European Commission

Experiments in Europe

Arjan Plompen

WPEC-33, 13 May 2021

Joint Research Centre

Sources

- JRC Geel
- n_TOF, CERN
- IFIN-HH, Bucharest
- CNRS/IPHC, Strasbourg
- HZDR Elbe, Dresden
- PTB, Braunschweig
- SANDA

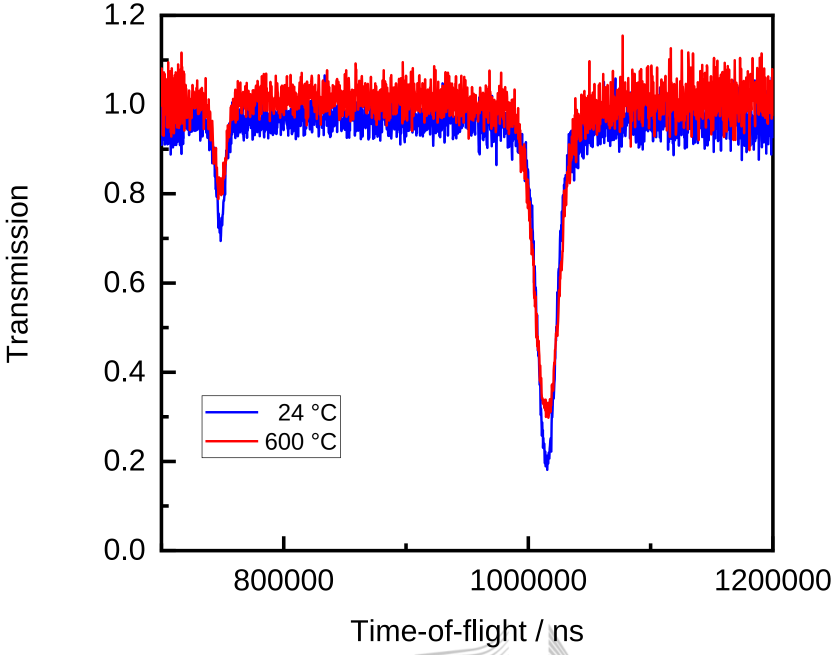
European Commission

ANDANTE: highlight

GELINA:

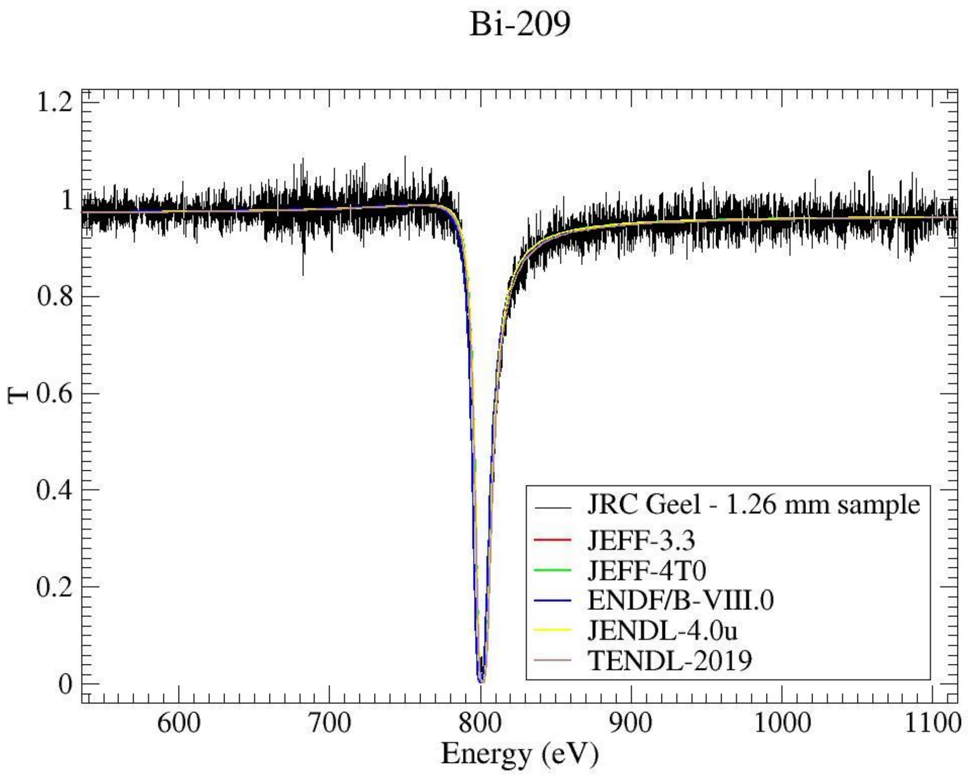
new transmission station for **high temperature cross section measurements** to study the **Doppler effect**

Comparison of experimental transmission for 1 mm W sample at room temperature and at 600° C



Bismuth_MYRRHA EUFRAT proposal

- To improve the evaluated data for Bismuth
- Included in EC Horizon2020 Project SANDA



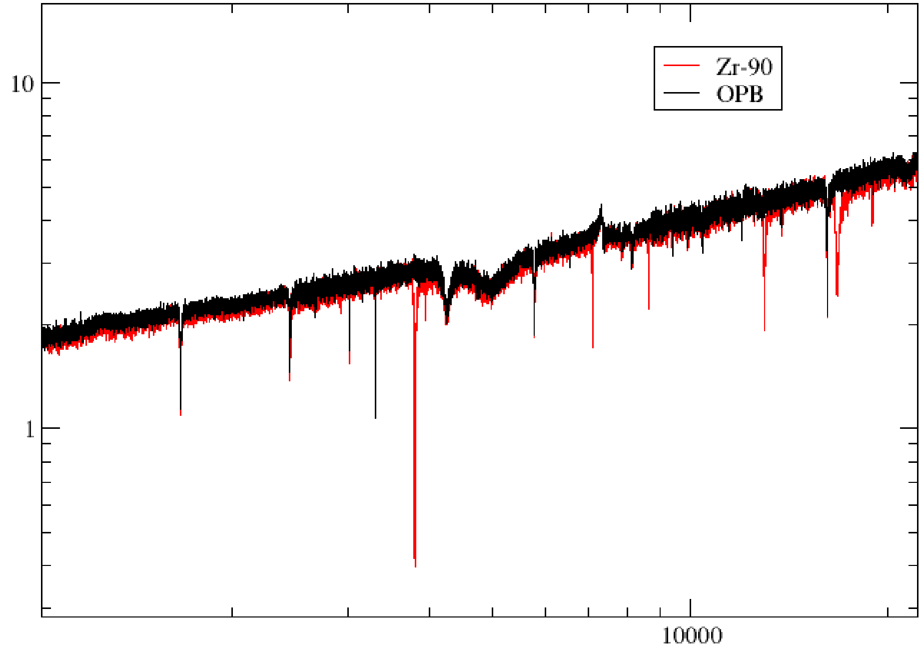
Comparison of experimental transmission for 1.26 mm sample with state-of-the-art nuclear data libraries at ^{209}Bi first resonance (802 eV).

Contributions to EXFOR database in 2020

- Results of time-of-flight transmission measurements for ^{nat}Ag at a 10 m station of GELINA R,INDC(EUR)-0036,2020. EXFOR entry 23533 (within EUFRAT).
- Results of time-of-flight transmission measurements for $^{155,157}Gd$ at a 10 m station of GELINA R,INDC(EUR)-0037,2020. EXFOR entry 23727 (within EUFRAT).
- Results of time-of-flight transmission measurements for ^{103}Rh at a 50 m station of GELINA . R,INDC(EUR)-0034,2020 . EXFOR entry 23455.

Criticality safety programme

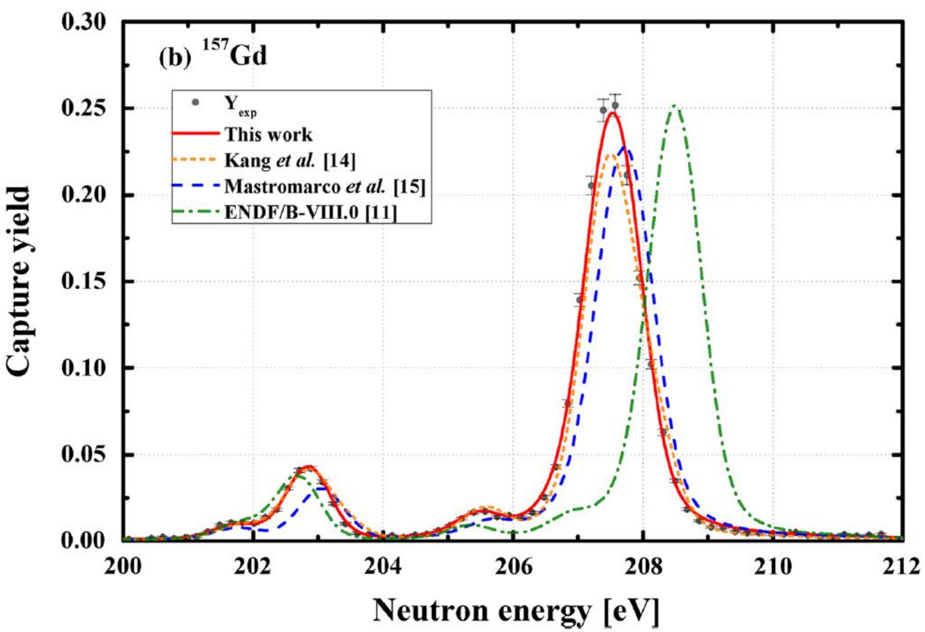
- ORNL DoE collaboration
- ^{nat}Ca and ^{nat}Ce reported and included in EXFOR (entries 23405 and 23322)
- ^{nat}V and ^{142}Ce recently submitted to EXFOR (in approval by NNDC)
- Currently transmission and capture experiments on ^{90}Zr ongoing.



Preliminary TOF spectra for ^{90}Zr transmission experiment

Experimental program on Gd isotopes

- Transmission (R,INDC(EUR)-0037,2020) and capture data (EPJA 56(2020)30) on natural and enriched isotopes.
- Evaluated data file with resonance parameters (<500 eV) in preparation.



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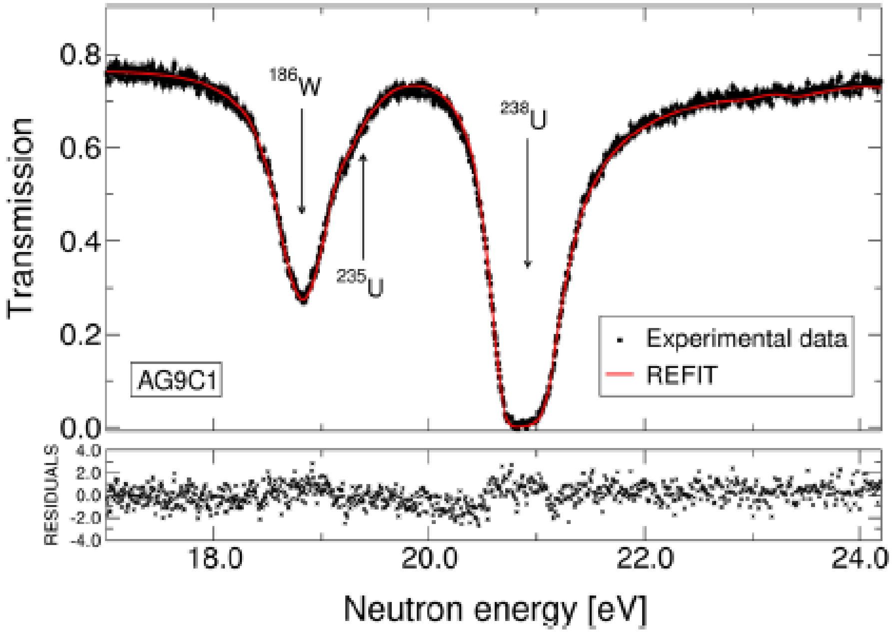
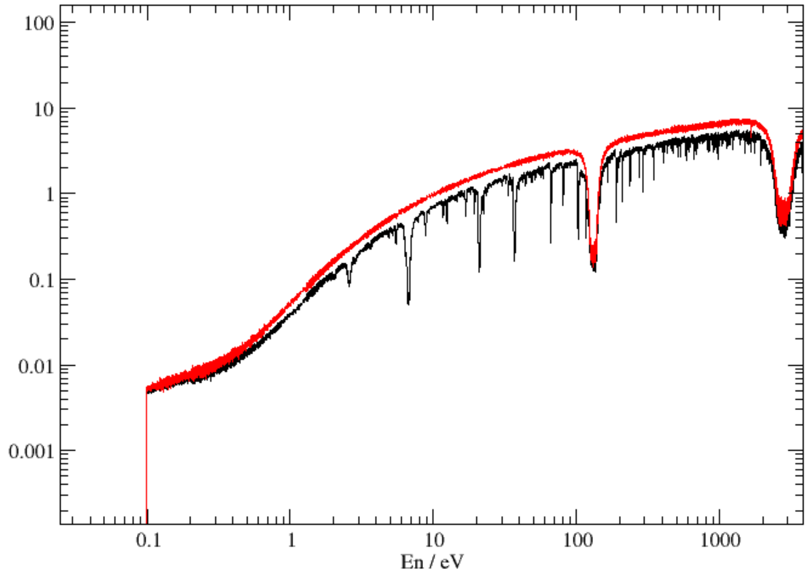
NRTA with MINERVE pellets

- Previous NRTA with pellets containing UO2 and Ag (JRNC 321 (2019) 519-530) or Tc (PRC 102 (2020) 015807)
- Currently measuring pellets containing UO2 and Gd with 5 different sizes of Gd grain to study systematic effects (EUFRAT proposal 2020 call)



NRTA for a pellet containing UO2+Ag, showing a significant amount of W not reported in the specifications

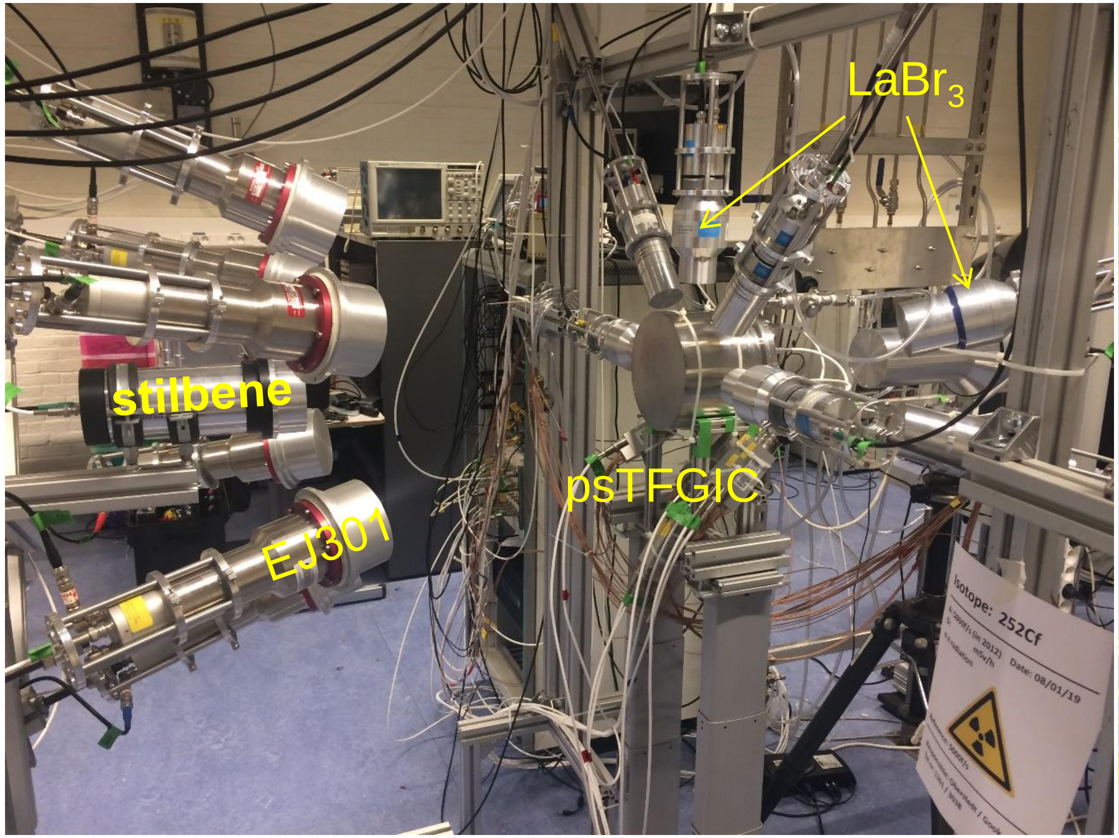


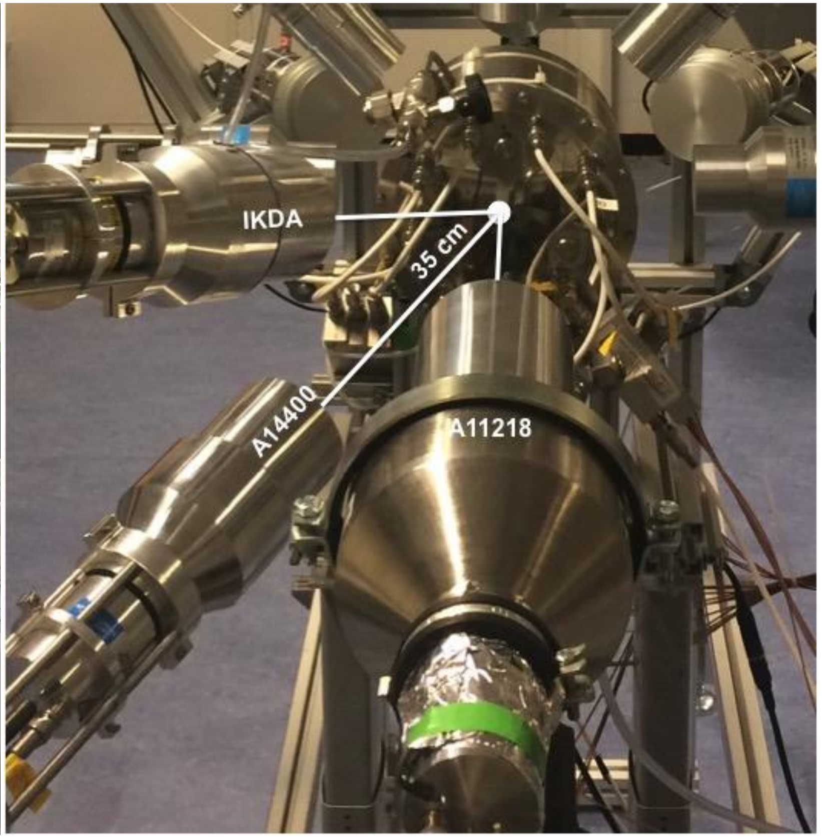
Preliminary transmission spectra for a pellet containing UO2+Gd grain

