PAC Report

Rachel Montgomery (Glasgow), Salvatore Fazio (Calabria), Rosi Reed (Lehigh)

EICUG and ePIC Collaboration Meeting
Jefferson Lab
June 14th 2025

Physics Working Groups (PWGs)

SIDIS

Meeting time: Tuesdays 8:30am ET (bi-weekly)

Mailing List: eic-projdet-semiincl-l@lists.bnl.gov

Indico: https://indico.bnl.gov/category/418/

Inclusive

Meeting time: Tuesdays 11am ET (bi-weekly, joint with BSM/EW)

Mailing List: eic-projdet-Inclusive-l@lists.bnl.gov

Indico: https://indico.bnl.gov/category/417/

Exclusive, Diffractive and Tagging

Meeting time: Mondays noon ET (bi-weekly)

Mailing List: eic-projdet-excldiff-l@lists.bnl.gov

Indico: https://indico.bnl.gov/category/419/

Jets and HF

Meeting time: Tuesdays 11:30am ET (bi-weekly)

Mailing List: eic-projdet-jethf-l@lists.bnl.gov

Indico: https://indico.bnl.gov/category/420/

BSM and EW

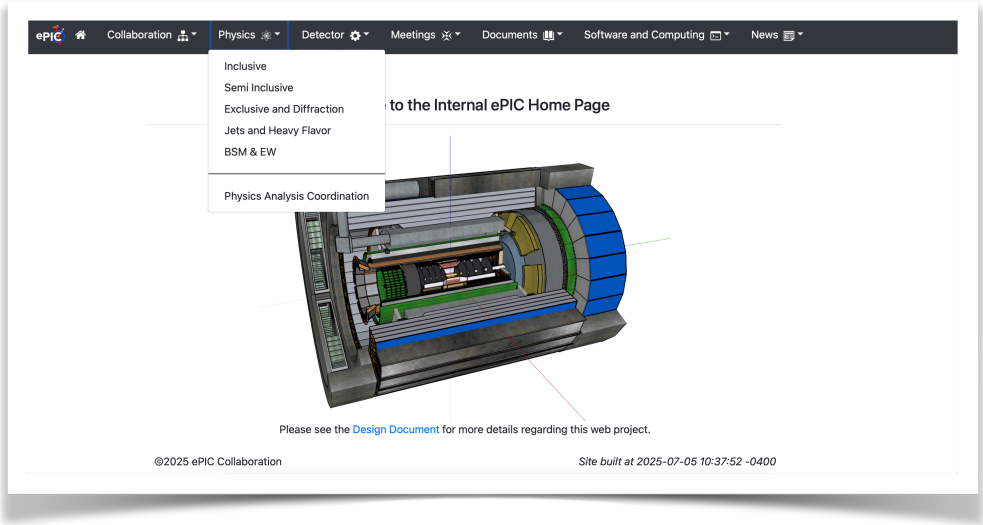
Meeting time: Tuesdays 8:30am ET (bi-weekly, joint with inclusive)

Mailing List: eic-projdet-jethf-l@lists.bnl.gov

Indico: https://indico.bnl.gov/category/420/

PWG info is on ePIC webpage

https://www.epic-eic.org/index-internal.html



Also:

- PAC meetings roughly every two weeks
  - https://indico.bnl.gov/category/475/
- Joint S&C and physics meetings roughly every month
  - https://indico.bnl.gov/category/435/

PWG Convenors

Inclusive
Tyler Kutz (Mainz)
Stephen Maple (Birmingham)

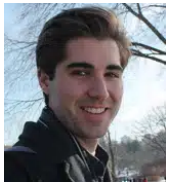
BSM and Precision EW
Ciprian Gal (JLab)
Juliette Mammei (Manitoba)

Semi-Inclusive
Stefan Diehl (Giessen)
Ralf Seidl (Riken)

Jets and Heavy Flavour
Olga Evdokimov (UIC)
Rongrong Ma (BNL)

Exclusive, Diffractive and Tagging
Raphaël Dupré (IJCLab)
Zhoudunming (Kong) Tu (BNL)

- PWG Convenors serve a two-year term
- PWG Convenor rotations staggered by one year
- Convenors in blue ending terms this year
- We send our deepest gratitude for their hard work!





- We will propose a new set of convenors at the upcoming CC meeting

More info at CC meeting





Win Lin (SBU)	Zuhal Seyma Demiroglu (SBU)	Anselm Vossen (Duke)	Shyam Kumar (INFN Bari)	Stephen Kay (York)
Inclusive	BSM and EW	SIDIS	Jets/HF	EDT

Now some PWG activities …

PWG working towards Physics Performance and Science Reach sections for Chapter 2 of preTDR

Also pursuing synergistic efforts e.g. extended physics paper for ePIC Collaboration (aligned with preTDR), other write-ups, and Early Science Document

… thank you to PWG convenors for inputs to following reports

(could not include everything! Many different activities and analyses are on-going! Only some examples here to give you a flavour!)

Exclusive, Diffractive, Tagging (EDT) Activities (K. Tu and R. Dupré)

Impressive list of active analyses in last 6 months!

ep	QA	AN
• DVCS	✓	✅
• DEMP	✓	✅
• DVMP (different final states)	✓	✅
• Exclusive pi0	✓	
• Diffractive DIS	✓	
• Kaon SF		

eA	QA	AN
• eD: spectator tagging, free neutron structure • eHe3: g1n	✓	✅
• eRu: diffractive DIS • eAu (diffractive phi, cohérent and incoherent)	✓	
• eA quasi-coherent VM production and nuclear breakup		
• eA rho' (pheno only)		

Framework ready for analysis notes (AN), https://github.com/eic/ExclusiveWG_Paper/tree/main/Analysis_Notes

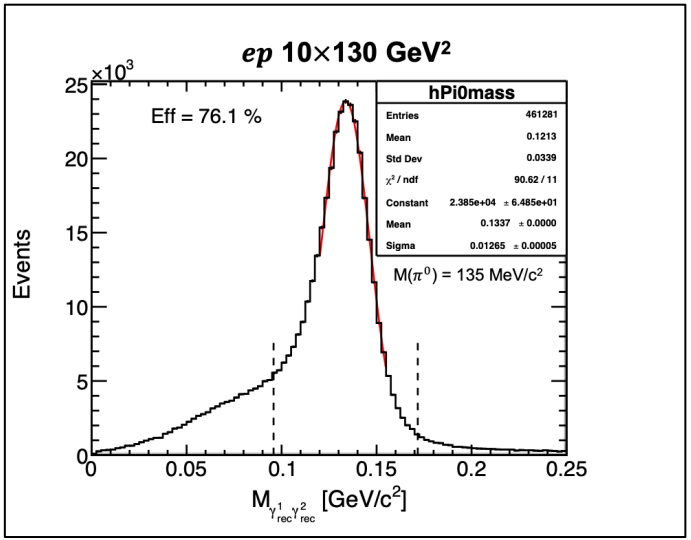
Many new exclusive simulation samples were run speedily, thanks to software and production team! For most recent campaign, see https://eic.github.io/epic-prod/RECO/25.06.1/

EDT Activities - 1

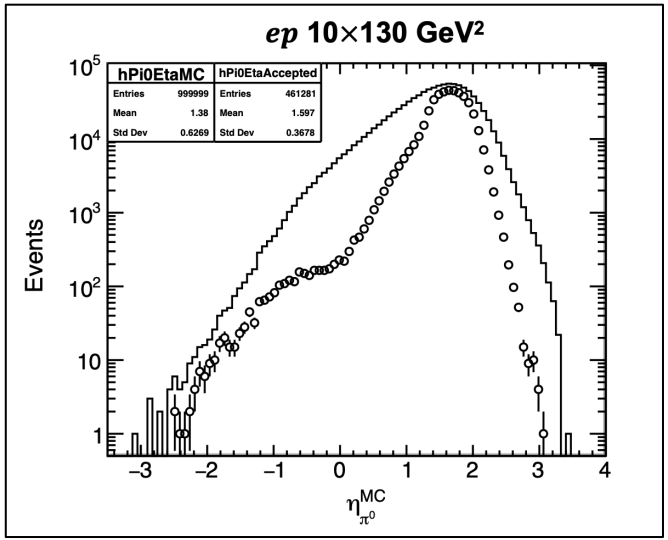
Exclusive pi0 production in ep - serves as both signal (GPD and OAM physics) and background to DVCS

