Analysis Coordinator Report

Rosi Reed

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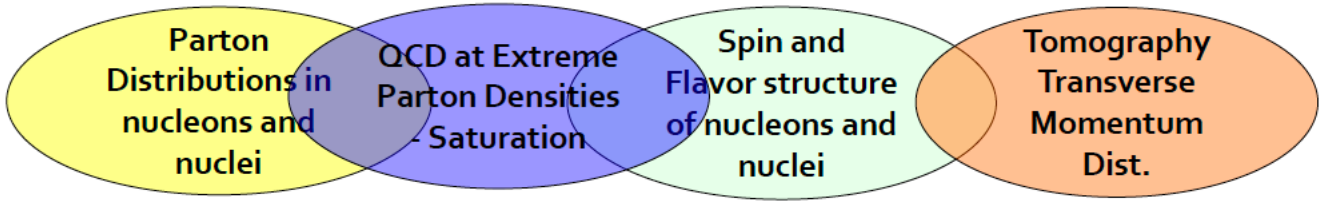
Dipartimento di FISICA

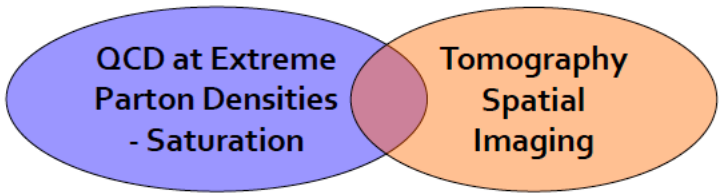
INFN
Gruppo Collegato di Cosenza
Istituto Nazionale di Fisica Nucleare

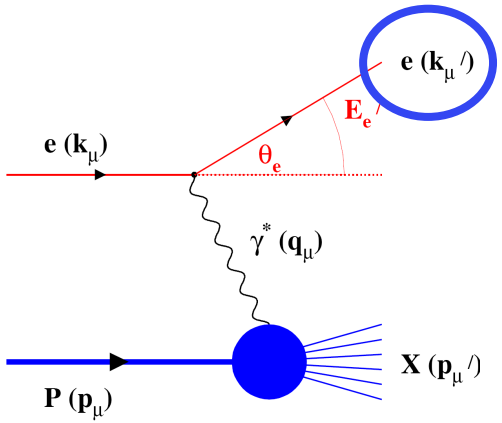
ePIC Collaboration Meeting

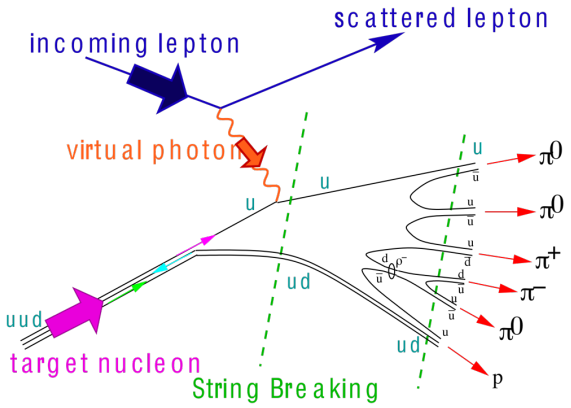
July 28, 2023

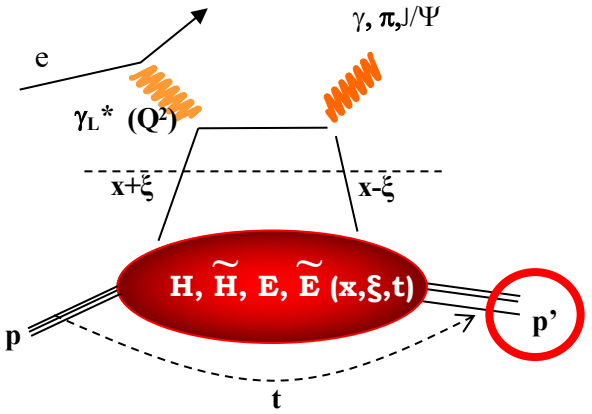
What process must be measured?











Inclusive DIS | **Semi-Inclusive DIS** | **Exclusive Reactions**

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

Many peculiar processes → 5 Physics Working Groups

SPOKESPERSON'S OFFICE
J. Lajoie (ISU), Spokesperson
S. Dalla Torre (INFN), Deputy Spokesperson

TECHNICAL COORDINATOR
Klaus Dehmelt (SBU)

ELECTRONICS, READOUT AND DAQ
Fernando Barbosa (JLab)
Jeff Landgraf (BNL)
Jin Huang (BNL)

TRACKING
Ernst Sichtermann (LBNL)
Matt Posik (Temple)

CALORIMETRY
Oleg Tsai (UCLA)

PID
Oskar Hartbrich (ORNL)
Thomas Ulrich (BNL)

FAR FORWARD/ FAR BACKWARD
Simon Gardner (Glasgow)
Nathaly Santiesteban (UNH)

SOFTWARE AND COMPUTING COORDINATOR
Markus Diefenthaler (JLab), Coordinator
Wouter Deconinck (Manitoba), Deputy
Sylvester Joosten (ANL), Deputy
Torre Wenaus (BNL), Deputy

PRODUCTION
Sakib Rahman (Manitoba)
Thomas Britton (JLab)

USER LEARNING
Holly Szumila-Vance (JLab)
Kolja Kauder (BNL)

VALIDATION
Tori Jeske (JLab)
Dmitry Kalinkin (Kentucky)

PHYSICS AND DETECTOR SIMULATION
Kolja Kauder (BNL)
Chao Peng (ANL)

RECONSTRUCTION
Shujie Li (LBNL)
Derek Anderson (ISU)

ANALYSIS TOOLS
Kong Tu (BNL)
TBD

STREAMING COMPUTING MODEL
Marco Battaglieri (INFN Genova)
Jin Huang (BNL)

