The multipolarity of the low-energy γ-strength from a radiative proton capture experiment

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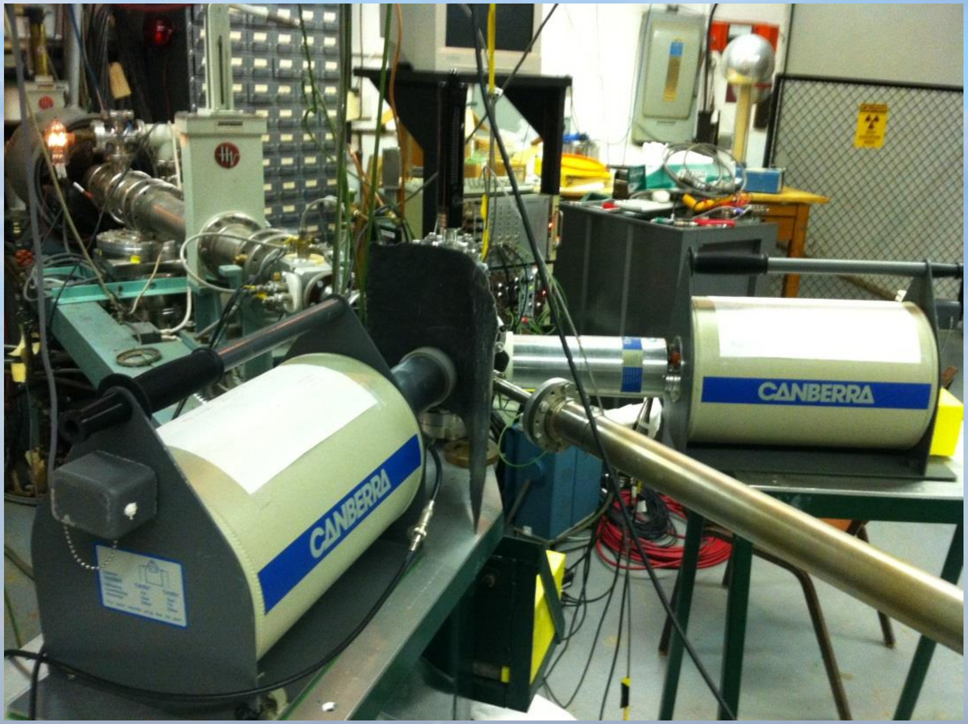
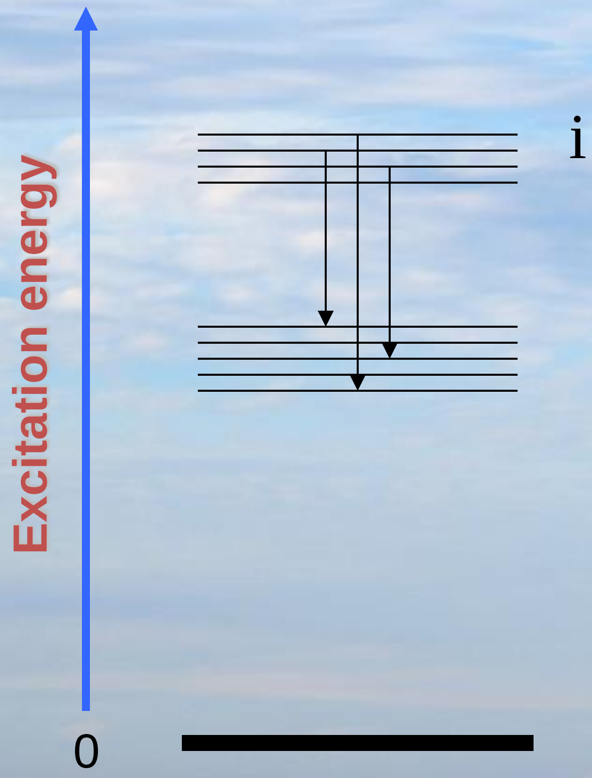
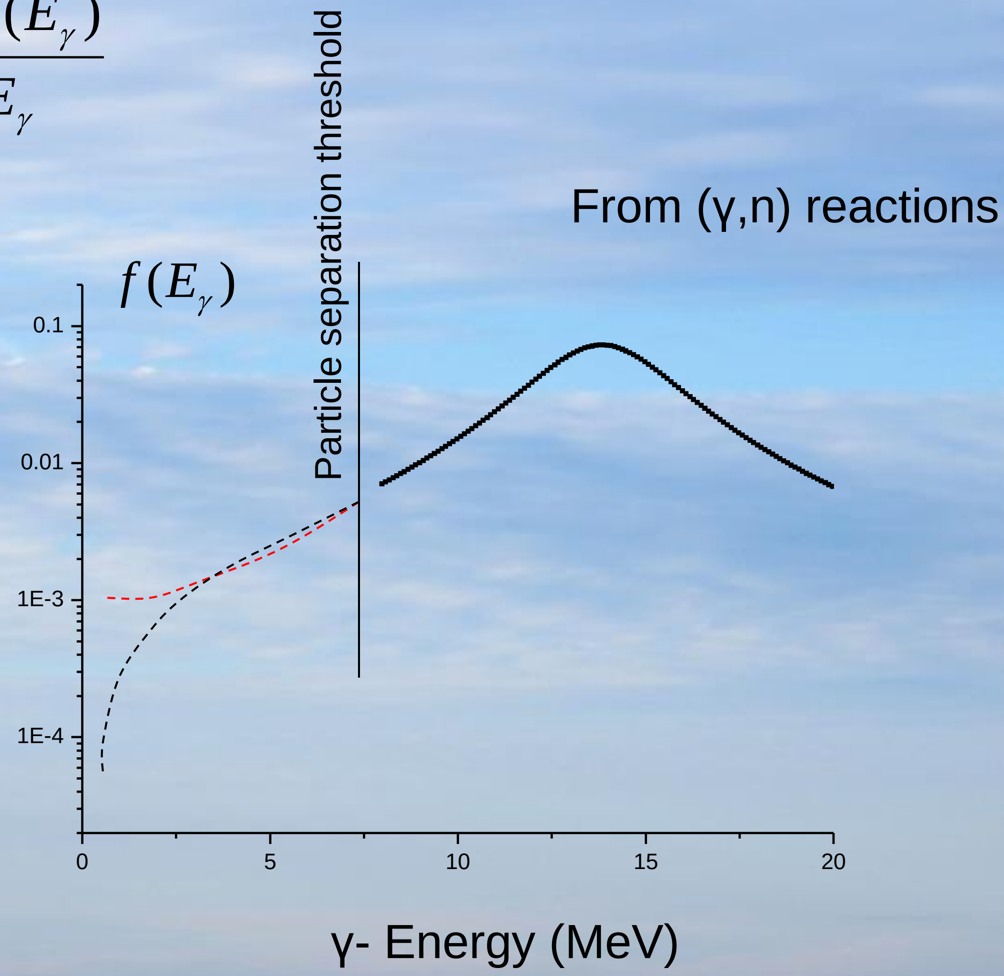


