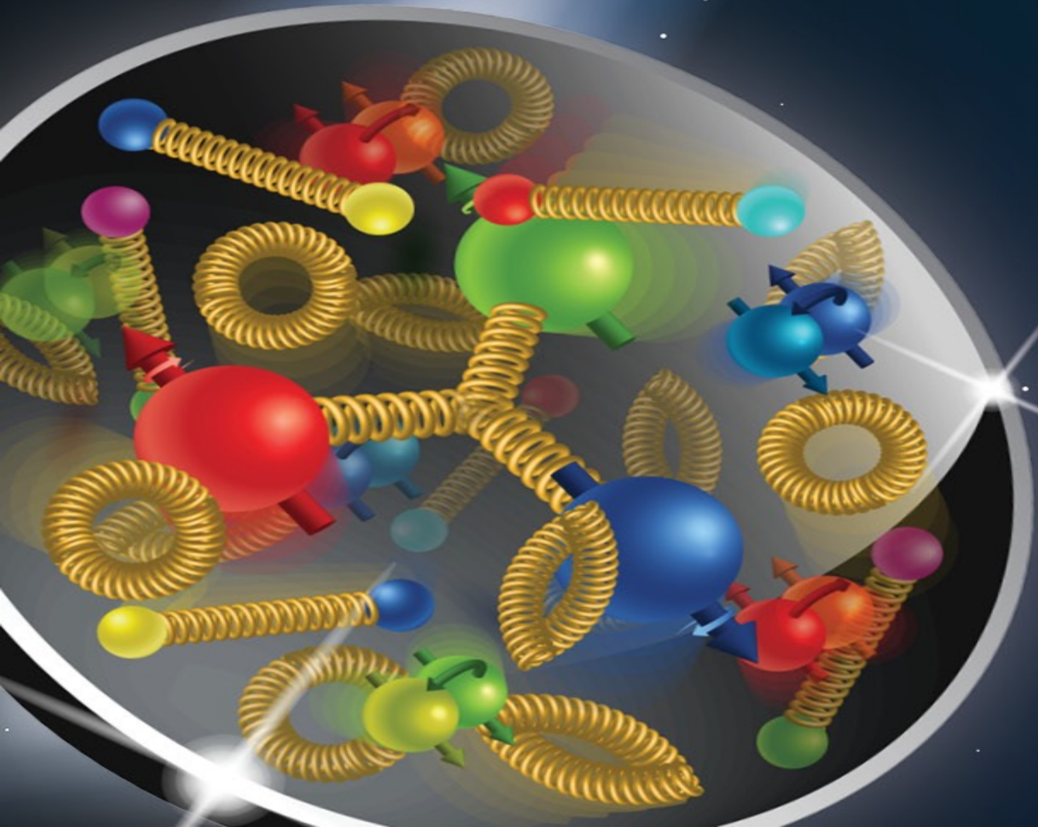
The quest to understand the fundamental structure of matter – outlook to an Electron-Ion Collider



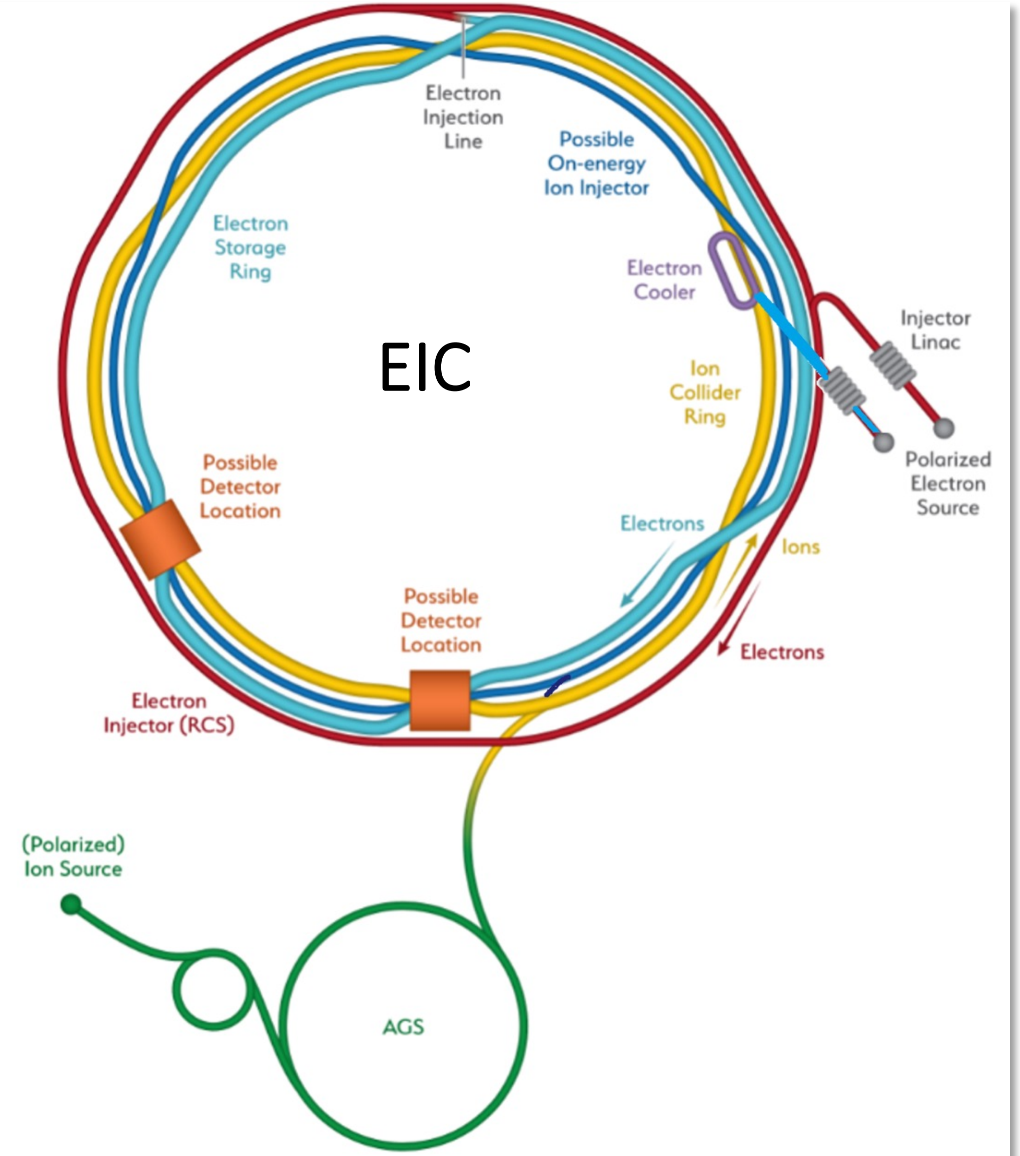
Or Hen

MIT

BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY Office of Science

The Electron Ion Collider (EIC)

- Being Built at Brookhaven National Lab
- ~ $2.4 billion investment
- Explore the structure of matter via QCD:
  - Origin of Nucleon Mass & Spin
  - Confinement
  - Nucleon / Nuclear Femtography
  - Dense Gluon States
  - BSM
- Start Operations in 2031
- Opportunity to get involved \w detectors design & construction



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- The Quest to Understand the Fundamental Structure of Matter
- The US-Based Electron-Ion Collider (EIC)
- EIC Science
  - Femtography
  - Mass
  - Spin
  - Hadronization
  - Dense Gluon States
- The ECCE EIC Detector
- EIC Summary – A Portal to a New Frontier

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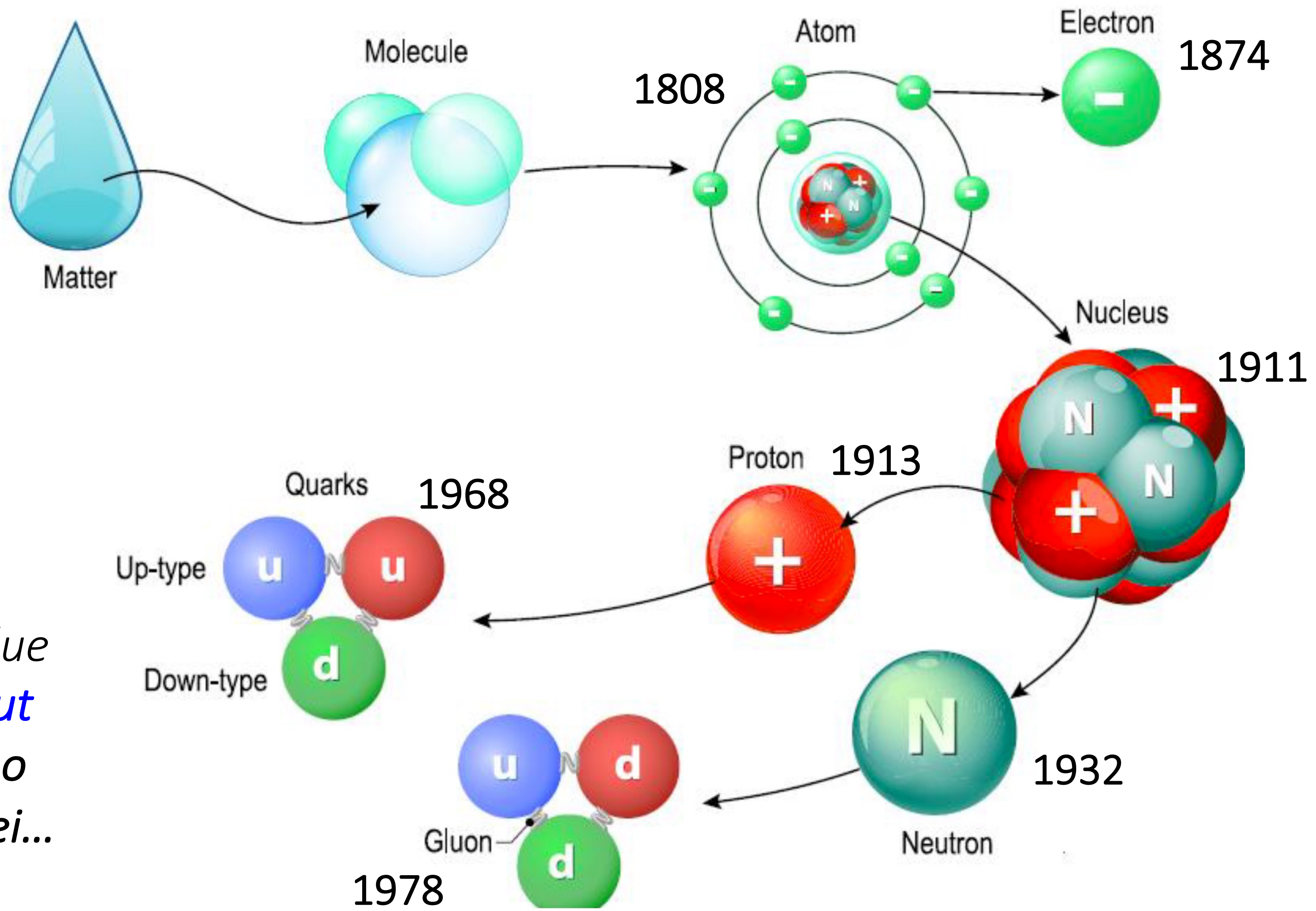
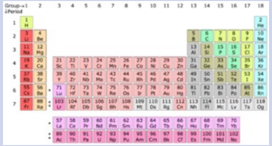
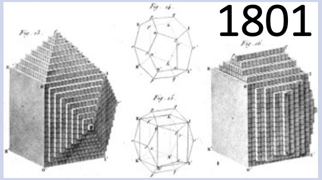
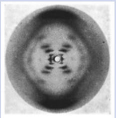
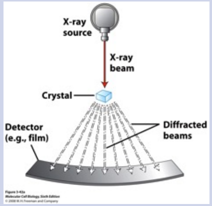
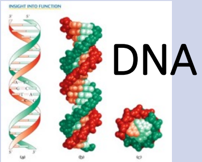
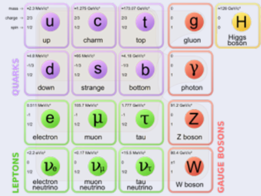
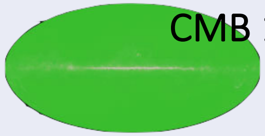
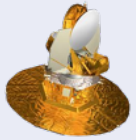
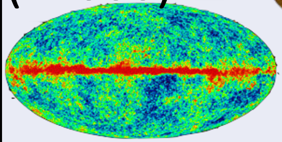
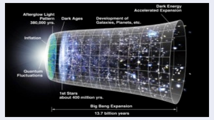
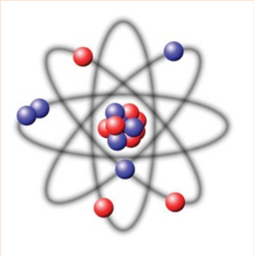
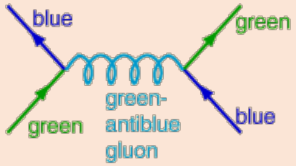
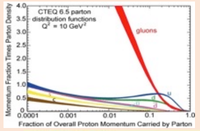
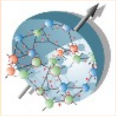
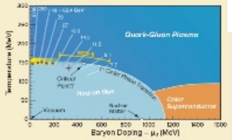
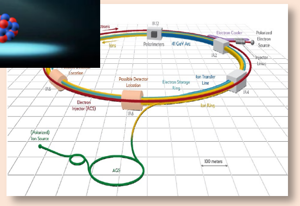
The Quest to Understand the Fundamental Structure of Matter



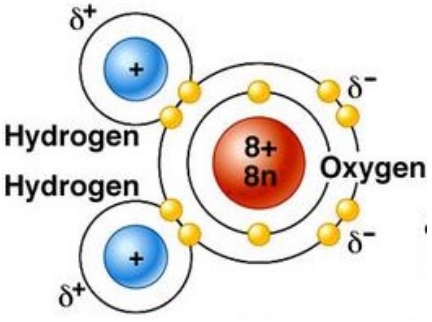
EIC: Understanding the Glue that Binds Us All - Without gluons, there would be no nucleons, no atomic nuclei… no visible world!

Dynamical System	Fundamental Knowns	Unknowns	Breakthrough Structure Probes	New Sciences, New Frontiers
Solids 	Electromagnetism Atoms 	Structure 1801 	X-ray Diffraction (~1920)  	Solid state physics Molecular biology DNA 
Universe 	General Relativity Standard Model 	Quantum Gravity, Dark matter, Dark energy. Structure CMB 1965 	Large Scale Surveys CMB Probes (~2000)  	Precision Observational Cosmology 
Nuclei and Nucleons 	Perturbative QCD Quarks and Gluons $\mathcal{L}_{QCD} = \overline{\psi}(i\partial\!\!\!/ - gA\!\!\!/)\psi - \frac{1}{2}\mathrm{tr}\, F_{\mu\nu}F^{\mu\nu}$ 	Non-perturbative QCD. Structure 2017   	Electron-Ion Collider (~2030)  	Structure & Dynamics in QCD 

Subatomic Matter is Unique

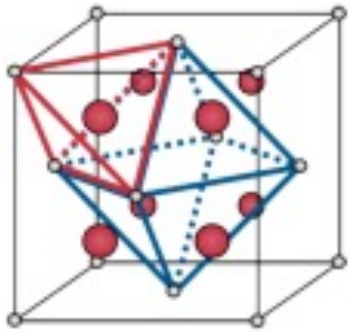
Most known matter has localized mass & charge centers (vast “open” space)

Molecule:



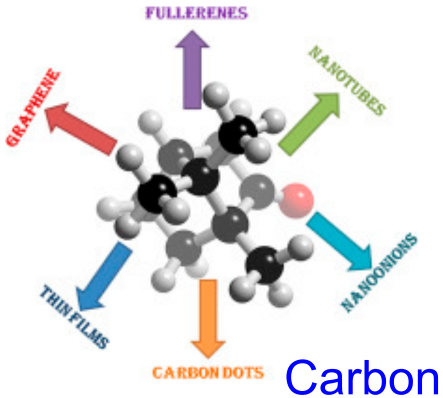
“Water”

Crystal:



Rare-Earth metal

Nanomaterial:



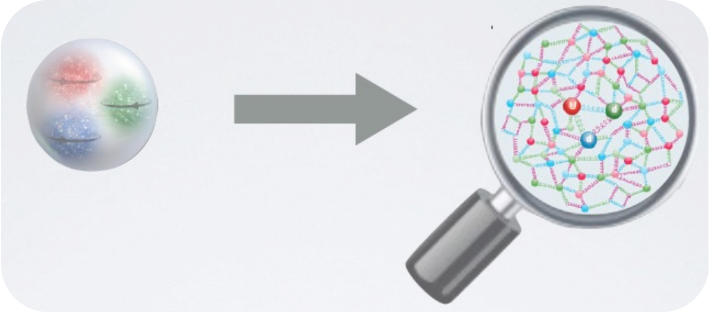
Carbon-based

Subatomic Matter is Unique

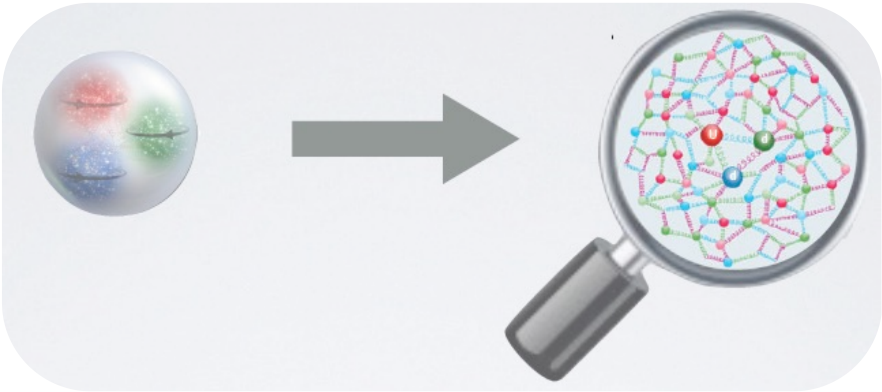
QCD matter is different!

Interactions & structures inextricably mixed (in protons & other forms of nuclear matter)

Observed properties such as mass & spin, emerge out of this complex system



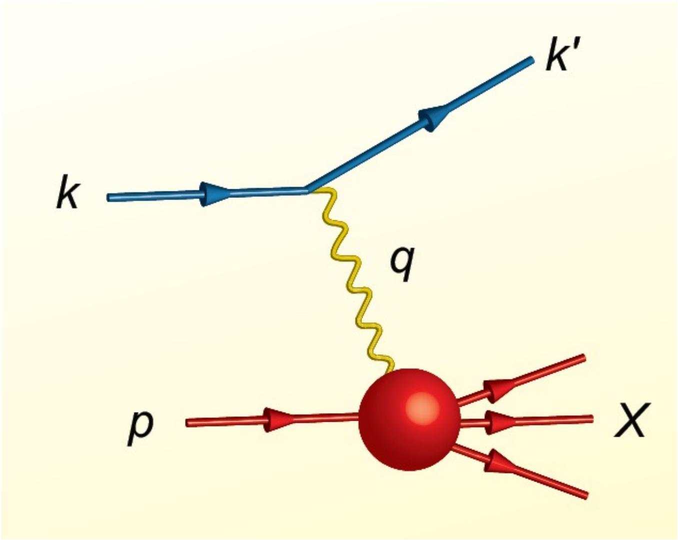
Imaging physical systems is key to gaining new understanding



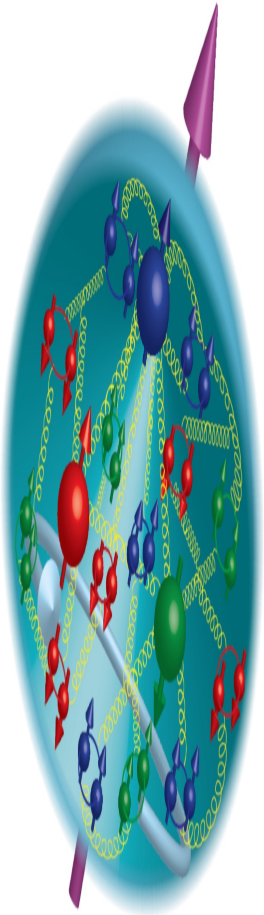
High-Energy Scattering: Longitudinal view

- Viewed from boosted frame.
  length contracted by $\gamma_{Breit} = \sqrt{1 + \frac{Q^2}{4M^2}}$
- Internal motion of constituents slowed down by time dilation – instantaneous charge distribution is seen.
- *x* is understood as the longitudinal momentum fraction
  valence quarks: $0.1 < x < 1$
  sea quarks: $x < 0.1$

J. Bjorken, SLAC-PUB-0571
March 1969

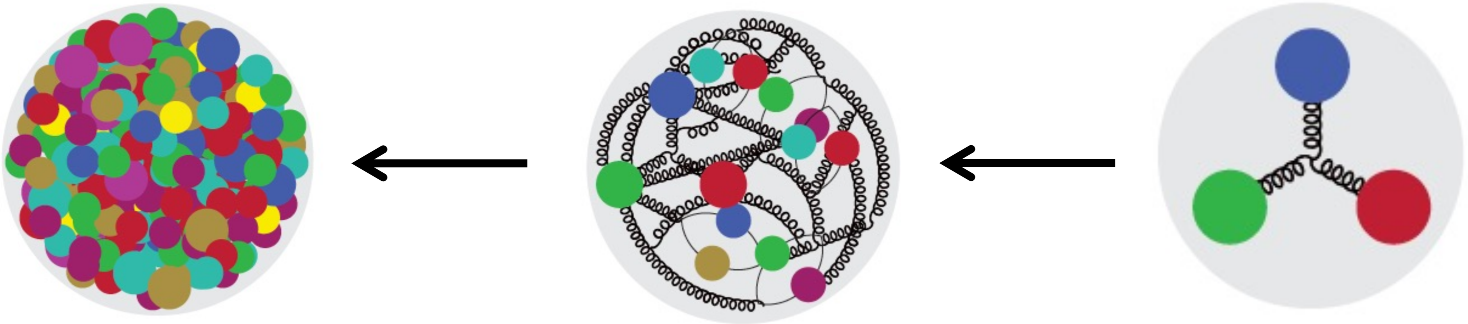


Lorentz Invariants
- $E^2_{CM} = (p+k)^2$
- $Q^2 = -(k-k')^2$
- $x = Q^2/(2p \bullet q)$

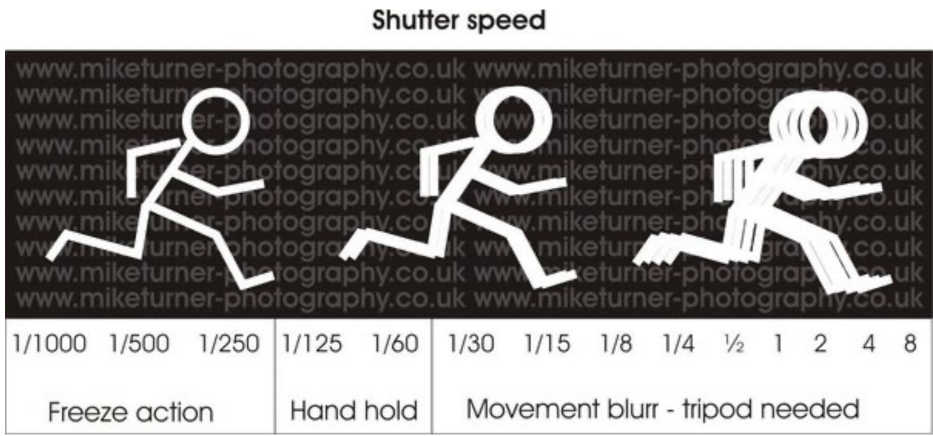


High-Energy Scattering: Longitudinal view

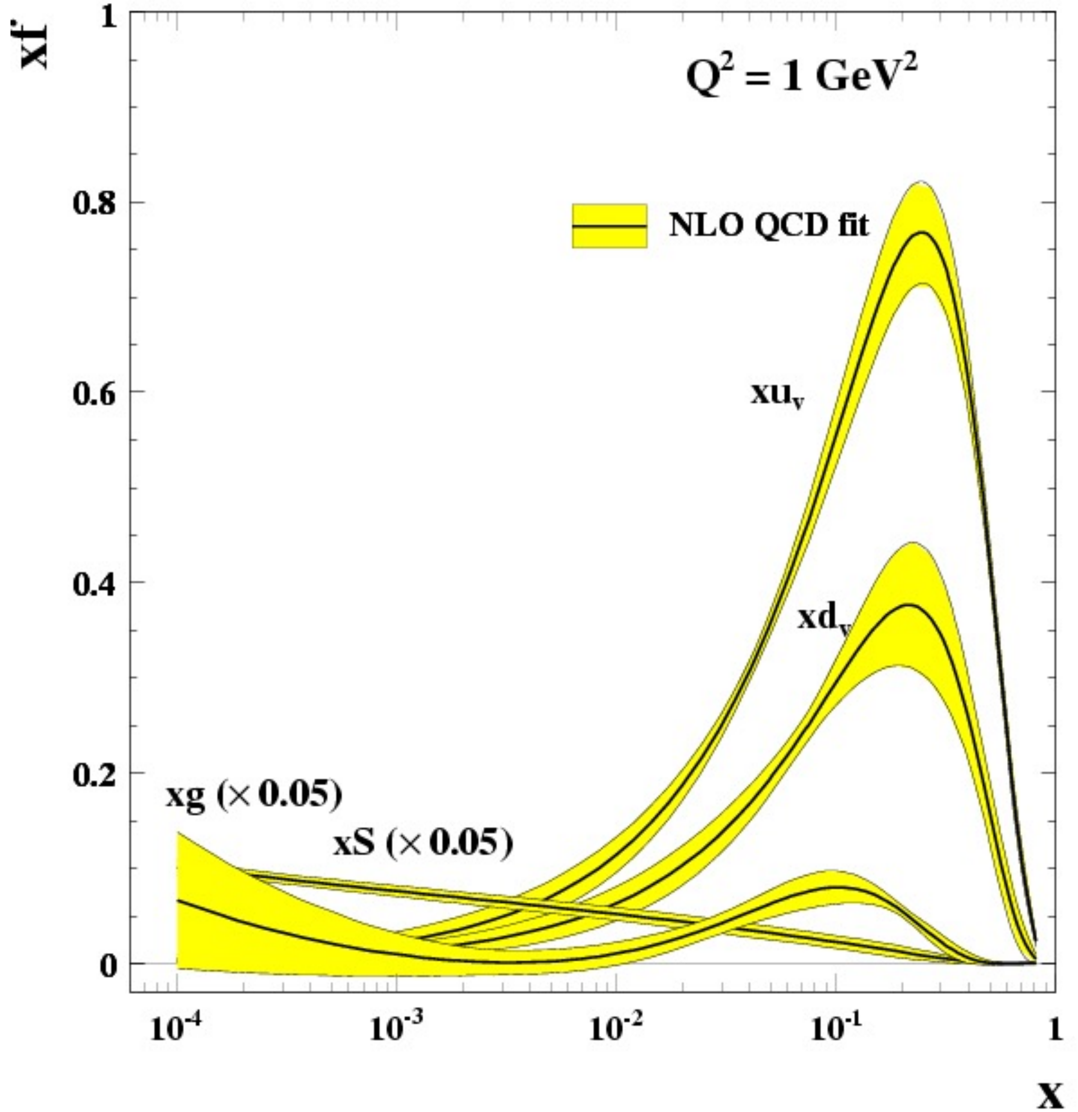
Snapshots where 0 < x < 1 is the shutter exposure time



