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γ-ray Energy Spectra and Multiplicities from the Neutron-induced Fission of ^{235}U using STEFF.

A.G. Smith, T. Wright, J. Billowes, J.Ryan, S.Warren, C. Gurrrero[▷◁],
L. Tassan-Got[⊗], A. Pollitt[*], O.Serot[†], I. Tsekhanovich[‡]

The University of Manchester, Manchester, M13 9PL, U.K.
[▷]CERN Physics Department, CH-1211 Genève 23, Switzerland.
[◁]Universidad de Sevilla, Sevilla, Spain
[⊗]IPN, Université Paris-Sud, 91406 ORSAY Cedex, France
[‡]Université de Bordeaux 1, Talence Cedex 33405, France
[†]CEA-Cadarache, DEN/DER/SPRC/LEPh, France
[*]Institut Laue-Langevin, 6 rue Jules Horowitz, 38042 Grenoble Cedex, France.

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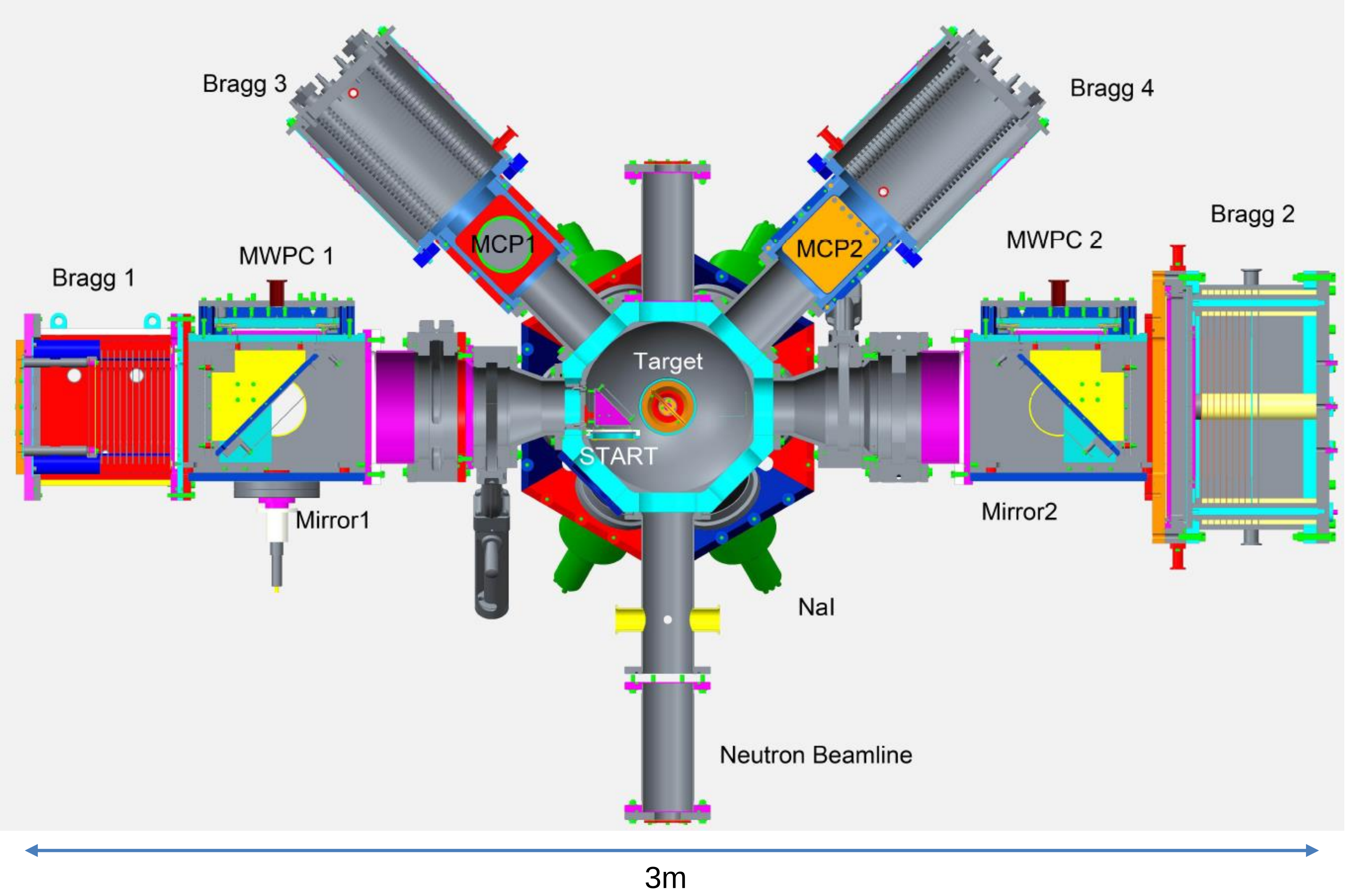
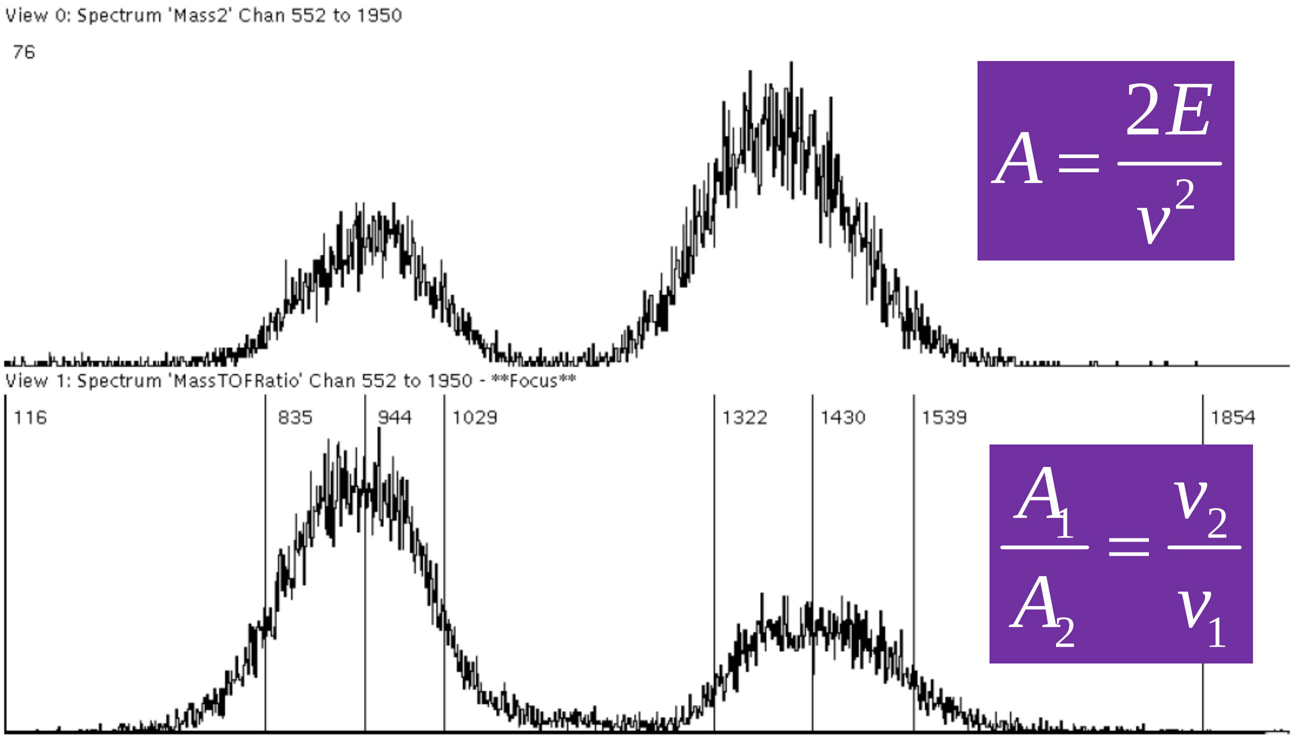
STEFF (with upgrade for EAR2)



