Differential cross sections for ^{12}C(n,α_0), ^{16}O(n,α_0) and ^{16}O$(n,\alpha_{1,2,3})$ between $E_n = 7.2$ and 10 MeV with an active-target Time Projection Chamber

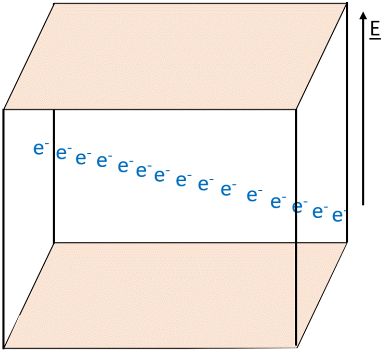
Jack Bishop - University of Birmingham

IOP 2026, 14th April 2026

Overview

Time Projection Chambers

How a Time Projection Chamber works



Why a TPC?

Typically used for performing studies with RIBs (Radioactive Ion Beams) - low intensity → **every ion counts**

Maximise statistics:

- Maximise target thickness
- Maximise (geometric) efficiency

TPCs:

- **Thick** target without loss of resolution
- $\approx 4\pi$ geometric efficiency
- Extremely-low energy thresholds

Aims

Use a TPC with neutron beams for neutron-induced reactions

Neutron-induced measurements with TexAT

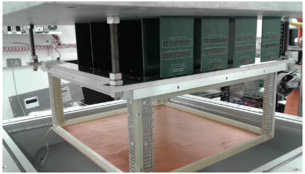
Neutron-induced measurements with TexAT

TexAT TPC - TEXas Active Target Time Projection Chamber
TPCs can be well-suited to many different types of neutron-induced measurements

Active-target (gas IS the target and readout medium) TPC filled with CO_2 looking to measure:

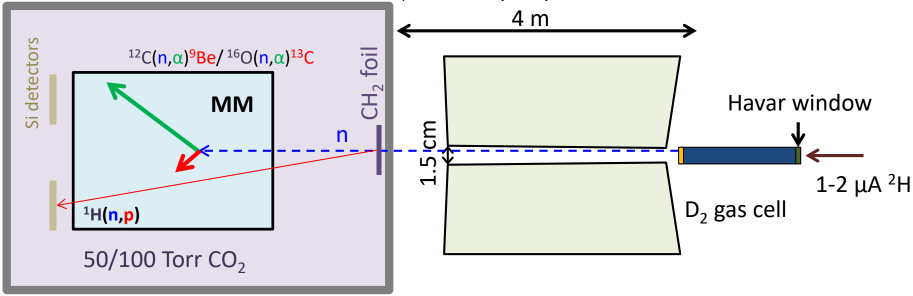
- $^{12}\mathrm{C}(n,\alpha_0)$, $^{16}\mathrm{O}(n,\alpha_0)$ and $^{16}\mathrm{O}(n,\alpha_{1,2,3})$ differential cross sections
- UK HRL 5% accuracy for $^{16}\mathrm{O}(n,\alpha_0)$ from $E_n = 2-20$ MeV
- Current 30% uncertainty leads to 100 pcm uncertainty for k_{eff}

Can be measured with the TexAT with 50/100 Torr CO_2 gas



Experimental setup

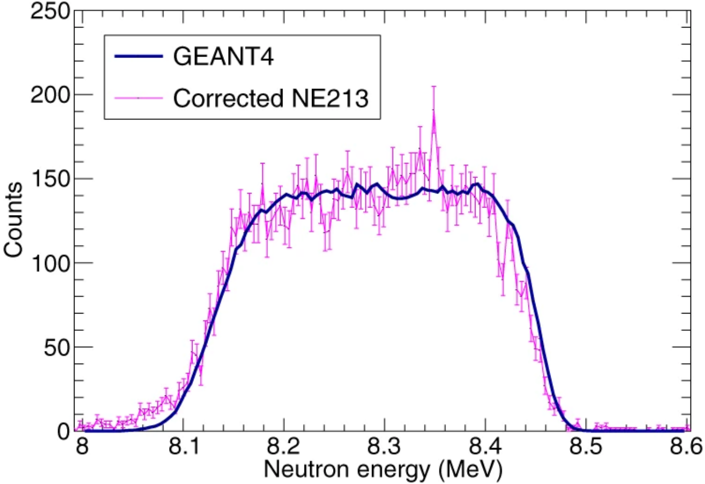
Edwards Accelerator Lab - Ohio University
Parasitic to nucl. astro. measurement - JB++ Nat. Comm. 13 2151 (2022)
7.98-cm-long gas cell generates 5000 n/s via d(d,n)



