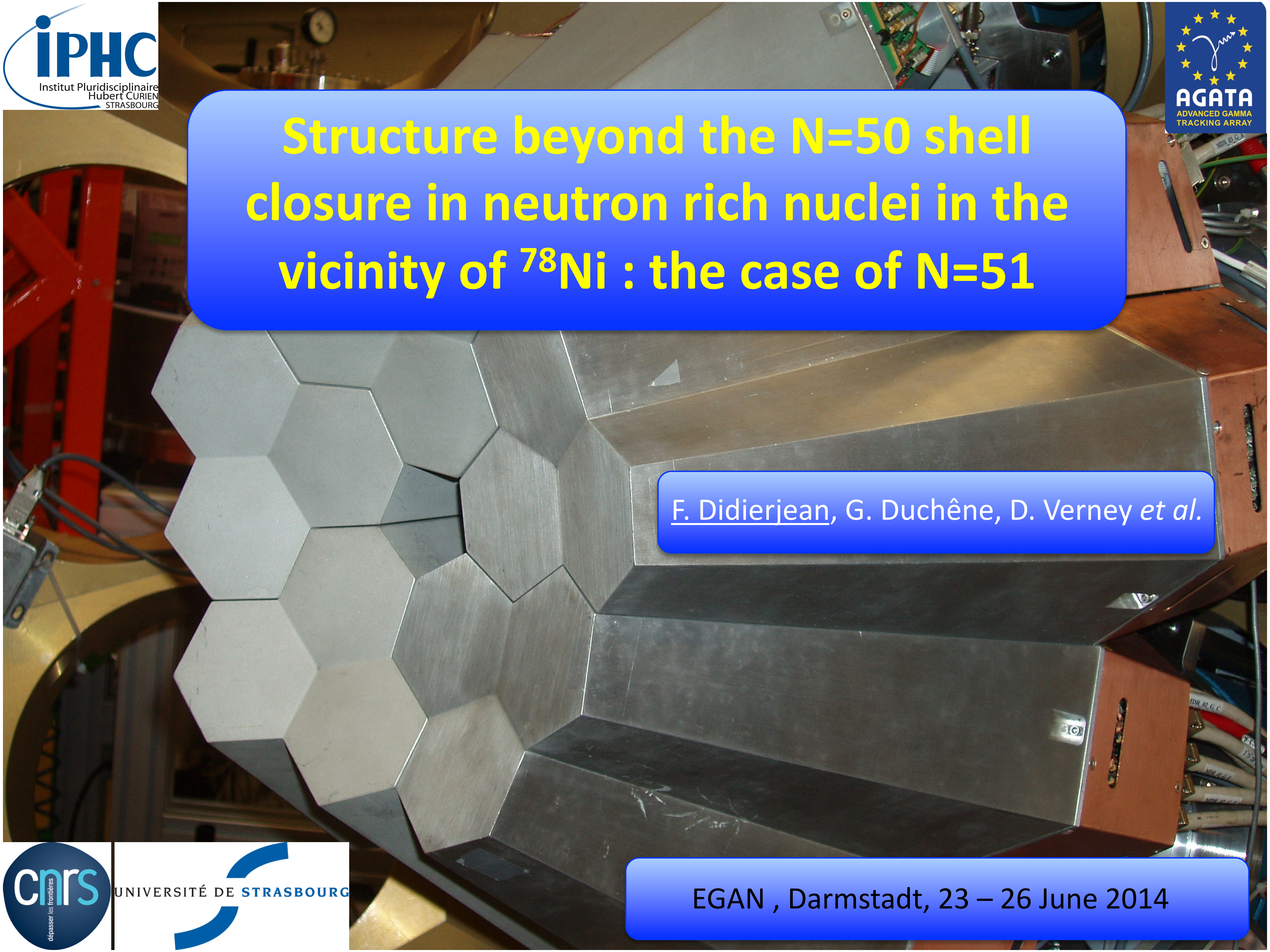
Structure beyond the N=50 shell closure in neutron rich nuclei in the vicinity of ^{78}Ni : the case of N=51

F. Didierjean, G. Duchêne, D. Verney *et al.*

EGAN , Darmstadt, 23 – 26 June 2014



Outline

physics motivations :

neutron orbitals above the N = 50 gap : levels of N = 51 isotones

Experimental setup :

AGATA . PRISMA . Cologne plunger

RDDS method :

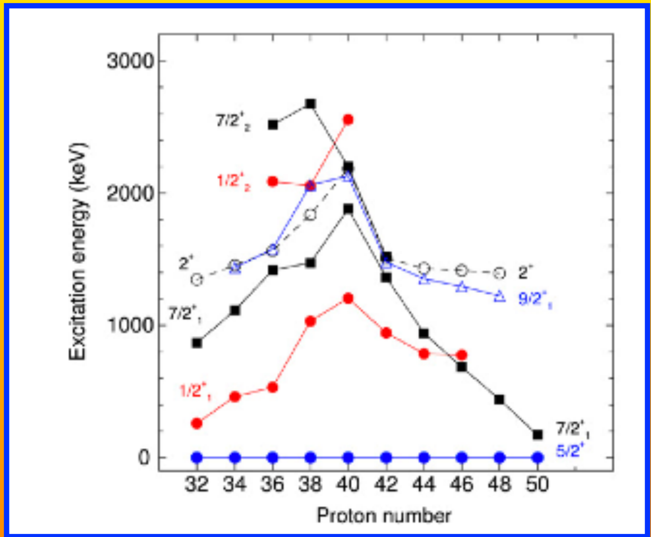
case of a known nucleus : ^{76}Ge

Lifetime measurements results :

analysis of $7/2^+$ state in ^{87}Kr

Conclusion

Physics motivations

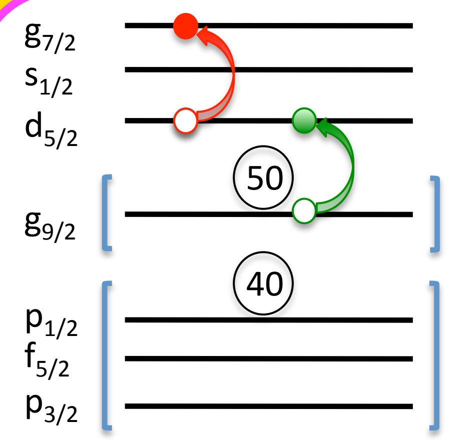


first excited states observed in N=51 isotones.

