Dipole Strength in the $^{235}U(\gamma,\gamma')$ Reaction up to 4.4 MeV*

Olena Yevetska

- Motivation
- Experimental setup
- Extraction of B(M1) transition strength
  - discrete transitions
  - fluctuation analysis
- Summary

SFB 634

*Supported by the DFG within SFB 634

Motivation

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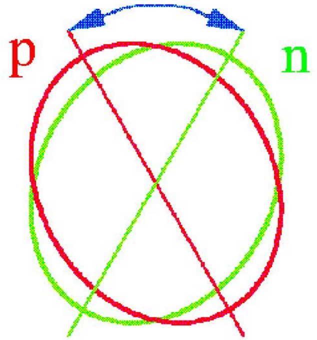
- Scissors mode: collective low-energy magnetic dipole excitation



Proton und neutron distributions oscillate about:
- their respective center-of-mass
- their respective major axes

- Deformed heavy **even**-mass actinide nuclei: ^{232}Th, ^{236}U, ^{238}U (2 – 4 MeV)
- Deformed heavy **odd**-mass actinide nuclei (coupling to an unpaired nucleon) - ?

- Tool to probe collective excitations: NRF

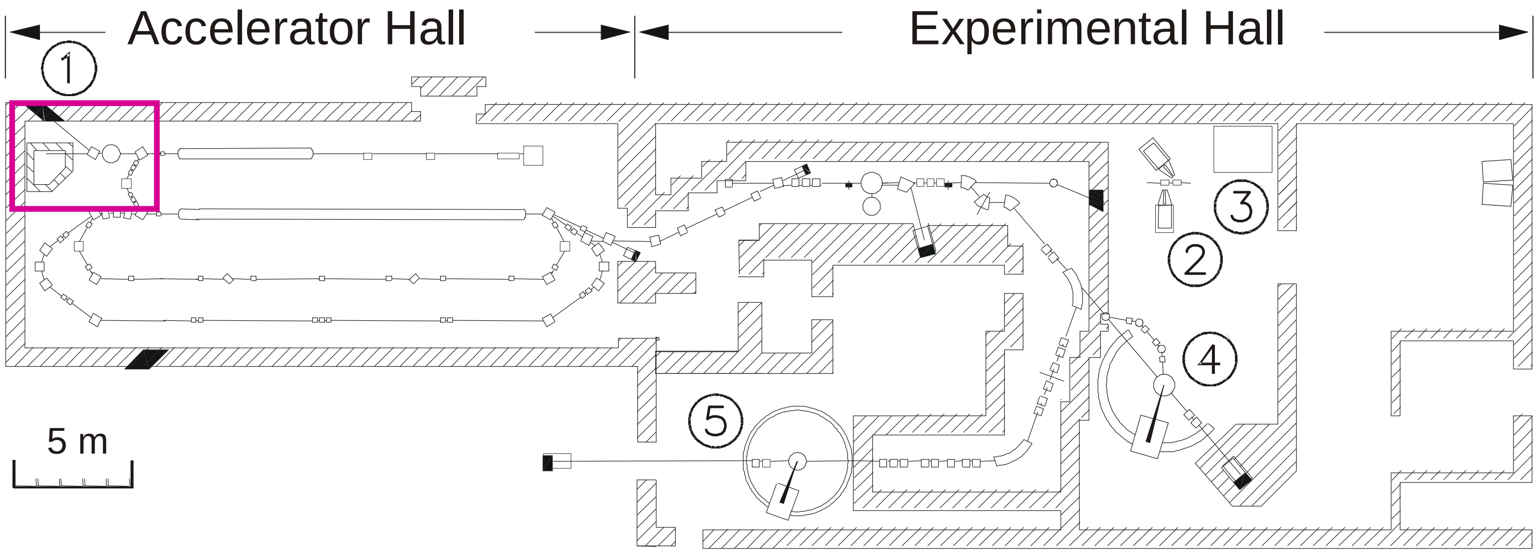
- ^{235}U

  W. Bertozzi *et al.,* Phys. Rev. **C78** (2008) 041601

  E_0 = 2.2 MeV

  Identification of HEU (nonintrusive inspection in cargo)
- This work: E_0 up to 4.4 MeV

S-DALINAC



Design Parameters

Maximum energy:	130 MeV
Energy spread :	10^{-4}
Maximum current:	20 µA
Material:	Niobium
Temperature:	2K

1. (γ,γ´) & (γ,n) - Experiments
2. Compton Scattering on Nucleon
3. (γ,γ´x)- Experiments at NEPTUN Tagger
4. (e,e´x) & 180°- Experiments at QCLAM Spectrometer
5. (e,e´) - Experiments at Lintott Spectrometer

