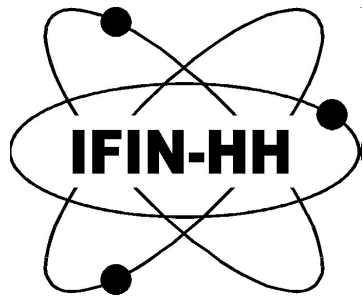


# Lecture 1.3

## Nuclear Structure

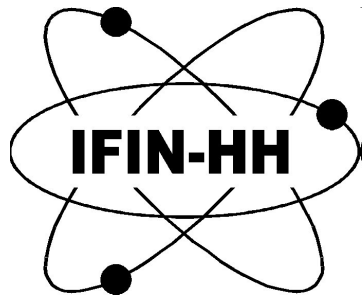
### Observables

Alexandru Negret



## Outline

- The spin and parity of the nuclear levels;
- Gamma ray multipolarity; The link between the multipolarity and the gamma intensity;  
The mixing ratio;
- The internal conversion and the conversion coefficient;
- The isospin;
- The reduced transition probabilities.

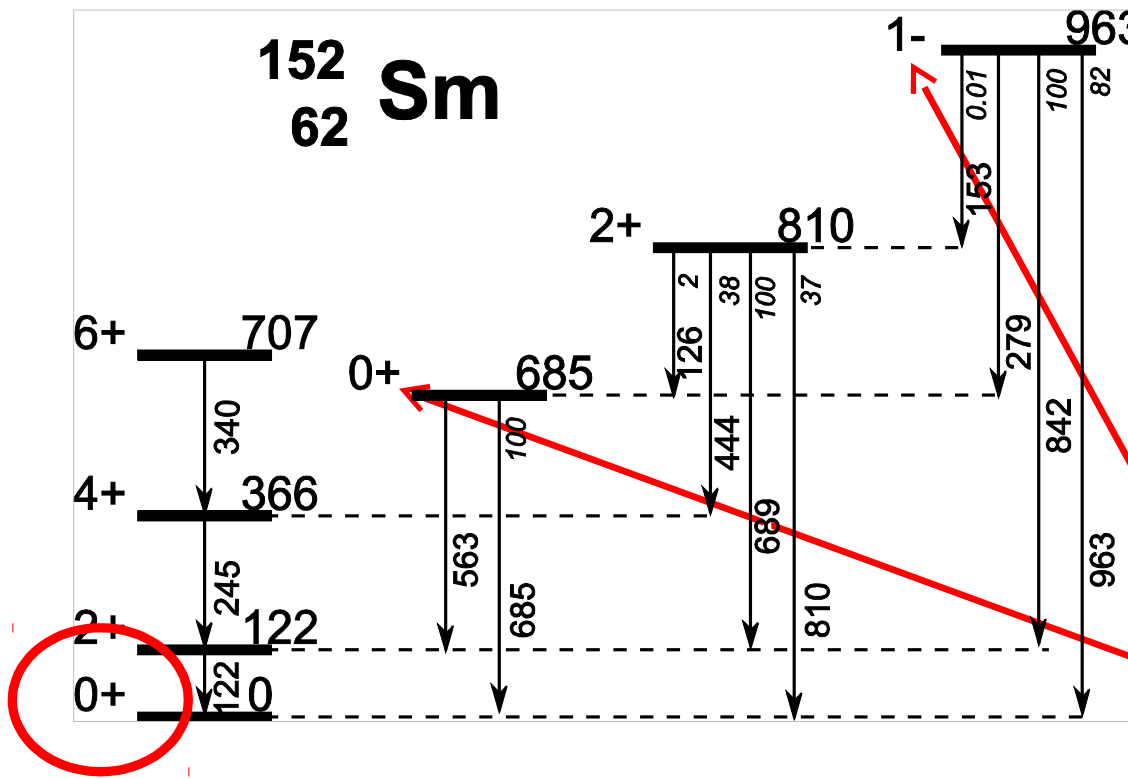


# The spin and parity

Spin = Total angular momentum of the nucleus excited on a certain level

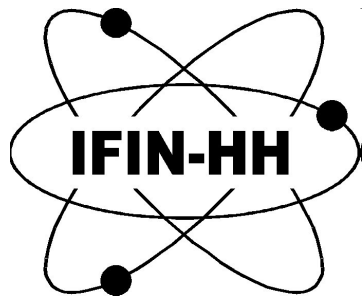
- Integer for even-even nuclei
- Half-integer for odd-even nuclei

