

# Измерване на времена на живот в ядрата

$^{208}\text{Po}$  и  $^{209}\text{Po}$

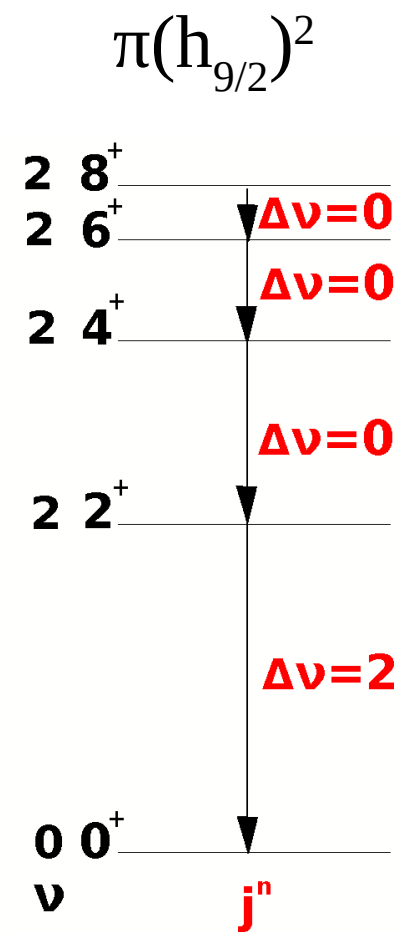
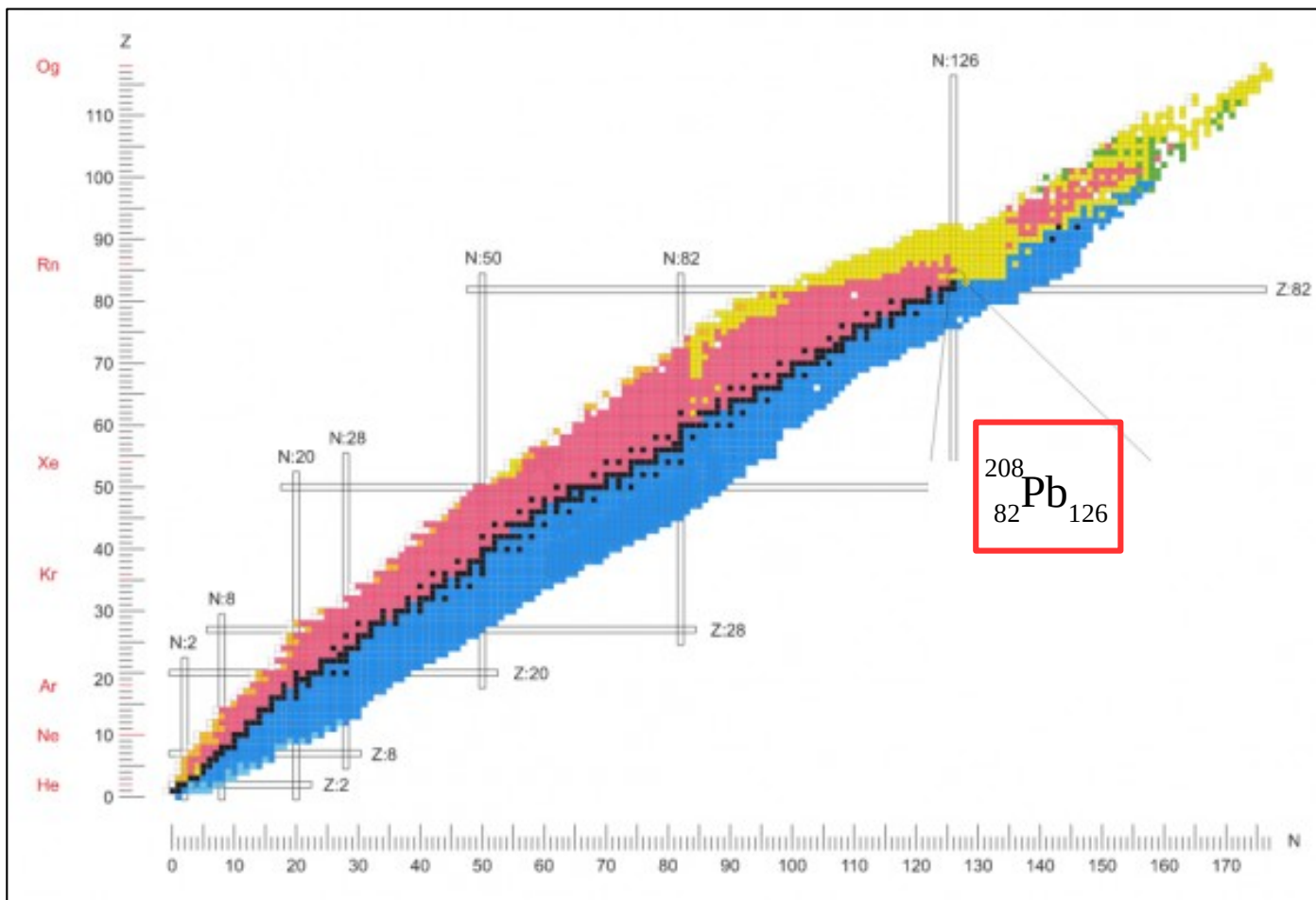


Атестационен семинар

Докторант : Милена Стоянова

Научен ръководител : проф. дфзн. Г. Райновски

# Мотивация

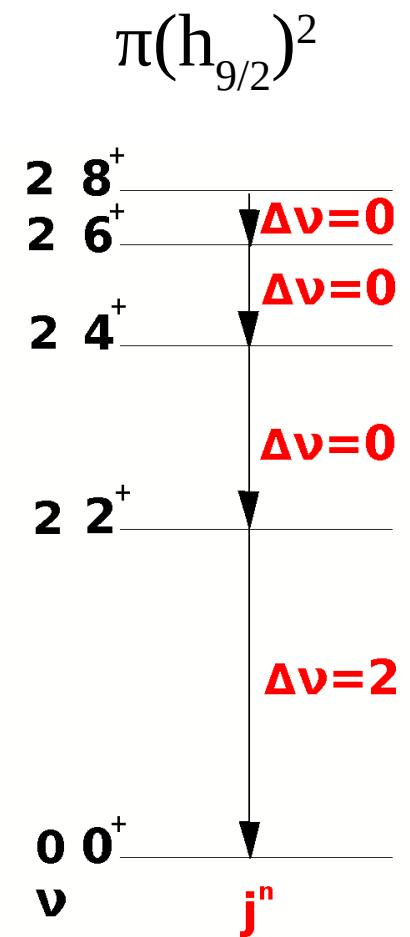


<b>Po204</b> 3.53 h 884.0, 270.1, 1016.3, 5.377 eV E 2.33	<b>Po205</b> 5i- 1.7 h 872.4, 1001.2, 849.8, 836.8, 0.22 eV E 3.55	<b>Po206</b> 8.8 d 1082.3, 511.3, 286.4, 807.4, 5.223 E 1.65	<b>Po207</b> 5i- 2.8 s, 5.80 h IT 268.1 814.5D, 300.5D E 2.91	<b>Po208</b> 2.898 a 5.115 291.8 v, 570.1, 601.5 E 2.91	<b>Po209</b> 1i- 102 a 4.300 260.5, 262.8 886.1 m 208.982430	<b>Po210</b> RaE, 138.38 d 5.3044 603.1 v (< 0.5 mb + 0.03) T <sub>1/2</sub> < 2 mb 209.982874	<b>Po211</b> 9i+ 25.2 s 7.27 8.85 569.2D, 1963.1D 210.988653	<b>Po212</b> ThC 45 s 11.65, 2034.4, 583.0 IT -36 E 2.98
<b>Bi203</b> 9i- 11.8 h j <sup>π</sup> 1.35(ω), 0.74 820.3, 829.2D, 897, 1847, α -4.85? v, 3.25	<b>Bi204</b> 8i+ 11.2 h 889.2D, 374.8D, 884.0, β <sup>+</sup> α E 4.44	<b>Bi205</b> 5i- 15.31 d j <sup>π</sup> 0.98 a 1764.3, 703.5, 987.6D, E 2.71	<b>Bi206</b> 0i+ 6.243 d j <sup>π</sup> 0.95 v 803.1, 881.0, 516.2, E 3.78	<b>Bi207</b> 9i- 32 a j <sup>π</sup> α 569.7, 1083.7D, E 2.397	<b>Bi208</b> (5i+) 3.60E5 a j <sup>π</sup> α E 2.678	<b>Bi209</b> 9i- 100 j <sup>π</sup> α 10 mb ± 18 mb, 0.18 α <sub>0</sub> < 0.3 μb 208.980389	<b>Bi210</b> 3.0E6 d j <sup>π</sup> α 4.340 4.340 285.2 305.2, 0.05, 0.2 E 1.161	<b>Bi211</b> 9i- 2.14 m RaE, AcC j <sup>π</sup> α 6.623, 6.279 351.1 β <sup>-</sup> α 210.98727
<b>Pb202</b> 3.54 h IT 787.0, 900.7, 422.1, 490.5, 459.7, E 0.05	<b>Pb203</b> 5i- 5.3E4 a 6.2 s, 2.164 d IT 825.2 820.3 279.2 E 0.97	<b>Pb204</b> 1.12 h, 1.4 IT 911.7, 899.2, 374.8, α <sub>0</sub> 0.70, 2.0 203.973044	<b>Pb205</b> 5i- 1.5E7 a j <sup>π</sup> α 4.5 E 0.0505	<b>Pb206</b> 24.1 RaG α <sub>0</sub> 0.027, 0.10 206.974466	<b>Pb207</b> 1i- 0.80 s, 22.1 IT 1063.7 569.7 AcD α <sub>0</sub> 0.70, 0.36 206.975897	<b>Pb208</b> ThD, 52.4 j <sup>π</sup> α 0.23 mb, 2.0 mb α <sub>0</sub> 8 μb 207.976852	<b>Pb209</b> 8i+ 3.25 h j <sup>π</sup> α 0.645 E 0.644	<b>Pb210</b> RaD, 22.3 a j <sup>π</sup> α 0.017, 0.061 46.5 e 3.72 v, 0.5 E 0.0635

