Inclusive Processes WG Summary

Pavia YR Meeting

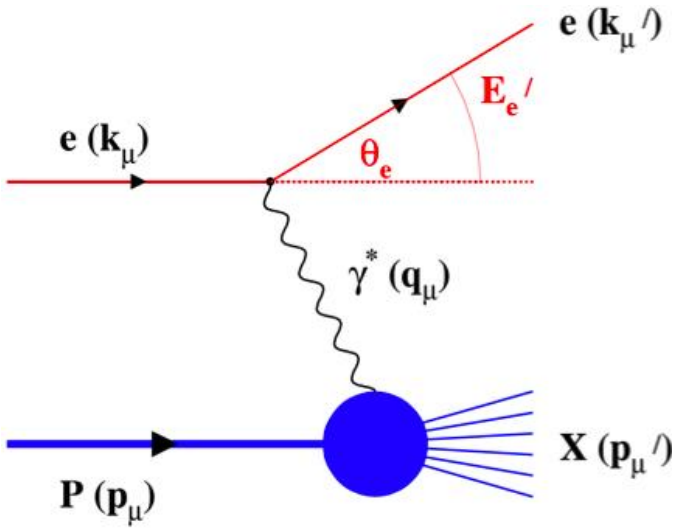
Barak Schmookler, Nobuo Sato, Renee Fatemi

Inclusive Physics of Interest

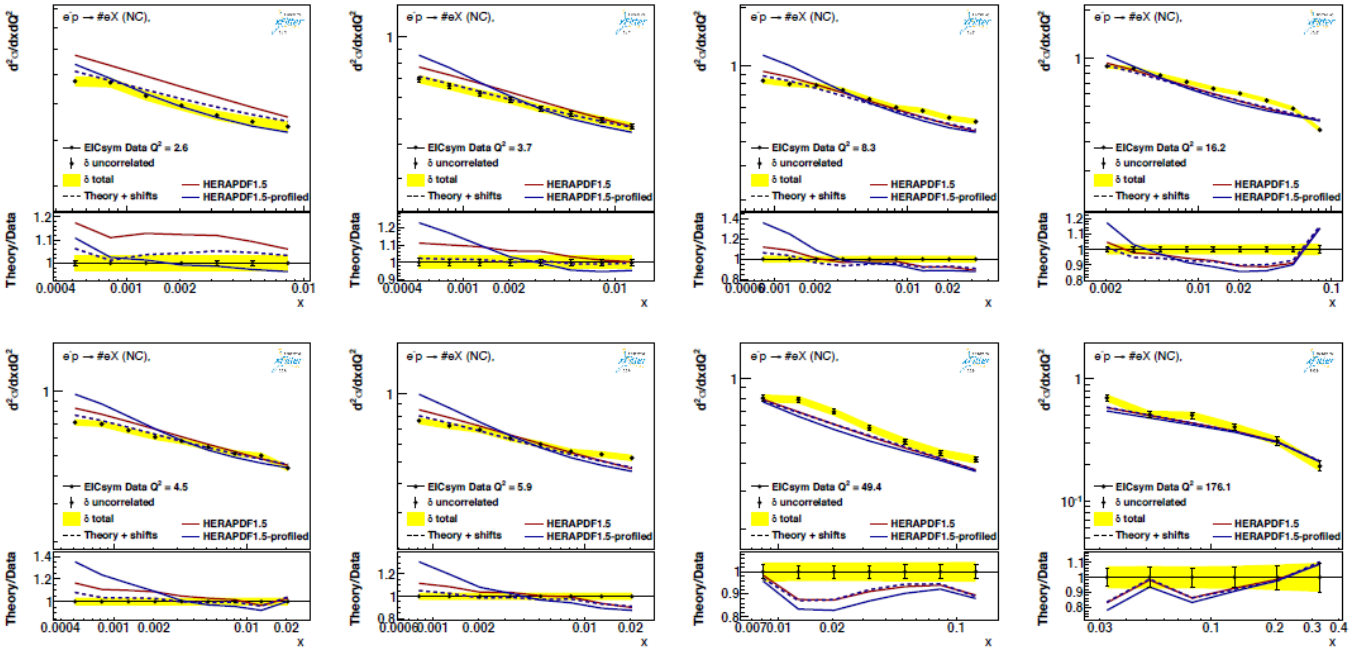
Measurement	Main Detector Requirements	Anticipated Plot	Physics Topic/goal	Responsible persons
inclusive $A_{\|\|}$ / $A_{\perp}$ for proton, deuterium, ^{3}He	Standard inclusive	$A_{\|\|}(x,y,Q^2)$,$A_{\perp}$ $g_1(x)$, $g_{2/T}(x)$ vs Q^2 $\Delta g(Q^2)$ vs x	Gluon & Quark Helicity $\Delta g(x,Q^2)$, Δu^+, Δd^+	Matt Posik Barak Schmookler
inclusive A_{PV}	Standard inclusive	A_{PV} vs x for $W^{+/-}$ $g^W{}_5(x)$ vs Q^2 $\Delta s^+(Q^2)$, $s^+(Q^2)$ vs x	Strange Pol and Unpolarized $\Delta s^+(x,Q^2)$, $s^+(x,Q^2)$	Hanjie Liu
$\boldsymbol{\sigma}_{red}(x,Q^2)$, $\boldsymbol{\sigma}^{c/b}{}_{red}(x,Q^2)$ → F_2, F_L, $F_2^{c/b}$	Standard inclusive + heavy quark tag	$\boldsymbol{\sigma}_{red}(x,y)$ vs Q^2 $\boldsymbol{\sigma}^{c/b}{}_{red}(x,y)$ vs Q^2 $g(Q^2)$ vs x	Proton PDFs $q(x,Q^2)$, $g(x, Q^2)$	Xiaoxuan Chu Matt Posik
$\boldsymbol{\sigma}_{red}(x,Q^2)$, $\boldsymbol{\sigma}^{c/b}{}_{red}(x,Q^2)$ → F_2, F_L, $F_2^{c/b}$	Standard inclusive + heavy quark tag	$\boldsymbol{\sigma}_{red}(x,y)$ vs Q^2 $\boldsymbol{\sigma}^{c/b}{}_{red}(x,y)$ vs Q^2 $F_L(Q^2)$ vs x $F^{c/b}{}_L(Q^2)$ vs x	Nuclear PDFs $q(x,Q^2)$, $g(x, Q^2)$	
$\boldsymbol{\sigma}_{red}(x,Q^2)$, $\boldsymbol{\sigma}^{c/b}{}_{red}(x,Q^2)$ → F_2, F_L, $F_2^{c/b}$	Standard inclusive + heavy quark tag	$\boldsymbol{\sigma}_{red}(x)$ vs Q^2 $\boldsymbol{\sigma}^{c/b}{}_{red}(x)$ vs Q^2 $\Delta F_L/F_L$ vs x, Q^2	Non-linear QCD dynamics	
EW inclusive A_{PV}	Standard inclusive	$A_{PV}(y)$ vs Q^2 $\sin^2\boldsymbol{\theta}_w$ vs Q^2	BSM & Precision EW ($\sin^2\boldsymbol{\theta}_w$)	
$\frac{d\sigma^{NC}}{dxdyd\phi}$ Triply differential NC X-sec	Standard inclusive	Updated Fig.6 in ***PhysRevD.98.115018*** for CM energies smearing.	Lorentz and CPT Violating Effects	Lunghi and Sherrill