Investigation of the de-excitation process in fission fragments (Stephan Oberstedt)

- Mass- and TKE-dependent prompt fission g-ray multiplicity
- Angular distribution of g-ray emission
- Isomeric yields
- Providing data for nuclear modelling (e.g. FIFRELIN)
- Collaboration with CEA (Valentin Piau’s PhD thesis)
- Measurements performed with VESPA++
  - Position-sensitive Twin Frisch-grid Ionization Chamber (psTFGIC)
  - Lanthanum-halide detectors for g-rays
  - EJ301 and stilbene detectors for neutrons

VESPA ++





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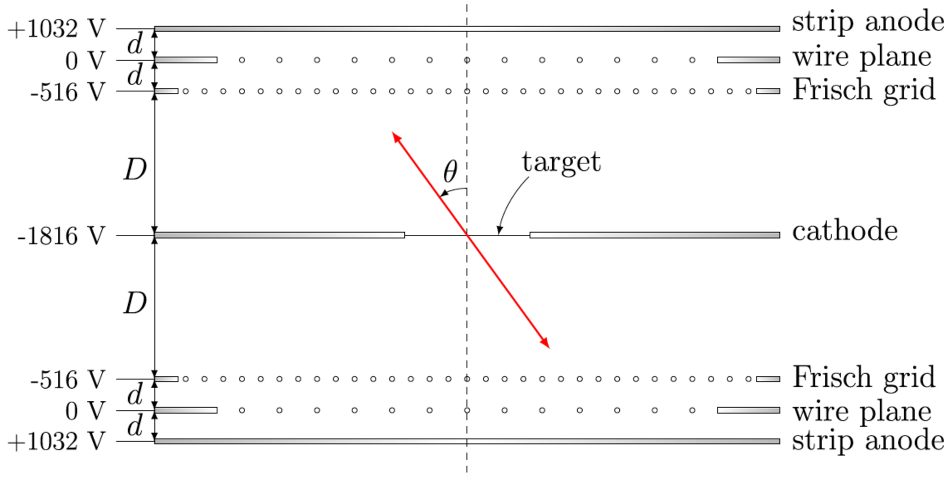
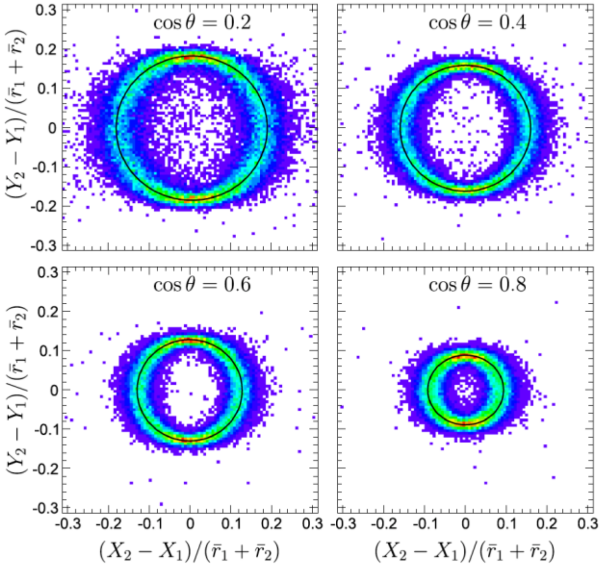
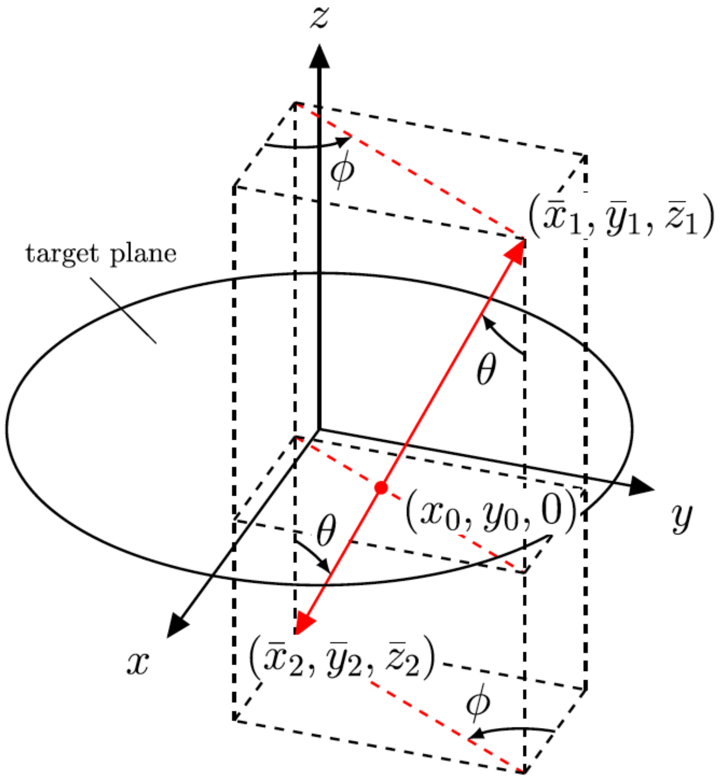
Position-sensitive FGIC

Suitable design for large targets !

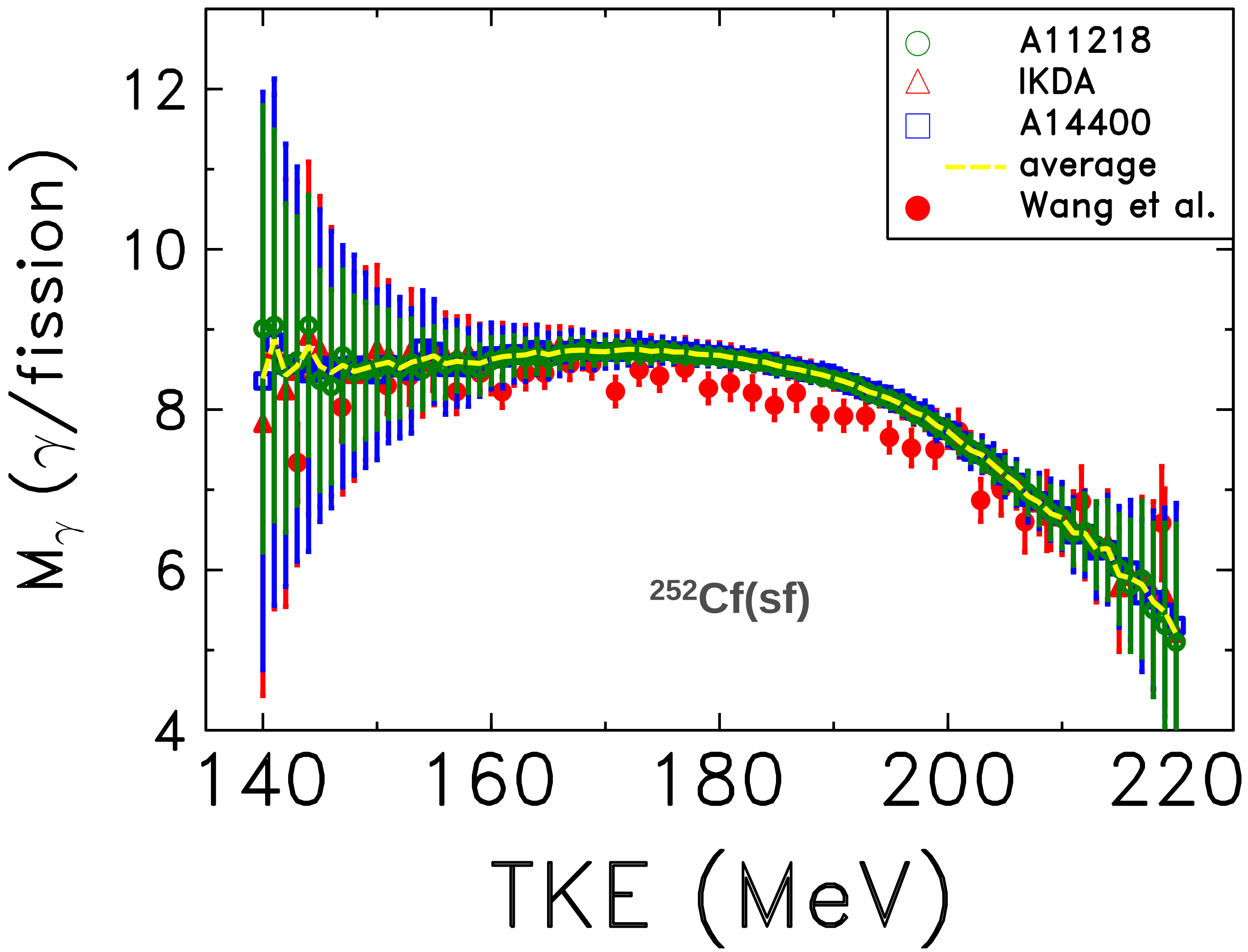


A. Göök et al., Nucl. Inst. Meth. A 830 (2016) 366–374





M_γ (TKE)



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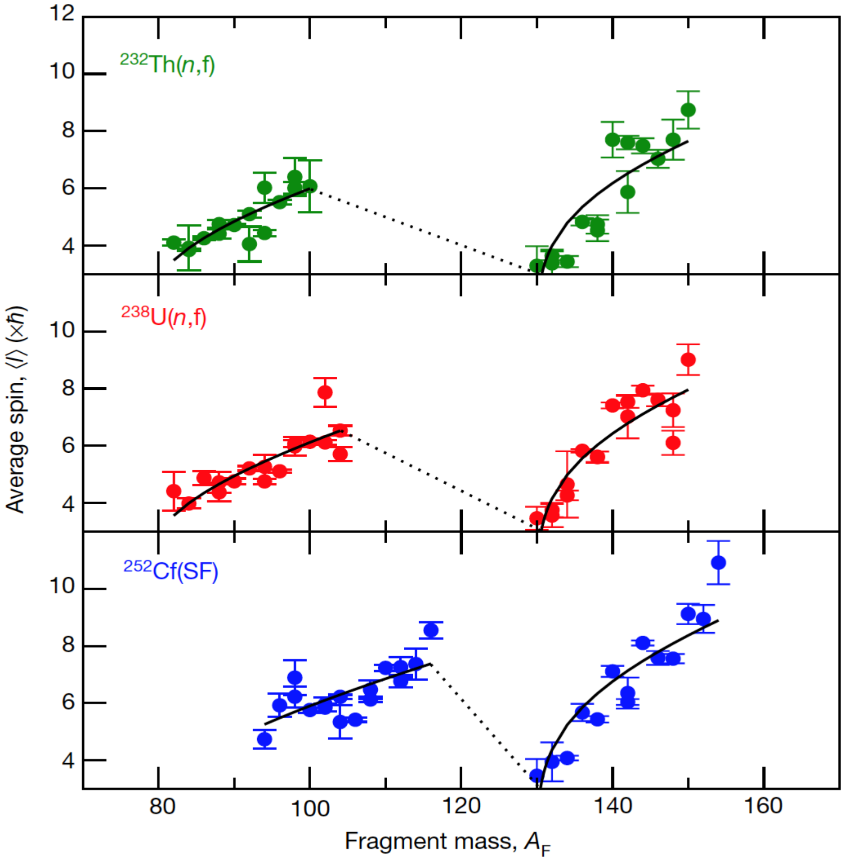
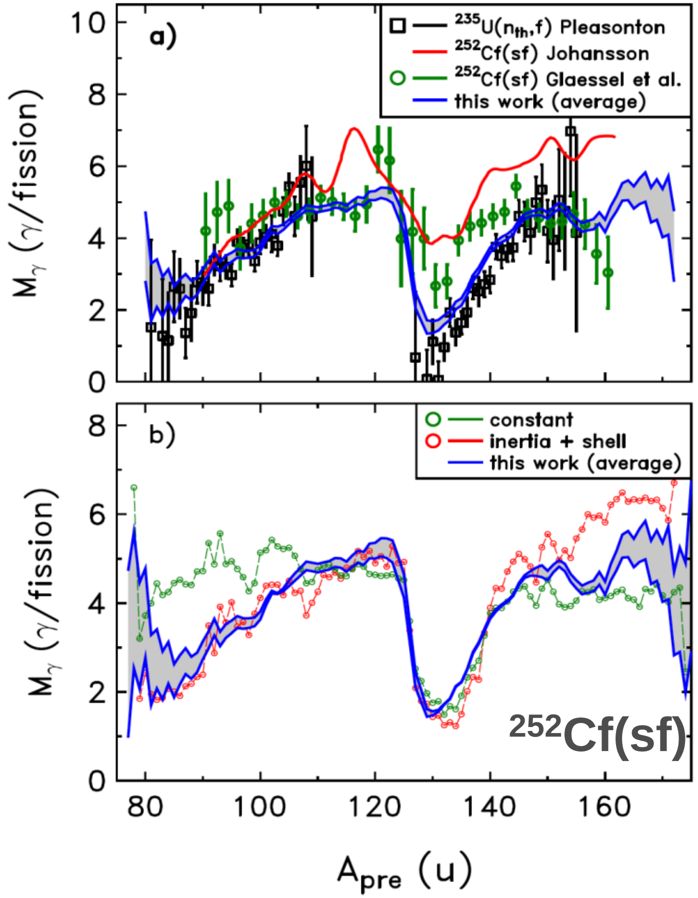
Average angular momentum and M_γ (A^*)

ν-Ball*1* (IJCLAb Orsay)



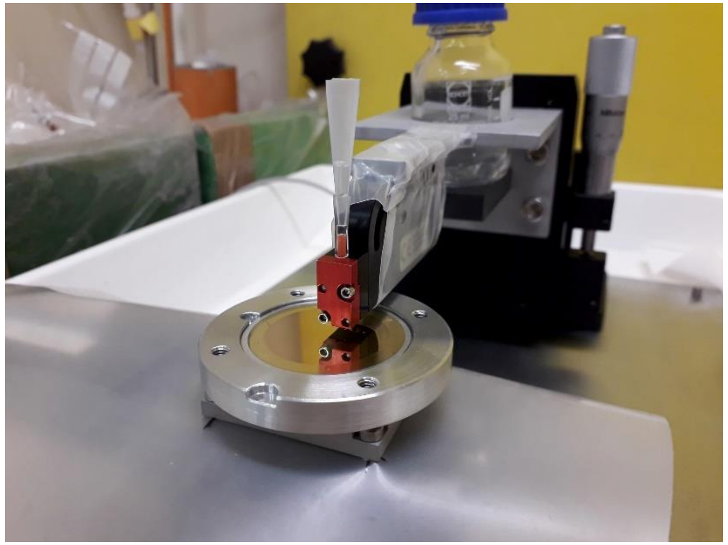
Nature 590:566 (2021)

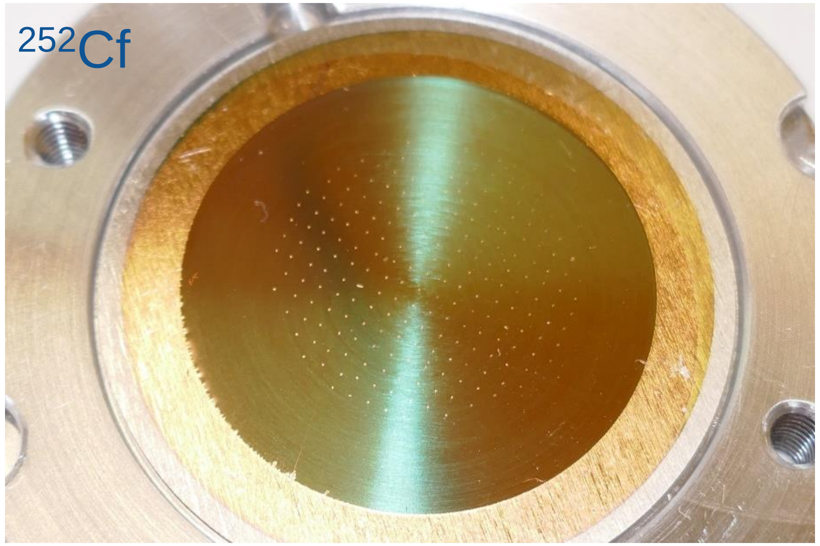
VESPA++ (JRC Geel)



Phys. Lett. B 817 (2021) 136293

Research on the fabrication of spectroscopic actinide targets





- Suitable for any isotope one can get into solution!

  K. Eberhardt et al., Johannes Gutenberg University, Mainz

  G. Sibbens et al., European Commission, JRC-Geel

  S. Oberstedt and C. Fontana sample characterization

Accelerator-based production of medical isotopes

- Irradiation of molybdenum nano-particle with neutrons or photons
    - ^{99}Mo extraction by centrifugation
    - Yield determination by means of gamma spectrometry

- Feasibility study for production of ^{225}Ac by neutrons or photons of ^{226}Ra

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ELBE nuclear facilities

- nELBE: worldwide unique photoneutron source with energies of 0.1 - 10 MeV, 10^4 s^{-1} cm^{-2} ,10 - 400 kHz, low instantaneous flux
  Fast neutron scattering, neutron transmission, neutron induced fission, time-of-flight measurements

- γELBE: worldwide unique bremsstrahlung source with endpoint energies up to 18 MeV, 10^8 photons s^{-1} cm^{-2}, cw mode, low-background setup.
  Photon scattering, photoactivation, high-resolution γ-spectroscopy.

