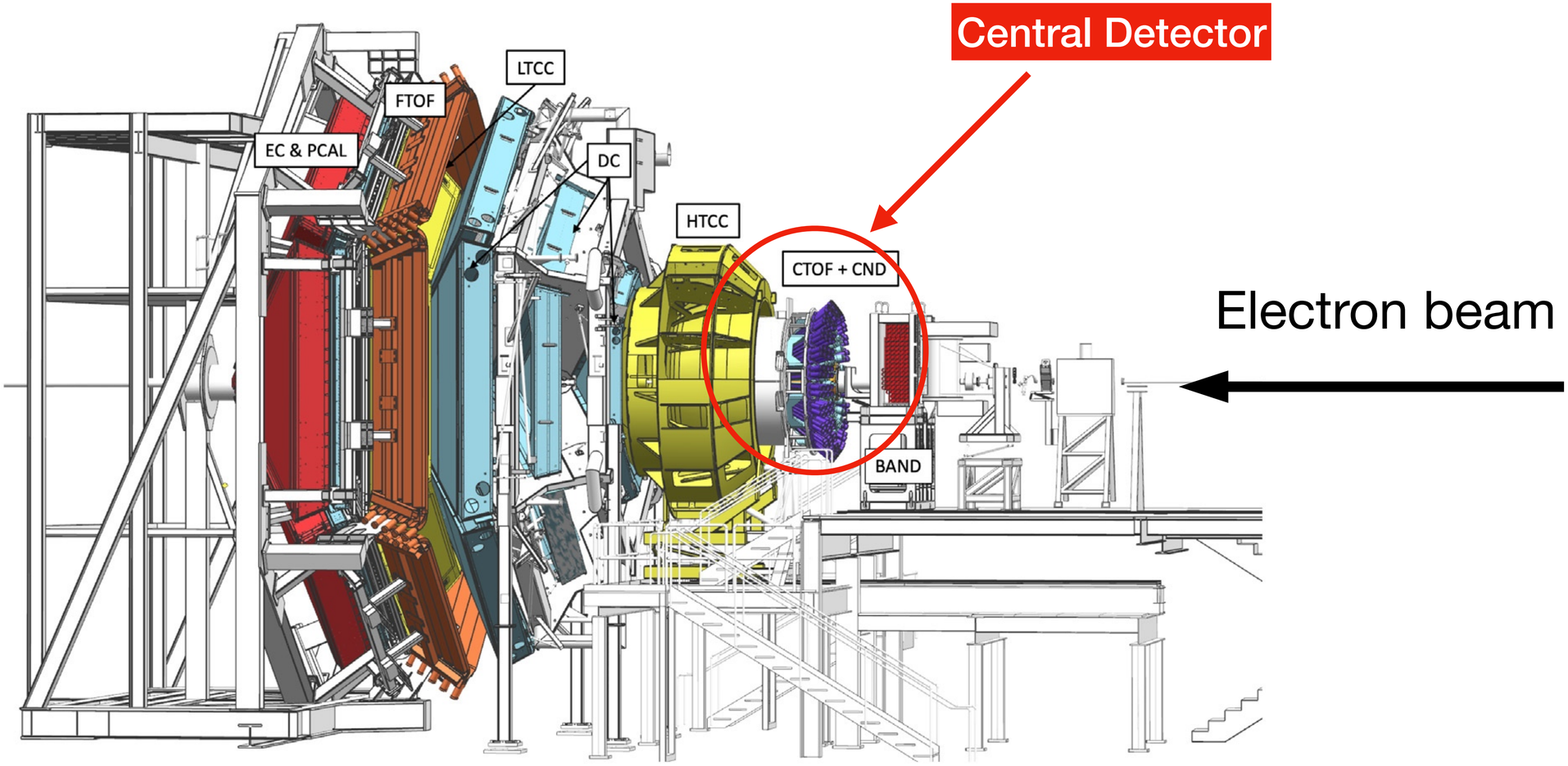
Neutron Detection Algorithm

2026 CLAS collaboration meeting

Igor Becker, 18 Nov 2026

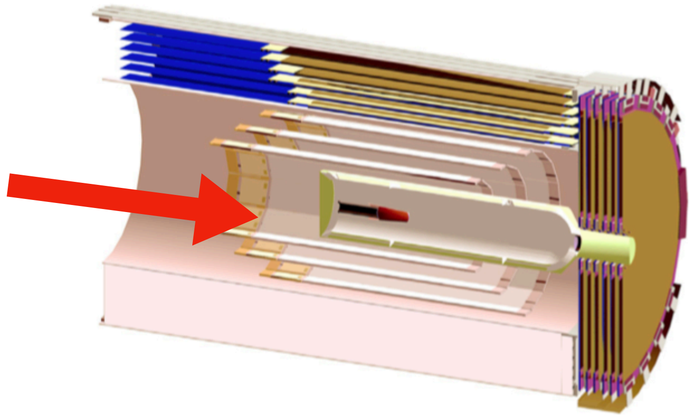
CLAS 12 Spectrometer



V. D. Burkert et al., NIM A 959 (2020) 163419 — CLAS12 Spectrometer

Central Detector

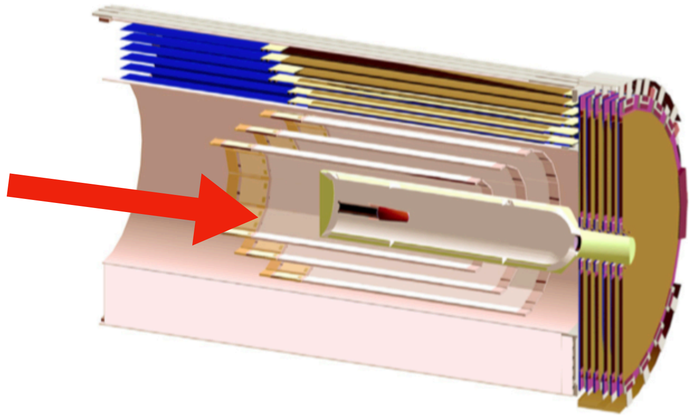
Central Vertex Tracker (CVT)

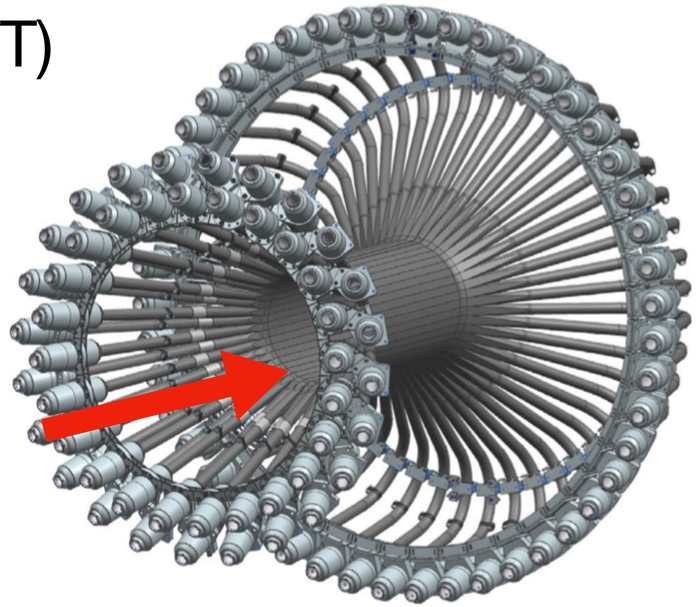


Measure momentum and vertex of charged particles

Central Detector

Central Vertex Tracker (CVT)





Measure momentum and vertex of charged particles

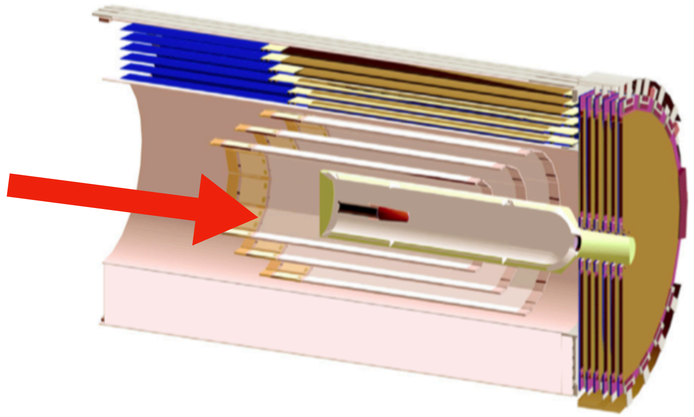
Central Time-of-Flight Detector (CTOF)

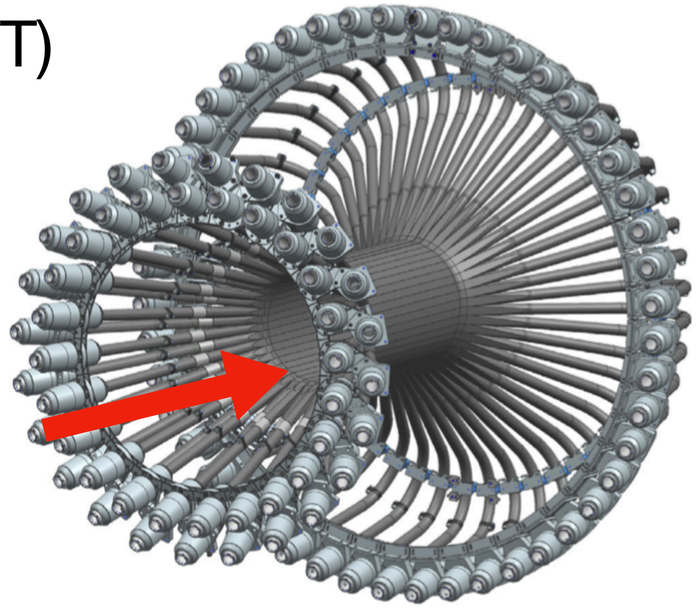
Identification of charged particles via time-of-flight measurements

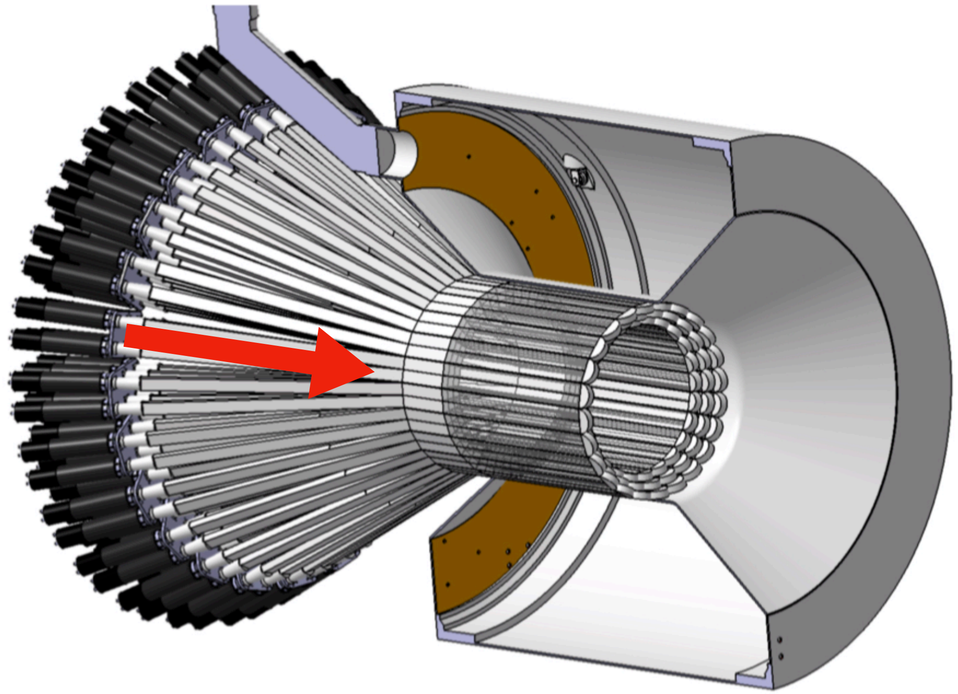
Central Detector

Central Neutron Detector (CND)

Central Vertex Tracker (CVT)







