MANCHESTER 1824

The University of Manchester

Prospects for STEFF at EAR2

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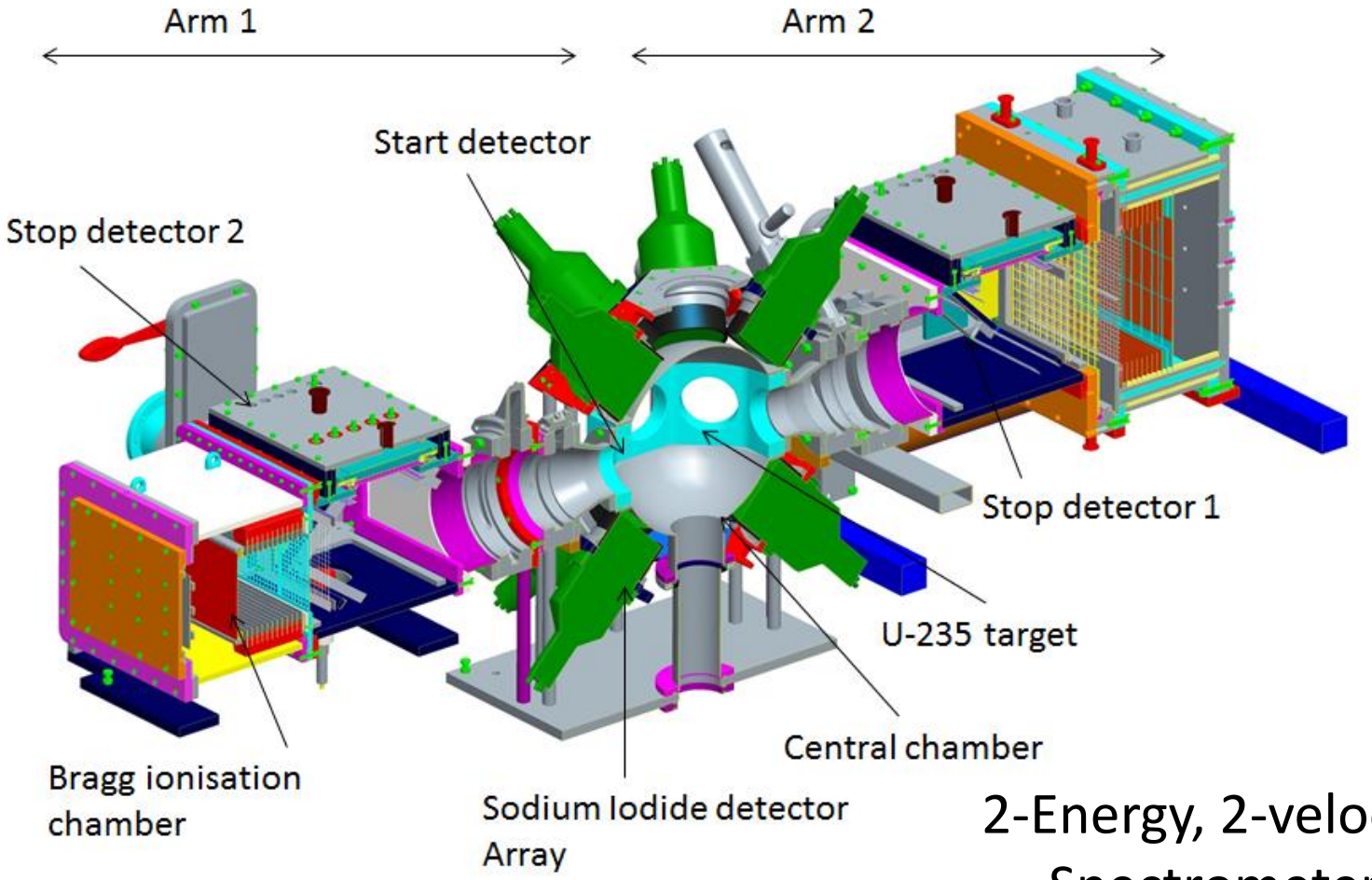
STEFF Design Objectives

- Binary spectrometer for fission fragments.
- Direct measurement of Energy, Mass, Atomic number and direction.
- Moderate solid angle with segmentation
- Coupled to gamma and neutron detector arrays.

Design

Solid angle 60 mstr



2-Energy, 2-velocity Spectrometer.

Fragment mass measurement

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

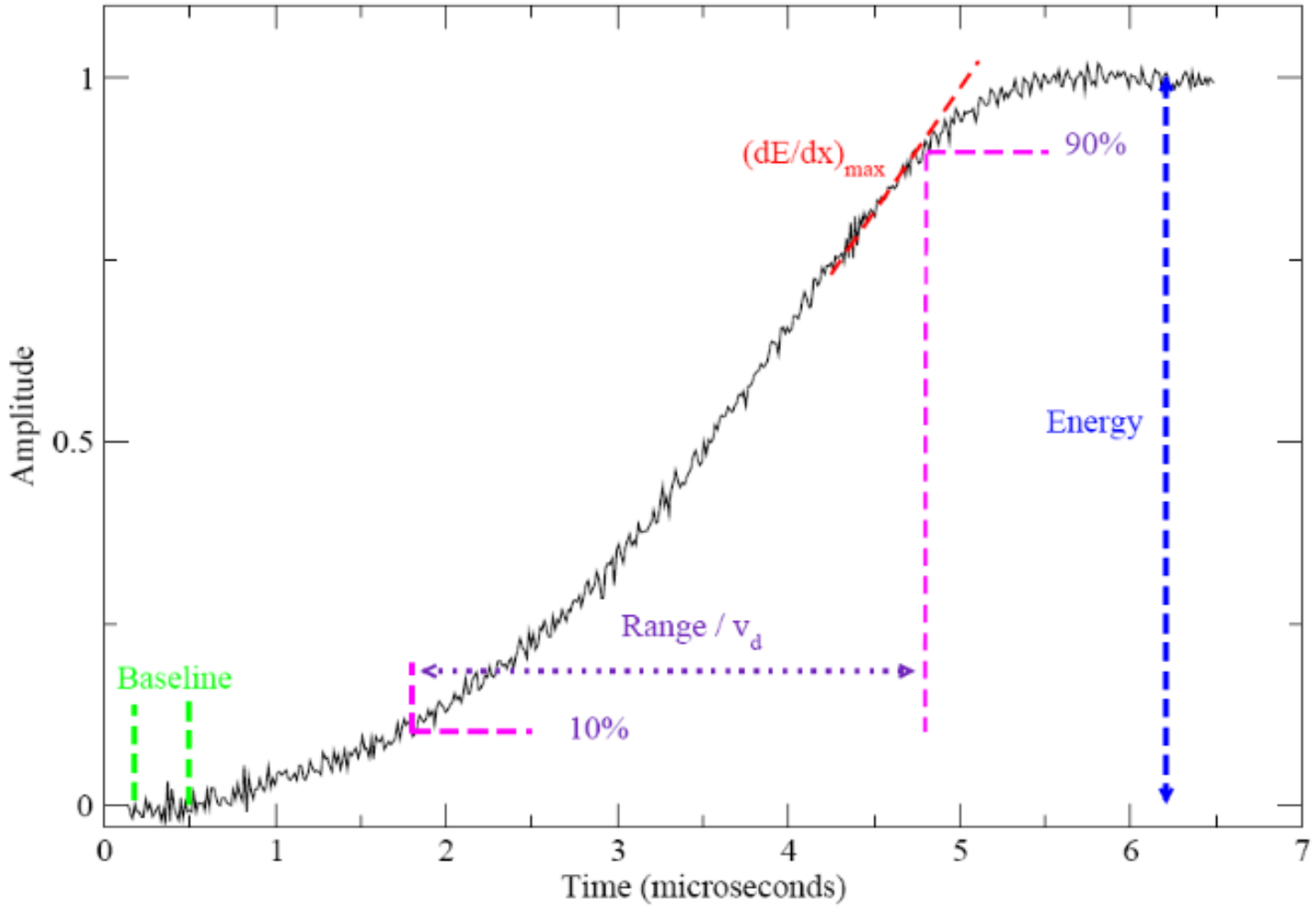
- Time-of-flight -> velocity
- Bragg Ionisation chamber->energy

