Experimental level densities and γ strength functions from the Oslo Method

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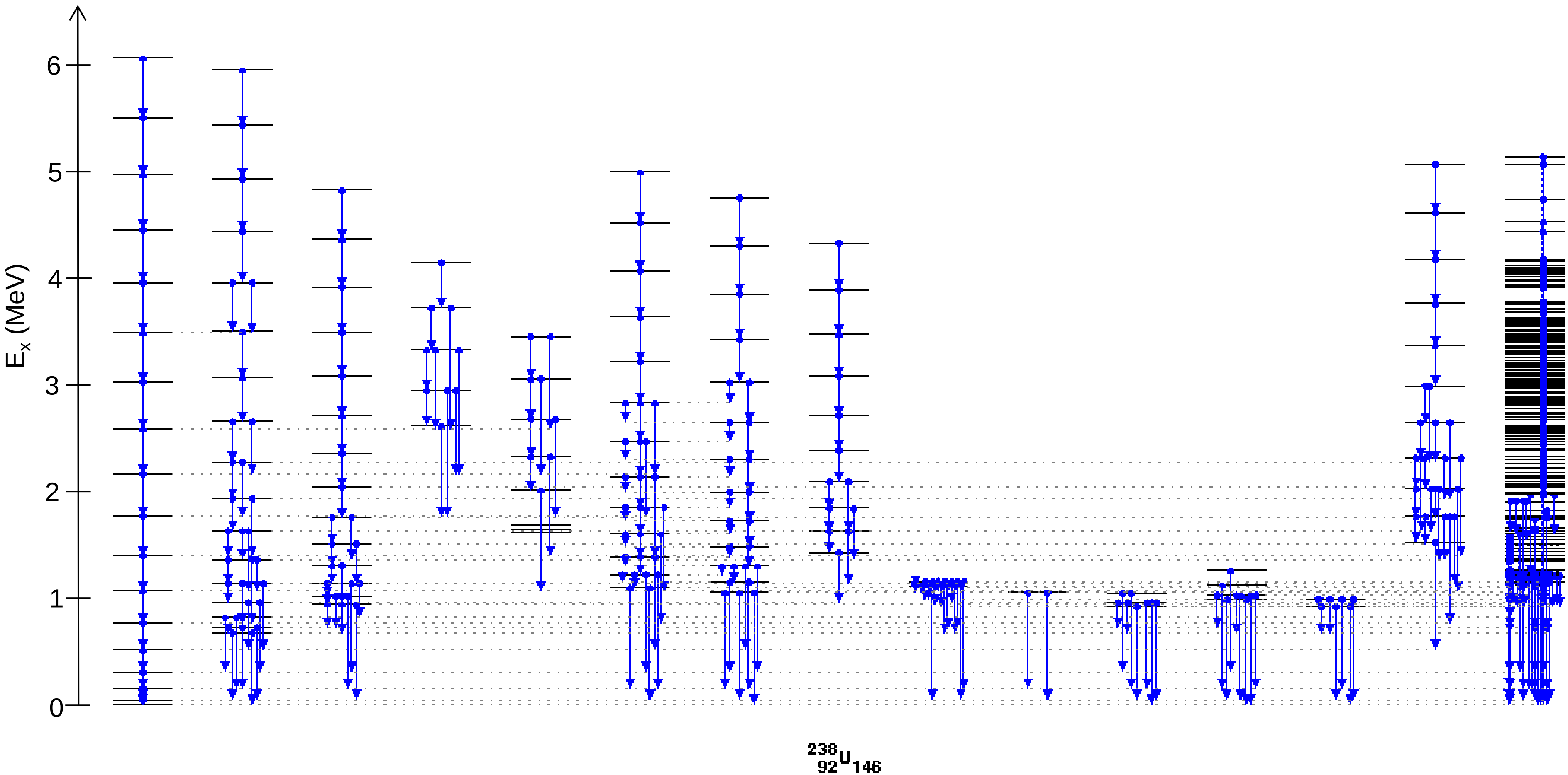
Magne Guttormsen, Andreas Görgen
et al.

Level density – discrete levels from spectroscopy

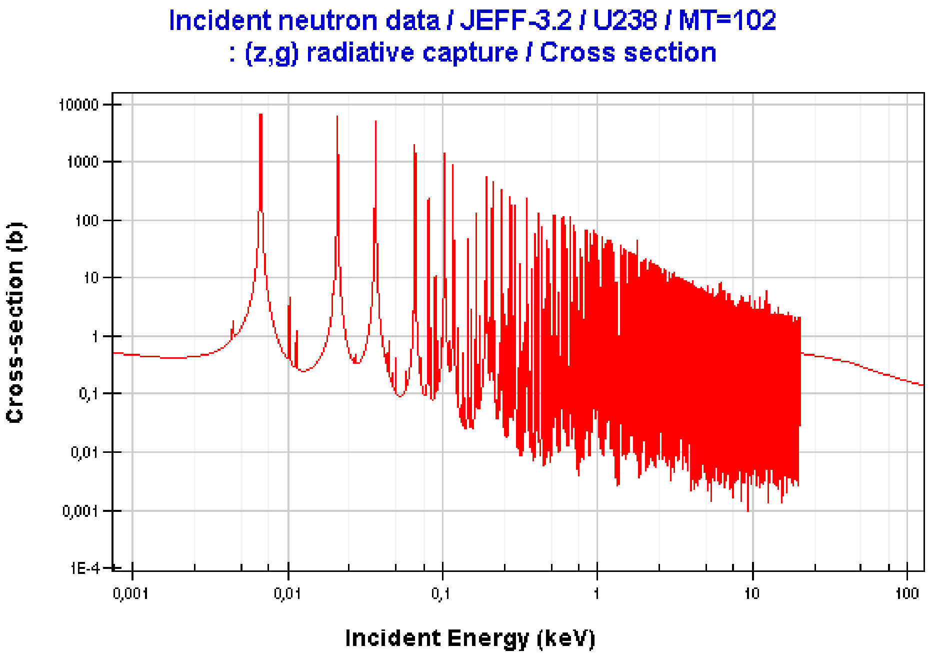


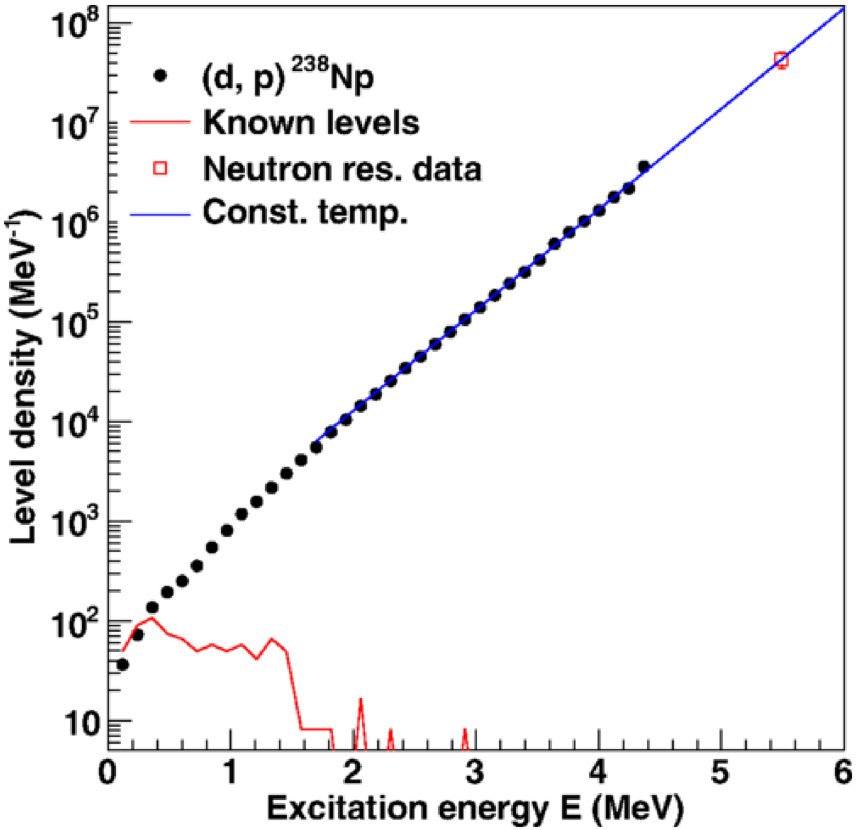
Level density: number of levels per energy bin from level counting

[0: 500]	4
[500:1000]	12
[1000:1500]	35
…	

Incomplete !

Level density at S_n from average neutron resonance spacing





neutron capture (n,γ):

