Jets and Heavy Flavor physics working subgroup

Pavia YR Meeting

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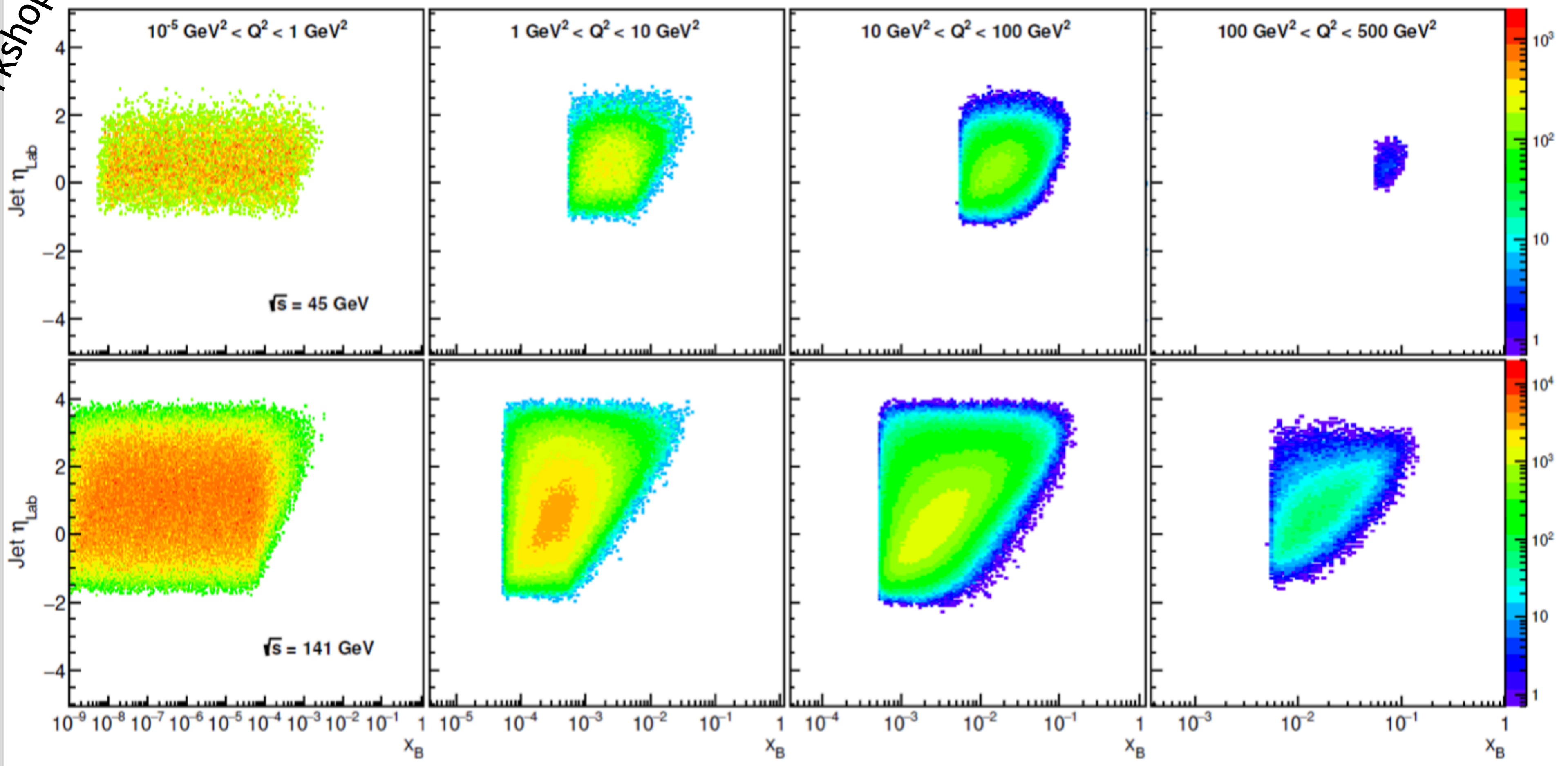
Our main physics-objectives continue to be:

Physics measurement	Channel
Longitudinal spin structure	Inclusive jet and dijet measurements
Sivers asymmetry, special focus on gluons	Jet, lepton-jet and di-jet measurements
Electroweak structure functions, charged currents	Jets, flavor separated jets, Longitudinally polarized reactions ep, parity violating asymmetries
TMDs, nuclear broadening, energy loss	D-jets and photon/lepton tagged jets, ep, eA
Longitudinal and transverse (TMD) fragmentation, shapes and splitting functions	Inclusive jet measurements -> hadrons in jets, energy flow, angularities
Energy loss and hadronization	Heavy mesons cross sections in comparison to light mesons in ep, eA
Charm and beauty content of nucleons and nuclei	Heavy flavor-tagged jets, ep, eA
Flavor and mass dependence of parton showers	Heavy flavor-tagged jet substructure, ep, eA, quarkonia in jets
Extraction of fundamental parameters, hadronization constants, α_s	Global event shapes, thrust, angularities, N-jettiness

