Experimental activities NEA DB

Arjan Plompen

EC-JRC-IRMM, SN3S unit

www.jrc.ec.europa.eu

Joint Research Centre

Content

Experimental activities

Sources: NDW fall 2013
ERINDA
ANDES

ANDES

Accurate nuclear data for nuclear energy sustainability

Coordinator: Enrique Gonzalez Ciemat

Measurements, evaluation, validation

3 M€ EC contribution, ~6M€ total effort

20 partners, 2010-2013

Inspired by HPRL, SG26, SG25, MANREAD, EUROTRANS-NUDATRA, CANDIDE

ERINDA

European research infrastructures for nuclear data applications

Coordinator: Arnd Junghans HZDR

Transnational access to facilities

1 M€ EC contribution, >2x total effort

16 partners, 2010-2013

Objectives: waste transmutation and Gen-IV

31 experiments, 3200 beam hours

HPRL as reference

EUFRAT

European facility for innovative reactor and transmutation neutron data

Coordinator: Wim Mondelaers
Transnational access to GELINA & VdG

0.5 M€ EC contribution, >2x total
1 partner, 2008-2012

Objectives: waste transmutation and Gen-IV, nuclear safety, methods

33 experiments
34 external labs
5985 beam hours

CHANDA

CIEMAT, ANSALDO, CCFE, CEA, CERN, CNRS, CSIC, ENEA, GANIL, GSI, 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

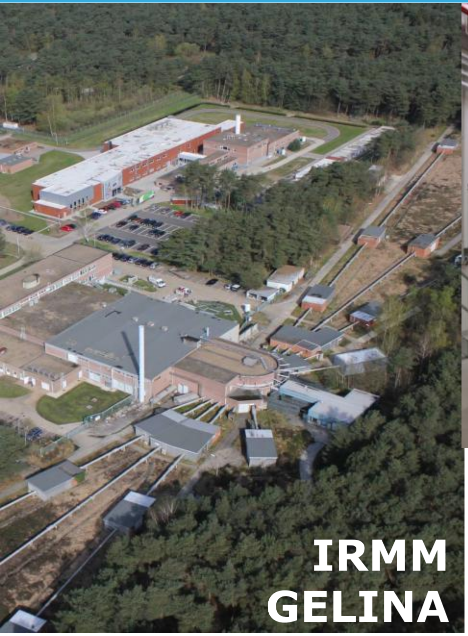
Challenges in nuclear data for the safety of European nuclear facilities

Coordinator: Enrique Gonzalez
Infrastructure coord. & development

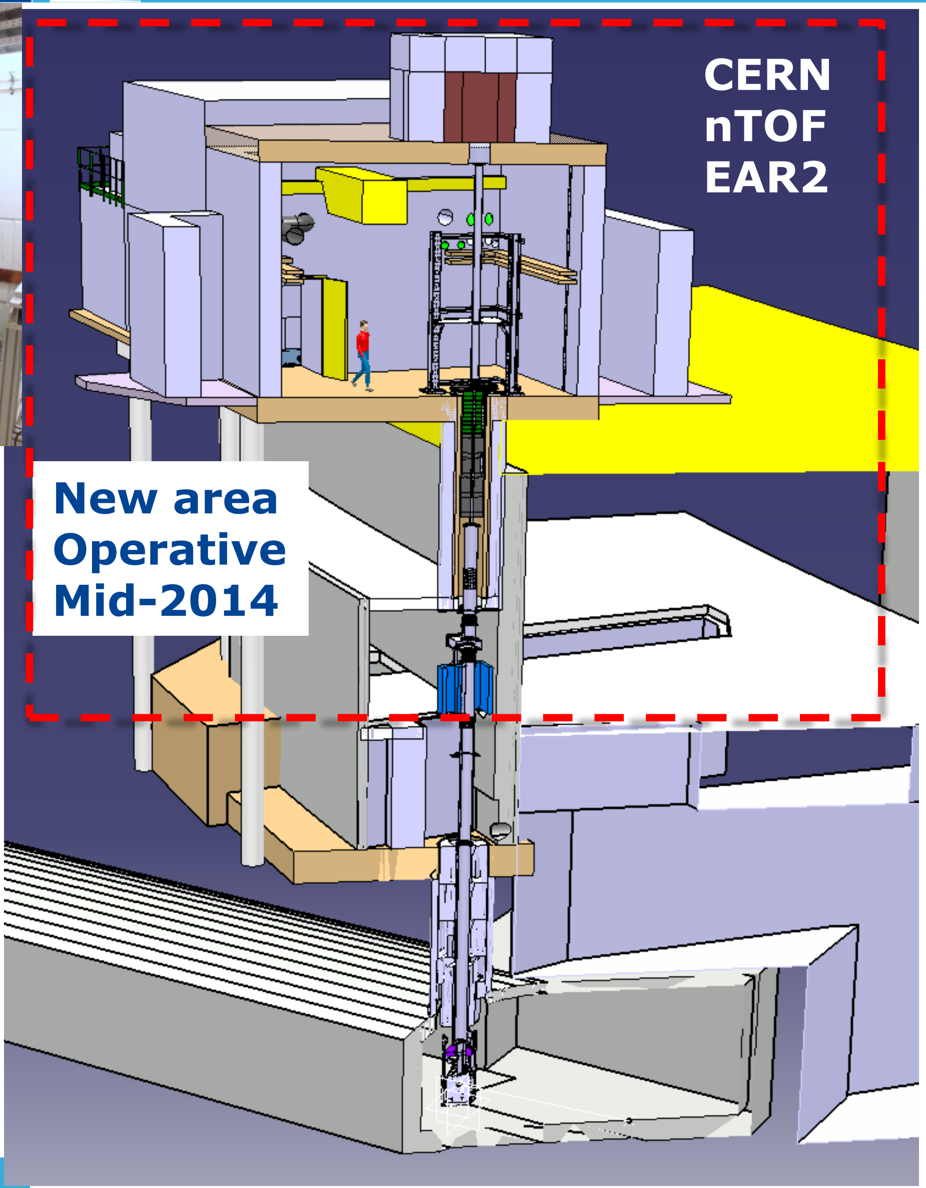
5.4 M€ EC contribution, ≈10M€ total
36 partners, 2013-2017

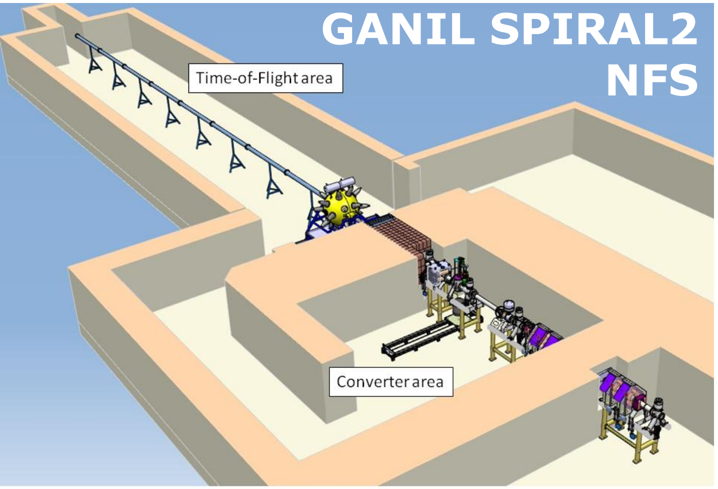
New neutron beams, new experimental equipment, new evaluation methods, Myrrha safety case, access to validation experiments, transnational access

Facilities


IRMM
GELINA


nELBE
HZDR

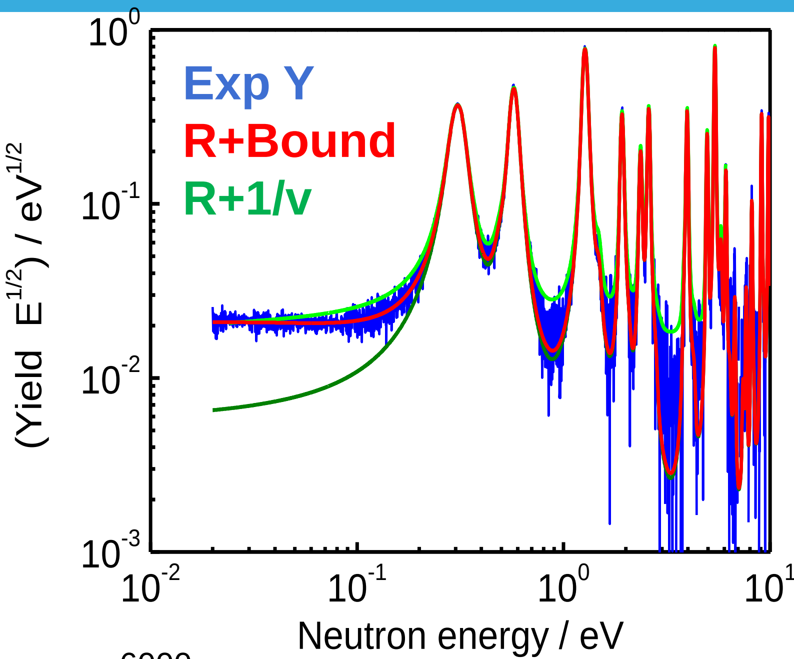

CERN
nTOF
EAR2
New area
Operative
Mid-2014


GANIL SPIRAL2
NFS
Time-of-Flight area
Converter area

^{241}Am(n,γ)

GELINA, P. Schillebeeckx et al.