$x \approx 10^{-4}$	$x \approx 10^{-2}$	$x \approx 0.3$
Probe non-linear dynamics	**Probe rad. dominated**	**Probe valence quarks**
short exposure time	**medium exposure time**	**long exposure time**



High-Energy Scattering: Longitudinal view

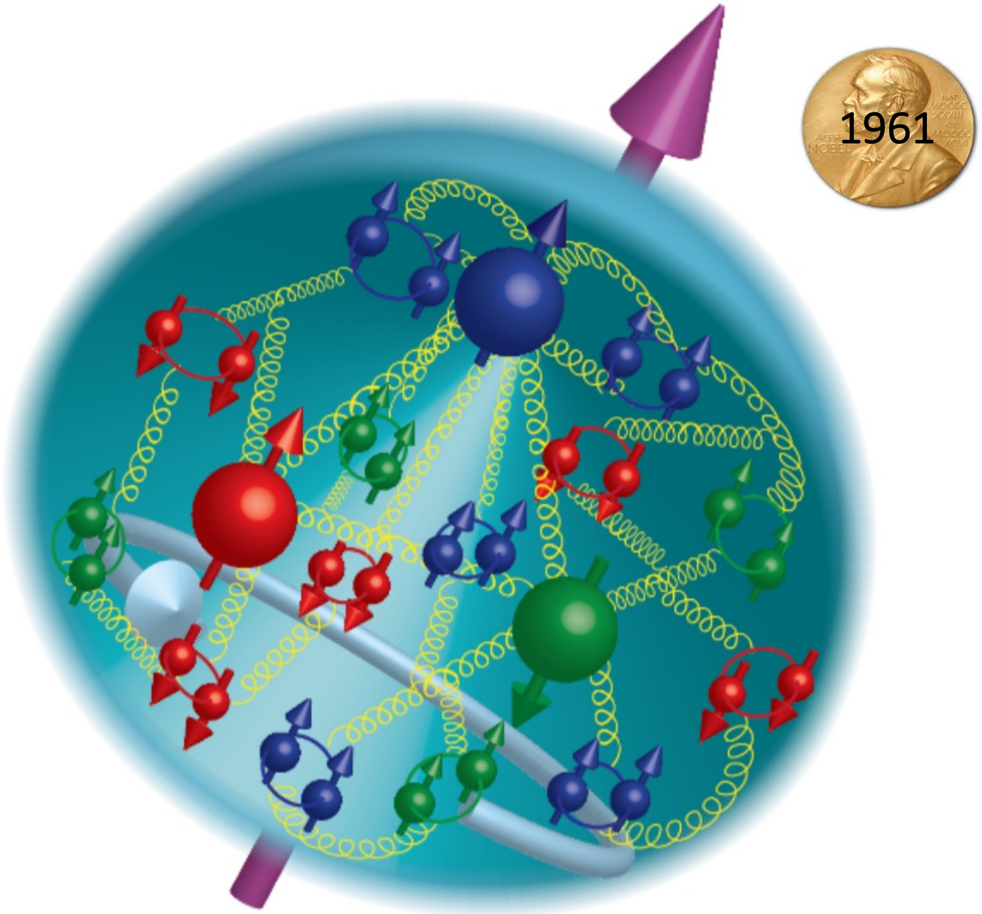


1/Q ~ spatial resolution

g – gluons
S – quark sea
u, d – up, down
valence quarks

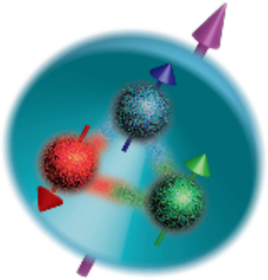
21^{st} Century view of the proton

- Elastic electron scattering determined charge & magnetism of nucleons
- ~ sphere with $\langle r_{ch} \rangle \approx 0.84$ Fermi
- The proton contains quarks, dynamically generated quark-antiquark pairs & gluons
- Quark and gluon momentum fractions well mapped out. (in Infinite Momentum Frame)
- Proton spin & mass have large contributions from quark-gluon dynamics

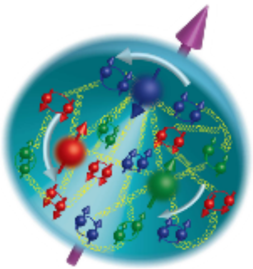


The EIC will, for the first time, provide a complete view of the structure of nucleons & nuclei and their emergent properties

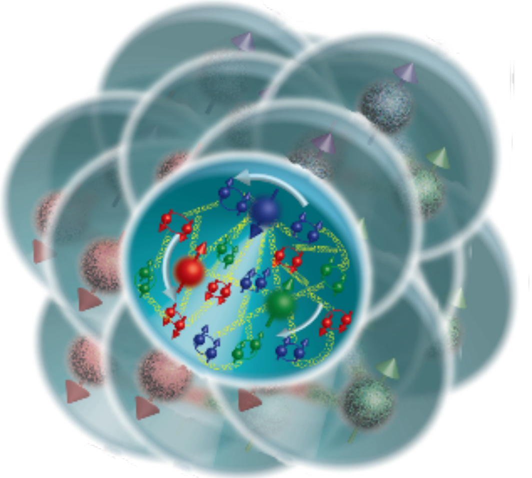
The Proton (1975)



The Proton (2015)



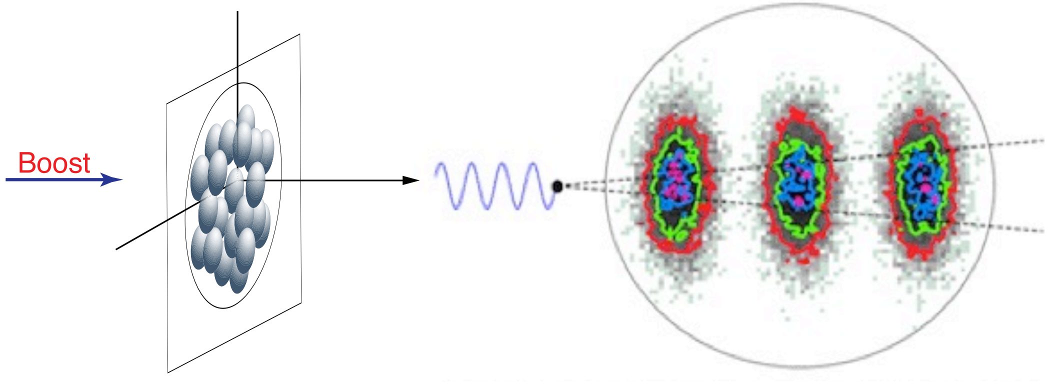
The Proton in a nucleus



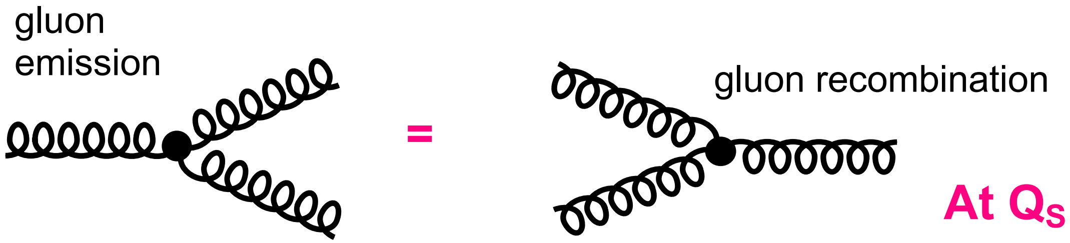
And much more QCD dynamics that can affect the identity of the protons and neutrons

The EIC will, for the first time, provide a complete view of the structure of nucleons & nuclei and their emergent properties

How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?



What happens to the gluon density in nuclei? Does it saturate at high energy, giving rise to a gluonic matter with universal properties in all nuclear matter?



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- **The US-Based Electron-Ion Collider (EIC)**
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  - Femtography
  - Mass
  - Spin
  - Hadronization
  - Dense Gluon States
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- EIC Summary – A Portal to a New Frontier

EIC Characteristics

- Center of mass energy: 20 – 140 GeV
  - Electrons: 2.5 – 18 GeV
  - Protons: 40 – 275 GeV
    (ions: Z/A x E_{proton})
- Luminosity: 10^{34} /cm^2/sec
- Polarization: <70% (both electron and ion)
- Ion Species: proton - Uranium
- Detectors: 2 interaction regions \w complete coverage (almost)

EIC vs. HERA

- Center of mass energy: 20 – **140** **(318)** GeV
  - Electrons: 2.5 – 18 (27.5) GeV
  - Protons: 40 – 275 (920) GeV
    (ions: Z/A x E_{proton})

- Luminosity: $\mathbf{10^{34}}$ $\mathbf{(10^{31})}$ /cm^2/sec

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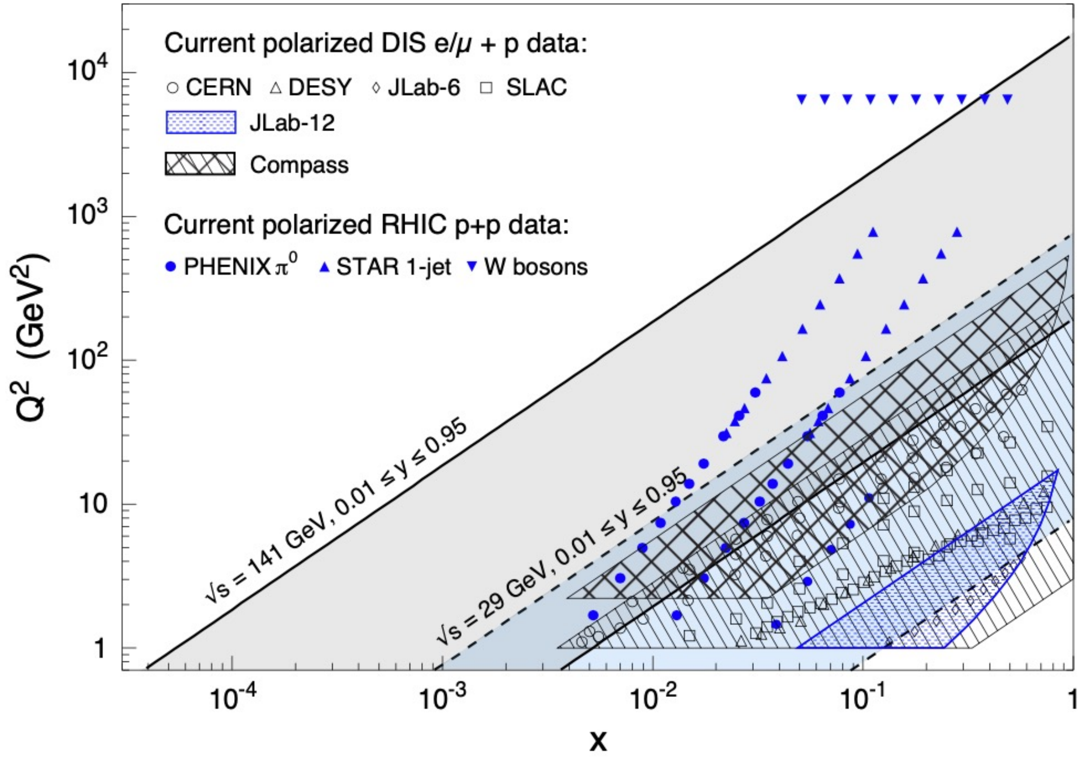
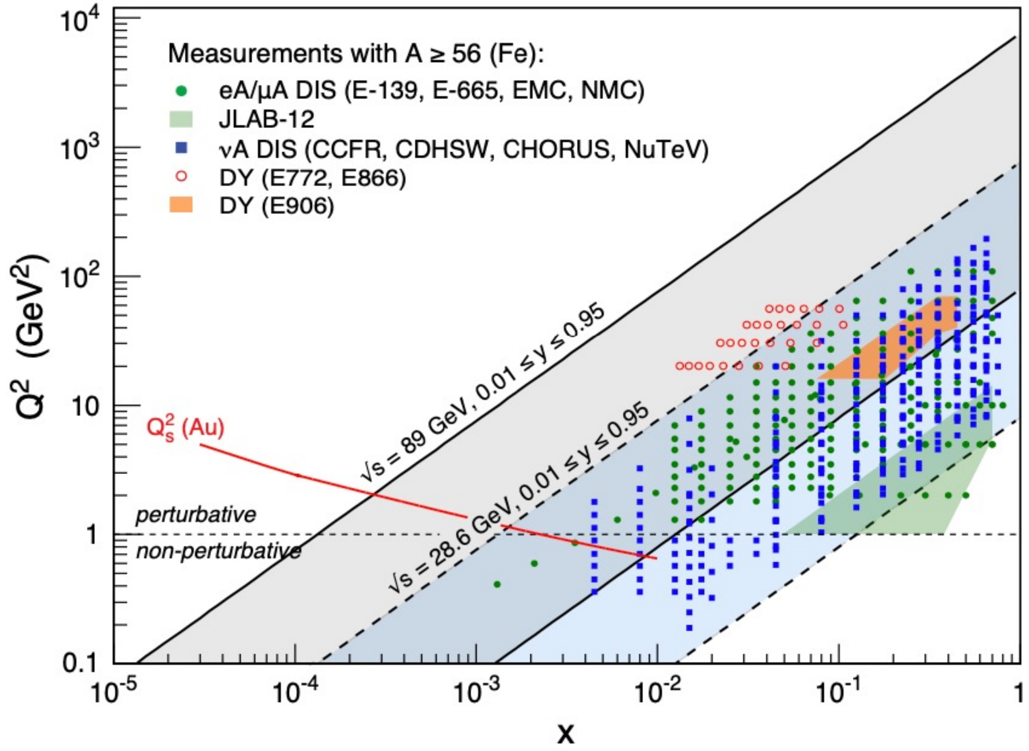
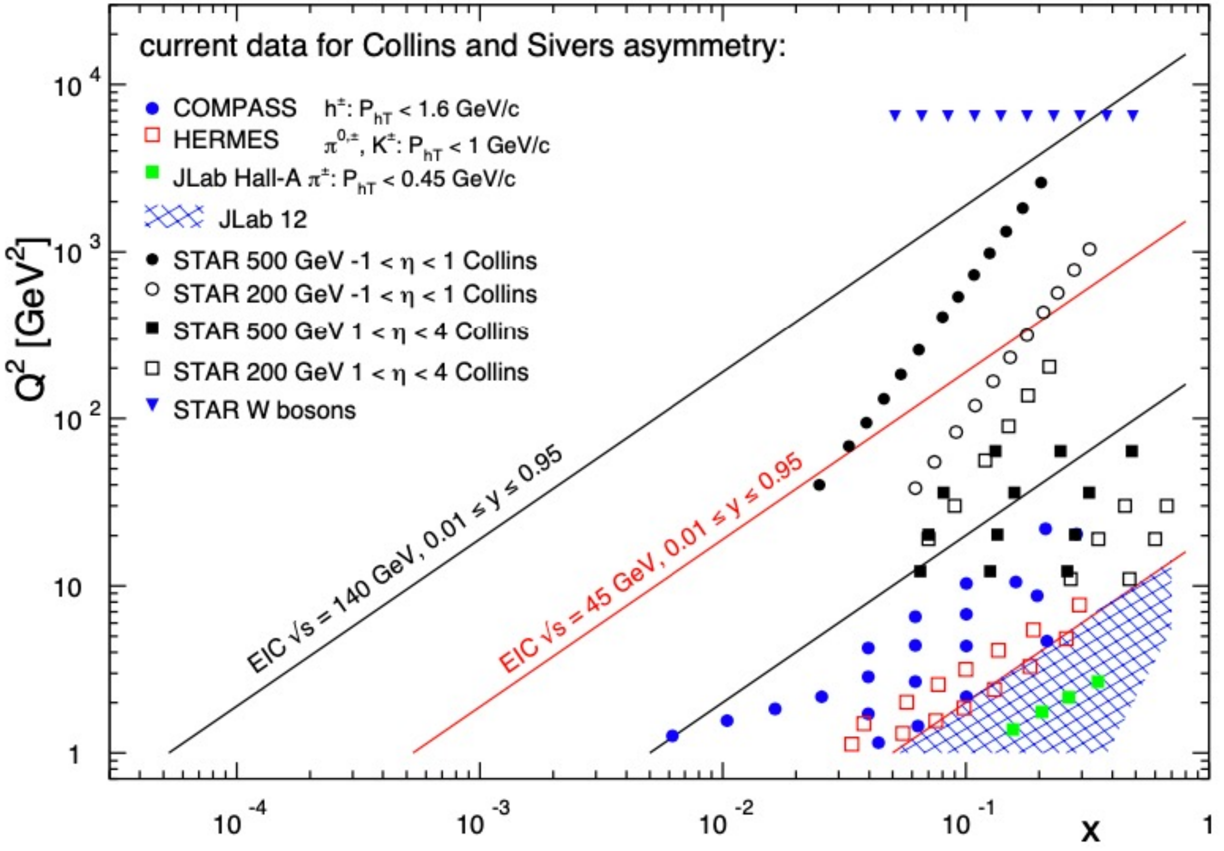
EIC is:
- Lower Energy
- Higher Luminosity
+ Hadron Polarization
+ Nuclear Beams
+ Modern Detector(s)