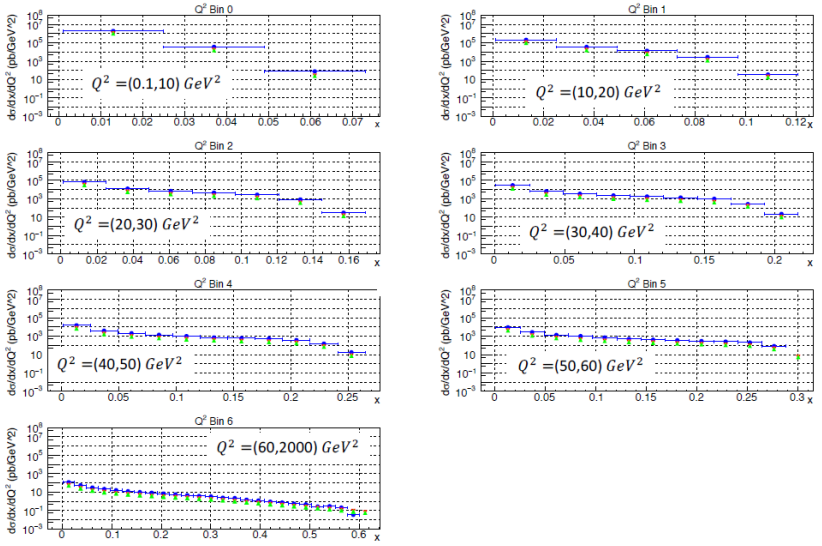
Neutral Current Cross Sections

Talks by Xiaoxuan Chu and Matt Posik



ep NC events with DJANGOH for 18 GeV x 275 GeV





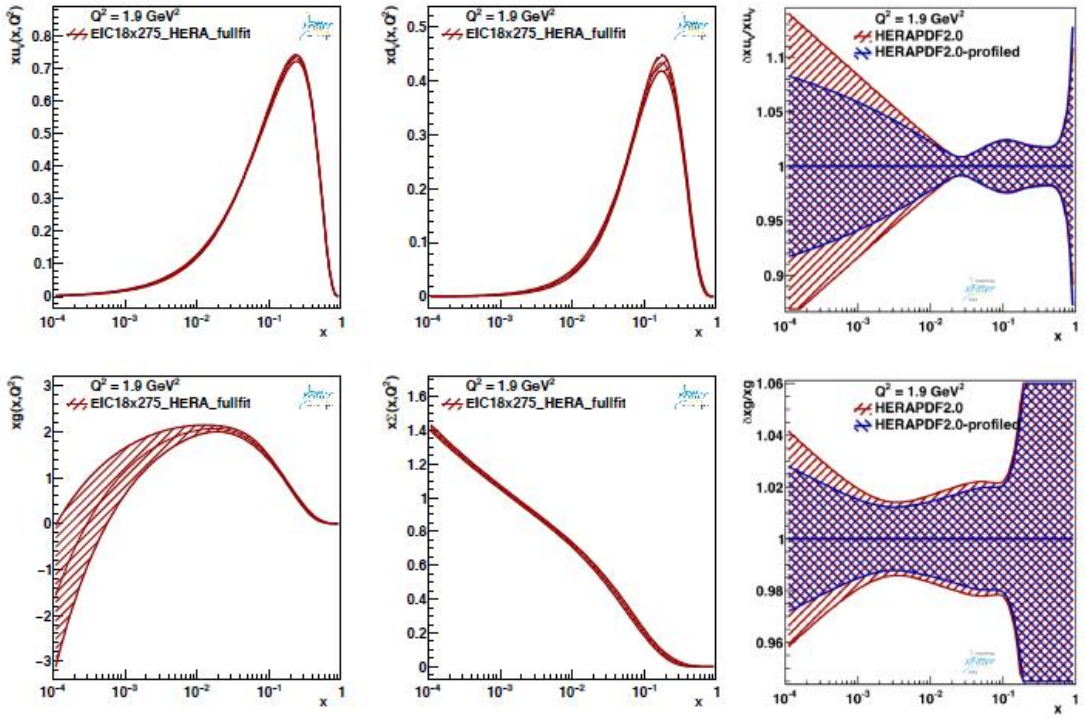
DJANGHO (w/o rad)