Fragment mass measurement

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



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

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

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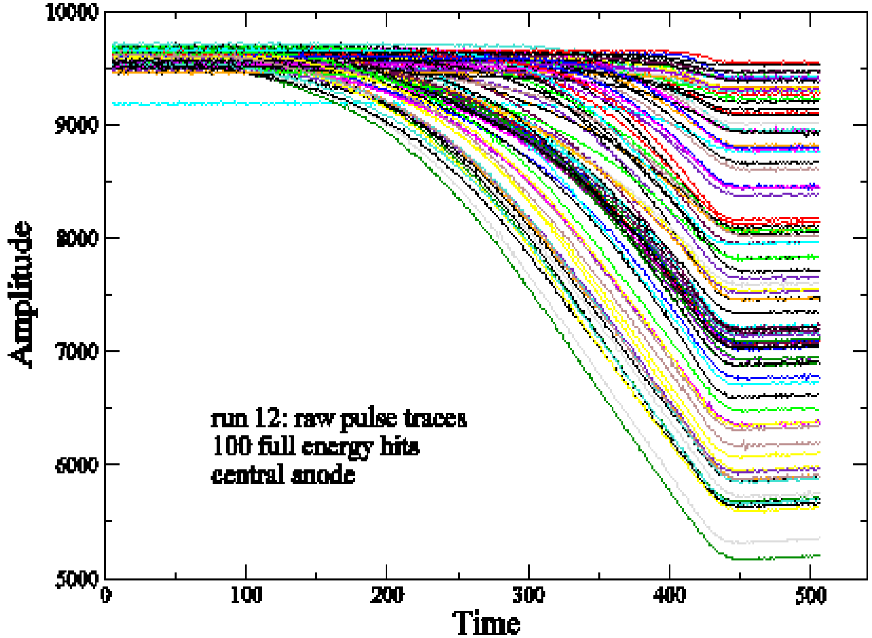
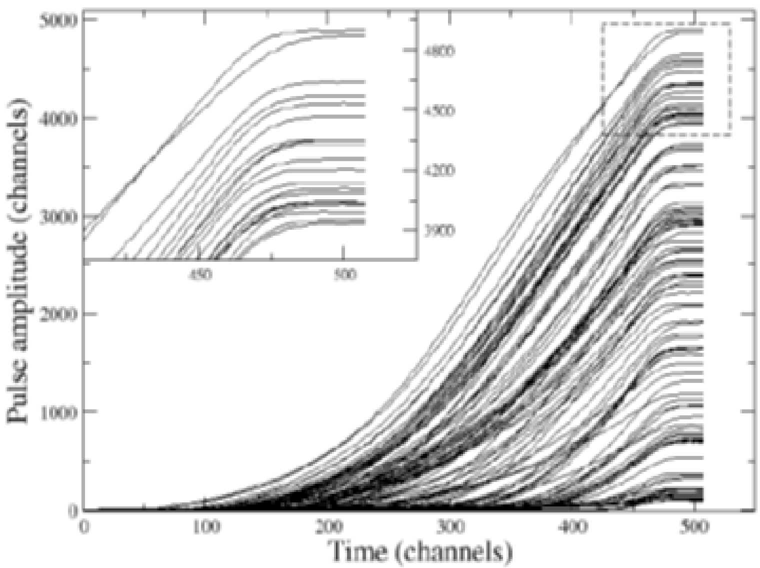
Digital Bragg Pulse Processing