Experimental Setup

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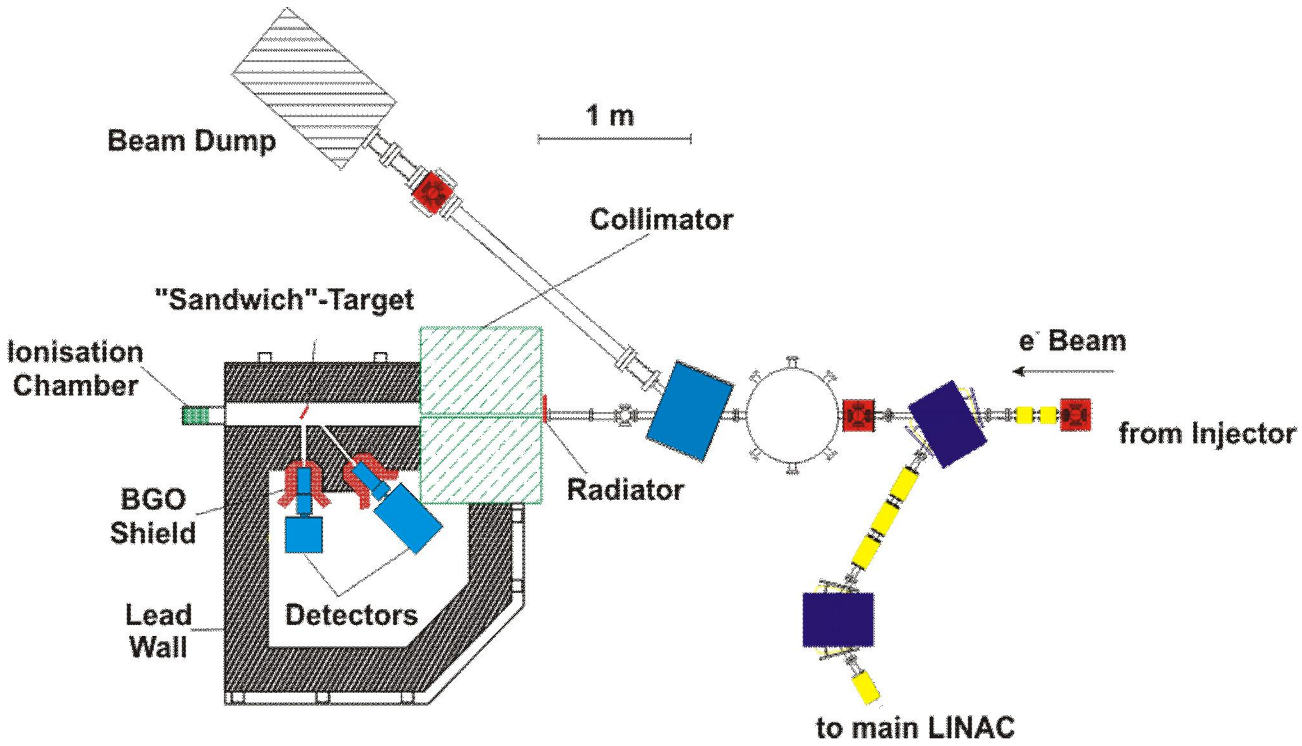
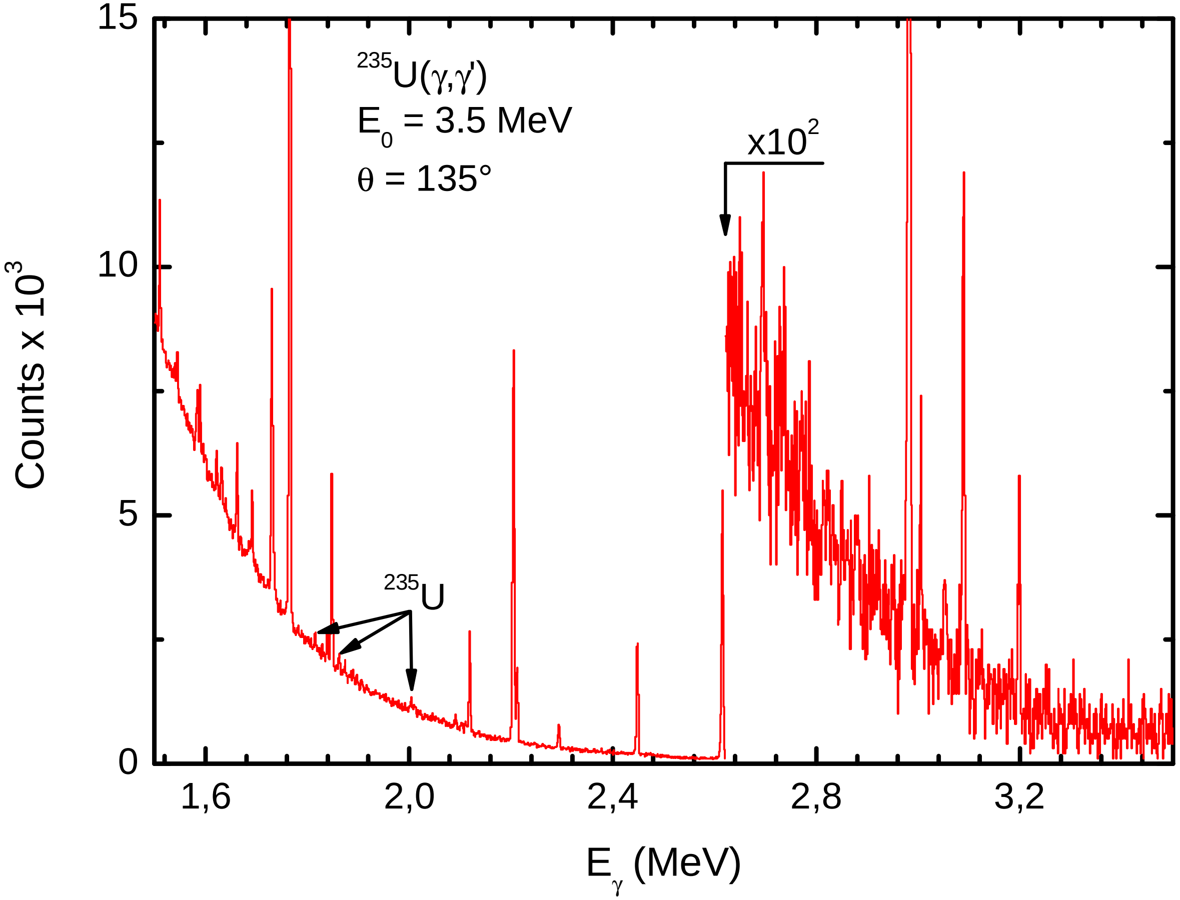


