The European Commission’s science and knowledge service

Joint Research Centre

European Commission

JEFF report on recent experiments

Arjan Plompen

OECD-NEA, WPEC, June 2019

European Commission

Contents

- Limited overview, on account of limited reporting at JEFF meetings
- JRC, collaborations IFIN-HH, IPHC, PTB, HZDR, ENEA, INFN, CEA
- n_TOF

CHANDA: SOLVING CHALLENGES IN NUCLEAR DATA FOR THE SAFETY OF EUROPEAN NUCLEAR FACILITIES

CP-CSA (Combination of Collaborative projects, Coordination and Support Actions) to the **EURATOM FP7-Fission-2013-4.1.2** (Support to a pan-European Integrated Research Infrastructure Initiative for increased safety of nuclear systems at EU level).

Start: 1 Dec. 2013.

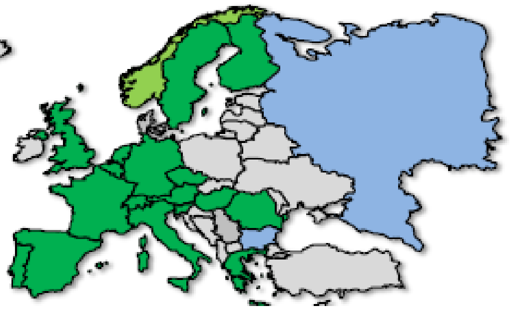
Duration: 54 months.

EU funding: 5.4 MEuro.

61 Deliverables

Participants:

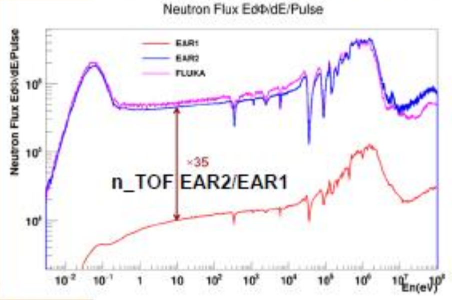
CIEMAT, ANSALDO, CCFE, CEA, CERN, CNRS, CSIC, ENEA, GANIL, HZDR, IFIN-HH, INFN, IST-ID, JRC, JSI, JYU, KFKI, NNL, NPI, NPL, NRG, NTUA, PSI, PTB, SCK, TUW, UB, UFrank, UMainz, UMan, UPC, UPM, USC, UU, UOslo. +U.Seville



CHANDA: 36 participants (18 countries)

New facilities

(n,n) and (n,n'): ELISA at 30 m @ JRC Geel

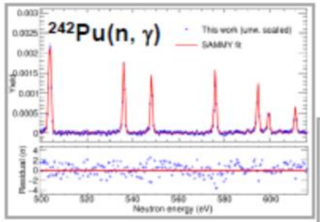


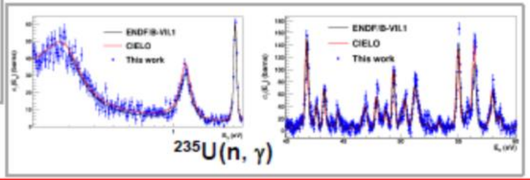
Differential measurements at CHANDA

(n,f) cross sections	(n,n), (n,xn) and (n,n'γ) cross sections
^{240,242}Pu(n,f)	^{nat}Fe(n,n)
^{237}Np(n,f)	^{nat}C(n,n)
^{235,238}U(n,f)	^{238}U(n,n'e-)
(n,γ) cross sections	^{48}Ti(n,n'γ)
^{235}U(n,γ)	^{7}Li(n,n'γ)
^{242}Pu(n, γ)	^{233}U(n,n'γ)
^{238}U(^{3}He,^{4}He)^{237}U, ^{238}U(^{3}He,t)^{238}Np, ^{238}U(^{3}He,d)^{239}Np	

Decay data	
^{95}Rb, ^{95}Sr, ^{98}Y, ^{98m}Y, ^{98}Nb, ^{98m}Nb, ^{99}Y, ^{100}Nb, ^{100m}Nb, ^{102}Nb, ^{102m}Nb, ^{103}Mo, ^{103}Tc, ^{108}Mo, ^{137}I, ^{138}I, ^{140}Cs, ^{142}Cs	γ ray and β decay emission probabilities with TAGS at JYFL
^{98,98m,99}Y, ^{135}Sb, ^{136}Te, ^{138,139,140}I	Neutron emission probabilities with the BELEN detector at JYFL

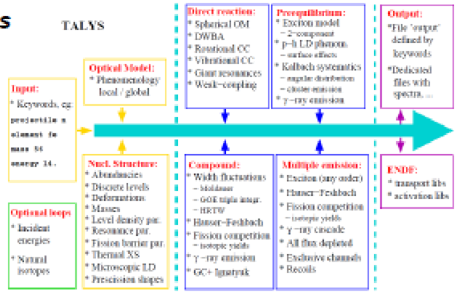
Fission yields	
^{238}U(n,f)	Penning trap at JYFL
^{233,235}U(n,f)	Isobaric beams at ILL
^{239,241}Pu(n,f)	Isobaric beams at ILL
^{235}U(n,f)	STEFF spectrometer at n_TOF/EAR2
^{235}U(n,f)	Orphee reactor at CEA/Saclay
^{238}U, ^{239}Np, ^{240}Pu, ^{244}Cm, ^{250}Cf	VAMOS spectrometer at GANIL
^{234,235,236,238}U(g,γ)	FRS spectrometer at GSI
^{238}U(n,f)	LICORNE + MINIBALL at IPN/Orsay

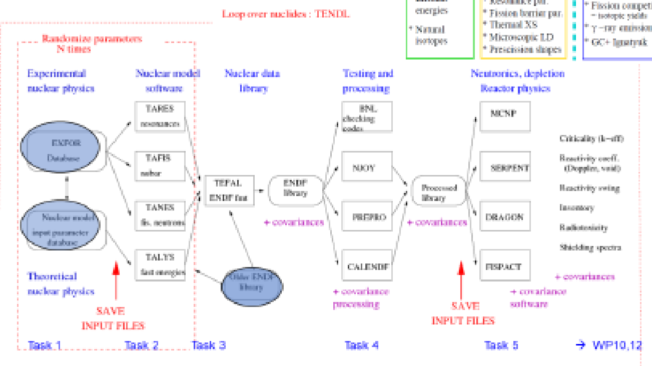




Evaluation: TALYS-1.9 and TENDL

From basic nuclear physics to nuclear technology

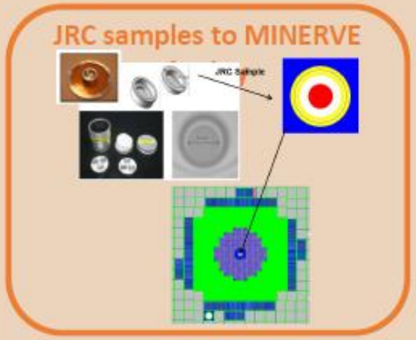




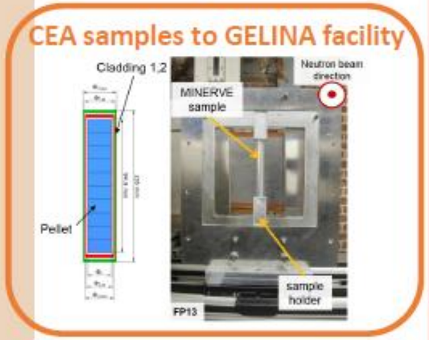
+ Systematic and comprehensive uncertainties and correlation libraries in the evaluation.

Validation: Innovative Integral Experiments

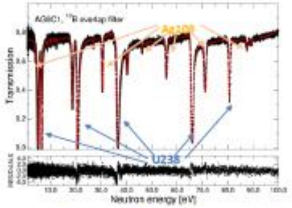
JRC samples to MINERVE



CEA samples to GELINA facility



- ⇨ First of a kind in the cross-check of experimental techniques based on common samples
- ⇨ Feasibility and interest demonstrated for using oscillation samples in ToF experiments



Plus validation using existing benchmark libraries and past and new integral experiments

SUPPLYING ACCURATE NUCLEAR DATA FOR ENERGY AND NON-ENERGY APPLICATIONS

Basic data

Coordinator: CIEMAT, Enrique Gonzalez Romero

H2020 Grant Agreement number: 847552

A proposal in negotiation for the EURATOM WP2018 for NFRP-2018-4

Proposed Start date: 01/09/2019

Duration: 48 months

Requested contributions: 3.5 MEuros

35 Partners: *CIEMAT*, Atomki, CEA, CERN, CNRS, CSIC, CVREZ, ENEA, HZDR, IFIN-HH, IRSN, IST-ID, JRC, JSI, JYU, KIT, NPI, NPL, NRG, NTUA, PSI, PTB, SCK-CEN, Sofia, TUW, UB, ULODZ, UMAINZ, UMANCH, UOI, UPC, UPM, USC, USE, UU.

19 countries (A, B, Bg, Cz, D, Es, Fi, F, Gr, H, I, NL, Pol, Pt, Ro, Slo, S, UK)

ARIEL

Accelerator and Research Reactor Infrastructures for Education and Learning

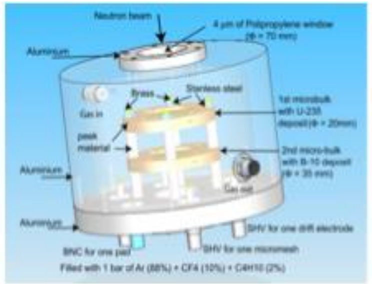
- EURATOM WP 2018 Coordination and Support Action
- Scheme offering access to research & training facilties
  ➔ Integration of access to neutron facilties with education and training in collaboration with ENEN
  - 23 participants, 1.7 M€
- Activities linked with the SANDA project, OECD/NEA, IAEA/NDS and TSOs (GRS, IRNS)
- Experiments in international teams at first rate facilities as „hands on“ training for early stage researchers
  PAC to select projects of highest scientific value
- Maintenance of competencies and development of multidisciplinary nuclear competencies

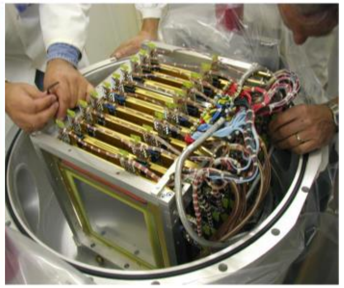
This could be
Your logo

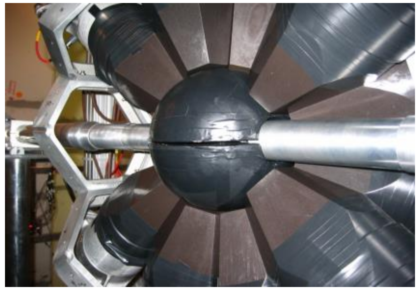
The n_TOF Collaboration
http://www.cern.ch/nTOF

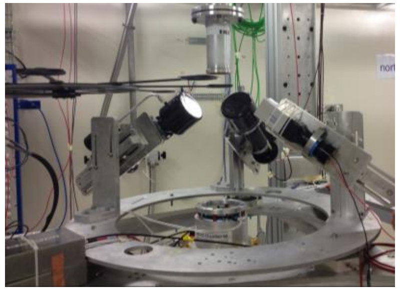
Status and perspectives of the neutron time-of-flight facility n_TOF at CERN

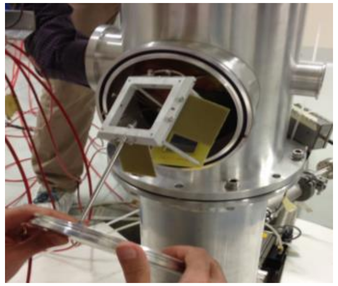
Enrico Chiaveri
Spokesperson of n_TOF Collaboration



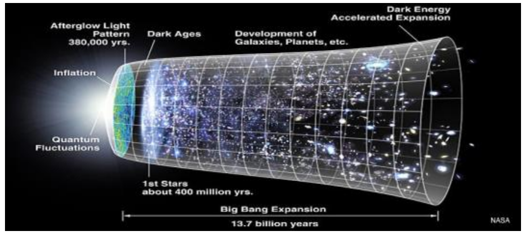


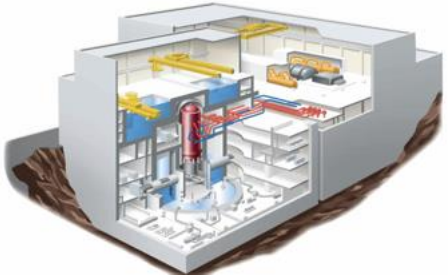






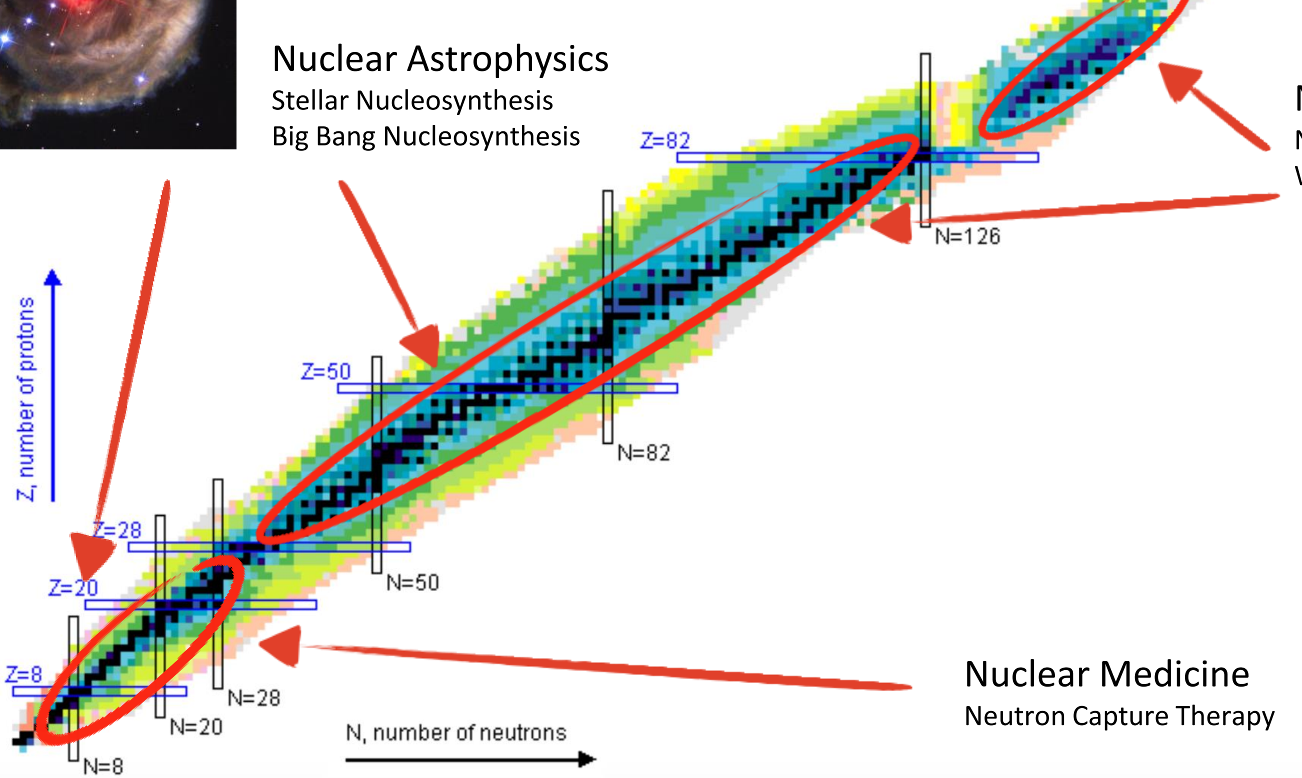
The n_TOF physics program: neutron-induced reaction measurements





Nuclear Astrophysics

Stellar Nucleosynthesis
Big Bang Nucleosynthesis

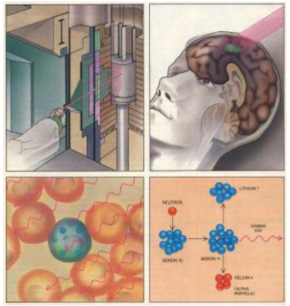


Nuclear Technologies

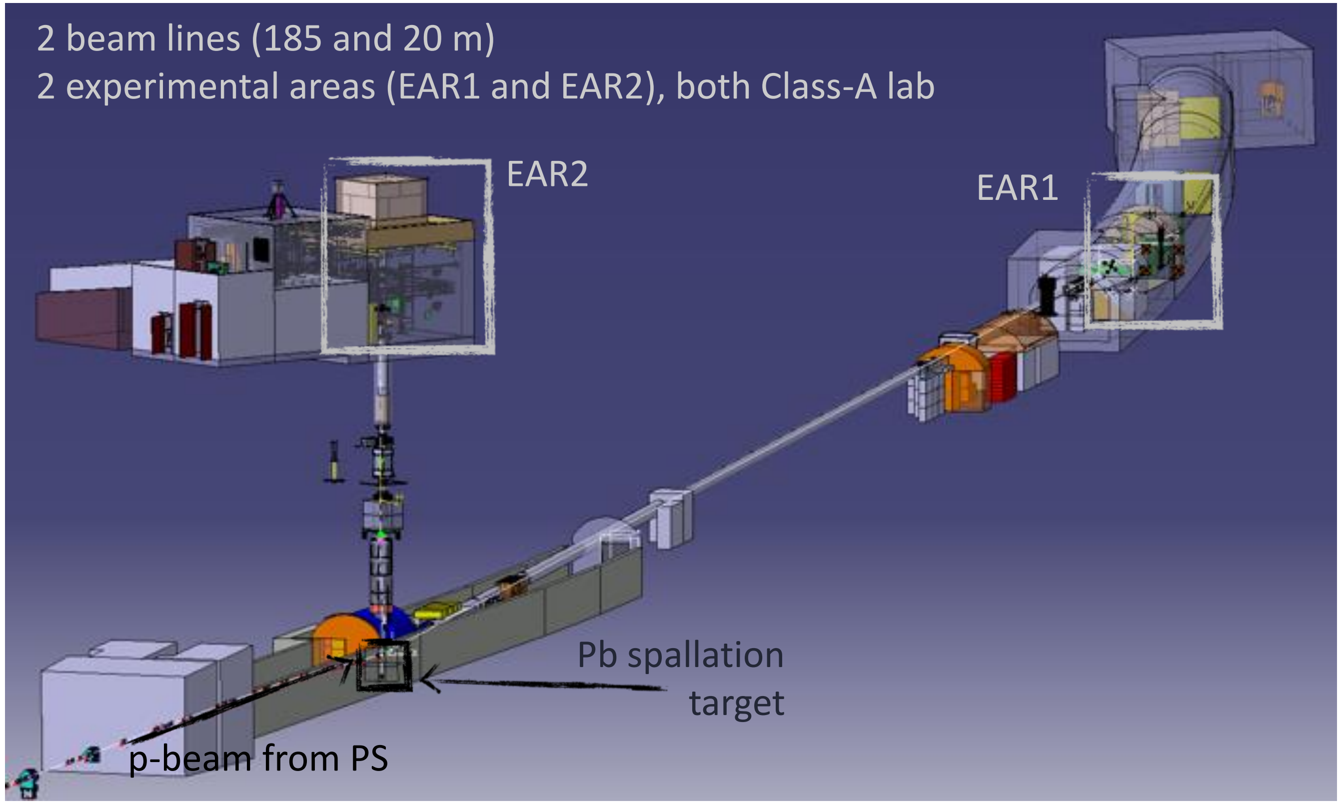
Nuclear reactors (energy production)
Waste management