- Digital Pulse Processing:
- High-pass filter
- Ballistic Def. Correction



- Integration
- Low-pass filter: noise reduction
- Currently Noise ~0.2 percent

Nuclear charge distribution for light mass group

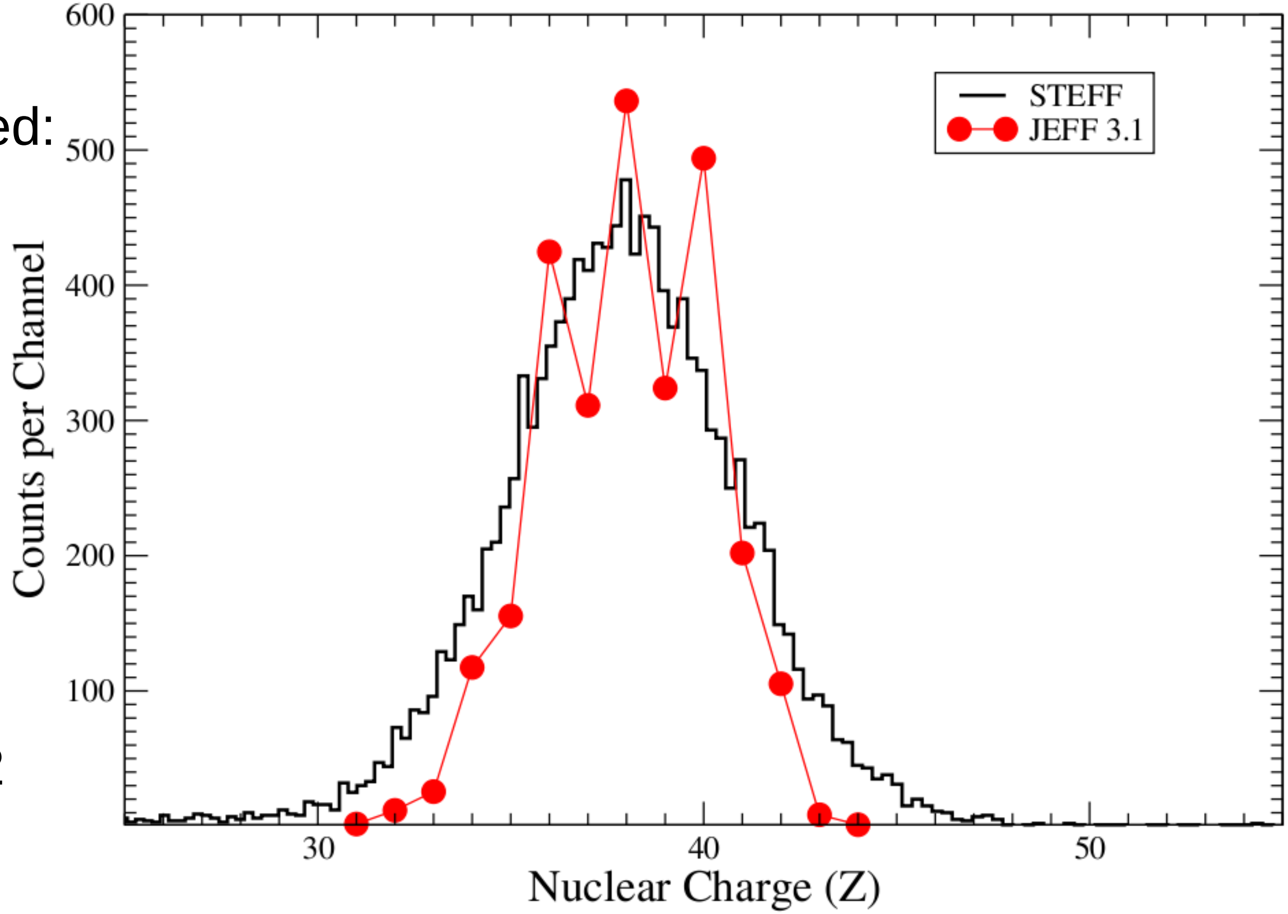
IC measurements, when velocity if fixed:

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

Where

$$b = 2/3$$

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



Gamma-ray Energy and Multiplicity

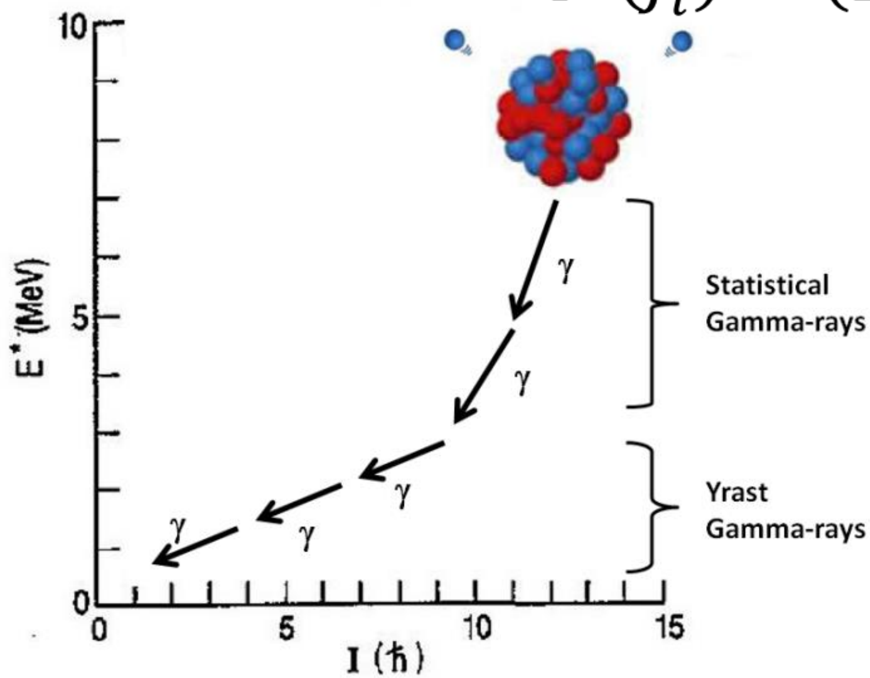
- Response to NEA High Priority Request of more accurate knowledge of heating caused by gamma emission in the next generation of nuclear reactors
- Coincidence with emission of prompt gamma rays as a function of the fragment mass and energy
- 12 NaI detectors around the uranium target provide a 6.8%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

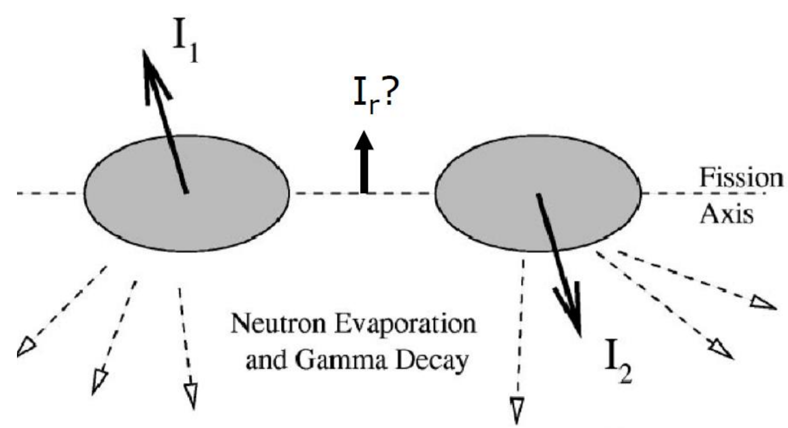
Gamma decay of fission fragment

Spin linked to γ **multiplicity** and **feeding** by statistical models.

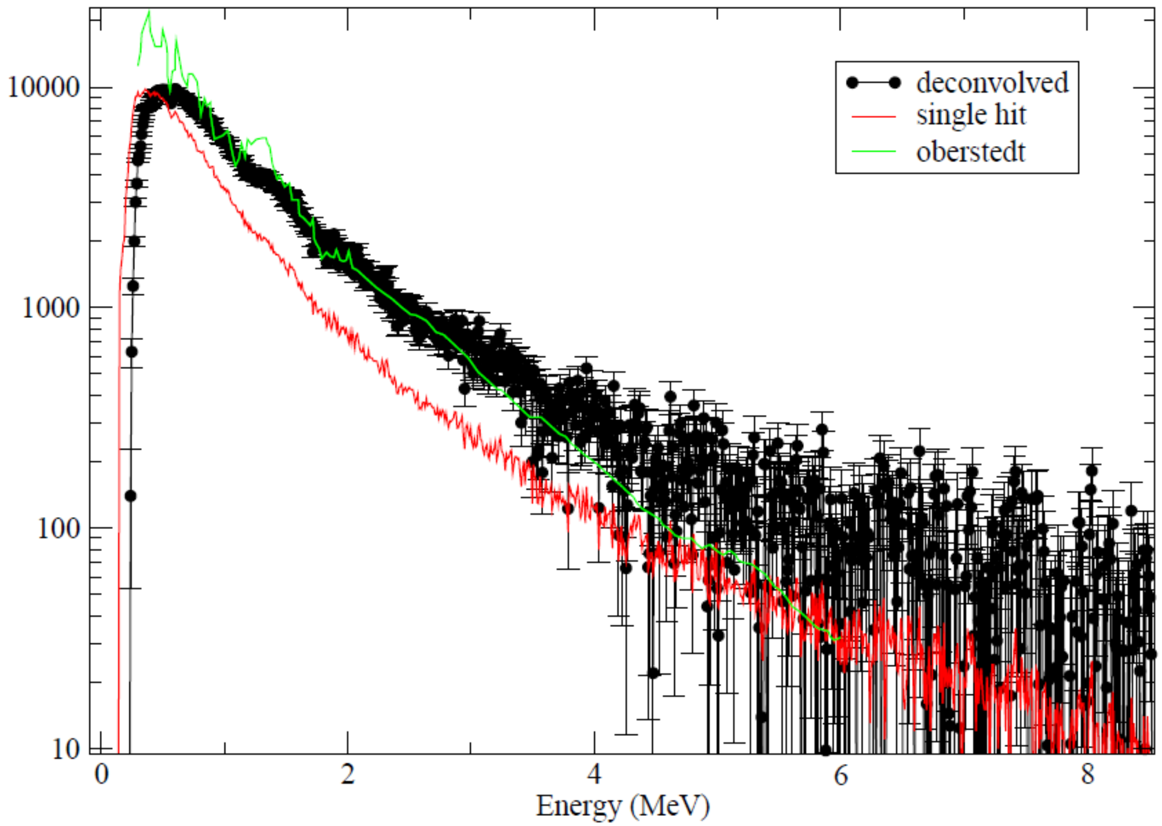
Spin alignment to γ-ray **angular correlations**