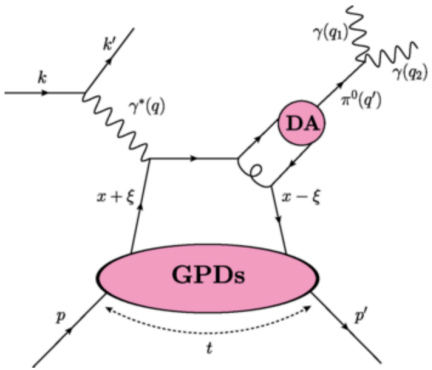
Nucleon tomography and spin programs

pi0 mass



pi0 efficiency



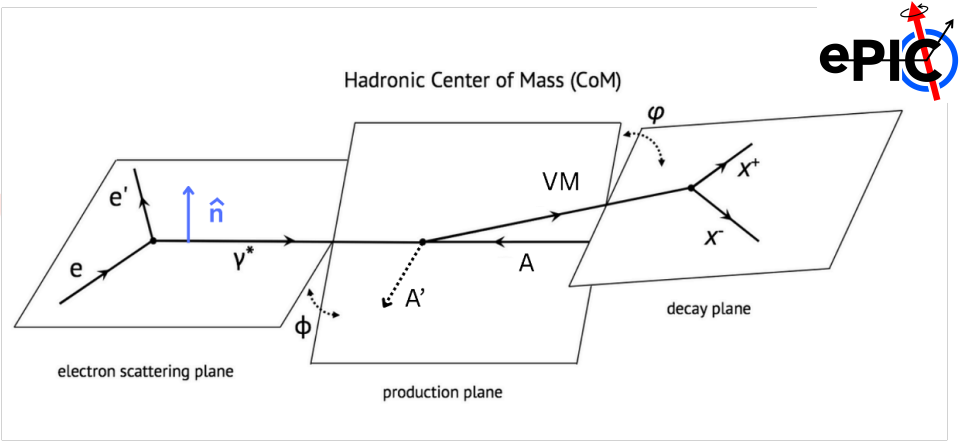


- pi0 efficiency low mid-rapidity due to cluster merging(?) - only one photon found
- Shine light on reconstruction algorithm for BIC

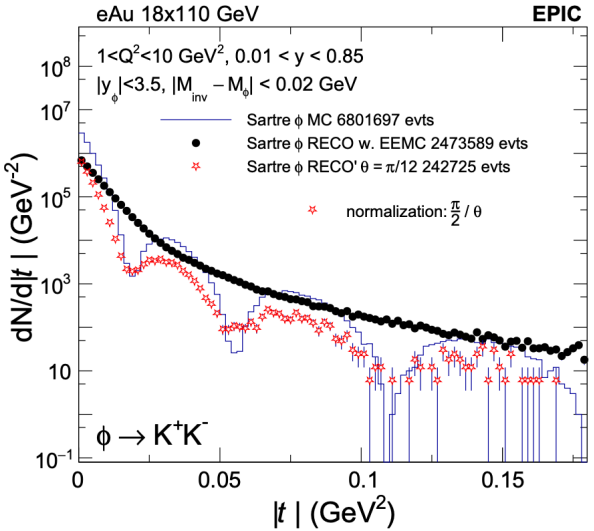
EDT Activities - 2

Projective imaging method enables gluon imaging in heavy nuclei via diffractive VM production

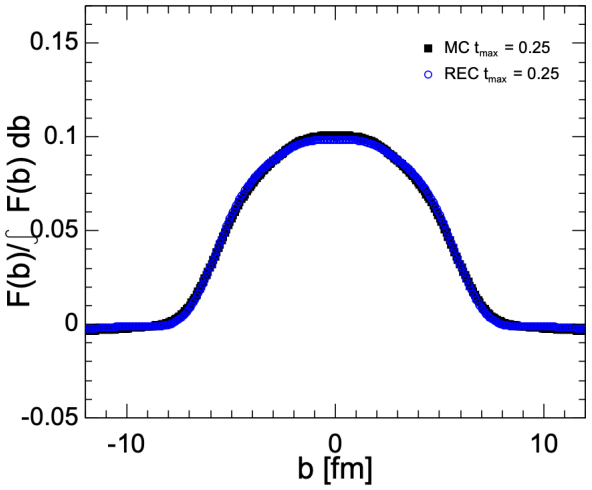
arXiv:2502.15596



t distribution

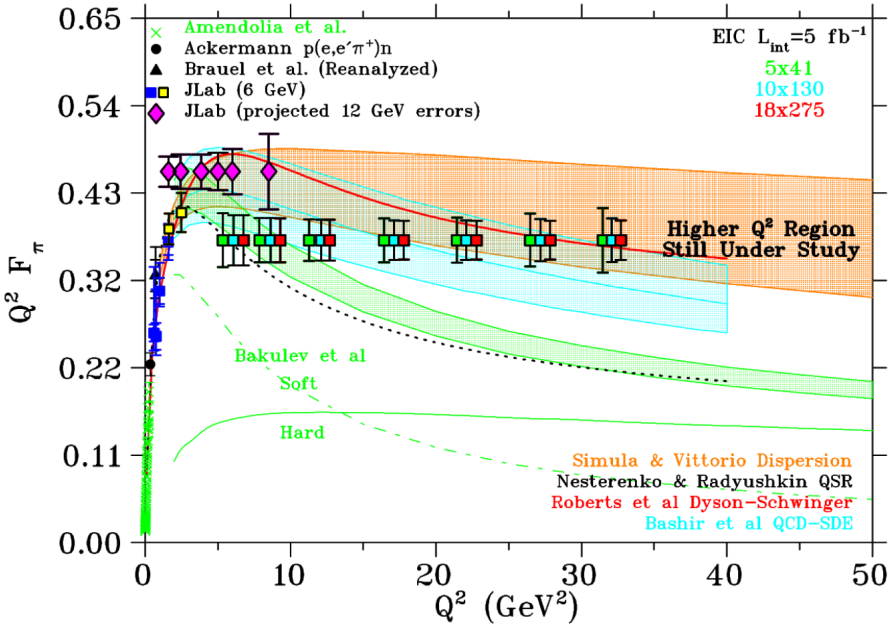


Transformation

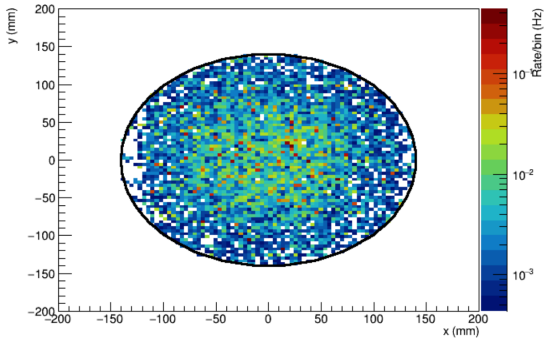


EDT Activities - 3

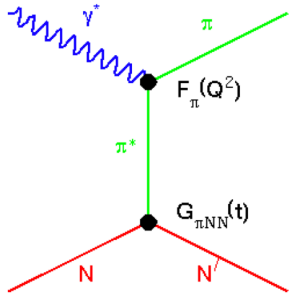
- Deep Exclusive Meson Production to probe pion structure
- Nucleon mass enigma
- EIC extends phase space in Q^2



ZDC essential for DEMP



- 10x130 high acceptance AB config



Synergies with and part of EIC Meson SF working group

First look at kaon SF studies will be presented at EDT workfest (Tue morning)

S. Kay (York), L. Preet, G. Huber (Regina), EIC Meson SF WG

EDT Next Steps

A first ePIC physics paper

- Draft in place (*have 8 pages now, aiming for 12-15*)
- Many results ready to be migrated into paper (AN is required in order to be considered for paper)
- First preliminary draft ready soon, hopefully Sep-Oct!

A the ePIC detector 2

during the first five years—referred to as Phase I of the central and forward tracking system with Multi Pattern (MPGDs) and AC-LGAD sensors for particles, electromagnetic and hadronic dedicated particle identification system ght and Cherenkov detectors, beamline fractive and exclusive measurements in hadron-going region, and luminosity w-Q^2 taggers for small scattering-angle ons. Additionally, the detector is exibility in mind, allowing upgrades or target specific physics topics as the EIC ails of these designs, see the official ePIC //www.epic-eic.org/) for reference.

