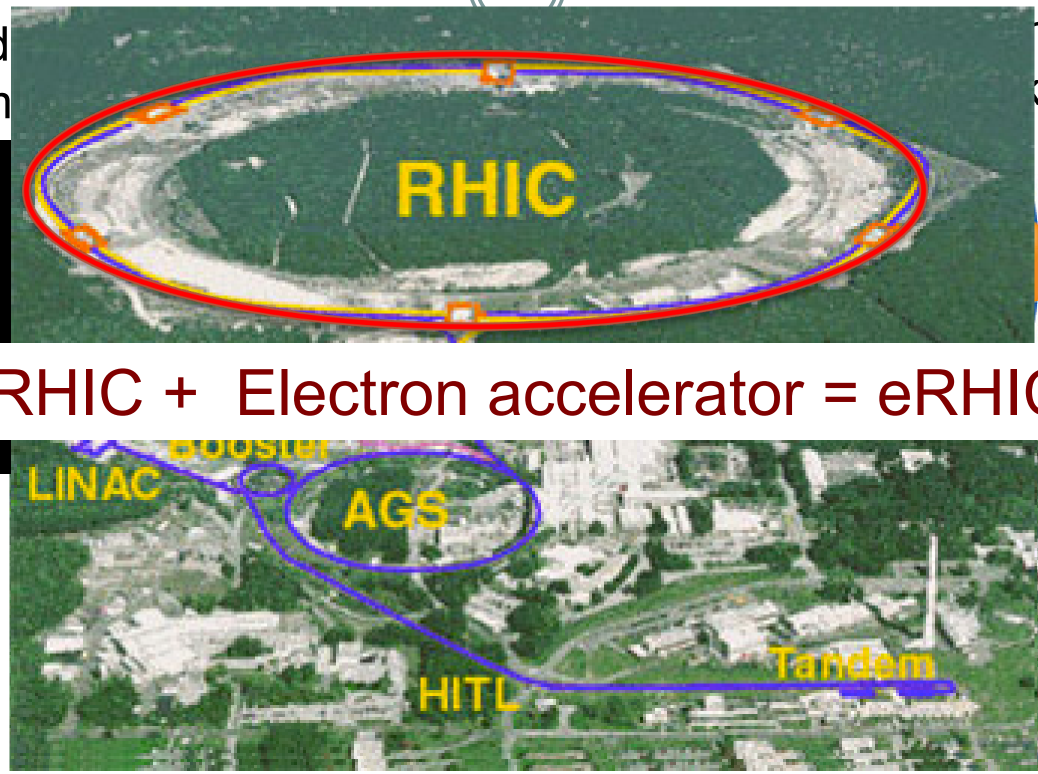
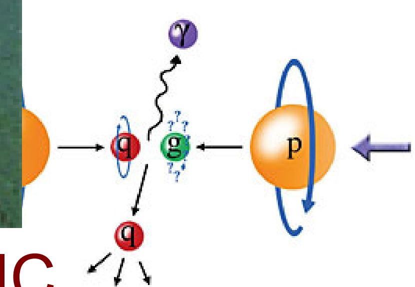
quark-gluon plasm





RHIC + Electron accelerator = eRHIC

n spin: gluon spin,
k and antiquark



From RHIC to eRHIC

Superfluid primord
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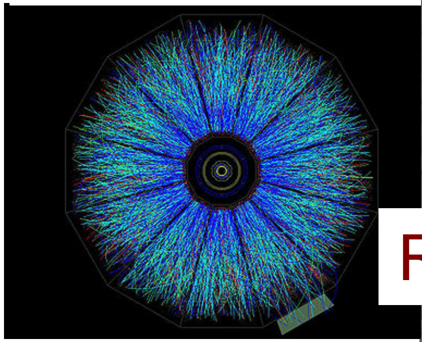

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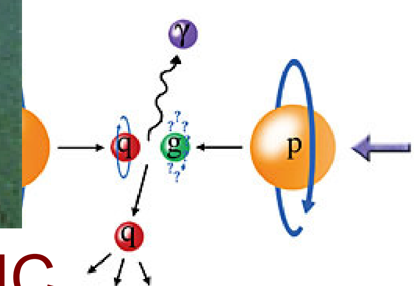