Studies prior to and since the Temple workshop are leading to better insights in detector needs; work in progress/continues

Jet Kinematics

Reminders from the Temple workshop (B. Page)



- Jet production extends quite far forward (proton going direction), especially at higher energies – forward tracking and calorimetry will be as important as mid-rapidity

arXiv:1911.00657

Jet η Vs Energy

Reminders from the Temple workshop (B. Page)

arxiv:1912.05931

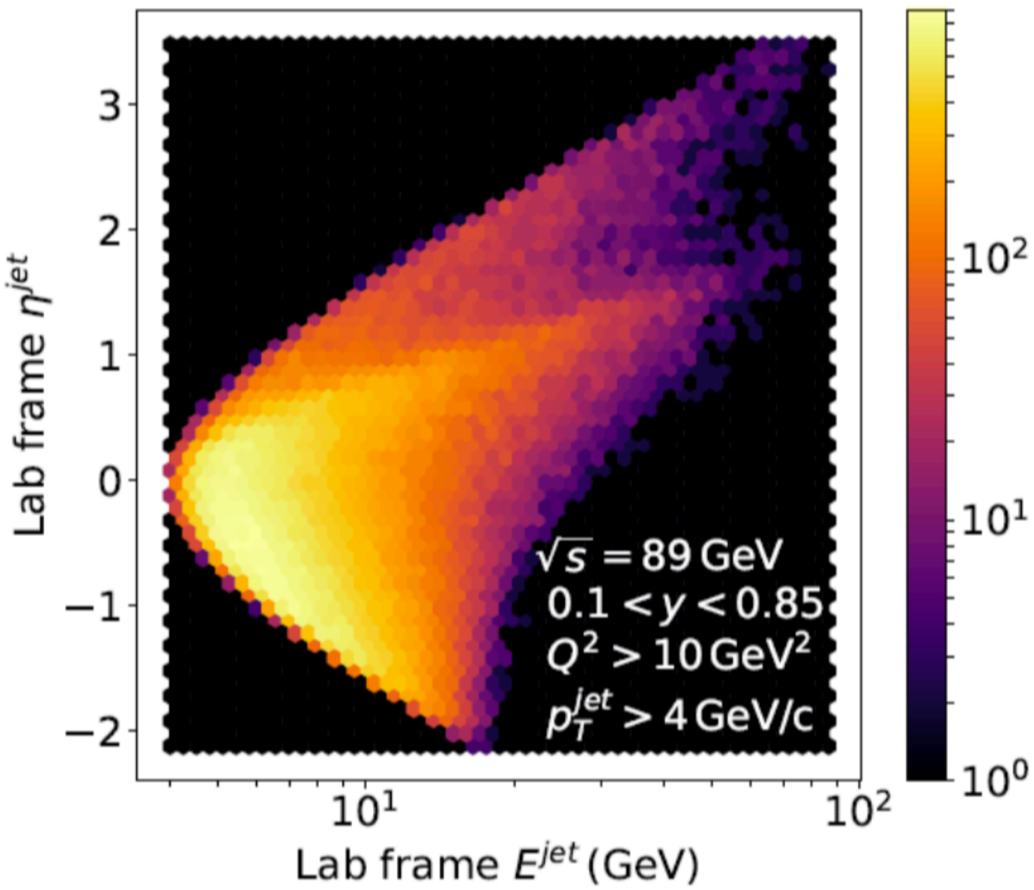
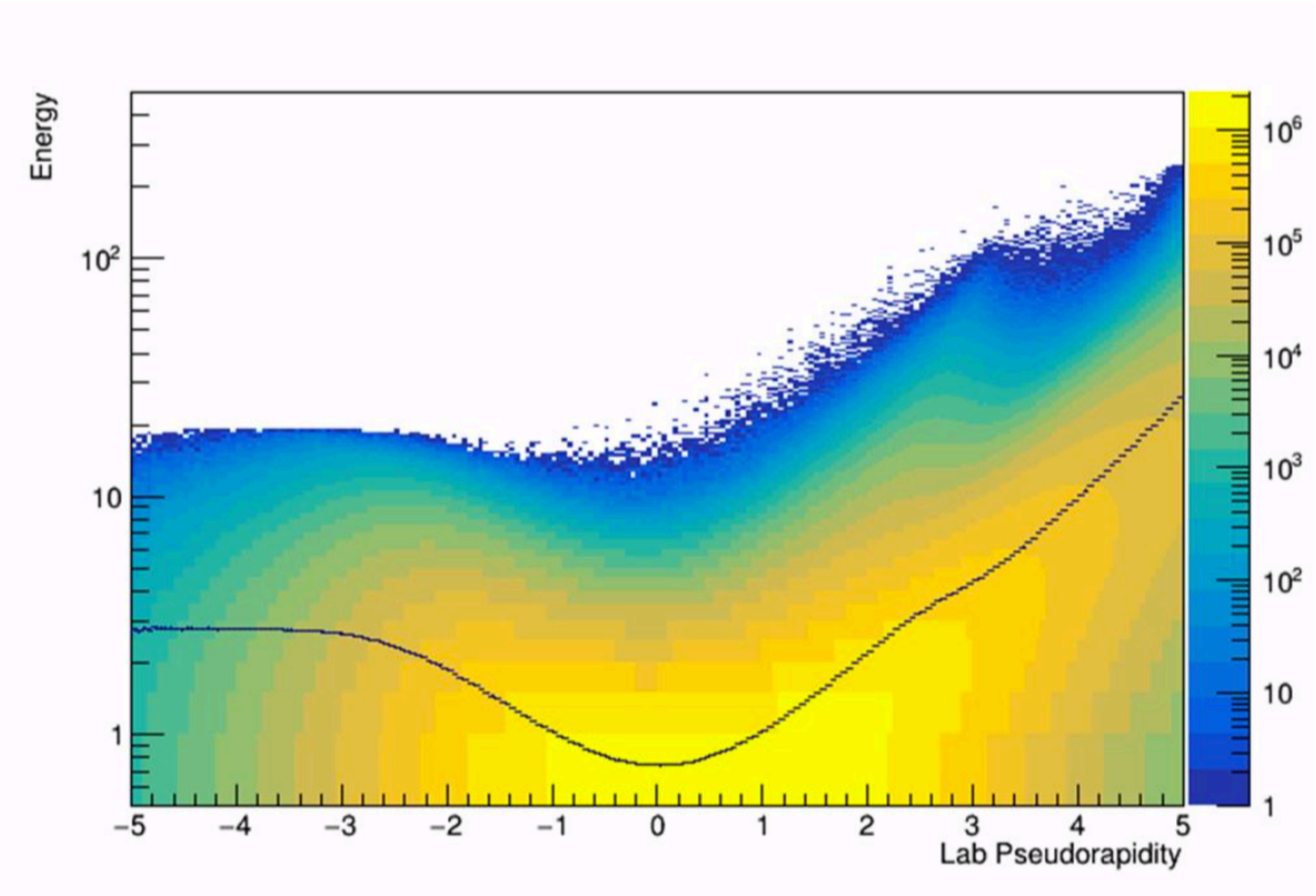