Nuclear Medicine

Neutron Capture Therapy



CERN n_TOF – Enrico Chiaveri I135



42 Institutions

(EU, India, Japan, Russia and Australia)

130 scientists

2 experimental areas at CERN

Nuclear Astrophysics

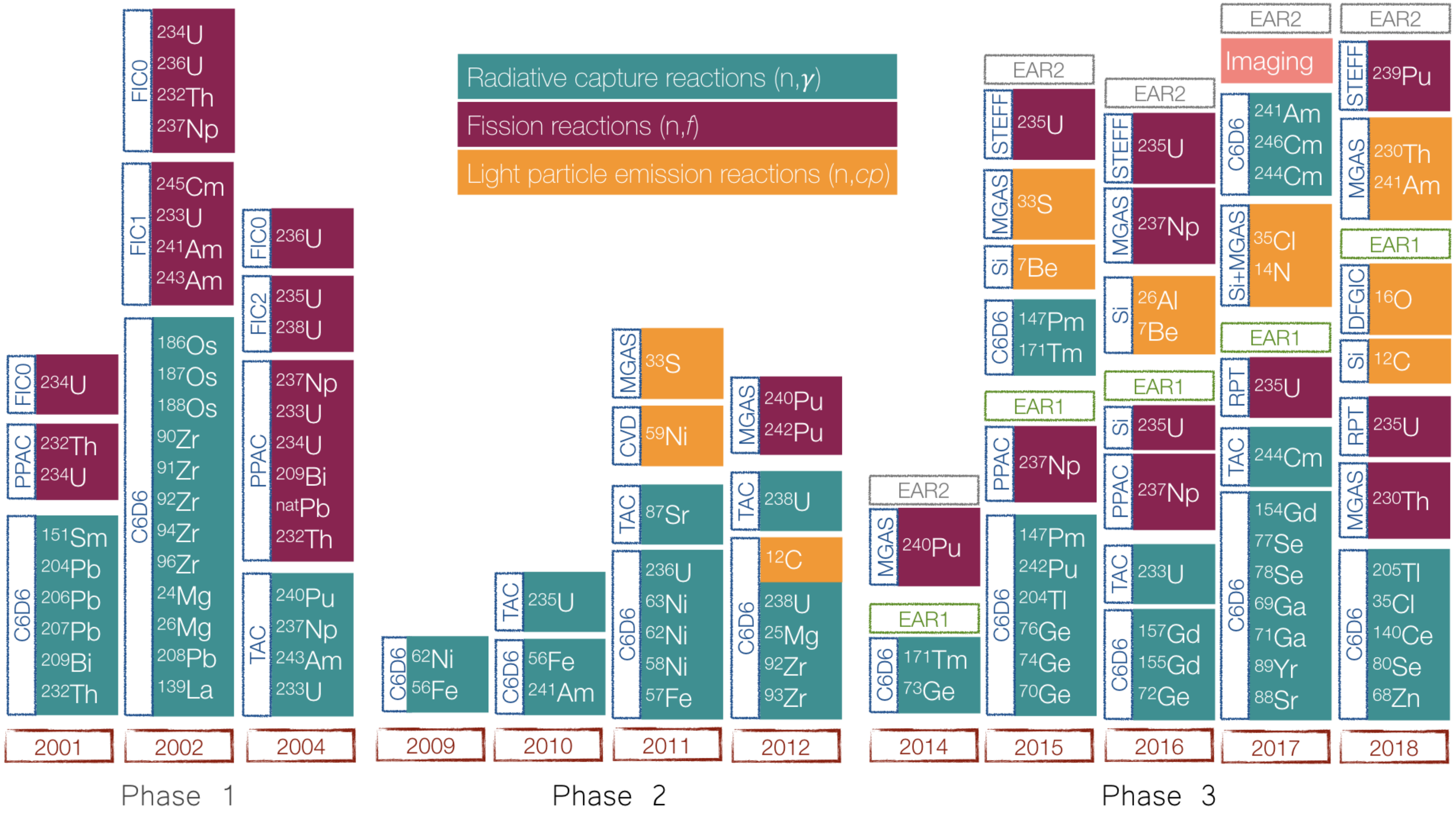
Nuclear Physics

Nuclear Application:

- Nuclear reactors (fission and fusion)
- Nuclear Waste Transmutation
- Nuclear Medicine

- Main feature of n_TOF is the synthesis of extremely high instantaneous neutron flux and excellent energy resolution
- Unique facility for measurements of radioactive isotopes (maximize S/N)
  - Branch point isotopes (astrophysics)
  - Actinides (nuclear technology)

The n_TOF physics program: neutron-induced reaction measurements



http://dx.doi.org/10.1051/epjconf/201714607003
http://www.nea.fr/dbdata/nds_jefreports/
http://dx.doi.org/10.1016/j.nds.2018.02.001
http://dx.doi.org/10.3327/jnst.48.1
https://twiki.cern.ch/NTOFPublic/DataDissemination

Further listening:
n_TOF related talks at ND2019

EAR1 data

R085 M. Bacak $^{233}U(n,\gamma/f)$
R239 Victor Alcayne $^{244}Cm/^{245}Cm$ (n,γ)
R095 Cristian Massimi $^{155}Gd,^{157}Gd$ (n,γ)
R201 Simone Amaducci ^{235}U (n,f)
R310 M. Mastromarco $^{154}GdU(n,\gamma)$
R246 Massimo Barbagallo $^{12}C(n,p/d)$
R087 J. Lerendegui-Marco $^{242}Pu(n,\gamma)$
R083 Andreea Oprea ^{241} Am (n, γ)
R402 Alice Manna $^{235}U(n,f)$
S409 Javier Preaena $^{33}S(n,\alpha)$ ^{30}Si
I268 Veatriki Michalopoulou $^{230}Th(n,f))$
S395 Sebastian Urlass $^{16}O(n,alpha)^{13}C$ (Poster)

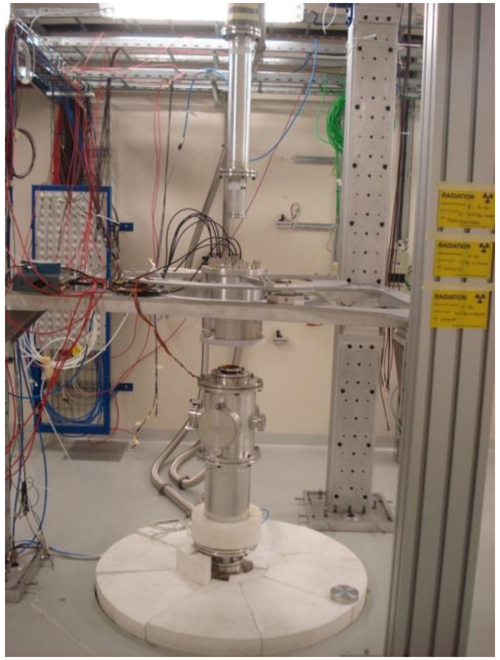
EAR2 data

R239 Victor Alcayne $^{244}Cm/^{245}Cm$ (n,γ)
S409 Javier Preaena $^{33}S(n,\alpha)^{30}Si$
I258 Nikolay Sosnin $^{235}U(n,f)/^{239}Pu(n,f)$
R270 A. Stamatopoulos $^{237}Np(n,f)$
I268 Veatriki Michalopoulou $^{230}Th(n,f))$
R269 Zinovia Eleme $^{241}Am(n,f)$

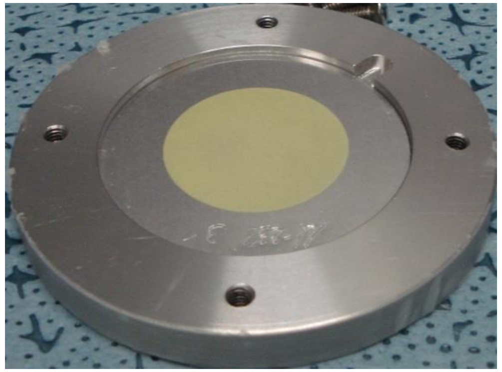
$^{237}Np(n,f)$ @ EAR2

Study of the neutron induced fission cross-section of ^{237}Np at CERN's nTOF facility over a wide energy range

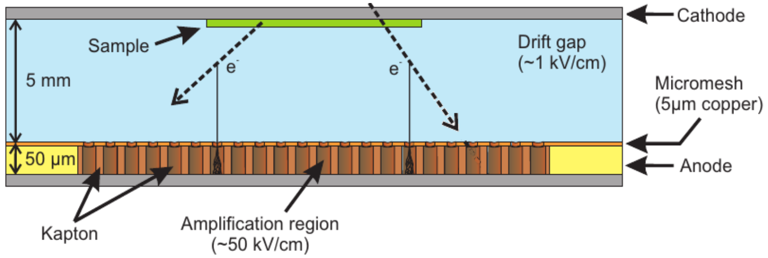
19.5 m vertical flight path



Samples from JRC-Geel

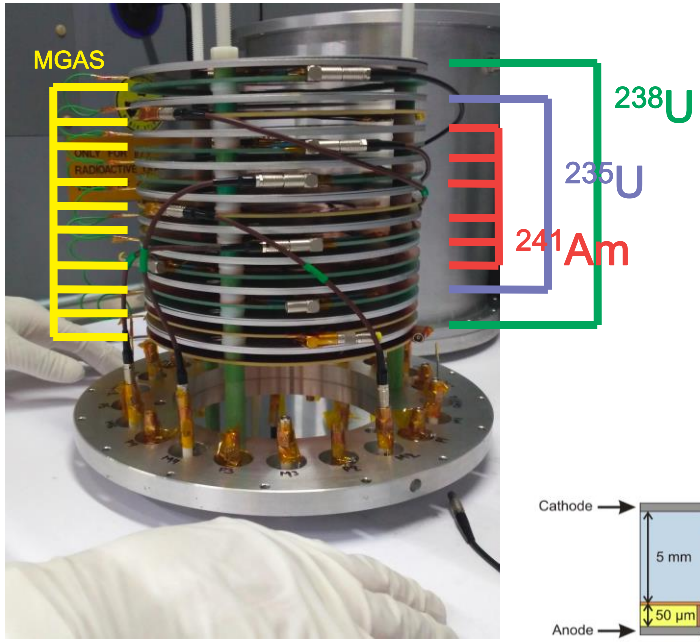


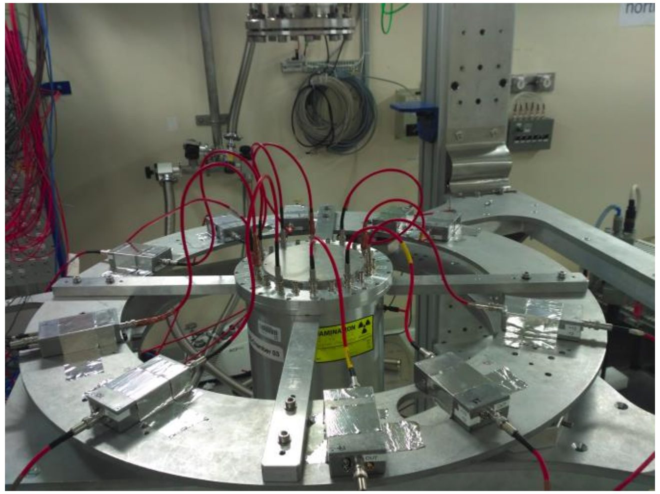
Fission fragment detection with Micromegas detectors

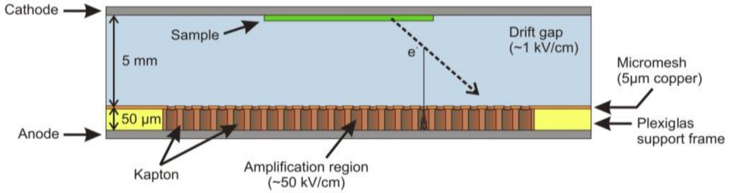


Interesting results in the MeV energy regime with high statistical accuracy

241Am(n,f) with Micromegas Detectors @ EAR2



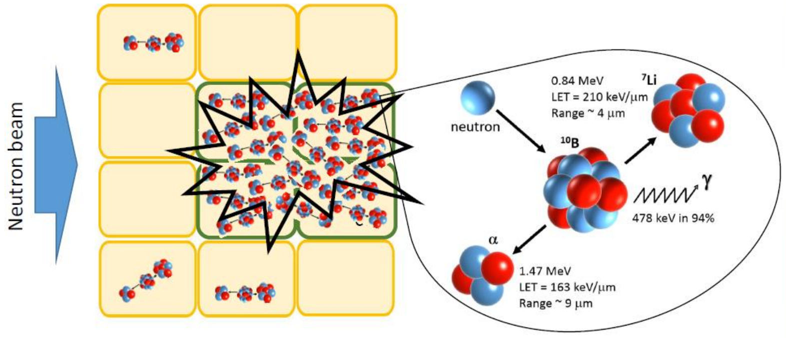




- EAR2
- Detectors: Micromegas
- Target Samples → 6 x ^{241}Am && Neutron flux monitor samples → 2 x ^{235}U && 2 x ^{238}U

$^{33}S(n,\alpha)^{30}Si$: two measurements at n_TOF.

BNCT principle



High selectivity ^{10}B-compounds → **3.5:1** (tumour to healthy tissue rate)

MOTIVATION: ^{33}S as target in Neutron Capture Therapy for tumors growing to the skin.

BASEMENT:

Large resonance at 13.5 keV in the $^{33}S(n,\alpha)$ but discrepant data are available.

^{35}S has been selectively accumulated in mice in large concentrations (mg/g).

Natural sulphur nanoparticles are commercially available.

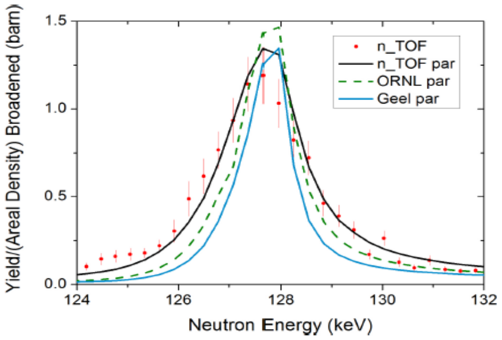
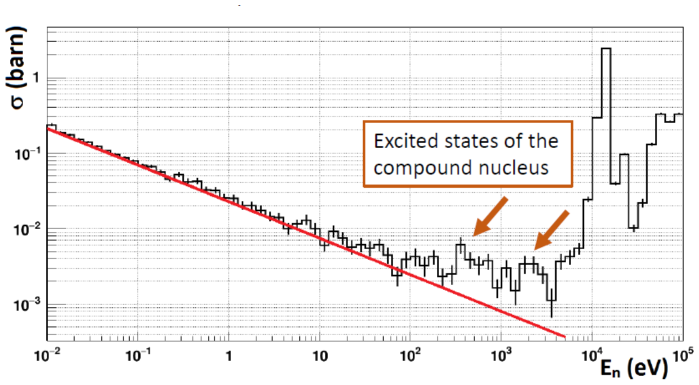
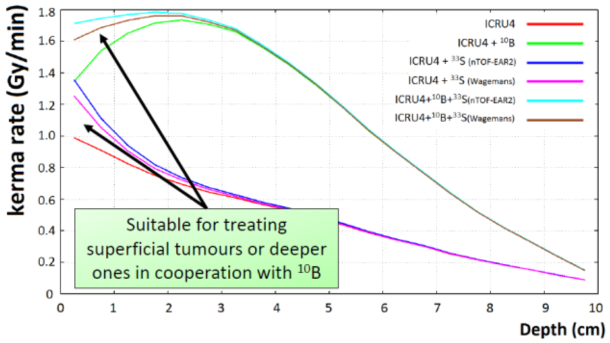


FIG. 8. *R*-matrix analysis from 124 to 132 keV. The n_TOF data (red points) are compared with the description of ORNL [5] (dashed green line), Geel [6] (blue line), and the present work (black line).

EAR1. We solved the discrepancy and we agreed with ORNL for the 13.5 keV resonance (the highest value of the resonance).



EAR2. The cross section has been measured for the first time below 10 keV and the 1/v behavior has been confirmed.

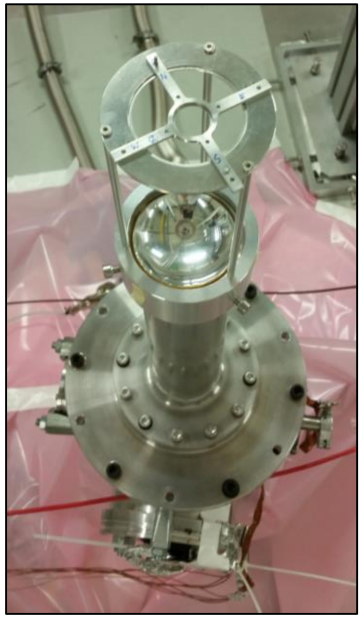


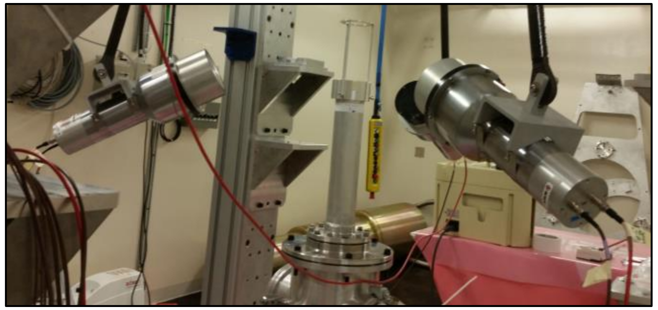
MC simulations of the dose in tumor show that S-NCT is possible in one conventional irradiation as BNCT experimental treatments.