IC main detector cutaway view. (to be riginal file)

The Phase I Exclusive Physics at the Electron-Ion Collider: Opportunities at the ePIC Experiment

ePIC Exclusive Working Group*

(Dated: July 7, 2025)

The first five-year run of the Electron-Ion Collider (EIC), known as Phase I, marks the beginning of a new era in the study of the quantum chromodynamics (QCD). During this initial stage, the EIC will provide high-luminosity collisions of polarized electrons with protons and a variety of nuclear species, enabling a broad and foundational experimental program. This paper presents the strategy for the exclusive physics program with the ePIC experiment during Phase I. Utilizing the collider's high-luminosity polarized beams and state-of-the-art detection systems, ePIC is designed to probe the spatial and momentum distributions of partons inside nucleons and nuclei, explore the onset of gluon saturation, and investigate the spin structure of both free and bound nucleons. We describe initial detector performance, simulation studies, and analysis methodologies developed to tackle central questions in QCD. The Phase I program is expected to deliver critical benchmarks for the EIC's long-term scientific goals, advancing our understanding of hadronic structure and laying the foundation for future discoveries.

CONTENTS

I. INTRODUCTION

The Electron-Ion Collider (EIC) is a next-generation particle accelerator currently under development at Brookhaven National Laboratory (BNL) in the United States. Designed as a cutting-edge facility for nuclear physics, the EIC will collide high-energy beams of polarized electrons with protons and atomic nuclei. This unique capability will allow scientists to explore the internal structure of matter with unprecedented precision, opening new windows into the fundamental structure of visible matter—particularly its strongly interacting nature, as described by the theory of Quantum Chromodynamics (QCD).

At the heart of the EIC's mission is the goal of imaging the internal structure of nucleons (protons and neutrons) and nuclei in terms of their quark and gluon constituents. Unlike previous accelerators, the EIC will provide high luminosity, a wide range of center-of-mass energies and nuclear species, and full control over the polarization of both the electron and hadron (proton and helium-3) beams. These features will enable precise measurements of parton distribution functions (PDFs), transverse momentum-dependent PDFs (TMDs), and generalized parton distributions (GPDs), offering multidimensional insight into how quarks and gluons generate the mass, spin, and internal dynamics of hadrons. Fundamental questions—such as the origins of mass and spin—are expected to be addressed by the EIC.

The EIC will also shed light on how gluons—the force carriers of the strong interaction—behave inside nuclei, and whether their densities saturate at high energies, as predicted by QCD. Understanding this gluon-dominated regime, sometimes referred to as the Color Glass Condensate, is essential for building a complete picture of nuclear matter under extreme conditions. Beyond its core physics goals, the EIC will serve as a powerful platform for technological innovation, workforce development, and international scientific collaboration, shaping the future of high-energy nuclear science.

To tackle the unprecedented challenges posed by QCD, the current strategy is to proceed step by step, requiring careful planning of a detailed experimental program. Given the complexity of operating a new collider facility, the plan is to run collisions with protons and various ions

* zhoudunming@bnl.gov; raphael.dupre@ijclab.in2p3.fr; stephen.kay@york.ac.uk

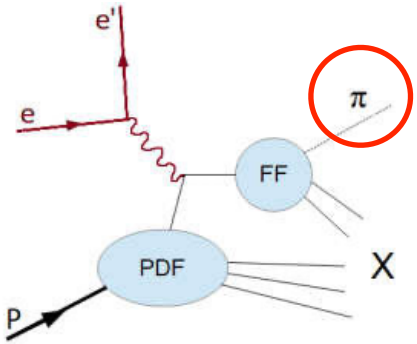
rward beamline detector system

forward detectors are required to enable ntirety of the exclusive physics program re final-states involve protons, neutrons, rious other particles at $\eta > 4.5$. There tems, all integrated with the outgoing e between ∼5.5 and 39 meters from the t. The far-forward subsystems, which or, Roman Pots (RP), off-momentum), , and the zero degree calorimeter n Fig. 2.

tor is embedded in the magnet bore, two sub-detectors: a charged particle electromagnetic calorimeter. Both will covering the angular region from 5.5 ven the mechanical constraints imposed location in the magnet (and respecting themselves) the detectors will be highly angles greater than ∼13 mrad. The he B0 detector is to accept forward going s, mostly protons, and photons. pots (RP) and off-momentum detector ems are both intended to tag far- and reconstruct their momenta. These

SIDIS Activities (R. Seidl and S. Diehl)

Formation of INFN SIDIS Group

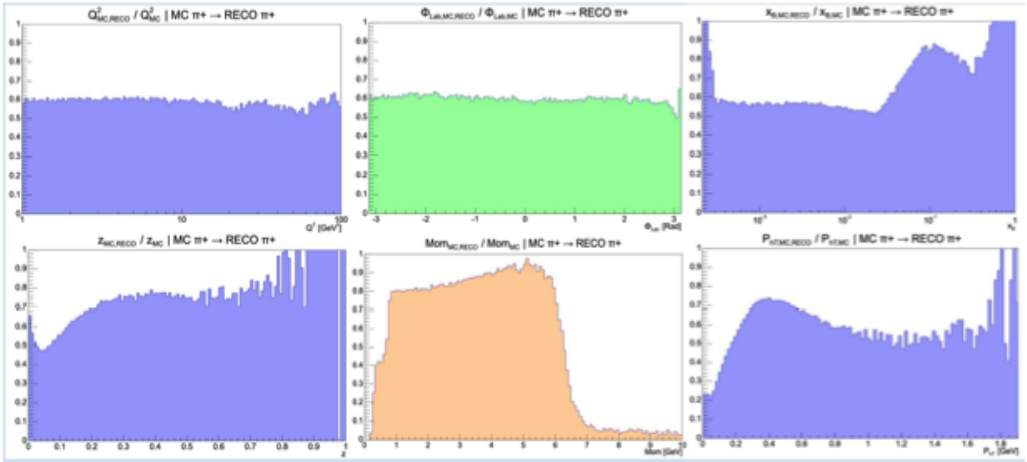


PID contamination and detector performance for SIDIS reconstruction

ITALIA-SiDIS-group update

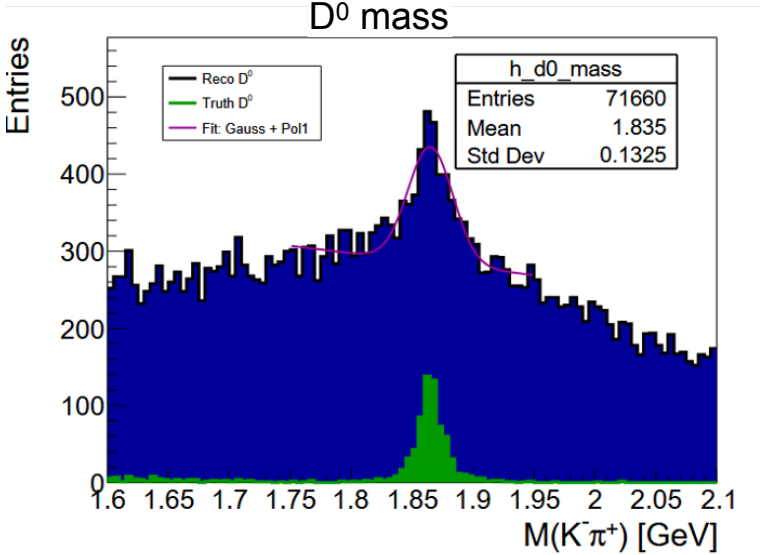
π^+ distributions, reconstruction efficiencies and contaminations for SIDIS analyses

Study the **contamination** effect reconstructions and the detector performance in the reconstructions with some hand-made manipulation of those contributions



