

UK Nuclear Data Network+ (UKNDN)

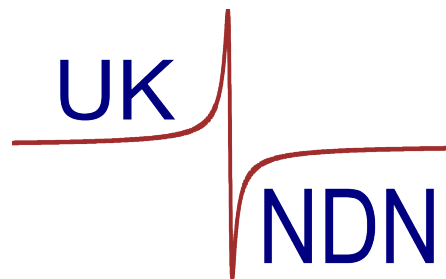
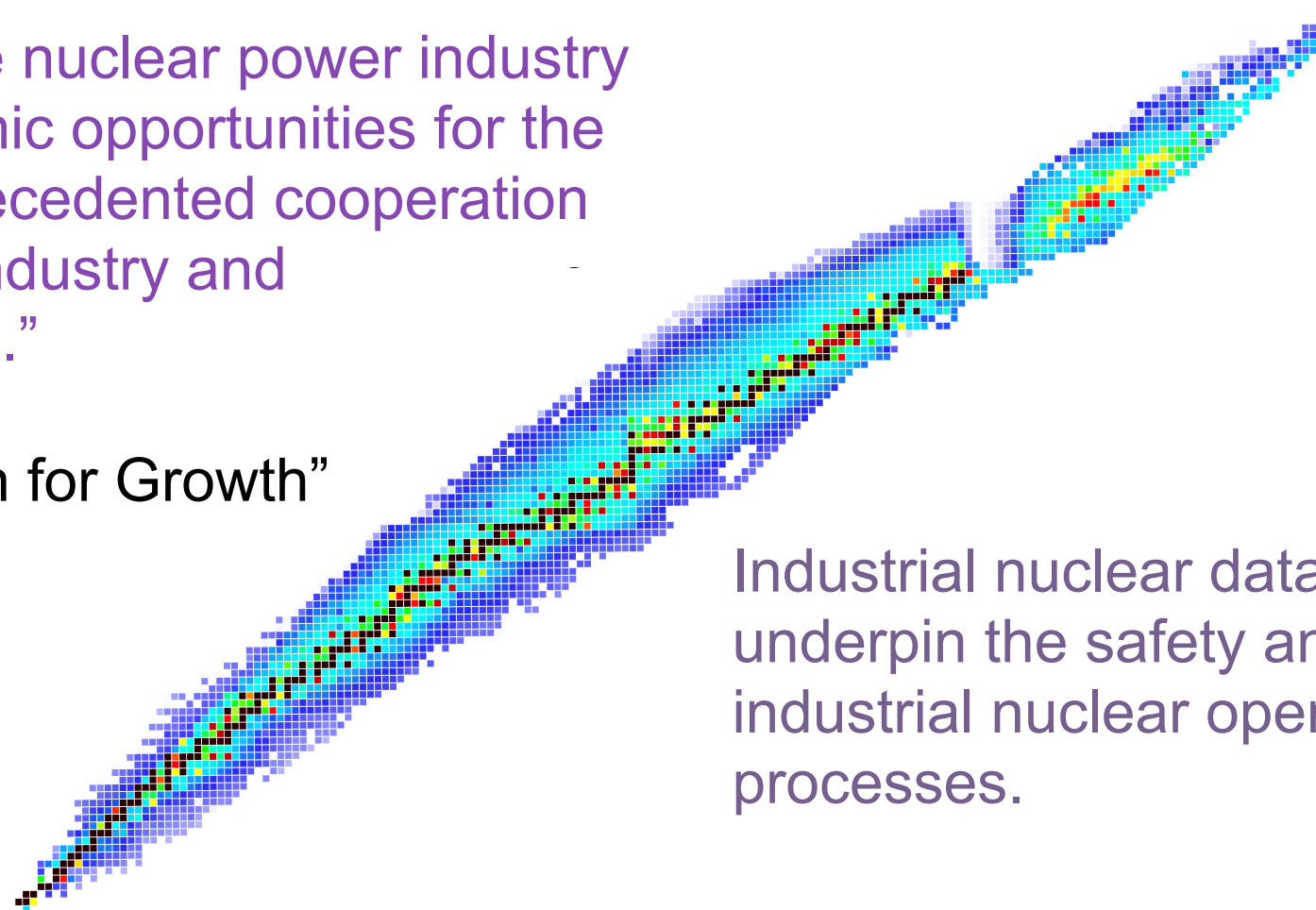
Paul Davies, UKNDN Manager

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“The revitalisation of the nuclear power industry offers important economic opportunities for the UK, which require unprecedented cooperation between government, industry and academia to be realised.”

Government’s “Our Plan for Growth”

Industrial nuclear data are those that underpin the safety and economics of industrial nuclear operations and processes.



Outline

- Brief outline of recent UK activity
- UK nuclear science forum
- UK nuclear data network objectives
- Funding
- Getting involved

Previous work

Strand 1 *Neutron capture cross section measurements at nTOF, CERN. Gavin Smith, Jon Billowes (Manchester) David Jenkins (York)*

PhD studentship (York) - Mark Vermeulen – Completed 2015

NDA Bursary (Manchester – Toby Wright – Completed 2014 (PDRA Manc)

Subscription to nTOF Collaboration (Manchester & York)

Strand 2 *Decay heat measurements of fission fragments with a TAS Paddy Regan, Zsolt Podolyak (Surrey), Gavin Smith (Manchester)*

PhD studentship (Surrey) - Simon Rice – Completed 2014 (now AWE)

Decay heat measurements for “Priority 1” nuclides identified by WPEC:
 ^{101}Nb , ^{105}Mo , $^{102,104,105,106,107}\text{Tc}$, ^{86}Br , ^{91}Rb , and ^{94}Sr



Previous work

Strand 3 *Neutron Fission Gamma Rays with STEFF*

Gavin Smith (Manchester), Paddy Regan, Zsolt Podolyak (Surrey)

NEA HP Request to measure Energy and Multiplicity of Fission Gammas

STFC studentship (Manchester) - Andy Pollitt - Completed 2013 (ILL)

EPSRC (Nuclear FiRST) - Lizzie Murray - Completed 2015

EPSRC (Nuclear FiRST) - Robert Frost

EPSRC (Nuclear FiRST) - Stuart Warren

EPSRC (Nuclear FiRST) - James Ryan

Toby Wright – PDRA based at CERN (FP7) Now Manchester Research Fellow (Nuclear Data)

Construction and upgrade of STEFF (Spectrometer for exotic fission fragments) for intended deployment at GANIL Neutrons for Science Facility (NSF)

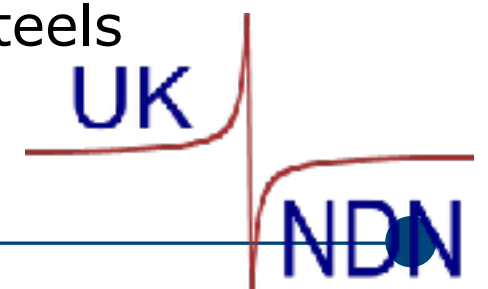
NSF was delayed, but a higher neutron flux facility now available at CERN.

The initial STEFF experiments have been run at CERN October 2015/June 2016

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- JEFF fission yield development for JEFF-3.3
 - ★1st test version distributed with JEFF community
 - ★2nd version under development
 - ★Will be released within JEFF community for testing in 2 weeks.
- Fission yield uncertainties
 - ★Current files have uncertainties on all quantities, both cumulative and independent yields, but covariance terms on independent yields are needed to produce uncertainty estimates on spent fuel compositions.
 - ★Working with WPEC and JEFF on developing these covariance terms and their usage.
- NTEC summer student studied the use of activation cross-section data to both estimate the component of uncertainty from this data for a given WAGR steel irradiation, and the major sources of uncertainty.
- This has led to a set of suggestions for future nuclear data measurements, based upon the most important activation products for this steel.
 - ★Note the following are composition dependent, but typical of similar steels



