Transverse Kinematic Imbalance Analysis and Pion Trackless Reconstruction at the Upgraded T2K Near Detector

UNIVERSITY OF OXFORD
WARWICK THE UNIVERSITY OF WARWICK
Weijun Li (weijun.li@physics.ox.ac.uk), University of Oxford
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T2K

Introduction

The T2K near detector has undergone an upgrade. The new active target, the Super Fine-Grained Detector (SFGD) (see poster by Tristan Doyle for more hardware details), is made up of about 2 million 1 cm^3 scintillation cubes, offering excellent timing resolution and isotropic tracking. The upgrade has been completed with the installation of two high angle time projection chambers and six time-of-flight planes, and is collecting data with a beam intensity above 700 kW **NOW**!

The excellent tracking capability of SFGD has enabled the application of novel techniques and holds great potential in improvement measurement resolution.

The pion trackless (TL) reconstruction

- Use the unique delay chain of the pion, $\pi \to \mu \to e$, as shown in Fig. 3, to both infer its presence and to reconstruct its momentum.
- Require no reconstructed pion track, hence lower reconstruction threshold, detailed in Table below.
- Achieve excellent pion momentum resolution, as shown in Fig. 4,
- Select a $\nu_\mu CC1\pi^+$ sample with high purity as shown in Fig. 5, based on NEUT 5.6.0.0.