Endpoint energy E_0, MeV	3.5	4.4
Electron beam current I_0, μA	20-40	40
Beam time, days	7	7

Target: 1.303 g of ^{235}U
Calibration standard: ^{27}Al

Spectrum



Strong fragmentation → Small strengths of individual levels
Enhanced background

Cross Sections (preliminary)

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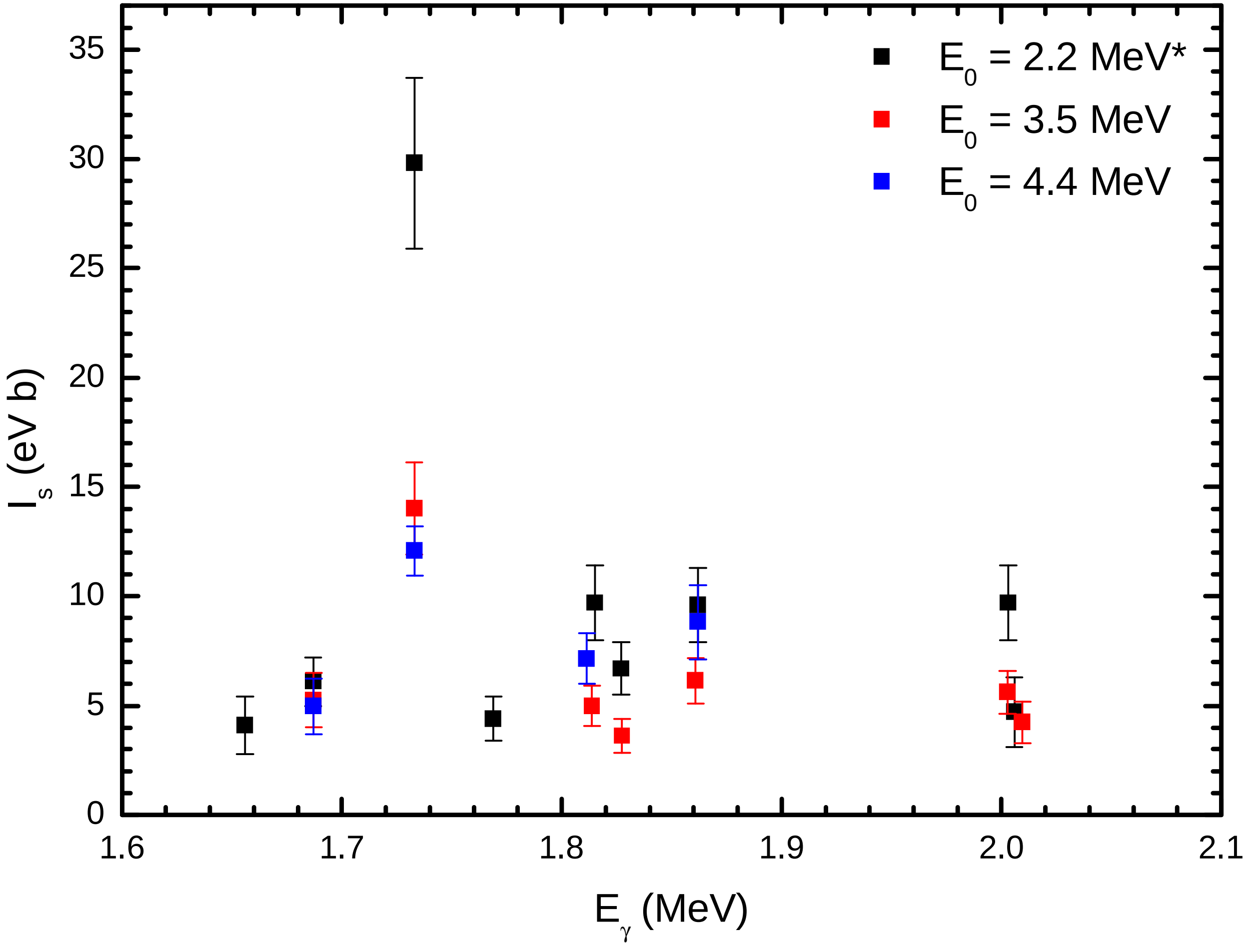
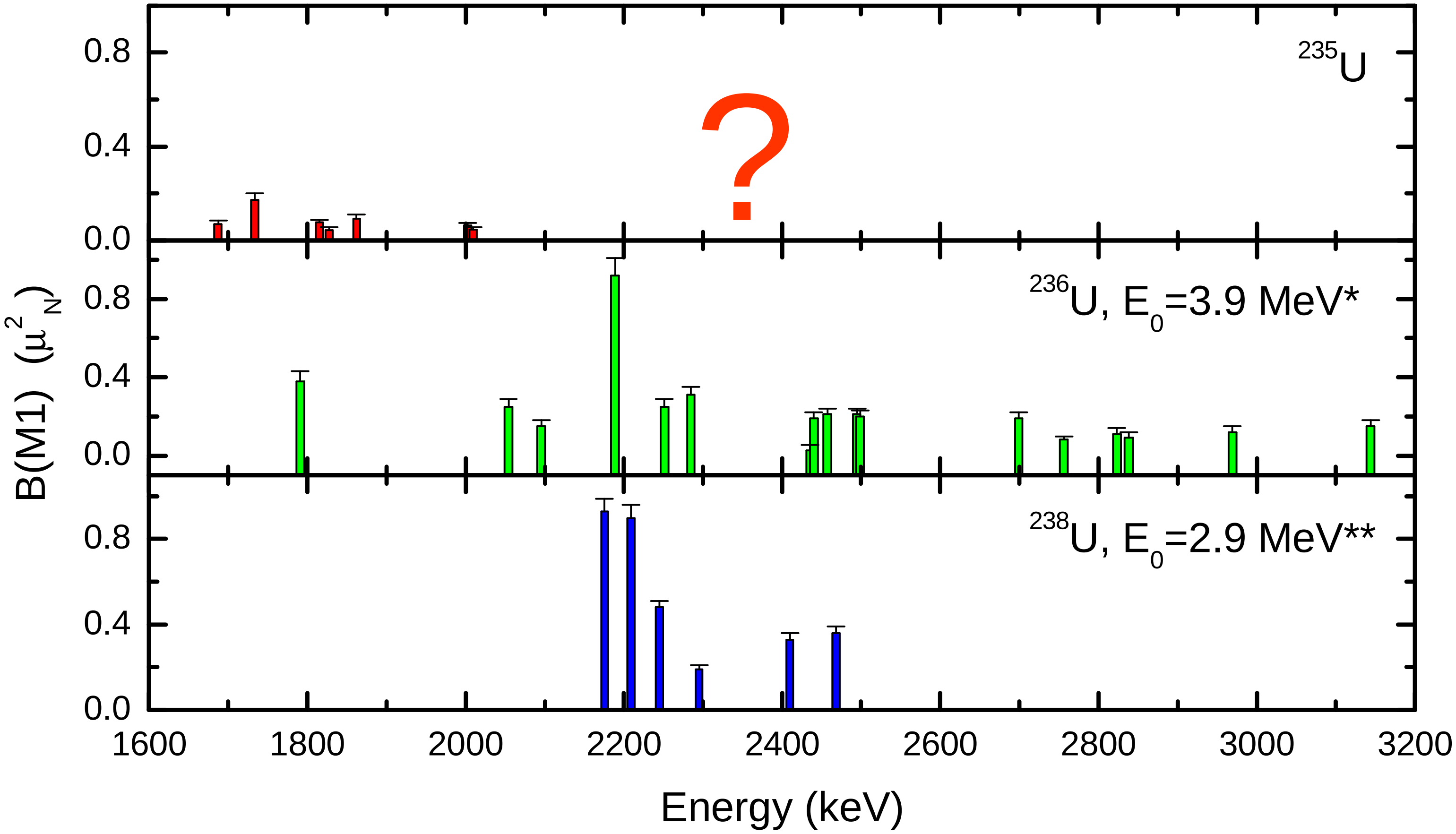