γ – strength function in continuum

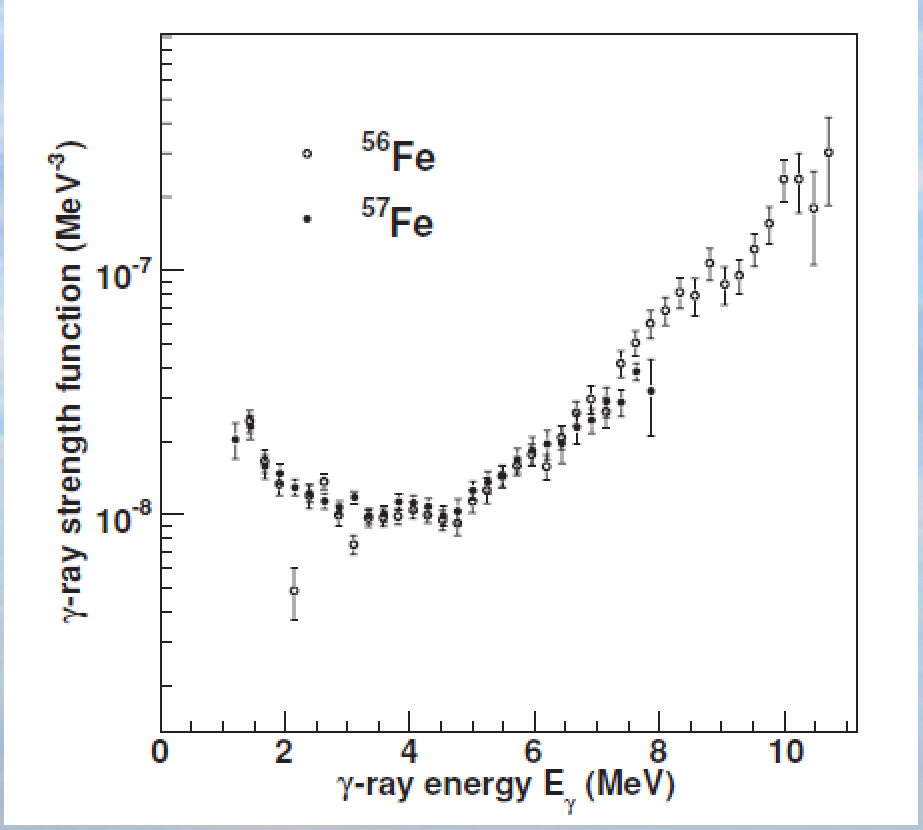
$$f(E_\gamma) = \frac{<\Gamma(E_\gamma)>}{E_\gamma^3 <D_i>} \sim \frac{\sigma_{\mathrm{abs}}(E_\gamma)}{E_\gamma}$$





