Investigation of Scissors Mode for $^{145,149,151}Nd$ Isotopes

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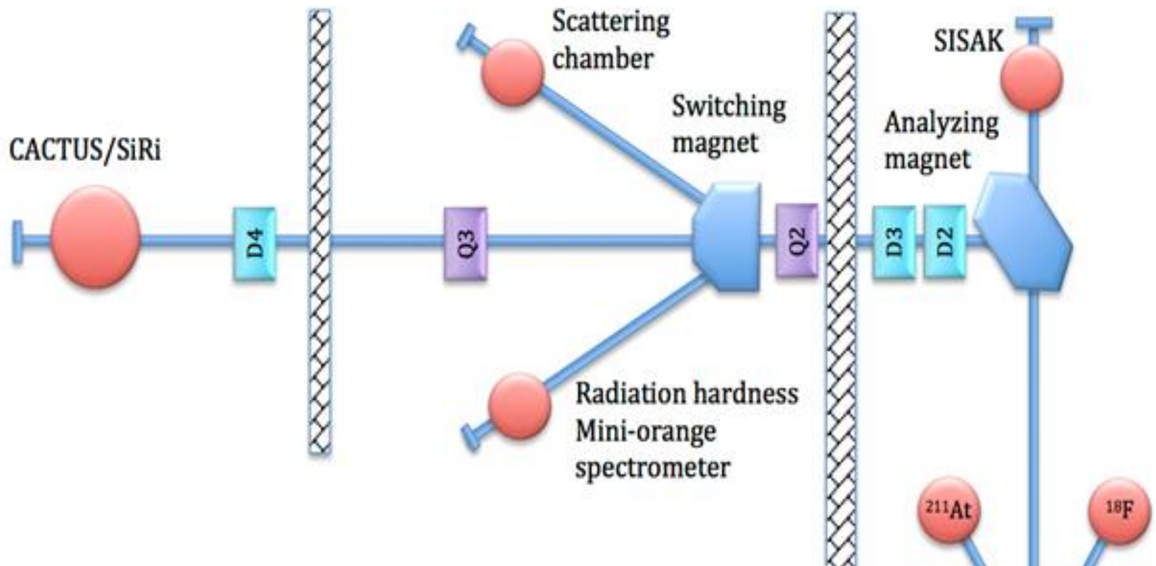
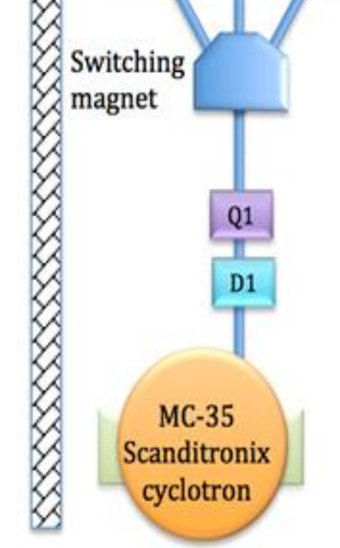
Experimental Setup

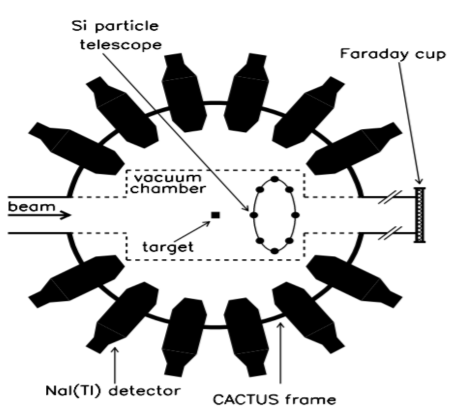
d beam at 13.5 MeV

$^{144}Nd(d,p)^{145}Nd$
$^{148}Nd(d,p)^{149}Nd$
$^{150}Nd(d,p)^{151}Nd$

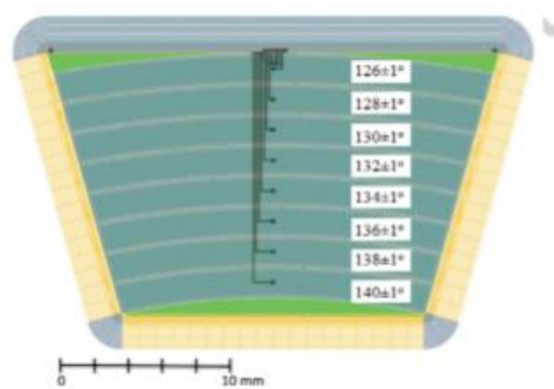




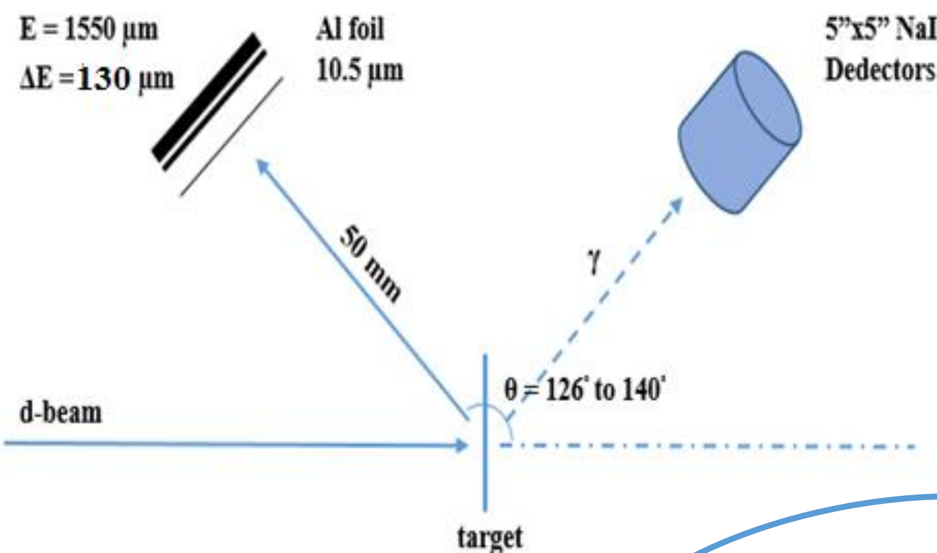
CACTUS: 28 NaI(TI), 5’’x5’’
(colimated)

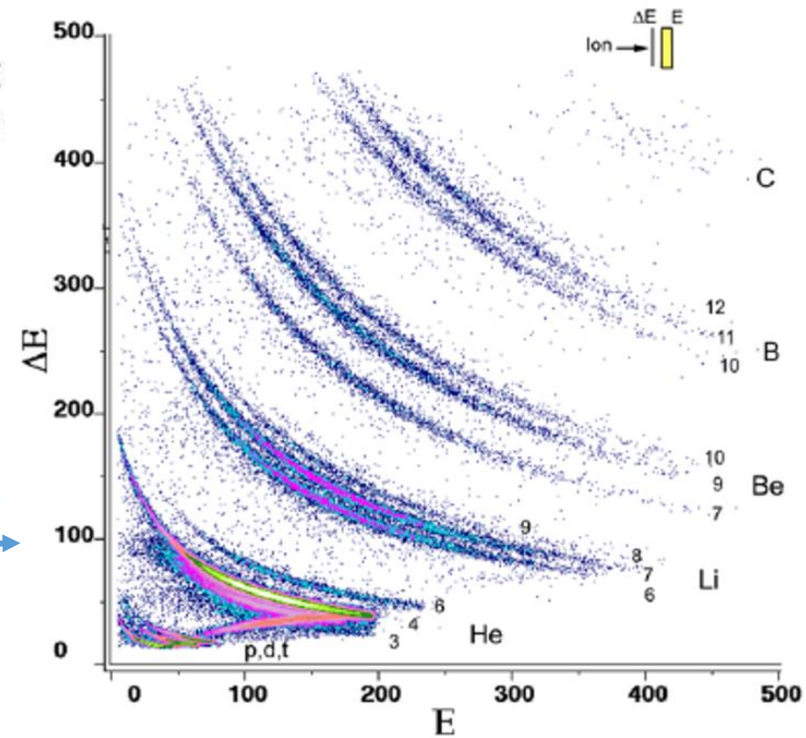


SiRi: 64x ΔE-E dedectors
(130 – 1550 μm)