Figure 4. Jet energy vs jet pseudorapidity (in the lab frame). η^{jet} is defined as positive in the proton (ion)-going direction. The jets are defined with radius $R = 1.0$ and the anti-k_T algorithm. The beam energies of the simulation are 20 GeV for the electron and 100 GeV for the proton.

Particle Energy Vs η

Reminders from the Temple workshop (B. Page)



New studies since Temple, for example those by Miguel Arratia et al. (Pavia WS), are further informing needs:

Table 1: Channels listed are increasingly demanding. For every row consider all requirements above as well. The (x, Q^2) dependence of the observables is omitted for brevity. Date: May 20, 2020, Miguel Arratia

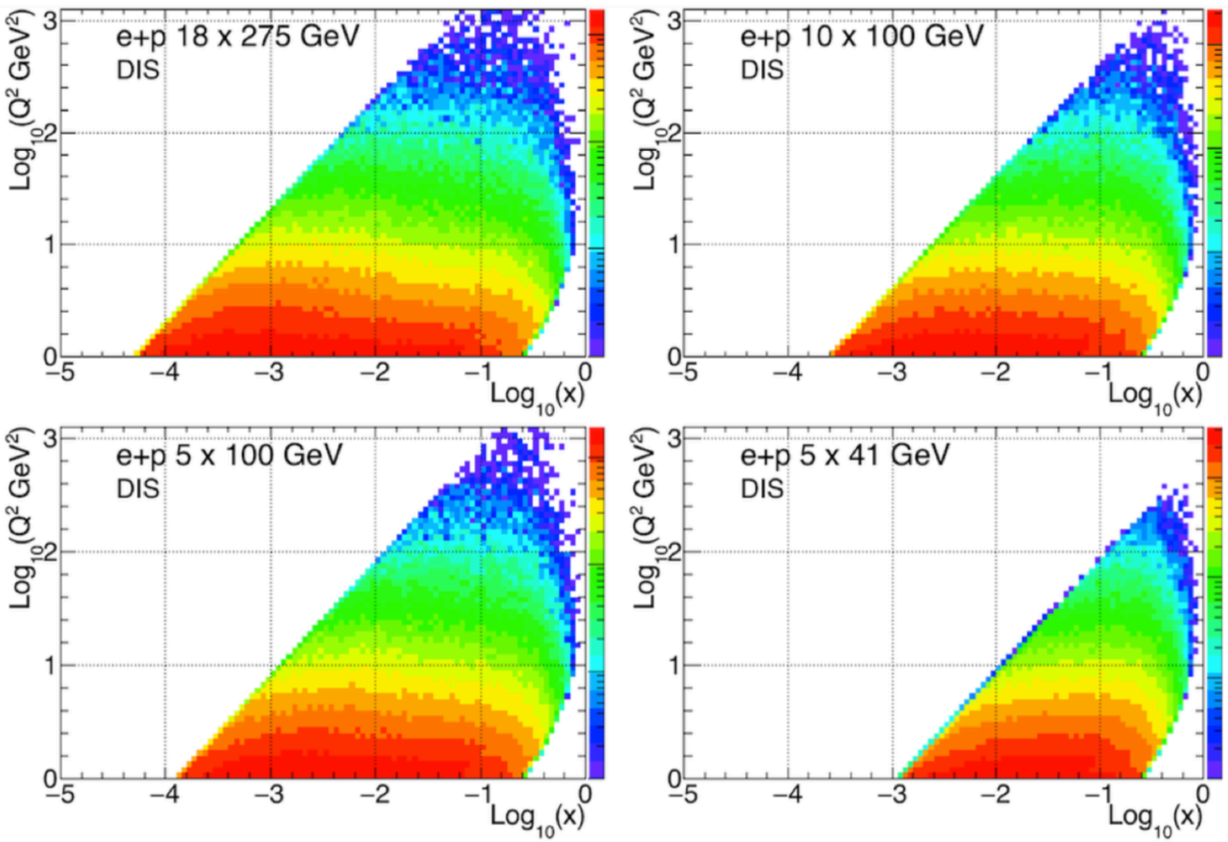
Channel	Observable	Goal	Physics-driven requirement	Category	numbers
e-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(\Delta\phi)$	k_T-dependence of quark Sivers	$\Delta\phi$ res. << intrinsic width $\sigma(\Delta\phi) < 0.02$ rad $R = 1.0 \rightarrow$ had. corr. $O(1)\%$ particle-flow reco	Jet res. Acceptance Granularity	jet $dE/E < 20\%/\sqrt{E}$ $\rightarrow$ ECAL&HCAL $dE/E < 60\%/\sqrt{E}$ 2π, $\|\eta\| < 3.5$ HCAL and ECAL endcap $\Delta\phi \times \Delta\eta \leq 0.025 \times 0.025$
h-in-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	q-transversity	dp/p at high $z <$ jet dE/E	Tracker PID	$dp/p < 3\%$ at 50 GeV, up to $\eta = 3.0$ up to $\eta < 3.5$ and 50 GeV
ν-jet (CC) 100 fb^{-1}	$d\sigma$, A_{UT}	u Sivers	$\Delta\phi << 0.3$ rad Bkg. rej. to phot and NC >70% survival prob. for 5 bins per-decade in x, Q^2	E_T^{miss} res. Acceptance Jet/E_T^{miss} res.	$dE_T^{miss}/E_T^{miss} < 15\%$ 2π, $\|\eta\| < 3.5$ HCAL and ECAL E>100 MeV thres. ECAL E>400 MeV thres. HCAL $p_T > 100$ MeV tracker $dx/x < 20\%$, $dE_T^{miss}/E_T^{miss} < 15\%$
h-in-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	u-transversity	—	—	—
c-jet (CC) 100 fb^{-1}	$d\sigma$, A_{LL}	s PDF& helicity	charm-tagging	Tracker PID	c-jet tag at $> 10\%$ (<0.05%) $\sigma(DCA) = 20\ \mu$m, up to $\|\eta\| = 3$ $\approx 100\%$ eff. TBD
h-in-c-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	s-transversity	—	—	—
c-jet (e^+ CC) 100 fb^{-1}	$d\sigma$, A_{LL}	$s/\bar{s}$ asymmetry	positrons	—	—