γ-strength function from Oslo type of experiments
Low energy upbend phenomenon

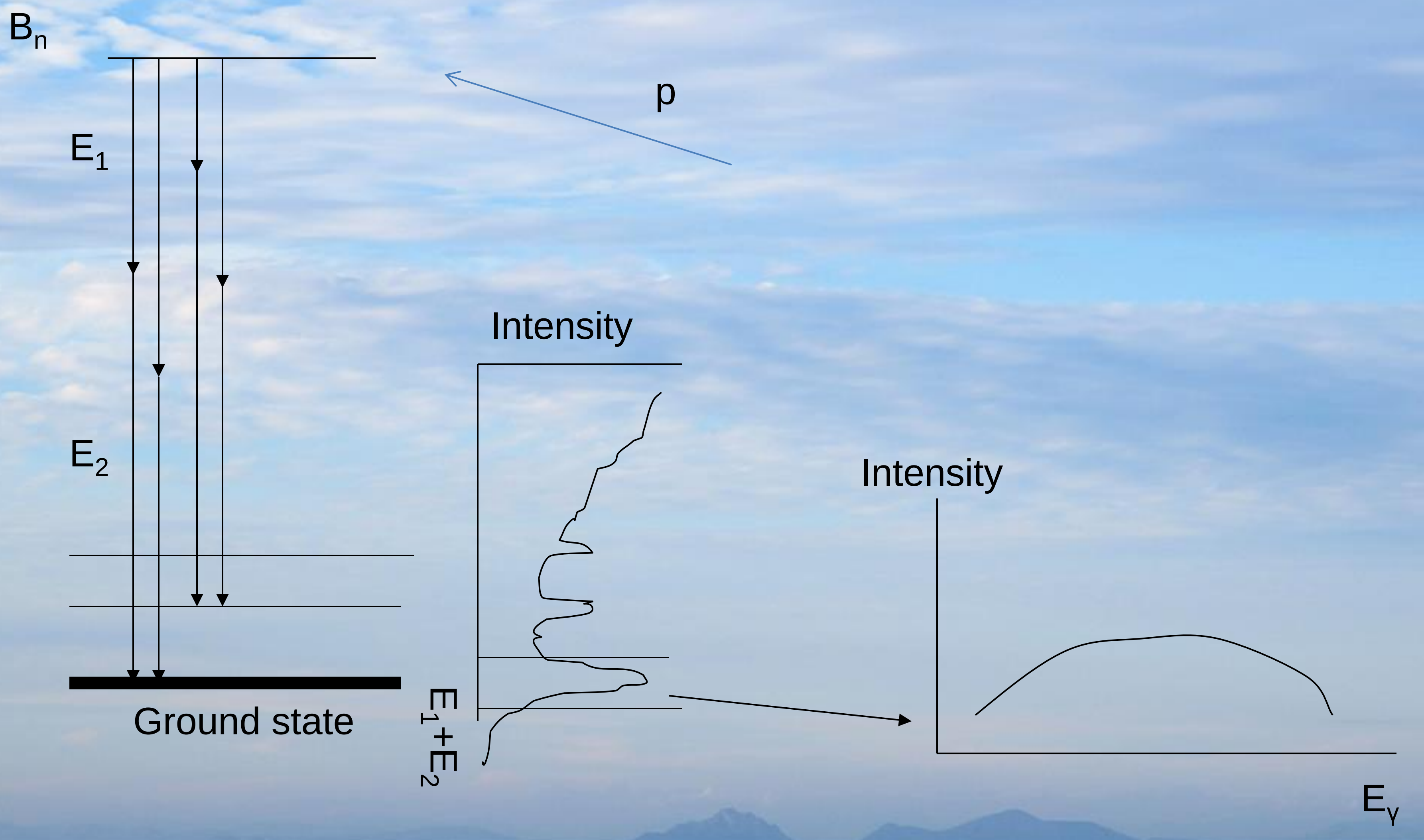
$$f_{tot} = (f_{E1} + f_{M1})$$



Problem of decomposition of the measured γ-strength into E1 and M1 components remains unsolved.

Phys.Rev.Lett. 93, 142504 (2004)

