Feasibility of the (n,γ) cross section measurements on ^{235}U and ^{239}Pu with a fission tagging C_6D_6 setup

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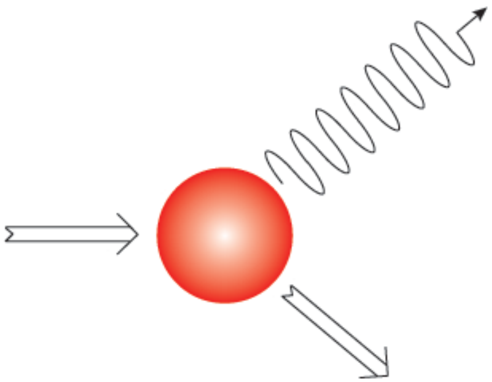


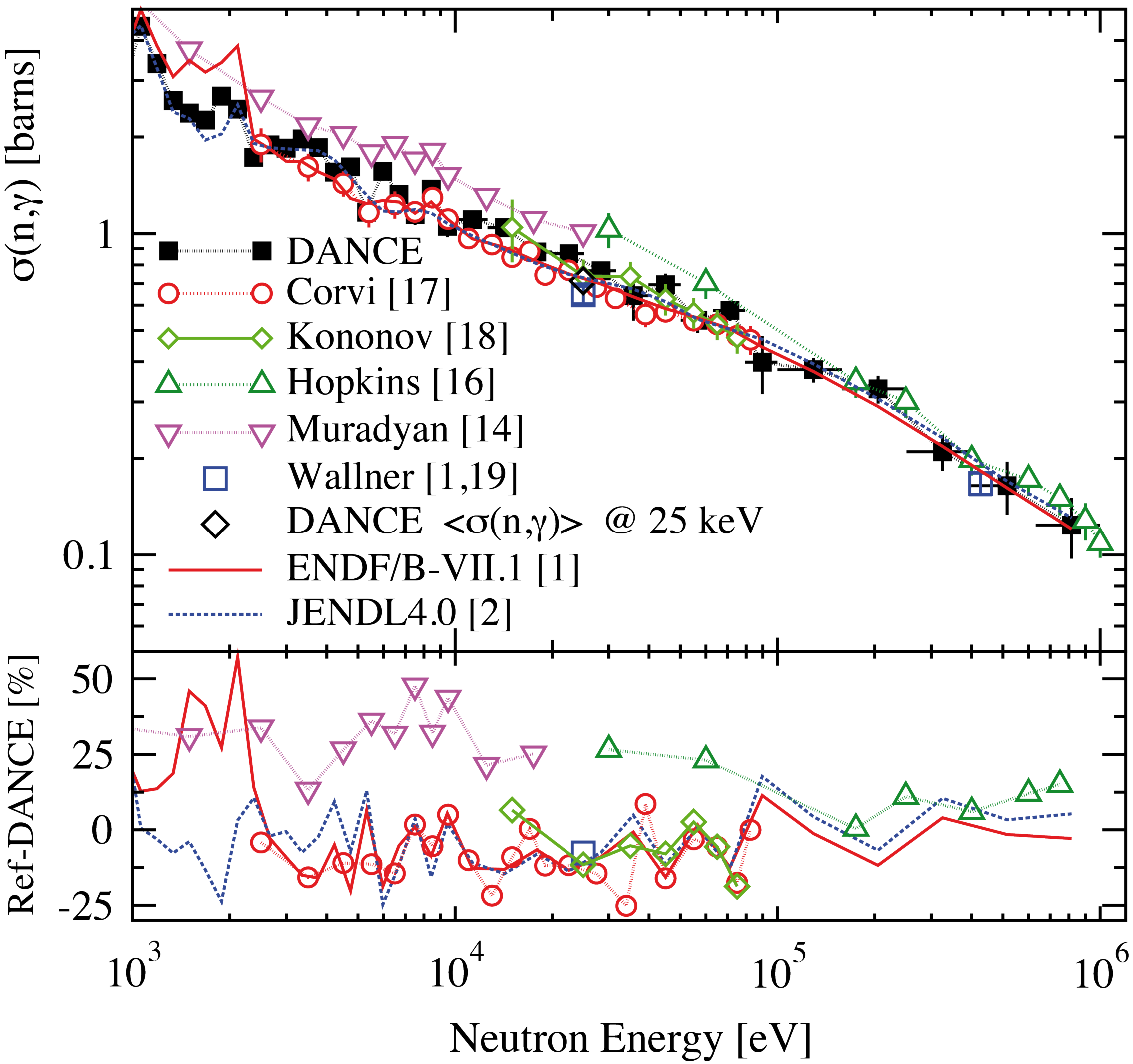
Need of accurate data

$^{235}U(n,\gamma)$ cross section	
Energy range	Target accuracy
100eV - 500eV	5%
500eV - 1keV	5%
1keV -2.25keV	5%
2.25keV- 5keV	8%
5keV - 10keV	8%
10keV - 20keV	8%
20keV - 30keV	8%
30keV - 40keV	3%
40keV - 90keV	3%
90keV -200keV	3%
200keV-400keV	3%
400keV-900keV	3%
900keV - 1MeV	3%

Estimated target accuracies WPEC Subgroup 26 for Advanced Reactors (Gen IV + others). Should serve as an “orientation”.

$^{239}Pu(n,\gamma)$ cross section		
Energy range	Estimated accuracy	Target accuracy
0.10 - 0.54 eV	1.4%	<1%*
2.03 - 9.12 keV	16%	2%-7%
9.12 - 24.8 keV	7%	3%-6%
24.8 - 67.4 keV	10%	3%-7%
67.4 - 183 keV	9%	3%-6%
183 - 498 keV	12%	3%-6%
0.498 - 1.35 MeV	18%	5%-10%

The recent data on ^{235}U(n,γ) from DANCE



Above 100 eV, deviations from the evaluated data are observed: ENDF/B-VII.1 values are consistently higher than the DANCE measurement.

Between 0.5 and 1 keV ENDF/B-VII.1 values are 10–15% higher and, in the interval from 1 to 2.5 keV, 30% higher. The JENDL-4.0 data are lower than the DANCE data, where the largest discrepancy of 20% is observed between 0.5–0.8 keV.

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

Goals and technique

- Perform a high precision measurement of the ^{235}U and ^{239}Pu (n,γ) cross sections.
- Develop a "novel" technique at n_TOF wich will overcome some of the limitations found with the TAC. The actual upper energy limit in the cross section measurements with the TAC seems to be < 10 keV, mainly due to the γ-flash.
- Comparison to the TAC data at low energies (E_n<500 eV).

4 C_6D_6 detectors developed and built by LNL (P. Mastinu et al.) with ~10% efficiency

2 possible fission tagging detectors with ~90% efficiency:

- Low background parallel plate avalanche chamber (in discussion with I. Durán and A. Plompen).
- Micromegas detector with Al contacts (no copper!).

Investigation of two alternative analysis techniques:
- Subtraction of the fission γ-ray background, taking into account the fission tagging efficiency.
- Normalisation to the fission cross section.

Samples

10 samples of ^{235}U with a total mass of ~30 mg (used for the TAC measurement)

Preferred option:

- 1 sample with 100 mg encapsulated in Al for the capture measurement. Feasible according to A. Plompen. Would be part of a target development inside CHANDA.
- 2 samples with 3 mg each for the fission tagging.

