SIDIS Physics working group

ePIC Collaboration meeting
January 11, 2023

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RIKEN

Organizational

- Meetings: roughly bi-weekly Tuesdays 8:30 ET (14:30 CET/22:30 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: please subscribe to eic-projdet-semiincl-l@lists.bnl.gov
- Mattermost https://eic.cloud.mattermost.com/main/channels/semi-inclusive
- Analysis framework: https://github.com/eic/epic-analysis + some standalone code

Main activities

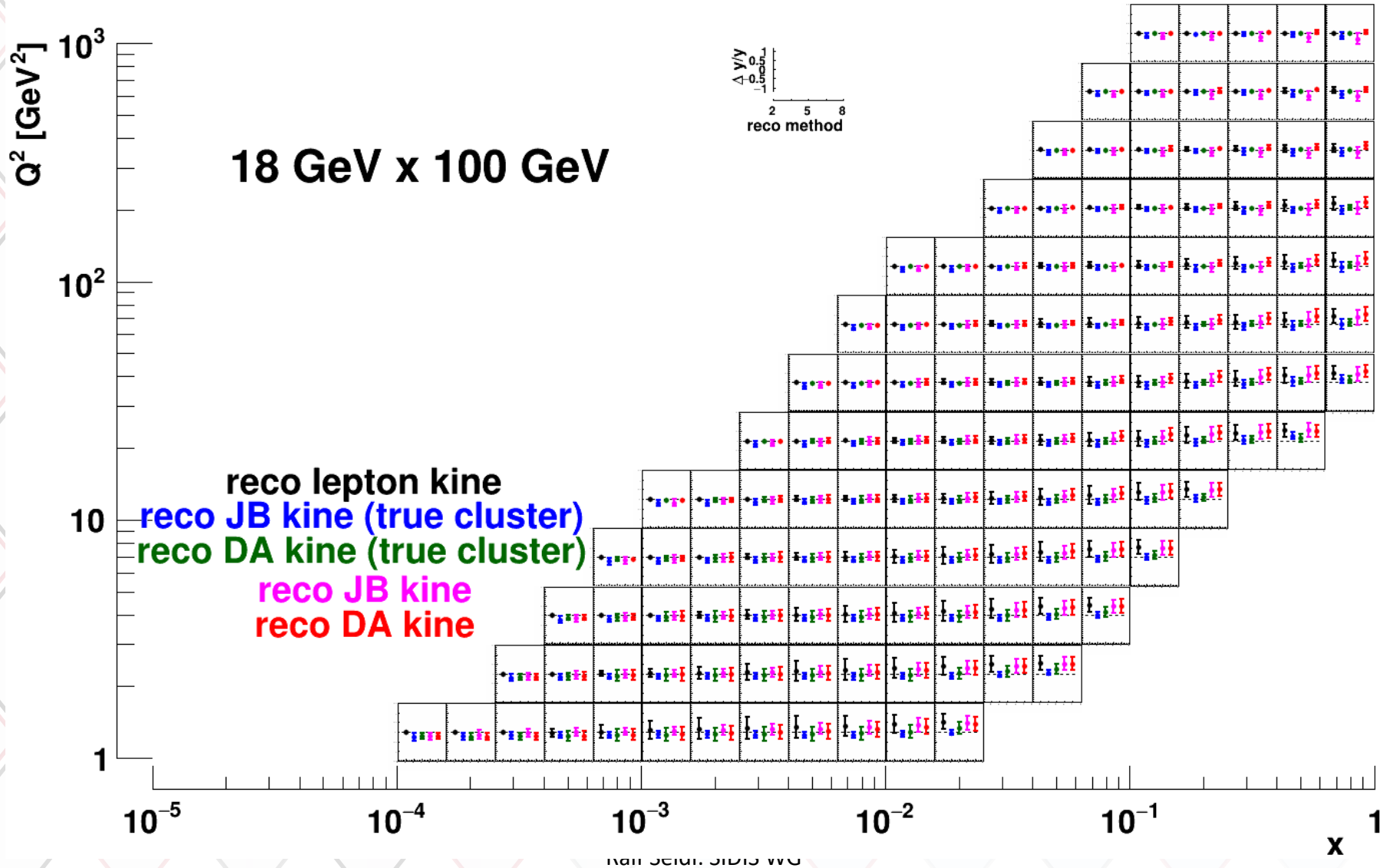
- Main strategy toward CD2/3a:
  - Revisit existing SIDIS studies on (SI)DIS kinematic variable resolutions, track changes with Detector configuration changes, try to optimize kinematic reconstruction even within a method (such as using either tracking or EMCal information for scattered lepton based 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

Existing simulations:

- Pythia6 (using pythiaeRHIC), without radiative corrections, in HepMC3 format, including crossing angle, 4 Q^2 bins: 1-10-100-100-10000 , (18x275,10x100,5x100,5x41), on rcf: */gpfs02/eic/DATA/YR_SIDIS/ep_AAxBBB/hepmc_ip6/noradcor/* in part on S3, including detector simulations at: *S3/eictest/EPIC/RECO/22.11.3/[epic_arches,epic_brycecanyon]/SIDIS/pythia6/ep_[18x275,5x41]/*
- Pythia6 (using pythiaeRHIC), with radiative corrections (radgen), in HepMC3 format, including crossing angle, 4 Q^2 bins: 1-10-100-100-10000 , (18x275,10x100,5x100,5x41), on rcf: */gpfs02/eic/DATA/YR_SIDIS/ep_AAxBBB/hepmc_ip6/radcor/* in part on S3, including detector simulations at:
- Dedicated Λ simulations (2M), Pythia8: on S3/eictest/ATHENA/EVGEN/SIDIS/Lambda and S3/eictest/EPIC/RECO/22.11.3/[epic_arches,epic_brycecanyon]/SIDIS/Lambda_ABCONV/

