γ-ray and Fragment (A,Z,E) distributions from ^{239}Pu(n,F) Measured with STEFF

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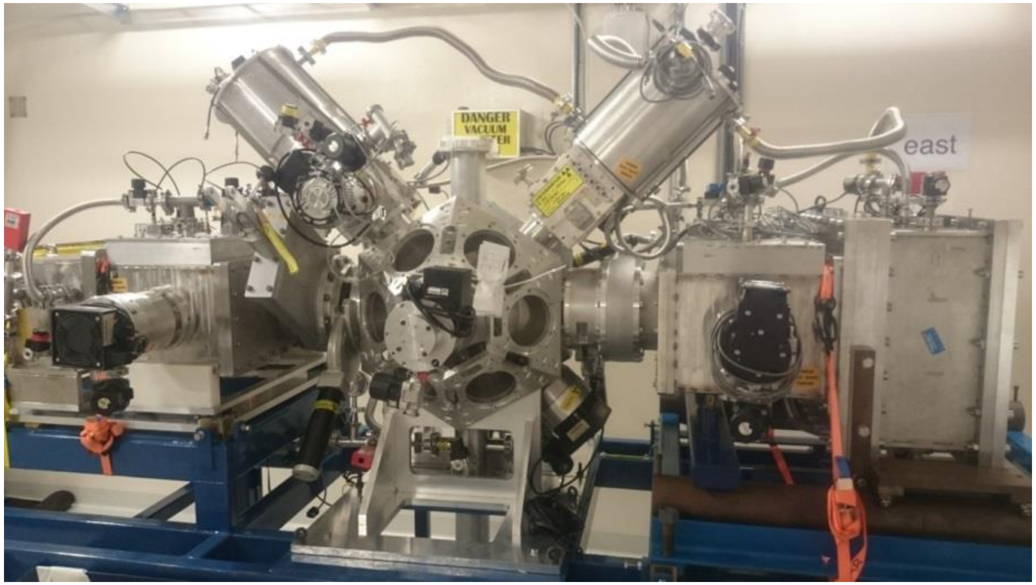
and the n_TOF Collaboration



Proposal for INTC 2018

* PhD Students starting 2016/2017

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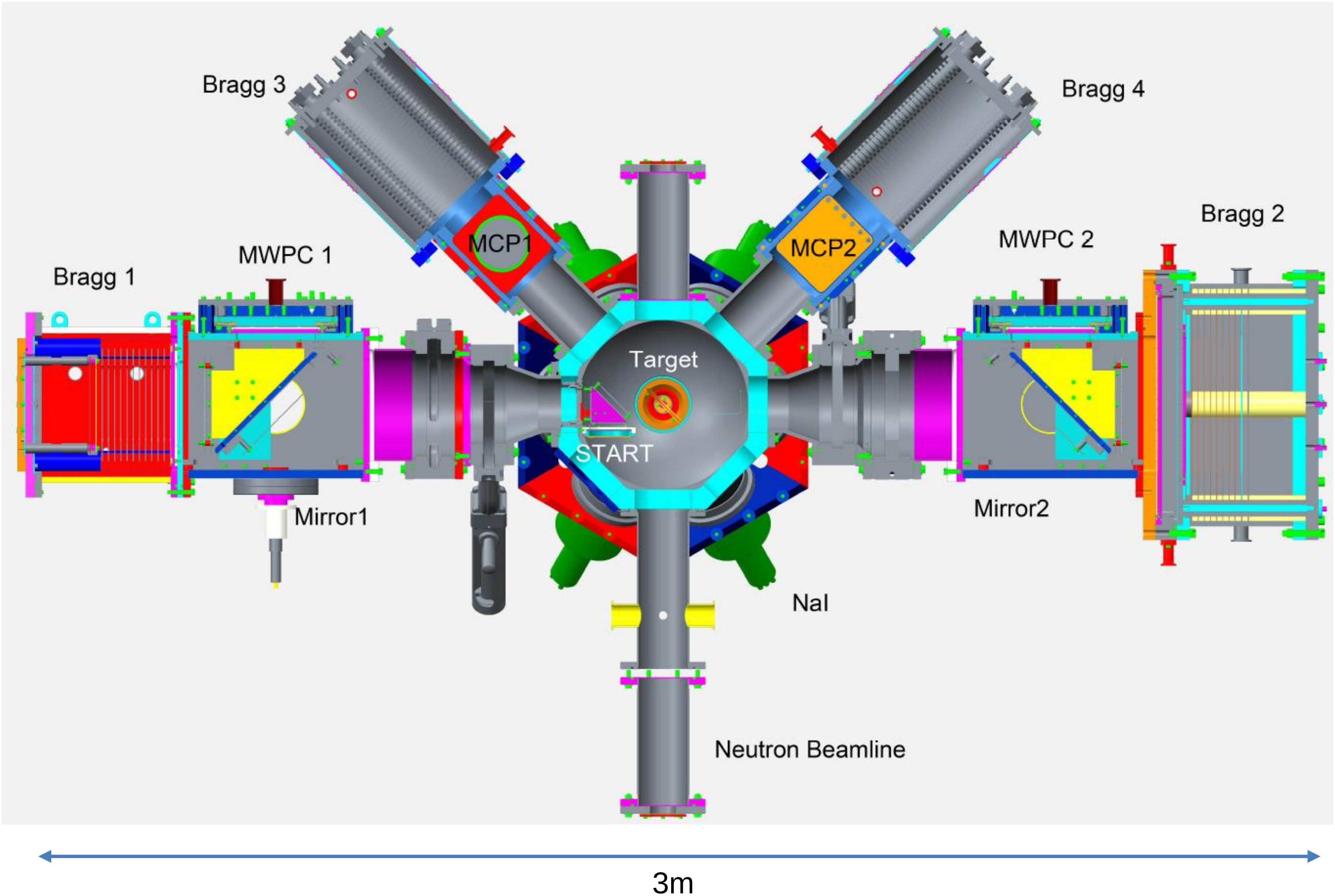
STEFF Proposal Objectives