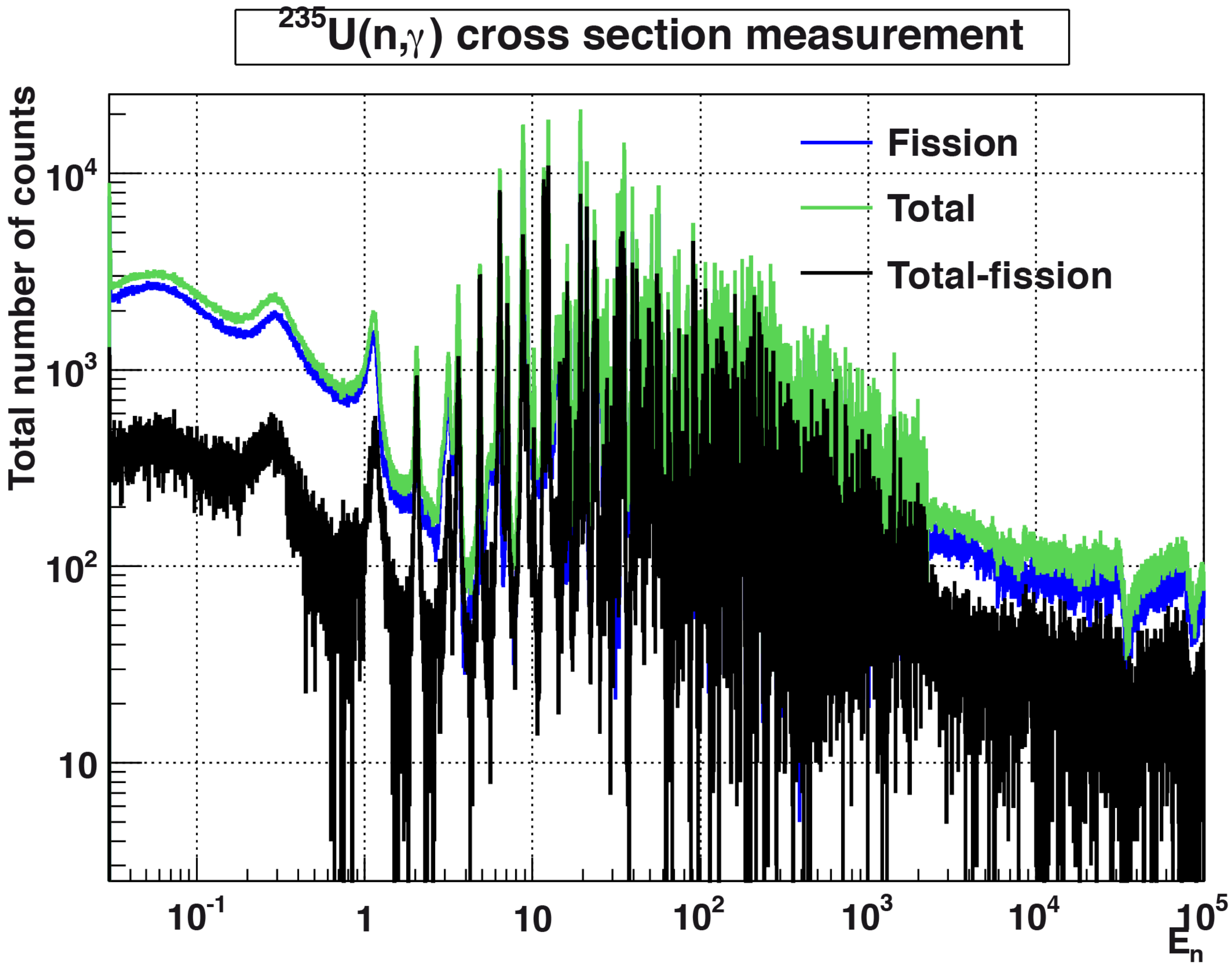
6 samples of ^{239}Pu with a total mass of ~15 mg (information from P. Schillebeeckx via C. Guerrero). Not sufficient for EAR-1 (would need 50 to 100 mg). Similar approach than the one used for ^{235}U.

Ref. nr	**^{239}Pu Purity**	**Preparation Method**	**Backing Material**	**Backing Dimensions**	**Spot size (diam.)**	**Spot size (L x H)**	**Area density g/cm^2**	**Certified parameter**
SP91045	99.9774	Vacuum deposition	Al	97x82x0.01 mm^3	50 mm		186 µg/cm^2	3657 (38) µg Pu
SP91066	99.9766	Vacuum deposition	Al	80 mm diam x 0.2 mm	60 mm		106 µg/cm^2	3010 (31) µg Pu
SP93104-50	99.1039	Electrolysis	Al		30 mm		371 µg/cm^2	2623 (26) µg Pu
SP93104-51	99.1039	Electrolysis	Al		30 mm		48 µg/cm^2	336 (34) µg Pu
SP93104-53	99.1039	Electrolysis	Al		30 mm		651 µg/cm^2	4600 (46) µg Pu
SP97062-8/1/2	99.98		PI-foil	70 x 55 x 0.5	45 mm		32 µg/cm^2	514 µg Pu