European Commission



$\sigma(n_{th},\gamma)$

749 ± 35 b

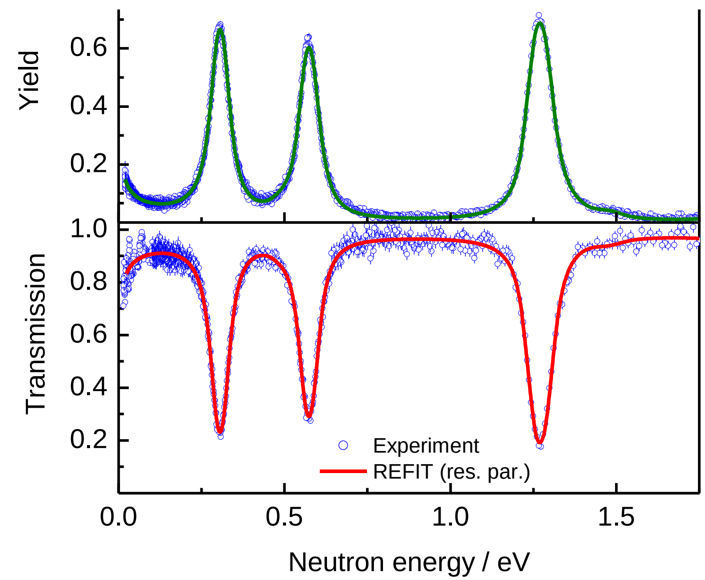
g_f = 1.00

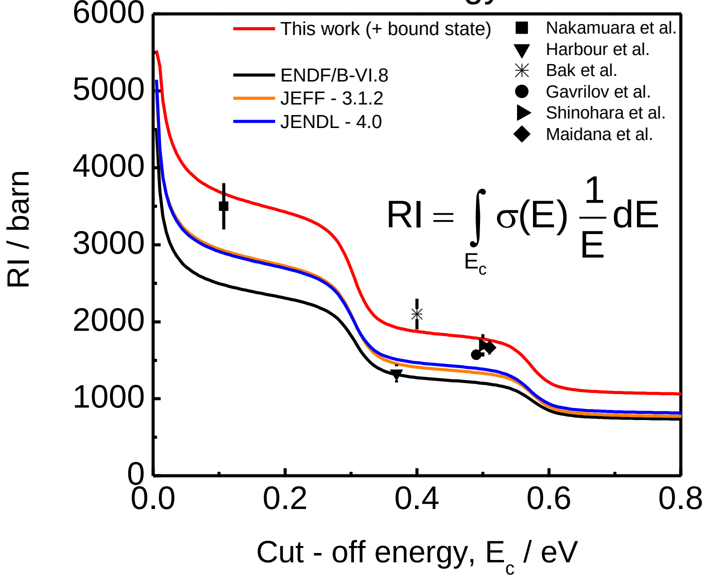
g_f = 1.04

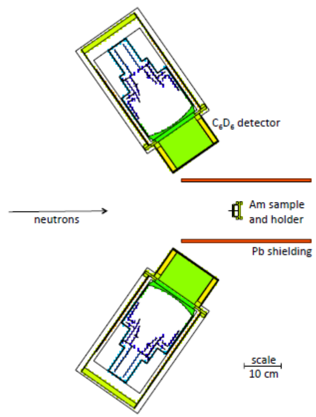
g_f = 1.05

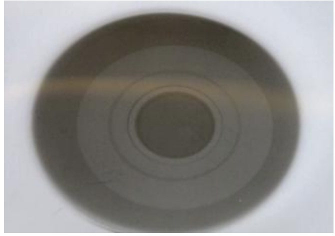
ATLAS

Normalization to transmission









mass: 324.6 ± 1.2 mg

area: 22.345 ± 0.030 cm^2

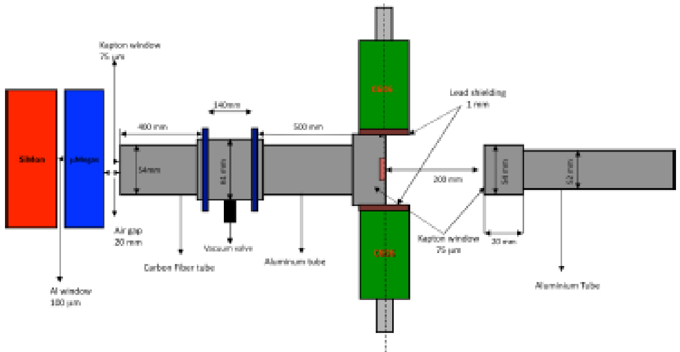
2.068 ± 0.010 10^{-4} at/b

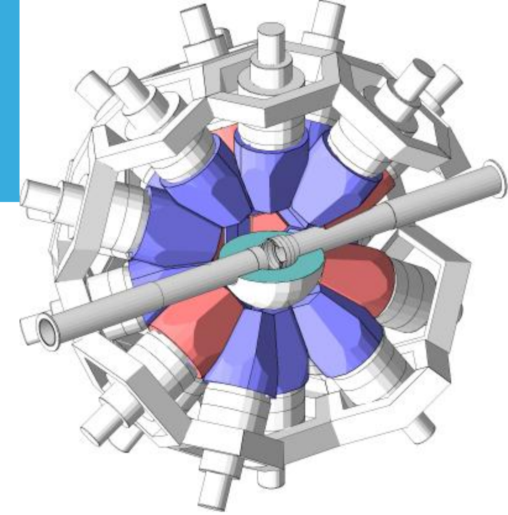
Joint Research Centre

$^{241}Am(n,\gamma)$; n_TOF

Total Absorption Calorimeter
C6D6

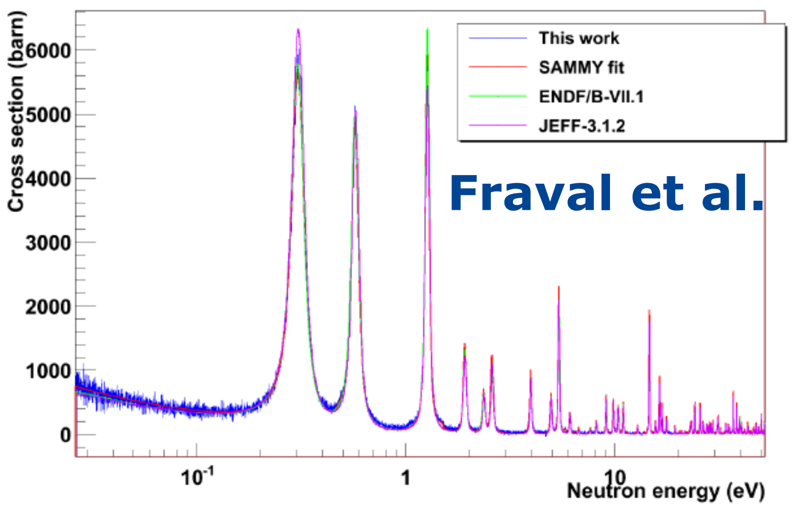
European Commission

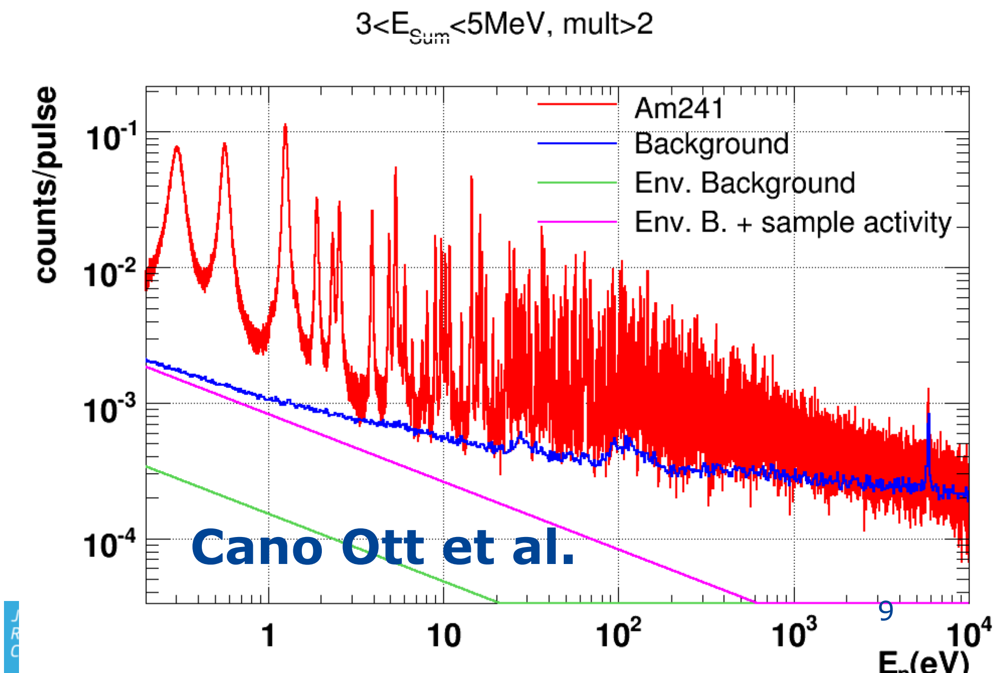




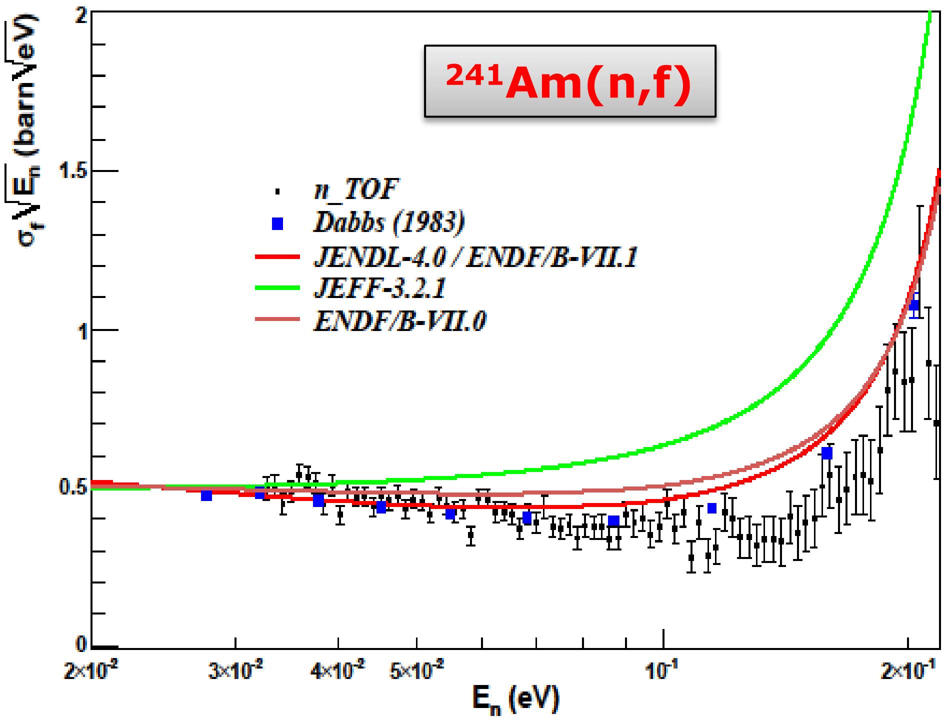
Normalization Au 1st resonance (abs)
σ_0 = 752(76) b

32.23(19) mg ^{241}Am
12.25 mm ø in Al_2O_3 in Al
Analysis TAC in progress
Energy range: 0.18 eV up to ~10 keV.





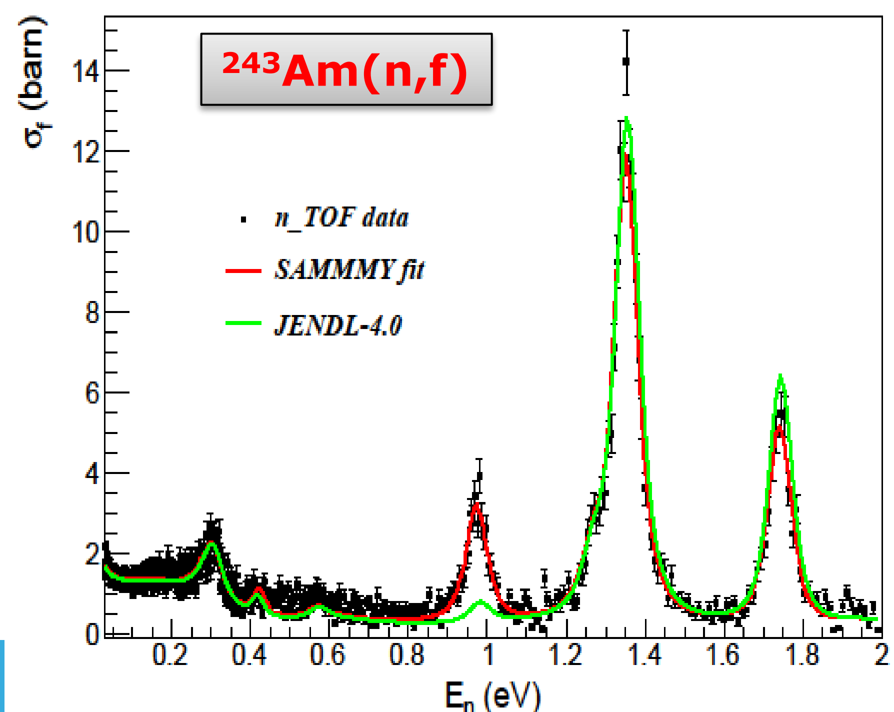
al. ND2013



The evaluated cross section of ^{241}Am(n,f) in JEFF-3.1.2 need a major revision below 1 eV.

M. Mastromarco *et al.*, in preparation

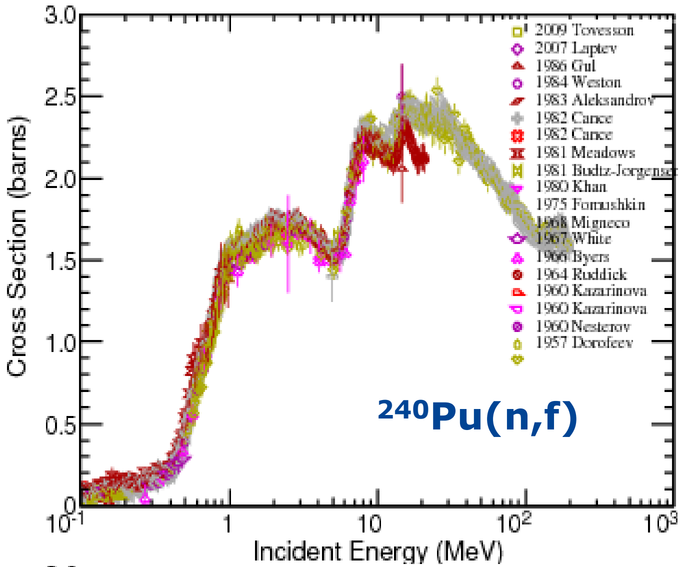
According to the n_TOF results on the ^{243}Am(n,f) cross sections, all libraries grossly underestimate the resonance around 1 eV (while for all other resonances differences are within 15%).

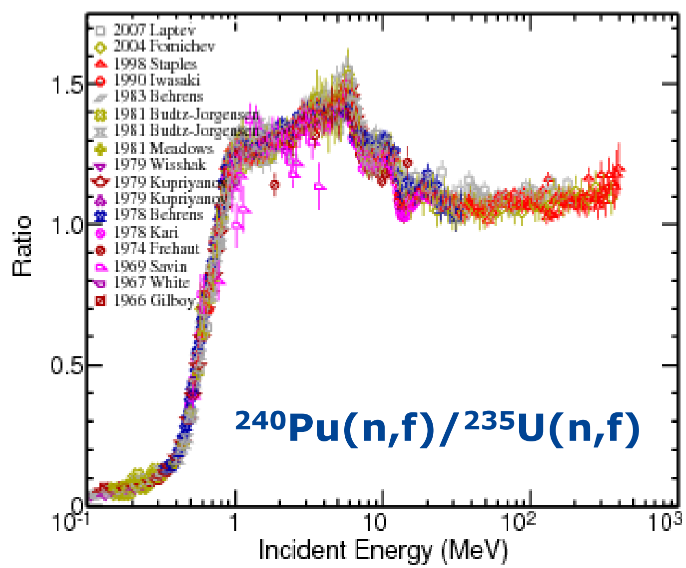


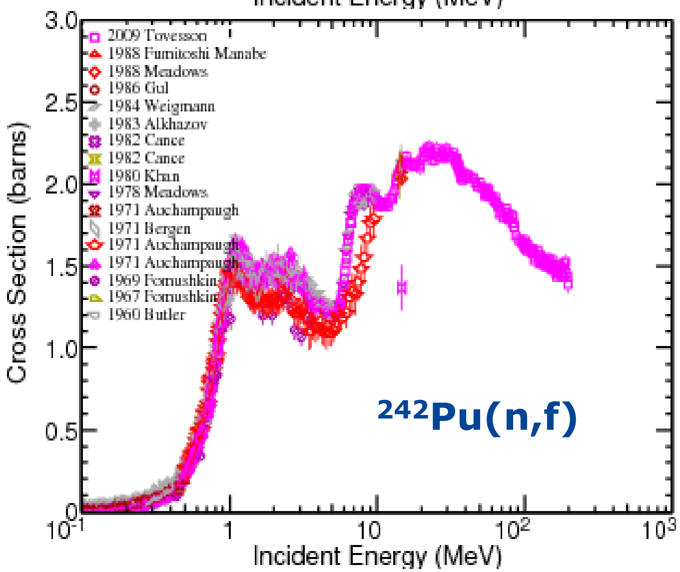
^{240,242}Pu(n,f)

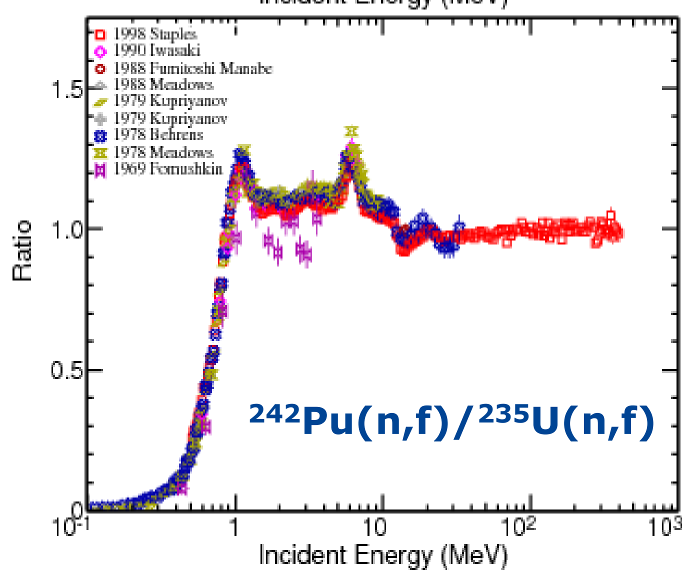
status

European









Despite considerable effort 10% spread

Many measurements claim 2% or better for the ratio

Many ratio data

Almost all relative to ^{235}U(n,f)

Alternatives being explored

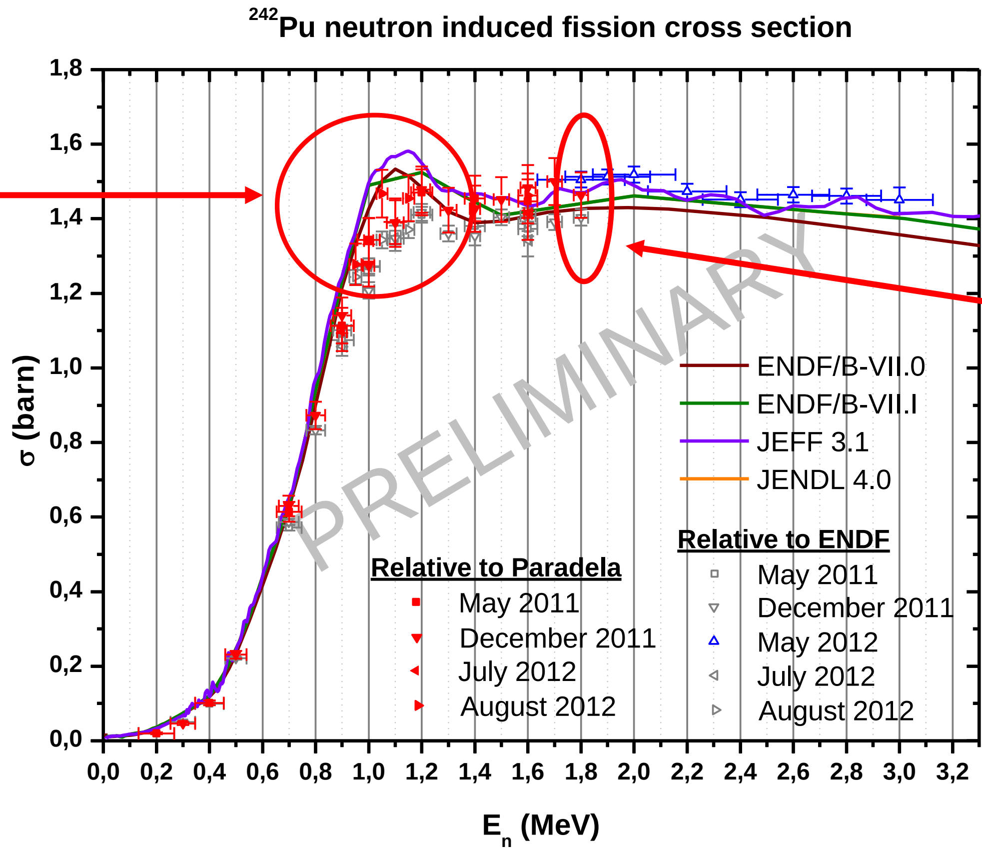
Frisch-grid

^{237}Np and ^{238}U as reference

European Commission

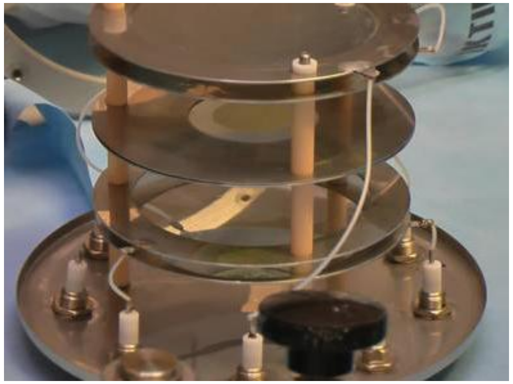
Paula Salvador Castiñeira et al.

Neutron induced fission cross section ^{242}Pu



~6%
(12%)

~ 3%
(7%)



^{237}Np(n,f) ENDF/B-VII.1 vs. Paradela et al.