ANALYSIS COORDINATORS
Salvatore Fazio (Unical)
Rosi Reed (Lehigh)

INCLUSIVE PHYSICS
Tyler Kutz (MIT)
Claire Gwenlan (Oxford)

EXCLUSIVE, DIFFRACTION AND TAGGING
Raphael Dupre (Orsay)
Rachel Montgomery (Glasgow)

SEMI-INCLUSIVE PHYSICS
Charlotte Van Hulse (Alcala)
Stefan Diehl (UConn)

JETS AND HEAVY FLAVOR
Olga Evdokimov (UIC)
Brian Page (BNL)

BSM AND PRECISION EW
Ciprian Gal (JLab)
Michael Nycz (Virginia)

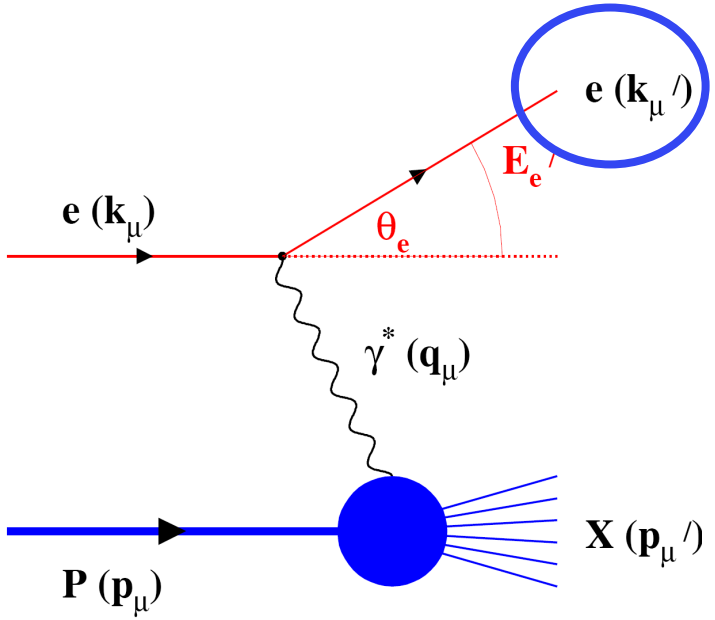
Analysis Coordination Meeting

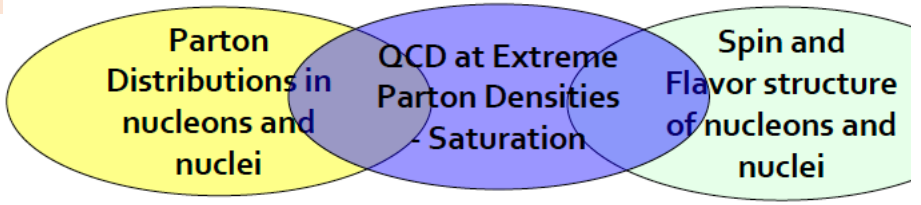
- every other Friday at 10:30 ET (staggered with the General Meeting)
- Coordinators + PWG conv.s + Reco POCs

Inclusive PWG

- Conveners:
  - Claire Gwenlan (claire.gwenlan@physics.ox.ac.uk)
  - Tyler Kutz (tkutz@mit.edu)

Focus: on measurements that involve detecting, identifying, and measuring the kinematics of the scattered electron



