



Софийски университет "Св. Климент Охридски"
Физически факултет
Катедра "Атомна физика"

В търсене на състояния със смесена симетрия в ядрото $Po-212$

Атестационен семинар

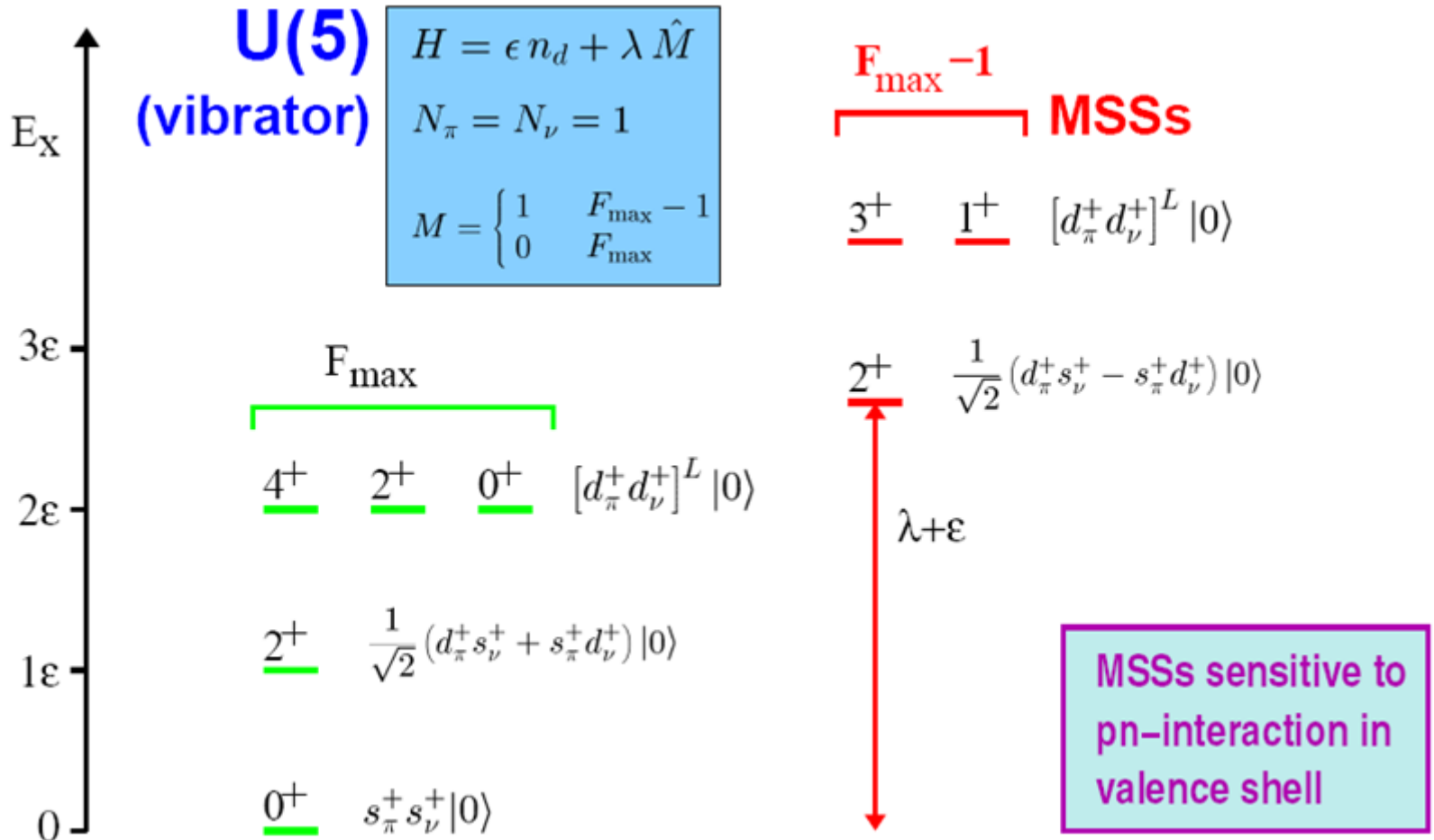
Докторант: Диана Кочева

Научен ръководител: Проф. дфзн Г. Райновски

СЪСТОЯНИЯ СЪС СМЕСЕНА СИМЕТРИЯ?

Еднофононното $2^+_{1,ms}$ състояние със смесена симетрия е фундаментално квадруполно-колективно изовекторно възбуждане във валентните слоеве на сферични ядра

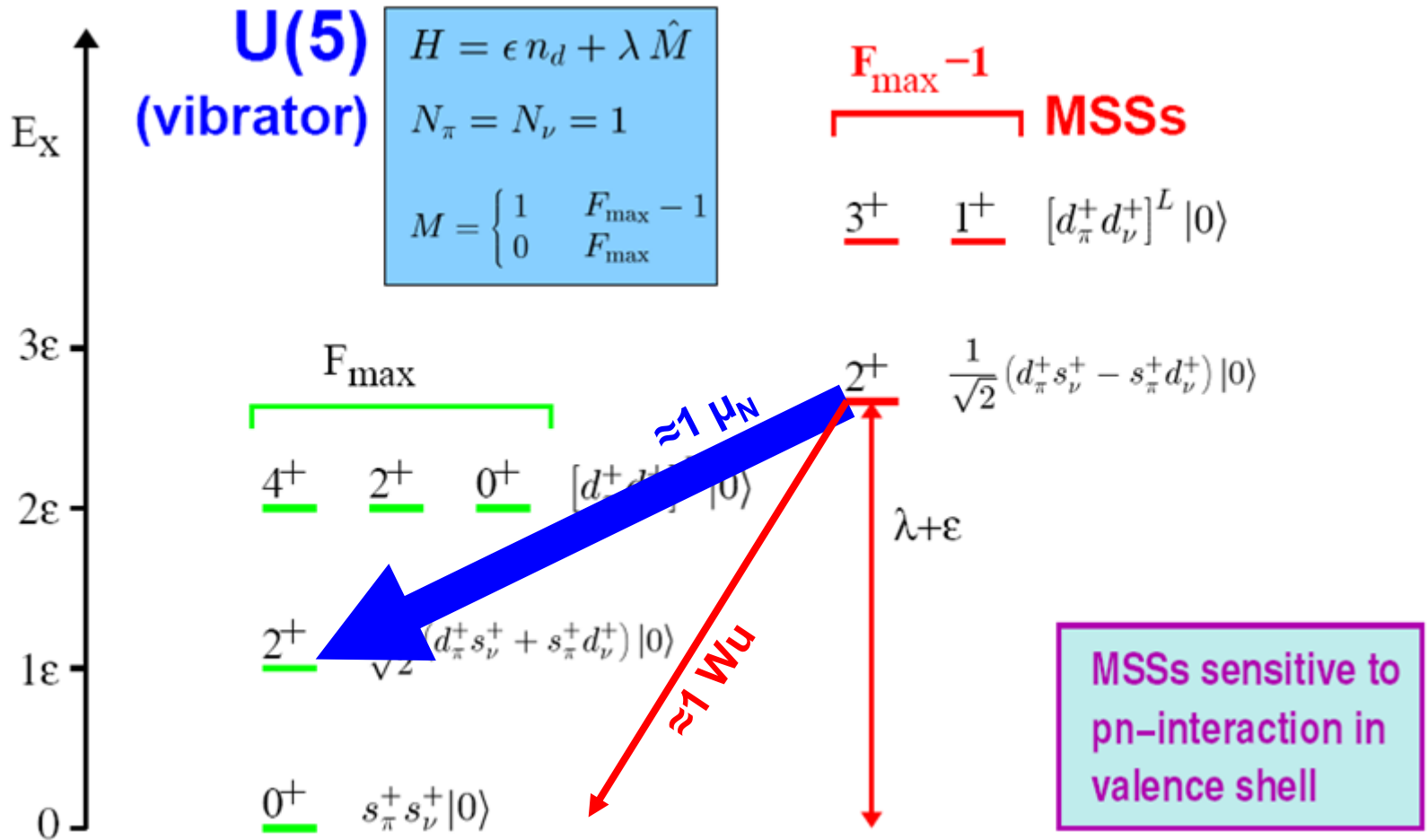
Пример: Хармоничен осцилатор, $N=2$



Състояния със смесена симетрия?