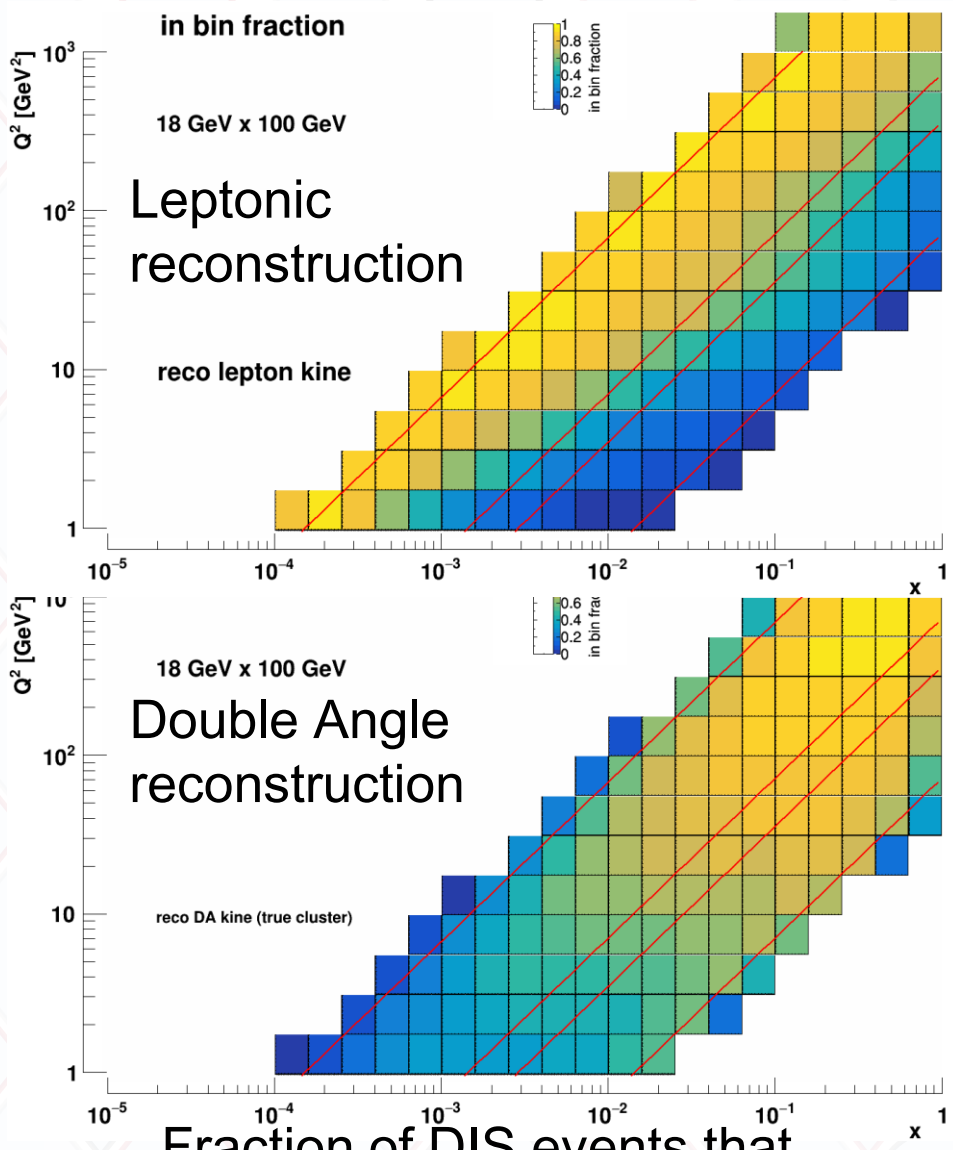
Energy	Q2min	Q2max	Xsec[pb]	#gen files	#events	Lumi [pb-1]
noradcor.18x275	1	10	8.09E+05	20	40M	4.95E+01
noradcor.18x275	10	100	7.09E+04	20	20M	2.82E+02
noradcor.18x275	100	1000	3.03E+03	40	4M	1.32E+03
noradcor.18x275	1000	100000	5.70E+01	20	1M	1.76E+04
noradcor.10x100	1	10	5.39E+05	20	40M	7.42E+01
noradcor.10x100	10	100	3.96E+04	20	20M	5.05E+02
noradcor.10x100	100	1000	1.20E+03	20	2M	1.67E+03
noradcor.10x100	1000	100000	4.29E+00	20	1M	2.33E+05
noradcor.5x100	1	10	4.46E+05	20	40M	8.96E+01
noradcor.5x100	10	100	2.90E+04	20	20M	6.89E+02
noradcor.5x100	100	1000	6.47E+02	20	2M	3.09E+03
noradcor.5x100	1000	100000	2.09E-01	20	0.2M	9.56E+05
noradcor.5x41	1	10	3.43E+05	20	40M	1.17E+02
noradcor.5x41	10	100	1.94E+04	20	20M	1.03E+03
noradcor.5x41	100	1000	2.22E+02	20	2M	9.01E+03
radcor.18x275	1	10	8.54E+05	20	40M	4.68E+01
radcor.18x275	10	100	1.46E+05	20	20M	1.37E+02
radcor.18x275	100	1000	6.92E+03	40	4M	5.78E+02
radcor.18x275	1000	100000	1.21E+02	20	1M	8.25E+03
radcor.5x41	1	10	3.73E+05	200	20M	5.36E+01
radcor.5x41	10	100	2.29E+04	1000	10M	4.37E+02
radcor.5x41	100	1000	2.58E+02	20	2M	7.76E+03

All y resolution widths and means



DIS kinematic reconstruction examples

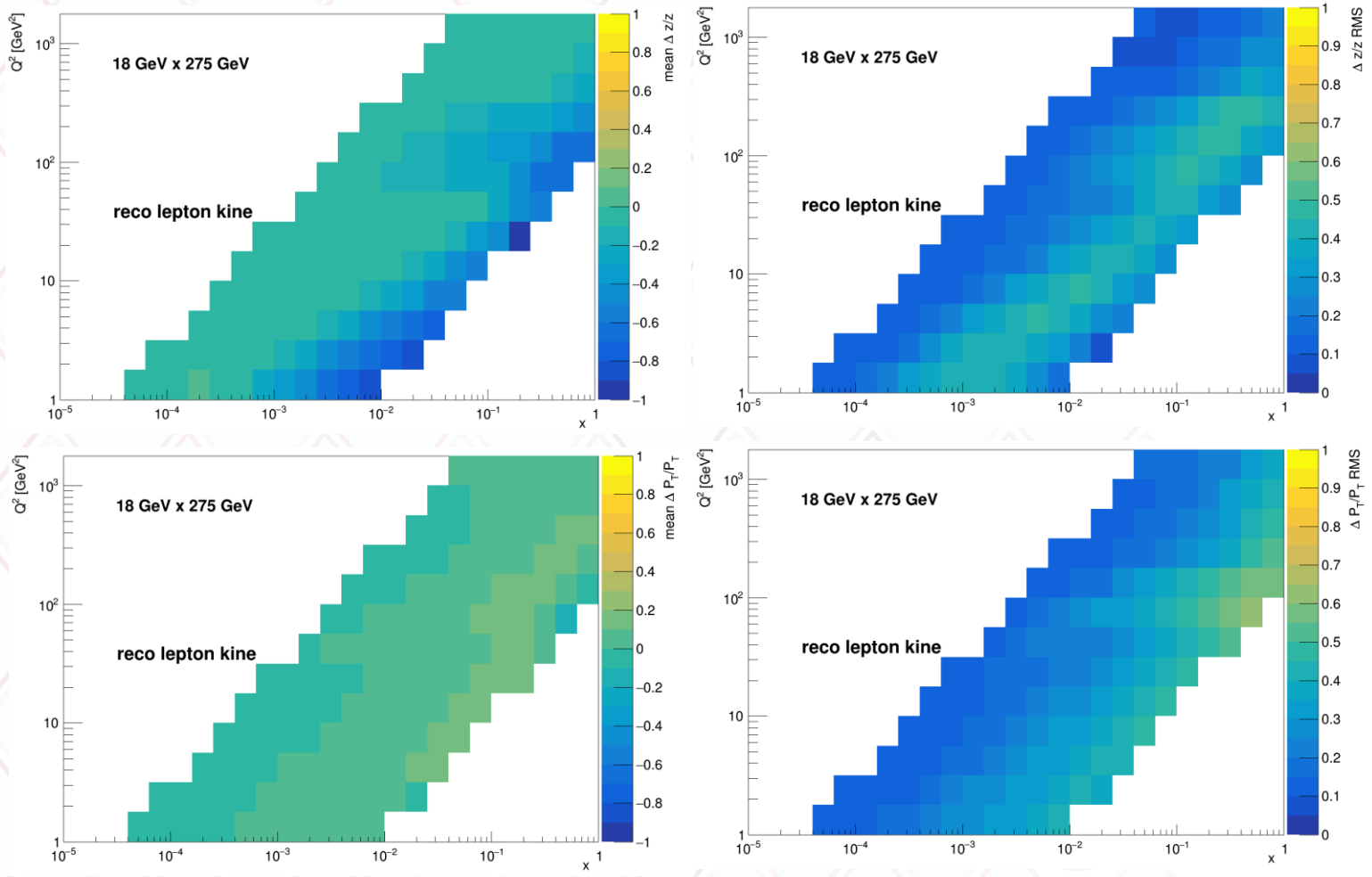
- Full Pythia6+GEANT simulations of the ECCE detector used for various (SI)DIS kinematic resolutions and for various reconstruction methods (lepton, Jaquet-Blondel, Double Angle, etc)
- x and y resolutions suffer from lepton method at lower y, partially recoverable in double angle method(hybrid of scattered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