Parity = The parity of the nucleus excited on a certain level



$J^\pi$

$J^\pi = 0^+$  for all even-even nuclei



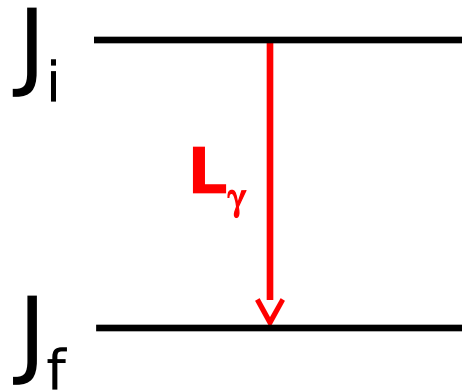
# The multipolarity of the gamma rays

Angular momentum & Parity conservation:

$$\vec{J}_i = \vec{J}_f + \vec{L}_\gamma$$

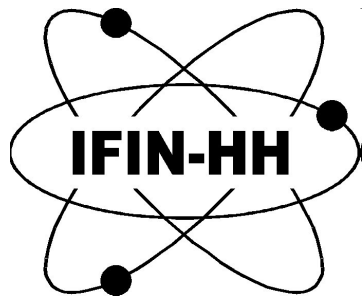
$$\pi_i = \pi_f \pi_\gamma$$

$$\pi_\gamma = \begin{cases} (-1)^L, EL \\ (-1)^{L+1}, ML \end{cases}$$



**The angular distribution of a gamma depends on the multipolarity.**

No Parity change => EL-even, ML-odd  
Parity change => EL-odd, ML-even



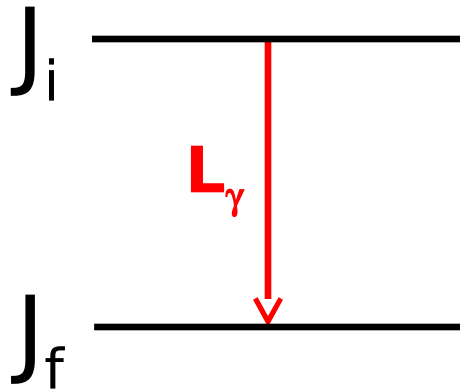
# Relation between multipolarity and intensity; Mixing ratio

In general:

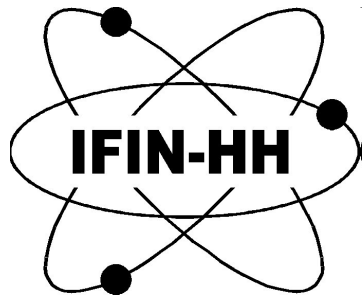
$$I(EL) \approx 600 \cdot I(EL+1)$$

$$I(ML) \approx 600 \cdot I(ML+1)$$

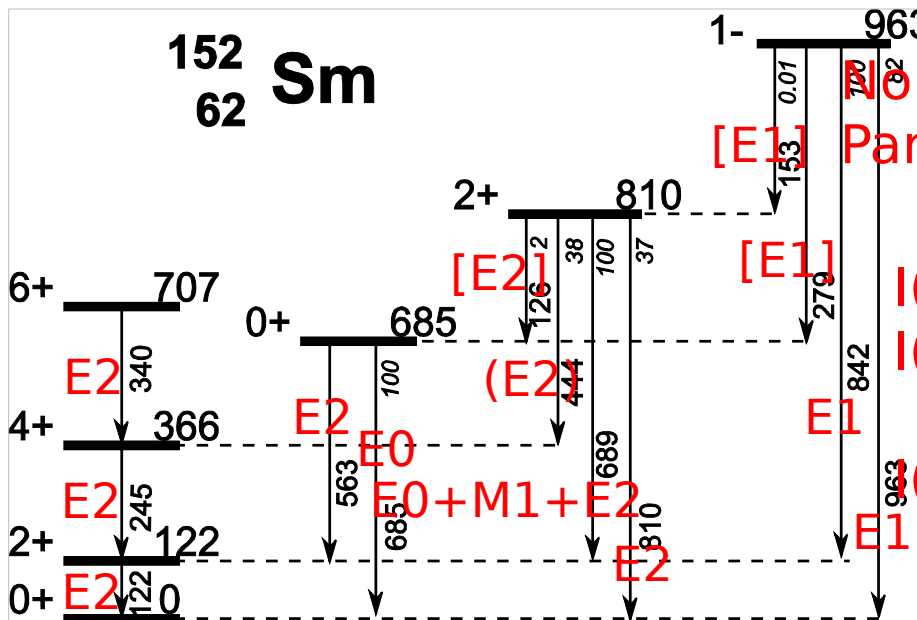
$$I(ML) \approx I(EL+1)$$



When a transition takes place from a level to another, various gamma multipolarities can be emitted => MIXING RATIO,  $\delta$   
M1+E2, M2+E3, M3+E4, etc.



# EXERCISE: determine the possible gamma multiplicities

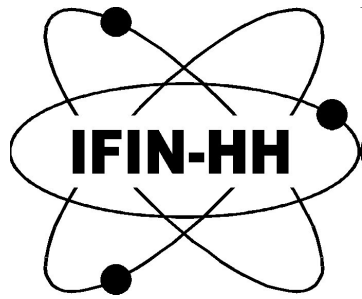


Parity change => EL-even, ML-odd  
 [E1] Parity change => EL-odd, ML-even

$$I(EL) \approx 600 \cdot I(EL+1)$$

$$I(ML) \approx 600 \cdot I(ML+1)$$

$$I(ML) \approx I(EL+1)$$



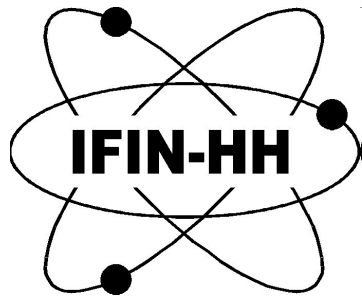
## The internal conversion

The probability of a gamma transition:  $\left\{ \begin{array}{l} \text{Increases when the energy increases} \\ \text{Increases when the multipolarity decreases} \end{array} \right.$

If the energy is very low, the **INTERNAL CONVERSION** may occur: an electron from the lower orbital of the atom captures the energy of the nucleus and it is emitted. The nuclear transition occurs and additional X rays are emitted from the electron shells.

The **internal conversion coefficient**,  $\alpha = \frac{\text{Number of de-excitations via electron emission}}{\text{Number of de-excitations via gamma emission}}$

Observation: L=0 transitions are totally converted  $\alpha=1$ .

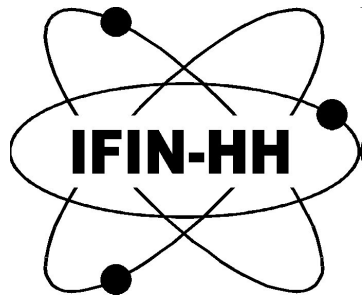


## Question

The probability of a gamma transition:  $\left\{ \begin{array}{l} \text{Increases when the energy increases} \\ \text{Increases when the multipolarity decreases} \end{array} \right.$

