SIDIS - Working Group
2nd
meeting

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May 26, 2021

Agenda

- Recap of charge
- Recap of last meeting
- Summary of kinematics/technology options
- Recap possible impact plots

- Summary of open software tasks
- Action item:
  - →Agree on first simulation steps/workforce
  - →Agree on channels to be investigated/workforce

Charge

- From the ***physics performance working groups***, the proposal will need the following information and/or actions:
-
  - **Identify the key physics observables described in the Yellow Report that pertain to your working group**
-
- In the Yellow Report, the community identified a number of physics goals and observables required at the EIC. Each physics group should identify which of these belongs within its purview, and formulate a plan for updating the YR plots using the actual detectors (and inactive materials!) that will be part of EIC@IP6.
-
  - **Which 2 or 3 plots will illustrate ability of EIC@IP6 to address NAS report/YR physics?**
-
- It will be crucial to identify a subset of all the possible performance plots for your physics area that should be included in the proposal. There is a strict page limit for proposals, and they must include a detailed description of the detector systems and their cost. Consequently, each physics working group should anticipate being able to fill only a few pages in the proposal.
-
- This, plus the limited time we have, requires identifying only a few performance plots for which your working group will carry out full simulations with the integrated EIC@IP6 detector. These most likely exist in more idealized form in the YR already. However, identifying the key plots early will allow the working group to work with the detector groups and inform the collaboration of the impact of specific technology choices.
-
  - **Are there any additional physics performance plots that would give a competitive advantage to this proposal?**

Recap

- Meeting time
- Discussed workforce
  - Exp: Duke, SBU (each about 1FTE)
  - Theory: HKCU (di-hadrons), INFN (upol TMD fits, transversity)
  - BNL?
- Potential impact plots/channels (see following slides)
  - single hadron SIDIS, Colllins, Sivers
  - Upol TMDs (evolution)
  - di-hadron gluon TMDs
  - sea quark (polarized) PDFs
  - (nPDFs/nFFs)
  - (lambda)
  - (cc)
- What are the unique features of Athena and how can this be used to differentiate our proposal?
  - PID → High impact feature for SIDIS
  - Large acceptance → hadronic reconstruction?
  - Large x, Q^2 coverage →high impact feature for SIDIS
  - High precision for high momentum tracks →impact?
    - Can this be used to reconstruct K_S / suppress background → use instead of charged kaons where PID becomes worse e.g. for seq quark (polarized) PDFs
  - ?

Next steps

- Need to understand consequences of technology choices
- Simulation!
- Final plots need to be with full simulation (dd4hep framework)
  - Not ready yet
- First evaluation with fast simulation→should be able to make rough estimate of technology choice impact

Tasks

- Identify SW point of contact
  - Communicate needs/ make sure we adhere to best practices

  →Chris Dilks?
- Setup of fast simulation, initial exploration of SIDIS phase space (Delphes)
  - Duane
- In charge of full simulations
  - Andrea Bressan is liason to EICUG computing
  - ?
- Initial investigation of ‘golden+’ channels? (or can we decide ad-hoc?)
  - Impact/update to YR plots
  - Identify critical detector components
  - Uniqueness

Kinematics coverages

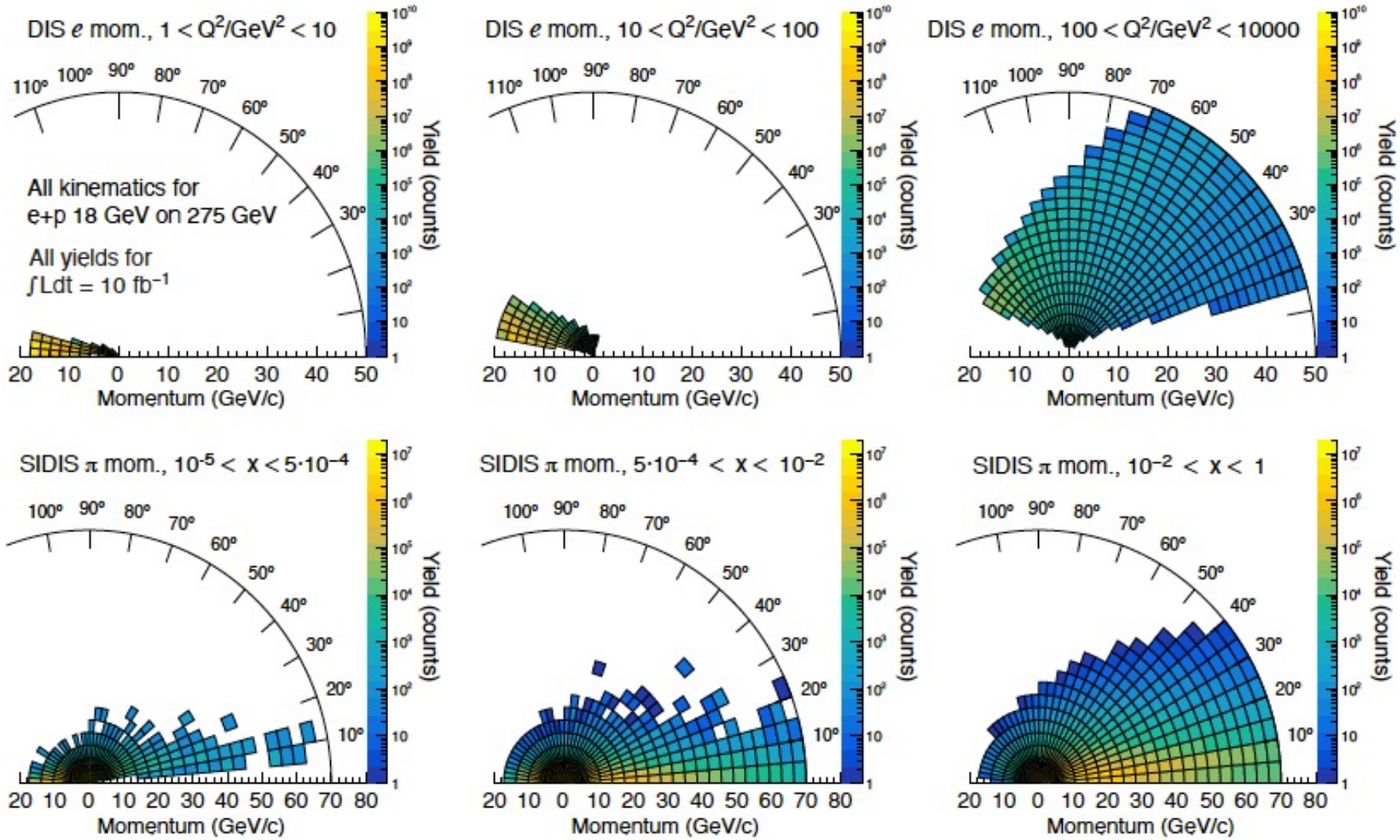
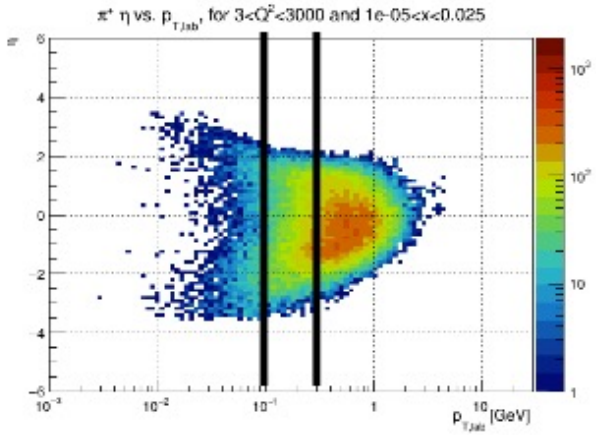
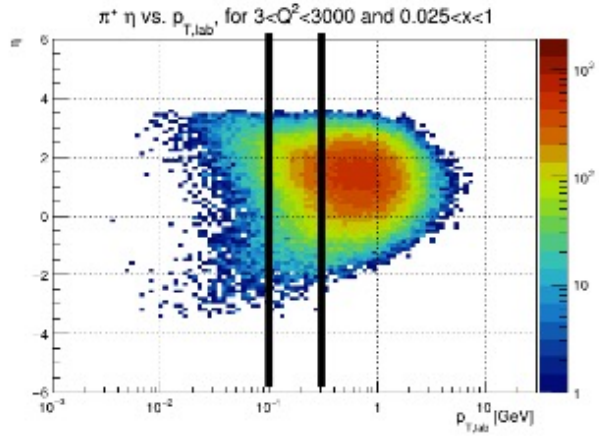