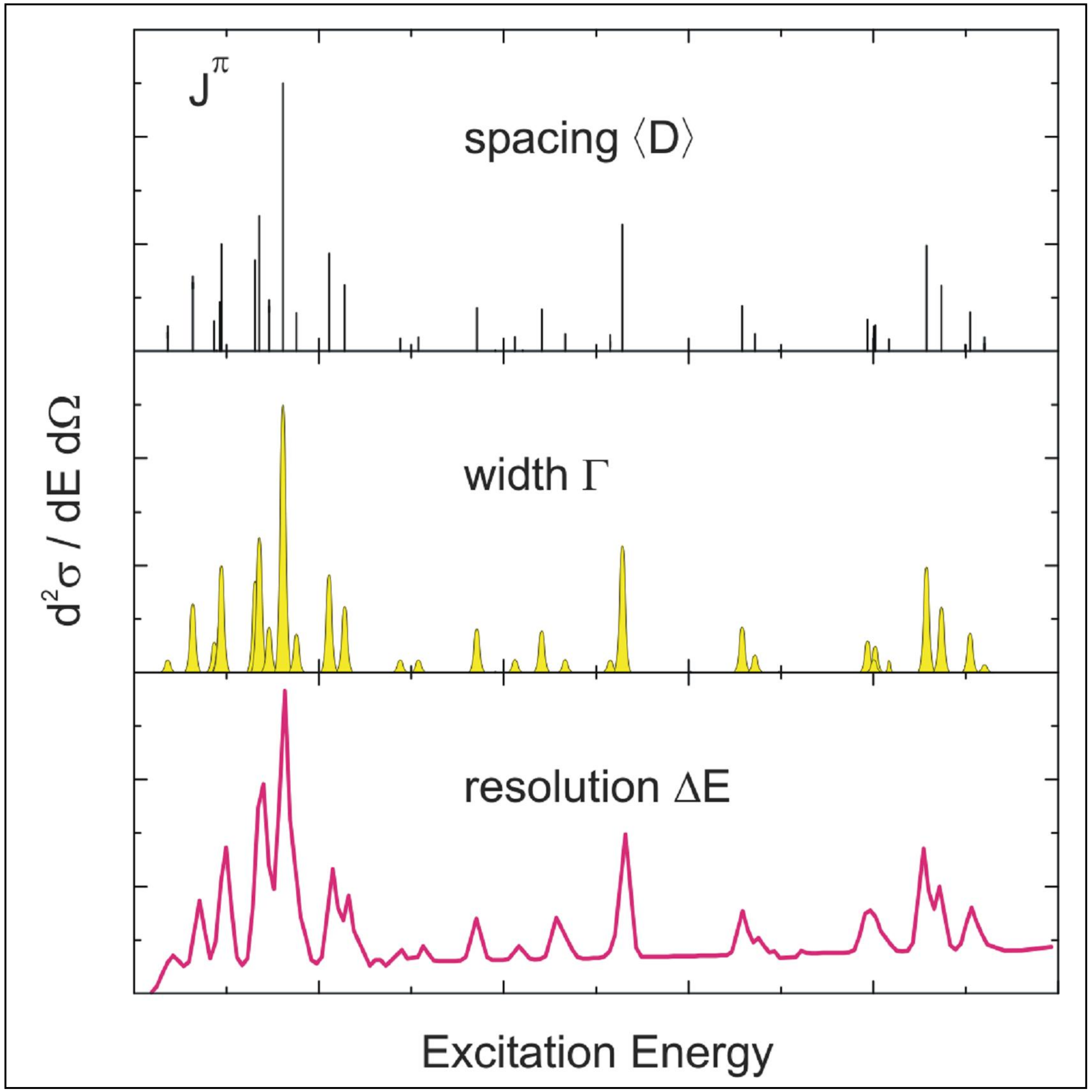
* W. Bertozzi *et al.*, Phys. Rev. **C78** (2008) 041601