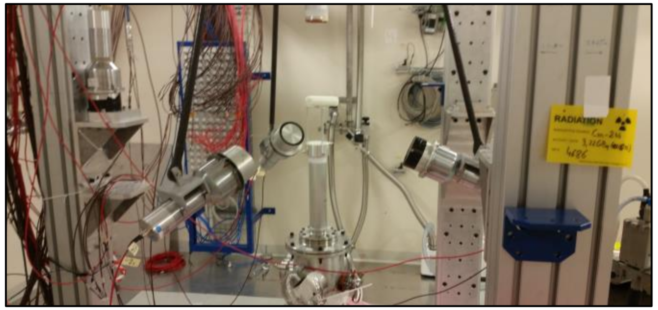
^{241}Am neutron capture cross section measured with C6D6 detectors at the n_TOF facility, CERN

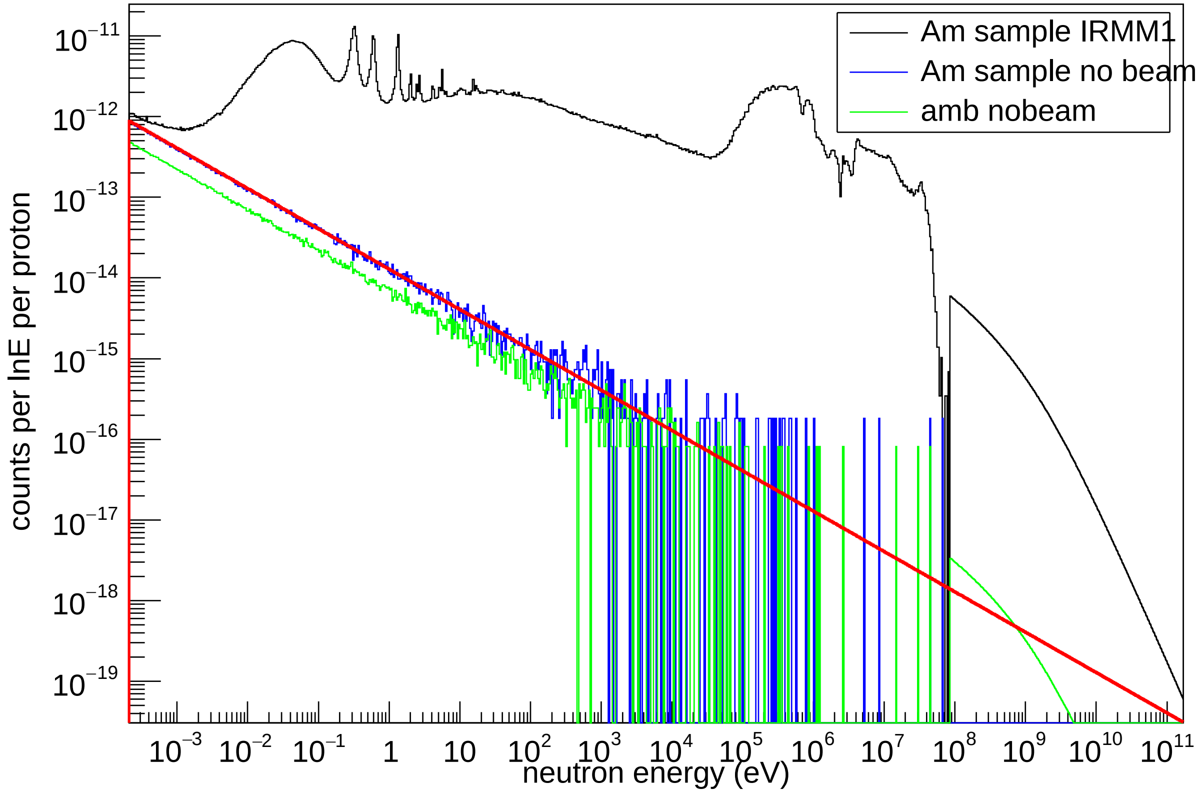
Andreea Oprea

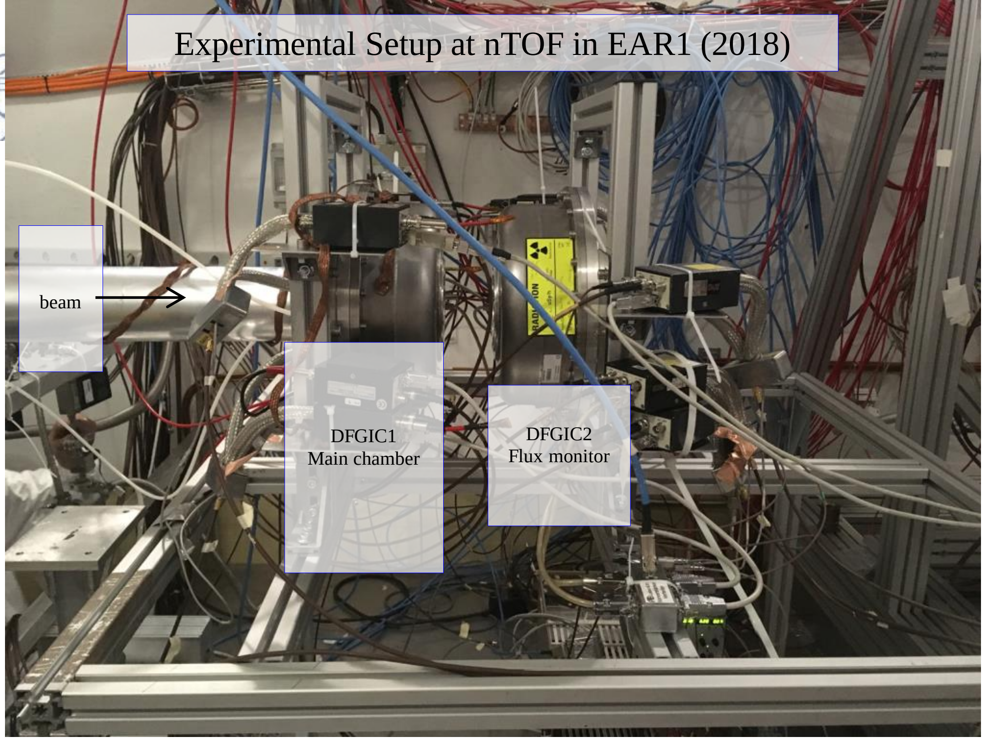
Why ^{241}Am(n,γ)

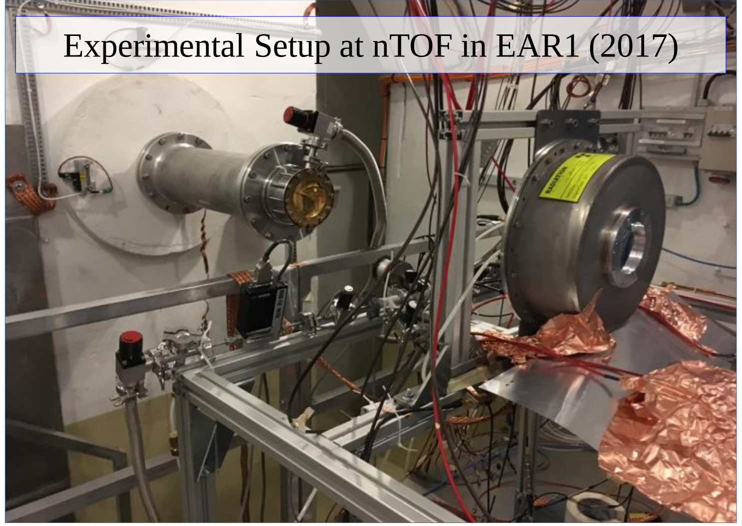




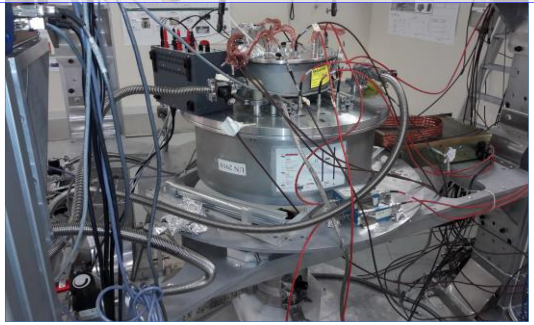


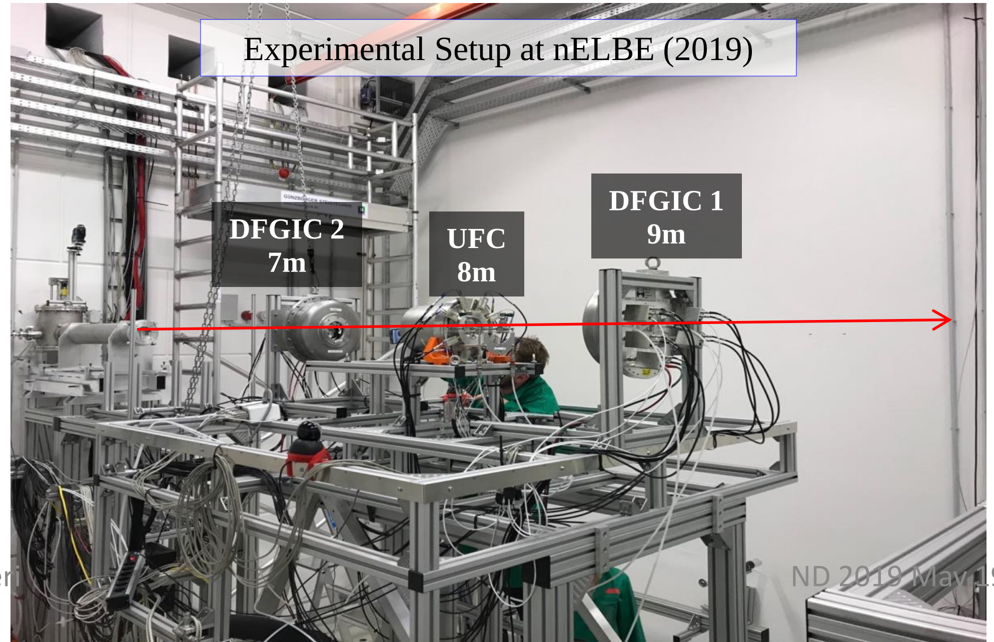




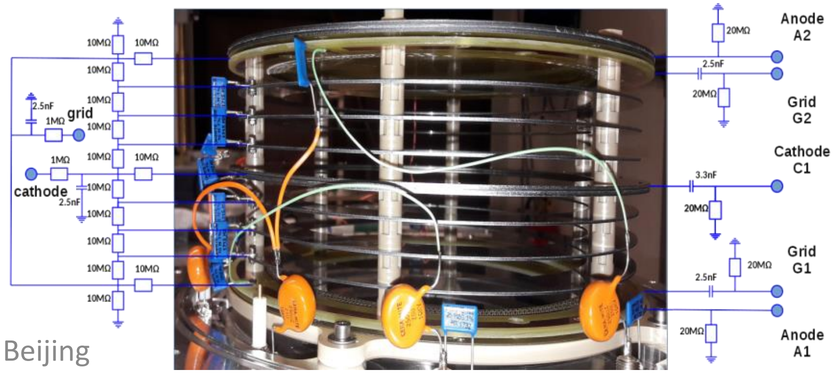


1st Switch test at nTOF in EAR2 (2018)





Beam



Nuclear Physics: nTOF

Example: Tracing the cosmological Lithium problem (CLiP)

Theory of Big Bang Nucleosynthesis predicts the abundance of primordial elements (H, He, Li)

Predictions agree with observations, except for ^7Li (factor 2-3 lower measured)

- 95% of primordial ^7Li produced by electron capture decay of ^7Be ($T_{1/2}$=53,2 days)
- Does a higher destruction rate of ^7Be explains the ^7Li deficit
- Neutron cross section measurements difficult due to lifetime of radioisotope and small sample mass

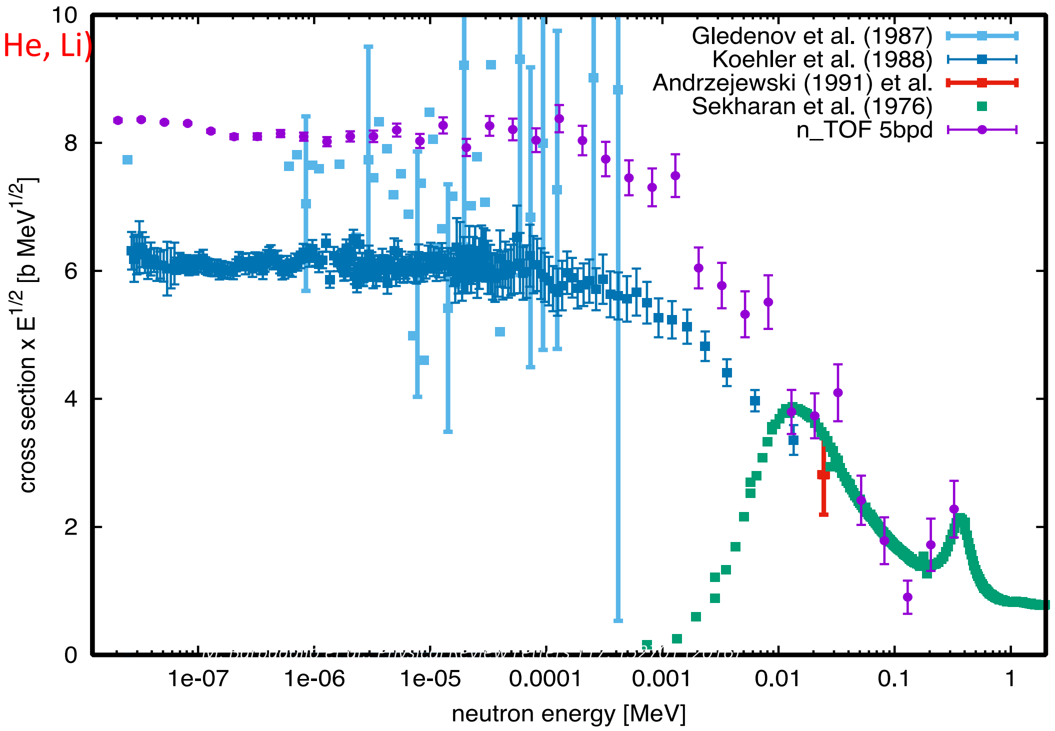
Measurements done at nTOF in 2015: $^7Be(n,a)^4He$ (40 GBq ^7Be sample)

And in 2016: $^7Be(n,p)^7Li$ (1 GBq sample produced via radioactive ^7Be beam at the CERN Radioactive Beam Facility ISOLDE

The $^7Be(n,a)^4He$ results show that the reaction rate in BBN calculation has been so far overestimated so the problem remains unsolved

The $^7Be(n,p)^7Li$ results show that the reaction rate in BBN calculation has been slighly underestimated. However the correction is not sufficient to provide a viable solution to the problem,

The nTOF results can finally rule out neutron-induced reactions as a potential explanation of the CLiP, leaving all alternative physics and astronomical scenarios still open



L. Damone et al., Physical Review Letters 121, 042701 (2018)

^{233}U α-ratio with fission tagging @ n_TOF

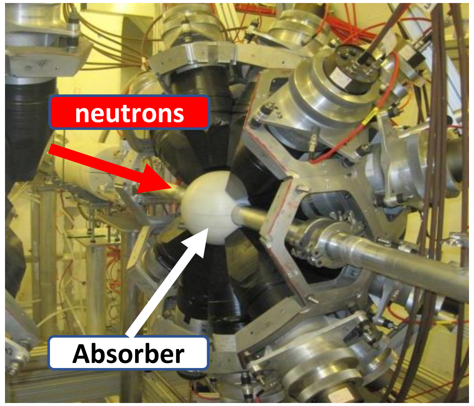
1. Experimental Setup

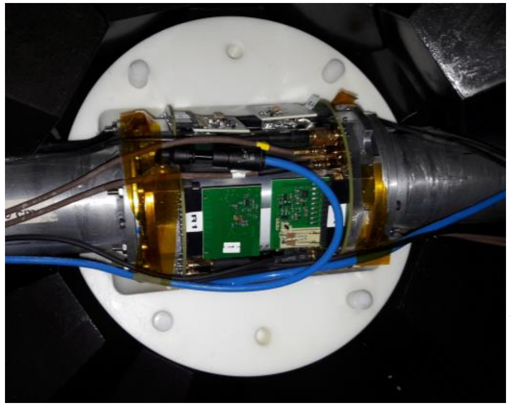
Total Absorption Calorimeter (TAC)

- 4π spherical array of BaF_2 crystals
- Sum energy E_{Sum} and crystal multiplicity m_{cr}

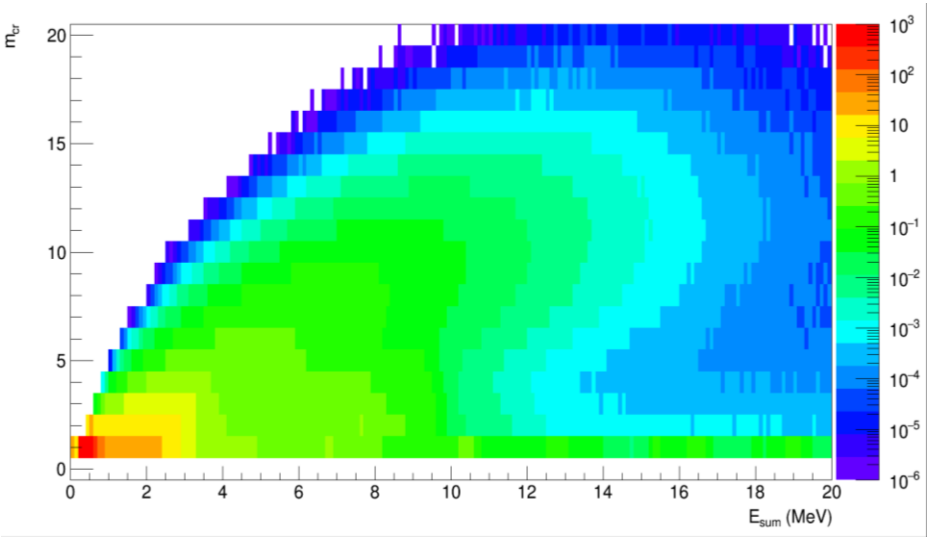
Novel FIssion CHamber (FICH)

- Compact & simple ionization cells
- Fast signals for high α-count rates
- 14 high purity unsealed ^{233}U deposits from JRC-Geel