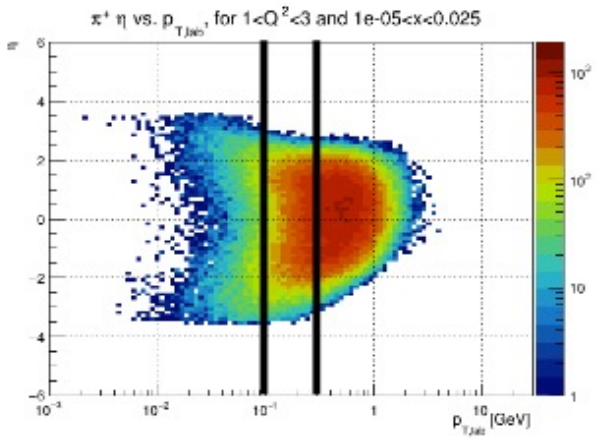
Figure 8.28: Top panel: Polar figures of the scattered DIS lepton momentum distributions for the highest collision energies for small to high momentum transfers from left to right. Bottom panel: Polar figures of SIDIS hadron momentum distributions for the highest collision energies for small to high x from left to right. All yields are extrapolated to 10 fb^{-1} of accumulated luminosity.

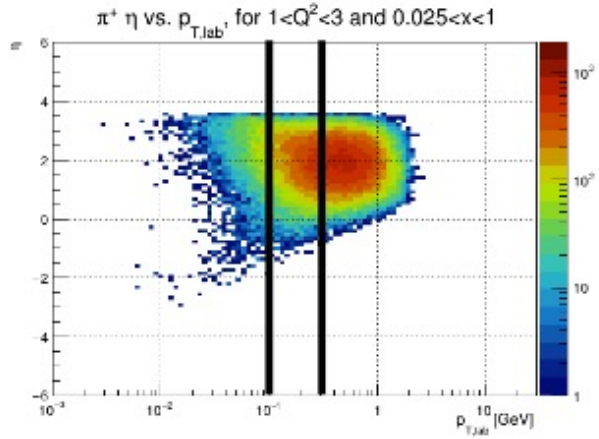
Kinematics pion $p_T > 0$

5x41

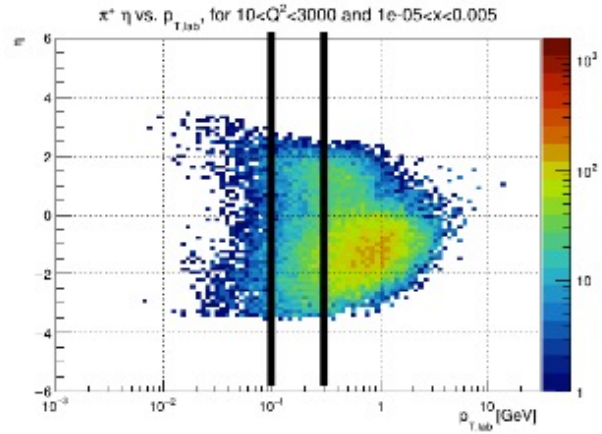


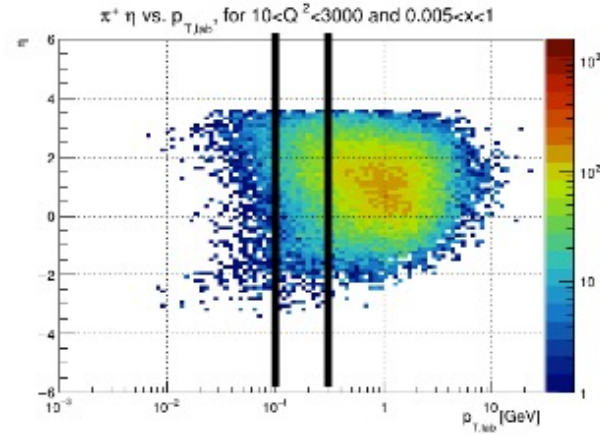


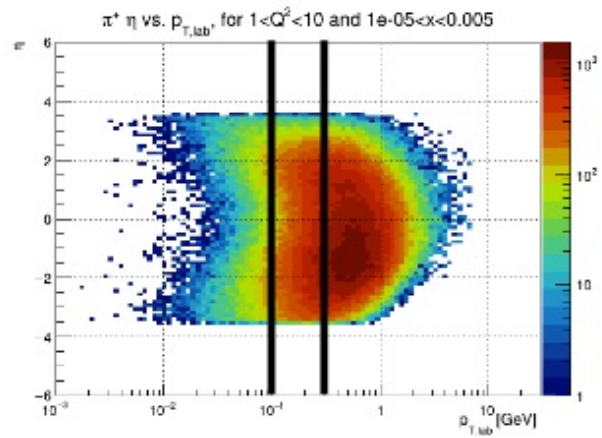


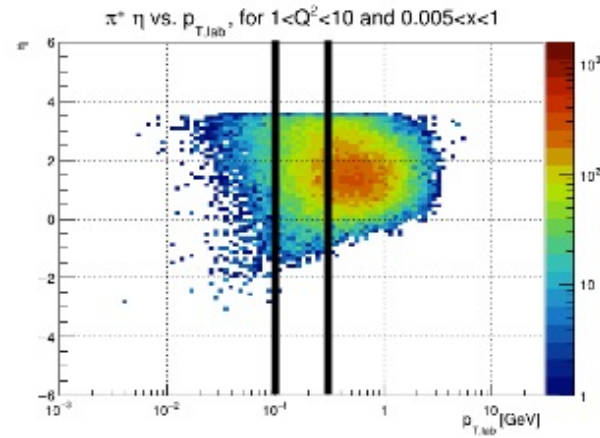


18x275









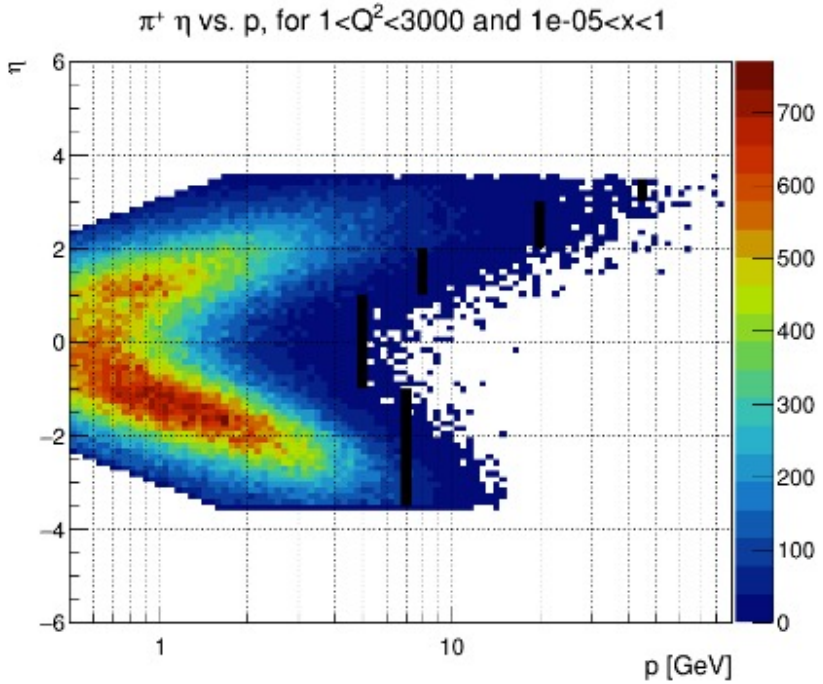
Lines drawn at test pion p_T cuts

- **p_T > 100 MeV**
- **p_T > 300 MeV**

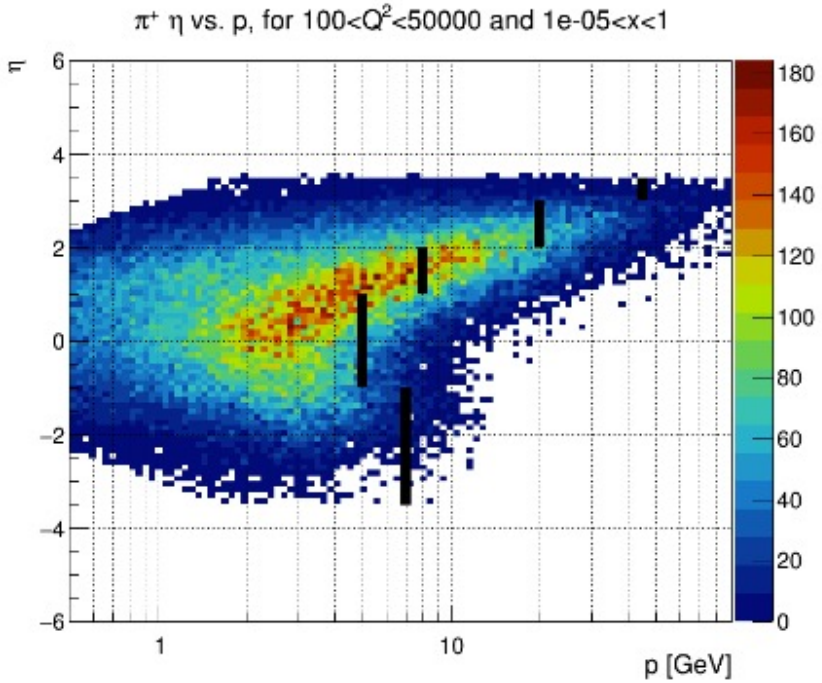
From chris

π^+ η vs. p distributions (from $\pi^+\pi^-$ dihadrons)

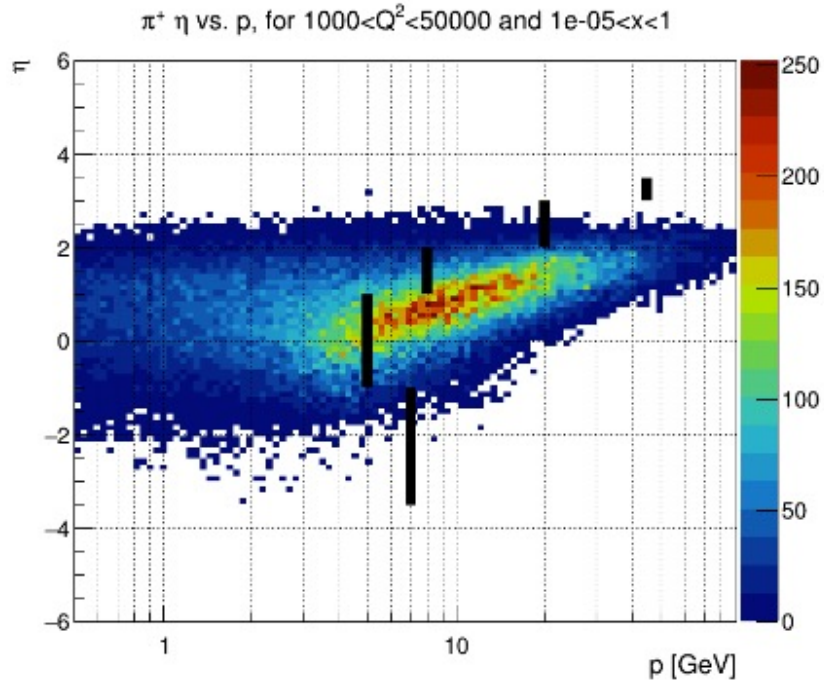
$Q^2 > 1$ GeV^2