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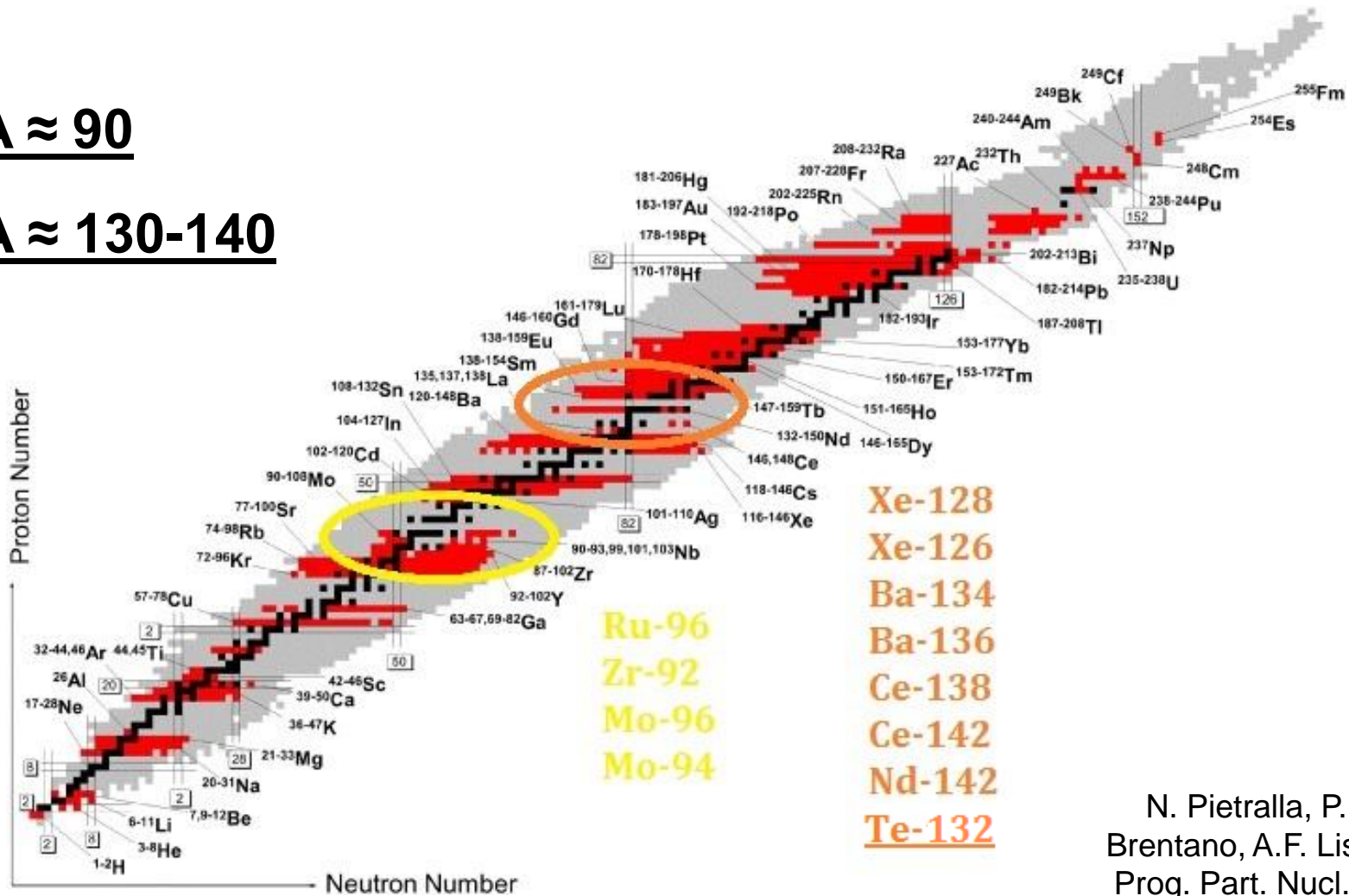
Пример: Хармоничен осцилатор, $N=2$



Къде?