D. Kocheva *et al*,  
*Eur.Phys.J.*  
**A 53**, 175 (2017)

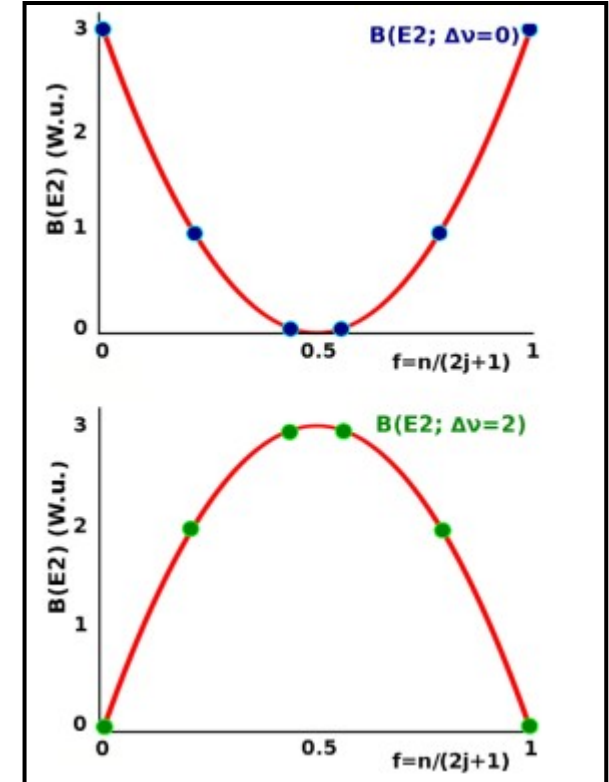
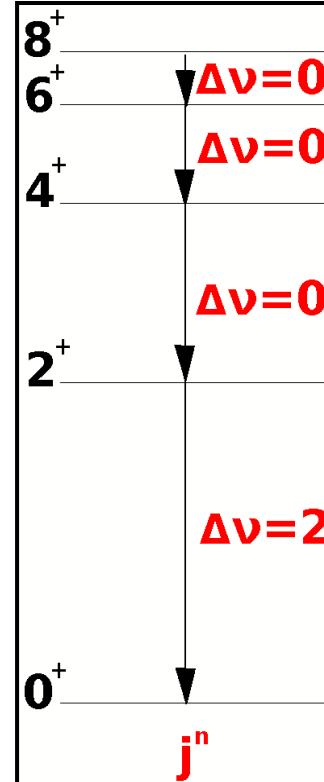
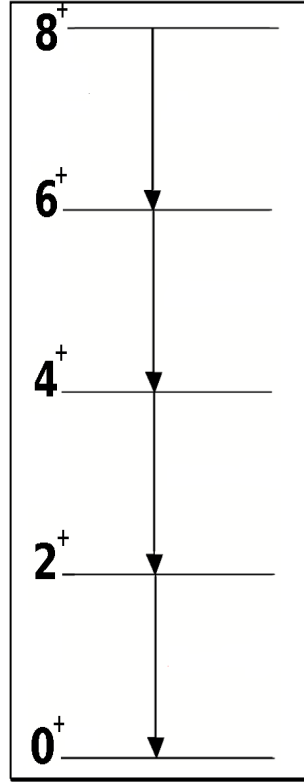
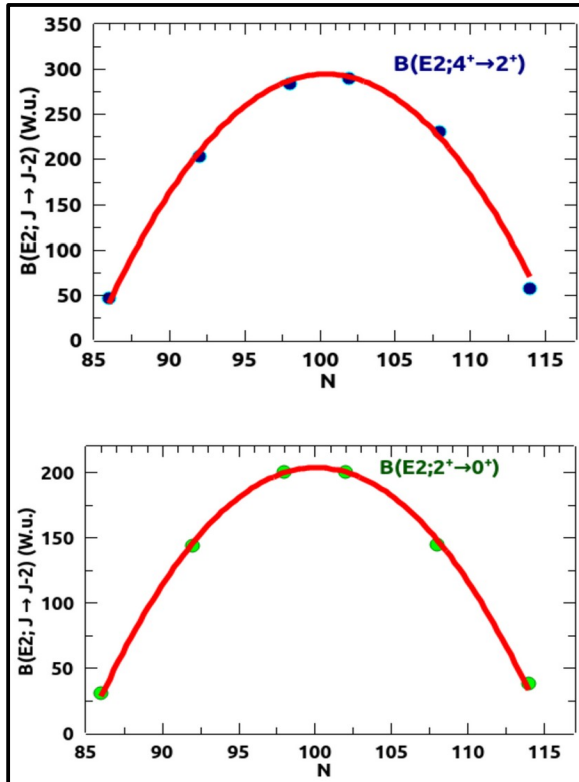
D. Kocheva *et al*,  
*Phys.Rev. C* **96**,  
044305 (2017)

M. Stoyanova *et al*,  
*Phys.Rev. C* **100**,  
064304 (2019)



# Мотивация

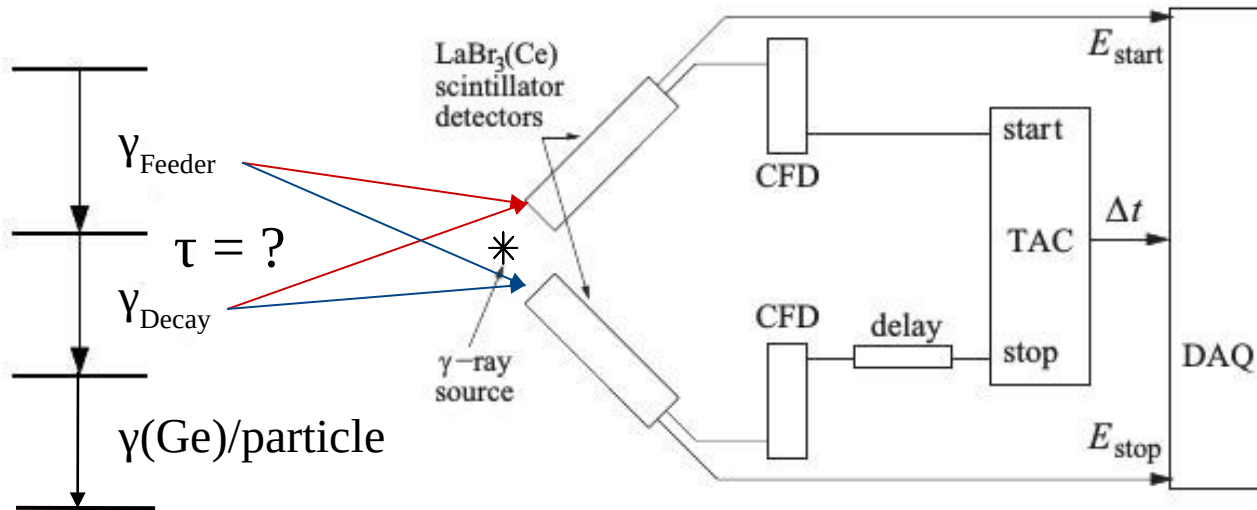
$$\pi(h_{9/2})^2$$



# Generalized Centroid Difference Method

J.- M. Régis,  
NIM Phys.  
Res. **A 726**,  
191 (2013)

J.-M. Régis,  
Phys. Rev.  
C  
**95**,054319  
(2017)



Sorting  
code

$$C^D = \langle t \rangle = \frac{\int t D(t) dt}{\int D(t) dt}$$

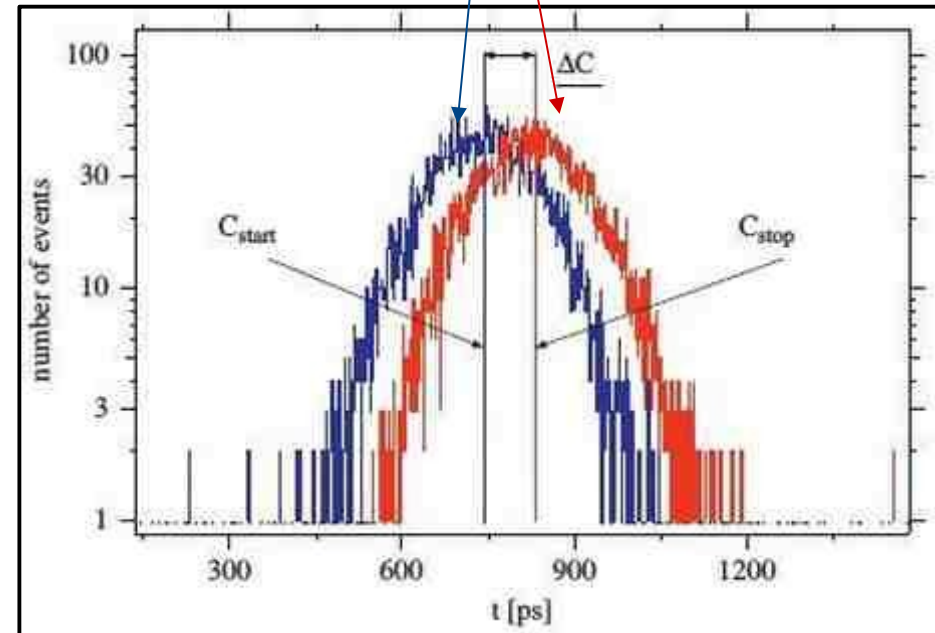
Experimental Centroid Difference :

$$\Delta C_{\text{exp}}(E_{\text{Feeder}}, E_{\text{Decay}}) = C_{\text{start}} - C_{\text{stop}}$$

$$\Delta C_{\text{FEP}} = \Delta C_{\text{exp}} + \frac{1}{2} \left[ \left( \frac{\Delta C_{\text{exp}} - \Delta C_{\text{BG}}}{p/b} \right)_{\text{feeder}} + \left( \frac{\Delta C_{\text{exp}} - \Delta C_{\text{BG}}}{p/b} \right)_{\text{decay}} \right]$$

$$\Delta C_{\text{FEP}}(E_{\text{Feeder}}, E_{\text{Decay}}) = \text{PRD}(E_{\text{Feeder}}, E_{\text{Decay}}) + 2\tau$$