NNL nuclear data activities

Activation product	Most significant reactions	In which cross sections would reducing the uncertainty give the most improvement in the final result
^3H	$^6\text{Li}(n,\alpha)^3\text{H}$, thermal.	$^9\text{Be}(n,\alpha)^6\text{He}$, fast.
^{14}C	$^{14}\text{N}(n,p)^{14}\text{C}$, thermal.	$^{14}\text{N}(n,p)^{14}\text{C}$, resonance.
^{36}Cl	$^{35}\text{Cl}(n,\gamma)^{36}\text{Cl}$, thermal.	$^{35}\text{Cl}(n,\gamma)^{36}\text{Cl}$, resonance.
^{39}Ar	$^{39}\text{K}(n,p)^{39}\text{Ar}$, fast. $^{39}\text{Ar}(n,\gamma)^{40}\text{Ar}$, thermal	$^{39}\text{K}(n,p)^{39}\text{Ar}$, fast. $^{39}\text{Ar}(n,\gamma)^{40}\text{Ar}$, thermal.
^{59}Ni	$^{58}\text{Ni}(n,\gamma)^{59}\text{Ni}$, thermal.	$^{58}\text{Ni}(n,\gamma)^{59}\text{Ni}$, thermal and resonance.
^{60}Co	$^{59}\text{Co}(n,\gamma)^{60}\text{Co}$, thermal and resonance. $^{59}\text{Co}(n,\gamma)^{60\text{m}}\text{Co}$, thermal and resonance.	$^{59}\text{Co}(n,\gamma)^{60\text{m}}\text{Co}$ thermal and resonance. $^{60}\text{Ni}(n,p)^{60\text{m}}\text{Co}$, fast. $^{59}\text{Fe}(n,\gamma)^{60}\text{Fe}$, thermal.
^{63}Ni	$^{62}\text{Ni}(n,\gamma)^{63}\text{Ni}$, thermal.	$^{62}\text{Ni}(n,\gamma)^{63}\text{Ni}$, thermal and resonance. $^{63}\text{Ni}(n,\gamma)^{64}\text{Ni}$, thermal
^{93}Mo	$^{92}\text{Mo}(n,\gamma)^{93}\text{Mo}$, fast and resonance.	$^{92}\text{Mo}(n,\gamma)^{93}\text{Mo}$, fast and resonance.
$^{93\text{m}}\text{Nb}$	$^{93}\text{Nb}(n,n)^{93\text{m}}\text{Nb}$, fast.	$^{93}\text{Nb}(n,n)^{93\text{m}}\text{Nb}$, fast
^{94}Nb	$^{93}\text{Nb}(n,\gamma)^{94\text{m}}\text{Nb}$, thermal and resonance. $^{93}\text{Nb}(n,\gamma)^{94}\text{Nb}$, resonance.	$^{93}\text{Nb}(n,\gamma)^{94}\text{Nb}$, fast. $^{93}\text{Nb}(n,\gamma)^{94\text{m}}\text{Nb}$, fast and resonance.

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The UK Nuclear Science Forum

(Chair: Dr Alan Nichols, former head of the Nuclear Data Section at IAEA)

Universities, Industry, UK's national labs (NNL, NPL, CCFE and AWE), Naval Nuclear Propulsion Programme physics working group (MOD, Rolls-Royce, AMEC Foster Wheeler and NNL), BAE Systems, EDF Energy, Public Health England, Nuclear Decommissioning Authority, Nuvia Ltd, Office of Nuclear Regulation and Sellafield Ltd, UK National Laboratories and Regulators,

<http://www.uknsf.org.uk>

The screenshot shows the homepage of the UKNSF website. At the top is a black header with the text 'UKNSF - UK Nuclear Science Forum' in white. Below this is a green navigation bar with links: 'Home', 'Advice on Nuclear Data', 'Nuclear Data Links', and 'Application for membership'. The main content area has a white background and contains several paragraphs of text. On the right side, there is a green box with contact information and a 'Members' section. At the bottom, there is a black footer with copyright information.

UKNSF - UK Nuclear Science Forum

Home | Advice on Nuclear Data | Nuclear Data Links | Application for membership

Welcome to the Home page of the UK Nuclear Science Forum (UKNSF).

The work of the UKNSF covers the measurement and evaluation of nuclear data for applications in the nuclear industry, nuclear medicine and protection of the environment.

Nuclear data includes radioactive decay data, fission yields, neutron production and reaction cross-sections, spectra and angular distributions of emitted particles, integral data (e.g., (a,n) for thick targets) and charged particle and photon cross sections.

The UKNSF advises the UK representatives to the NEA Databank and the IAEA Nuclear Data Section on the needs of the UK in the field.

Membership is open to all users, measurers and evaluators of nuclear data in the UK. There are two meetings a year, usually in May and November.

Contact:
Nigel Hawkes
Tel: 020 8943 7064
Email: nigel.hawkes@npl.co.uk

Members
[Login to members area](#)

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Beyond EPSRC Nuclear Data Grant - Network+

Manchester

- STFC is providing some T&S, technical support, and 50% of an n_TOF subscription (first time STFC has supported this area of applied nuclear physics)
- FP7 project and group funds provides some PDRA support

York

- No funding

Surrey

- STFC providing some T&S and some PDRA support (shared) for further reactor decay heat measurements.
- NDA Bursary (2014) for fission fragment decay data.
- NPL links (with Paddy Regan, Gavin Lotay) in decay heat spectroscopy

Current Research Council Support

- Small levels of support through STFC Consolidated Grants
- **Global Challenges Network+ Application (STFC)**

