# Nuclear Physics Planning for an Electron-Ion Collider

*Steve Vigdor*

*Workshop on Electron-Nucleus Collider Physics*

*Rockefeller University, May 14, 2010*


**"An EIC with polarized beams has been embraced by the U.S. nuclear science community as embodying the vision for reaching the next QCD frontier."**

**How can we realize this vision?**

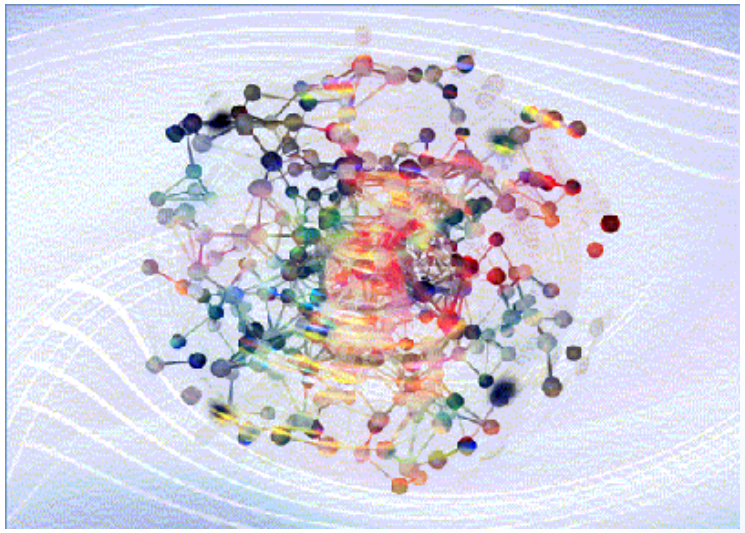
BROOKHAVEN NATIONAL LABORATORY

*a passion for discovery*

Office of Science
U.S. DEPARTMENT OF ENERGY

# EIC ⇒ Important Extension of RHIC Science

*"Condensed matter physics with a force of a different color"*

**What are the unique quantum many-body manifestations of a *non-Abelian* gauge theory? Are there lessons for other fundamental (e.g., EW) theories, that are harder to subject to laboratory investigation?**

1) ***Does asymptotic freedom ⇒ dense (in color charge) ideal gas QGP? Find "near-perfect" strongly correlated liquid behavior instead !***

2) ***Does rich vacuum structure ⇒ sphalerons near QGP transition & local symmetry violation? Observed behavior consistent with local (chiral magnetic) P- and CPV; ~ B-violation @ EW phase transition?***

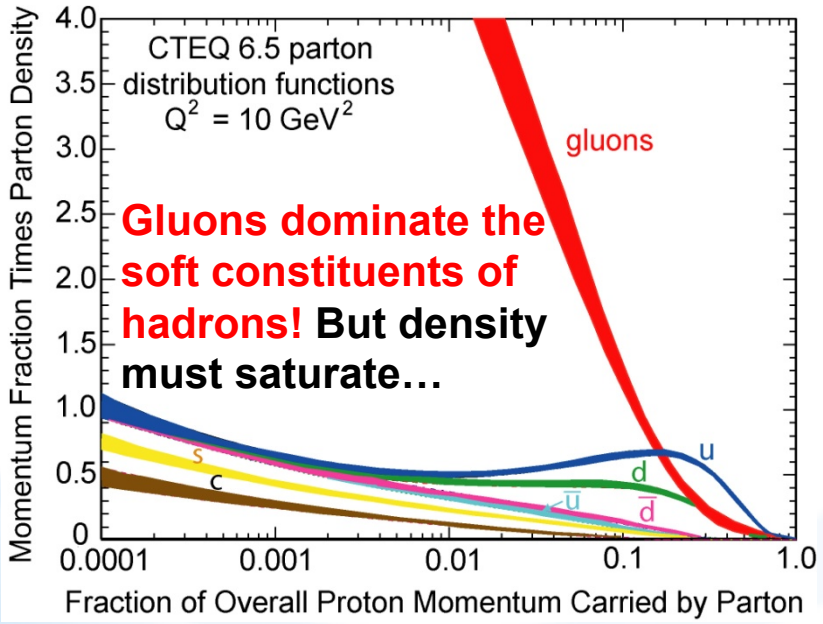
3) ***Do gluon self-interactions ⇒ universal saturated gluonic matter in hadrons and nuclei? Hints at RHIC, need EIC for definitive answer.***

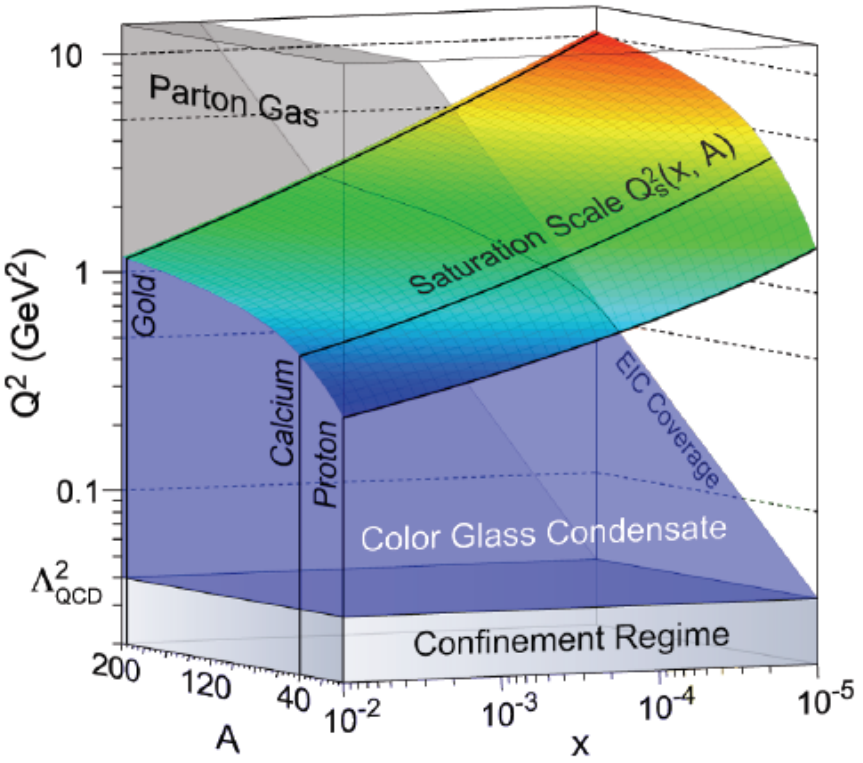
# EIC Science: Gluon-Dominated Cold Matter in e+A

**Search for supersymmetry @ LHC, ILC (?):** ***seeking to unify matter and forces***

**Electron-Ion Collider:** ***reveal that Nature blurs the distinction***

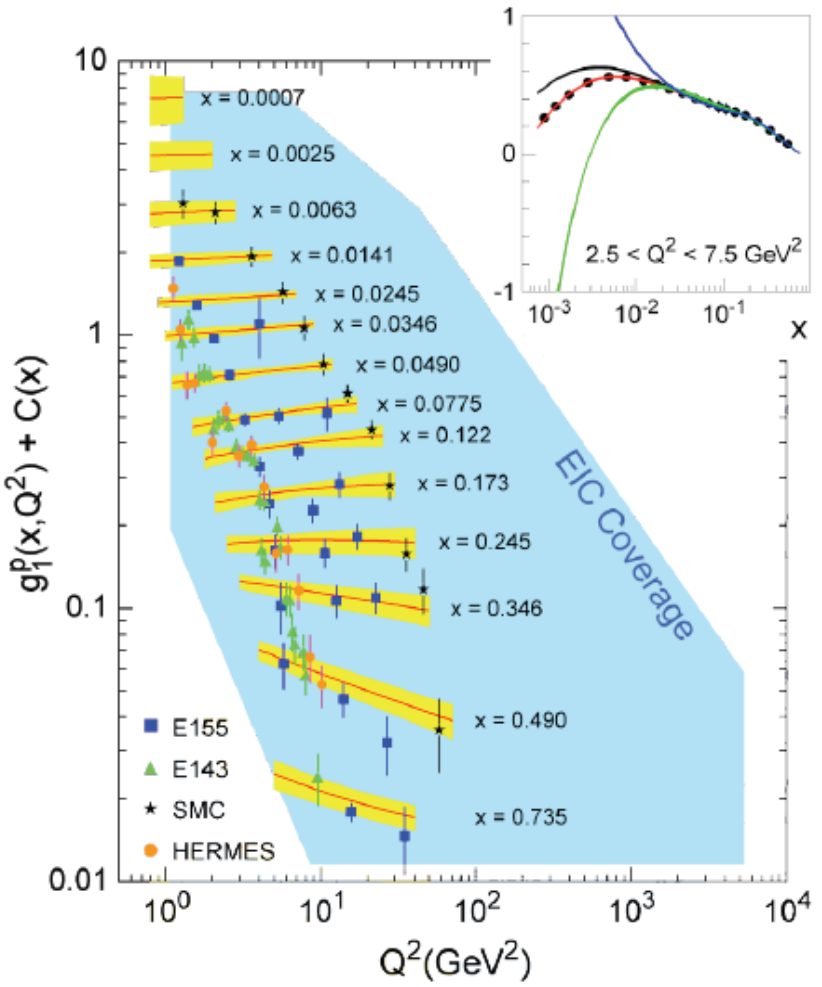
**Deep inelastic scattering @ HERA ⇒**




**EIC probes *weak* coupling regime of very high gluon density, where gauge boson occupancy >> 1.** ***All ordinary matter has at its heart an intense, semi-classical force field*** **-- can we demonstrate its universal behavior? Track the transition from dilute parton gas to CGC? "See" confinement reflected in soft-gluon spatial distributions inside nuclei?**

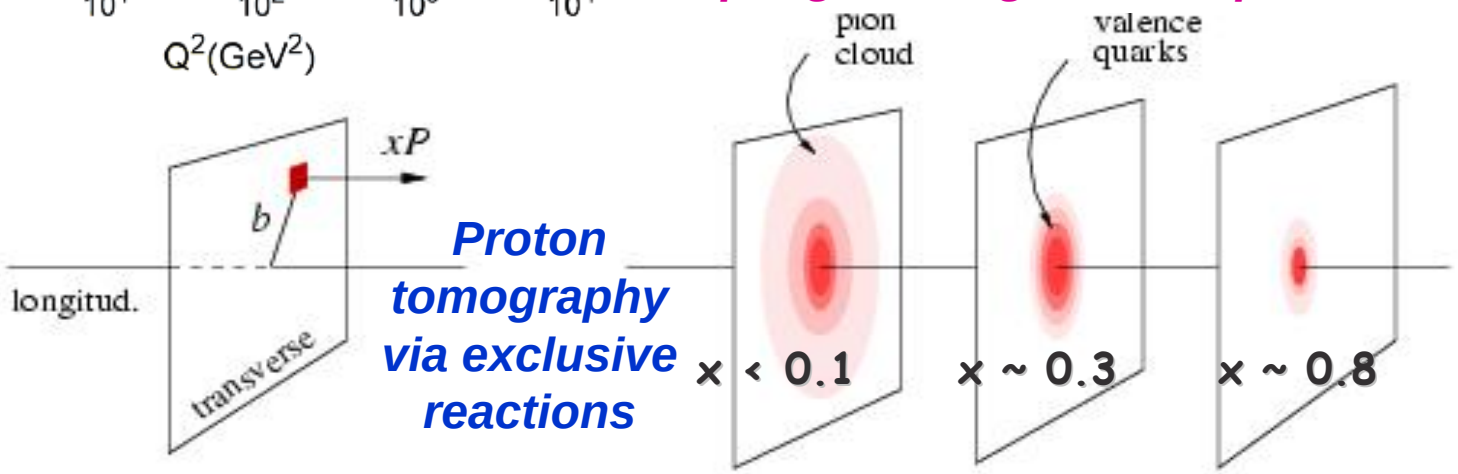
# EIC $\vec{e} + \vec{N} \Rightarrow$ Important Extension of Nucleon Structure Studies at HERA, RHIC, JLab,…




