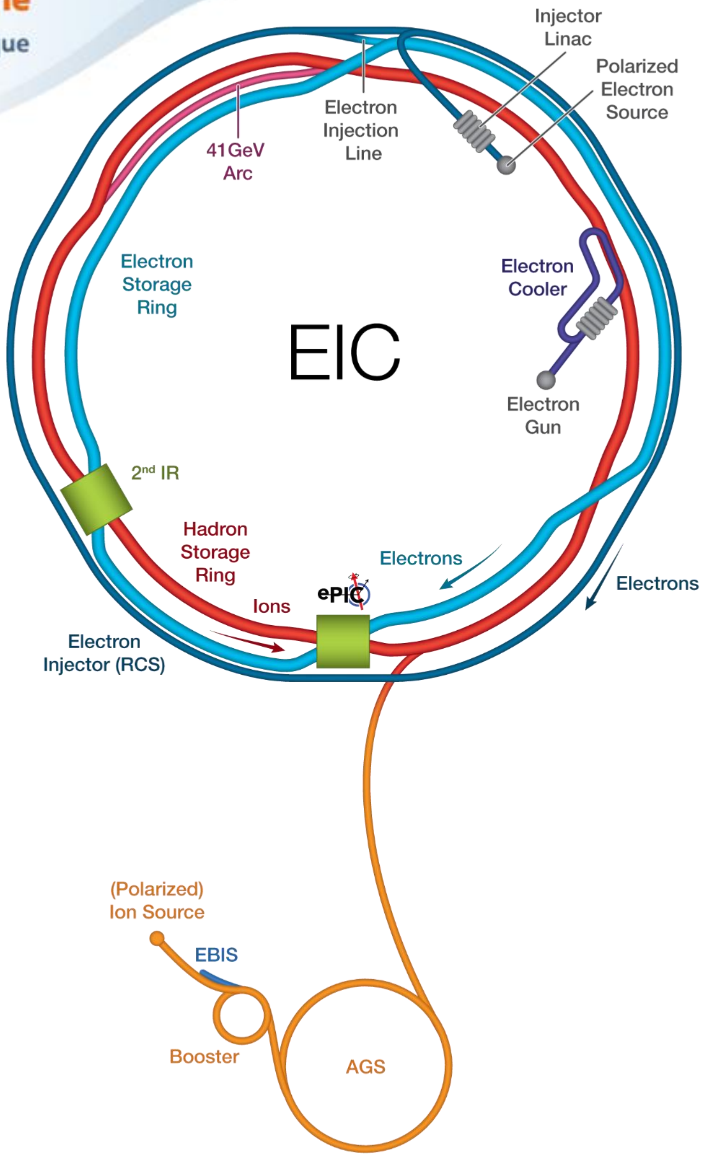

Exclusive, Diffractive and Tagged Physics at ePIC:

Physics Opportunities and Detector Systems

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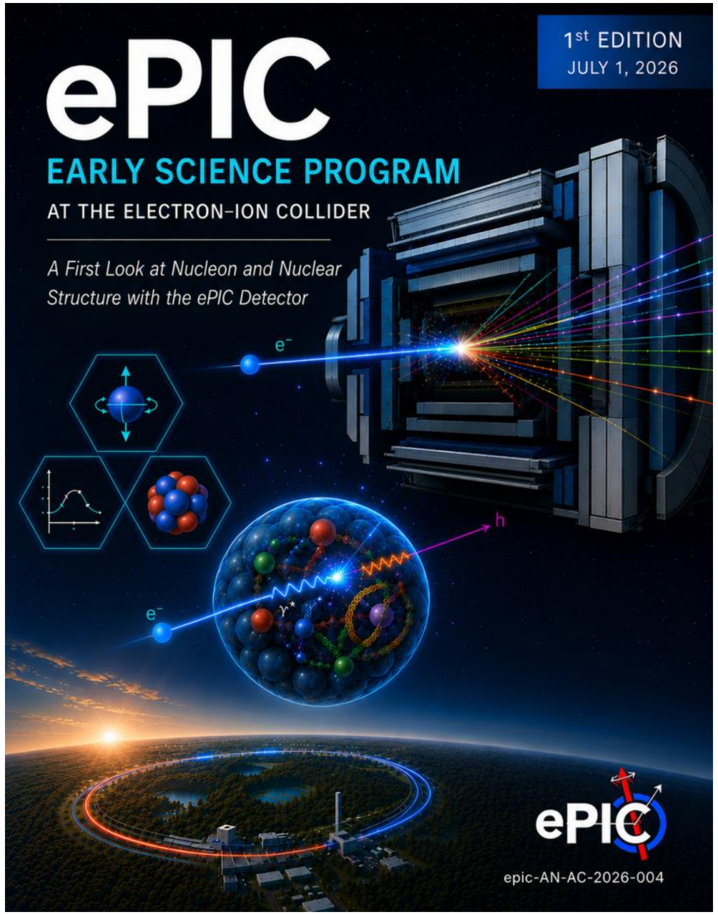
Outline

1	**Why early science?**	Sections 1–3: charge, NAS pillars and running assumptions.
2	**Selected physics channels**	Exclusive, diffractive and tagged channels: t, rapidity gaps and spectators.
3	**Which detectors make it possible**	Roman Pots/OMD first; backward ECal for defining DIS kinematics.
4	**Flagship early channels**	DVCS/CFFs, vector mesons in nuclei, spectator tagging and meson structure.
5	**What remains for full EIC**	Limitations, upgrade path and conclusion

ePIC Early Science Report



1st EDITION
JULY 1, 2026

ePIC

EARLY SCIENCE PROGRAM

AT THE ELECTRON–ION COLLIDER

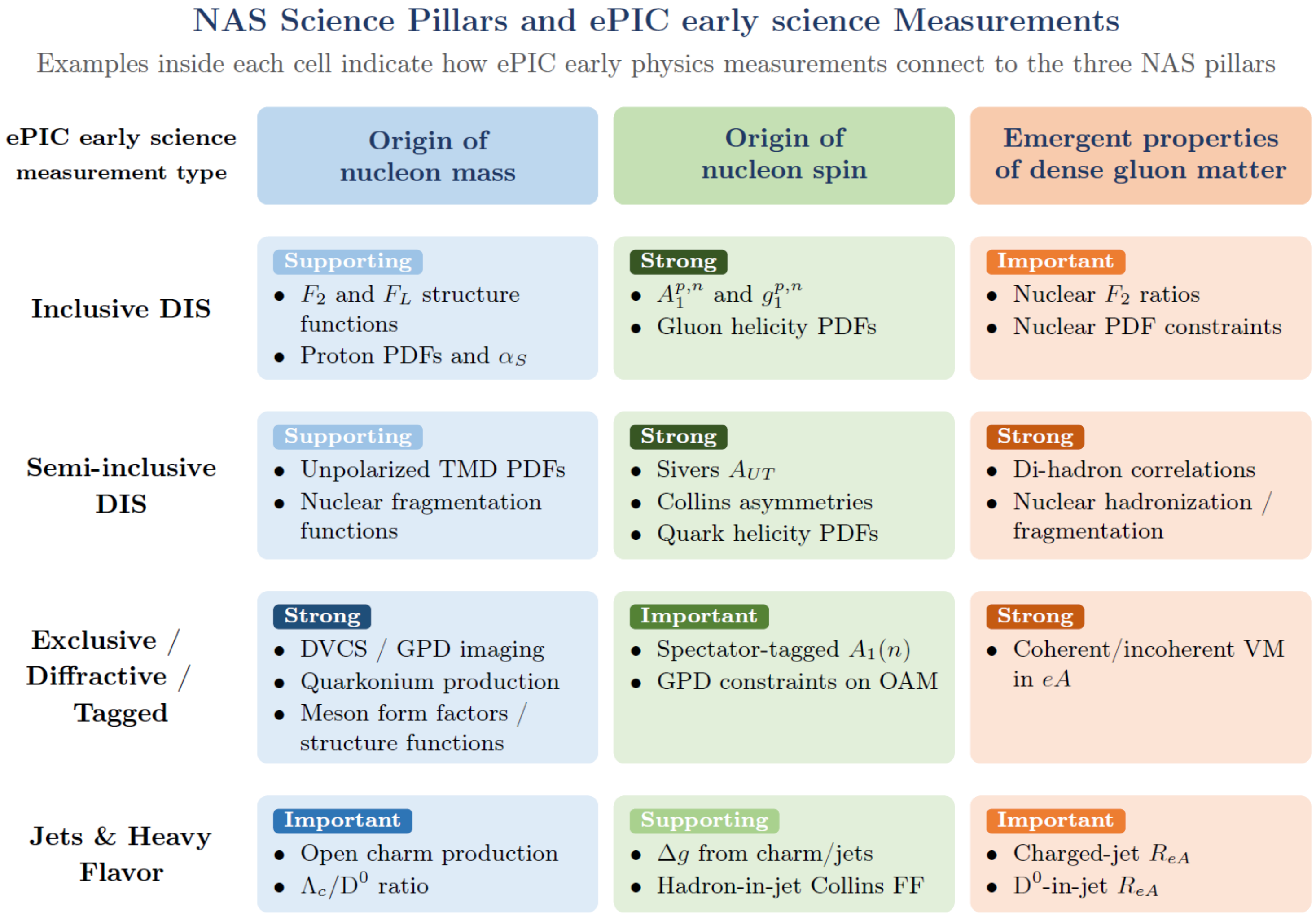
A First Look at Nucleon and Nuclear Structure with the ePIC Detector

