Opportunities in the EIC 2^{nd} detector program

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on behalf of the BNL EIC 2nd Detector Group

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BNL LDRD Program

- Strengthen case for the EIC 2nd detector
  - Cross-checking
  - Cross-calibration
  - Broaden physics program

- Provide a realistic detector concept
  - Complementary to ePIC in terms of physics reach, precisions and systematics
  - Suggestions on new and developing technologies

BNL EIC 2nd Detector Group

ep & eA Physics + Conceptual Detector Design

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Blue: members of BNL EIC 2nd Detector LDRD

Physics Programs

	Measurement	Physics	Requirements and Challenges
BNL LDRD scope	Double polarized e+D	Transversity in transverse polarized eD collisions →gluons' role in nuclear binding	
	Positron beams	● Providing electro-weak data for fundamental studies: quark axial and vector couplings ● Extends the capabilities of the physics with exclusive measurements	As for electron beams
	Real photon beams through Compton scattering	Enables the generation of a polarized real photon beam →understanding the formation of for example new charmed mesons via spectroscopy measurements →a full complementary approach to LHCb and Belle-II	TBD
	2nd focus integrated in the IR	Soft particles down to p_T ~0 GeV →new understanding of the structure of nuclei	Extended auxiliary detector capabilities
	Fixed targets	Access to very high x physics → complementary to STAR, LHCb and ALICE	Acceptance for fixed target kinematics

Physics Programs

Target to facility upgrades

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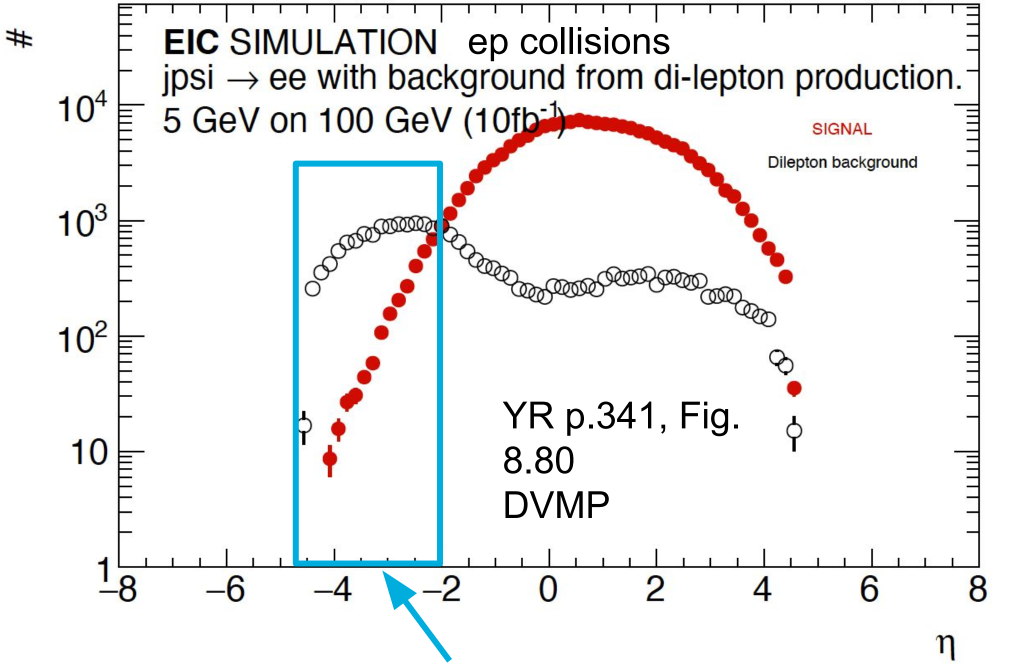
Consensus from Temple Meeting	Diffractive dijet	Wigner Distribution	•forward scattered proton/nucleus •low pT particles
	DVCS on nuclei	Nuclear GPDs	•forward scattered proton/nucleus •High-resolution photon
	Baryon/Charge Stopping	Origin of Baryon number in QCD	•PID •low pT π/K/p
	F2 at low x and Q^2	Probes transition from partonic to color dipole regime	•Maximize Q^2 tagger down to 0.1 GeV^2 •integrate into IR.
	Coherent VM Production	Nuclear shadowing and saturation	High-resolution tracking for precision t reconstruction

Concepts for Muon ID

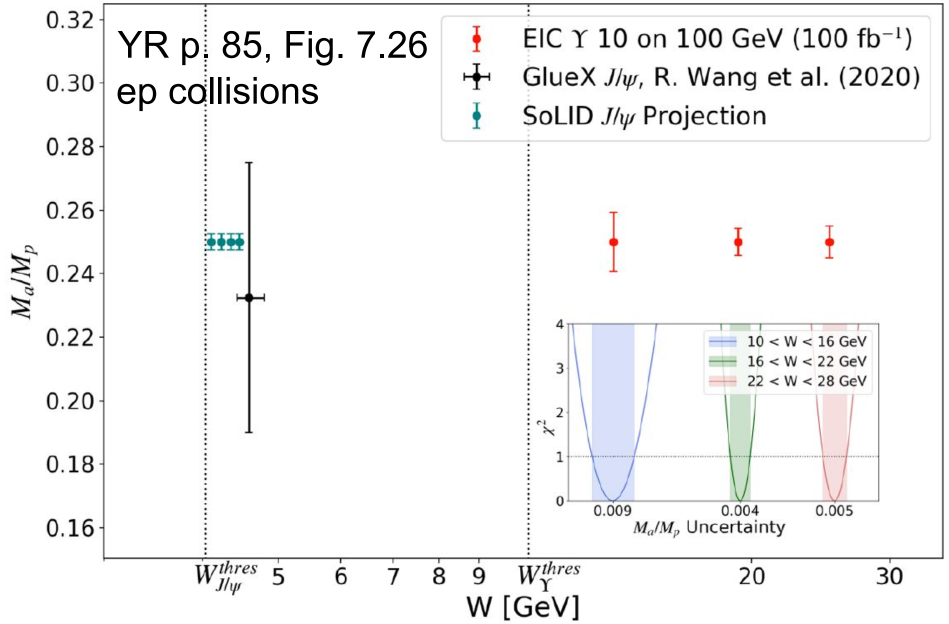
Arguments

- Heavy quarkonia →μ+μ- in exclusive measurements
  - Cleaner signal in quarkonium reconstruction compared to di-electron
  - Reduce ambiguity to the scattered electrons
  - Gluon distributions
  - Proton mass – trace anomaly using near-threshold production measurements
  - Hadronization
- Potentially **DVMP / TCS → Nuclear GPDs**
- Complementary to ePIC: quarkonium reconstruction with different decay channels
- Cross-checking with ePIC



Large background at backward region when use di-electron channel

In consideration: Υ measurements at the EIC can extend the W coverage in trace anomaly study



