Project Detector
SIDIS working group

Project Detector bi-weekly meeting

May 27, 2022

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Organizational

- Meetings: for the time being bi-weekly Tuesdays 9:15 EDT (15:15 CEST/22:15 JST)
- Indico agenda: https://indico.bnl.gov/category/418/ (subscribe to either this or general project-detector indico calendar to automatically see in your calendar)
- Mailing list: eic-projdet-semiincl-l@lists.bnl.gov
- Chat: Slack/Mattermost? → follow software group guidance
- Software framework choices: Follow the software group (may be determined by timescale to CD2/3 review as all pieces available in Fun4All), create interface to sidis-eic framework

Computing and simulation needs

- Main strategy toward CD2/3a:
  - Revisit existing SIDIS studies on (SI)DIS kinematic variable resolutions, track changes with Detector configuration changes, try to optimize kinematic reconstruction even within a method (such as using either tracking or EMCal information for scattered lepton based method, etc)
  - Single hadron A_{LL} and Sivers/Collins/unpol TMD studies using reweighting based on parameterizations from global fits. Keep demonstrating feasibility of main physics goals.
  - Similar studies on di-hadrons for DiFFs, Gluon Sivers, di-hadrons for saturation
- Longer term strategy:
  - Proper treatment of radiative effects and its impact on physics results
  - Study the variation of physics impact using different generators and different PDF/FF (both polarized and unpolarized) parameterizations
  - Preparation of realistic unfolding for kinematic smearing and PID misidentification
  - Gain understanding of dominant sources of systematic uncertainties to concentrate on reducing those

Computing and simulation needs ctnd.

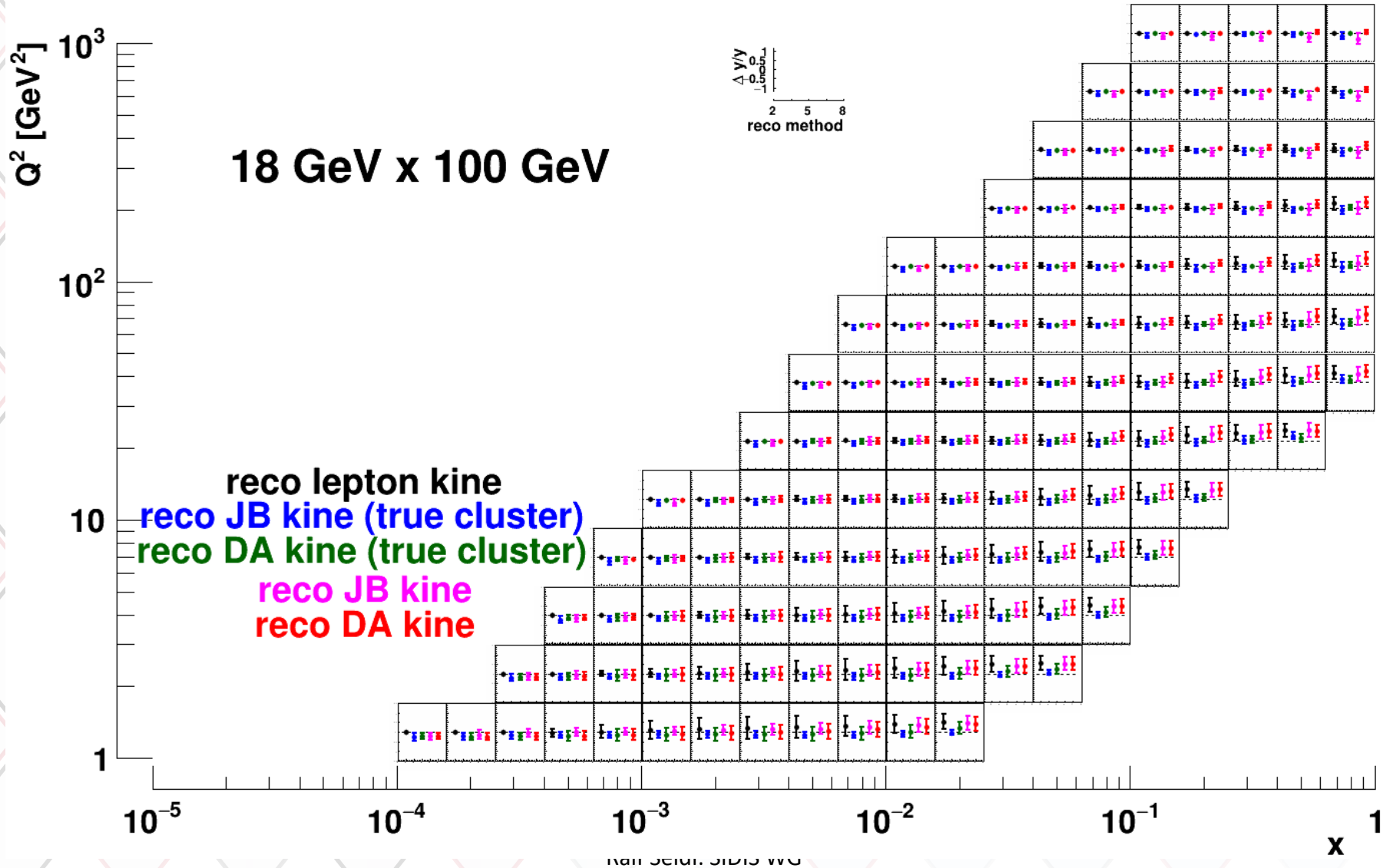
- Software strategy:
  - Assumption to continue with Fun4All given timeframe to CD2/3a but generally plan to work mostly agnostic of it (for analyzers) by using either TTrees from EventEvaluator (EE) output directly for analysis (similar to ECCE proposal for SIDIS group) or create interface to Chris Dilks' sidis-eic framework.
  - The latter would create TTrees including all (SI)DIS kinematic variables to enable easier start for students, etc.
  - Perform several consistency tests for SIDIS variable reconstruction between framework and existing standalone codes based on EE output.
- Requested simulations:
  - Rerun existing pythiaeRHIC files used in YR and ECCE proposal (see also https://wiki.bnl.gov/eicug/index.php/ECCE_Simulations_Working_Group) through full Detector Simulation, reconstruction and EventEvaluator: On rcf in: /gpfs02/eic/DATA/YR_SIDIS/ep_AxB/
  - Similar settings but Pythia6 w/o ISR/FSR
  - dedicated generators Radgen or Djangoh
  - dedicated Lambda production: eictest/ATHENA/EVGEN/SIDIS/Lambda (existing)
  - Pythia8 and PDF/FF set comparisons

Kinematic resolution studies

- Continue studying the kinematic (SI)DIS resolutions for different reconstruction methods, sets of information used and assumptions
  - Electron: track ↔ EMCAL
  - chrg. Hadron: track ↔ HCAL
  - Neutrals →cluster isolation
  - eID/PID
- Check resolutions with detector configuration changes, optimize the reconstruction
- Explore ML techniques (potentially as part of framework)