$A \approx 90$

$A \approx 130-140$

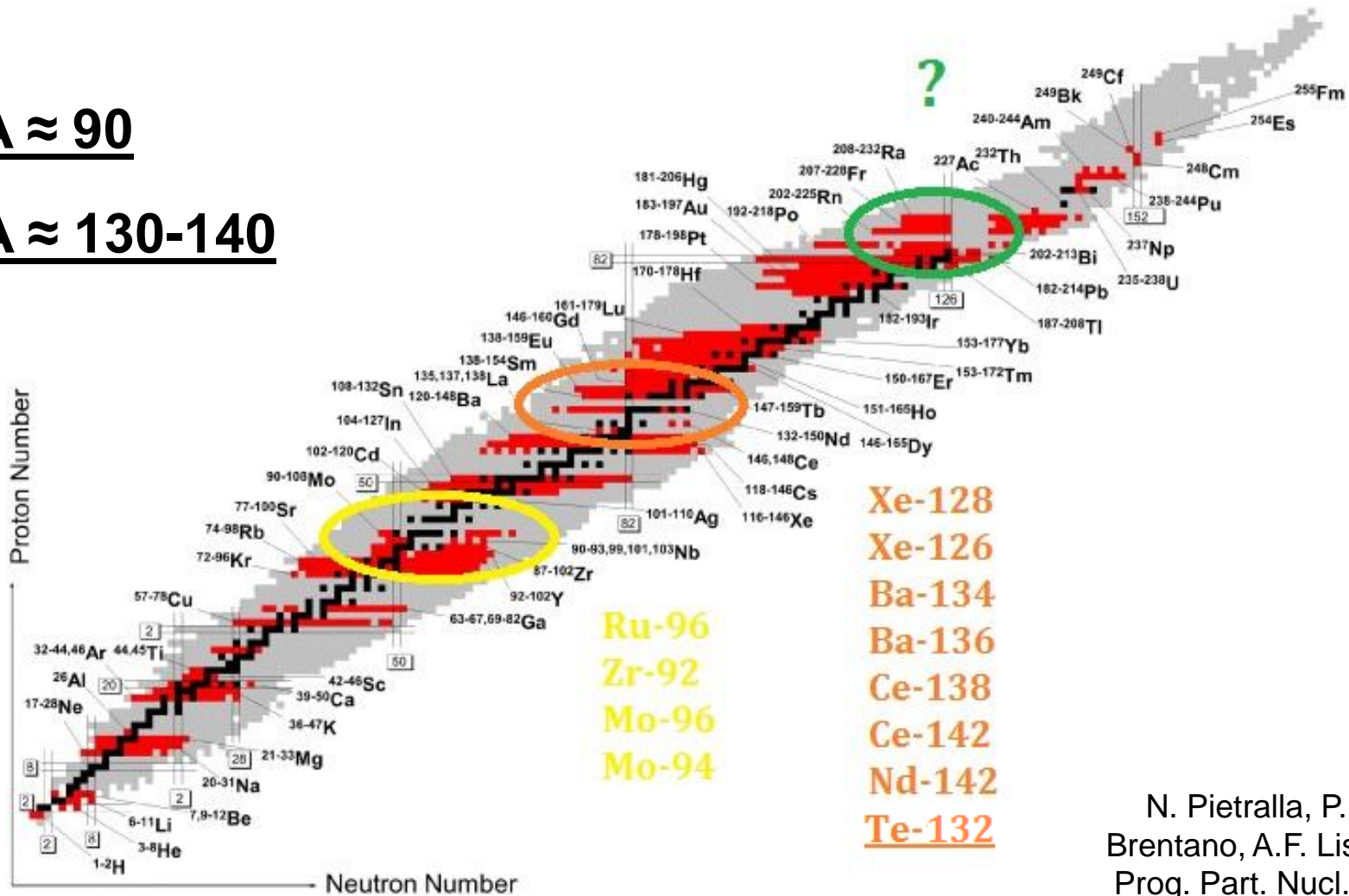


N. Pietralla, P. von
Brentano, A.F. Lisetskiy,
Prog. Part. Nucl. Phys.
60, 225 (2008).

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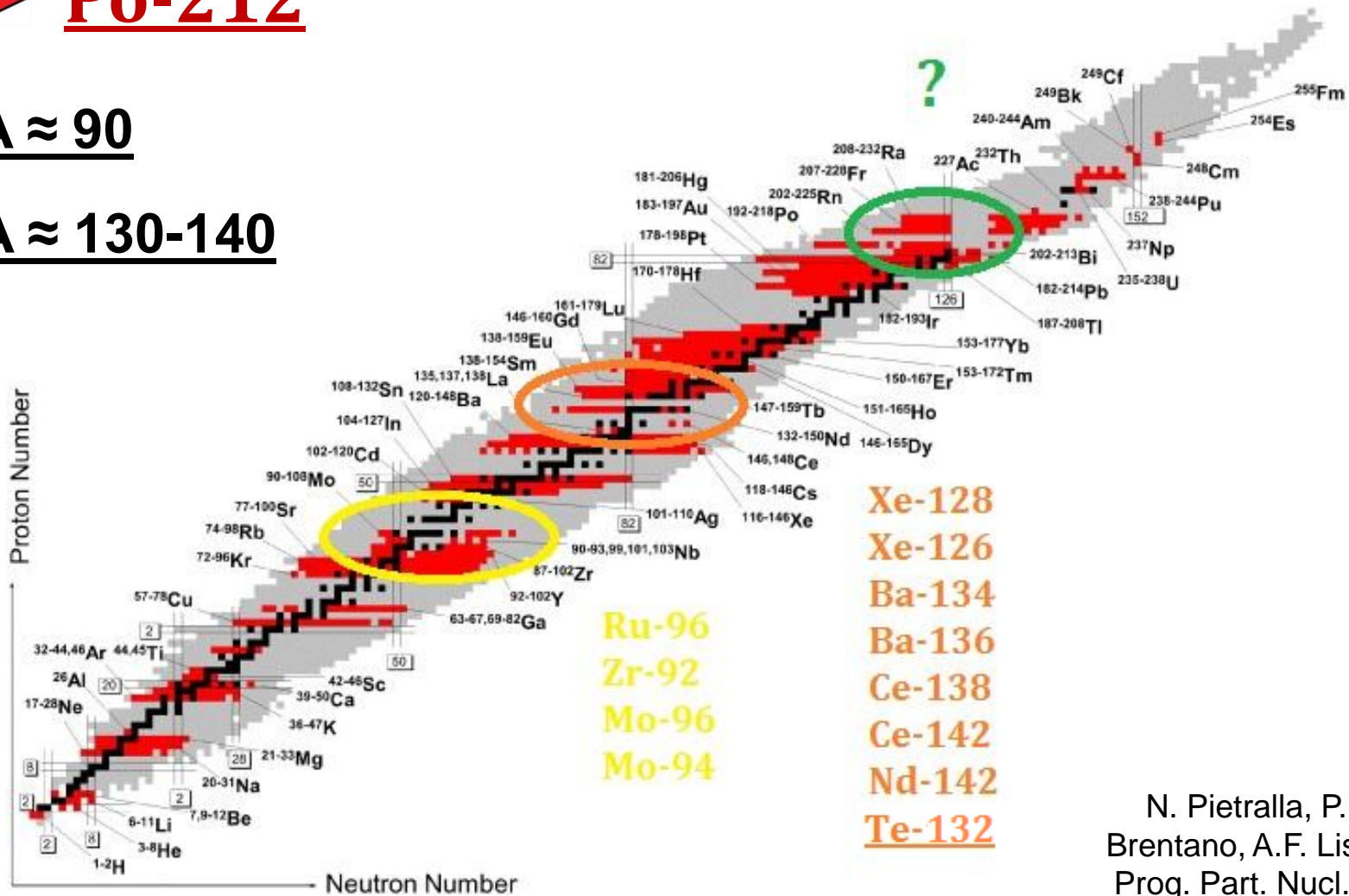
N. Pietralla, P. von Brentano, A.F. Lisetskiy,
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Къде?

→ Po-212

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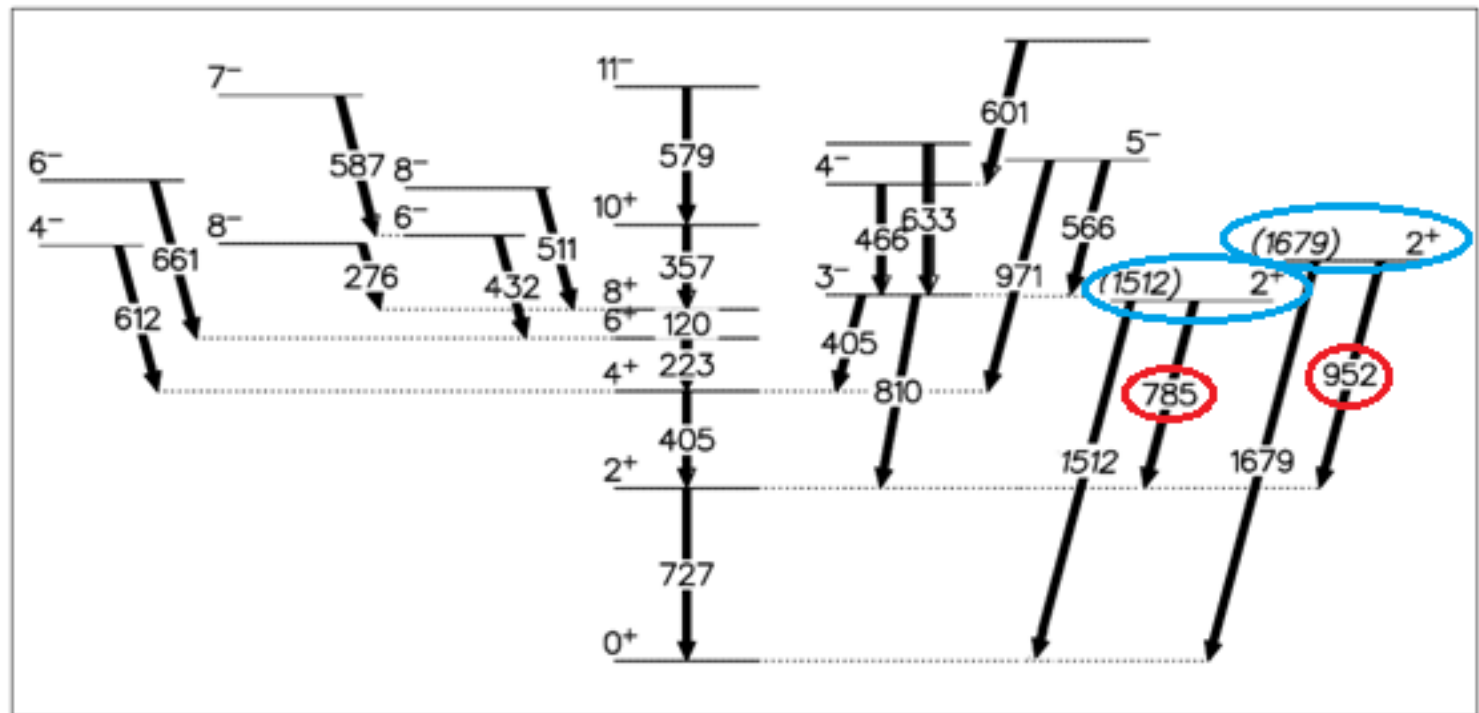


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Експериментални наблюдаеми, необходими за идентификацията на еднофононно ССС

→ Силен M1-преход

- Спин и четност: 2^+
- Времена на живот: много късоживуци - стотици фемтосекунди;
- Отношения на разклонение на γ -разпад: основен канал към 2^+
- Отношение на мултиполно смесване: $|\delta| < 1$



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$$E_{level} = 1512 \text{ keV}$$