$Q^2 > 100$ GeV^2



$Q^2 > 1000$ GeV^2



- Vertical lines denote PID p limits
- Majority of Q^2>1000 GeV^2 data will have less than 3σ PID separation

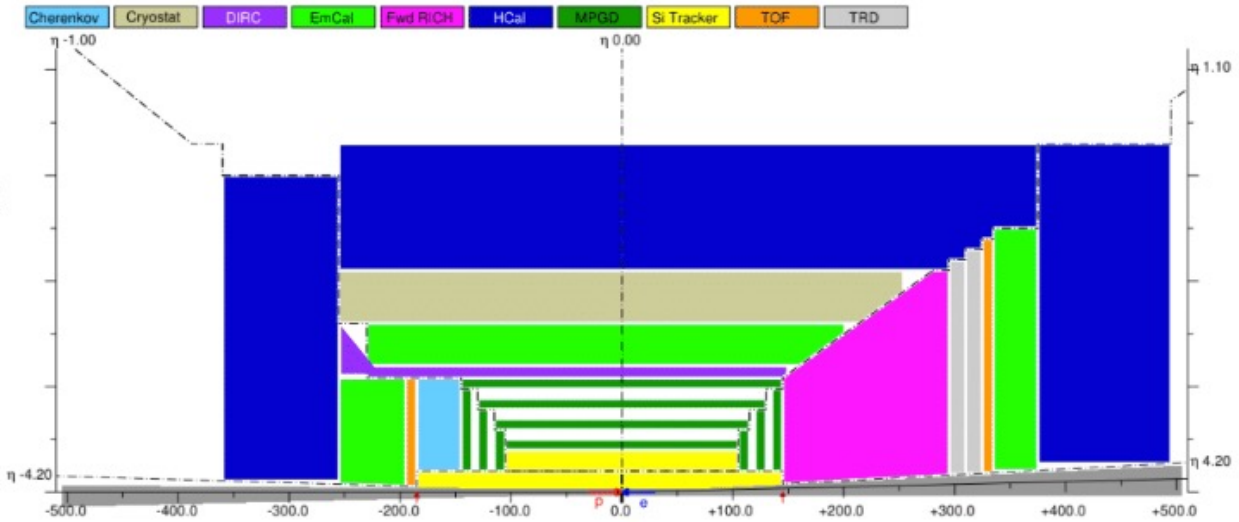
Slide from Yulia (https://www.dropbox.com/s/18okpfnud1886rq/6_ATHENA_YuliaFurletova.pptx?dl=0)
These are the main options we should evaluate

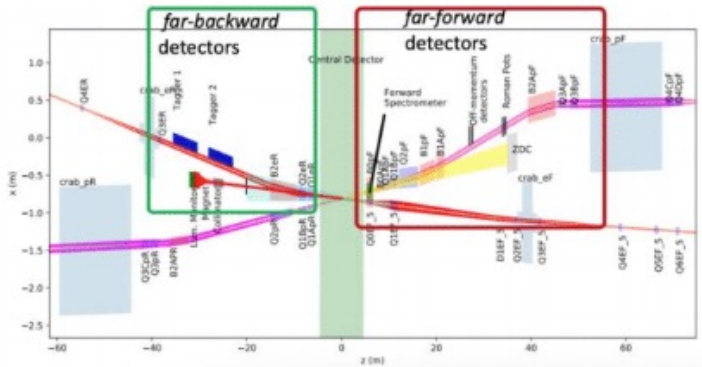
Detector technology discussion

Main open points identified so far:

- *Tracking*
  - hybrid vs full Si
  - Different gaseous tracker options
  - Large trackers in the forward/backward region
- *PID in the barrel*
  - Confirmation of the current approach vs completion with extra detectors
  - Which photon sensors ?
  - Which role for TOF? Where?
- *HCal*
  - Re-analysis of the needs and options
- … more will come

Hybrid version of MPGD + Si tracker
(discussions between eRD6, eRD22 & eRD25)

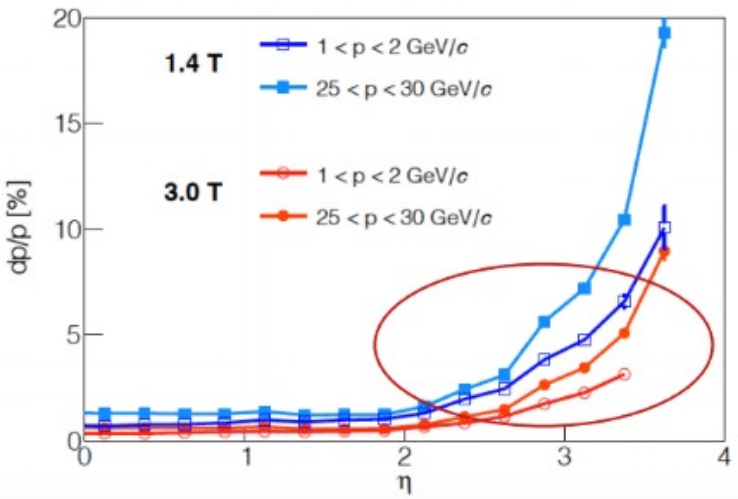




SC1 glass

Dec 2020: 2cm x 2cm x 40cm (10-20 X0)