$$\tau = \frac{1}{2} (\Delta C_{\text{FEP}} - \text{PRD})$$



# Експерименти

$^{208}\text{Po}$

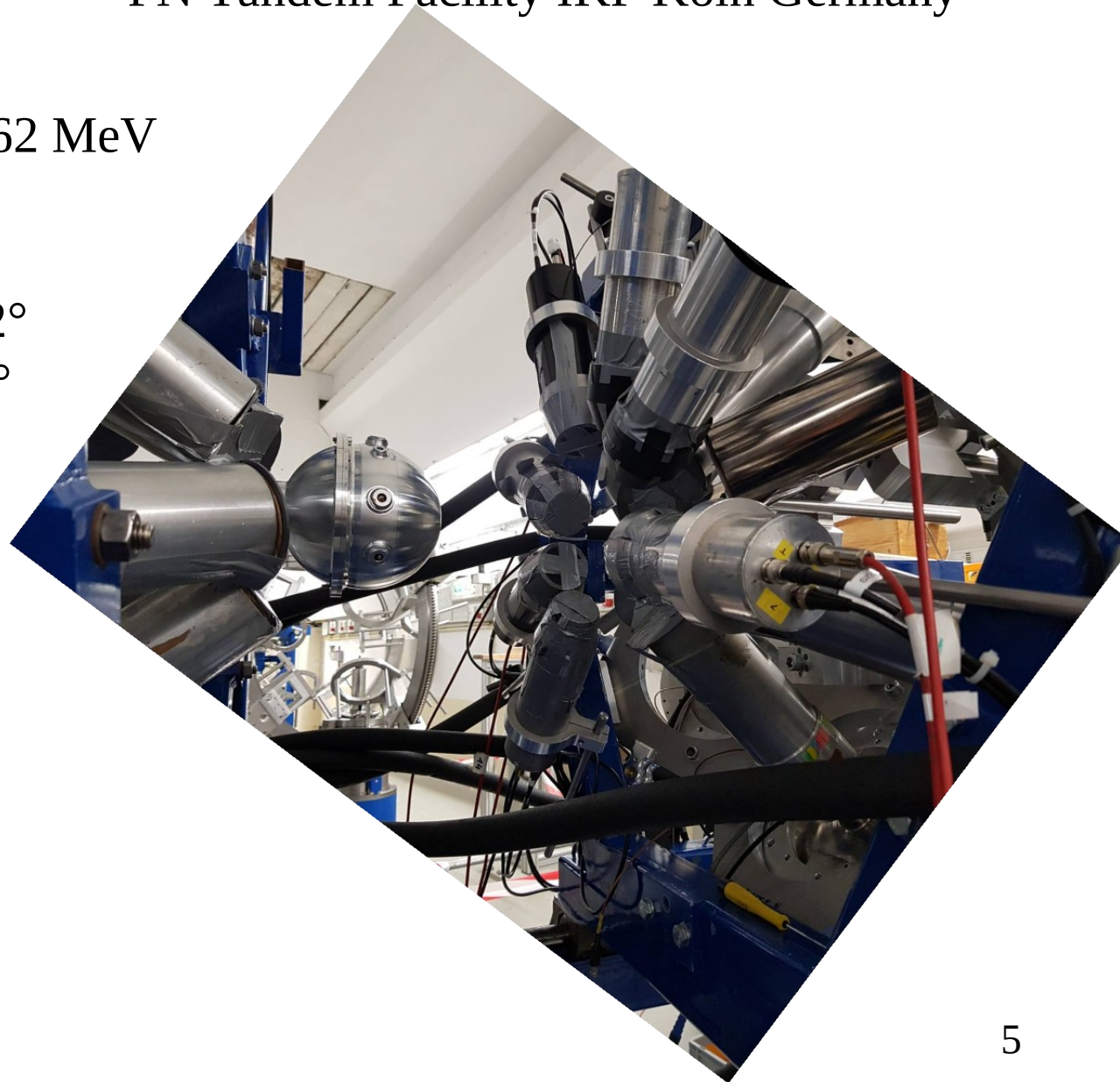
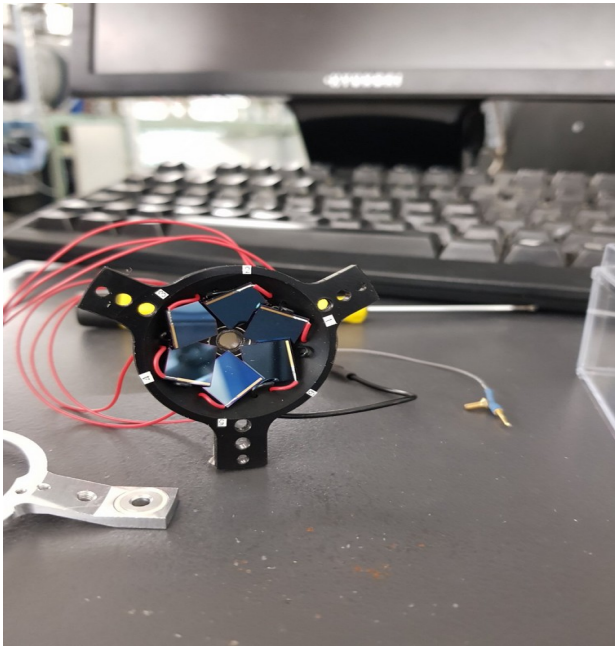
FN Tandem Facility IKP Köln Germany

Reaction :  $^{204}\text{Pb}(^{12}\text{C}, ^8\text{Be})^{208}\text{Po}$  at 62 MeV

Target : 23 mg/cm<sup>2</sup>

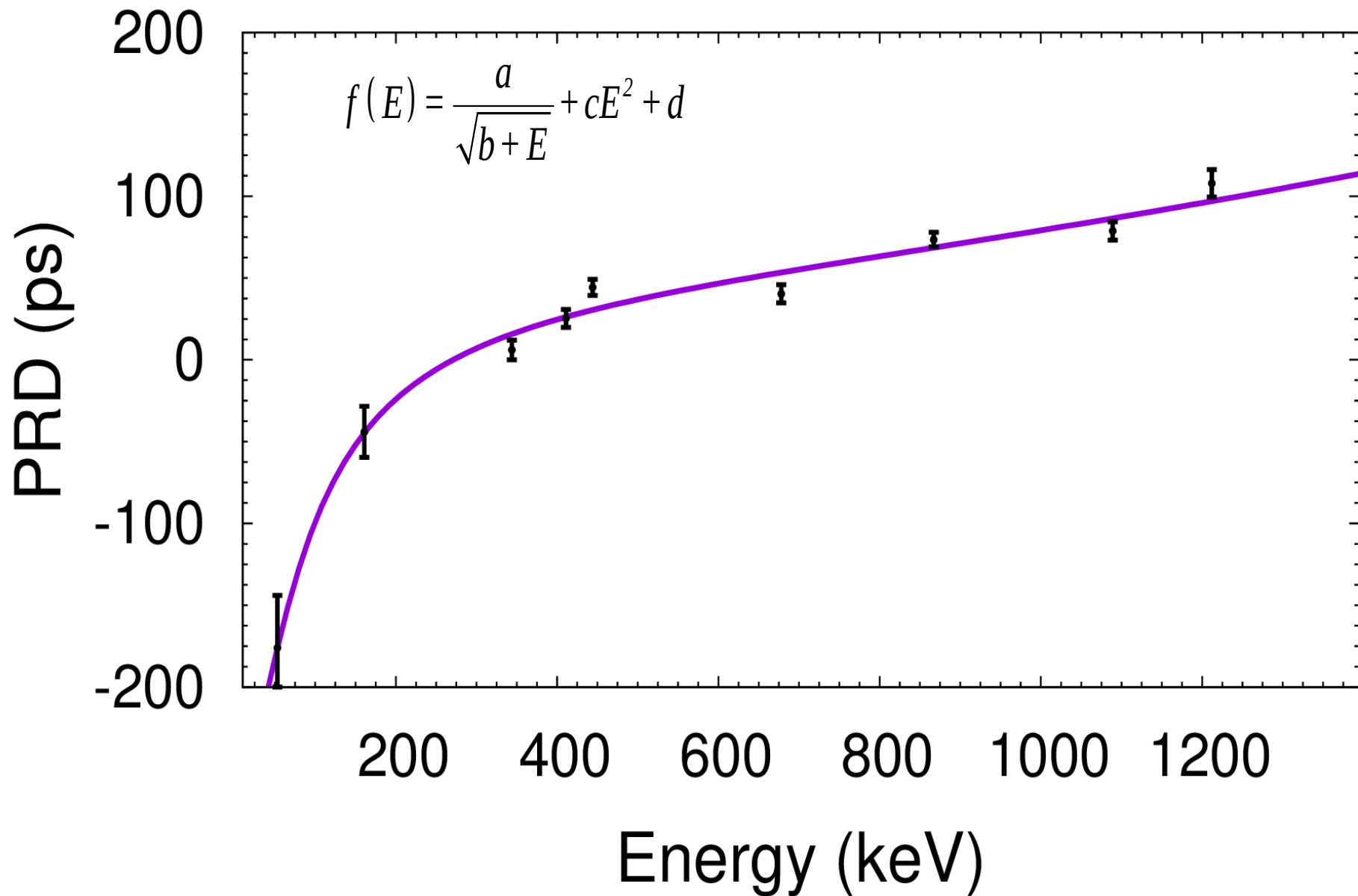
Al foil 80 μm

- 6 HpGe at 45° и 5 HpGe at 142°
- 6 solar cells between 117°- 167°
- 7 LaBr<sub>3</sub>(Ce) at 90°

