OPPORTUNITA' DI EIC PER I GRUPPI ITALIANI

Contalbrigo Marco
INFN Ferrara

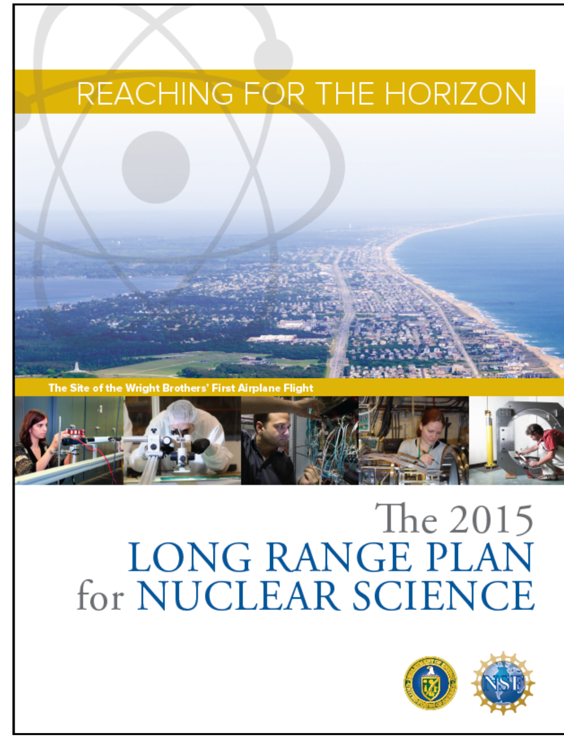
Giornata sulle opportunita' del progetto EIC
Gennaio 17, 2017 - Muse Sant'Agostino, Genova

The 2015 Long Range Plan for Nuclear Science

Nuclear Science Advisory Committee (NSAC) and American Physics Society – Division of Nuclear Physics (APS-DNP) partnered to tap the full intellectual capital of the U.S. nuclear science community in identifying exciting, compelling, science opportunities

Recommendations:

- The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. ***The highest priority in this 2015 Plan is to capitalize on the investments made.***
- The observation of neutrinoless double beta decay in nuclei would…have profound implications.. ***We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.***
- Gluons…generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain…. These can only be answered with a powerful new electron ion collider (EIC). ***We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.***
- ***We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.***



NP is implementing these recommendations which are supported in the President's FY 2017 request

DOE NP Stewardship

Talk at JLab User Group Meeting June 2016 Dr. Jehanne Gillo
Division Director, Facilities and Project Management
DOE/Office of Nuclear Physics

2007 LRP Recommendations:

- We recommend completion of the 12 GeV CEBAF Upgrade at Jefferson Lab. The Upgrade will enable new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon descriptions of nuclei, and the nature of confinement.

  Over 96% complete; restart of science in FY2017

- We recommend construction of the Facility for Rare Isotope Beams (FRIB), a world-leading facility for the study of nuclear structure, reactions, and astrophysics. Experiments with the new isotopes produced at FRIB will lead to a comprehensive description of nuclei, elucidate the origin of the elements in the cosmos, provide an understanding of matter in the crust of neutron stars, and establish the scientific foundation for innovative applications of nuclear science to society.

  Construction ~60% complete, 10.5 weeks ahead of schedule

- We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries. These experiments aim to discover the nature of the neutrino, yet-unseen violations of time-reversal symmetry, and other key ingredients of the New Standard Model of fundamental interactions. Construction of a Deep Underground Science and Engineering Laboratory is vital to U.S. leadership in core aspects of this initiative.

– Projects underway (KATRIN, CUORE, Majorana Demonstrator, FNPB, neutron EDM)

- The experiments at the Relativistic Heavy Ion Collider have discovered a new state of matter at extreme temperature and density—a quark-gluon plasma that exhibits unexpected, almost perfect liquid dynamical behavior. We recommend implementation of the RHIC II luminosity upgrade, together with detector improvements, to determine the properties of this new state of matter.

  Upgrade completed

JLab Director

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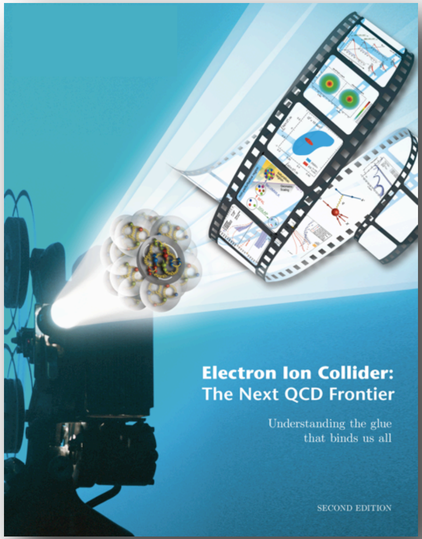
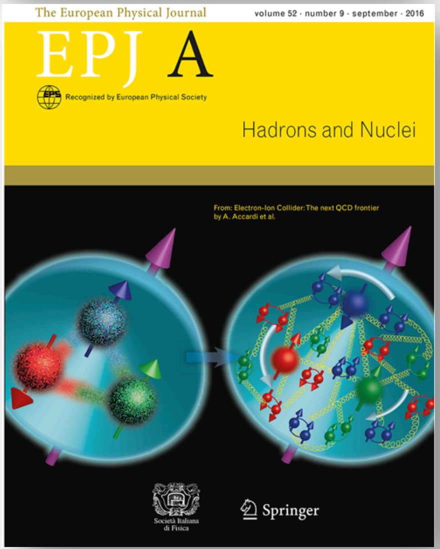
Stuart Henderson appointed director of DOE's Jefferson Lab

Having an accelerator physicist at the helm may also help Jefferson Lab as it looks to its longer term future. Although Jefferson Lab's clear priority is making the most of the 12-GeV upgrade, nuclear physicists want to build a high-energy electron-proton collider and set that as their long-term priority in **a long-range plan formulated in 2015**. That project likely couldn't be completed until the late 2020s at the earliest, but Henderson says he's eager to help pursue the long-range plan. "The attraction [of the directorship] is to be able to have an impact at a higher level," he says.