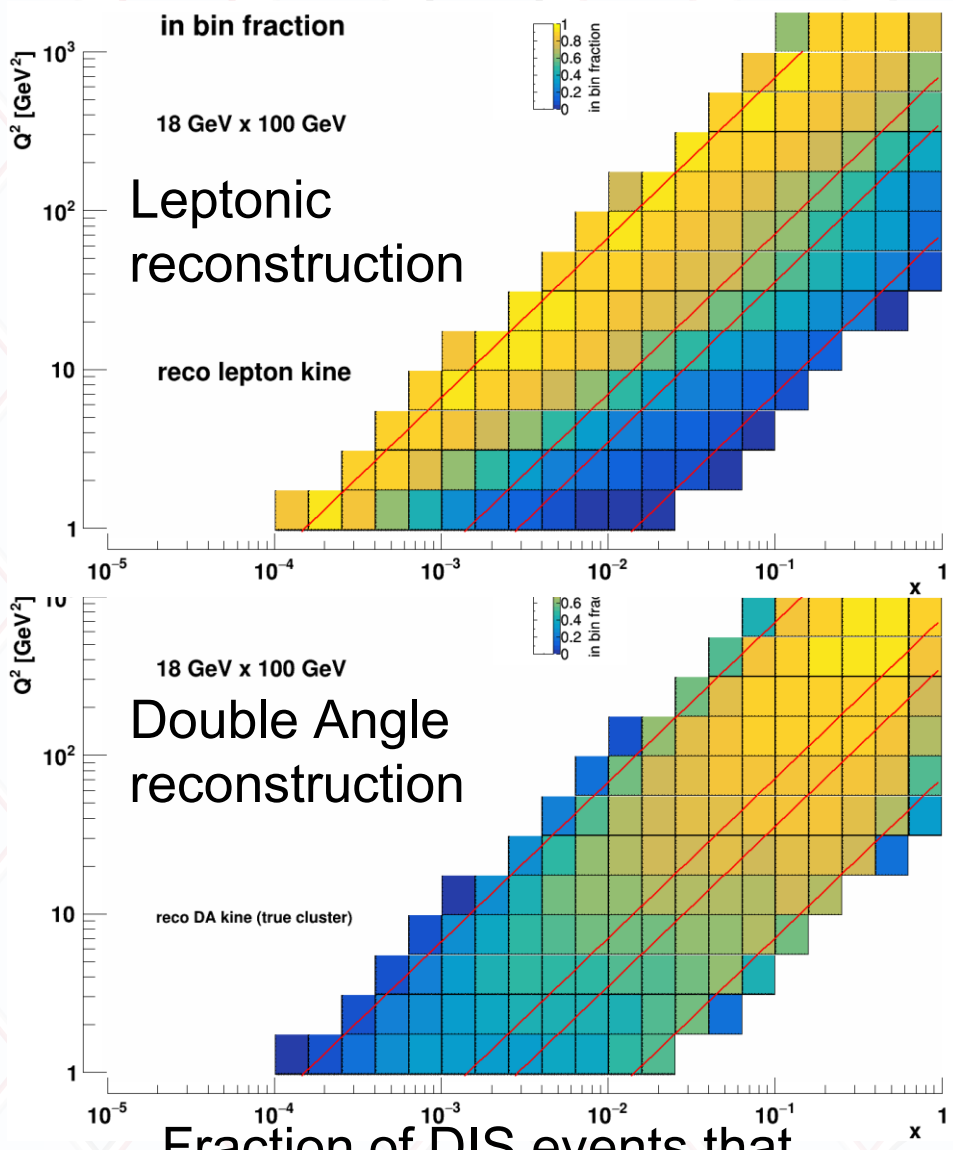
- Questions to SC, Software and simulations groups and other WGs:
  - Is there a global DIS kinematic class/branch planned for all reco methods? Or should we continue with Chris' framework/standalone solutions? At least better to coordinate between Inclusive, SIDIS and Jet WGs
  - Is there a global eID and hadron PID planned?
  - Interplay between track and cluster information, particle flow, isolation criteria

All y resolution widths and means



DIS kinematic reconstruction examples

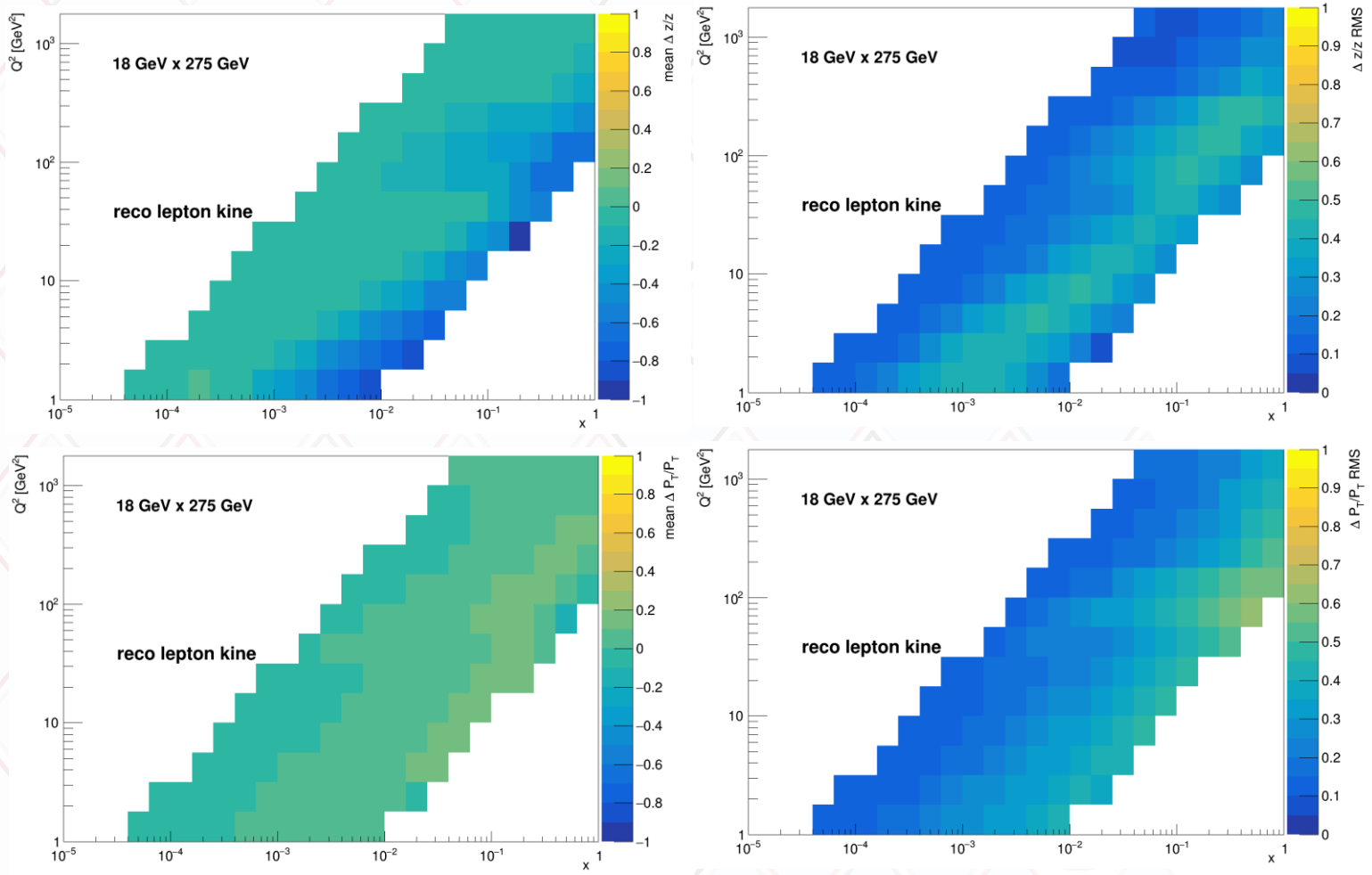
- Full Pythia6+GEANT simulations of the ECCE detector used for various (SI)DIS kinematic resolutions and for various reconstruction methods (lepton, Jaquet-Blondel, Double Angle, etc)
- x and y resolutions suffer from lepton method at lower y, partially recoverable in double angle method(hybrid of scattered lepton + hadronic final state)



