Nuclear Data - Need, Capabilities, Opportunities

Nuclear Physics Forum, Manchester, July 2025

Bjoern Seitz, University of Glasgow

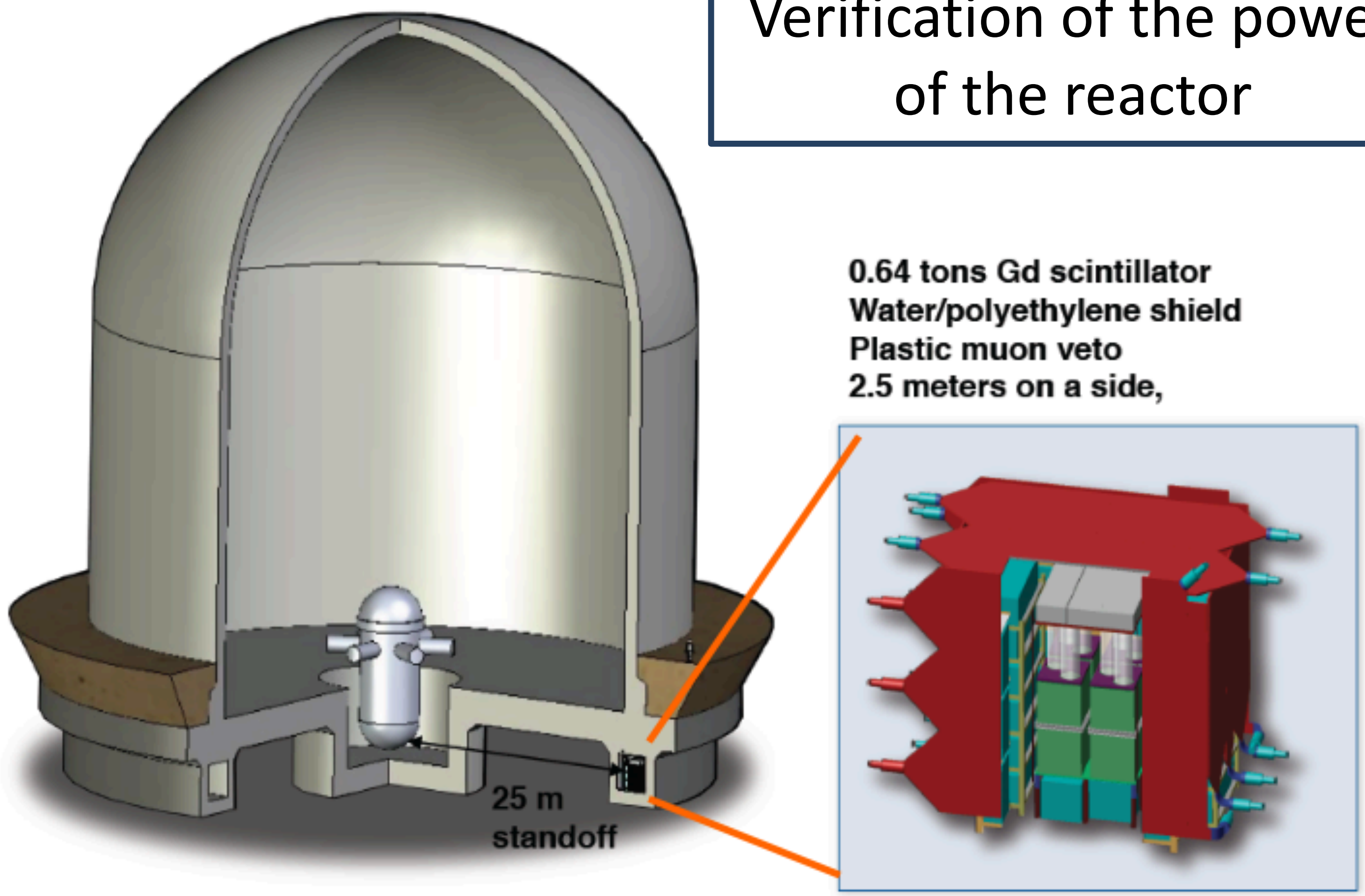
Applied v Physics

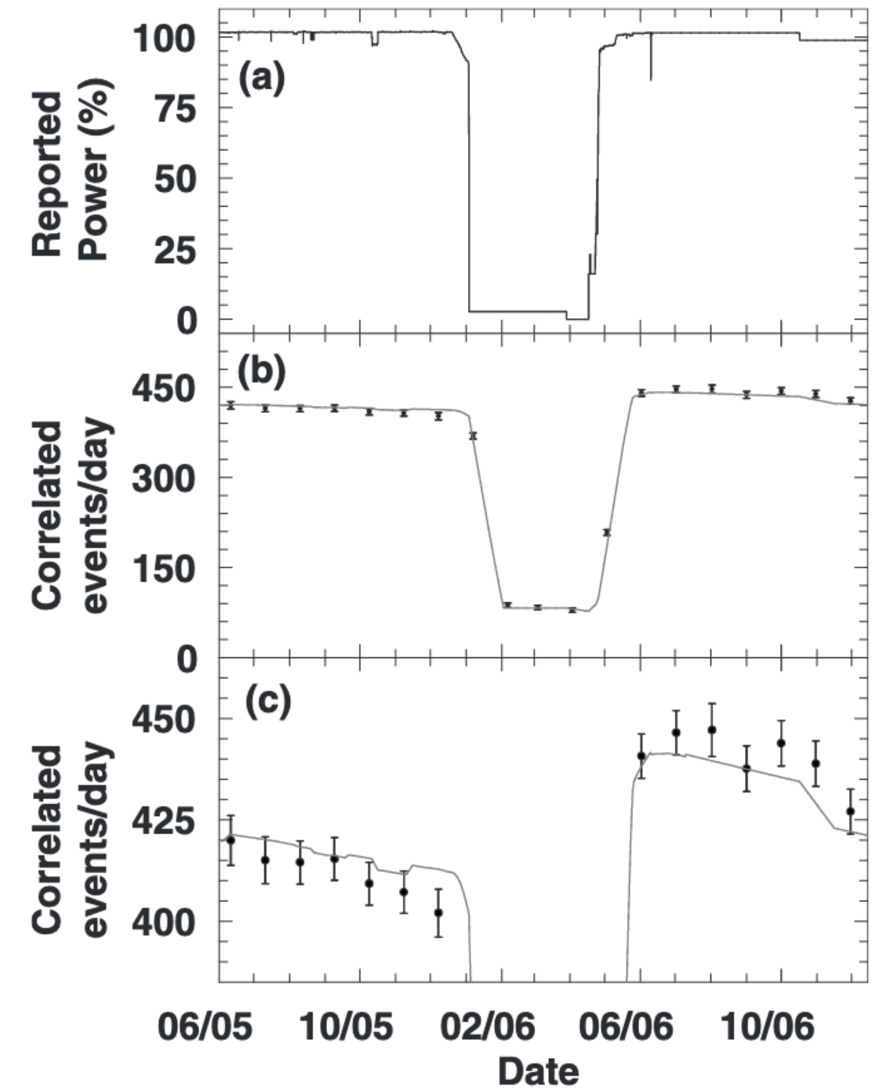
Much more **catchy** title

Using *ghost particles* to **catch** a nuclear program or a nuclear bomb?

Applied ν Physics

Verification of the power of the reactor





Bowden, N. S., Bernstein, A., Dazeley, et. Al. (2009 *Journal of Applied Physics*, *105*(6), 064902.

Applied ν Physics

University of Glasgow

Exclude the existence of Pu production facilities

Science & Global Security, 19:28–45, 2011

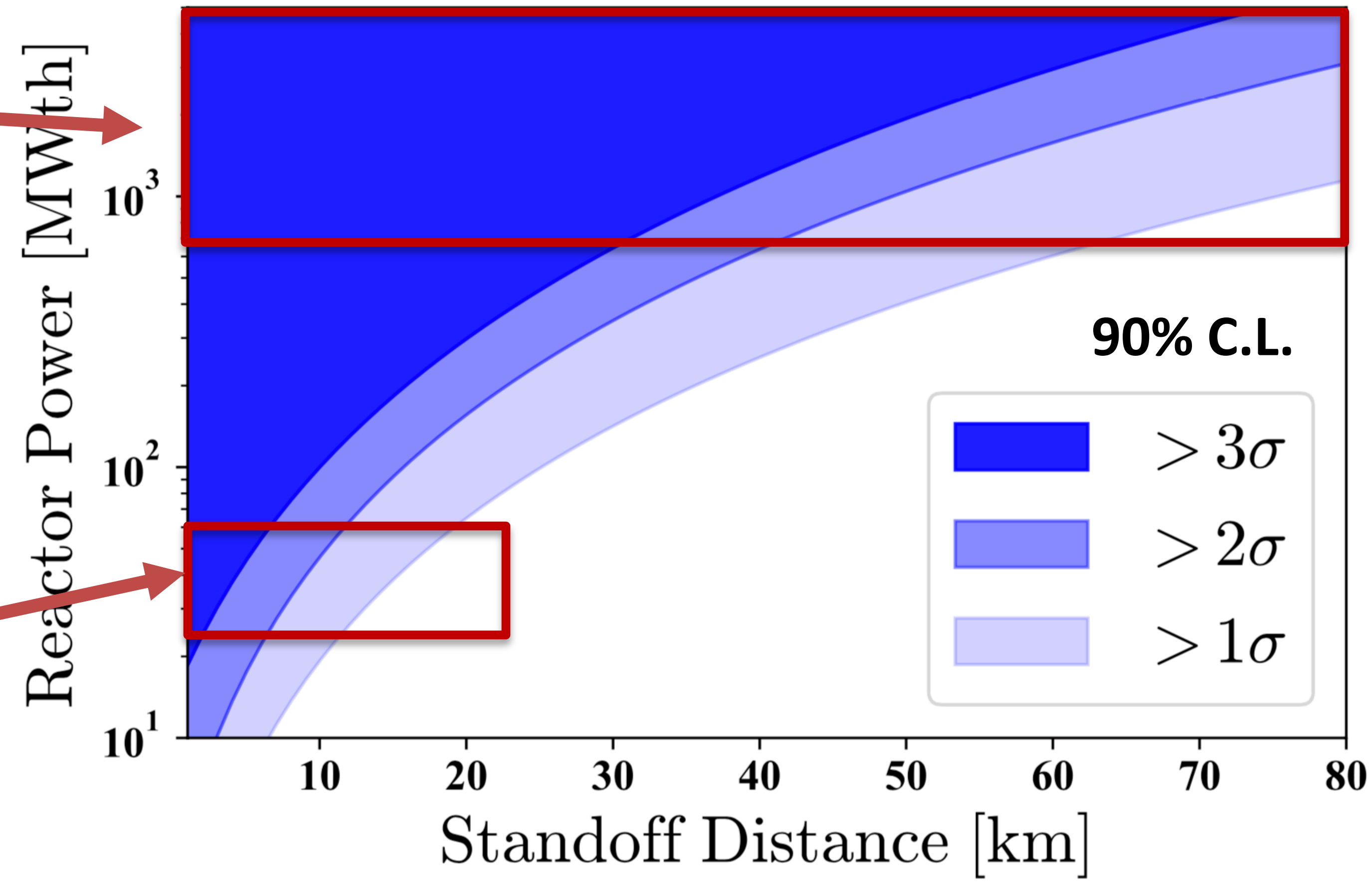
Reactor	Type	Power (MWt) (design/upgraded)
AD	once-through	1450/2000
ADE-1	once-through	1450/2000
ADE-2	closed-circuit	1450/1800

Krasnoyarsk plutonium production reactors.

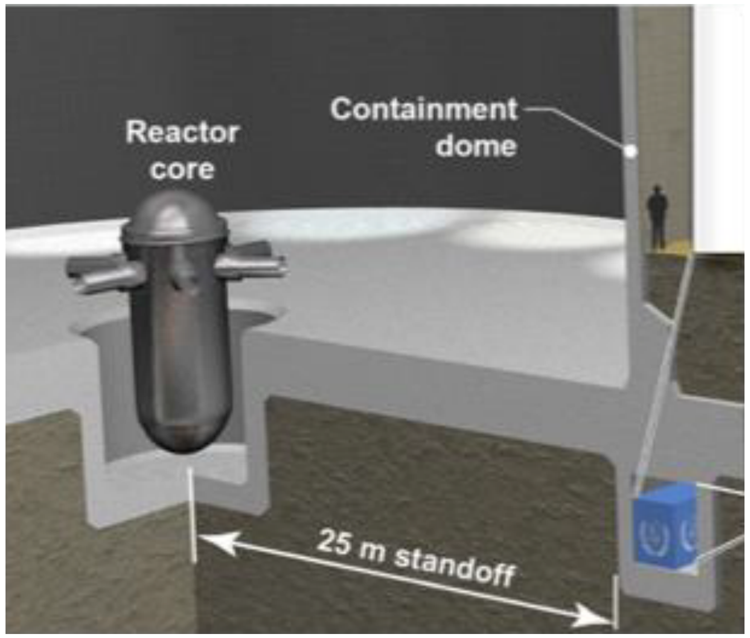
Exclude the existence of research reactors

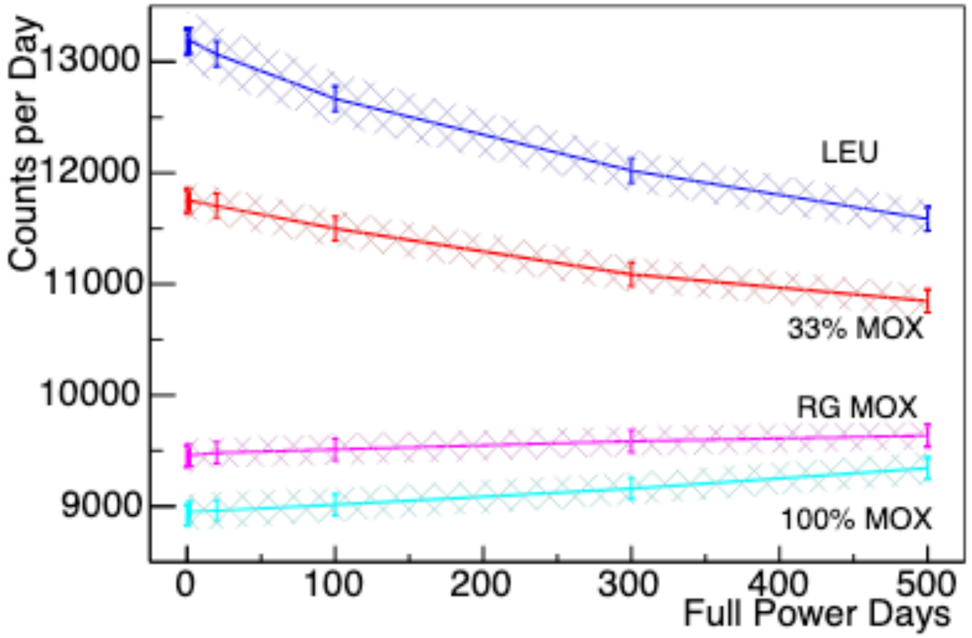
Satellite image of the heavy water reactor at Arak, Iran, May 2012. Image credit Digital Globe and Google Earth