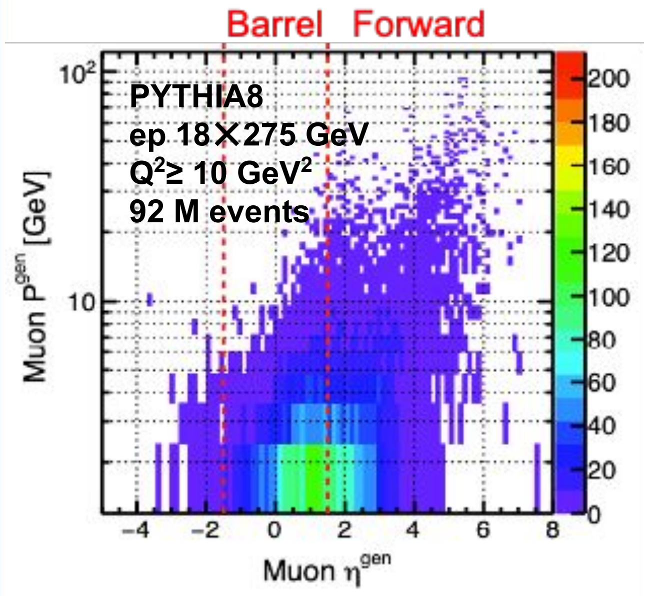
Challenge: require low p_T measurements

Concepts for Muon ID

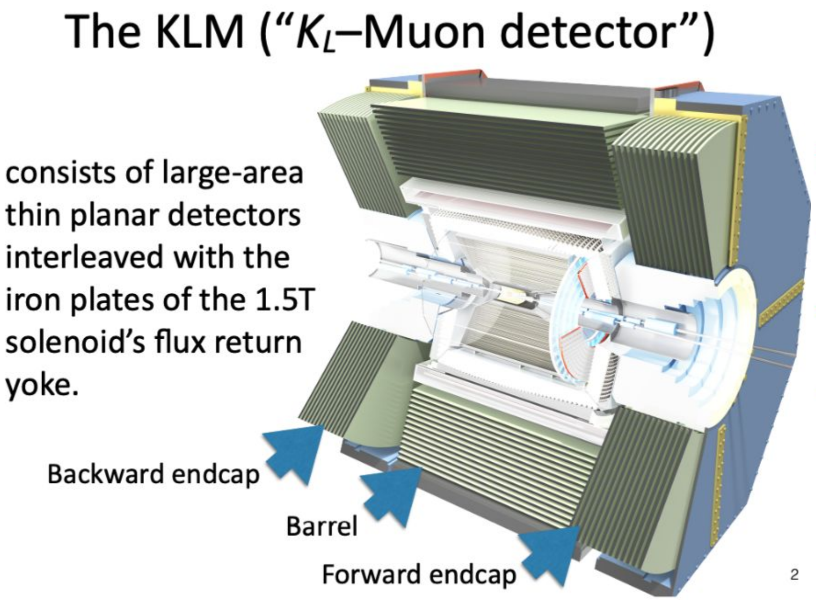
<u>How to proceed</u>

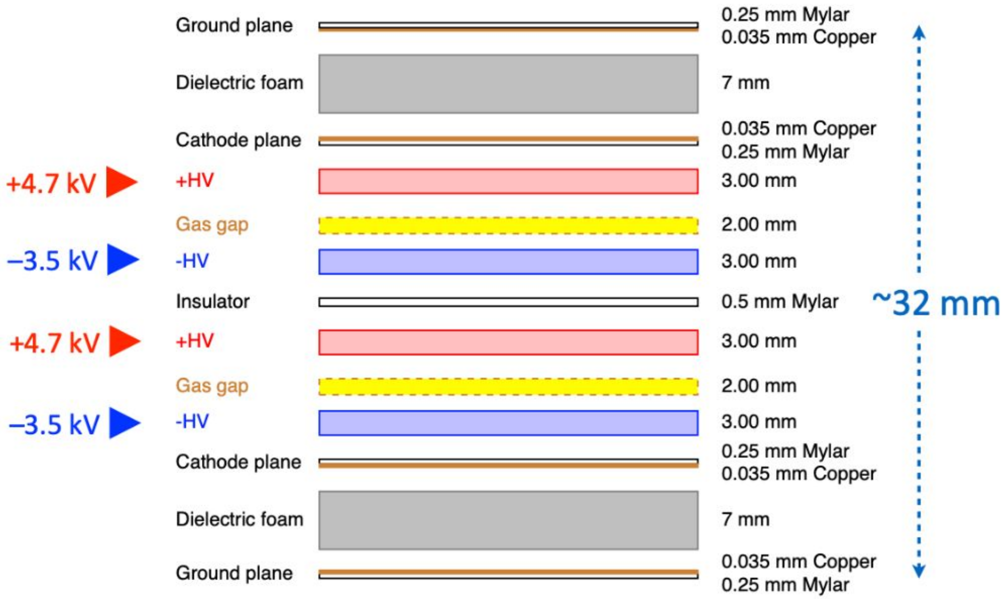
- Muon kinematics→ Identify detector coverage
- Example muon ID technology: KLM at the B factory in KEK

  Can KLM provide calorimetry performance?