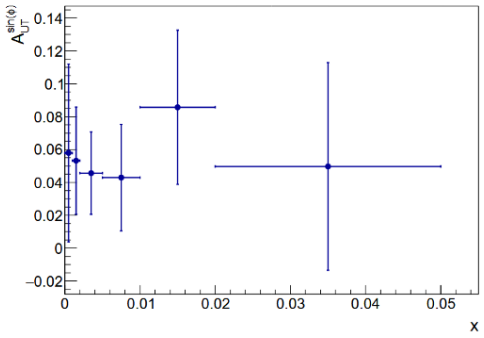
SIDIS Activities

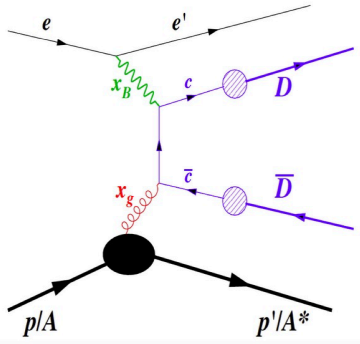
Gluon Sivers Studies using D0 mesons



Procedure

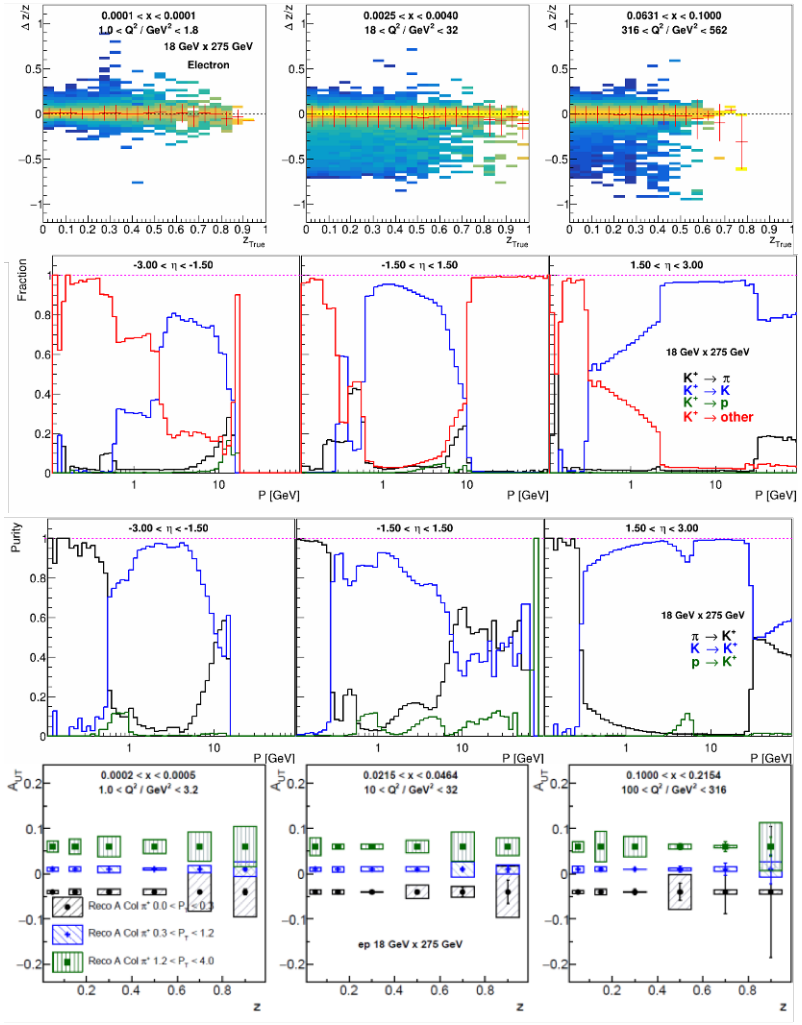
A constant asymmetry amplitude $A = 0.05$ was introduced in all events





$$c \to D^0(c\bar{u}) \to K^- \pi^+$$

- Use D0 mesons to access gluon Sivers function since open HF production mostly through parton-gluon fusion process → gluon structure, spin, 3D imaging …
- Successfully reconstruction of D0 meson candidates in reconstructed data
- Artificially introduced azimuthal asymmetries (in generated variable) reconstructed well



SIDIS Activities

Benchmark possibilities via plots from preTDR

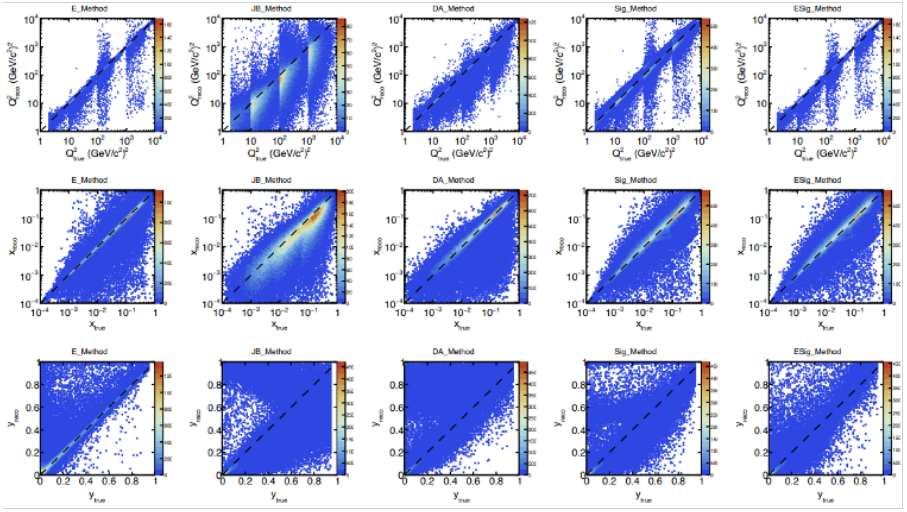
- SIDIS kinematic variable resolution plots
  - compare previous Vs current production(s)
- PID: Compare efficiencies/purities
  - depends on status of PID look up tables
- Sivers/Collins asymmetries (probe spin-momentum correlations in nucleon structure)
  - How to quantify level of smearing? Compare “systematic uncertainties” (difference in true vs reco) for different productions?
- General difficulty: many bins relevant, select a few for benchmarks?

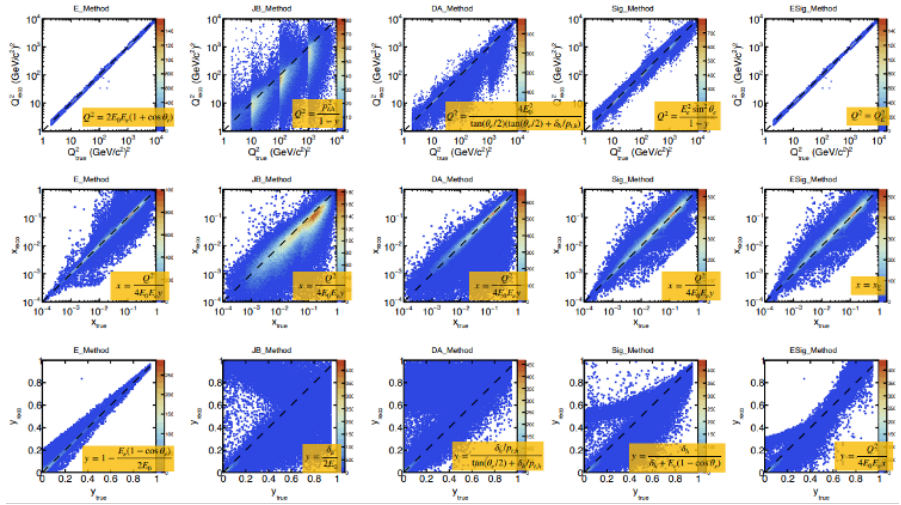
Ralf Seidl (Riken)

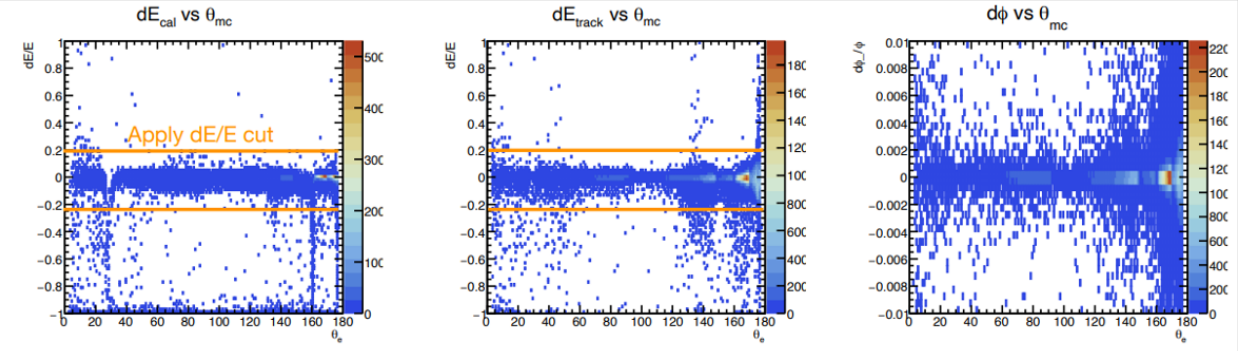
Inclusive Activities (S. Maple, T. Kutz)