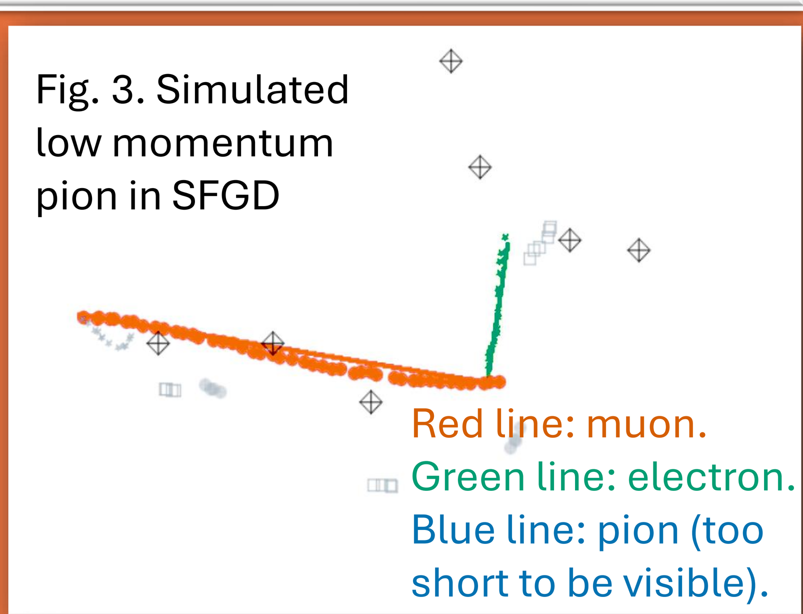

Fig. 3. Simulated low momentum pion in SFGD

TPC	SFGD (w/ tracks)	SFGD (w/o tracks)
100 MeV/c	~80 MeV/c	~50 MeV/c

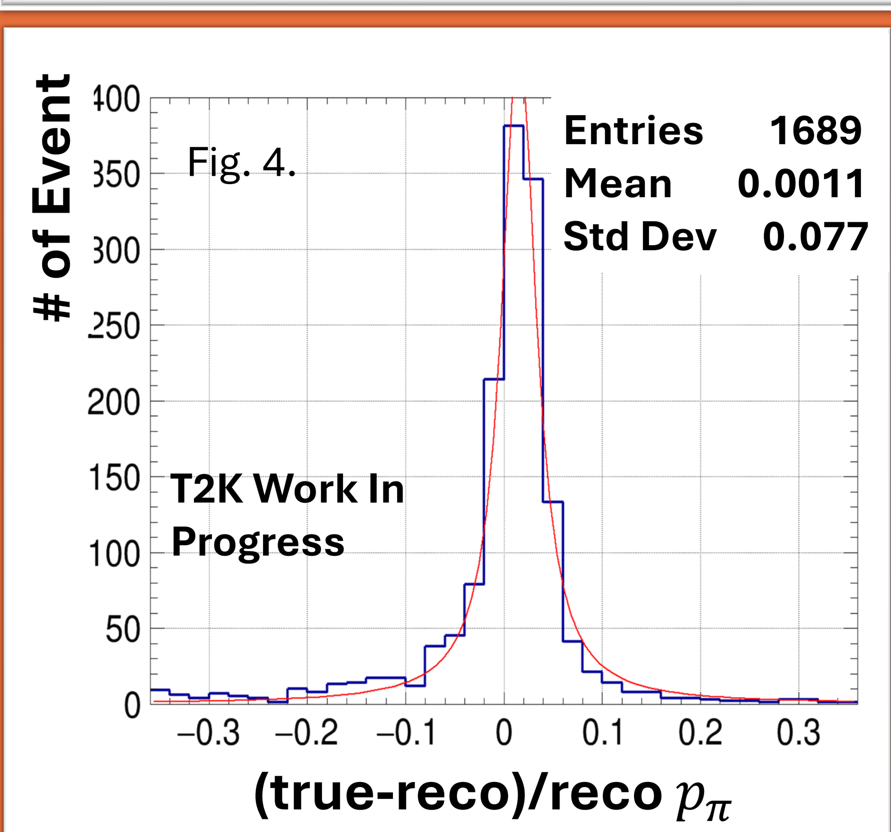

Fig. 4.

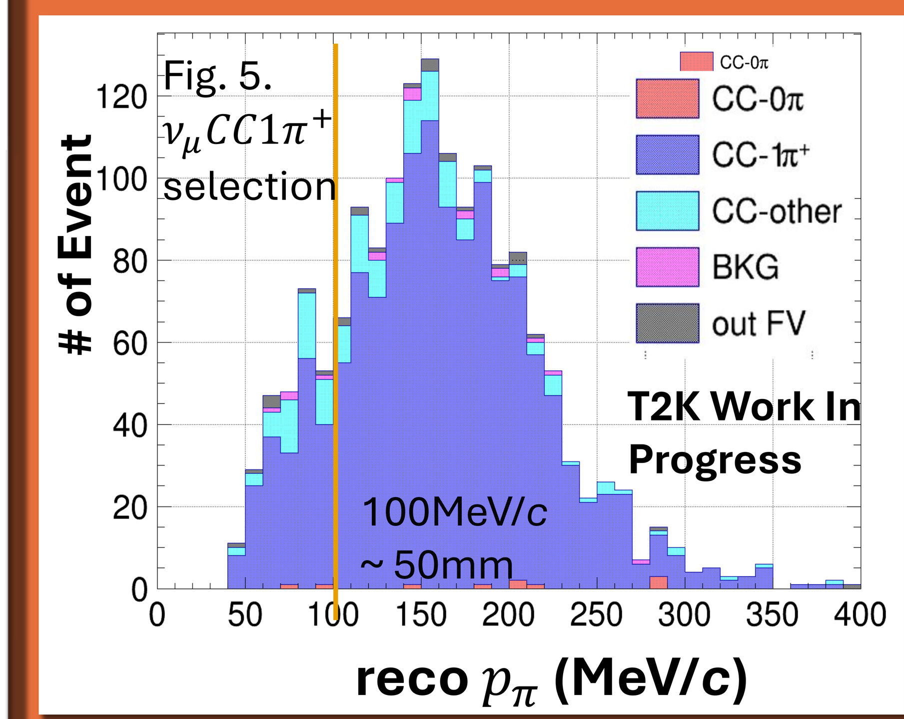

Fig. 5.

Centre-of-momentum (COM) variables

- $\Delta^{++} \to p + \pi^+$ - two-body decay - proton and pion kinematics are calculated exactly in the Δ^{++} rest frame.
- Without/with Final State Interactions (FSI), the p-π^+ COM frame =/≠ Δ^{++} rest frame, as shown in Fig. 6.