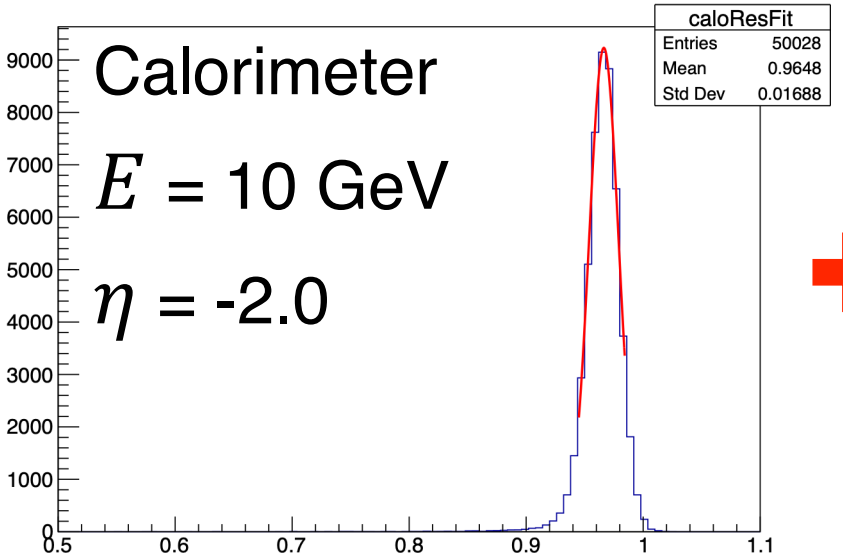


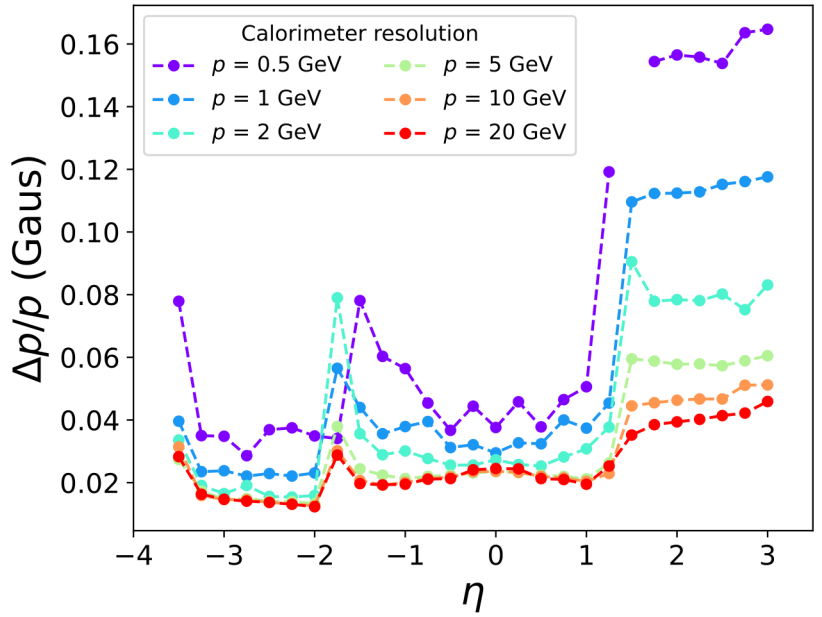
Meeting time: Mondays (biweekly) at 12pm ET
Mailing list: eic-projdet-Inclusive-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/417/
Mattermost: https://chat.epic-eic.org/main/channels/inclusive-physics

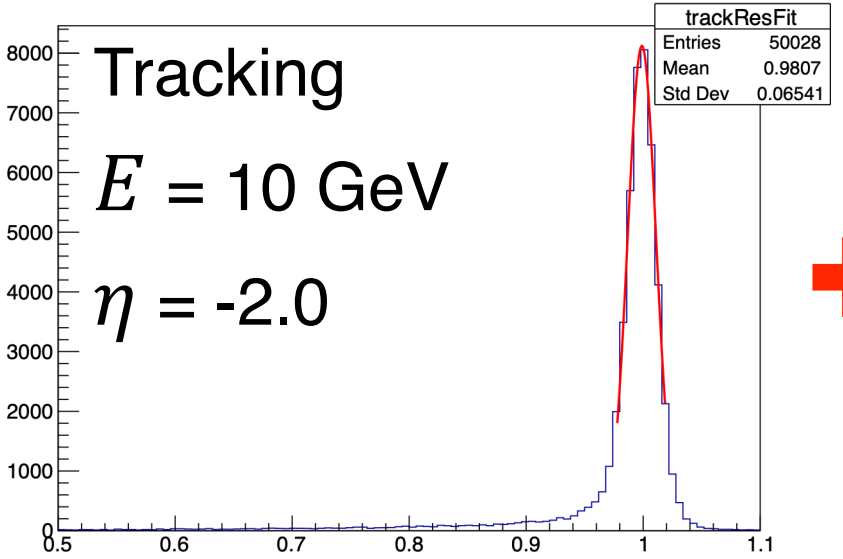
Inclusive: benchmarks

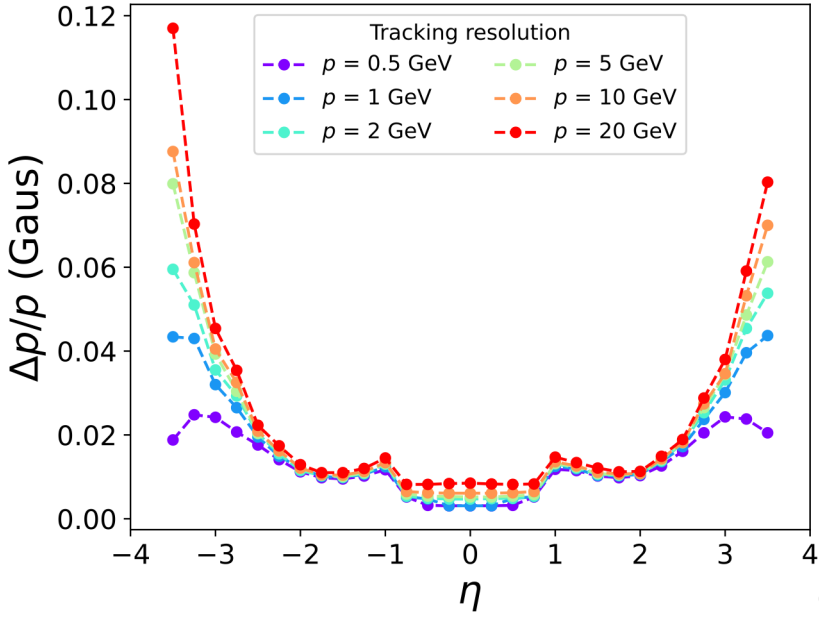
Submitted to SCC

- Tracking/calorimeter resolutions from single-particle simulation
- Working on similar macro for y, x_B, and Q^2 resolutions









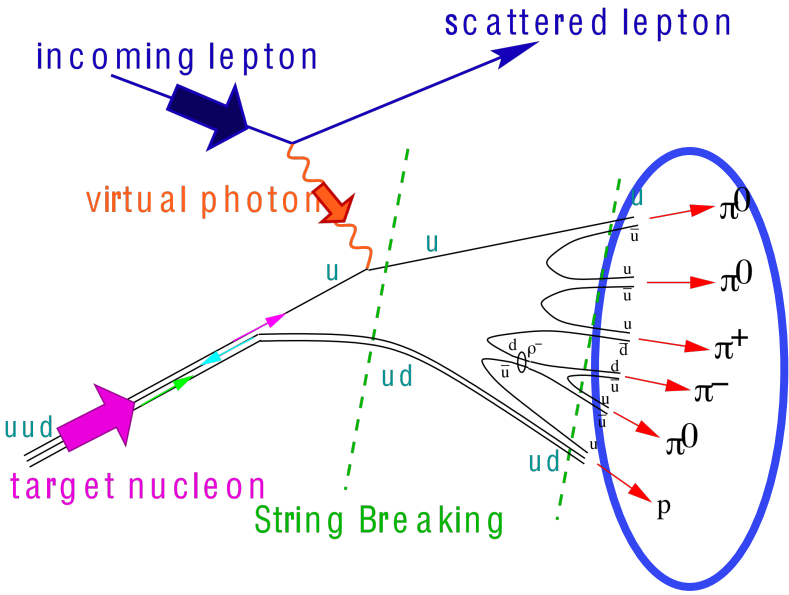
Inclusive: contributions to EICrecon + outlook