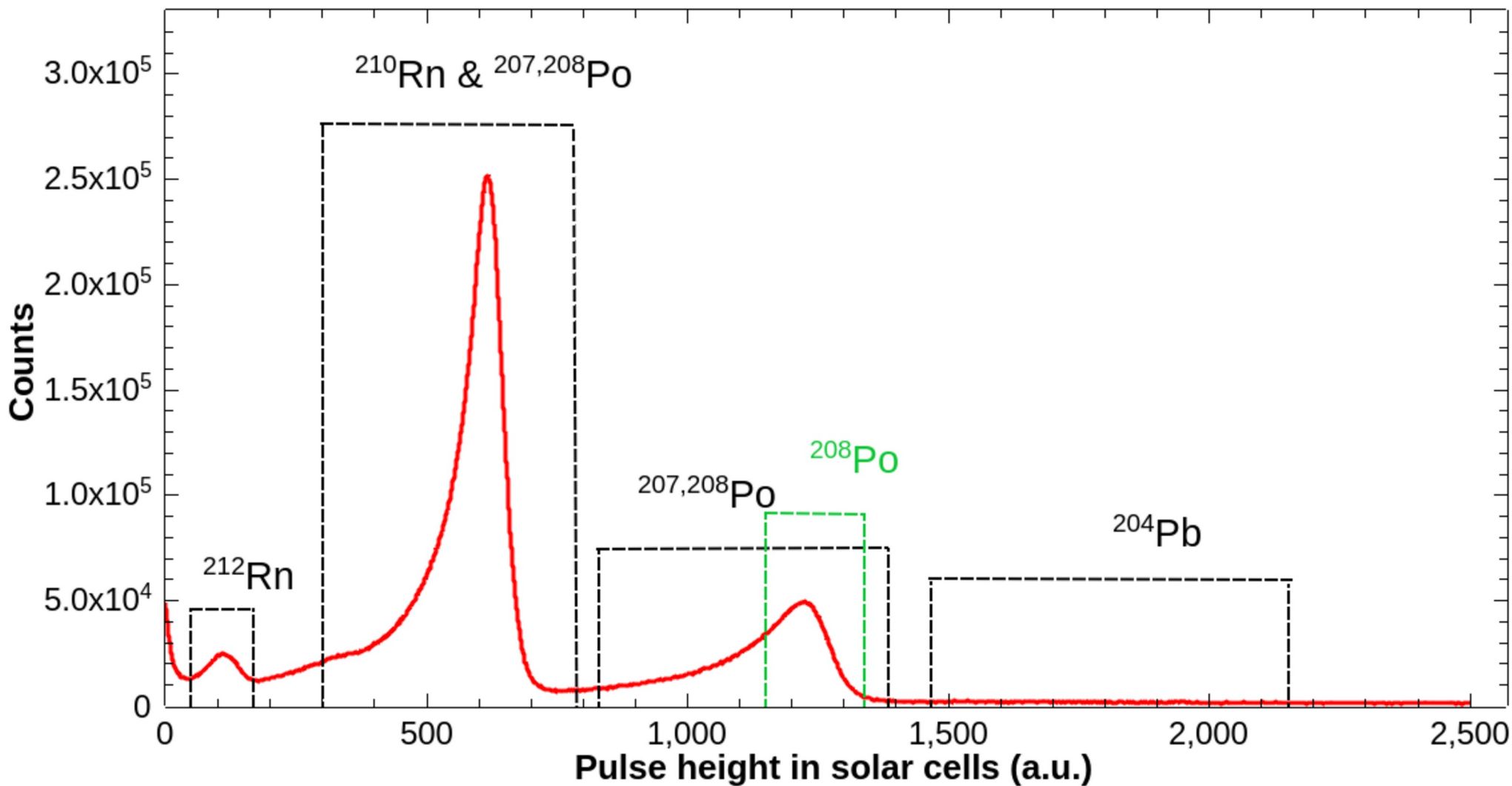


# Результати $^{208}\text{Po}$

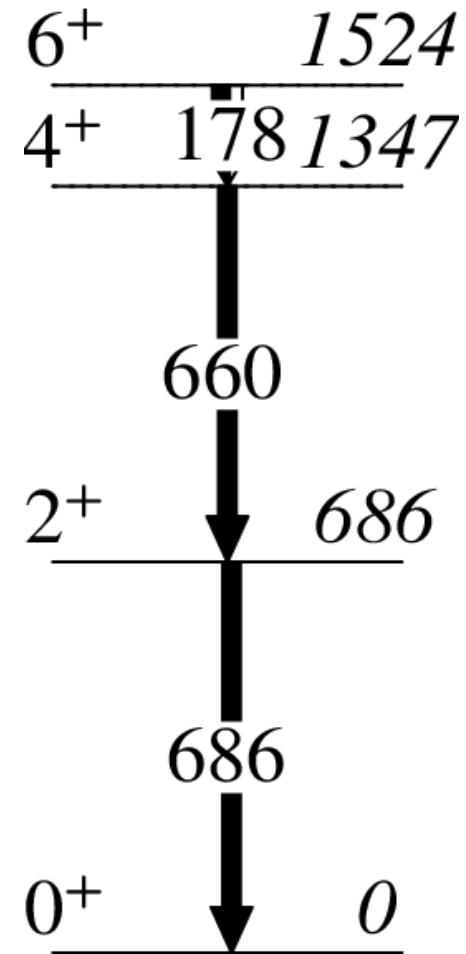
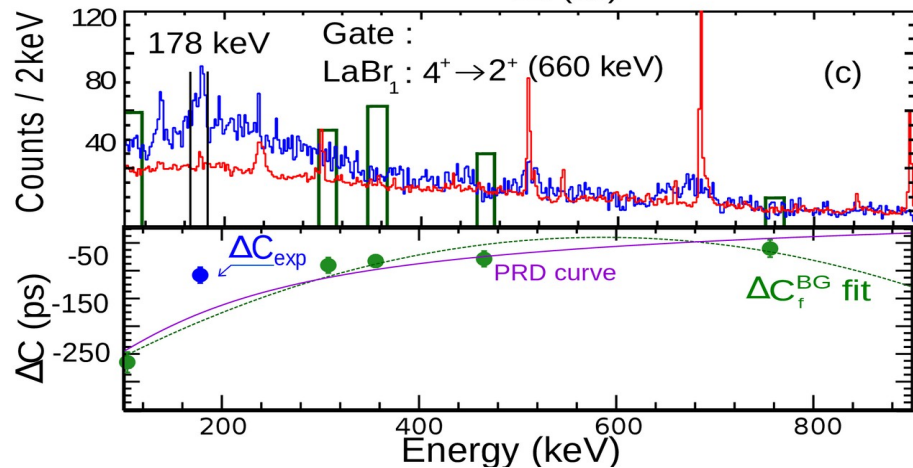
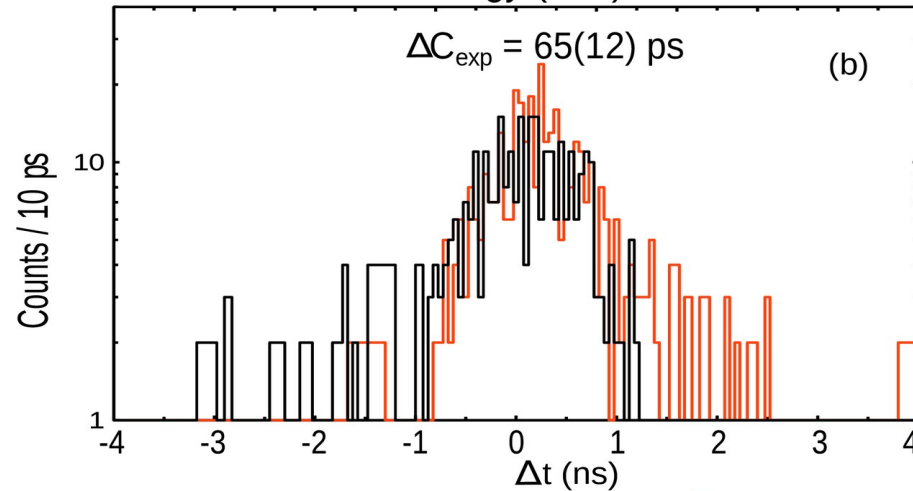
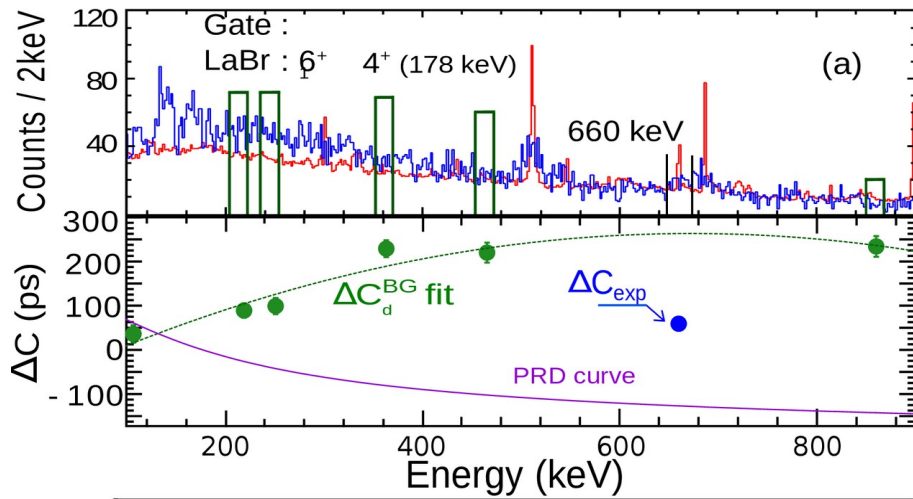
$$\text{PRD}(E_{\text{Feeder}}, E_{\text{Decay}}) = \Delta C(E_{\text{Feeder}}, E_{\text{Decay}}) - 2\tau$$