Inclusive DIS coverage

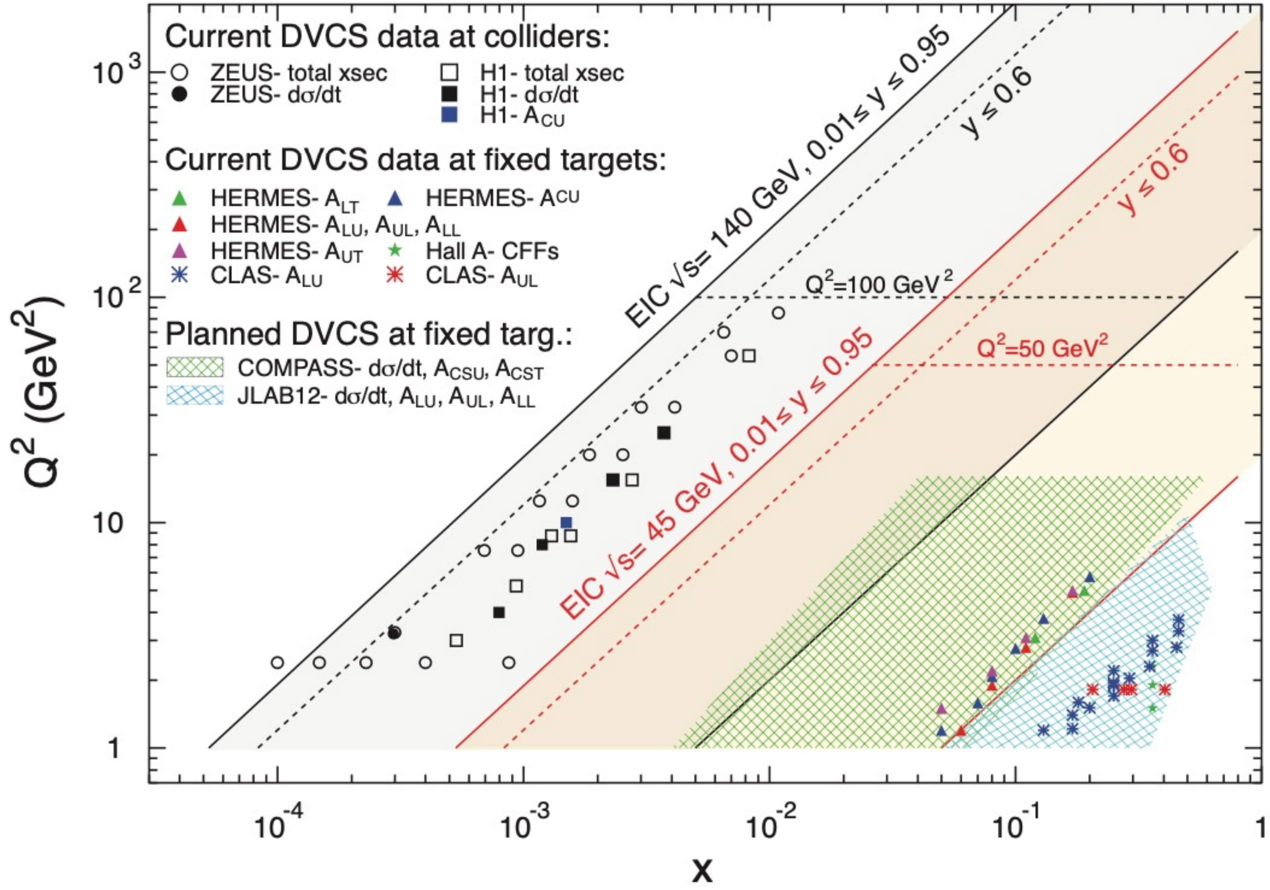




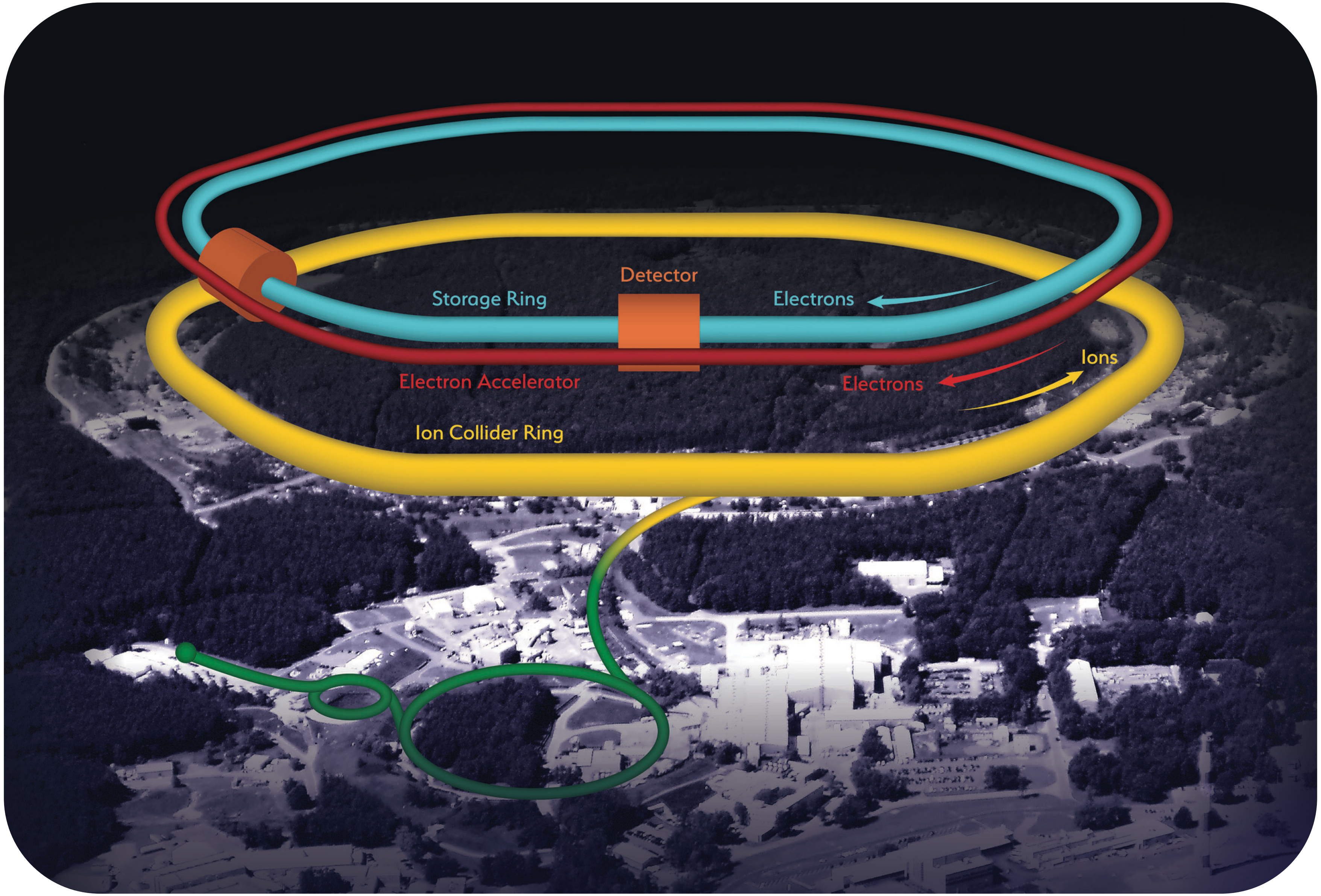
Semi-Inclusive DIS coverage



DVCS coverage



EIC @ Brookhaven National Lab



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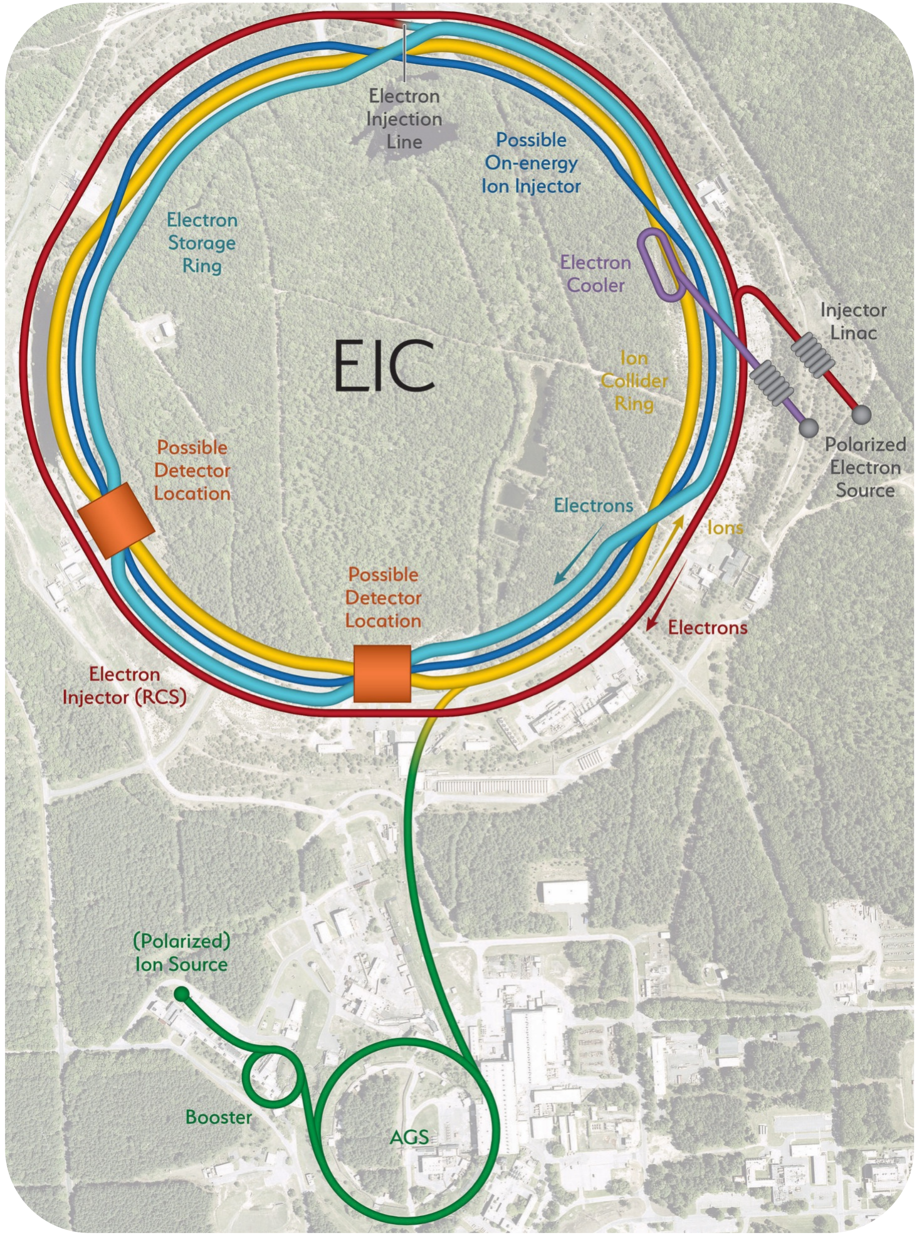
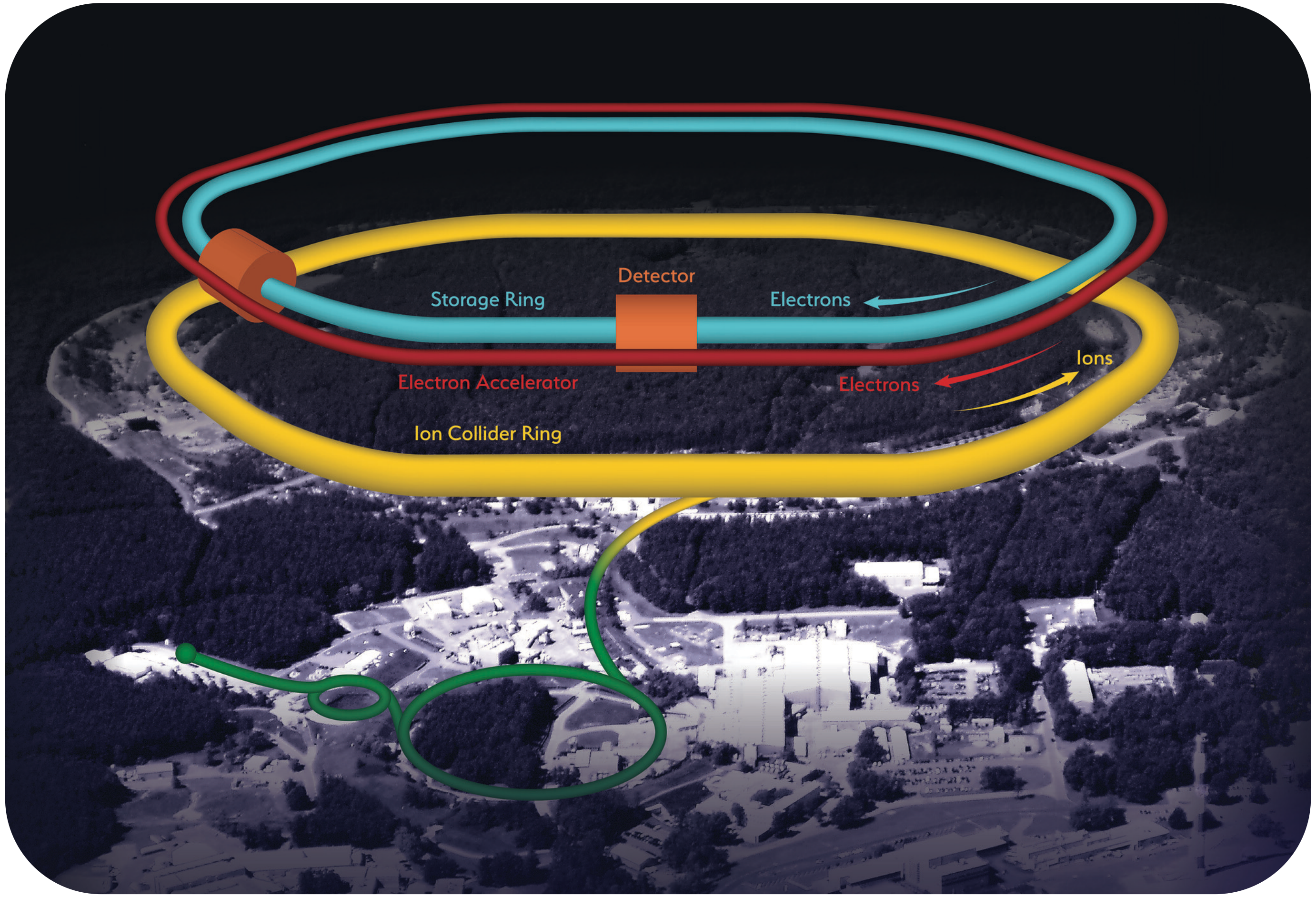


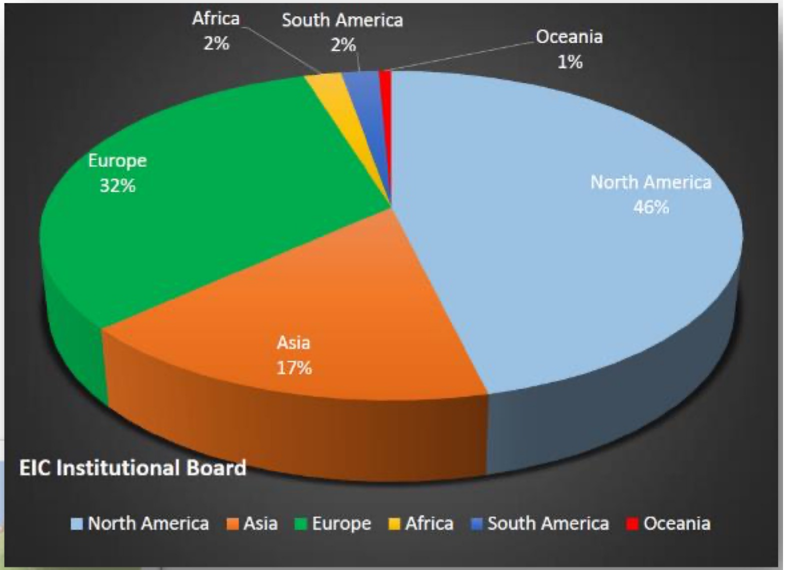


EIC Users Community

EIC Users Group Formed in 2016
EICUG.ORG

Status January 2021:

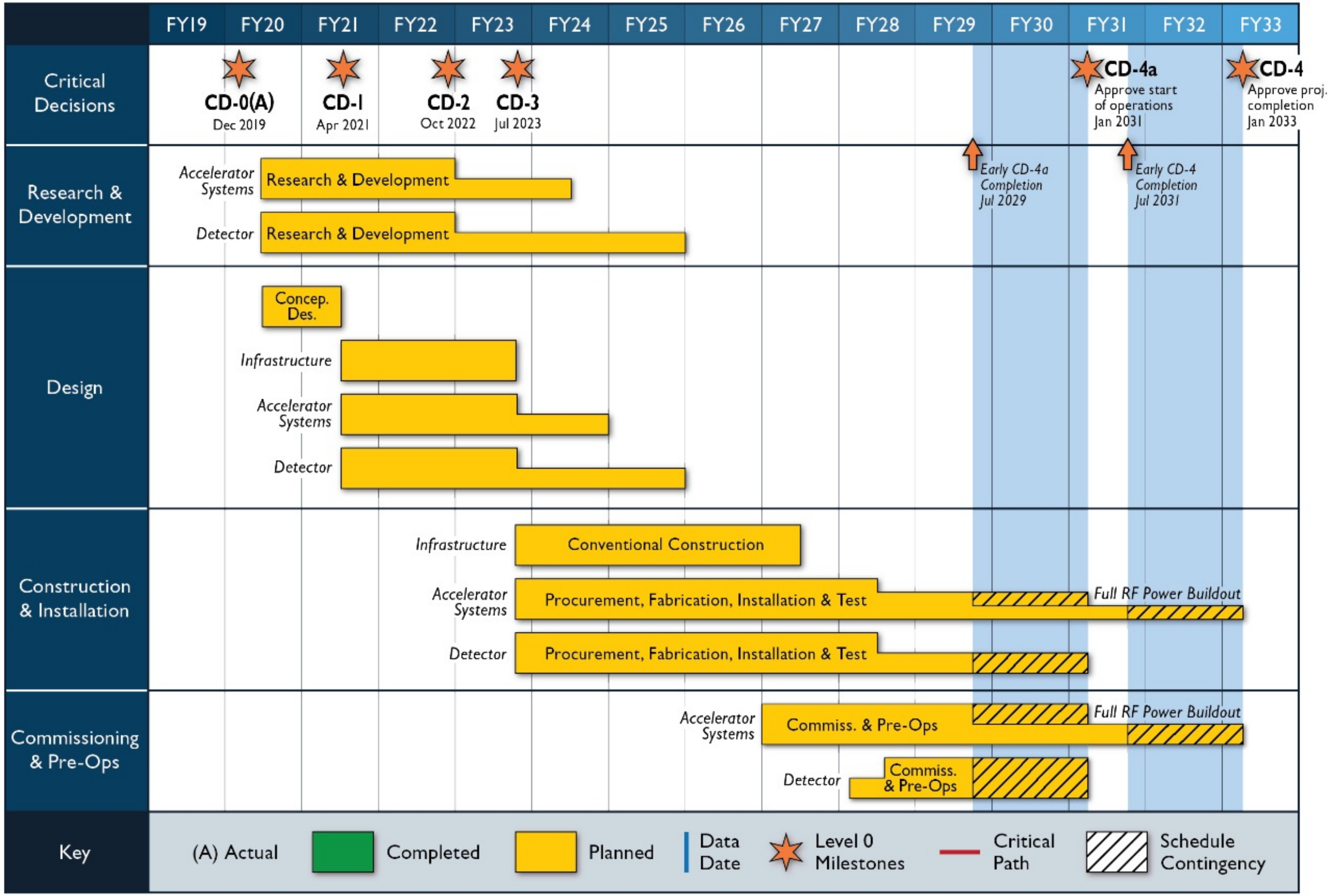
- Collaborators 1243
- Institutions 250
- Countries 34



Annual EICUG Meetings

2016	UC Berkeley
2016	Argonne
2017	Trieste, Italy
2018	Washington, DC
2019	Paris, France
2020	Miami
2021	TBD
2022	Warsaw, Poland

EIC Schedule



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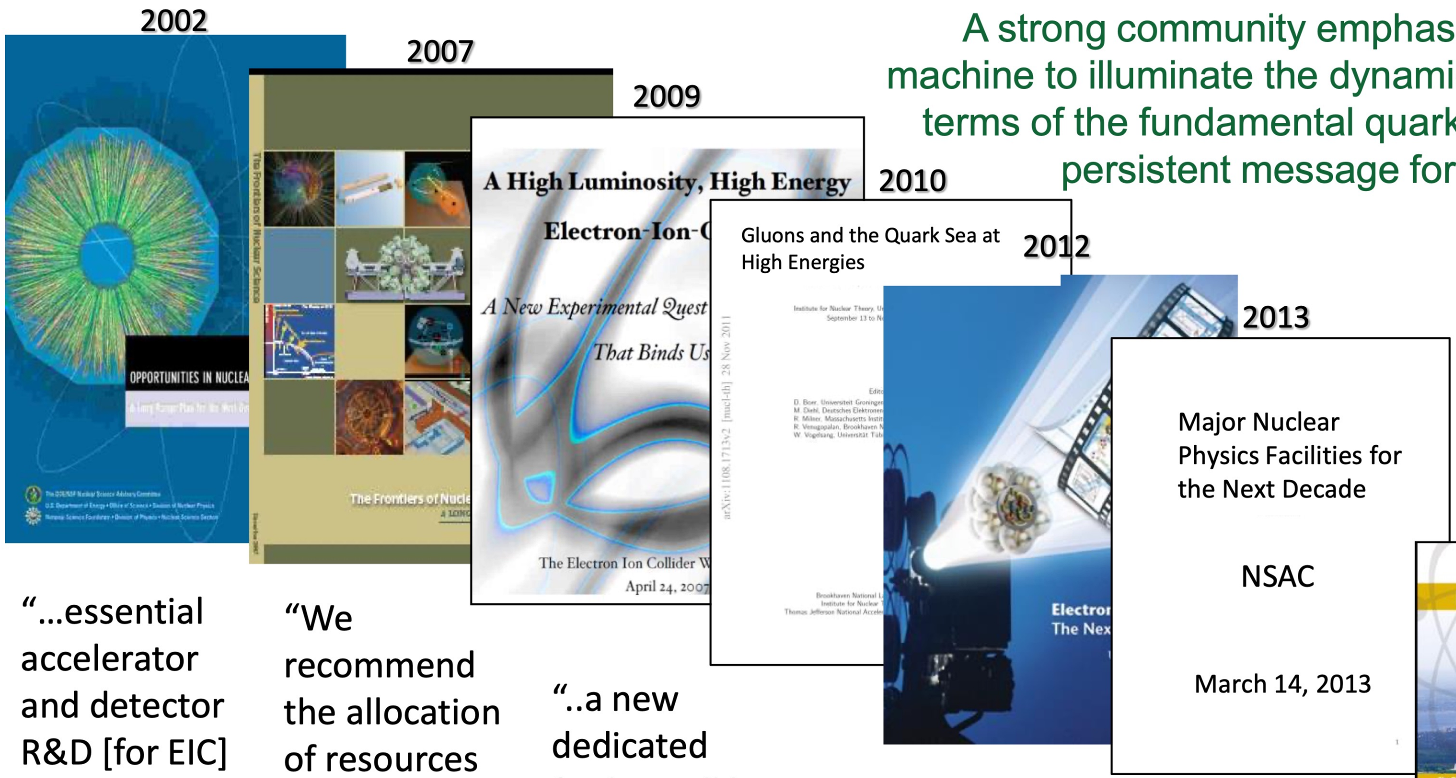
Developing the EIC Science Case

A strong community emphasis on the urgent need for a machine to illuminate the dynamical basis of hadron structure in terms of the fundamental quark and gluon fields has been a persistent message for almost two decades



"…essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

"We recommend the allocation of resources …to lay the foundation for a polarized Electron-Ion Collider…"

"..a new dedicated facility will be essential for answering some of the most central questions."

"The quantitative study of matter in this new regime [where abundant gluons dominate] requires a new experimental facility: an Electron Ion Collider."

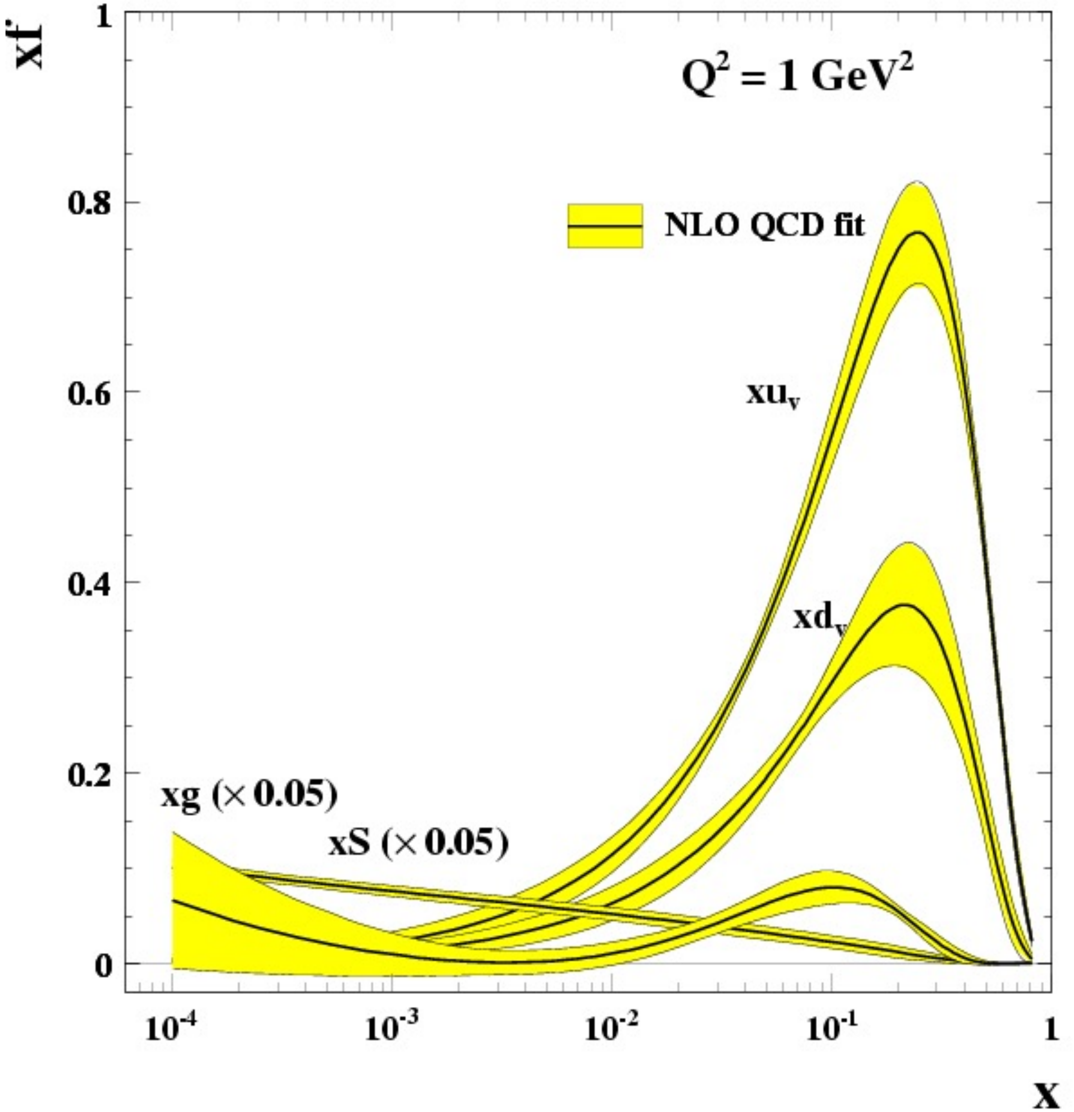
Electron-Ion Collider *absolutely central* to the nuclear science program of the next decade.

"a high-energy high-luminosity polarized EIC [is] the highest priority for new facility construction following the completion of FRIB."

EIC Science

1. How do the nucleonic properties such as mass and spin emerge from partons and their underlying interactions?
2. How are partons inside the nucleon distributed in both momentum and position space?
3. How do color-charged quarks and gluons, and jets, interact with a nuclear medium? How do the confined hadronic states emerge from these quarks and gluons? How do the quark-gluon interactions create nuclear binding?
4. How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions? What happens to the gluon density in nuclei? Does it saturate at high energy, giving rise to a gluonic matter with universal properties in all nuclei and even nucleons?

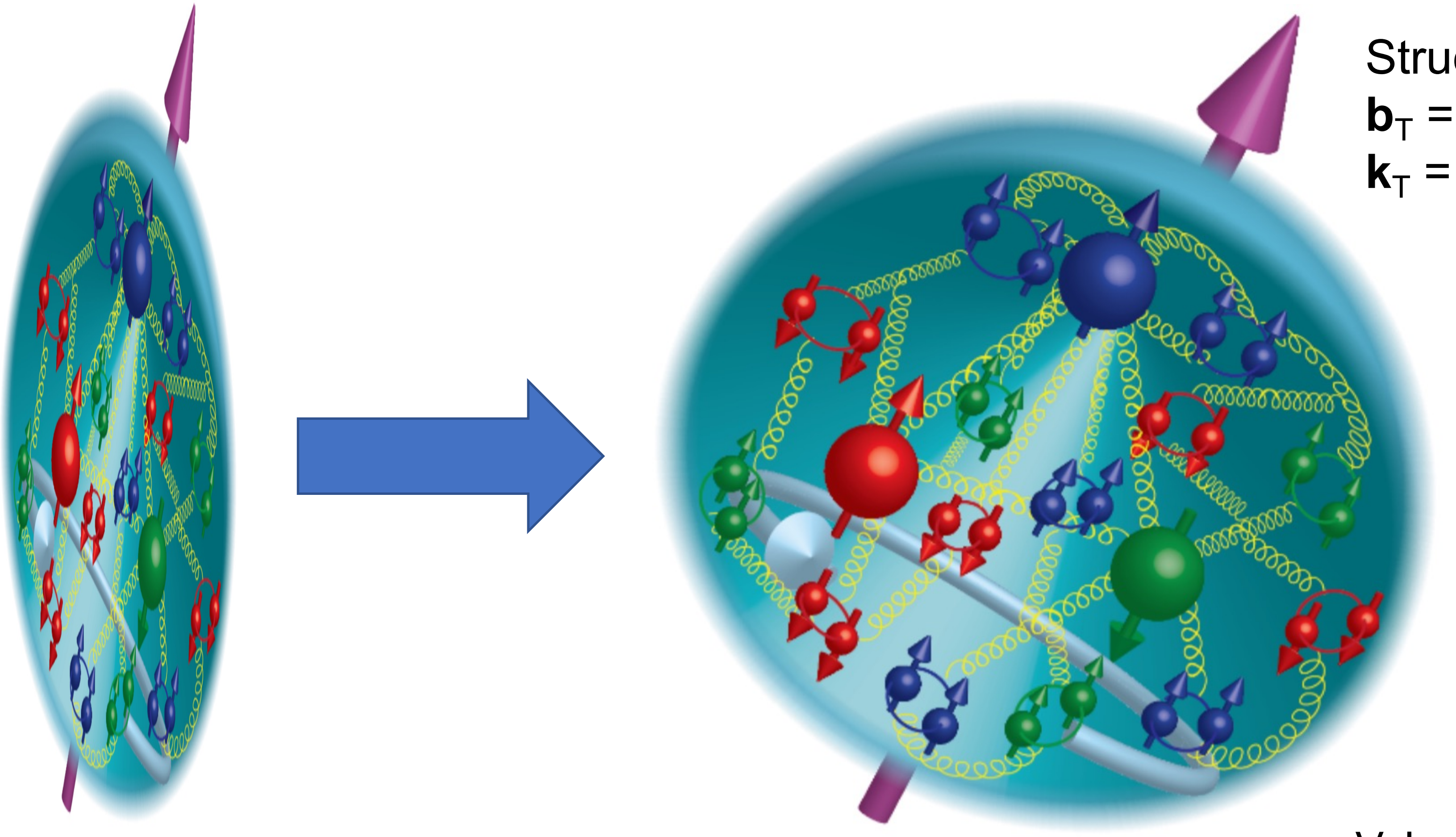
High-Energy Scattering: Longitudinal view



1/Q ~ spatial resolution

g – gluons
S – quark sea
u, d – up, down
valence quarks

High-Energy Scattering: Going 3D



Structure mapped in terms of
$\mathbf{b}_T$ = transverse position
$\mathbf{k}_T$ = transverse momentum

Goal:
Unprecedented
21st Century Imaging
of Hadronic Matter

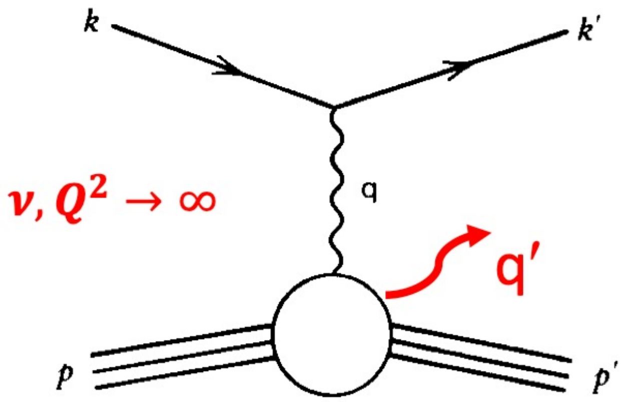
Valence Quarks: JLab 12 GeV
Sea Quarks and Gluons: EIC

High-Energy Scattering: Going 3D

After decades of study, we have the experimental and theoretical tools to systematically move beyond a 1D momentum fraction (x_B) picture of the nucleon.

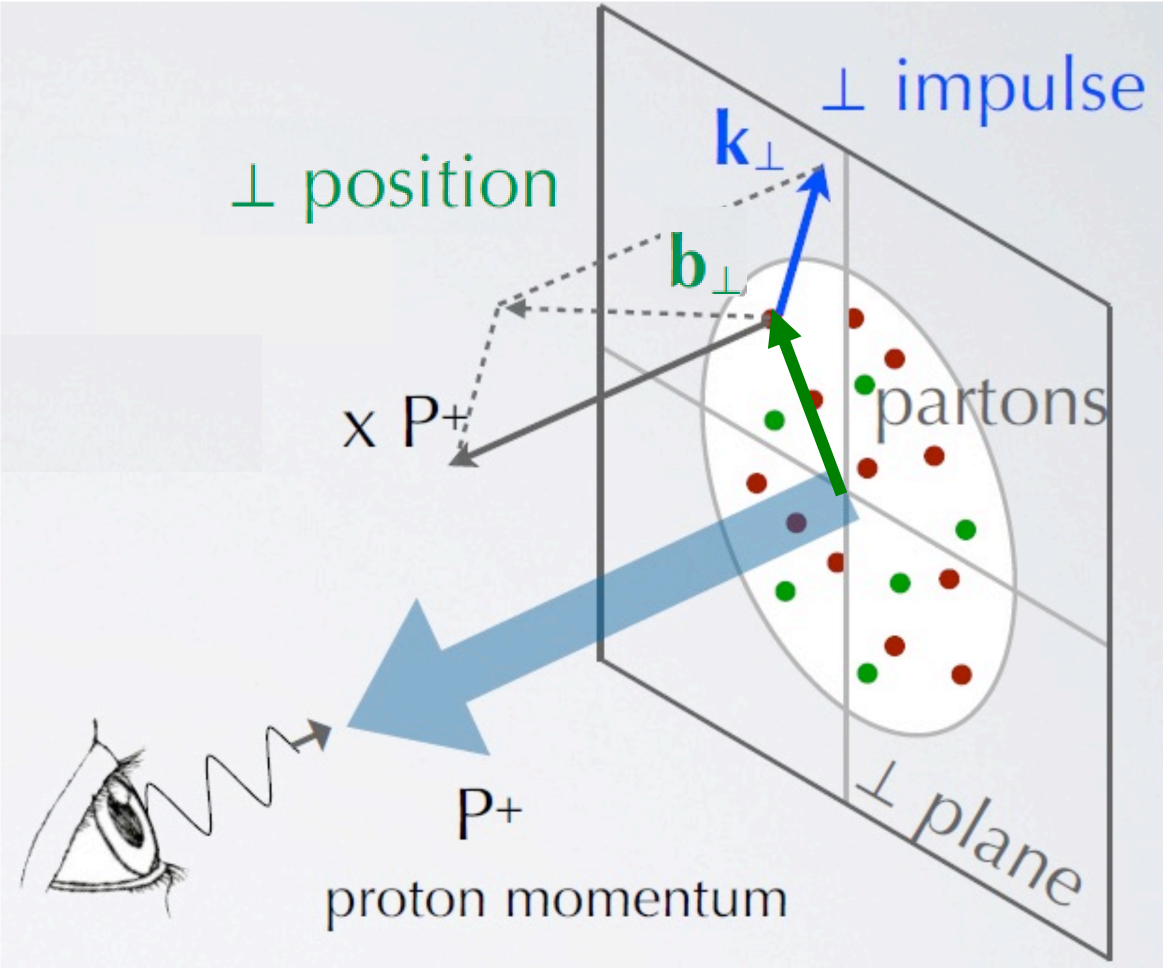
- High luminosity, large acceptance experiments with polarized beams & targets.
- Theoretical models in terms of a 5D Wigner distributions (3D momentum & transverse spatial distributions).

Deep Exclusive Scattering (DES) cross sections sensitive to quarks \w longitudinal momentum fraction $\mathbf{x_B}$ @ transverse location $\mathbf{b_T}$.