Momentum resolution improvement for large momentum particles at large rapidity:



Channels

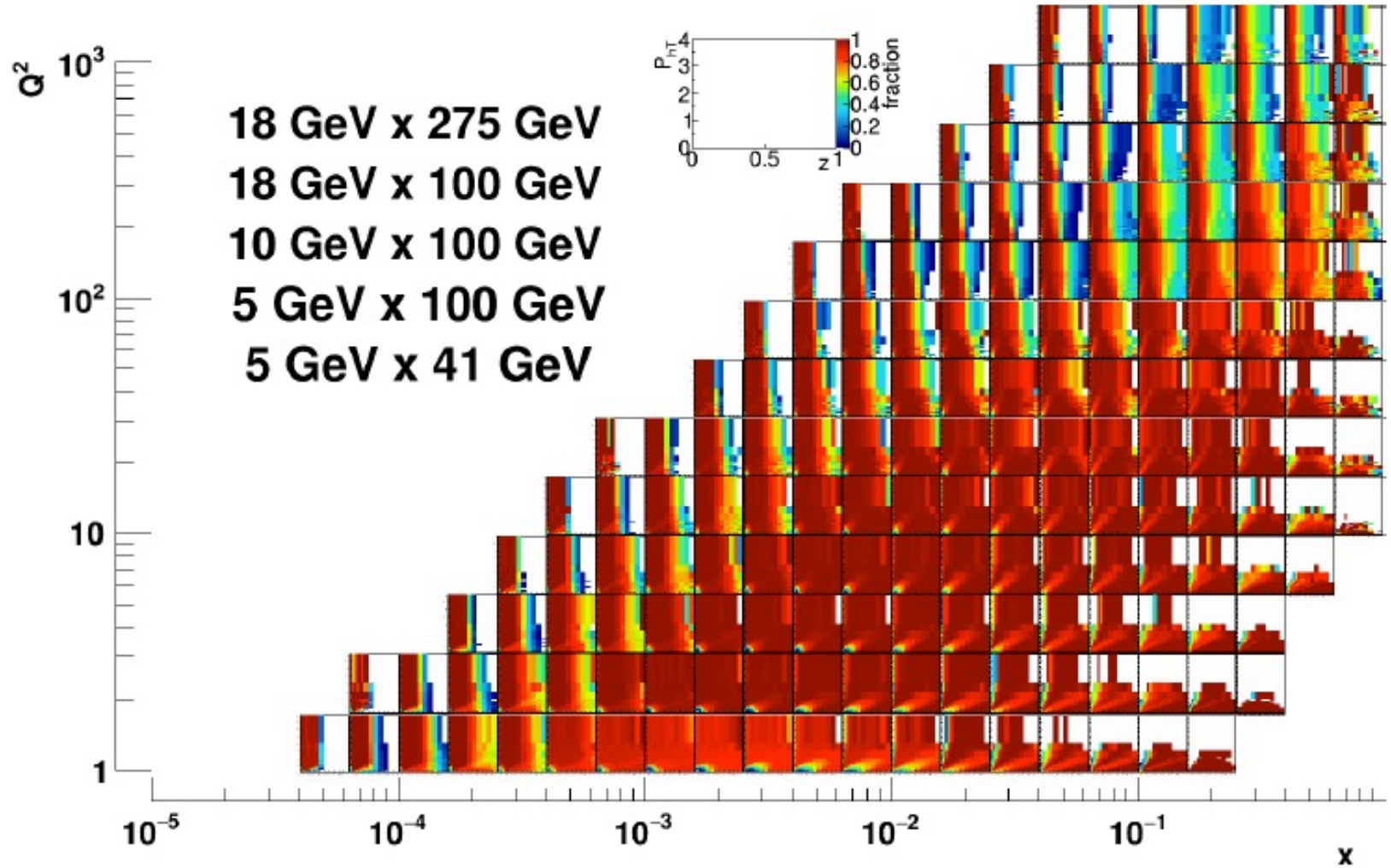


Figure 8.29: PID acceptance fractions as a function of pion fractional energy z and transverse momentum P_{hT} in bins of x and Q^2, taking into account all collision energies. The fractions are evaluated by calculating the yield of accepted pions within the PID momentum ranges described in the text normalized by all pions.The standard DIS event selection criteria are applied.

Sivers

- Golden channel
- Nicely combines evolution and polarization dependent TMD extraction
- Kaons?
- Theory dependence?
- Difficult to pin down impact of phase space coverage on impact plots
  - Can this be shown w/ and w/o certain phase space

- Candidate for impact plots?

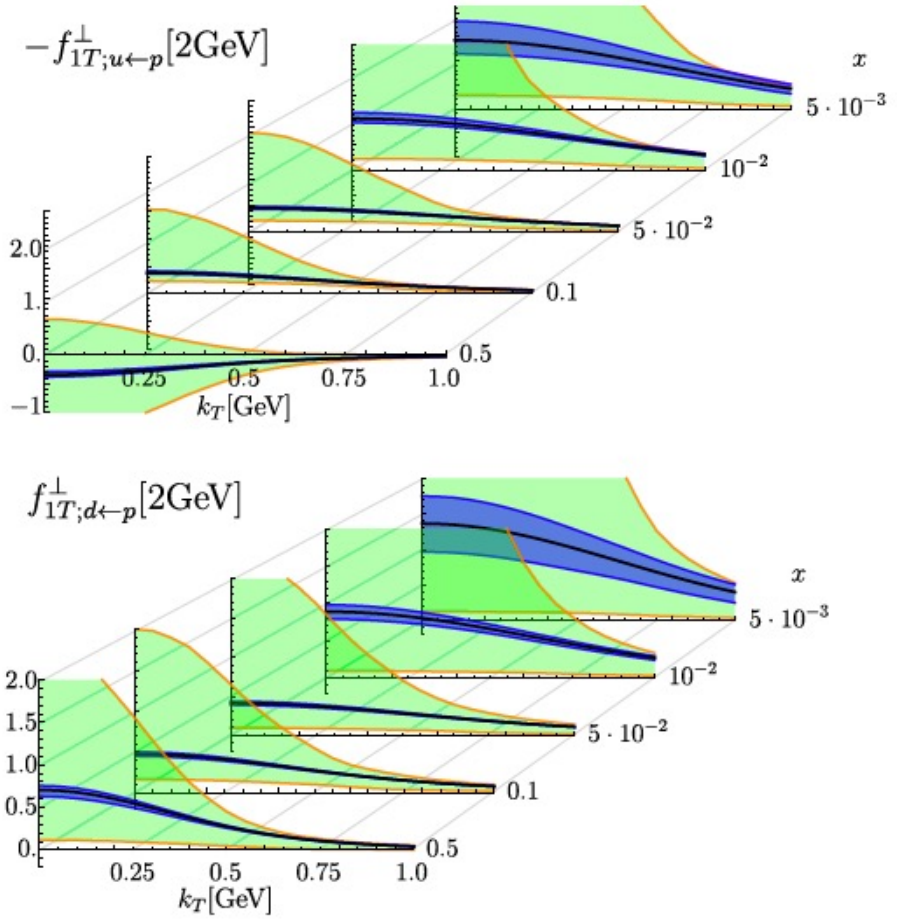


Figure 7.53: Expected impact on up and down quark Sivers distributions as a function of the transverse momentum k_T for different values of x, obtained from SIDIS pion and kaon EIC pseudodata, at the scale of 2 GeV. The green-shaded areas represent the current uncertainty, while the blue-shaded areas are the uncertainties when including the EIC pseudodata.

Collins/Transversity (similar di-hadrons)

- Golden/silver channel

- Possible critique:
  - What about impact of other experiments before EIC? (SoLID, Compass, RHIC)
  - (this is similar to Sivers, but Sivers has additional TMD evolution questions that need EIC)

- →prefer Sivers plots?