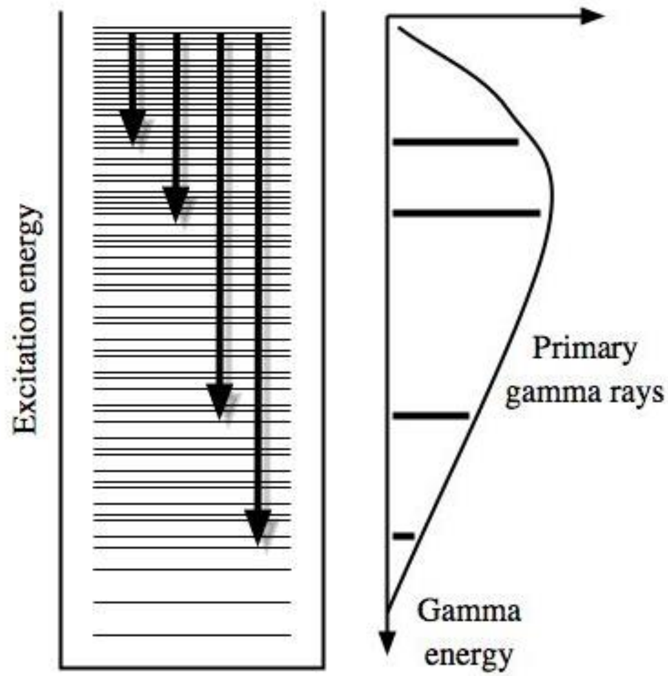
- resolve states with eV resolution
- level density at $E_x = S_n$

s-wave capture populates states with $I = I_{gs} \pm \frac{1}{2}$

- need model for spin distribution to get level density for all states

Oslo method “fills the gap” between discrete states and S_n

γ-decay in the (quasi-)continuum



- high level density
- levels overlap
- no discrete states anymore

$$P(E_x, E_\gamma) \propto \rho(E_x - E_\gamma) T(E_\gamma)$$

$\rho(E_x - E_\gamma)$ level density at the final energy

$$\mathcal{T}(E_\gamma) = 2\pi \sum_{XL} E_\gamma^{2L+1} f_{XL}(E_\gamma)$$

γ transmission coefficient

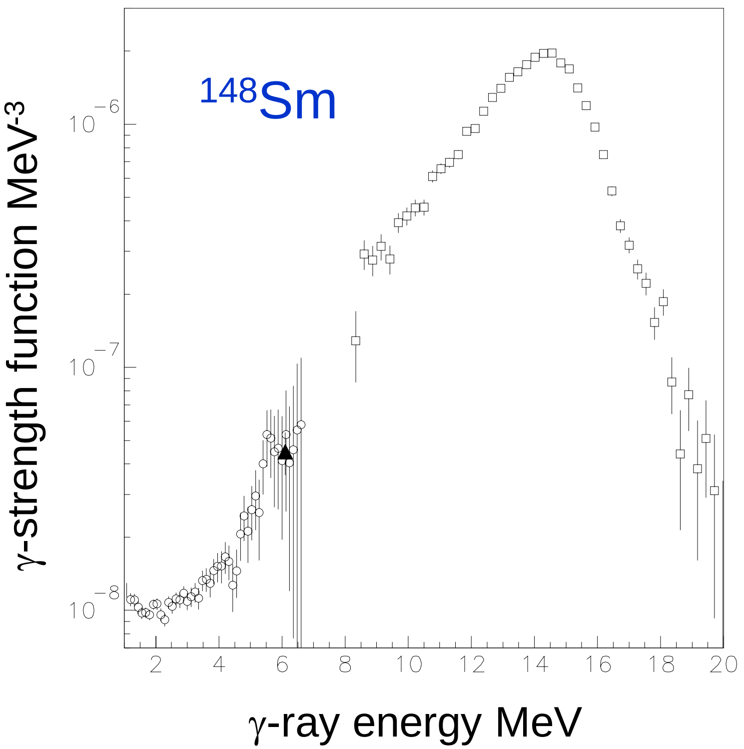
Assuming dominance of dipole radiation (*E*1 and *M*1)

$$f(E_\gamma) \simeq \frac{1}{2\pi} \frac{\mathcal{T}(E_\gamma)}{E_\gamma^3}$$

γ strength function

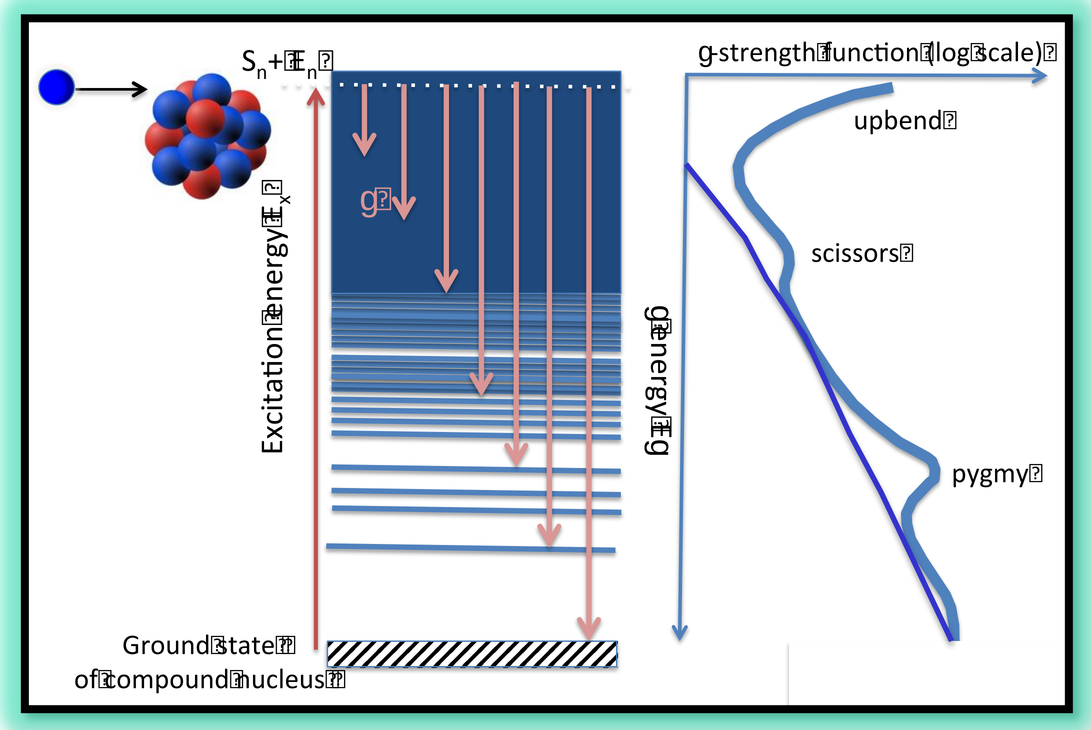
average strength for emission of a γ ray of energy E_γ

