$^{237}Np(n,f)$ Cross Section: new data impact

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Talk content

1. Brief motivation of the talk
2. $^{237}Np(n,f)$ final results obtained at n_TOF
3. Discussion about the impact of recent results

Why we measured ^{237}Np(n,f)?

- New reactor concepts (fast reactors, ADS…) require more accurate nuclear data in the fast neutron range: discrepancies evaluations
- Np-237 is an abundant long-live nuclear waste: good candidate for incineration in fast reactors
- New neutron facilities with larger intensities, extended neutron energy range and higher energy resolution

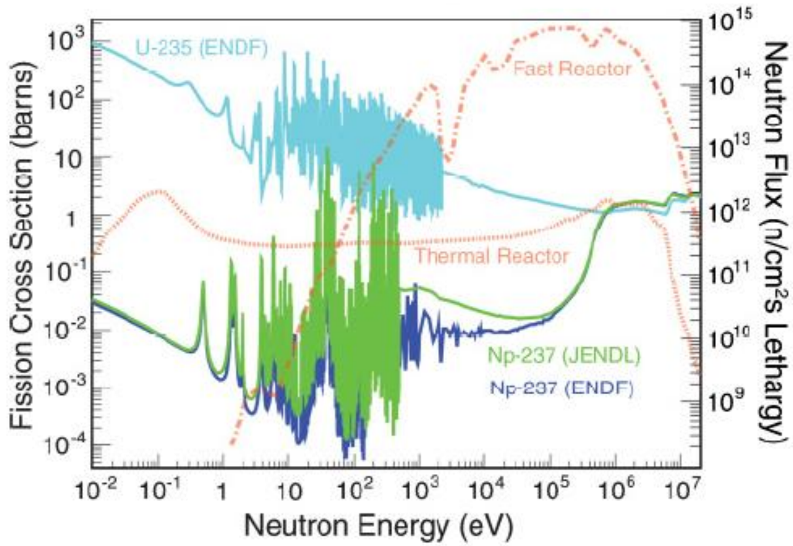
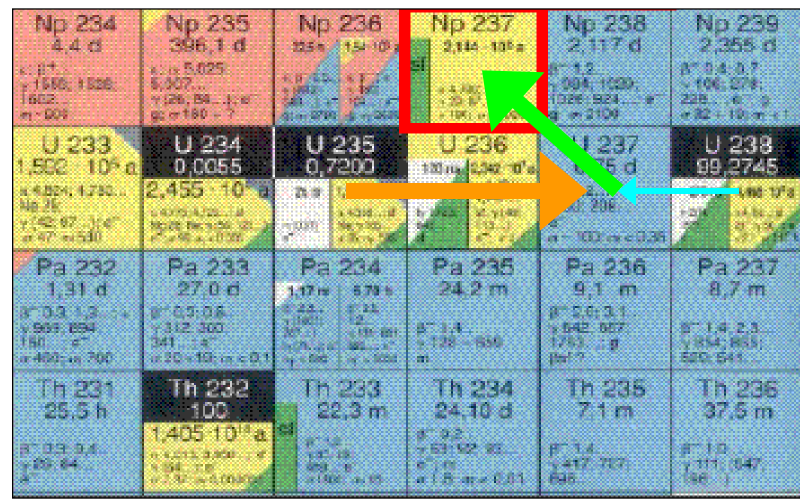


Figure from Phys. Rev. C 75, 034610 (2007)



Status of ^{237}Np(n,f) data

- Extensive set of old experimental results above fission threshold… But they show strong discrepancies.

- Experimental data reported after 2000 (EXFOR):
  - Shcherbakov et al. [1] in 2001 (PNPI)
  - ~~Paradela et al. [2] in 2006 (n_TOF)~~ ----------- Superseded for [5]
  - Tovesson and Hill [3] in 2007 (Los Alamos)
  - Basunia et al. [4] in 2007 (Berkeley)

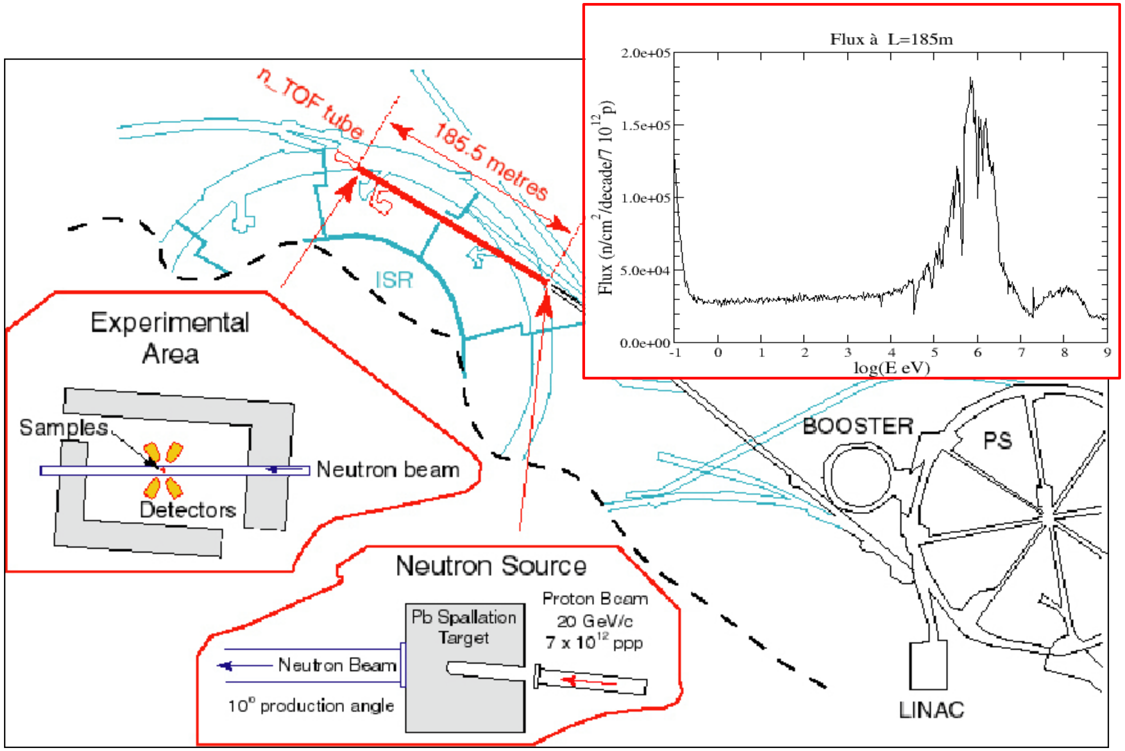
- Re-analysed n_TOF data [5] in 2010

1. Proc. of ND2001
2. Proc. of Physor 2005
3. Phys. Rev C 75, 034610 (2007)
4. Nucl. Inst. Meth. B 267, 1899 (2009)
5. Phys. Rev. C (Accepted for publication)

