The n_TOF Collaboration, www.cern.ch/n_TOF

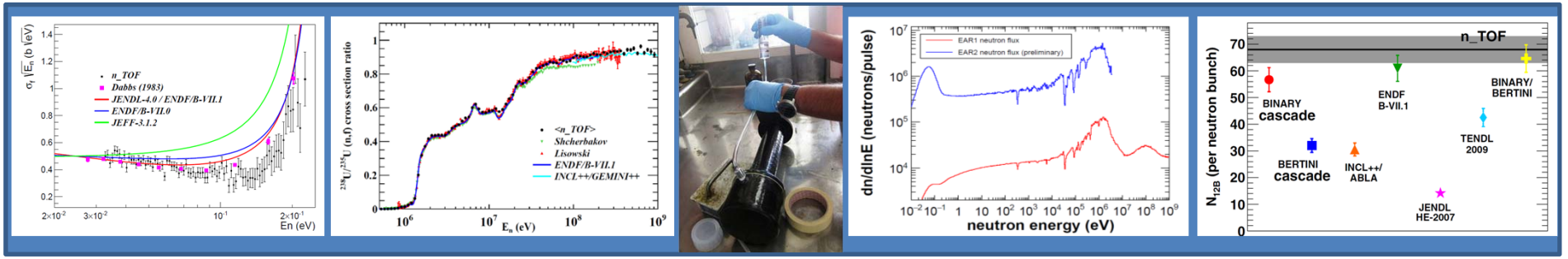
NEA Nuclear Data Week

JEFF – CHANDA Meeting 27-30 April 2015

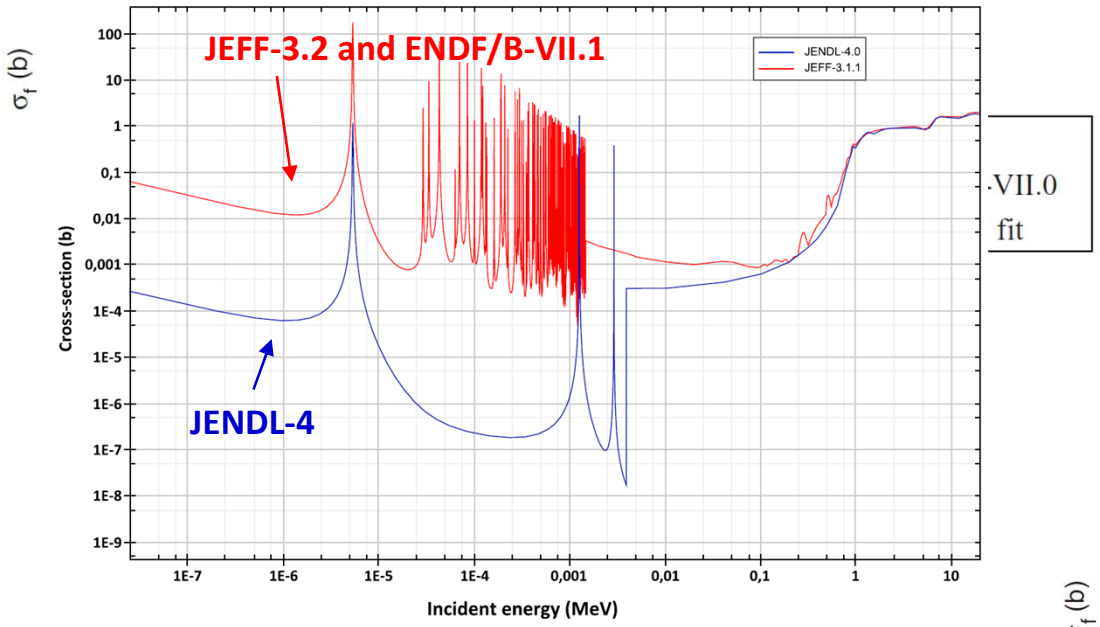
Fission Results, Capture Detectors … and More

Nicola Colonna

Istituto Nazionale Fisica Nucleare, Sezione di Bari



The fission cross-section of ^{236}U



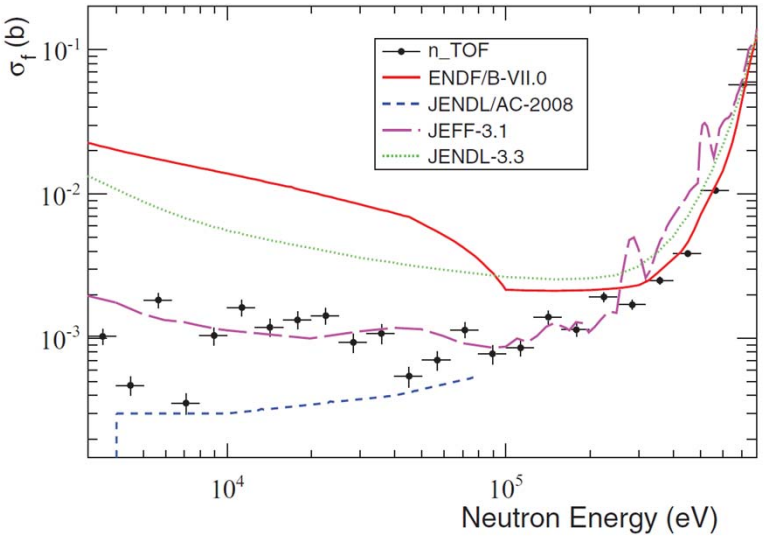
Half-life: **2.34x10^{7} y**
Sample: **21.4 mg (/4)**
Activity: **13 kBq** (each sample)
Contamination of **^{235}U 0.05%**

n_TOF data **confirm** results from GELINA (C. Wagemans et al.).

Below a few keV, **ENDF and JEFF overestimate** cross section (x100).

Resonances in ENDF and JEFF are **from ^{235}U** !!

JENDL-4 is (mostly) correct

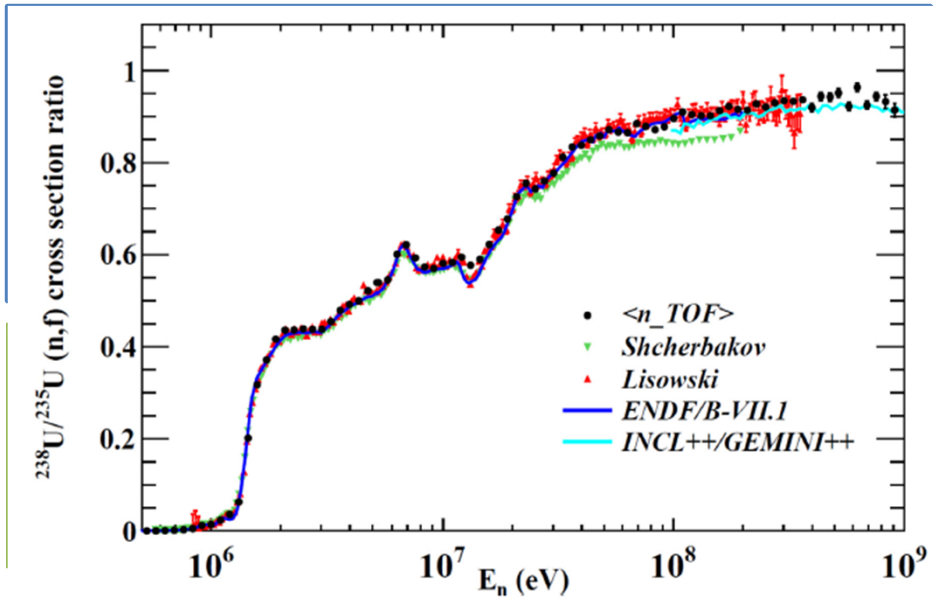


PHYSICAL REVIEW C **84**, 044618 (2011)

