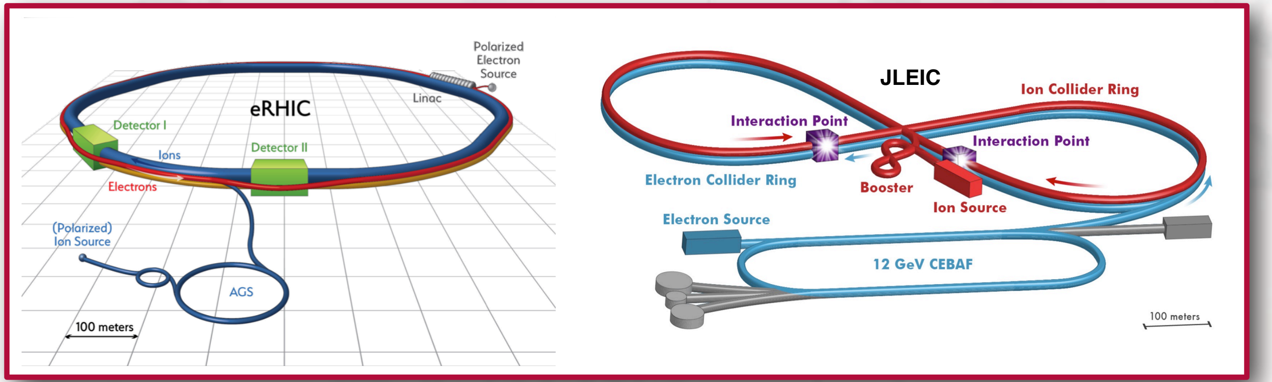
Status and Perspectives of a US-based Electron-Ion Collider (EIC)

Bernd Surrow

TEMPLE UNIVERSITY®

Electron-Ion Collider facility concepts



U.S. DEPARTMENT OF ENERGY | Office of Science

DOE NP contract: DE-SC0013405

Outline

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- The EIC Physics Pillars

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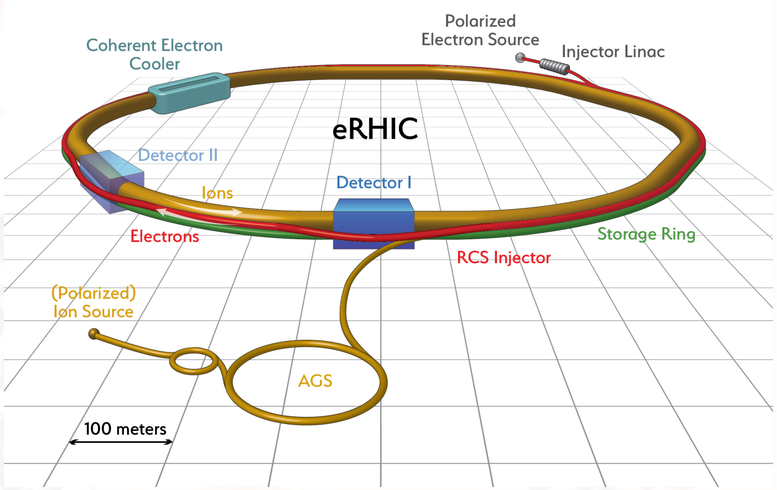

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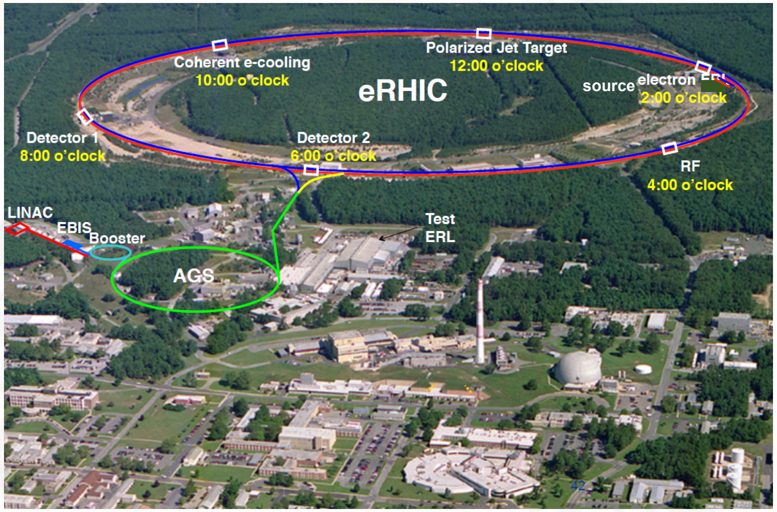

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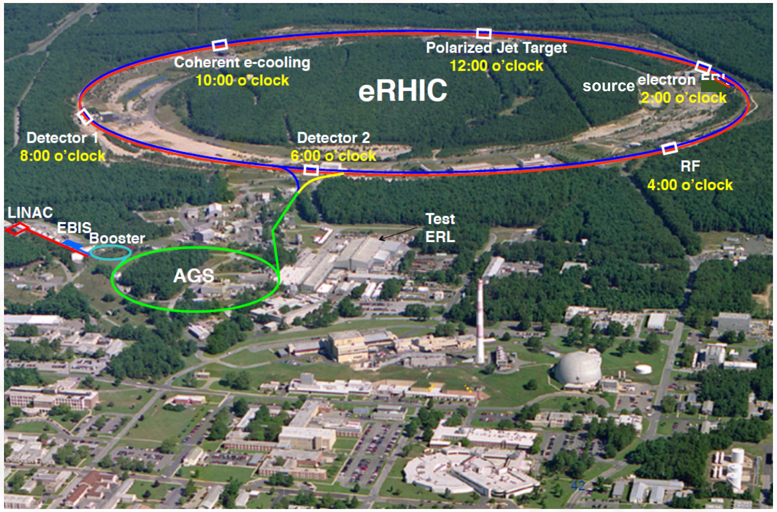

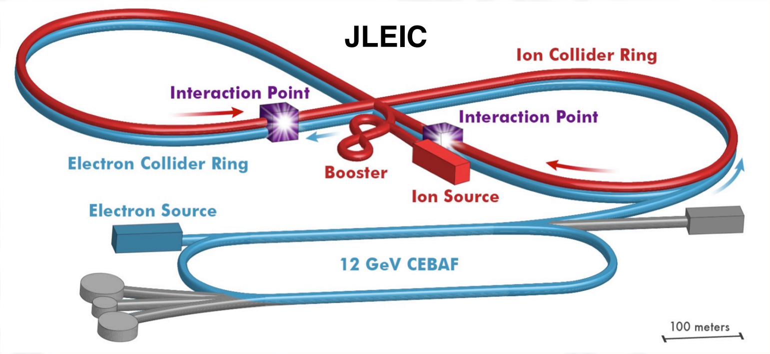

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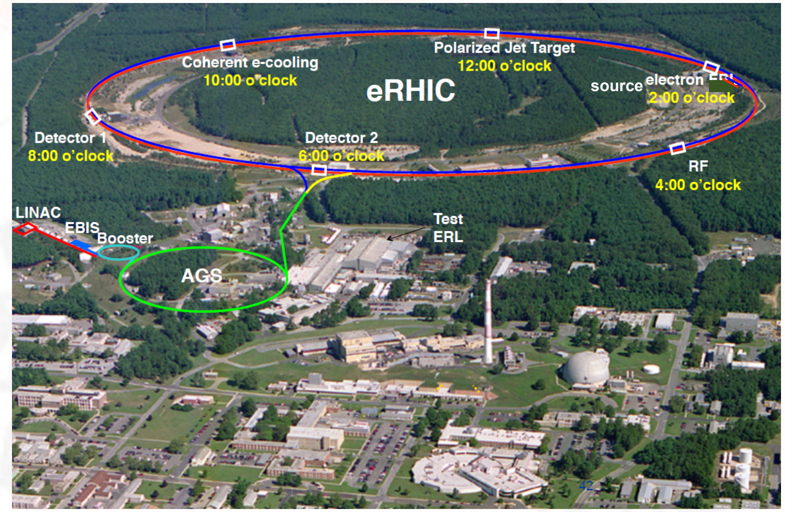

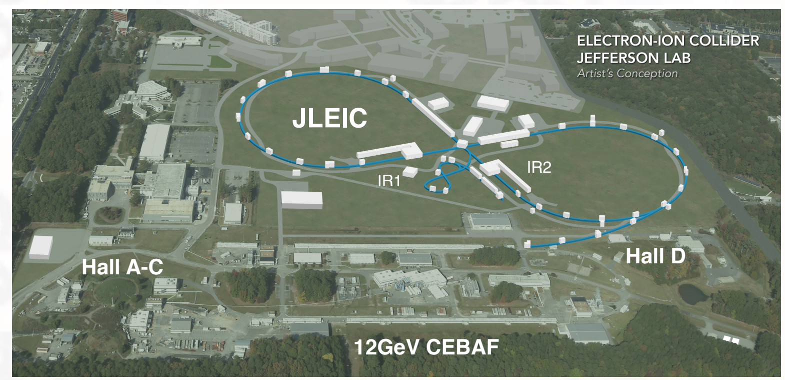

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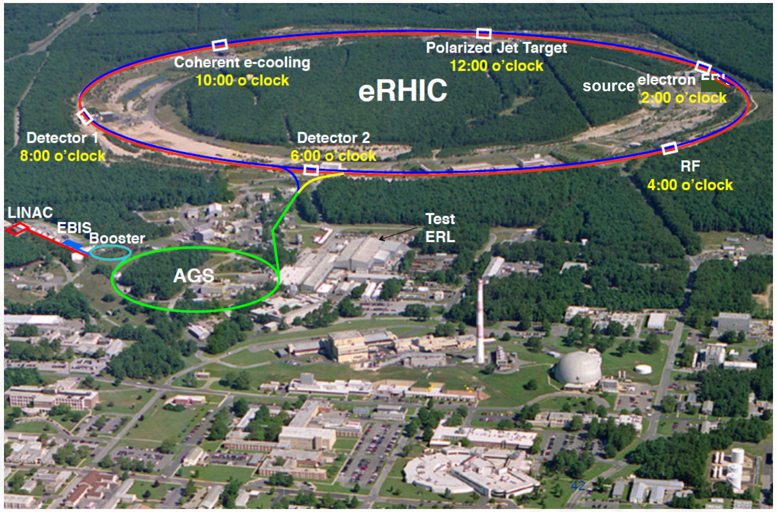

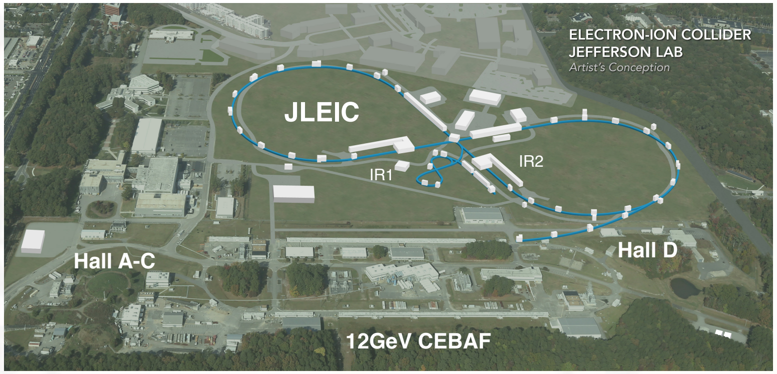

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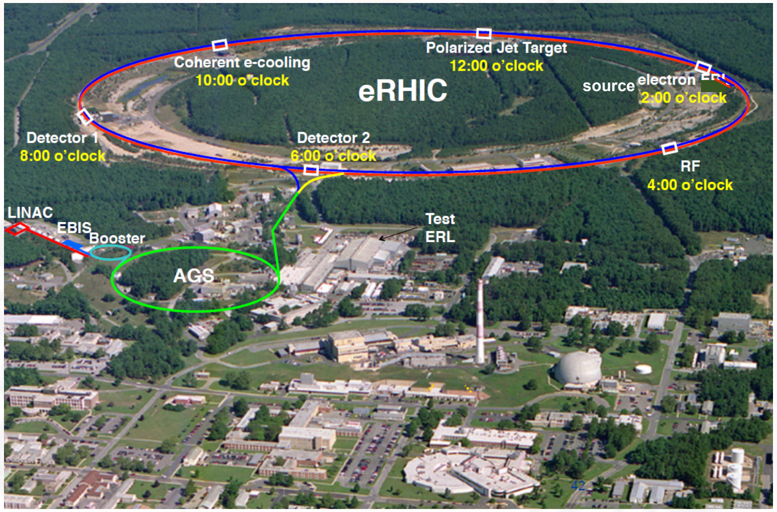

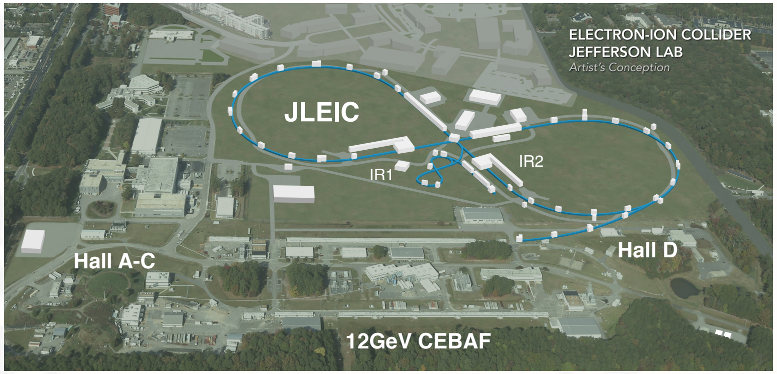

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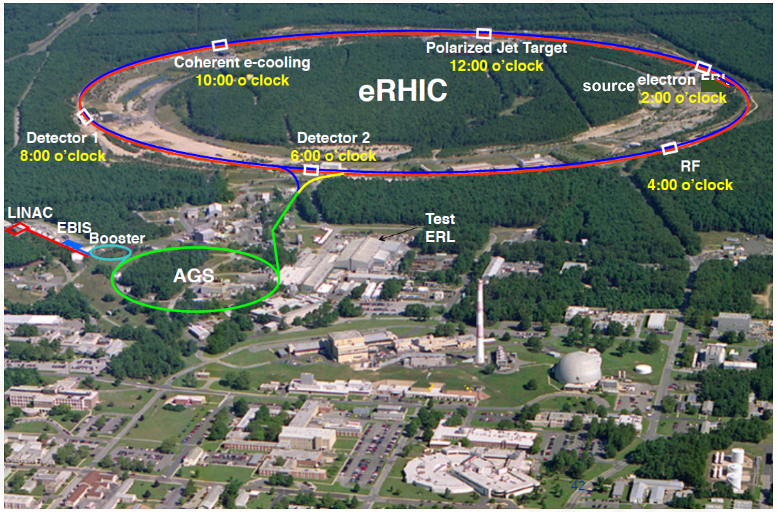

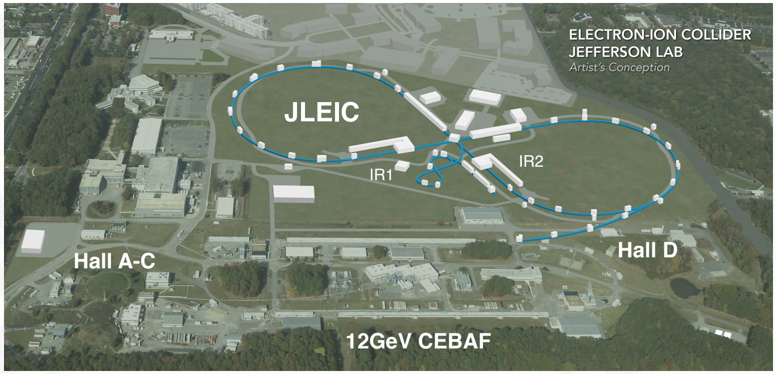

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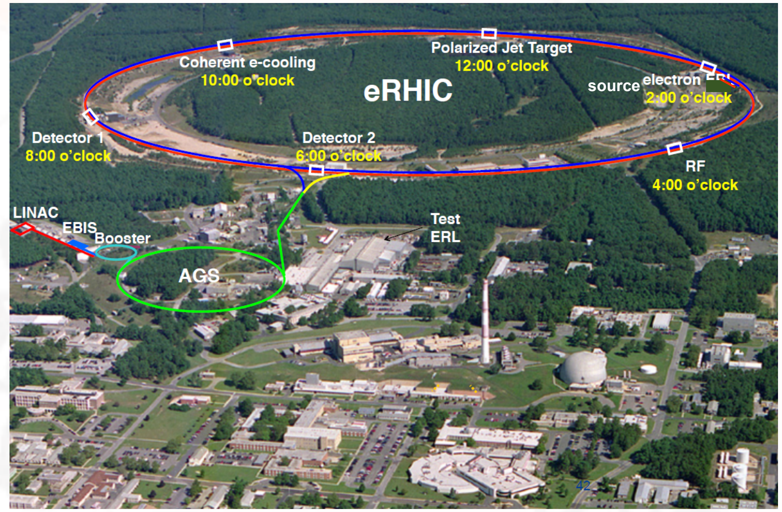

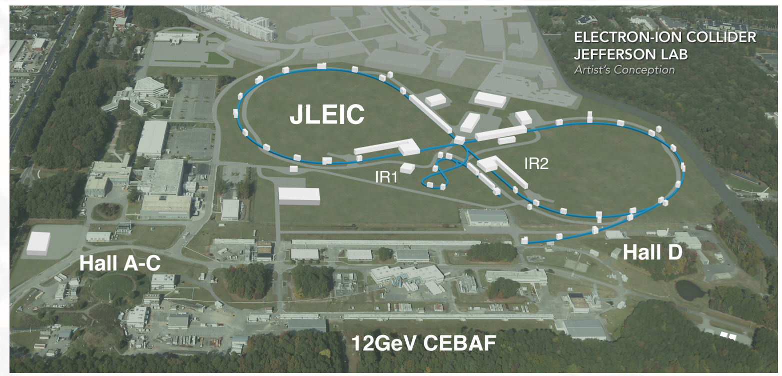

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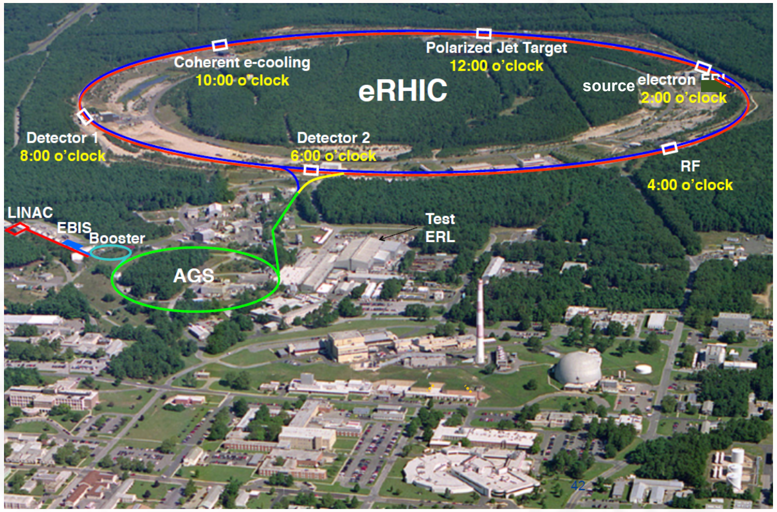

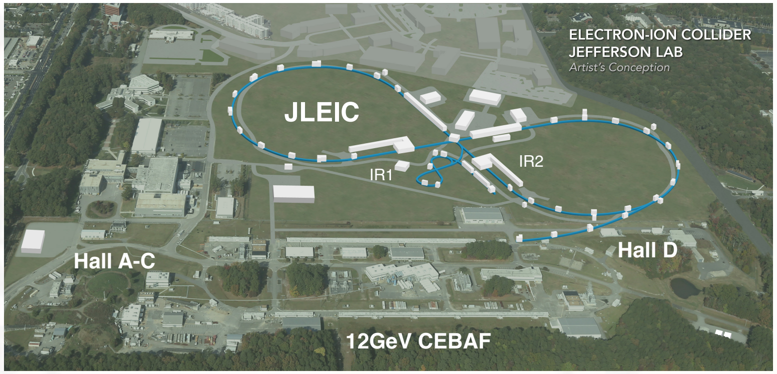

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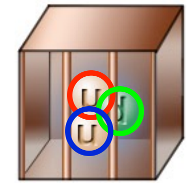

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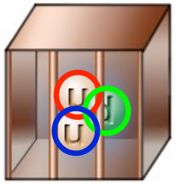

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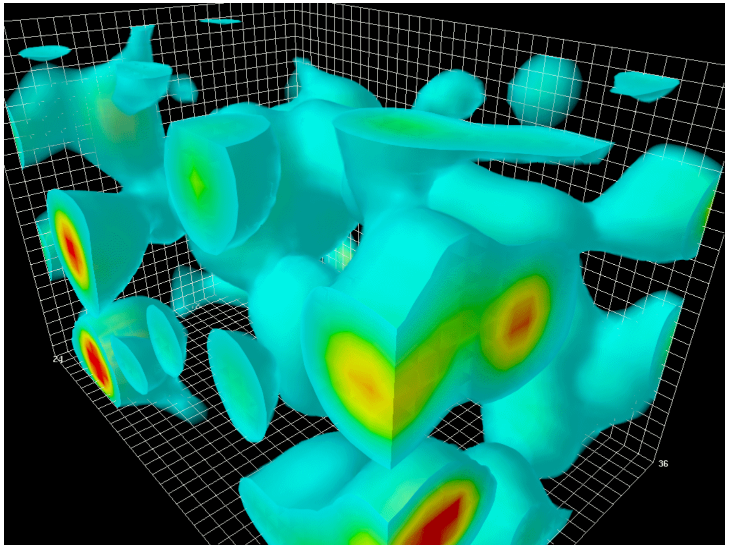

D. Leinweber: Quantum fluctuations in gluon fields

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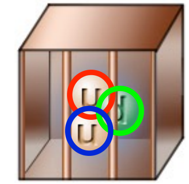

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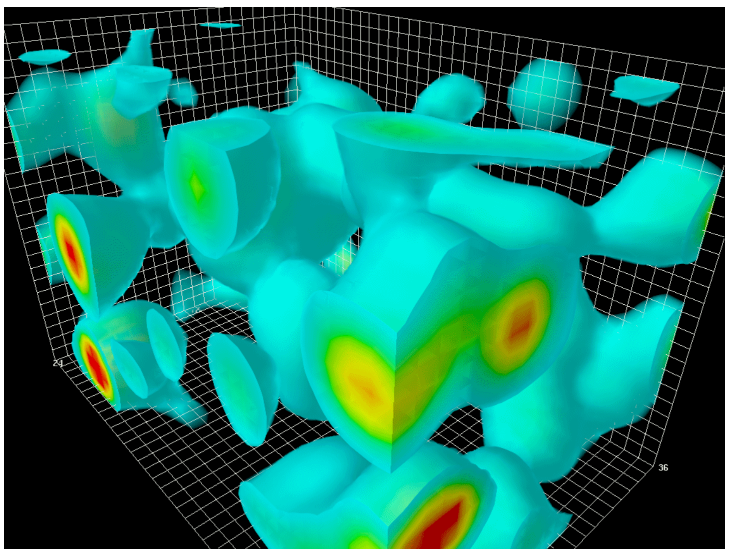

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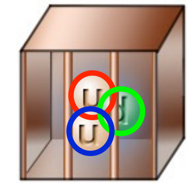

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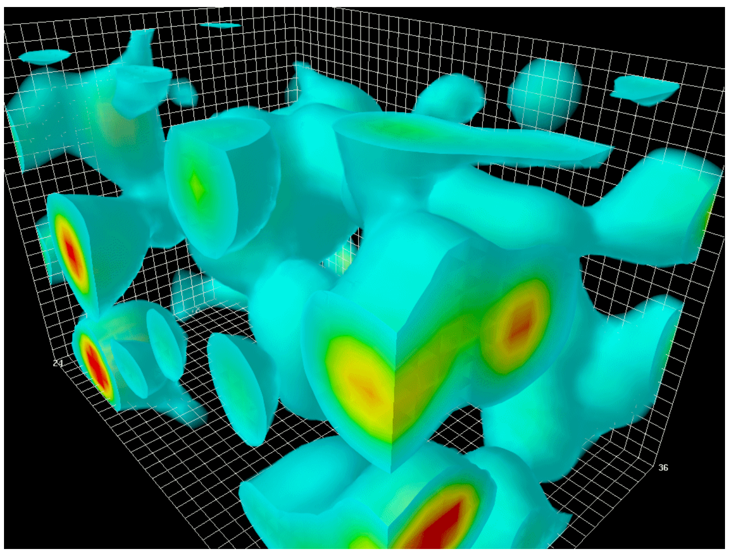

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Major goal:

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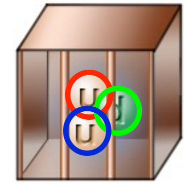

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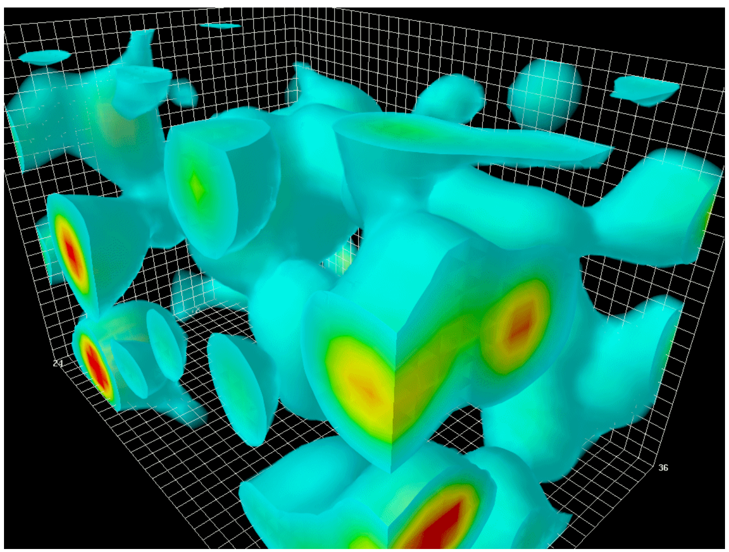

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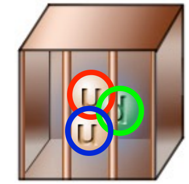

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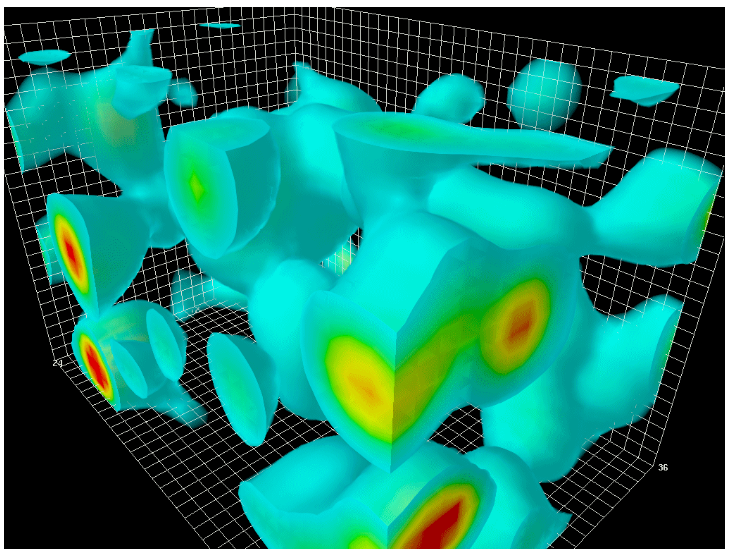

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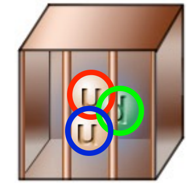

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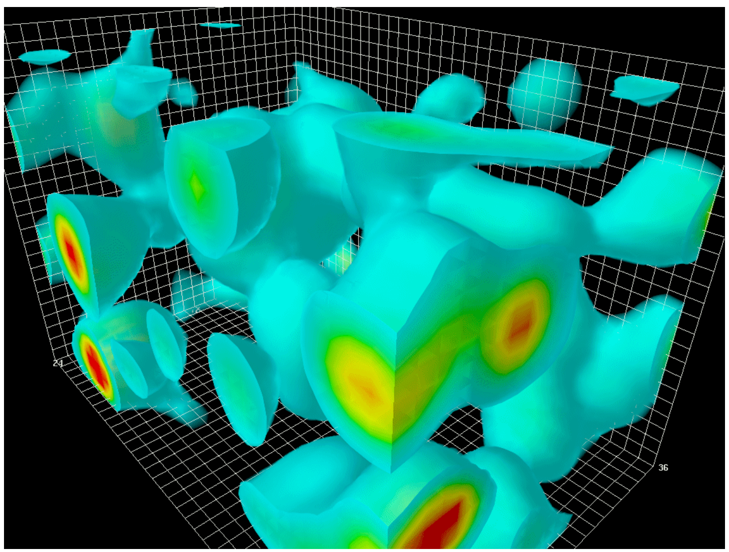

D. Leinweber: Quantum fluctuations in gluon fields

Major goal:

Understanding QCD interactions and emergence of hadronic and nuclear matter in terms of quarks and gluons

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1) Tomography of hadrons and nuclear matter in terms of quarks and gluons
2) Synergy of experimental progress and theory

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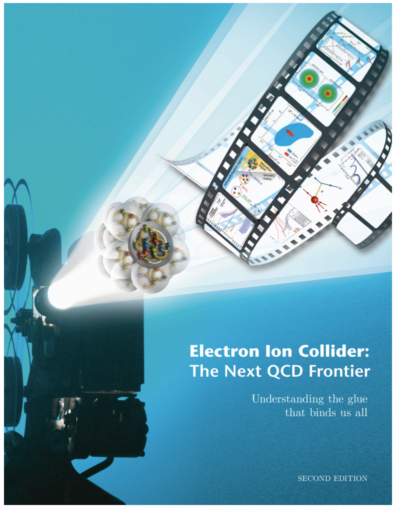

Understanding the glue that binds as all!