WATCHMAN Exclusion Contour: One-Year Dwell Time, Gd-Doped Water

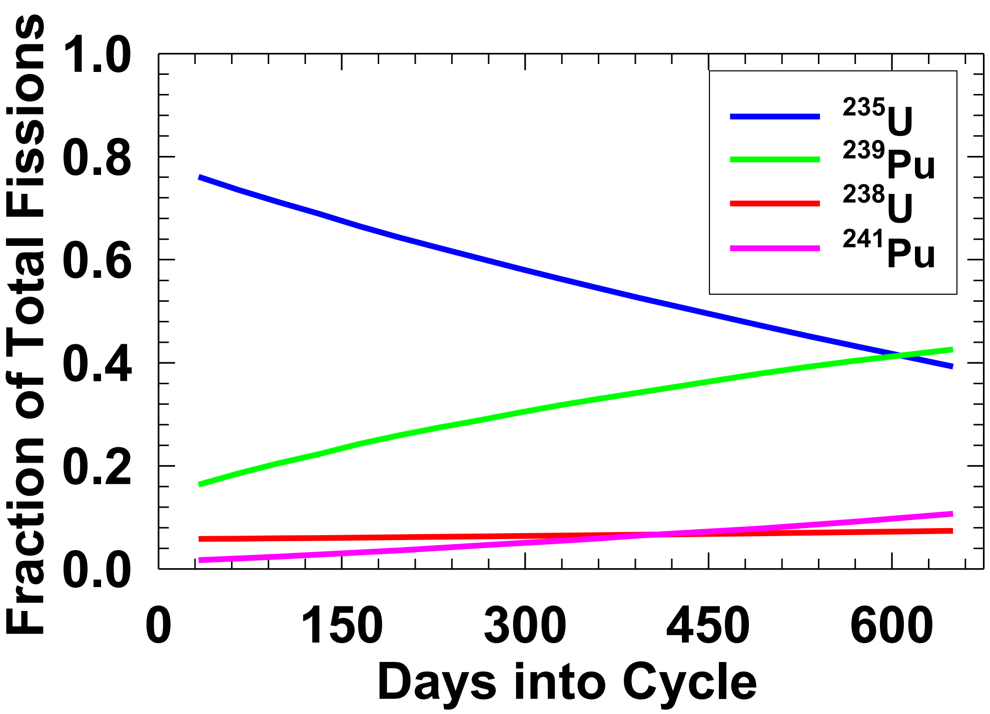


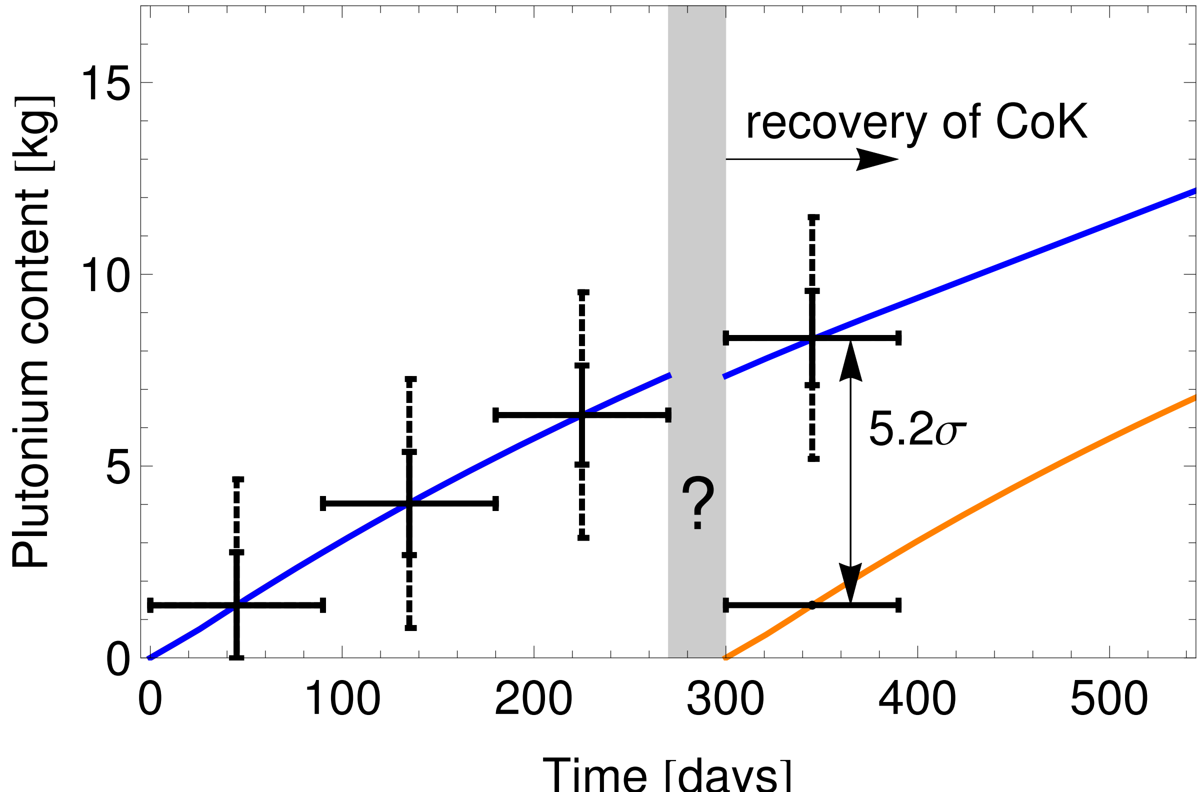
A case study



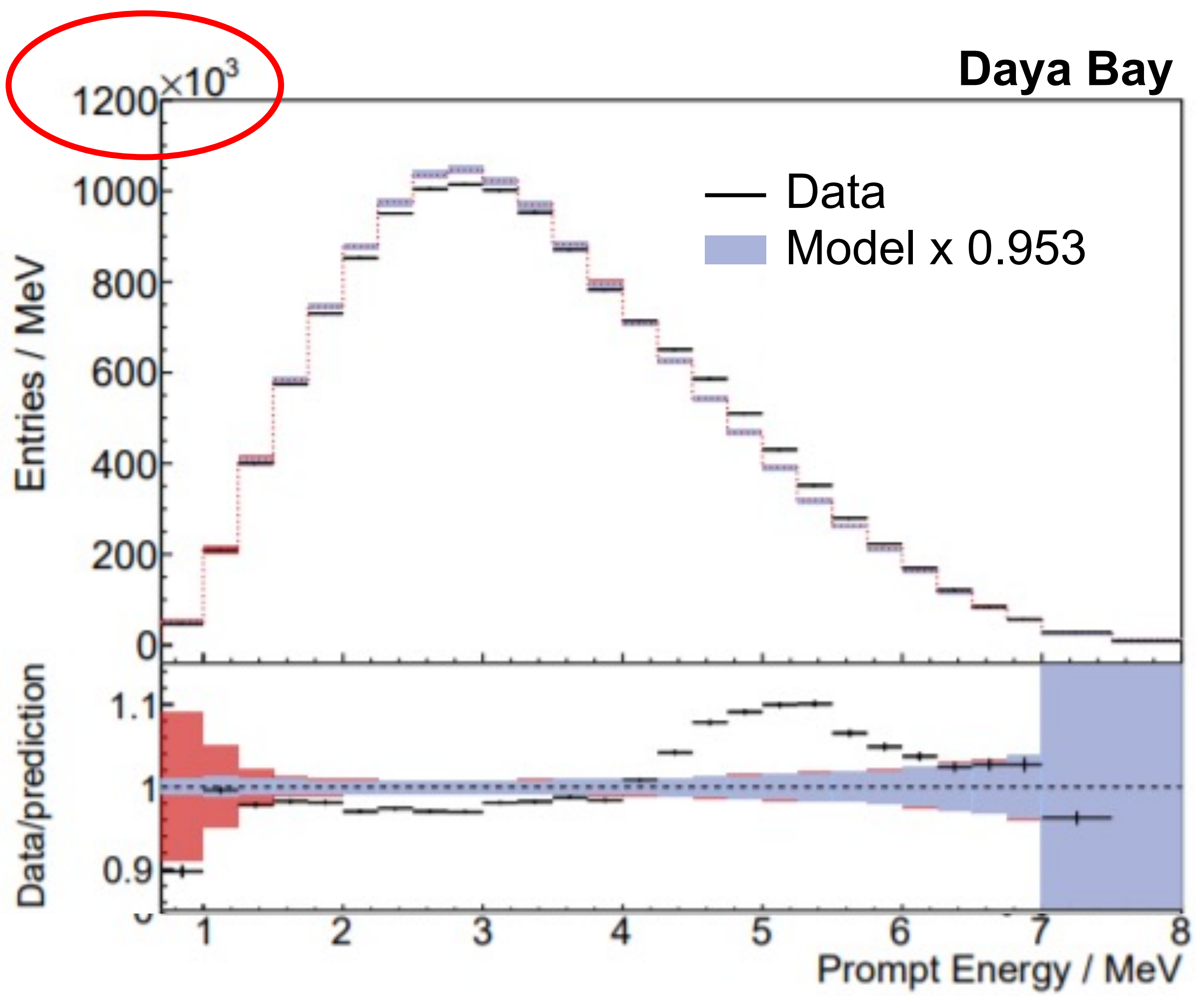


Bernstein, Adam, Nathaniel S. Bowden, and Anna S. Erickson. *Physical Review Applied* 9.1 (2018): 014003.



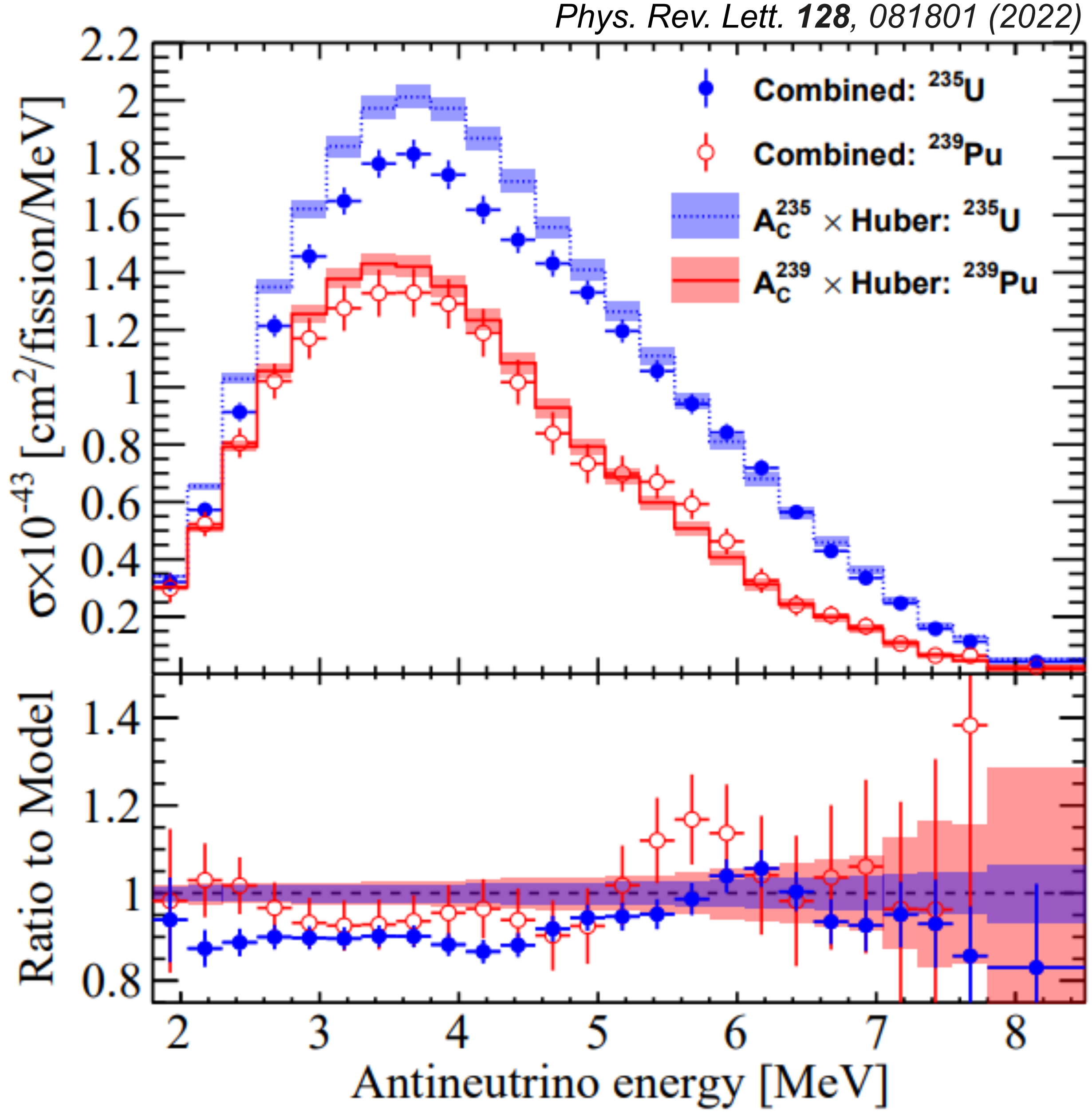


The need for nuclear data



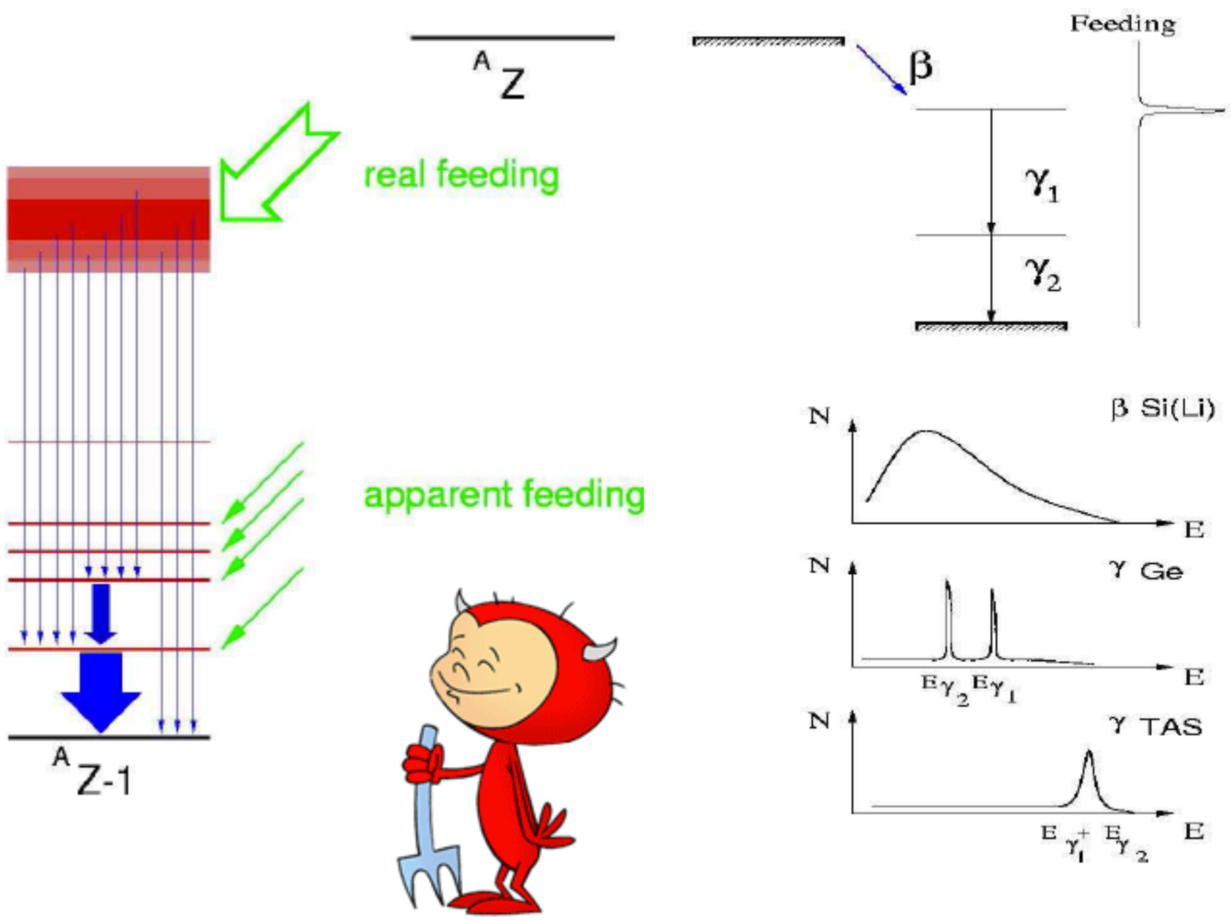
Phys. Rev. Lett. 123, 111801 (2019)

Phys. Rev. Lett. ***128****, 081801 (2022)*



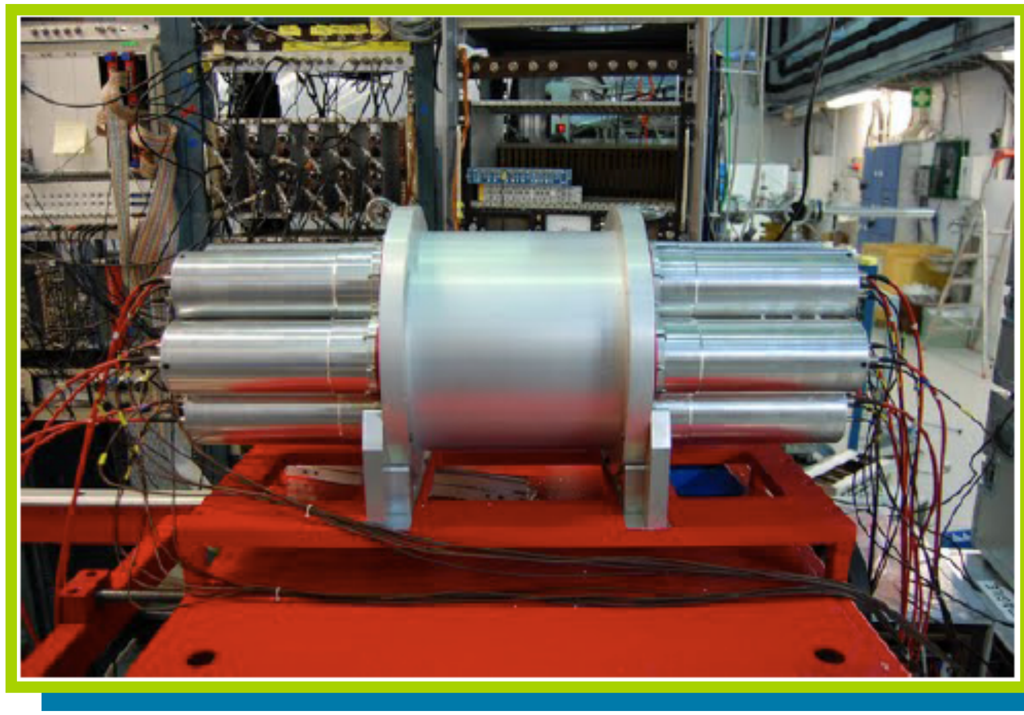
Solution: Total Absorption Spectroscopy (TAS)

Big cristal, 4π => A TAS is a calorimeter !