Comparison with other Uranium Isotopes



* R.D. Heil *et al.*, Nucl. Phys. **A476** (1988) 39
** J. Margraf *et al*., Phys. Rev. **C42** (1990) 771

Fluctuation Analysis



- one spin and parity J^{π}
- $D / \langle D \rangle$ Wigner

  $I / \langle I \rangle$ Porter-Thomas
- $\Gamma < \langle D \rangle$
- $\Gamma < \langle D \rangle < \Delta E$

Fluctuation Analysis

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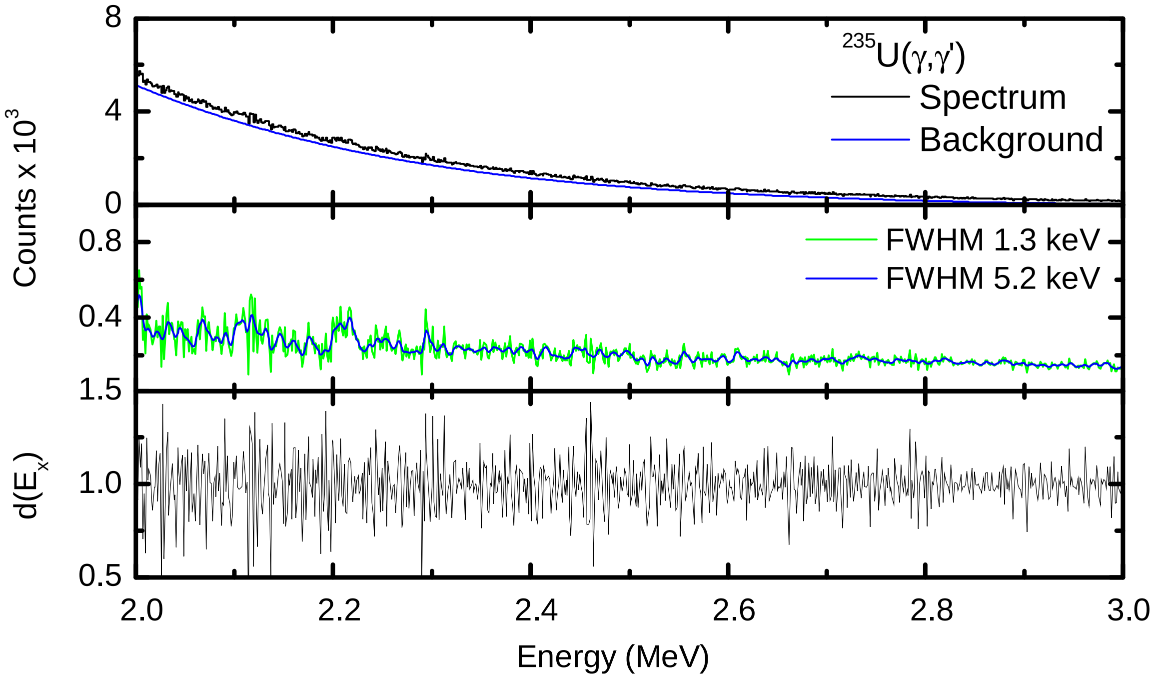
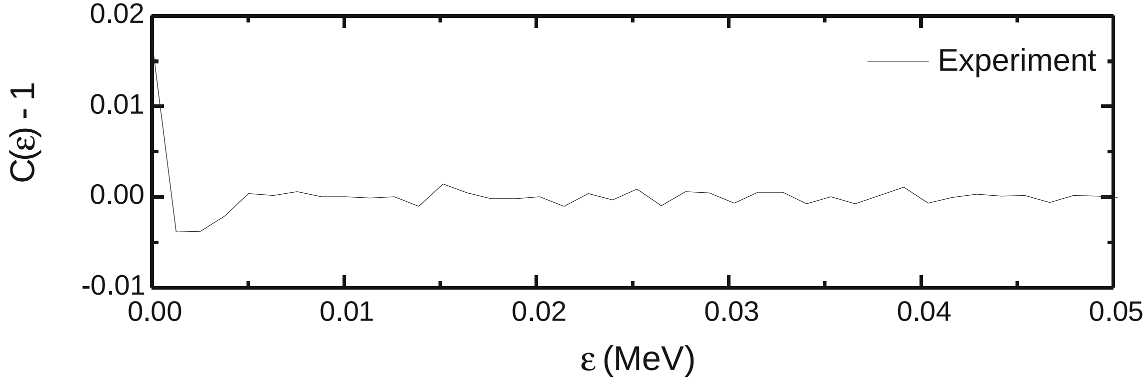
Spectrum