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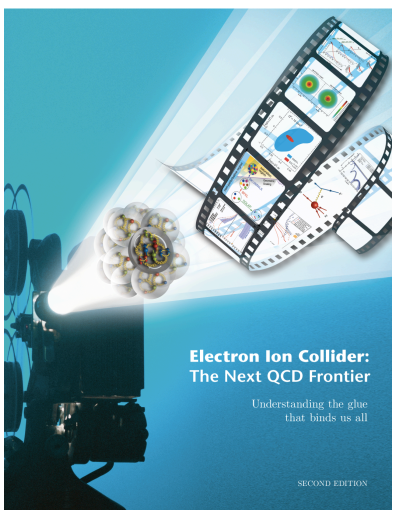

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Parton Distributions in Nuclei

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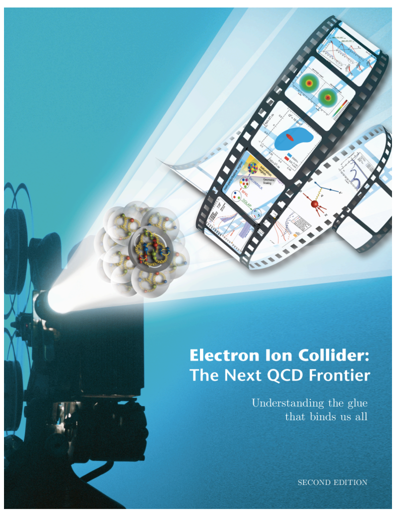

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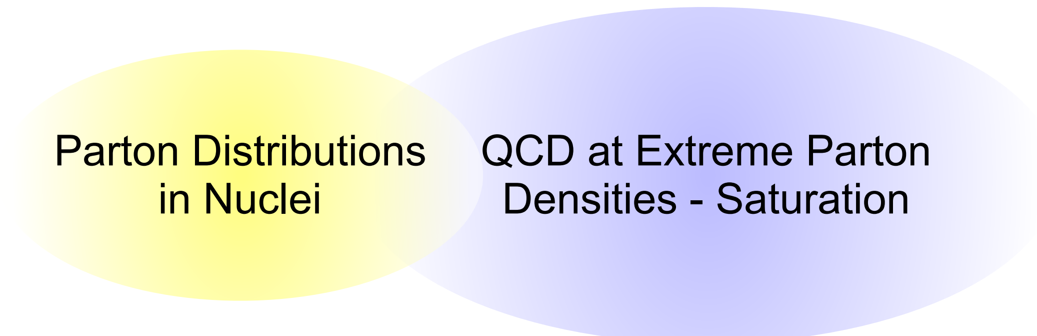

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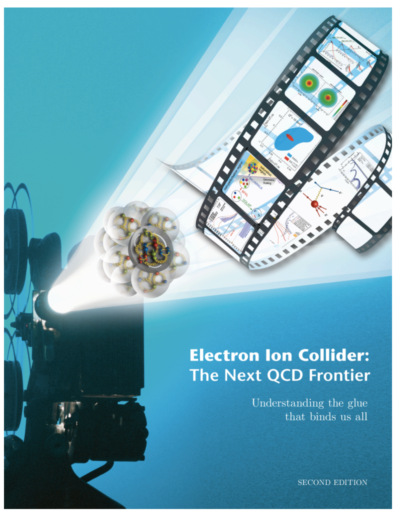

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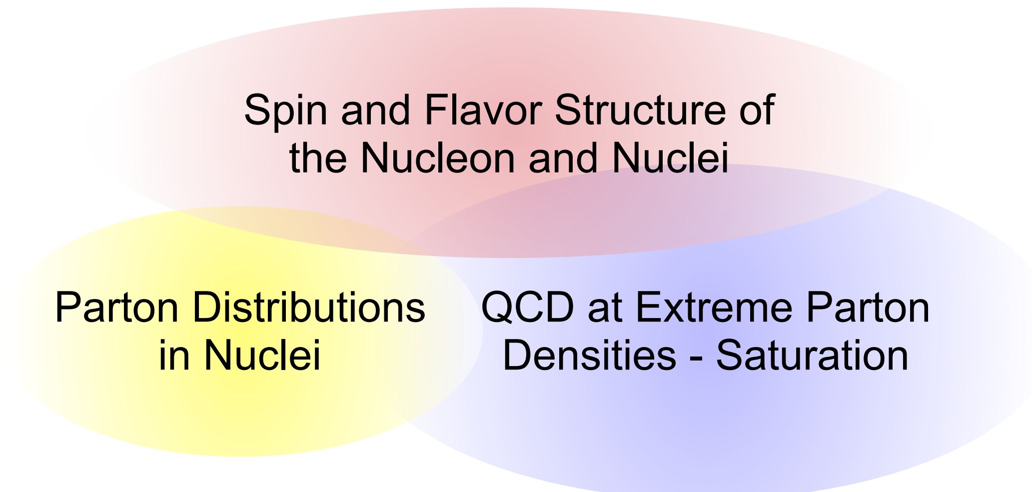

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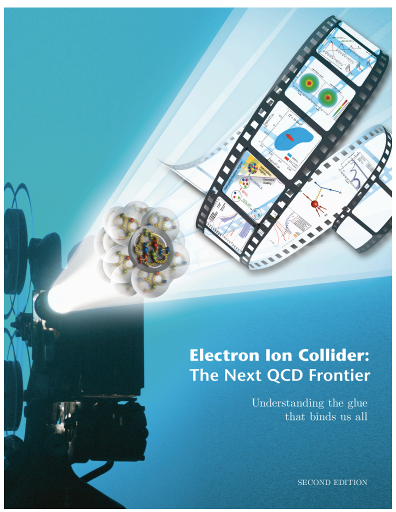

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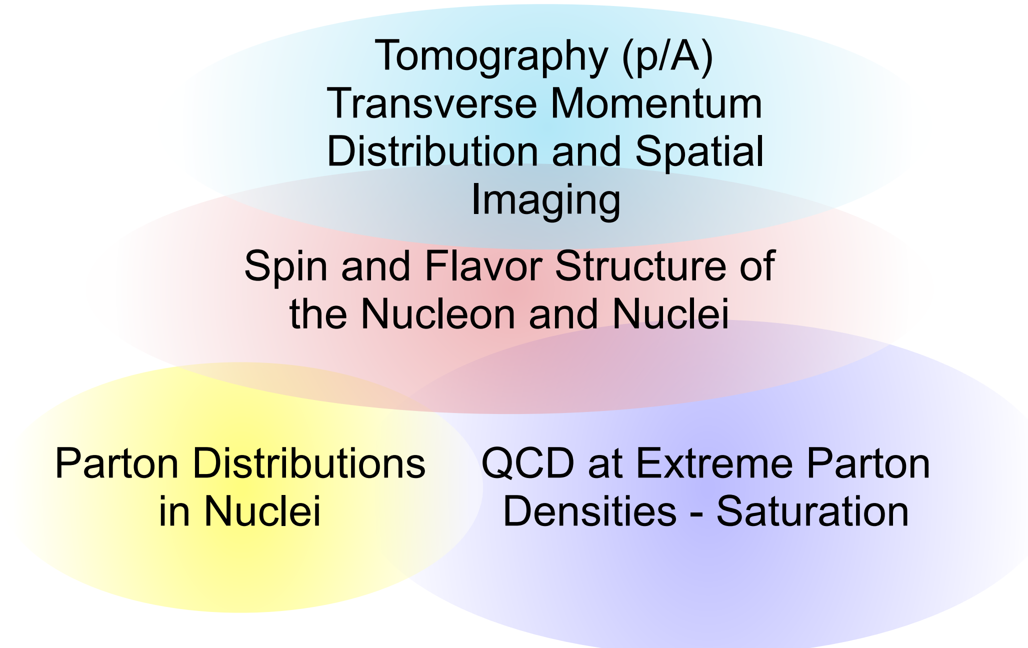

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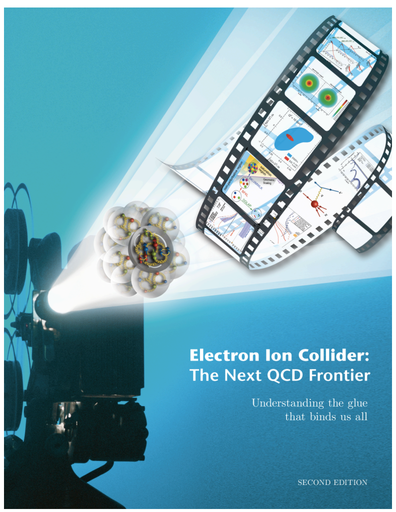

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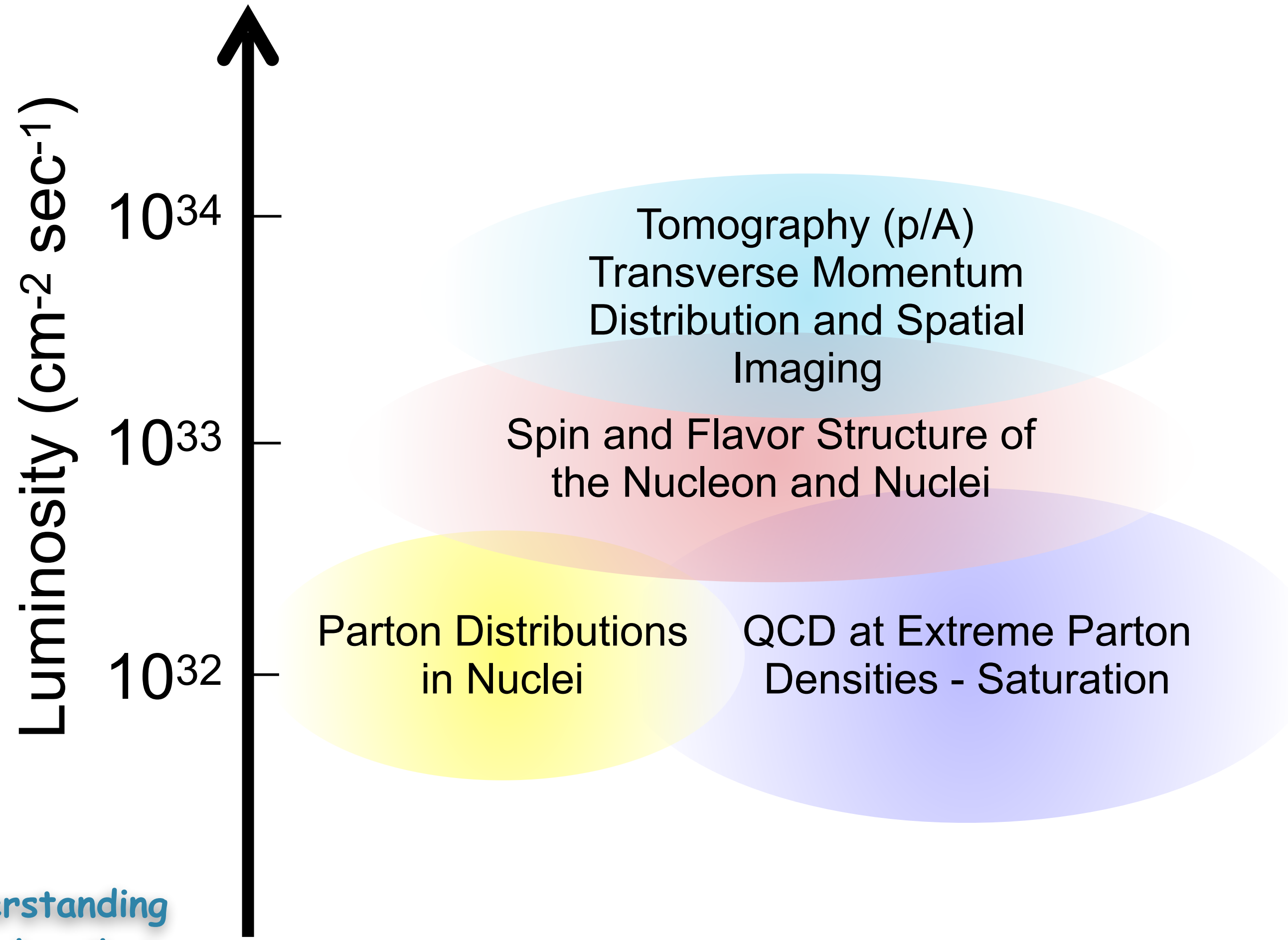

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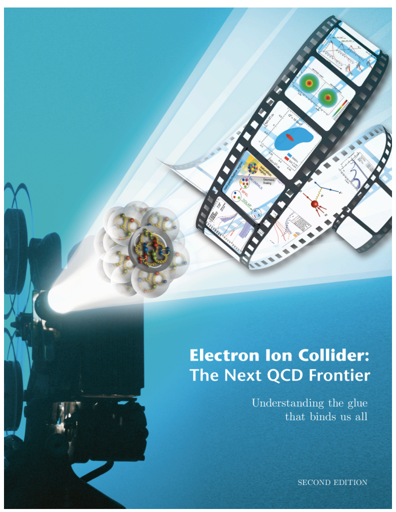

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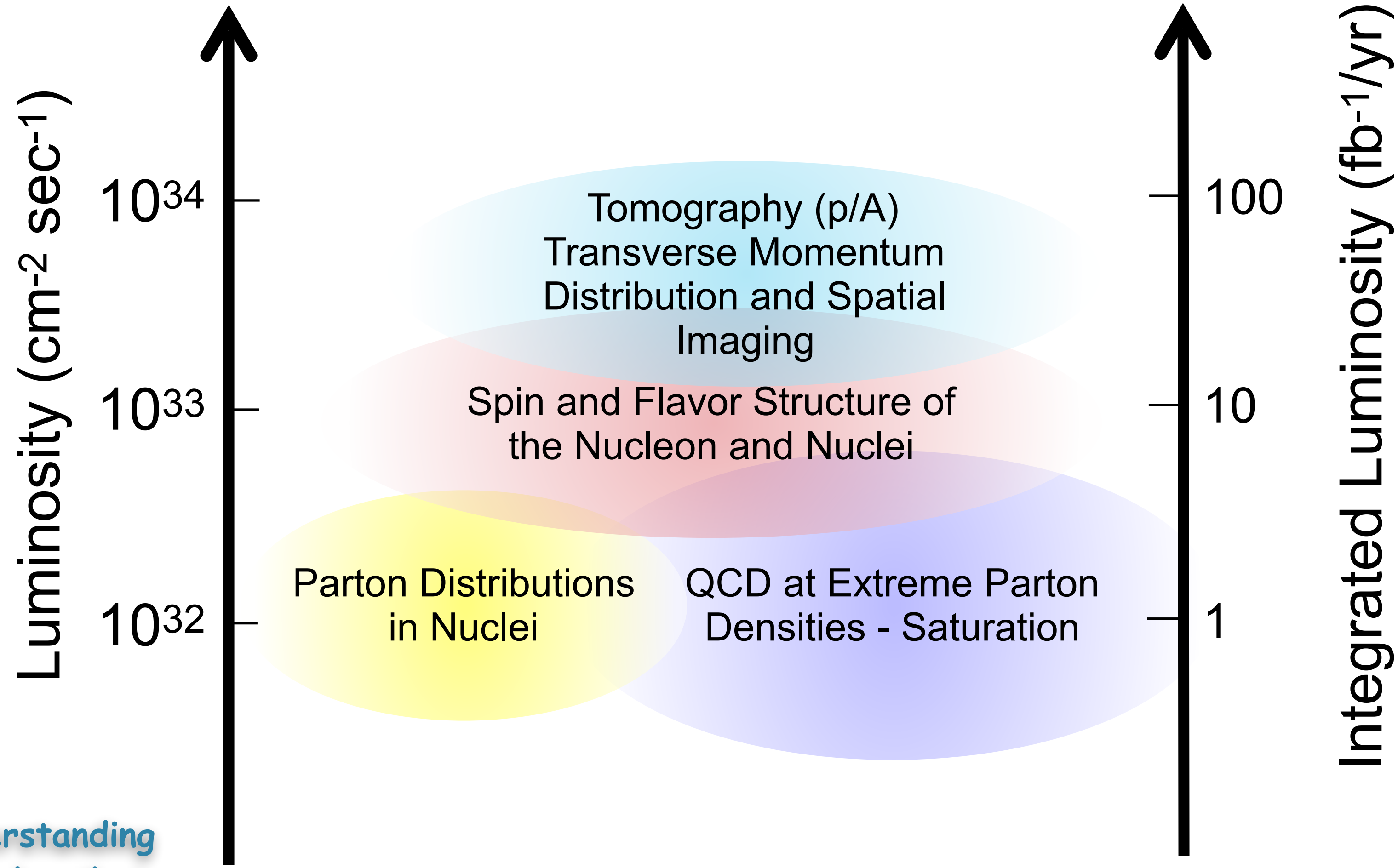

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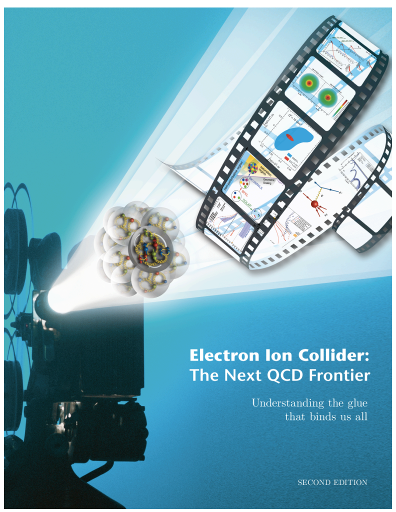

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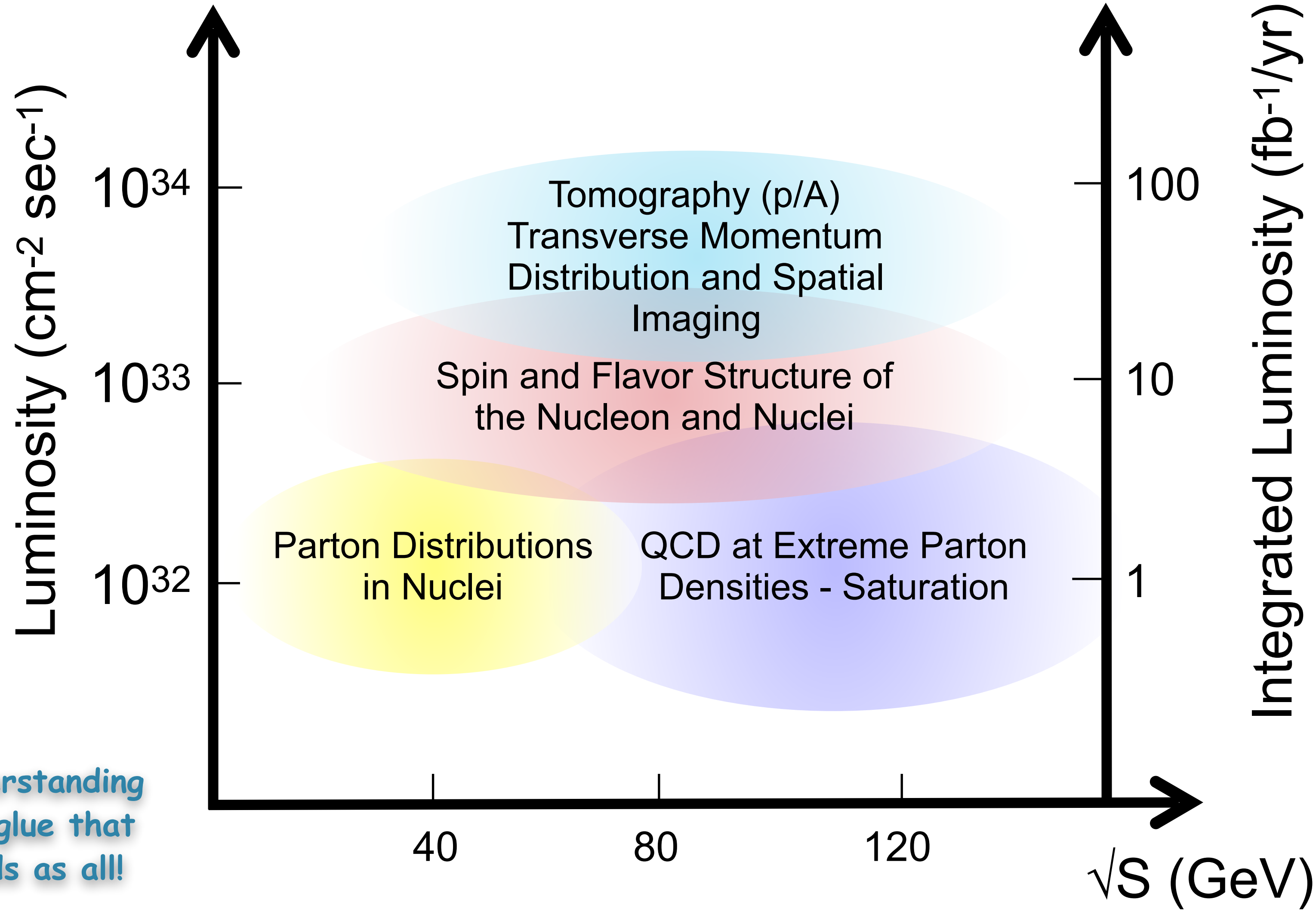

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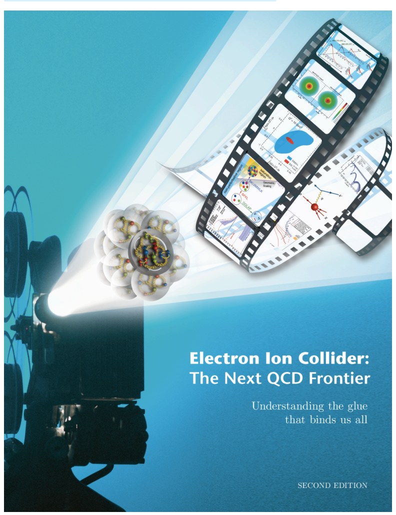

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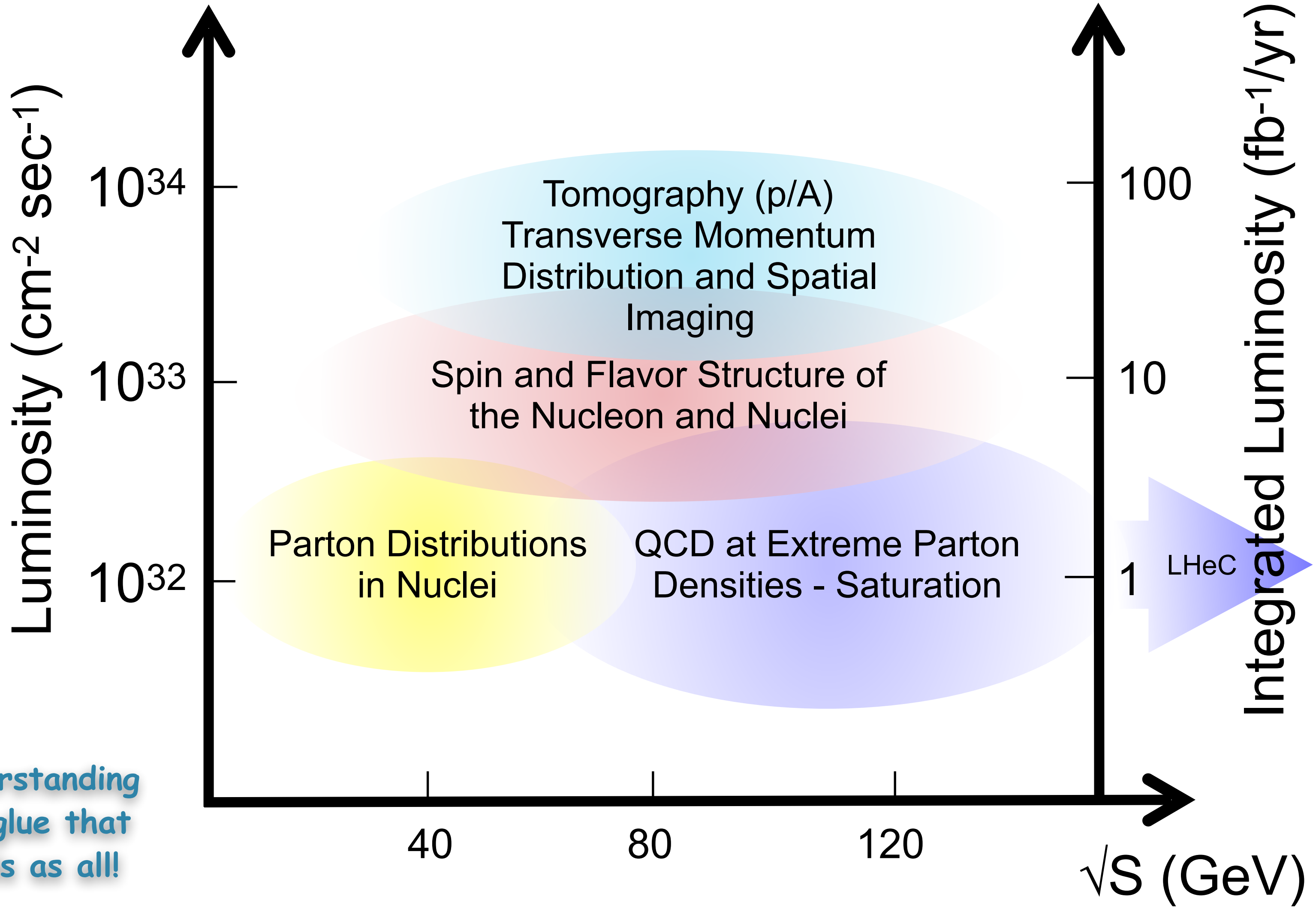

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- QCD dynamics

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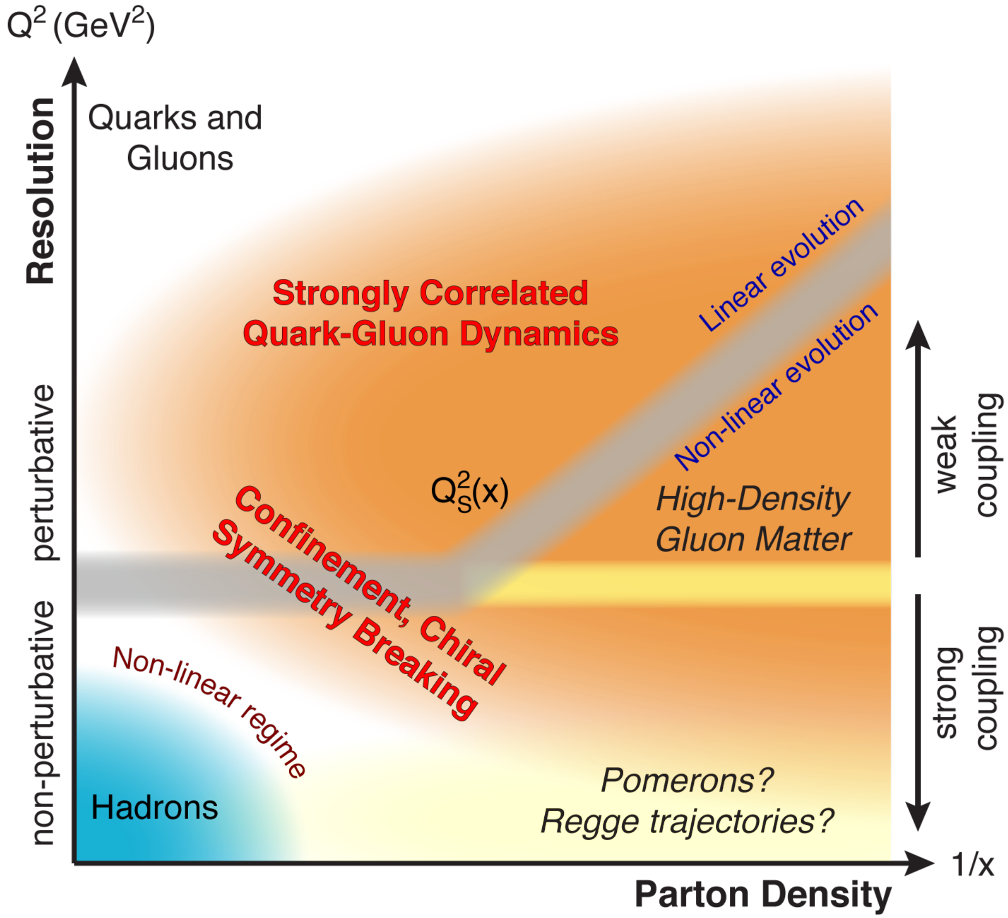

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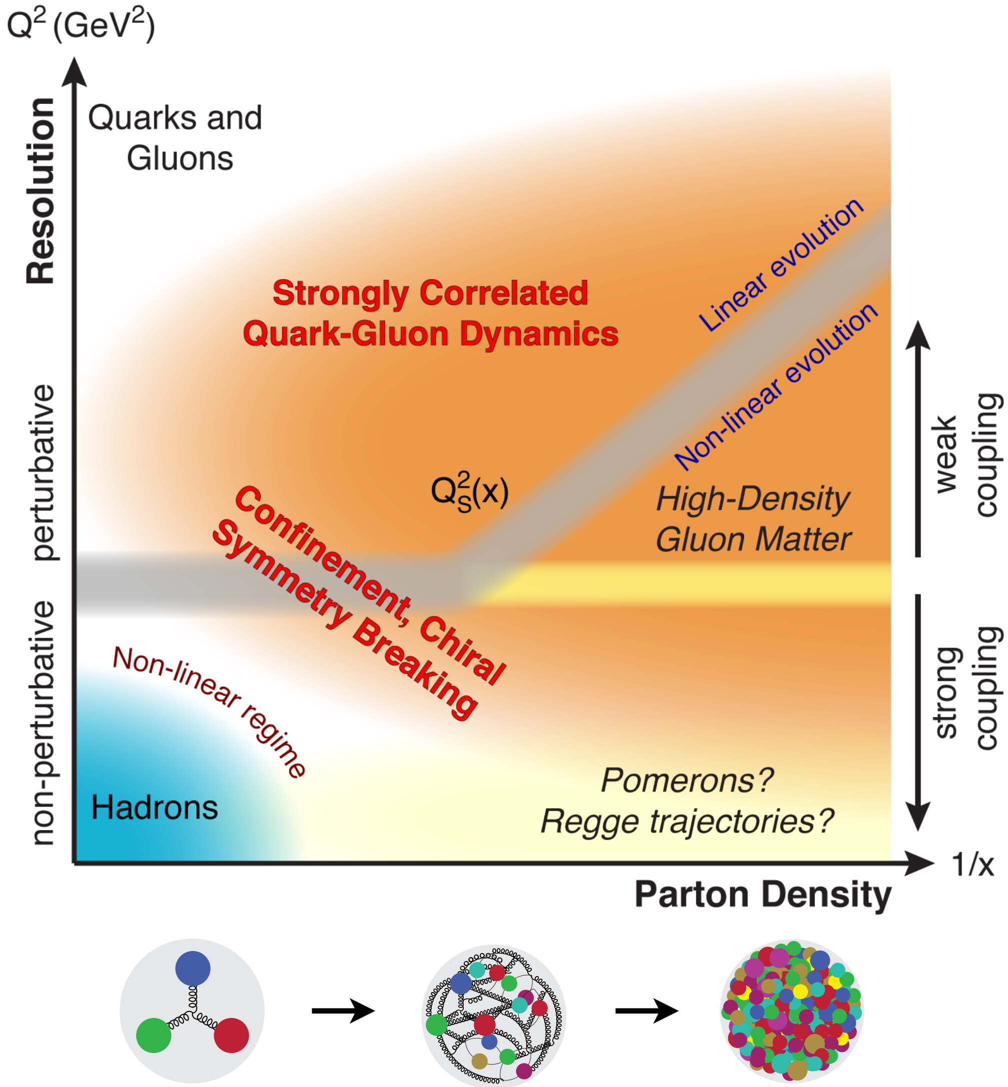

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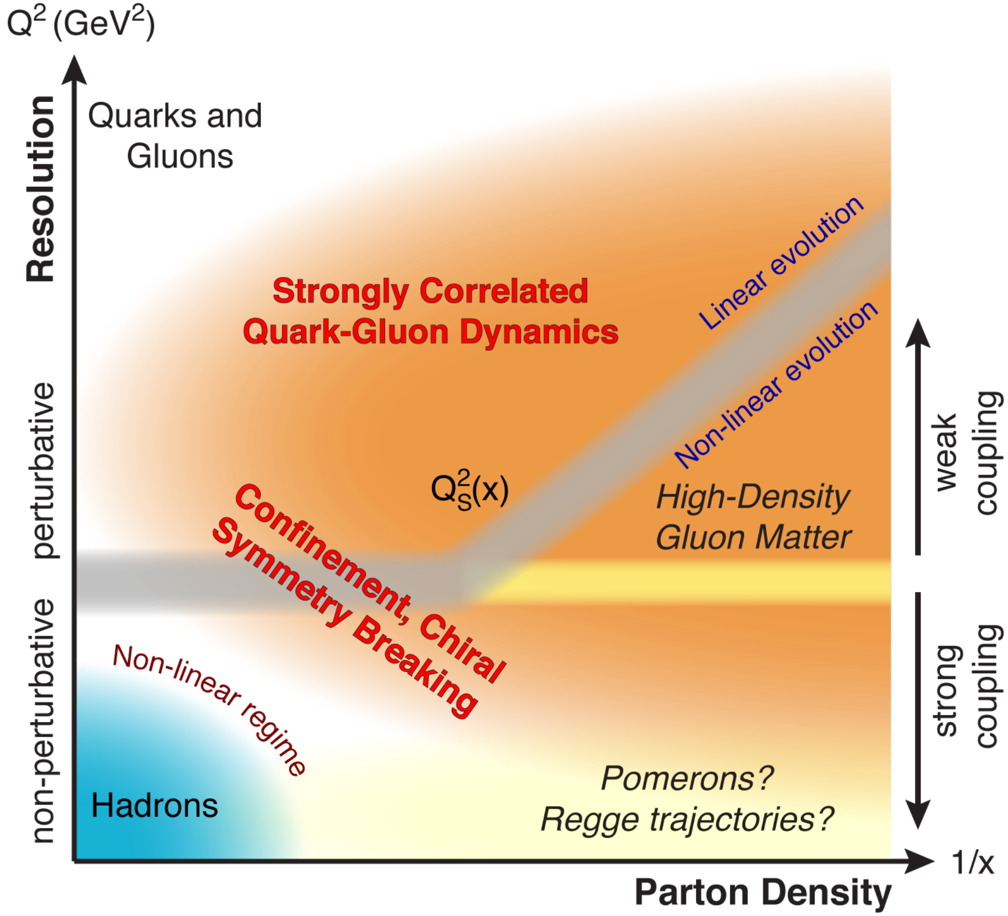
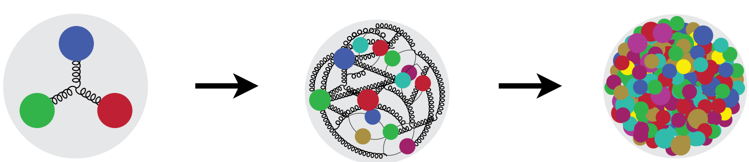


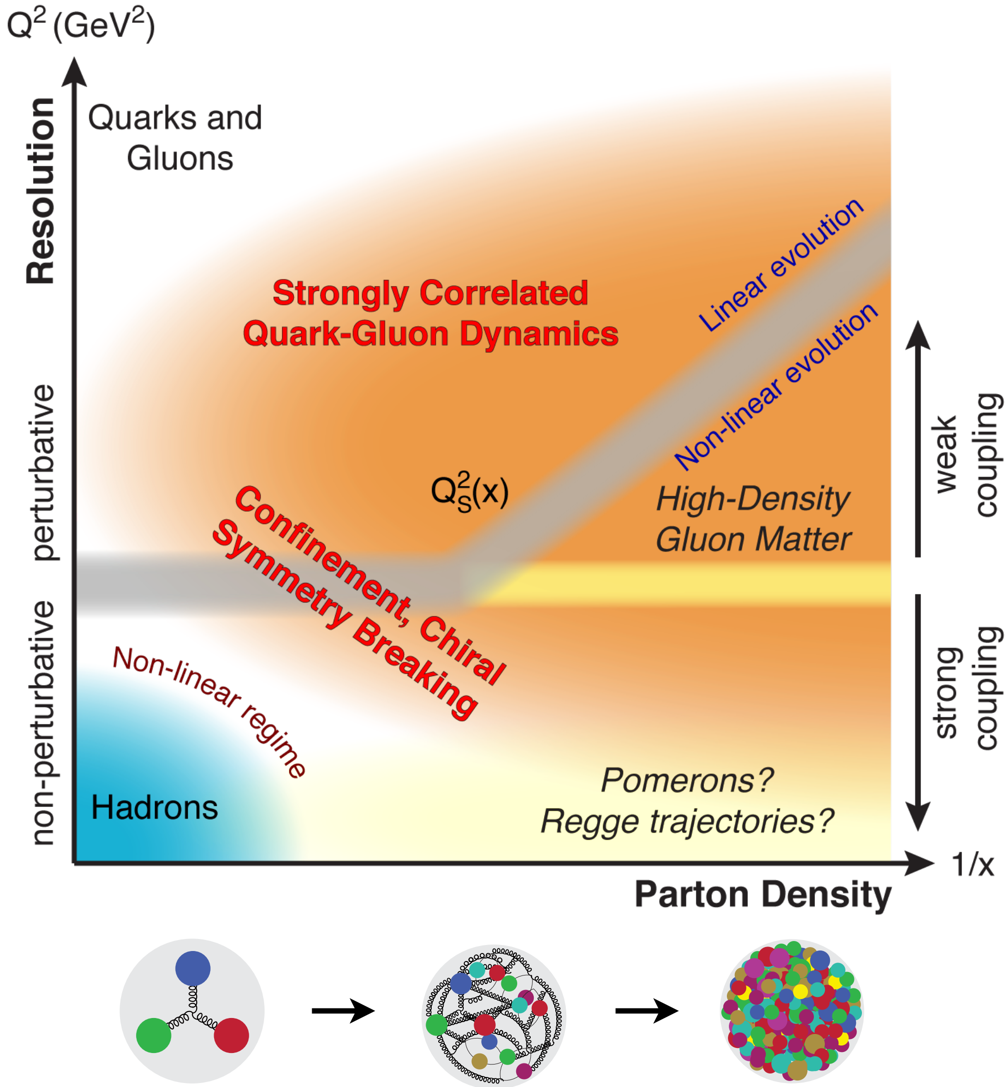


- Explore QCD landscape in various aspects over a wide range in x and Q^2 - Heavy nuclei at high energy critical to explore high-density gluon matter!