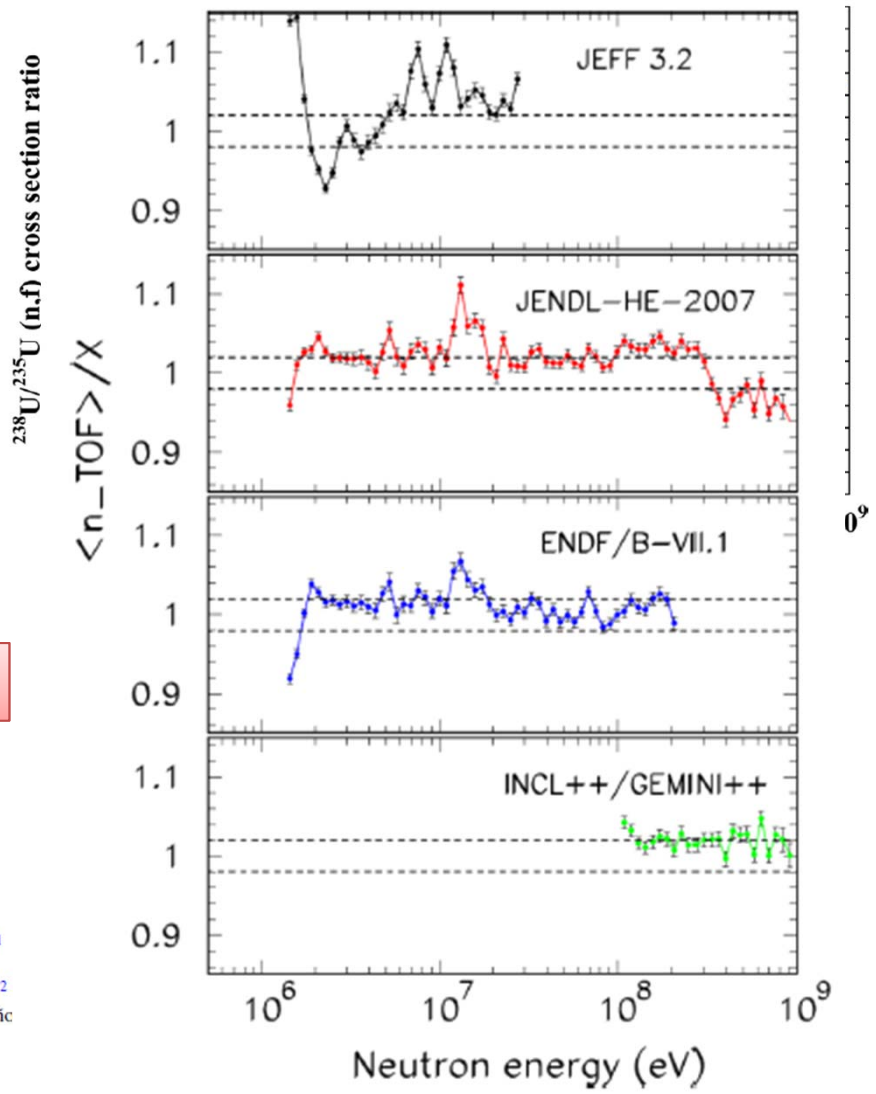
Measurement of the ^{236}U(n,f) cross section from 170 meV to 2 MeV at the CERN n_TOF facility

R. Sarmento,[1] M. Calviani,[2] J. Praena,[14] N. Colonna,[3] F. Belloni,[4] I. F. Gonçalves,[1] P. Vaz,[1] G. Aerts,[17] H. Alvarez,[26] F. Alvarez-Velarde,[5] S. Andriamonje,[2] J. Andrzejewski,[6] P. Assimakopoulos,[7] L. Audouin,[8] M. Barbagallo,[3] G. Badurek,[9] P. Baumann,[10] F. Becvar,[11] E. Berthoumieux,[17] F. Calvino,[12] D. Cano-Ott,[5] R. Capote,[13,14] C. Carrapiço,[1] A. Carrillo de Albornoz,[1] P. Cennini,[15] V. Chepel,[16] E. Chiaveri,[2] G. Cortes,[18] A. Couture,[19] J. Cox,[19] M. Dahlfors,[15] S. David,[8] M. Diakaki,[34] Dolfini,[21] C. Domingo-Pardo,[22] W. Dridi,[17] I. Duran,[26] C. Eleftheriadis,[23] L. Ferrant,[8] A. Ferrari,[15] [16] H. Frais-Koelbl,[13] K. Fuji,[4] W. Furman,[24] E. Gonzalez, Guerrero,[5,2]

The $^{238/235}$U(n,f) cross section ratio



JEFF 3.2 needs a revision on this important ratio



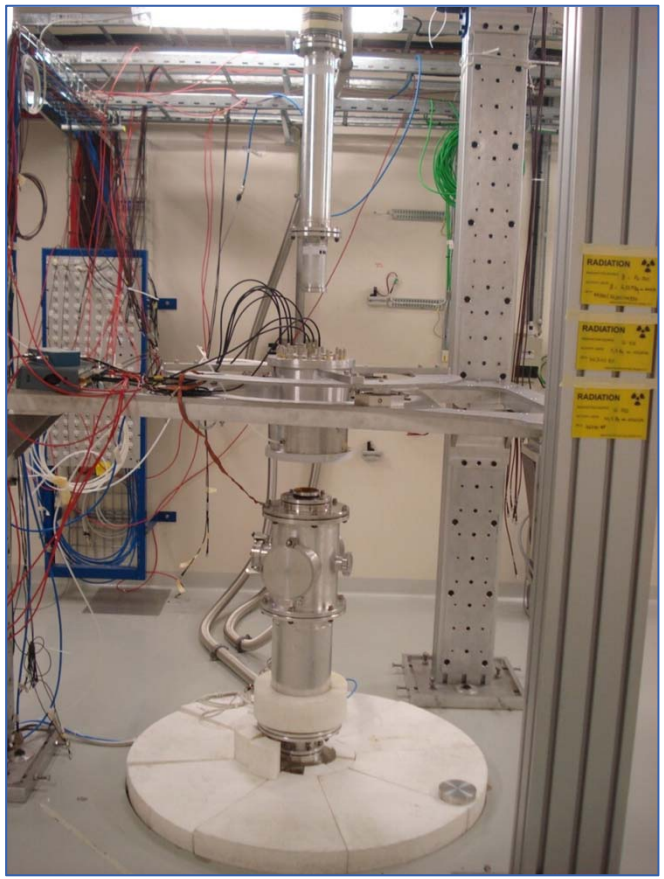
PHYSICAL REVIEW C 00, 004600 (2015)

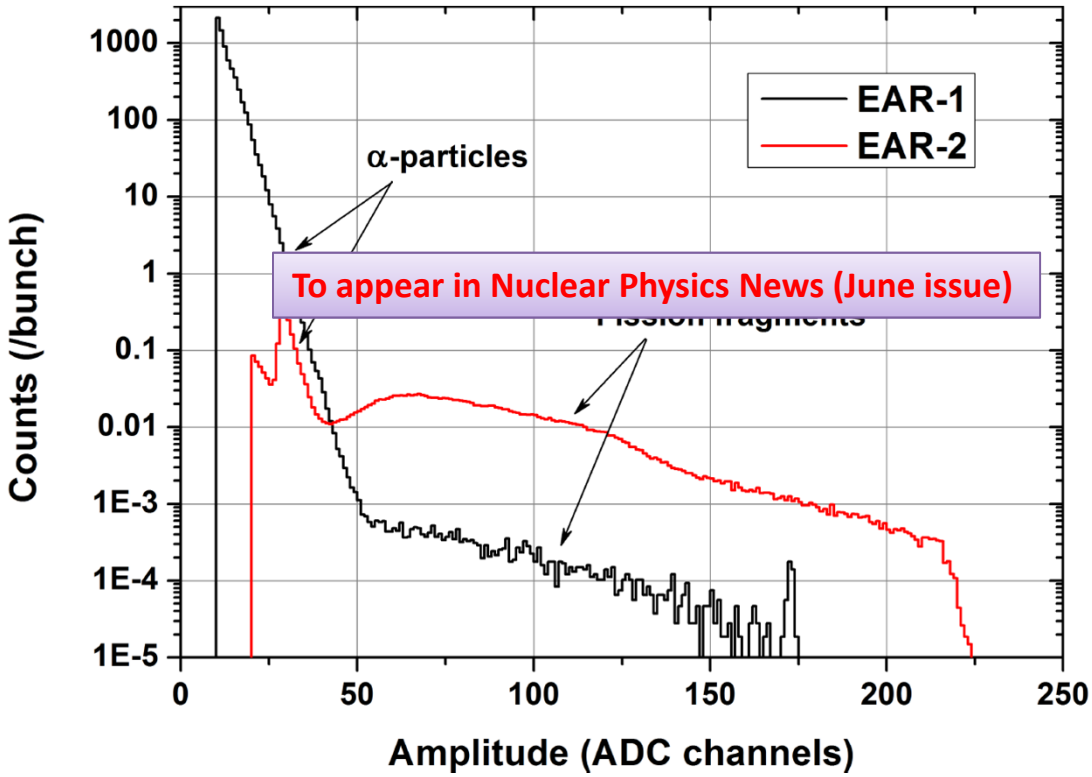
High-accuracy determination of the ^{238}U/^{235}U fission cross section ratio up to ≈ 1 GeV at n_TOF at CERN