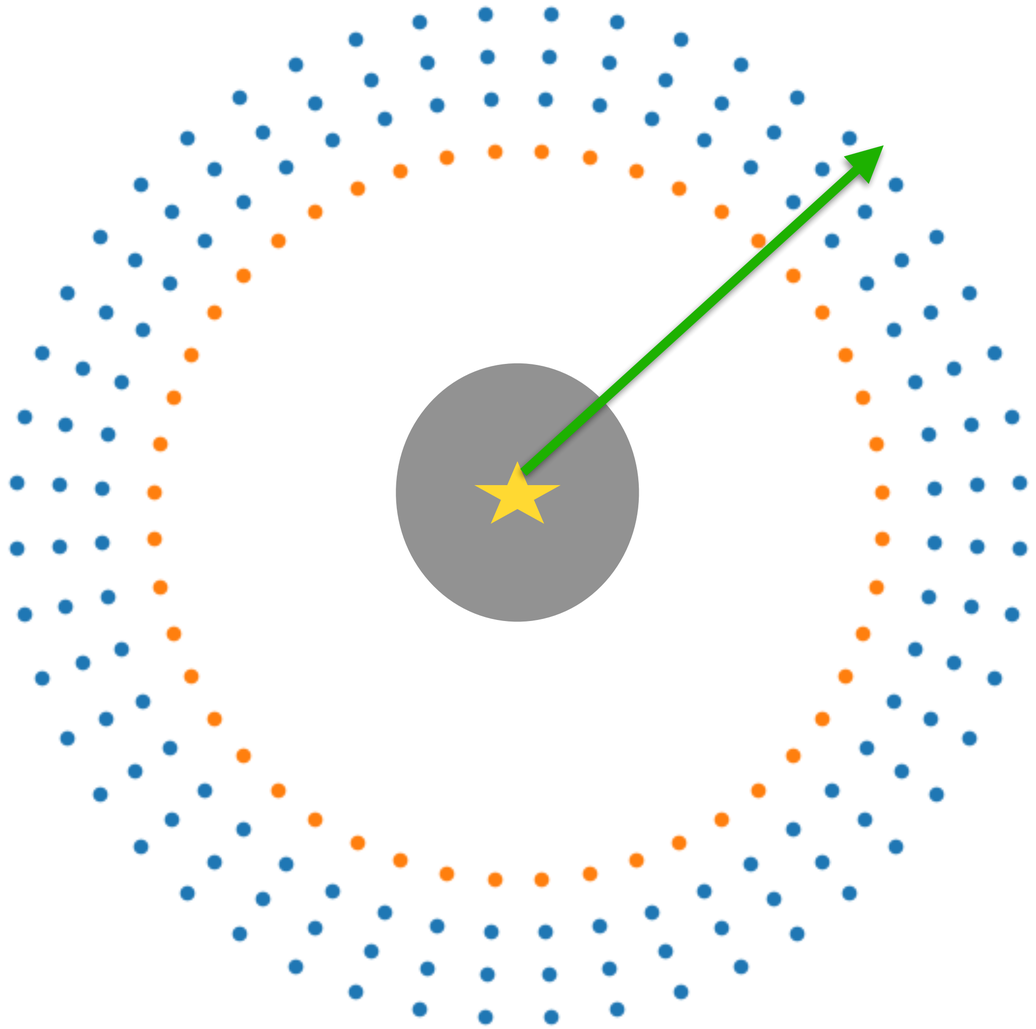
Measure momentum and vertex of charged particles

Central Time-of-Flight Detector (CTOF)

