



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

High-Flux Accelerator-Driven Neutron Facility (HF-ADNeF) at the University of Birmingham

Jack Bishop

Neutron Detector and Facility Workshop
17th September 2026



Overview

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Case Studies

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Case 2: Boron Neutron Capture Therapy

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Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

HF-ADNeF



High-Flux Accelerator Driven Neutron Facility (HF-ADNeF)

Overview

Jack Bishop

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



- Neutron Therapeutics machine
- ECR ion source (currently hydrogen)
- Hyperion type: 0.4-2.6 MV single-ended electrostatic acceleration
- Easily achievable and stable > 30 (up to 50) mA protons delivered onto (600 rpm) rotating Li target
- Solid Li target, 0.3-mm-thick, copper backed and water cooled to produce neutrons via ${}^7\text{Li}(p, n)$



Target room

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



- $\approx 3 \times 3 \text{ m}^2$ of space in the room
- Lead shielding to protect from ^7Be accumulated in the target ($\sim \text{TBq}$)
- 42 mm from target to outside of vacuum vessel (incl. 3 mm Cu, 7 mm graphite, 6 mm Ti)





Neutron yields - 30 mA protons

Overview

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HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

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Case 5: Neutron Spectroscopy and Forensics

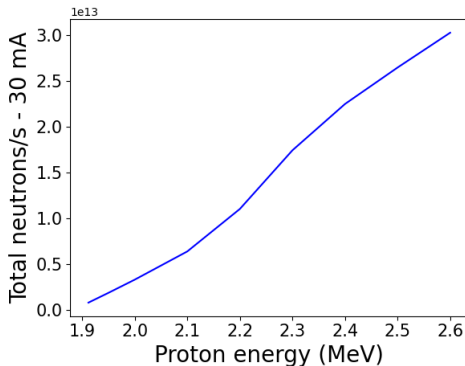
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Basic TPC overview

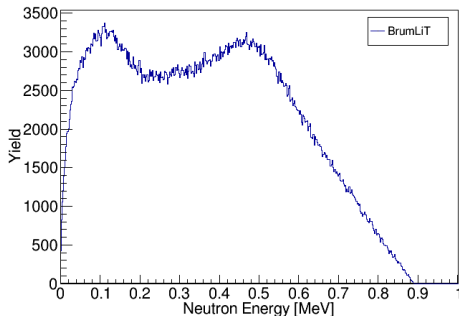
Overview

Overview

Team/funding



$E_p = 2.6$ MeV



2×10^{11} n/s/cm² at 30 mA, full energy (or 10^9 thermal in graphite moderator)
Hammer approach: hit target as hard as you can, little control over energy²
(scalpel approach is low background+scatter, mono-energetic beam)

To be used complementarily with other facilities

²See future slides



Broad applications

Overview

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HF-ADNeF

Case Studies

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Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

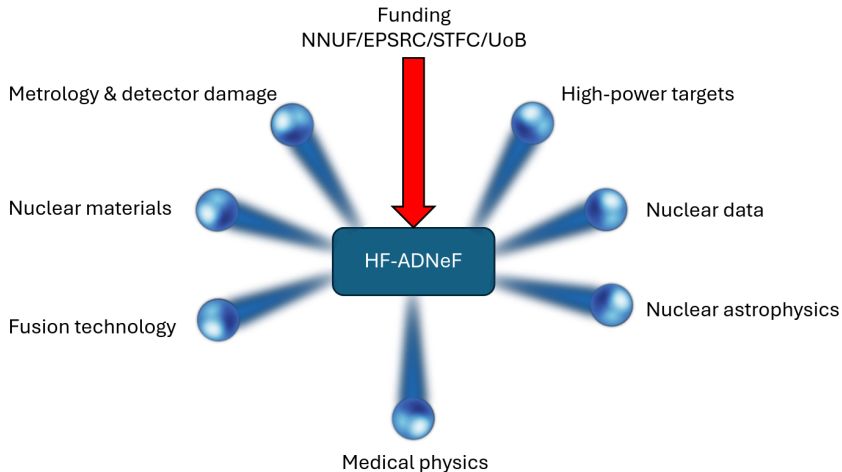
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding





Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Case Studies



Case 1: Nuclear Astrophysics/Nuclear Data

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Motivation:

- Measurement of (n, γ) cross sections
- Nuclear astro. - production of elements via the s-process
- Nuclear data - (n, γ) cross sections also important for waste management/decommissioning

Advantage:

- High intensity available allows for measurement of small samples with cross sections down to μb within few hours of beam with good statistics
- Varying the beam energy $\rightarrow$ vary the neutron energy spectrum $\rightarrow \sigma(E)$ from white source



Maximum energy measurements

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

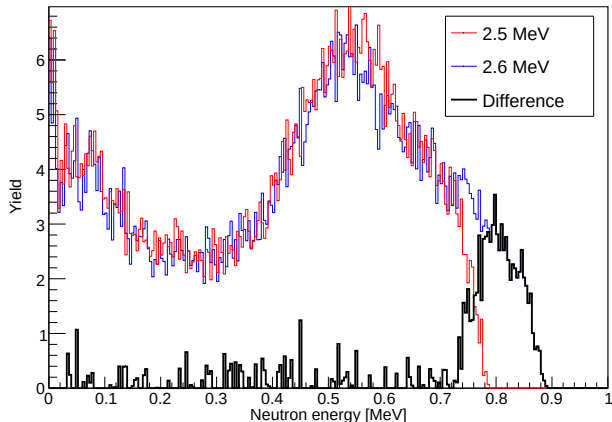
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Overview

Overview

Team/funding

- Running two measurements, one at $E_p = 2.6$ MeV and one at $E_p = 2.5$ MeV
- Difference between the two gives pseudo-Gaussian around $E_n = 0.8$ MeV





Low energy measurements

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

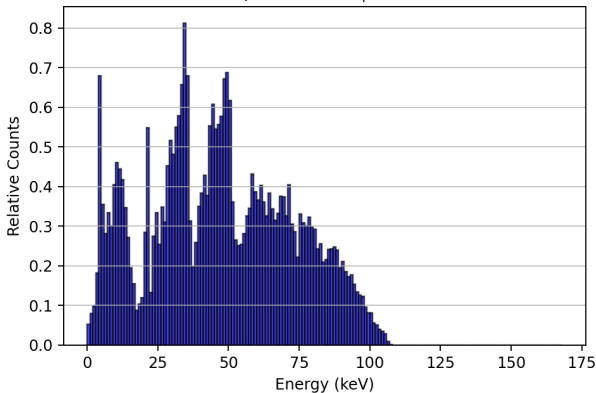
Overview

Overview

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Choosing $E_p = 1.912$ MeV, get quasi-Maxwell Boltzmann spectrum

Neutron Spectrum at $E_p = 1.912$ MeV



Currently limited by scattering through 4-mm-thick Ti wall To be replaced



Moving towards double-activation studies

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

- Direct neutron capture studies of nuclei one neutron from stability
- Double activation method - breed one neutron extra nucleus to get sufficient two neutron extra nuclei
- Incredibly high flux needed ($\text{Yield} \propto \phi^2$)
- Design changes can enhance to $\approx 10^{12} \text{ n/s/cm}^2$
- If intermediate nucleus has shorter half life, β -delayed gamma spec can reveal the yield amongst a significant background at large times
- AMS also an option for stable nuclei



Case 2: Boron Neutron Capture Therapy: Why neutrons?

