Preparatory experiments for FATIMA at the Bucharest Tandem accelerator

S. Pascu, on behalf of the FATIMA collaboration

IFIN-HH

Outline:

- Status of the FATIMA array;
- The new ROSPHERE array in Bucharest;
- Isospin mixing in ^{35}Ar-^{35}Cl from E1 transitions;
- Measurement of E1 transition strengths in the N=Z nucleus ^{50}Mn;
- Lifetime measurements in ^{168}Yb;
- Evolution of collectivity in neutron-rich tungsten isotopes;
- Conclusions

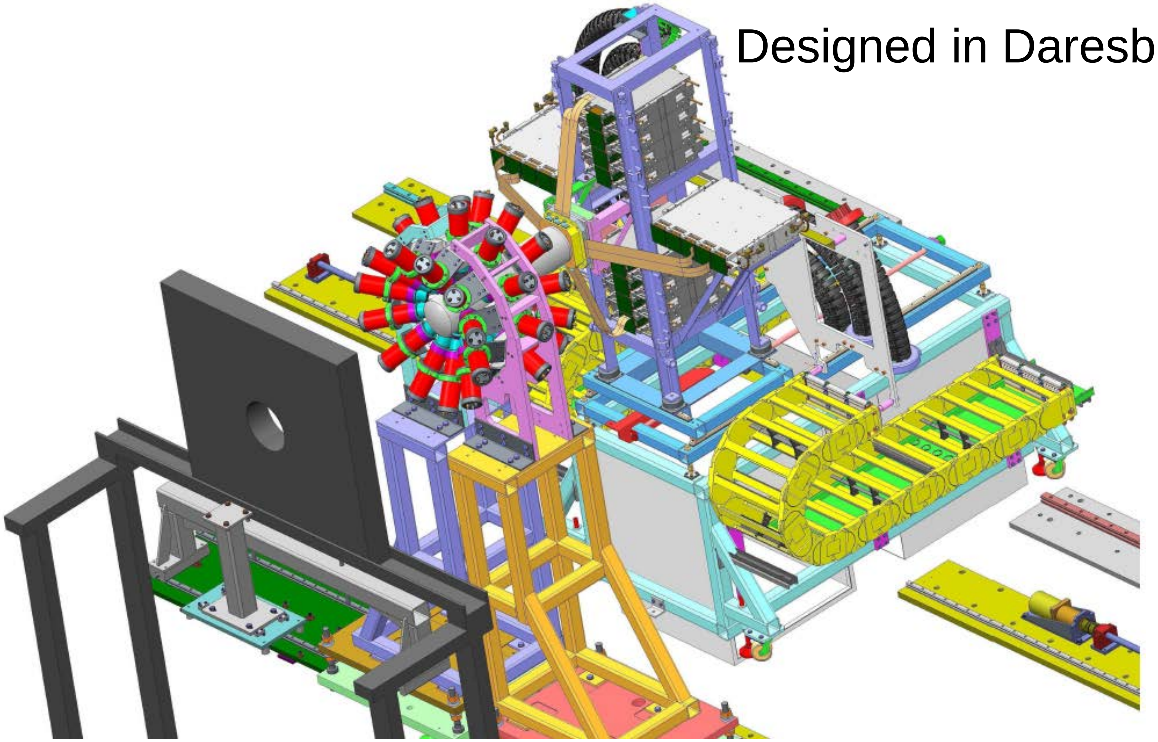
1. Status of the FATIMA array

Collaboration:

UK
Bulgaria
Germany
Romania
Spain

- Placed around implantation point
- Well established method for lifetime measurement;
- Exotic nuclei from beta-decay and from isomers at DESPEC

Designed in Daresbury



LaBr3(Ce) fast-timing array

Frame and detectors in Surrey

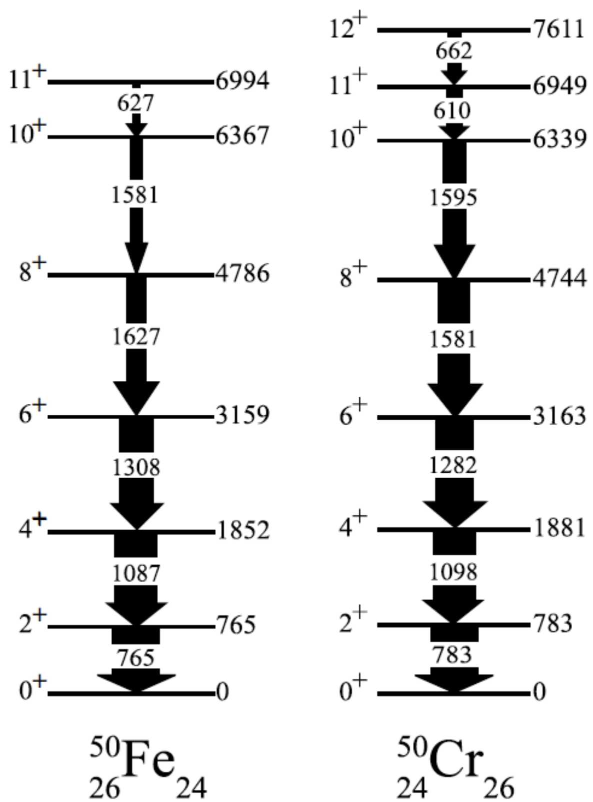
2. The new ROSPHERE array in Bucharest

- 25 positions;
- Usually in a mixed configuration: 14 HPGe and 11 $LaBr_3$;
- Fast-timing measurements;
- Plunger measurements;
- Spring campaign of experiments: 31.03.2015

2. Isospin mixing in ^{35}Ar-^{35}Cl from E1 transitions

Without any isospin symmetry breaking

The **excitation energies** would be identical in mirror nuclei



The **transition strengths** would be (almost) identical in mirror nuclei

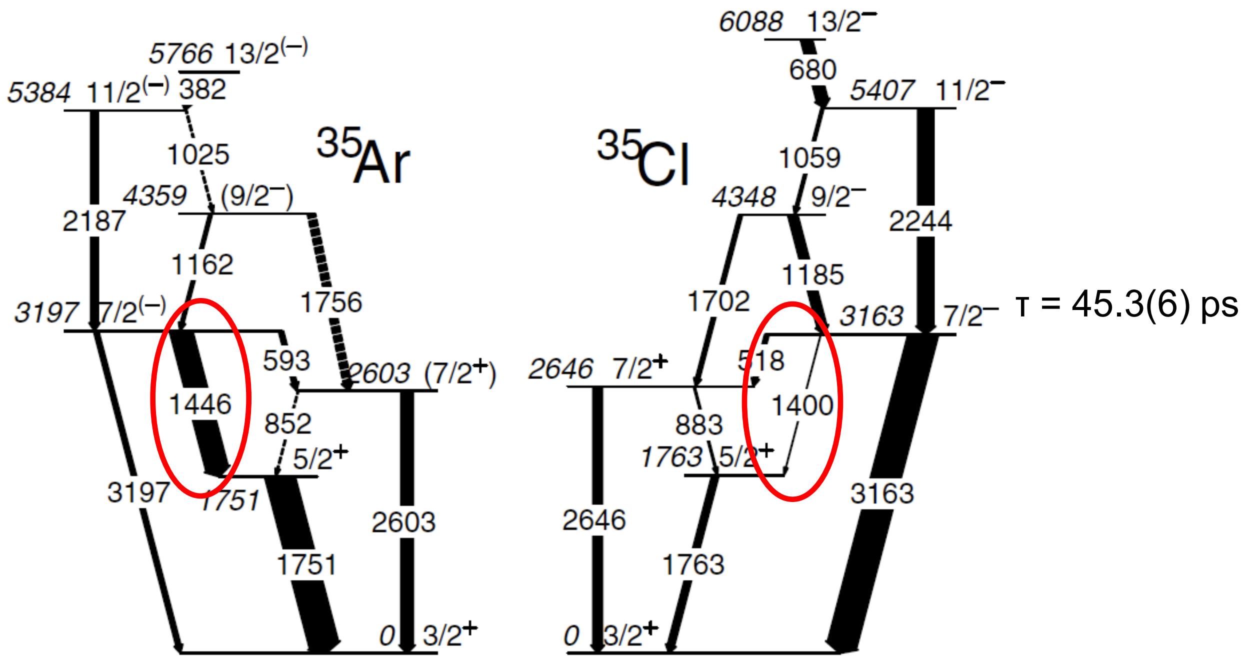
Lifetime of the 7/2- state in ^{35}Ar

τ ≈ 7 ps
Equal B(M2)

^{35}Cl: B(E1)=2*10^{-8} W.u.
^{35}Ar: B(E1)=3*10^{-5} W.u.

