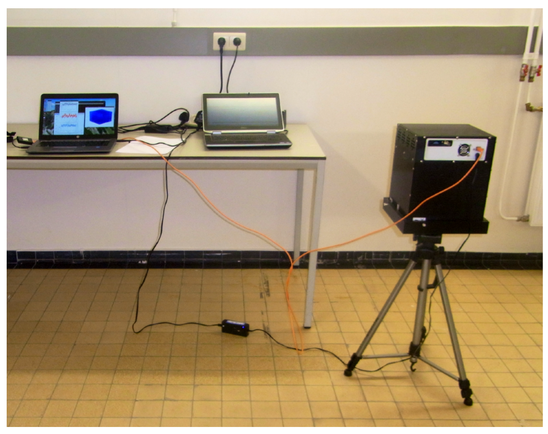
Robust neutron field direction and spectrum measurement demonstrated with the nFacet 3D detector

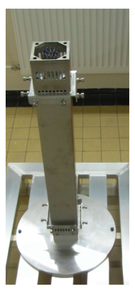
Nicholas Reed & Antonin Vacheret
Imperial College London, London UK

nFacet 3D dual neutron-gamma detector

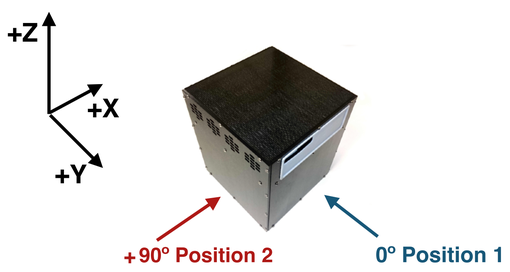
- Dual detection of neutron and gamma-ray signals
  - Current system is at TRL 6/7
- Combine the use of plastic scintillator and phosphor screens for signal separation between neutron and gamma
  - Dimensions are 30 cm x 25 cm x 25 cm
- Total weight is 15 kg (8 kg active)
- Easily deployable (~15 mins installation) with power and data connection to laptop computer
- System measure neutron **counts**, **direction** and **identify** the type of source in real time. It records timestamped, list-mode data for offline processing [1]



IPNDV exercise at SCK•CEN



- Located in the BR1 building
  - Measured neutrons and gamma-rays from MOX fuel assemblies
  - Field test demonstration in realistic conditions: neutron background present. Access to radiation controlled area with relatively short time to set up

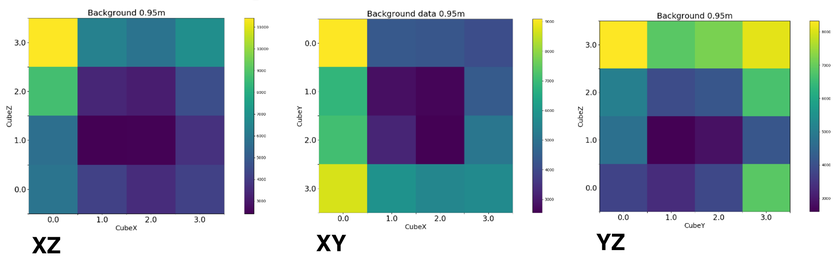


MOX fuel neutrons direction

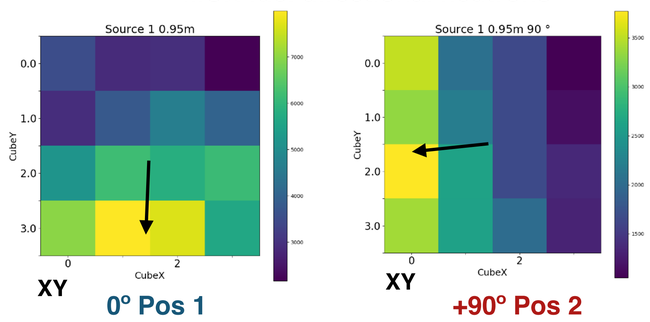
MOX fuel neutron field characterisation

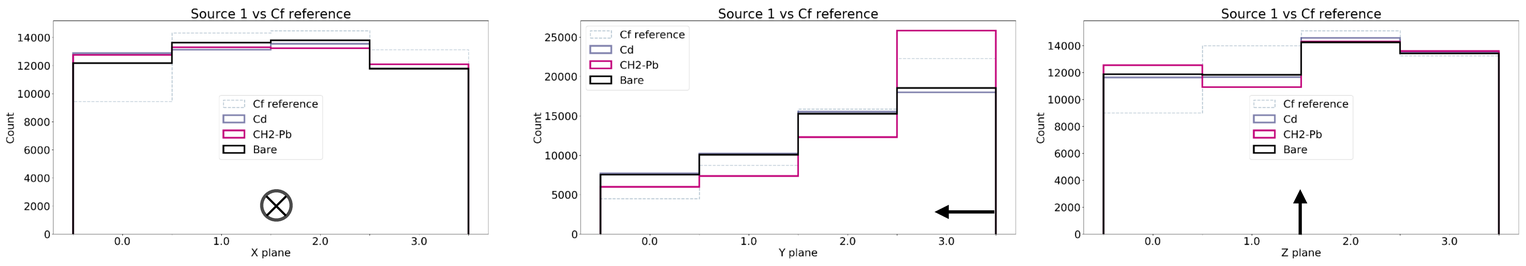
- Two types of **MOX assemblies** were characterised. Color maps proportional to cube rates summed over each projection planes are shown for background data and in presence of assemblies. Data normalised to same exposure time.
- MOX assembly measurements in **3 configurations** (bare assembly, Cd shielded and CH2+Pb shielded were compared to **a reference distribution** with a **Cf-252 source**
  1. Effect of neutron moderation is clearly seen
  2. Good agreement is found with reference Cf source
  3. Difference seen is from re-scattering component