γ-strength function

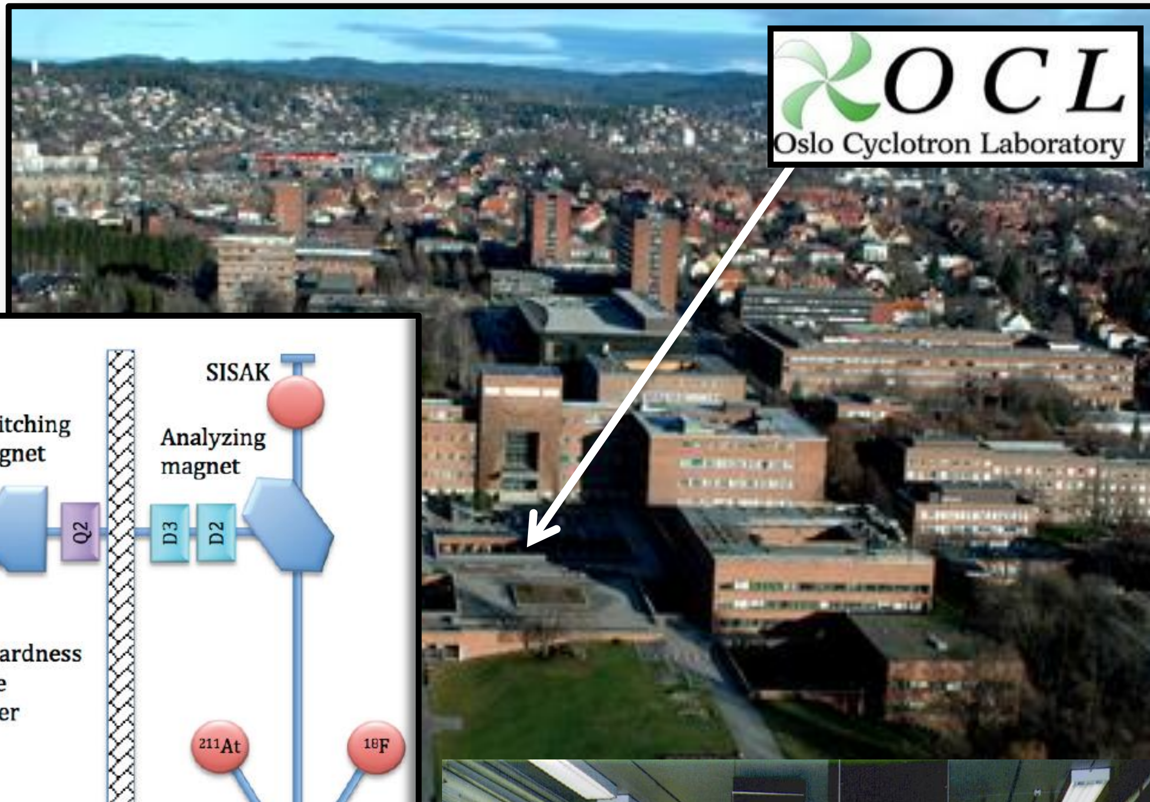


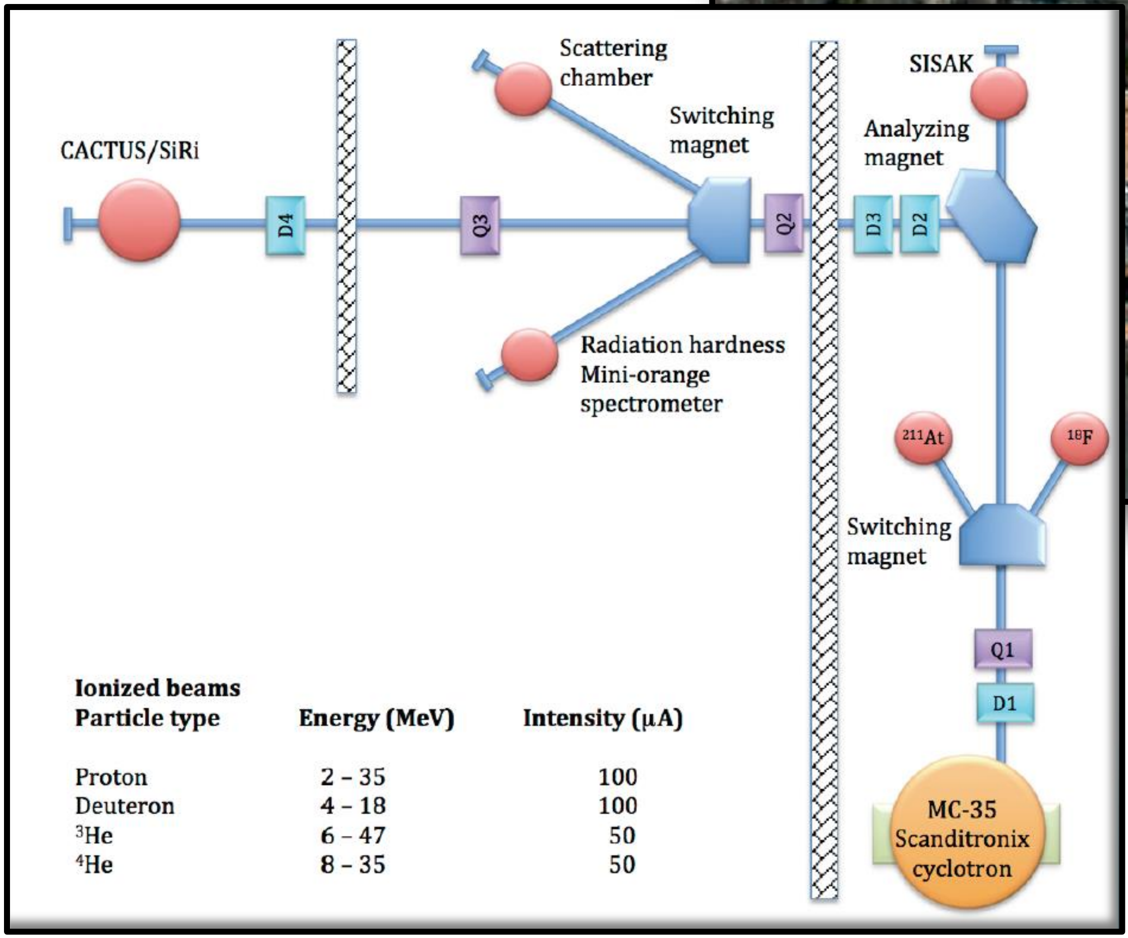
at high energy:
dominated by the GDR

Oslo method provides data on
the low-energy tail of the GDR



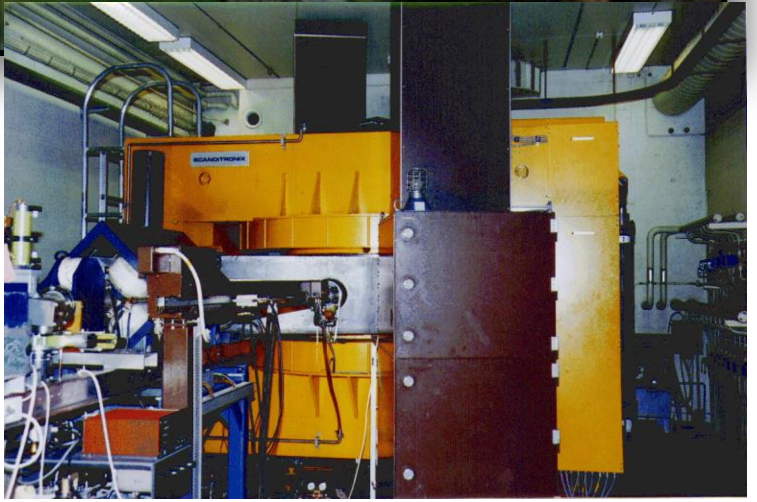
The Oslo Cyclotron Laboratory





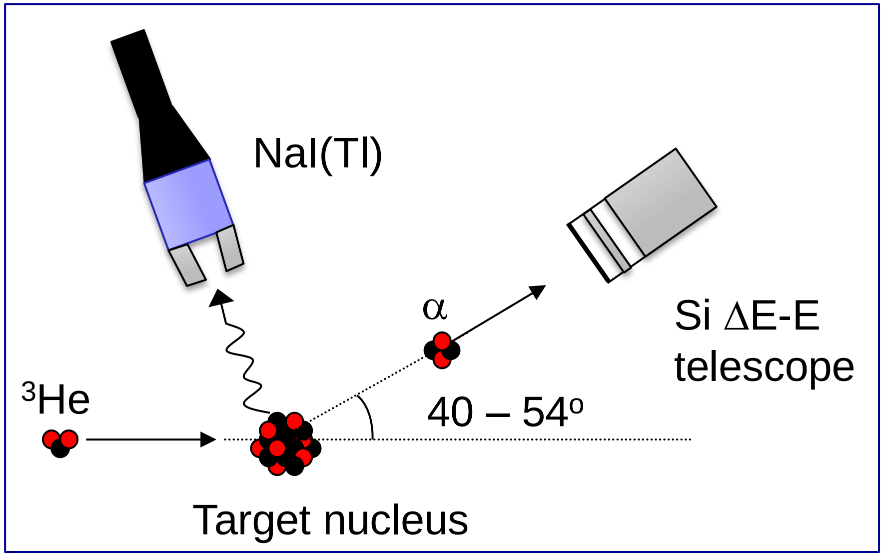
Ionized beams

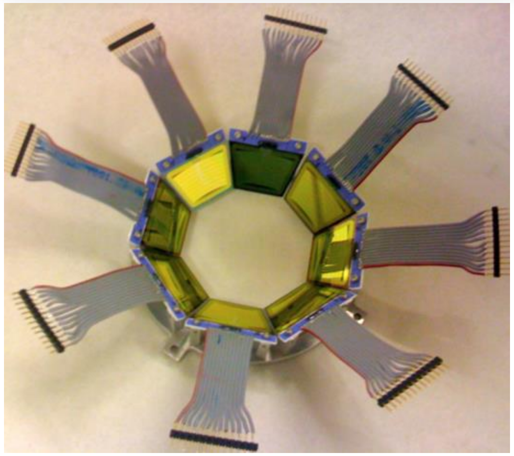
Particle type	**Energy (MeV)**	**Intensity (μA)**
Proton	2 – 35	100
Deuteron	4 – 18	100
^{3}He	6 – 47	50
^{4}He	8 – 35	50

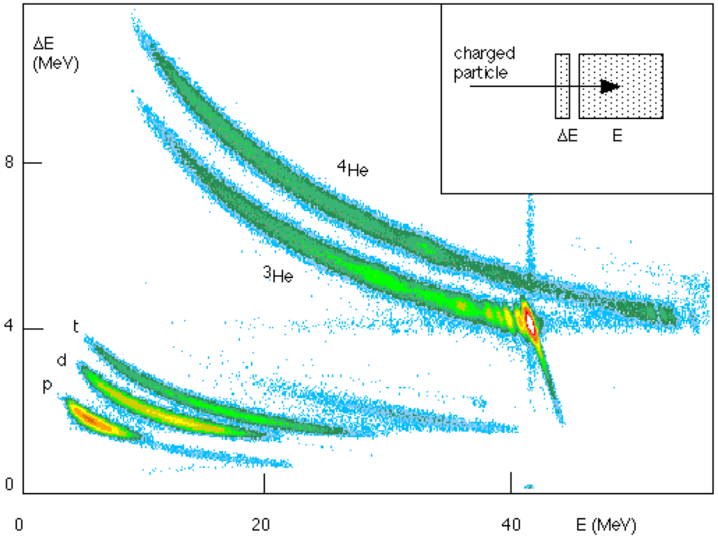


Experimental Setup

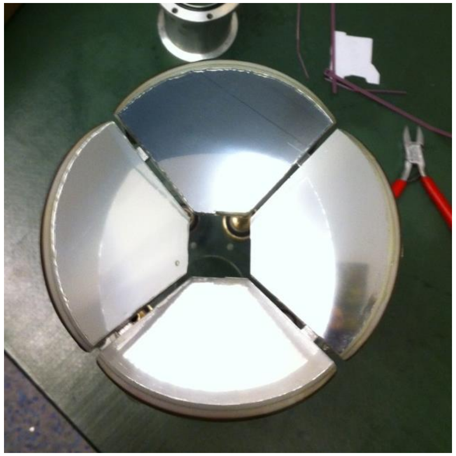
- CACTUS: 28 5” x 5” NaI(Tl)
- SiRi: Si ΔE-E particle telescopes
- PPAC fission detector