ePIC

epic-AN-AC-2026-004

- Prepared in response to a BNL/JLab charge: identify science possible before the ramp-up to full EIC capability.
- Uses realistic early-running beam configurations and full ePIC detector simulations.
- Section 6 is dedicated to Exclusive and Diffractive physics.
- As far as ePIC subdetectors:
    - Inclusive DIS begins with the scattered electron.
    - Exclusive, diffractive and tagged measurements require the whole event: e′, γ or meson, recoil proton, nuclear breakup vetoes and spectator fragments.
    - Roman Pots / OMD provide the essential forward-proton and spectator information. The backward ECal anchors the electron-going electromagnetic reconstruction.

ePIC science and the NAS pillars



NAS Science Pillars and ePIC early science Measurements

Examples inside each cell indicate how ePIC early physics measurements connect to the three NAS pillars

ePIC early science measurement type	Origin of nucleon mass	Origin of nucleon spin	Emergent properties of dense gluon matter
Inclusive DIS	**Supporting** • F_2 and F_L structure functions • Proton PDFs and α_S	**Strong** • $A_1^{p,n}$ and $g_1^{p,n}$ • Gluon helicity PDFs	**Important** • Nuclear F_2 ratios • Nuclear PDF constraints
Semi-inclusive DIS	**Supporting** • Unpolarized TMD PDFs • Nuclear fragmentation functions	**Strong** • Sivers A_{UT} • Collins asymmetries • Quark helicity PDFs	**Strong** • Di-hadron correlations • Nuclear hadronization / fragmentation
Exclusive / Diffractive / Tagged	**Strong** • DVCS / GPD imaging • Quarkonium production • Meson form factors / structure functions	**Important** • Spectator-tagged $A_1(n)$ • GPD constraints on OAM	**Strong** • Coherent/incoherent VM in eA
Jets & Heavy Flavor	**Important** • Open charm production • Λ_c/D^0 ratio	**Supporting** • Δg from charm/jets • Hadron-in-jet Collins FF	**Important** • Charged-jet R_{eA} • D^0-in-jet R_{eA}

Origin of mass

DVCS/GPD imaging, vector mesons, meson form factors and meson structure functions.

Origin of spin

Spectator-tagged neutron observables and GPD constraints relevant to orbital angular momentum.

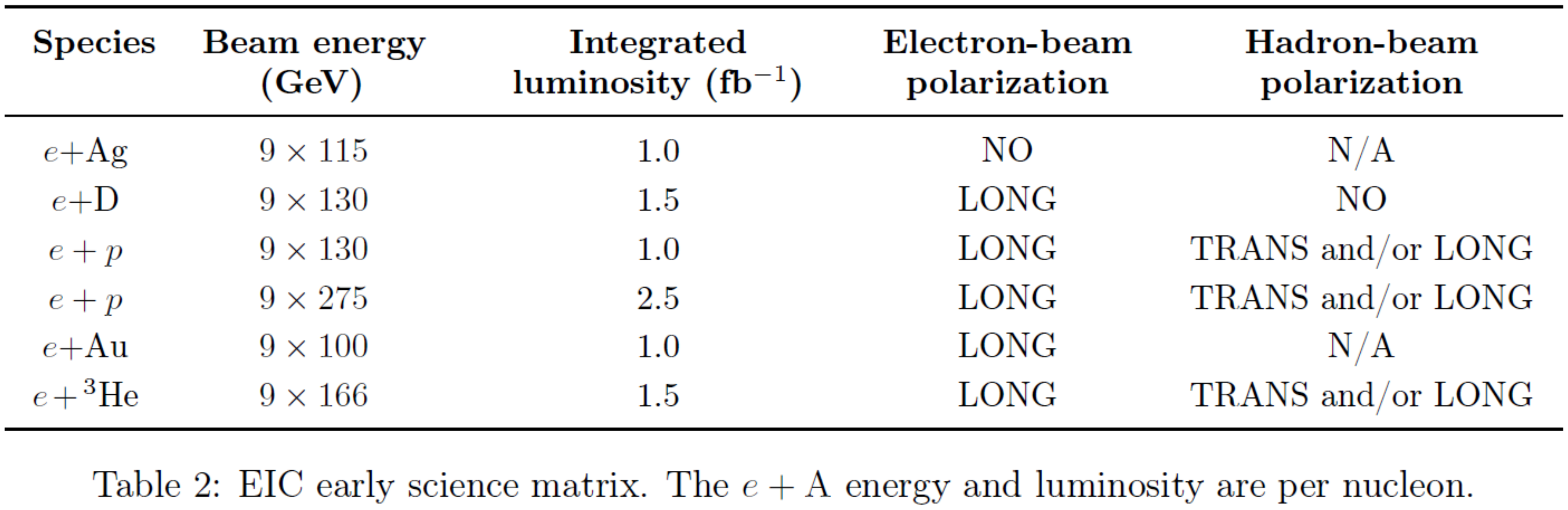
Dense gluonic matter

Coherent/incoherent vector-meson production in e + A accesses average gluon density and fluctuations.

Detector implication:

The “exclusive/diffractive/tagged” row becomes real only with forward particles and electromagnetic final states reconstructed well.

Early running assumptions



Species	Beam energy (GeV)	Integrated luminosity (fb^{-1})	Electron-beam polarization	Hadron-beam polarization
e+Ag	9×115	1.0	NO	N/A
e+D	9×130	1.5	LONG	NO
$e+p$	9×130	1.0	LONG	TRANS and/or LONG
$e+p$	9×275	2.5	LONG	TRANS and/or LONG
e+Au	9×100	1.0	LONG	N/A
$e+{}^3$He	9×166	1.5	LONG	TRANS and/or LONG

Table 2: EIC early science matrix. The $e + \mathrm{A}$ energy and luminosity are per nucleon.

- Baseline electron beam: 9 GeV, with an upgrade path to 18 GeV.
- Initial e + A running supports early diffractive and low-multiplicity nuclear measurements.
- Polarized e + p and e + ^{3}He unlock spin and tagged-neutron observables.
- Far-forward commissioning determines when proton and spectator tagging can be fully exploited.

