First evidence of low energy upbend in germanium isotopes

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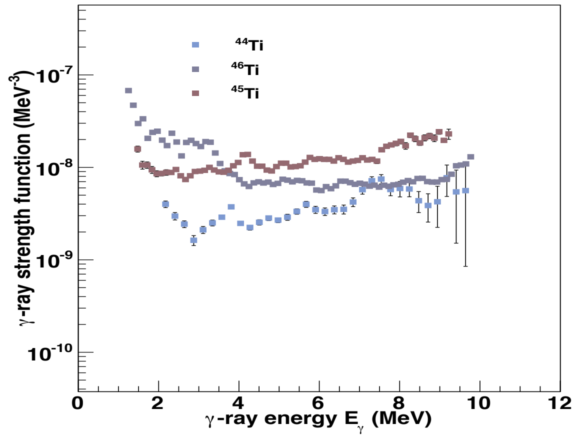
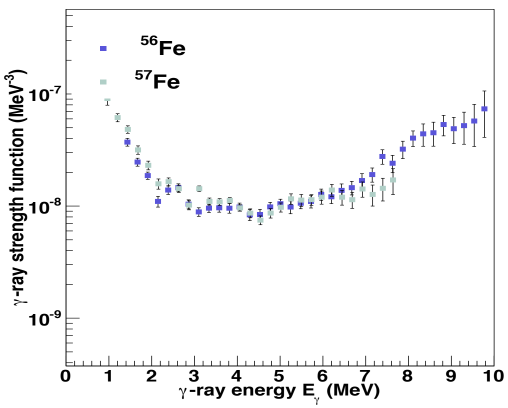
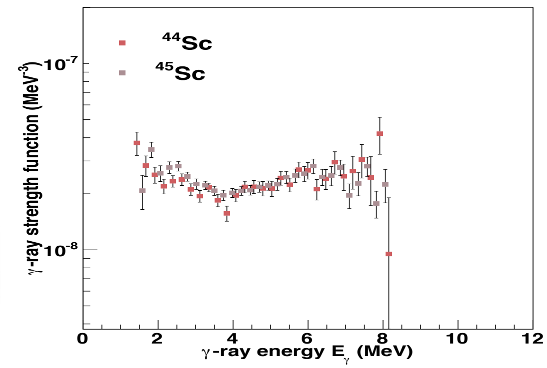
(n,γ)-REACTION RATES



r-PROCESS

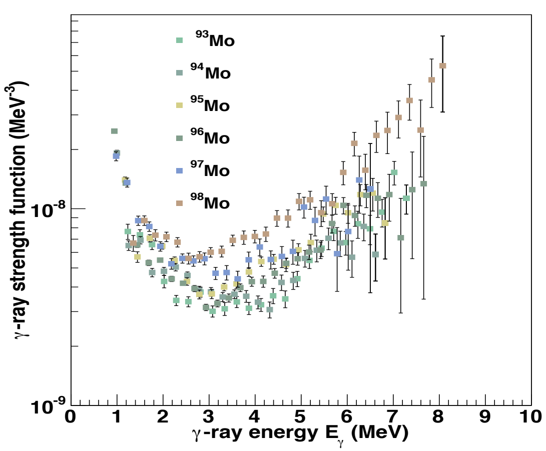


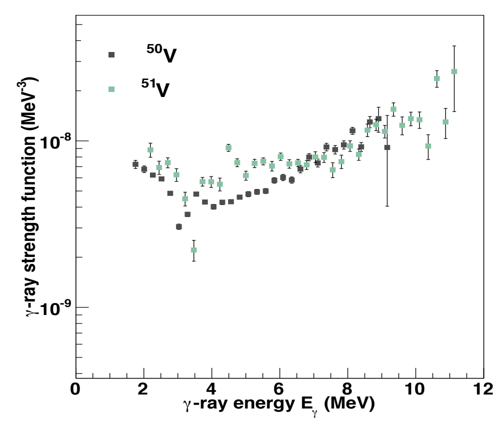
THE LOW ENERGY ENHANCEMENTS...



Electromagnetic character?

MULTIPOLARITY?





NEWS :

(…about multipolarity and electromagnetic character)

Evidence for the dipole nature of the low energy enhancement in ^{56}Fe,
A. C. Larsen et al., Phys. Rev. Lett. 111, 242504 (2013)

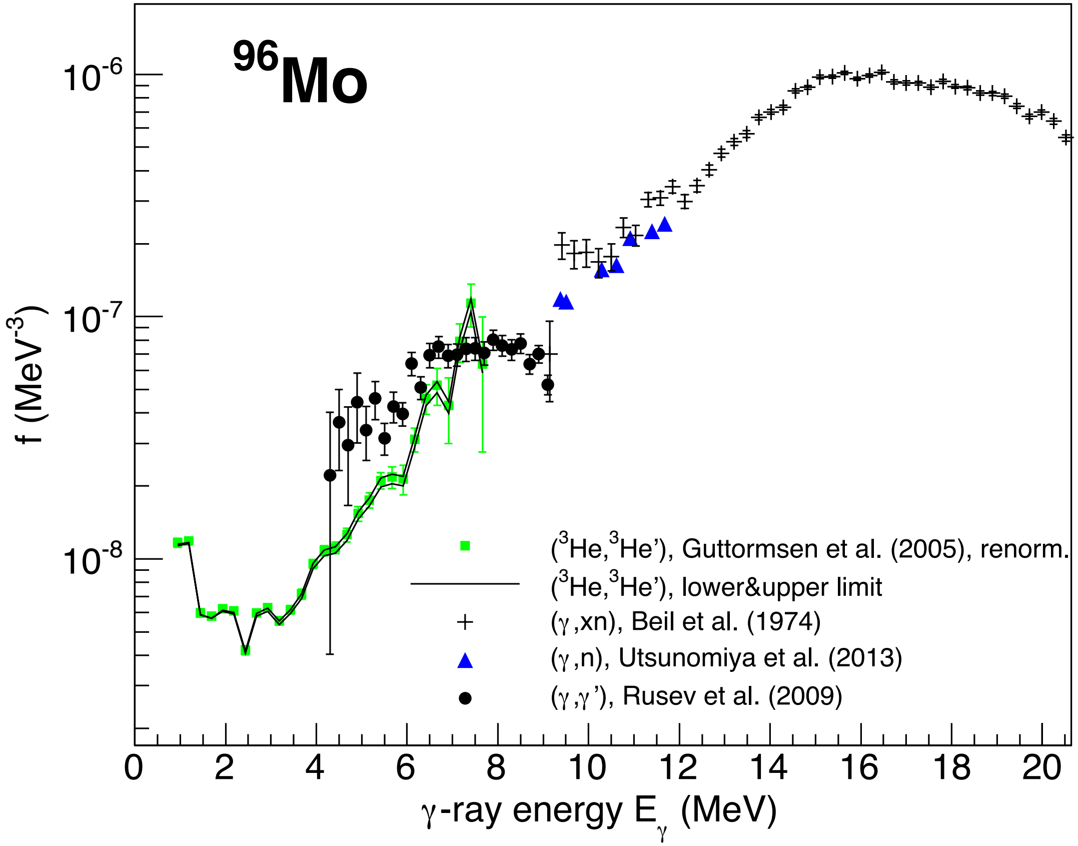
&

Two theoretical explanations:

Argues for E1
E. Litvinova and N. Belov, Phys. Rev. C 88, 031302(R) (2013)

