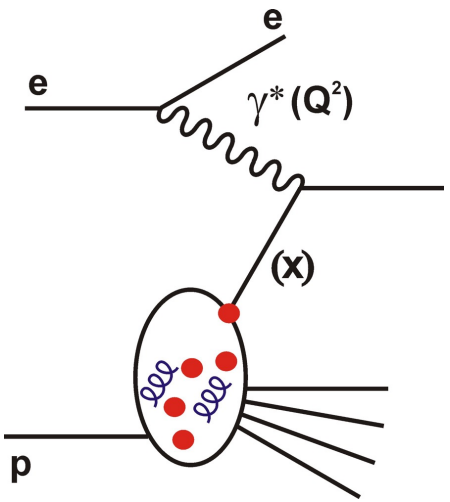
Inclusive Physics at EIC: Introduction

EPIC Collaboration Meeting
11 January 2023

Paul Newman (Birmingham)
with Claire Gwenlan (Oxford), Tyler Kutz (MIT),
Barak Schmookler (UC Riverside)



Following talks:

Kinematic Reconstruction ¶

Speaker: Stephen Maple (University of Birmingham)

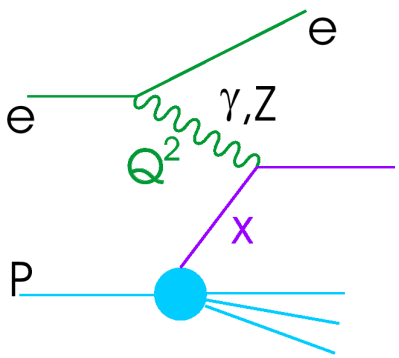
Reconstruction and analysis work

Speaker: Tyler Kutz (MIT)

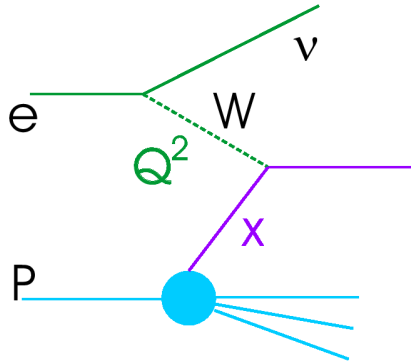
Barrel ECAL requirements for inclusive analyses

Speaker: Barak Schmookler (UC Riverside)

Inclusive Scattering Observables



Neutral Current:
ep → eX



Charged Current:
ep → νX

`Inclusive' refers to anything we can measure starting from the inclusive neutral and charged current processes

$$Q^2 = -q^2 \qquad x = \frac{-q^2}{2p \cdot q}$$

$$y = \frac{p \cdot q}{p \cdot e} \qquad Q^2 \simeq sxy.$$

- Over-constrained kinematics are a huge advantage in (NC) DIS … x, Q^2 can be reconstructed from the electron, the hadronic recoil or a combination

- Hadronic final state understanding also important for background rejection and reconstructing kinematics in CC

… starting point is electron identification & reconstruction, plus *inclusive* hadronic final state reconstruction.

Inclusive Scattering Derived Measurements

… inclusive measurements lead to a long list of underlying physics quantities…

Measurement	Physics Topic/goal
$\sigma_{red,NC(CC)}(x,Q^2) \rightarrow F_2, F_L$	Proton PDFs (and neutron) $q(x,Q^2)$, $g(x, Q^2)$
$\sigma_{red,NC(CC)}(x,Q^2) \rightarrow F_2, F_L$	Nuclear PDFs $q(x,Q^2)$, $g(x, Q^2)$ Non-linear QCD dynamics
Inclusive $A_{\|\|} / A_{\perp}$ for proton, deuterium, ^3He	Gluon & Quark Helicity $\Delta g(x,Q^2)$, Δu^+, Δd^+