- γELBE and nELBE are unique user facilities (**LKII**)

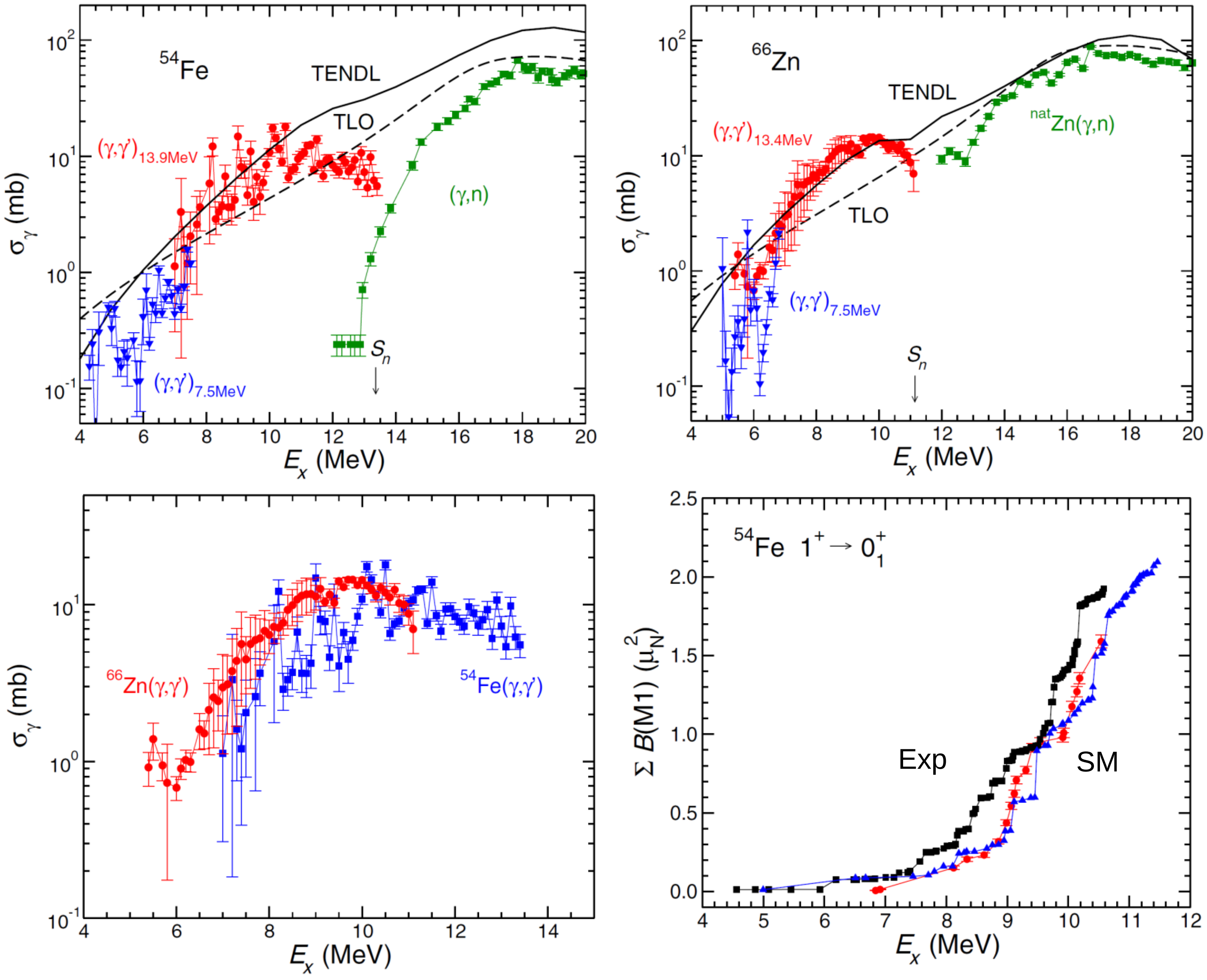
- **Uniqueness through continuous wave operation with high average currents and excellent time resolution**

Accelerator and Research reactor Infrastructures for Education and Learning ARIEL

ARIEL 09/2019- 02/2024

- EURATOM fission programme 2018
  Education & training activities; transnational access for neutron beam facilities (**Coord. HZDR**) 2 M EUR

Electric and Magnetic Dipole Strength in ^{54}Fe and ^{66}Zn



Experiments with bremsstrahlung at γELBE and with polarized, mono-energetic photons at HIγS:

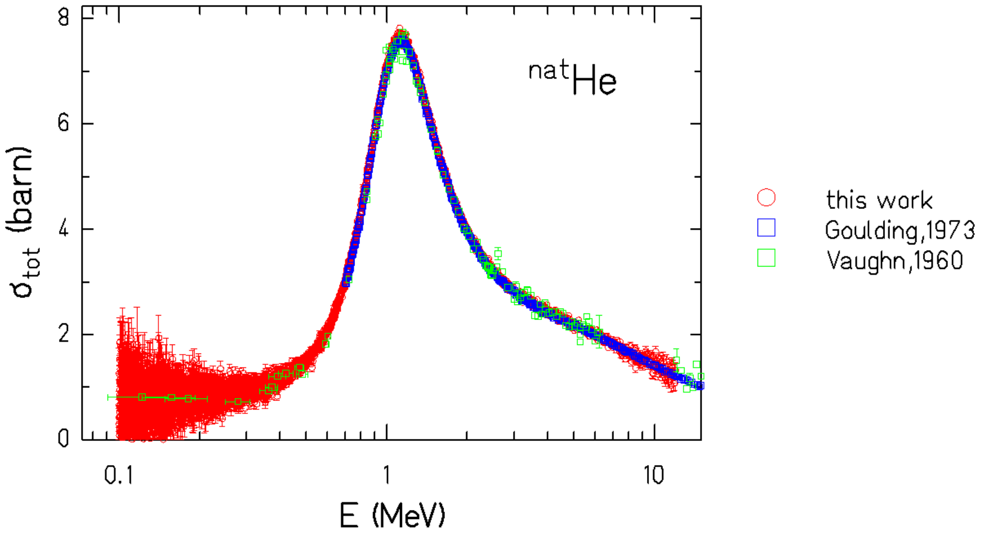
- Photoabsorption cross sections σ_γ
- Separation of discrete E1 and M1 strengths

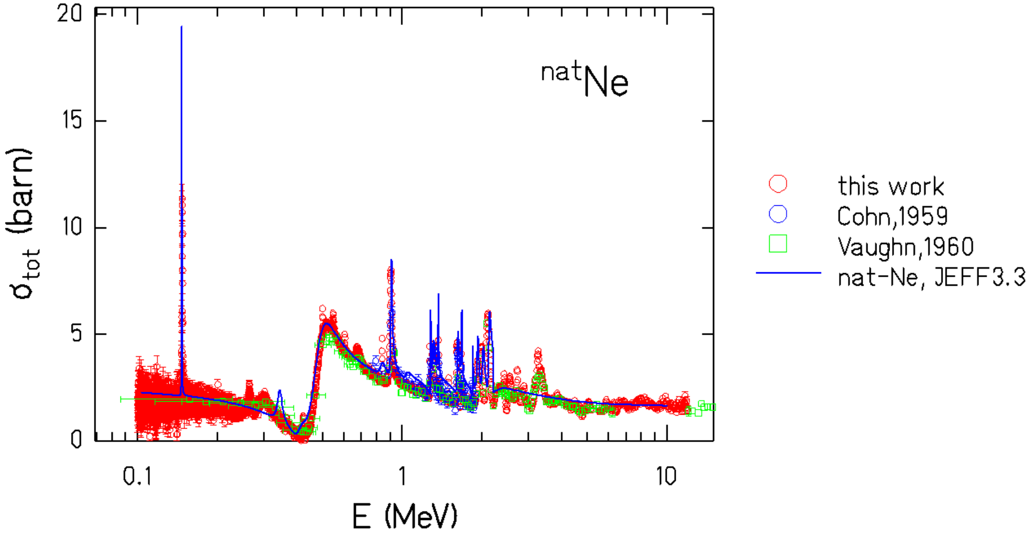
- Structures in σ_γ of ^{54}Fe (N=28)
- Smooth σ_γ in ^{66}Zn (N=36)

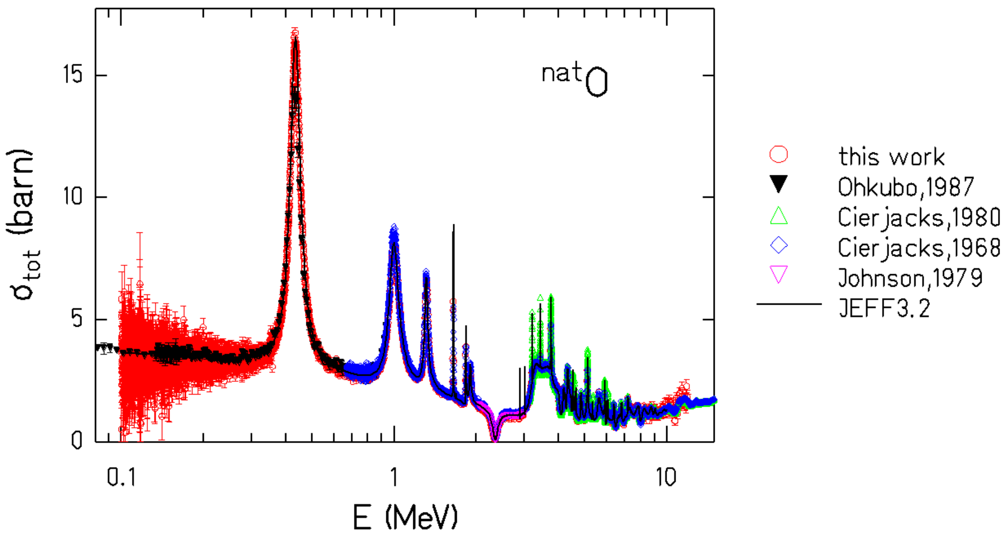
B(M1,$1^+ \rightarrow 0^+$) values compared with shell-model predictions

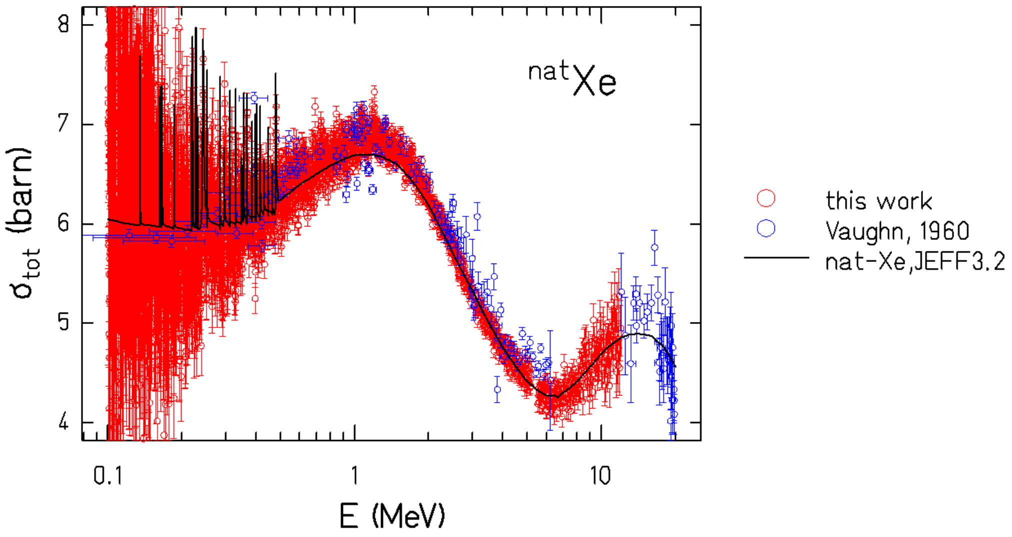
R. Schwengner *et al.*, Phys. Rev. C **101**, 064303 (2020)
R. Schwengner *et al.*, Phys. Rev. C **103**, 024312 (2021)

Transmission measurements in the fast neutron range at nELBE









A. Junghans et al., EPJ Web of Conferences **239**, 01006 (2020)

JEFDOC-2039

$^{16}O(n,\alpha)$ cross section normalization measured at GELINA

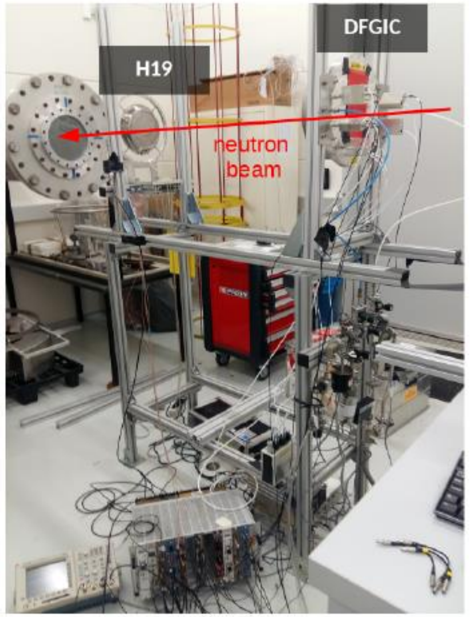
Sebastian Urlass[1],
A. Junghans[1], R. Beyer[1], T. Kögler[1], D. Weinberger[1],
G. Alerts[2], J.-C. Drohe[2], A. Göök[2], J. Heyse[2], S. Kopecky[2], S. Moscati[2], M.Nyman[2], C. Paradela[2], A. Plompen[2], P. Schillebeeckx[2], D. Vendelbo[2], M.Vidali[2], R. Wynants[2].
R. Nolte[3] and L. Tassan-Got[4].

April 21, 2021

[1] HZDR [2] JRC [3] PTB [4] IJCLab

This work forms part of the PhD thesis of Sebastian Urlass, TU Dresden 2021, in preparation.

$^{16}O(n,\alpha)$ reaction measurement at GELINA



Flight Path (FP) station 16-60m:

- neutron beam diameter: 63mm
- duration: 2 weeks (9.5 days)
- rep. rate: 400Hz

Detectors:

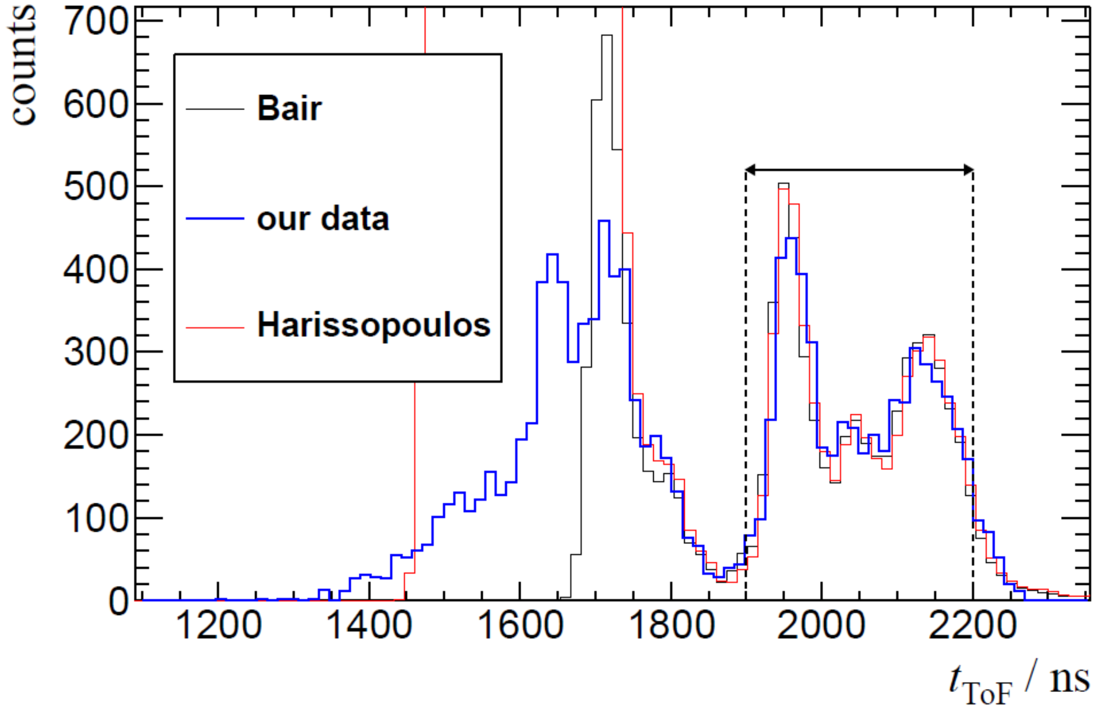
- H19 fission Ionization Chamber[1]
- Frisch Grid Ionization Chamber (FGIC)

[1] R. Nolte et al. Nucl. Sc. and En.:156, 197–210 (2007).

Sebastian Urlass, recommendation for normalization $^{16}O(n,\alpha)^{13}C$

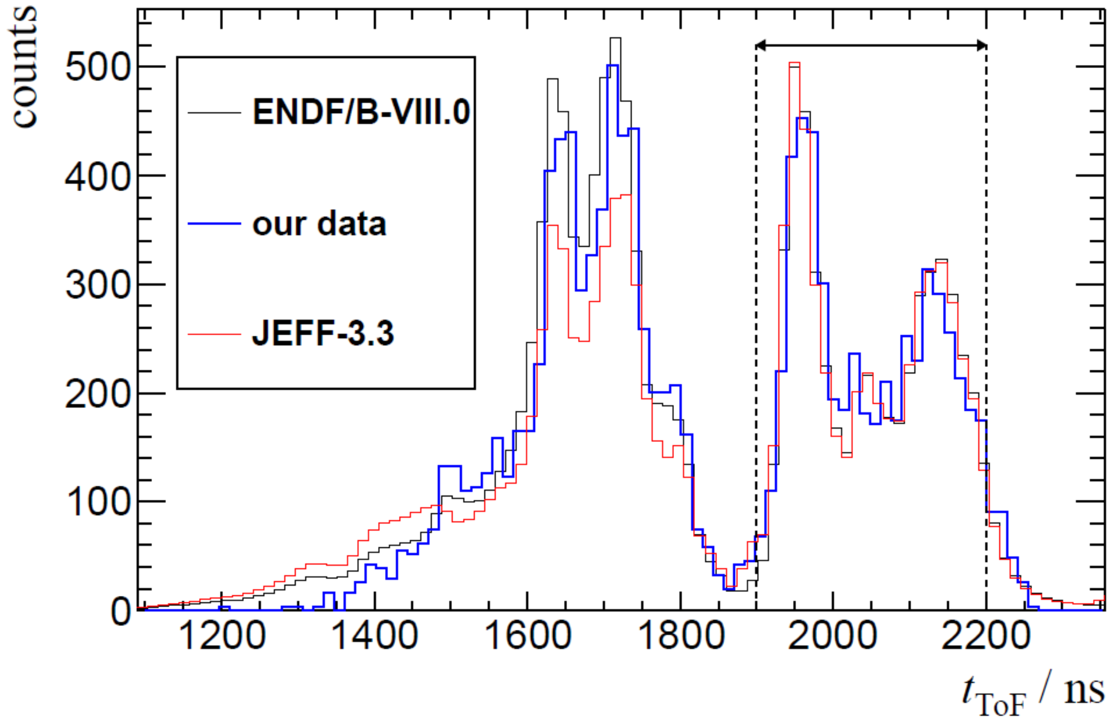
- Jefdoc-2039 (unc. 6%)

- normalization region between 1900-2200ns (4-5.3MeV)



0.86 · **Bair** and **1.31** · **Harissopoulos**

- normalization region between 1900 - 2200 ns (4 - 5.3 MeV) avoid incomplete energy deposition at higher energies



0.92 · **ENDF/B-VIII.0** and **1.26** · **JEFF 3.3**

Thick target yield measurements: $^{nat}C(n,a)$ tty

- Macklin and Gibbons (a) and Bair (b) at the ORNL van de Graaff and tandem used a large graphite sphere with BF4 proportional counters for 4pi neutron counting
- West and Sherwood at the NPL van de Graaff used a large polyethylene cylinder with ^{3}He proportional counters for 4pi neutron counting.
- Liskien and Paulsen used the JRC-Geel van de Graaff to determine the double differential spectra of the emitted neutrons. These were energy and angle integrated.

