Electron Ion Collider : machine and detector status

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IPNO, GDR workshop
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- Introduction
- Accelerator concepts at JLab and RHIC
- Detector design for an EIC
- Current work and planning
- Conclusion

BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab
EXPLORING THE NATURE OF MATTER

DISCLAIMER

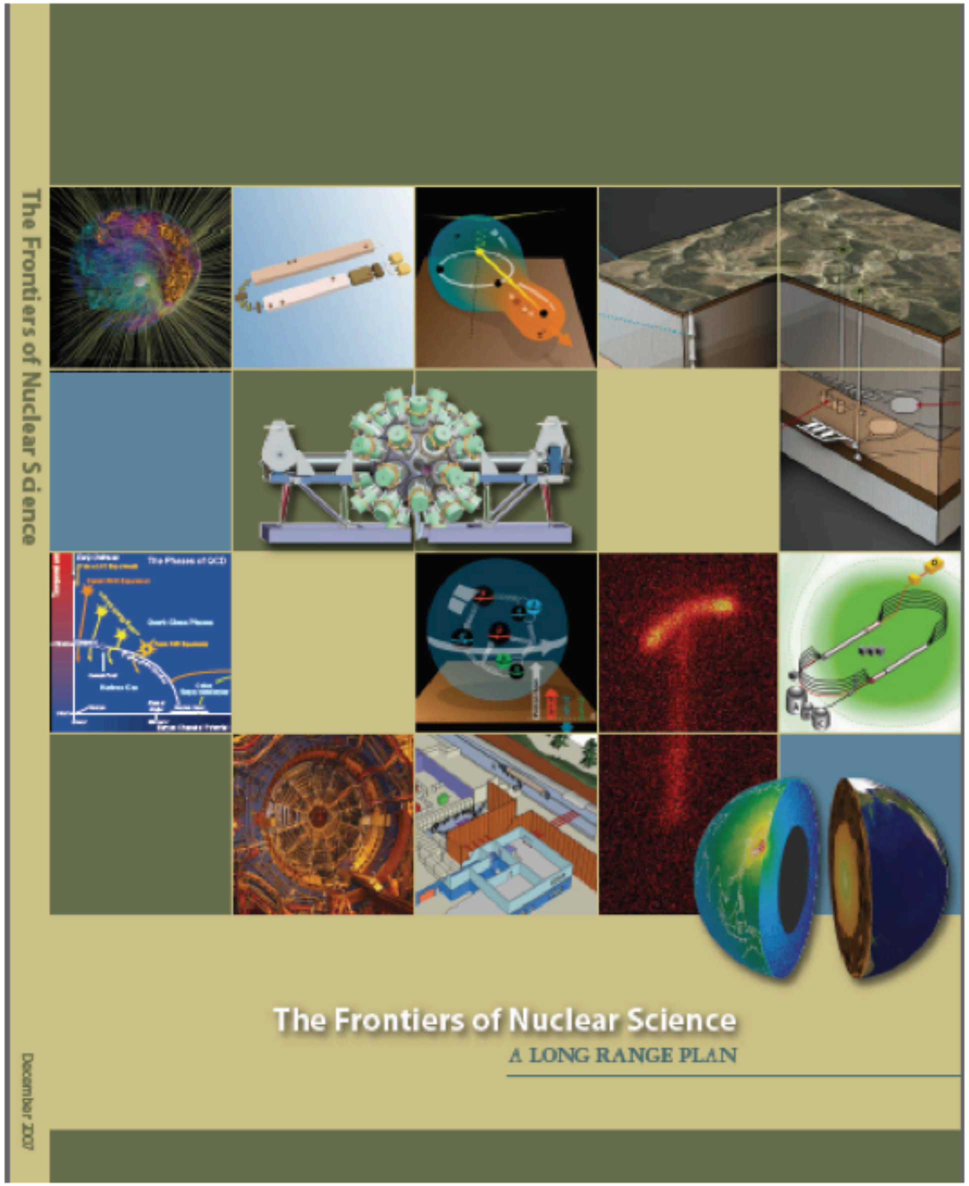
I AM NOT (yet) AN EXPERT !

Information compiled from selected
presentations at the INT 2010 workshop
(in particular : A. Deshpande, R. Ent, T. Horn)

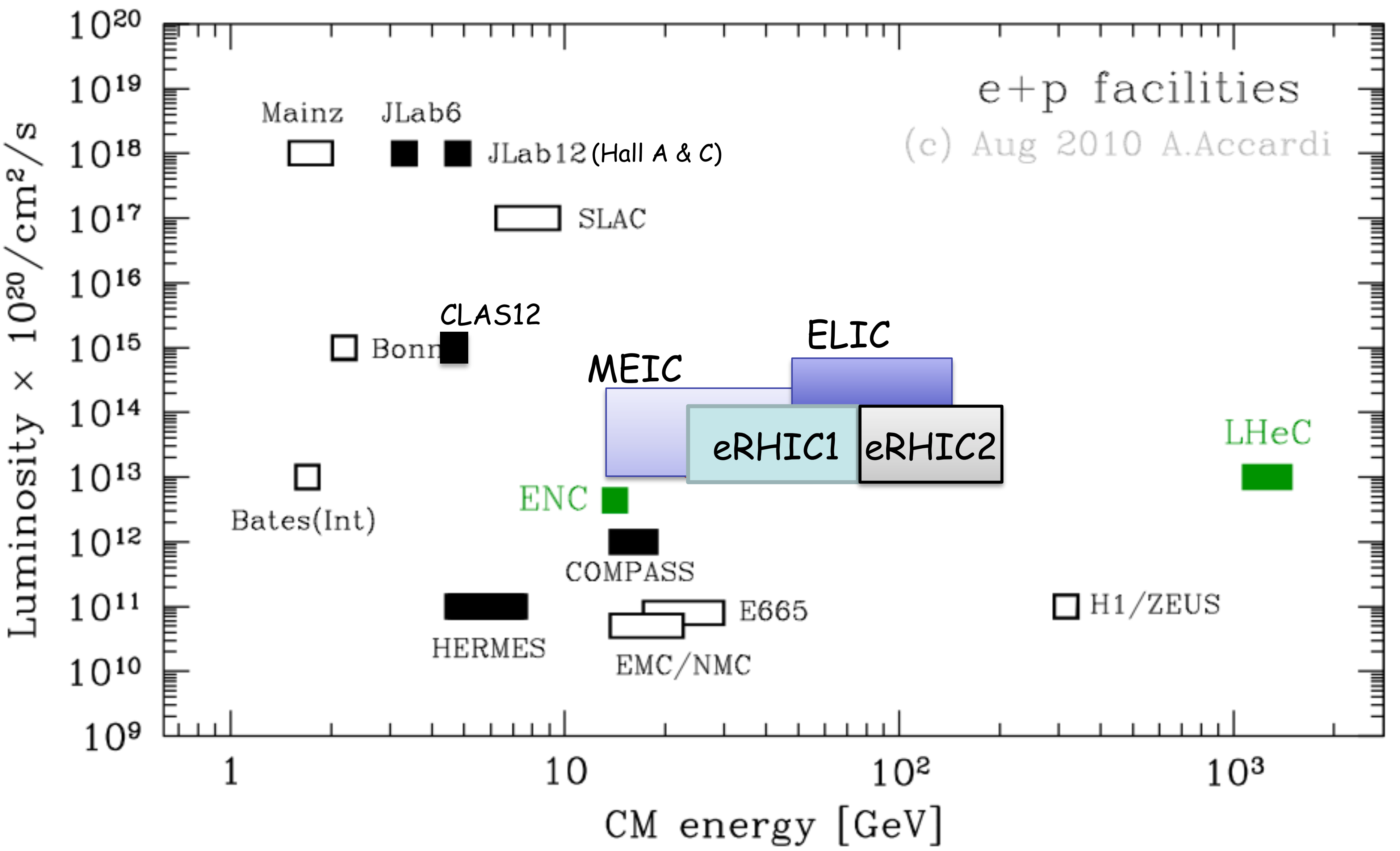
Official start : NSAC 2007 Long Range Plan

"An **Electron-Ion Collider (EIC)** with polarized beams has been **embraced by the U.S. nuclear science community** as embodying the vision for **reaching the next QCD frontier**. EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and complementary to those planned for the next generation of accelerators in Europe and Asia. In support of this new direction:

We recommend the allocation of resources to develop accelerator and detector technology necessary to lay the foundation for a polarized Electron Ion Collider. The EIC would explore the new QCD frontier of strong color fields in nuclei and precisely image the gluons in the proton."