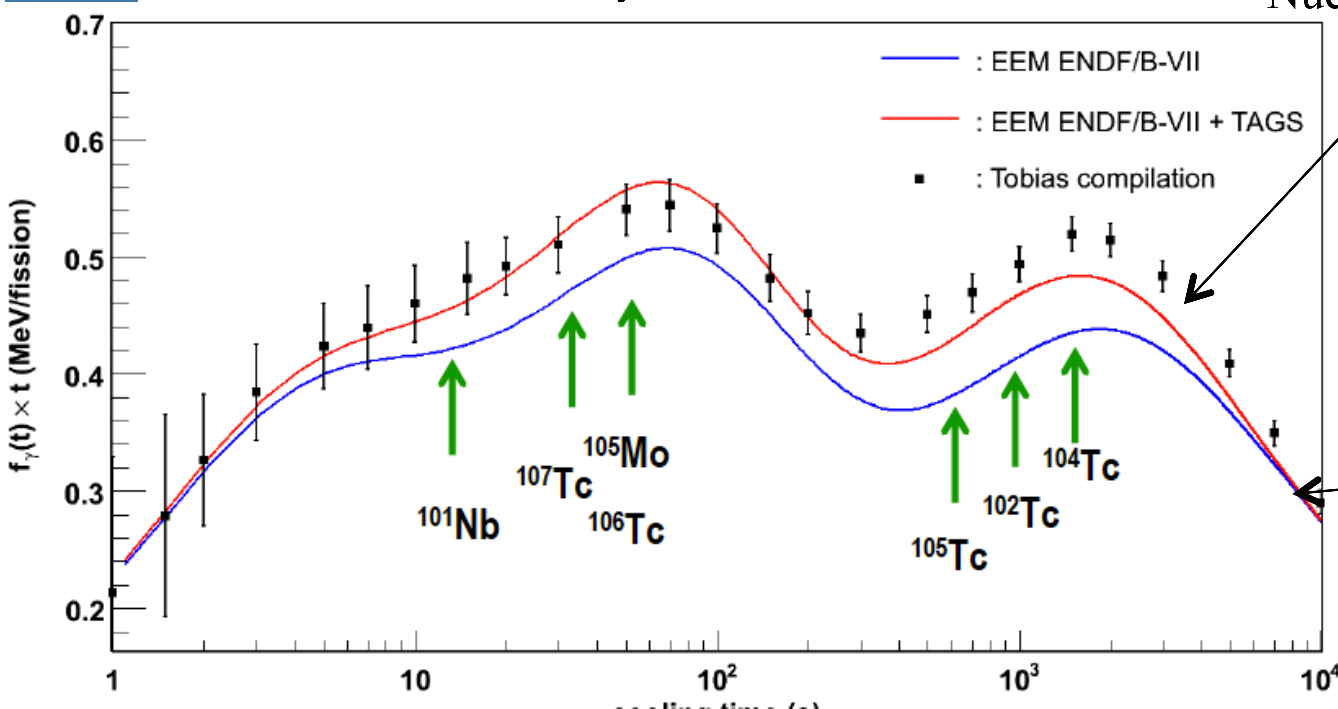
Picture from A. Algora

** J.C.Hardy et al., Phys. Lett. B, 71, 307 (1977)



- 12 BaF_2 covering ~4π
- Detection efficiency of γ ray cascade ~ 100%
- Si detector for β

Electromagnetic component of ^{239}Pu decay heat



TAS measurements: $^{102;104–107}$Tc, ^{105}Mo, and ^{101}Nb:

Nuclei from Nuclear Science NEA/WPEC-25 (2007), Vol. 25

Integral measurement of reference

IFIC of Valencia (J.L. Tain et A. Algora et al.):
Algora et al., Phys. Rev. Lett. 105, 202501 (2010),
D. Jordan, PhD thesis, Univ. Of Valencia 2010
D. Jordan, A. Algora et al. Phys. Rev. C 87, 044318 (2013)

Summation method calculations of the decay heat (~850 nuclei !!!!)

University of Glasgow

UK nuclear science forum

Nuclear data includes…

- Radioactive decay data
- Fission yields
- Neutron production
- Charged particle and photon cross sections
- Spectra and angular distributions of emitted particles
- Integral data
- Neutron cross sections
- Experimental measurements

From UKNSF.org.uk

University of Glasgow

UK nuclear science forum

ND2025 — 16TH NUCLEAR DATA FOR SCIENCE AND TECHNOLOGY CONFERENCE, JUNE 22ND – 27TH | MADRID (SPAIN) | 2025

ND needs in Europe & elsewhere

- **Decommissioning of NPP and waste management**: Data to support radiological characterization, source term estimation, and long-term disposal.
- **Gen-IV, SMRs & ATFs.** Advanced concepts such as Molten Salt Reactors, High Temperature Gas cooled Reactors. Advanced Technology Fuels.
- **Fusion reactors.** Driven by the construction of ITER (Cadarache-FR) and IFMIF-DONES (Granada-ES) facilities.
- **Nuclear astrophysics.**
- **Space exploration.** The European Space Agency (ESA) plans to develop fission reactors for spacecraft propulsion and power generation. Cosmic radiation dose to astronauts.
- **Cancer therapy.** Proton therapy and ^{12}C heavy ion therapy are growing in Europe (public and also private healthcare). Theranostics and imaging are also demanding new and more accurate nuclear data (**large number of talks in ND2025**).
- **Dosimetry.** Continuous increase in safety requirements for exposed workers and
- **Geological survey and environmental sciences.** Non-destructive techniques, radiotracers…
- **Nuclear forensics and safeguards.** Enhanced data requirements for trace detection and characterization of illicit materials.

Plenary talks by M. Kerveno (fission), A. Algora (decay data), A. Mengoni (astrophysics), S.M. Qaim (medical applications) and M. Gilbert (fusion)

The virtuous circle

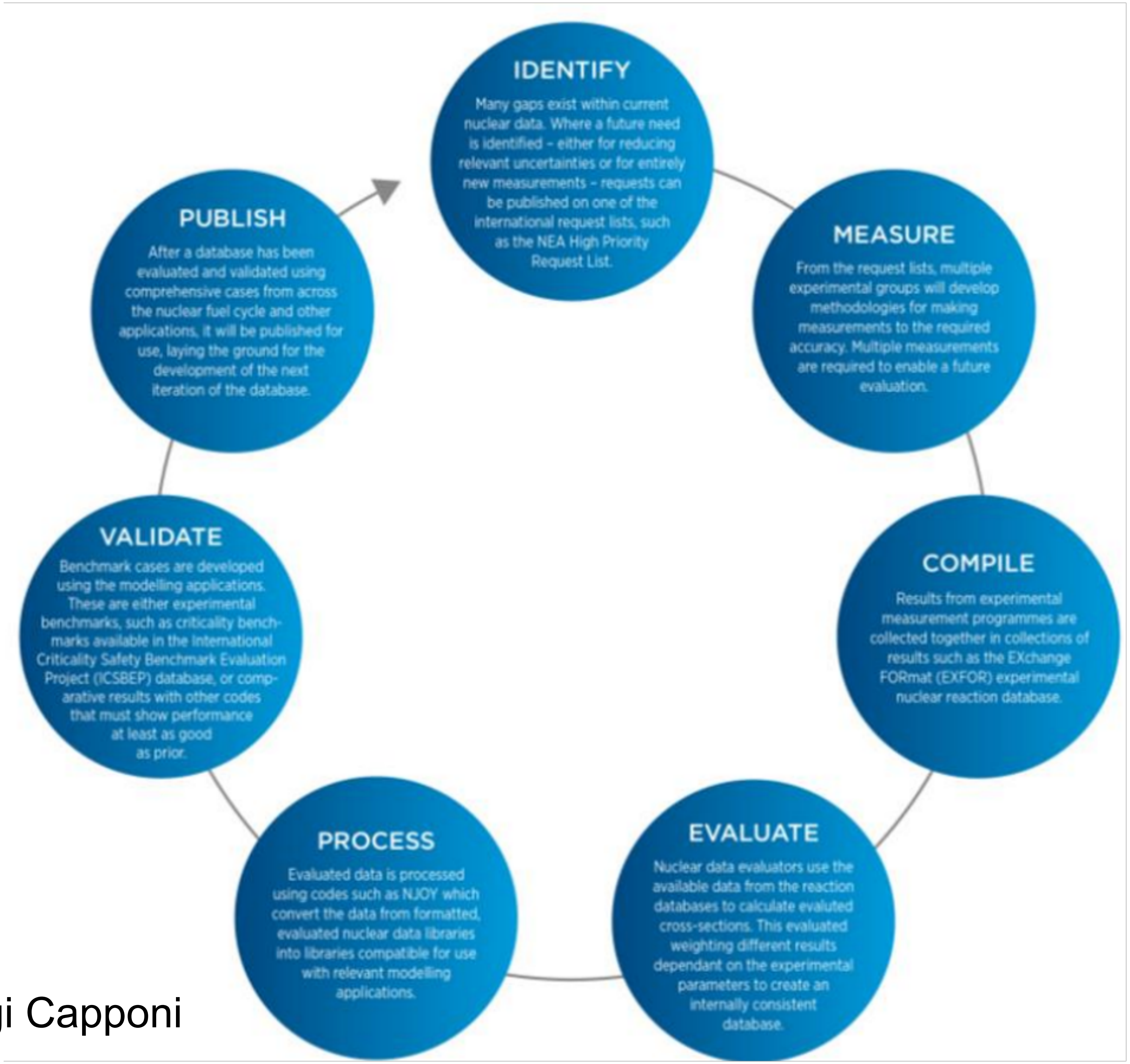
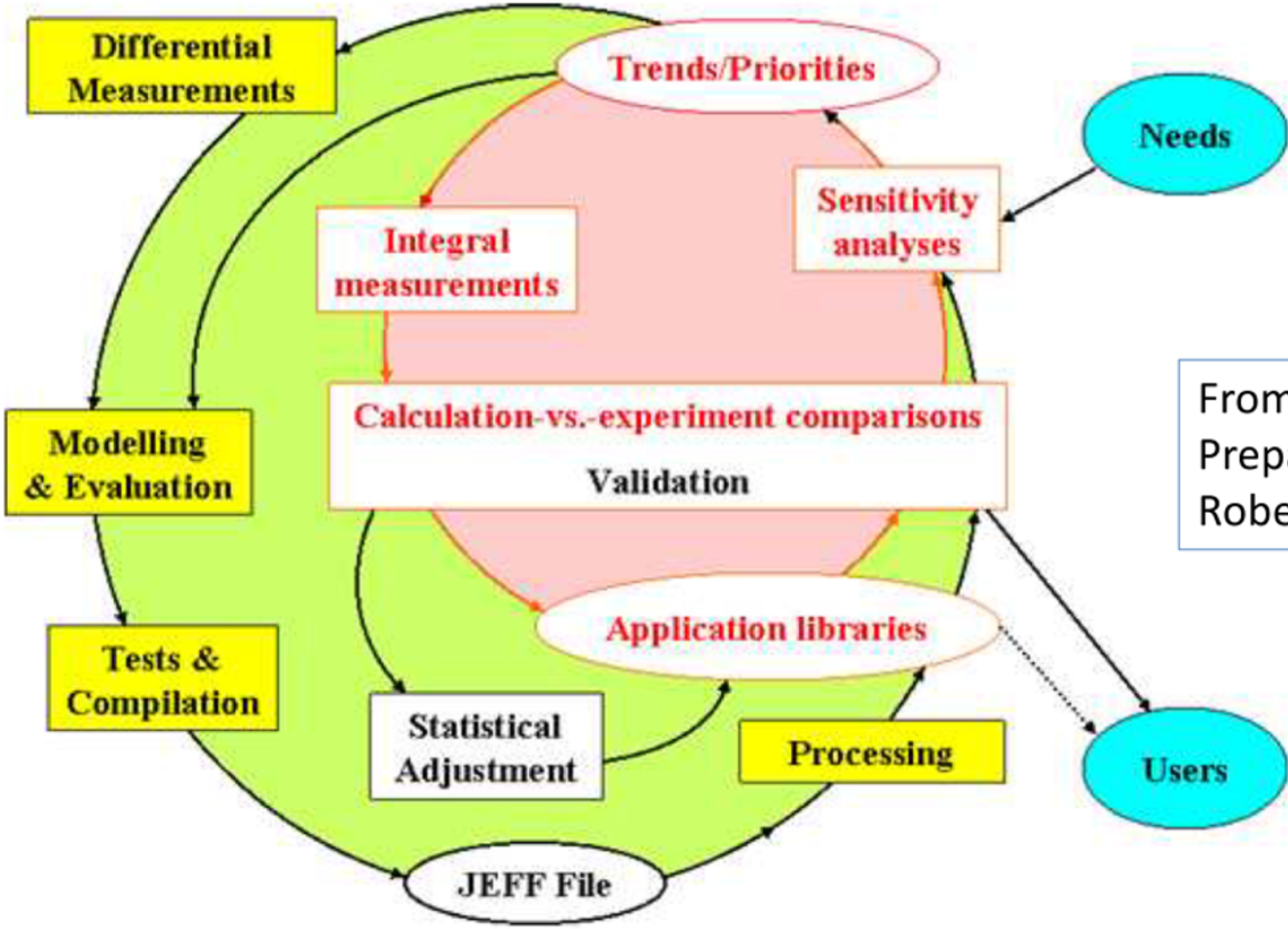