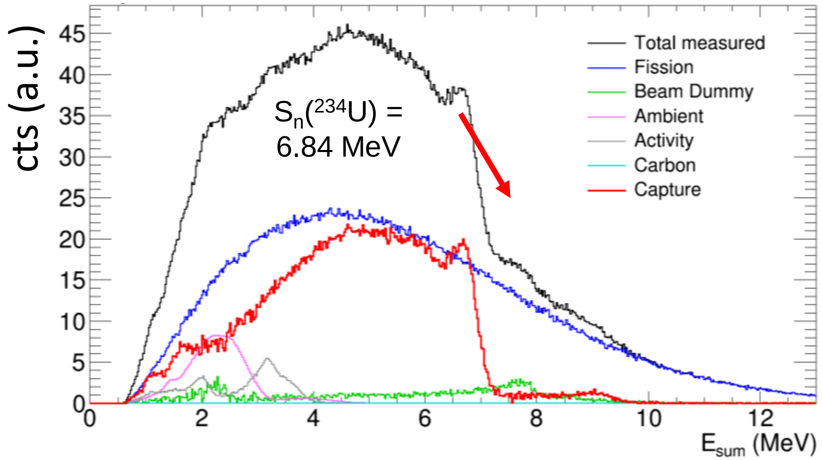




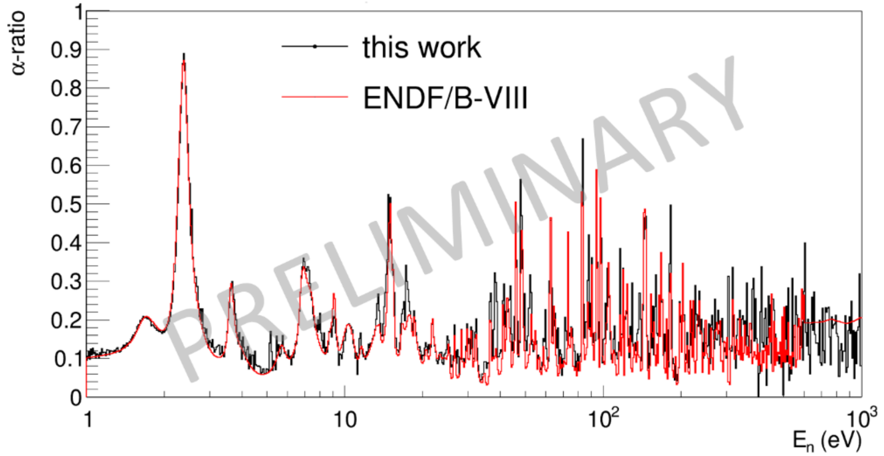
2. Total TAC response



3. Background subtraction

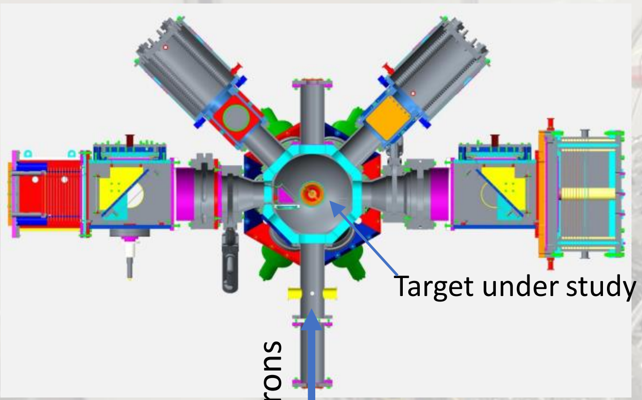


4. Preliminary α-ratio

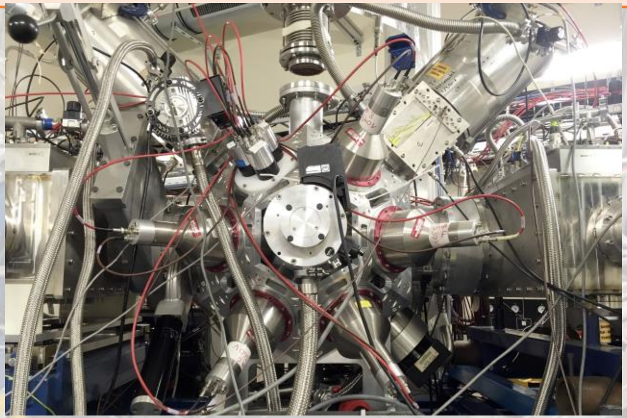


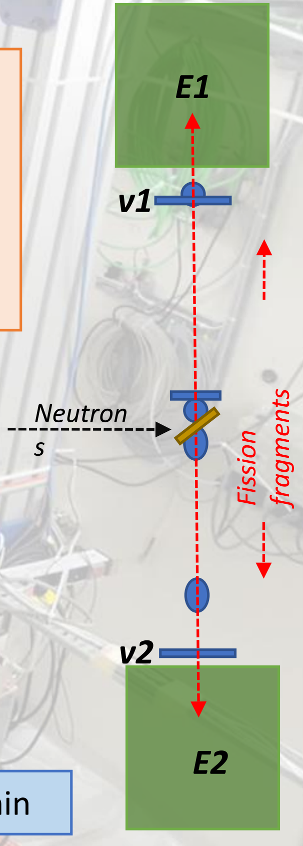
STEFF at n_TOF

Part of the fission programme -> focused on measurements of interest for applied nuclear energy



- **S**pec**t**rometer for **E**xotic **F**ission **F**ragments
  - ***2E2v*** device to measure fission **Z** and **A** yields
  - Prompt fission γ-ray properties measured with an array of scintillators





- ^{235}U(n,f) measured in **2015** and **2016**
- ^{239}Pu(n,f) measured in **2018**
- Future measurements?

^{235}U

^{239}Pu

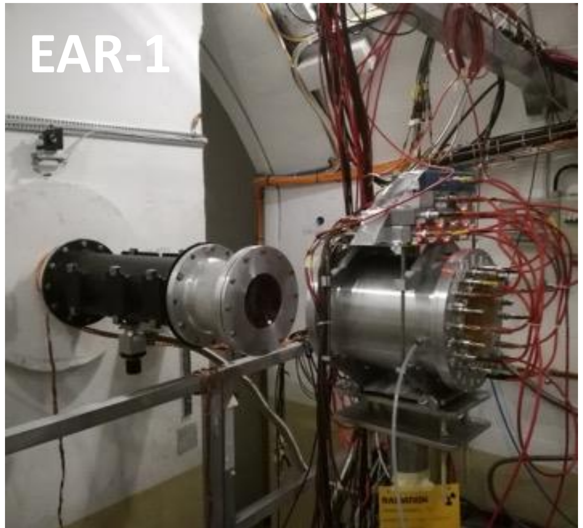
For more information see talk from N. Sosnin

^{230}Th at EAR-1 and EAR-2 of n_TOF

- ^{230}Th is a natural but rare isotope
- Plays an important role in the ^{232}Th/^{233}U fuel cycle
- Is very interesting in the study of the fission process
- However the existing experimental data cover the energy range between 220 keV to 25 MeV with many discrepancies among them

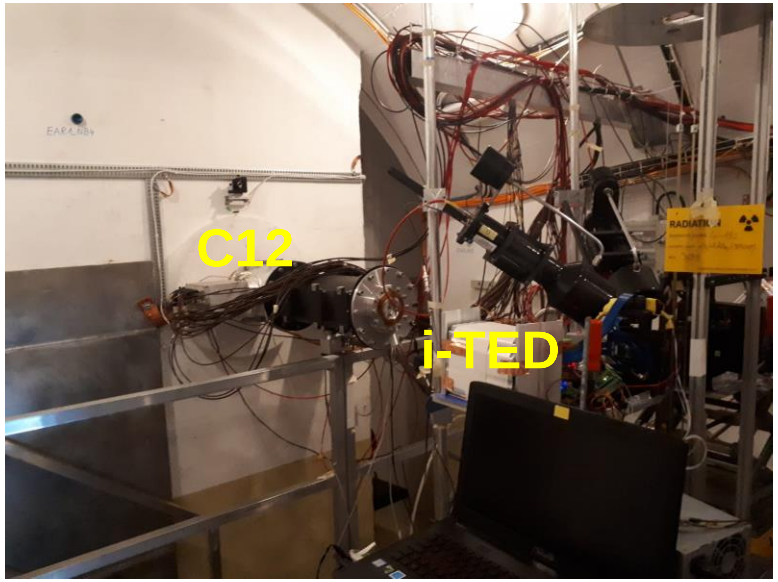
Measurements at EAR-1 and EAR-2 of n_TOF with a setup based on Micromegas detectors to cover a **wide energy range** (meV up to a few hundred MeV)

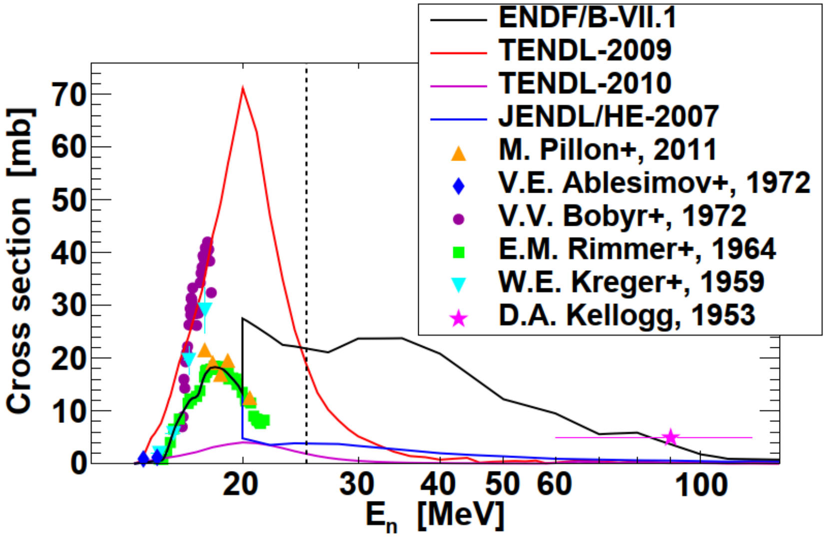
EAR-1: High energy resolution to measure the high energy region
EAR-2: High flux to measure below the fission threshold



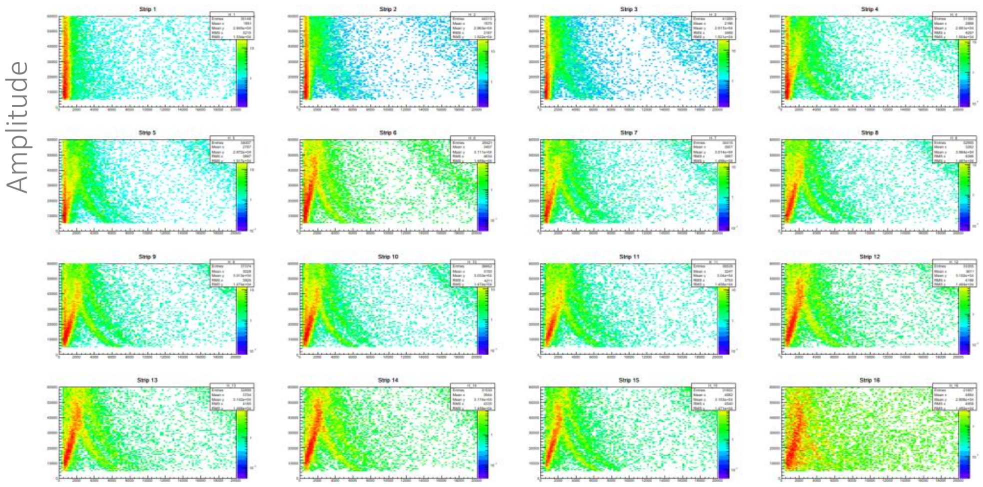
$^{12}C(n,p/d)$ cross-section measurement

$^{12}C(n,p/d)$ (CERN-INTC-2017-001/INTC-P-488) → Cross-section above threshold up to 30 MeV for medical applications and nuclear technologies

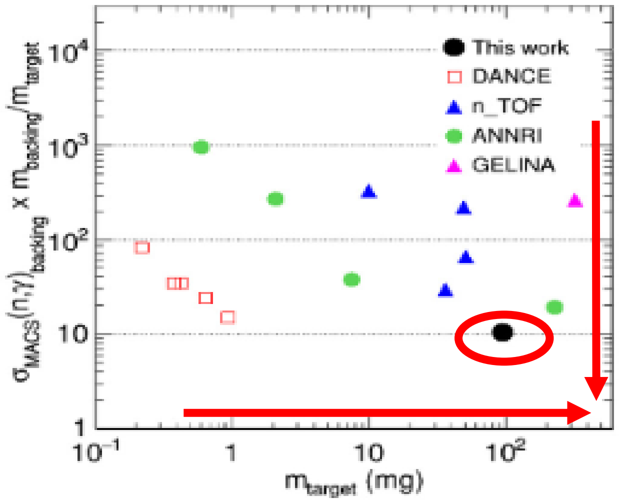




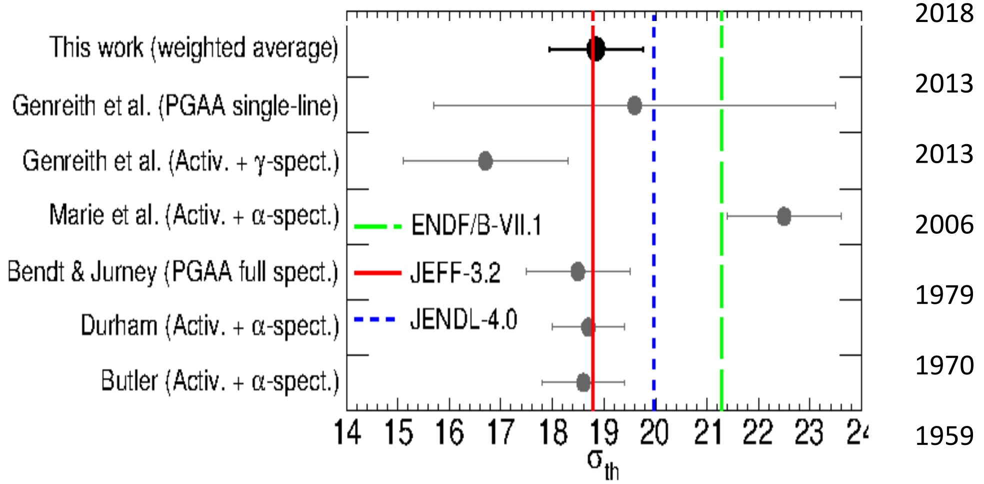
2 Silicon telescopes at different angles



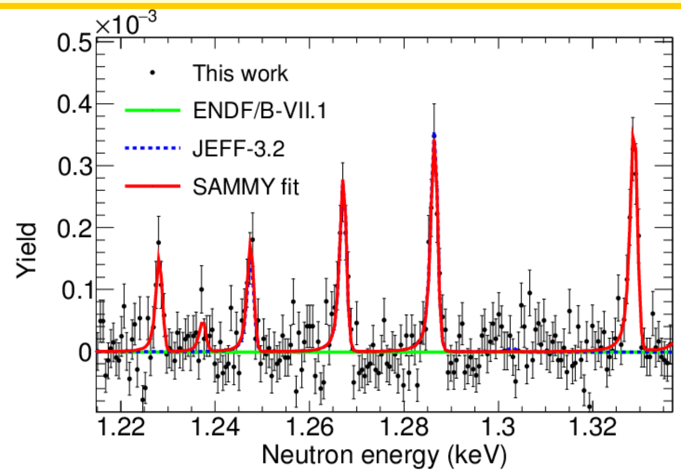
Innovative ^{242}Pu targets[1]: High mass + backings transparent to neutrons



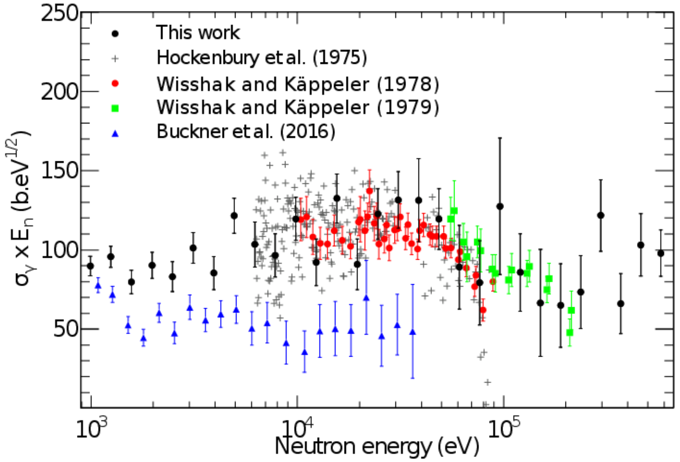
Thermal point [2]: Improved accuracy combining prompt gamma and decay measurements



Resonance region[3]: 251 new resonances up to 4 keV (now JEFF-3.3 En<1.3 keV)



Fast region[4]: 1st measurement En>250 keV, agreement with Wisshak and Kaeppeler



[1] C. Guerrero et al., J. Lerendegui-Marco et al., Nucl. Instrum. Methods A **925**, 87-91 (2019)
[2] J. Lerendegui-Marco, C. Guerrero et al., Eur. Phys. J. A **55,** 63 (2019)
[3] J. Lerendegui-Marco, C. Guerrero et al., Phys. Rev. C **97**, 024605 (2018)
[4] J. Lerendegui-Marco, C. Guerrero et al., Phys. Rev. C (submitted 2019)

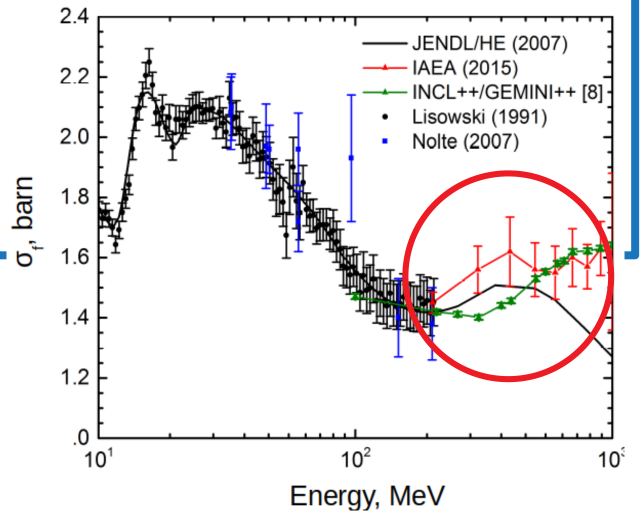
Measurement of the $^{235}U(n,f)$ cross section relative to n-p scattering up to 1 GeV