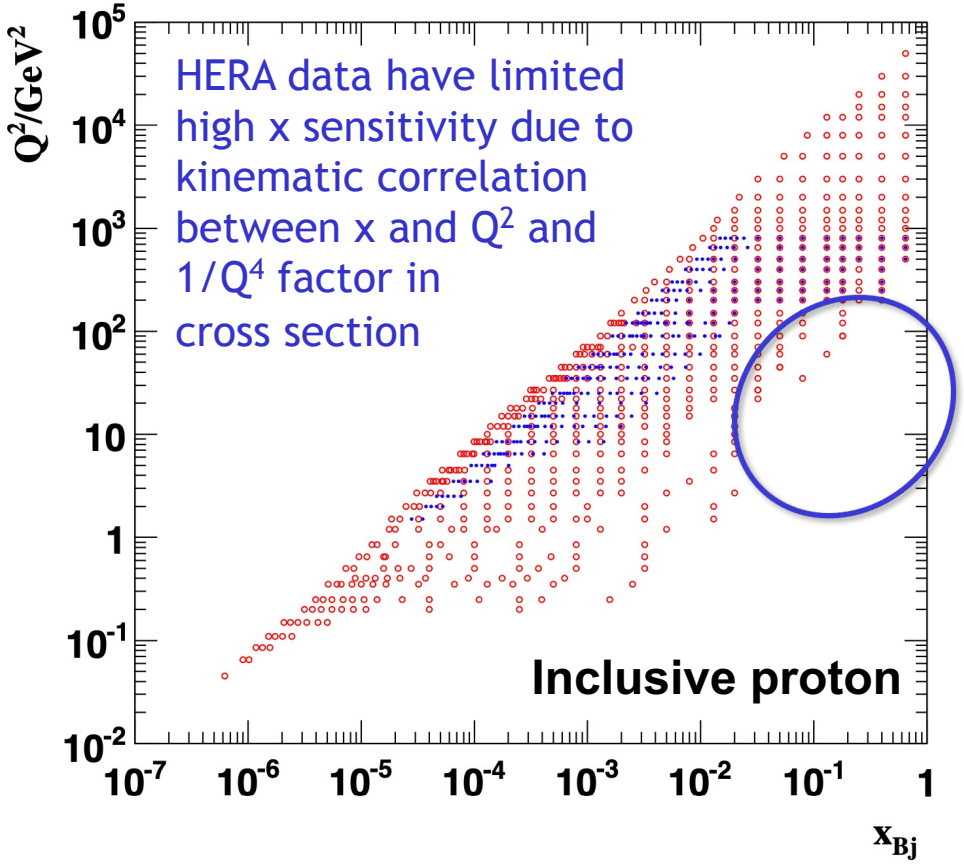
Also topics covered in other working groups …

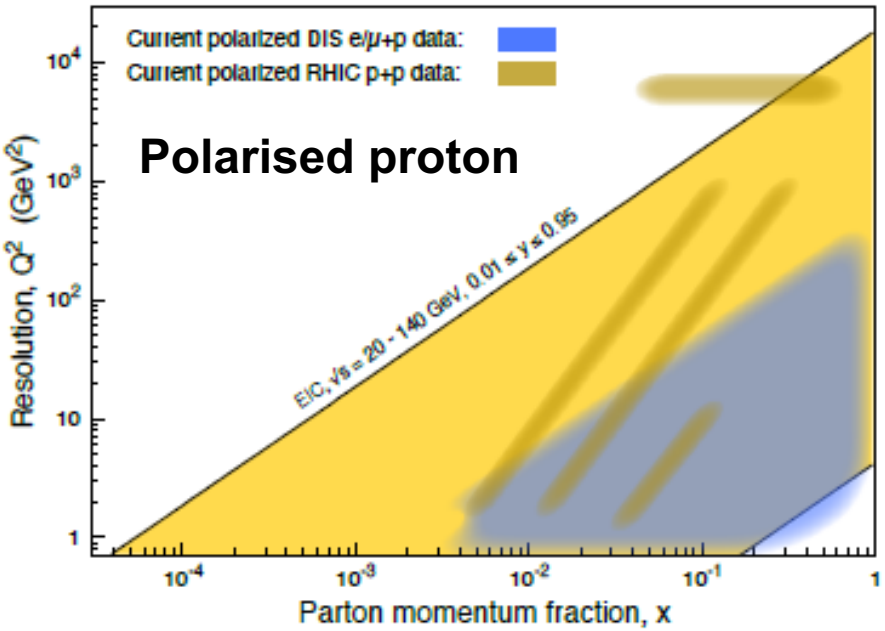
- Also electroweak parameters ($\sin^2\theta_W$, M_W, g_A^F, g_V^F)
- Exotic searches (leptoquarks, excited leptons, compositeness …)

