Designing the TMD-SIDIS Experiment: Simulation-Driven Detector Optimization

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BACKGROUND

- Distribution Functions in nuclear physics are used to describe the structure of nucleons using their kinematic variables.
- Nuclear physicists are currently interested in Transverse Momentum Dependent (TMD) distribution functions.
- TMDs for spin-$\frac{1}{2}$ particles have been studied, but not tensor-polarized spin-1 nuclei such as the deuteron.
- TMDs are accessed through Semi-Inclusive Deep Inelastic Scattering (SIDIS) experiments.
  - SIDIS experiments take place at a higher energy range, making the experiment less like a pool table, and more like an explosion.

THE EXPERIMENT

- The experiment studied here is a SIDIS experiment to be conducted at Jefferson Lab in Virginia.
- Process is $e + D \rightarrow e' + \pi^+ + X$
- Incident beam energy of 11 GeV
- Experiments are very expensive to run, so detector placement is very important.
- Final goal: extract tensor polarized structure functions from cross section formula

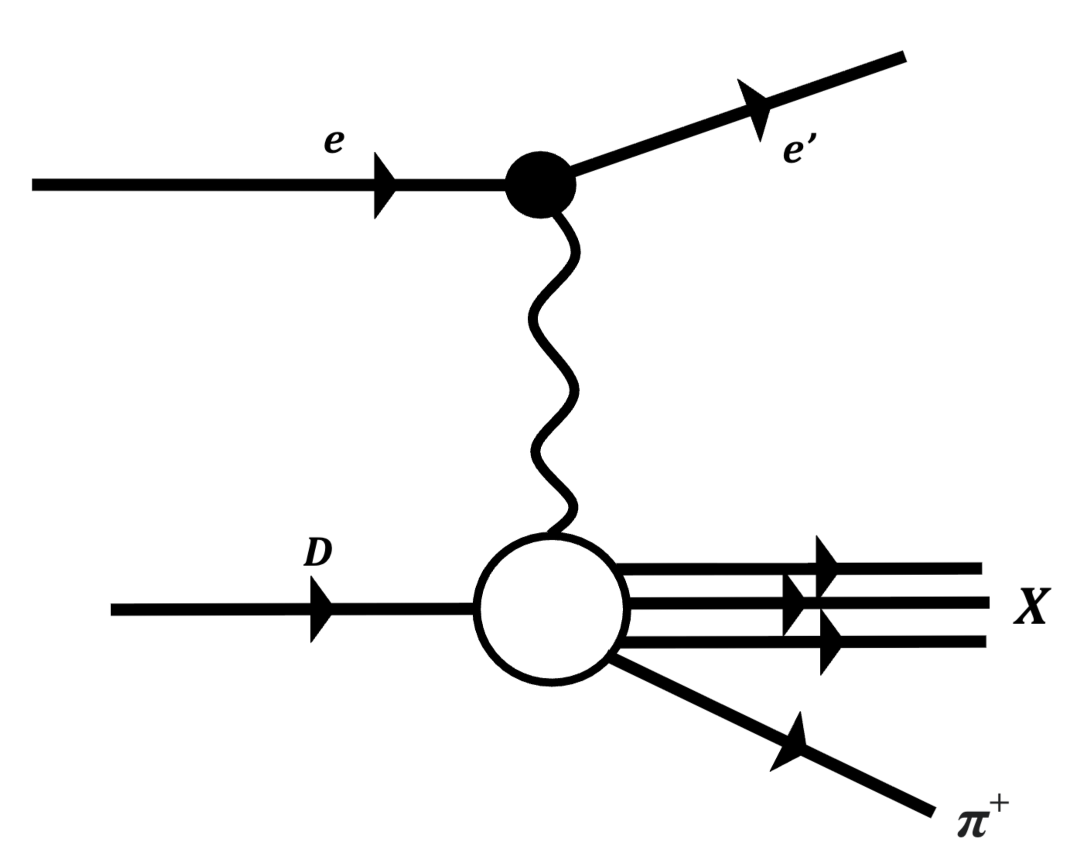

Fig. 1: Diagram of SIDIS process.