$$\frac{\Delta A}{A} = \sqrt{\left(\frac{\Delta E}{E}\right)^2 + \left(2\frac{\Delta T}{T}\right)^2}$$

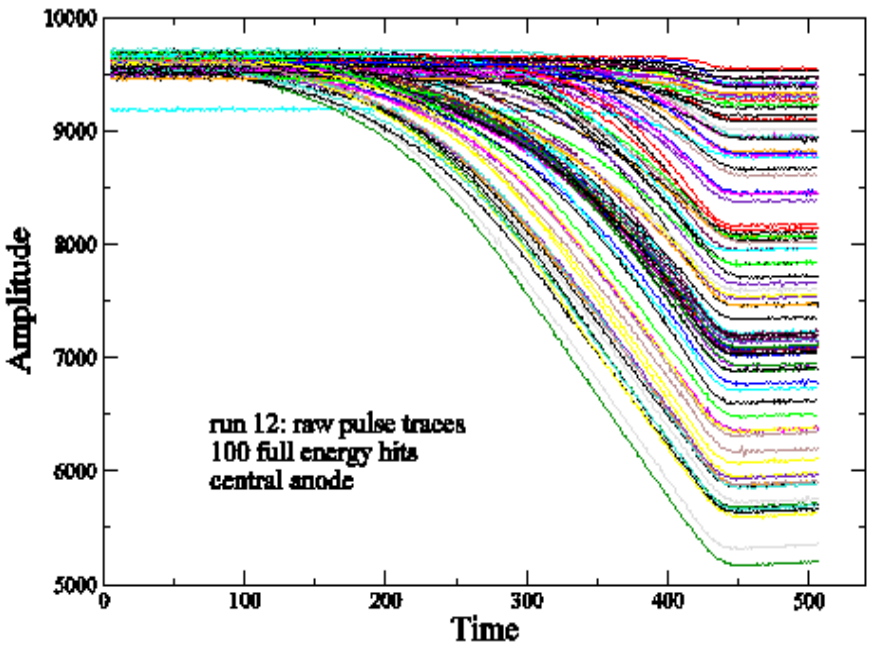
Design Objective mass resolution

2.2% 1% 1%

Characteristics of bragg pulse

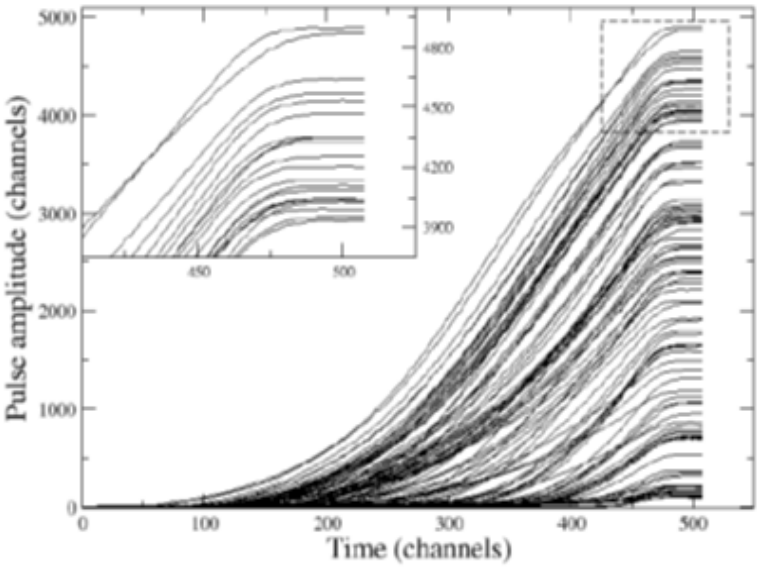


Digital Bragg Pulse Processing



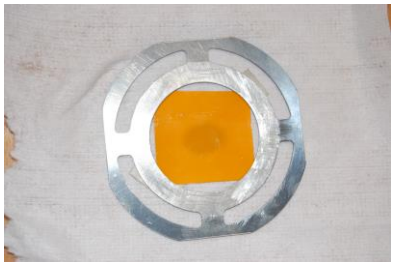
- Digital Pulse Processing:
- High-pass filter
- Ballistic Def. Correction

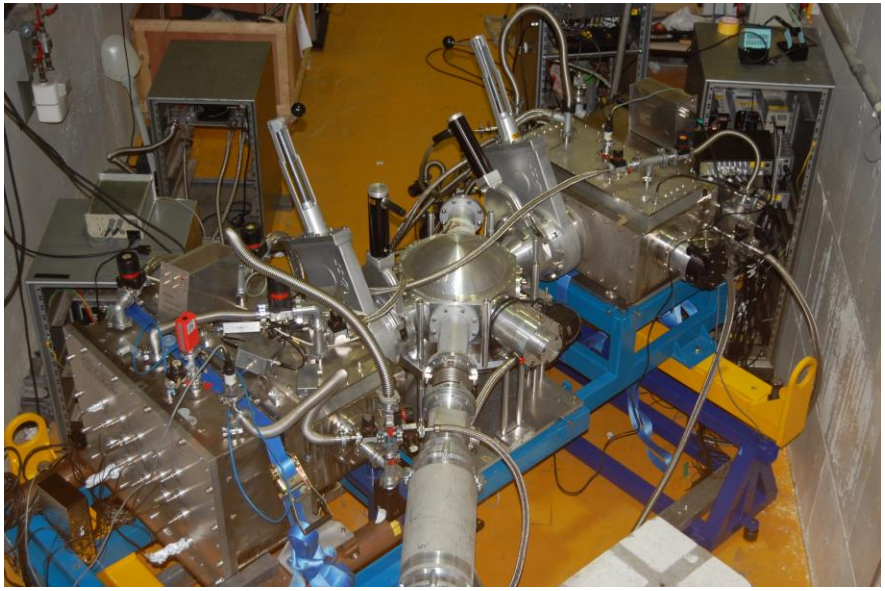
- Integration
- Low-pass filter: noise reduction
- Currently Noise ~0.2 percent