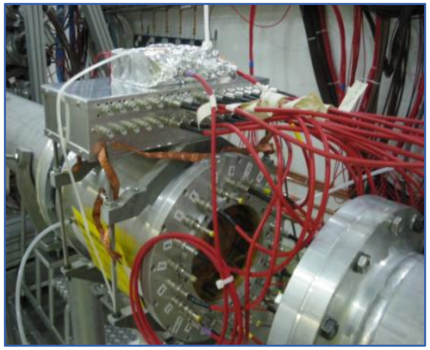
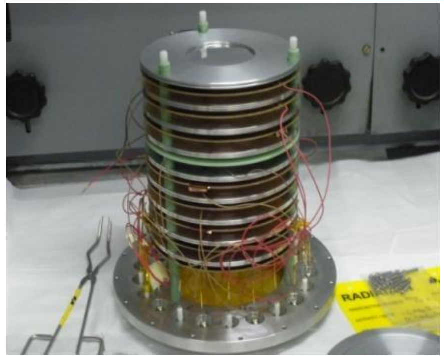
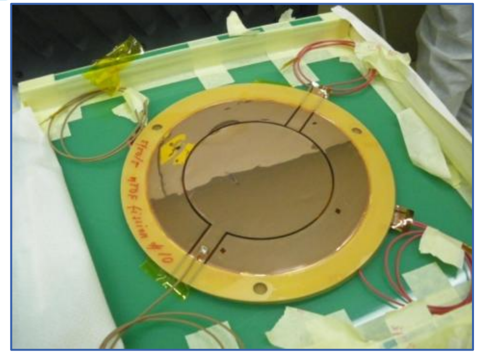
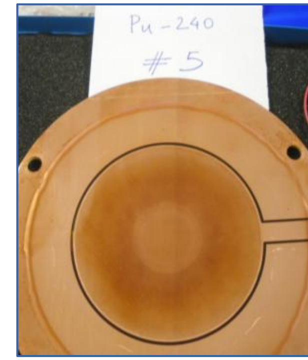
Latter agrees best with ^{238}U(n,f) as reference

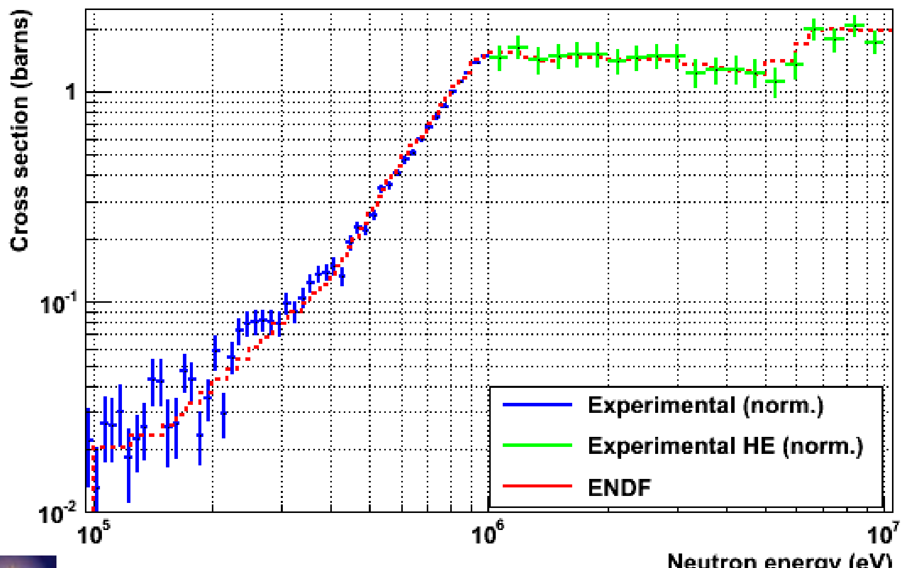
New data ^{237}Np(n,f): Diakaki et al., NTUA+Demokritos

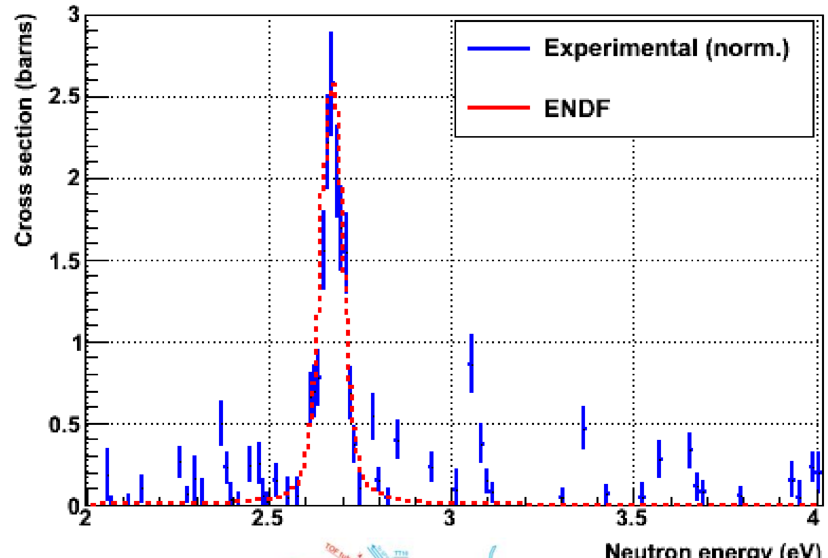
C. PARADELA *et al.*
PHYSICAL REVIEW C **82**, 034601 (2010)

Joint Research Centre

Alternatives being explored
Micromegas detectors
relative to $^{235}U(n,f)$

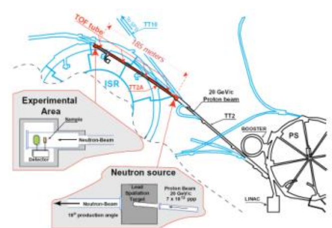









A. Tsinganis et al.

PRELIMINARY data (normalised to ENDF)



European Commission

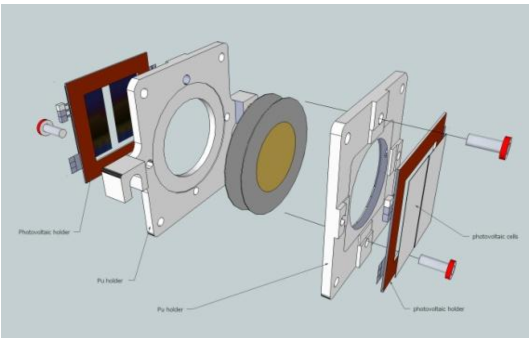
Joint Research Centre

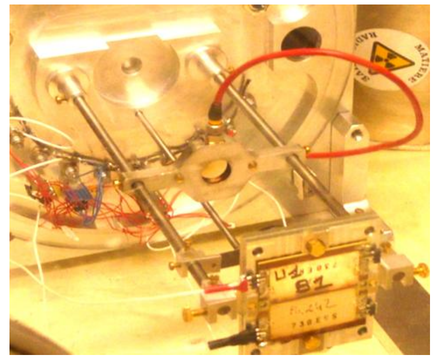
Alternatives being explored
Solid state detectors
H(n,n)H reference

CENBG

Solar cells
>0.85% 4π

^{240}Pu: 14 MBq (1.7 mg)
^{242}Pu: 0.2 MBq (1.7 mg)

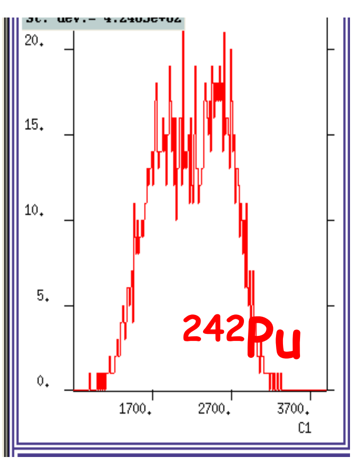


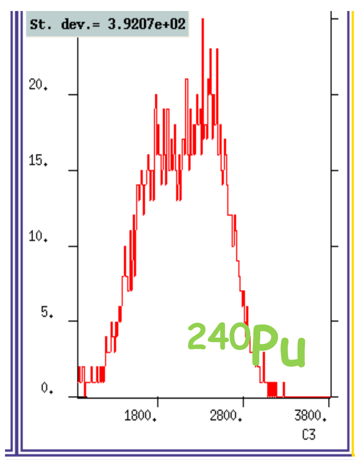


Recoil proton telescope
Si detector
Polypropylene $(C_3H_6)_n$

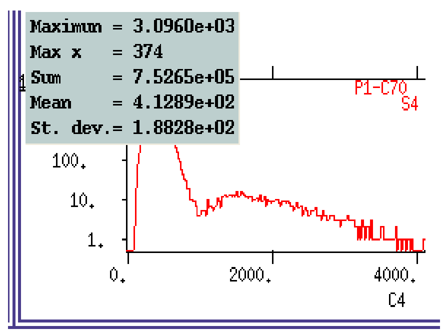
G. KESSEDJIAN *et al.*
PHYSICAL REVIEW C **85**, 044613 (2012)

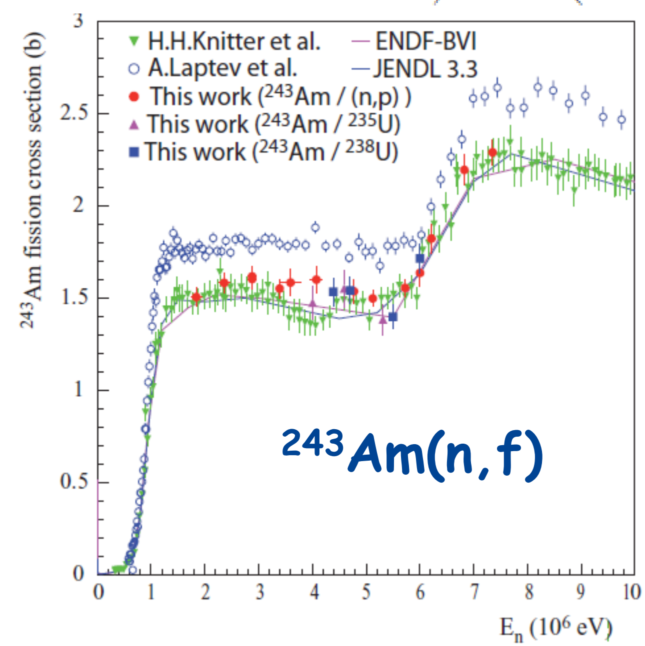
Very good α-FF separation





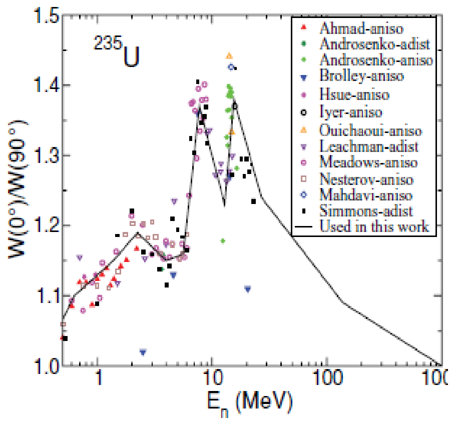
After experiment
Radiation damage
^{240}Pu side

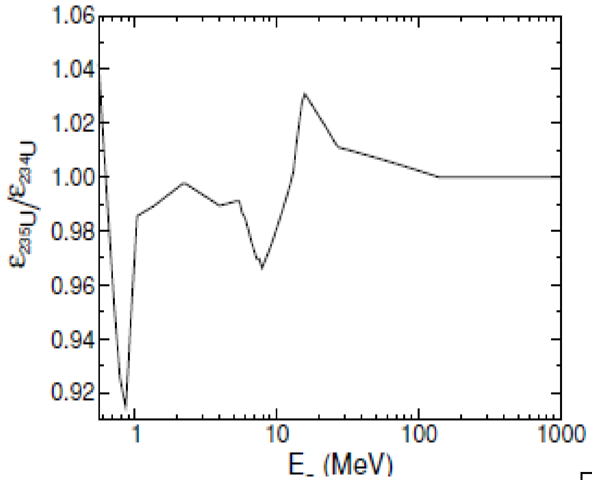


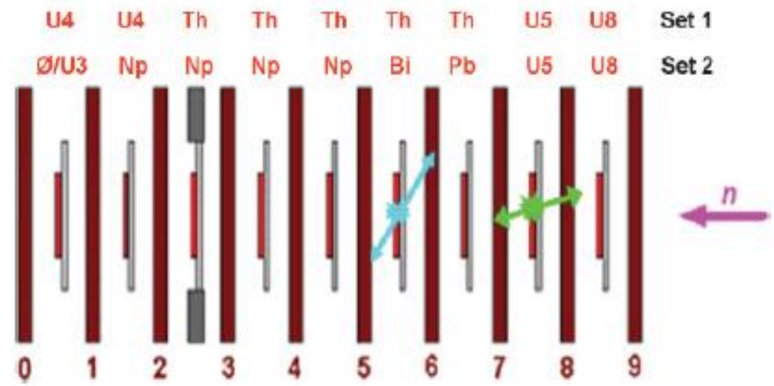


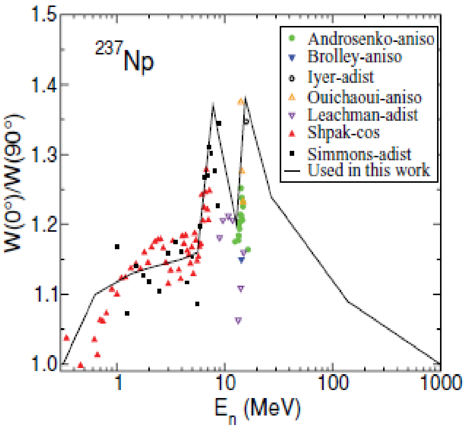
Alternatives being explored

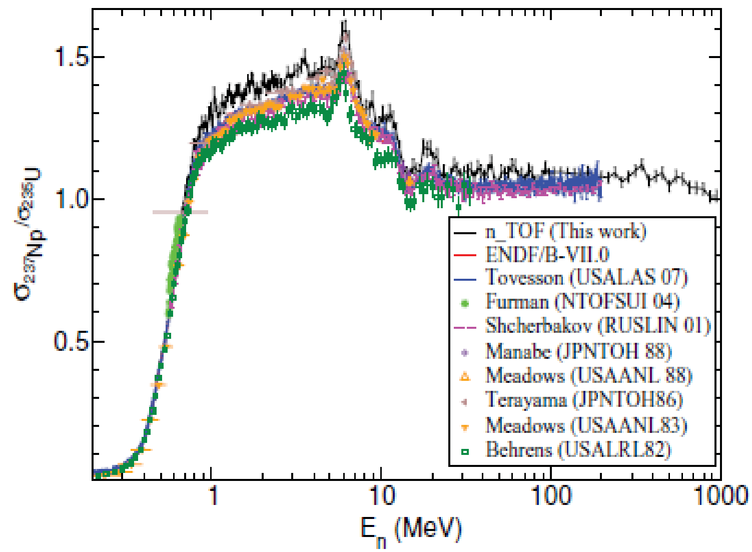
PPAC relative to $^{235}U(n,f)$







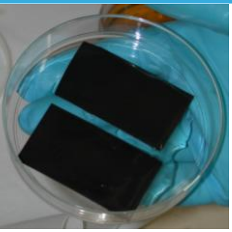


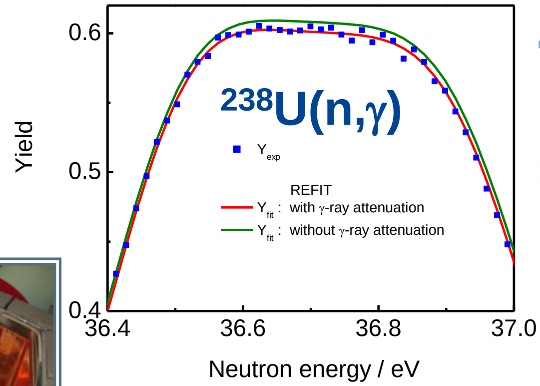


Paradela et al. PRC82(2010)034601

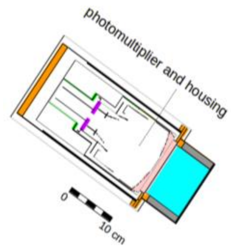
$^{237}Np(n,f)/^{235}U(n,f)$

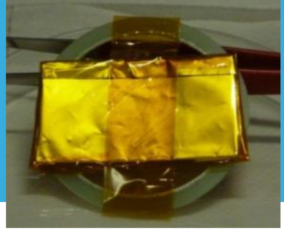
Other challenges
ANDES project

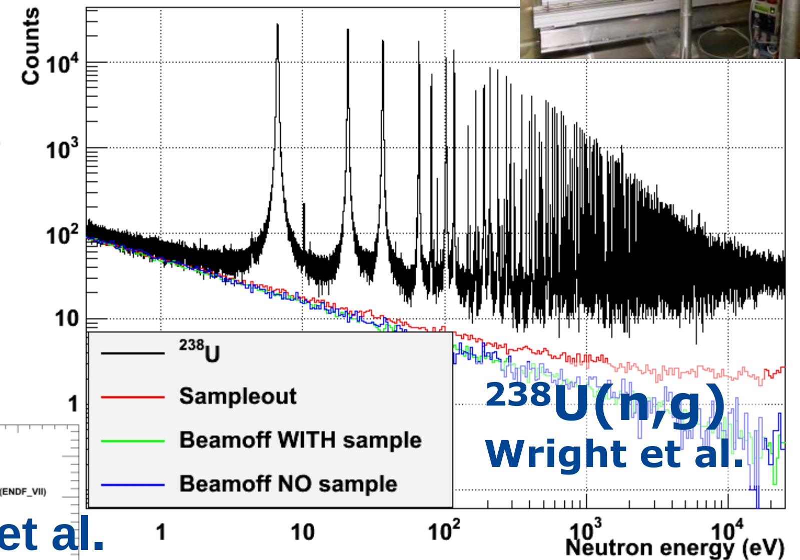


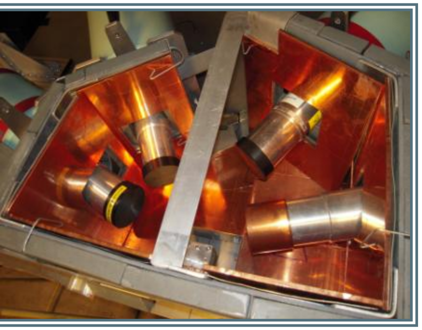


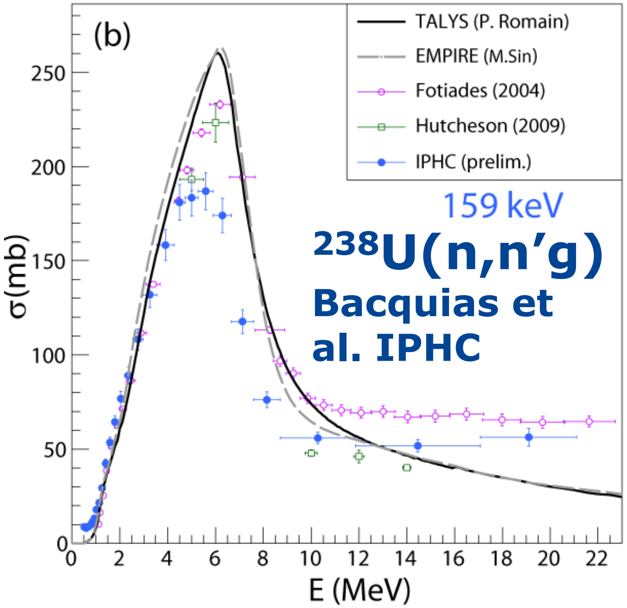
Lampoudis et al.