The EIC detector: ePIC

Tracking:
- New 1.7T solenoid
- Si MAPS Tracker
- MPGDs (µRWELL/µMegas)

PID:
- Backward pfRICH
- Barrel hpDIRC
- Forward dRICH
- Barrel & Forward TOF

Calorimetry:
- Backward HCal (Steel+scint)
- $PbWO_4$ EMCal in backward direction
- Sampling & Imaging Barrel EMCal
- Outer HCal (sPHENIX re-use)
- Finely segmented EMCal +HCal in forward direction

🟦 hadronic calorimeters

🟪 Solenoidal Magnet

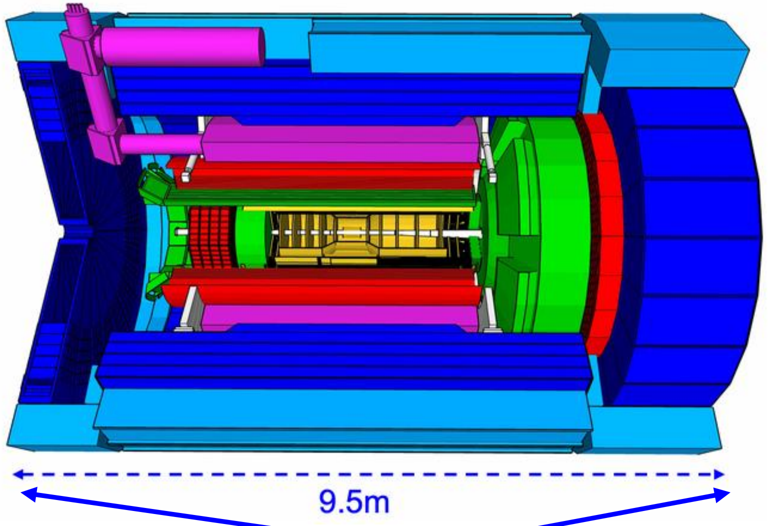
🟥 e/m calorimeters

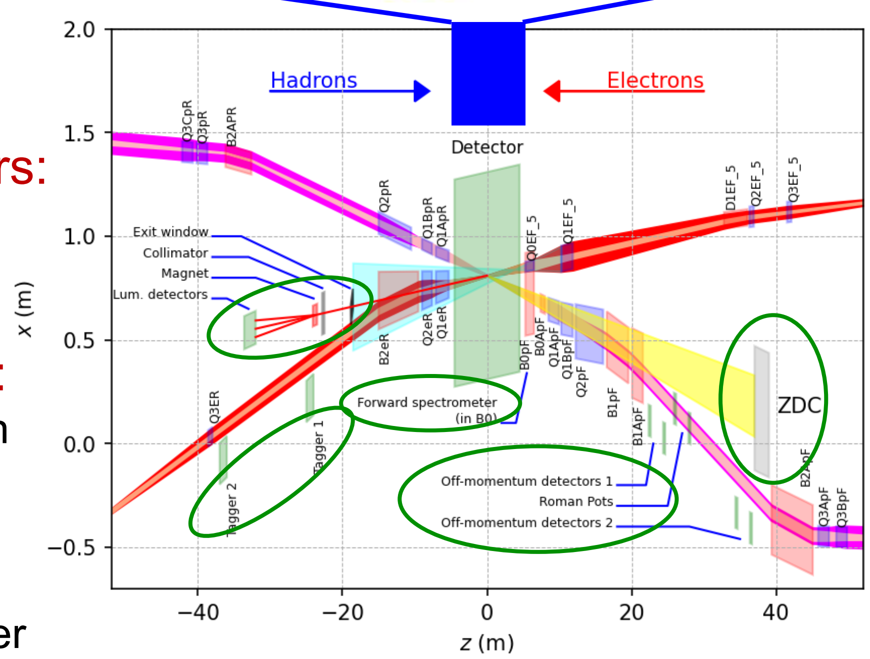
🟩 ToF, DIRC, RICH detectors

🟨 MPG trackers

🟨 MAPS tracker

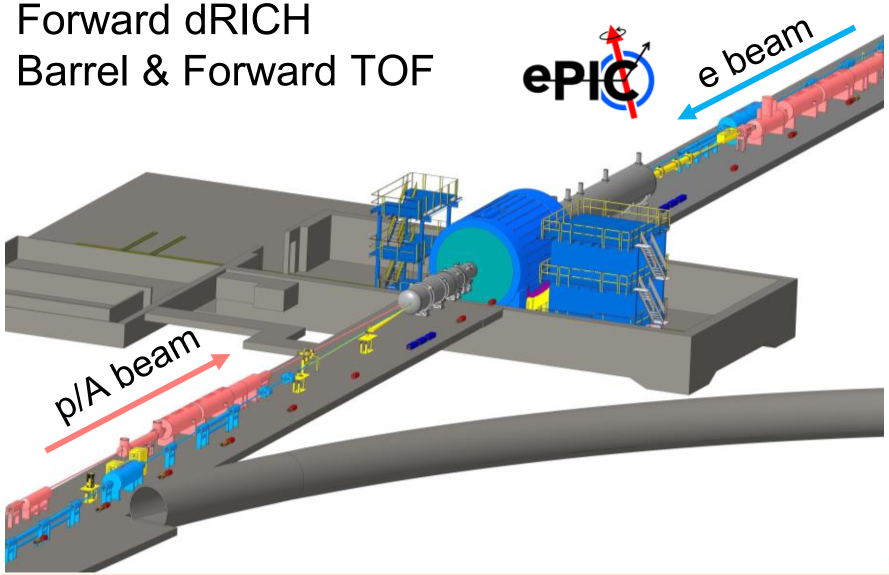
25 subdetectors incl. polarimeters



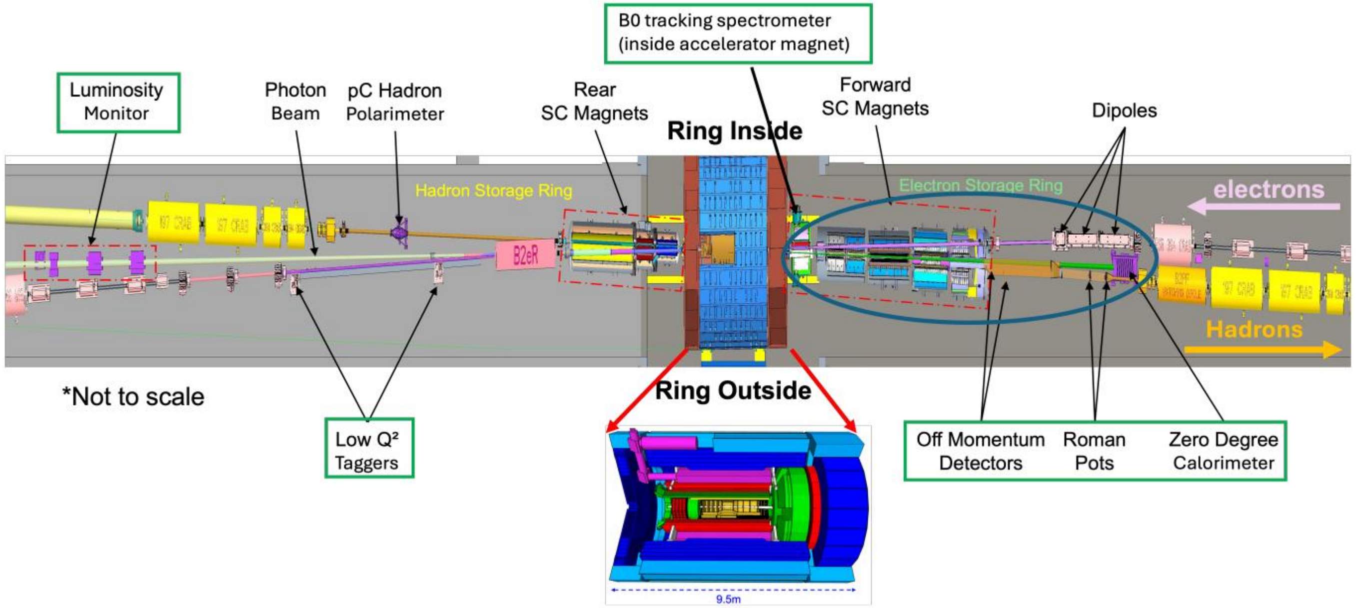


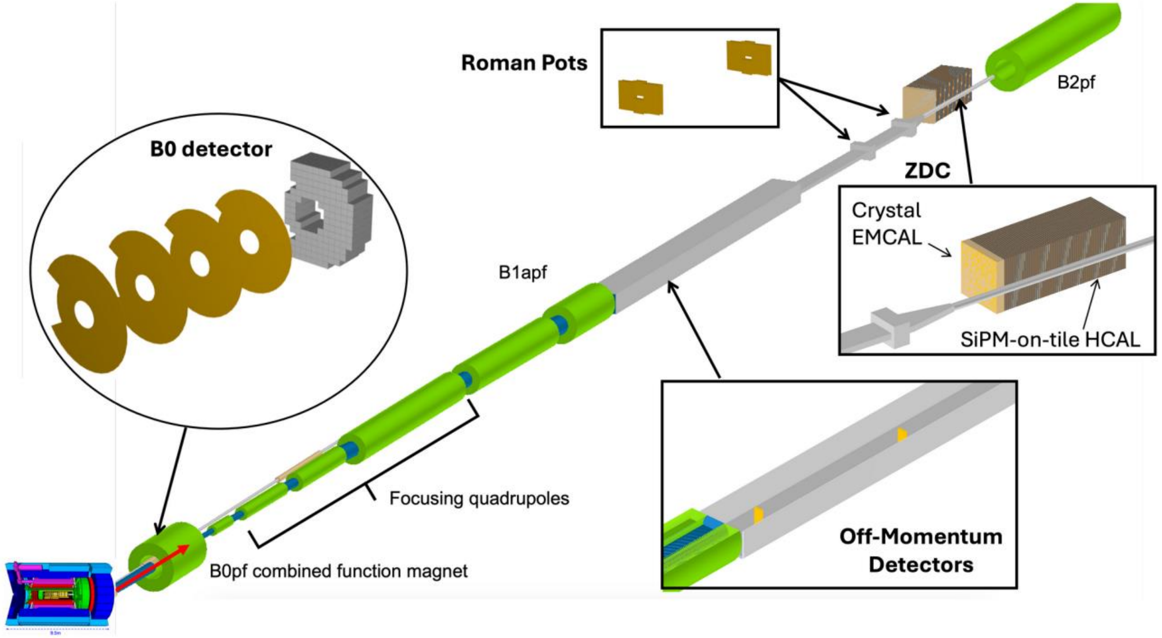
Far-Backward Detectors:
- Luminosity monitor.
- Low-Q^2 Tagger

Far-Forward Detectors:
- B0 Tracking and Photon Detection
- Roman Pots and Off-Momentum Detectors.
- Zero-Degree Calorimeter



The ePIC far-forward system





Why far-forward?