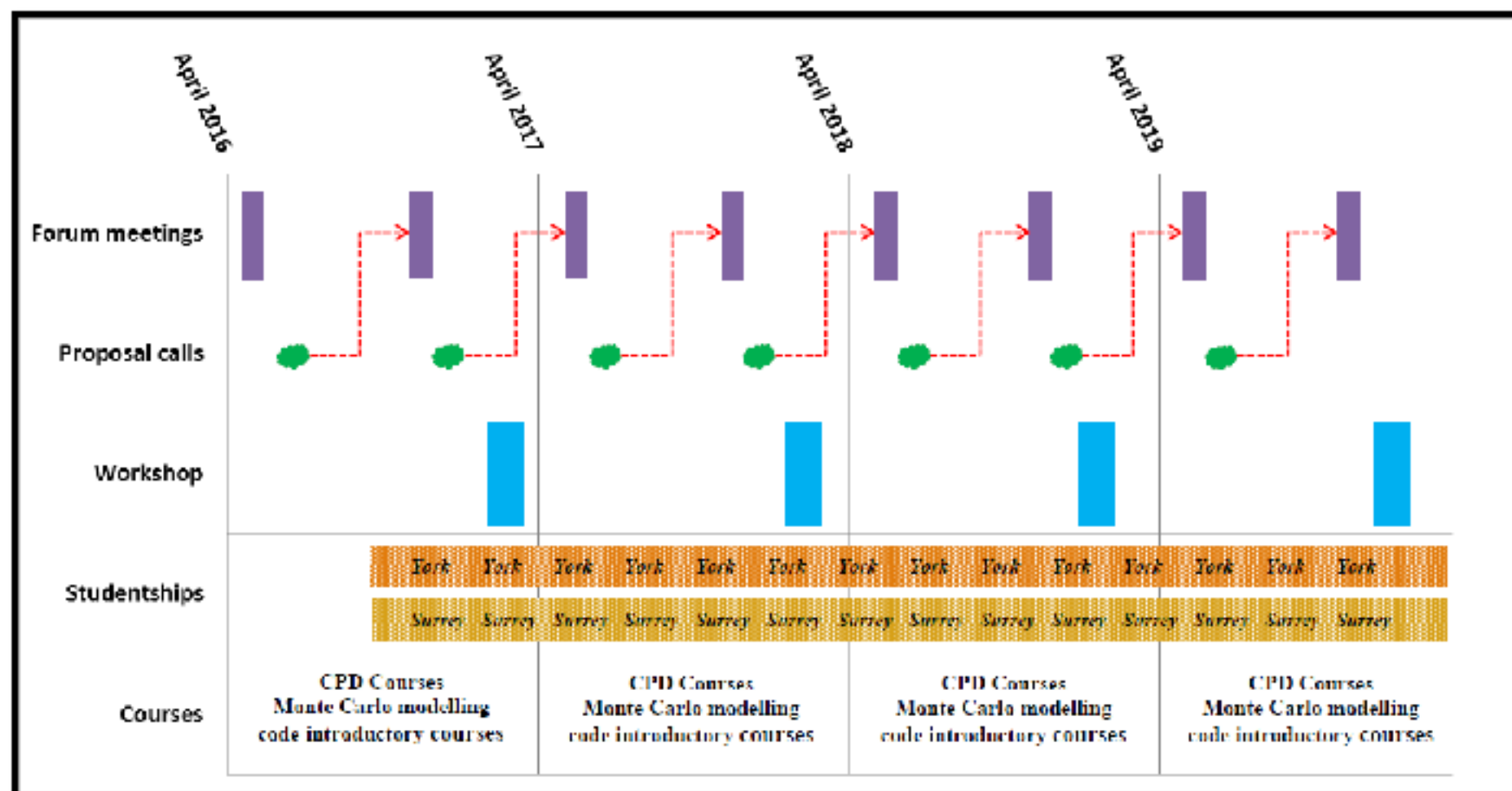


Objectives of UKNDN

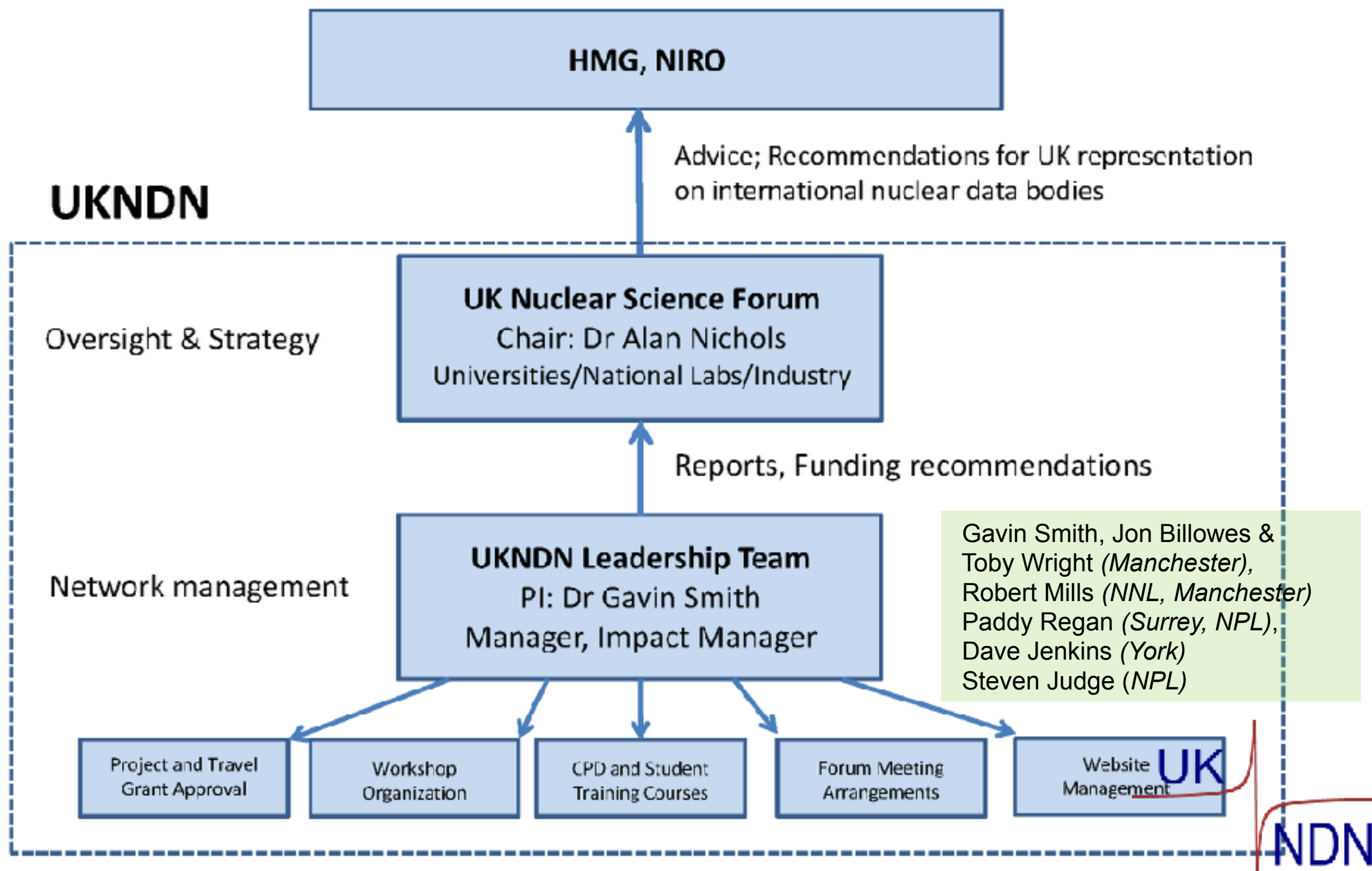
- Establish a strong connection between academia, industrial partners, national labs, regulators and UK representatives on international nuclear data committees (IAEA, NEA)
- Facilitate the measurement, analysis and dissemination of industrial nuclear data
- Address the **Energy Global Challenge** by responding to the nuclear data needs of industry, particularly as new reactor technologies are developed.

UKNDN Activities

- n_TOF Subscription for Manchester and York (£35k)
- Small research projects (£10k or £50k); call twice a year.
- Research-related travel in the area of nuclear data (£2k)
- Educational support through CPD training (NTEC, etc.)
- Annual workshops (First one CARM, NPL, November 2016)
- 2 x 50% studentships at York and Surrey
 - Adam Brown (York) started in May (Sup: D. Jenkins)
 - Surrey studentship now awarded for a later start
- Allow interim support for UKNSF (£6k PA)



UKNDN - Structure



The UK Nuclear Science Forum

(Chair: Dr Alan Nichols, former head of the Nuclear Data Section at IAEA)

UK representatives on: NEA Nuclear Science Committee, IAEA Nuclear Data Section Cross Section Evaluation Working Group (National Nuclear Data Center, Brookhaven, USA).

The Forum will meet twice a year in May and November and will expand its functions to:

- Receive six-monthly reports from the Leadership Team
- Endorse funding recommendations for the Leadership Team's Project Approval Panel
- Provide advice and guidance on activities (workshop themes, course topics, other activities) to the Leadership Team

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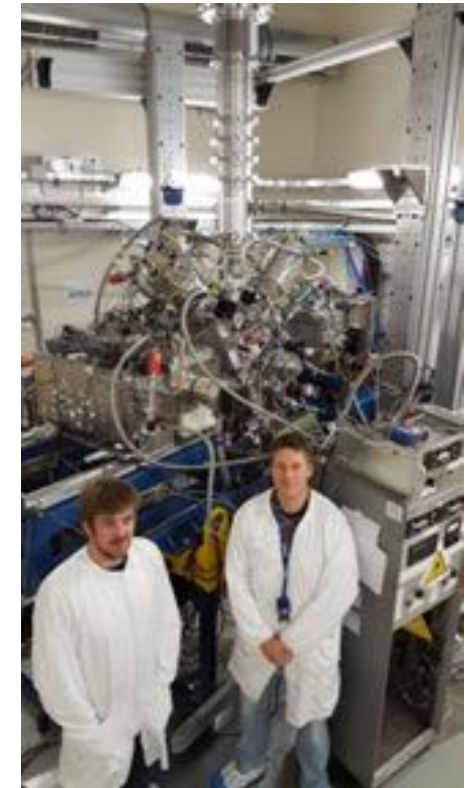
© 2008. This site is created and maintained by the [National Physical Laboratory](#)

UK NDN

Travel funding

The Network will provide financial support for full time post-graduate students and early career researchers to attend CPD courses relevant to nuclear data measurement and application provided, for example, by the Nuclear Technology Education Consortium (NTEC). Courses available include:

- Nuclear fuel cycle
- Reactor Physics Criticality and Design
- Radiation and Radiological Protection
- Experimental Reactor Physics
- Radiation Shielding



In addition, the Network will organize courses as required for new users of Monte Carlo radiation transport codes such as MCNP and GEANT4.

Projects funding

The Network will provide financial support for small projects:

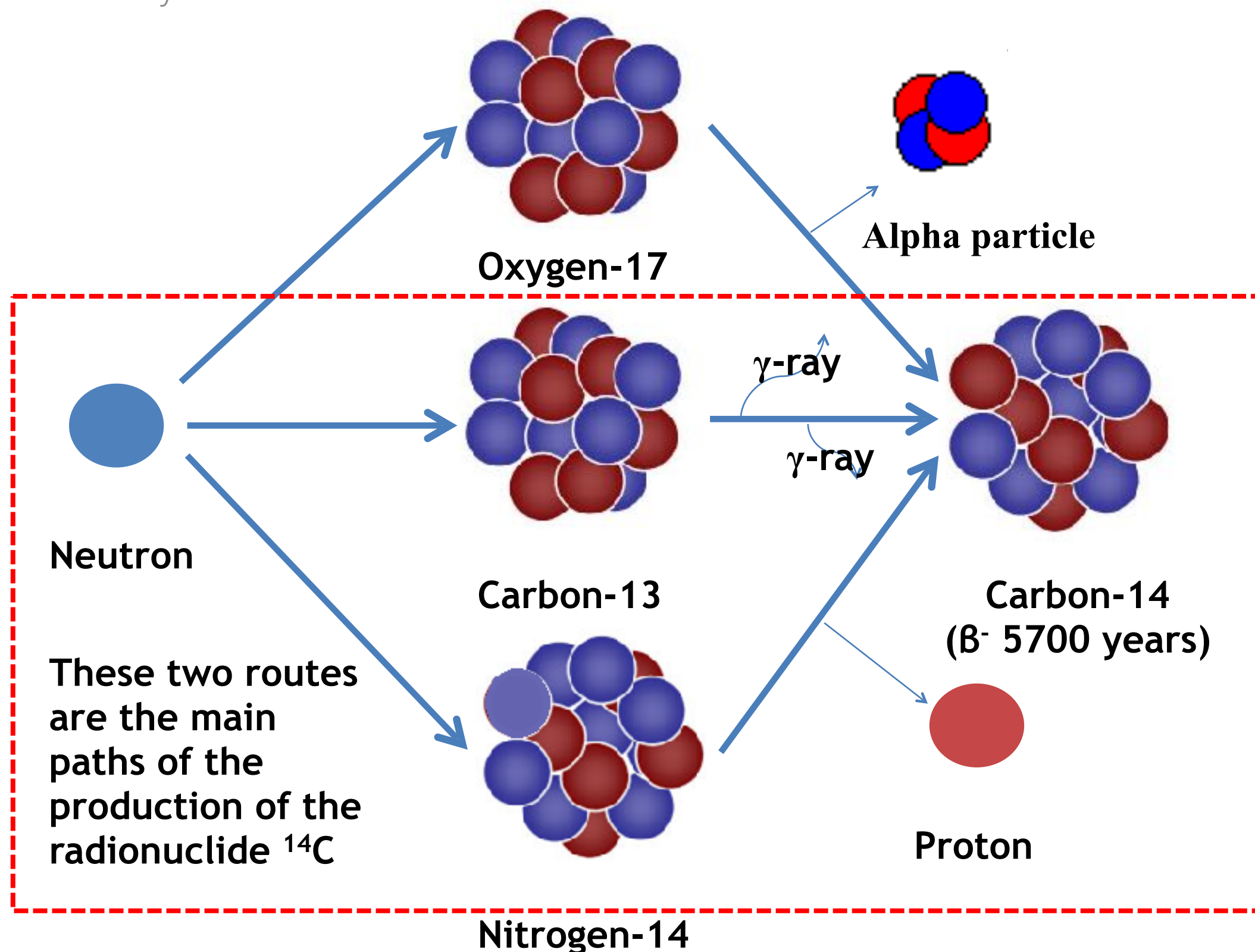
- £20k for scoping projects
- £50k for larger projects
- Calls twice per year, currently circulated on the UK Acad list, IoP Nuclear and Industry group, Individuals who have previously shown interest.
- Project proposals are reviewed by an academic and industry reviewer
- Approval comes from the NSF at the May/November meetings.

