UNIVERSITY OF BIRMINGHAM | SCHOOL OF PHYSICS AND ASTRONOMY

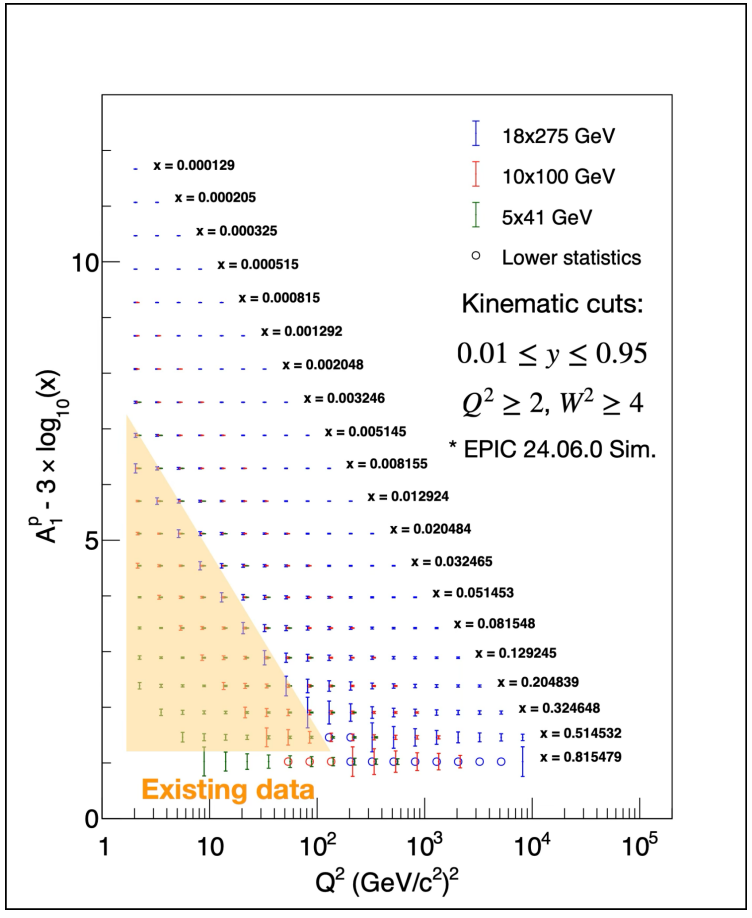
Inclusive PWG Readiness for Early Science

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					

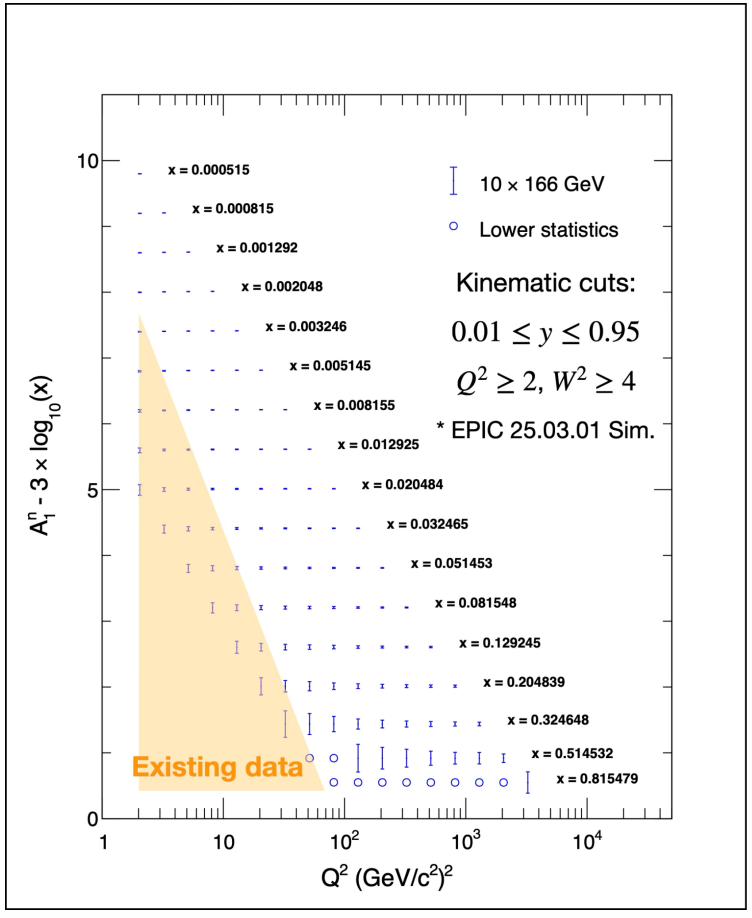
- e-(moderately heavy)A in Year 1 followed by e-d in Year 2
- (Polarised) e-p runs at two c.o.m. energies (Years 2-4)
- e-(heavy)A (gold) Years 4-5
- (Polarised) e-^{3}He Year 5

Double spin asymmetry (proton)

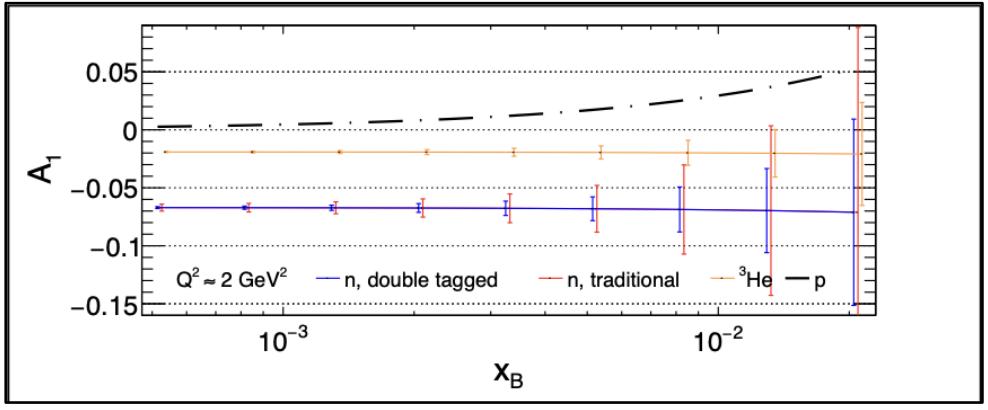


- $A_{||}$ can be measured starting in year 2/3
- $A_{\perp}$ can be measured starting in year 2/3
- Note: plot shows non-early science beam configurations **(to be updated)**
  - e-p 10x130 GeV will cover area similar to 10x100 GeV
  - e-p 10x250 will cover between 10x100 GeV and 18x275 GeV
- Shown are statistical uncertainties for EIC nominal settings. A_1 uncertainty is statistically dominated.