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

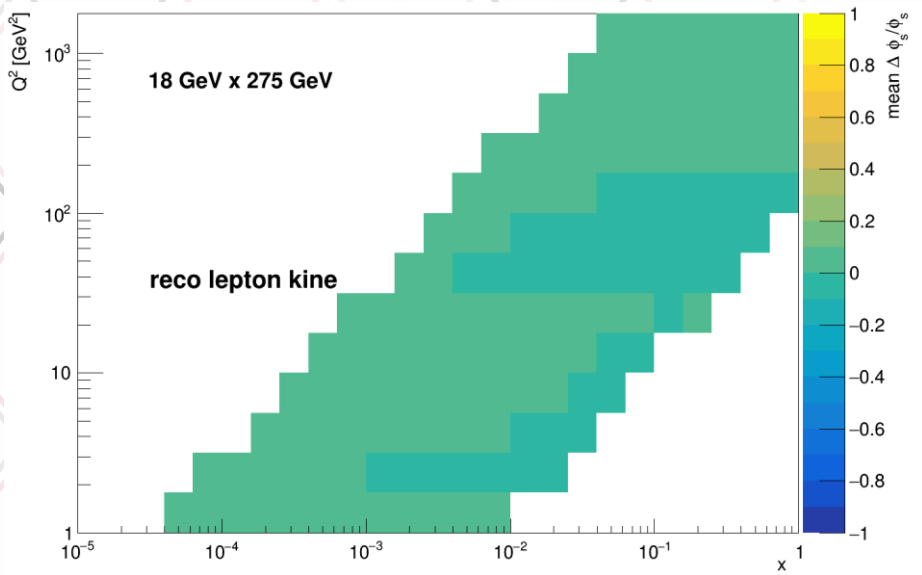
Example of SIDIS resolutions studies

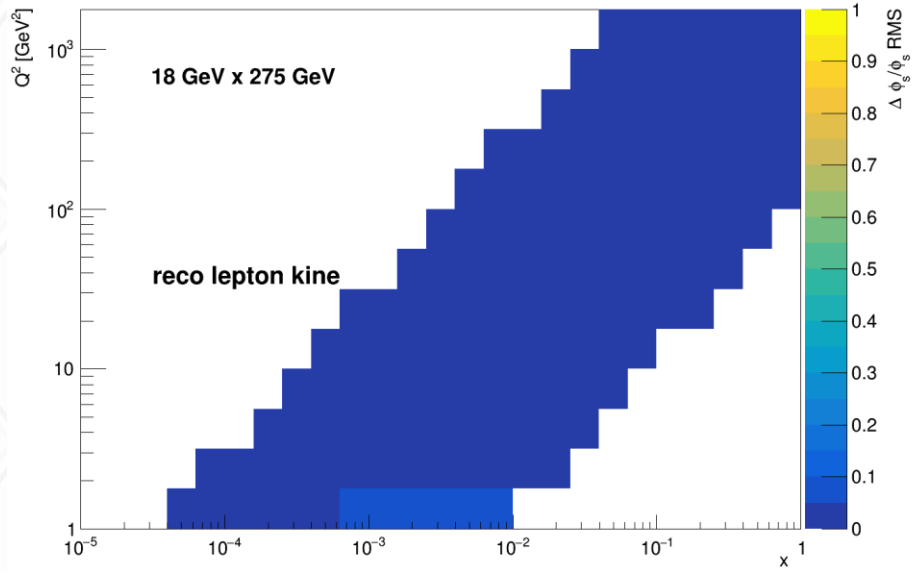
- Full Pythia6+GEANT simulations of the ECCE detector for various (SI)DIS kinematic resolution and reconstruction methods:
  - z resolution suffers in lepton method at lower y, partially recoverable in double angle method
  - p_T and azimuthal angles ϕ_h, ϕ_S very robust

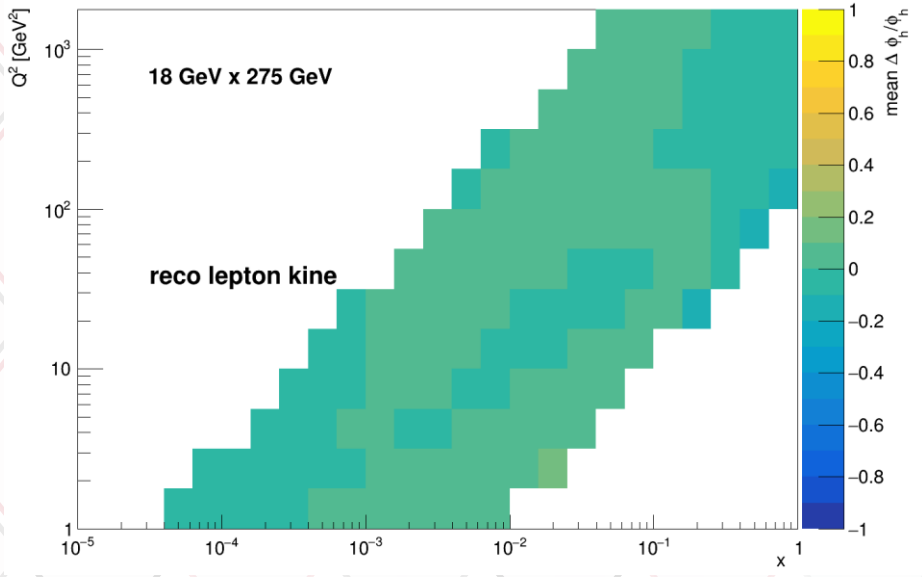


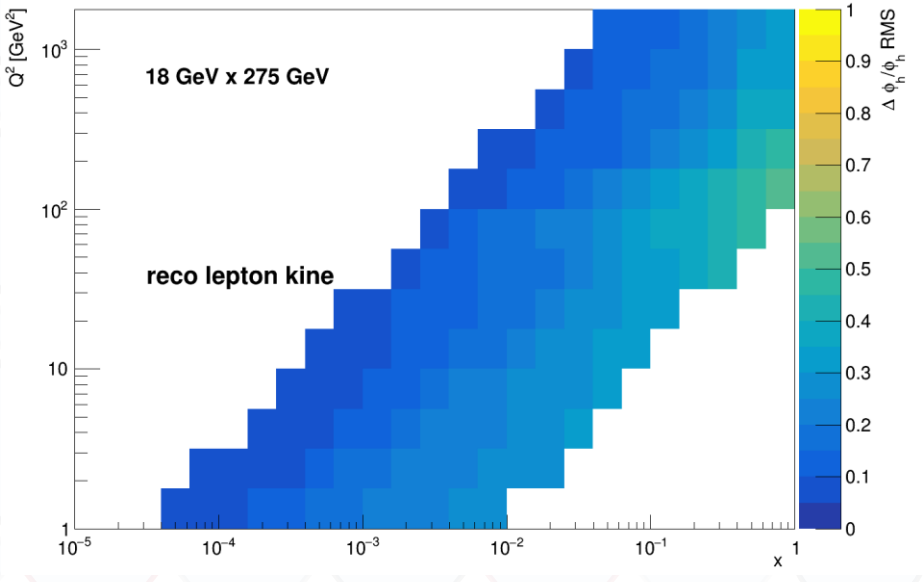
Similar studies by
Matthew McEneaney (Duke), not shown