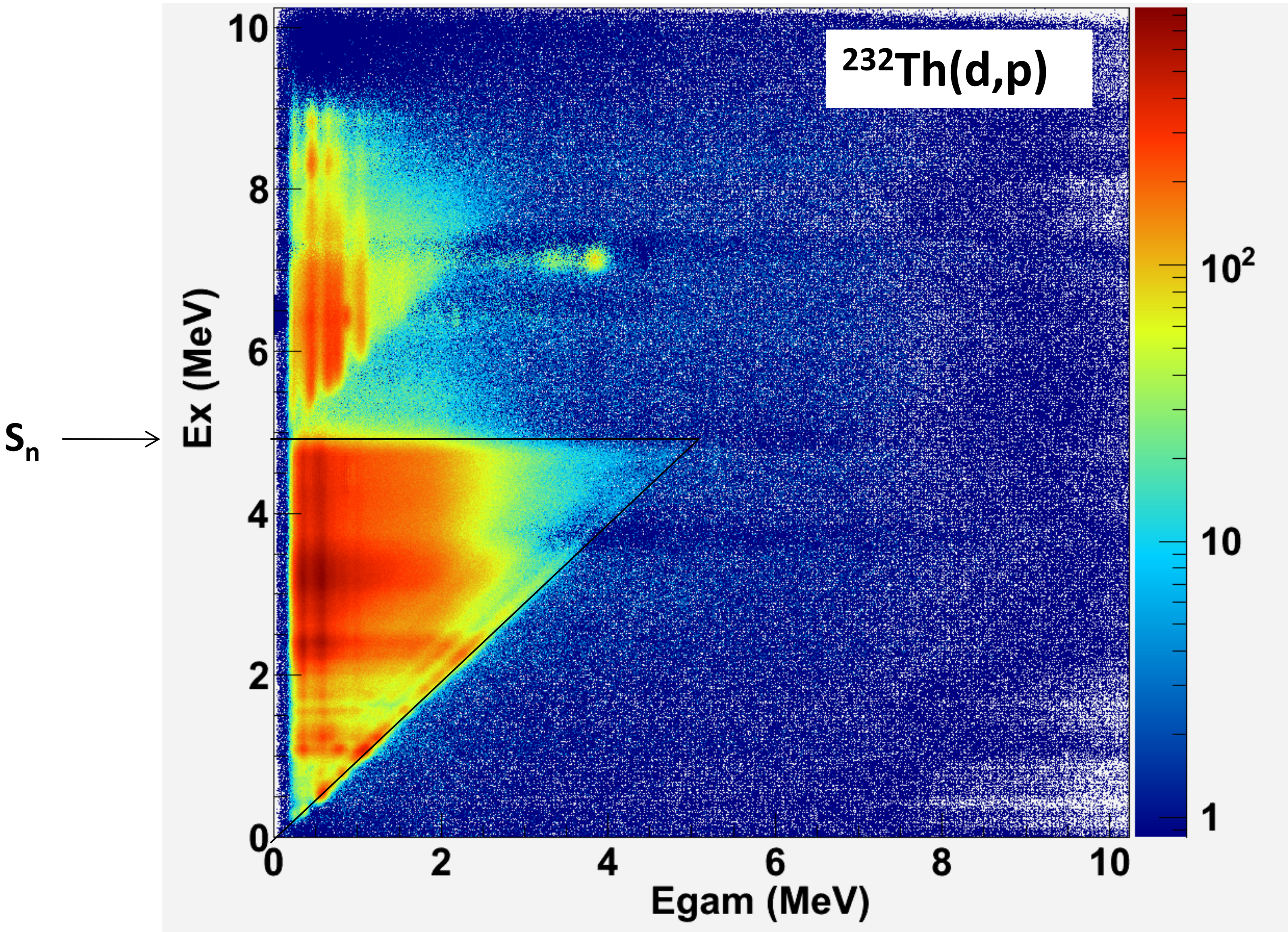




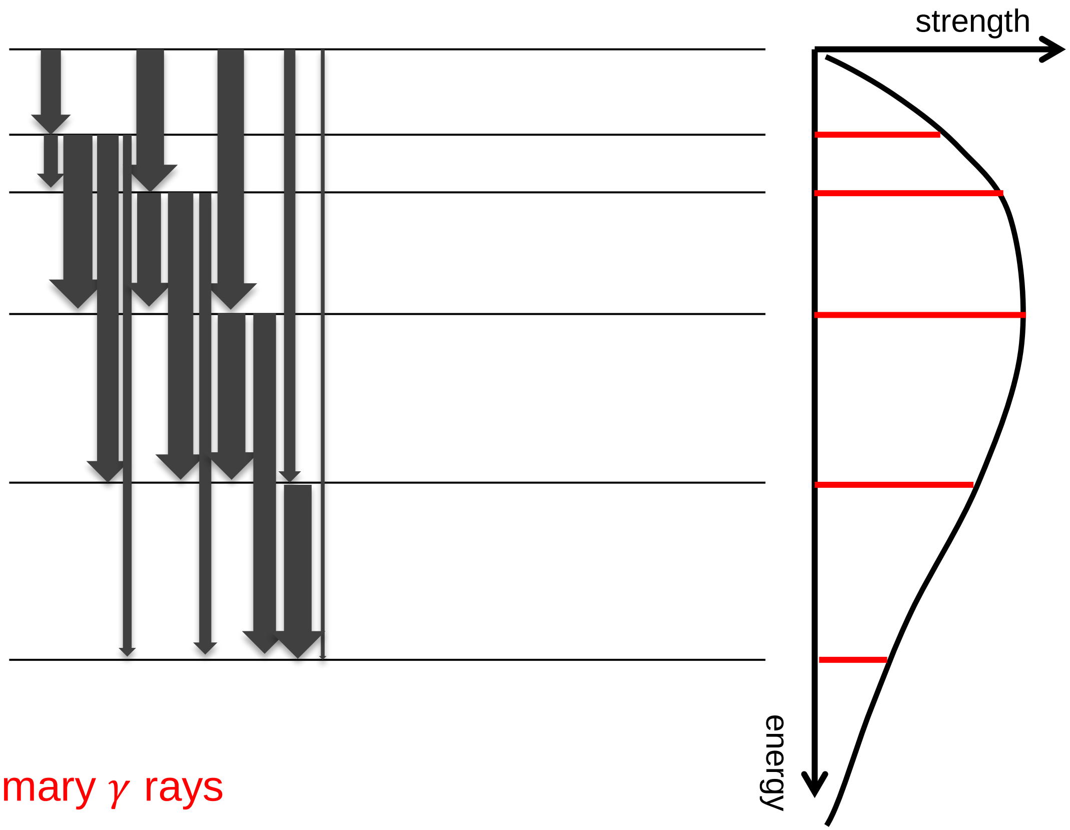
- particle ID from Si telescope
- E_x from reaction kinematics
- γ-ray spectrum for given E_x

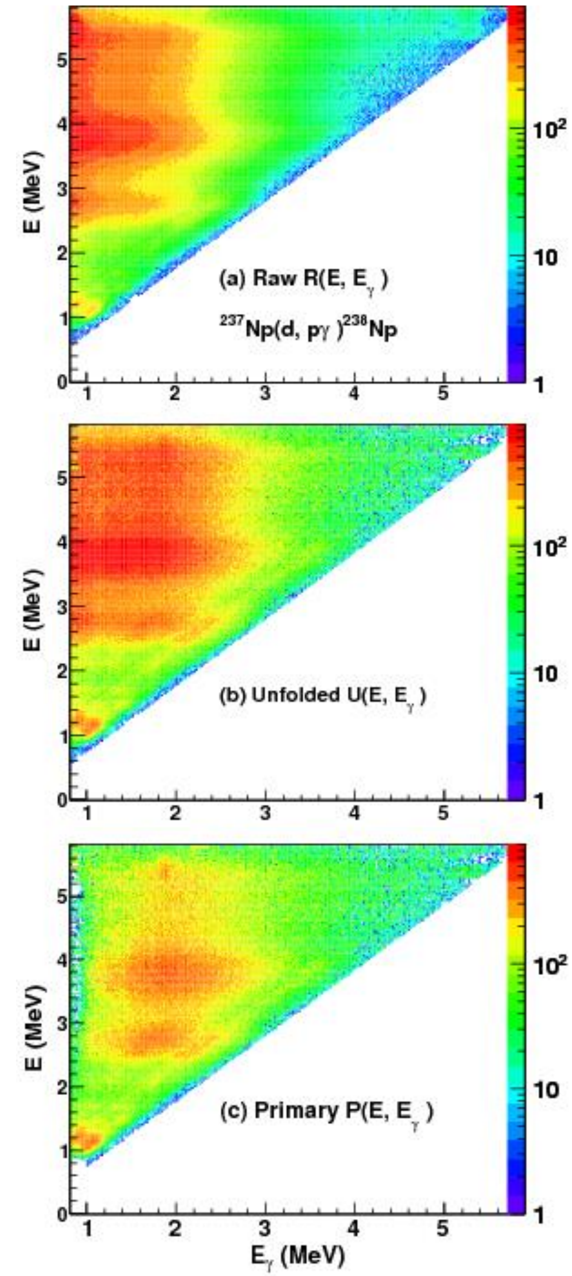


$E_x - E_\gamma$ matrix



Isolating primary γ rays





primary γ rays

subtract weighted sum of transitions below

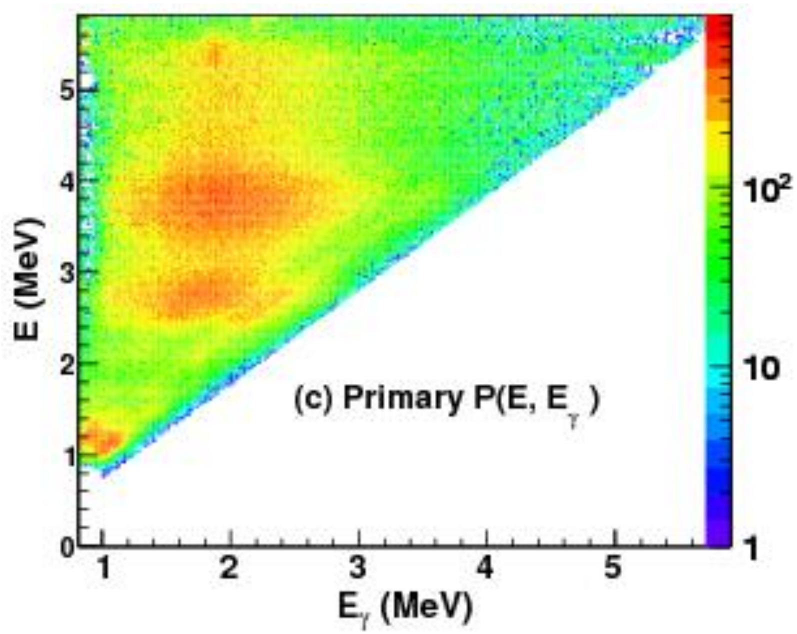
the stronger an energy bin is fed, the more has to be subtracted