Double spin asymmetry (neutron)

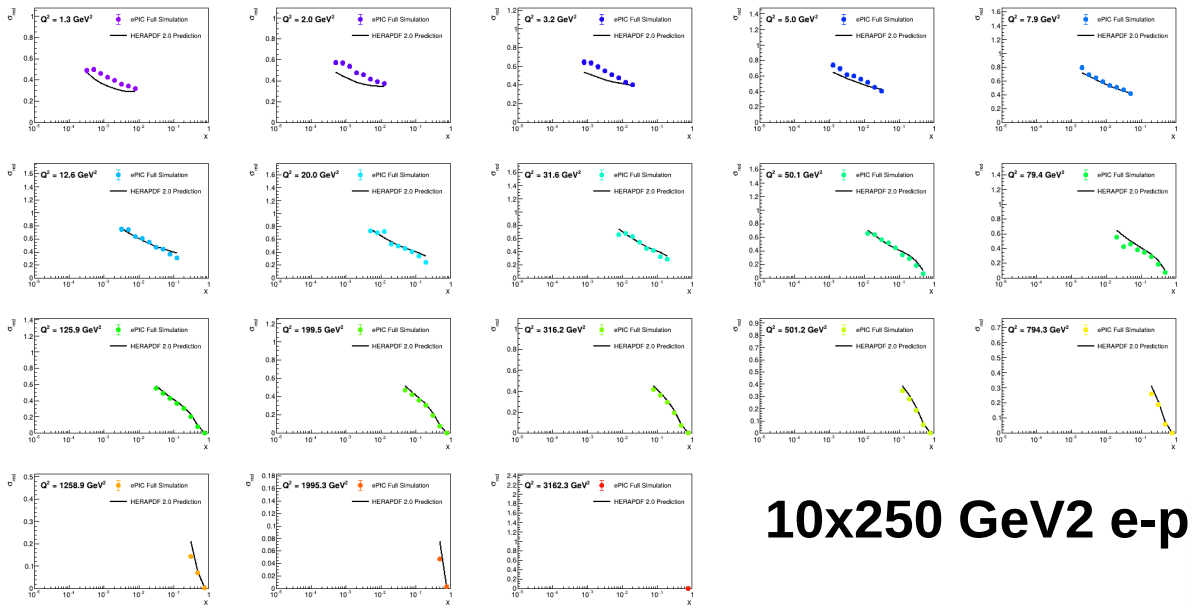


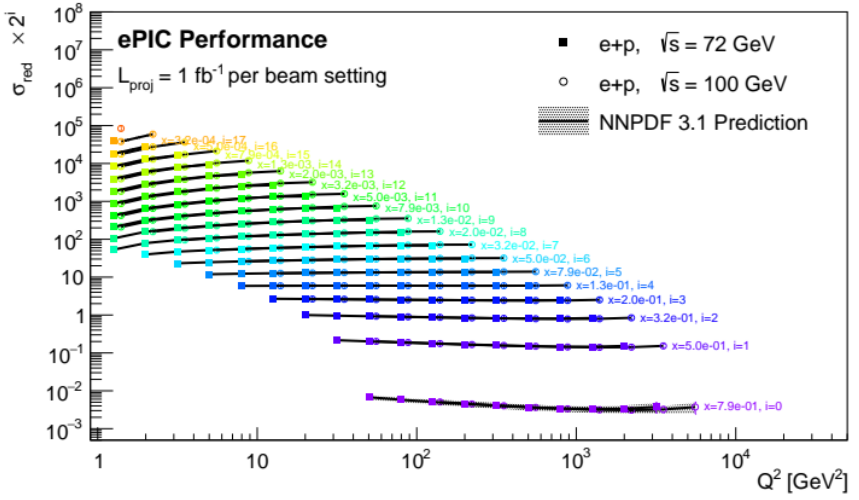
- Can be extracted from $A_1{}^3He$ using inclusive method or directly measured via double spectator tagging



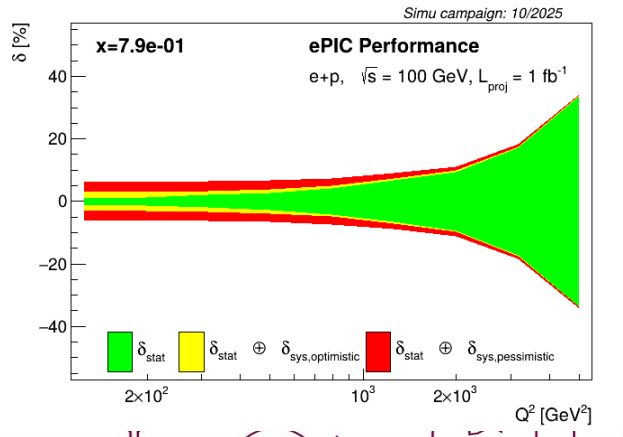
e-p reduced cross sections (hence F_2)