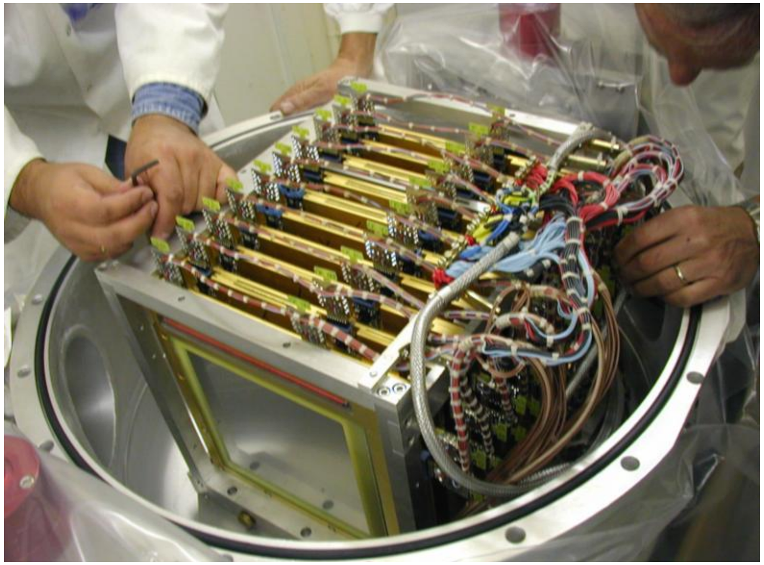
^{237}Np(n,f) measurement at n_TOF

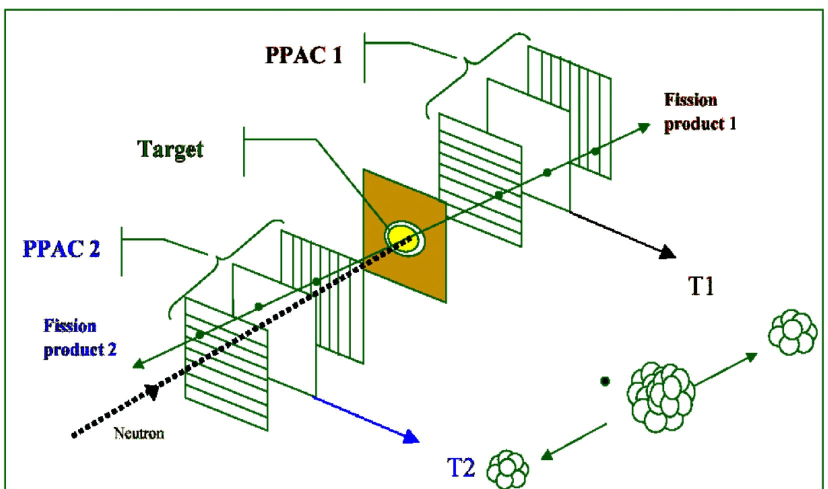
n_TOF Facility Characteristics:

- High instantaneous flux (~5x10^{6} n/burst on fission targets)
- Low duty cycle (16 ms / 2 s)
- Large energy range (from thermal region to 1 GeV)
- Excellent energy resolution (6% @ 1 GeV up to 10^{-4} @ 1 eV)



^{237}Np(n,f) measurement at n_TOF





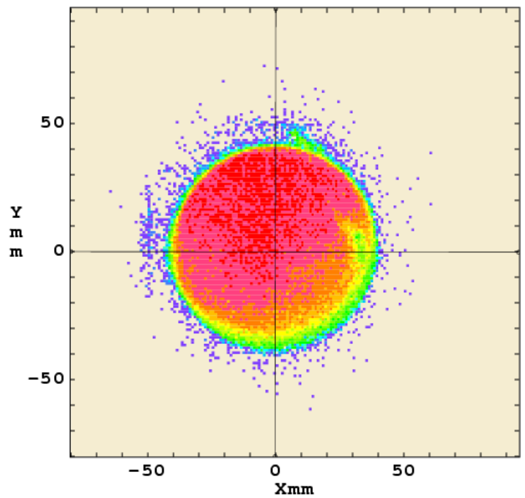
New experimental setup:

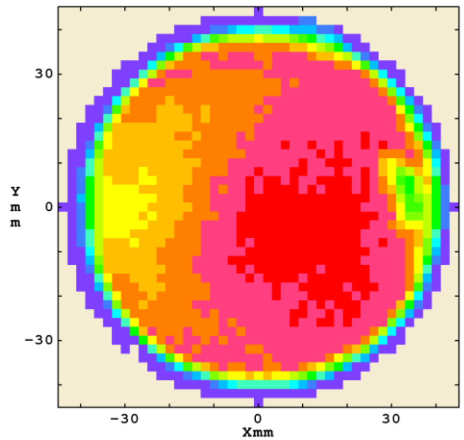
- Experimental setup based on Parallel Plate Avalanche Counters (PPAC) developed at IPN Orsay.
- Thin-layer setup: both fission fragments in coincidence
- Fast anode signals for timing and position-sensitive stripped cathodes (beam profile)
- Four ^{237}Np targets simultaneously. ^{235}U and ^{238}U targets as references
- Flash-ADC DAQ. Off-line signal analysis.

