



Selected aspects of nuclear photonics

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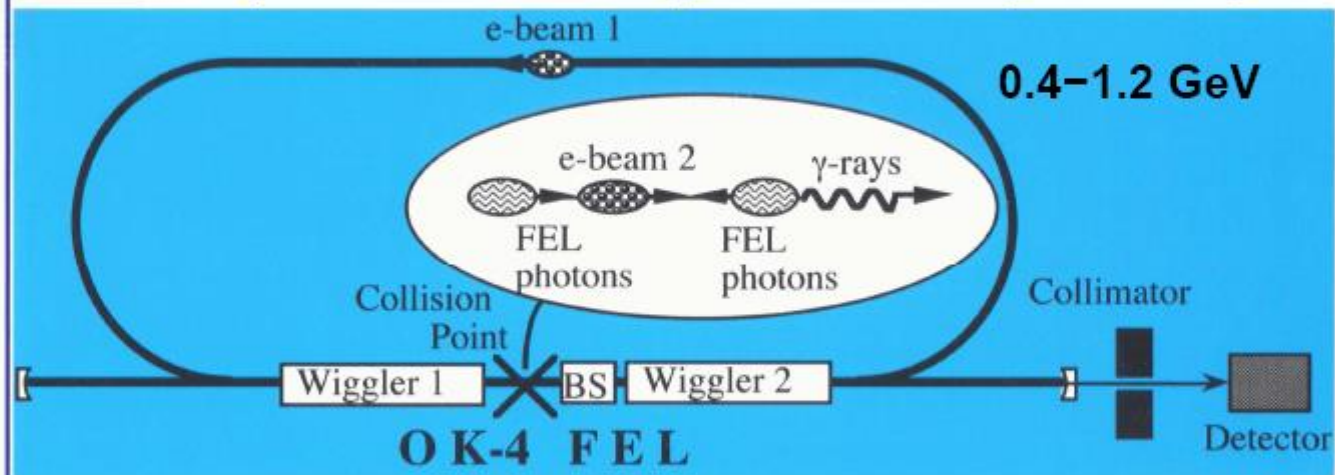
Compton backscattered photon beams

High Intensity γ -Ray Source (HIgS)



H.R.Weller, V.N.Litvinenko
Duke University, Durham, NC, U.S.A.

Compton Backscattering of Intra-cavity Laser Light



2 - 60 MeV

1.7 - 6.4 eV

~ 1000

$$E_\gamma = \frac{4\gamma^2 E_{ph}}{(1+r+\gamma^2\theta^2)}; \quad r = \frac{4\gamma E_{ph}}{mc^2}; \quad E_{ph} = \frac{2\gamma^2 hc}{\lambda_w(1+K_w^2/2)}; \quad \gamma = \frac{E_e}{mc^2};$$

nearly monochromatic, tunable, completely polarized

Photo-induced nuclear reactions

(γ, γ') or (γ, x)

Photon: intrinsic angular momentum $L=1\hbar$

Momentum $p_\gamma = E_\gamma/c$ basically negligible

Photo-excitation almost exclusive spin selective to $J^\pi = 1^\pi$ levels

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 \Rightarrow low interaction cross section