The EIC Physics Pillars

- QCD dynamics / Parton distributions in nuclei

arXiv:1708.01527



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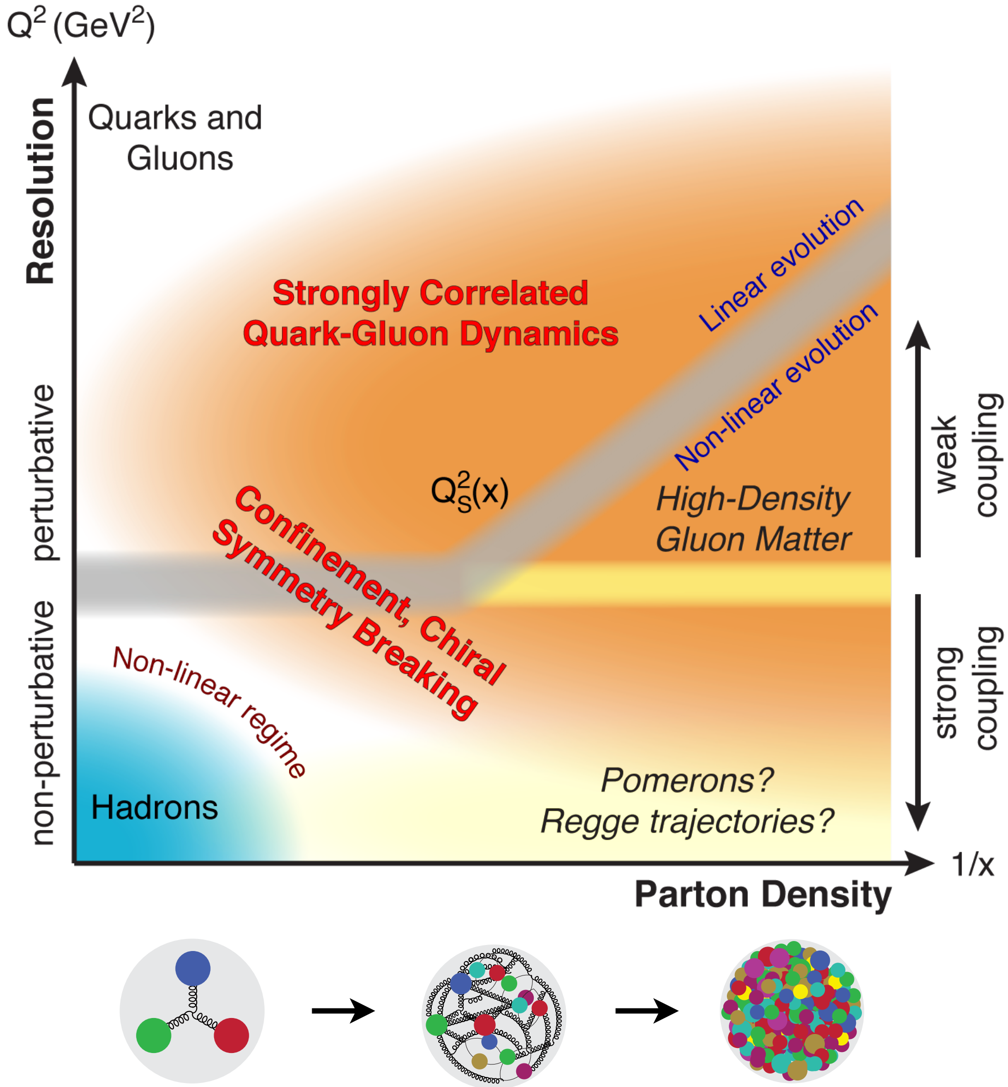
The EIC Physics Pillars

QCD dynamics / Parton distributions in nuclei



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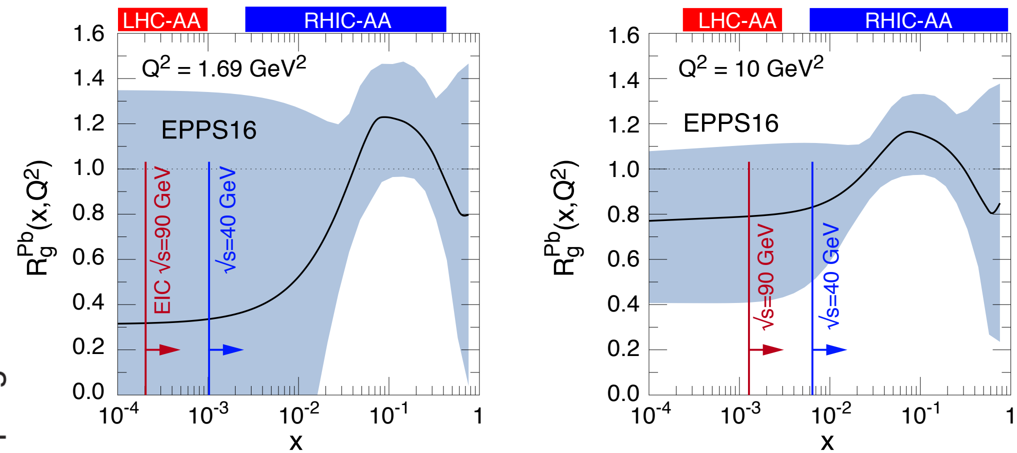

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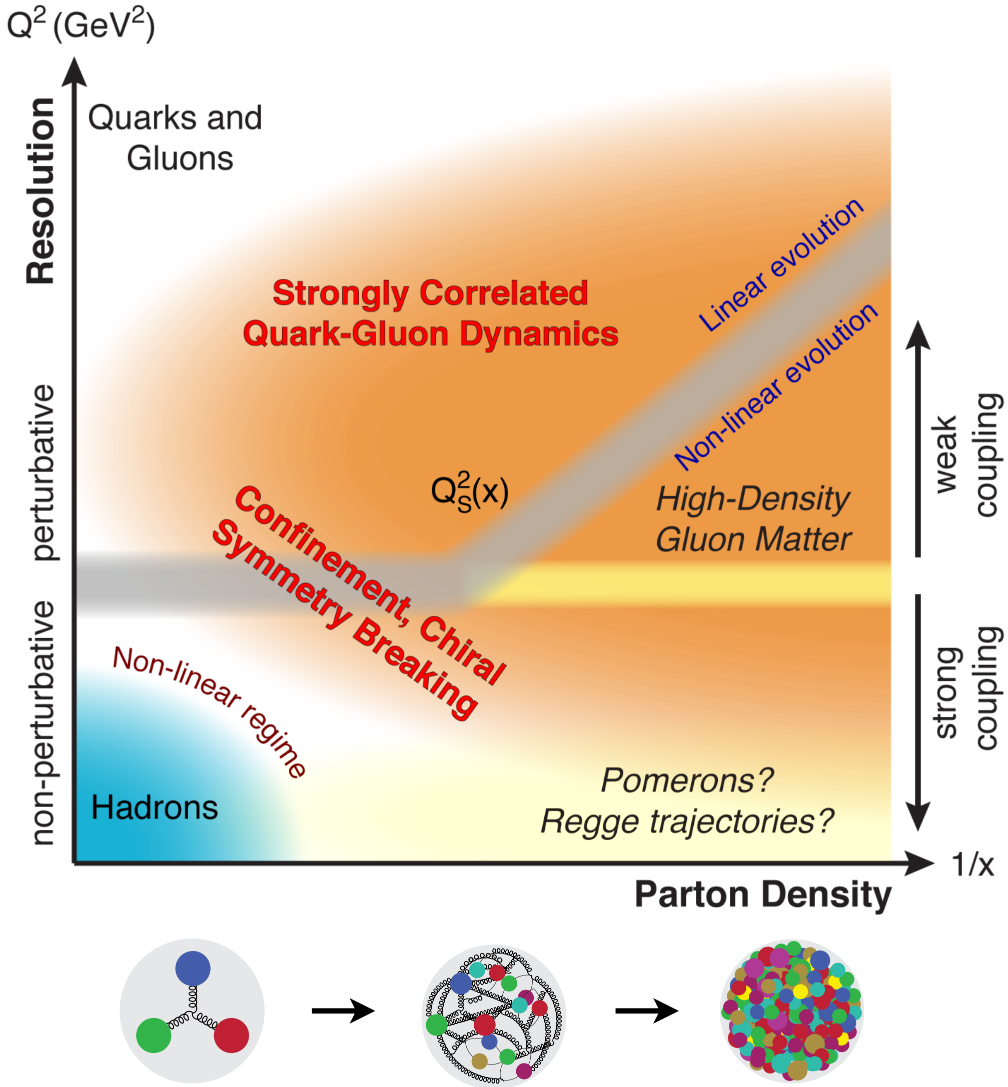

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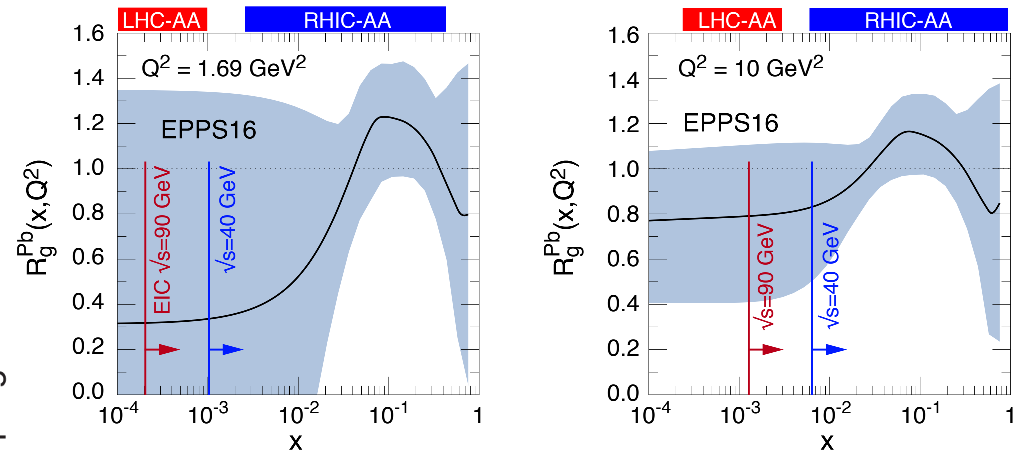
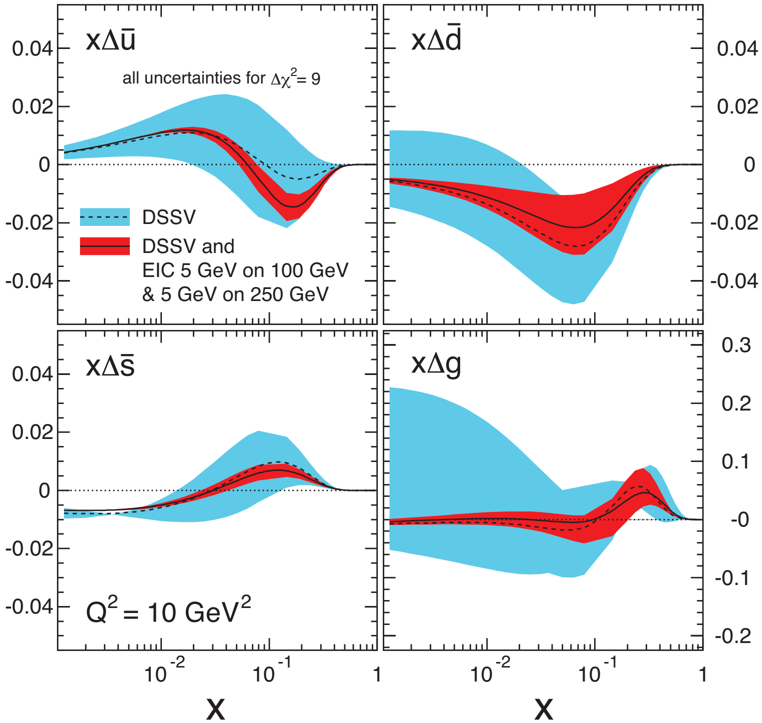


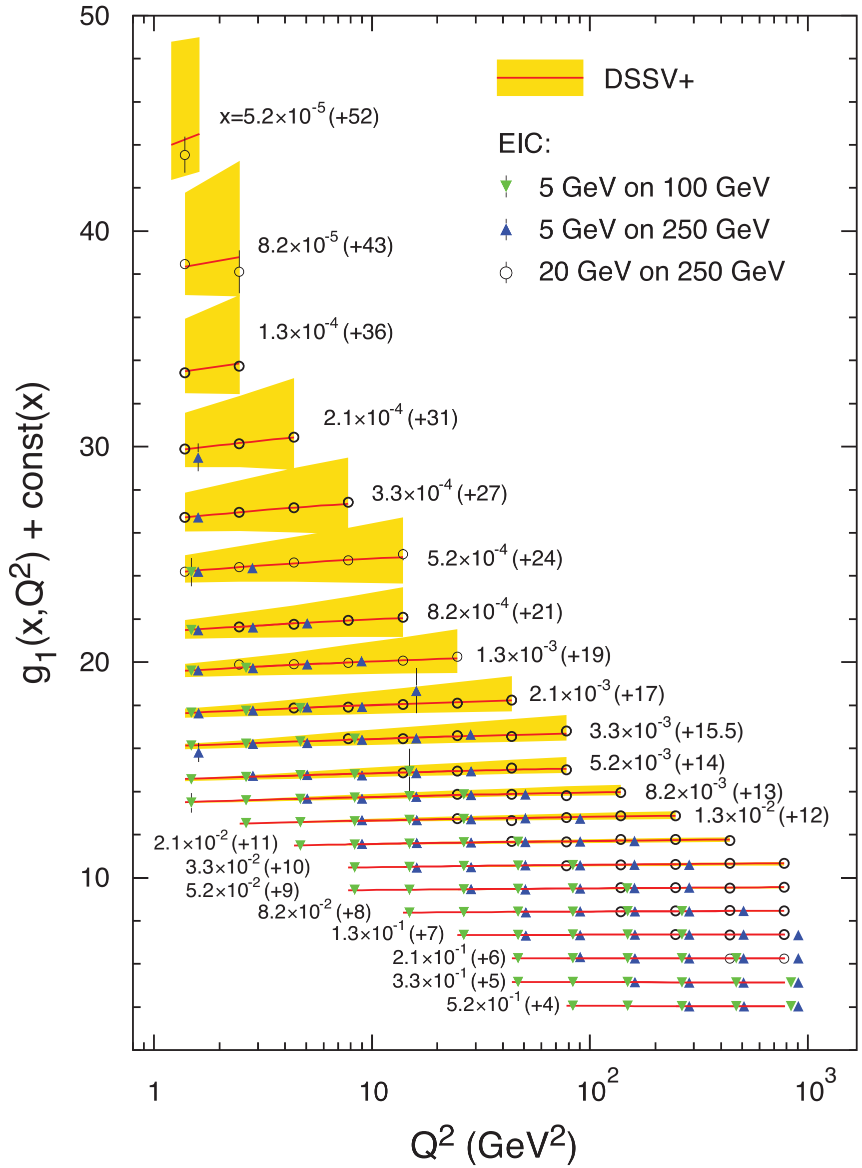
- Study modifications of gluons in nuclear environment complementing LHC-AA and RHIC-AA programs.

- Explore QCD landscape in various aspects over a wide range in x and Q^2 - Heavy nuclei at high energy critical to explore high-density gluon matter!

The EIC Physics Pillars

- Spin and Flavor Structure of the Nucleon





- g_1 stat. uncertainty projections for $10 fb^{-1}$ for range of CME in comparison to DSSV+ predictions incl. uncertainties
- EIC impact on helicity distributions of anti-u, anti-d and s quarks together with gluons

The EIC Physics Pillars

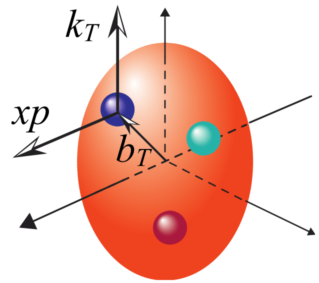
- Transverse Momentum Distribution and Spatial Imaging

The EIC Physics Pillars

- Transverse Momentum Distribution and Spatial Imaging

$f(x, k_T)$ 1+2D $\quad \int d^2b_T \quad W(x, b_T, k_T) \quad \int d^2k_T \quad$ $f(x, b_T)$ 1+2D

Transverse Momentum Distribution (TMD) ← Wigner Distribution → Impact Parameter Distribution



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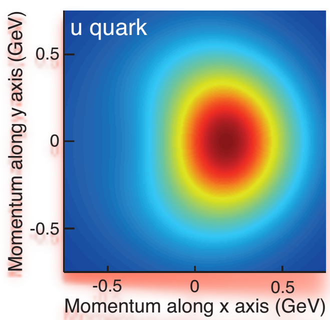
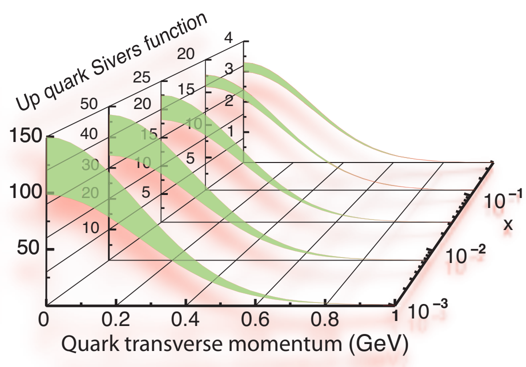
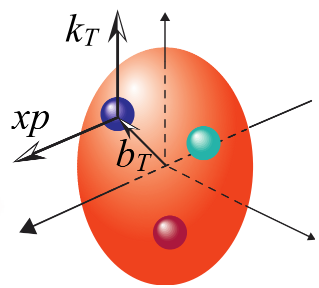
Transverse Momentum Distribution (TMD) — Wigner Distribution — Impact Parameter Distribution

quarks







- Spin-dependent 1+2D momentum space (transverse) images from semi-inclusive scattering

The EIC Physics Pillars

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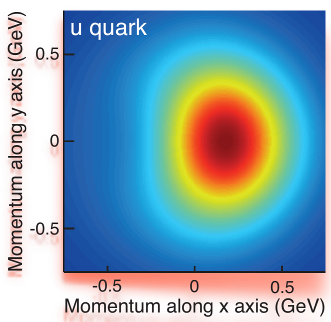
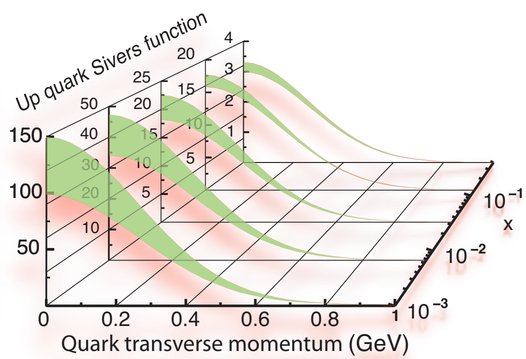
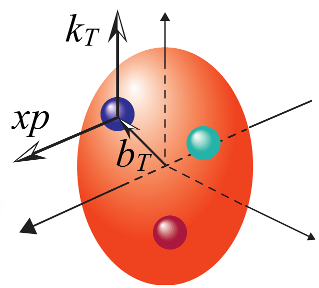
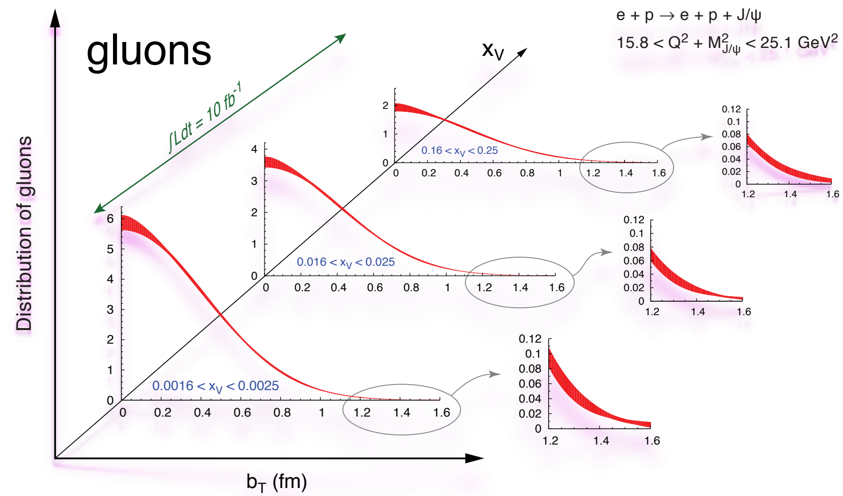






gluons



Fourier transf.
$b_T \longleftrightarrow \Delta$: $t = -\Delta^2$

$H(x, 0, t)$

$\xi = 0$

$H(x, \xi, t)$

Generalized Parton Distribution (GPD)

- Spin-dependent 1+2D momentum space (transverse) images from semi-inclusive scattering
- Spin-dependent 1+2D impact parameter (transverse) images from exclusive scattering

The EIC Facility Concepts

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- Requirements

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  - Machine:
    - High luminosity: $10^{33}cm^{-2}s^{-1}$ - $10^{34}cm^{-2}s^{-1}$
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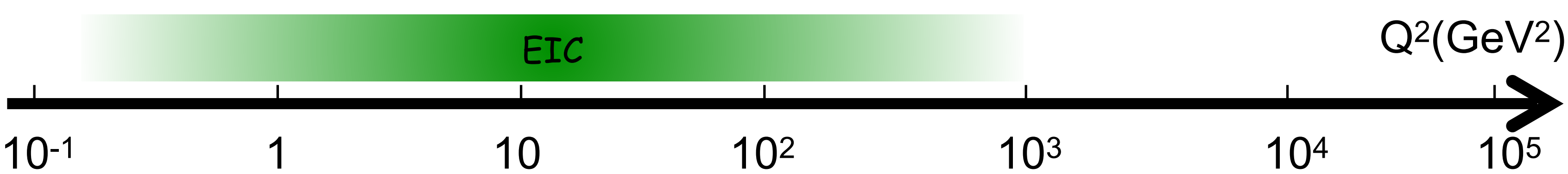

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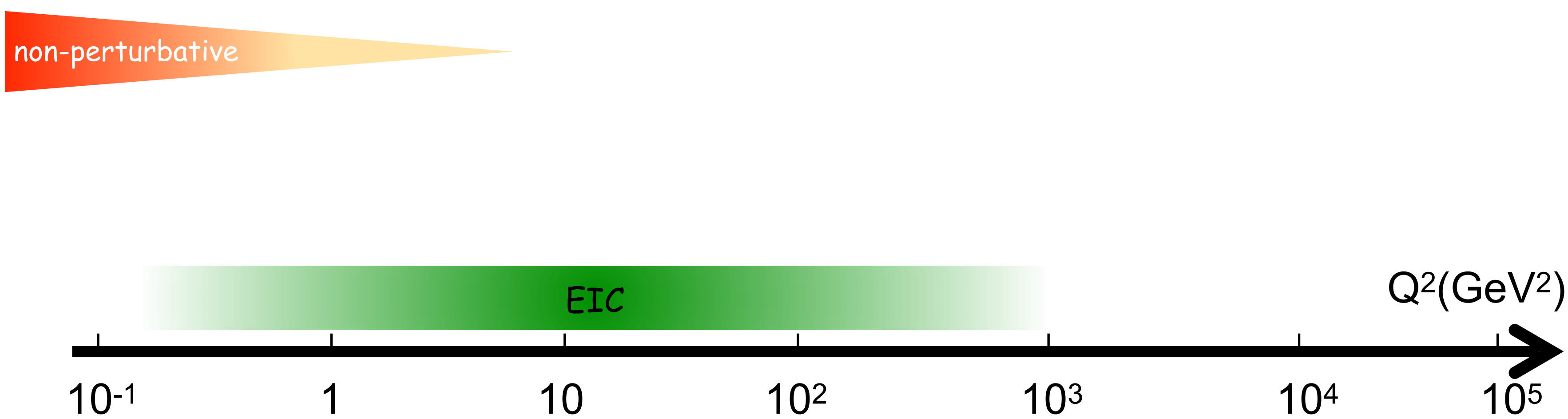

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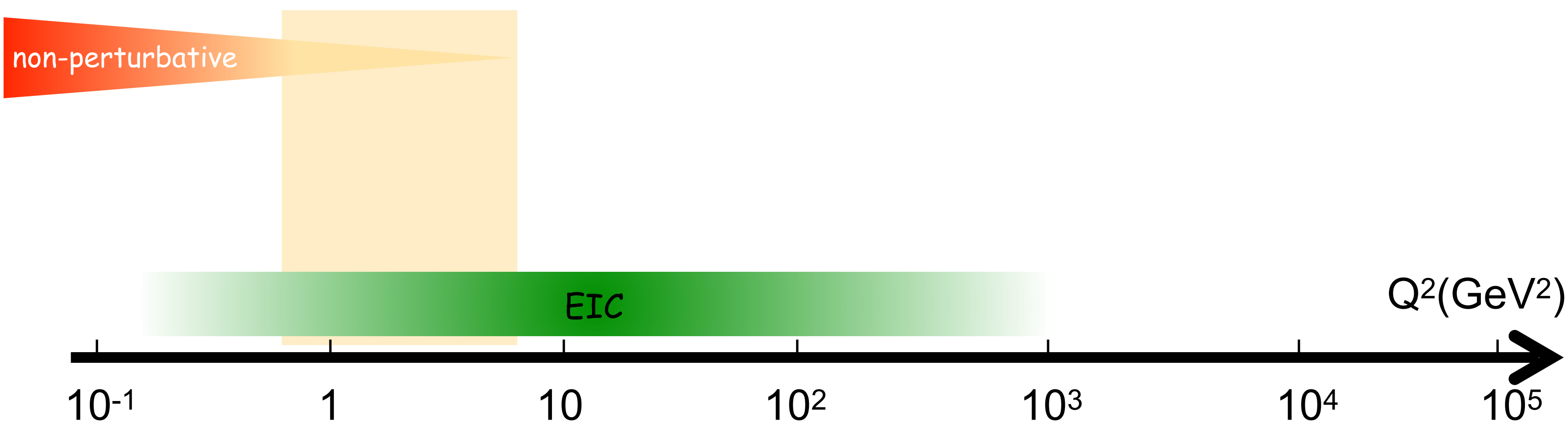

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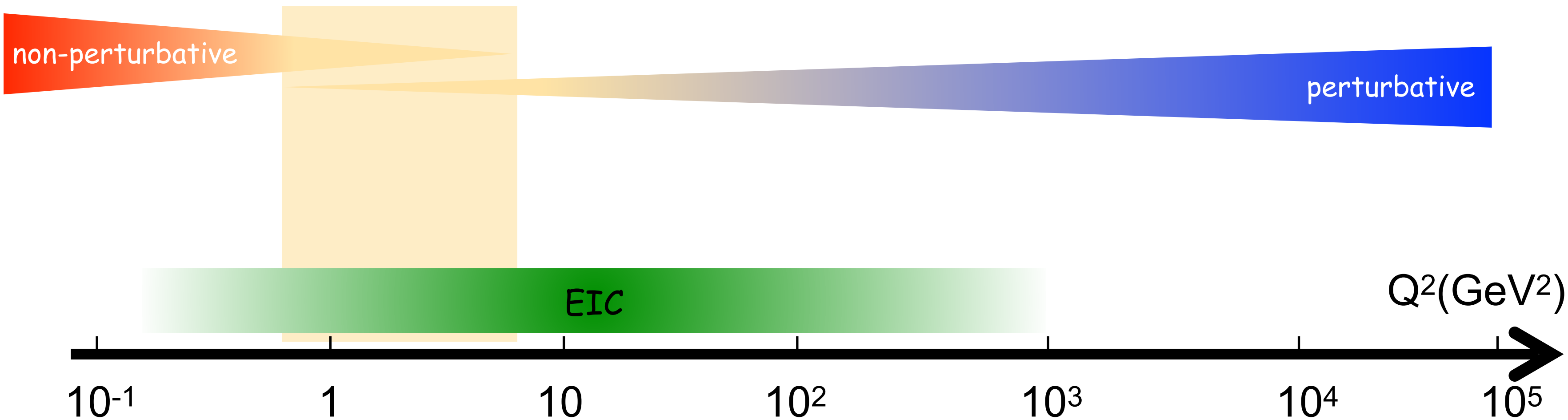

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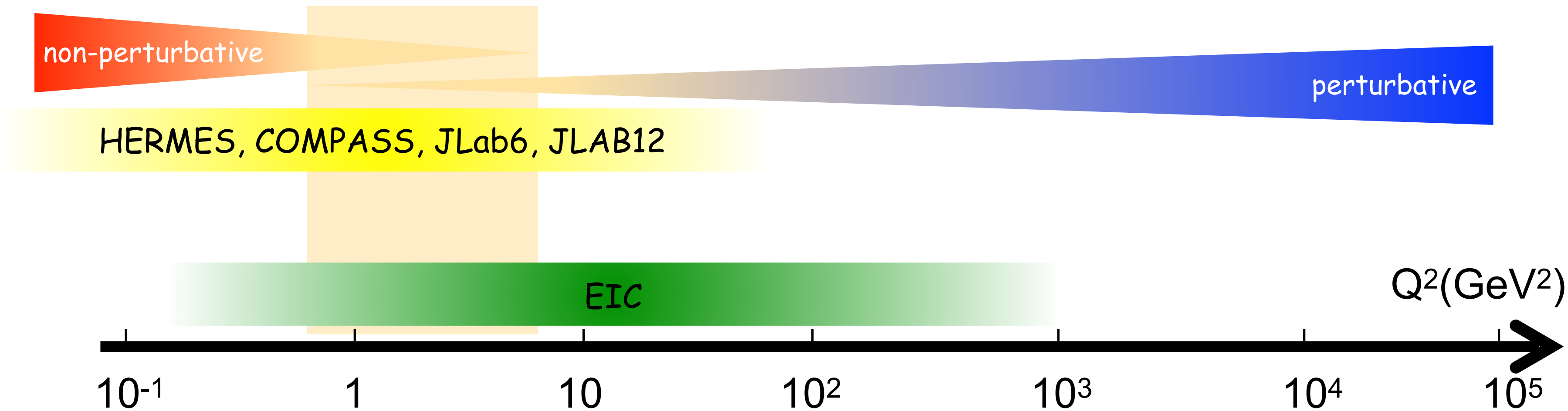