- ***$\vec{DIS}$, $\gamma$-gluon fusion $\Rightarrow \Delta G(x >$ few $\times 10^{-4})$***
- ***Bjorken sum rule test to $\lesssim \pm 2\%$***
- ***SIDIS for low-x sea-quark polarization and transverse spin studies***

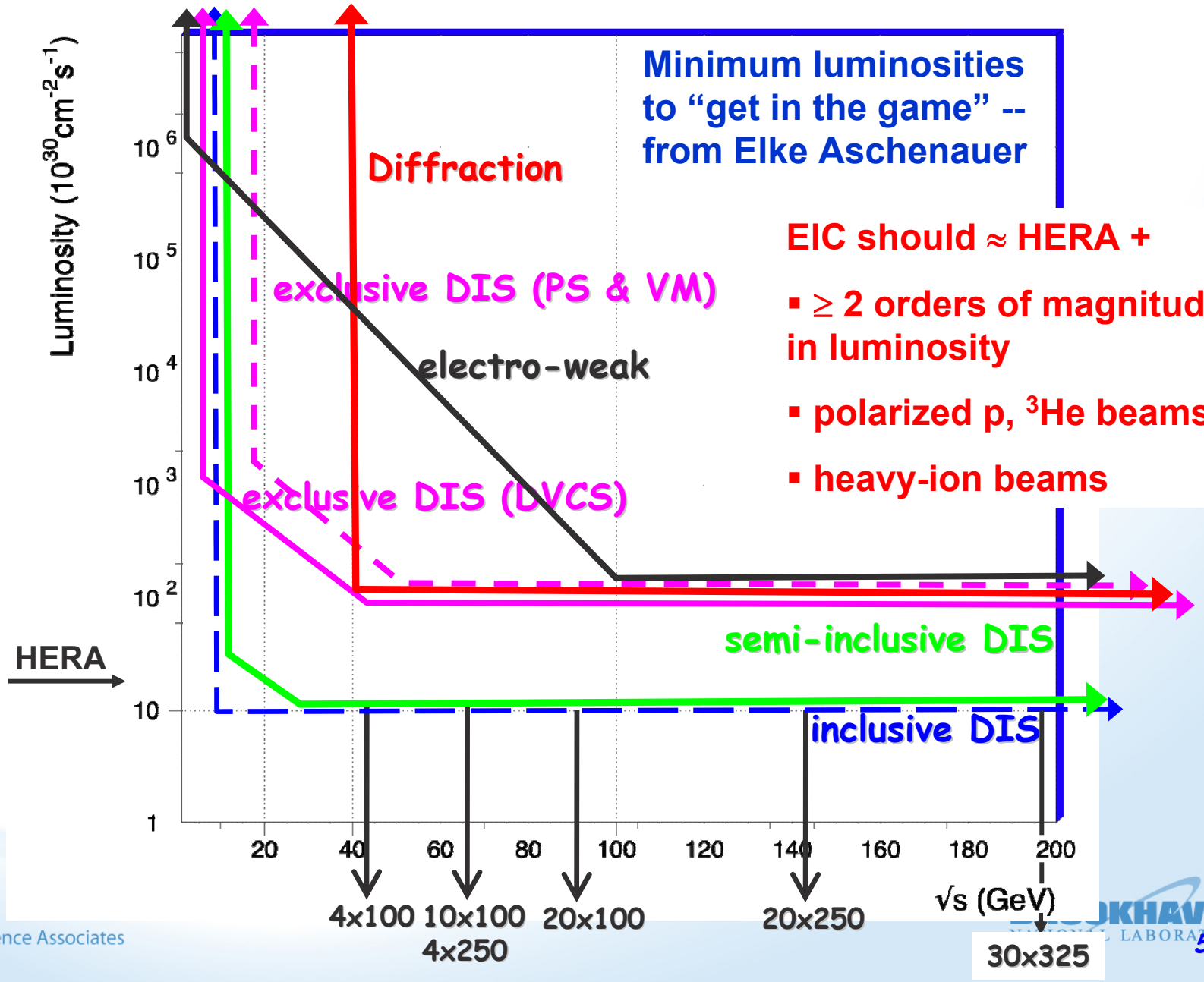
**More luminosity-hungry:**

- ***Polarized DVCS, exclusive reactions + LQCD $\Rightarrow$ GPD's $\Rightarrow$ map low-x transverse position-dep. PDF's; $J_q$ from Ji sum rule; $J_g$?***
- ***High-$Q^2$ $\vec{e}$+p,d parity viol'n $\Rightarrow$ weak coupling running below Z-pole***




***Proton tomography via exclusive reactions***

# The √s vs. luminosity landscape



# Get Good Advice

## EIC Advisory Committee (to JLab and BNL)

Joachim Bartels (Universitait Hamburg, DESY)
Allen Caldwell (Max-Planck Institute for Physics, Munich)
Albert De Roeck (CERN)
Walter Henning (ANL, Chair)
David Hertzog (University of Illinois)
Xiangdong Ji (University of Maryland)
Robert Klanner (DESY)
Al Mueller (University of Columbia)
Katsunobu Oide (KEK)
Naohito Saito (JPARC)
Uli Wienands (SLAC)

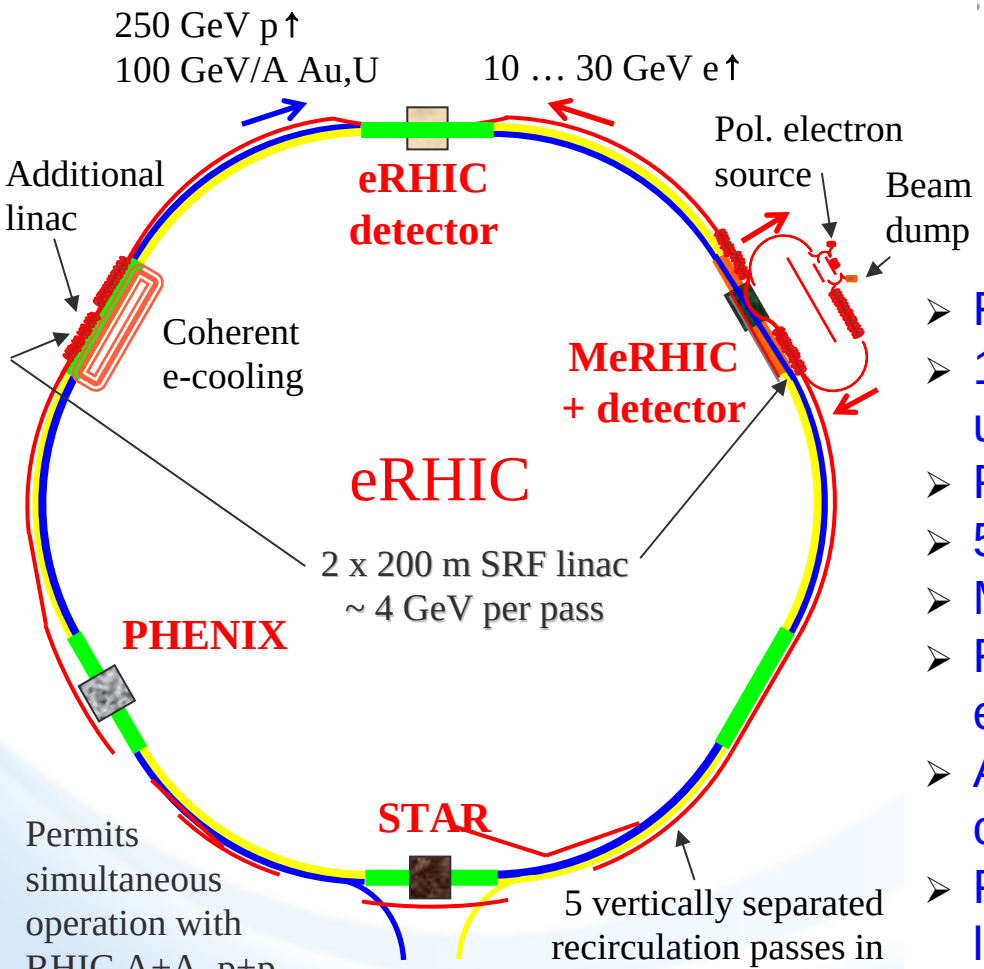
***1st meeting 2/16/09. 2nd meeting 11/02/09.***

# Special Issues for Nov. 2-3, 2009 EICAC Meeting

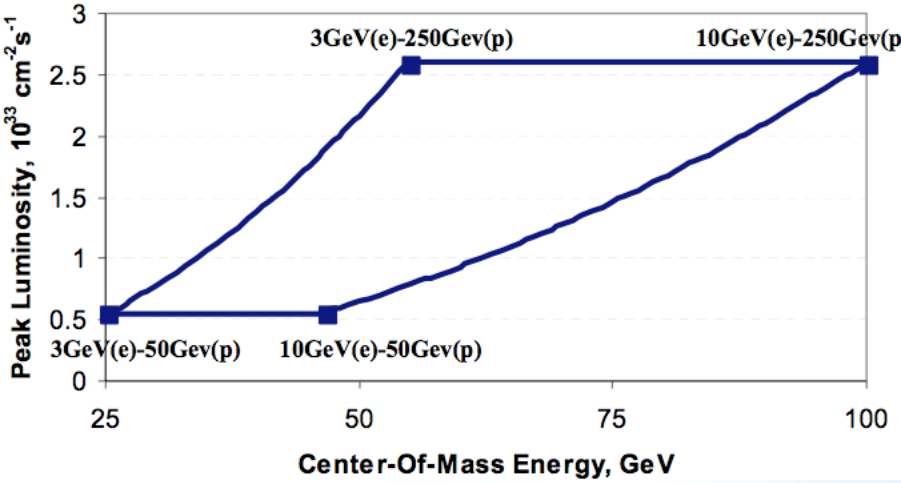
1) *Recommendations regarding viable, coherent R&D program and funding level for next ~5 years – to inform ONP Funding Opportunity Announcement for FY10*
2) *Advice re the basic EIC conundrum -- how to steer a path toward a compelling facility proposal, through the following competing demands:*

