European Commission

GELINA at JRC Geel

Arjan Plompen

NSTAPP, CERN, 20y n_TOF, 22 November 2021

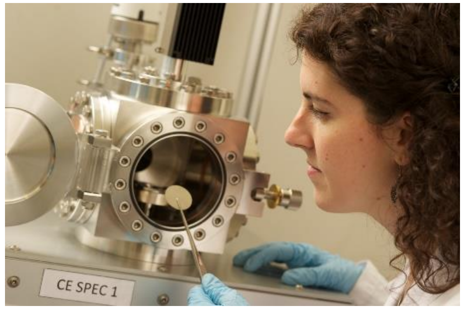
Joint Research Centre

EURATOM research infrastructure JRC Geel

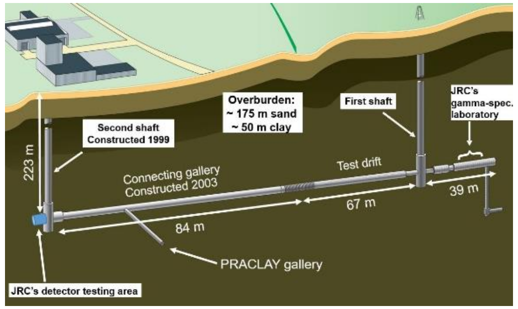
GELINA

METRO

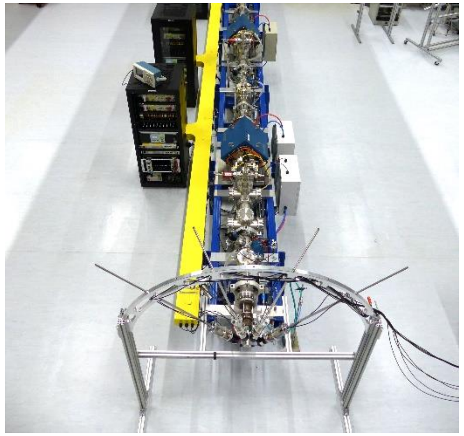
RADMET



HADES



MONNET



TARGET

- **Nuclear data**
- **Metrological tools for nuclear safety, security and safeguards**
- **Radionuclide metrology**

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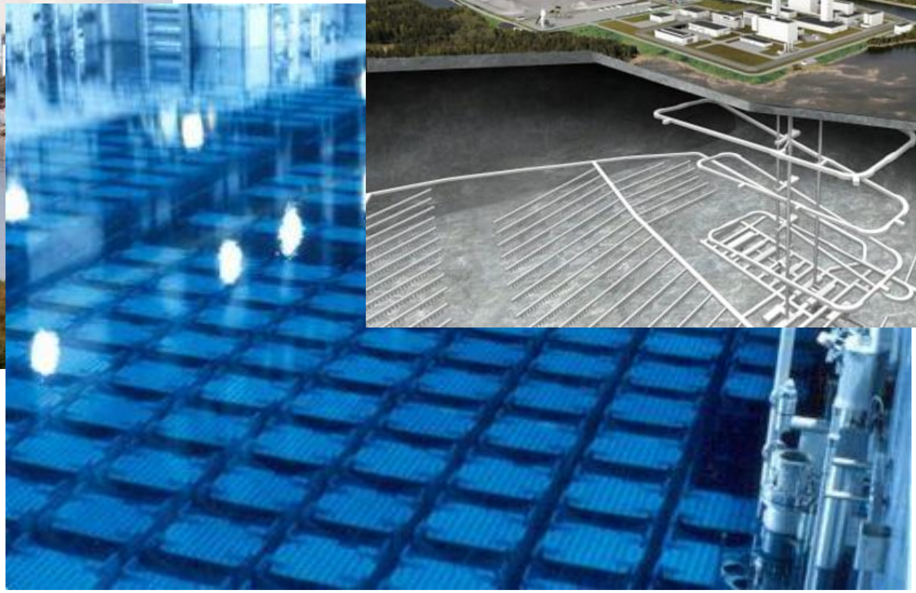
Nuclear data – major use

Source: Vattenfall.com



Source: World-nuclear.org

Source: SKB

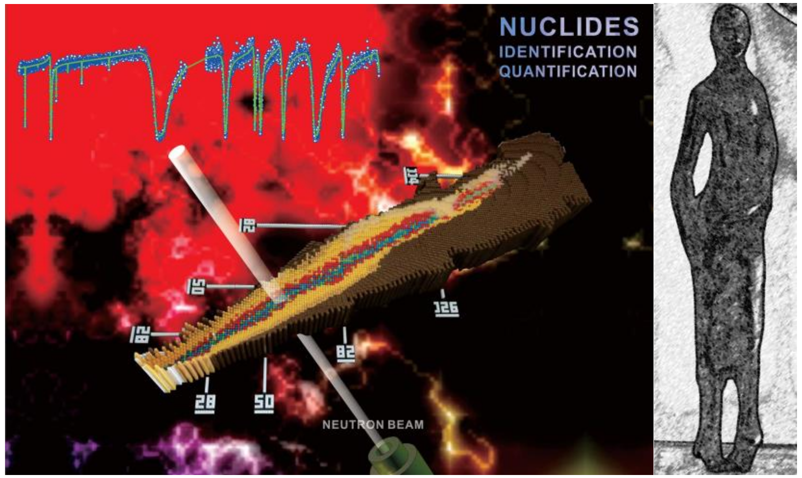
800 TWh/year in EU-27 + UK

Nuclear fuel investment of order 10 000 M€/year

1.500 tons spent nuclear fuel in Switzerland – use of nuclear data can reduce cost (more than 100 M€ for final repository)

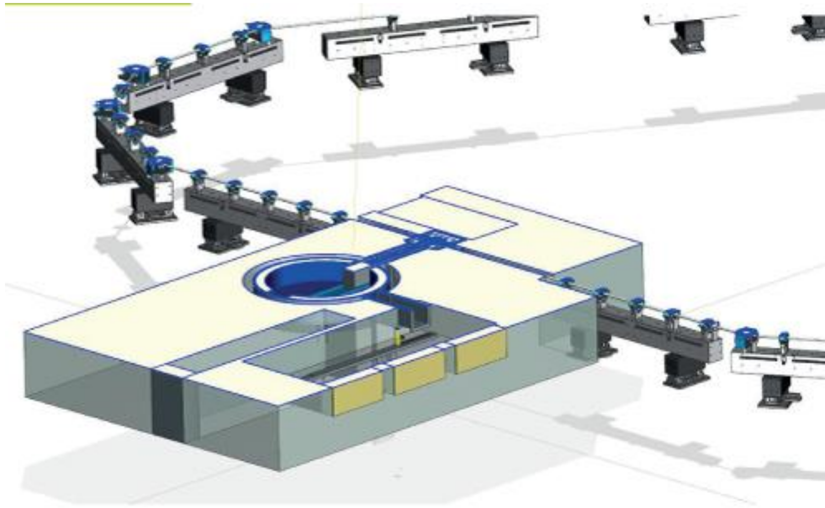
50.000 tons spent nuclear fuel in Europe

