The n_TOF Collaboration, www.cern.ch/nTOF

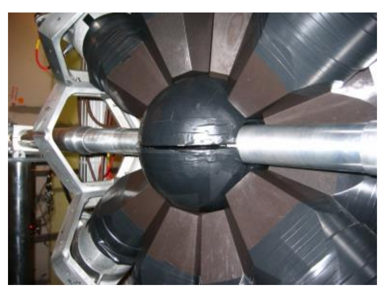
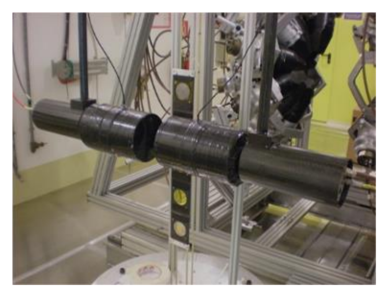
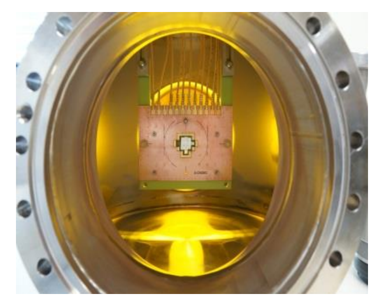
Summary of n_TOF measurements performed in 2012

(CERN 44th INTC meeting, June 26th 2013)

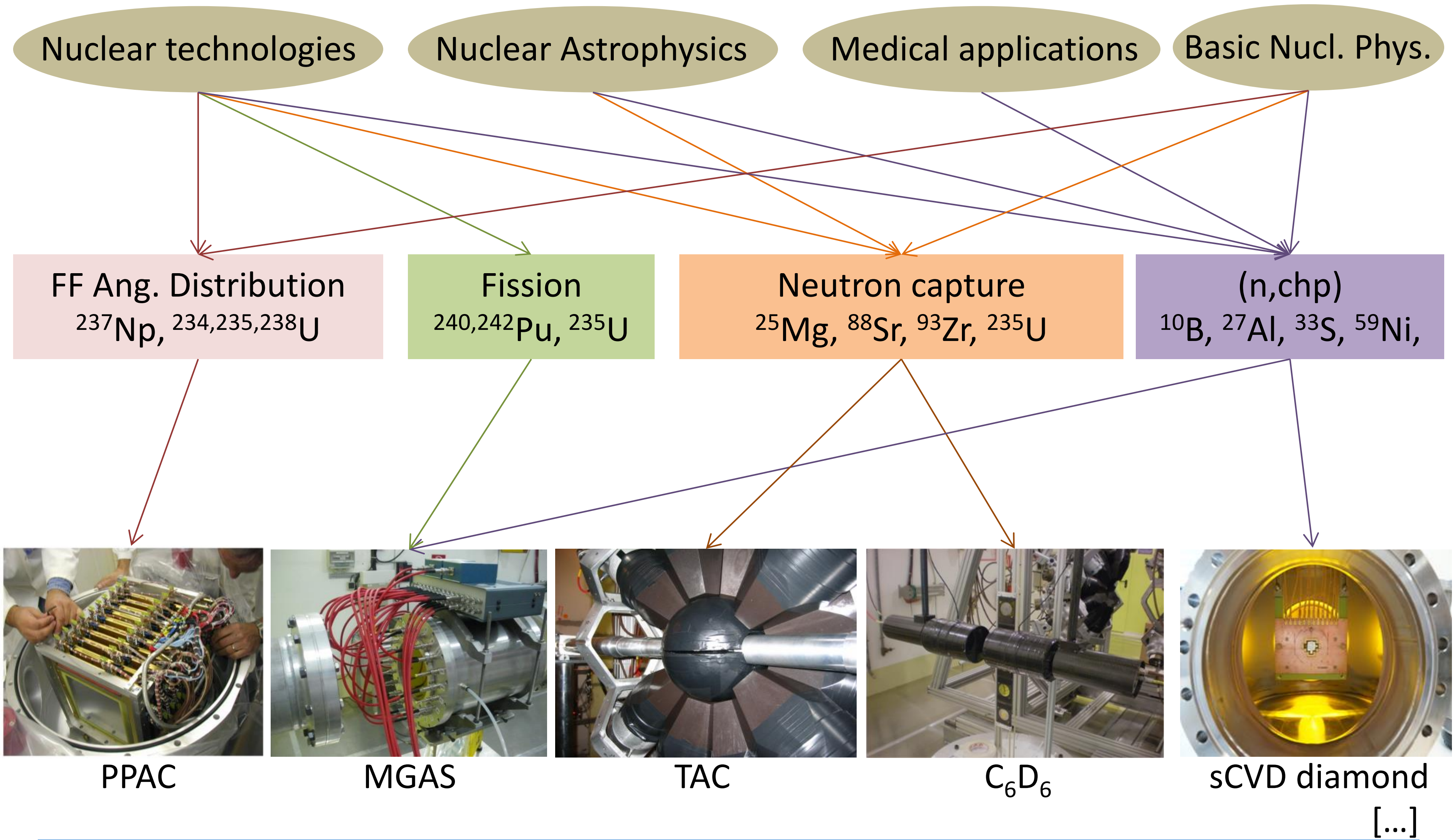
Carlos GUERRERO (CERN Fellow)

n_TOF Run and Analysis Coordinator



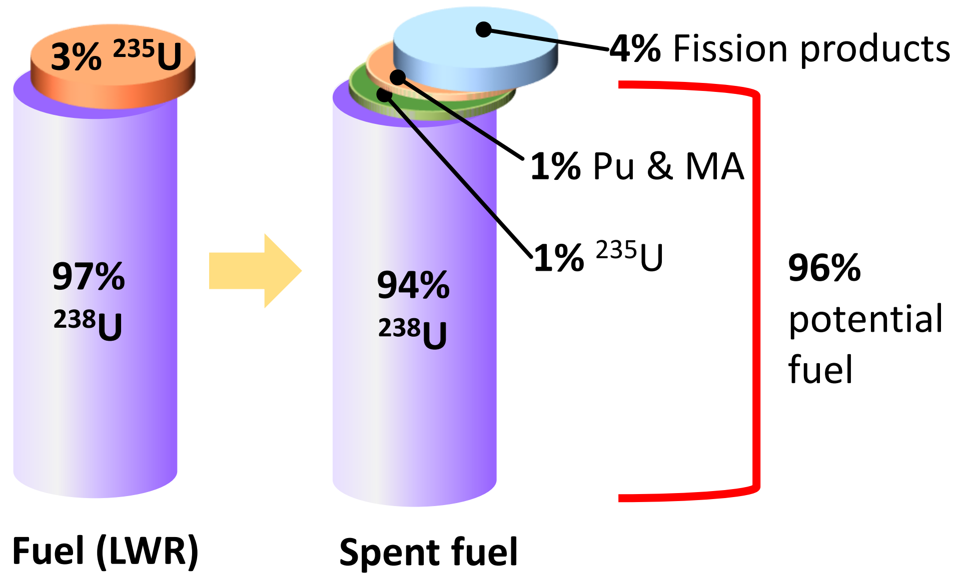




n_TOF measurements in 2012



Cross sections for Nuclear Technology

Cross sections for Nuclear Technology



New nuclear reactor concepts:

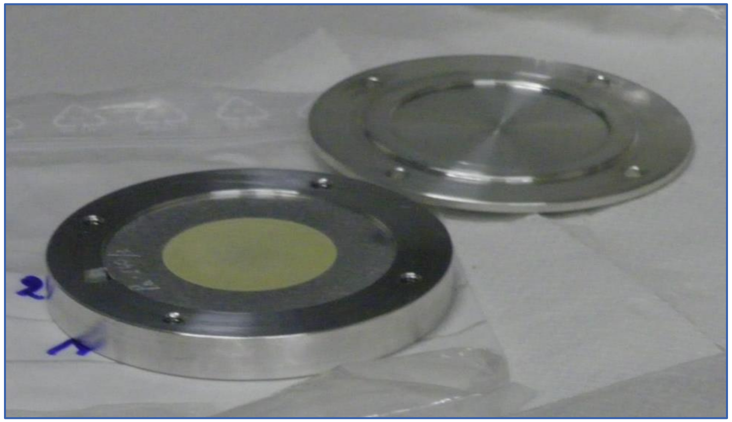
a) Gen-IV: Fast reactors that can operate with fuels including U, Pu and MA
b) ADS (Accelerator Driven Systems): dedicated nuclear waste burners