The exclusive program depends on particles at very forward rapidity: protons, neutrons, photons and nuclear fragments in the outgoing hadron direction.

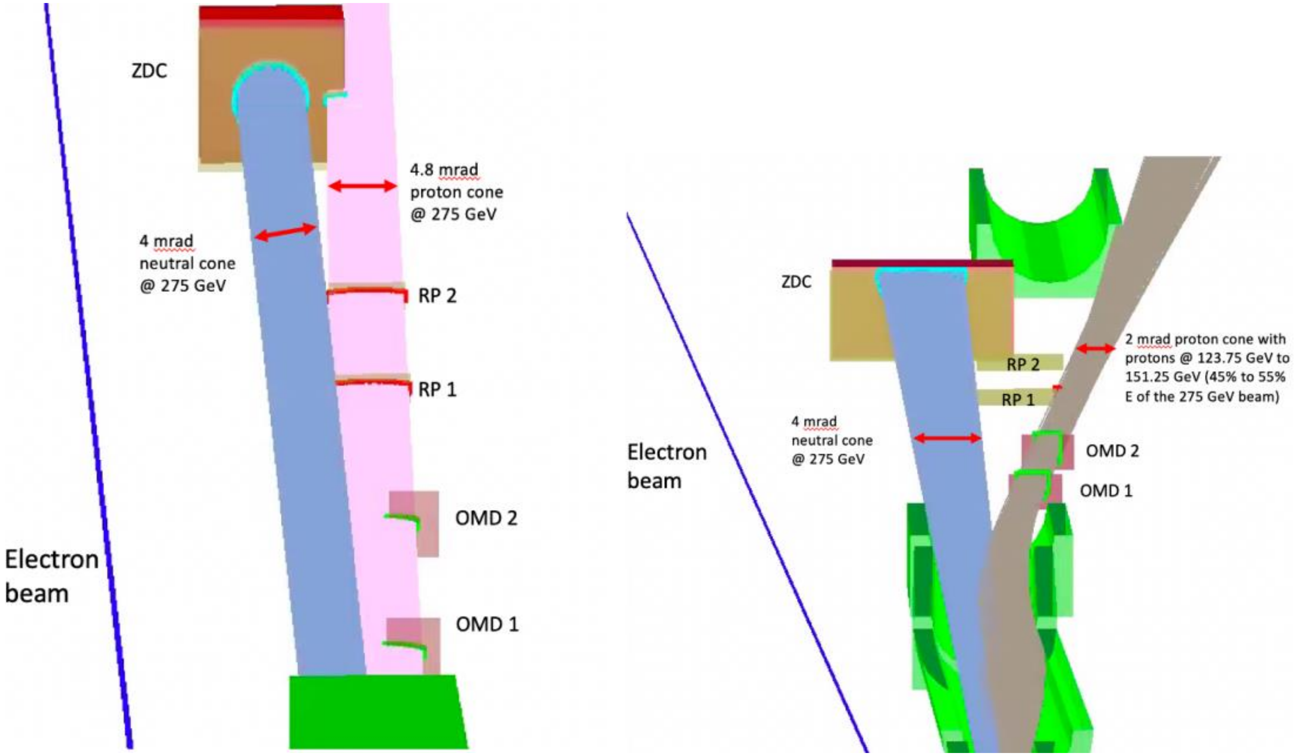
Subsystem complementarity:

B0 tracker/calorimeter, Roman Pots, Off-Momentum Detectors and ZDC cover complementary angular and rigidity regions between about 5.5 and 39 m from the IP.

For Exclusive, Diffractive and Tagged measurements, far-forward detection provides the recoil, spectator and breakup information

Roman Pots and Off-Momentum Detectors

Tagging across rigidity



Roman Pots:
Near-beam silicon planes tag far-forward protons with $x_L > 65\%$. They are essential for recoil-proton detection in DVCS and exclusive vector-meson production.

Off-Momentum Detectors:
OMD cover lower-rigidity protons, roughly $25\% \leq x_L \leq 65\%$, matching spectator protons from light-nucleus breakup.

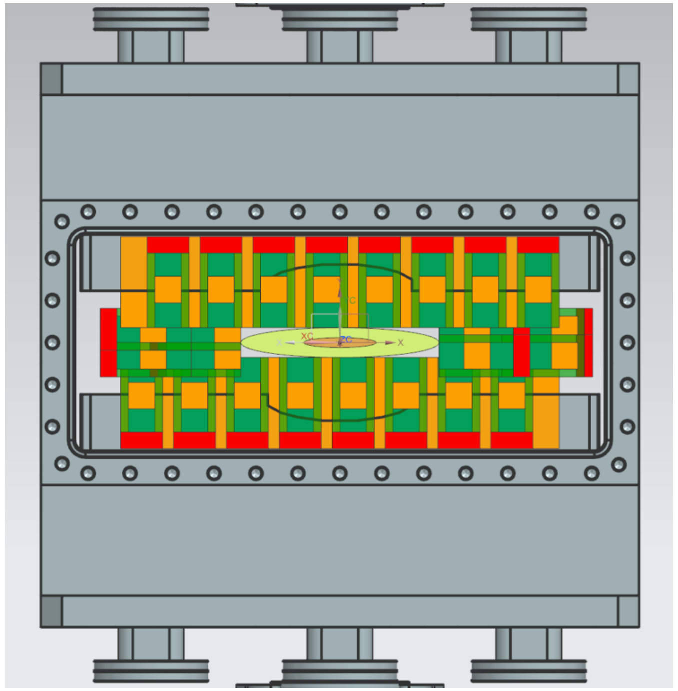
Together:
They provide nearly continuous far-forward proton acceptance for recoil tagging, spectator tagging and nuclear-breakup control.