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Motivation:

- Want to minimise the dose to healthy tissue and maximise dose to bad tissue

Approach:

- Bombard boron-loaded patient with neutrons
- High XS $^{10}\text{B}(n,\alpha) \rightarrow$ localised damage

Advantage:

- High neutron flux needed for patient throughput
- Non-clinical machine ideal for research into underlying mechanics

Open questions:

- What form of boron works best?
- Microscopic distribution of boron?
- **Calculating dose delivered from neutron flux - (gamma spec. in high neutron-intensity environment?)**



Thermal stack

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

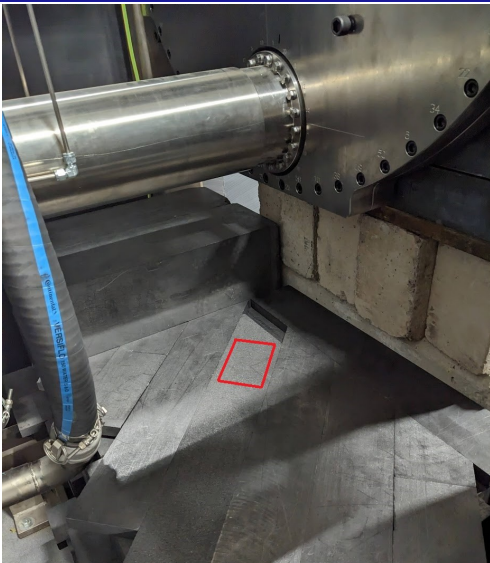
And Now For Something Completely Different

Basic TPC overview

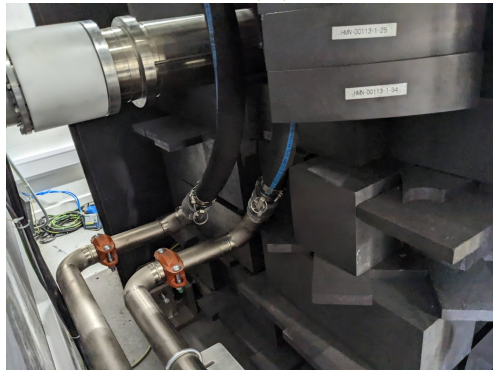
Overview

Overview

Team/funding



1 m³ of graphite for thermal irradiations: $\approx 10^9$ n/s/cm²





Case 3: Materials Damage

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Motivation:

- Next-generation steel/materials for fusion/adv. modular (Gen IV) reactors

Approach:

- Maximise the damage to give a lifetime dose to e.g. plasma-facing materials

Advantage:

- Doing everything in terms of proton damage doesn't always translate
- Want to go to high dpa $\rightarrow$ weeks of neutron irradiation for lifetime doses
- Large setup area ($3 \times 3 \times 3 \text{ m}^3$) means large rigs (e.g. water loops) can be irradiated
- Future combined beams can take H, He beams simultaneously with n irradiation

Also going to be used to neutron damage **AGATA-like HPGe crystals** to understand damage response - **Chris Everett (Liverpool)**



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Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Motivation: £200M UKAEA programme: Lithium Breeding Tritium Innovation
Small in-situ tests of lithium capsules - measure tritium production/extraction
One possible major 'no-go' for fusion: Tritium Breeding Ratio

"The annual tritium consumption of a fusion power plant operating at 1 GW fusion power is 55.6 kg per full power year (FPY) or 152 g per full power day (FPD)."

Context: ^3H activity: 3.57×10^{14} Bq/g. 3×10^{13} n/s at HF-ADNeF $\rightarrow$ 0.5 mg/year

Tests: Small lithium ceramic breeder tests irradiated this year to investigate tritium production (UOB). Making tritium is easy - getting it 'out' reliably is the hard bit!