Nuclear data – innovation

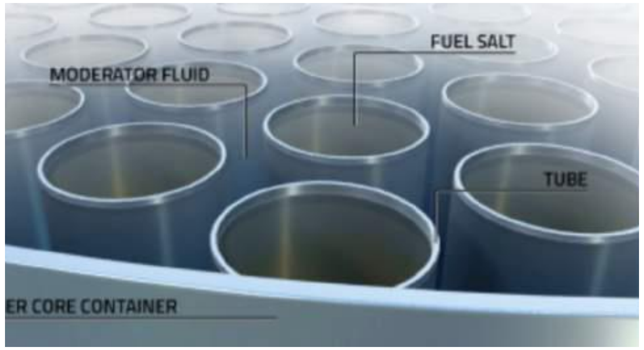


Source: iJAAS / JRC

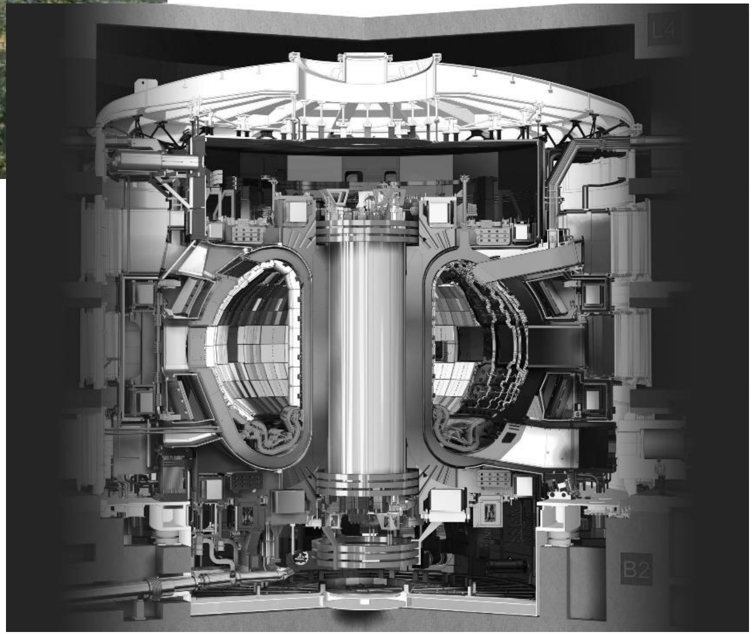
Source: myrrha.be



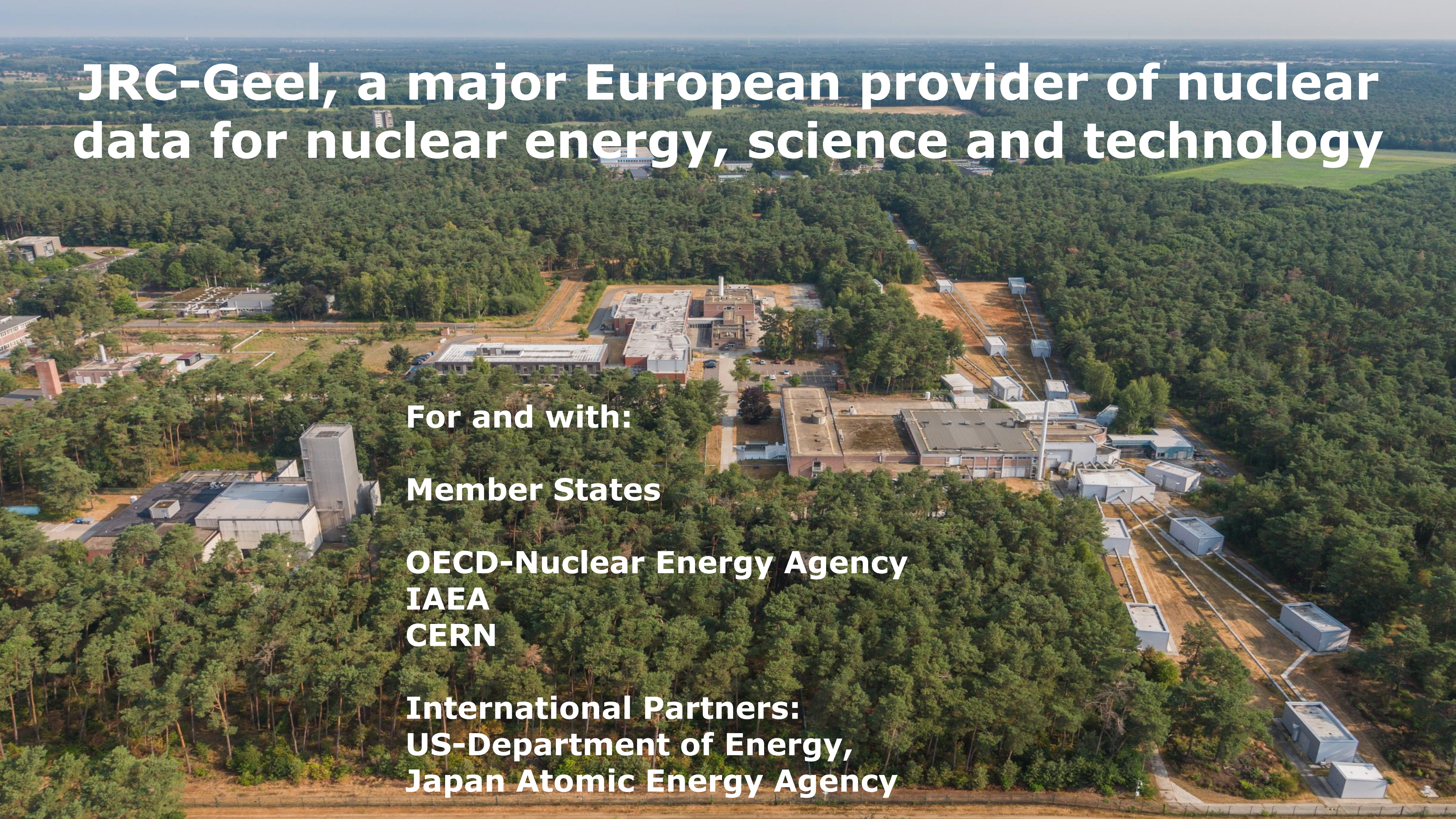
Source: ire.eu



Source: IAEA SMR book 2018



Source: iter.org



JRC-Geel, a major European provider of nuclear data for nuclear energy, science and technology

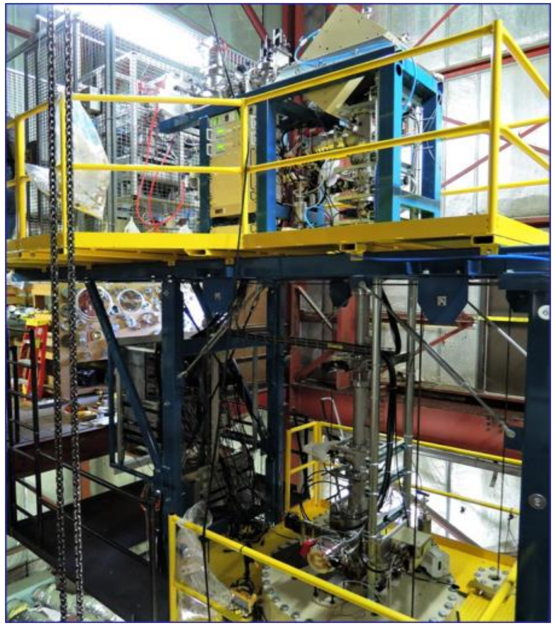
For and with:

Member States

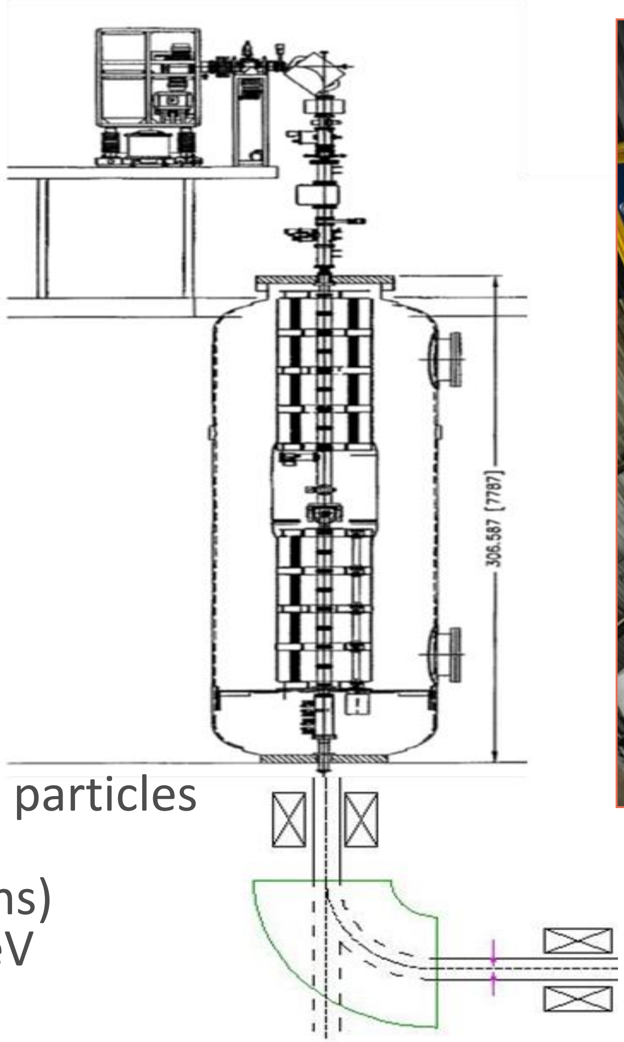
OECD-Nuclear Energy Agency
IAEA
CERN

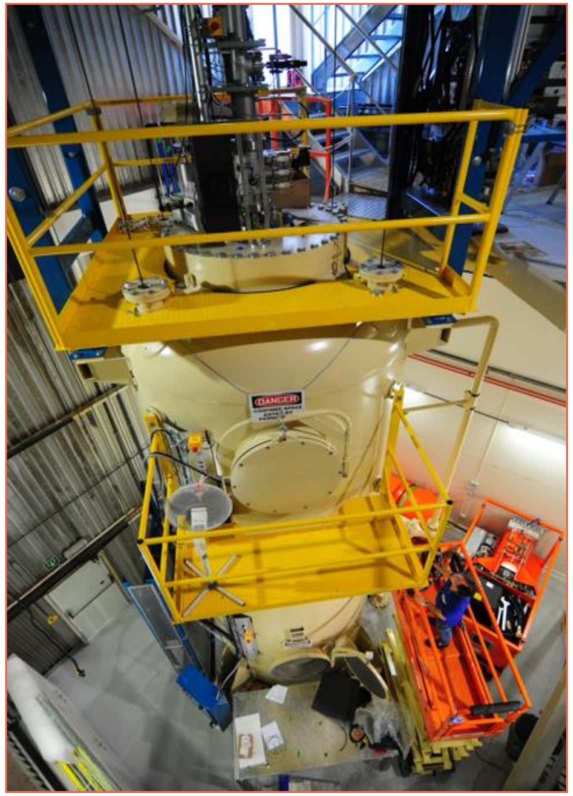
International Partners:
US-Department of Energy,
Japan Atomic Energy Agency

MONNET: MONo-energetic NEutrons by Tandem



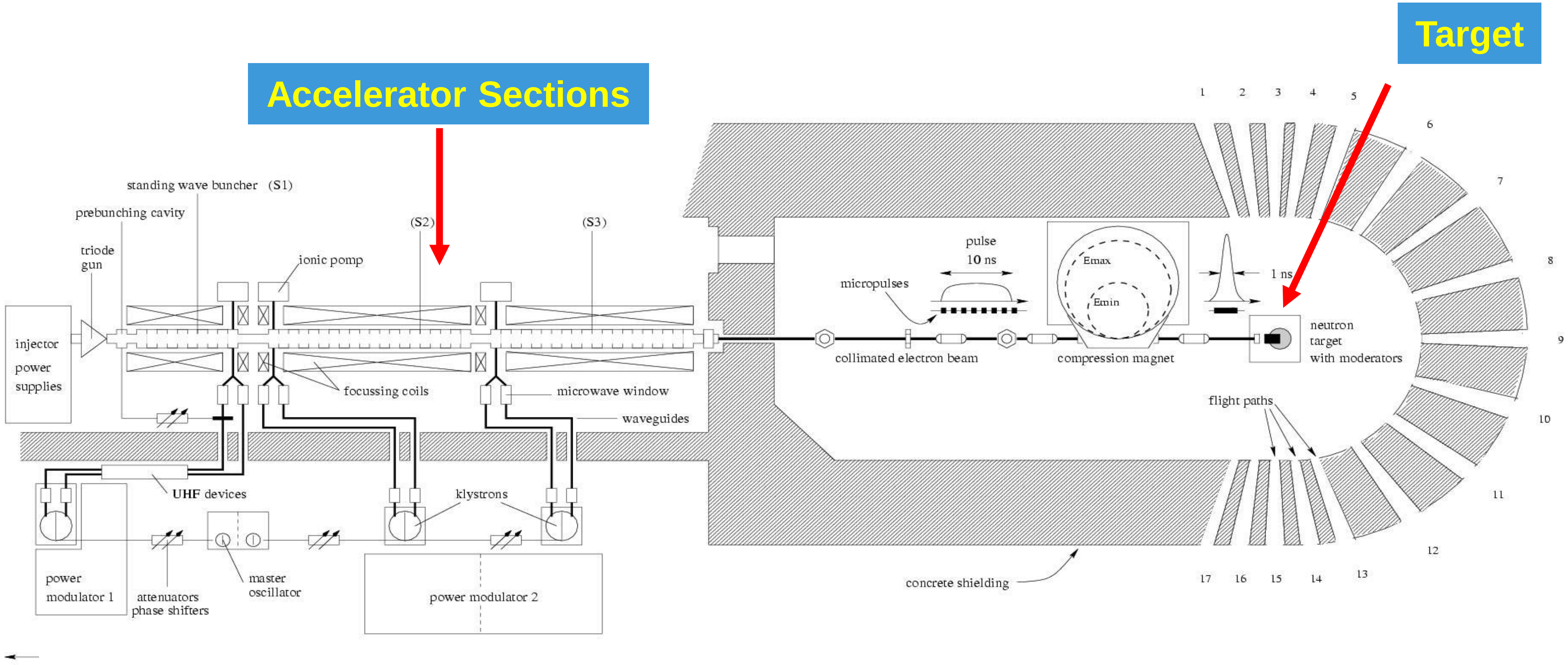
3.5 MV NEC Tandem





- Protons, deuterons and alpha particles
- DC (p,d < 50 μA)
- Pulsed beam available (1 – 2 ns)
- Energy range: 200 keV – 7 MeV

GELINA - Electron Linear Accelerator



Normal Operating Parameters

Average Current	: 70 μA	Frequency	: up to 800 Hz
Maximum Electron Energy	: 130 MeV	Pulse Width	: 1-2 ns
Mean Power	: 7 kW	Neutron Flux	: 2 x 10^{13} 1/s