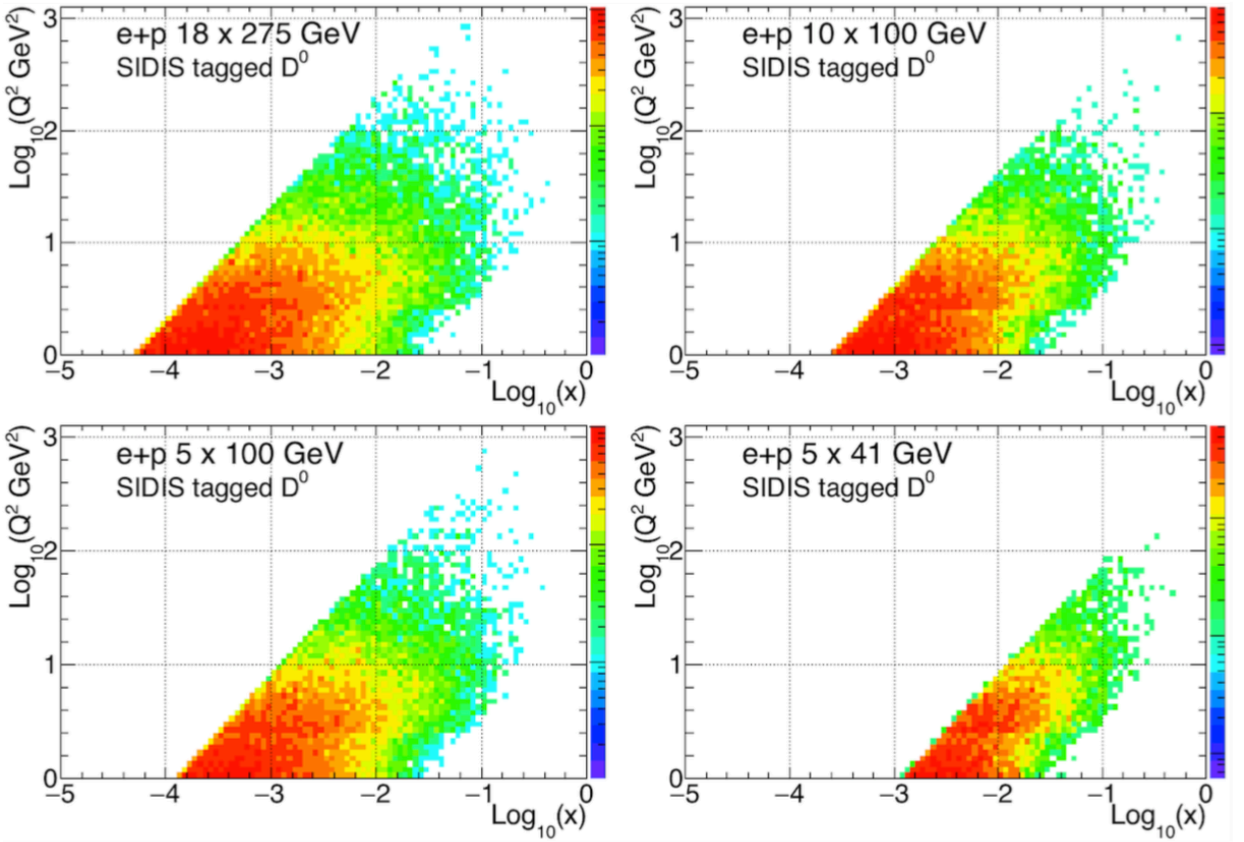
Not the final word, work continues/remains. However, e.g. HCAL continues to be about tails not resolution,
tracking requirements e.g. for Collins measurement
appear less stringent than those put forward by PID DWG.

Heavy Quark Kinematics

log(Q²) vs. log(x)