Imaging via Nuclear Femtography

Structure mapped
in terms of
b$_T$ = transverse position
k$_T$ = transverse momentum



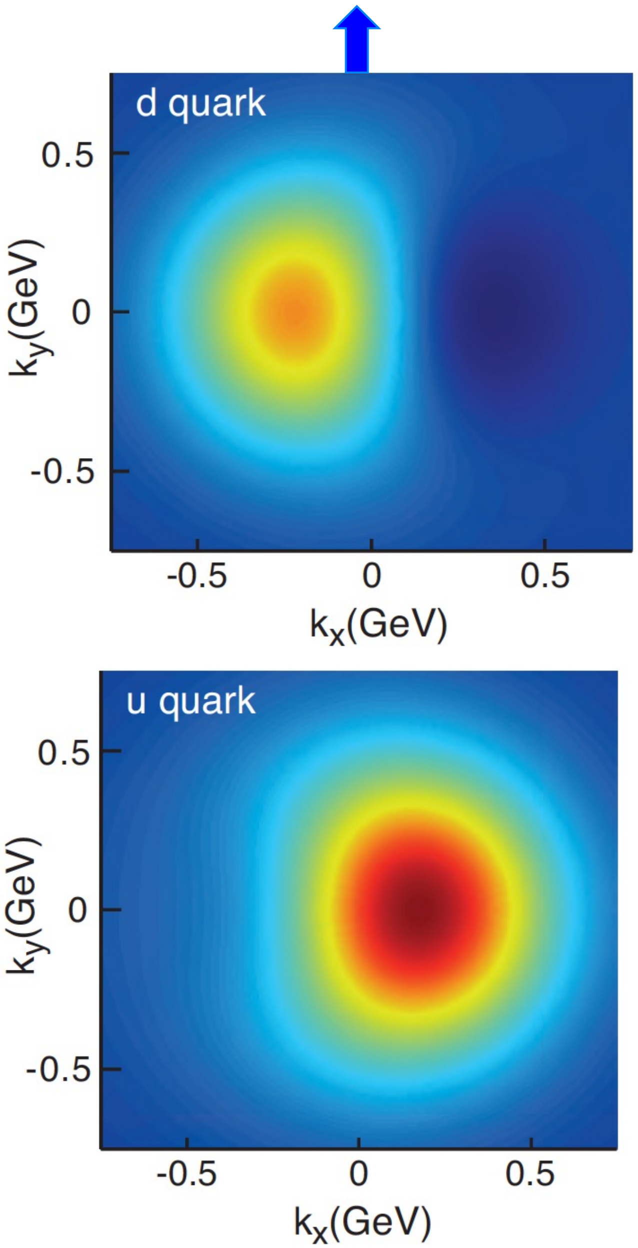
Also information on orbital angular momentum: **r** x **p**

Confined Motion: Transverse Momentum Distributions of Quarks & Gluons

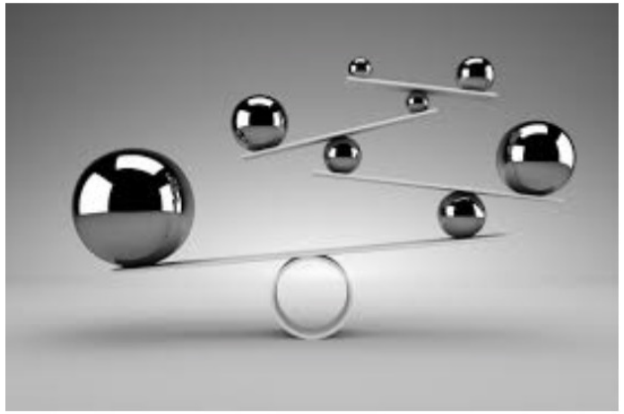
- Polarized transverse momentum distribution measurements provide a powerful new window to QCD

- Transverse Momentum Distributions directly related to orbital motion

- For example, we can explore for the first-time interference in quantum phases due to the color force – impossible with previous 1D experiments

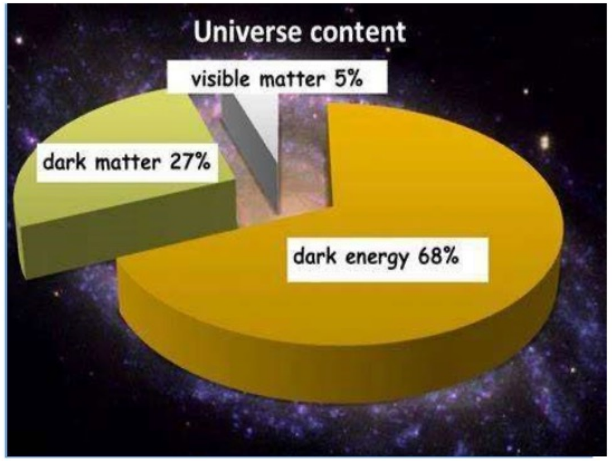


Mass scales in QCD

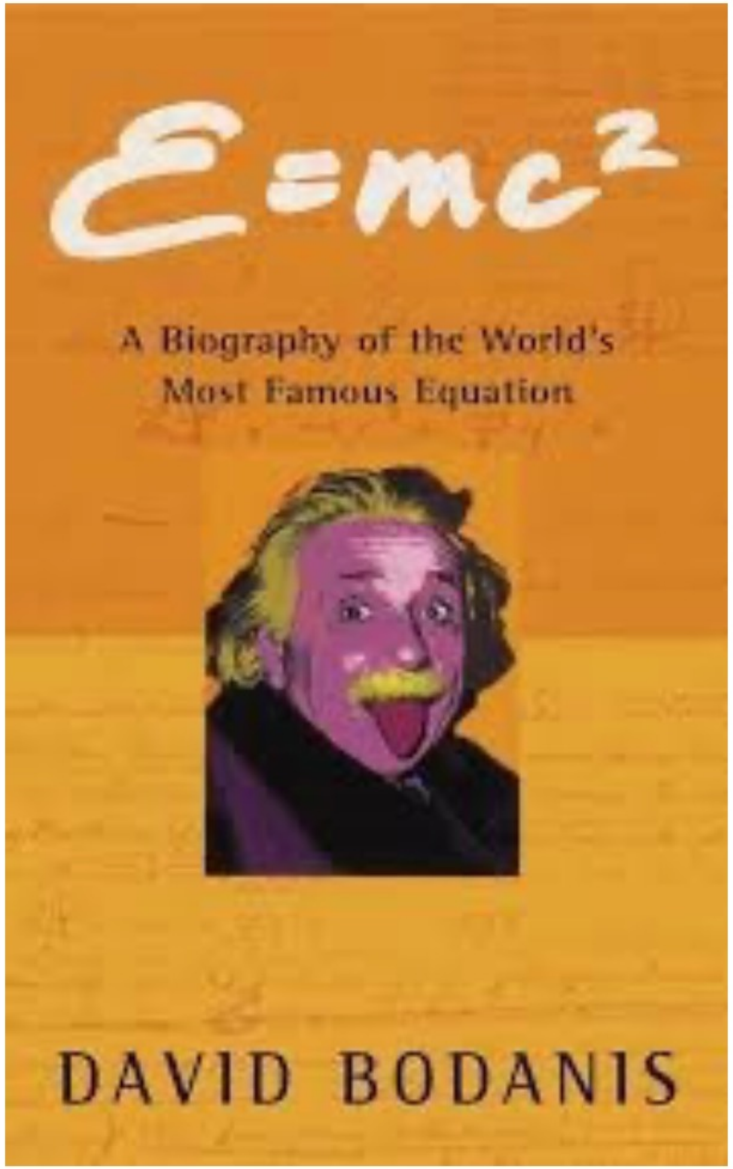


- The nucleon mass is determined by two different mass scales:
- **Quark masses**
  - Just like the electron mass in atomic physics, determined by Higgs mechanism
  - Electroweak symmetry breaking scale.
- **QCD scale Λ_{QCD}**
  - QCD scale Λ_{QCD} does not appear directly in the lagrangian: dimensional transmutation
  - Free parameter

Nucleon mass in astrophysics and cosmology



- Proton and neutron masses account for 5% of the energy of the Universe
- The mass is the gravity charge which determines the stellar formation dynamics: **supernova, neutron stars, blackholes**



- “It appears far more natural to consider every inertial mass as a store of energy” ,

Dec. 1907, A. Einstein

Saving energy in the nucleon mass

- As the Universe expands and cools, the only way to store the hot plasma energy is to form color-neutral droplets (nucleons) of quark and gluons, locking their kinetic energies inside.

Mass from QCD dynamics

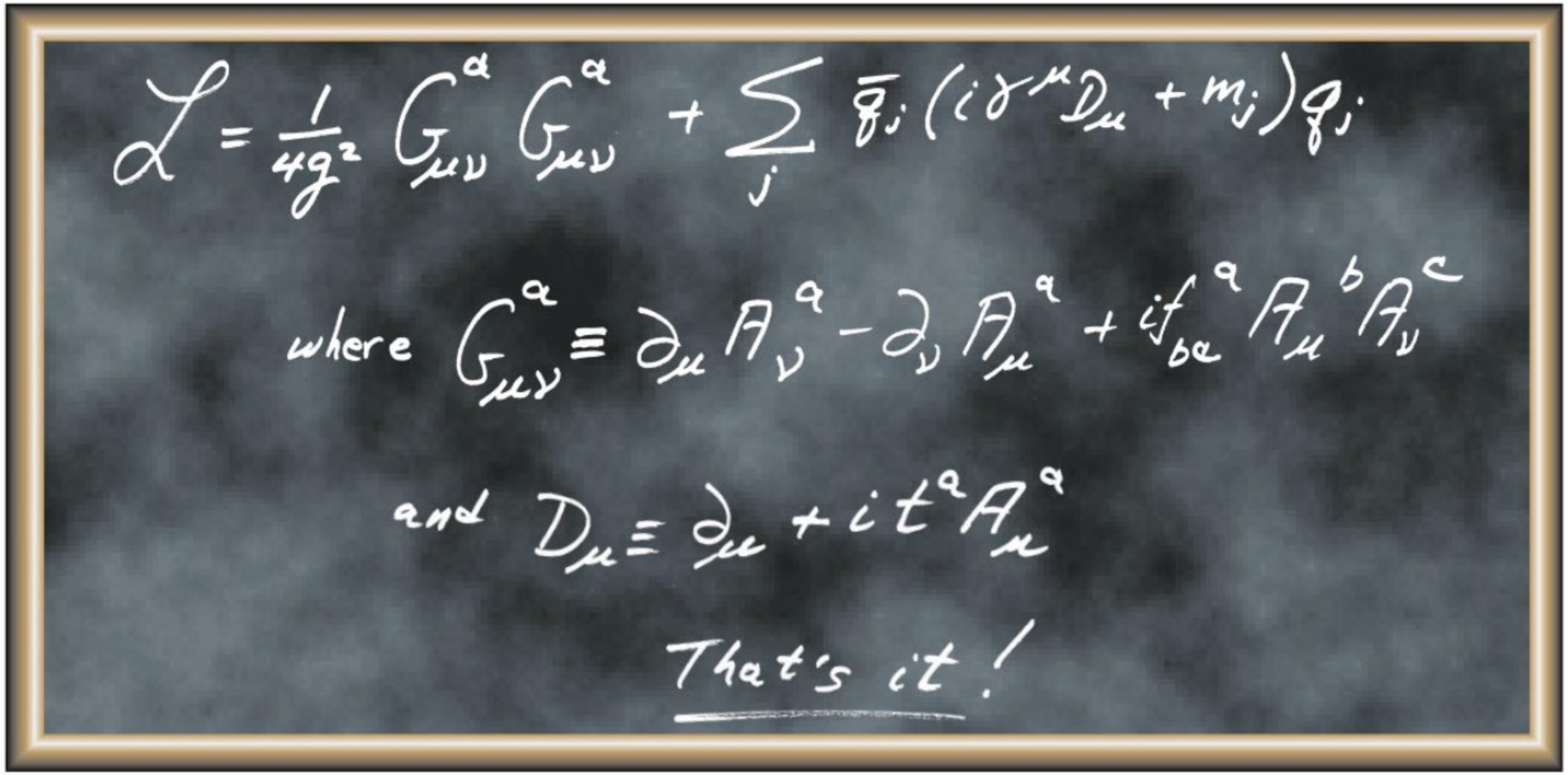
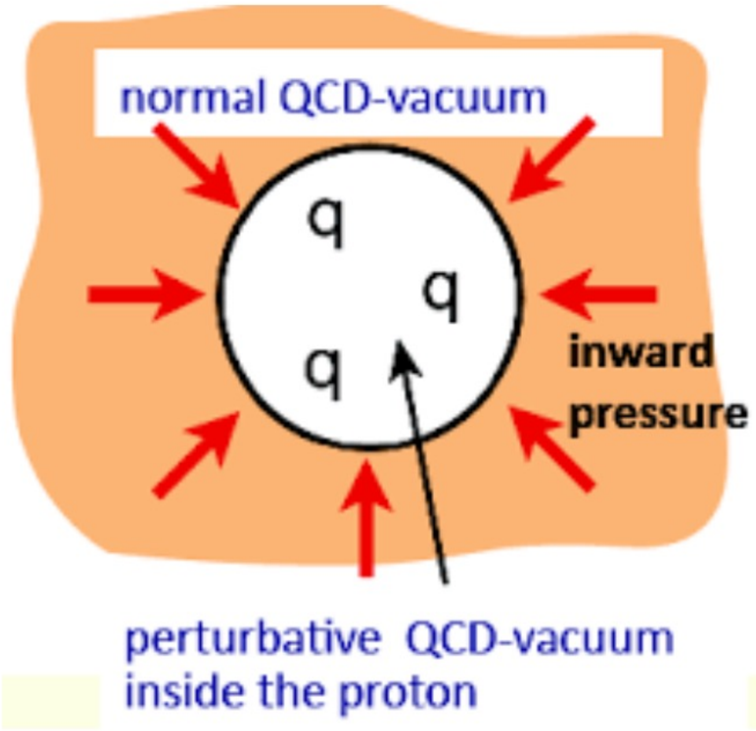


FIGURE 1. THE QCD LAGRANGIAN $\mathcal{L}$ displayed here is, in principle, a complete description of the strong interaction. But, in practice, it leads to equations that are notoriously hard to solve. Here m_j and q_j are the mass and quantum field of the quark of jth flavor, and A is the gluon field, with spacetime indices μ and ν and color indices a, b, c. The numerical coefficients f and t guaran-

Changing the QCD scale

- What happens if we can change Λ_{QCD} by a factor of 10 or 1/10? How will the world change?
  - The Earth may be closer to or further from the Sun, may rotate faster and slower around it?
  - The neutron can be lighter than the proton?
  - Nuclear energy production and details of star evolution will be very different?
  - Atoms and molecules will remain the similar size?
  - Feeling of hot and cold might be different?
  - Superconductivity phenomena might enhanced or decreased?
  - Change of gravity may affect biology evolution?

Role of color confinement



M.I.T. Bag Model

- The boundary condition generates discrete energy eigenvalues.

$$\varepsilon_n = \frac{x_n}{R}$$

R - radius of the Bag

x_1=2.04

$$E_{kin}(R) = N_q \frac{x_n}{R}$$

N_q = # of quarks inside the bag

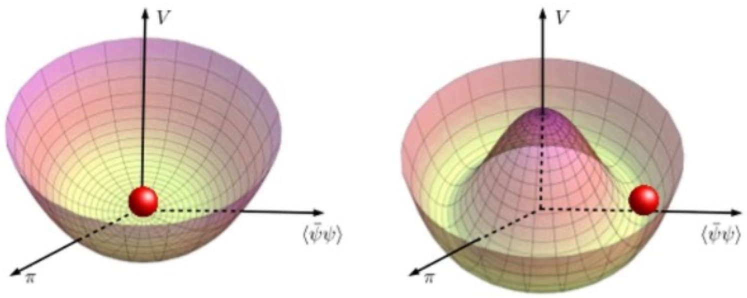
$$E_{pot}(R) = \frac{4}{3}\pi R^3 B$$

B – bag constant that reflects the bag pressure

26

Mass = quark kinetic energy + B(scalar-field condensate)

Role of chiral symmetry breaking

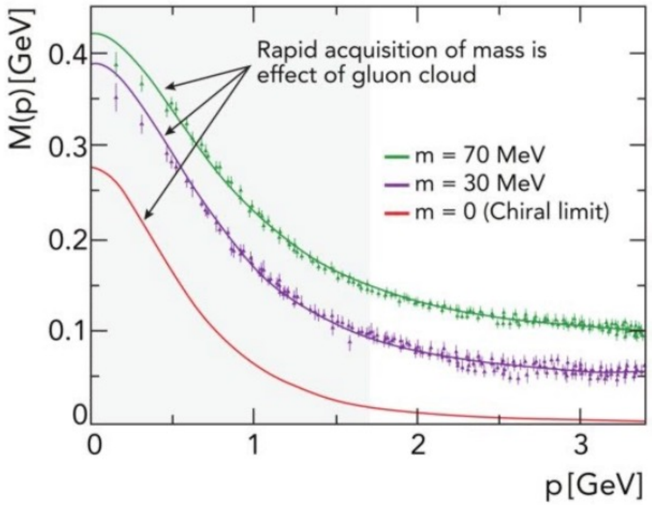


- SSB of chiral symmetry

  Goldstone bosons: π, K

  Chiral condensate $\langle \bar{\psi}\psi \rangle \neq 0$

- Quarks acquire an effective mass? NJL models etc.



Mass of the nucleon

- Internal mass as a store of energy

$$mc^2 = \langle N|\hat{H}_{QCD}|N\rangle$$

- For any relativistic system, the Hamiltonian can be separated into two terms,

$$\hat{H}_{QCD} = \hat{H}_T + \hat{H}_S$$

This separation is a fundamental property of relativity and both parts are scale invariant

Tensor and scalar energies

- Tensor energy $E_T = \langle H_T \rangle$ is related to the usual **kinetic and potential energy** sources
- Scalar energy $E_S = \langle H_S \rangle$ is related to related to **scale-breaking properties of the theory**, as such as quark mass m_q and trace anomaly:
  - In the massless limit, the classical theory is scale-invariant.
  - Due to UV divergences, the scale invariance is broken, the trace of EMT is now zero, $T^\mu_\mu \neq 0$. Composite scalar fields which could have scale-breaking vacuum expectation values

$$\langle \bar{\psi}\psi \rangle, \quad \langle F^2 \rangle$$

Splitting the QCD energy sources

- Four different type energies (X. Ji, PRL, 1995)

$$H_{QCD} = H_q + H_m + H_g + H_a$$

$$H_q = \int d^3x \ \bar{\psi}(-iD \cdot \alpha)\psi$$ ← Quark energy

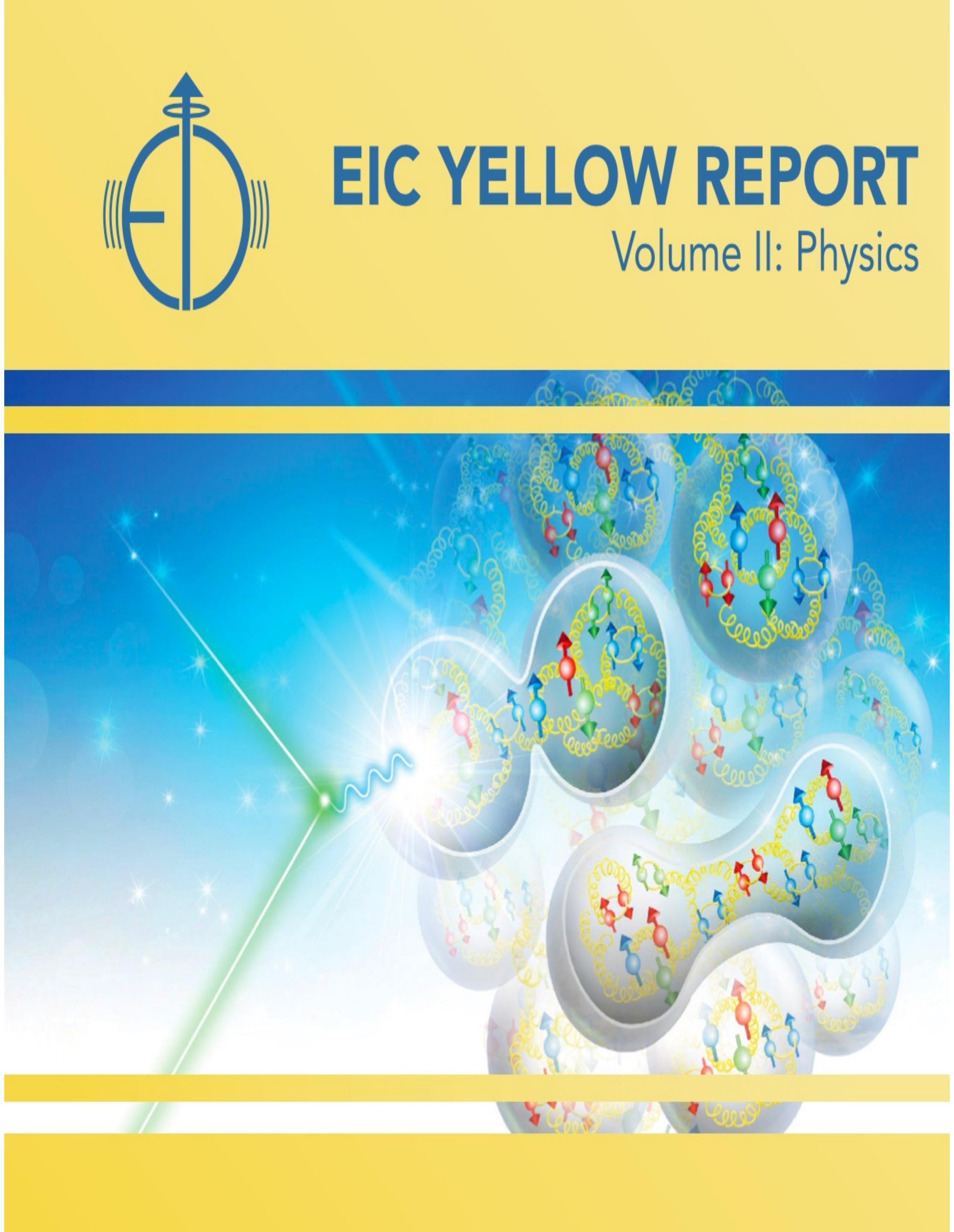
$$H_m = \int d^3x \ \bar{\psi}m\psi$$ ← Quark mass

$$H_g = \int d^3x \tfrac{1}{2}(E^2 + B^2)$$ ← Gluon energy

$$H_a = \int d^3x \ \frac{9\alpha_s}{16\pi}(E^2 - B^2)$$ ← Quantum Anomalous Energy (QAE)

Questions related to QCD fundamentals

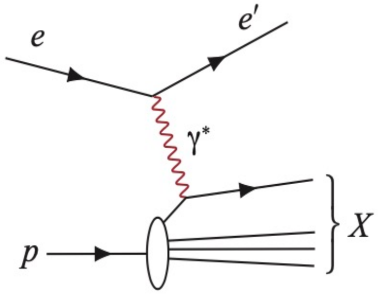
- What is the role of confinement in the proton mass?
- What is the role of chiral symmetry breaking in the proton mass?
- Does the relativistic virial theorem tell us something deep about the mass?
- What is the role of quantum anomalous energy (QAE) in the nucleon mass?
- Why are the nucleon resonances separated by large mass gap? (why quark model works?)
- Why the nucleon-nucleon potential is attractive (one pion change)?



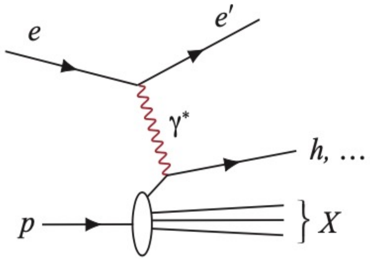
arxiv: 2103.05419

Key EIC Reactions

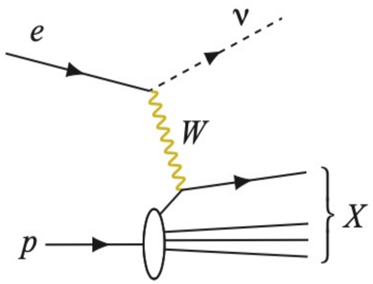
Neutral-current Inclusive DIS: $e + p/A \longrightarrow e' + X$; for this process, it is essential to detect the scattered electron, e', with high precision. All other final state particles (X) are ignored. The scattered electron is critical for all processes to determine the event kinematics.



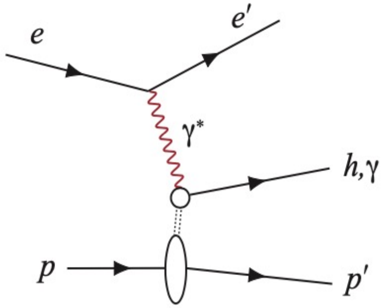
Semi-inclusive DIS: $e + p/A \longrightarrow e' + h^{\pm,0} + X$, which requires measurement of *at least one* identified hadron in coincidence with the scattered electron.



Charged-current Inclusive DIS: $e + p/A \longrightarrow \nu + X$; at high enough momentum transfer Q^2, the electron-quark interaction is mediated by the exchange of a $W^{\pm}$ gauge boson instead of the virtual photon. In this case the event kinematic cannot be reconstructed from the scattered electron, but needs to be reconstructed from the final state particles.

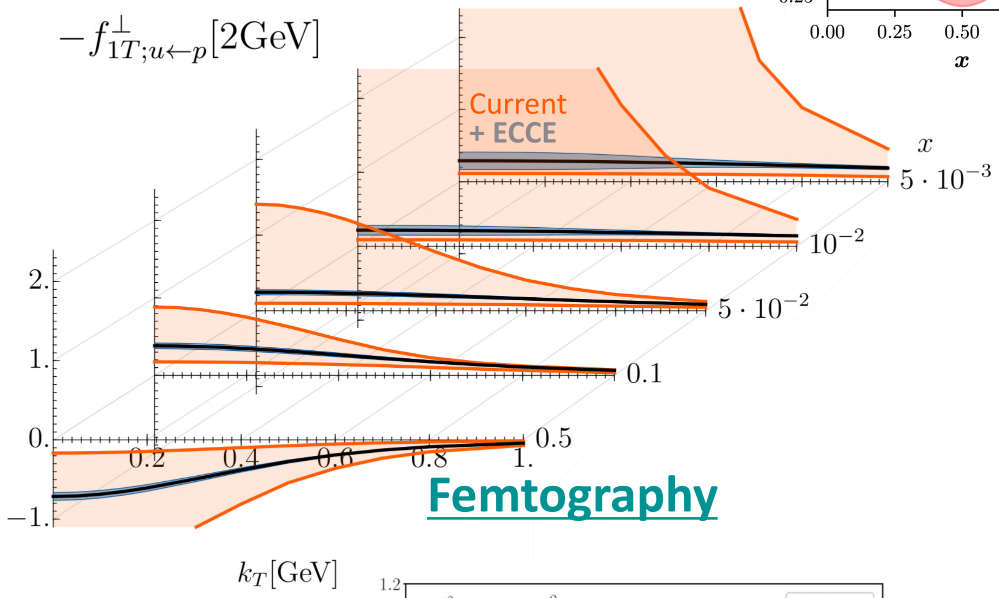


Exclusive DIS: $e + p/A \longrightarrow e' + p'/A' + \gamma/h^{\pm,0}/VM$, which require the measurement of *all* particles in the event with high precision.