- **Track propagator factory**
  - TrackSegmentCollection for each event saved in PODIO output
  - Outstanding issues:
    - Include all material in material map (not just material in tracking volume)
    - Debugging memory corruption in TrackPoint surface ID
- **Next tasks**
  - More inclusive physics benchmarks
  - Track matching factory (once track propagator is complete)
  - Continue contributing to electron ID efforts
  - Physics studies!
    (Start with cross sections and double-spin asymmetries)

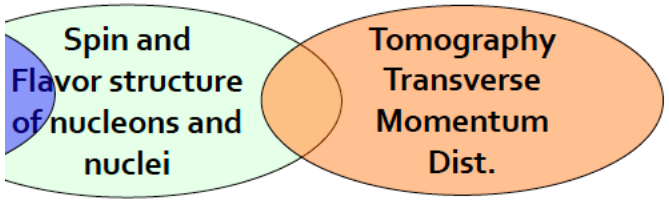
SiDIS PWG

- Conveners:
  - Charlotte Van Hulse (charlotte.barbara.van.hulse@cern.ch)
  - Stefan Diehl (stefan.diehl@uconn.edu)

Focus: on measurements that require detecting, identifying and measuring a final state hadron or hadrons in addition to the scattered electron



Meeting time: Tuesdays (biweekly) at 8:30am ET
Mailing list: eic-projdet-semiincl-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/418/
Mattermost: https://chat.epic-eic.org/main/channels/semi-inclusive



SiDIS: physics channels & benchmarks

- Collinear double-helicity asymmetry [sea-quark helicity PDFs]
- Unpolarised TMD measurements [spin-independent TMD PDFs/FFs]
- Unpolarised TMD measurements [spin-independent TMD PDFs/FFs]
- Sivers and Collins asymmetry [Sivers TMD, transversity, tensor charge, Collins FF]
- Dihadron asymmetry [transversity, tensor charge, collinear dihadron FF]
- High-pT dihadron asymmetry [gluon Sivers]
- Lambda polarization [polarized FF]
- Back-to-back hadrons to probe saturation

Detector benchmarks:

- (SI)DIS resolutions and coverages / acceptances (x_B, Q^2, z, P_T, Φ_h)

  → Overlap to inclusive PWG
- Purity of pions and kaons vs. momentum (e/π K/π separation)
- Reconstruction efficiencies for Lambdas and maybe others

  [maybe in combination with exclusives]

SiDIS: status & outlook

- Benchmarks framework ready
  - see talk by C. Dilks: https://indico.bnl.gov/event/17018/contributions/67903/attachments/43129/72509/sidis-eic.pdf

Github: https://github.com/eic/epic-analysis

Analysis efforts:

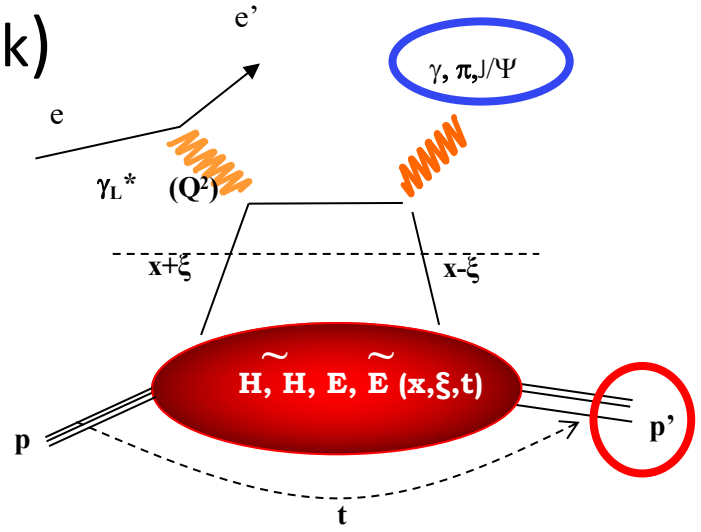
- realistic PID (priority: high)
- impact study of tracking resolution (priority: high)
- radiative effects (priority: high)
- inclusion of realistic simulations with background (priority: medium-high)
- inclusion of new PDF/FF set to study variation of outcome (priority: medium)
- implementation of unfolding (priority: medium, sufficient simulation needed)

An overview on detailed studies done so far can be found here:

https://indico.bnl.gov/event/17621/contributions/70630/subcontributions/2135/attachments/45495/76765/2023_01_11_ePIC_SIDIS.pdf
https://indico.bnl.gov/event/15342/contributions/65968/attachments/42422/71057/WG_SIDIS_EICUGJuly22.pdf

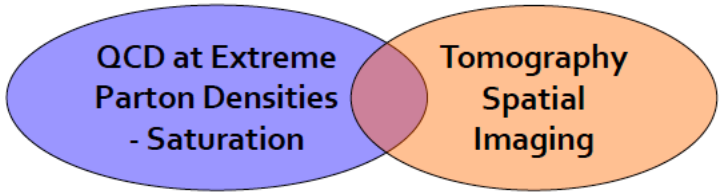
Exclusive + Diffraction + Tagging PWG

- Conveners:
  - Raphael Dupré (raphael.dupre@ijclab.in2p3.fr)
  - Rachel Montgomery (Rachel.Montgomery@glasgow.ac.uk)