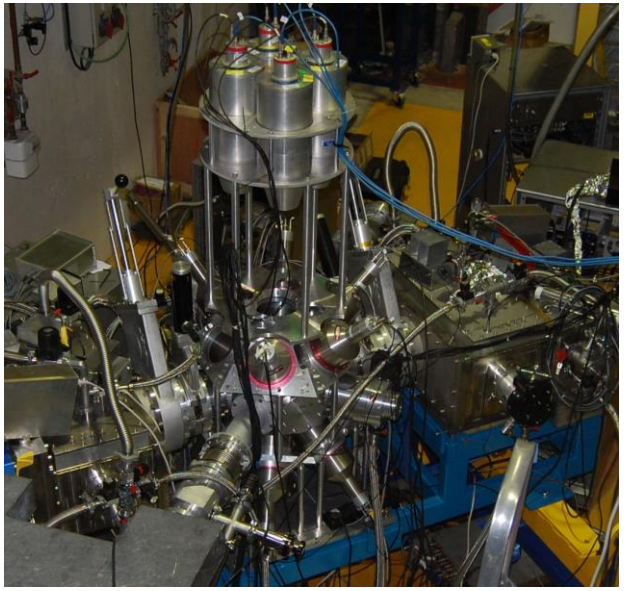


STEFF @ ILL

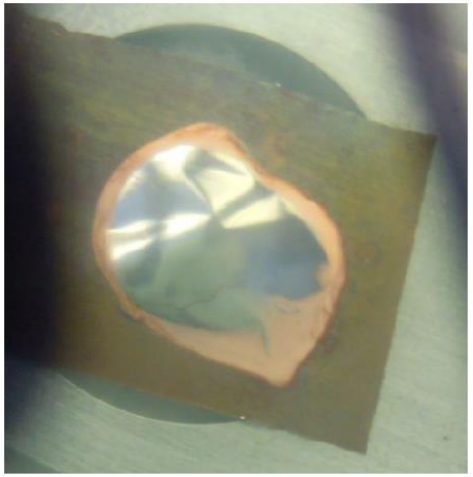
- Installed at PF1B Institut Laue-Langevin, Grenoble for 2x 25 days
- ^{235}U target 100µgcm^{-2} on a Nickel backing
- Thermal neutron flux 1.8x10^{10} neutrons cm^{-2}s^{-1}
- Measured mass resolution 4 amu