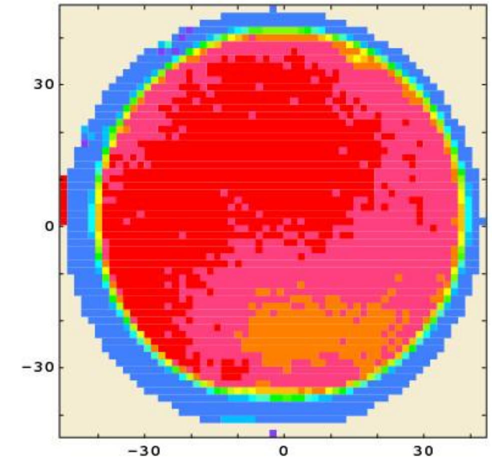
$^{237}Np(n,f)$ measurement at n_TOF

Detailed target characterisation:

- Thin and high purity samples (>99.9 % for ^{237}Np)
- Targets studied by:
  - α counting: mass and spatial distribution and contaminants
  - α energy losses: backing thickness
  - RBS: mass and target composition (oxygen and hydrogen content)







^{237}Np(n,f) measurement at n_TOF

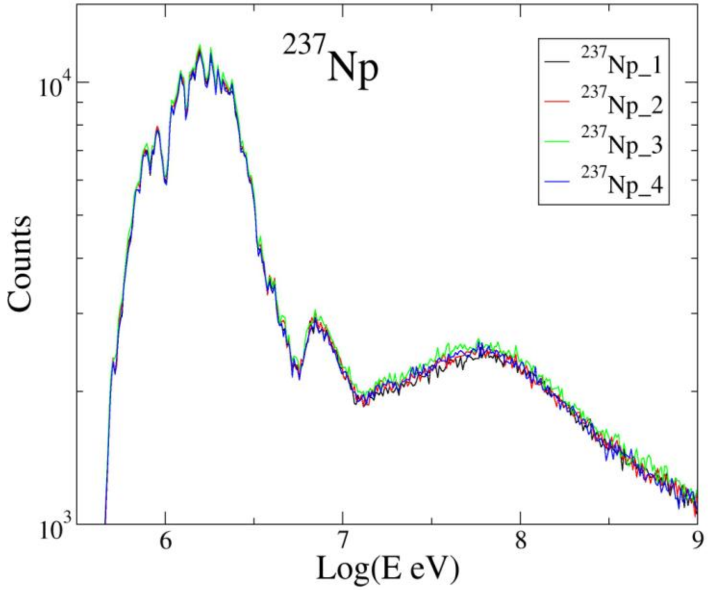
$$\frac{\sigma_i(E)}{\sigma_j(E)} = \frac{C_i(E)}{C_j(E)} \cdot \frac{\Phi_j(E)}{\Phi_i(E)} \cdot \frac{N_j}{N_i} \cdot \frac{\varepsilon_j(E)}{\varepsilon_i(E)}$$

$$\Phi_j(E) = \Phi_i(E)$$

The ratio of efficiencies is affected by the thickness of the samples+backings+angular distribution

Cross section estimation:

- Flux attenuation less 1 % in the larger resonances.
- Detection efficiency is limited to ~50% due to angular acceptance.
- Efficiency differences among Np targets are less than 3 % which include differences due to backing and target thicknesses and inhomogeneities and to detector performances.

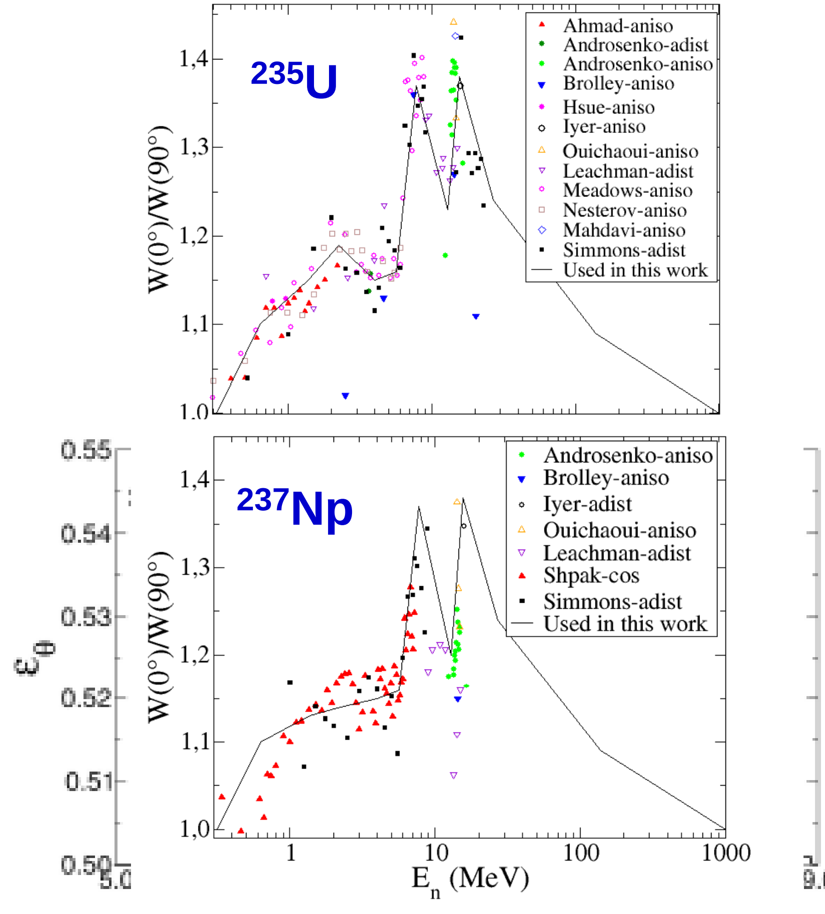


^{237}Np(n,f) measurement at n_TOF

Additional corrections for targets with different samples:

- Different oxygen content in neptunium and uranium targets (known from RBS)
- Different fission fragment angular distribution: anisotropy correction depends on energy.