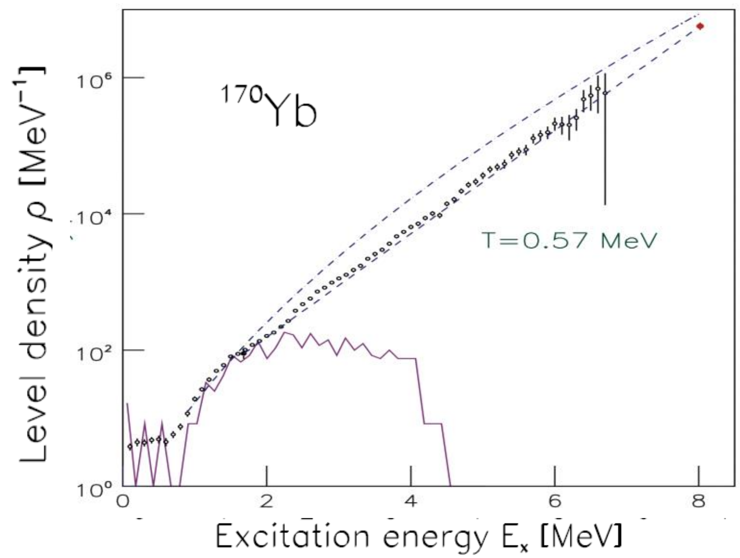
weighting function = γ strength function

iterative procedure, converges quickly

M. Guttormsen et al.,
NIM A 255, 518 (1987)

Level density and γSF from primary γ-ray matrix



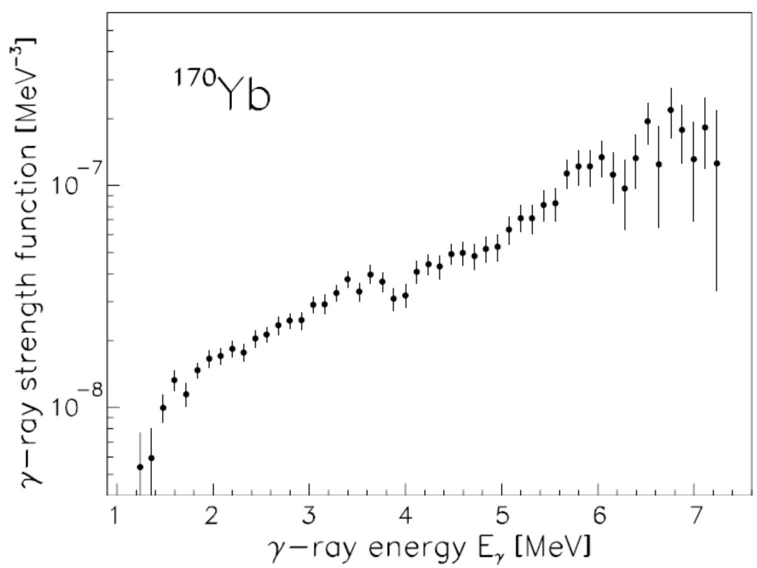


$$P\left(E_x, E_\gamma\right) \propto \rho\left(E_x - E_\gamma\right) T\left(E_\gamma\right)$$

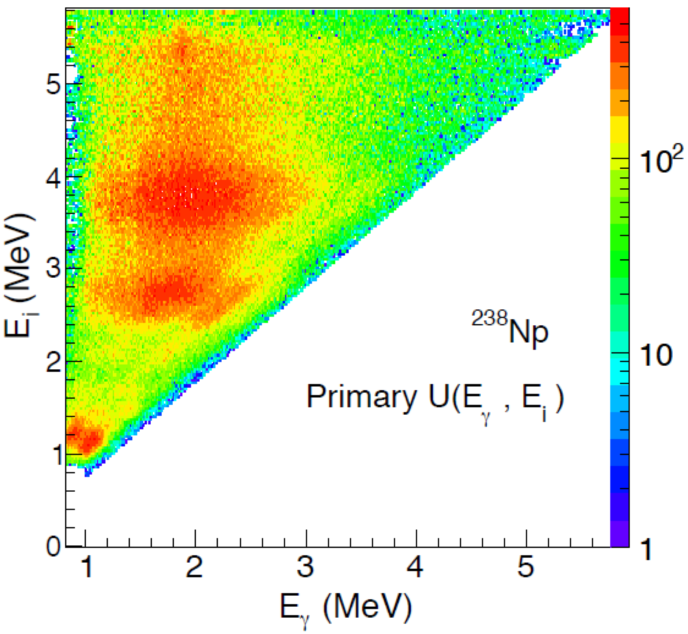
$n \times m$ matrix $\quad$ n vector $\quad$ m vector

- χ^2 minimization
- normalization to discrete states and D_0

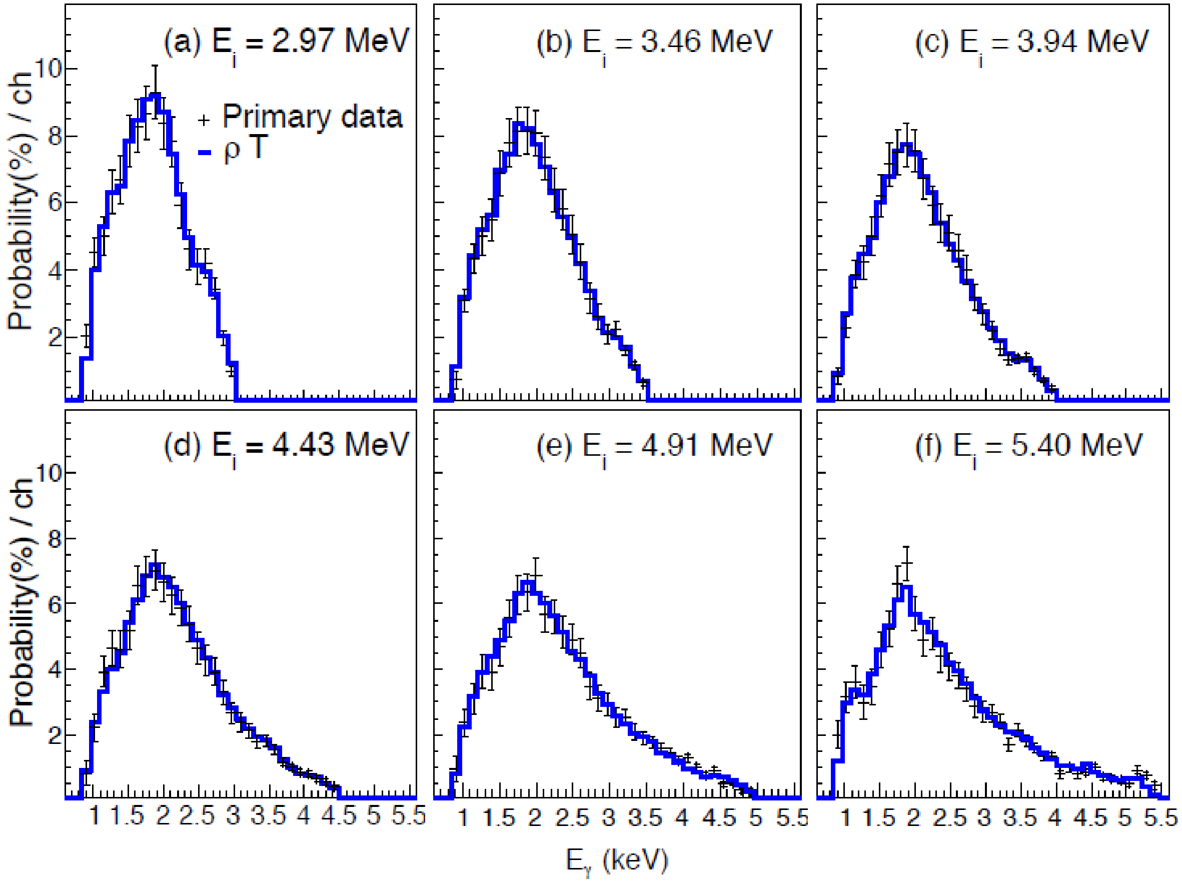
A. Schiller et al.,
NIM A 447, 498 (2000)