BERKELEY LAB



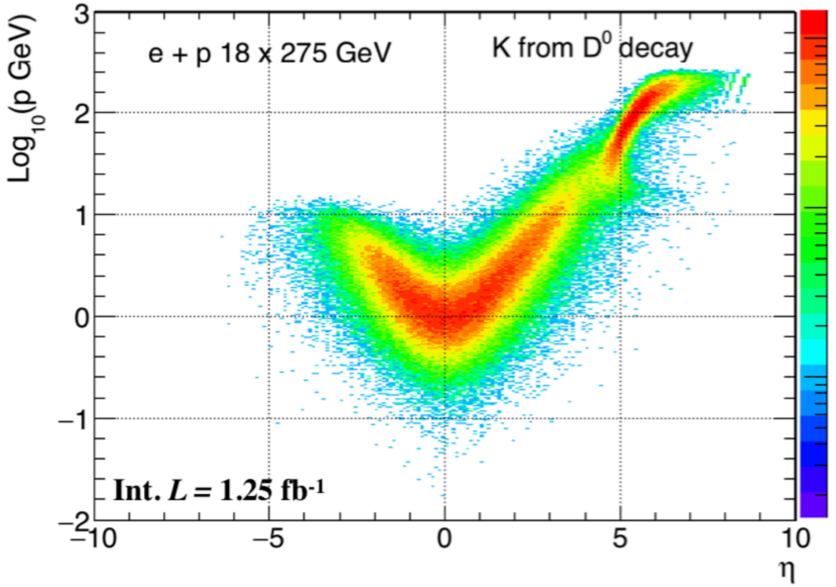


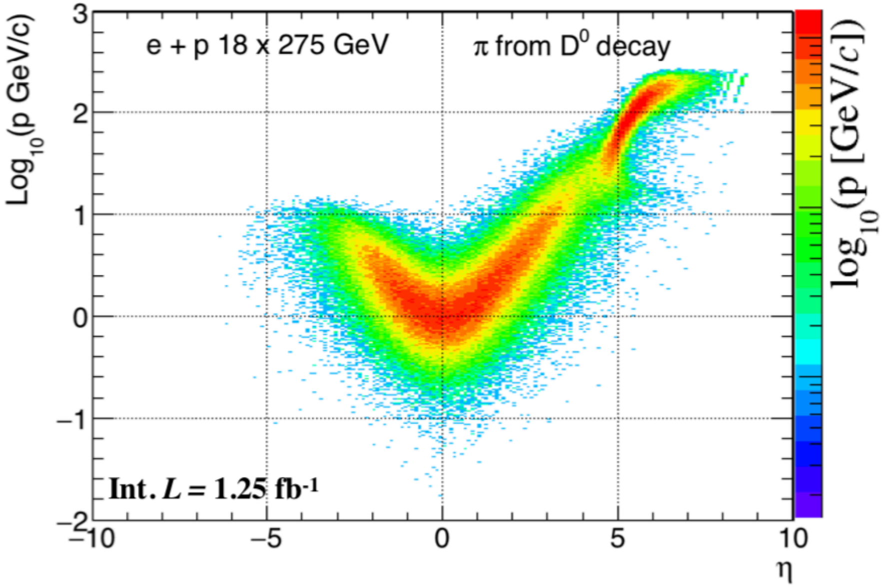
- **Energies for electron + proton collision program**

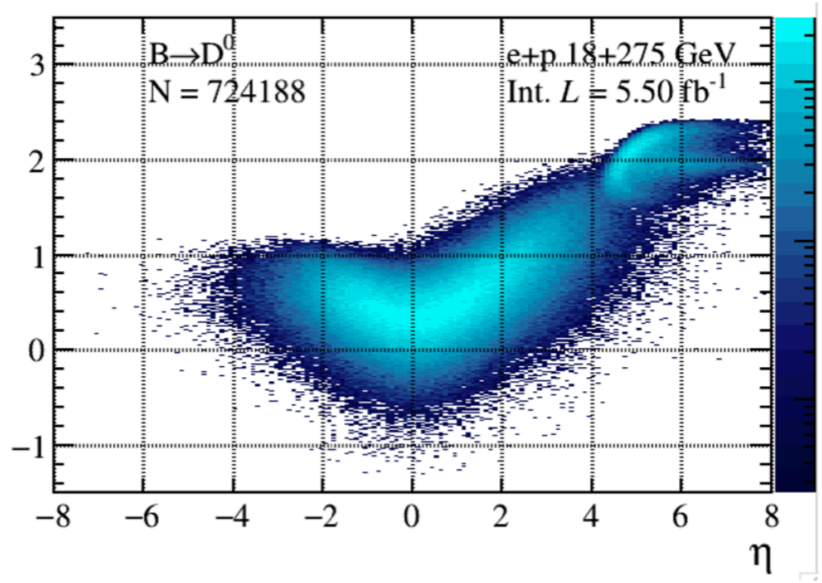
Matt Kelsey et al (Pavia WS), and complementary work.

Heavy Quark Kinematics

Heavy-Flavor Decay Distributions







- Charm and bottom decay products within $|\eta|<3$
- Similar distributions for other charm hadron decays and $B \to D^+$/Lepton decays

Matt Kelsey et al (Pavia WS), and complementary work.