10x130 GeV2 e-p



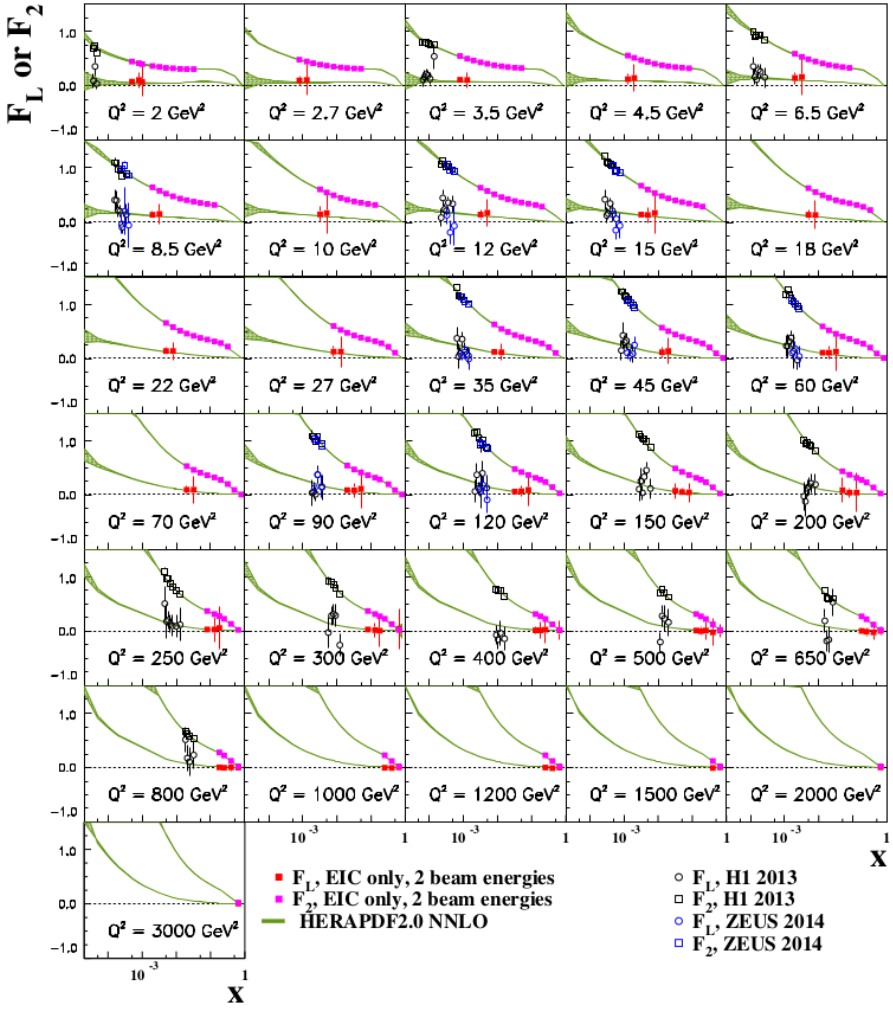


10x250 GeV2 e-p



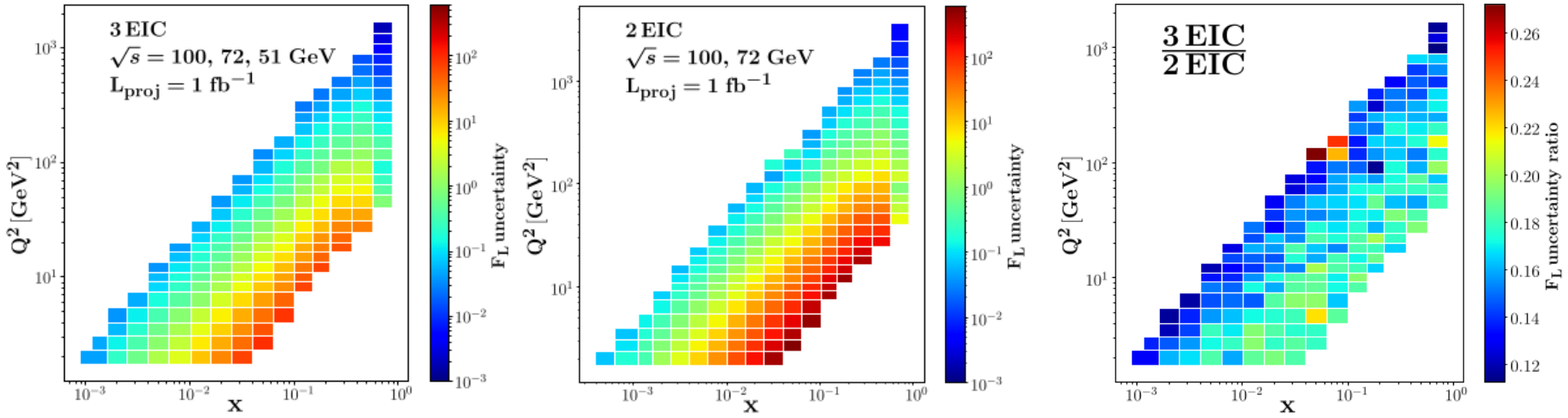
- σ_{red} can measured for any beam config - if F_L taken from theory prediction, F_2 can be extracted in each beam config (model-dependent)
- **Above**: ePIC full sim (pythia6 events) compared to pdf prediction
  - Statistical uncertainties (9.18 fb-1) on plot - but very small (up to a few percent at highest x and Q^2)

(Model-independent) proton structure functions



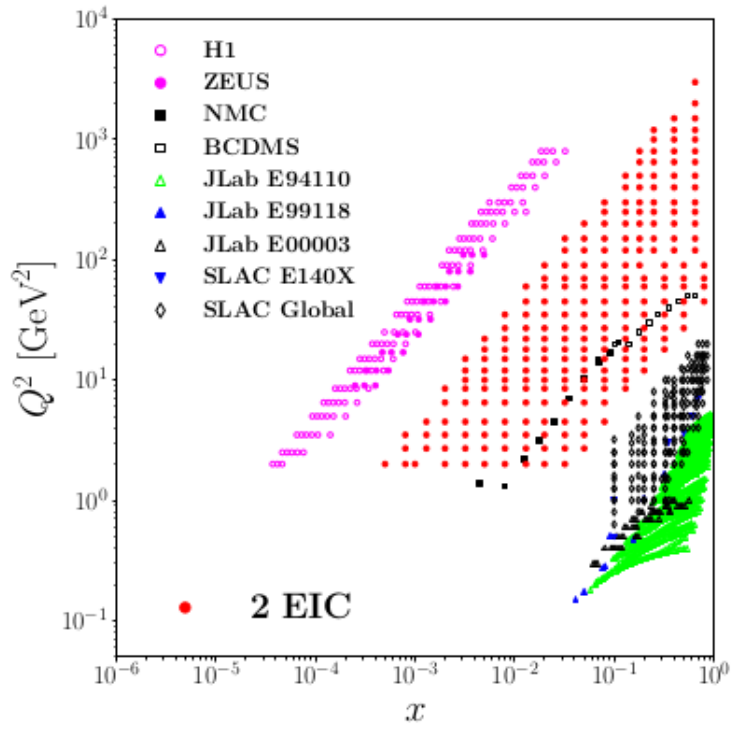
- For 2 (ideally 3+) beam energy configurations, F_L and F_2 can be simultaneously extracted (model independent) in overlap region
- Plot shows possible points and errors, compared to HERAPDF 2.0 and HERA data
  - Assume 10x130 and 10x250 GeV^2 e-p configs and stat errors from 1 fb-1 per config
  - Conservatively assume 1.9% point-to-point uncorrelated uncertainty and 3.4% normalisation fully correlated between configs
  - Only points with $\delta FL<0.5$ are plotted - F_L point available for each F_2 point, but large errors