F.W. Prosser and G.I. Harris, PRC **4**, 1611 (1971)

τ ≈ 350 ps

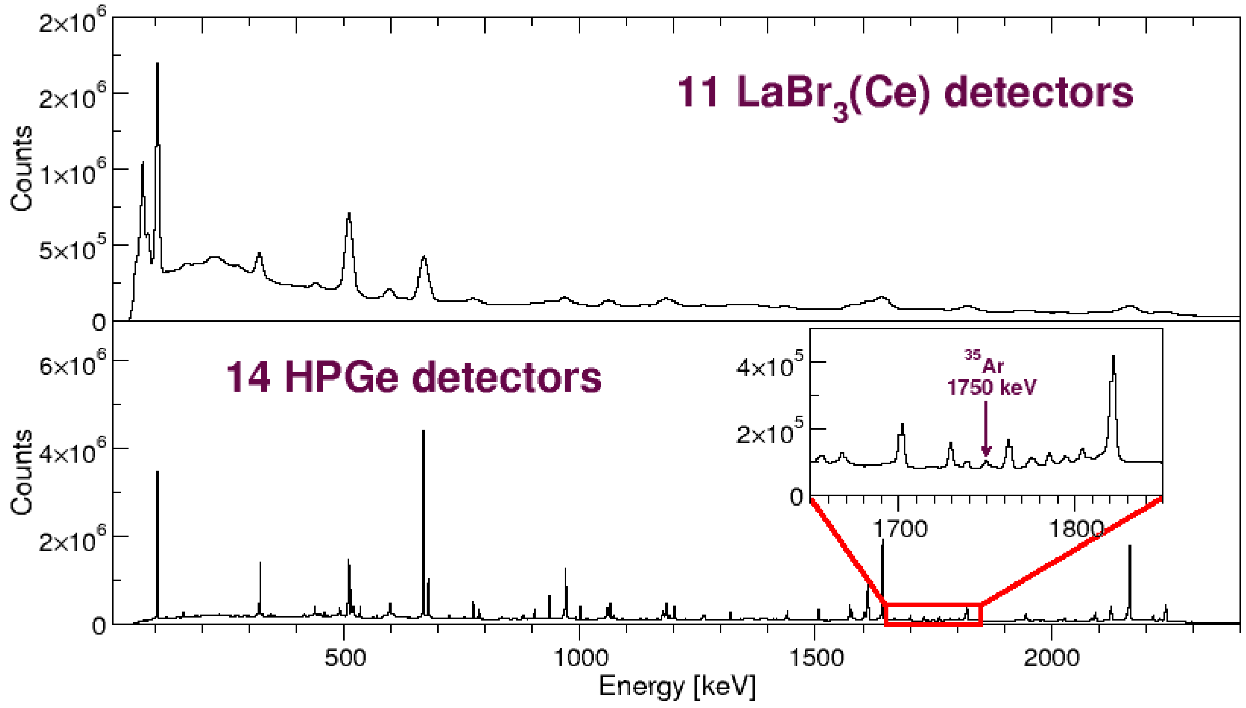


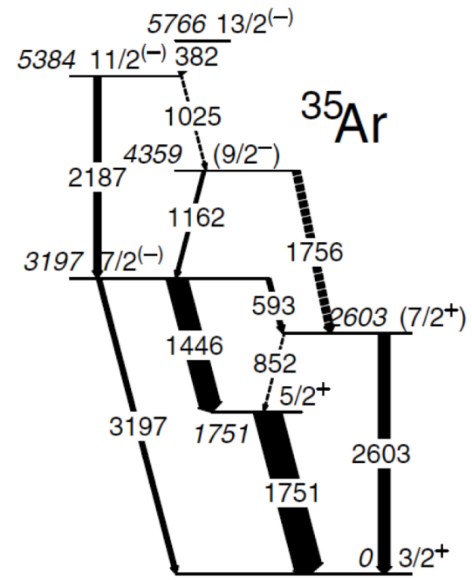
J. Eckman *et al.*, PRL **92**, 132502 (2004)

ROSPHERE experiment on ^{35}Ar

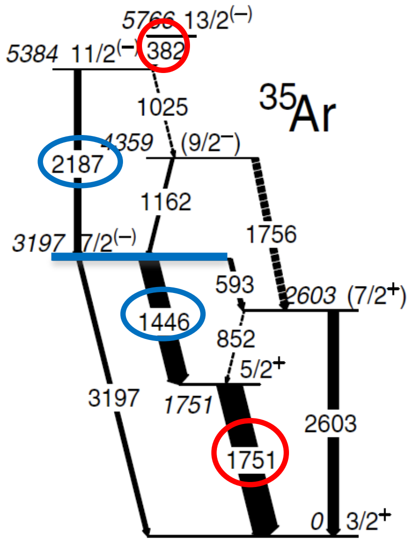
$^{28}Si\ (^{12}C,\alpha n)\ ^{35}Ar$ @50MeV

ROSPHERE: 14HPGe + 11 $LaBr_3$:Ce

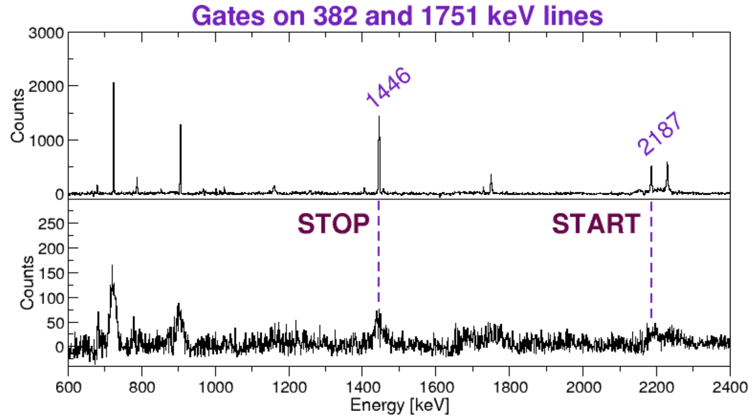


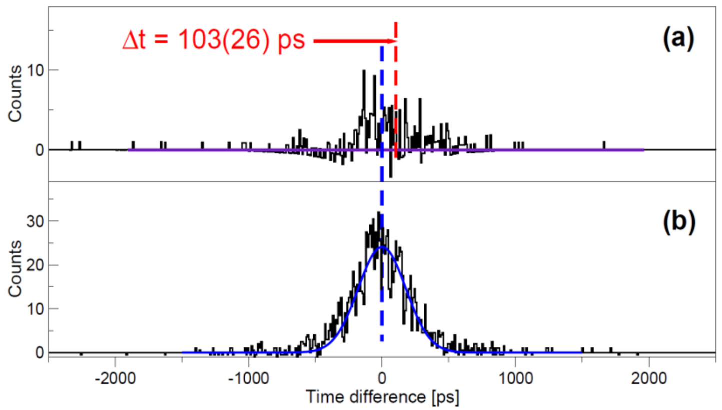


Results of the ROSPHERE experiment



Transition	^{35}Ar		^{35}Cl	
$7/2^- \longrightarrow$	B(E1)[W.u]	B(M2)[W.u.]	B(E1)[W.u]	B(M2)[W.u.]
$7/2^+$ (1)	$0.49(15) \times 10^{-5}$	-	$1.30(8) \times 10^{-5}$	-
$5/2^+$ (1)	$2.1(5) \times 10^{-6}$	-	$1.8(4) \times 10^{-8}$	0.008(4)
$3/2^+$ (gs)	-	<0.021(7)	-	0.258(6)