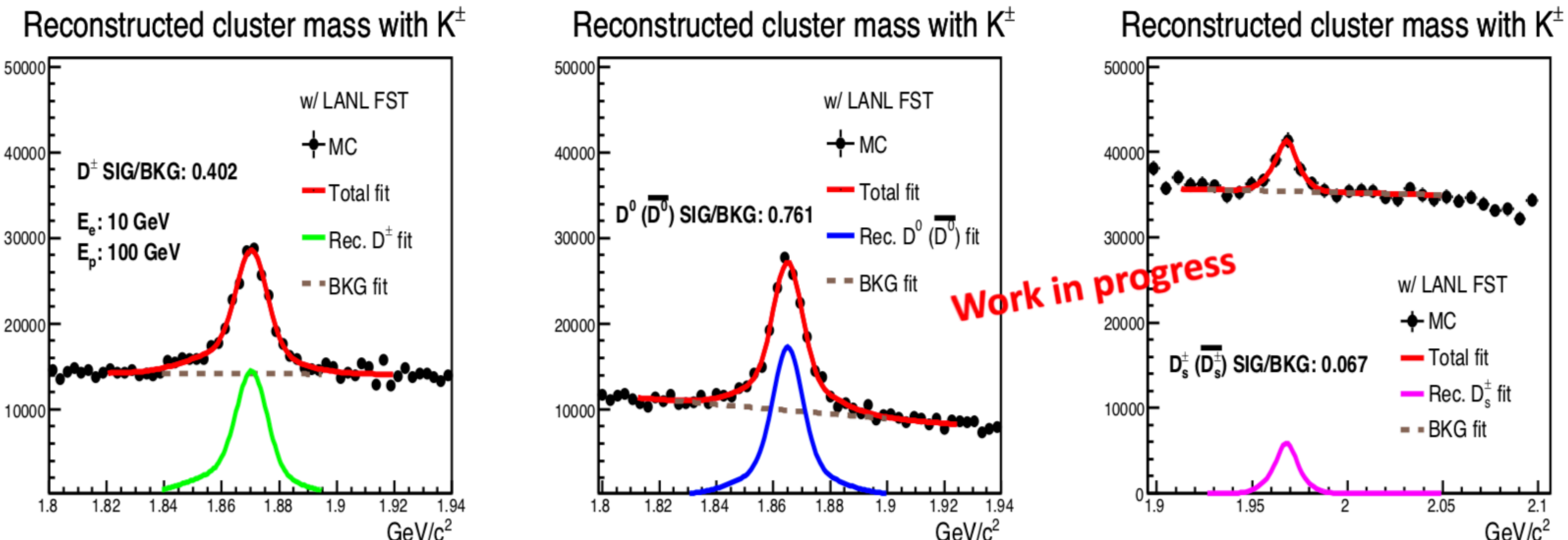
Heavy Quarks - Momentum Resolution

Reconstructed D mesons in PYTHIA8 simulation

Los Alamos NATIONAL LABORATORY EST.1943

- In 10 GeV electron and 100 GeV proton collisions with integrated luminosity: 10 fb^{-1}.
- Reconstructed D meson mass distributions.
  - Tracking η cut: 1 to 3 and track efficiency set at 95%.
  - The performances are based on 100% $K/\pi/p$ separation.
  - Charged track clusters that contain $K^{\pm}$ with a decay length (DCA) cut.

Xuan Li et al (Pavia WS), and complementary work.



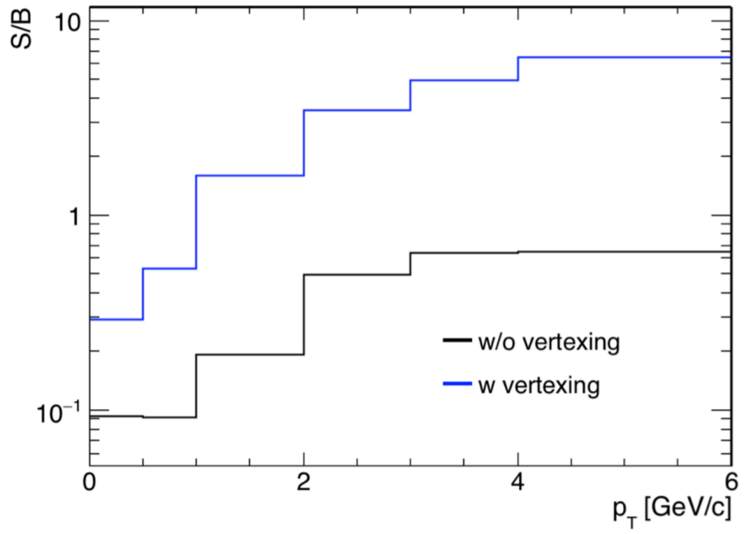
Heavy Quarks - Vertex Resolution

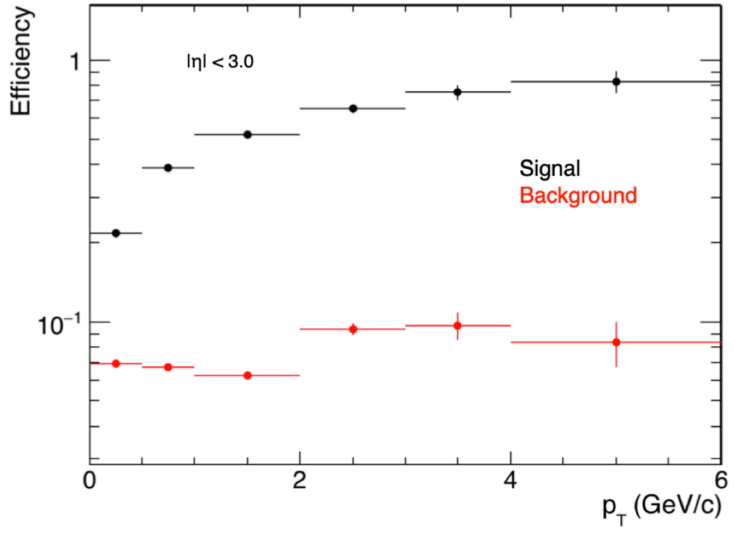
Interested parties from Birmingham, LANL, LBNL, … are taking active part in the Tracking DWG
are contributing actively to GEANT-based / full simulations,

Fast HQ simulations have started to consider vertexing beyond fixed-number smearing/assumptions
to take into account event-topology by fitting vertices.