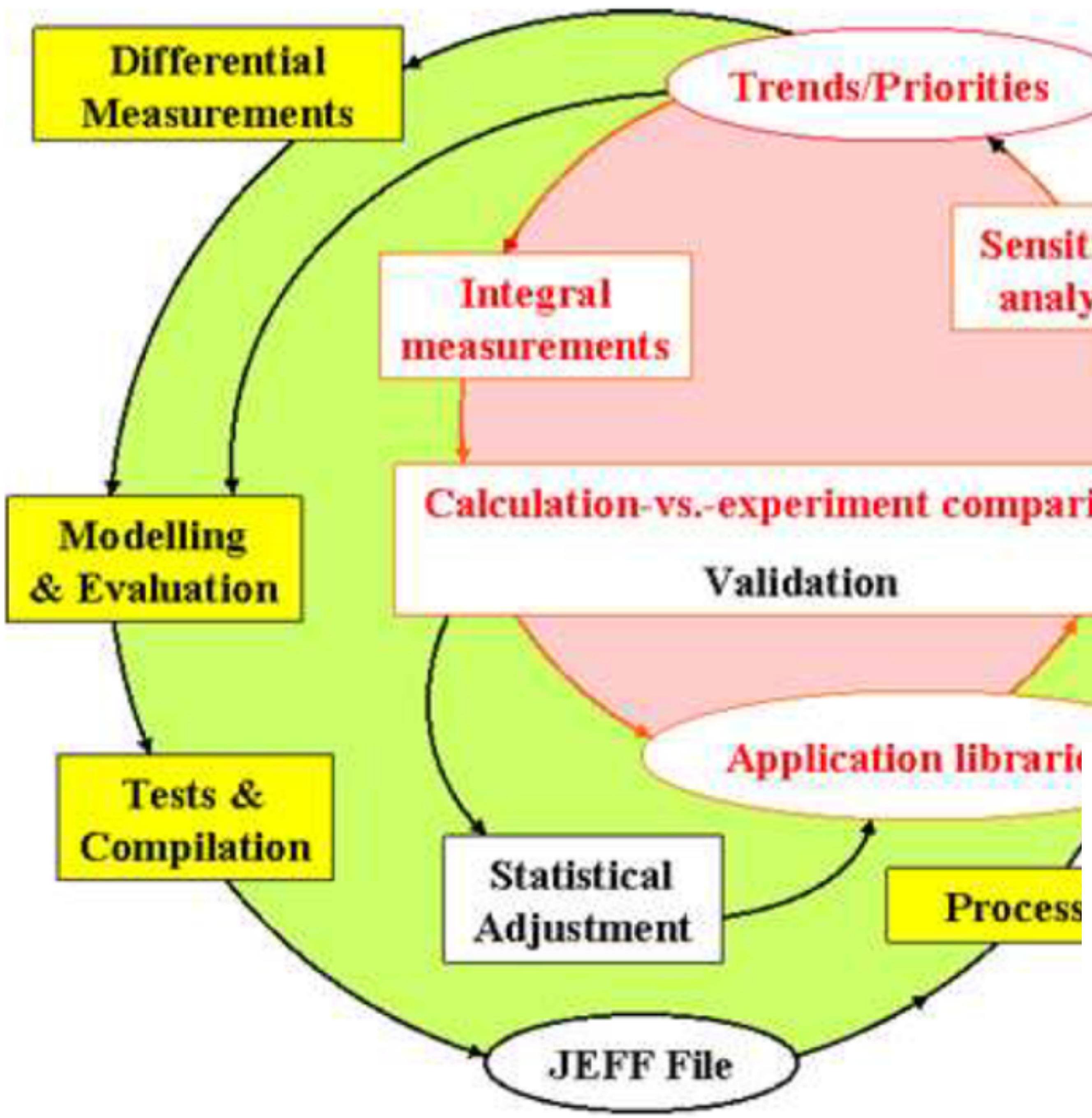
Figure from Luigi Capponi

JEFF - Joint Evaluated Fission and Fusion File



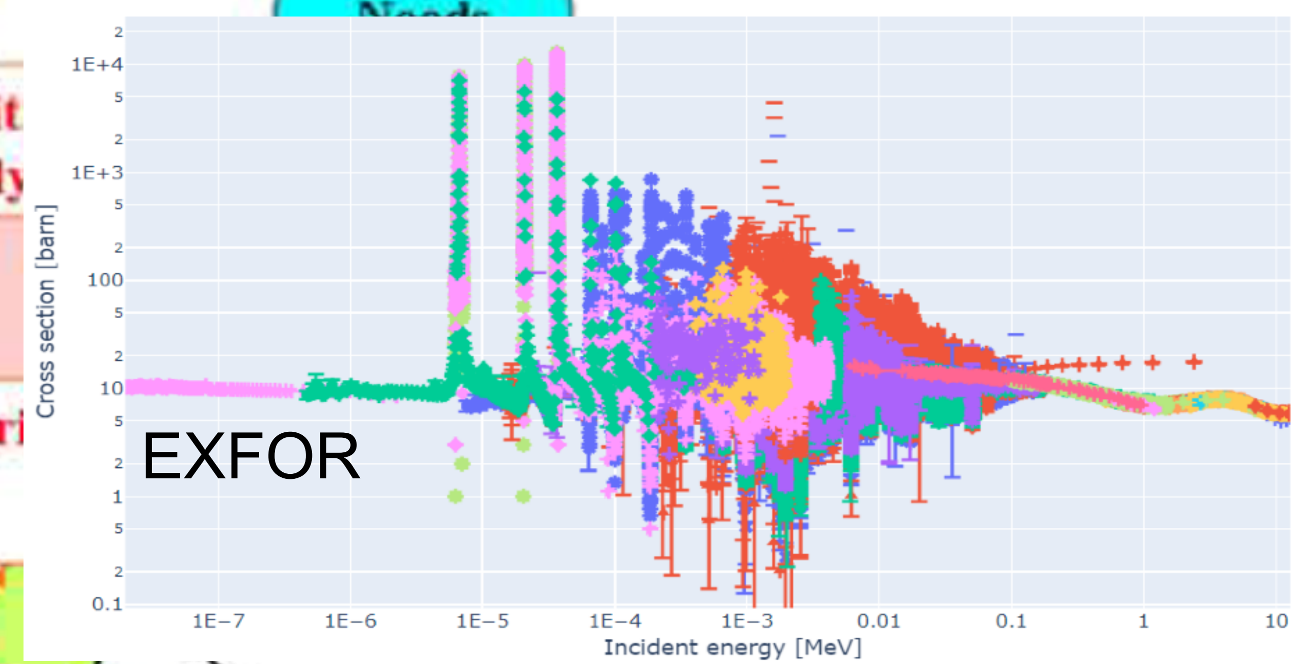
From JEFF
Prepared by
Robert Jacqmin

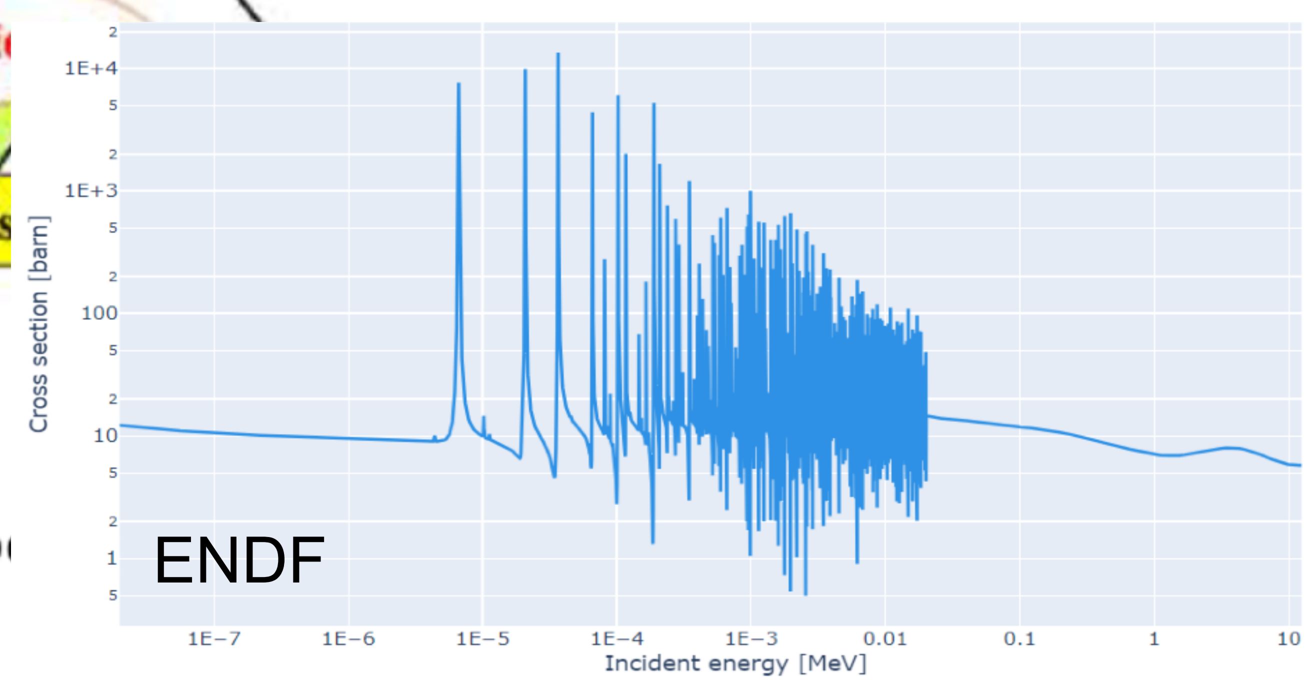
JEFF - Joint Evaluated Fission and Fusion File



Dr Robert Mills, National Nuclear Lab

U-238 (n, total)



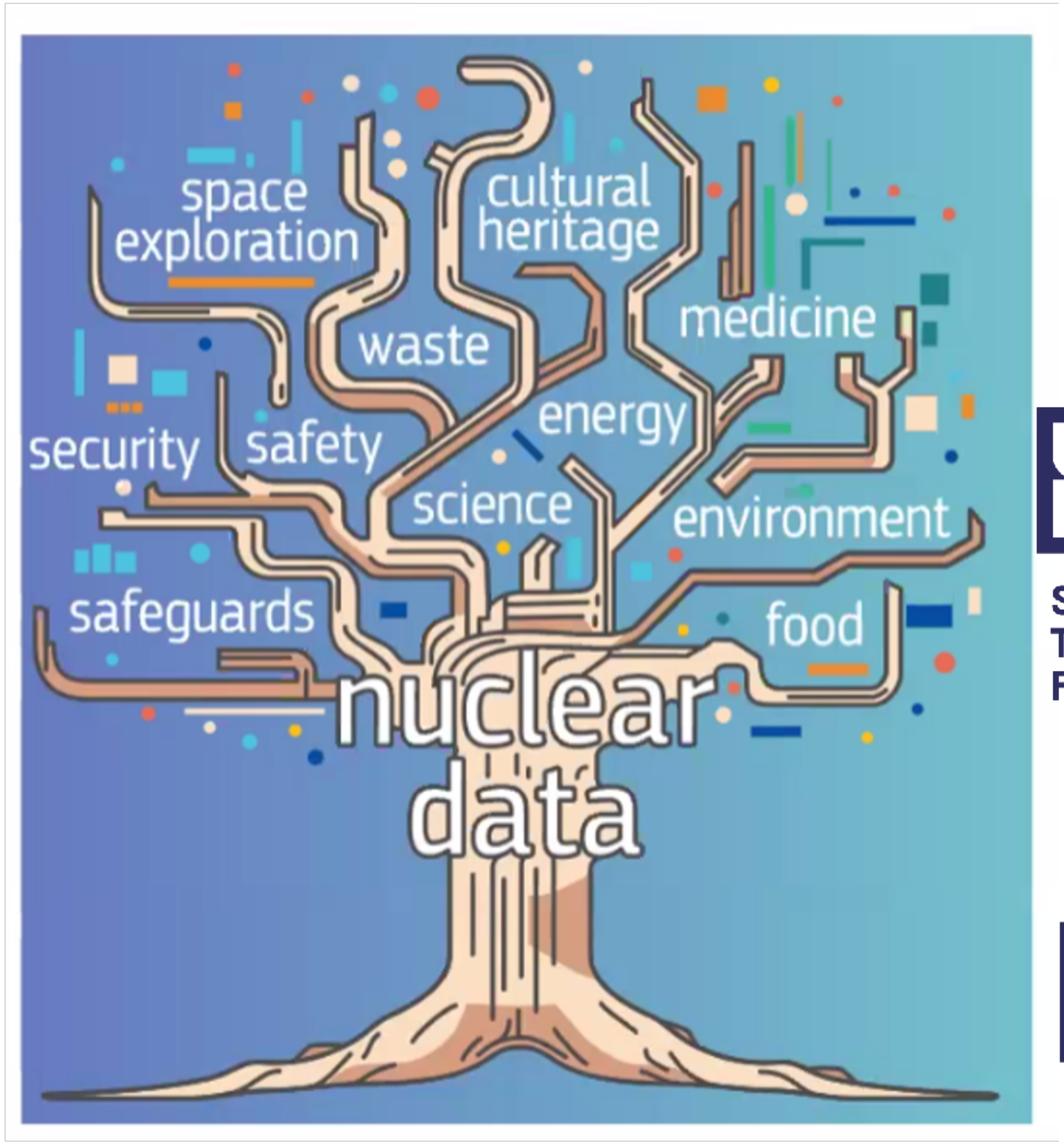


Nuclear stakeholders

UK Atomic Energy Authority

United Kingdom National Nuclear Laboratory

AWE NUCLEAR SECURITY TECHNOLOGIES



NPL National Physical Laboratory

NHS

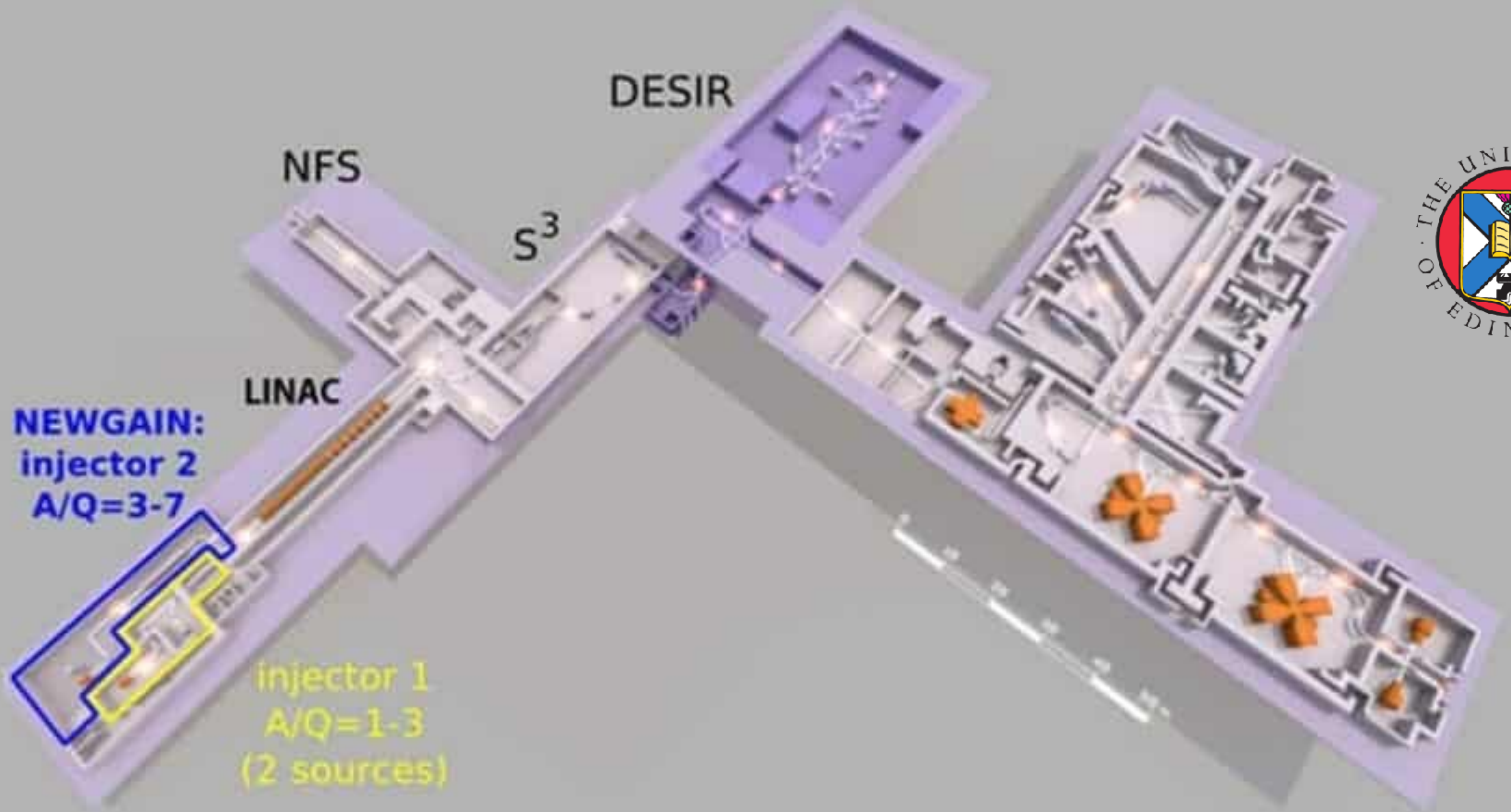
UKRI Science and Technology Facilities Council