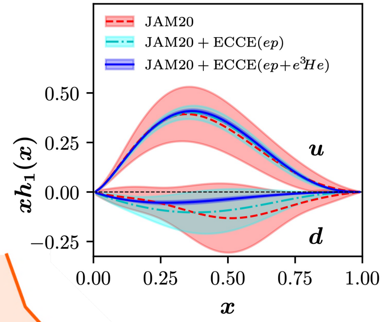


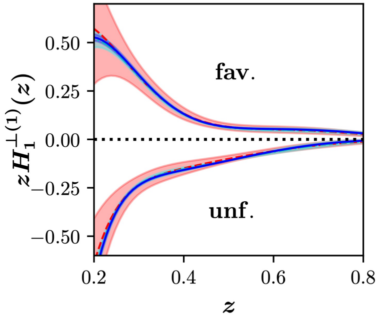
EIC Physics

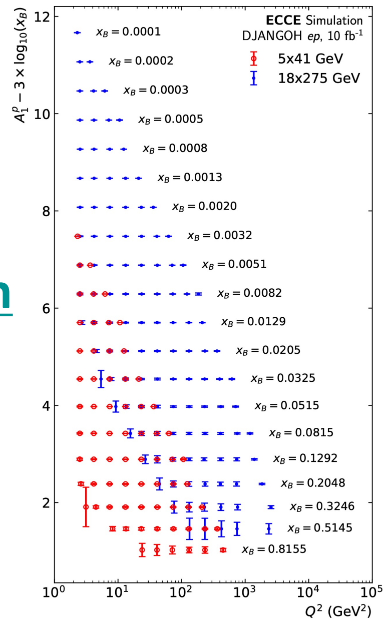
Femtography



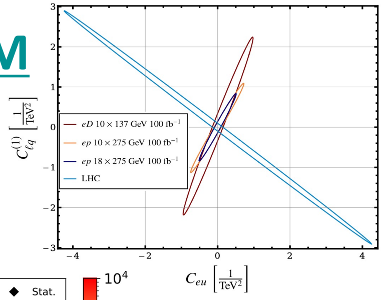
Spin



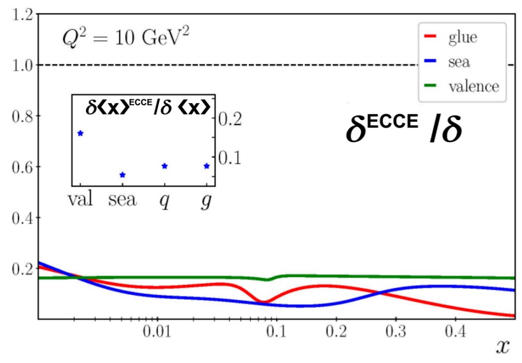




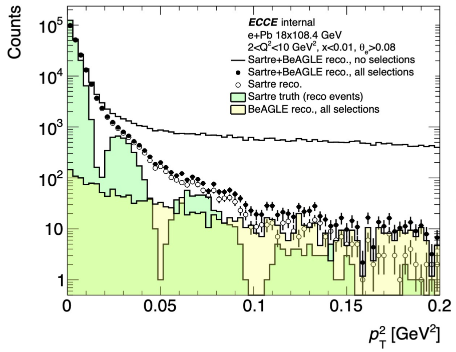
SM

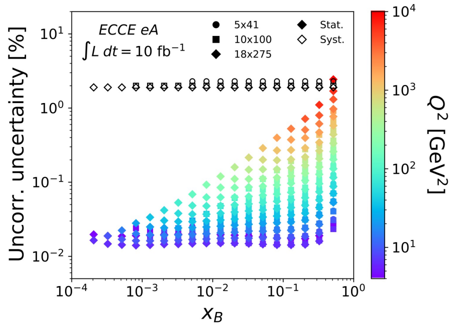


Mass



Gluons





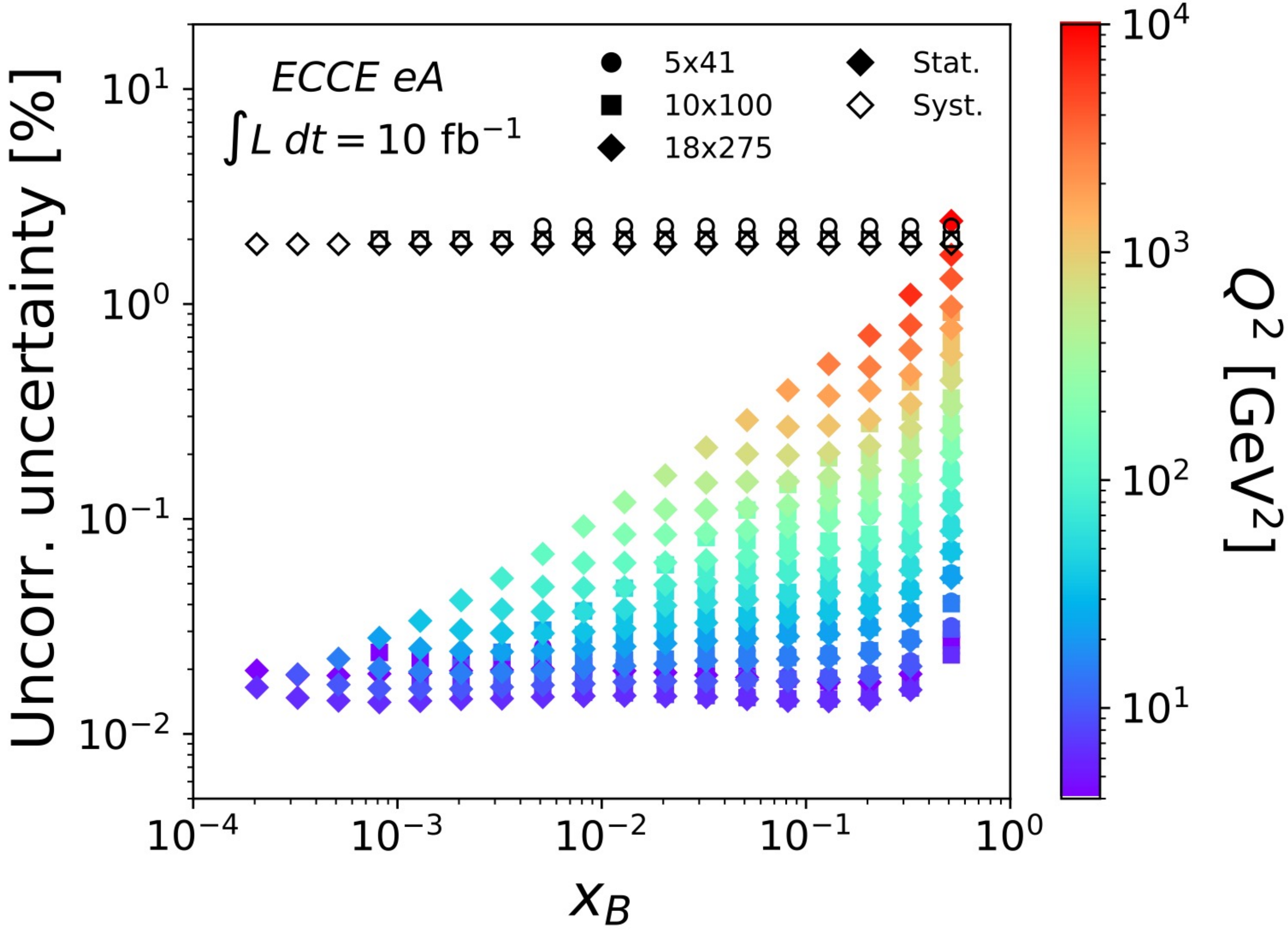
Multi-dimensional Imaging of Nucleons, Nuclei, and Mesons

Global Properties & Parton Structure of Hadrons

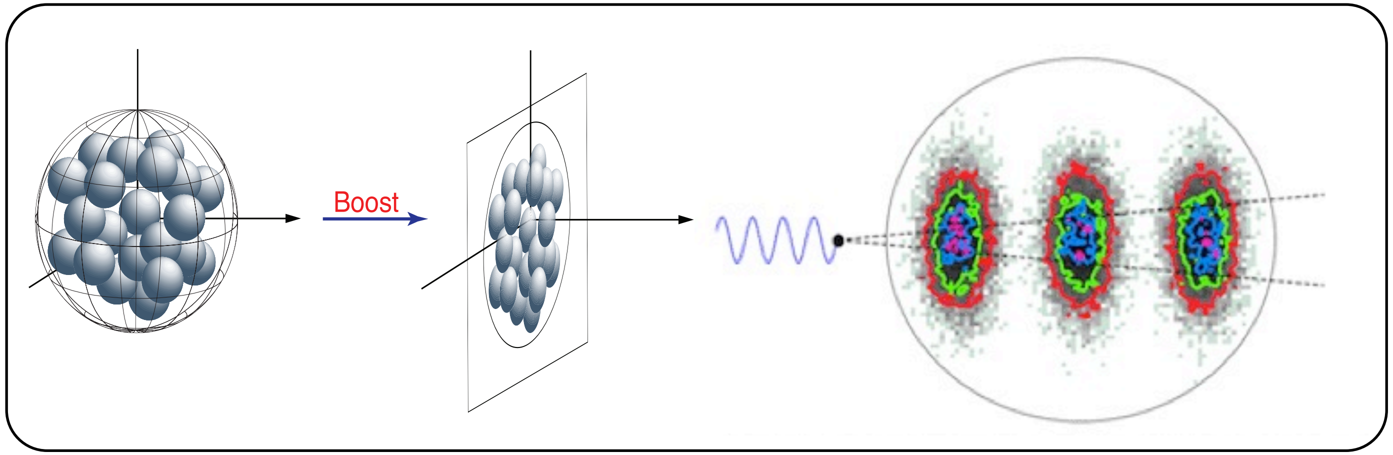
The Nucleus: A Laboratory for QCD

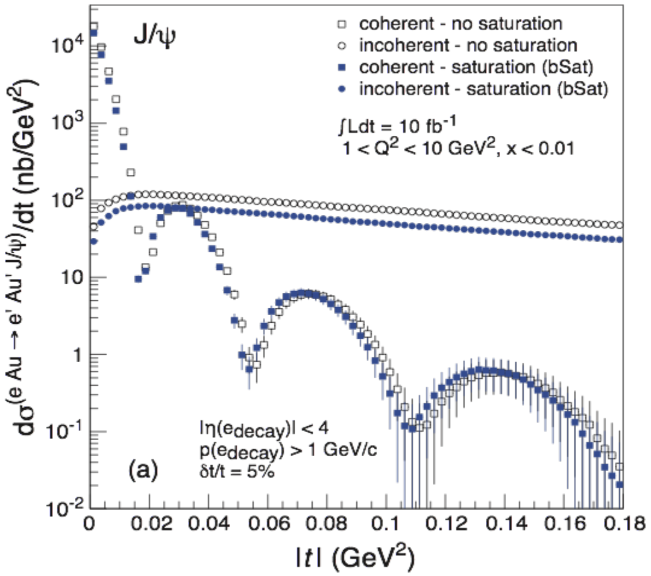
Electroweak and BSM

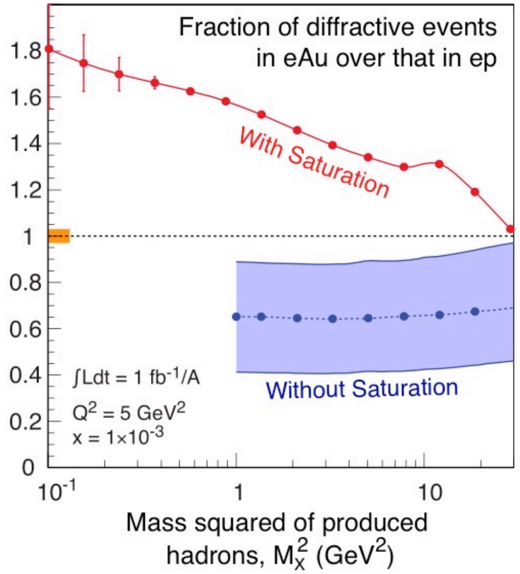
Nuclear PDFs



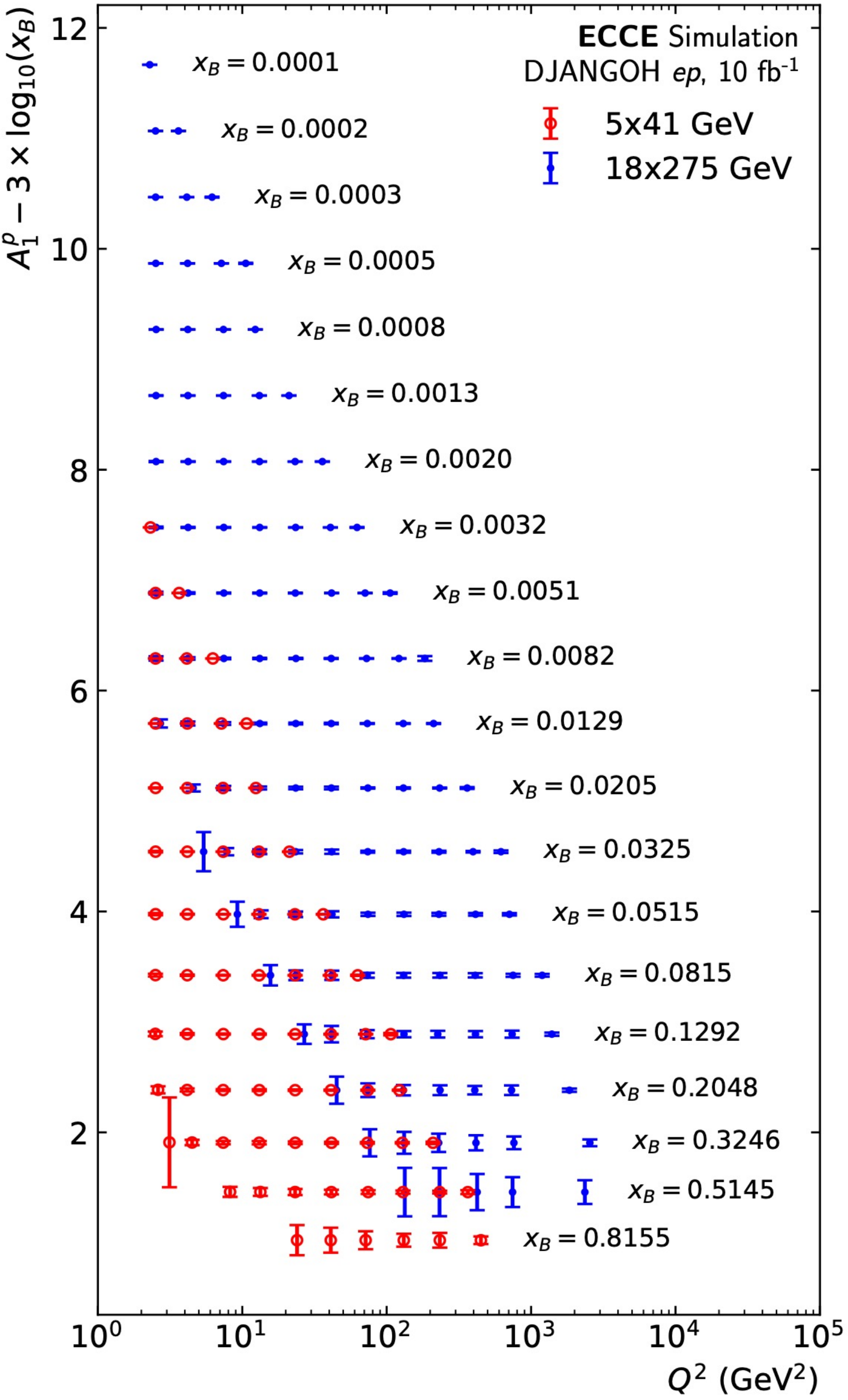
Imaging Gluons & looking for Saturation

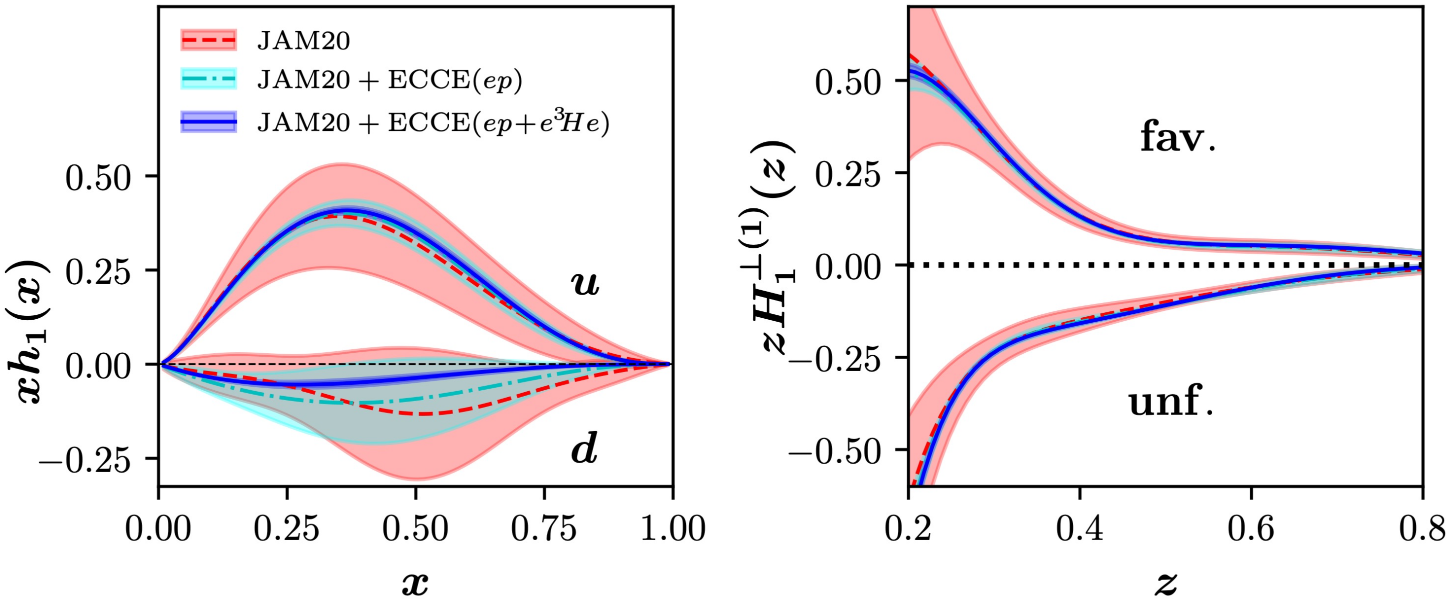


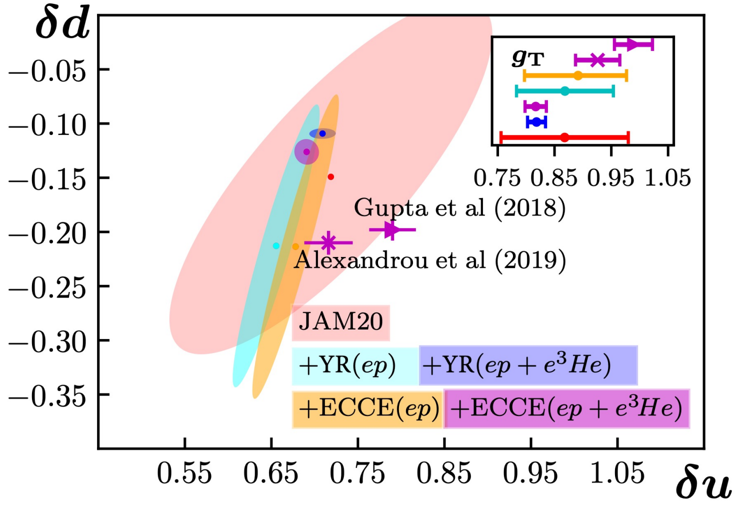




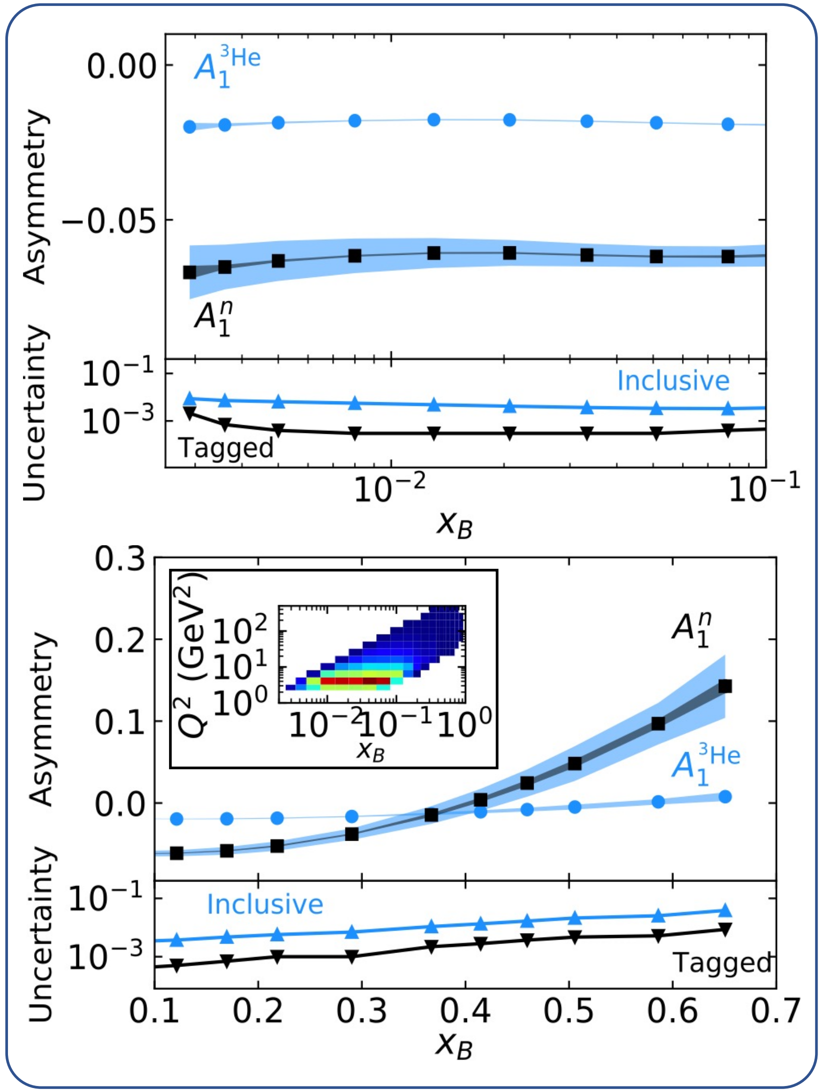
Spin Structure



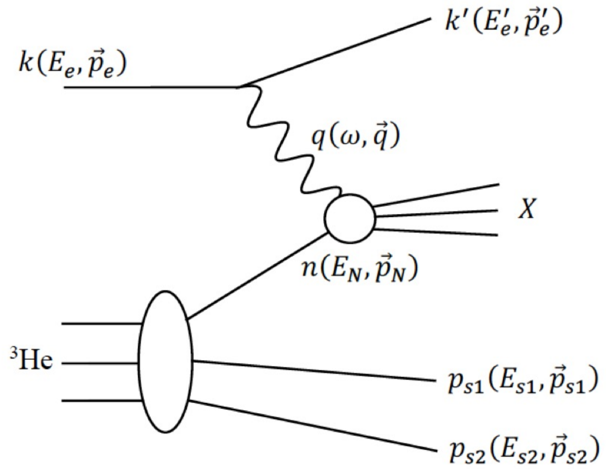




Neutron Spin from Double Tagging



Friscic and Nguyen et al.,
Phys. Lett. B, In-Print (2021)



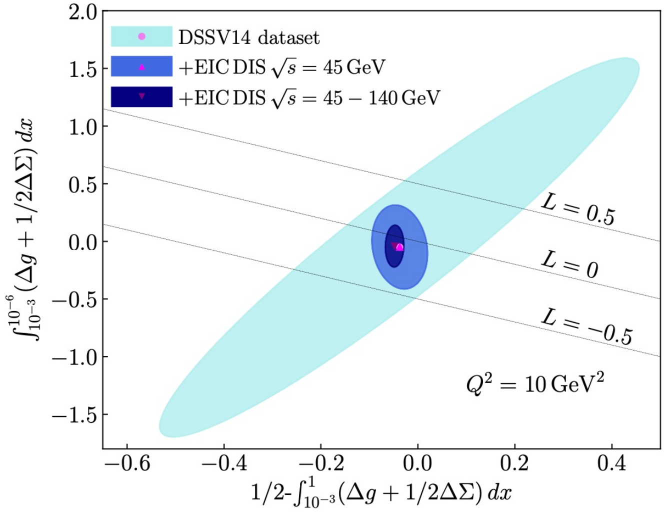


Figure 7.17: Room left for potential orbital angular momentum contributions to the proton spin at $Q^2 = 10\,\text{GeV}^2$, according to present data and future EIC measurements.

Outline

- The Quest to Understand the Fundamental Structure of Matter
- The US-Based Electron-Ion Collider (EIC)
- EIC Science
  - Femtography
  - Mass
  - Spin
  - Hadronization
  - Dense Gluon States
- **The ECCE EIC Detector**
- EIC Summary – A Portal to a New Frontier

EIC Detector

DOE released a call for ‘Collaboration Proposals for EIC detectors’

Submitted on Dec. 1st 2021. Review ongoing.

Strong interest in International involvement

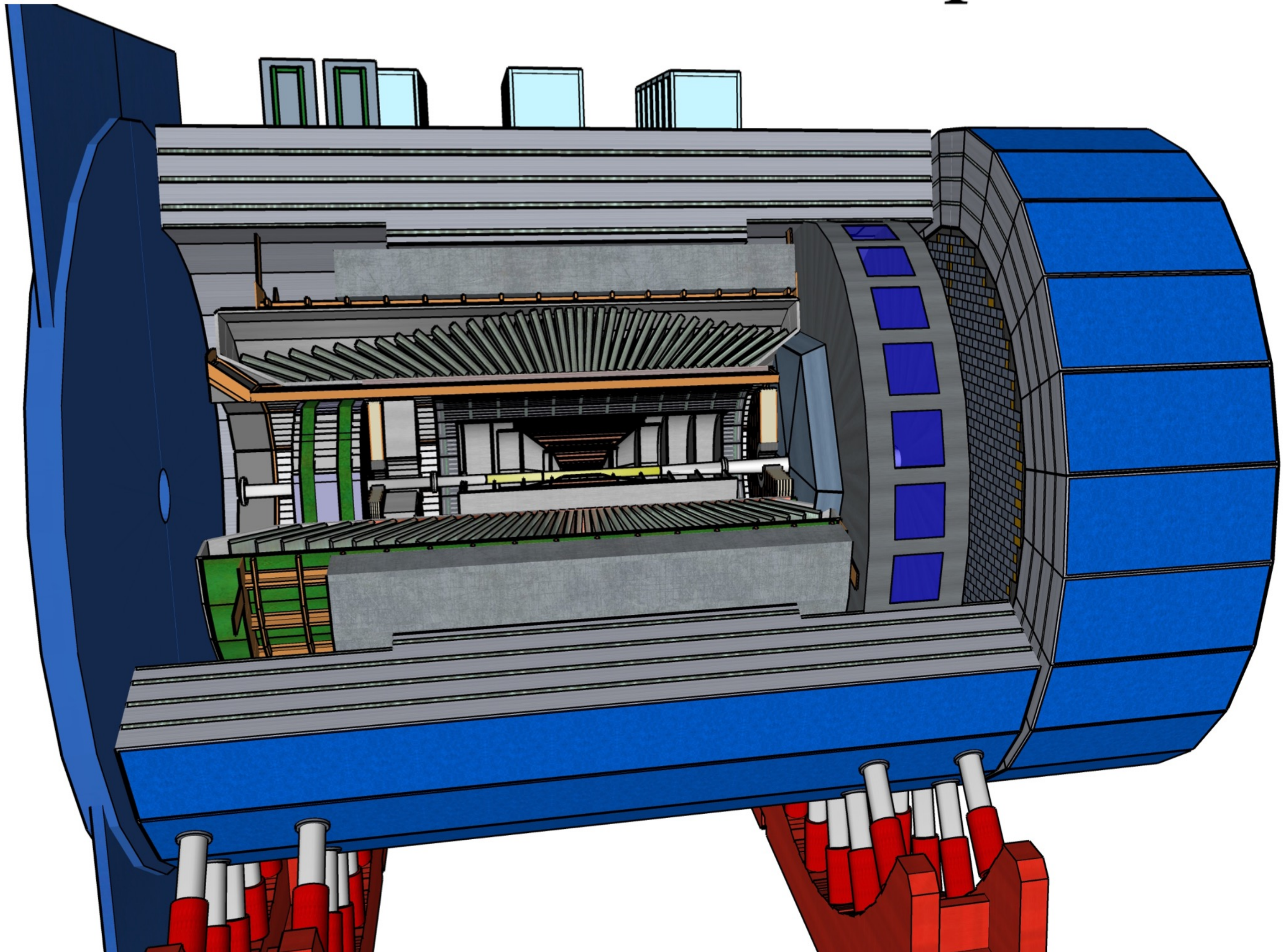
Excellent opportunity to take leadership & make an impact!