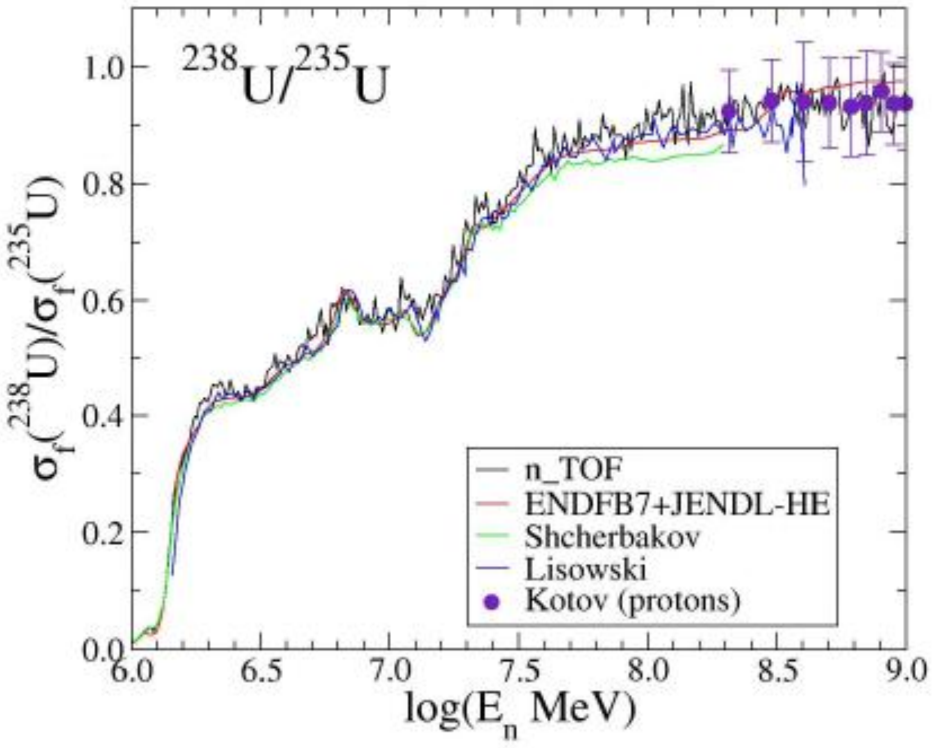
$$\varepsilon_\theta = \frac{\int_{0.5}^{1} W(\cos\theta)\,d(\cos\theta)}{\int_{0}^{1} W(\cos\theta)\,d(\cos\theta)}$$



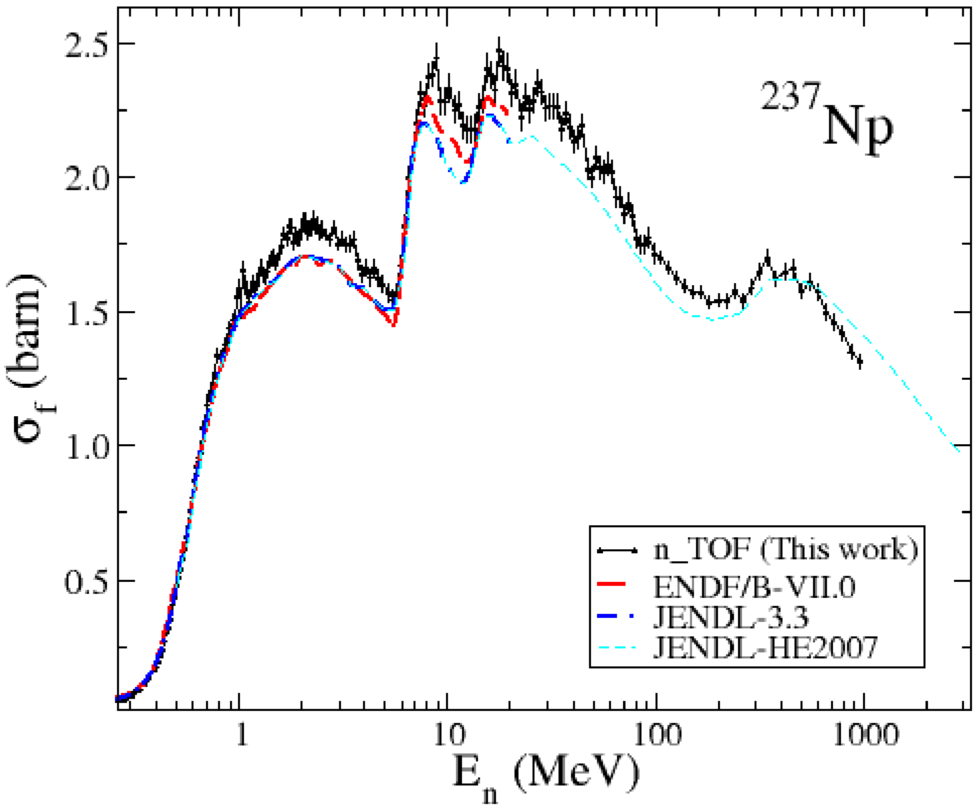
Results obtained at n_TOF

PPAC results reproduce the ENDF/B-VII $^{238}U/^{235}U$ ratio within 3 % accuracy.

$^{234}U(n,f)$ and $^{233}U(n,f)$ cross sections are also well reproduced



Results for Np-237



- Same shape but 5-6% higher than current evaluations (our systematic error is less than 4%)

Status of ^{237}Np(n,f) data

- Recent experimental data in the MeV region:
  - Shcherbakov et al. [1]: ToF and /U-235
  - Tovesson and Hill [2,3]: ToF and /U-235
  - Basunia et al. [4]: Surrogate Ratio Method
  - N_TOF [5]: ToF and /U-235