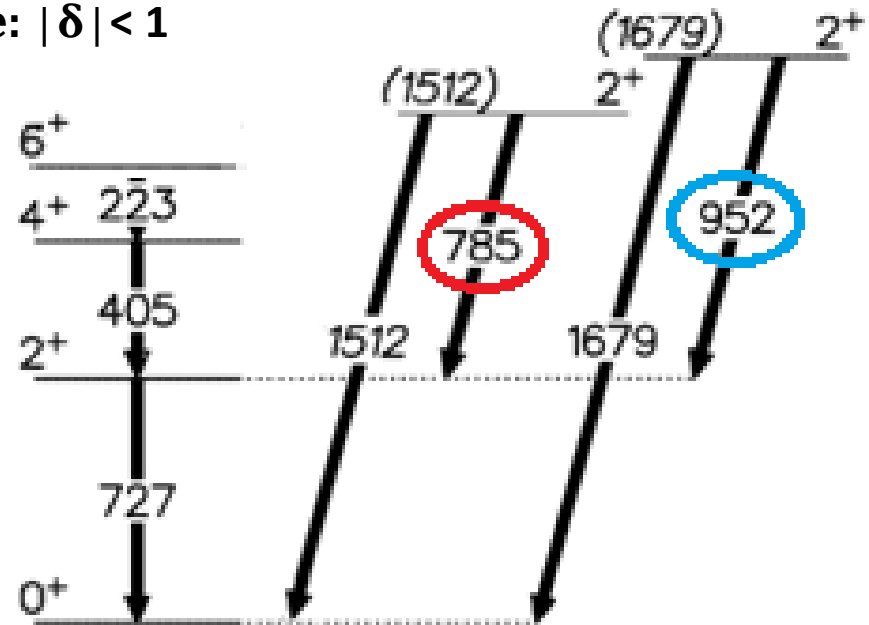
$$BR \left(\frac{\lambda(2^+ \rightarrow 2^+)}{\lambda(2^+ \rightarrow 0^+)} \right) = \frac{100(1)}{26(3)}$$

$$\delta_{E2/M1} = 0.09(3)$$

$$E_{level} = 1679 \text{ keV}$$

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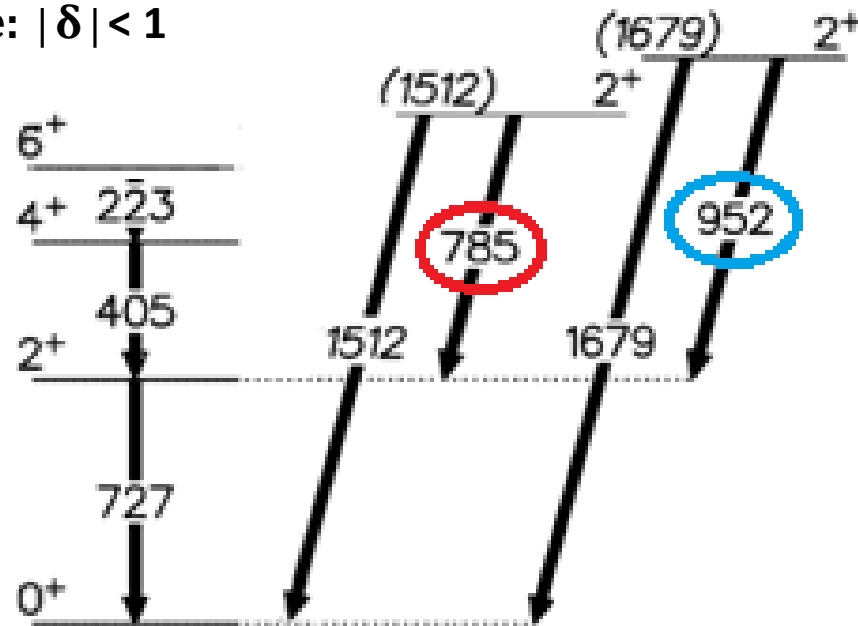
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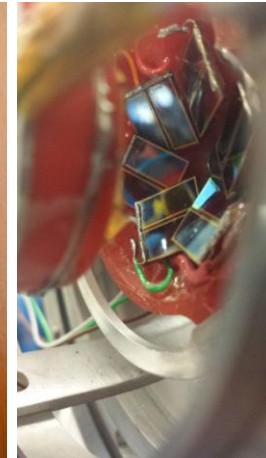
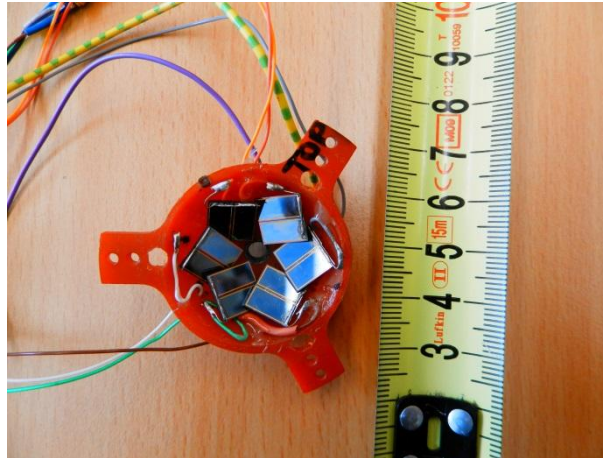
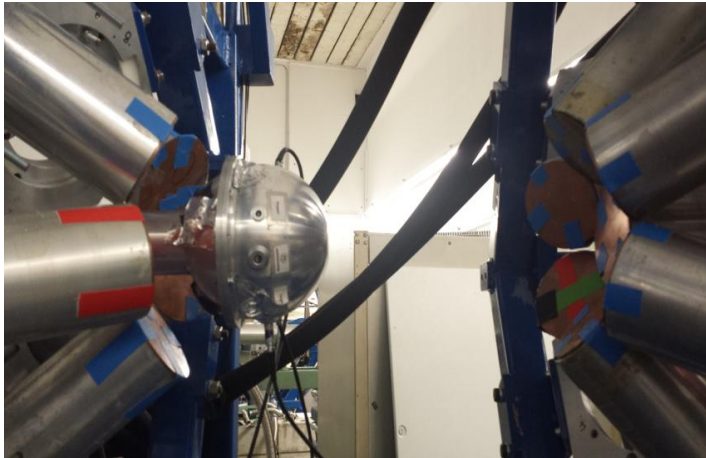


→ **Времената на живот = ?**

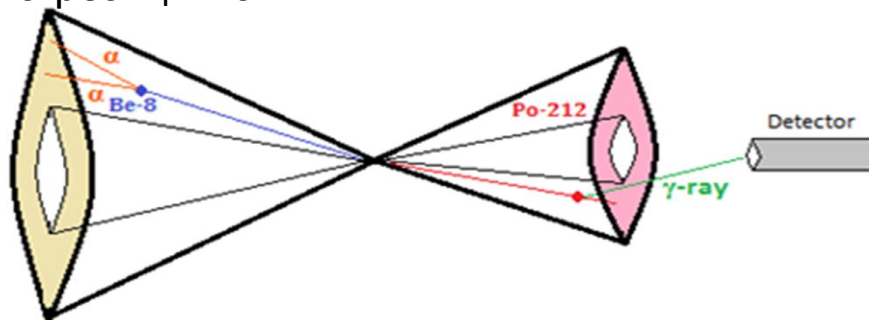
Експериментална част

Тандемен ускорител в Кьолн, Германия

- Реакция – $^{208}\text{Pb}(^{12}\text{C},^8\text{Be})^{212}\text{Po}$ @ 62 MeV ($V_{\text{col}} \approx 64$ MeV);
- Мишена – 10 mg/cm^2 ^{208}Pb (99% обогатена);
- Експериментална установка – „плънджерно устройство“:
 - 5 HpGe детектора на 142.3° , 6 HpGe детектора на 35.0° и 1 HpGe детектор на 0° ;
 - пръстен от 6 соларни клетки (10 mm × 10 mm) покриващи ъгъл м/у 116.8° - 167.2° ;
 - основен тригер - γ - α или γ - γ съвпадения;