Identification of charged particles via time-of-flight measurements

Neutron detection

Central Detector



Interaction Vertex

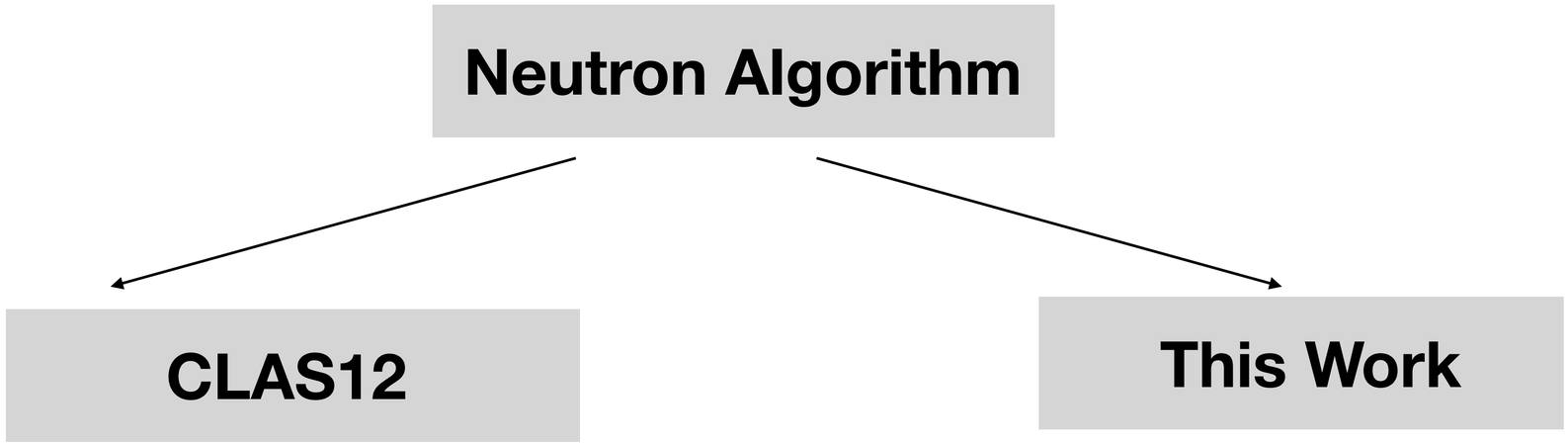
Particle Path

CVT

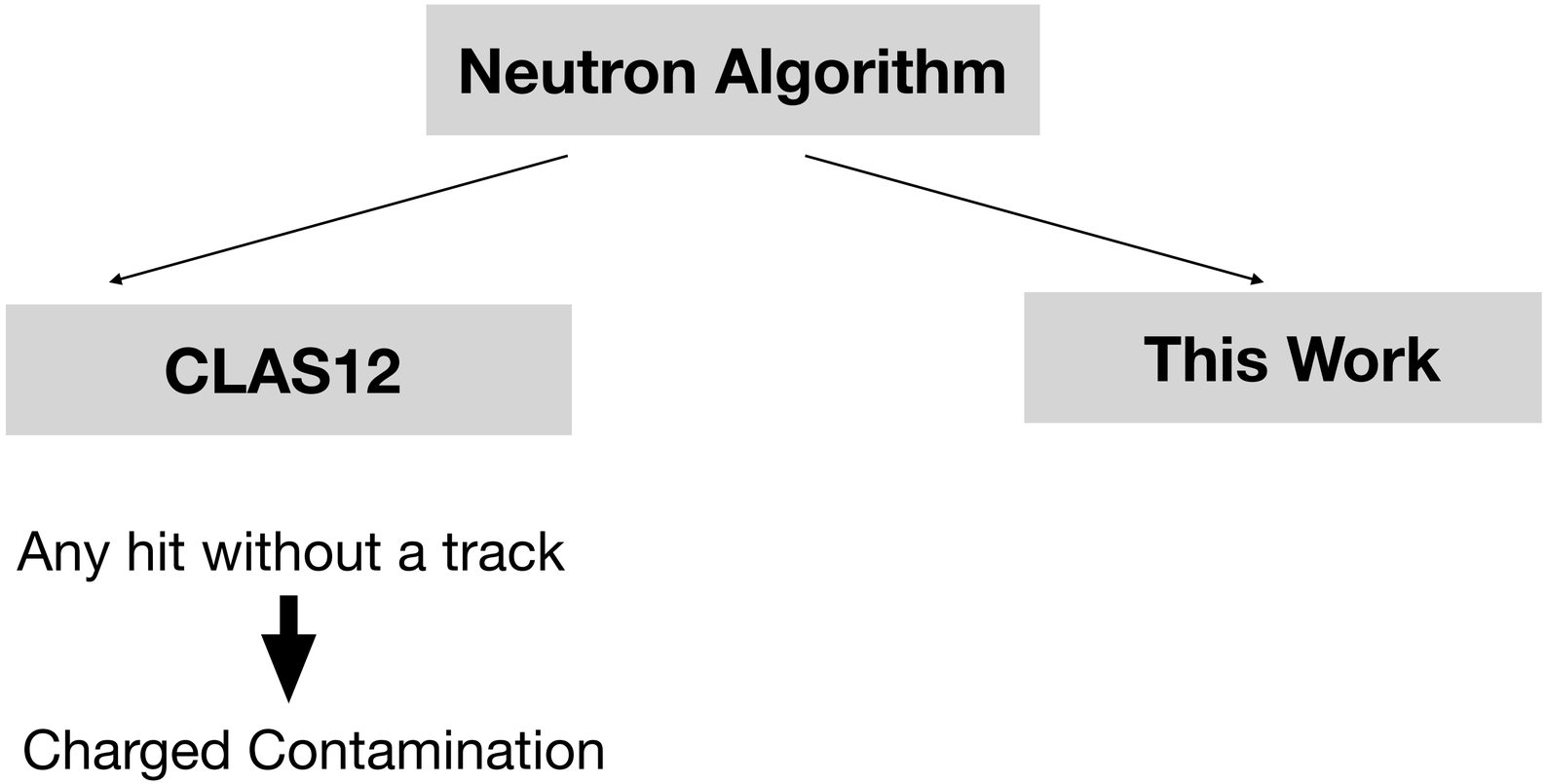
CTOF bar

CND bar

Need for a new neutron algorithm



Need for a new neutron algorithm



Need for a new neutron algorithm

Neutron Algorithm

CLAS12

Any hit without a track

↓

Charged Contamination

This Work

Independent of a track

Based on interaction probability

↓

Reduced Contamination

CTOF bar

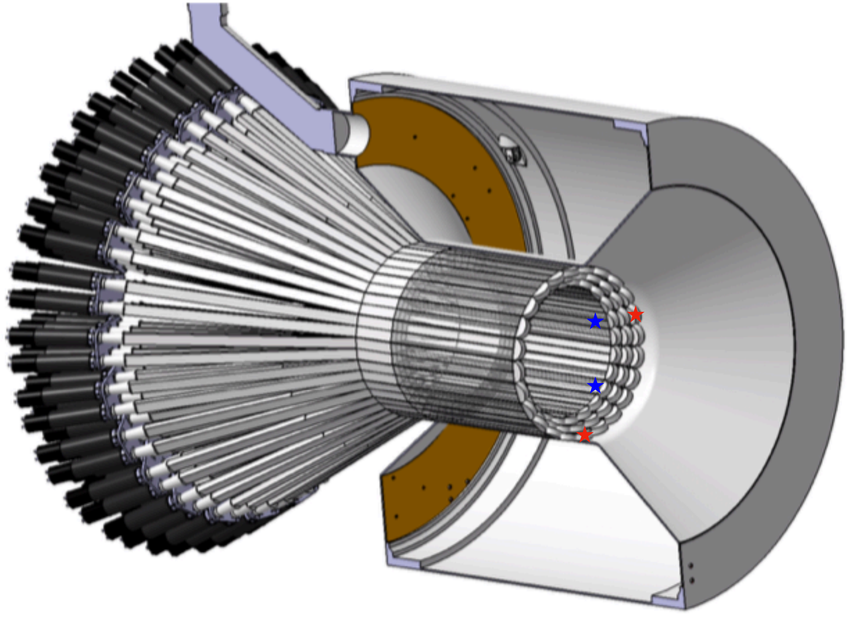
CND bar

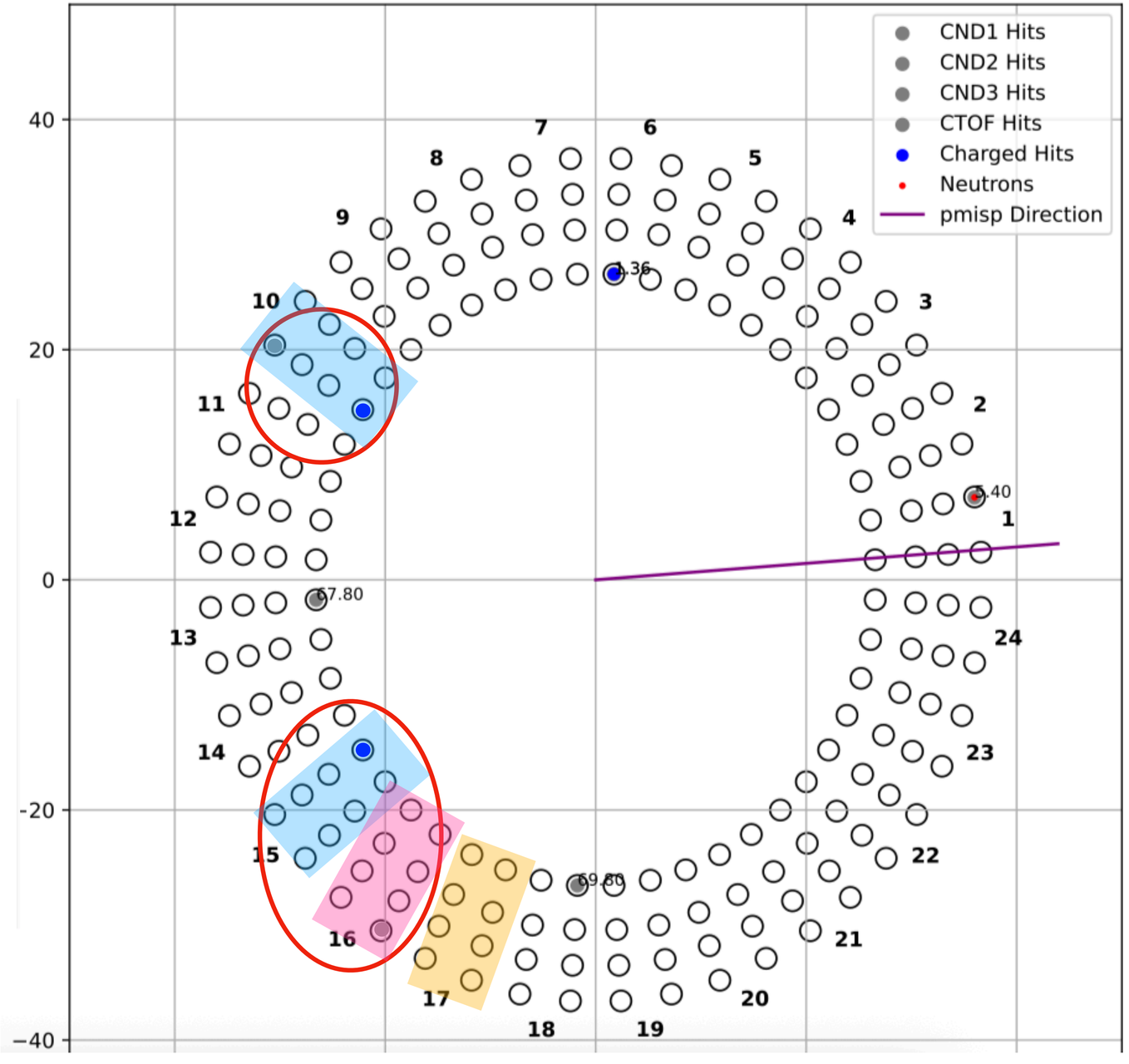


Neutron detection algorithm

- Removed any CND hits in close proximity of a CTOF hit

Proximity range: ±1 sector and ±10ns

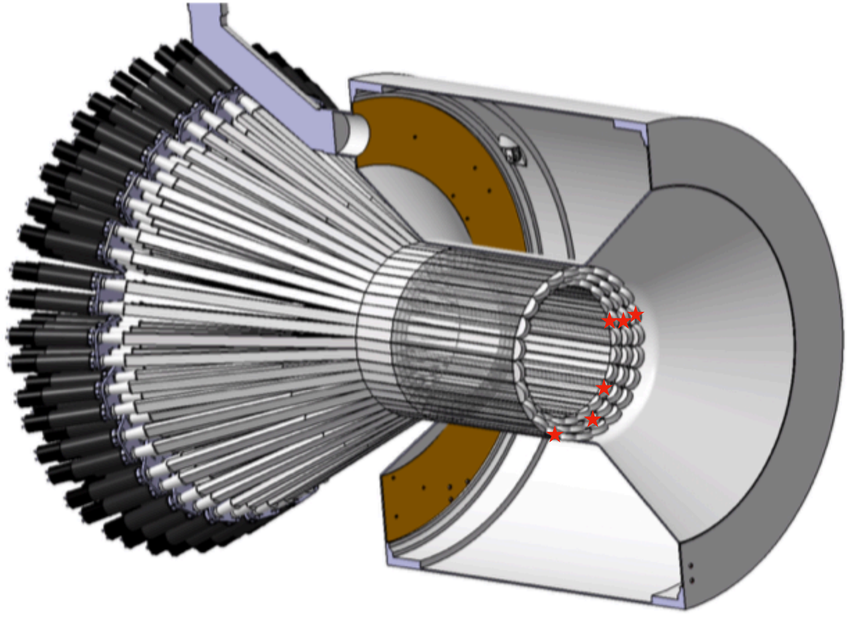


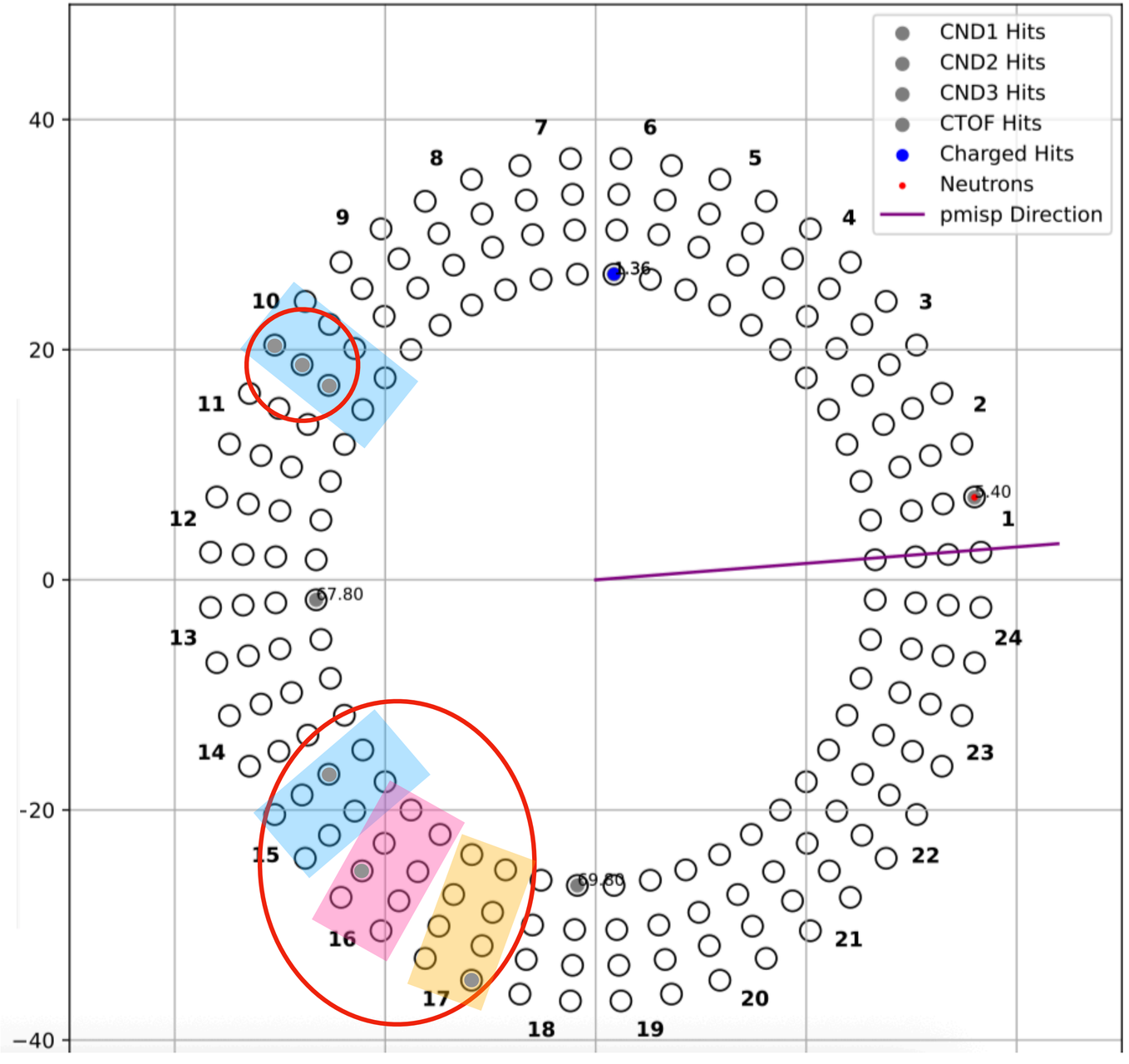


Neutron detection algorithm

- Removed CND hits where there’re matching hits on all 3 detectors in close proximity