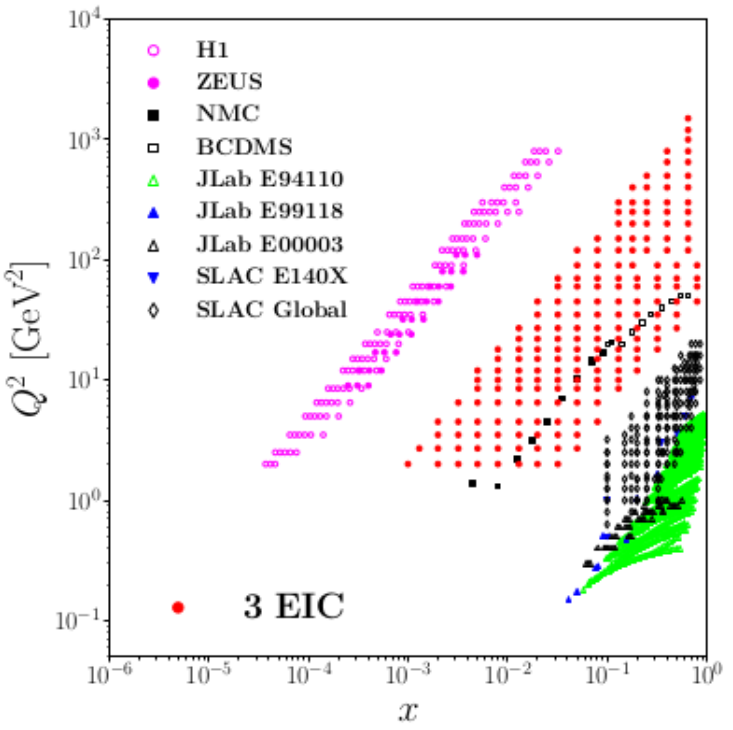
Uncertainty on F_L



- Require 2 or more σred measurements to extract FL
- Systematics dominate σred precision - only need ~1fb^{-1} per beam config!
- **Adding a third, lower, beam energy config (5x130 GeV^2) offers a factor of ~5 improvement in uncertainty**

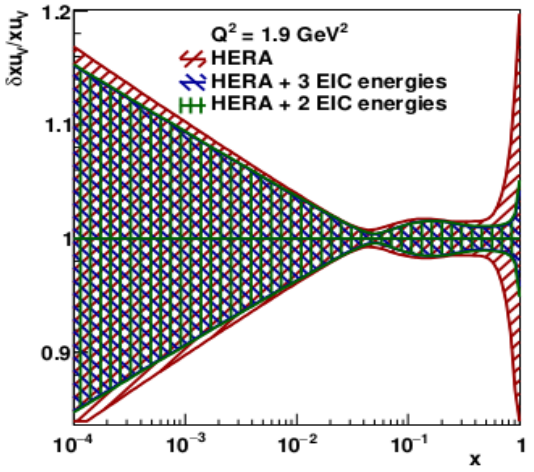
Phase space for F_L (and model-independent F_2)

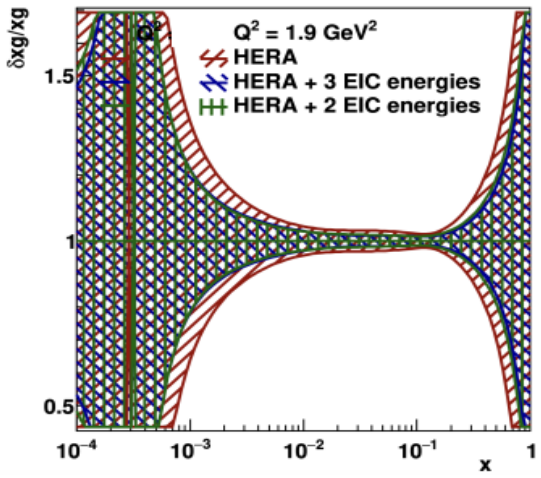


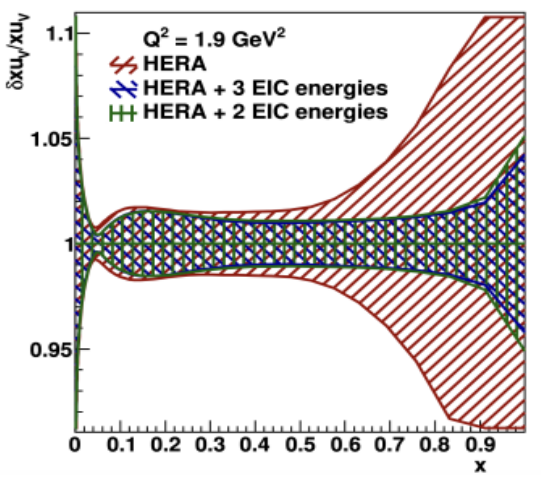


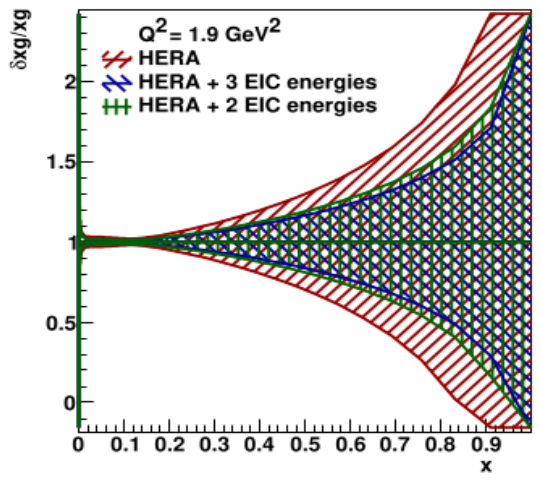
- Early Science EIC bridges gap between fixed target and HERA
- Note that right-hand plot has smaller phase space as a requirement of 3 overlapping σ_{red} measurements is chosen in this case

Impact on proton PDFs (HERAPDF 2.0)

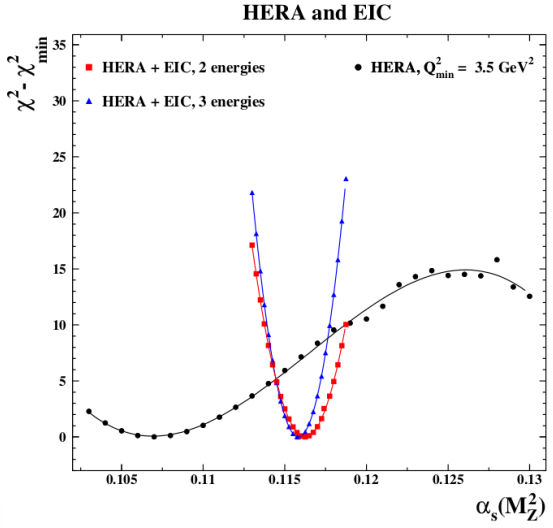








- Potentially large improvement in up-valence and gluon PDFs at large x with 2+ e-p beam configs in early science
  - Moderate improvement at low x
  - Only small difference for 2 vs 3 e-p configs, and only at large x
- Could constrain $\alpha_s(M_Z^2)$ to ~ 0.7%



Early Science – what we have so far

	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
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Note: the eA luminosity is per nucleon					

- e-p cross sections, F_2, (F_L?)
- Impact on proton PDFs, α_s
- A_1^p, g_1^p
- $A_1{}^3He$, A_1^n, g_1^n