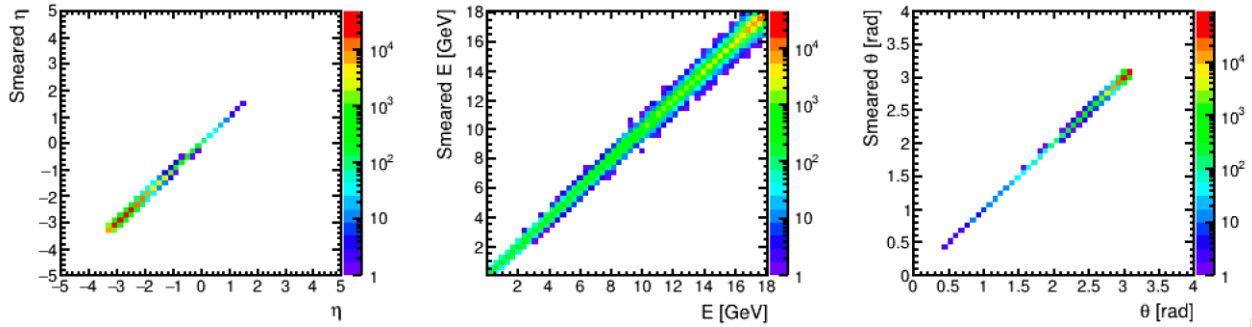
JAMEIC

NNPDF

Neutral Current Cross Sections – Smearing and Impact

Talks by Xiaoxuan Chu and Matt Posik



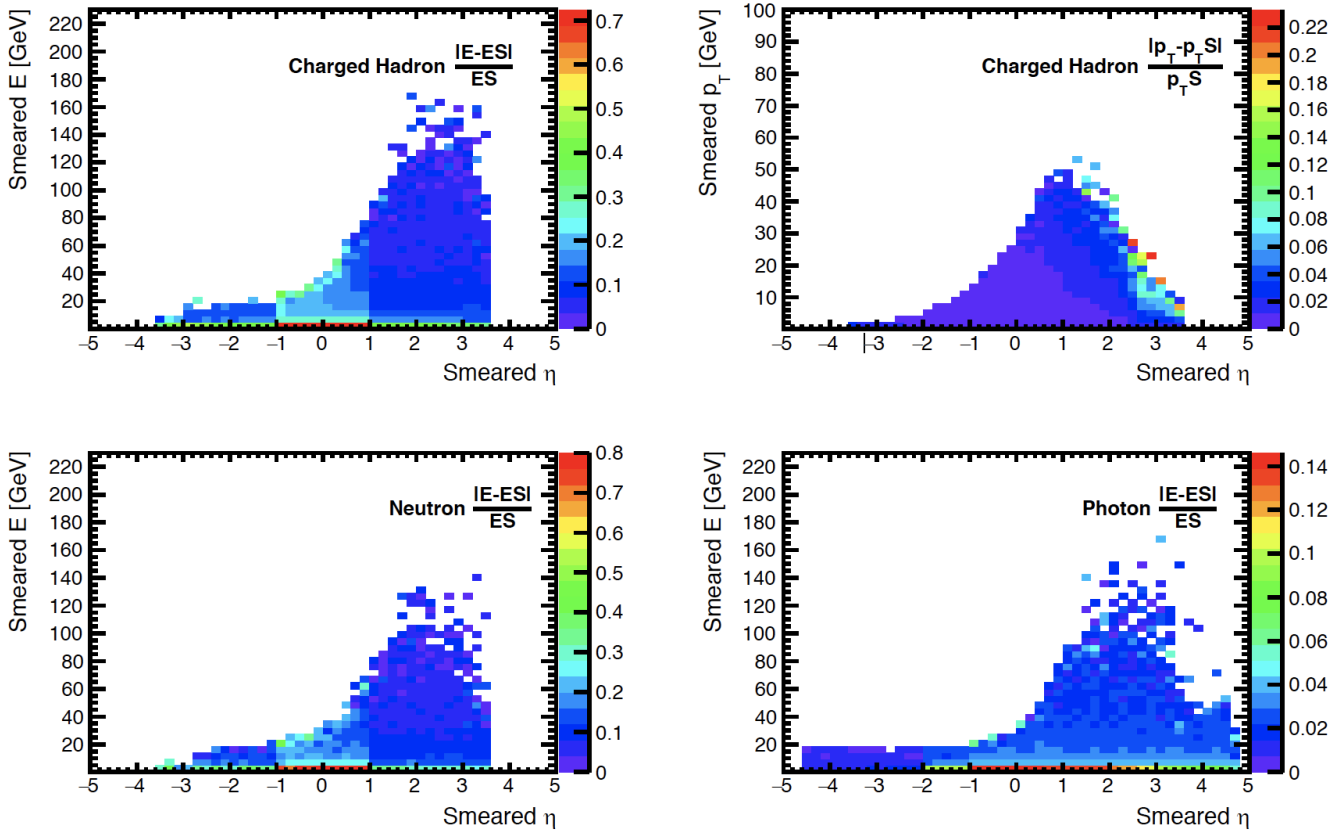


- EIC pseudo-data has been compared to theory cross sections.
- EIC data at vertex level can constrain PDFs
- An eic-smear study is ongoing starting with the standard handbook detector
- Studies are being conducted of the phase space where reconstruction of the kinematic variables using the scattered electron is feasible. Future studies of kinematic reconstruction using hadronic methods at low y will be performed.