EIC Comprehensive Chromodynamics Experiment

ATHENA

A Totally Hermetic Electron-Nucleus Apparatus

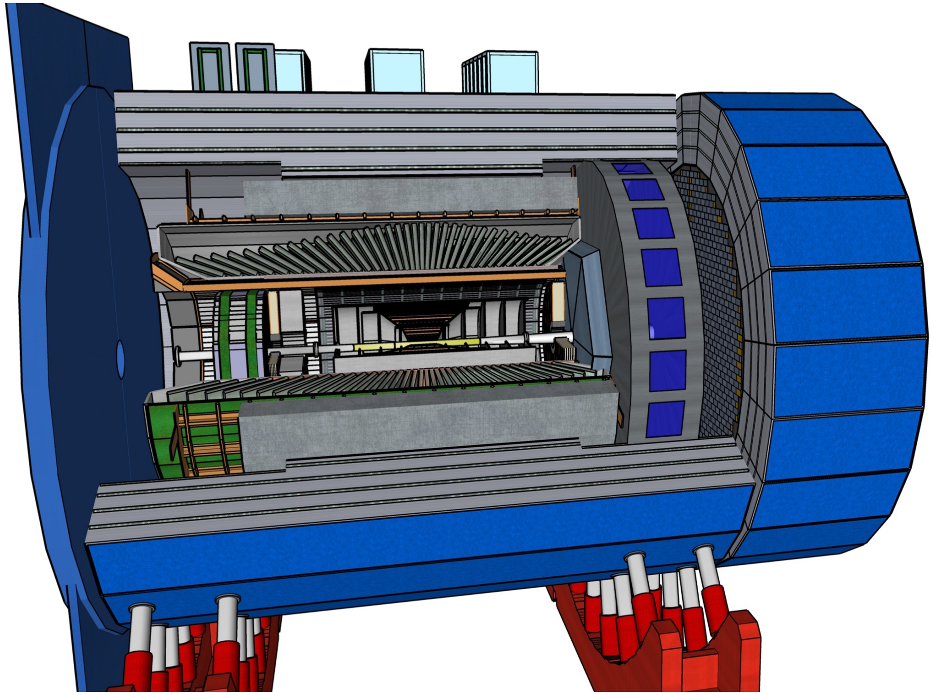
EIC Comprehensive Chromodynamics Experiment



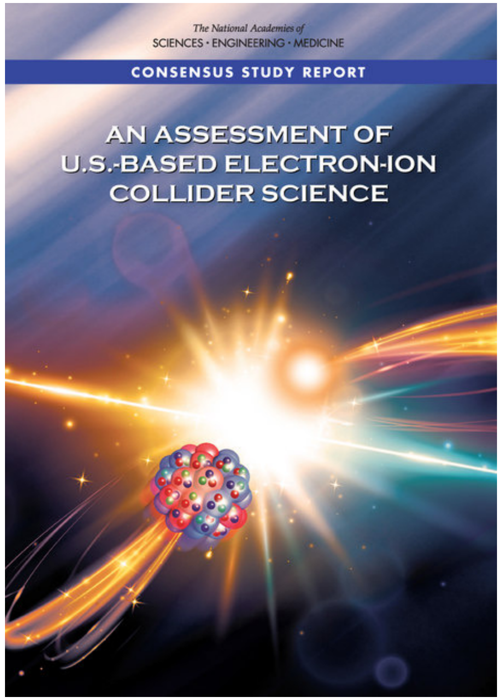
What's ECCE?

Scientists from 96 institutions

Designing (& building!) a detector



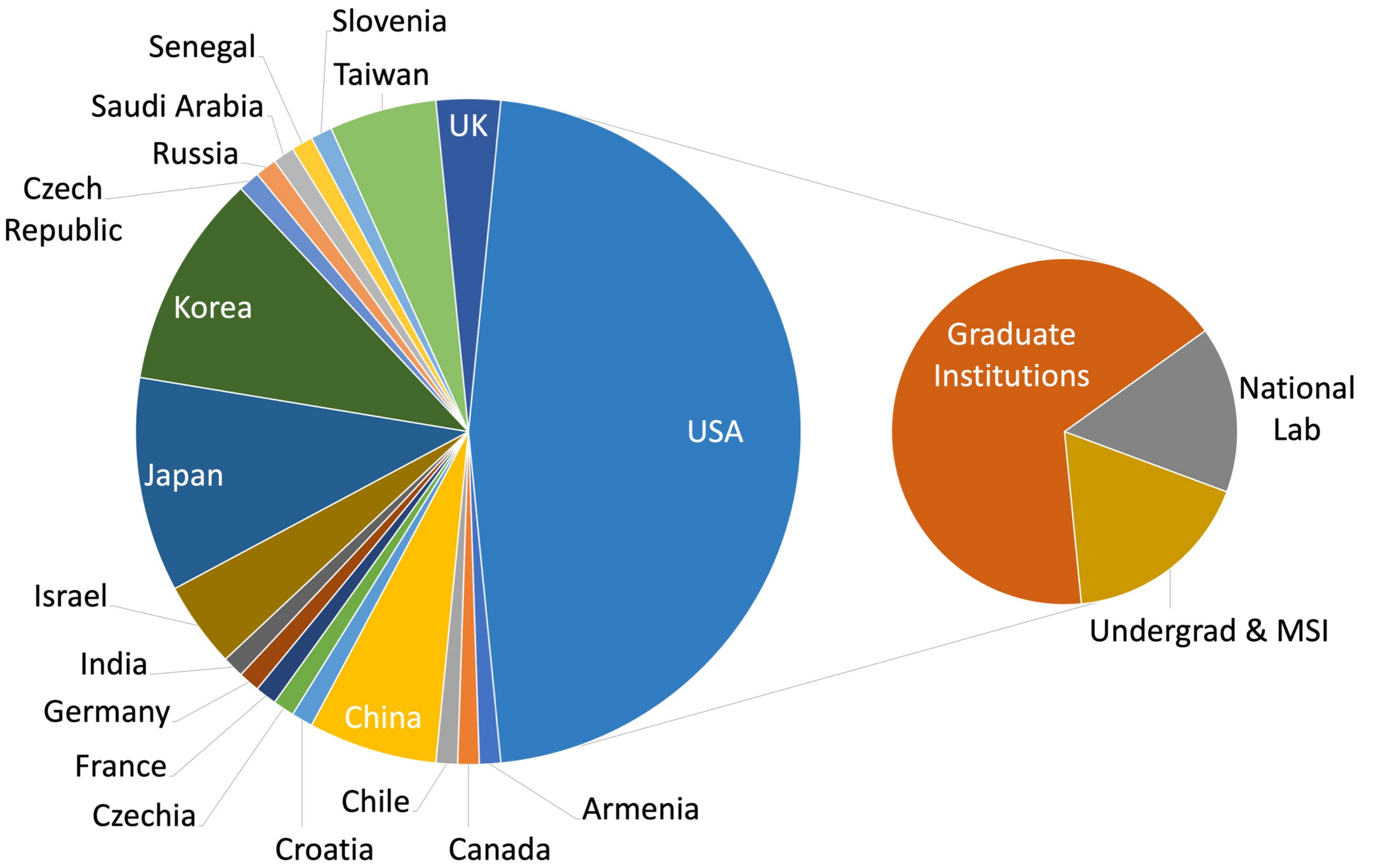
To deliver on EIC science mission



ECCE Consortium

96 institutions from:
- All RHIC experiments,
- All JLab Halls,
- All LHC experiments.

Experience with relevant projects, most recently:
- ALICE Tracking, Calorimetry, Readout,
- sPHENIX tracking, calorimetry, readout, Computing, Infrastructure,
- GlueX DIRC, Computing
- Hall C NPS,
- SBS GEM Trackers,
- CMS far-forward detectors, Computing, timing upgrade,
- ....



ECCE Consortium

EIC Project POC
Rolf Ent (JLab)

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John Lajoie (ISU)

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- Computing and Software
  Joe Osborn (ORNL)

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Christine Nattrass (UTK, co-chair)
Simonetta Liuti (UVA)
Elena Long (UNH)

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Ken Read (ORNL)

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- Far Forward/Far Backward*
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  Yuji Goto (RIKEN), Igor Korover (MIT)
- Tracking
  Xuan Li (LANL),
  Nilanga Liyanage (UVA)
- Calorimetry
  Friederike Bock (ORNL), Yongsun Kim (Sejong U.)
- Particle ID
  Greg Kalicy (CUA),
  Xiaochun He (GSU)
- Magnetic Field
  Paul Brindza (JLab),
  Renuka Rajput-Ghoshal (JLab)
- DAQ/Electronics/Readout
  Chris Cuevas (JLab),
  Martin Purschke (BNL)

***Alex Jentsch, Yulia Furletova**
(far-forward/backward POC)

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- Semi-Inclusive
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- BSM and Precision Electroweak
  Sonny Mantry (UNG), Xiaochao Zheng (UVa)

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Peter Steinberg (BNL)

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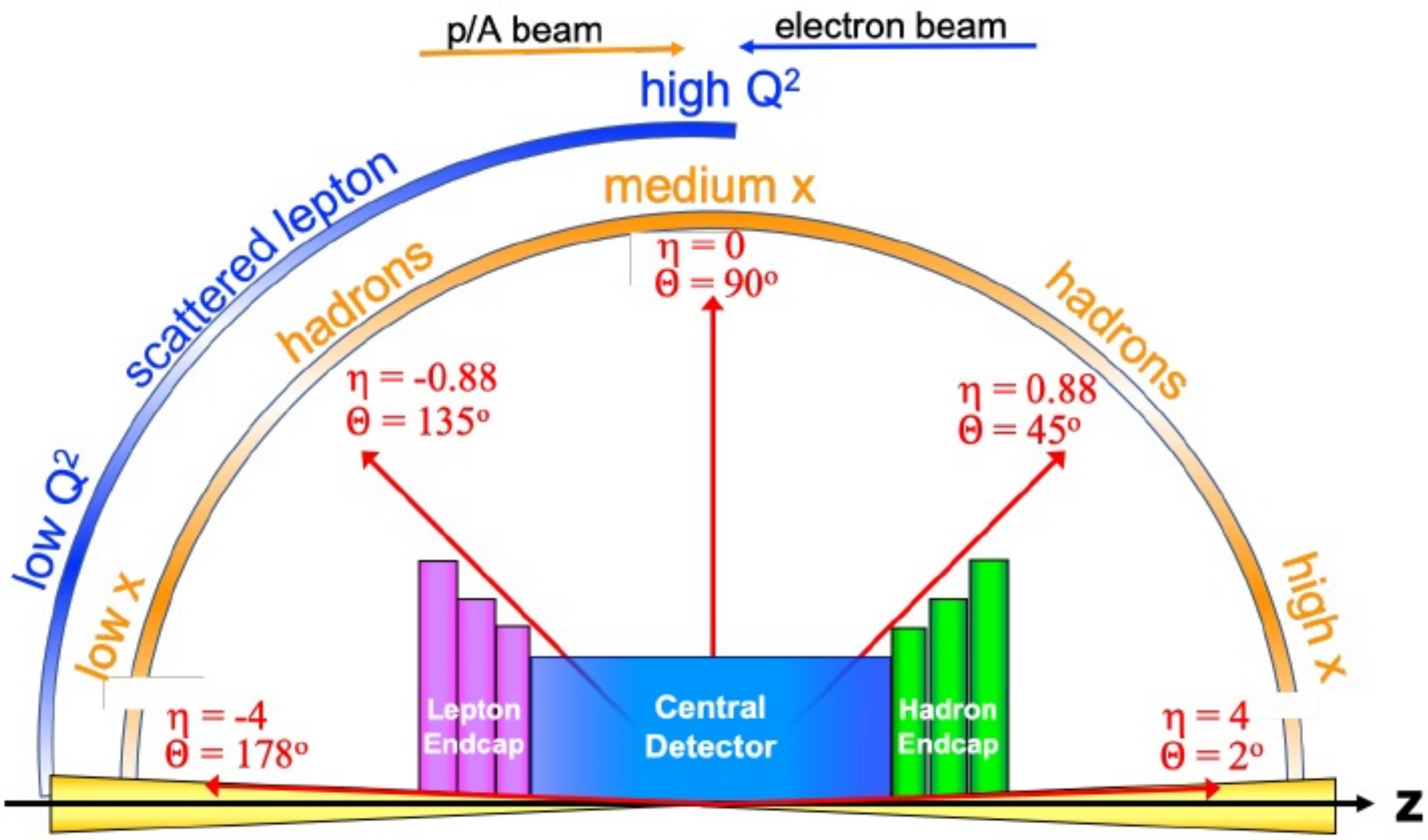
- Proposal Editing, Verification and Version Control
- Costing and Management

EIC Detector



EIC Detector Layout

HCal

↑

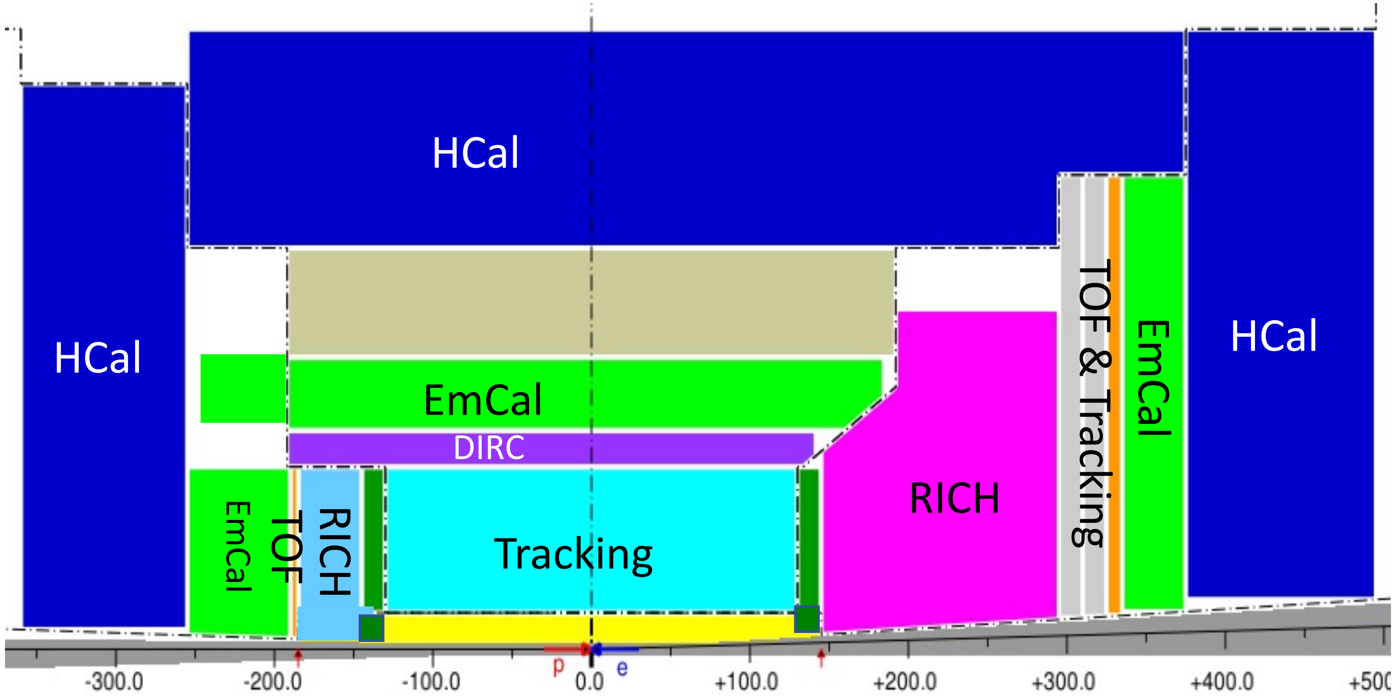
EM-Cal

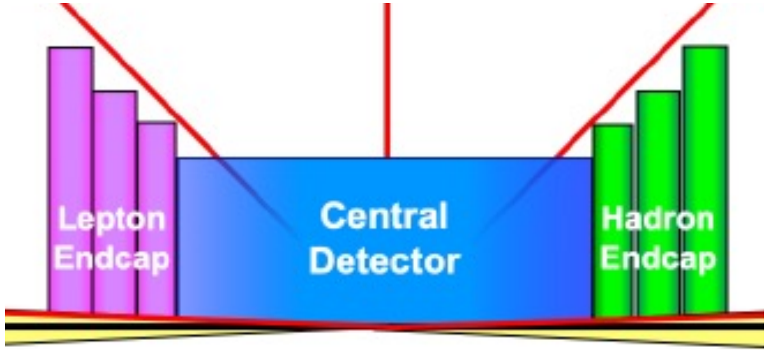
↑

Cherenkov & TOF PID

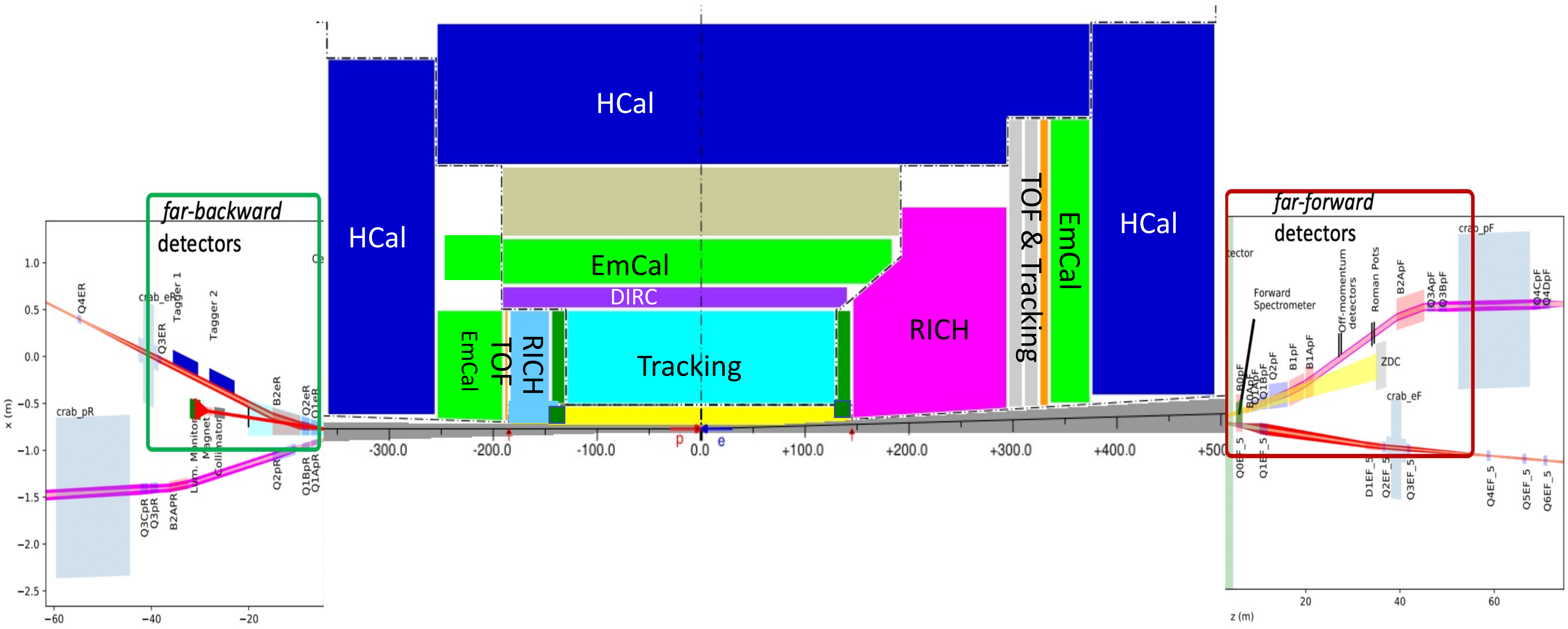
↑

Tracking

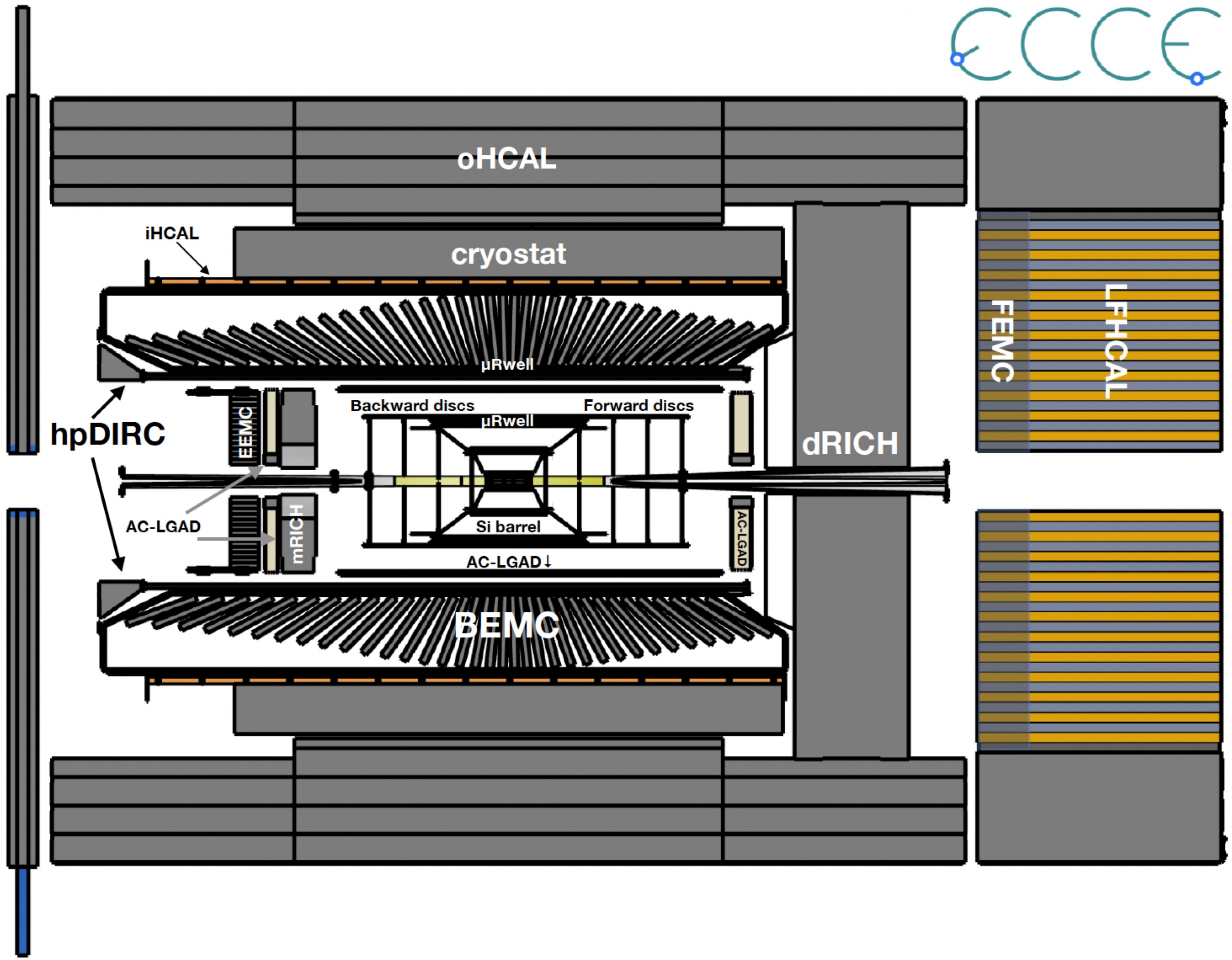


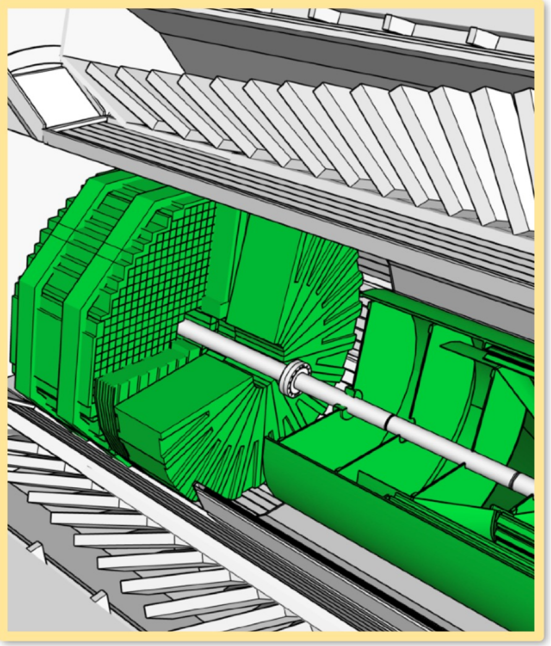


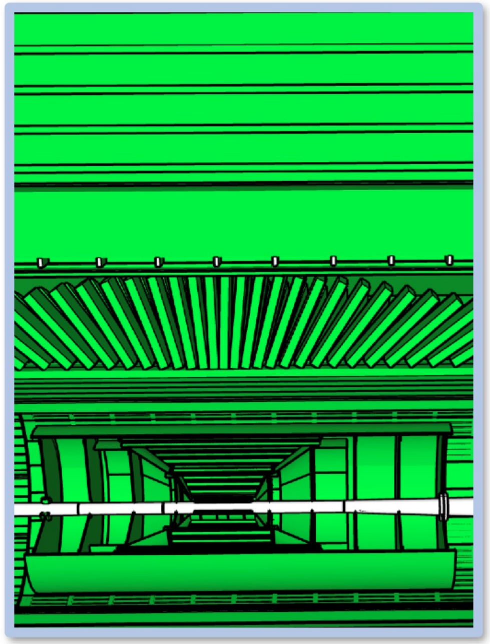
EIC Detector Layout

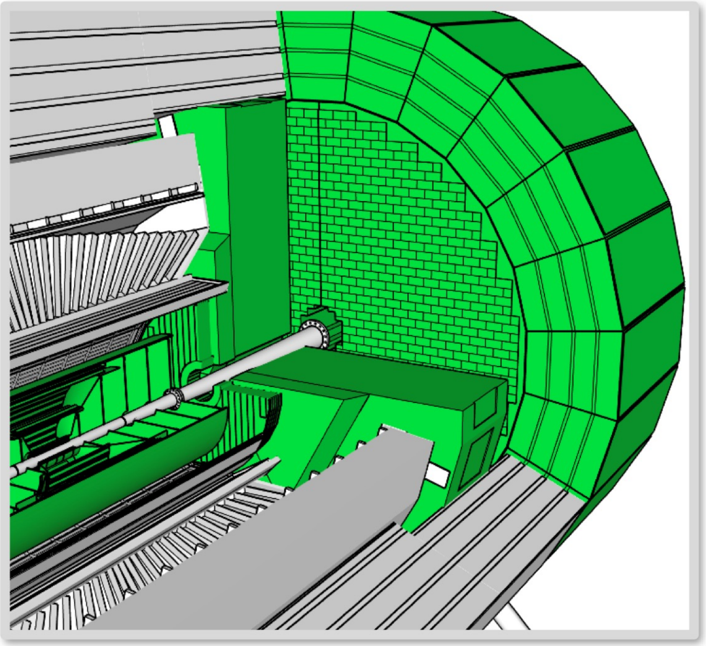


ECCE Central Detector









Backward Endcap

Tracking:

- ITS3 MAPS Si discs (x4)
- AC-LGAD

PID:

- mRICH
- AC-LGAD TOF
- $PbWO_4$ EM Calorimeter (EEMC)

Barrel

Tracking:

- ITS3 MAPS Si (vertex x3; sagitta x2)
- µRWell outer layer (x2)
- AC-LGAD (before hpDIRC)
- µRWell (after hpDIRC)

h-PID:

- AC-LGAD TOF
- hpDIRC

Electron ID:

- SciGlass EM Cal (BEMC)

Hadron calorimetry:

- Outer Fe/Sc Calorimeter (oHCAL)
- Instrumented frame (iHCAL)

Forward Endcap

Tracking:

- ITS3 MAPS Si discs (x5)
- AC-LGAD

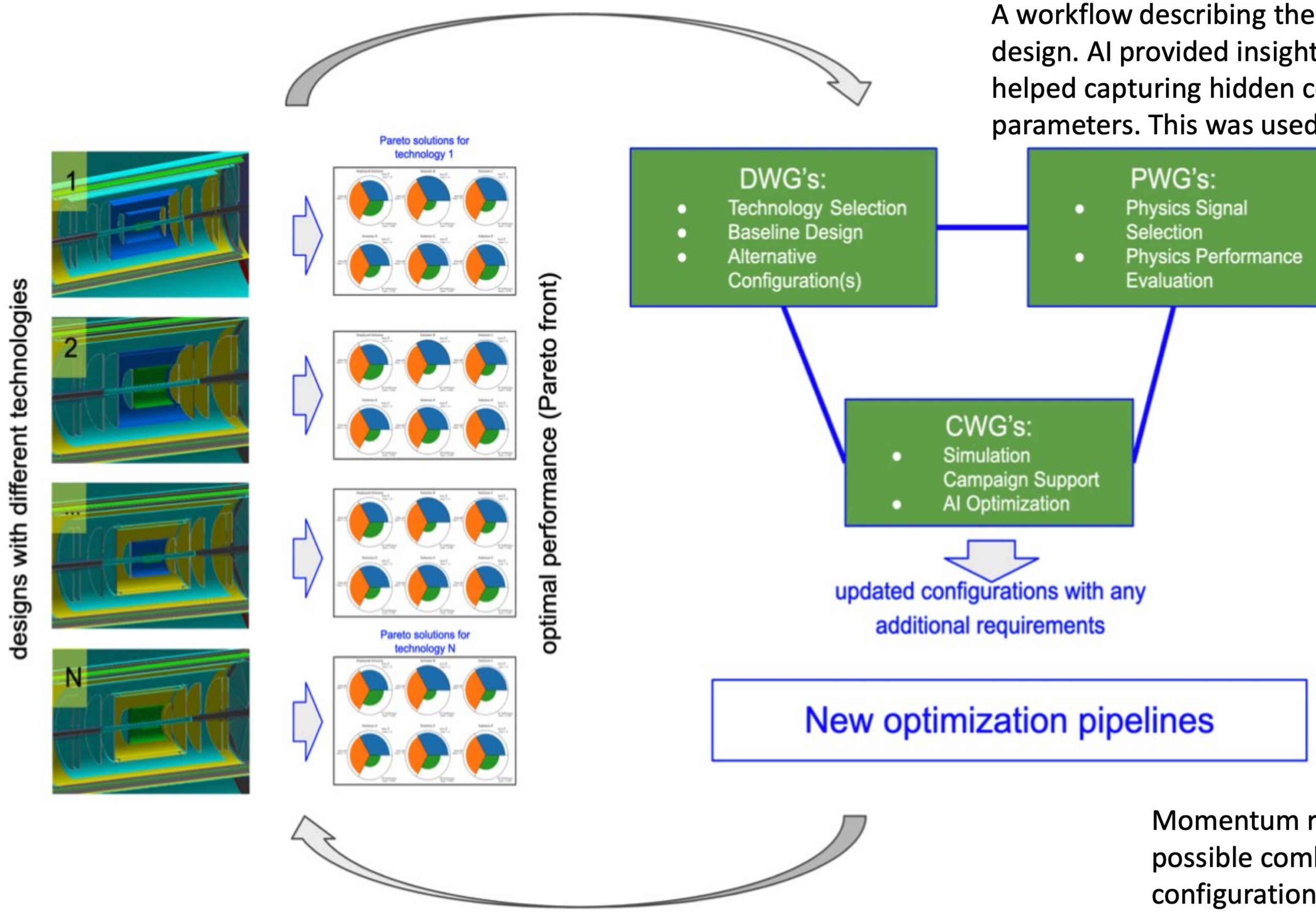
PID:

- dRICH
- AC-LGAD TOF

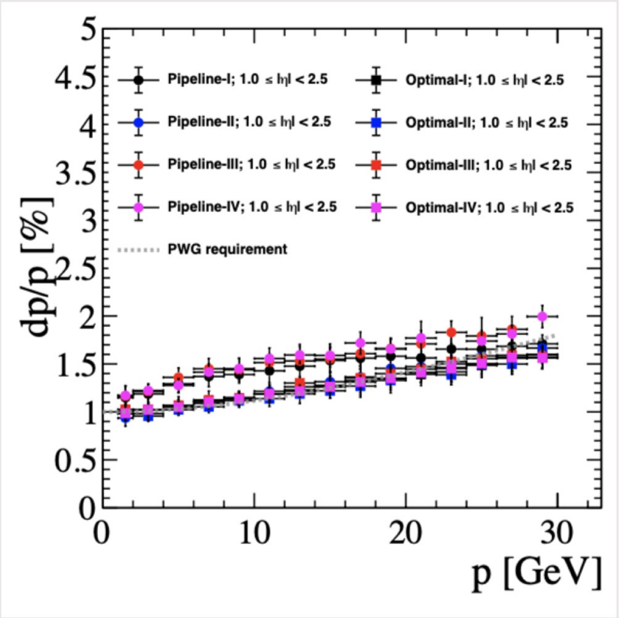
Calorimetry:

- Pb/ScFi shashlik (FEMC)
- Longitudinally separated hadronic calorimeter (LHFCAL)

AI Assisted Detector Design

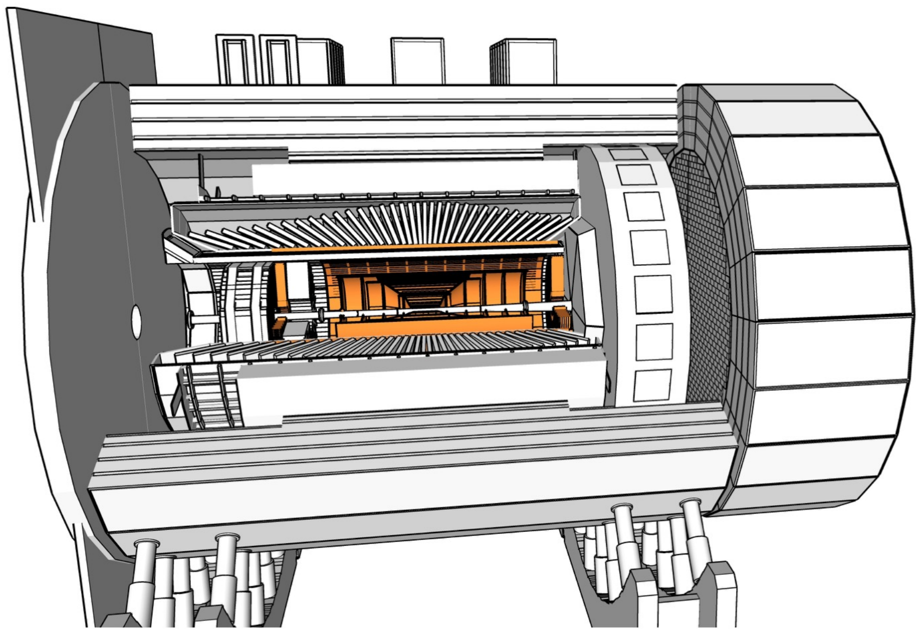


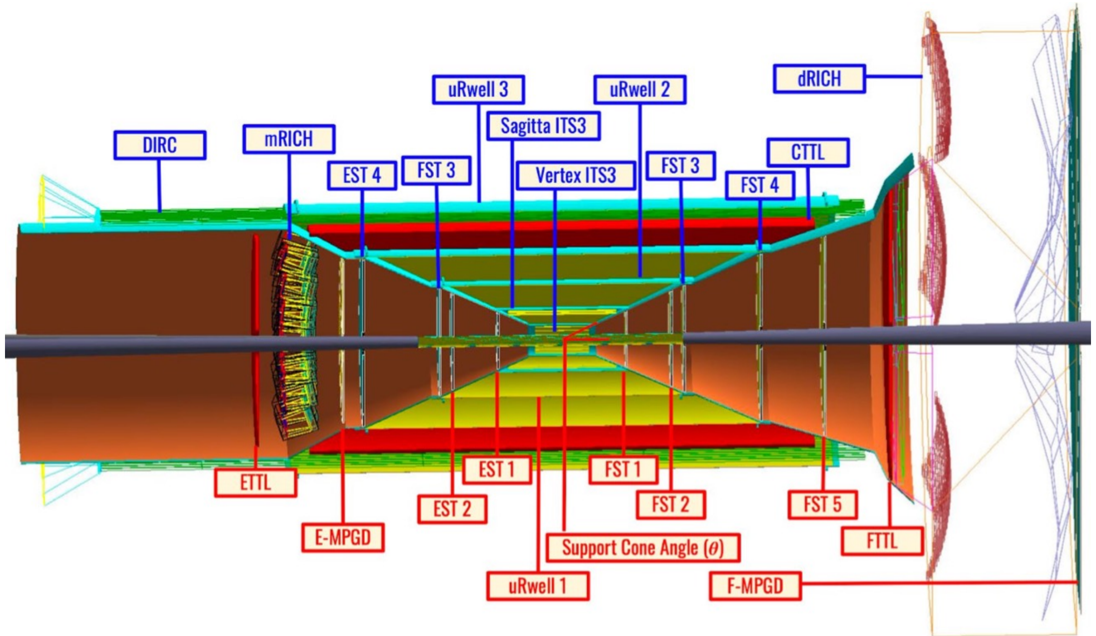
A workflow describing the iterative process of detector design. AI provided insights for technology choices and helped capturing hidden correlations among the design parameters. This was used to steer the design

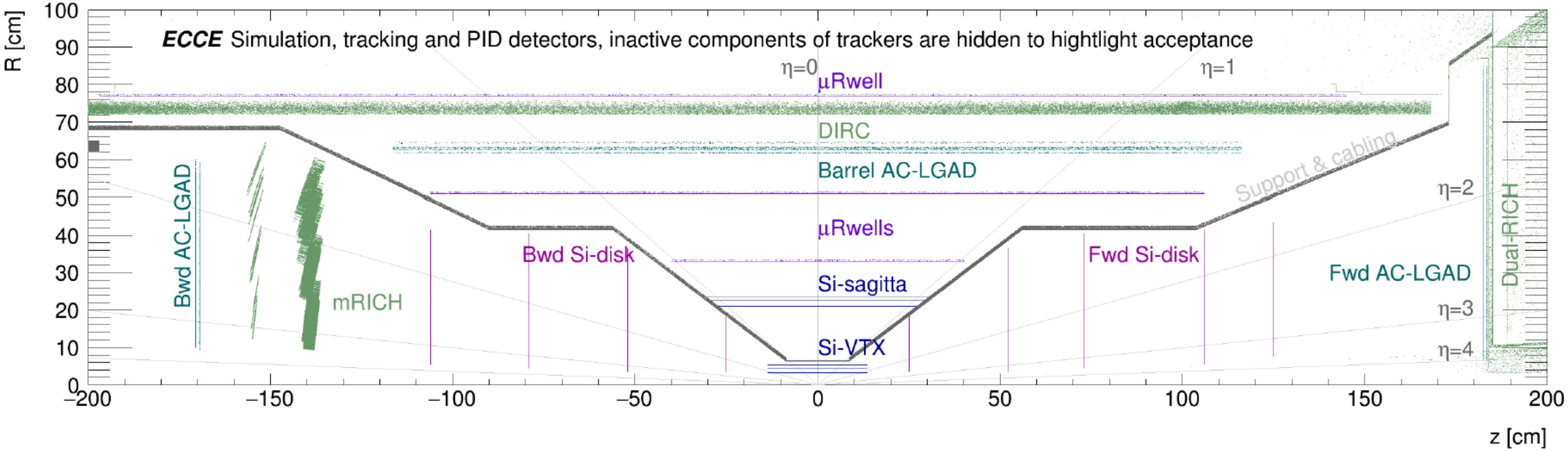


Momentum resolution of different pipelines corresponding to different possible combinations of technology optimized with AI. The AI-optimized configuration outperformed the original designs in all η bins.

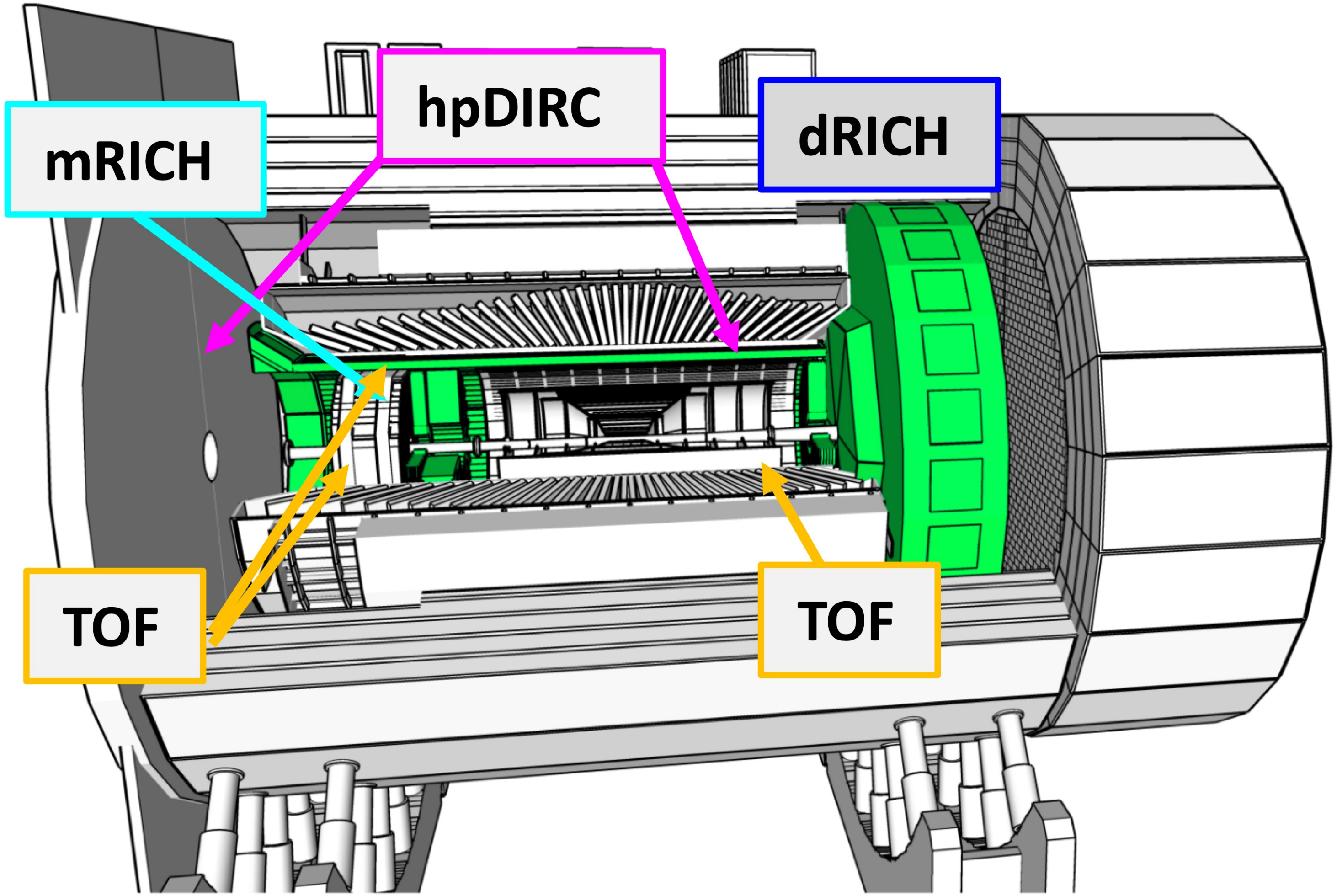
Particle Tracking

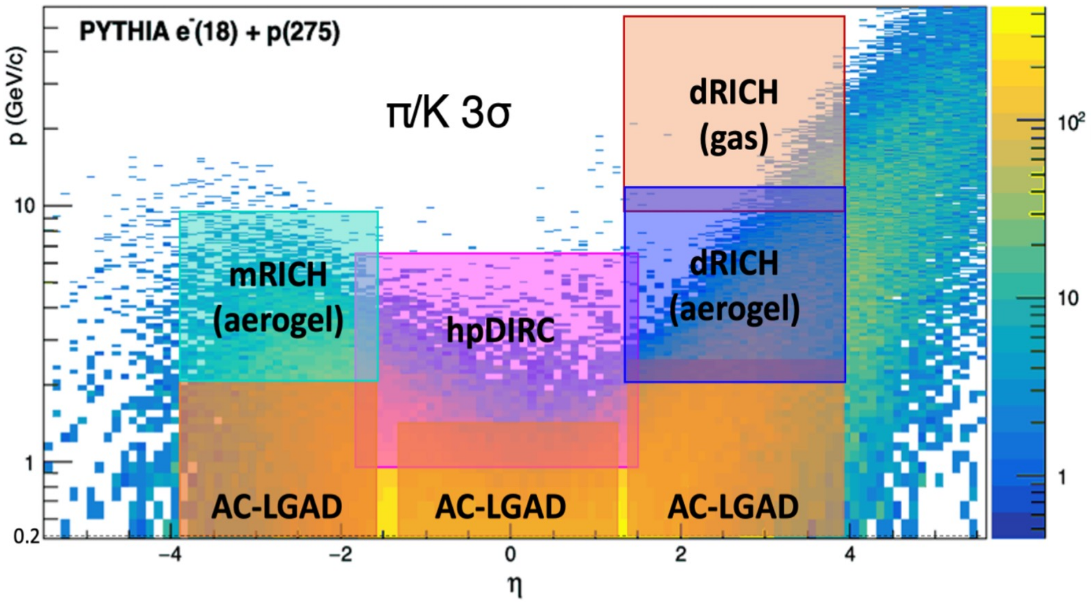






Particle Identification (PID)

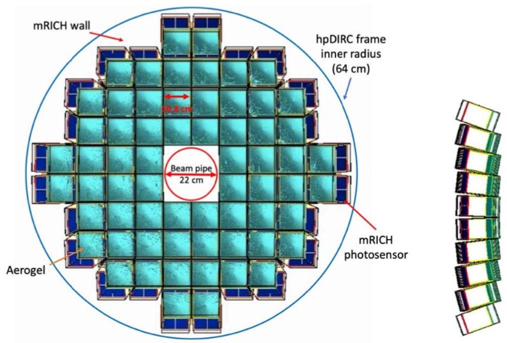


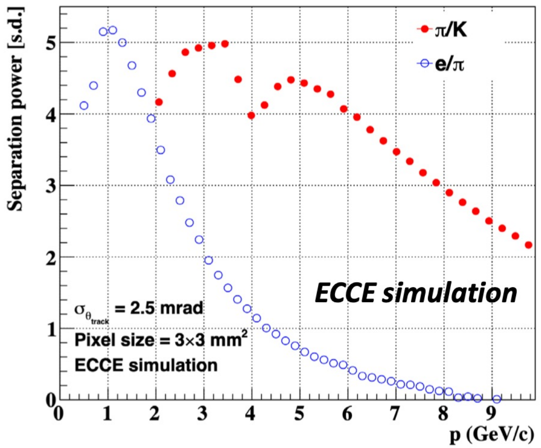


Cerenkov PID

Backward PID

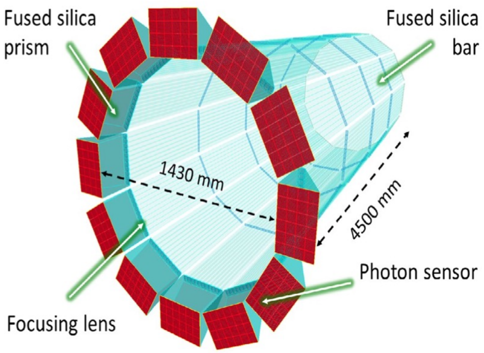
Compact version of a conventional aerogel-based proximity focusing RICH

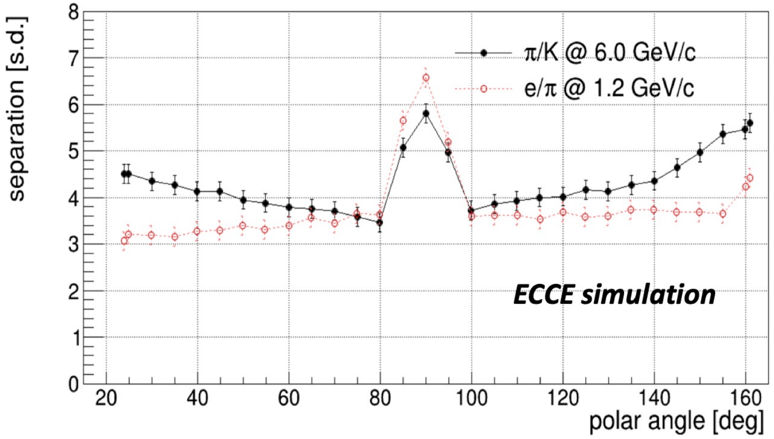




Barrel PID

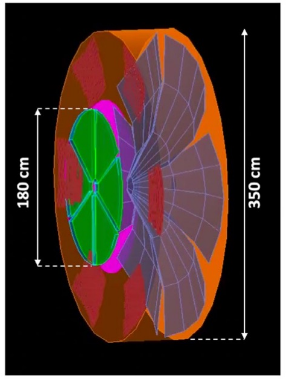
- Radially compact (~ 5cm)
- hpDIRC with better optics and <100 ps timing (π/K up to ~6 GeV/c)

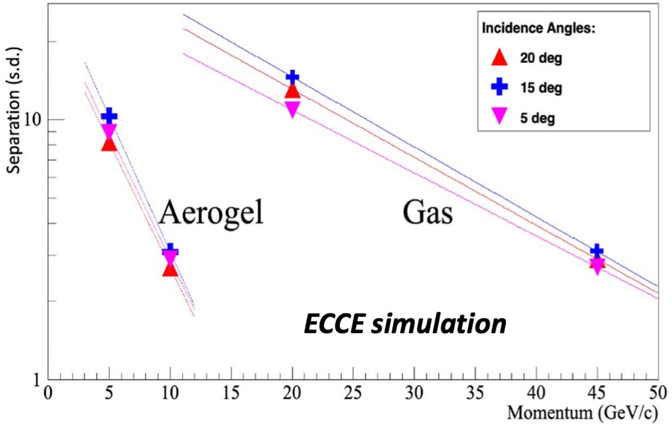




Forward PID

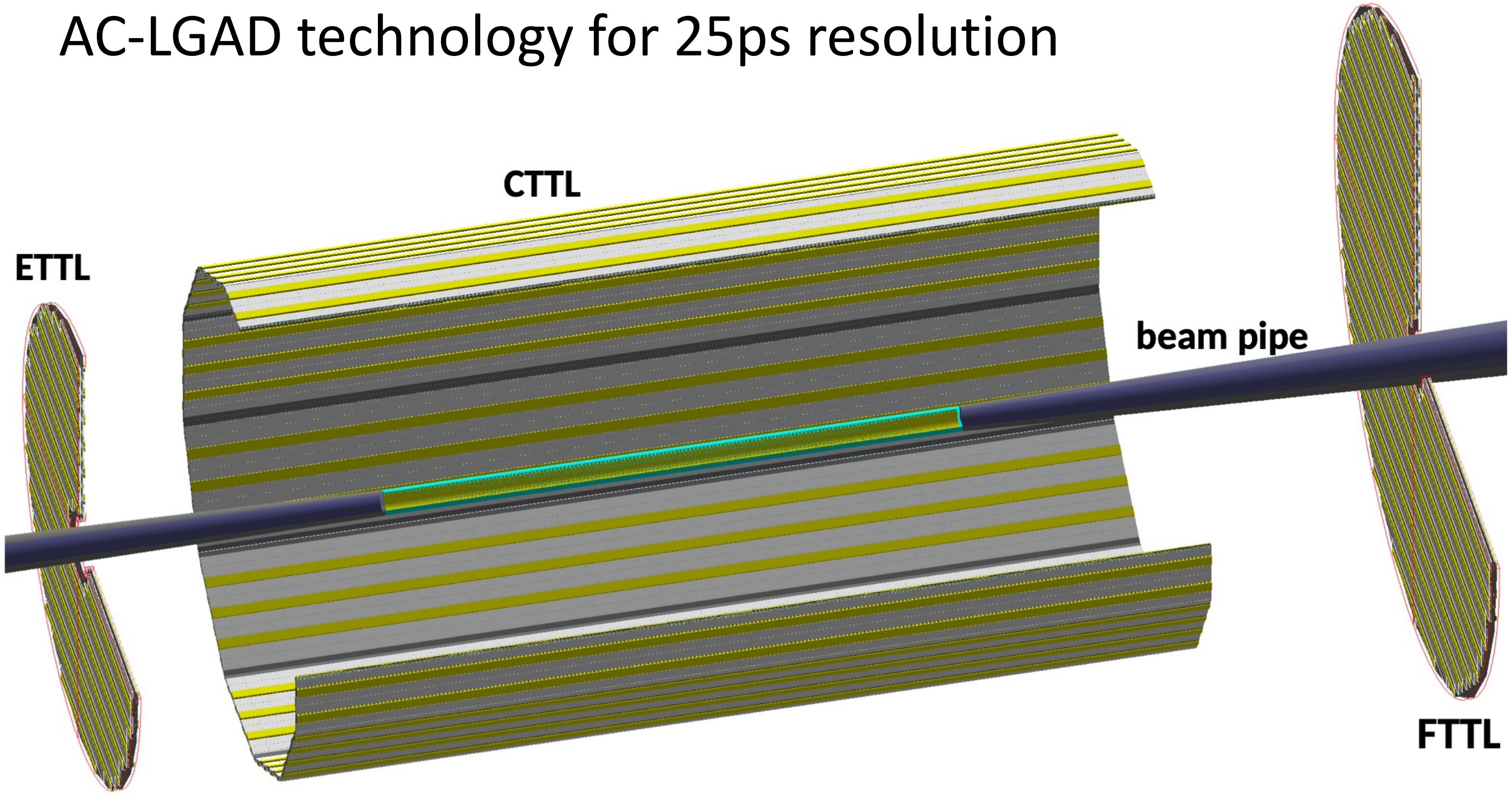
Use a combination of aerogel and C_mF_n with indices of refraction matching EIC momentum range in the forward endcap. Similar to LHC-b, HERMES, JLAB/Hall-B, …