Detector System

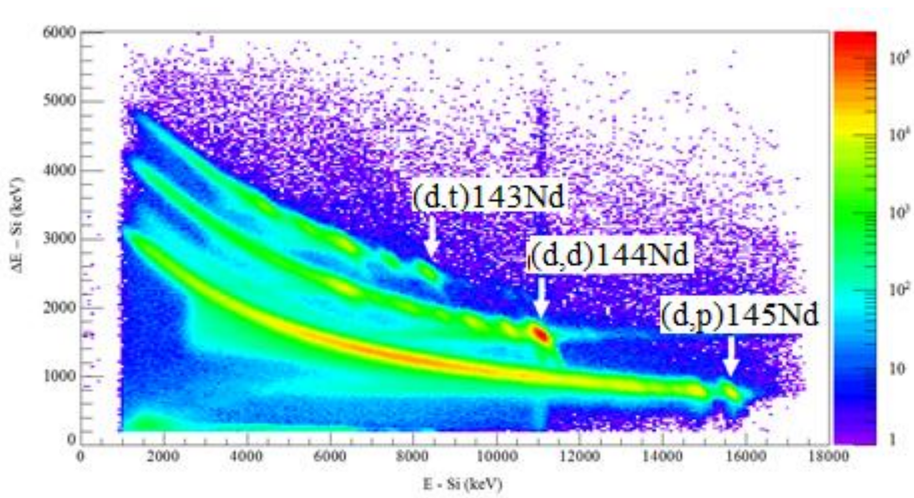




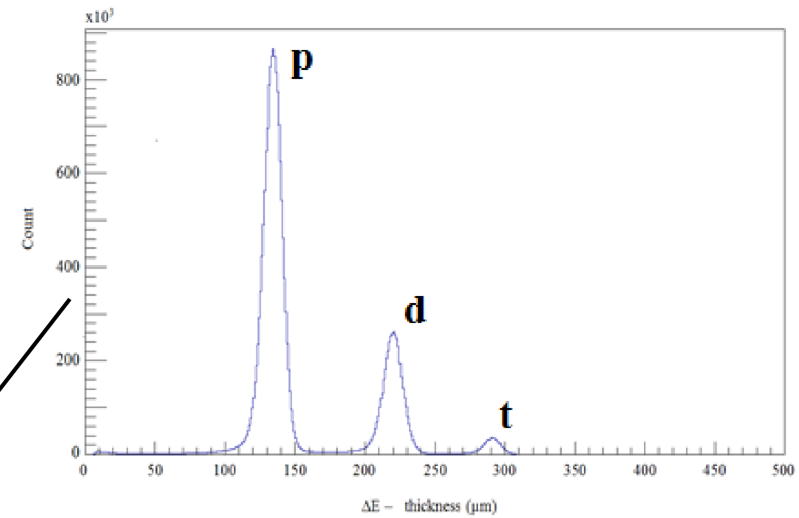
Bethe Bloch Formula:

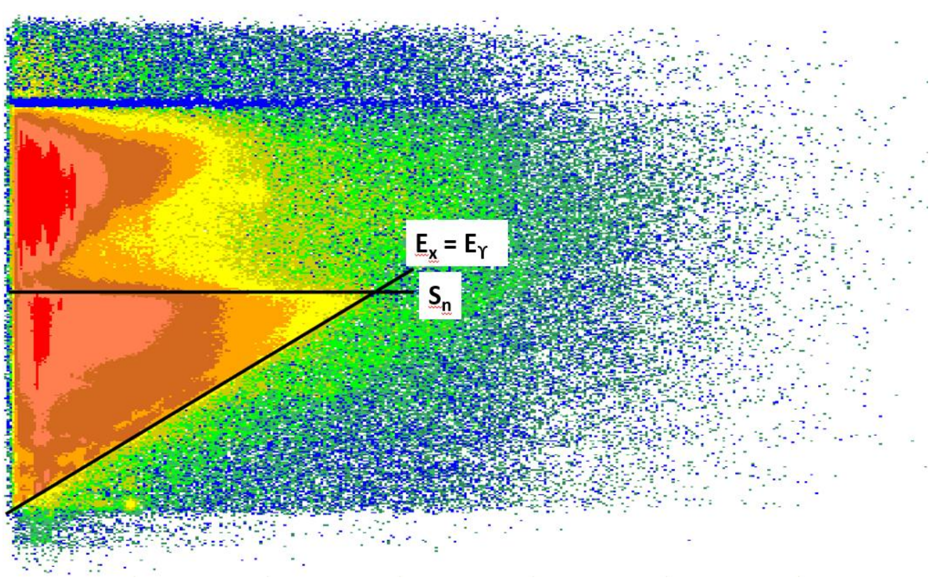
$$\frac{dE}{dx} = 2\pi N_o r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{z}{\beta} \left[ln \left(\frac{2m_e \gamma^2 v^2 W_{max}}{I^2} - 2\beta \right) \right]$$