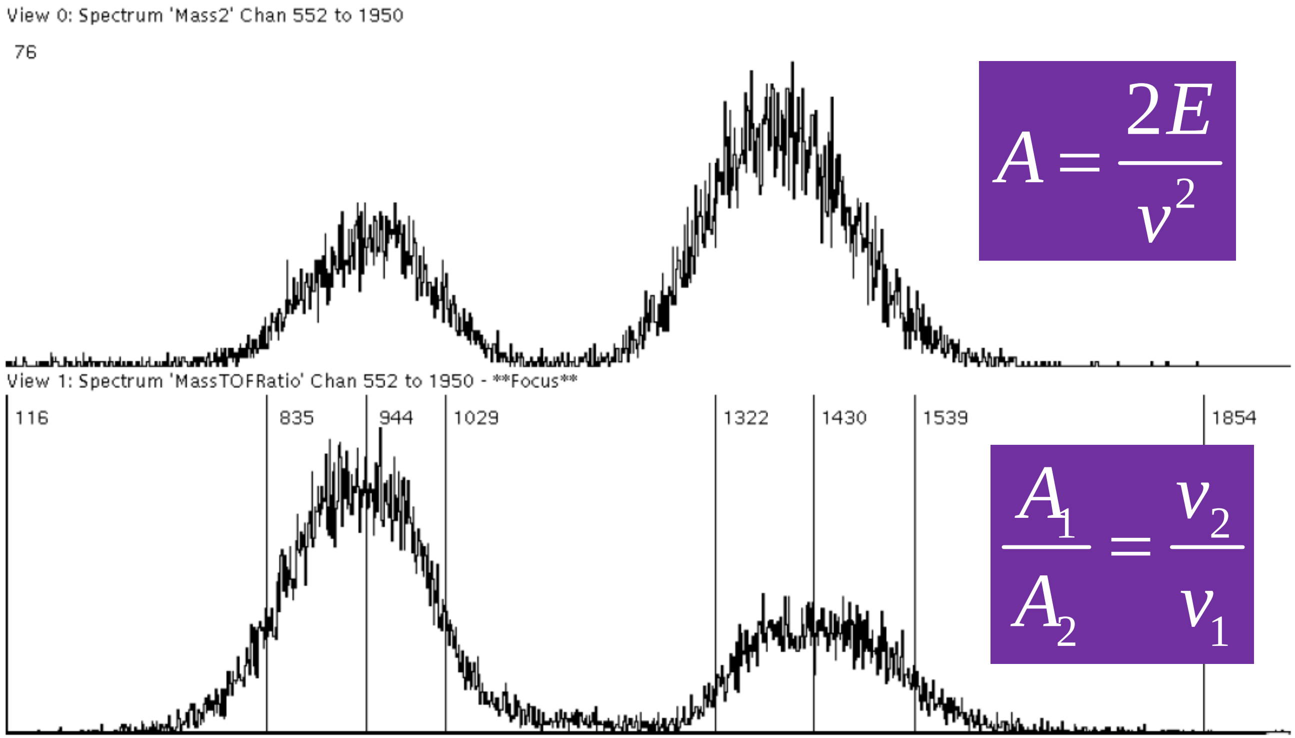
- To use STEFF at EAR2 to study neutron-induced fission of ^{239}Pu
- Measurement of E,A,Z and directions of fragments.
- Use gamma multiplicities to look at spin effects.
- Meet NEA high-priority request for gamma-ray data.
- Study fragment angular distributions vs. A,Z and E (E_x).

STEFF (with upgrade for EAR2)



Fragment mass measurement

- Time-of-flight -> velocity
- Bragg Ionisation chamber->energy
- Mass resolution 4 amu