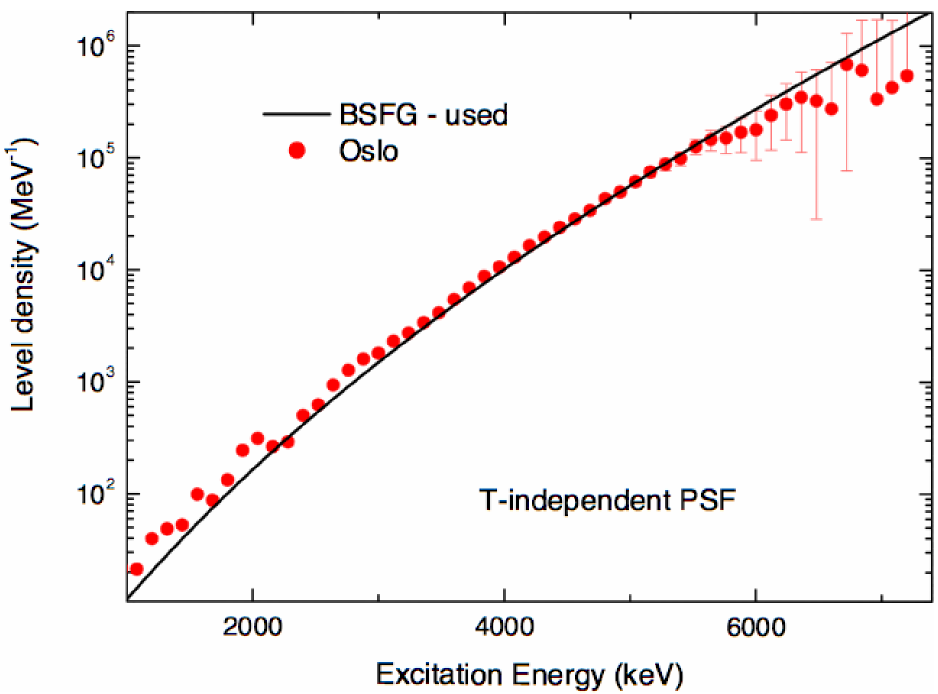
Quality of the fit

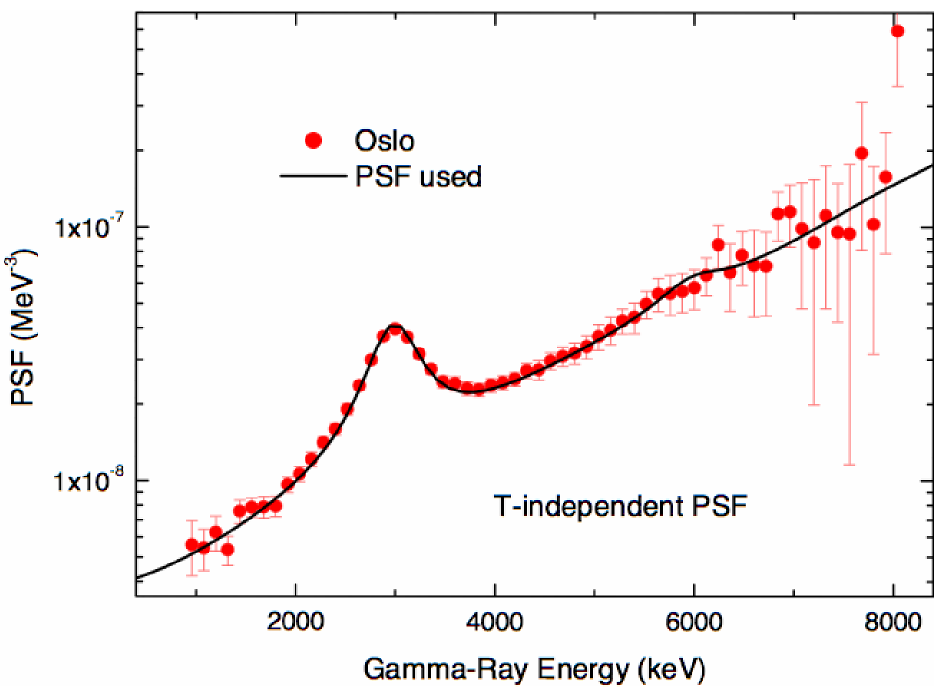


$$P(E_x, E_\gamma) \propto \rho(E_x - E_\gamma)\, T(E_\gamma)$$

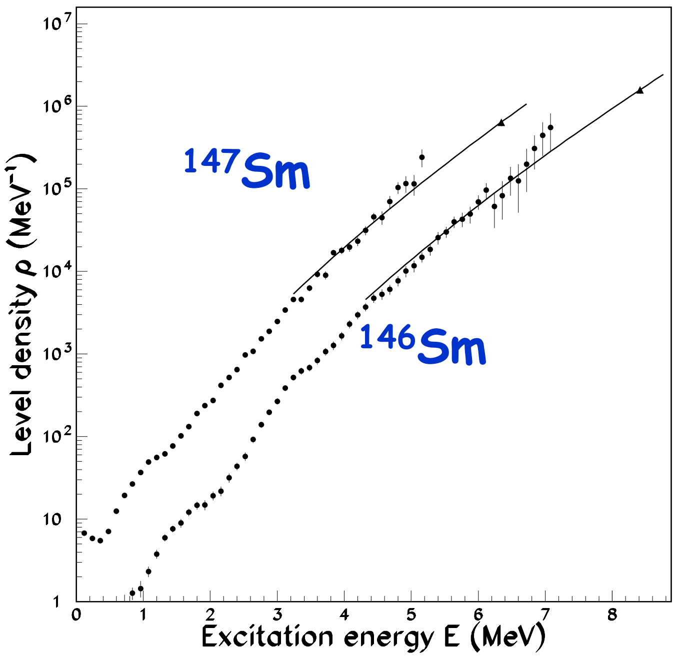


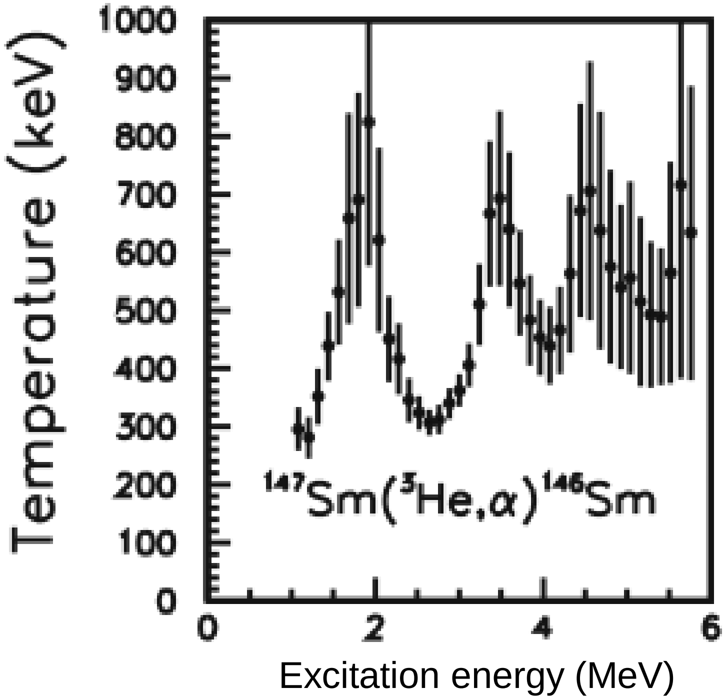
Blind test of method using DICEBOX simulations





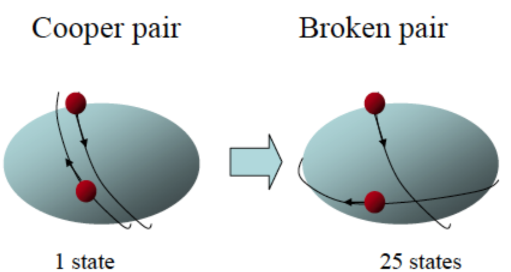
Level density and thermodynamic properties





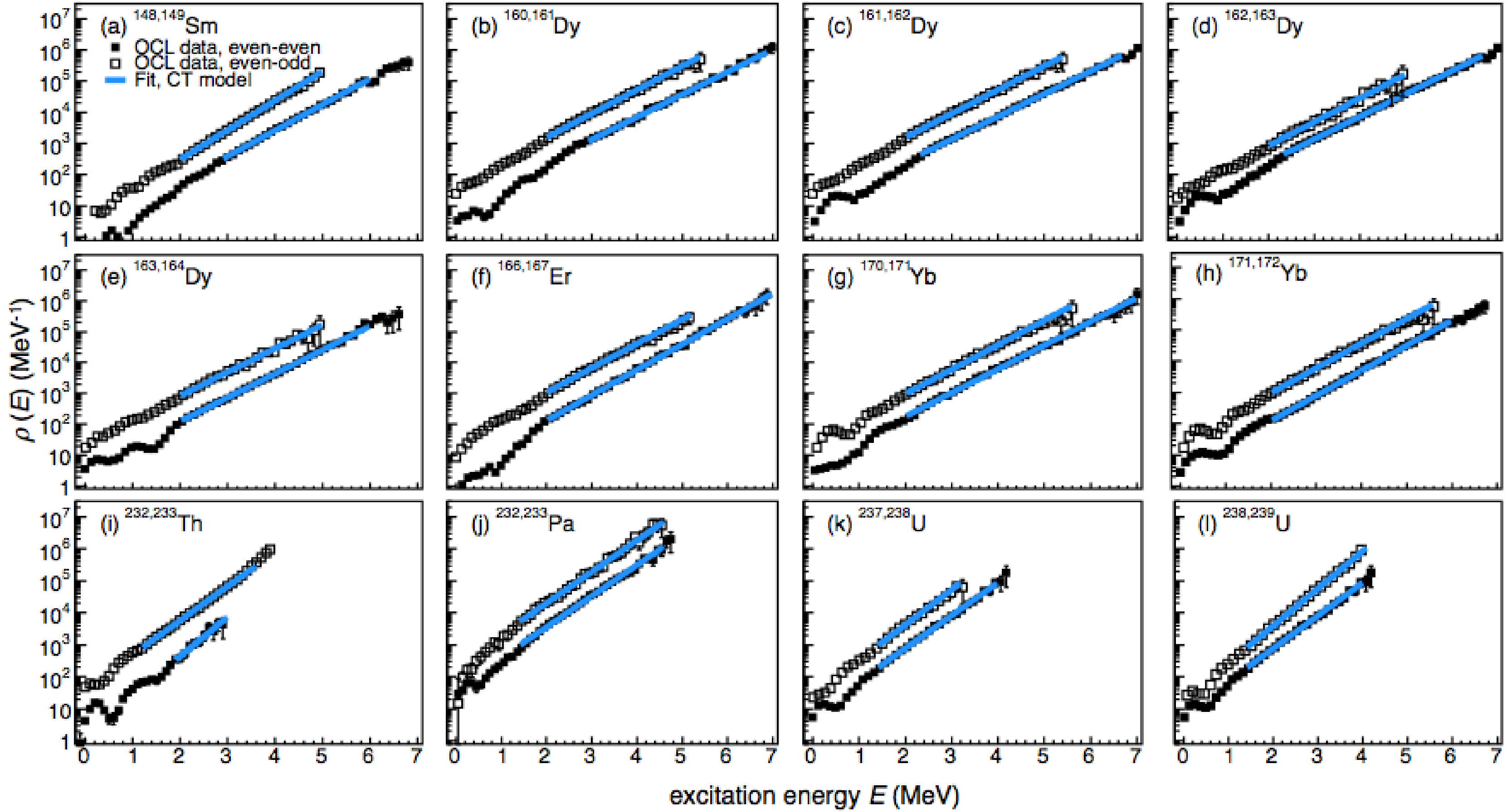
entropy: $$S(E) = k_B \ln\left(\frac{\rho(E)}{\rho_0}\right)$$

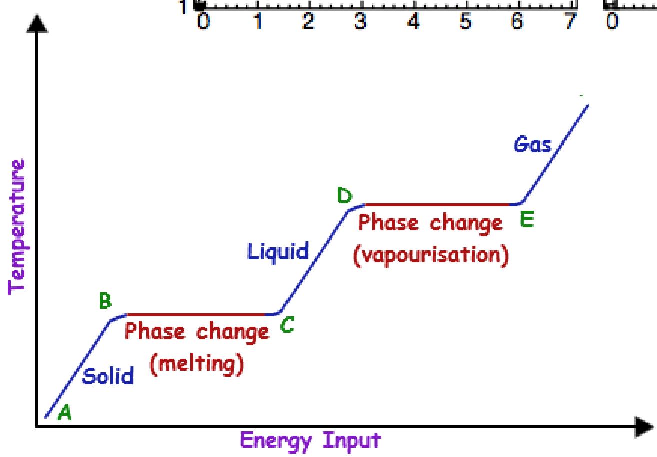
temperature: $$T(E) = \left(\frac{\partial S(E)}{\partial E}\right)^{-1}$$