C. Paradela,[1,2] M. Calviani,[3] D. Tarrío,[1,4] E. Leal-Cidoncha,[1] L. S. Leong,[5,6] L. Tassan-Got,[5] C. Le Naour,[5] I. Duran,[1] N. Colonna,[7,*] L. Audouin,[5] M. Mastromarco,[7] S. Lo Meo,[8] A. Ventura,[9] G. Aerts,[10] S. Altstadt,[11] H. Álvarez,[1] F. Álvarez-Velarde,[12] S. Andriamonje,[10] J. Andrzejewski,[13] G. Badurek,[14] M. Barbagallo,[7] P. Baumann,[15] V. Bécares,[12] F. Bečvář,[16] F. Belloni,[2] B. Berthier,[5] E. Berthoumieux,[10] J. Billowes,[17] V. Boccone,[3] D. Bosnar,[18] M. Brugger,[3] F. Calviño

^{240}Pu(n,f) in EAR2@n_TOF

Task 8.1: Development of innovative techniques and instrumentation for fission cross section measurements



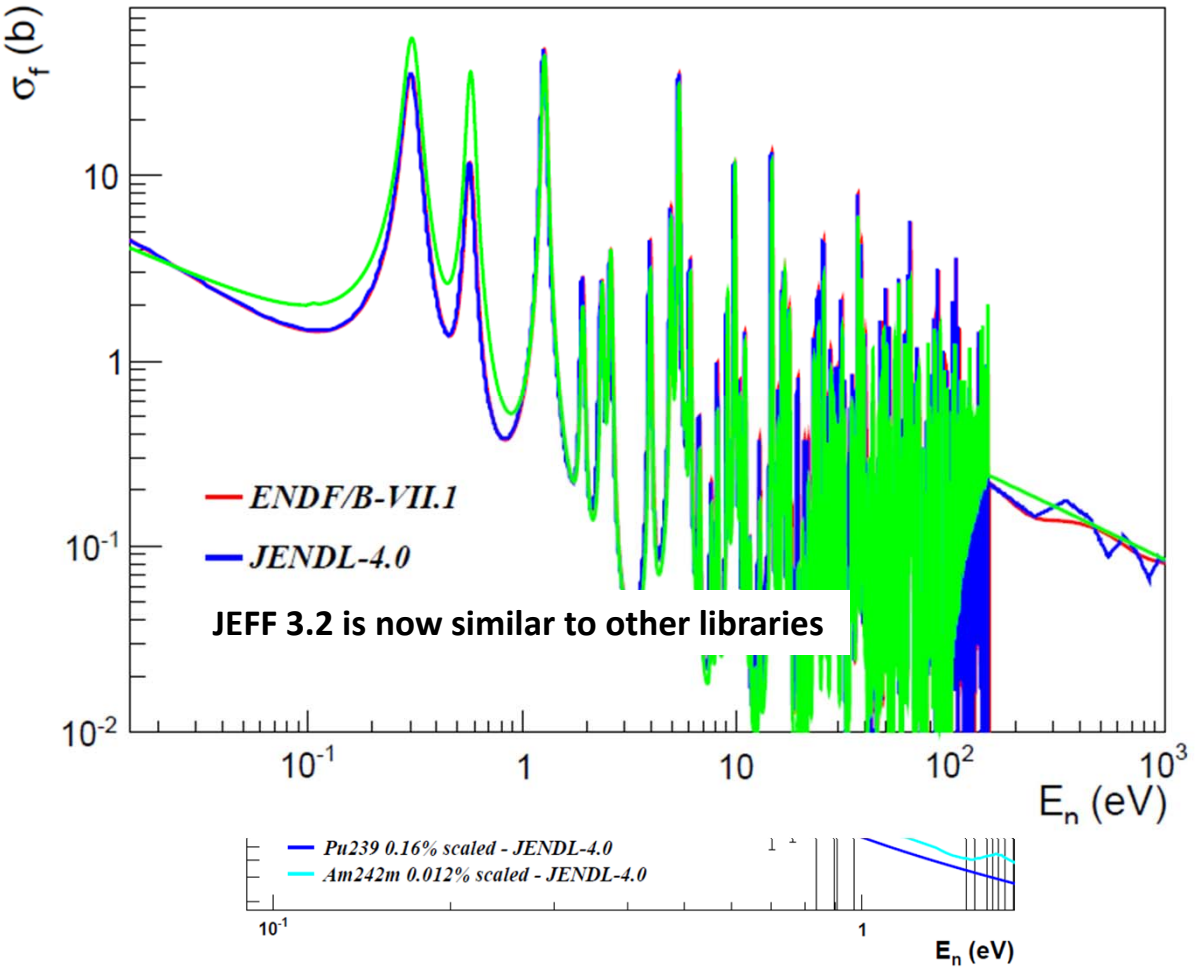


Don't miss the next talk by **Andrea Tsinganis**

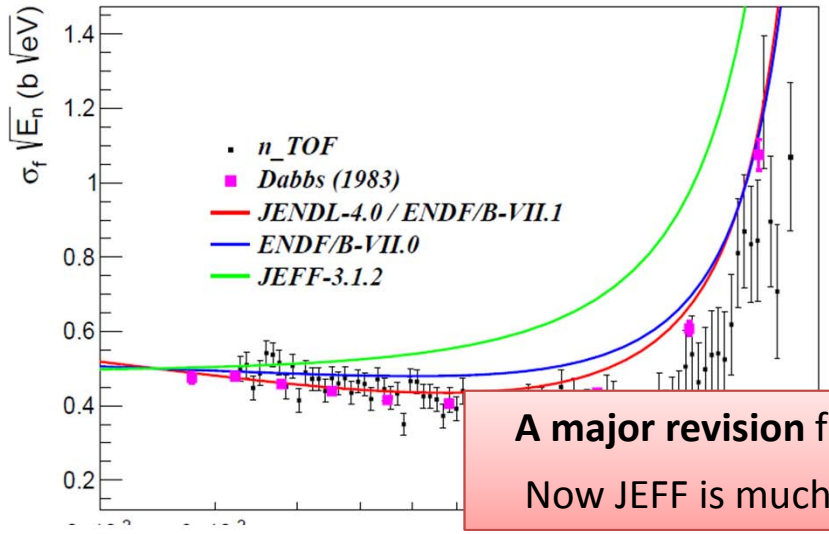
(I've seen things you people wouldn't believe…)