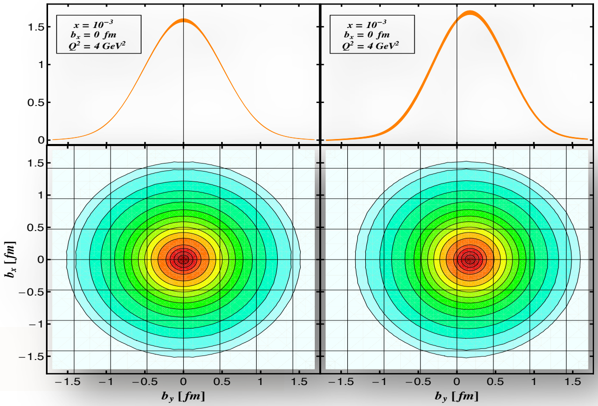
The Electron Ion Collider

Accardi et al., Eur. Phys. J. A (2016) 52: 268 arXiv: 1212.1701.v3

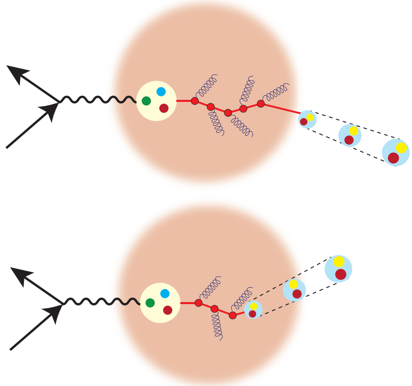




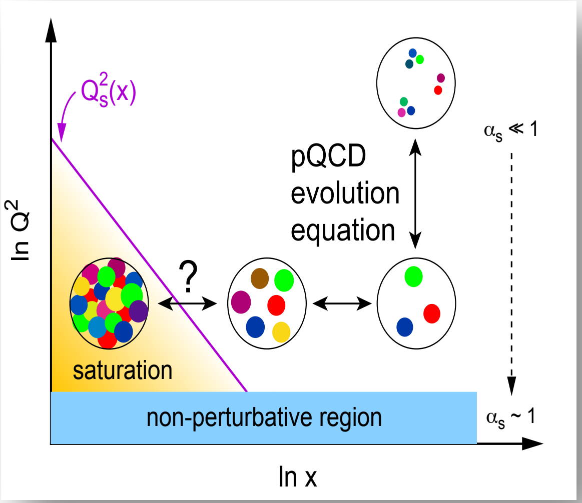
3D Imaging of Nucleon Structure



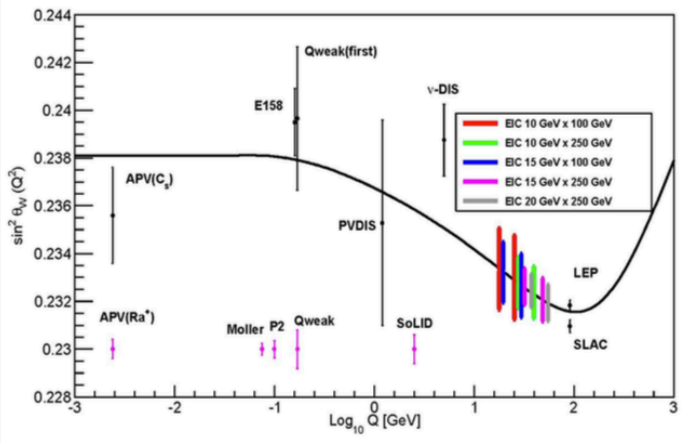
Hadronization in cold QCD matter



Gluon Saturation



EW Physics

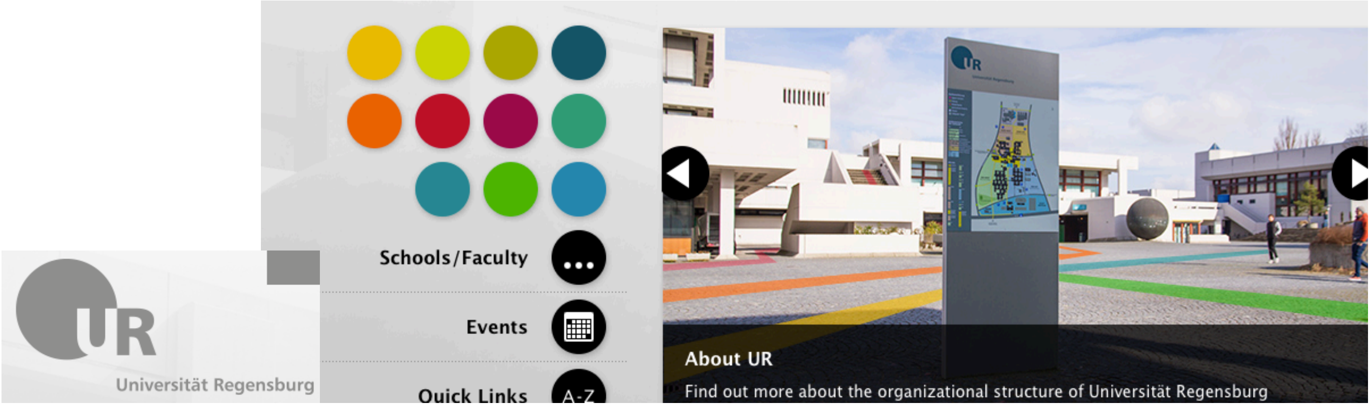


The POETIC Conference

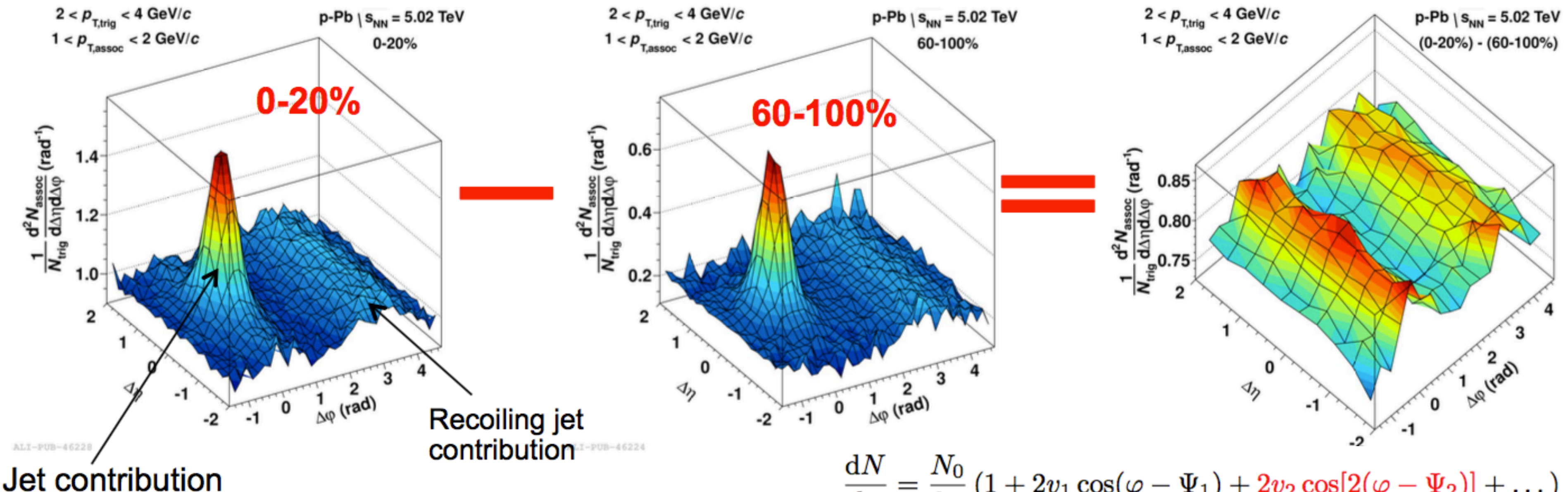
2016

2017

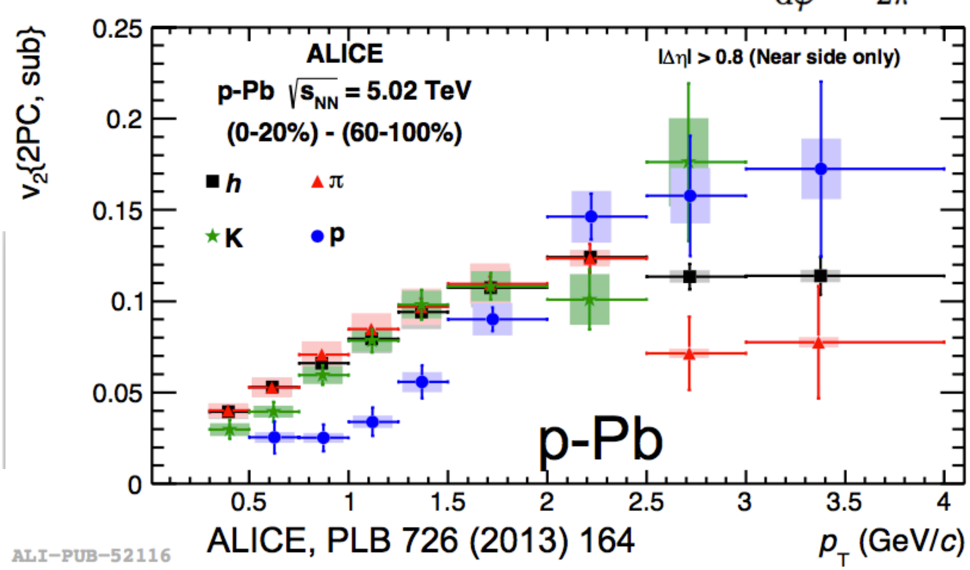
2018

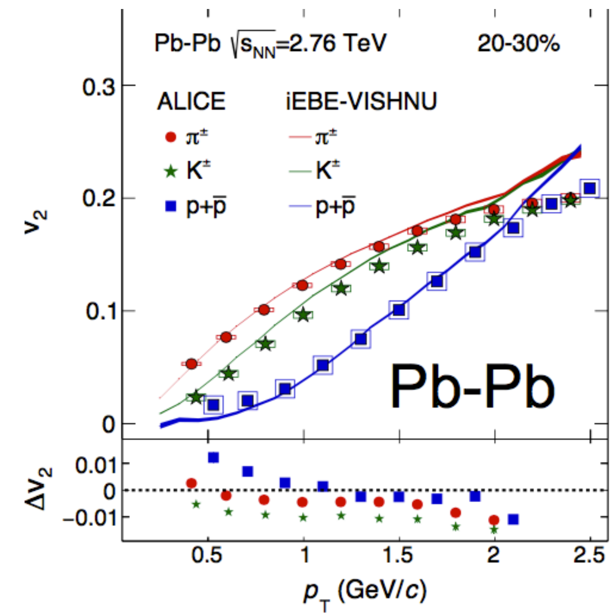


Elliptic Flow



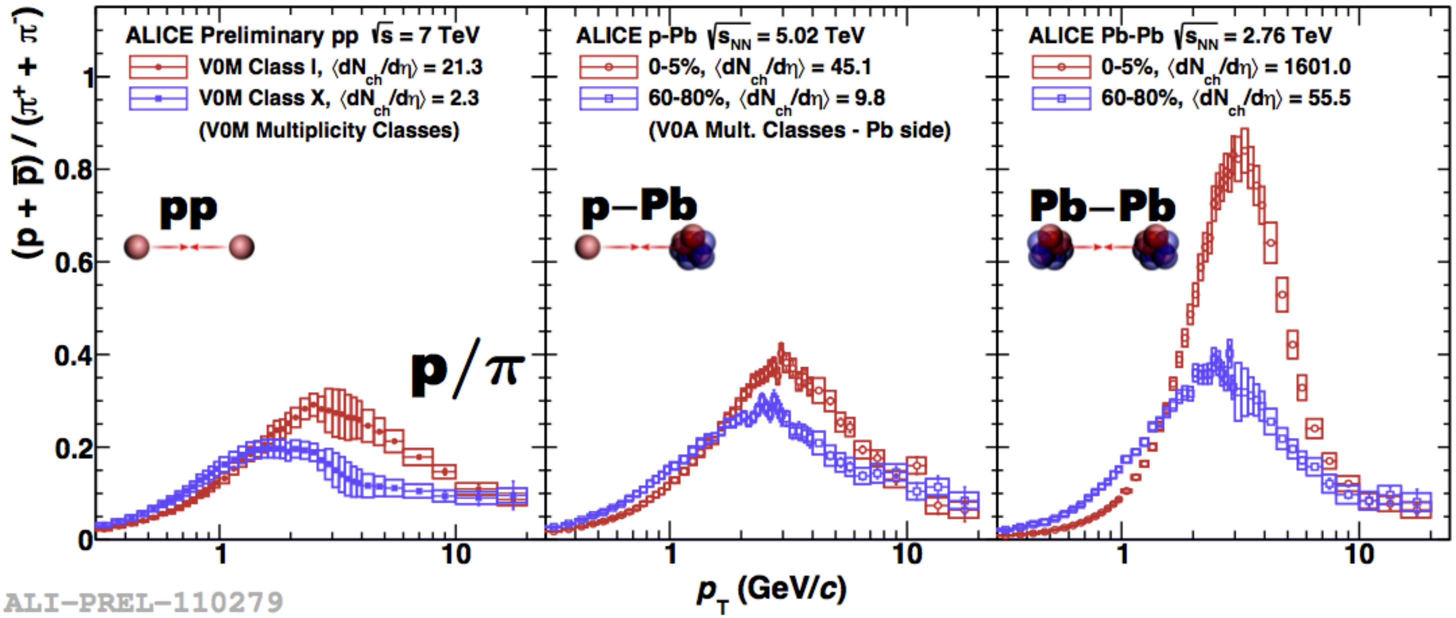
$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi}\left(1 + 2v_1\cos(\varphi - \Psi_1) + 2v_2\cos[2(\varphi - \Psi_2)] + \ldots\right)$$





ALICE

Hadron Multiplicity Ratio



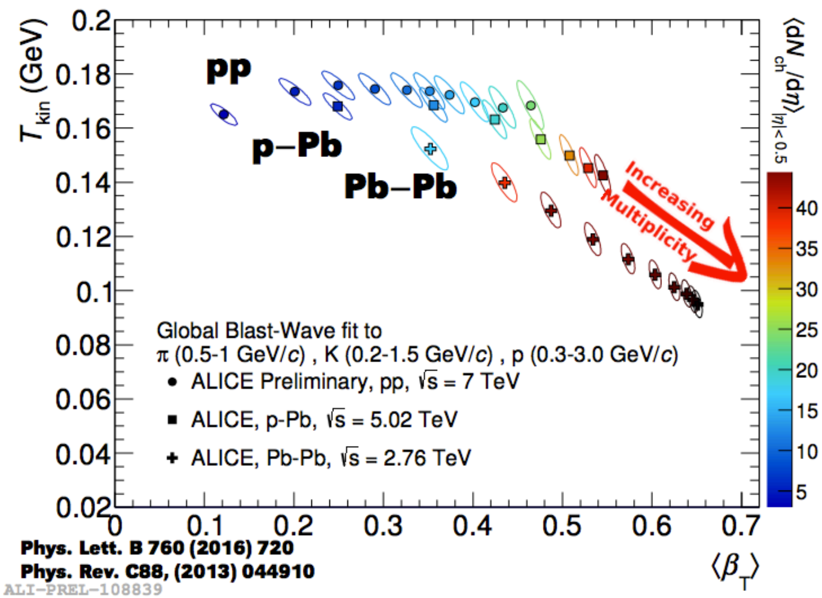
Similar features in Pb-Pb, p-Pb and even p-p at high multiplicity

Where QGP is really formed and manifest ?

Collective effects even for the “simple” proton ?