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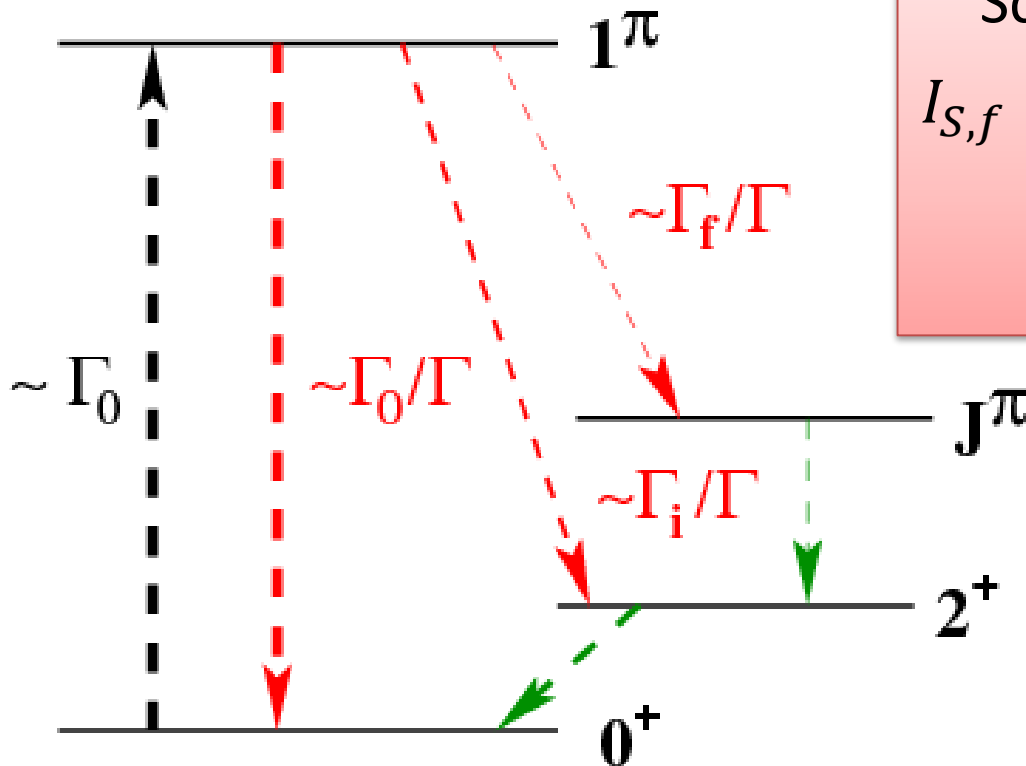
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Φ_γ at available facilities targets in order of grams required
(ELI-NP \approx mg) \Rightarrow only (quasi-) stable isotopes

Photo-induced nuclear reactions

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Above particle threshold (in particular neutron) multiple decay paths.
Below only γ rays



Scattering cross section:

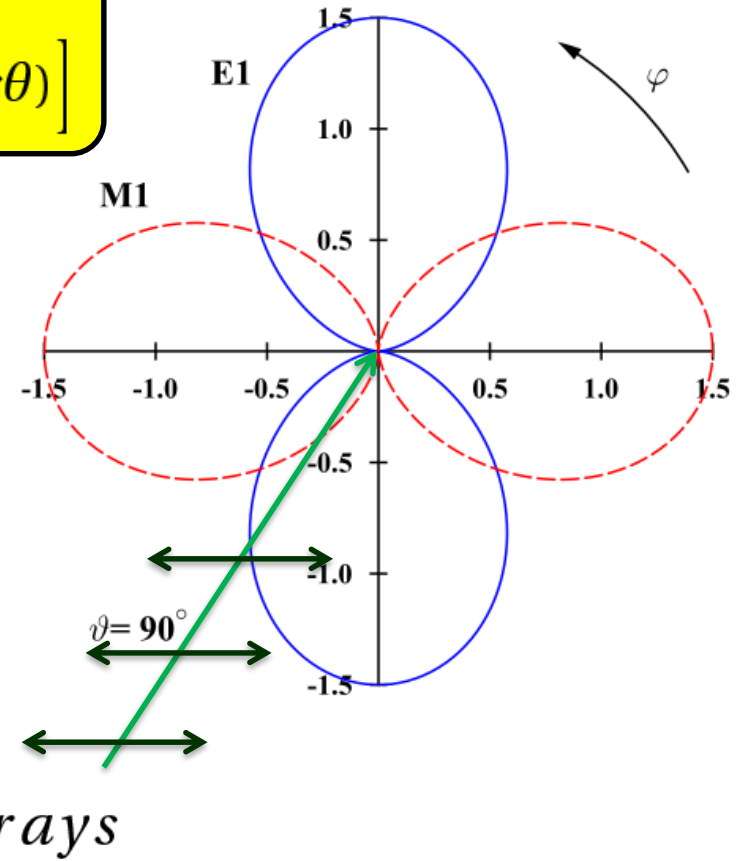
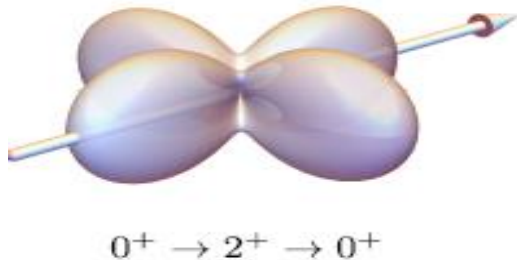
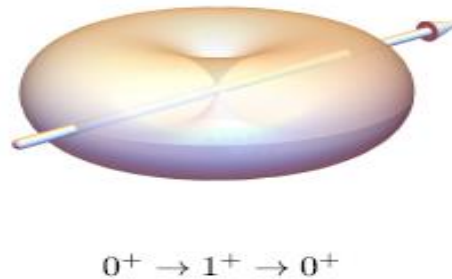
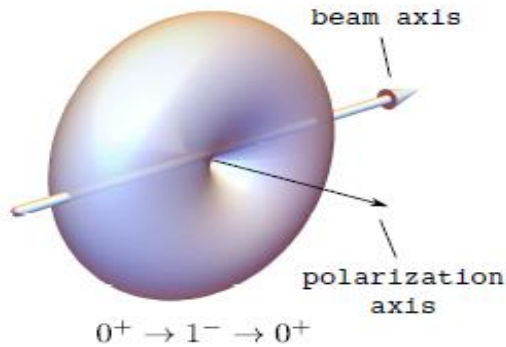
$$I_{S,f} \propto \Gamma_0 \cdot \frac{\Gamma_f}{\Gamma}, \text{ with } \Gamma = \sum_f \Gamma_f$$

$$\propto \frac{N_{\gamma, det}}{\phi_\gamma \cdot W(\theta, \phi)}$$

Parity measurements using polarised photon beams

$$0^+ \rightarrow 1^\pi \rightarrow 0^+$$

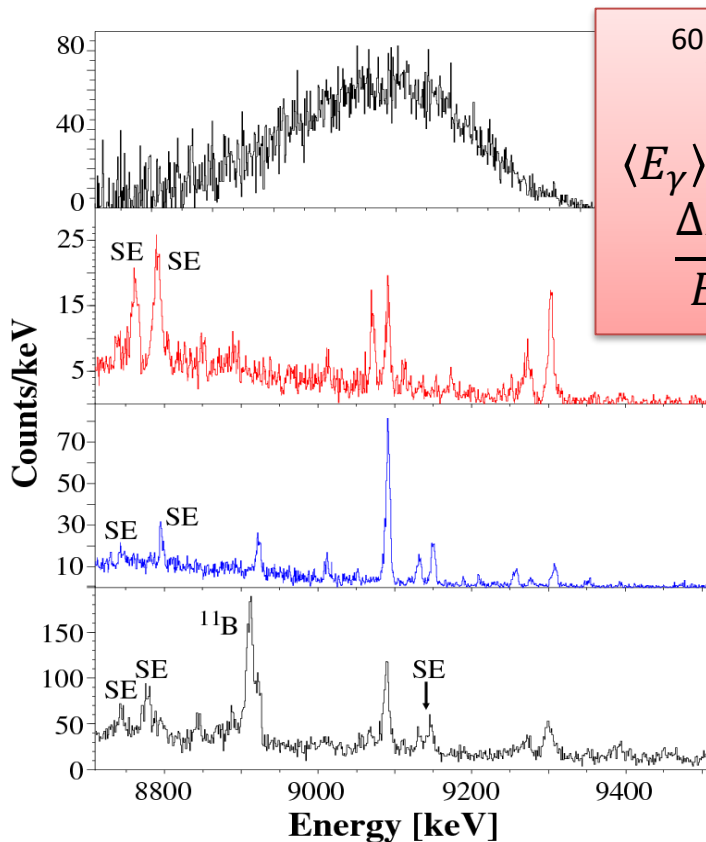
$$W(\theta, \phi) = 1 + \frac{1}{2} \left[P_2(\cos\theta) + \frac{1}{2} \pi \cos(2\phi) P_2^{(2)}(\cos\theta) \right]$$