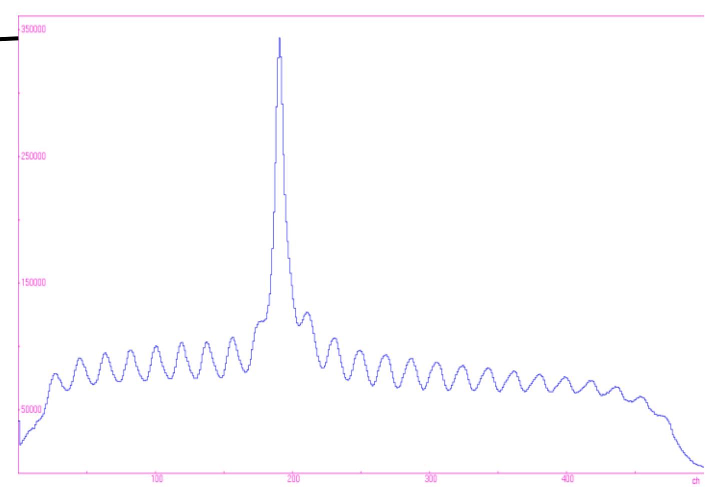
Coincidence Matrix



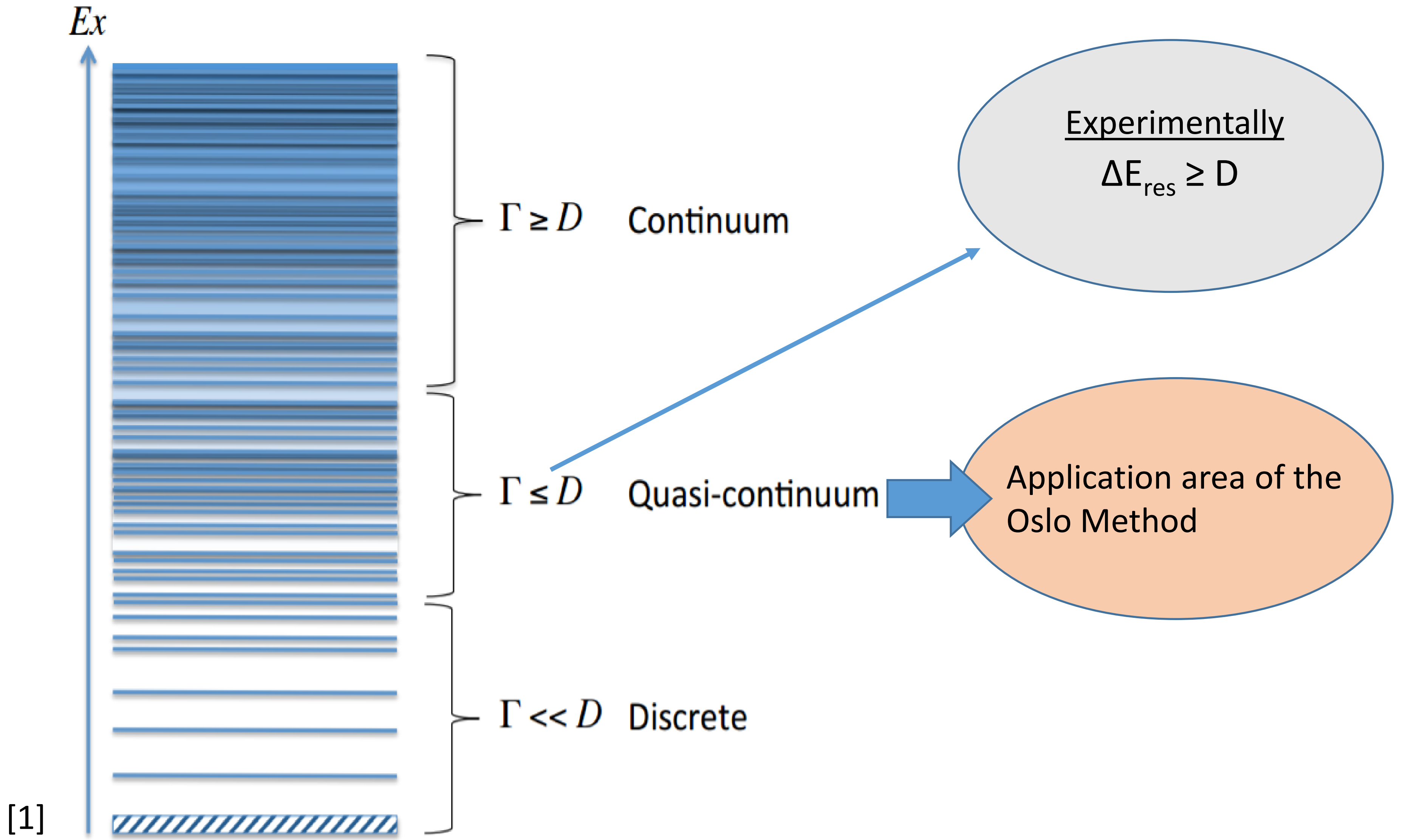
ΔE = 130µm , E = 1550 µm







Nuclear Excitations



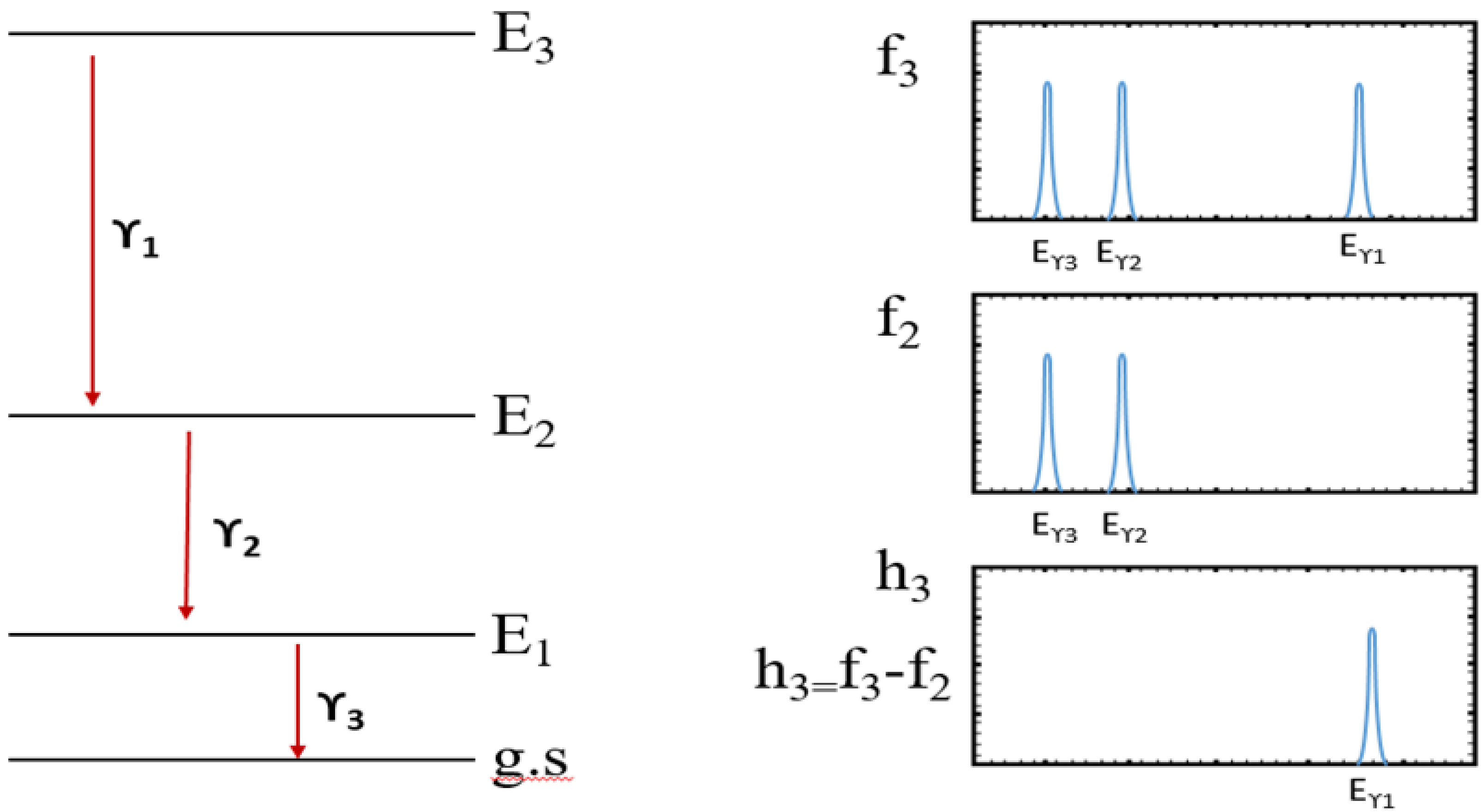
[1] M. Guttormsen et al.: Experimental level desities of atomic nuclei

The Oslo Method

- Obtaining particle – gama coincidences
- Unfold coincidence matrix with detector response
- Extract primary gama matrix from unfolded matrix
- Extract level density and gSF simultaneously
- Normalization procedure [2,3]