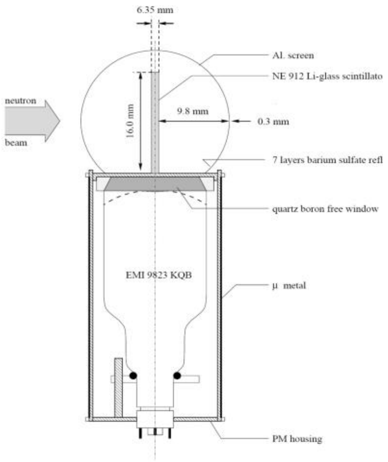
GELINA - Experimental set-ups

- Transmission
  - 10 m, 30m, 50 m
- Capture
  - 10 m, 30 m, 60 m
- Elastic sattering
  - 30 m
- In-elastic scattering
  - 30 m, 100 m
- Fission, (n,p), (n,α),
  - 10 m

GELINA - Experimental set-ups

Transmission

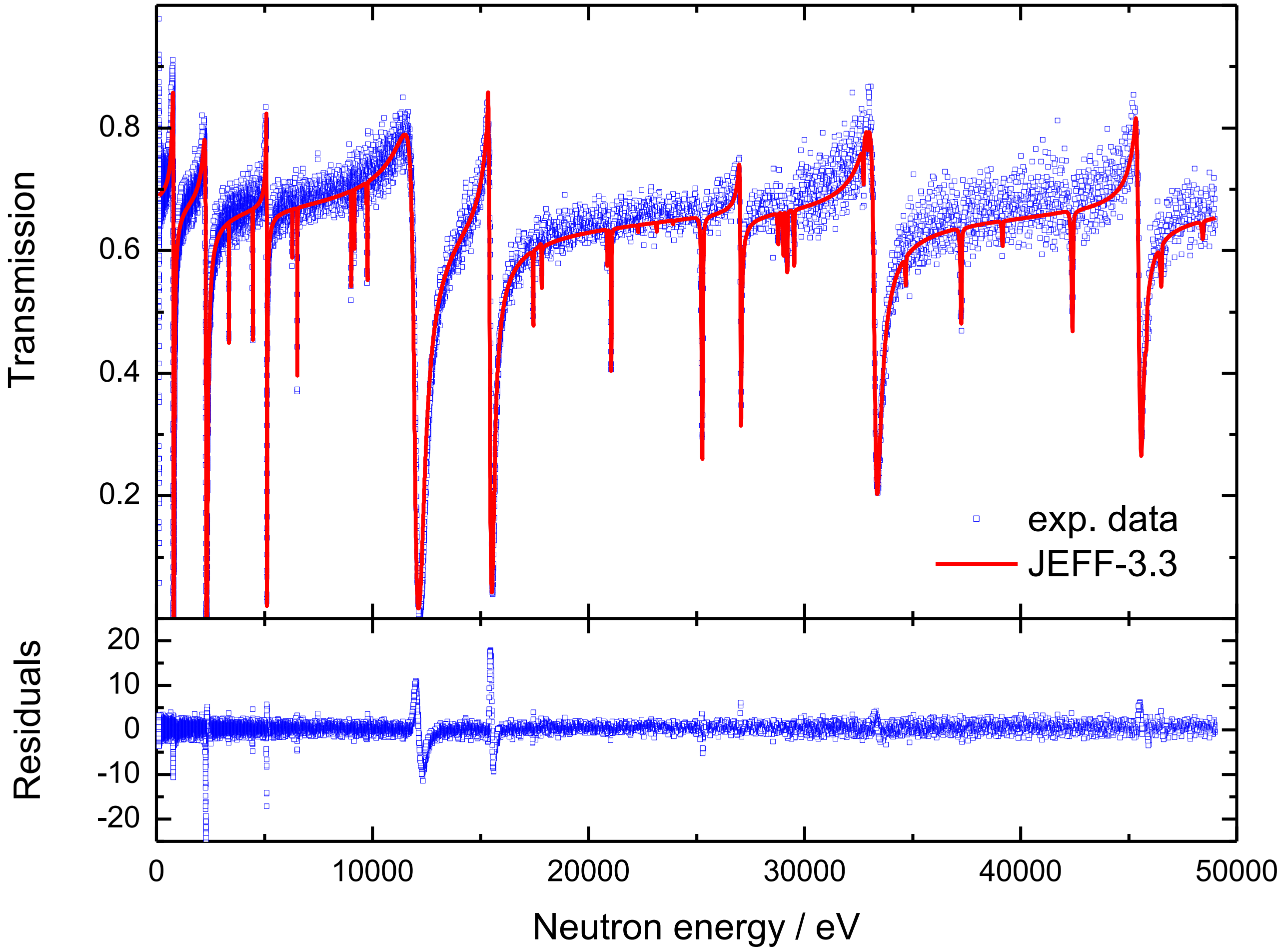
– **10 m, 30 m, 50 m**



Detectors

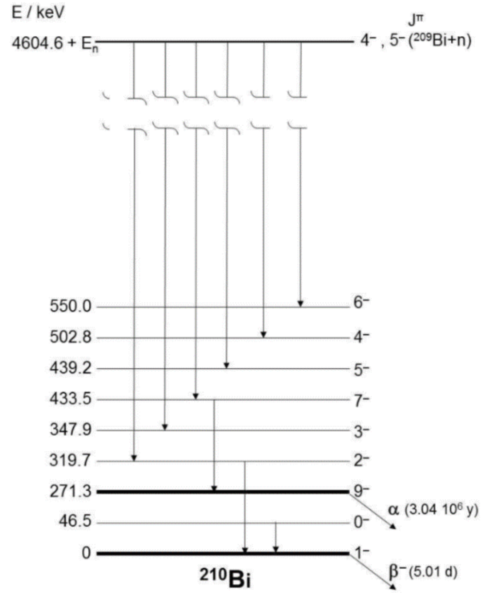
Low energy :	^{6}Li(n,t)α	Li-glass
High energy :	H(n,n)H	Plastic scintillator or NE213 type

New evaluation for ^{209}Bi + n



Project in collaboration with SCK•CEN and JAEA

- Improve RP for ^{209}Bi
- Capture at GELINA (60m)
- Determine branching ratio J-PARC: $\sigma_{\gamma,g} / \sigma_{\gamma,m}$



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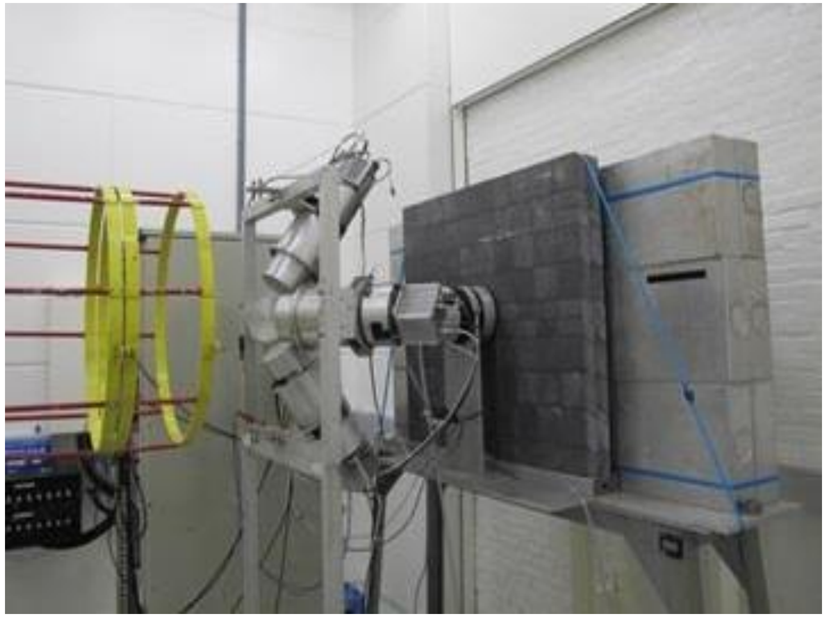
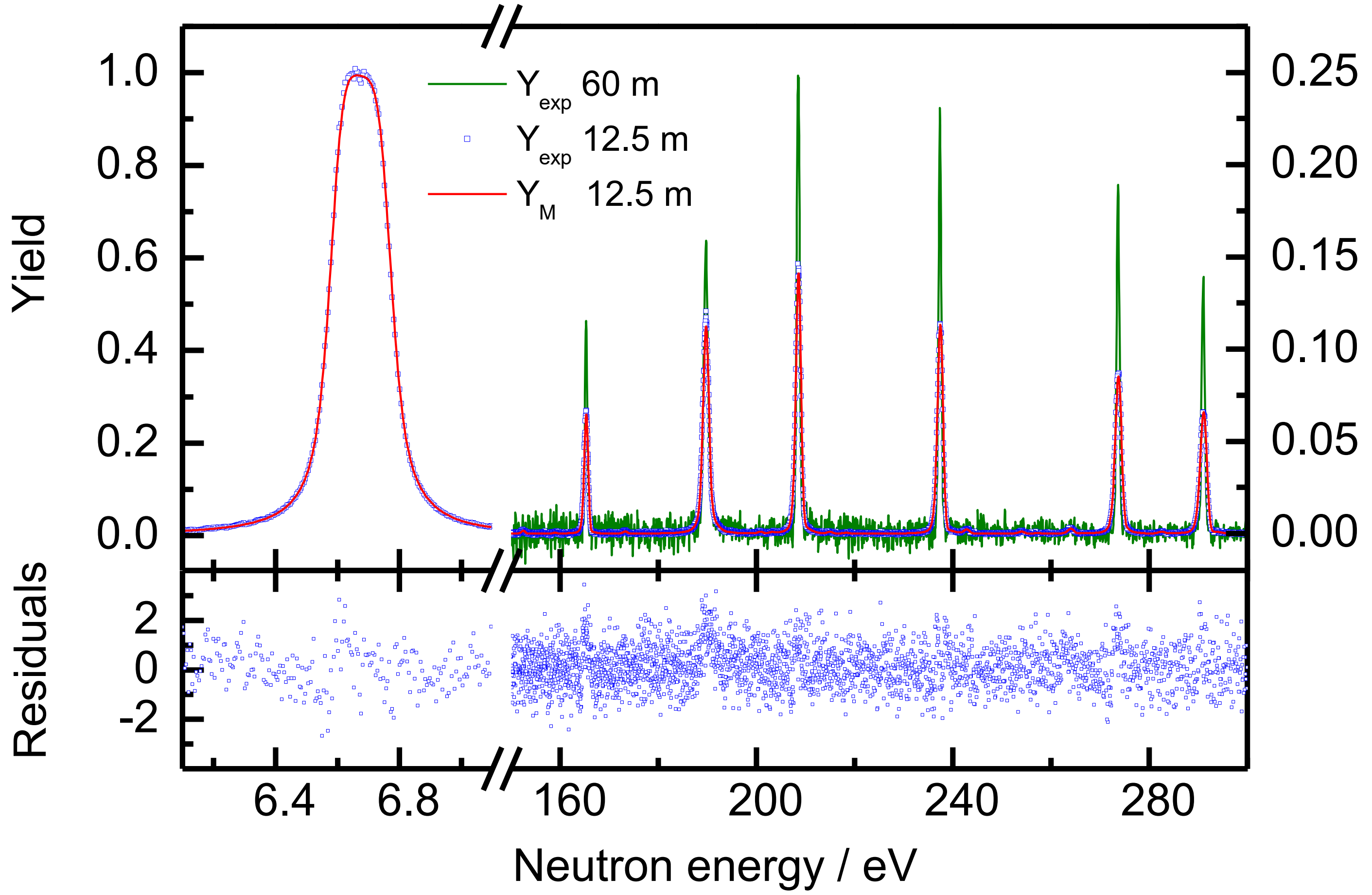
GELINA - Experimental set-ups

