Physics Analysis activities at the ePIC experiment

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[BNL-INT Joint Workshop: Bridging Theory and Experiment at the Electron-Ion Collider]

INT, Seattle - June 2-6, 2025

EIC science pillars

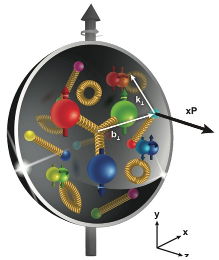
The EIC will unravel the different contribution from the quarks, gluons and orbital angular momentum

SPIN is one of the fundamental properties of matter.
All elementary particles, but the Higgs carry spin.
Spin cannot be explained by a static picture of the proton
It is the interplay between the intrinsic properties and interactions of quarks and gluons

Does the mass of visible matter emerge from quark-gluon interactions?

Atom: Binding/Mass = 0.00000001
Nucleus: Binding/Mass = 0.01
Proton: Binding/Mass = 100

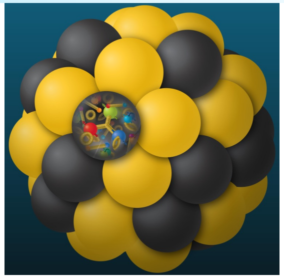
For the proton the EIC will determine an important term contributing to the proton mass, the so-called “QCD trace anomaly



How can we understand their dynamical origin in QCD?
What is the relation to Confinement

How are the quarks and gluon distributed in space and momentum inside the nucleon & nuclei?

How do the nucleon properties emerge from them and their interactions?

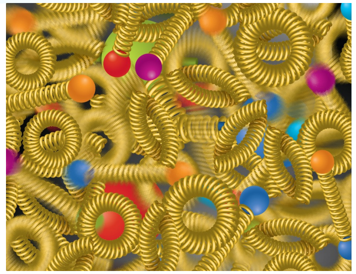


How do the confined hadronic states emerge from quarks and gluons?

Is the structure of a free and bound nucleon the same?

How do quarks and gluons, interact with a nuclear medium?

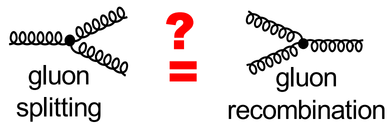
How do the quark-gluon interactions create nuclear binding?



What happens to the gluon density in nuclei? Does it saturate at high energy?

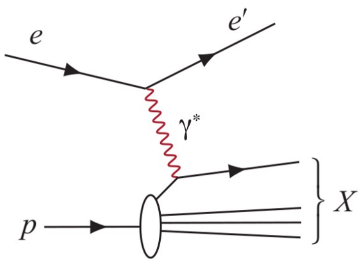
How many gluons can fit in a proton?

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



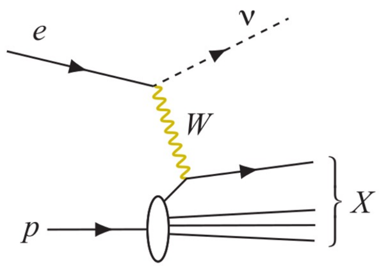
What process must be measured?

DIS event kinematics - scattered electron or final state particles (CC DIS, low y)



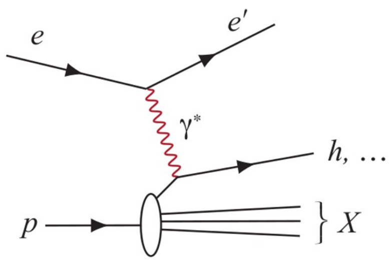
Neutral Current DIS

- Detection of scattered electron with high precision - event kinematics



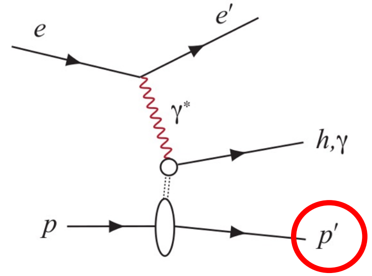
Charged Current DIS

- Event kinematics from the final state particles (Jacquet-Blondel method)



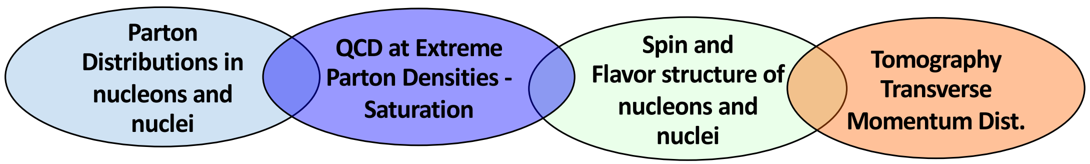
Semi-Inclusive DIS

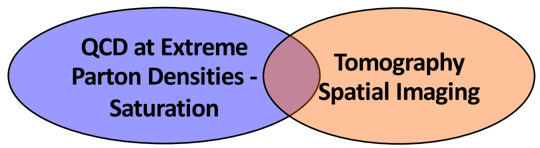
- Precise detection of scattered electron in coincidence with at least 1 hadron



Exclusive Processes

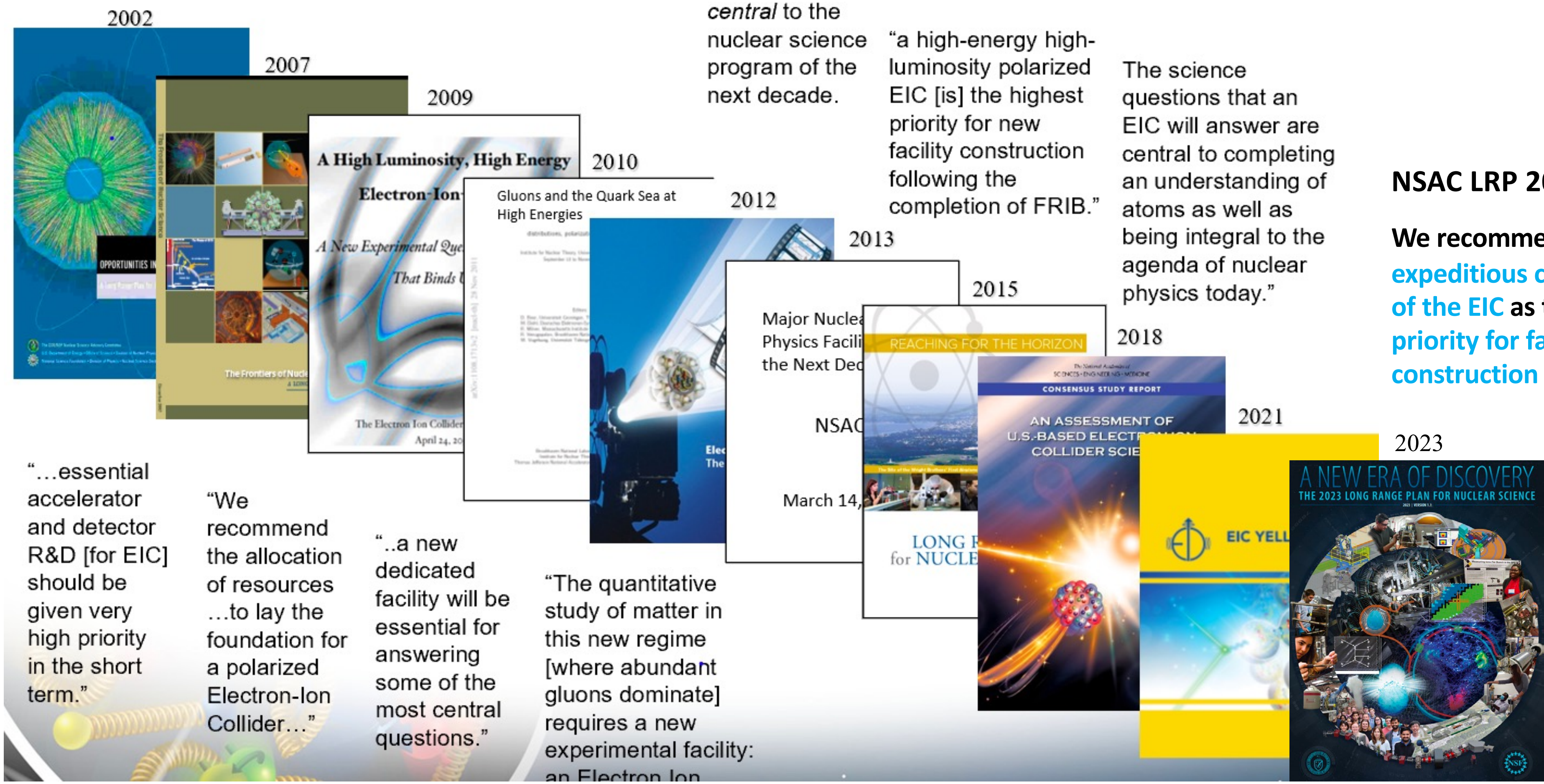
- Detection of all particles in event





$\int \mathcal{L}dt$: $\sim 1\ \mathrm{fb}^{-1}$ $\sim 10\ \mathrm{fb}^{-1}$ $\sim 100\ \mathrm{fb}^{-1}$

> 20 years long pathway!



"…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

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."

The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today."

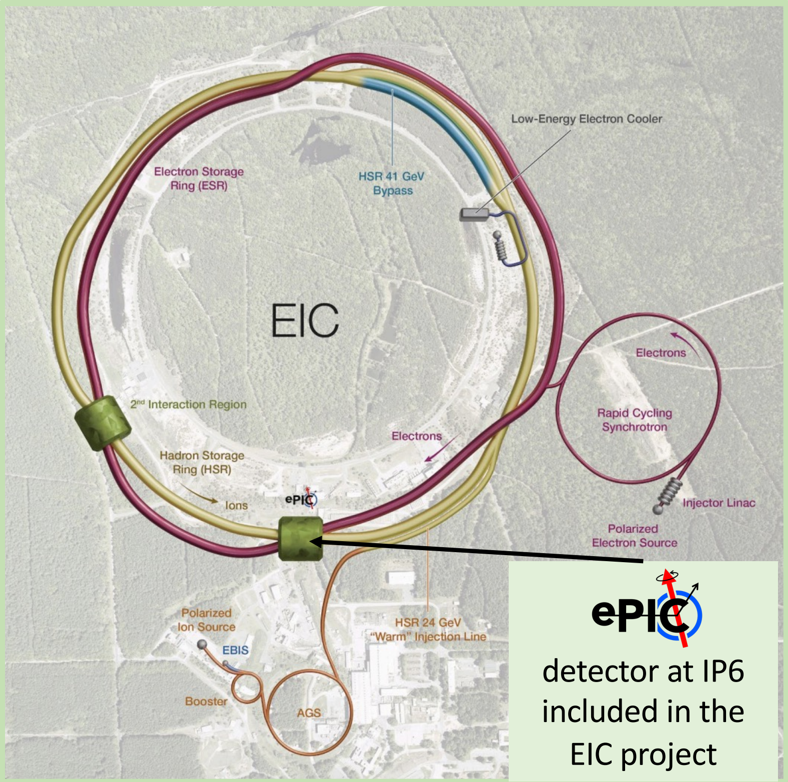
NSAC LRP 2023:

We recommend the expeditious completion of the EIC as the highest priority for facility construction

The Electron-Ion Collider

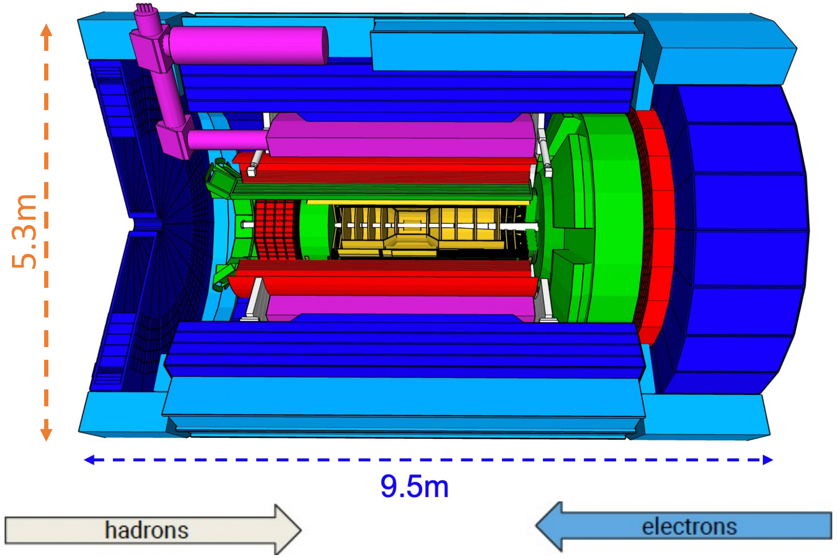
A DOE approved project!
Could be the only new collider
in the coming ~20-30 years

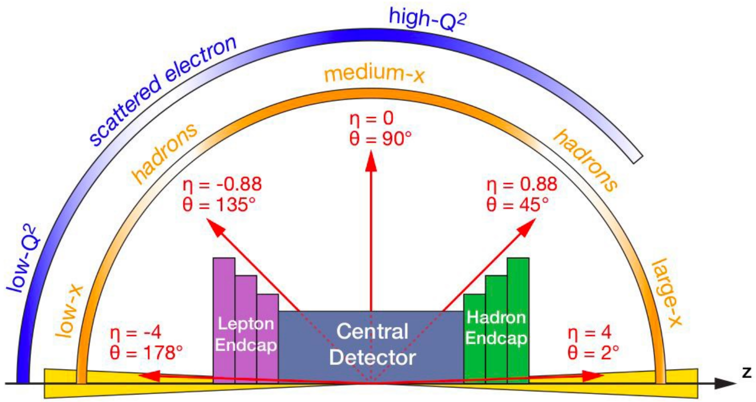
- ✓ Add a 5 to 18 GeV electron storage ring
- ✓ Two interaction regions, IP6 and IP8
- ✓ High Luminosity: 10^{33}-10^{34} cm^{-2}s^{-1} (~10^2-10^3 * HERA)
- ✓ Flexible √s = 29-141 GeV (per nucleon)
- ✓ Highly polarized (~70%) $e^{\uparrow}, p^{\uparrow}, d^{\uparrow}, He^{\uparrow}$, flexible spin pattern
- ✓ Wide variety of nuclear beams: (D to U)



World's first Polarized electron-proton/light ion and electron-Nucleus collider

The ePIC detector





Tracking

- New 1.7 T solenoid
- Si MAPS (vertex, barrel, forward, backward disks)
- MPGDs (µRWELL/µMegas) (barrel, forward, backward disks)

Particle identification

- High performance DIRC (barrel)
- Dual radiator (aerogel+gas) RICH (forward)
- Proximity focusing RICH (aerogel) (backward)
- TOF (~30ps): AC-LGAD (barrel and forward)