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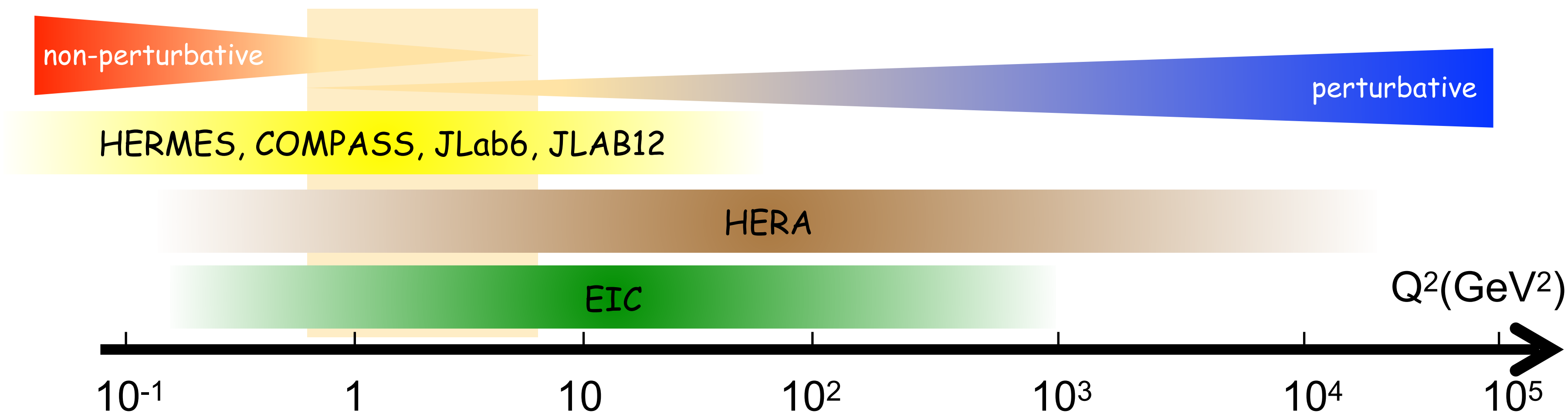
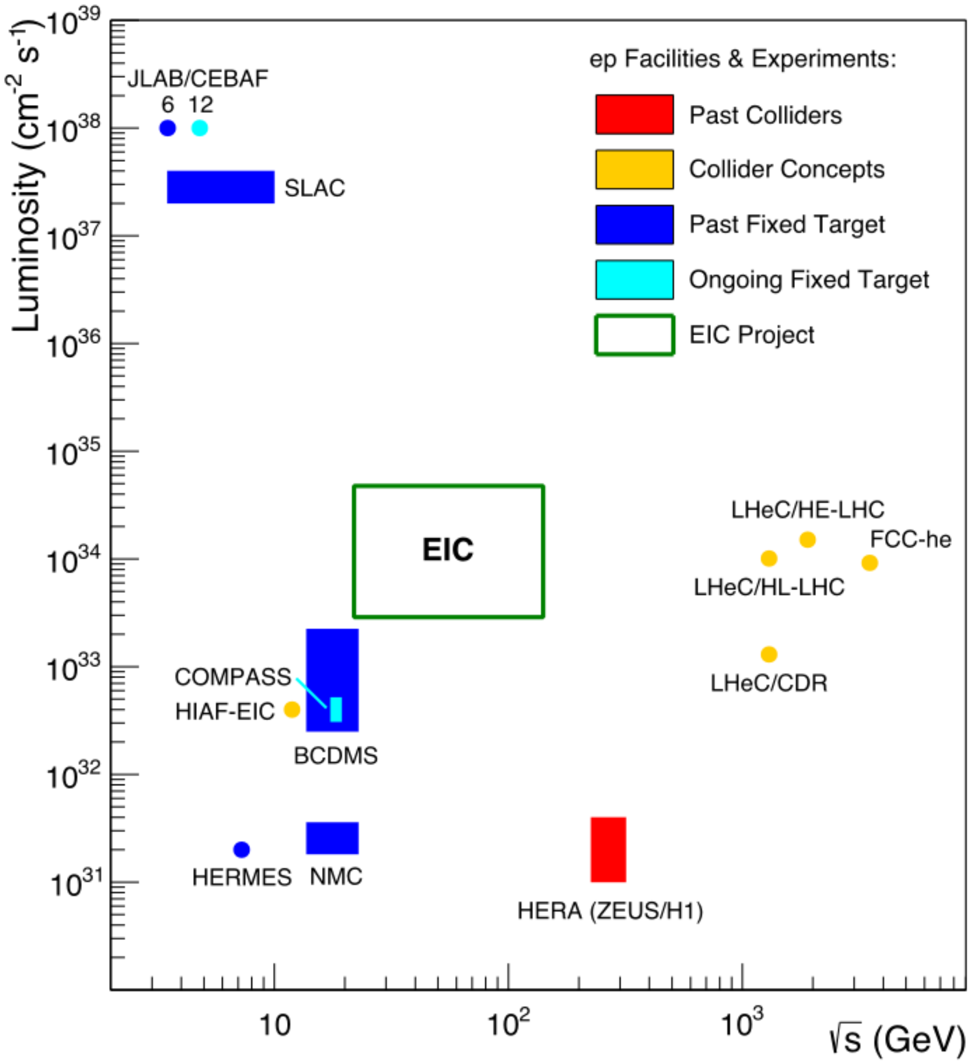
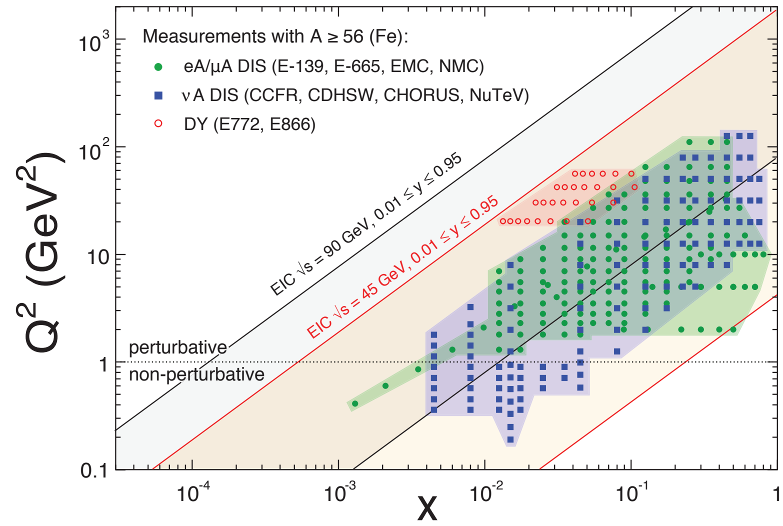


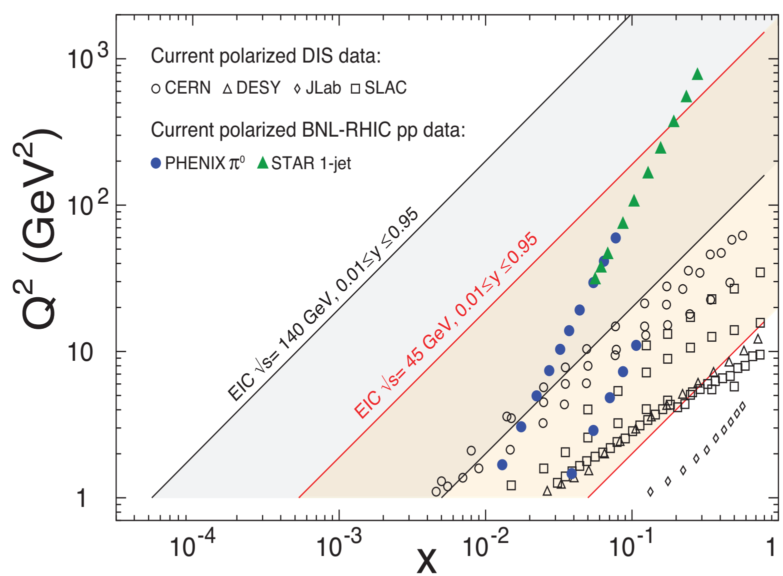
The EIC Facility Concepts

- Luminosity / CME / Kinematic coverage





eA



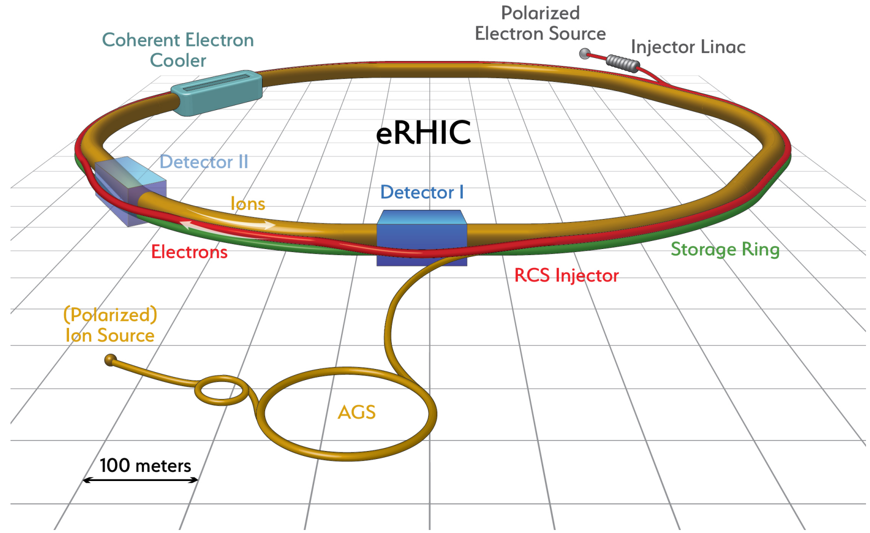
ep

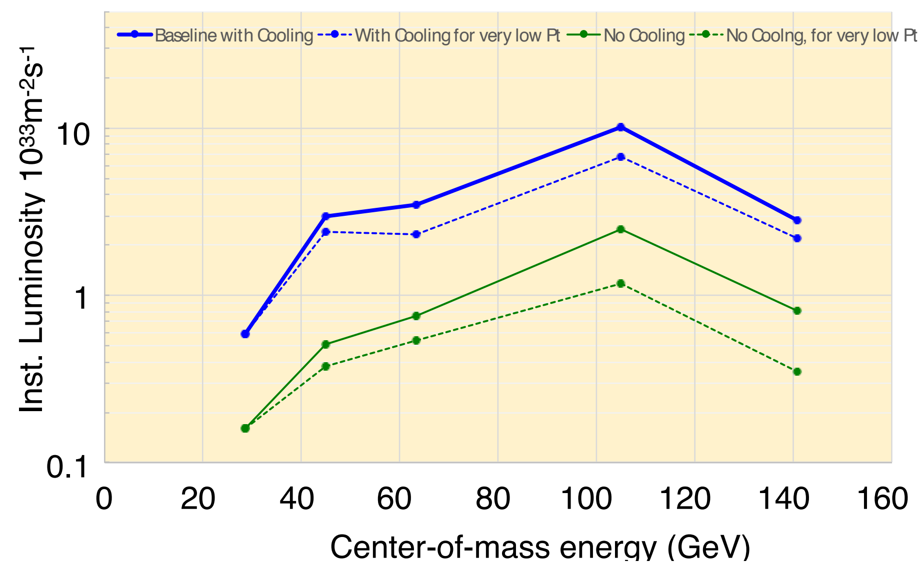
arXiv:1212.1701

The EIC Facility Concepts

V. Ptitsyn

- eRHIC layout and parameters
  - eRHIC design concept:
    - Added electron storage ring (5-18GeV) (~80% pol.) with up to 2.1A e-current and 10MW max. RF power
    - Proton beams up to 275GeV (~70% pol.) and ion beams up to 100GeV/n - existing RHIC facility
    - ^{3}He and possibly d / A up to U
    - Repetition rate: 112.6MHz (With cooling)
    - Flat proton beam formed by cooling
    - Polarized electron source and 400MeV injector linac
    - On-energy polarized electron injector
    - Alternative approach of e-ERL accelerator considered in past / Technology risks addressed by R&D

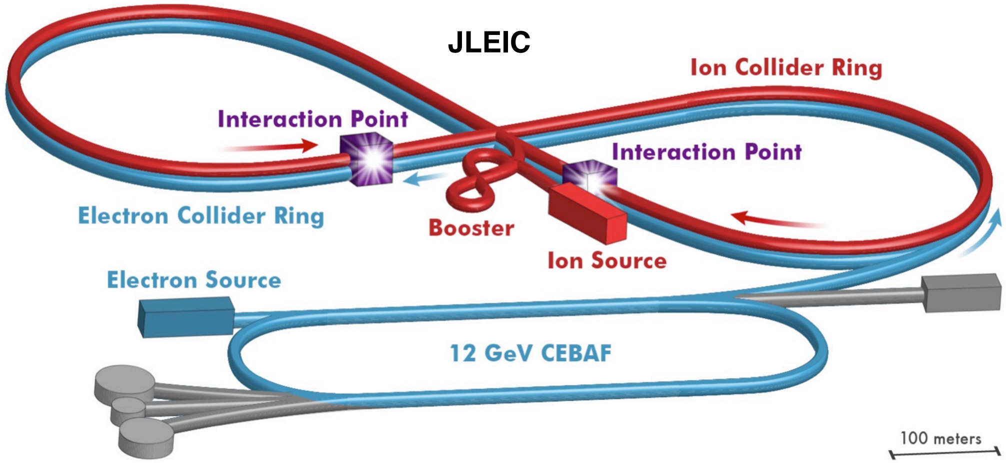


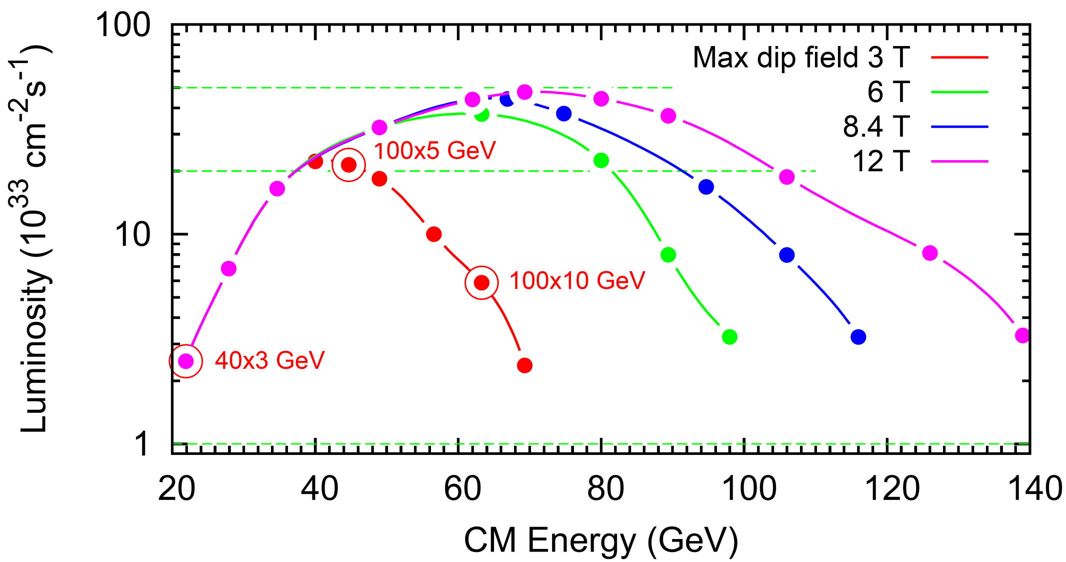


The EIC Facility Concepts

Y. Zhang

- JLEIC layout and parameters
  - JLEIC design concept:
    - Polarized electrons 3 to 12GeV and polarized protons 40 to 100-400GeV and ions 40 to 160GeV/u - Polarization > 70%
    - Polarized light ions d, ^{3}He and possibly Li / A above 200 (Au,Pb)
    - Electron complex with CEBAF as full energy injector and collider ring up to 12GeV
    - Ion complex with source and linac, booster and collider ring
    - Polarization - Figure-8 topology for ions rings / Spin precessions in left/right section of Figure-8 arrangement cancel
    - Repetition rate: 476MHz - High lumi. concept!





The EIC Detector Concepts

- Overview of processes and final states

arXiv:1212.1701

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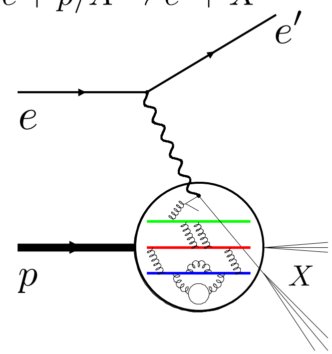
$e + p/A \rightarrow e' + X$



Inclusive DIS

- Inclusive: Unpolarized $f_i(x,Q^2)$ and helicity distribution $\Delta f_i(x,Q^2)$ functions through unpolarized and polarized structure function measurements (F_2, F_L, g_1)
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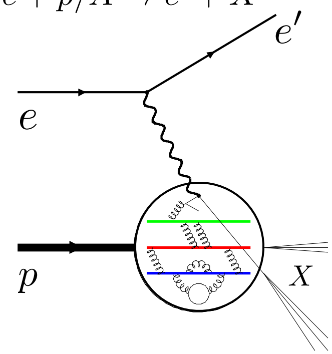
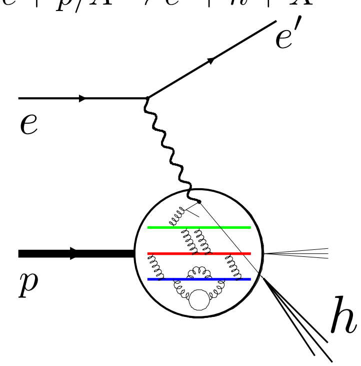
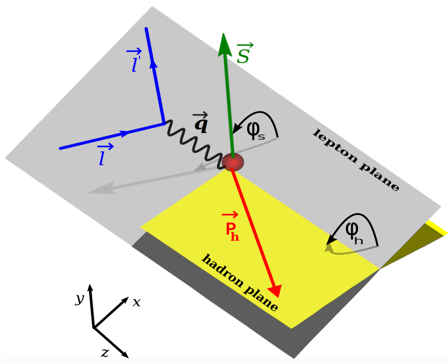


Inclusive DIS

Semi-Inclusive DIS (SDIS)

$e + p/A \rightarrow e' + h + X$





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- SDIS: Flavor tagging through hadron identification studying FF / TMD's (Transverse momentum, k_T, dependence) requiring azimuthal asymmetry measurement - Full azimuthal acceptance
- Heavy flavor (charm / bottom): Excellent secondary vertex reconstruction

The EIC Detector Concepts

Overview of processes and final states

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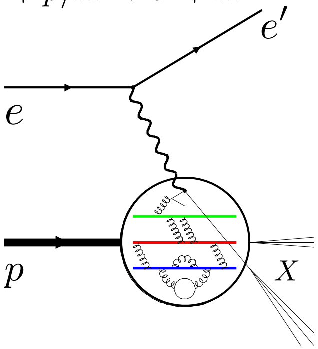

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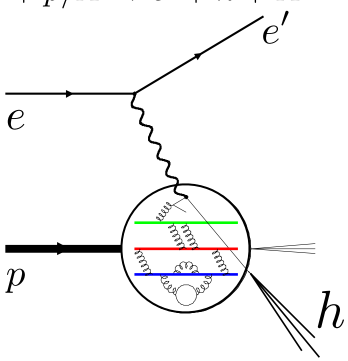

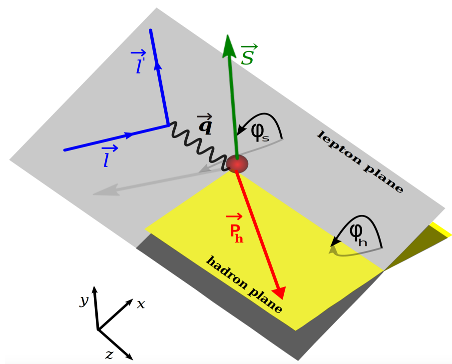

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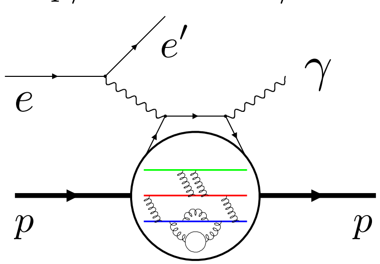
$e + p/A \rightarrow e' + N'/A' + \gamma/m$



Deeply-Virtual Compton Scattering (DVCS)

- Exclusive: Tagging of final state proton using Roman pot system studying GPD's (Impact parameter, b_T, dependence) using DVCS and VM production
- eA: Impact parameter determination / Neutron tagging using Zero-Degree Calorimeter (ZDC)

The EIC Detector Concepts

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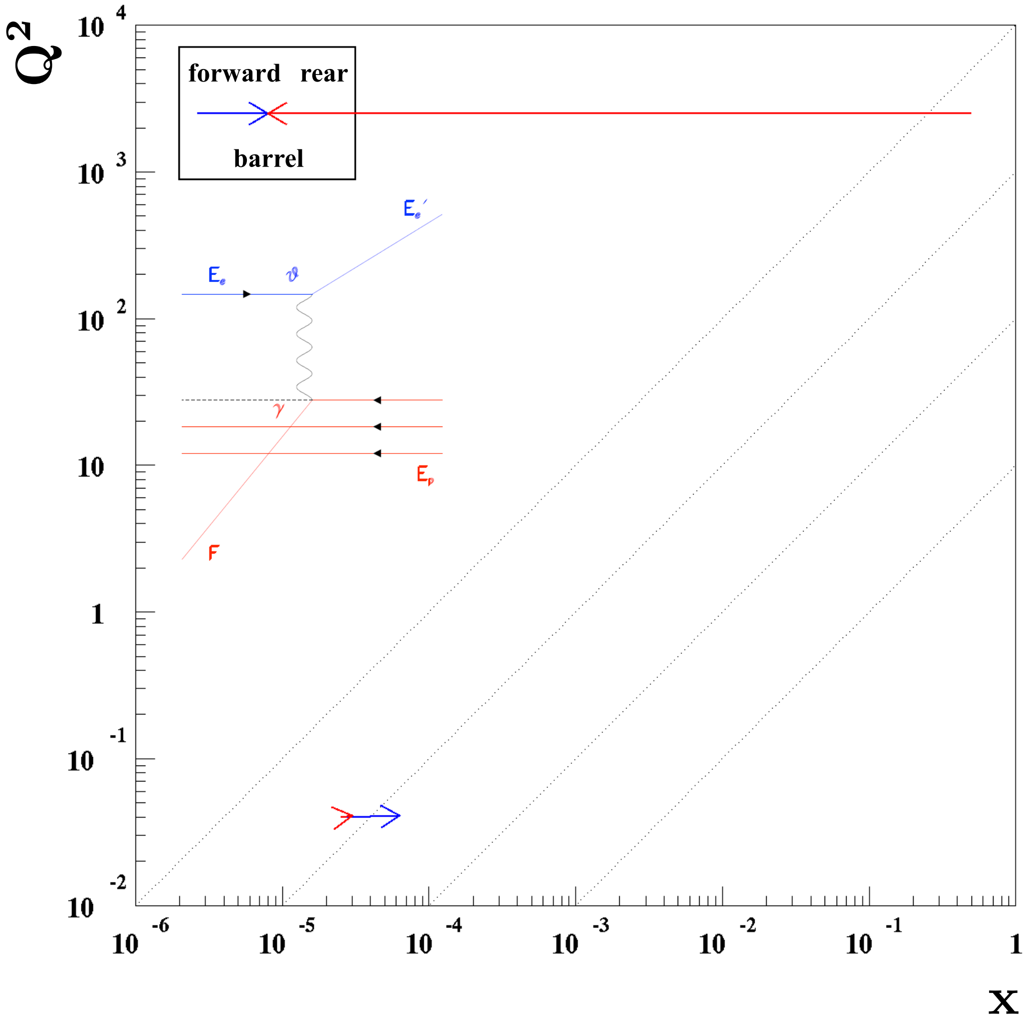

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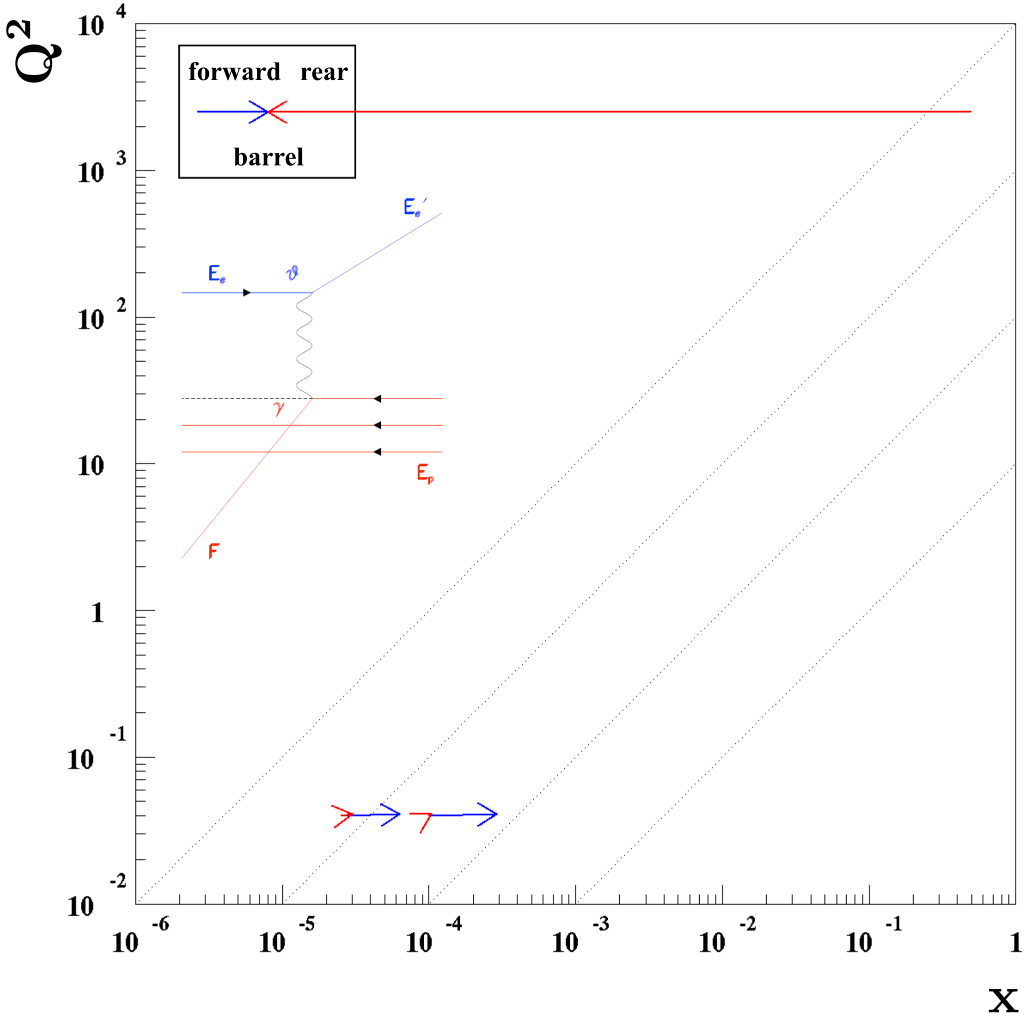

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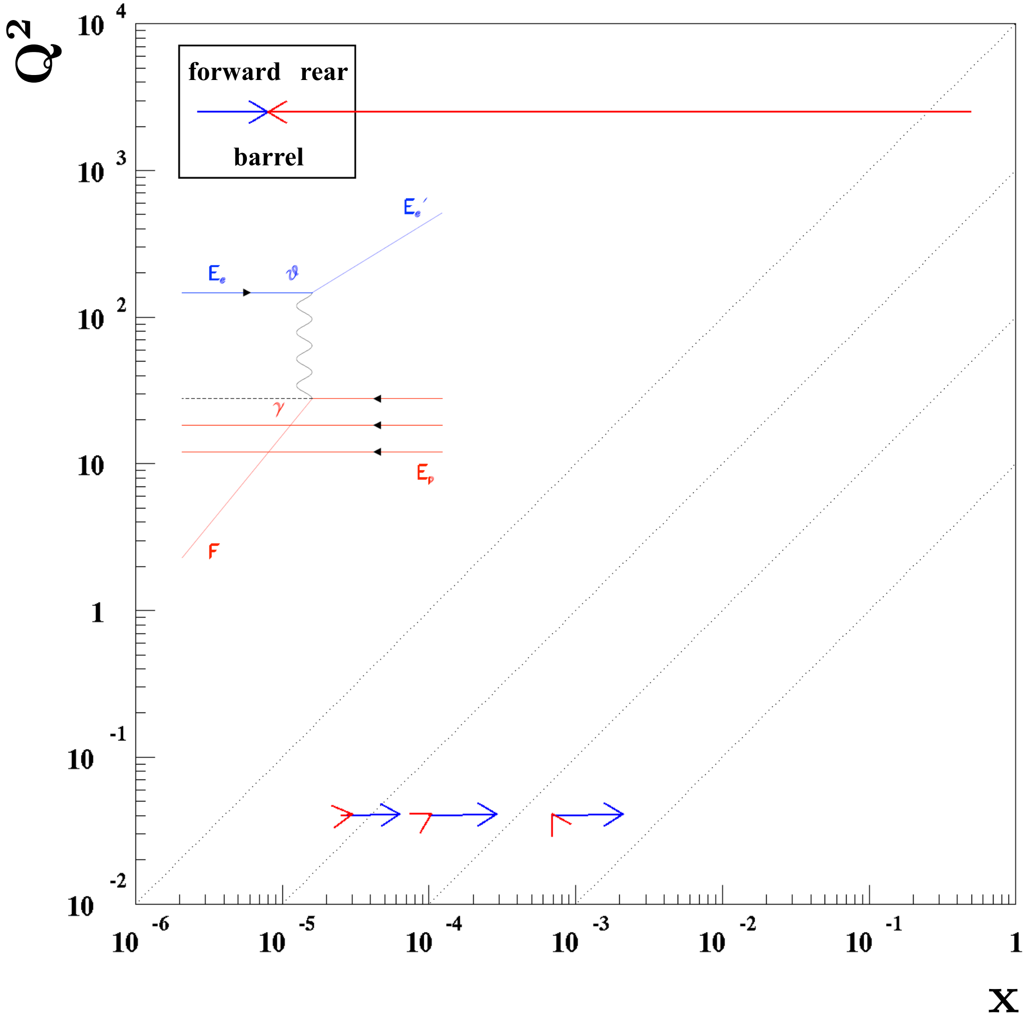

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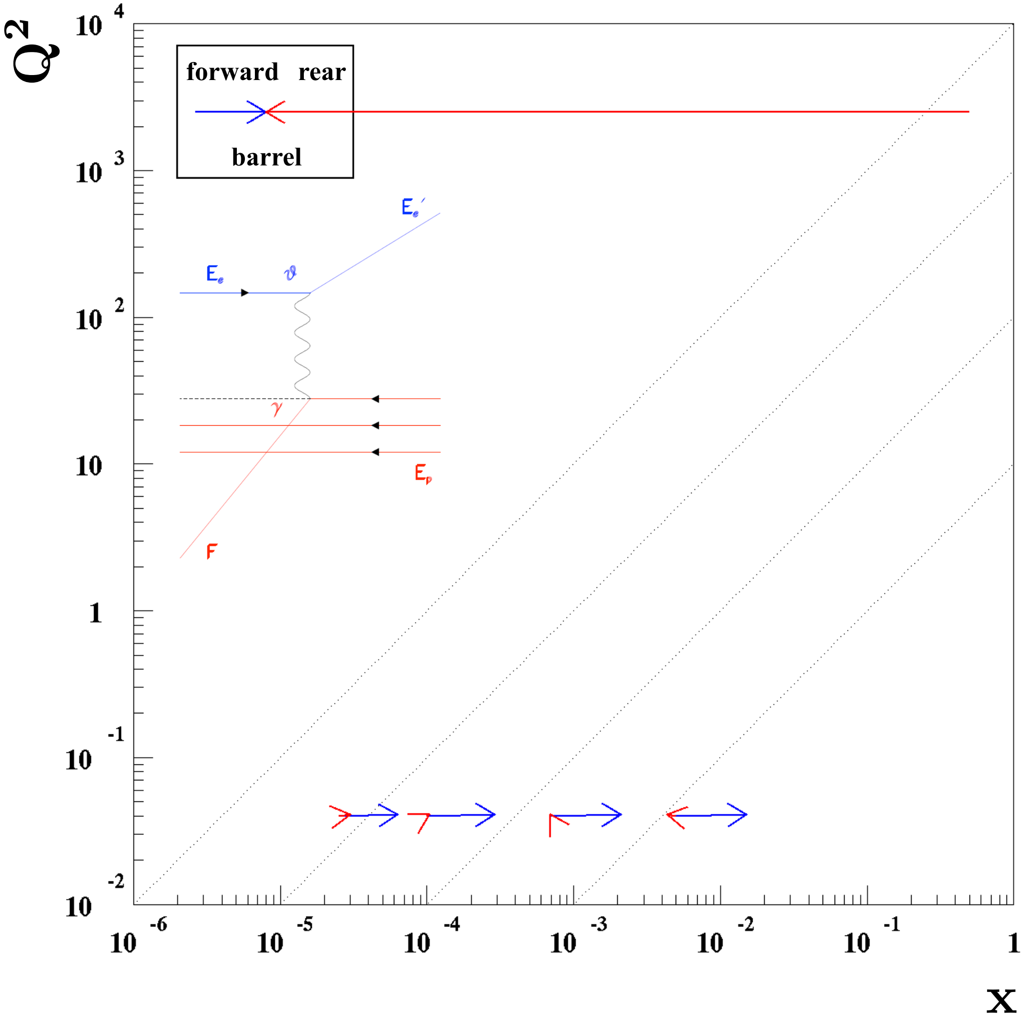

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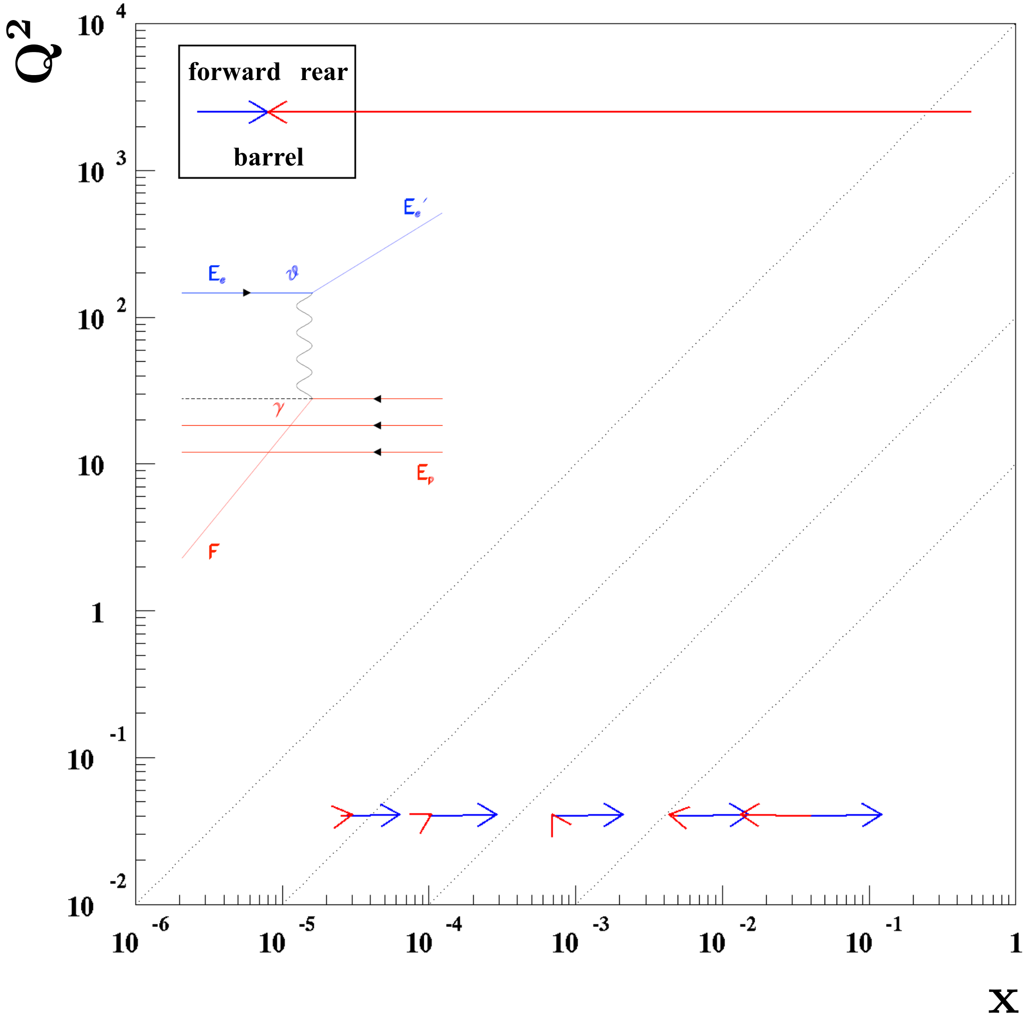