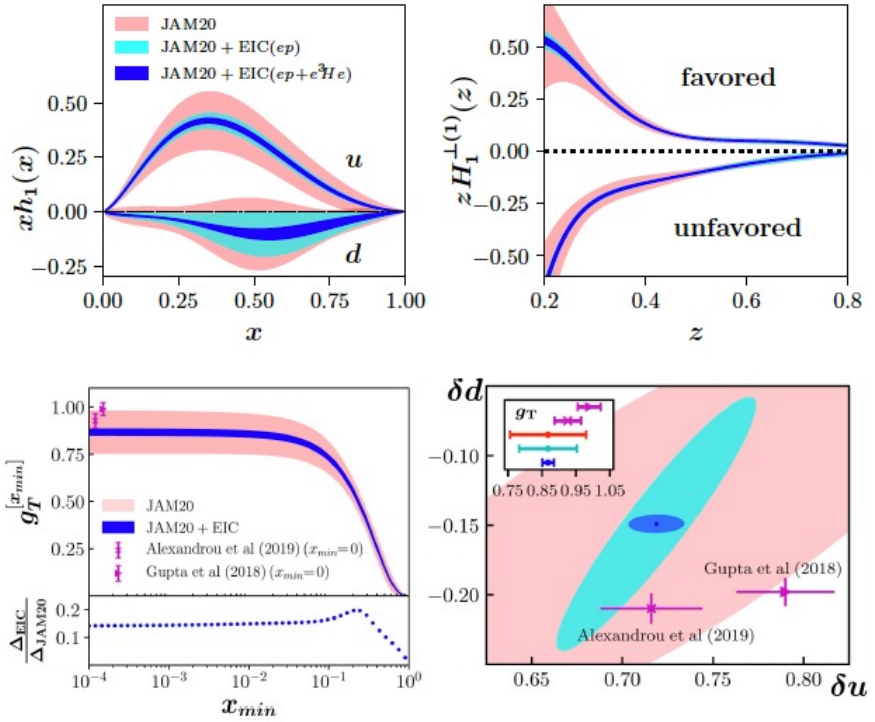
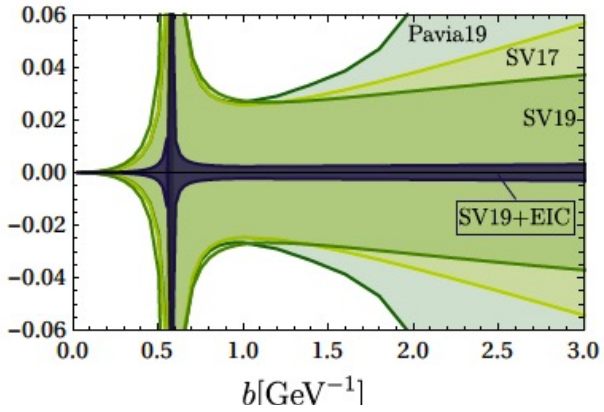


Figure 7.54: Top: Expected impact on the up and down quark transversity distributions and favored and unfavored Collins function first moment when including EIC Collins effect SIDIS pseudodata from e+p and e+He collisions [517]. Bottom left: Plot of the truncated integral $g_T^{[x_{min}]}$ vs. x_{min}. Also shown is the ratio $\Delta_{\rm EIC}/\Delta_{\rm JAM20}$ of the uncertainty in $g_T^{[x_{min}]}$ for the re-fit that includes pseudodata from the EIC to that of the original JAM20 fit [228]. Note that the results from two recent lattice QCD calculations [518, 519] are for the full g_T integral (i.e., $x_{min} = 0$) and have been offset for clarity. Bottom right: The impact on the up quark (δu), down quark (δd), and isovector (g_T) tensor charges and their comparison to the lattice data.

Upol TMDs/TMD evolution

- Golden channel
- Needs high x, Q^2 coverage

- Too theory dependent?
- Difficult to pin down impact of phase space coverage on impact plots
  - Can this be shown w/ and w/o certain phase space



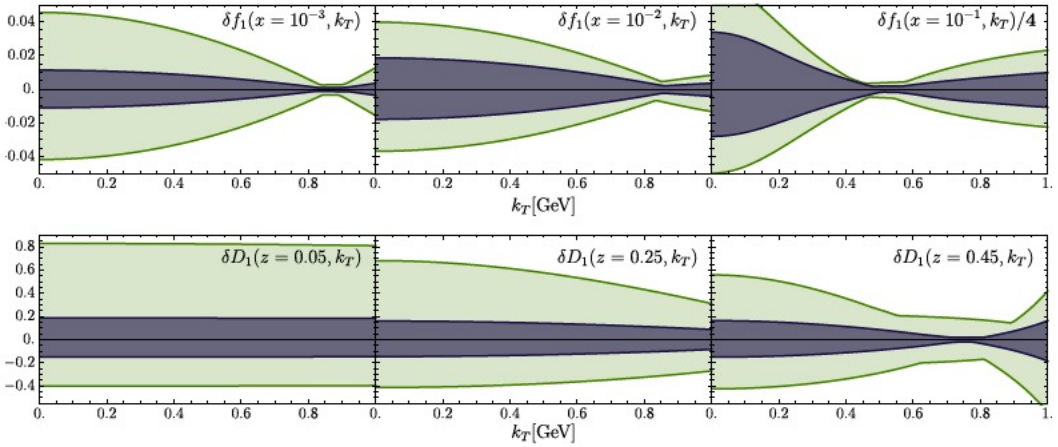


Figure 7.52: Comparison of relative uncertainty bands (i.e. uncertainties normalized by central value) for up-quark unpolarized TMD PDFs (upper panel) and $u \to \pi^+$ pion TMD FFs (lower panel), at different values of x and z as a function of k_T, for $\mu = 2$ GeV. Lighter band is the SV19 extraction, darker is SV19 with EIC pseudodata.

Sea quark helicities

- Golden channel
- Highlights need for good kaon PID
  - Can this be done with K_S ? Any advantages?
- Candidate for impact plot?

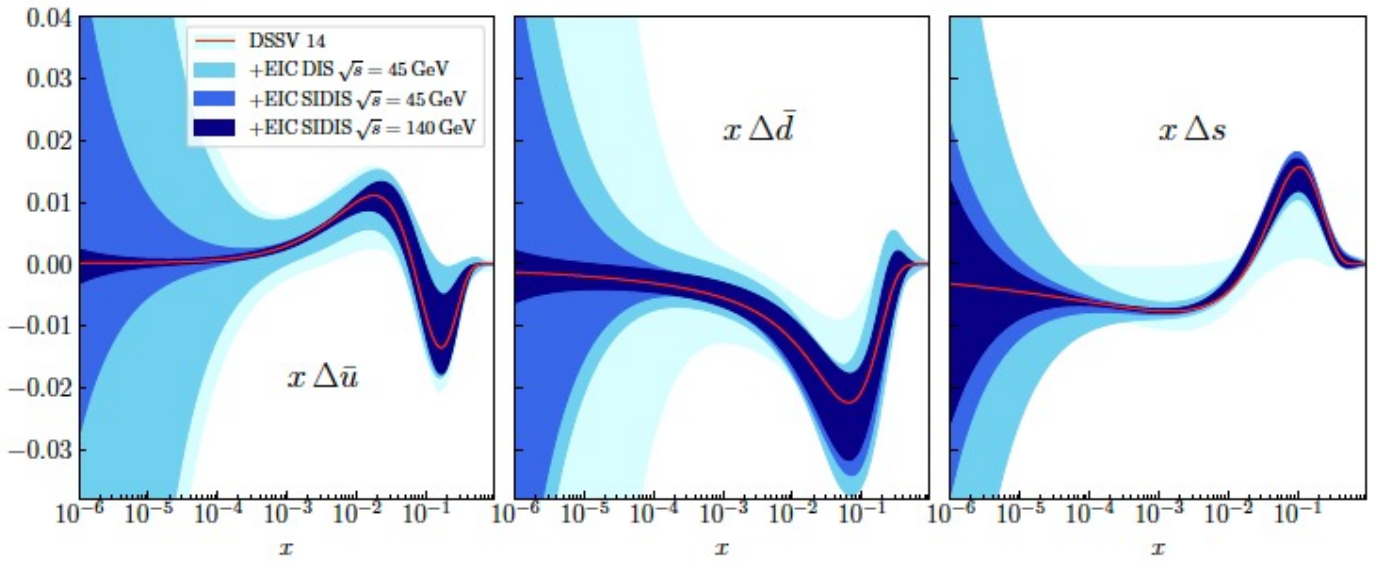


Figure 7.19: Impact of SIDIS measurements at the EIC on the sea quark helicities $x\Delta\bar{u}$, $x\Delta\bar{d}$ and $x\Delta s$ as a function of x at $Q^2 = 10\ \mathrm{GeV}^2$.