- *JLab and BNL agree that a staged facility approach is most likely to succeed; OS would like < $0.5 B project*
- *A 1st stage machine will already be expensive (> several $100M) and is unlikely to address all the science goals*
- *JLab- and BNL-centric user communities have related, but distinct, science priorities ⇒ distinct facility designs*
- *1st stage must already have compelling science "deliverables"*
- *Both designs require challenging, multi-year R&D programs to demonstrate technology, luminosity reach*
- *Convergence on a unified, convincing plan is essential in time for next NP LRP (~2012-13)*

- ***Start with MeRHIC: 4 GeV electron ERL to ⇒ collisions at one IP with already existing RHIC ion beams***
- ***Later add e linac sections in RHIC tunnel to increase energy & # IP's***

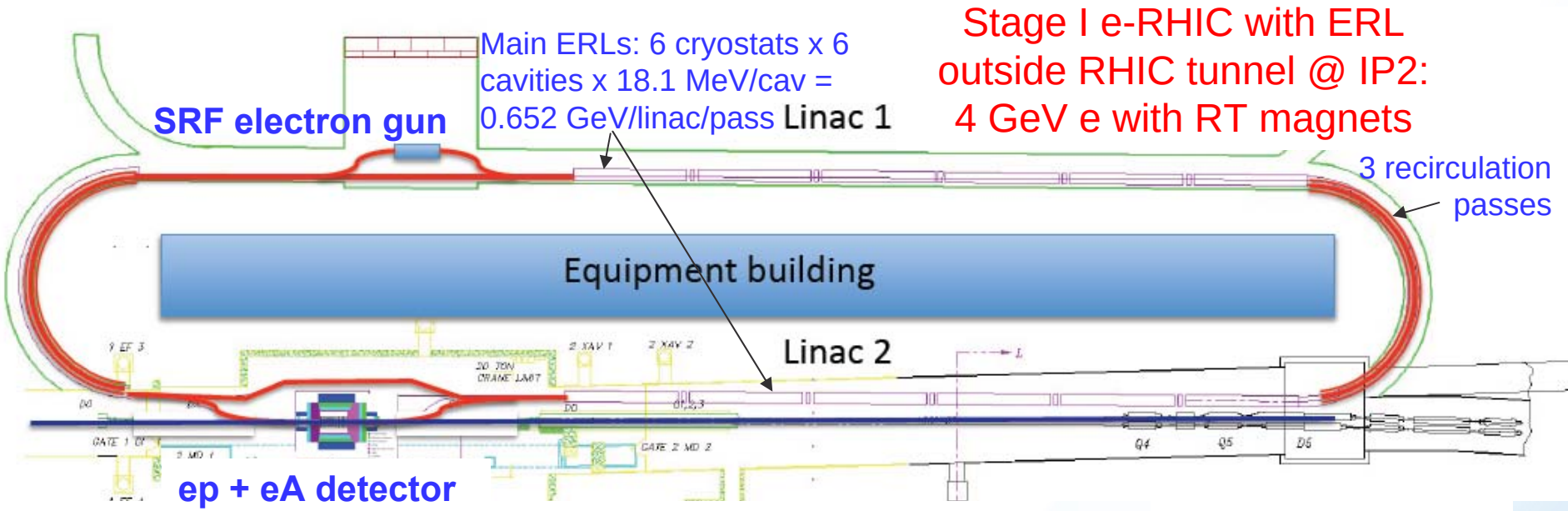



## eRHIC @ BNL, as of 11/09




- Full use of MeRHIC
- 10 GeV electron design energy. Possible upgrade to 20 – 30 GeV.
- Peak luminosity: $3 \times 10^{33}$ cm$^{-2}$ s$^{-1}$
- 5 recirculation passes in the RHIC tunnel
- Multiple electron-hadron IP's possible
- Full polarization transparency at all energies for the electron beam
- Ability to take full advantage of transverse cooling of the hadron beams
- Possible options to include polarized $e^+$ at lower luminosity: compact storage ring or ILC-type polarized positron source

# Considerable FY09 Progress on Design of Possible 1st (Medium Energy, MeRHIC) Stage



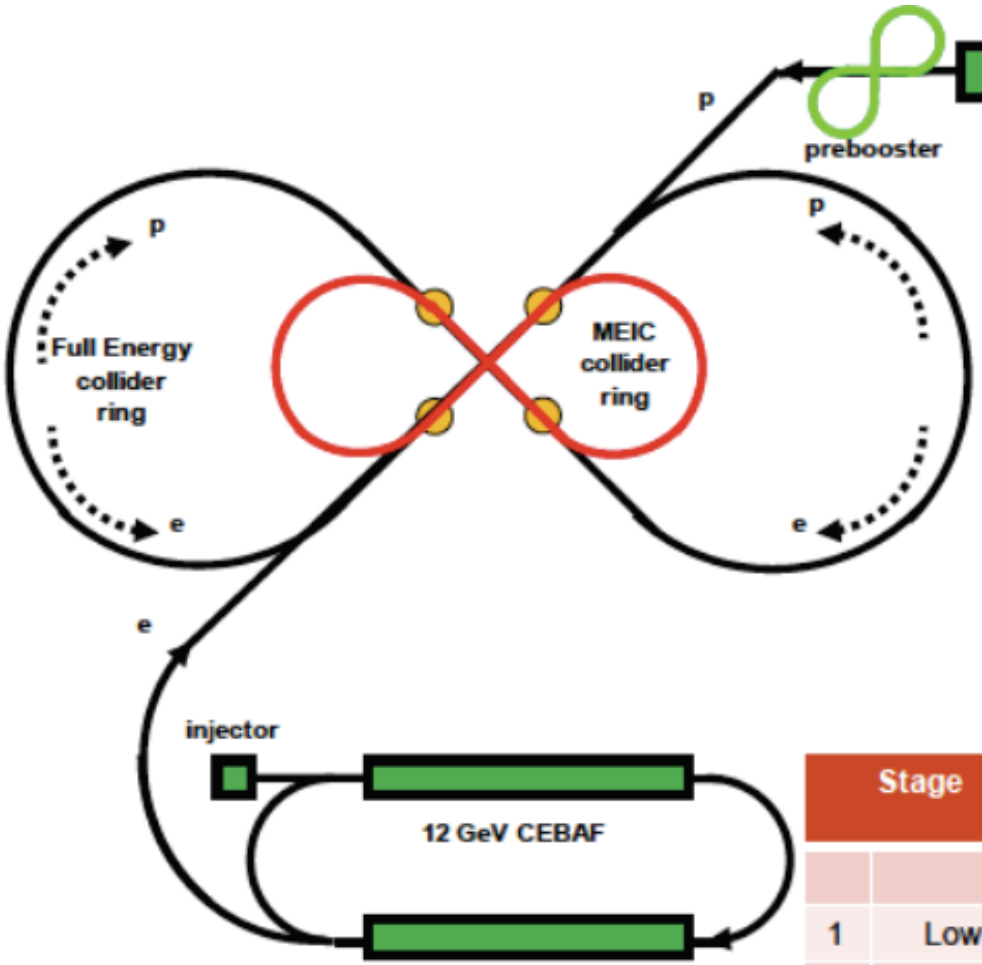

- ***Would enable 4 GeV $\vec{e}$ on 100 GeV/N heavy ions and 250 GeV $\vec{p}$, with most equipment to be reused later in full EIC***
- ***1st look at saturation surface for nuclei in e+A DIS: confirm nuclear "oomph" factor & measure gluon densities relevant to RHIC initial state; e+A diffraction tests of high gluon occupancy***
- ***$\vec{e}$-$\vec{p}$ program extending $\overrightarrow{DIS}$, adding: transverse-spin SIDIS over broad $Q^2$-range $\Rightarrow$ TMD evolution; detection of boosted target fragments to probe spin-dependent correlations in nucleon.***
- ***Cost ~ $350 M (FY09) without detector, exp't hall or beam cooling***

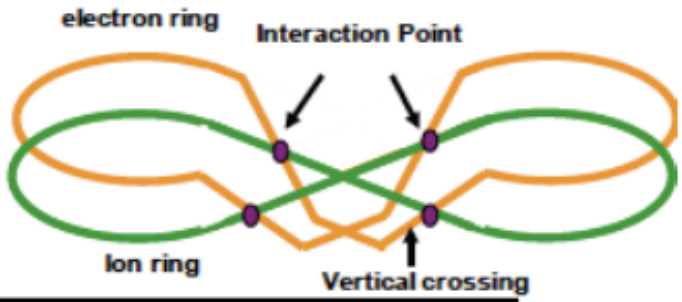
# eRHIC parameters for 40m insertion length IP

| | MeRHIC | | eRHIC with CeC | |
|---|---|---|---|---|
| | p (A) | e | p (A) | e |
| Energy, GeV | 250 (100) | 4 | 325 (125) | 20 <30> |
| Number of bunches | 111 | | 166 | |
| Bunch intensity (u) , $10^{11}$ | 2.0 | 0.31 | 2.0 (3) | 0.24 |
| Bunch charge, nC | 32 | 5 | 32 | 4 |
| Beam current, mA | 320 | 50 | 420 | 50 <10> |
| Normalized emittance, 1e-6 m, 95% for p / rms for e | 15 | 73 | 1.2 | 25 |
| Polarization, % | 70 | 80 | 70 | 80 |
| rms bunch length, cm | 20 | 0.2 | 4.9 | 0.2 |
| β*, cm | 50 | 50 | 25 | 25 |
| Luminosity, x $10^{33}$, $cm^{-2}s^{-1}$ | 0.1 -> 1 with CeC | | 2.8 | |

< Luminosity for 30 GeV e-beam operation will be at 20% level>, limited by synchrotron radiation loss rate