Proximity range: ±1 sector and ±10ns

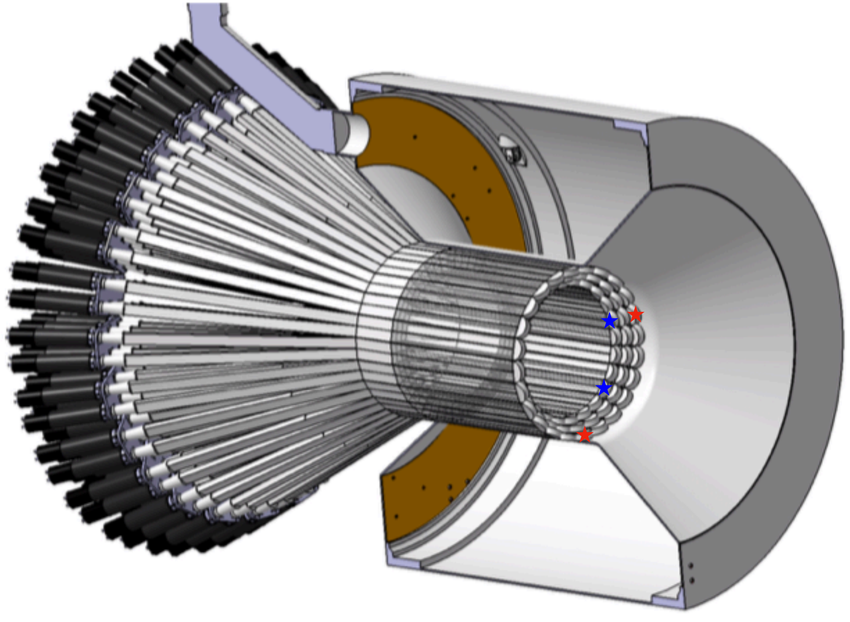


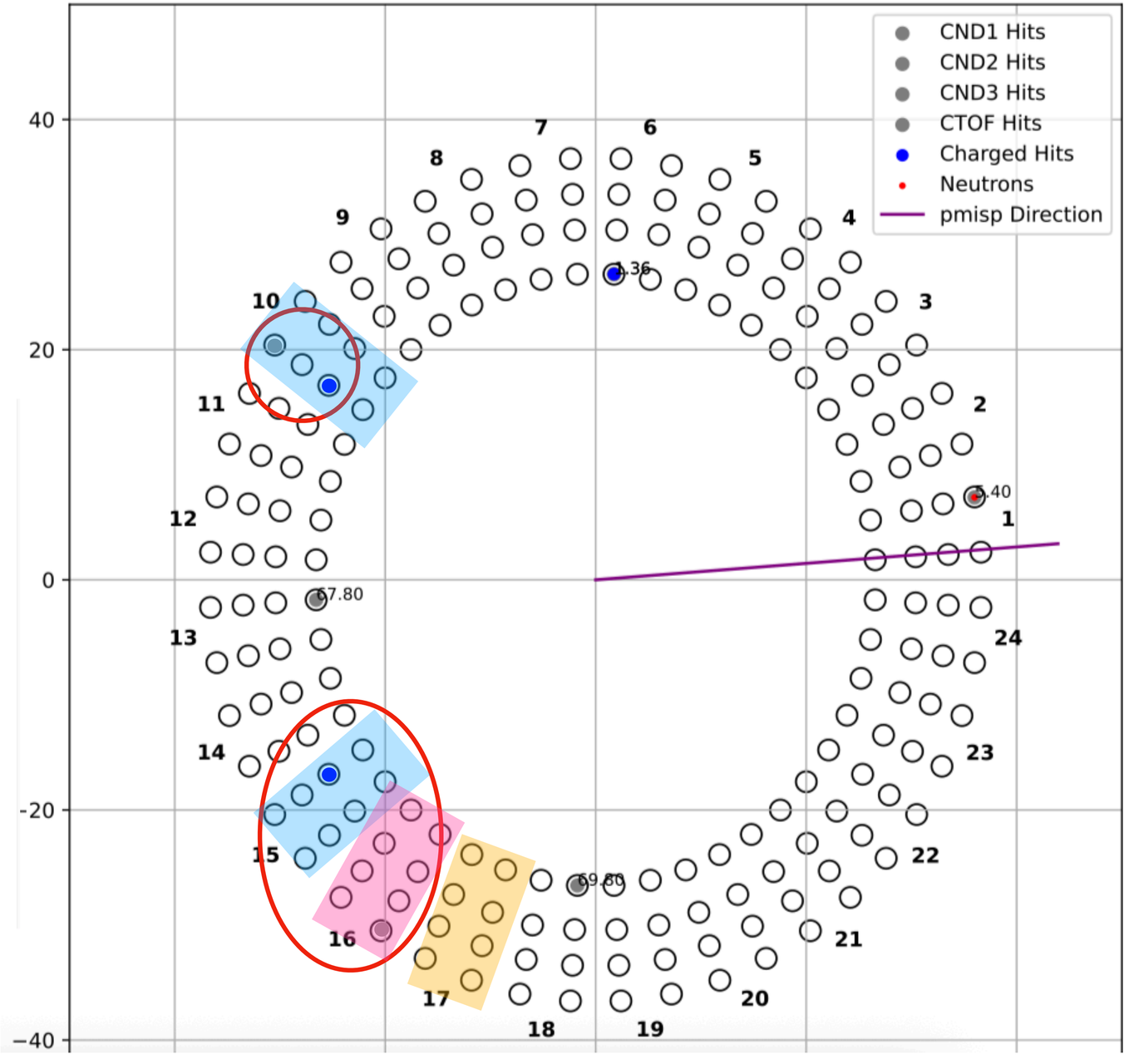


Neutron detection algorithm

- Removed any CND hits in close proximity of a charged hit

Proximity range: ±1 sector and ±10ns

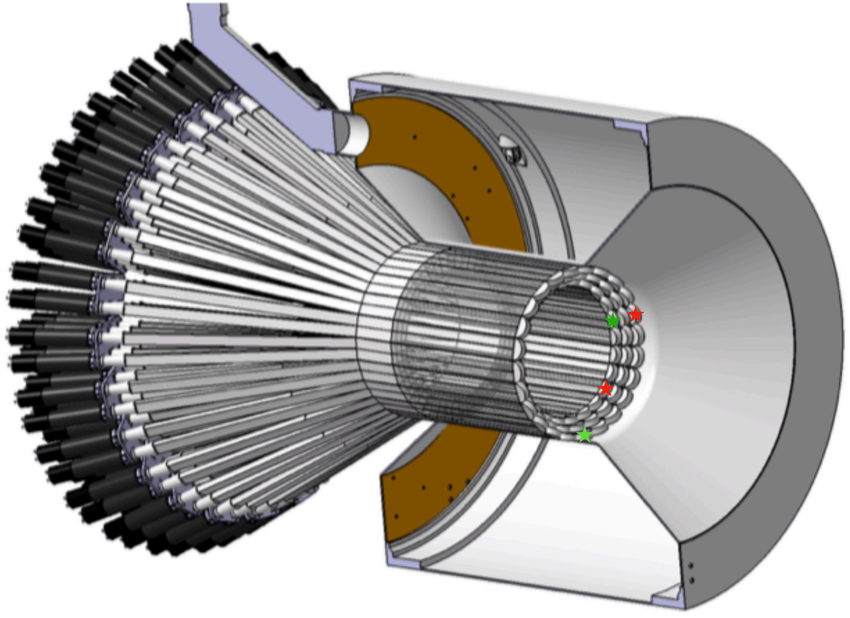


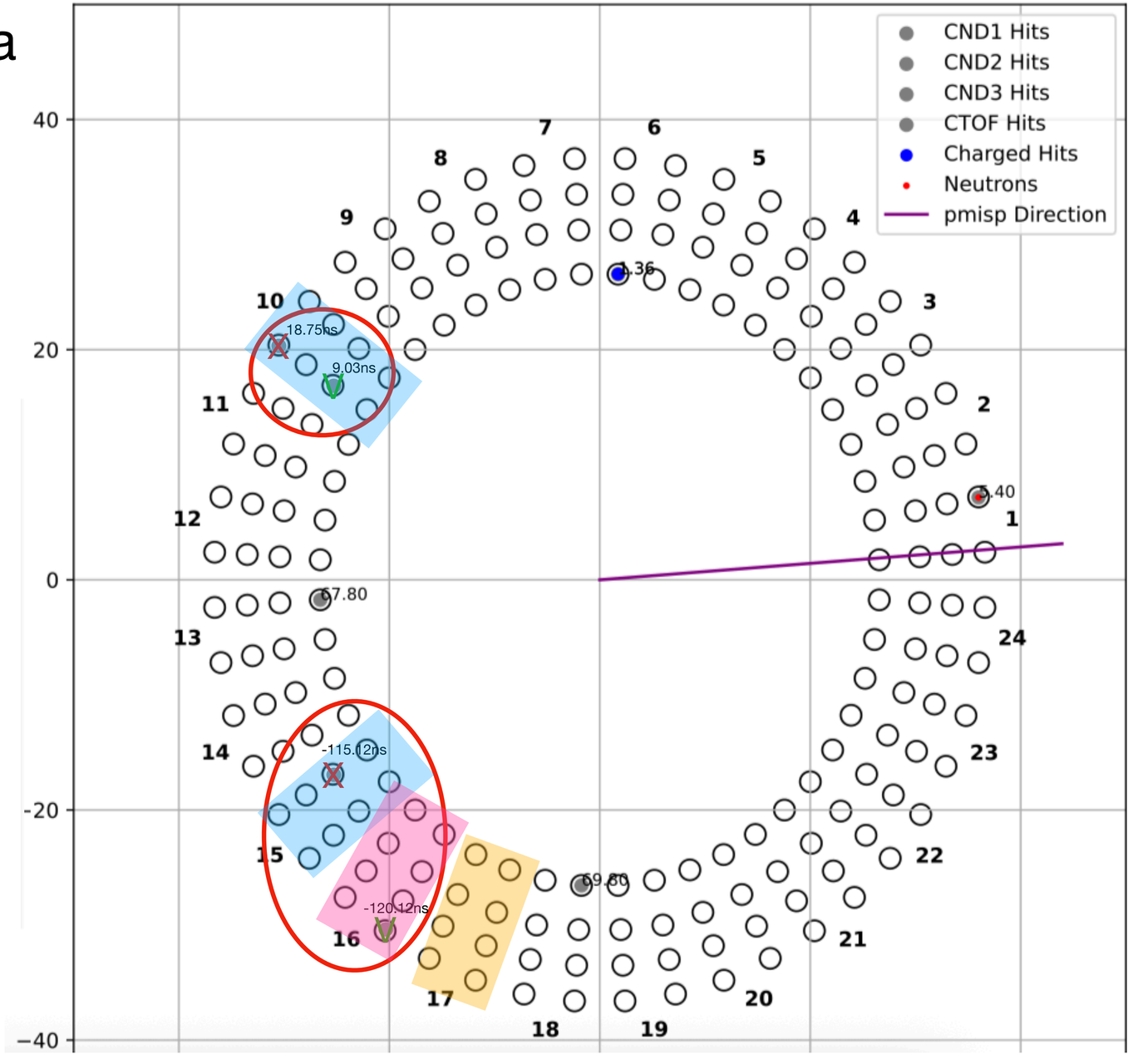


Neutron detection algorithm

- Clustered remaining CND hits into a single neutron if they’re in close proximity of each other and summed their dep. energy

Proximity range: ±1 sector and ±10ns





Algorithm Stages

Three Layer Rejection

Charge-hit proximity veto

CTOF veto

FoF clustering

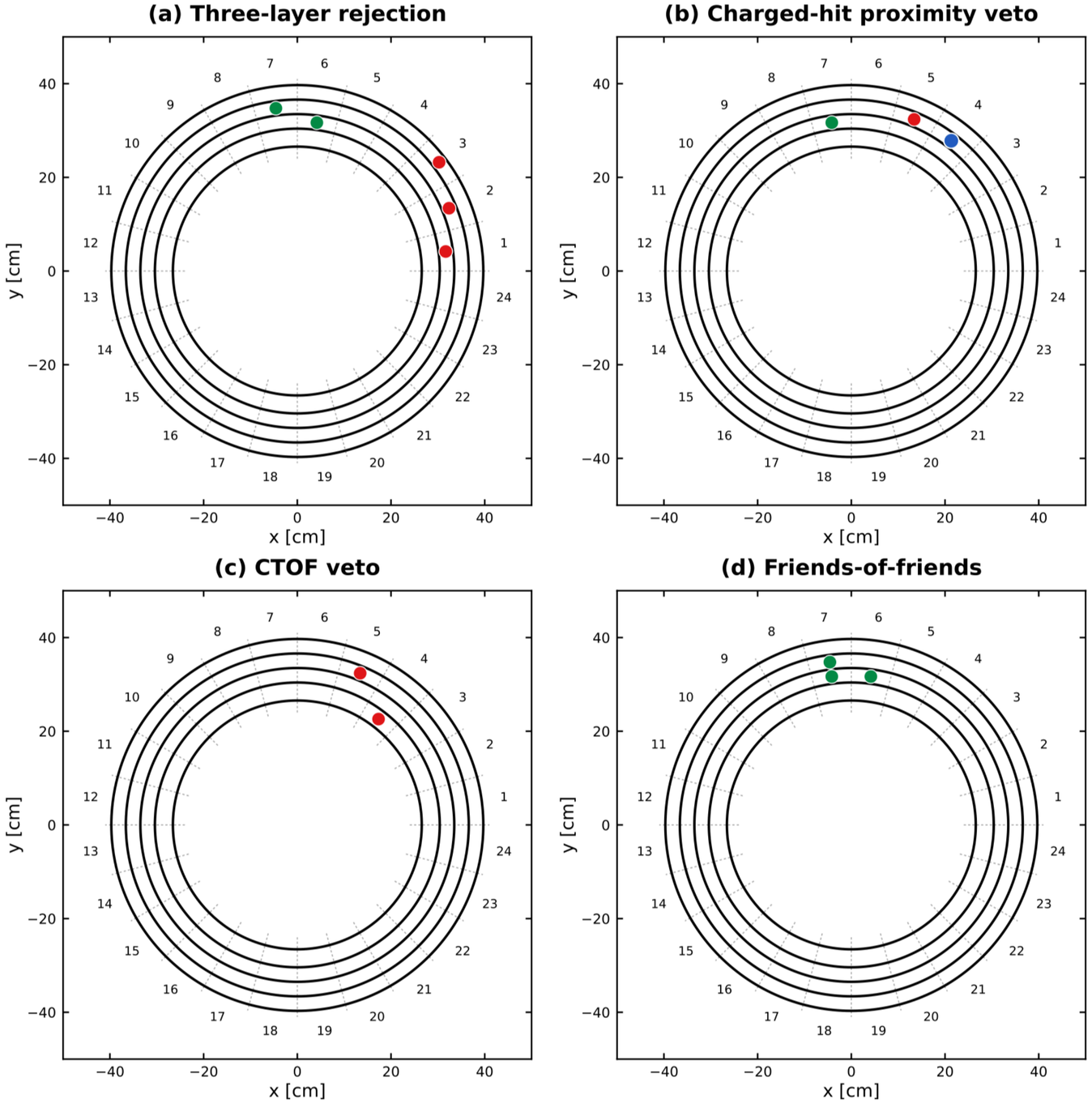


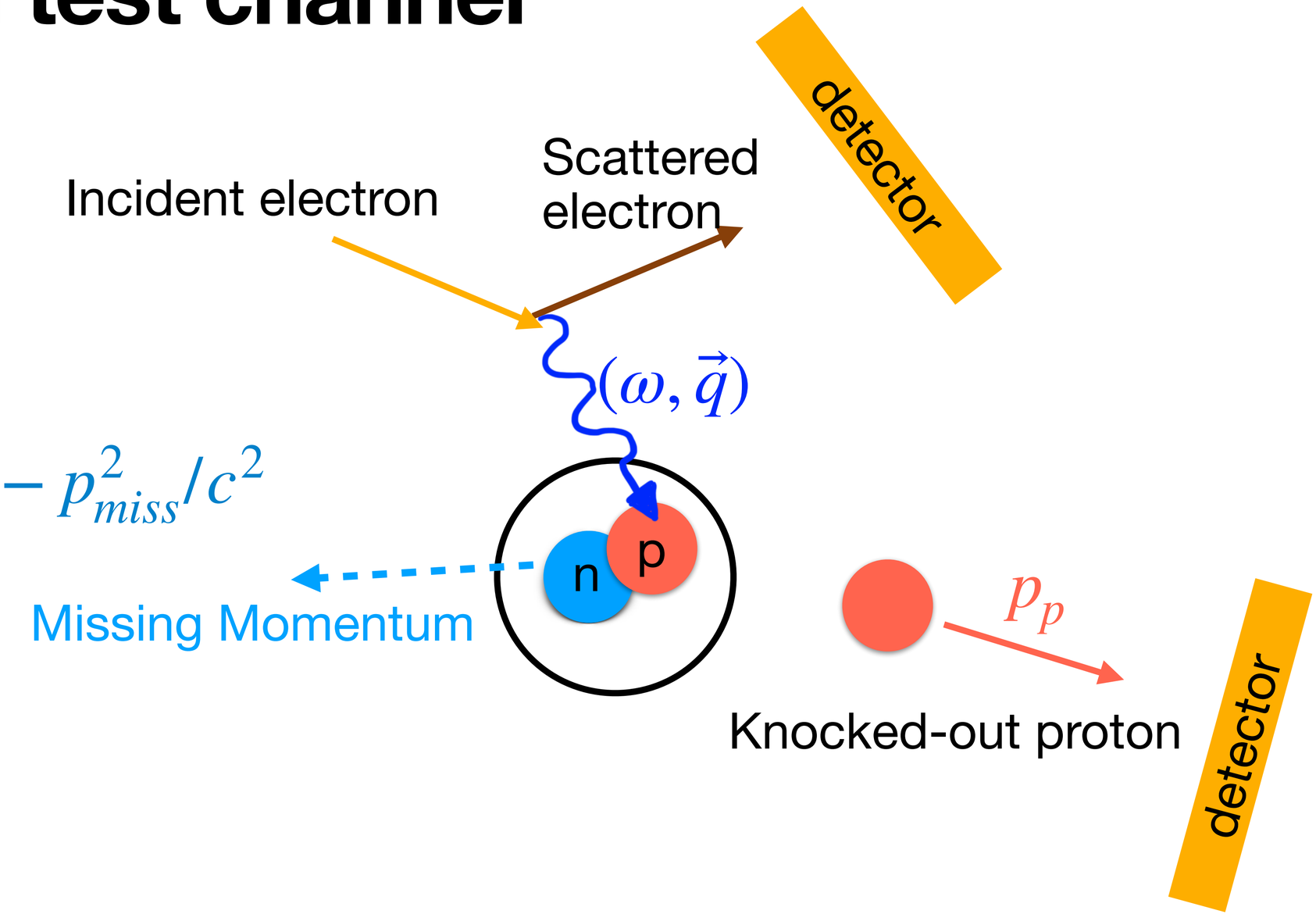
Figure 2: Examples of the hit-level neutron-reconstruction steps. Green markers denote accepted CND hits, red markers denote rejected CND hits, and the blue marker in panel (b) denotes a charged-particle-associated hit that triggers the proximity veto.