Azimuthal angles







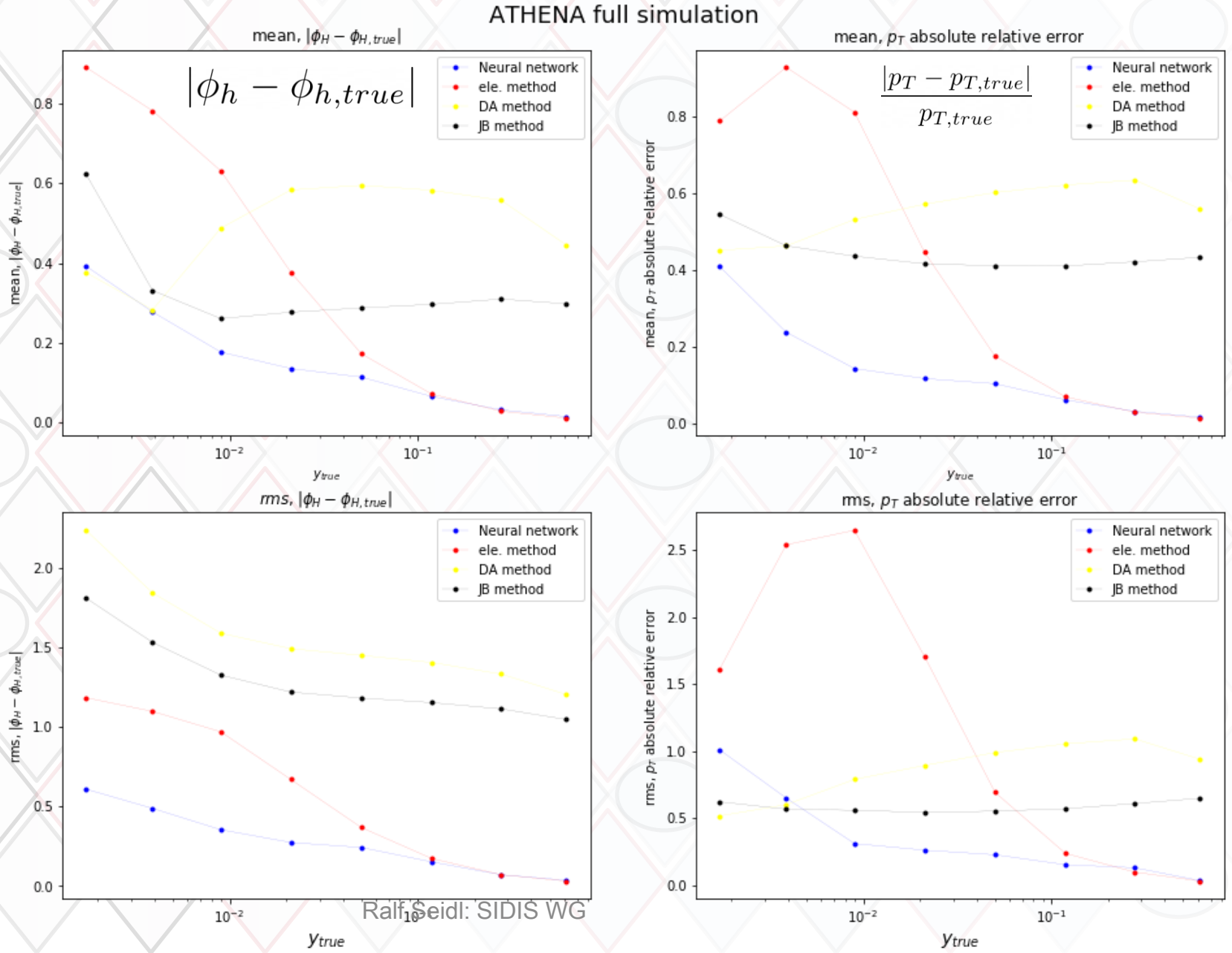


ML optimization studies

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

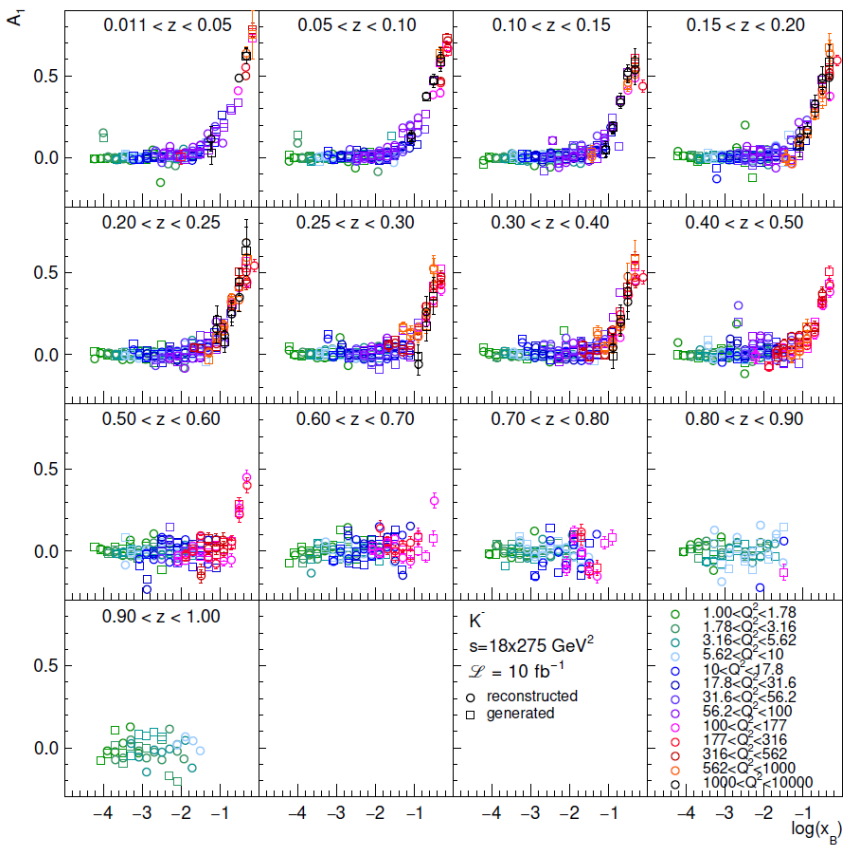
- SIDIS data generated with PYTHIA-6 : 5x41 GeV^2 and 18x275 GeV^2
- Full reconstruction through GEANT simulation (ECCE July concept)
- DIS cuts: $Q^2>1$ GeV^2; $0.01<y<0.95$ and $W^2>10$ GeV^2
- Based on reconstructed scattered electron
- Weighting of events at parton level at NLO:

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

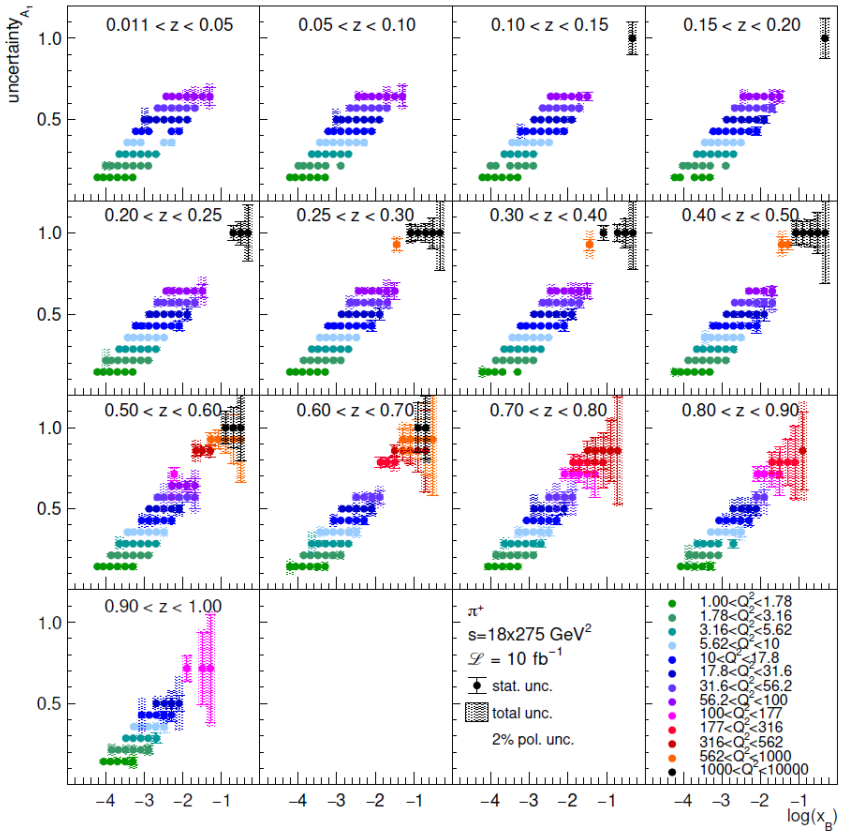
  - $\Lambda=\pm1$: relative beam helicity orientation
  - Δ: DSSV14 helicity distributions
  - $D^{q,g\to h}$ DSS14 pion and kaon fragmentation function
  - Unpolarised F^h_{UU}: NNPDF30_nlo_as_0118 and DSS14 FFs
  - Weighting only for pythia processes: 99, 131-136
  - For ratio of longitudinal and transverse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