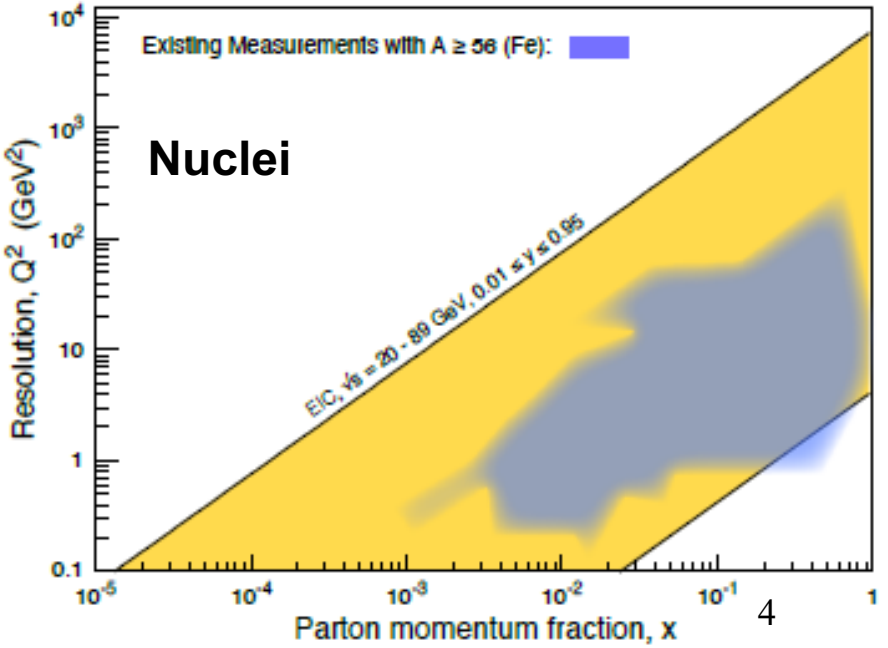
Kinematic Coverage v Existing Data

- ~2 new orders of magnitude for polarised ep and eA

- Precision in large x unpolarised ep beyond the fixed target region.