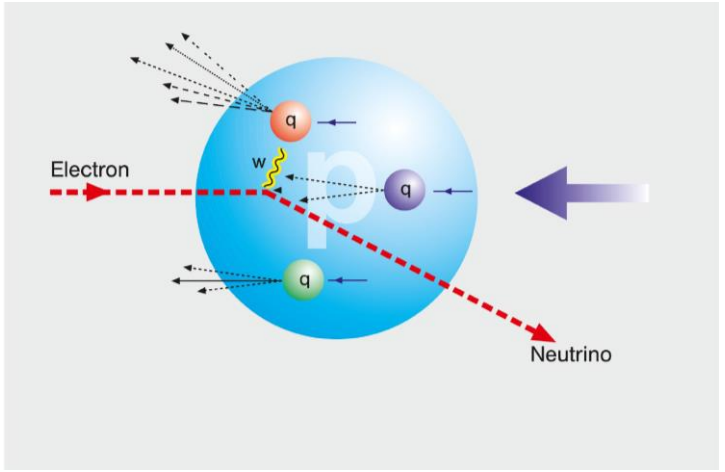
Charged Current Cross Sections

Resolution map

Talk by Xiaoxuan Chu



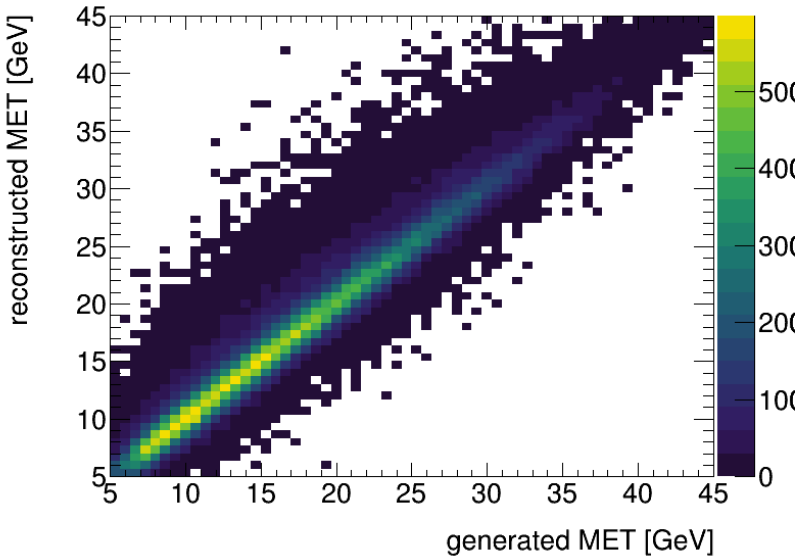
$$x_{JB} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y_{JB} = \frac{(E - p_z)_h}{2E_e}; \quad Q^2_{JB} = \frac{p^2_{t,h}}{1 - y_{JB}}$$



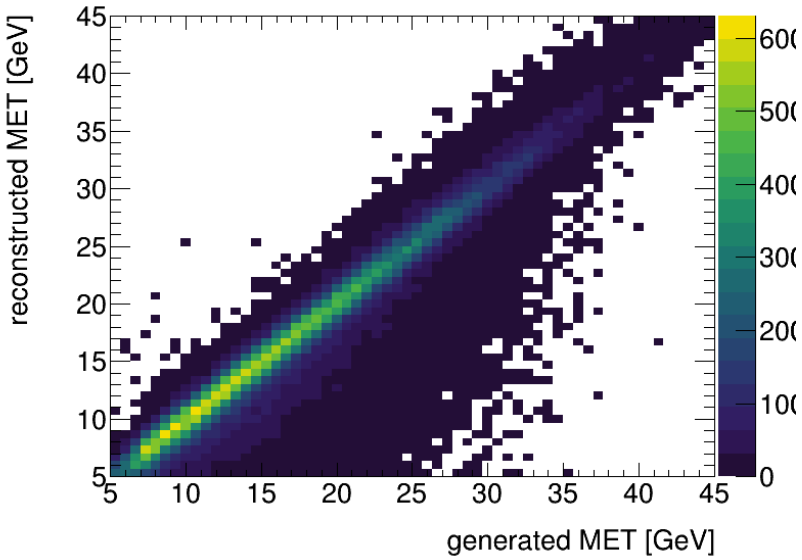
- Acceptance studies show it is critical to include photon energy as well as charged hadron energy
- Kinematic reconstruction not highly dependent on threshold in calorimeters
- Reconstruction of kinematic variables highly dependent on detector resolutions. Kinematic resolution decreases with energy/p_T and at mid-rapidity.
- Conclusion : Need full Ecal+Hcal coverage

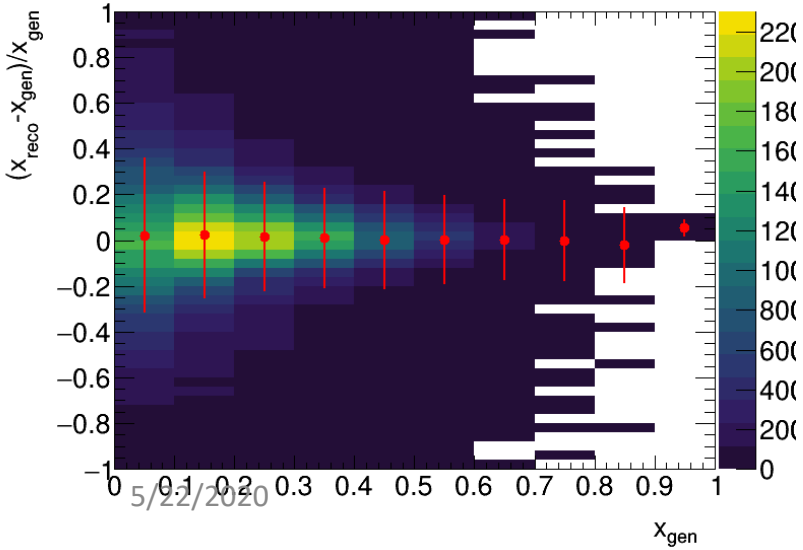
CC via Missing Transverse Energy (MET)