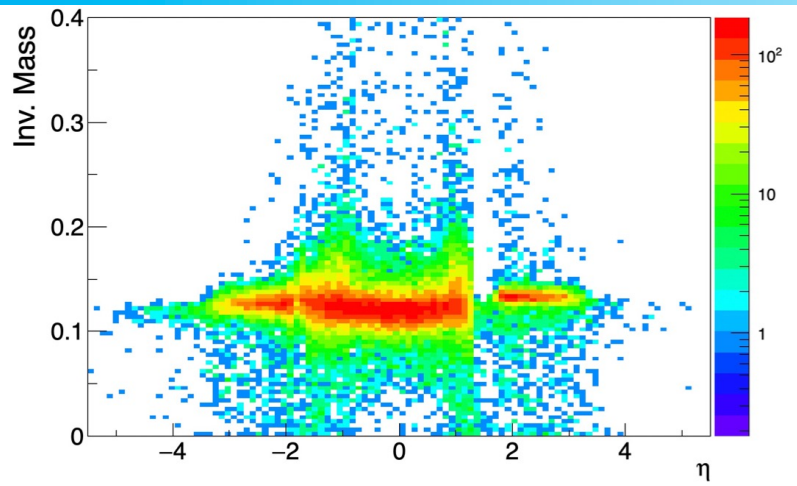


Focus: on measurement that require detecting the scattered proton/ion, whether it remains intact or not, together with all the final state produced particles, in addition to the scattered electron

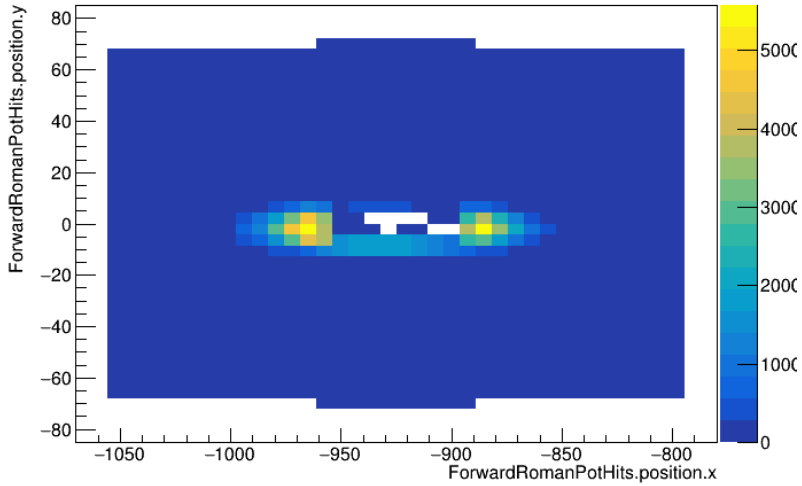
Meeting time: Mondays (biweekly) at 12pm ET
Mailing list: eic-projdet-excldiff-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/419/
Mattermost: https://chat.epic-eic.org/main/channels/phys-exclusive-diffractive



Exclusive+Diff+Tagging: Deeply Virtual Comton Scattering



Above: ePIC background pi0 study reconstructed from endcap photons I. Korover (see DIS 2023 slides)

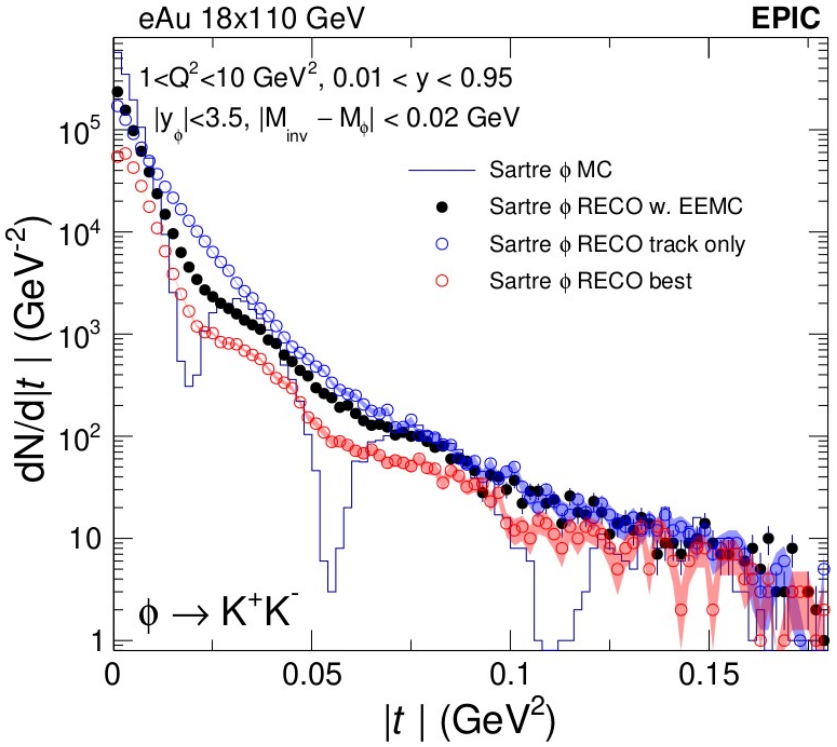


Above: FF magnetic steering developments now correctly steering He4 in FF region, hit in RP shown (G. Penman ECR slides)

- Regular DVCS (ep and eA)
  - Plans to add ep DVCS as a benchmark (I. Korover, A. Jentsch)
  - See also N. Ramasubramanian talk ECR workshop
  - eA status reported by G. Penman at ECR workshop: recently working w/ A. Jentsch on forward steering of ^{4}He in ePIC sim and momentum reconstruction in EICrecon (default was not working for light ions)
- Exclusive meson production
  - Study of π^0 as a background to the DVCS has existing analysis in tandem with DVCS - discussions on next steps in progress
  - DEMPGen development progress for pion and kaon (lambda/sigma) production (S. Kay, G. Huber, L. Preet) (see https://github.com/JeffersonLab/DEMPGen/tree/v1p0_release)
- Plans to look more into tagged DVCS soon
  - To study neutron DVCS, possibly for nuclear effects as well – develop benchmark for FF region