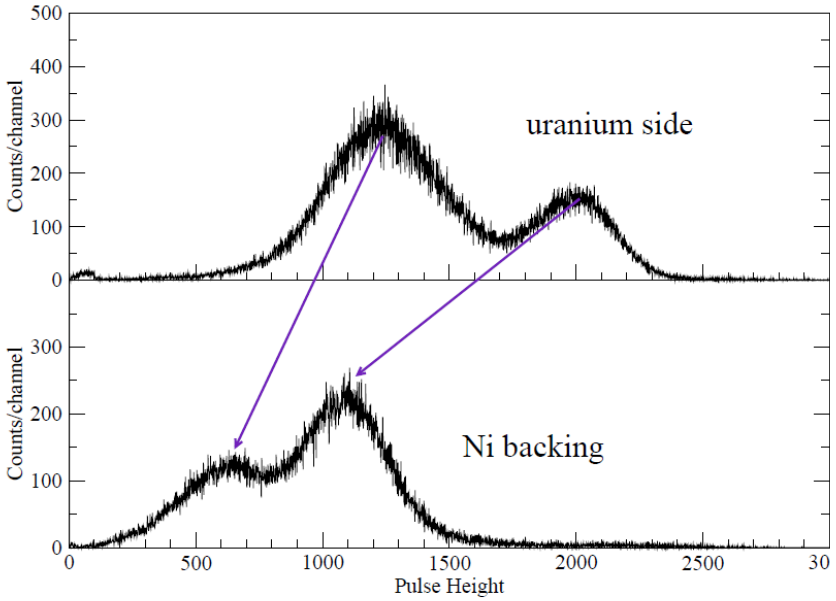


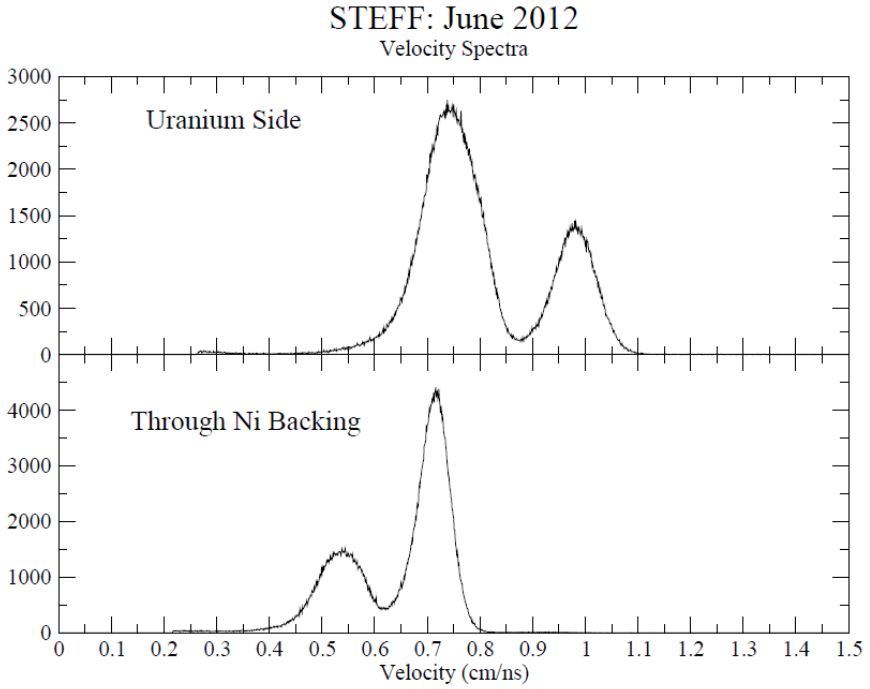


Stopping in the Target

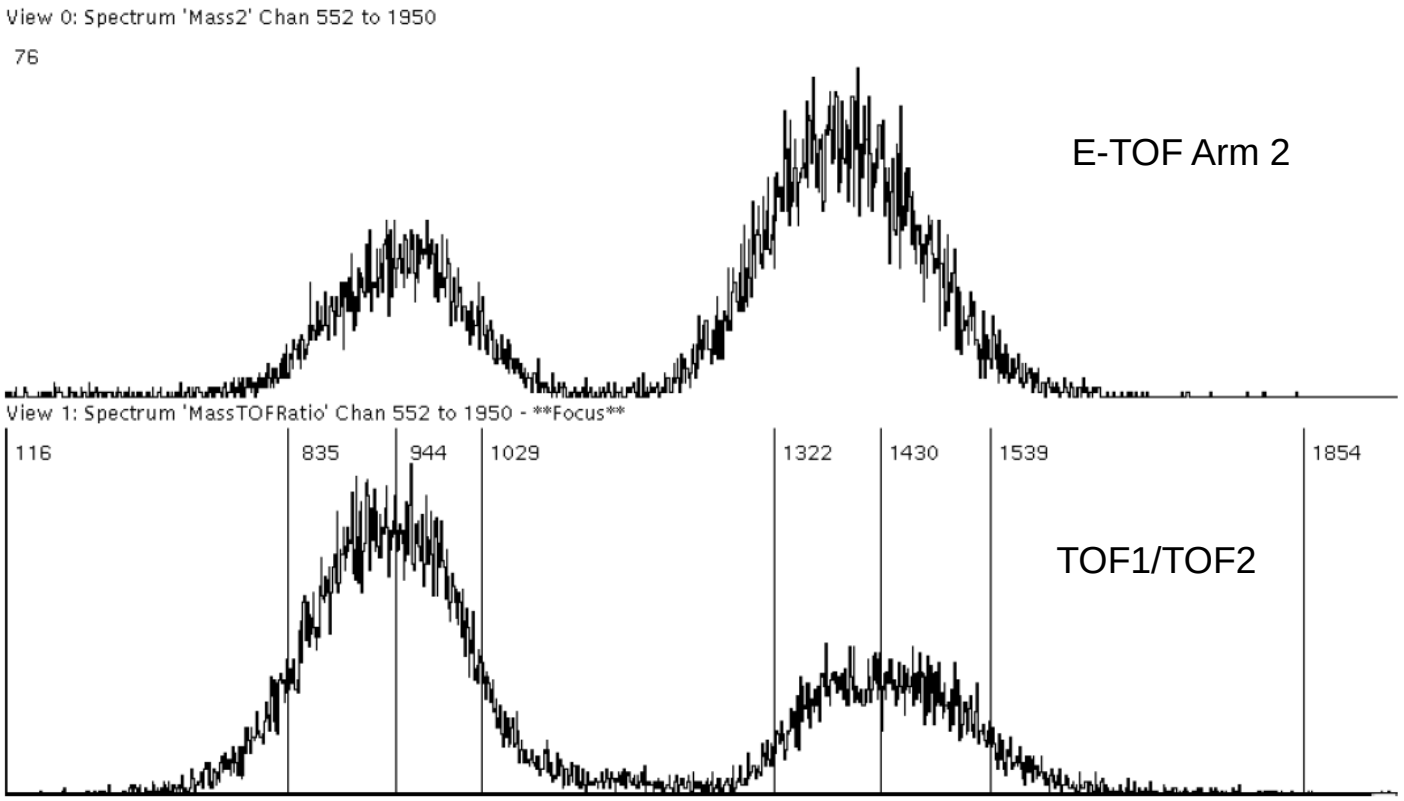


$100\,\mu g\,cm^{-2}\ ^{235}U$ on a $50\,\mu g\,cm^{-2}$ Ni foil





Two methods for mass measurement



10 chans/AMU

Nuclear charge distribution for light mass group

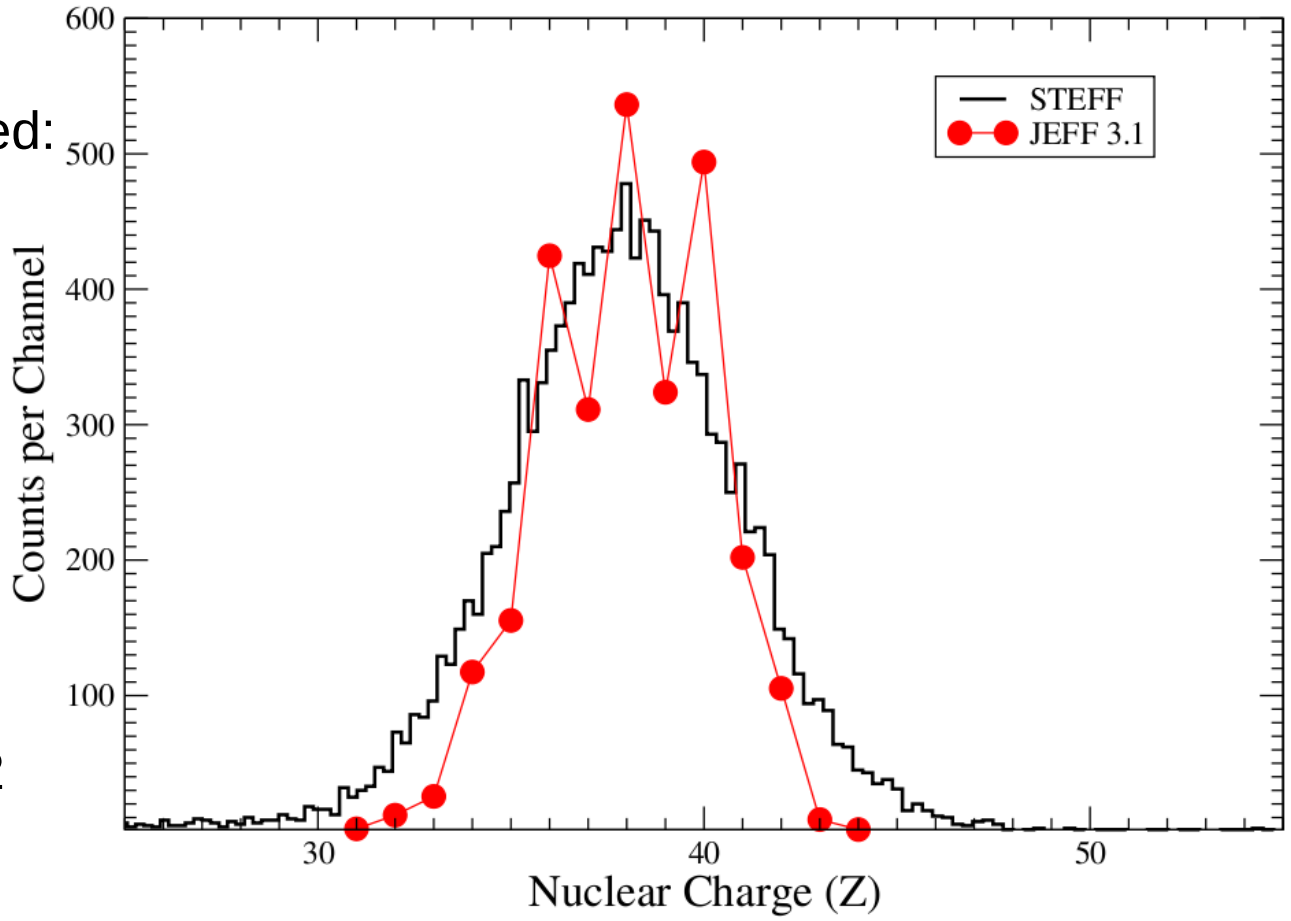
IC measurements, when velocity if fixed:

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

Where

$$b = 2/3$$

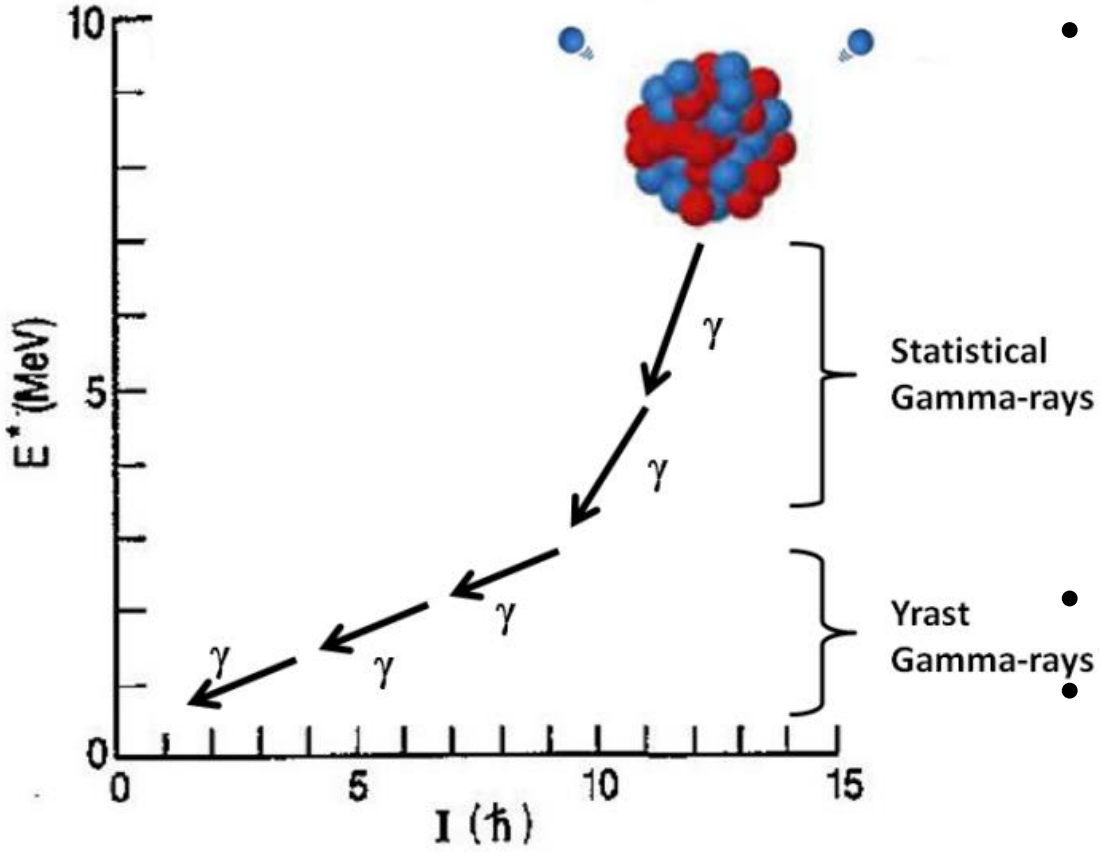
before any corrections: Sensitivity to Z (FWHM) of about 2 units.



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

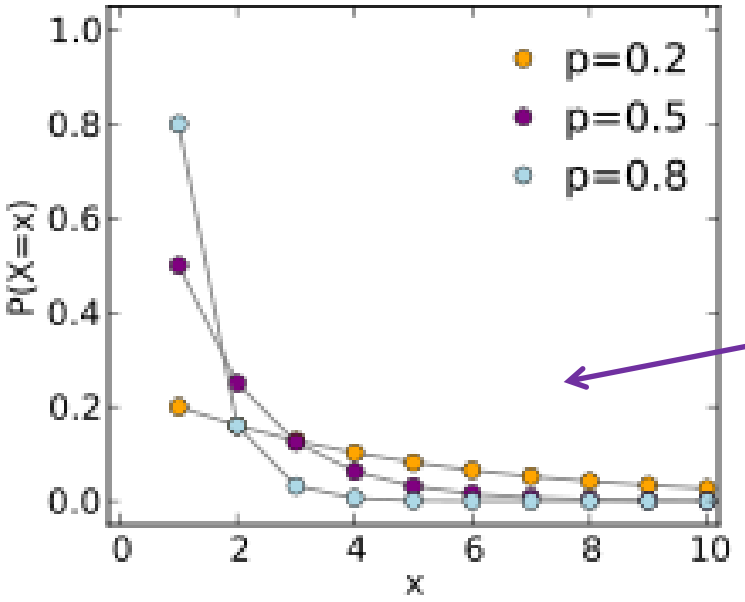


- As fragment cools, statistical and yrast emissions remove angular momentum and lower excitation energy.
- Overall multiplicity
- yrast & statistical contributions

Monte Carlo simulation (decay)

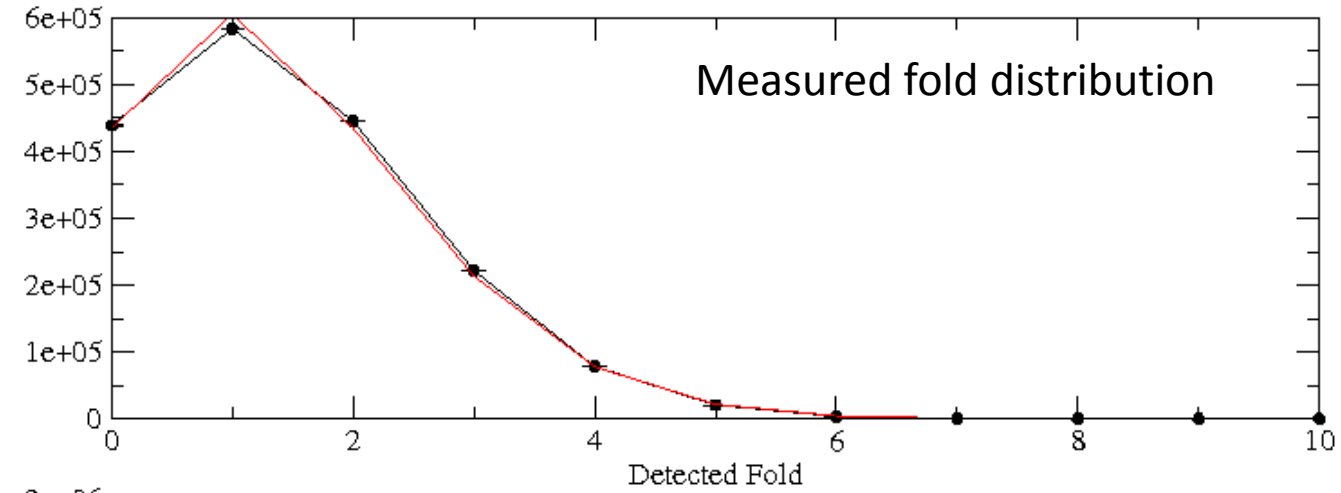
Probability of spin state is generated based statistical model:

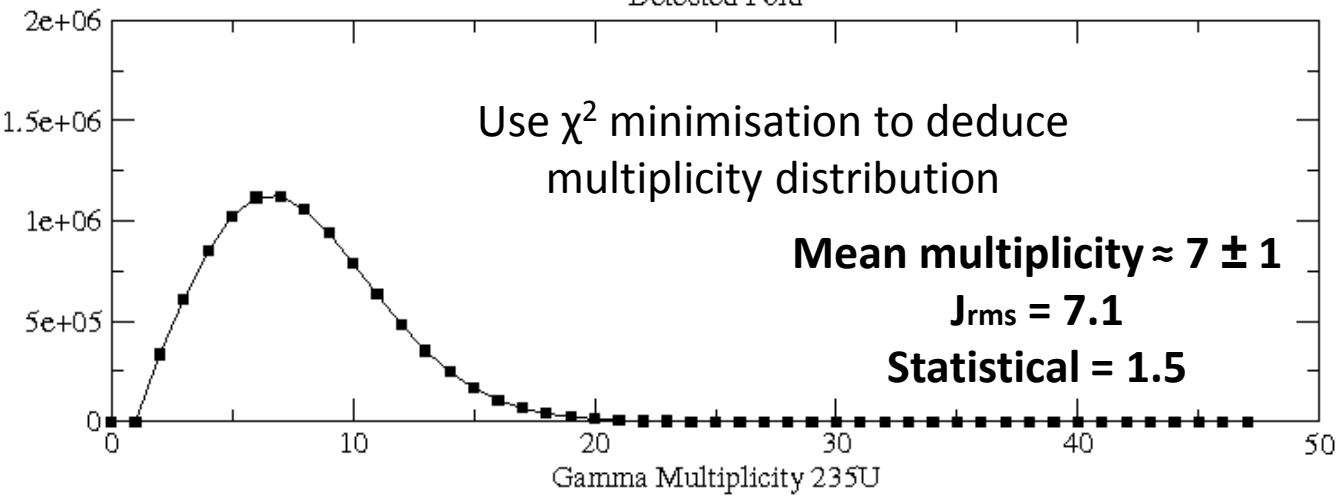
$$P(J_i) \propto (2J+1) exp\left\{\frac{(J_i+\frac{1}{2})^2)}{B^2}\right\}$$



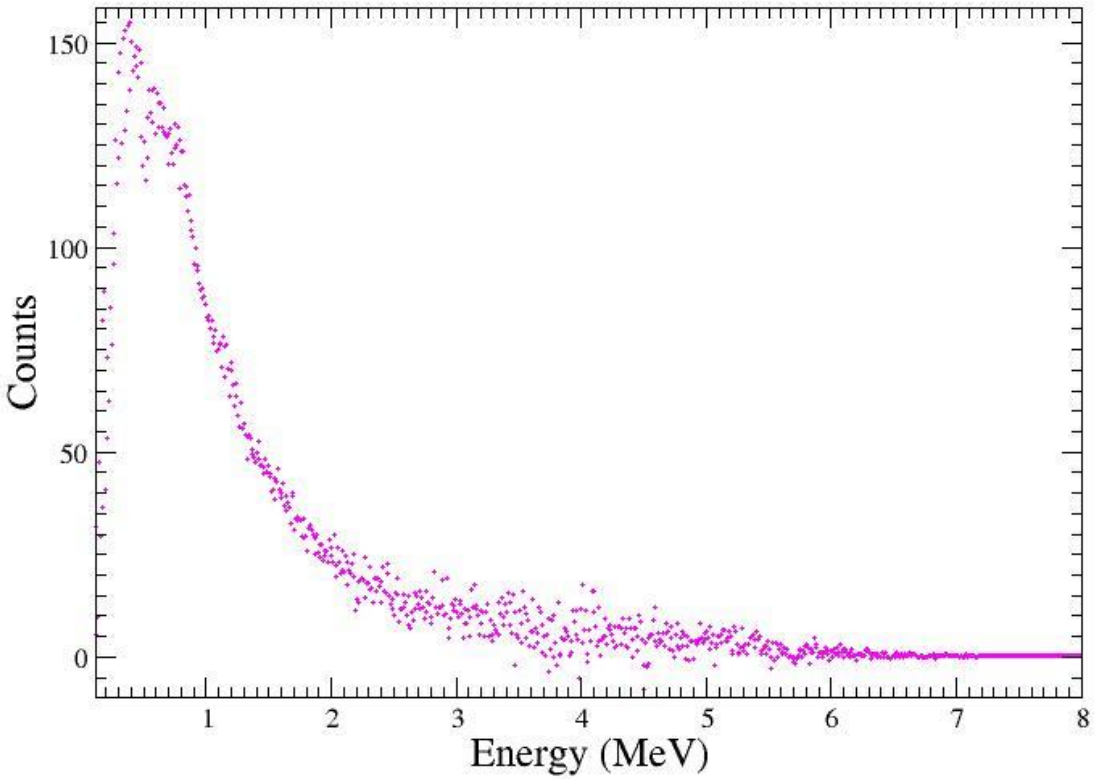
- Number of yrast gamma rays linked to mean spin ~ B.
- Geometric distributions give statistical gamma rays for each fragment.
- Interaction with array: ε, scattering