Fraction of DIS events that stay in their x-Q^2 bins

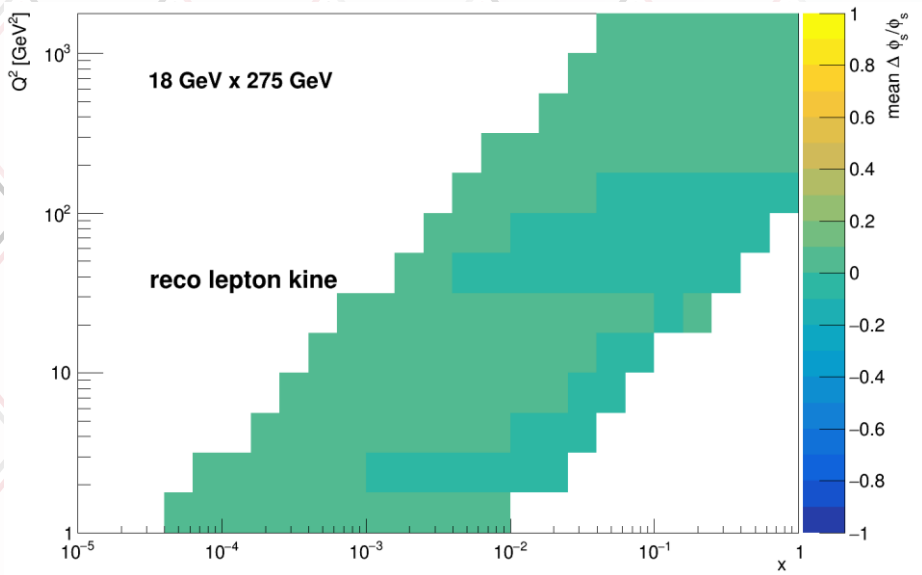
Example of SIDIS resolutions studies

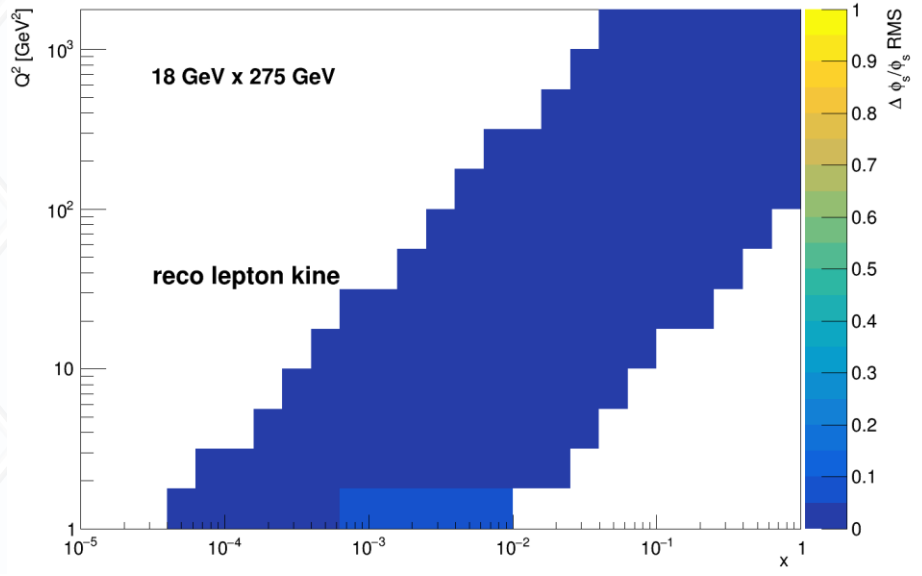
- Full Pythia6+GEANT simulations of the ECCE detector for various (SI)DIS kinematic resolution and reconstruction methods:
  - z resolution suffers in lepton method at lower y, partially recoverable in double angle method
  - p_T and azimuthal angles ϕ_h, ϕ_S very robust

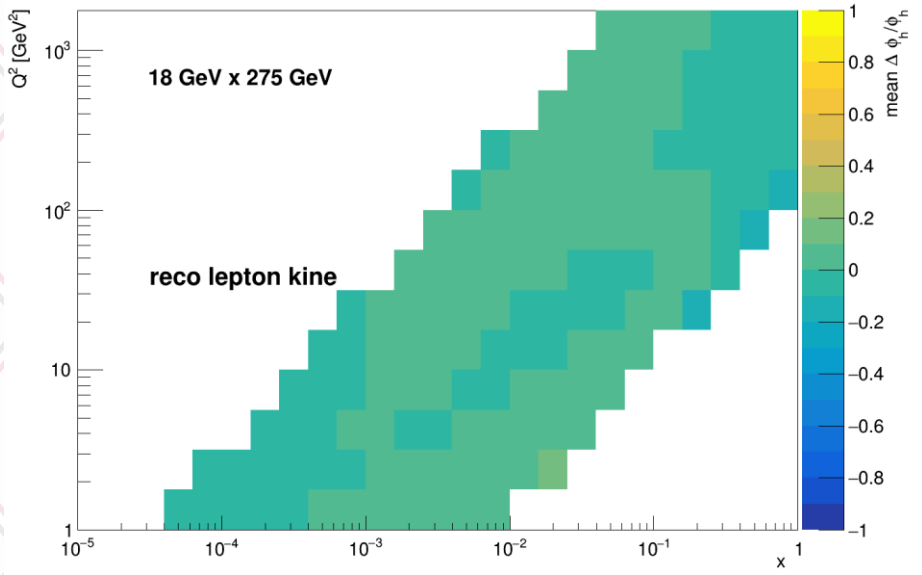


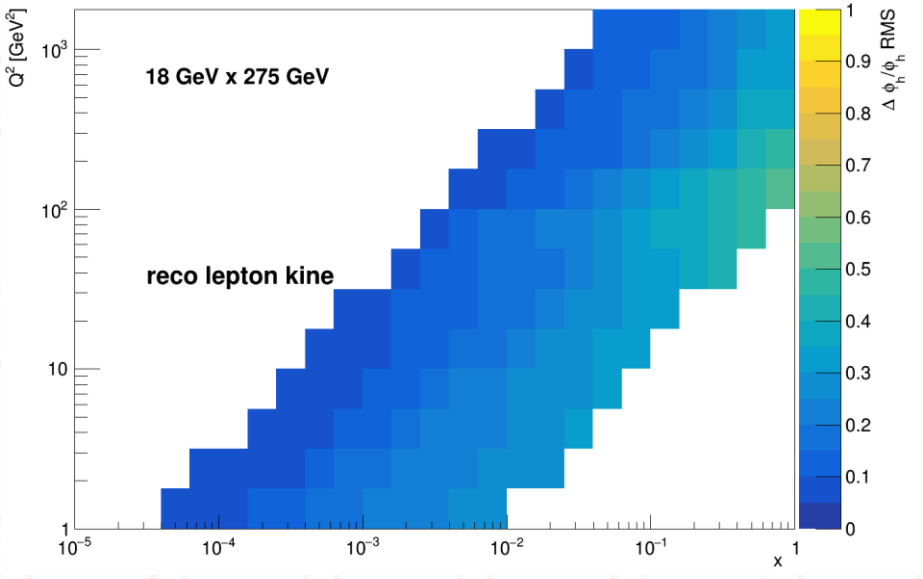
Similar studies by
Matthew McEneaney (Duke), not shown