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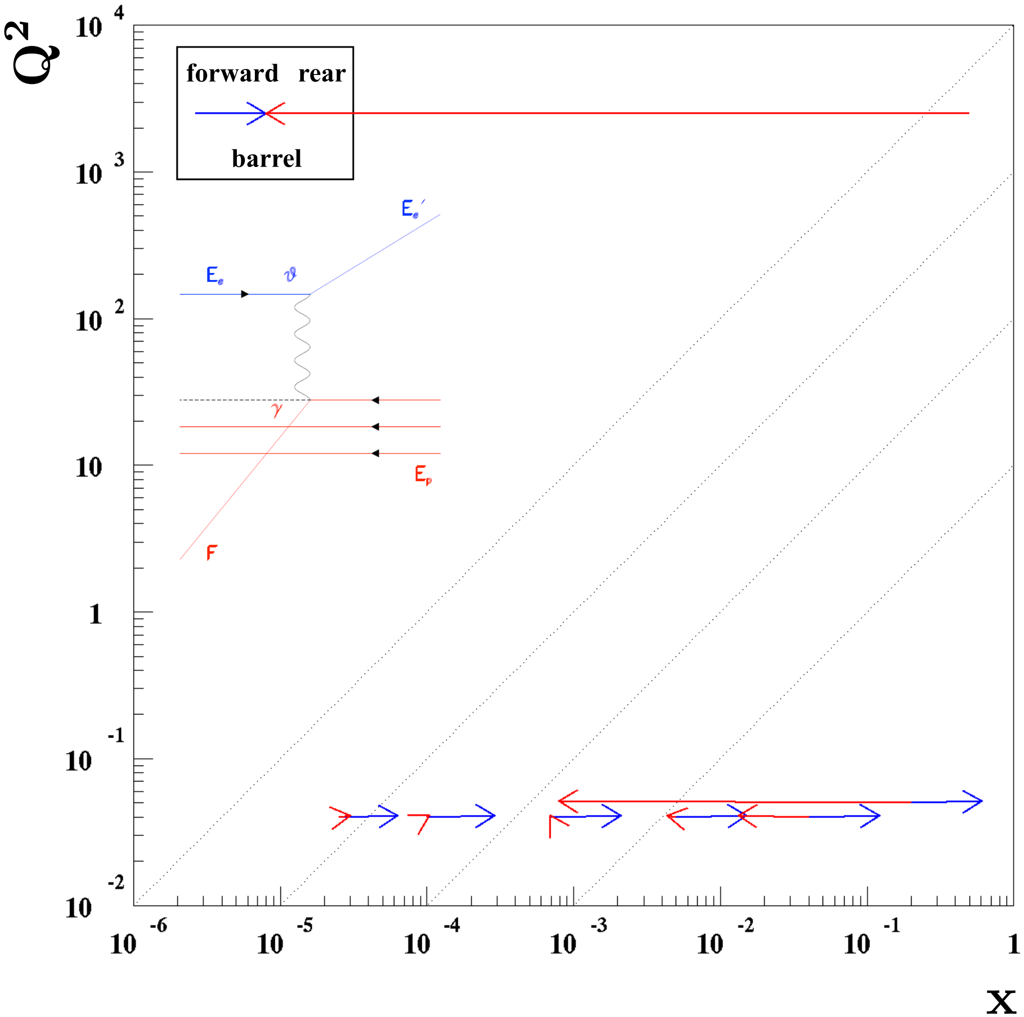

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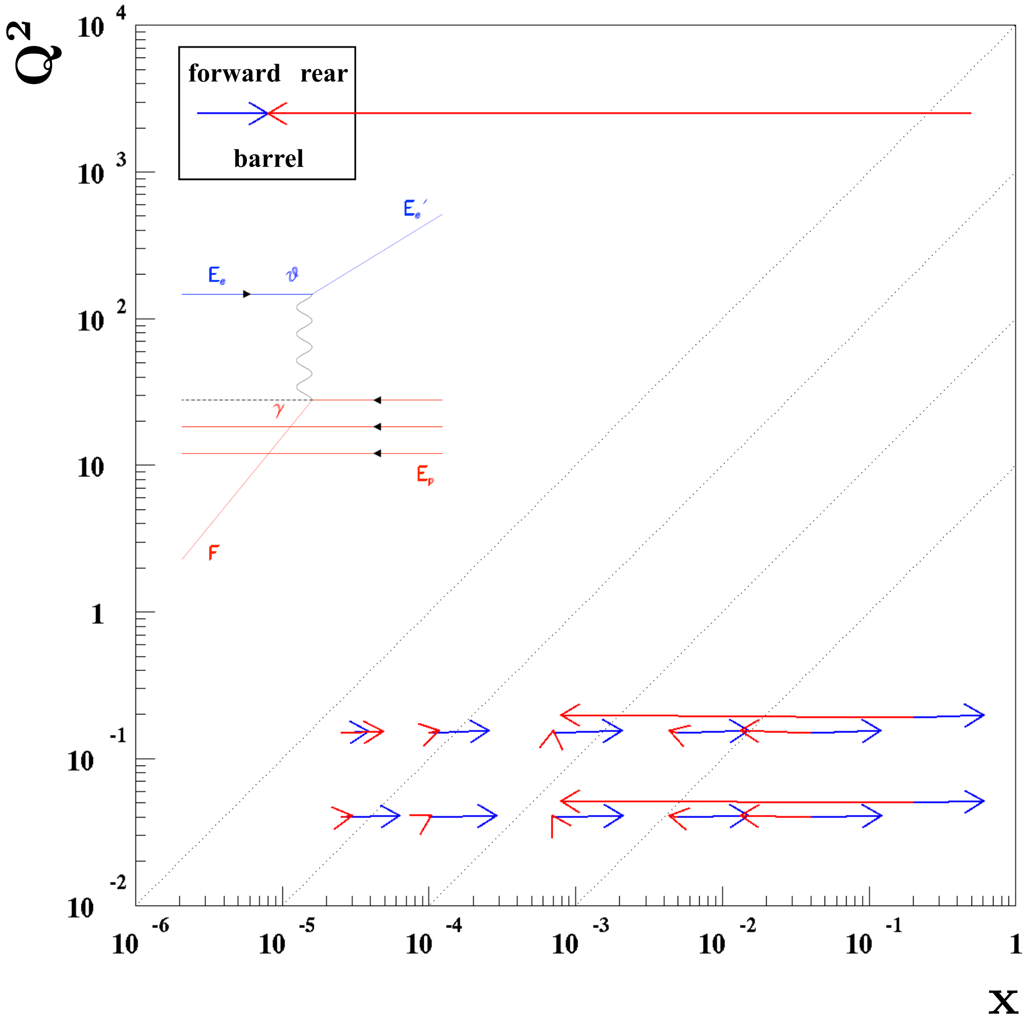

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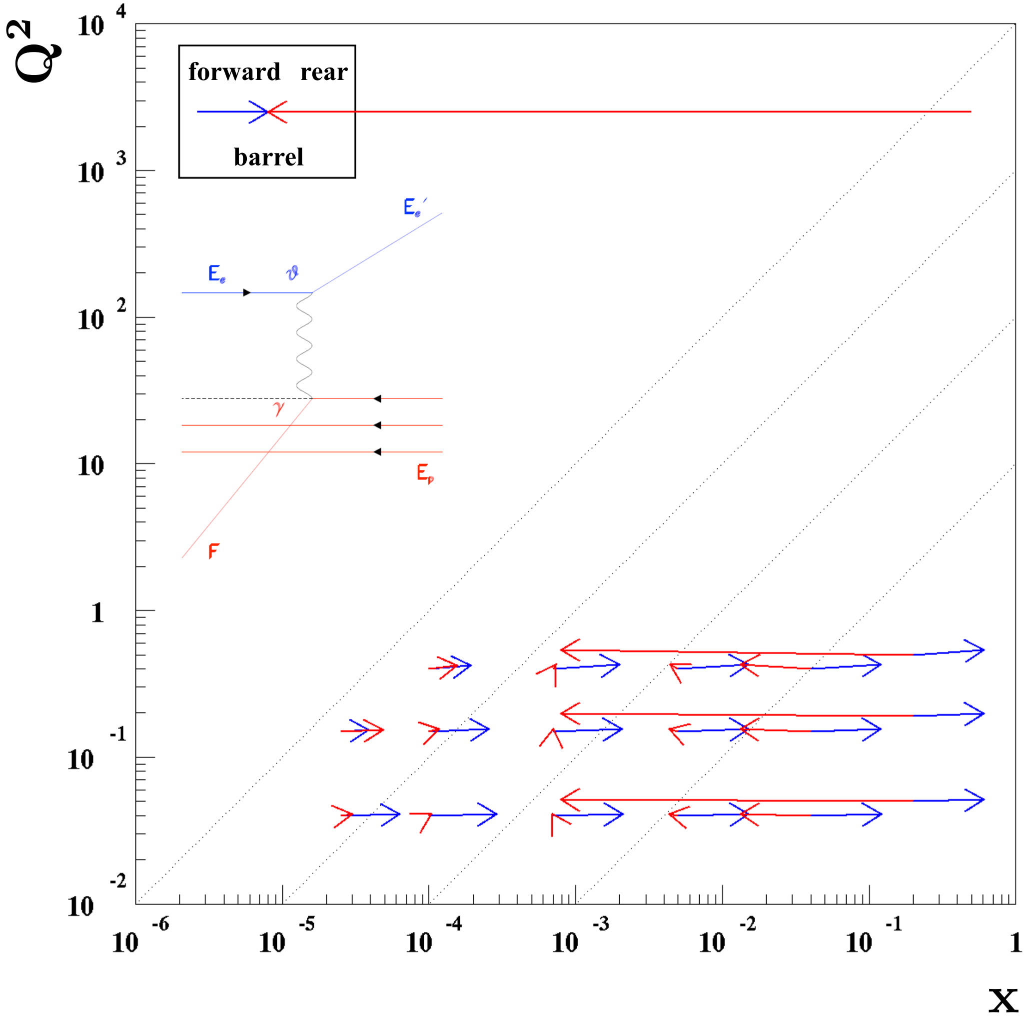

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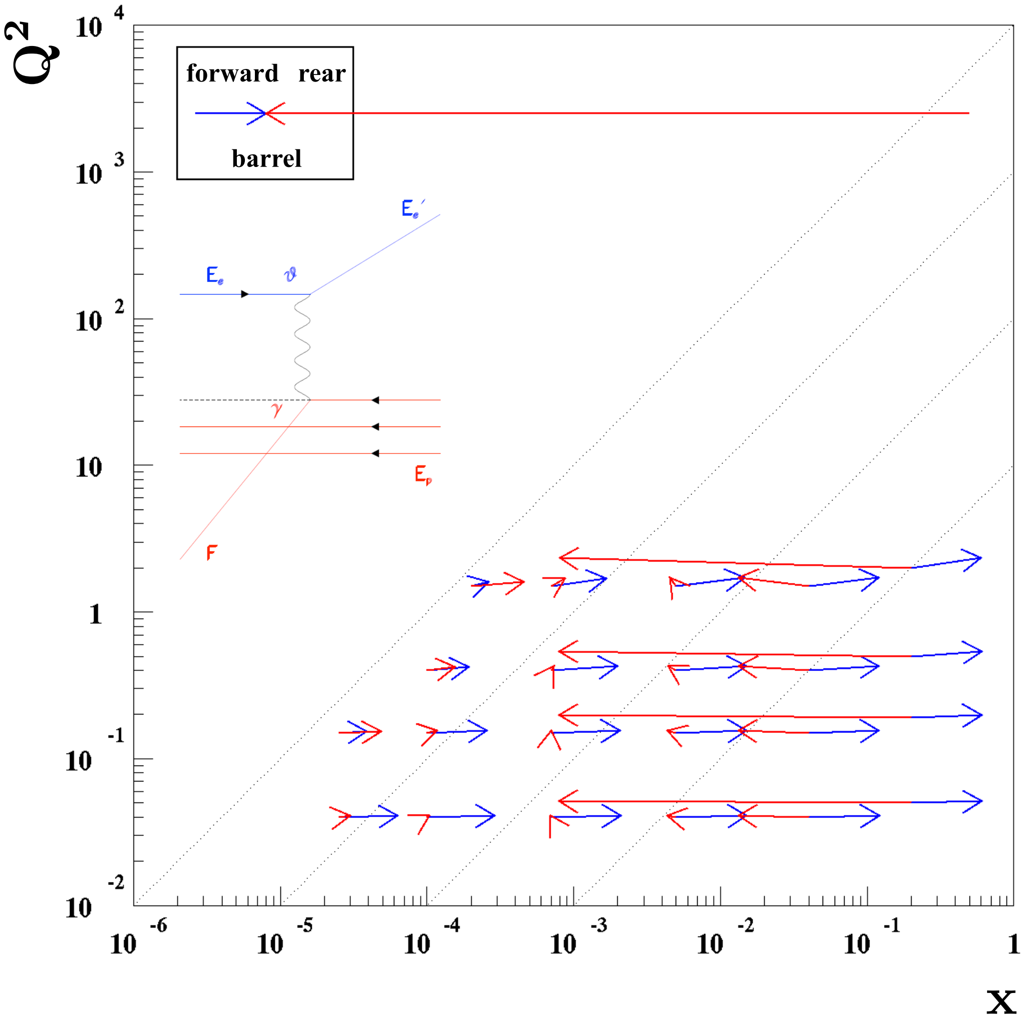

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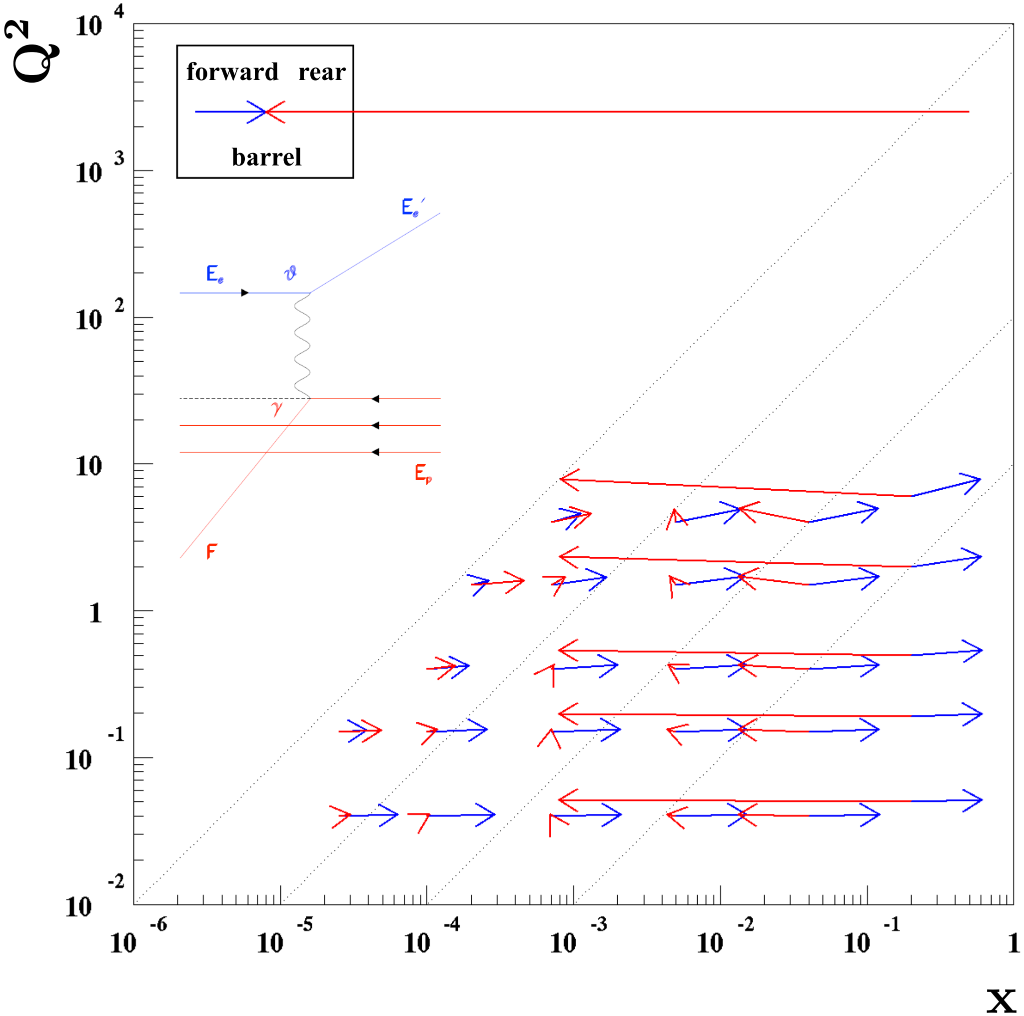

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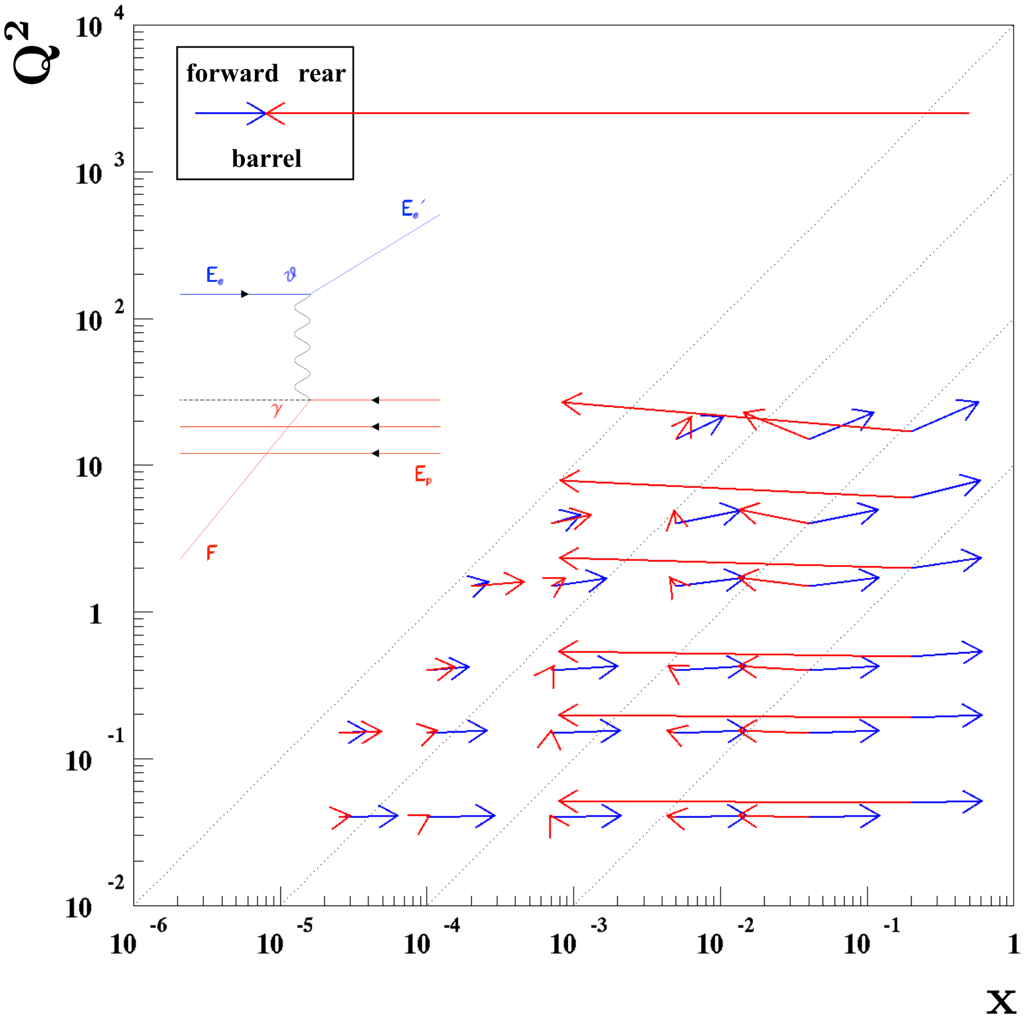

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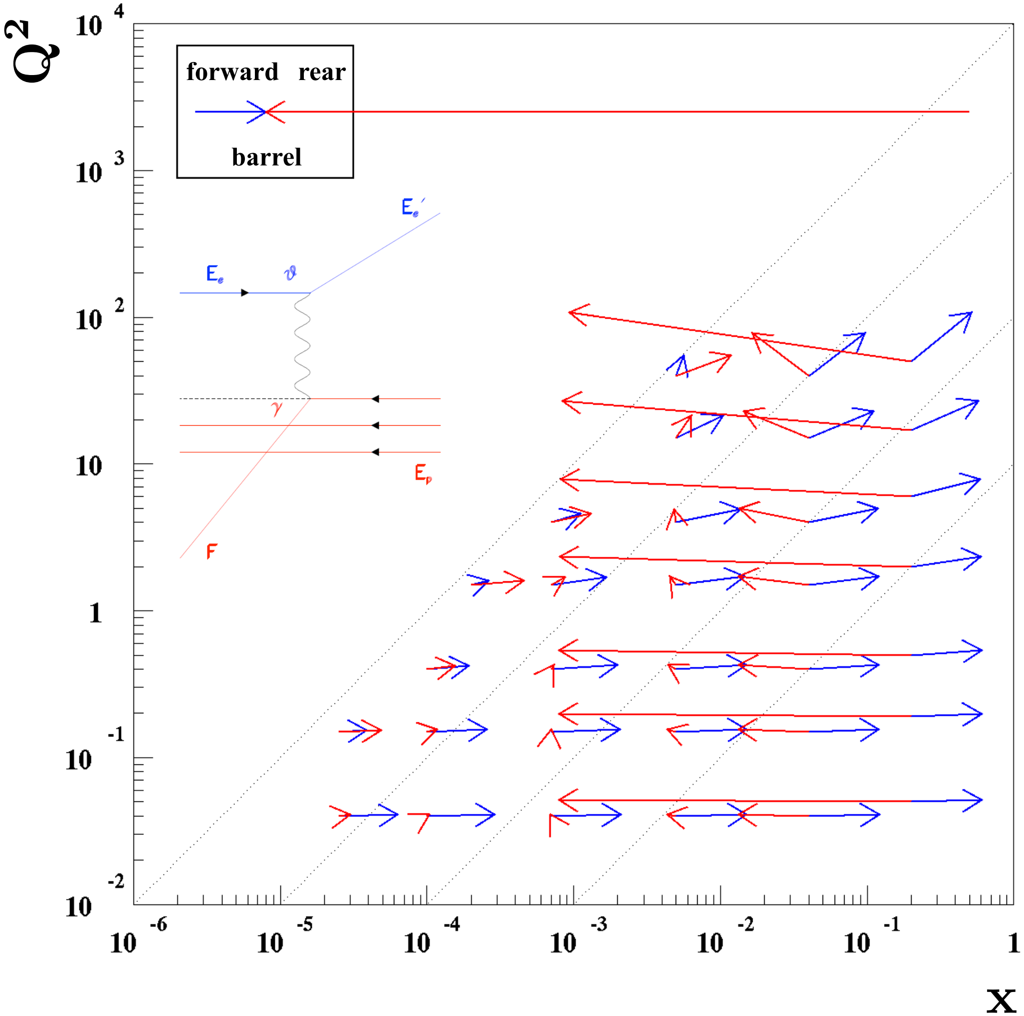

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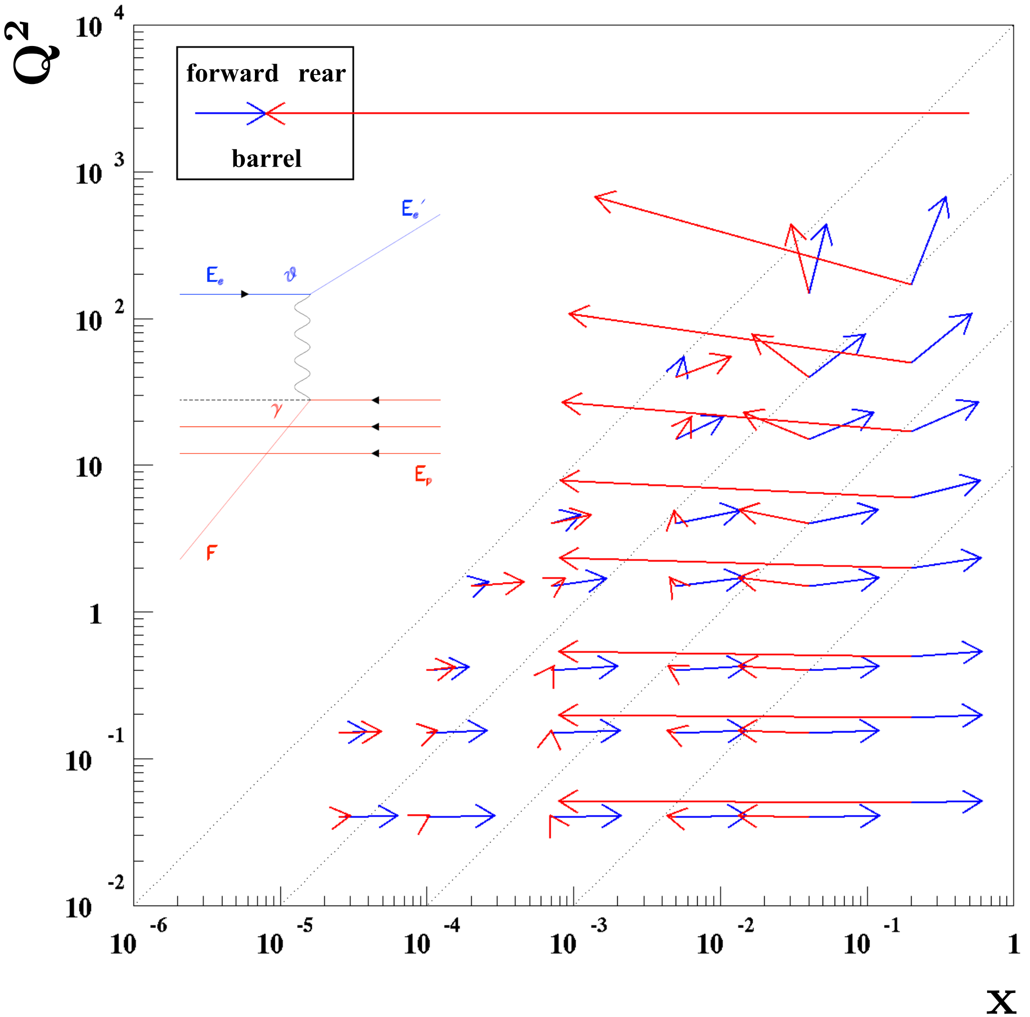

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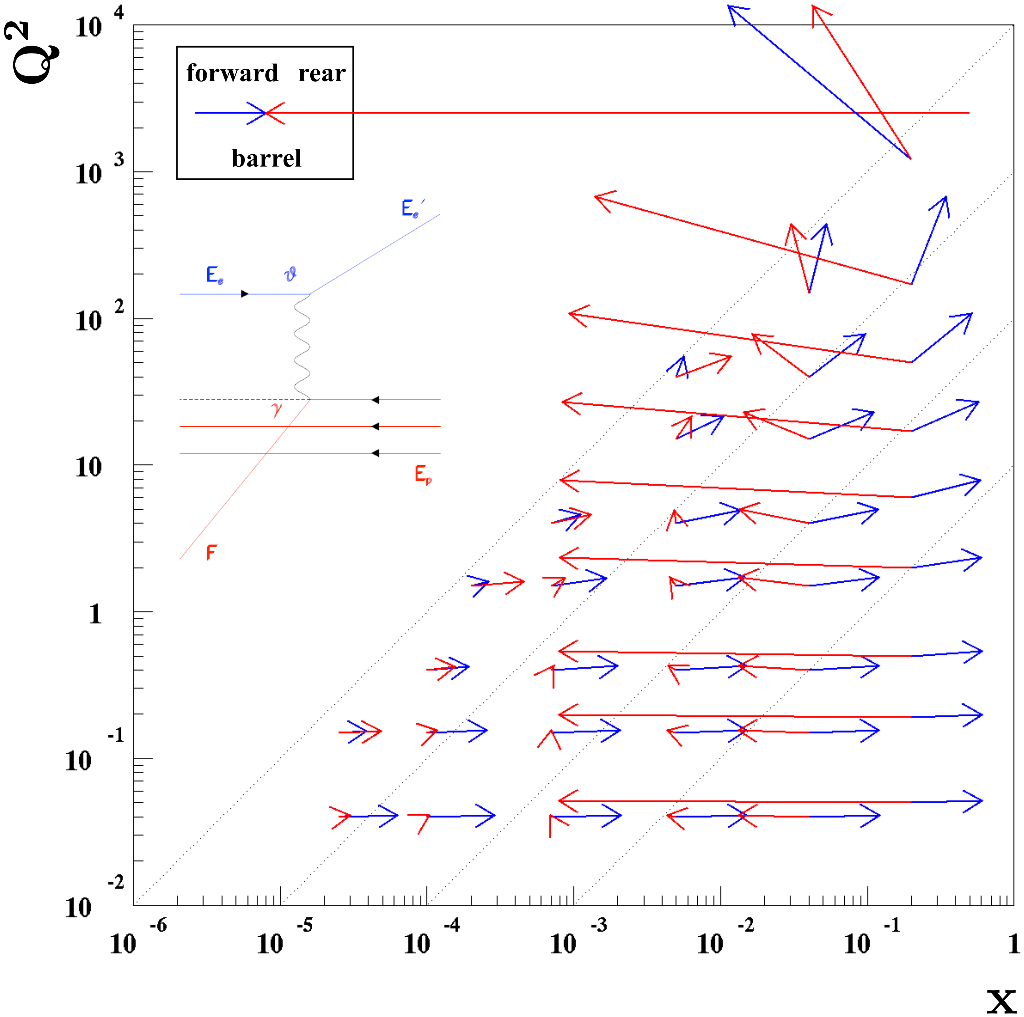

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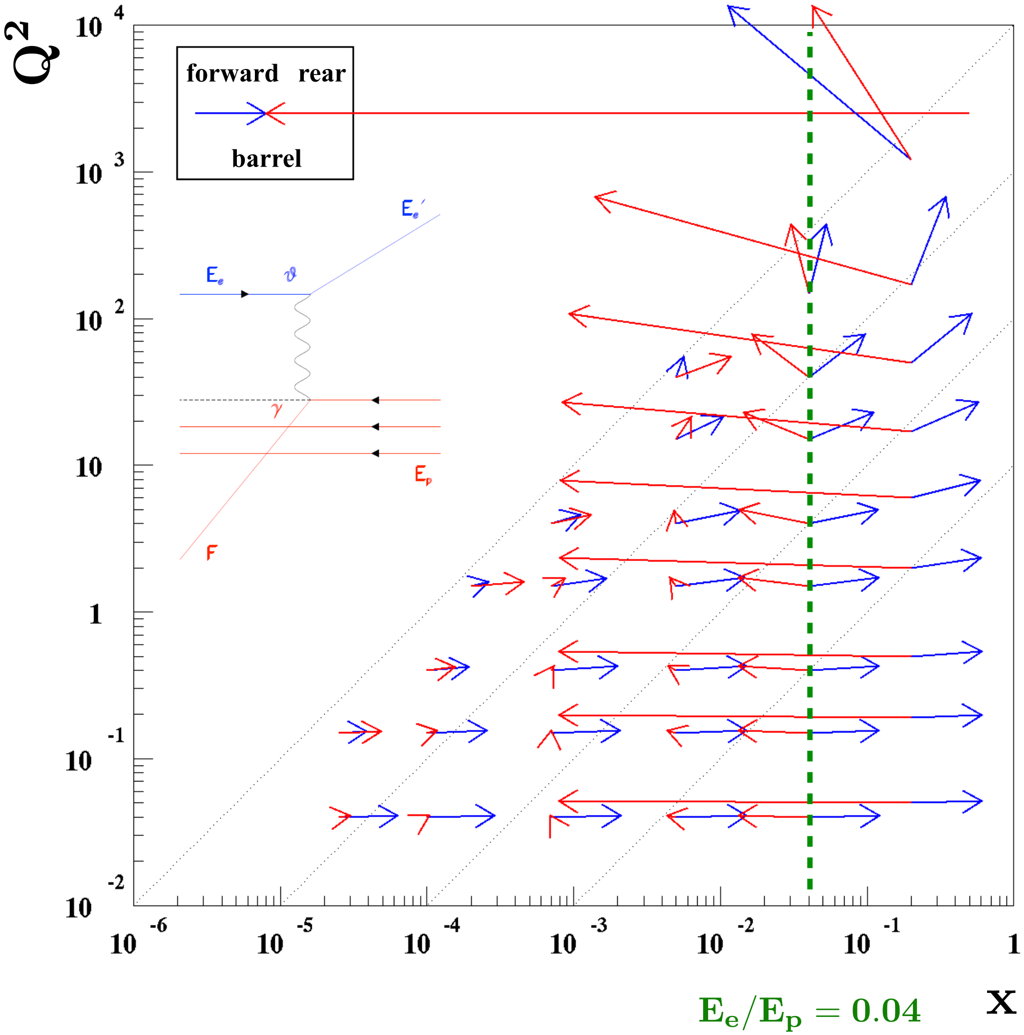

Kinematic peak location!