$$A = \frac{2E}{v^2}$$

Single Arm

$$\frac{A_1}{A_2} = \frac{v_2}{v_1}$$

Both Arms Needed

Nuclear charge distribution for light mass group

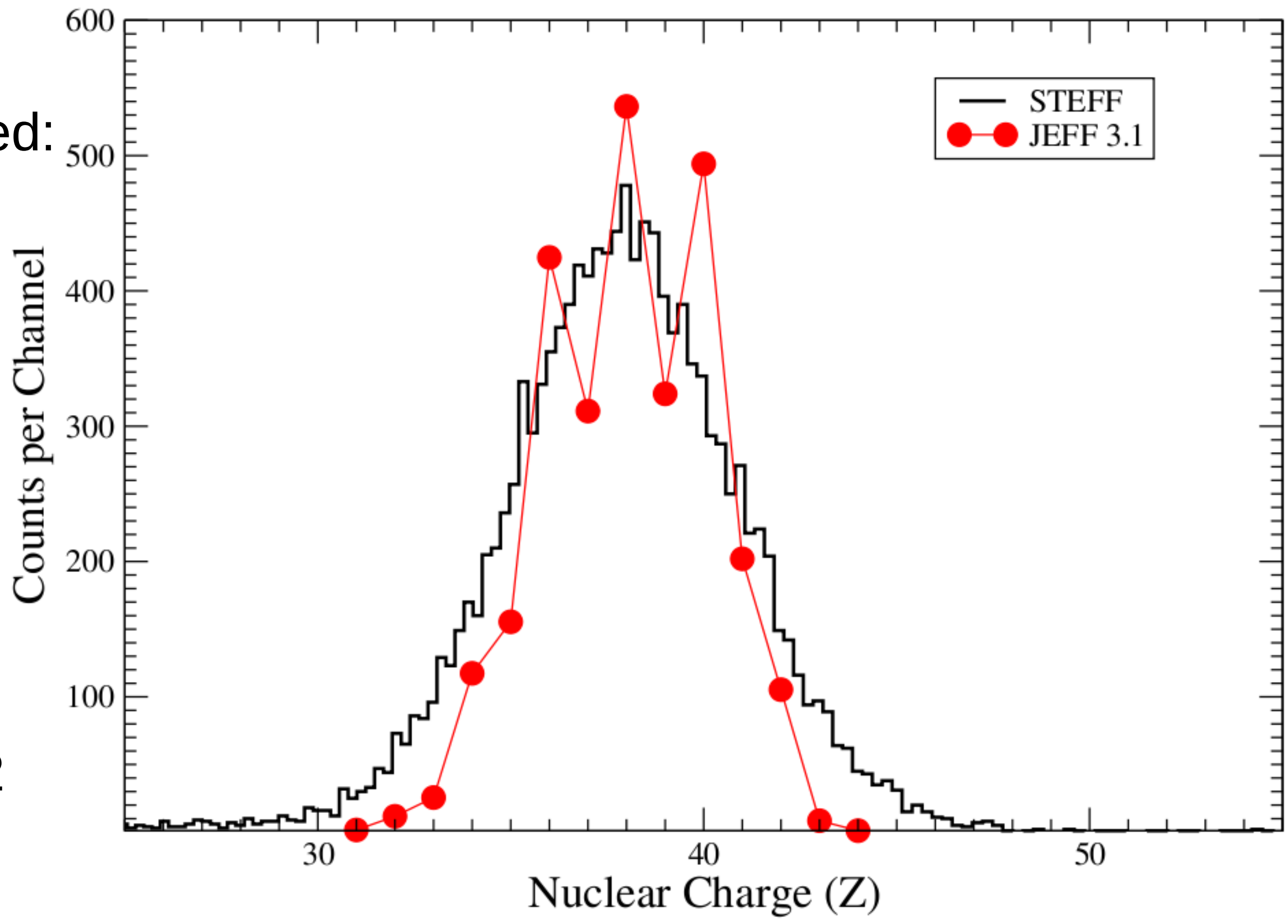
IC measurements, when velocity if fixed:

$$\frac{dE}{dx} \propto Z^b$$

Where

$$b = 2/3$$

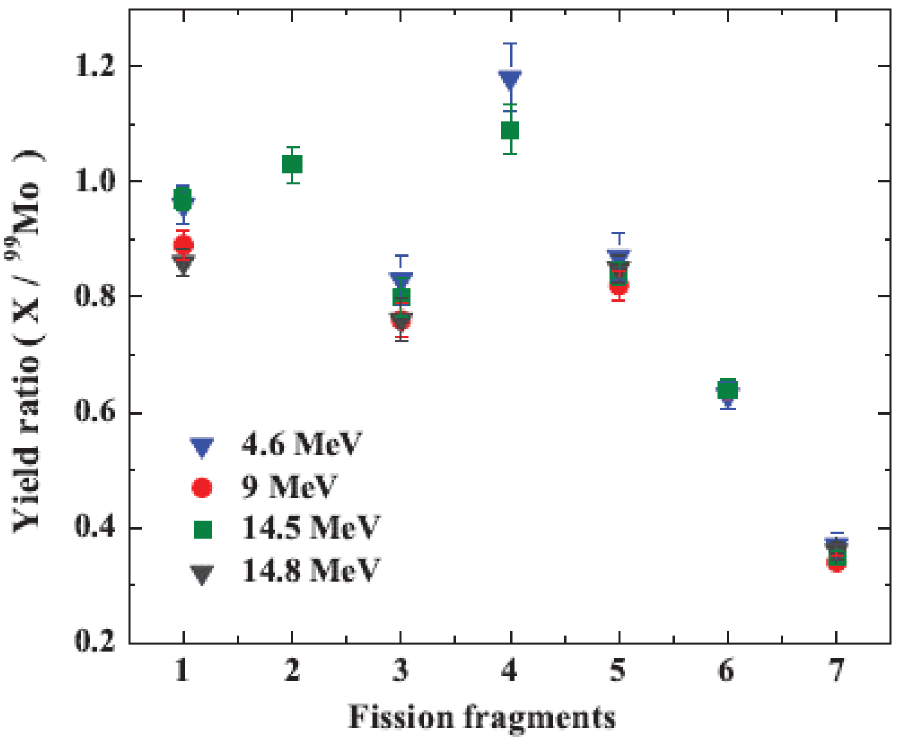
before any corrections: Sensitivity to Z (FWHM) of about 2 units.