Azimuthal angles







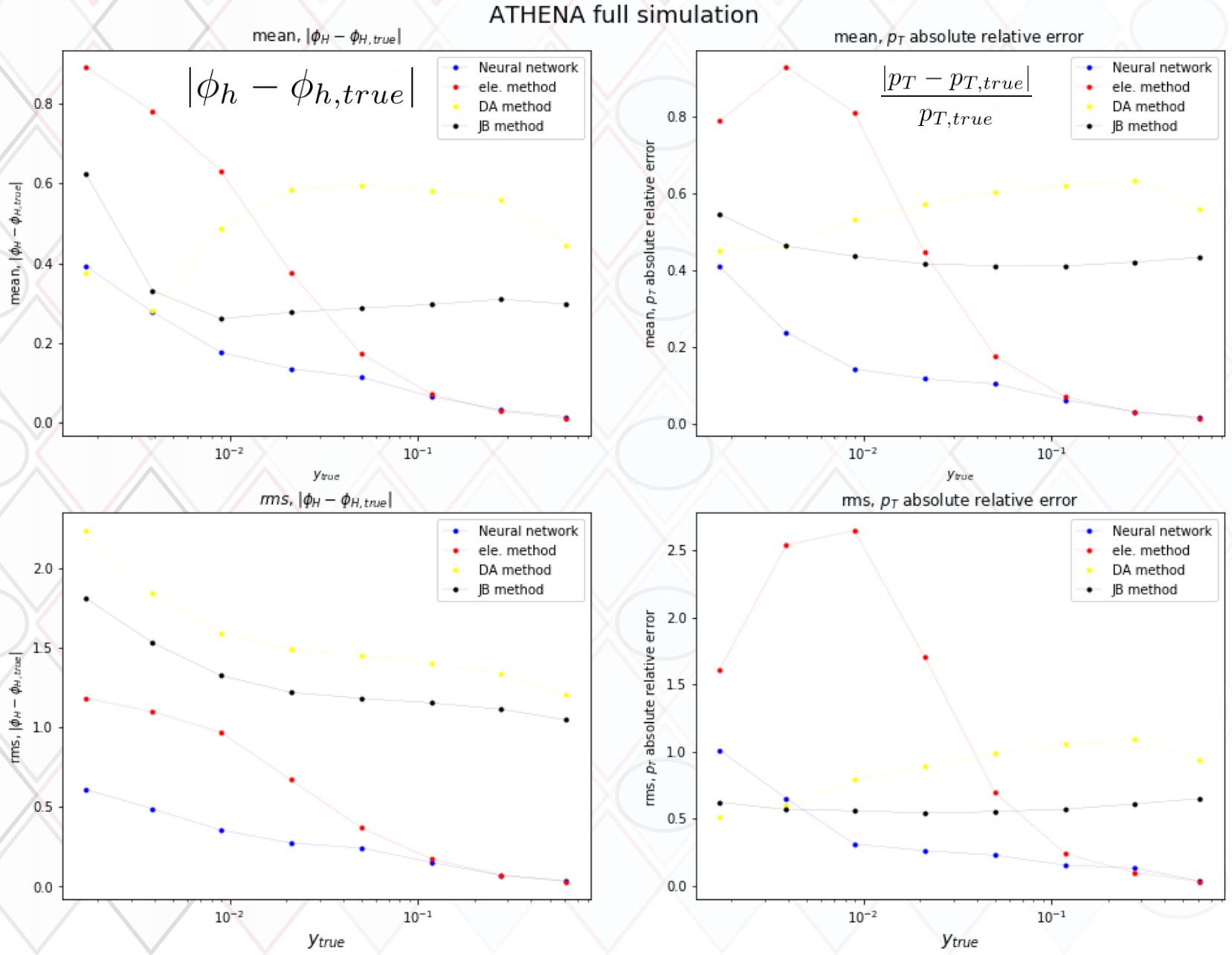


ML optimization studies

ATHENA full simulation, 10x275, pi+, z > 0.2

- Comparison with other HFS/hybrid methods vs y_{true}
- NN by far best performance for azimuthal angle, and at least equaling electron method for large y

Connor Pecar (Duke)



Analysis of longitudinal double-spin asymmetry

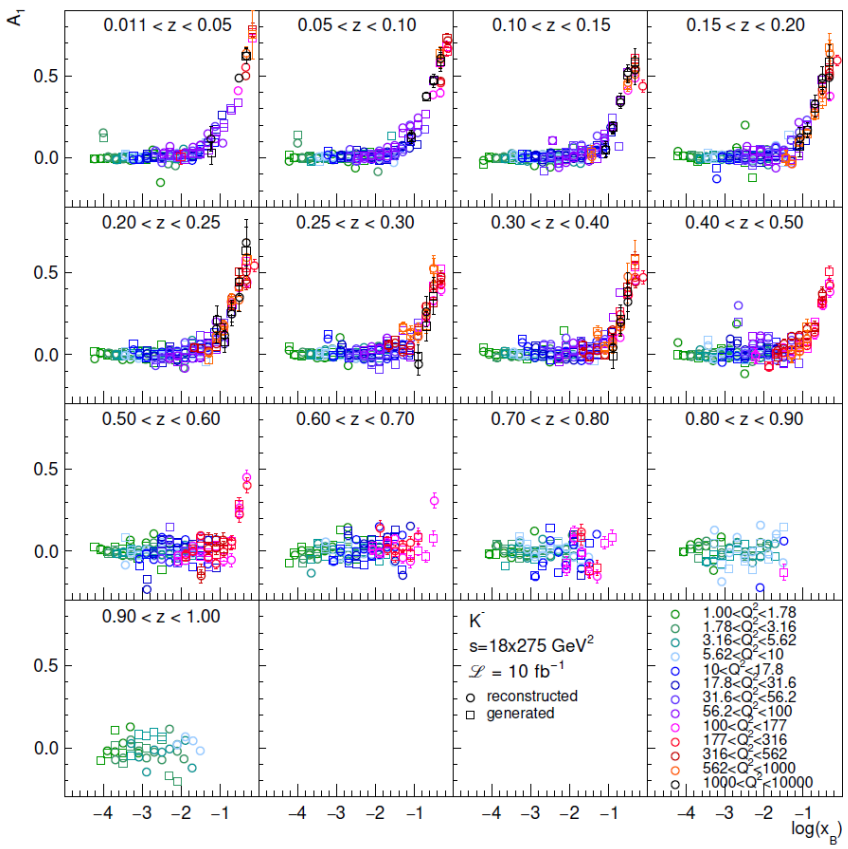
- SIDIS data generated with PYTHIA-6 : 5x41 GeV^2 and 18x275 GeV^2
- Full reconstruction through GEANT simulation (ECCE July concept)
- DIS cuts: $Q^2>1$ GeV^2; $0.01<y<0.95$ and $W^2>10$ GeV^2
- Based on reconstructed scattered electron
- Weighting of events at parton level at NLO:

$$1 + \Lambda D(y) \frac{\Delta \otimes D^{q,g\to h}}{F^h_{UU}}$$

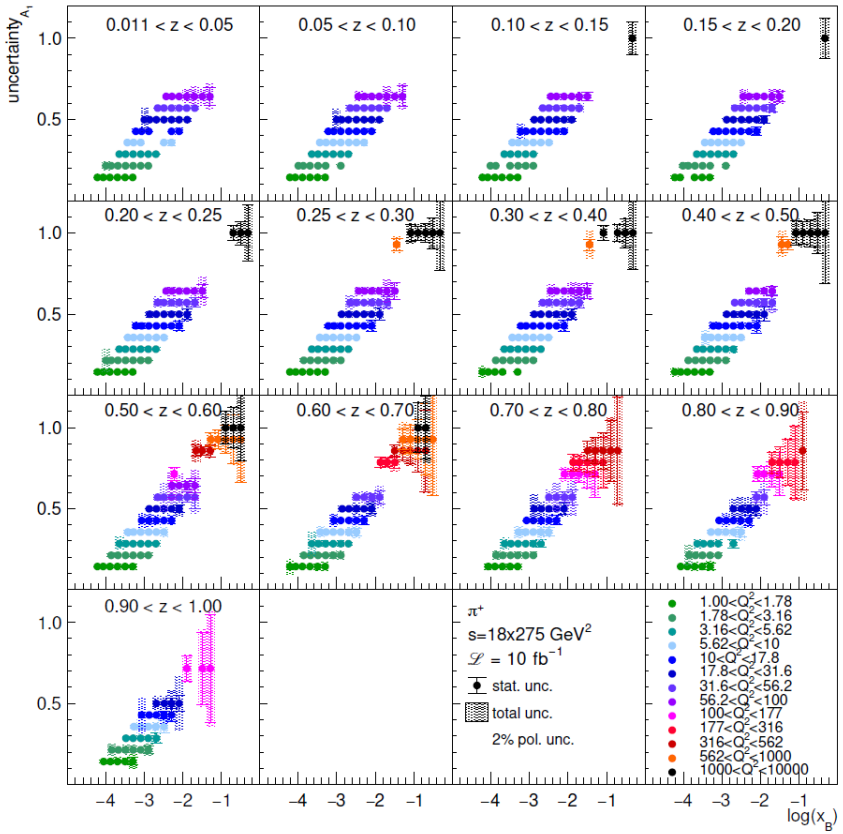
  - $\Lambda=\pm1$: relative beam helicity orientation
  - Δ: DSSV14 helicity distributions
  - $D^{q,g\to h}$ DSS14 pion and kaon fragmentation function
  - Unpolarised F^h_{UU}: NNPDF30_nlo_as_0118 and DSS14 FFs
  - Weighting only for pythia processes: 99, 131-136
  - For ratio of longitudinal and transverse γ* cross section in D(y): Phys. Lett. B, 452:194–200, 1999
  - D(y) set to 1 for evaluation of systematics