EIC Generic R&D programs: #18 KLM-type detector

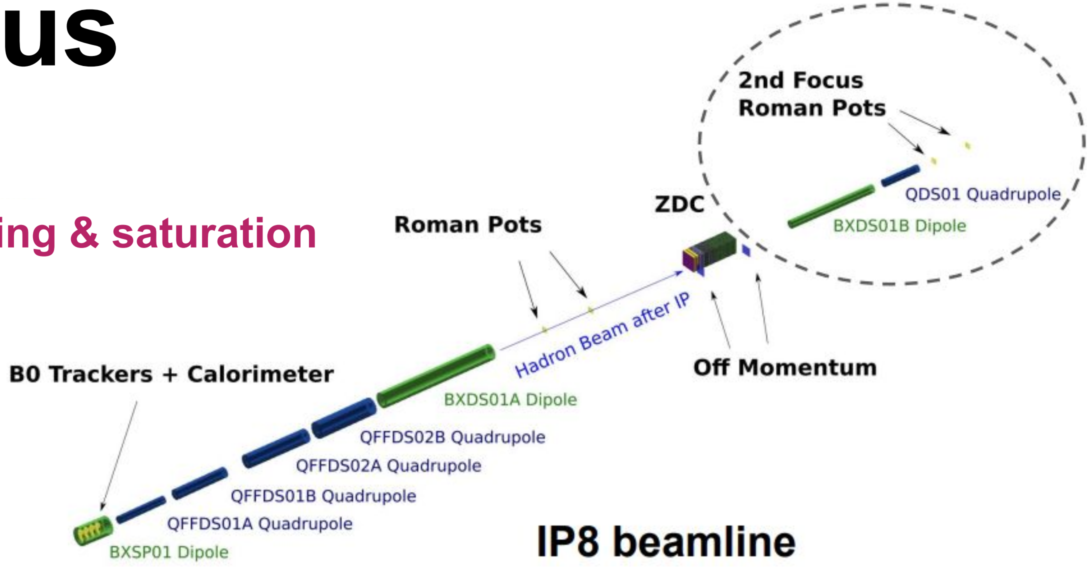




https://doi.org/10.1016/S0168-9002(99)01383-2

- Glass-electrode resistive plate counters
- >90% muon efficiency at 1.7<p<4 GeV

Concepts for the 2nd Focus



Argument

Higher probability to detect near-beam particles at the Roman Pot

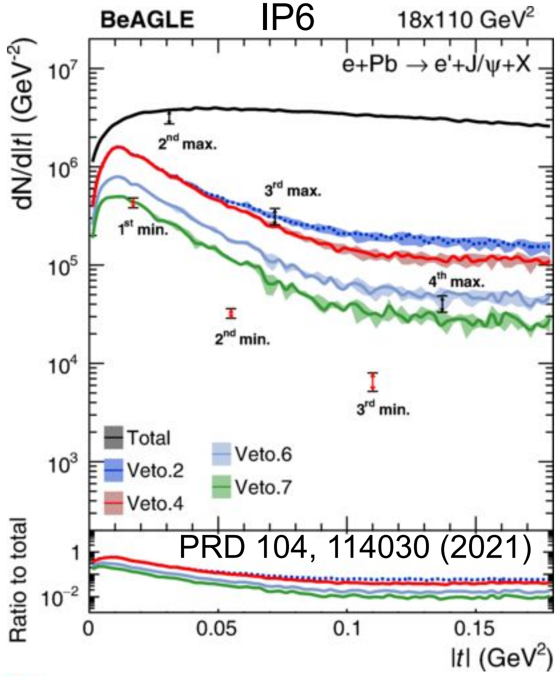
→ Better **coherent/incoherent event tagging → nuclear shadowing & saturation**

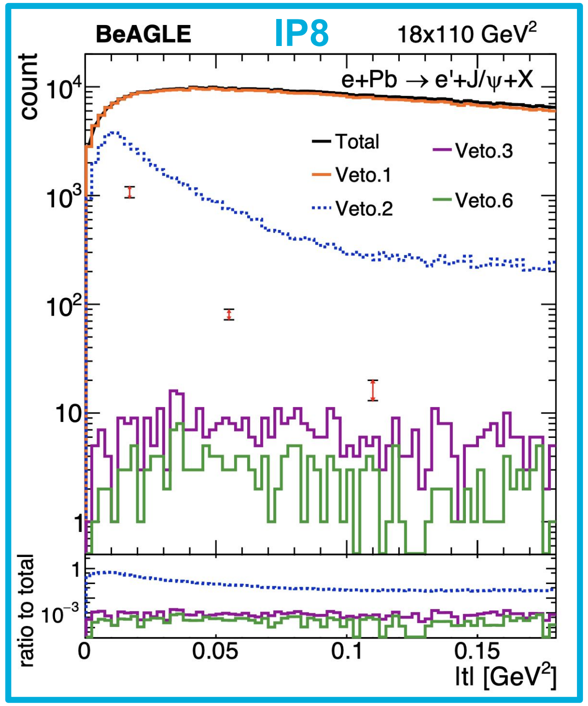
→ DVCS on nuclei → nuclear GPDs

→ Diffractive dijets → Wigner distributions

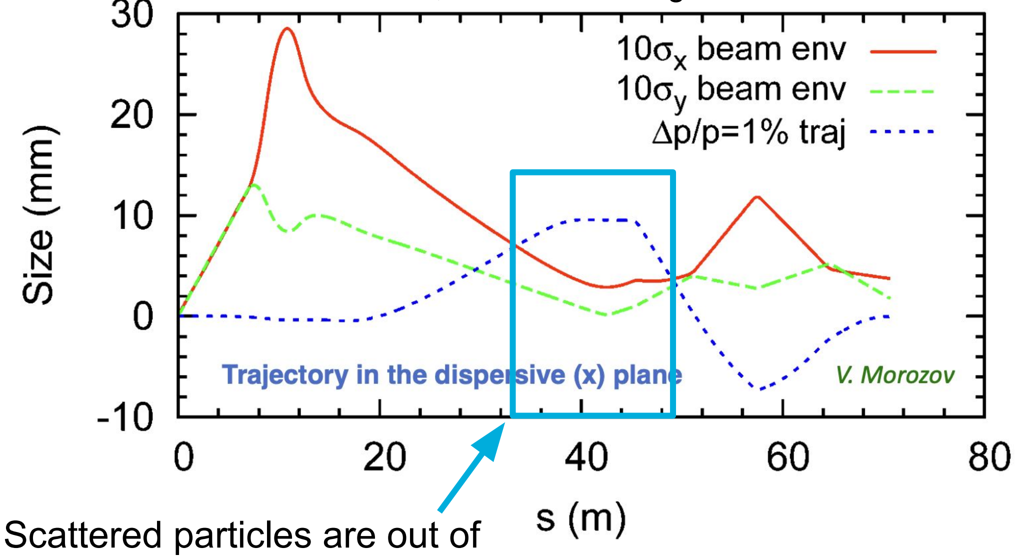
→ Nucleon tomography and energy-momentum tensor