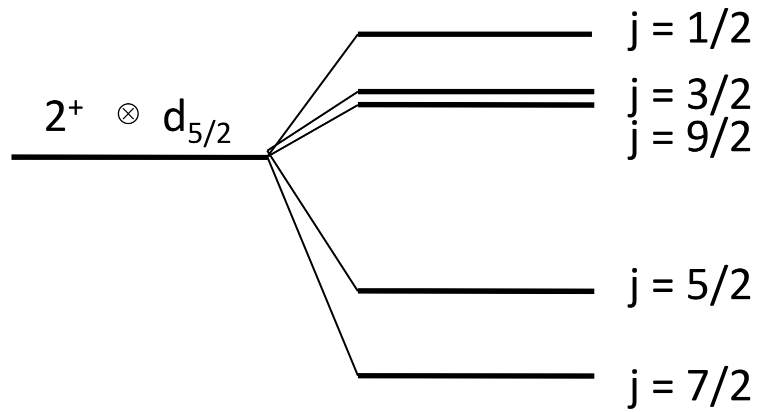
the 5/2+ ground state spin has been established

the 7/2+ state corresponds to an excitation into the $g_{7/2}$ orbital

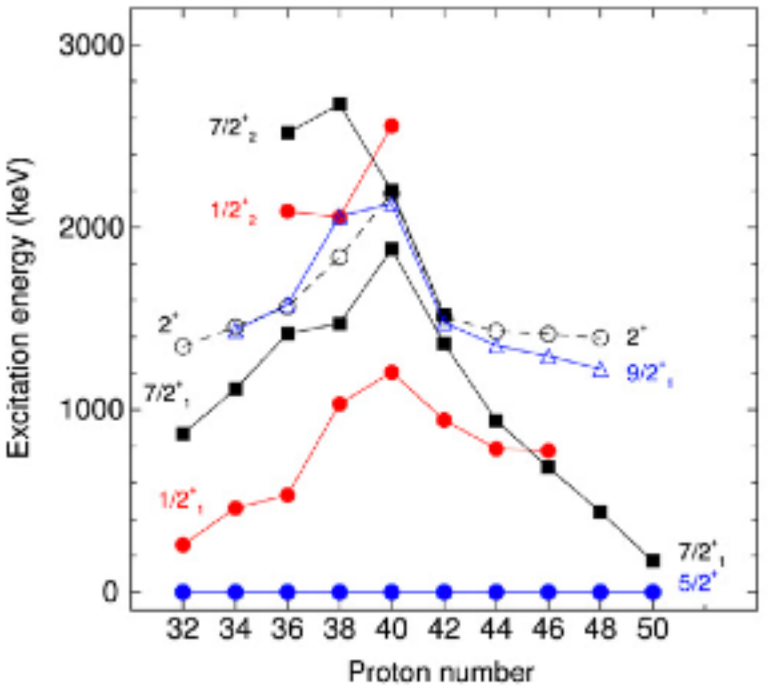
the 9/2+ state is build on a 2p – 1h configuration



the coupling of the $d_{5/2}$ orbital to the first 2+ excitation of the proton N=50 core leads to a 1/2+ to 9/2+ multiplet of 5 collective states



Physics motivations



The first 7/2+ and 9/2+ follow the evolution of the 2+ core excitation of N=50 core.

This leads us to conclude that these states are most likely build on the collective configuration.

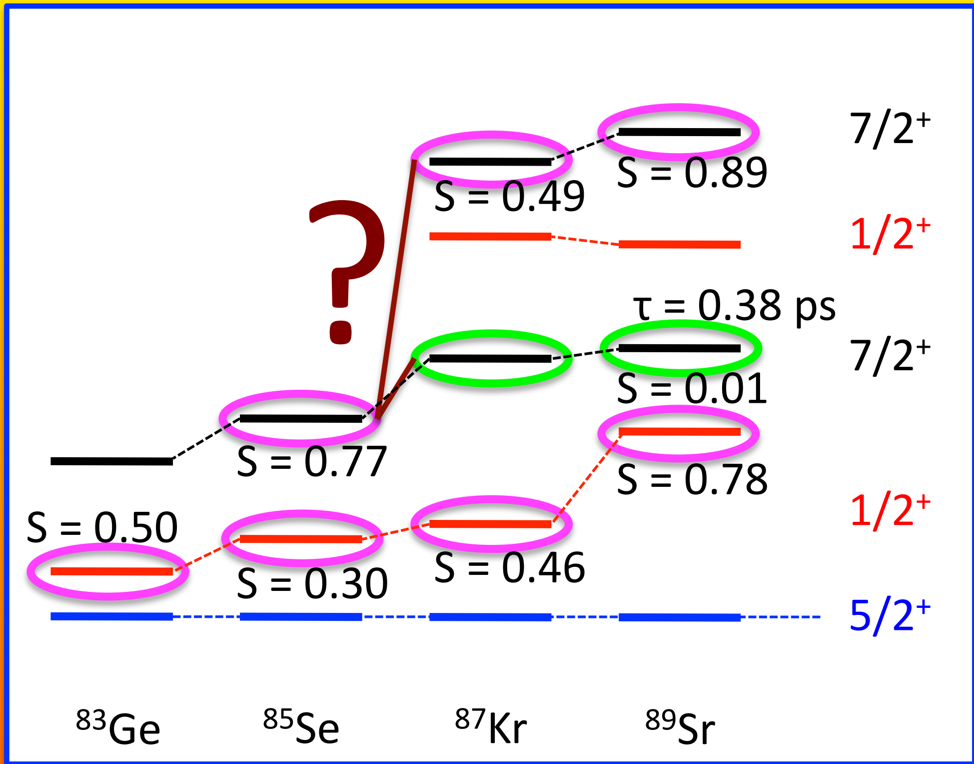
Physics motivations

^{89}Sr and ^{87}Kr :
$1/2^{+}$ and 7/2+ states have been populated by (d,p) transfert reactions.

States with largest spectroscopic factors correspond likely to single particle configurations.

States with small spectroscopic factors correspond likely to a collective configuration.

^{85}Se :
a possible inversion has been observed.