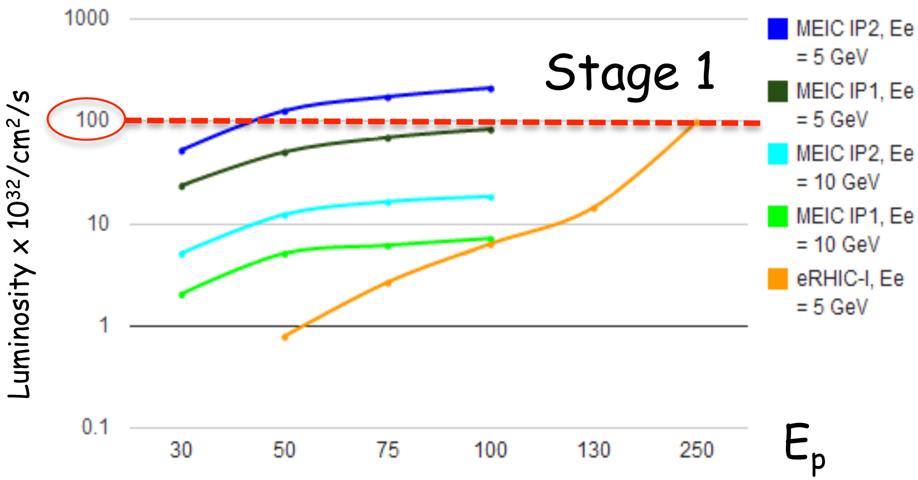
Lepton-Proton/Ion machines world-wide

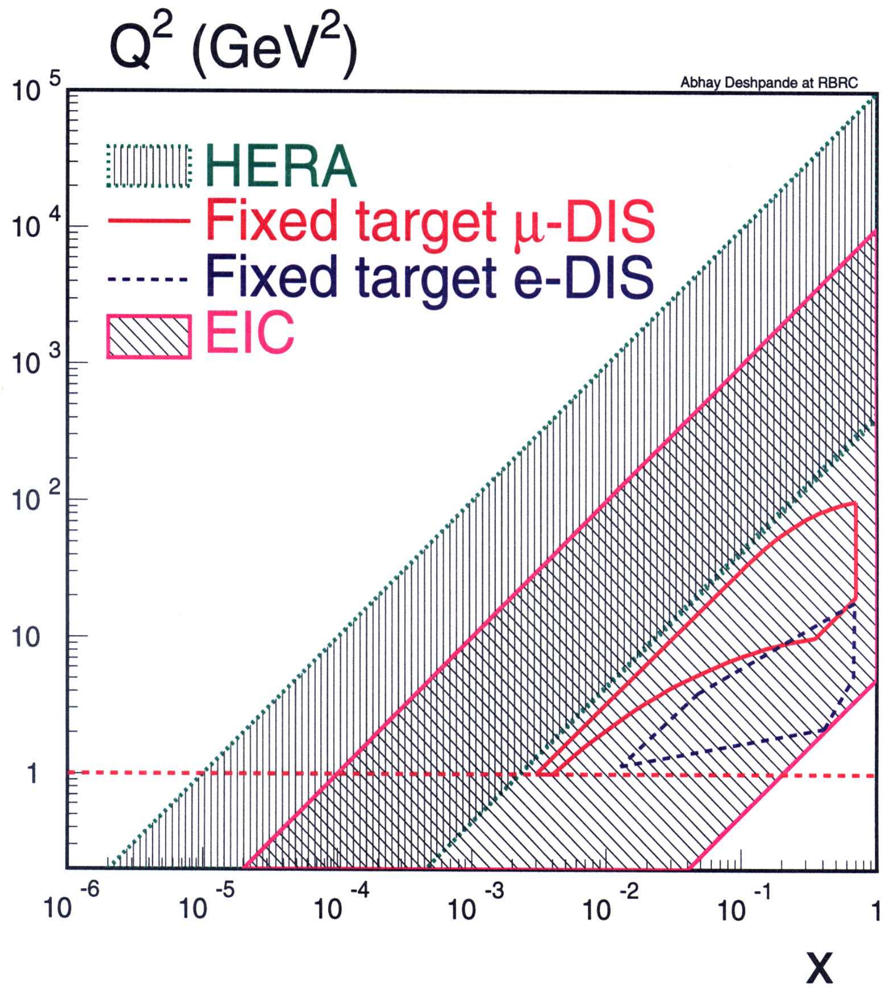


Basic machine parameters

Base EIC Requirements *per Executive Summary INT Report :*

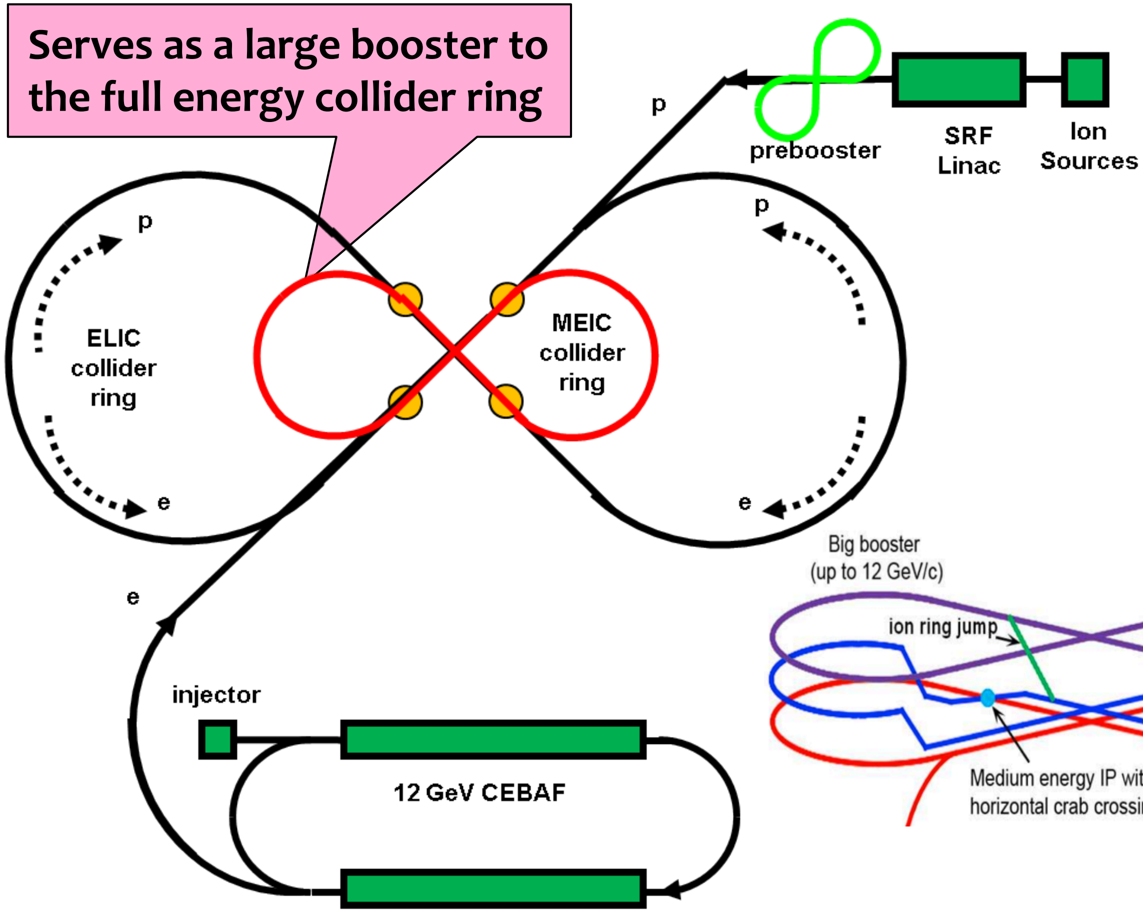
- Range in cm energies $\sqrt{s}$~20-70 & variable
- Fully-polarized (>70%), longitudinal and transverse
- Ion species up to A = 200 or so
- High luminosity: **about 10^{34}** e-nucleons cm^{-2} s^{-1}
- Multiple interaction regions
- Upgradable to higher energies