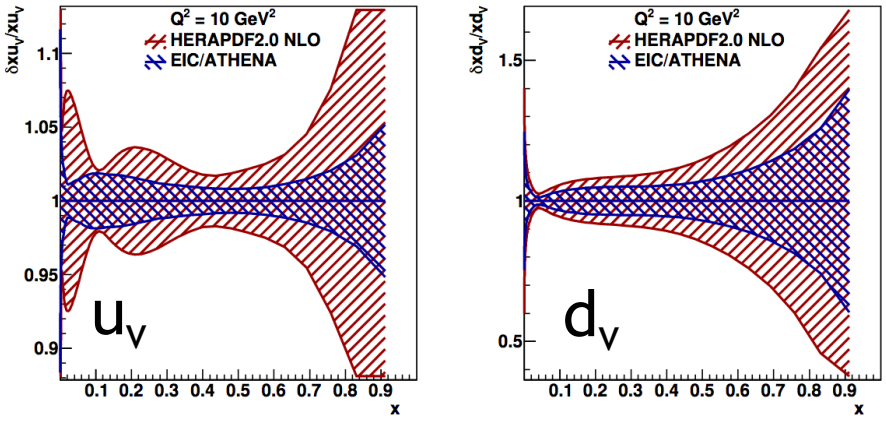


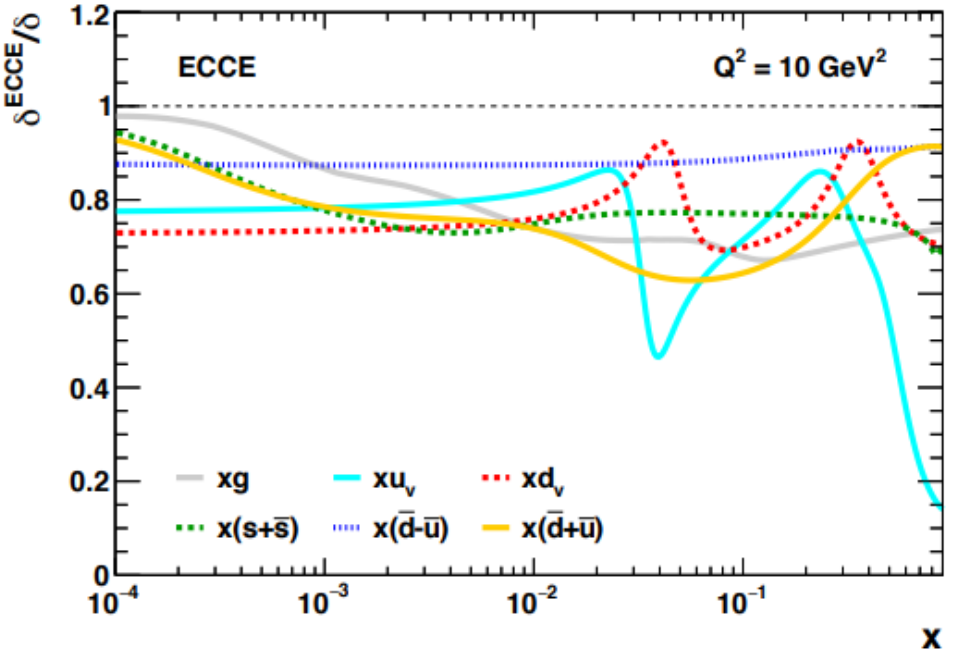




ECCE and ATHENA studies of potential impact 1) Inclusive proton PDFs

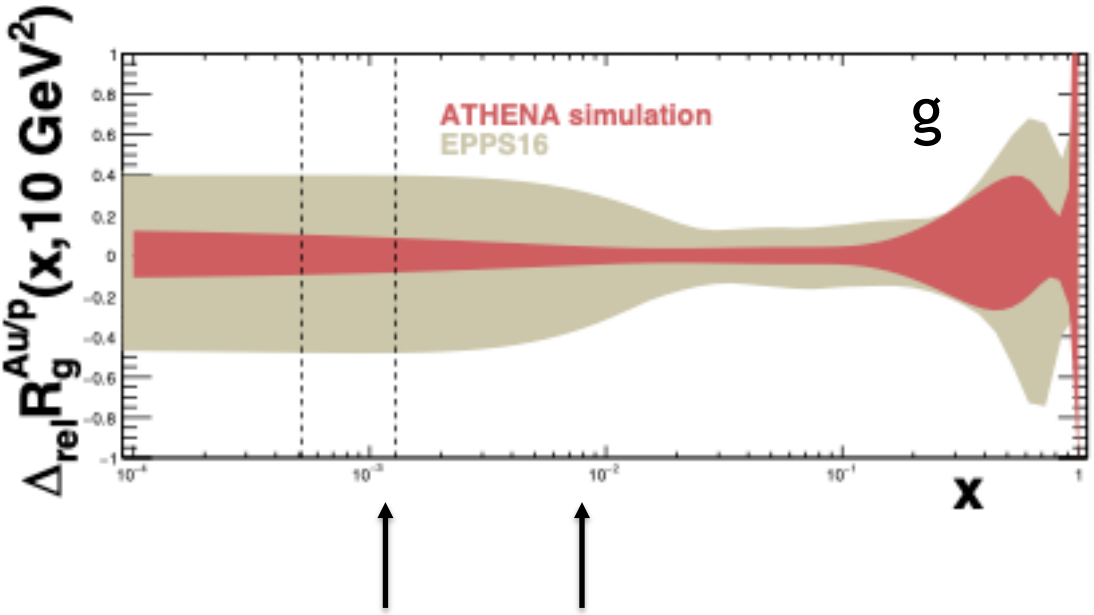
- EIC will bring significant reduction in uncertainties relative to previous DIS-only extractions for all parton species, particularly at large x