Capture

– **10 m, 30 m, 60 m**



$^{238}U(n,\gamma)$ resonance shape analysis: REFIT

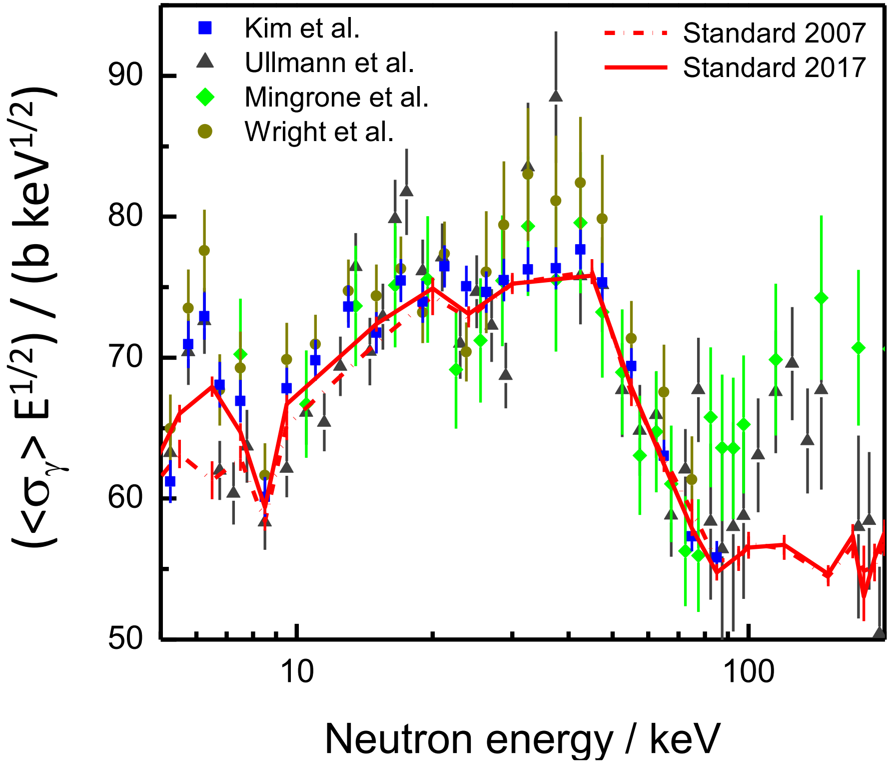


Kim et al., EPJA 52 (2016) 170

GLSQ analysis for n + ^{238}U: $\sigma(n,\gamma)$

Experimental data from :

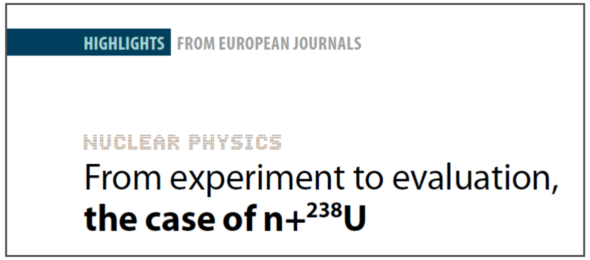
- Standard 2007
- Kim et al. (GELINA) (~ 2%)
- Ullmann et al. (LANSCE)
- Mingrone et al. (n_TOF)
- Wright al. (n_TOF)



⇒ GMA analysis (GLSQ)

⇒ New evaluation for ^{238}U + n in RRR and URR

Dr. K. Kim, Dr. Y.-O. Lee
KAERI, Nuclear Data Center, Daejeon



Kim et al., EPJA 52 (2016) 170
Sirakov et al., EPJA 53 (2017) 199

europhysicsnews THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

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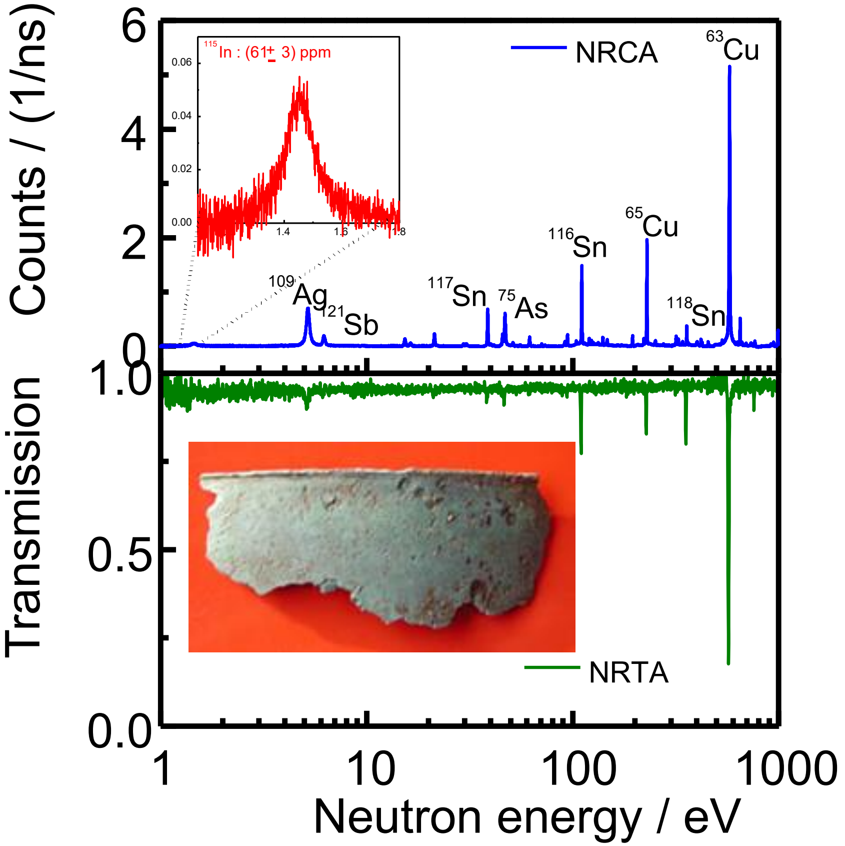
NRTA and NRCA



Postma et al., Czech. J. Phys. 53 (2003) A233

Areal density Cu: 0.55 (2) g/cm^2

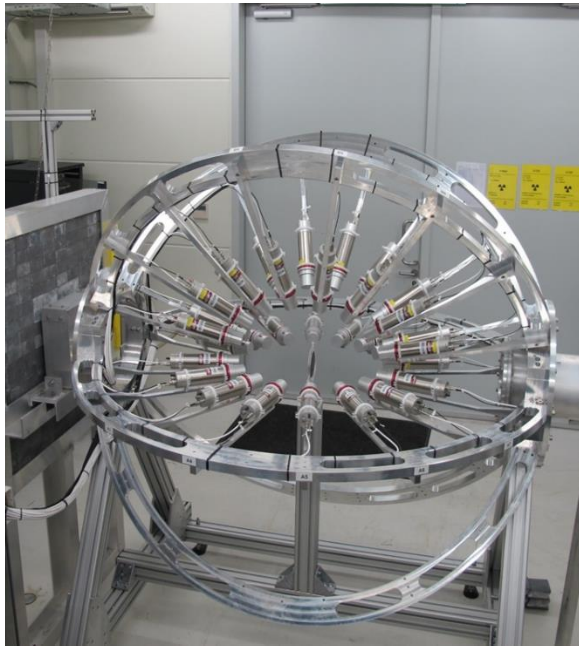
Element	wt%			Isotope	E_r / eV
Cu	**77.76**	±	**0.11**	^{63}Cu	579.0
				^{65}Cu	230.0
Sn	**20.85**	±	**0.10**	^{112}Sn	94.8
				^{116}Sn	111.2
				^{117}Sn	38.8
				^{118}Sn	45.7
				^{119}Sn	222.6
				^{120}Sn	427.5
				^{124}Sn	62.0
As	**0.34**	±	**0.01**	^{75}As	47.0
Sb	**0.20**	±	**0.02**	^{121}Sb	6.24
				^{123}Sb	21.4
Ag	**0.09**	±	**0.01**	^{107}Ag	16.3
				^{109}Ag	5.2
Fe	**0.77**	±	**0.10**	^{56}Fe	1147.4
In	**0.0061**	±	**0.0003**	^{115}In	1.46