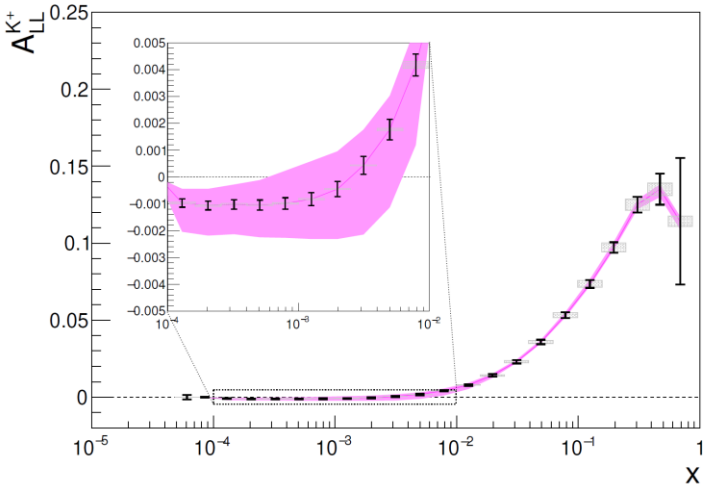
Sea quark helicities

Re-weighted asymmetries



Projected uncertainties



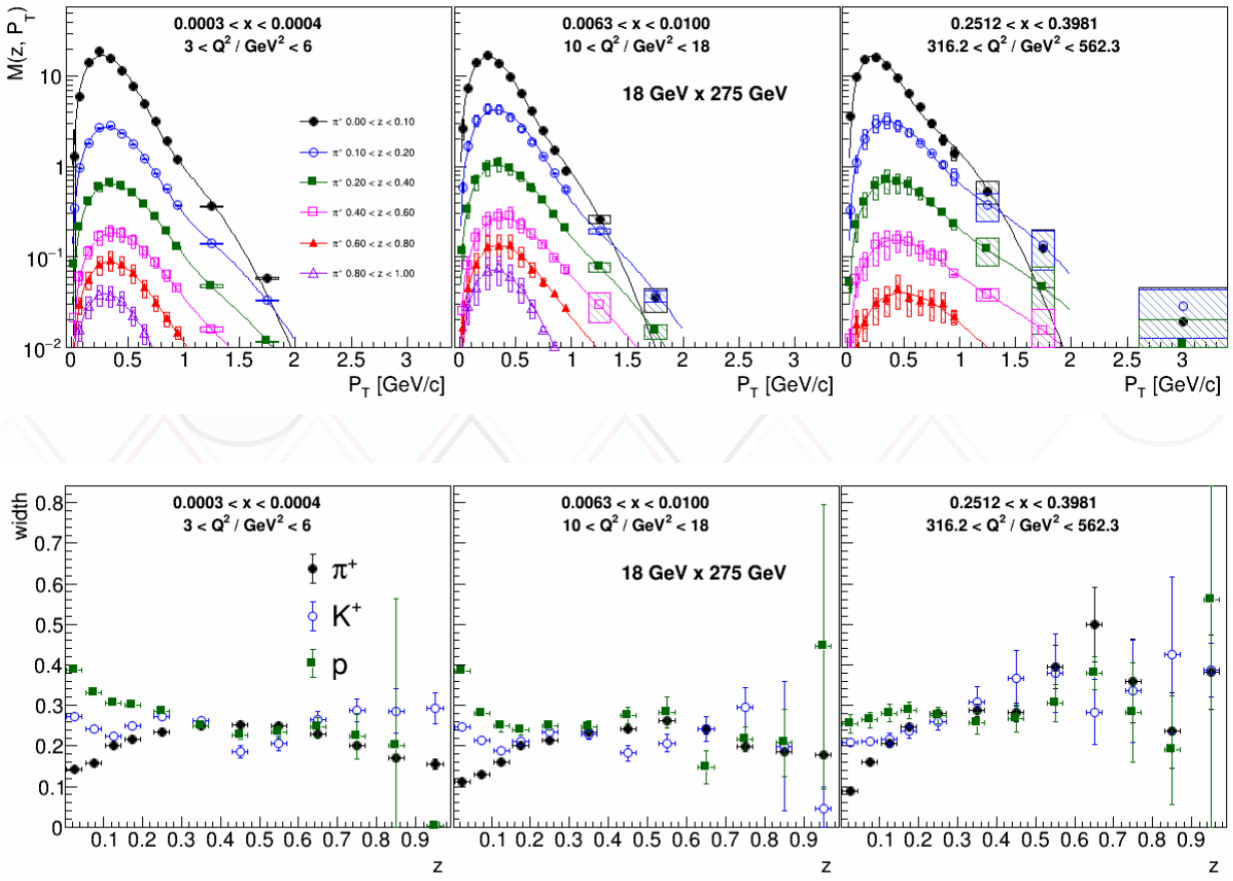


Duane Byer (Duke)

Charlotte van Hulse

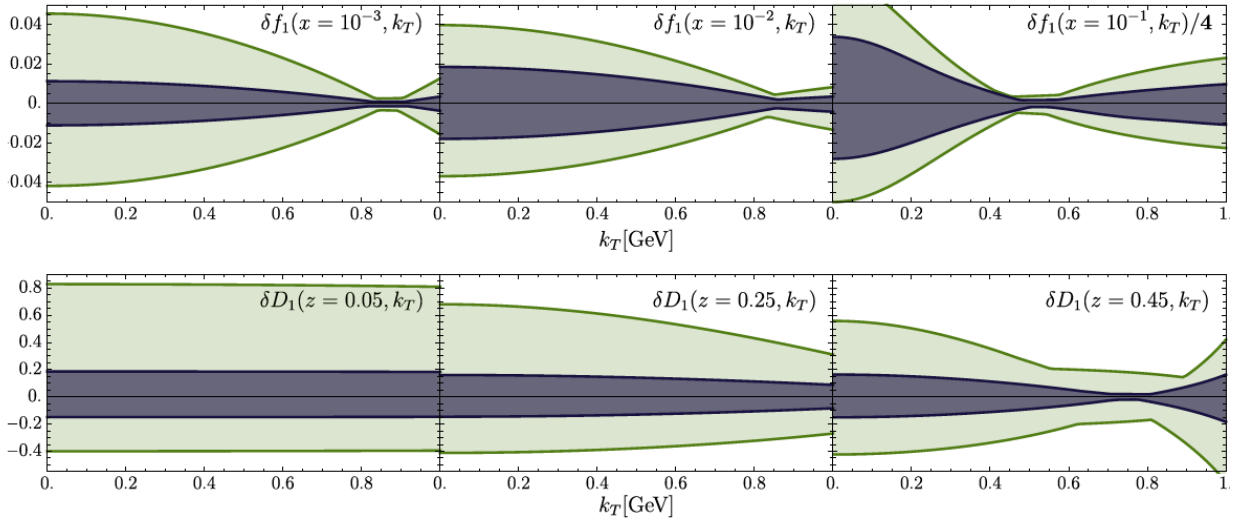
z-dependence of multiplicities and widths