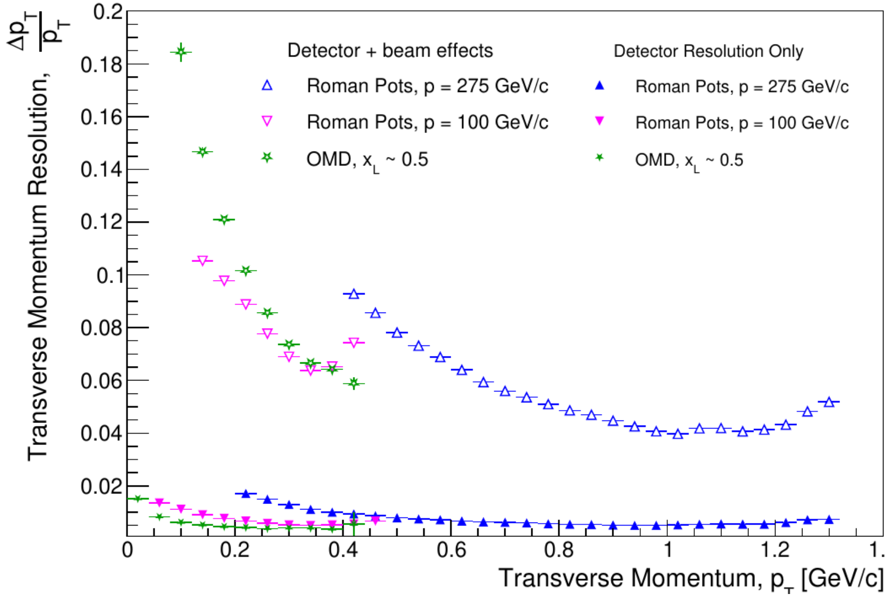
Low-pT acceptance is a machine–detector interface issue: Roman Pots trade luminosity against approach to the beam; OMD can tag off-momentum spectators at pT ≈ 0.

Physics processes & detector subsystems

Physics Measurements	What must be reconstructed	Key detectors
DVCS / GPD imaging	e′ + γ + recoil proton; t and exclusivity	Roman Pots; EEEMCal for e/γ
Diffractive vector mesons	VM decay + recoil/nuclear state; coherent vs incoherent	RP/OMD/ZDC tags and vetoes
Spectator-tagged DIS	low-pT spectator proton(s) from D or 3He breakup	OMD and Roman Pots across xL
Meson structure	forward neutron/Λ tags plus electron kinematics	ZDC/forward tagging + EEEMCal

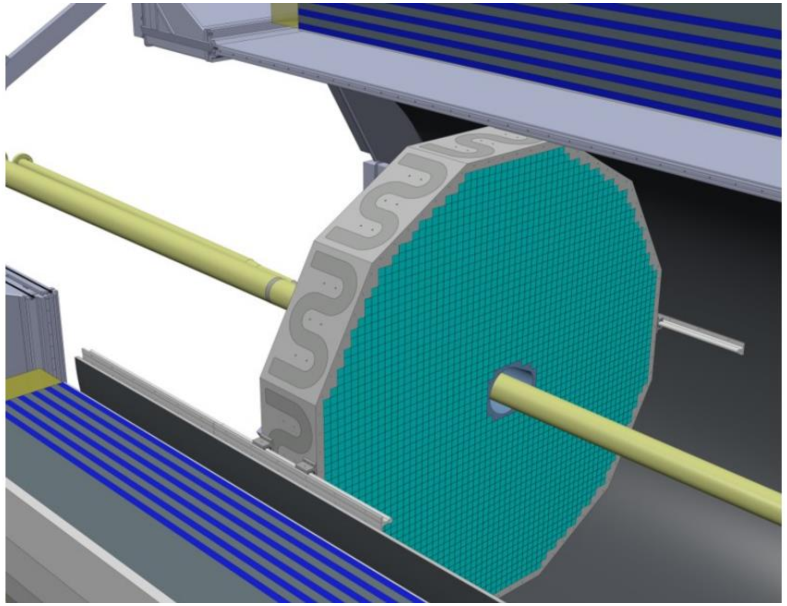
Roman Pots: AC-LGAD tracking

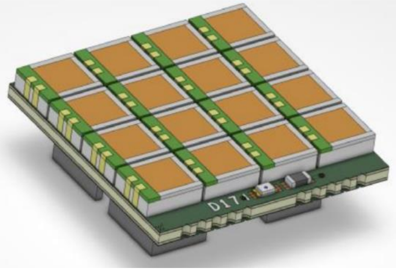




- “Potless” silicon tracking planes operate directly in the machine vacuum.
- Pixellated AC-LGAD sensors with EICROC readout provide space and time information.
- The design minimizes edge dead area to maximize acceptance near the beam.
- Target performance: pT resolution better than about 10% near pT ≈ 1 GeV/c; beam optics are a major contribution.

Backward ECal





Design concept

A compact homogeneous PbWO4/PWO-II crystal calorimeter located in the electron-going endcap, covering roughly $-3.5 < \eta < -1.8$.

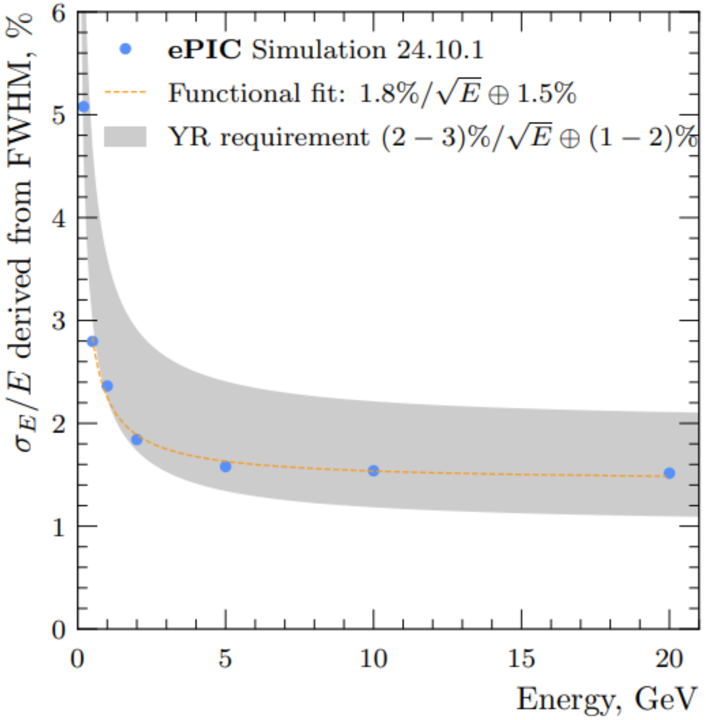
Readout concept

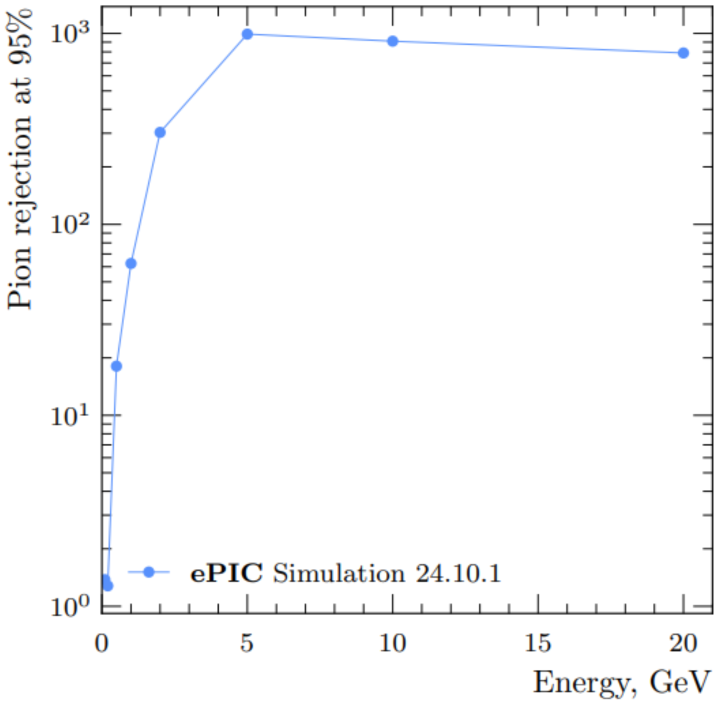
Each crystal is read out with SiPM arrays; LED monitoring tracks gain and stability over time.

- Measures scattered electrons and final-state photons in the electron-going region.
- Important for exclusive kinematic closure when e′ or γ is backward.
- Secondary to Roman Pots in this talk, but essential to the full exclusive reconstruction chain.

EEEMCal provides the electromagnetic side of event; Roman Pots / OMD provide the forward hadronic side.