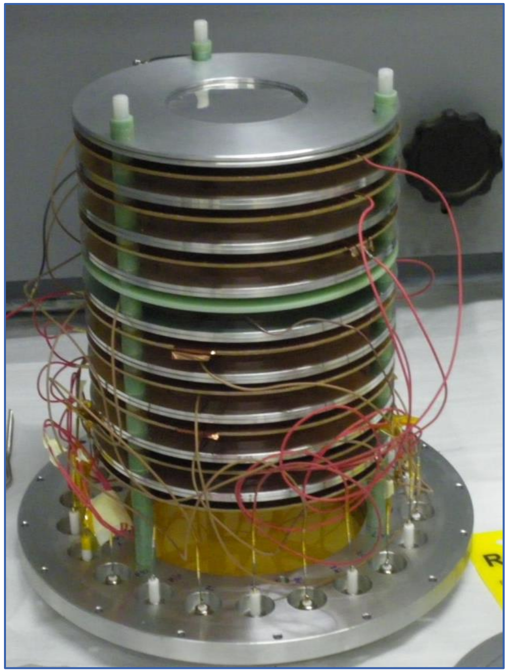
New fuels composition and different neutron energy regime call for new reactions, whose cross sections are not known with the required accuracy.

Measurement of the fission cross-section of ^{240}Pu and ^{242}Pu at CERN's n_TOF Facility

^{242}Pu	
^{238}Pu	0.002719%
^{239}Pu	0.00435%
^{240}Pu	0.01924%
^{241}Pu	0.00814%
^{242}Pu	**99.96518%**
^{244}Pu	0.00036%
Mass	**3.0mg**
Activity	**0.13 MBq**

Also spontaneous fission!!

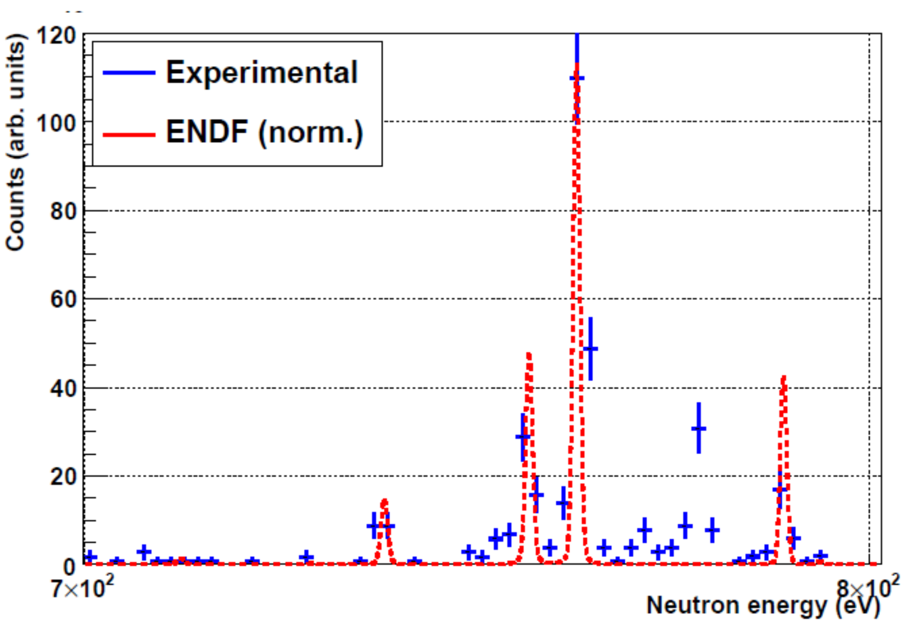


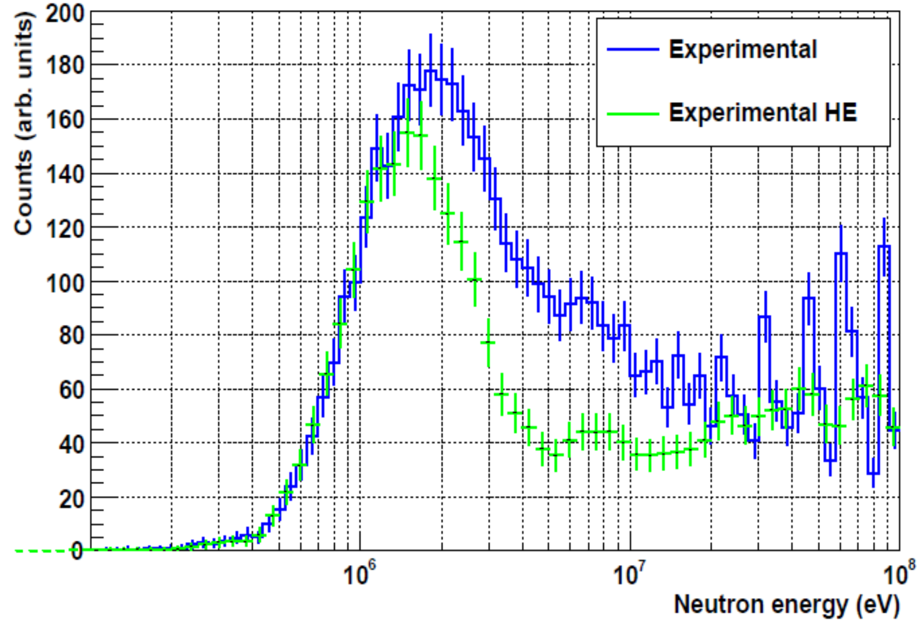


A. Tsinganis (PhD)
CERN (CH) & NTUA (Greece)

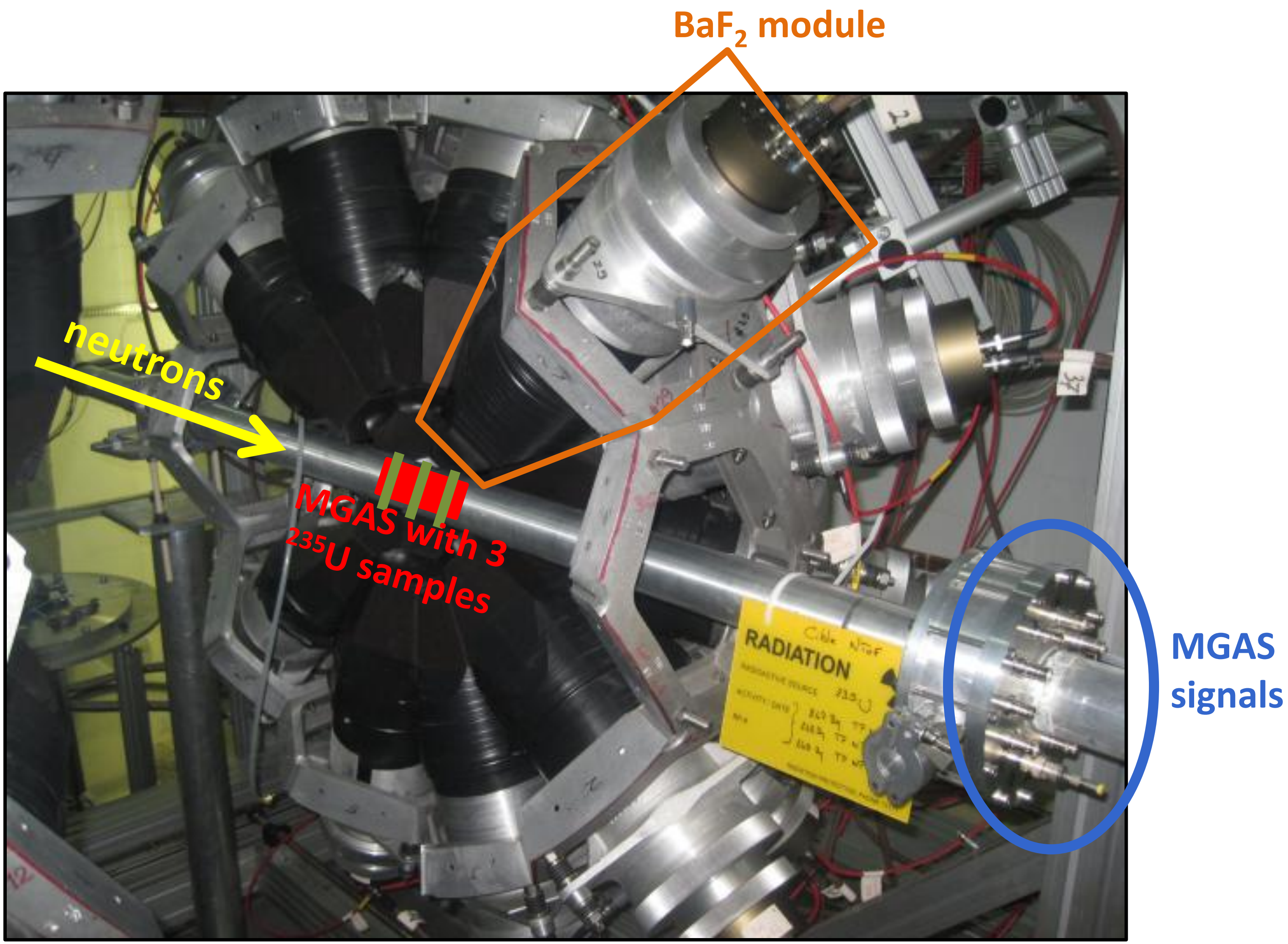
Measurement of the fission cross-section of ^{240}Pu and ^{242}Pu at CERN's n_TOF Facility