N. Marginean *et al.*, to be published

Isospin mixing from E1 transitions

Considering **isospin mixing** in both initial and final state (major component T=1/2, minor component T=3/2):

Diagonal   Non-diagonal   Measured matrix element

$$\begin{cases} M(E1;1) + M(E1;2) = \pm\sqrt{B(E1;T_z)} & \text{(eg: } ^{35}\text{Cl)} \\ M(E1;1) - M(E1;2) = \pm\sqrt{B(E1;-T_z)} & \text{(eg: } ^{35}\text{Ar)} \end{cases}$$

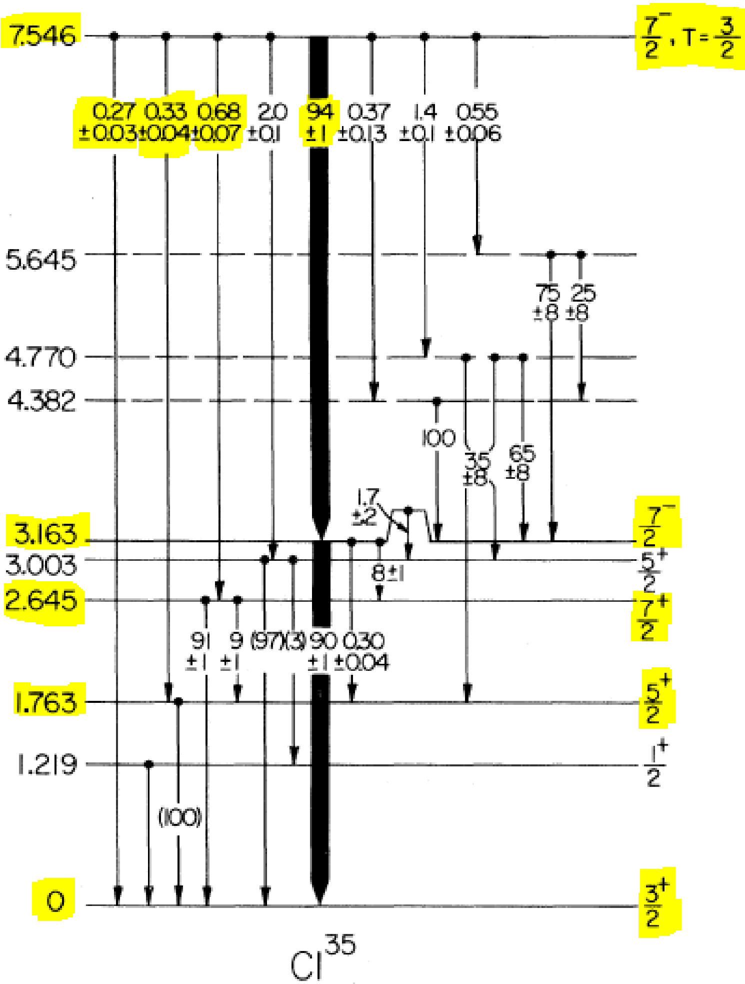
$$M(E1;1) = \frac{\sqrt{B(E1;Tz)} + \sqrt{B(E1;-Tz)}}{2}$$

$$M(E1;2) = \frac{\sqrt{B(E1;Tz)} - \sqrt{B(E1;-Tz)}}{2}$$

Reduced matrix elements for pure transitions (ΔT=0 or ΔT=1) (no mixing):

E1 transition	B(E1;1)[W.u.]	B(E1;2)[W.u.]
$7/2^- \longrightarrow 7/2^+$	$8.5(10) \times 10^{-6}$	$4.8(25) \times 10^{-7}$
$7/2^- \longrightarrow 5/2^+$	$6.3(14) \times 10^{-7}$	$4.3(11) \times 10^{-7}$

Upper limits of the isospin mixing

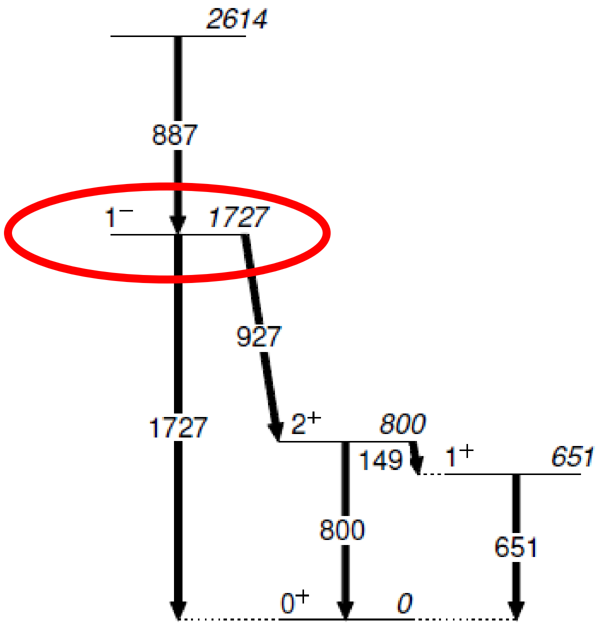


F.W. Prosser and G.I. Harris, PRC **4**, 1611 (1971)

Transition	Type	α^2 %
$7/2^- \longrightarrow 7/2^+$	E1	0.41(23)
$7/2^- \longrightarrow 5/2^+$	E1	1.9(6)