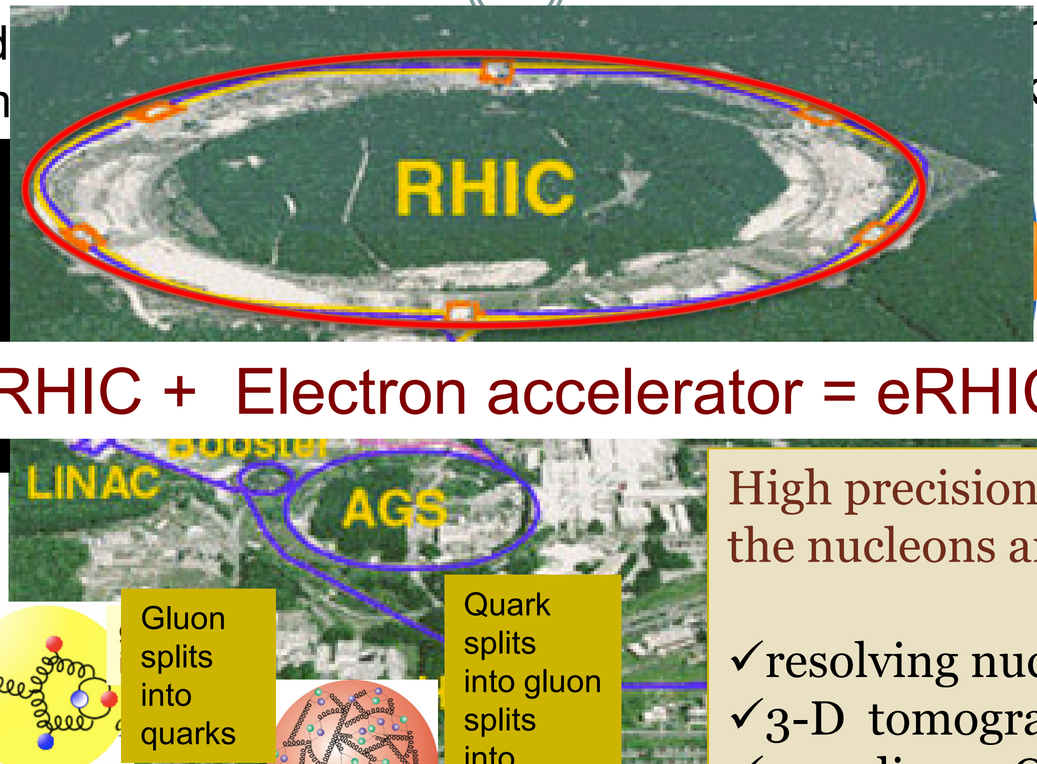

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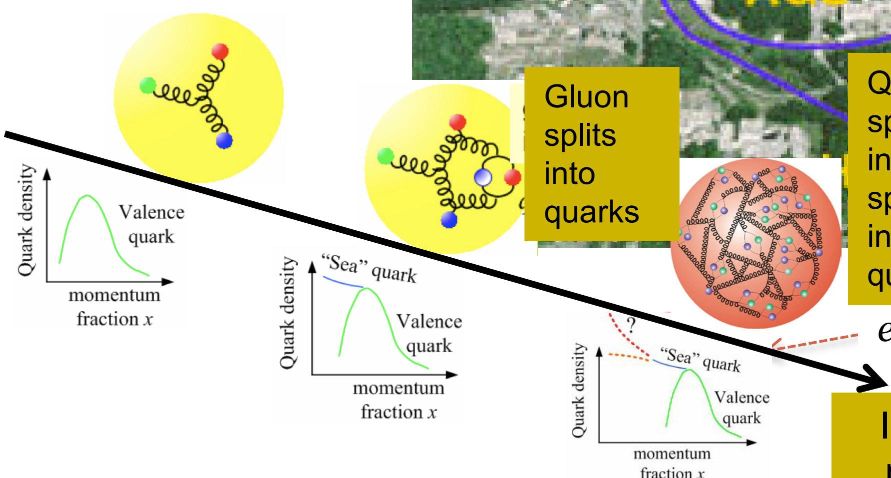