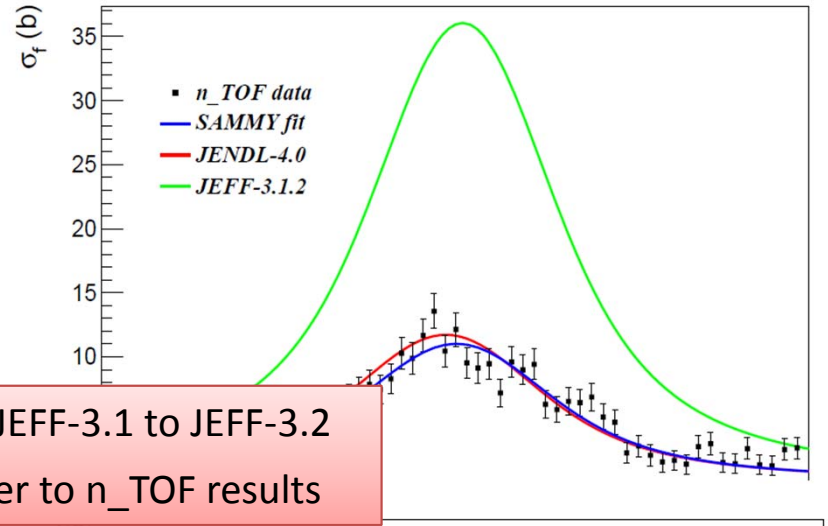
The ^{241}Am(n,f) at n_TOF

Half-life: **432 y**
Sample: **2.26 mg (/8)**



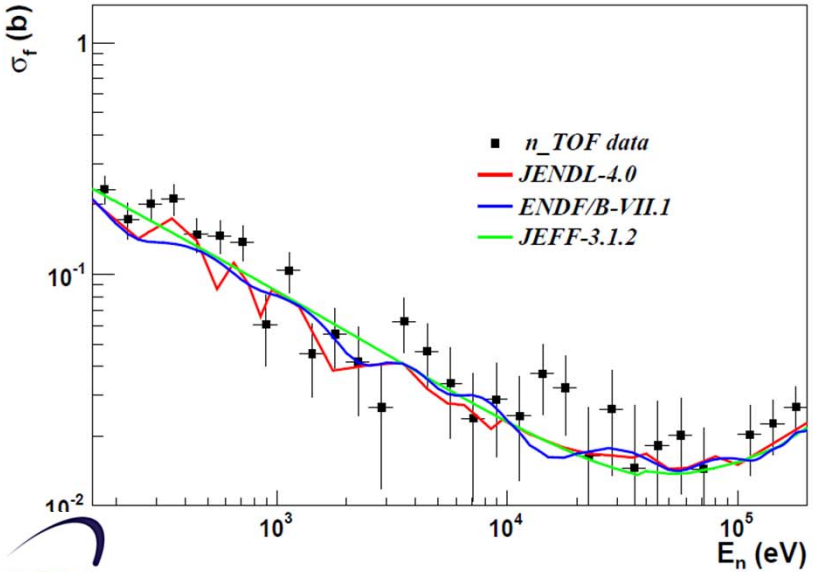
The ^{241}Am(n,f) at n_TOF

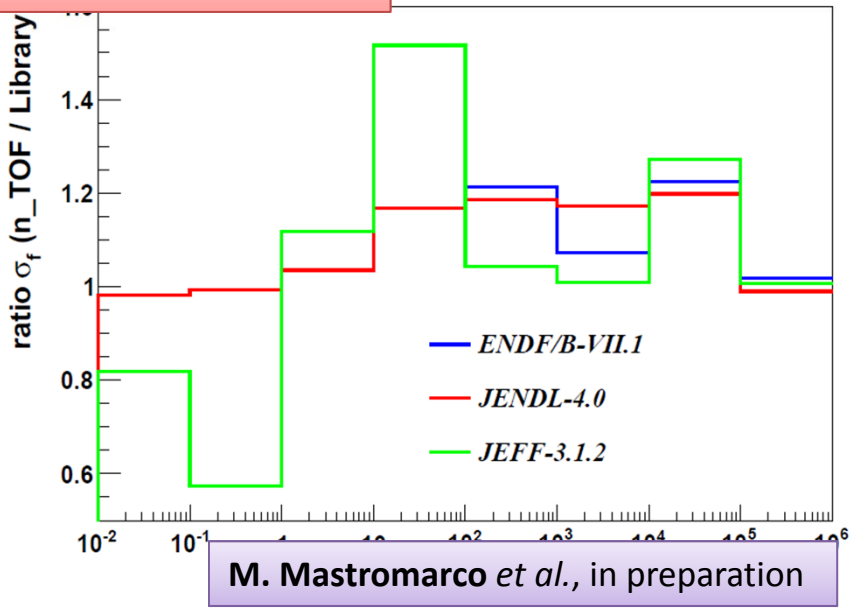




A major revision from JEFF-3.1 to JEFF-3.2

Now JEFF is much closer to n_TOF results





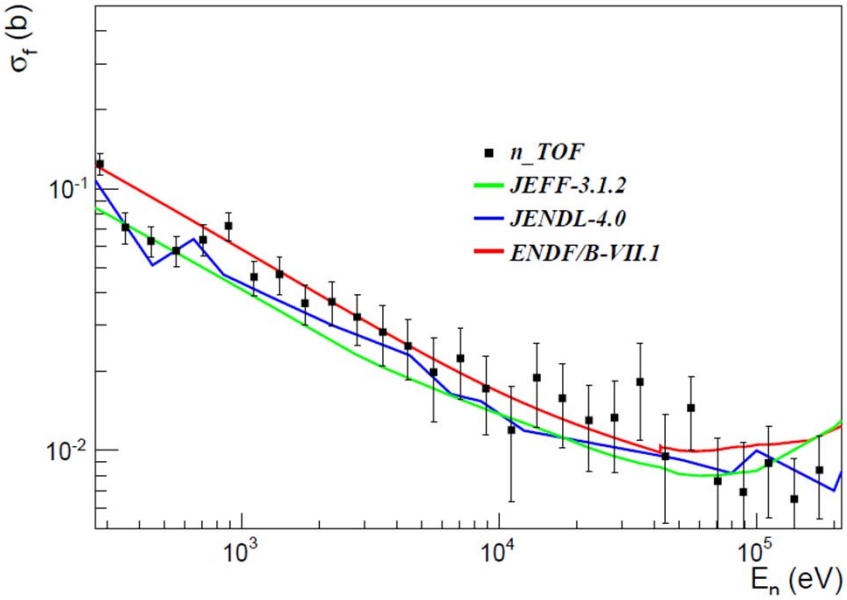
M. Mastromarco *et al.*, in preparation

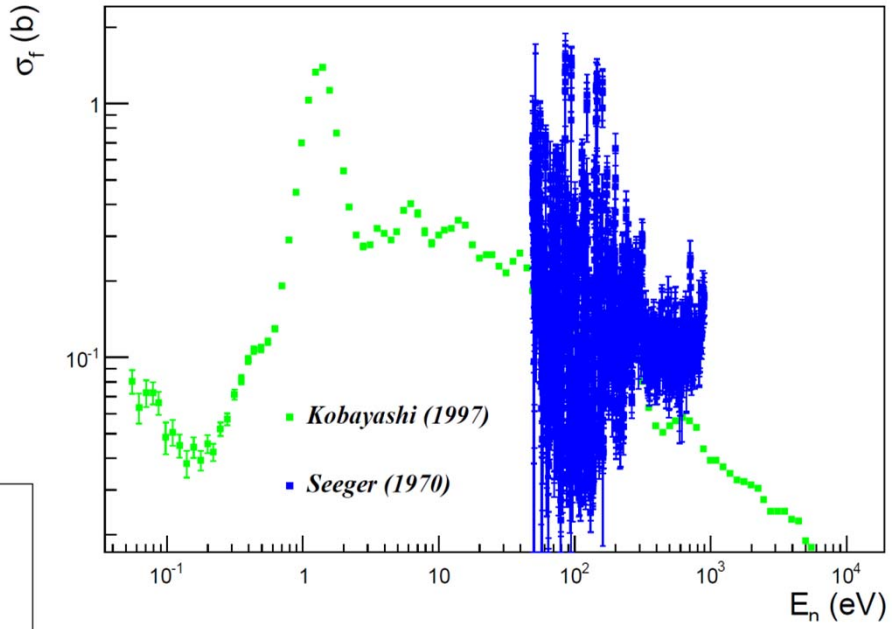
The ^{243}Am(n,f) at low energy

Half-life: **7370 y**
Sample: **4.8 mg (/8)**
Activity: **4.4 MBq** (each sample)
Contamination (declared): **^{241}Am 2.5%**
Contamination (undeclared): **^{239}Pu , ^{242m}Am**

JEFF 3.2 same cross section as JENDL-4

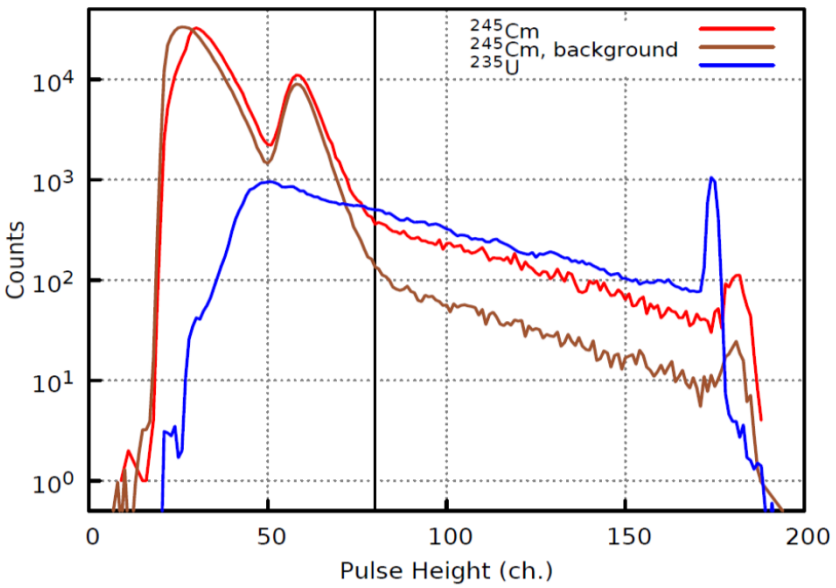
ENDF/B-VII.1 differs in the first small resonance