METHODS

- Experiment can be simulated using LiuSIDIS framework in ROOT to optimize placement of detectors.
- Set parameters to match desired experiment
- Identify peak scattering angle for both the scattered electron beam and the scattered pion
- Plot kinematic variables in that region, and identify peak momentum values

RESULTS

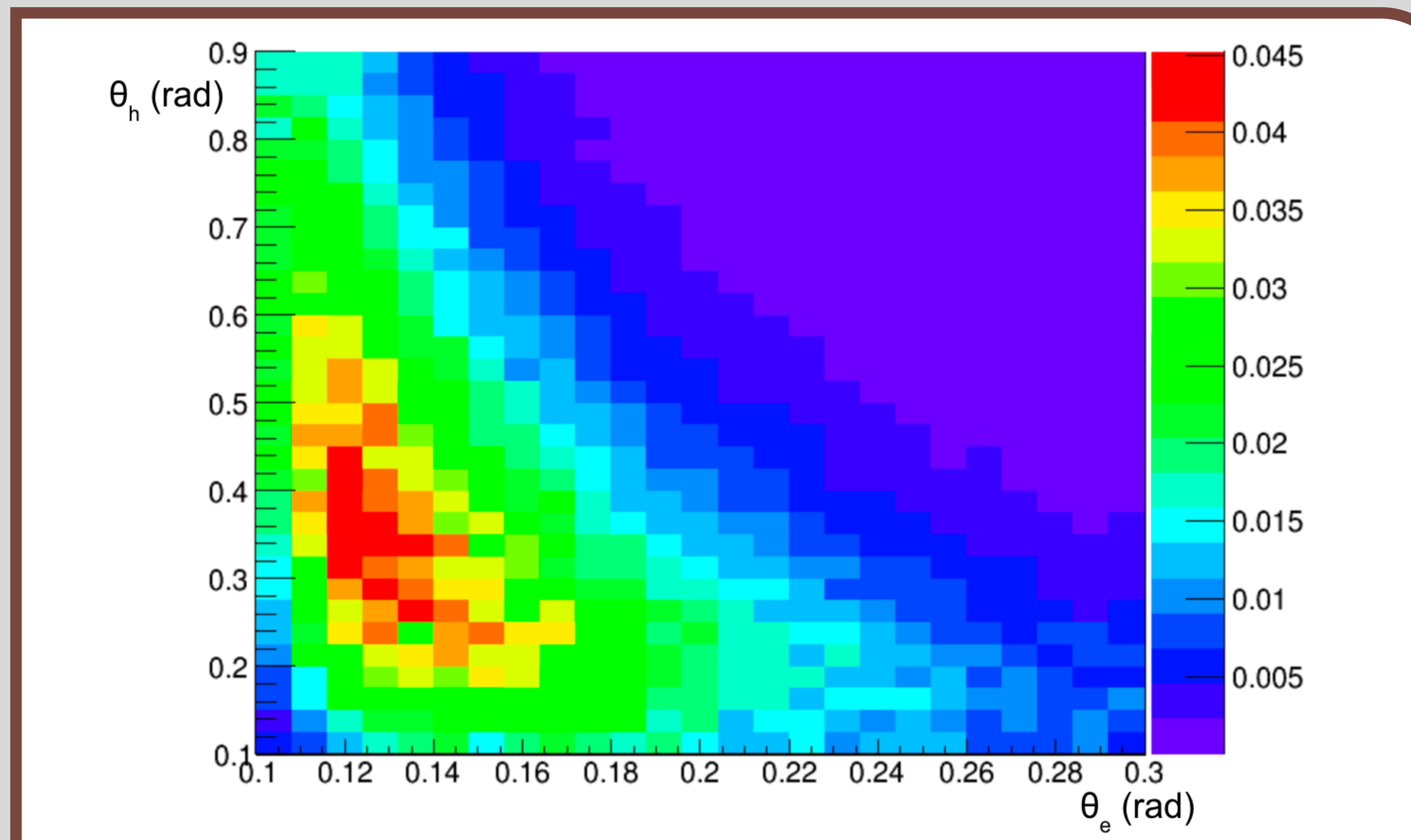

Fig. 2: Histogram comparing scattering angles for the SIDIS reaction. Peak determined to be at θ_e=0.128 rad (7.35°) and θ_h=0.37 rad (18.8°).