$\beta_T \rightarrow$ **radial velocity**

$T_{kin} \rightarrow$ **kinetic freeze-out temperature (particle decoupling)**

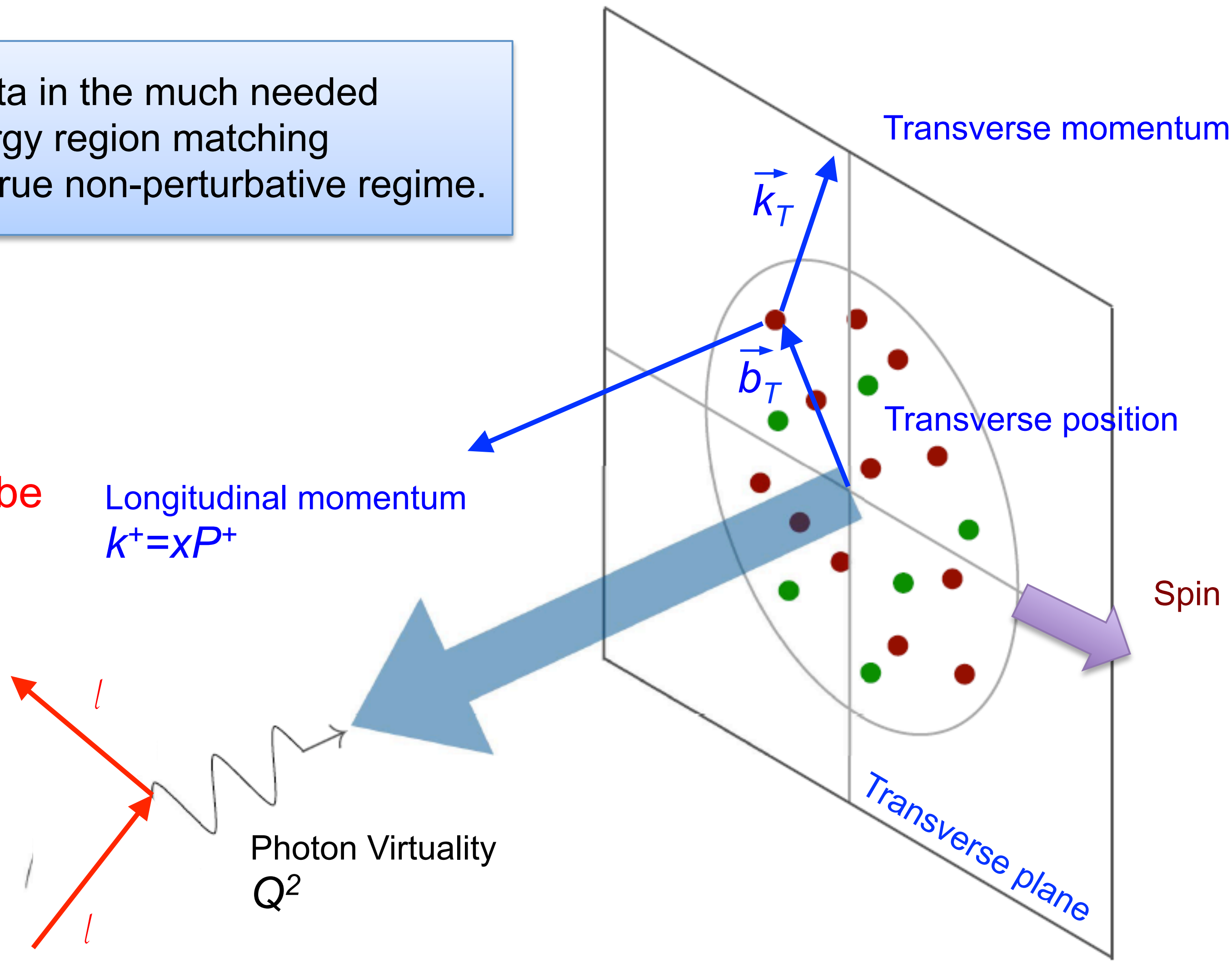


Accessing Parton Dynamics

EIC will provide data in the much needed "intermediate" energy region matching "pure" pQCD with true non-perturbative regime.

Confinement Scale

High Energy Probe
Hard Scale



EIC Parameters

Key parameters:
Energy, Luminosity, Polarization

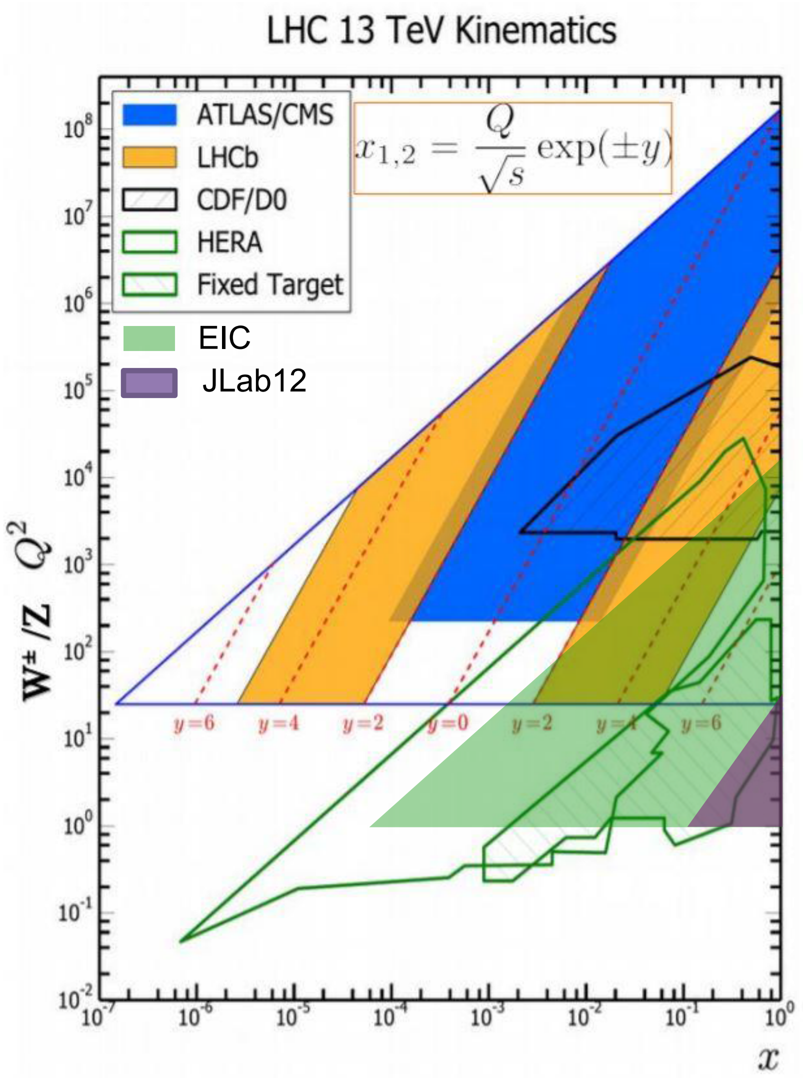
For e-N collisions:

- ✓Polarized beams: e, p, d/^{3}He
- ✓E_e =5-10 (20) GeV
- ✓Luminosity L_{ep} ~ 10^{33-34} cm^{-2} sec^{-1}
- ✓20-100 (140) GeV Variable C.M.

For e-A collisions:

- ✓Wide range in nuclei up to A above 200 (Au, Pb)
- ✓Luminosity per nucleon same as e-p
- ✓Variable center of mass energy

World's first
Polarized e-N & e-A collider



The EIC Options

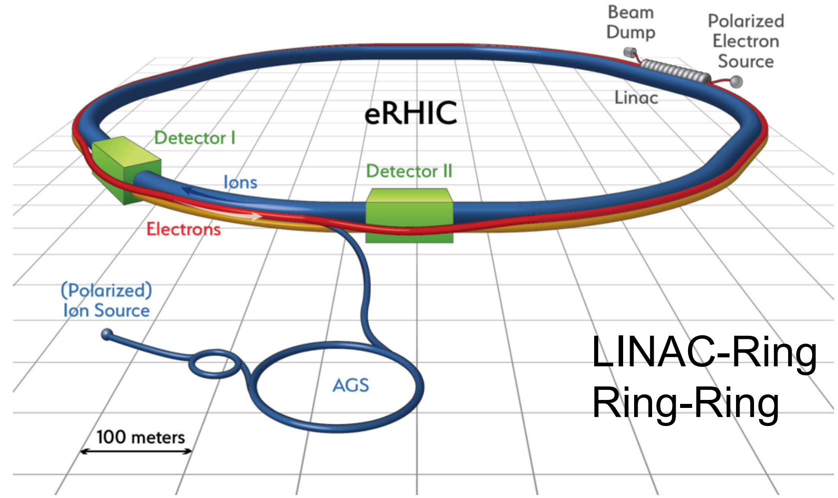
Two options of realization with various technological challenges

arXiv:1409.1633

Energy range:
e-: 15-20 GeV
p : 100-250 GeV

1.3 GeV ERL

eRHIC



LINAC-Ring
Ring-Ring

Both designs use DOE's significant investments in infrastructure


MEIC Design Summary

January 20, 2015

Author List

S. Abeyratne[6], D. Barber[2], A. Bogacz[1], P. Brindza[1], Y. Cai[8], A. Camsonne[1], A. Castilla[7], P. Chevtsov[10], E. Daly[1], Y. S. Derbenev[1], D. Douglas[1], V. Dudnikov[11], R. Ent[1], B. Erdelyi[6], Y. Filatov[4], D. Gaskell[1], J. Grames[1], J. Guo[1], L. Harwood[1], A. Hutton[1], C. Hyde[7], K. Jordan[1], A. Kimber[1], G. A. Krafft[1,7](editor), A. Kondratenko[3], M. Kondratenko[3], R. Li[1], F. Lin[1], T. Mann[9], P. McIntyre[9], T. Michalski[1], V.S. Morozov[1], P. Nadel-Turonski[1], Y.M. Nosochkov[8], P. N. Ostroumov[5], K. Park[7], F. Pilat[1], M. Poelker[1], N. J. Pogue[9], R. Rimmer[1], Y. Roblin[1], T. Satogata[1], A. Sattarov[9], M. Spata[1], R. Suleiman[1], M. Sullivan[8], A. Sy[1], C. Tennant[1], H. Wang[1], M-H Wang[8], S. Wang[1], U. Wienands[8], H. Zhang[1], Y. Zhang[1], Z. Zhao[1]

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1

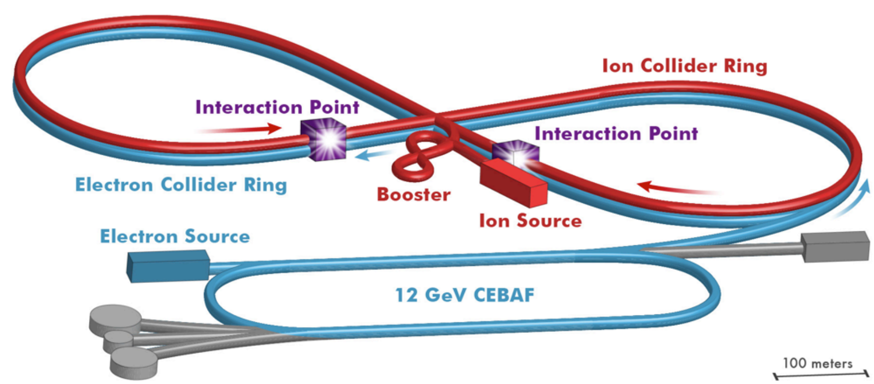
arXiv:1504.07961

Energy range:
e-: 3-10 GeV
p : 20-100 GeV

Figure-8 ring to preserve polarization

JLEIC

Ring-Ring



EIC Distinct from (the past) HERA

- Luminosity 100-1000 times that of HERA
  - Enable 3D tomography of gluons and sea quarks in protons
- Polarized protons and light nuclear beams
  - Critical to all spin physics related studies, including precise knowledge of gluon's spin & angular momentum contributions from partons to the nucleon's spin
- Nuclear beams of all A (p→U)
  - To study gluon density at saturation scale and to search for coherent effects like the color glass condensate and test its universality
- Center mass variability with minimal loss of luminosity
  - Critical to study onset of interesting QCD phenomena
- Detector & IR designs mindful of "Lessons learned from HERA"
  - No bends in e-beam, maximal forward acceptance….