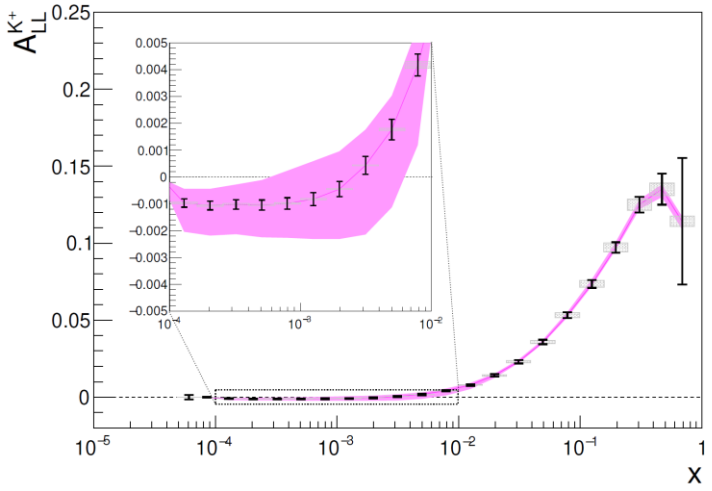
Sea quark helicities

Re-weighted asymmetries



Projected uncertainties



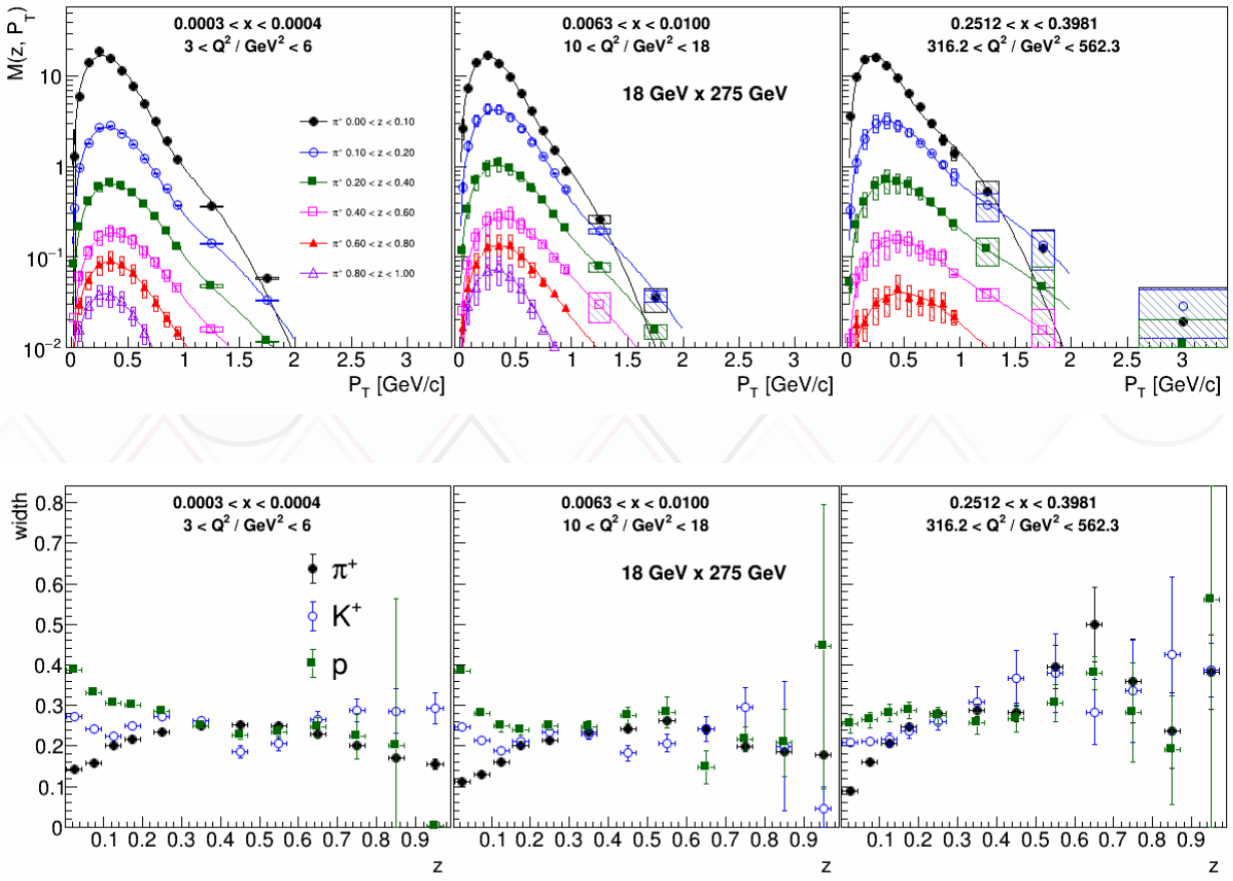


Duane Byer (Duke)

Charlotte van Hulse

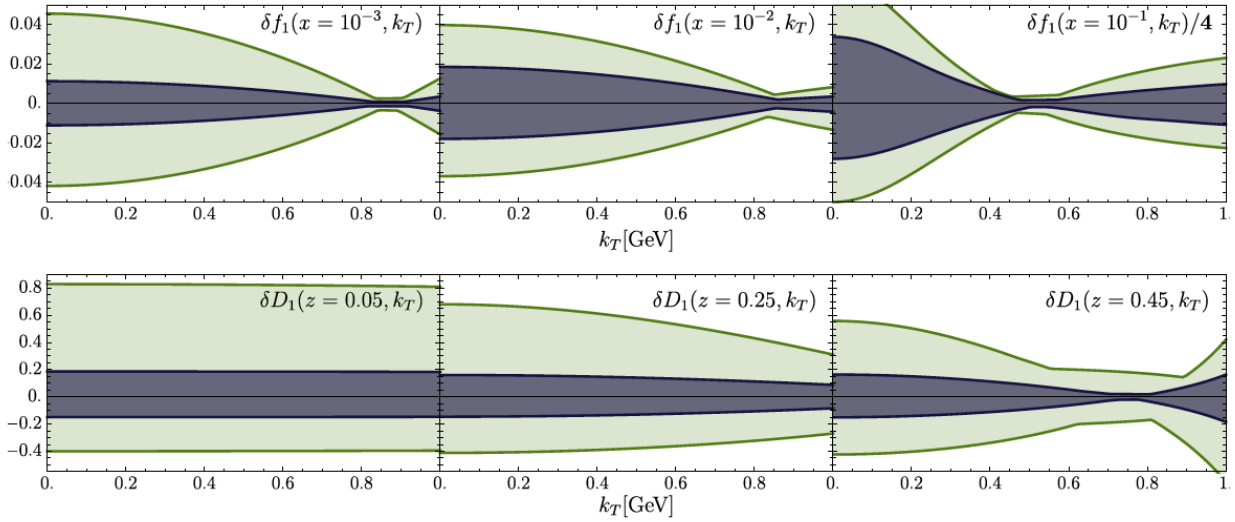
z-dependence of multiplicities and widths

- Top: Explicit z dependence of select pion multiplicities in 3 x-Q^2 bins, including the double-Gaussian fits
- Bottom: behavior of the narrow Gaussian widths vs z for pions, kaons and protons
- Small z discrepancies likely due to target fragmentation