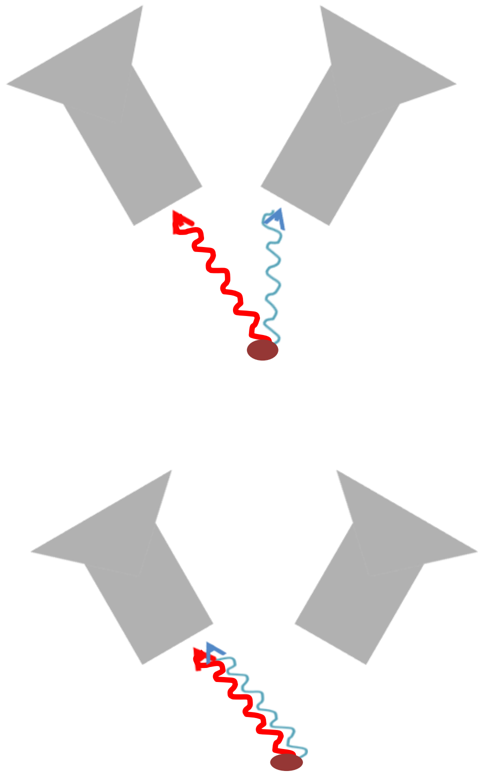
$$P\left(J_i\right) \propto (2J+1)exp\left\{\frac{(J_i+\frac{1}{2})^2)}{B^2}\right\}$$





^{235}U Single γ Energy distribution (ILL)



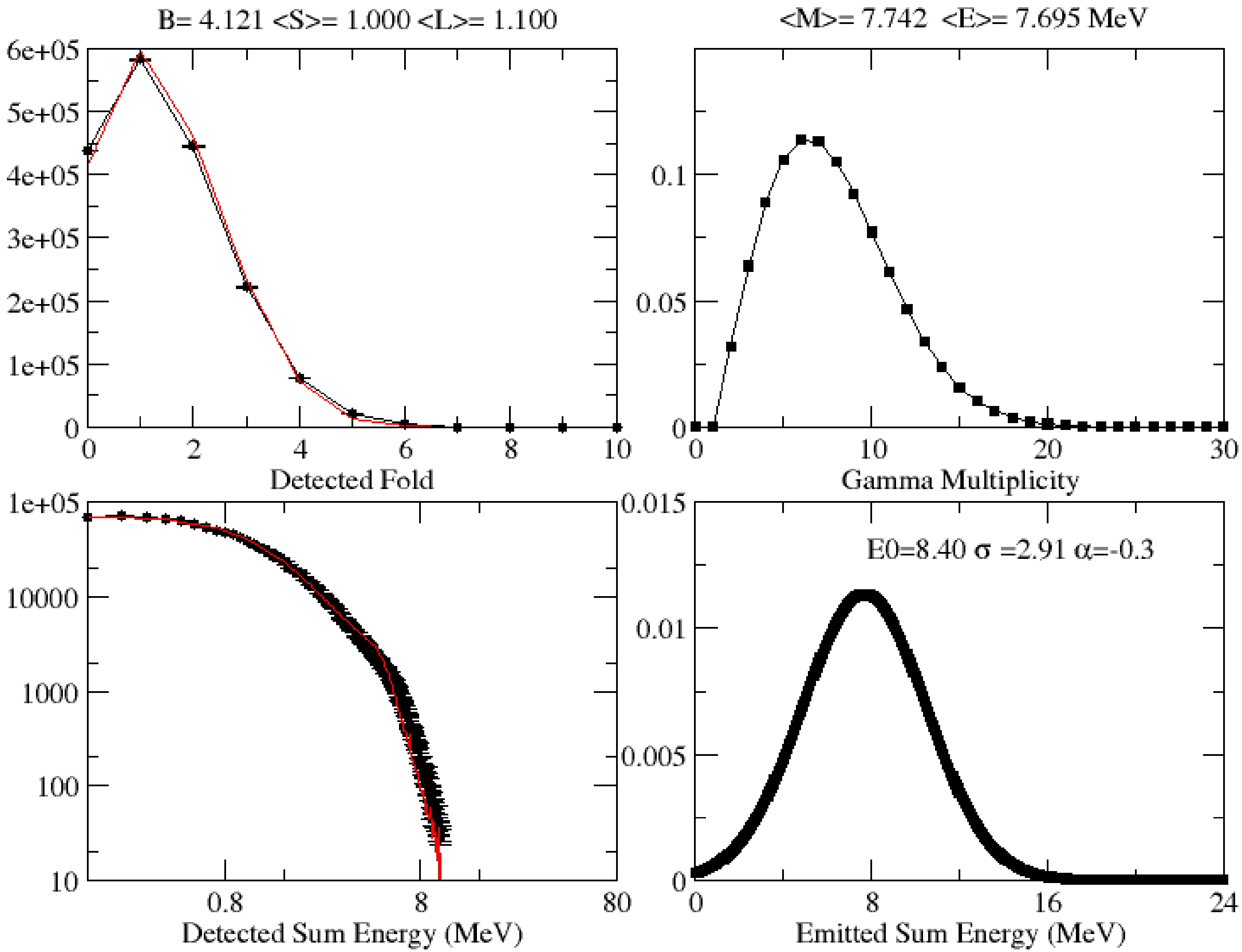


•Time random coincidences removed

•Multiple-hit effects removed (GEANT4)