Smoothed spectra

Stationary spectrum



Autocorrelation function



Fluctuation Analysis

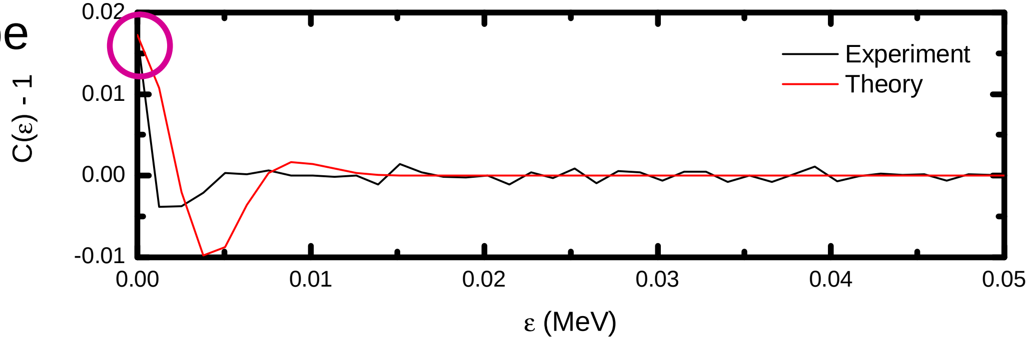
- $$C(\varepsilon) = \frac{\langle\, d(E_x)\, d(E_x+\varepsilon)\,\rangle}{\langle\, d(E_x)\,\rangle\,\langle\, d(E_x+\varepsilon)\,\rangle}$$ autocorrelation function

- $$C(\varepsilon=0)-1 = \frac{\langle\, d^2(E_x)\,\rangle - \langle\, d(E_x)\,\rangle^2}{\langle\, d(E_x)\,\rangle^2}$$ variance

- $$C(\varepsilon)-1 = \frac{\alpha\,\langle\, D\,\rangle}{2\sigma\sqrt{\pi}} \times f(\sigma,\varepsilon)$$ level spacing ⟨D⟩

- Mean level spacing ⟨D⟩ from the theoretical model

→ Vary the background shape



S. Müller *et al.*, Phys. Lett. **B113** (1982) 362
P.G. Hansen *et al.*, Nucl. Phys. **A518** (1990) 13

Variance α

- States of one and the same spin and parity J^π: $\alpha = \alpha_W + \alpha_{PT}$

- States of *n* mixed spins and parities: g.s. $7/2^-$ ⟶ $5/2^\pm$, $7/2^\pm$, $9/2^\pm$
  variances from the overlap of the distributions for each J^π:

$$\alpha = \alpha_D + \alpha_I$$

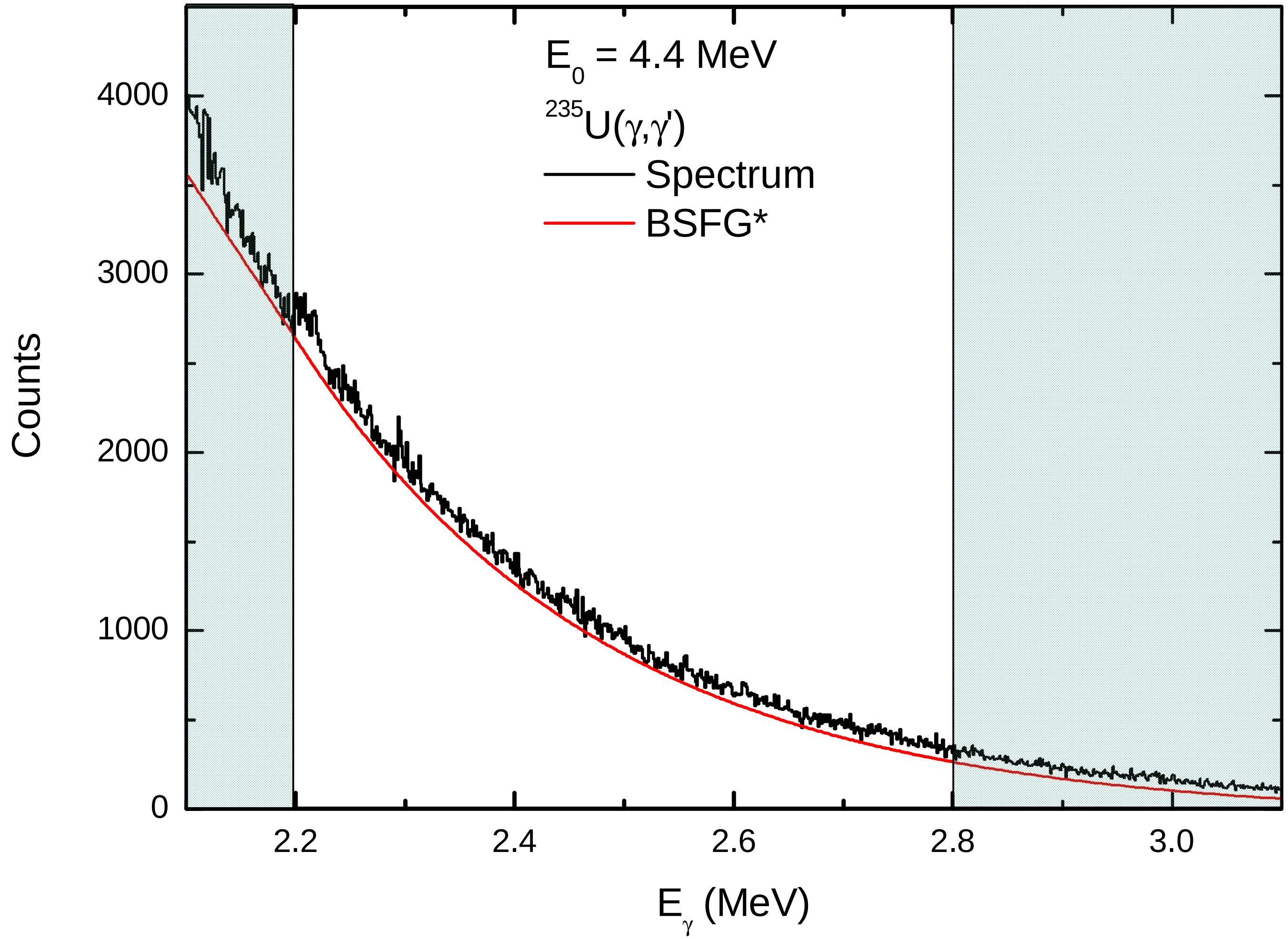
$$= \alpha_D + 3\frac{\sum_{i=1}^{n}(N_i\langle\Gamma_0\rangle_i)^2 \cdot \sum_{i=1}^{n} N_i}{\left(\sum_{i=1}^{n} N_i\langle\Gamma_0\rangle_i\right)^2} - 1$$