Better neutron acceptance at IP8 because of the larger crossing angle





P. Nadel-Turonski, EIC UG meeting at Warsaw 2023



Scattered particles are out of beam envelope at the 2nd focus

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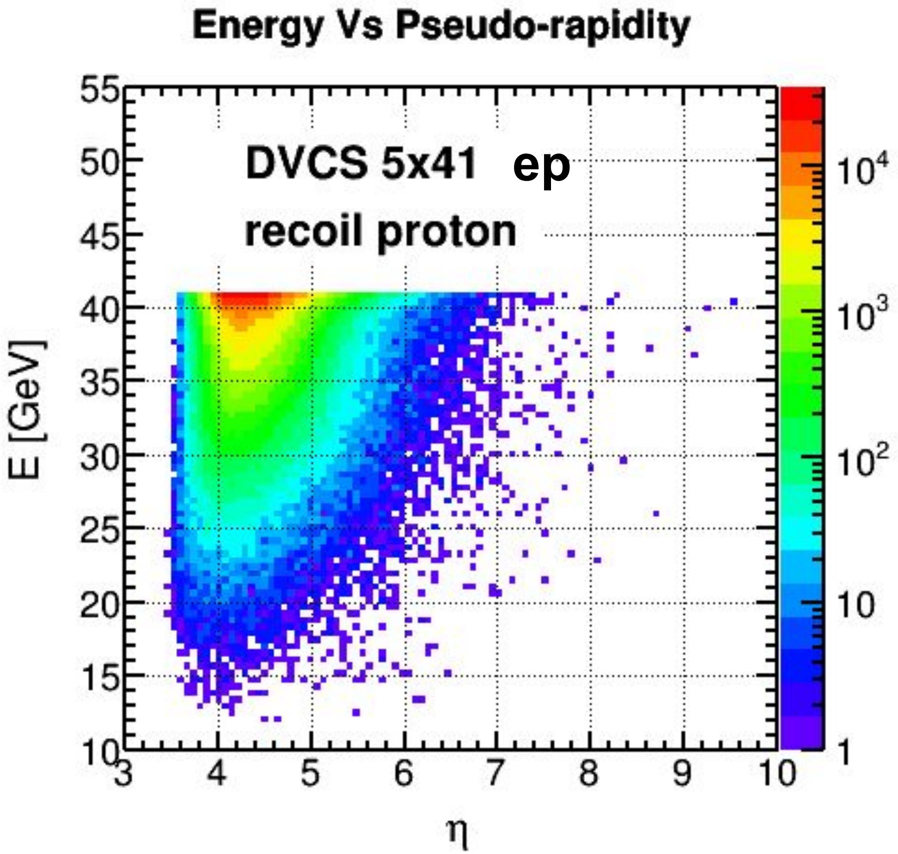
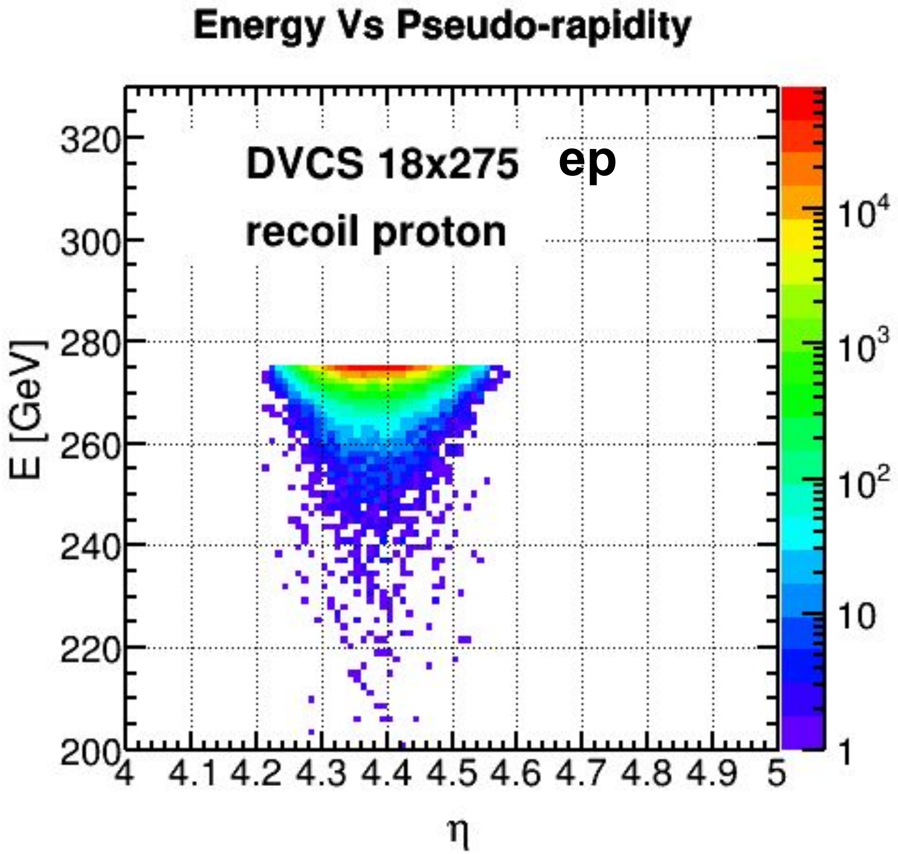
Concepts for the 2nd Focus

Requirements

High rapidity acceptance and low p_T tracking





Included crossing angle (IP6 IR) and beam effects

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Concept of Low-Q^2 Measurements

<u>Arguments</u>

Probe the transition of perturbative to non-perturbative QCD
→ $0.1 \leq Q^2 \leq 2$ GeV^2 coverage

<u>ePIC limitations</u>

- Limited acceptance of crystal endcap calorimeter
- Realistic estimated rapidity down to $\eta \sim -3.5$ or $Q^2 = 1$ GeV^2
- Low-Q^2 tagger covers from < 0.1 GeV^2

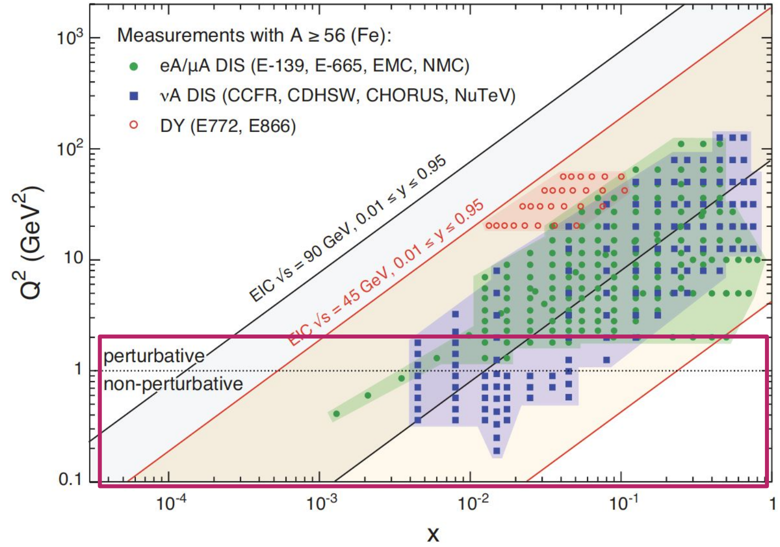
<u>Discussions within the Community</u>

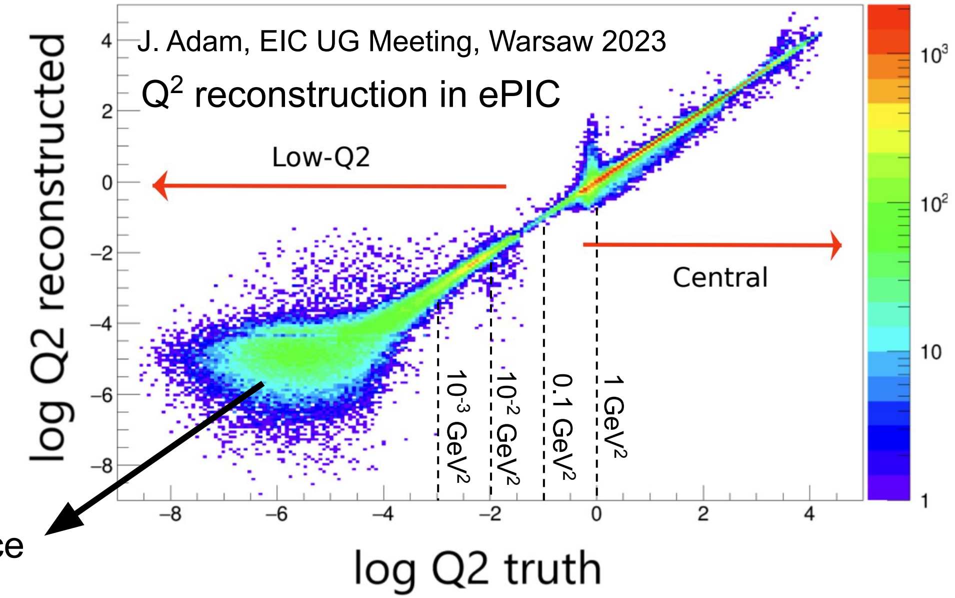
- Miguel suggested backward calorimeter close to the beam pipe