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

Using GEANT4 simulations of response functions of NaI detectors



Fragment Angular Distributions

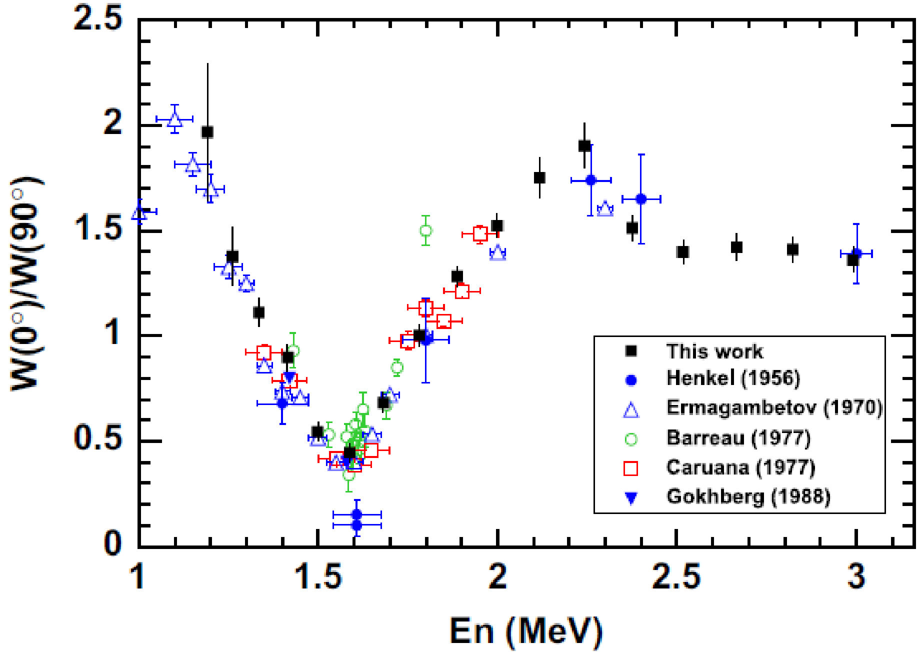


Fig. 10. Dependence of the anisotropy parameter on the neutron energy in the ^{232}Th(n,f) reaction. Present data are indicated by the black squares for comparison with previous results [15,19–22].

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Constrains calculations of fission barrier. STEFF: Anisotropy with A,Z,E* ?

Rate Calculation for STEFF@EAR2

- Target 25cm^2 ^{235}U at $100\,\mu g\ \mathrm{cm}^{-2}$
- Beam flux $7.54\times10^{6}\,\mathrm{n\,cm}^{-2}\times0.4\,\mathrm{s}^{-1}$
- Neutron energy range 1eV - 10 MeV
- 3×10^{18} protons (~30 days running time)
- Intrinsic Fragment detection efficiency 0.5*
- 5×10^{5} Fragment-gamma events with A,Z,E
- 5.6 fissions per pulse in 3ms†; Δt_{γ}~15ns

*For both fragments. Limited by efficiency of STOP : to be improved. S.Warren PhD project.
† charge collection in anodes in ~3us.

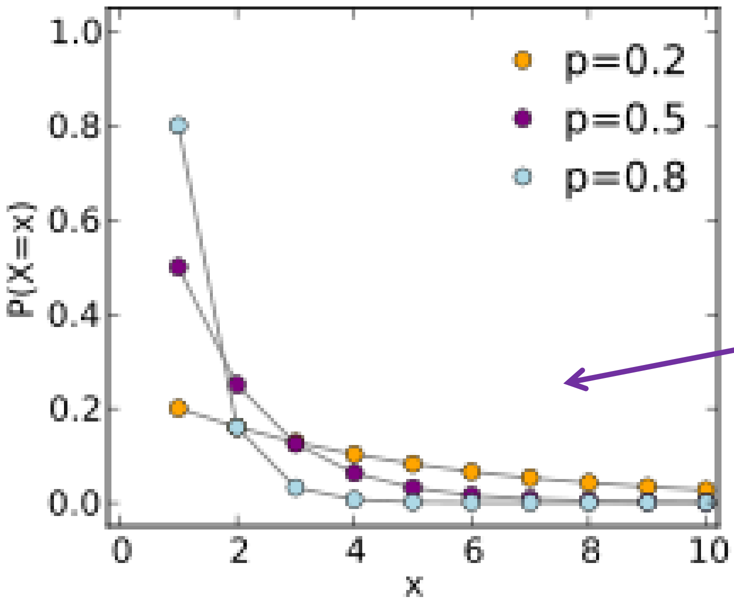
STEFF Proposal Objectives

- To move STEFF to a EAR2 to study neutron-induced fission.
- Measurement of E,A,Z and directions of fragments.
- Use gamma multiplicities and angular distributions 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).

Monte Carlo simulation (decay)