E.M. Calorimetry

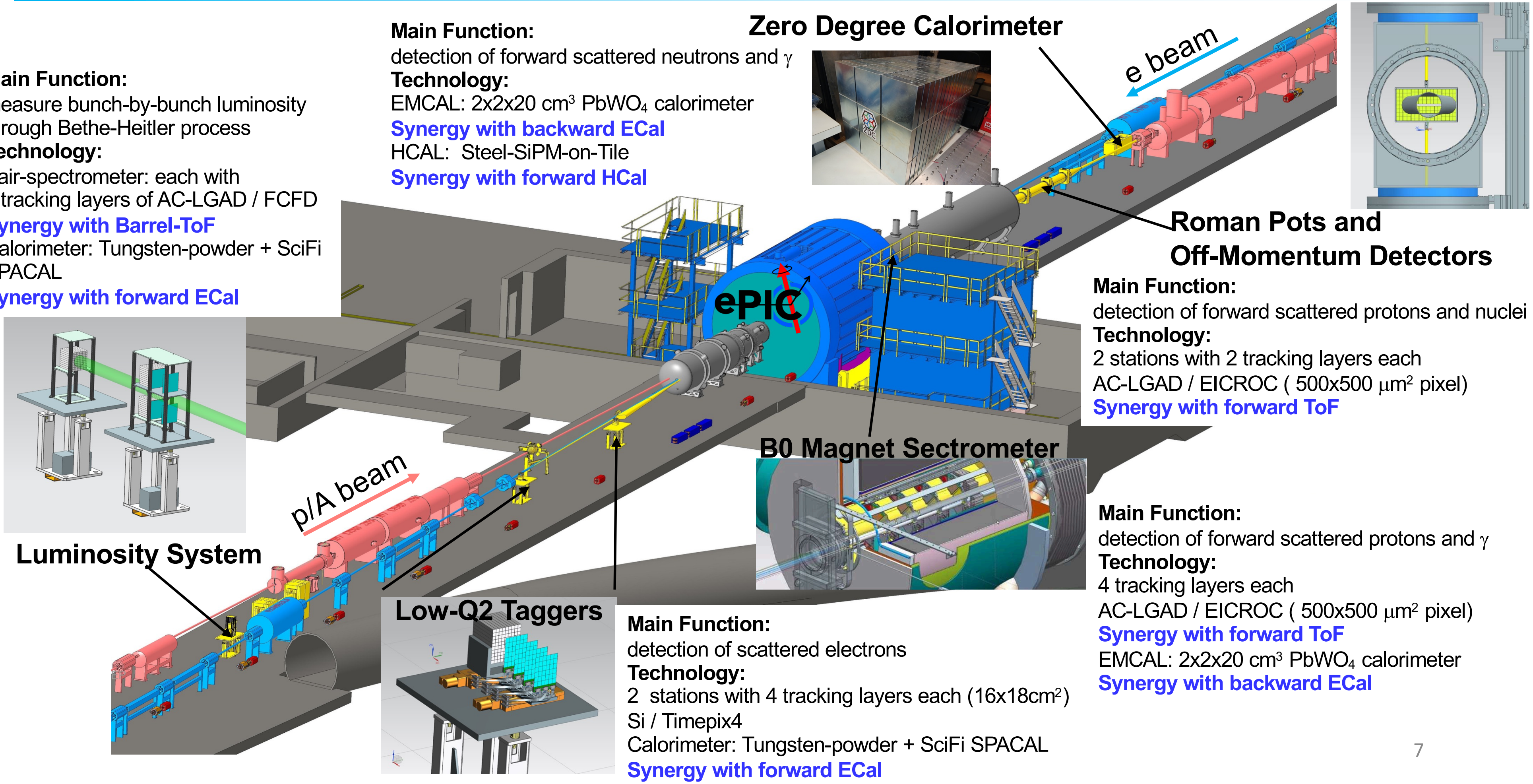
- Imaging EMCAL (barrel)
- W-powder/ScFi (forward)
- $PbWO_4$ crystals (backward)

Hadronic Calorimetry

- Fe/Scint reuse from sPHENIX (barrel)
- Steel/Scint - W/Scint (backwards/forward)

DAQ: streaming/triggerless with AI

Far forward/backwards detectors



Luminosity System

Main Function:
measure bunch-by-bunch luminosity through Bethe-Heitler process
Technology:
Pair-spectrometer: each with
2 tracking layers of AC-LGAD / FCFD
Synergy with Barrel-ToF
Calorimeter: Tungsten-powder + SciFi SPACAL
Synergy with forward ECal

Zero Degree Calorimeter

Main Function:
detection of forward scattered neutrons and γ
Technology:
EMCAL: 2x2x20 cm^3 $PbWO_4$ calorimeter
Synergy with backward ECal
HCAL: Steel-SiPM-on-Tile
Synergy with forward HCal

Roman Pots and Off-Momentum Detectors

Main Function:
detection of forward scattered protons and nuclei
Technology:
2 stations with 2 tracking layers each
AC-LGAD / EICROC (500x500 μm^2 pixel)
Synergy with forward ToF

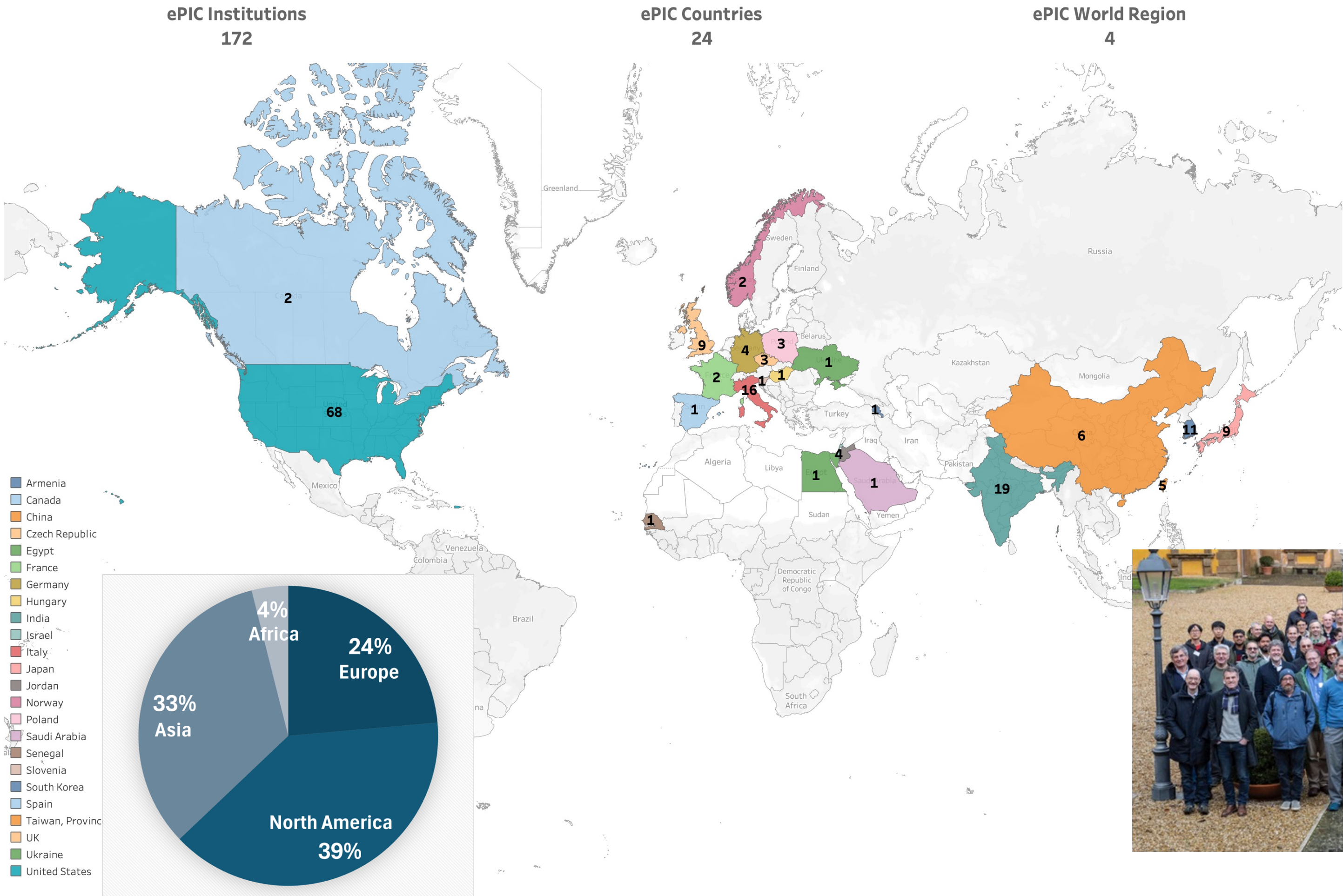
B0 Magnet Sectrometer

Main Function:
detection of forward scattered protons and γ
Technology:
4 tracking layers each
AC-LGAD / EICROC (500x500 μm^2 pixel)
Synergy with forward ToF
EMCAL: 2x2x20 cm^3 $PbWO_4$ calorimeter
Synergy with backward ECal

Low-Q2 Taggers

Main Function:
detection of scattered electrons
Technology:
2 stations with 4 tracking layers each (16x18cm^2)
Si / Timepix4
Calorimeter: Tungsten-powder + SciFi SPACAL
Synergy with forward ECal

The ePIC Collaboration



A truly global pursuit for a new experiment at the EIC

25 Countries

178 Institutions and counting!

~1000 scientists and counting!

Structure of the ePIC Physics Working Groups

ANALYSIS COORDINATORS
Salvatore Fazio (Cosenza) - Rachel Montgomery (Glasgow)
Rosi Reed (Lehigh) - deputy

- Each PWG convener is for a two-years term staggered
- Conveners in blue are ending their term in July 2025
- PWGs typically meet by-weekly

INCLUSIVE PHYSICS
Tyler Kutz (MIT)
Stephen Maple (Birmingham)

Mailing list: eic-projdet-Inclusive-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/417/

SEMI-INCLUSIVE PHYSICS
Stefan Diehl (UConn)
Ralf Seidl (RIKEN)

Mailing list: eic-projdet-semiincl-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/418/

JETS AND HEAVY FLAVOR
Olga Evdokimov (UIC)
Rongrong Ma (BNL)

Mailing list: eic-projdet-jethf-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/420/

EXCLUSIVE, DIFFRACTION AND TAGGING
Raphael Dupre (Orsay)
Zhoudunming Tu (BNL)

Mailing list: eic-projdet-excldiff-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/419/

BSM AND PRECISION EW
Ciprian Gal (JLab)
Juliette Memmei (Manitoba)

Mailing list: eic-projdet-semiincl-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/421/

ePIC Technical Design Report

pre–TDR (60% design completion) ⟹ December 2025

TDR (90% design completion) ⟹ ~ late 2026

- (pre)TDR are a deliverable of the EIC Project (project manager acts as editor)
  - describe the accelerator + ePIC experiment
  - Chapter 8: (hundreds pages) focus on the ePIC Detector Description, basic performance, Software, and data preservation
  - Chapter 2: (~60 pager) focus on holistic detector performance, physics performance and science reach
    - Holistic detector performance → Technical Coordinator office acts as editor
    - Physics and science reach → Analysis Coordinators act as editors
    - We envision the **publication of a spin—off physics performance paper(s)**

EIC Early Science Report

- **Previous workshops:**
  - **Sep. 13, 2024:** https://indico.bnl.gov/event/24432/
  - **Jan. 2025, plenary at Coll. Meeting:** https://agenda.infn.it/event/43344/timetable/#20250122.detailed
  - **Apr. 2025, CFNS @ Stony Brook:** https://indico.cfnssbu.physics.sunysb.edu/event/410/overview
- **Goal of this exercise:**
  - **Highlight *meaningful* and *impactful* science within early years of running without undermining the importance of achieving full EIC capabilities**
  - ***Meaningful***: The EIC early science program must engage the collaboration; it must get the collaboration excited about working hard for the future. It must have a balance of *breadth* and *depth*
  - ***Impactful***: The EIC early science program must take the first steps down the path to realizing the EIC science goals
- **Deliverable:**
  - **Report to be published by the ePIC Collaboration (~mid 2026)**

EIC Early Science Matrix

- What machine capabilities can we expect for Early Science?
  - See Sergei Nagaitzev's talk in the first Early Science Workshop: https://indico.bnl.gov/event/24432/
- Matrix based on latest news by the Project:
  - See Elke Aschenauer's talk at the Collab. Meeting in Frascati: https://agenda.infn.it/event/43344/contributions/250126/

	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG

Note: the eA luminosity is per nucleon

NB: ePIC installation plan calls for the full ePIC to be installed year-1 (exception for roman pots and OMD)

Highlights on the performance on some physics measurements of the ePIC detector

- ALL IS A WORK IN PROGRESS!
- Software framework, event reconstruction, tools... are being finalized and are evolving as we speak!

Scientific goals: origin of the mass of visible matter

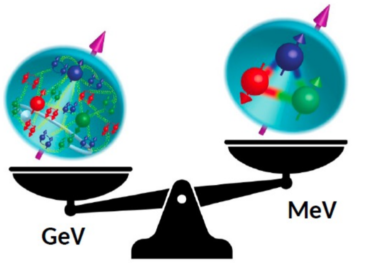
- Gluons have no mass and quarks are very light, but nucleons and nuclei are heavy, making up for most of the visible mass in the Universe
- Visible matter only made of constituents of light mass: masses emerge from quark-gluon dynamics

Proton (valence quarks: uud) → $m_p = 940$ MeV

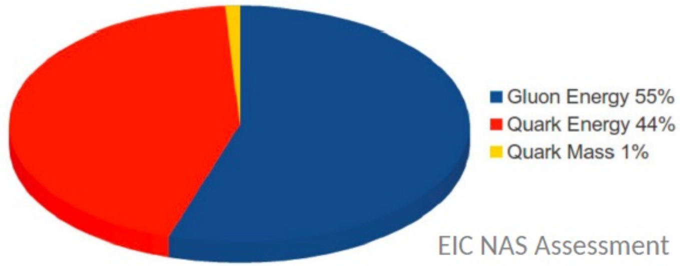
- The mass is dominated by the energy of highly relativistic gluonic field
- EIC can determine an important contribution term to the proton mass, the so-called “QCD trace anomaly” ⟼ accessible in exclusive reactions (e.g. Υ photoproduction near threshold)

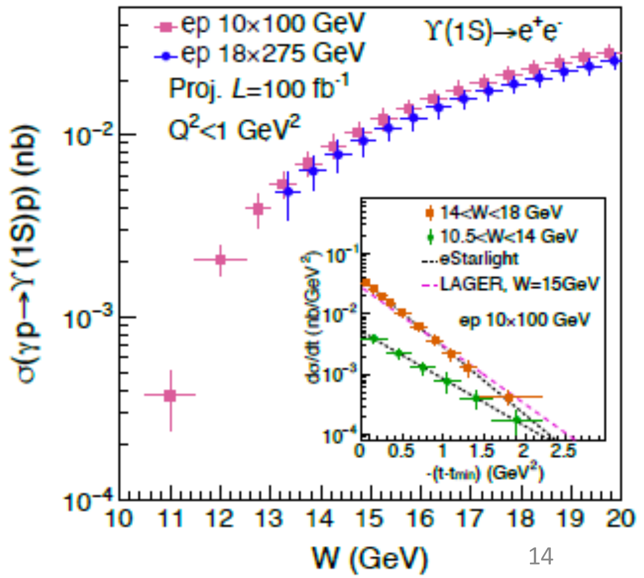
Key detector performance:

- Acceptance and low material for VM decay leptons
- Resolution of lepton pair inv. mass
- Muon id

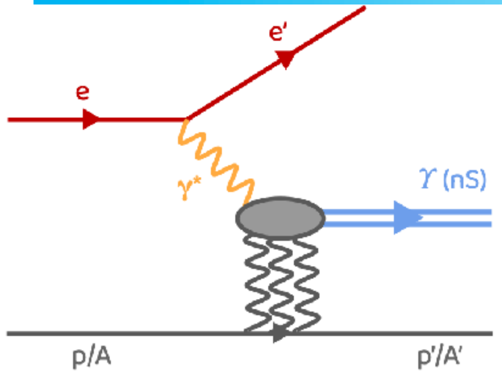


Contributions to the total mass of the nucleon



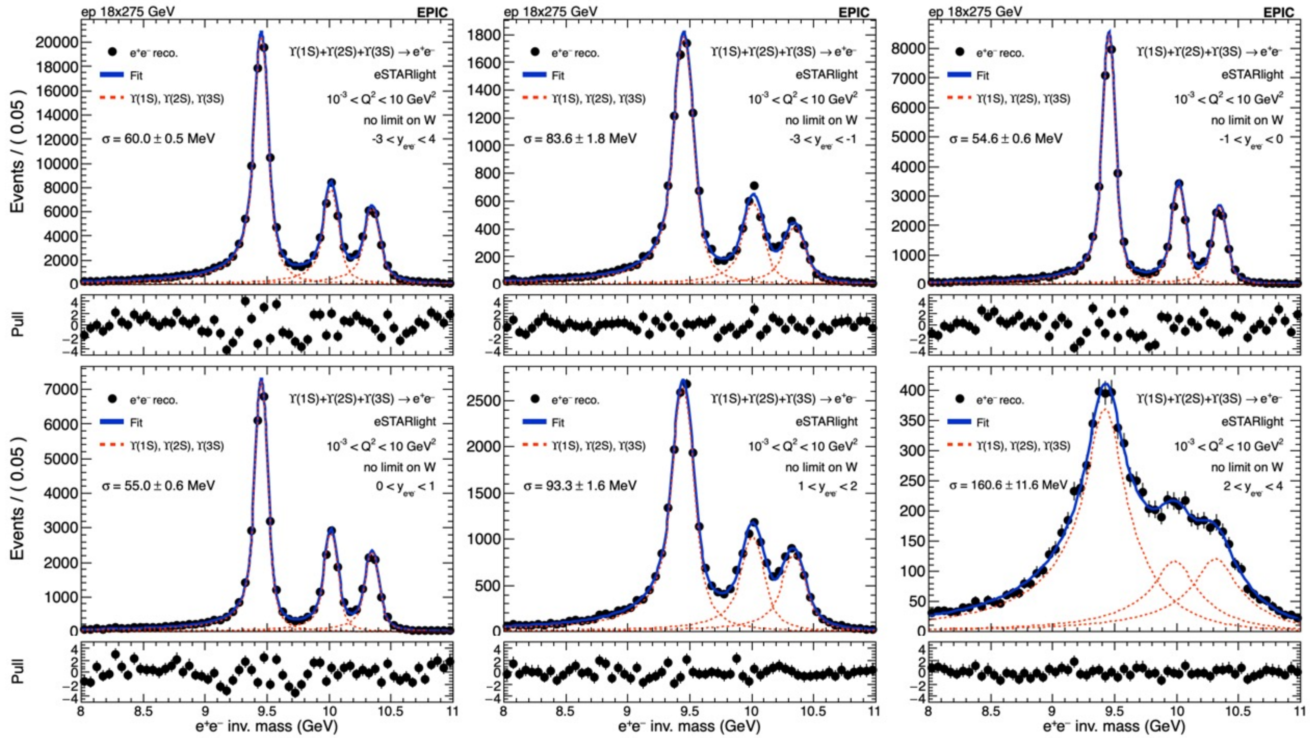


ePIC performance: Υ production



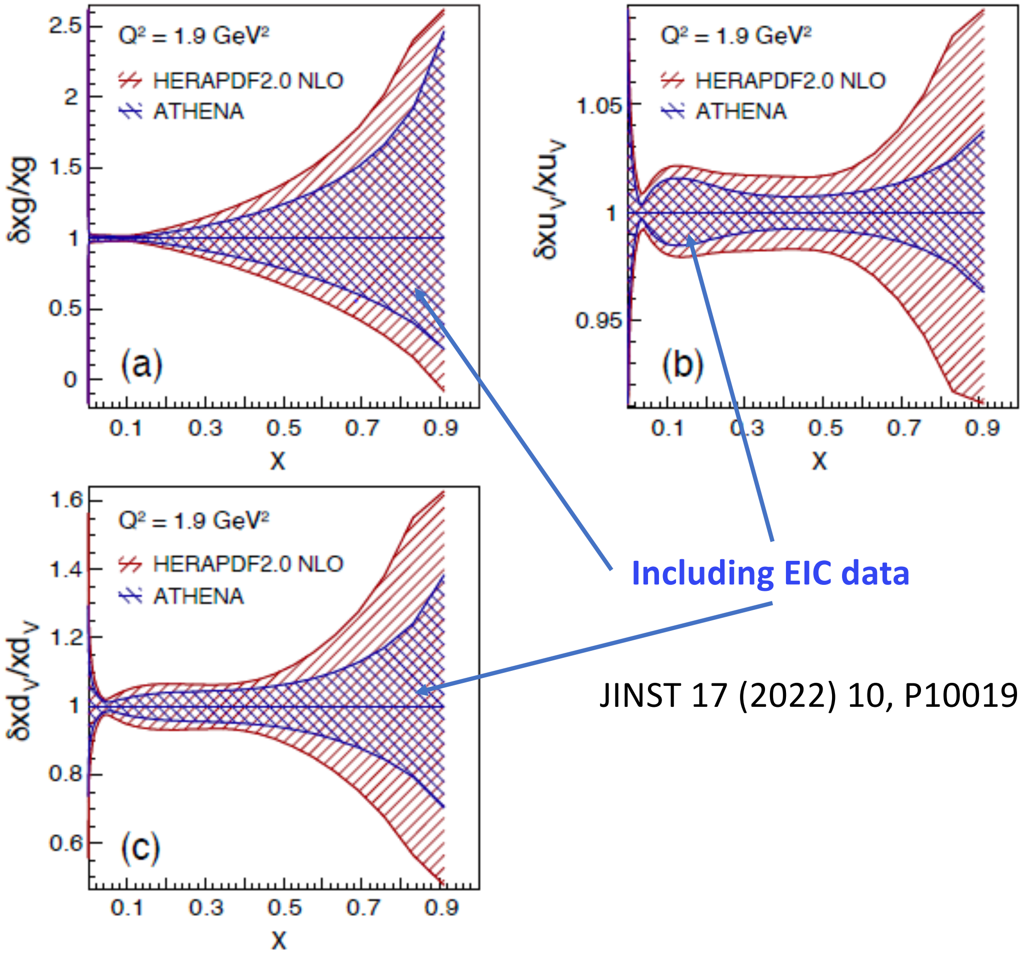
- Sensitivity to gluon distributions
- Challenges: tracking resolution is crucial
- First studies at low Q^2
  - Ratio yields 1 : 0.45 : 0.33 from STARlight paper
  - Fitted with the **Double-Sided Crystal Ball function**
  - $m_{\Upsilon nS} = m_{\Upsilon 1S} \frac{\text{PDGmass}_{nS}}{\text{PDGmass}_{1S}}$

$\Upsilon(1S), \Upsilon(2S), \Upsilon(3S) \rightarrow e^+e^-$



left -> right: Different rapidity intervals

Scientific goals: proton PDFs



JINST 17 (2022) 10, P10019

Proton PDFs @ EIC

- $F_2(x, Q^2)$ **largely studied at HERA**
- Nevertheless, a better precision often needed for precise calculations!
  --> explore specific kinematics
- EIC impact on HERA + LHC global fits, as estimated at the times of detector proposals in 2022 (ATHENA)
- High-*x* region: constrain of both gluons and flavor-separated valence quarks

Key detector performance:
- Electron ID
- Fine *y* resolution over large phase space

ePIC performance: DIS kinematics with ePIC

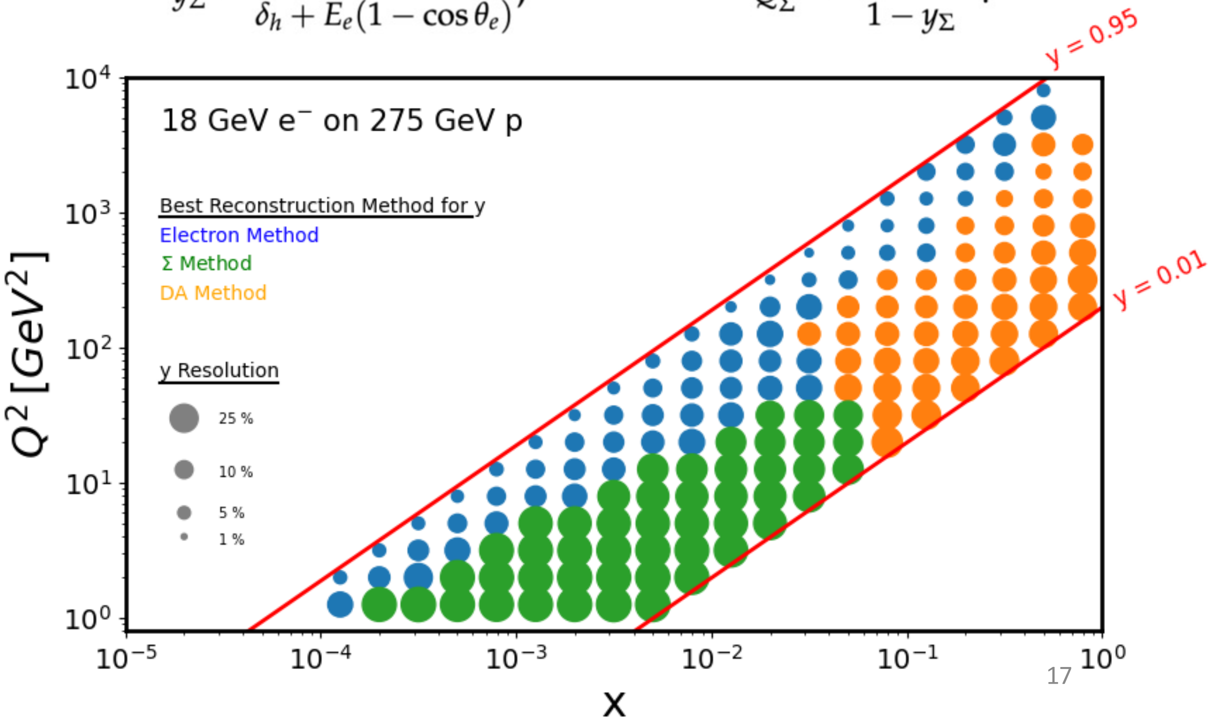
Kinematic Resolutions

$$y_e = 1 - \frac{E_e(1-\cos\theta_e)}{2E_0}, \qquad Q_e^2 = 2E_0E_e(1+\cos\theta_e).$$

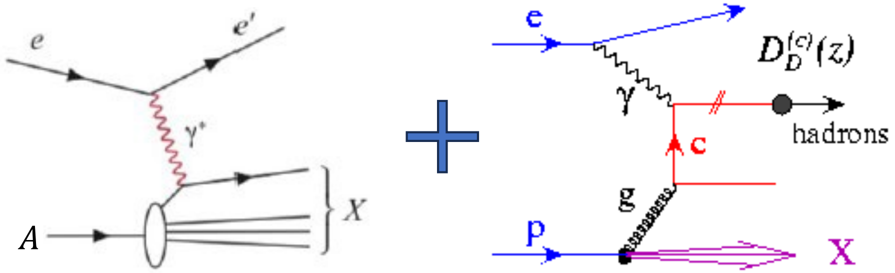
$$y_{DA} = \frac{\alpha_h}{\alpha_e+\alpha_h}, \qquad Q_{DA}^2 = \frac{4E_0^2}{\alpha_e(\alpha_e+\alpha_h)}$$

$$y_\Sigma = \frac{\delta_h}{\delta_h + E_e(1-\cos\theta_e)}, \qquad Q_\Sigma^2 = \frac{E_e'^2\sin^2\theta_e}{1-y_\Sigma}.$$

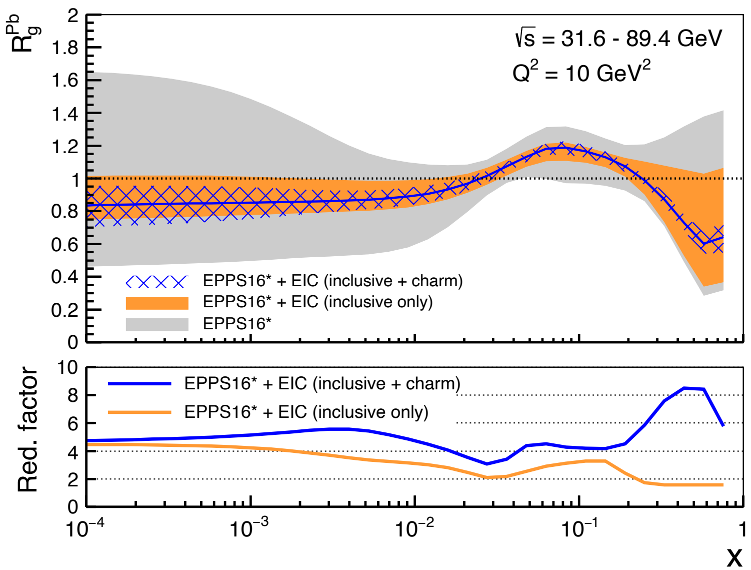
- Reconstruct inclusive kinematics using various methods
  - → **compare reconstruction performance**
  - Color of point indicates best method for *y* (inelasticity)
  - Size of point indicates *y* resolution
- **~30% or better *y* resolution across $x - Q^2$ plane**



Scientific goals: nuclear PDFs



- **Inclusive DIS in e+A**
  - tag the scattered electron
- **Charm production:**
- Direct access to gluons at medium to high x by tagging **photon-gluon fusion**



E.C. Aschenauer, S. F., M.A.C. Lamont, H. Paukkunen, P. Zurita
[Phys. Rev. D 96, 114005 (2017)]