# EIC and MEIC @ JLab, as of 11/09



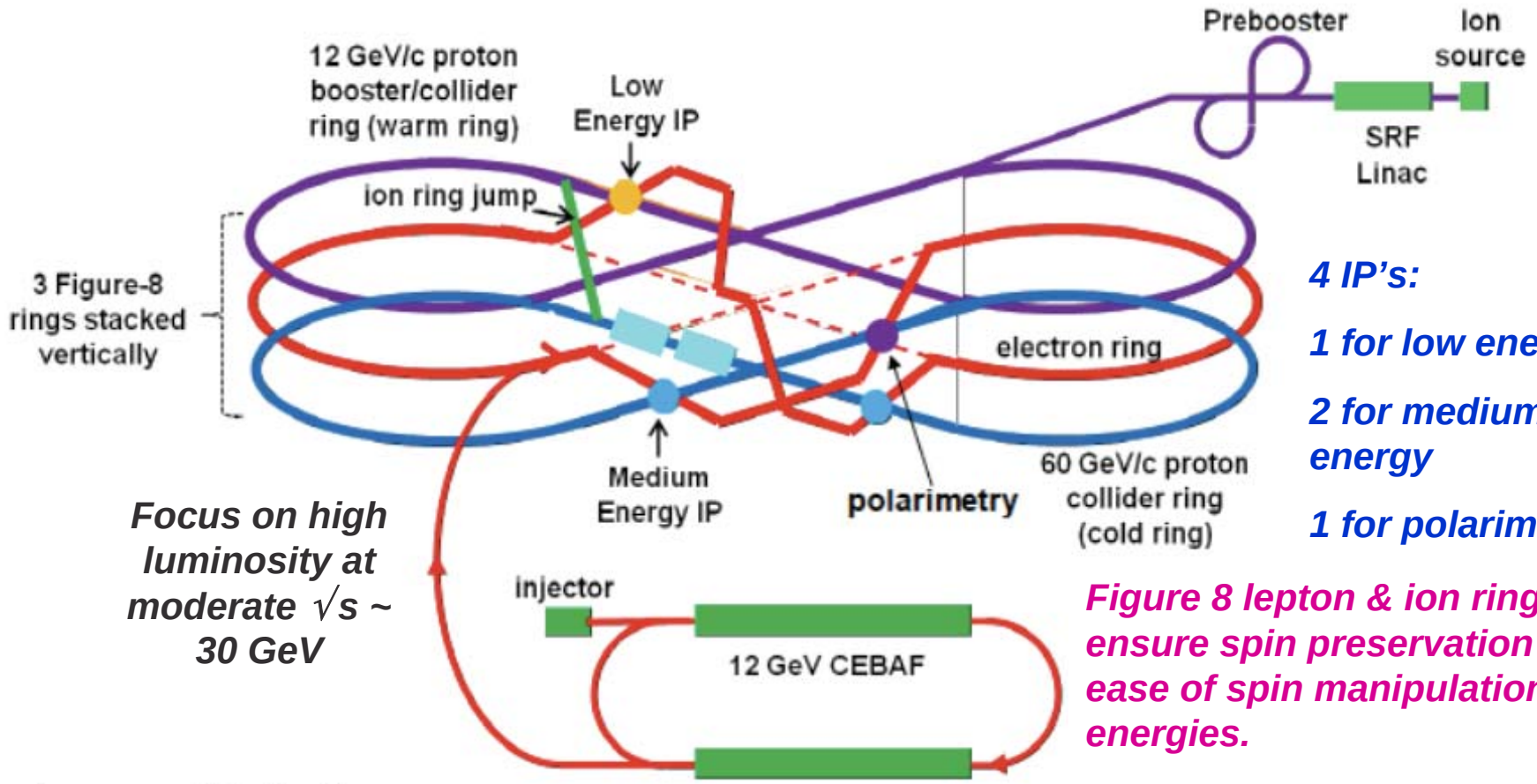




| HE Ring Dimensions | m |
|---|---|
| Circumference | 1800 |
| Radius | 140 |
| Width | 280 |
| Length | 695 |
| Straight | 306 |

| Stage | | Max. Energy (GeV/c) | | Ring Size (m) | | Ring Type | | IP # |
|---|---|---|---|---|---|---|---|---|
| | | p | e | p | e | p | e | |
| 1 | Low | 12 | 5 (11) | 630 | 630 | Warm | Warm | 1 |
| | Medium | 60 | 5 (11) | 630 | 630 | Cold | Warm | 2 |
| 2 | Medium | 60 | 10 | 600 | 1800 | Cold | Warm | 4 |
| 3 | High | 250 | 10 | 1800 | 1800 | Cold | Warm | 4 |

*Courtesy of G. Krafft*

# MEIC Detail




*Focus on high luminosity at moderate $\sqrt{s}$ ~ 30 GeV*

*Courtesy of G. Krafft*

***4 IP's:***

***1 for low energy***

***2 for medium energy***

***1 for polarimetry***

***Figure 8 lepton & ion rings ensure spin preservation and ease of spin manipulation at all energies.***

***Simultaneous operation with CEBAF fixed-target program is possible.***

# ELIC Main Parameters

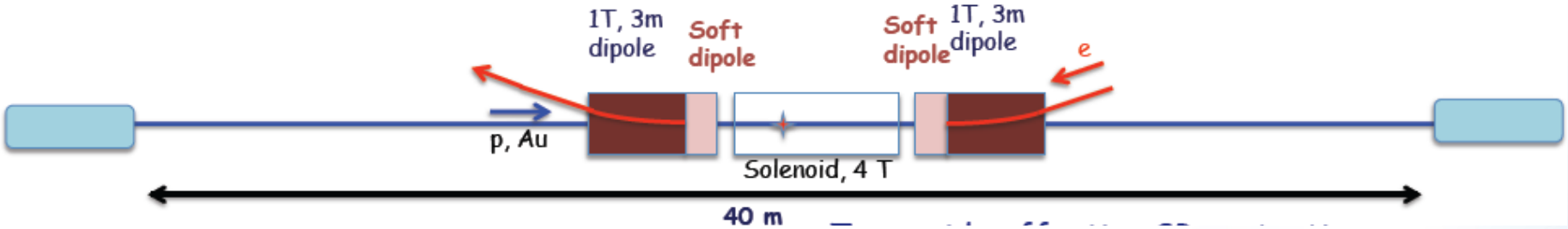
| | | | | | | |
|---|---|---|---|---|---|---|
| Beam Energy | GeV | 250/10 | 150/7 | 60/5 | 60/3 | 12/3 |
| CM energy s | $GeV^2$ | 10000 | 4200 | 1200 | 720 | 144 |
| Collision frequency | MHz | | | 499 | | |
| Particles/bunch | $10^{10}$ | 1.1/3.1 | 0.5/3.25 | 0.74/2.9 | 1.1/6 | 0.47/2.3 |
| Beam current | A | 0.9/2.5 | 0.4/2.6 | 0.59/2.3 | 0.86/4.8 | 0.37/2.7 |
| Energy spread | $10^{-4}$ | | | ~ 3 | | |
| RMS bunch length | mm | 5 | 5 | 5 | 5 | 50 |
| Horiz.. emit., norm. | μm | 0.7/51 | 0.5/43 | 0.56/85 | 0.8/75 | 0.18/80 |
| Vert. emit. Norm. | μm | 0.03/2 | 0.03/2.87 | 0.11/17 | 0.8/75 | 0.18/80 |
| Horizontal beta-star | mm | 125 | 75 | 25 | 25 | 5 |
| Vertical beta-star | mm | | | 5 | ⇒ Very strong final focus! | |
| Vert. b-b tune shift/IP | | 0.01/0.1 | 0.015/.05 | 0.01/0.03 | .015/.08 | .015/.013 |
| Laslett tune shift | p-beam | 0.1 | 0.1 | 0.1 | 0.054 | 0.1 |
| Peak Lumi/IP, $10^{34}$ | $cm^{-2}s^{-1}$ | 11 | 4.1 | 1.9 | 4.0 | 0.59 |

High energy | Medium energy | Low energy

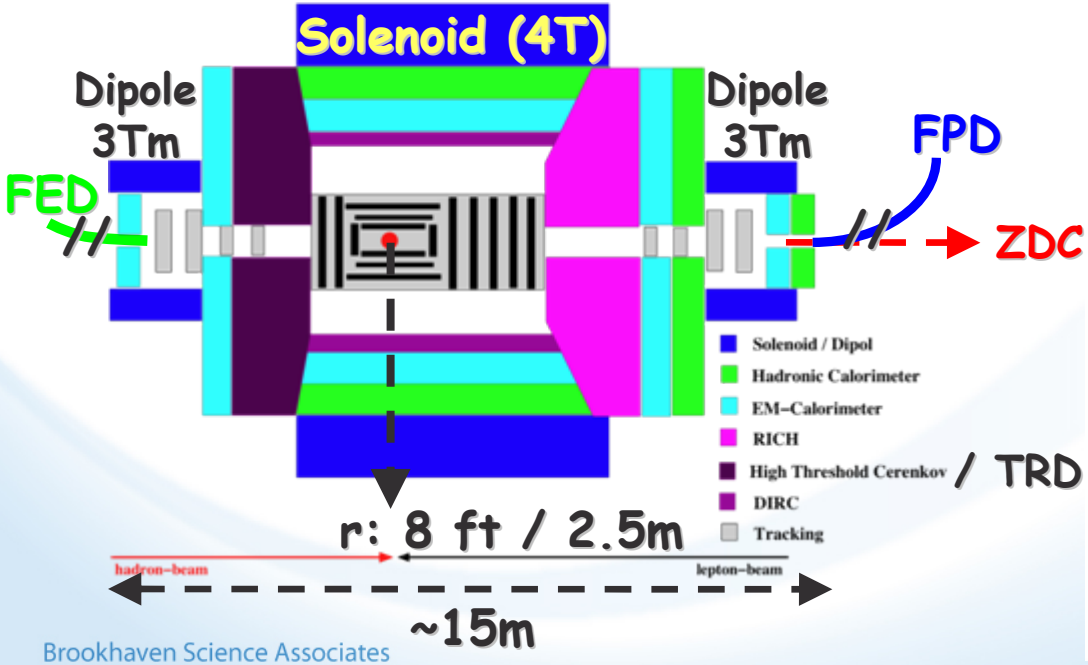
# Detector and IR Design Begun in Earnest

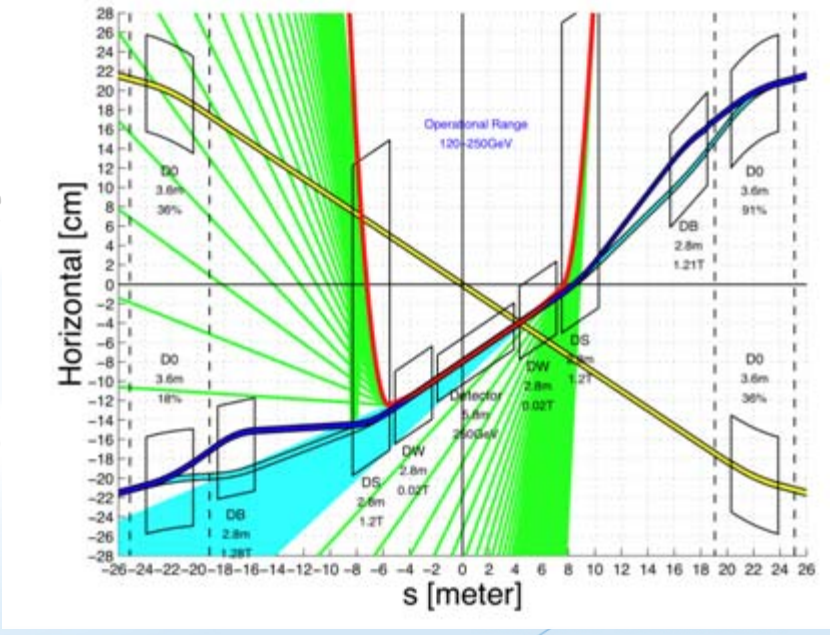
## MeRHIC 4 GeV e x 250 GeV p/100 GeV Au

Remove DXes – 40 m to detect particles scattered at small angles




***Use soft (~0.05 T) bend for final bending of e beam to IP, to shield detector from all but the very softest synchrotron radiation***



# Quotes from Nov. 2009 EICAC Report on Science and Community Convergence

• The [Fall 2010] INT Program should be used to articulate the *theoretical motivation*, but also to compare those goals with reality by examining the sensitivities of simulated experiments. An outcome should be the science / machine matrix discussed earlier. At the conclusion of the INT program, we can anticipate some follow-up event(s) in 2011 where the joint community agrees on the theme of a final White Paper.

• The EIC Community appears to be made of two sub-groups, roughly associated with the BNL or JLab concepts for the machine…it is our opinion that there remains time for vigorous debate about scientific options and priorities; however, for full consideration at the next LRP, one coherent, joint-QCD-community request should be made.