Method of two-step γ – cascades from capture reactions



Measurement of γ-strength function at Edwards Lab. of Ohio University

$^{55}Mn(p,2\gamma)^{56}Fe$

γ-strength of ^{56}Fe

$^{55}Mn(d,n)\,^{56}Fe$

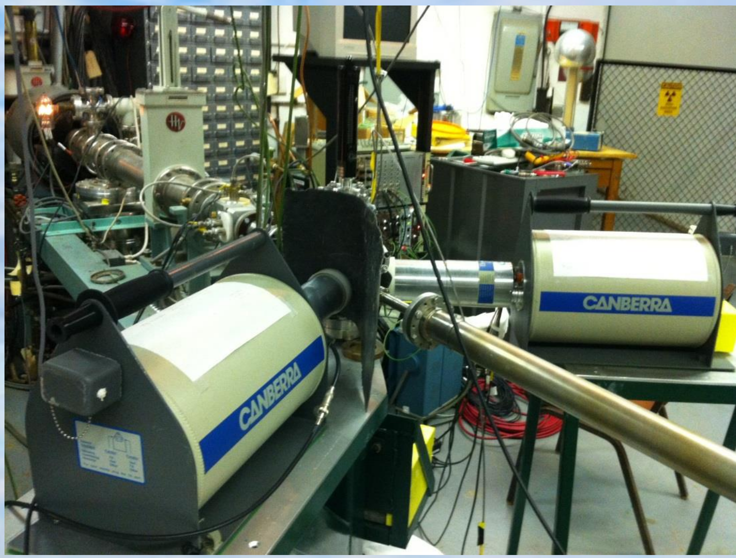
Level density of ^{56}Fe

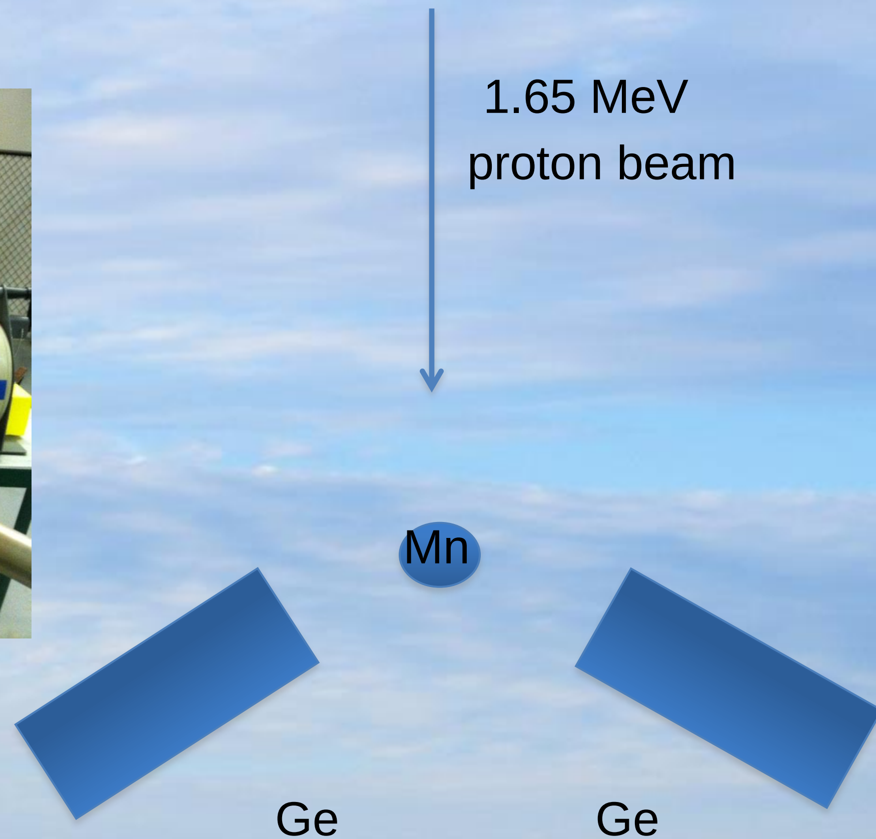
1. Level density was obtained from neutron evaporation spectra.
   A. Voinov et al., Phys. Rev. C 74, 014314 (2006).