Gluon splits into quarks

Quark splits into gluon splits into quarks …

eRHIC

Increasing resolution

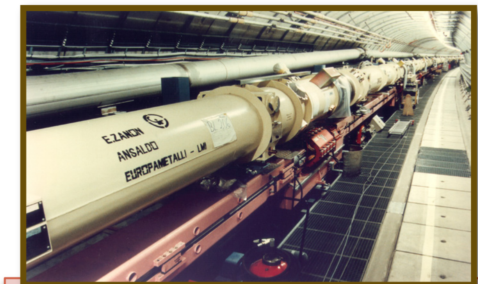
High precision microscope for the nucleons and nuclei:

✓resolving nucleon spin puzzle
✓3-D tomography of nucleons
✓ non-linear QCD regime of high gluon densities (saturation)

Design choices

L_{peak}, $cm^{-2}s^{-1}$ ~5 10^{31} ~4 10^{32} up to 1.5 10^{34}

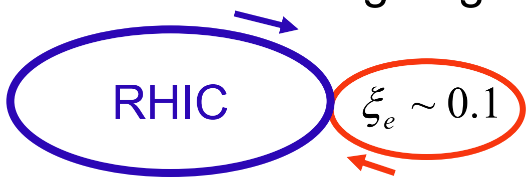
HERA



Compared with HERA eRHIC will have:

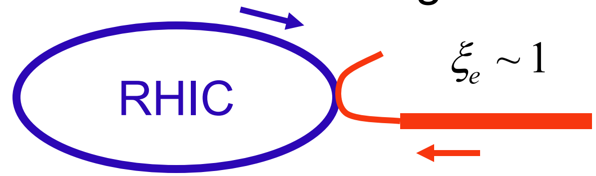
- Polarized proton and ^3He
- Heavy ion beams
- Considerably higher luminosity

eRHIC ring-ring



- 10 GeV storage ring
- ZDR in 2004
- Fundamental luminosity limits:
  - Beam-beam
  - SR power loss (total and per m)

eRHIC linac-ring



- Large allowed beam-beam on electrons
- Electron energy beyond 10 GeV
- Simple energy staging by increasing the linac length
- No e-polarization issues with spin resonances

Luminosity

Reaching high luminosity:

•high average electron current (50 mA = 3.5 nC * 14 MHz):
  •energy recovery linacs; SRF technology
  •high current polarized electron source
•cooling of the high energy hadron beams (Coherent Electron Cooling)
•β^*=5 cm IR with crab-crossing

