UK Atomic Energy Authority

Nuclear Data: rewards for the right library choice

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FISPACT-II workshop

25 November 2020, online

CCFE
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Nuclear Data (ND): who always needs its good quality

Fission: NPPs and research reactor facilities, …

Fusion: research tokamaks, ITER, DEMO, …

Medicine: diagnostics, Gamma Knife radiosurgery, brachytherapy, …

Applied physics: accelerators, neutrino labs, …

Aerospace: satellites, rovers, deep space missions, …

Security/Defense: interrogation, radioprotection, non-proliferation

…

ND: what needs to be accurate

Reaction cross-section

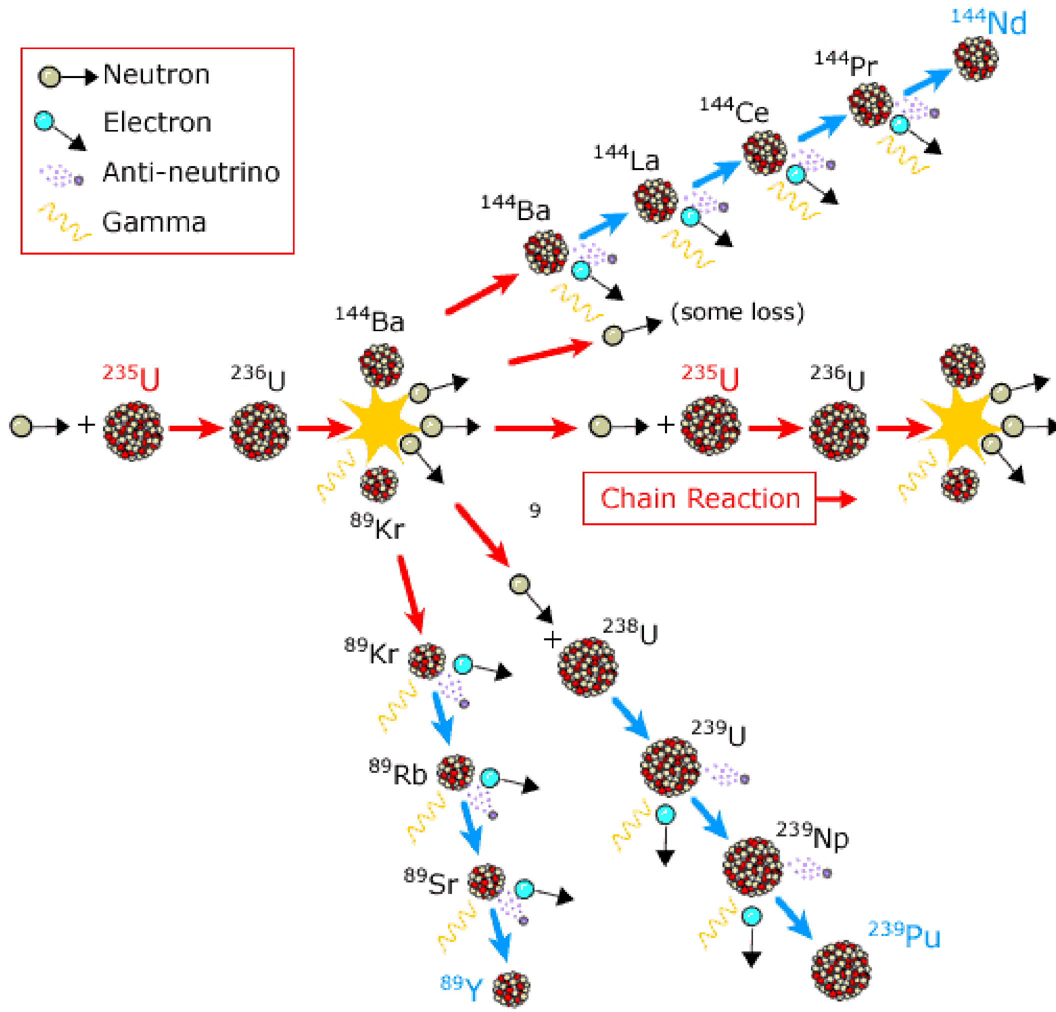
- availability for various reaction channels
- evaluated and experimental data

Fission product yields

- predicted with high accuracy

Decay Data:

- radionuclides inclusion
- half-life
- decay modes, Q-values
- associated α, β, γ – spectra
- (anti)neutrinos