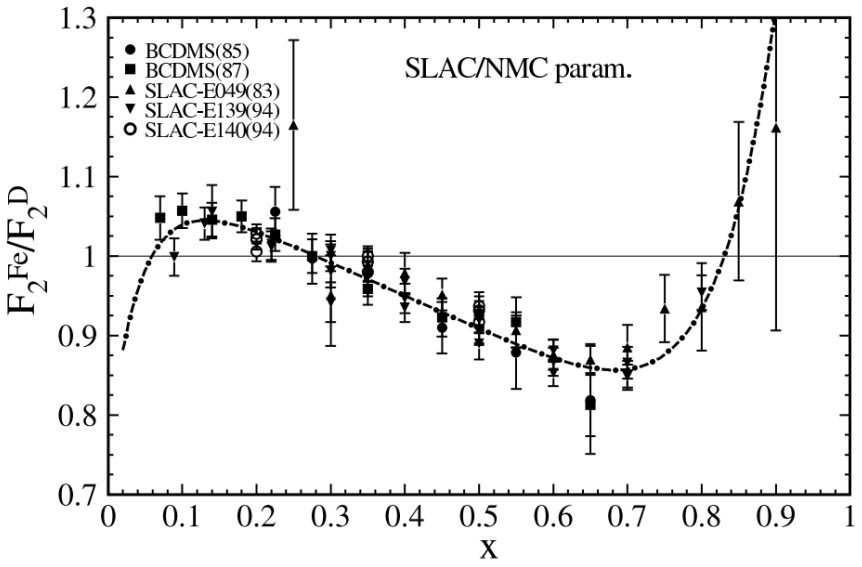
We some interesting projections to include for e-p and e-^{3}He runs so the goals should be:

→ Get something together for e-(heavy)A

→ Improve upon existing results though e.g. more detailed systematics studies, eID development etc.

What can we do in time?

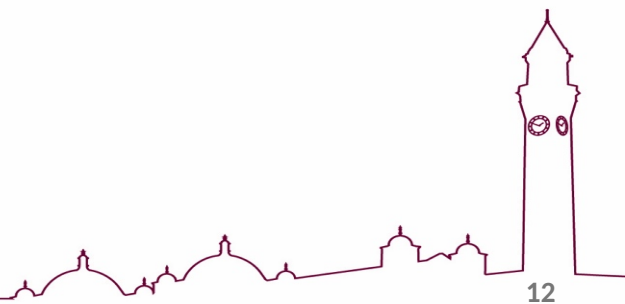
- Time scale is short – will need to prioritise
  - Important to get **something** for eRu/eCu or eAu produced
  - To me, a cross section/structure function ratio plot would be ideal
  - Also need to make sure that are systematics estimates are as well justified as we can make them in this time
  - Several studies are possible



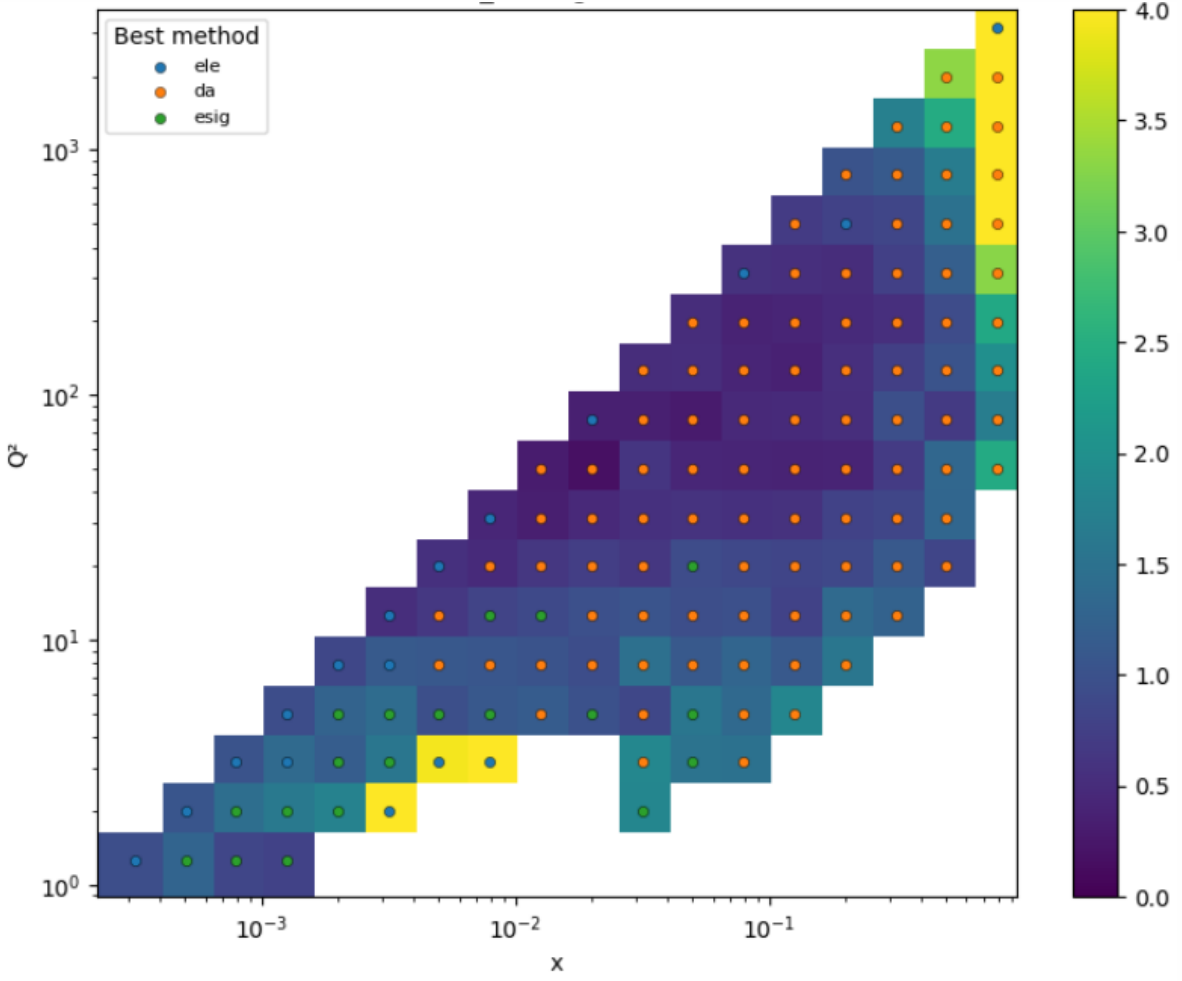
Systematic uncertainty	Achieved at H1/ZEUS*	Expected at EIC†	Possible studies
Electron finder efficiency	0.2-5% (increase w y)	???	Tighten and relax cuts used in e-finding → study variation in efficiency
Electron energy scale	0.5-1.9% (increase w y) (1-5% on σ)	???	Take a guess – using 0.5% for now?
Electron polar angle	1mrad	???	Take a guess – use track angle reso for now?
Hadronic energy scale	2% (0.5-4% on σ)	???	Take a guess – using 1% for now?
Photoproduction background	10% (0.5-3% on σ)	2% on σ	Compare number of events produced by different generators that are reconstructed as DIS
QED radiative corrections	0.3-2% (increase w x,y)	1%	Compare size of radiative correction in bins with different event generators/generator settings
Luminosity	1.5%	1%	Use ~~1%~~ 1.5%?
Polarisation	N/A	<1% ?	Use ~~1%~~ 1.5%?