The EIC Detector Concepts

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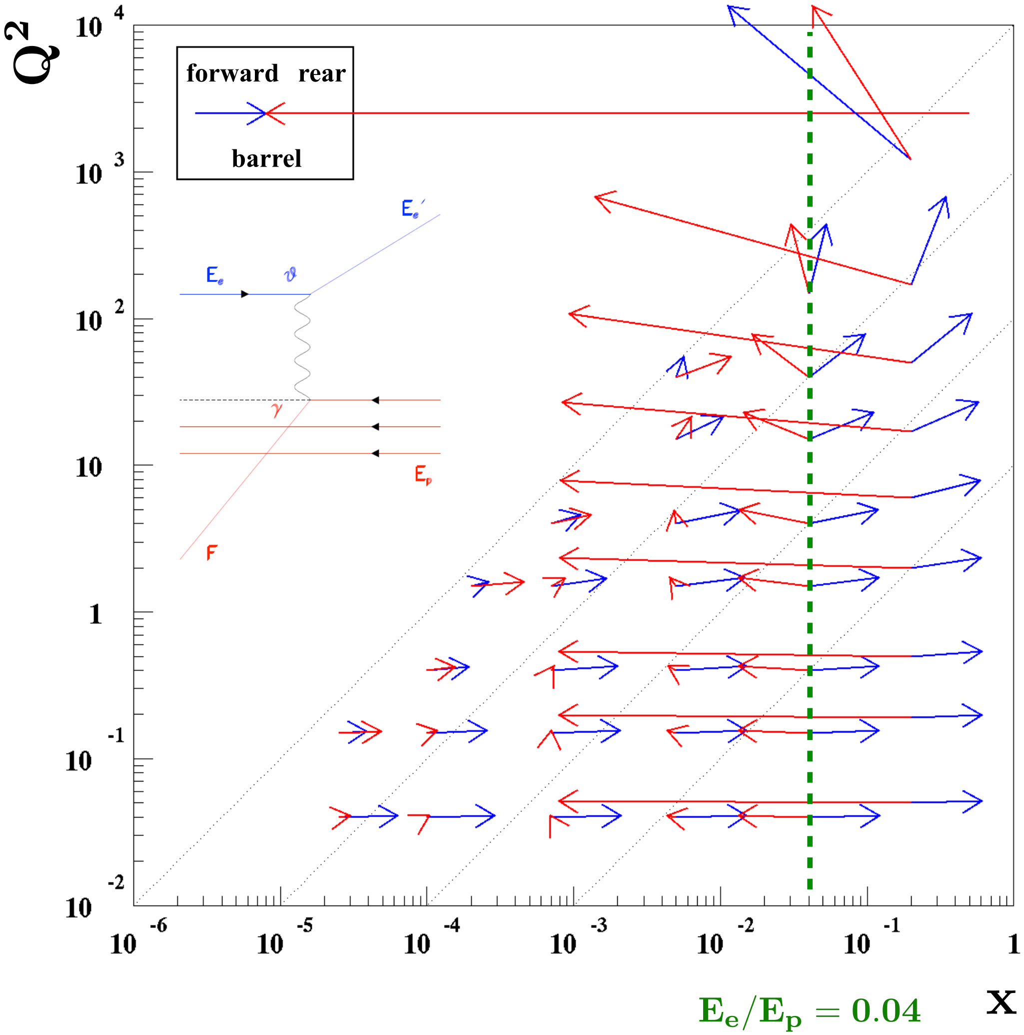
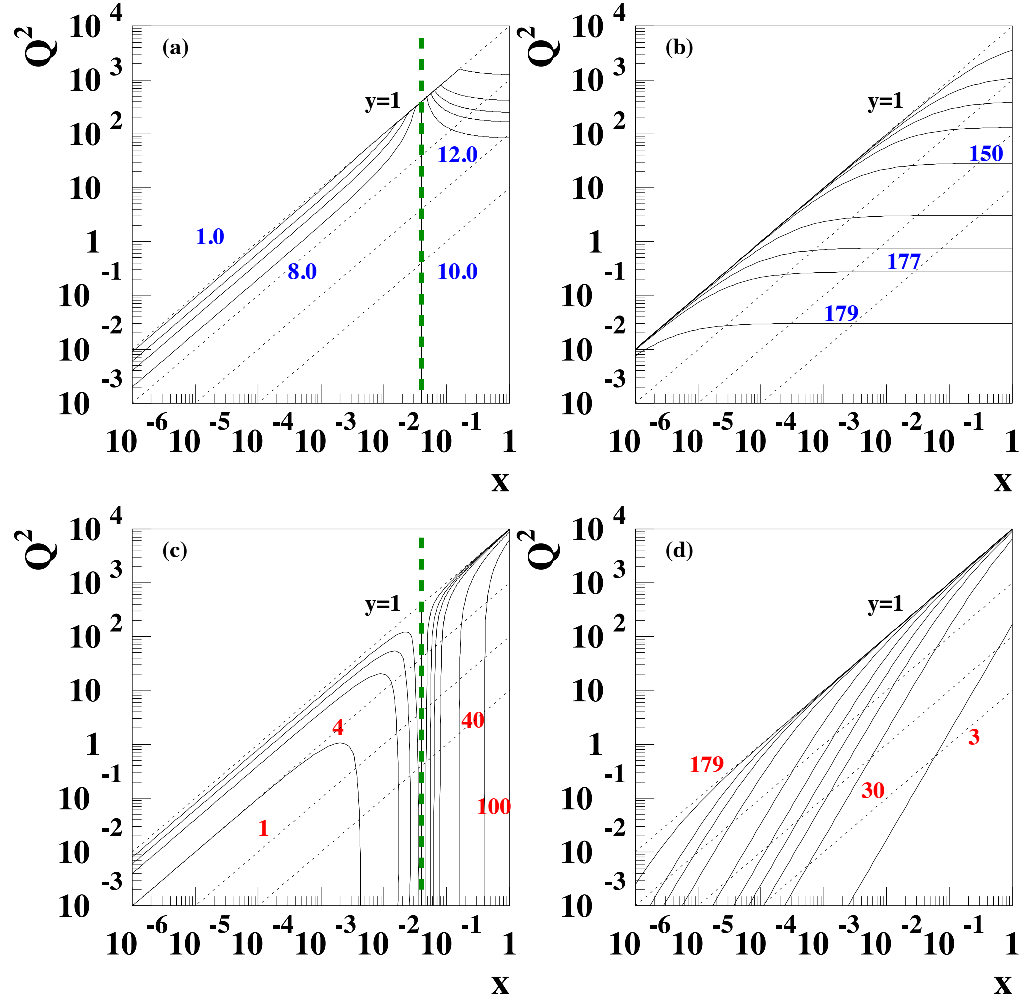


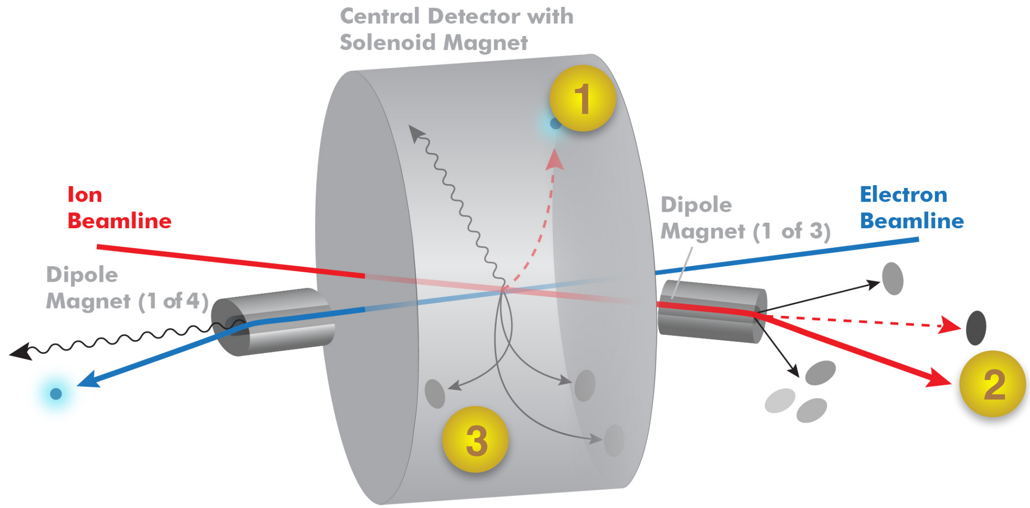


Kinematic peak location!

The EIC Detector Concepts

- Overview of general requirements

arXiv:1212.1701



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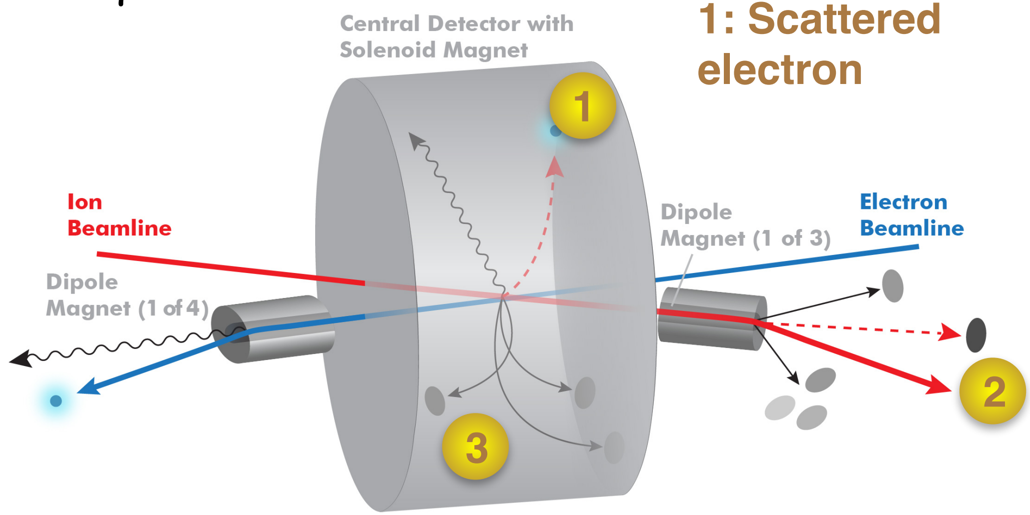

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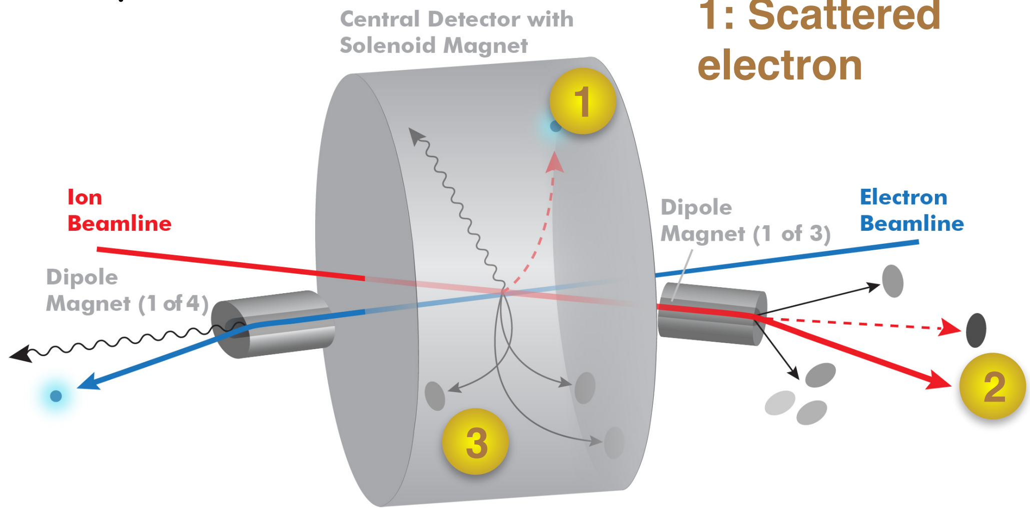

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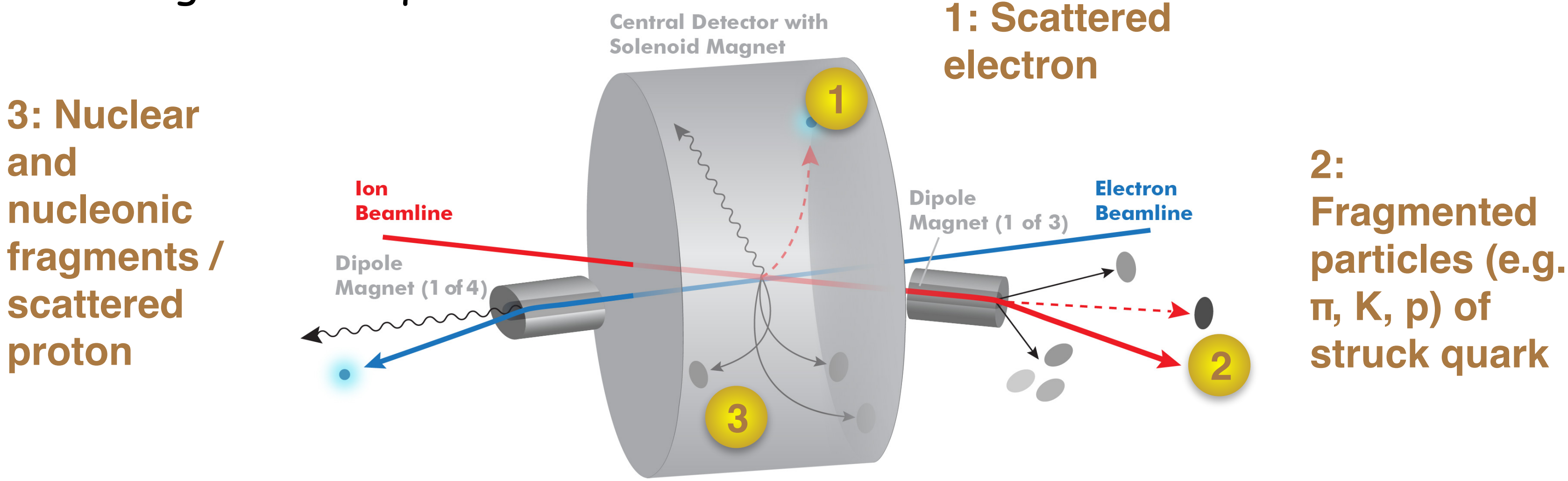

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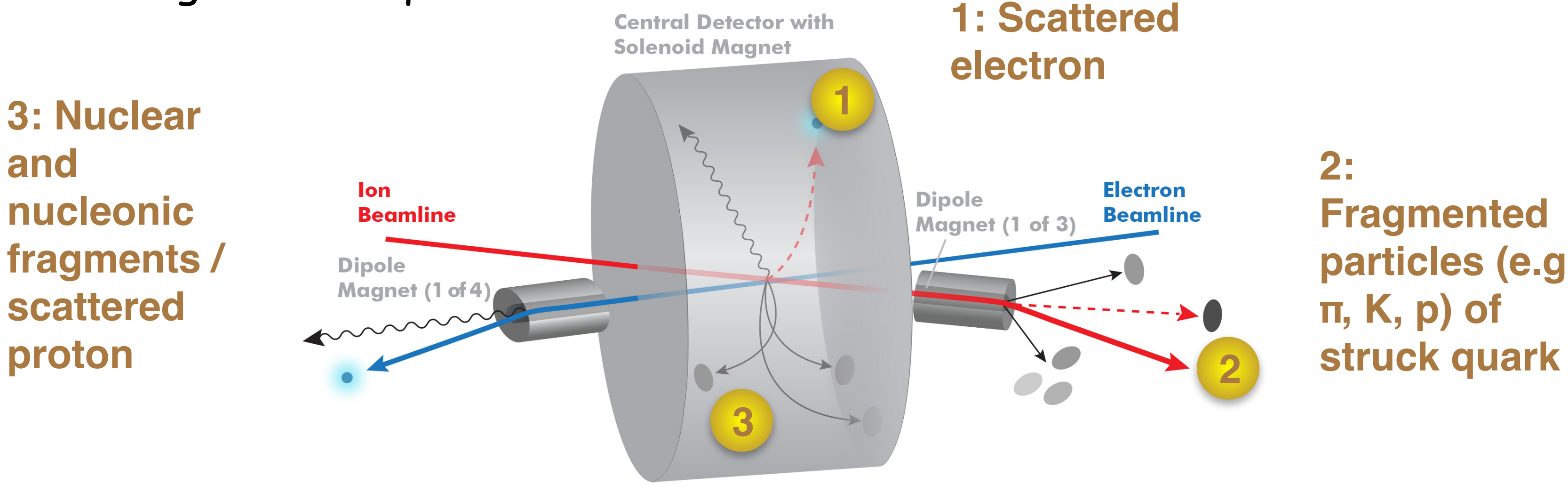

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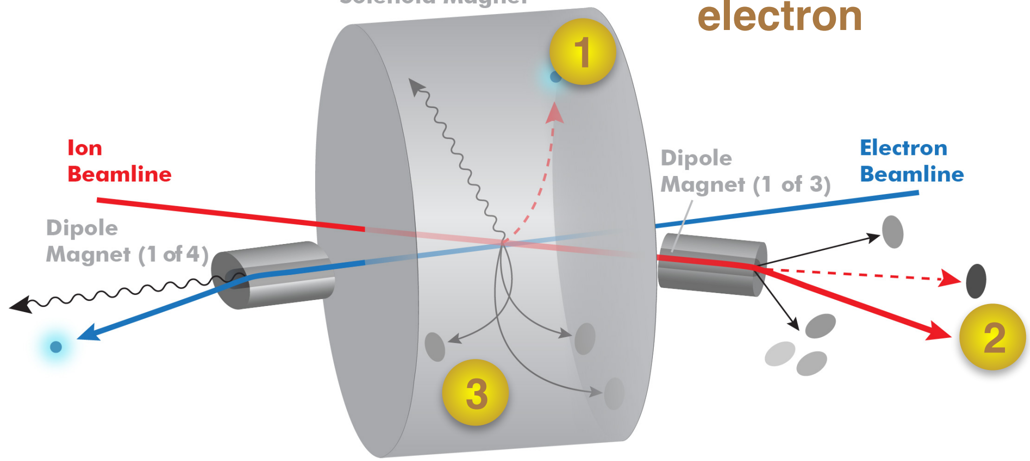

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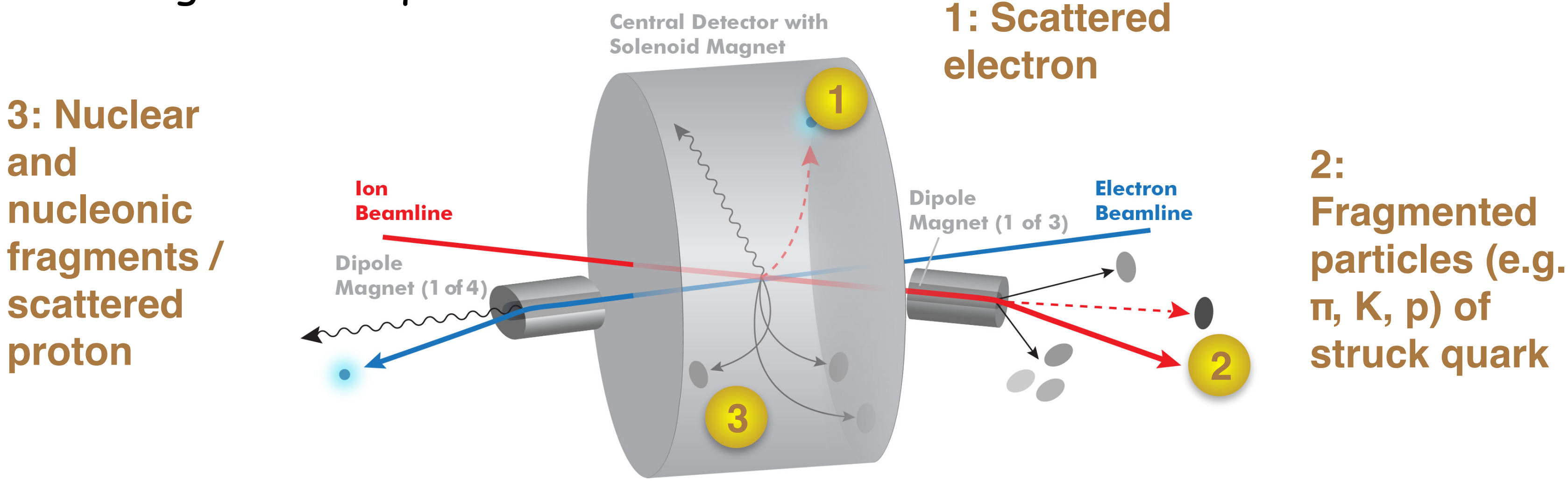

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The EIC Detector Concepts

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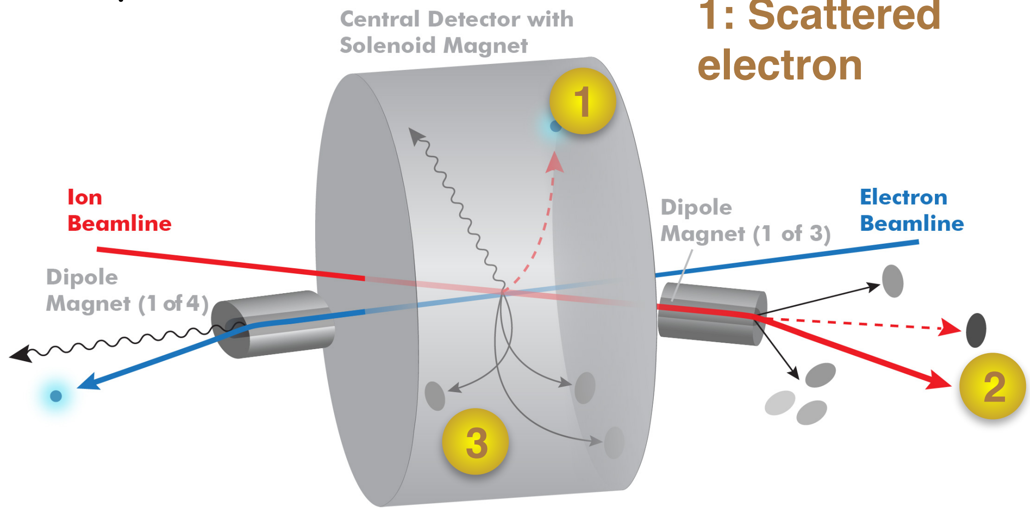

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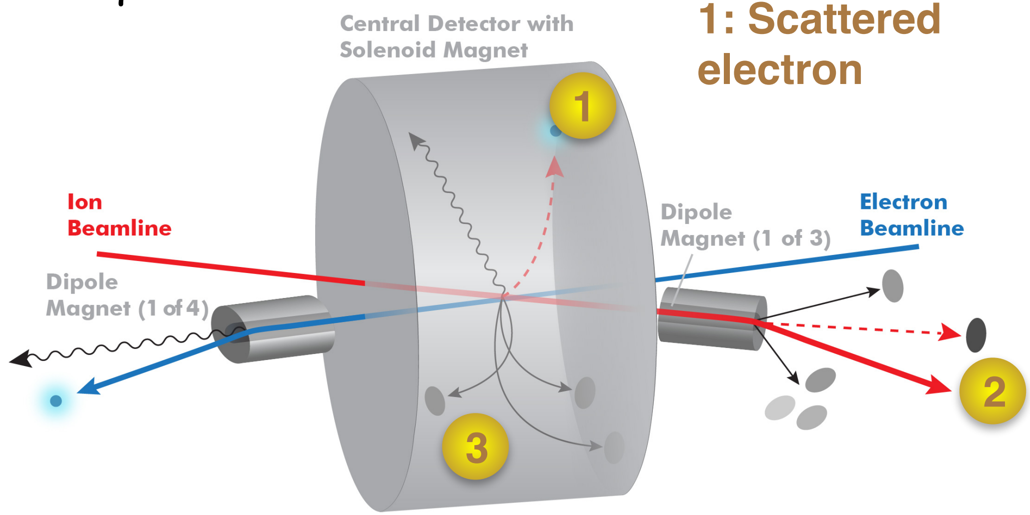

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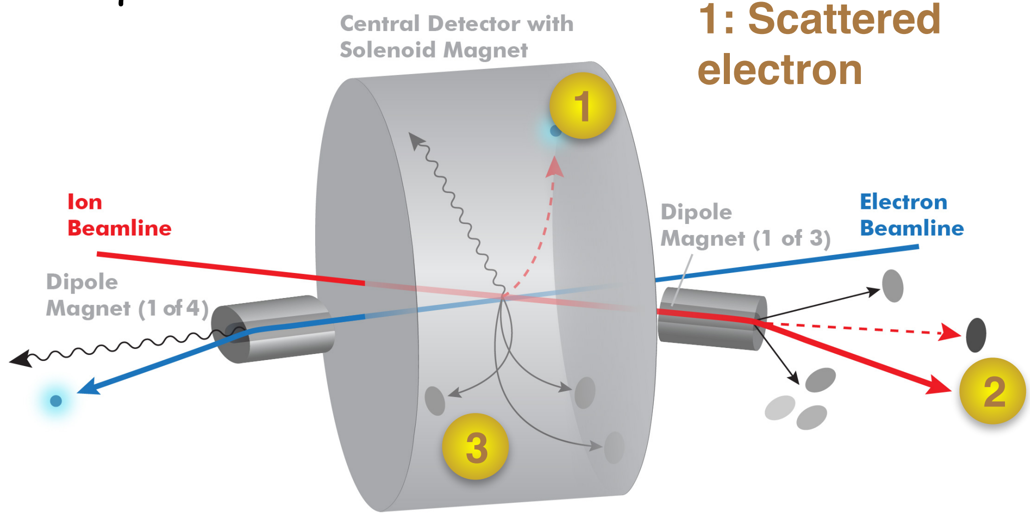

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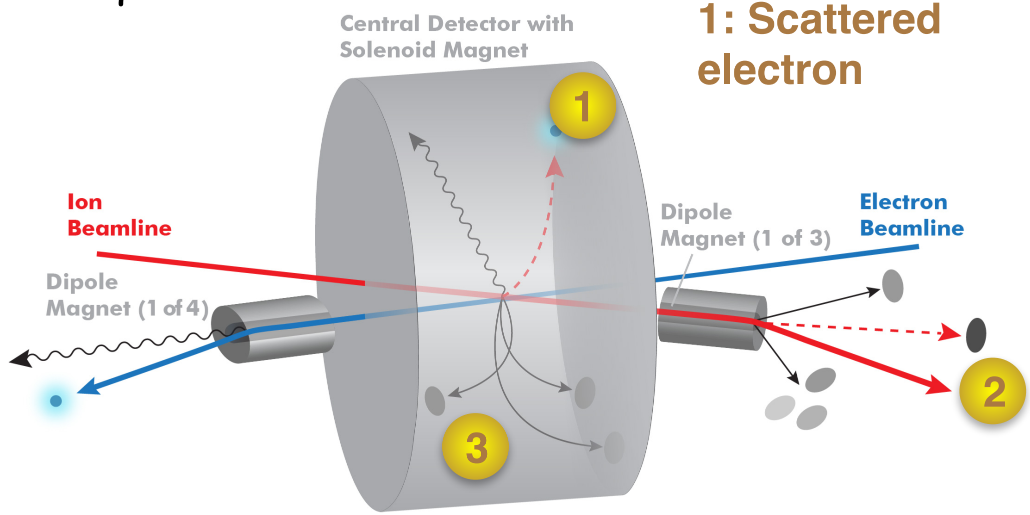

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Overview of general requirements

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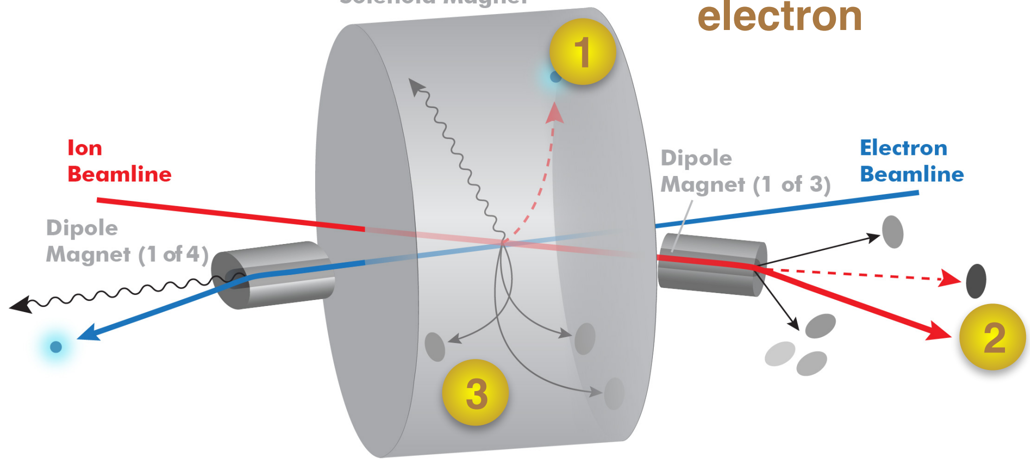

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- Luminosity (Absolute and relative) and local polarization direction measurement

The EIC Detector Concepts

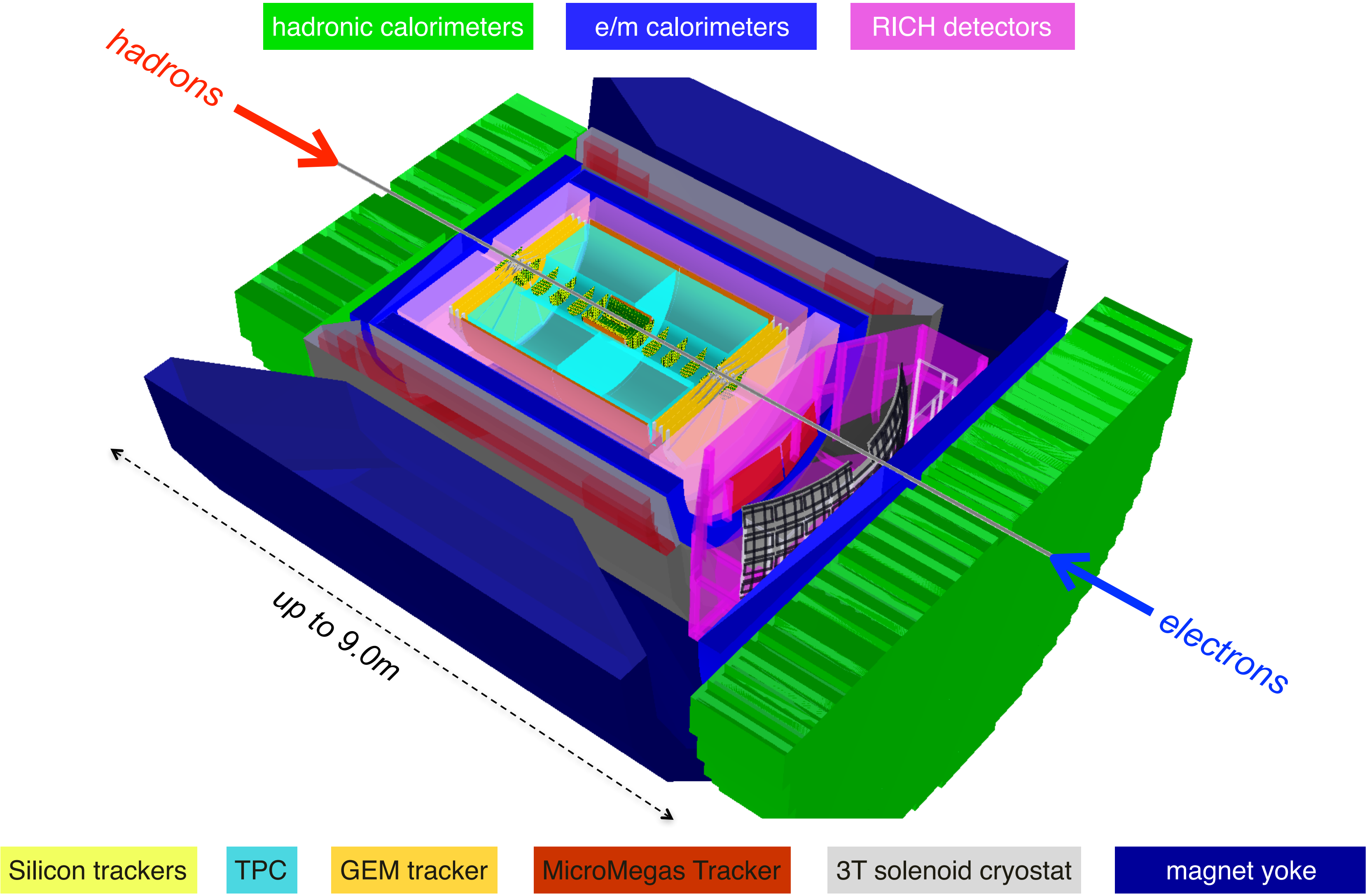
- Generic Detector R&D program for an EIC
  - In January 2011, BNL, in association with JLab and the DOE Office of NP, announced a generic detector R&D program to address the scientific requirements for measurements at a future EIC facility.
  - Goals:
    - Enable successful design and timely implementation of an EIC experimental program
    - Develop instrumentation solutions that meet realistic cost expectations
    - Stimulate the formation of user collaborations to design and build experiments
  - Peer-reviewed program funded by DOE and managed by BNL with $1M/year to $1.5M/year Initiated and coordinated by Tom Ludlam (BNL) until 2014 / Since 2014 coordinated by Thomas Ullrich (BNL)
  - Key to success: Standing EIC Detector Advisory Committee
    - Current members: Marcel Demarteau (ANL), Carl Haber (LBNL), Peter Krizan (Ljubljana), Ian Shipsey (Oxford), Rick van Berg (UPenn), Jerry Va'vra (SLAC) and Glenn Young (JLab)
    - Past members: Robert Klanner (Hamburg) and Howard Wieman (LBL)
  - Wide range of R&D programs: Calorimetry / Tracking (GEM, MicroMegas, TPC) incl. silicon / Particle ID (TRD, Dual-RICH, Aerogel RICH, DIRC, TOF) / Polarimetry / Background / Simulation Tools /

https://wiki.bnl.gov/conferences/index.php/EIC_R%25D

The EIC Detector Concepts

A. Kiselev

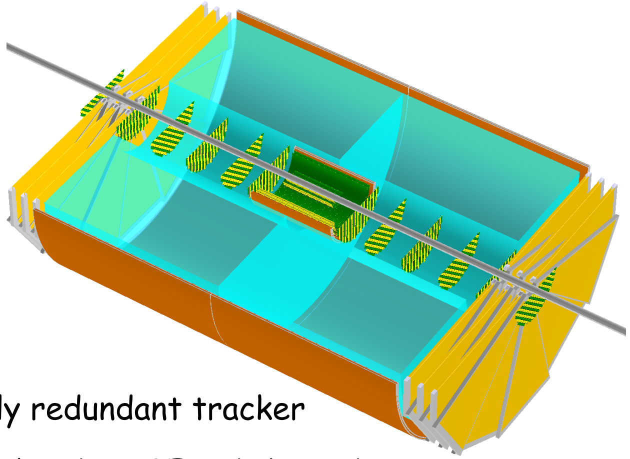
- Detector design: BEAST (1) - BNL



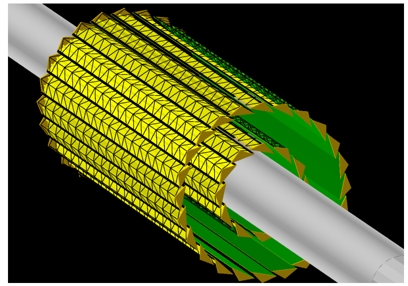
The EIC Detector Concepts

A. Kiselev

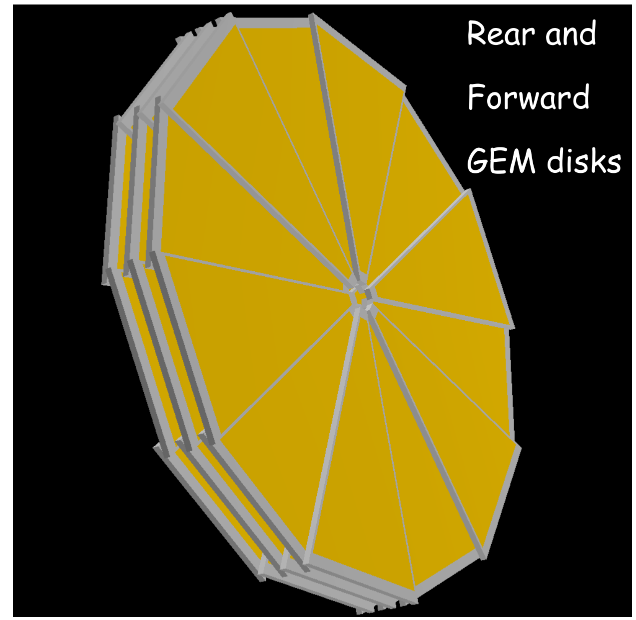
- Detector design: BEAST (2) - BNL

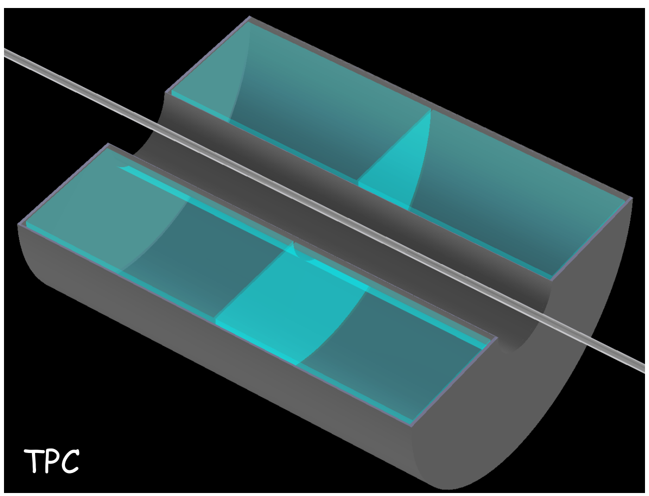


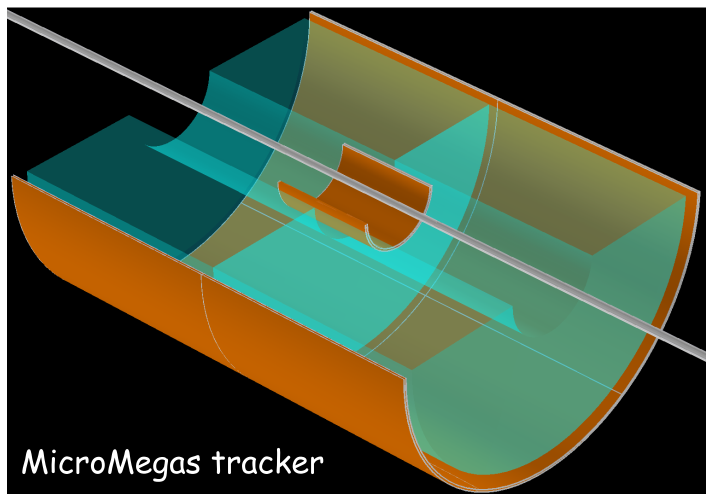
Highly redundant tracker (TPC / endcap GEM disks and MAPS vertex detector)