Normalisation via $^{1}H(n,p)$ + BCI

Experimental setup

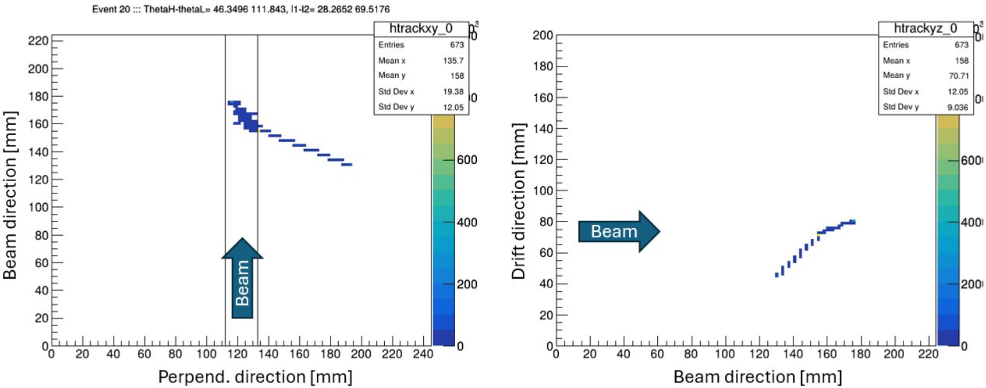
NE213 ETOF spectrum - convoluted flat-top energy spectrum