- 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

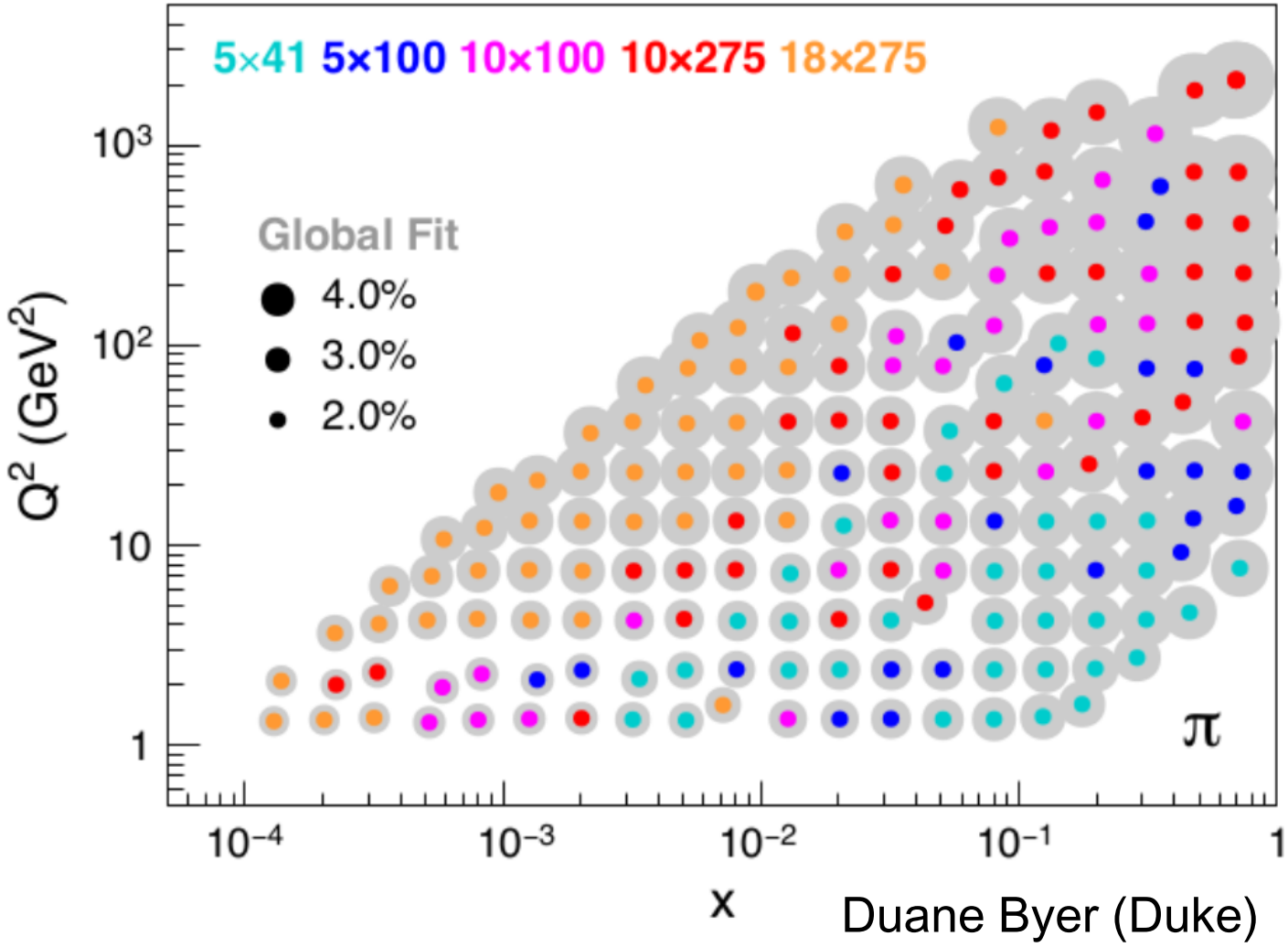


Impact for unpolarized TMD functions

- 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)

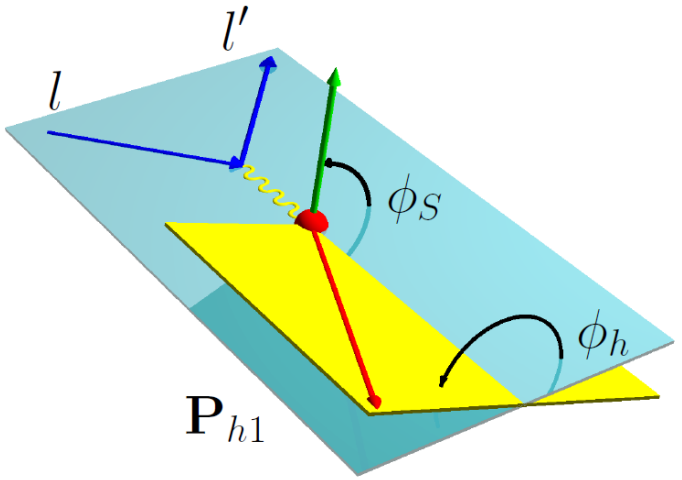
grey blobs = uncertainties from **PV17**

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

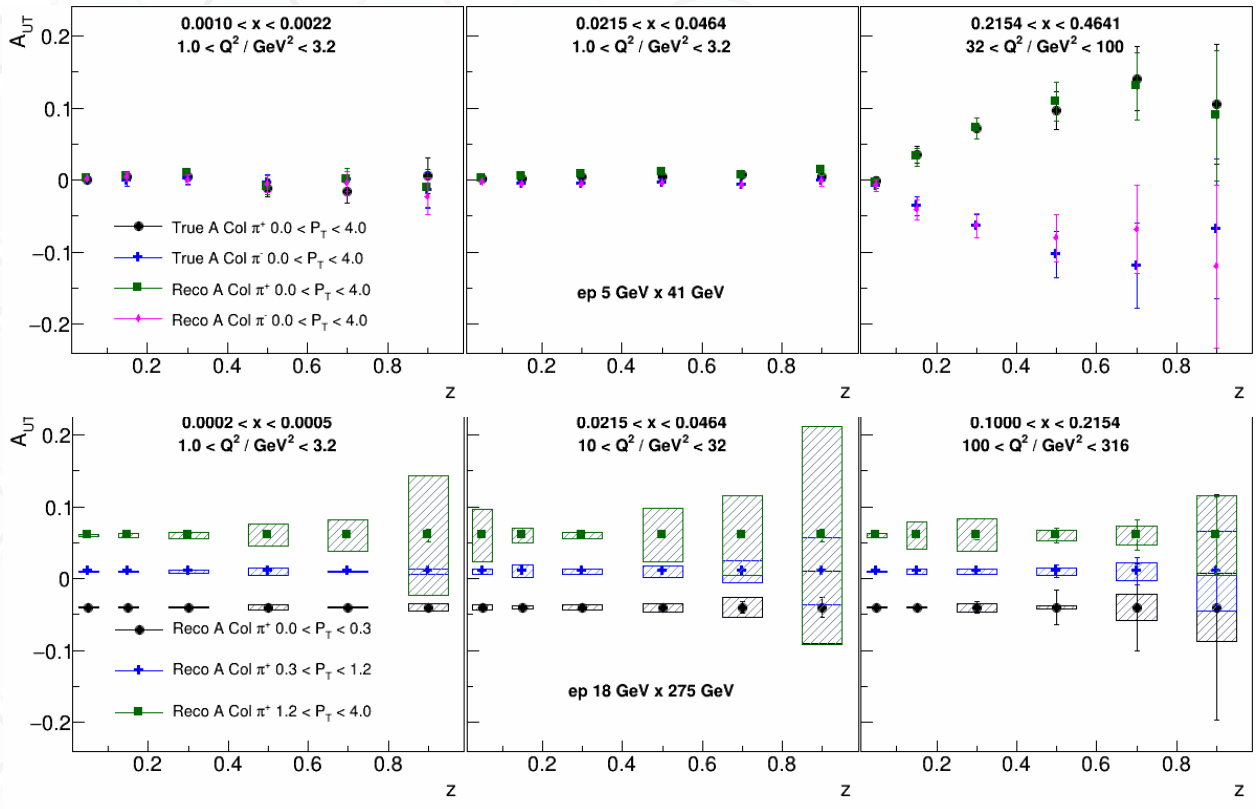
- Reweight events according to true parton flavor q, hadron h, x, z, Q^2, P_{hT}, azimuthal angles and random spin orientiation
- $ep^{\uparrow} \rightarrow e'hX$
- A_{UT} asymmetries (Unpolarized lepton beam, Transversely polarized target)
- Different azimuthal modulations related to Sivers effect ($\sin(\phi-\phi_s)$)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