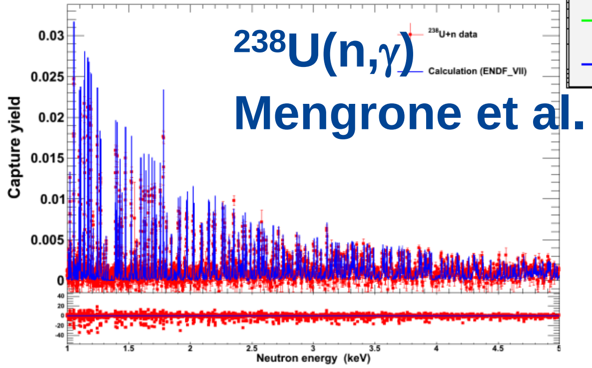


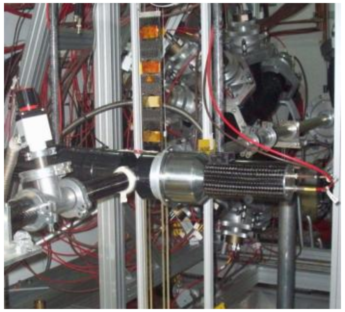


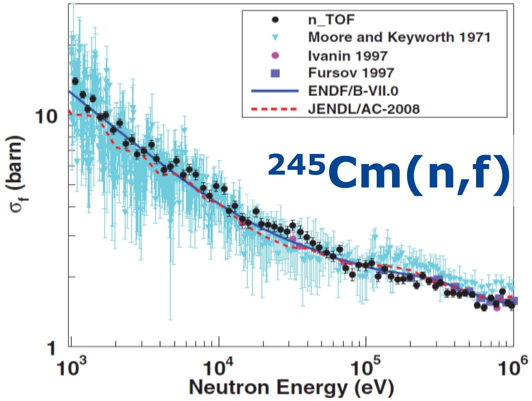












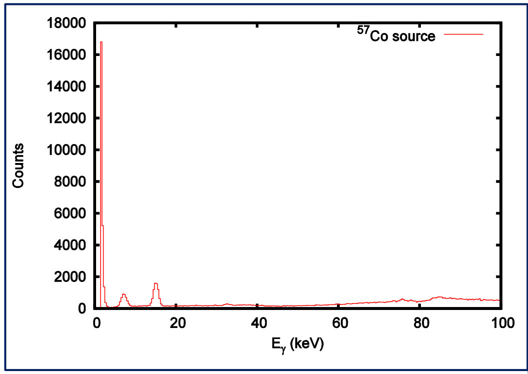
Calviani et al.: ^{245}Cm(n,f), PRC85(2012)034616

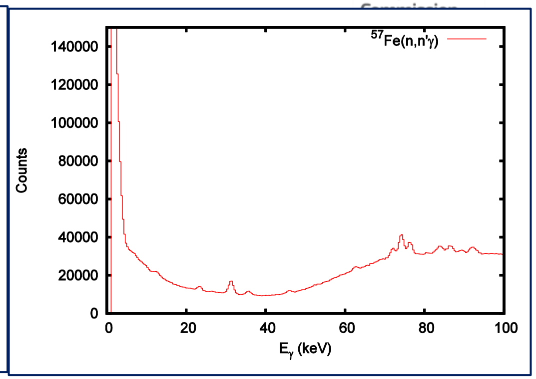
Belloni et al., ^{241}Am(n,f) EPJA49(2013)2

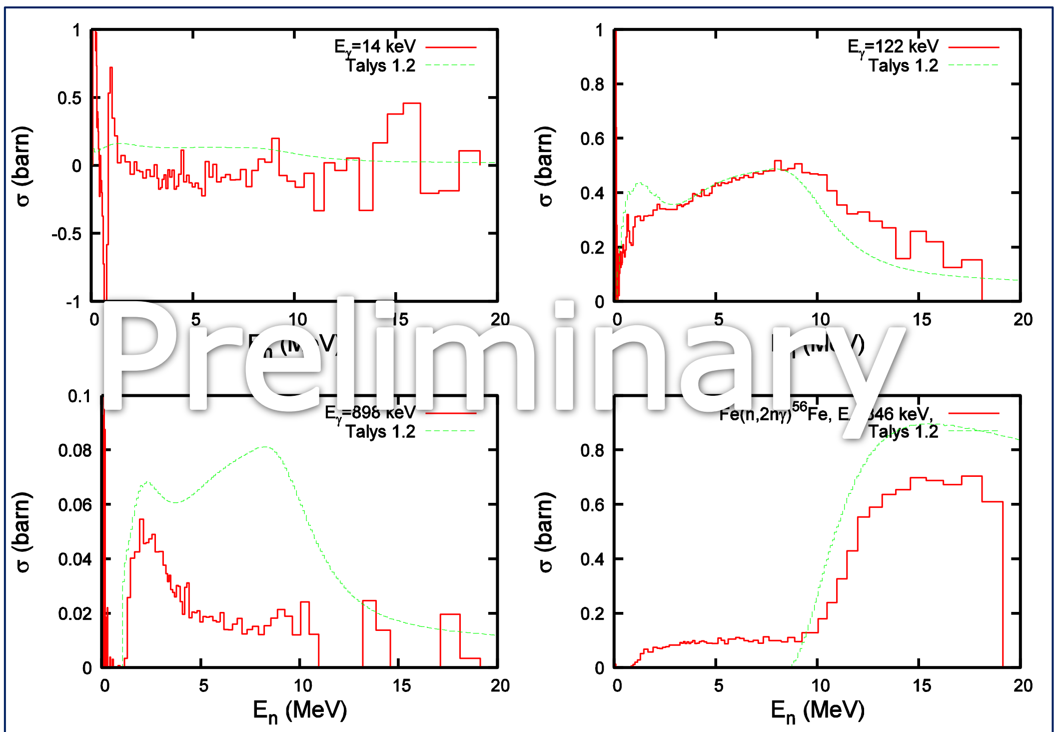
Belloni et al., ^{243}Am(n,f) EPJA47(2011)160

Measurements for $^{57}Fe(n,n'\gamma)^{57}Fe$ @ IRMM

A. Negret







Motivation

Fe – main structural material for any facility. ^{nat}Fe previously measured at IRMM.

Natural abundancies: ^{56}Fe – 91.75%, ^{57}Fe – 2.12%.

The first excited level in ^{56}Fe is at 847 keV. Therefore the neutron inelastic scattering on iron can occur at lower energies only on ^{57}Fe.

The $^{57}Fe(n,2n\gamma)^{56}Fe$ measurement – important correction for $^{56}Fe(n,n'\gamma)^{56}Fe$ measurement performed with a natural target.

Difficulties

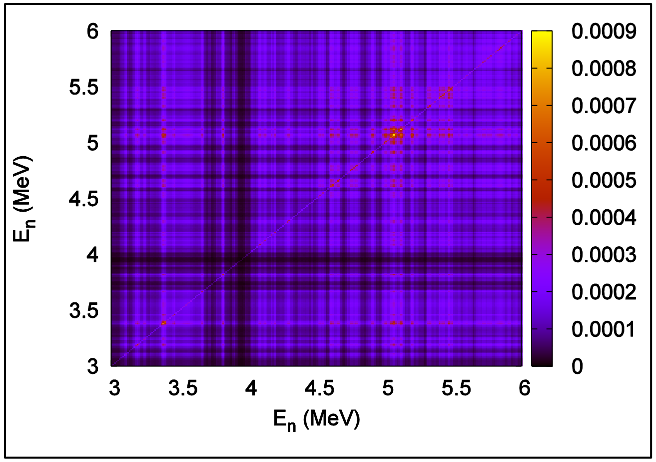
Very low energy gamma rays: 14 keV (conversion coef. 8.56(26)), 122 keV

Expensive enriched ^{57}Fe target, strange shape, borrowed from Oak Ridge Nat. Lab.

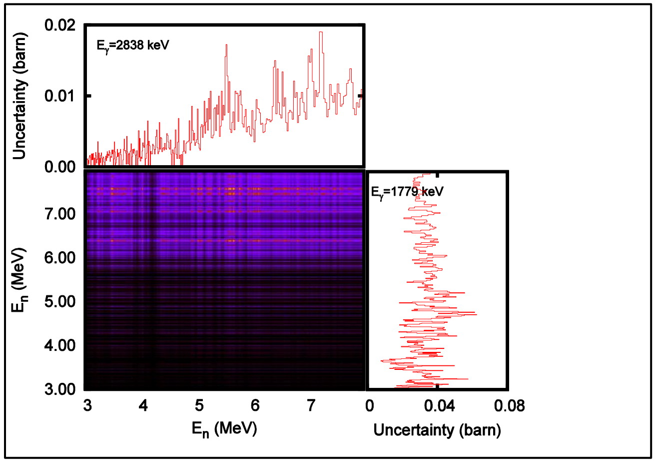
Finalization of covariances for $^{28}Si(n,n')$

A. Negret

Covariance matrix for the 1779 keV gamma production cross section



Covariance matrix for the 1779 keV versus 2838 keV gamma production cross section

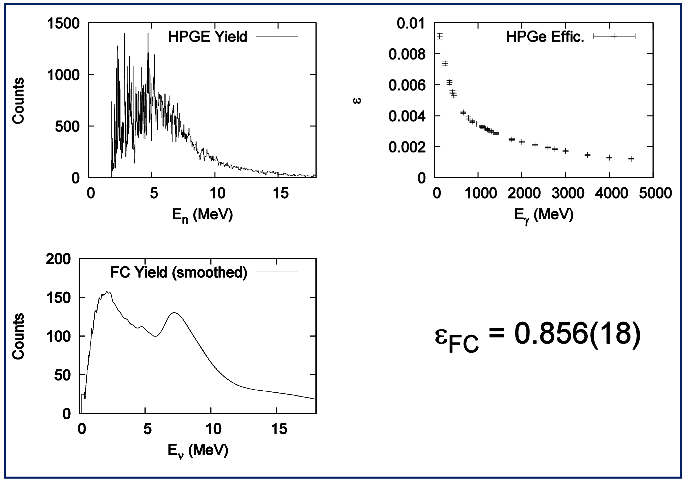


The Method:

Based on a Monte Carlo approach:
Simulate the experiment n times by generating the observables used for the calculation of the cross sections:

- **HPGe yields**
- **HPGe efficiency**
- **FC yield**
- **FC efficiency**

$$cov(x,y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}).$$



Summary
JEFF-GEDEPEON
Data measurements
Integral experiments
Facilities

Arjan Plompen

Program

Low energy cross sections
- IRMM and n_TOF

Activation cross sections
- NPI and CCFE

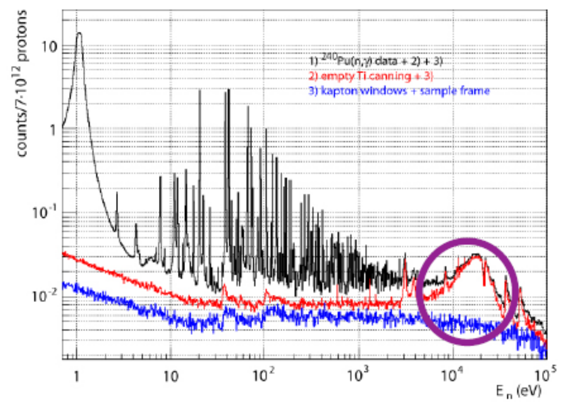
Surrogate technique
- Capture
- IPNO, CENBG, OCL, …

Fission yields
- ILL/Lohengrin
- GANIL Spider/VAMOS
  - A>238
- GSI SOFIA
  - A<238

Decay data
- JYFL/IGISOL
- TAS, BELEN

n_TOF

Example: $^{240}Pu(n,\gamma)$



F. Gunsing et al.
Two measurement campaigns
2002-2004
2009-2012
Many recent publications and ongoing measurement and analysis campaigns

EXFOR compilation ongoing

Phase 2:
235U(n,g)+(n,f) simult.
87Sr(n,g) spins
63Ni, 197Au, 241Am(n,g)
240,242Pu(n,f)
(n,a)

capture C_6D_6
- $^{24,25,26}Mg$
- ^{56}Fe
- $^{90,91,92,93,94,96}Zr$
- ^{139}La
- ^{151}Sm
- $^{186,187,188}Os$
- ^{197}Au
- $^{204,206,207,208}Pb$
- ^{209}Bi
- ^{232}Th

capture BaF_2
- ^{197}Au
- $^{233,234}U$
- ^{237}Np
- ^{240}Pu
- ^{243}Am

fission FIC
- ^{232}Th
- ^{237}Np
- $^{233,234,235,236,238}U$
- $^{241,243}Am$
- ^{245}Cm