Backward Ecal performance





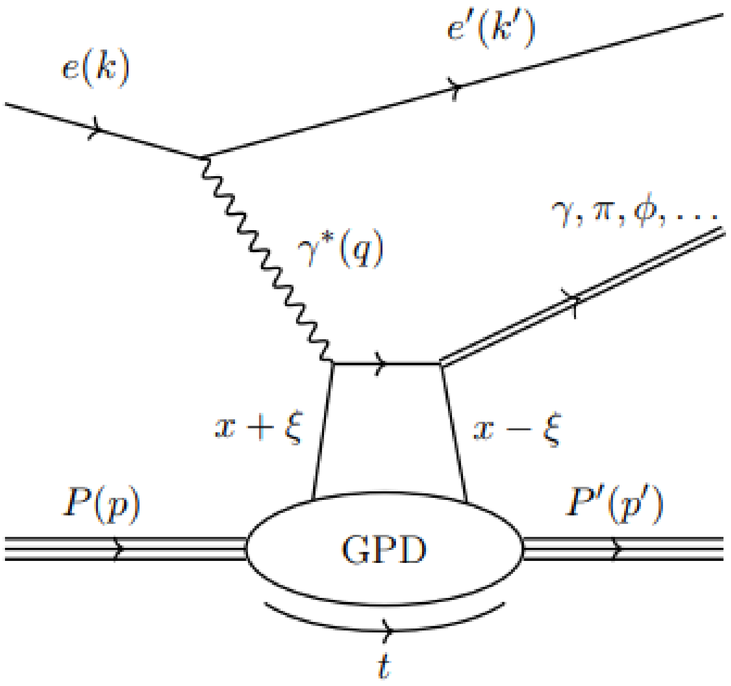
Physics-driven requirements
The EEEMCal must cover electromagnetic showers from about 0.1–18 GeV for scattered electrons, with sensitivity to lower-energy photons and deposits used in reconstruction.

Resolution target
Required energy resolution is about (2–3)%/√E ⊕ (1–2)%, and full-detector simulations show performance consistent with that requirement.

Impact
Better electron and photon reconstruction strengthens missing-momentum checks, background rejection and over-constrained kinematics for DVCS and exclusive meson channels.

For exclusive physics the backward ECal improves the electromagnetic side of the event and defines the DIS kinematics

Exclusive processes

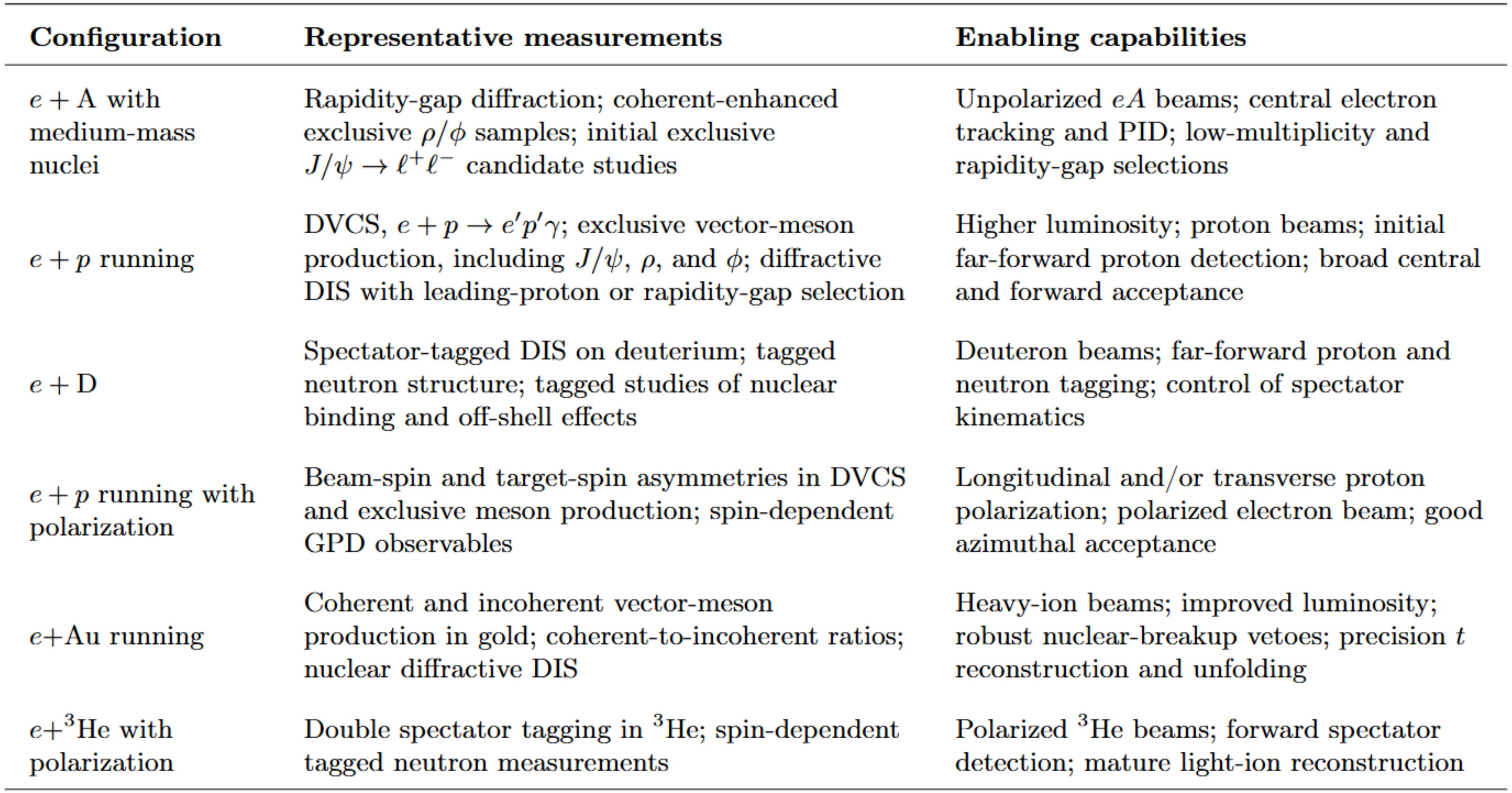


- DVCS: photon final state; cleanest GPD/CFF access.
- Vector mesons: exclusive heavy quarkonia probes gluons.
- Tagged reactions: spectators or leading baryons control nuclear and meson structure.
- Detector hermiticity: all visible particles, vetoes and forward tags over-constrain the event.

The momentum transfer t in exclusive channels encodes transverse spatial information about quarks and gluons.

Measure t well → start turning cross sections into spatial information.