EIC Detector Challenges

Specific requirements to move beyond the longitudinal description

- Resolve partons in nucleons

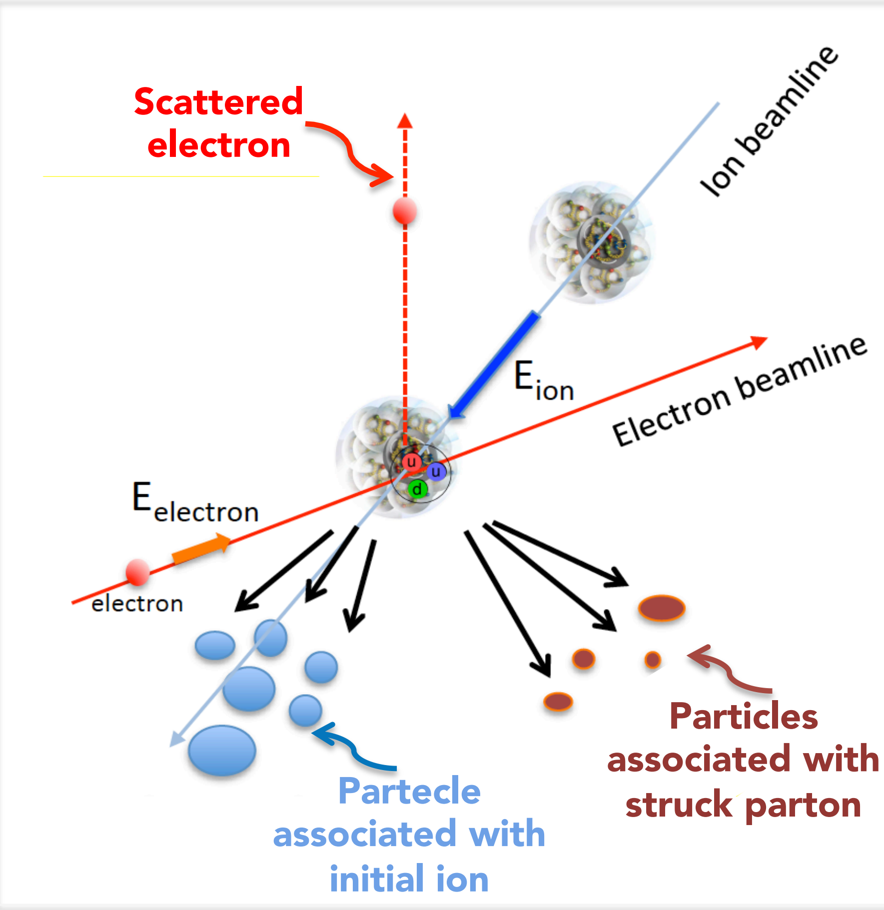
  ➔ high beam energies and luminosities Q^2 up to **~1000 GeV²**

- Need to resolve quantities (k_t, b_t) of the order **a few hundred MeV** in the proton
  Correlated quantitites, multi-D analyses

  ➔ High Granularity, wide dynamic range

- Need to detect **all types of remnants** to seek for correlations:
  - scattered electron
  - particles associated with initial ion
  - particles associated with struck parton

  ➔ Large acceptance, Forward particle detection, Excellent PID



The Path Forward for the EIC

- National Academy of Science Review of the EIC
  - Report due around end of 2017
  - NuPECC LRP support for the science would be very valuable.
- Accelerator R&D program ~7$M/year in FY17
- Generic Detector R&D program ~$1.3M/year

- There is a real opportunity for international sources to make a big impact on the physics goals and scope.

Don Geesaman at NuPECC Town Meeting, 13 January 2017

The Path Forward for the EIC

- National Academy of Science Review of the EIC
  - Report due around end of 2017
  - NuPECC LRP support for the science would be v y valuable.
- Accelerator R&D program ~7$M/year in FY1
- Generic Detector R&D program ~$1.3M/y

Science Case

Technology Gain

- There is a real opportunity for international sources to make a big impact on the physics goals and scope.

Don Geesaman at NuPECC Town Meeting, 13 January 2017

National Academy of Science Review

- **DOE charge to National Academy of Science (NSAC meeting - March 2016)**

The committee will assess the scientific justification for a US domestic electron ion collider facility, taking in to account current international plans and existing domestic facility infrastructure. In preparing its report, the committee will address the role that such a facility could play in the future of nuclear physics, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics.

- **Committee assembled**
- **First organizational meeting in February 2017**
- **Expect resolution in Fall/Winter 2017**

Charges to the Committee

In particular, the committee will address the following questions:

1. What is the merit and significance of the science that could be addressed by an EIC facility and what is its importance in the overall context of research in nuclear physics and the physical sciences in general?

2. What are the capabilities of other facilities, existing and planned, domestic and abroad, to address the science opportunities afforded by an EIC? What unique scientific role could be played by a domestic EIC that is complementary to existing and planned facilities at home and abroad?

3. What are the benefits of US leadership in nuclear physics if a domestic EIC were constructed?

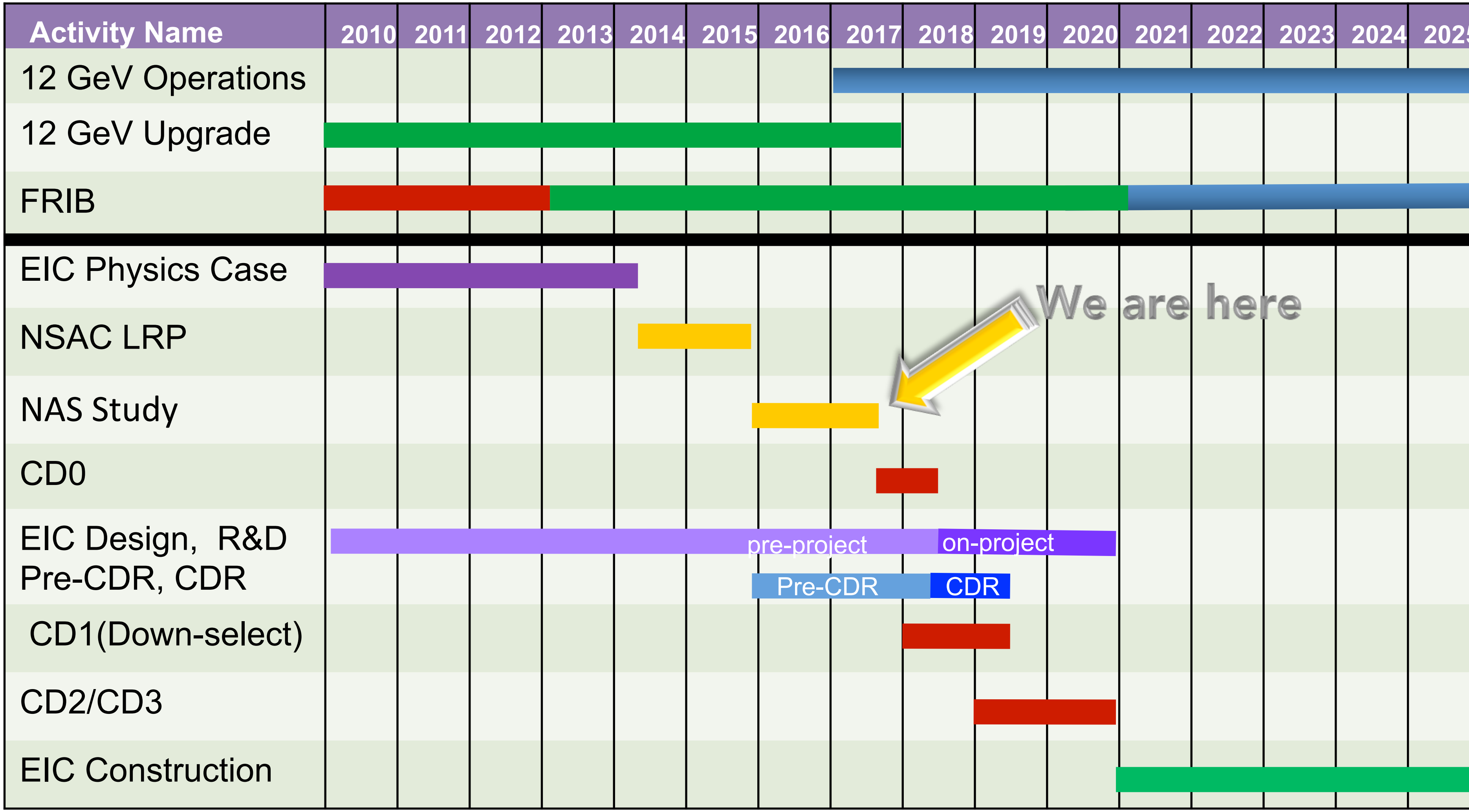
4. What are the benefits to other fields of science and to society of establishing such a facility in the US?

NAS Panel Membership

Ani Aprahamian, Co-Chair (University of Notre Dame)
Gordon Baym, Co-Chair (U. Illinois at Urbana-Champaign)
Christine Aidala (University of Michigan)
Richard Milner (MIT)
Ernst Sichtermann (LBNL)
Zein-Eddine Meziani (Temple University)
Thomas Schaefer (NC State University)
Michael Turner (University of Chicago)
Wick Haxton (University of California-Berkeley)
Kawtar Hafidi (Argonne)
Peter Braun-Munzinger (GSI)
Larry McLerran (University of Washington)
Haiyan Gao (Duke)
John Jowett (CERN)