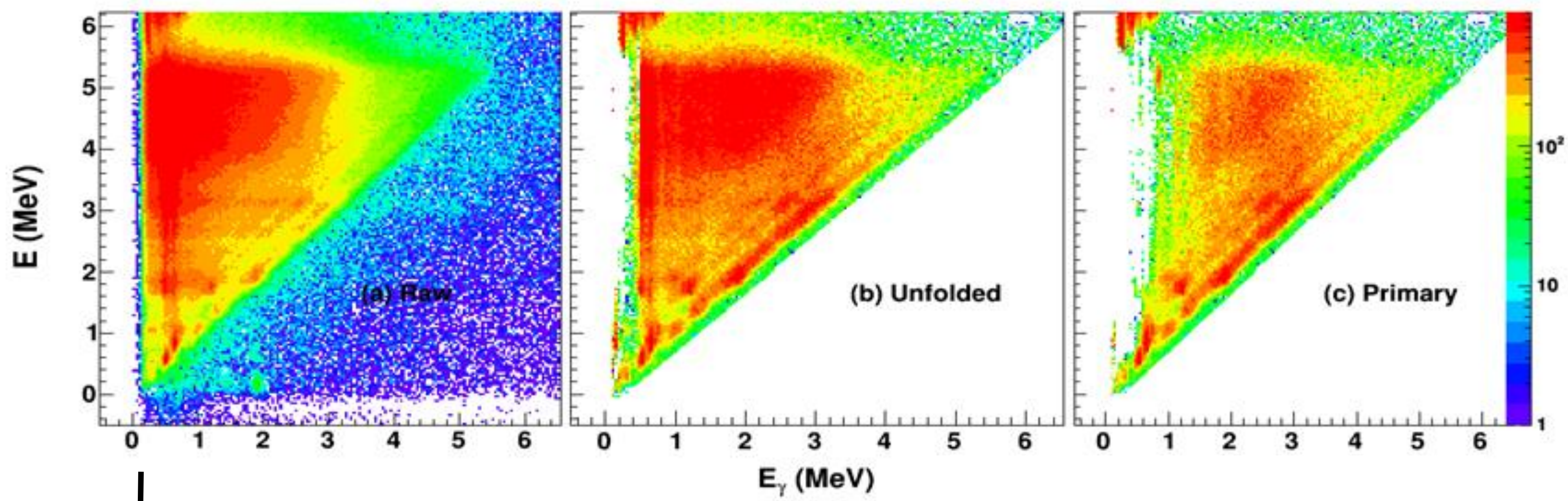
[2] M. Guttormsen et al.: The unfolding of continuum gamma-ray spectra
[3] M. Guttormsen et al.: The first generation of gamma-rays from hot nuclei

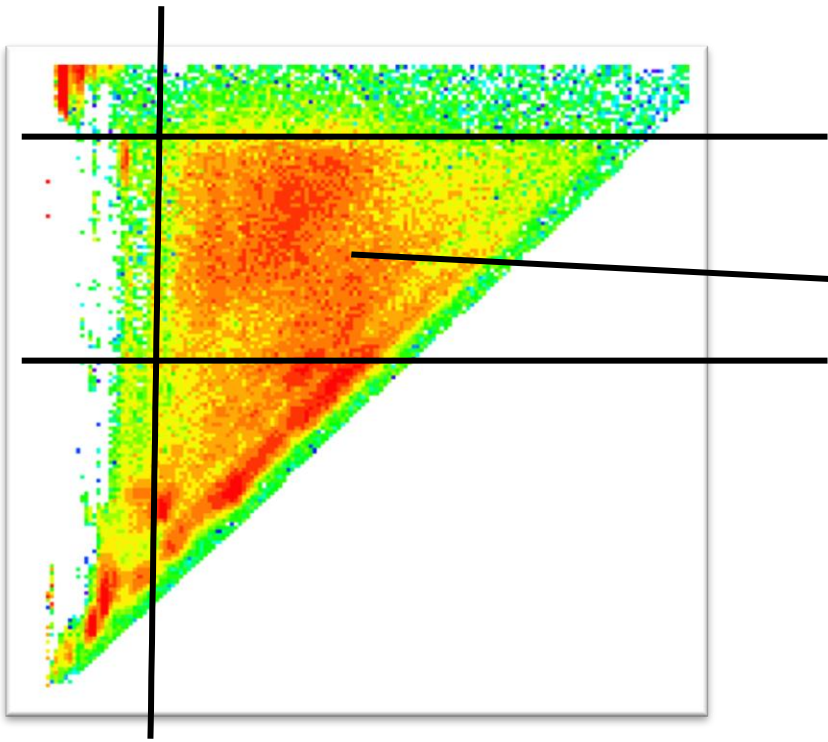
Extracting Primary Matrix



- Under the asssumption that the gamma ray decay pattern is independent of the population mechanism. (Excited state either populated by directly or by gamma emission)

Axel-Brink Hypotesis





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

Axel-Brink Hypotesis

$$P(E_i, E_\gamma) \propto \mathcal{T}(E_\gamma)\rho(E_i - E_\gamma)$$

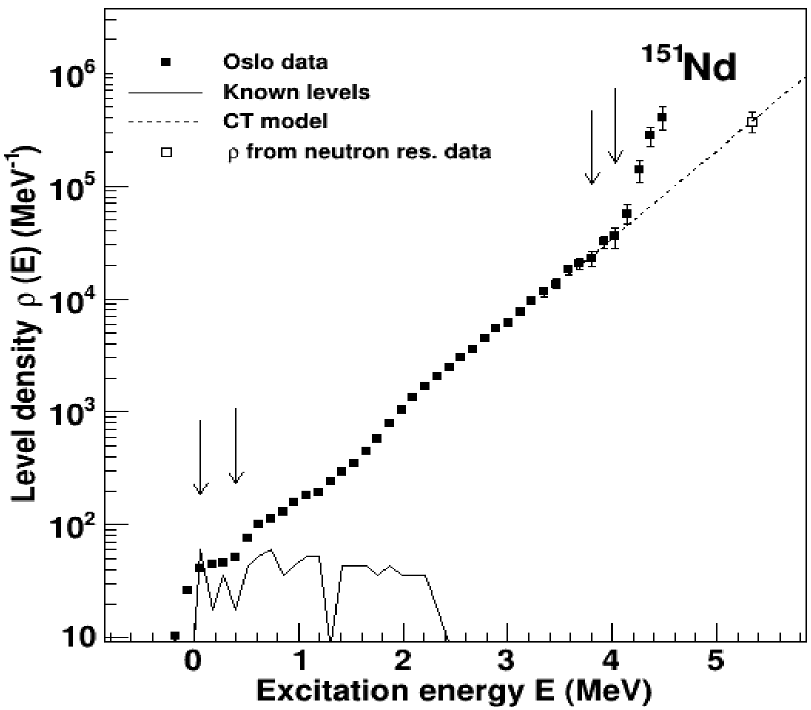
known unknown unknown

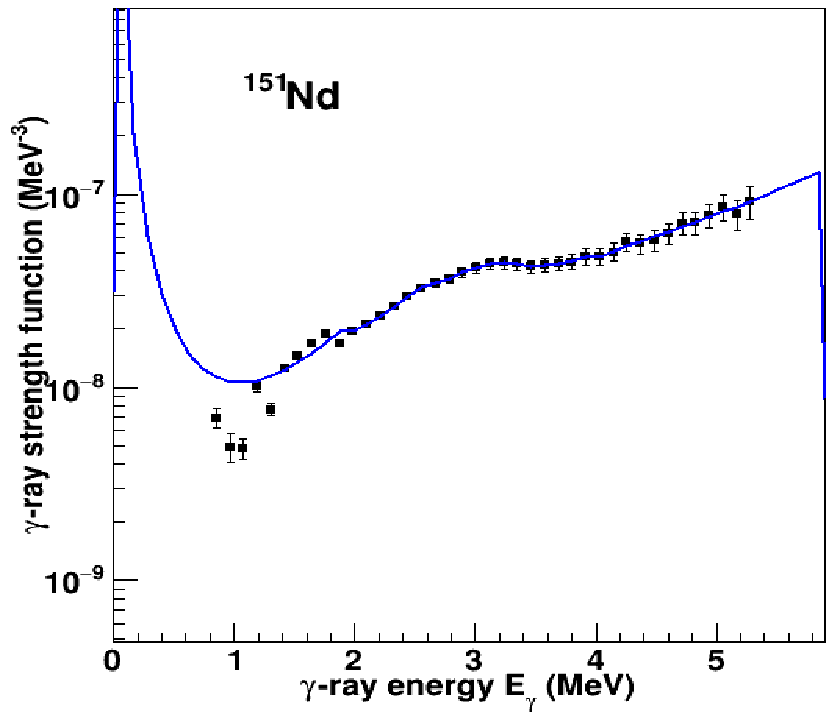
$$P(E_i, E_\gamma) \propto \mathcal{T}(E_\gamma)\rho(E_i - E_\gamma)$$