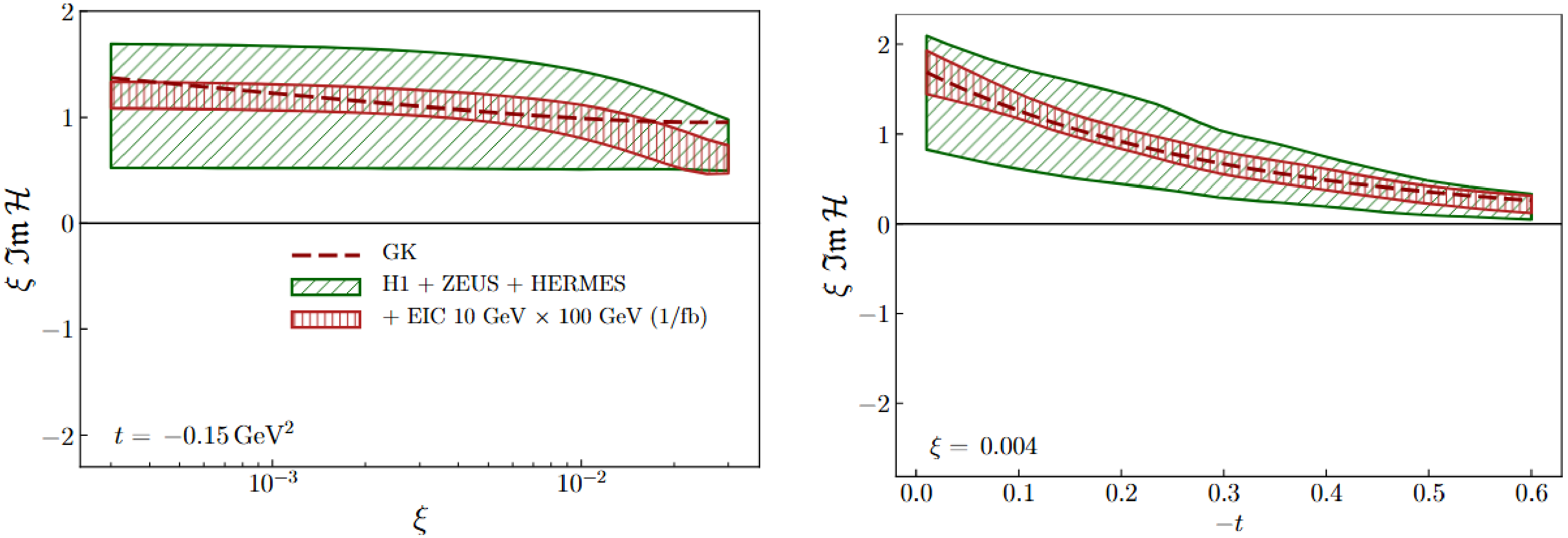
Staged physics program



Configuration	**Representative measurements**	**Enabling capabilities**
$e + \mathrm{A}$ with medium-mass nuclei	Rapidity-gap diffraction; coherent-enhanced exclusive ρ/ϕ samples; initial exclusive $J/\psi \to \ell^+\ell^-$ candidate studies	Unpolarized eA beams; central electron tracking and PID; low-multiplicity and rapidity-gap selections
$e + p$ running	DVCS, $e + p \to e'p'\gamma$; exclusive vector-meson production, including J/ψ, ρ, and ϕ; diffractive DIS with leading-proton or rapidity-gap selection	Higher luminosity; proton beams; initial far-forward proton detection; broad central and forward acceptance
$e + \mathrm{D}$	Spectator-tagged DIS on deuterium; tagged neutron structure; tagged studies of nuclear binding and off-shell effects	Deuteron beams; far-forward proton and neutron tagging; control of spectator kinematics
$e + p$ running with polarization	Beam-spin and target-spin asymmetries in DVCS and exclusive meson production; spin-dependent GPD observables	Longitudinal and/or transverse proton polarization; polarized electron beam; good azimuthal acceptance
e+Au running	Coherent and incoherent vector-meson production in gold; coherent-to-incoherent ratios; nuclear diffractive DIS	Heavy-ion beams; improved luminosity; robust nuclear-breakup vetoes; precision t reconstruction and unfolding
e+^{3}He with polarization	Double spectator tagging in ^{3}He; spin-dependent tagged neutron measurements	Polarized ^{3}He beams; forward spectator detection; mature light-ion reconstruction

- First e + A: rapidity gaps, low multiplicity and coherent enhancement; far-forward vetoes mature the measurement.
- e + p: DVCS and exclusive VMs; Roman Pots turn forward protons into t and exclusivity handles.
- e + D / e + 3He: spectator tagging; OMD/RP connect nuclear breakup to neutron structure and spin.
- Later e + Au: coherent/incoherent VM production; ZDC/OMD/RP help separate intact and breakup channels.

DVCS: impact on Compton Form Factors

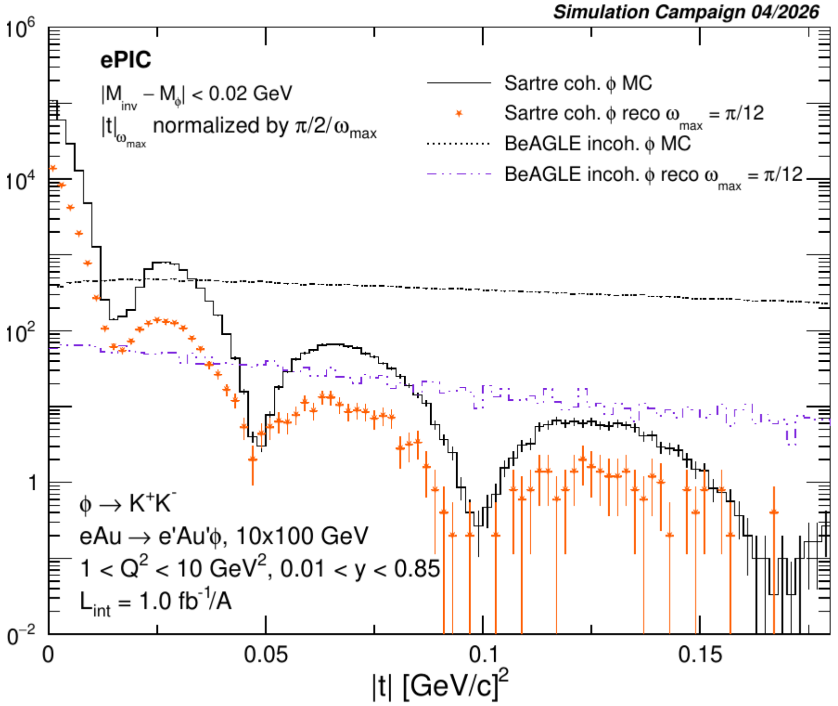


Early Physics Impact:

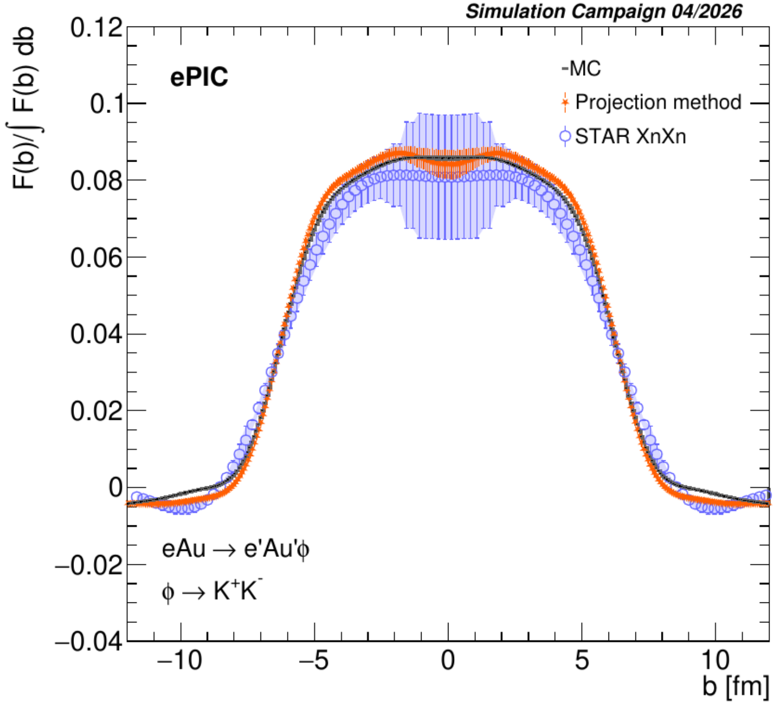
Projected DVCS data narrow uncertainty bands on Im H, one of the Compton form factors entering the DVCS amplitude.

- Roman Pots: tag the recoil proton and improve t reconstruction/exclusivity.
- Backward/central EM calorimetry: measure scattered e and final-state photon over a broad η range.
- Tracking + calorimetry: control e/γ kinematics and missing-mass closure.
- Full EIC need: fine multidimensional binning remains luminosity limited.

Coherent φ in e+Au: diffraction & *g* imaging



Projection-method |t| reconstruction resolves the diffractive structure and follows the MC truth more closely than the standard method.