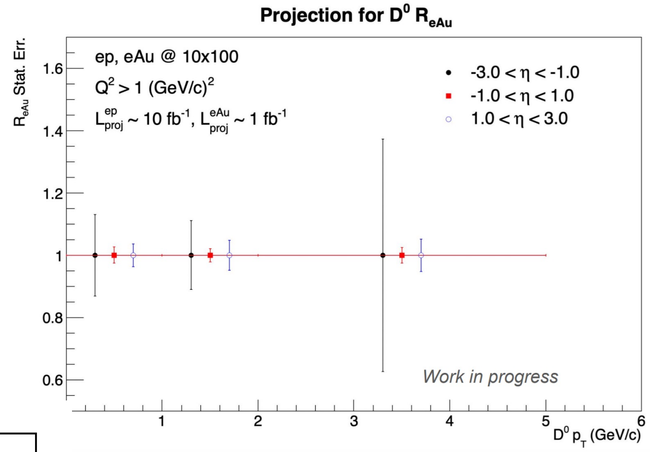
- The EIC provides a factor ~10 larger reach in Q^2 and at low-x compared to available data
  - Higher $\sqrt{s}$ energy constrains gluons at mid- and low-x
  - charm has a dramatic effect at high-x

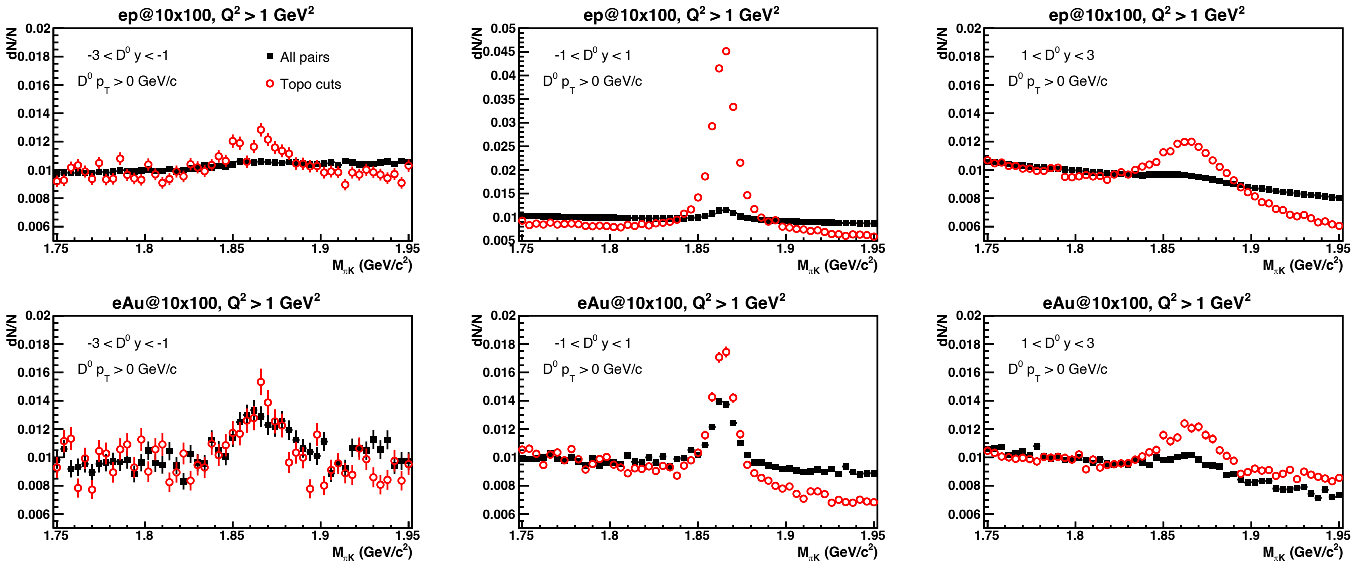
Key detector performance:

- Vertexing (for charm tagging)
- Electron ID
- Fine resolution in y over a large phase space

ePIC performance: Open D^0 reconstruction with ePIC

- Open D^0 reconstruction
  - projected statistical precision for $D^0\ R_{eAu}$
  - Invariant mass distributions of π + K pairs vs different D^0 rapidity intervals
  - › Assessing tracking performance

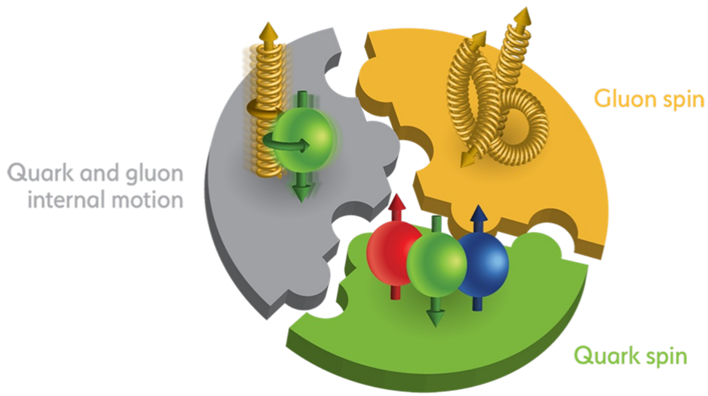




Scientific goals: source of the proton's spin

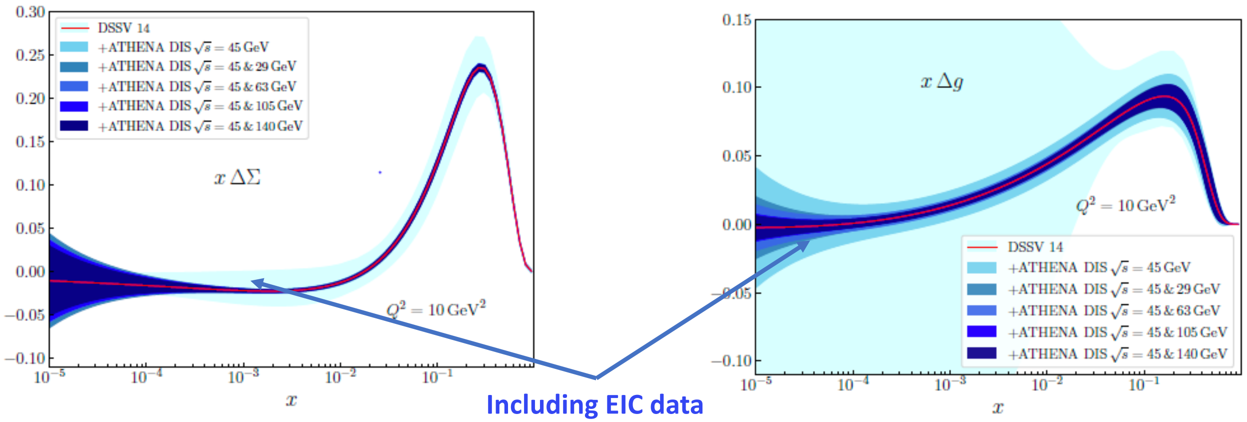
Jaffe and Manohar "sum rule" [Nucl. Phys. B337, 509 (1990)]

$$\frac{1}{2}\hbar=\left\langle P,\frac{1}{2}\right| J^z_{QCD}\left|P,\frac{1}{2}\right\rangle=\underbrace{\sum_q \frac{1}{2}S^z_q}_{\text{total u+d+s quark spin}}+\overbrace{S^z_g}^{\text{gluon spin}}+\underbrace{\sum_q L^z_q+L^z_g}_{\text{angular momentum}}$$



- **Observable:** double spin asymmetries
- **DIS** scaling violations determine **gluons** at small *x*

1/2 - Quarks - Gluons = orb. angular momentum



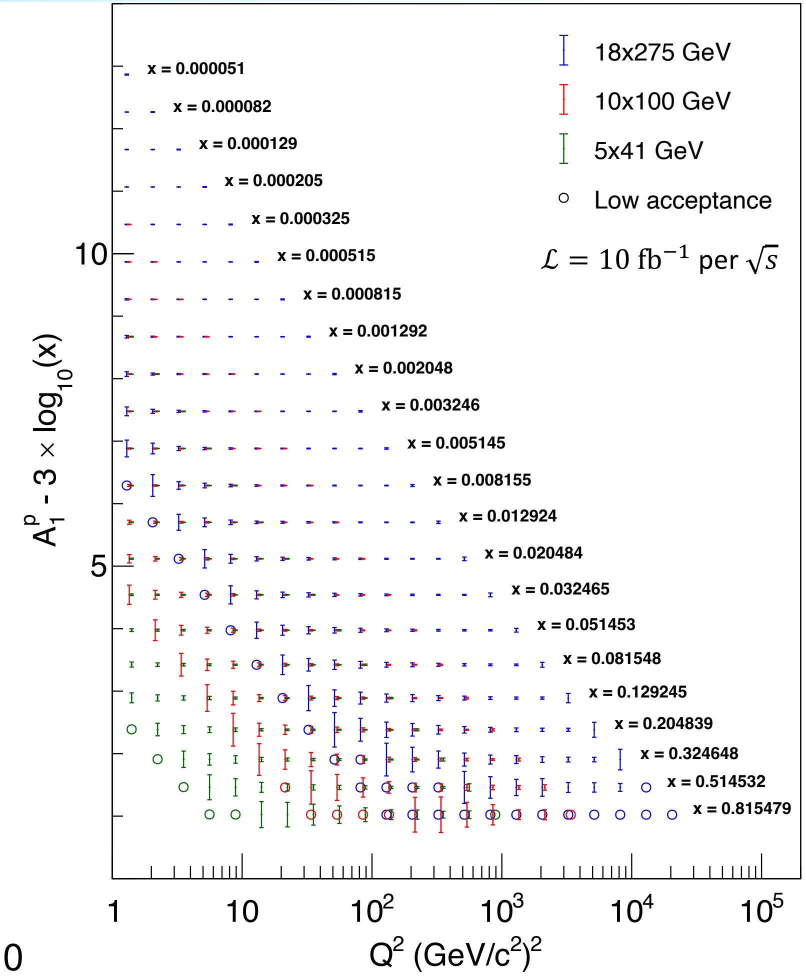
ePIC performance: Double Spin Asymmetries - A_1^p

Fully simulated A_1^p determination

- Realistic eID
  - Electron method
  - Acceptance and Bin migrations from simulation
- A_1^p calculated according to parametrization

$$A_{||} = \frac{\sigma_{\downarrow\Uparrow} - \sigma_{\uparrow\Uparrow}}{\sigma_{\downarrow\Uparrow} + \sigma_{\uparrow\Uparrow}}, \quad A_{\perp} = \frac{\sigma_{\downarrow\Rightarrow} - \sigma_{\uparrow\Rightarrow}}{\sigma_{\downarrow\Rightarrow} + \sigma_{\uparrow\Rightarrow}}$$

$$\rightarrow A_1 \approx g_1/F_1$$



Q2 > 2 GeV2, W > 4 GeV2 0.05 < y < 0

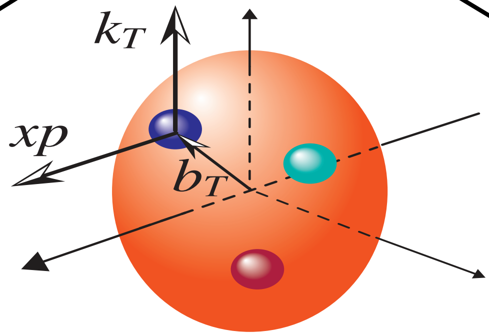
Multidimensional imaging of quarks and gluons

Wigner functions

offer unprecedented insight into confinement and chiral symmetry breaking

$W(x,b_T,k_T)$

Momentum space $\int d^2b_T$ $\rightarrow$ $f(x,k_T)$



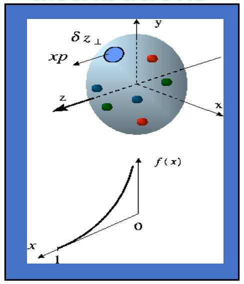
$\int d^2k_T$ $\rightarrow$ $f(x,b_T)$ *Coordinate space*

Spin-dependent 3D **momentum space** images from **semi-inclusive scattering** → Transverse-Momentum Depentent distributions (**TMDs**)

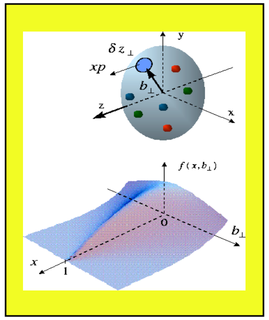
Spin-dependent 2D **coordinate space** (transverse) + 1D (longitudinal momentum) images from **exclusive scattering** →Generalized Parton Distributions (**GPDs**)

Scientific goals: GPDs

Longitudinal momentum & helicity distributions

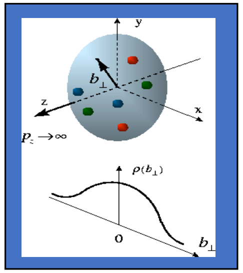


$f(x)$
parton densities



$H(x, \xi, t)$
GPDs

transverse charge & current densities



$F(t)$
form factors

N / q	U	L	T
U	H		E_T
L		$\tilde{H}$	$\tilde{E}_T$
T	E	$\tilde{E}$	H_T $\tilde{H}_T$

Spin-½ hadron: **4 chiral-even** (H, E and their polarized-hadron versions $\tilde{H}$, $\tilde{E}$) and **4 chiral-odd** (H_T, E_T, $\tilde{H}_T$, $\tilde{E}_T$) quark and gluon **GPDs at leading twist**

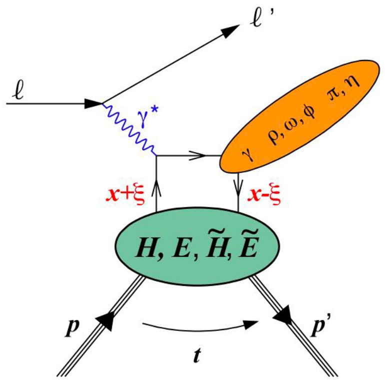
Like usual PDFs, GPDs are non-perturbative functions **defined via the matrix elements of parton operators**:

$$F^q = \frac{1}{2}\int \frac{dz^-}{2\pi} e^{ix\bar{P}^+z^-} \langle p'|\bar{q}(-\frac{1}{2}z)\gamma^+ q(\frac{1}{2}z)|p\rangle|_{z^+=0,\mathbf{z}=0}$$

$$= \frac{1}{2\bar{P}^+}\left[H^q(x,\xi,t,\mu^2)\bar{u}(p')\gamma^+ u(p) + E^q(x,\xi,t,\mu^2)\bar{u}(p')\frac{i\sigma^{+\alpha}\Delta_\alpha}{2m_N}u(p)\right]$$

- Experimental access to GPDs via Compton Form Factors (CFFs)

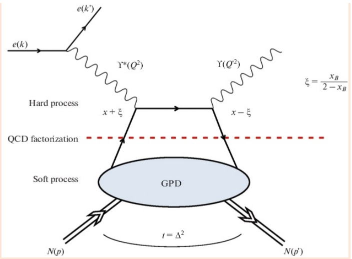
$$\mathcal{H}(\xi, t) = \sum_q e_q^2 \int_{-1}^{1} dx\, H^q(x,\xi,t)\left(\frac{1}{\xi - x - i\varepsilon} - \frac{1}{\xi + x - i\varepsilon}\right)$$

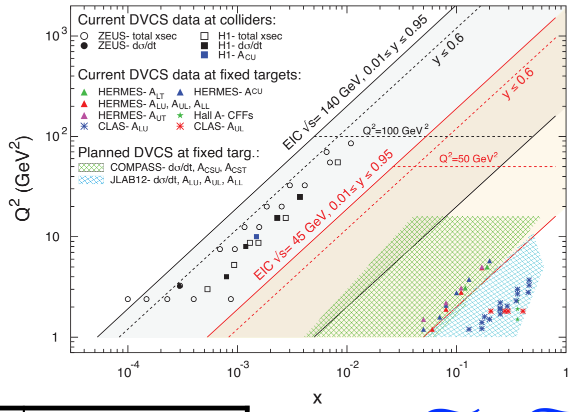


Accessing GPDs in exclusive processes

Real photon (DVCS):

- Very clean experimental signature
- No VM wave-function uncertainty
- Hard scale provided by Q^2
- Access to the whole set of GPDs
- Sensitive to both quarks and gluons [via Q^2 dependence of xsec (scaling violation)]





Only possible at EIC: from valence quark region, deep into the sea!