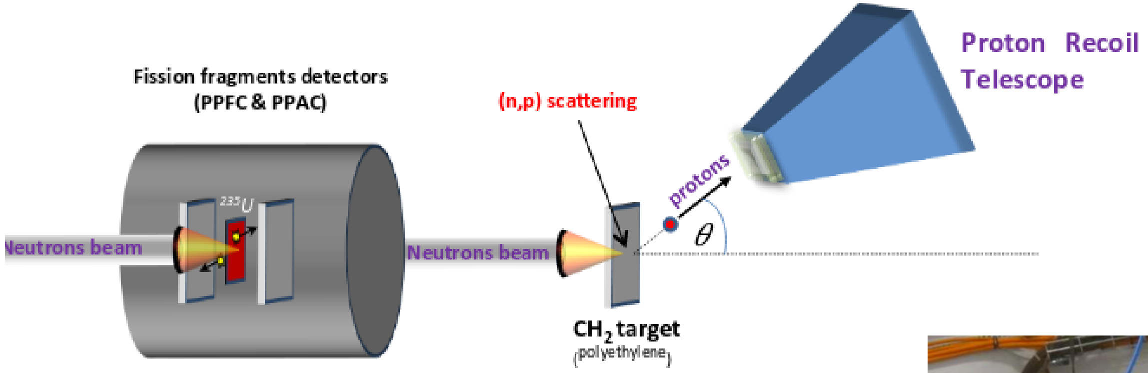
235U(n,f) is one of the most significant cross-section

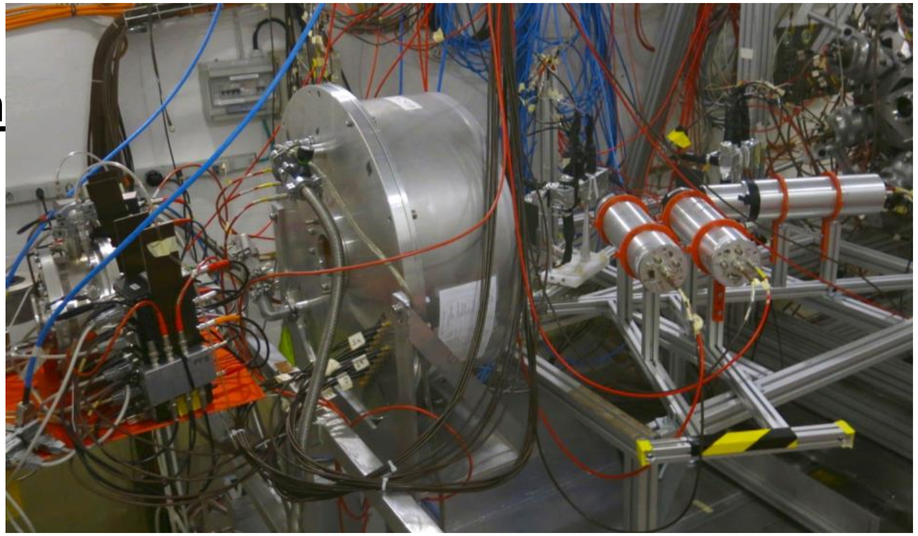
standards at 0.025 eV and [0.15-200] MeV

BUT there are no experimental data above 200 MeV,

despite its importance







The goal: the **simultaneous measurement**

the neutron induced fission cross section of ^{235}U

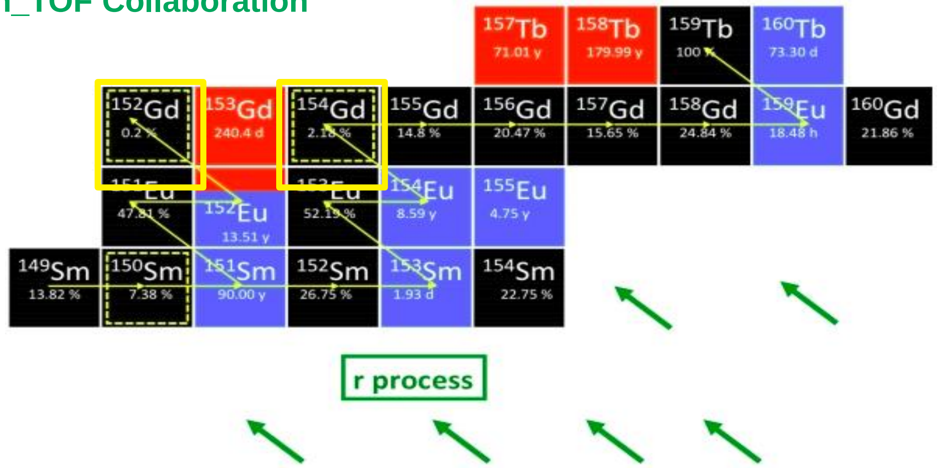
2 Chambers

the (n,p) scattering flux

The ^{154}Gd neutron capture cross section measured at the CERN n_TOF facility

Mario Mastromarco for the n_TOF Collaboration

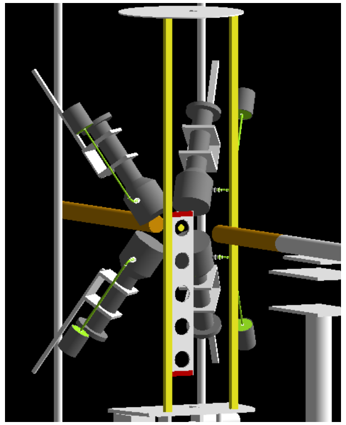
The ^{152}**Gd** and ^{154}**Gd** can be produced **only via the s-process** because they are shielded against the β-decay chains from the r-process region by the stable samarium isobars.



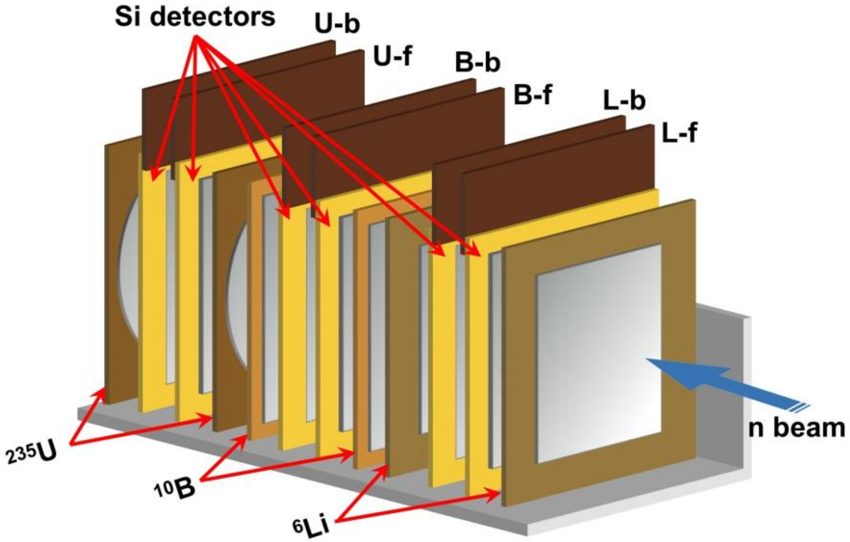
Author / library	MACS @ 30 keV (mb)
ENDF/B-VII (2011)	953.3 +/- 37.0
JENDL-4.0 (2010)	992
JEFF-3.1 (2005)	862
Wisshak (1995)	1028 +/- 12 → 1088
Beer (1988)	878 +/- 27
Shorin (1974)	1278 +/- 102 →1184

Although several experimental and theoretical values can be found in literature, **MACS of ^{154}Gd calculated at 30 keV from previous results differs by more than 15%**.

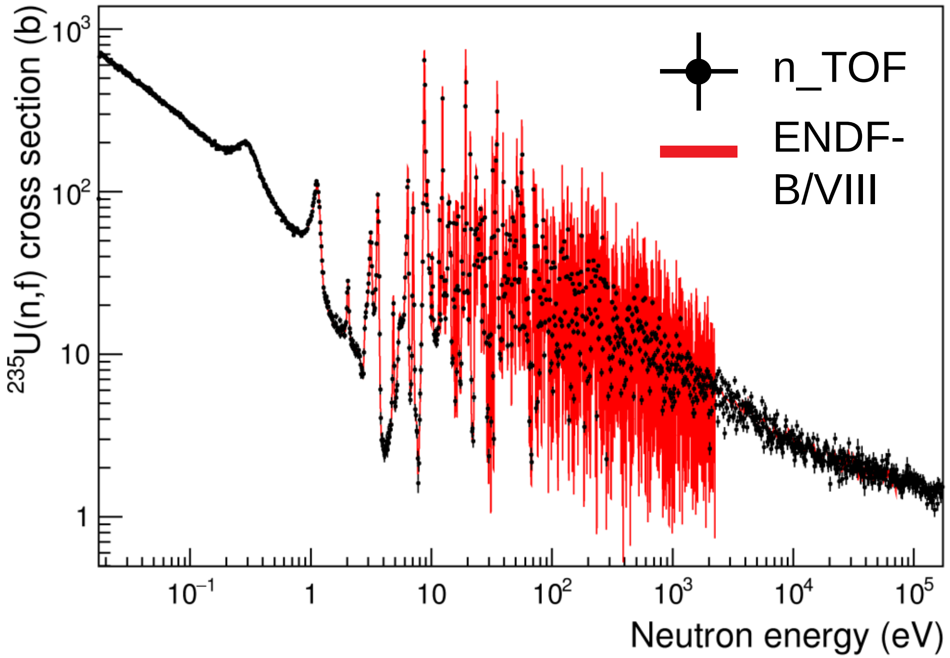
Measurements performed in 2017 **@ n_TOF EAR1**, **flight path 184 m**, with **4 liquid scintillator detectors**



Measurement of ^{235}U(n,f) Cross Section Below 150 keV



The ^{235}U(n,f) fission cross section was measured between two standards, thermal and 150 keV, with a new setup based on in-beam silicon detectors. ^{6}Li(n,t) and ^{10}B(n,α) have been used as references.



Talk scheduled Wednesday 22th May 15:10 room 203

For and with

Member States

OECD-NEA
IAEA

International partners

European Commission

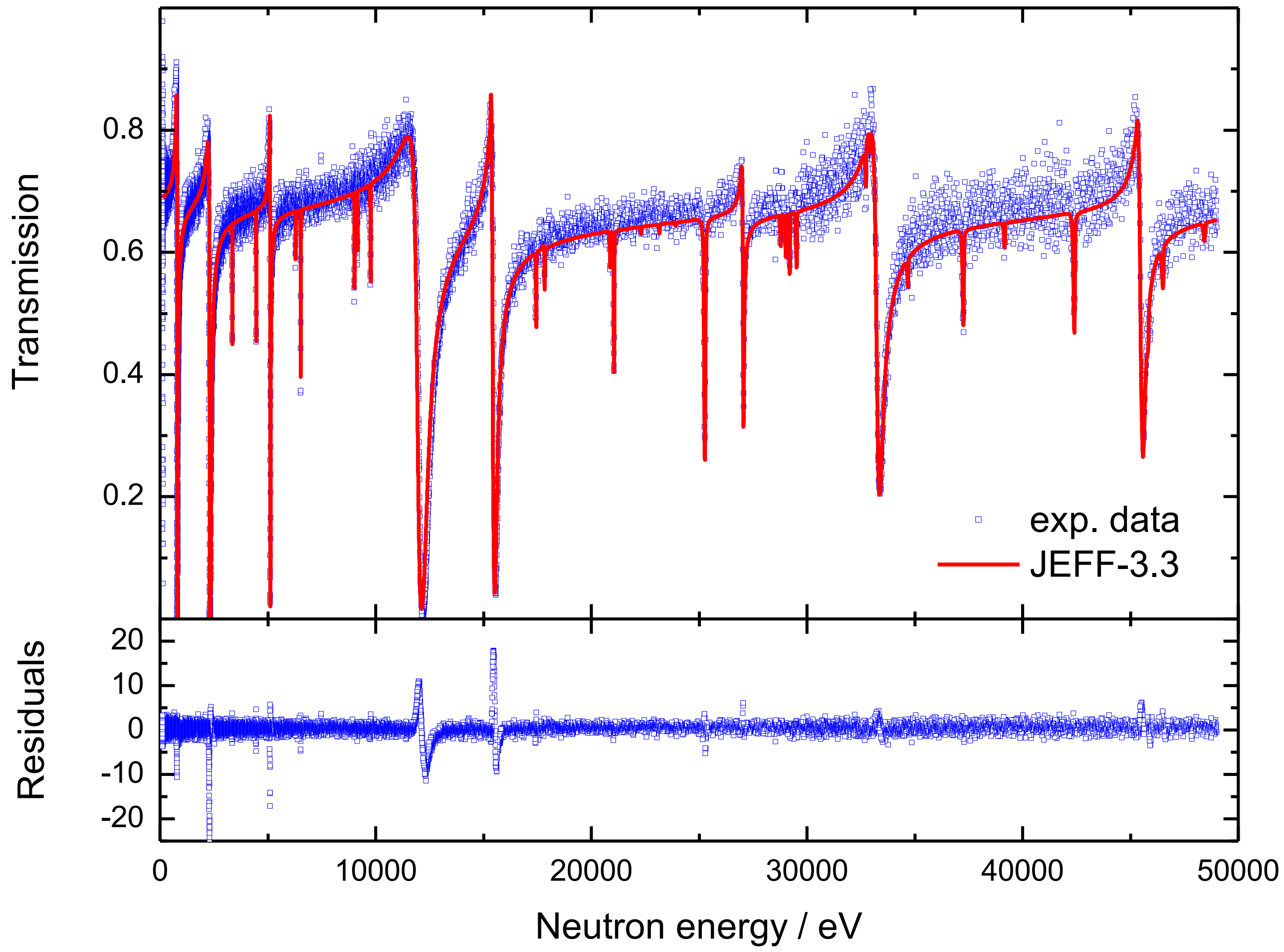
Nuclear facilities at JRC Geel (Jan Heyse I080)

GELINA
neutron time-of-flight facility for high-resolution neutron measurements

MONNET
tandem accelerator based fast neutron source

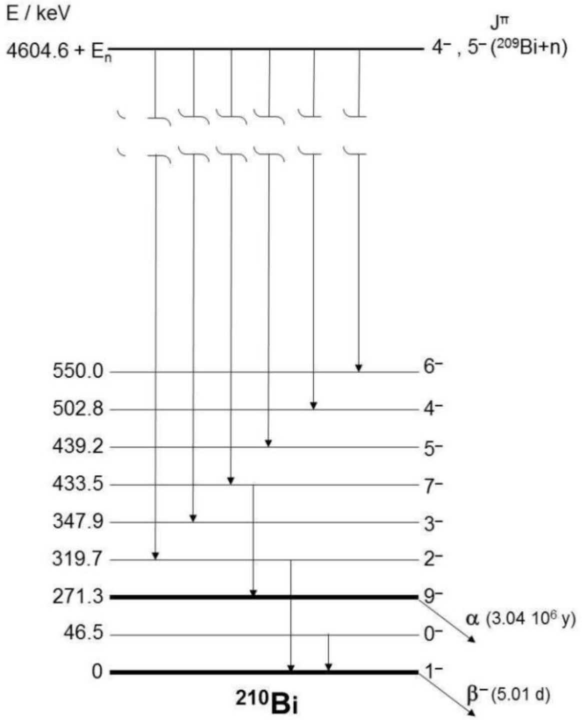
- ^{209}Bi + n with SCK•CEN and JAEA
- Crit. Safety with ORNL
- ^{154,155,157}Gd + n – Cristian Massimi R095
- ^{107,109}Ag RP < 1000 eV – L. Salamon S097
- ^{241}Am capture and transmission normalization free
- Neutron resonance and transmission analysis (NDA)
- Setup development for scattering and fission
- Neutron multiplicities and FF 239Pu(n,f)

New evaluation for ^{209}Bi + n



Project in collaboration with SCK•CEN and JAEA

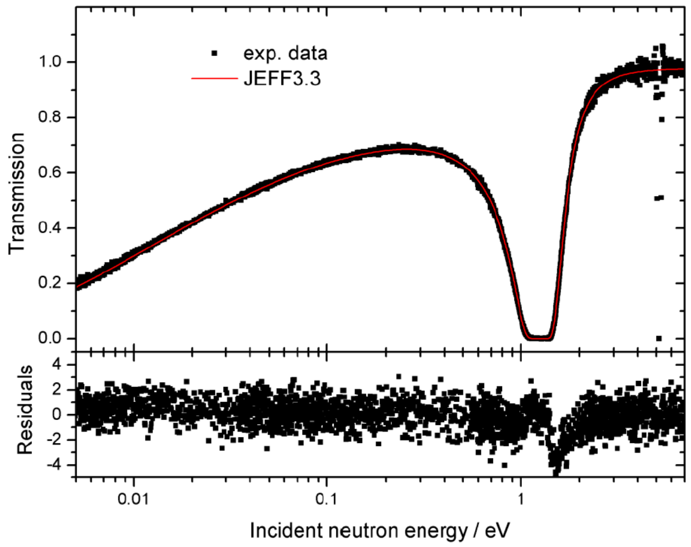
- Improve RP for ^{209}Bi
- Capture at GELINA (60m)
- Determine branching ratio J-PARC: $\sigma_{\gamma,g} / \sigma_{\gamma,m}$



^{103}Rh + n (SNF, criticality safety)

Measurements at GELINA

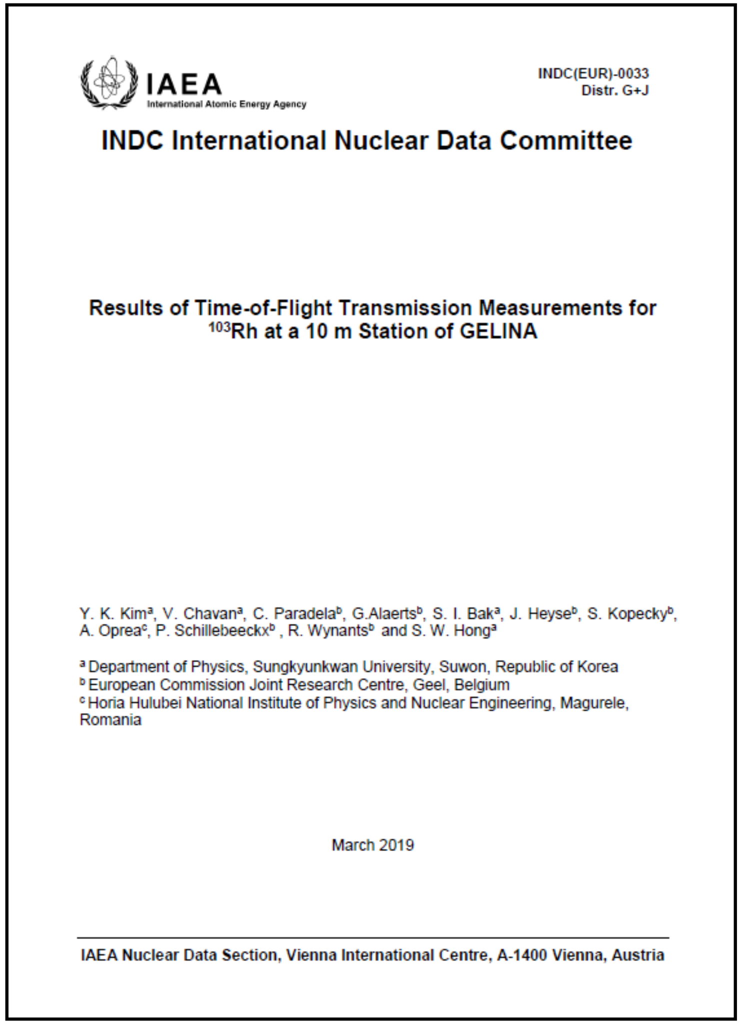
- Transmission at 10m and 50 m
- Capture at 12.5 m