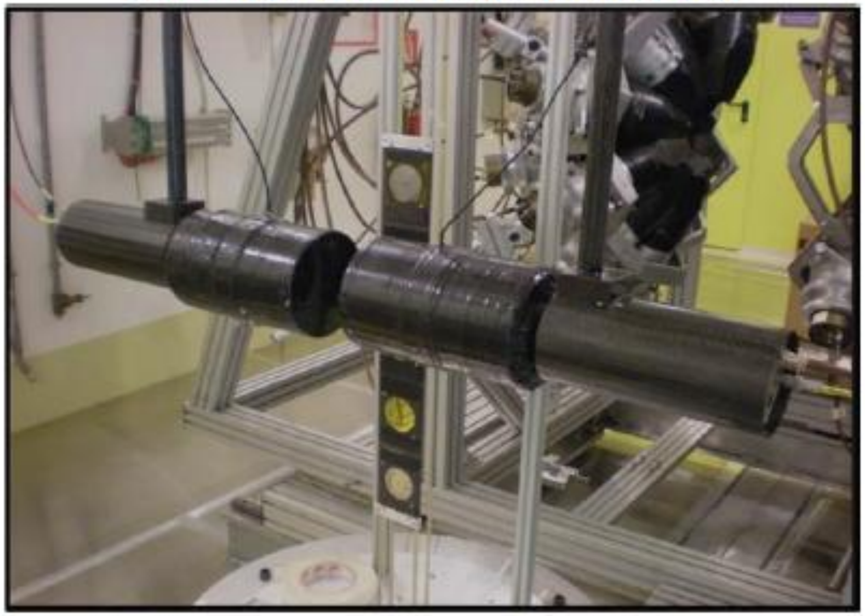
fission PPAC
- ^{nat}Pb
- ^{209}Bi
- ^{232}Th
- ^{237}Np
- $^{233,234,235,238}U$

n_TOF Phase2 (2009-2012):
Stellar nucleosynthesis cross section measurements

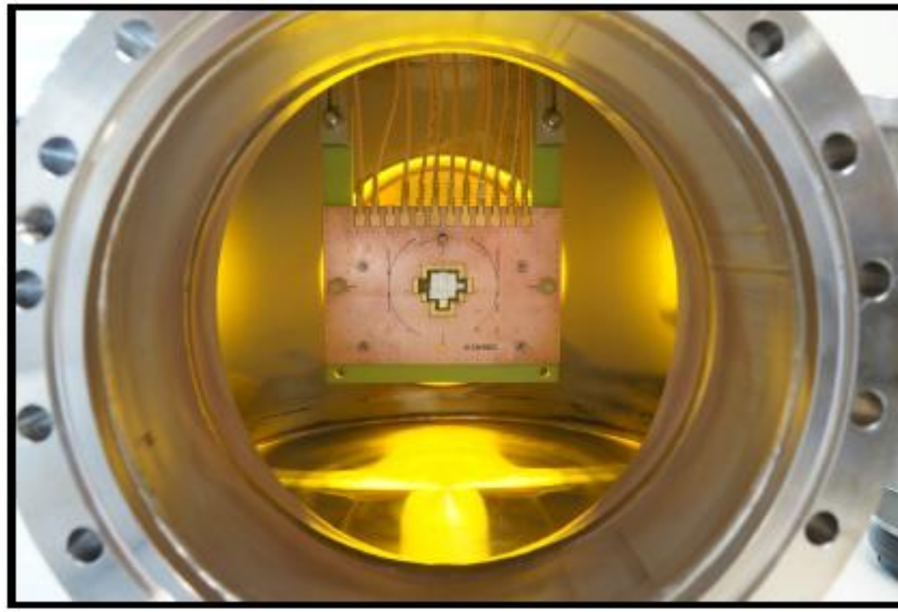
Neutron capture and (n,α) cross sections for the *s*-process:

$\sigma(n,\gamma)$: ^{25}Mg, ^{54,56,57}Fe, ^{58,62,63}Ni and ^{93}Zr
$\sigma(n,\alpha)$: ^{33}S and ^{59}Ni

C6D6 (carbon fiber) scintillators

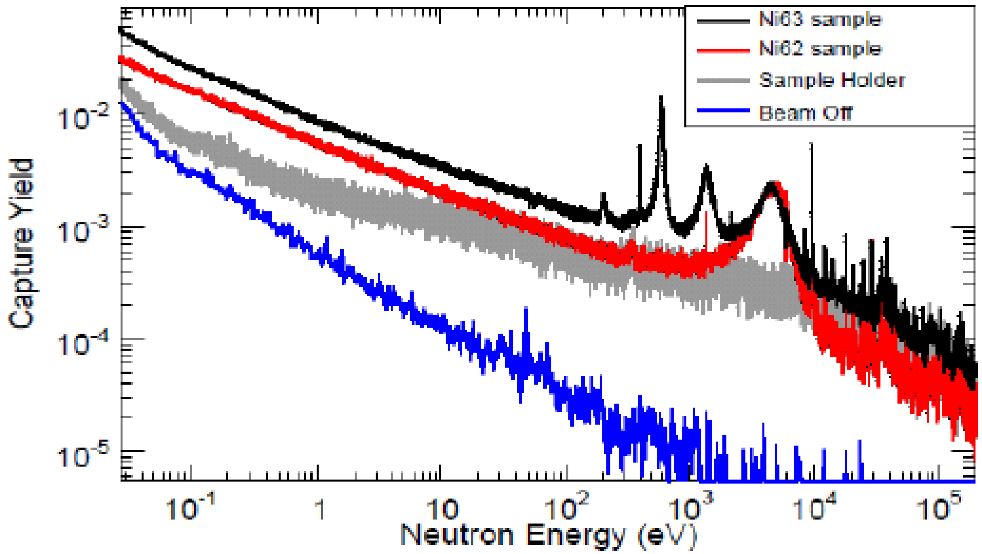


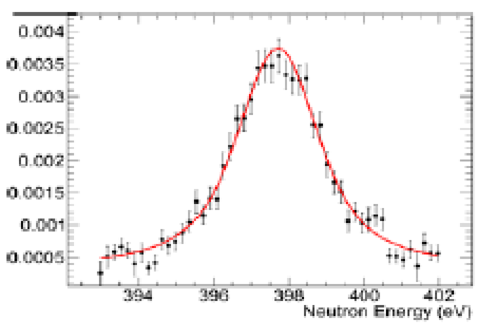
mosaic-sCVD diamond detector

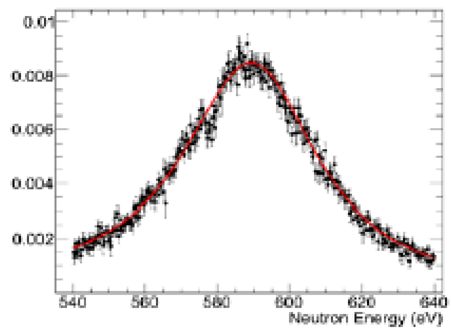


^{63}Ni(n,g) MACS in the keV region

First RRR measurement ever



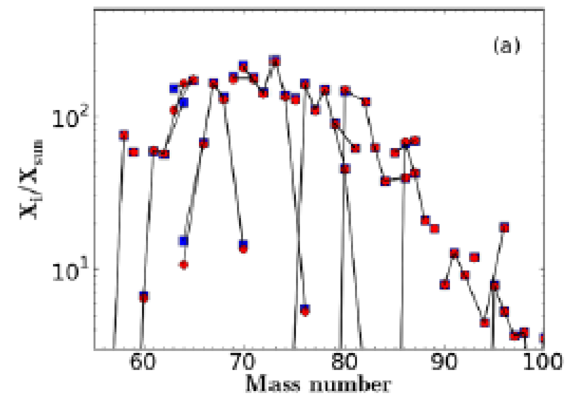


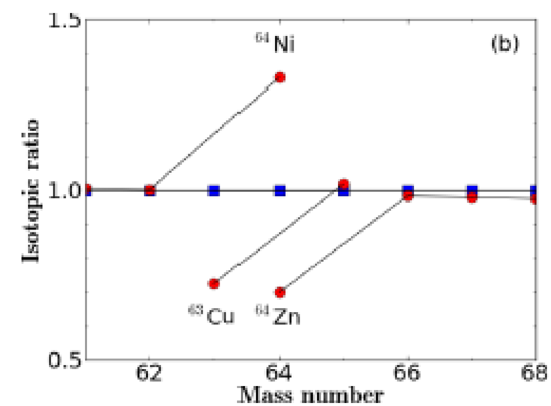


C. Lederer et al., Phys. Rev. Lett. **110** (2013) 022501

Measured MACS 2-2.5 higher than the model calculated values:

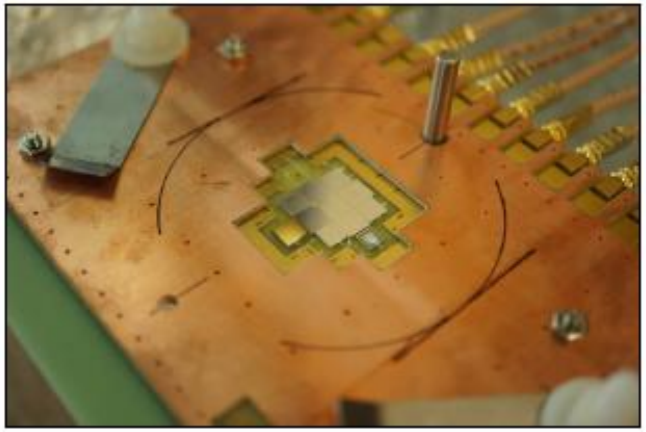
some isotopic stellar abundances (^{64}Ni, ^{63}Cu, ^{64}Zn) change up to ~40%.

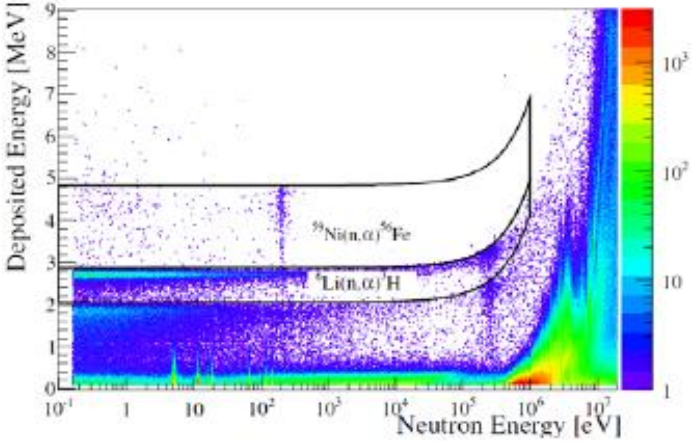




$^{59}Ni(n,\alpha)$ resonance at 200 eV

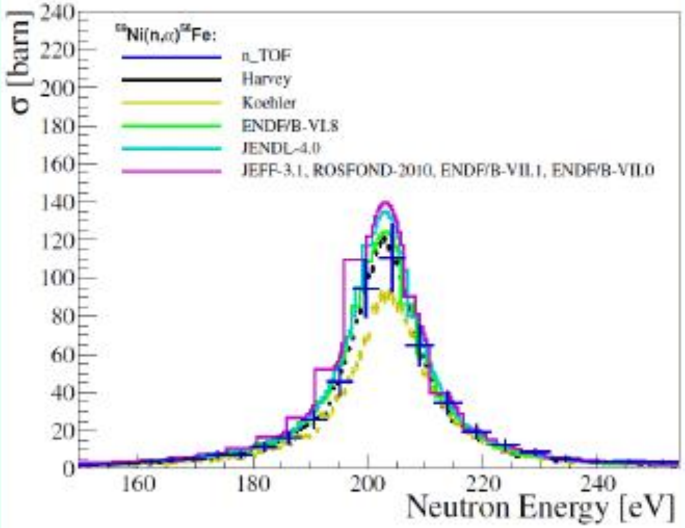
Development of diamond array for (n,chp) reactions





C. Weiss et al., "The (n,α) reaction in the *s*-process branching point ^{59}Ni", Nuclear Data Sheets (2013) (in press)

Solved the 30% discrepancy between the two previous measurement.
New recommendation for evaluated nuclear data files.



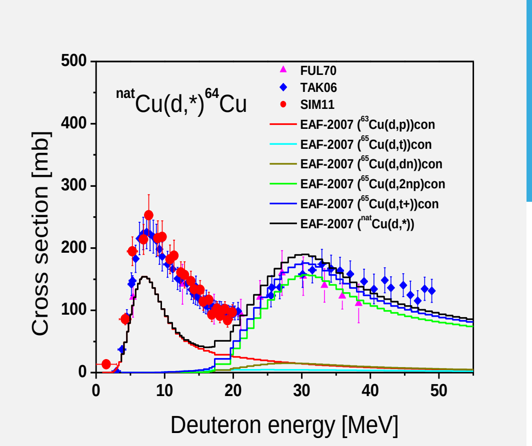
Opens the door to a new type of measurements, in particular at the new 20 m beam line n_TOF-EAR2.

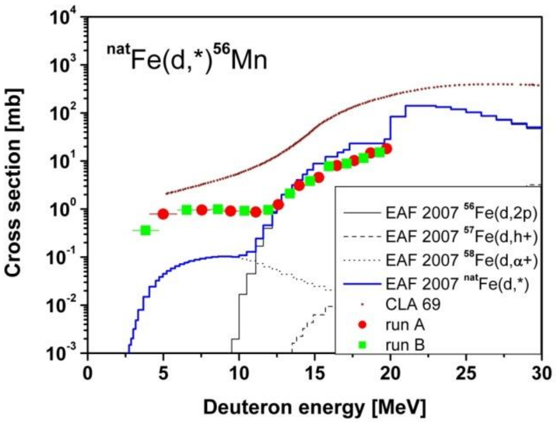
NPI

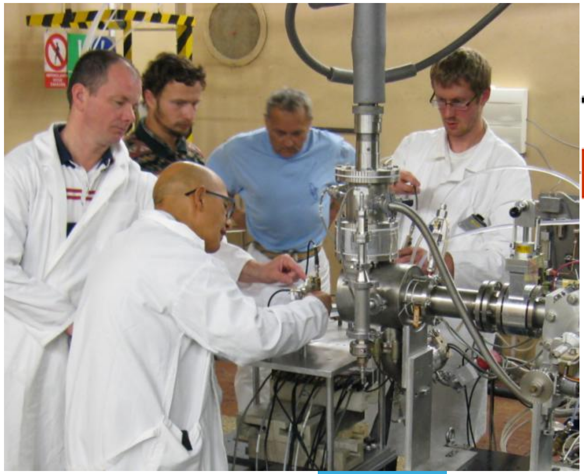
M. Majerle et al.
n,p,d activation cross sections

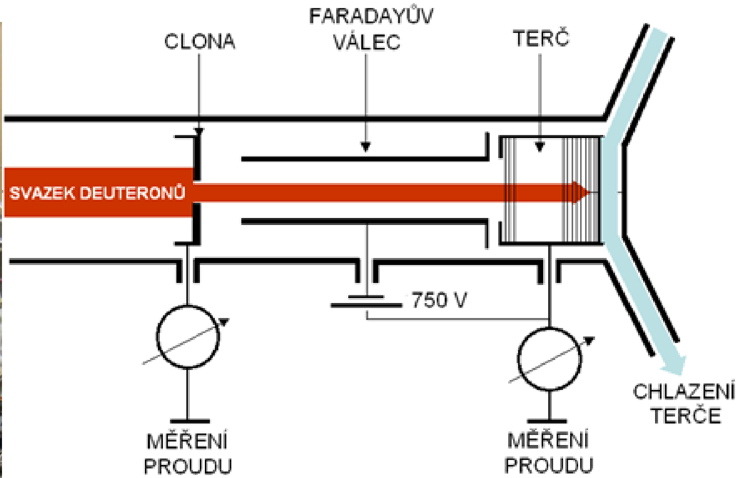
Neutrons
white beam, p,3He+D2O
qm beam, p+7Li

Fusion
ERINDA
NFS



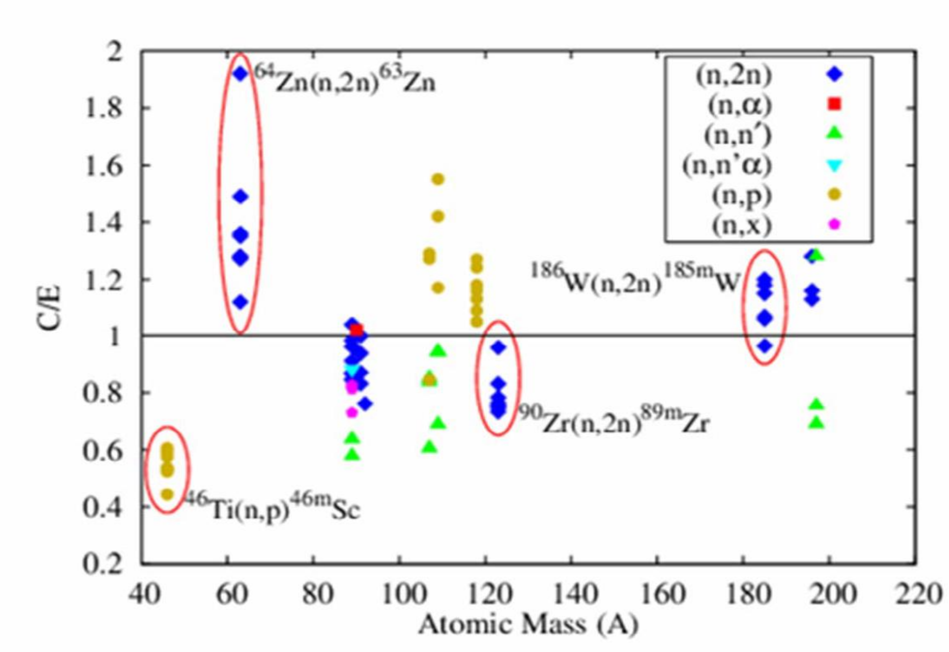






CCFE

14 MeV benchmark data at ASP (AWE)
Setup development
2.5 10^{11} n/s
Associated particle technique



Surrogate technique

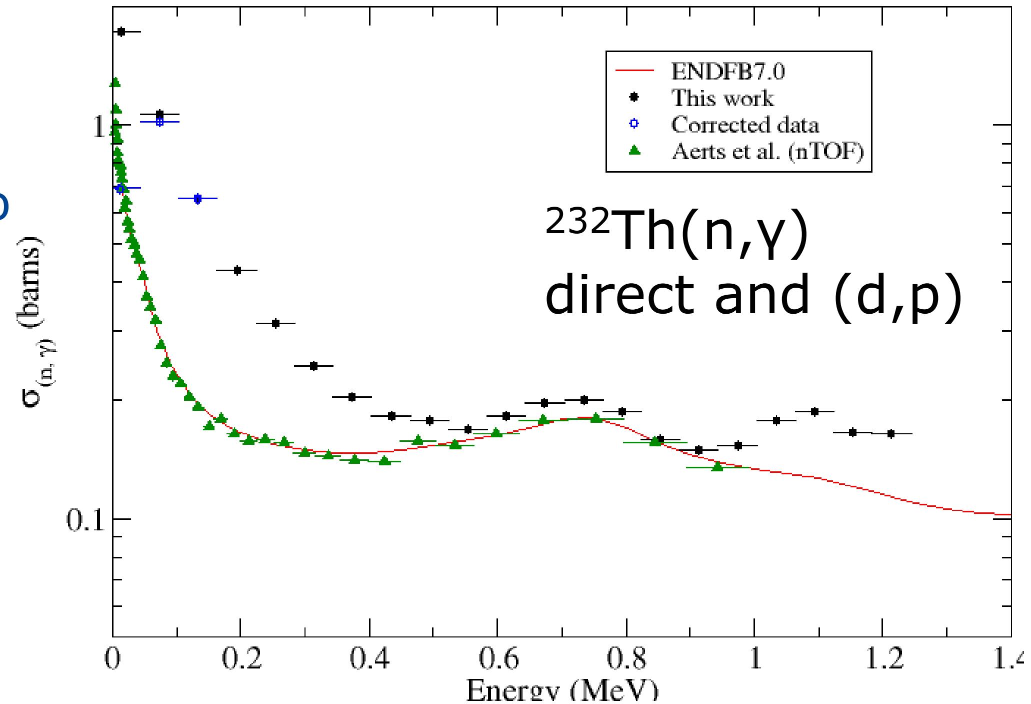
J. Wilson IPNO (CENBG, CEA, OCL)