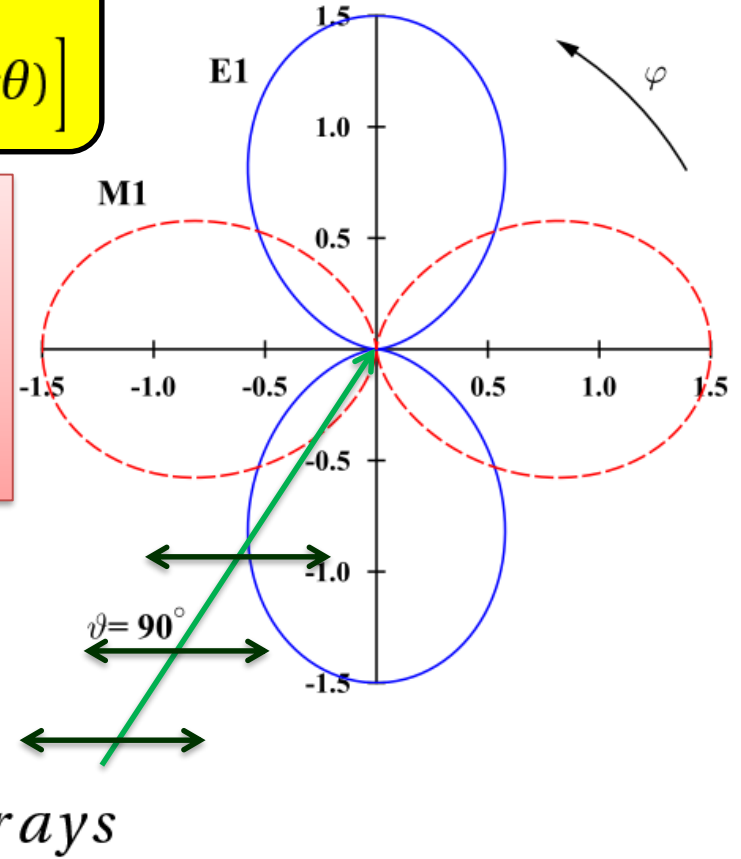
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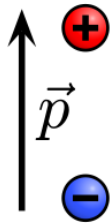
$^{60}\text{Ni}(\vec{\gamma}, \gamma')$
at HIGS
 $\langle E_\gamma \rangle = 9.1 \text{ MeV}$
 $\frac{\Delta E_\gamma}{E_\gamma} \approx 3\%$