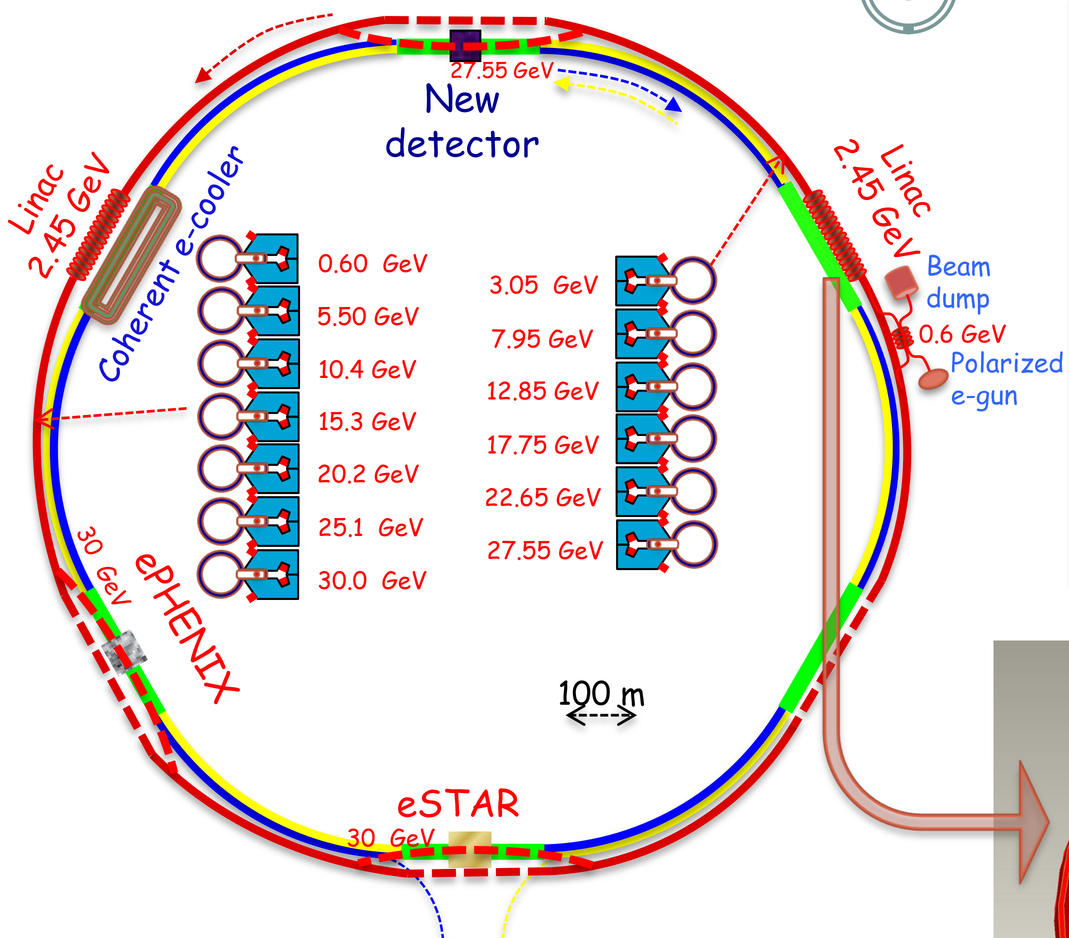
Limiting factors:
-hadron $\Delta Q_{sp} \leq 0.035$
-hadron $\xi \leq 0.015$
-polarized e current ≤ 50 mA
-SR power loss ≤ 7 MW

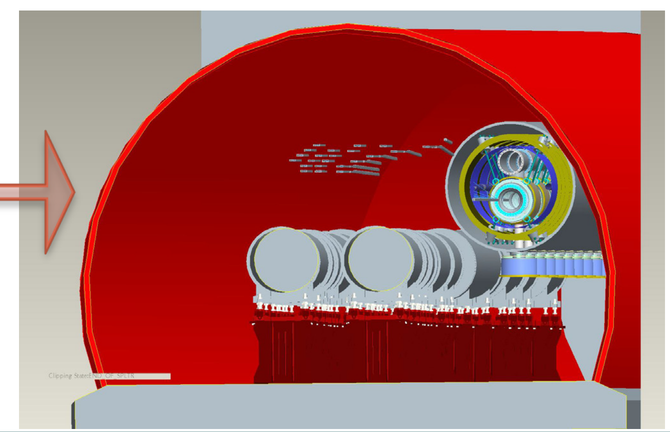
Polarized e-p luminosities in 10^{33} cm^{-2} s^{-1} units

		Protons					
	E, GeV	**50**	**75**	**100**	**130**	**250**	**325**
Electrons	**5**	0.07 7	0.26	0.62	1.4	9.7	15
	10	0.07 7	0.26	0.62	1.4	9.7	15
	20	0.07 7	0.26	0.62	1.4	9.7	15
	30	0.015	0.05	0.12	0.28	1.9	3

ERL-based eRHIC is a triple IP collider

5 to 30 GeV e⁻ x 325 GeV p - 130/u Au





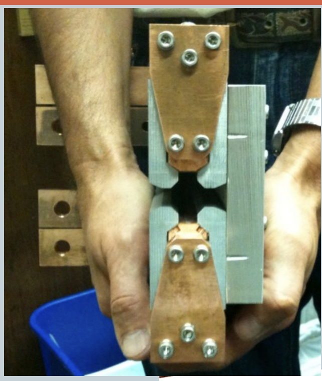
✓All-in tunnel staging approach uses two energy recovery linacs and 6 recirculation passes to accelerate the electron beam.