GELINA - Experimental set-ups

Elastic scattering

– **30 m**

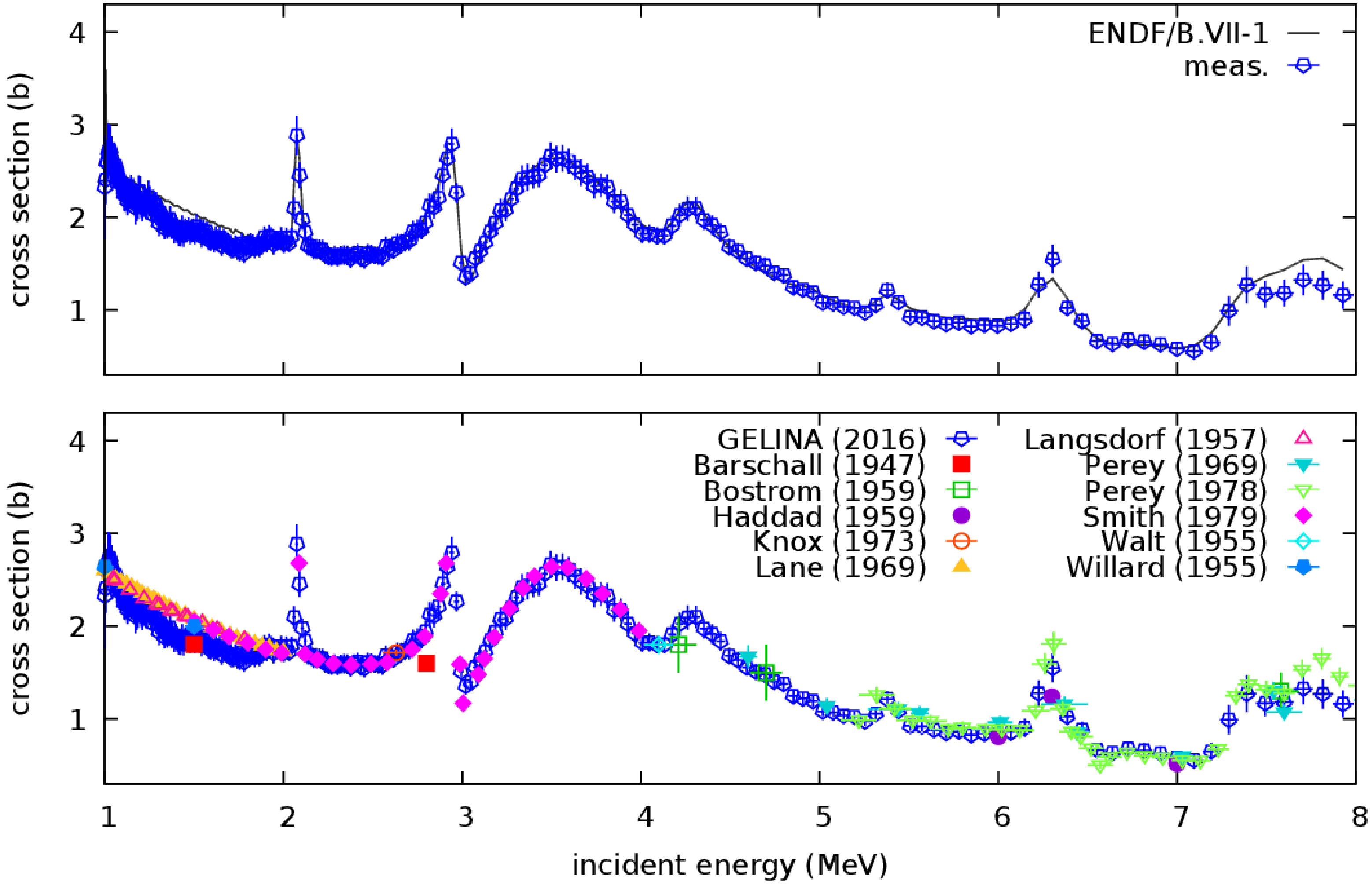
ELISA

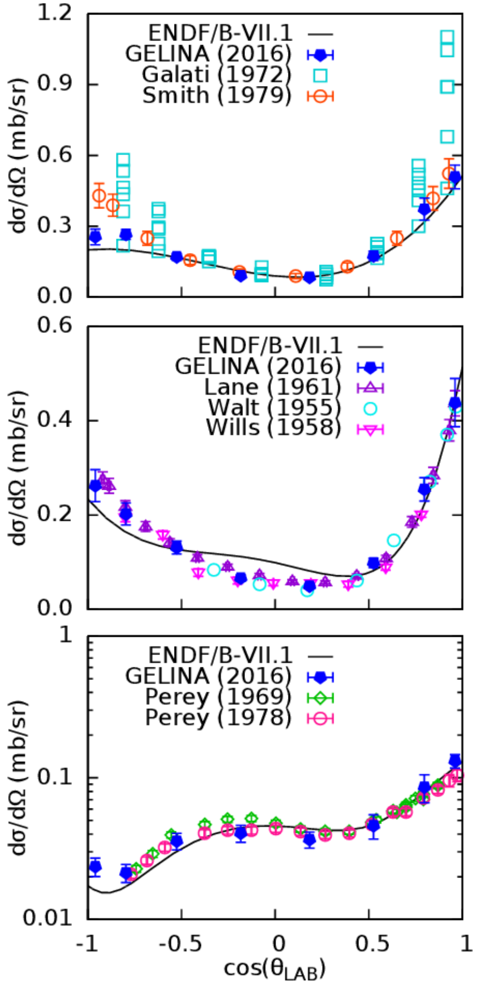


ELastic and Inelastic Scattering Array

- 32 liquid organic scintillators
  - 16 EJ301 (NE213)
  - 16 EJ315 (C6D6)
- n/g discrimination
- Time resolution ~1 ns
- Flux by ^{235}U fission chamber
- ^{nat}C, ^{56}Fe
- Ongoing ^{54}Fe, ^{23}Na, (^{56}Fe enr)

$^{nat}C(n,n)$: test set-up and procedures





E = 2.08 – 2.10 MeV

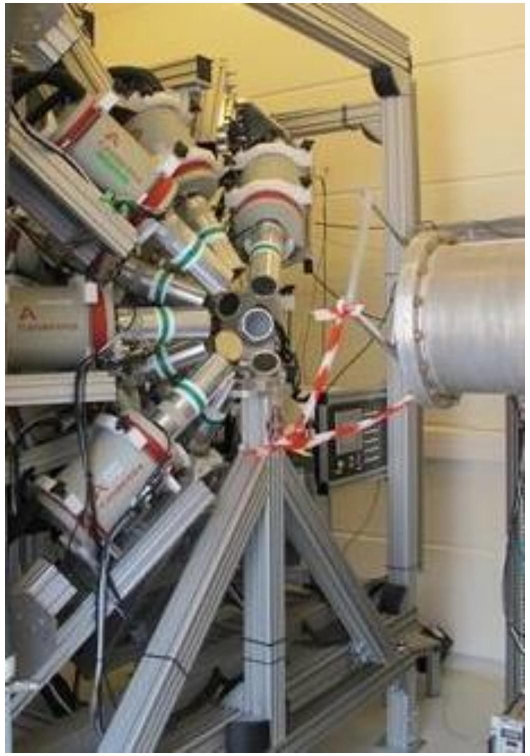
E = 4.07 – 4.11 MeV

E = 6.95 – 7.05 MeV

GELINA - Experimental set-ups

Inelastic scattering

– **100 m, GAINS**

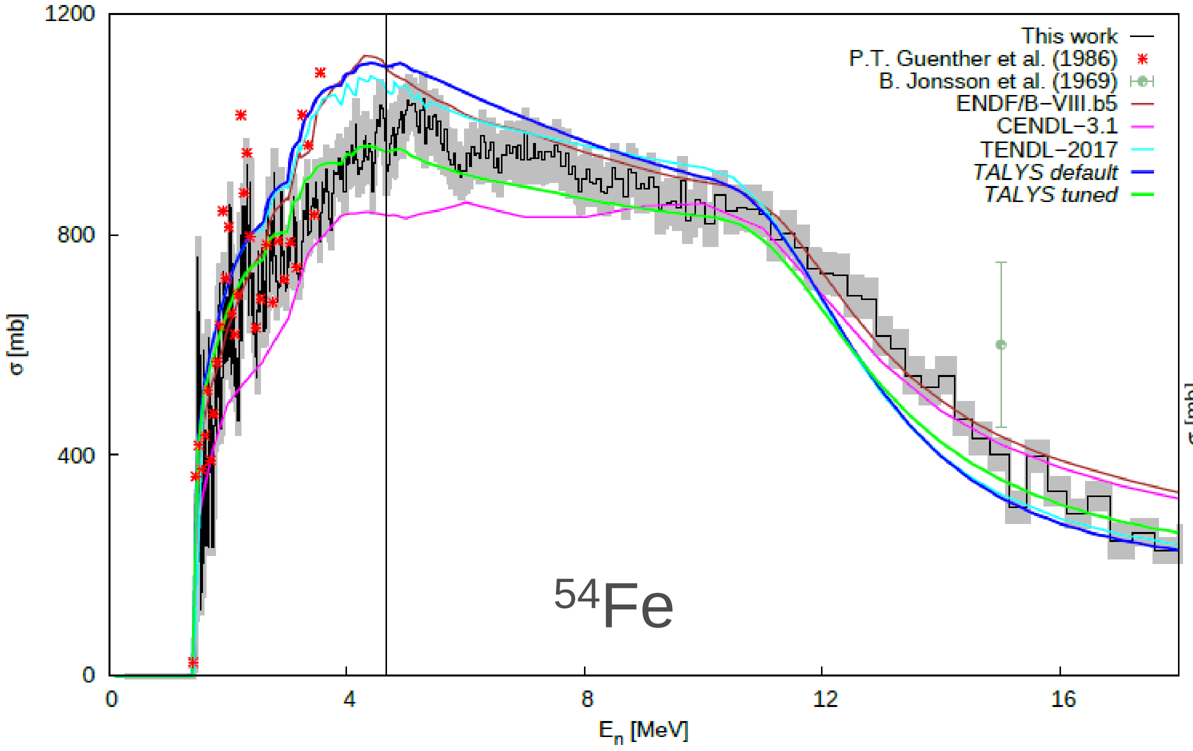


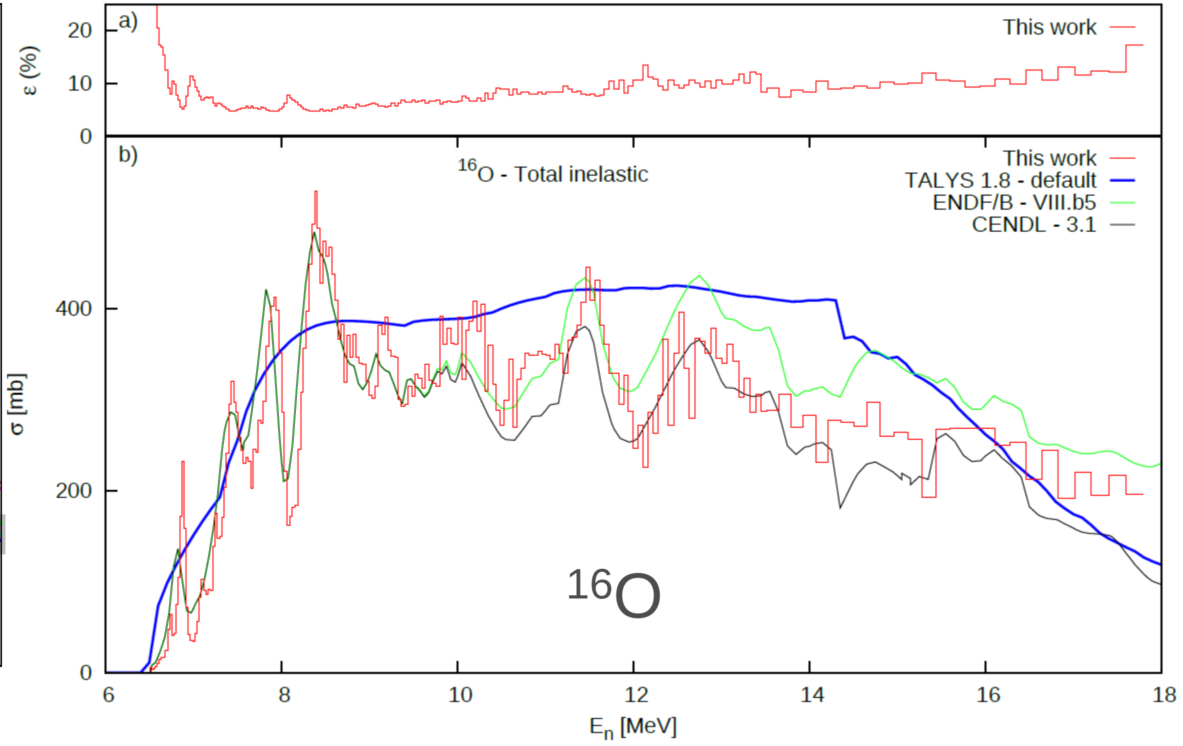
- 12 HPGe detectors:
  - 4 @ 110°
  - 4 @ 150°
  - 4 @ 125°
- ^{235}U Fission chamber
- Flight Path: 100 m
- Repetition rate: 800 Hz
- Neutron energy 0 – 20 MeV
- Flux ~2000 neutrons/cm^{2}s

Examples: ^{54}Fe(n,n'g) and ^{16}O(n,n'g)