R. Macklin and J. Gibbons, "Absolute neutron yields from thick target $^{nat}C(\alpha,n)$," *Nucl. Sci. Eng.*, vol. 31, p. 343, 1968.

J. Bair, "Absolute neutron yields from alpha-particle interaction with thick targets of natural carbon," *Nucl. Sci. Eng.*, vol. 51, p. 83, 1973.

D. West and A. Sherwood, "Measurements of thick-target (α,n) yields from light elements," *Ann. Nucl. Energy*, vol. 9, p. 551, 1982.

G. Jacobs and H. Liskien, "Energy spectra of neutrons produced by alpha-particles in thick targets of light elements," *Ann. Nucl. Energy*, vol. 10, p. 541, 1983.

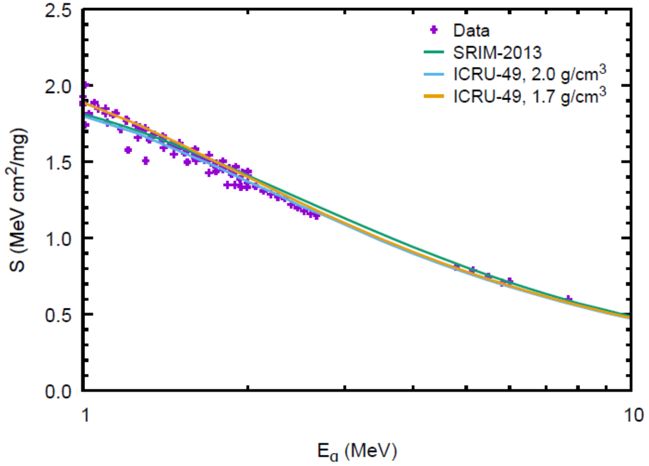
Normalization of thin target data for $^{13}C(n,a)$

- Converted to cross sections in case they were stated as S-factors (low energy)
- Converted to thick target yields when the data covered a wide enough energy range.
- Some data sets were complemented at low energy to allow a meaningful integration.

$$S(E_\alpha) = \frac{m(^{13}C)}{m(^{13}C) + m(\alpha)} E_\alpha e^{2\pi\eta} \sigma(E_\alpha)$$

$$Y(E_\alpha) = \frac{a(^{13}C) N_A}{M} \int_0^{E_\alpha} \frac{\sigma_{n,\alpha}(E)}{L(E)} dE$$

- Stopping powers L(E) were taken from SRIM and from ASTAR/ICRU-49.
- Yields vary 2% depending on the choice of L(E)



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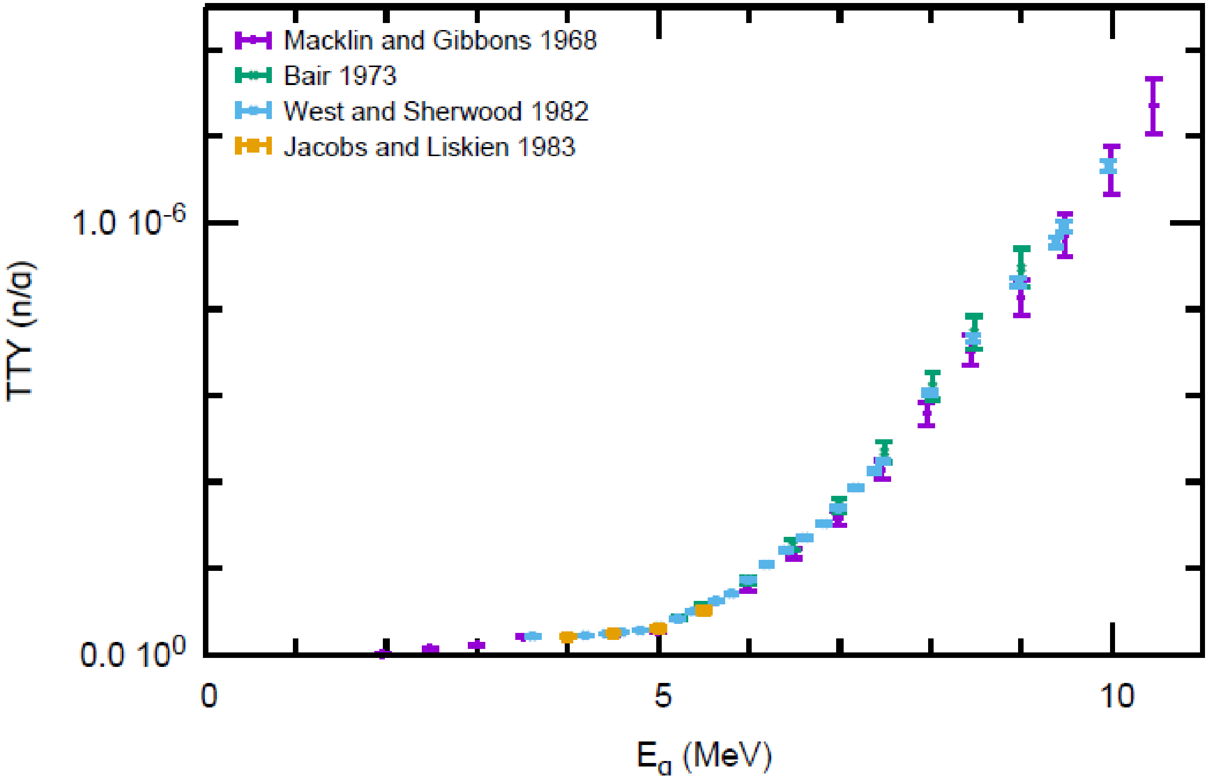
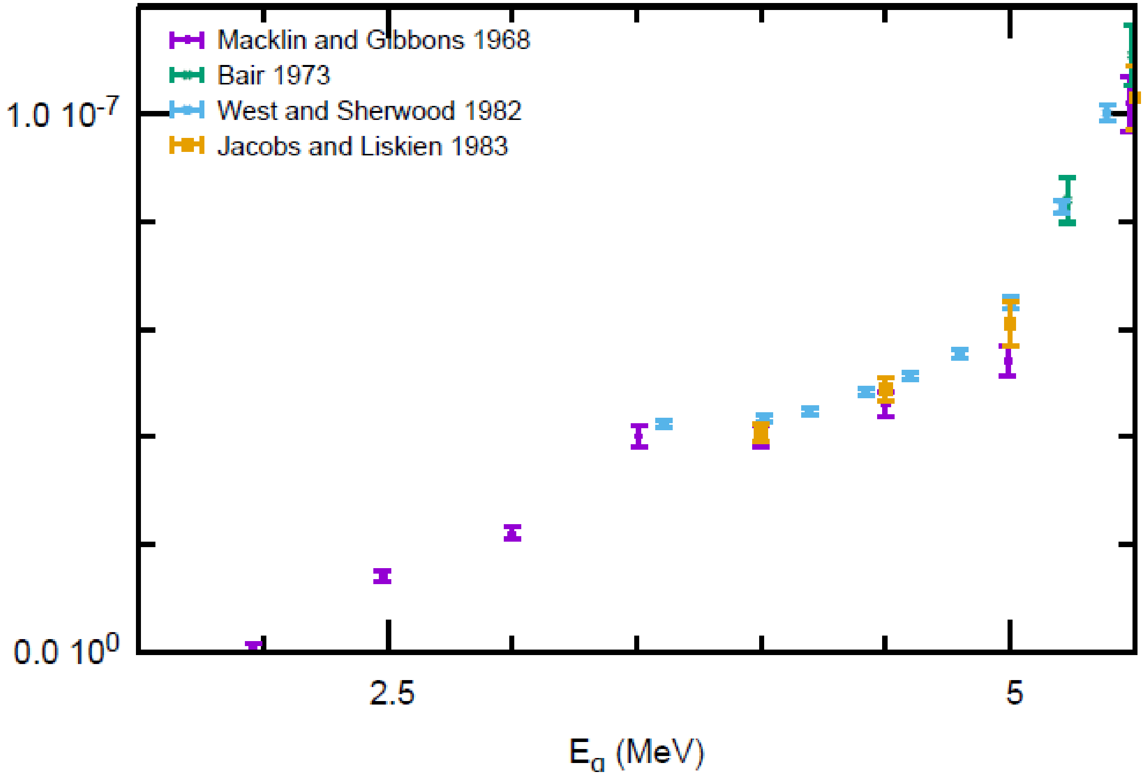
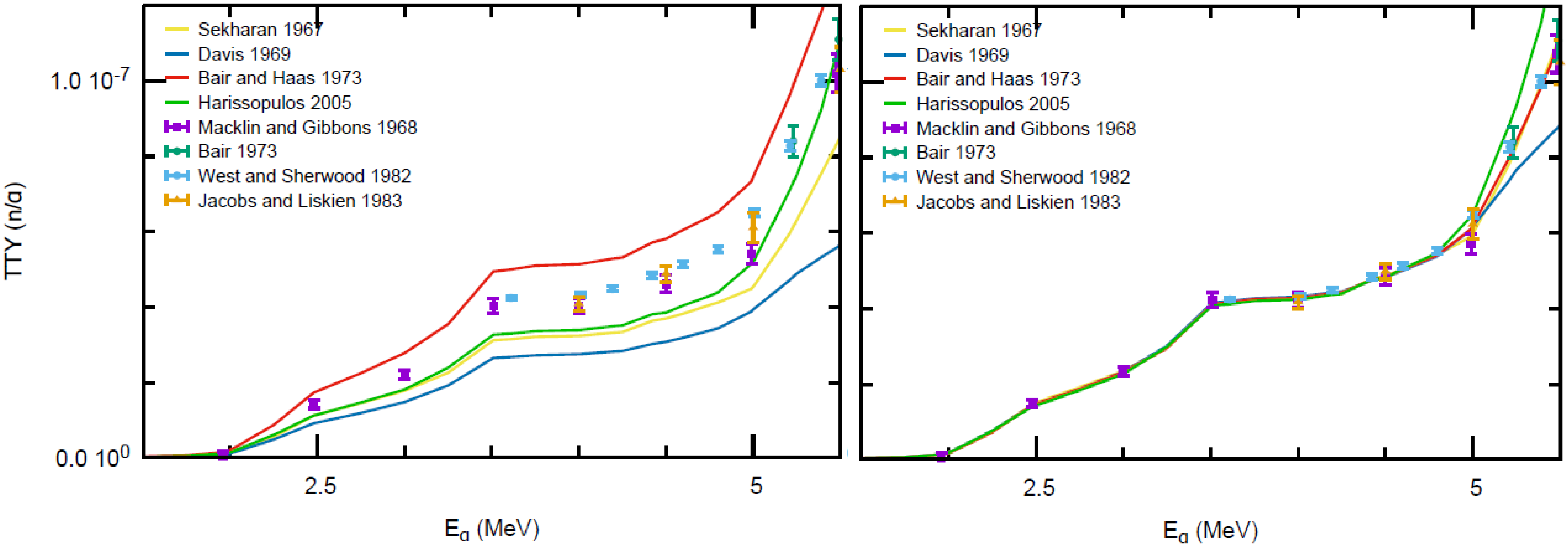
What does it look like?

- Useful range for normalization is from 3.5 to 5 MeV in E_a

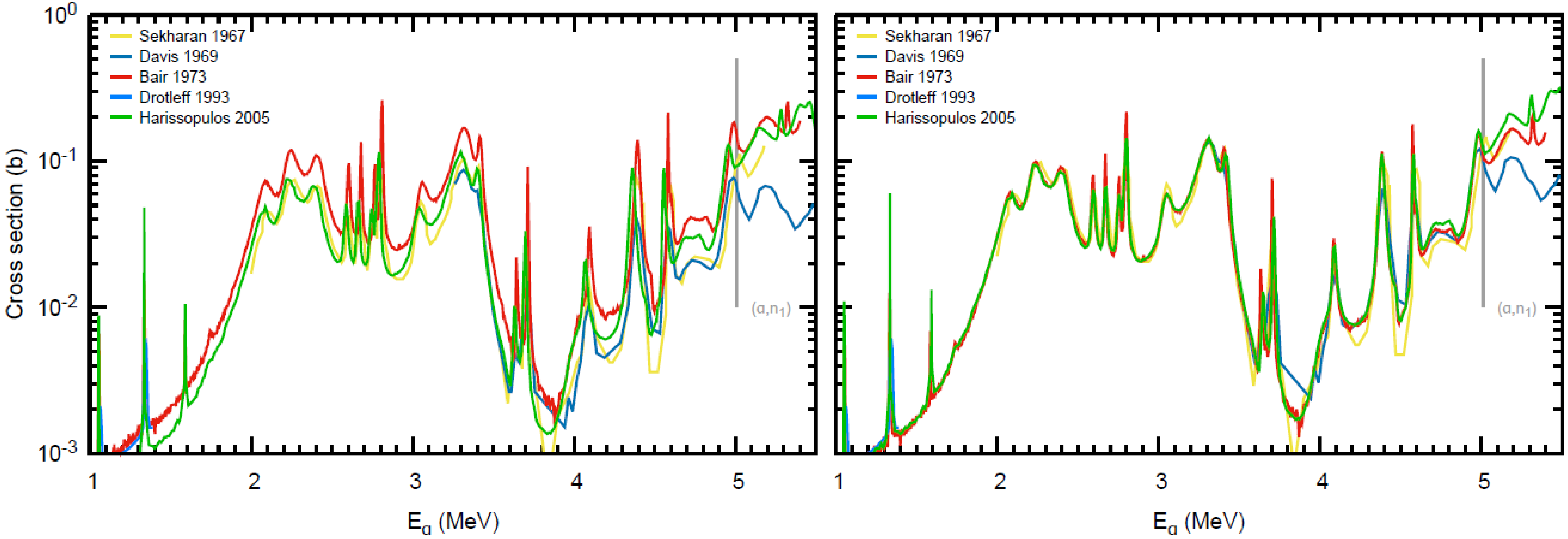




Before and after normalization: TTY



Before and after normalization: $^{16}O(n,a)$



Summary for normalization

Differences between Sebastian's work and the normalization based on West and Sherwood by me are within the uncertainty of the TTY normalization of 8%

Sebastian's work provides an excellent new experimental confirmation for the TTY results.

	Urlaß	Plompen	Pigni&Croft[3]
Reference reaction(s)	$^{16}O(n,\alpha_0)$ yield	West&Sherwood[4] $^{13}C(\alpha,n)$ TTY	Bair[5] $^{13}C(\alpha,n)$ TTY, Harissopoulos[6] reson. at 1MeV
uncertainty mainly due to	6% statistics	8% ^{13}C abundance	9% ^{13}C abundance
scaling factors			
ENDF/B-VIII.0	0.92	0.89	
JEFF-3.3	1.26	1.25	
Bair&Haas[7]	0.86	0.85	0.8
Harissopoulos[6]	1.31	1.27	1.15

Conclusions

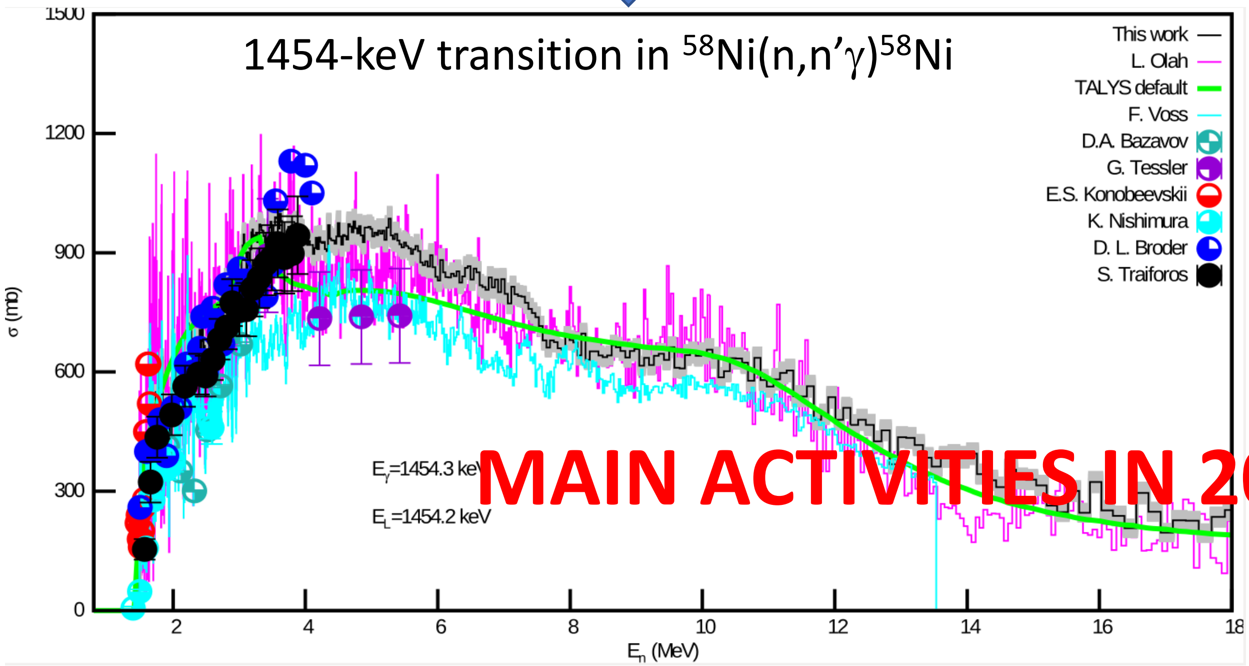
- There is now an unambiguous result for the normalization of thin target $^{13}C(a,n)$ data and historical $^{16}O(a,n)$ data.
- It is based on measurements of the thick target yield of $^{nat}C(a,n)$.
- It is confirmed by a new independent measurement by Sebastian Urlaß and coworkers from HZDR, CERN and JRC Geel that was pioneered at CERN and HZDR with final results from GELINA.
- The new evaluation of Luiz Leal (adapted since JEFF-3.3) follows the proposal of this work for the normalization.
- For energies above 5.6 MeV the new evaluation still needs a further increase of the (n,a) cross section.
- This is relevant since 50% of the $^{16}O(n,a)$ reaction occurs with E_n>5 MeV.