Fission Product Yield Study of ^{235}U, ^{238}U and ^{239}Pu Using Dual-Fission Ionization Chambers

C. Bhatia,[1,*] B. Fallin,[1] C. Howell,[1] W. Tornow,[1] M. Gooden,[2] J. Kelley,[2] C. Arnold,[3] E. Bond,[3] T. Bredeweg,[3] M. Fowler,[3] W. Moody,[3] R. Rundberg,[3] G. Rusev,[3] D. Vieira,[3] J. Wilhelmy,[3] J. Becker,[4] R. Macri,[4] C. Ryan,[4] S. Sheets,[4] M. Stoyer,[4] and A. Tonchev[4]

Nuclear Data Sheets 119 (2014) 324–327



Add to yield data – thermal to 10 MeV and measure Z distributions

Gamma-ray Energy and Multiplicity

- Response to NEA High Priority Request of more accurate knowledge of heating caused by gamma emission in the next generation of nuclear reactors
- Coincidence with emission of prompt gamma rays as a function of the fragment mass and energy
- 12 NaI detectors around the uranium target provide a 6.8% photo peak detection efficiency. Augment with 6 small LaBr3 detectors from UKNDN.

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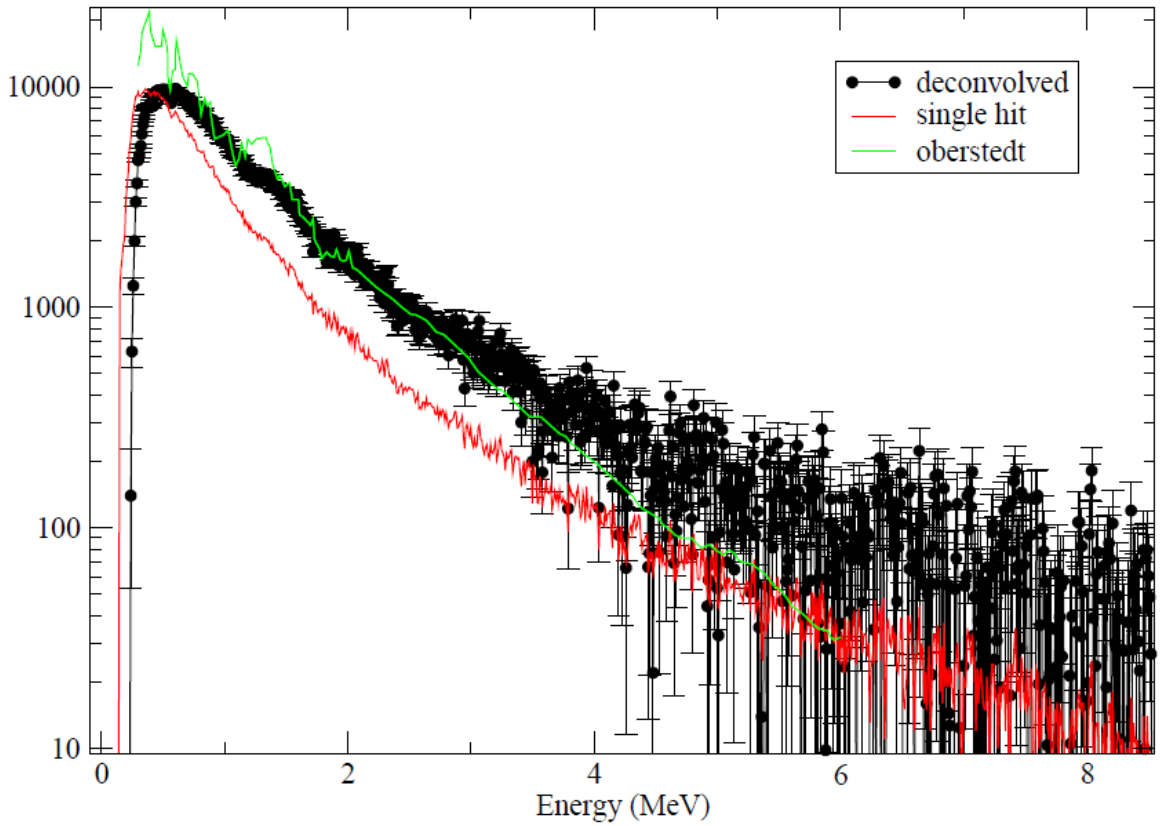
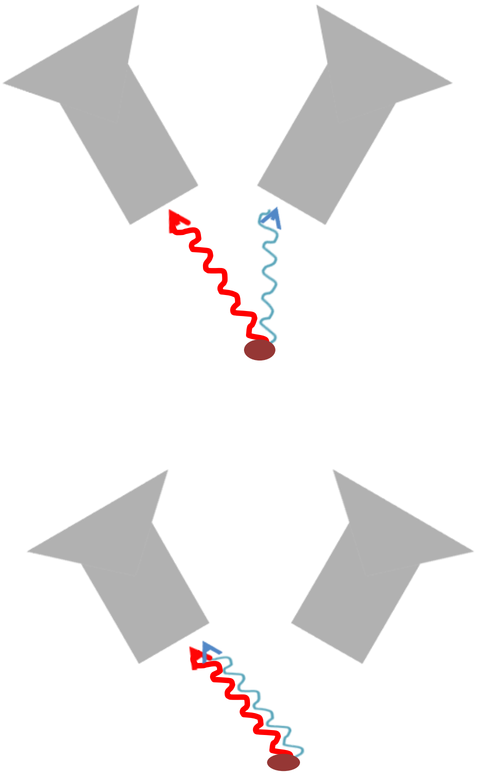
^{235}U Single γ Energy distribution