With only 30% of the statistics analyzed, the ^{242}Pu data look promising, both in the **RRR** and the **high energy** region, up to at least 200 MeV!

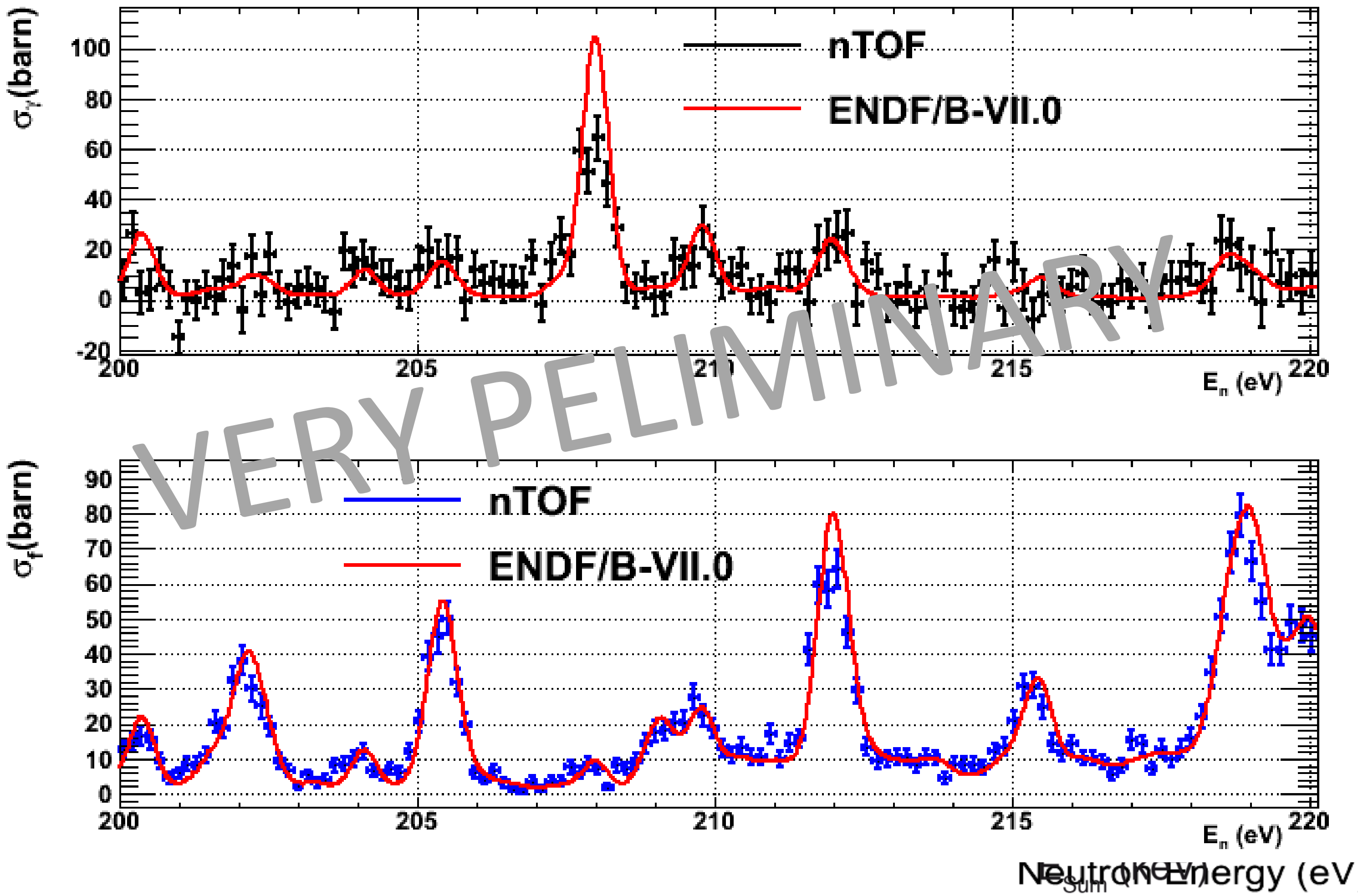




A. Tsinganis (PhD)
CERN (CH) & NTUA (Greece)


BaF_2 module
neutrons
MGAS with 3 ^{235}U samples
MGAS signals
RADIATION

Measurements of neutron-induced capture and fission reactions on ^{235}U: cross sections and α ratios, photon strength functions and prompt γ-ray from fission