1. Proc. of ND2001
2. Phys. Rev C 75, 034610 (2007)
3. Nucl. Sci. Eng.159, 94 (2008)
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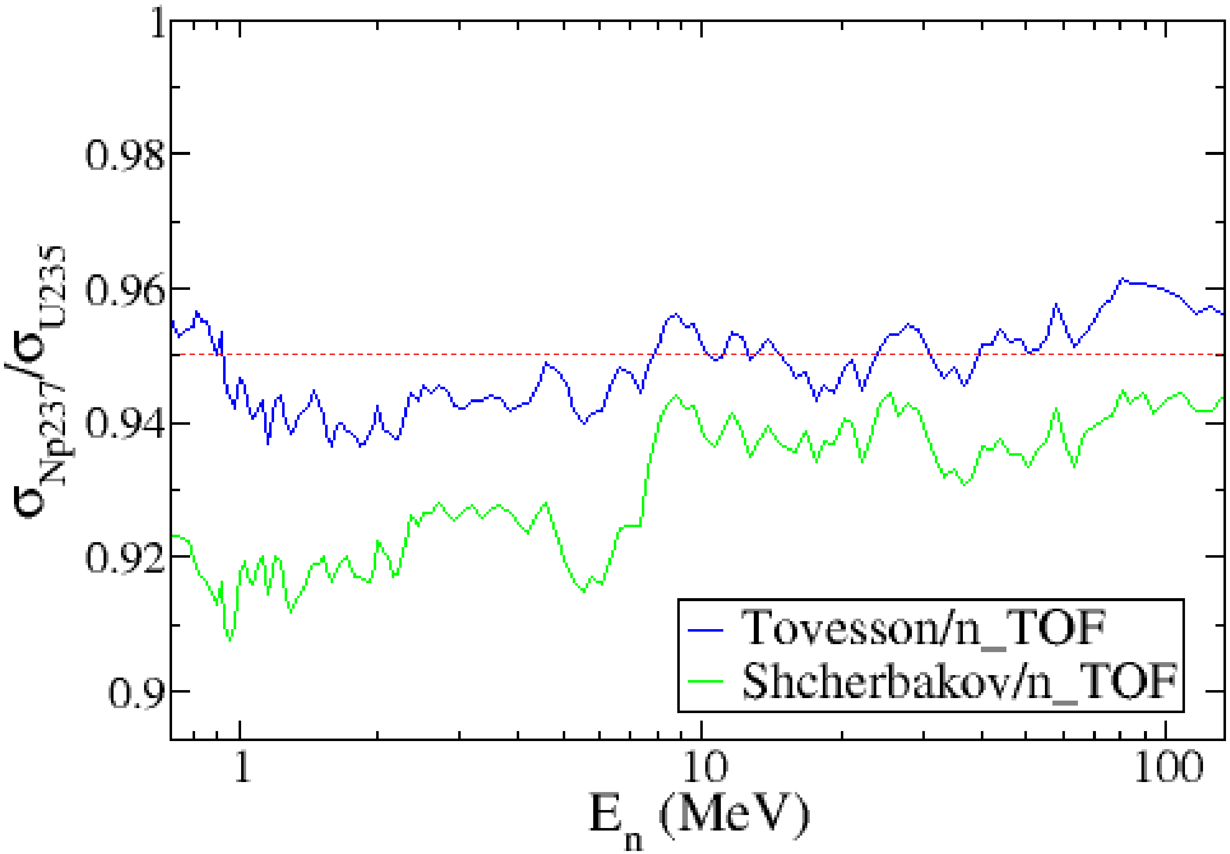
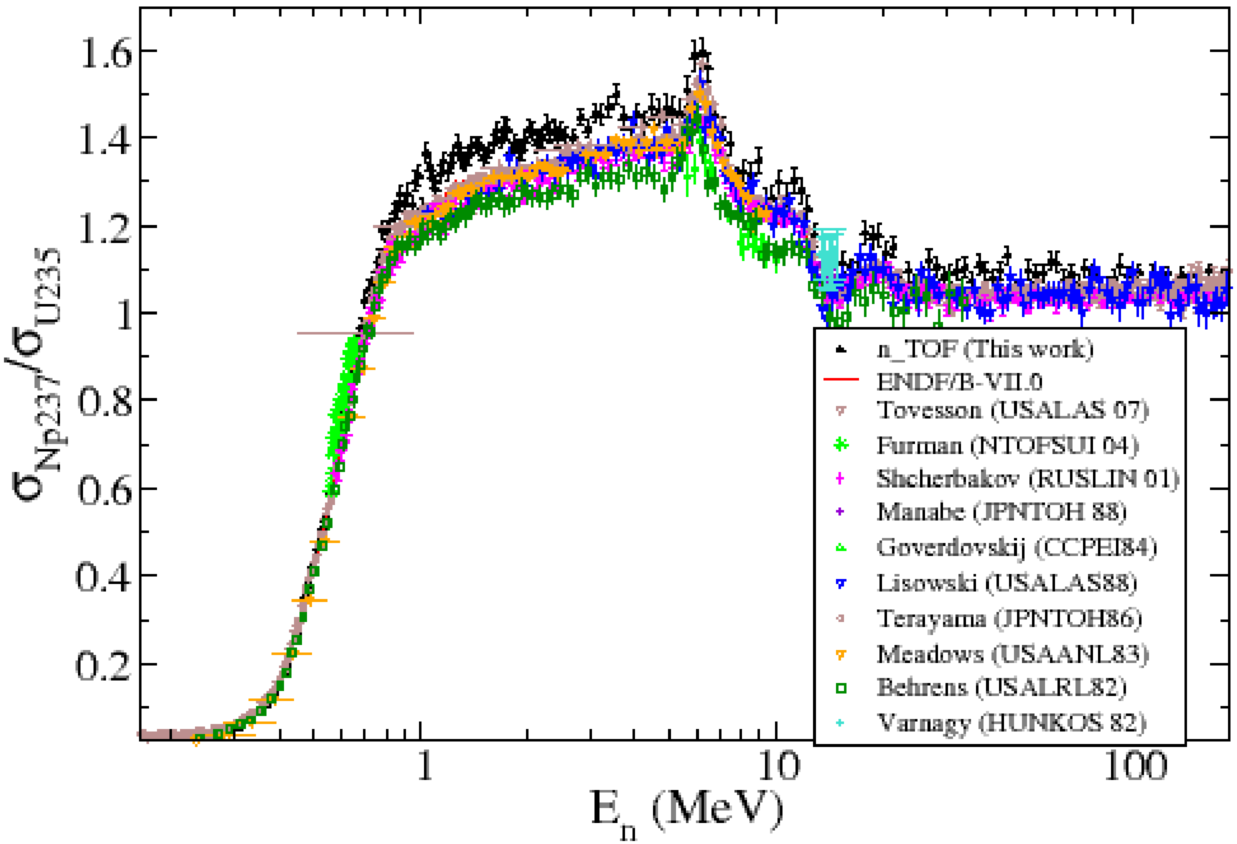
$^{237}Np/^{235}U$ ratio