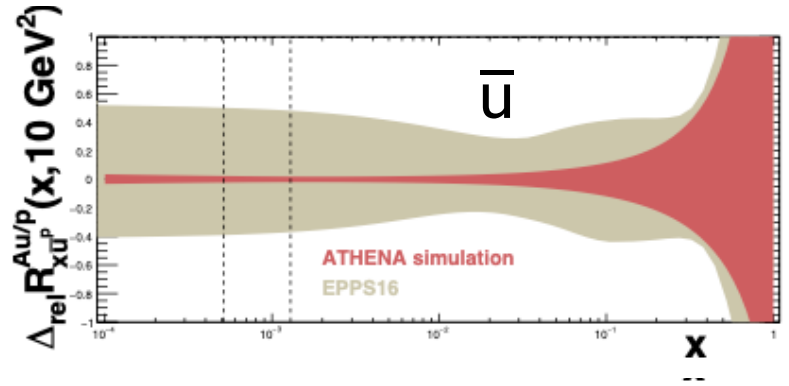


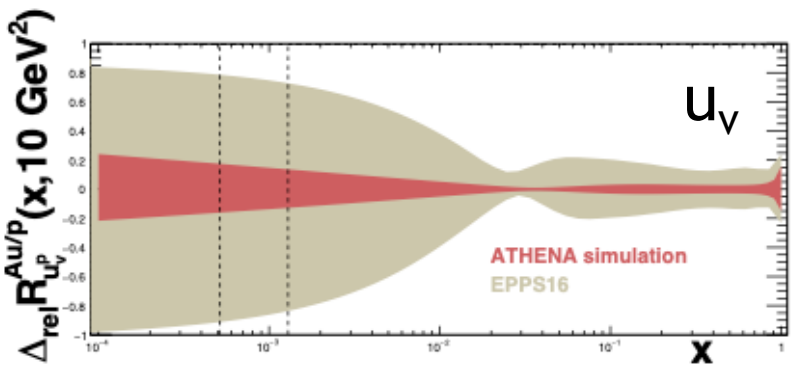


ECCE and ATHENA studies of potential impact 2) Nuclear PDFs

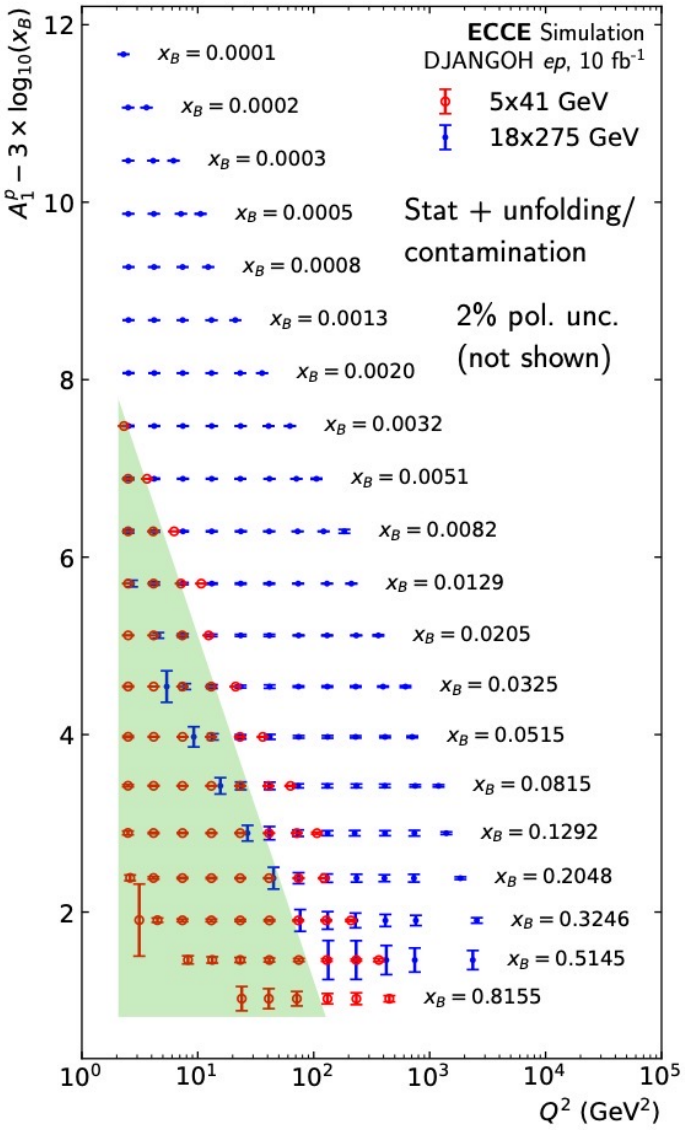
- Projected uncertainty on gluon nuclear modification factor, comparing EIC-only potential with EPPS'16 global fits
  - → Factor ~ 2 improvement at x~0.1
  - → Very substantial improvement in newly accessed low x region