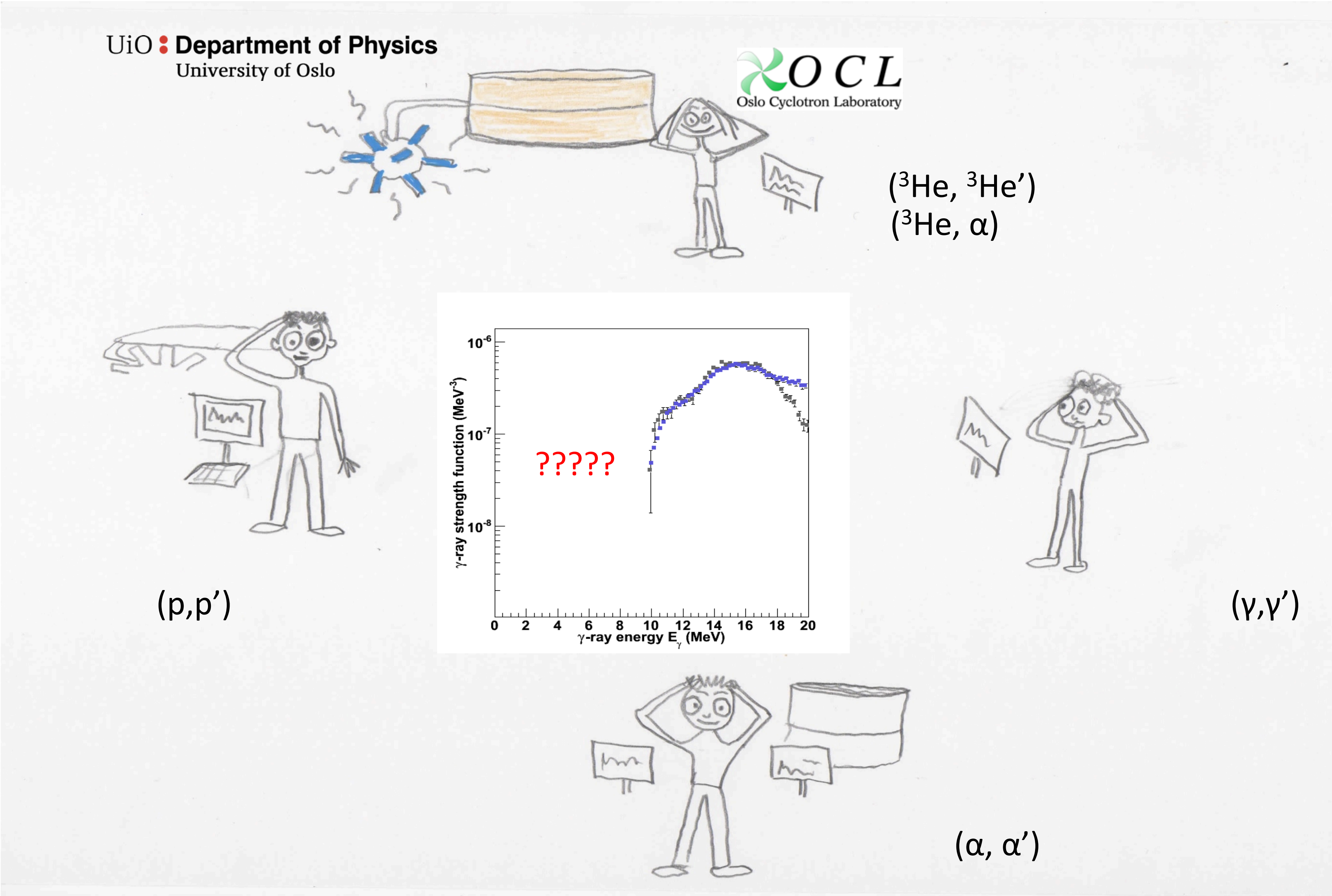
Argues for M1
R. Schwengner, S. Frauendorf, and A. C. Larsen, Phys. Rev. Lett. 111, 23504 (2013)

Many people measuring the same property…?

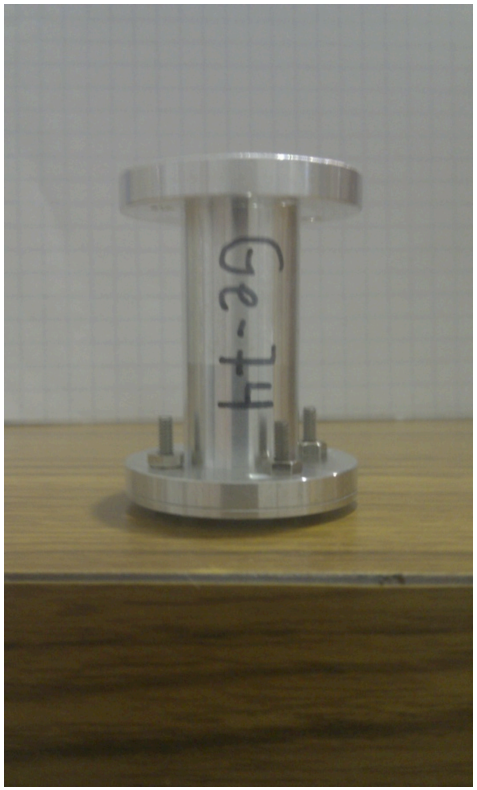


Need for some common case?

The ^{74}Ge experimental campaign



OCL & NewSUBARU



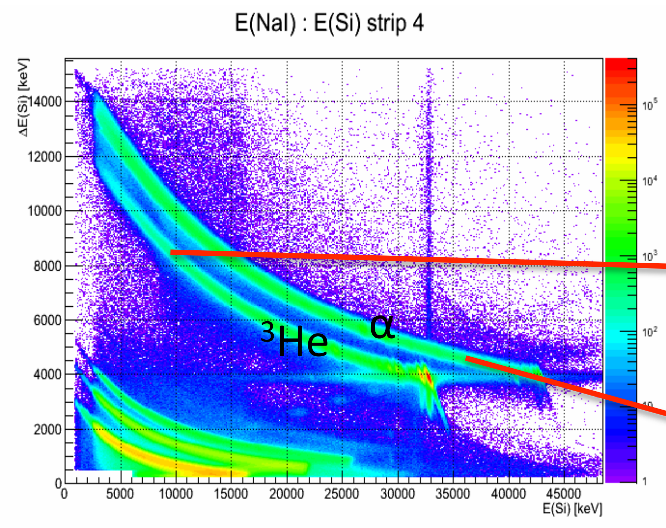
(γ, n)

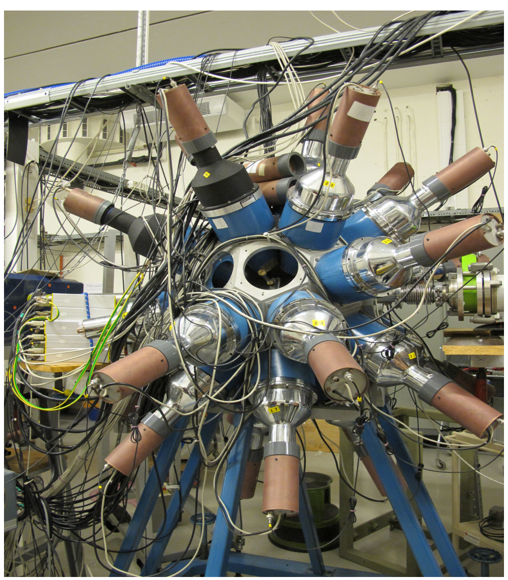
(^{3}He,^{3}He’)
(^{3}He, α)