Thoughts?

Backup



Early systematics studies (Only 3 sources)



- Total uncertainty taken from sum in quadrature of statistical uncertainty ($1fb^{-1}$) and the average uncertainty from each systematic (0.5*(|+ve| + |-ve|))
- Plot the total uncertainty from the method that gives the best value
  - Require purity & stability > 30%
- Important: only considering 3 sources here, of which only 1 impacts the DA method → this spread will change with inclusion of more systematics

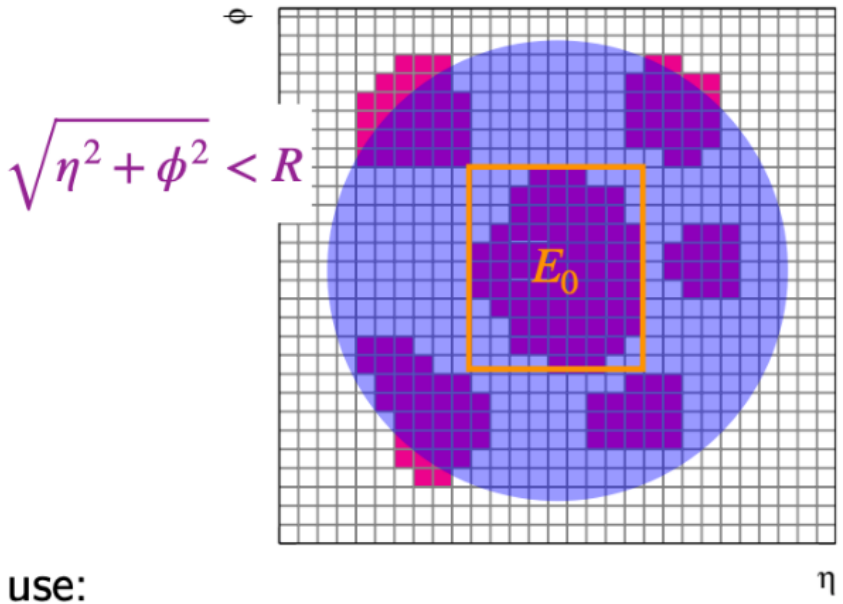
Electron Finding

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

- Loop over all reconstructed particles, and apply cuts on:
  - Require negative tracks
  - $0.9 < E/p < 1.2$
  - Isolated cluster

    $R = 0.4$

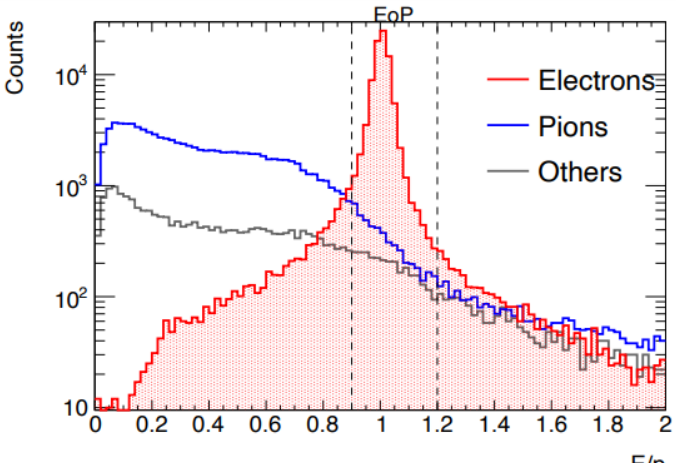
    $E_0 / \Sigma E_R < 0.9$

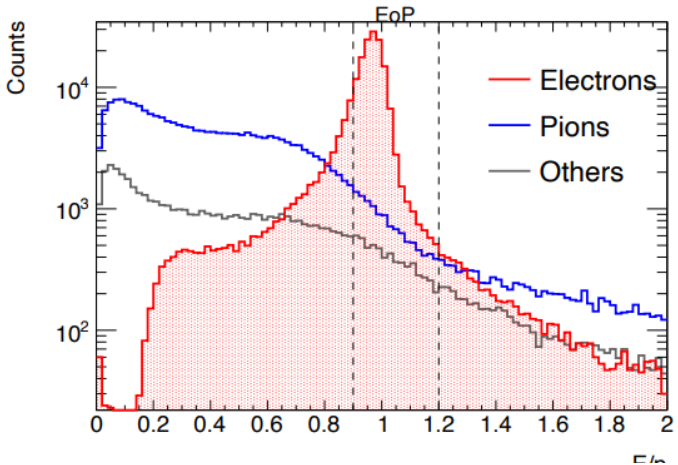


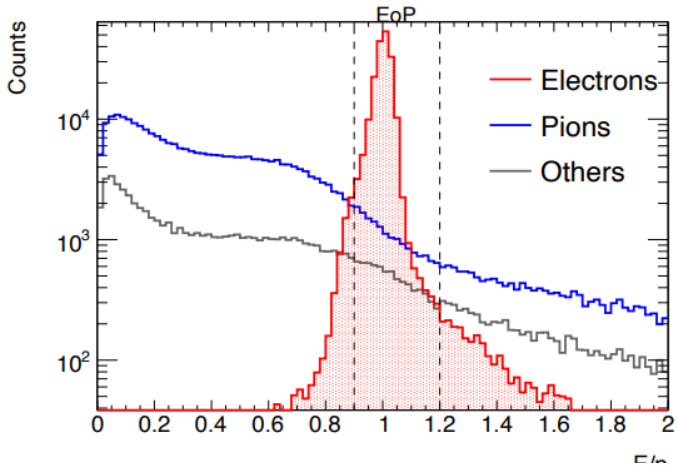
- If > 1 particles in collection, can use:
  `edm4eic::ReconstructedParticle SelectHighestPT(edm4eic::ReconstructedParticleCollection)`