M. Mastromarco *et al.*, in preparation

The ^{245}Cm(n,f) reaction



Half-life: **8500 y (18.1 y)**
Sample: **1.71 mg (/4)**
Activity: **87 MBq** (each sample)
Contamination (declared): **^{244}Cm 6.6%**

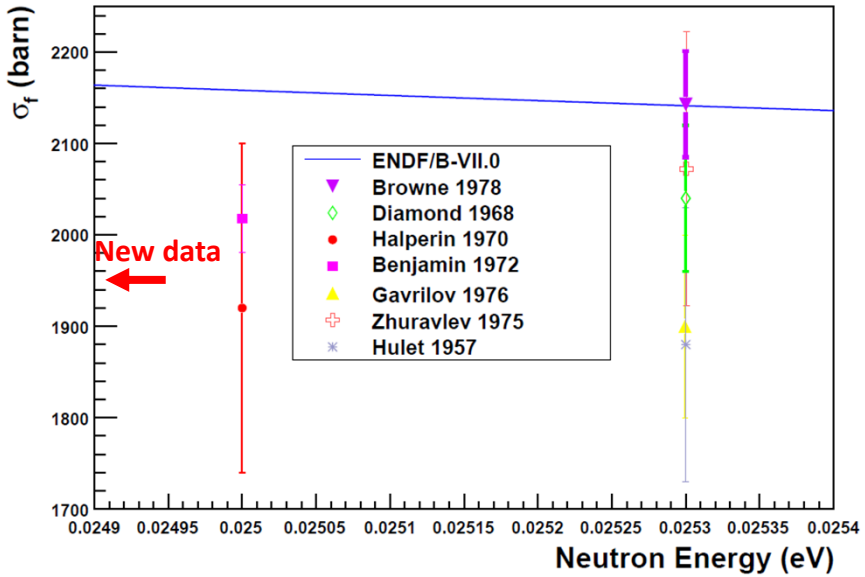
Very large α background (**0.1 GBq**)

High thresholds necessary (large uncertainty in efficiency corrections). Only cross section shape with good accuracy (3%).

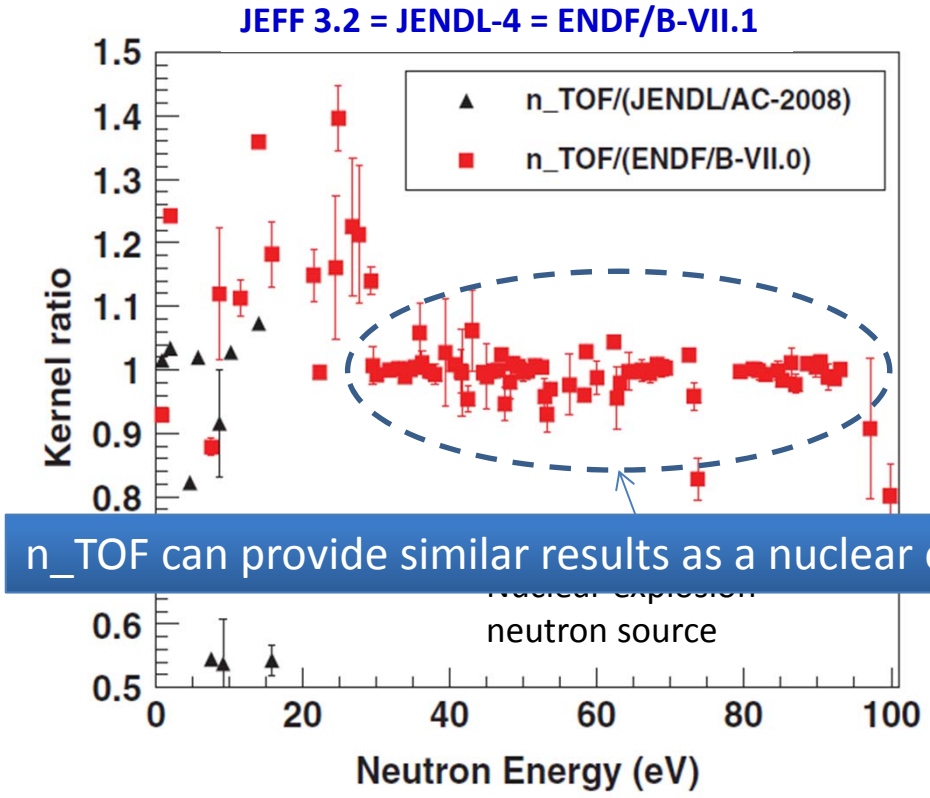
For absolute cross section, need to normalize to "recommended value" at thermal energy.

However, **large uncertainty (30%)** on thermal data.

Used two recent measurements of the thermal cross section (ILL and SCK-Mol) that agree within 5%.



The ^{245}Cm(n,f) reaction



Half-life: **8500 y**
Sample: **1.71 mg**
Activity: **87 MBq** (each sample)
Contamination (declared): **^{244}Cm 6.6% (18.1 y)**

Below 30 eV, two **(very old)** measurements exist, showing **large discrepancies**.

Above 30 MeV, **only one** measurement with neutrons from a **nuclear test**.

n_TOF can provide similar results as a nuclear explosion (but with fewer side effects …)

From thermal energy to 30 eV a **revision of the evaluations** is needed.

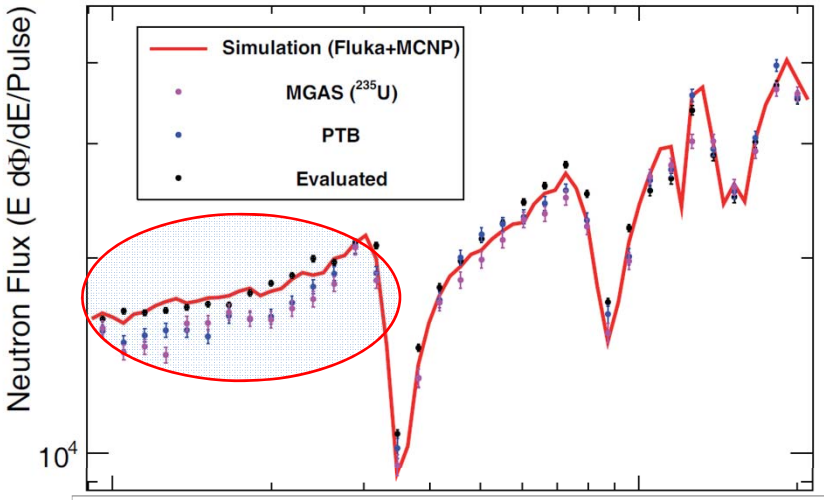
Above 30 eV, n_TOF confirm previous data and evaluations.

PHYSICAL REVIEW C **85**, 034616 (2012)

Neutron-induced fission cross section of ^{245}Cm: New results from data taken at the time-of-flight facility n_TOF

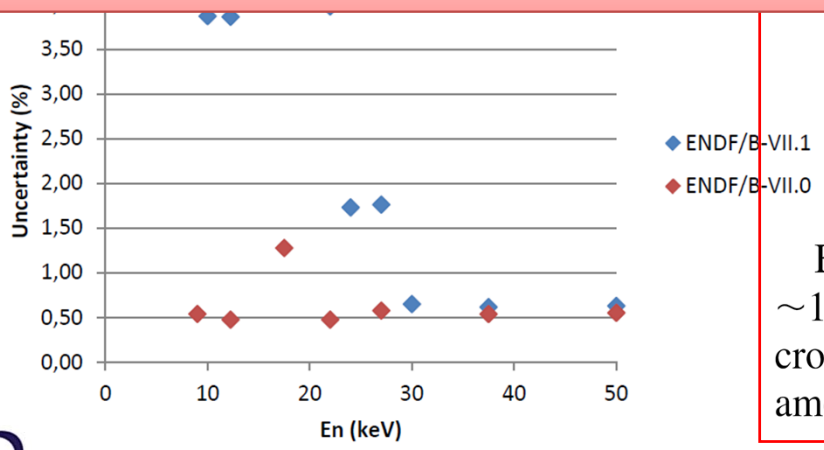
M. Calviani,[1,2,*] M. H. Meaze,[3,†] N. Colonna,[3] J. Praena,[4] U. Abbondanno,[5] G. Aerts,[6] H. Alvarez,[7] F. Alvarez-Velarde,[8] S. Andriamonje,[2,6] J. Andrzejewski,[9] P. Assimakopoulos,[10,‡] L. Audouin,[11] G. Badurek,[12] M. Barbagallo,[3] P. Baumann,[13] F. Bečvář,[14] F. Belloni,[5,6] B. Berthier,[11] E. Berthoumieux,[6] F. Calviño,[15] D. Cano-Ott,[16] R. Capote,[4,17] C. Carrapiço,[6,18] P. Cennini,[2] V. Chepel,[19] E. Chiaveri,[2] G. Cortes,[15] A. Couture,[19] J. Cox,[19] M. Dahlfors,[2] S. David,[11] I. Dillmann,[20]

^{235}U(n,f) between 10 and 30 keV



The **flux** calculated on the basis of the ^{235}U(n,f) cross section **found systematically lower** than "expected" in the 10-30 keV range (***M. Barbagallo et al., Eur. Phys. J A 49 (2013) 156***).
The (n,f) cross section in this range potentially overstimated by 6-8%.