γ strength function above S_n

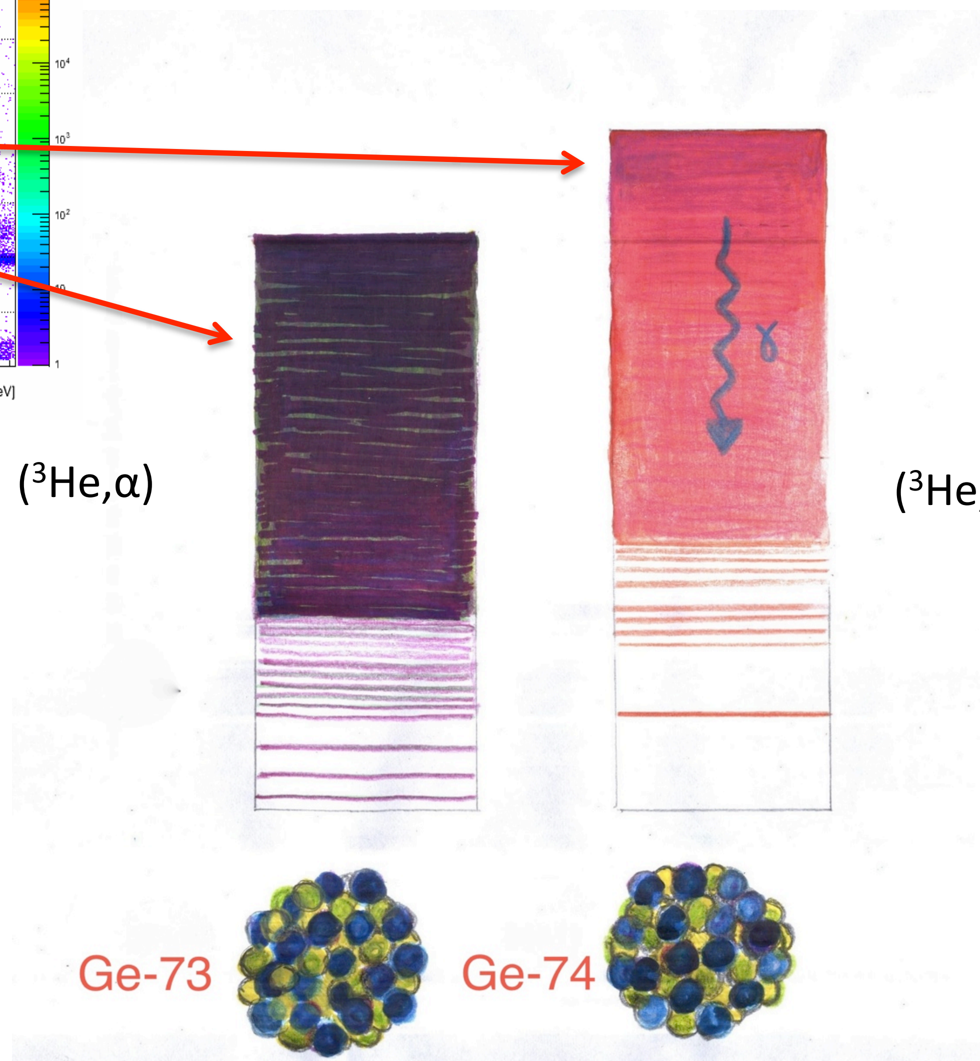
γ strength function below S_n

^{74}Ge & bonus nucleus ^{73}Ge



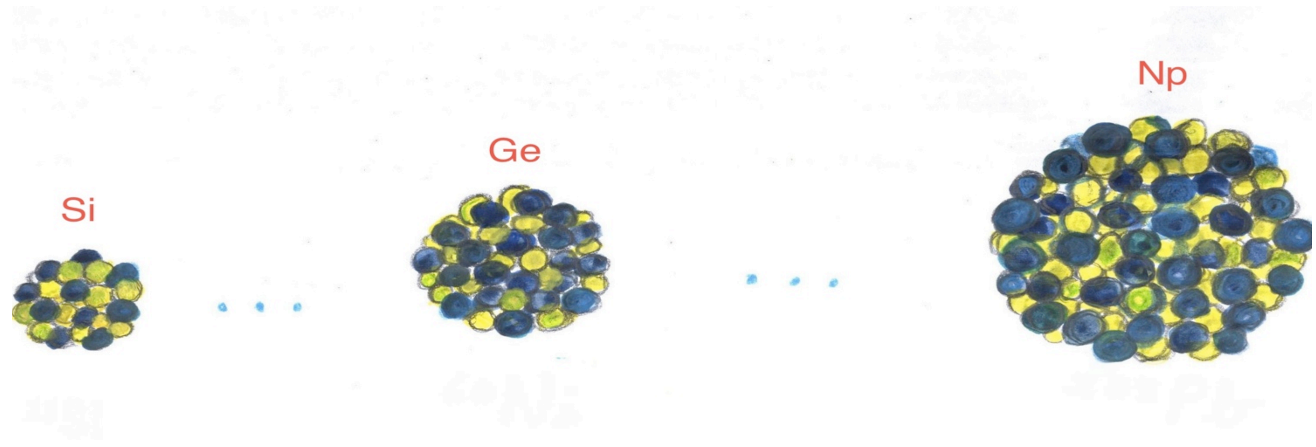


(³He,α)



(³He, ³He')

The Oslo method



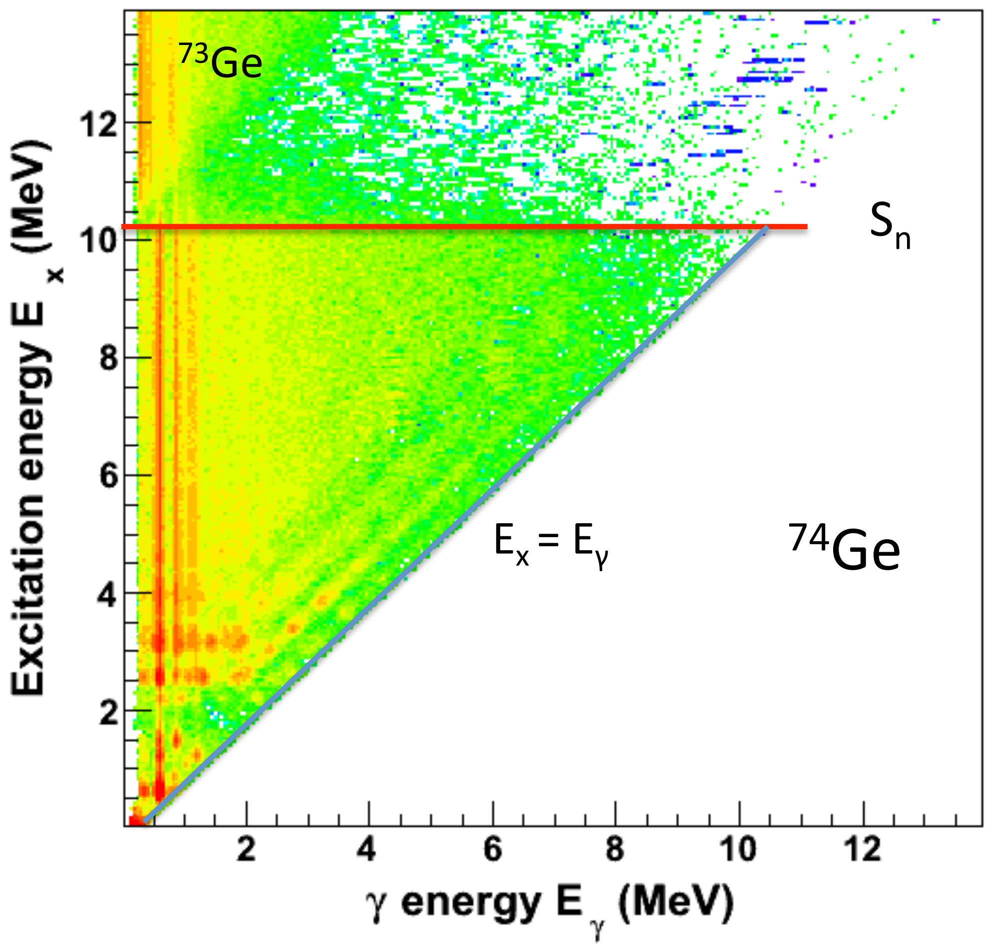
(i) Unfolding of the γ spectra for each excitation energy

(ii) Isolation of primary γ rays

(iii) Extraction of the functional form of the level density and γ ray transmission coefficient

(iiii) Normalization of the level density and γ strength functions

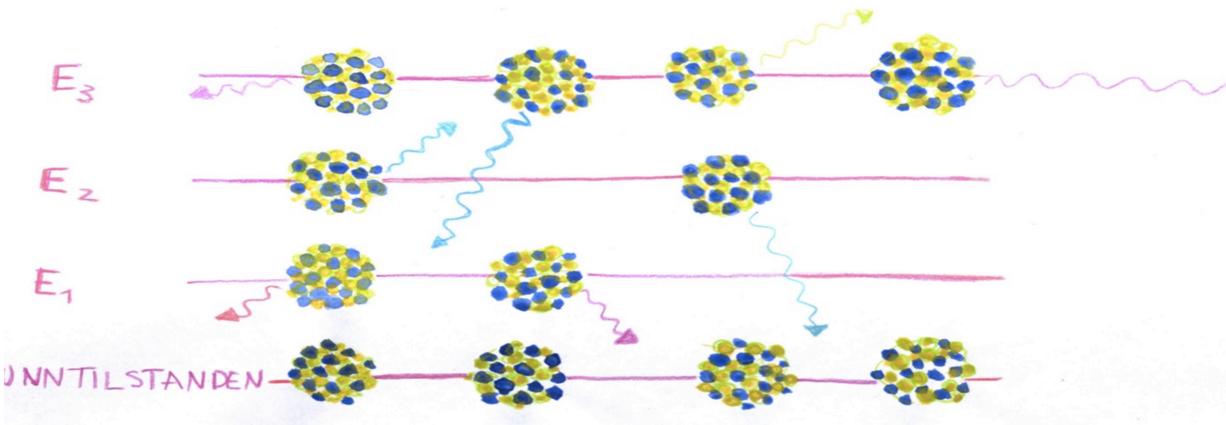
Startpoint of the Oslo method: particle-γ coincidence matrix