[4]

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

$$\tilde{\mathcal{T}}(E_\gamma) = \mathcal{T}(E_\gamma)f(E_\gamma) \Longrightarrow \tilde{\mathcal{T}}(E_\gamma) = T(E_\gamma)B\exp(\alpha E_\gamma)$$



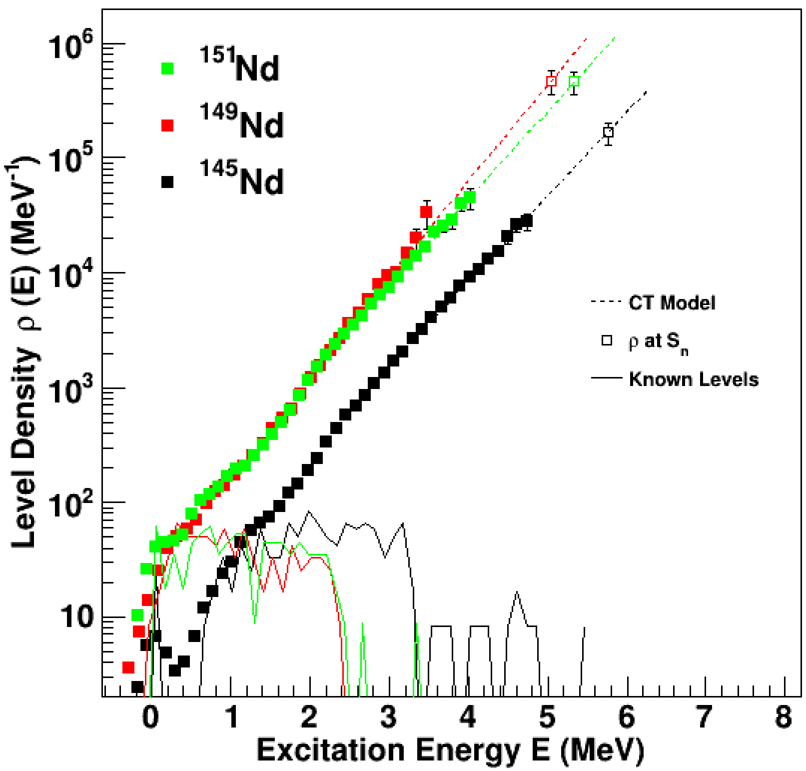


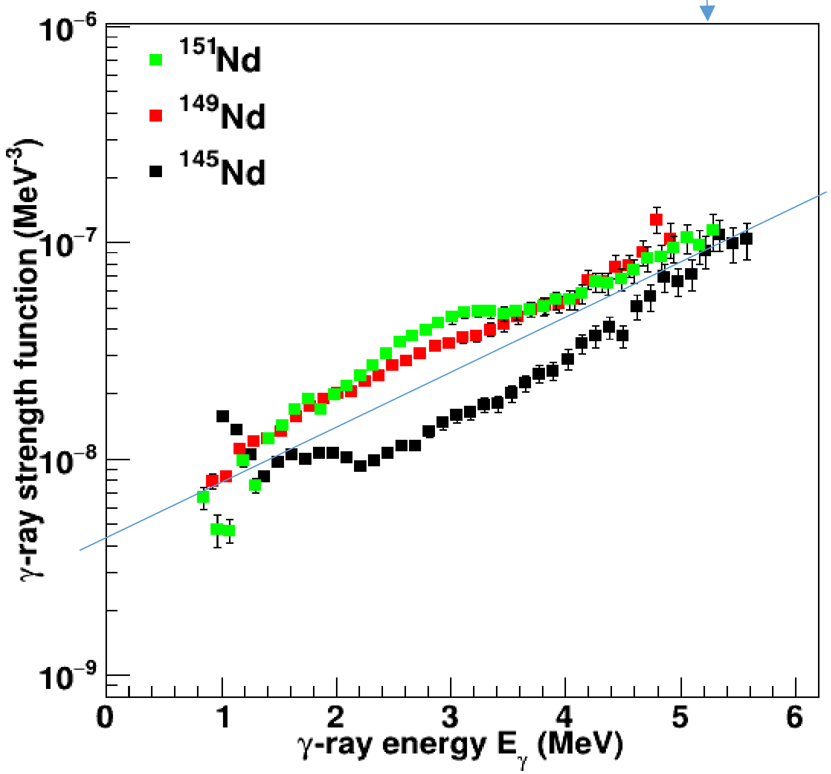
[4] A. Schiller et al: Extraction of level density and gamma strength function from primary gamma spectra

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

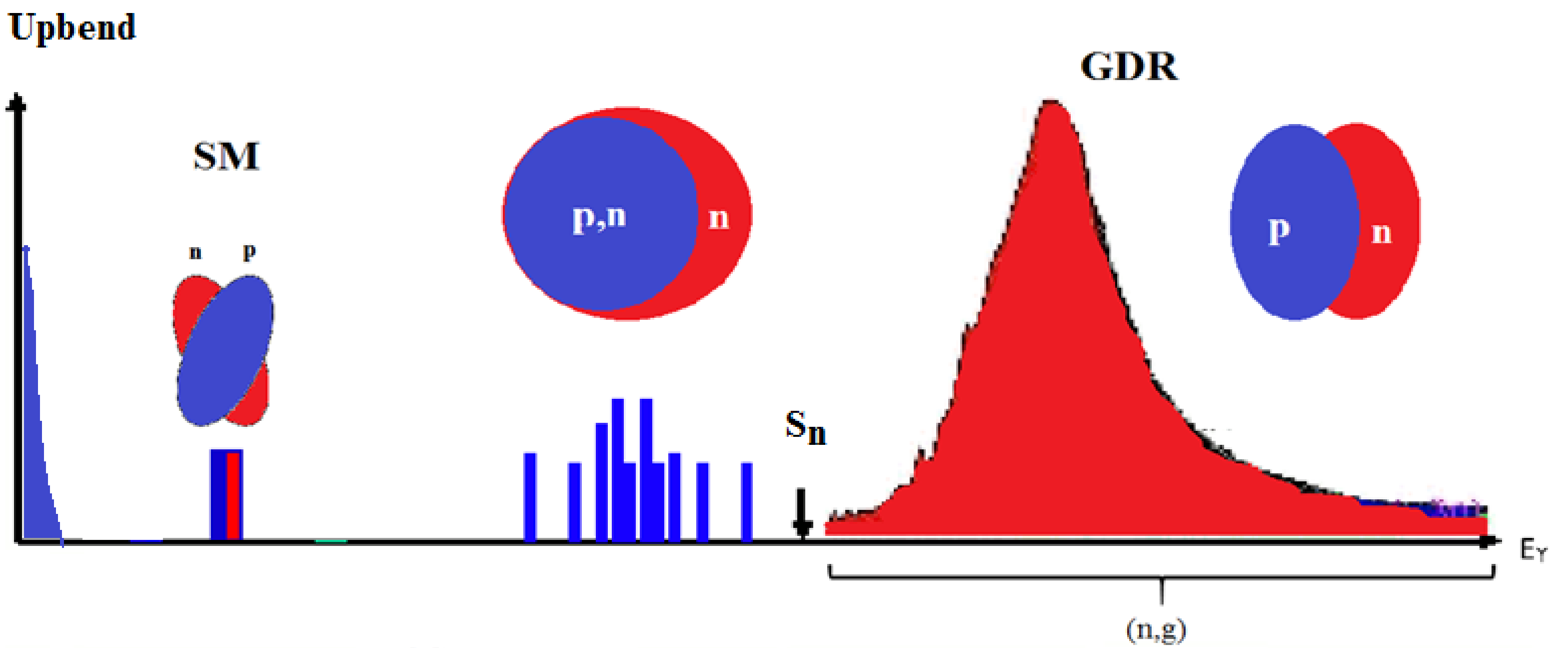
$$\tilde{\mathcal{T}}(E_\gamma) = \mathcal{T}(E_\gamma) B \exp(\alpha E_\gamma)$$

$$f(E_\gamma) = \frac{1}{2\pi} \frac{\mathcal{T}(E_\gamma)}{E_\gamma^3} \quad [5]$$