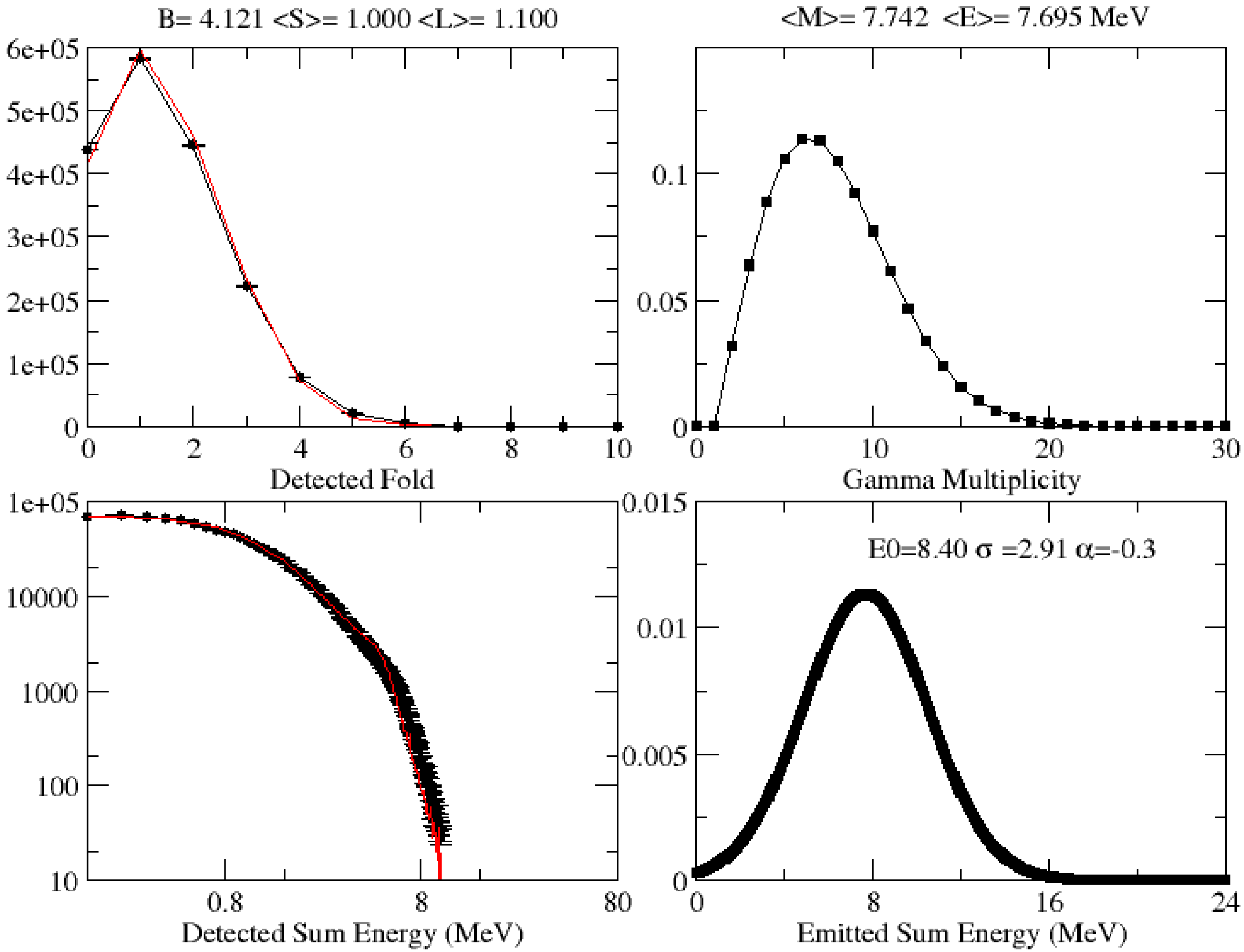


•Time random coincidences removed

•Multiple-hit effects removed (GEANT4)

• Deconvolution (Compton/Backscatter, etc. removal) using GEANT4 response functions.