2. γ-strength function is analyzed from two-step cascade spectra

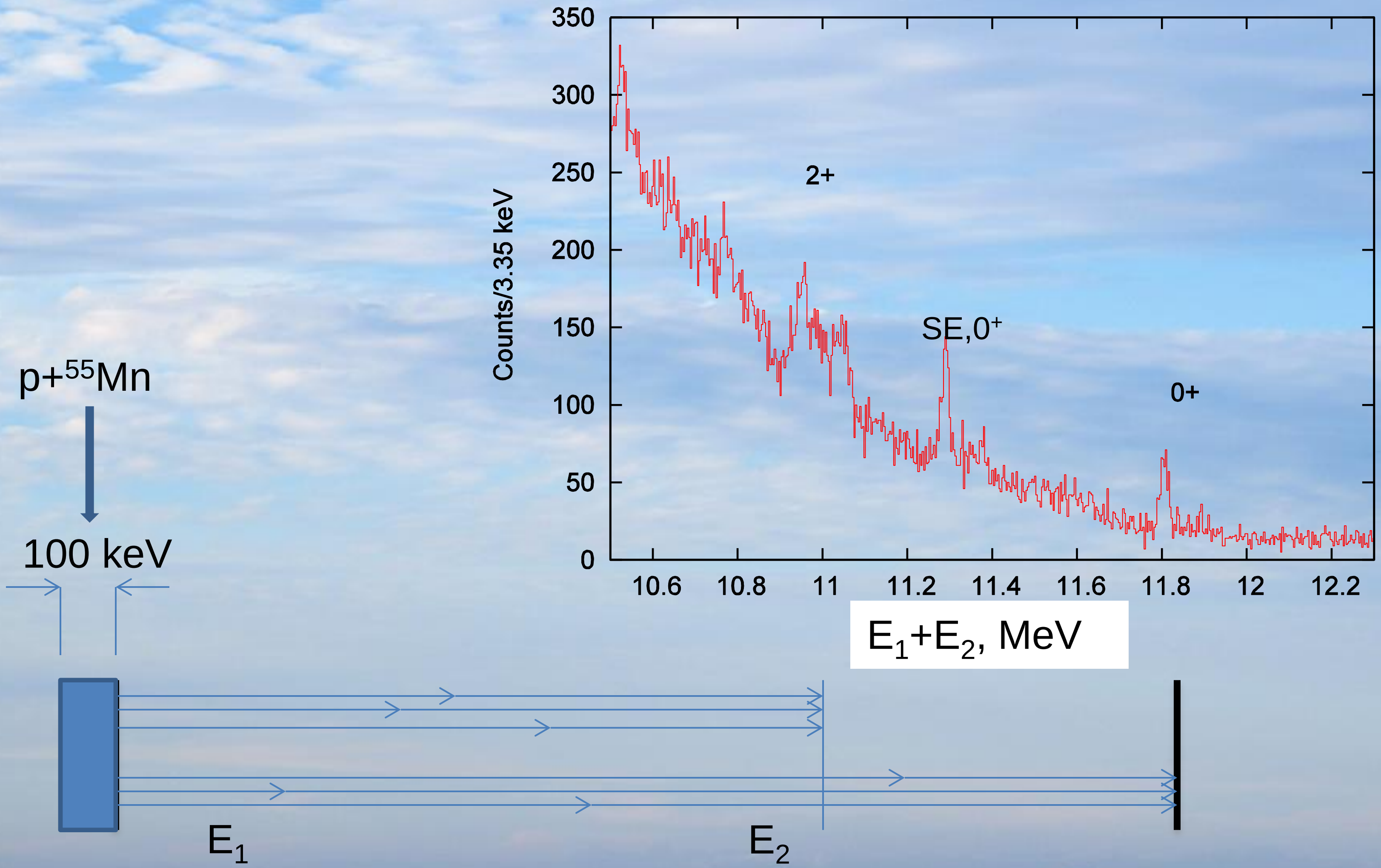
$^{55}Mn(p,2\gamma)\,^{56}Fe$ reaction at E_p=1.65 MeV

Experimental scheme





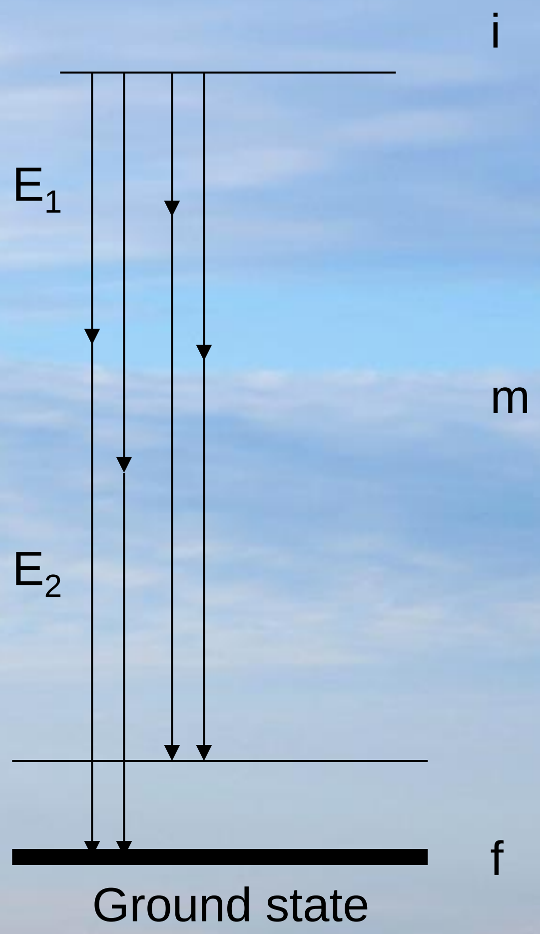
Cascade γ-decay following p+^{55}Mn reaction



Calculations

$$I_{if}(E_1,E_2) = \sum_{XL,XL',J^\pi_m} \frac{\Gamma^{XL}_{im}(E_1)}{\Gamma_i} \rho(E_m,J^\pi_m) \frac{\Gamma^{XL'}_{mf}(E_2)}{\Gamma_m} + \sum_{XL,XL',J^\pi_{m'}} \frac{\Gamma^{XL}_{im'}(E_2)}{\Gamma_i} \rho(E'_m,J^\pi_{m'}) \frac{\Gamma^{XL'}_{m'f}(E_1)}{\Gamma_{m'}}$$

$$\Gamma^{XL}_{i\to m}(E_\gamma) = f_{XL}(E_\gamma) E_\gamma^{2L+1} D_i$$



Level density: from $^{55}Mn(d,n)^{56}Fe$ reaction

Initial spin distribution: optical model parameters, RIPL-3, A.J.Koning et al Nucl. Phys. A713, 231 (2003).