Case 5: Neutron Spectroscopy and Forensics

Overview

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HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Lots of other uses for high neutron intensity - nuclear forensics:

- National Heritage: Slate samples from a church in Scotland
- Which slate site did these originate from? Multiple benchmark samples to compare to
- Neutron activation and gamma spectroscopy to identify micro-inclusions (e.g. La very clear from short tests)
- Ultra-low background Dark Matter experiment at Boulby
- XLZD - liquid xenon detector
- Identifying sources of contaminant: uranium in PTFE tape, neutron irradiation to make ^{239}U (then ^{239}Np)
- Activation to measure parts per trillion from gamma spectroscopy at Boulby



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

And Now For Something Completely Different



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TPC for neutrons

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

If the only tool you have
is a hammer, **you tend to
see every problem as a
nail**



Abraham Maslow



Existing detectors have problems with low energies and high fluxes¹

¹Foils OK with whatever flux but not real time diagnostics and energy thresholds are an issue



TPC basics

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

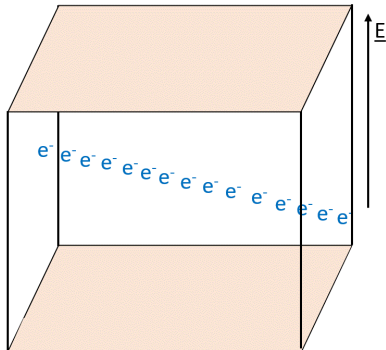
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Basic TPC overview

Overview

Overview

Team/funding





Operation mode 1: DC readout for high rates

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

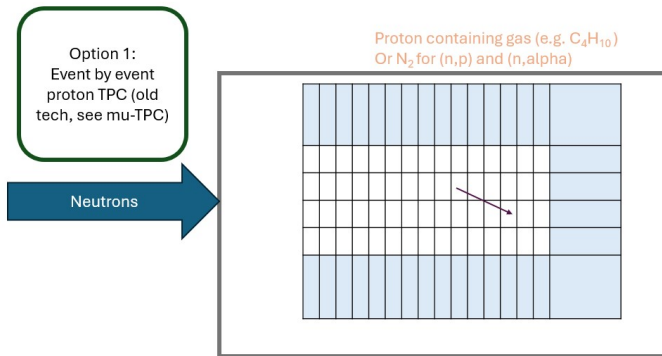
Overview

Overview

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Incident neutron rate is way too high for most conventional detectors → turn that into an advantage!

Position sensitive drift chamber - no gain required → DC mode charge readout





Operation mode 2: Rad-hard proton recoil detector

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

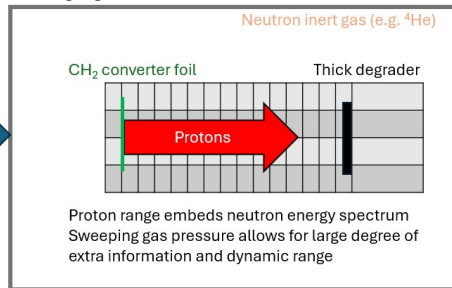
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Expand on this idea with CH_2 target and look at collimated neutron beam
Gas is rad-hard, price may be very competitive against diamond proton recoil telescopes ($\approx 60\text{k€}$) with better dynamic range

Option 2:
High-flux thin-foil
proton recoil
(TPR) ionisation
chamber

Neutrons

- Incredibly high rate means charge deposited on pads is effectively constant, therefore read integrated charge rather than individual events (à la FC)
- No gas gain needed





Operation mode 3: Solid targets

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

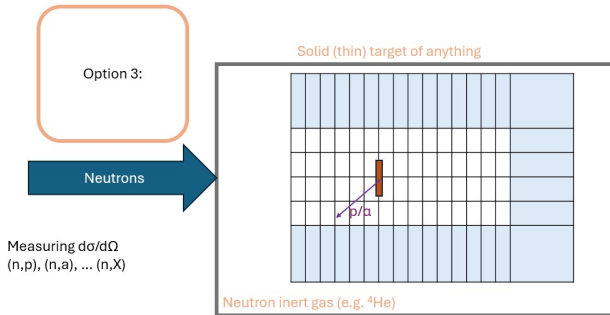
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Overview

Overview

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Not everything can be a gas (without burning everyone you love)