Electron finder development/testing - external library produced (not shown here) Tyler Kutz (Mainz)

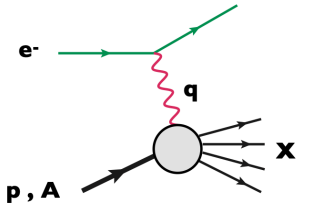
DIS Kinematic Reconstruction Validation/Optimisation - Q^2, x, y





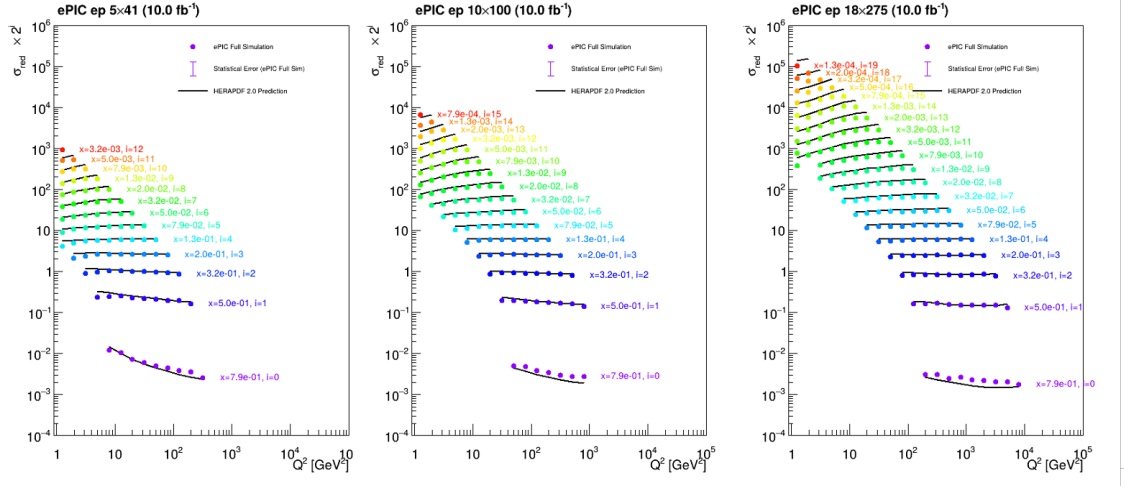


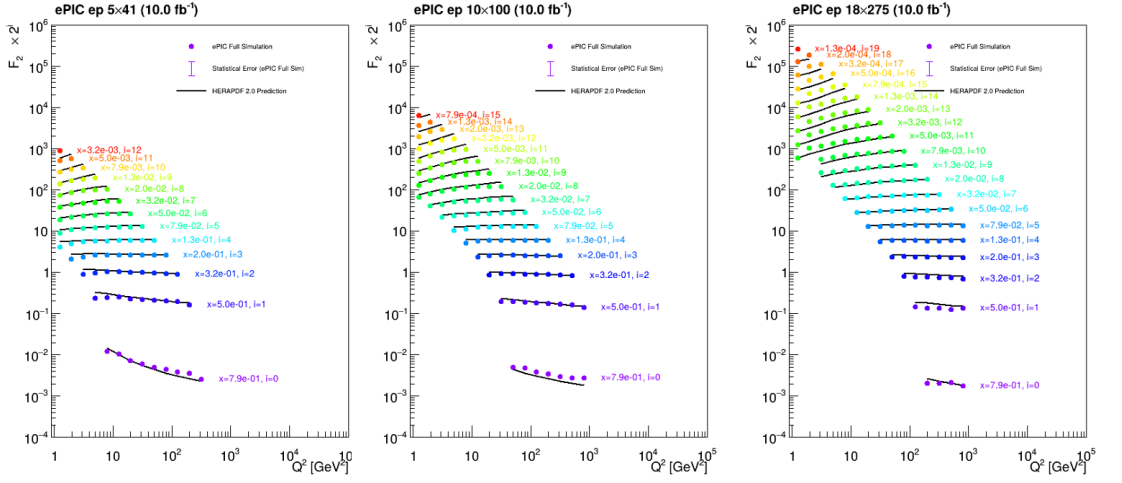
Improved understanding of regions where reconstructed + true kinematics show poor reconstruction



Win Lin (SBU)

Inclusive Activities





Neutral Current Cross-sections + F_2

Inclusive structure of proton and PDFs

Extraction of NC cross-sections using simulation campaigns

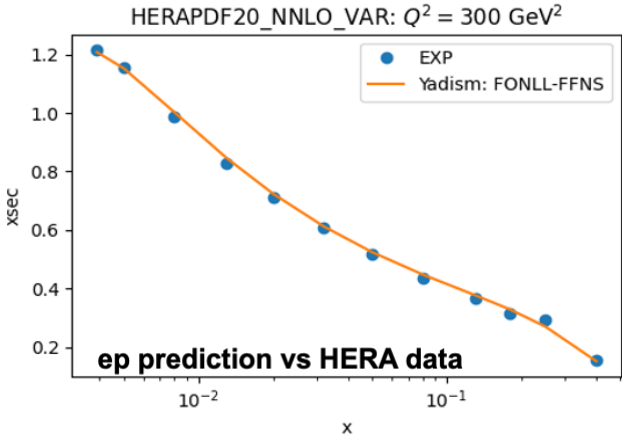
Conversion of σ_{red} to F_2

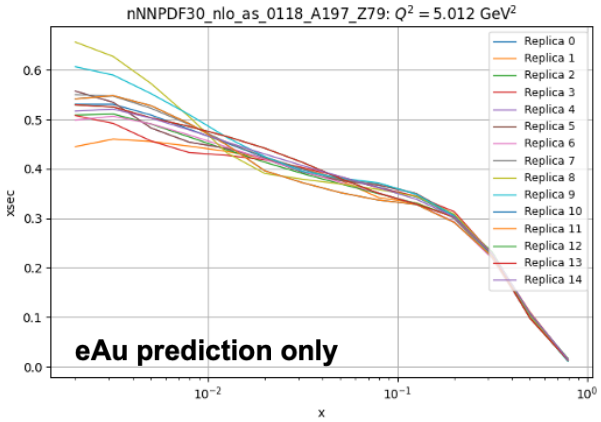
Includes statistical uncertainties

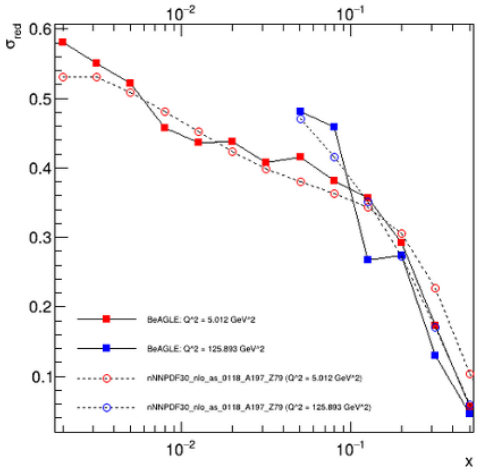
Work on systematic uncertainties progressing (not shown here)

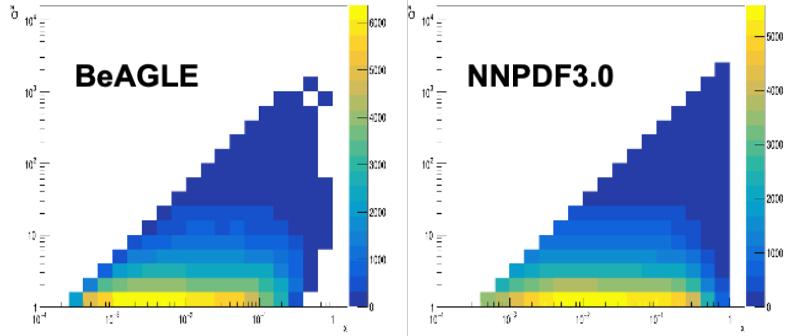
Inclusive Activities

Neutral Current eA Cross-sections





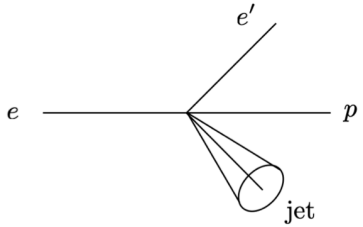




Compare bin yields from generator w/ PDF prediction

- Nuclear modifications of inclusive structure
- Initial look at eAu reduced cross sections
- Along with model testing and event generator validation
- Small sample
- Will revisit larger sample in future campaign