Using GEANT4 simulations of response functions of STEFF NaI detectors



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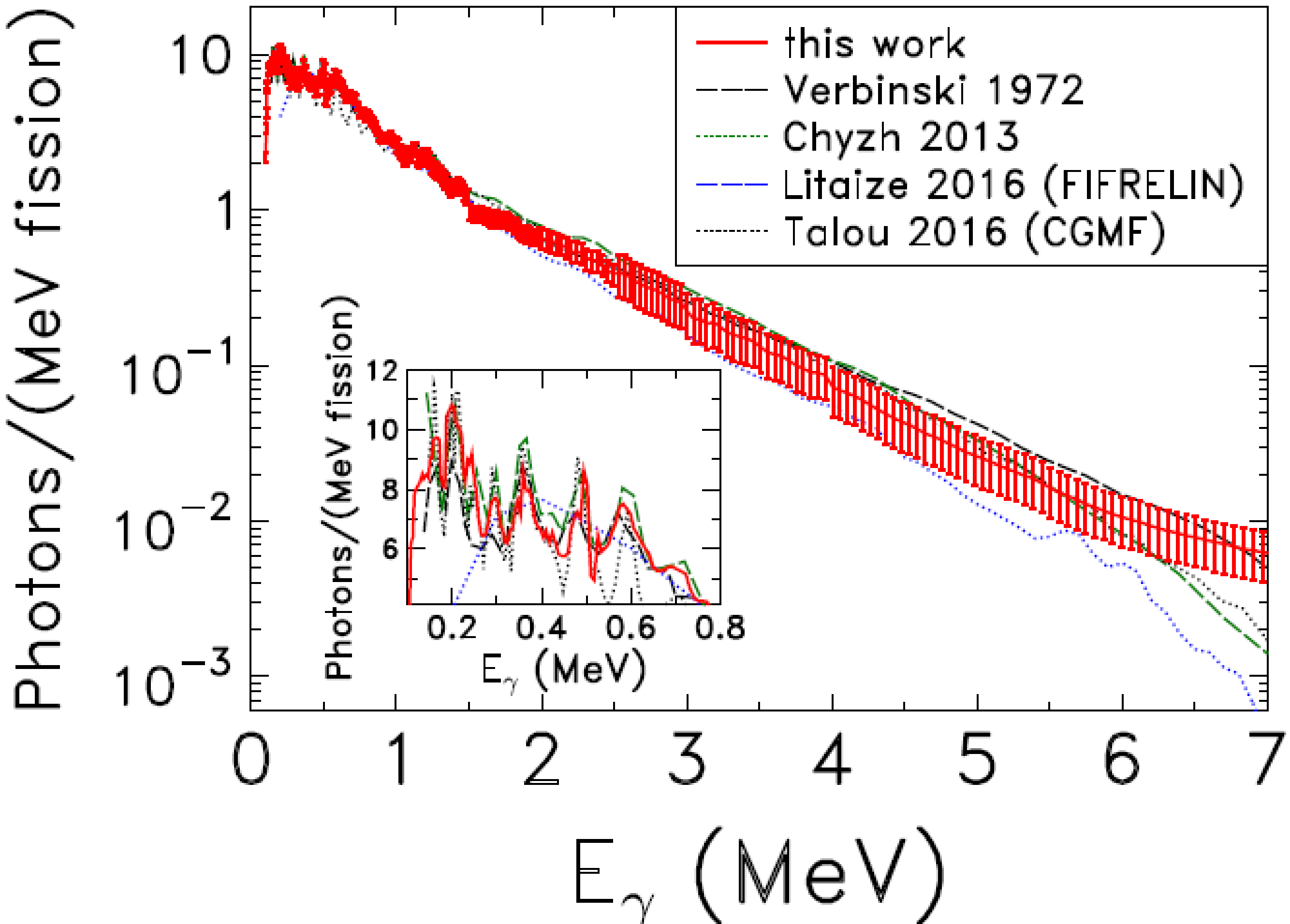
nTOF