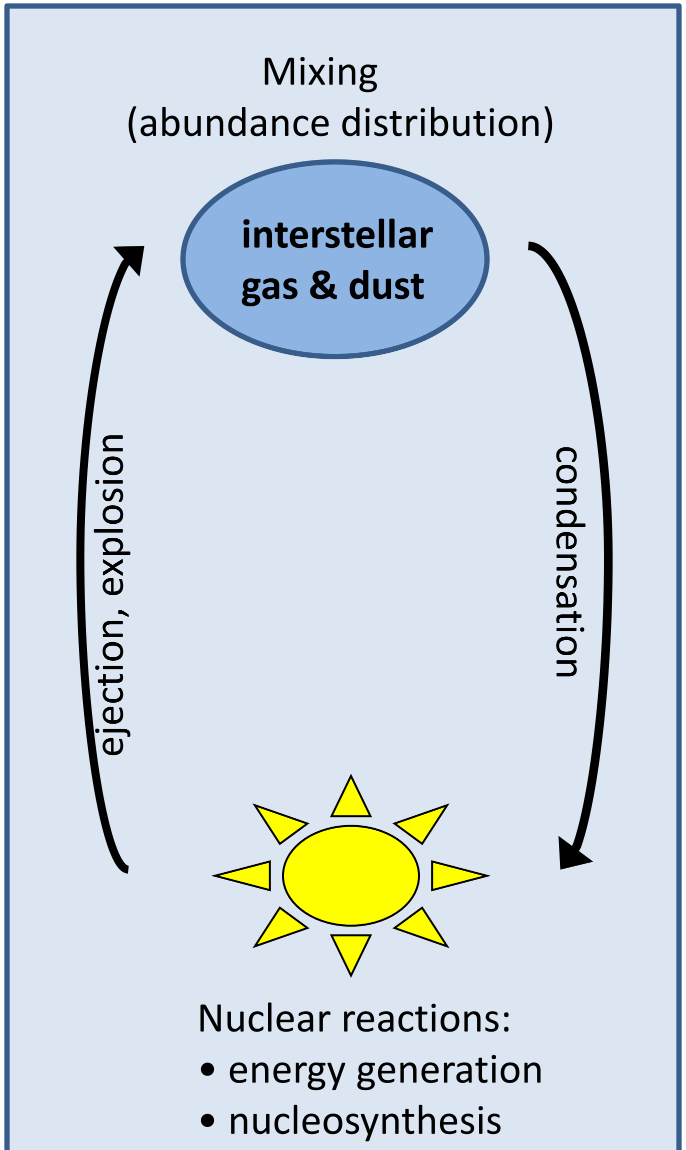
Captu

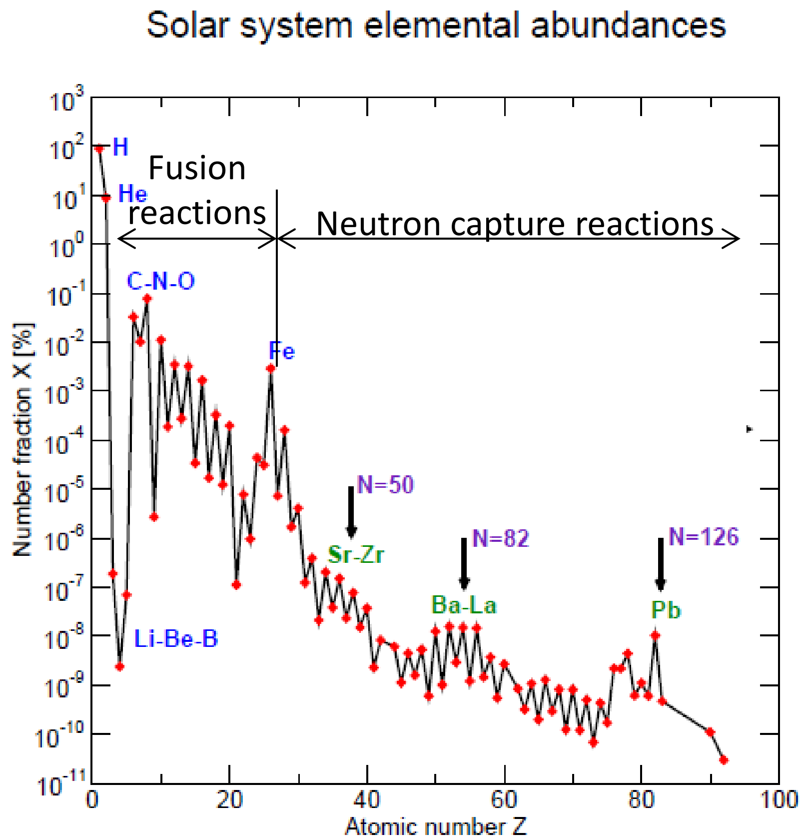
High

J. Balibrea (PhD)
CIEMAT (ES) and CERN (CH)

Cross sections for Astrophysics (nucleosynthesis of elements)

Cross sections for Astrophysics (nucleosynthesis of elements)





Chemical elements beyond Iron are synthesized via neutron capture reactions in stars:

~ ½ by the *s*-process (red giants)

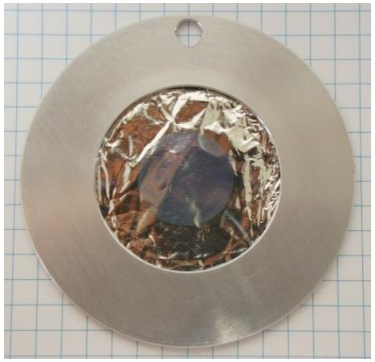
~ ½ by the *r*-process (explosive)

Sample from ORNL (USA):

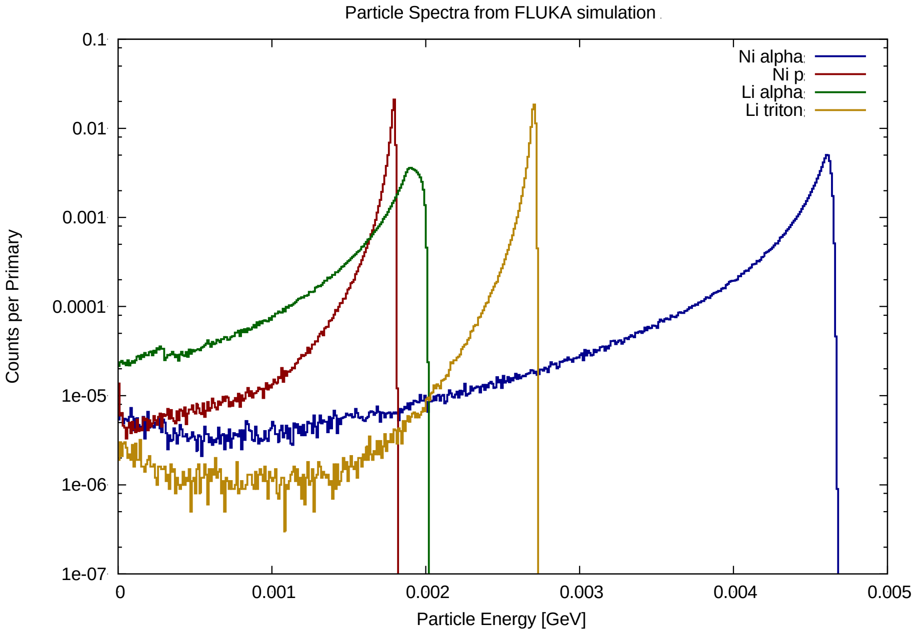
205±5 μg LiF: 95% ^{6}Li (thickness = 394 nm)

180±5 μg metallic Ni: 95% ^{59}Ni => 516 kBq

→ **Lowest mass measured at n_TOF to date!**



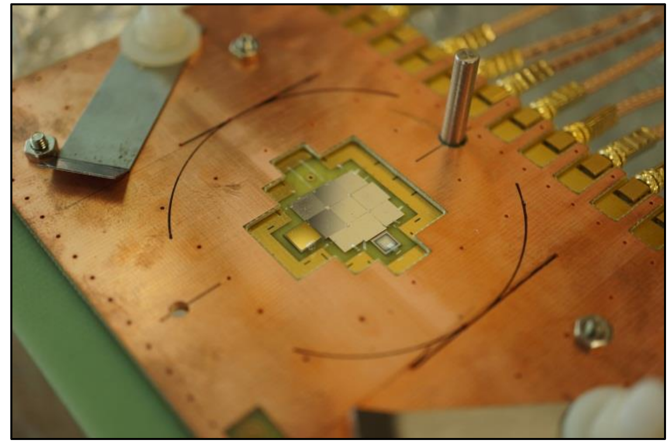
Reaction	Particle	E_{max} [MeV]
^{59}Ni(n,α)^{56}Fe	α	4.76
^{59}Ni(n,p)^{59}Co	p	1.82
^{6}Li(n,α)t	α	2.06
^{6}Li(n,α)t	t	2.73