Idea of separation of the total E1+M1 strength into its E1 and M1 component

$f_{total}=f_{E1}+f_{M1}$ from Oslo experiment

$I_{\gamma\gamma} \sim f_{E1}f_{M1}$ from two-step cascade experiment

Monte Carlo simulations of strength functions and cascade spectra

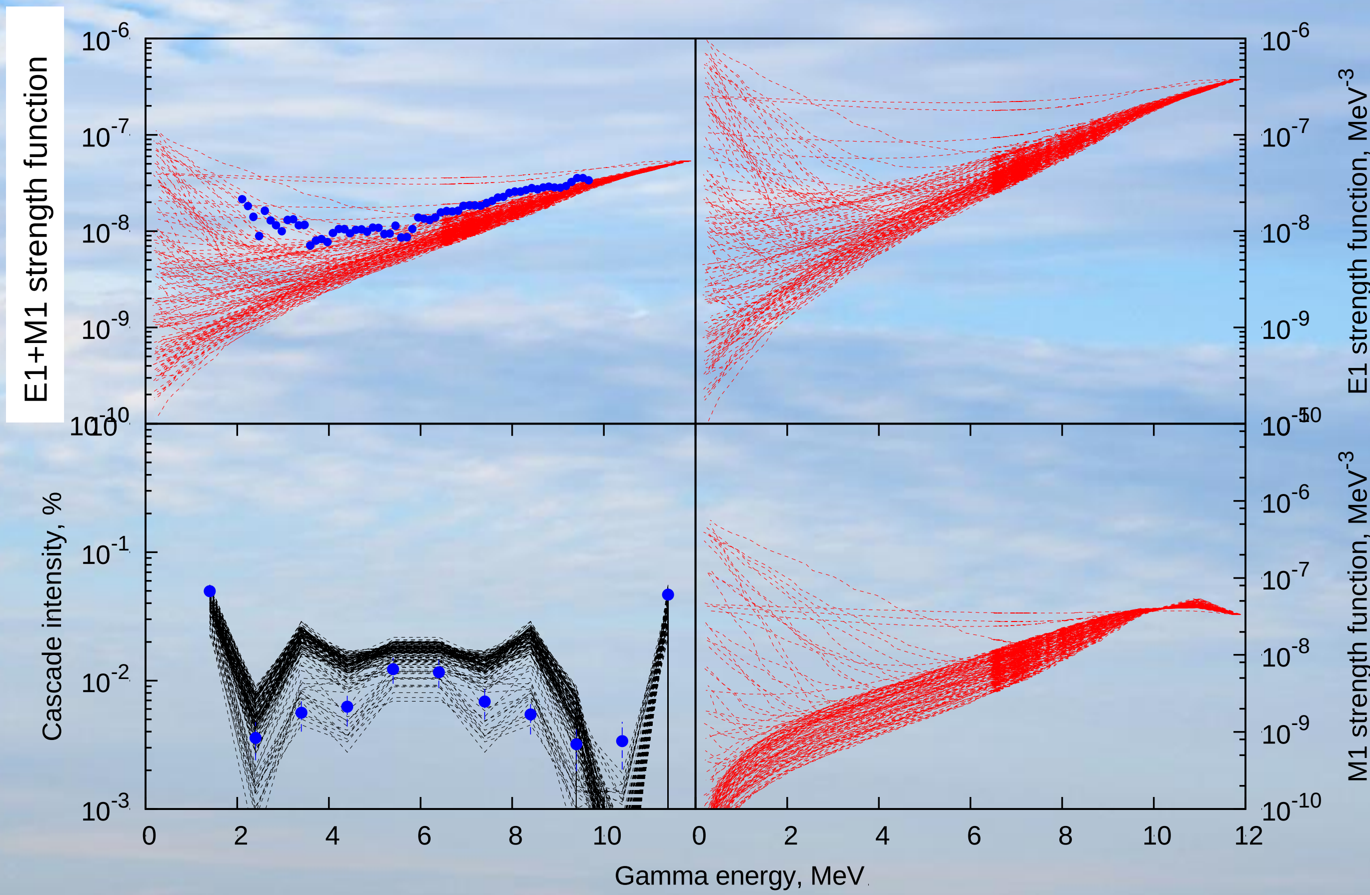
$$f_{E1}(E_\gamma) = \frac{1}{3\pi^2\hbar^2c^2}\frac{0.7\sigma_{E1}\Gamma_{E1}^2(E_\gamma^2+4\pi^2T^2)}{E_{E1}(E_\gamma^2-E_{E1}^2)^2},$$

$$\Gamma_{E1}(E_\gamma,T) = \frac{\Gamma_{E1}}{E_{E1}^2}(E_\gamma^2+4\pi^2T^2).$$