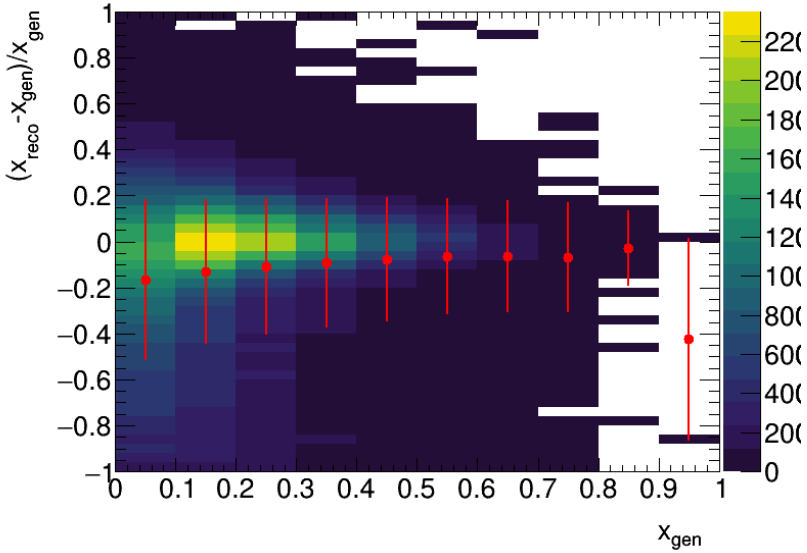
HCAL

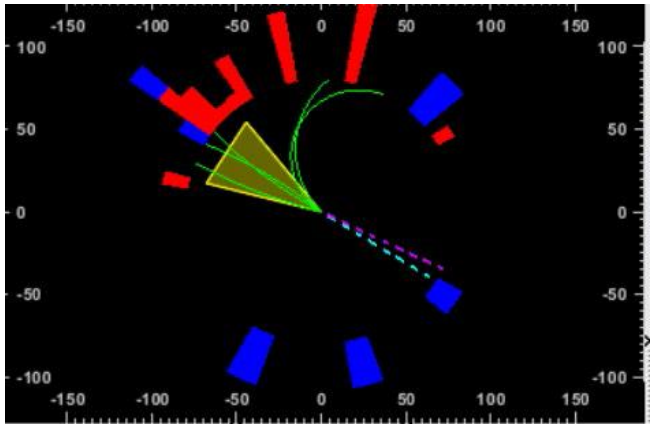


No HCAL









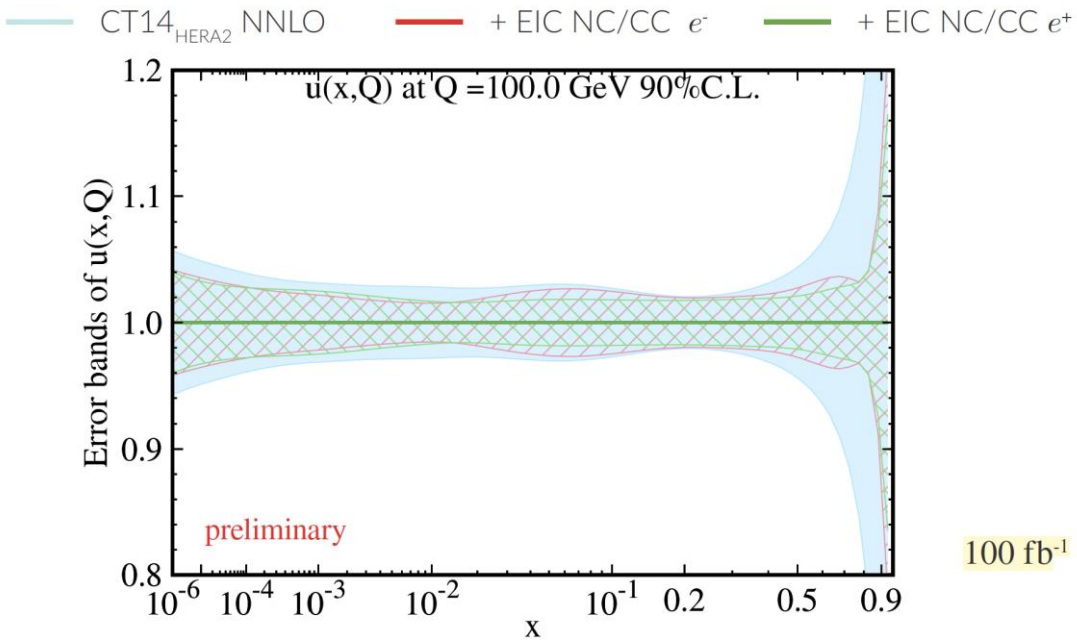
Talk by Miguel Arratia

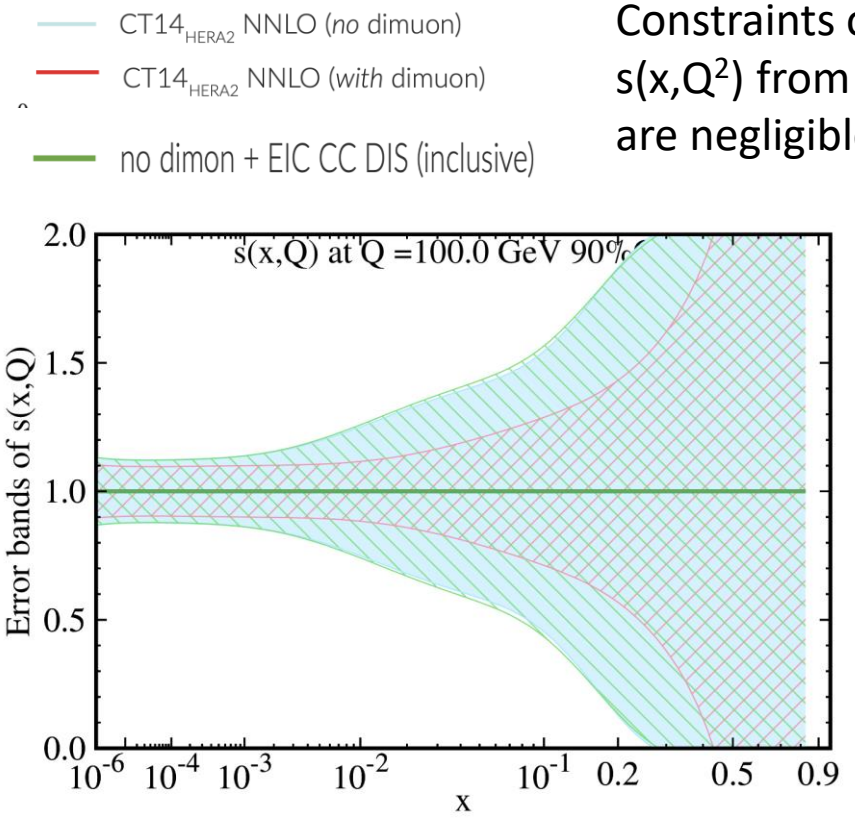
- Proposal to treat MET as a “physics object”
- Full HCAL coverage required
- Resolution budget dominated by long-lived neutral hadrons
- Challenge is to push MET measurement to low Q^2

Constraints of CC on PDFs

Talk by Tim Hobbs

Fits of EIC pseudo-data show significant high x constraints on u from e- NC+CC data