How to get involved in UKNDN

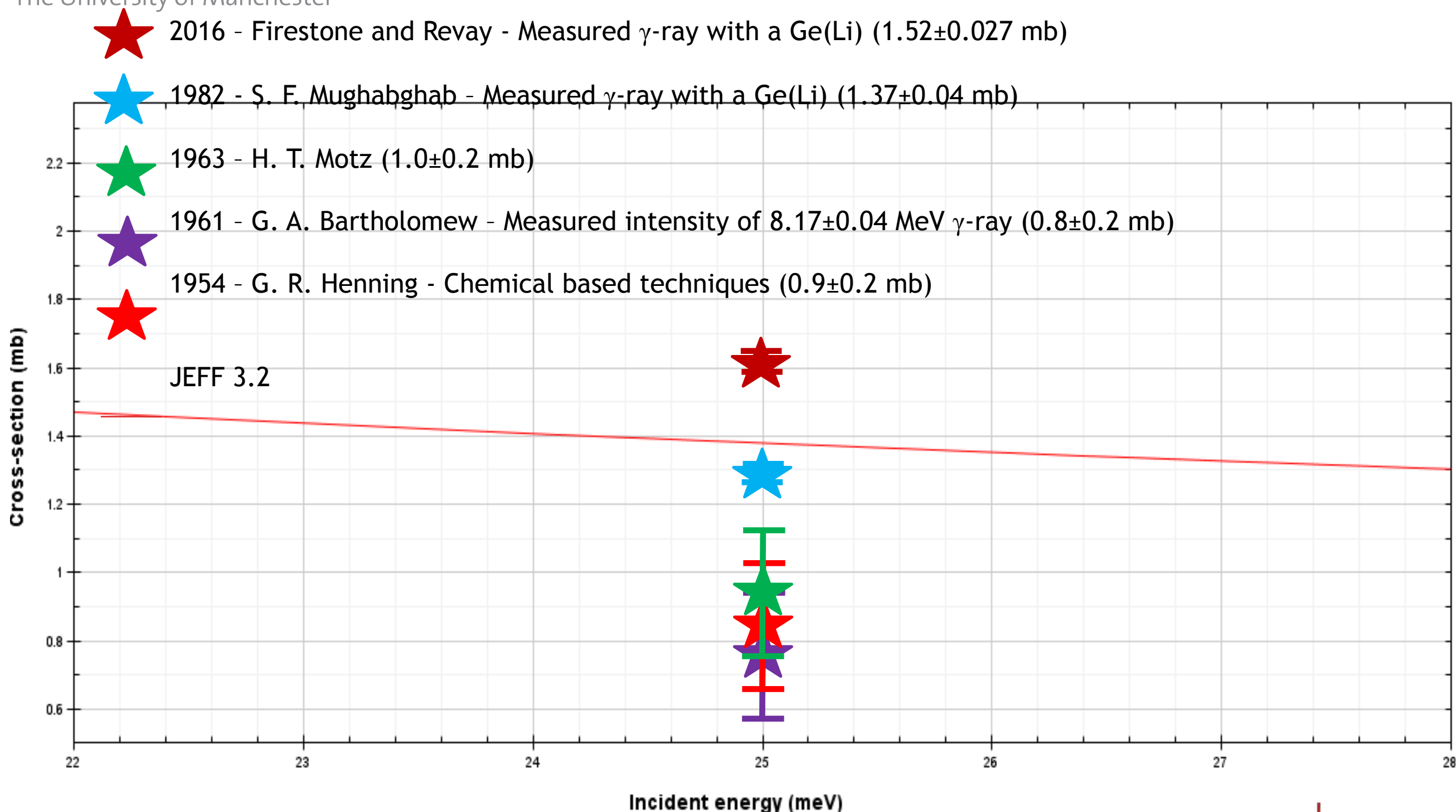
- Submit an application for project or travel funding –
Collaboration with institution eligible for RCUK funding
- Participate in Workshops/CPD etc.
CARM & GEANT4 Workshop Manchester 2017
Proposals for Nuclear Data Meetings/Workshops
- Join UKNSF
- Contacts for UKNDN – Proposals/Comments etc.
Website: ukndn.ac.uk
Email: ukndn@manchester.ac.uk
pauljohn.davies@manchester.ac.uk

^{14}C Production

Large amounts
found in
irradiated
graphite in
reactors



The University of Manchester



Current evaluations are all based off the two precise measurements, however this disagrees with all previous activation based experiments.

UKNSF request list

UKNSF(2007)P220

NOT FOR PUBLICATION

ASAT-0427

UKNSF(2007)P220

UK Nuclear Science Forum: Request List - 1996

Compiled by A.L. Nichols

May 1996

Table 1: Measurements

Item No.	Isotopes	Parameter	Energy Range	Accuracy (1 σ)	Category	Requester's name and comments	Measurer's name and comments
1	⁴³ Ca	N, 2P \rightarrow 42Ar	FR	$\pm 30\%$	2	R.A. Forrest (UKAEA): fusion activation	
2	50V	N, N α \rightarrow 46Sc N, α \rightarrow 47Sc	FR	NEN $\pm 100\%$ N, α $\pm 20\%$	2	R.A. Forrest (UKAEA): fusion activation	
3	⁹⁵ Mo, ⁹⁷ Tc, ¹⁰¹ Rh, ¹⁰³ Ru, ¹⁰⁵ Ag, ¹³³ Cs, ¹⁴³ Nd, ¹⁴⁵ Nd, ¹⁴⁷ Sm, ¹⁴⁹ Sm, ¹⁵⁷ Sm, ¹⁵⁹ Eu and ¹⁵⁵ Gd	Capture cross section	THR, 2250 (fusion) neutron spectra neutron	$\pm 5\%$	1	N.T. Gelliford (AEA Technology) and C.H. Zimmerman (BNF plc): burn-up credit based on fusion product absorption effects - integral measurements may suffice	Resonance integral measurements have been made in DIM data assessment is required prior to a further measurement
4	Cd, In, Ag, Eu, Gd, Dy, Er and Hf	Capture cross section (non-isotopic)	THR	$\pm 5\%$	2	C.H. Zimmerman (BNF plc): use as absorber materials	
5	¹⁰³ Rb	N, 3N \rightarrow $\pm 3\gamma$ ¹⁰¹ Rb	Above threshold energy	$\pm 20\%$	2	C.H. Zimmerman (BNF plc): no measurements reported	
6	¹²⁰ Sn, ¹²⁴ Sn	N, γ \rightarrow ¹²¹ Sn, ¹²⁵ Sn	FR	$\pm 5-10\%$	2	R.A. Forrest (UKAEA): fusion activation	
7	¹⁰¹ Mo	Half-life, mean β and γ energies, branching ratios and decay data	-	$\pm 5-10\%$	2	D.J. Edens (Magnox Electric): ²³⁹ Pu decay heat discrepancies at 1000sec cooling	