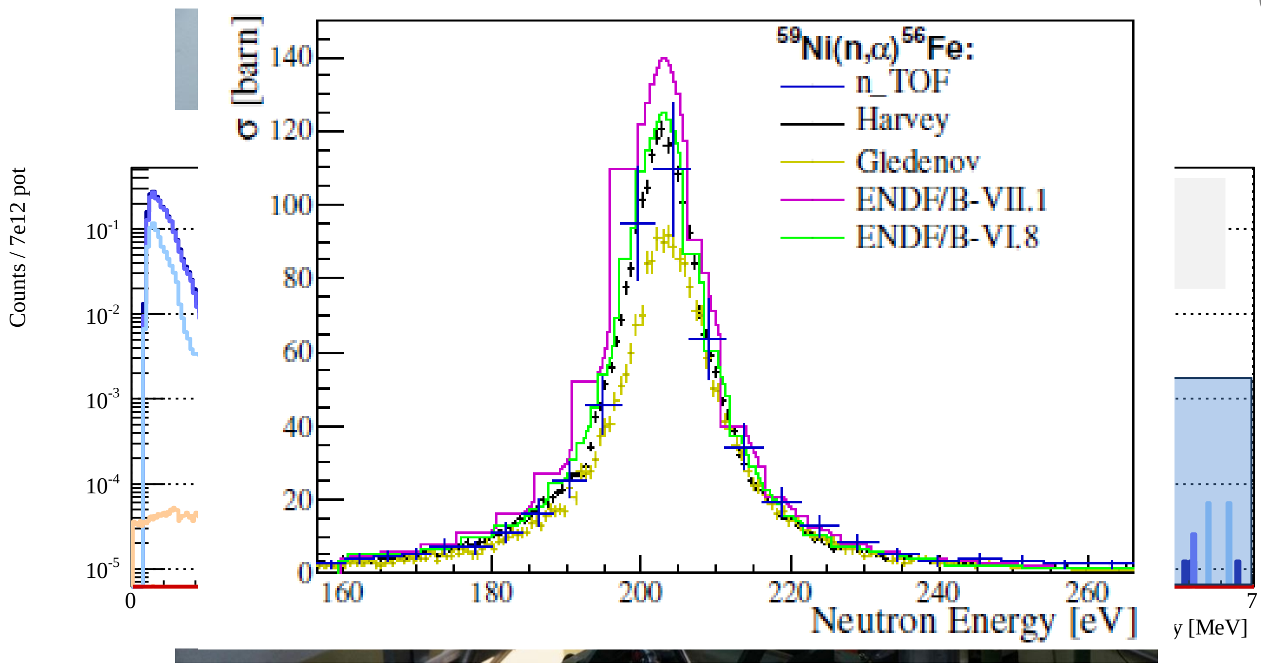
New development

Array of 9 sCVD diamond diodes:

1. Thickness: 150 μm
2. Detector size 5x5 mm^2 (each)
3. Electrodes: 200 nm Al



CIVIDEC



C. Weiss (PhD)
CERN (CH) and TUW (AUSTRIA)

The *s-process* and ^{25}Mg: a neutron poison!

"Main component"

^{22}Ne(α,n)^{25}Mg is a **neutron source** in **AGB stars**:

$1M_{sun} < M < 3M_{sun}$

- **kT=8 keV and kT=25 keV**

"Weak component"

^{22}Ne(α,n)^{25}Mg is the **main neutron source** in **massive stars:** $M > 10 - 12M_{sun}$

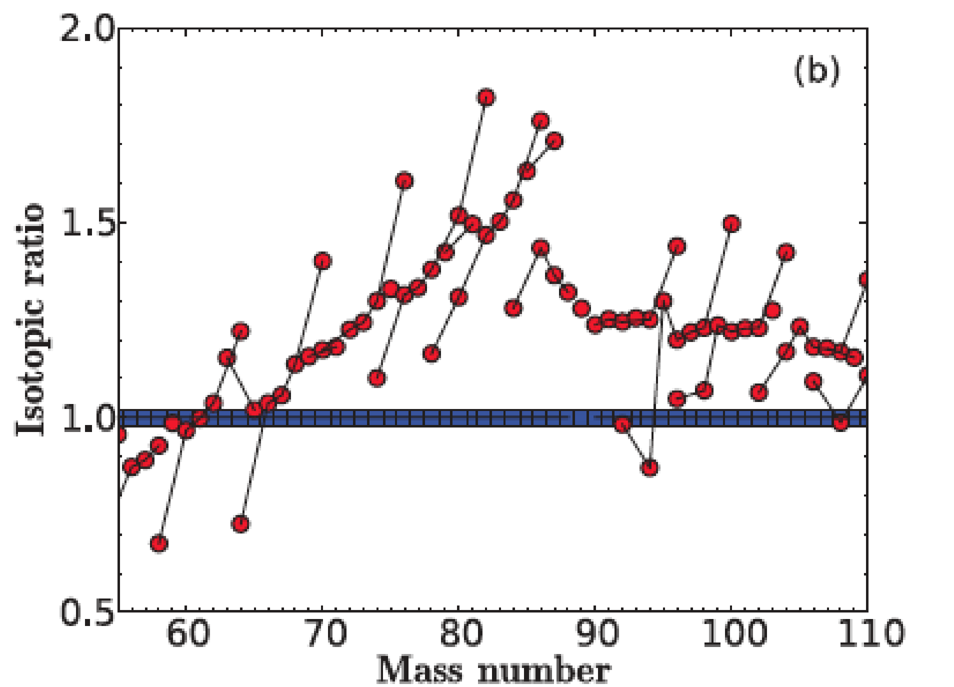
- **kT=25 keV and kT=90 keV**

^{22}Ne(α,n)^{25}Mg is a neutron source in AGB stars and the main one in massive stars, subsequently ^{25}Mg becomes a neutron poison trough the ^{25}Mg(n,γ) reaction

PHYSICAL REVIEW C 85, 044615 (2012)

Resonance neutron-capture cross sections of stable magnesium isotopes and their astrophysical implications

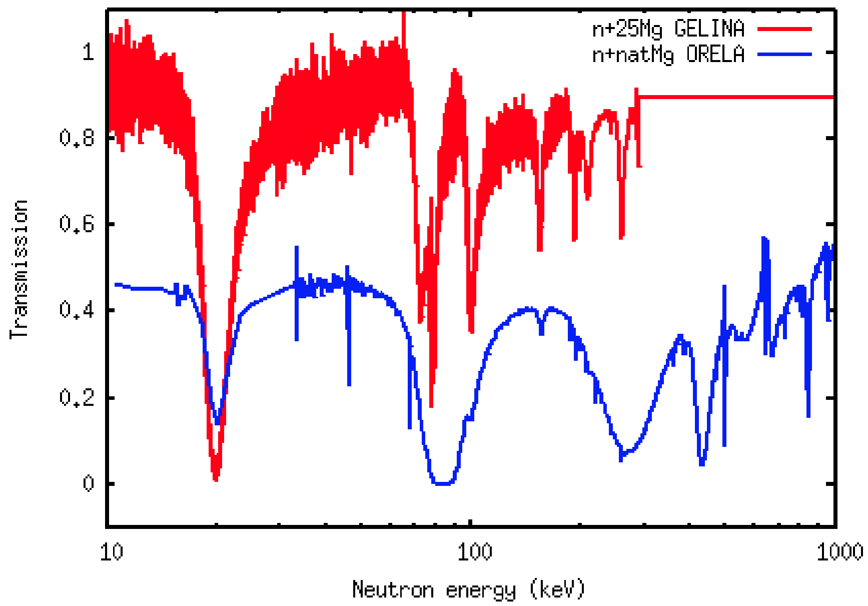
C. Massimi,[1,2,*] P. Koehler,[3] S. Bisterzo,[4] N. Colonna,[5] R. Gallino,[4] F. Gunsing,[6] F. Käppeler,[7] G. Lorusso,[5] A. Mengoni,[8,9] M. Pignatari,[10] G. Vannini,[1,2] U. Abbondanno,[11] G. Aerts,[6] H. Álvarez,[12] F. Álvarez-Velarde,[13] S. Andriamonje,[6] J. Andrzejewski,[14] P. Assimakopoulos,[15,†] L. Audouin,[16] G. Badurek,[17] M. Barbagallo,[5] P. Baumann,[18] F. Bečvář,[19] F. Belloni,[11] M. Bennett,[20] E. Berthoumieux,[6] M. Calviani,[9] F. Calviño,[21] D. Cano-Ott,[13] R. Capote,[8,22] C. Carrapiço,[23,6] A. Carrillo de Albornoz,[23] P. Cennini,[9] V. Chepel,[24] E. Chiaveri,[9] G. Cortes,[25] A. Couture,[26] J. Cox,[26] M. Dahlfors,[9] S. David,[16] I. Dillmann,[7] R. Dolfini,[27] C. Domingo-Pardo,[28] W. Dridi,[6] I. Duran,[12] C. Eleftheriadis,[29] M. Embid-Segura,[13] L. Ferrant,[16,†] A. Ferrari,[9] R. Ferreira-Marques,[24] L. Fitzpatrick,[9] H. Frais-Koelbl,[8] K. Fujii,[11] W. Furman,[30]