# Результати $^{208}\text{Po}$







$\tau(4^+, {}^{208}\text{Po}) = 125(31)$  ps

**Нов результат**

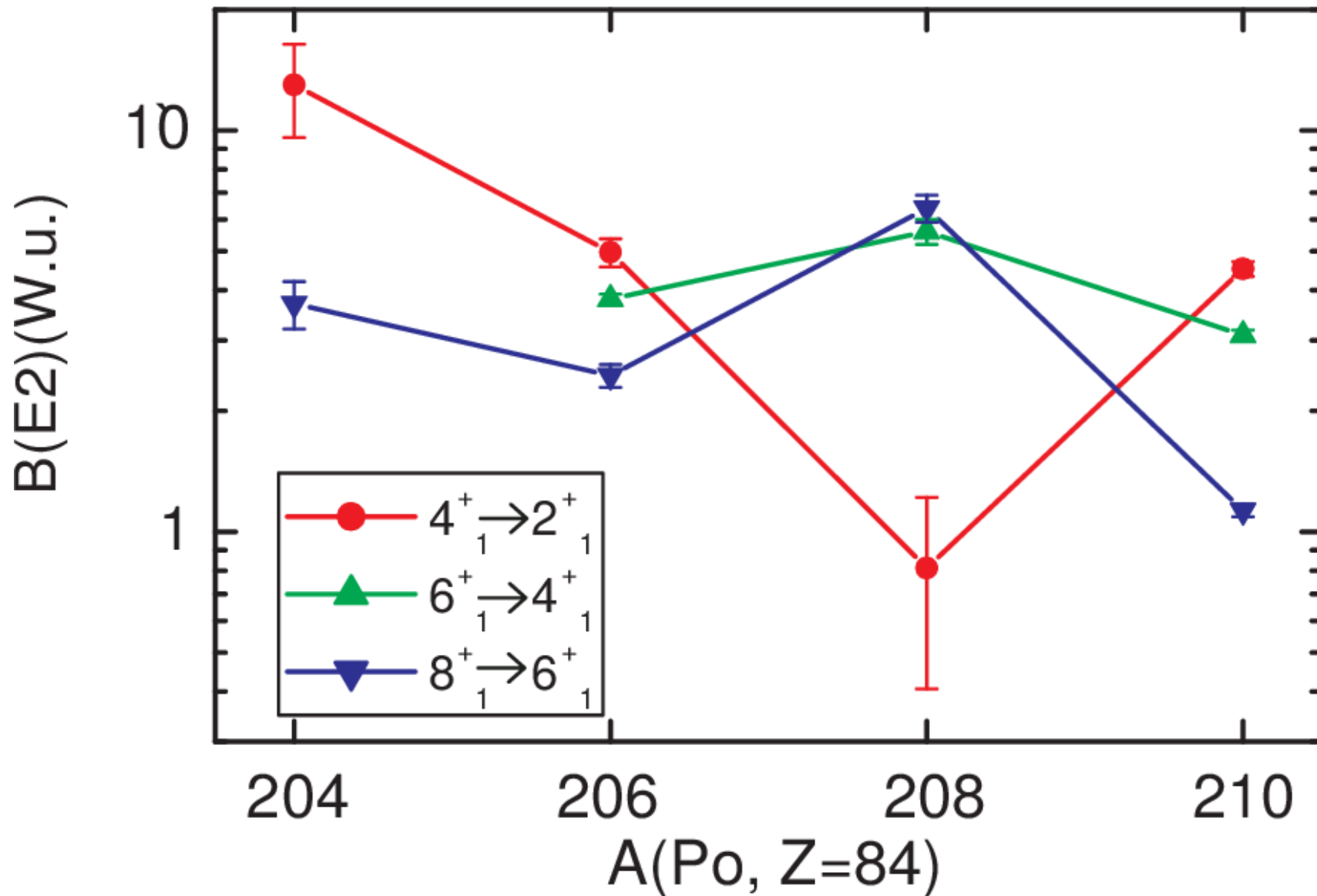
# Резултати $^{208}\text{Po}$

Nucleus	$J_i^\pi$	$J_f^\pi$	$E_\gamma$ (keV)	$\alpha$	$I_\gamma$ %	$\tau$ (ps)	$B(E2)$ (W.u.)
$^{204}\text{Po}$	$4_1^+$	$2_1^+$	516	0.0297	100	23(6)	13(3)
$^{206}\text{Po}$	$4_1^+$	$2_1^+$	477	0.0359	100	89(7)	5.0(4)
$^{208}\text{Po}$	$4_1^+$	$2_1^+$	660	0.0173	100	125(31)	0.7(2)

M. Stoyanova et al.,  
Phys.Rev. C **100**,  
064304 (2019)

M. Stoyanova et al.,  
J. Phys.: Conf. Ser.  
**1555**, 012019 (2020)

# Результати $^{208}\text{Po}$



# Експерименти

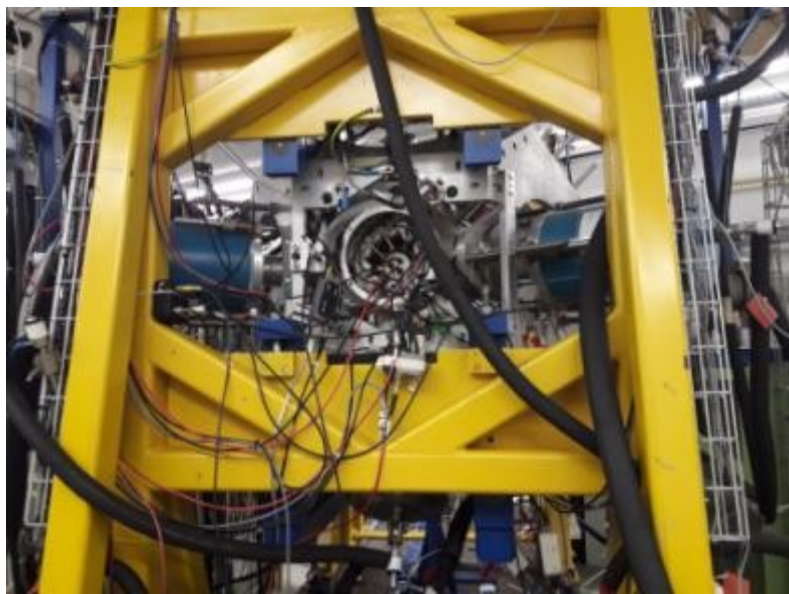
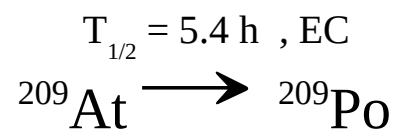
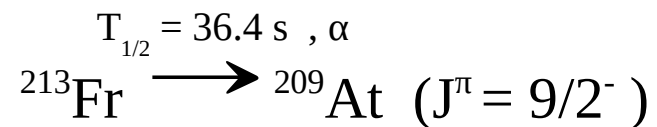
$^{209}\text{Po}$

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Reaction :  $^{206}\text{Pb}(^{11}\text{B},4n)^{213}\text{Fr}$  at 56 MeV