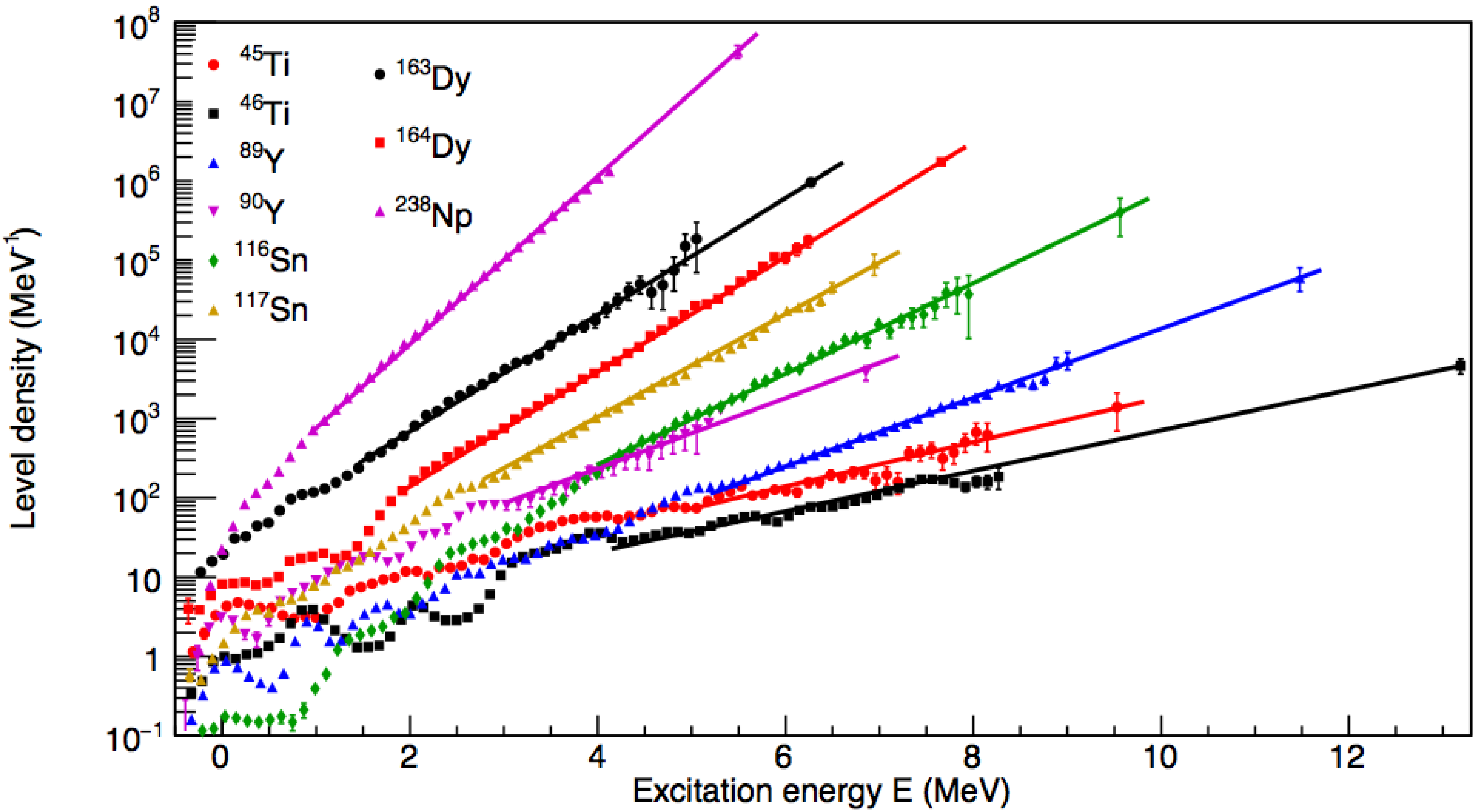
pairing phase transition

Constant temperature behavior

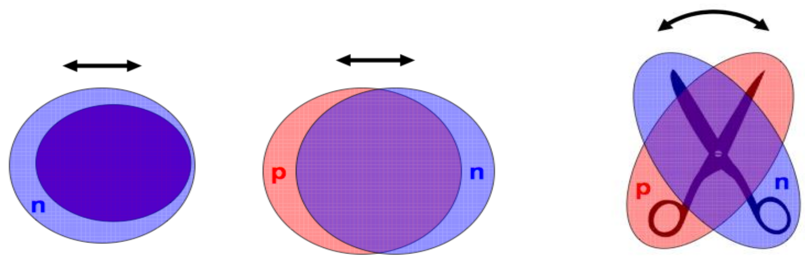


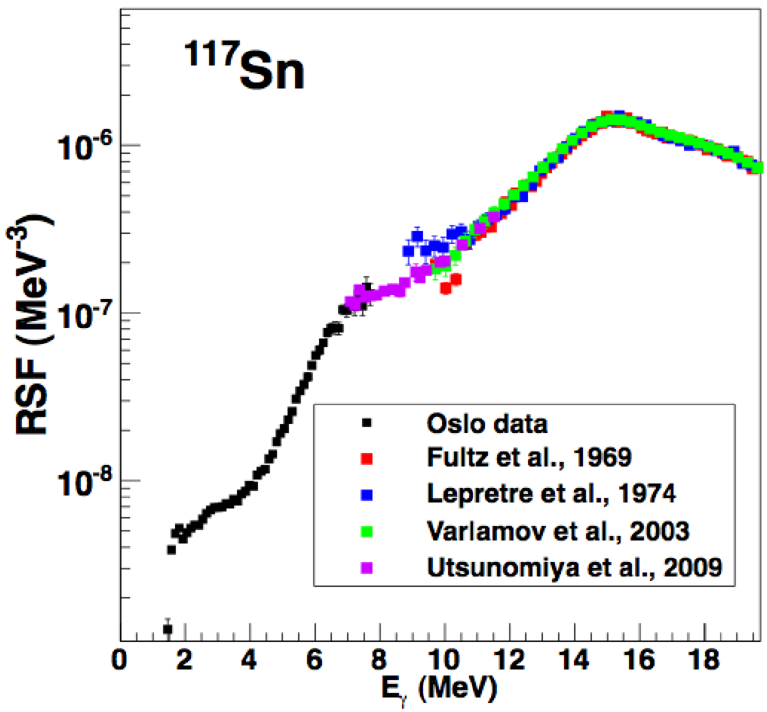


Constant temperature behavior

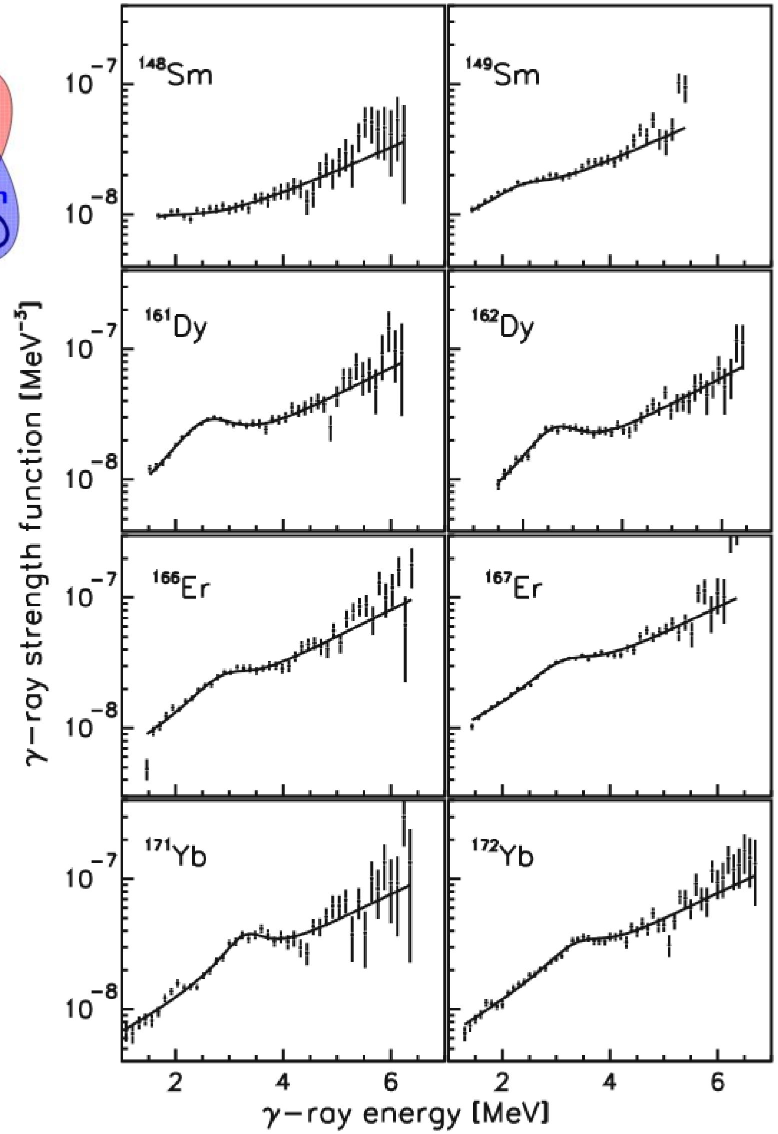


Small (Pygmy) resonances on the tail of the Giant Dipole Resonance



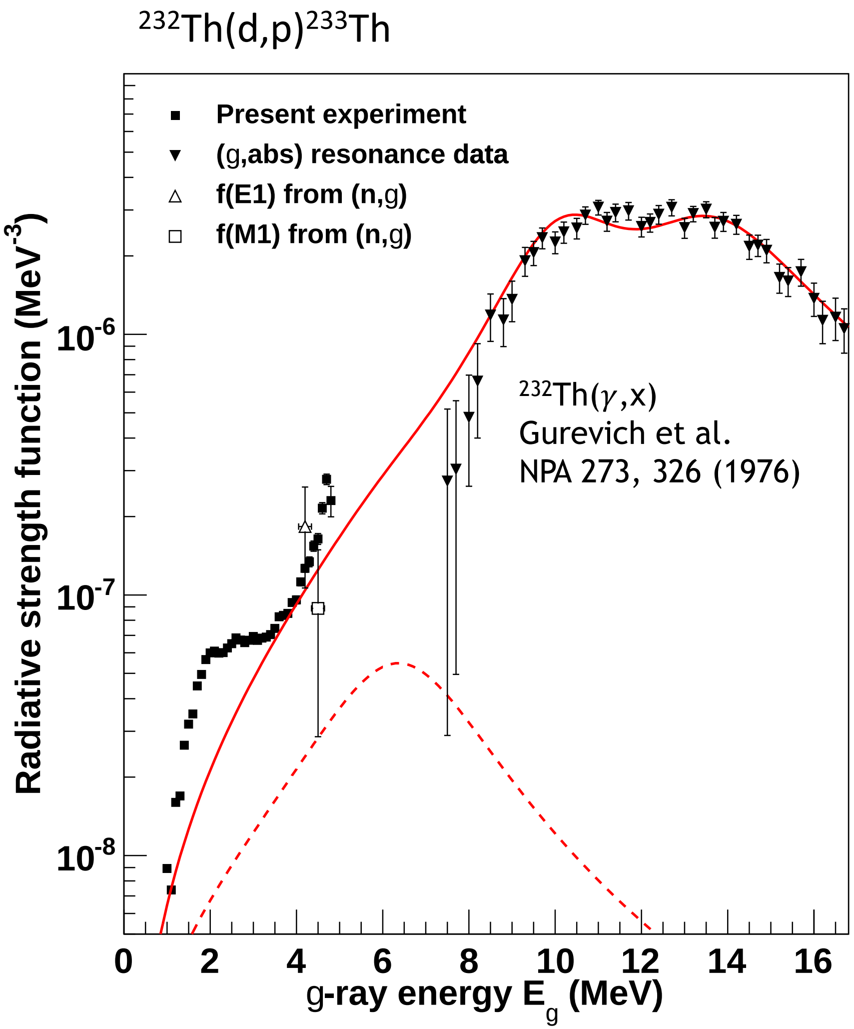


Utsunomiya et al., PRC 80, 055806 (2009);
Agvaanluvsan et al, PRL 102, 162504 (2009)