  Concern of thick material budget from the beam pipe

- This is a tricky one that requires full simulations with mockup beam pipe

EIC white paper, p.5, Fig. 1.5





Angular divergence of the beam

Concepts for Fixed Target

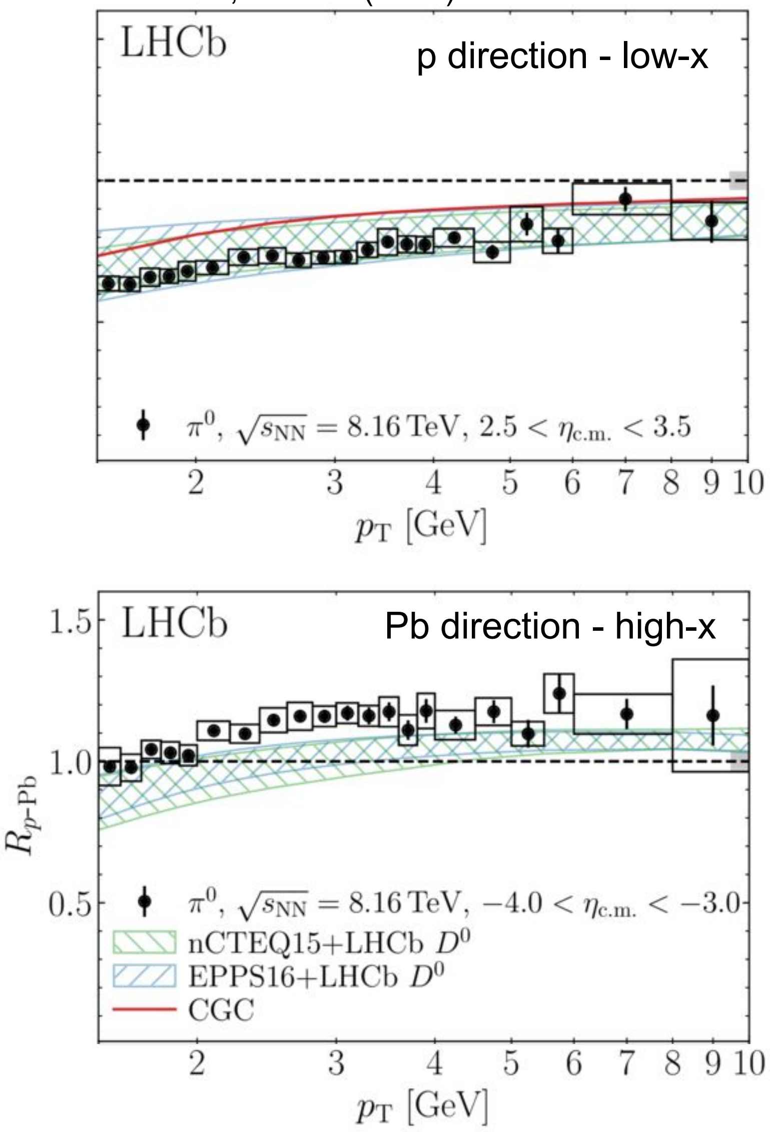
Arguments

- high x and low Q^2
- Complementary to CLAS12 measurements and other JLab experiments
  - **DVCS → nuclear GPD**
  - Spin physics with polarized gas target
- Complementary to fixed-target measurements at STAR, LHCb and ALICE
  - Constrain nuclear PDFs
  - Parton fragmentations
  - Nuclear shadowing

Kinematics at fixed target is very different from one at colliding beams:

Everything goes backward

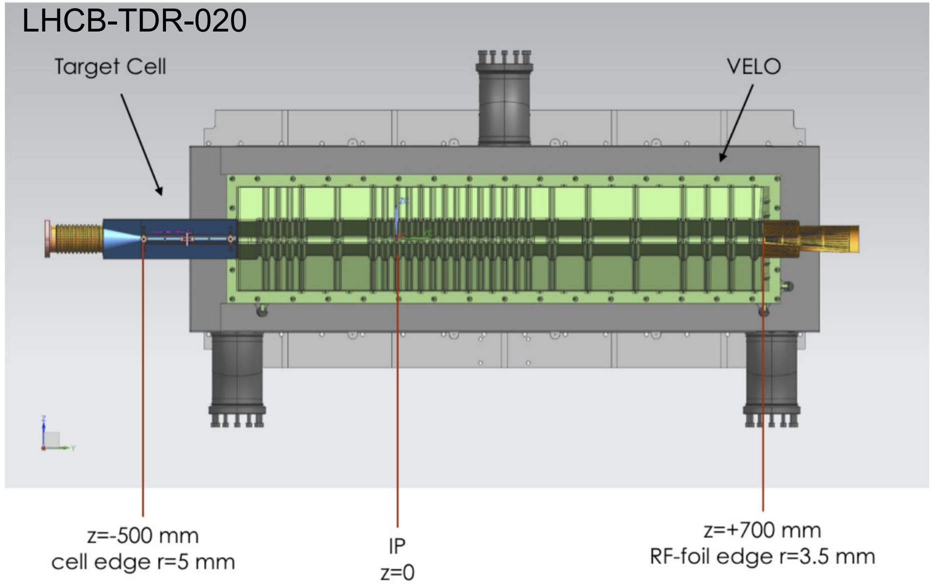
PRL 131, 042302 (2023)



Concepts for Fixed Target

- Fixed-target setup along with beam-beam collisions configurations
  - LHCb SMOG simultaneous beam-beam or beam-gas-target collisions
  - STAR gold target inside beam pipe
- Detector subsystems needed
  - Full range (backward+central+forward) tracking system
  - Backward EMcal to measure scattered e^-
  - e/h separation (PID) in backward region for hadron fragments with pfRICH?