• To progress further, some assurance from lab managements would be useful, stating that, which ever facility scheme will be chosen in the end of the evaluation process, both laboratories are committed to making it a success together.

# Quotes from EICAC Report on Facility Design & Strategy

• The EICAC is impressed with the…work…on accelerator designs since the last meeting… the two laboratories are at very different levels of design maturity.

• It is the growing view of several members of EICAC that as soon as possible a "down select" should be made…there is much R&D that needs to be done…addressing all the challenges of both [designs] is expensive and perhaps unwarranted. The highest priority on the facility side is to develop the JLAB design to a stage similar to where the BNL design is at present.

• In terms of strategy…the EICAC feels that the proponents might consider aiming for *the* EIC facility from the beginning, with a medium-range performance scope and future upgrade opportunities.

• It may…be wise to consider the possibility of more than one interaction region to satisfy these different [science and detector] requirements. This would also provide a natural way for different physics communities to group themselves.

# Quotes from EICAC Report on Accelerator R&D Priorities

**Highest priority:**

- Design of JLab EIC
- High current (e.g. 50 mA) polarized electron gun
- Demonstration of high energy – high current recirculation ERL
- Beam-Beam simulations for EIC
- Polarized 3He production and acceleration
- Coherent electron cooling

**High priority, but could wait until decision made:**

- Compact loop magnets
- Electron cooling for JLab concepts
- Traveling focus scheme (it is not clear what the loss in performance would be if it doesn't work; it is not a show stopper if it doesn't)
- Development of eRHIC-type SRF cavities

**Medium Priority:**

- Crab cavities
- ERL technology development at JLAB

# Quotes from EICAC Report on Path to "Down Select"

• [At Fall 2020 INT Workshop]: i) For each of the two directions, it would be very useful to prepare a concrete list of the requested measurements (including the scientific motivation, kinematic region, required accuracy etc.); and/or ii) each of the two groups should investigate to what extent their scientific goals could be reached by the other machine (i.e. 'proton imaging' etc by the BNL design, 'saturation' etc by the JLab version).

• …it would be useful to define a few sets of parameters (energy, luminosity, polarization) based on the expectations from each machine for simulation studies. Available space at the IR should also be defined. These can then be put together with detector designs to understand the physics capabilities for the signature (and other) measurements. These results should then be put together with expected cost, time scale for the accelerator development, and possibilities for future upgrades to higher energies and luminosity in determining which accelerator option is to be backed by the community.

# Quotes from EICAC Report on Detector Development

• The EICAC feels that there is no need at this point to carry out detailed GEANT simulations, but rather to study responses based on parameterizations. The trade-off between the resolutions and acceptances of the detectors on the one hand, and luminosity, polarization and beam energies on the other hand for the physics can be understood with these kinds of studies.

• In a prioritized way, R&D suggested for the near term should begin to address the following areas:

-Low-mass vertex-tracker/tracker, and integration of a TRD detector in the tracker

-particle identification at mid-rapidity for particles with momenta up to 4 GeV, e.g., using DIRC technology

-low cost photon detection, e.g., SiPMs

-ion polarimeters

• The EICAC considers it important that the detector R&D efforts are conducted jointly for MeRHIC and MEIC. Contacts with other communities like LHeC are also strongly encouraged.

# Recent Developments on Accelerator R&D + Design

1) *"Gatling gun" approach to multi-cathode high-current polarized electron source begun at BNL with LDRD funds, complementing ongoing work on high-current ERL and compact recirculation arc magnet development.*

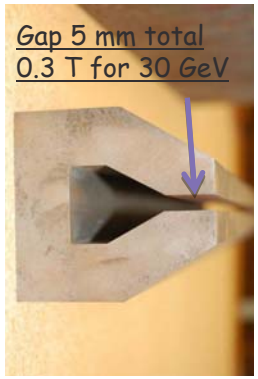
2) *Nuclear Physics Office at DOE announces new funding opportunity for R&D on next-generation NP accelerators. Will submit Coherent Electron Cooling proof-of-principle project jointly between BNL and JLab.*

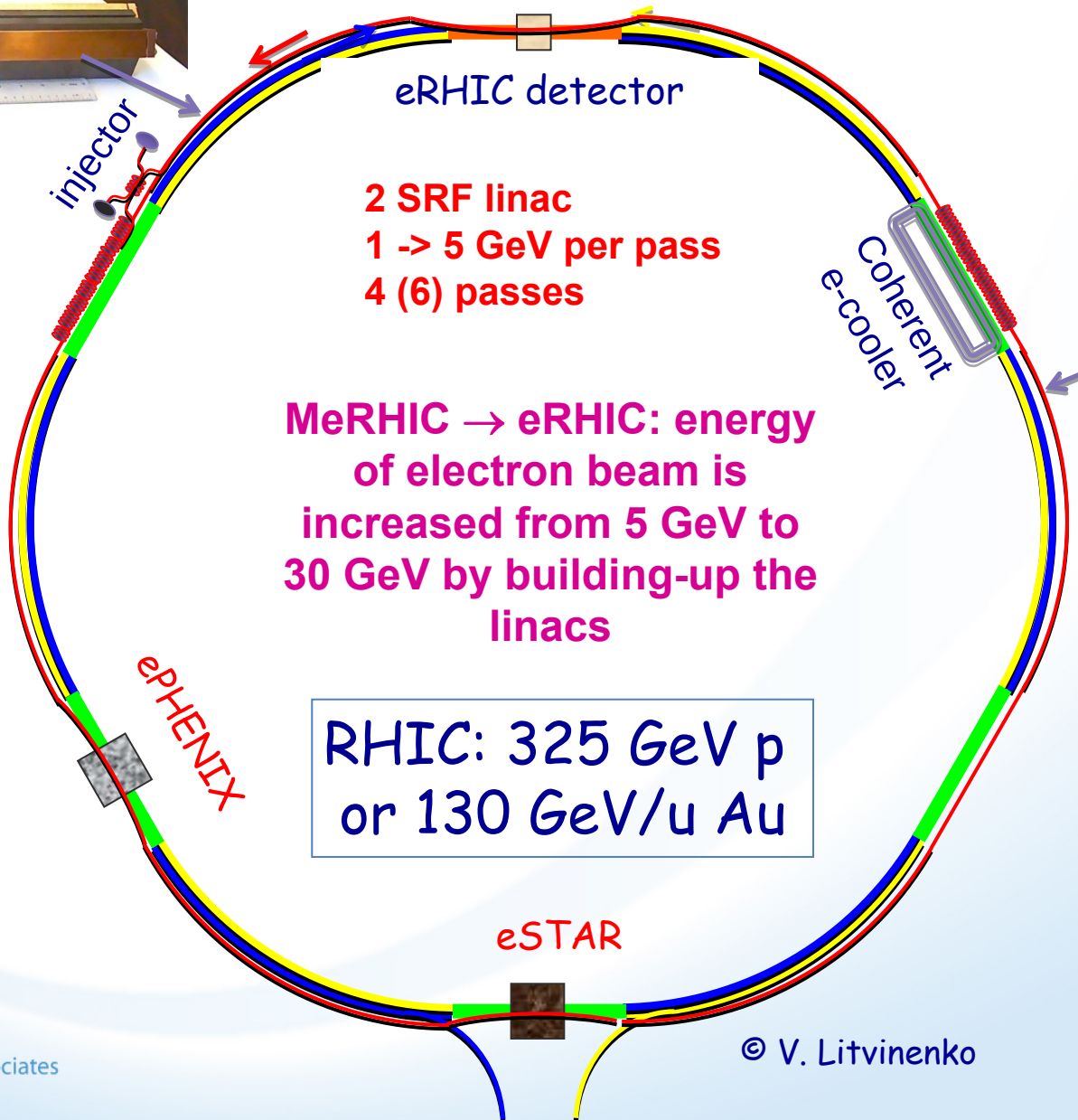
3) *JLab fleshing out MEIC design, aiming toward detailed design and cost review in Summer 2010.*

4) *BNL evaluating cost reductions + allowance for multiple IR's (including higher-luminosity IR with close-in quadrupoles) by incorporating (M)eRHIC recirculation paths within RHIC tunnel, reusing parts of existing RHIC experiment halls and detectors (see next slides).*

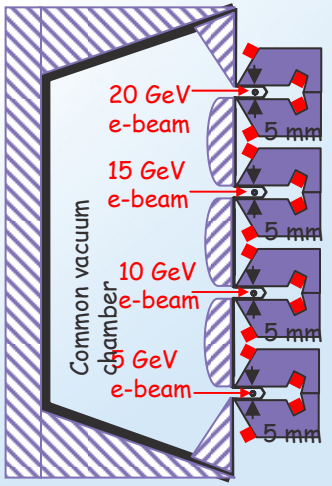
5) *BNL considering additional use of MeRHIC in RHIC tunnel as base for X-ray FEL of very high rep rate and high spectral brilliance, to advance state of the art for inelastic X-ray scattering studies of condensed matter systems.*

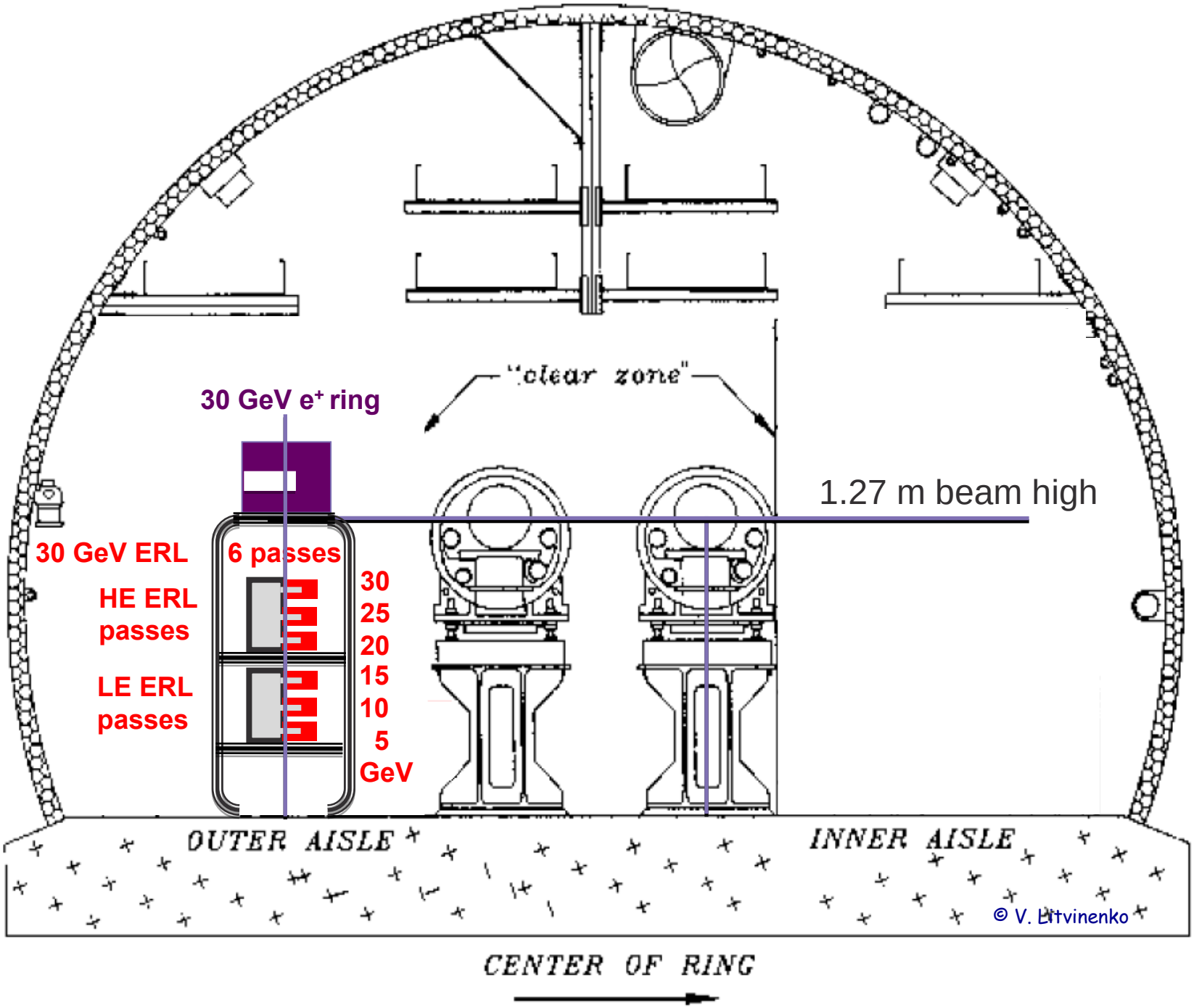
# Alternative eRHIC Design Under Active Consideration