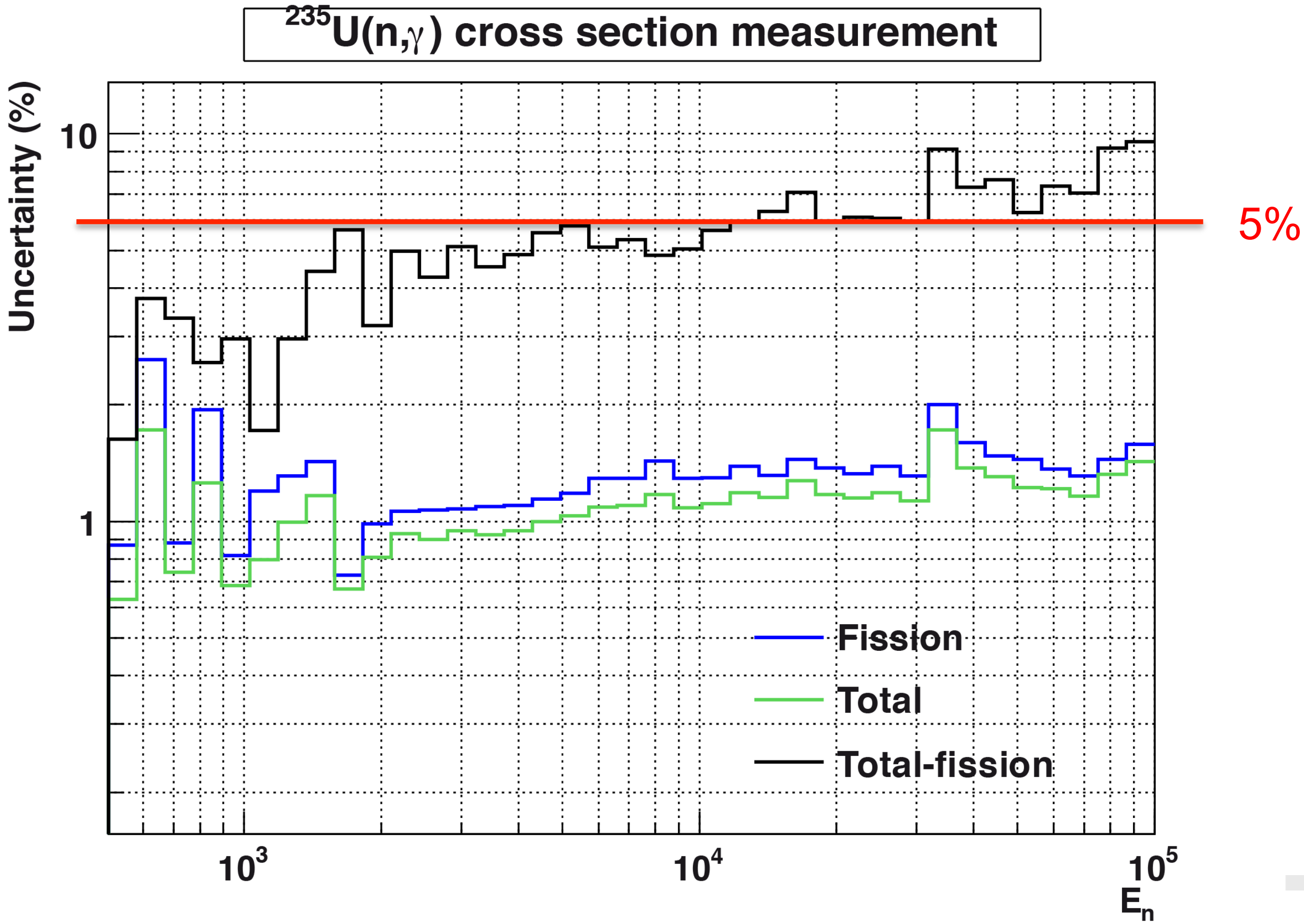
$$N_{\gamma} = N_{total} - \lambda N_{fission}$$

Fission to total ratio			**70%**						
Total				**Fission**			**Capture**		
Counts	Unc.	**Rel. Unc.**	lambda	Counts	Unc.	**Rel. Unc.**	Counts	Unc.	**Rel. Unc.**
10000	100	**1,0%**	2,80	2500	50	**2,0%**	3000	172	**5,73%**