Sea quark PDFs

- Similar reasoning to sea quark helicities

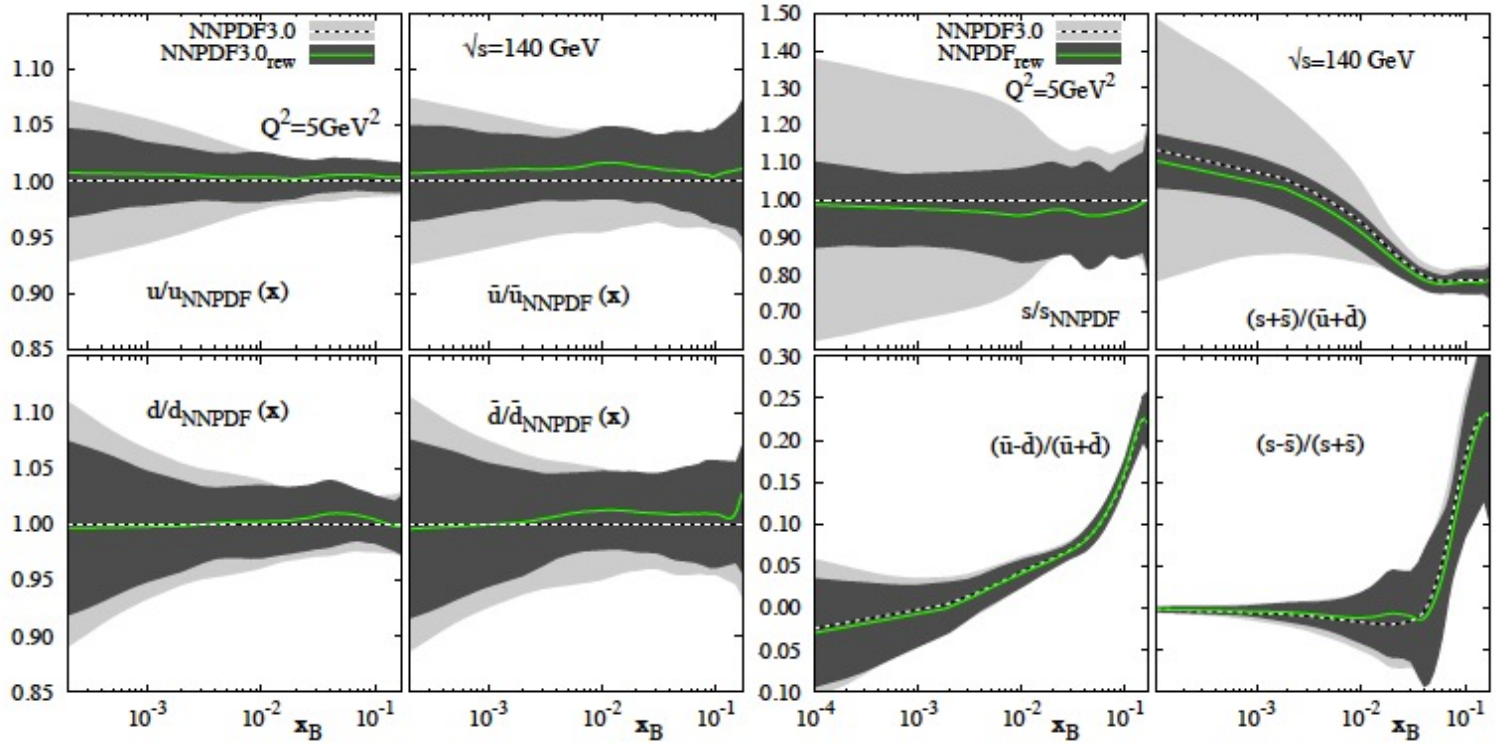


Figure 7.8: Expected impact on the unpolarized (sea) quark PDFs when adding SIDIS information from pions and kaons in *ep* collisions. The baseline NNPDFs were take from Ref. [59].

FFs

- EIC impact moderat
  →not a high impact measurement?

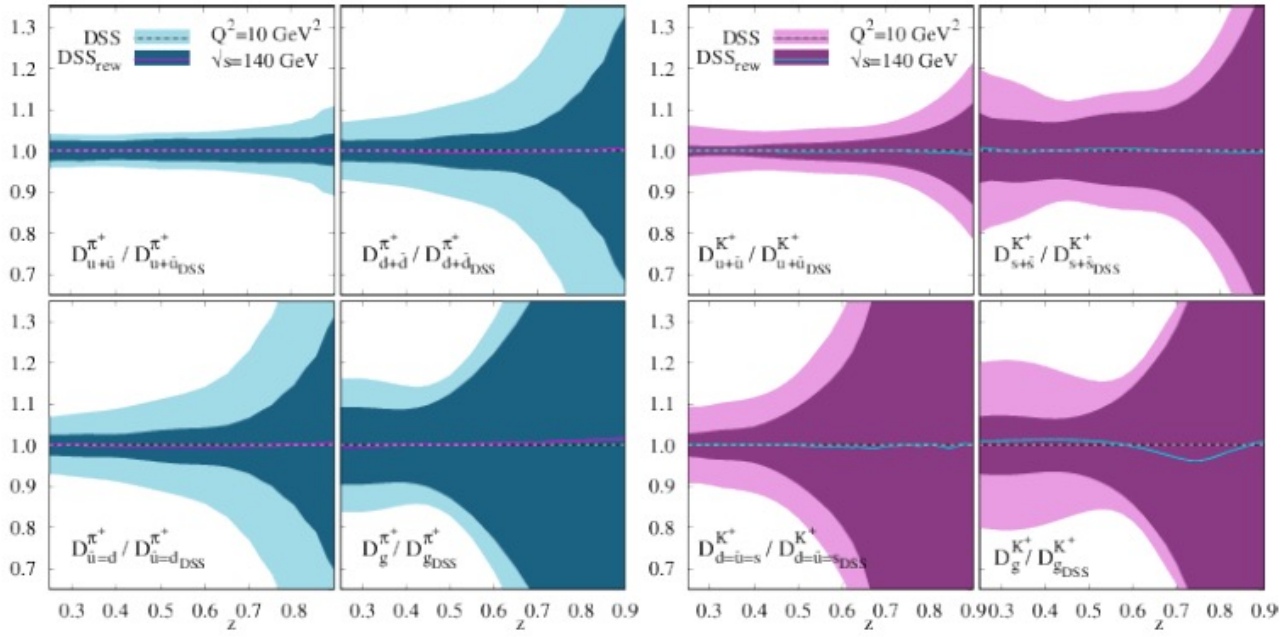
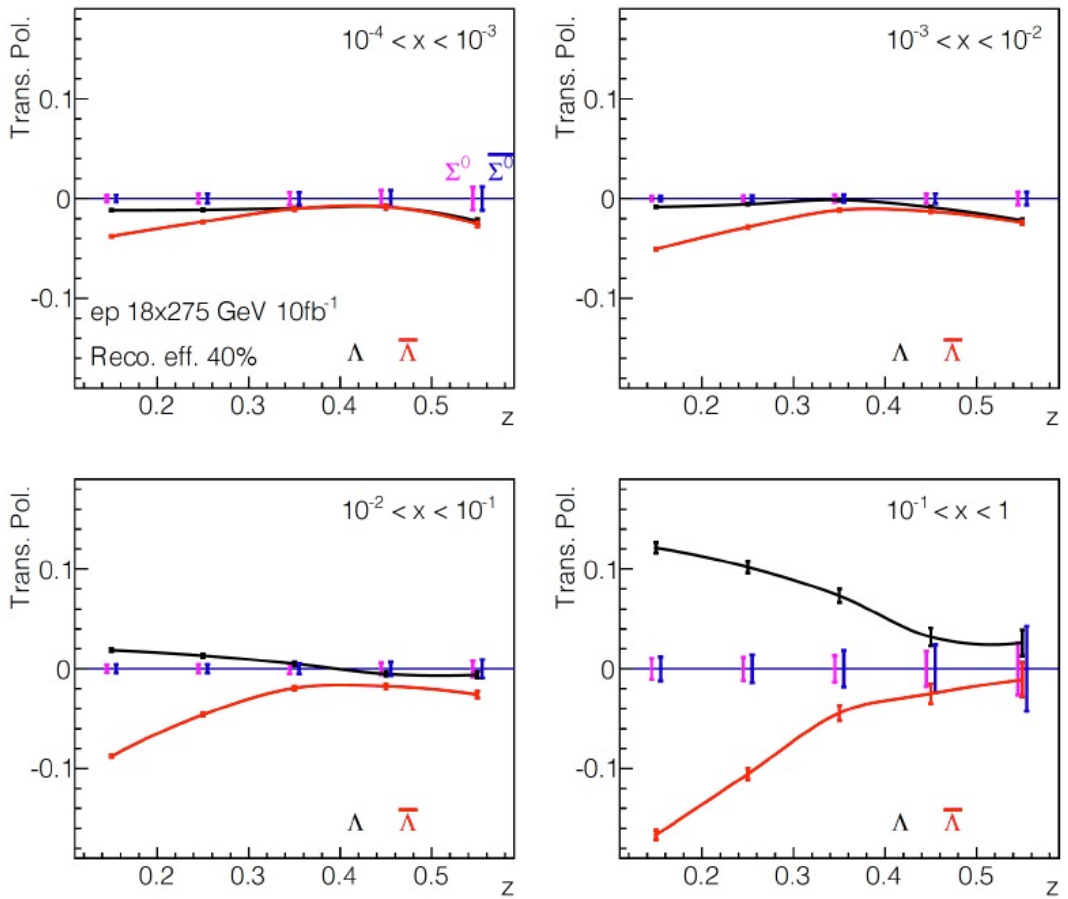