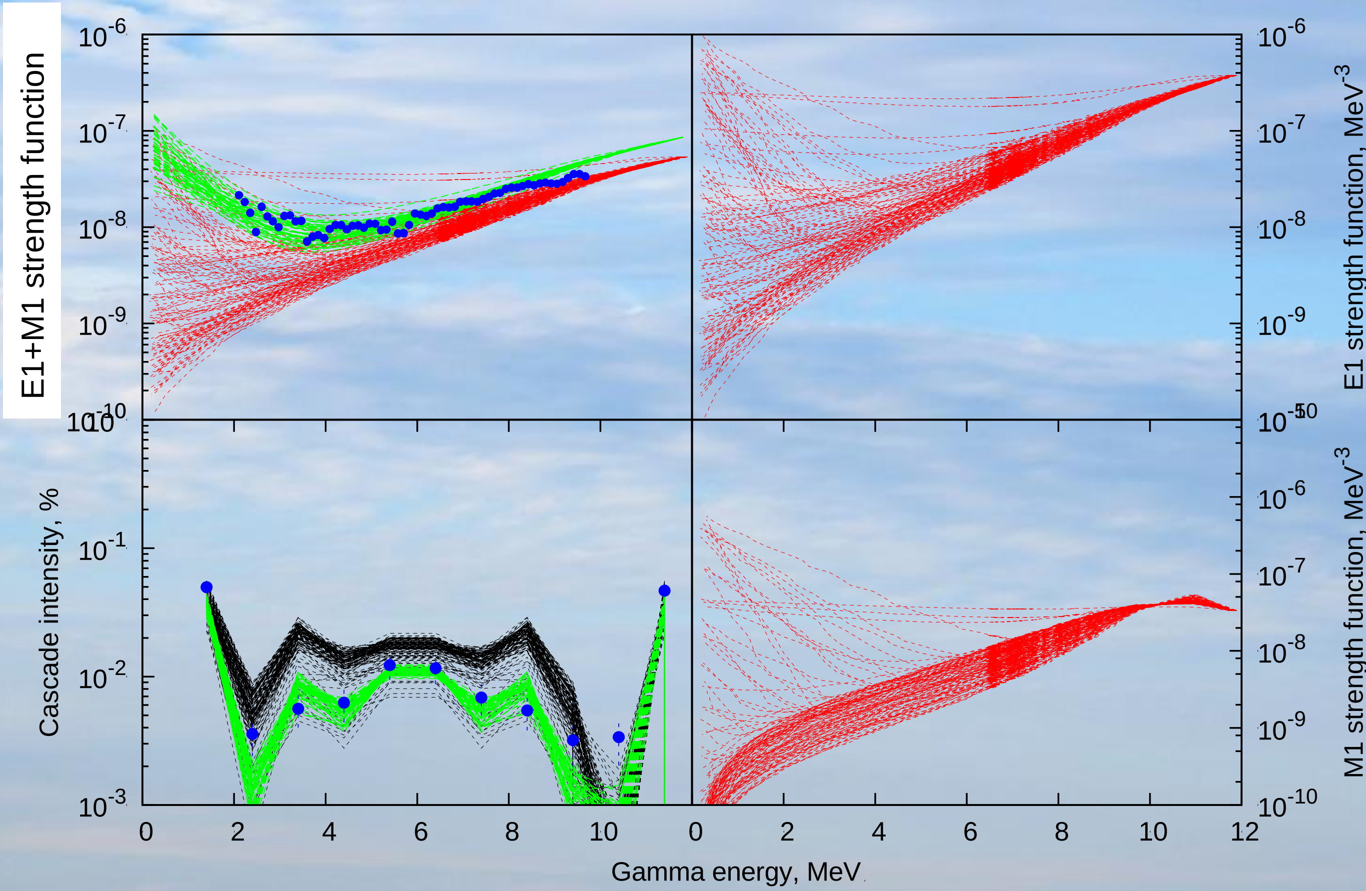
$$f_{M1}(E_\gamma) = \frac{1}{3\pi^2\hbar^2c^2}\frac{\sigma_{M1}E_\gamma\Gamma_{M1}^2}{(E_\gamma^2-E_{M1}^2)^2+E_\gamma^2\Gamma_{M1}^2}.$$

$$f_{rand}(E_\gamma)=f_{E1}(E_\gamma)+f_{M1}(E_\gamma)+A\exp(-BE_\gamma)$$

T, Γ_{M1}, A, B – random value inputs



E1+M1 strength function
Cascade intensity, %
E1 strength function, MeV^{-3}
M1 strength function, MeV^{-3}
Gamma energy, MeV
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{0}
10^{-1}
10^{-2}
10^{-3}
0 2 4 6 8 10 12