✓Staging: the electron energy will be increased in stages, from 5 to 30 GeV, by increasing the linac lengths .

✓Up to 3 experimental locations

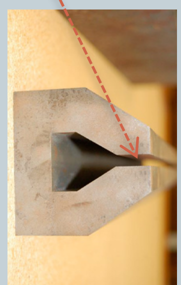
eRHIC R&D items

Compact magnets



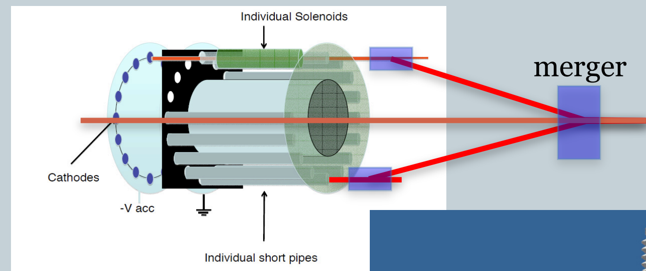
Y.Hao,
G.Mahler,
V.Litvinenko

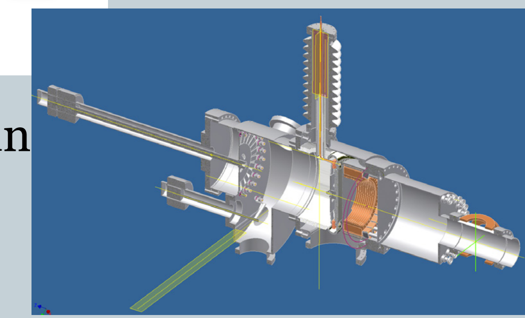
Gap 5 mm total
0.3 T for 30 GeV



- More than 14000 magnets in electron beam lines
- Small gap -> efficient and inexpensive-> low cost eRHIC
- Dipole, quadrupole and vacuum chamber prototypes have been constructed
- Magnetic measurements : dipole prototype meets specification

50 mA polarized electron source





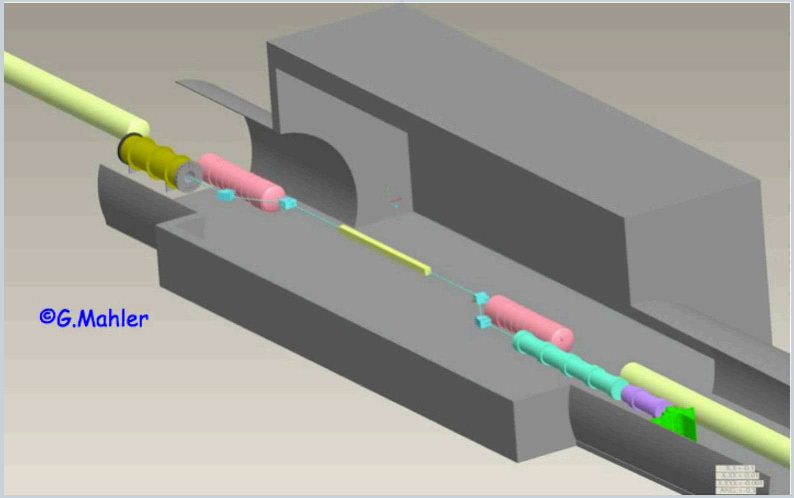
BNL Gatling Gun
the current from multiple cathodes is merged

- Mechanical design has been developed
- Ready for prototype construction
- X.Chang et al. WEP263

- **Alternative development by MIT: large cathode gun (E. Tsentalovich).**
  Also ready to built the prototype