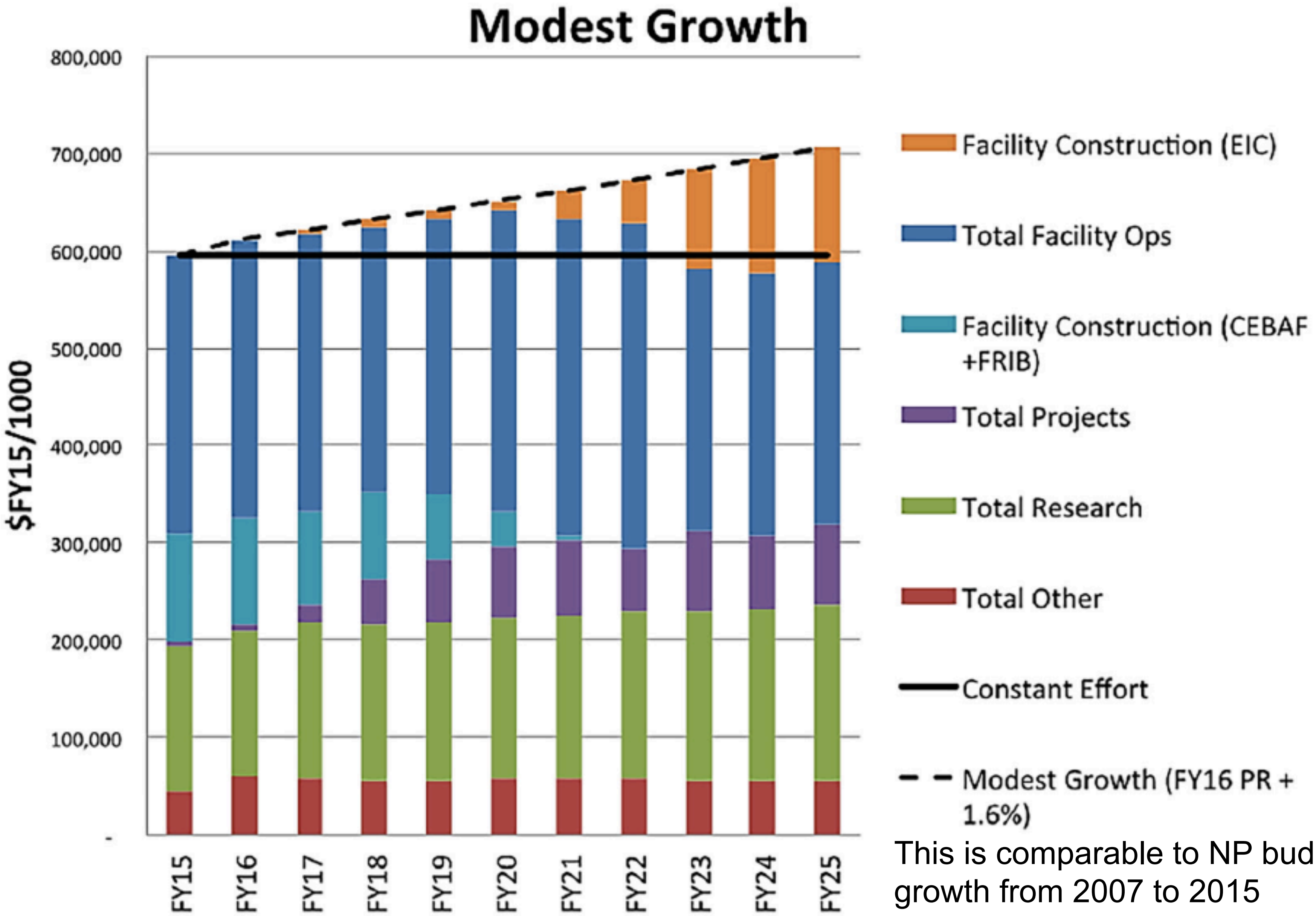
First Meeting: Feb. 1-2

EIC Timeline



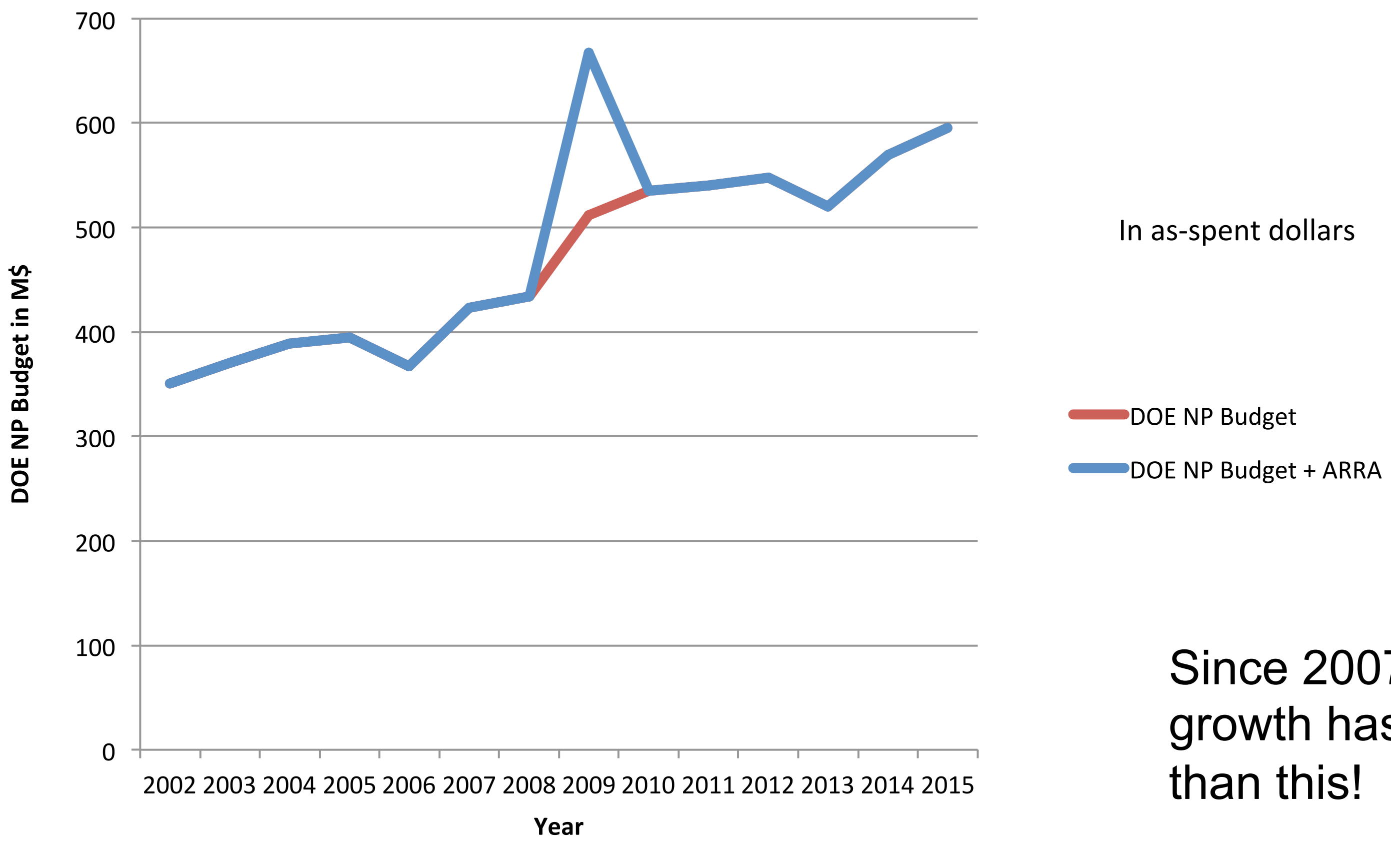
CD0 = DOE "Mission Need" statement; CD1 = design choice and site selection (VA/NY)
CD2/CD3 = establish project baseline cost and schedule

DOE NP Budget Projections



This is comparable to NP budget growth from 2007 to 2015

Realistic Projection ?
DOE NP Budget history Since the 2007 LRP



Since 2007, the real growth has been larger than this!

NSAC-LRP Initiatives

A: Theory Initiative

Advances in theory underpin the goal that we truly understand how nuclei and strongly interacting matter in all its forms behave and can predict their behavior in new settings.

To meet the challenges and realize the full scientific potential of current and future experiments, we require new investments in theoretical and computational nuclear physics.

- *We recommend new investments in computational nuclear theory that exploit the U.S. leadership in high-performance computing. These investments include a timely enhancement of the nuclear physics contribution to the Scientific Discovery through Advanced Computing program and complementary efforts as well as the deployment of the necessary capacity computing.*
- *We recommend the establishment of a national FRIB theory alliance. This alliance will enhance the field through the national FRIB theory fellow program and tenure-track bridge positions at universities and national laboratories across the U.S.*
- *We recommend the expansion of the successful Topical Collaborations initiative to a steady-state level of five Topical Collaborations, each selected by a competitive peer-review process.*

3D Phenomenology

DOE funded topical collaboration dedicated to TMDs

Topical Collaboration for the Coordinated Theoretical Approach to Transverse Momentum Dependent (TMD) Hadron Structure in QCD

TMD Collaboration

The TMD Collaboration
Spokespersons: William Detmold (MIT) and Jianwei Qiu (BNL)

Co-Investigators - (in alphabetical order of institutions):
Jianwei Qiu and Raju Venugopalan (Brookhaven National Laboratory)
Thomas Mehen (Duke University)
Ted Rogers (Jefferson Laboratory and Old Dominion University)
Alexei Prokudin (Jefferson Laboratory and Penn State University at Berks)
Feng Yuan (Lawrence Berkeley National Laboratory)
Christopher Lee and Ivan Vitev (Los Alamos National Laboratory)
William Detmold, John Negele and Iain Stewart (MIT)
Matthias Burkardt and Michael Engelhardt (New Mexico State University)
Leonard Gamberg (Penn State University at Berks)
Andreas Metz (Temple University)
Sean Fleming (University of Arizona)
Keh-Fei Liu (University of Kentucky)
Xiangdong Ji (University of Maryland)
Simonetta Liuti (University of Virginia)

- 5 years of funding
- 18 institutions
- Theory, phenomenology, lattice QCD
- Several postdoc and tenure track positions to be created
- "To address the challenges of extracting novel quantitative information about the nucleon's internal landscape"
- "To provide compelling research, training, and career opportunities for young nuclear theorists"

3D Phenomenology

Has|QCD
HADRONICS STRUCTURE AND QCD

HOME TEAM 3D SPIN WORKS NEWS CONTACTS

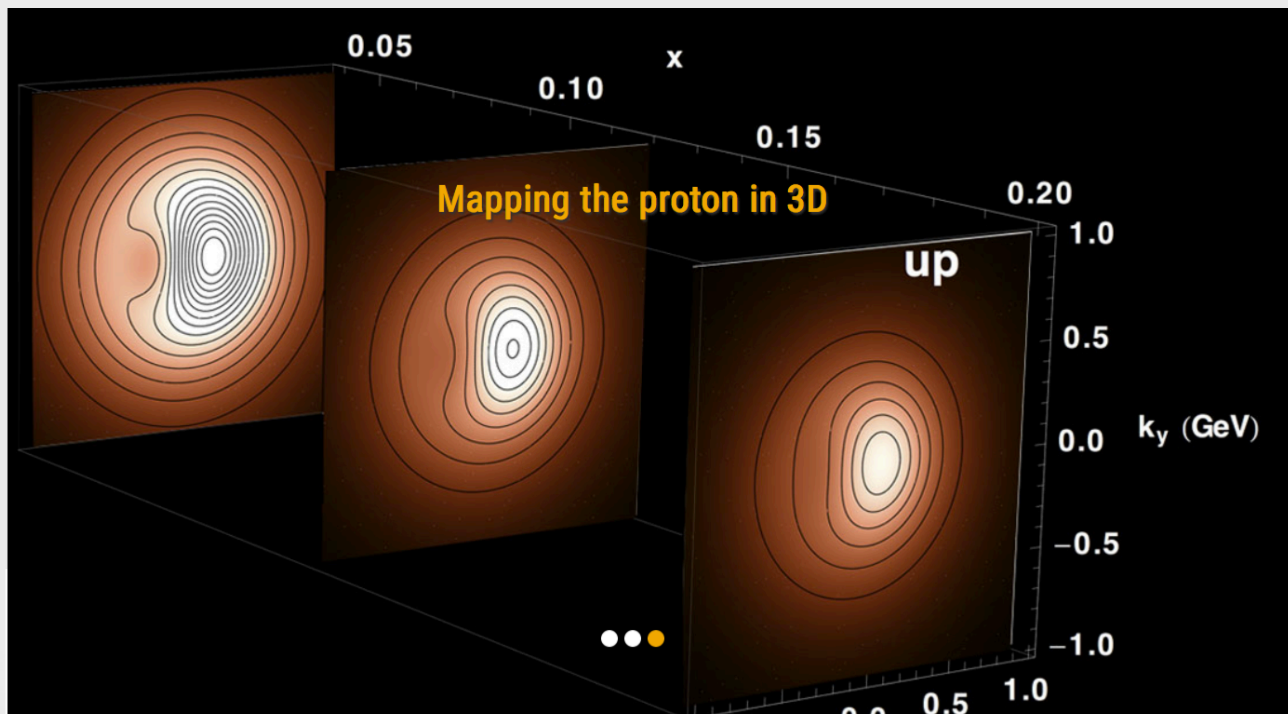
http://www.hadronicphysics.it/hasqcd/index.php/3d-spin/

A. Bacchetta
ERC Consolidator Grant

devoted to the study of the properties of transverse momentum distributions and their extraction from experimental data

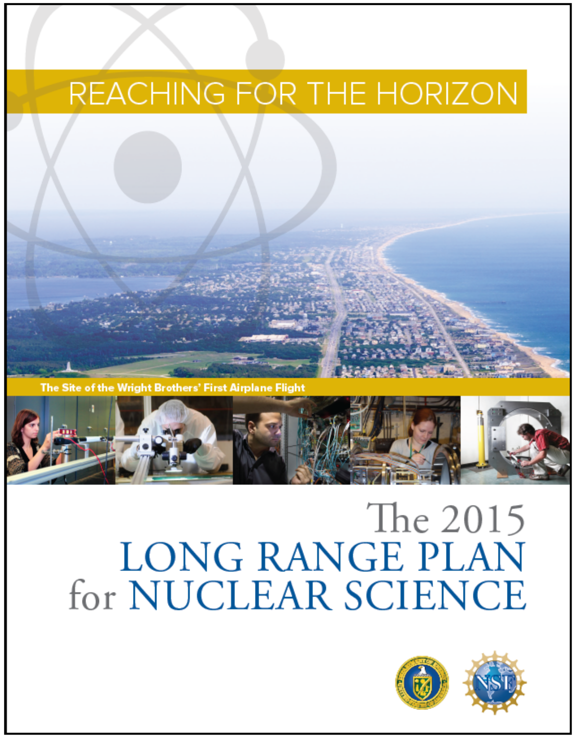
Home / 3d Spin

3DSPIN
MAPPING THE PROTON IN 3D



B: Initiative for Detector and Accelerator Research and Development
U.S. leadership in nuclear physics requires tools and techniques that are state-of-the-art or beyond. Targeted detector and accelerator R&D for the search for neutrinoless double beta decay and for the Electron Ion Collider is critical to ensure that these exciting scientific opportunities can be fully realized.