ND: evaluated and experimental

General Purpose Libraries	Special Purpose Libraries	Older Nuclear Data Libraries
• BROND-3.1	• ADL-3	• ACTL-82
• CENDL-3.1	• EADL-92	• BROND-2.2
• ENDF/B-VII.1	• EAF-2010	• CENDL-2.1
• JEFF-3.2	• EEDL-92	• EAF-2007
• JENDL-4.0	• EFF-2.4	• ENDF/B-IV,V,VI,VII.0
• RUSFOND-2010	• EPDL-92	• ENDL-78,86
• Standards 2006	• FENDL-2.1	• FENDL-11,20
• TENDL	• IRDFF-1.0	• INDL/V-85, INDL/A-86
	• JEFF-3.1/A	• IRDF-85,90,2002
	• JEFF-3.1.1/RDD	• JEFF-2.2,3.0,3.1(.n)
	• JEFF-3.1.1/FY	• JENDL-3.3,3.2
	• JENDL/AC-2008	• RNPL/A
	• JENDL/AN-2005	• UKCROUCH-3i
	• JENDL/HE-2007	• UKIFYA-1
	• JENDL/PD-2004	• UKIFYU-1
	• JENDL/FPD-2011	• UKFY-2,3,4
	• JENDL/FPY-2011	• UKFPDD-2
	• MENDL-2	• UKHEDD-1,2,2.x
	• PADF-2007	• UKPADD-1,2,3,6.x
	• RRDF-98	• UKNDL-2
	• UKFY-4.1	
	• UKHEDD-2.6	

EXFOR:

Experimental Nuclear Reaction Data

FISPACT-II can handle all ENDF-6 files including:

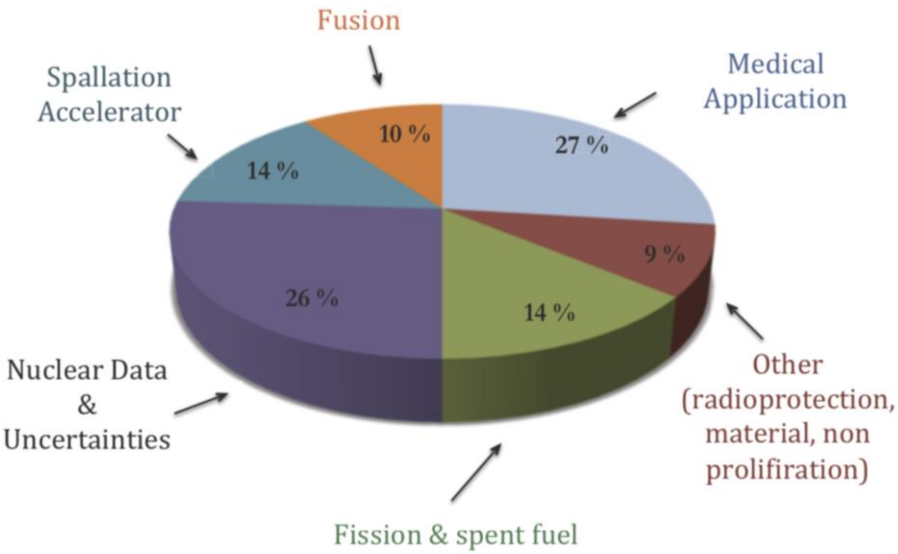
JEFF-3.X
JENDL-4.0u and 2015/16
IRDFF-II (xs - issues noted)
ENDF/B-VIII.0
UKDD-12
as well as legacy EAF
...

Comparisons between libraries can quickly demonstrate unresolved issues in xs/decay/FY data that might affect the simulation results

More details: https://www.oecd-nea.org/dbdata/data/nds_eval_libs.htm
https://fispact.ukaea.uk/nuclear-data/
http://www-nds.ciae.ac.cn/exfor/endf.htm
https://www.nndc.bnl.gov/nudat2/
http://amdc.in2p3.fr/web/nubase_en.html

TENDL-2019 cross-section library release

https://tendl.web.psi.ch/tendl_2019/tendl2019.html



Segmentation of TENDL publications by application area, over the years 2008-2017

Presentation by D. Rochman.
The new TENDL-2019 nuclear data library.
JEFF meeting, 25 April, 2019, OECD NEA
Paris, France