- Questions
  - **Luminosity and statistical feasibility**
  - **Kinematics of fixed-target events**
  - Material budget due to the beam pipe
  - Machine induced background



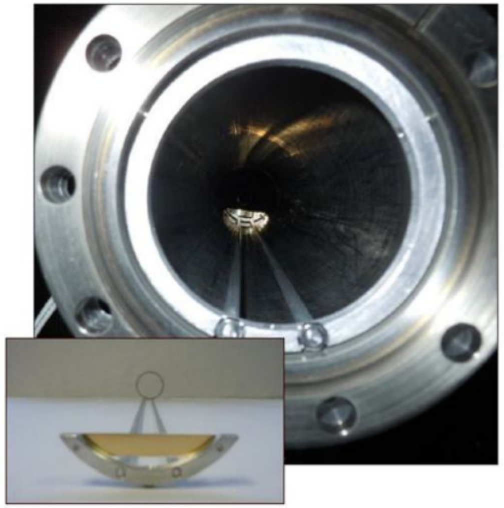
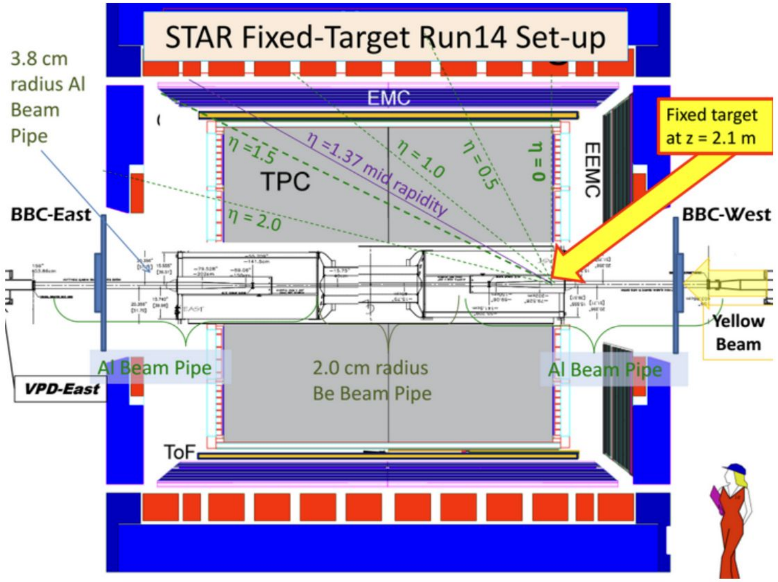


Figure 1. Photo of the gold target and its support structure.

Larger pseudorapidity coverage depends on the IP location



doi:10.1088/1742-6596/742/1/012022

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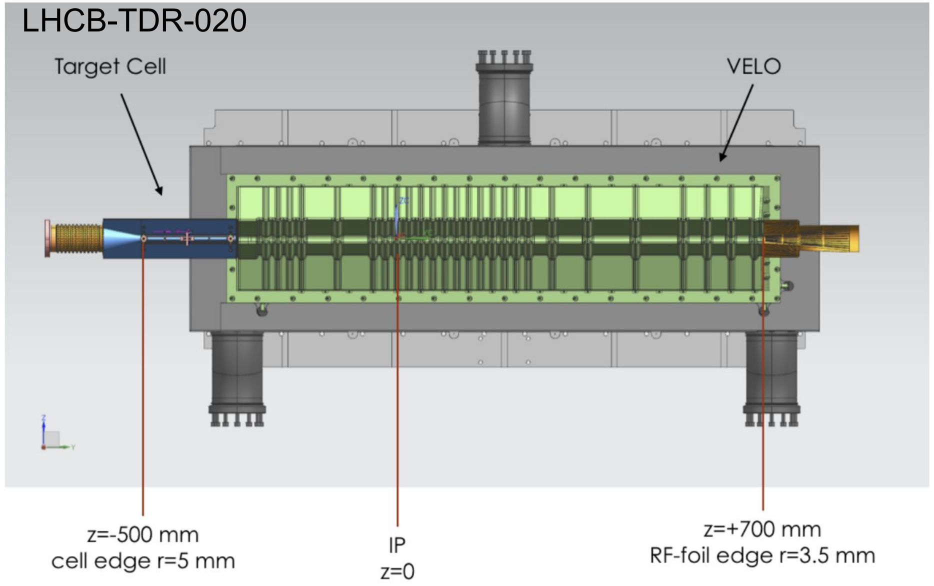