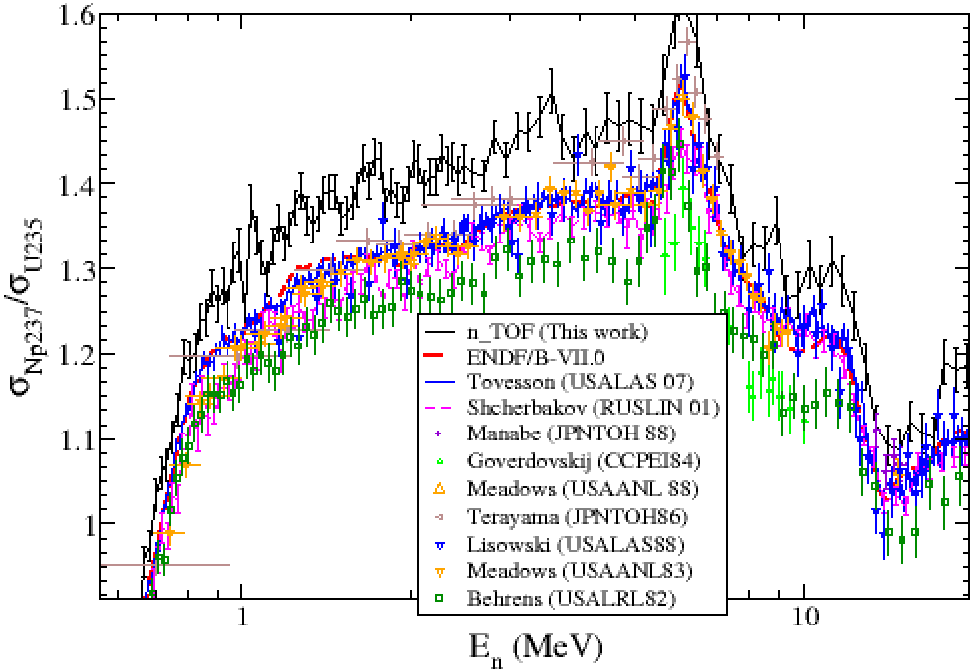
- Our data present a shape with the energy similar to previous
- However, an absolute offset is clear

$^{237}Np/^{235}U$ ratio



- Most of the measurements use ^{235}U as reference.
- Ratio comparison independent of ^{235}U evaluation used

$^{237}Np/^{235}U$ ratio



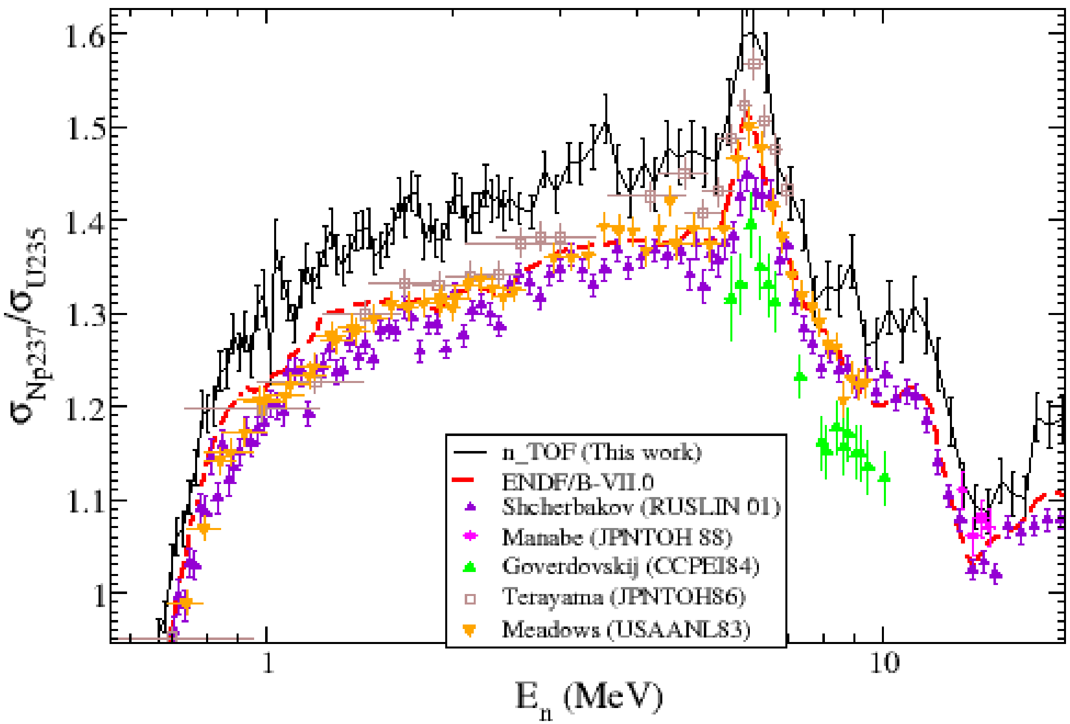
Many of the sets are close to ENDF/B-VII, but …

- Lisowski data[1] (ENDF/B-VI) is normalized to Meadows data[2]
- Tovesson data is normalized to ENDF/B-VI @ 14.8 MeV
- Behrens measurement gets the sample mass from chemical analysis, while Meadows uses half-lifes, but recommends α counting.
- Shcherbakov data: threshold method (maybe normalised)

1. Proc. of ND88, Mito
2. Nucl. Sci. Eng. 85, 271 (1983)

$^{237}Np/^{235}U$ ratio

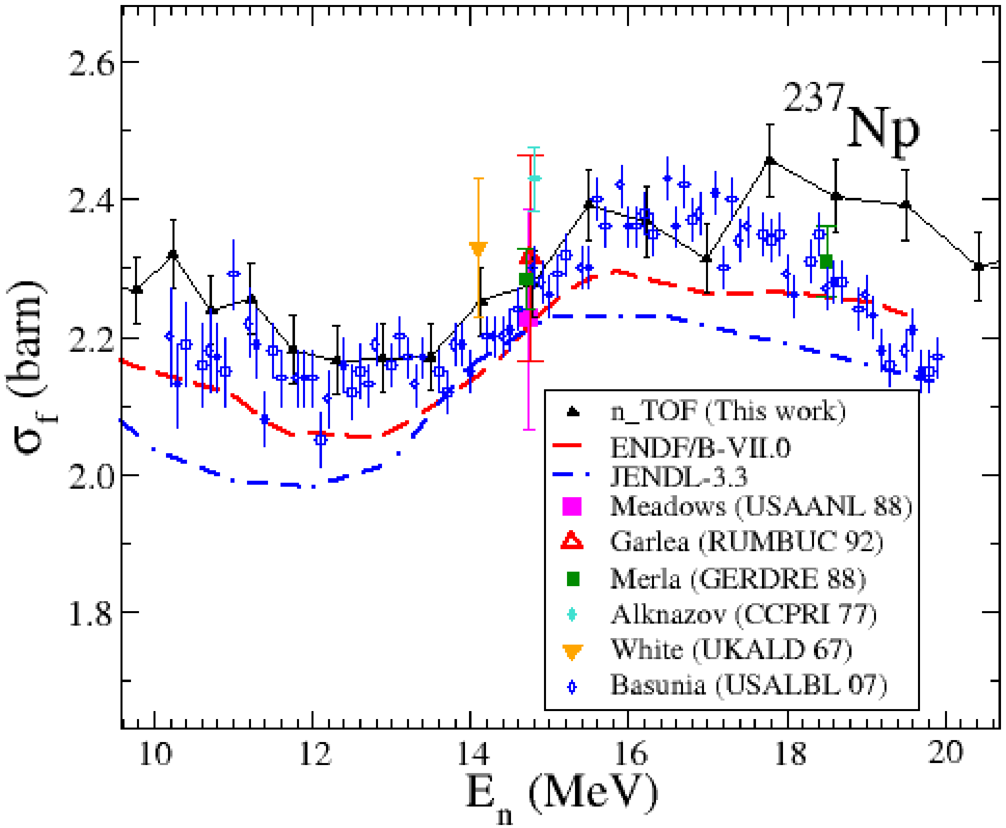
After removing the measurements described as normalized or problematic:



Results at 14 MeV region

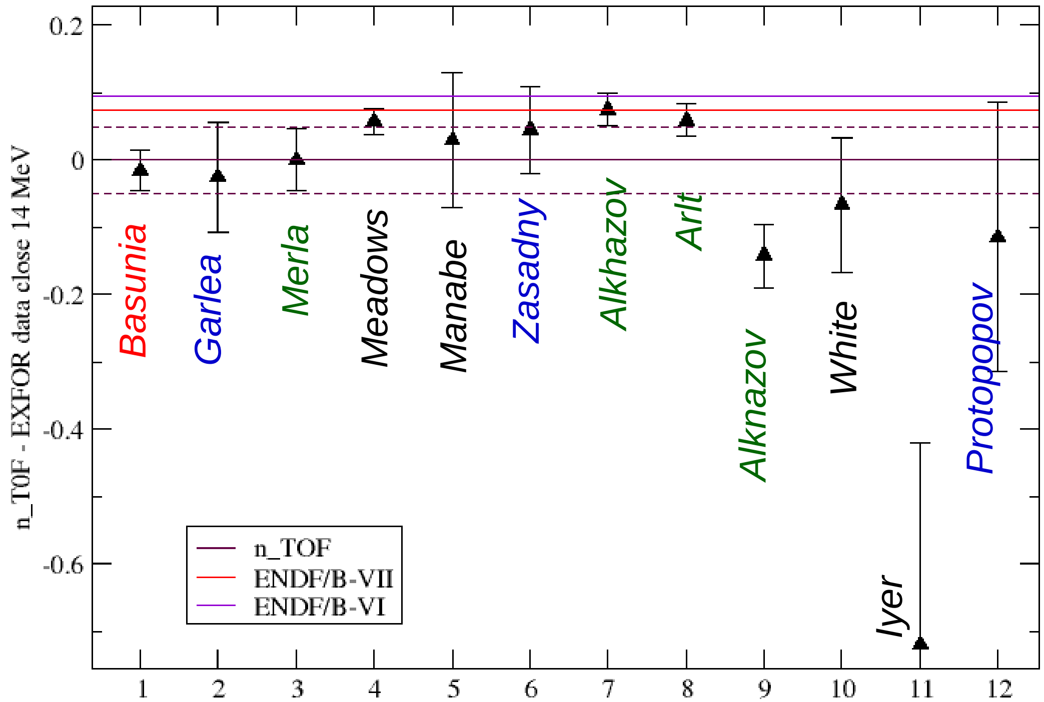
Other than ToF measures:

- Basunia et al. (SRM) provide the cross sections between 10 and 20 MeV
- Several measurements with monoenergetic sources around 14 MeV (D-T sources)



Comparison to 14.8 MeV data

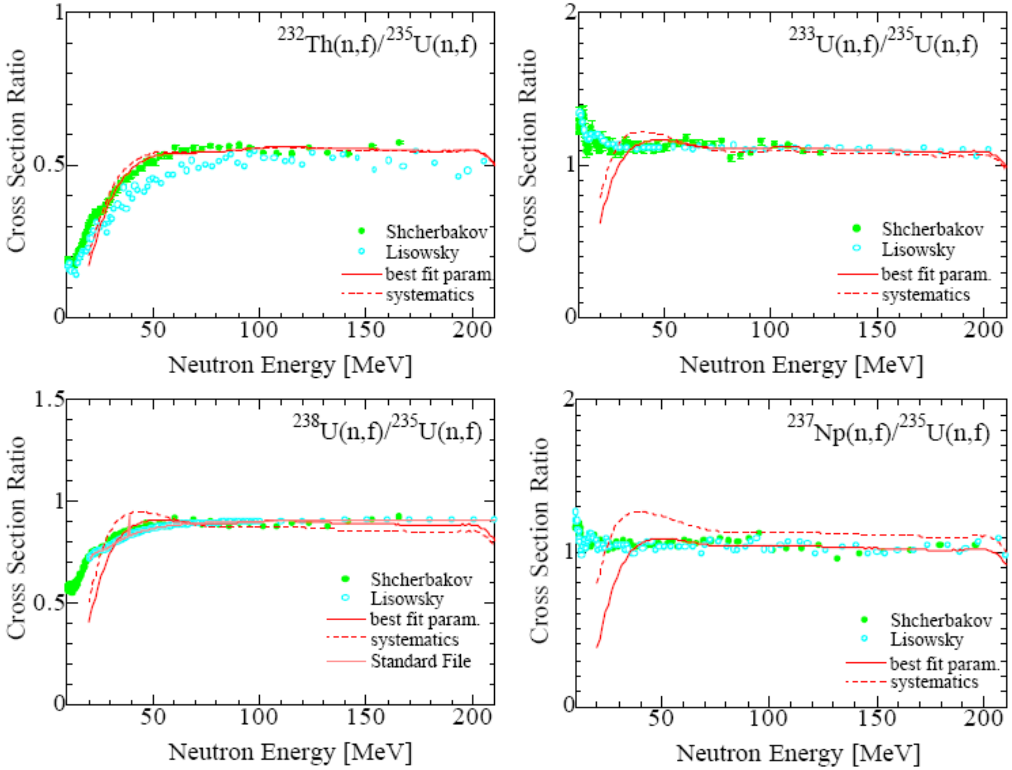
- Tovesson uses ENDF/B-VI value at this energy for the normalization: large differences.
- Our data are compatible with most of them. *Meadows* at 14 MeV is not compatible with ENDF/B-VI