In the well known case of ^{89}Sr, lifetime measurements has been performed which confirm the collectivity or single particle configuration of the states.

Physics motivations

It is relatively easy to distinguish the 2 configuations by lifetime measurements :

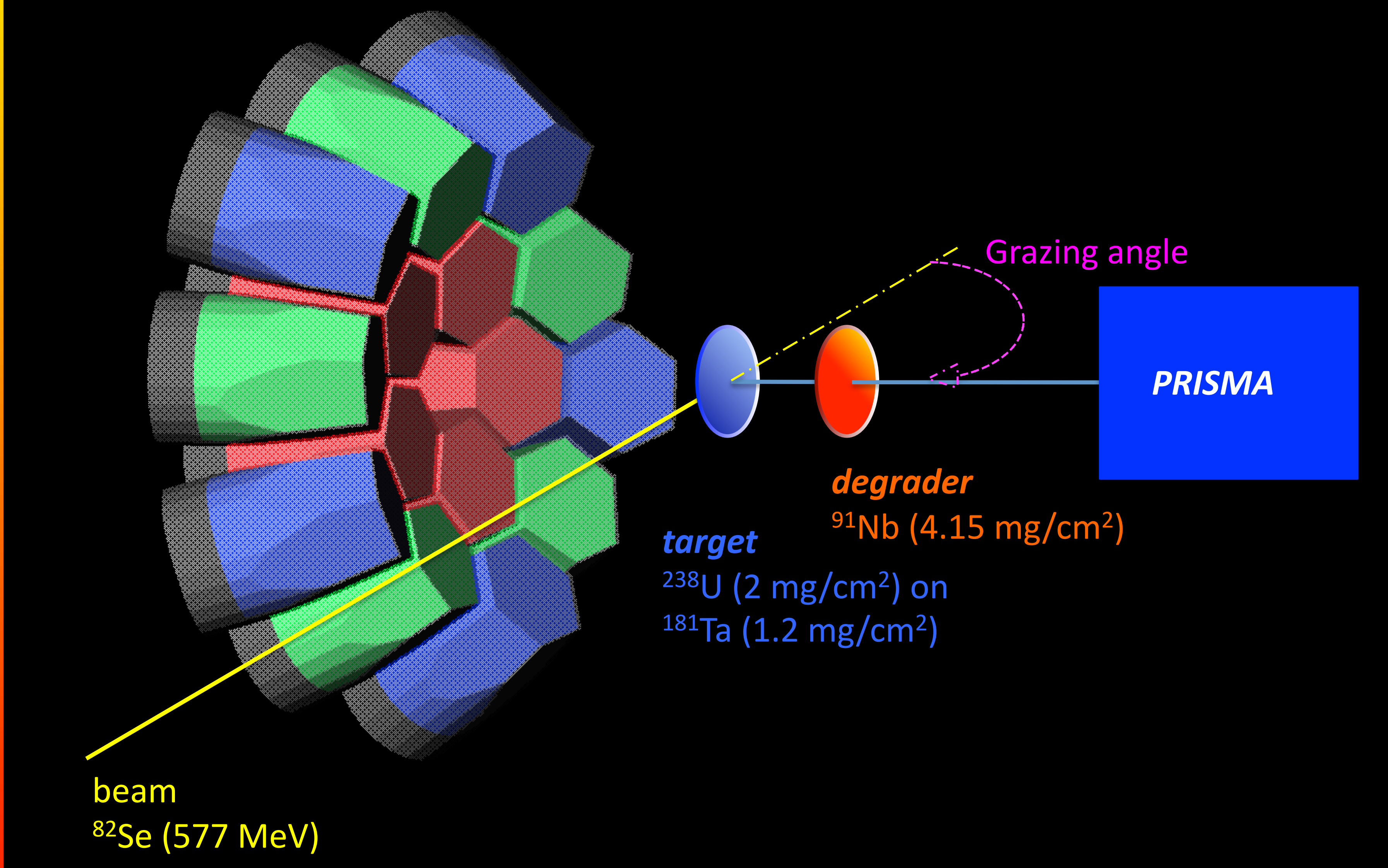
the collective states $7/2^+$ (or $9/2^+$) [$2^+ \otimes d_{5/2}$] will deexcite very quickly to the $5/2^+$ ground state by a transition of the proton core $2^+ \rightarrow 0^+$. They are about 2 orders of magnitude faster compared to the single particle states deexcitations such as $g_{7/2}$ (or $g_{9/2}$) $\rightarrow$ $d_{5/2}$.