Energy thresholds (once in the gas) can be as low as a few keV



Operation mode 4: Gas targets

Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

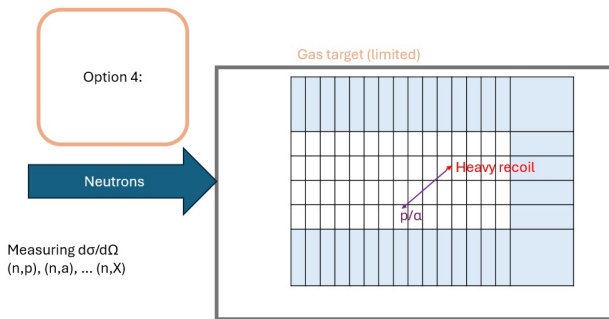
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Basic TPC overview

Overview

Overview

Team/funding



Previously used with TexAT TPC to measure $^{12}\text{C}(n,\alpha)$ and $^{16}\text{O}(n,\alpha)$:
J. Bishop JPG **53**, 6 (2026)



Overview

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Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Overview



Overview

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

- High-intensity tuneable-energy neutron source up to 0.9 MeV maximum energy with protons
- Deuteron beams: hear about this later by John Murphy!
- Currently available: Up to 3×10^{13} n/s $\rightarrow$ 2×10^{11} n/s/cm²
- Huge variety of science/engineering cases being addressed
- Beam time can be bought for commercial uses or small amounts for collaborative (publishable) work available
- If you are interested in a possible future neutron TPC - let me know

Email: j.bishop.2@bham.ac.uk



Facility Info

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



Engineering and
Physical Sciences
Research Council

UNIVERSITY OF
BIRMINGHAM



HF-ADNeF funded by EPSRC Grant number EP/T011335/1 and the University of Birmingham

Access funds previously available through NNUF - scheme restarting



The Team

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

Presented on behalf of the UOB team:

Carl Wheldon, Tzany Kokalova, Ben Phoenix, Stuart Pirrie, Joey O'Neill, Neil Curtis, Martin Freer, plus a great crew of PhD students!





An advert: UK MPGD Workshop - Oct 8 2026

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding

STARTS

Thu 8 Oct 2026

9:30

ENDS

Thu 8 Oct 2026

16:00

WHERE

Institute of Physics
37 Caledonian Road
N1 9BU
London
United Kingdom



This one-day workshop aims to bring together researchers, students, and technical experts already working with, or interested in Micropattern Gaseous Detectors to foster communication, share expertise, and explore opportunities for future collaboration. The workshop will provide a platform for participants to present their ongoing research, discuss future development needs and potential applications, identify common challenges, and strengthen connections within MPGD users community in the UK. In addition, the meeting seeks to assess the interest and potential for establishing a coordinated UK-MPGD users collaboration that could support future scientific and technological initiatives.

In-person | London and South East | Particle and nuclear | IOP members

STEM professionals



Photo Gallery - HF-ADNeF

Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

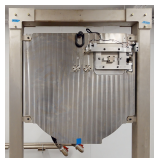
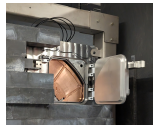
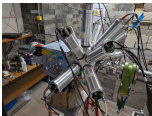
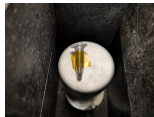
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding





Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

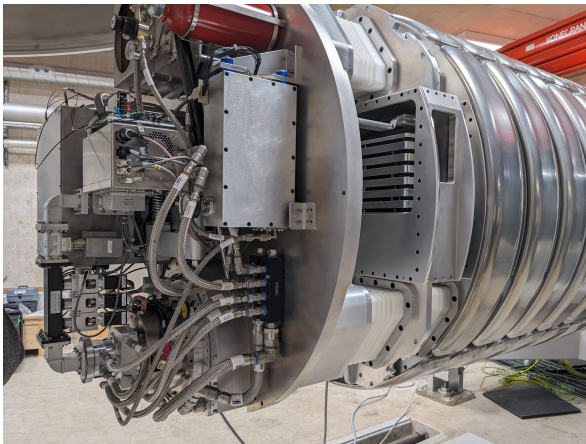
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► [Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