2 barrel layers of MAPS sensors (20X20µm2) with ~0.3% X/X_0 per layer / Similar technology for forward and rear disks







The EIC Detector Concepts

N. Feege

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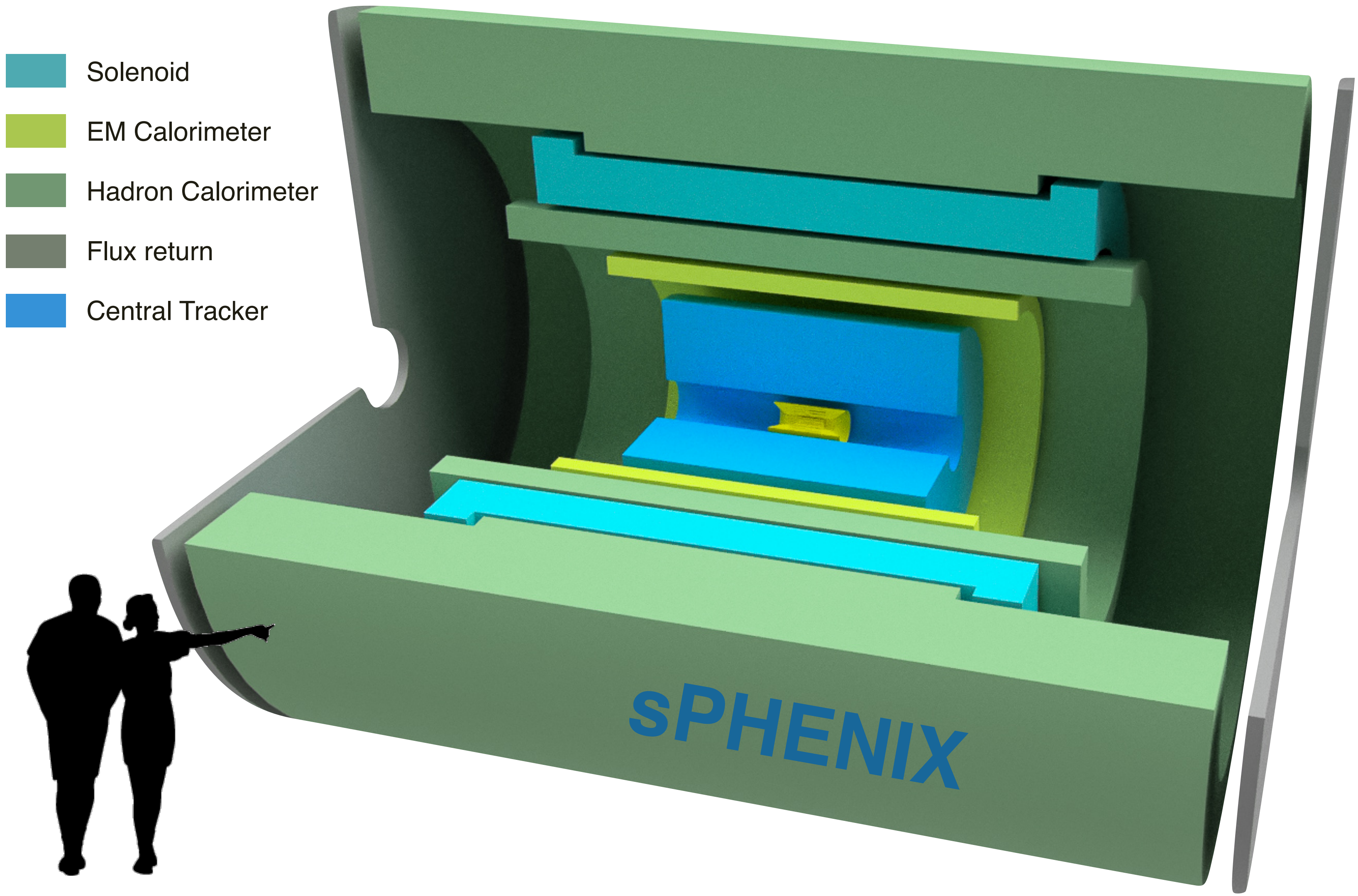

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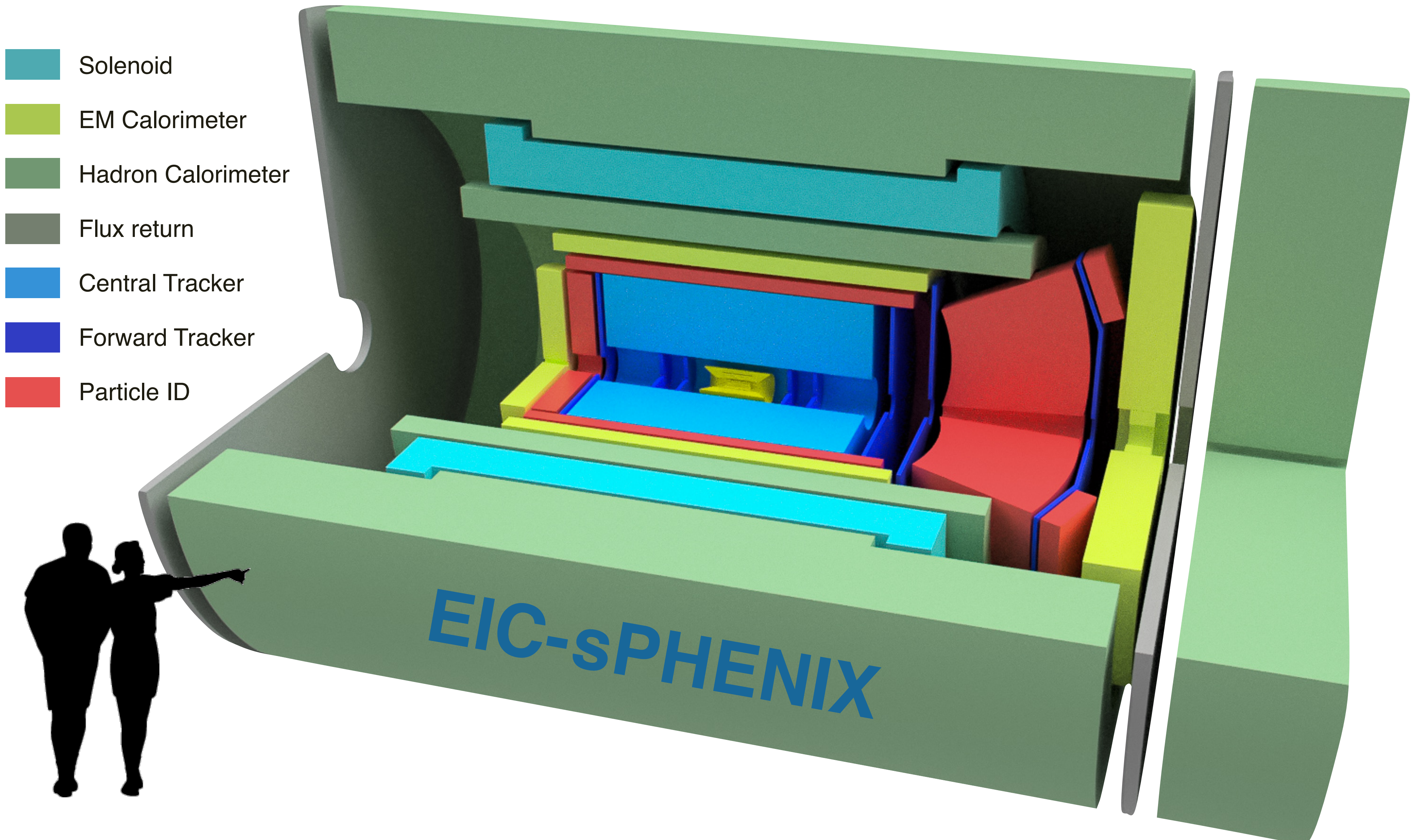

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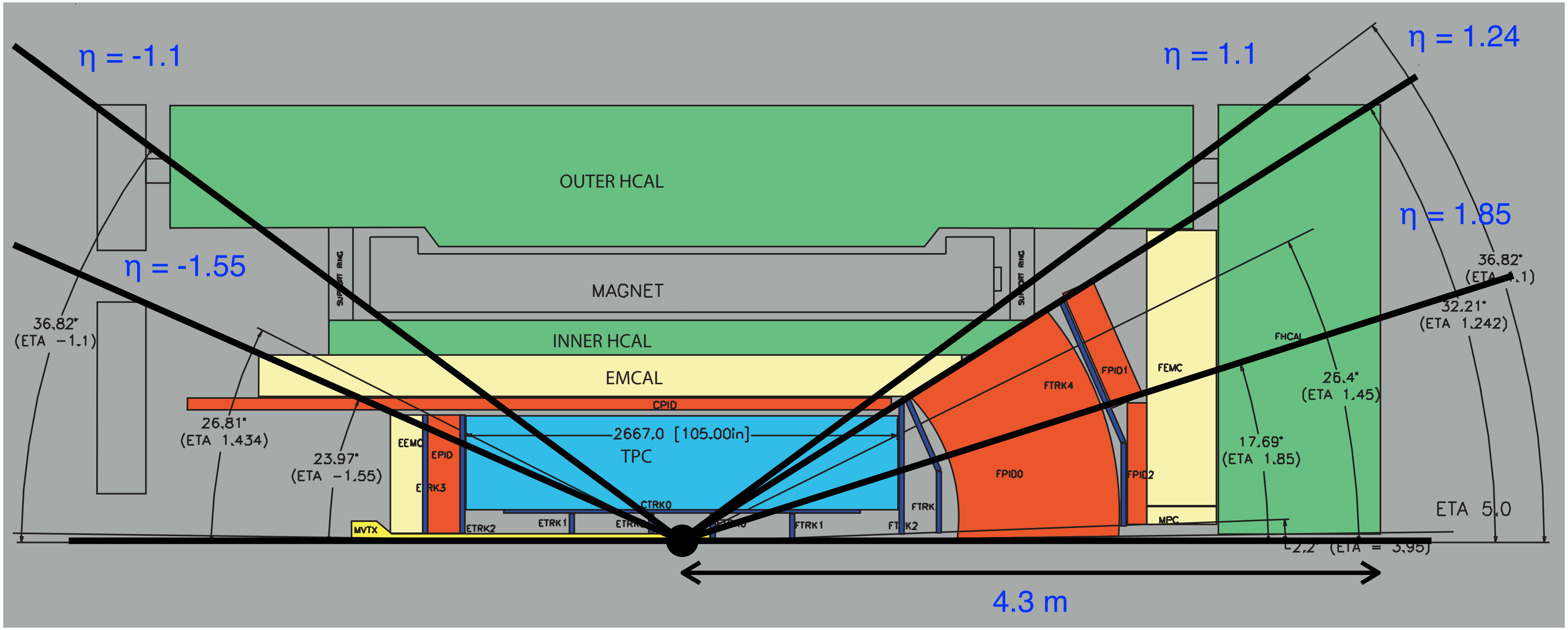
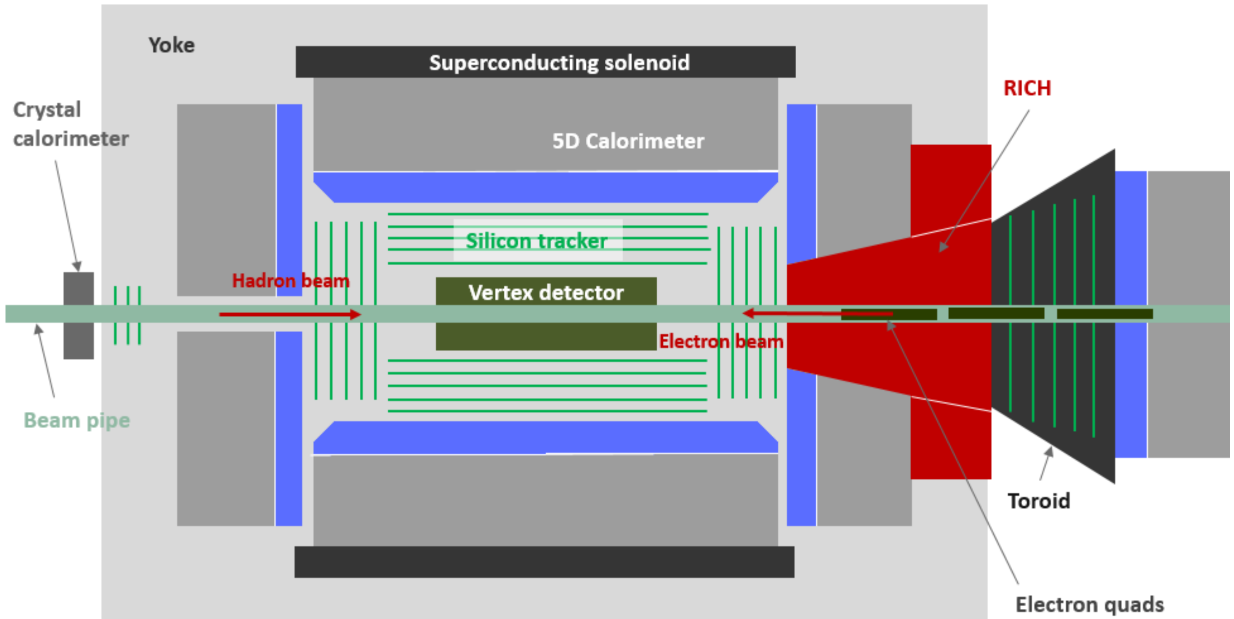


-4 < η < -1.55	$PbWO_4$	2 cm x 2 cm	2.5% / √E ⊕ 1%
-1.55 < η < 1.24	W-SciFi	0.025 x 0.025	16% / √E ⊕ 5%
1.24 < η < 3.3	PbScint	5.5 cm x 5.5 cm	8% / √E ⊕ 2%
3.3 < η < 4	$PbWO_4$	2.2 cm x 2.2 cm	12% / √E
-1.1 < η < 1.1	Fe Scint + Steel Scint	0.1 x 0.1	81% / √E ⊕ 12%
-1.24 < η < 5	Fe Scint	10 cm x 10 cm	70% / √E

The EIC Detector Concepts

☐ Detector design: TOPSiDE - JLab

W. Armstrong

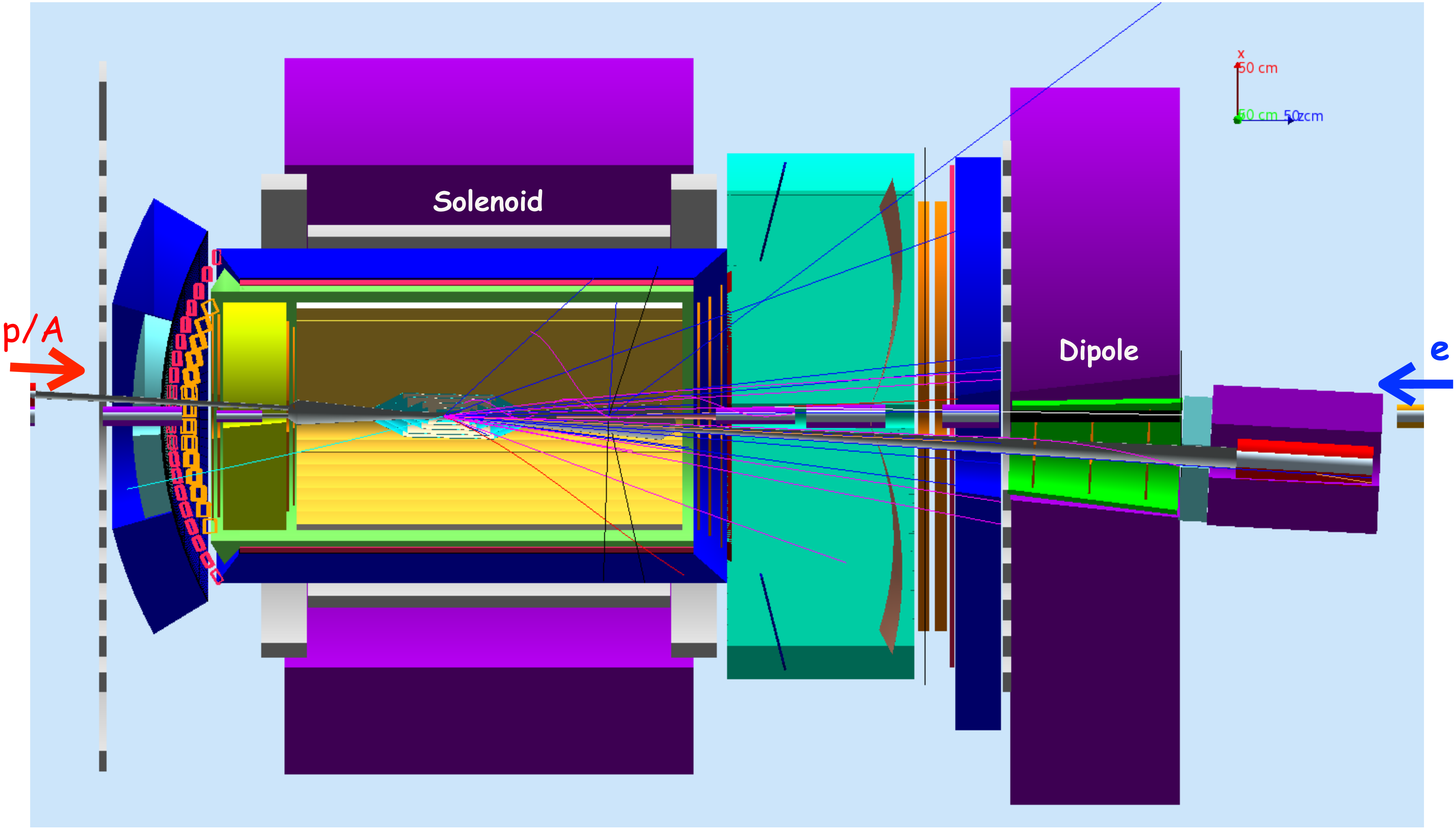


- TOPSiDE: Timing Optimized PID Silicon Detector for the EIC
- Features:
  - Ultra-fast Si detectors (UFSD TOF) (PID π/K/p separation)
  - Highly granular imaging calorimeters and particle flow algorithms (PID of hadrons/neutrals and background rejection)
  - Full particle-ID over entire central and rear regions ($-5 < \eta < 3$)
  - Forward detectors ($3 < \eta < 5$): UFSD TOF and RICH PID (π/K/p separation for SIDIS) / Dipole or Toroid for p measurement
  - Rear detectors ($-5 < \eta < -3$): UFSD TOF for full PID (No RICH needed!) / Crystal calorimeter for optimal energy resolution

The EIC Detector Concepts

- Detector design: JLEIC (1) - JLab

M. Diefenthaler



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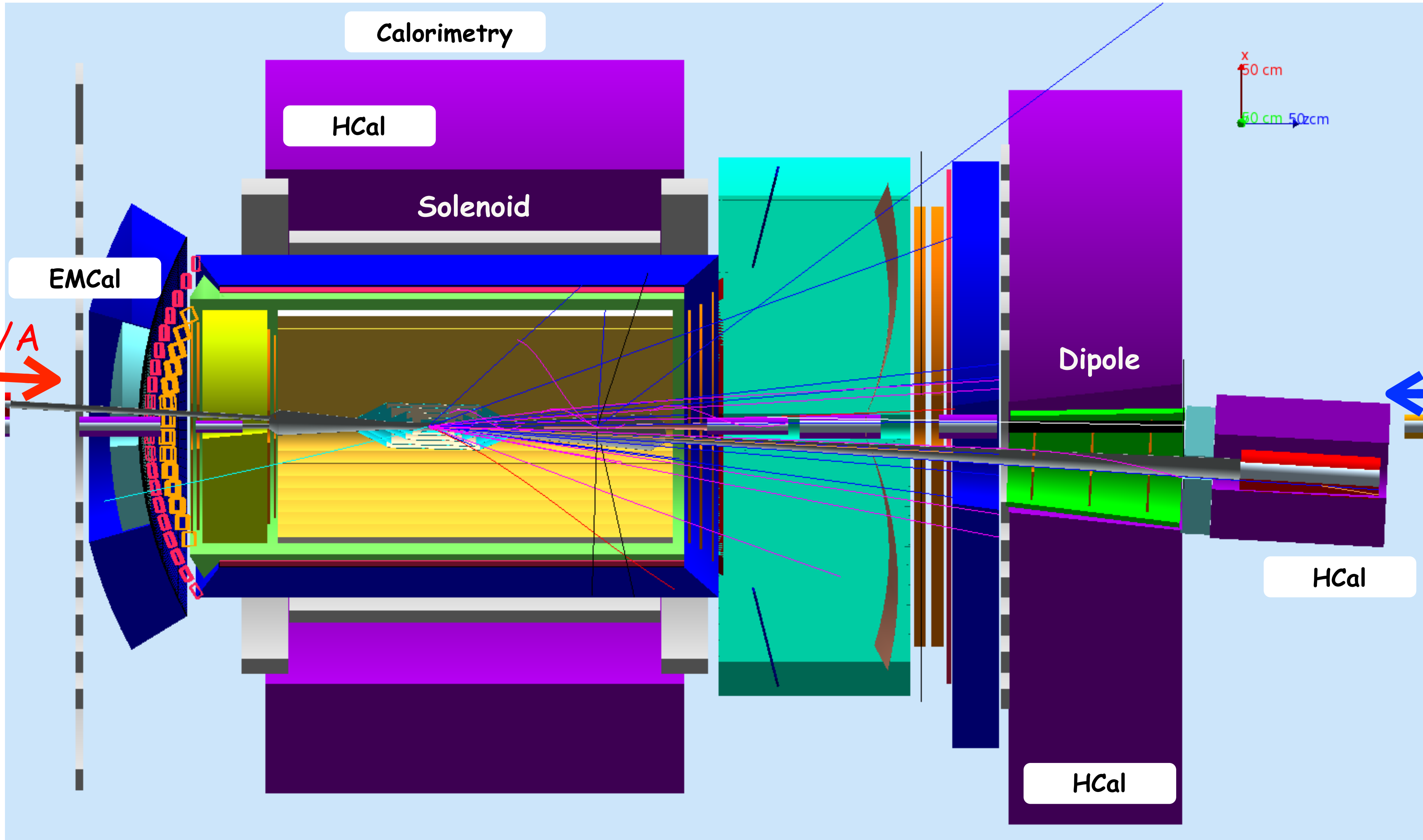

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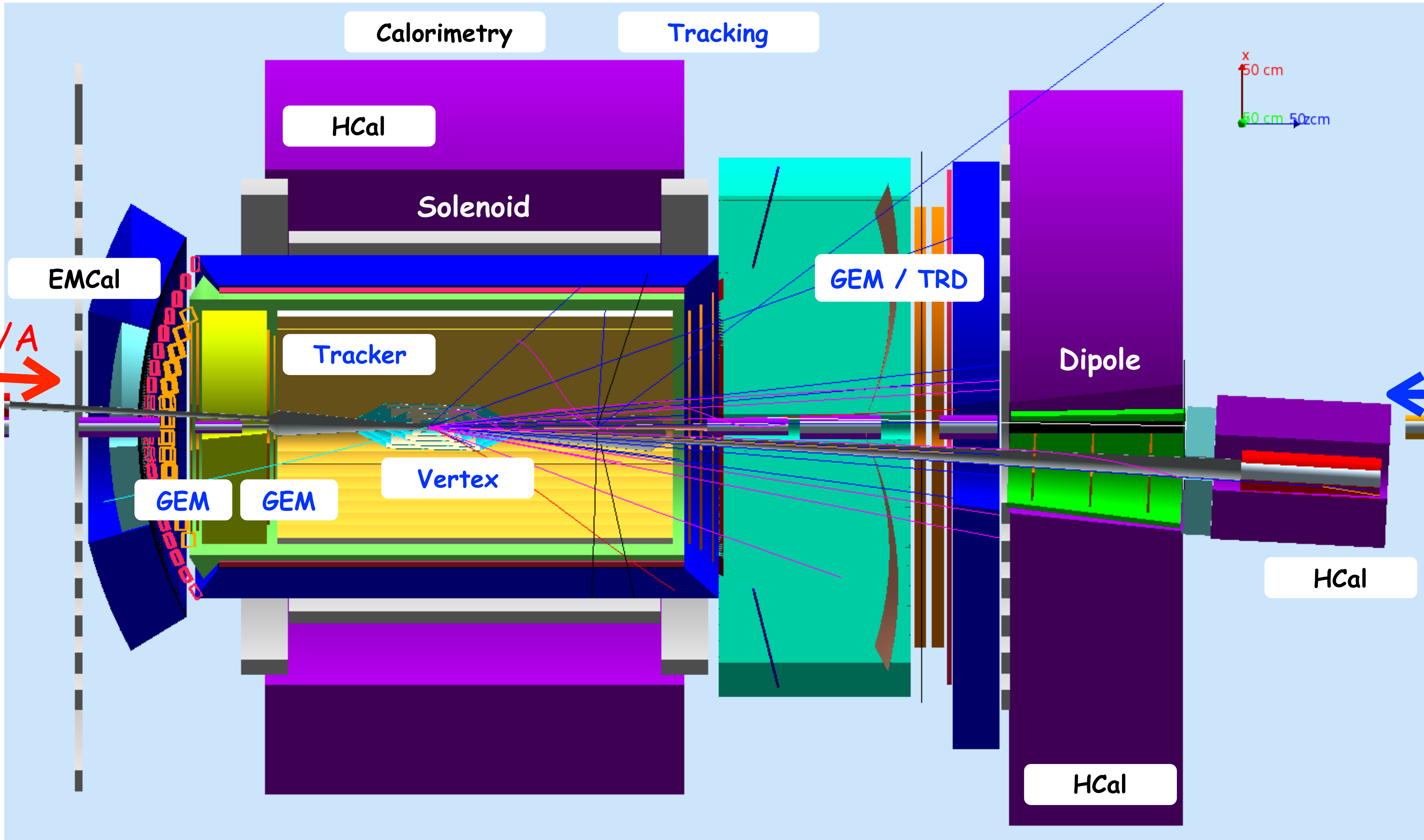

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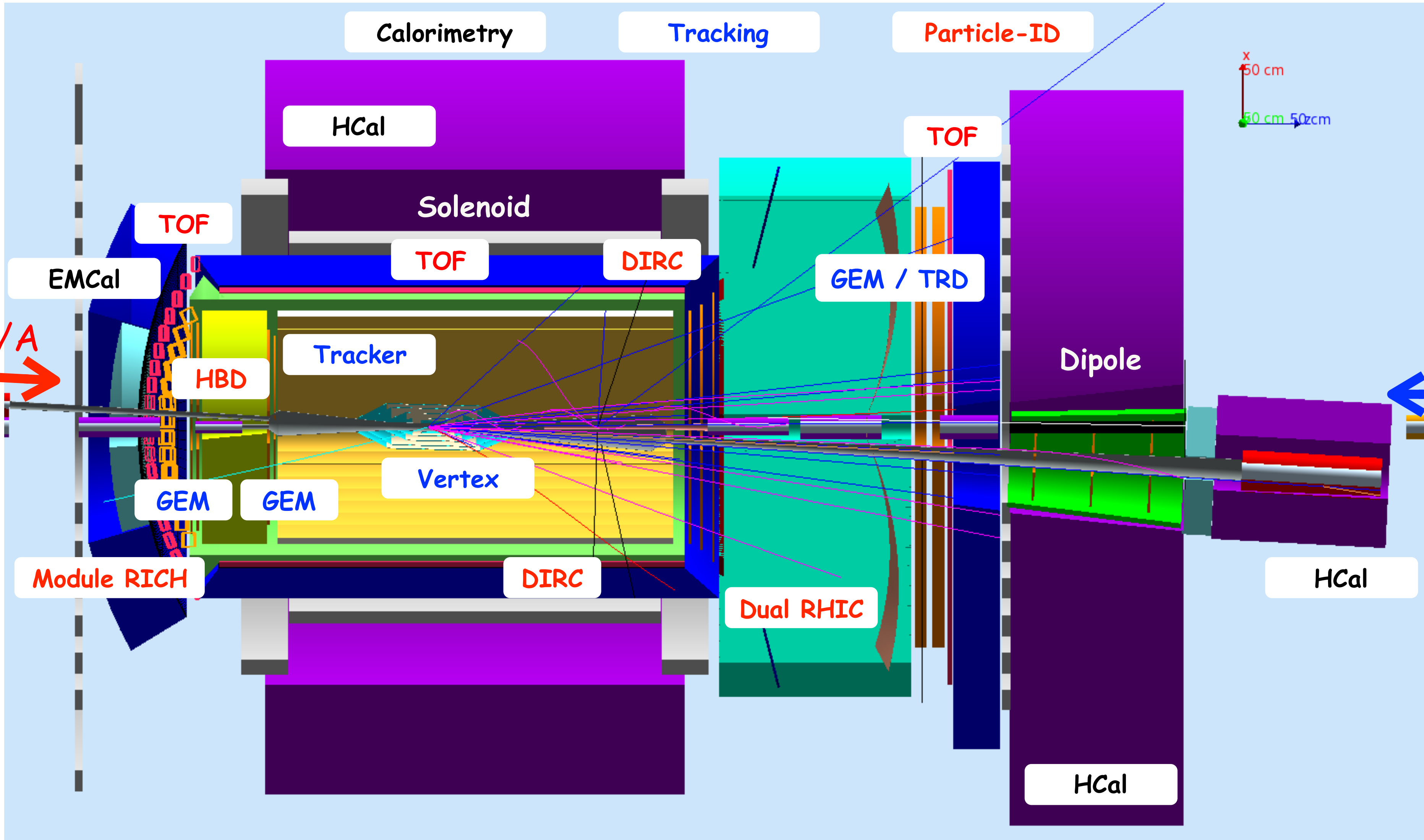