^{235}U Gamma-ray multiplicities





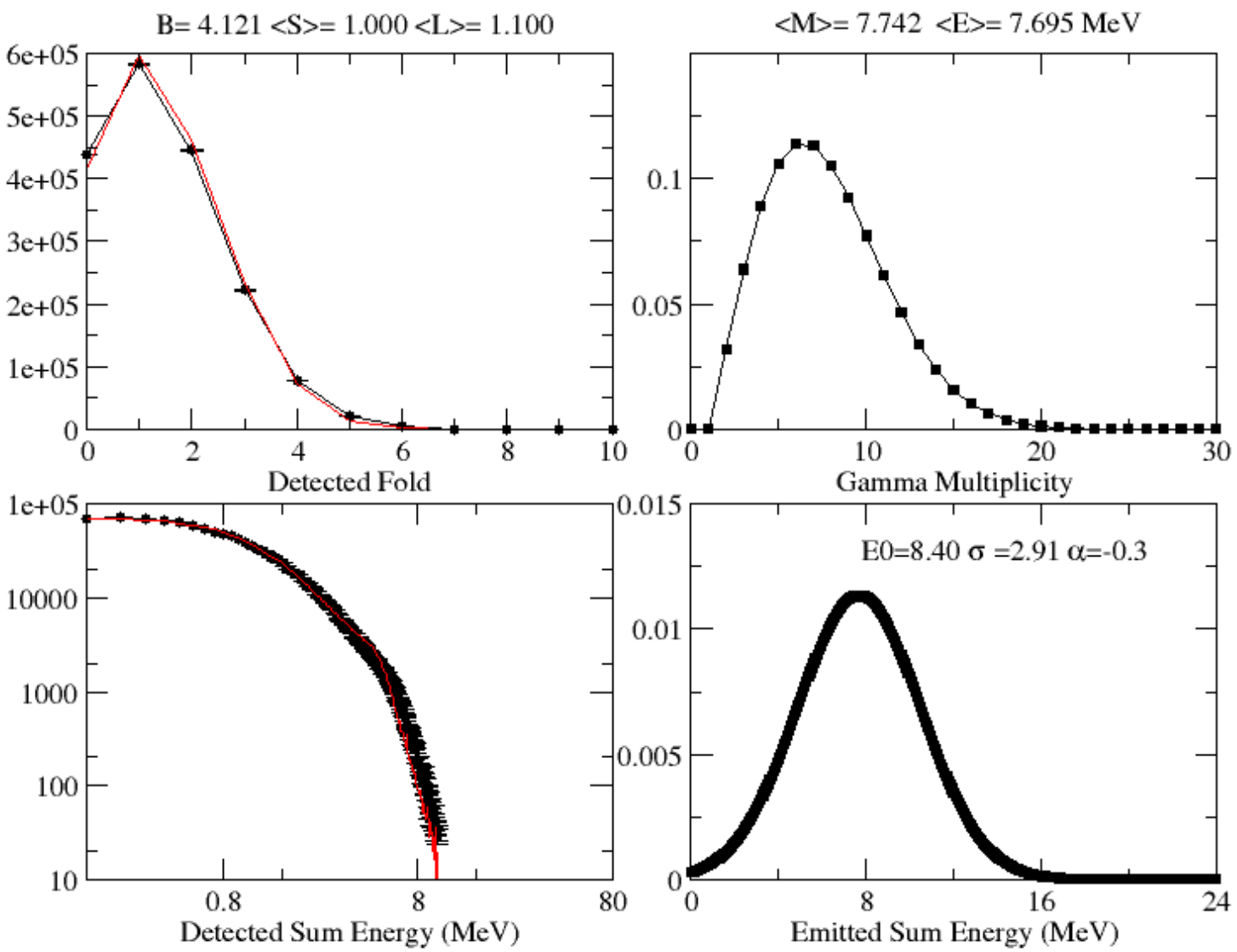
Gamma Energy Spectra



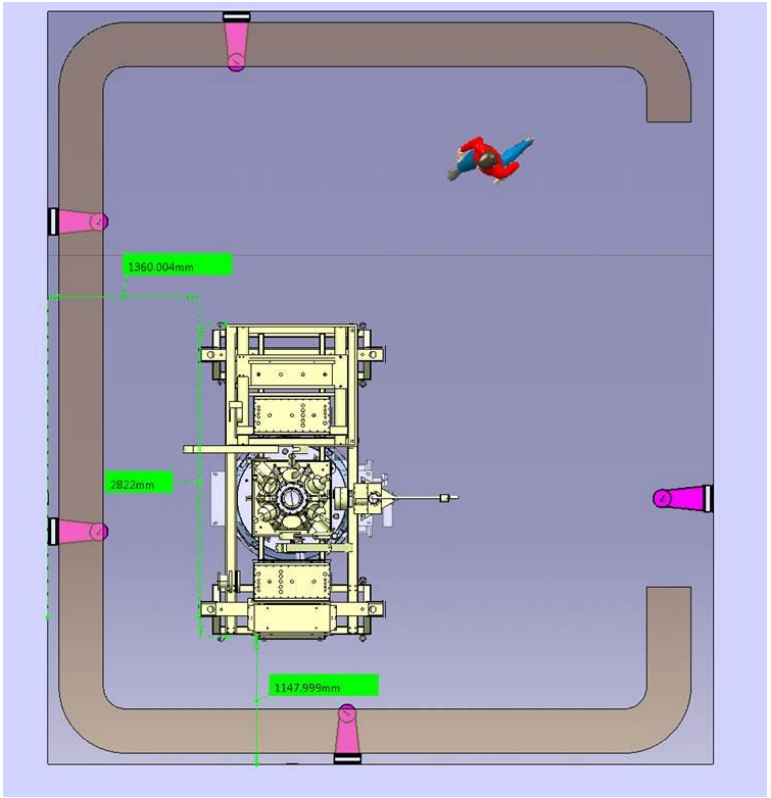
Deconvolved NaI spectra using GEANT4 NaI response functions

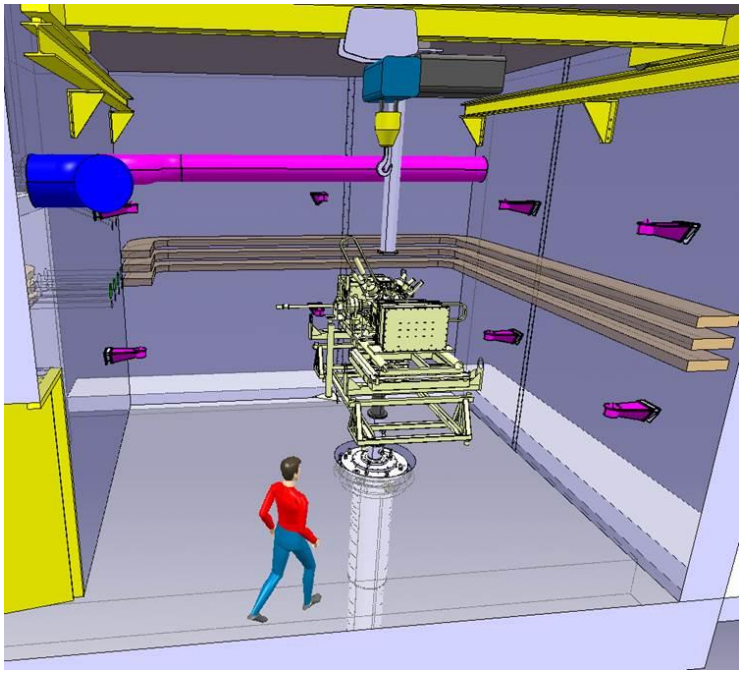
Can we combine with multiplicities to obtain Gamma Sum Energy?