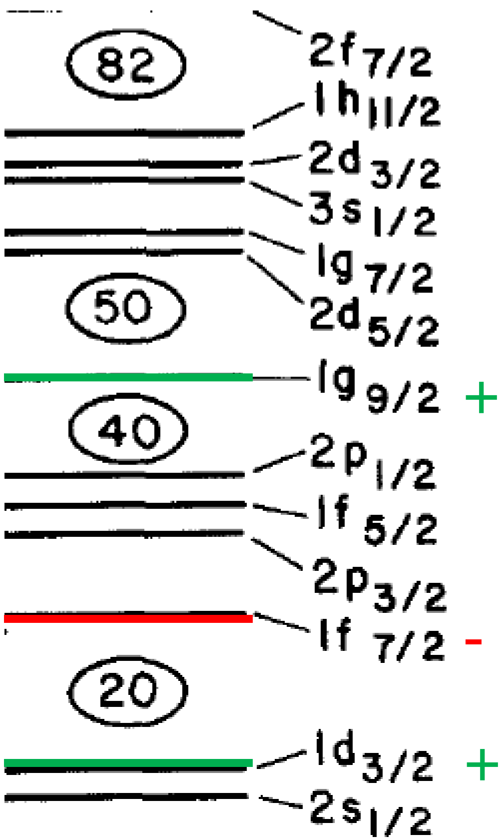
N. Marginean *et al.*, to be published

3. Measurement of E1 transition strengths in the N=Z nucleus ^{50}Mn



^{50}Mn

A. Schmidt *et al.*, PRC **62**, 044319 (2000)



$f_{7/2}$ x $d_{3/2}$

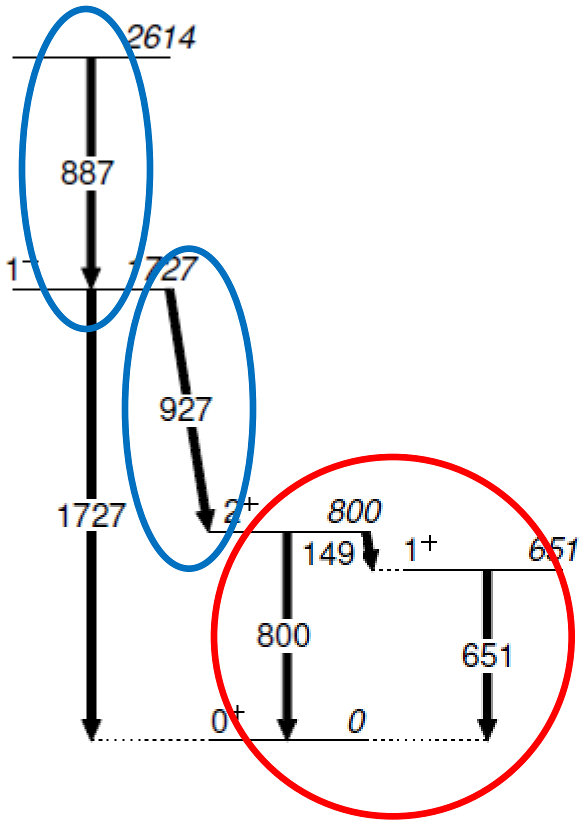
$f_{7/2}$ x $g_{9/2}$

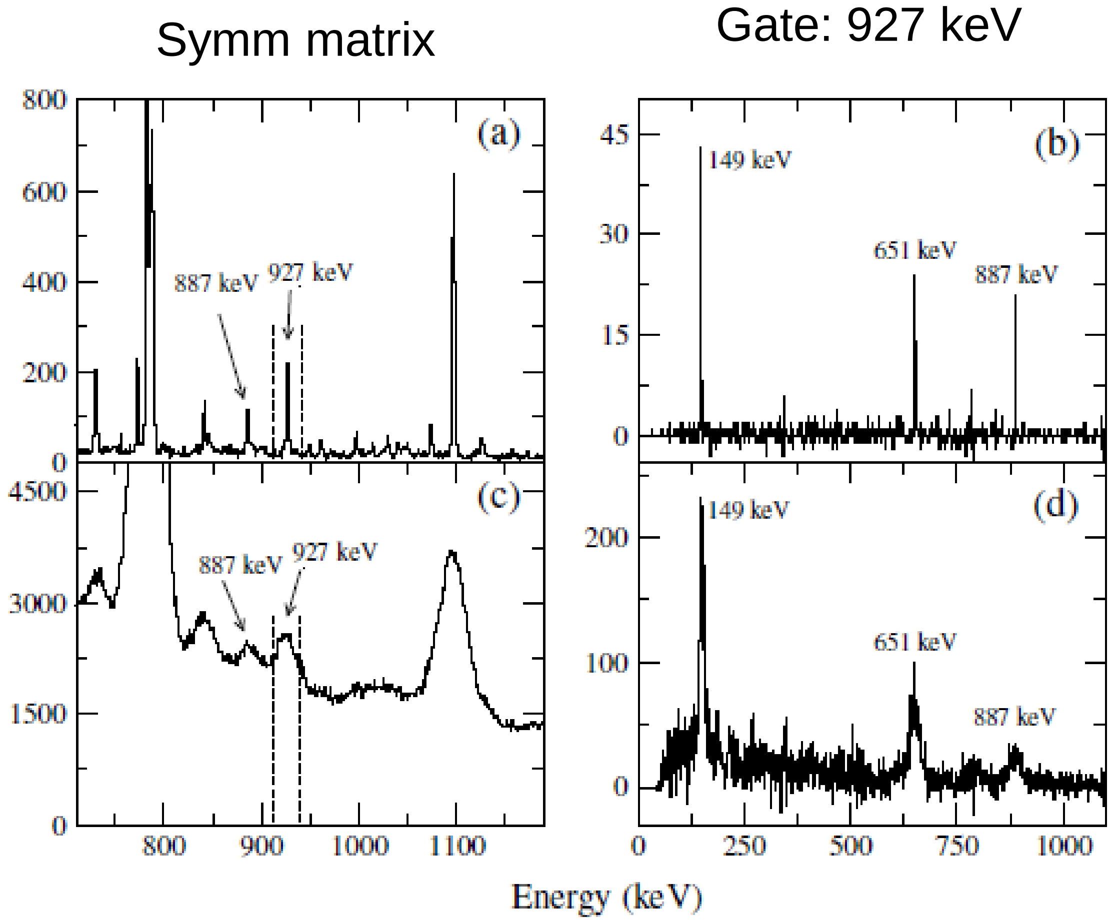
^{47}V:

B(E1;5/2^{+}→3/2^{-})

~10^{-4} W.u.