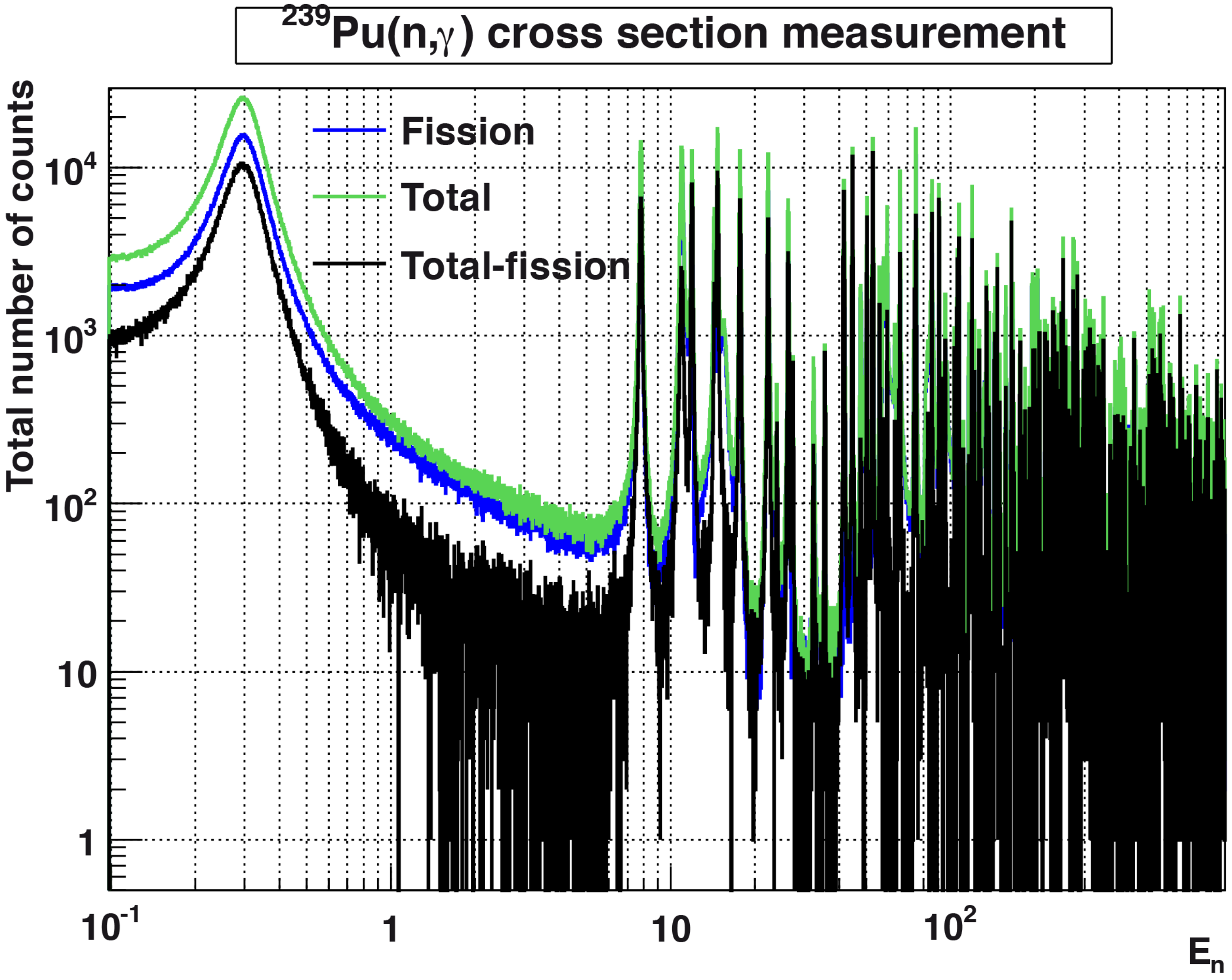
Total statistics for a 100 mg sample, $3 \cdot 10^8$ protons, 1000 bins/decade and a 10% detection efficiency.