Algorithm test channel

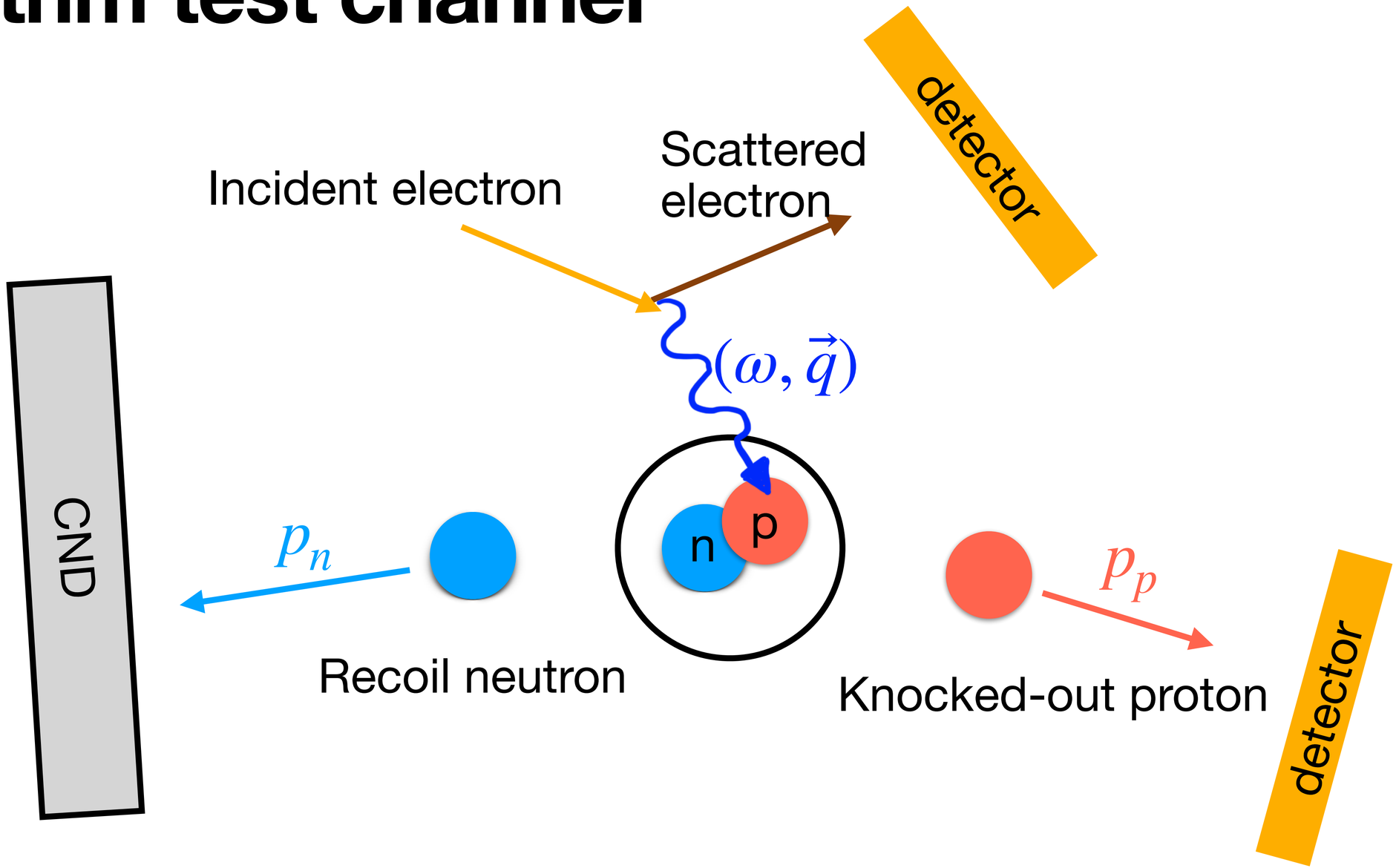
$$\vec{p}_{miss} = \vec{q} - \vec{p}_p$$

$$E_{miss} = \omega - E_p$$

$$M^2_{miss} = E^2_{miss}/c^4 - p^2_{miss}/c^2$$



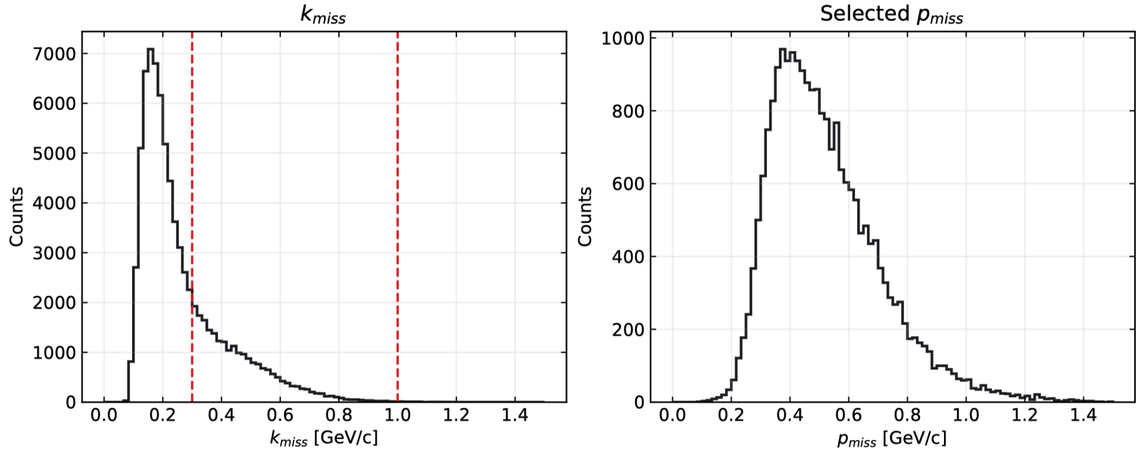
Algorithm test channel

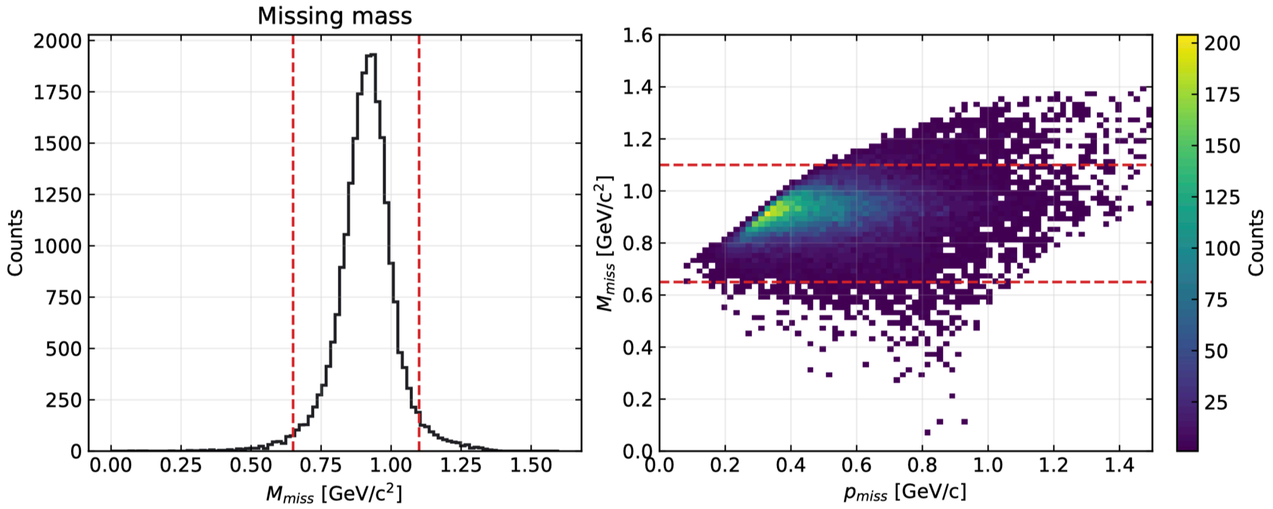


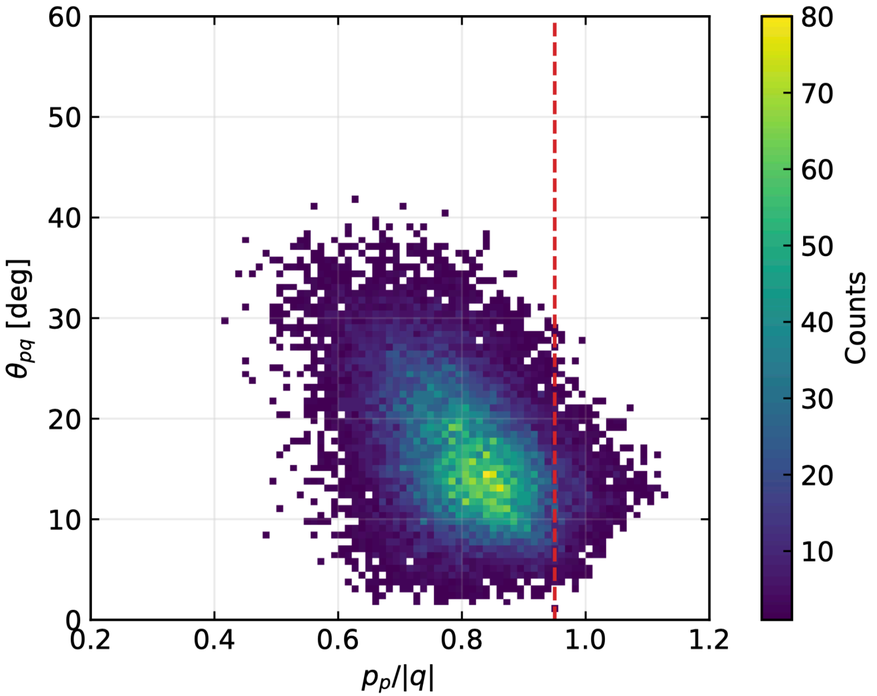
E’p selection cuts

Table 2: Nominal $e'p$ event-selection requirements. Angles are quoted in degrees.

Quantity	Requirement	Purpose
Proton multiplicity	$n_p = 1$	Define the $e'p$ topology
Q^2	$> 1.0\,\mathrm{GeV}^2$	Basic hard-scattering selection
x_B	> 1.2	Suppress the inelastic tail
Electron vertex z_e	$-5 < z_e < 0$ cm	Select the target volume
Leading-proton momentum p_p	$> 1.0\,\mathrm{GeV/c}$	Fast struck-proton candidate
Proton–q ratio	$p_p/\lvert\vec{q}\rvert < 0.95$	Suppress high-ratio missing-mass tail
k_{miss}	$0.30 < k_{\mathrm{miss}} < 1.00\,\mathrm{GeV/c}$	Approved SRC selection
θ_{miss}	$50^\circ < \theta_{\mathrm{miss}} < 110^\circ$	CND angular coverage
p_{miss}-veto	Pass	Unambiguous projected neutron path
M_{miss}	$0.65 < M_{\mathrm{miss}} < 1.10\,\mathrm{GeV/c^2}$	Neutron missing-mass region



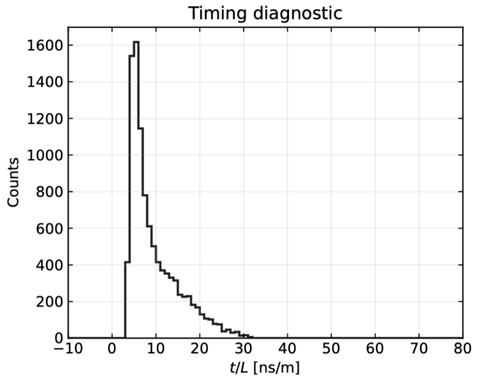


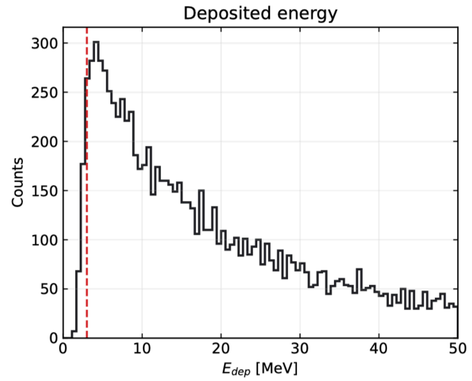


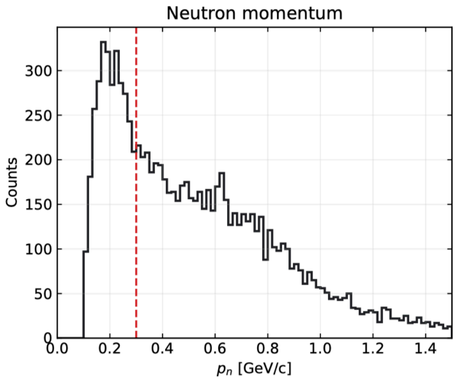
E’pn Selection Cuts

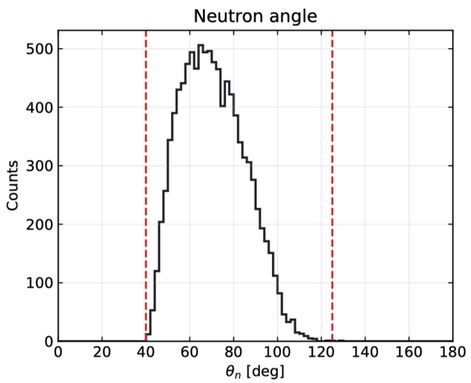
Table 4: Nominal reconstructed-neutron requirements.