ASAT-0427
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2000-1-0000-000

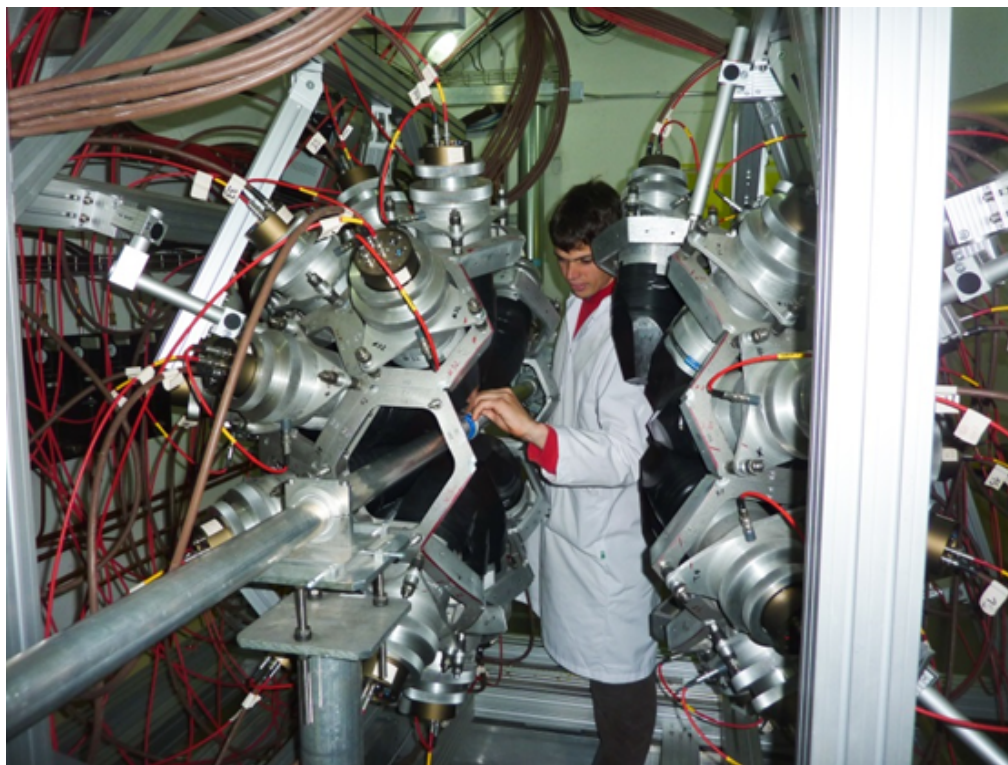
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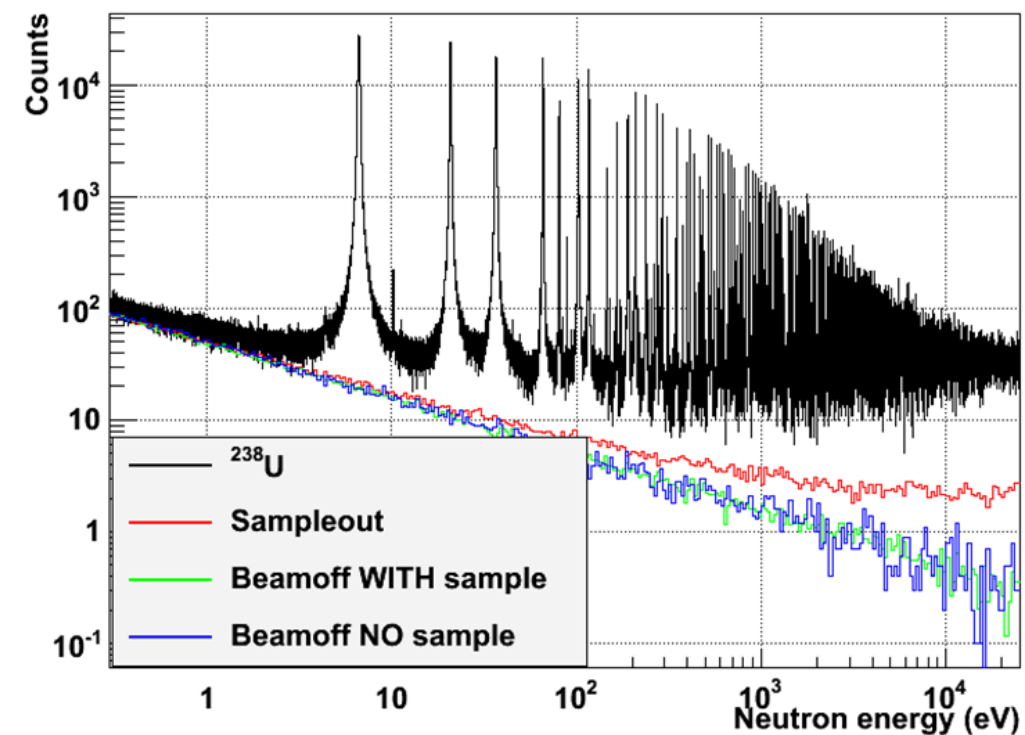
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Subscription to nTOF Collaboration (Manchester & York)

NEA request to measure $^{238}\text{U}(n,\gamma)$ cross section with 2% accuracy from 100 eV to 25 keV



Hands on work at the n_TOF facility, CERN measuring a ^{238}U sample



University involvement:

- **Manchester** – $^{238}\text{U}(n,\gamma)$ measurement (above)
- **York** – $^{236}\text{U}(n,\gamma)$ measurement

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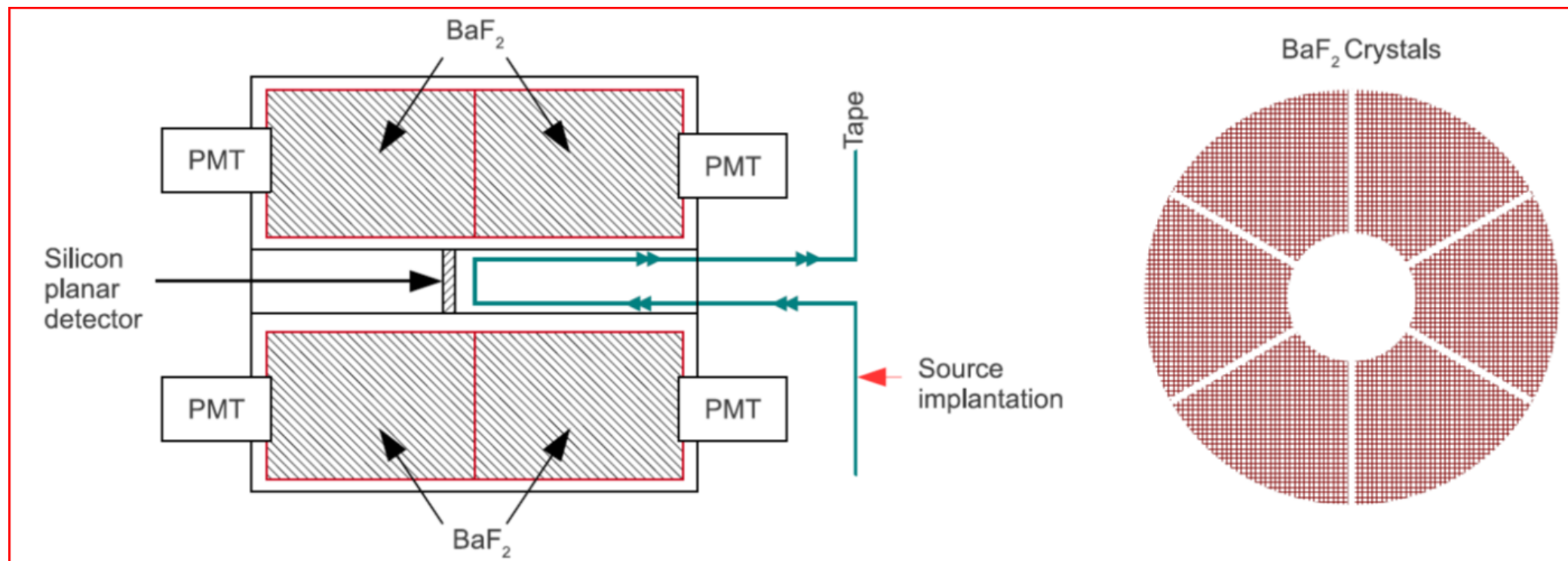
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TAS:
Total
Absorption
Spectrometer

Unique features of Jyväskylä Accelerator Laboratory, Finland:

- “IGISOL” ion source – provides even refractory elements in 1 ms
- Penning trap – can separate isobars (and even isomers) by exact mass and deliver to TAS detector

Strand 3 Neutron Fission Gamma Rays with STEFF

Gavin Smith (Manchester), Paddy Regan, Zsolt Podolyak (Surrey)