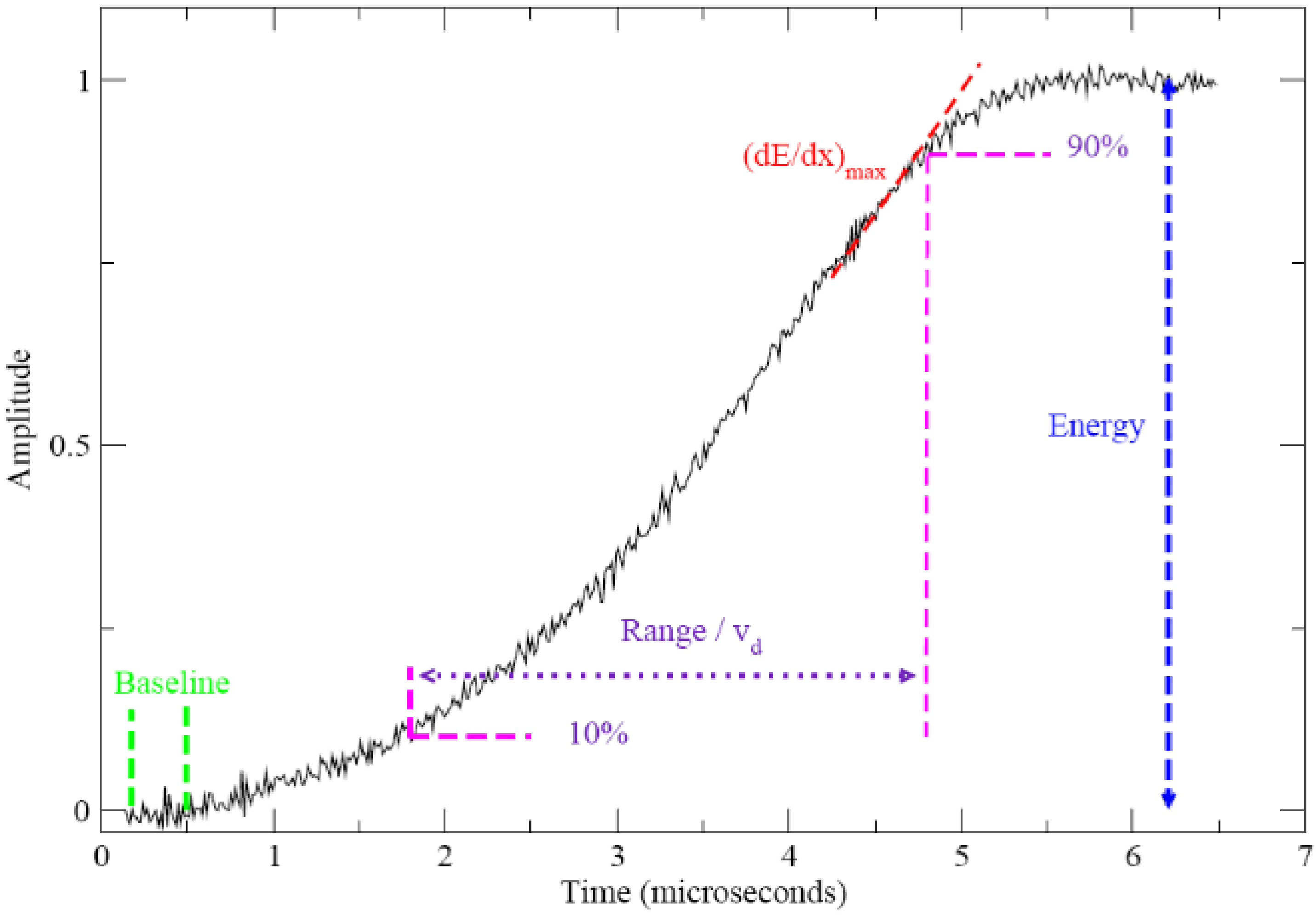
Probability of spin state is generated based statistical model:

$$P\left(J_i\right) \propto (2J+1)exp\left\{\frac{(J_i+\frac{1}{2})^2)}{B^2}\right\}$$



- Number of yrast gamma rays linked to mean spin ~ B.
- Geometric distributions give statistical gamma rays for each fragment.
- Interaction with array: ε, scattering

Characteristics of bragg pulse



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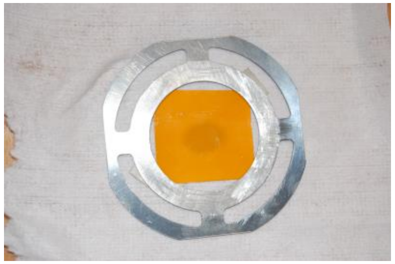
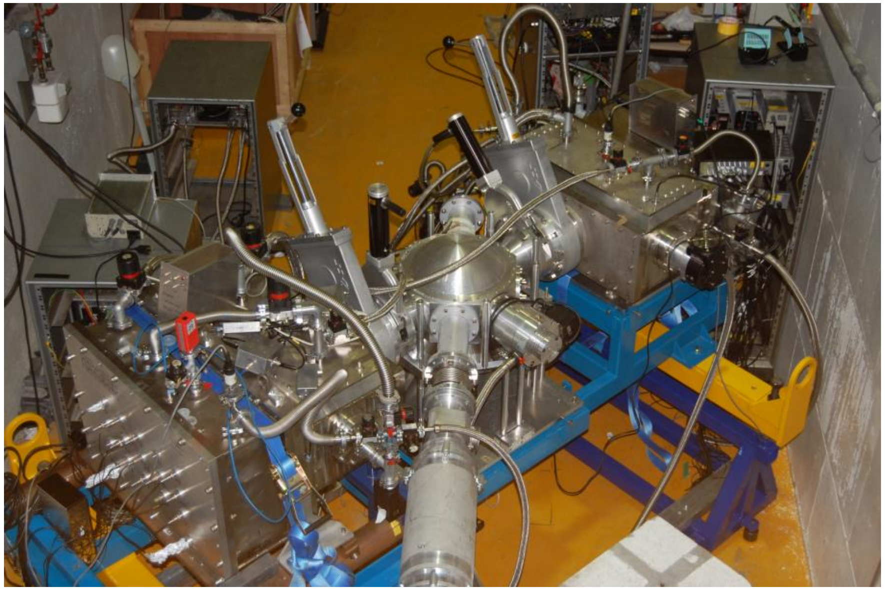
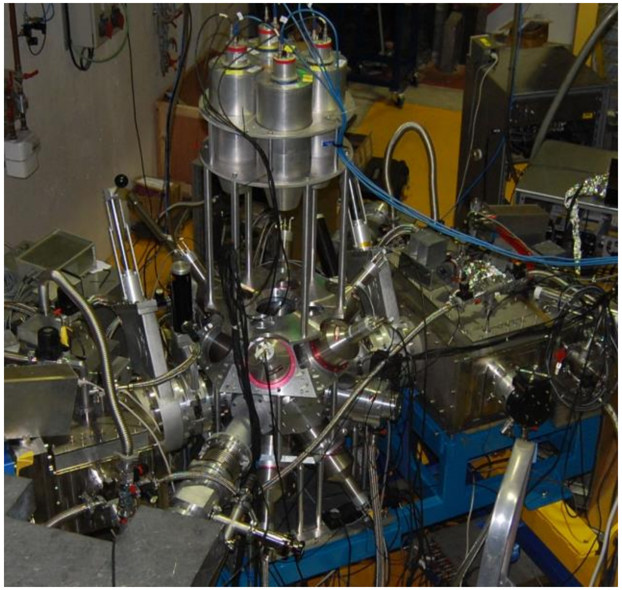
STEFF @ ILL