Hard Exclusive Meson Production (HEMP):

- Uncertainty of wave function
- Hard scale provided by $Q^2 + M^2$
- J/Psi, Y → direct access to gluons, $c\bar{c}$, or $b\bar{b}$ pairs produced via $q(g) - g$ fusion
- Light VMs → quark-flavor separation
- Psedoscalars → helicity-flip GPDs

$H^q \; E^q$

ρ⁰	2u+d, 9g/4
ω	2u–d, 3g/4
ϕ	s, g
ρ⁺	u–d
J/ψ, Υ	g

$\widetilde{H}^q \; \widetilde{E}^q$

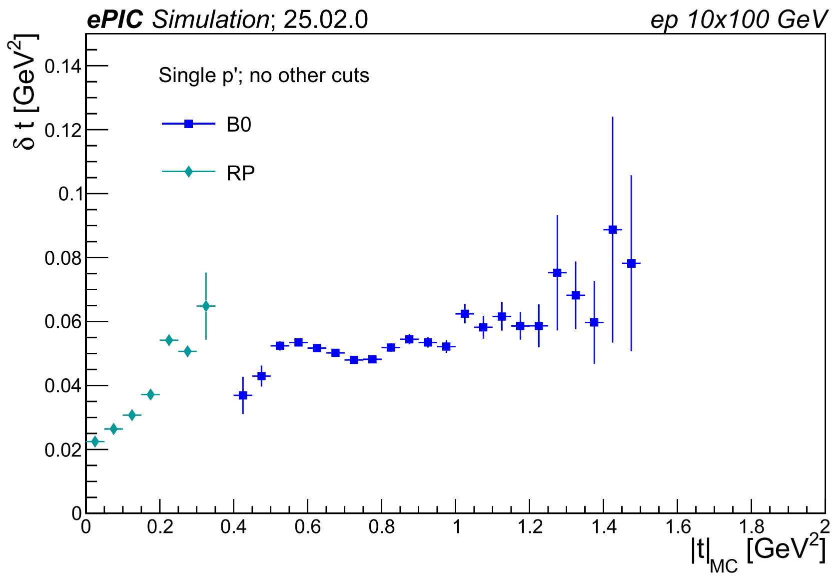
π^0	2Δu+Δd
η	2Δu–Δd

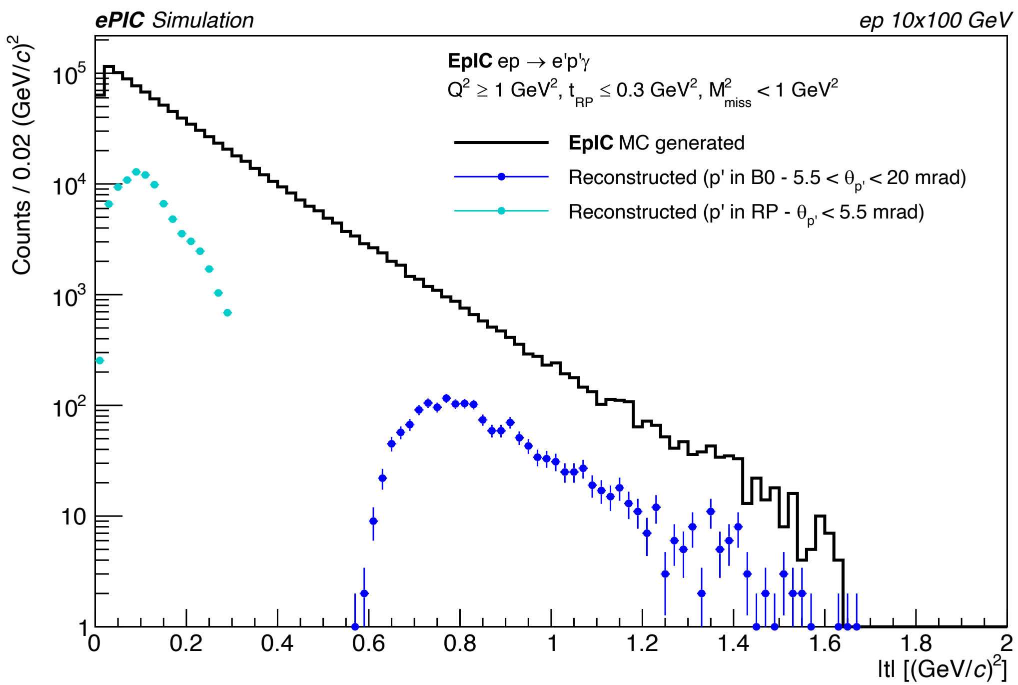
Key detector performance:

- γ/π^0 separ. in ECAL for DVCS
- Acceptance and low material for VM decay leptons
- Resol. of lepton pair invariant mass
- Scattered electrons over full kinematics
- t- lever arm in FF spectrometers

ePIC performance: proton momentum via f.f. spectrometers

$t = -(p' - p)^2$, in exclusive and diffractive processes is directedly measured via far forward trackers, roman pots (RPs) and B0





Reconstructed t not corrected for acceptance
Optimization studies ongoing!

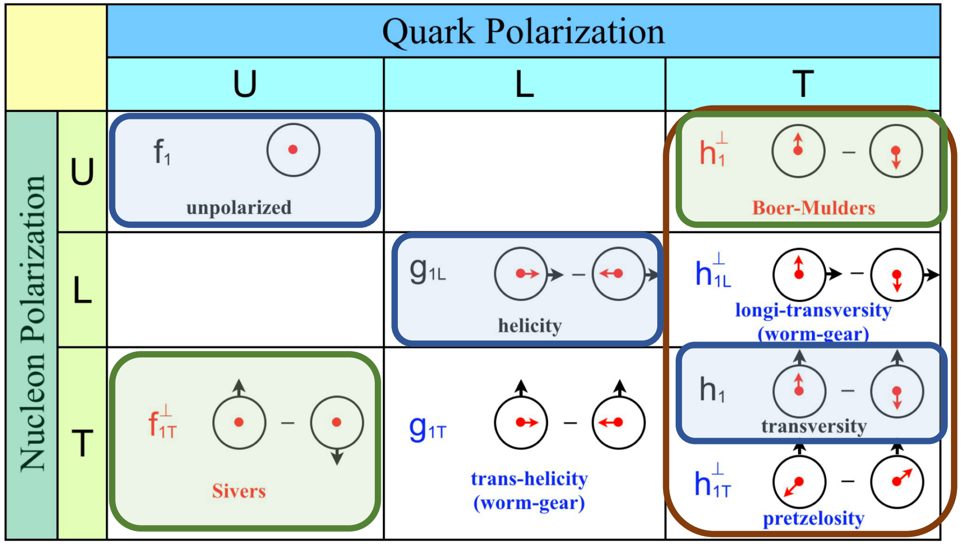
Scientific goals: TMDs

TMDs surviving integration over k_T

Time-reversal odd TMDs describing **strength of spin-orbit correlations**

Chiral odd TMDs

Note: off-diagonal part vanishes without parton's transverse motion



Non-zero strength of spin-orbit correlations → indication of parton OAM

- **Sivers:** correlations of transverse-spin direction and the parton transverse momentum
- **Boer-Mulders:** correlations of parton transverse spin and parton transverse momentum
- Collins: fragmentation of a transversely polarized parton into a final-state hadron

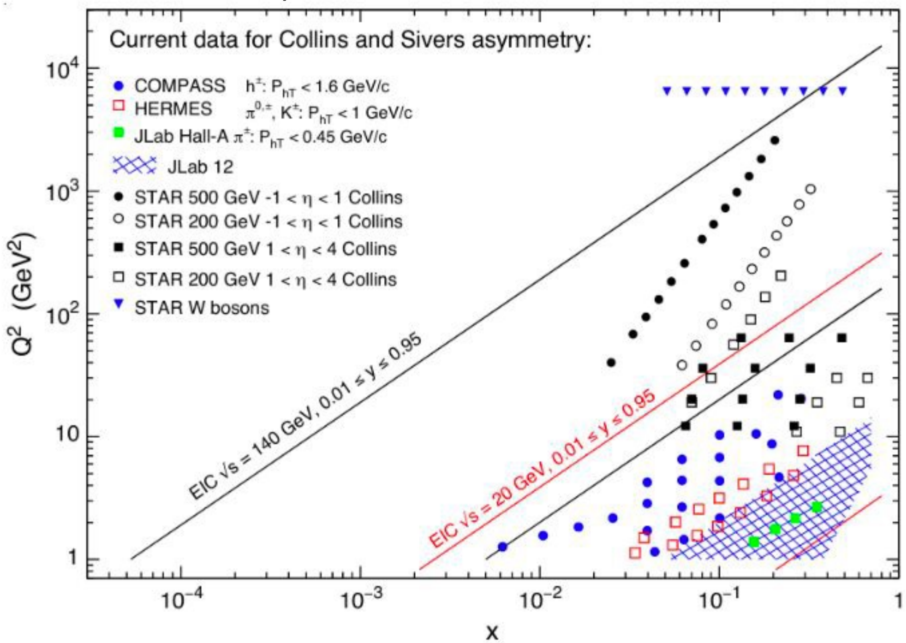
Scientific goals: TMDs

EIC will access TMDs primarily through SIDIS for single hadrons, as well as other semi-inclusive processes with the production of di-hadrons and jets

What we want to measure: $$\frac{d\sigma}{dx\, dQ^2\, dz\, d\phi_S\, d\phi_h\, dp_T^h}$$

- **6-fold differential cross sections in SIDIS**
- **Azimuthal asymmetries and their modulations**

EIC Yellow Report: kin. reach for Sivers and Collins



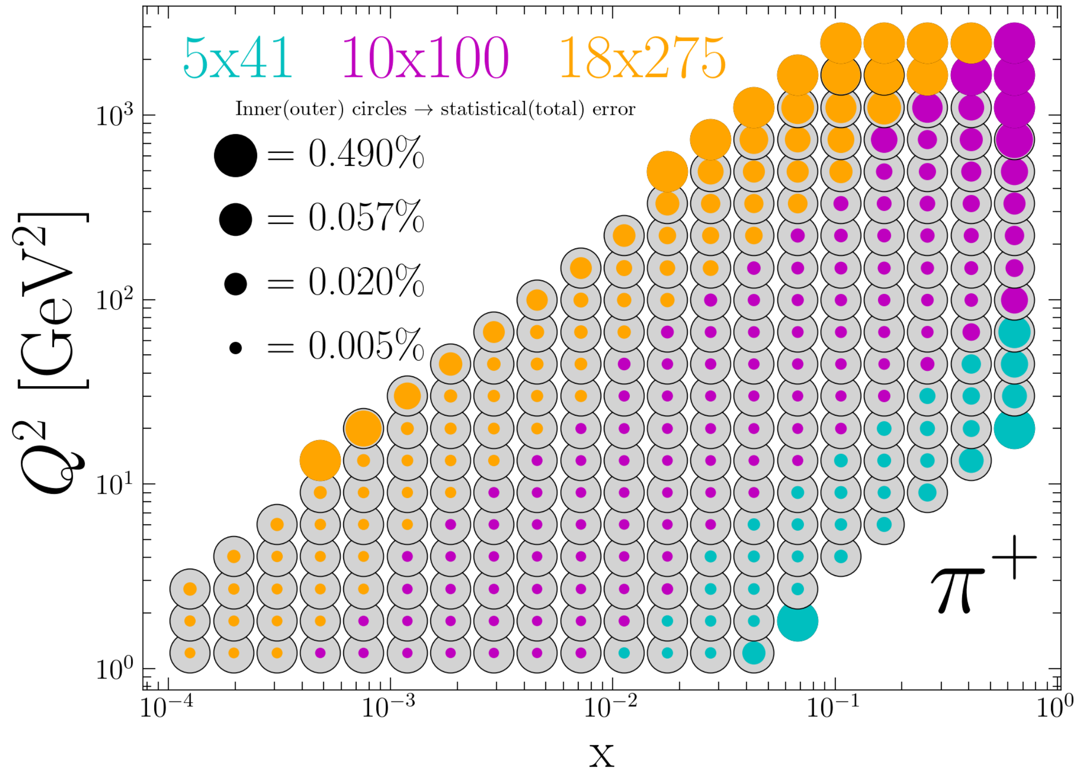
EIC envisions a rich program to probe spin-orbit effects within the proton and during hadronization, and explore the 3D spin structure of the proton in momentum space

- Extends the SiDIS kinematic coverage of an order ~2 in both x and Q^2

Key detector performance:

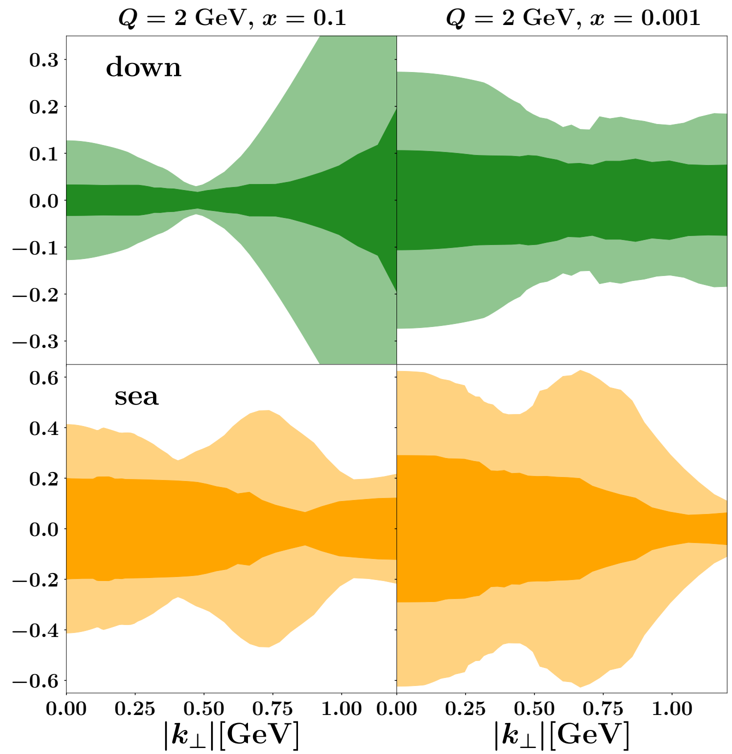
- Azimuthal acceptance
- PID
- Acceptance
- Vertexing (heavy flavor)
- Quality of tracking
- HCal (for jets)

ePIC performance: Unpolarized TMDs



Expected statistical/total uncertainty of un-polarized TMD PDFs for π+

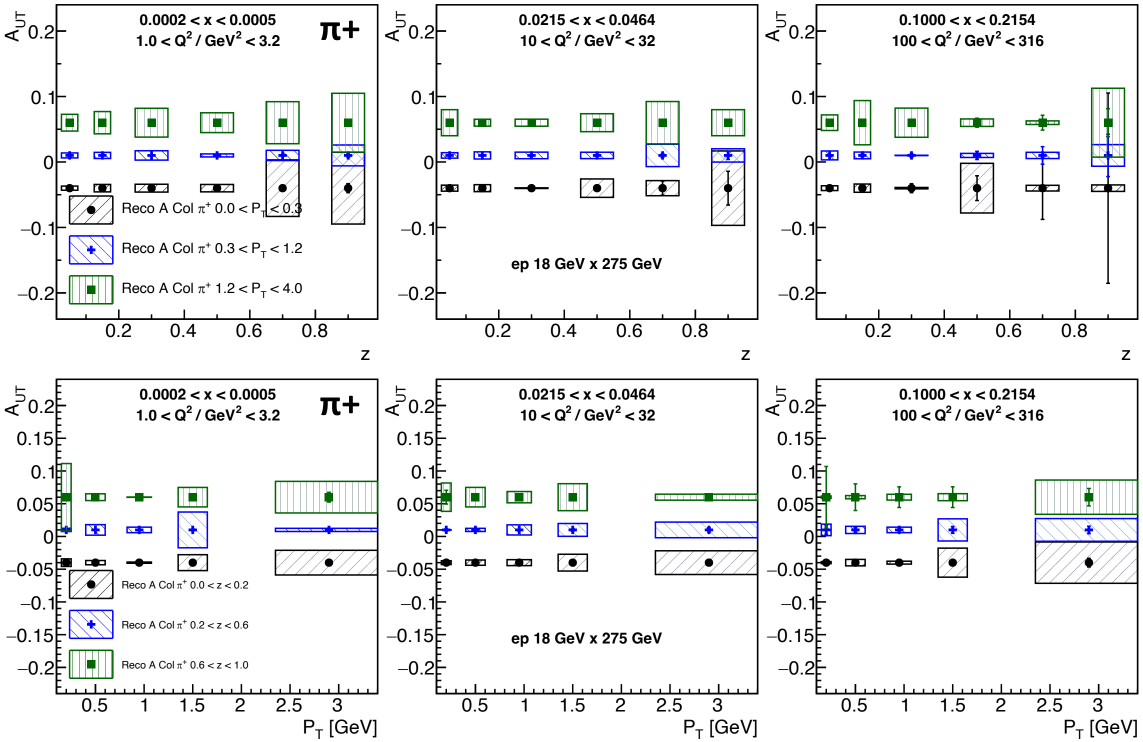
- Inner (outer) circles: statistical(total) uncertainty
- Colors: beam energy configuration with highest statistics in a bin



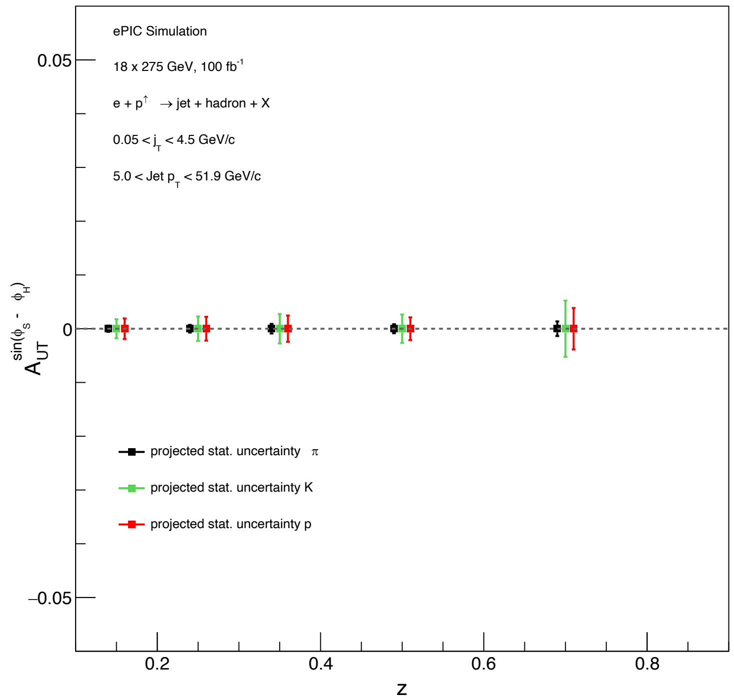
Uncertainties based on the MAP24 global TMD fit

- Lighter shades: based on existing data
- Darker shades: after including ePIC data

ePIC performance: Collins Asymmetries



18x275 GeV – 100 fb^{-1}

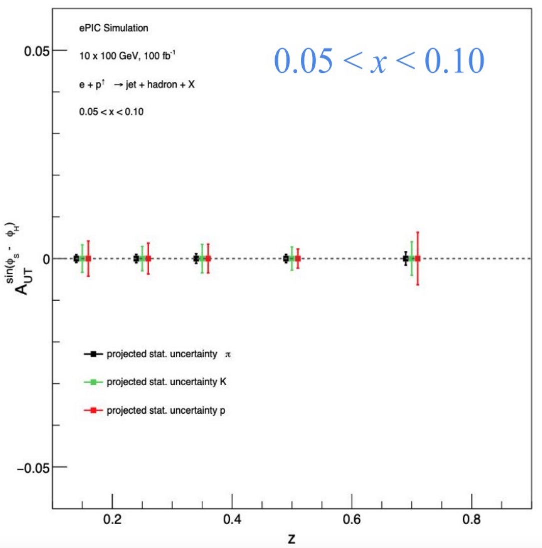


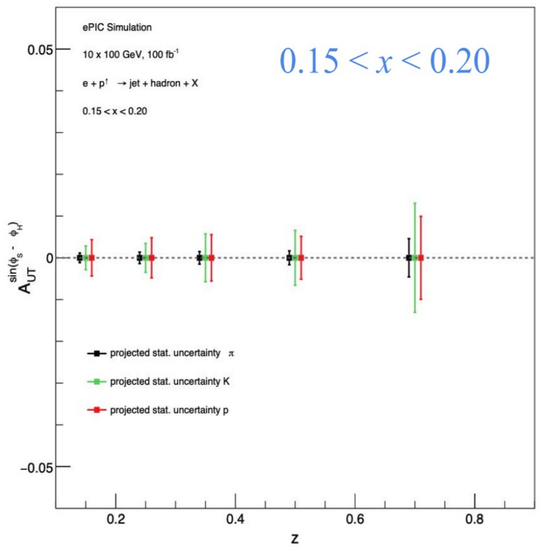
- Collins asymmetries can be obtained from identified hadrons within jets
- The Collins FF plotted vs the fractional hadron momentum z and transverse momentum relative to the jet momentum and its axis
- Projections assume a 10 fb^{-1} luminosity

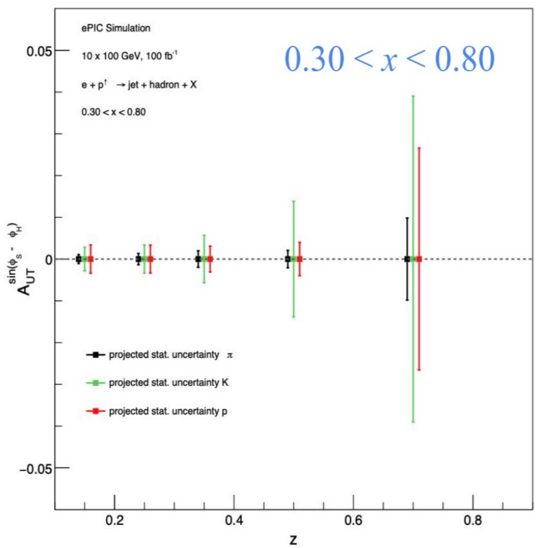
- **Collins Asymmetry:** effect due to convolution of quark transversity (h_1^q) and Collins FF ($H_{1\pi/q}^{\perp}$)
  - Advantage of jet+hadron Collins over single hadron SIDIS:
    - jets provide proxy for fragmenting parton

ePIC performance: Collins Asymmetries

ep @ 10x100, L = 100 fb^{-1}



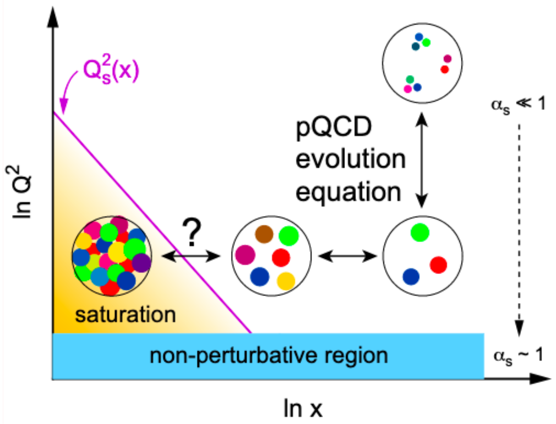




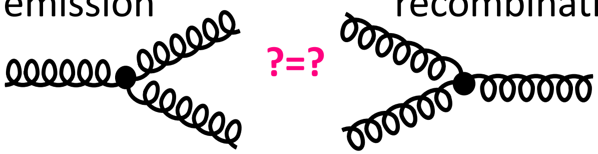
- Projected statistical precision for π, K, p Collins Asymmetry

- **Collins Asymmetry:** effect due to convolution of quark transversity (h_1^q) and Collins FF ($H_{1\pi/q}^{\perp}$)
  - Advantage of jet+hadron Collins over single hadron SIDIS: jets provide proxy for fragmenting parton

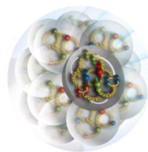
Scientific goals: gluon saturation

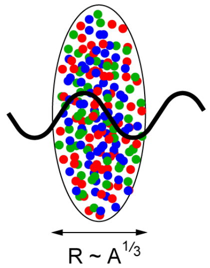


gluon emission ?=? gluon recombination



$$(Q_s^A)^2 \sim cQ_0^2\left(\frac{A}{x}\right)^{1/3}$$

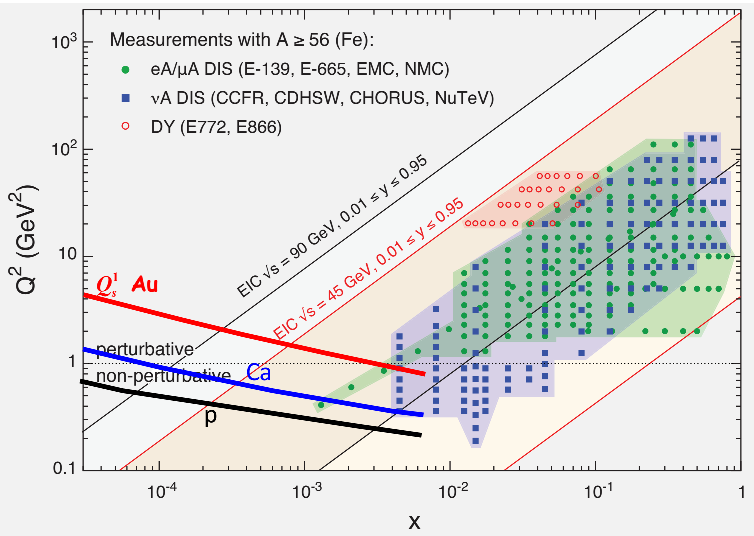




$L \sim (2m_N x)^{-1} > 2\, R_A \sim A^{1/3}$

Probe interacts coherently with all nucleons

Gold: 197 times smaller effective *x* !



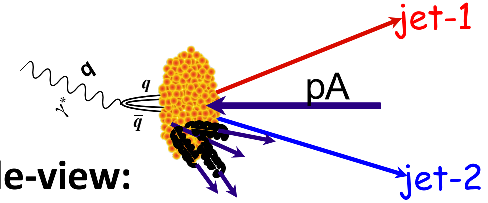
→ EIC will map the transition between a non-saturated and a saturated regime with high precision, by making use of a large range of nuclei and spin

→ With its flexible ion source, we will be able to measure the A-dependence of the saturation scale $Q_s(x)$

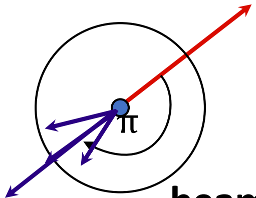
→ a fundamental landmark of QCD

Scientific goals: gluon saturation

Di-hadron correlations



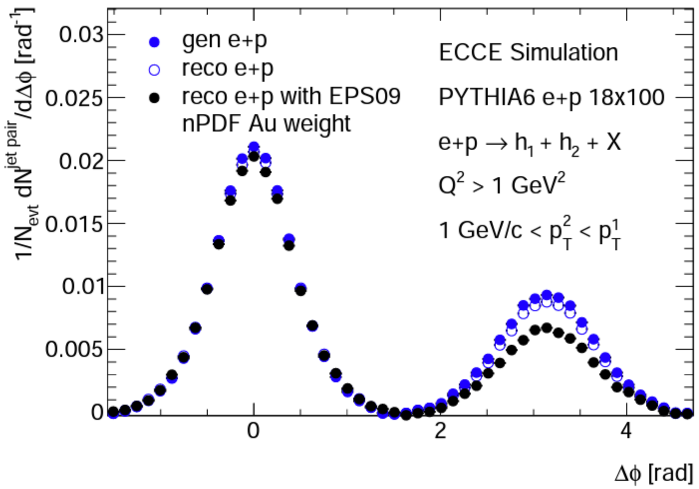
side-view:

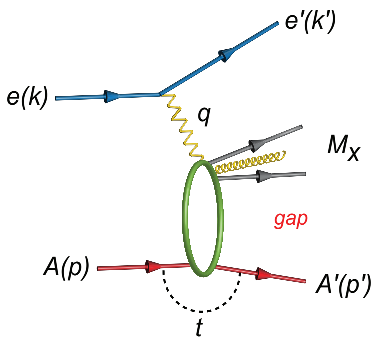


beam-view:

Low gluon density (ep):
pQCD predicts 2→2 process
⇒ back-to-back di-jet

High gluon density (eA):
2 → many process
⇒ expect broadening of away-side





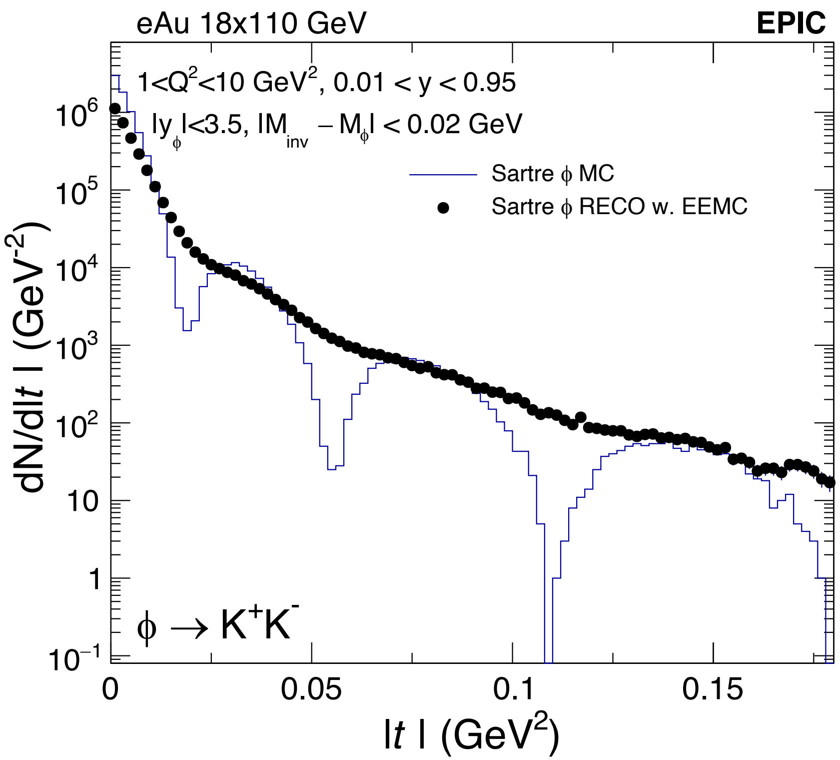
Diffraction

High sensitivity to gluon density
in linear regime $\sigma \sim [g(x,Q^2)]^2$

Key detector performance:

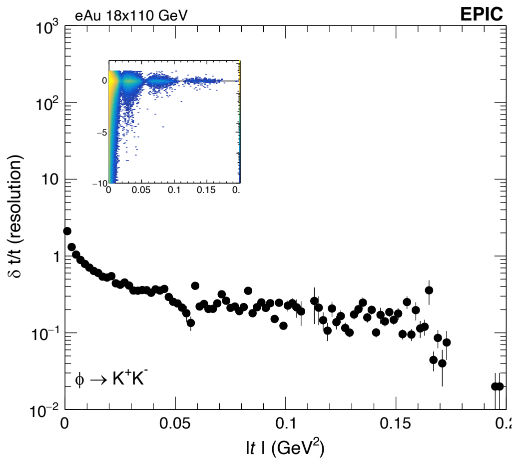
- Quality of detection at mid rapidity
- Reconstruction of dijets (dihadron)
- Particle ID

ePIC performance: DVMP in e-A



$$eAu \to \phi \to K^+K^-$$

- Coherent electroproduction of ϕ meson in eA
- Sensitivity to gluon saturation
- Challenges: PID and FF detectors crucial to measure the decay kaons, reconstruct $|t|$ and **veto the incoherent part**
- Figure: challenge of vetoing incoherent still not overcome
- … but ongoing studies (not yet shown) are very promising for improving the reconstruction of the minima in the coherent xsec.

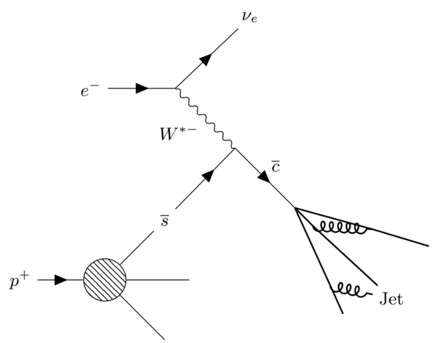


Scientific goals: jets as a versatile probe

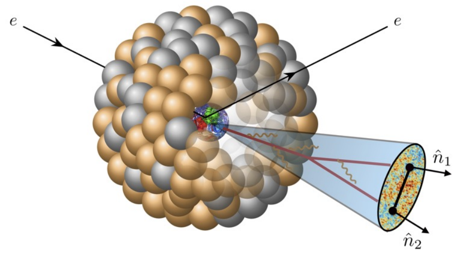
- **Jets are extremely powerful probes!**
  - Dynamically generated, sensitive to ***many*** scales
  - Good proxy for parton kinematics
  - Like SIDIS (multiple particles in FS), but also encode correlations between particles
    - → **Via both jet clustering & substructure**

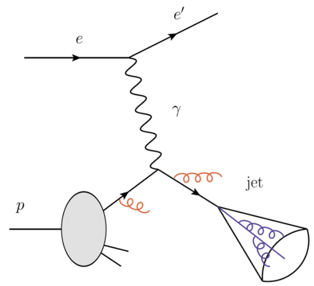
- Can provide input on all areas of EIC physics program
  - **(n)PDFs,**
    - e.g. PRD 102, 074015 (2020)
  - **Spin/flavor structure of nuclei,**
    - e.g. PRD 103, 074023 (2021)
  - **Saturation/extreme parton density,**
    - e.g. PRL 116, 202301 (2016)
  - **TMDs/GPDs,**
    - e.g. PRL 116, 202301 (2016)
  - **Cold nuclear matter effects,**
    - e.g. arXiv:2308.08143

PRD 103, 074023 (2021)

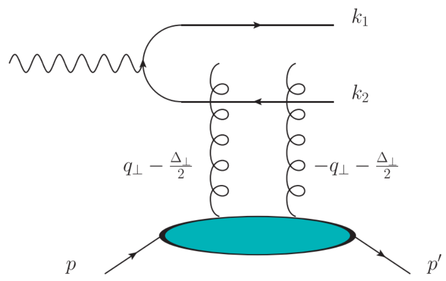


arXiv:2308.08143



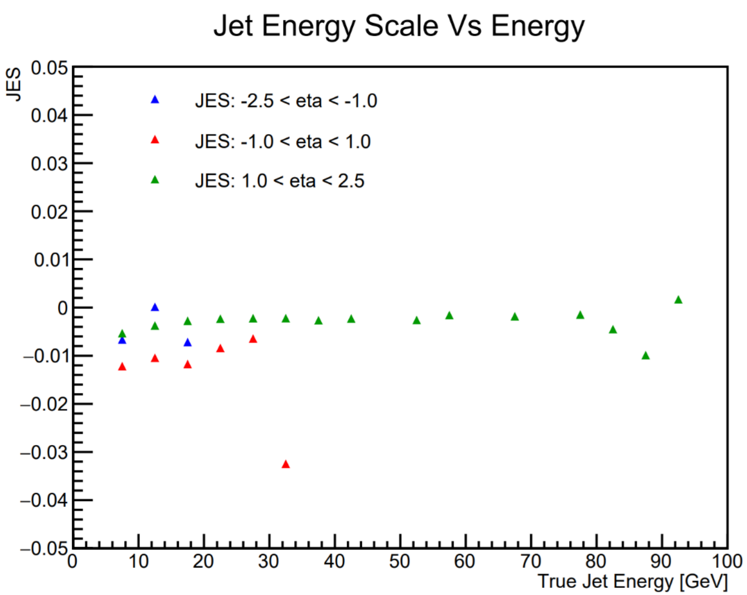


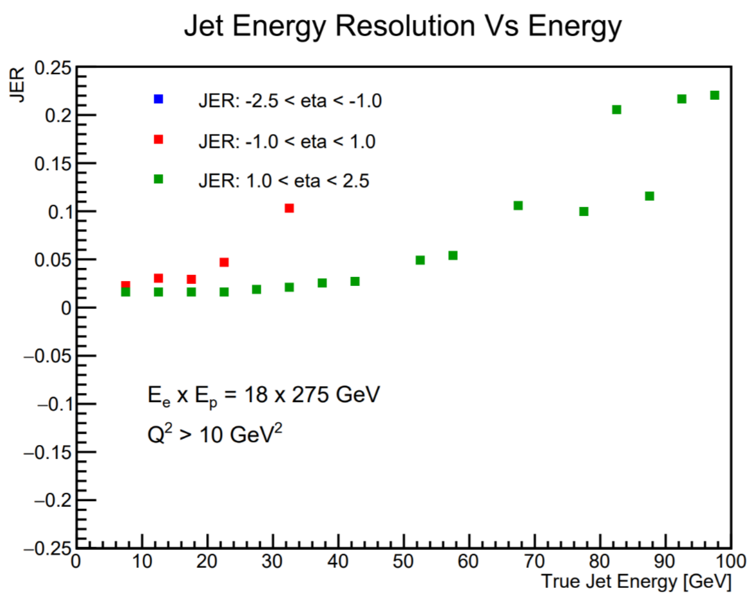
PRD 102, 074015 (2020)



PRL 116, 202301 (2016)

ePIC performance: jets Energy Scale/Resolution

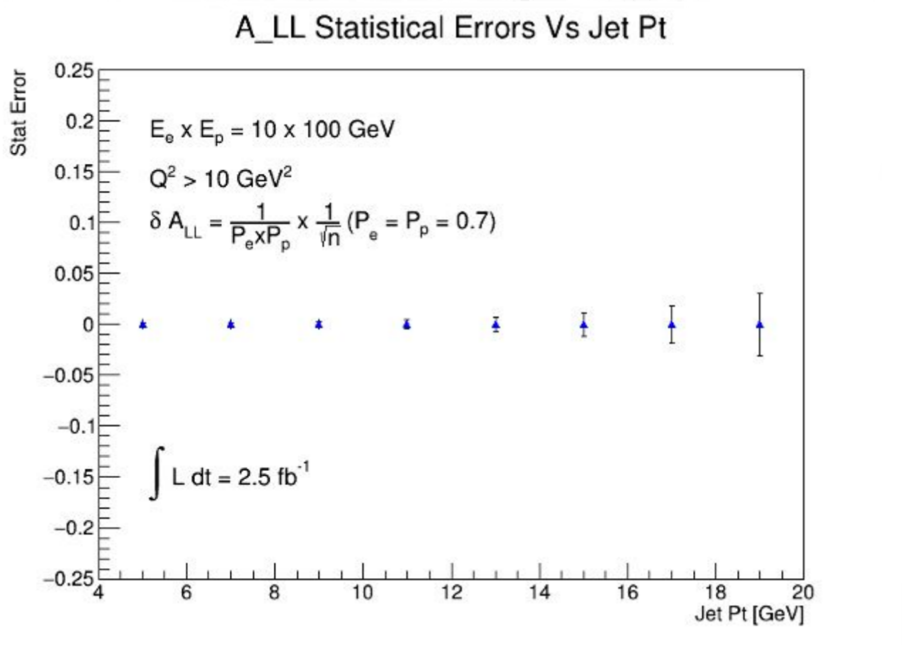


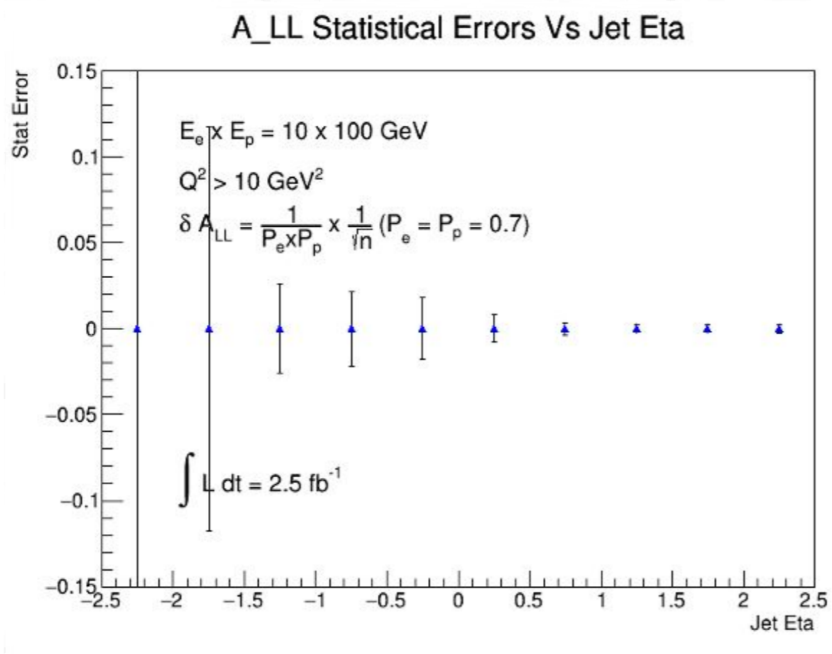


- **Above:** JES (left) & JER (right) for **charged jets**
  - Reco jets from tracks, truth jets from stable final particles
  - Jets matched via $\Delta R = \Delta\varphi \oplus \Delta\eta < 0.1$

- Only charged particles used due to lack of adequate algorithm, and **to assess tracking performance**
  - → **Note:** baseline particle flow algorithm a development priority for 2025

ePIC performance: jet A_{LL}





- **Double-spin asymmetry (A_{LL}):** $(\sigma_{\rightrightarrows} - \sigma_{\leftrightarrows})/(\sigma_{\rightrightarrows} + \sigma_{\leftrightarrows})$
  - Measured $A_{LL} \propto$ sum of convolutions of parton helicity distributions
  - Provides crucial constraints on polarized PDFs

- **Figures:** projected statistical precision for jet A_{LL}
  - CoM energy & luminosity approximate the anticipated e+p conditions in years 2, 3 of EIC