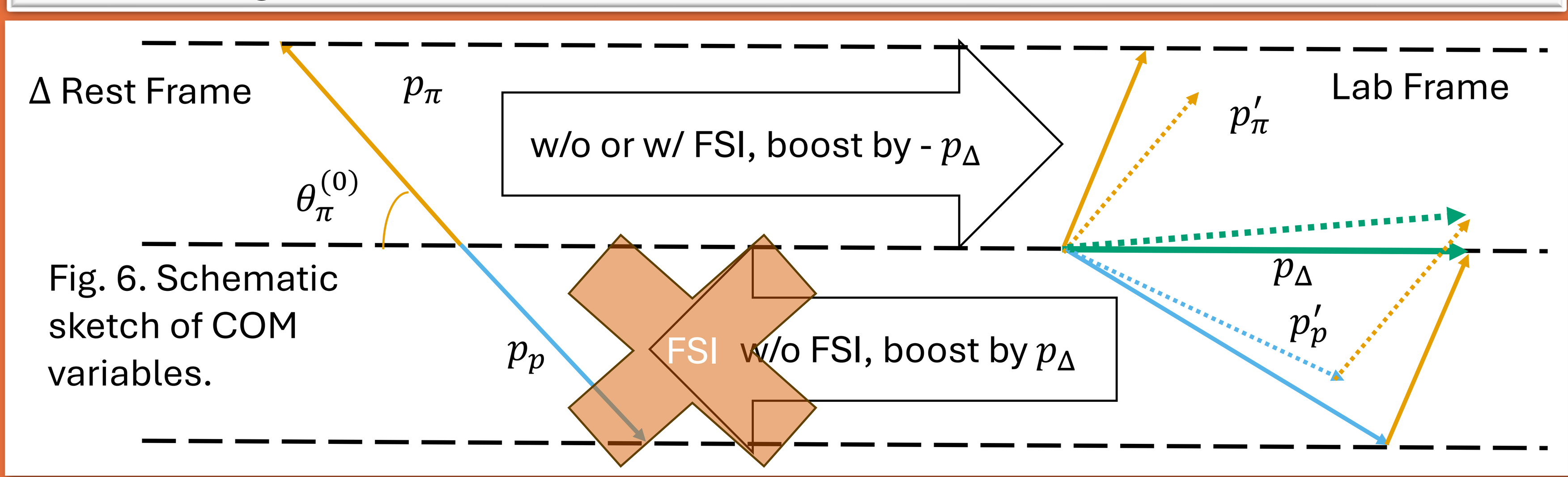

Fig. 6. Schematic sketch of COM variables.

- Using only kinematics of hadronic products, COM variables, e.g. the pion decay angle, $\theta_\pi^{(0)}$, are independent of the initial nucleon state, as shown in Fig. 7, with different short-range correlation ratios, R_{SRC}..
- Distributions of COM variables probe FSI and select hydrogen events, as shown in Fig. 8.