Investigation of applicability to capture

Comparison of direct capture to surrogate method

Yb, U, Th

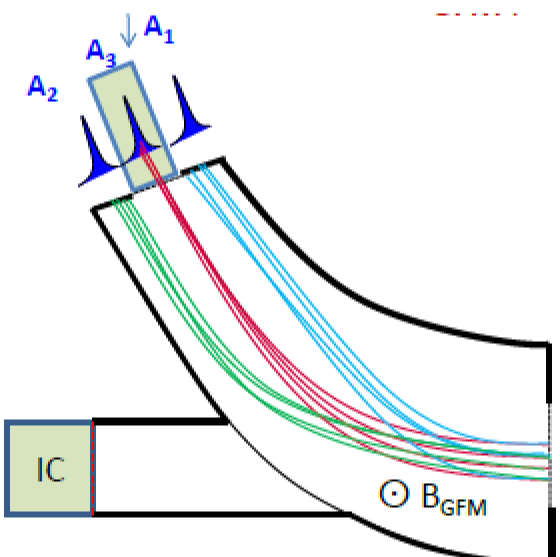
^{3}He and d-induced

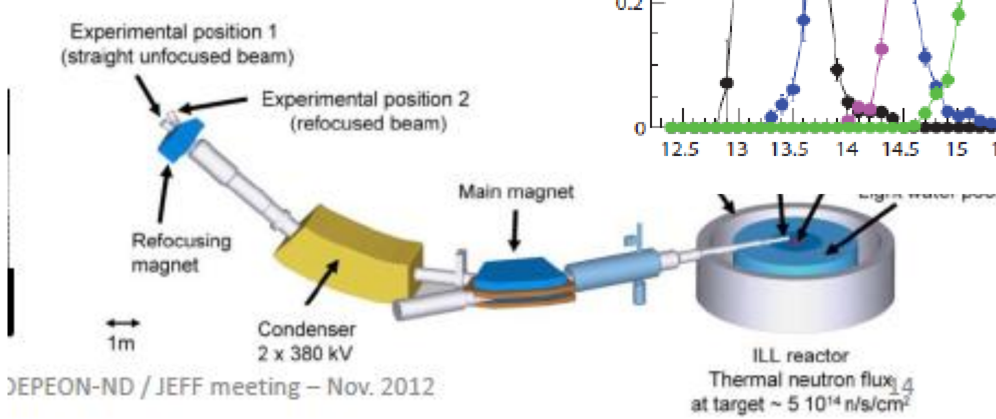


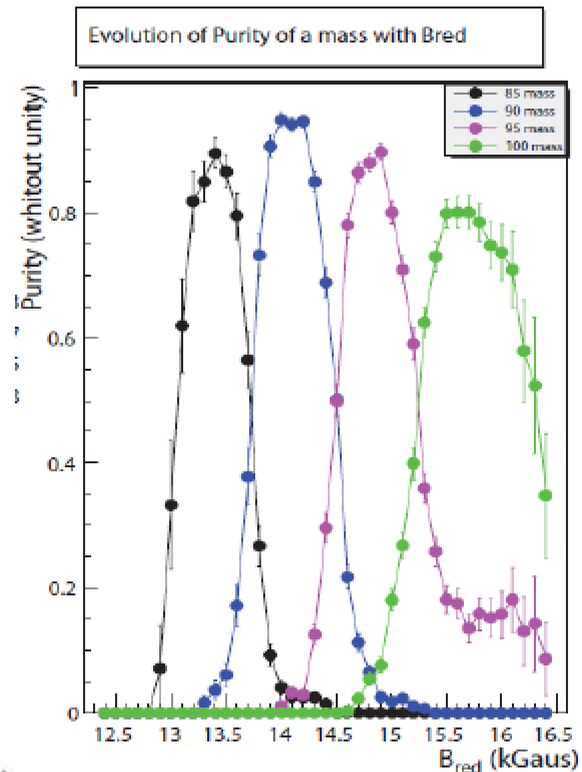
Fission yields at ILL/Lohengrin

G. Kessedjian LPSC
(CNRS, CEA, ILL)

Upgrade of Lohengrin with
gas-filled magnet







Fission yield measurements at GANIL

F. Farget, C. Rodriguez et al.

$^{238}U+^{12}C$ 6.14 MeV/u fission

Inelastic fission ^{238}U

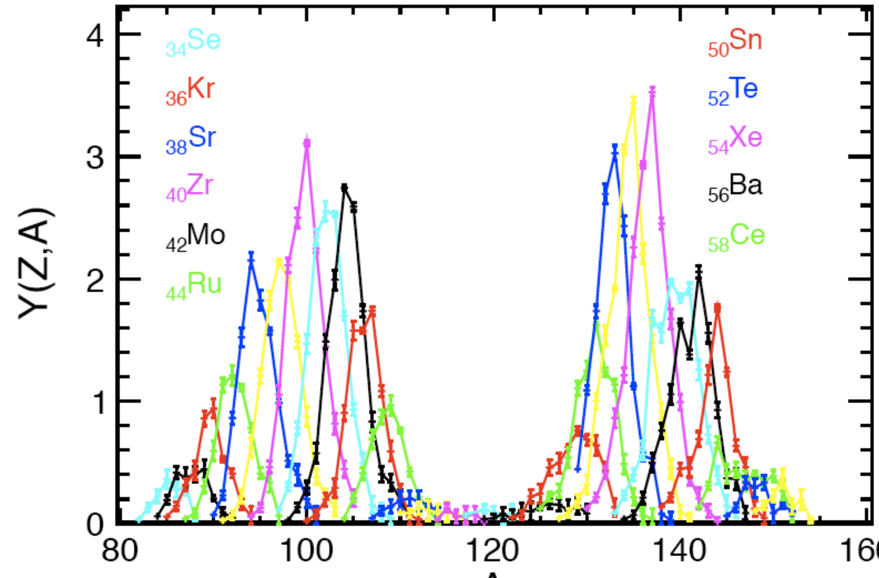
Fusion-fission ^{250}Cf Ex=45 MeV

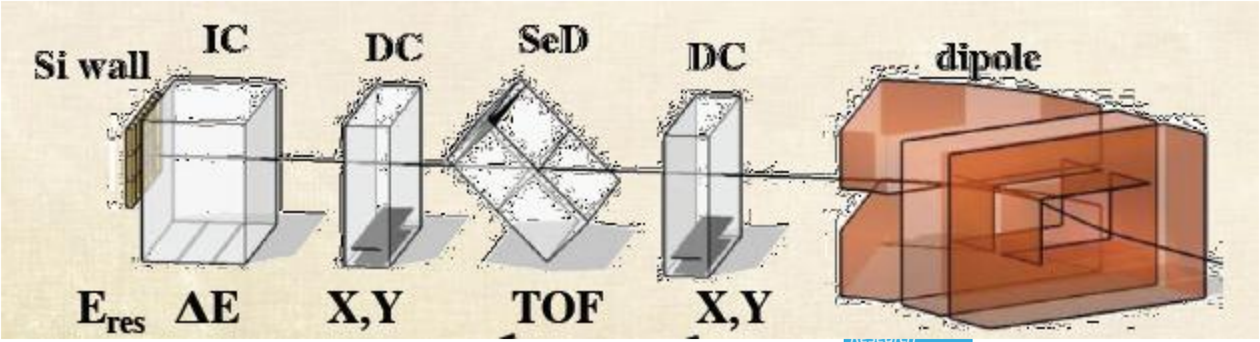
Transfer-fission (1-10 mb)

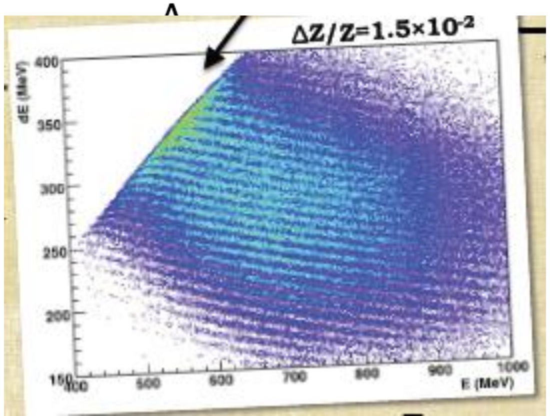
^{239}Np, $^{240,241}Pu$, Am, Cm

E_x=10 MeV (5 MeV fwhm)

Spider dE-E, VAMOS, EXOGAM

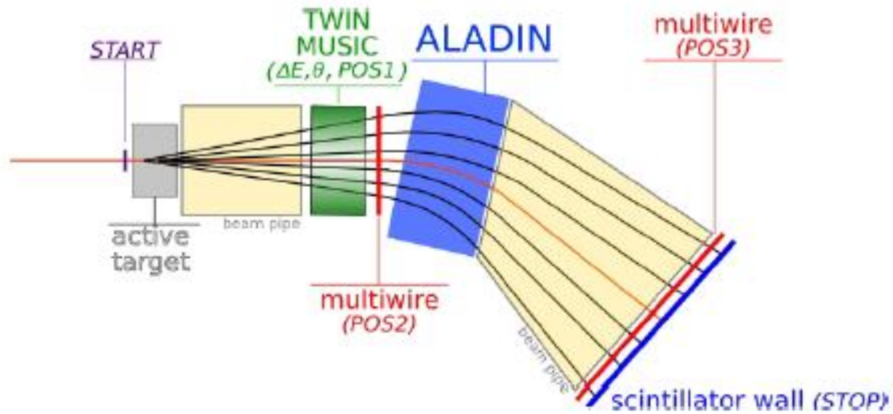


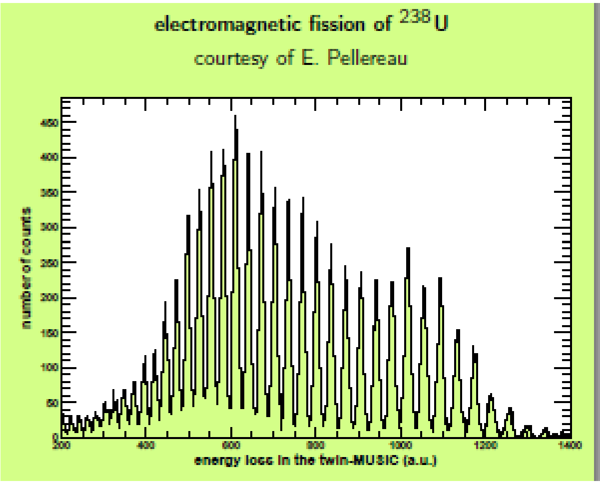




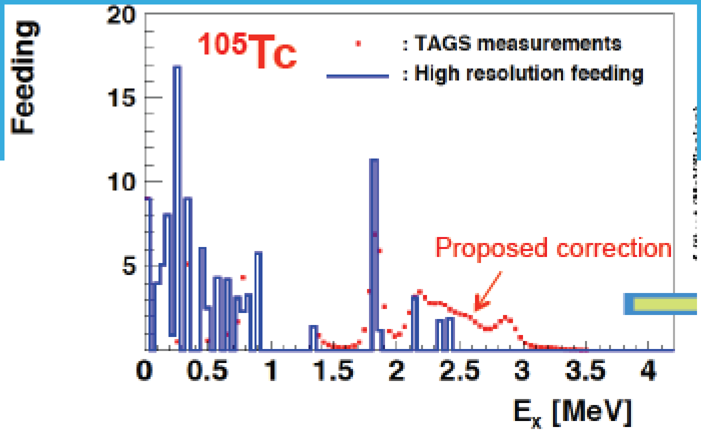
Fission yield measurements at GSI

A.Chatillon CEA (GSI, CNRS)
SOFIA
Studies of fission with Aladin
Coulex-induced fission of relativistic projectiles (A<238)
600 MeV/u $^{236}U(\gamma,f)$
Aims at full A and Z resolution for b
fragments
First runs: applications 50% of beam time
Under development

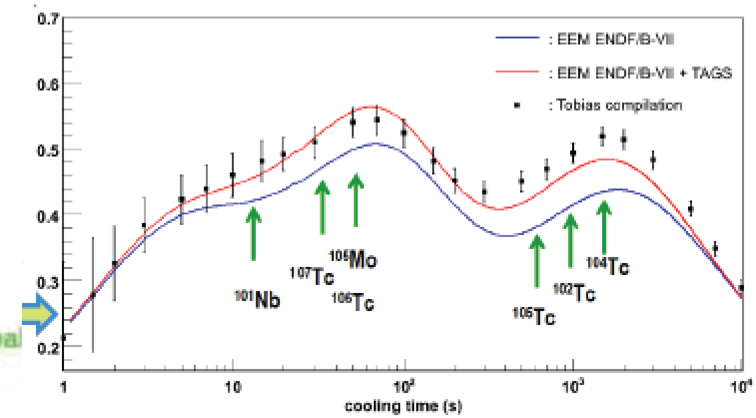


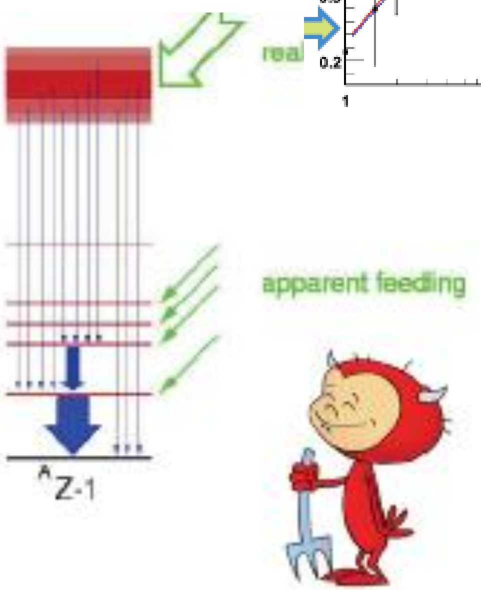


Decay data measurements at JYU

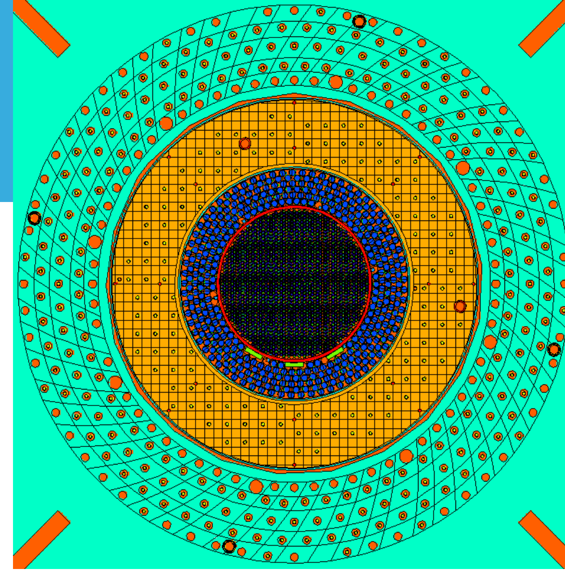


M. Fallot Subatech
(JYU, CNRS, IFIC, U. Surrey, Ciemat)
JYFL – IGISOL
TAS spectrometer
Summation issues for gammas, betas and neutrinos for beta decay of FPs
Pandemonium effect
Addressing key isotopes identified by WPEC