UKRI Natural Environment Research Council

UKRI Engineering and Physical Sciences Research Council

Figure from Luigi Capponi

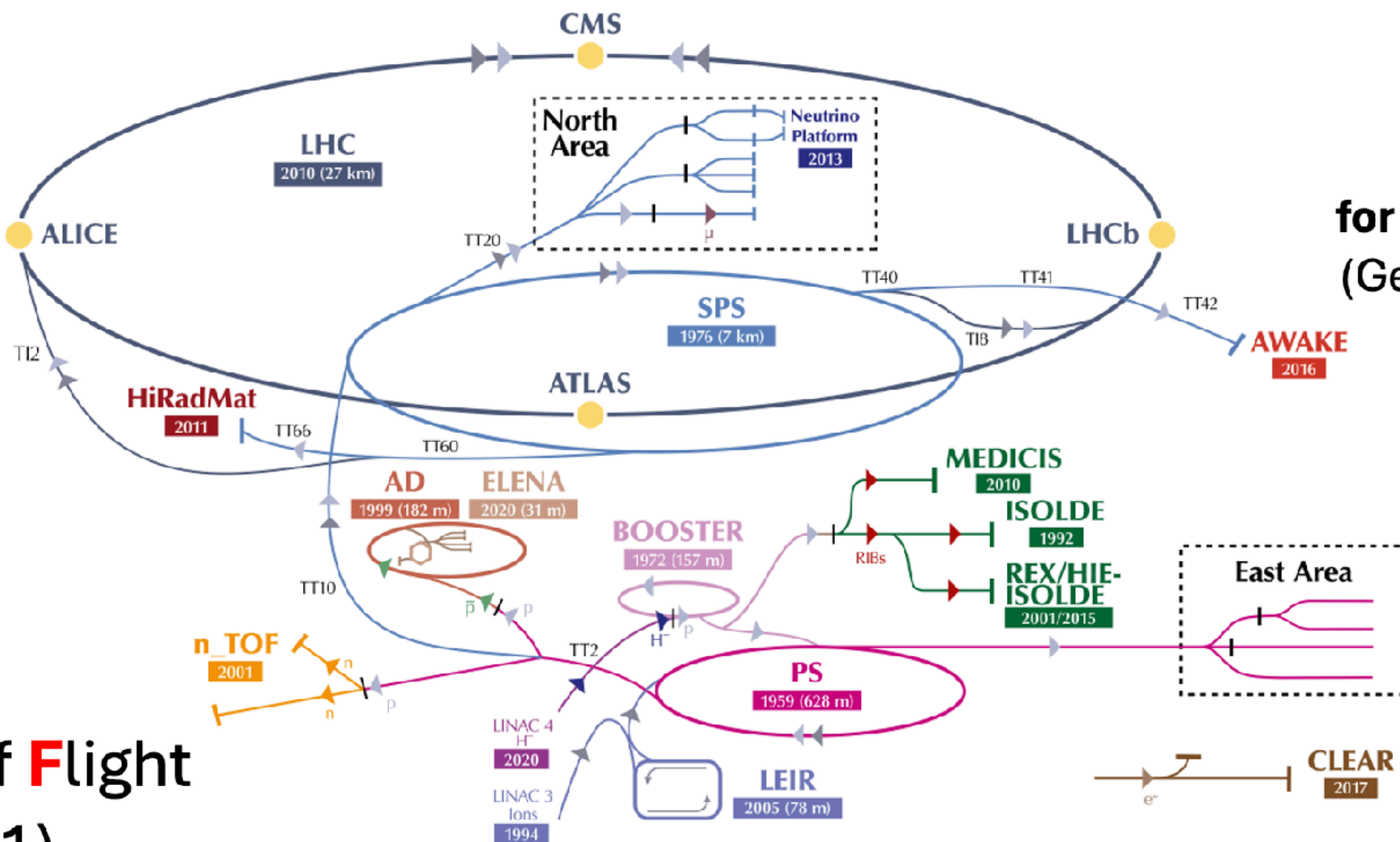
Fundamental Science AND applications



Fundamental Science AND applications

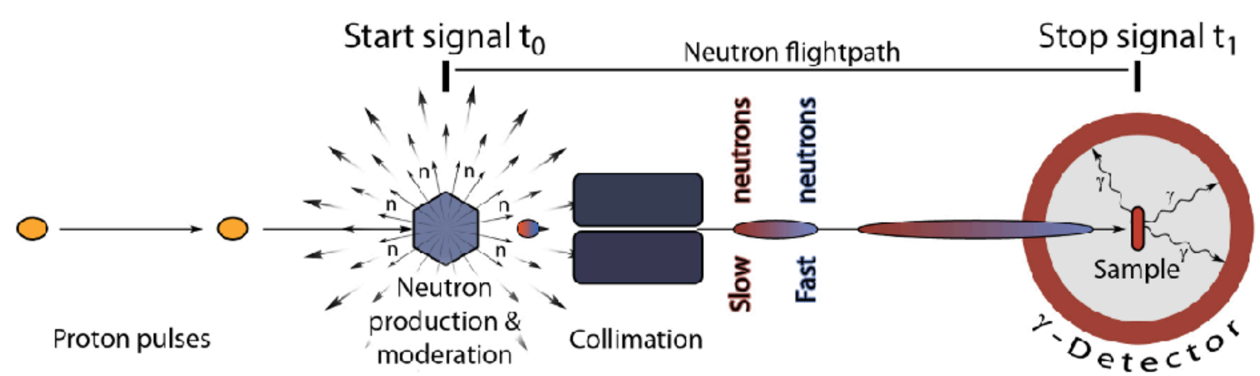
n_TOF @ CERN

CERN: European Organization for Nuclear Research
(Geneva, Switzerland)



Neutron Time Of Flight facility (2001)

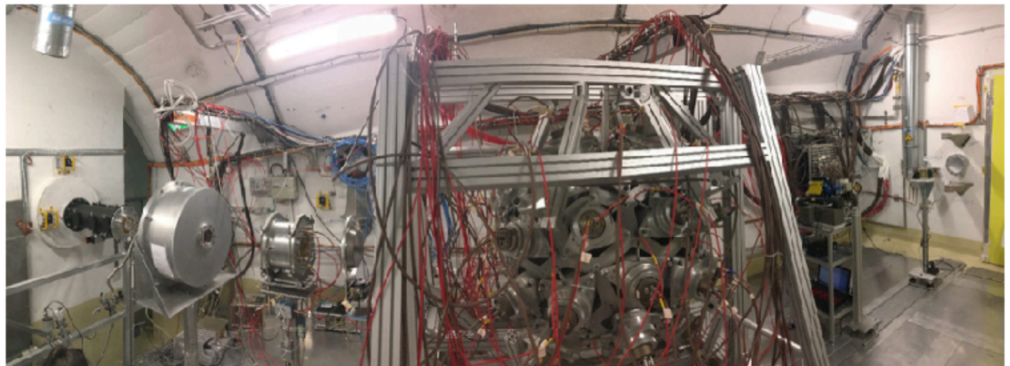
150 researchers
40 research institutions/teams
20 PhD students/year



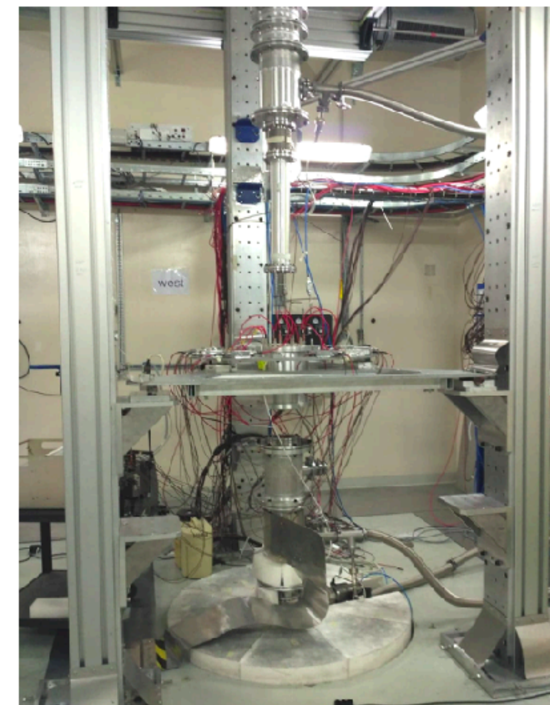
Nuclear Data Workshop, University of Glasgow, 15/7/2025

Slides from Toby Wright

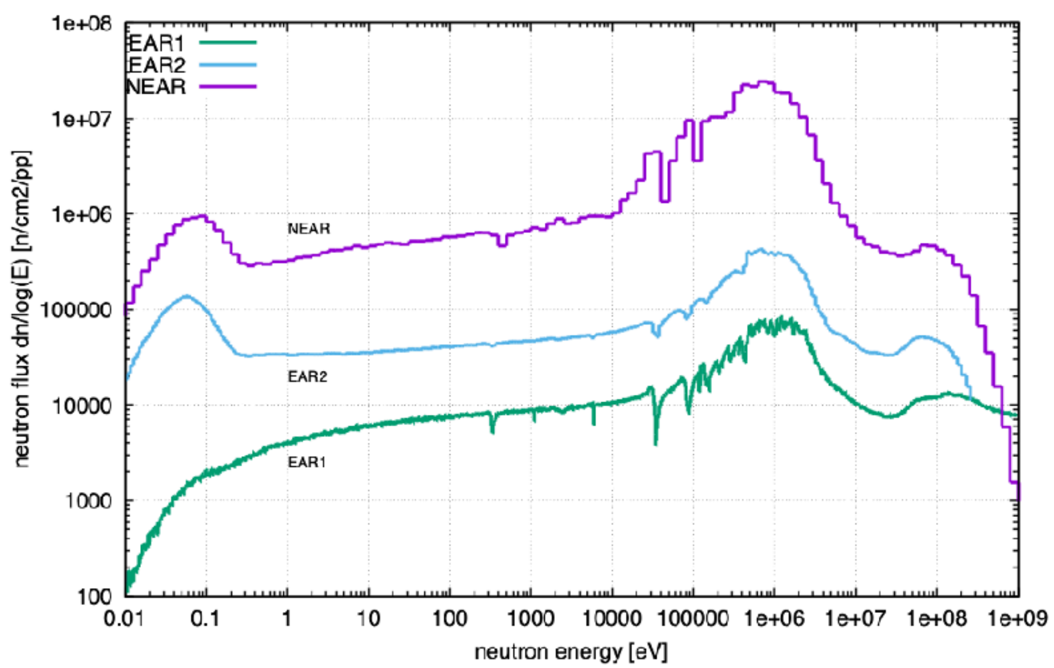
n_TOF facility



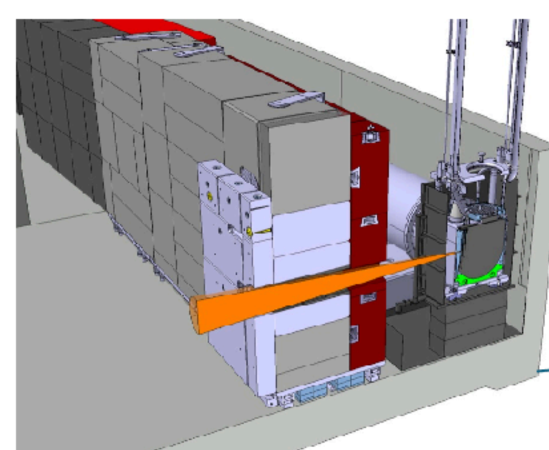
EAR1 (2001)
185 m
10^5 n/cm^2/pulse
$\Delta E/E \sim 10^{-4}$



EAR2 (2014)
19 m
10^7 n/cm^2/pulse
$\Delta E/E \sim 10^{-3}$



NEAR (2021)
2.4 m, 10^9 n/cm^2/pulse

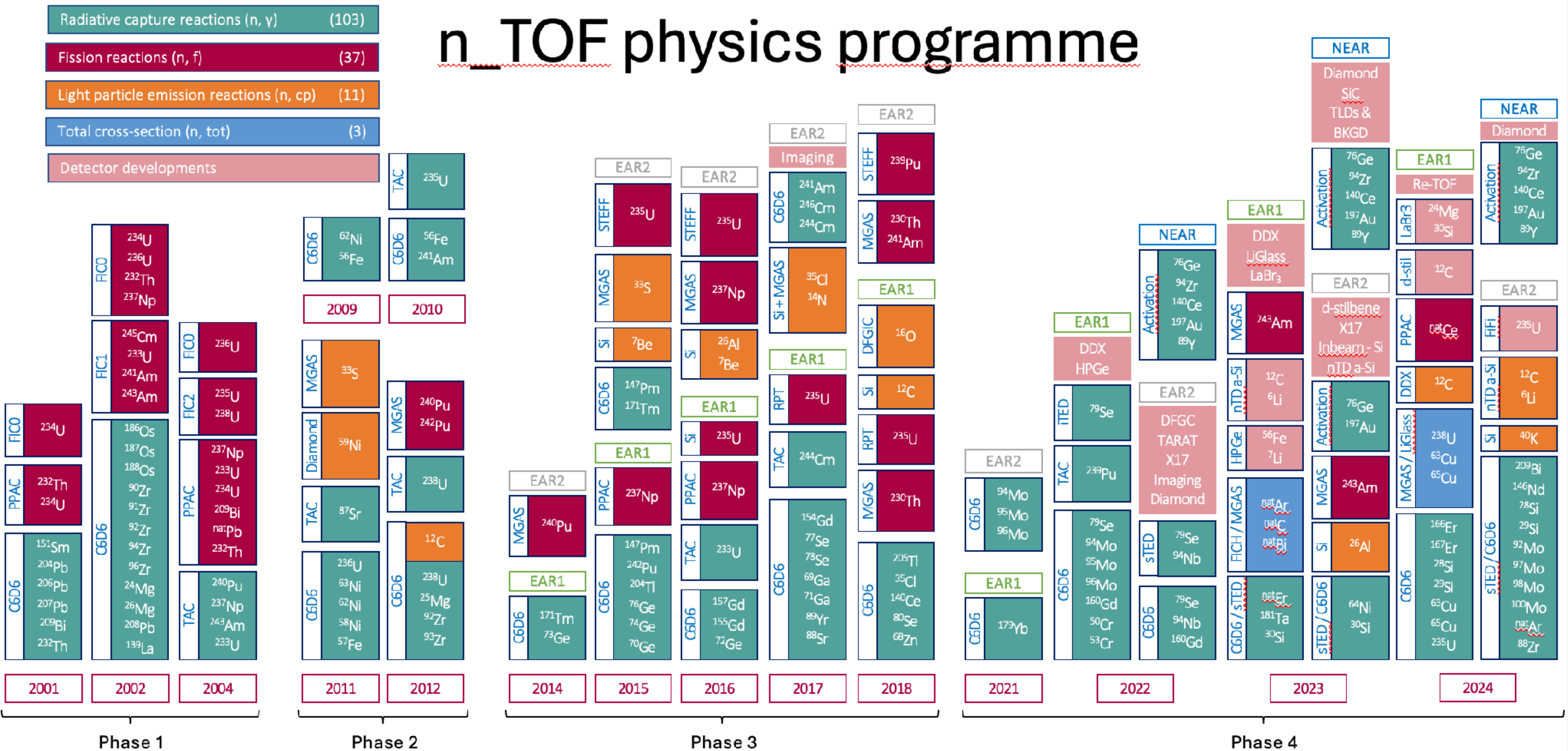


N_2 gas cooled Pb spallation target

p^+ @ 20 GeV/c
Avg. 0.2 Hz

Slides from Toby Wright

You name it, they measure it...



Nuclear Data Workshop, University of Glasgow, 15/7/2025

Slides from Toby Wright

You name it, they measure it...

NEA Nuclear Data High Priority Request List

HPRL Main	High Priority Requests (HPR)	General Requests (GR)	Special Purpose Quantities (SPQ)		New Request	EG-HPRL (SG-C)
			Standard	Dosimetry		

Results of your search in the request list

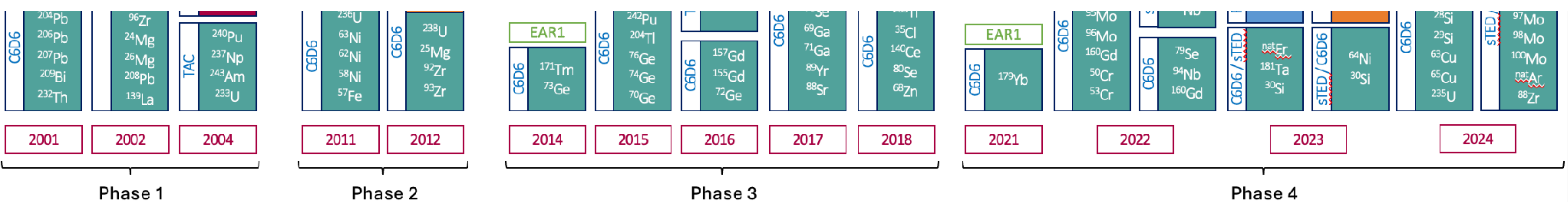
Requests are shown from the following list(s):

Special Purpose Quantities (SPQ)
Standard (Special Purpose Quantities)

Explanations of each column can be found in the table heads. To view the details of a request, please click on the **link symbol** after the request ID.
To send a comment on a particular entry, please view the request, and click on the '**letter**' symbol there.