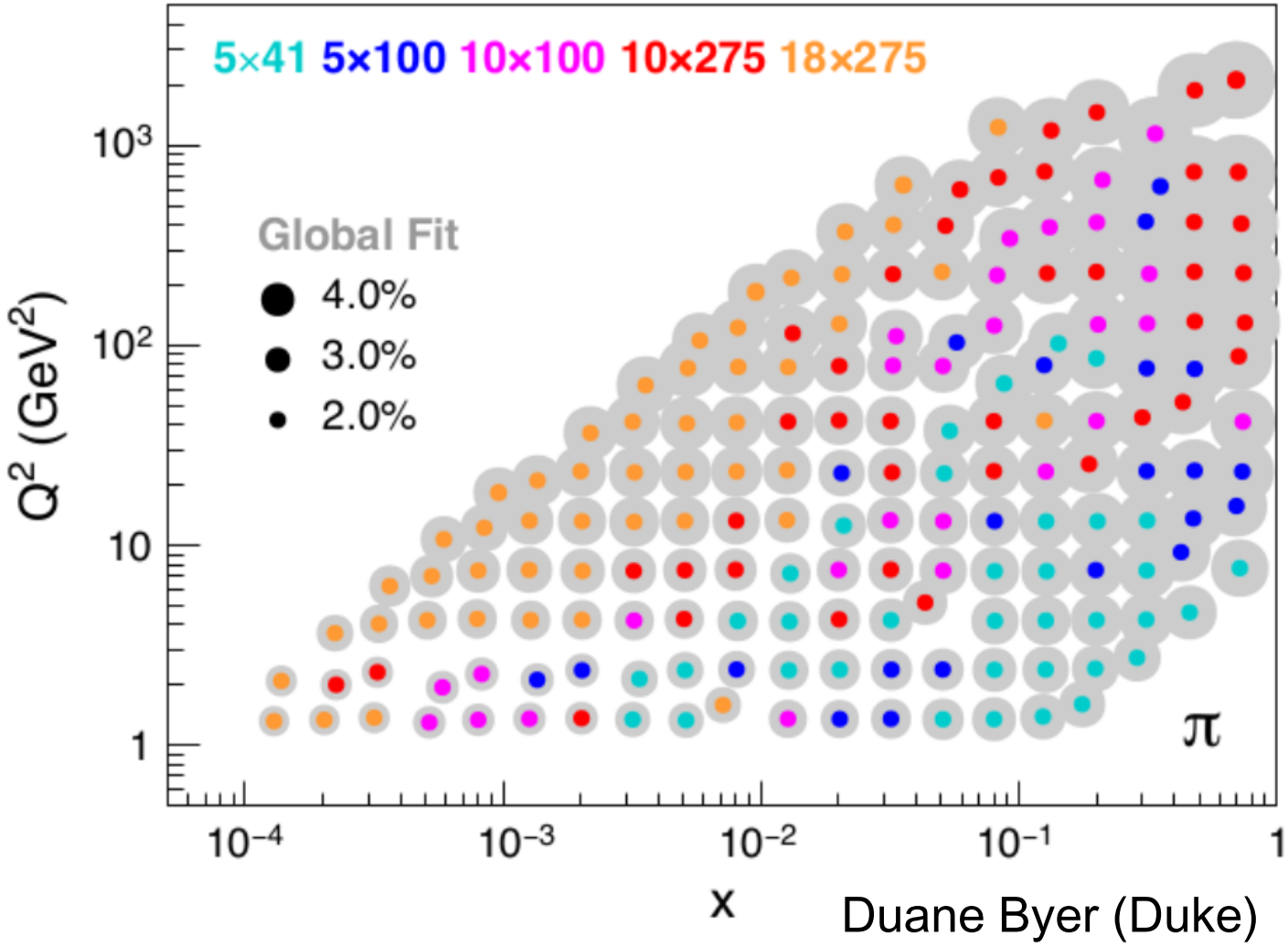


Impact for unpolarized TMD functions

- Similar to YR impact studies following the latest SV global fit (https://arxiv.org/abs/1912.0653 2) for the unpolarized TMDs based on the existing SIDIS +DY data
- Impact figure still that from YR, needs to be replaced (but little differences expected)



Sensitivies on unpol TMDs from Pavia



Duane Byer (Duke)

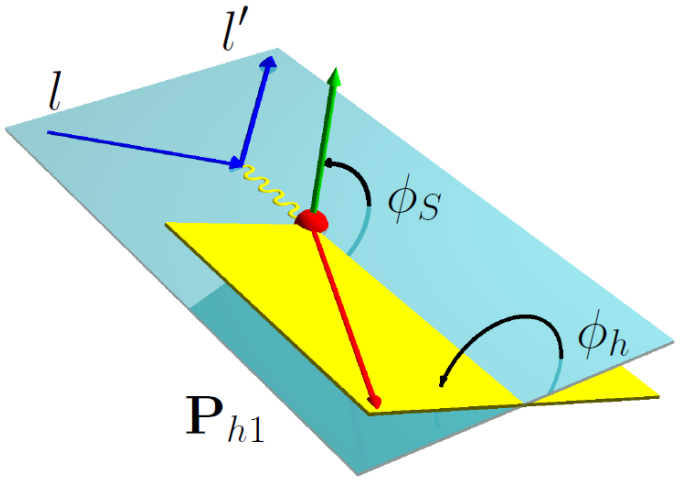
grey blobs = uncertainties from **PV17**

colored blobs = projected uncertainties at various **ATHENA** configurations (including 3% systematic error)

at each (Q^2,x) bin, configuration with largest impact is shown

Sivers/Collins measurements in SIDIS

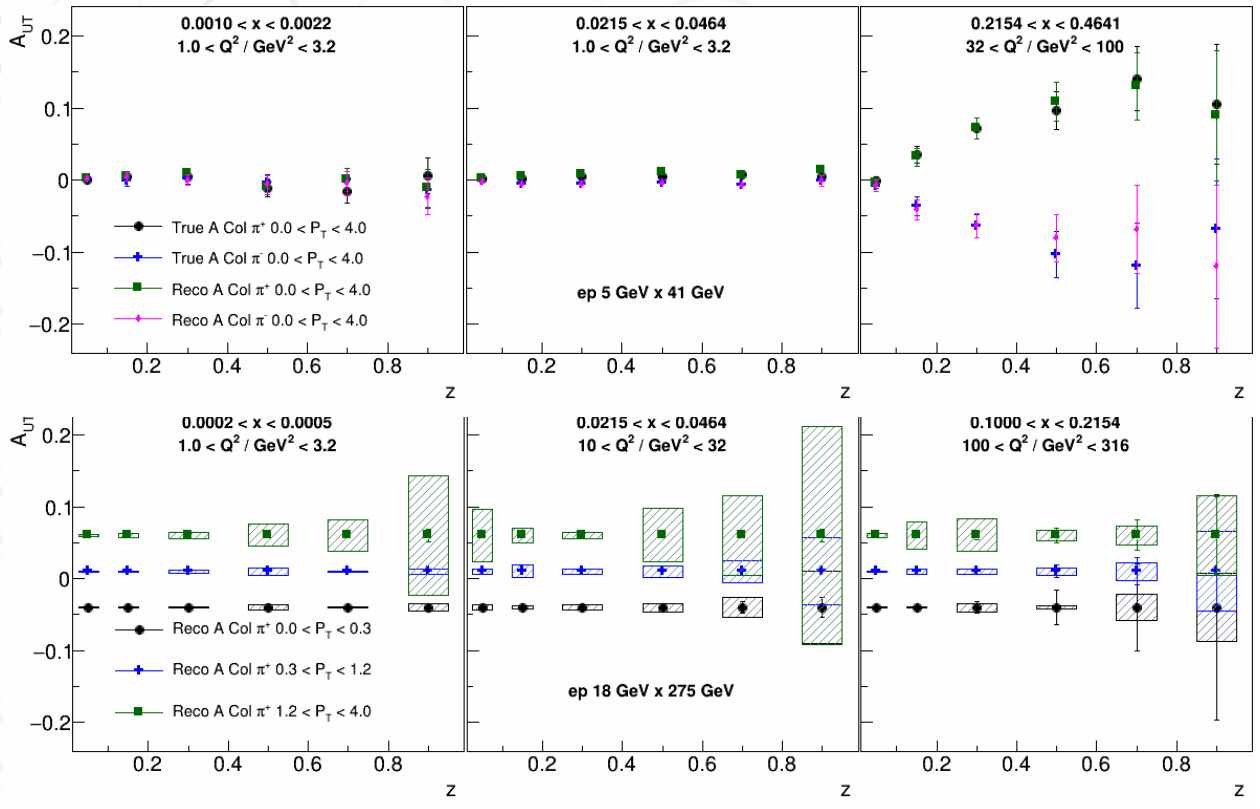
- Reweight events according to true parton flavor q, hadron h, x, z, Q^2, P_{hT}, azimuthal angles and random spin orientiation
- $ep^{\uparrow} \rightarrow e'hX$
- A_{UT} asymmetries (Unpolarized lepton beam, Transversely polarized target)
- Different azimuthal modulations related to Sivers effect ($\sin(\phi-\phi_s)$) and Collins effect ($\sin(\phi+\phi_s)$)
- Fit simultaneously in the reconstructed events and calculate asymmetries