- *We recommend* ***vigorous detector and accelerator R&D in support of*** *the neutrinoless double beta decay program and* ***the Electron Ion Collider****.*



EIC Accelerator Development

Accelerator R&D program ~7$ M/year in FY17

- NSAC Cost review: January 2015
- DOE-NP will increase EIC accelerator R&D in FY17 through 'tax' on JLab/BNL:
  - In addition to the R&D FY17 funds NP will redirect and pool ~2.6% operations funds President request from JLAB and BNL
- A Priority Review Committee convened on Nov 29- Dec 2 to prioritize areas and topics, report in mid January 2017
- A funding opportunity announcement (FOA) call for proposal will follow at a later date in 2017

The Detector R&D Program

Detector R&D program ~1.3 $ M/year in FY17

- Still focus on generic technology advance
  Not yet targeted on specific solutions
- Open to foreign Istitutions: Abroad expertise is very welcomed
- Flexible support: Funds for hardware and personnel
- Post-doc positions (3 years maximum) to promote career progresses
- Summer meeting: review reports and call for new proposals
  Last Meeting held in July 6-7, ANL
- Winter meeting: progress report
  FY17 Mid-term review on January 26-27, BNL

The Detector R&D Program

R&D program to provide seed funding for promising research ideas

Focus more on the research aspects rather than the development aspect.

The research proposal should crisply articulate the R&D program with achievable milestones for key performance parameters.

The proposal should clearly indicate how the EIC science will benefit from the R&D and what physics channels will be enabled by the research proposal.

Focus on EIC needs:

Moderate rate and background
Polarisation control
4π acceptance, forward detection….

The Detector R&D Program

Program manager: Thomas Ullrich (BNL)

Standing Advisory Committee:

Marcel Demarteau* (Argonne)
Carl Haber (LBNL)
Peter Krizan (Ljubljana)
Ian Shipsey (Purdue)
Rick Van Berg (UPenn)
Jerry Va'vra (SLAC)
Glenn Young (JLab)
*chair







FY2017 Funding Period

- Record participation
  - 17 proposals
  - 8 new proposals
  - eRD12 successfully completed

EIC Detector R&D Activities

Report of the 11th Meeting held on 6-7 July, 2016

- ✔ eRD3: Fast and lightweight EIC integrated tracking system (barrel MM, fwd GEM)
- ✔ eRD6: Tracking Consortium for the EIC (TPC, fwd GEM)
- ✔ eRD3/eRD6 Targeted R&D

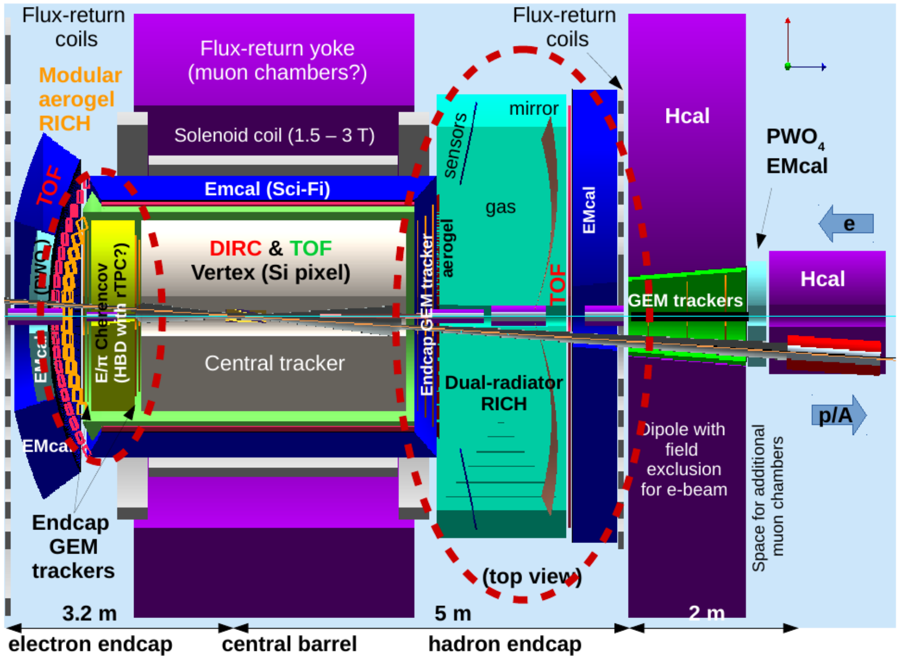
  INFN-Trieste: Thick GEM and MM for tracking and PID (MPGD)

- ✔ eRD14: Integrated particle identification for a future EIC (barrel DIRC, fwd RICH, TOF)

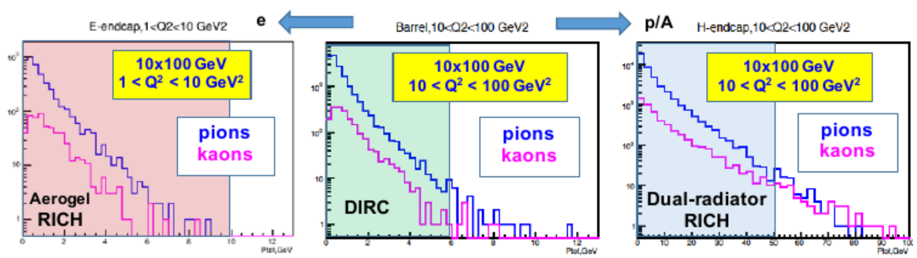
  INFN-Roma1: Dual RICH
  INFN-Ferrara: MA-PMT readout electronics

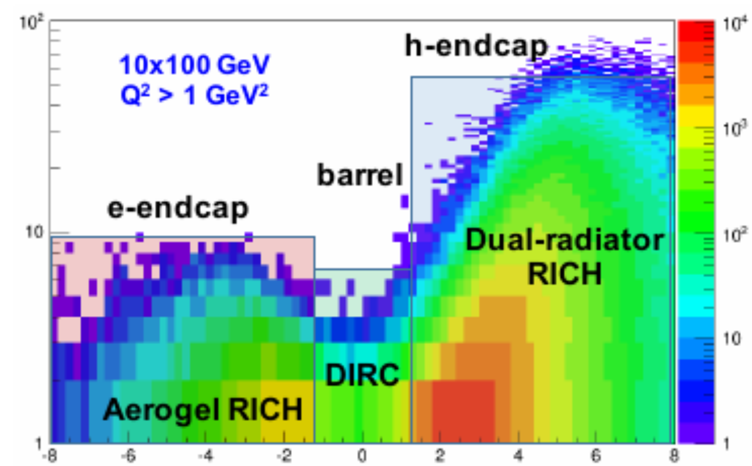
- ✔ eRD1: Calorimetry for the EIC ($PbWO_4$, Sampling W powder ScFi)
- ✔ eRD2: Magnetic Field Cloaking Device (YBCO layers)
- ✔ eRD12: Polarimetry, Luminosity and low Q2 tagger for the EIC into the IR (done)
- ✔ eRD15: Compton Polarimetry
- ✔ eRD16: MAPS for the EIC (Vertex tracker)
- ✔ eRD17: DPMJETHybrid 2.0

EIC Detector



The JLab central detector concept includes a DIRC, a dual-radiator and a modular aerogel RICH detectors and a 4π TOF for the PID. Three models of the EIC detector are under study at JLab and BNL, with slightly different layouts of the hadron identification. The PID consortium aims to develop an integrated solution useful for both BNL and Jlab.



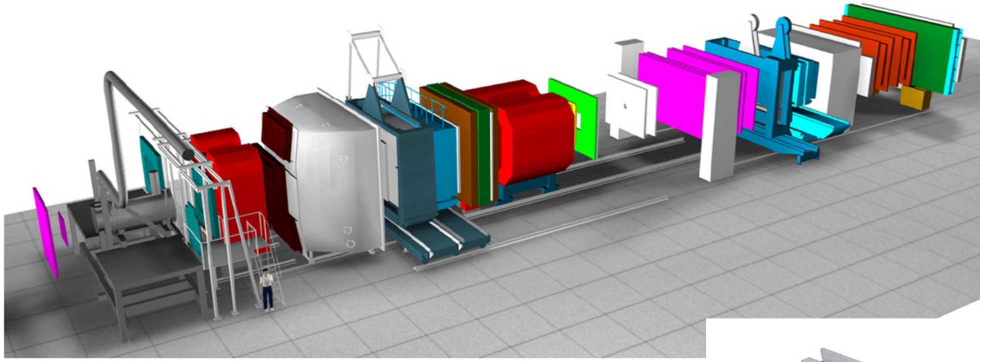


10 GeV e and 100 GeV p is a common JLab/BNL setting
Maximum momentum coverage is Important for physics (i.e. SIDIS)

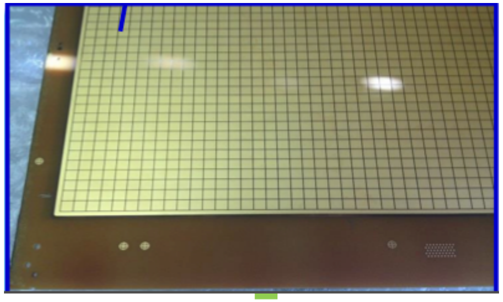
e-endcap: aerogel RICH with TOF (or dE/dx) for lower momenta

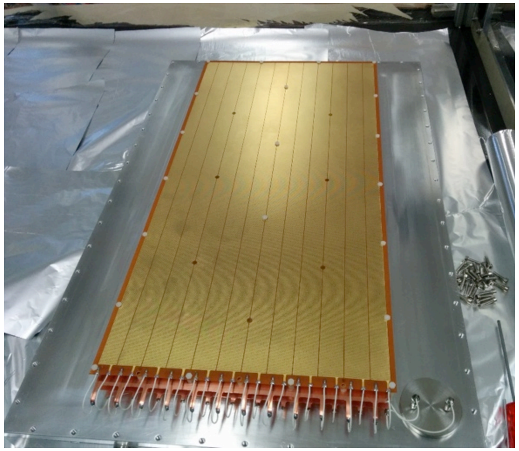
h-endcap: combined gas and aerogel RICH to cover the full range with TOF

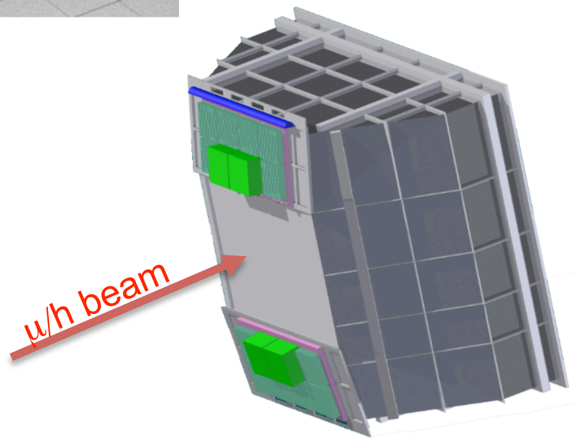
Thick GEM

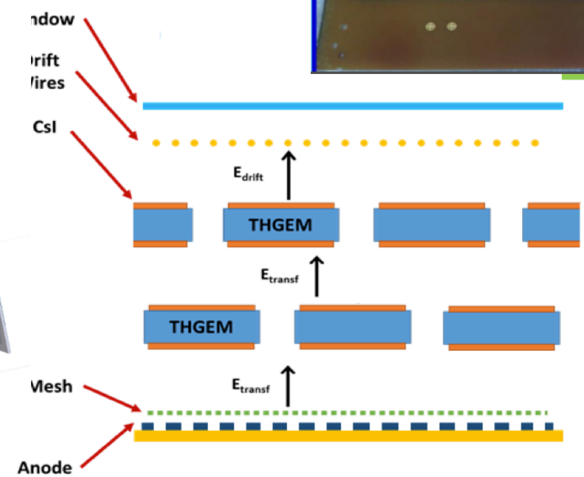


GEM expertise from COMPASS RICH
for Cherenkov detector and tracking (eRD6)