Prompt-fission γ-ray spectral characteristics from $^{239}Pu(n_{th}, f)$



A. GATERA *et al.* PHYSICAL REVIEW C **95**, 064609 (2017)

Prompt γ-ray production in neutron-induced fission of ^{239}Pu

Cover this energy region and higher →

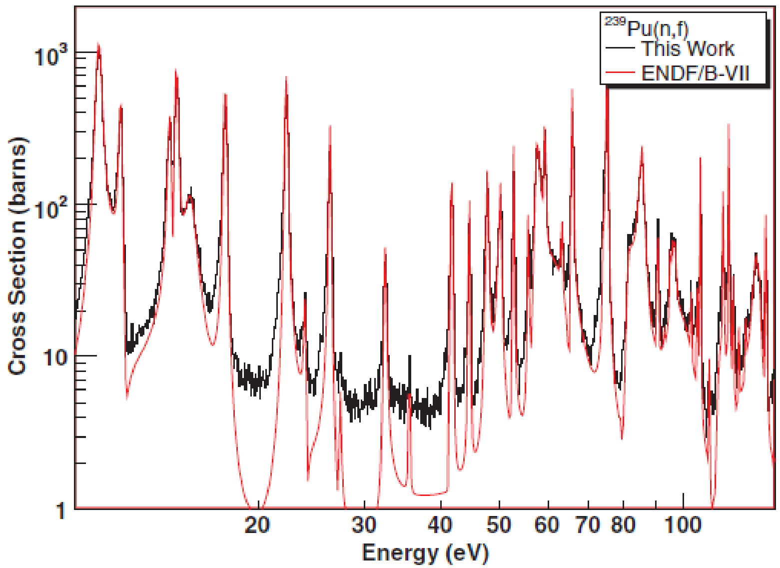
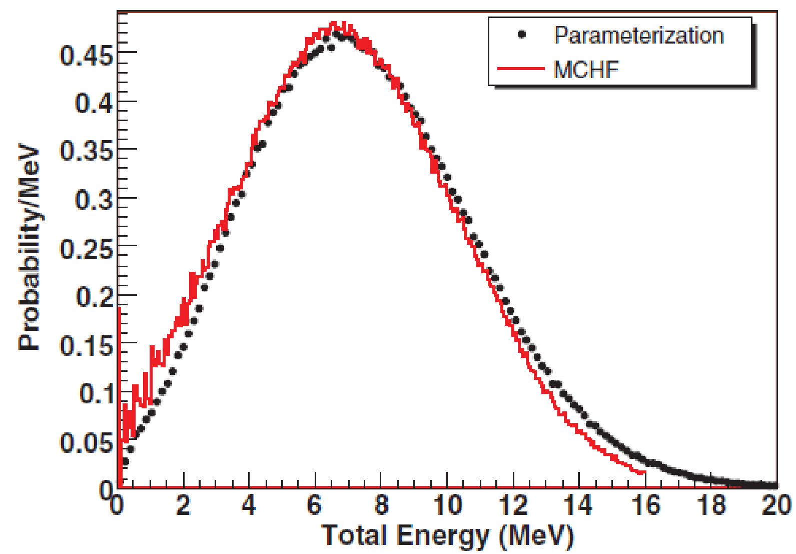


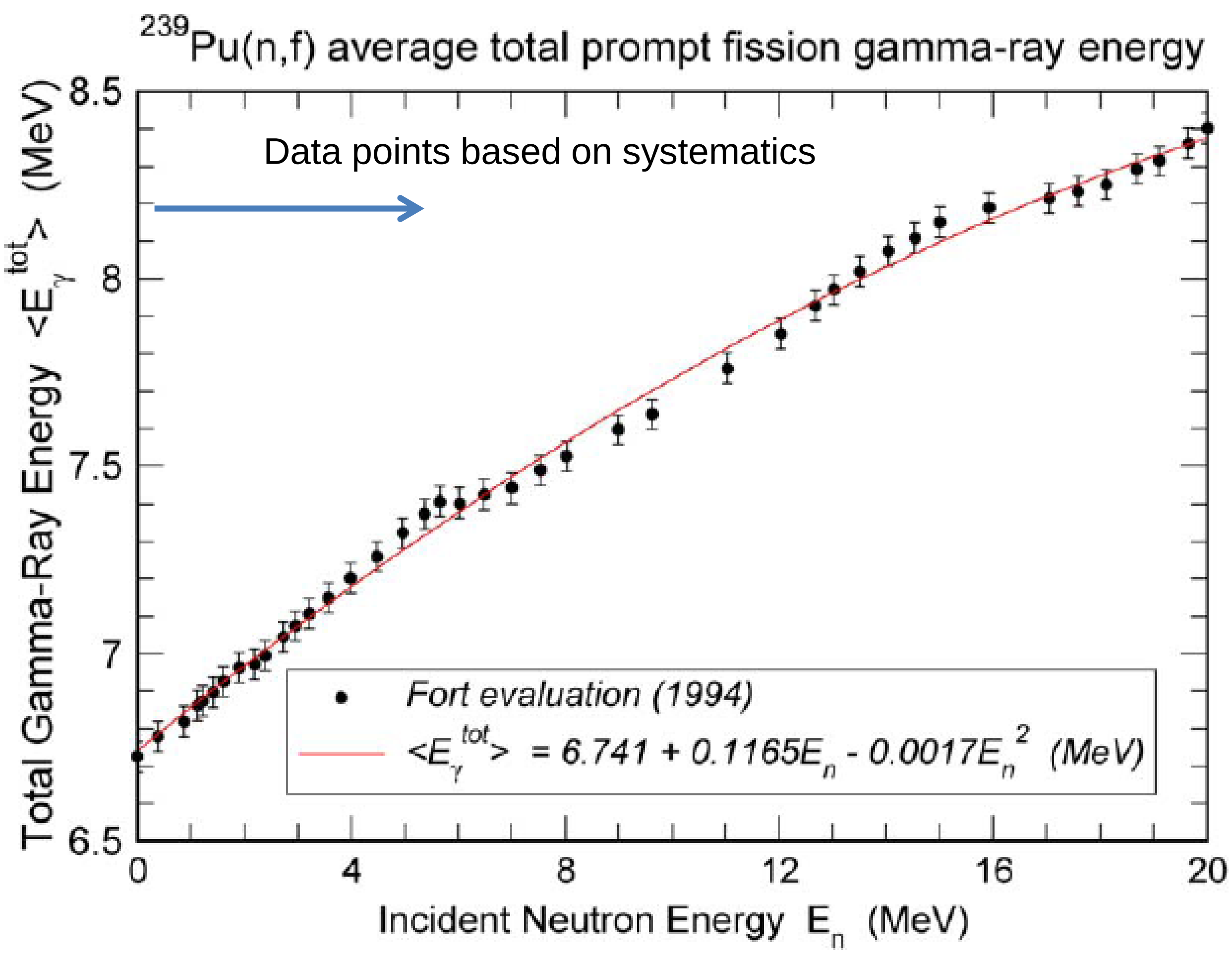
FIG. 1. (Color online) ^{239}Pu(n,f) cross section measured using the fission-tagging PPAC for neutrons from 10 to 140 eV. Also shown is the Doppler-broadened ENDF/B-VII.0 evaluated cross section.