Nuclear E1 response

Electric dipole

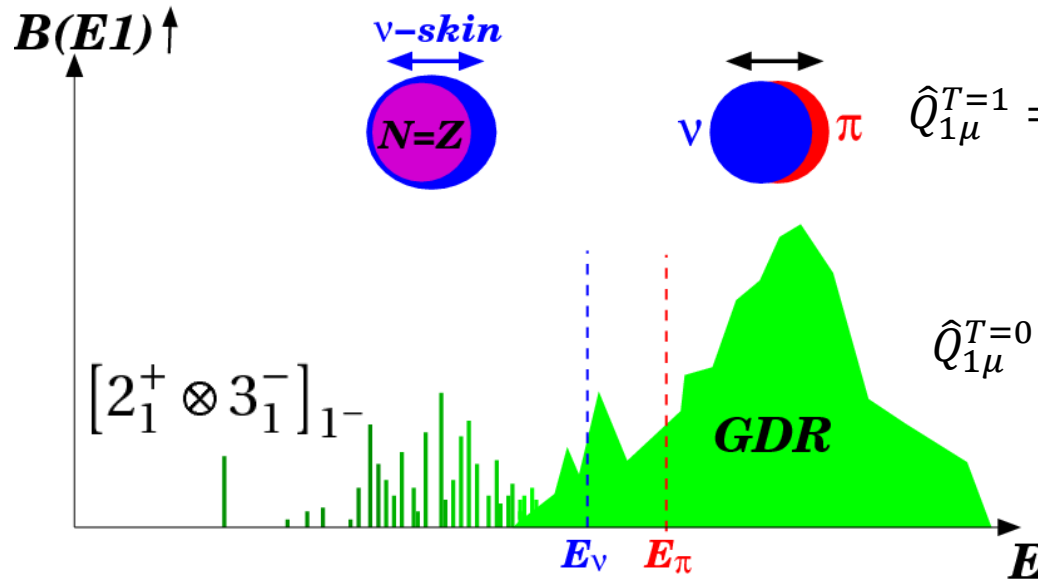
Mechanism



Not possible!!!
Only protons are charged

Divide center of charge
and center of mass

E1 strength in spherical nuclei



Isovector

$$\hat{Q}_{1\mu}^{T=1} = \frac{N}{A} \sum_{p=1}^Z r_p Y_{1\mu}(\hat{r}_p) - \frac{Z}{A} \sum_{n=1}^N r_n Y_{1\mu}(\hat{r}_n)$$

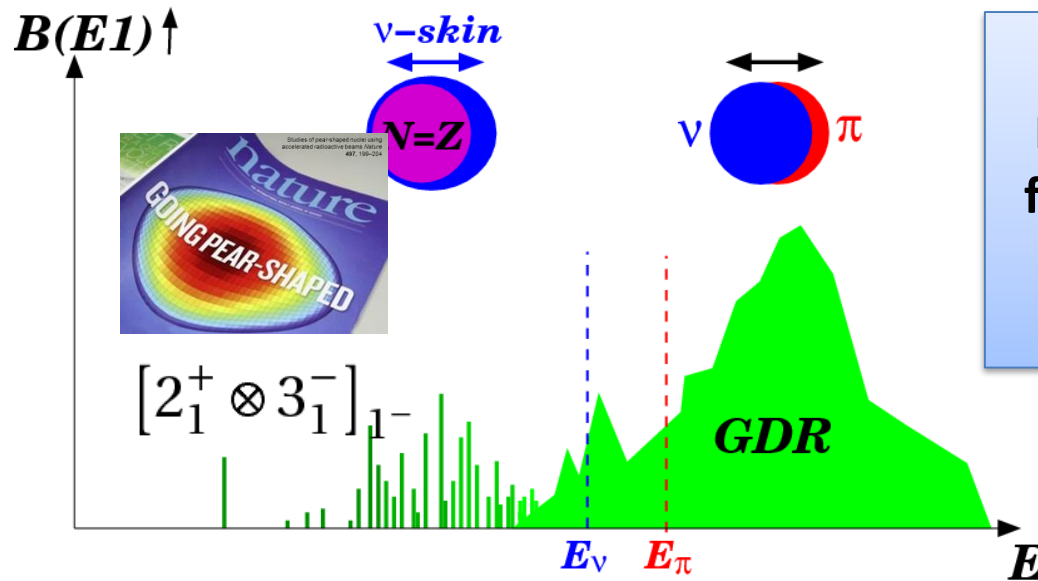
Isoscalar

$$\hat{Q}_{1\mu}^{T=0} = \sum_{i=1}^Z r_i^3 Y_{1\mu}(\hat{r}_i) - \eta \sum_{i=1}^A r_i Y_{1\mu}(\hat{r}_i)$$