Vertically separated recirculating passes.
# of passes will be chosen to optimize eRHIC cost




"clear zone"
30 GeV e+ ring
1.27 m beam high
30 GeV ERL
6 passes
HE ERL passes
LE ERL passes
30
25
20
15
10
5
GeV
OUTER AISLE
INNER AISLE
© V. Litvinenko
CENTER OF RING

# Luminosity in eRHIC for strong focus IP

| | eRHIC IR1 | |
|---|---|---|
| | p /A | e |
| Energy (max), GeV | 325/130 | 20 |
| Number of bunches | 166 | 74 nsec |
| Bunch intensity (u) , $10^{11}$ | 2.0 | 0.24 |
| Bunch charge, nC | 32 | 4 |
| Beam current, mA | 420 | 50 |
| Normalized emittance, 1e-6 m, 95% for p / rms for e | 1.2 | 25 |
| Polarization, % | 70 | 80 |
| rms bunch length, cm | 4.9 | 0.2 |
| β*, cm | 5 | 5 |
| Luminosity, $cm^{-2}s^{-1}$ | $1.4 \times 10^{34}$ | |

Luminosity for 30 GeV e-beam operation will be at 20% level

# A Strawman Path to the Next Long Range Plan

1) *Follow narrow-focus FY10 workshops with full exploration of EIC science and facility capabilities at Fall 2010 INT Workshop.*

2) *After INT Workshop, small Steering Committee oversees writing of single, community-wide White Paper laying out full EIC science program in broad, compelling strokes at the start, followed by sufficient detail on "golden" experiments to establish credibility. Complete White Paper draft by late FY11. Describe science program for full-energy and full-luminosity EIC, but with clear science deliverables for 1st stage.*

3) *Spring 2011: JLab, BNL, EIC Collaboration, EICAC, DOE define facility design down-select criteria and review mechanism.*

4) *Down-select review by Spring 2012, informed by latest R&D results on critical technologies and apples-to-apples bottom-up cost estimate comparison for competing designs.*

5) *Fall 2012: update White Paper with realizable EIC design, cost range, performance goals, science deliverables and upgrade paths, in preparation for Spring 2013 LRP resolution meeting.*

# Backup Slides

# EICAC Advice from Feb. 09 Meeting Forms Basis of This Talk!

***EICAC requested next meeting on Fall '09 schedule, for 2 days to allow deeper discussion, and with following major deliverables:***

- ❑ ***Coherent R&D plan, timeline, milestones & resource needs***
- ❑ ***Short list of "golden measurements" & what will be learned***
- ❑ ***Initial cost-performance-science reach matrix***
- ❑ ***Implications of golden exp'ts for detector requirements + R&D***

***Other EICAC recommendations:***

- Further develop the schedule including approximate resource-loading, to provide a timeline for major decisions (including, if at all possible, site decision), technical developments, and (staged) realization
- In particular, strive for a timeline (under reasonable assumptions) that provides for data taking before 2020

# Choose "Golden" Experiments That Set Machine/Detector Performance Requirements

***e.g.,***

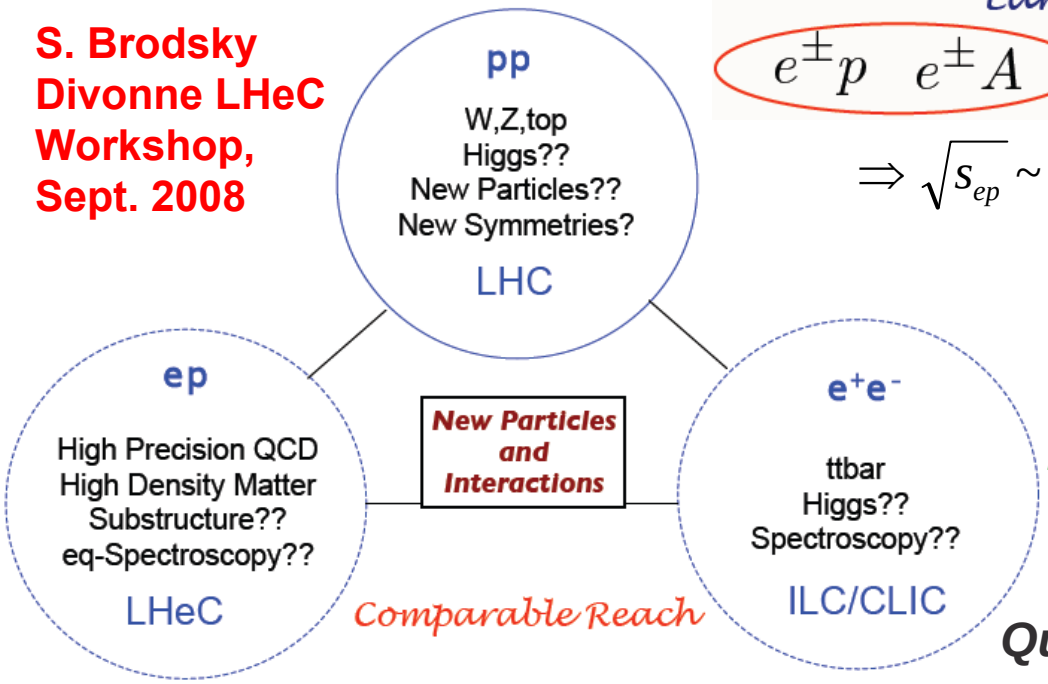
- ***inclusive DIS for indirect ($F_2$) determination of gluon densities in heavy nuclei, extension of spin structure ($g_1$)***
- ***direct determination of gluon densities by $F_L$ (emphasis on energy variability of machine, detector)***
- ***diffractive measurements to probe spatial distribution of gluons in e+A***
- ***deep exclusive reactions to map GPD's***
- ***parity-violating asymmetries at high $Q^2$***

***Detailed simulations needed to demonstrate feasibility, determine requirements***

# Higher- and lower-energy electron-ion colliders now under consideration in Europe:

- ***LHeC @ CERN:*** at Conceptual Design Report stage

**S. Brodsky Divonne LHeC Workshop, Sept. 2008**




Large Hadron-Electron Collider

$e^{\pm}p \quad e^{\pm}A$ $\quad E_e = 40 \rightarrow 140\ \text{GeV} \quad E_p = 1 \rightarrow 7\ \text{TeV}$

$$\Rightarrow \sqrt{s_{ep}} \sim 1\ \text{TeV} \ @\ L_{ep} \sim 2\times 10^{32}\,\text{cm}^{-2}\text{s}^{-1}$$

***Main LHeC focus on "new physics" (e.g., SUSY, lepto-quarks, lepton and quark substructure) and precision SM physics. Overlaps EIC focus on high-density QCD @ low-x end of reach.***

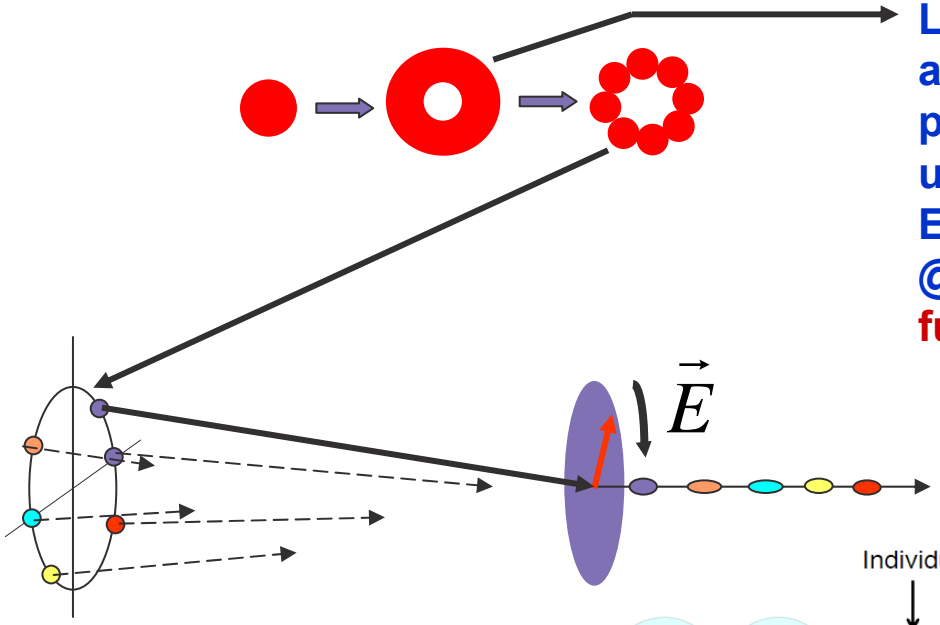
***Question: how fits with SLHC, CLIC?***

- ***ENC @ FAIR:*** ***3 GeV $\vec{e}^{-}$ ⊗ 15 GeV $\vec{p}$ @ L ~ $10^{33}$ in High-Energy Storage Ring ⇒ polarized parton distributions with higher precision in kinematic region scanned in fixed-target experiments. Case at preliminary stage.***

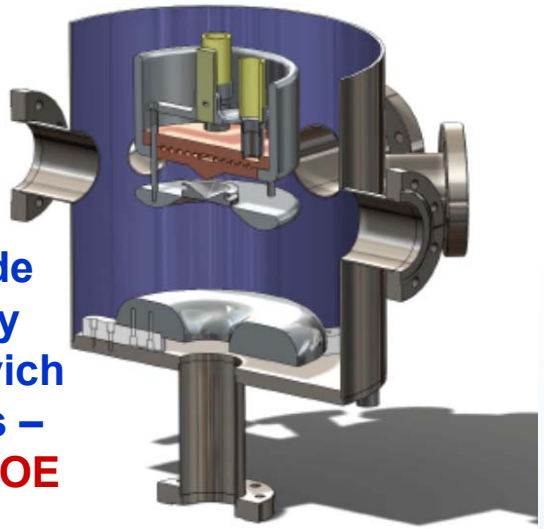
***Opportunities abound for joint accelerator & detector R&D***