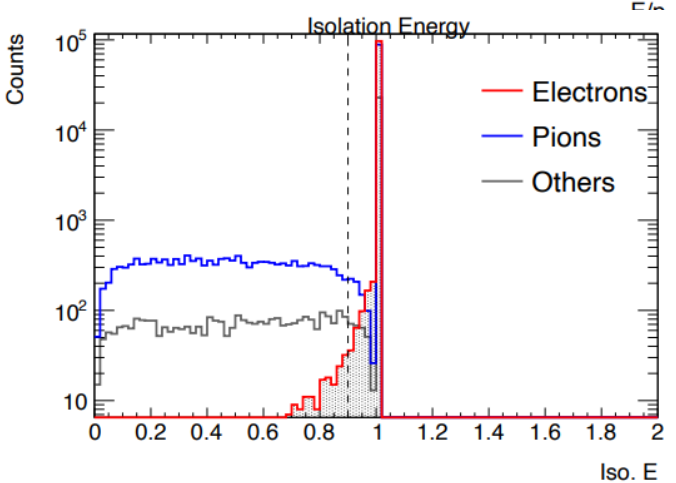
Slide from T. Kutz

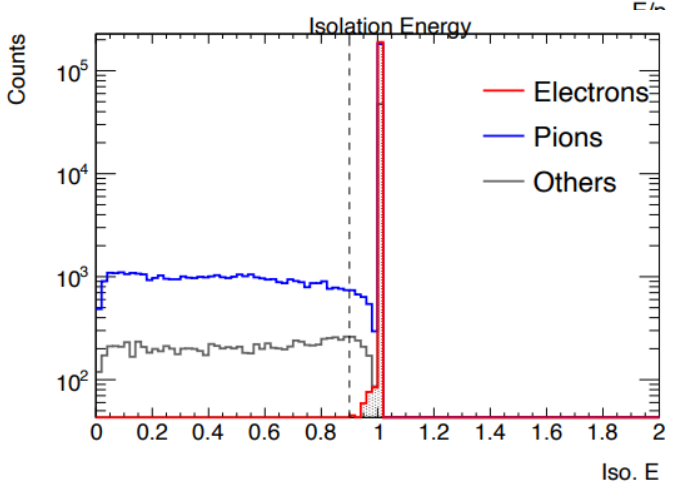
Electron Finding

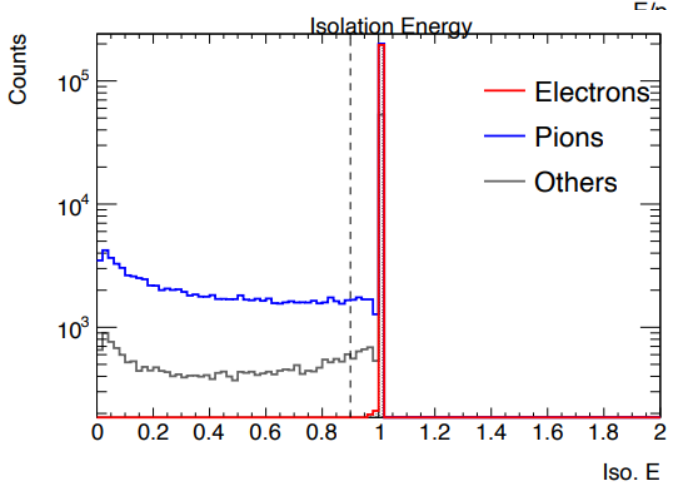






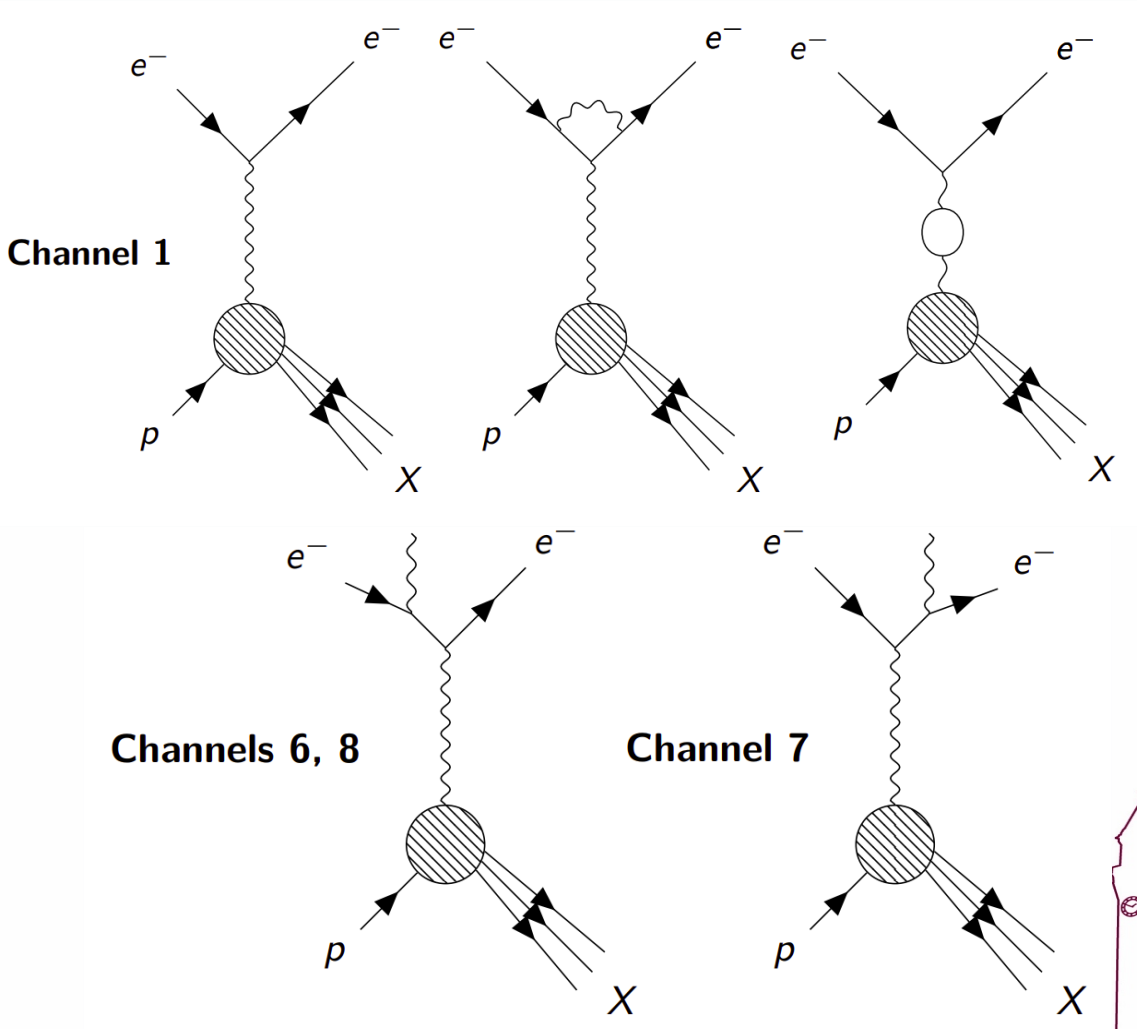






QED Radiative Effects

- Djangoh 4.6.21 used to generate 18x275 GeV^2 e-p events
  - ISR/FSR=ON and OFF
  - Q^2>1,10,100,1000
  - W>3GeV
- Channel 1: Non Radiative NC
- Channel 6: ISR
- Channel 7: FSR
- Channel 8: “Compton event”