calculated lifetimes of the 7/2+ states done by D. Verney

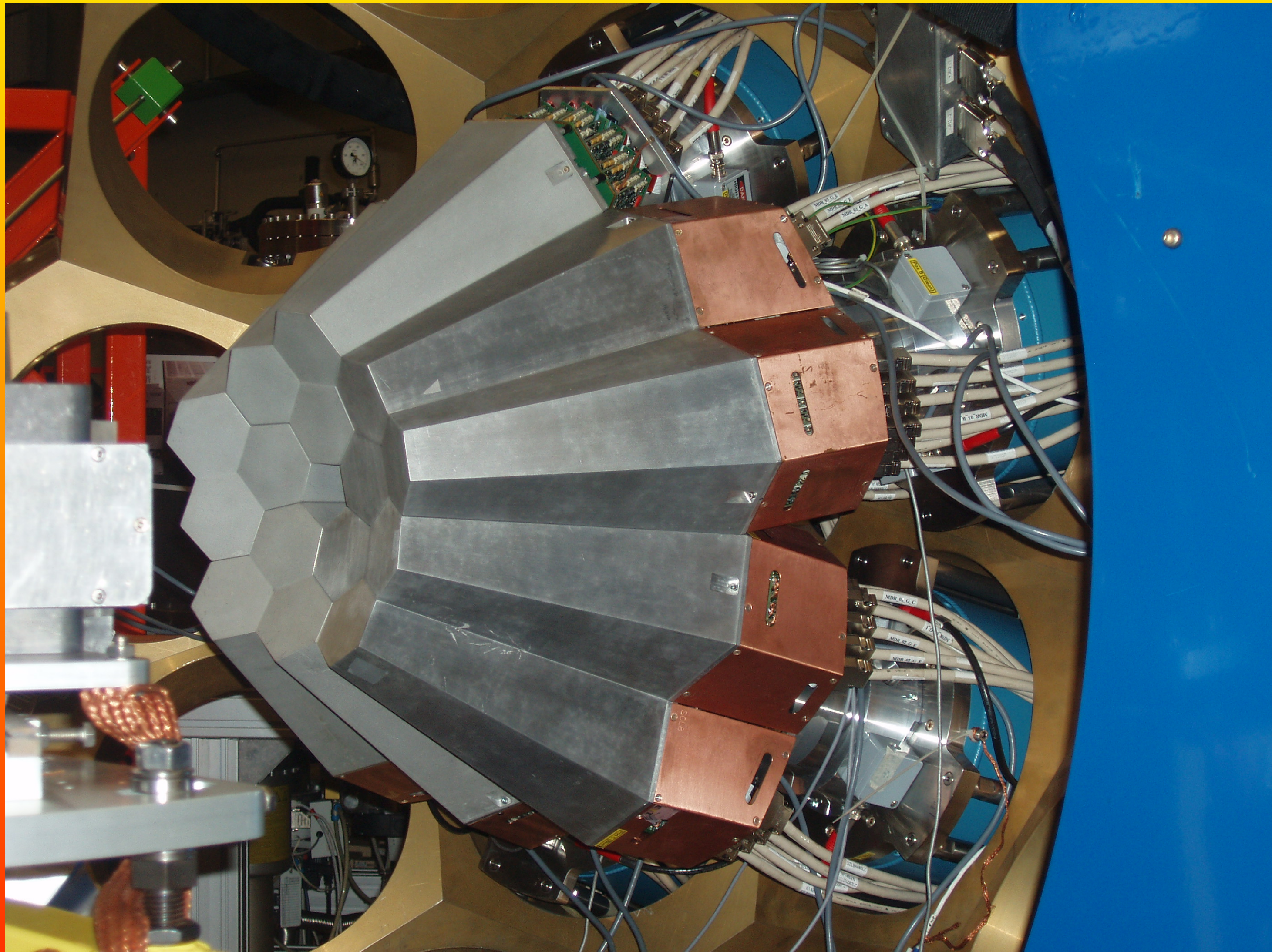
nucleus	$T(7/2^+)$ $2^+ \otimes d_{5/2}$	$T(7/2^+)$ $0^+ \otimes g_{7/2}$
^{89}Sr	0.11 ps	10.3 ps
^{87}Kr	0.13 ps	16.1 ps
^{85}Se	0.29 ps	55.1 ps
^{83}Ge	0.70 ps	214 ps

Experimental set-up - Lifetime measurements

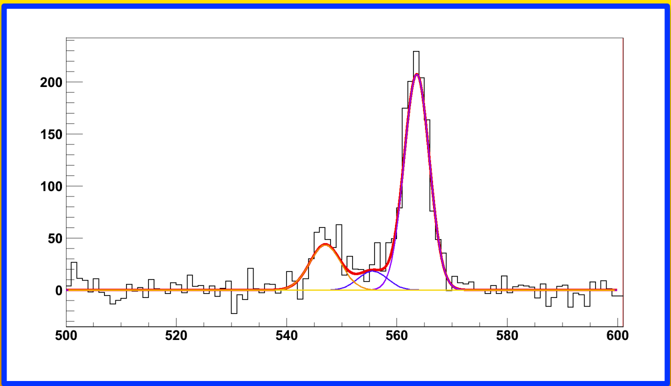
Recoil Distance Doppler Shift Method



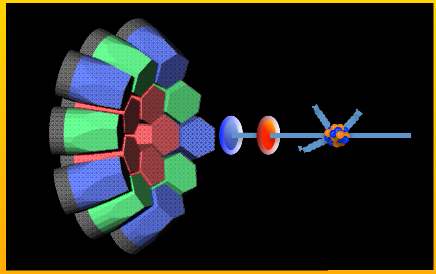
Experimental setup

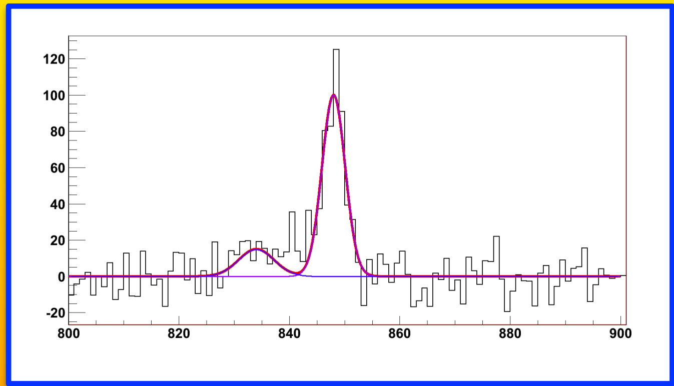


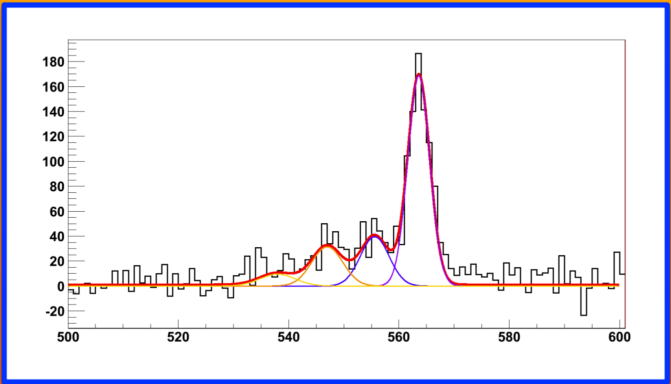
Principle of the RDDS method : case of ^{76}Ge