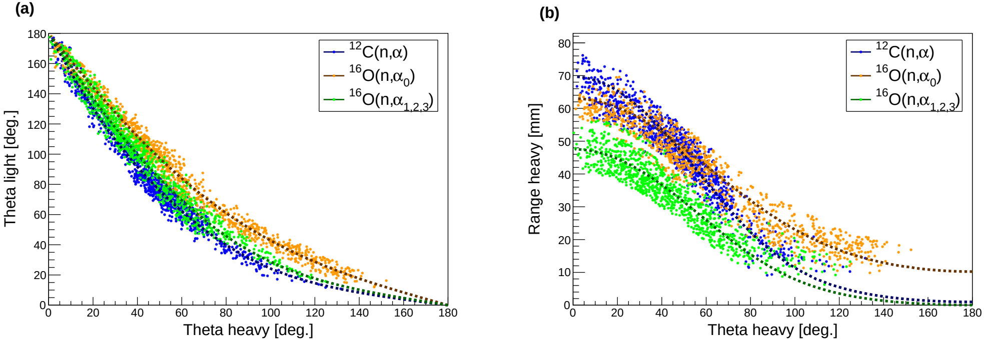
Channel separation

Example Event

Tracks fit with RANSAC-based method - RANSChiSM



Channel separation

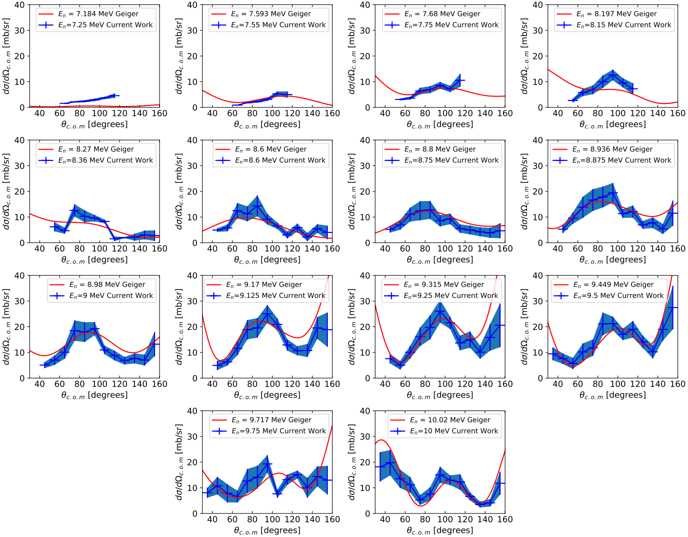


Combining multiple variables allows for reasonable channel separation

Probability of being the three channels evaluated event-by-event using χ^2 evaluation

Results

Differential cross sections: ^{12}C



Red line: Geiger result from $^{9}\mathrm{Be}(\alpha, n_0)$, scaled to Kuvin $^{12}\mathrm{C}(n, \alpha_0)$ total cross sections

Well described up to $E_n = 10$ MeV (equiv. $E_\alpha = 5.1$ MeV)

Method and channel separation validated

Integrated cross sections

Total cross section

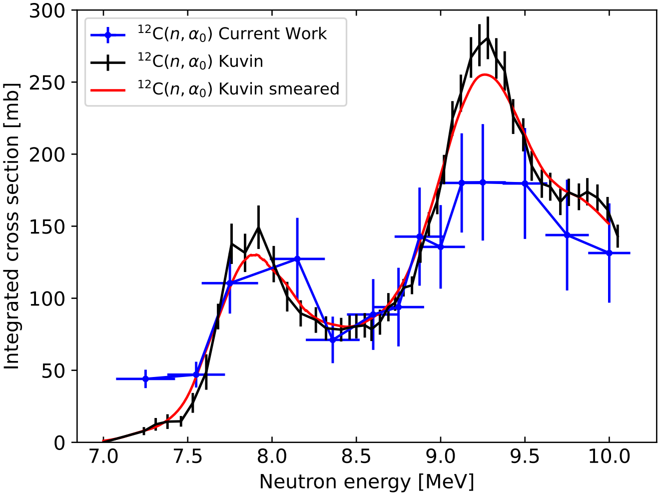
How to go from differential to total when you don't measure everything?

$$\sigma = 2\pi \frac{\left(\int_{\theta_l}^{\theta_h} \frac{d\sigma}{d\Omega} \sin\theta d\theta\right)\left(\int_0^{\pi} \sin\theta d\theta\right)}{\left(\int_{\theta_l}^{\theta_h} \sin\theta d\theta\right)} = 4\pi \frac{\int_{\theta_l}^{\theta_h} \frac{d\sigma}{d\Omega} \sin\theta d\theta}{\int_{\theta_l}^{\theta_h} \sin\theta d\theta}, \quad (1)$$

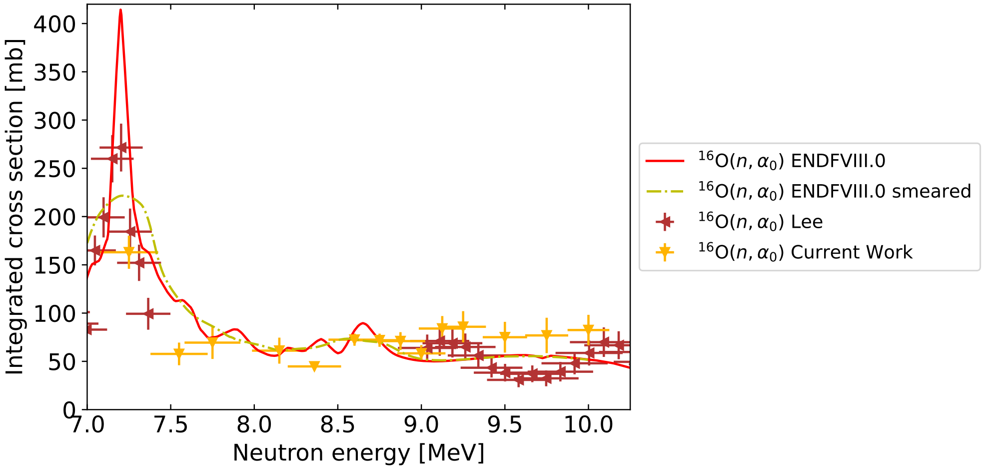
Just integrate over the bit you **do** have with appropriate weighting to account for unmeasured section