# Accelerator R&D Already Under Way: $\vec{e}^-$ Guns

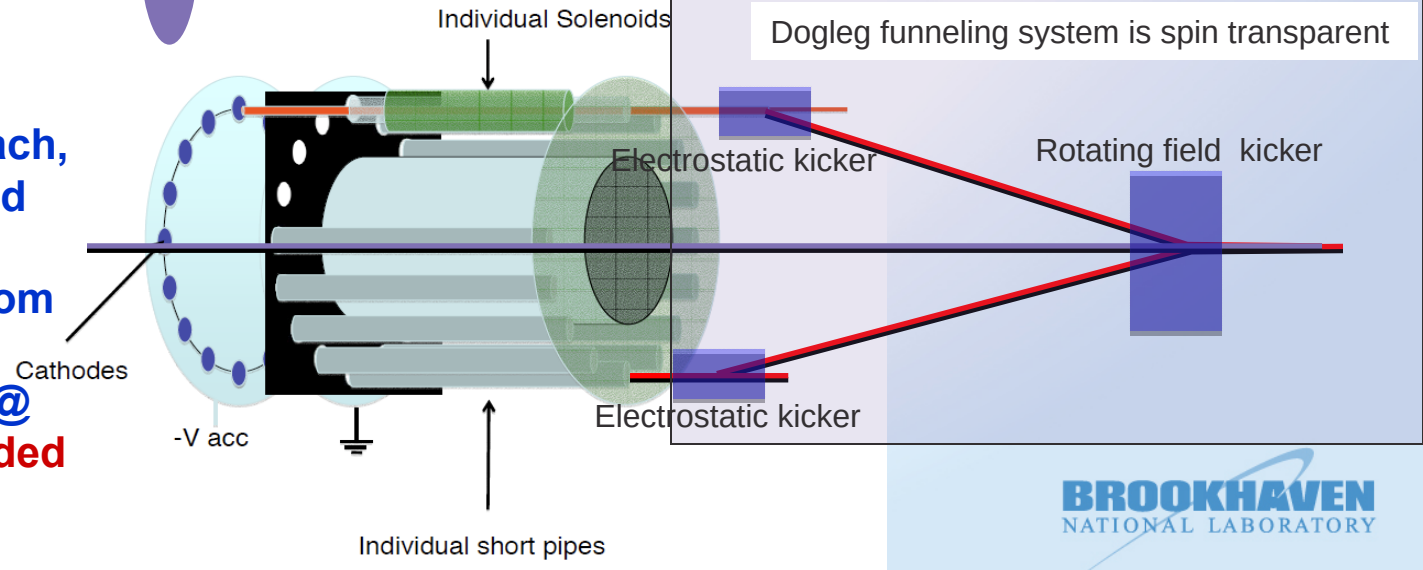
***To relax limitation from ion bombardment damage of photocathode, increase area:***




**Large annular photocathode under test by E. Tsentalovich @ MIT/Bates – funded by DOE**

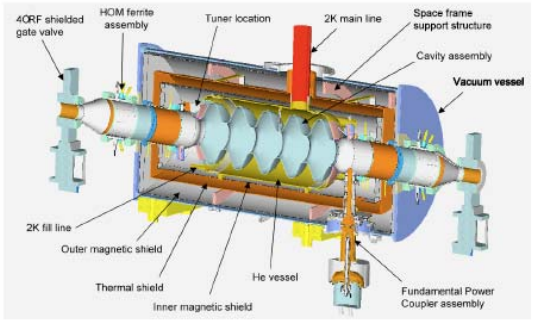


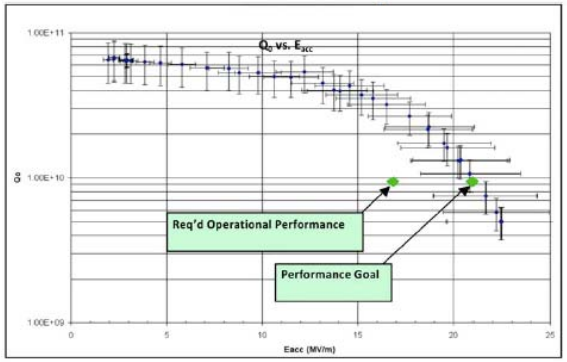
**"Gatling gun" approach, using rotating RF field to recombine successive pulses from 24 2-mA guns under design by I. Ben-Zvi @ BNL – 2-gun test funded by BNL LDRD**



# Accelerator R&D Already Under Way: II

## A Prototype eRHIC Cavity

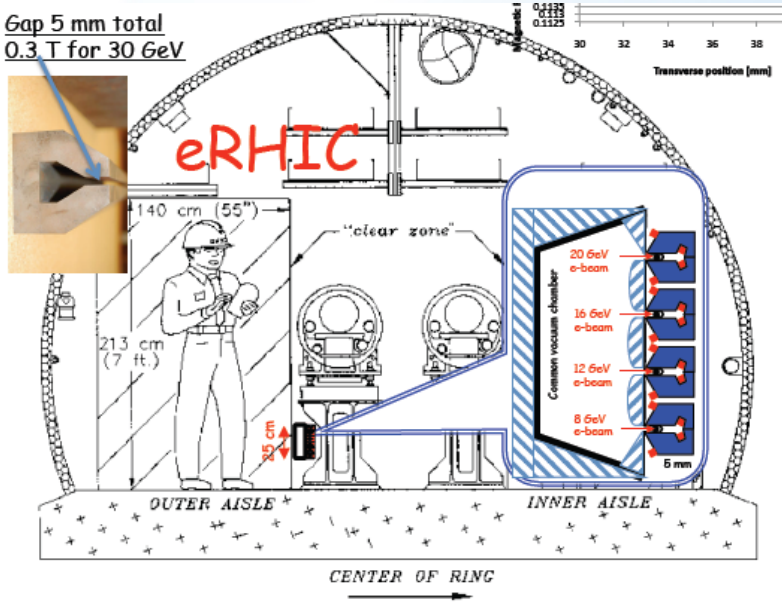


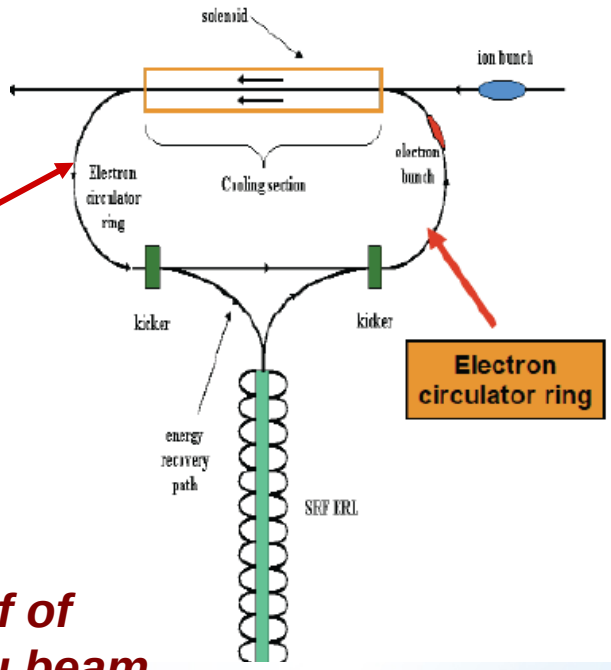

***R&D 20 MeV ERL under construction @ BNL to demonstrate high-current performance. Utilizes 704 MHz SRF cavity designed for this purpose – Q=1 × $10^{10}$ @ 20 MV/m demonstrated, exceeding required performance.***

***Funded by DOE, Navy, BNL***

***Compact (5 mm gap) dipoles, to allow multiple vertical passes within single vacuum enclosure around RHIC tunnel, under development via BNL LDRD funds.***



# Extensive R&D Needed on High-Energy Hadron Beam Cooling

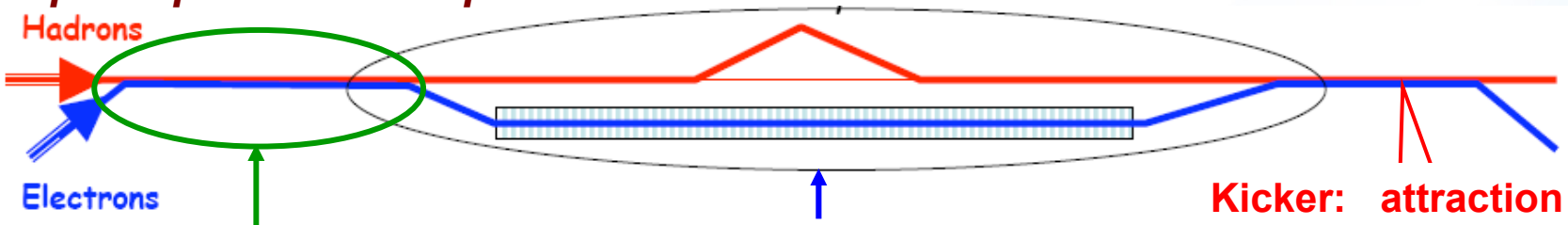



*JLab proposes SRF ERL-based electron cooler.*
*Present state of the art from FNAL:*

***4.34 MeV e @ 0.5 A DC***

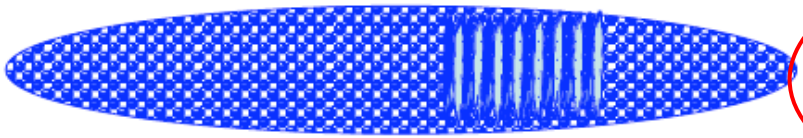
*MEIC requires up to **33 MeV e**, EIC up to **136 MeV e @ up to 3A CW** !*

*BNL proposes novel Coherent e-Cooling, with proof of principle test to be performed on RHIC 40 GeV/A Au beam*