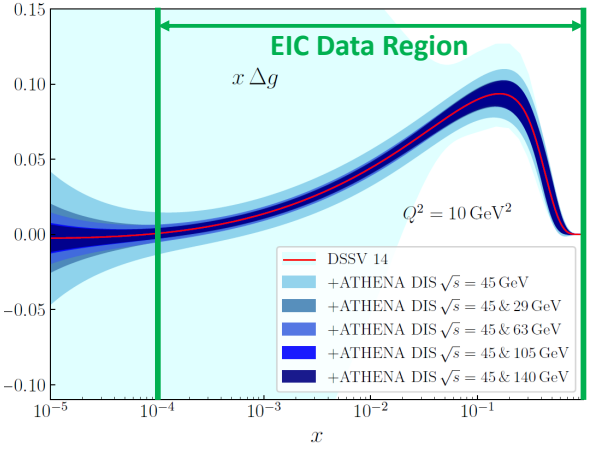


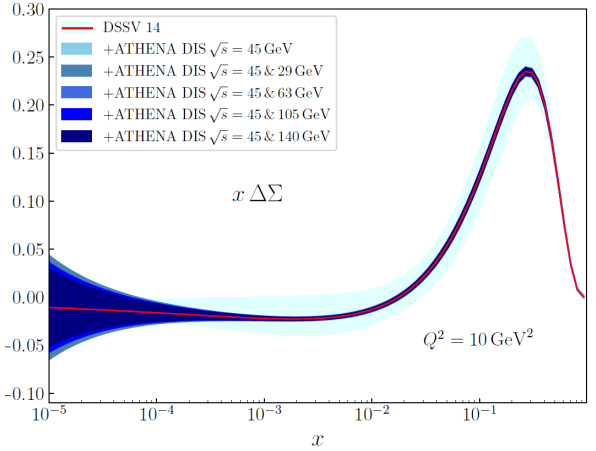
ECCE and ATHENA studies of potential impact 3) Spin structure



- EIC measures virtual photon asymmertry / double spin asymmetry down to x ~ 5 x 10^{-3} for 1 < Q^2 < 100 GeV^2

- Very significant impact on polarised gluon and quark densities using only inclusive polarised ep data





Limitations and Next Steps

Inputs to simulated data used in impact studies so far

- Acceptances - well understood
- Kinematic resolution – fairly well understood, can be improved
- Statistical uncertainties - well modelled and rarely dominant
- Systematic uncertainties – HELP!!!
  - → So far educated guesswork based on past experiments and (crude?) expectations of EIC performance
  - → Some potentially dangerous sources (dominant at HERA):
    - Electron energy scale calibration (intermediate y)
    - Photoproduction background to electron (high y)
    - Hadronic energy scale calibration and / noise (low y)

Next steps with ePIC: Full event-by-event MC simulations of measurements

- Next best thing to real data
  - → Refine expectations of physics impact
  - → Point the way for more detailed work
  - → Refine detector design.