Figure 7.84: Pion (left) and kaon (right) FFs obtained from the global DSS analyses [914, 915] (dashed line with light uncertainty bands) and obtained from the global DSS analyses with the inclusion of EIC pseudo-data, at a c.m.s. energy $\sqrt{s} = 140$ GeV, (continuous line with dark uncertainty bands) [55], both normalized to the DSS best fit. The shaded bands reflect the statistical uncertainties from the pseudo-data (evaluated at a luminosity of 10 fb^{-1}) and the uncertainties from the PDFs. The upper (lower) row corresponds to the (un)favoured fragmentation.



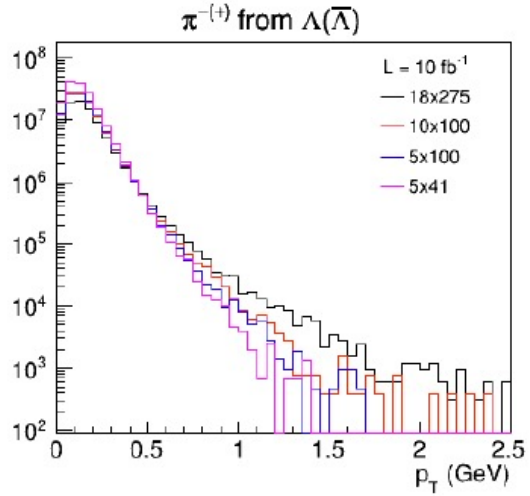
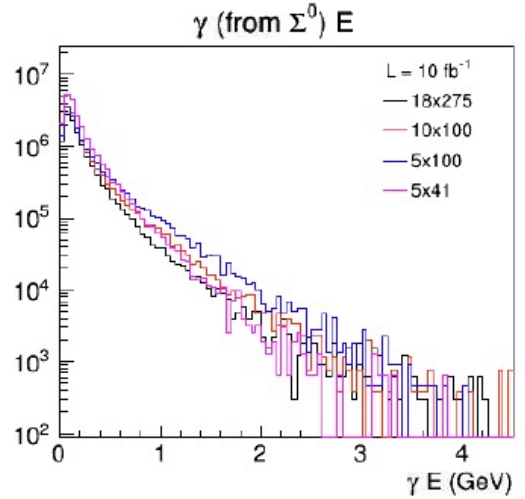


Figure 8.34: Transverse momentum and en
$\Lambda\gamma$ respectively.



y spectrum of pions from $\Lambda \to p\pi$ and $\Sigma^0 \to$

- Novel measurement
- Still significant systematics from feed-down
- Mainly needs low p_T acceptance
- Too ‘excotic’ to be impact plot?

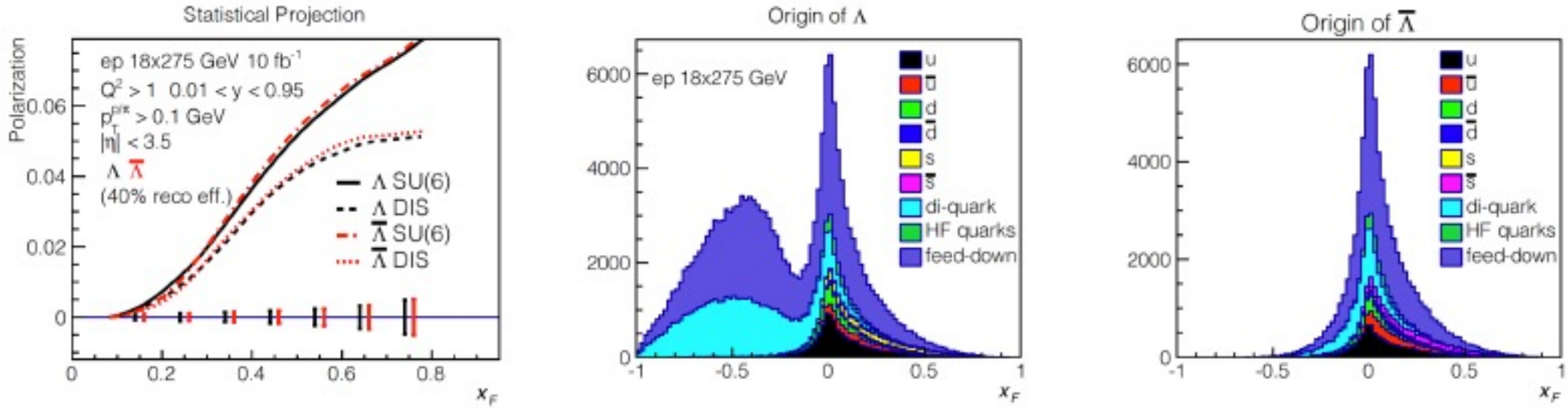


Figure 7.85: Left panel: Projection of longitudinal spin transfer for Λ and $\bar{\Lambda}$ from proton beam at 18$\times$ 275 GeV at EIC. The curves are from model predictions [933]. The two right hand panels show the origin of the reconstructed $\Lambda/\bar{\Lambda}$. In the current fragmentation region a significant fraction originates from feed-down. A dominant part of the feed-down component is contributed by $\Sigma^0 \to \Lambda\gamma$. For more information, see Ref. [934].