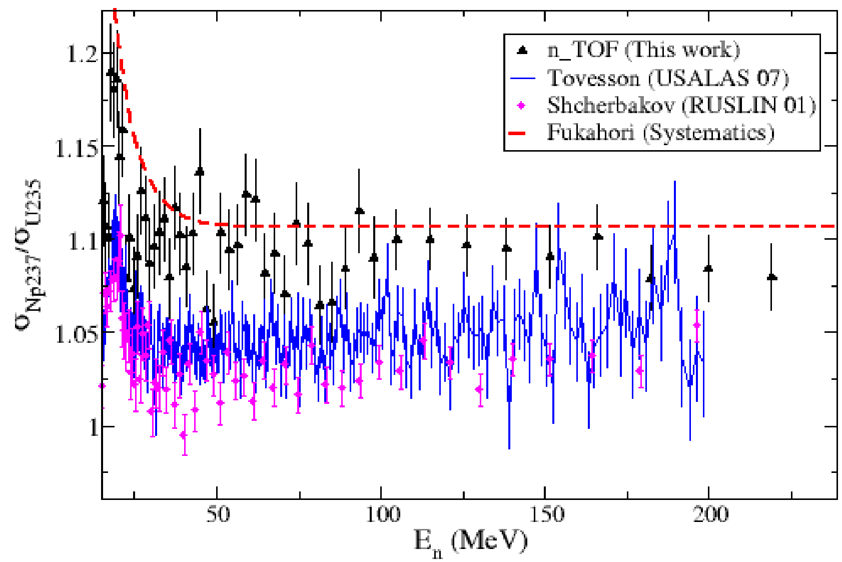


Fukahori systematics

Comparisons of fission ratio to ^{235}U calculated by FISCAL code with LANL (Lisowsky) and PNPI (Shcherbakov)

"Except ^{237}Np case, FISCAL can reproduce the experimental data well"*





- FISCAL results in agreement with the ^{237}Np n_TOF data for intermediate energies

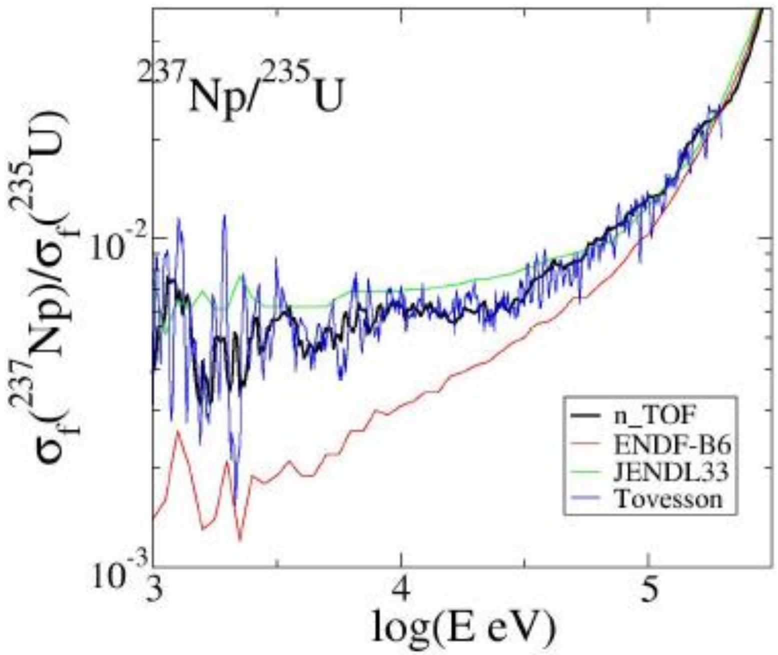
**T. Fukahori. Present status of JENDL-HE File (2002)*

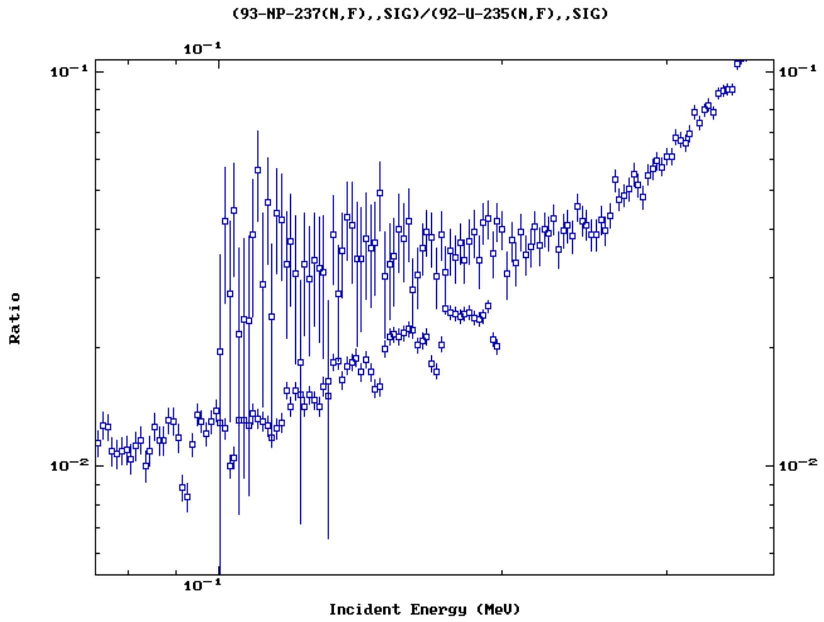
Summary and conclusions

- New high-resolution data for Np-237 between 1 eV and 1 GeV without normalization to previous data. Extensive characterisation of the target properties and the detection efficiency.
- General agreement with the Tovesson (ENDF/B-VII) shape, but discrepancies in the cross section absolute value (~5 % factor).
- ENDF-B/VII results to be mainly based in Meadows data (1983).
- Other recent works are close to our results: SRM, systematics, integral measurements.
- Need of ^{237}Np(n,f) re-evaluation. New measurements for confirmation.

Thanks for your attention

σf for ^{237}Np in the unresolved region





Discrimination with coincidences