ID	View	Target	Reaction	Quantity	Energy range	Sec.E/Angle	Accuracy	Cov	Field	Date
43S	STD	1-H-1	(n,el)	SIG,DA	10 MeV-20 MeV	4 pi	1-2	Y	Standard	13-MAY-11
100S	STD	92-U-235	(n,f),(p,f)	SIG	100 MeV-500 MeV		5	Y	Standard	11-APR-18
101S	STD	92-U-238	(n,f),(p,f)	SIG	100 MeV-500 MeV		5	Y	Standard	11-APR-18

Number of requests found: 3 (out of a total of 112 requests).
Download consolidated output report



MANCHESTER 1824
The University of Manchester

nTOF

Slides from Toby Wright

Neutrons are needed (and provided)

UK neutron sources – accelerator based

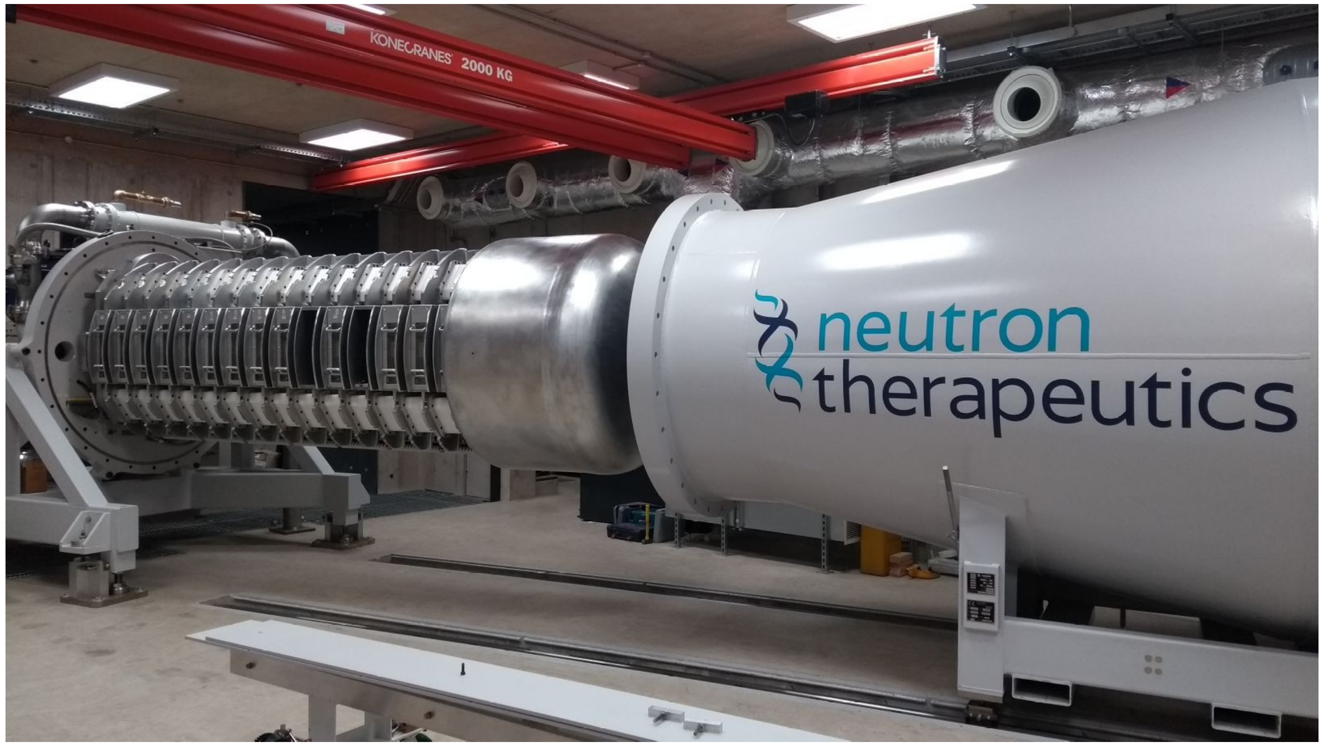
Source	Production method	Details	Intensity
National Physical Laboratory (NPL)	3.5 MV Van de Graaff	p, d, <80 µA. Targets Sc, LiF, D, T… (air cooled)	E.g. 13-19 MeV (T) 0.05-0.63 MeV (Li) $2x10^7$ /s/cm^2 Mono energetic
AWE, Aldermaston	Electrostatic 350 kV	d ions, <15 mA. Target tritium (TBq) (water cooled)	14 MeV <$2.5x10^{11}$ /s
Rutherford Appleton Laboratory	ISIS – Spallation (RFQ+Linac+Synchrotron) 800 MeV protons at <200 µA 50 Hz. 160 kW, W target+Ta clad 30 beam lines. Two examples given used for irradiation.	E.g. ChipIR: White neutron source with neutron energies up to 800 MeV	$1x10^7$ /s/cm^2 [10-800 MeV, $5.8x10^6$ /s/cm^2]
		E.g. EMMA: Thermal neutrons – water moderated. 25 meV Maxwell-Boltzmann + epithermal tail	<$2x10^6$ /s/cm^2 pulsed at 40 Hz
	NILE (DC beams but pulsing available)	DT source	14 MeV <$1x10^8$ /s/cm^2
		DD source	2.5 MeV <$1x10^5$ /s/cm^2
High flux Accelerator-Driven Neutron Facility, Birmingham	2.6 MV electrostatic	p, d, 50 mA. Target Li (water cooled)	0.1-1 MeV <$1x10^{12}$ /s/cm^2 (p)

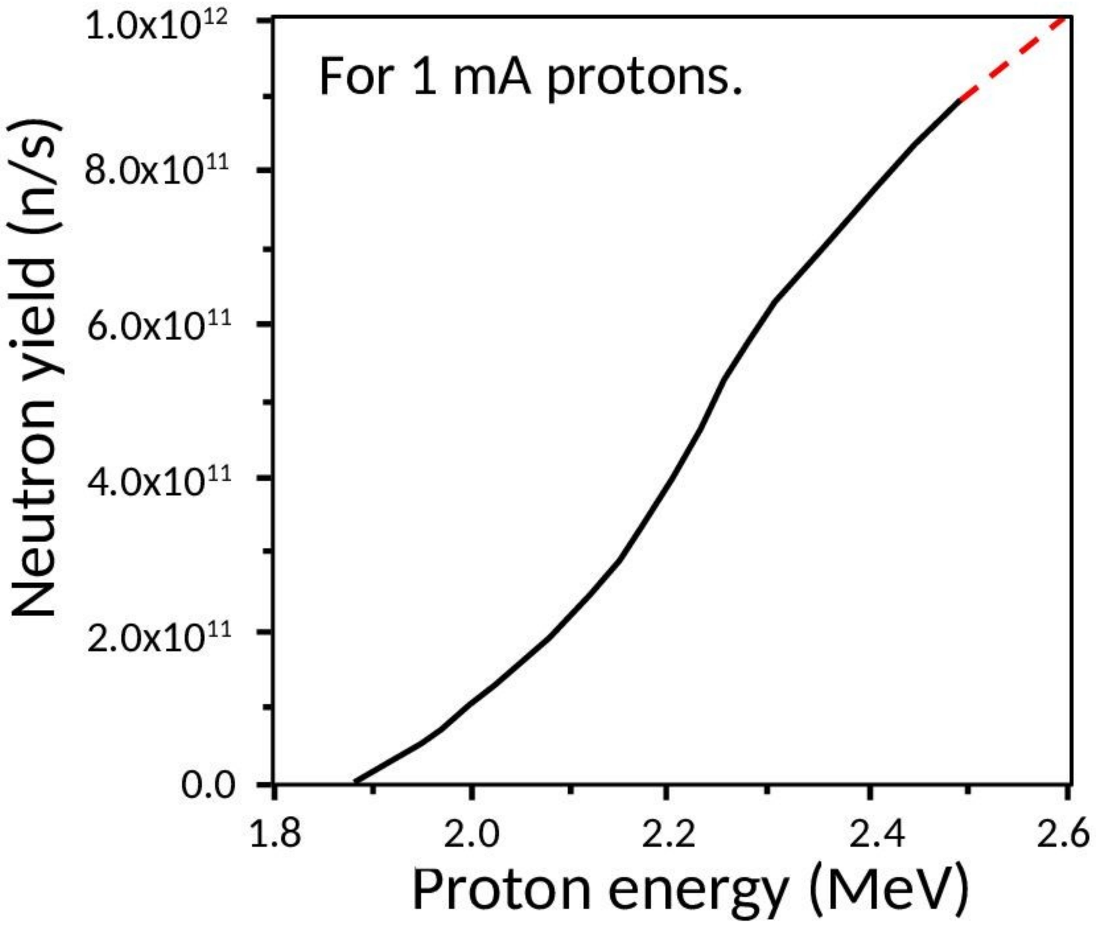
Slides from Carl Wheldon and Dawid Hampel

Neutrons are needed (and provided)

High Flux Accelerator-Driven Neutron Facility

The electrostatic accelerator is designed for beams of protons and deuterons and currents of <50 mA, nominally at up to 2.6 MeV, but 2.8 MeV is the maximum.





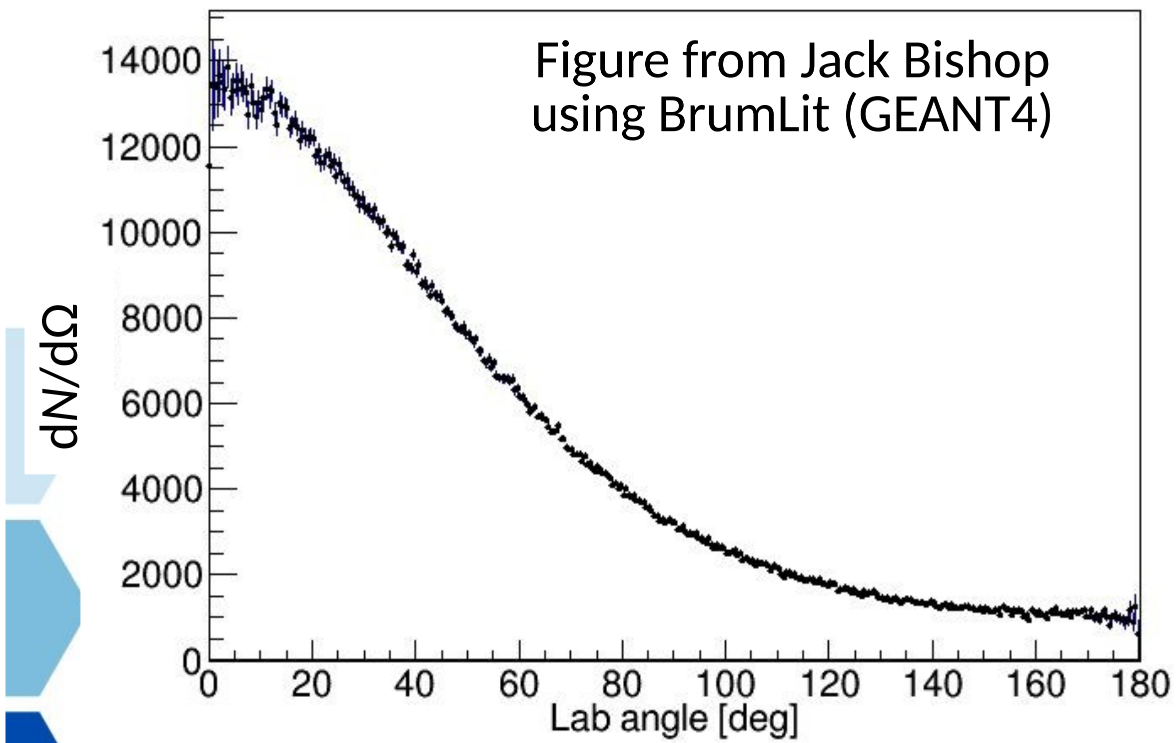
Neutron yield figure adapted from figure 2 of J.C. Yanch *et al.*, Medical Physics **19** 709 (1992).

Slides from Carl Wheldon and Dawid Hampel

Neutrons are needed (and provided)

Neutron production

Proton & deuteron beams accelerated to 2.6 MeV		
	protons (*p*)	deuterons (*d*)
Reaction	^{7}Li(*p*,*n*)^{7}Be	^{7}Li(*d*,*n*)^{8}Be
Q-value	−1.64 MeV	**+15.03 MeV**
Max. *n* energy	0.9 MeV	17.2 MeV



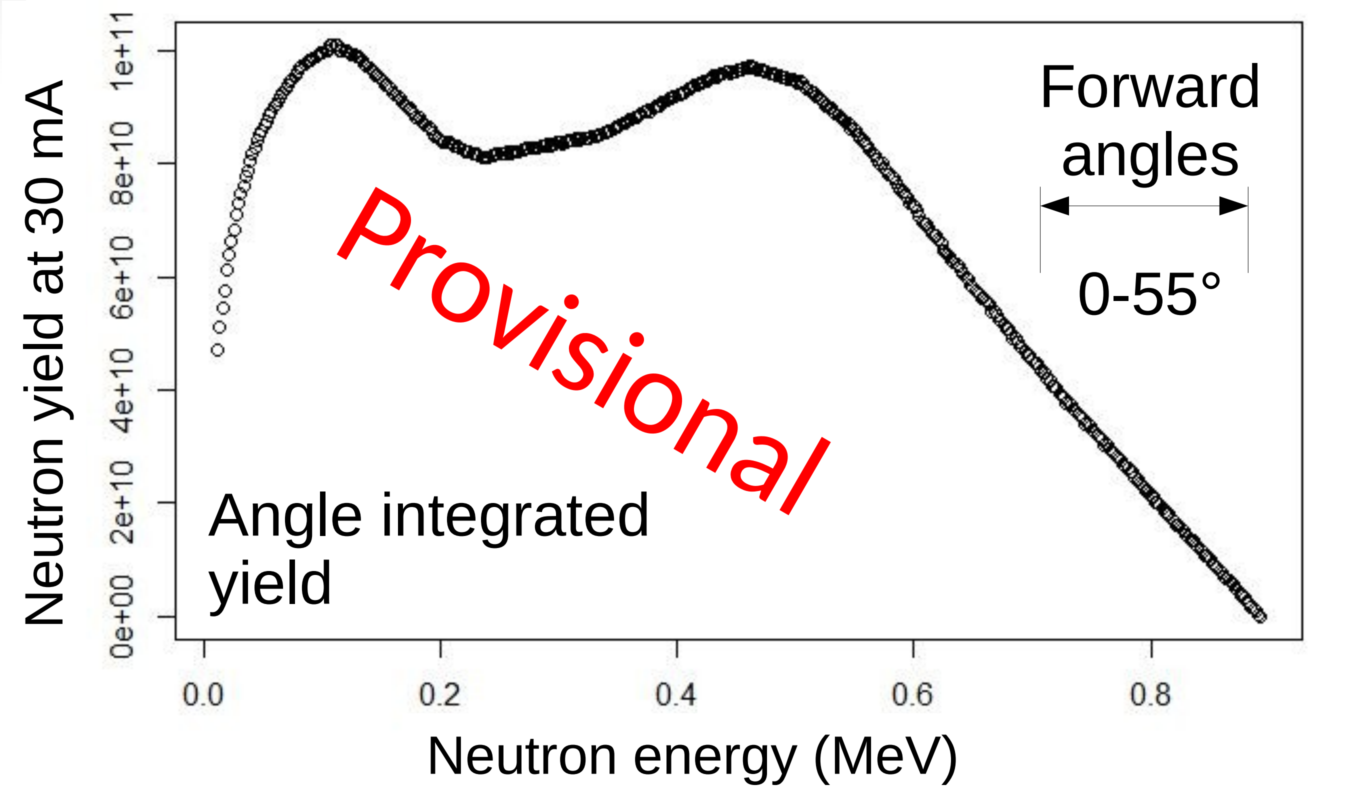


Figure by Ben Phoenix with input from Daniel Minsky (CNEA, Argentina), MCNP.

Beam energy is below threshold for reactions on most materials other than lithium.