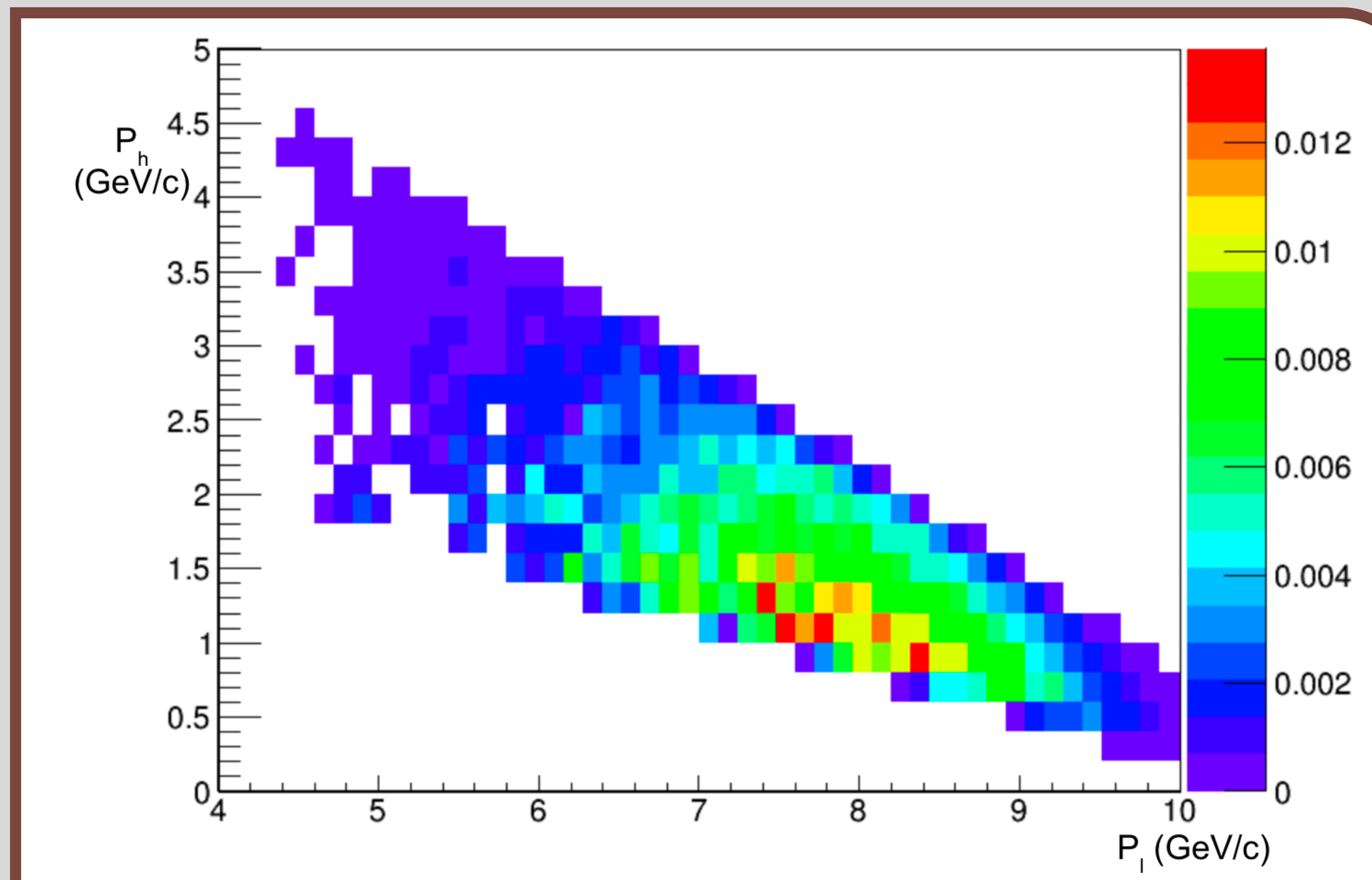

Fig. 3: Histogram comparing momentum for scattered particles.