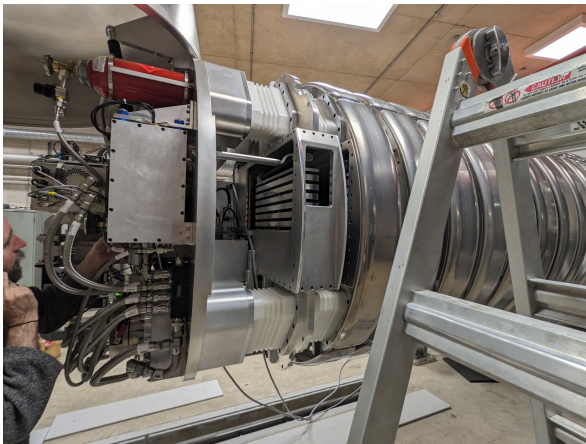
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► [Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► Back to gallery



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► Back to gallery



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► Back to gallery



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► Back to gallery



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

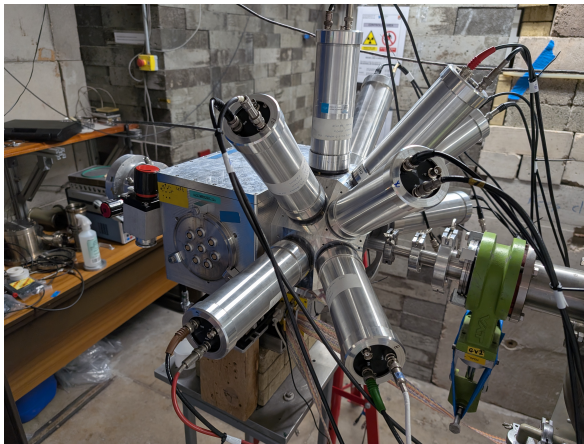
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

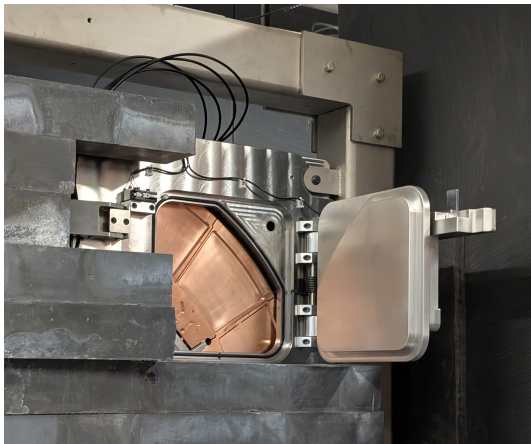
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► Back to gallery



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



[► Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

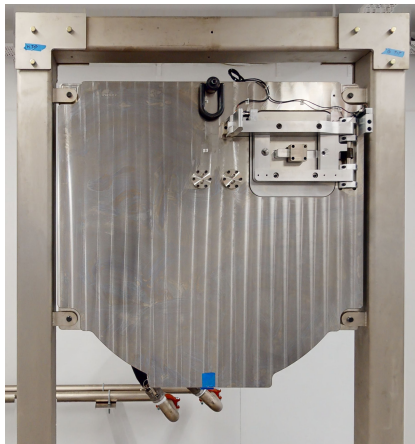
And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► [Back to gallery](#)



Overview

Jack Bishop

HF-ADNeF

Case Studies

Case 1: Nuclear Astrophysics/Nuclear Data

Case 2: Boron Neutron Capture Therapy

Case 3: Materials Damage

Case 4: LiBRTI project - tritium breeding

Case 5: Neutron Spectroscopy and Forensics

And Now For Something Completely Different

Basic TPC overview

Overview

Overview

Team/funding



► Back to gallery