With $\sin(\theta)$ weighting, angles around 90° are most important anyway!

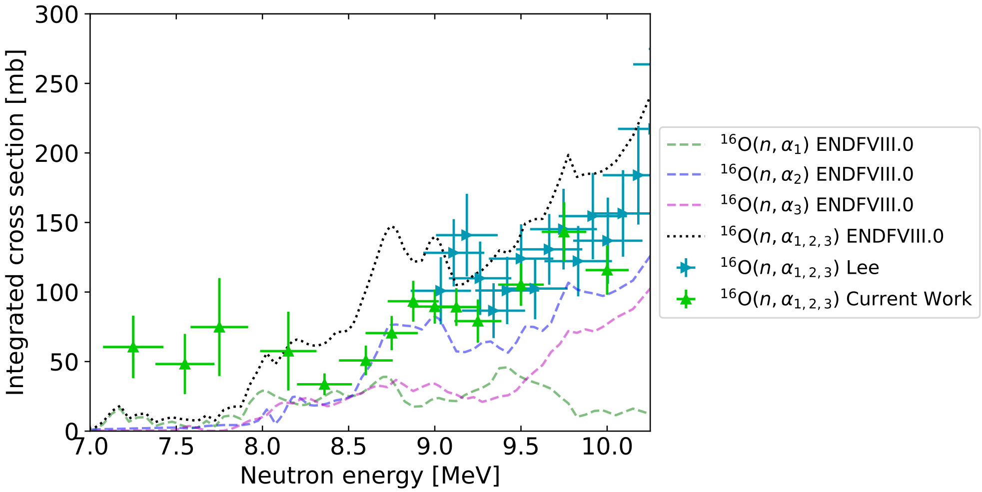
Total cross section: $^{12}C(n, \alpha_0)$



Total cross section: $^{16}O(n,\alpha_0)$



Total cross section: $^{16}O(n,\alpha_{1,2,3})$



Conclusion

Conclusion

- Possibility for variety of neutron-induced measurements with a TPC
- Limited by 'good' gases for active target
- Measurements for $^{12}\mathrm{C}/^{16}\mathrm{O}(n,\alpha)$ differential XS to improve R-Matrix evaluations of these reactions at higher energies
- Uncertainty ranges from 7-24% for $^{16}\mathrm{O}(n,\alpha_0)$ (c.f. previous 30%)
- Uncertainty ranges from 15-45% for $^{16}\mathrm{O}(n,\alpha_{1,2,3})$
- Publication in review now. Also at: arxiv:2601.02841v1

Acknowledgements

J. Bishop,[1,2]
C.E. Parker [2]
R. Smith[3]
Tz. Kokalova [1]
G.V. Rogachev [2,4,5]
C. Wheldon [1]
S. Ahn [2]
E. Koshchiy [2]
K. Brandenburg, [6]
C.R. Brune [6]
R.J. Charity [7]
J. Derkin [6]
N. Dronchi [8]
G. Hamad [6]
Y. Jones-Alberty [6]
T.N. Massey [6]
Z. Meisel [6]
E.V. Ohstrom [8]
S.N. Paneru [6]
E.C. Pollacco [9]
M. Saxena [6]
N. Singh [6]
L.G. Sobotka [7,8,10]
D. Soltesz [6]
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