TABLE II. Average multiplicity and total gamma energy.

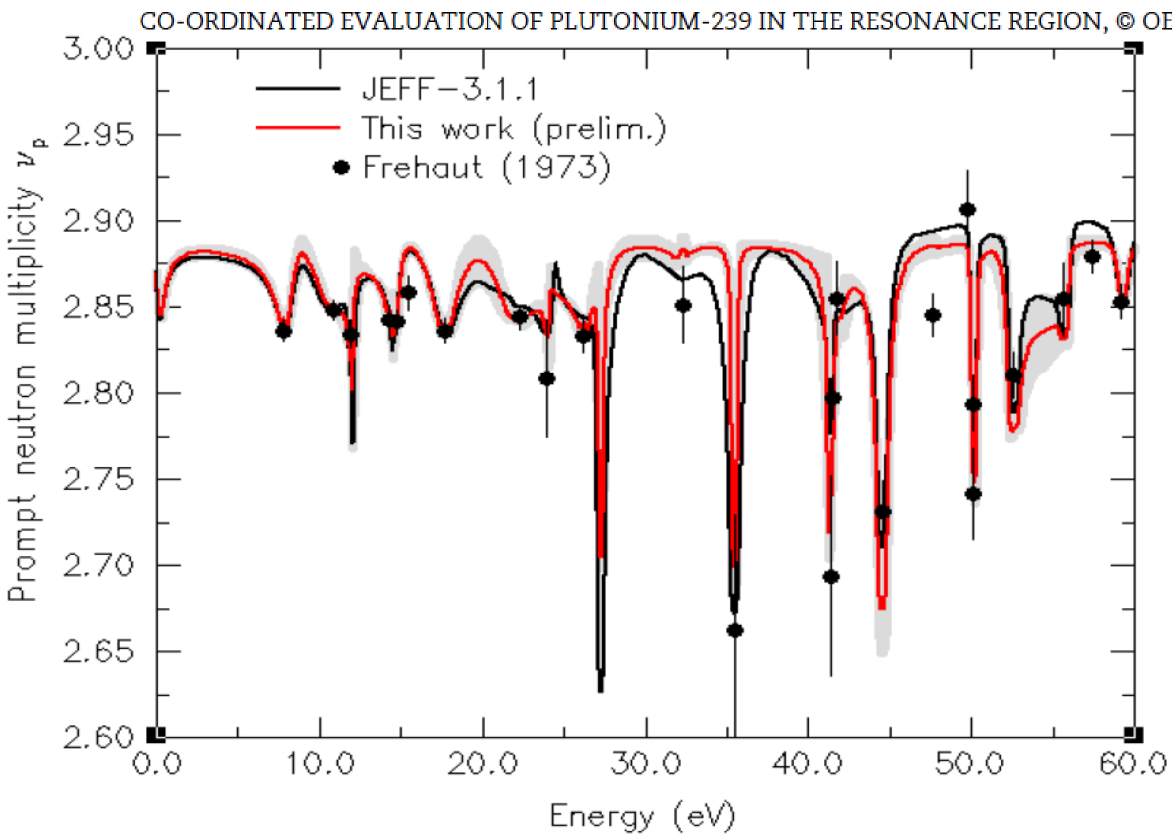
	$\langle M \rangle$	$\langle E_{tot} \rangle$ (MeV)
This work	7.15 ± 0.09	7.46 ± 0.06
Pleasonton [1]	6.88 ± 0.35	6.73 ± 0.35
Verbinski [2]	7.23	6.81
MCHF (150 keV)	6.57	6.99
ENDF/B-VII.1 [11]	7.783	6.74
Unfolded [13]	7.50	7.30



D.G. Madland / Nuclear Physics A 772 (2006) 113–137



Multiplicity Variation – Resolved Resonaces



Variation due to competition between (n,f) and (n,γf) for $J^{\pi} = 0^{+}$ and $J^{\pi} = 1^{+}$ s-wave resonances

$$\sigma_f^{obs}(E) = \sigma_f(E) + \sigma_{\gamma f}(E)$$

Can something similar be seen in gamma multiplicities?

STEFF@EAR2 ^{239}Pu Experiment

- Target 25cm^2 ^{239}Pu at $30\,\mu g\ \mathrm{cm}^{-2}$
- Both STEFF arms with Small Collimator
- Neutron energy range thermal - 10 MeV
- 6×10^{18} protons (~60 days running time)
- 10 (5”x4”) NaI + 6 small LaBr3
- 2×10^{6} Fragment-gamma events with A,Z,E
- ~5 fissions per pulse