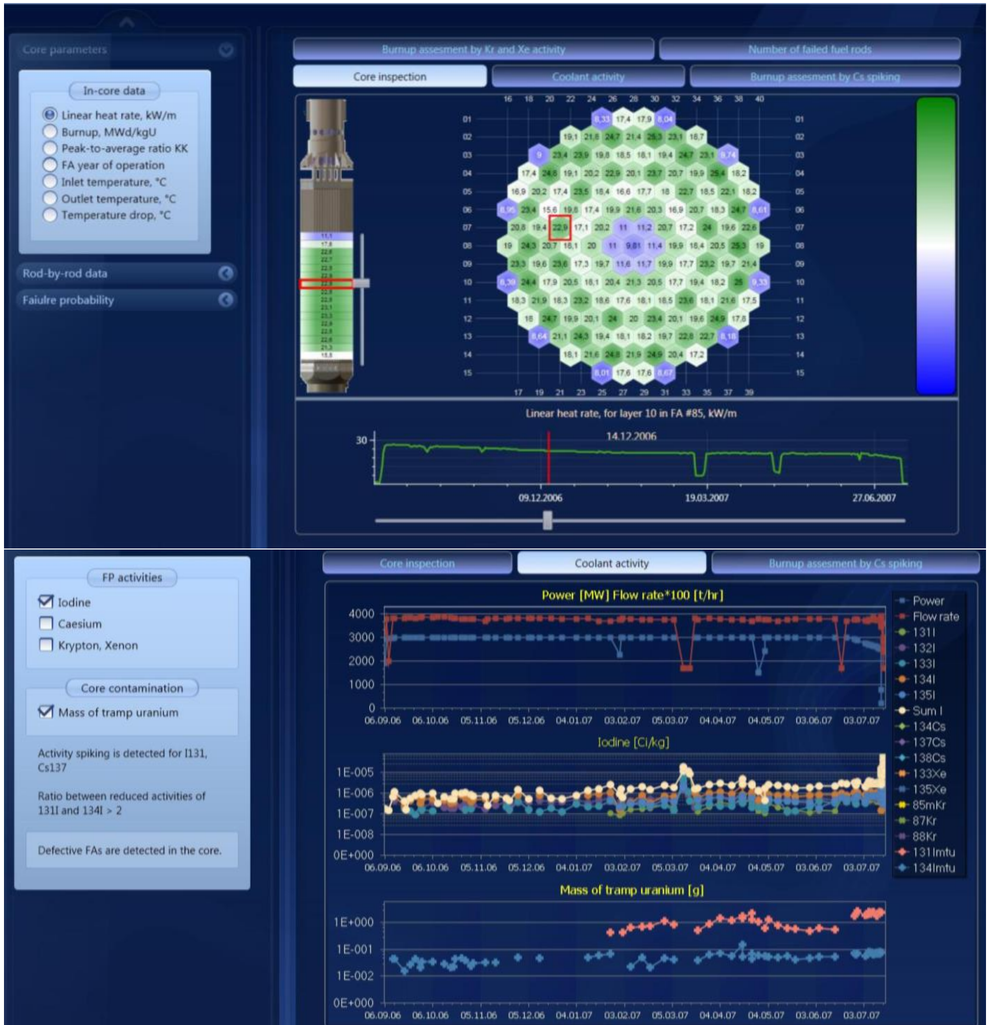
PAUL SCHERRER INSTITUT PSI

TENDL-2019, what is new ?

- New T6:
  - Newest code versions,
  - more verifications,
  - Linux RedHat/Mac,
  - tested with latest compilers
- TENDL-2019 Beta versions already available (https://tendl.web.psi.ch/tendl_2019/tendl2019.html)
- Similar structure as the previous TENDL libraries
  - 2813 isotopes, 200 MeV, with covariances
  - Neutrons, protons, deuterons, tritons, He3, alphas, and gammas
  - ACE ?
  - ENDF-6 files in different options (MF3 MT5 at 0, 20 or 60 MeV)
  - EAF files
  - MF32 and/or MF33
  - Input files
  - Random files

ND for Energy: Nuclear power plants

Fuel Cladding Integrity monitoring at operating WWER power units



I.A. Evdokimov et al. Development of the Expert System for fuel monitoring and analysis in WWER-1000 units. INTERNATIONAL CONFERENCE ON WWER FUEL PERFORMANCE, MODELLING AND EXPERIMENTAL SUPPORT (2011)

Iodine radionuclides activity in primary coolant:

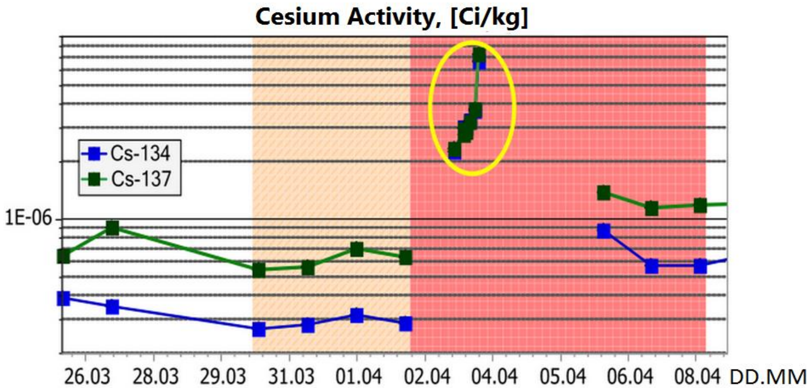
- Detection of the moment when a rod leakage occurs in the core
- Estimation of the extent of cladding degradation in a leaking fuel rod: small/large defect, secondary failure, fuel washout, mass of tramp uranium in the core (I-134)
- Fuel failure criteria: operational limits (I-131)

Noble gas activity in primary coolant:

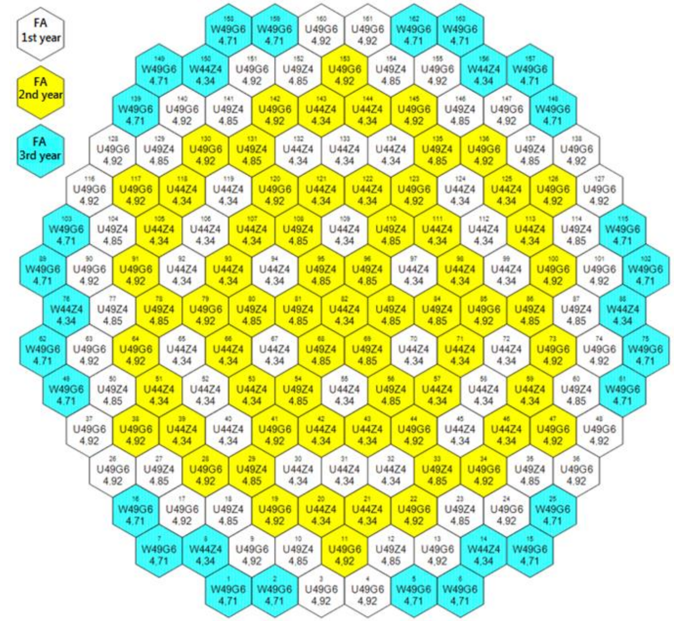
- Detection of the secondary failure in the core
- Leaking fuel burnup estimation relying on the activity ratio of ^{88}Kr and ^{85m}Kr to ^{135}Xe

ND for Energy: Nuclear power plants

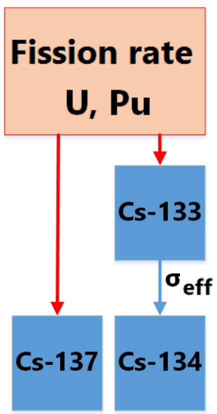
Technique for the burnup evaluation of leaking fuel in WWERs during reactor operation:
$^{134}Cs/^{137}Cs$ activity ratio at spike-events

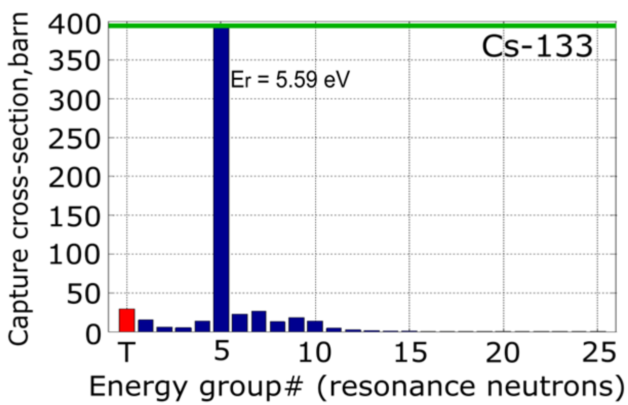


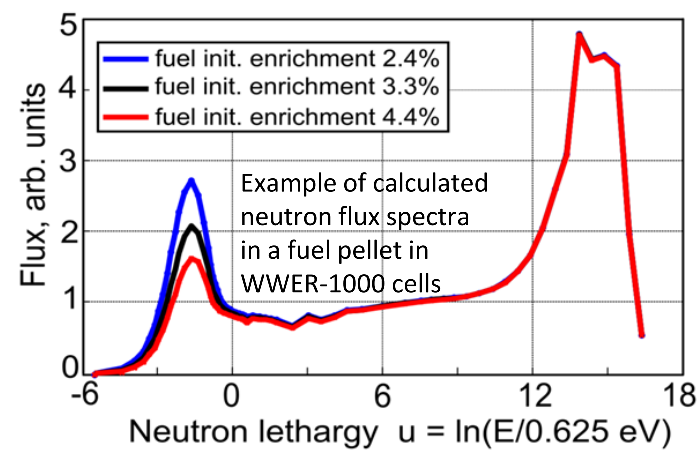
Example of ^{134}Cs and ^{137}Cs spike-event
during a power transient