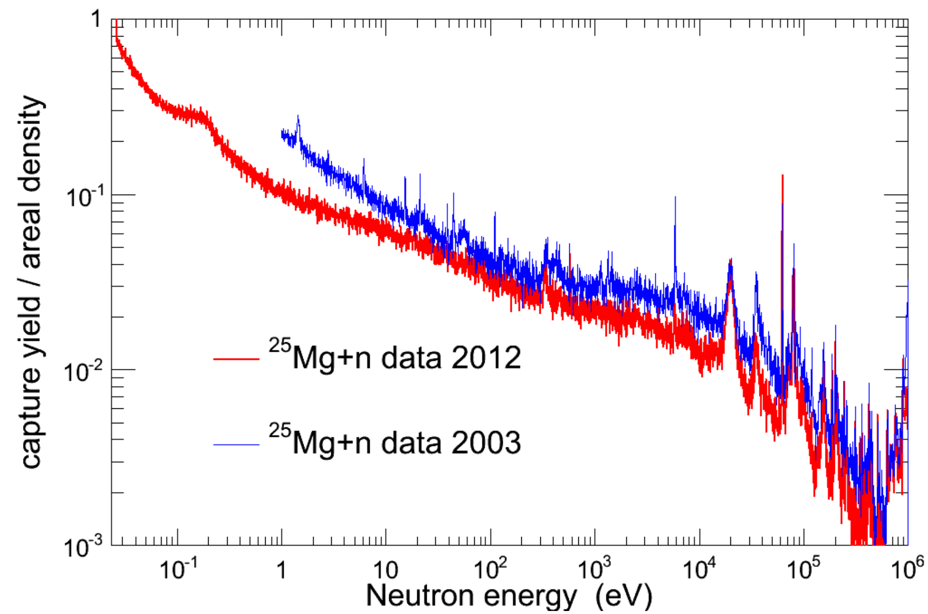


^{22}Ne(α,n)^{25}Mg is a neutron source in AGB stars and the main one in massive stars, subsequently ^{25}Mg becomes a neutron poison trough the ^{25}Mg(n,γ) reaction

The measurement on 2003 suffered from some uncertainties that now have been highly reduced by

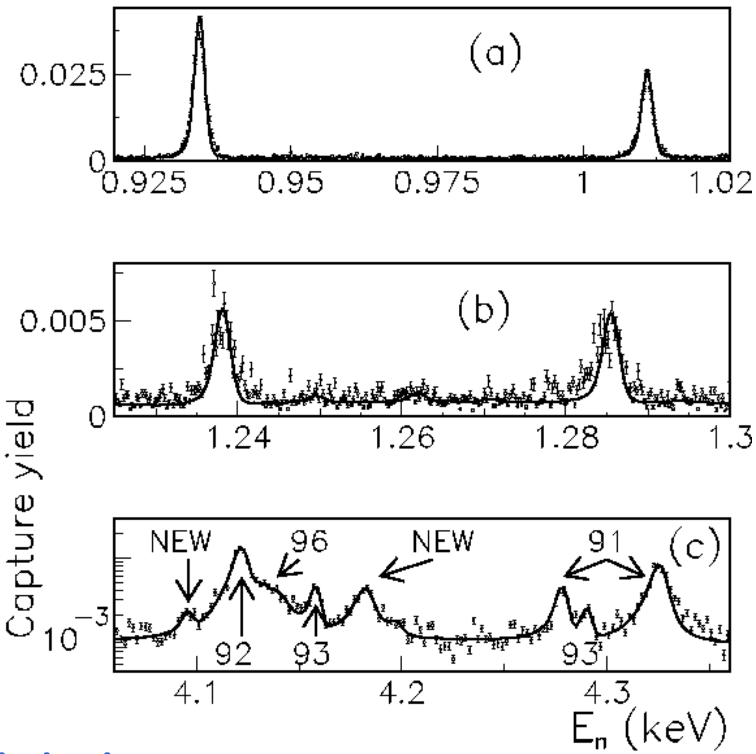
1. Using a highly pure metallic sample
2. Measuring both capture (@n_TOF) and total (@JRC/IRMM/GELINA) cross sections
3. Using the upgrade n_TOF facility (highly reduced γ-background since 2010)

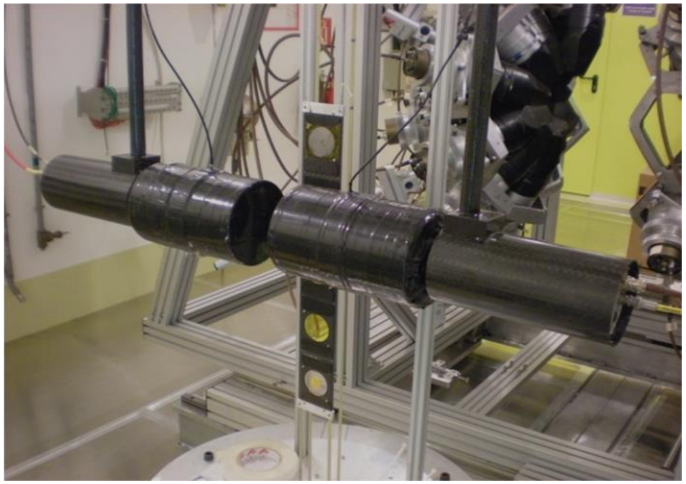




Neutron capture cross section of ^{93}Zr

G. Tagliente et al., Phys. Rev. C 87, 014622 (2013)
"The $^{93}Zr(n,\gamma)$ reaction up to 8 keV neutron energy"





Limitations:

- Al+Ti capsule because of sample activity
- High in-beam γ-ray background

Thanks to the availability of a Type A experimental area (since 2010) the measurement has been repeated:

- Absence of Al+Ti capsule
- Lower in-beam γ-ray background

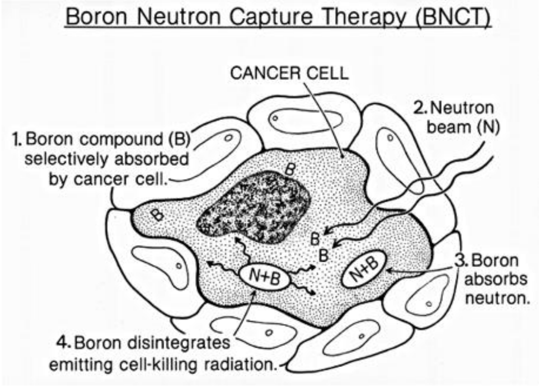
Both result in lower background, and thus:

- **Better accuracy**
- **Higher neutron energy limit**

G. Tagliente
INFN-Bari (IT)

Cross sections for Medical Physics (Neutron Capture Therapy)

^{33}S as a cooperative target for NCT



$^{33}S(n,\alpha)^{30}Si$	$^{10}B(n,\alpha)^{7}Li$
E_α~3.1 MeV	$E_{Li}\approx$0.84 MeV $E_\alpha\approx$1.47 MeV
LET≈126 keV/μm (optimal value ~100)	LET(Li)=162 keV/μm LET(α)=196 keV/μm
x_α~15 μm	x_{Li}~5 μm x_α~8 μm
$E_n\approx$13 keV -> **σ(n,α)≈20 barns?**	E_n~eV -> σ(n,α)≈3840 b E_n~keV -> σ(n,α)≈5 b
No gamma	$E_\gamma\approx$0.48 MeV

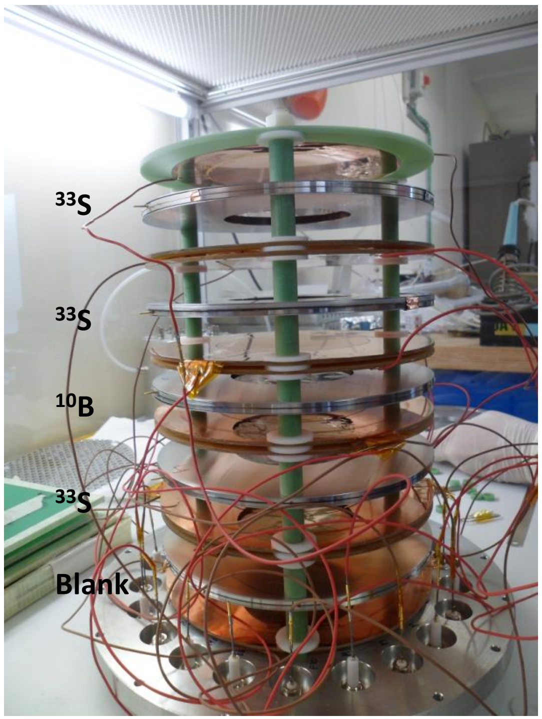
I. Porras, Phys. Med. Biol. 53 (2008)