RESULTS

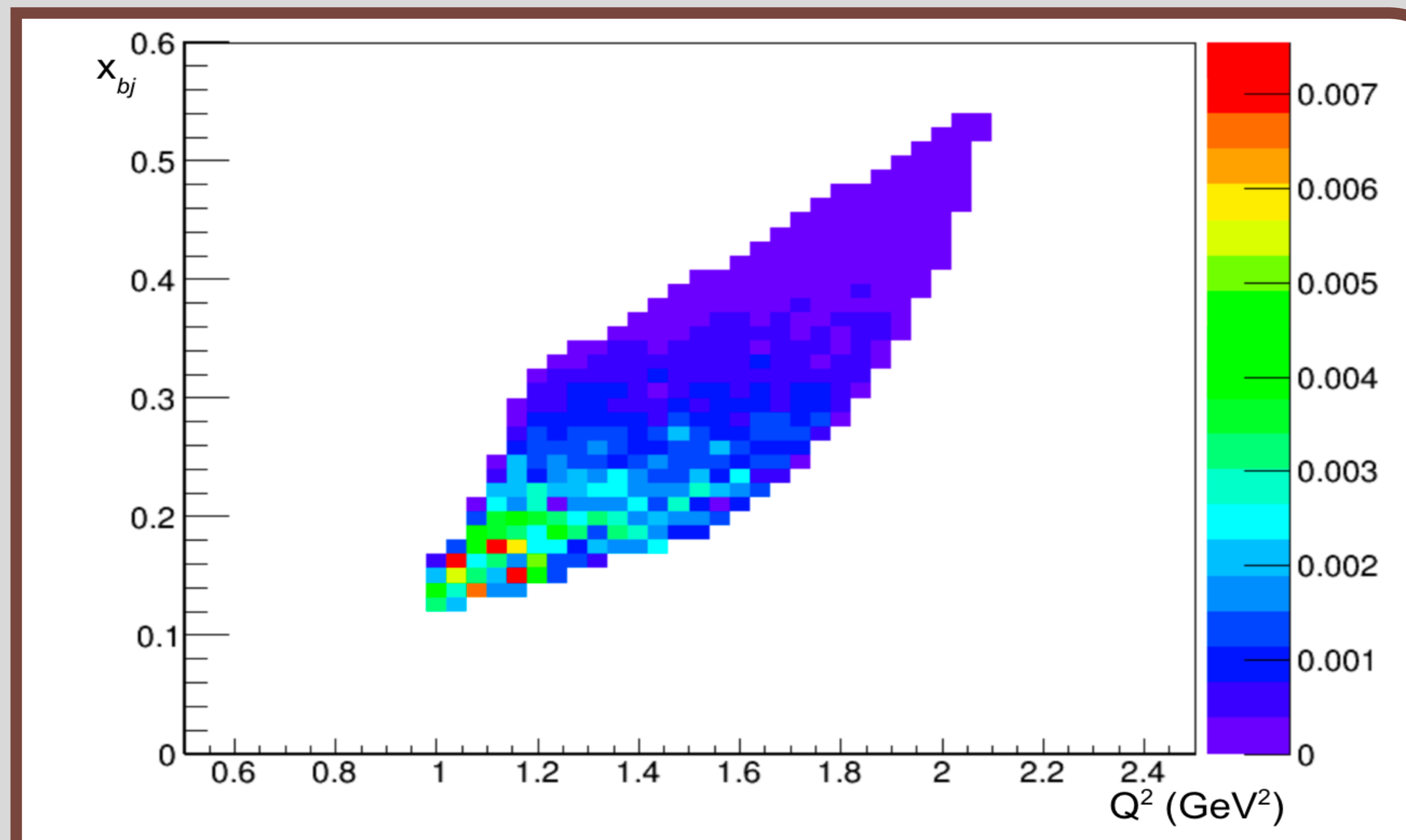

Fig. 4: Histogram of Bjorken x and momentum transfer restricted to peak angles and momentums.