Collaboration:
Sungkyunkwan University, Suwon

See poster Dr. V. Chavan

Reporting of EXFOR data based on AGS



IAEA
International Atomic Energy Agency

INDC(EUR)-0033
Distr. G+J

INDC International Nuclear Data Committee

Results of Time-of-Flight Transmission Measurements for ^{103}Rh at a 10 m Station of GELINA

Y. K. Kim[a], V. Chavan[a], C. Paradela[b], G.Alaerts[b], S. I. Bak[a], J. Heyse[b], S. Kopecky[b], A. Oprea[c], P. Schillebeeckx[b], R. Wynants[b] and S. W. Hong[a]

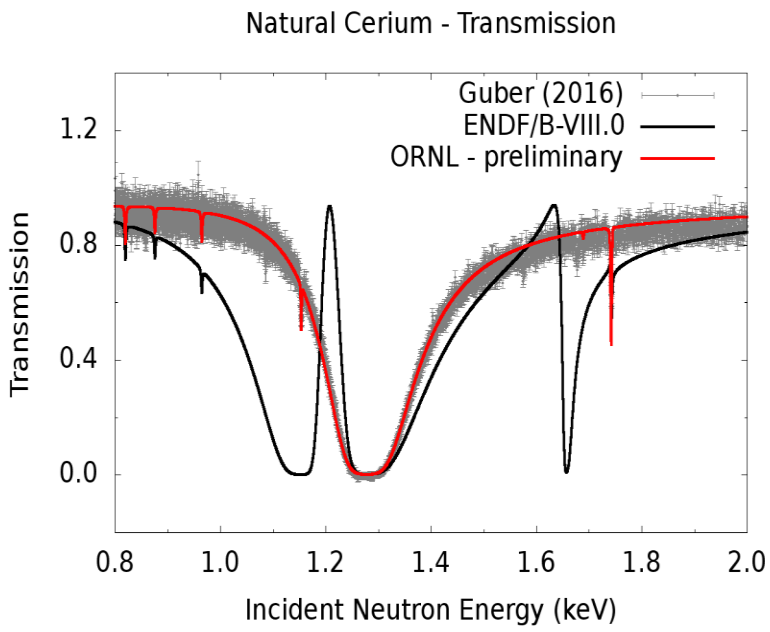
[a] Department of Physics, Sungkyunkwan University, Suwon, Republic of Korea
[b] European Commission Joint Research Centre, Geel, Belgium
[c] Horia Hulubei National Institute of Physics and Nuclear Engineering, Magurele, Romania

March 2019

IAEA Nuclear Data Section, Vienna International Centre, A-1400 Vienna, Austria

Collaboration with ORNL (criticality safety, Burnup Credit)

Nuclide	Transmission	Capture		Status
^{nat}Ce	FP4 50m	FP14 60m	2014	EXFOR data produced.
^{51}V	FP4 50m	FP14 60m	2015	Data reduction finished; EXFOR in preparation
^{139}La	FP4 50m	FP14 60m	2017	Data reduction ongoing
^{142}Ce	FP4 50m	FP14 60m	2019	Experiments ongoing



E_i (eV)	Γ_n^{old} (meV)	l^{old}	Γ_n^{new} (meV)	l^{new}
1152.7	50000	0	50	1
1657	10000	0	10	1

Collaboration with INFN Bologna: $^{154,155,157}Gd + n$

(n,γ) measurements at nTOF (180 m) using $^{155,157}Gd$ enriched samples complemented by measurements at GELINA

Mastromarco et al. EPJA 55 (2019) 9

– transmission at 10m

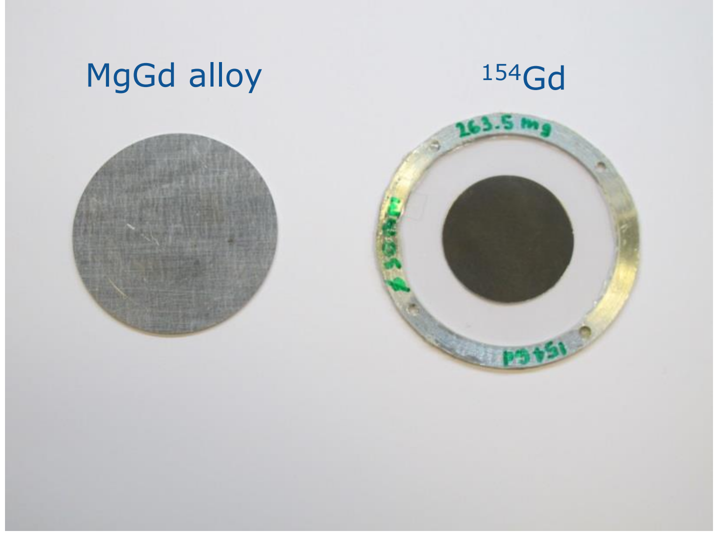
– capture at 12.5 m

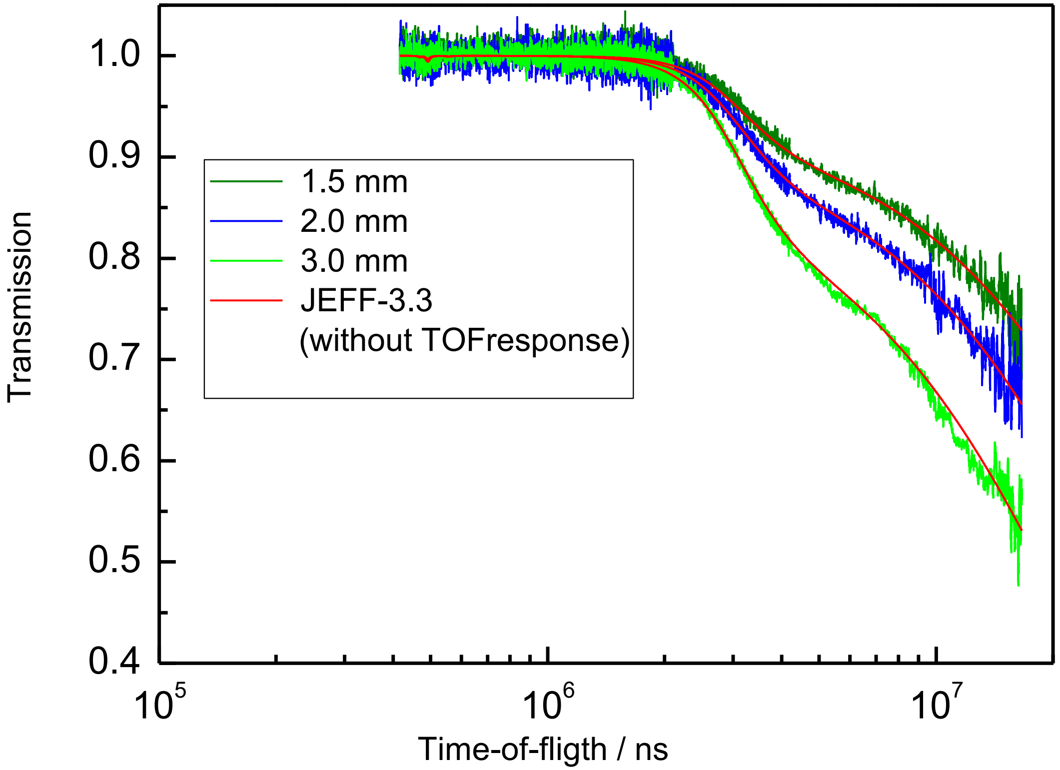
using $^{155,157}Gd$ + ^{154}Gd enriched samples and special MgGd alloys

Table 2. Features of the Gd samples with uncertainties declared by the provider.

Isotope	Abundance %	% contamination of $^{155 \text{ or } 157}Gd$	% main contaminant	Weight mg	Areal density atoms/barn $\times 10^{-8}$
^{155}Gd	91.74 ± 0.18	1.14 ± 0.01	5.12 ± 0.18 ^{156}Gd	100.6 ± 0.1	12440 ± 40
^{155}Gd	91.74 ± 0.18	1.14 ± 0.01	5.12 ± 0.18 ^{156}Gd	10.0 ± 0.1	1236 ± 12
^{157}Gd	88.32 ± 0.01	0.29 ± 0.01	9.10 ± 0.01 ^{158}Gd	191.6 ± 0.1	23390 ± 60
^{157}Gd	88.32 ± 0.01	0.29 ± 0.01	9.10 ± 0.01 ^{158}Gd	4.7 ± 0.1	574 ± 12

Collaboration with INFN Bologna: $^{154,155,157}Gd + n$



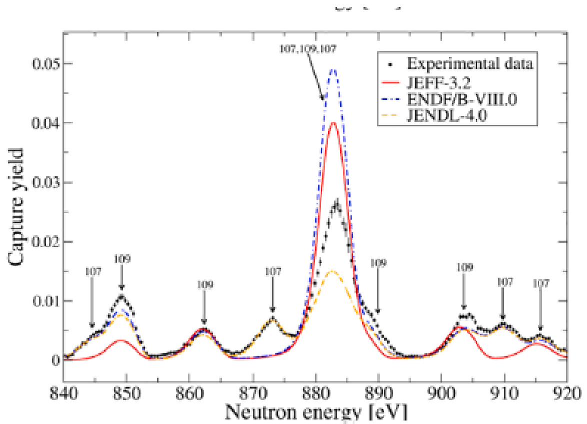


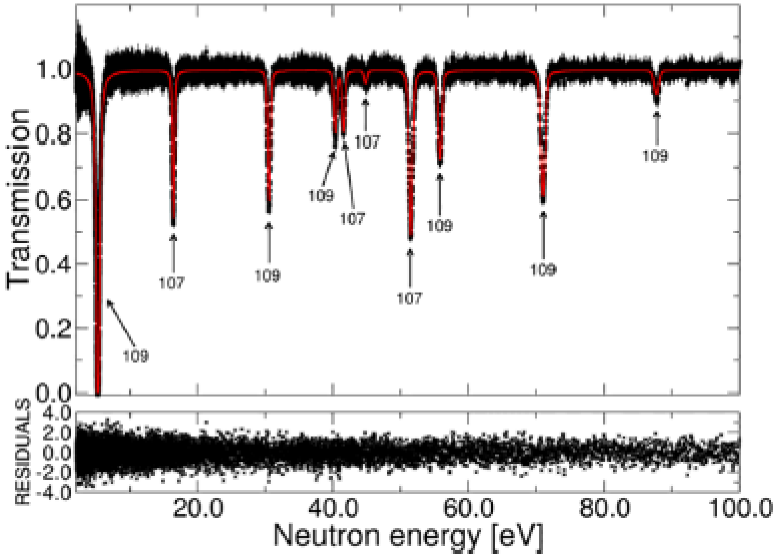
Evaluation of ^{107,109}Ag resonance parameters < 1000 eV

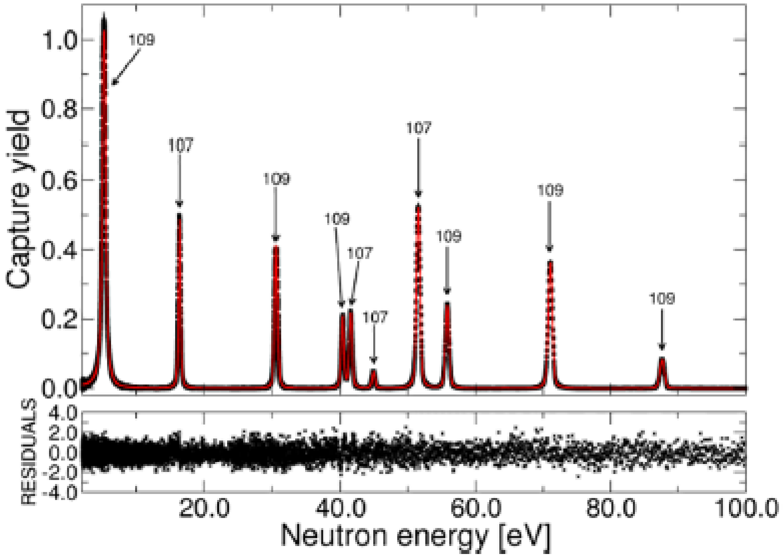
- Transmission : 10 m
- Capture : 12.5 m

Table 1
Characteristics of metallic disc samples used for transmission (indicated with T) and capture (indicated with C) experiments. Areal densities of the samples were calculated from the measured weights and the areas of the samples.

Sample	Thickness [mm]	Diameter [mm]	Weight [g]	Area [cm^2]	Areal density [at/b]	Transmission/Capture
nat Ag	0.25	80	14.3653 (1)	50.3087 (4)	1.59411×10^{-3} (2)	C
nat Ag	0.126	80	6.6366 (1)	50.3088 (3)	7.3646×10^{-4} (1)	T, C
nat Ag	0.06	80	3.4056 (1)	50.2376 (89)	3.7845×10^{-4} (8)	T, C
^{197}Au	0.5	81	50.9234 (1)	51.4538 (22)	3.0259×10^{-3} (1)	C
^{208}Pb	/	80	/	/	/	C







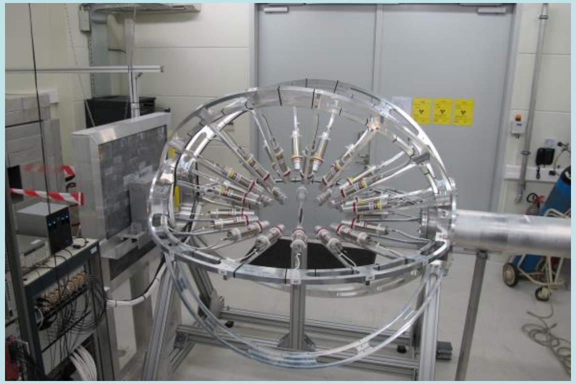
Šalamon et al. NIMB 446 (2019) 19

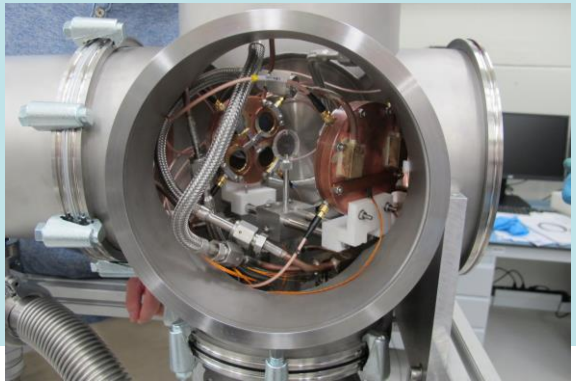
European Commission

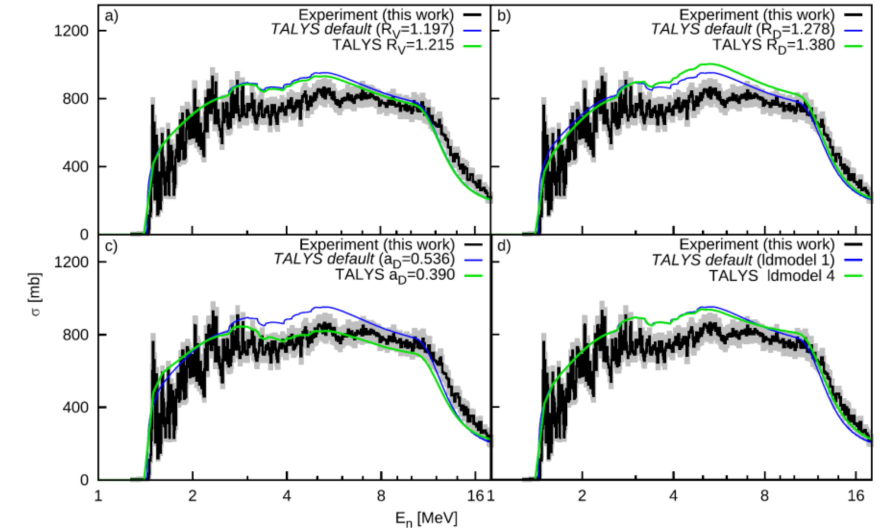
Inelastic scattering with GAINS & Grapheme

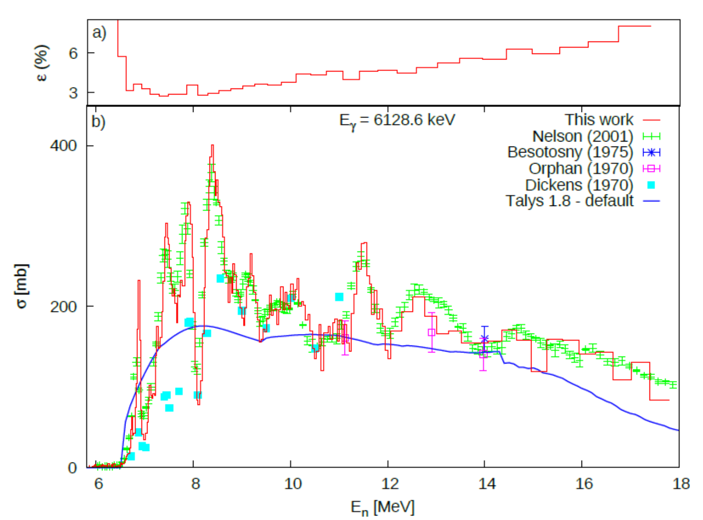
Collaboration with CNRS-IPHC, HZDR, IFIN-HH, PTB

- Reaction mechanisms & nuclear structure from (n,xng): Maelle Kerveno R236
- Gamma production cross sections - GAINS Overview: Alexandru Negret I075
- ^{54}Fe: 2+ to g.s. decay - Adina Olacel R077
- ^{16}O: example of 3- to g.s. decay - Marian Boromiza R076
- ^{7}Li: Roland Beyer R078
- New setups Markus Nyman I127