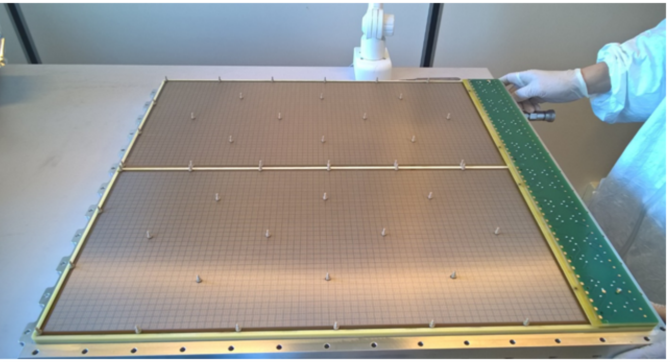


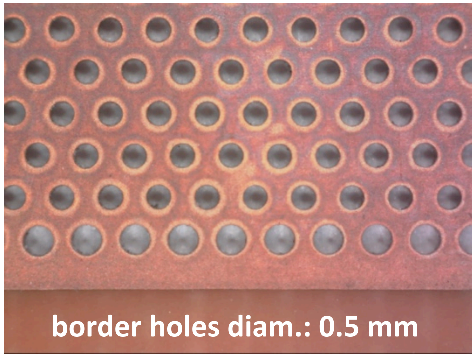






THGEM
Coated
with CsI





Program

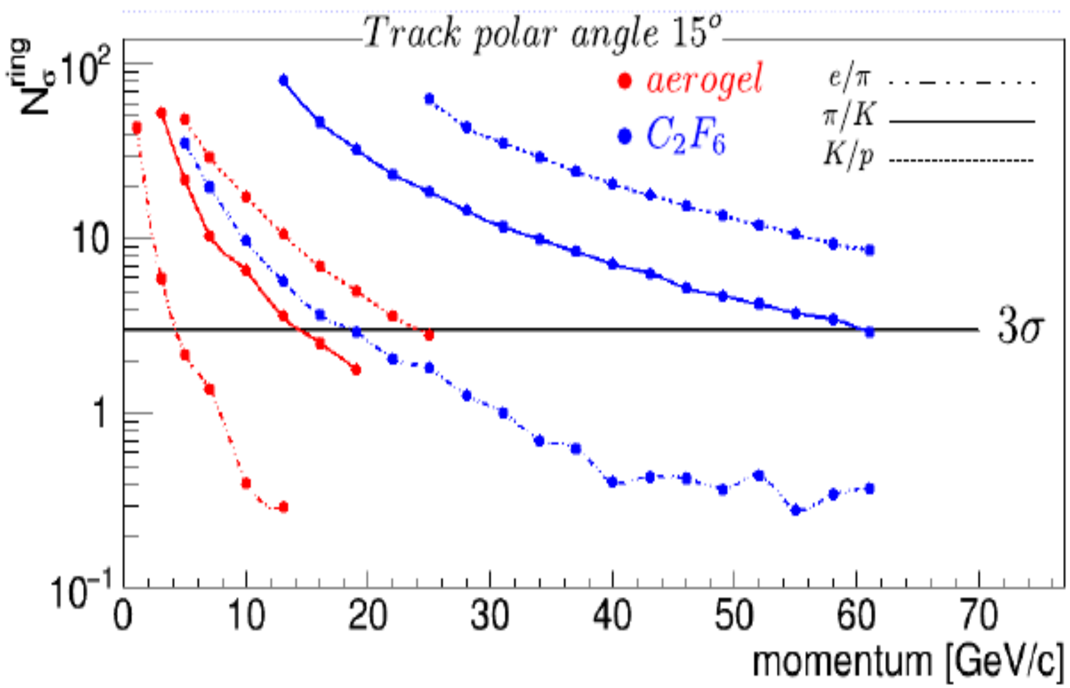
- Novel THGEM material
- Miniature Pads
- THGEM vs GEM
- IBF optimization
- Operation w/ Fluorocarbon

Dual-Radiator RICH

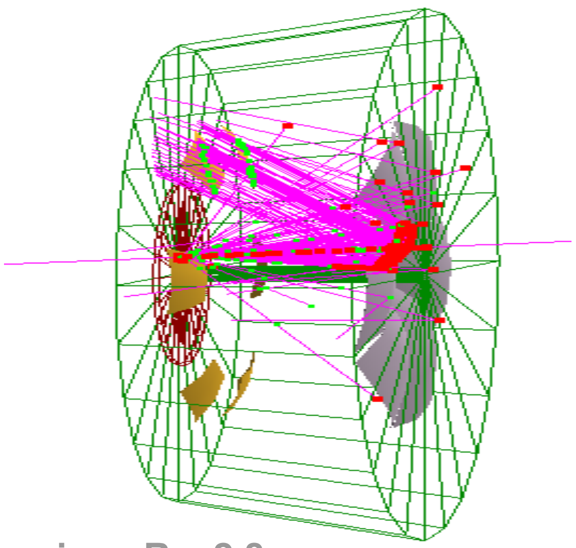
4 cm aerogel (n=1.02) & 160 cm C_2F_6 (or CF_4) gas

- Focusing mirror configuration (focal -plane away from the beam, reduced area and background)
- *RICH is in magnetic field (3T in the simulation)*

Discrimination power for particle types



Geant4 (GEMC) simulation



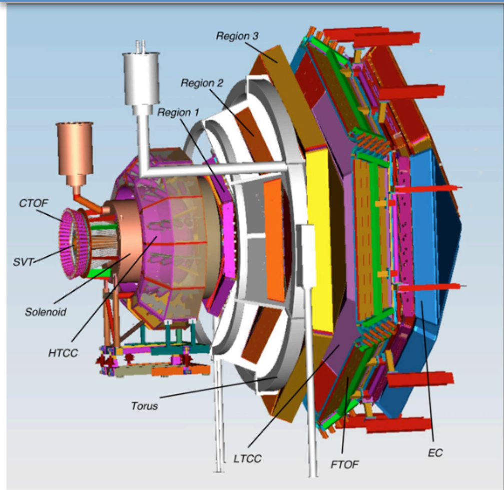
mirror R = 2.8 m

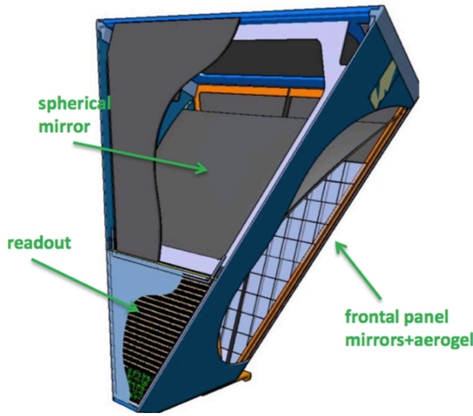
Photo-detector: spherical shape, *8500 cm²* (per sector), pixel size 3 mm

<u>6 sectors</u> of 60° in azimuthal angle

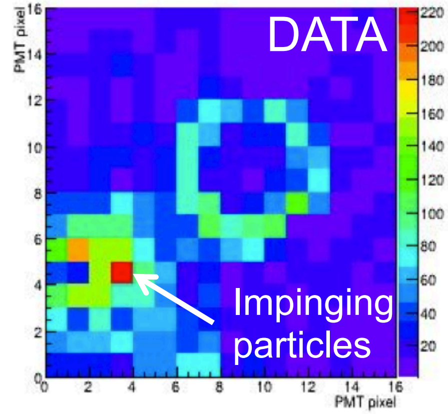
Reconstruction by Inverse Ray Tracing algorithm. Improved clarity of aerogel and n = 1.02 allow pi/K separation up to 13 GeV/c at 3 sigma

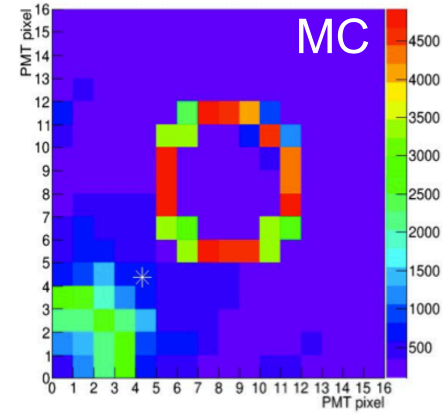
Modular RICH

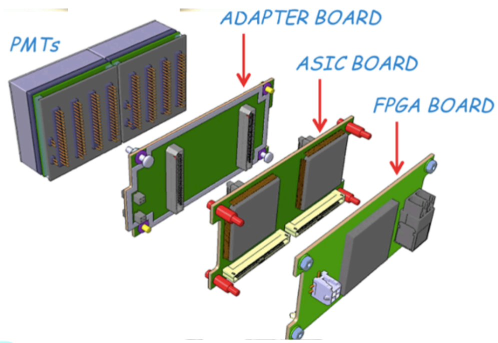


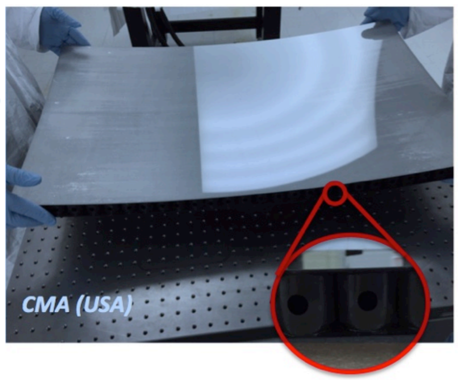


Test beam of small EIC mRICH prototype to validate fresnel lens focalization

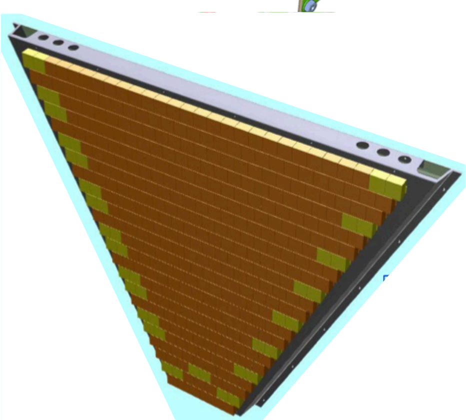


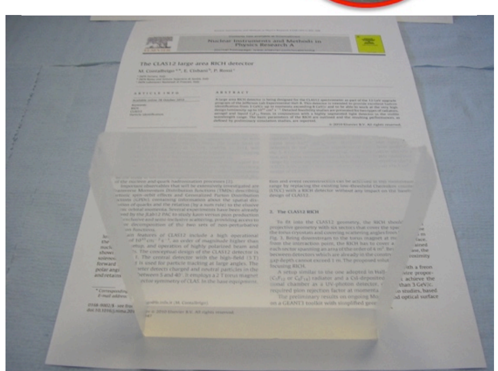


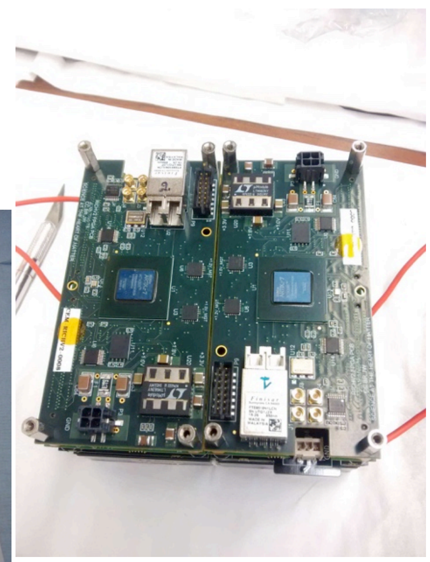


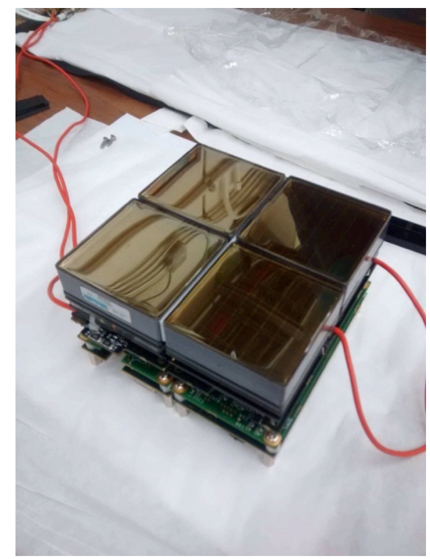


Cherenkov detector expertise from CLAS12 for aerogel radiator and readout electronics