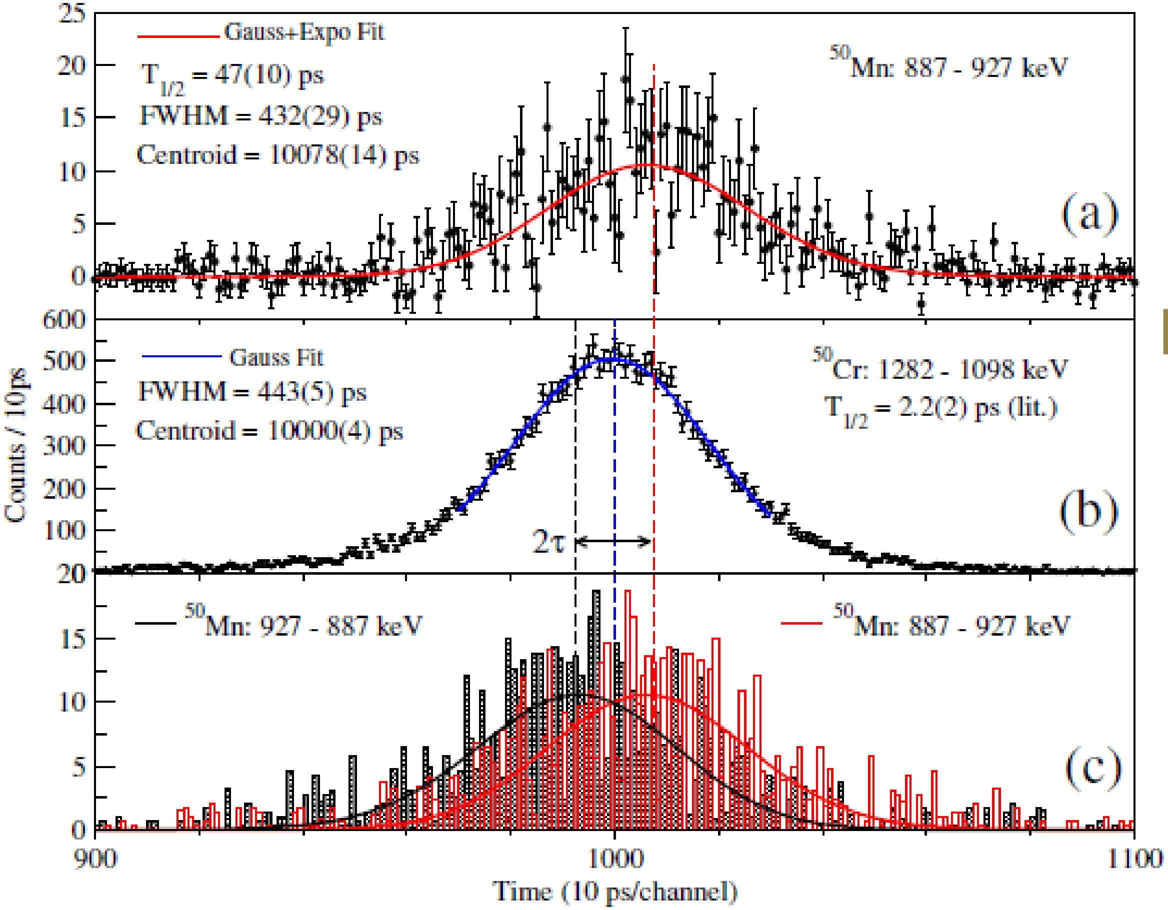
Results of the experiment





R. Lica *et al.*, to be published

Results of the experiment



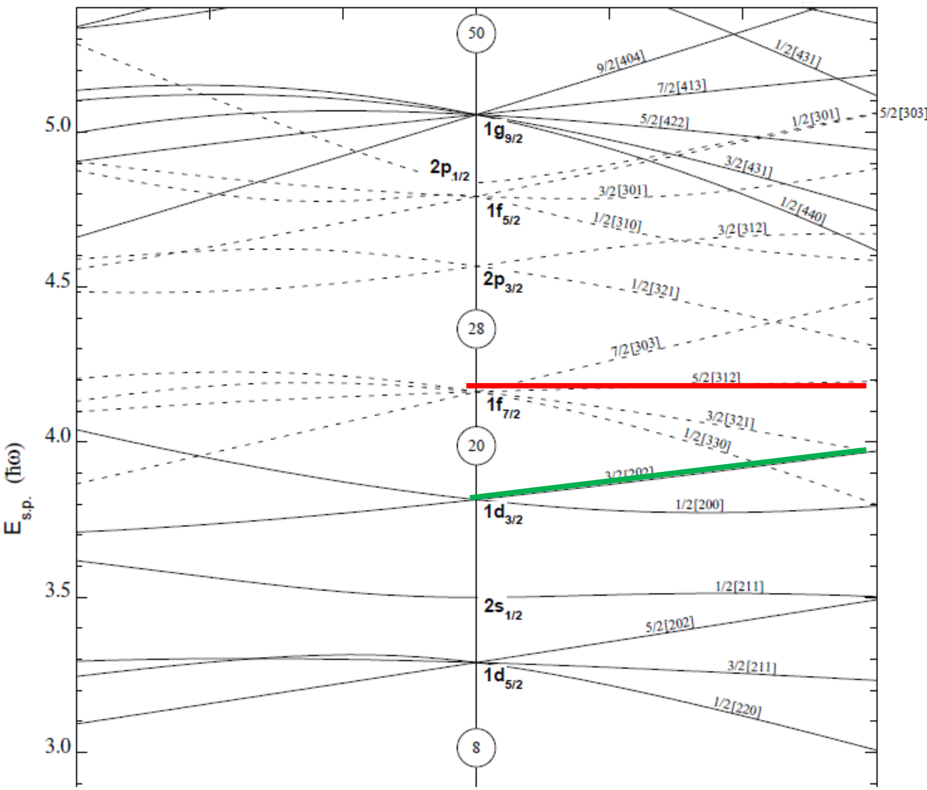
$T_{1/2}$ = 51 (5) ps

B(E1;1$^-$ → 2$^+$) = 4.0 (4) •10^{-6} W.u.

B(E1;1$^-$ → 0$^+$) = 1.2 (1) •10^{-6} W.u

R. Lica *et al.*, to be published

B(E1) estimations from the Nilsson model



Det Kongelige Danske Videnskabernes Selskab

Matematisk-fysiske Meddelelser, bind **29**, nr 16

Dan Mat Fys Medd **29**, no 16 (1955)

BINDING STATES
OF INDIVIDUAL NUCLEONS IN
STRONGLY DEFORMED NUCLEI

BY

SVEN GÖSTA NILSSON

B(E1) estimations from the Nilsson model

$N = 2 \quad \Omega = \frac{3}{2}$

base vectors: $|221+\rangle$, $|222-\rangle$

	$\eta = -6$	-4	-2	2	4	6
8	2 000	1 895	2 228	4 035	5 198	6 424
	1 000	1 000	1 000	1 000	1 000	1 000
	— 0 500	— 0 781	— 1 281	— 2 851	— 3 766	— 4 712
7	— 3 000	— 2 228	— 1 895	— 2 368	— 2 865	— 3 424
	1 000	1 000	1 000	1 000	1 000	1 000
	2 000	1 281	0 781	0 351	0 266	0 212

$$B(E\lambda,\ I \rightarrow I') = e^2\left(1+(-)^{\lambda}\frac{Z}{A^{\lambda}}\right)^2\left(\frac{\hbar}{M\omega_0}\right)^{\lambda}\frac{2\lambda+1}{4\pi}$$
$$\left|\langle I\lambda K K'-K | I\lambda I'K'\rangle + b_{E\lambda}(-)^{I+K}\langle I\lambda K\ -K'-K | I\lambda I'\ -K'\rangle\right|^2 G^2_{E\lambda} \qquad (3$$

where

$$b_{E\lambda} = \frac{(-)^{K+1/2+l}}{G_{E\lambda}}\left\{\sum_{l'l}\langle N'l'|r^{\lambda}|Nl\rangle\sqrt{\frac{2l+1}{2l'+1}}\langle l\lambda 0 0 | l\lambda l' 0\rangle \sum_{\Lambda'\Lambda\Sigma'\Sigma}\delta_{-\Sigma',\Sigma}\, a'_{l'\Lambda'}\, a_{l\Lambda}\langle l\lambda\Lambda\ -K'-K | l\lambda l'\ -\Lambda'\rangle\right\} \qquad (35$$

$$G_{E\lambda} = \sum_{l'l}\langle N'l'|r^{\lambda}|Nl\rangle\sqrt{\frac{2l+1}{2l'+1}}\langle l\lambda 0 0 | l\lambda l'\ 0\rangle \sum_{\Lambda'\Lambda\Sigma'\Sigma}\delta_{\Sigma'\Sigma}\, a'_{l'\Lambda'}\, a_{l\Lambda}\langle l\lambda\Lambda K'-K | l\lambda l'\Lambda'\rangle \qquad (35\,b)$$

93.5% $d_{3/2}$
6.5 % $d_{5/2}$

$B(E1;1^- \rightarrow 0^+) \sim 10^{-4}$ W.u.

More realistic estimations of the E1 strength

$$b^{\dagger}_{K\tau} = \sum_{j\geq K} x_{jK\tau} c^{\dagger}_{jK\tau}$$

(D. Delion, private communication)

$$H = \sum_{\tau=p,n} \left[\sum_{I_\tau} (\epsilon_{I_\tau} - \lambda_\tau) N_{I_\tau} - \frac{1}{4} G_\tau \sum_{I_\tau} \hat{I}_\tau P_0^{\dagger}(I_\tau I_\tau) \sum_{I'_\tau} \hat{I}'_\tau P_0(I'_\tau I'_\tau) \right]$$
$$- \frac{1}{4} \sum_{\lambda=0,1,2} F_\lambda \sum_{I_p I_n} \sum_{I'_p I'_n} \left[P^{\dagger}_\lambda(I_p I_n) \otimes \tilde{P}_\lambda(I'_p I'_n) \right]_{00} ,$$

→ B(E1;1^- → 0^+) ~ 10^{-4} W.u.