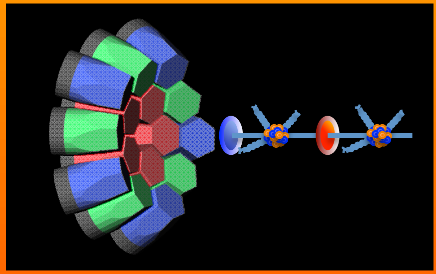
plunger distance : 54 µm

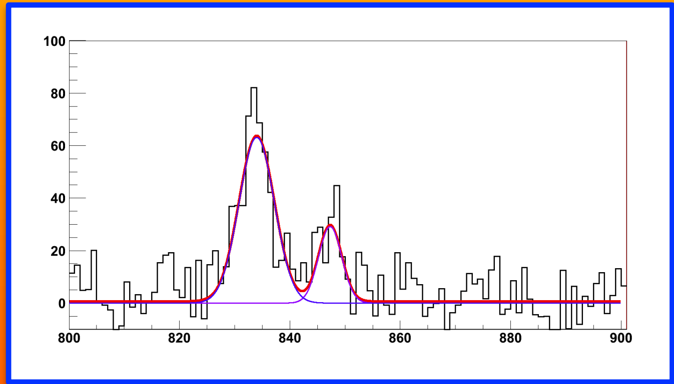


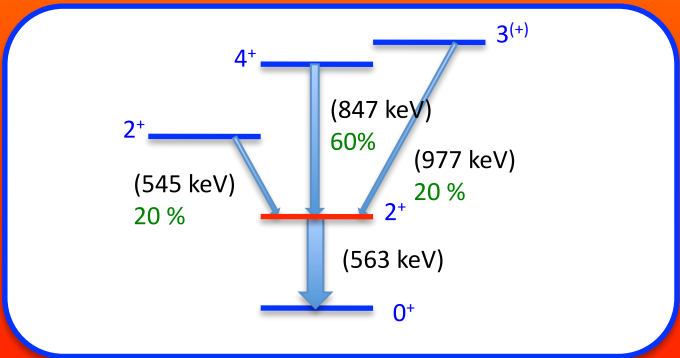




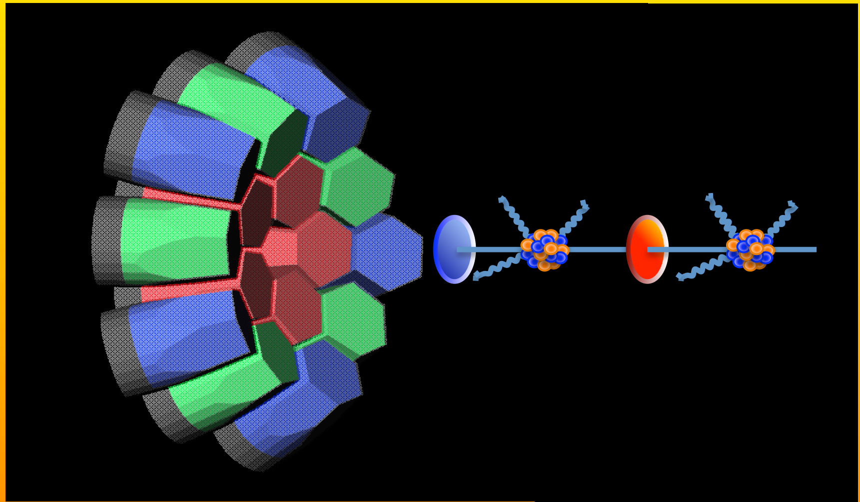
plunger distance : 277 µm

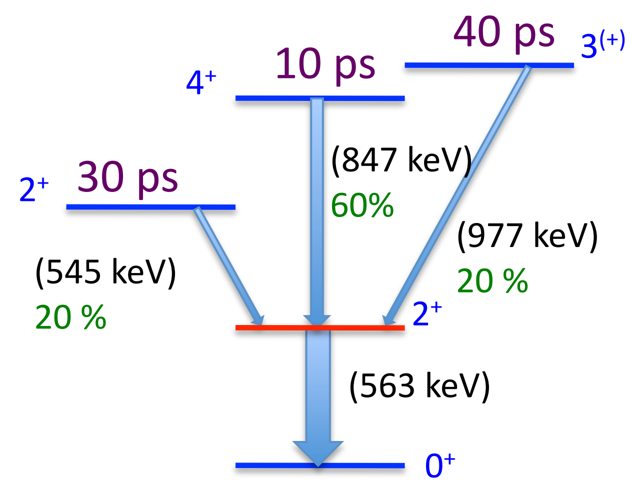






Measurement of the lifetime of the first 2^+ in ^{76}Ge





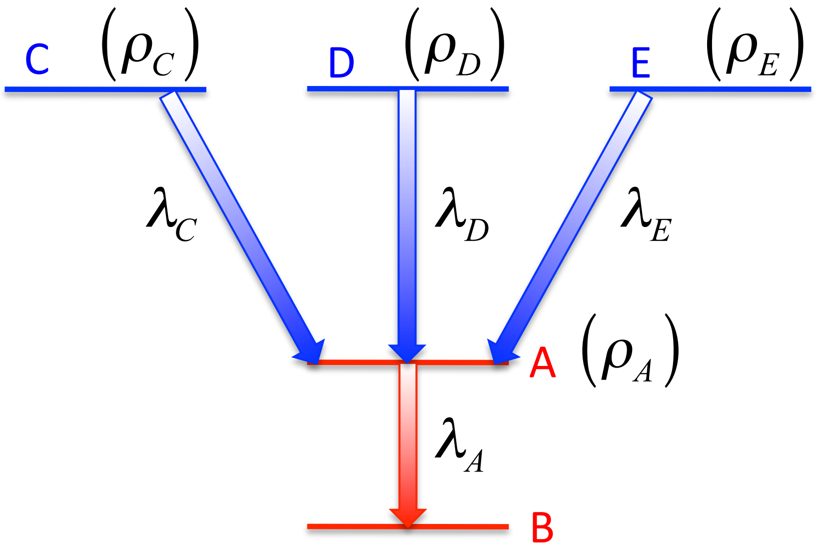
d : distance between target and degrader
τ : lifetime of the transition
v : speed of the γ emitter

$$R_i = \frac{I_u}{I_u + I_s}$$

$$\tau_i = -\frac{d}{v \, . \, Ln(R_i)}$$

Measurement of the lifetime of the first 2^+ in ^{76}Ge

Decay chain coming from
independant decays



$$\begin{cases} \dfrac{d\ N_C}{dt} = -\lambda_C N_C \\ N_C(t) = \rho_C .\exp(-\lambda_C t) \end{cases}$$

$$\begin{cases} \dfrac{d\ N_D}{dt} = -\lambda_D N_D \\ N_D(t) = \rho_D .\exp(-\lambda_D t) \end{cases}$$