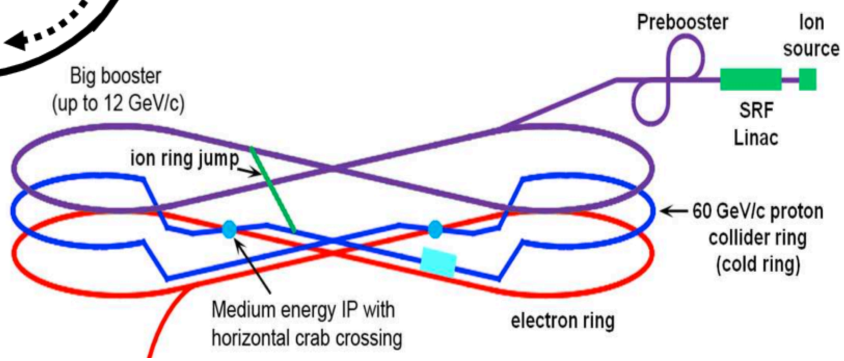




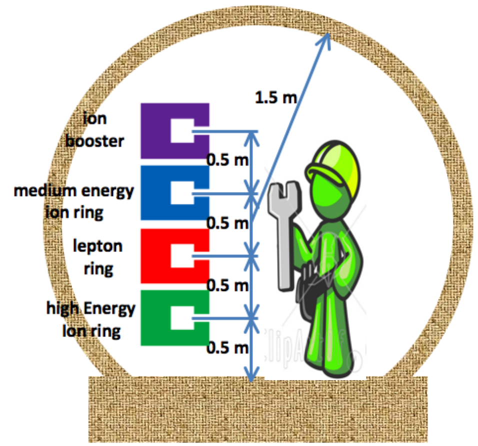
JLab : 749MHz
RHIC : 13.5 MHz

JLab design, Stages 1 (MEIC) & 2 (ELIC)