Several evidences of a problem in the ^{235}U(n,f) cross section between 10 and 30 keV
Need to investigate it further (a new measurement is planned at n_TOF)



PRL 109, 202506 (2012) PHYSICAL REVIEW LETTERS week ending 16 NOVEMBER 2012

J. B. Wilhelmy, C. Y. Wu, and J. A. Becker
[1]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA
[2]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
(Received 25 July 2012; published 16 November 2012)

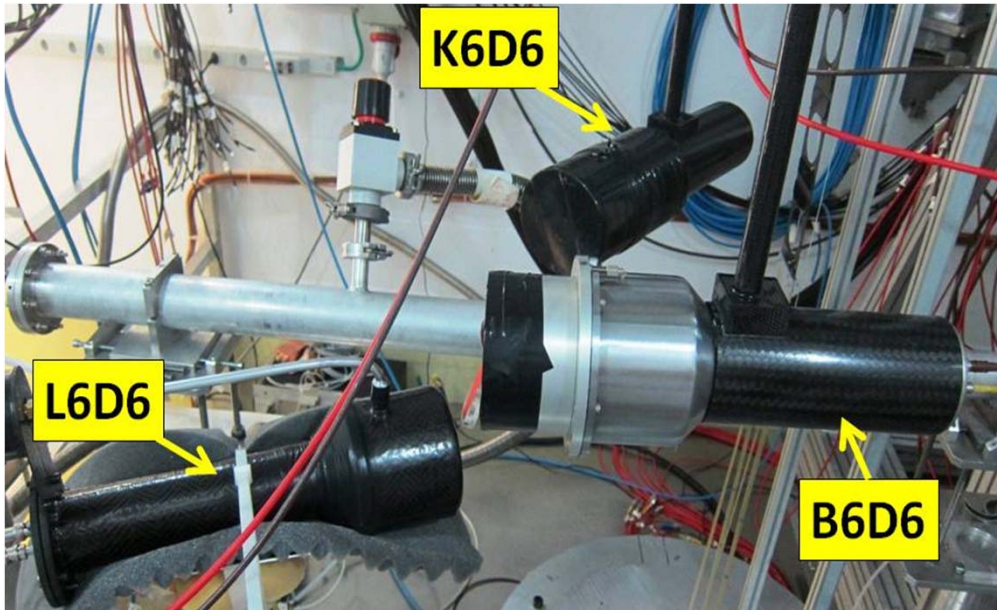
Between 10 and 30 keV, the DANCE cross sections are ~10% larger than both the ENDF/B-VII.1 and JENDL-4.0 cross sections. Significant discrepancies are observed among other measurements [14–18]. Neutron flux at

The new carbon-fiber C_6D_6 detectors for n_TOF

Task 7.2: Total energy detectors

A **new type** of low-sensitivity **C_6D_6 detector** has been built for measurements of **neutron capture** cross sections at **n_TOF**. The detector is **entirely made of carbon fiber**.

Filling operation simplified: avoid air bubbles inside



Mass largely reduced, compared with commercial B6D6 detectors

The construction of the detectors

Four detectors completely assembled and characterizes (used in 2014 during the **commissioning of EAR2@n_TOF**).

Material available for **six more detectors** (4 for EAR1 and 2 spares).

A few months delay due to **US Navy**

All detectors should be ready by now.

TRIESTE

Un sottomarino per la Marina Usa costruito a Trieste FOTO

Ora le prove in mare al Polo nautico sul canale navigabile. Il sindaco Cosolini in visita alle sei aziende dell'area

di Silvio Maranzana

INDUSTRIA MARINA USA SOMMERGIBILI SOTTOMARINI

05 dicembre 2014

76 Condividi

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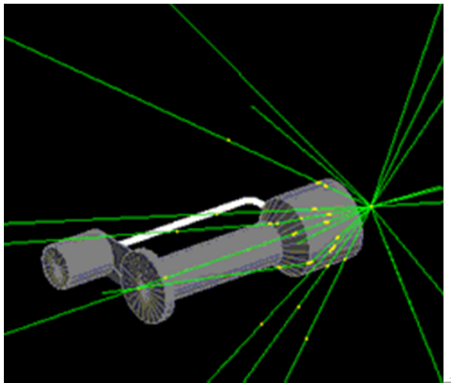
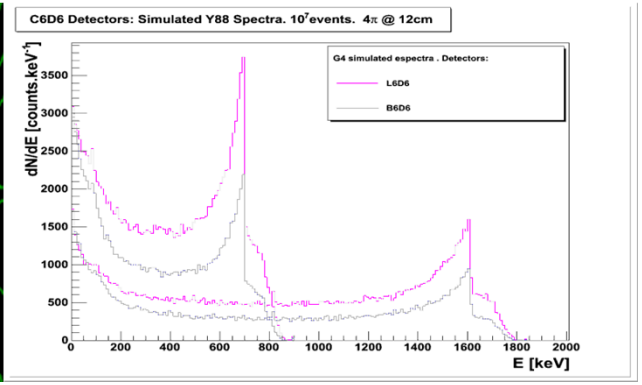
Il sindaco Cosolini indica il prototipo di sommergibile per la Marina americana

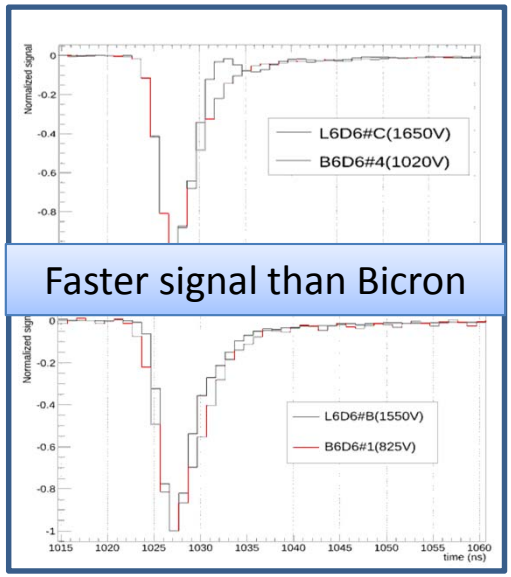
http://ilpiccolo.gelocal.it/trieste/cronaca/2014/12/05/news/un-sottomarino-per-la-marina-usa-costruito-a-trieste-1.10434542?ref=search

Characterization and test of the new C_6D_6

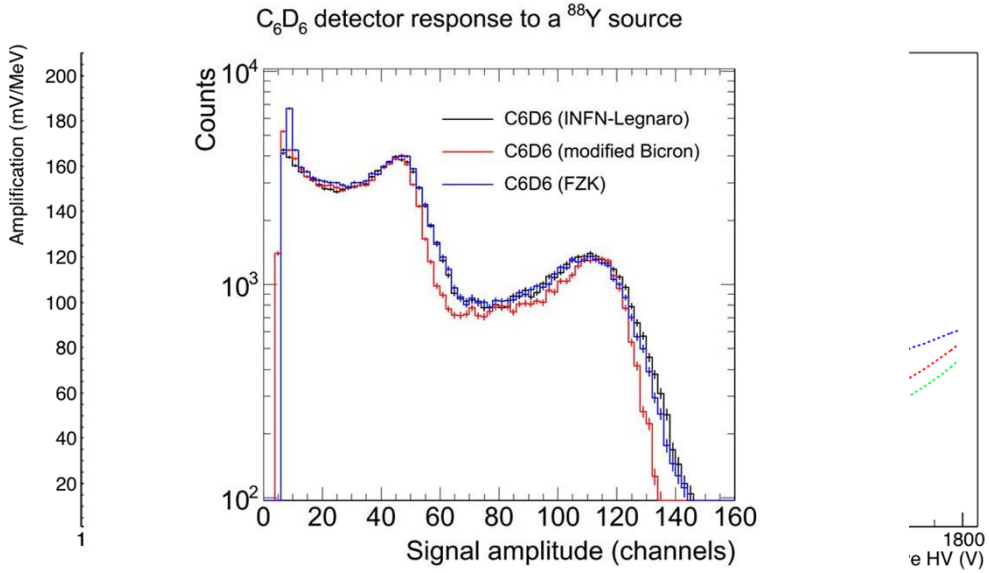
Simulations with Geant 4 (J. Larendegui, USC), and **calibration and tests** (F. Mingrone, INFN, Bologna) indicate **better performances** relative to commercial Bicron detectors.