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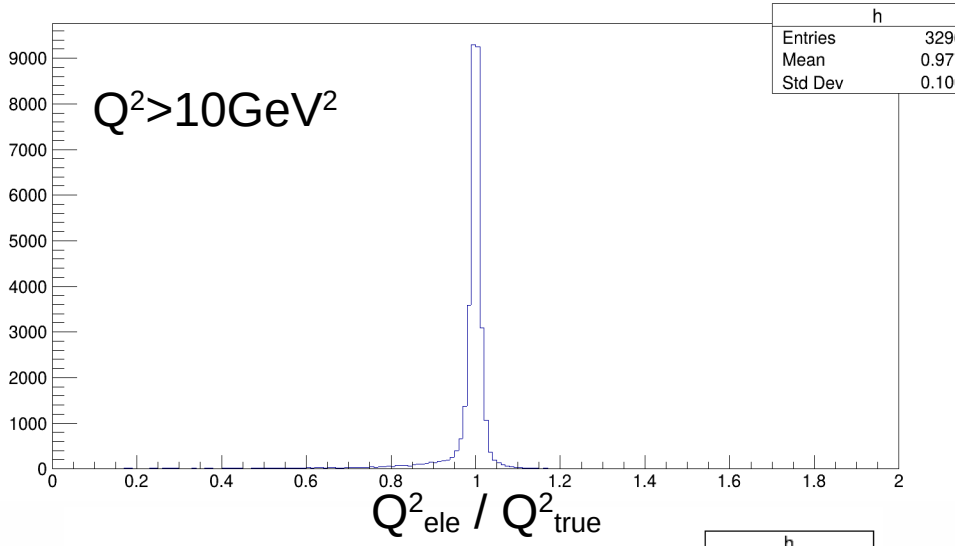

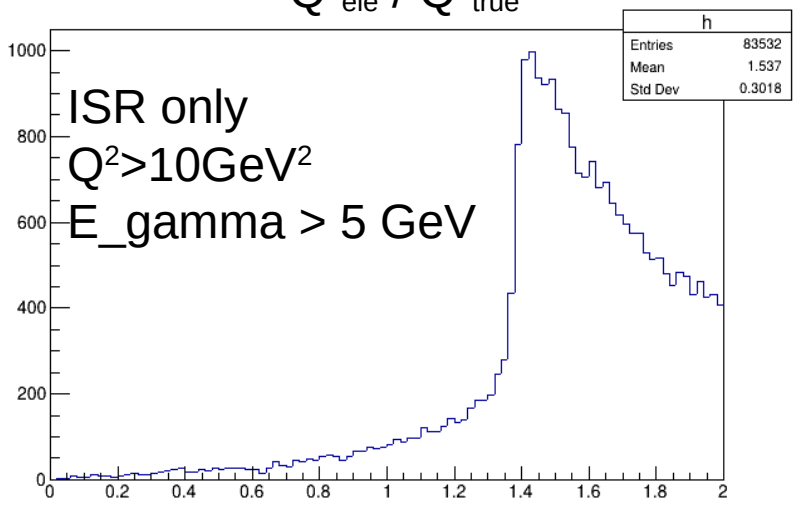

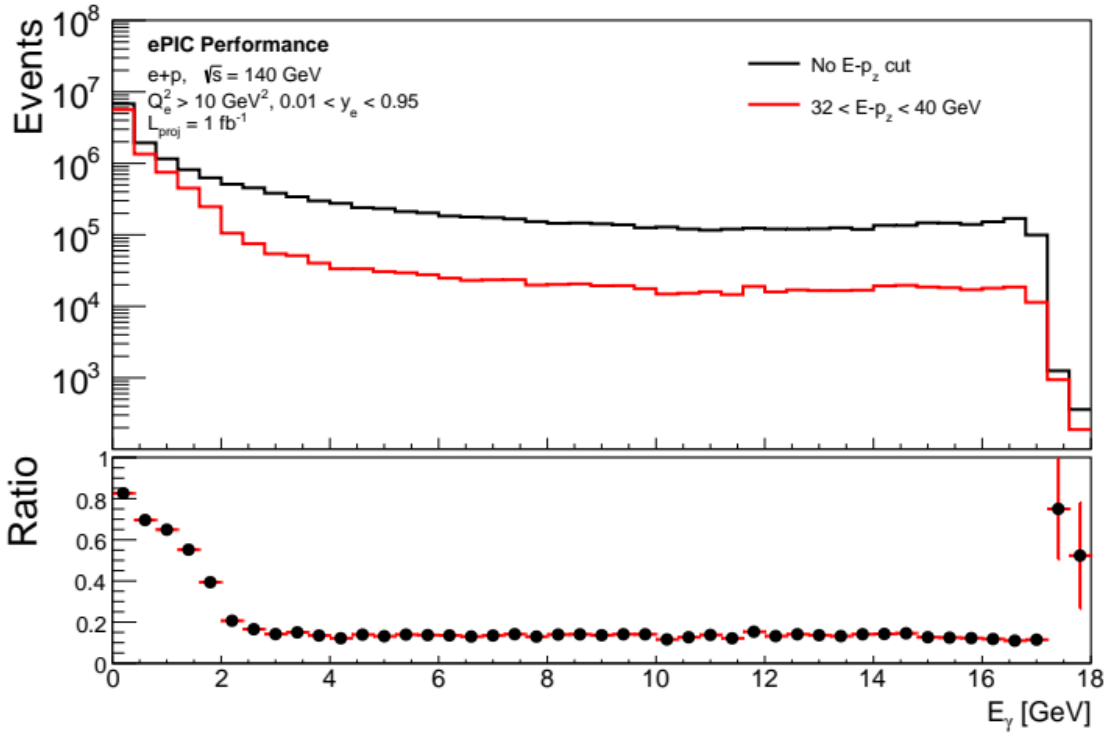

- High energy ISR throws off kinematic reconstruction
  - Can suppress through E-p_z cut