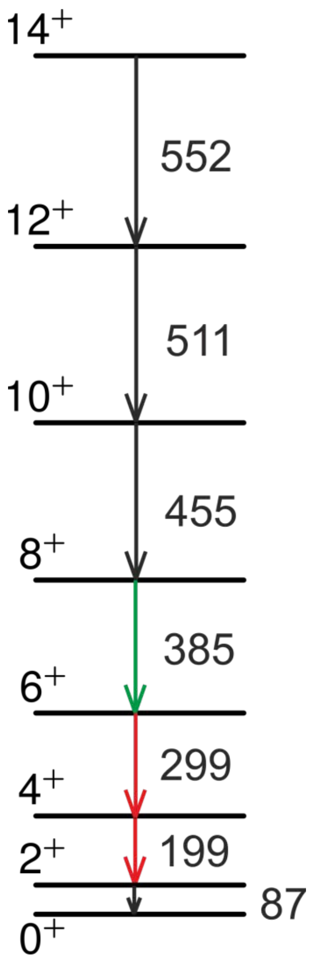
D. Delion, private communication

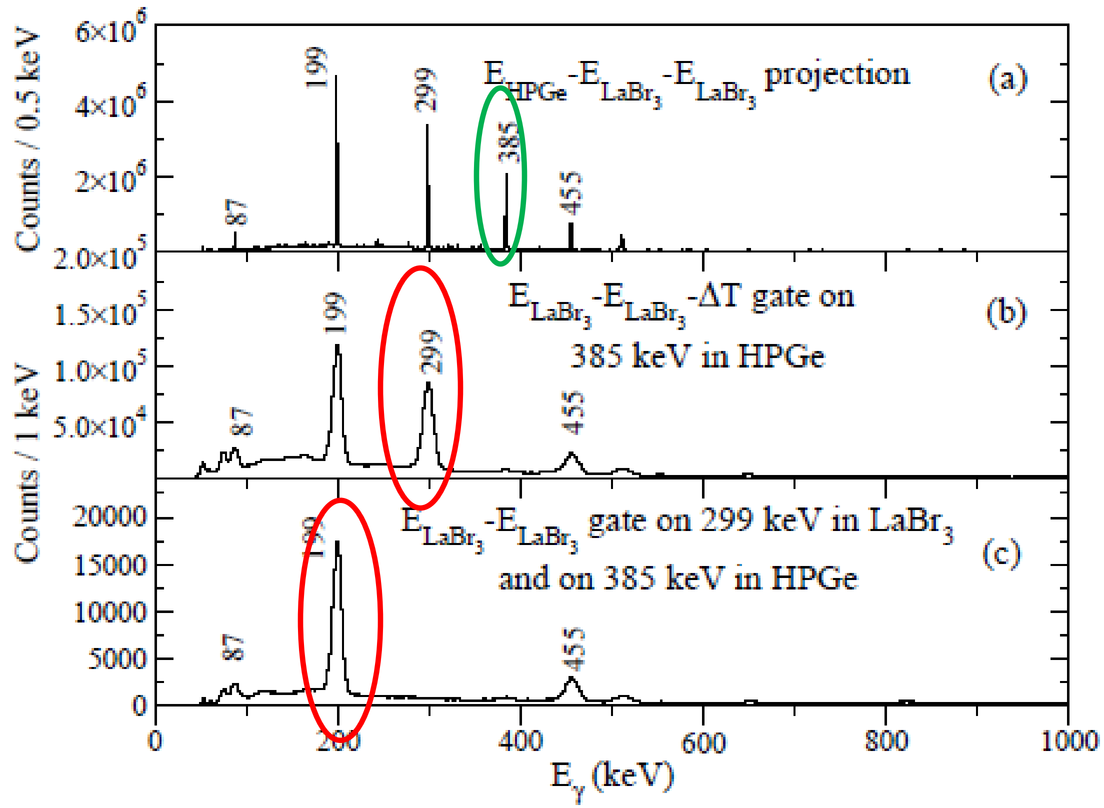
$$\left(c^{\dagger}_{j_p} \otimes c^{\dagger}_{j_n}\right)^{T0}_{JM} = \left(c^{\dagger}_{j_p} \otimes c^{\dagger}_{j_n}\right)_{JM} \frac{1 + (-)^{j_p + j_n + J + T}}{\sqrt{2}} , \quad T = 0, 1$$

→ B(E1;1^- → 0^+) = $0.9 \cdot 10^{-6}$ W.u.

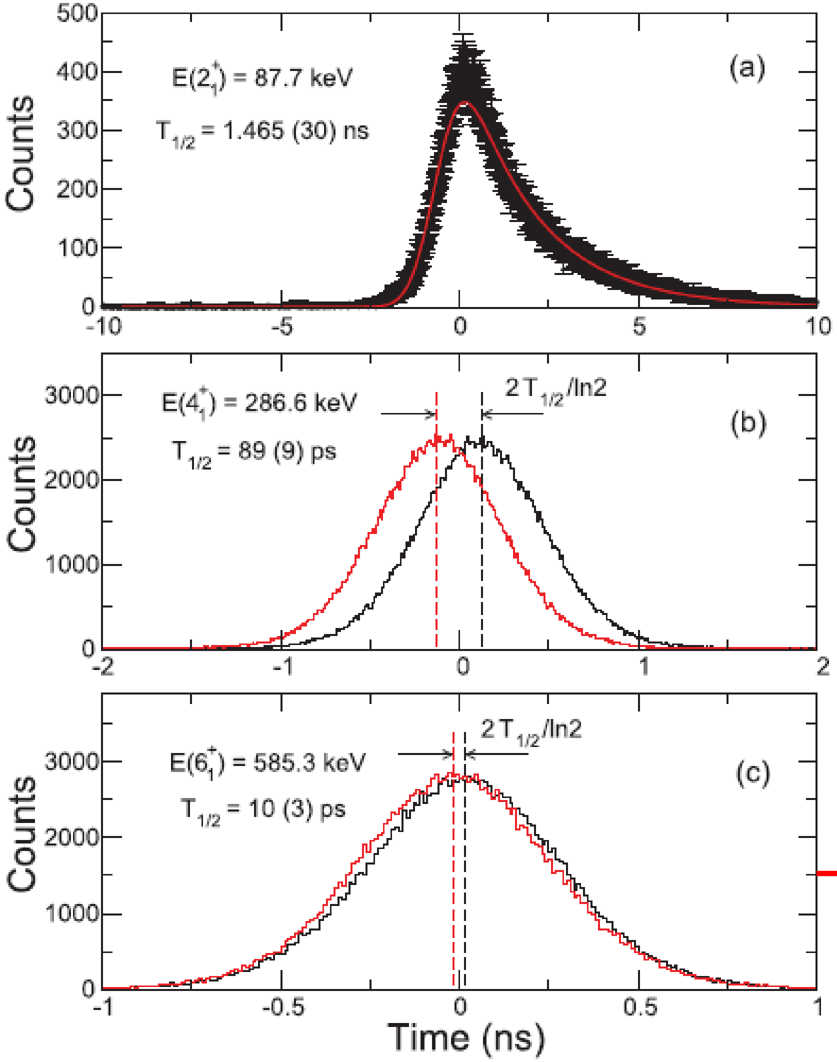
B(E1;1^- → 2^+) = $1.4 \cdot 10^{-6}$ W.u.