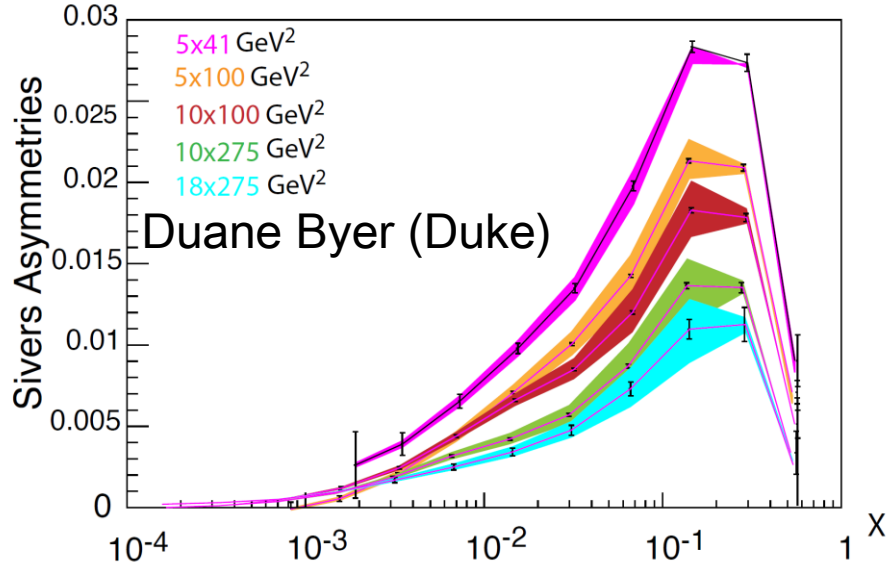


- Input structure functions (polarized and unpolarized) from Torino global fits (arXiv:0812.4366, arXiv:0805.2677) as in https://github.com/prokudin/tmd-parametrizations/

Asymmetries and Projections

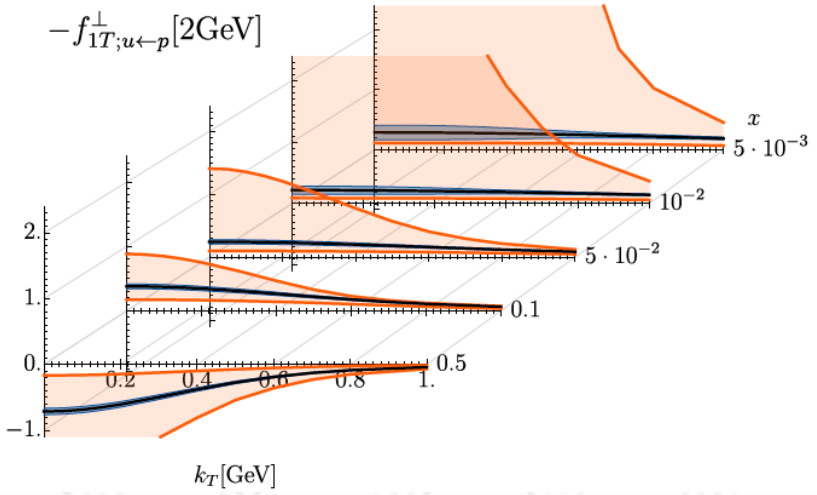
- Systematic uncertainties estimated from differences between true and reconstructed asymmetries → they are likely largely overestimated since most of the kinematic smearing would be unfolded, but give a sense of where uncertainties still might be larger due to that unfolding

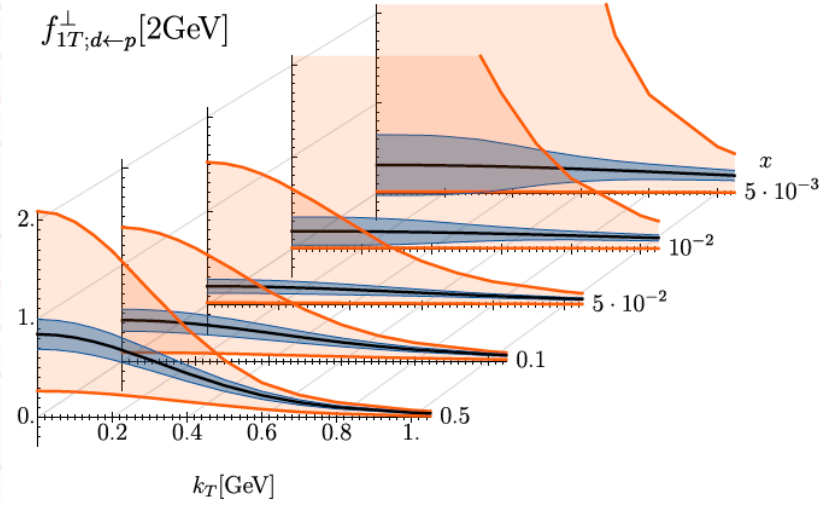




Impact for Sivers functions

- Similar to YR impact studies following the latest BPV global fit (arXiv:2103.03270) for the Sivers function based on the existing SIDIS +DY data
- Uncertainties are shown for current level of knowledge on up/down Sivers functions at various x vs kt and expected impact from ECCE

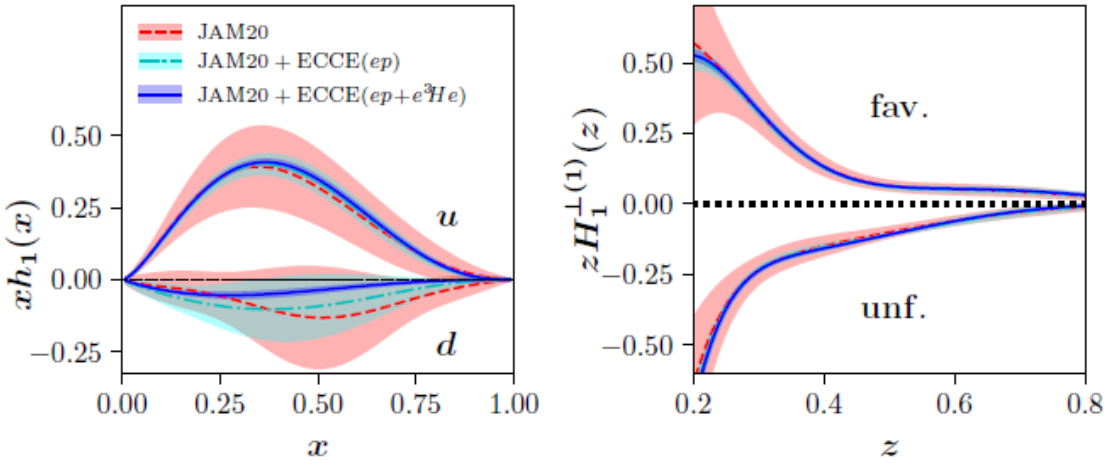


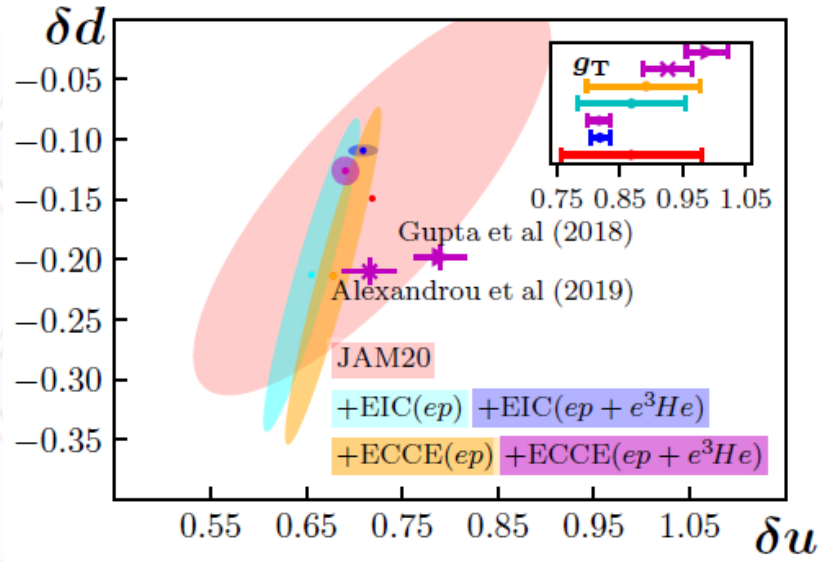


Tensor charge impact

- Similar to Gamberg et al *Phys.Lett.B* 816 (2021) 136255

  (for YR) use fitting code from latest global fit Cammarota et al arXiv:2002.08384 to extract impact on Transversity, Collins functions and tensor charges
- Together with projected JLAB12 data precision to compare with Lattice results (and check for possible discrepancies)