Exclusive+Diff+Tagging: Virtual Meson Production

- Many active studies and plans for VM production
  - Many mesons (J/ψ, ϒ, φ, ρ, ω...)
  - Studying **all** across all rapidities and Q^2 will be very important test of ePIC capabilities for this physics
- Lots of existing analysis and lots of projects
  - New ep simulations for J/ψ, ϒ, φ planned with lAger (Argonne) and DEEPsim (Virginia Tech)
  - Coherent versus incoherent VMP benchmark being proposed
    - Plots will include |t| resolution for veto coherent/incoherent test, as well as dsigma/dt
- Tagging of a nucleon from deuterium
  - Largely using BeAGLE Phys.Rev.D 106 (2022) 1, 012007
  - Studies done to extract the free neutron from deuterium
  - Now extended to explore nuclear effects such as the EMC effect
- Tagging on various target and processes
  - Tagged DVCS, ^{3}He tagging, heavy nuclei...
- Backward-angle (u-channel) production
  - Results for virtual mesons (ω, ρ) published PRC **106**, 015204 (2022) (Z. Sweger, S. Klein)
  - See Zachary Swerger's talk
- Sullivan process – many topics on-going by several groups
  - Generator updates for π/kaon structure function (R. Trotta et al.)
  - Pion DVCS (simulation in ePIC framework shown by O. Bylund et al.)

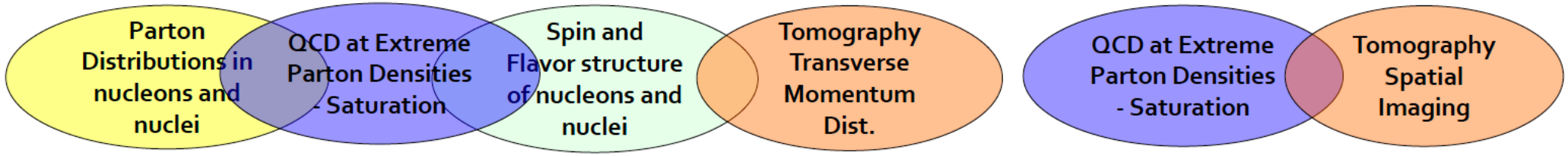


Above: phi study in ePIC at Q2>1GeV2 (Z. Tu DIS slides)

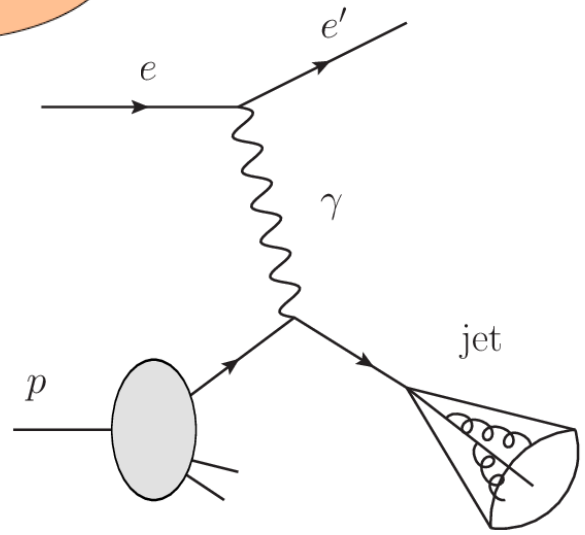
See Kong Tu's talk

JETS + Heavy Flavor

- Conveners: Olga Evdokimov (evdolga@uic.edu), Brian Page (bpage@bnl.gov)



Focus: on measurements that involve high momentum exchanged processes, which could produce a spray of final state particles or hadrons that have one or more heavy quark constituents



Meeting time: Wednesdays (biweekly) at 12:00pm ET
Mailing list: eic-projdet-jethf-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/420/
Mattermost: https://chat.epic-eic.org/main/channels/phys-jets-hf
Wiki page: https://wiki.bnl.gov/eic-project-detector/index.php/JetsHF

JETS + HF: ongoing work

❑ (Charged) Jet benchmarks are in place

- ➢ Monitor phase space (eta, phi, energy) distribution of jets at reco and truth level
- ➢ Monitor JES/JER as tracking algorithms and detailed tracker geometry changes
  - ▪ Check consistency between JES and track efficiency
- ➢ Updates will be necessary as jet factories evolve

❑ Tracking benchmarks are being developed

- ➢ Current focus on track efficiency (by particle species) to compare with JES
- ➢ Further work needed to allow more detailed monitoring and further QA cuts
  - ▪ Associations between Reconstructed Particles and tracks

❑ Update jet factories to use multi-factory framework

- ➢ Enable PODIO functionality
- ➢ See EICrecon pull request 767 (https://github.com/eic/EICrecon/pull/767)

JETS + HF: planned work + open issues

- Create relations between edm4eic::ReconstructedParticle types and edm4eic::Track types
  - Needed for heavy flavor benchmarks
  - See Issue 725 (https://github.com/eic/EICrecon/issues/725)
  - Allow access to more track parameters from jet object for QA and monitoring
  - General: Better coordination between Jets/HF and Track reconstruction groups needed

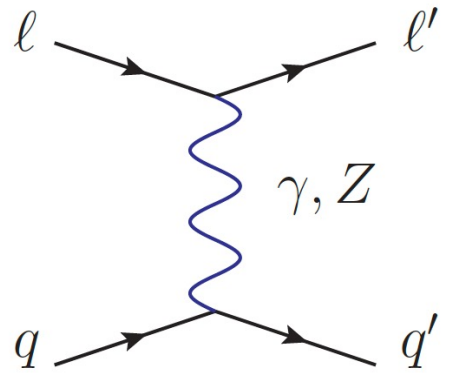
- Update Jet EDM
  - Currently, jets are stored as edm4eic::ReconstructedParticle type
  - Need more ”jet appropriate” container (handle area, calibrations, etc)
  - See Issue 724 (https://github.com/eic/EICrecon/issues/724)