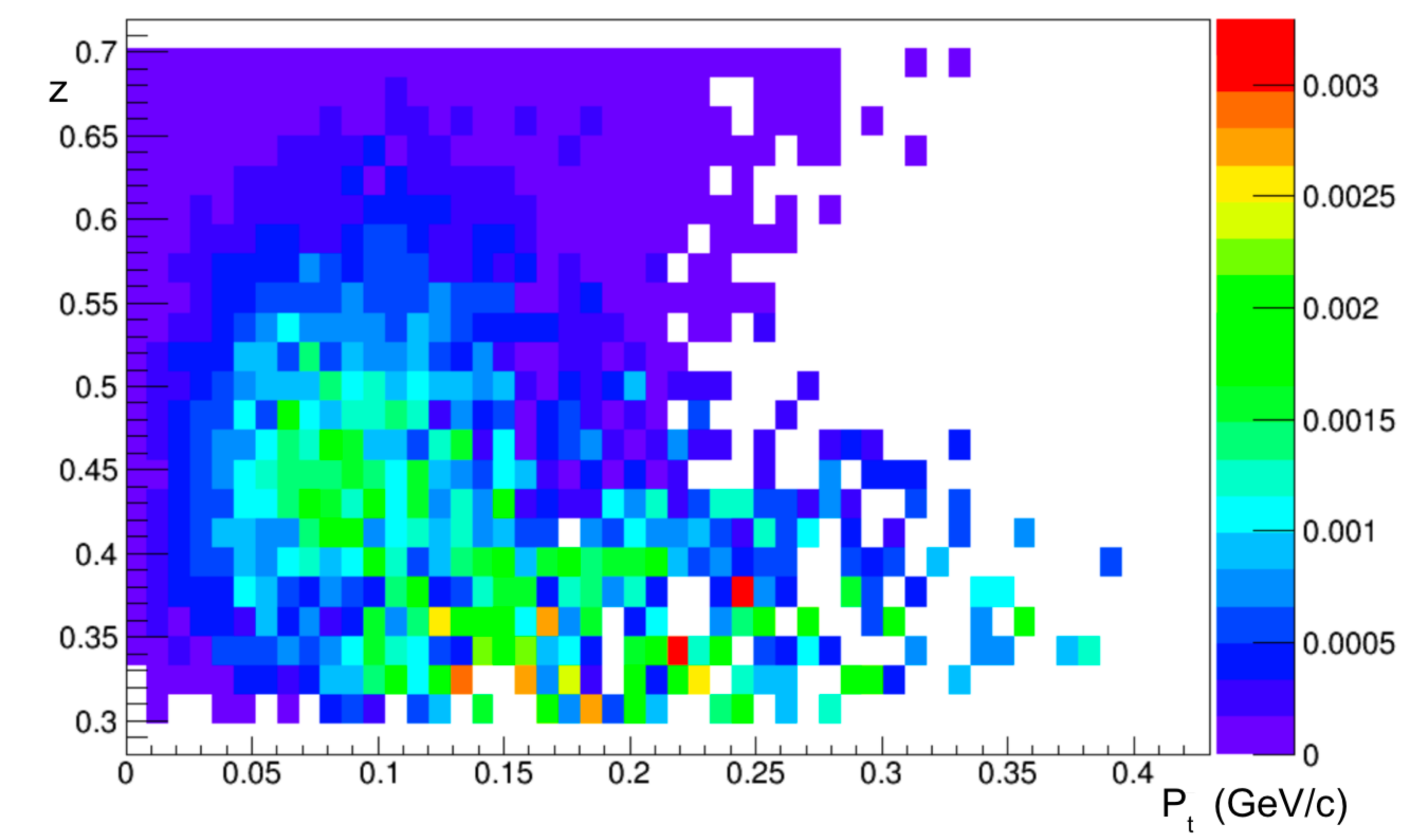

Fig. 5: Transverse momentum and fragmentation fraction for at the peak angles and momentums.

CONCLUSION AND FUTURE WORK

- Create larger set to try and populate graphs
- Use data to predict results for structure functions

Based on the current dataset, SHMS should be placed 7.35° the beamline at a momentum setting of 7.33 $^{GeV}/_{c}$, and SBS should be placed 18.8° from the beamline in the opposite direction, at a momentum setting of 1.35 $^{GeV}/_{c}$.

$$\frac{d\sigma}{dx\ dy\ d\psi\ dz\ d\phi_h\ dP_{h\perp}^2} = \frac{y^2\alpha^2}{2(1-\epsilon)xyQ^2}\left(1+\frac{\gamma^2}{2x}\right)\Big[F_{UU,T} + \epsilon F_{UU,L} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_h\ F_{UU}^{\cos\phi_h} + \epsilon\cos(2\phi_h)\ F_{UU}^{\cos(2\phi_h)} + \lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h\ F_{LU}^{\sin\phi_h} + S_\parallel\Big\{\sqrt{2\epsilon(1+\epsilon)}\sin\phi_h\ F_{UL}^{\sin\phi_h} + \epsilon\sin(2\phi_h)\ F_{UL}^{\sin 2\phi_h}\Big\} + S_\parallel\lambda_e\Big\{\sqrt{1-\epsilon^2}\ F_{LL} + \sqrt{2\epsilon(1-\epsilon)}\cos\phi_h\ F_{LL}^{\cos\phi_h}\Big\} + T_{\parallel\parallel}\Big\{F_{U(LL),T} + \epsilon\ F_{U(LL),L} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_h\ F_{U(LL)}^{\cos\phi_h} + \epsilon\cos(2\phi_h)\ F_{U(LL)}^{\cos 2\phi_h} + \lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h\ F_{L(LL)}^{\sin\phi_h}\Big\}\Big]$$