Nuclear E1 response

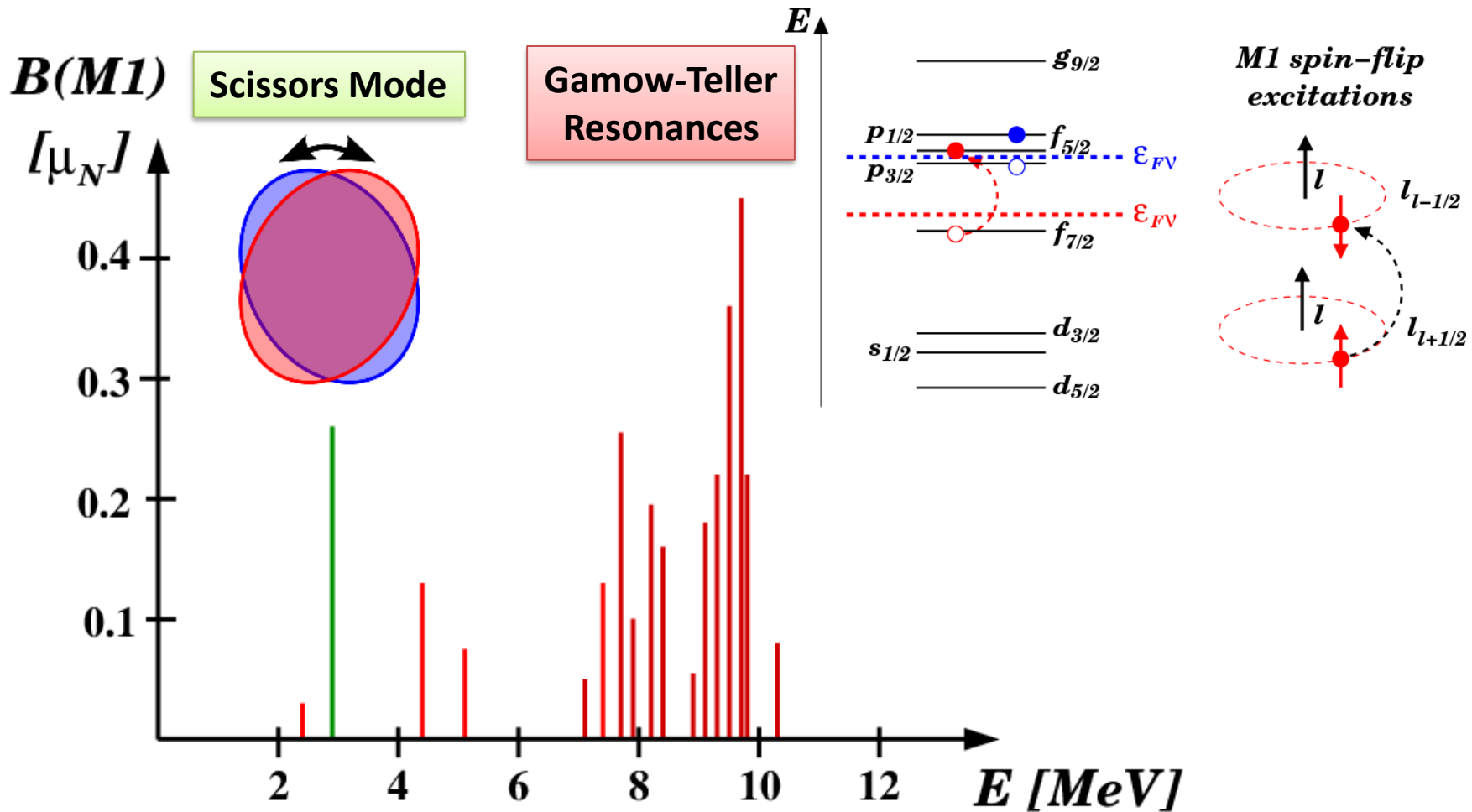
Implications

- E1 strength near threshold(s) enhances neutron/proton capture rates
⇒ r- and s-process flows
- Neutron skin (?) related to nuclear Equation of State ⇒ Neutron star properties
- What if nucleus has static quadrupole and octupole deformation?
⇒ enhancement of a possible CP-violating nuclear Schiff moment