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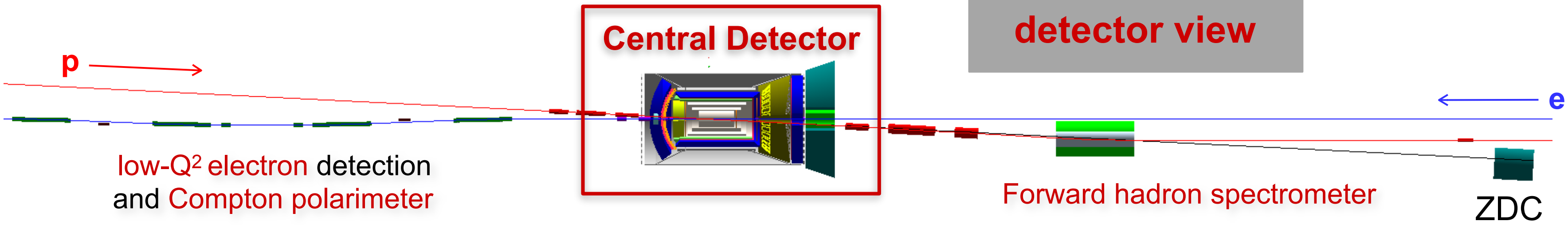

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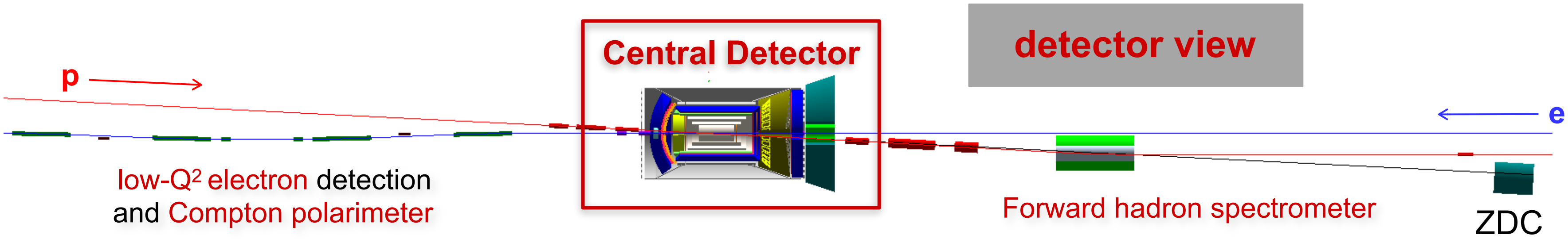
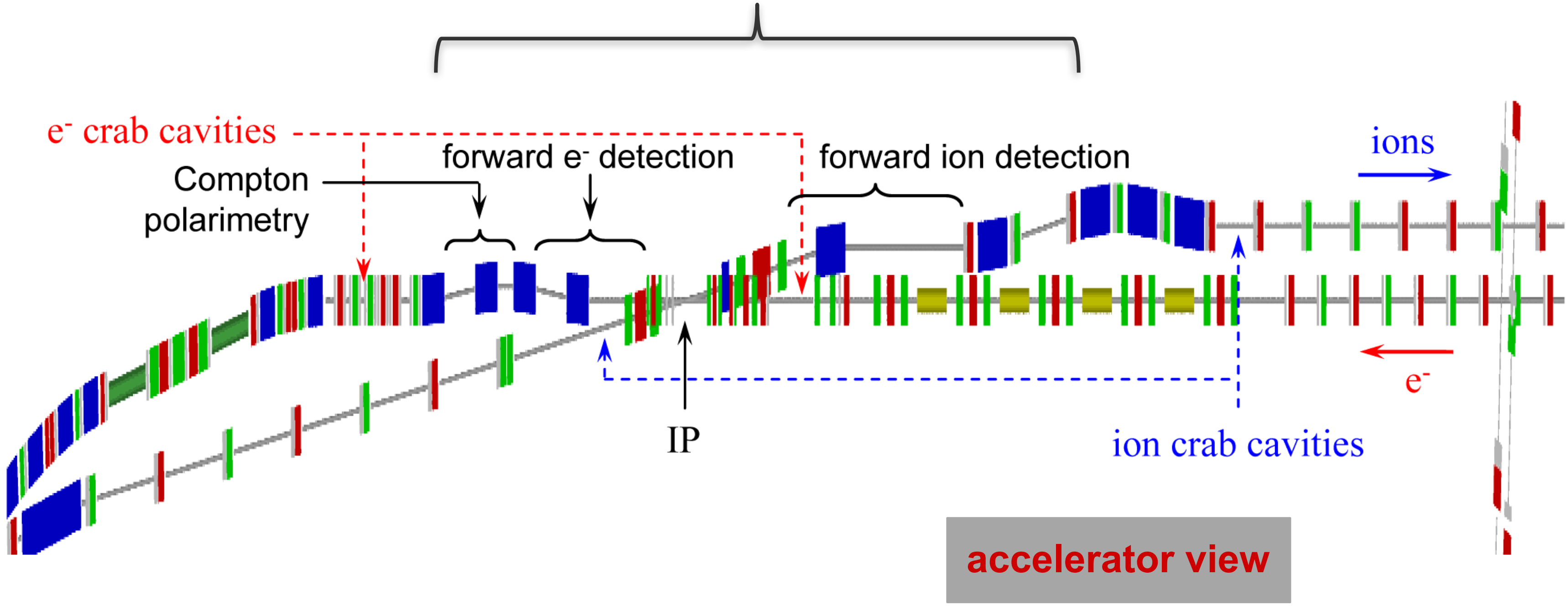


Extended detector: 80m

30m for multi-purpose chicane, 10m for central detector, 40m for the forward hadron spectrometer

fully integrated with accelerator lattice



The EIC Detector Concepts

arXiv:1212.1701

The EIC Detector Concepts

- Auxiliary detector systems: Luminosity (Abs. / Rel.) and Polarimetry

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- Luminosity (Absolute / Relative)
    - Bethe-Heitler process ($e+p \rightarrow e+\gamma+p$) successfully used at HERA I/II (QED theory precision ~0.2%) / Systematic uncertainty achieved ~1-2%. For polarized beam-mode, polarization dependence. Systematic uncertainty of e/p polarization and theory uncertainty will limit abs./rel. luminosity - Critical for asymmetry measurements in particular at low x.

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Polarimetry: Lepton

- Compton back-scattering / HERA used two setups of measuring trans. (TPOL) and long. (LPOL) polarization and achieved for sys. uncertainties 3.5% (TPOL) and 1.6% (LPOL) at HERA I / 1.9% (TPOL) and 2.0% (LPOL) at HERA II. Prospect to improve precision to ~1%.

The EIC Detector Concepts

- Auxiliary detector systems: Luminosity (Abs. / Rel.) and Polarimetry

arXiv:1212.1701

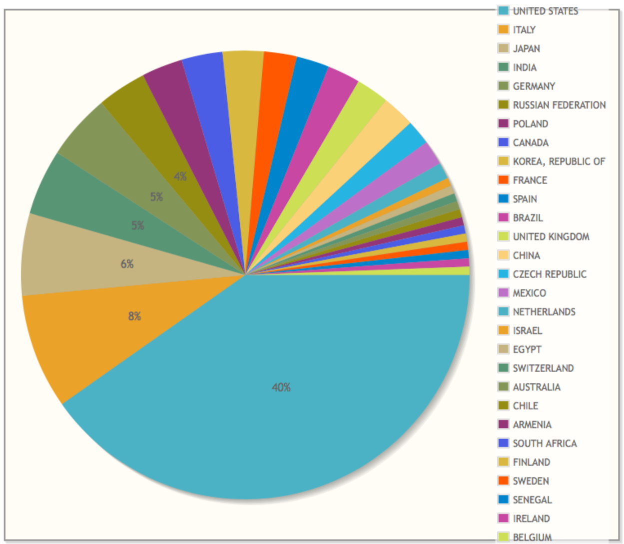
  - Luminosity (Absolute / Relative)
    - Bethe-Heitler process ($e+p \rightarrow e+\gamma+p$) successfully used at HERA I/II (QED theory precision ~0.2%) / Systematic uncertainty achieved ~1-2%. For polarized beam-mode, polarization dependence. Systematic uncertainty of e/p polarization and theory uncertainty will limit abs./rel. luminosity - Critical for asymmetry measurements in particular at low x.
  - Polarimetry: Lepton
    - Compton back-scattering / HERA used two setups of measuring trans. (TPOL) and long. (LPOL) polarization and achieved for sys. uncertainties 3.5% (TPOL) and 1.6% (LPOL) at HERA I / 1.9% (TPOL) and 2.0% (LPOL) at HERA II. Prospect to improve precision to ~1%.
  - Polarimetry: Hadron
    - Extensive experience at RHIC from polarized p program. Two aspects are relevant: Absolute and relative polarization measurement.
      - Absolute: Elastic scattering of polarized p on polarized hydrogen jet target
      - Relative: High statistics bunch-by-bunch polarized proton on carbon fiber target
      - Achieved precision: 3.3% (Run 13 - 255GeV polarized p beam) for single-spin asymmetry
      - Further improvements from stability control of hydrogen jet target / carbon-fiber target and energy calibration of recoil silicon detectors.

The EIC Users Group

WWW-page: www.eicug.org

EIC User Group and R&D activities

- EIC User Group:
  - EICUG organization established in summer 2016
  - In numbers....: 817 members (470: Experimentalists / 163: Theorists / Accelerator Scientists: 142 / Support: 3 / Other: 39), 173 institutions, 30 countries, 7 world regions
  - World map:



- R&D activities:
  - EIC Detector R&D program operated by BNL with ~$1M / year
  - EIC Accelerator R&D with ~$7M / year

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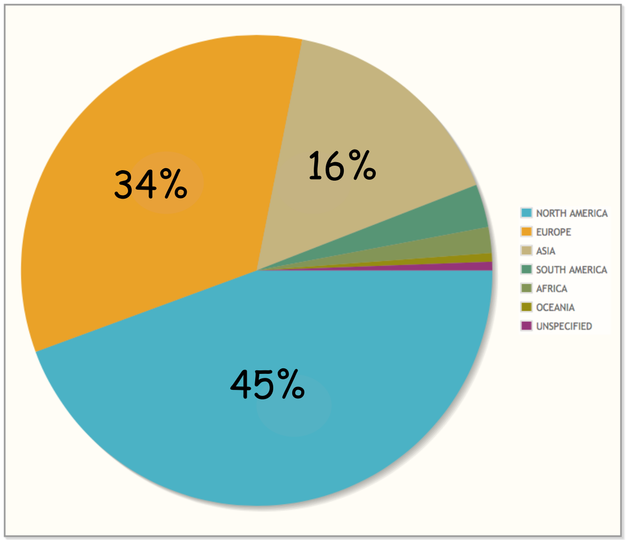

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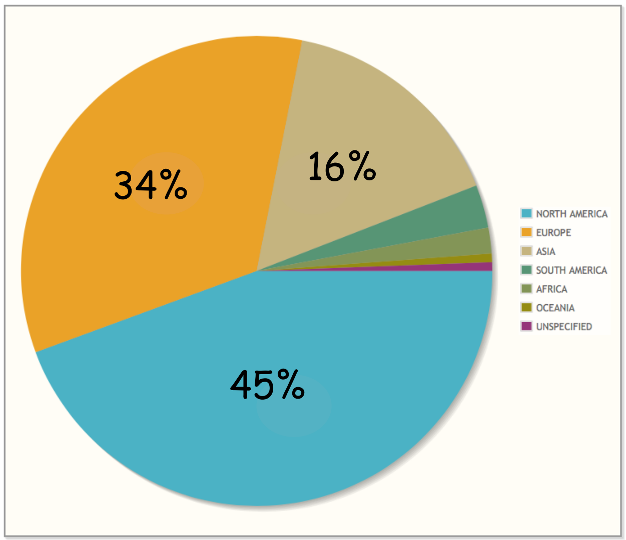

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Internationalization is critical!

The EIC Users Group

- EIC community activities / Conferences and Workshops

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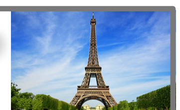
EICUG2019, Paris, France
July 22-26, 2019



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Programs related to EIC

The EIC Users Group

- EIC community activities / Conferences and Workshops

Highly Active EIC Community!

Programs related to EIC

The US Long-Range Plan

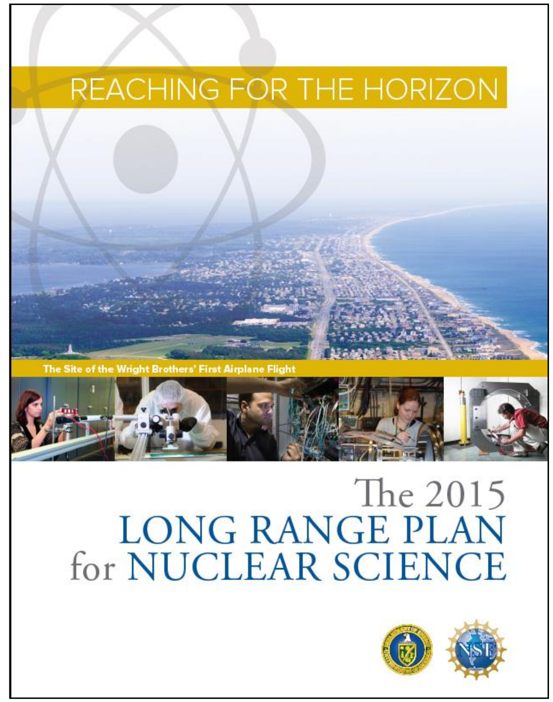
T. Hallman

- NSAC Long-Range Plane 2015

The 2015 Long Range Plan for Nuclear Science

Recommendations:

1. Capitalize on investments made to maintain U.S. leadership in nuclear science.
2. Develop and deploy a U.S.-led ton-scale neutrino-less double beta decay experiment.
3. Construct a high-energy high-luminosity polarized electron-ion collider (EIC) as the highest priority for new construction following the completion of FRIB.
4. Increase investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.



The FY 2018 Request supports progress in important aspects of the 2015 LRP Vision

U.S. DEPARTMENT OF ENERGY | Office of Science   NSAC Meeting   June 2, 2017   16

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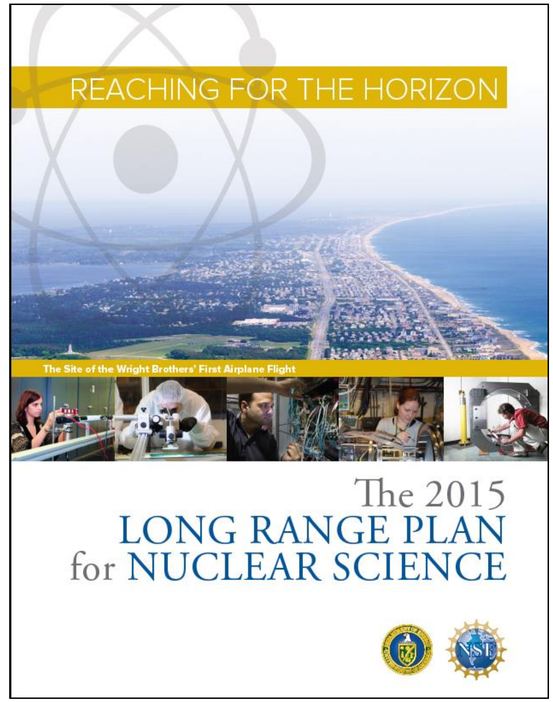

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T. Hallman

- NAS review request by DOE: US-based EIC Science Assessment

Next Formal Step on the EIC Science Case is Continuing

THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE
Division on Engineering and Physical Science
Board on Physics and Astronomy
U.S.-Based Electron Ion Collider Science Assessment

Summary

The National Academies of Sciences, Engineering, and Medicine ("National Academies") will form a committee to carry out a thorough, independent assessment of the scientific justification for a U.S. domestic electron ion collider facility. In preparing its report, the committee will address the role that such a facility would play in the future of nuclear science, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics. The need for such an accelerator will be addressed in the context of international efforts in this area. Support for the 18-month project in the amount of $540,000 is requested from the Department of Energy.

"U.S.-Based Electron Ion Collider Science Assessment" is now getting underway. The Chair will be Gordon Baym. The rest of the committee, including a co-chair, will be appointed in the next couple of weeks. The first meeting is being planned for January, 2017

U.S. DEPARTMENT OF ENERGY | Office of Science   NSAC Meeting   June 2, 2017   19

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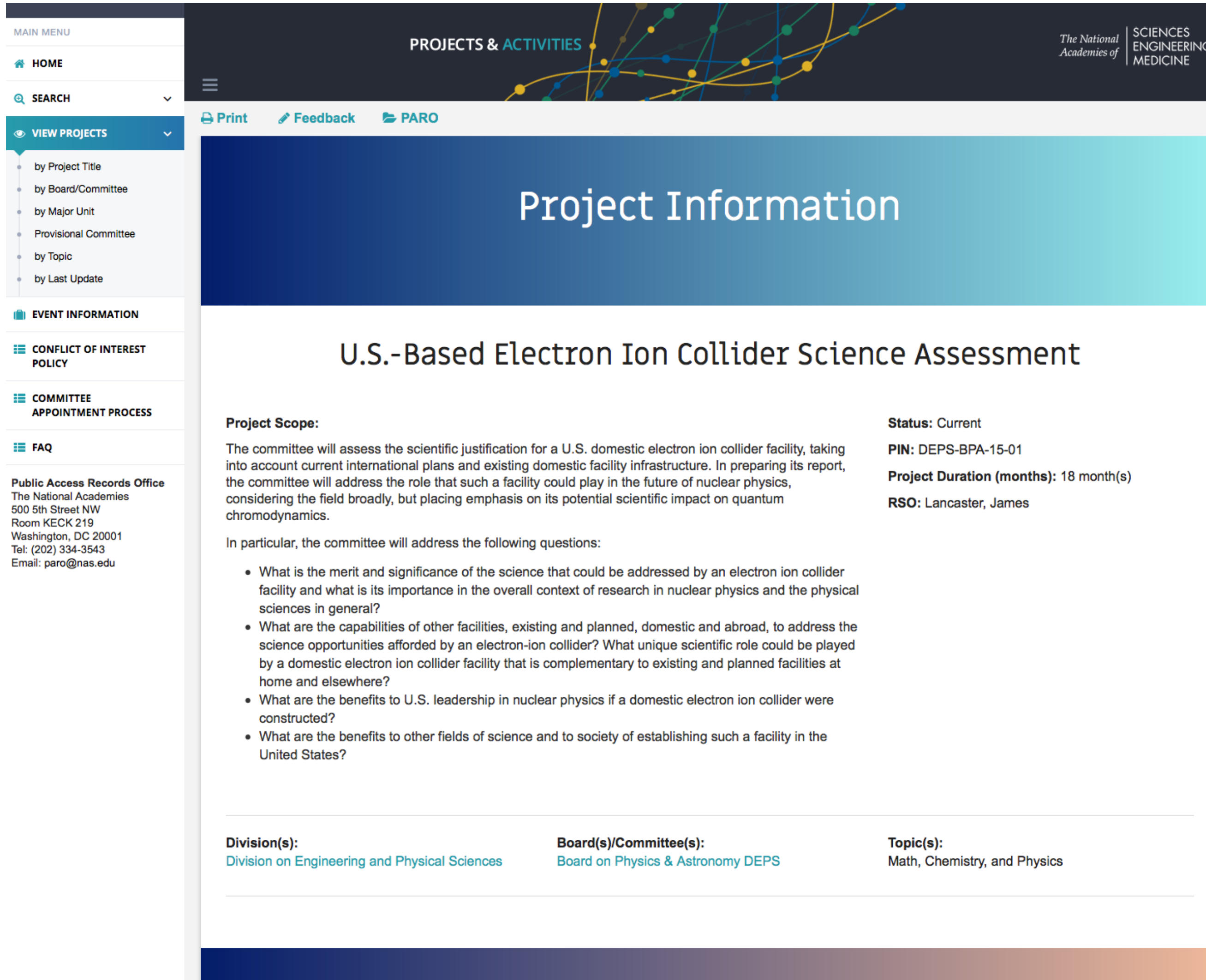
The EIC Science Assessment by the US NAS

- NAS charge and status

https://www8.nationalacademies.org/pa/projectview.aspx?key=49811



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Email: paro@nas.edu

PROJECTS & ACTIVITIES

The National Academies of SCIENCES ENGINEERING MEDICINE

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Project Information

U.S.-Based Electron Ion Collider Science Assessment

Project Scope:

The committee will assess the scientific justification for a U.S. domestic electron ion collider facility, taking into 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.

In particular, the committee will address the following questions:

- What is the merit and significance of the science that could be addressed by an electron ion collider facility and what is its importance in the overall context of research in nuclear physics and the physical sciences in general?
- What are the capabilities of other facilities, existing and planned, domestic and abroad, to address the science opportunities afforded by an electron-ion collider? What unique scientific role could be played by a domestic electron ion collider facility that is complementary to existing and planned facilities at home and elsewhere?
- What are the benefits to U.S. leadership in nuclear physics if a domestic electron ion collider were constructed?
- What are the benefits to other fields of science and to society of establishing such a facility in the United States?

Status: Current
PIN: DEPS-BPA-15-01
Project Duration (months): 18 month(s)
RSO: Lancaster, James

Division(s): Division on Engineering and Physical Sciences
Board(s)/Committee(s): Board on Physics & Astronomy DEPS
Topic(s): Math, Chemistry, and Physics

- **Charge**: Focus on **scientific justification** besides impact to other fields in science and society
- **Status**: NAS report released 07/24/2018!

The EIC Science Assessment by the US NAS

- NAS Webinar and NAS report release: 07/24/2018

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July 24, 2018

FOR IMMEDIATE RELEASE

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An Assessment of U.S.-Based Electron-Ion Collider Science

The National Academies of SCIENCES · ENGINEERING · MEDICINE

The National Academies were asked by the U.S. Department of Energy (DOE) to examine the scientific importance of an EIC, as well as the international implications of building domestic EIC facility. The committee that conducted the study and wrote the report concluded that the science that could be addressed by an EIC is compelling and would provide long-elusive answers on the nature of matter. An EIC would allow scientists to investigate where quarks and gluons, the tiny particles that make up neutrons and protons, are located inside protons and neutrons, how they move, and how they interact together. While the famous Higgs mechanism explains the masses of the quarks, the most significant portion of the mass of a proton or neutron comes from its gluons and their interactions. Crucial questions that an EIC would answer include the origin of the mass of atomic nuclei, the origin of spin of neutrons and protons – a fundamental property that makes magnetic resonance imaging (MRI) possible, how gluons hold nuclei together, and whether emergent forms of matter made of dense gluons exist.

The report says a new EIC accelerator facility would have capabilities beyond all previous electron scattering machines in the U.S., Europe, and Asia. High energies and luminosities – the measure of the rate at which particle collisions occur – are required to achieve the fine resolution needed, and to reach such intensities and energy levels requires a collider where beams of electrons smash into beams of protons or heavier ions. Comparing all existing and proposed accelerator facilities around the world, the committee concluded that an EIC with high energy and luminosity, and highly polarized electron and ion beams, would be unique and in a position to greatly further our understanding of visible matter.

"An EIC would be the most sophisticated and challenging accelerator currently proposed for construction in the U.S. and would significantly advance accelerator science, and more specifically collider science and technologies, here and around the world," said committee co-chair Gordon Baym, Center for Advanced Study Professor Emeritus, George and Ann Fisher Distinguished Professor of Engineering Emeritus, and Research Professor at the University of Illinois at Urbana-Champaign. "The realization of an EIC is absolutely crucial to maintaining the health of the field of nuclear physics in the U.S. and would open up new areas of scientific investigation."

Currently, the Brookhaven National Laboratory (BNL) in Long Island, New York, has a heavy ion collider, and the Thomas Jefferson National Accelerator Laboratory (JLab) in Newport News, Virginia, has very energetic electron beams. Both labs have proposed design concepts for an EIC that would use their already available infrastructure, expertise, and experience. The report, without favoring one over the other, says that taking advantage of the existing facilities would make development of an EIC cost-effective and reduce associated risks that come with building a large accelerator facility. While both labs have well-developed designs for an EIC, both would require considerable R&D to fully deliver on the compelling science questions. The report states DOE R&D investment has been and would continue to be crucial to minimizing design risks in a timely fashion and to addressing outstanding accelerator challenges.

The committee added that along with advancing nuclear science, an EIC would also benefit other areas such as astrophysics, particle physics, accelerator physics, and theoretical and computational modeling. It would also play a valuable role in sustaining the U.S. nuclear physics workforce in the coming decades. Moreover, it would have a significant role in advancing more broadly the technologies that would result from the research and development undertaken in the implementation and construction of an EIC in the U.S. The report emphasizes that an EIC is the only high-energy collider being planned for construction in the U.S. currently, and building such a facility would maintain U.S. leadership in accelerator collider science while benefiting the physical sciences.

"The science that an EIC would achieve is simply unique and would ensure U.S. leadership in nuclear science as well as the accelerator science and technology of colliders around the world," said committee co-chair Ani Aprahamian, Freimann Professor of Experimental Nuclear Physics at the University of Notre Dame.

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- NAS Webinar and NAS report release: 07/24/2018

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The report says a new EIC accelerator facility would have capabilities beyond all previous electron scattering machines in the U.S., Europe, and Asia. High energies and luminosities – the measure of the rate at which particle collisions occur – are required to achieve the fine resolution needed, and to reach such intensities and energy levels requires a collider where beams of electrons smash into beams of protons or heavier ions. Comparing all existing and proposed accelerator facilities around the world, the committee concluded that an EIC with high energy and luminosity, and highly polarized electron and ion beams, would be unique and in a position to greatly further our understanding of visible matter.

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- Webinar on Tuesday, July 24, 2018 - Public presentation and report release

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- Gordon Baym (Co-chair): Webinar presentation

"The committee finds that the science that can be addressed by an EIC is compelling, fundamental and timely."

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The report says a new EIC accelerator facility would have capabilities beyond all previous electron scattering machines in the U.S., Europe, and Asia. High energies and luminosities – the measure of the rate at which particle collisions occur – are required to achieve the fine resolution needed, and to reach such intensities and energy levels requires a collider where beams of electrons smash into beams of protons or heavier ions. Comparing all existing and proposed accelerator facilities around the world, the committee concluded that an EIC with high energy and luminosity, and highly polarized electron and ion beams, would be unique and in a position to greatly further our understanding of visible matter.

"An EIC would be the most sophisticated and challenging accelerator currently proposed for construction in the U.S. and would significantly advance accelerator science, and more specifically collider science and technologies, here and around the world," said committee co-chair Gordon Baym, Center for Advanced Study Professor Emeritus, George and Ann Fisher Distinguished Professor of Engineering Emeritus, and Research Professor at the University of Illinois at Urbana-Champaign. "The realization of an EIC is absolutely crucial to maintaining the health of the field of nuclear physics in the U.S. and would open up new areas of scientific investigation."

Currently, the Brookhaven National Laboratory (BNL) in Long Island, New York, has a heavy ion collider, and the Thomas Jefferson National Accelerator Laboratory (JLab) in Newport News, Virginia, has very energetic electron beams. Both labs have proposed design concepts for an EIC that would use their already available infrastructure, expertise, and experience. The report, without favoring one over the other, says that taking advantage of the existing facilities would make development of an EIC cost-effective and reduce associated risks that come with building a large accelerator facility. While both labs have well-developed designs for an EIC, both would require considerable R&D to fully deliver on the compelling science questions. The report states DOE R&D investment has been and would continue to be crucial to minimizing design risks in a timely fashion and to addressing outstanding accelerator challenges.

The committee added that along with advancing nuclear science, an EIC would also benefit other areas such as astrophysics, particle physics, accelerator physics, and theoretical and computational modeling. It would also play a valuable role in sustaining the U.S. nuclear physics workforce in the coming decades. Moreover, it would have a significant role in advancing more broadly the technologies that would result from the research and development undertaken in the implementation and construction of an EIC in the U.S. The report emphasizes that an EIC is the only high-energy collider being planned for construction in the U.S. currently, and building such a facility would maintain U.S. leadership in accelerator collider science while benefiting the physical sciences.

"The science that an EIC would achieve is simply unique and would ensure U.S. leadership in nuclear science as well as the accelerator science and technology of colliders around the world," said committee co-chair Ani Aprahamian, Freimann Professor of Experimental Nuclear Physics at the University of Notre Dame.

The study was sponsored by DOE. The National Academies of Sciences, Engineering, and Medicine are private, nonprofit institutions that provide independent, objective analysis and advice to the nation to solve complex problems and inform public policy decisions related to science, technology, and medicine. The National Academies operate under an 1863 congressional charter to the National Academy of Sciences, signed by President Lincoln. For more information, visit http://national-academies.org.

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The EIC Science Assessment by the US NAS

- NAS Webinar and NAS report release: 07/24/2018

http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=25171&_ga=2.209086742.50427317.1532451645-1385917444.1532451645

- Webinar on Tuesday, July 24, 2018 - Public presentation and report release
- Gordon Baym (Co-chair): Webinar presentation

"The committee finds that the science that can be addressed by an EIC is compelling, fundamental and timely."

- "Glowing" report on a US-based EIC facility!

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July 24, 2018

FOR IMMEDIATE RELEASE

A Domestic Electron Ion Collider Would Unlock Scientific Mysteries of Atomic Nuclei, Maintain U.S. Leadership in Accelerator Science, New Report Says

WASHINGTON – The science questions that could be answered by an electron ion collider (EIC) – a very large-scale particle accelerator – are significant to advancing our understanding of the atomic nuclei that make up all visible matter in the universe, says a new report by the National Academies of Sciences, Engineering, and Medicine. Beyond its impact on nuclear science, the advances made possible by an EIC could have far-reaching benefits to the nation's science- and technology-driven economy as well as to maintaining U.S. leadership in nuclear physics and in collider and accelerator technologies.

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The EIC Science Assessment by the US NAS

- NAS report main findings: Webinar on July 24, 2018 (1)

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BOARD ON PHYSICS AND ASTRONOMY (BPA)

An Assessment of U.S.-Based Electron-Ion Collider Science

A study under the auspices of the
U.S. National Academies of Sciences, Engineering, and Medicine

Gordon Baym and Ani Aprahamian, Co-Chairs

The study is supported by funding from the DOE Office of Science.
(Further information can be found at: https://www.nap.edu/25171)

Committee Membership

Gordon Baym, Co-Chair (Illinois): theoretical many-particle physics
Ani Aprahamian, Co-Chair (Notre Dame): nuclear experiment

Christine Aidala (Michigan):	heavy ion experiment
Richard Milner (MIT):	high energy electron experiment
Ernst Sichtermann (LBNL):	heavy ion experiment
Zein-Eddine Meziani (Temple):	high energy electron experiment
Thomas Schaefer (NC State U):	theoretical nuclear physics
Michael Turner (Chicago):	theoretical astronomy, cosmology
Wick Haxton (UC Berkeley):	theoretical nuclear physics
Kawtar Hafidi (Argonne):	high energy electron experiment
Peter Braun-Munzinger (GSI):	heavy ion experiment
Larry McLerran (Washington):	theoretical nuclear physics
Haiyan Gao (Duke):	high energy electron experiment
John Jowett (CERN):	accelerator physics
Lia Merminga (Fermilab):	accelerator physics

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Committee Statement of Task -- from DOE to the BPA

The committee will assess the scientific justification for a U.S. domestic electron ion collider facility, taking into 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.

In particular, the committee will address the following questions:

- What is the merit and significance of the science that could be addressed by an electron ion collider facility and what is its importance in the overall context of research in nuclear physics and the physical sciences in general?
- What are the capabilities of other facilities, existing and planned, domestic and abroad, to address the science opportunities afforded by an electron-ion collider?
- What unique scientific role could be played by a domestic electron ion collider facility that is complementary to existing and planned facilities at home and elsewhere?
- What are the benefits to U.S. leadership in nuclear physics if a domestic electron ion collider were constructed?
- What are the benefits to other fields of science and to society of establishing such a facility in the United States?

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The EIC Science Assessment by the US NAS

- NAS report main findings: Webinar on July 24, 2018 (2)

Bottom Line

The committee unanimously finds that the science that can be addressed by an EIC is compelling, fundamental, and timely.

The unanimous conclusion of the Committee is that an EIC, as envisioned in this report, would be a unique facility in the world that would boost the U.S. STEM workforce and help maintain U.S. scientific leadership in nuclear physics.

The project is strongly supported by the nuclear physics community.

The technological benefits of meeting the accelerator challenges are enormous, both for basic science and for applied areas that use accelerators, including material science and medicine.

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The EIC Science Assessment by the US NAS

- NAS report main "global" findings
  - Finding 1: An EIC can uniquely address three profound questions about nucleons - neutrons and protons - and how they are assembled to form the nuclei of atoms:
    - How does the mass of the nucleon arise?
    - How does the spin of the nucleon arise?
    - What are the emergent properties of dense systems of gluons?
  - Finding 2: These three high-priority science questions can be answered by an EIC with highly polarized beams of electrons and ions, with sufficiently high luminosity and sufficient, and variable, center-of-mass energy.
  - Finding 5: Taking advantage of existing accelerator infrastructure and accelerator expertise would make development of an EIC cost effective and would potentially reduce risk.
  - Finding 7: To realize fully the scientific opportunities an EIC would enable, a theory program will be required to predict and interpret the experimental results within the context of QCD, and furthermore, to glean the fundamental insights into QCD that an EIC can reveal.

An Assessment of
U.S.-Based Electron-Ion Collider Science

Committee on U.S.-Based Electron-Ion Collider Science Assessment

Board on Physics and Astronomy

Division on Engineering and Physical Sciences

A Consensus Study Report of

The National Academies of
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Washington, DC
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- Towards a future EIC facility

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  - Best guess for completion of EIC facility construction would be after 2025, around 2025-2030 - in roughly a decade from now!

Summary

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- **EIC Physics Pillars**: EIC facility will address fundamental questions on the structure and dynamics of nucleons and nuclei in terms of quarks and gluons using precision measurements including:
  - Parton Distributions in Nuclei / QCD at Extreme Parton Densities - Saturation
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An exciting time is ahead of us to realize a future EIC facility!