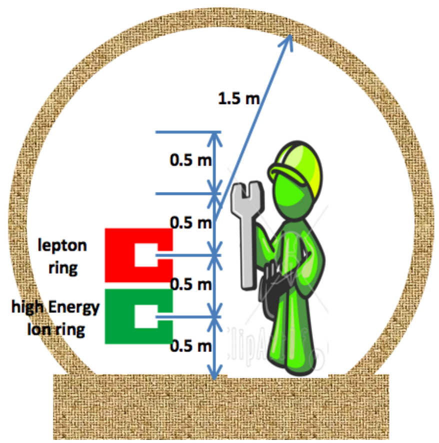




Straight section



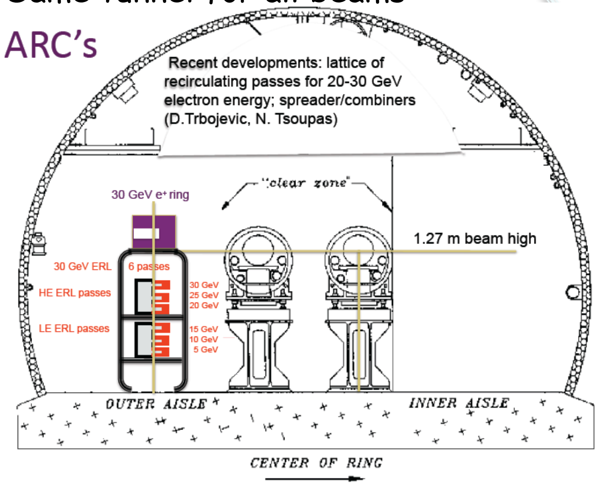
Arc

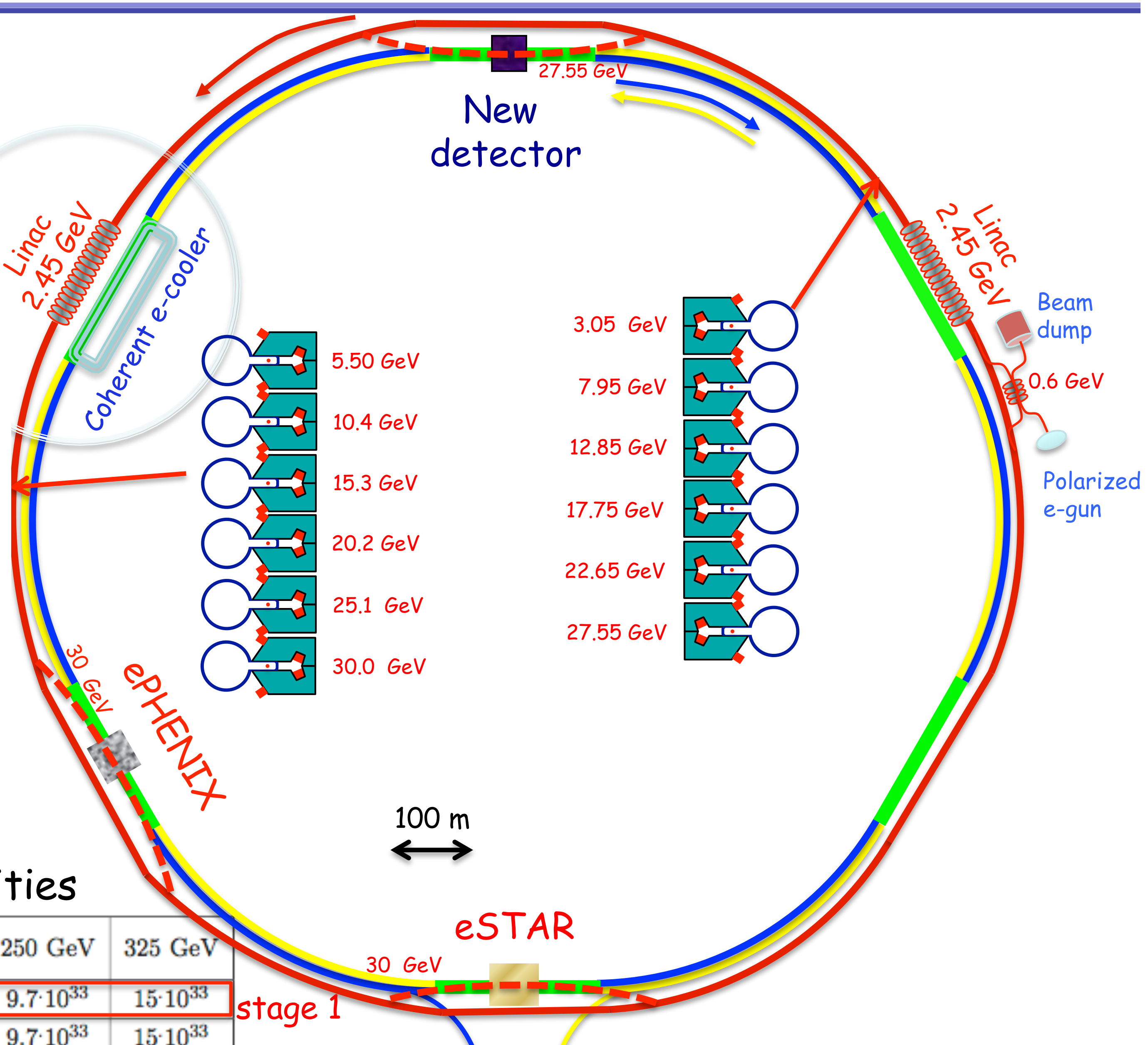


Stage	Max. Energy (GeV/c)		Ring Size (m)	Ring Type		IP #
	p	e		p	e	
Medium	96	11	1000	Cold	Warm	3
High	250	20	2500	Cold	Warm	4

RHIC realization

Same tunnel for all beams





polarized e & p luminosities

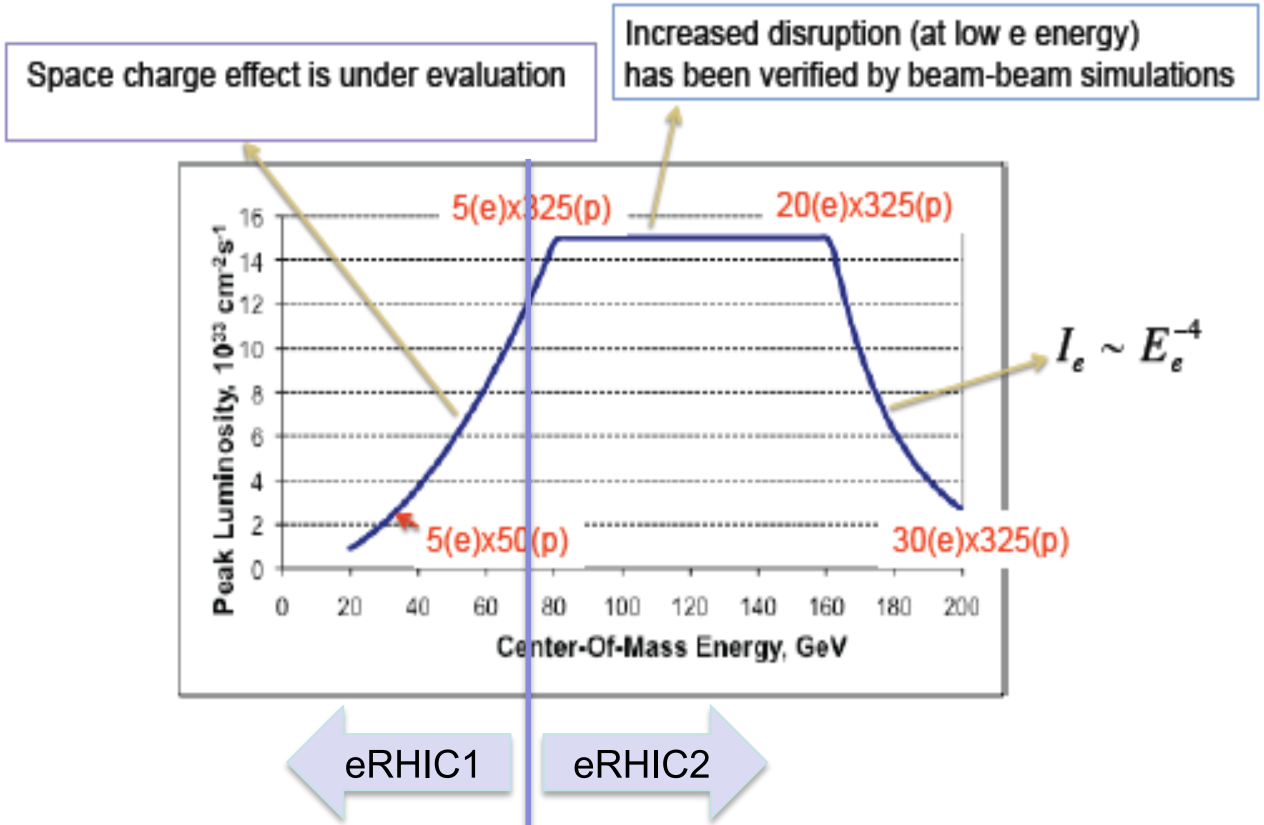
Electrons \ Protons	100 GeV	130 GeV	250 GeV	325 GeV
5 GeV	$0.62 \cdot 10^{33}$	$1.4 \cdot 10^{33}$	$9.7 \cdot 10^{33}$	$15 \cdot 10^{33}$
10 GeV	$0.62 \cdot 10^{33}$	$1.4 \cdot 10^{33}$	$9.7 \cdot 10^{33}$	$15 \cdot 10^{33}$
20 GeV	$0.62 \cdot 10^{33}$	$1.4 \cdot 10^{33}$	$9.7 \cdot 10^{33}$	$1.5 \cdot 10^{33}$
30 GeV	$0.12 \cdot 10^{33}$	$0.3 \cdot 10^{33}$	$1.9 \cdot 10^{33}$	$3 \cdot 10^{33}$

stage 1

$E_e \leq 30$ GeV and $E_p \leq 325$ GeV
or $E_A \leq 130$ GeV/u

eRHIC staged installation

Luminosity vs. √s



Stage 1 eRHIC:
ePHENIX & eSTAR
5 GeV e^- beam

Stage 2 eRHIC:
Dedicated eRHIC detector
20-30 GeV e^- beam

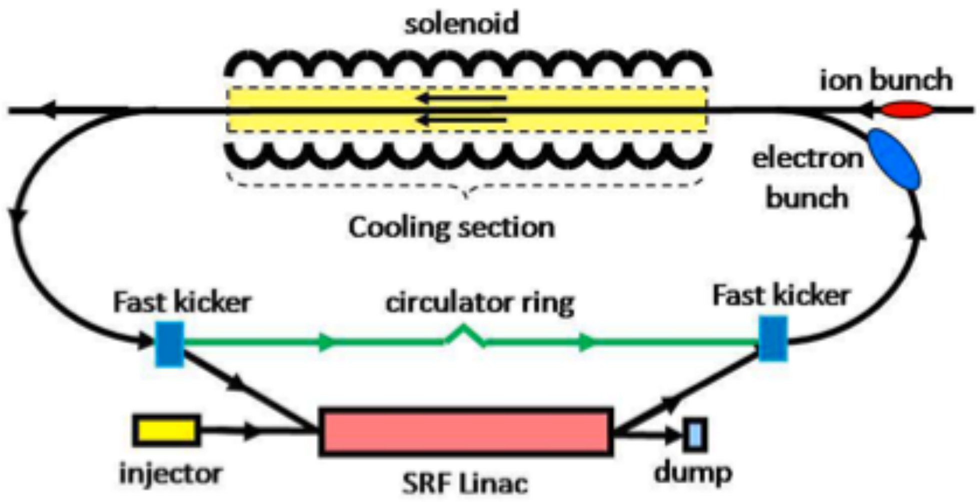
The key for high luminosity : electron cooling

Electron cooling is a means to increase the phase space density of a stored ion beam. It is crucial to reduce the bunch length and suppress the intra-beam scattering induced beam heating and emittance growth in collision mode. It is a necessity to achieve high luminosity.