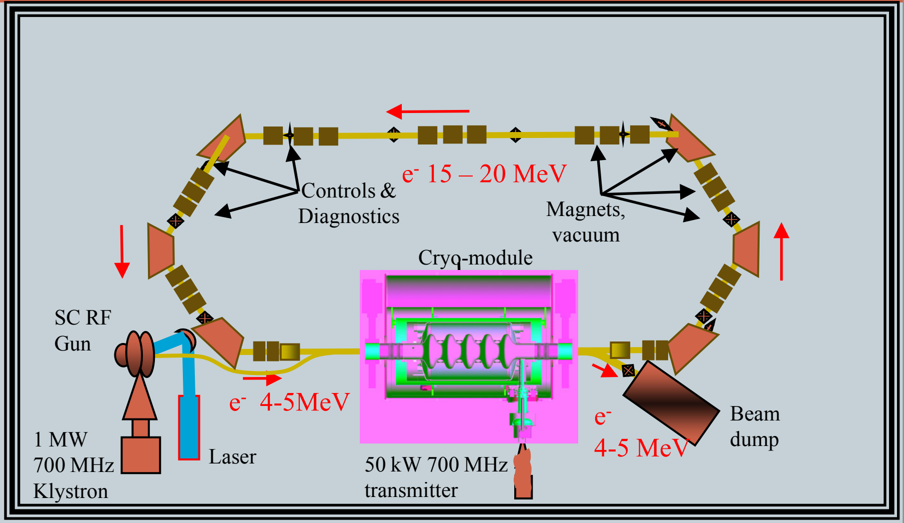
R&D test facilities

PoP of Coherent Electron Cooling



- DOE funded
- Collaboration: BNL, Jefferson Lab, Tech-X Corporation
- Projected dates: 2013-2014
- Aim : to demonstrate cooling
- G. Wang et al., THOBN3

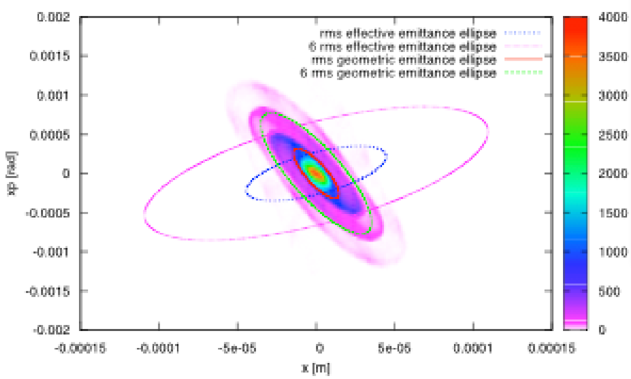
Energy Recovery Linac



- E=20 MeV
- The energy recovery with high beam current (up to 0.5 A CW)
- First tests later this year
- D. Kayran et al., THP006

Design Study Highlights

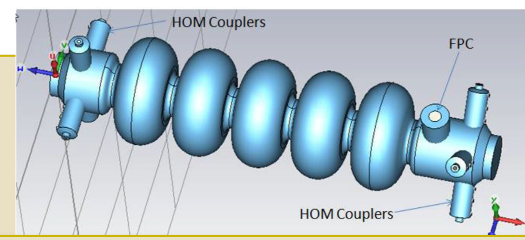
Disruption simulations; D=140



Beam-beam simulations: disruption, kink instability, parameter fluctuations.

Hadron beam kink instability feedback :
Y. Hao et al., TUOAN4

- HOM tolerances from BBU simulations
- Up to 12.3MeV/m real estate gradient
- Compact cryostat; No quadrupoles in the linacs