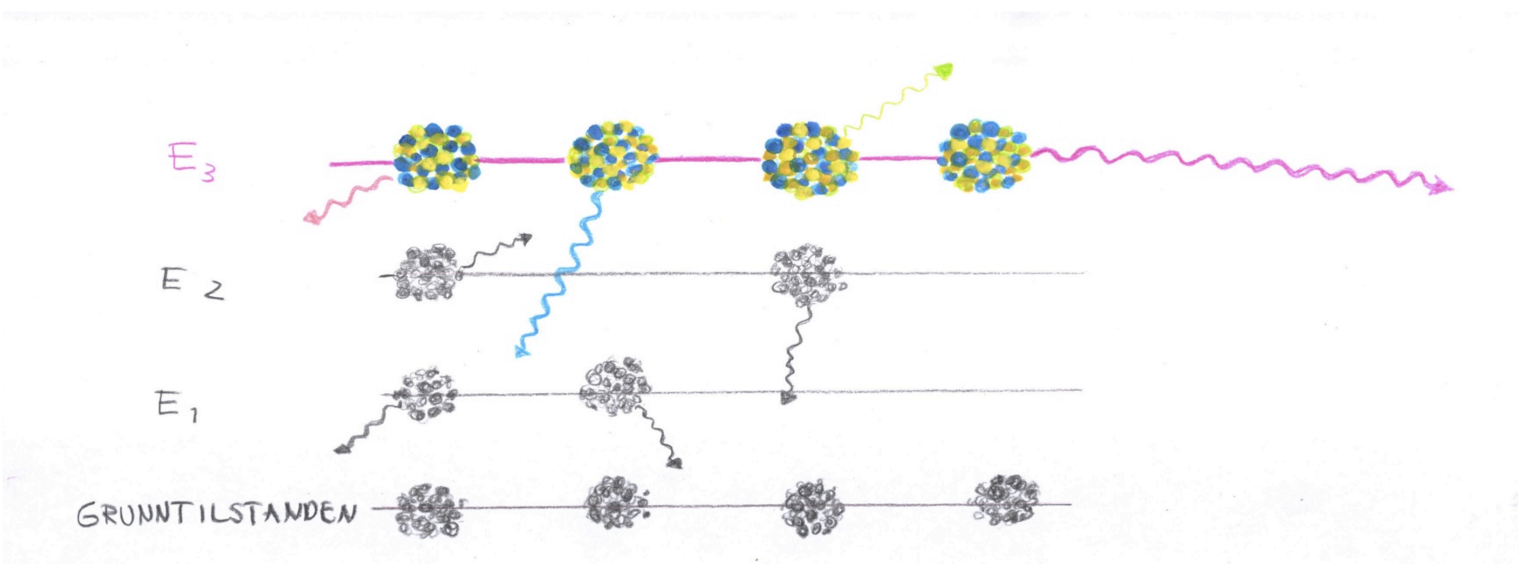


OBS!
Any γ in the cascade

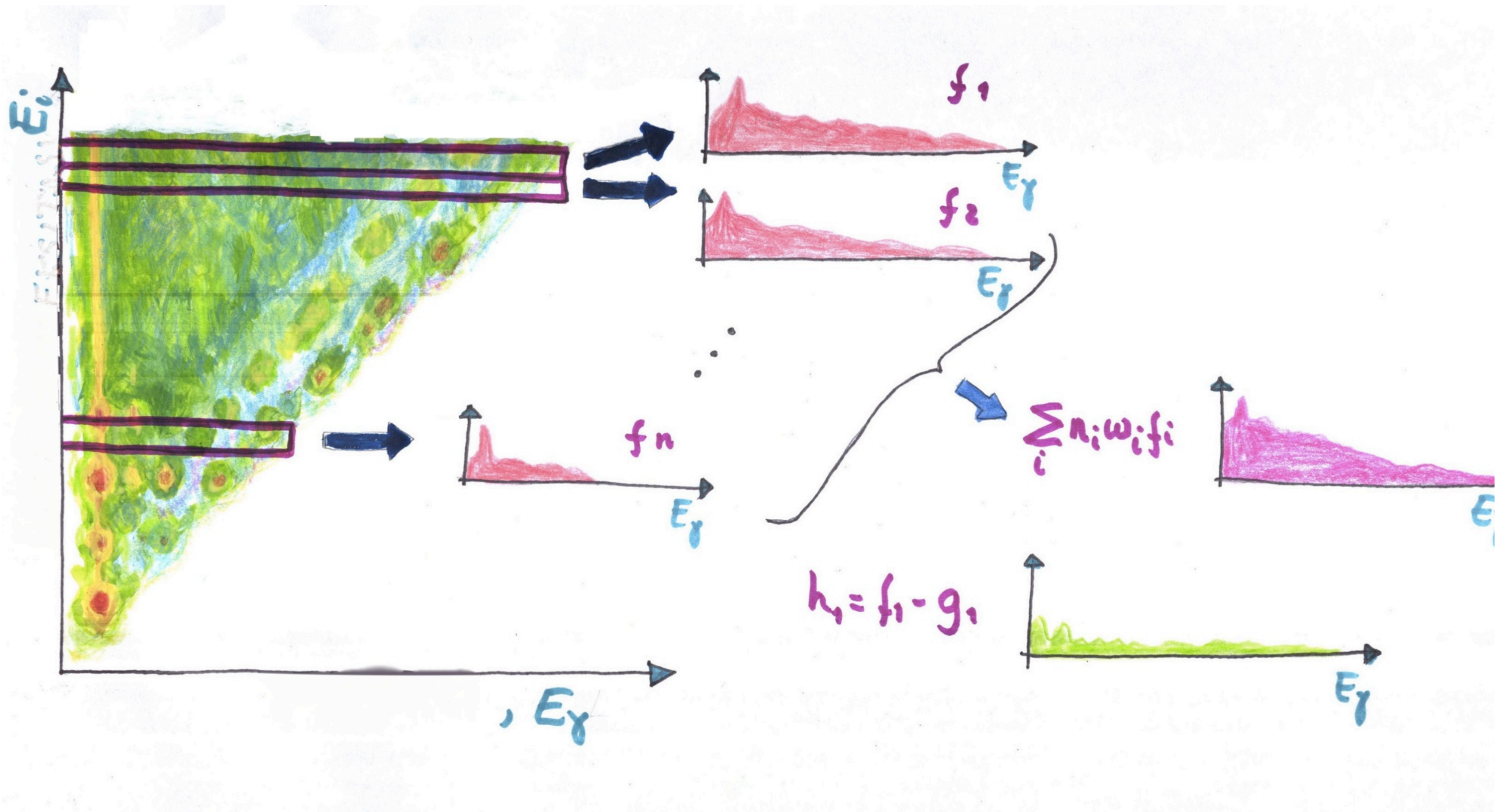
Next step: separate first emitted γ in each cascade

Generations of gammas

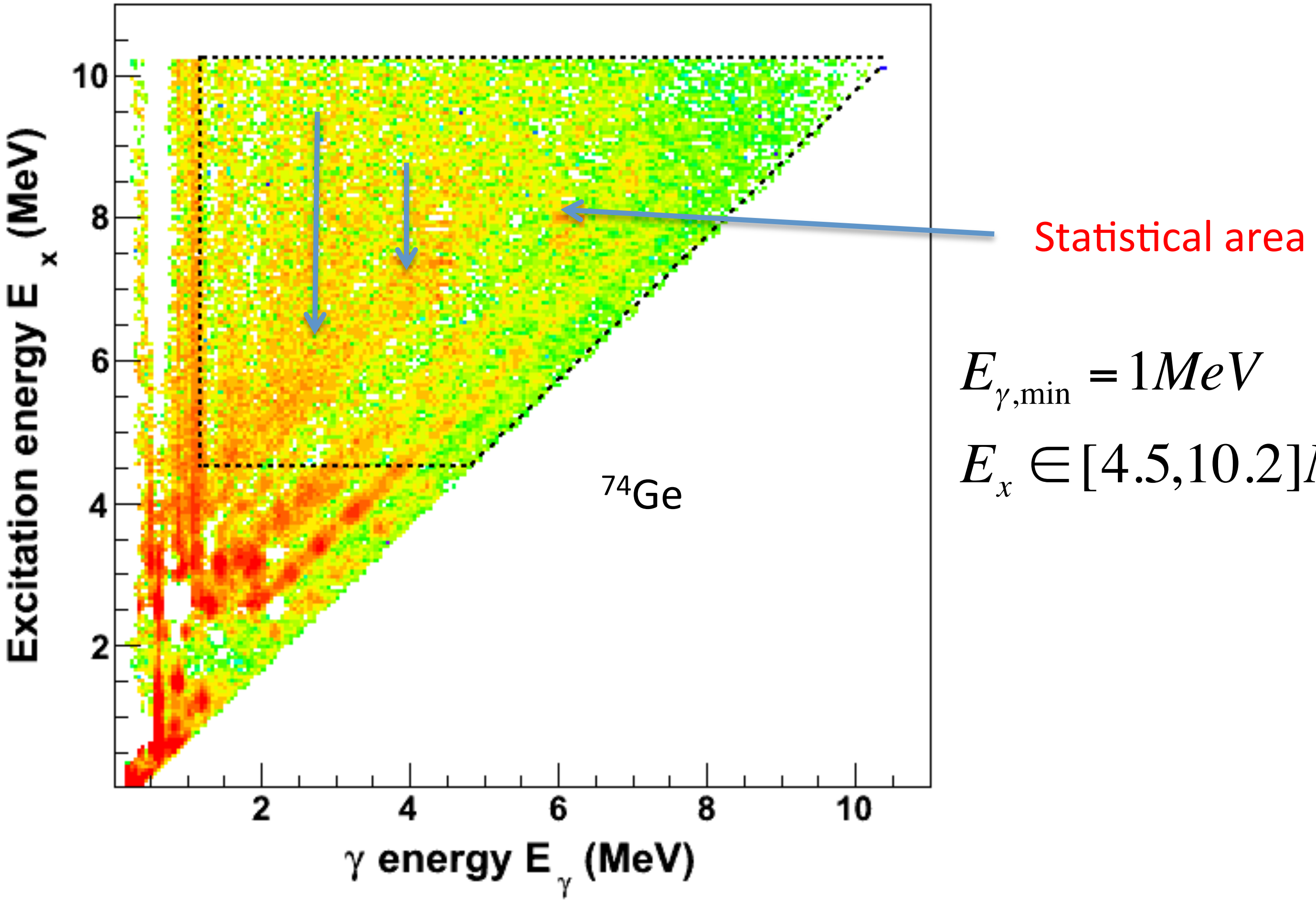




First generation method



First generation matrix



$$E_{\gamma,\min} = 1 MeV$$

$$E_x \in [4.5, 10.2] MeV$$

Extraction of level density and γ-ray transmission coefficient

Here we assume that:

$$P(E,E_\gamma) \propto \rho(E-E_\gamma)\tau(E_\gamma)$$

This ansatz is based on Fermi's Golden Rule and the Brink (Axel) hypothesis

The factorization:

- Normalize $P(E,E_\gamma)$ so that

$$\sum_{E_\gamma=E_\gamma^{\min}}^{E} P(E,E_\gamma)=1.$$

- Theoretical estimate of experimental primary γ matrix:

$$P_{th}=\frac{\tau(E_\gamma)\rho(E-E_\gamma)}{\sum_{E_\gamma=E_\gamma^{\min}}^{E}\tau(E_\gamma)\rho(E-E_\gamma)}$$

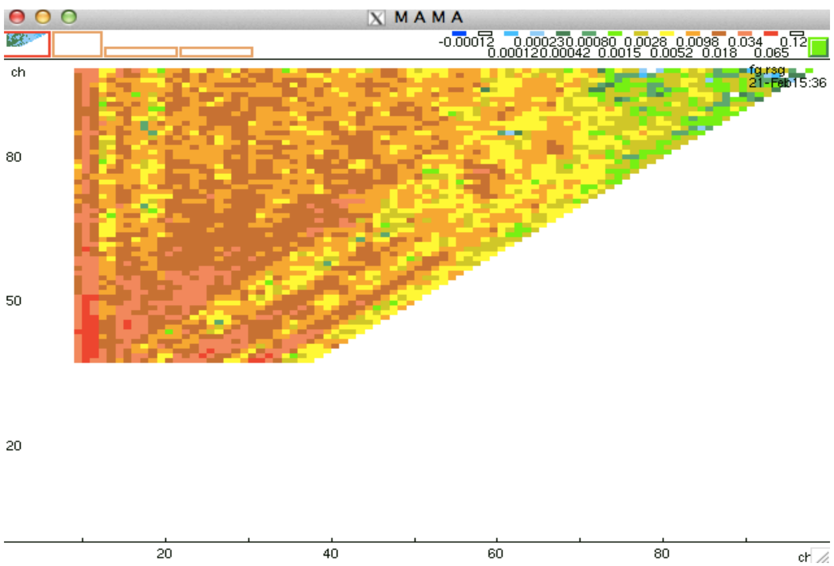
- First trial function:

$$\rho^{(0)}=1,$$

$$P(E,E_\gamma)=\frac{\tau^{(0)}(E_\gamma)}{\sum_{E_\gamma=E_\gamma^{\min}}^{E}\tau^{(0)}(E_\gamma)}$$

- Higher-order estimates through least chi-square minimization:

$$\chi^2 = \frac{1}{N_{free}} \sum_{E=E_{\min}}^{E_{\max}} \sum_{E_\gamma = E_\gamma^{\min}}^{E} \left[\frac{P_{th}(E,E_\gamma) - P(E,E_\gamma)}{\Delta P(E,E_\gamma)} \right]^2$$



Normalization is needed…

The Oslo method provides functional form of level density and gamma transmission coefficient, but not the slope or absolute value…

$$\tilde{\rho}(E-E_\gamma) = \rho(E-E_\gamma) A \exp[\alpha(E-E_\gamma)]$$

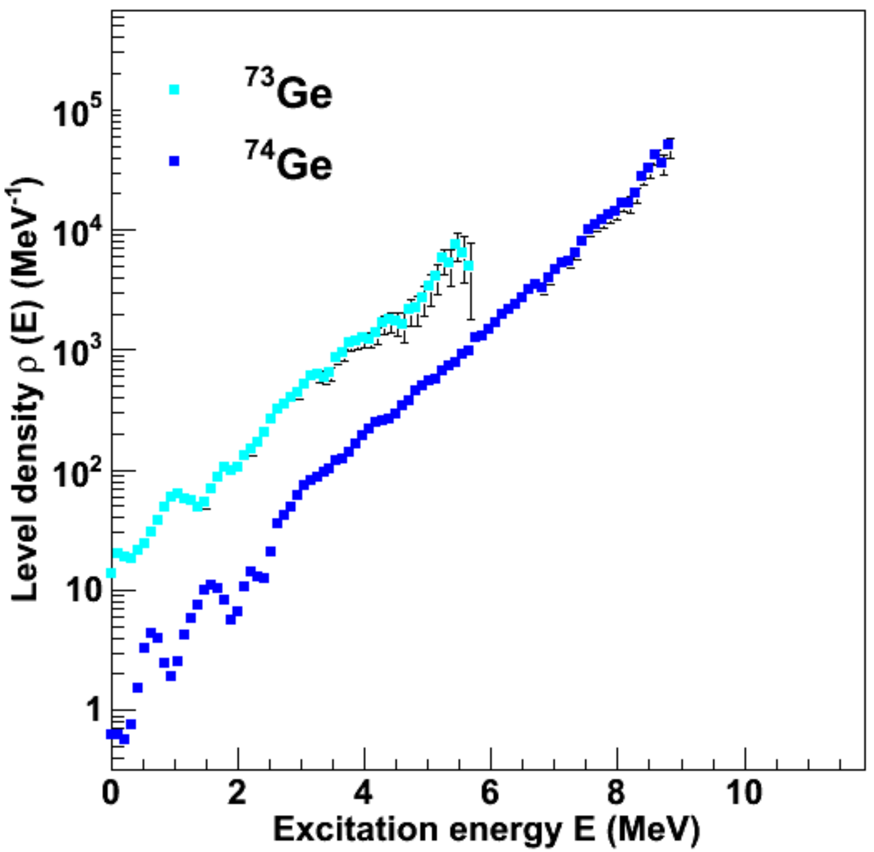
$$\tilde{\tau}(E_\gamma) = \tau(E_\gamma) B \exp(\alpha E_\gamma)$$

Level density: known discrete levels at low E_x
information from neutron-resonance experiments at S_n

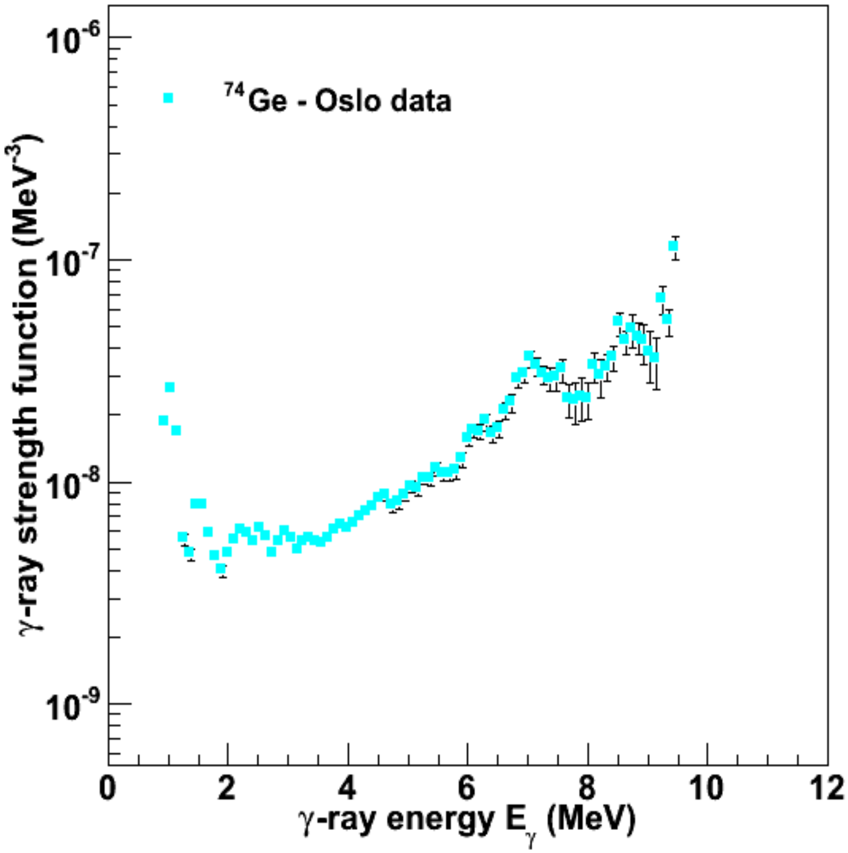
Gamma strength function: average, total radiative width