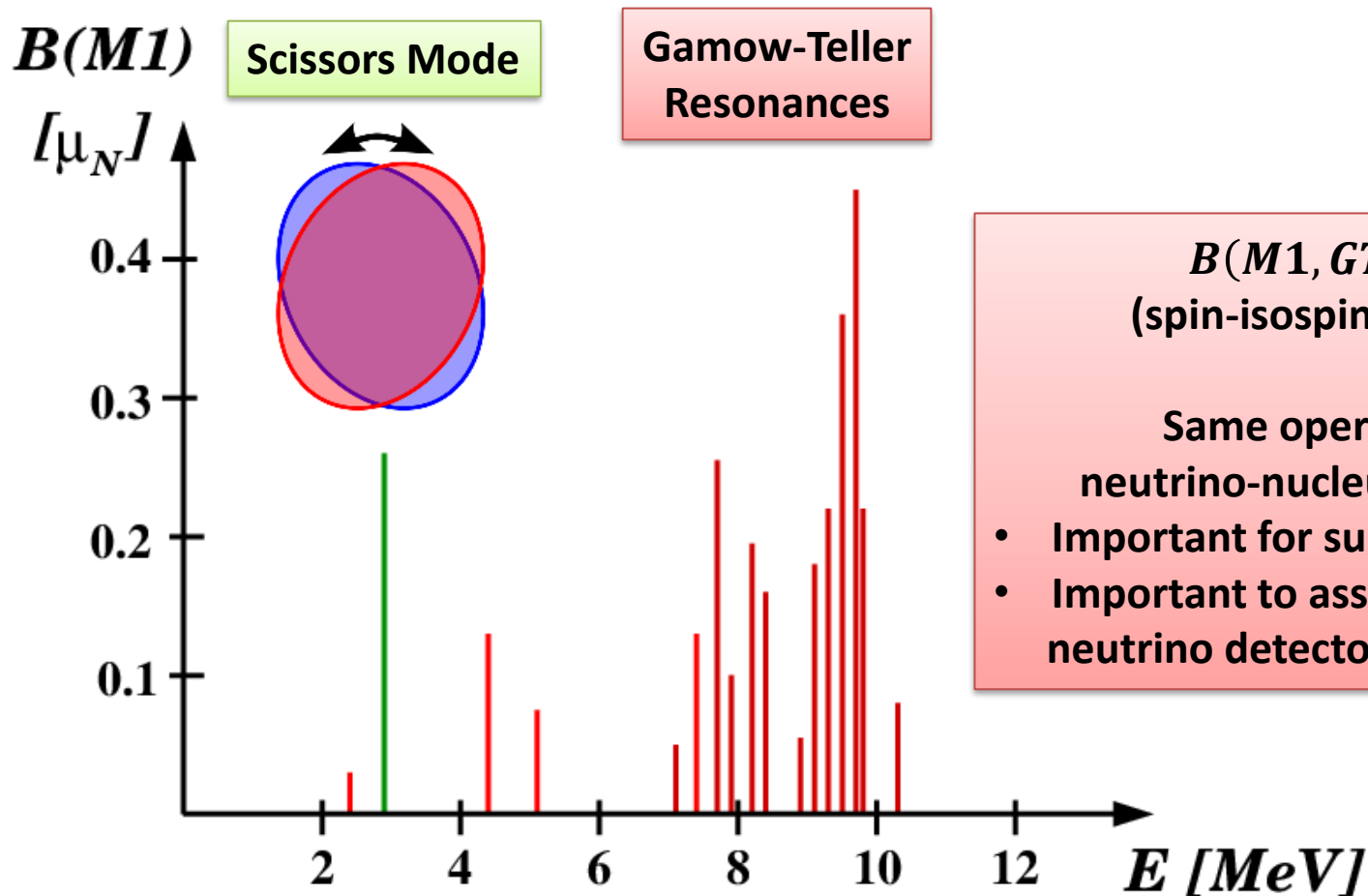


At present:
Enhancement of β -decay rates
for the three main contributors
to the
reactor antineutrino anomaly