[5] J. Kopecky, M. Uhl: Test of gamma-ray strength functions in nuclear reaction model calculations



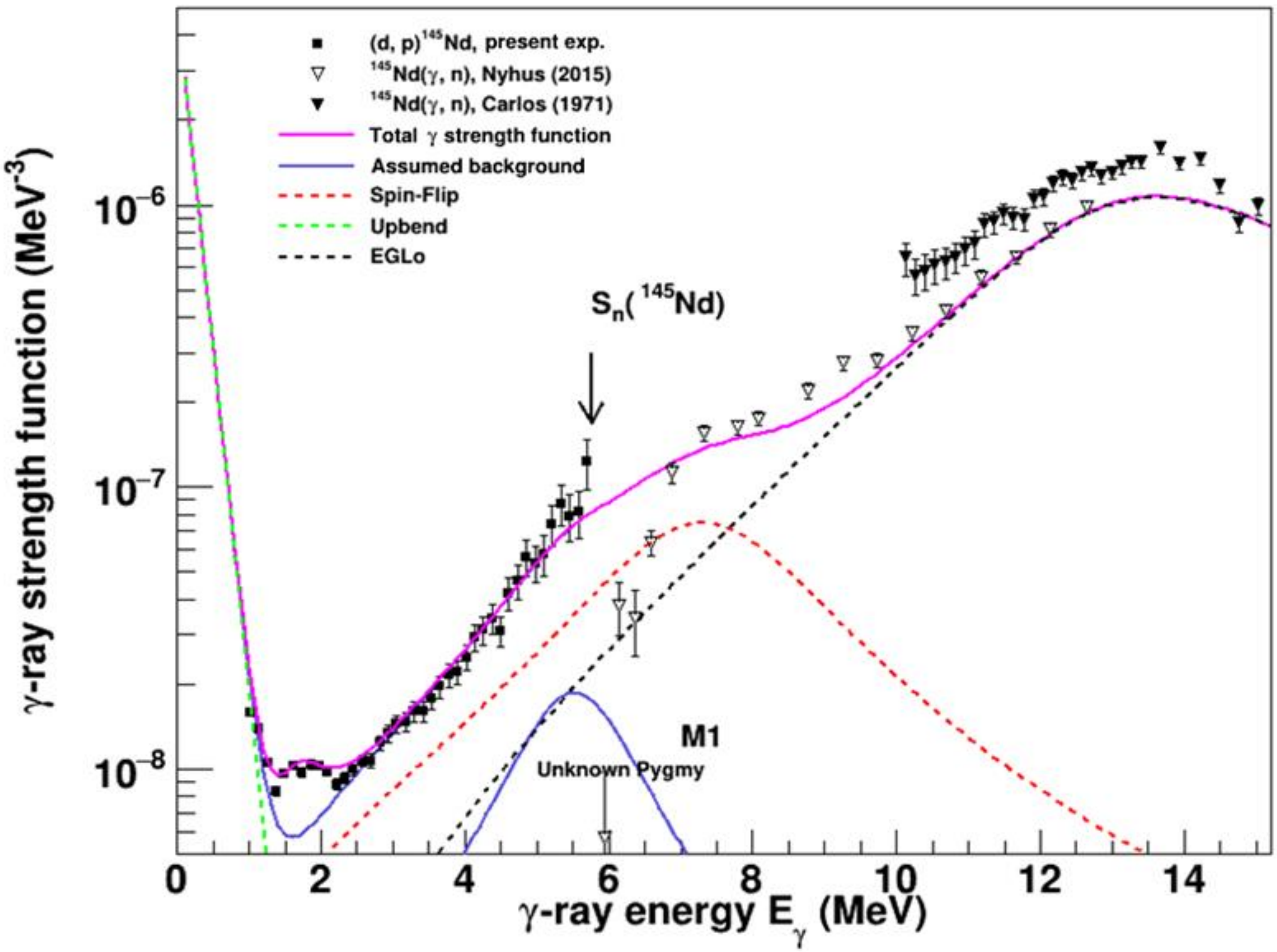
$$f_{tot} = f_{E2} + f_{E1} + f_{M1} + f_{sci}$$