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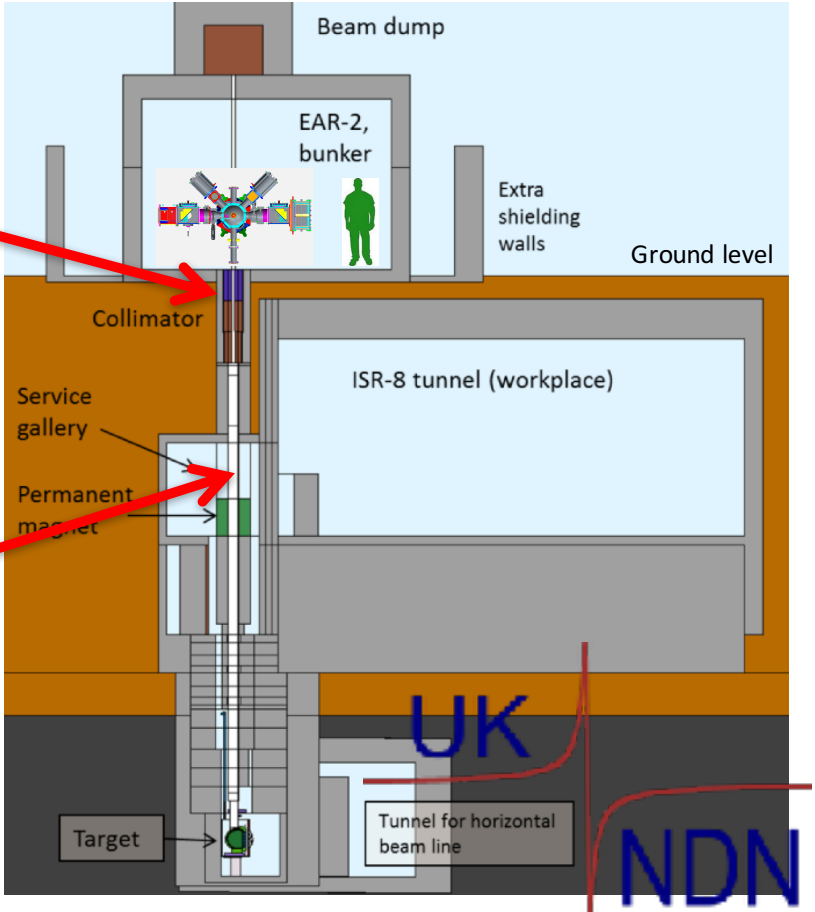
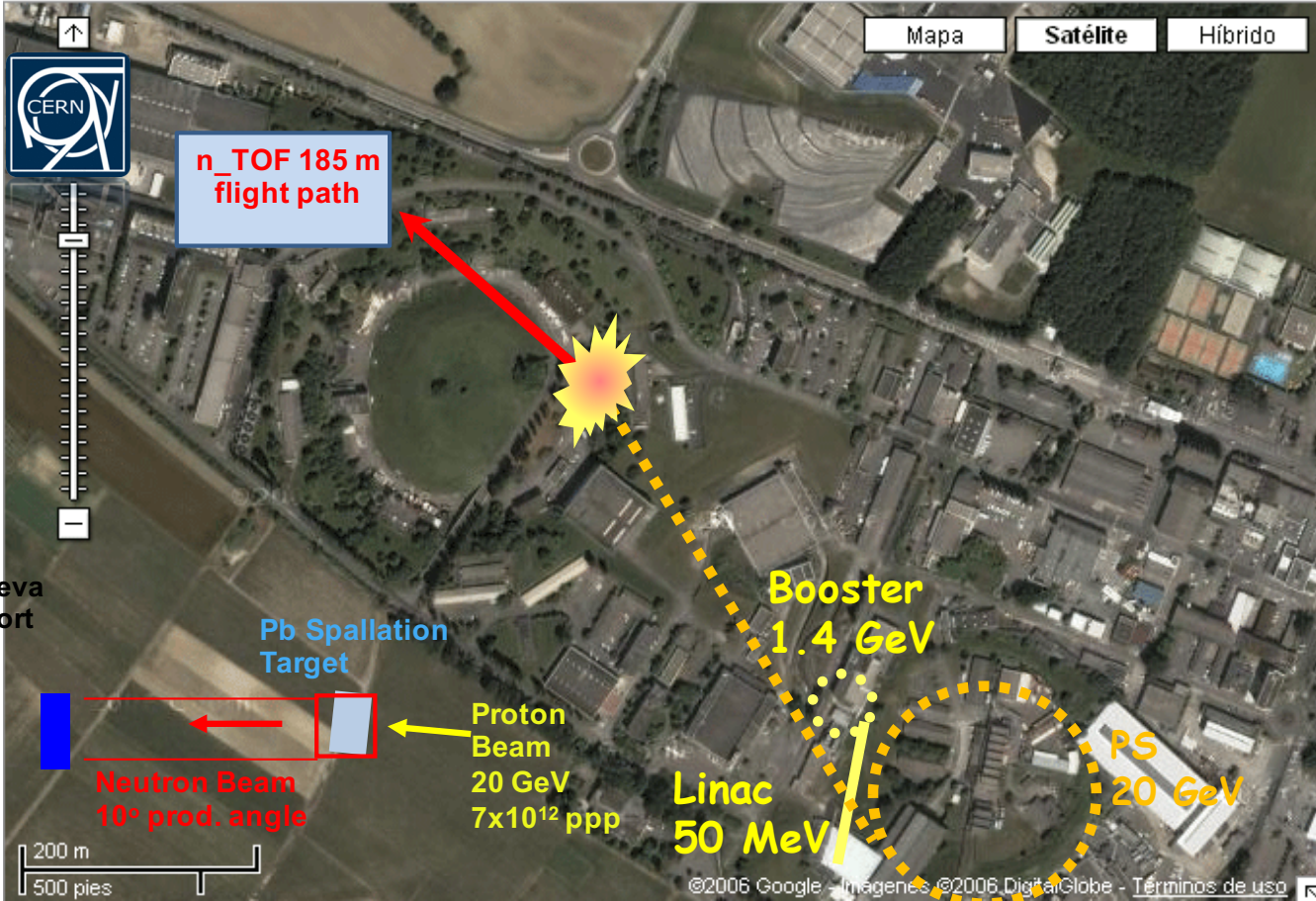
The initial STEFF experiments have been run at CERN October 2015/June 2016



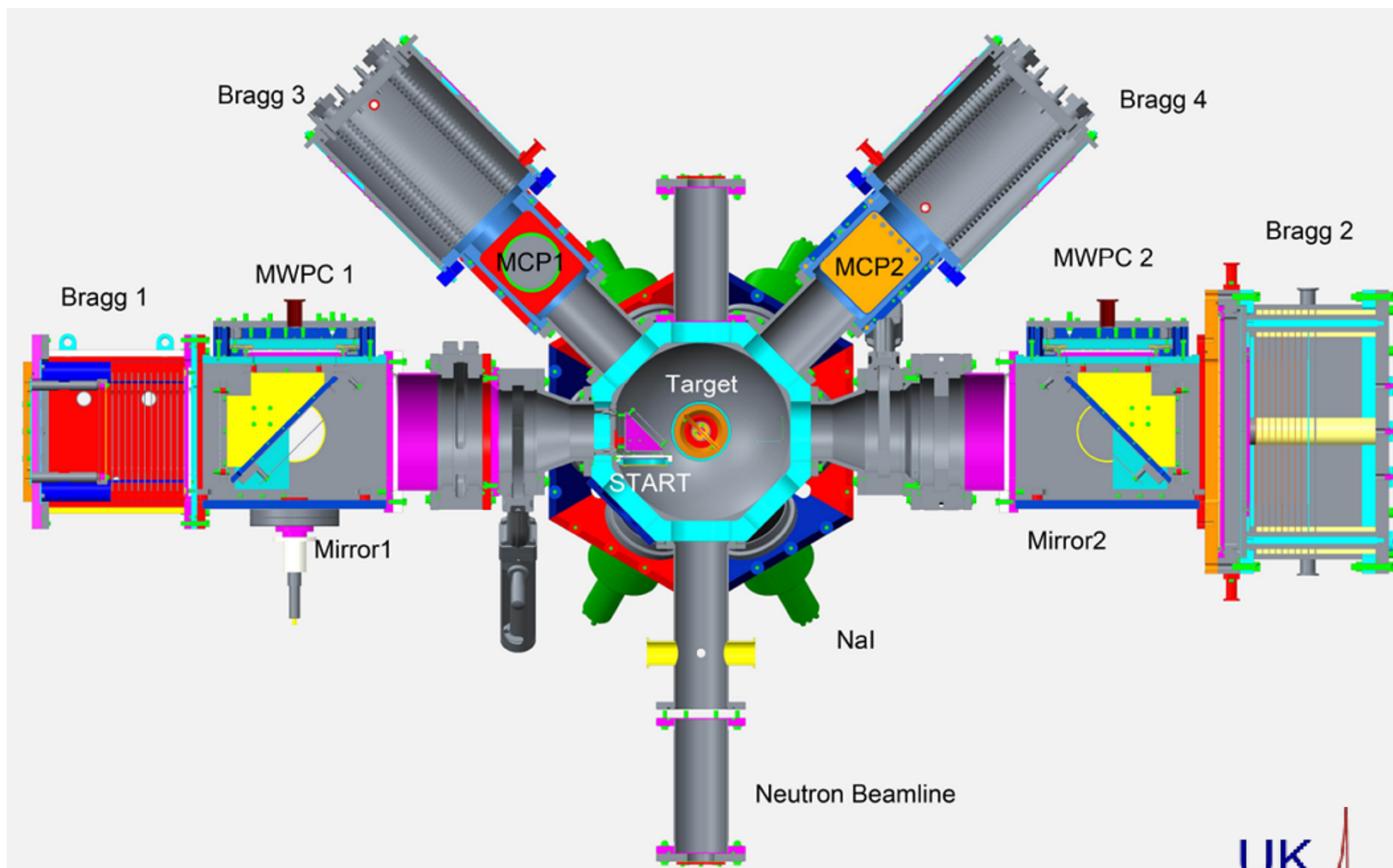


Large Hadron Collider Super proton synchrotron Neutron Time-of-Flight facility Proton synchrotron