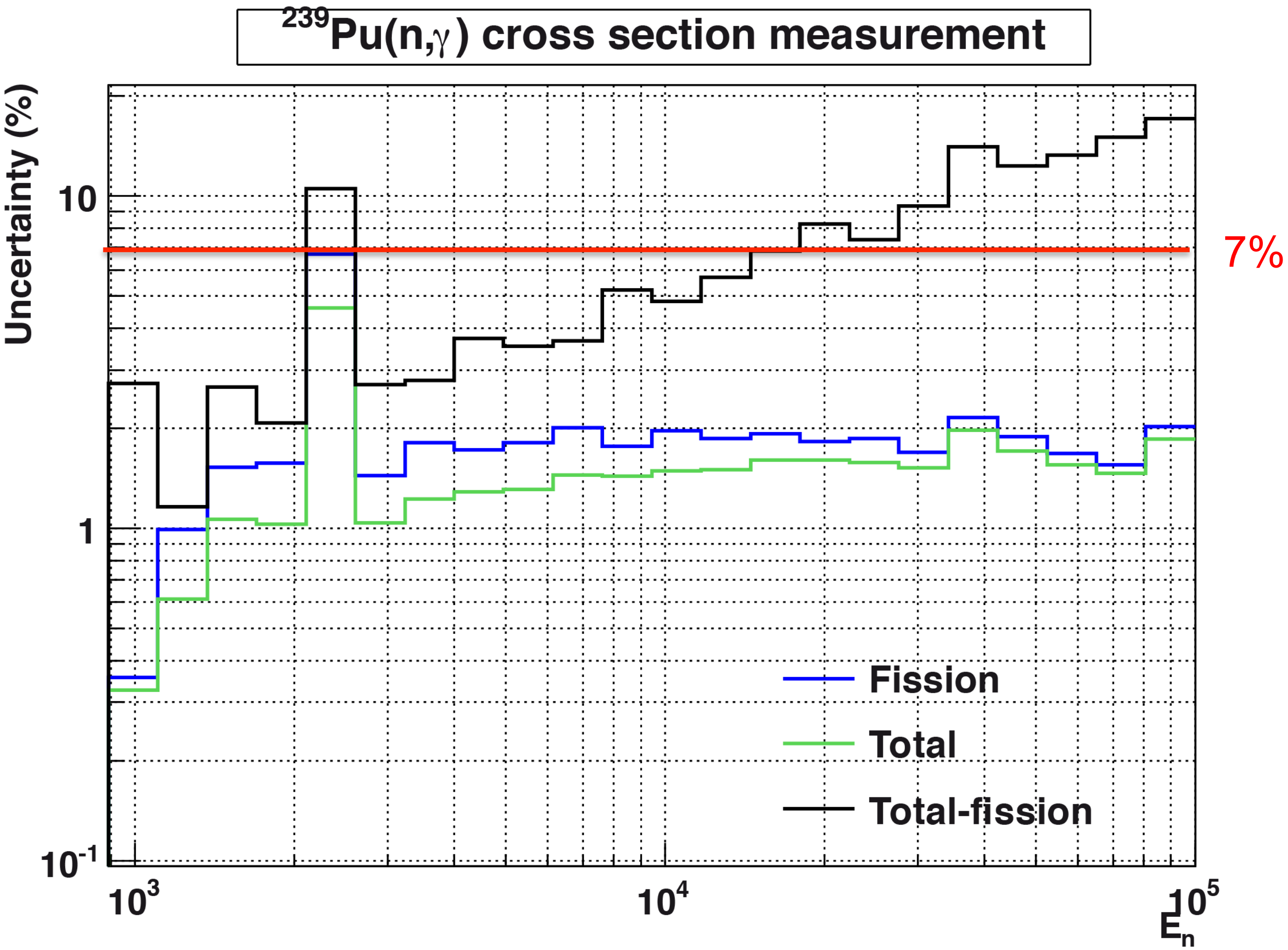
Total statistics for a 100 mg sample, $3 \cdot 10^8$ protons, 15 bins/decade and a 10% detection efficiency. The statistical uncertainty in the background is 1-2%.
The statistical uncertainty in the fission background can be reduced by having a few bins/decade.



Total statistics for a 50 mg sample, $3 \cdot 10^8$ protons, 1000 bins/decade and a 10% detection efficiency.



Total statistics for a 50 mg sample, $3 \cdot 10^8$ protons, 10 bins/decade and a 10% detection efficiency.



Summary and conclusions

The two measurements are very appealing but extremely difficult and "innovative". At present, it does not seem possible to reach the 10 keV – 100 keV neutron energy range with the TAC.

Goal: to produce high accuracy data.

^{235}U (not less than $4\cdot10^{18}$ protons, $3\cdot10^{18}$ for the thick target, $1\cdot10^{18}$ for the thin target)

If a 100 mg sample of ^{235}U is available, it would be preferable to perform the measurement at EAR-1 because of the much better understood experimental conditions and better energy resolution (i.e. resolving power).

Due to the novelty of the technique and the intrinsic difficulties, a test measurement of reduced statistics ($1\cdot10^{8}$ protons) will be proposed. The test could be performed at the end 2014 if the detectors and samples are available (CHANDA project)

Next proposal on ^{239}Pu

Even if a 50 mg sample is available, it is a better case for EAR-2. At EAR-1, the target accuracies required are reached up to a 20 keV.

We are still interest in performing the (n,γ) measurements of Minor Actinides if the samples are available: ^{238}Pu, ^{242}Pu (See Carlos' and Emilio's proposal), **^{244}Cm**, ^{245}Cm.