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



Proteus @ PSI

G. Perret
PROTEUS past experiments for nuclear data validation
Spectral Indices
Gas-Cooled Fast Reactor

New models for past expts
ND validation

More may be done
Eg HCLWR

- General good agreement between predictions and experimental results is seen in the PuO_2/UO_2 lattice with the exception of:

Library	F8/F9	C7/F9	C2/F9	F2/F9	(n,2n)2/C2
ENDF/B-VII.0	-	-	-	0.913 (2.1%)	1.084 (2.9%)
JEFF-3.1	-	0.951 (2.4%)	-	-	1.112 (3.2%)
JENDL-3.3	1.032 (1.4%)	0.953 (2.4%)	0.931 (1.6%)	-	-
ENDF/B-VII.1	-	-	-	0.935 (2.1%)	-
JEFF-3.1.1	-	-	-	-	-
JENDL-4.0	-	-	-	-	1.126 (3%)

- Better agreement with the latest libraries (B71, J31 and JN40)
- All results are in good agreement with JEFF-3.1.1
- Some trends:
  - J31 -> J311: Capture in ^{237}Np improved, Fission in ^{237}Np worsen
  - B70->B71: Fission in ^{232}Th improved

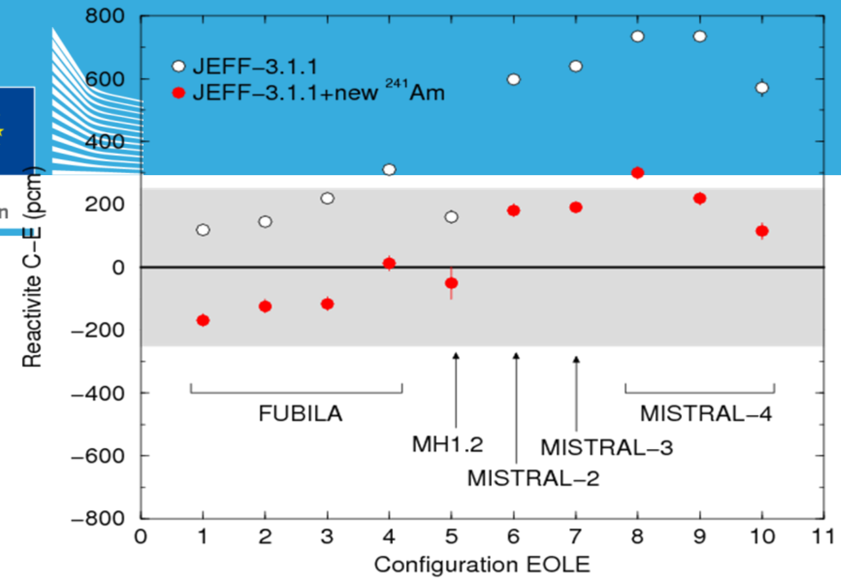
Research Centre

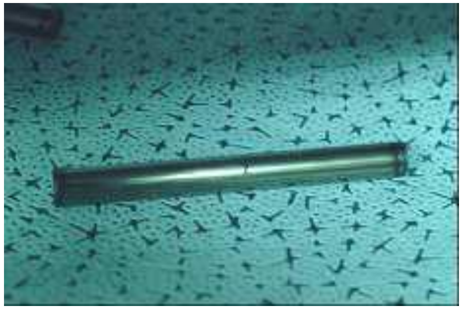
INTEGRAL MEASUREMENTS AT CEA CADARACHE

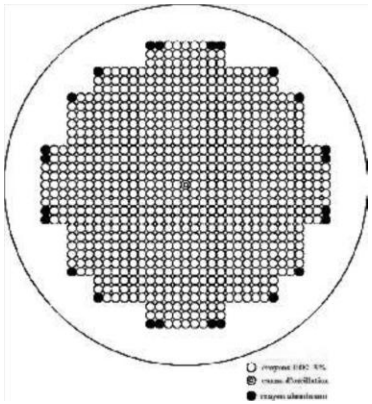
P. Leconte et al.
CEA has a commitment to benchmark experiments with scheduled upgrades

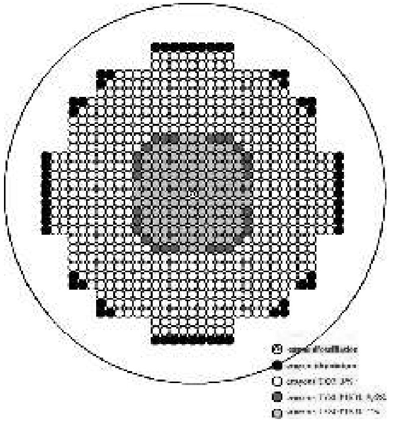
MINERVE 10y (+?)
EOLE (to 2022)
MASURCA (2017+)

MINERVE 2014 open for collaboration on isotopes with recent capture/fission meas.





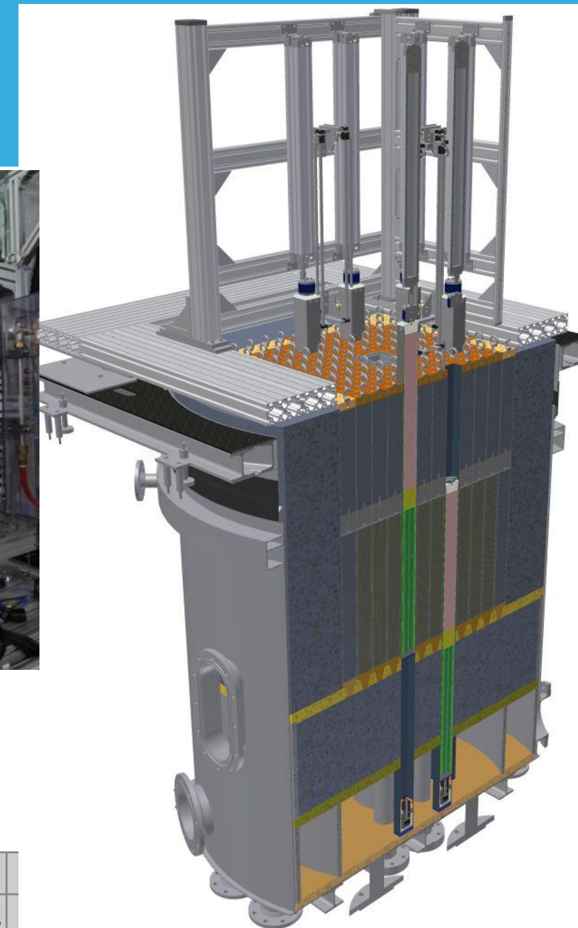


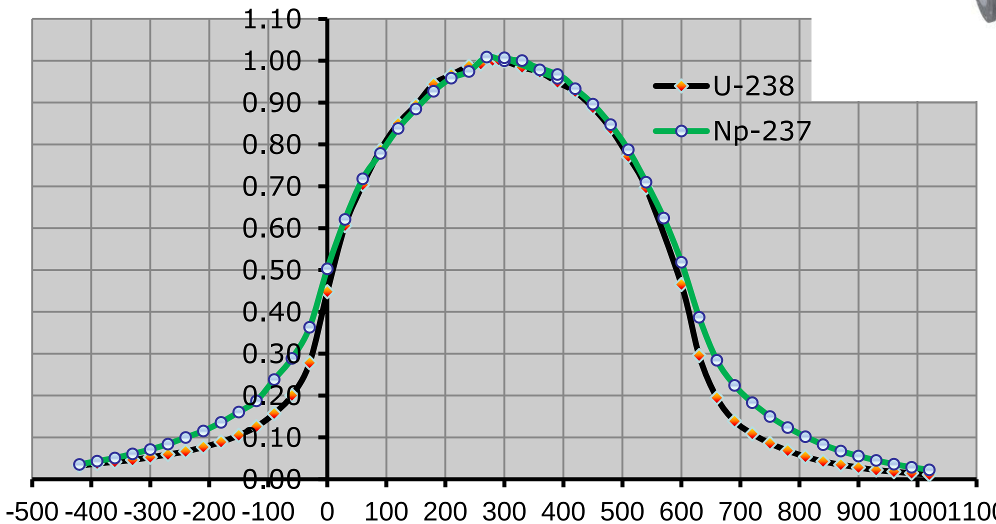


GUINEVERE at SCK

A. Billebaud et al. (LPSC, SCK-CEN, CNRS, …)

VENUS-F 30% enr-U & Pb
Critical & subcritical
DT generator 1 mA pulsed, dc, tripped





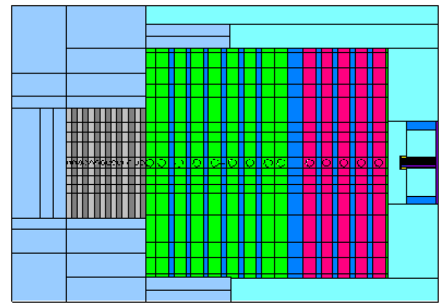
20 YEARS OF FUSION NEUTRONICS EXPERIMENTS AT FNG

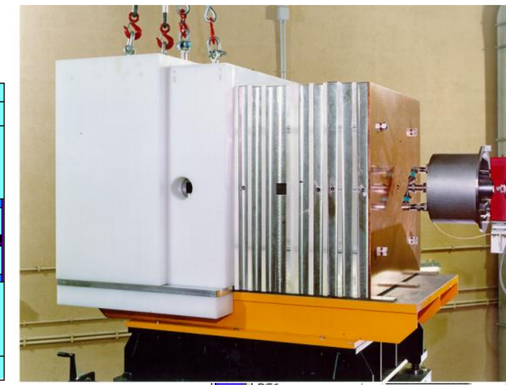
M. Angelone et al.
ENEA Frascati

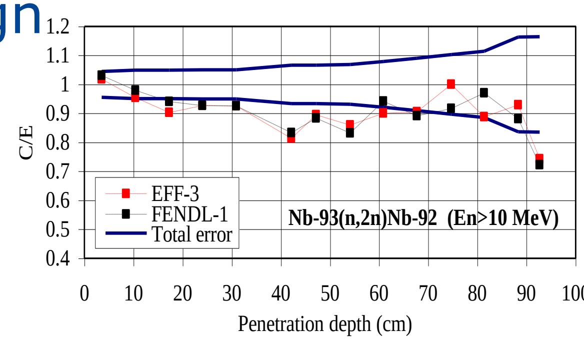
Design oriented experiments in support of ITER nuclear design

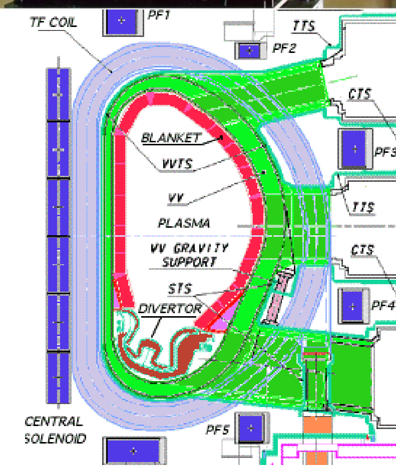
Experiments for validation of EFF / EAF

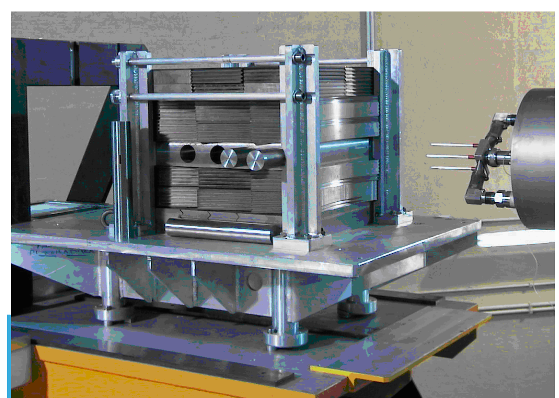
Activation Experiments



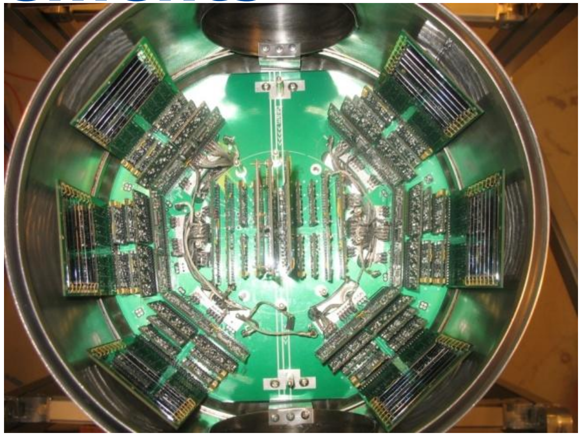




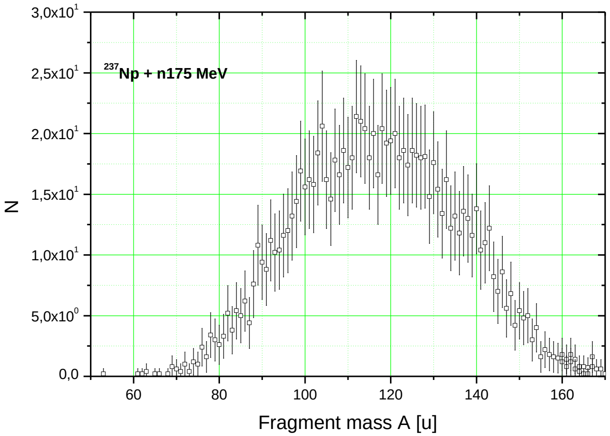




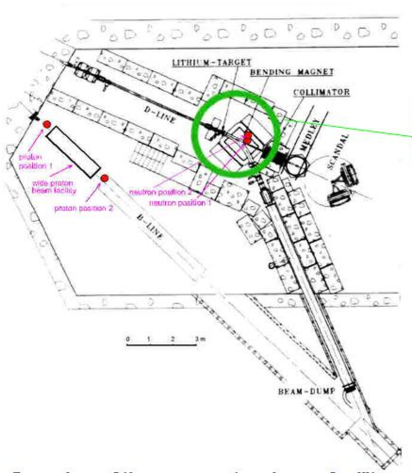
High-energy nuclear data measurements at The Svedberg Laboratory



A. Prokofiev, TSL UU
Quasi mono-energetic neutrons
P+Li
Overview of 10 years of meas.
Involvement in ERINDA
ANITA setup (white spectrum)
Close user position (High intensity)
Collaborations with NPI, NFS, AMS/Vera

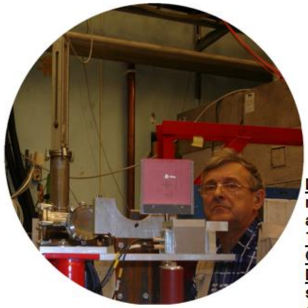


Wide proton beam facility



Overview of the new neutron beam facility

Neutron irradiation positions



Proton irradiation position

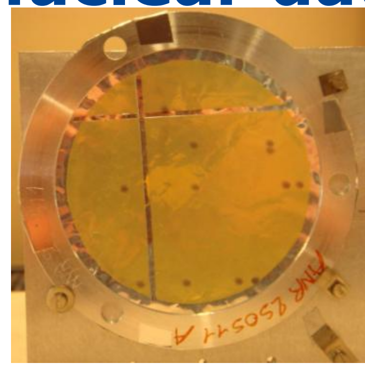
Detectors: Thin-film breakdown counters (TFBC) for measurements at both neutrons and protons
Targets: WO_3 layers ~2 mg/cm^2 thick on aluminum backings
Geometry: Sandwich
Determination of detection efficiency : Calibration with ^{252}Cf source corrected by model calculation taking into account differences between properties of fission fragments.