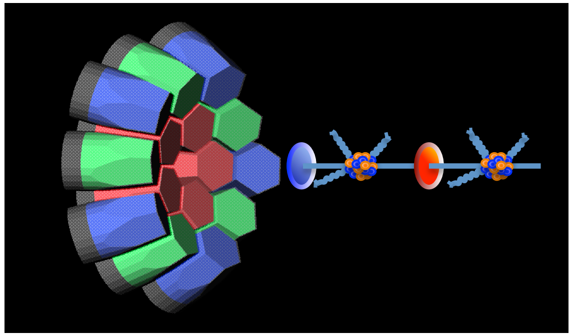
$$\begin{cases} \dfrac{d\ N_E}{dt} = -\lambda_E N_E \\ N_E(t) = \rho_E .\exp(-\lambda_E t) \end{cases}$$

$$\frac{d\ N_A}{dt} = \lambda_C N_C + \lambda_D N_D + \lambda_E N_E - \lambda_A N_A$$

Measurement of the lifetime of the first 2^+ in ^{76}Ge

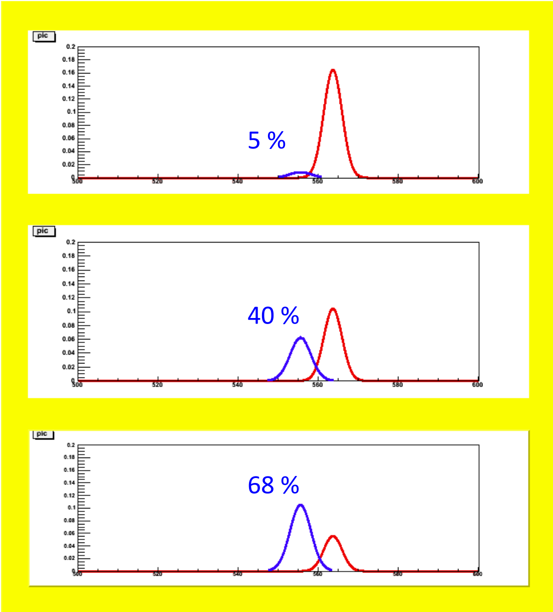
γ acumulation during the plunger time of flight :

$$\lambda_A \int_0^t N_A(t)\,dt = \rho_C\left(1 - e^{-\lambda_A t}\right) + \frac{\lambda_A \rho_C \lambda_C}{\lambda_A - \lambda_C}\left[\frac{1}{\lambda_C}\left(1 - e^{-\lambda_C t}\right) - \frac{1}{\lambda_A}\left(1 - e^{-\lambda_A t}\right)\right]$$
$$+ \frac{\lambda_A \rho_D \lambda_D}{\lambda_A - \lambda_D}\left[\frac{1}{\lambda_D}\left(1 - e^{-\lambda_D t}\right) - \frac{1}{\lambda_A}\left(1 - e^{-\lambda_A t}\right)\right]$$
$$+ \frac{\lambda_A \rho_E \lambda_E}{\lambda_A - \lambda_E}\left[\frac{1}{\lambda_E}\left(1 - e^{-\lambda_E t}\right) - \frac{1}{\lambda_A}\left(1 - e^{-\lambda_A t}\right)\right]$$