- Work on Particle Flow Tasks
  - Produce factories and algorithms
  - Visualization and analysis software
  - Coordinate with Reconstruction Group

See Brian’s talk next for more detail

Beyond Standard Model + Precision Electro-Weak PWG

- Conveners:
  - Ciprian Gal (ciprian@jlab.org)
  - Michael Nycz (dfe3ks@virginia.edu)



Beyond
EIC «core science»

Focus: on measurements of the cross-sections, helicities of electroweak gauge bosons that can lead to a better understanding of quark-level electroweak couplings and the potential for measurements beyond the standard model

Meeting time: Tuesdays (biweekly) at 8:30am ET
Mailing list: eic-projdet-semiincl-l@lists.bnl.gov
Indico: https://indico.bnl.gov/category/421/
Mattermost: https://chat.epic-eic.org/main/channels/ew-bsm

BSM + Precision EW: ongoing efforts

- Weak Mixing angle
  - building upon previous ECCE study
  - Neutral-current electroweak physics and SMEFT studies at the EIC
    - Investigating the impact of various unfolding methods
- Charge Lepton Flavor Violation (CLFV)
  - Muon Identification

Current Workforce (Actively performing analysis)

- ~ 3 part-time Postdoc

Postdoc workforce is comprised of newer members, so we anticipate increasing involvement and overall contribution to the upcoming ePIC simulation and validation campaign

The interplay between Physics and S&C

When you talk to people in Physics WGs

- I wish I could do my favorite physics studies, but... reconstruction must be improved!
- Where's my electron finder?
- I want secondary vertices!
- Oh, I can't do *this* if the software doesn't do *that*!

When you talk to people in S&C and Reco. WGs

- We want to implement *that* into the reco frame, but it's a huge effort and takes time
- Personpower! Where is everyone!?
- We need physics benchmarks for the continuous assessment of the ePIC detector

S&C Coordinators + Analysis Coordinators meeting
May 17th

… All right, we need to come together!

- Indico at: https://indico.bnl.gov/event/19473/
- Live notes at: Live Notes
- Identified **4 priorities**:
  - **Electron Finder**: Developing an efficient and accurate algorithm for identifying electrons and identifying the scattered electron of the DIS process
  - **Vertexing and PID**: Enhancing the vertexing capabilities and particle identification techniques to study heavy flavor physics
  - **Particle Flow**: Improving the jet reconstruction using particle flow information
  - **Low-Q^2**: Integration of the low-Q^2 tagger into the reconstruction framework for precise measurements of photo production and vector mesons

Formation of the Reconstruction Task Squadrons

Points of Contact (POCs) for each squadron

Electron Finder: Daniel Brandenburg (brandenburg.89@osu.edu)

Vertexing and PID: Shujie Li (shujieli@lbl.gov)

Particle Flow: Derek Anderson (dmawxc@iastate.edu)

Low-Q^2: Simon Gardner (simon.gardner@glasgow.ac.uk)

Contact the POC to get involved in activities ASAP!

Electron Finder

Goal / Product: Provide identified (DIS) electron info

- Progress in May / early June (for June Sim Campaign)
  - PR #666: Provides association containers + truth associations (Wouter Deconinck et al.)
  - Identified immediate need, discussion of design / integration plan
- Major Tasks (June):
  - Electron-pion separation, implementation of E/p cuts using existing association information (*volunteer?*)
  - Track Projection Factory: provide track projections at relevant detectors (Tyler Kutz)
  - Track Match Factory: Matching of projecting tracks to clusters (*volunteer?*)
  - DIS lepton identification (Andrii Verbytskyi) + implementation
  - Integrated Electron Finder Factory (Daniel Brandenburg)
    - See talk on Friday (July 28th, 4:50 pm)!
- These tasks make progress towards two goals for July sim campaign
  - Setup complete framework: utilize existing association + simple electron id + existing DIS lepton finder -> output DIS lepton

Vertexing & PID

Goal / Product: Provide reconstruction of secondary vertices and particle identification

- **Three primary tasks:**
  1) Integrate primary vertexing in reconstruction
  2) Integrate vertex information in ePIC data model
  3) Survey common secondary vertex reconstruction packages
- **Task (1):**
  - **Done** and in for the July campaign!
  - Implemented by **Joe Osborne** and **Barak Schmookler**
- **Tasks (2)** and **(3)** in progress…

Particle Flow

Goal / Product: improve jet reconstruction using particle flow information

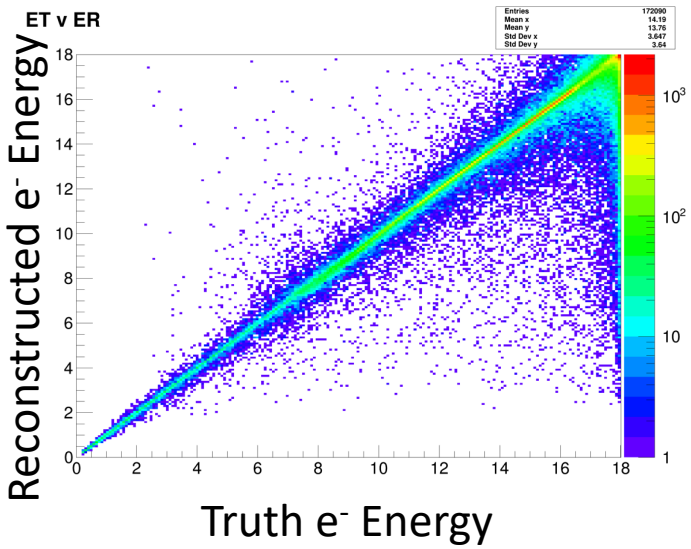
- distinct regions for PF at ePIC
  - **Barrel/Backward:** JER set by tracker + EMCal
    - ☞ Need tracks to deconvolve clusters for neutrals
  - **Forward:** JER can be improved by combining track + calorimeter information
    - ☞ Need to separate overlapping clusters