WWER-1000 core: 163 assemblies,
various fuel enrichment and irradiation history







Sources: O. Vilkhivskaya, PHYSOR2020 and INTERNATIONAL CONFERENCE ON WWER FUEL PERFORMANCE, MODELLING AND EXPERIMENTAL SUPPORT (2017)

ND for Nuclear Energy research: Fusion - JET

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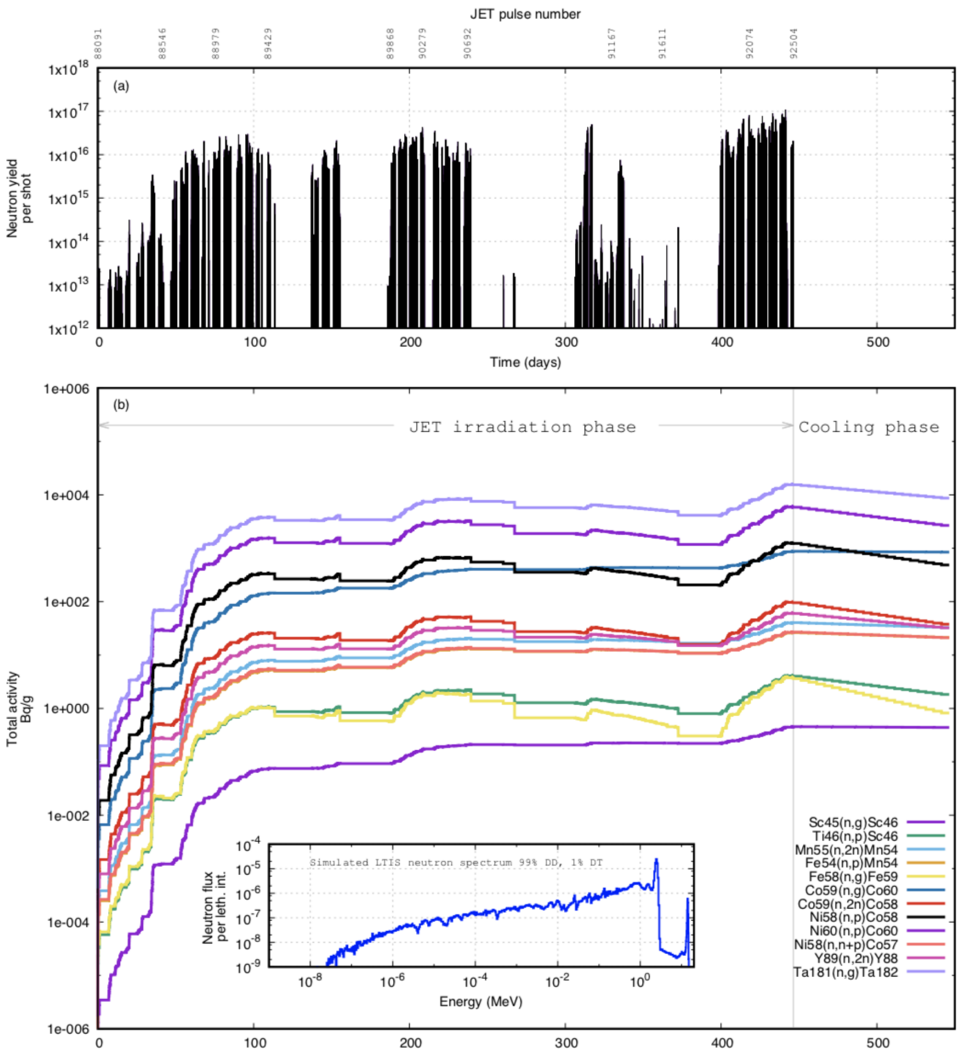
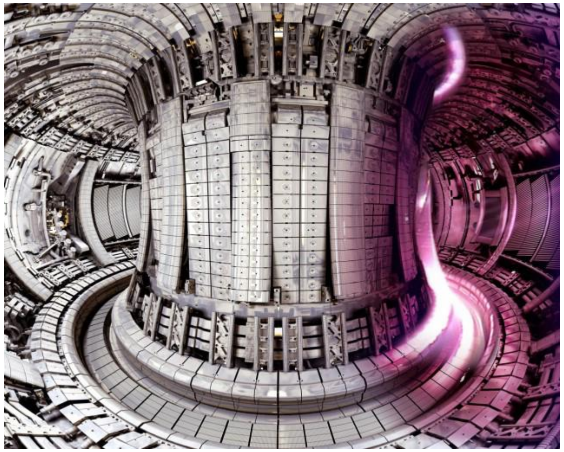