A. Olacel et al., Eur. Phys. Journal A54, 183 (2018)

M. Boromiza et al., Phys. Rev. C101, 024604 (2020)





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GELINA - Experimental set-ups

Inelastic scattering

– **30 m, GRAPhEME**

GeRmanium array for Actinides PrEcise MEasurements

- Inelastic scattering set-up
- 5 planar HPGe detectors, one segmented (36 pixels)
- Neutron flux monitoring with a ^{235}U fission chamber
- ^{235}U, ^{238}U, ongoing ^{233}U, ^{232}Th, W

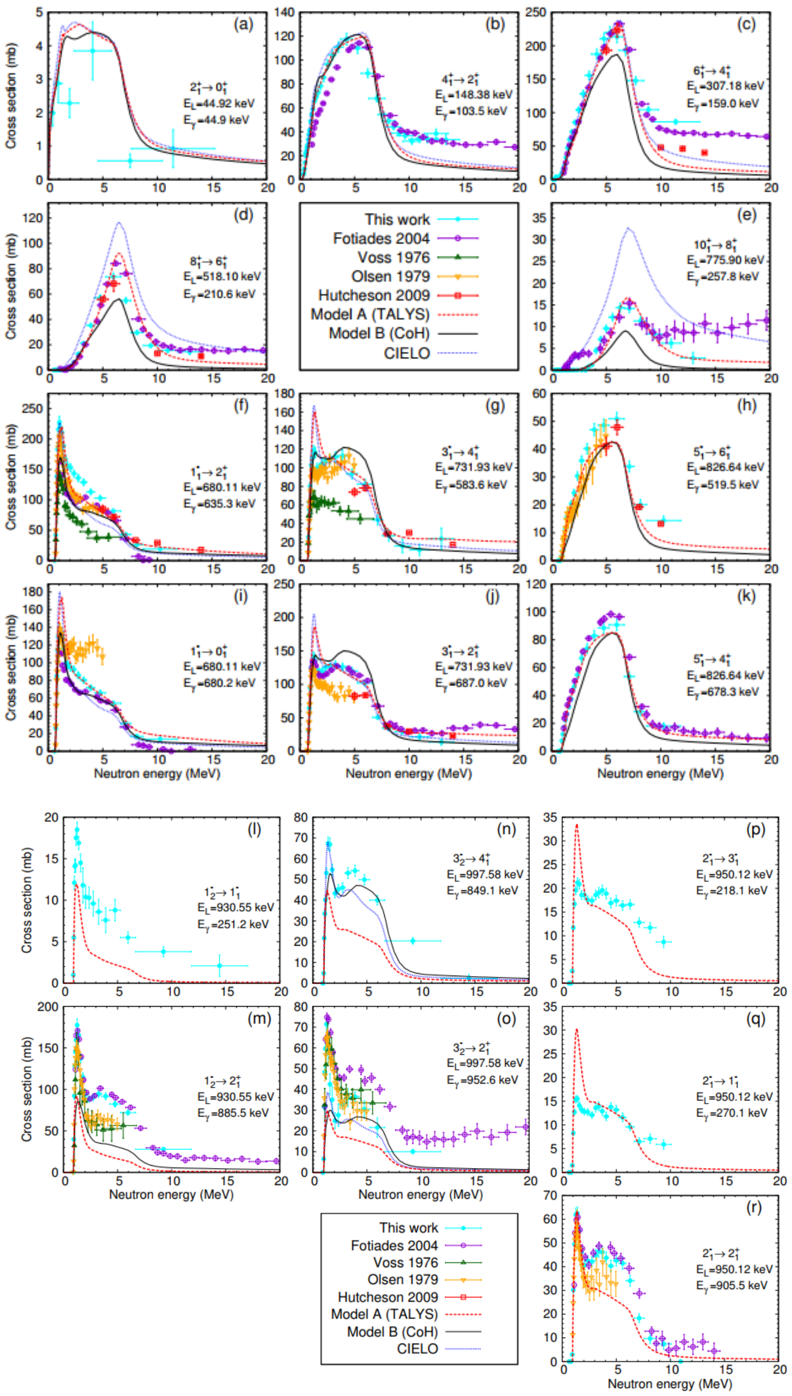
GRAPhEME : ^{238}U measurements

Measurement of ^{238}U(n, $n\gamma$) cross section data and their impact on reaction models,
M. Kerveno, M. Dupuis *et al.*
Phys. Rev. C **104**, 044605 (2021) DOI :10.1103/PhysRevC.104.044605
- EXFOR entry 22795 (being updated)

PHYSICAL REVIEW C
covering nuclear physics

Main results:

- **Cross section data for 18 γ transitions** (five never measured before) compared to TALYS, EMPIRE and CoH codes.
- **New information** about **branching ratio** have been obtained.
- **Microscopic modeling of the preequilibrium emission** improved the spin distribution description and then improve the prediction for (n, n'γ) transition at high spin level in the GS band.
- Some of the **interband transitions are shown to be very sensitive** to the choice of **prescription for discrete levels γ decay** that are not given in the RIPL3 library.
- **Large uncertainties** in the **current modeling** are related to the **knowledge of the decay scheme**: poorly known branching ratios and an incomplete information of the discrete states above 1.3 MeV.
- Other aspects of the modeling, such as **variation of the *E*1 and *M*1 strength functions** that define the γ decay from continuum levels, were **shown to be of importance** and should be studied more in detail in the context of (n, $n\gamma$) reactions.

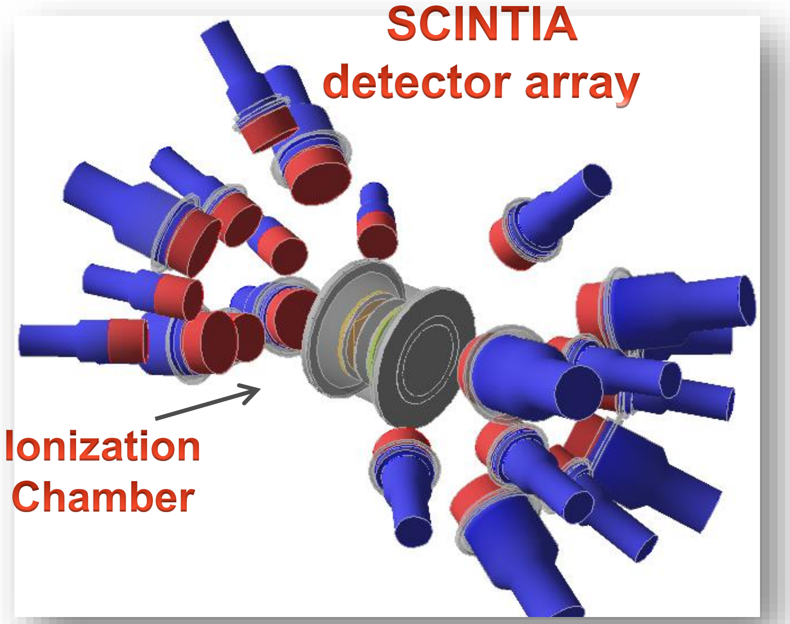


To come next: 20 others (n, n'γ) XS but also (n, 2nγ) and (n, 3nγ) XS

GELINA - Experimental set-ups

Fission studies

– **10 m**



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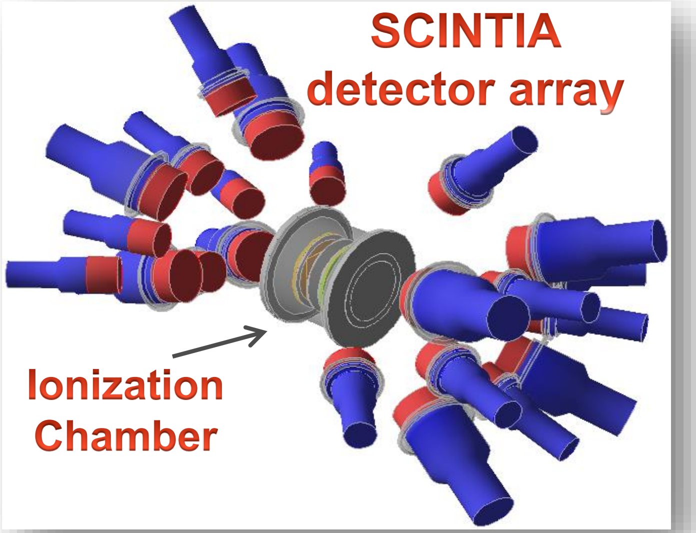
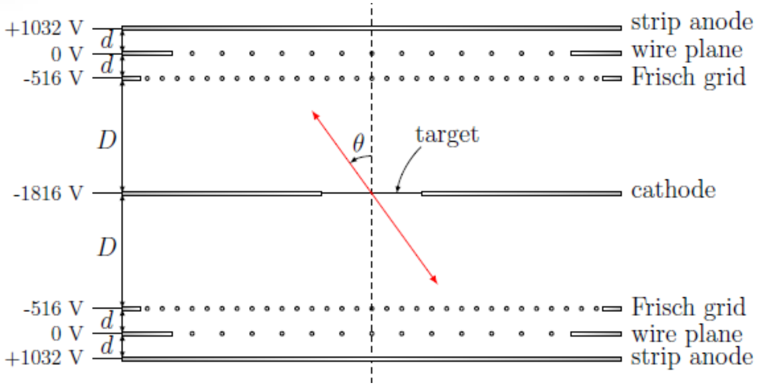
Fission fragment properties and prompt fission neutrons

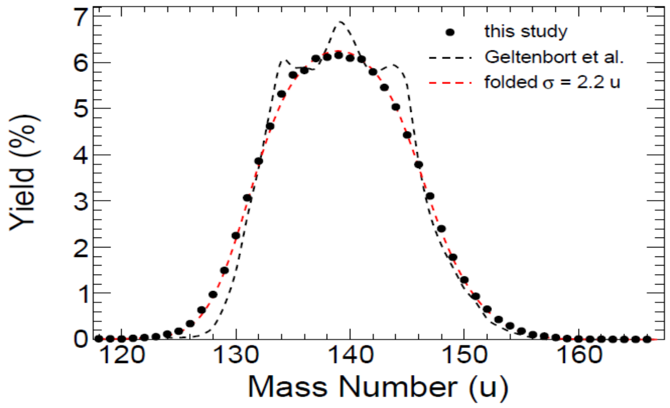


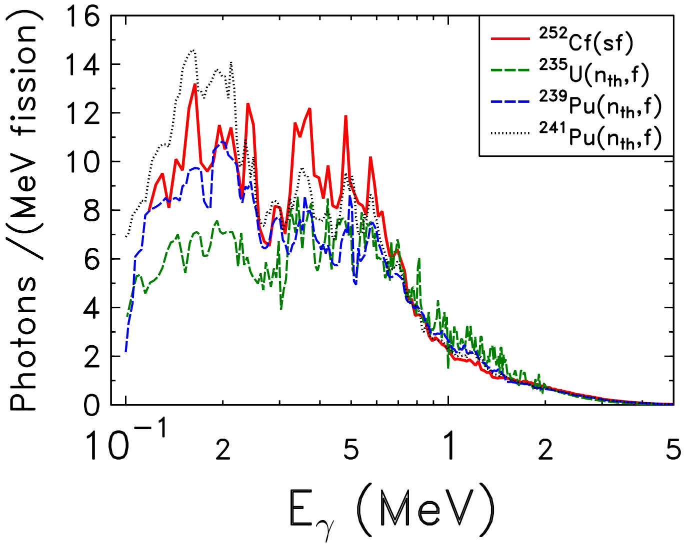
- Fission fragments by **twin position sensitive IC** (2PIC)
  - Fragment energy
  - Fragment masses - 2E-technique
  - Fission axis orientation
- Prompt fission neutrons
  - 22 x **Scintillators**
  - Energy : time-of-flight