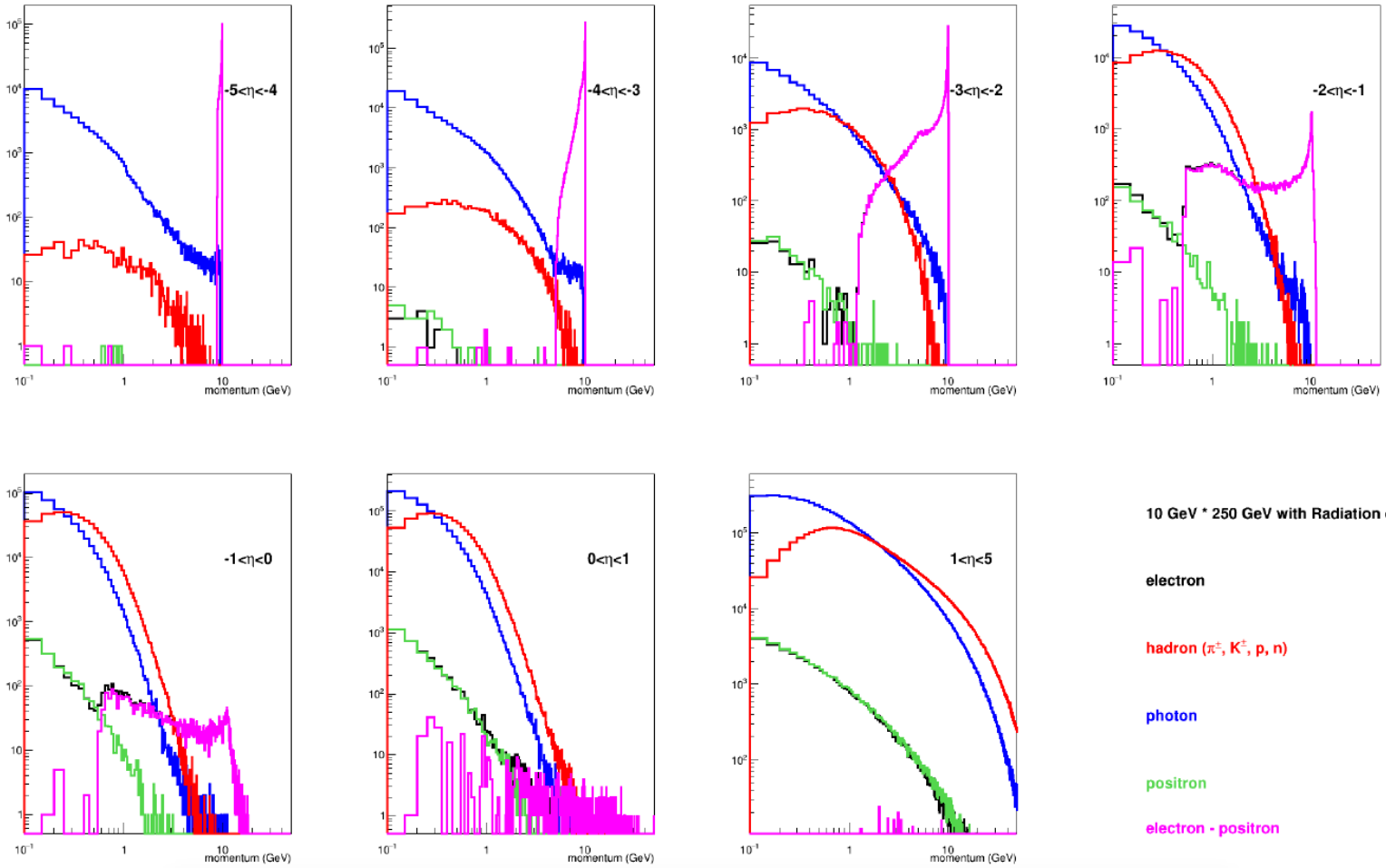


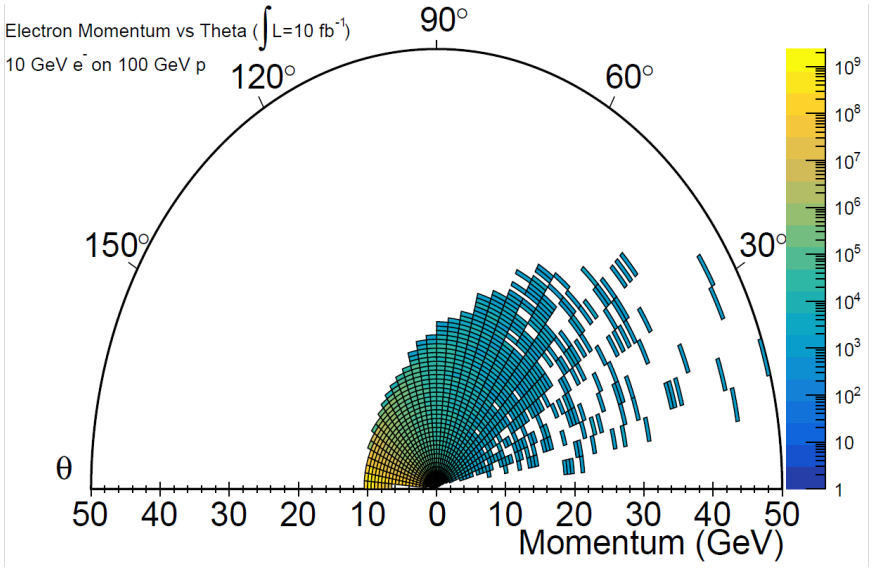


Constraints on $s(x,Q^2)$ from CC are negligible

Electron Identification

Talk by Hanjie Liu





- DJANGOH and PYTHIA event generators allow us to see distribution of scattered electron and other particles as a function of angle and momentum
- High electron reconstruction efficiencies are required in the regions dictated by the electron hit maps
- Hadron suppression factors needed to have high purity for the scattered electron are currently being determined as a function of angle and momentum

Electroweak Physics at the EIC

Talk by Ciprian Gal

With parity violation and $Q^2 << Z^2$

Inclusive electron measurements

pol. electron & unpol. nucleon:

$$A_{beam} = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha}\left[g_A^e \frac{F_1^{\gamma Z}}{F_1^{\gamma}} + g_V^e \frac{Y_-}{2Y_+}\frac{F_3^{\gamma Z}}{F_1^{\gamma}}\right]$$

unpol. electron & pol. nucleon:

$$A_L = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha}\left[g_V^e \frac{g_5^{\gamma Z}}{F_1^{\gamma}} + g_A^e \frac{Y_-}{Y_+}\frac{g_1^{\gamma Z}}{F_1^{\gamma}}\right]$$