4. Lifetime measurements in ^{168}Yb





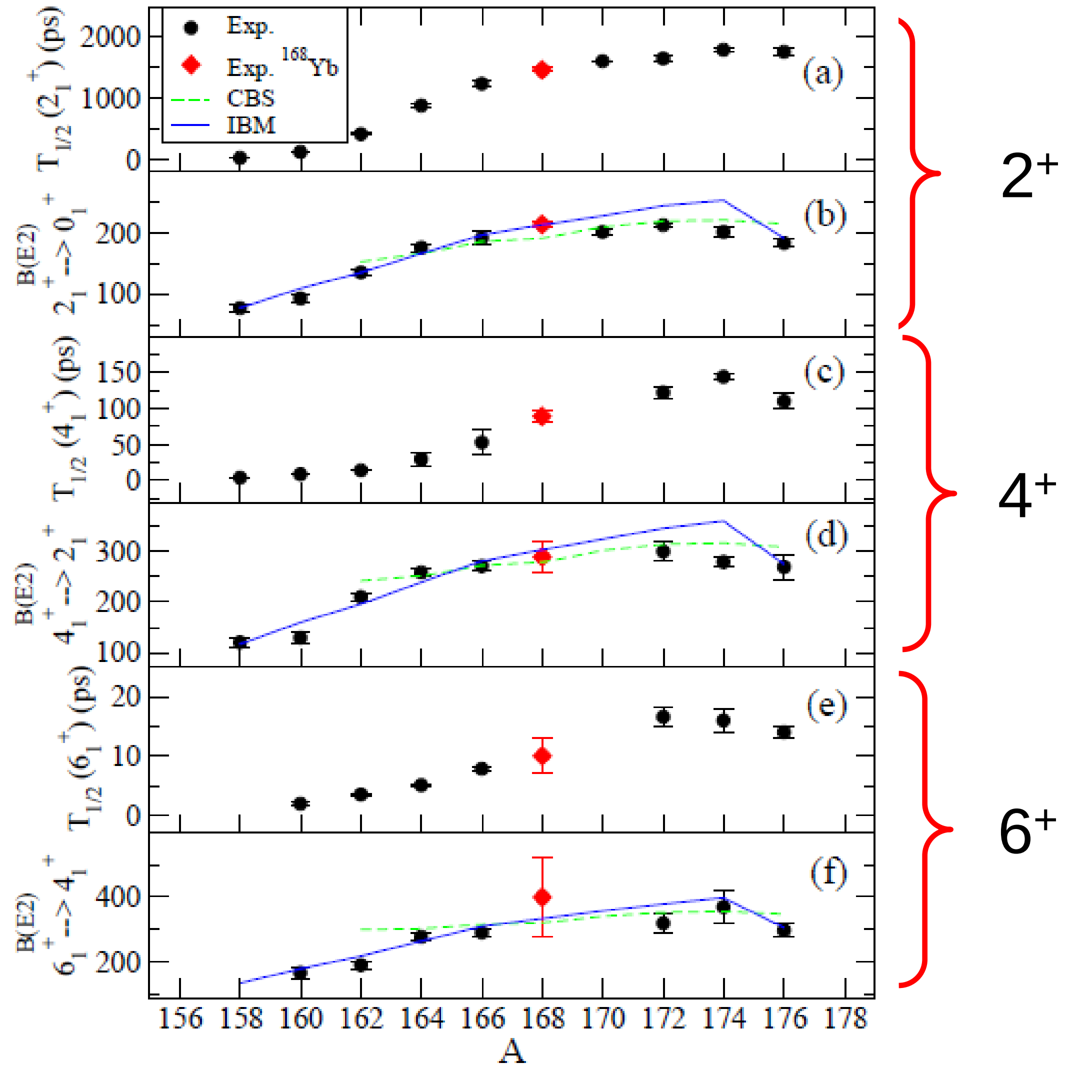
Results of the experiment



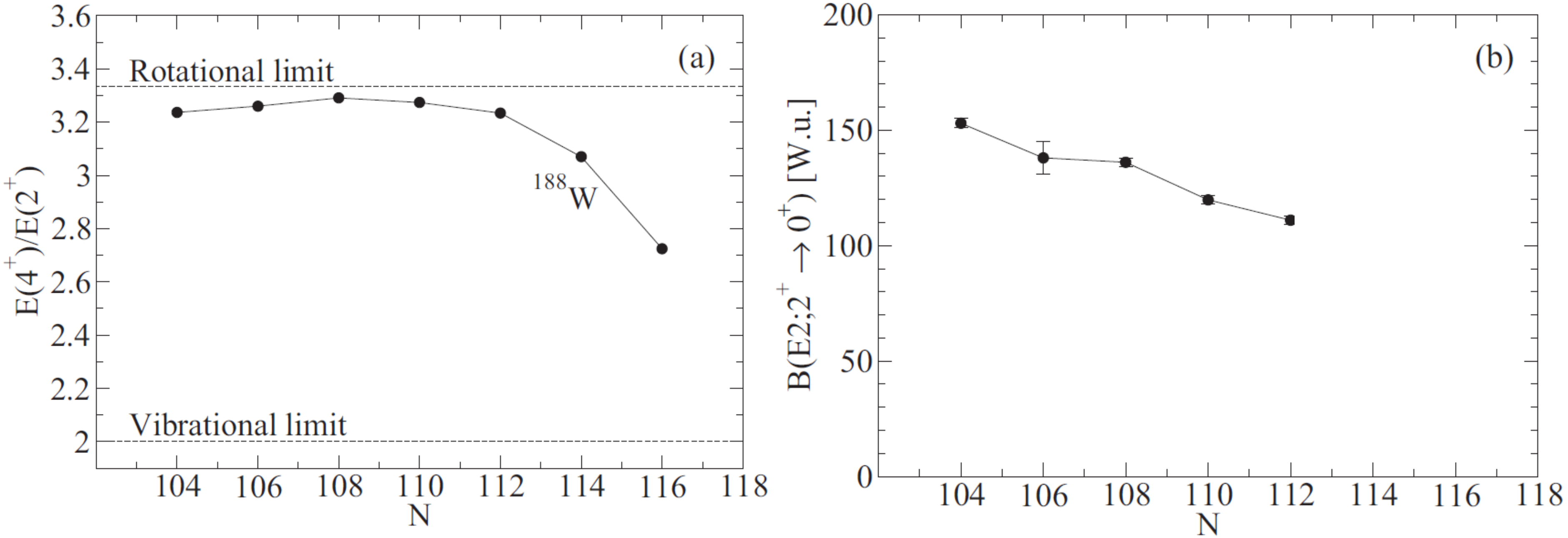
E_{level} (keV)	J_i^π	K_i^π	$T_{1/2}$ (ps)	$B(E2; J_i \rightarrow J_i - 2)$ (W.u.)
87.73(1)	2_1^+	0_1^+	1465(30)	213(5)
286.55(2)	4_1^+	0_1^+	89(9)	290(30)
585.25(5)	6_1^+	0_1^+	10(3)	400(120)