How to :

- Mono-energetic cold electron beam is merged with ion beam which is cooled through Coulomb interaction.
- Electron beam is renewed and the velocity spread of the ion beam is reduced in all three planes.

Difficult R&D for JLab, even more so for RHIC because electron cooling efficiency drops as momentum squared.



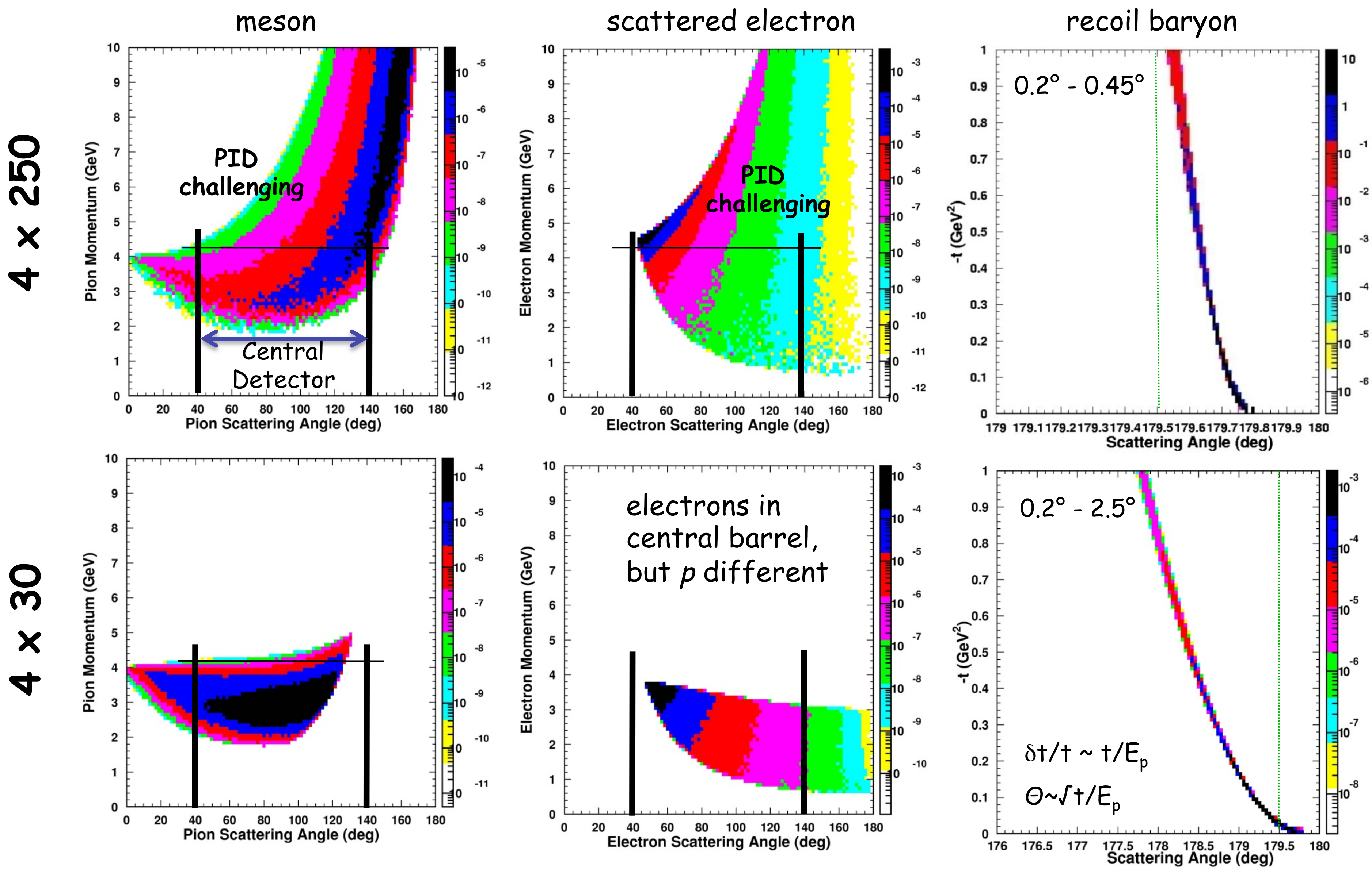
EIC detector requirements

Mostly driven by exclusive or semi-inclusive physics

- Hermeticity (also for hadronic reconstruction methods in DIS)
- Particle identification (needed for SIDIS too)
- Momentum resolution
- Forward detection of recoil baryons (also baryons from nuclei)
- Muon detection (J/Ψ)
- Photon detection (DVCS, π^0)
- Very forward detection (spectator tagging, diffractive mechanisms, coherent nuclear, etc)
- Vertex resolution (displaced vertex, i.e. charm)
- Hadronic calorimetry (jet)

In general, e-p and even more e-A colliders have a large fraction of their science related to the detection of what happens to the ion beams. The struck quark remnants can be guided to go to the central detector region with Q^2 cuts, but the spectator quark or struck nucleus remnants will go in the forward (ion) direction.

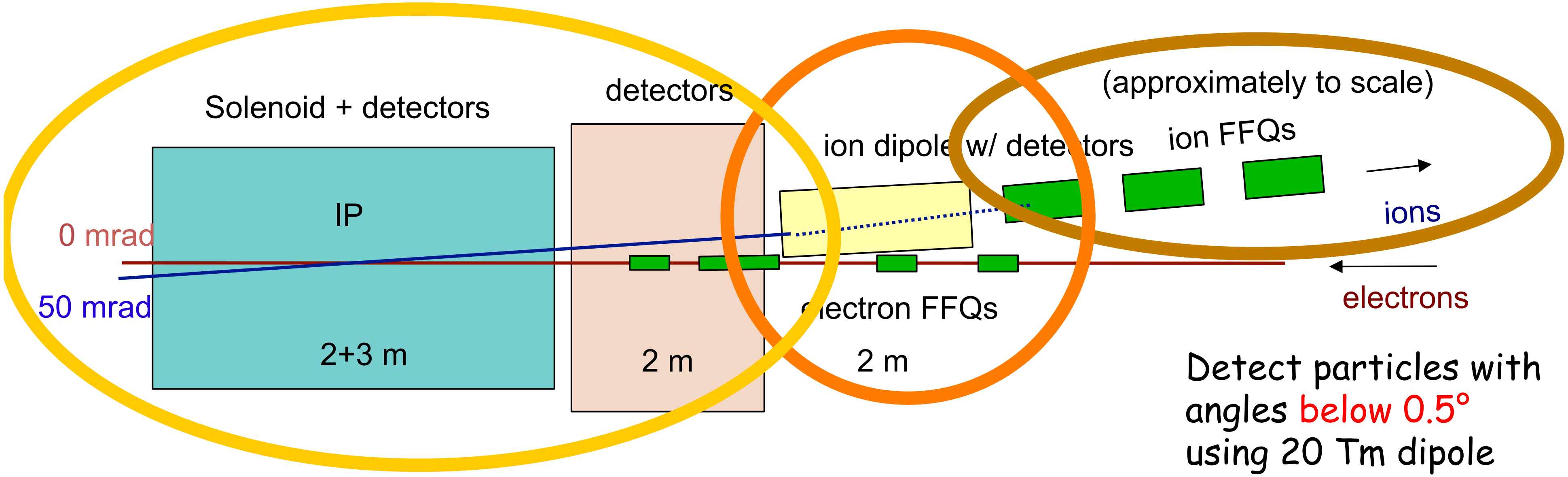
Example : light meson electroproduction



Challenges: PID for e- and mesons in central region,
very low angle baryon detection (need 0.2-5° with 1mr resolution !)