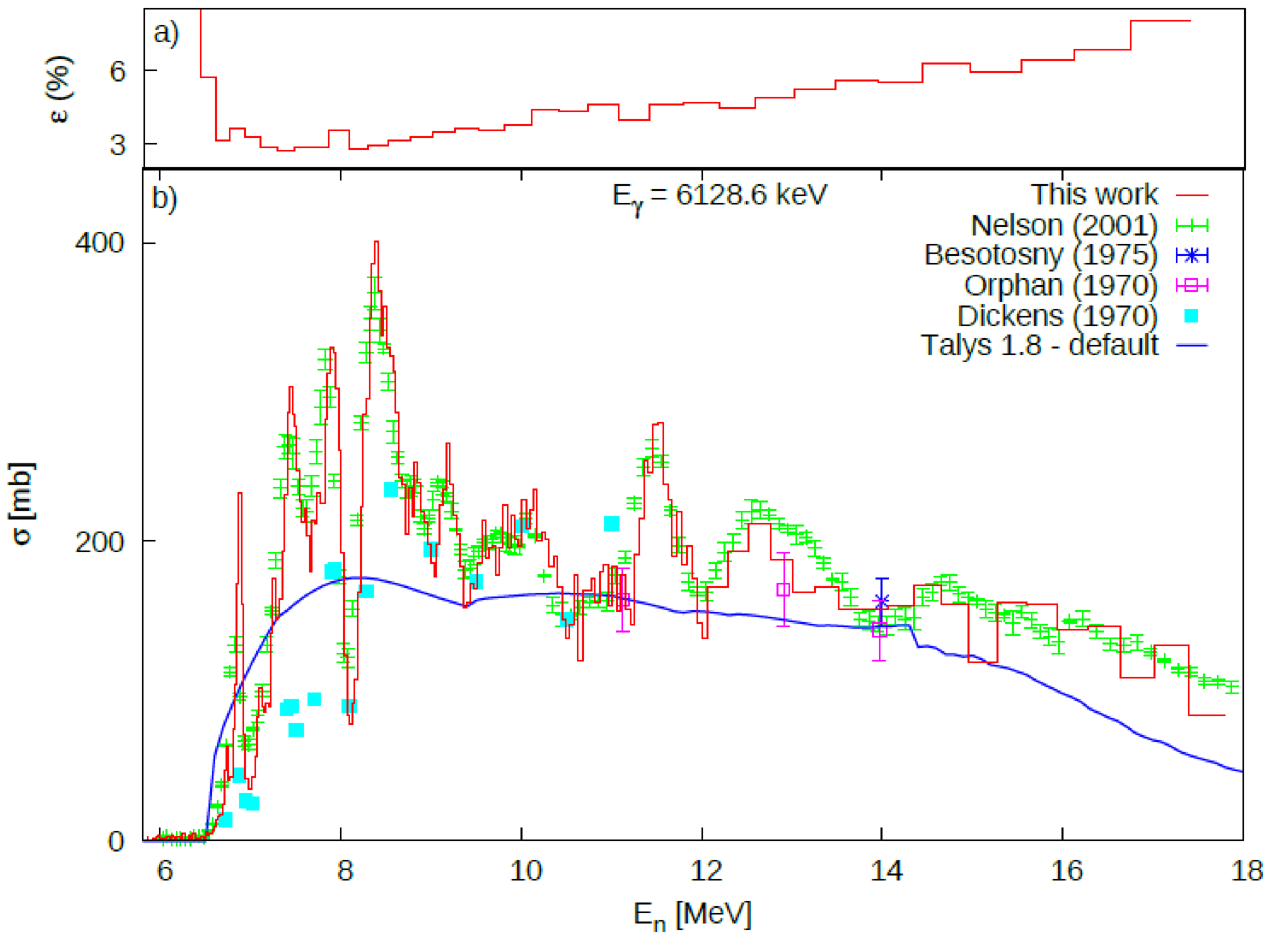




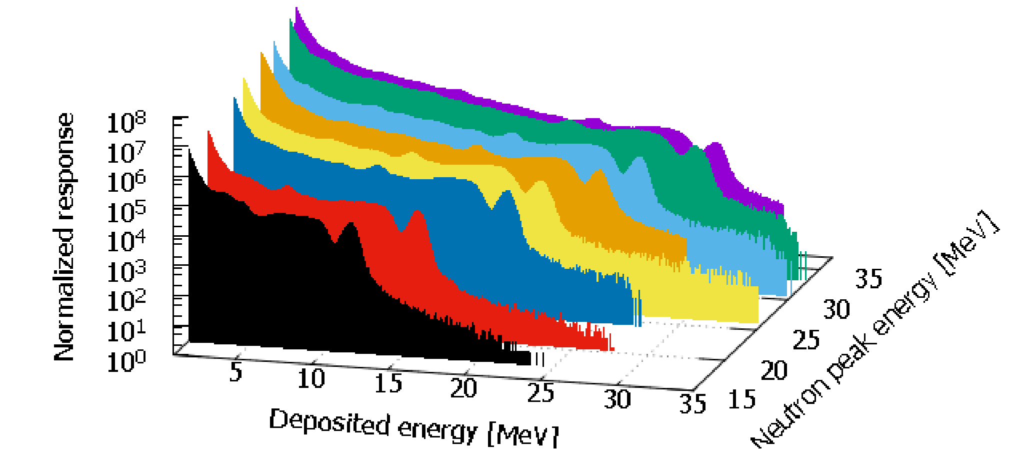


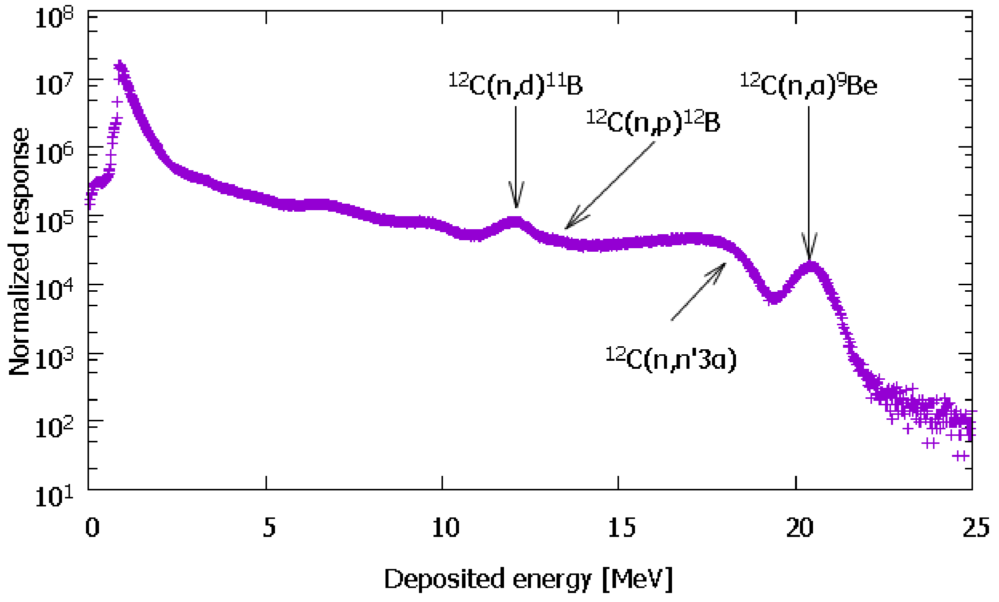


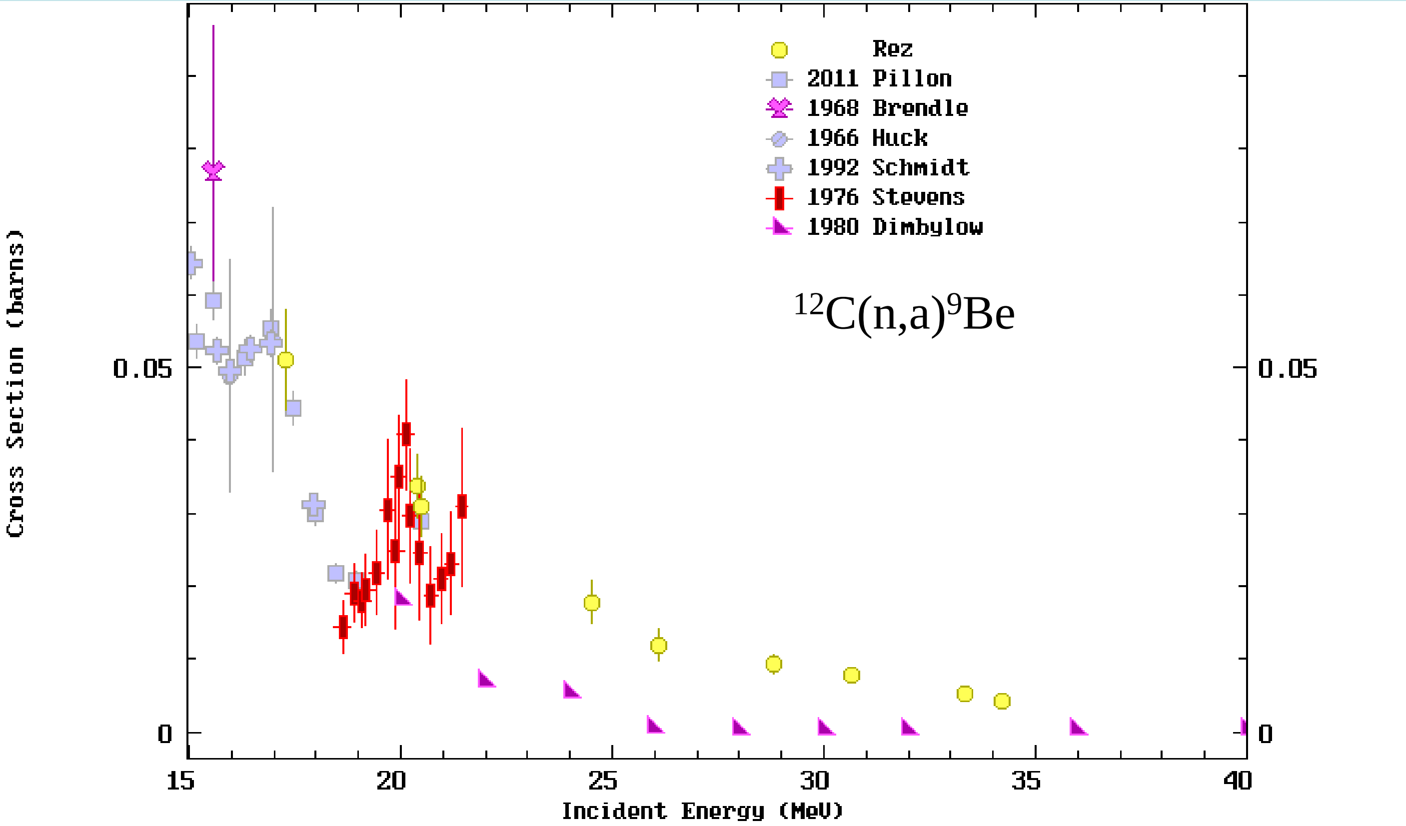
$^{16}O(n,n'g)$, Marian Bormiza, IFIN-HH (RO)

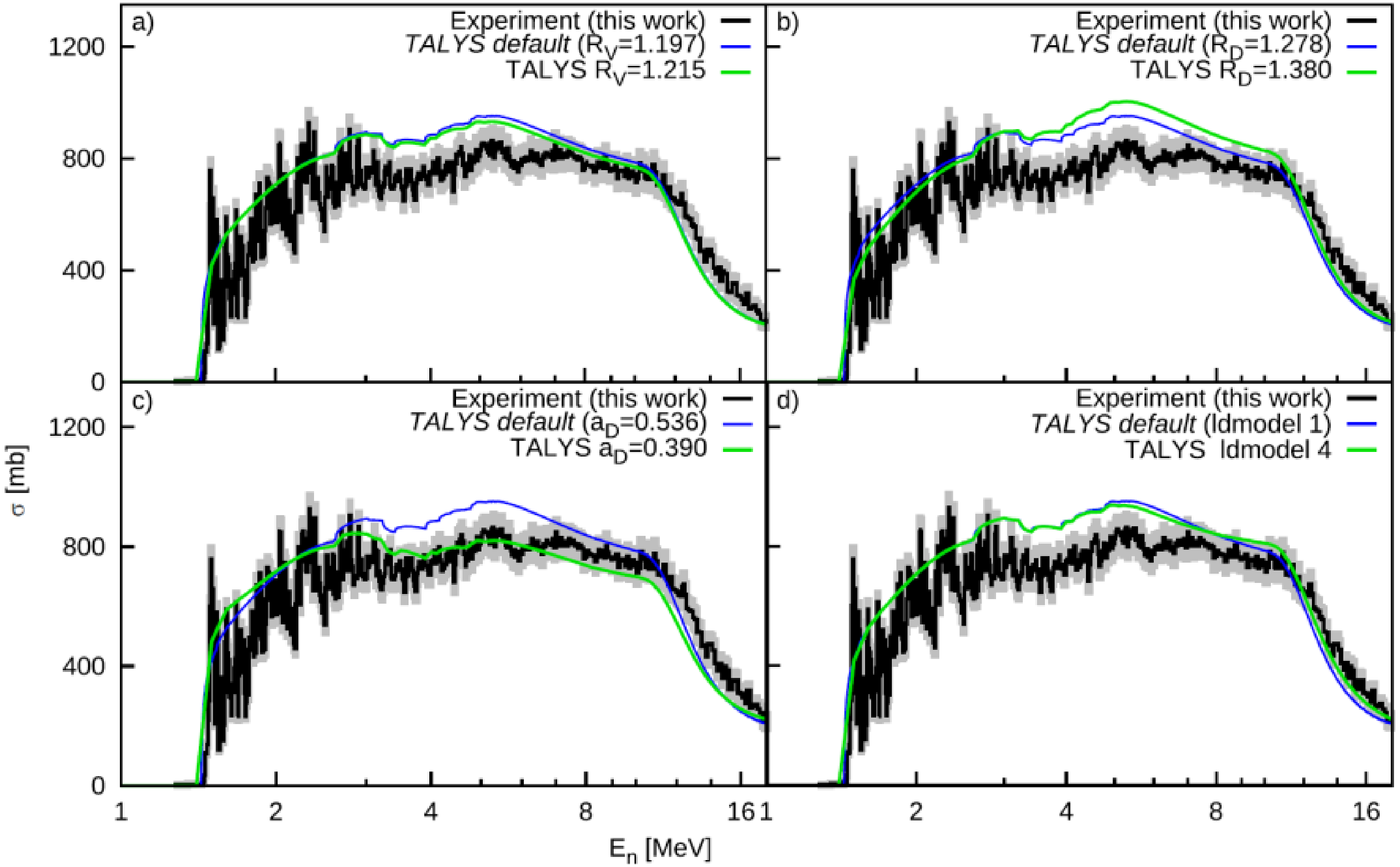


n+12C reactions from n on diamond
Mitja Majerle, NPI Rez, CR








a)
Experiment (this work)
TALYS default (R_V=1.197)
TALYS R_V=1.215
b)
Experiment (this work)
TALYS default (R_D=1.278)
TALYS R_D=1.380
c)
Experiment (this work)
TALYS default (a_D=0.536)
TALYS a_D=0.390
d)
Experiment (this work)
TALYS default (ldmodel 1)
TALYS ldmodel 4
σ [mb]
0
400
800
1200
1
2
4
8
16
E_n [MeV]

n-d scattering by recoil spectra in a proportional counter

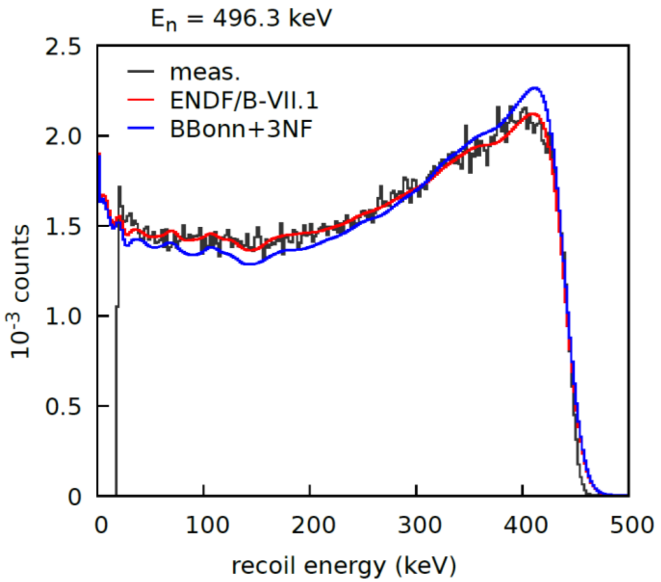
Elisa Pirovano – R079

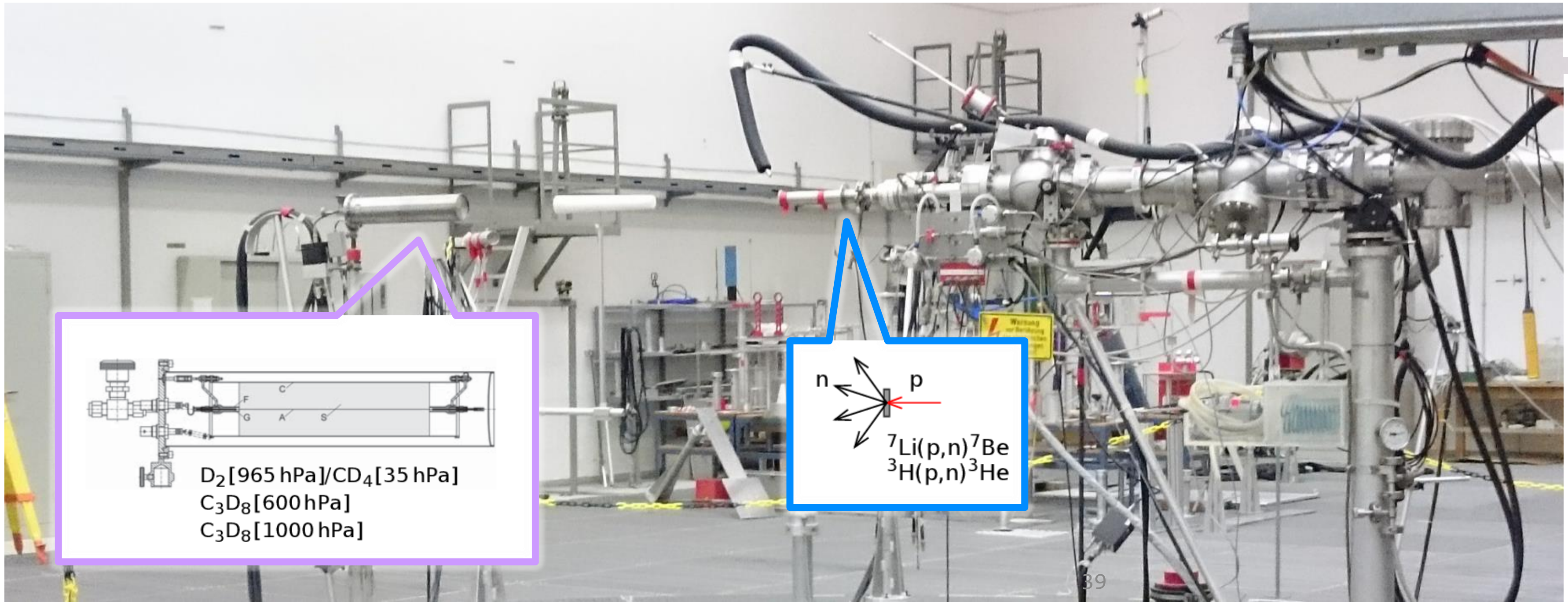
- measurement at the PTB VdG
- quasi-monoenergetic neutrons via $^{7}Li(p,n)$ or $^{3}H(p,n)$
- energy range 400 keV – 2.5 MeV
- different gas mixtures/pressures to limit the escape of recoil deuterons