Nuclear M1 response

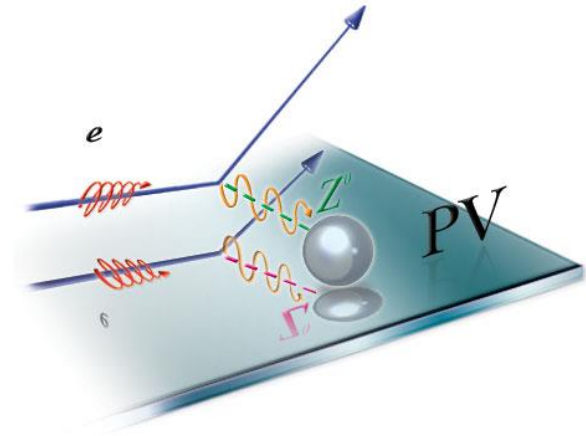


Nuclear M1 response

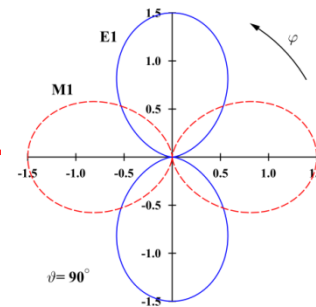
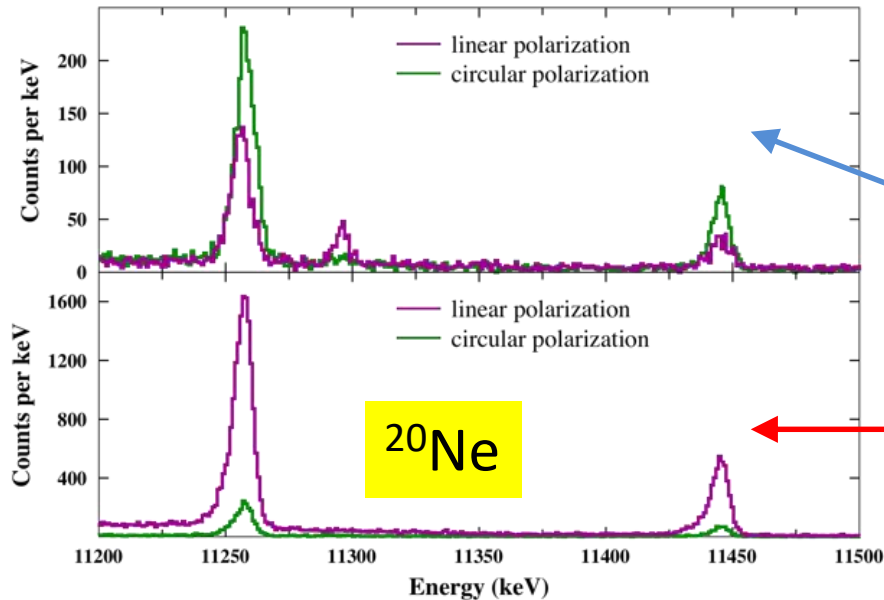


Polarisation sensitivity: search for P-violating effects

$$\text{Effects} \propto \frac{\langle J^+ | V_{PNC} | J^- \rangle}{E_+ - E_-}$$



[Http://irfu.cea.fr/Sphn/Parity](http://irfu.cea.fr/Sphn/Parity)



J.Beller, C.Stumpf, M.Scheck et al., PLB **741**, 128 (2015)