Background neutrons



MOX fuel directional neutrons



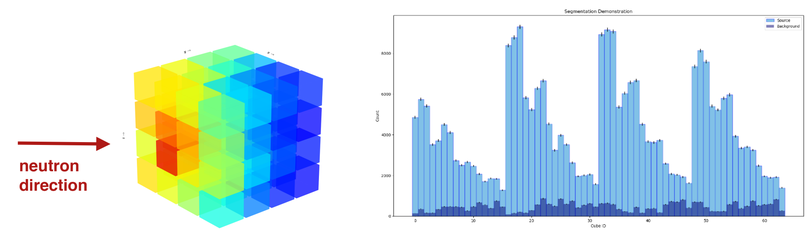


Applicability to disarmement verification

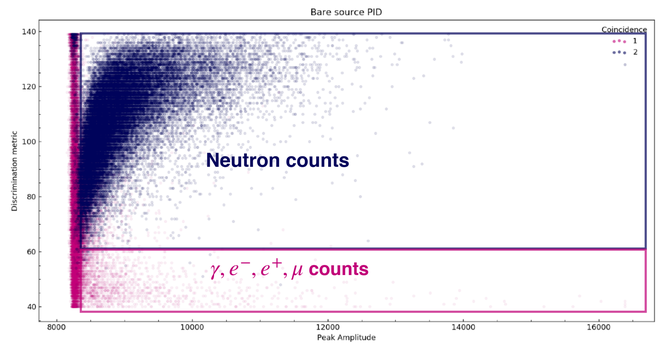
- Directional measurement based on detector rotation allows for robust localisation of source and separation from other potential neutron fields present during the verification
- Combination of directional and neutron energy sensitivity can be used to provide reference templates

Detector principle

- The nFacet system is He-3 free. It uses effective segmentation to construct an image of the neutron field that depends on the energy distribution and direction of the field.

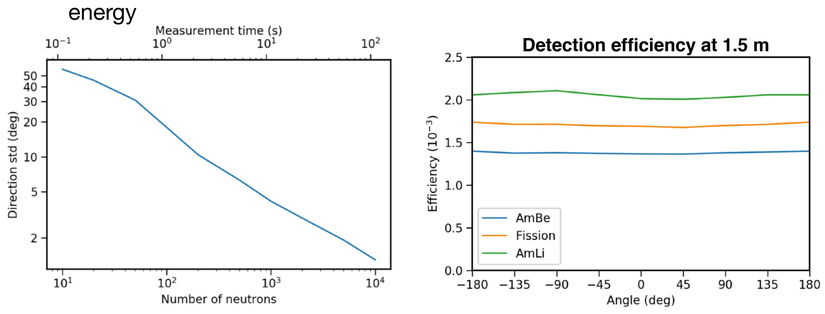


- Shape of directional component different from background. Information can be used to provide better detection sensitivity than count rate-based measurements
- Stopping power distribution in segments is used to infer the type of neutron source measured
- Excellent neutron-gamma signal discrimination based on pulse shape

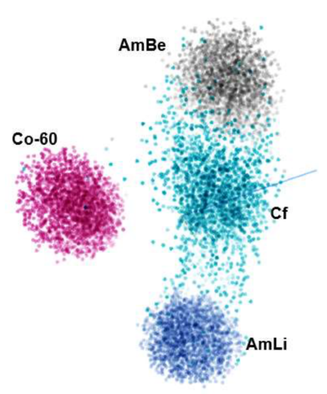


Validation of performance

- Direction resolution was measured using calibrated sources at the National Physical Laboratory.
- Detector has uniform 360 deg sensitivity to a wide range of neutron energy



- Cube rate information can be used directly to identify the type of source.
- Combination of segmentation and signal discrimination provides clear separation between neutron and gamma-ray fields
- Detector already fulfil requirements for source detection: **Vehicle monitor** and **pedestrian monitor** (ANSI N42.38-2006) [2]



Outlook

- Work in progress to develop the interface and deploy machine learning algorithms for online classification of signals [3] and high level decision.
- Current upgrade to new sensors and trigger logic will provide better sensitivity to gamma energy and neutron scattered events

Imperial College London

[1] nFacet.com

[2] A. Vacheret et al. *nFacet 3D: Sensitive detection for timely source detection and identification*. Nuclear Security Detection Workshop, University of Surrey, Guilford, UK. (2019)

[3] J. Griffiths, S. Kleinegesse, D. Saunders, R. Taylor and A. Vacheret. *Pulse Shape Discrimination and Exploration of Scintillation Signals Using Convolutional Neural Networks.* (2018)