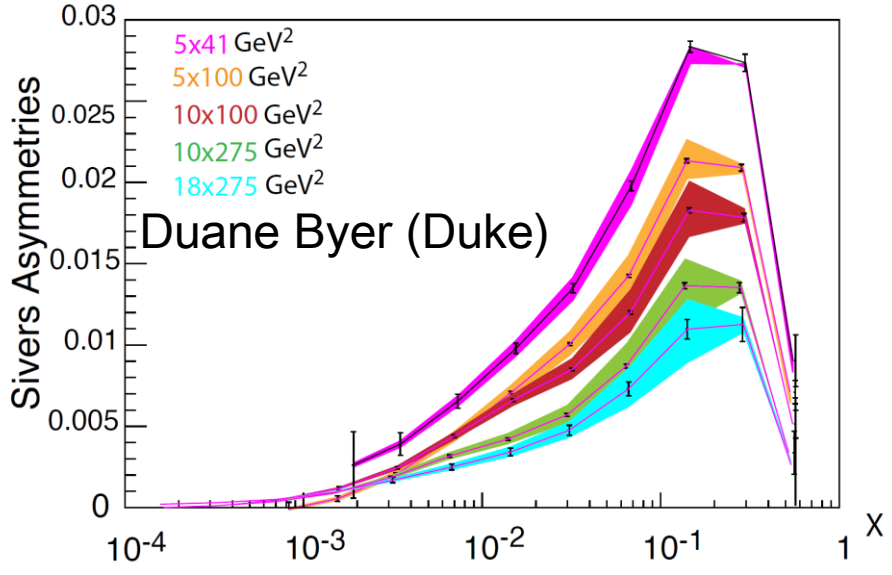


- Input structure functions (polarized and unpolarized) from Torino global fits (arXiv:0812.4366, arXiv:0805.2677) as in https://github.com/prokudin/tmd-parametrizations/

Asymmetries and Projections

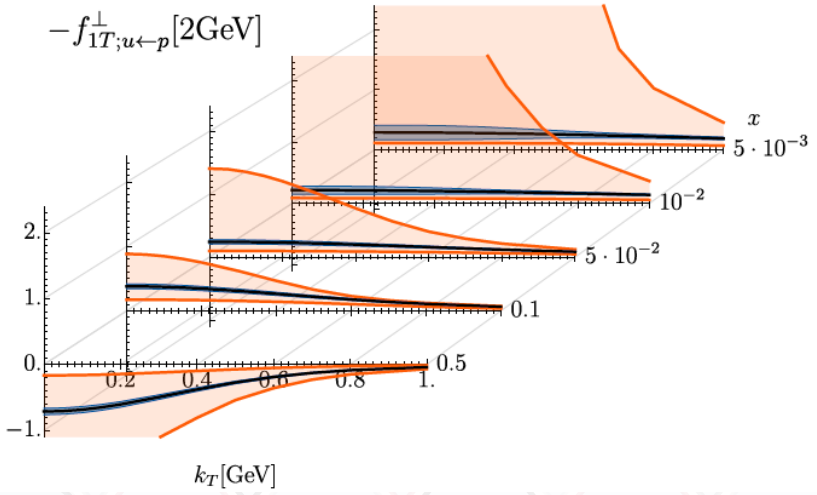
- Systematic uncertainties estimated from differences between true and reconstructed asymmetries → they are likely largely overestimated since most of the kinematic smearing would be unfolded, but give a sense of where uncertainties still might be larger due to that unfolding

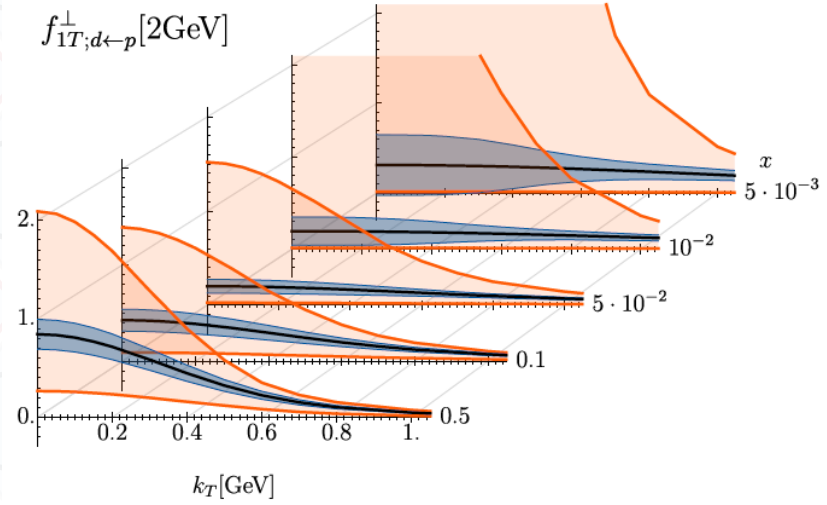




Impact for Sivers functions

- 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



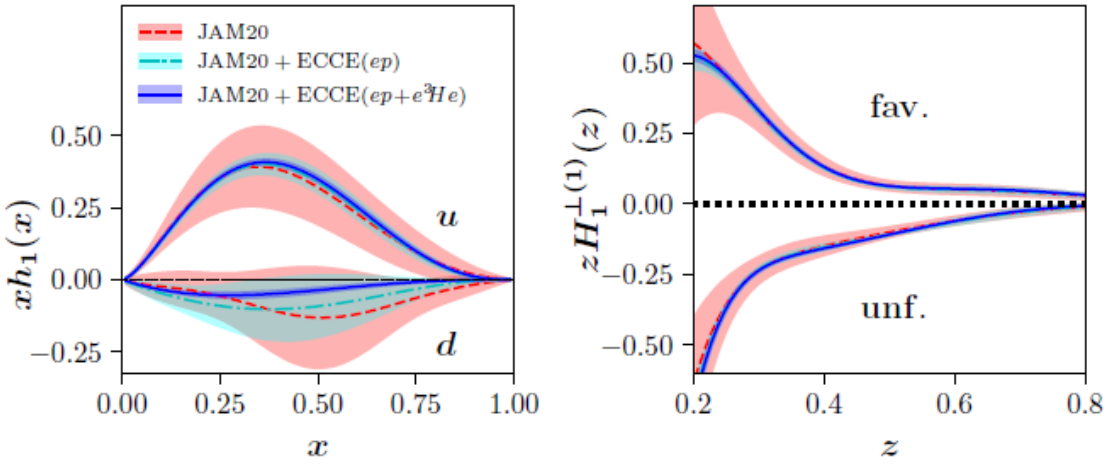


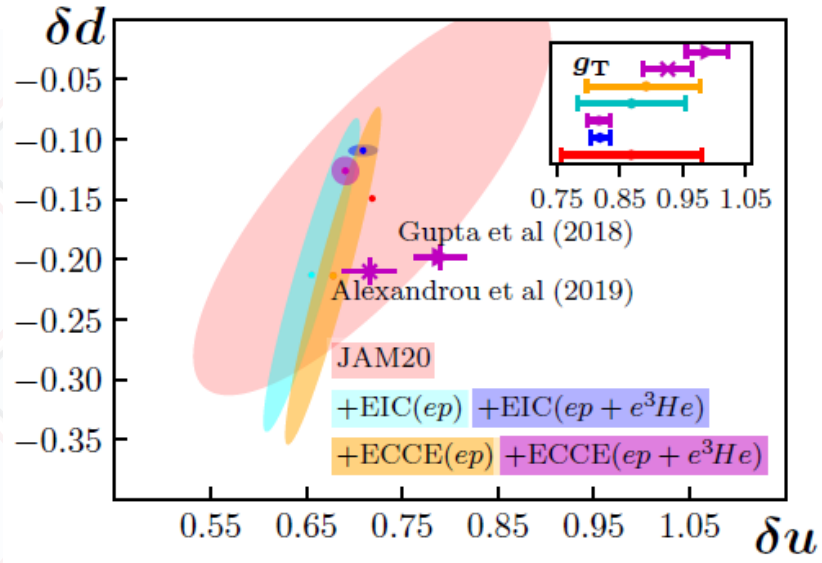
Tensor charge impact

- 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)