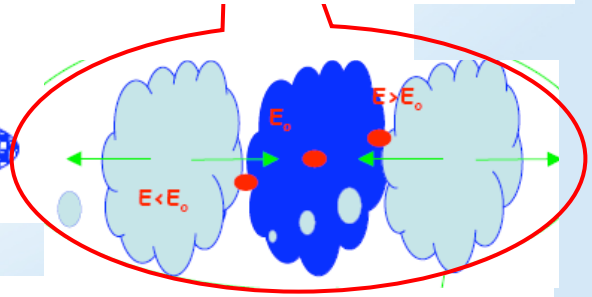



**Modulator: hadron beam structure introduces density modulation in e-beam**

**Wiggler: FEL amplification (x $10^{2-3}$) of e-beam modulations, while chicane adds dispersion to h beam**

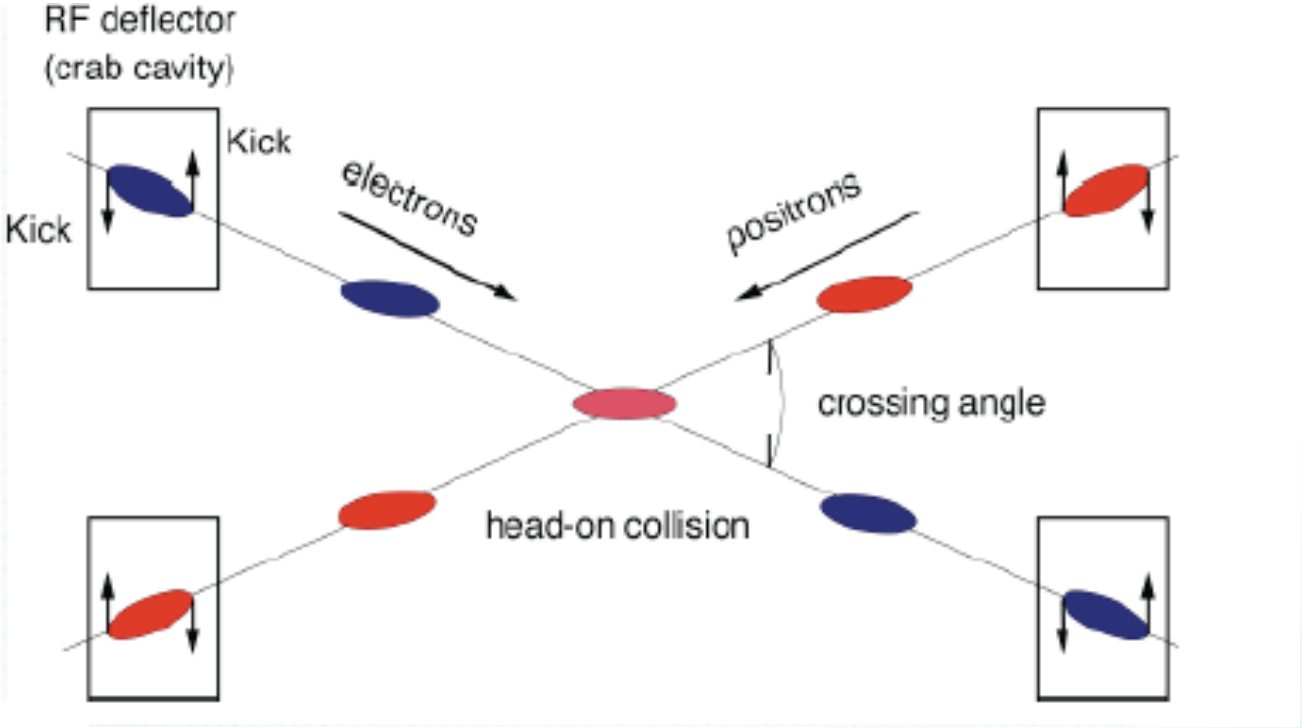


**Kicker: attraction to e-beam density peak reduces ion-beam E spread.**

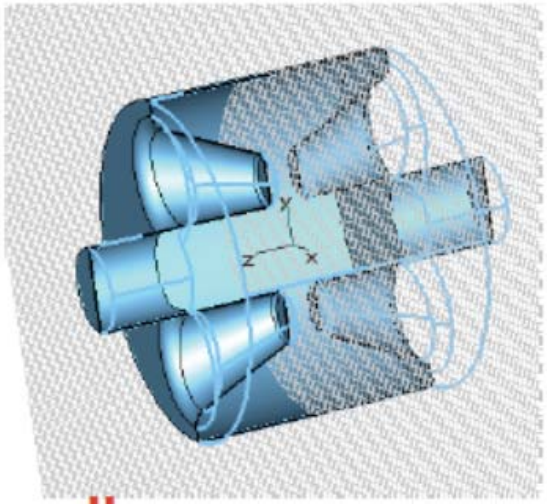



**CeC** *of high-energy hadron beams: high-gain FEL based on high-brightness ERL ⇒ potential to boost EIC ( and LHC? RHIC p+p?) luminosities.*

# R&D Needed on Crab Crossing to Boost Luminosity of Collisions at Non-Zero Crossing Angle




**Multi-cell TM110 and Loaded Structure of Crabbing Cavity (JLab/Cockcroft/Lancaster)**



# ELIC R&D and Path Forward

## Short Term Design Goals

•focusing on completion of a conceptual design with sufficient technical details for delivering to the next EIC AC meeting
•Scaling back several key parameters (particularly, increasing vertical beta-star to 2 cm) for reducing immediate R&D requirements, however still preserving high luminosity
•Concentrating available resources and manpower strategically to a minimum set of required R&D issues
•Optimizing ELIC design iteratively

## ELIC Long Term R&D Issues

- IR design with chromatic compensation
- High energy electron cooling
- Crab crossing and crab cavity
- Forming high intensity low energy ion beam
- Beam-beam effect
- Beam polarization and tracking
- Traveling focusing for very low energy ion

## Intermediate ELIC R&D Goals

**Focal Point 1**: Complete Electron & Ion Ring designs
sub tasks: Insert interaction region design
Chromaticity correction w/ tracking
**Led by Ya. Derbenev & A. Bogacz (JLab)**

**Focal Point 2**: IR design, feasibilities of advanced schemes
sub tasks: Develop a complete IR design
Beam dynamics with crab crossing
Traveling final focusing
**Led by M. Sullivan (SLAC)**

**Focal Point 3**: Conceptual design of ion injector/prebooster
sub tasks: bunch dynamics & space charge effect
**Led by P. Ostroumov (ANL)**

**Focal Point 4**: Beam-beam interaction
sub tasks: Single and multiple IPs
With crab crossing and/or space charge
**Led by Y. Zhang & B.Terzic (JLab)**

## Established Collaborations

- Interaction region design — M. Sullivan (SLAC)
- ELIC ion complex front end — P. Ostroumov (ANL)
  - Ion source — V. Dudnikov, R. Johnson (Muons, Inc)
    V. Danilov (ORNL)
  - SRF Linac — P. Ostroumov (ANL), B. Erdelyi (NIU)
- Beam-beam simulation — J. Qiang (LBNL)

*FT (GPD) : momentum space → impact parameter space:*

[M. Burkardt, M. Diehl 2002]

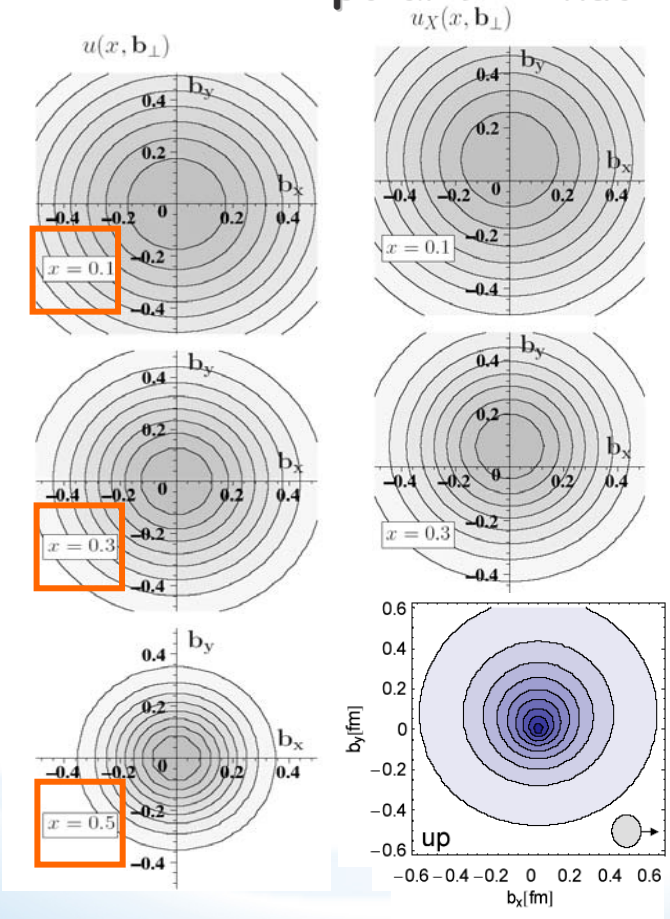
# Proton Tomography

probing partons with specified long. momentum @transverse position $b_\perp$

polarized nucleon:

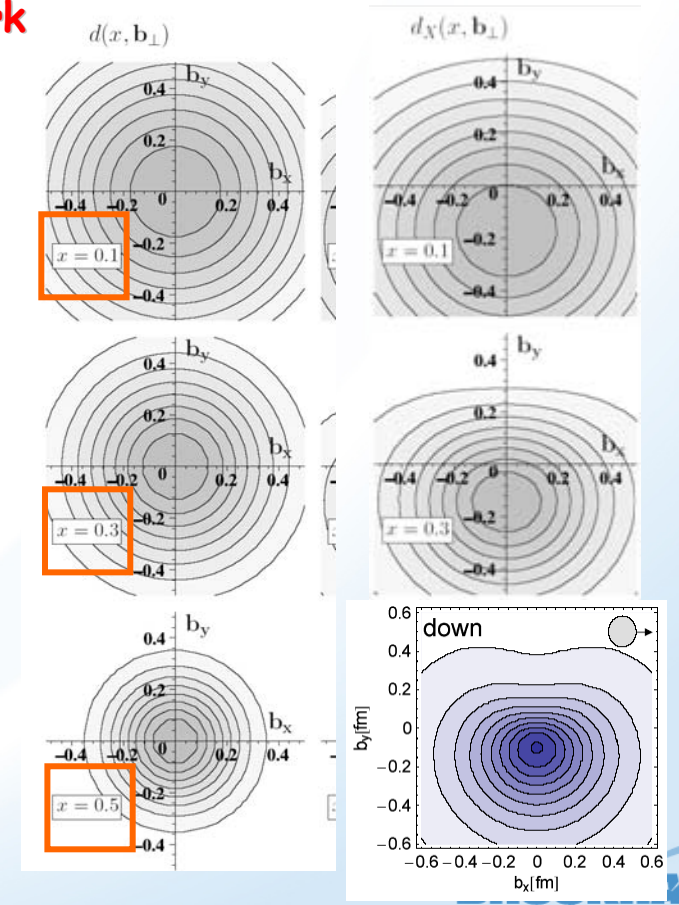
u-quark

[ξ=0]




from lattice

d-quark



# Detector Requirements (E. Aschenauer)

- ep-physics
  - the detector needs to cover inclusive (ep -> e'X) → semi-inclusive (ep -> e'X hadron(s)) → exclusive reactions (ep -> e'p$\pi$)
    - large acceptance absolutely crucial
    - particle identification ($\pi$,K,p,n) over wide momentum range
    - excellent vertex resolution (charm)
    - particle detection for very low scattering angle
  - small systematic uncertainty for e/p polarization measurements
  - very small systematic uncertainty for luminosity measurement
- eA-physics
  - requirements very similar to ep
    - most challenging get information on recoiling heavy ion from exclusive and diffractive reactions.

# Spring Workshop on electron-Nucleus Collider Physics



14 May 2010 *CERN*



## Nuclear Physics planning for an eIC

**Id:** 3
**Place:** *CERN*
NYC

Room:
**Starting date:** 14-May-2010 10:40 (America/New_York)
**Duration:** 35'
**Presenters:** Dr. VIGDOR, Steve