Cern: n_ToF



STEFF: Spectrometer for Exotic Fission Fragments



Entrance window 95mm diameter

3m

UK

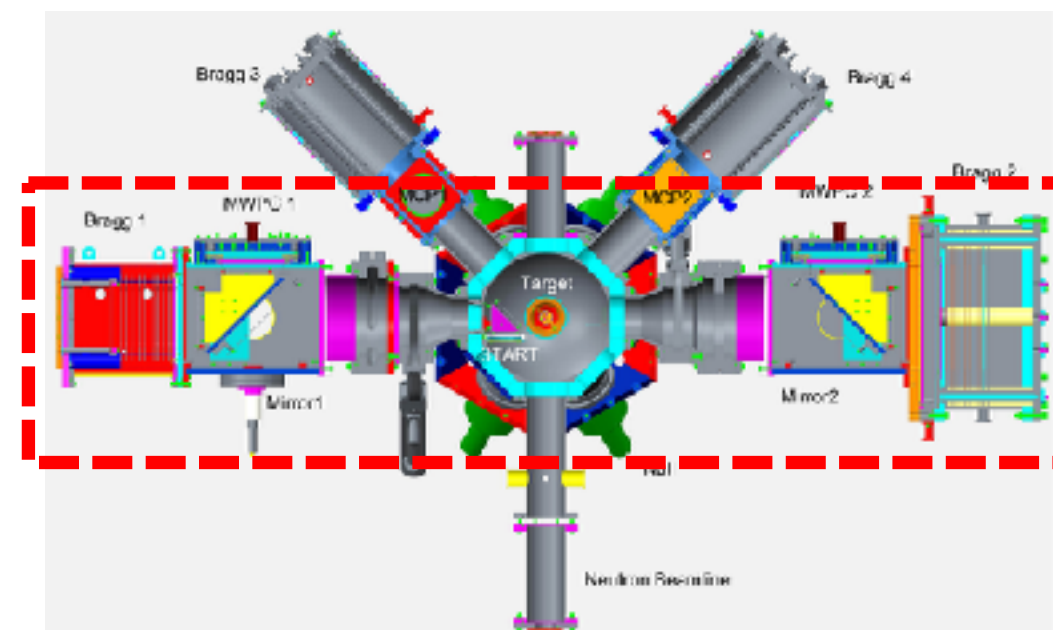
NDN

STEFF Overview – Fission Fragment (FF) Detectors

Main axis (arms one and two)

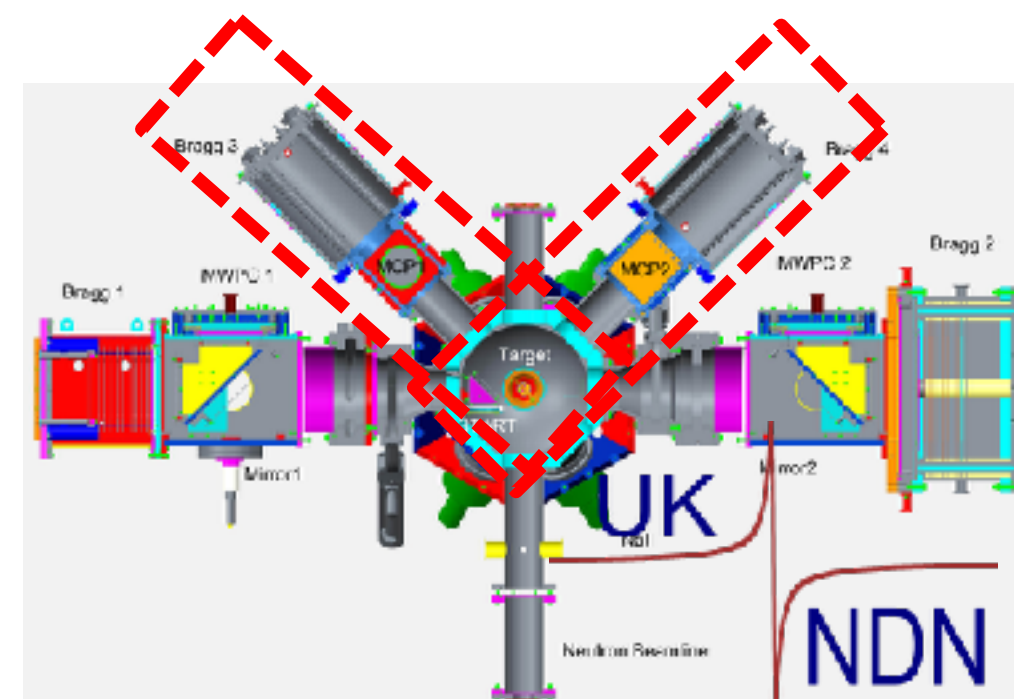
Secondary electron timing detectors for FF time-of-flight measurements:

- Flight path 1 m
- Timing resolution 400 ps
- Intrinsic counting efficiency ~70%
- Ionization chambers (100 mbar isobutane)
 - Solid angle ~ 0.03 sr
 - 15 segments
 - Energy resolution ~1.6%
 - Intrinsic counting efficiency ~100%



Secondary axes (arms three and four)

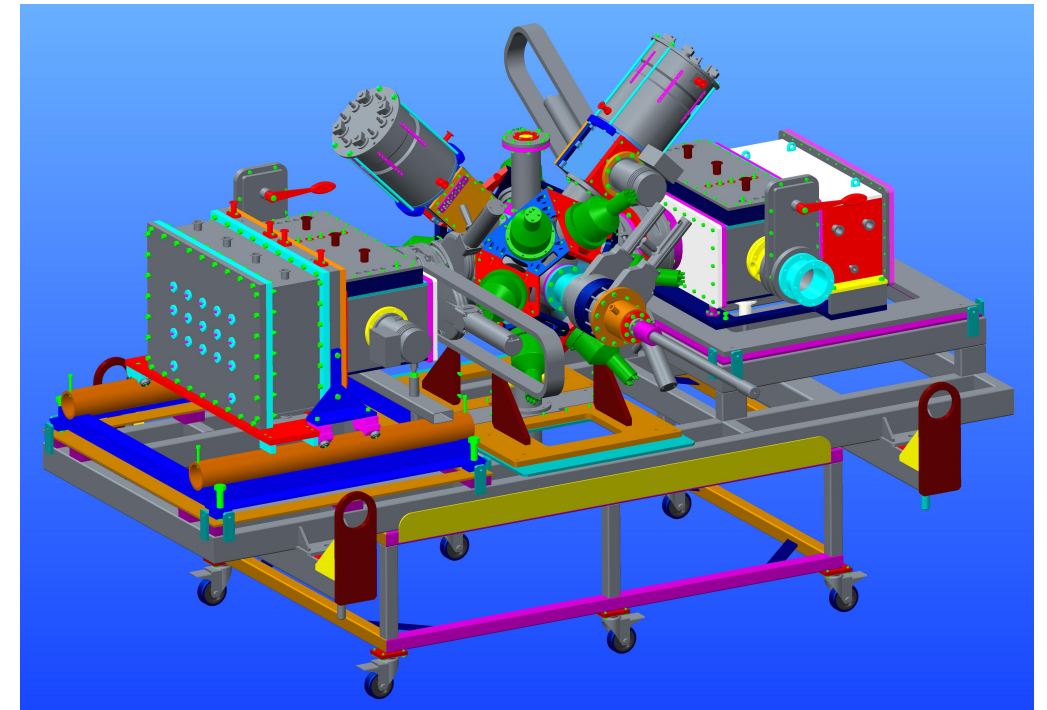
- Secondary electron timing detectors for FFs
 - Timing resolution ~400 ps
 - Intrinsic counting efficiency ~80%
- Ionization chambers (100 mbar isobutane)
 - Solid angle ~0.03 sr
 - Energy resolution ~1.6%
 - Intrinsic counting efficiency ~ 100%



γ -ray detection

Nal

- Array of 12 (5"x4") Nal crystals surrounding the central chamber
 - Geometrical solid angle 3.8 sr (~30%)
 - Photopeak Array efficiency ~6.8% @ 0.662 MeV
 - Energy resolution ~7-8% @ 0.662 MeV
 - Timing resolution ~5 ns
 - Decay time 230 ns



LaBr₃

- Possibility of replacing one Nal with a LaBr₃ crystal
 - 1x1inch
 - Geometrical solid angle 20 msr (~0.15%)
 - Efficiency ~0.05% @ 0.662 MeV
 - Energy resolution ~4% @ 0.662 MeV
 - Timing Resolution ~300 ps
 - Decay time 26 ns