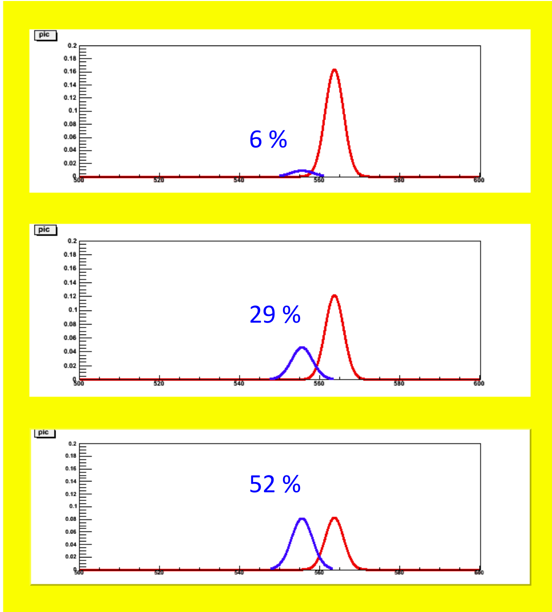


Measurement of the lifetime of the first 2^+ in ^{76}Ge

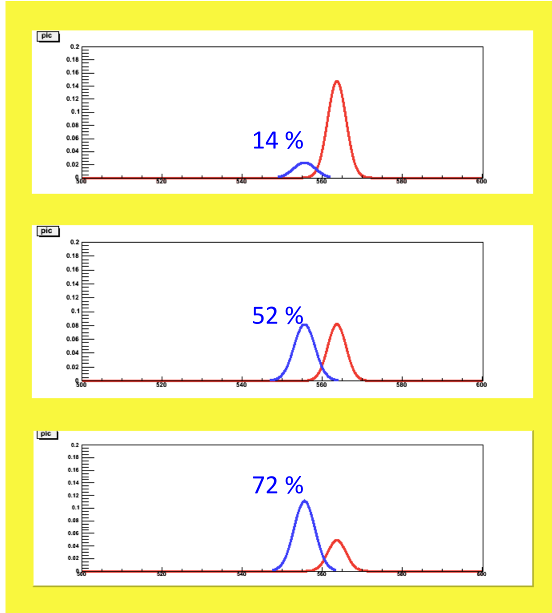
first 2^+ lifetime = 5 ps



first 2^+ lifetime = 15 ps



first 2^+ lifetime = 25 ps



Experimental measurements

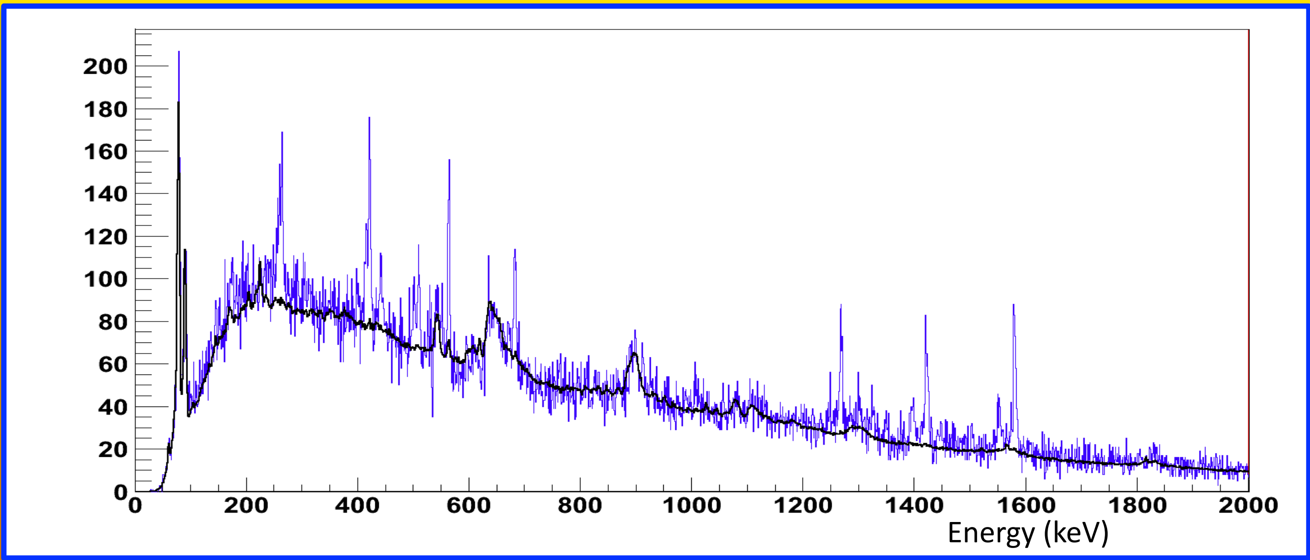
relative shifted component :

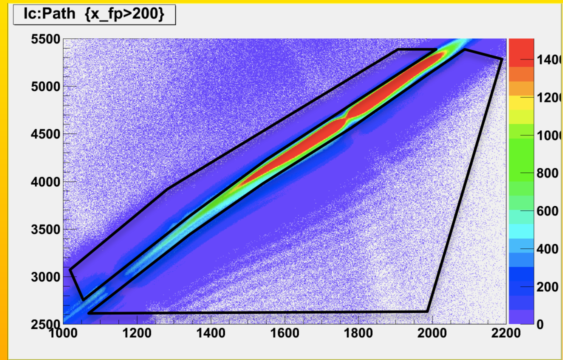
at 53.9 µm	0.09 (6)
at 276.9 µm	0.24 (5)
at 526.5 µm	0.44 (9)

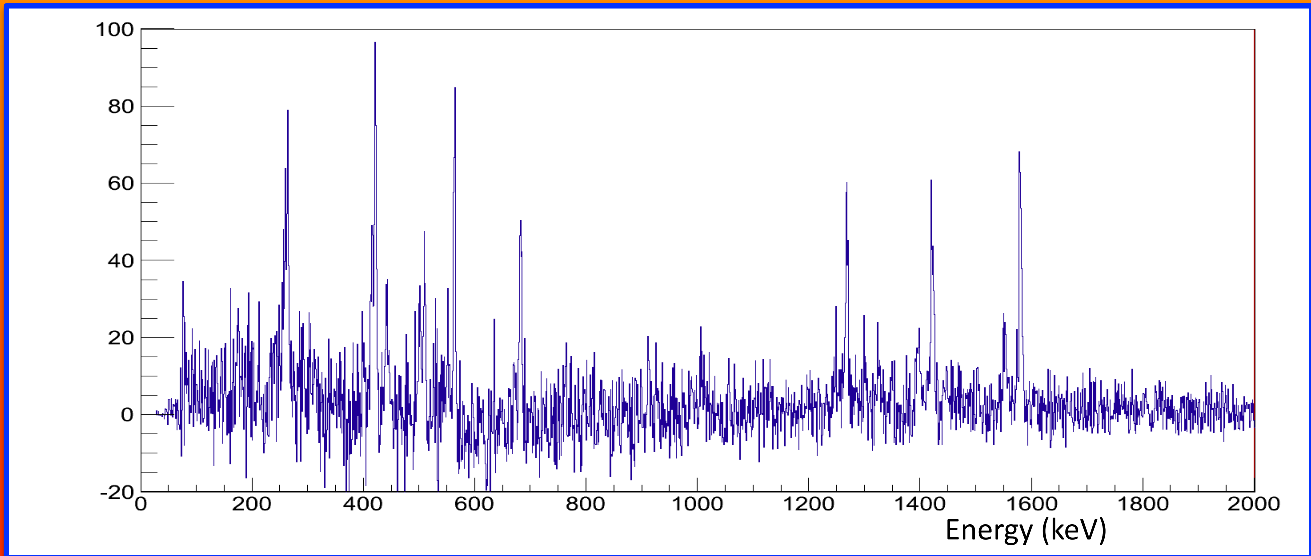
$\tau \approx 15 \pm 5$ ps

same order of magnitude than the previous lifetime measurements (27 ps)