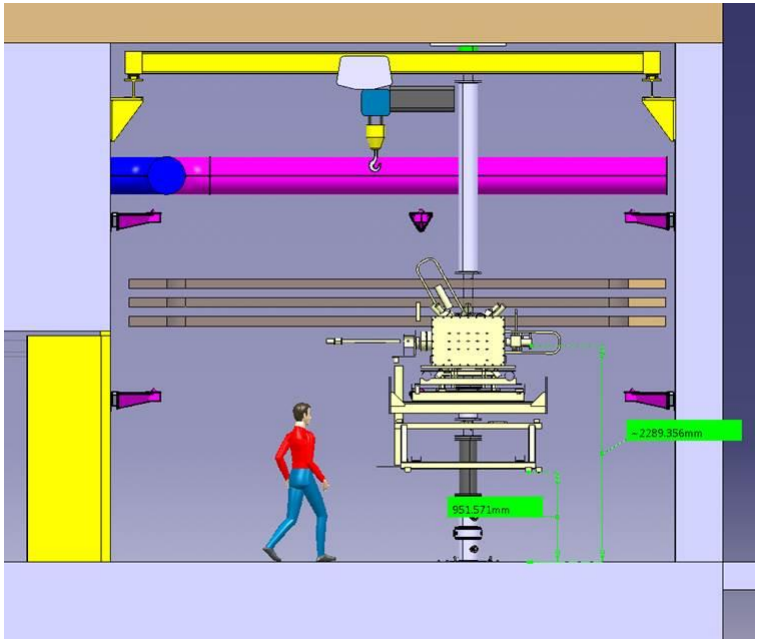
Using GEANT4 simulations of response functions of NaI detectors

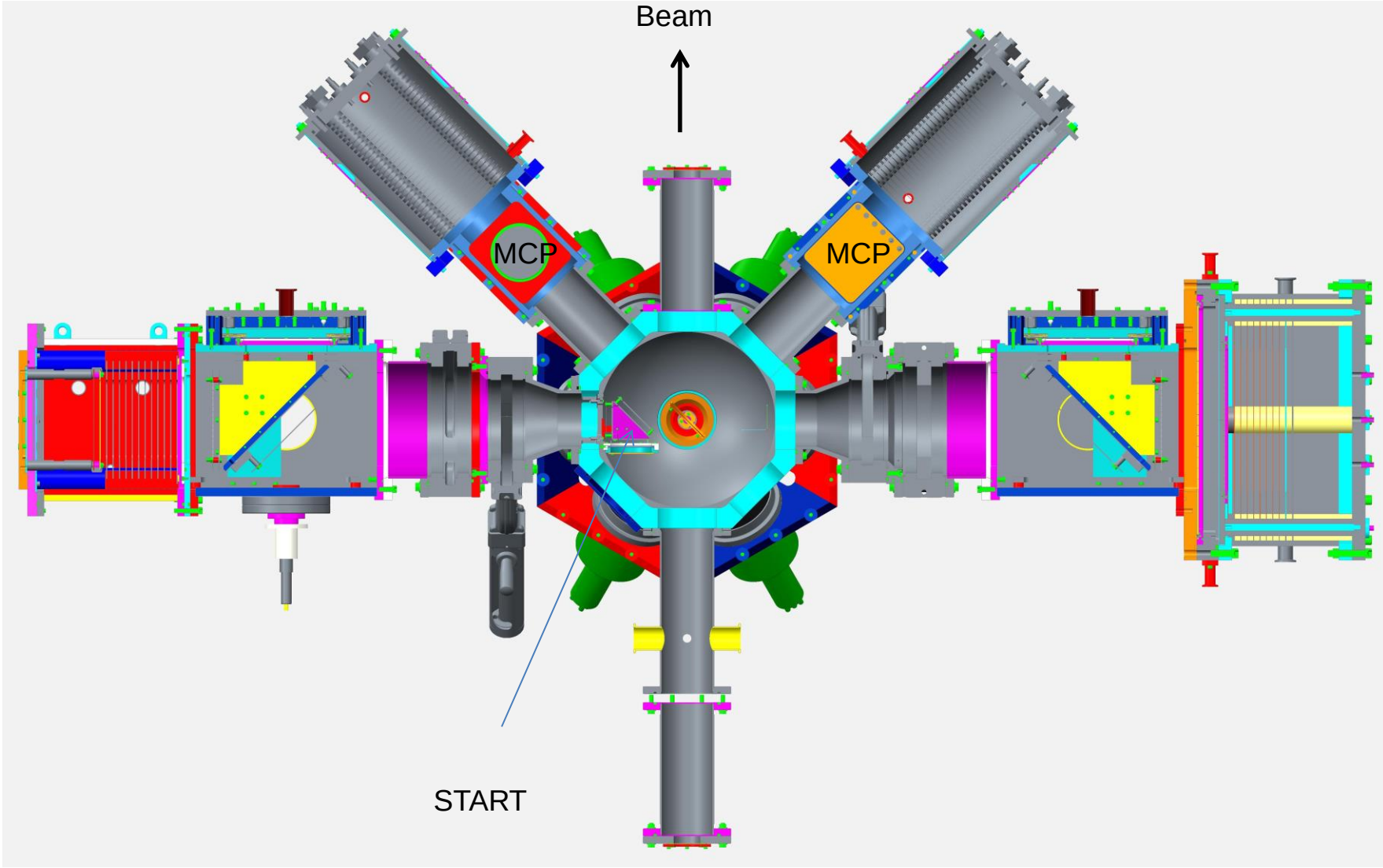


STEFF @ EAR2








Beam
MCP
MCP
START

Rate Calculation for STEFF@EAR2

- Target 25cm^2 ^{235}U at $100\,\mu g\ \mathrm{cm}^{-2}$
- Beam flux per pulse: $7.54\times10^{6}\ \mathrm{n\,cm}^{-2}$
- Neutron energy range 0.02eV - 10 MeV
- protons used 3.0×10^{18}
- Intrinsic Fragment det. efficiency 0.5-1.0*
- 2.4×10^{6} Fission 1.7×10^{6} Fragment-gamma
- Peak fissions ~5.6/pulse in 10ms†; γ Δt~10ns

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

Rate calculations: J.Ryan/T.Wright

Energy Range	Neutron Flux ($cm^{-2}\,s^{-1}$)	Fission Detection Rate (Total) per pulse	Fission Detection Rate (with TOF) per pulse	Fragment-γ per pulse
0.02-10 eV	1.64×10^6	3.88	1.13	2.66
10 eV - 1 keV	1.07×10^6	1.26	0.37	0.86
1-100 keV	1.36×10^6	0.29	0.08	0.20
0.1-10 MeV	3.00×10^6	0.15	0.05	0.11
10-200 MeV	4.78×10^6	0.03	0.01	0.02
Total	$\mathbf{7.54 \times 10^6}$	**5.62**	**1.64**	**3.85**

Analysis of system dead time effects needed

Measurements with STEFF at EAR2

- Replace single MWPCs with multi-layered MWPCs (S.Warren)
- Gamma Flash: test with NaI detector (J.Ryan T.Wright)
- Include two new arms: SED/MCP/Bragg
- Gamma Energies and Multiplicities vs. neutron energy
- Angular distributions; Fragment Angular momentum
- Ternary fission?