MAIN ACTIVITIES IN 2020 - Bucharest group

$^{nat}Ni(n,n'\gamma)^{nat}Ni$ @ GELINA

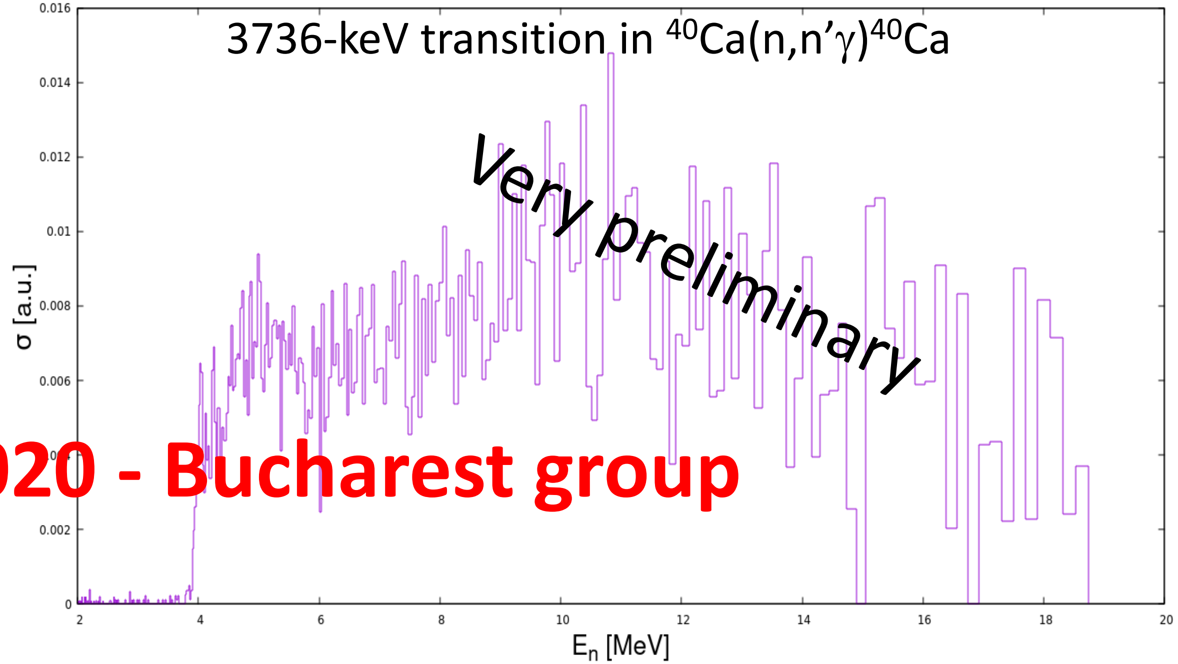
$^{58}Ni(p,p'\gamma)^{58}Ni$ @ 9-MV Tandem Accelerator of IFIN-HH, Bucharest

- Data analysis finalised for both measurements
- Article in preparation & to be submitted to Physical Review C



Ongoing experimental campaign @ GELINA

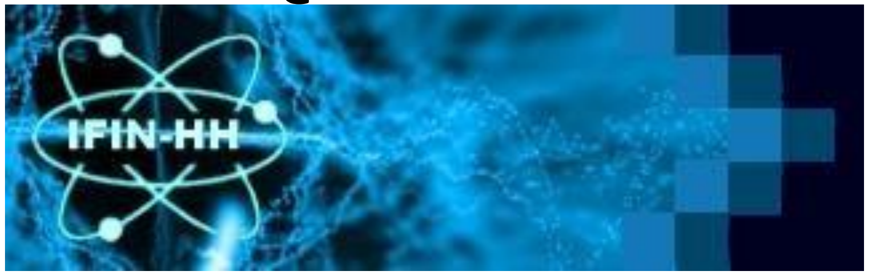
- $^{40}Ca(n,n'\gamma)^{40}Ca$ & $^{19}F(n,n'\gamma)^{19}F$ measurements
- Preliminary data analysis



$^{40}Ca(p,p'\gamma)^{40}Ca$ @ IFIN-HH

- Experiment proposed by the French collaborators (Gregoire Henning, Maelle Kerveno, Philippe Dessagne) within ARIEL
- Experiment proposal accepted by the ARIEL PAC but pending due to travel restrictions (COVID pandemic)

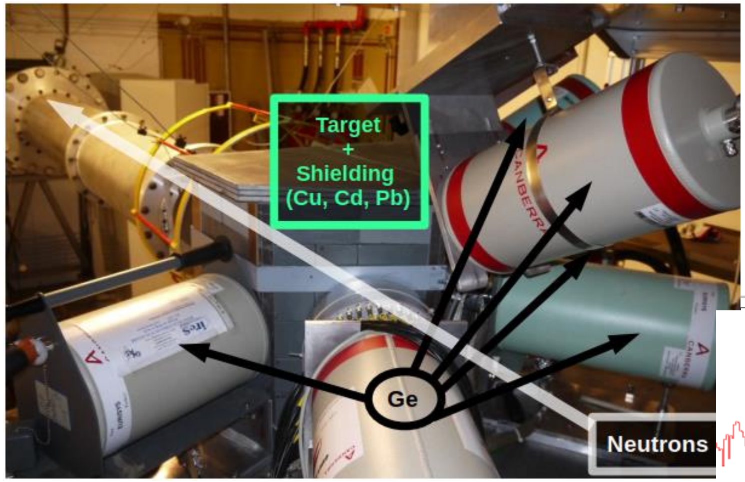
Ongoing data analysis for a previous $^{57}Fe(p,p'\gamma)^{57}Fe$ measurement @ IFIN-HH



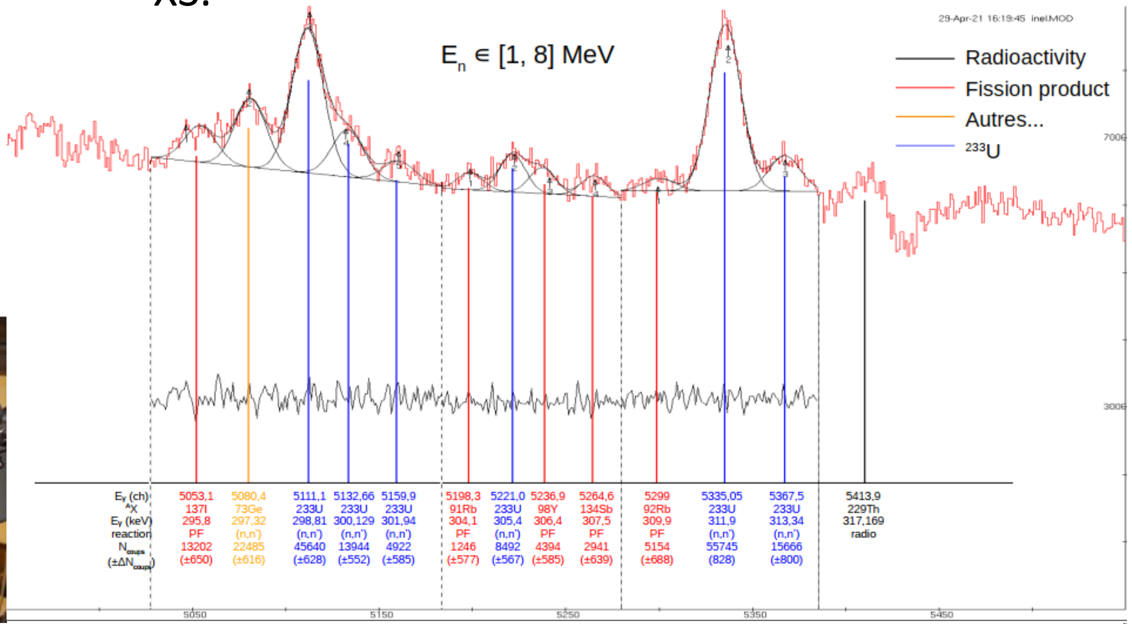
GRAPhEME

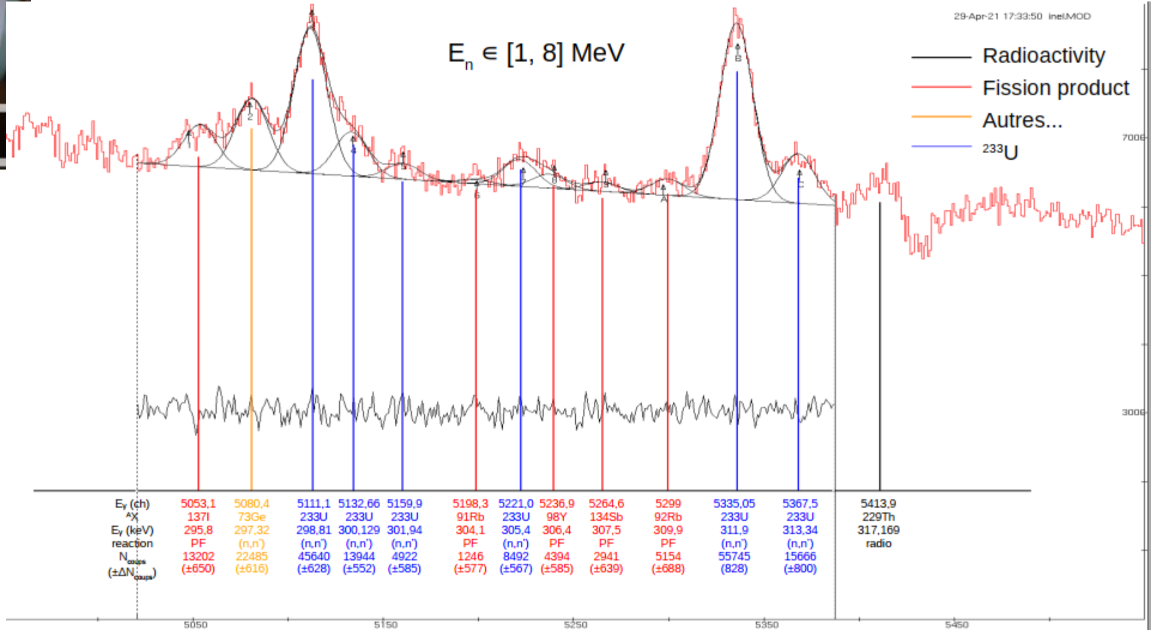
- 233U data analysis is in progress, encouraging results are coming.

PhD F. Claeys



In blue g-transitions from 233U. At least, for 6 of them, François will be able to determine XS.



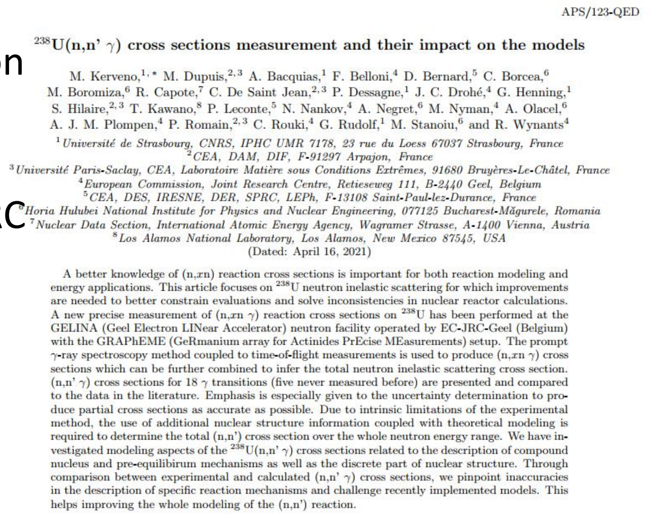


Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

GRAPhEME

- The preparation/purification of the 239Pu samples has started.
- The experimental setup will be upgraded regarding the acquisition system (FASTER) and the added of a new planar detector.

- The measured 238U(n,xn g) cross sections will be published in PRC (paper submitted). The reported work is the result of a close collaboration with theoreticians (CEA/DAM, LANL, IAEA).


APS/123-QED

^{238}U(n,n' γ) cross sections measurement and their impact on the models

M. Kerveno,[1,*] M. Dupuis,[2,3] A. Bacquias,[1] F. Belloni,[4] D. Bernard,[5] C. Borcea,[6] M. Boromiza,[6] R. Capote,[7] C. De Saint Jean,[2,3] P. Dessagne,[1] J. C. Drohé,[4] G. Henning,[1] S. Hilaire,[2,3] T. Kawano,[8] P. Leconte,[5] N. Nankov,[4] A. Negret,[6] M. Nyman,[4] A. Olacel,[6] A. J. M. Plompen,[4] P. Romain,[2,3] C. Rouki,[4] G. Rudolf,[1] M. Stanoiu,[6] and R. Wynants[4]

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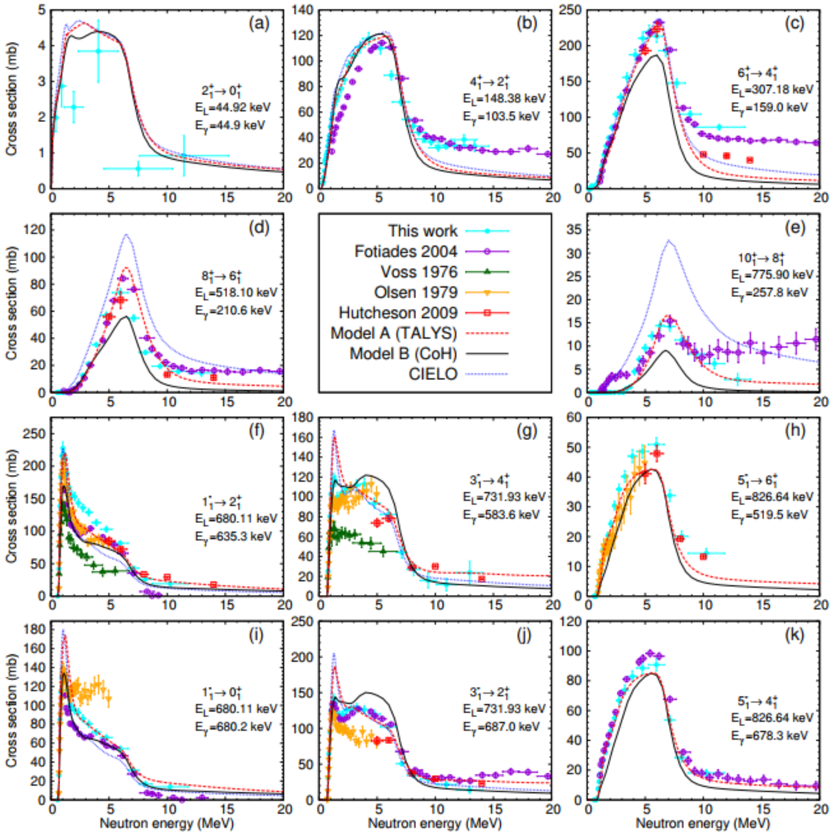
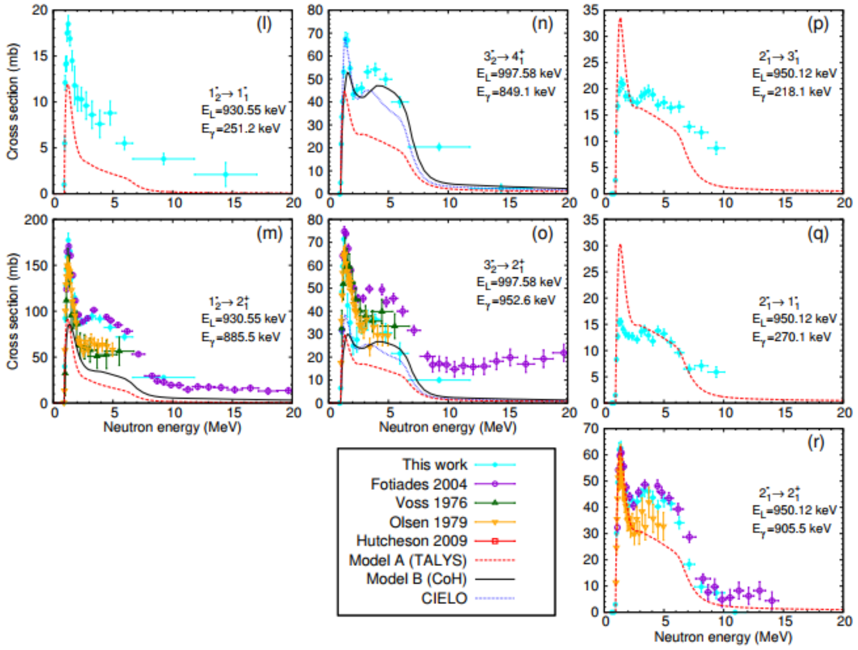
[3] *Université Paris-Saclay, CEA, Laboratoire Matière sous Conditions Extrêmes, 91680 Bruyères-Le-Châtel, France*
[4] *European Commission, Joint Research Centre, Retieseweg 111, B-2440 Geel, Belgium*
[5] *CEA, DES, IRESNE, DER, SPRC, LEPh, F-13108 Saint-Paul-lez-Durance, France*
[6] *Horia Hulubei National Institute for Physics and Nuclear Engineering, 077125 Bucharest-Măgurele, Romania*
[7] *Nuclear Data Section, International Atomic Energy Agency, Wagramer Strasse, A-1400 Vienna, Austria*
[8] *Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*