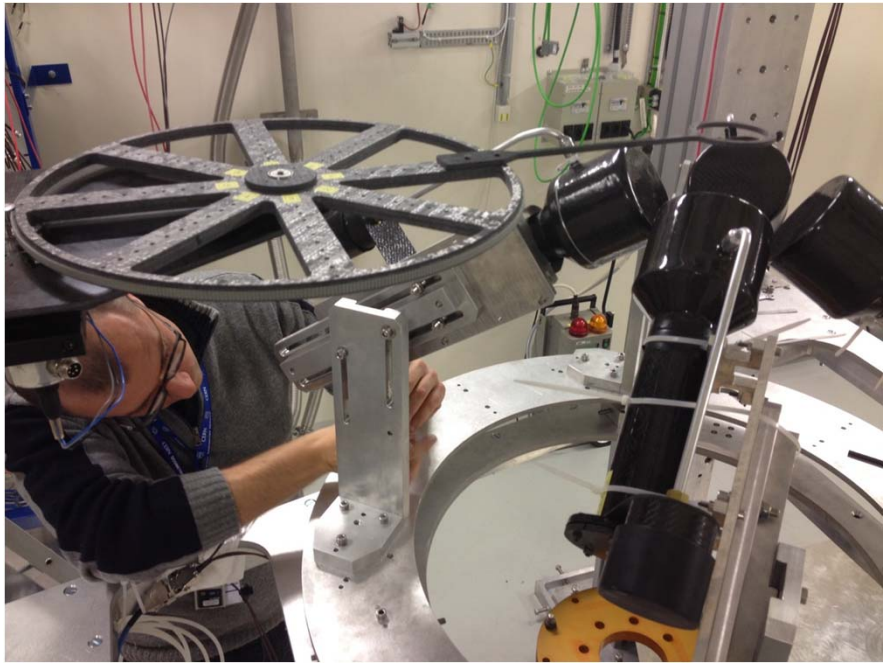


Faster signal than Bicron



C_6D_6 detector response to a ^{88}Y source

Mounting the detectors in EAR2@n_TOF



The new C_6D_6 have been complemented with a carbon-fiber **sample exchanger**, and **mounted in EAR2**.

A temporary **alluminum structure** is used for holding the detectors (it was made in a hurry and will be **replaced in the near future**).

The use of the **new C_6D_6** is foreseen for the next capture cross section measurements **both in EAR1 and EAR2**.

The challenging measurement of the $^{12}C(n,p)^{12}B$ reaction

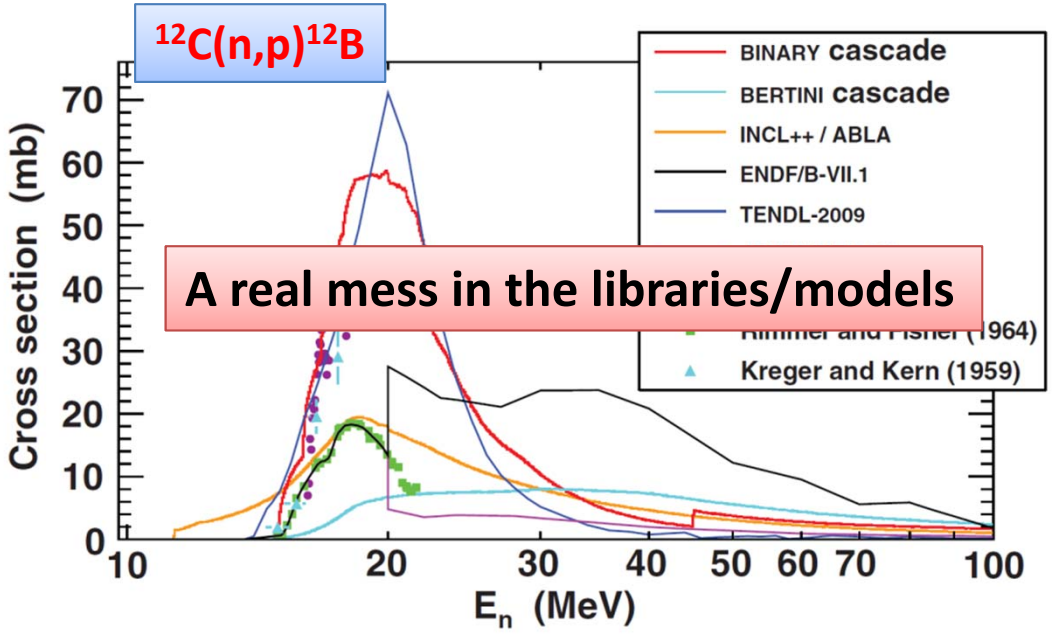
Task 2.1: Identifications of possible synergies with fundamental physics and other applications

The $^{12}C(n,p)^{12}B$ reaction of **interest for a wide range of applications:**

- Hadrotherapy (^{nat}C abundant in tissues)
- Radiation protection (shielding)
- Space applications
- Fusion research

- Very difficult to measure the energy dependence by **detecting the proton.**
- Three measurement **very discrepant !**

- Energy-integrated cross section by activation technique (decay of the product of neutron irradiation).
- Cannot be used for radionuclides with short half-life.



Half life of ^{12}B **is 20 ms** !!!

We have investigated **innovative techinques** at n_TOF for **measuring reactions** of interest for a variety of applications (fusion, radioprotection, hadrotherapy, etc…)

An innovative technique for challenging measurements

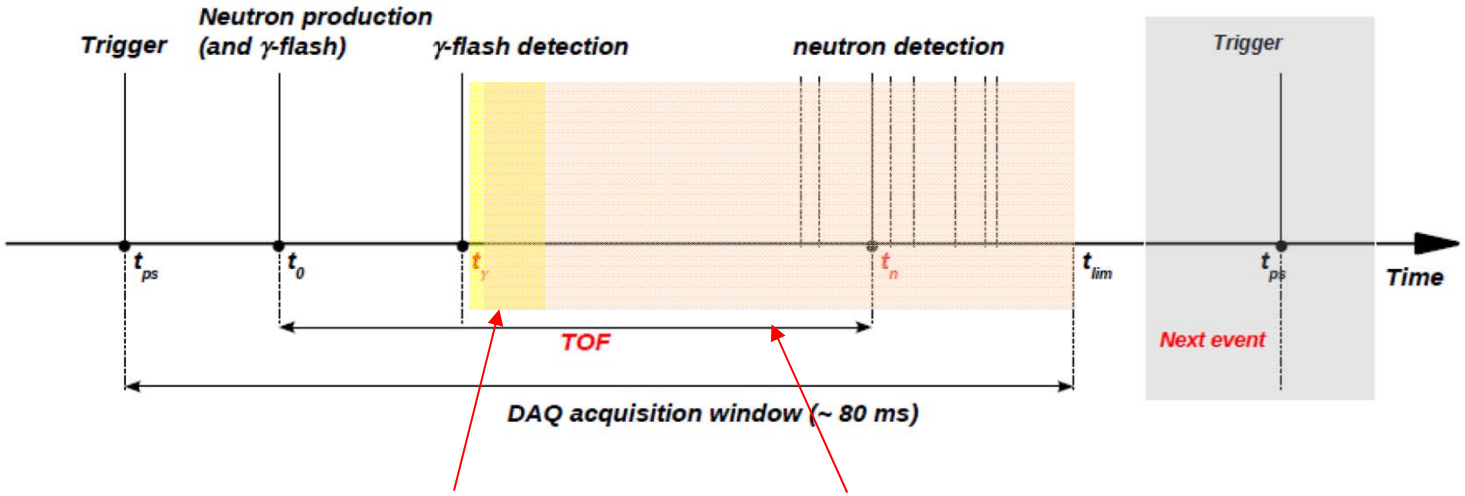
In-beam activation analysis

- We have developed at n_TOF the **"in-beam" activation"** technique, that allows to study radionuclides **of millisecond half-life**
- Technique applied to the **$^{12}C(n,p)^{12}B$** reaction whose cross section is highly uncertain.