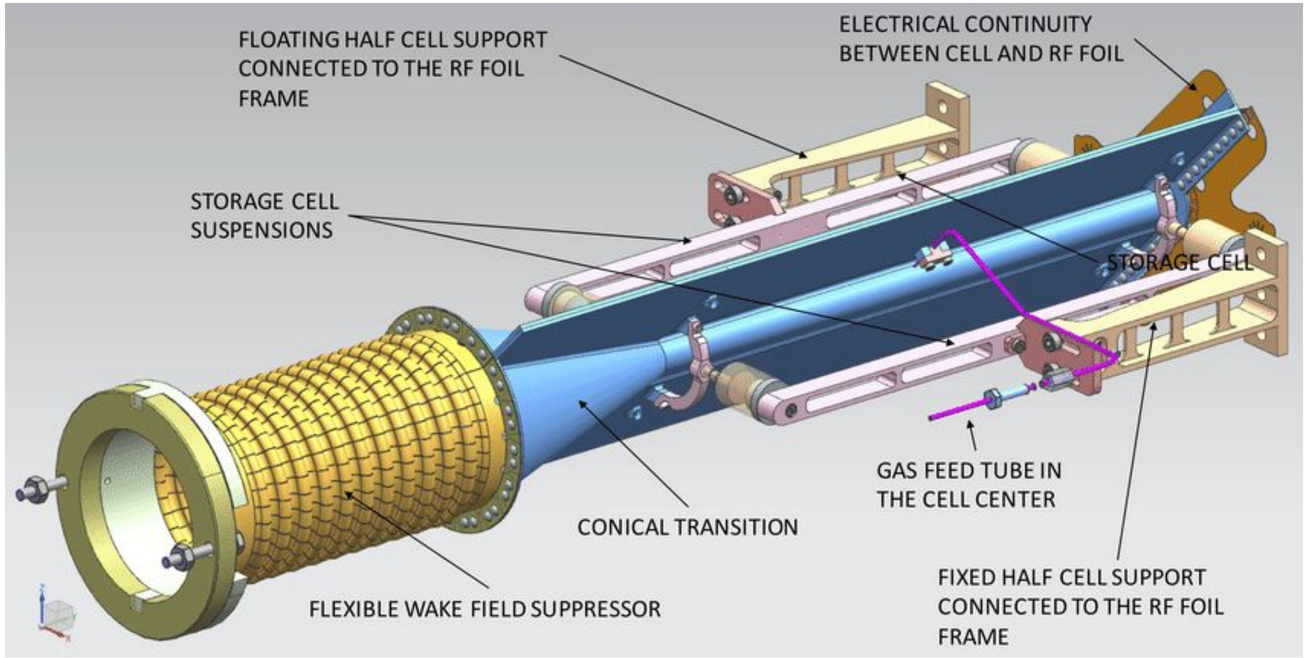

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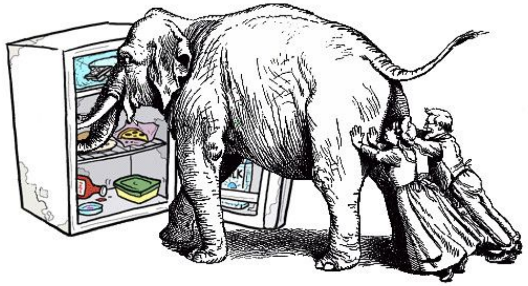
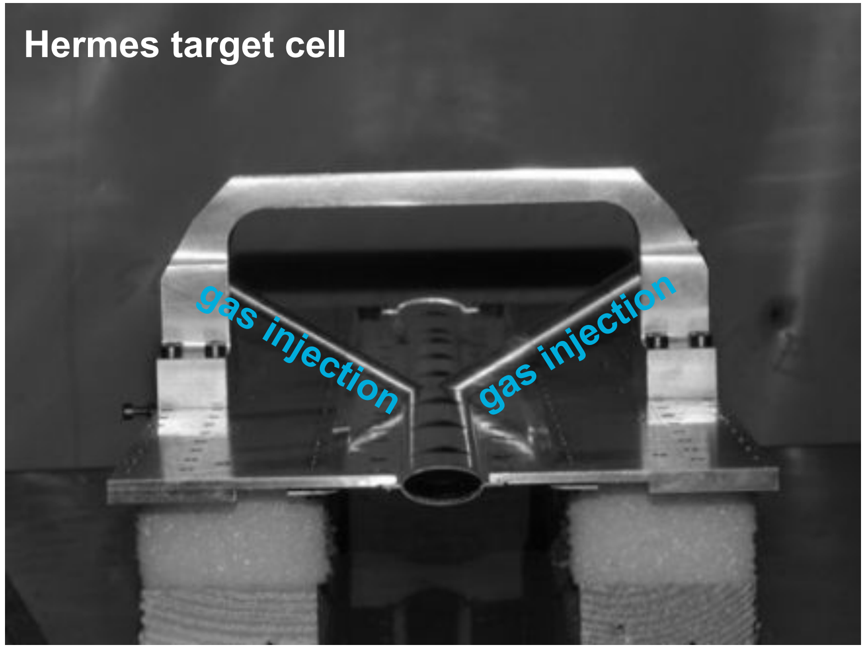
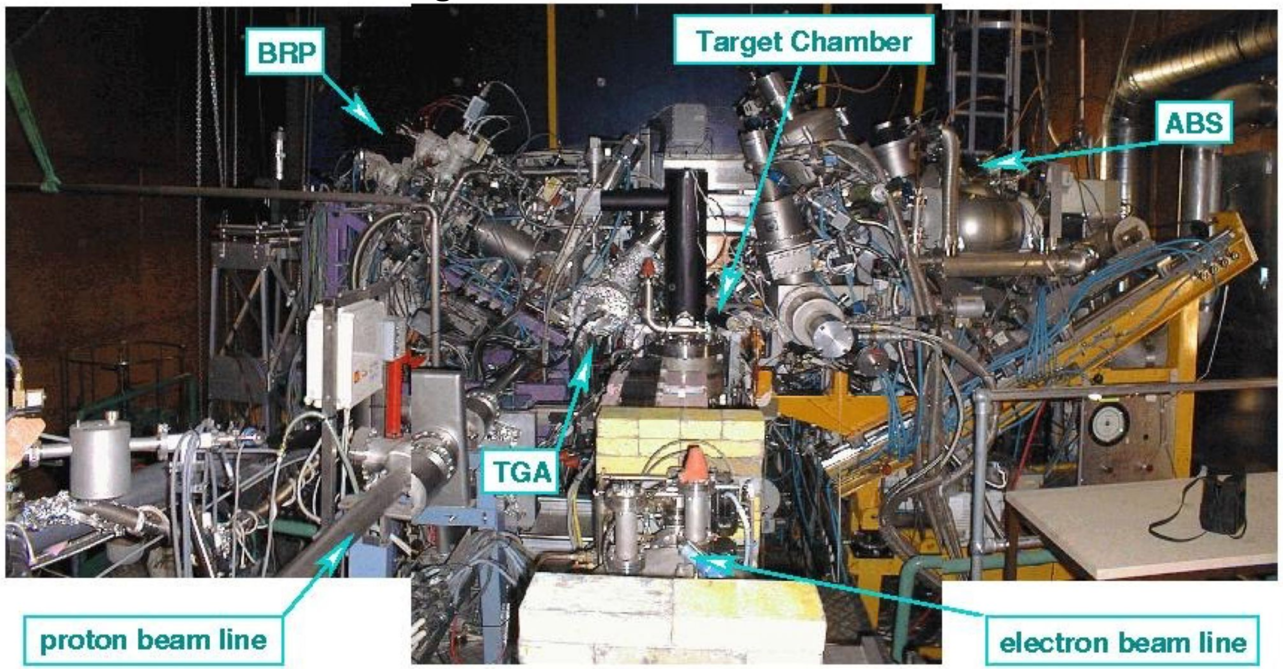
- Questions
  - **Space for polarimeter?**





Hermes target cell with the Breit Rabi Polarimeter



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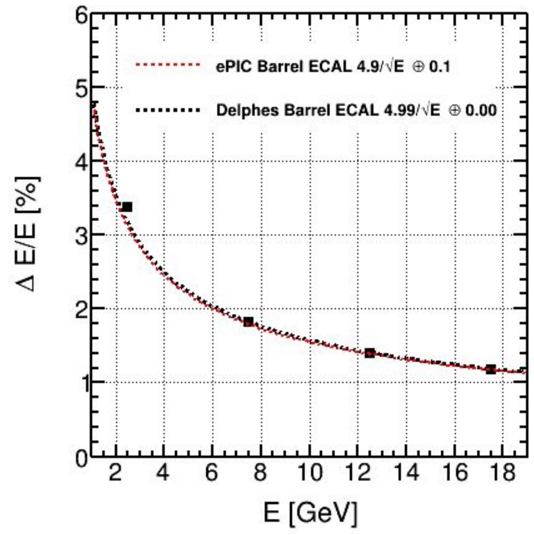
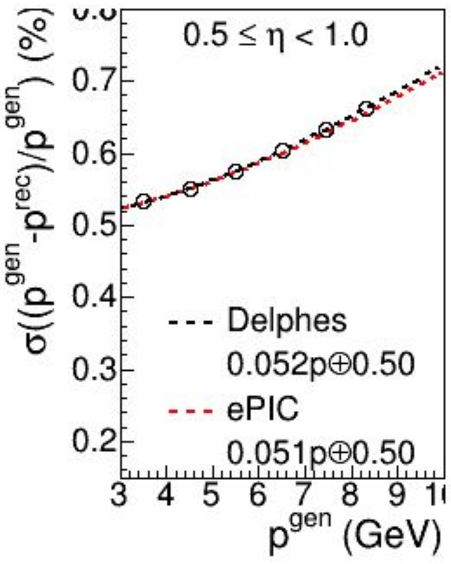
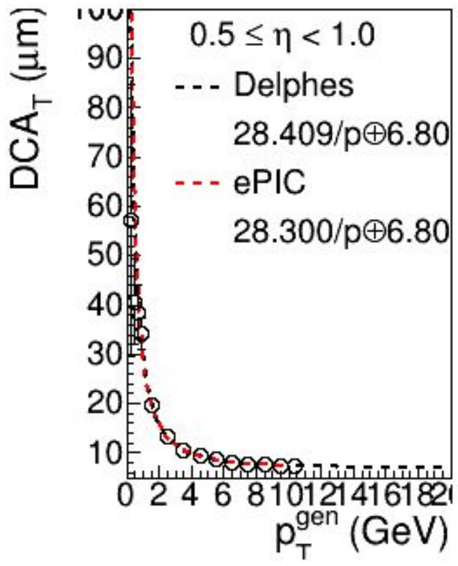
Summary: Concepts for the 2nd Detector