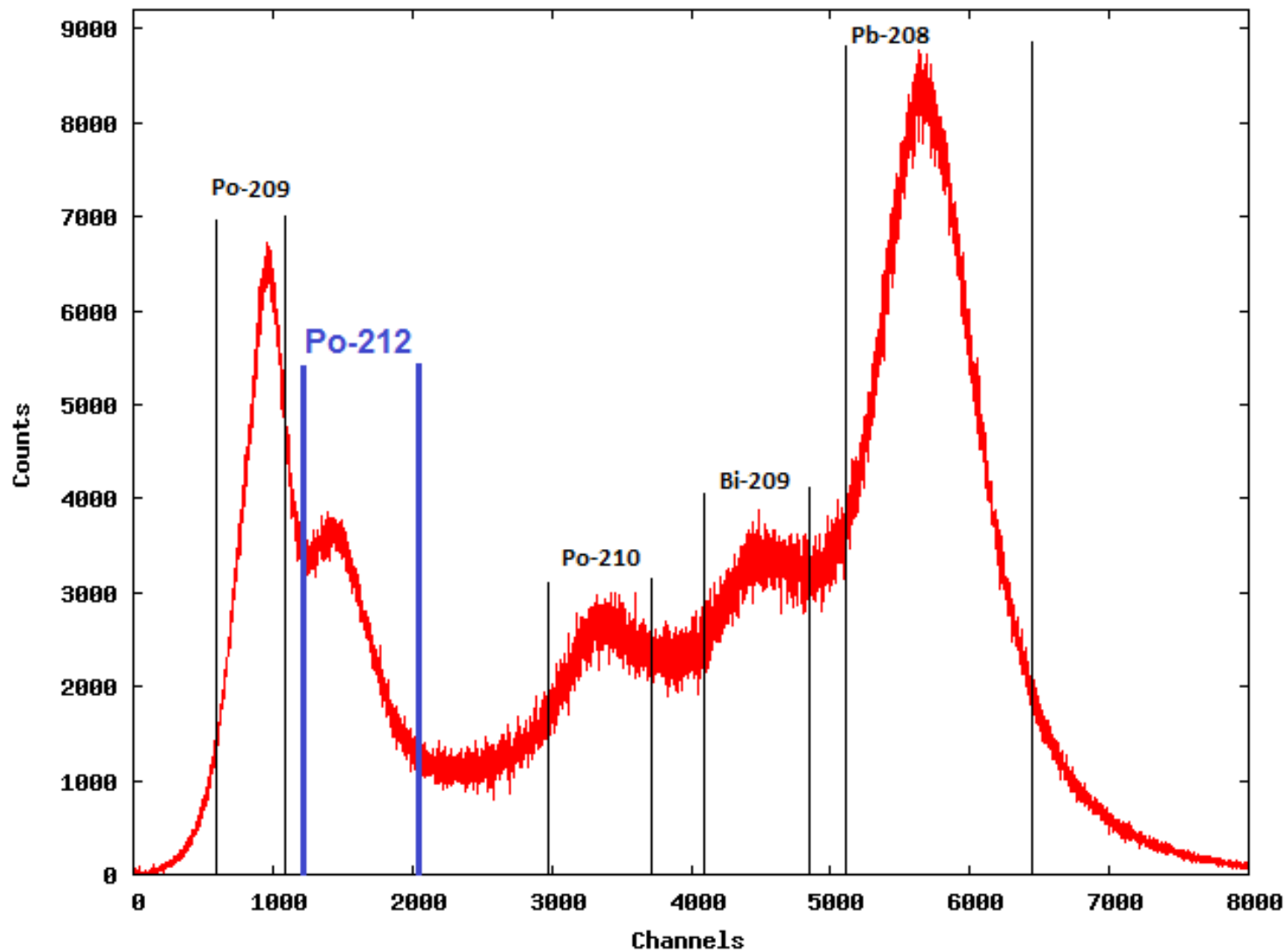


- Кинематика на реакцията

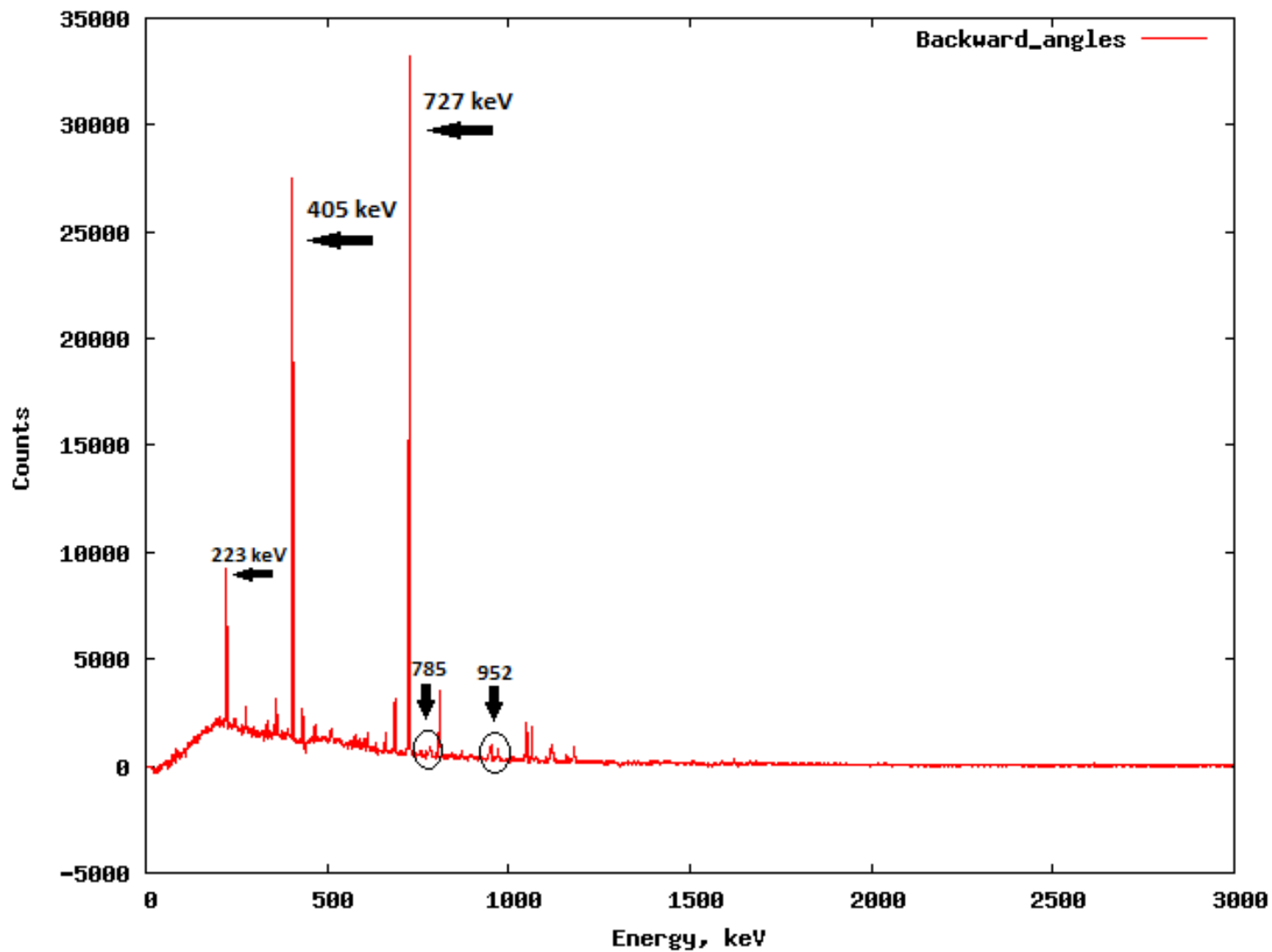


$$\langle v_0(^{212}\text{Po}) / c \rangle \approx 0.9$$