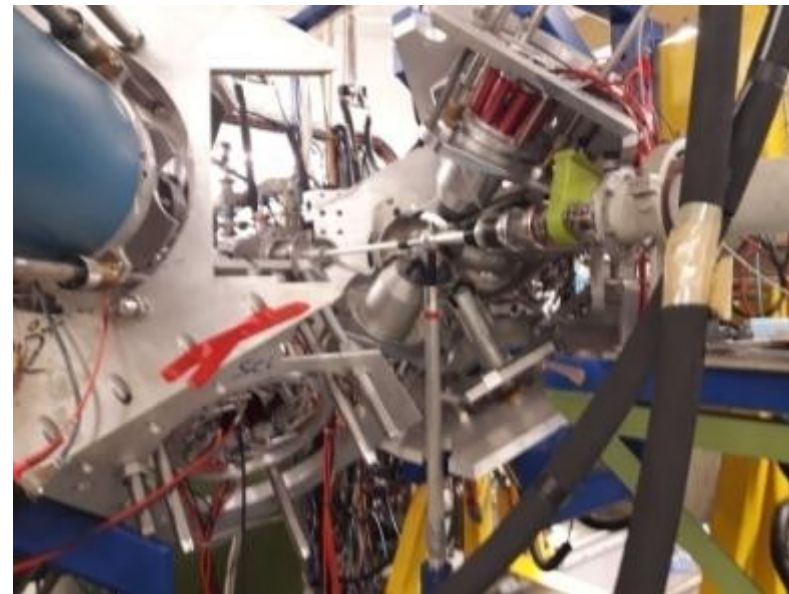
Target : 14.5 mg/cm<sup>2</sup>

Backing : 130 mg/cm<sup>2</sup> Au



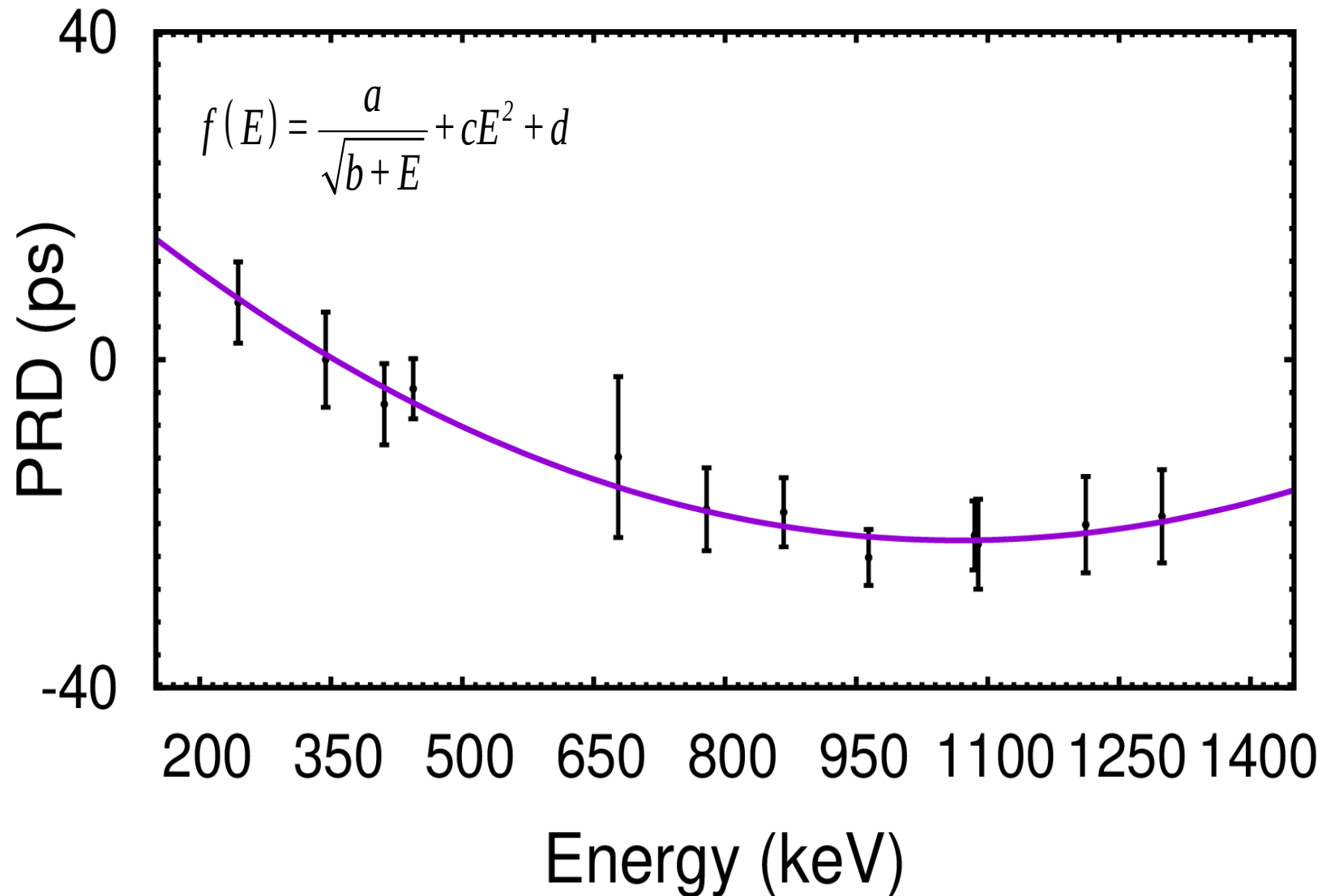
8 HpGe detectors

12 LaBr<sub>3</sub>(Ce)

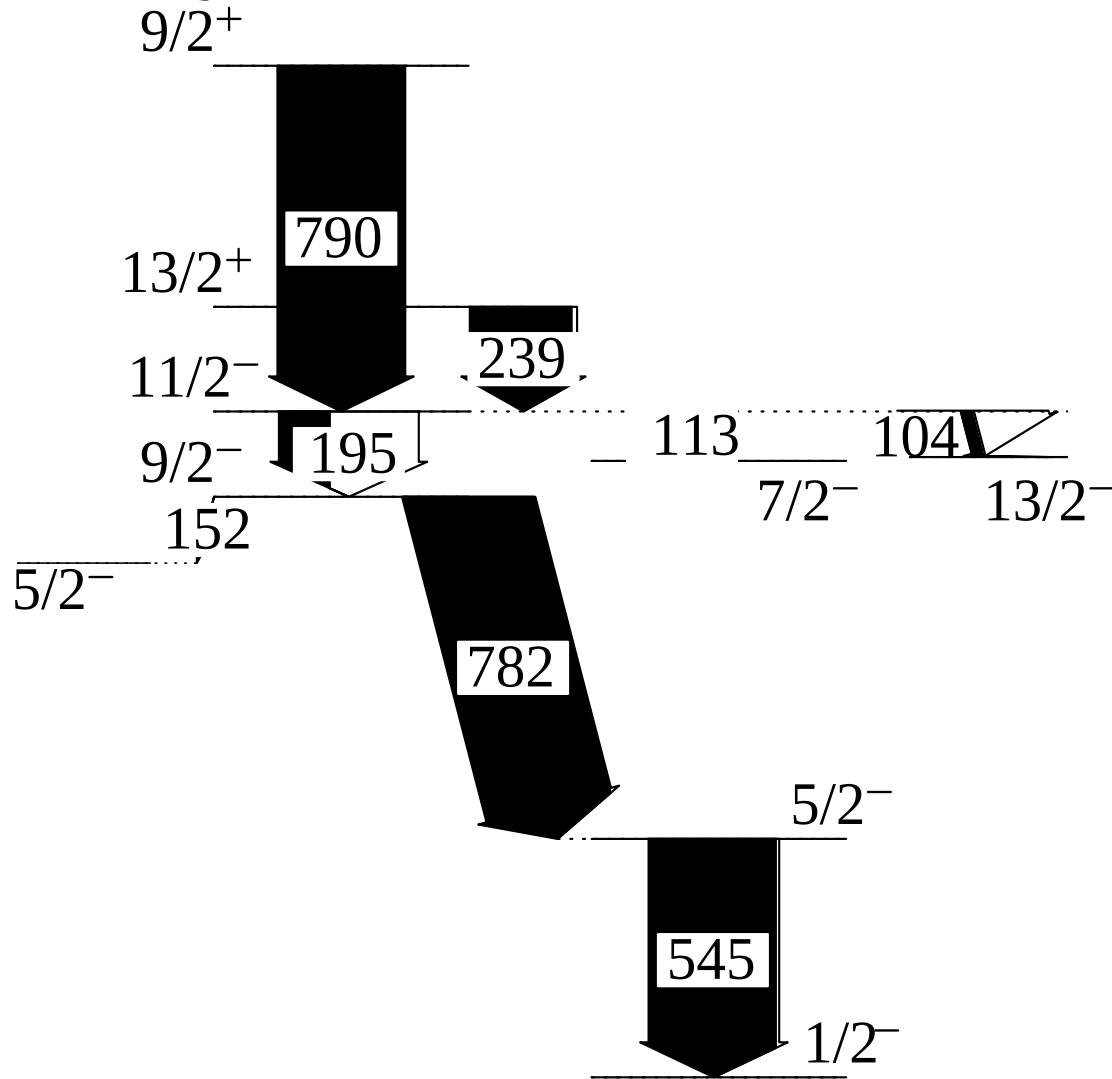


# Результати $^{209}\text{Po}$

$$\text{PRD}(E_{\text{Feeder}}, E_{\text{Decay}}) = \Delta C(E_{\text{Feeder}}, E_{\text{Decay}}) - 2\tau$$

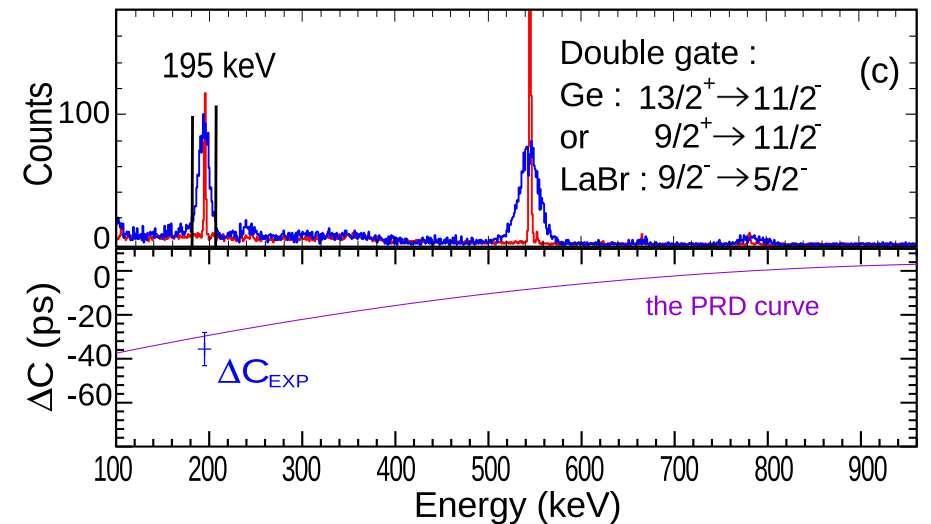
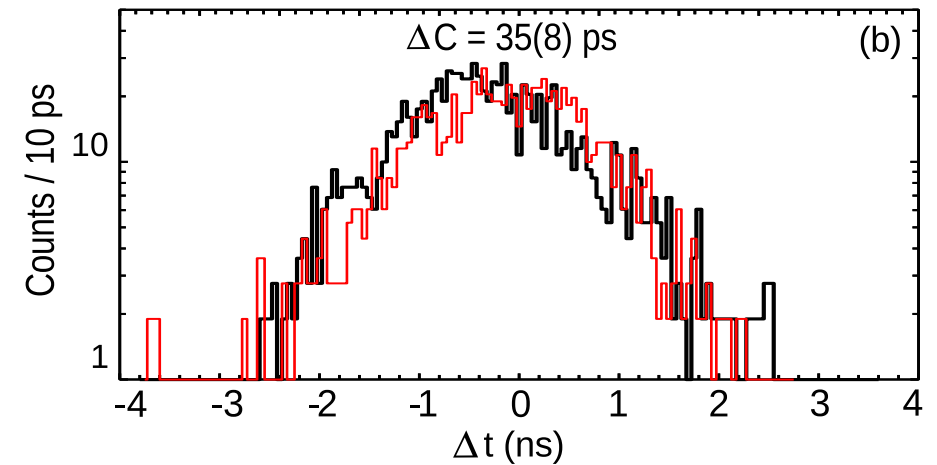
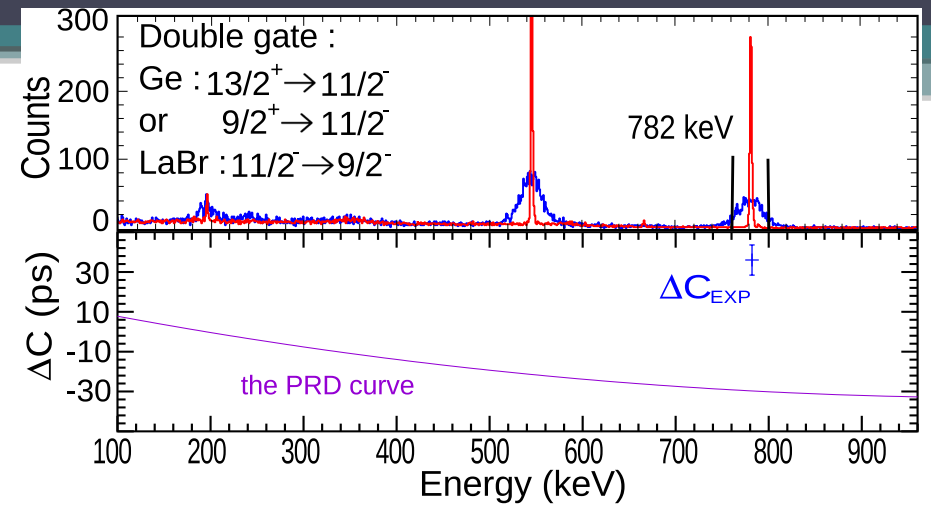


# Результати $^{209}\text{Po}$



$\tau(9/2^-) = 30(6) \text{ ps}$

**Нов результат**



# Результати $^{209}\text{Po}$

1 W.u. = 73.67 e<sup>2</sup>fm<sup>4</sup>

$E_{\text{level}}$ (keV)	$J^{\pi}_i$	$J^{\pi}_f$	$E_{\gamma}$ (keV)	$\alpha$	$I_{\gamma}$ %	$\tau$ (ps)	$B(E2)$ (e <sup>2</sup> fm <sup>4</sup> )
<b>1327</b>	$9/2^-_1$	$5/2^-_1$	782	0.0120	100(3)	<b>30(6)</b>	<b>92(19)</b>
		$5/2^-_2$	151.4	1.319	0.097(28)		<b>327(89)</b>

$$E_{2^+}({}^{210}\text{Po}) \simeq \text{C.G.}({}^{209}\text{Po}) = \frac{\sum E_{\text{level}}(2J+1)}{\sum (2J+1)} \quad J=(1/2, \dots, 9/2)$$