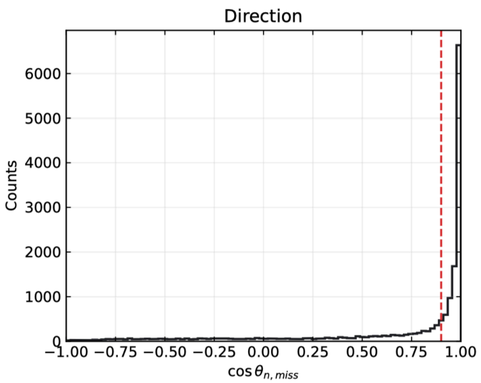
Quantity	Requirement	Purpose
p_n	$> 0.30\,\mathrm{GeV/c}$	Reconstructed-neutron threshold
θ_n	$40^\circ < \theta_n < 125^\circ$	CND acceptance
E_{dep}	$> 3\,\mathrm{MeV}$	Suppress noise and small deposits
$\cos\theta_{n,\mathrm{miss}}$	> 0.9	Directional agreement with p_{miss}
$p_n - p_{\mathrm{miss}}$	$-0.135 < p_n - p_{\mathrm{miss}} < 0.178\,\mathrm{GeV/c}$	Fitted $\mu \pm 2\sigma$ consistency window