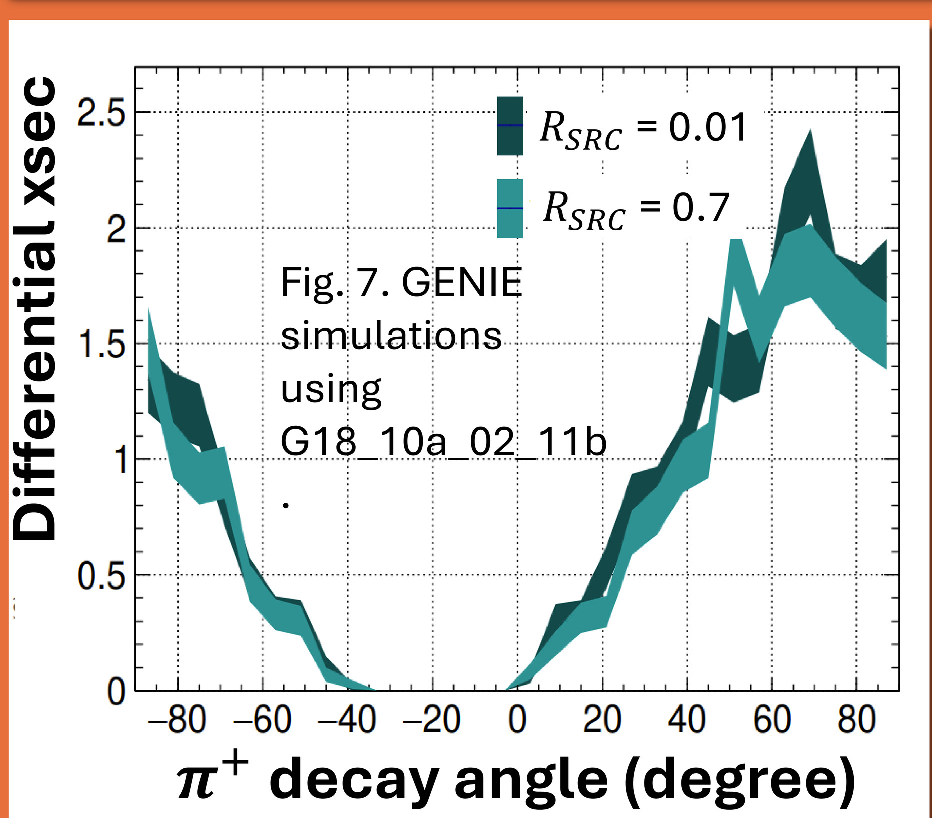

Fig. 7. GENIE simulations using G18_10a_02_11b.

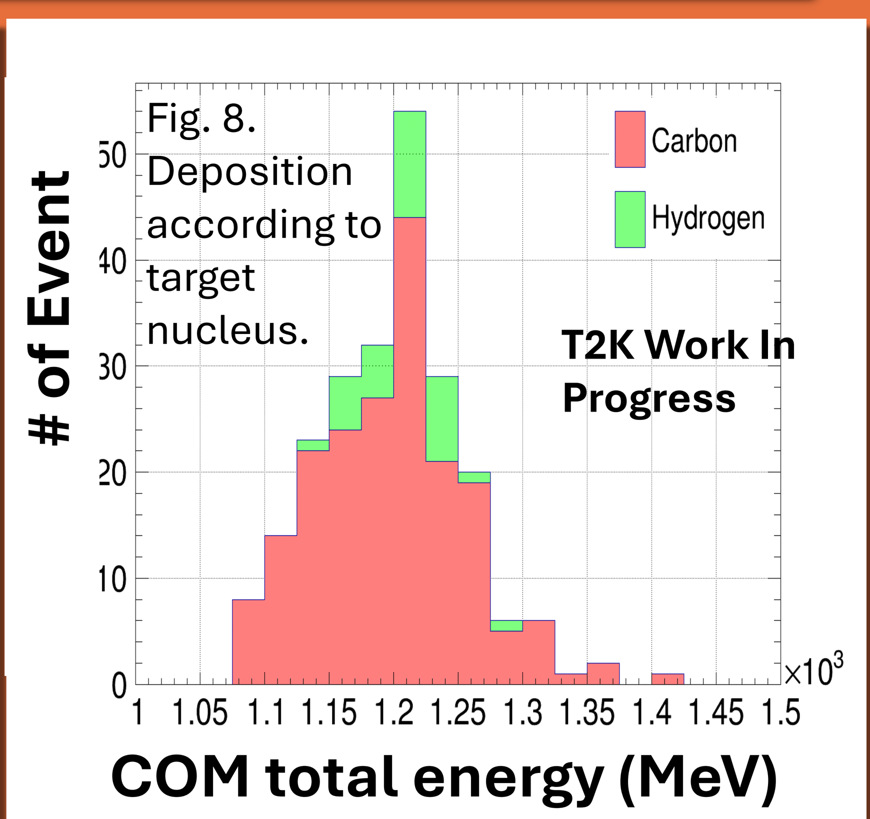

Fig. 8. Deposition according to target nucleus.

Transverse Kinematic Imbalance (TKI)

- Schematic sketch of TKI variables are shown in Fig. 9 [1,2].
- Probe both initial nucleon states and FSI.
- Require high kinematic reconstruction quality.
- The Elastically Scattered and Contained (ESC) proton technique [3] – exploiting the granularity of SFGD, select protons with high dE/dx at the last few nodes.
- The $\nu_\mu CC0\pi1(ESC)p$ selection has excellent resolution and minimal bias in p_p, and thus also in TKI variables, e.g. $\delta\alpha_T$, as shown in Fig. 10 and 11 respectively.