New Detector R&D Proposals

Report of the 11th Meeting held on 6-7 July, 2016

- ✔ Detailed Simulations of Machine Background Sources and the Impact to Detector Oper.
- ✔ Developing Analysis Tools and Techniques for the EIC

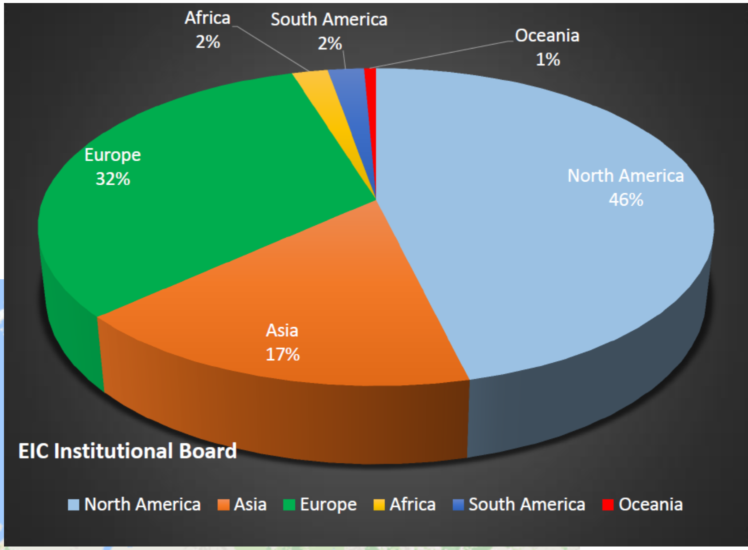
INFN - Trieste

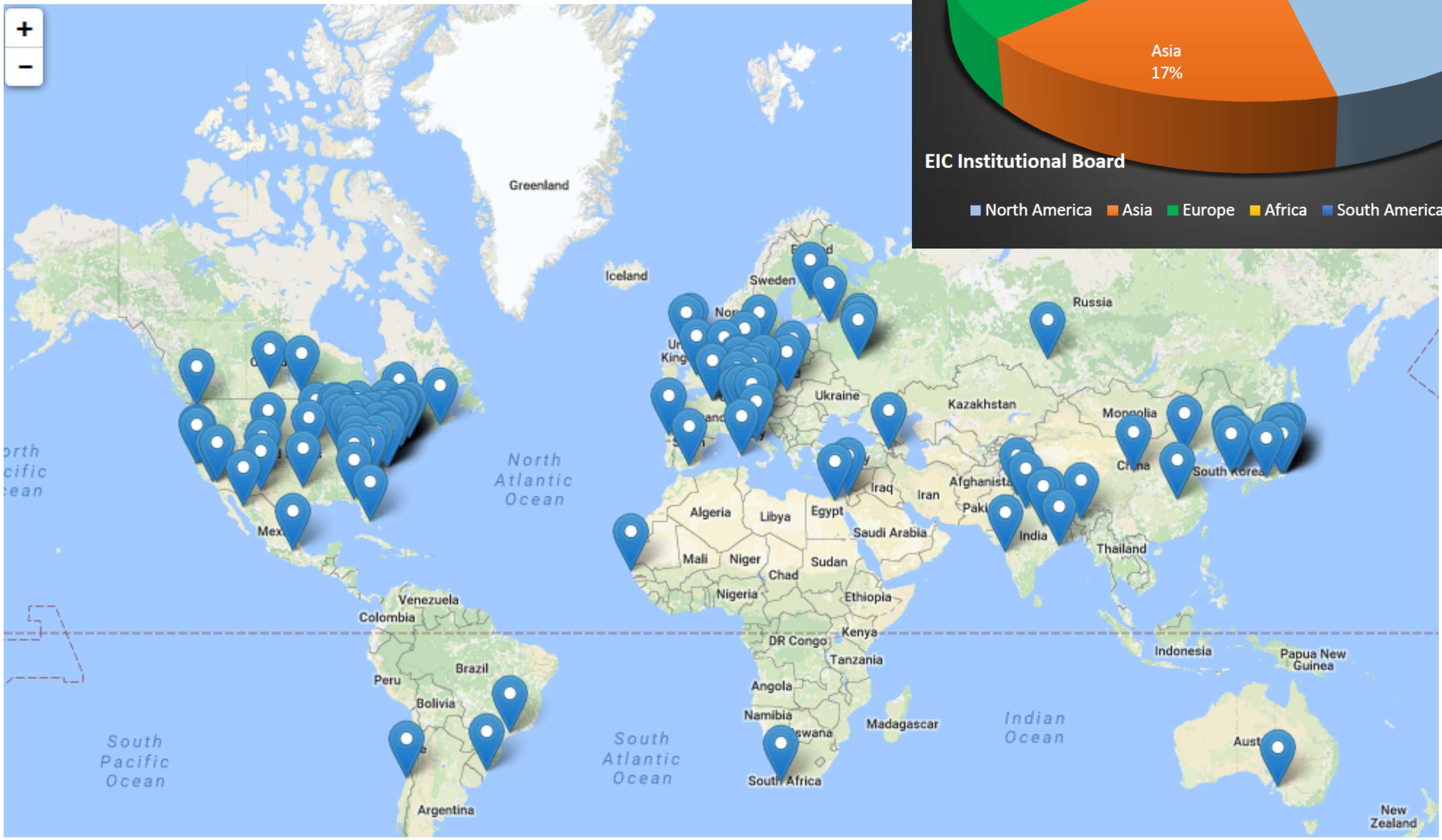
- ✔ Performance characteristics of the SiD detector for deep inelastic events at the EIC
- ✔ Precision Central Silicon Tracking & Vertexing for the EIC
- ✔ Developing Imaging Hadron Calorimetry
- ✔ Realizing Radiation Tolerant Magnetic Immune Radiation Detector Readout Using Optical Phase-modulation-based Electro-optical Coupling
- ✔ Precision Timing at the Electron Ion Collider
- ✔ Monolithic Fast Timing Silicon Detectors

670 collaborators, 28 countries, 150 institutions... (December, 2016)

(no students included as of yet)

IB Chair: Christine Aidala (University of Michigan)





Good opportunity to stay tuned (still informal joining procedure)

EICUG – Steering Committee

Chair: Abhay Desphande (Stony Brook University)
Vice-Chair: Bernd Surrow (Temple University)

IB-Chair: Christine Aidala (University of Michigan)

Regular Members:

John Arrington (ANL)
Charles Hyde (Old Dominion University)
Marco Radici (INFN - Pavia)

Lab Representatives:

Elke Aschenauer (BNL)
Rikutaro Yoshida (JLab)

European Representative
Asian Representative

EICUG meeting in Trieste, July 2017

- EICUG – EIC User Group (http://www.eicug.org/web/)
  - The community supporting EIC
  - 663 inscribed so far (experimentalists and theorists) – 45 from INFN

- Previous meetings: January 2016, Berkley July 2016, Argonne
  - Agenda: physics detectors accelerators

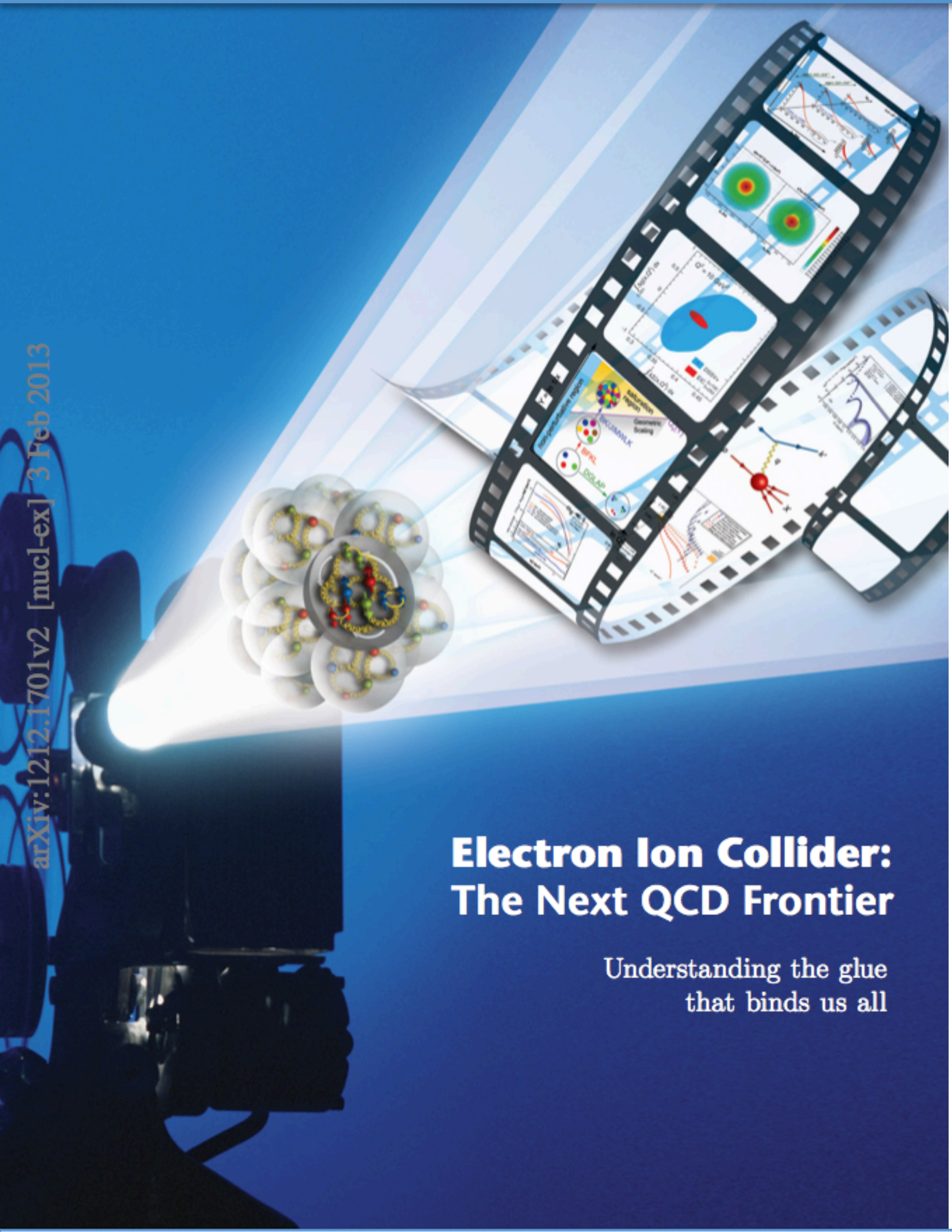
INFN initiative towards the formation of an international community

The JULY 2017 meeting of the EICUG will be host at INFN – Trieste

18-22 July 2017

- **Goals:**
  - Offer an opportunity to the whole INFN to learn more about – open to everyone !
  - Allow the interested INFN physicists to meet together in the right context to start forming a coherent community
  - More in general: offer an opportunity to European scientists, including the young component, to get in contact with EIC

The Next QCD Frontier



EIC is a unique opportunity
for a comprehensive QCD study
and possible breakthroughs

A strong effort is ongoing to make it
a reality by a motivated,
experienced and open community
all over the world

It offers immediate opportunities
for supported R&D activities
on science and technology

This projects deserve the strongest
support as we may all benefit !!

NSAC-LRP Recommendations

RECOMMENDATION III

Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new Electron Ion Collider (EIC), providing unprecedented precision and versatility. The realization of this instrument is enabled by recent advances in accelerator technology.

We recommend a high-energy high-luminosity polarized Electron Ion Collider as the highest priority for new facility construction following the completion of FRIB.

The EIC will, for the first time, precisely image gluons in nucleons and nuclei. It will definitively reveal the origin of the nucleon spin and will explore a new Quantum Chromodynamics (QCD) frontier of ultra-dense gluon fields, with the potential to discover a new form of gluon matter predicted to be common to all nuclei. This science will be made possible by the EIC's unique capabilities for collisions of polarized electrons with polarized protons, polarized light ions, and heavy nuclei at high luminosity.