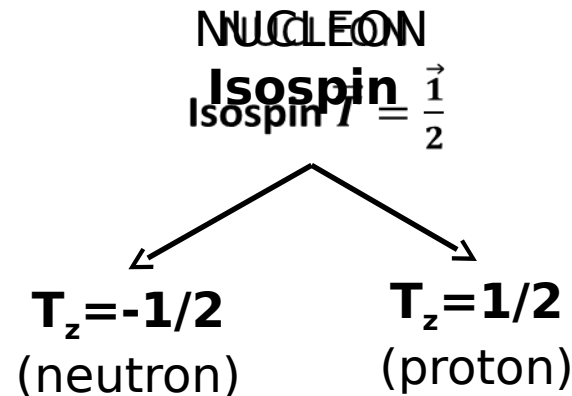
If the energy is very low, the nucleus can lose the excitation energy through INTERNAL CONVERSION

What happens if the transition energy is high (internal conversion impossible) and the multipolarity is very high (gamma transition very improbable)?

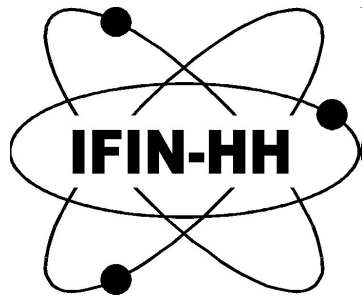


# The isospin

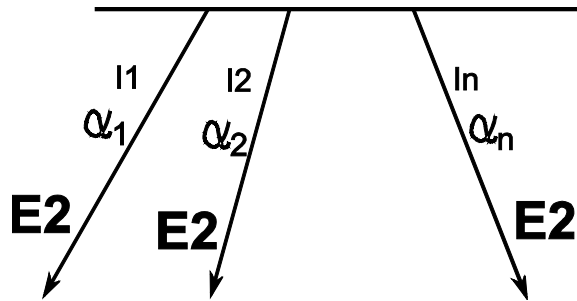
Except for their charge, the proton and neutron are almost identical:  
They have almost the same mass  
The nuclear force acts almost the same on the two of them



In this approach, in a certain nucleus all levels will have  $T_z = (Z-N)/2$ , but various isospin values compatible with  $T_z$ .



# The reduced transition probability: $B(E\lambda), B(L\lambda)$



Partial half life  $T_{1/2}^{\gamma i} = \frac{56.3}{E_{\gamma}^5 B(E2) \downarrow}$   
**s keV e<sup>2</sup>b<sup>2</sup>**

Exp. half life  $T_{1/2}^{exp} = T_{1/2}^{\gamma i} \frac{I_i + \alpha_i I_i}{\sum_{i=1}^n (I_i + \alpha_i I_i)}$

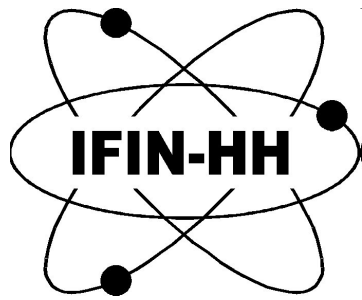
## Single Particle Units:

$$B(E\lambda)_{SP} \uparrow = \frac{2\lambda + 1}{4\pi} \left( \frac{3}{\lambda + 3} \right)^2 (0.12A^{1/3})^{2\lambda} \quad \mathbf{e^2b^\lambda}$$

$$B(E2)_{SP} \uparrow = 2.97 \cdot 10^{-5} A^{4/3} \quad \mathbf{e^2b^2} \quad 1e^2b^2 = 10^4 e^2fm^4$$

## Weisskopf Units:

$$B(E2) \downarrow = \frac{1}{5} B(E2) \uparrow$$



## Summary

- The spin and parity of the nuclear levels;
- Gamma ray multipolarity; The link between the multipolarity and the gamma intensity;  
The mixing ratio;
- The internal conversion and the conversion coefficient;
- The isospin;
- The reduced transition probabilities.