MEIC/ELIC detector : Recoil baryon detection

Three-stage strategy using 50 mrad crossing angle



Central detector, more detection space in ion direction as particles have higher momenta.

Detect particles with angles down to 0.5° (10 mrad) before ion FFQs.

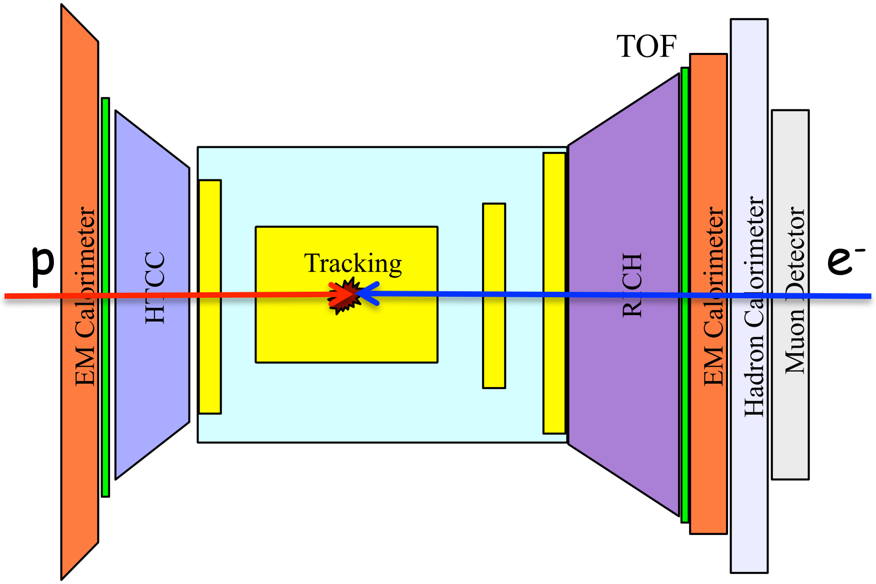
Need 2 Tm dipole (for 100 GeV proton beams) in addition to central solenoid.

Detect particles with angles below 0.5° using 20 Tm dipole beyond ion FFQs.

MEIC/ELIC detector : Endcaps

Electron side (left)

- Bore angle: ~45° (line-of-sight from IP)
- High-Threshold Cerenkov (e/π)
- Time-of-Flight Detectors
  - Hadrons, event reconstruction, trigger
- Electromagnetic Calorimeter (e/π)



Ion side (right)

- Bore angle: 30-40° (line-of-sight from IP)
- Ring-Imaging Cerenkov (RICH)
- Time-of-Flight Detectors (event recon., trigger)
- Electromagnetic Calorimeter
  - Pre-shower for γ/π° -> γγ
  - (very small opening angle at high p)
- Hadronic Calorimeter (jets)
- Muon detector (J/Ψ production at low Q^2)

Space constraints

- Electron side has a lot of space
- Ion side limited by distance to FFQ quads (7 m)

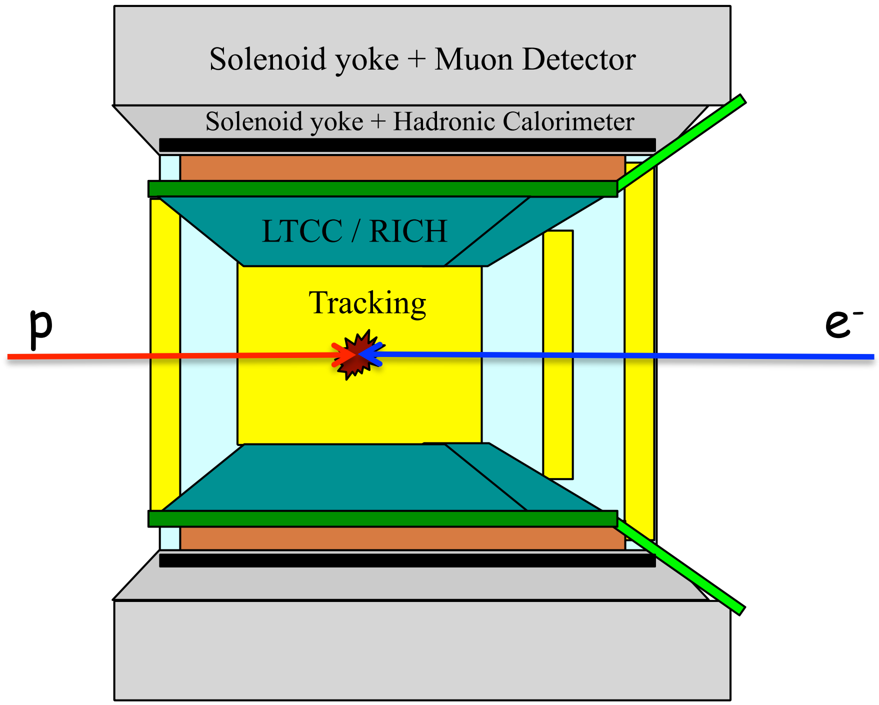
MEIC/ELIC detector : Central Detector

Solenoid Yoke, Hadron Calorimeter, Muons

- 3-4 T solenoid with about 4 m diameter
- Hadronic calorimeter and muon detector integrated with the return yoke (*à la* CMS)