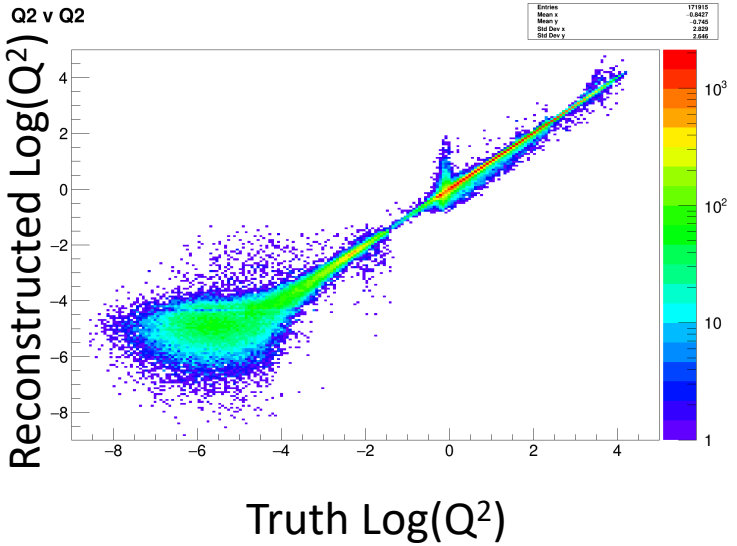
- **Two initial tasks:**
  1) Survey existing implementations of **p**article **f**low (PF)
  2) Explore necessity of custom approach (rather than an existing package) in the barrel and backwards regions
- Special Jet/HF meeting occurred on the 13th
  - ☞ Heard from Matt Nguyen (LLR) and Antonio da Silva (ISU) about particle flow experience at CMS and sPHENIX
- Now moving forward with prototyping
- **Current Status:** see talk by Daniel Brandenburg on Friday (July 28th, 4:50 pm)!

Low-Q^2 Tagger

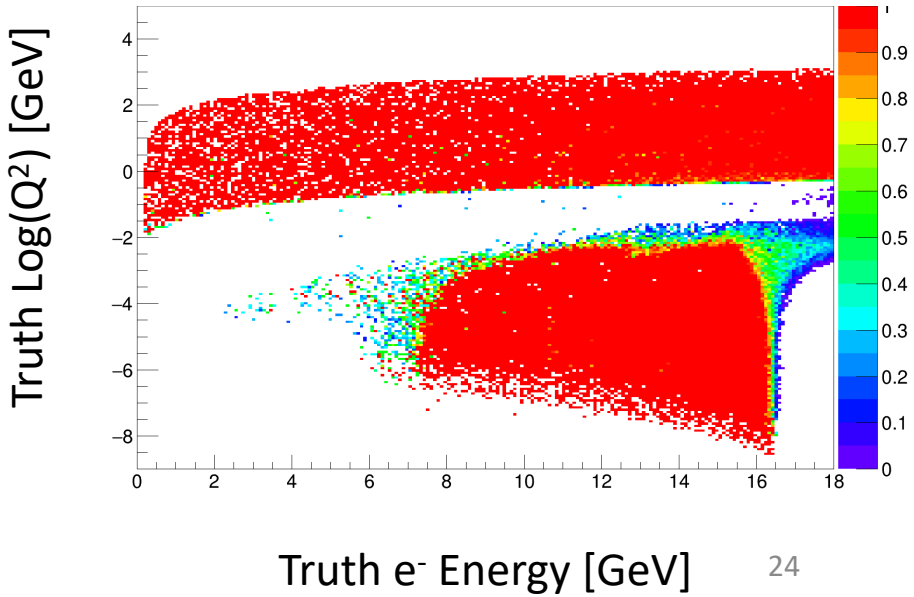
- Available for testing in branch on github - [266-integrate-lowq2-tagger-reconstruction]
- Very basic clustering and track reconstruction - limits number of hits
  - Needs improvement for full background inclusion
  - Exploring GraphNN to one shot tracks from all possible combinations
- Electron momentum reconstruction using standard NN
  - Very good reconstruction
  - Need discussions on how to include ML in EICrecon

Beamline setting integration into workflow
Requires metadata handling decisions with the wider collaboration.
Work at every stage of software stack required to persist necessary information.
Still early days.





Total ePIC Quasi-Real Photoproduction Acceptance



Wrapping up…

- 4 “task squadron” priorities: Electron Finder, Vertexing and PID, Particle Flow, Low-Q^2
  - Need volunteers to join efforts
  - How do I join: email the Point-of-Contact for your favorite task!
- PWG Benchmarks being implemented
- HOW do I join a PWG?
  - step 1: email the conveners of your favorite PWG and subscribe the mailing list!
  - step 2: join the (bi)weeky meetings
  - step 3: actively engage in studies and efforts

WE WANT YOU


BACKUP

JETS + HF: benchmarks

- Initial set of jet benchmarks
  - Kinematic Distributions (Jet pT, Eta, Phi, E, correlations)
  - Reconstructed / Generator Jet Delta R
  - Duplicate Track Plots
  - Jet Energy Resolution / Scale (Vs Eta and E)
- Root macro for generating these quantities using RDataFrames (mostly) exists - needs a little more work
- Based on ReconstructedJets and GeneratedJets branches of EICrecon output
  - Currently track-only
  - Should change GeneratedJets factory to only include charged truth particles
- **See Brian's talk next for more detail**