Very short lifetime for the fast-timing method

Comparison with the neighboring isotopes

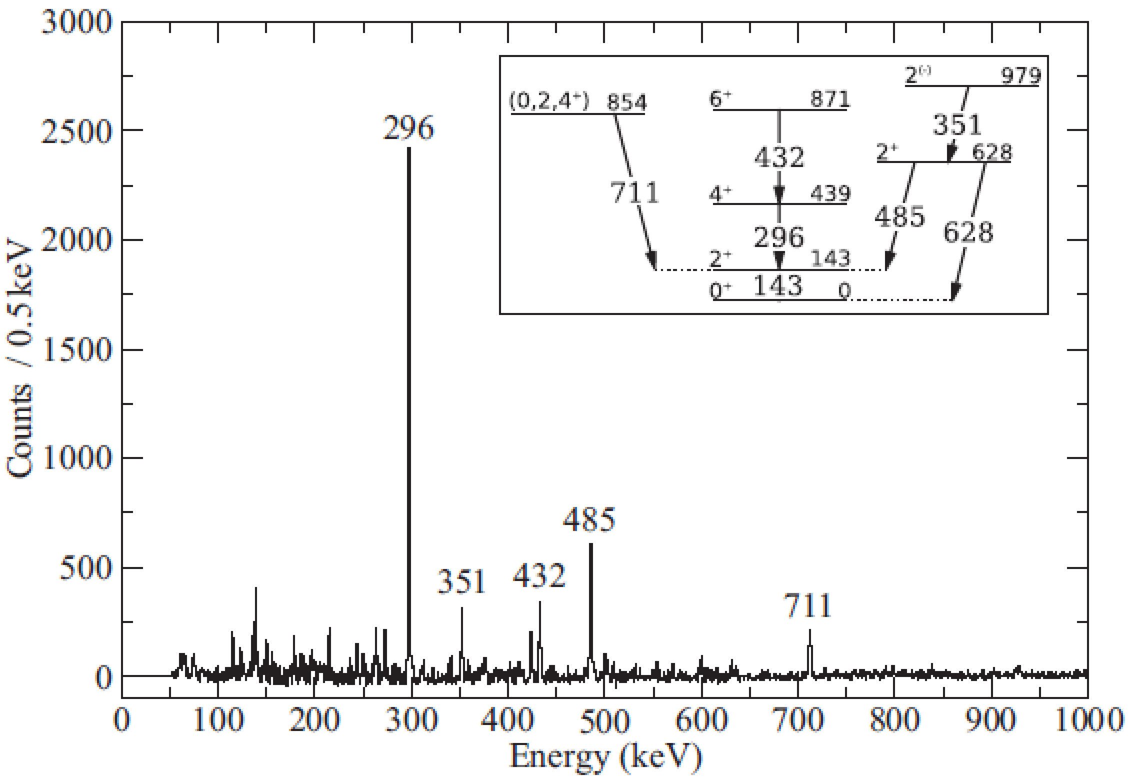


5. Evolution of collectivity in neutron-rich tungsten isotopes



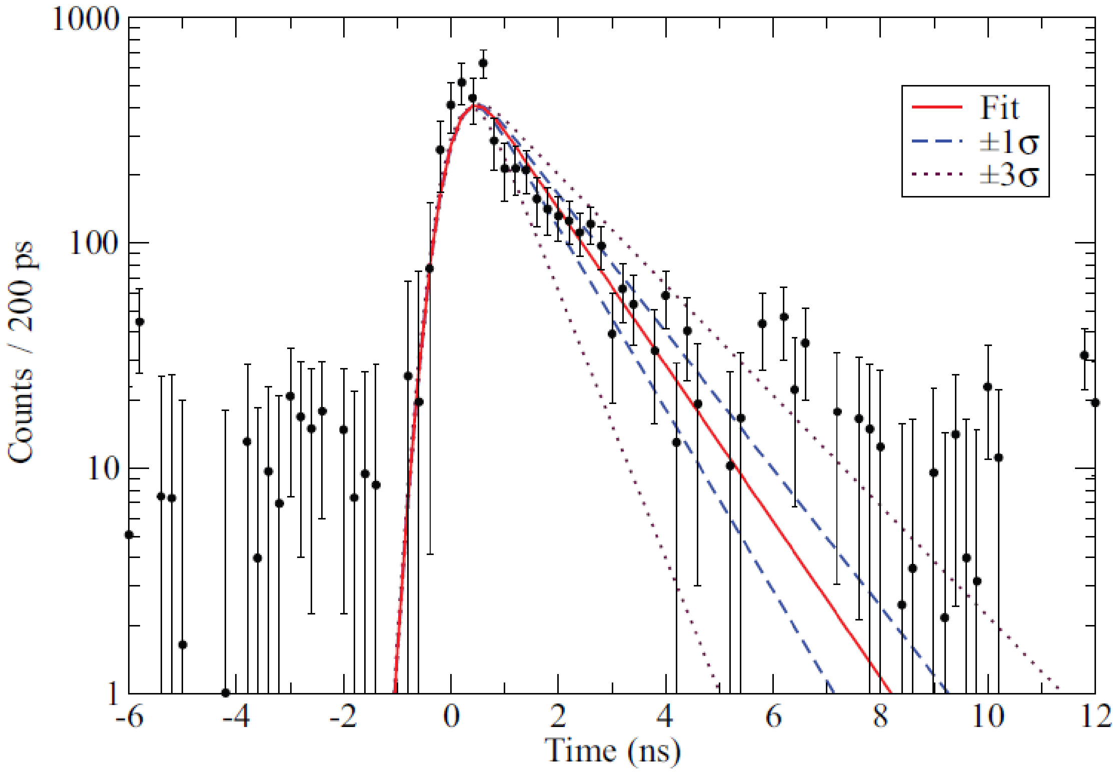
Experimental details

- $^{186}W(^{7}Li,\alpha p)^{188}W$
- $E_{7Li} = 31$ MeV
- d = 16 mg/cm^2 ^{186}W
- $\sigma \sim 0.5$ % of γ- γ
- 8 HPGe and 11 $LaBr_3$



P. Mason *et al.*, PRC **88**, 044301 (2013)

Results of the experiment

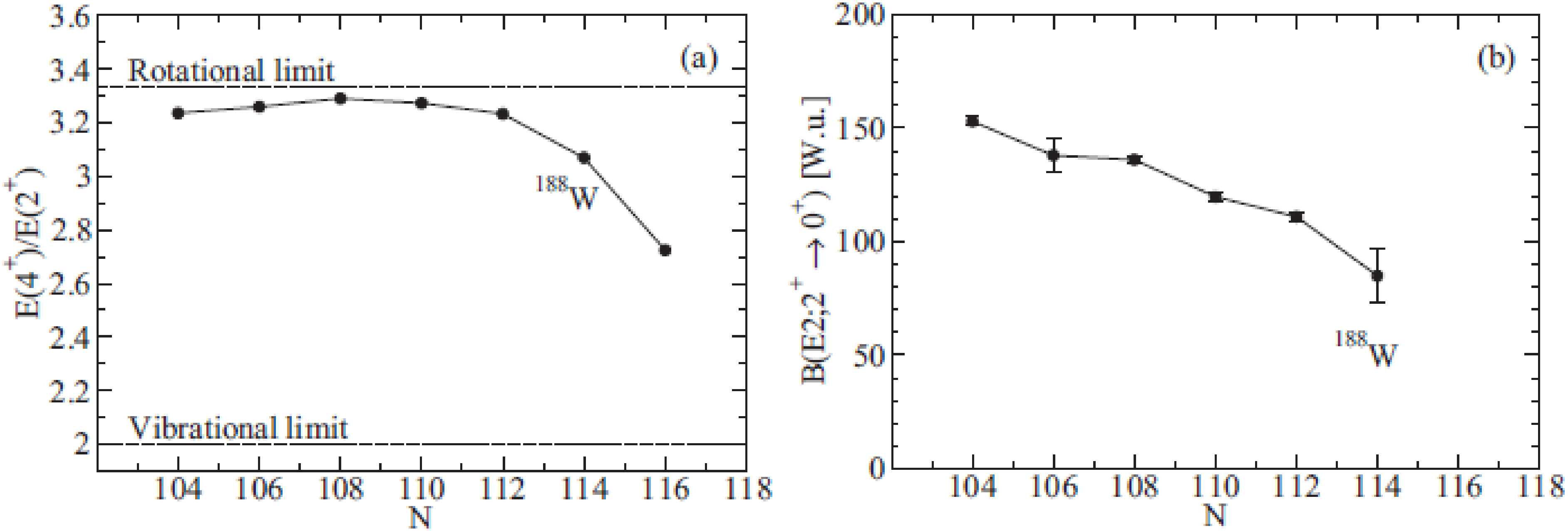


P. Mason *et al.*, PRC **88**, 044301 (2013)

$T_{1/2}$ = 0.87 (12) ns

B(E2;2^+ → 0^+) = 85 (12) W.u.

Results of the experiment



P. Mason *et al.*, PRC **88**, 044301 (2013)

6. Preliminary results from RIKEN

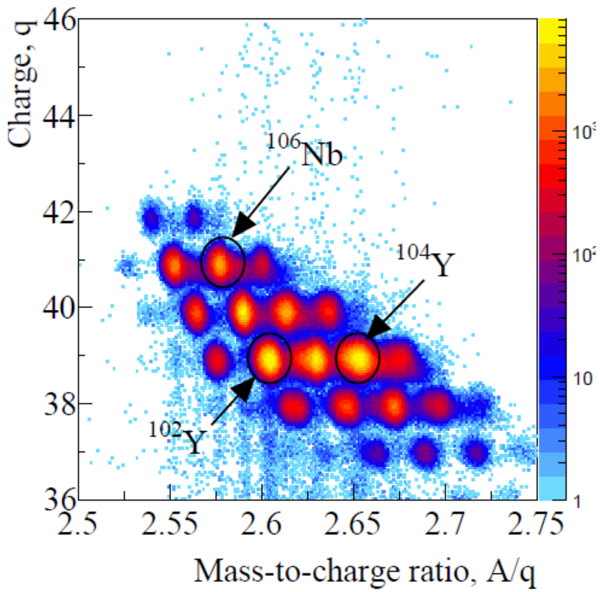
- 18 $LaBr_3$ detectors FATIMA collaboration coupled with EURICA array
- Testing with fragmentation beam in spring 2013

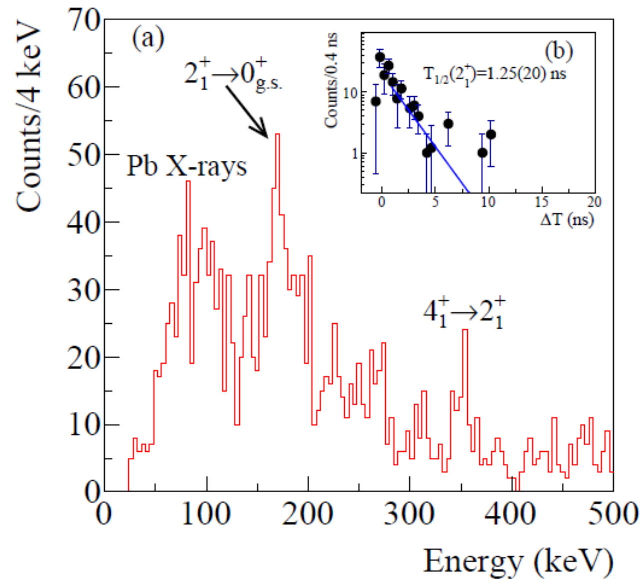
6. Preliminary results from RIKEN

ENSDF data: $T_{1/2}$ (2^+) = 1.25 (3) ns

D. DE Frenne and A. Negret, Nucl. Data Sheets 109, **943** (2008)

^{106}Mo





F. Browne et al., Acta Phys. Pol., Zakopane 2014

7. Conclusions

- Status of the FATIMA array
- New ROSPHERE array in Bucharest
- Isospin mixing determination from known E1 transitions;
- E1 transition strengths in N=Z nuclei;
- Very short lifetime measurement in ^{168}Yb;
- Evolution of collectivity in neutron-rich tungsten isotopes;
- Further lifetime measurements in neutron-rich nuclei