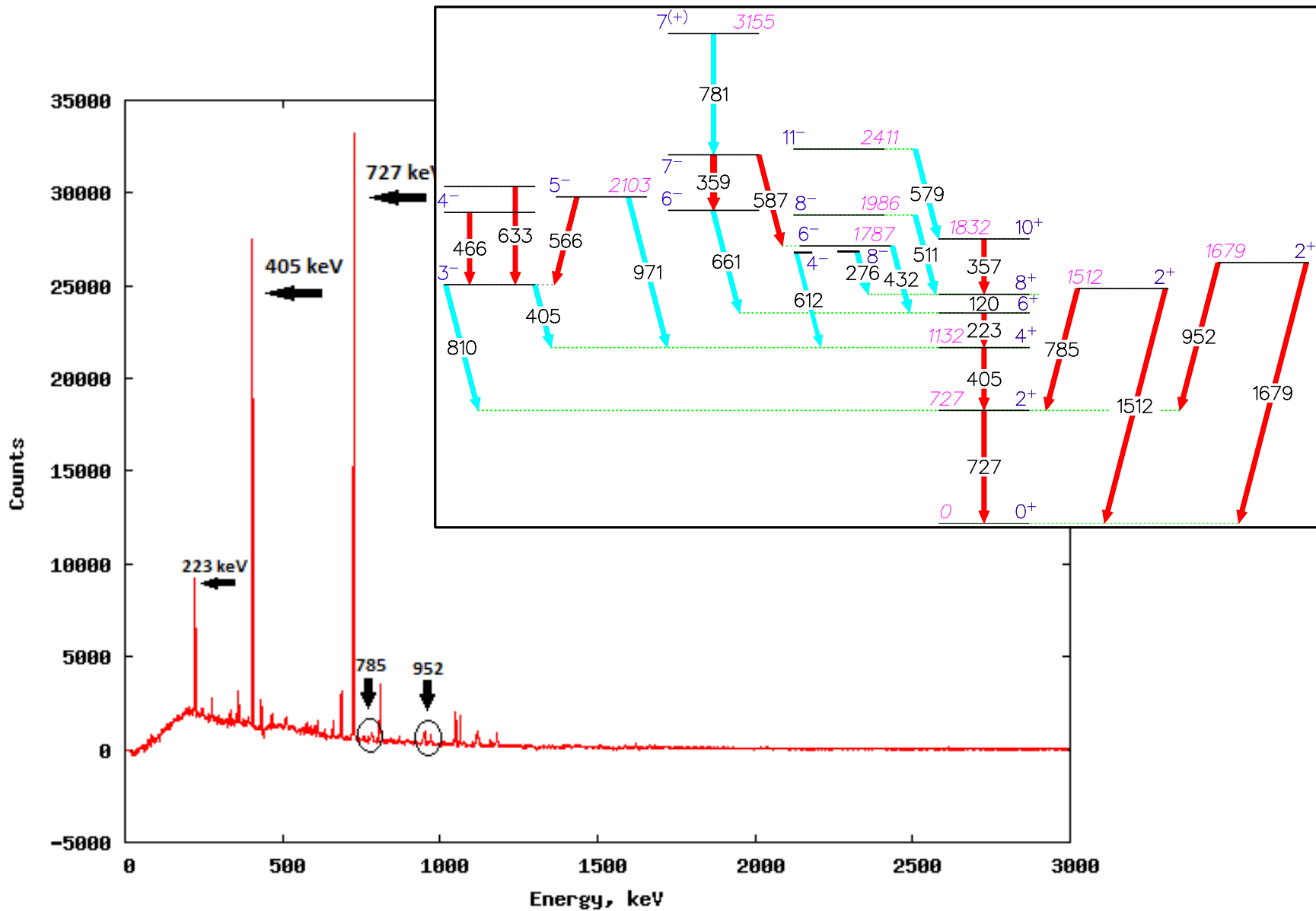
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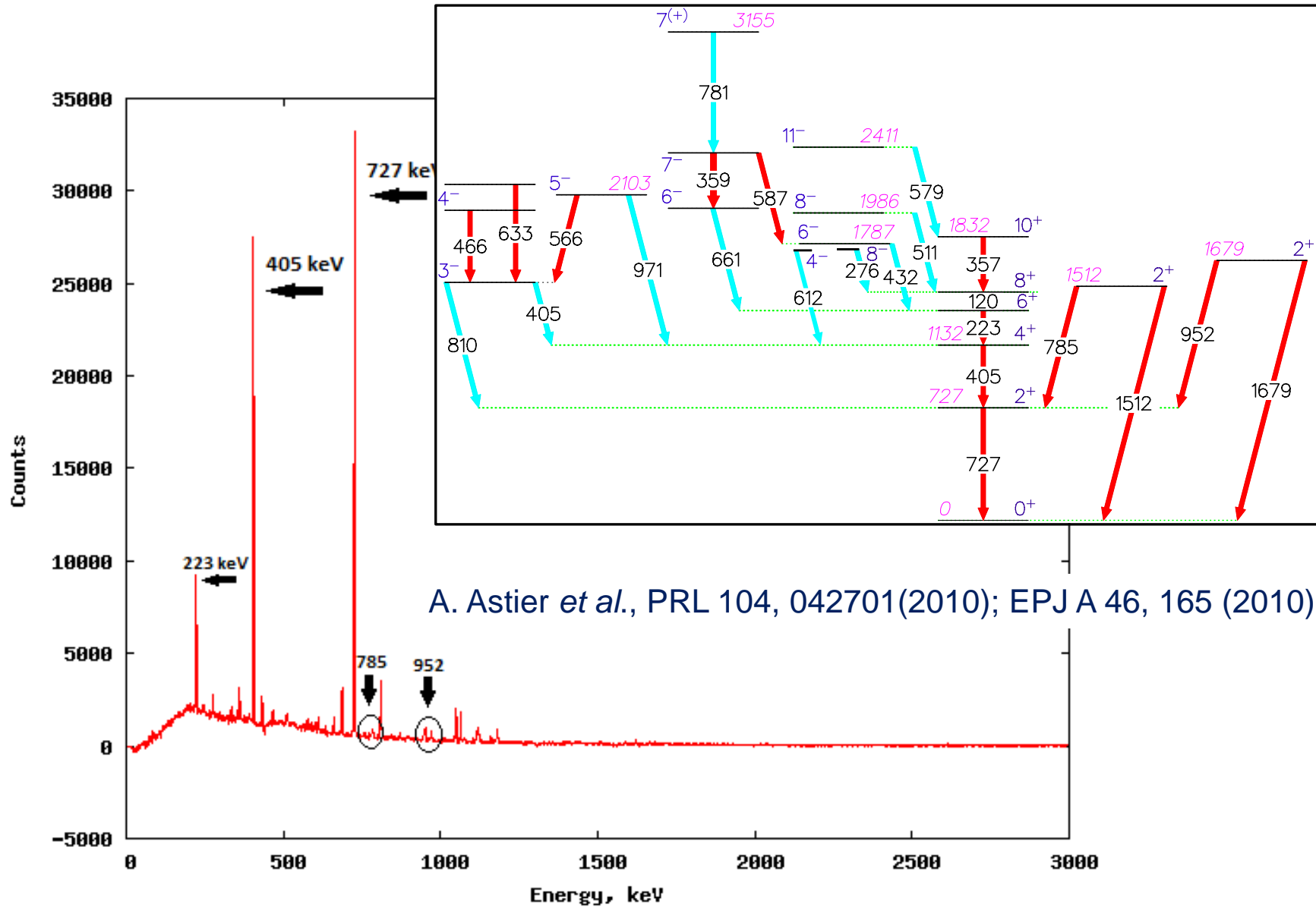
Експериментална част