$$F_1^{\gamma Z} = \sum_f e_{q_f}(g_V)_{q_f}(q_f + \bar{q}_f)$$

$$F_3^{\gamma Z} = 2\sum_f e_{q_f}(g_A)_{q_f}(q_f - \bar{q}_f)$$

$$g_1^{\gamma Z} = \sum_f e_{q_f}(g_V)_{q_f}(\Delta q_f + \Delta\bar{q}_f)$$

$$g_5^{\gamma Z} = \sum_f e_{q_f}(g_A)_{q_f}(\Delta q_f - \Delta\bar{q}_f)$$

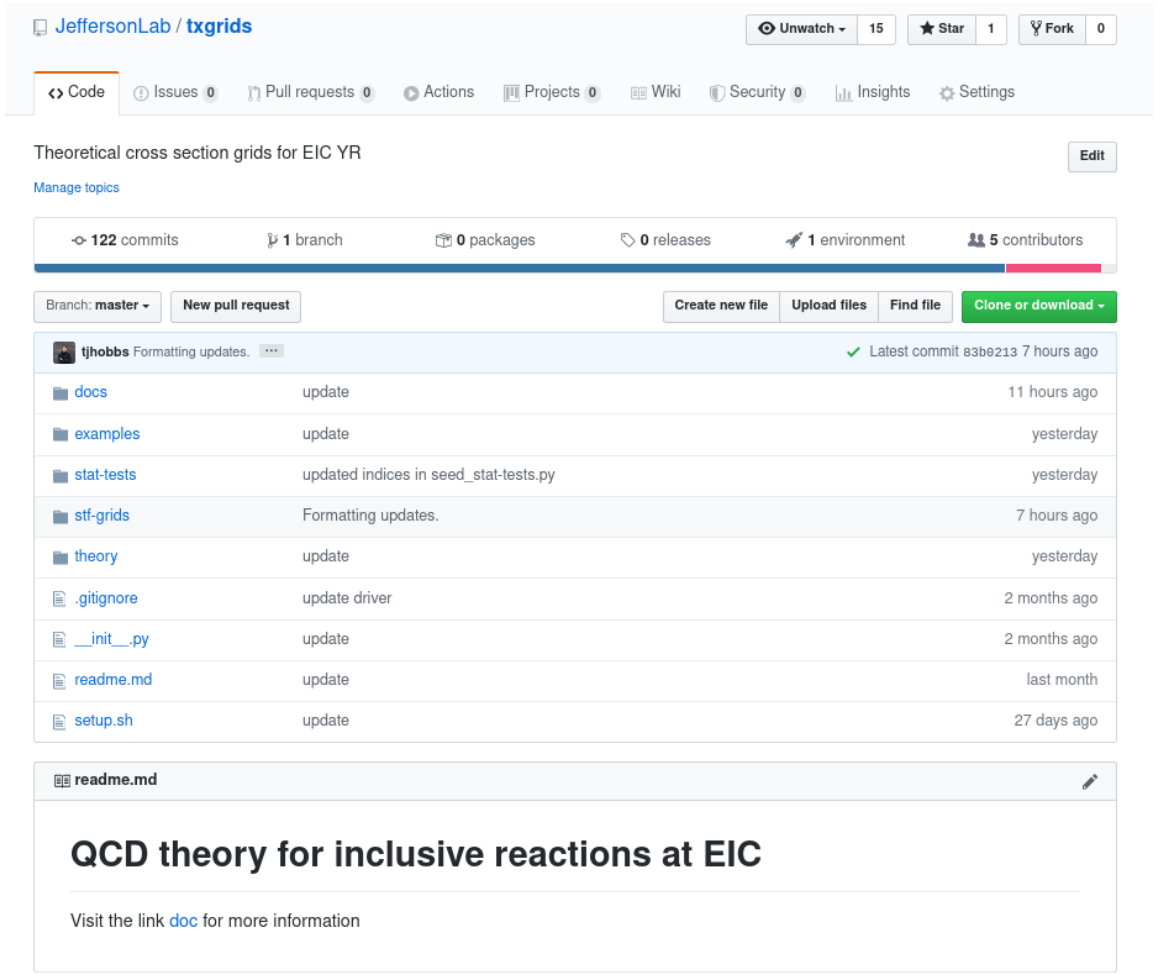
- Summary of recent EIC workshop on electroweak and BSM physics
- Relevant to the inclusive group yellow report effort will be upcoming studies on electron-proton and electron-deuteron DIS, as well as work on Lorentz-violating effects

Updates from Theory

Talk by Rabah Abdul Khalek

- *Arxiv* for structure functions interpolation tables: CT, NNPDF, JAM, KN ...
- LHAPDF interface
- Python routines to compute cross sections

https://github.com/JeffersonLab/txgrids



Updates from Theory

Talk by Rabah Abdul Khalek

- Consolidate index convention
- Benchmarks for total cross sections and structure functions

https://jeffersonlab.github.io/txgrids/_build/html/index.html

LHAPDF grids

Structure function index convention

$(T = p, n, d, \ldots, A)$

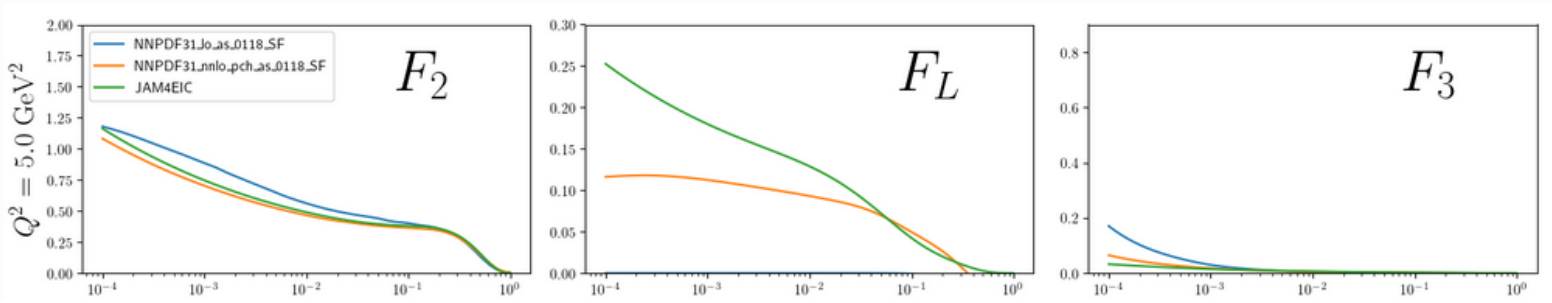
Reaction	Structure Functions	Index
$e^{\pm} + T \to e^{\pm} + X$	F_2^{γ}, F_L^{γ}	900, 901
	$F_2^{\gamma Z}$, $F_L^{\gamma Z}$, $F_3^{\gamma Z}$	902, 903, 904
	F_2^{Z}, F_L^{Z}, F_3^{Z}	905, 906, 907
	F_2^{NC}, F_L^{NC}, F_3^{NC}	908, 909, 910