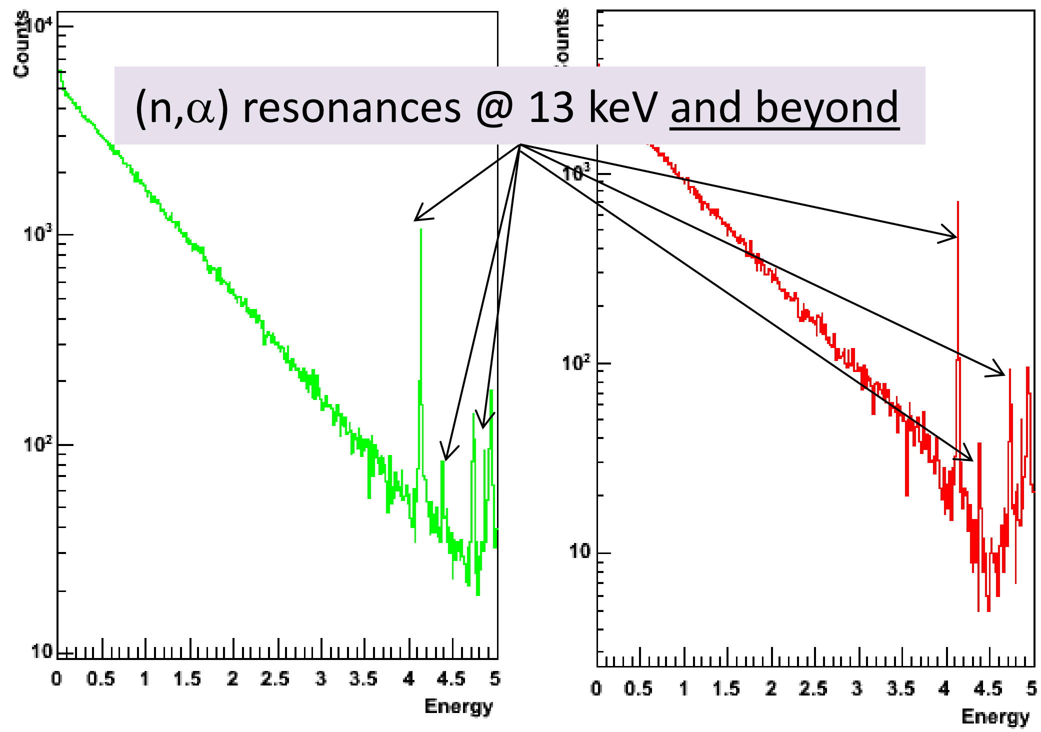
Measurement carried out in November-December 2012

10 MGAS detectors with 10 samples back-to-back:

^{33}S thin (x4), ^{33}S thick (x2), blanks (x2), ^{10}B (x2)

[*samples prepared at CERN by W. Vollenberg*]

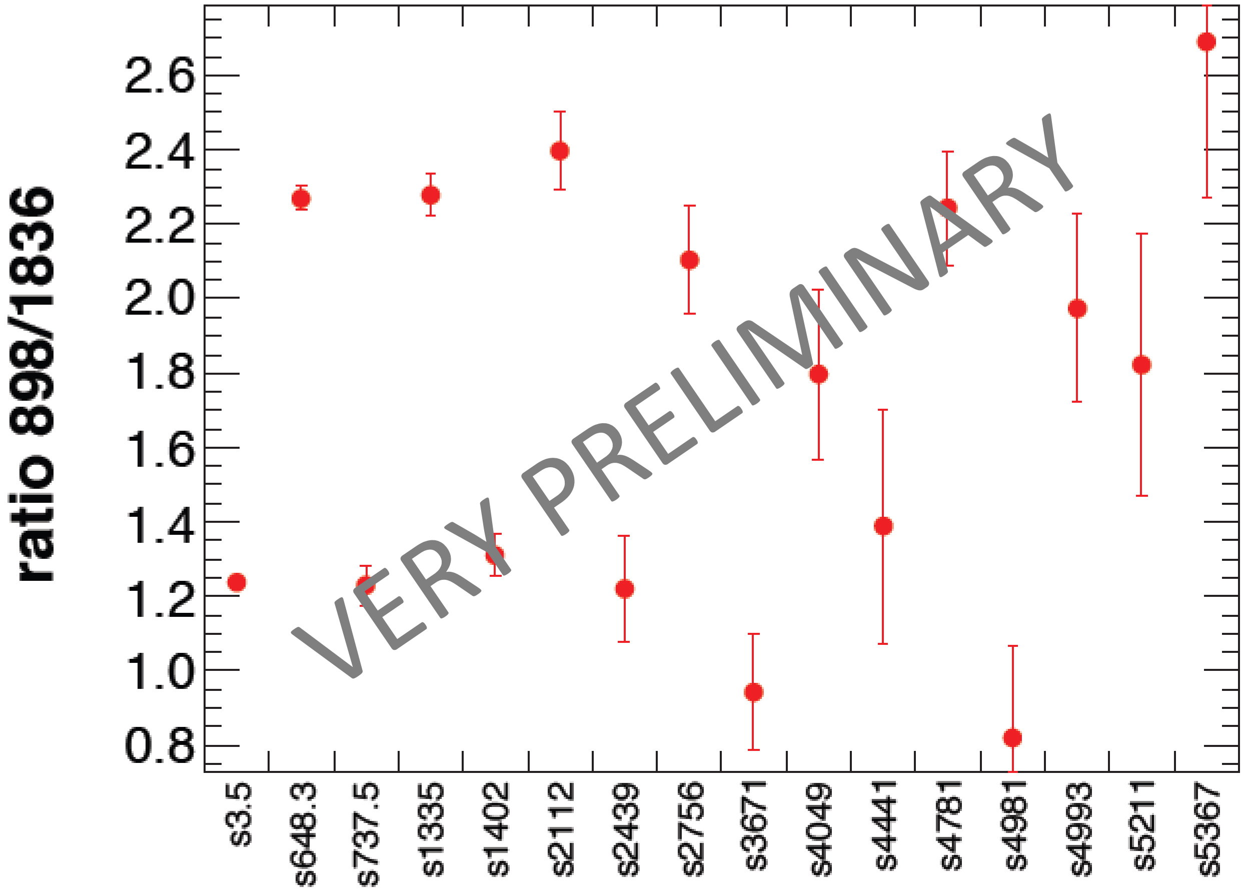




Basic Nuclear Physics

Pilot experiment to measure **spin-dependent level densities** in ^{87}Sr with BaF_2 TAC by:

- Exploit gamma-ray spectra from decay from resonance state
- gamma-ray multiplicity spectra
- primary gamma-rays (presence, angular distribution)



Fragment Angular Distributions in the $^{234}U(n,f)$ and $^{236}U(n,f)$ reactions