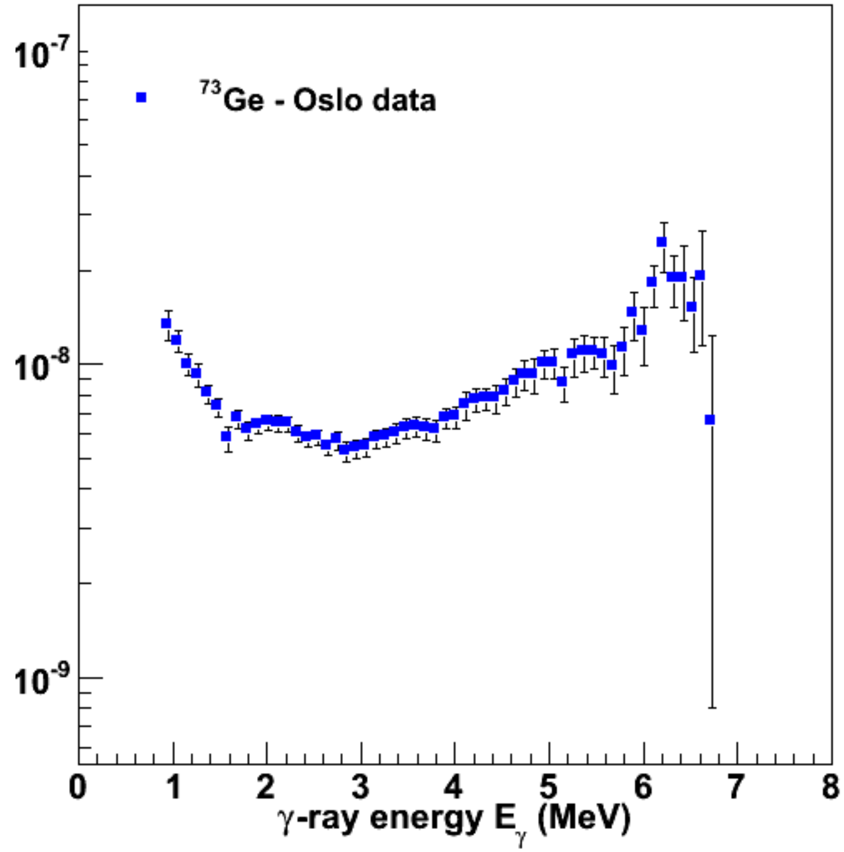
γ-decay in this area is dominated by dipole radiation, so γSF is dominated by dipole radiation, so we have: $f(E_\gamma) \approx \tau(E_\gamma)/2\pi E_\gamma^3$

Preliminary results:



Upbend?



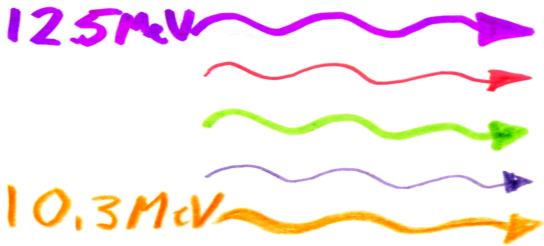


Similar to existing data, good agreement in strength between the two isotopes.

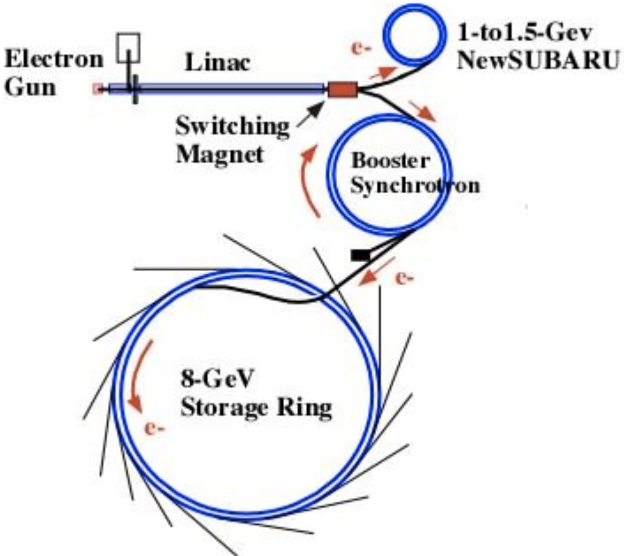
The campaign???

(p,p') data : Clear signs of upbend
(α, α') data : Not yet resolved
(γ, γ') data: Under analysis

The photo-neutron experiment



NewSUBARU synchrotron radiation facility

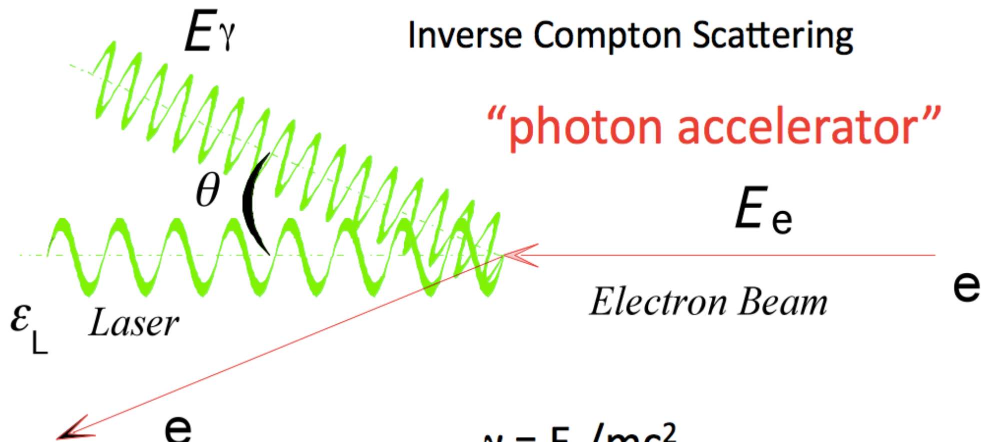


- Experimental collaboration: several Sm, Nd, Dy isotopes investigated.
- And ^{74}Ge☺

Relativistic electrons vs eV photons

Laser Compton backscattered
-ray beams are ideal because:

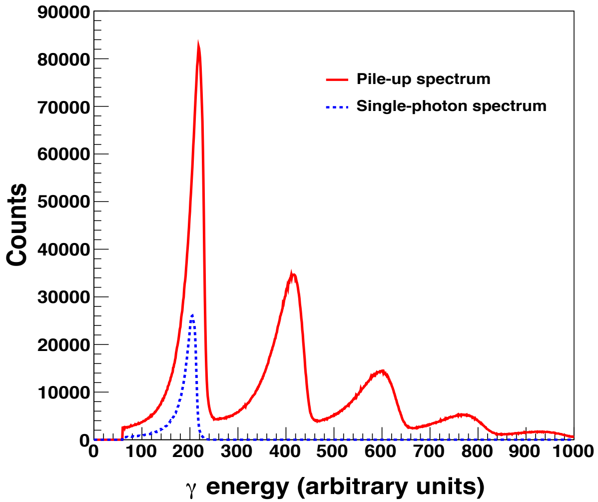
- ❖ Almost monochromatic
- ❖ Tuneable energies



$\gamma = E_e/mc^2$

$$E_\gamma = \frac{4\gamma^2 \varepsilon_L}{1 + (\gamma\theta)^2 + 4\gamma\varepsilon_L/(mc^2)}$$

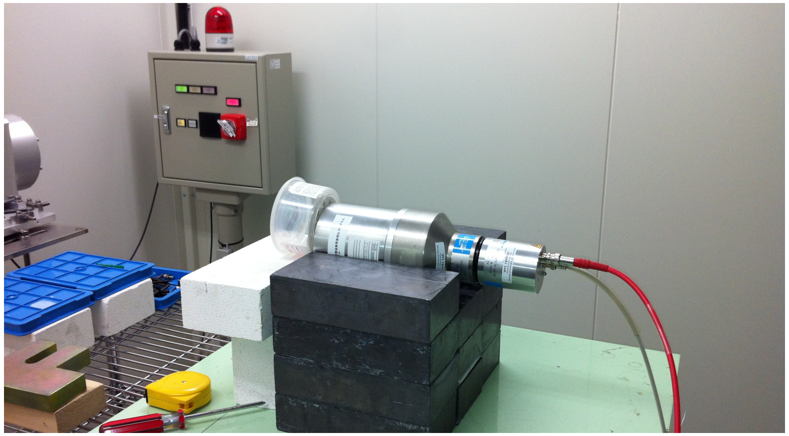
20 ^{3}He proportional counters



$$\int_{S_n}^{E_{\max}} n_\gamma(E_\gamma)\sigma(E_\gamma)dE_\gamma = \frac{N_n}{N_t N_\gamma \xi \varepsilon_n g}$$

Efficiencies!!!

Counting!