Jets and HF Activities (R. Ma, O. Evdokimov)



- Working towards preTDR and early science
- Simulations requested: D0 and Lc filtered ep and eAu events with 10x100 and 5x41

- Jets
  - JES and JER
  - Jet mass
  - Jet R_{eAu} with different radii
  - Hadron-in-jet Collins
  - Nucleon EEC

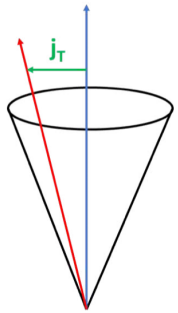
Analyzers: K. Adkins, D. Anderson, D. Lemos, B. Page, …

- Heavy Flavor
  - Track pointing resolution
  - Charm structure function
  - Lc/D0 ratios in ep, eAu
  - D0 R_{eAu}
  - D0-tagged jets

Analyzers: B. Dongwi, S. Kumar, R. Ma, A. Thakur, D. Thomas, C. Yang, …

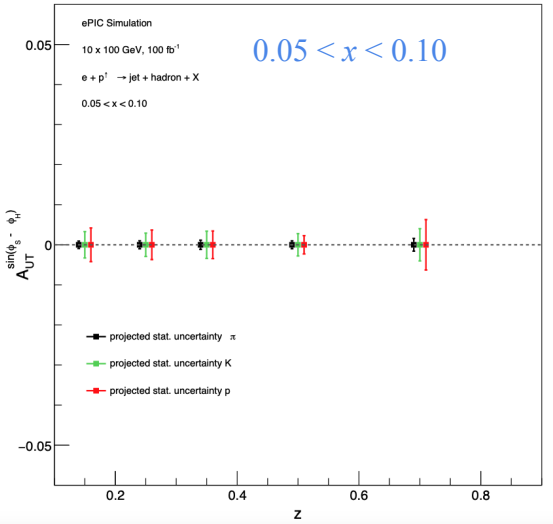
Jets and HF Activities

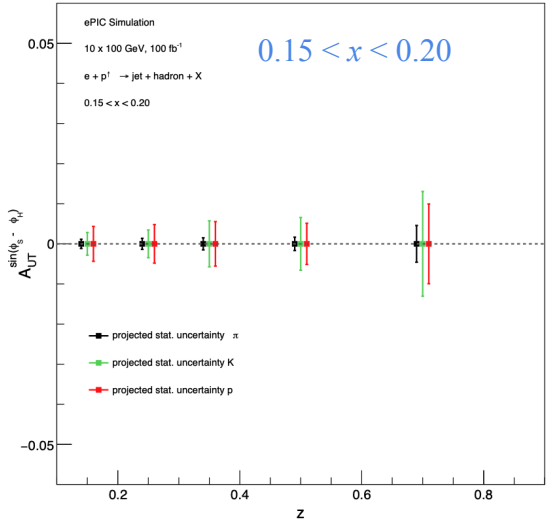
Hadron-in-jets: Collins Asymmetry

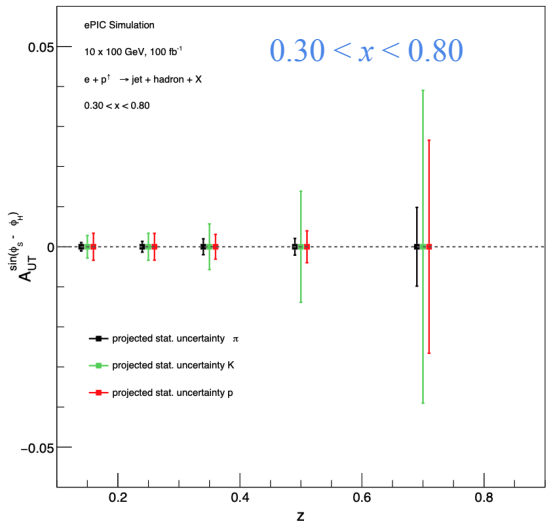


Probe for quark transversity, TMD FFs,TMD evolution, 3D imaging

ep @ 10x100





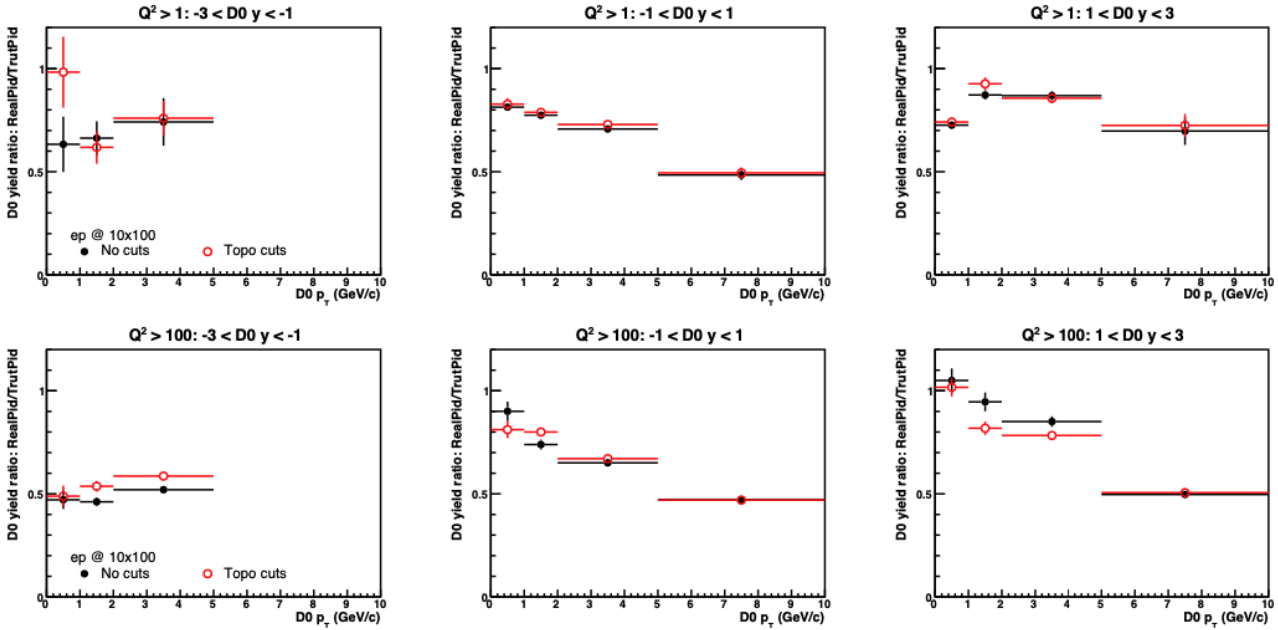


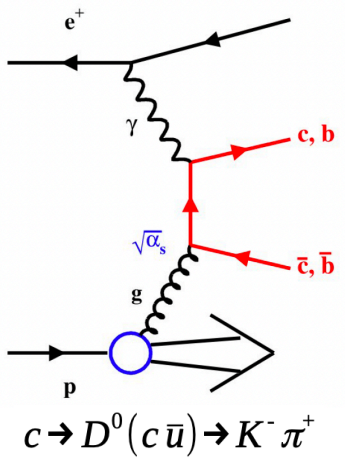
- Projected statistical uncertainties shown for different hadrons in different x bins
- Next: include Q^2 binning

Kevin Adkins (Morehead)