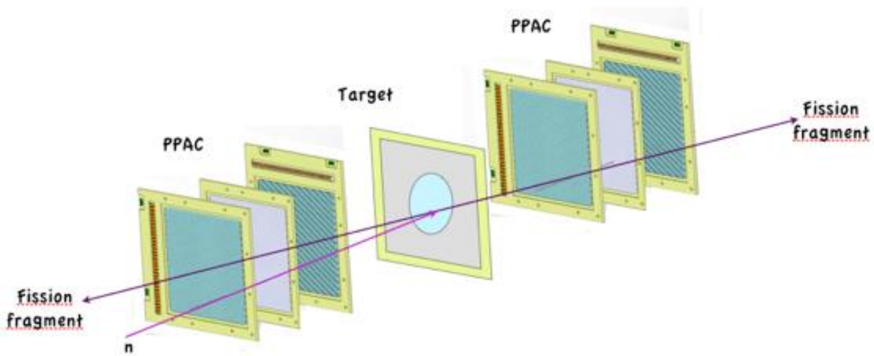


Figure 1 : stainless steel cylinder

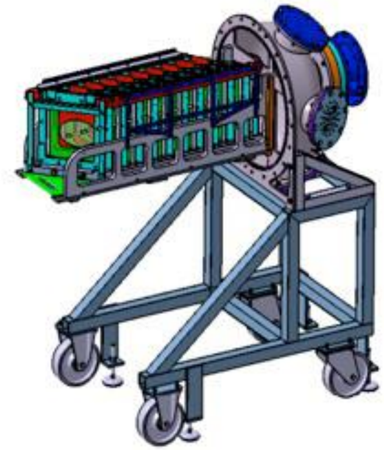
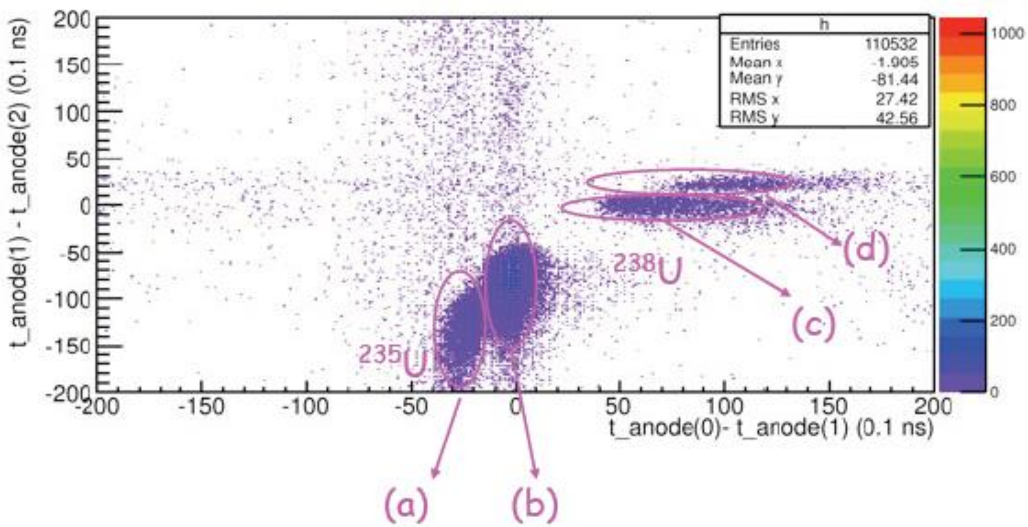


Figure 2: aluminum bottom + detectors and targets



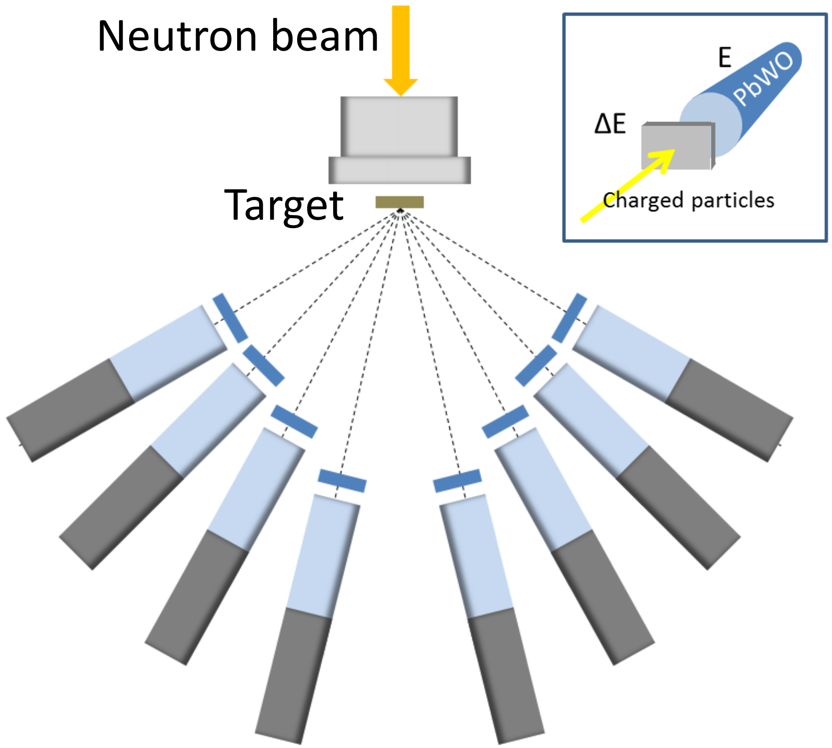
(a) HF from ^{235}U target
(b) LF from ^{235}U target
(c) LF from ^{238}U target
(d) HF from ^{238}U target

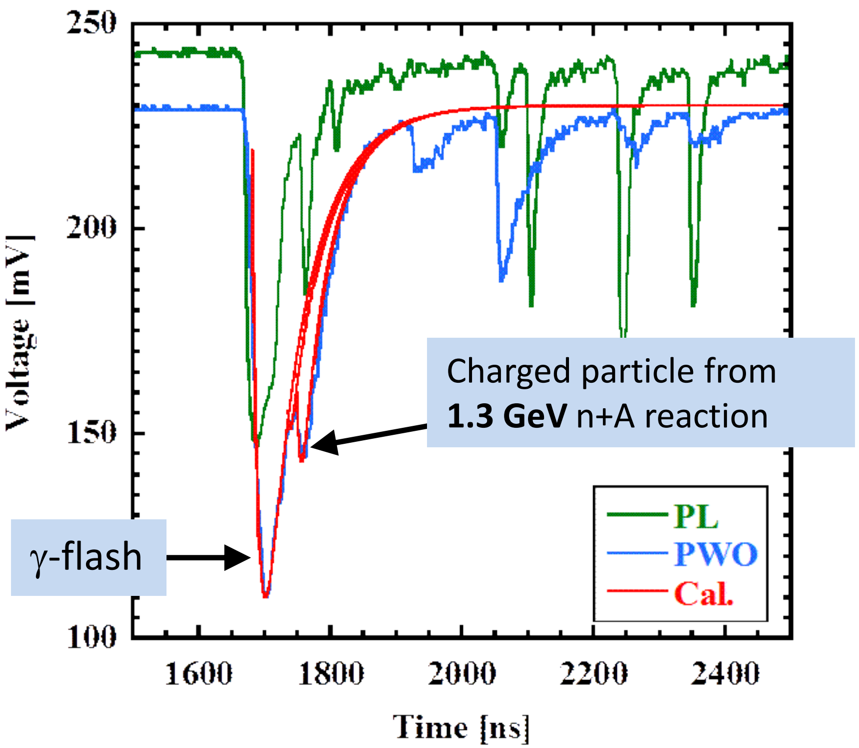
Feasibility study for measuring (n, α) and (n,d) reactions at (very) high energies GeV

(p,p'), (p,n): 0.1 – 1.5 GeV
(p,d): 0.3 and 0.4 GeV, 0.558 GeV, 1.2 GeV
(p, α) : 0.16 and 0.2 GeV, 1.2 GeV
(p,p') at low energy : 40-60 MeV

Nucl. Instr. Meth. B 291, 38-44 (2012)
Phys. Rev. C 86, 034610, (2012)
Only this Intranuclear Cascade model is capable of predicting light cluster production

First test for studying these reactions (at high energy) when induced by neutrons





Y. Uozumi
Kyushu University (Japan)

“Parasitic” experiments @ n_TOF beam dump

- R. Palomo et al.(U. Sevilla, Spain)

Irradiation of 3D silicon detectors with high energy neutrons

- S. Puddu, F. Murtas and M. Silari (CERN/RP)

Test of a position sensitive GEM neutron detector

- S. Puddu, F. Murtas and M. Silari (CERN/RP)

Test of a movable GEM array as beam profiler

- C. Tecla, F. Murtas and M. Silari (CERN/RP)

Tests with Medipix detectors at n_TOF

- R. Palomo and I. Villa (U. Sevilla and IFCA, Spain)

FBG fibers response to high energy neutrons

- M. Tardocchi (CNR-IFP, Milano, Italy)

Diamond detector test under a neutron beam

Conclusions

In 2012 the n_TOF facility has operated braking several n_TOF records:

- Maximum number of experiments in a single campaign (10 dedicated + 6 parasitic)
- Highest integrated beam intensity in a single campaign ($\sim 1.9 \times 10^{19}$)
- Highest number of published papers in a year (1 PRL, 5 PRC, 3 EPJ-A, 2 NIM-A)