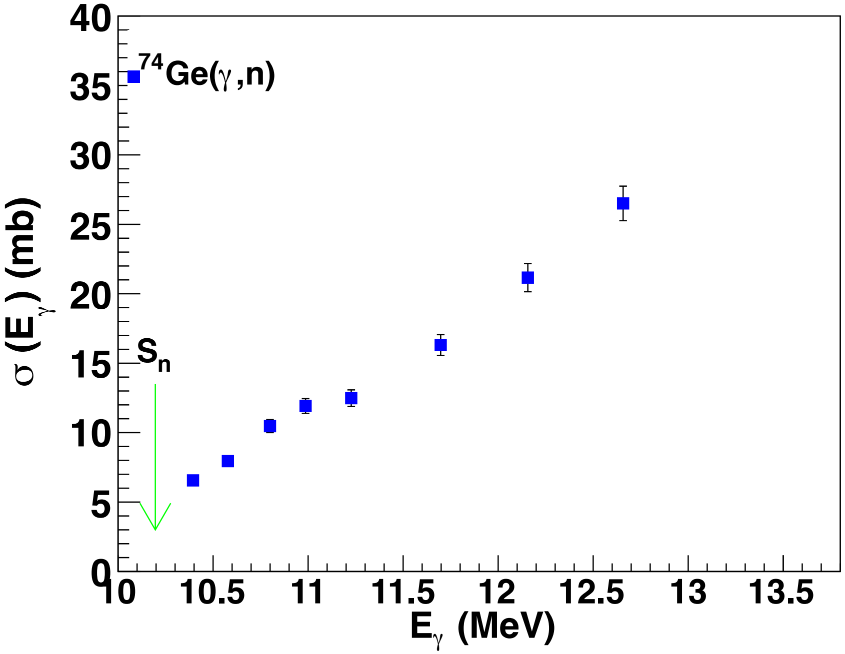


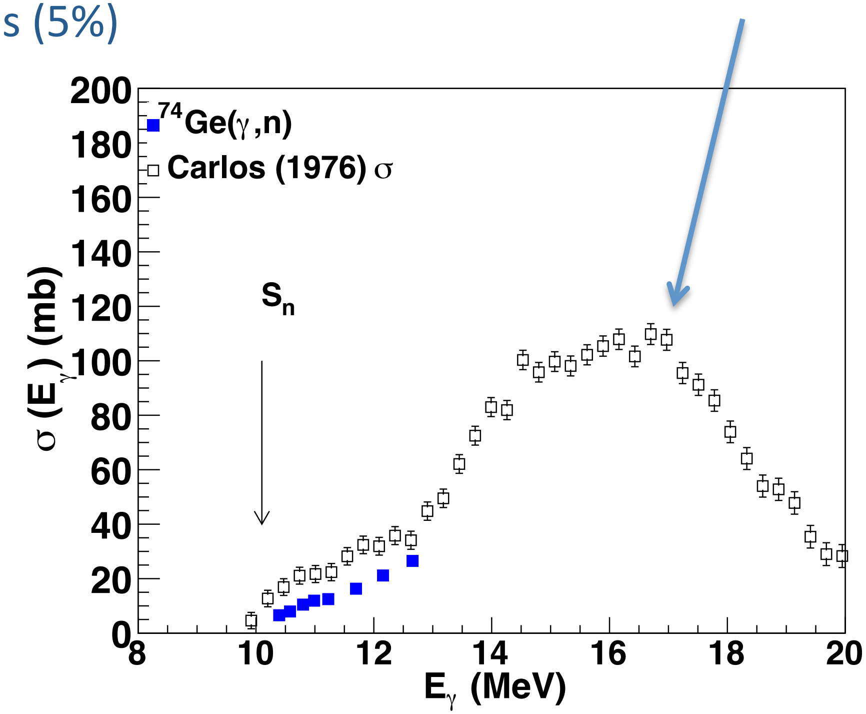
Solve integral using
Taylor expansion method

(γ, n) cross sections

- A bit low (16%), no structure
- Small uncertainties (5%)

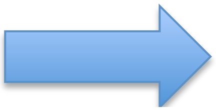
From positron annihilation in flight

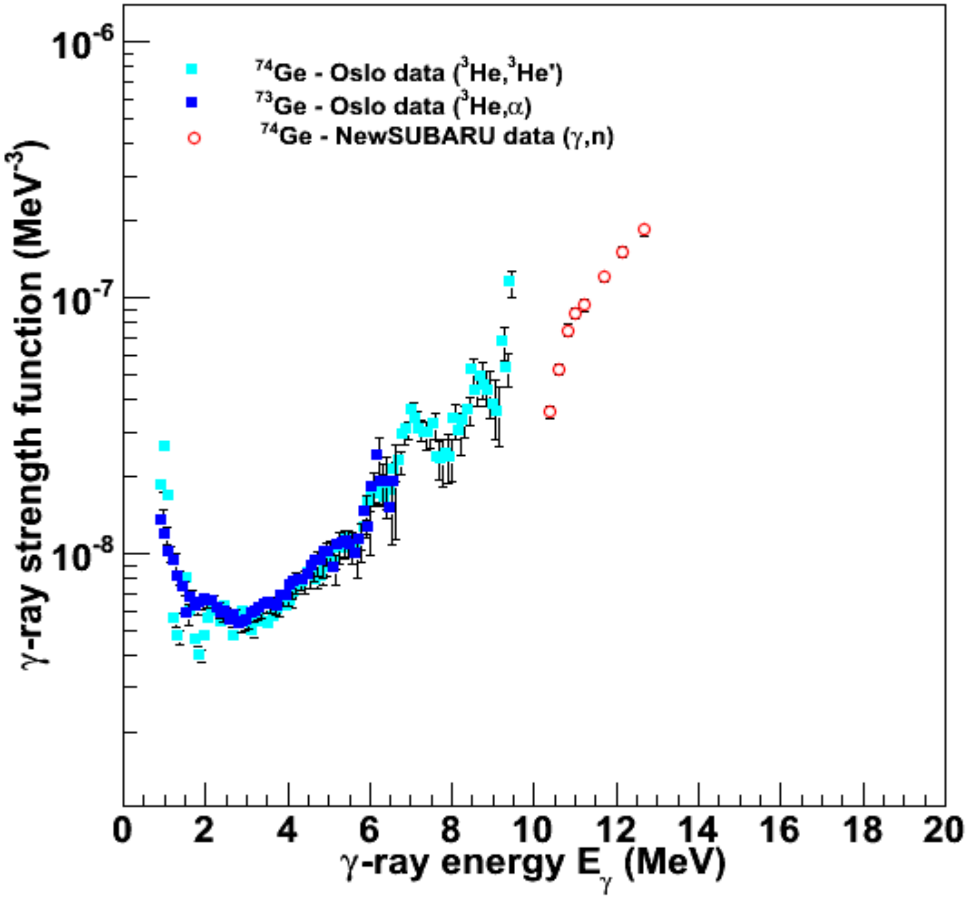




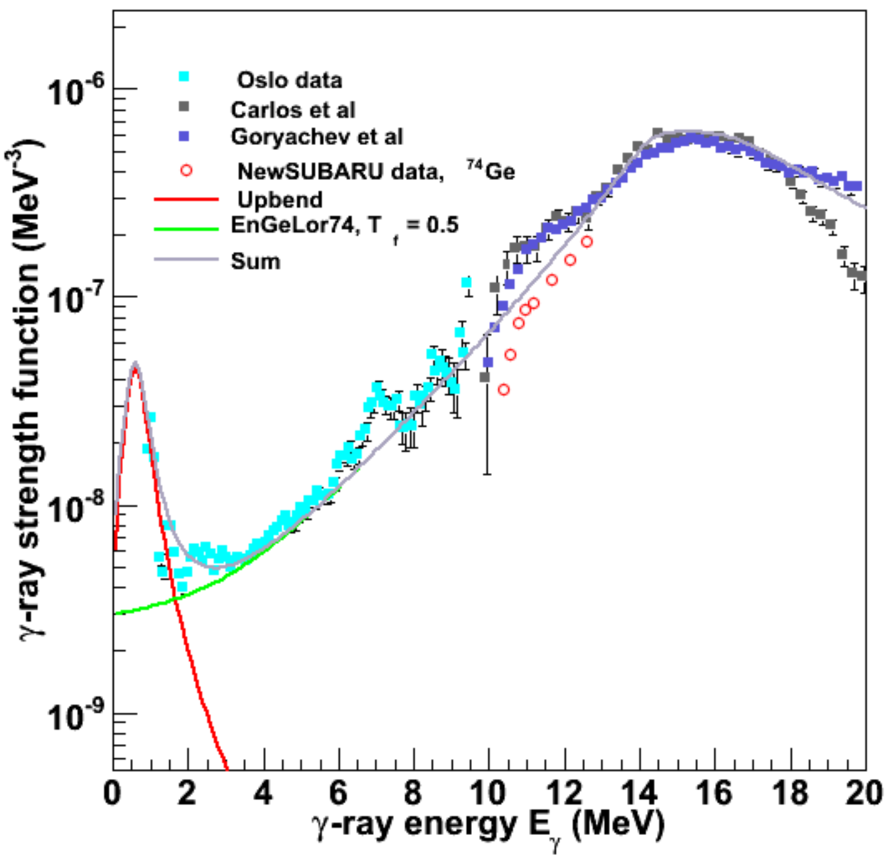
$$f(E_\gamma) = \frac{1}{3\pi^2\hbar^2c^2}\frac{\sigma(E_\gamma)}{E_\gamma}$$

Detailed balance





Modeling the upbend:



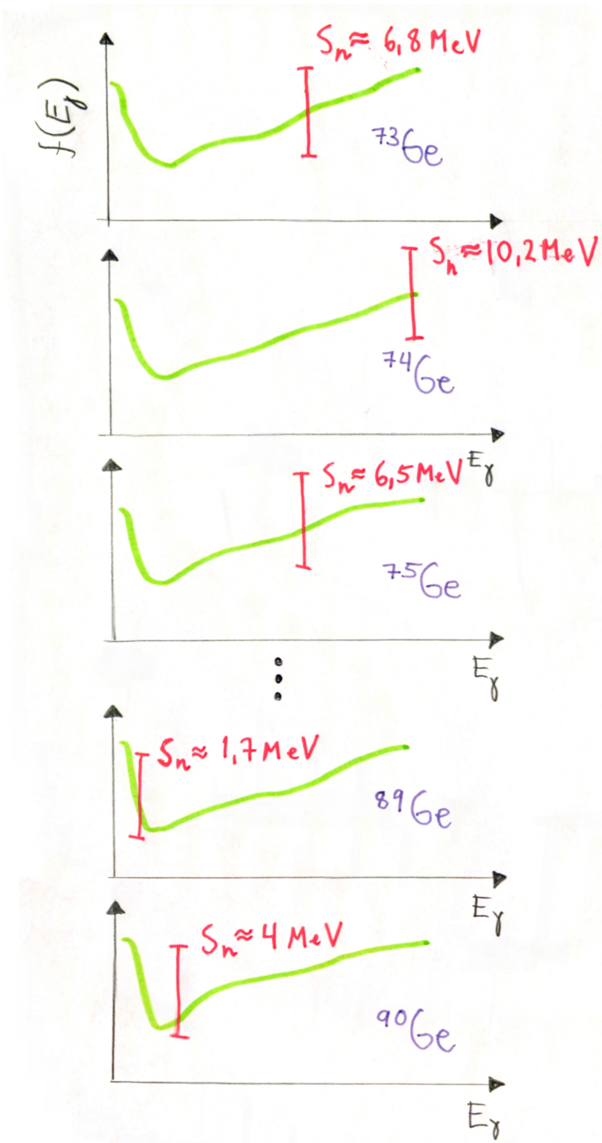
Calculate (n,γ) astrophysical reaction rates using TALYS.

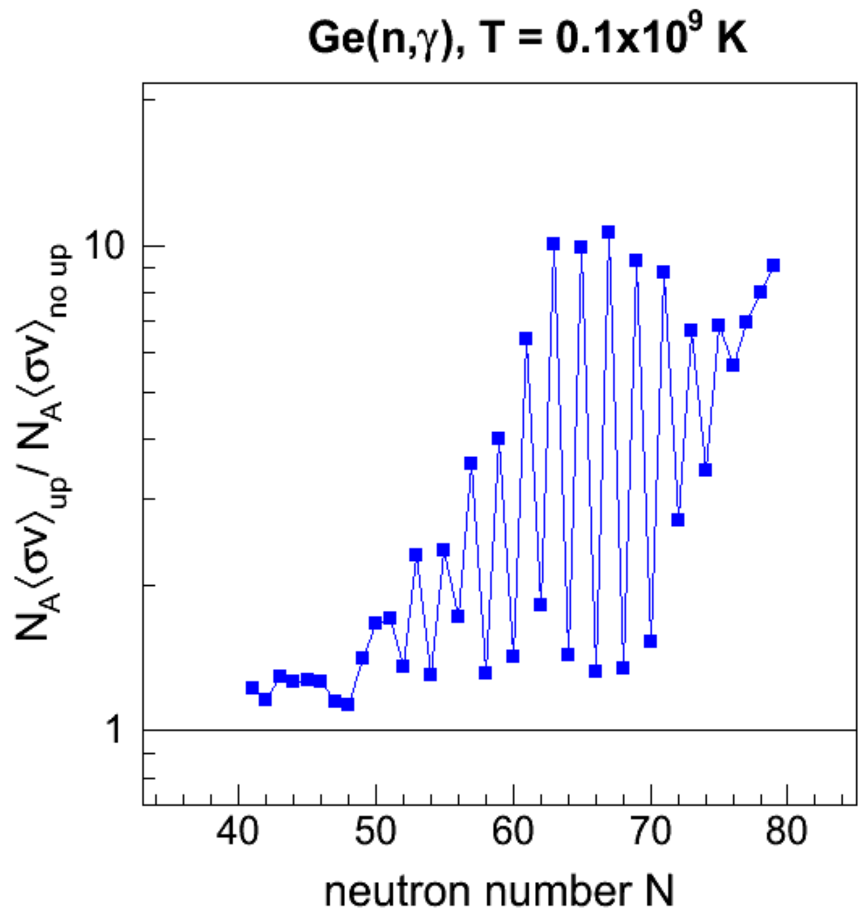
Input:
Level density:E1 QRPA
Strength function: Combinatorial + Hartree-Fock-Bogoliubov (with Skyrme force)

M1, Lorentzian upbend

This enhancement may have a large effect for extremly neutronrich nuclei!

Effect on (n,γ) reaction rates



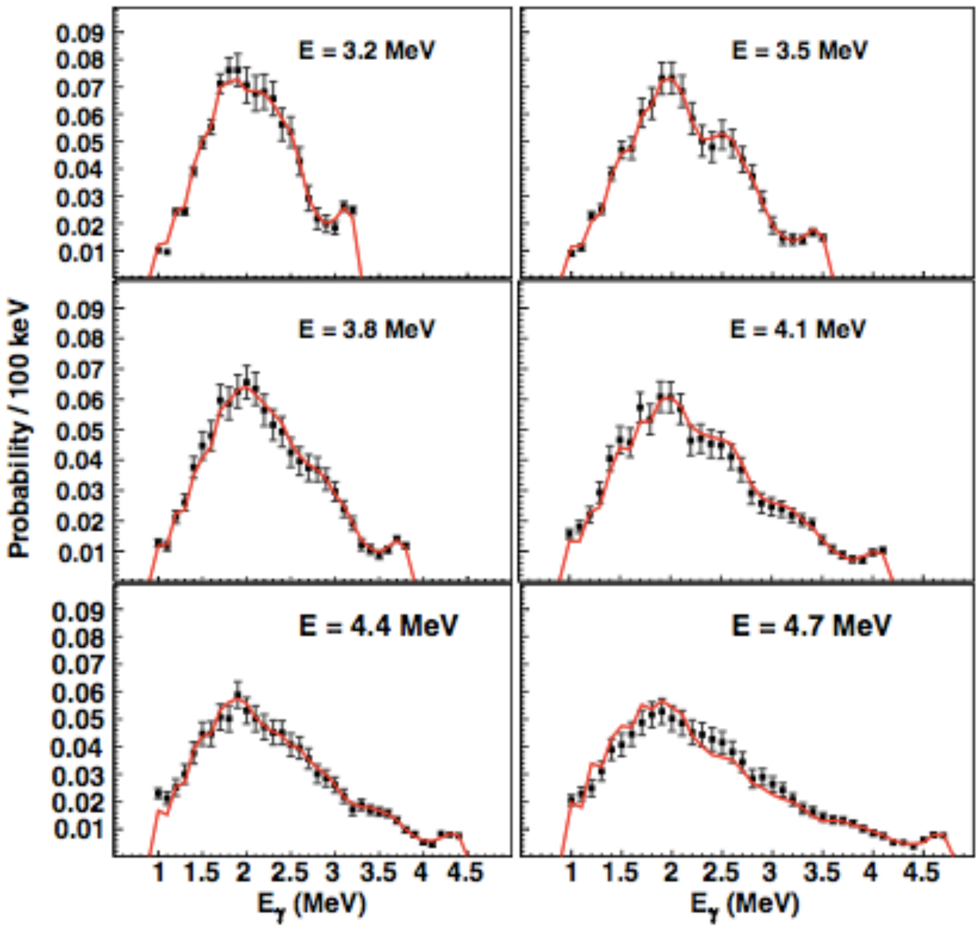


Same upbend for all isotopes???

- We use the same strength on upbend for all isotopes.
- Best we can do for the moment, but we now have data from MSU for ^{76}Ge, show similar upbend to that of in ^{73,74}Ge.
- Preparing proposal for measuring ^{78,80}Ge to see if the upbend is still there and looks the same.

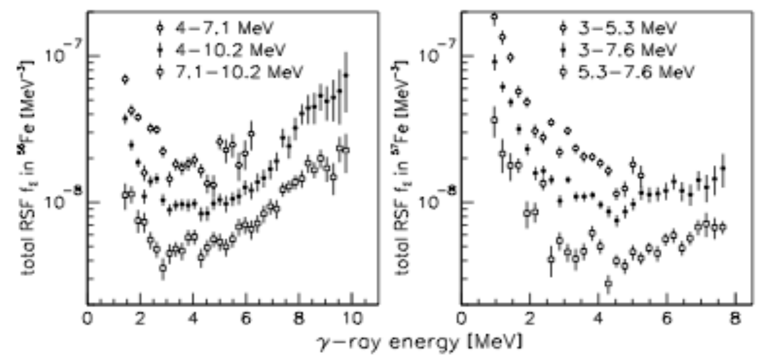
THANK YOU FOR
LISTENING

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



^{233}Th

A. Voinov et al., Phys. Rev. Lett. **93**, 142504 (2004)



^{56}Fe ^{57}Fe