Slides from Carl Wheldon and Dawid Hampel

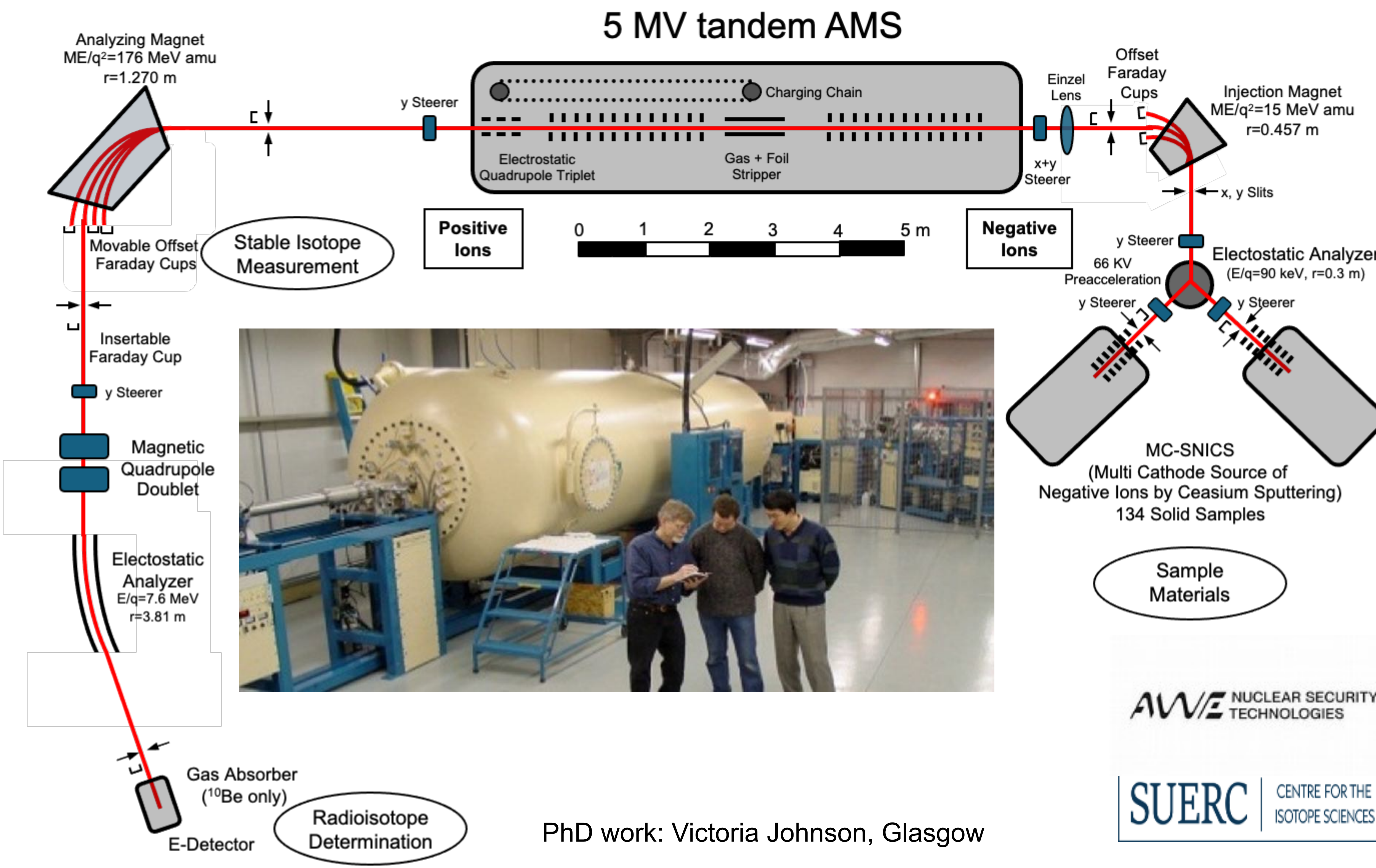
Neutrons are needed (and provided)

HF-ADNeF — research/impact opportunities

- **Nuclear materials research** under neutron irradiation [fission/fusion communities including associated industries, e.g. CCFE, First-light fusion, NNL etc.].
- **Nuclear fission and fusion data**, e.g. neutron capture cross section data [fission/fusion and nuclear physics communities].
- **Nuclear waste management** — understanding the long term effects of radiation on material characteristics [nuclear industry/NDA/NNL, nucl. eng. academics].
- **High power target development** [other facilities inc. medical and fusion devices, ourselves (future liquid lithium target) and the fusion community (fuel breeding)].
- **Medical physics** — from radiobiology to boron neutron capture therapy developments, e.g. for BNCT. Medical isotope cross sections measurements and production.
- **Industrial and space research** on the effect of radiation [detectors and space research communities — extension of cyclotron work in these areas].
- **Nuclear Metrology** — calibrated and controllable neutron source availability and testing new radiation monitoring systems [neutron source standards and characterisation, e.g. the National Physical Laboratory].
- **Nuclear (astro)physics** — the neutron spectrum is close to that in stellar environments [nuclear physics/nuclear astrophysics communities — feasibility grant (STFC)].

Slides from Carl Wheldon and Dawid Hampel

AMS laboratory (current)

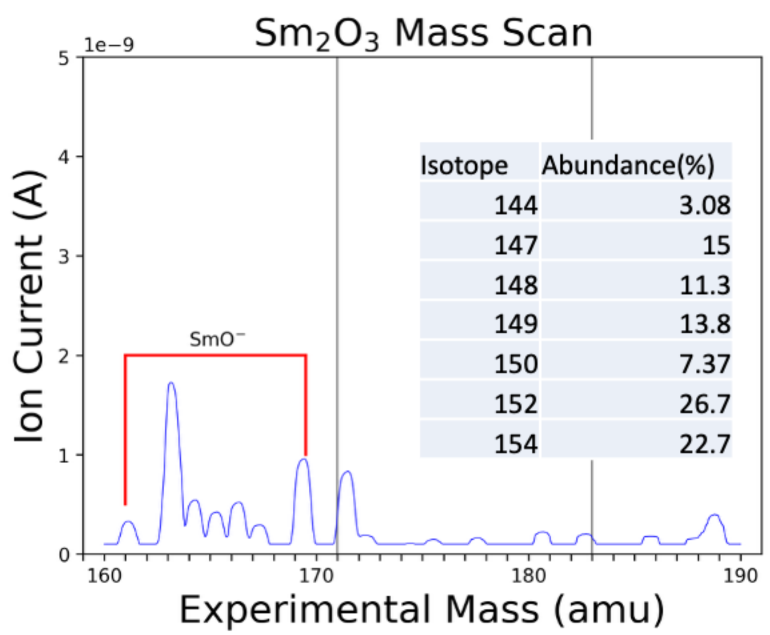


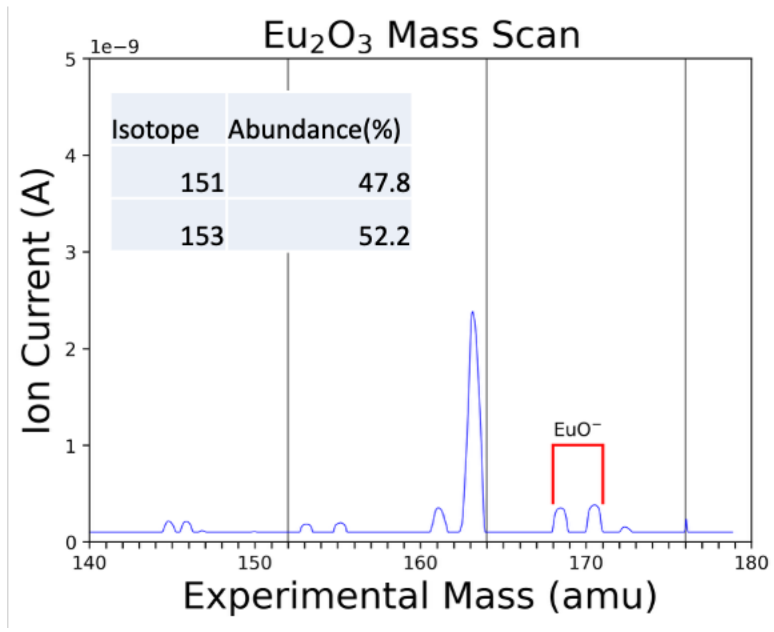
PhD work: Victoria Johnson, Glasgow

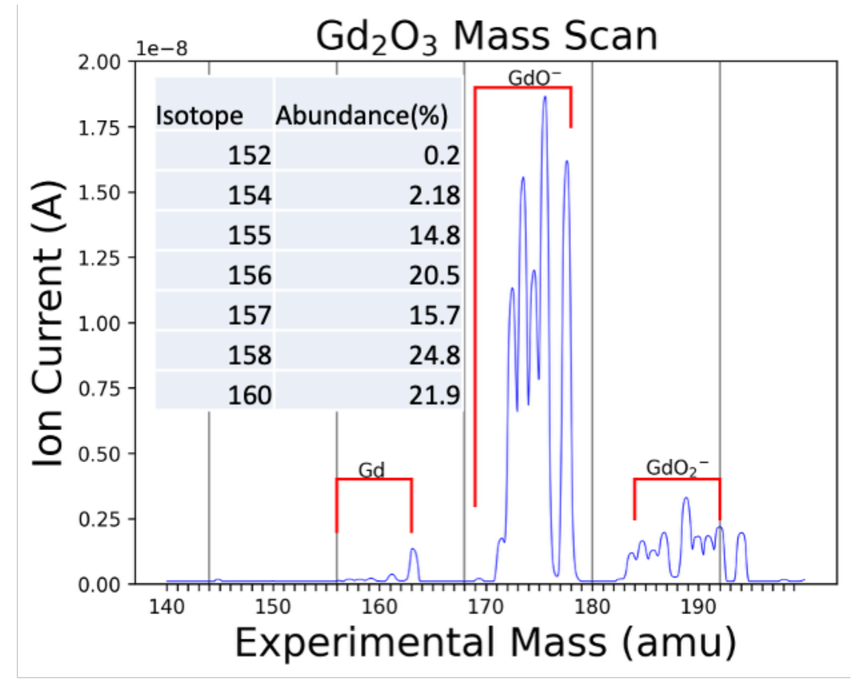
AWE NUCLEAR SECURITY TECHNOLOGIES

SUERC CENTRE FOR THE ISOTOPE SCIENCES

Initial Lanthanide Oxide Scans







- Minimal amounts of pure lanthanides
- All stable isotopes are visible
- Peaks match relative abundance

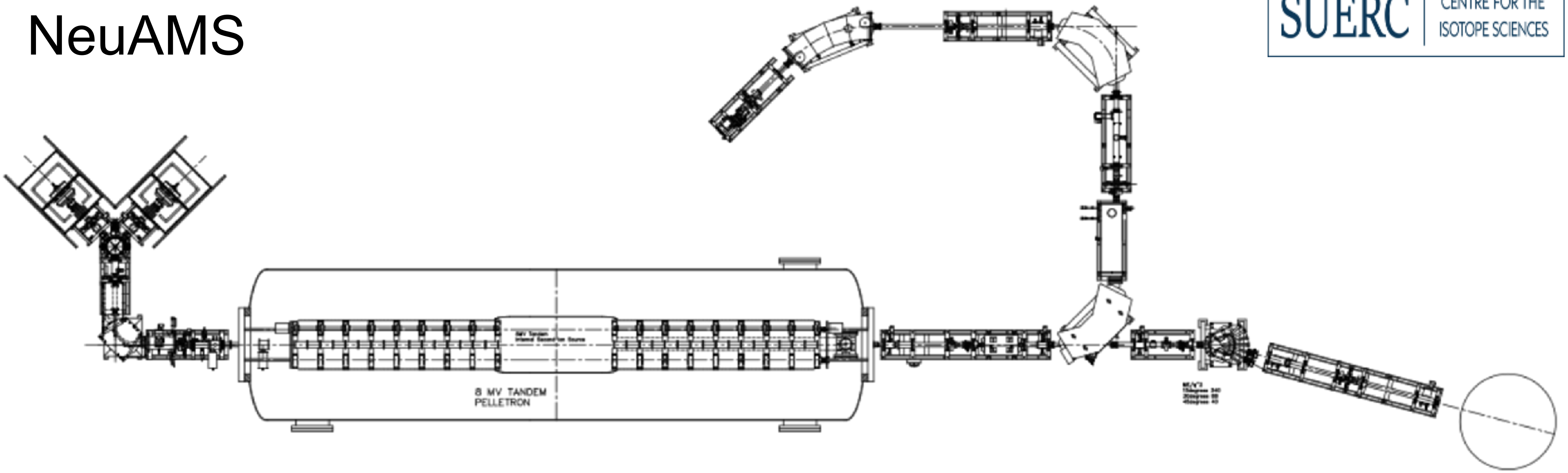
PhD work: Victoria Johnson, Glasgow

AWE NUCLEAR SECURITY TECHNOLOGIES

SUERC CENTRE FOR THE ISOTOPE SCIENCES

AMS laboratory (future)

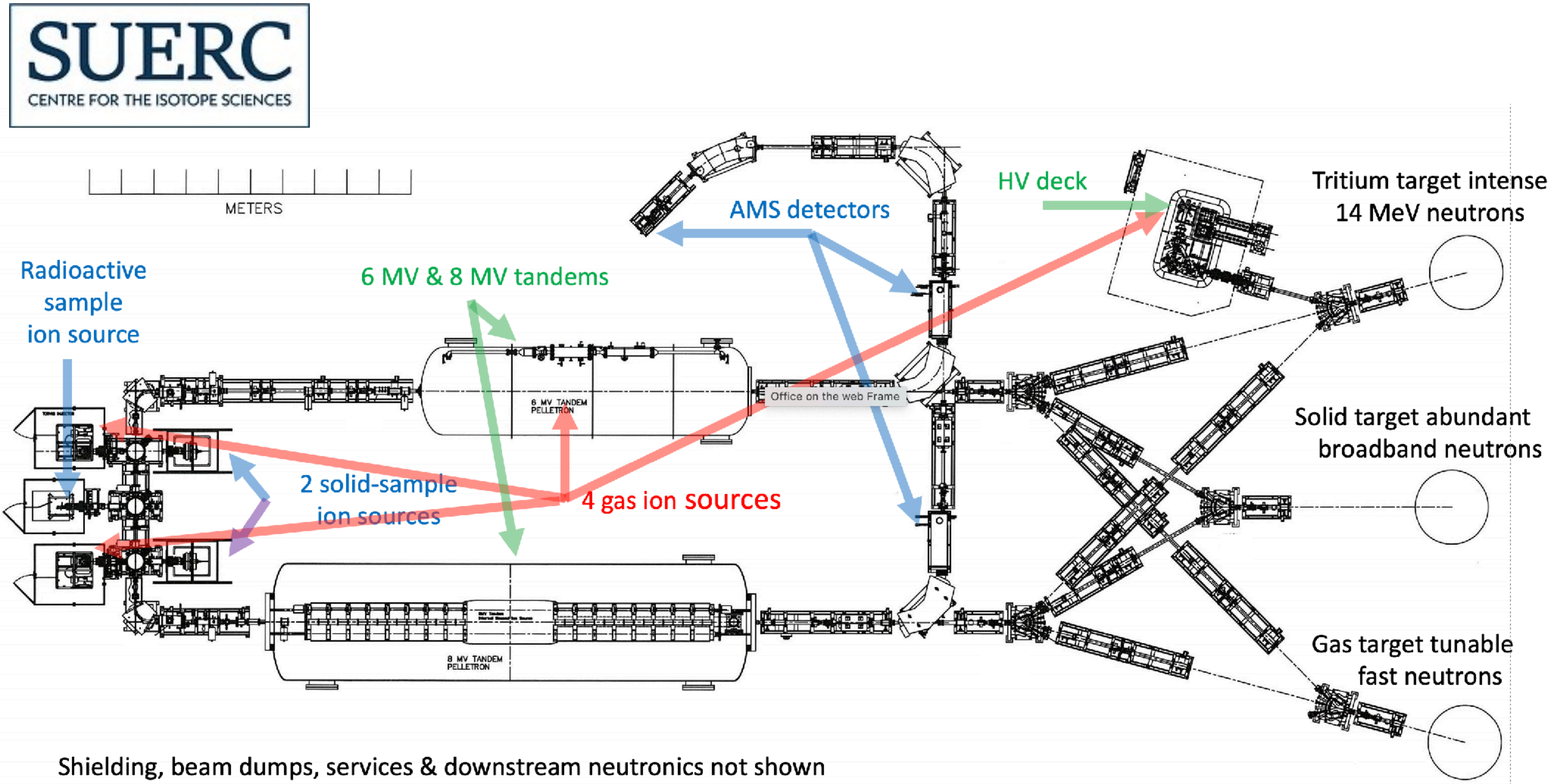
NeuAMS



- Next-gen fusion neutronics & full range AMS
- p-Pu ultrasensitive AMS over full mass range
- National security, physical, material & life sciences
- Exceptional 8 MV modern accelerator
- Unique accelerator-driven gas-target neutrons
- ~10^8/sec/sr 0->20 MeV anisotropic fast neutrons via inverse kinematics