(an ePIC) Summary

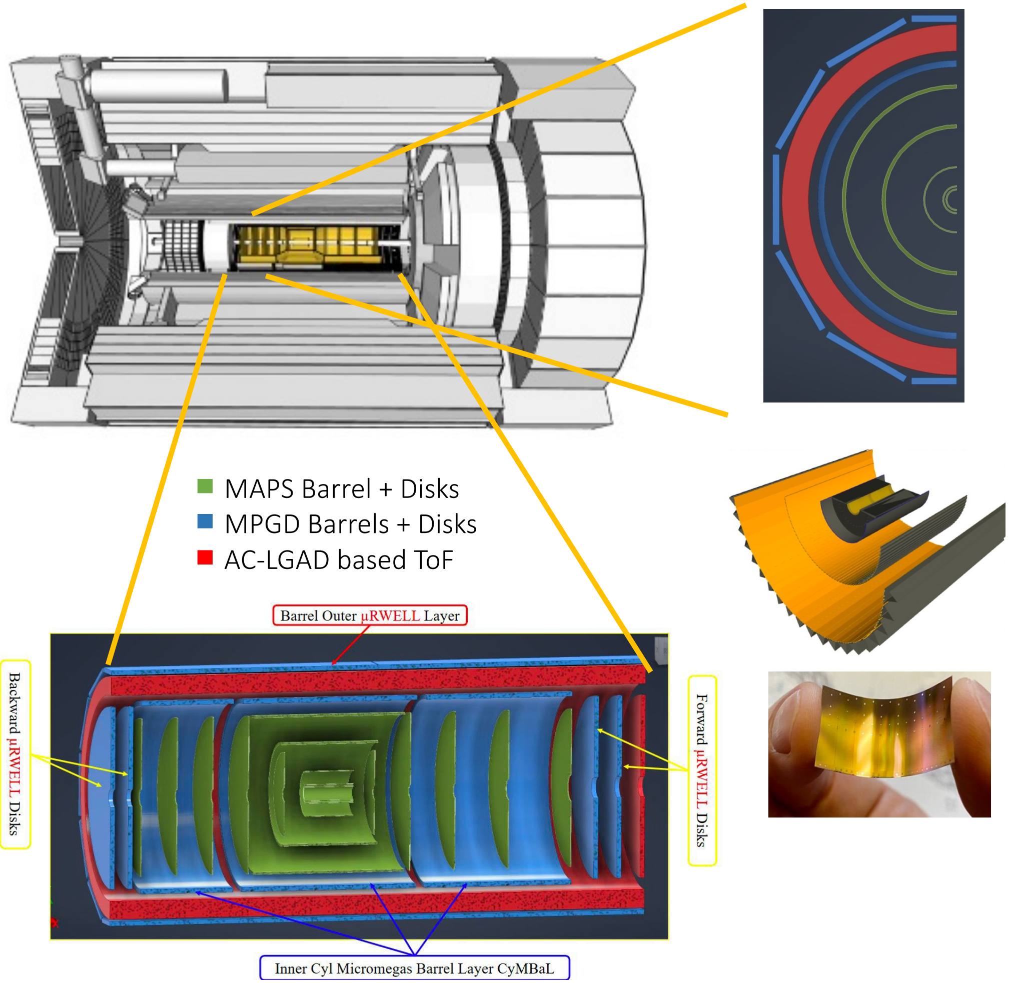
- ✓ The EIC provides an unprecedented opportunity for the ultimate understanding of QCD
  - ❖ Over two decades, the nuclear physics community has developed the scientific and technical case for the Electron-Ion Collider
  - ❖ It might be the only new collider in the world for the next decades
- ✓ The ePIC Collaboration was formed in Spring ‘22 with a successful merging of several proposal efforts
  - ❖ ePIC is approved as part of the EIC project, and progressing according to schedule
  - ❖ The ePIC detector is an enormous undertaking that will require participation and expertise from both the US (Labs and Academia) communities, as well as the international contributions (60% of Institutions from abroad world-wide)

New excitement ahead

- Event reconstruction at the ePIC experiment being finalized & novel analysis tools being developed
  - New, more realistic, impact studies
  - TDR has a chapter on physics studies
  - Report on Early Science
- It is NOW the right time to join the efforts and get involved!

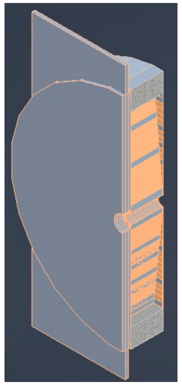

BACKUP

Tracking

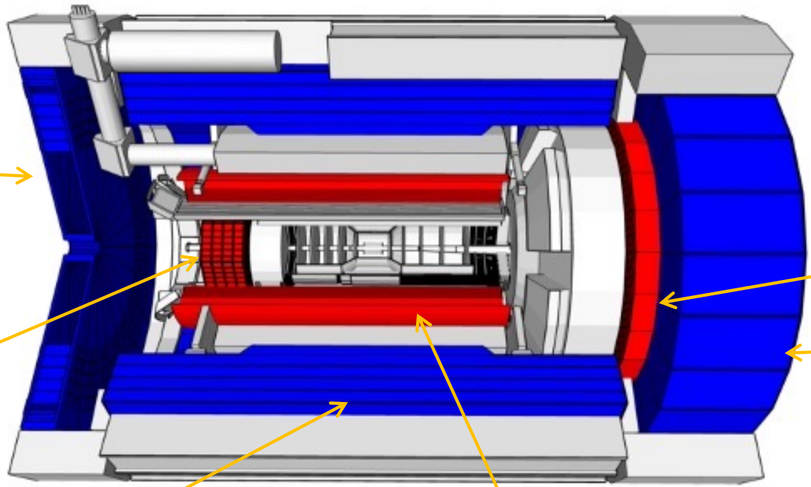


- MAPS Tracker:
  - Small pixels (20 μm), low power consumption (<20 mW/cm^2) and low material budget (0.05% to 0.55% X/X_0) per layer
  - Based on ALICE ITS3 development
  - Vertex layers optimized for beam pipe bake-out and ITS-3 sensor size
  - Forward and backward disks
- MPGD Layers:
  - Provide timing and pattern recognition
  - Cylindrical μMEGAs
  - Planar μRWell's before hpDIRC - Impact point and direction for ring seeding
- AC-LGAD TOF and AstroPix (BECAL):
  - Additional space point for pattern recognition / redundancy
  - Fast hit point / Low p PID

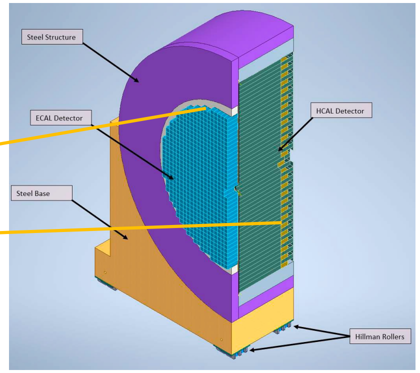
Calorimetry



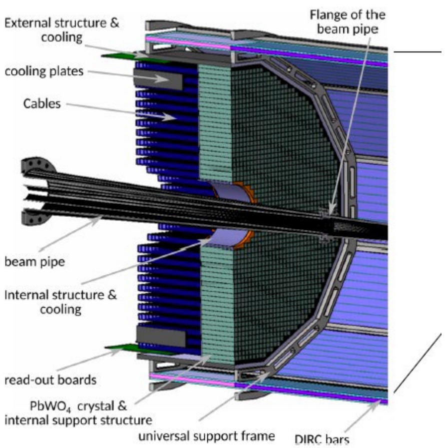
Backwards HCal
Steel/Sc
Sandwich
tail catcher



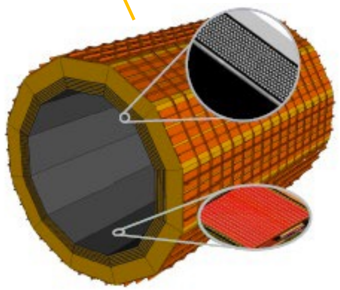
Forward EMCal
High granularity W/SciFi
a unique technology allowing to achieve
e/h ~1 (response to hadrons)



Backwards EMCal
PbW04 crystals, SiPM photosensors

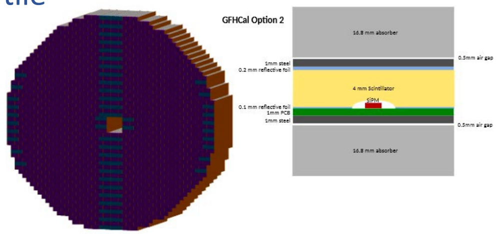


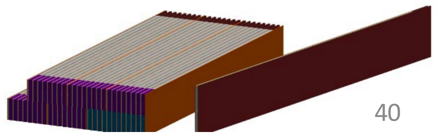
Barrel HCAL
Fe/Sc sandwich, ~3.5λ
(sPHENIX re-use)



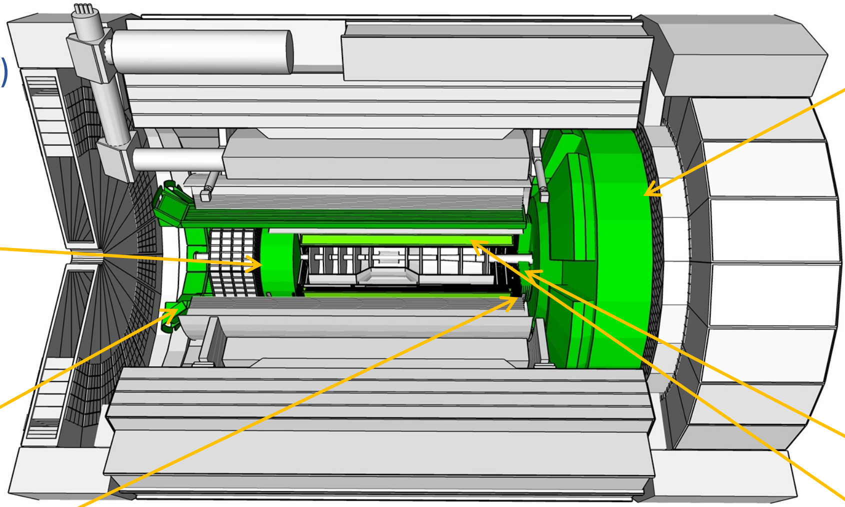
Barrel EMCAL
4 (6) layers of imaging calorimetry
by Astropix MAPS,
and sampling calorimetry by Pb/SciFi

Forward Hcal
SiPMs on tile



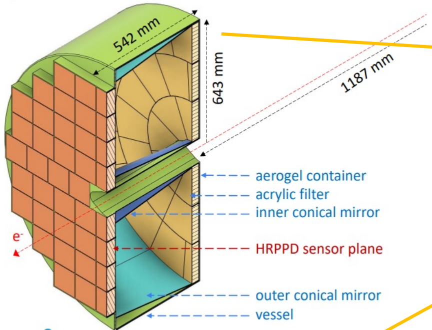


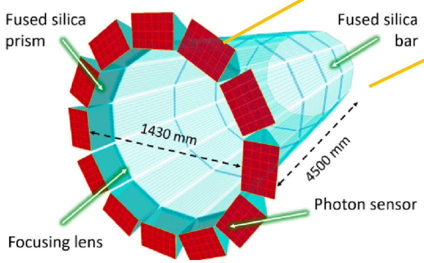
Particle ID



Proximity Focused (pfRICH)

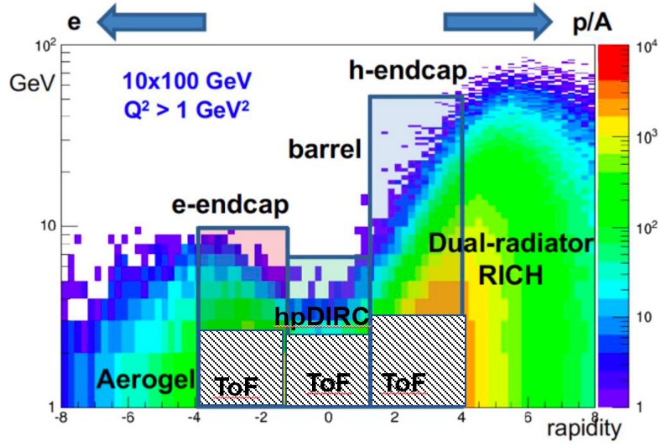
- Aerogel with Long proximity gap (~40 cm)
- Sensor: HRPPDs
- 3σ π/K sep. up to 9 GeV/c

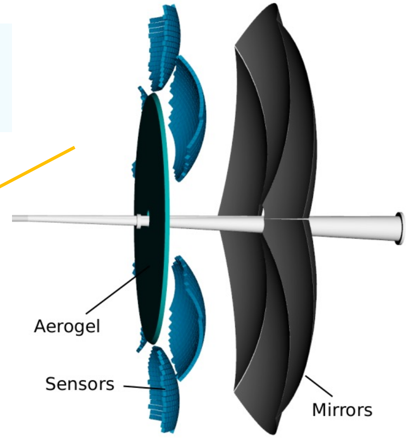




High-Performance DIRC

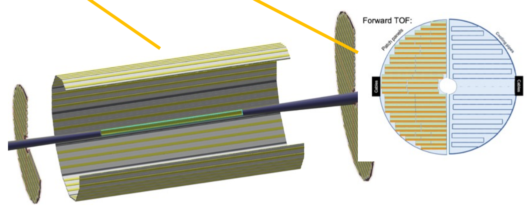
- Quartz bar radiator (BaBAR bars) light detection with MCP-PMTs
- 3σ π/K sep. at 6 GeV/c





Dual-Radiator RICH (dRICH)

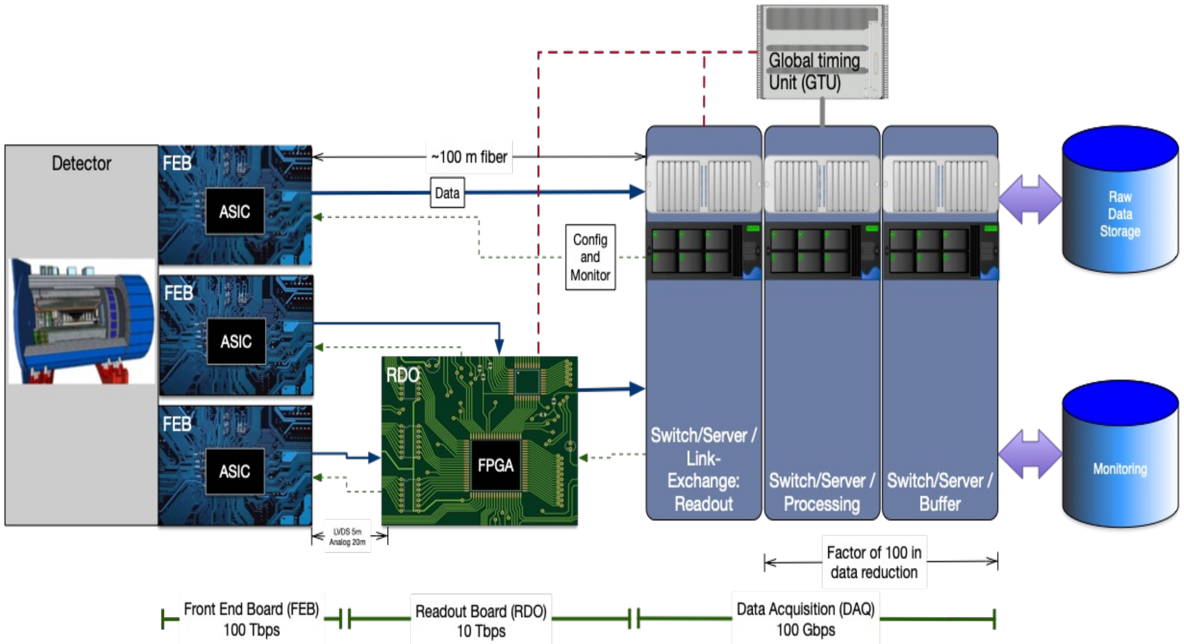
- C_2F_6 Gas Volume and Aerogel
- Single photon sensors (SiPMs)
- π/K 3σ sep. at 50 GeV/c



AC-LGAD TOF (~30ps)

- Accurate space point for tracking / Low p PID
- Forward disk and central barrel

Streaming DAQ



- No External trigger
- All collision data digitized, but zero suppressed at FEB
- Low / zero dead-time
- Event selection can be based on full data from all detectors (in real-time, or later)
- Collision data flow is independent and unidirectional

  → no global latency requirements
- Avoiding hardware triggers avoids complex custom hardware and firmware