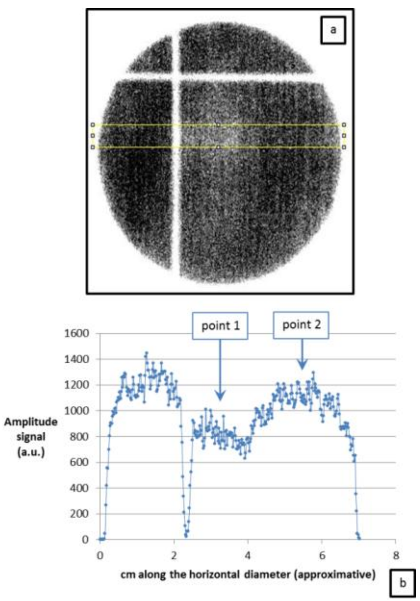
Multi-layer TFBC fission chamber

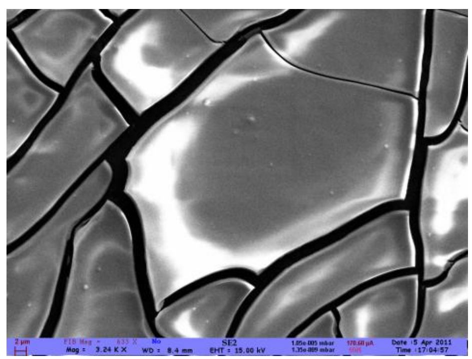
Radioactive targets for nuclear data

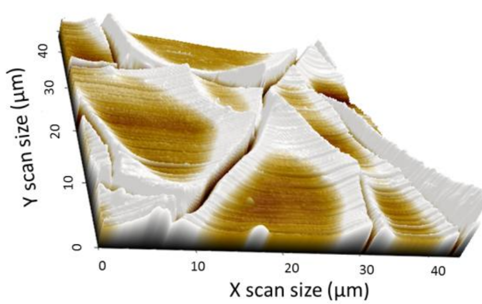
C.O. Bacri et al. (IPNO, CACAO)
Emphasised good targets for high quality measurements

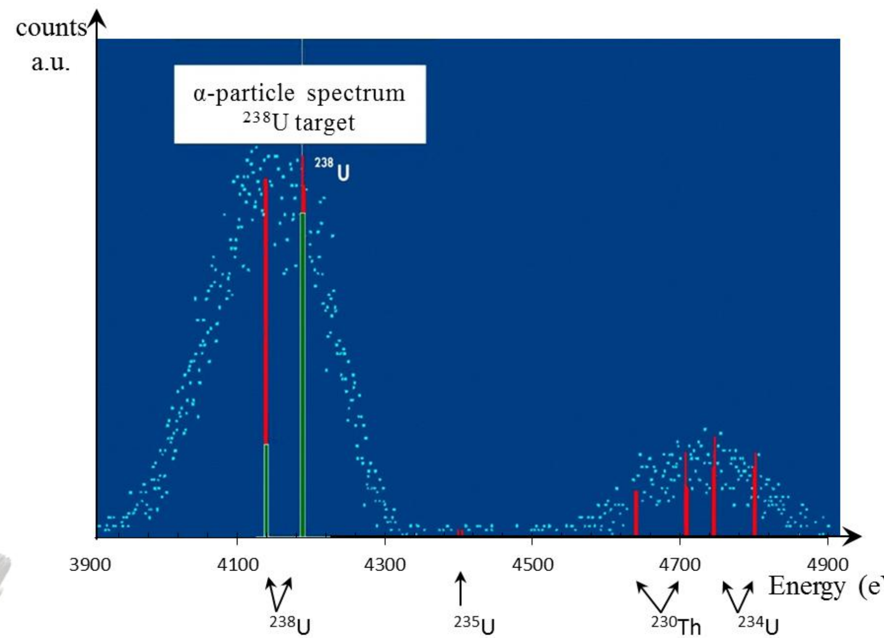
Production and characterisation



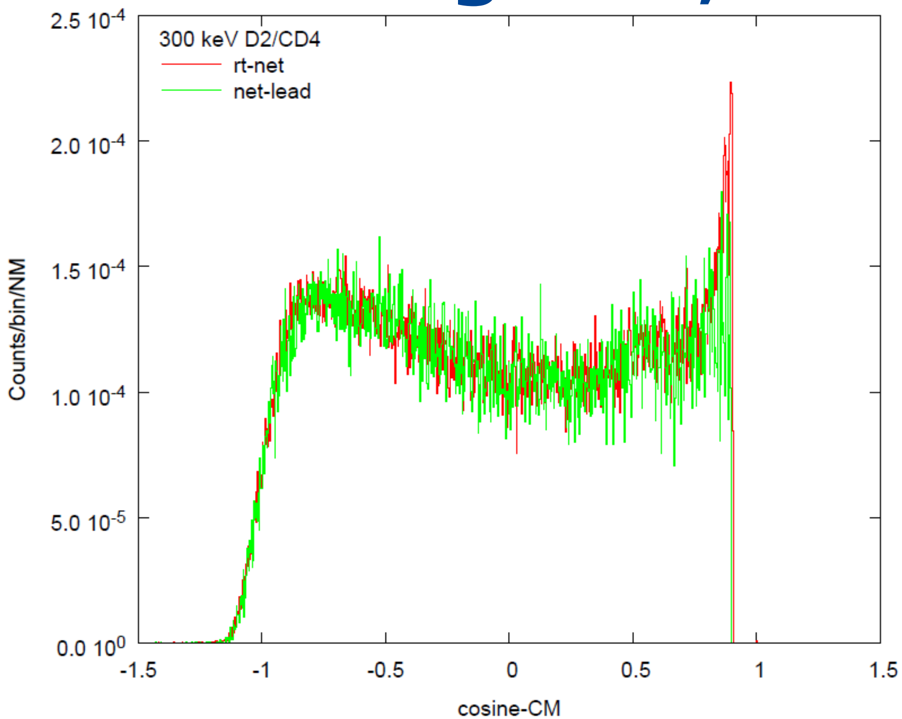


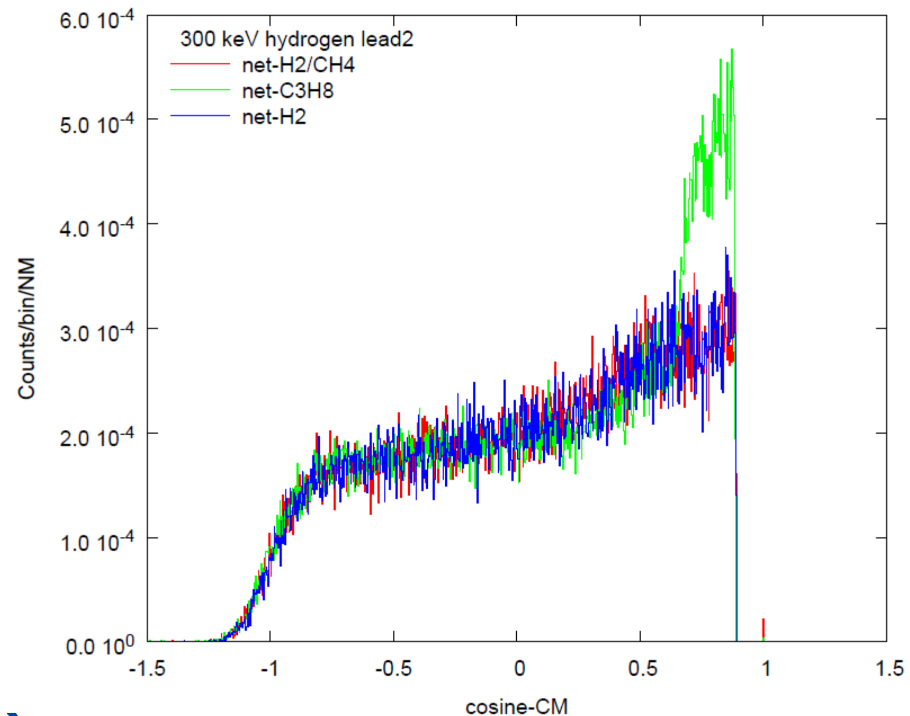






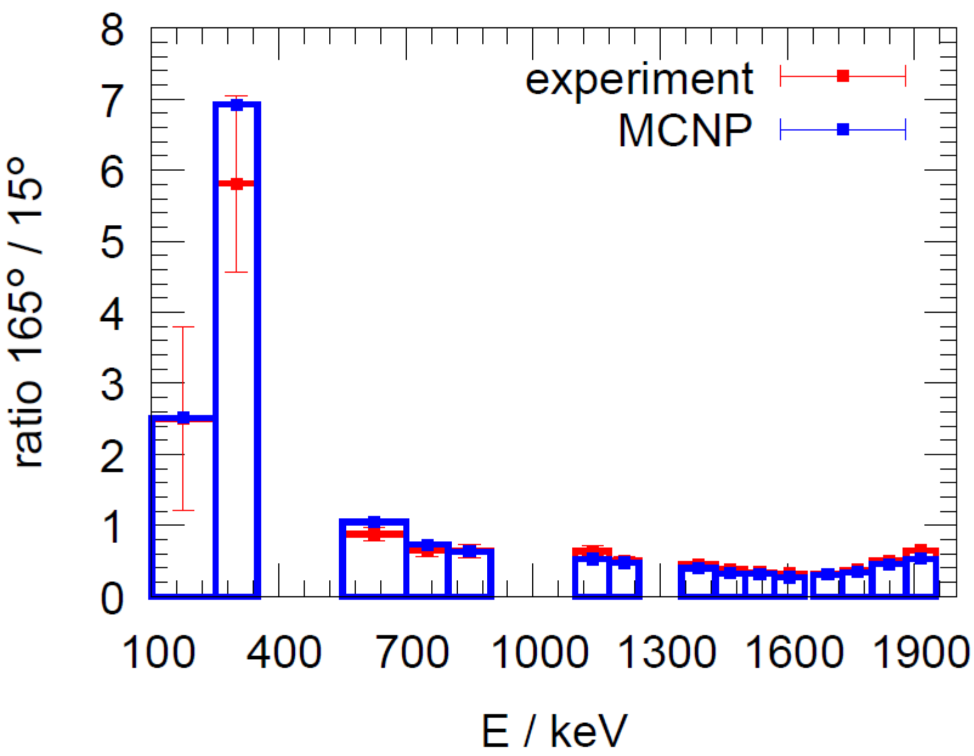
Scattering n+d, PC PTB, ERINDA

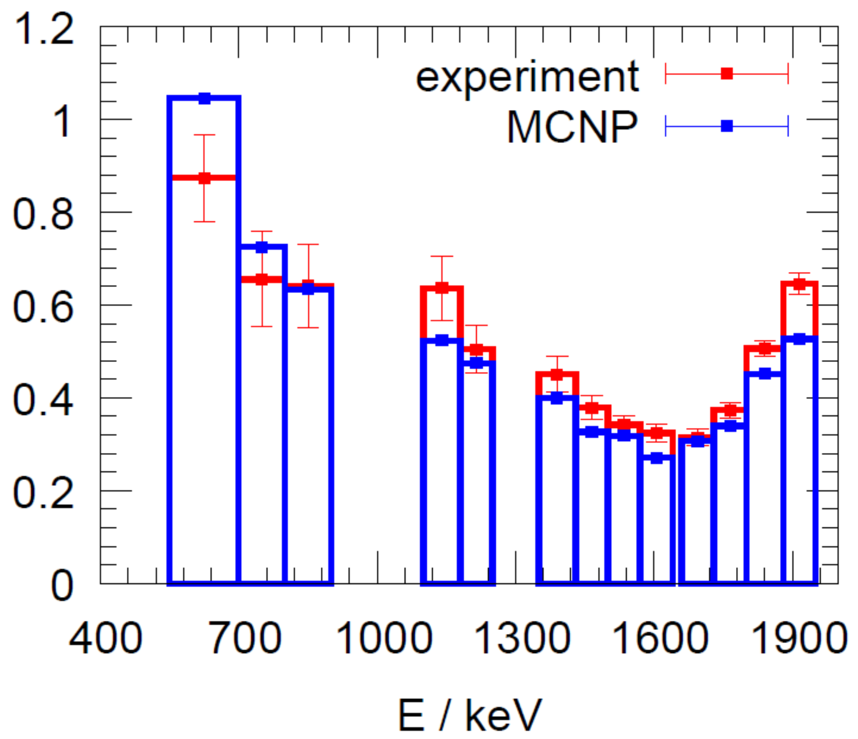




nd (left) compared w. np (right)
150-500 keV, 5 energies (here 300 keV)
Broad cosine range;

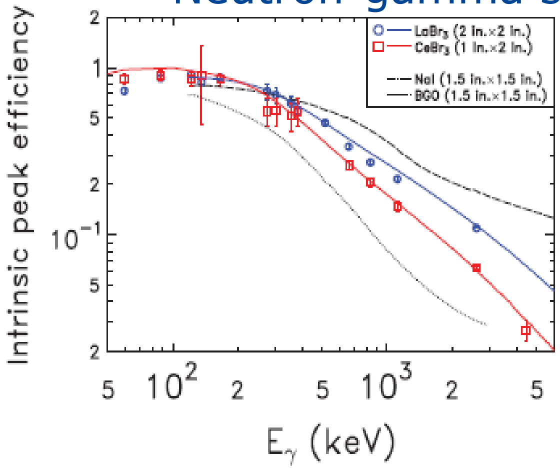
Results compared with MCNP & ENDF/B-VII (ongoing: Bonn-B and ds/do)

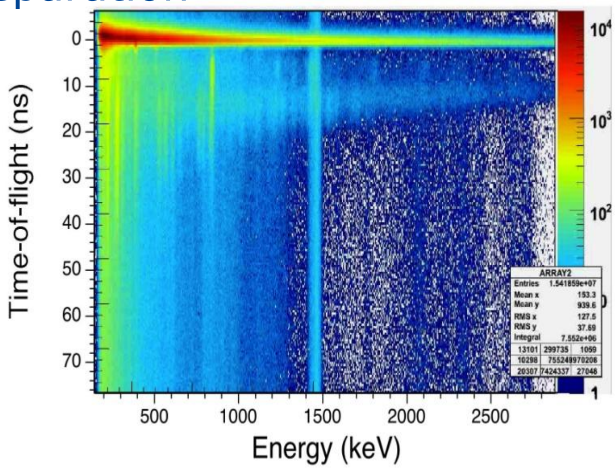


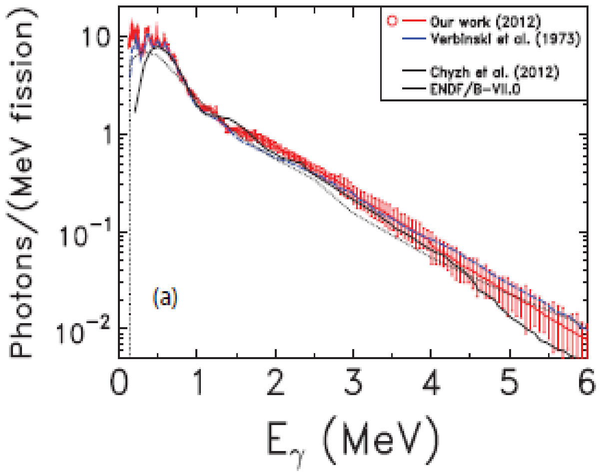


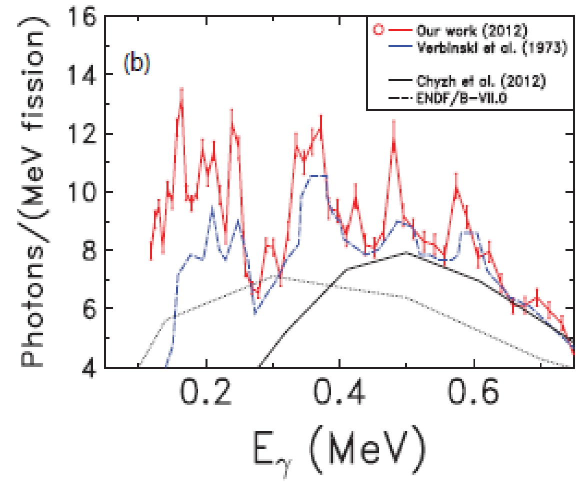
Prompt fission gammas

New gamma-ray detectors: $LaBr_3$, $LaCl_3$, $CeBr_3$
Testing and characterisation
First demonstration ^{252}Cf
Ongoing/nearly completed ^{235}U
TOF, FIC vs gamma detector
Neutron-gamma separation









PRC87(2013)024601 Billnert et al.
<Eg> lower, <Ng> higher; effectively a softer spectrum
Should affect photon transport

Summary

- Broad range of experimental activities in EU
- National programs (main source of funding)
- European coordination (ANDES, ERINDA, EUFRAT)
- CHANDA will aim for new capabilities: method development, new facilities
- Nuclear Data Weeks at OECD-NEA connect JEFF evaluation work and experimental efforts aimed at application (role EWG)