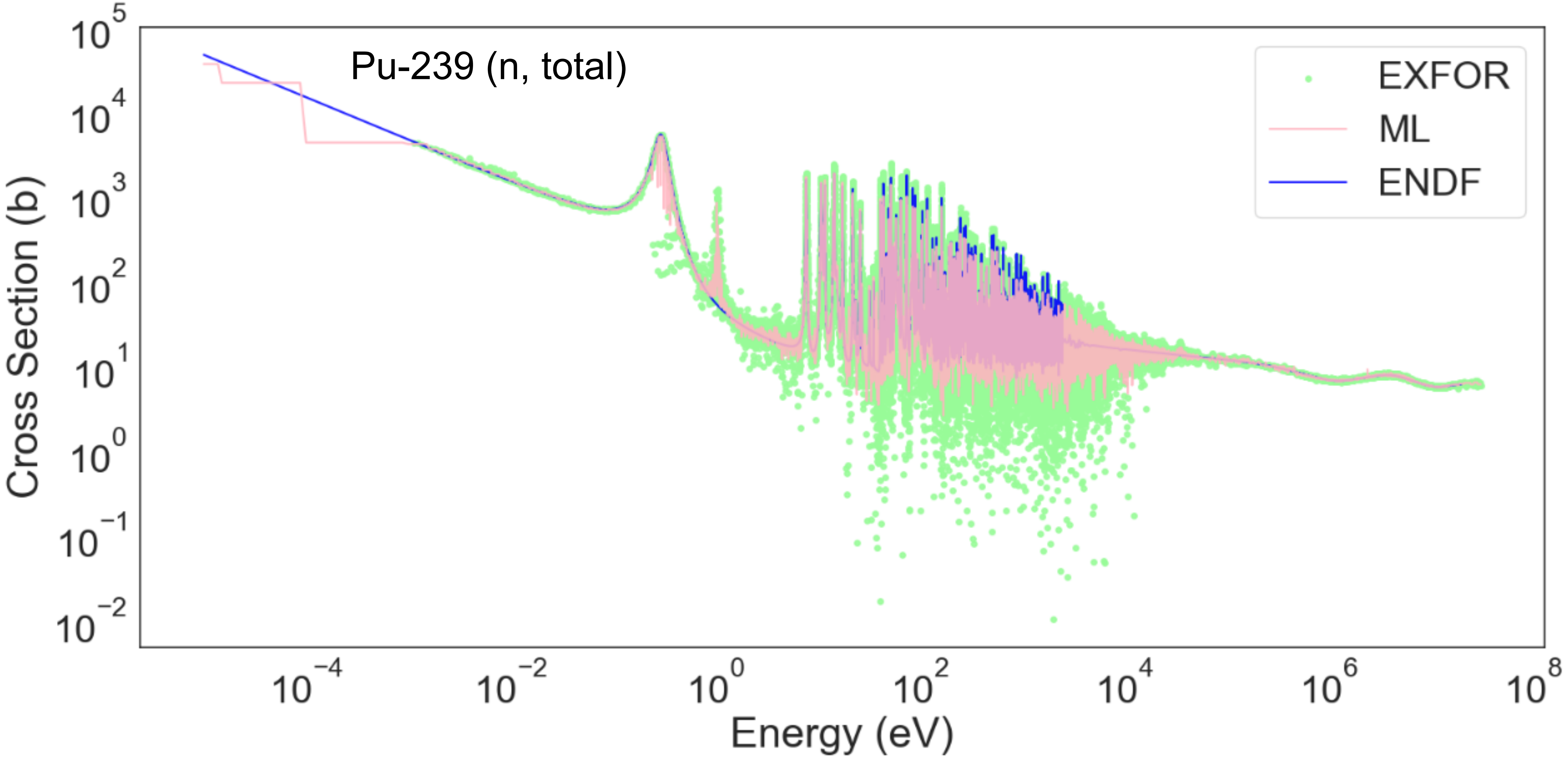
Concept by Stewart Freeman, SUERC and UofG

AMS laboratory (even better future)

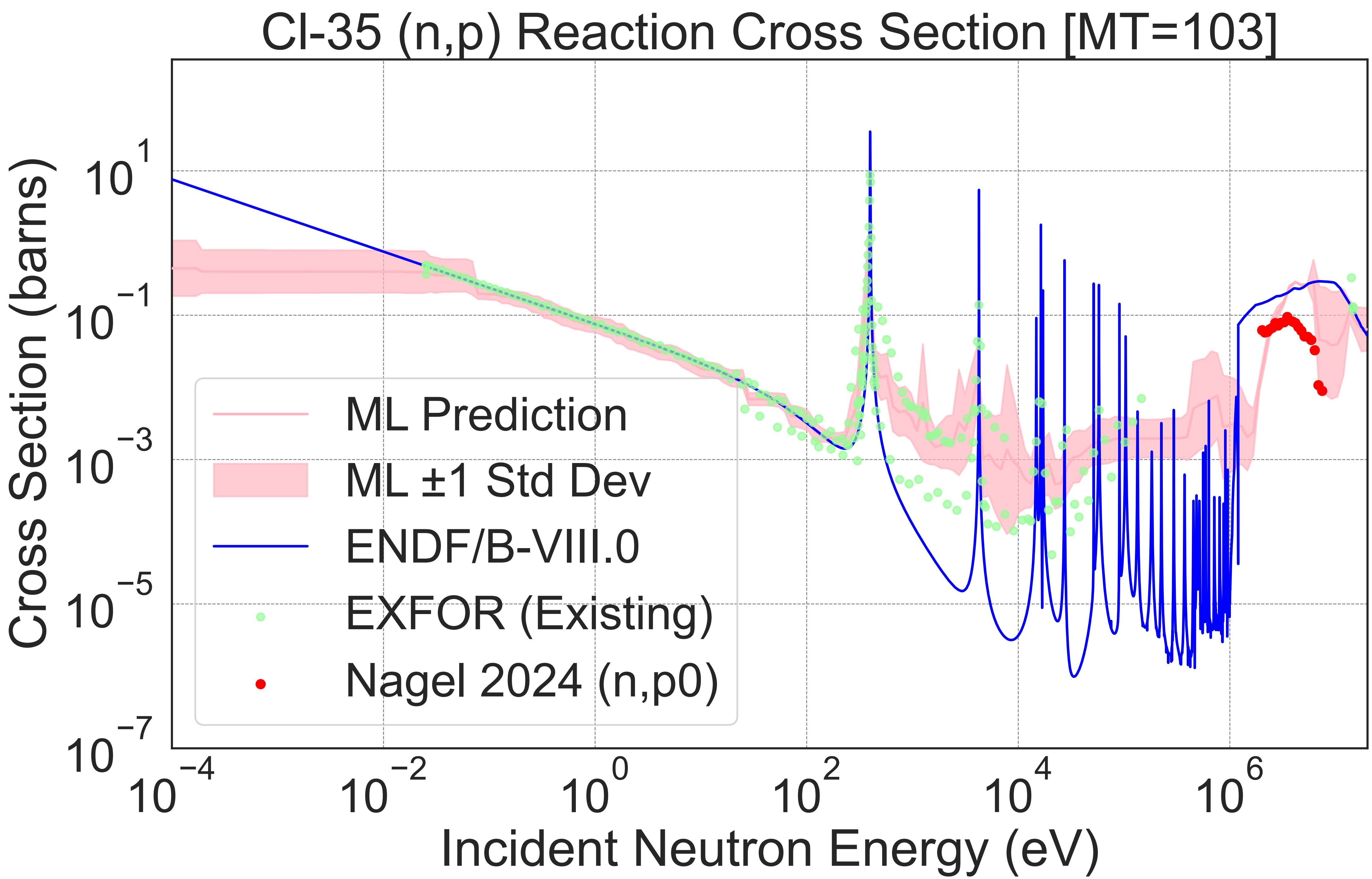


Concept by Stewart Freeman, SUERC and UofG

Computer Marvels - ML and Quantum Computing

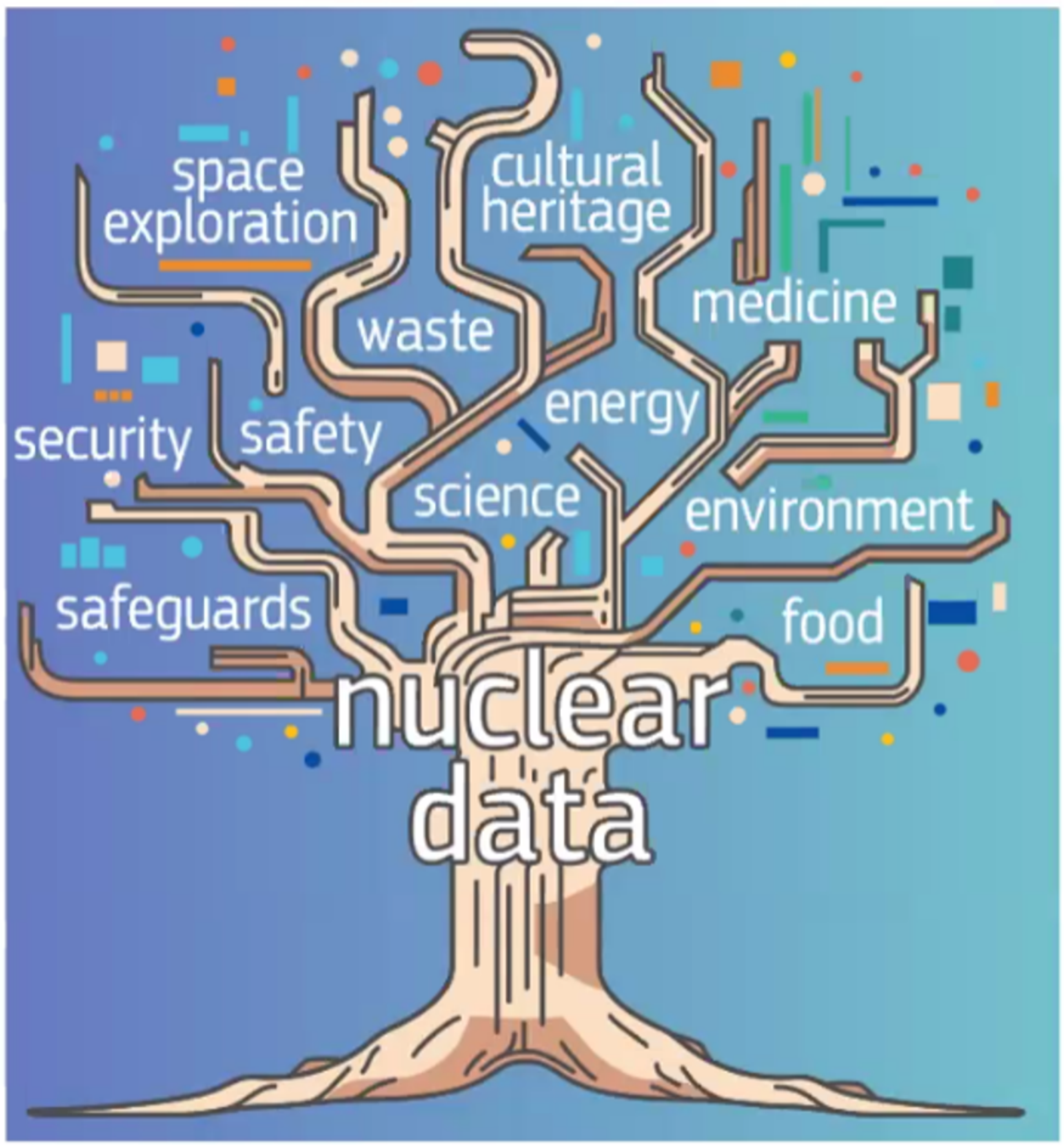


Computer Marvels - ML and Quantum Computing



Plus fantastic work at Surrey using Quantum Computing

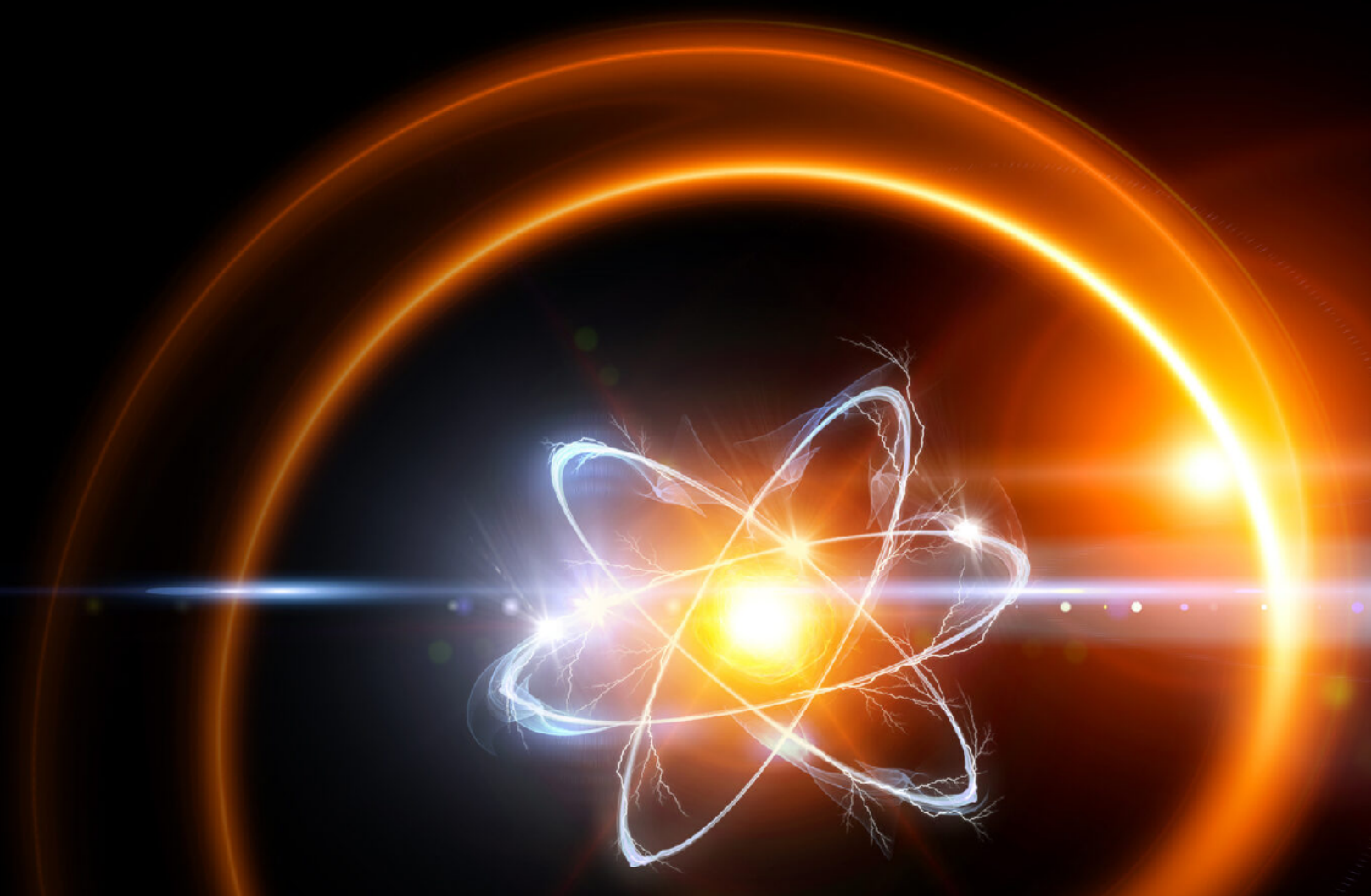
Summary



- Nuclear Data are vital for fission, fusion, fundamental research, decommissioning, healthcare…
- Cross council research area
- Bringing together industry, government agencies, academia
- Fundamental and applied science
- UK has capabilities, expertise and opportunity to make global impact
- Need to bring the communities together
  ➜ planned IOP conference

University of Glasgow

Why did he not talk about …



… Nuclear Theory?

➜ talk by Paul Stevenson

… the needs and plans for AWE?

➜ talk by James Benstead

University of Glasgow

Thank you very much for your attention

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