Figure 4: (a) JET neutron yield per pulse between 27/08/2015 and 15/11/2016; (b) Simulated specific activities calculated over time for dosimetry foils located within the long-term irradiation station assembly, exposed to JET experimental campaigns calculated using FISPACT-II.



Deuterium-Tritium (DT) experiments: scheduled **2020**

$$^{2}H + ^{3}H \rightarrow ^{4}He + n$$

L. W. Packer et al. (2018) Activation of ITER materials in JET: nuclear characterisation experiments for the long-term irradiation station. Nucl. Fus. **58**

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ND for Nuclear Energy: xs data for fusion examples

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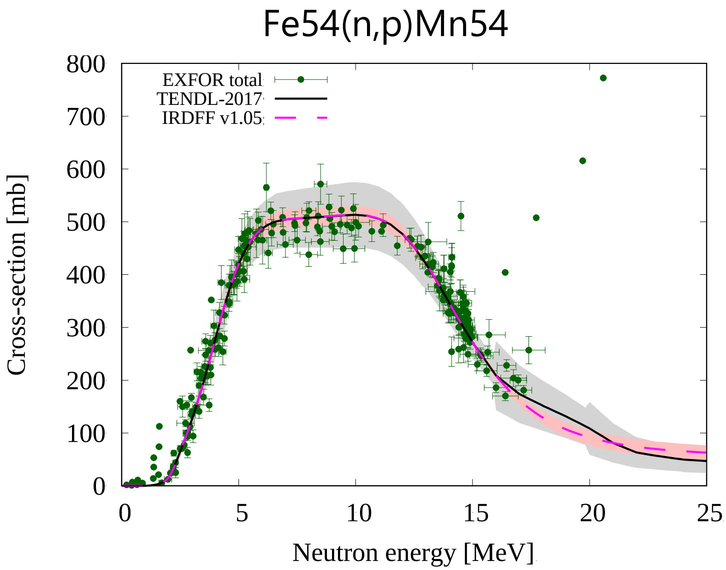