$\parallel$   $\parallel$   $\parallel$   $\parallel$   $\parallel$   $\parallel$   $\parallel$   $\parallel$

1181 keV      vs.      1258 keV

$$\pi(h_{9/2})^{+2} \otimes \nu(2f_{5/2})^{-1}$$

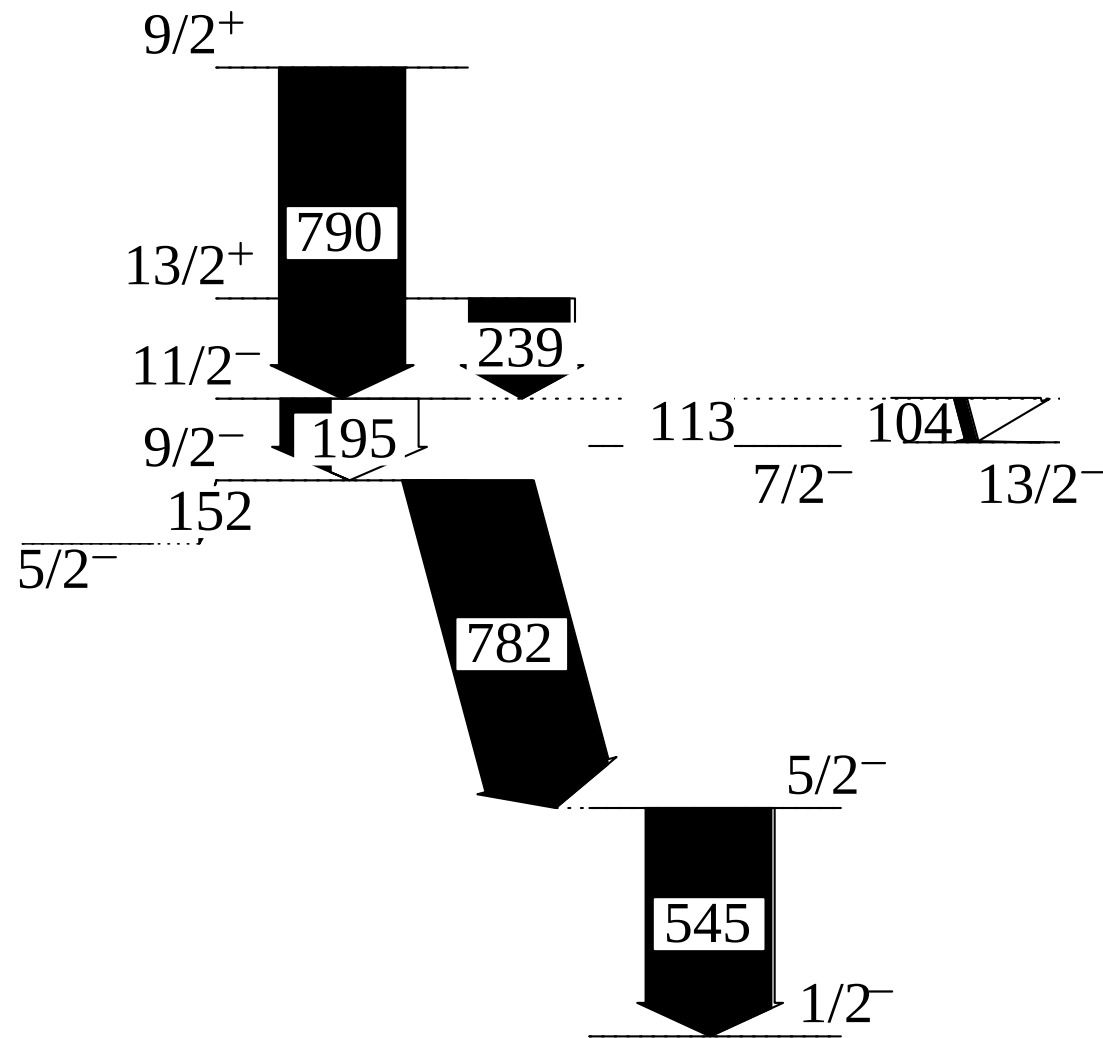
$$2^+ \otimes (2f_{5/2}^{-1})$$

$$B(E2; 2^+_1 \rightarrow 0^+_1) {}^{210}\text{Po} \simeq B(E2; 9/2^-_1 \rightarrow 5/2^-_1) {}^{209}\text{Po}$$

$\parallel$   $\parallel$

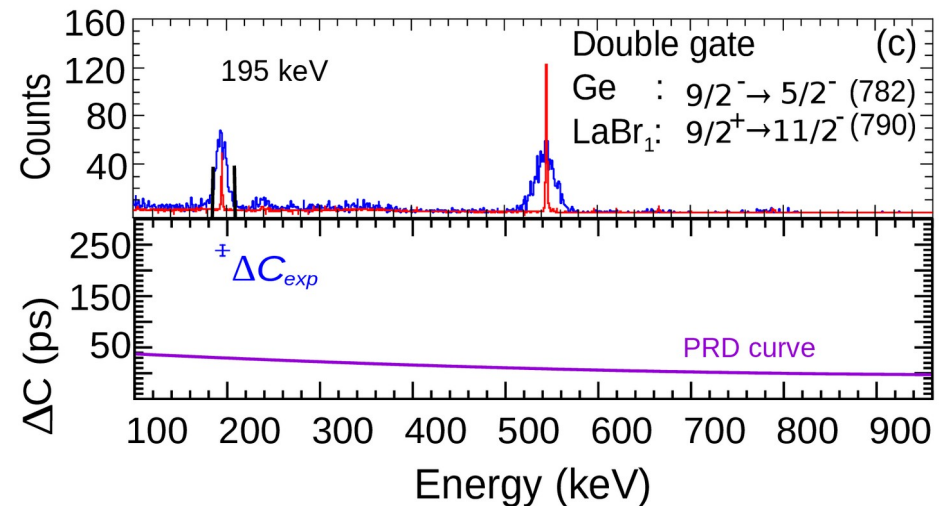
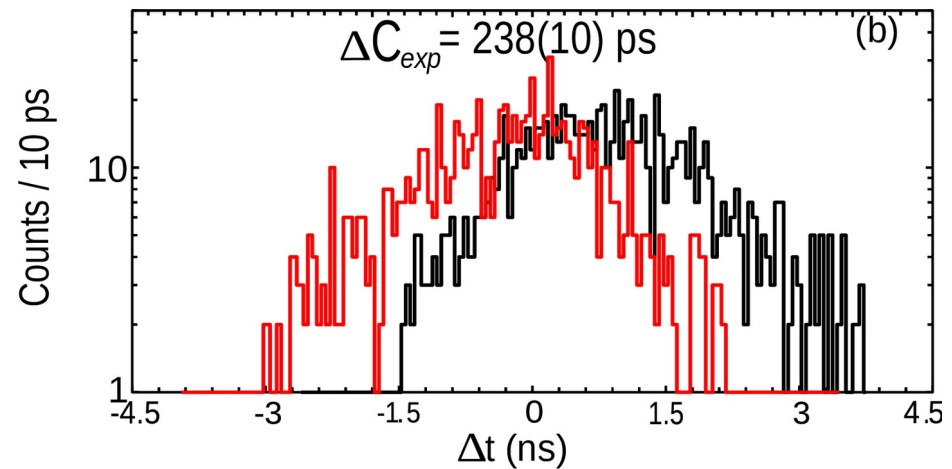
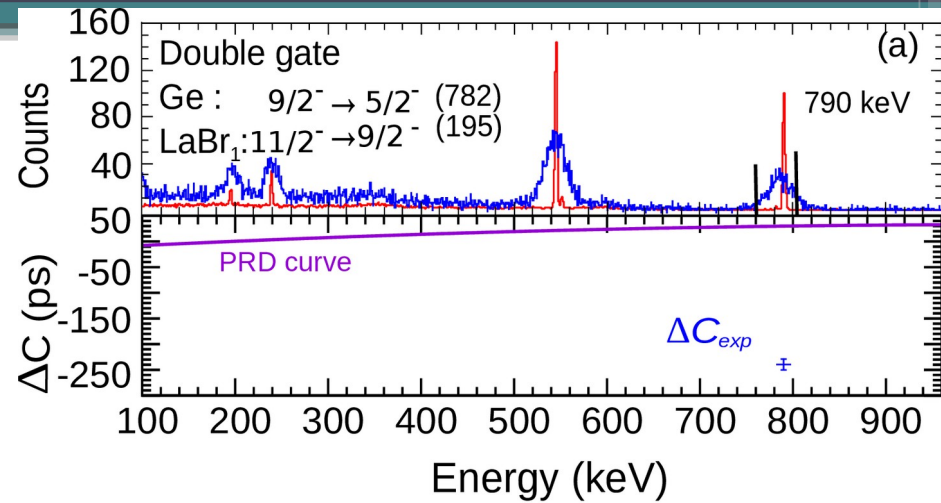
**136(21) e<sup>2</sup>fm<sup>4</sup>**      vs.      **92(19) e<sup>2</sup>fm<sup>4</sup>**