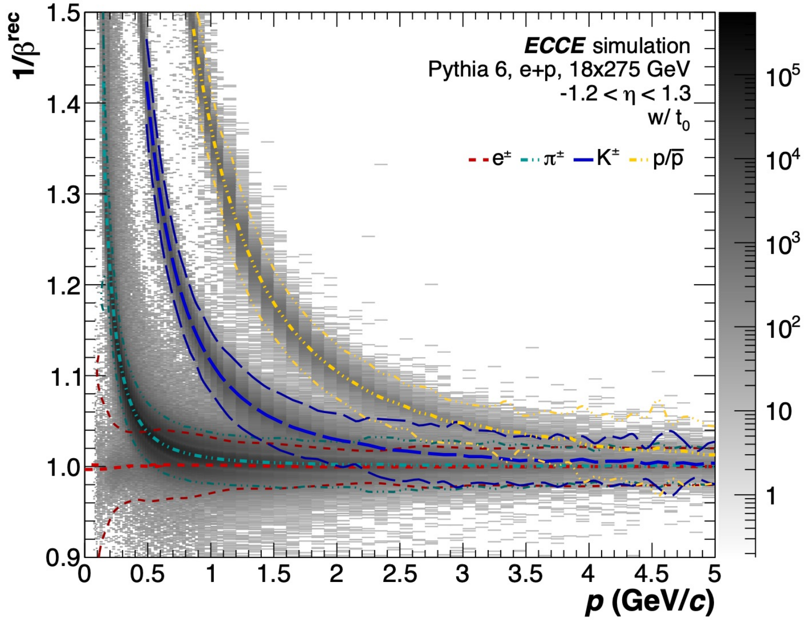




Time-Of-Flight (TOF) PID

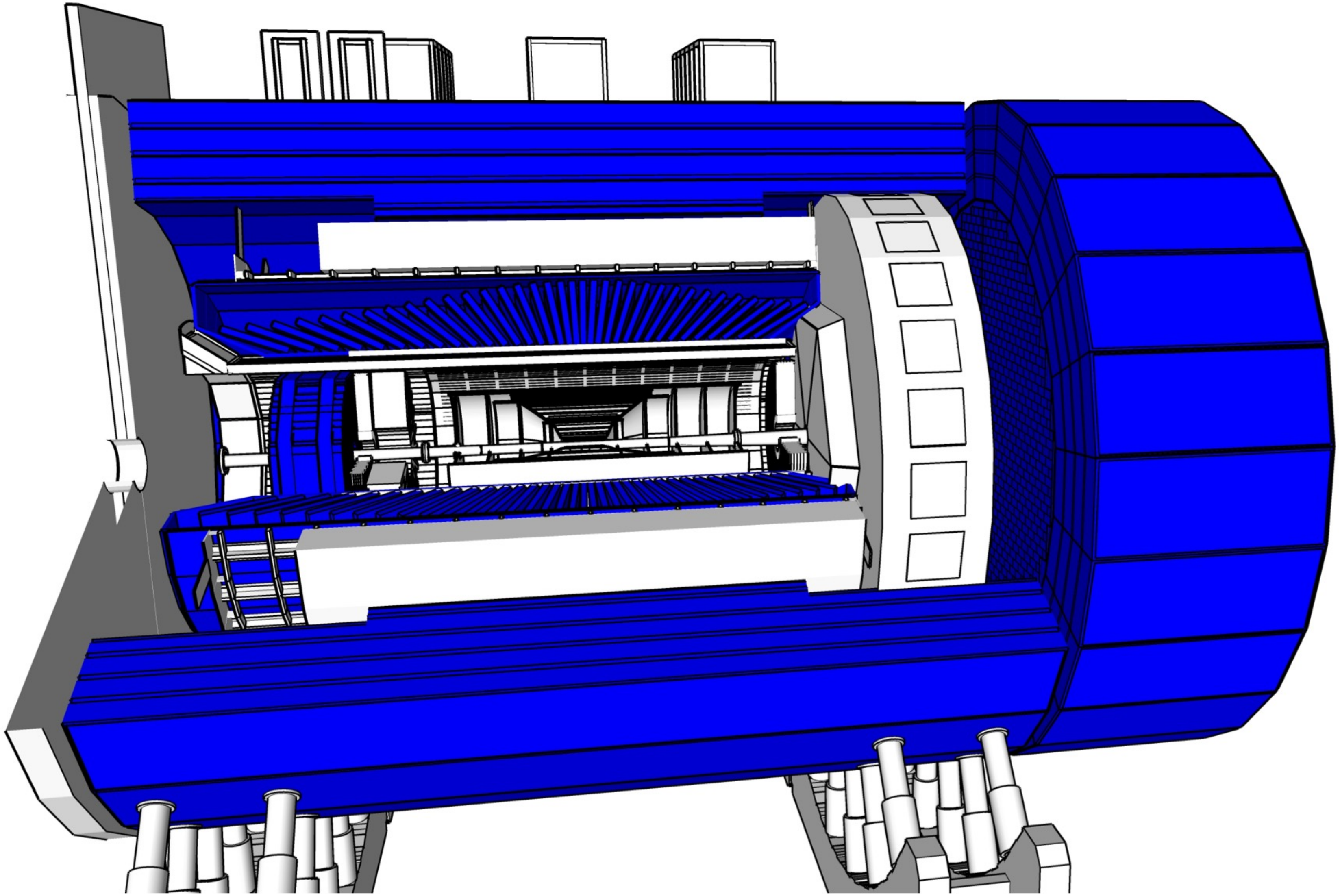
AC-LGAD technology for 25ps resolution





PID	ETTL	CTTL	FTTL
e/π	< 0.5	< 0.45	< 0.6
π/K	< 2.1	< 1.3	< 2.2
K/p	< 3.3	< 2.2	< 3.7

Calorimetry



Calorimetry

Backward ECAL (EEMC)

Homogeneous calorimeter based on high-resolution $PbWO_4$ crystals

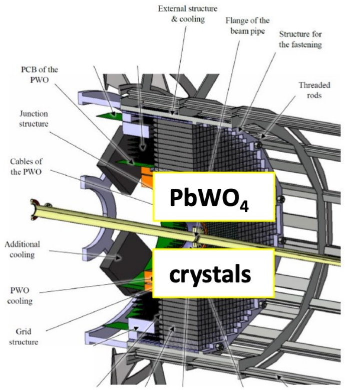


Figure from the EIC EEEMCAL Consortium design report

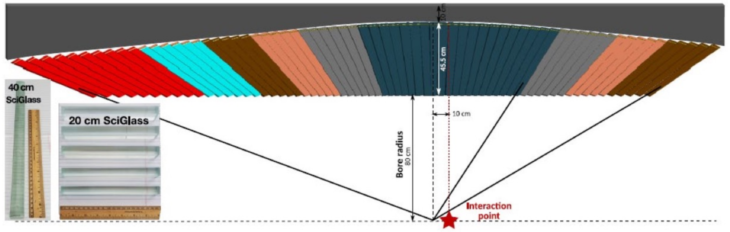
Backward ECAL

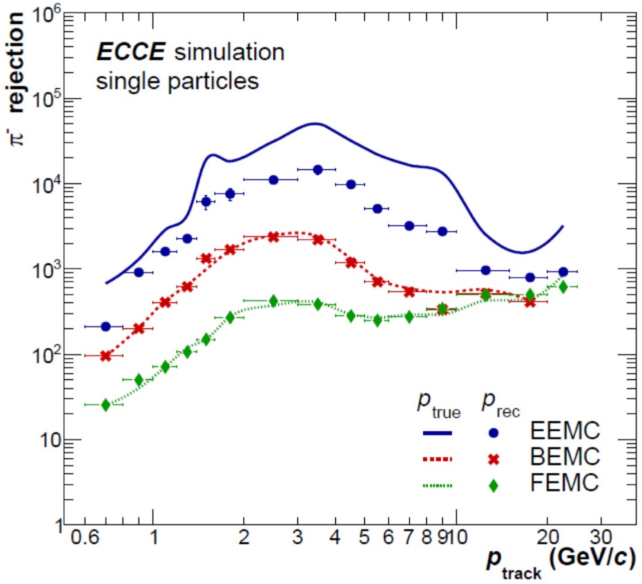
η	[-4 .. -1.8]
σ_E/E	2%/√E+1%*

*Based on prototype beam tests and earlier experiments

Barrel ECAL (BEMC)

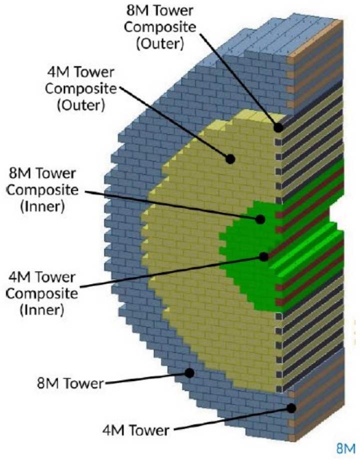
Homogeneous, projective calorimeter based on SciGlass, cost-effective alternative to crystals





Forward ECAL (FEMC)

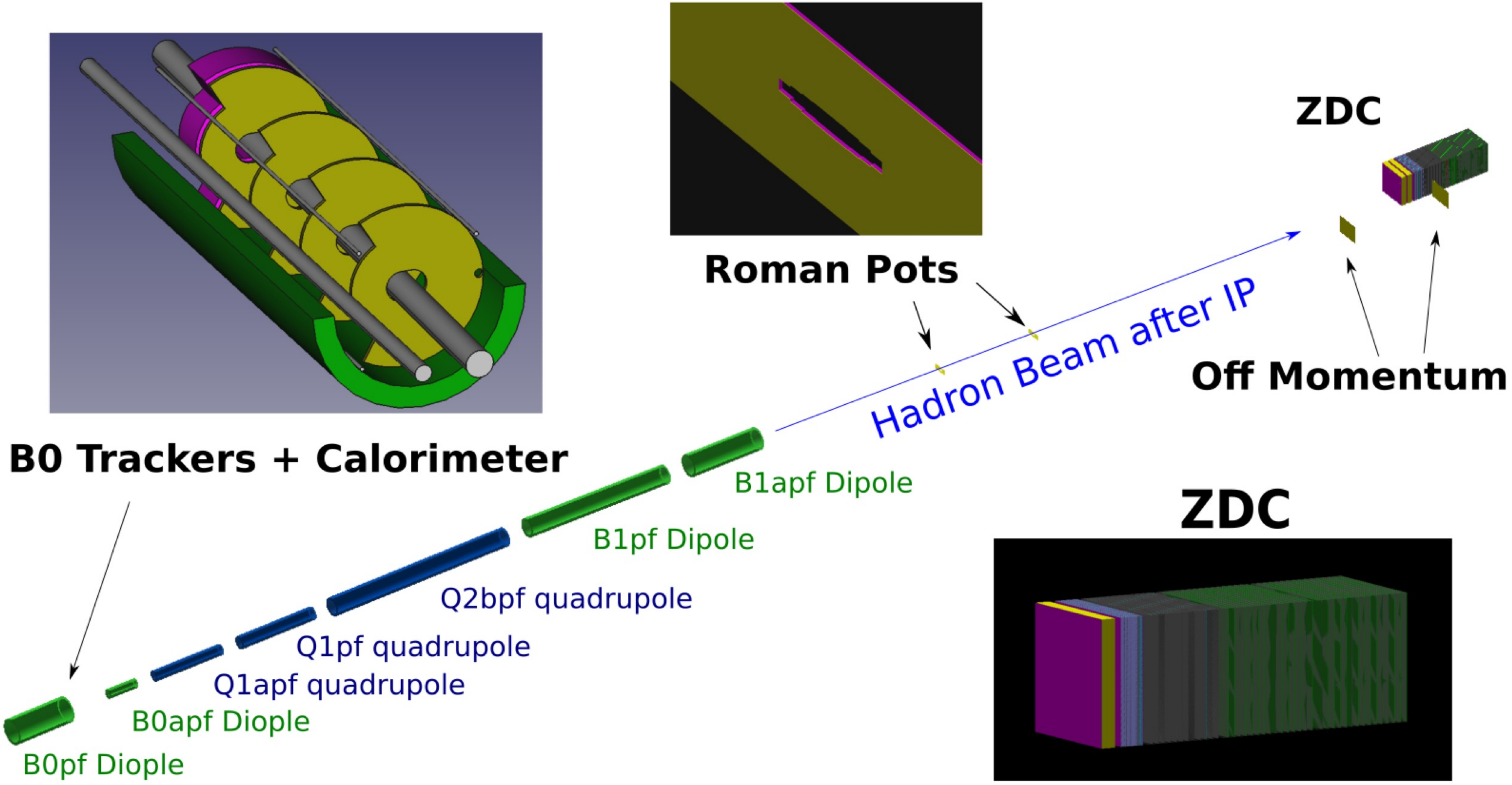
Highly-granular shashlik sampling calorimeter based on Pb/SC



	Barrel ECAL	Forward ECAL
η	[-1.7 .. 1.3]	[1.3 .. 4]
σ_E/E	2.5%/√E+1.6%*	7.1%/√E+0.3%

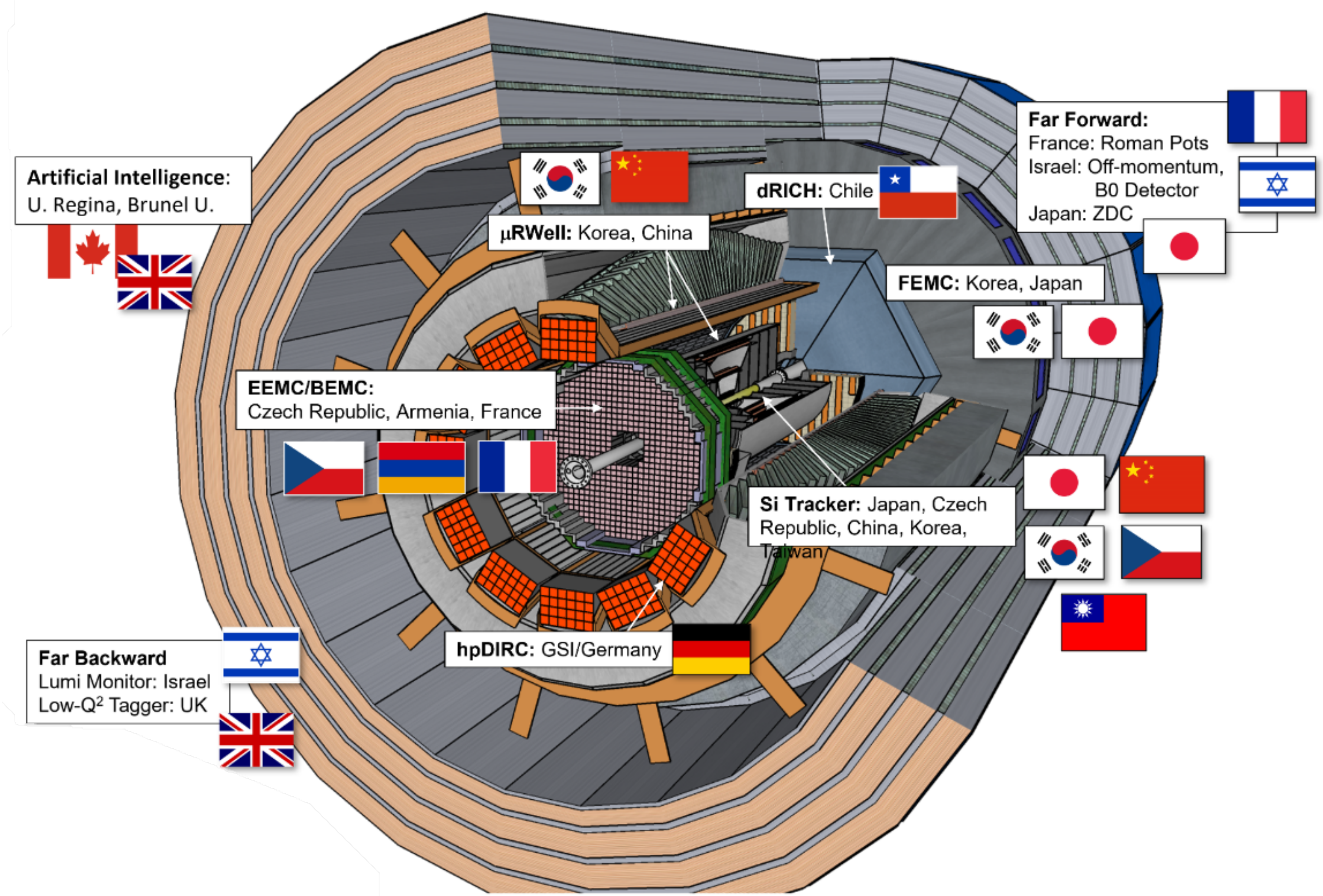
*Based on prototype beam tests and earlier experiments

ECCE EM calorimeters provide the required coverage, meet the physics energy resolution, and pion suppression in all three regions (endcaps, barrel)

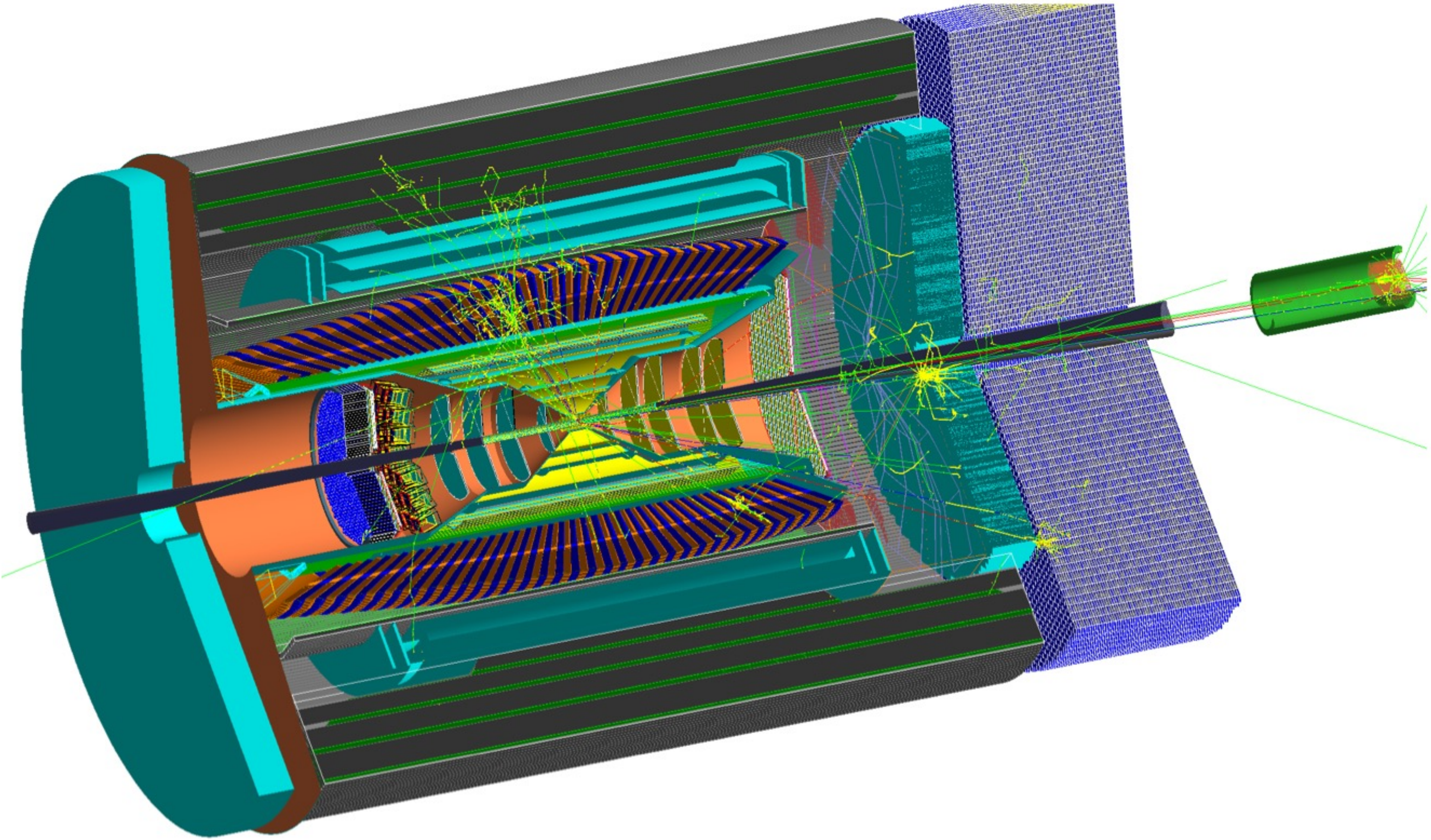

Roman Pots
ZDC
Off Momentum
Hadron Beam after IP
B0 Trackers + Calorimeter
B1apf Dipole
B1pf Dipole
ZDC
Q2bpf quadrupole
Q1pf quadrupole
Q1apf quadrupole
B0apf Diople
B0pf Diople

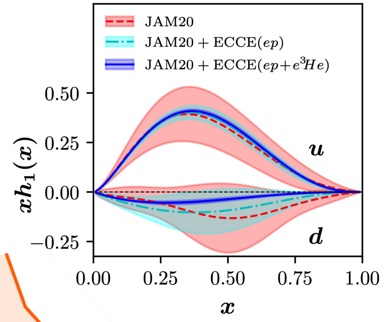
Starting ECCE construction 😁

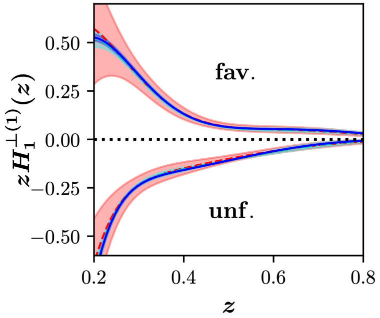
Large International Involvement

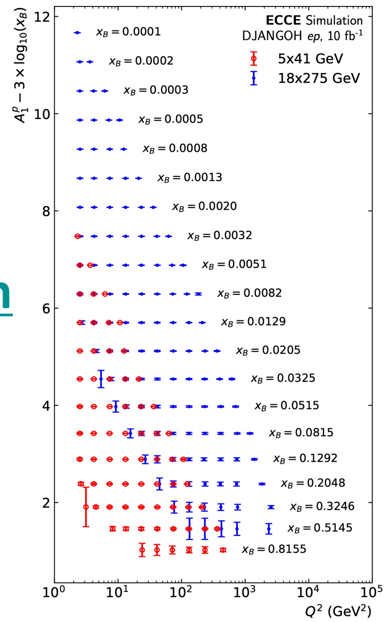


Full Geant4 studies done

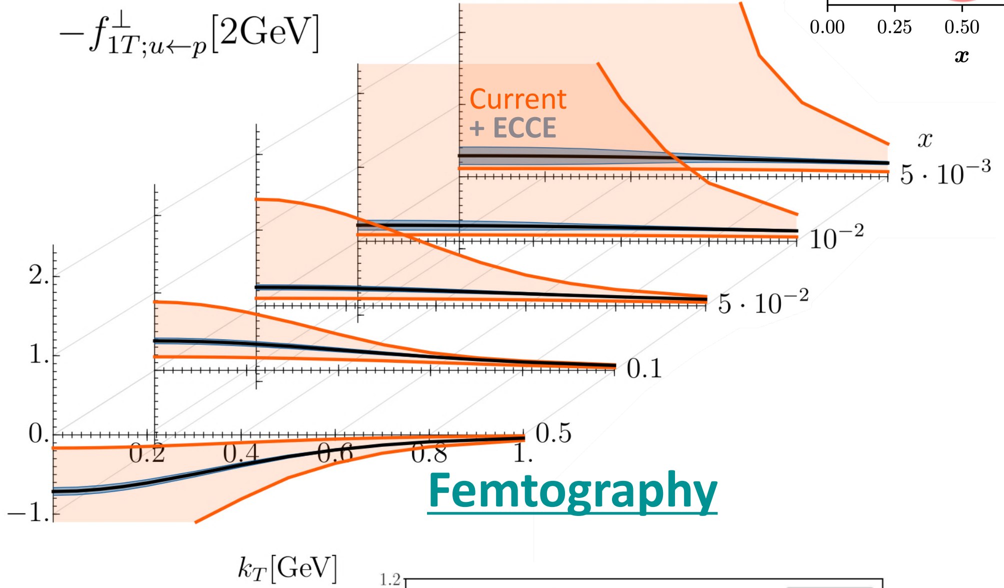








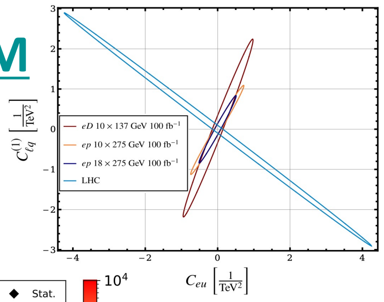
Spin



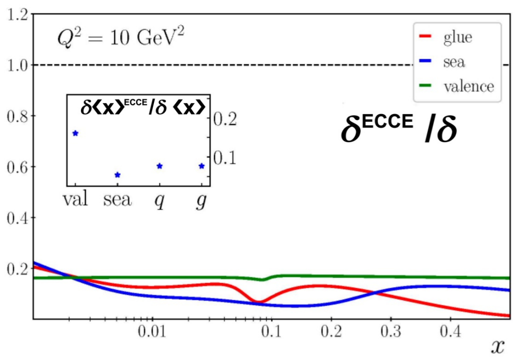
EIC Physics

Femtography

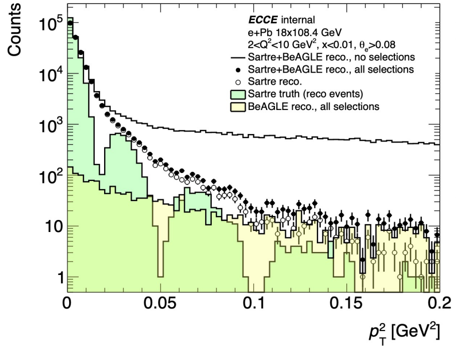
SM

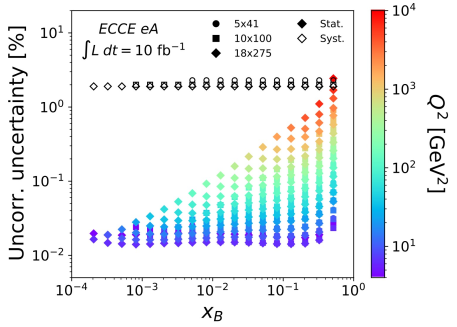


Mass



Gluons





“State-of-the-art from scratch” ☺

- Si tracking
- Calorimetry
- Precision TOF (~25ps)

  …
- Triggerless readout
- AI-based inversion techniques / tracking / readout

Summary:

Through a series of community-led studies, the EIC stands on a rigorous scientific basis that aims to revolutionize our understanding of nucleon and nuclear structure via QCD.

The EIC accelerator is a formal project at BNL. CD-1 granted in 2021, on track for first measurements in 2031.

International project! Many opportunities to get involved.