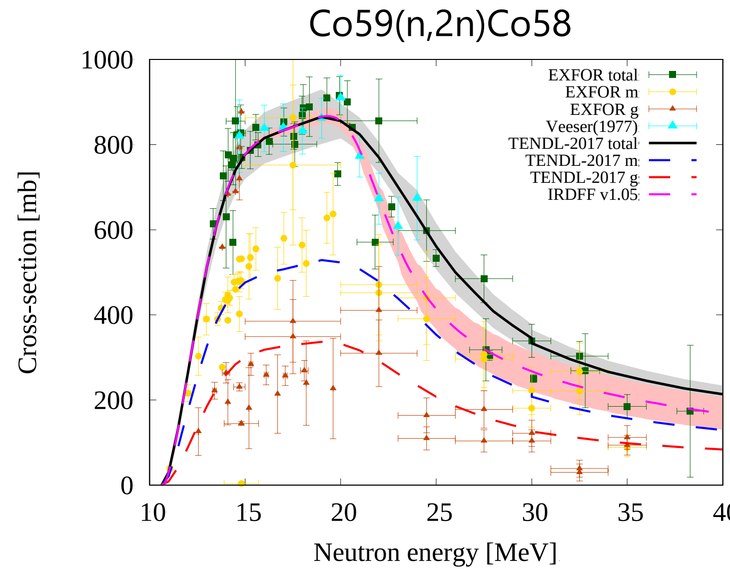

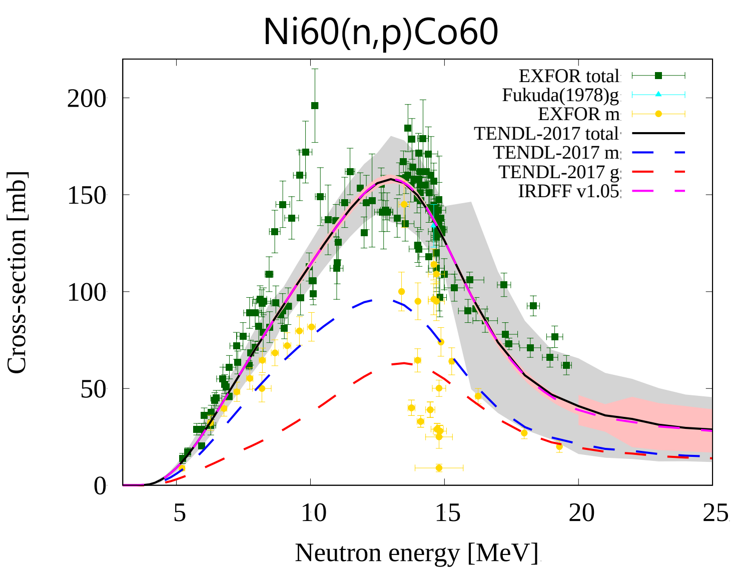

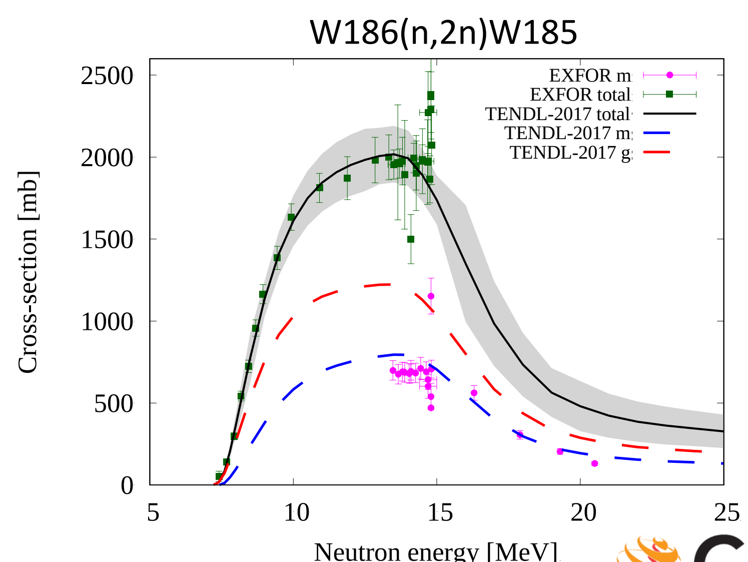

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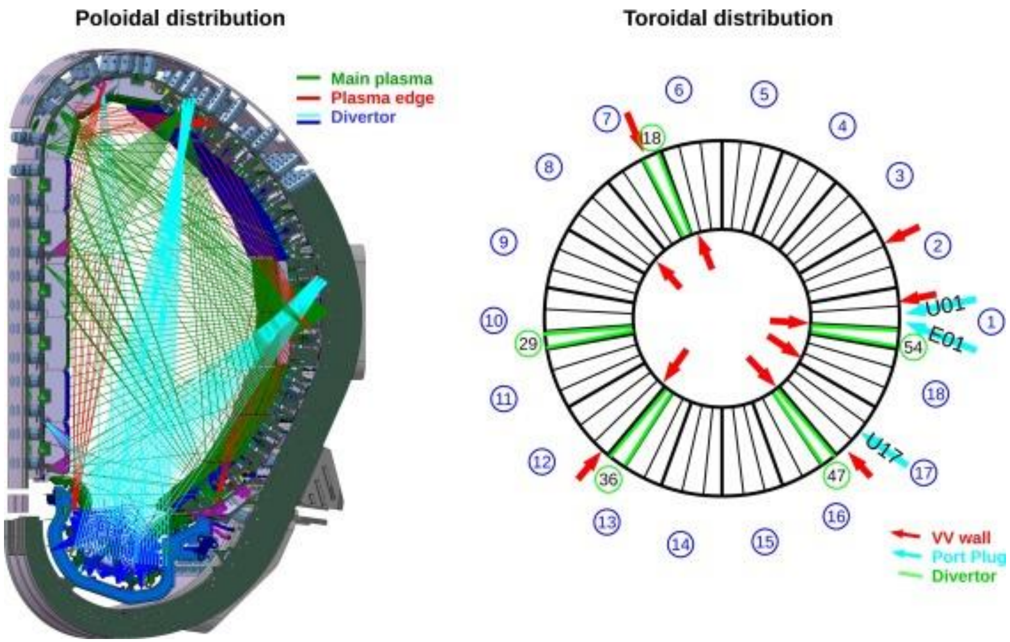
ND for Nuclear Energy: Fusion - ITER