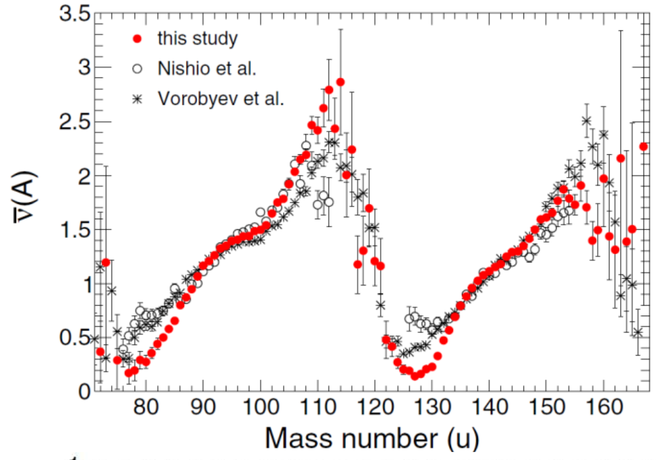
Position sensitive electrode

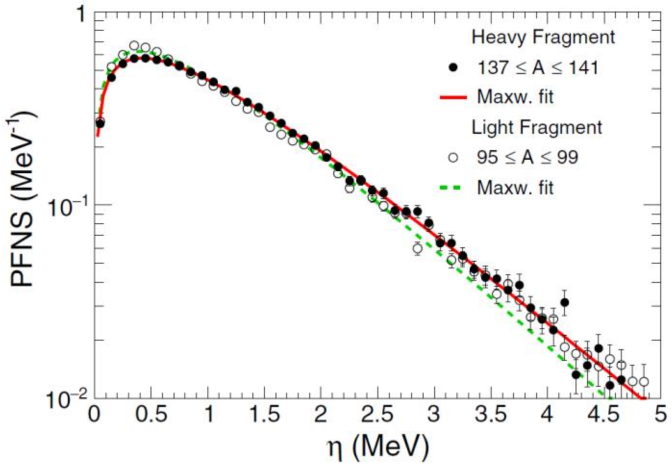
^{235}U(n,f) FP + prompt fission neutrons + γ-rays





Oberstedt et al., EPJ A 51 (2015) 178

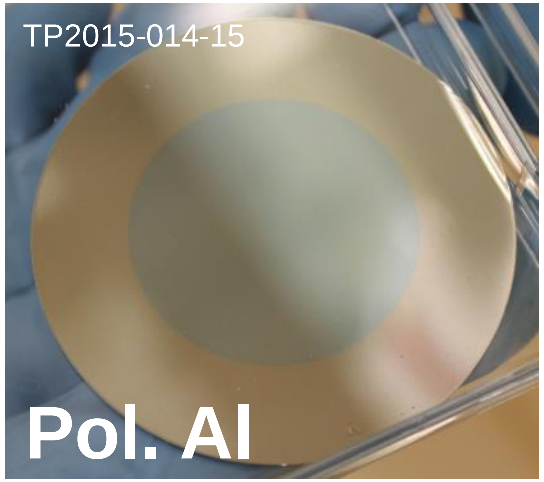




Göök et al., PRC98, 044615 (2018)

Target Preparation

- Vacuum deposition



<u>material</u>: ^{238}U

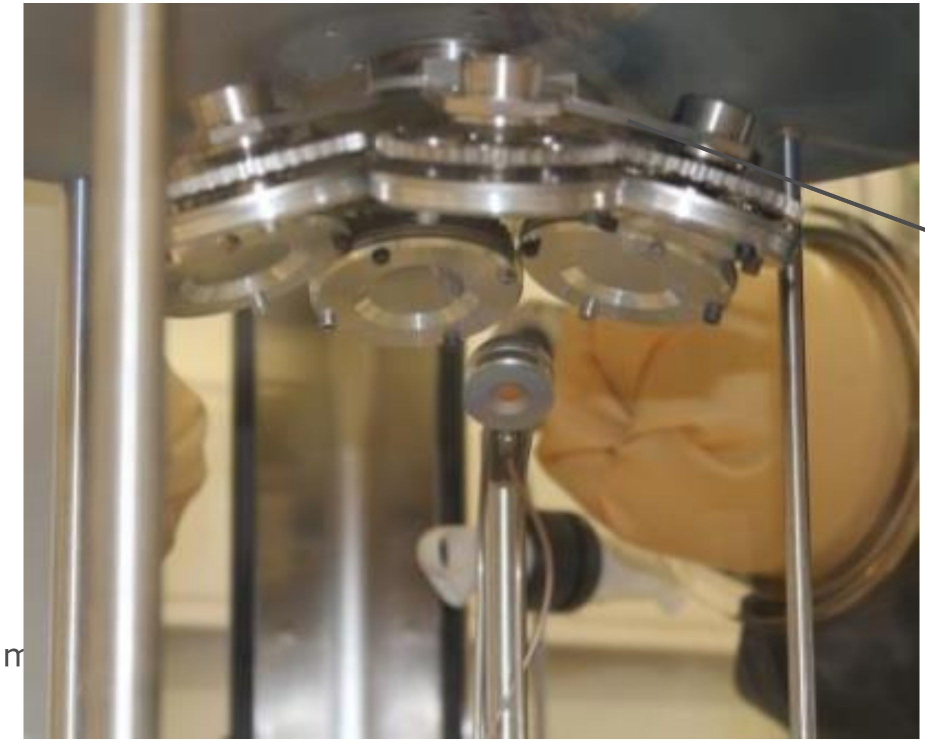
<u>method</u>: vacuum deposition

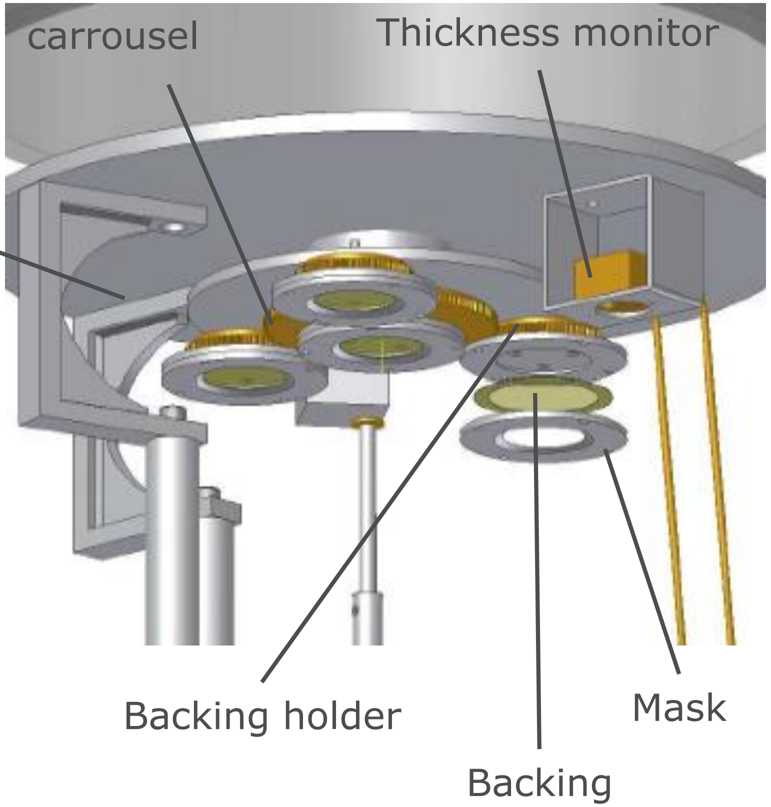
<u>deposit diameter</u>: 30 mm

<u>substrate</u>: 0.25 mm thick, Ø 50 mm

<u>mass</u> ^{238}U : 0.3 mg

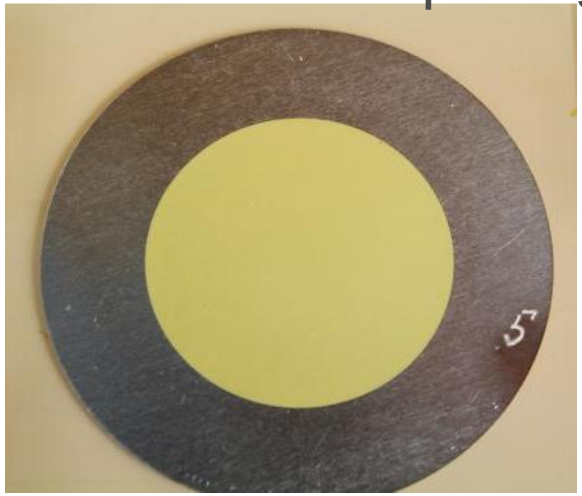
<u>areal density</u> ^{238}U : 48 µg cm^{-2}