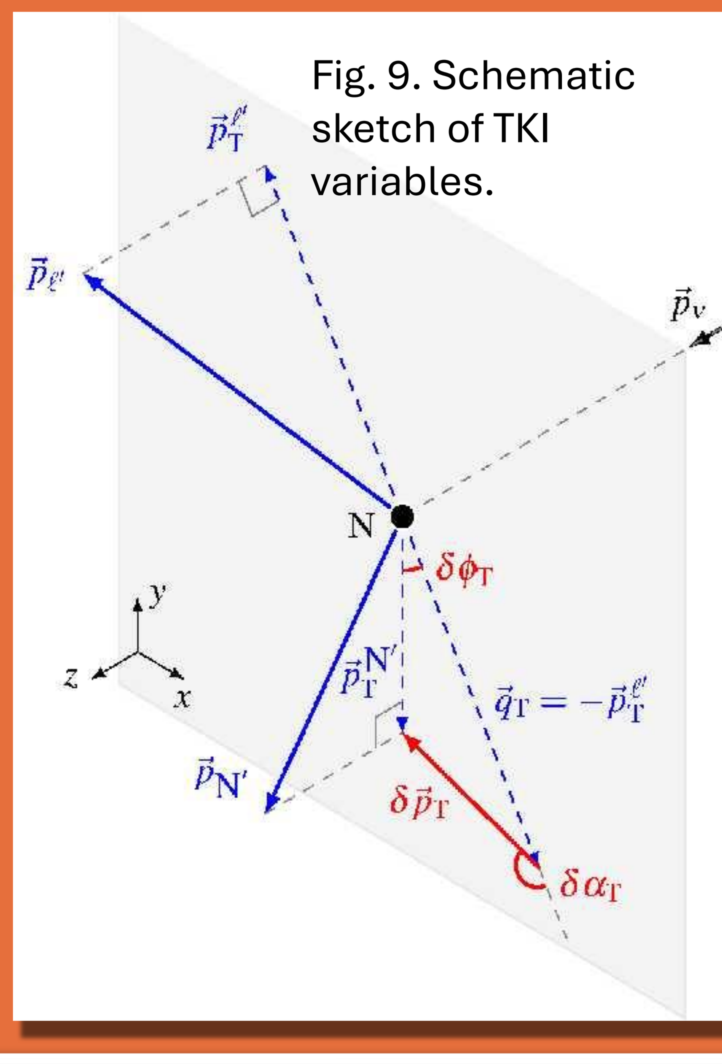

Fig. 9. Schematic sketch of TKI variables.

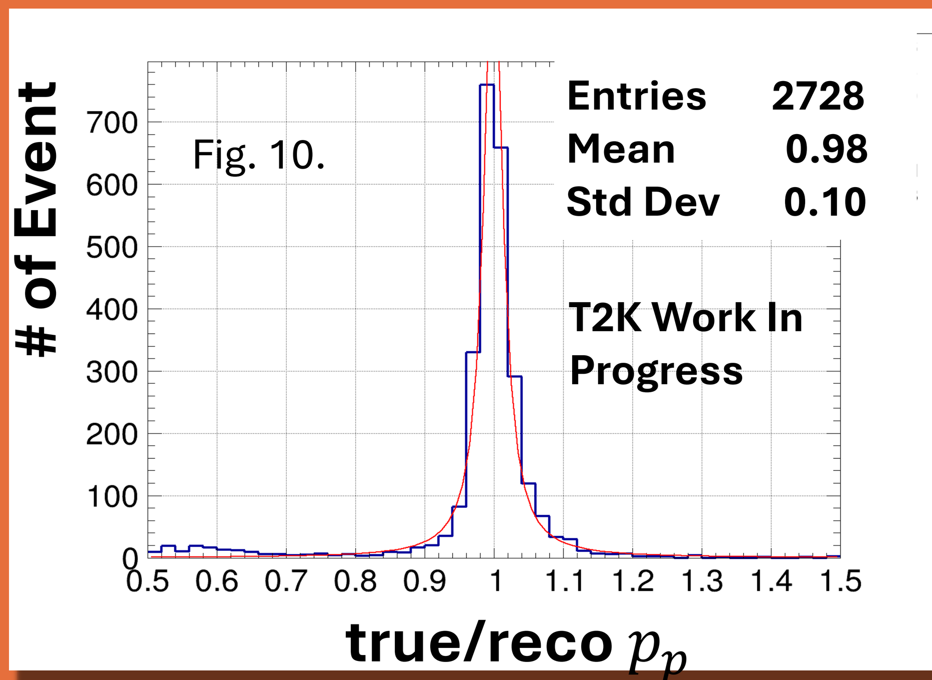

Fig. 10.