measurements / observables	Arguments / Physics	Detector subsystem(s)	Tasks
Muon	● Quarkonium→μμ ○ Gluon distribution, proton mass, hadronization ○ Potentially TCS → Nuclear GPDs ● Provide cleaner channel compared to di-electron ● Complementary to and cross-checking with ePIC	Muon ID e.g. KLM	● Muon Kinematic distributions ● Muon ID performance ● Statistical feasibility
Scattered electrons	● Complete exclusive measurements in low-Q^2 regime ● Probing the transition from perturbative to non-perturbative QCD	low-Q^2 tagger	Extended auxiliary detector capabilities
● DVCS ● Coherent VM Production ● Diffractive dijet	Low p_T and high rapidity coverages to reach small x ● Nuclear GPDs ● Nuclear shadowing & saturation ● Wigner Distribution	Secondary focus (far-far-forward)	Extended auxiliary detector capabilities
Scattered electron and fragments in forward region in fixed target	● high x and low Q^2 ● Complementary to CLAS12 DVCS → nuclear GPDs ● Complementary to STAR, LHCb and ALICE nPDF, parton fragmentations	Fix target cell Tracking EMcal PID	● Acceptance for fixed target event kinematics ● Statistical feasibility ● Tracking system ● EMcal performance for scattered high energy electron ● Backward e/h separation up to 18 GeV

Current Study using Delphes







- Created ePIC detector configuration card using parameterizations (tracking and calorimetry resolution/efficiency and PID)
- **Limits**: Hard to evaluate effects of magnetic field/material

Plans

Move on to DD4HEP or other full simulation softwares

- Lookup kinematics distributions of ep/eA events
- Setup detector simulations using existing ePIC softwares
- Run full simulations
- Determine physics benchmarks
- Determine detector configurations

Backup

Available Simulated Events/ Event Generators

From detector proposal:

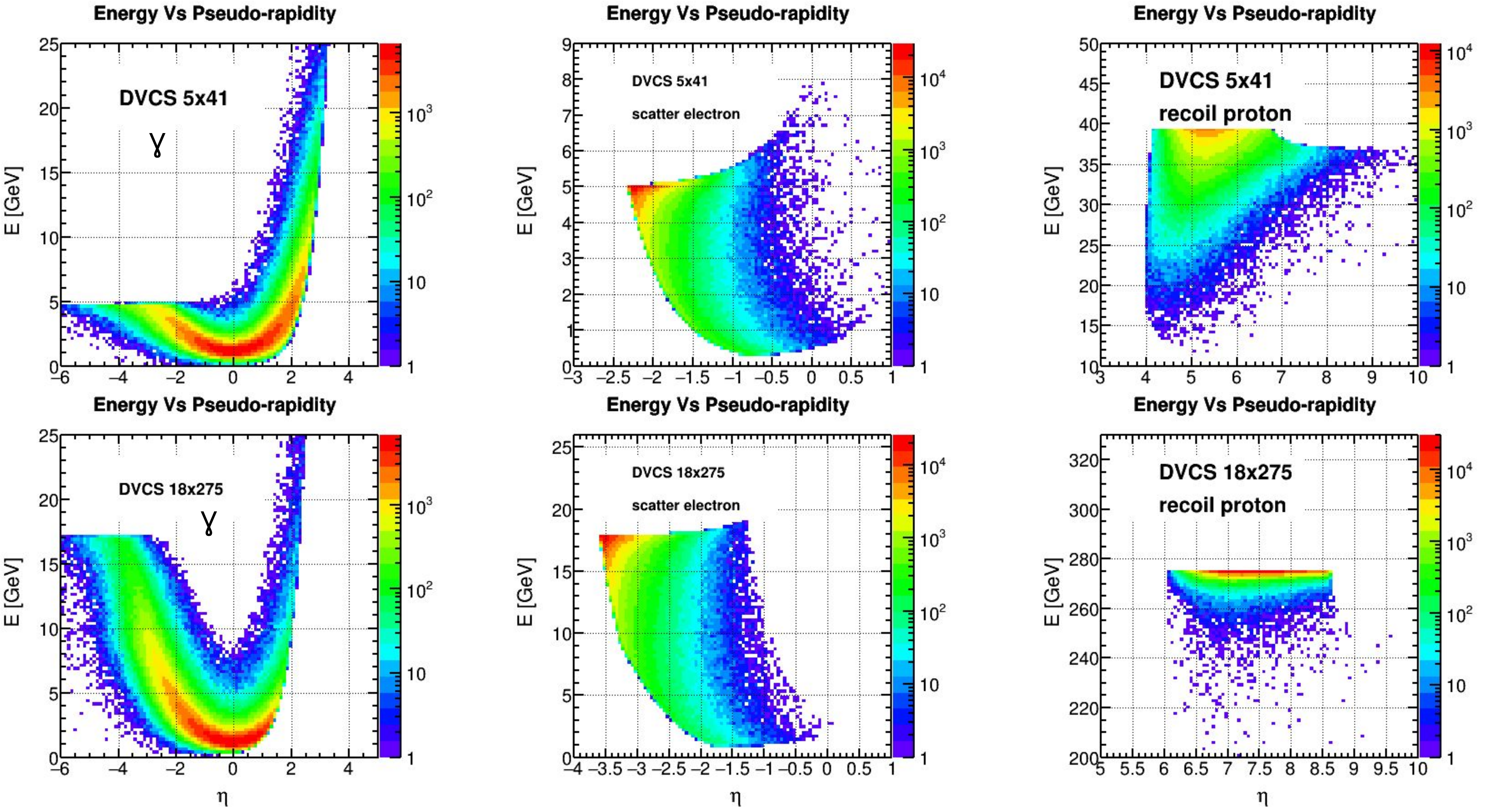
- https://wiki.bnl.gov/eicug/index.php/ECCE_Simulations_Working_Group
- https://dtn01.sdcc.bnl.gov:9001/buckets
- Cavet: different crossing angles

eA event generators

- BeAGLE
- eSTARLight

DVCS Kinematics

no crossing angle and beam effects



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