Particle Identification

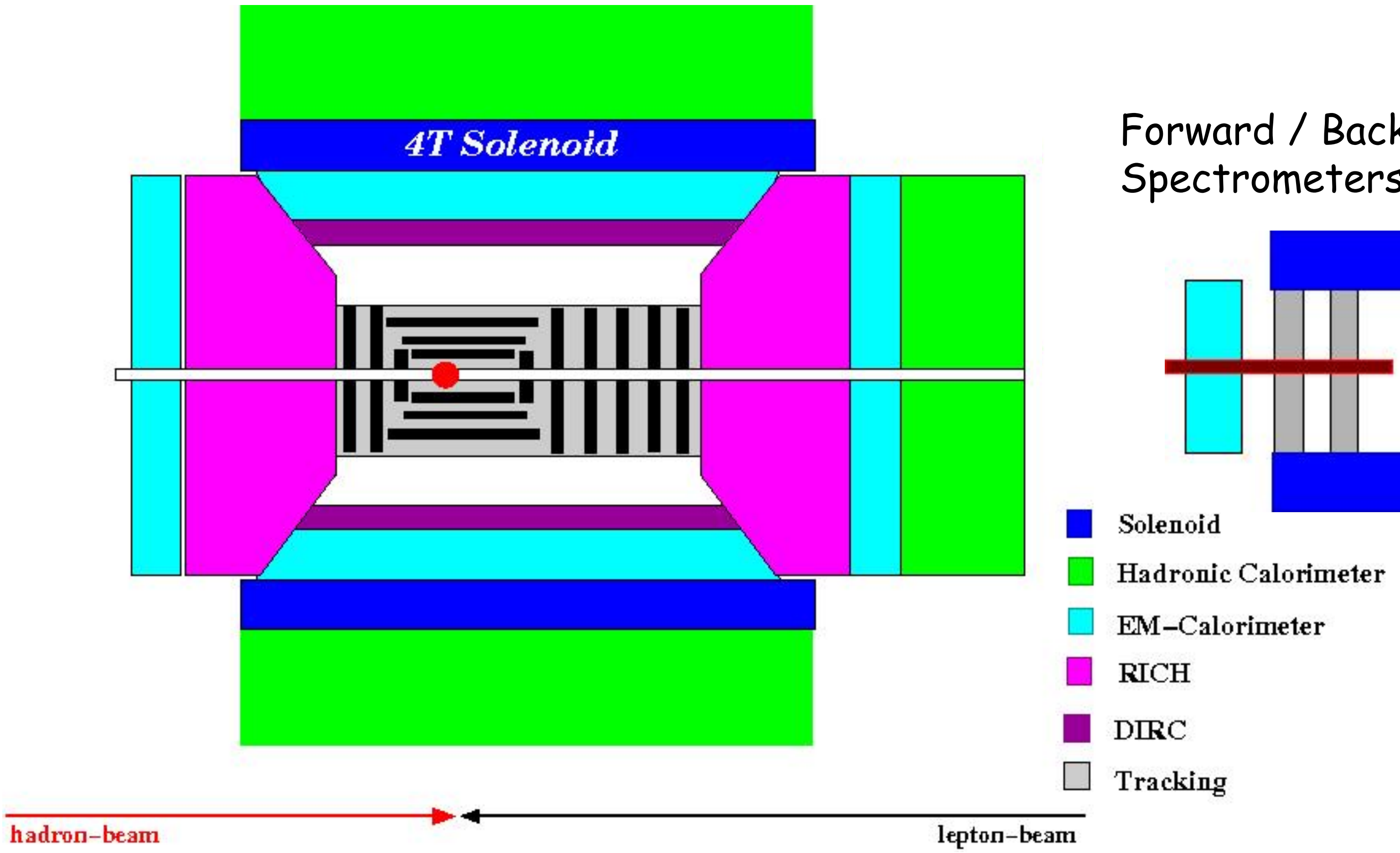
- TOF for low momenta
- π/K separation options
  - DIRC up to 4 GeV
  - DIRC + LTCC (or RICH): up to 9 GeV
- p/K separation
  - DIRC up to 7 GeV
- e/π separation
  - C_4F_8O Low Threshold CC up to 3 GeV



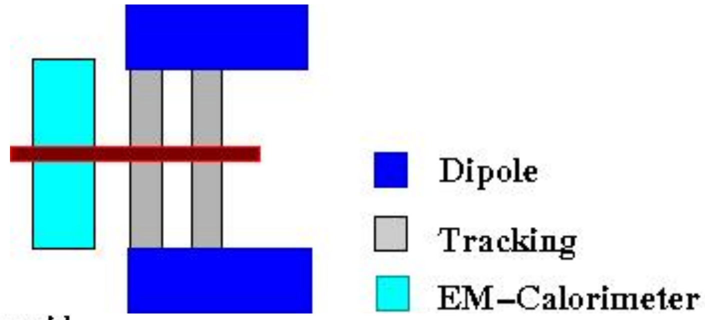
Tracking

- Low-mass vertex tracker
- GEM-Micromegas-based central tracker
- Endcap trackers

Stage 2 eRHIC : New detector

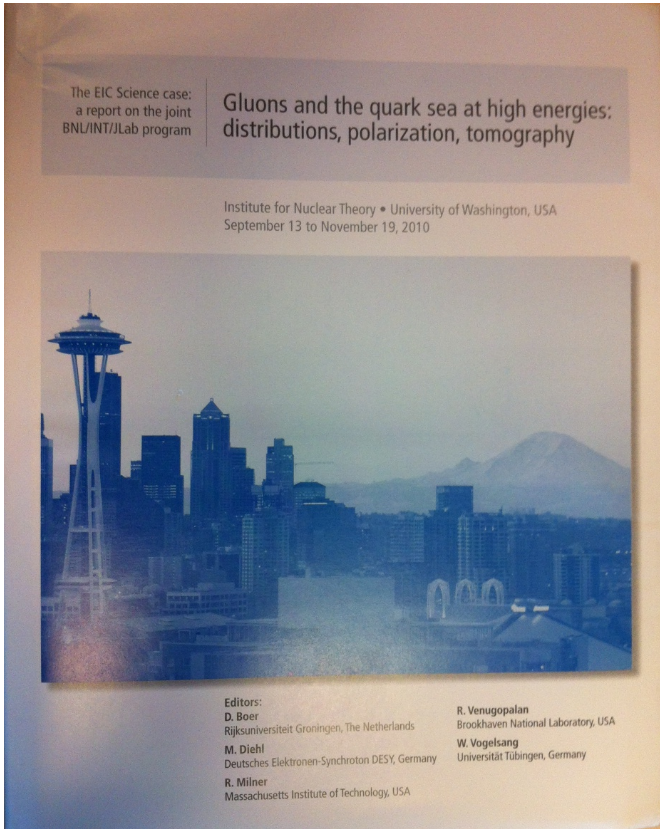


Forward / Backward Spectrometers:



High acceptance -5 < η < 5 central detector
Good PID and vertex resolution
Tracking and calorimeter coverage the same → good momentum resolution, lepton PID
Low material density → minimal multiple scattering and bremsstrahlung
Very forward electron and proton detection → maybe dipole spectrometers