Benchmarks

NC cross sections

name	values	theory	$\sqrt{S}$	kin. cuts
NNPDF31_lo_as_0118_SF	$9.1826 \times 10^8 \pm 3.2447 \times 10^5$(fb)	LO	140.7GeV	$Q^2_{\min} = 1.0\,(\mathrm{GeV}^2)$ $W^2_{\min} = 10.0\,(\mathrm{GeV}^2)$
NNPDF31_nnlo_pch_as_0118_SF	$7.8199 \times 10^8 \pm 3.1779 \times 10^5$(fb)	NNLO	140.7GeV	$Q^2_{\min} = 1.0\,(\mathrm{GeV}^2)$ $W^2_{\min} = 10.0\,(\mathrm{GeV}^2)$
JAM4EIC	$8.0504 \times 10^8 \pm 3.2625 \times 10^5$(fb)	NLO	140.7GeV	$Q^2_{\min} = 1.0\,(\mathrm{GeV}^2)$ $W^2_{\min} = 10.0\,(\mathrm{GeV}^2)$

Structure functions



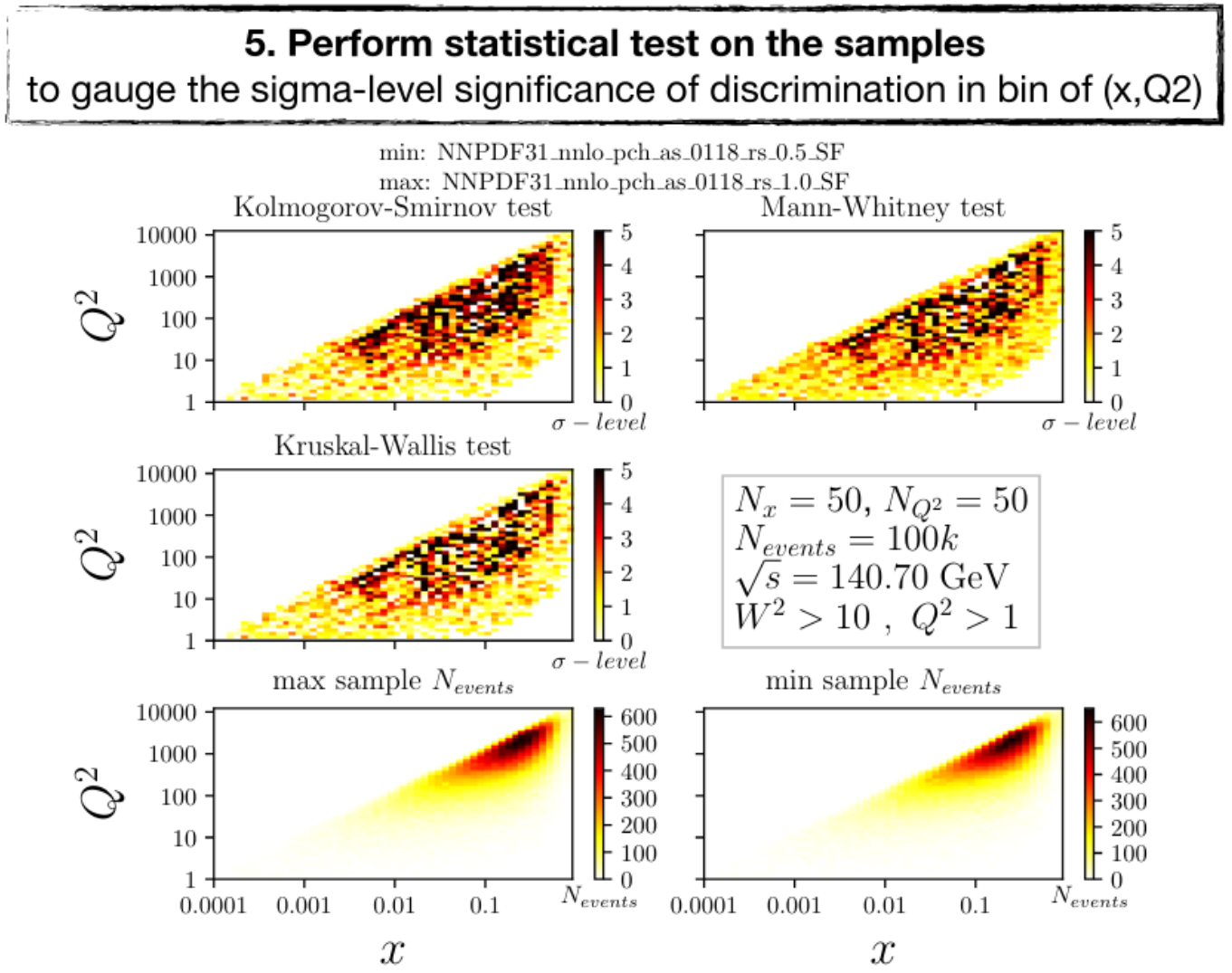
New statistical tools for impact studies

Why? Avoid the need for carrying out global analysis for each detector setup

How? event level test using KS-test, t-test and more to compute *p*-values or sigma-level significance

Example test event samples using two different underlying laws (small *Rs* vs. large *Rs*)

Talk by Rabah Abdul Khalek



Summary

- We have developed a framework for generating EIC pseudo-data and for conducting impact studies for different detector acceptance and resolution parameterizations
- Work has been done on cross section reconstruction at the vertex level for unpolarized electron-proton NC and CC scattering
- We plan to focus much of our attention now on the polarized and unpolarized NC channels
  - This will require a dedicated study on electron identification and purity
  - We will also conduct impact studies using reconstructed cross sections and asymmetries
- The theoretical framework for reweighting the generated data is in place and is being vetted, but we need to implement the full QED radiative correction procedure with reweighting