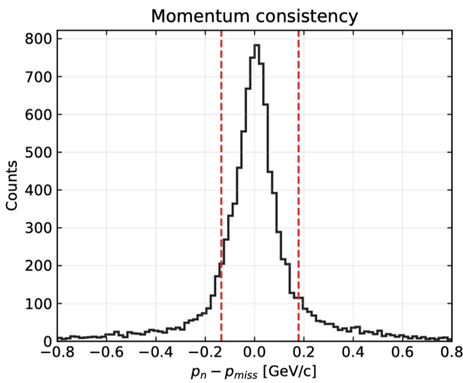


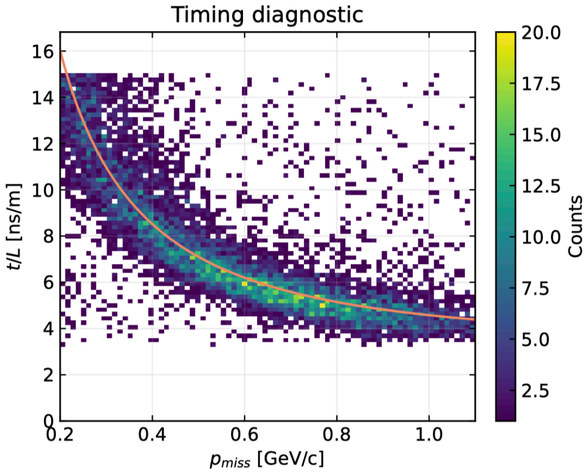


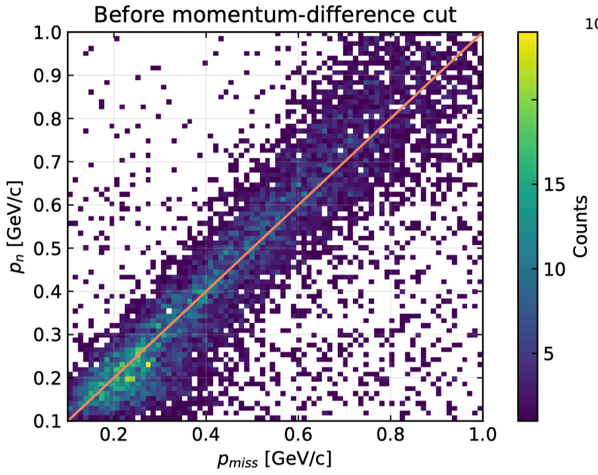




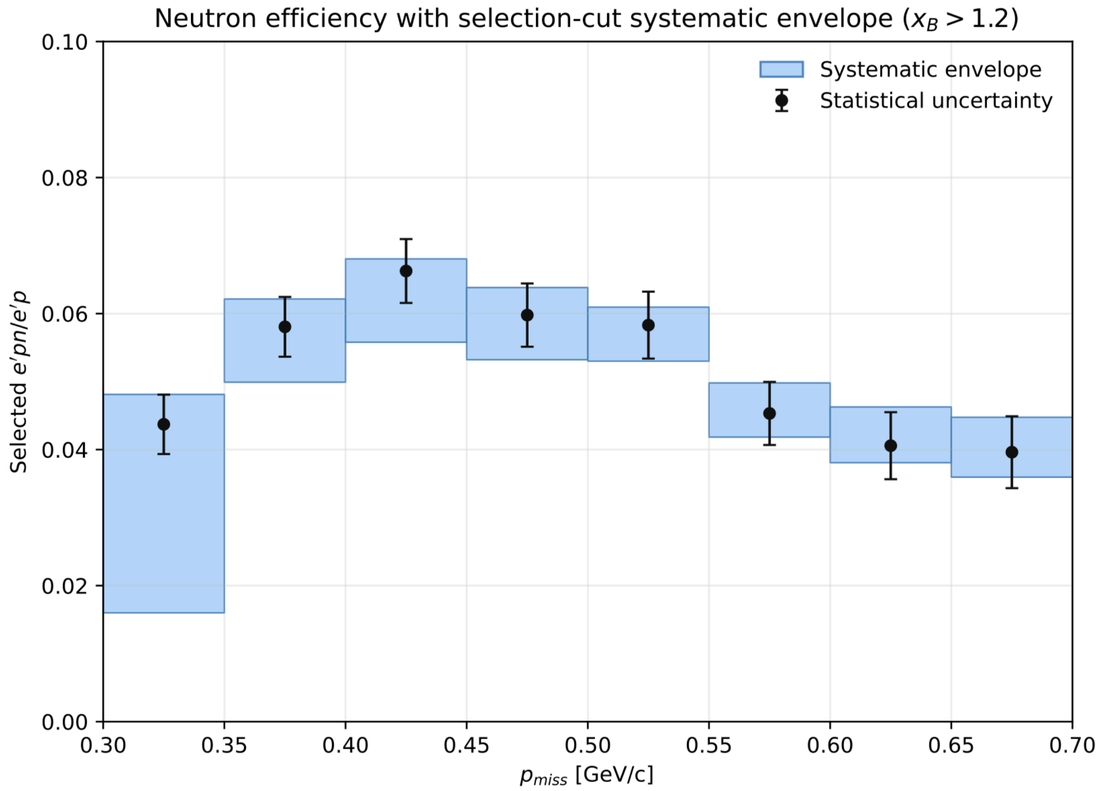




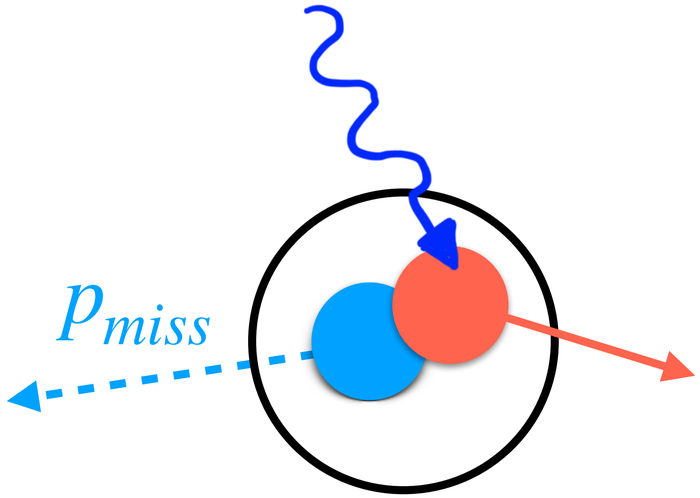




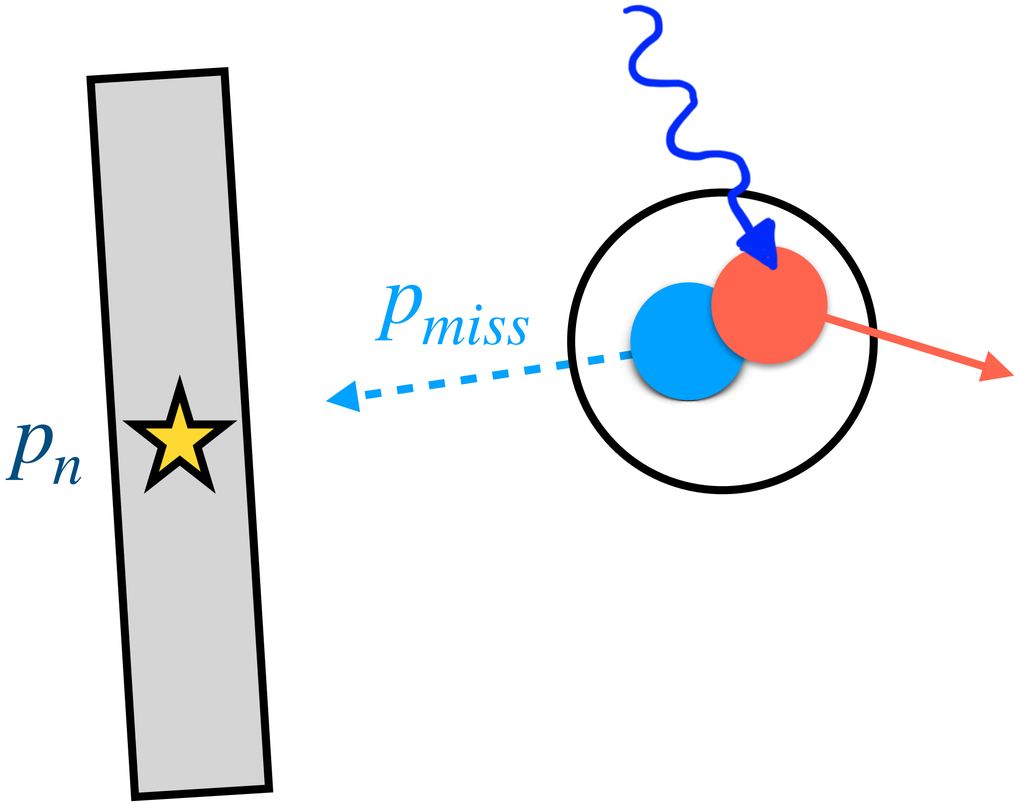
Algorithm Efficiency



Detector Resolution

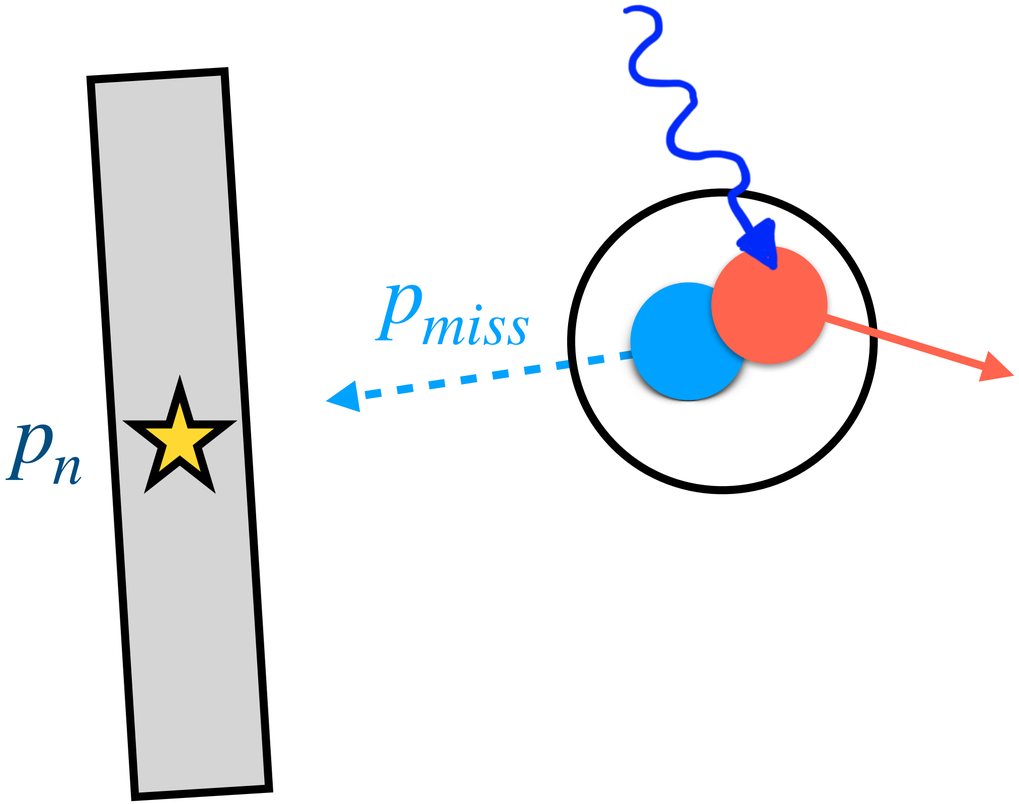


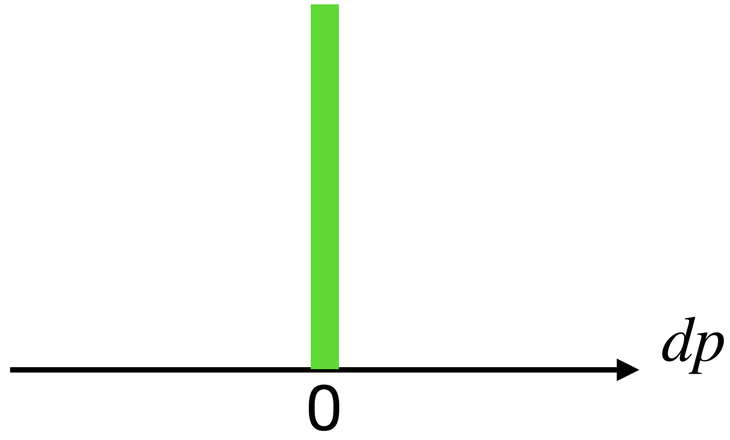
Detector Resolution



Detector Resolution

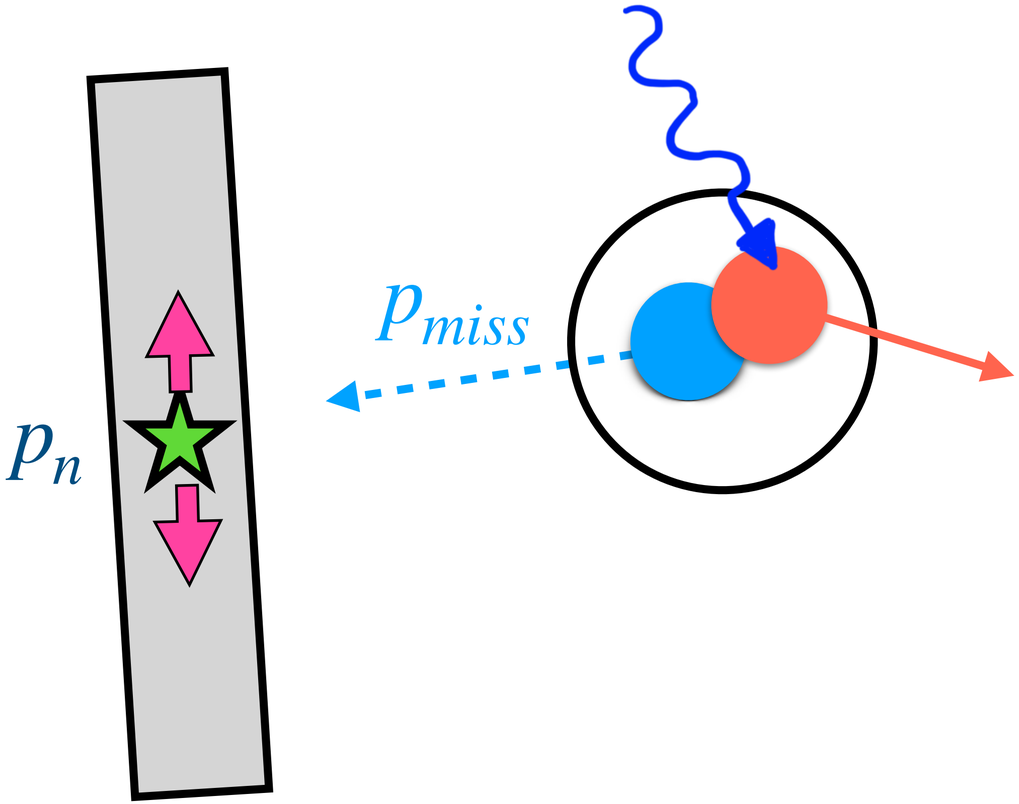
- In Deuterium $dp = p_{miss} - p_n = 0$

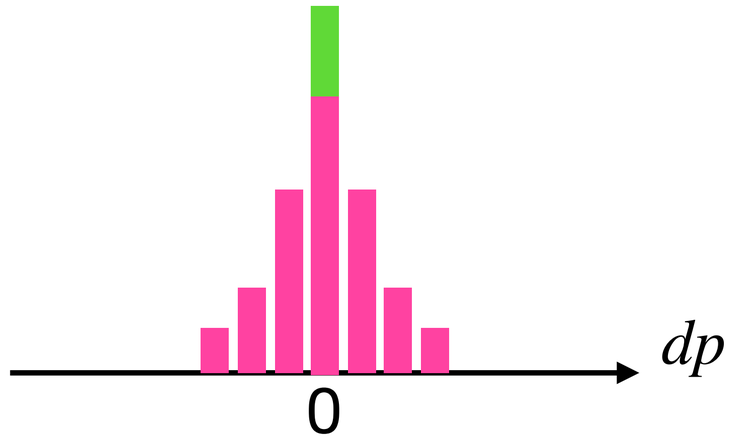




Detector Resolution

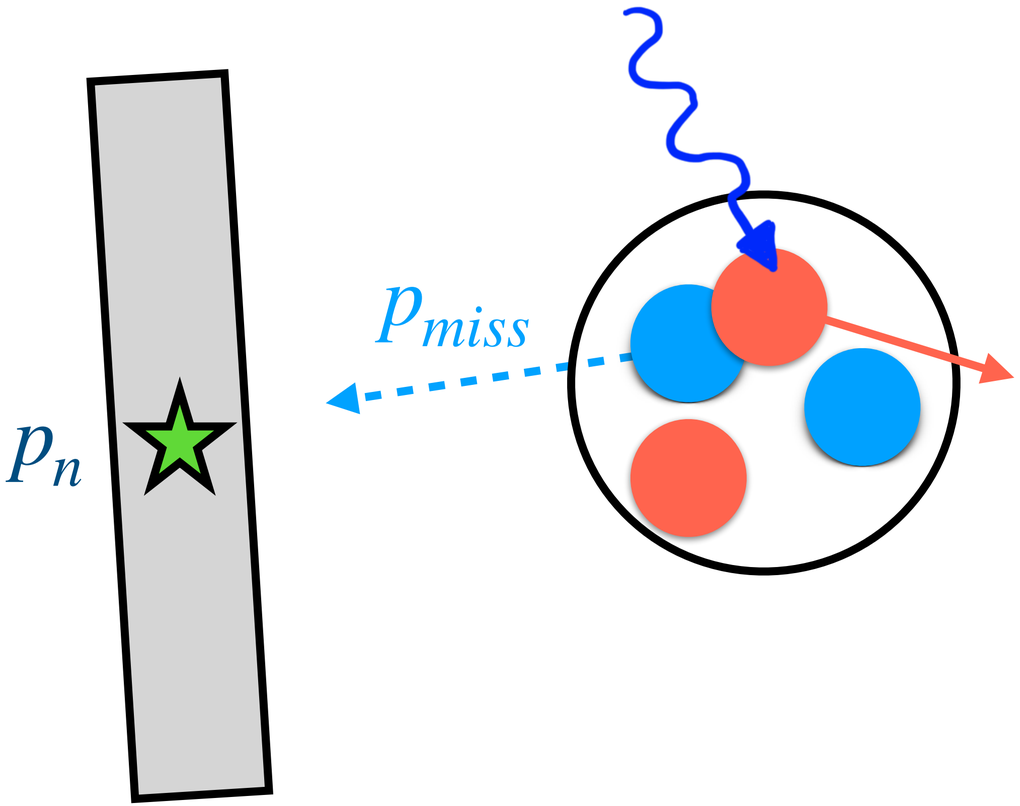
- In Deuterium $dp = p_{miss} - p_n = 0$





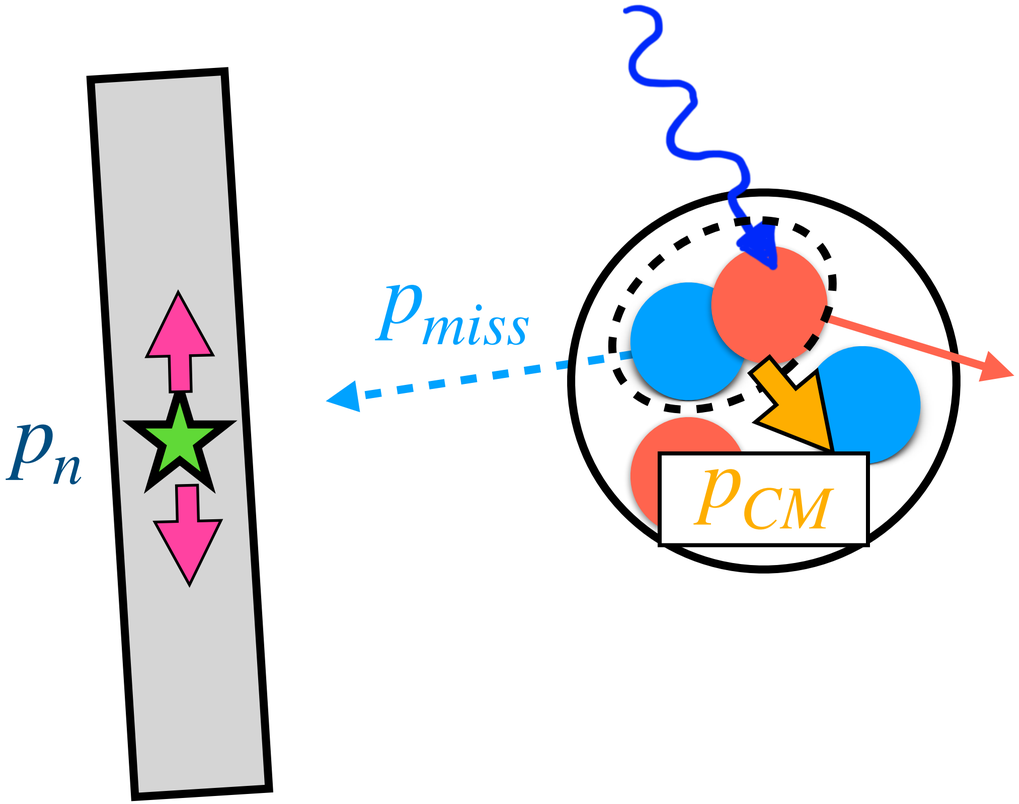
Helium-4 Center of Mass Motion

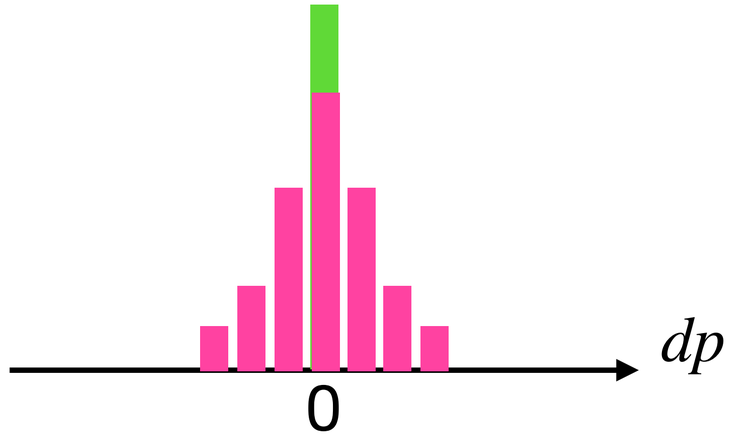
- In Helium-4 $dp = p_{miss} - p_n \neq 0$