(Dated: April 16, 2021)

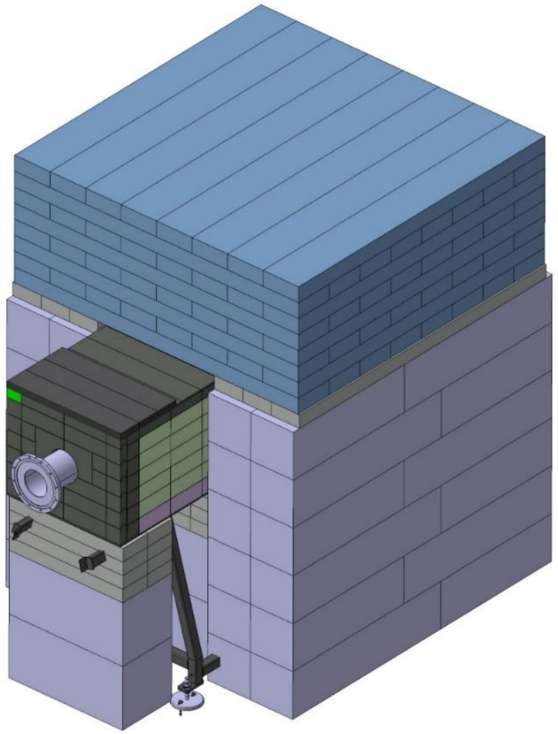
A better knowledge of (n,xn) reaction cross sections is important for both reaction modeling and energy applications. This article focuses on ^{238}U neutron inelastic scattering for which improvements are needed to better constrain evaluations and solve inconsistencies in nuclear reactor calculations. A new precise measurement of (n,xn γ) reaction cross sections on ^{238}U has been performed at the GELINA (Geel Electron LINear Accelerator) neutron facility operated by EC-JRC-Geel (Belgium) with the GRAPhEME (GeRmanium array for Actinides PrEcise MEasurements) setup. The prompt γ-ray spectroscopy method coupled to time-of-flight measurements is used to produce (n,xn γ) cross sections which can be further combined to infer the total neutron inelastic scattering cross section. (n,n' γ) cross sections for 18 γ transitions (five never measured before) are presented and compared to the data in the literature. Emphasis is especially given to the uncertainty determination to produce partial cross sections as accurate as possible. Due to intrinsic limitations of the experimental method, the use of additional nuclear structure information coupled with theoretical modeling is required to determine the total (n,n') cross section over the whole neutron energy range. We have investigated modeling aspects of the ^{238}U(n,n' γ) cross sections related to the description of compound nucleus and pre-equilibirum mechanisms as well as the discrete part of nuclear structure. Through comparison between experimental and calculated (n,n' γ) cross sections, we pinpoint inaccuracies in the description of specific reaction mechanisms and challenge recently implemented models. This helps improving the whole modeling of the (n,n') reaction.

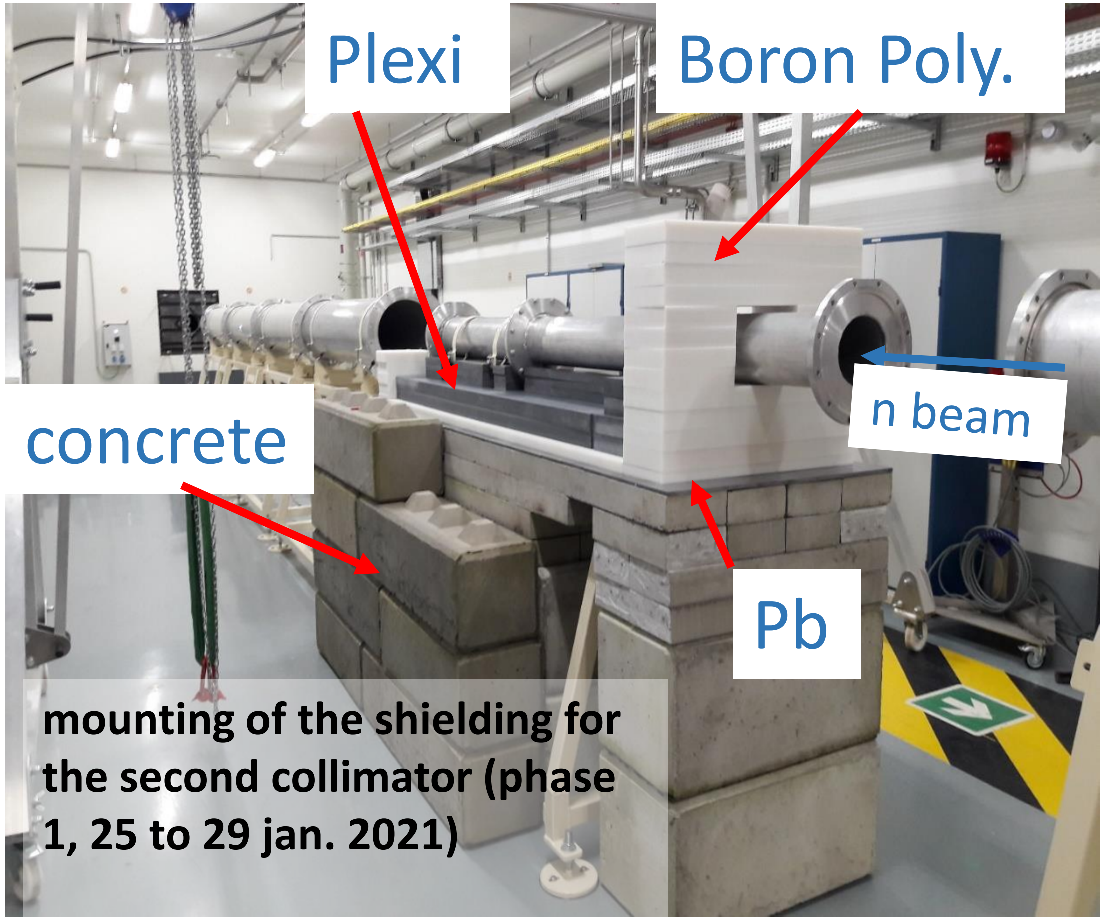




NFS

The finalization of the mounting of the second collimator with its shielding will be achieved before this summer. Beam time has been accepted by the GANIL PAC to study the background conditions at 30 m in view of the realization of (n,xn g) measurements with GAINS and GRAPhEME. The test will be performed in September 2021.



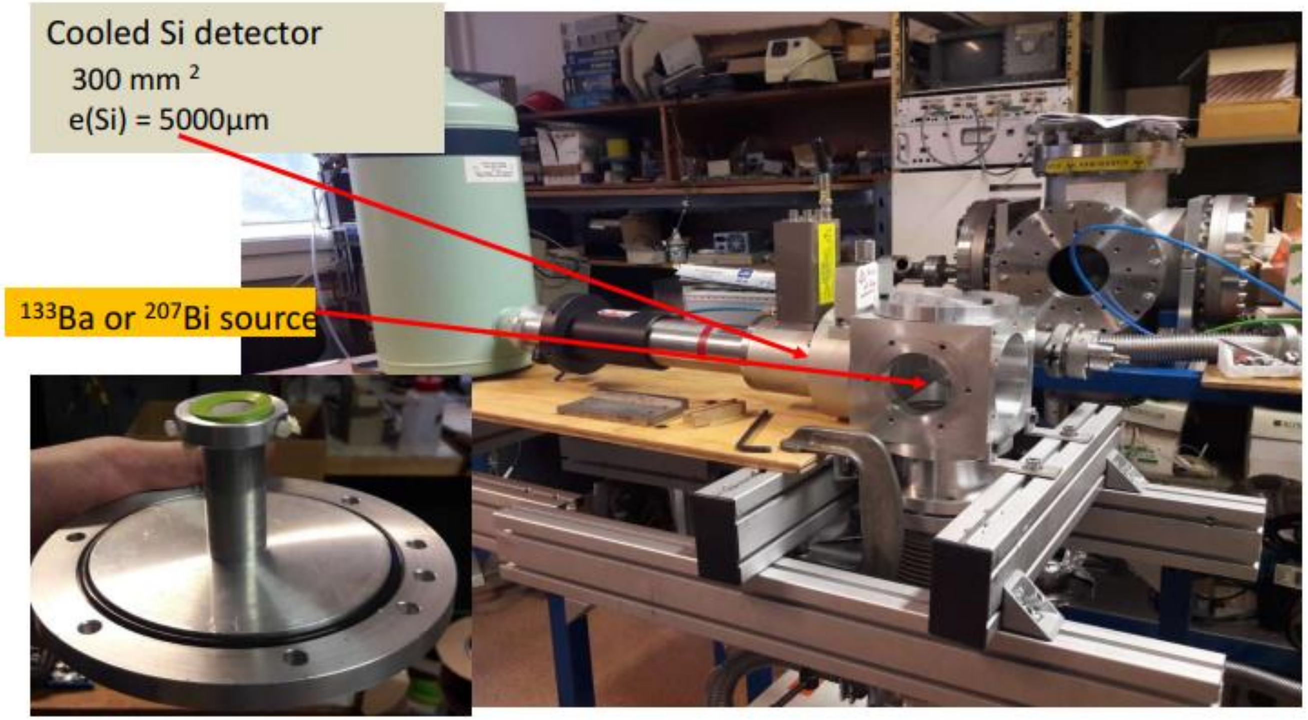


mounting of the shielding for the second collimator (phase 1, 25 to 29 jan. 2021)

Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

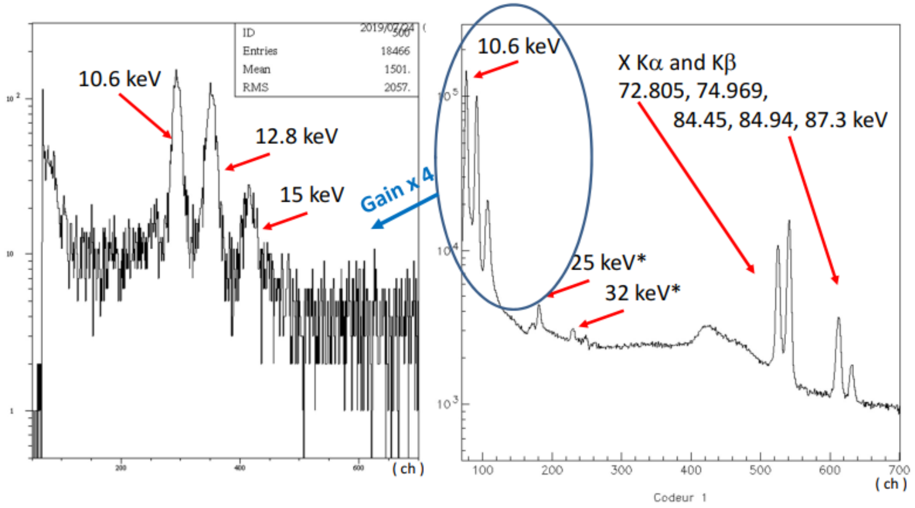
DELCO

June-July 2019
new Si cristal (N2L cooled)



After several investigations, the collaboration has now a suitable detector for the observation of electrons coming from internal conversion process in actinides. Tests with 238U sample are planned as soon as it will be possible to go on site.

Energy distribution at low energy



* Transitions from Ba, In

Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

Ongoing work at n_TOF, CERN

Summary of the November 2020 n_TOF meeting

For further information check the n_TOF data dissemination page:

https://twiki.cern.ch/twiki/bin/view/NTOFPublic/DataDissemination

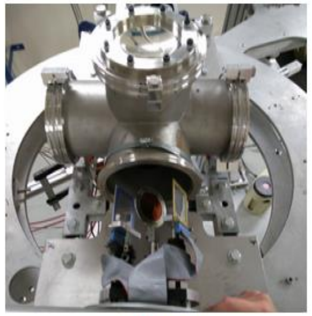
Progress report on the measurement of the $^{14}N(n,p)$ reaction at EAR2

Pablo Torres-Sánchez,
J. Praena, I. Porras

University of Granada

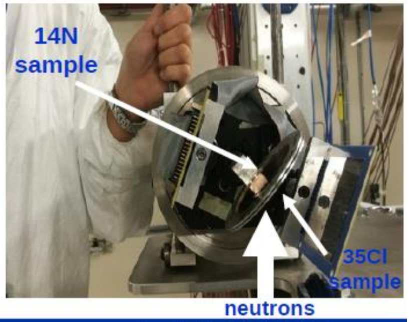
UNIVERSIDAD DE GRANADA

DSSSD Setup



DSSSD UGR-CNA
Chamber Edimburgh-n_TOF.
Setup of experiment in collaboration with
C. Lederer-Woods,
S.J. Lonsdale, R. Garg,
M. Dietz and M. Sabaté-Gilarte.

DSSSD setup with back-to-back 14N and 35Cl samples
Additional runs with dummy (Al backing) and a 10B reference



Outlook

Next steps with DSSSD:

- Data below 200 keV is ok
- Find a solution to the count loss at the resonance region
  - Check possible pulse misidentification during rootfile production
- Error estimation calculations for DSSSD
- Extend range at least to the first resonance
  - Apply SAMMY fit including the RF to extract resonance parameters
- Prepare a Draft for publication

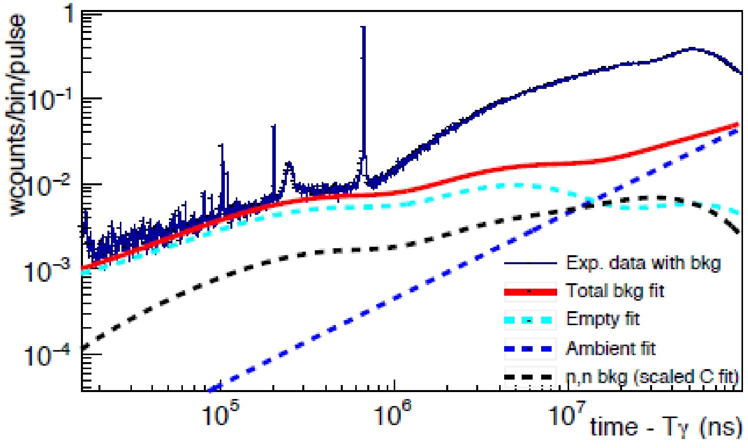
$^{35}Cl(n,\gamma)$ analysis update

(June 2018, EAR1 — C6D6)

S. Bennett, T. Wright, I. Porras and the n_TOF collaboration

virtual collaboration meeting

November 25, 2020



- so far in the analysis:
  - data quality
  - detector response & calibration
  - dead-time corrections
  - time-to-energy
  - weighting-functions & suitable cascades
  - background subtraction
  - sample contaminant checks (ICPMS)
- yet to complete:
  - check on low energy flux with SiMON
  - production of yield & SAMMY analysis (13 visible resonances)
- unsolved issues:
  - unidentified high energy counts
- Alternative TED method — potential for heavy nuclei (0^+ g.s.?)

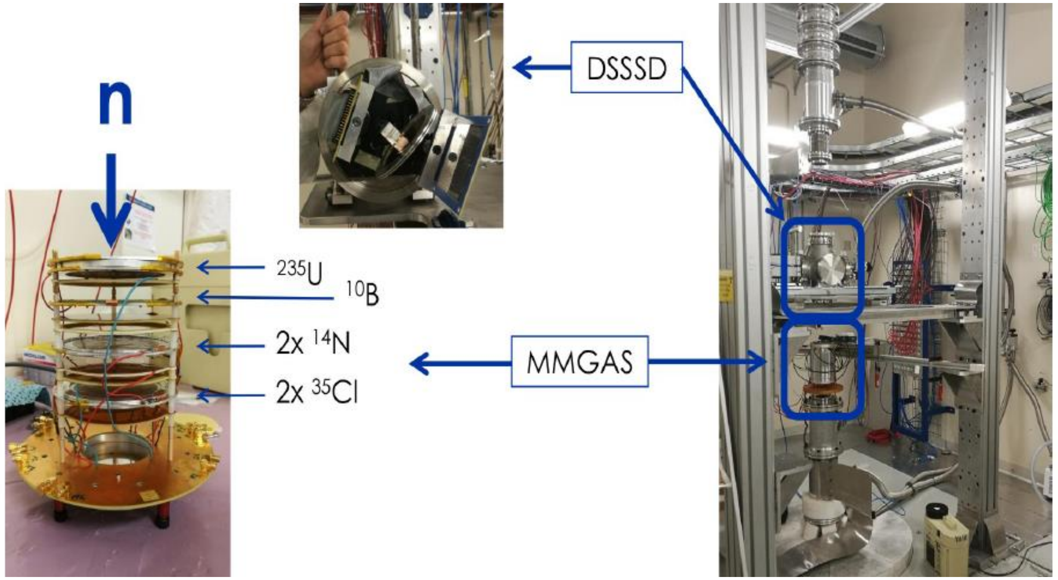
F. García-Infantes, J. Praena,
I. Porras and P. Torres
University of Granada, Spain

Current status of the analysis of the $^{35}Cl(n,p)^{35}S$ reaction

UNIVERSIDAD DE GRANADA

n_TOF Collaboration meeting
November 26-27, 2020

Motivation: BNCT and astrophysics

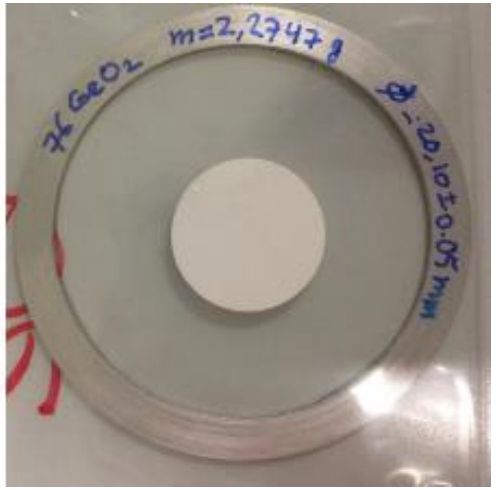


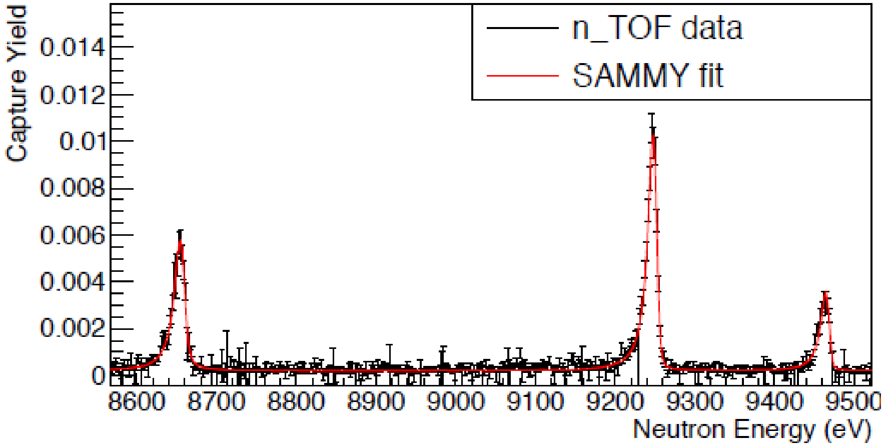
Neutron capture cross sections of ^{76}Ge at n_TOF EAR-1

A. Gawlik, C. Lederer-Woods, M. Krtička, S. Valenta,
J. Perkowski, J. Andrzejewski and the n_TOF Collaboration

Collaboration meeting
26/11/2020

ISOTOPIC DISTRIBUTION in ^{76} Ge target					
ISOTOPE	^{70} Ge	^{72} Ge	^{73} Ge	^{74} Ge	^{76} Ge
CONTENT(%)	0.06	0.09	0.06	11.33	88.46





Summary

- we parameterized 47 resonances up to neutron energy of 94 keV, 41 in RRR (from thermal to 52 keV)
- Statistical analysis of the resonance parameters – still ongoing
  - MACS for 5 -100 k_BT – combined with ENDF or/and with predicted cross section based on the RRR parameters (Milan & Standa)
- Final uncertainty estimation
- and of course.. paper (draft is almost ready)

Thank you for your attention!