550 lines-of-sight (LOS):

- 71 cameras observing the whole plasma
- detector type: metal resistor bolometer
- **Pt** absorber/SiN/**Pt** resistor
- radiation measurements: soft-X to the infrared
- tomographic reconstructions of the spatially resolved radiation profile
- withstand thermal loads due to *n and γ* heating

ITER bolometers: currently tested to 0.1 dpa

If used in DEMO: can suffer damage of 3dpa at 3m from the FW

Pt absorbers need to be tested at damage >0.1 dpa

H. Meister. Current status of the design of the ITER bolometer diagnostic. Fus. Eng. Des. **120** (2017)

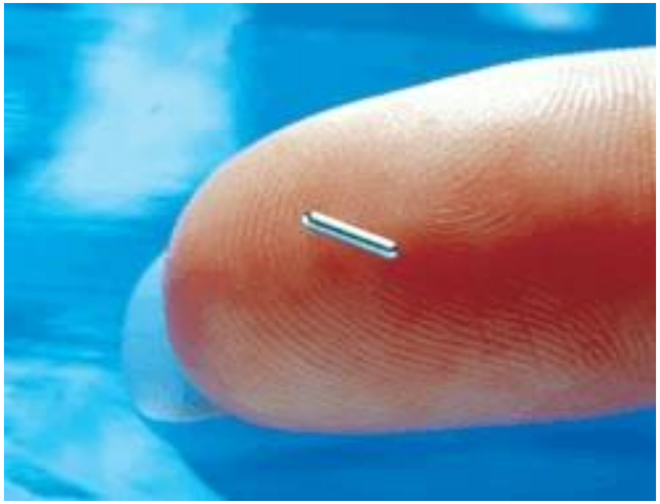
ND for Medicine: Brachytherapy

Example: Iodine seeds

- **Iodine-125 (in Zr/Ti cladding)**
- **$T_{1/2}$ = 59.49 days**
- **emits low-energy photons (35 keV)**
- **reactor-produced:**

^{124}Xe (n,γ) → ^{125m}Xe (57 s) → ^{125}I (59.4 d)
^{124}Xe (n,γ) → ^{125g}Xe (19.9 h) → ^{125}I (59.4 d)

- **leading producer: Canada**
- **therapy of tumours**



Source: https://www.eisenhowerhealth.org

Recommended nuclear data for medical radioisotope production: diagnostic gamma emitters

F. T. Tárkányi[1] · A. V. Ignatyuk[2] · A. Hermanne[3] · R. Capote[4] · B. V. Carlson[5] · J. W. Engle[6] · M. A. Kellett[7] · T. Kibedi[8] · G. N. Kim[9] · F. G. Kondev[10] · M. Hussain[11] · O. Lebeda[12] · A. Luca[13] · Y. Nagai[14] · H. Naik[15] · A. L. Nichols[16] · F. M. Nortier[6] · S. V. Suryanarayana[15] · S. Takács[1] · M. Verpelli[4]

Received: 23 May 2018 / Published online: 3 October 2018

Journal of Radioanalytical and Nuclear Chemistry (2019) 319:487–531
https://doi.org/10.1007/s10967-018-6142-4

Other emitters:

Photon sources: Co-60, Cs-137, Cs-133, Ir-192, I-125, Pd-103
Beta sources: Sr-90/Y-90
Neutron sources: Cf-252

ND for Aerospace: power sources

source: www.nasa.gov
October 2013

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^{238}Pu: power source for satellites and NASA's deep space missions

- first launched into Earth orbit in 1961, Radioisotope Thermoelectric Generators (RTGs) have flown on 27 space missions involving 46 RTGs
- optimizing power levels over a minimum lifetime of 14 years and ensuring a high degree of safety
- Pu-238 produced at HFIR reactor (ORNL) by Np-237 irradiation with neutrons
- uncertainty in Np-238 fission product evaluation → uncertainty in target heating

The Curiosity rover took this self portrait on the surface of Mars, with its MMRTG power source visible at the rear.

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ND for Aerospace: Mars 2020

Go nuclear data!

Power for Mars 2020 rover: the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). Image Credit: NASA/JPL-Caltech (18.10.2019)

https://mars.nasa.gov/mars2020/news/