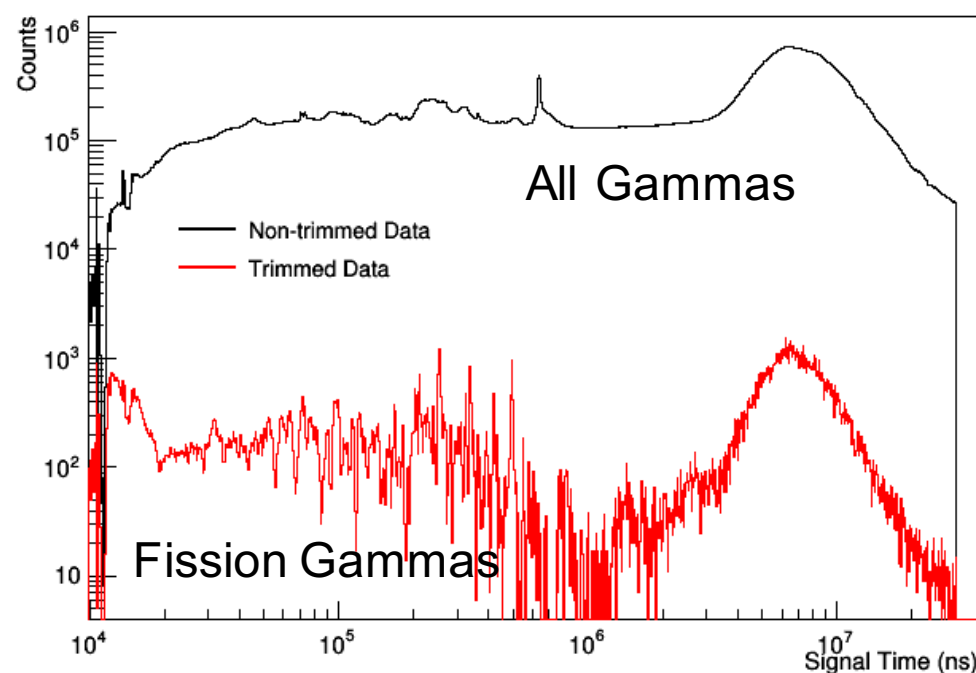


Calibration of two Nal and one LaBr₃ detectors

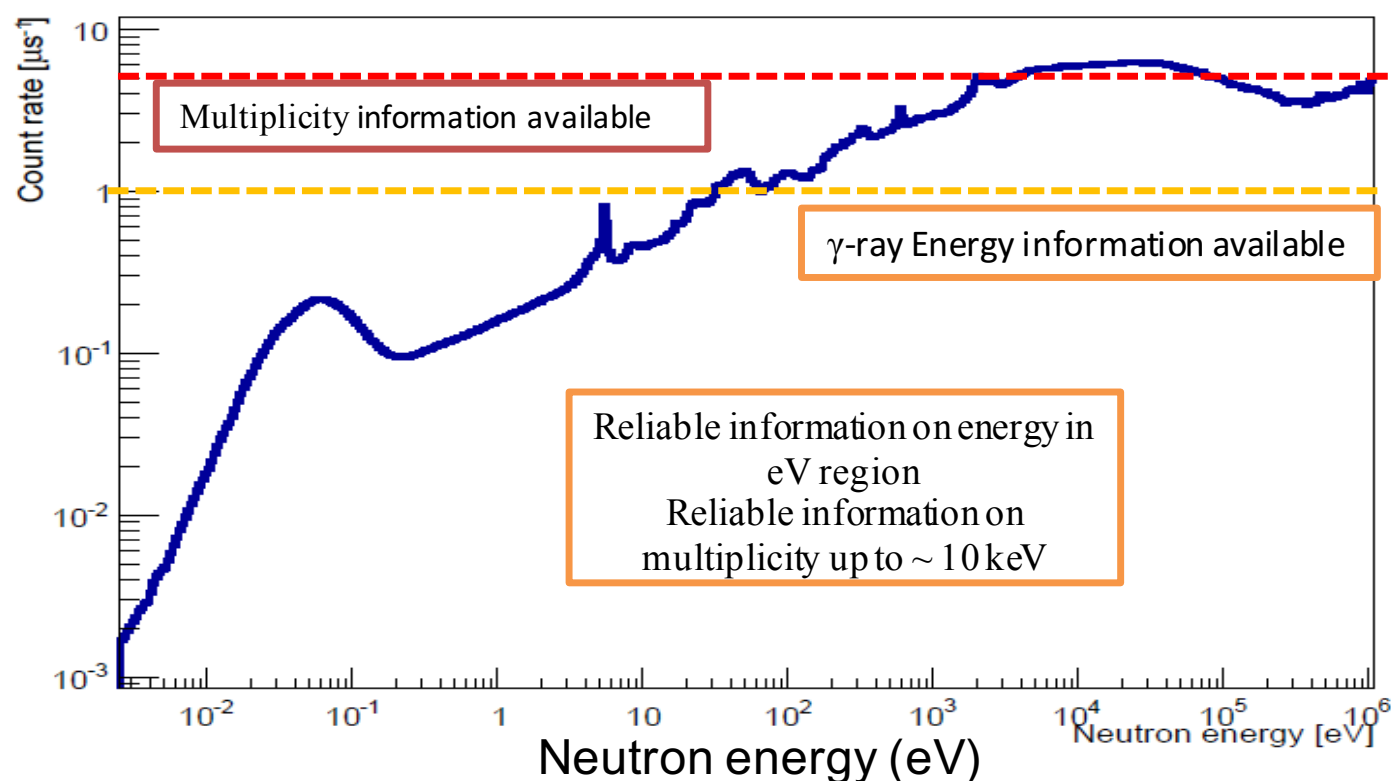
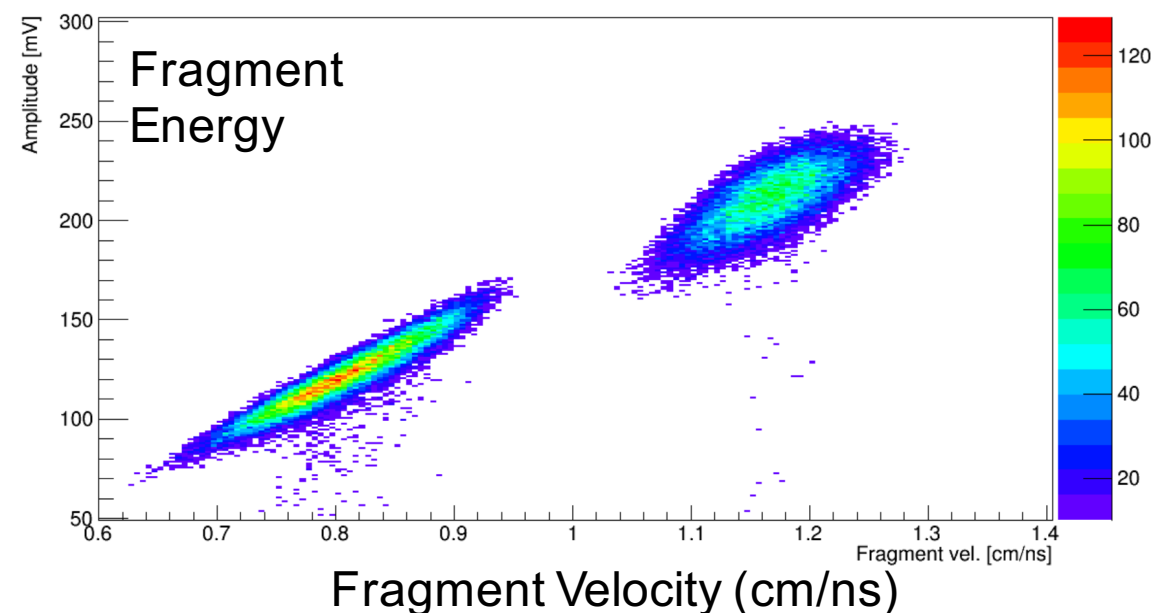
FF and γ -ray detection

STEFF Measures Fission Gamma Rays in Environment
With Raw S/N~0.001

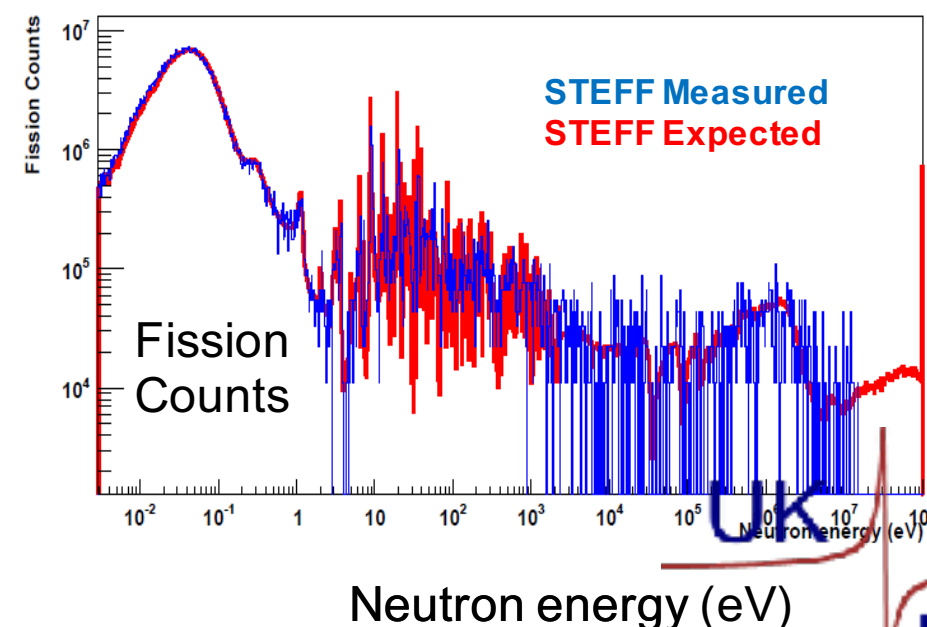
NAID Detector Timing Spectrum



Bragg fission fragments



Comparison of evaluated fission rates and measured fission rates



Connected International Data Activities

CIELO - Evaluation of ^{238}U neutron capture is a priority; significant input from Manchester

CHANDA - Manchester is part of this FP7 project and organised the 3rd School for Neutron Resonance Analysis at IRMM GEEL (Dec 2014 T.Wright)

ANDES - FP7 project; Manchester main author of one of the deliverables (^{238}U capture)