# Результати $^{209}\text{Po}$



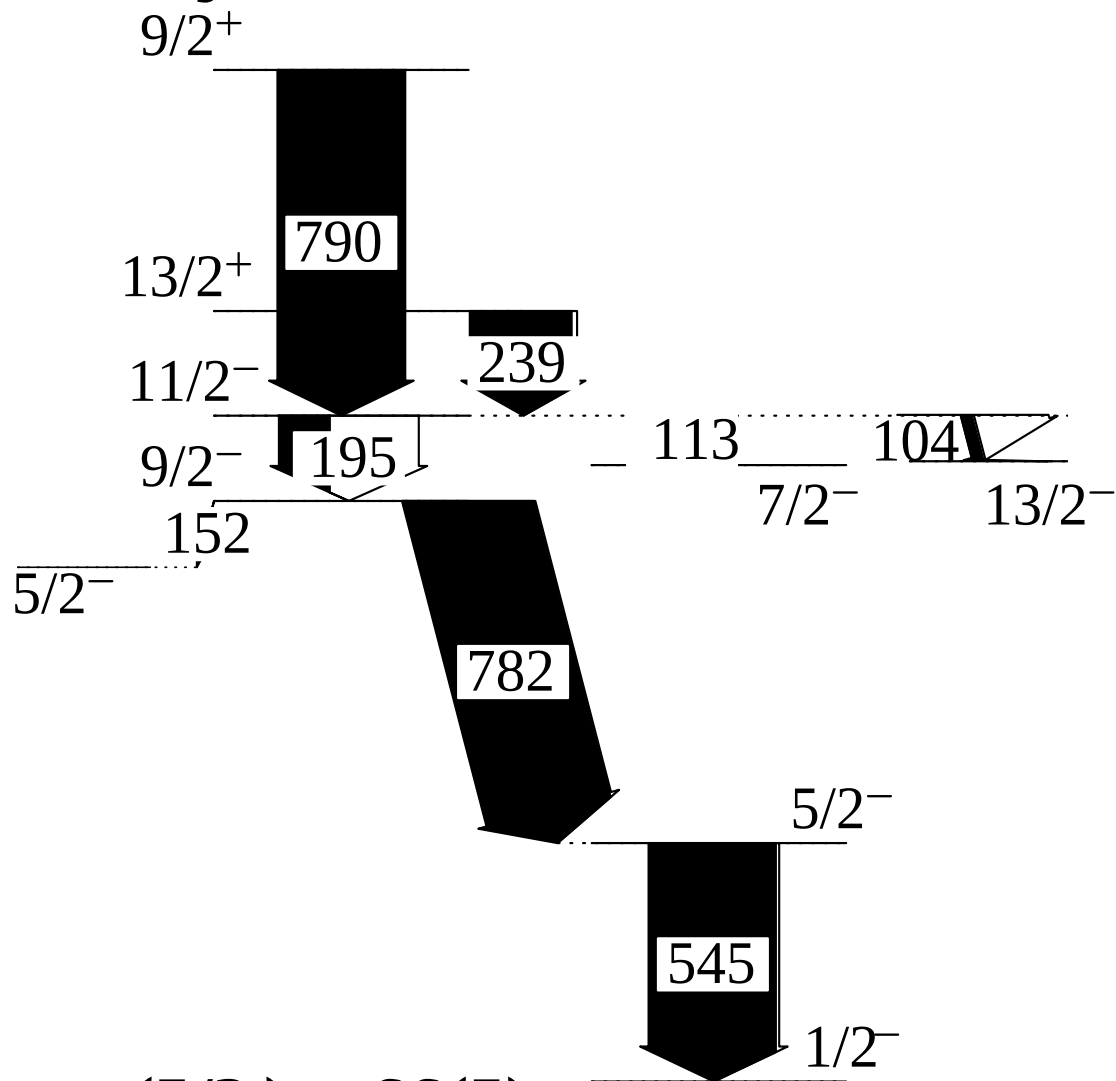
$$\tau_{\text{exp}}(11/2^-) = 105(6) \text{ ps}$$

$$\tau_{\text{lit}}(11/2^-) = 101(29) \text{ ps}$$



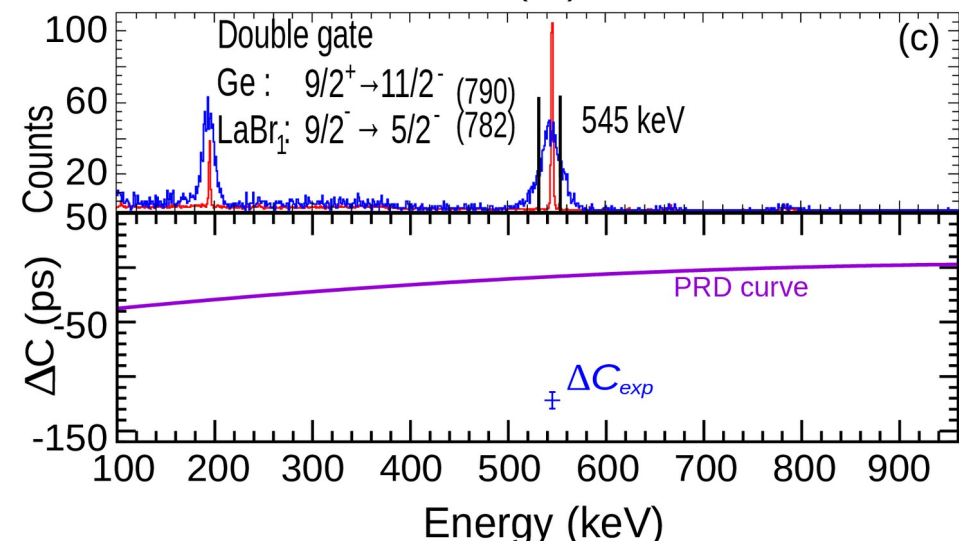
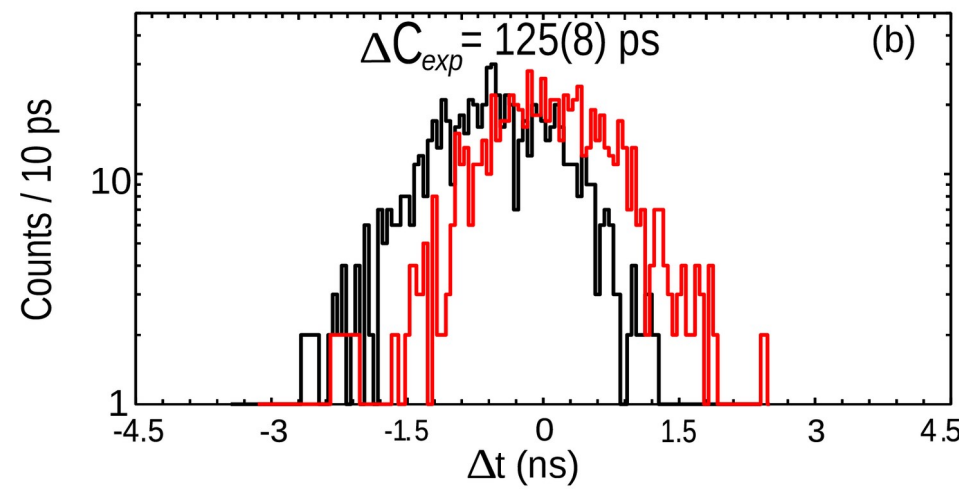
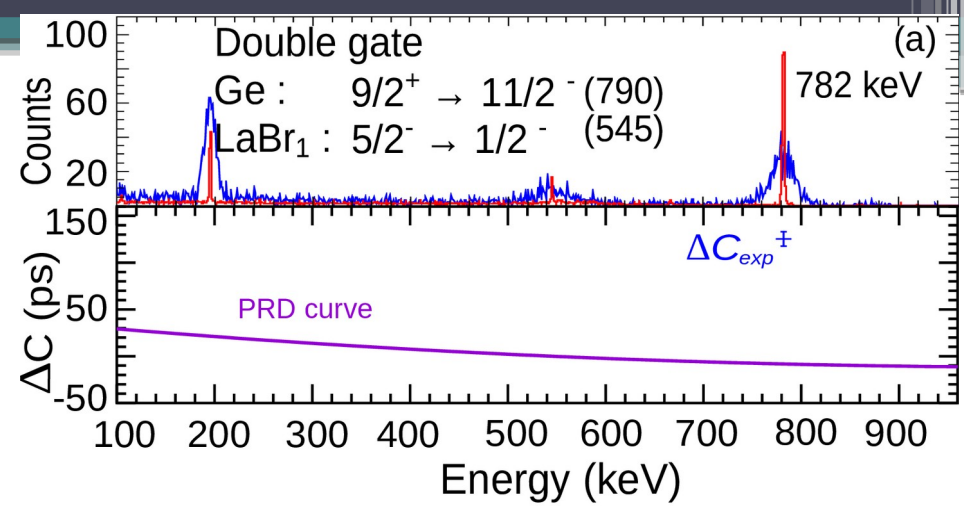


# Результати $^{209}\text{Po}$



$$\tau_{\text{exp}}(5/2^-) = 66(5) \text{ ps}$$

$$\tau_{\text{lit}}(5/2^-) = 101(29) \text{ ps}$$



# Заклучение

За четно-четните полониеви изотопи :

1.  $8^+_{1}$  и  $6^+_{1}$  състоянията имат едночастичен характер
  2.  $4^+_{1}$  състоянието има колективен характер
  3. За  $4^+_{1}$  състоянието, преходът от едночастичен характер към колективен се осъществява между  $N = 122$  и  $N = 120$
- 

4. Теоретични сметки за ядрото  $^{209}\text{Po}$

## **Участие в конференции за целият период на докторантурата :**

1. Nuclear Structure and related topics, 03-09.06.2018, Burgas, Bulgaria;
2. 10th Jubilee International Conference of the Balkan Physics Union, 26-30.08.2018 , Sofia, Bulgaria;
3. Euroschool on exotic beams, 25-31.08.2019, Aarhus, Denmark;
4. XXIII international school on nuclear physics, neutron physics and applications, 22-28.09.2019, Варна, България;

## Публикации свързани с дисертацията за целият период на докторантурата:

1. M. Stoyanova et al, J. Phys.: Conf. Ser. **1555**, 012019 (2020)
2. M. Stoyanova et al., Phys. Rev. C **100**, 064304 (2019)
3. V. Karayonchev,..., M. Stoyanova et al., Phys. Rev. C **99**, 024326 (2019)
4. M. Stoyanova et al., EPJ Web of Conferences **194**, 03002 (2018)

## Други публикации:

1. P. Petkov, M. Stoyanova, Bulg. J. Phys. **42**, 565–571,(2015)
2. D. Kocheva,..., M. Stoyanova,...,et al., Eur.Phys.J. A **53**, 175 (2017)
3. D. Kocheva,..., M. Stoyanova,...,et al., IOP Journal of Physics : Conf. Series **1023**, 012019 (2018)
4. R. Kern,..., M. Stoyanova,...,et al., EPJ Web of Conferences **194**, 03003 (2018)
5. D. Kocheva,..., M. Stoyanova,...,et al., J. Phys.: Conf. Ser. **1555** 012020 (2020)
6. R. Kern,..., M. Stoyanova,...,et al., J. Phys.: Conf. Ser. **1555** 012027 (2020)
7. D. Tonev,..., M. Stoyanova,...,et al., PLB-D-20-00725, submitted

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