- Installed in pf1b Institut Laue-Langevin, Grenoble for 2x 25 days
- ^{235}U target $100 \mu g cm^{-2}$ on a Nickel backing
- Thermal neutron flux 1.8×10^{10} neutrons $cm^{-2} s^{-1}$
- Measured mass resolution 4 amu

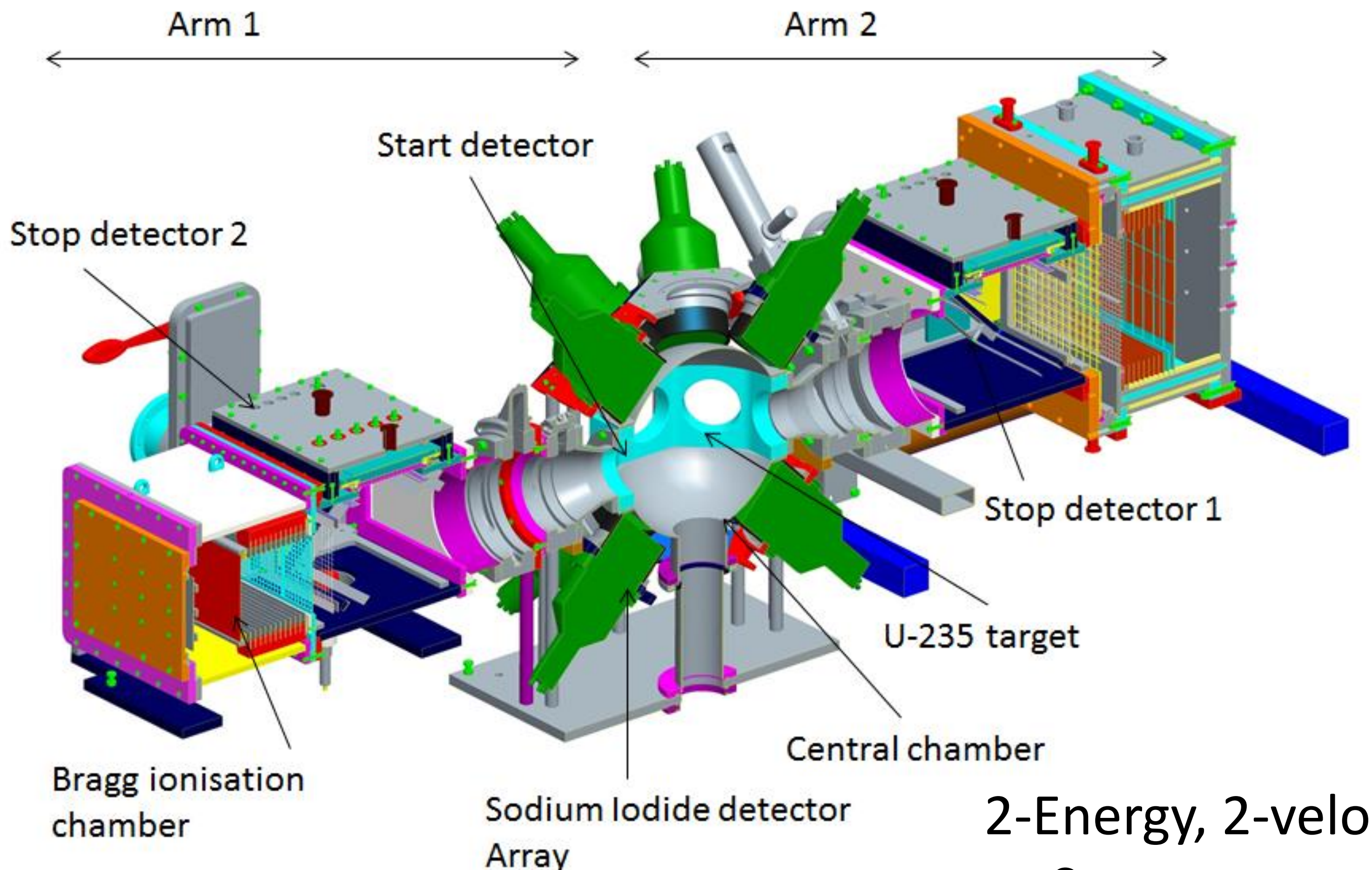






Design

Solid angle 60 mstr



2-Energy, 2-velocity
Spectrometer.