Jets and HF Activities

Truth vs. real PID in D0 study: PID efficiency





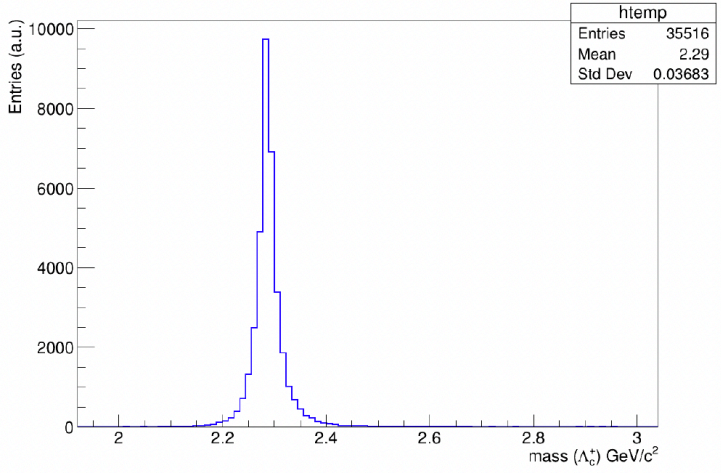
- HF production, eg D0 or Lc, probe gluon content of proton
- Also studying track pointing resolution in xy plane with D0 reconstruction (see Detector Performance and Physics Observable Workfest for more)

Jets and HF Activities

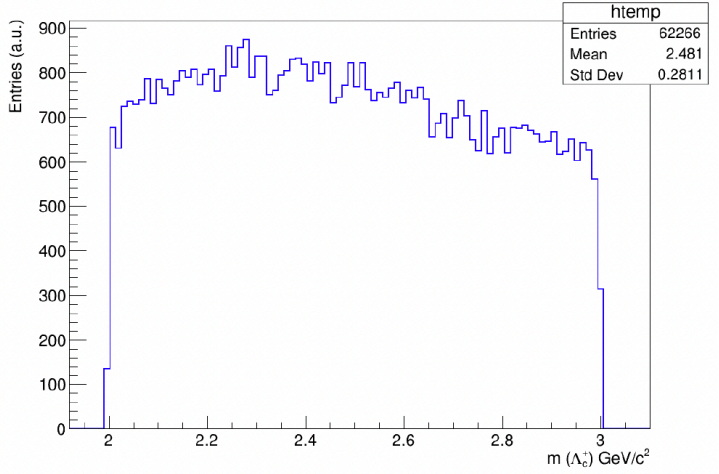
First look at Lc sample

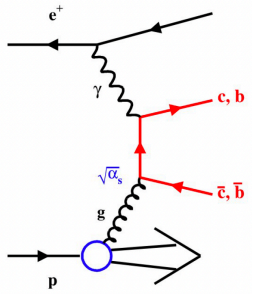
Ongoing: applying machine learning for reconstruction

Signal: Signal from Λ_c^+ Sample + Signal from DIS Sample

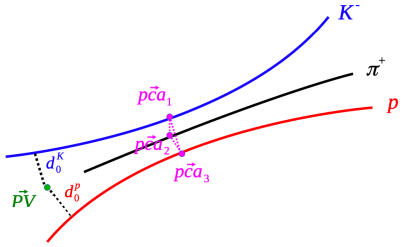


Background: Background from DIS Sample





$$c \rightarrow \Lambda_c^+(udc) \rightarrow p K^- \pi^+$$



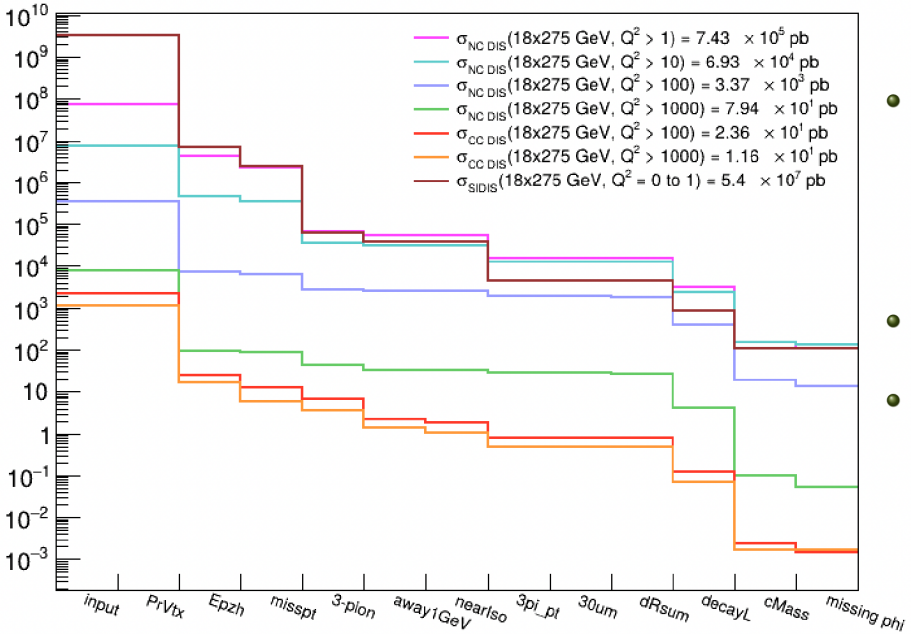
Shyam Kumar
(INFN Bari)

BSM and EW Activities (J. Mammei and C. Gal)

- Selection criteria for e → τ leptoquark transitions
- Charged lepton flavour violation → beyond standard model physics

leptoquark framework

$$e + p \rightarrow \tau + X$$



- **Calculation of Cuts/Selection Criteria:** Defined and applied selection cuts for leptoquark (LQ) processes, as well as for Neutral Current (NC) DIS, Charged Current (CC) DIS, and Semi-Inclusive DIS (SIDIS), to identify $e \rightarrow \tau$ transitions. Analysis done using the highest available center-of-mass energy configuration of $\sqrt{s} = 141$ GeV, corresponding to 18 GeV electron and 275 GeV proton beams.
- Determined the number of events that survived each selection cut, assuming an integrated luminosity of $\mathcal{L} = 100\ \mathrm{fb}^{-1}$.
- Computed the statistical uncertainty per bin using, $\texttt{Bin Error}_S = \sqrt{\mathcal{N}} \times \frac{\sigma}{\mathcal{N}_{\text{total}}} \times \mathcal{L}$, for the expected number of events per $\mathcal{L} = 100 fb^{-1}$, where σ is the total cross section.

More in depth updates and discussions at workfests
Everyone welcome!

- Exclusive, Diffractive and Tagging
  - Tue 8am - noon
  - Thur 2pm - 5:15pm
- Jets and Heavy Flavour
  - Tue 8am - noon
- Physics Observables and Detector Performance
  - Wed 1:30pm - 3:30pm Combined session with tracking
  - Wed 3:45pm - 5:30pm Other detectors

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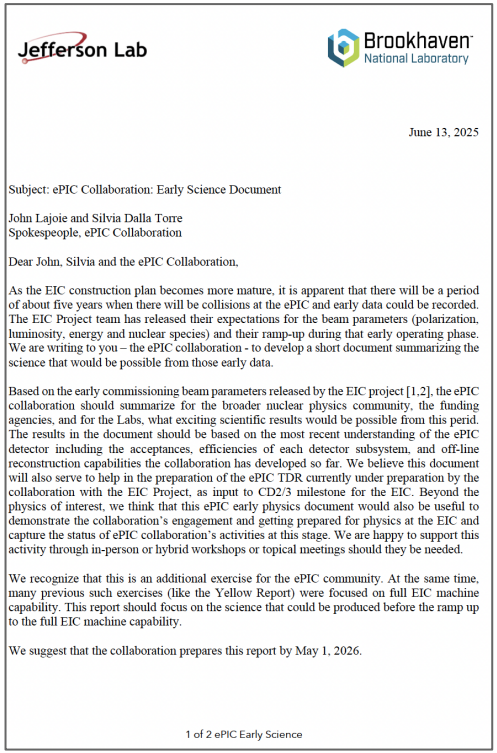
- Priority 5: Develop results validation scheme for talks/reviews documentation
  - PWGs have developed internal procedures. Need to start posting plots/outcomes of reviews

ePIC/EIC Early Science Activities

Charge from D. Dean (JLab) and A. Deshpande (BNL)



Jefferson Lab

Brookhaven National Laboratory

June 13, 2025

Subject: ePIC Collaboration: Early Science Document

John Lajoie and Silvia Dalla Torre
Spokespeople, ePIC Collaboration

Dear John, Silvia and the ePIC Collaboration,

As the EIC construction plan becomes more mature, it is apparent that there will be a period of about five years when there will be collisions at the ePIC and early data could be recorded. The EIC Project team has released their expectations for the beam parameters (polarization, luminosity, energy and nuclear species) and their ramp-up during that early operating phase. We are writing to you – the ePIC collaboration - to develop a short document summarizing the science that would be possible from those early data.