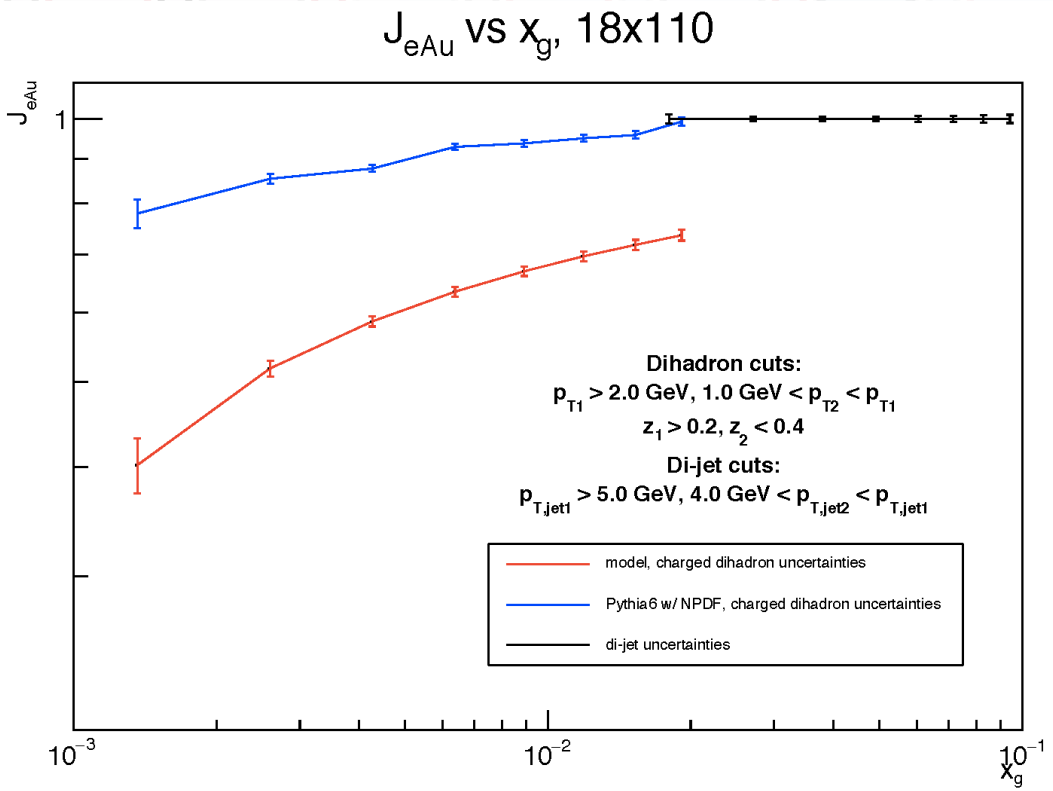




Gluon saturation studies (back-to-back dihadrons)

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

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



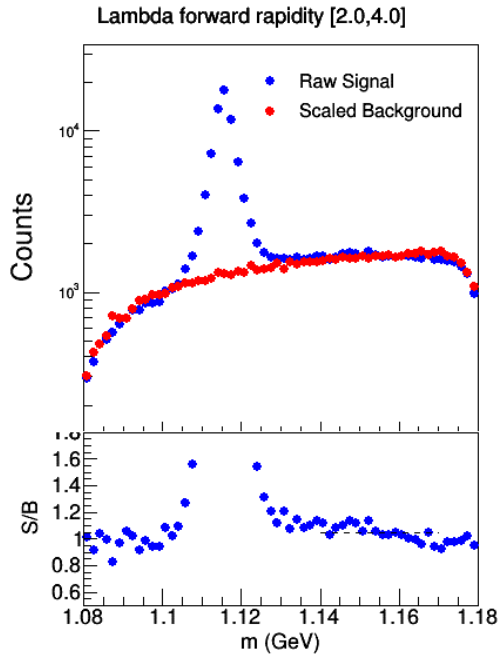
EIC dijet cuts from: Phys. Rev. D 101, 072003 (2020), Page, Chu, Aschenauer

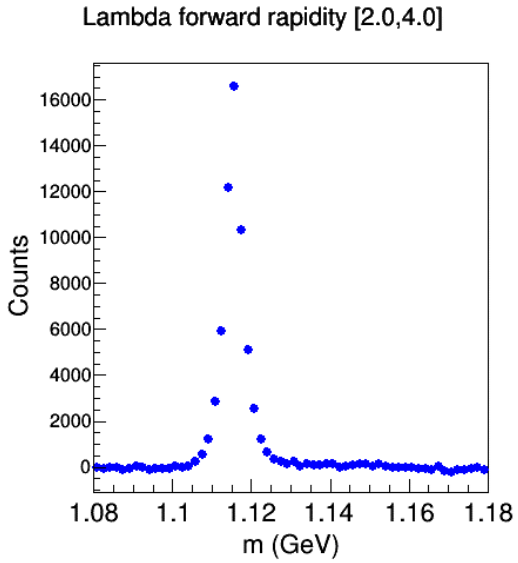
Fast simulation, scaled to 10 fb^{-1}

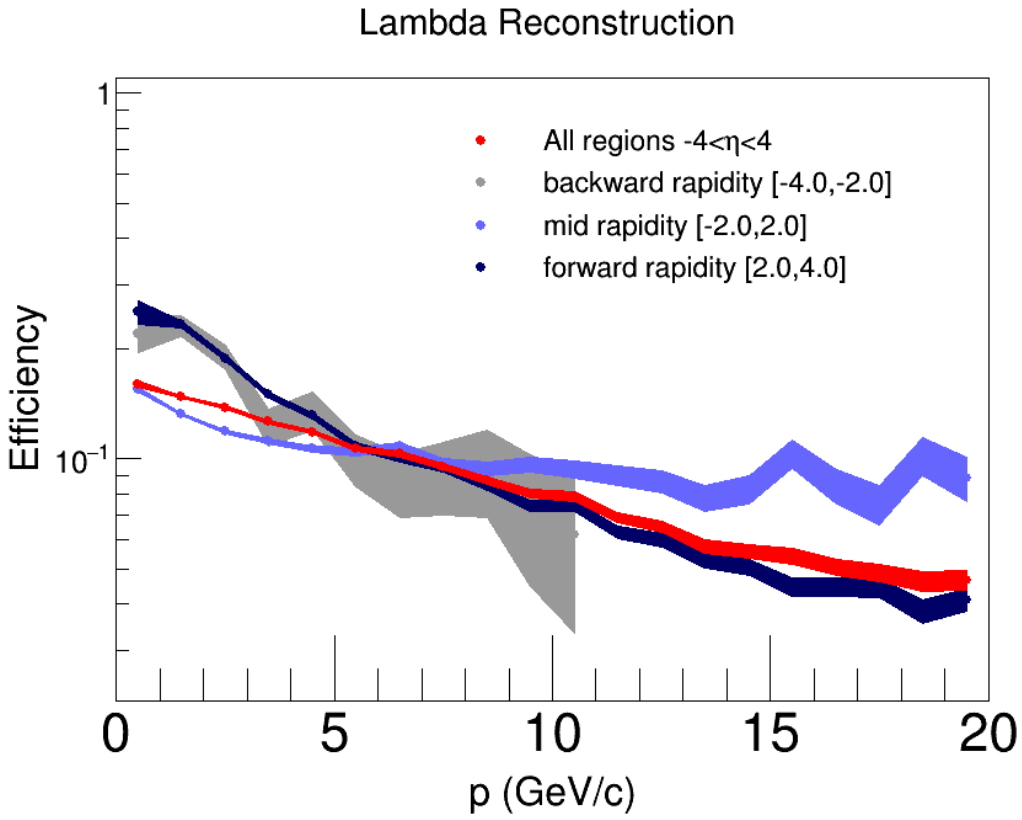
Connor Pecar (Duke)

- 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

Lambda studies







Enea Prifti (UIC)

Summary

- Continuing the studies performed by ECCE and ATHENA on
  - (SI)DIS resolutions
  - A_{LL} measurements
  - Unpolarized TMDs
  - Sivers/Collins and DiFF asymmetries
  - Back-to-back di-hadron asymmetries
  - Lambdas
- Moved from Fun4All framework to epic-analysis