Helium-4 Center of Mass Motion

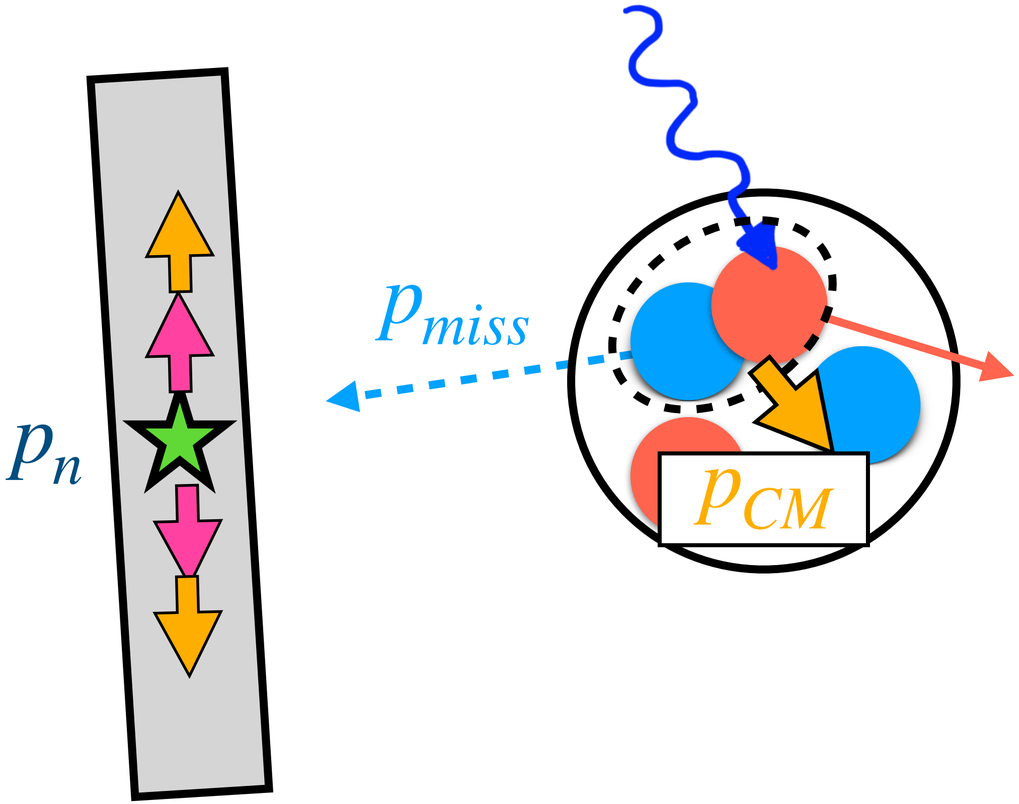
- In Helium-4 $dp = p_{miss} - p_n \neq 0$

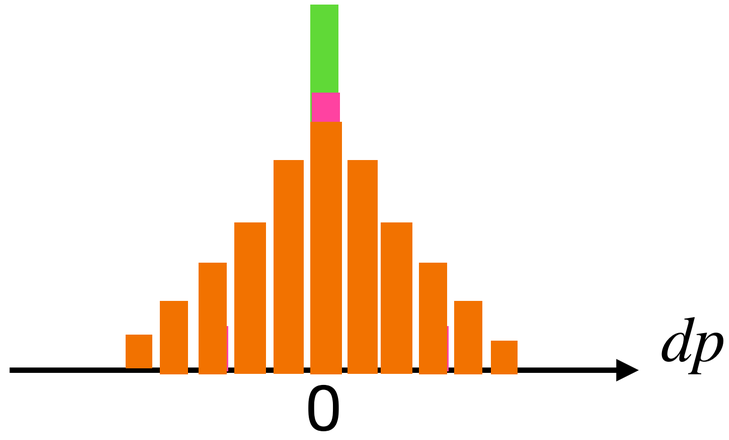




Helium-4 Center of Mass Motion

- In Helium-4 $dp = p_{miss} - p_n \neq 0$

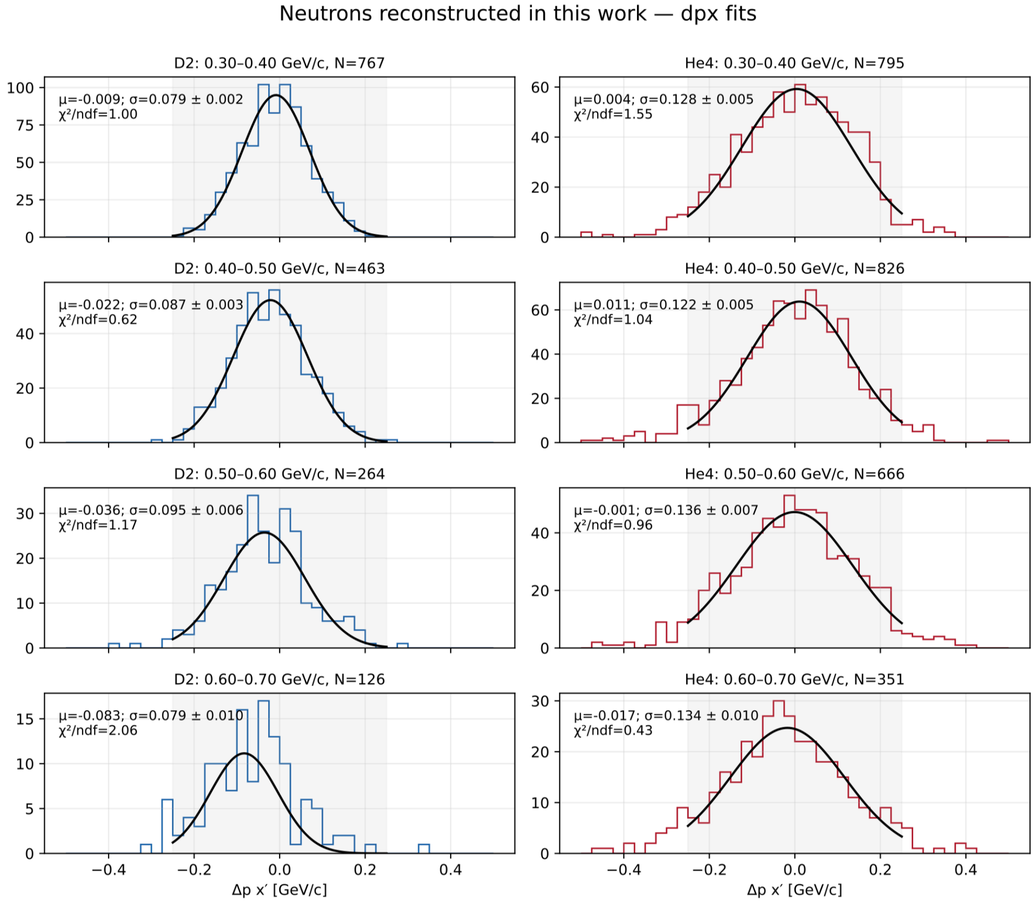


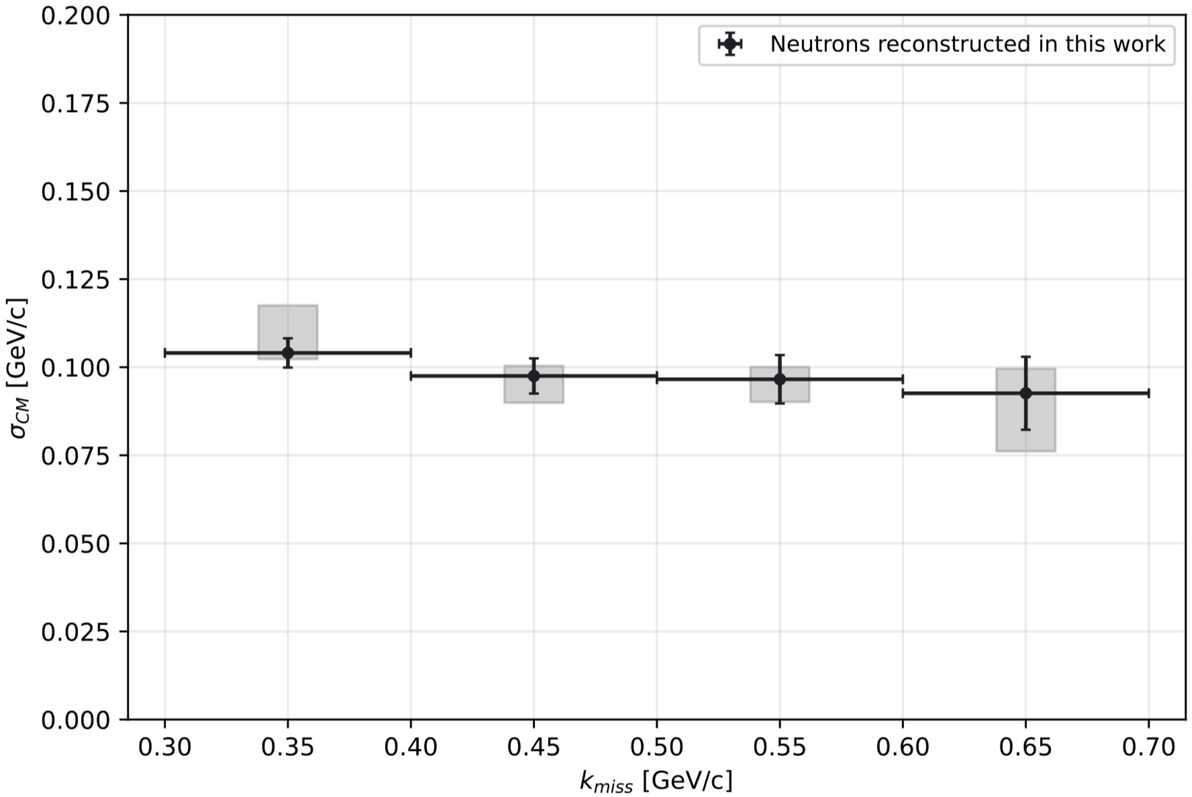


Helium-4 Center of Mass Motion

$$\sigma_{CM}^2 = \sigma_{\mathrm{He}}^2 - \sigma_{\mathrm{D}}^2$$

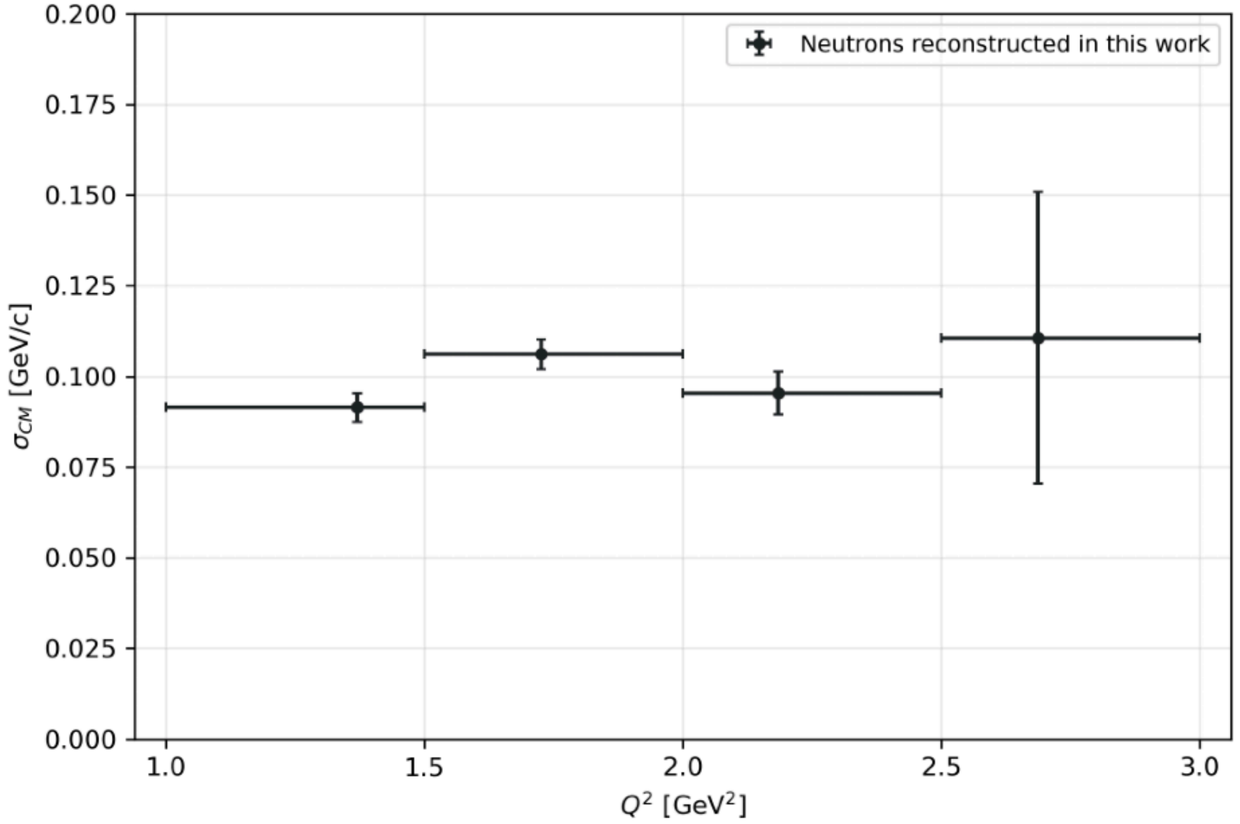
$$\overline{\sigma}_{\mathrm{CM},T} = \left(97.7 \pm 3.5\,(\mathrm{stat})\,^{+2.7}_{-4.3}\,(\mathrm{syst})\right)\ \mathrm{MeV}/c.$$





Helium-4 Center of Mass Motion

Q2 (in)dependence



Summary

- Development and validation of a dedicated neutron-identification algorithm for the CLAS12 Central Neutron Detector

- Extraction of the center-of-mass motion of correlated pn pairs in Helium-4

$$\overline{\sigma}_{\mathrm{CM},T} = \left(97.7 \pm 3.5\,(\mathrm{stat})\,^{+2.7}_{-4.3}\,(\mathrm{syst})\right)\ \mathrm{MeV}/c.$$