E1+M1 strength function
E1 strength function, MeV^{-3}
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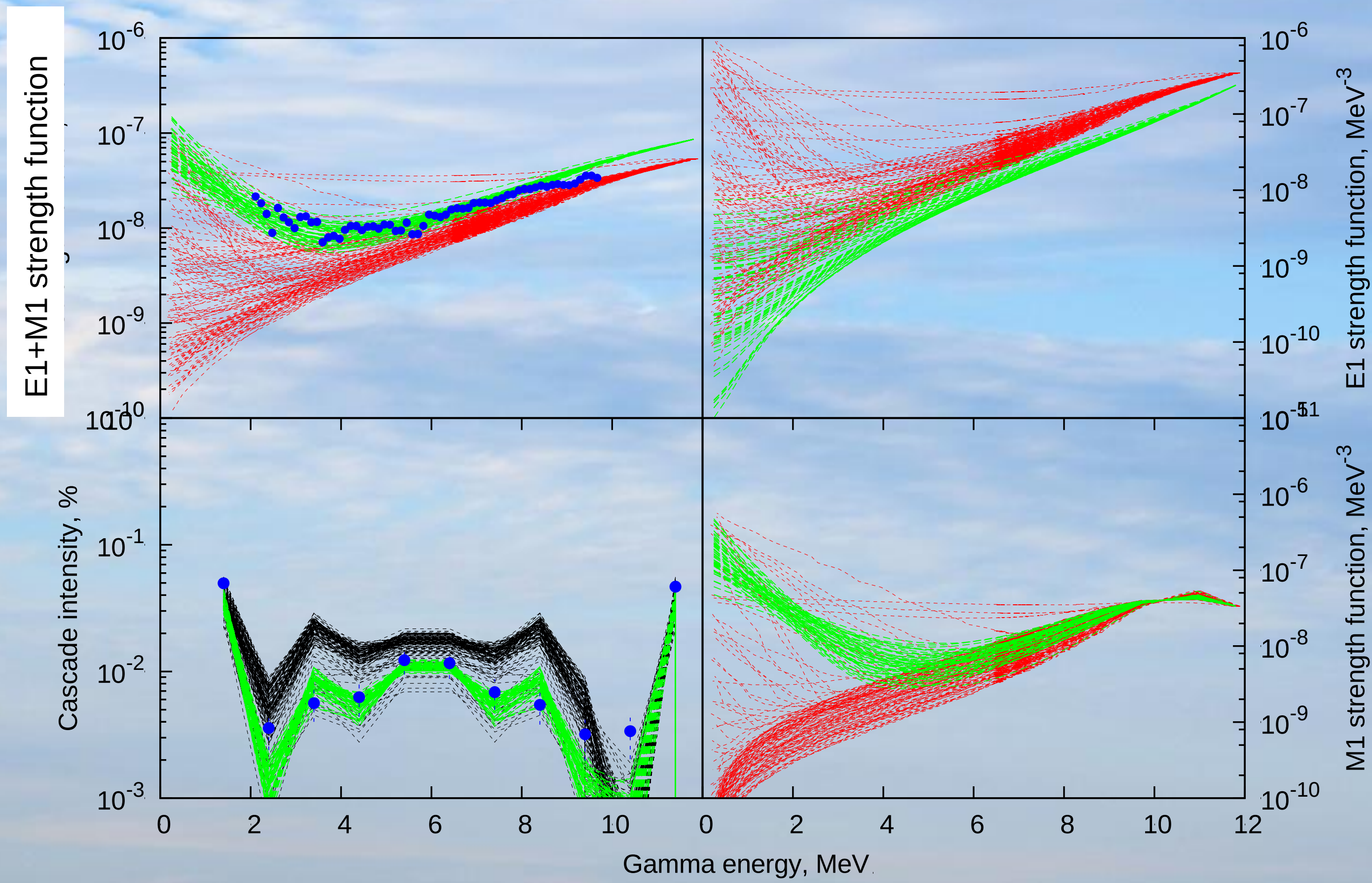
0 2 4 6 8 10 0 2 4 6 8 10 12


E1+M1 strength function
Cascade intensity, %
E1 strength function, MeV^{-3}
M1 strength function, MeV^{-3}
Gamma energy, MeV
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-1}
10^{-2}
10^{-3}
0
2
4
6
8
10
12

Conclusions

- The γ-strength function for 56Fe has been studied with combination of (p,2γ), (d,n) reactions and results from Oslo experiments.

- The decomposition of γ-strength into E1 and M1 components has been performed with simulations which support M1 low-energy enhancement.

Consistent with :

A. Voinov et al, Phys.Rev. C 81, 024319 (2010) ^{60}Ni

R. Schwengner et al, Phys.Rev.Lett. 111, 232504 (2013) ^{90}Zr, ^{94,95,96}Mo