nPDF/nFF

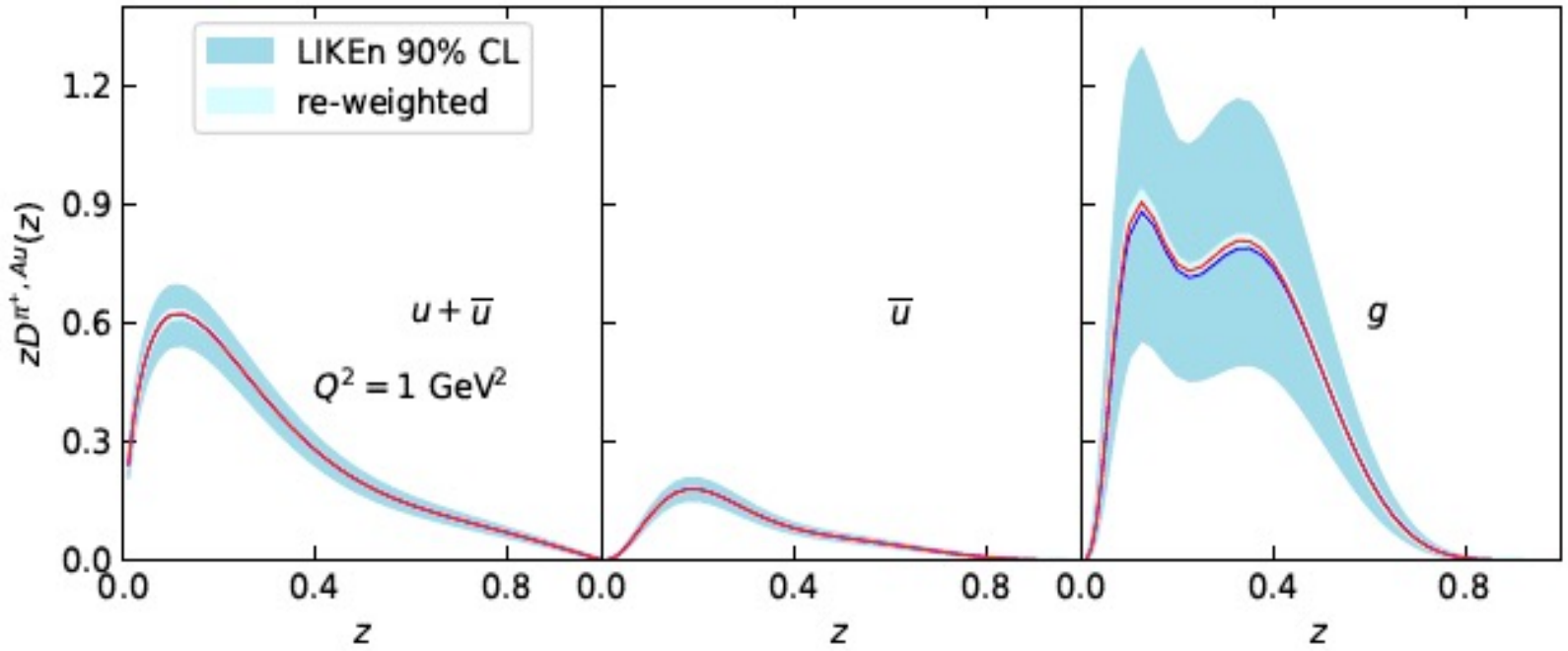


Figure 7.90: Nuclear FFs LIKEn21 for Au and impact of EIC pseudodata at $\sqrt{s} \sim 30$ GeV for $u + \bar{u}$ (left), $\bar{u}$ (center) and gluon (right). Similar results are found for higher $\sqrt{s}$.

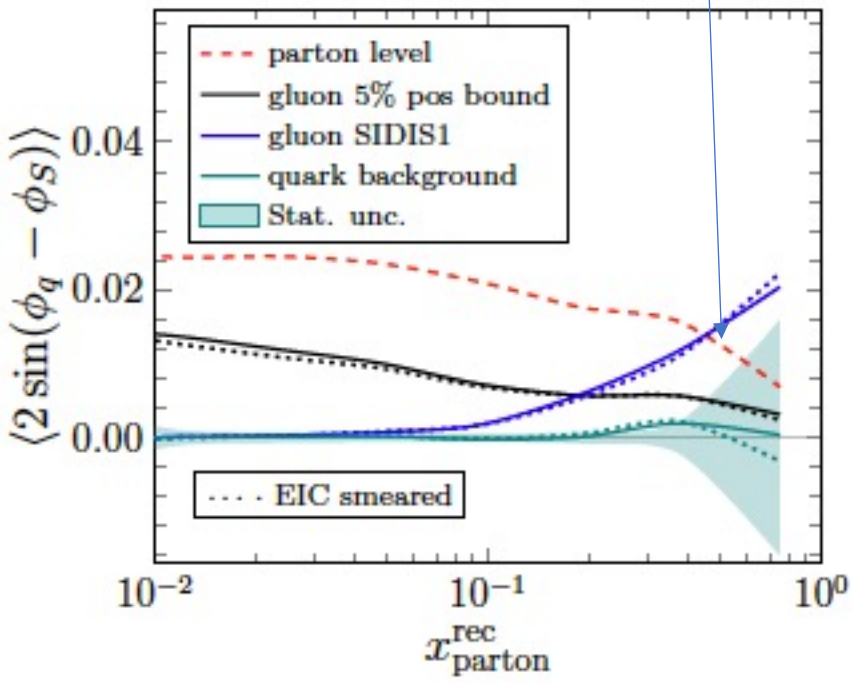
- High impact

Di-hadron/jet gluon TMDs

- Golden channel
- Highlights acceptance (?)
- Needs high Q2

  →profits from hadronic final state reconstruction for high x?

What drives these uncertainties?



CC

→might be best addressed by DIS group

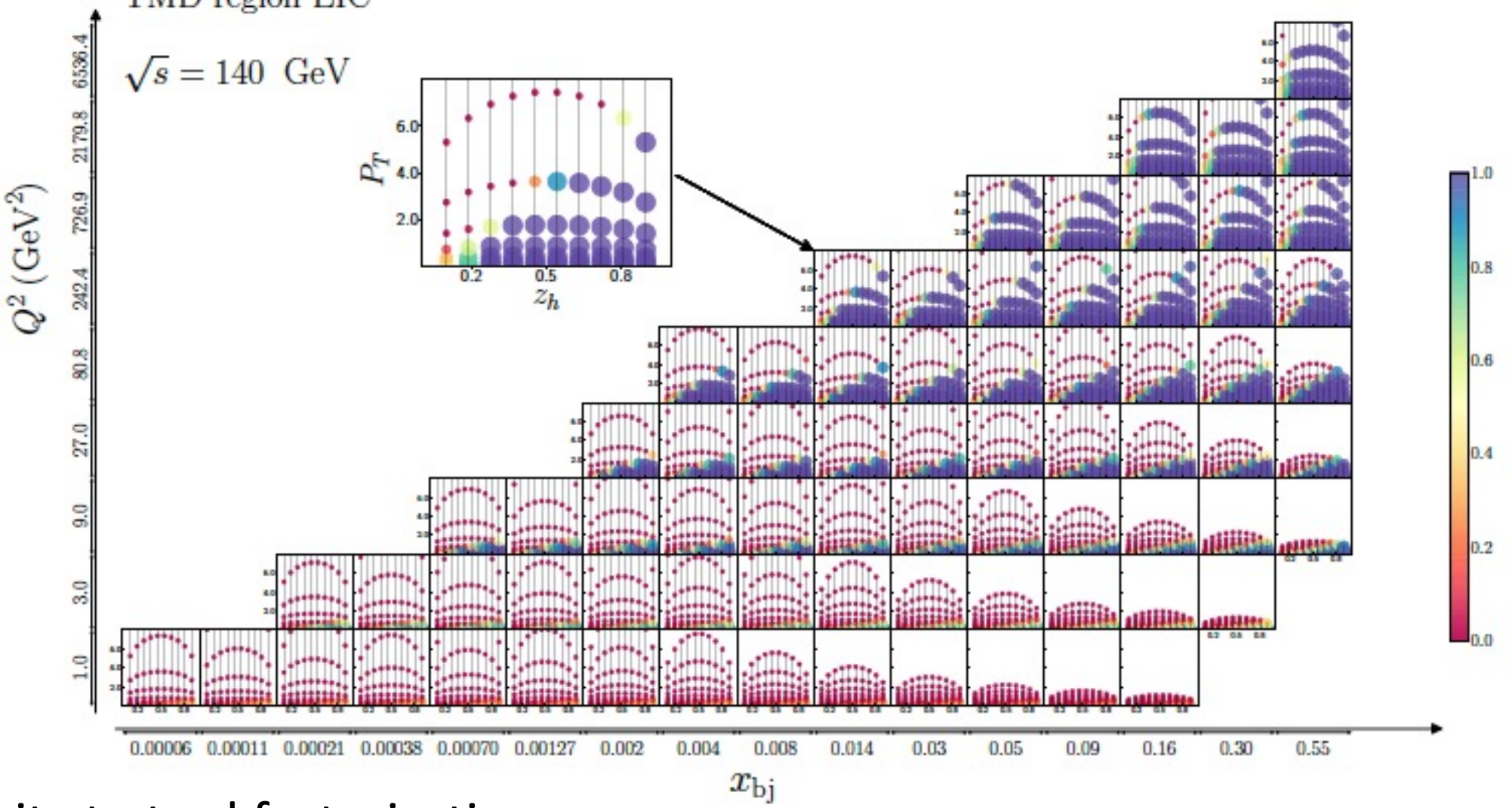
Software tasks

- Produce fast simulation samples
  - Investigate channels
- Start producing full simulations and exploring options to evaluate technology options
  - Learning by doing?
  - What data sets will we need for each channel? (only allocated ~10M events per channel [might be more if we ‘pool’ data between channels, WGs])
- First stab at impact plots..?

Discussion topics

- Task list reasonable?
- Do we already know which impact plots?
  - Suggestion: SIDIS coverage (PID), Sivers (+evolution), sea quark helicity,
- How much do we have to improve YR simulations?
  - Systematics..?
- How can we help getting full simulation data?
  - Get involved in subsystem simulation?

Backup



- Affinity to tmd factorization

  →overlap with Athena region? Resolution in that region?