$C_{up} e^{(-\xi_{up} E_\gamma)}$

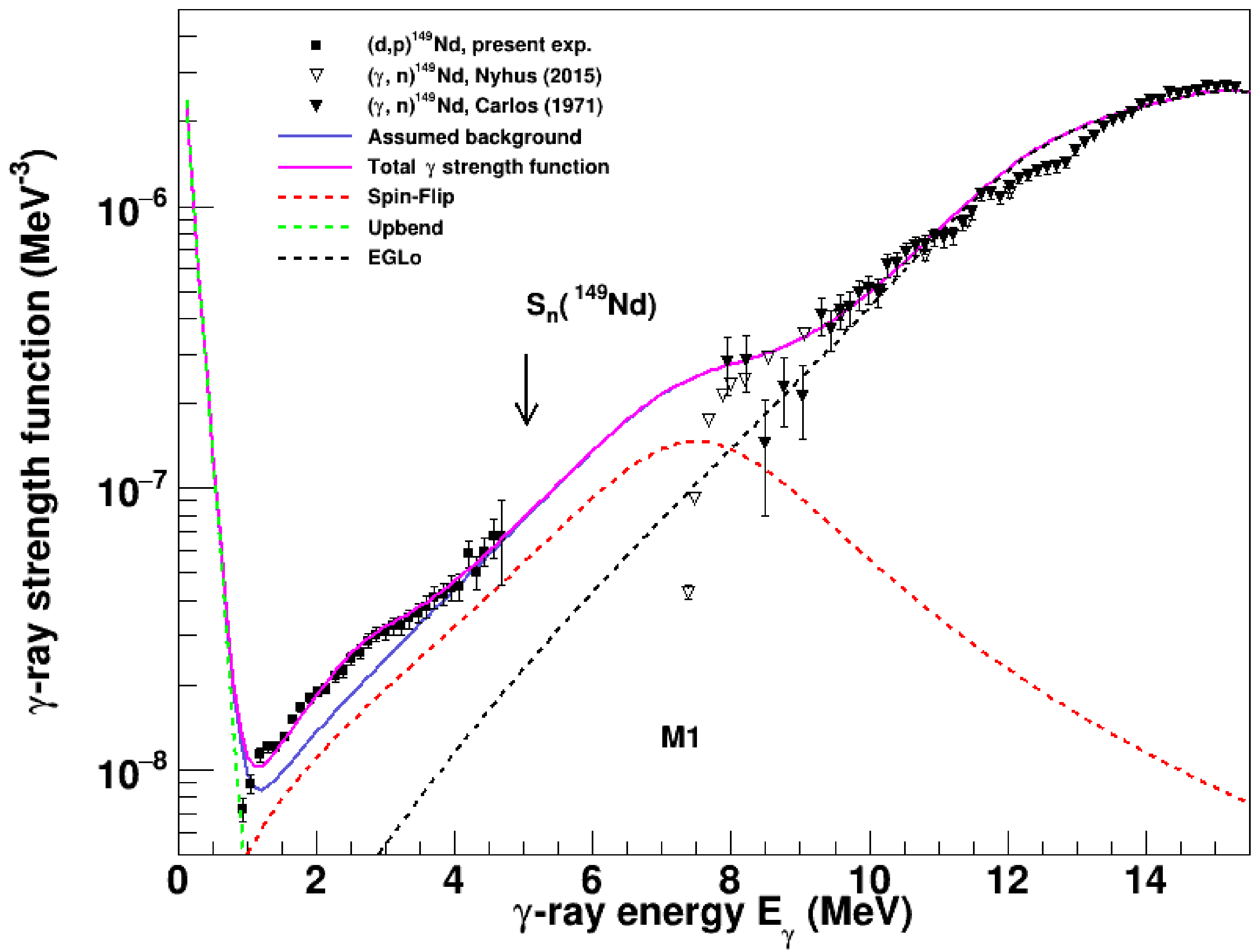
EGLo

GMDR
SpinFlip

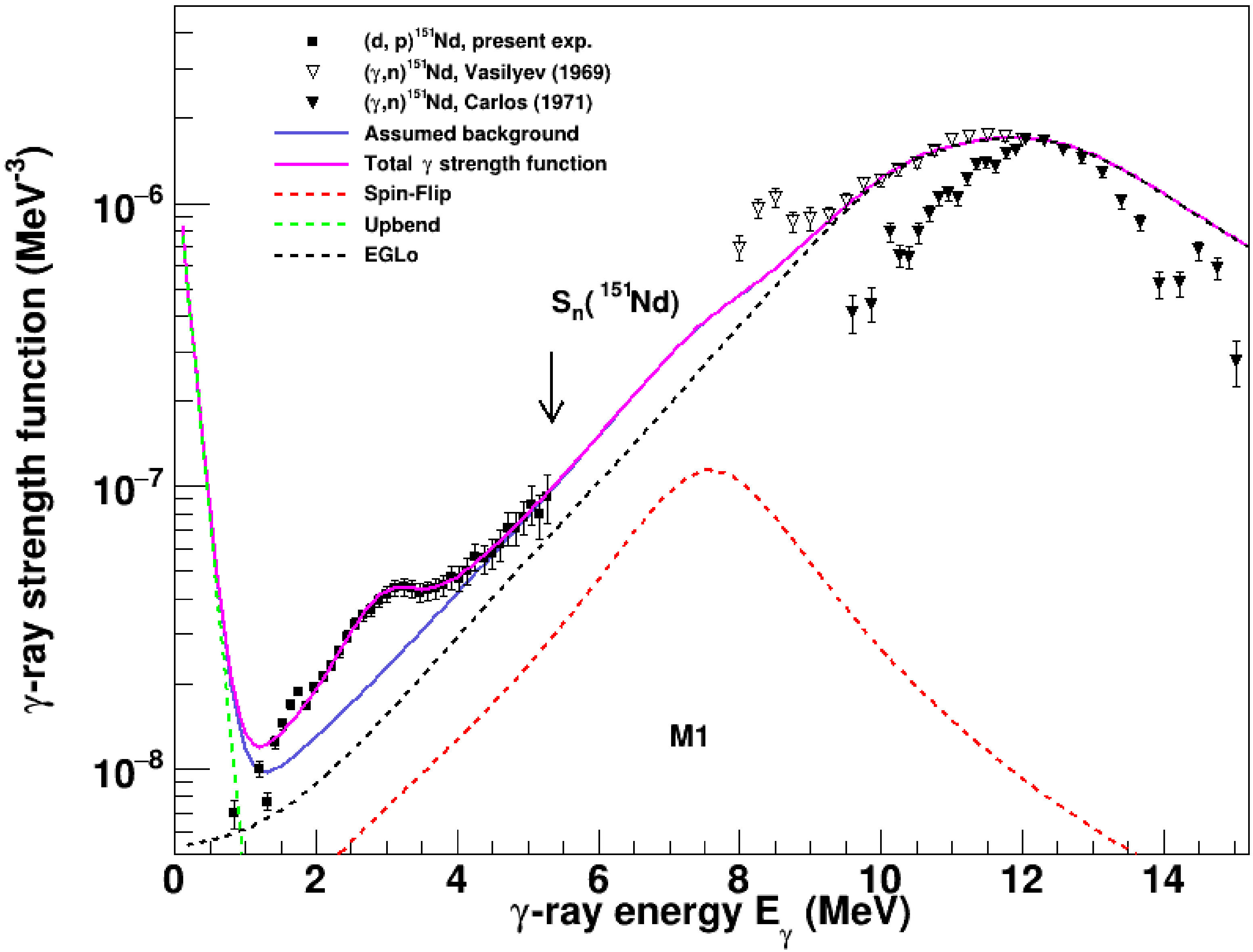
Assuming
Lorentzian
pygmy
resonance



[6] H. T. Nyhus et al.: Photoneutron cross sections for neodymium isotopes
[7] P. Carlos et al.: The giant dipole resonance in the transition region for the neodymium isotopes

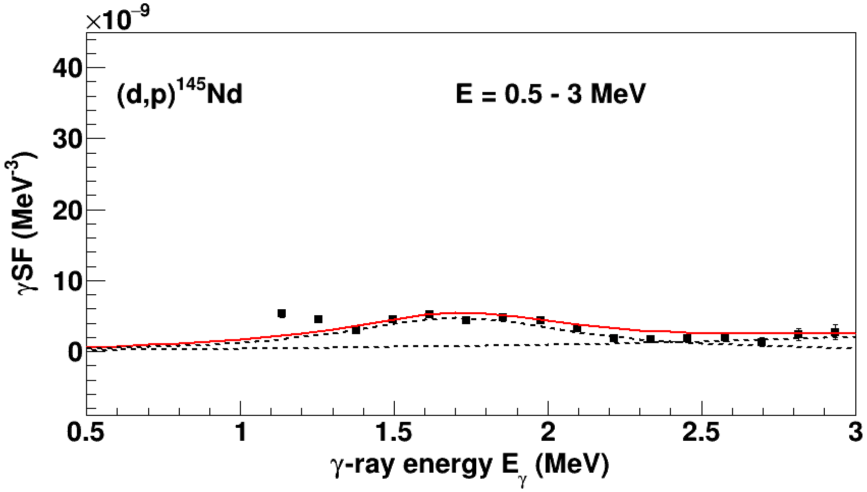


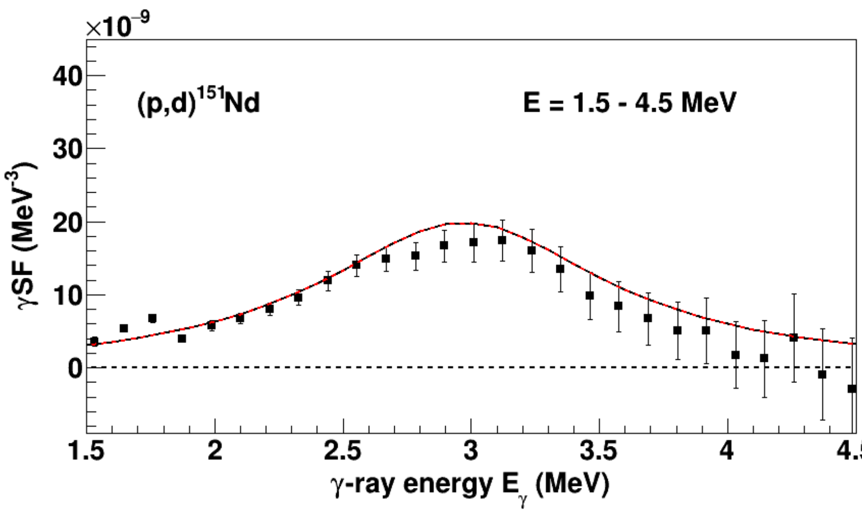
(d,p)149Nd, present exp.
(γ, n)149Nd, Nyhus (2015)
(γ, n)149Nd, Carlos (1971)
Assumed background
Total γ strength function
Spin-Flip
Upbend
EGLo
Sn(149Nd)
M1
γ-ray strength function (MeV-3)
γ-ray energy Eγ (MeV)