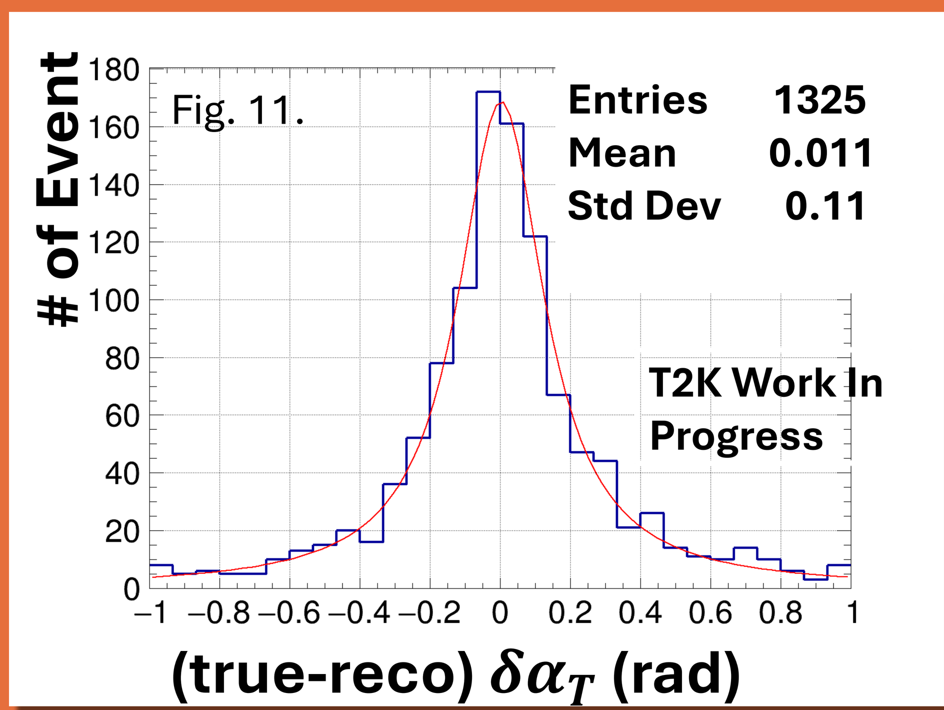

Fig. 11.

- Combine the π^+ TL reconstruction and the ESC proton technique to select a $\nu_\mu CC1\pi^+1p$ sample.
- Excellent resolution for TKI variables, e.g. p_N, as shown in Fig. 12.
- A promising ~40% decrease in the width of double TKI, δp_{TT}, for hydrogen events from previous TPC-based estimation [1], as shown in Fig. 13.
- Combining TKI with COM variables could lead to a high-purity hydrogen sample.