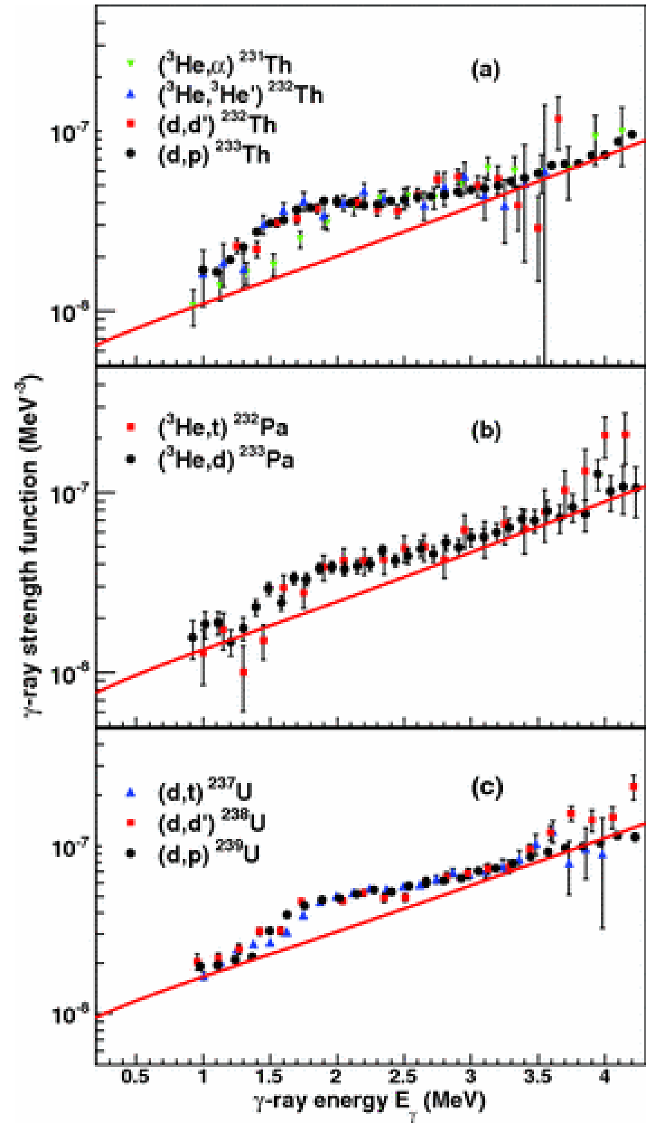


S.Siem et al. PRC 65, 044318 (2002)

The scissors resonance in the actinide region

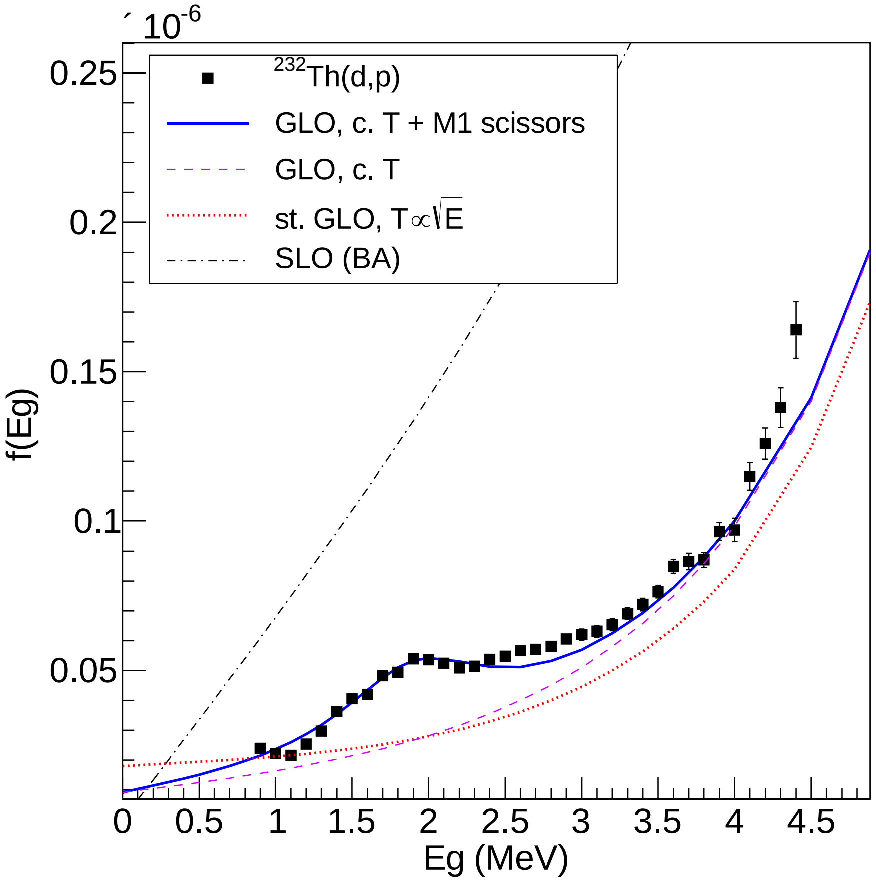


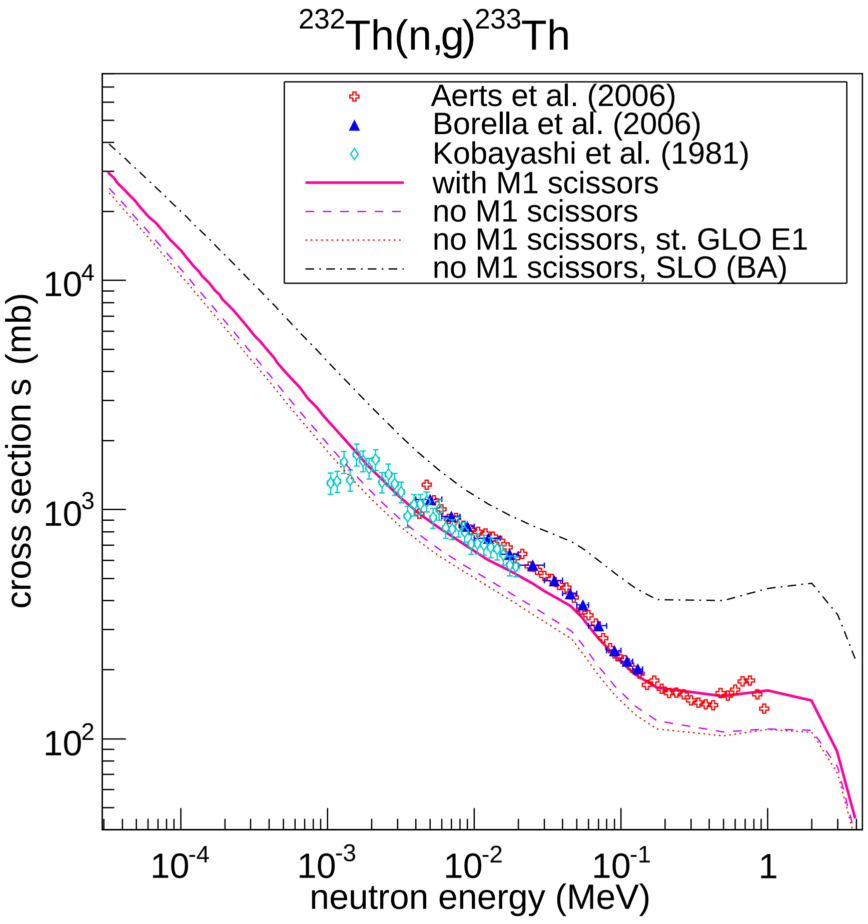
M. Guttormsen et al
PRL 109, 162503 (2012)



M. Guttormsen et al.
PRC 89, 014302 (2014)

Influence of the scissors resonance on the (n,γ) cross section





(n,γ) cross sections using experimental level densities and γSF