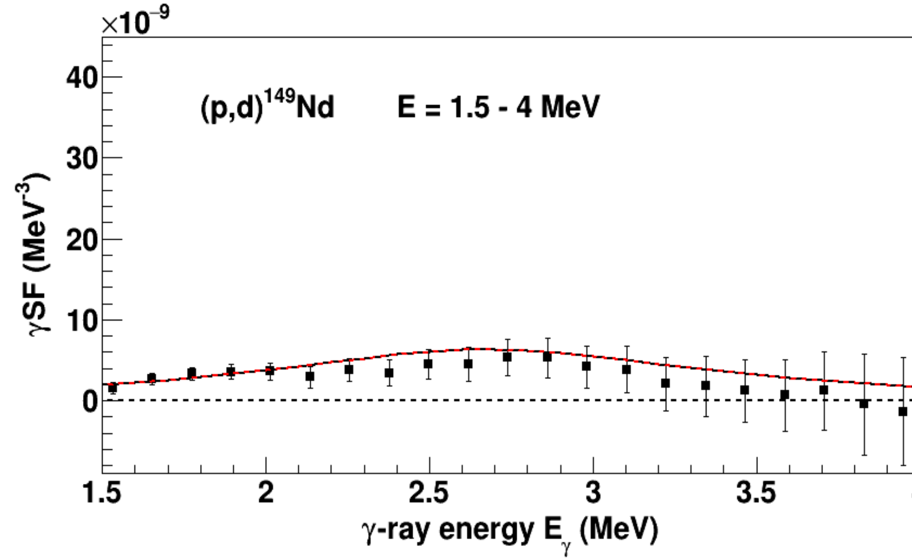


[8] O.V. Vasilyev et al.: Giant resonance in the energy region of transition from spherical nuclei to deformed ones.

Scissors Mode in ^{145,149,151}Nd







$$f_{\mathrm{E1}}^{\mathrm{EGLO}}(E_\gamma, T_f) = \frac{1}{3\pi^2\hbar^2c^2}\sigma_r\Gamma_r \left[E_\gamma \frac{\Gamma_K(E_\gamma, T_f)}{(E_\gamma^2 - E_r^2)^2 + E_\gamma^2\Gamma_K^2(E_\gamma, T_f)} + 0.7\frac{\Gamma_K(E_\gamma = 0, T_f)}{E_r^3} \right] \ [\mathrm{MeV}^{-3}].$$

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

Nuclei	ω_{GDR} (MeV)	Γ_{GDR} (MeV)	σ_{GDR} (mb)	ω_{M1} (MeV)	Γ_{M1} (MeV)	σ_{M1} (mb)
145Nd	14.7	7.8	160	7.50	3.20	3.1
149Nd	13.7	5.8	150	7.75	3.17	4.0
151Nd	12.1	4.68	135	7.70	2.65	2.82

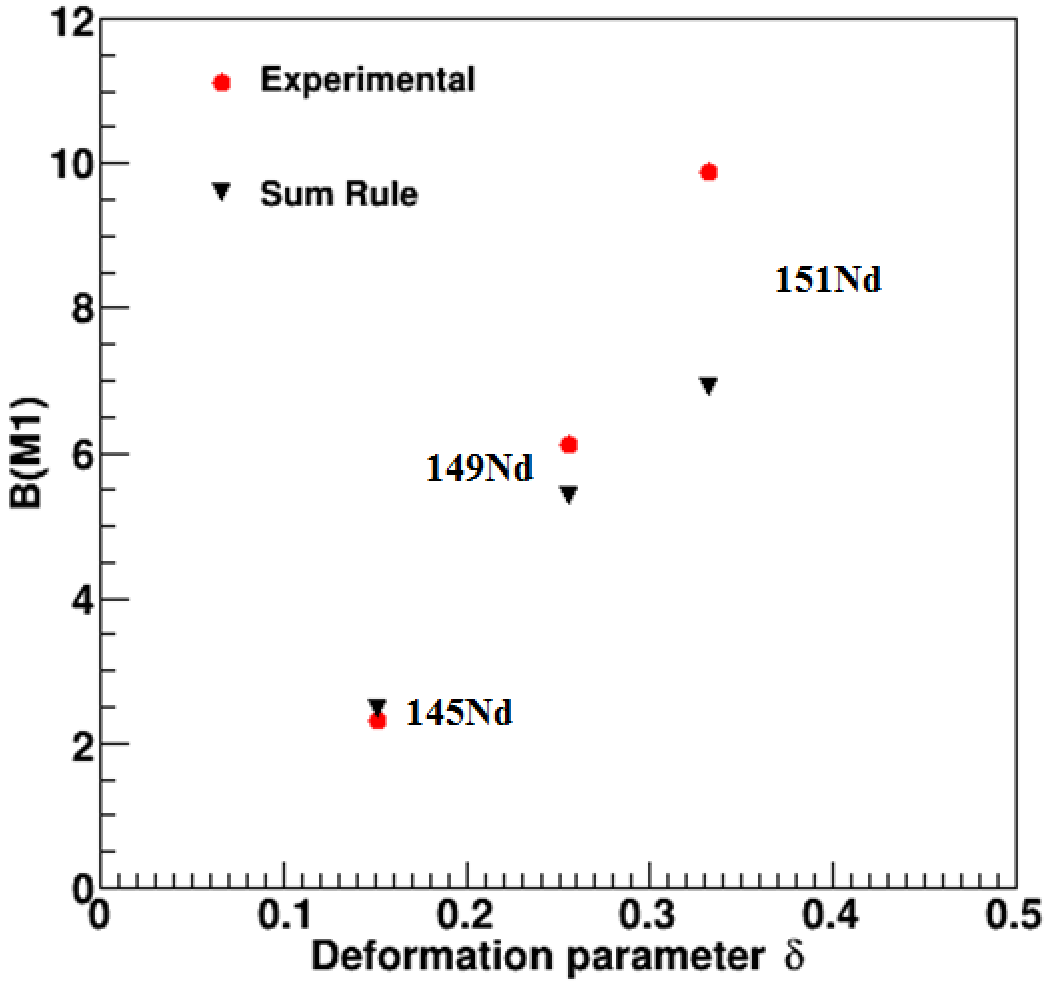
[9] J.Enders et al.: Parameter-free description of orbital magnetic dipole strength

$$B_{\mathrm{SR},i} = \frac{9\hbar c}{32\pi^2}\left(\frac{\sigma_{\mathrm{SR},i}\Gamma_{\mathrm{SR},i}}{\omega_{\mathrm{SR},i}}\right).$$

$$B_{\mathrm{SR}} = \omega_{\mathrm{SR}}^{\mathrm{exp}}\frac{3}{4\pi}\left(\frac{Z}{A}\right)^2\Theta_{\mathrm{rigid}}$$

Nuclei	Experimental Results			β_2	B(M1) (μ_N^2)	Sum Rule [9]	
	ω_{SR} (MeV)	Γ_{SR} (MeV)	σ_{SR} (mb)			ω_{SR} (MeV)	B(M1) (μ_N^2)
145Nd	1.77(10)	1.1(6)	0.105(5)	0.160	2.304	1.14	2.46
149Nd	2.92(20)	1.94(10)	0.26(3)	0.270	6.099	2.43	5.42
151Nd	3.13(5)	1.37(5)	0.69(5)	0.350	9.89	3.03	6.89

Sum Rule Results



A	δ
145	0.151
149	0.255
151	0.331

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Thank you for your attention