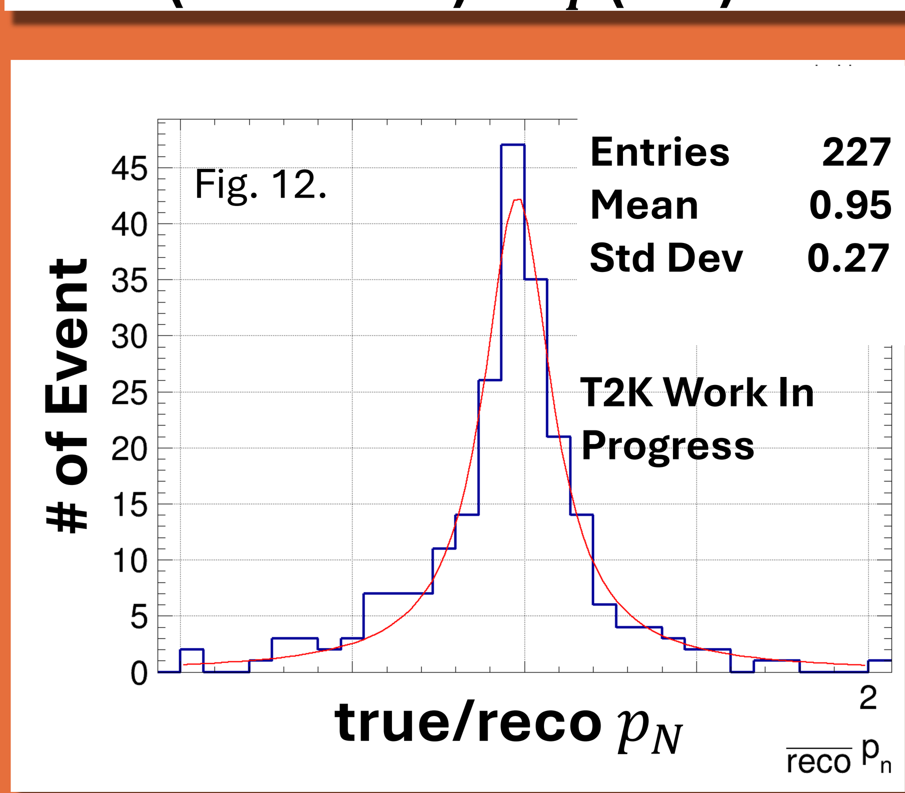

Fig. 12.

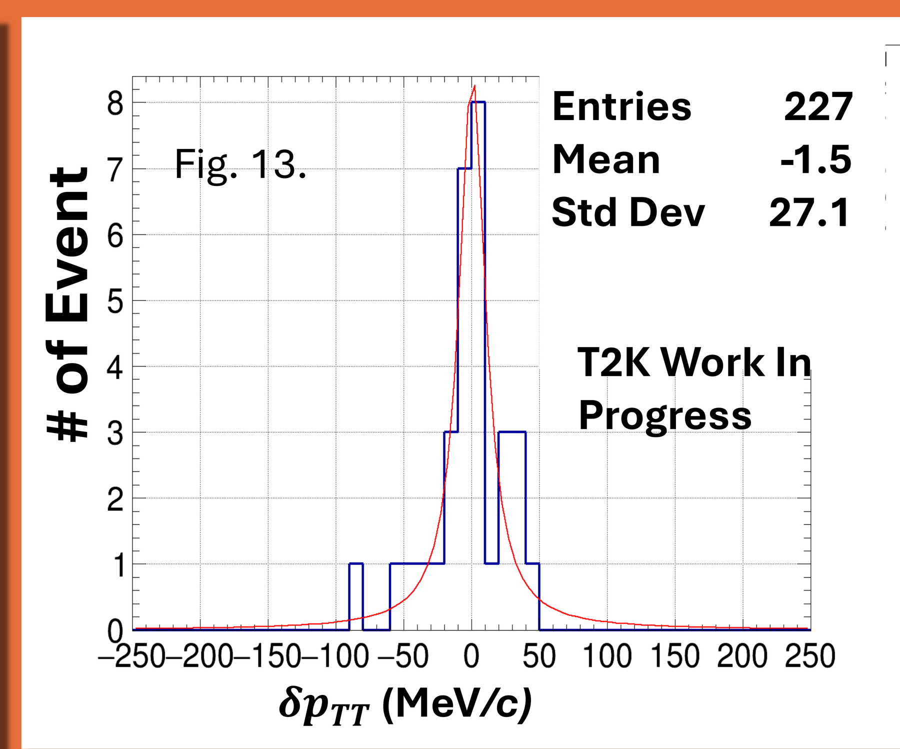

Fig. 13.

Conclusion

SFGD has great resolution and lower thresholds leading to better measurements of important quantities, like the TKI variables, and enabling a novel pion trackless reconstruction method. Additionally, exploiting the capability of measuring hadronic kinematics in SFGD, an innovative set of variables, the COM variables, are derived, which are excellent FSI probes independent from initial nucleon states.

References

[1] X.-G. Lu, D. Coplowe, R. Shah et al., Phys. Rev. D 92 (2015) 051302
[2] X.-G. Lu, L. Pickering, S. Dolan et al., Phys. Rev. C 94 (2016) 015503
[3] Lu, X.-G., M. Betancourt, and for the MINERvA Collaboration. Journal of Physics: Conference Series 888, no. 1 (1 September 2017): 012120.