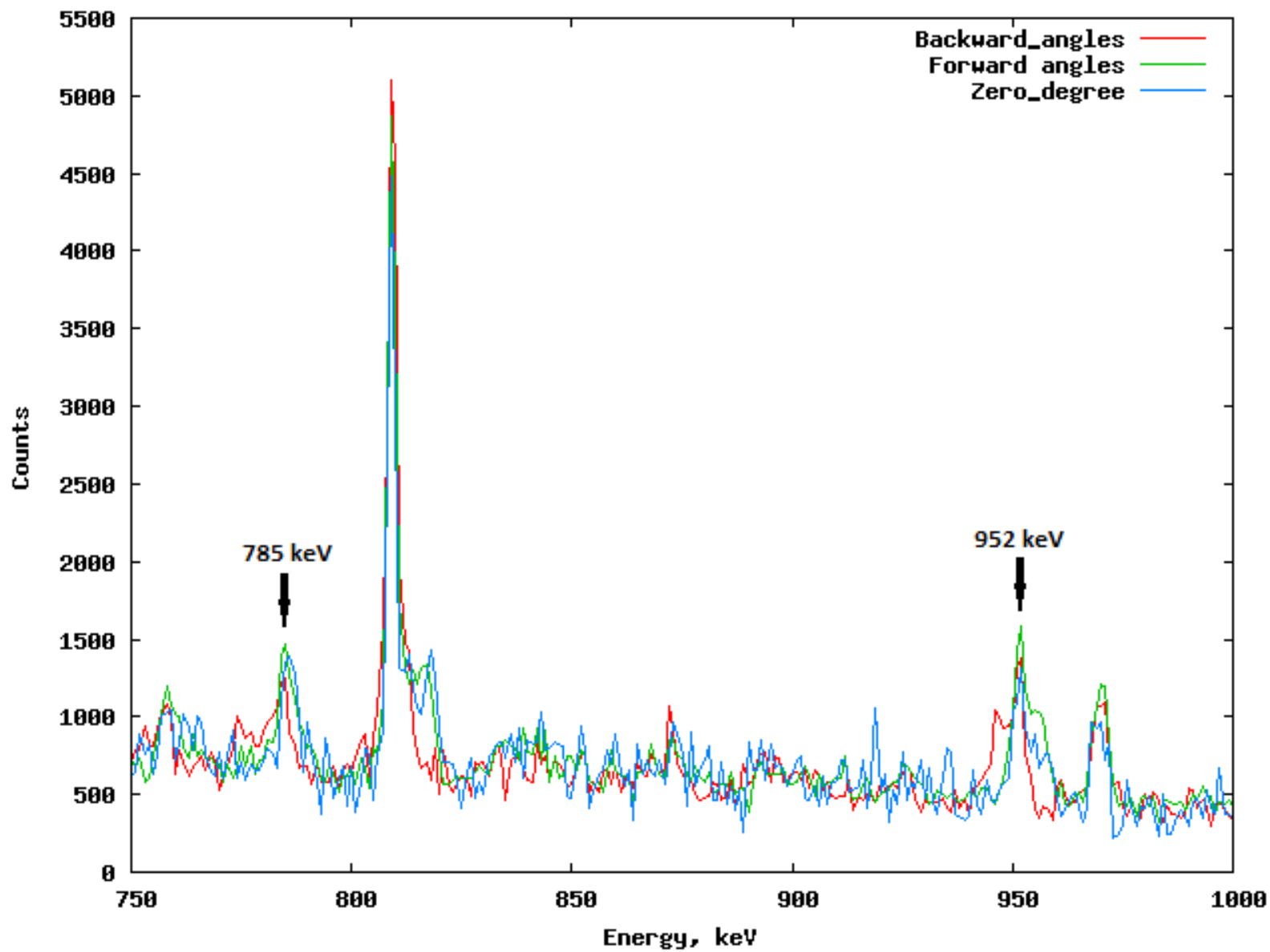
Експериментална част



Експериментална част



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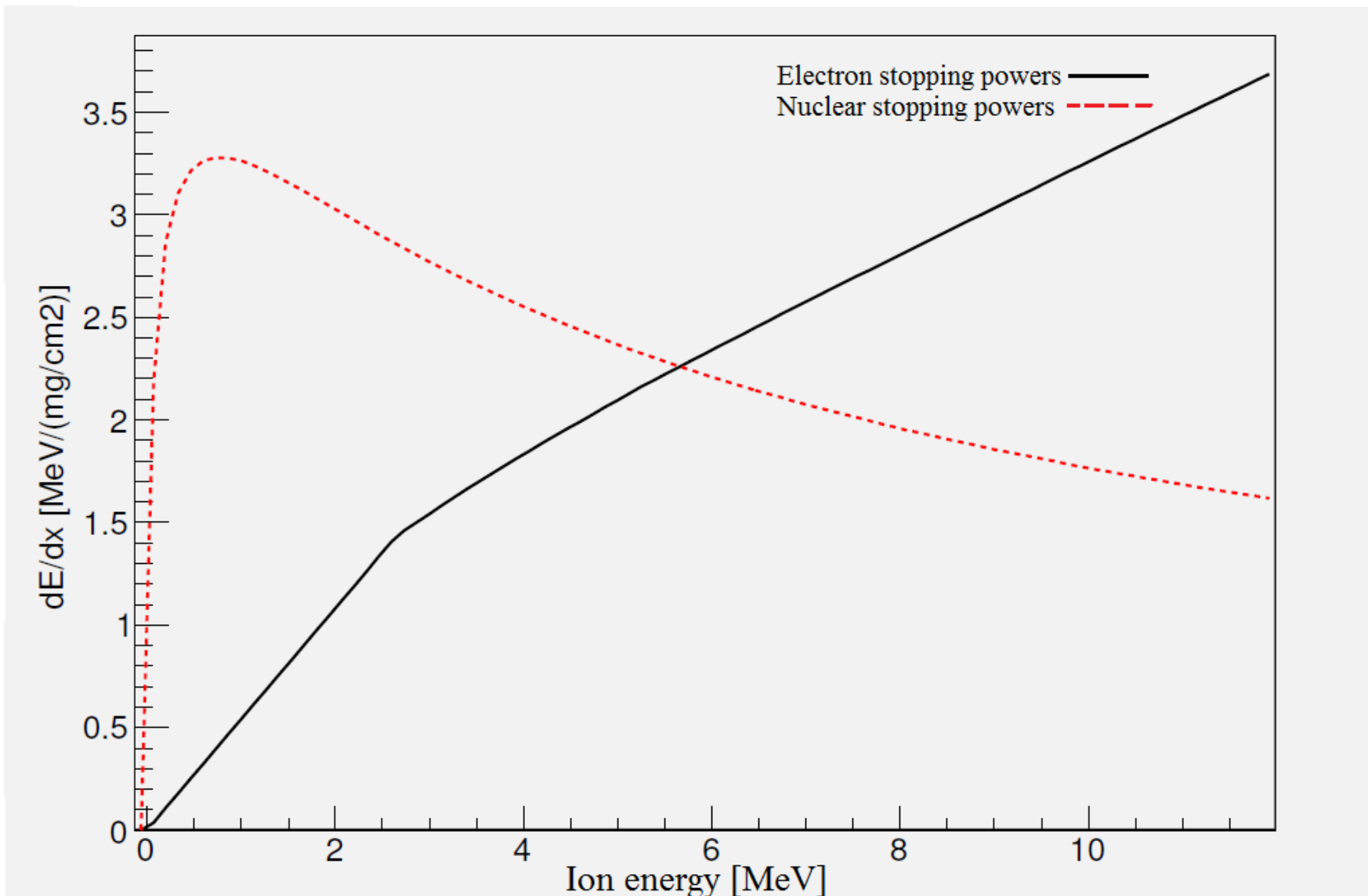


Експериментална част – line-shape analysis

- 1) Cologne-Sofia DSA analysis (based on **P. Petkov** *et al.*, NPA 640, 293 (1998); Nucl. Instrum. Methods Phys. Res. A 431, 208 (1999):
 - The slowing-down process - Monte Carlo simulation based on the **modified DESASTOP**
 - Electronic stopping (continuous process) – electronic stopping powers from modified **Northcliffe&Schilling tables**;
 - Nuclear stopping (discrete process) – **complete Monte-Carlo approach** with cross sections based on the formalism of **Lindhard, Scharff, Schiøtt reduced by 30%**;

- 2) Analysis Program for Continuous Angle DSAM – APCAD (**C. Stahl**, thesis, TU Darmstadt 2015):
 - The slowing-down process - Monte Carlo simulation based on **GEANT4**:
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Stopping Powers for Po-212 in Pb-208



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 - The HpGe detector response and the experimental set-up geometry;
 - The kinematics restrictions (particle detector);
 - Feeding history – from the γ - γ coincidence data;

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6^- at 2016 keV, $E_\gamma=661.3$ keV

	A. Astier et al., PRL 104, 042701(2010); EPJ A 46, 165 (2010)	Analysis 1	Analysis 2
τ(ps)	0.49(16)	0.50(4)	0.47(3)

Експериментална част - резултати от APCAD

785.3 keV

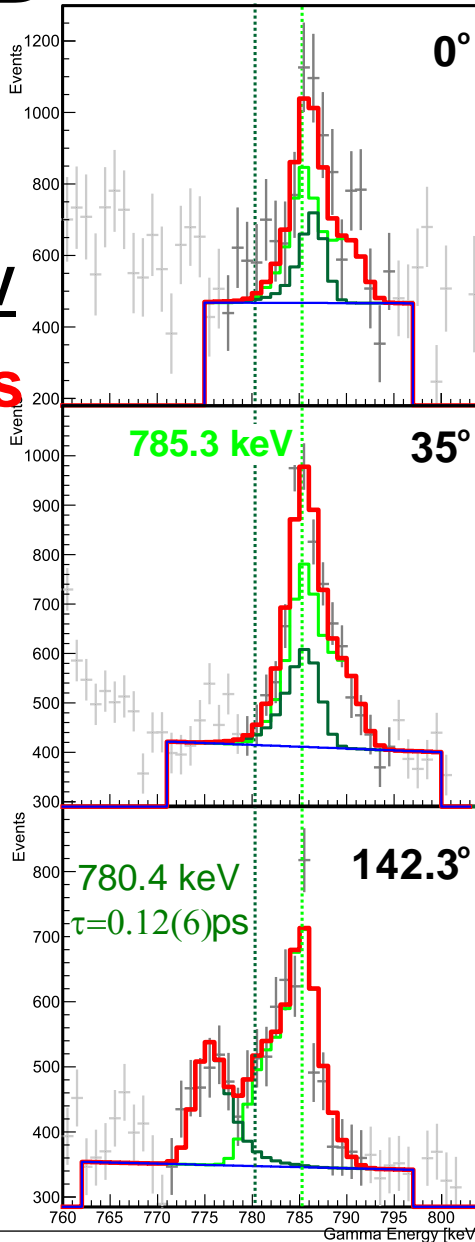
$2^+_2 \rightarrow 2^+_1$

2^+_2 @ 1512 keV

$\tau = 0.69(6)$ ps

$\delta = +0.09(3)$

BR=100(1)/26(3)