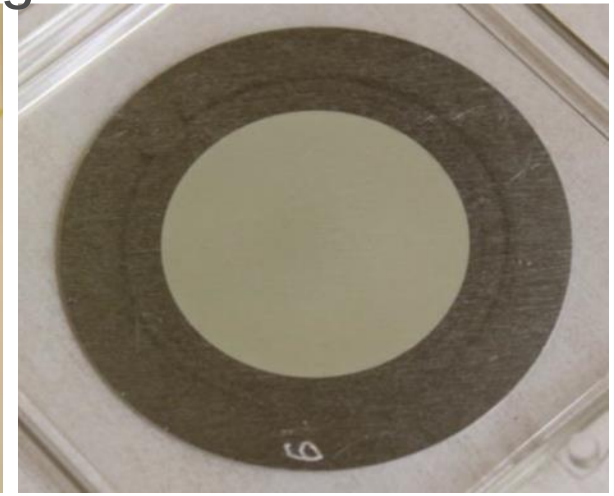


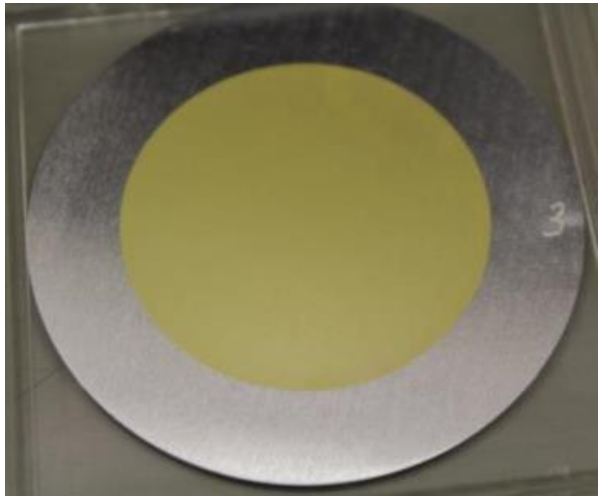


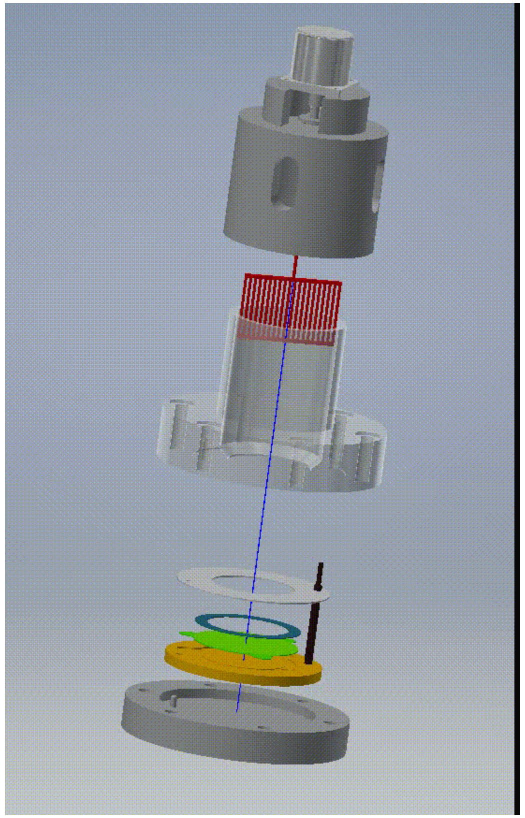
Target Preparation

- Molecular plating









^{238}U layer

Material: 99.999% ^{238}U

Deposit Ø: 30 mm

Backing: 0.25 mm Al Ø 50 mm

Mass ^{238}U: 1.9 mg

Areal density ^{238}U: 265 μg·cm^{-2}

^{237}Np layer

Material: ^{237}Np

Deposit Ø: 30 mm

Backing: 0.25 mm Al Ø 50 mm

Mass ^{237}Np: 1.4 mg

Areal density ^{237}Np: 204 μg·cm^{-2}

^{235}U layer

Material: 99.934% ^{235}U

Deposit diameter: 40 mm

Backing: 0.25 mm Al Ø 60 mm

Mass ^{235}U : 3.5 mg

Areal density ^{235}U: 279 μg·cm^{-2}

European Commission

JRC – CERN collaboration on nuclear data

- Collaboration
  - JRC is member of the n_TOF collaboration, collaboration board and editorial board
  - JRC – Geel staff participate in experiments at n_TOF
  - JRC – Geel target preparation facilities used for experiments at n_TOF
  - nTOF collaboration members perform detector tests at GELINA
- Coordination of nuclear data measurement capabilities and expertise
- Pooling and preparation of high quality nuclear targets for nuclear data measurements
- Supporting international nuclear data projects (e.g. EXFOR, CIELO, JEFF)
- Strengthen partnership and role in European nuclear data networks, promoting infrastructures and transnational access (CHANDA, SANDA)
- Knowledge transfer and training
  - Neutron Resonance Analysis Schools (2008, 2011, 2014, 2017)
  - n_TOF winter school (2018)
  - Mobility grants: PhD students from CERN at JRC Geel

Scientific output

Physics Letters B 804 (2020) 135405

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

ELSEVIER

Measurement of the ^{154}Gd(n,γ) cross section and its astrophysical implications

Cross section **measurements** at the n_TOF facility **at CERN** have been **complemented** by transmission **measurements at GELINA** to

- improve the accuracy
- reduce the uncertainty

A B S T R A C T

The neutron capture cross section of ^{154}Gd was measured from 1 eV to 300 keV in the experimental area located 185 m from the CERN n_TOF neutron spallation source, using a metallic sample of gadolinium, enriched to 67% in ^{154}Gd. The capture measurement, performed with four C_6D_6 scintillation detectors, has been complemented by a transmission measurement performed at the GELINA time-of-flight facility (JRC-Geel), thus minimising the uncertainty related to sample composition. An accurate Maxwellian averaged capture cross section (MACS) was deduced over the temperature range of interest for s process nucleosynthesis modelling. We report a value of 880(50) mb for the MACS at $kT = 30$ keV, significantly lower compared to values available in literature. The new adopted ^{154}Gd(n,γ) cross section reduces the discrepancy between observed and calculated solar s-only isotopic abundances predicted by s-process nucleosynthesis models.

Cross sections for neutron induced capture reactions are of primary importance for a better understanding of the origin of elements heavier than iron through stellar nucleosynthesis modelling.

European Commission

Scientific output

PHYSICAL REVIEW C **104**, L032803 (2021)

Letter

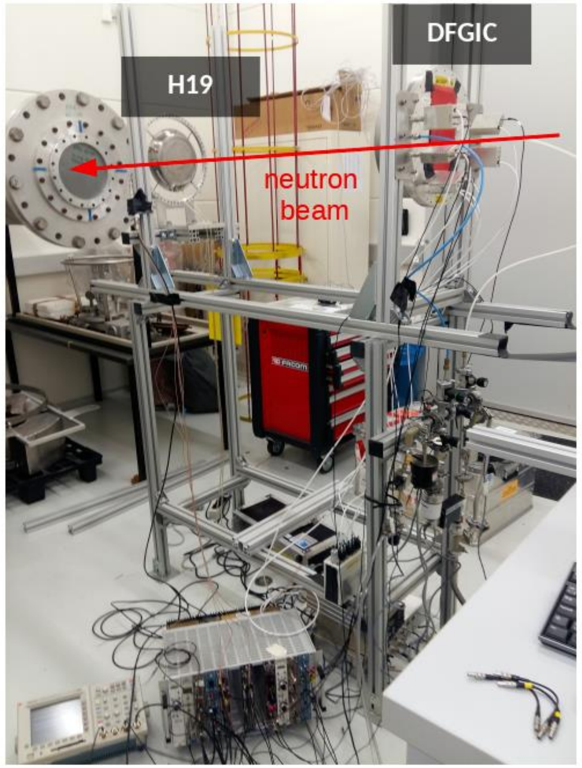
Destruction of the cosmic γ-ray emitter ^{26}Al in massive stars: Study of the key ^{26}Al(n, α) reaction

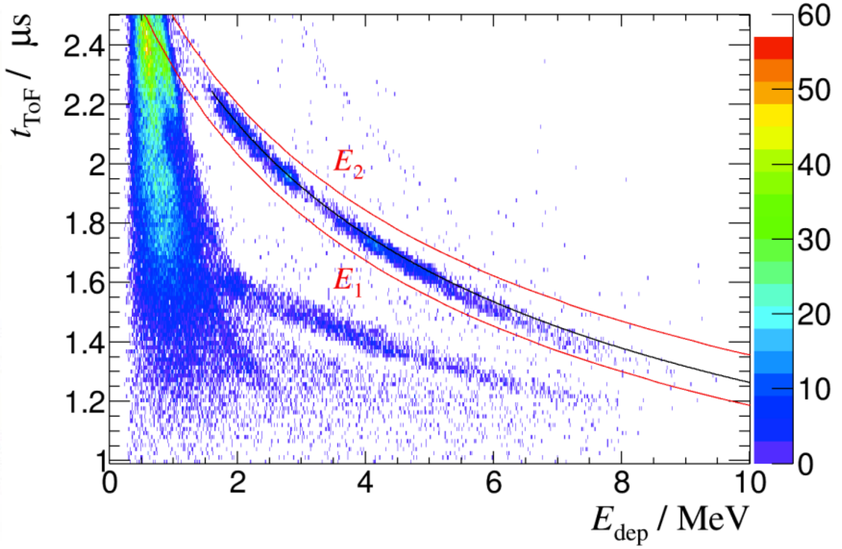
C. Lederer-Woods,[1,*] P. J. Woods,[1] T. Davinson,[1] A. Estrade,[1,†] J. Heyse,[2] D. Kahl,[1,‡] S. J. Lonsdale,[1] C. Paradela,[2]
P. Schillebeeckx,[2] O. Aberle,[3] S. Amaducci,[4,5] J. Andrzejewski,[6] L. Audouin,[7] M. Bacak,[8,3,9] J. Balibrea,[10] M. Barbagallo,[11]

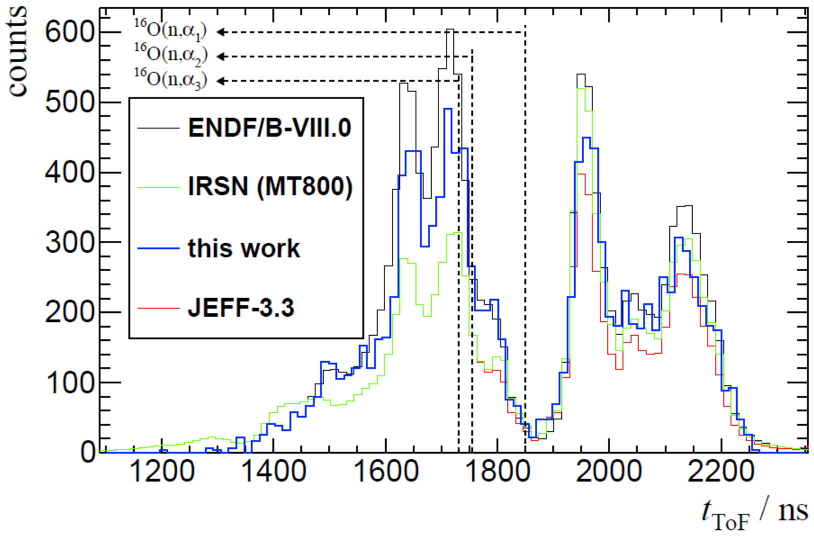
Neutron destruction reactions of the cosmic γ-ray emitter ^{26}Al are of importance to determine the amount of ^{26}Al ejected into our galaxy by supernova explosions and for ^{26}Al production in asymptotic giant branch stars. We performed a new measurement of the ^{26}Al(n, α) reaction up to 160-keV neutron energy at the neutron time-of-flight facilities n_TOF at CERN and GELINA at EC-JRC. We provide strengths for ten resonances, six of them for the first time. We use our data to calculate astrophysical reactivities for stellar temperatures up to 0.7 GK. Our results resolve a discrepancy between the two previous direct measurements of this reaction, and indicate higher stellar destruction rates than the most recently recommended reactivity.

$^{16}O(n,a)^{13}C$

- Sebastian Urlass, CERN, HZDR







S. Urlass[1], A. Plompen[2], A. Junghans[1], S. Kopecky[2], R. Beyer[1], T. Kögler[1], A. Göök[2], M.Nyman[2], C. Paradela[2], P. Schillebeeckx[2] and L. Tassan-Got[3].

Summary

- JRC – Geel infrastructure for neutron data measurements:
  - GELINA neutron time-of-flight facility
  - MONNET quasi mono-energetic neutron facility
  - Target preparation laboratory
- Support to nuclear data applications – evaluated nuclear data libraries (JEFF)
  - Neutron induced reactions
  - Fission observables
  - Detector development
  - Target preparation
  - Validation measurements
  - Evaluations
- Emphasis on collaborations with stakeholders
- Open Access (EUFRAT)

  https://ec.europa.eu/jrc/en/research-facility/open-access