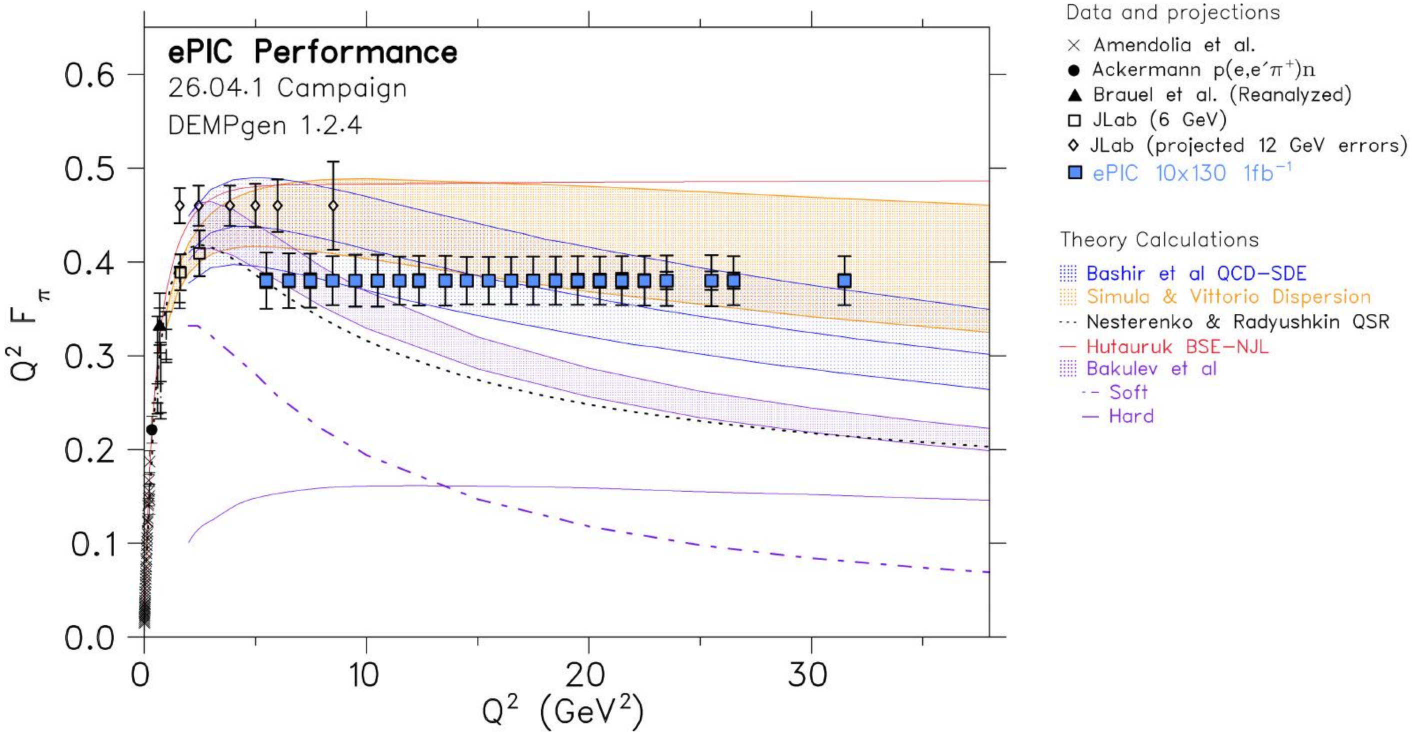


The Fourier–Bessel transform converts the measured |t| distribution into the transverse gluon spatial profile.

Key detectors:

OMD/RP/ZDC vetoes and tags control coherent vs incoherent breakup; electron and kaon reconstruction controls exclusivity

Meson structure measurements



Pion form factor:

Forward neutron tagging in ep → e′ π+ n enables access to Q^2F_π in collider kinematics.

Pion / kaon structure:

Tagged semi-inclusive measurements provide a route to pion and kaon structure functions; Λ tagging is a key handle for kaon structure.

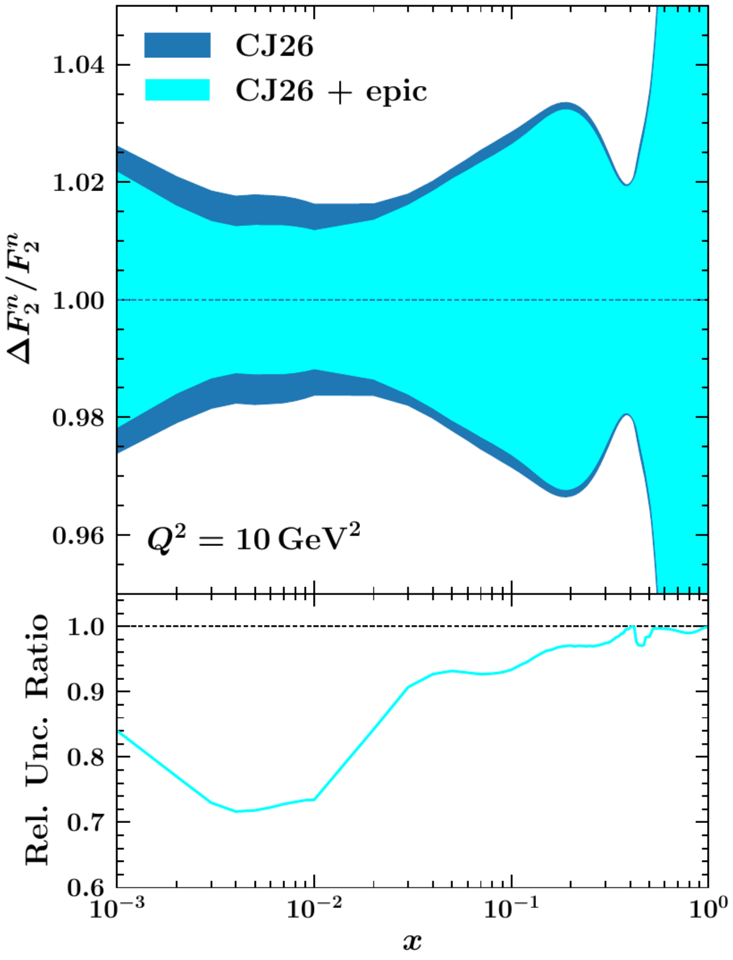
Detector subsystems:

ZDC and far-forward instrumentation provide the tag; the backward ECal anchors scattered-electron kinematics entering the extraction.

Current pion form-factor projections include statistical and assumed systematic contributions; dedicated detector-level systematics remain to be finalized.

Spectator-tagged deuteron data: F_2^n

CJ26 baseline uncertainty on F_2^n at $Q^2 = 10\ \text{GeV}^2$, compared with CJ26 + ePIC spectator-tagged pseudo-data.



- Use deuterium as an effective neutron target: e+d → e' + X + p_{spec}
- A low-momentum spectator proton tags DIS on the neutron and fixes the initial p/n configuration.
- Extrapolation to the deuteron pole selects the large-separation p+n limit, where the struck neutron is effectively free.
- This minimizes nuclear binding and final-state-interaction corrections, enabling a clean extraction of the free-neutron structure function F_2^n).

- The relative uncertainty is reduced over a broad x range; around $x \simeq 5\times10^{-3}$, about 2% → 1.5% (≈25–30% reduction)
- This brings neutron-structure uncertainties closer to the scale required for deuteron shadowing tests and robust flavor-separated PDF constraints

F_2^n is a concrete early deliverable unlocked by far-forward tagging

Detector takeaway for exclusive physics

Roman Pots

- Recoil protons in DVCS and exclusive VMs
- t reconstruction and exclusivity
- Near-beam acceptance / machine interface

Off-Momentum Detectors

- Spectator protons from D and 3He
- Low-pT tagged DIS
- Overlap with RP for calibration

Backward ECal

- Scattered e and photons in electron-going region
- Kinematic closure and background rejection
- High-resolution EM reconstruction

Detector performance becomes t-resolution, clean exclusivity and spectator tagging

EIC early running: limitations

Kinematic reach	9 GeV electrons limit the low-x frontier; fully entering saturation requires the 18 GeV upgrade path.
Luminosity	Early luminosities are powerful for benchmarks but limit fine multidimensional binning in x, Q^2 and t.
GPD tomography	DVCS can initiate the CFF/GPD program; quantitative model-independent tomography needs full luminosity.
Saturation	Coherent VM imaging in e + A provides early constraints; discovery-level saturation studies need full energy and luminosity.
Rare channels	Near-threshold quarkonium and some hard-probe channels are deferred beyond the early configuration.

Detector framing: early ePIC validates and begins the program; full EIC capability completes the NAS science case

Summary and conclusion

Early ePIC will produce a coherent set of measurements addressing all three NAS pillars

Physics

DVCS, vector mesons, diffraction, spectator tagging and meson structure start quark/gluon imaging in proton and nuclear systems.

Detector

Roman Pots / OMD provide the decisive far-forward proton and spectator handles; EEEMCal strengthens electron-going EM reconstruction.

Outlook

Early science is a high-impact first stage and a validation platform; full EIC energy, luminosity and mature detector operation complete the mission.

The exclusive, diffractive and tagged program shows the essential character of early ePIC science: detector-enabled imaging begins immediately, while the full EIC remains indispensable for the complete NAS science case