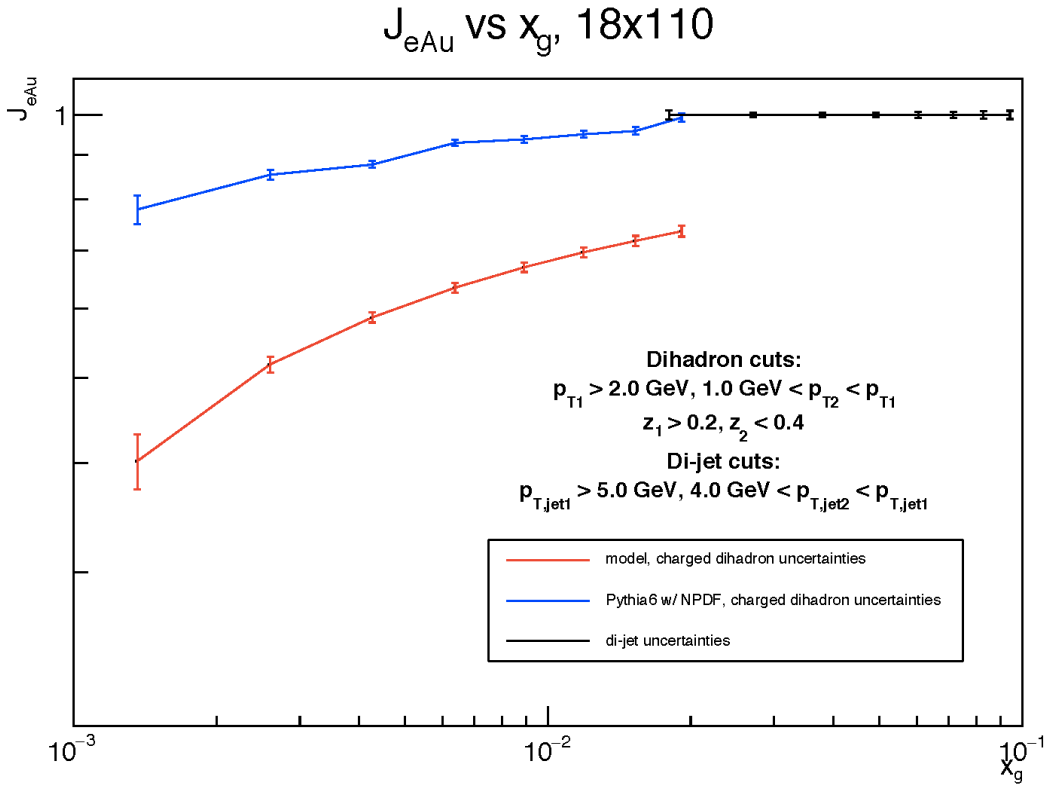




Gluon saturation studies (back-to-back dihadrons)

- Potential to probe gluon saturation with high-pT gluon dijets/dihadrons
- Away side suppression from e+p to e+A

$$J_{eA} = \frac{1}{A^{1/3}} \frac{\sigma_{eA}^{pair}/\sigma_{eA}}{\sigma_{ep}^{pair}/\sigma_{ep}}$$



EIC dijet cuts from: Phys. Rev. D 101, 072003 (2020), Page, Chu, Aschenauer

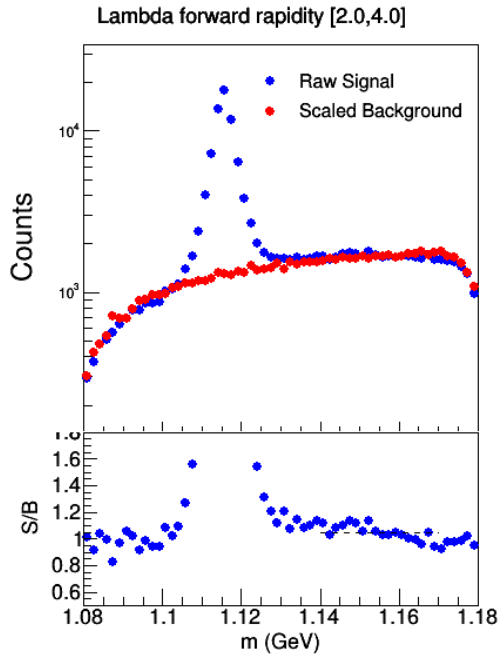
Fast simulation, scaled to 10 fb^{-1}

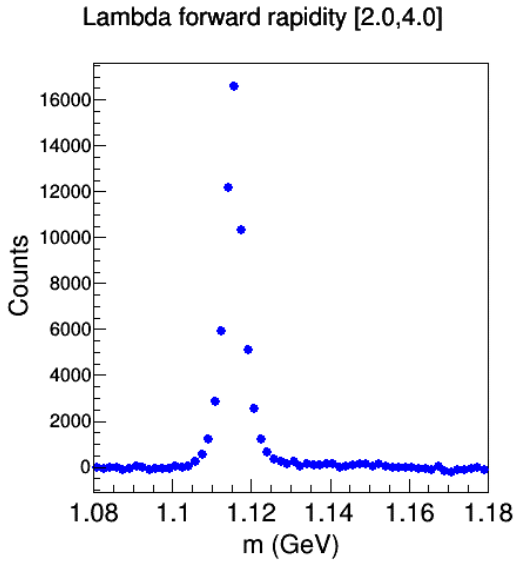
Connor Pecar (Duke)

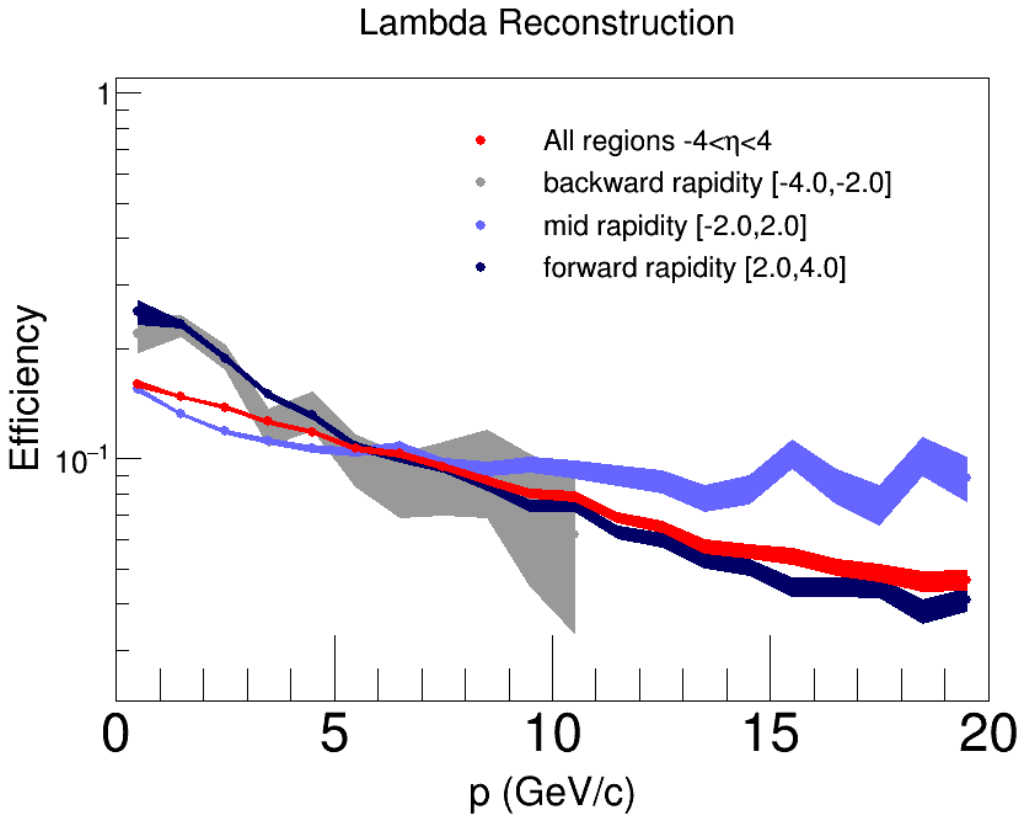
- Red - ATHENA projected dihadron uncertainties on model from Phys.Rev.D. 89, 074037
- Blue - JeAu using NPDF for Au and p, dihadron uncertainties
- Black - dijet uncertainties, no model calculation

RIKEN

Lambda studies







Enea Prifti (UIC)

Summary

- Continue the studies performed by ECCE and ATHENA on
  - (SI)DIS resolutions (coordinate with other WGs?)
  - A_{LL} measurements
  - Unpolarized TMDs
  - Sivers/Collins and DiFF asymmetries
  - Back-to-back di-hadron asymmetries
  - Lambdas
- Use EventEvaluator directly and create interface to sidis-eic framework

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