Questions to address

- Calibrating the energy scales of ePIC calorimeters?
- Combining basic detector functionality with kinematic cuts to optimise electron selection purity (especially as $y \rightarrow 1$)
- Optimising scattered electron energy resolution through combined use of tracking and ECAL information
- Combining track and calorimeter information into an overall hadronic final state 'energy flow' reconstruction algorithm
- Developing novel neutral current kinematic reconstruction methods
- Do we have ISR completely under control?
- Dedicated studies of charged current DIS
- Dedicated studies of the $Q^2 \rightarrow 0$ ('photoproduction') regime?
- Developing external collaborations with theory and phenomenology colleagues on Monte Carlo development and fitting /inference

Some Specific Open Tasks

https://wiki.bnl.gov/EPIC/index.php?title=Inclusive#Inclusive_Physics_Analysis

Software development

Tasks listed in this section require making contributions to shared software repositories. These repositories are not ow
below (e.g., "Implement calorimeter clusterization") simply define tasks that are critical to Inclusive Physics. If a task lis
listed below will be completed by people outside of the Inclusive Physics WG, either due to overlapping interests or rec

EICrecon

- **Description:** Implement reconstruction algorithms in EICrecon that are necessary for inclusive physics analyses:
  - Calorimeter clusterization
  - Track and track projection
  - Matching truth/MC information
  - PID detector parameterizations
- **Work Start:** October 2022
- **Expected Duration:** 1-2 months
- **Required Expertise:** Medium/High
- **Contact:** Tyler Kutz (tkutz@mit.edu)
- **Notes:** Official task list for EICrecon is maintained under "Projects" in the GitHub repository
- **Links:**
  - EICrecon on GitHub
  - EICrecon tasks

sidis-eic (name change pending)

- **Description:** Implement algorithms in sidis-eic that are necessary for inclusive physics analyses:
  - Track-cluster matching
  - Kinematic reconstruction
  - Electron identification
- **Work Start:** November 2022
- **Expected Duration:** 1-2 months
- **Required Expertise:** Medium/High
- **Contact:** Tyler Kutz (tkutz@mit.edu)
- **Notes:** Official task list for sidis-eic is maintained under "Issues" in the GitHub repository
- **Links:**
  - sidis-eic on GitHub
  - sidis-eic tasks

Inclusive Physics Analysis

Detector performance benchmarks

- **Description:** Create streamlined analysis flow for generating plots to benchmark detector performance:
  - Electron acceptance
  - Detector resolution
  - Efficiency/purity of electron identification
- **Work Start:** November 2022
- **Expected Duration:** 1-2 months
- **Required Expertise:** Medium/High
- **Contact:** Barak Schmookler (barak.schmookler@stonybrook.edu) & Tyler Kutz (tkutz@mit.edu)

Systematic uncertainties

- **Description:** Perform more rigorous studies of potential systematics in inclusive analyses
- **Work Start:** January 2023
- **Expected Duration:** 6-12 months
- **Required Expertise:** Medium/High
- **Contact:** Paul Newman (paul.newman@cern.ch)

Kinematic Reconstruction Development

- **Description:** Work towards better methods of (x,Q2) reconstruction as appropriate to the EIC:
  - Optimised hadron treatment (particle flow?) in Jacquet-Blondel, Double angle and (e)-Sigma methods
  - Kinematic fitting methods
  - Machione learning methods
- **Work Start:** Anytime
- **Expected Duration:** Open-ended
- **Required Expertise:** Medium
- **Contact:** Paul Newman (paul.newman@cern.ch), Stephen Maple (scm@hep.ph.bham.ac.uk), Barak Schmookle

Inclusive Physics in the Photoproduction Limit

- **Description:** Investigate EPIC capabilities in the Q2->0 limit
  - Understand beam-line detector capabilities and background sources (liaison with far backward group)
  - Investigate, benchmark and optimise Monte simulations
  - Simulate inclusive photoproduction and evaluate achievable precision
- **Work Start:** Anytime
- **Expected Duration:** 6-12 months
- **Required Expertise:** Medium
- **Contact:** Paul Newman (paul.newman@cern.ch) & Claire Gwenlan (claire.gwenlan@physics.ox.ac.uk)

All are welcome!