α_D – variance of the level spacing distribution
α_I – variance of the intensity distribution

N_i – average number of states
$\langle\Gamma_0\rangle$ - average g.s. transition width

⟵ Even-mass neighbour ^{236}U

Background for ^{235}U at 135°



* T.Rauscher *et al.*, Phys. Rev. **C56** (1997) 1613

Unresolved Transition Strength (preliminary)

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Energy region: 2.2 – 2.8 MeV

^{236}U: $\Sigma B(M1)\text{-} = (2.94 \pm 0.23)\mu^2_N$

^{238}U: $\Sigma B(M1)\text{-} = (3.19 \pm 0.24)\mu^2_N$

^{235}U:

$\Sigma B(M1)\text{-} = (3.6 \pm 0.4)\mu^2_N$ (E_0 = 3.5 MeV)

$\Sigma B(M1)\text{-} = (3.7 \pm 0.4)\mu^2_N$ (E_0 = 4.4 MeV)

Summary

ü Measurement $^{235}U(\gamma,\gamma')$ up to 4.4 MeV

ü Extraction of B(M1) transition strength:

- discrete transitions up to 2.2 MeV
- fluctuation analysis for higher energies

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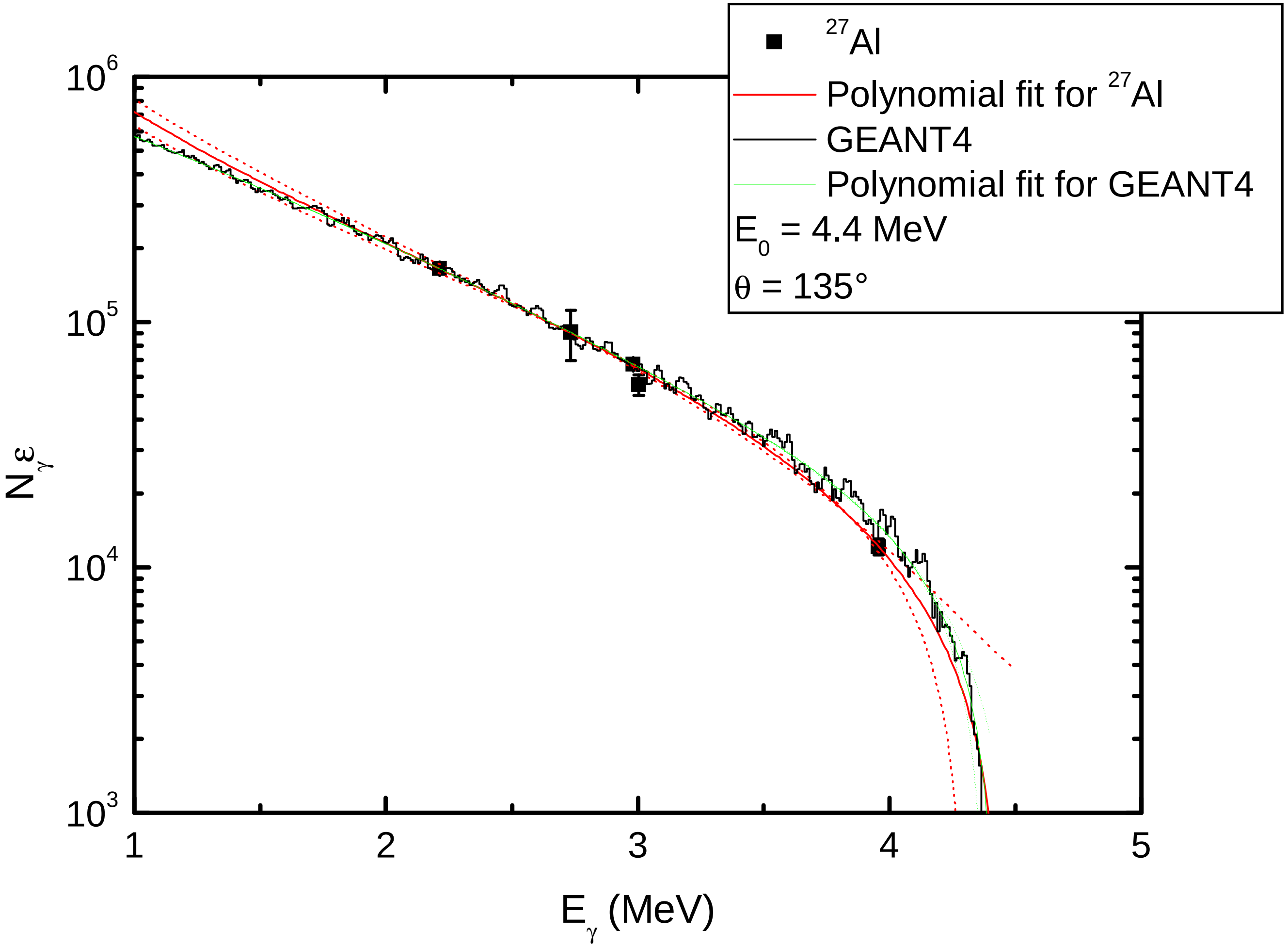
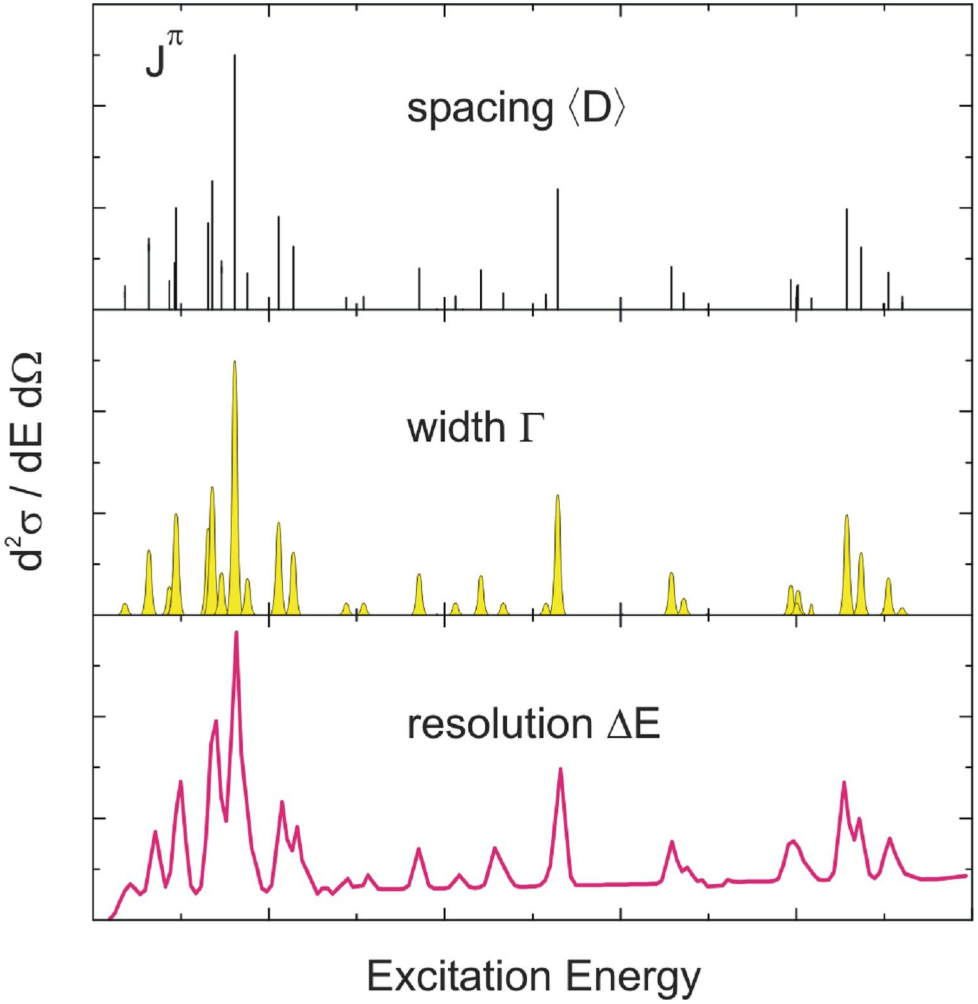
Photon Flux and Efficiency



Fluctuation Analysis



$$\frac{D}{<D>}$$ Wigner

$$\frac{I}{<I>}$$ Porter-Thomas

$$\Gamma \quad < \quad <D>$$

$$\Gamma \quad < \quad <D> \quad < \quad \Delta E$$

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$$I_s^i = \frac{A_i}{N_{Al} \cdot N_\gamma(E_x, E_0) \cdot \varepsilon(E_i) \cdot W_{eff}^i(\theta) \cdot \frac{\Delta\Omega}{4\pi}}$$

$\frac{signal}{background}$ ← Strong fragmentation → Small strengths of individual levels
Enhanced background