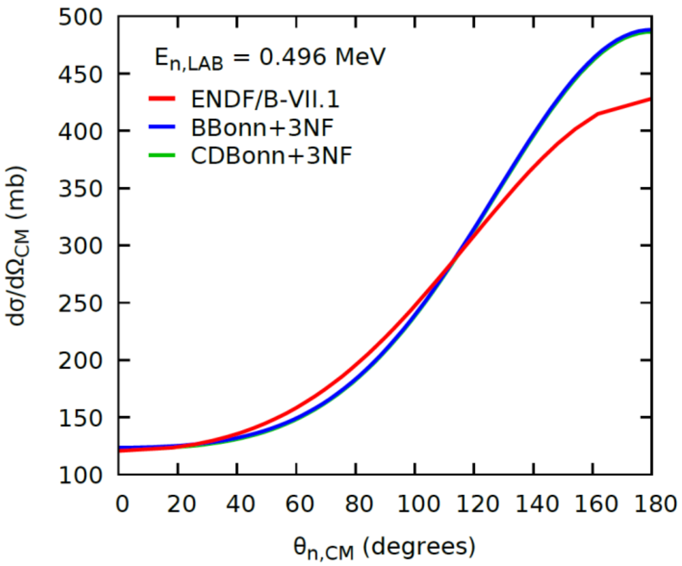
400 – 875 keV

875 – 2500 keV

D_2/CD_4	neutron energy:	400 – 625 keV
C_3D_8 600 hPa		625 keV – 1.25 MeV
C_3D_8 1000 hPa		1.25 – 2.5 MeV

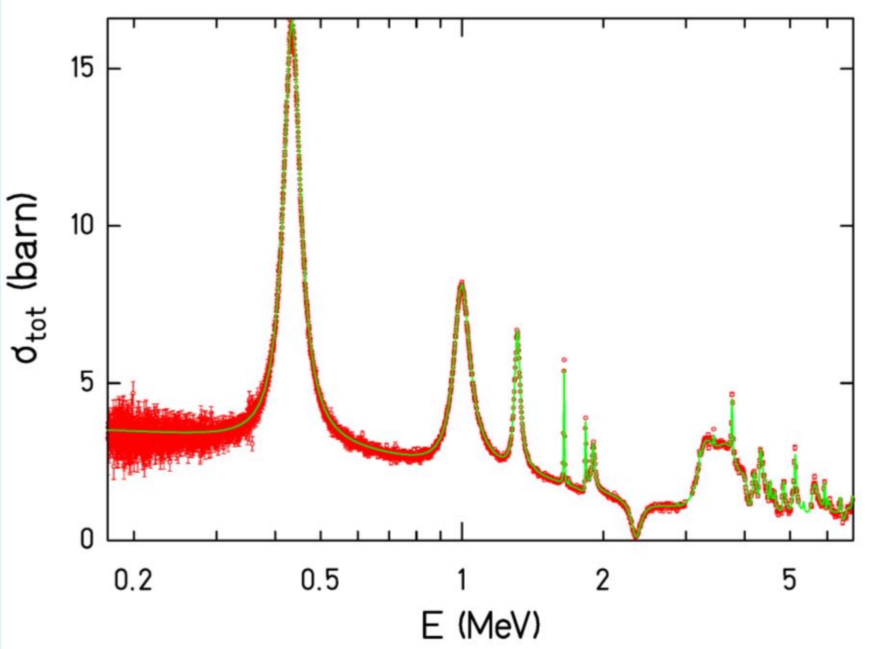


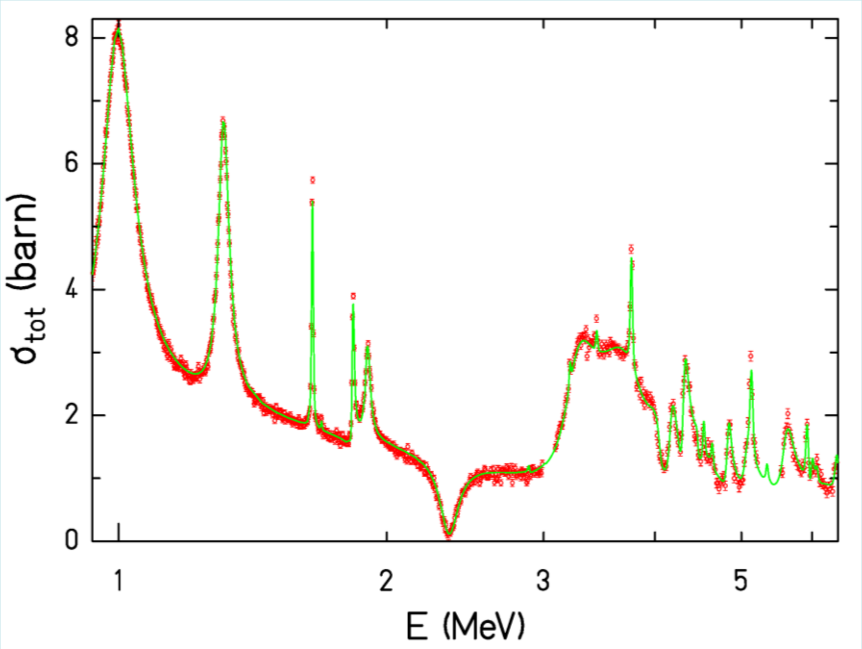




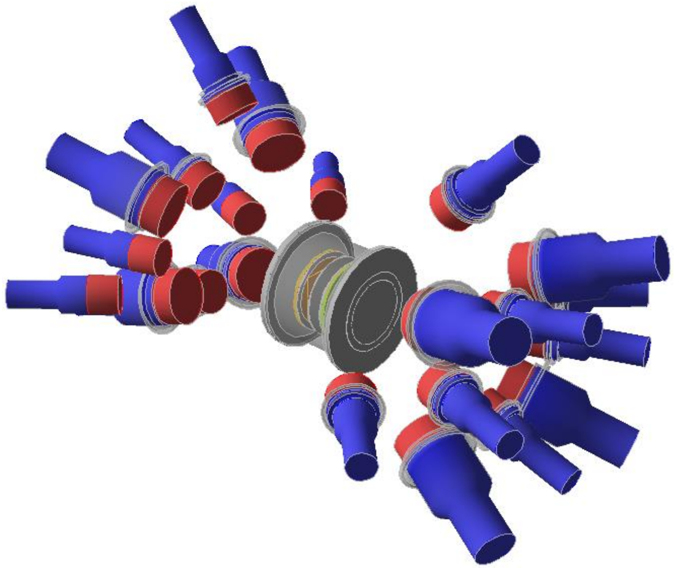
O(n,tot) – HZDR (CHANDA)

- Transmission station HZDR – nELBE (see I240)
- JEFF-3.2, response folded (green); data (red)

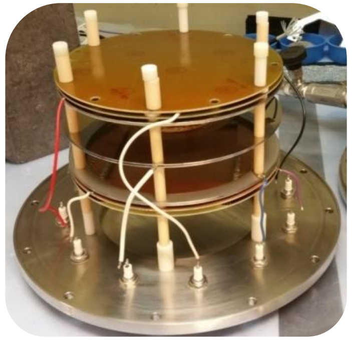


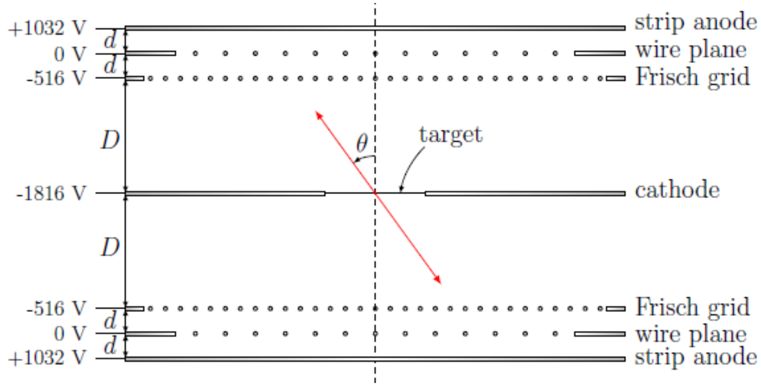


Fission fragment properties, prompt fission neutrons & γ-rays



- Fission fragments by Twin Frisch-Gridded Ionization
  - Fragment energy
  - Fragment Masses - 2E-technique
  - Fission axis orientation
- Prompt fission neutrons
  - 12 x Scintillators (NE213 equivalent)
  - Energy : time-of-flight
- Prompt fission γ-rays
  - LaBr, CeBr scintillators



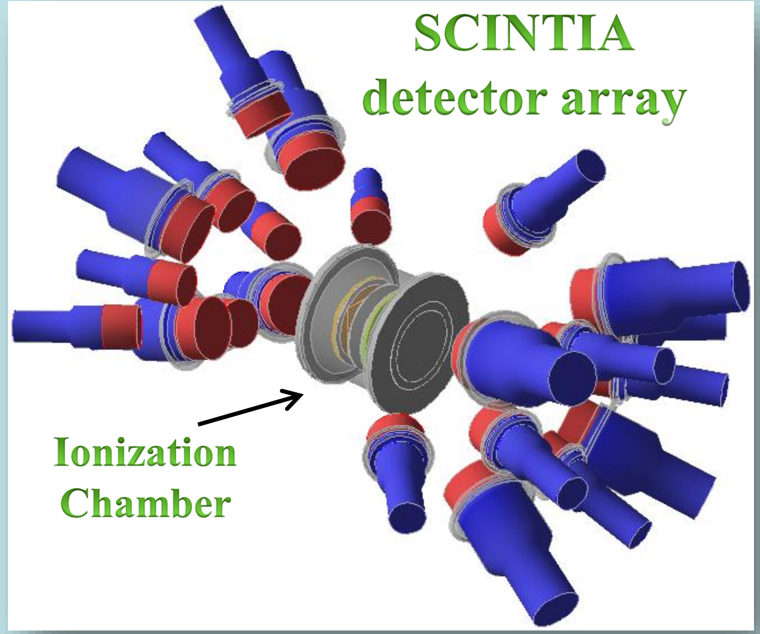


Position sensitive electrode

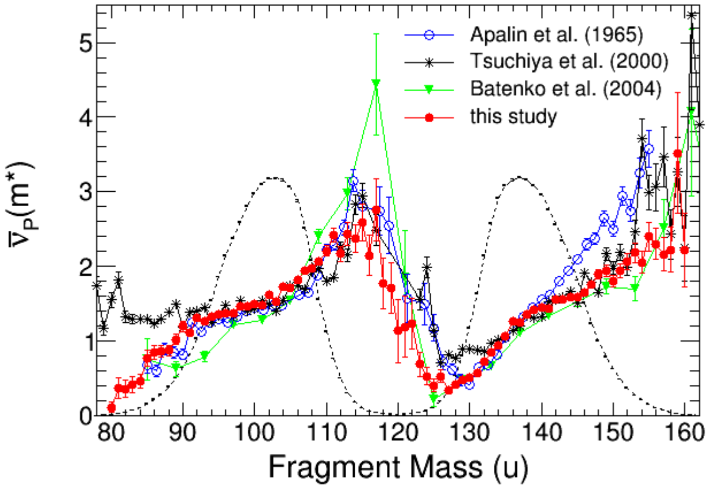
European Commission

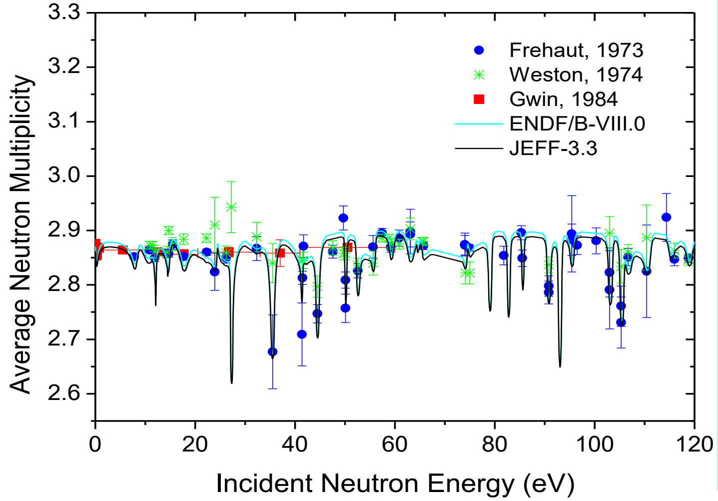
Neutron multiplies and fission fragments in ^{239}Pu(n,f)

Alf Göök R259



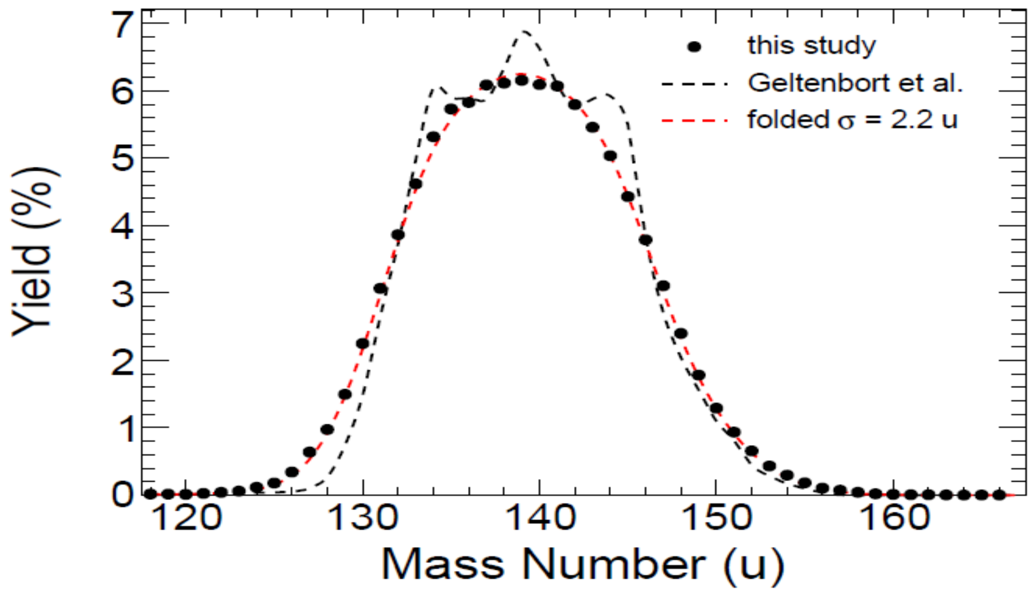
- Measurements related to NEA – High priority request (99H)
  - new $\nu_p(E_n)$ data in resonance neutron induced fission
  - Fluctuating $\nu_p(E_n)$ in resonance range
  - Fluctuating fragment Y(A,TKE)
- Experiment to investigate correlation ν_p(A,TKE) at GELINA



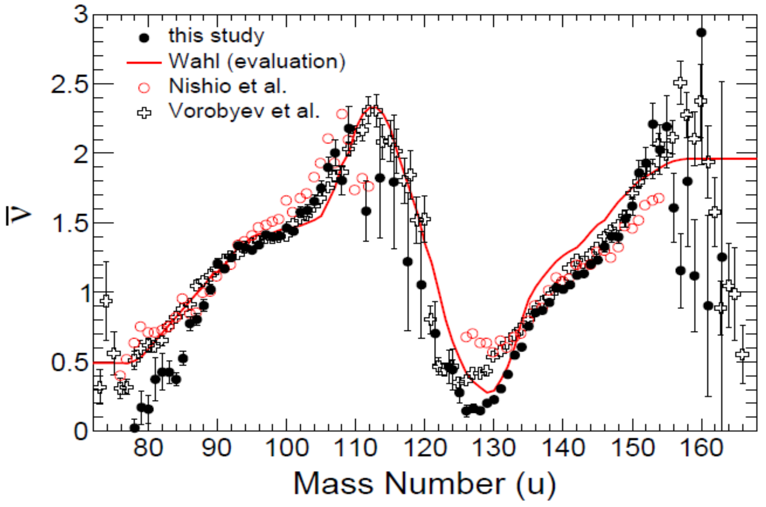


European Commission

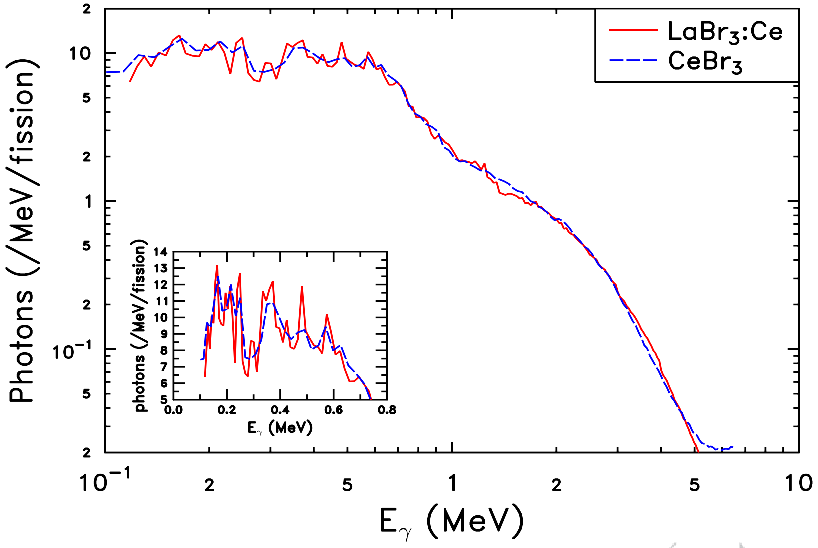
e.g. $^{235}U(n,f)$



Yield (%)
Mass Number (u)
this study
Geltenbort et al.
folded σ = 2.2 u



this study
Wahl (evaluation)
Nishio et al.
Vorobyev et al.
Mass Number (u)



LaBr3:Ce
CeBr3
Photons (/MeV/fission)
Eγ (MeV)