The capture setup (**carbon fiber C_6D_6**) used to **detect the electrons** from the **^{12}B decay** (6.5 MeV average energy).

Background contributions small.

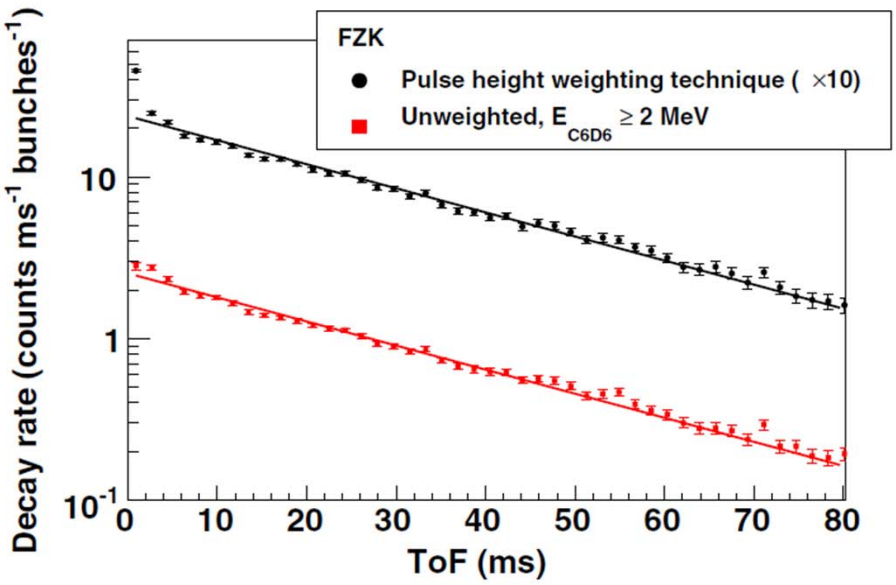
Measure the decay over **several half-lives** thanks to the **very low repetition** rate of n_TOF (20 ms vs 1.2 s).



"Activation" time

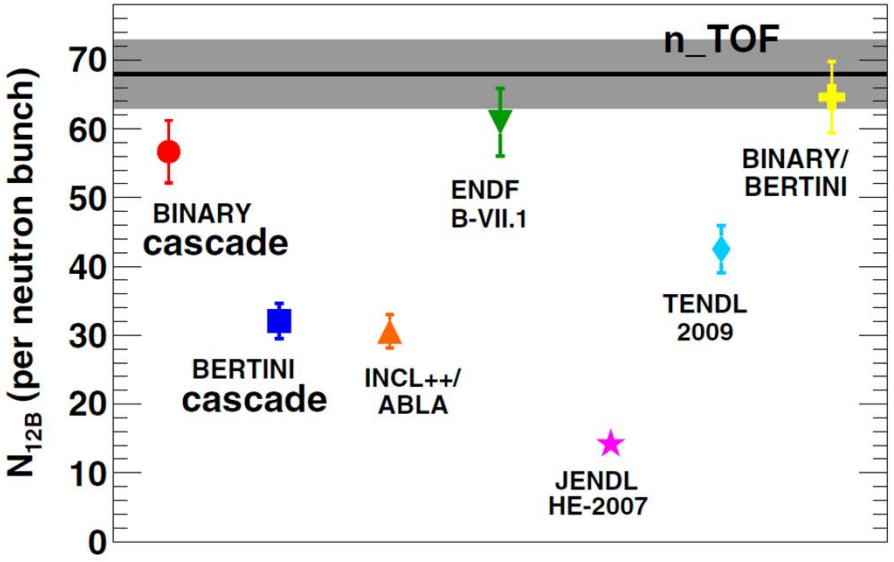
Decay time

Results on the $^{12}C(n,p)^{12}B$ reaction



- From the count-rate of ^{12}B, we get the **energy-integrated $^{12}C(n,p)^{12}B$ cross section**.
- Most libraries and **models do not reproduce** the measured ^{12}B production.
- Good agreement with **TALYS** (optimized parameters), and **"Binary Cascade"** (in Geant4).

- The **count rate** as a function of time shows the **expected exponential decay** (20 ms)
- Background pratically absent.



RAPID COMMUNICATIONS

PHYSICAL REVIEW C 90, 021601(R) (2014)

Measurement of the $^{12}C(n,p)^{12}B$ cross section at n_TOF at CERN by in-beam activation analysis

P. Žugec,[1] N. Colonna,[2,*] D. Bosnar,[1] A. Mengoni,[3] S. Altstadt,[4] J. Andrzejewski,[5] L. Audouin,[6] M. Barbagallo,[2] V. Bécares,[7] F. Bečvář,[8] F. Belloni,[9] E. Berthoumieux,[10] J. Billowes,[11] V. Boccone,[12] M. Brugger,[12] M. Calviani,[12] F. Calviño,[13] D. Cano-Ott,[7] C. Carrapiço,[14] F. Cerutti,[12] E. Chiaveri,[12] M. Chin,[12] G. Cortés,[13] M. A. Cortés-Giraldo,[15] L. Cosentino,[16] M. Diakaki,[17] C. Domingo-Pardo,[18] R. Dressler,[19] I. Duran,[20] C. Eleftheriadis,[21] A. Ferrari,[12] P. Finocchiaro,[16] K. Fraval,[10]

CHANDA Publications (so far)

P. Zugec, N. Colonna, et al., (The n_TOF Collaboration)
Measurement of the $^{12}C(n, p)^{12}B$ cross section at n_TOF at CERN by in-beam activation analysis
Physical Review C 90, 021601(R) (2014)

P. Zugec et al., (The n_TOF Collaboration)
GEANT4 simulation of the neutron background of the C6D6 set-up for capture studies at n_TOF
Nuclear Instruments and Methods A 760, 57 (2014)

C. Paradela et al., (The n_TOF Collaboration)
High-accuracy determination of the $^{238}U/^{235}U$ fission cross section ratio up to ≈ 1 GeV
at n_TOF at CERN
Physical Review C 00, 004600 (2015)

A few more papers ready to be submitted or in preparation

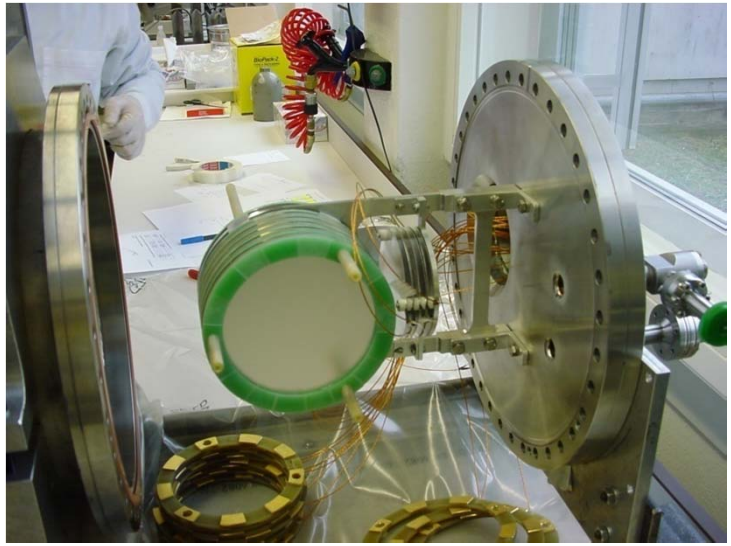
Work In Progress

Thank you

The fission measurements at n_TOF

The fission cross-section of ^{241,243}Am and ^{245}Cm was measured at n_TOF in the first experimental campaign with a fast ionization chamber (FIC).

Neutron beam →



M. Calviani et al., Nucl. Instr. Meth. A 594, 220 (2008)

Due to the **several problems**, the data analysis was quite complicated. In the first data analysis, only the **energy dependence of the cross-section** had been determined, but no **absolute value**.

Aim of the ANDES Subtask 1.3.e was to determine the **fission cross sections with high accuracy**, by combining the n_TOF data with other measurements for absolute normalization.