What is happening right now



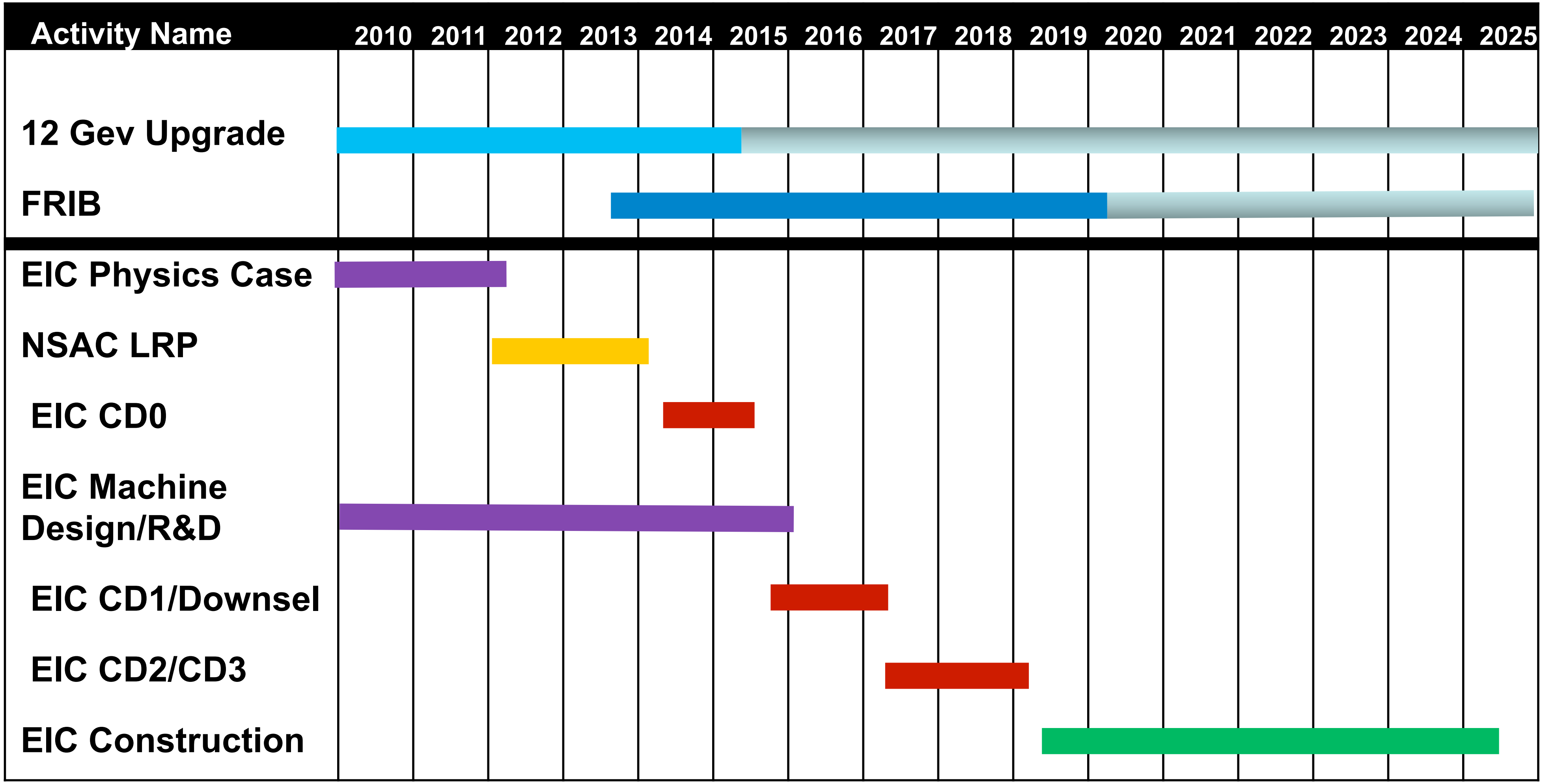
- Just published INT report arXiv:1108.1713v1 (Gluons and the quarks sea at high energies: distributions, polarization, tomography)

- R&D proposal calls at BNL for Nov. 14th

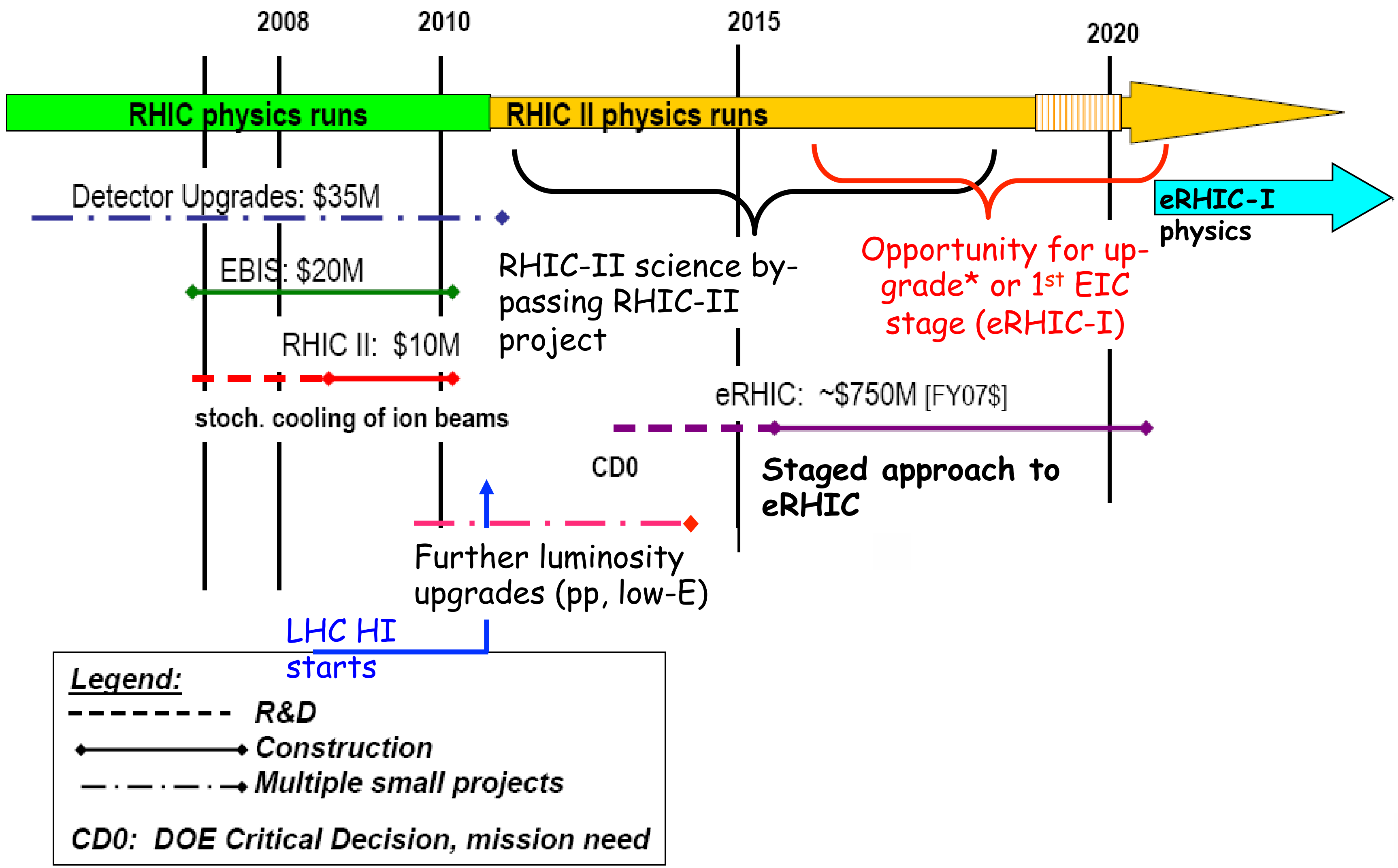
- Currently working on EIC White Paper for NSAC Long Range Plan 2013

Steering committee: A. Deshpande (Stony Brook), Z-E. Meziani (Temple), J. Qiu (BNL), T. Ullrich (BNL), Y. Kovchegov (Ohio State), E. Sichtermann (LBNL), W. Vogelsang (Tubingen), M. Diehl (DESY), F. Sabatié (Saclay), H. Gao (Duke), F. Yuan (LBNL), K. Kumar (U Mass), M. Ramsey-Musolf (Wisconsin), A. Hutton (Jlab), T. Roser (BNL), E. Aschenauer (BNL), T. Horn (CUA), A. Mueller (Columbia), R. Holt (ANL)

Realization of an EIC at JLab



Realization of an EIC at RHIC



Conclusion & Outlook

Exciting new science (C. Marquet's talk) with an exciting and challenging accelerator/detector project.

Two competing projects at JLab and RHIC using existing facilities.

White paper writing in progress, will be discussed at NSAC Long Range Plan in 2012-2013.

CD0 as early as 2014 if all goes well, will need a choice of location by then. For now, project completion foreseen for 2022-2025.

Europe's involvement is still low on the experimental side (plenty of interested theorists however).

Anyone is welcome to join the effort !