Based on the early commissioning beam parameters released by the EIC project [1,2], the ePIC collaboration should summarize for the broader nuclear physics community, the funding agencies, and for the Labs, what exciting scientific results would be possible from this perid. The results in the document should be based on the most recent understanding of the ePIC detector including the acceptances, efficiencies of each detector subsystem, and off-line reconstruction capabilities the collaboration has developed so far. We believe this document will also serve to help in the preparation of the ePIC TDR currently under preparation by the collaboration with the EIC Project, as input to CD2/3 milestone for the EIC. Beyond the physics of interest, we think that this ePIC early physics document would also be useful to demonstrate the collaboration's engagement and getting prepared for physics at the EIC and capture the status of ePIC collaboration's activities at this stage. We are happy to support this activity through in-person or hybrid workshops or topical meetings should they be needed.

We recognize that this is an additional exercise for the ePIC community. At the same time, many previous such exercises (like the Yellow Report) were focused on full EIC machine capability. This report should focus on the science that could be produced before the ramp up to the full EIC machine capability.

We suggest that the collaboration prepares this report by May 1, 2026.

1 of 2 ePIC Early Science

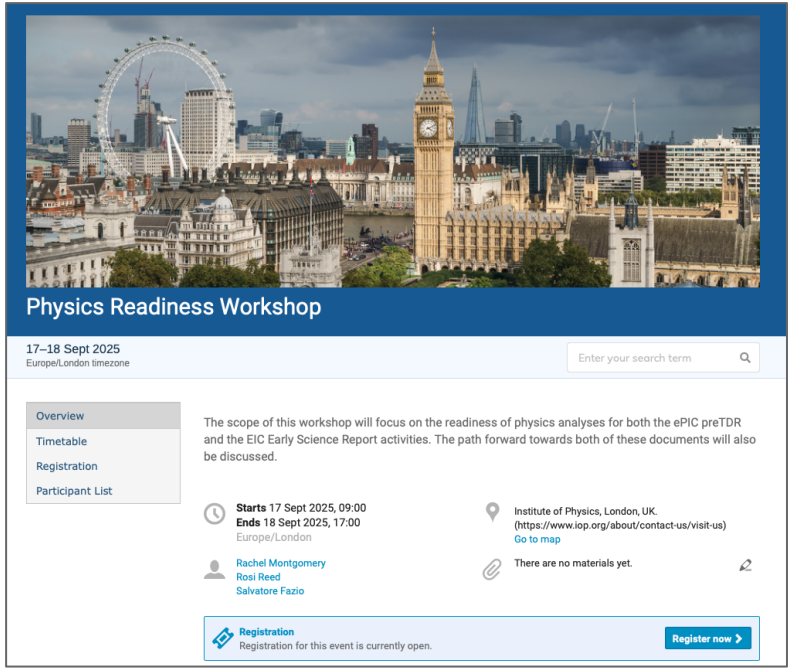
- CFNS-funded Early Science Workshop in April 2025,SBU
- https://indico.cfnssbu.physics.sunysb.edu/event/410/
  - 82 participants (33 in person)
  - 2 days
  - Day 1 - theory
  - Day 2 - projections by PWGs, discussions on SW, individual contributions
  - More detailed summary in previous ePIC general meeting (https://indico.bnl.gov/event/25903/)

- Lots of synergy between preTDR efforts and Early Science

- Much of what is currently being carried out for preTDR will be applied to Early Science for May 1st deadline

Physics Readiness Workshop

Next workshop: 17th and 18th September
Institute of Physics (IOP) Headquarters
London (UK)



https://indico.global/event/15249/overview

- Excited to launch a series of Physics Readiness Workshops
- Scope:
  - preTDR analysis updates
  - preTDR next steps
  - Early science analysis updates
  - Early Science Document next steps
- Hope to see you there in person!
- (remote participation available)
- Registration available soon
- Speak to us if you require travel support
- UKRI STFC are kindly supporting next workshop → we can help ECR travel
- Follow up workshop: ~ Feb 2026, University of Calabria (Italy)
- Early Science Writing workshop Spring 2026

Summary

- PWG convenor rotation in process
- **Lots** of exciting activities on-going in PWGs, implementing QA procedures, engaged and progressing nicely towards preTDR
- Anyone interested to join the PWGs is more than welcome!
  - If you need help getting started - chat to us
- Early Science Workshop took place April 2025 and Early Science Document due 1st May - many preTDR studies are synergistic with these activities
- Progress being made on 2025 priorities - further developments continue
- Physics Readiness Workshop Sept 2025 in London
- Lots of interesting physics expected at workfests

Back up follows

Early Science Matrix

	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

Table: E. Aschenauer (BNL)

Highlights from discussions - day 1

- **For details on the many topics covered at the Workshop → talks are posted on indico**
  - We have also recorded the discussions
- Discussion on day 1: Yuri guided us throughout each process proposed by theory speakers now and at Frascati's meeting. The discussion was very constructive
  - First years: EIC will already double the combined HERA luminosity for protons and add more capabilities: ion species form light to heavy, polarization of beams…
  - Some studies will have a sizable impact already at this *"limited"* luminosity
    - Some obvious examples: extraction of PDFs on proton, nuclear effects and A dependence in nPDFs, inclusive diffraction, dihadron correlation, some TMDs
    - New opportunities: proton FL combined with HERA
- Some processes are critical for setting the analysis framework and ensure success in the long term. Can be initially performed in wider kinematical bins to insure statistics:
  - example: exclusive measurements for GPDs
- Some processes are likely too statistics or energy hungry and will need a full EIC
  - Exclusive heavy mesons at threshold for the proton mass, saturation at low x
- We will compile a detailed list of processes discussed

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https://indico.bnl.gov/event/25903/contributions/106656/attachments/61559/105728/Summary_ESWorkshop_GM_2May2025_v2.pdf

Highlights from discussions - day 2

- On day 2 Markus led a discussion on simulation needs and coordination
- Better coordination is needed to help S&C planning ahead:
  - List of generator and configurations need and upcoming requests
  - Why a config. is needed, e.g.: pre-TDR, Early science, detector/background studies
  - Priority of each configuration
- Computing power is not infinite, and a campaign is planned for each month
  - DIS and SIDIS samples are the most requiring ones in terms of computing resources
    - SIDIS at Q2=0 samples require, alone, ~60% of the resources
- It is inconvenient to turn ON/OFF certain configurations at each campaign
- A proposed alternative: when resources are an issue, run the most demanding sample staggered every other month
  - Example: the Q2=0 sample is mainly used for detector studies, occasionally by physics. They can be run every other month
- We will follow up at our next joint S&C + Physics Analysis meeting

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Inclusive Activities

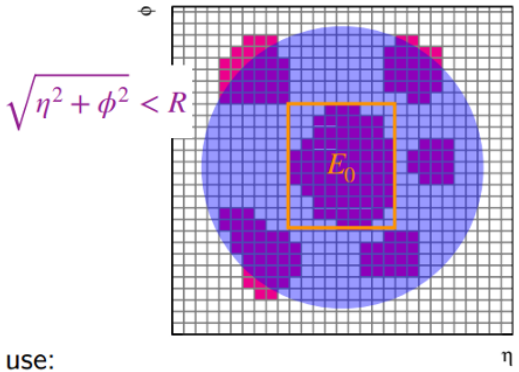
Electron finder development and testing

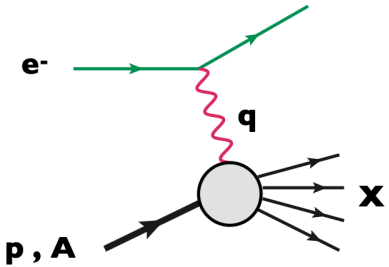
Tyler Kutz (Mainz)

- External library for electron-finder produced
- Useful for development, or as part of analysis scripts

`edm4eic::ReconstructedParticleCollection ElectronID::FindScatteredElectron()`

- Loop over all reconstructed particles, and apply cuts on:
  - Require negative tracks
  - $0.9 < E/p < 1.2$
  - Isolated cluster
    $R = 0.4$
    $E_0/\Sigma E_R < 0.9$





- If > 1 particles in collection, can use:
  `edm4eic::ReconstructedParticle SelectHighestPT(edm4eic::ReconstructedParticleCollection)`