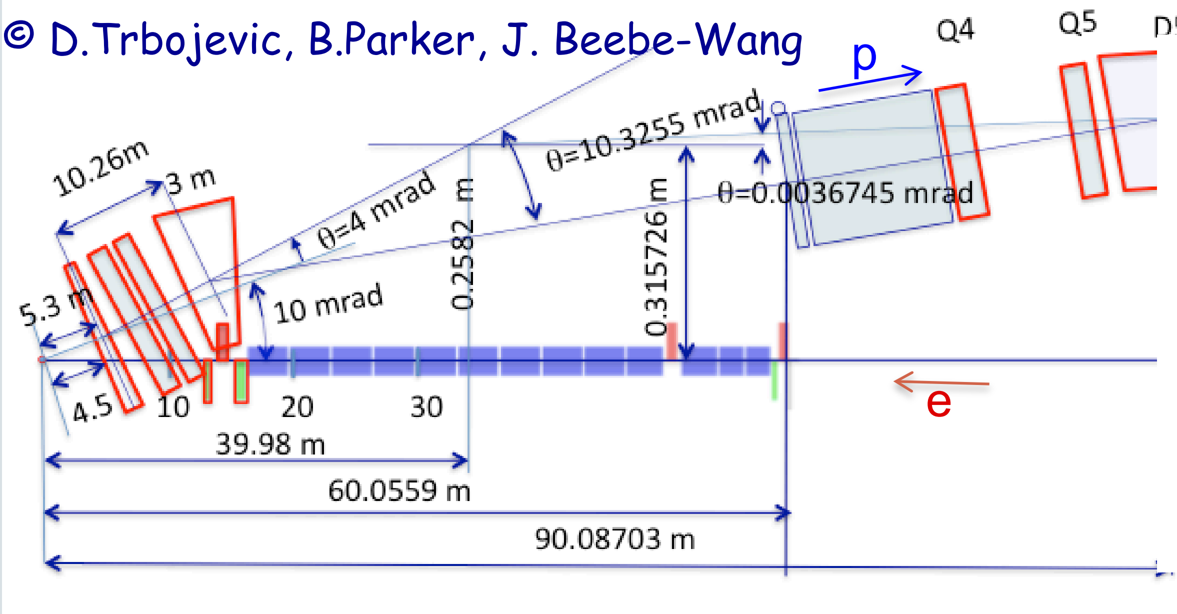
New design of 704 MHz cavity (BNL III):
-reduced peak surface magnet field
-reduced cryogenic load
Wencan Xu et al., FROBS6

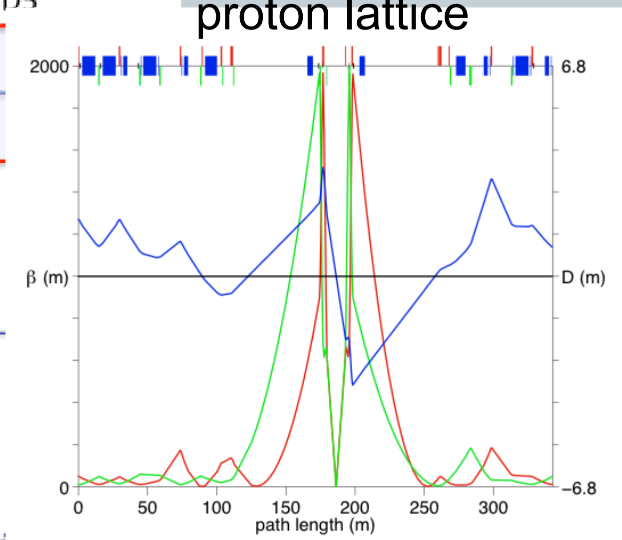
•Energy loss and energy spread compensation.
•How small can be beam pipe size?
Surface roughness effect (the experiment planned at BNL ATF with extruded Al pipe)

•CSR shielding effect on the energy spread
(V. Yakimenko et al., WEP107)

Lattice: D. Trbojevic et al., next talk

The design of high-lumi IR with β*=5 cm





- 10 mrad crossing angle and crab-crossing
- High gradient (200 T/m) large aperture Nb_3Sn focusing magnets
- Arranged free-field electron pass through the hadron triplet magnets
- Integration with the detector: efficient separation and registration of low angle collision products
- Gentle bending of the electrons to avoid SR impact in the detector

Summary

- ✓ The design of eRHIC is well advanced.
- ✓ The eRHIC luminosity in ERL-based design reaches above 10^{34} cm^{-2} s^{-1}.
- ✓ The electron lattice and interaction region design have been developed, and critical beam dynamics issues have been evaluated.
- ✓ Considerable progress on crucial R&D items has been achieved: polarized source; compact magnets; cavities and cryomodule.
- ✓ Important conceptual tests are in preparation: CeC and the ERL facility.