THE UNIVERSITY of EDINBURGH

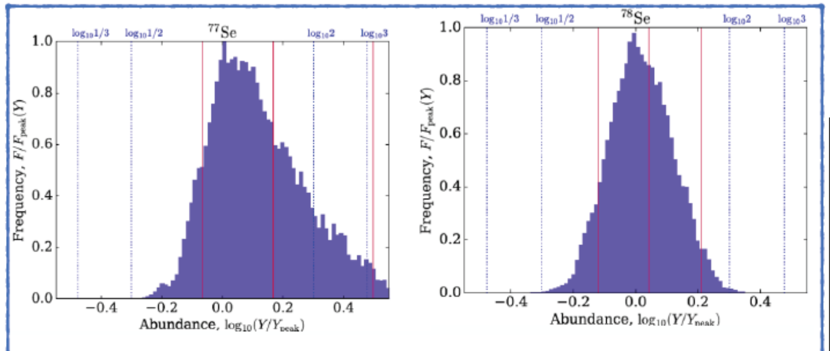
nTOF CERN erc European Research Council

^{77,78}Se(n,γ) Measurement : Status Update (Part I)

Ruchi Garg

University of Edinburgh, UK

Astrophysical Motivation



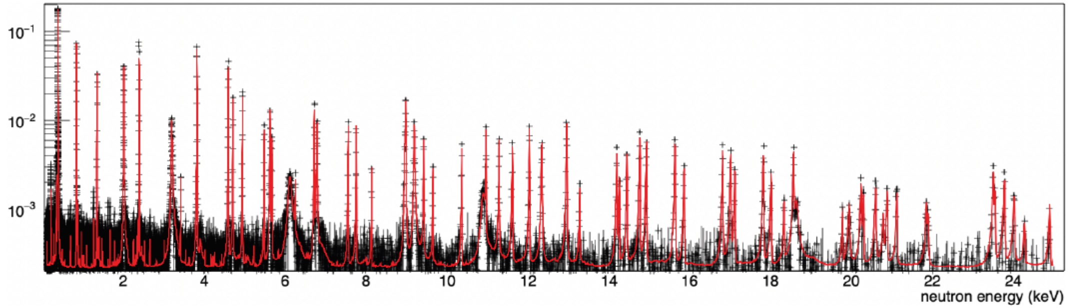
Abundance distributions of ^{77}Se and ^{78}Se isotopes in 10,000 iterations of the weak s-process

A detailed sensitivity study of the (weak) s-process by Nishimura *et al.* showed strong correlation between uncertainties in ^{77,78}Se abundances and ^{77,78}Se(n,γ) reaction rates uncertainties.

[MNRAS 469, 1752-1767 (2017)]

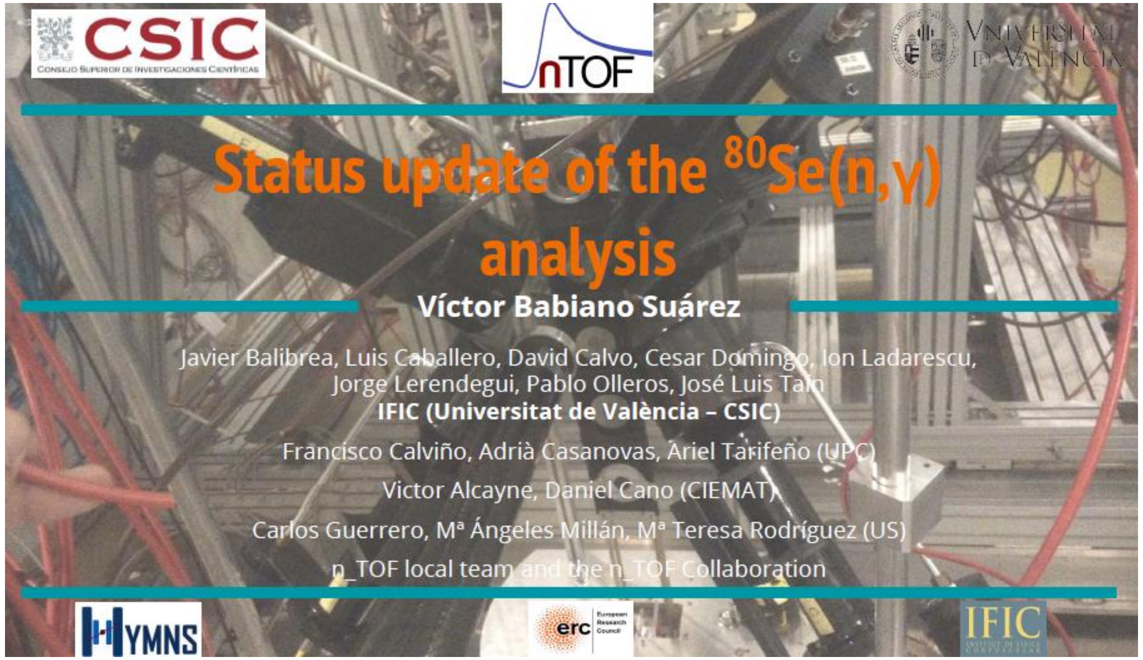
Data analysis - Sammy fits to Se78 spectrum

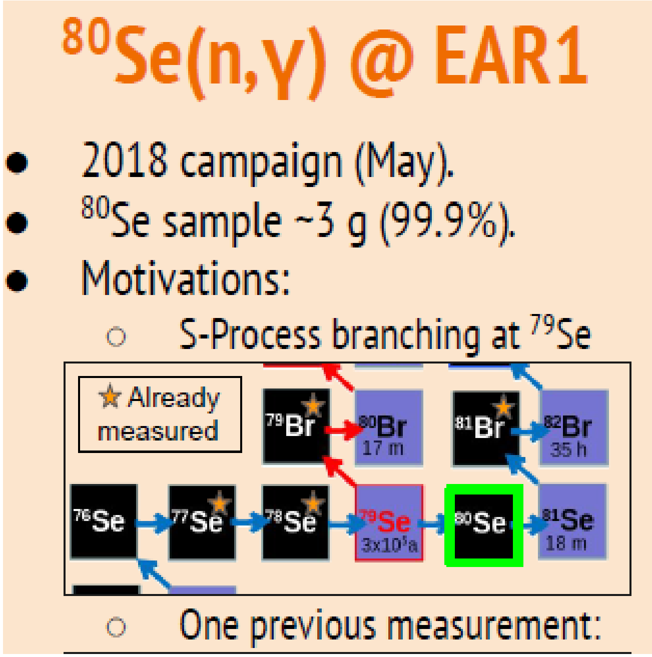
- Previously measured - 21 resonances between 0.38 - 40 keV.
- Sammy fitting to present data: 0.1 - 25 keV - 52 new resonances.
- Normalisation of the beam fraction on sample is evaluated using the saturation plateau of the 4.9 eV Au resonance.
- Flat background assumed in single resonance fitting.



Conclusion

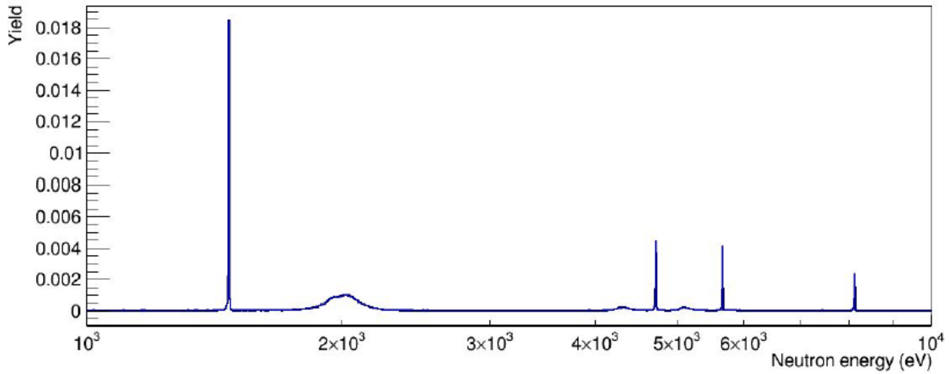
- Neutron induced reaction cross sections are required for reproducing the abundances of elements heavier than iron.
- Experimental data with high accuracy is required for the stellar modelling.
- Data analysis on the ^{77,78}Se and ^{68}Zn measurement is ongoing.
- Next steps:
  - Resonance fitting in the RRR (Resolved Resonance Region) - possibly as high as 100 keV.
  - MACS calculation.





Preliminary capture yield

- Neutron energy between 1 keV and 10 keV.



Summary and outlook

Analysis of the experiment is now ongoing.

Until now, we have studied:

- Effects of rebounds.
- The count rate and gain stability of the C_6D_6 detectors.
- Weighting functions and their uncertainties.
- PHWT correction factors.
- The flux correction from the evaluated version.

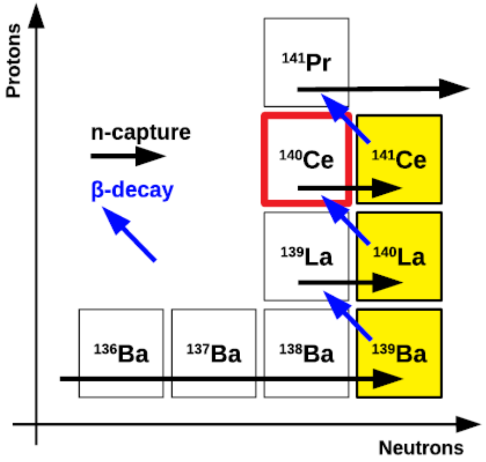
Study currently ongoing:

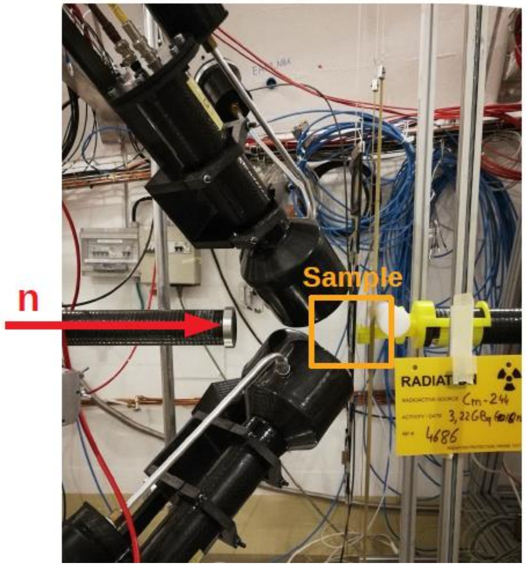
- Finding background components

Next steps:

- Determine the experimental capture yield.
- R-Matrix analysis with SAMMY.
- Astrophysical interpretations of the results.

Status of $^{140}Ce(n,\gamma)$



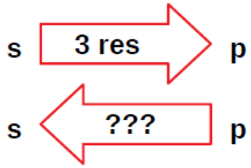


Target	Protons
Ce140	1.92E+18
Dummy	2.04E+17
Pb	7.54E+16
Empty	7.57E+16
Gold	4.78E+16
Ce140 + filters	9.00E+16
Dummy + filters	9.80E+16
Pb + filters	1.40E+17
Total	2.65E+18

Conclusions and perspectives

A measurement of $^{140}Ce(n,\gamma)$ cross section has been successfully performed at n_TOF, the resonance analysis has been carried out up to 65 keV and the parameters of s and p waves has been estimated.

Next steps will be:



1) Check the correctness of the p-wave assignment.

2) Complete the work on resonances average parameters and spacing.

3) Compute the MACS.

4) Include the new MACS in the stellar model and evaluate the impact.

Results of the ^{203}Tl(n,γ) and of ^{204}Tl(n,γ) measurements

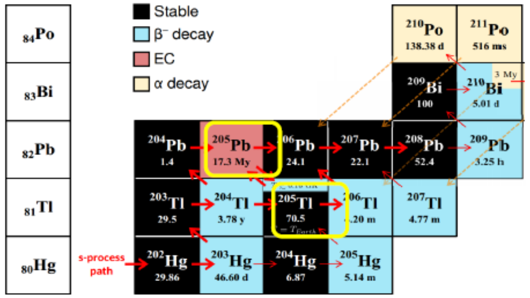
Summary, conclusions, future work

^{204}Tl(n,γ) analysis results

- **Challenges due to sample and exp. setup successfully overcome**
- Newly developed self-normalization procedure (employing ^{203}Tl new data) **allowed to analyse for the first time ever capture resonances** between 100 eV and 5 keV of neutron energy
- 1 keV MACS bounds, semi-empirical extrapolation of the MACS at higher temperatures
- Results hint to an **increase of the MACS** ➡ **Reduction in the s-process ^{204}Pb production**

Future work

- Possible new theoretical calculations of $^{203\text{-}204}$Tl(n,γ) capture cross section based on n_TOF experimental results
- Simulations with the NuGrid post-processing nucleosynthesis tools to study impact in the ^{204}Pb abundance and the ^{205}Pb/^{204}Pb ratio for the s-process chronometer
- Tackling last capture cross sections for a comprehensive analysis of the s-process termination
  - **^{205}Tl(n,γ): under analysis**
  - **^{205}Pb(n,γ): proposal for production of a sample**



- **^{204}Tl(n,γ) measurement of a 15 mg ^{204}Tl sample was successfully performed at n_TOF thanks to:**
  - Sample production expertise at ILL (France) and PSI (Switzerland)
  - Exceptional features of the facility (high luminosity and resolution)
  - Specifically adapted experimental setup
  - Development of a device allowing to a spatial characterization of the sample

- **^{203}Tl(n,γ) results**
  - New experimental data under 3 keV of neutron energy
  - Lower kernels in the 3 to 12 keV range compared to previous experiment
  - **Improved MACS at ^{13}C-pocket nucleosynthesis temperatures**, constrained value at higher energies
  - ^{205}Tl(n,γ) measurement in 2018 employing a natural thallium sample, 5x times more massive sample, expected improvement in resonance data

A. Casanovas[1], A.Tarifeño-Saldivia[1], C. Domingo-Pardo[2], F. Calviño[1], C. Guerrero[3], J. Lerendegui-Marco[2], S. Heinitz, D. Schumann[4], U. Koester[5] J.L Taín[2], J. M. Quesada[3]

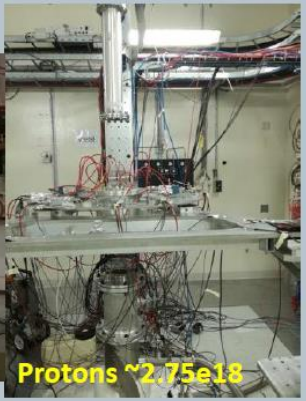
[1] Universitat Politècnica de Catalunya (UPC), Barcelona, Spain
[2] Instituto de Fisica Corpuscular (CSIC-Universitat de Valencia), Valencia, Spain
[3] Universidad de Sevilla, Spain
[4]Paul Scherrer Institute, Switzerland

Status of the ^{230}Th(n,f) analysis at EAR-1 and EAR-2

V. Michalopoulou[1,2], A. Stamatopoulos[2], R. Vlastou[2], M. Kokkoris[2], A. Tsinganis[1], M. Diakaki[3], Z. Eleme[4], N. Patronis[4], J. Heyse[5], P. Schillebeeckx[5], L. Tassan-Got[1], M. Barbagallo[1], N. Colonna[6], S. Urlass[1], D. Macina[1], E. Chiaveri[1]
and the n_TOF Collaboration[7]

[1]CERN, [2]NTUA, [3]CEA-Cadarache, [4]UoI, [5]JRC-IRMM,[6]INFN-Bari, [7]www.cern.ch/ntof

- Same experimental setup at EAR-1 and EAR-2 (**Micromegas**)
- **Fission collimator** at both areas
- Different active mass of the samples (8 cm EAR-1 / 6 cm EAR-2)
- Targets produced at JRC-Geel (Characterization is performed currently at JRC-Geel)