D^0 S/B and Efficiency

Matt Kelsey et al (Pavia WS).





- **Reiterating nice improvement of D^0 S/B with vertexing**
  - Factor of 10(2) for high(low) p_T
- **Modest signal efficiency with "by-eye" cuts**

Ouarkonia and exotics

Los Alamos
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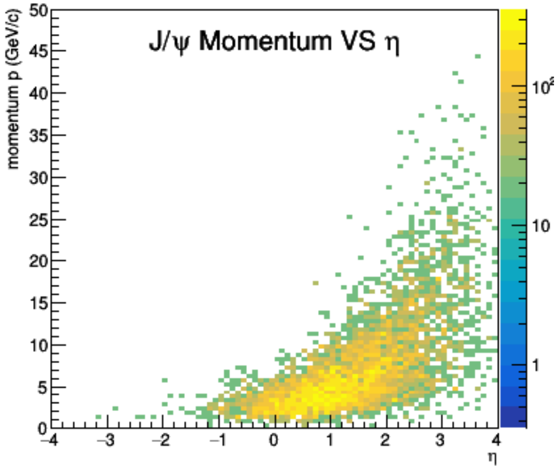
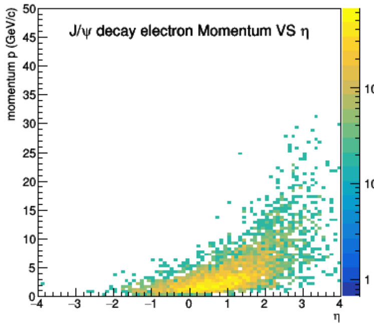
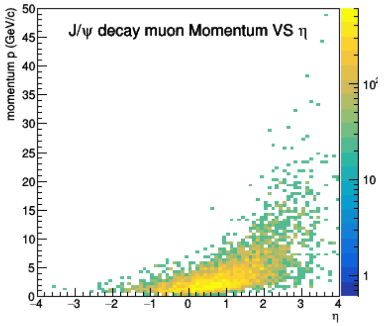
EST. 1943
M.Durham et al.

18 GeV electron + 275 GeV proton with integrated luminosity at 10 fb^{-1}. Minimum Q^2 = 10 (GeV/c)^2



J/psi

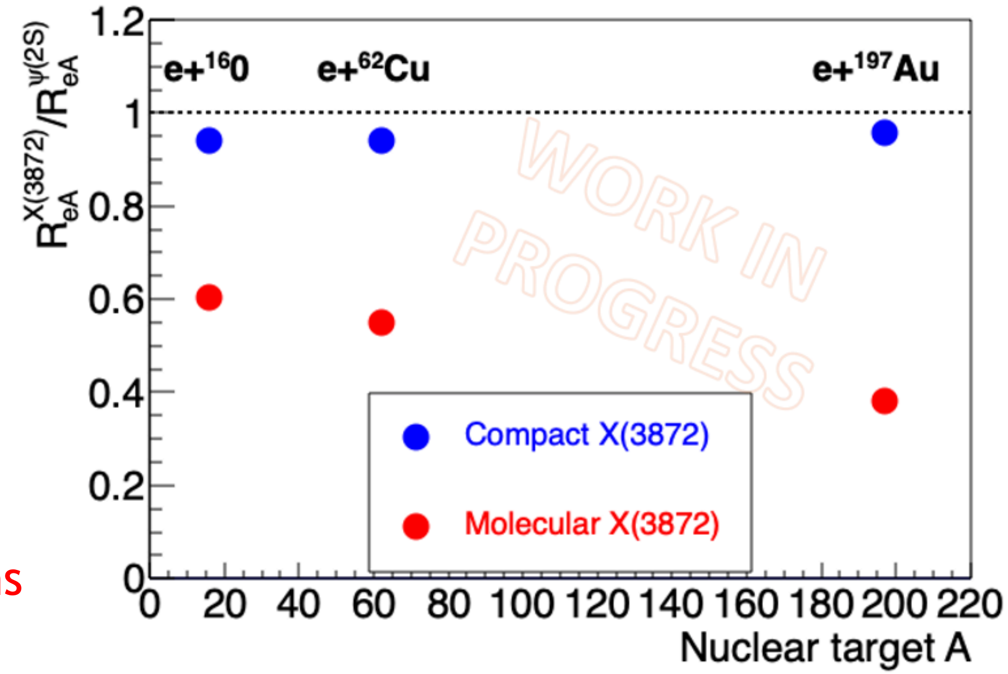




Decay products: electrons, muons

Requires: Tracking performance consistent or better than the EIC handbook requirement. Good electron ID, and/or muon ID

Relative modification of X(3872)/



- **Potential for decisive discrimination between X(3872) structure models at the EIC.**