952.1 keV

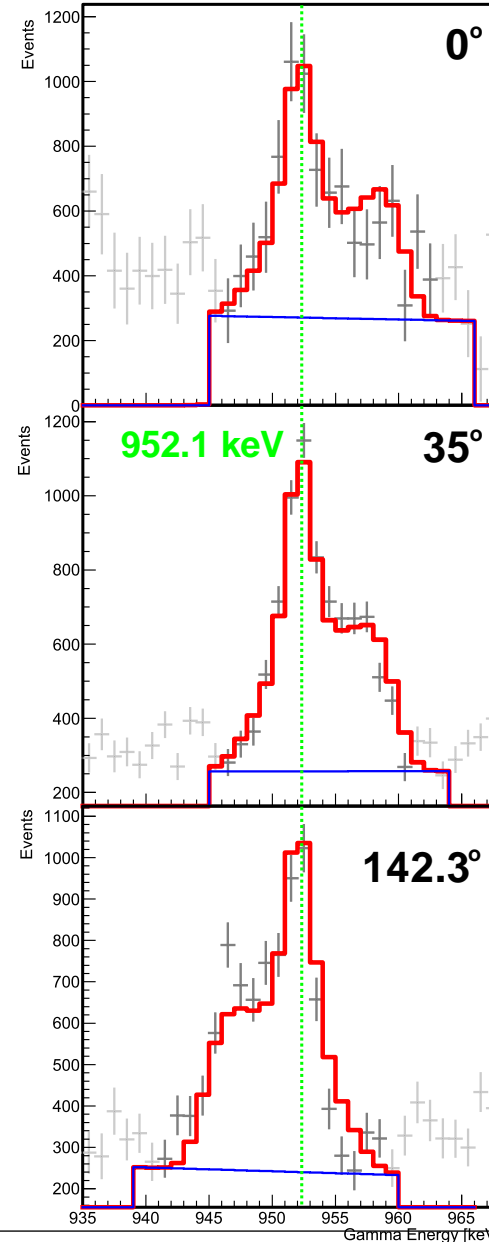
$2^+_3 \rightarrow 2^+_1$

2^+_3 @ 1679 keV

$\tau = 0.74(7)$ ps

$\delta = +0.65(50)$

BR=100(19)/25(8)



Експериментална част – резултати от двата анализа

E_{level} (keV)	J^π	J_{final}^π	E_γ (keV)	I_γ ^a	α ^b	δ ^c	τ (ps) Analysis I	τ (ps) Analysis II	τ (ps) Adopted	Transition strength ^d
1512	2_2^+	0_1^+	1512.7	26(3)			0.73(7)	0.69(6)	0.71(9)	$B(E2) = 29(4)$
		2_1^+	785.4	100(1)	0.0408(2)	0.09(3)				$B(M1) = 0.126(16)$
1679	2_3^+	0_1^+	1679.7	35(8)			0.82(4)	0.74(7)	0.78(8)	$B(E2) = 20(5)$
		2_1^+	952.1	100(19)	0.020(5)	0.65(50)				$B(M1) = 0.042(20)$
										$B(E2) = 290(273)$

^aFrom Ref. [23].

^bTotal electron conversion coefficients. From Ref. [23].

^cFrom Ref. [20].

^d $B(E2)$ values are given in $e^2\text{fm}^4$ (1 W.u. = 75.09 $e^2\text{fm}^4$), and the $B(M1)$ values are given in μ_N^2 . In the calculations for the transitions strengths we have assumed vanishing α -decay branches.

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Ниско спинови състояния с положителна четност в ядрото на Po-212

Single-shell approximation + empirical interaction from neighboring nuclei (P. Van Isacker)

$$^{212}\text{Po}: \quad ^{208}\text{Pb} + \nu(2g_{9/2})^2 + \pi(1h_{9/2})^2$$

$$\text{Basis states: } |(2g_{9/2})^2 J_\nu, (1h_{9/2})^2 J_\pi; J\rangle \equiv |J_\nu J_\pi J\rangle$$

$$\langle J_\nu J_\pi J | \hat{H} | J'_\nu J'_\pi J \rangle = (V_{\nu\nu}^{J_\nu} + V_{\pi\pi}^{J_\pi}) \delta_{J_\nu J'_\nu} \delta_{J_\pi J'_\pi} + 4 \sqrt{(2J_\nu + 1)(2J_\pi + 1)(2J'_\nu + 1)(2J'_\pi + 1)} \sum_R \begin{bmatrix} j_\nu & j_\pi & J_\pi & J_\nu \\ R & j_\pi & J & j_\nu \\ j_\nu & j_\pi & J'_\pi & J'_\nu \end{bmatrix} V_{\nu\pi}^R$$

$V_{\nu\nu}^{J_\nu}$: from the experimental spectrum ($0^+ - 8^+$) of ^{210}Pb (2ν in $2g_{9/2}$) } seniority spectra

$V_{\pi\pi}^{J_\pi}$: from the experimental spectrum ($0^+ - 8^+$) of ^{210}Po (2π in $1h_{9/2}$) }

$V_{\nu\pi}^R$: from the experimental spectrum ($0^- - 9^-$) of ^{210}Bi

M1 operator:

$$\hat{T}_\mu(M1) = \sqrt{\frac{3}{4\pi}} \sqrt{\frac{j(j+1)(2j+1)}{3}} [g_\nu (\nu_j^\dagger \times \tilde{\nu}_j)_\mu^{(1)} + g_\pi (\pi_j^\dagger \times \pi_j)_\mu^{(1)}]$$

$$j = j_\nu = j_\pi = 9/2 \quad \left\{ \begin{array}{l} g_\nu = -0.33\mu_N \\ g_\pi = +0.91\mu_N \end{array} \right. \left\{ \begin{array}{l} ^{209}\text{Pb}: \mu(9/2_{1,\text{gs}}^+) = -1.4735(16)\mu_N \\ ^{209}\text{Bi}: \mu(9/2^-, 1, \text{gs}) = +4.1103(5)\mu_N \end{array} \right.$$

E2 operator:

$$\hat{T}_\mu(E2) = -\sqrt{\frac{(2j-1)(2j+1)(2j+3)}{64\pi j(j+1)}} (N + \frac{3}{2}) b^2 [e_\nu (\nu_j^\dagger \times \tilde{\nu}_j)_\mu^{(2)} + e_\pi (\pi_j^\dagger \times \pi_j)_\mu^{(2)}]$$

$$b \approx 1.0A^{1/6} \text{ fm} \quad \left\{ \begin{array}{l} e_\nu = 0.88 \\ e_\pi = 1.11 \end{array} \right. \left\{ \begin{array}{l} B(E2; 8^+ \rightarrow 6^+) \\ \text{in } ^{210}\text{Pb and } ^{210}\text{Po} \end{array} \right.$$

Изовекторно състояние в ^{212}Po

$$\begin{aligned} |2_1^+\rangle &= 0.488 |J_\nu = 0, J_\pi = 2, J = 2\rangle + 0.819 |J_\nu = 2, J_\pi = 0, J = 2\rangle + \dots & 87\% \\ |2_2^+\rangle &= 0.813 |J_\nu = 0, J_\pi = 2, J = 2\rangle - 0.517 |J_\nu = 2, J_\pi = 0, J = 2\rangle + \dots & 93\% \end{aligned}$$

- Почти ортогонални състояния;
- Състои се от протонни и неутронно $S (J_{\nu(\pi)}=0)$ и $D (J_{\nu(\pi)}=2)$ двойки;
- 2_2^+ състояние има изовекторна природа;



Идентифицирано беше първото ниско лежащо изовекторно състояние в областта около двойно-магичното ядро Рь-208.

Благодаря за вниманието!



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