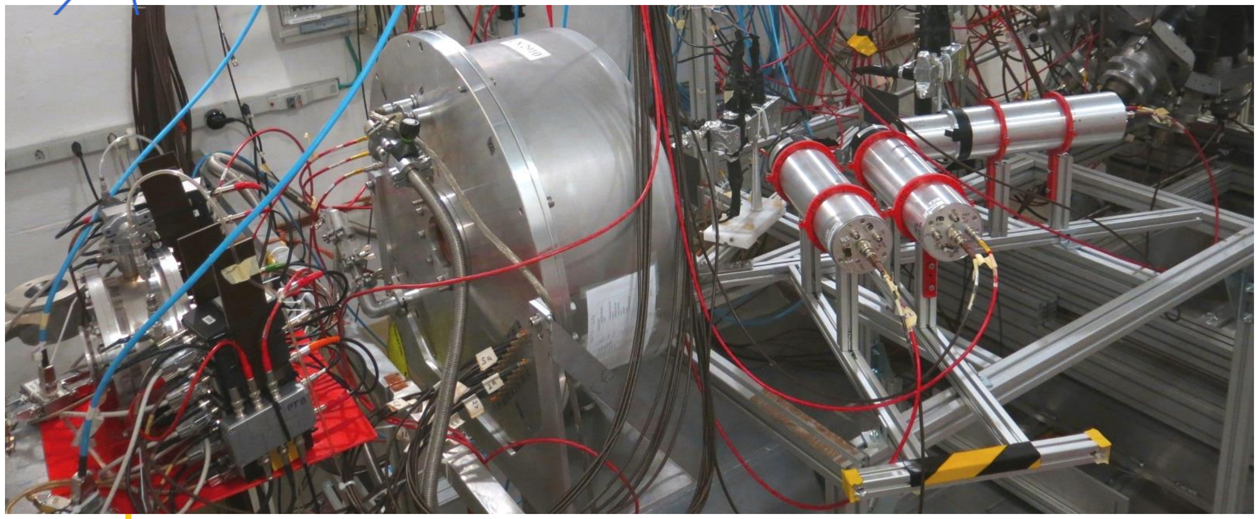
Isotope	Mass μg/cm^2	Activity MBq/sample
^{230}Th	44 - 115	1.69 – 4.41
^{235}U	72	$5.88 \cdot 10^{-4}$
^{238}U	287	$1.80 \cdot 10^{-4}$
^{10}B	8	-
Targets diameter 8 cm		

Next steps

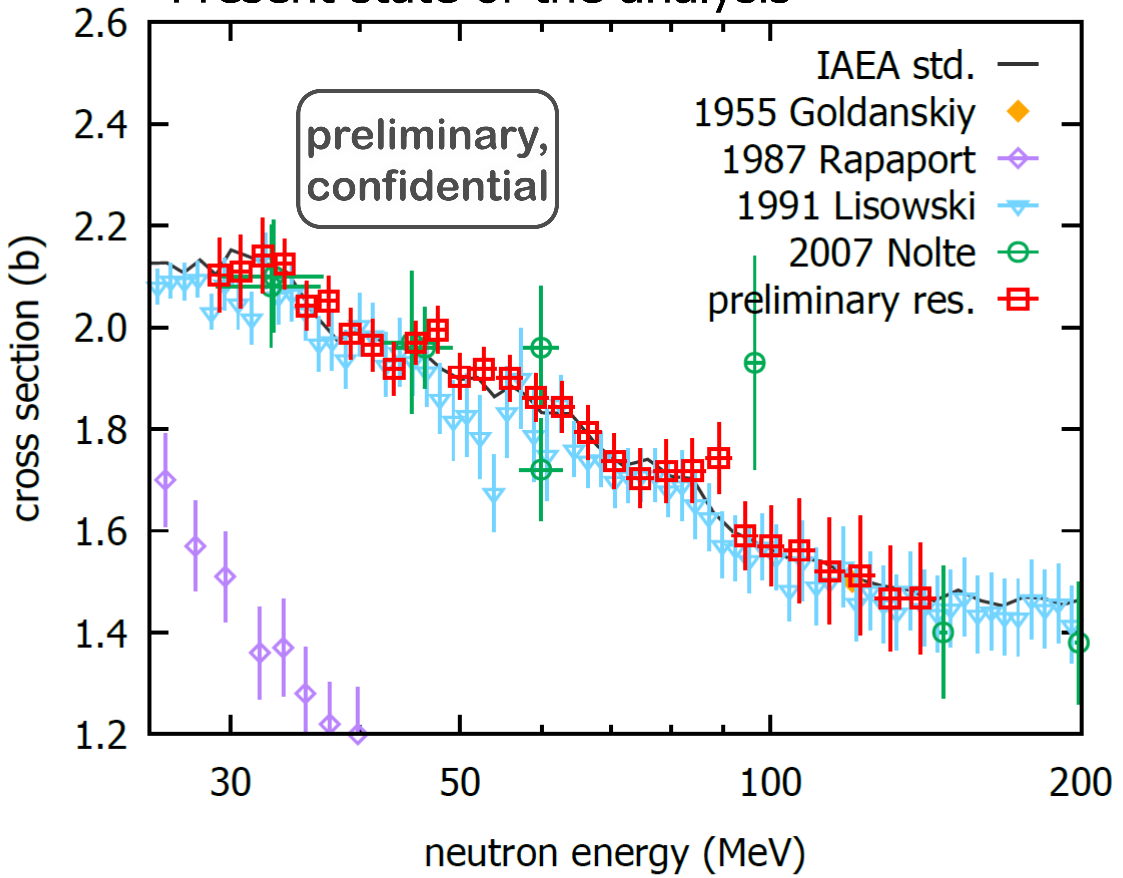
- Correction for lost FF for the ^{230}Th targets
- Final mass values for the ^{230}Th targets in collaboration with JRC-Geel
- Final cross-section values
- Finish the PhD write up

Measurement of $^{235}U(n,f)$ relative to $^{1}H(n,n)$ in the energy range from 30 to 150 MeV at n_TOF

- $^{235}U(n,f)$ cross section: most important secondary standard for neutron flux measurements above 20 MeV
- Request from IAEA/NDS of new experimental data in the energy range from 20 MeV to 1 GeV
- Measurement carried out in 2018 at CERN n_TOF



Present state of the analysis

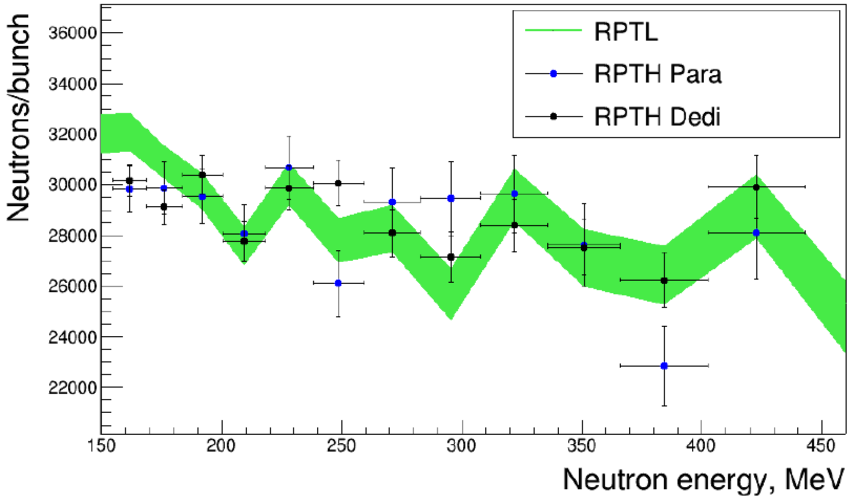


Presented at the Consultants Meeting on Neutron Data Standards, IAEA, 12-16 October 2020

$^{235}U(n,f)/^{1}H(n,p)$ measurement

Two RPTs for redundancy and maximum energy range: PTB (150 MeV) and INFN (0.5-1 GeV), simultaneous data taking

INFN RTPs at E_n >200 MeV



Summary

- MCNP/Geant4 agreement can be within ~1-2% if everything is thoroughly tested
  - input cross section libraries, relativistic effects, forced collisions
- Developed MC model to determine the FC-efficiency energy dependence, biggest difficulty is the inhomogeneity of the deposits
  - maybe characterisation at the reference fields at PTB?
- RPTs in agreement, chambers not quite
- Analysis above 200 MeV very promising!
- results from 30 to 150 MeV consistent with the IAEA evaluation
- statistical uncertainty: 4-10% (PTB detectors only)

Update on gamma-ray analysis with STEFF

n_TOF Virtual Collaboration Meeting

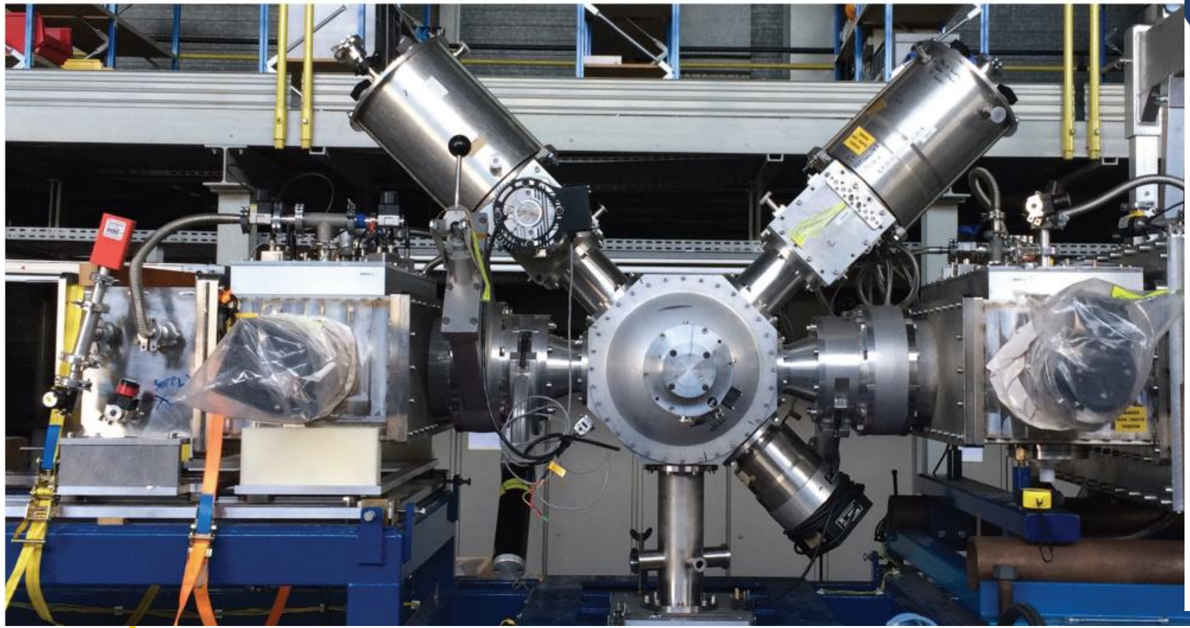
26th November 2020

Adhitya Sekhar*

*On behalf of STEFF team

The University of Manchester

SpecTrometer for Exotic Fission Fragments (STEFF)



Summary + Next steps

- Fission gating
- Background subtraction
- Gain correction
- Multiple hits subtraction
- Deconvolution
- Neutron subtraction

Methodology currently being refined with ILL data to be used with n_TOF data (^{235}U & ^{239}Pu)

↑

Moving from treatment as an array to handling of individual detectors separately

Ongoing work of the SANDA and ARIEL projects

Summary of the February 2021 meeting

Both started 6 months before the covid-19 outbreak

Progress is seriously hampered by travel restrictions

Some examples of the wide scope and interesting plans for measurements are given as appetizer. Results will hopefully follow in the coming years.

For further information, check: https://indico.cern.ch/event/999813/

Measurement of $^{239}Pu(n,\gamma)$ and α–ratio at EAR1 with TAC + fission detectors

V. Alcayne[1], J. Andrzejewski[2], M. Caamaño[4], F. Calviño[5], D. Cano-Ott[1], C. Domingo[6], I. Durán[3], B. Fernández[4], A. Gawlik[2], E. Gónzalez-Romero[1], C. Guerrero[7], J. Heyse[3], T. Martínez[1], E. Mendoza[1], J. Perkowski[2], A. Plompen[7], J.M. Quesada[7], P. Schillebeeckx[3], G. Sibbens[3], A. Tarifeño[5]

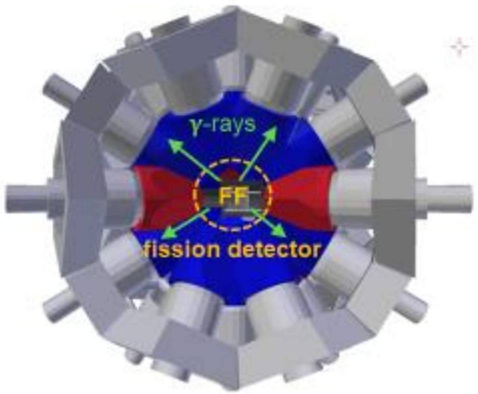
[1]CIEMAT, Spain
[2]University of Lodz, Poland
[7]JRC Geel
+
[4]U. Santiago de Compostela
[5]U. Politécnica de Cataluña
[6]IFIC – CSIC
[7]U. Sevilla

Experimental technique

Fission tagging: γ-rays in coincidence (fission background) and anticoincidence (capture signal) with the fission detector. (*J. Balibrea et al.*, PRC 102, 2020)

$$Y_\gamma = \frac{c_{aco,\gamma} - \frac{1-\epsilon_f^*(E_n)}{\epsilon_f^*(E_n)} c_{tag} - c_{oth,\gamma}}{\epsilon_\gamma \phi_N}$$

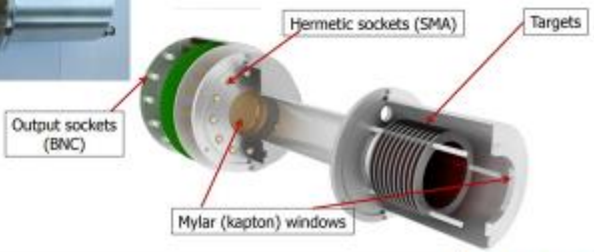
c_{tot} = counts in the TAC.
c_{tag} = counts in the TAC in coincidence with the ionisation chambers.
c_{oth} = background in the TAC.
ϵ_f^* = fission tagging efficiency.
ϵ_γ = capture detection efficiency.



The new fission chamber

A new multi target fission chamber has been built taking into account the following important characteristics:

1. **Low mass** intercepting the neutron beam, to minimize the background in the TAC due to captures and elastically scattered neutrons.
2. Good **discrimination** between **alphas (2 MBq/mg)** and **fission fragments (5 mm gap)**.
3. Small **pile-up** effects.



The samples will be provided by JRC-Geel

I. Ten thin ^{239}Pu **samples will be manufactured at JRC-Geel** with a total mass of ~**10 mg (1 mg/sample)**.

The samples will be placed inside the fission detector, in the center of the TAC. The limitations come from the signal-to-background ratio.

Overall uncertainties: ~3% below 100 eV and 4-6% between 100 eV and 1keV.

II. A thick sample, in order to extend the measurement to higher neutron energies.

This sample will be measured **without fission detector**. With **~80 mg** we could extend the measurement **up to 10 keV**.

Overall uncertainties: 3-4% between 100 eV and 10 keV.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of ^{94,95,96}Mo(n,γ) relevant to Astrophysics and Nuclear Technology

September 10, 2020

M. Busso[1,2], D. M. Castelluccio[1,3], P. Console Camprini[1,3], N. Colonna[1], S. Cristallo[1,4], C. Domingo-pardo[5], A. Guglielmelli[1,3], J. Heyse[6], S. Kopecky[6], C. Lederer-Woods[7], A. Manna[1,8], C. Massimi[1,8], P. Mastinu[1], A. Mengoni[1,3], P.M. Milazzo[1], R. Mucciola[1,2], C. Paradela-Dobarro[6], T. Rauscher[9], F. Rocchi[3], P. Schillebeeckx[6], N. Sosnin[7], N. Terranova[1,3], G. Vannini[1] and the n_TOF Collaboration[10]

[1] Istituto Nazionale di Fisica Nucleare, INFN, Italy
[2] University of Perugia - Perugia, Italy
[3] Agenzia per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, ENEA, Italy
[4] Istituto Nazionale di Astrofisica, INAF - Teramo, Italy
[5] Instituto de Fisica Corpuscular, CSIC - Universidad de Valencia, Spain
[6] European Commission, Joint Research Centre, Geel, Belgium
[7] School of Physics and Astronomy, University of Edinburgh, United Kingdom
[8] Department of Physics and Astronomy, University of Bologna, Italy
[9] Department of Physics, University of Basel, Basel, Switzerland
[10] www.cern.ch/n_TOF

Spokesperson: Cristian Massimi (cristian.massimi@bo.infn.it)
Technical coordinator: Olivier Aberle (olivier.aberle@cern.ch)

Courtesy of
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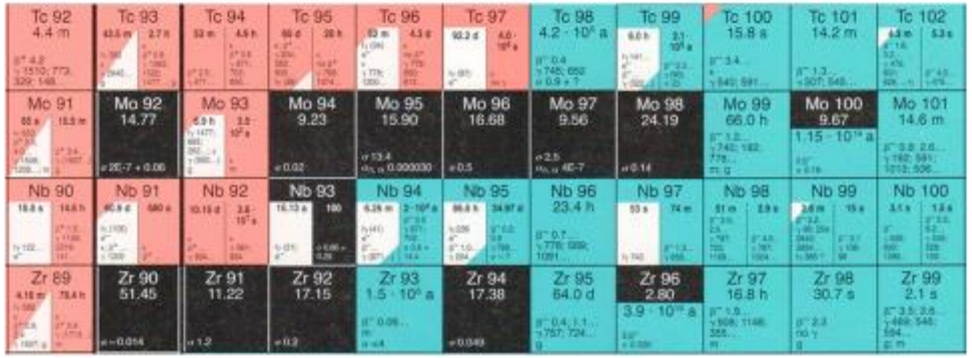
Why ^{94,95,96}Mo?

Molybdenum is relevant for **nuclear astrophysics** and **nuclear technology** and presently **known with large uncertainties**.



Conclusions

To improve the status of evaluated data libraries for Mo isotopes and in particular **to improve the quality of the recommended capture cross sections**, a **collaborative effort** has been planned as part of the **SANDA project** supported within the EU Horizon 2020 framework programme:

- capture measurements at n_TOF
- Transmission measurements GELINA

using isotopically enriched Mo metallic samples.

Requested protons: 8×10^{18} protons on target
Experimental Area: EAR1 and EAR2

European Commission