^{87}Kr spectrum : all distances : background substraction

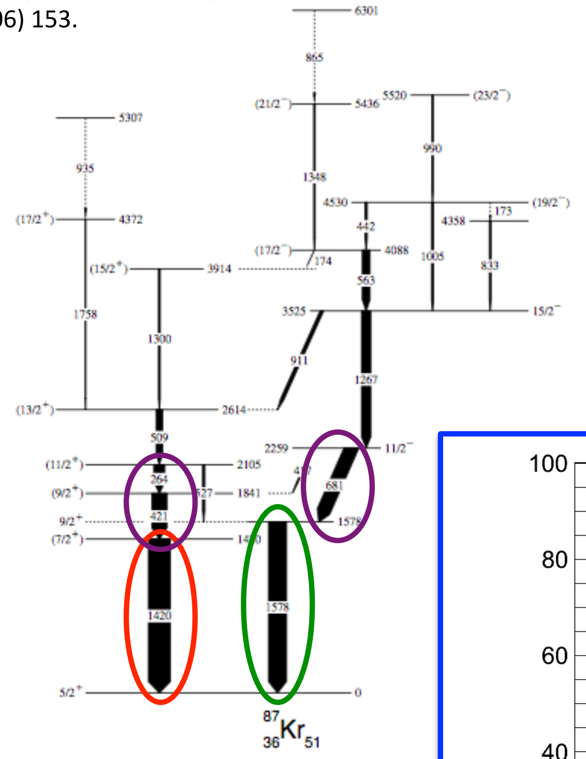






^{87}Kr spectrum : all distances

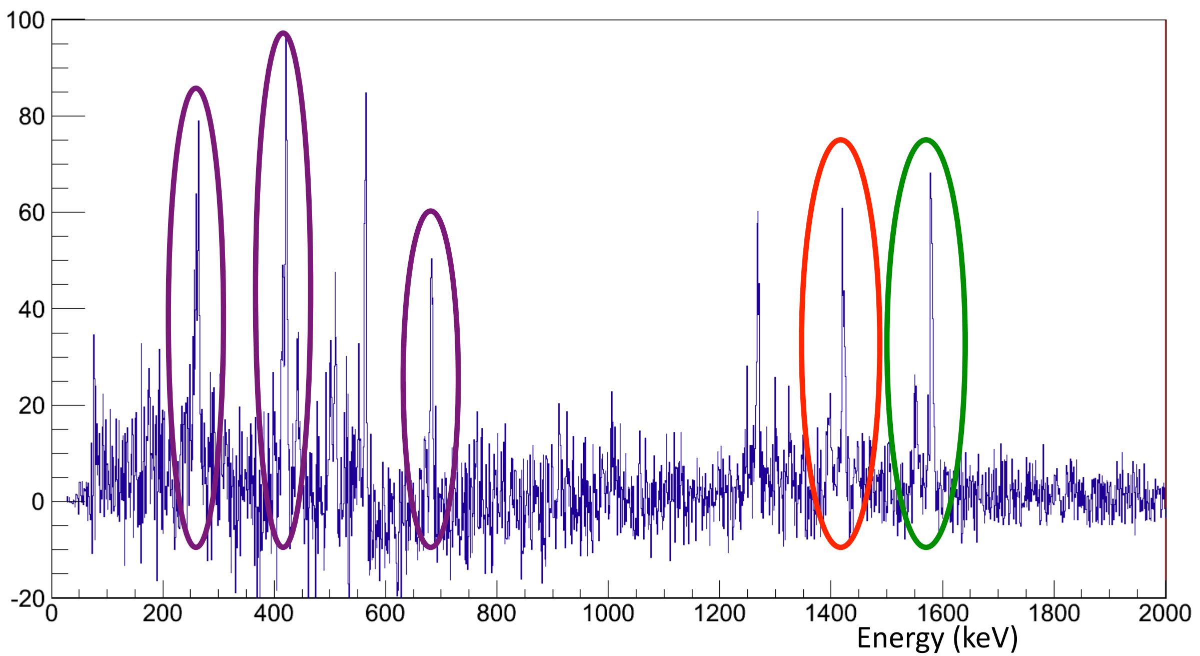
M.G. Porquet et al. Eur. Phys. J. A 28 (2006) 153.



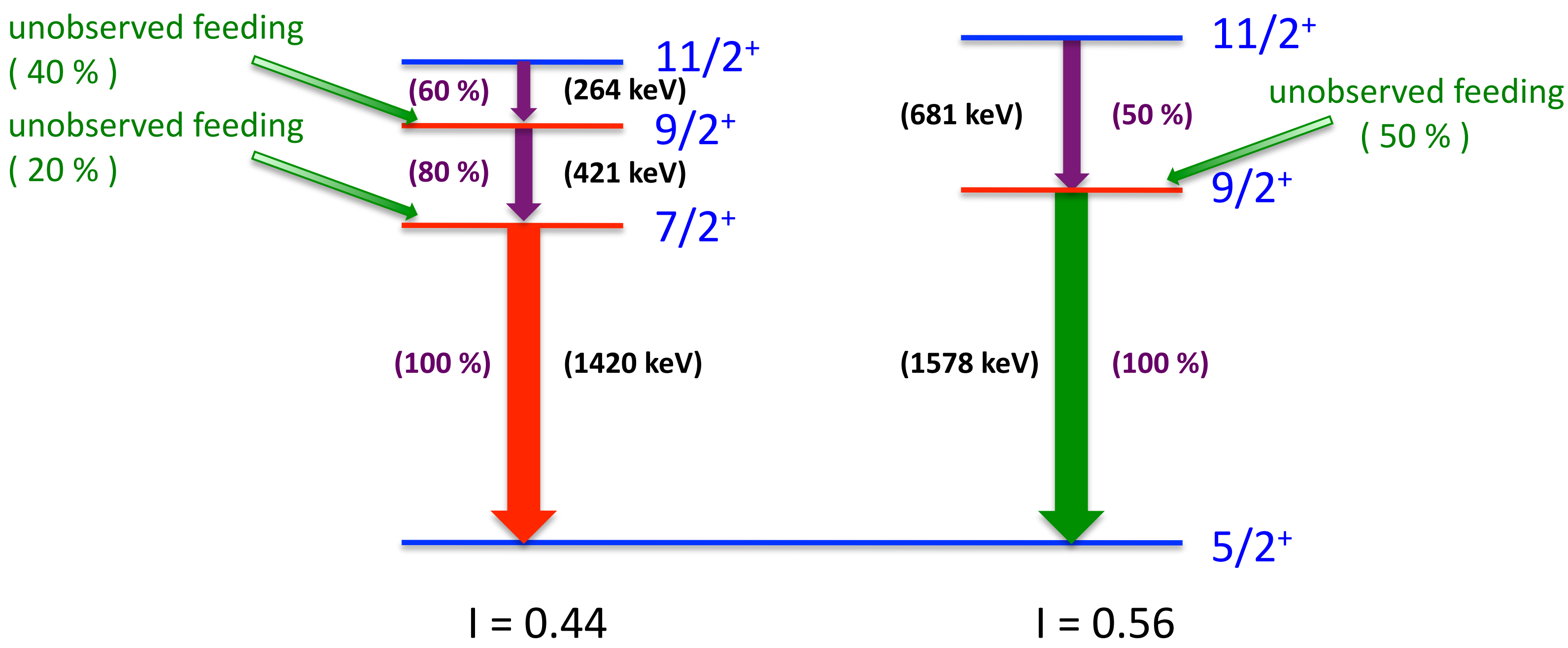
$9/2^+ \rightarrow 5/2^+$

$7/2^+ \rightarrow 5/2^+$

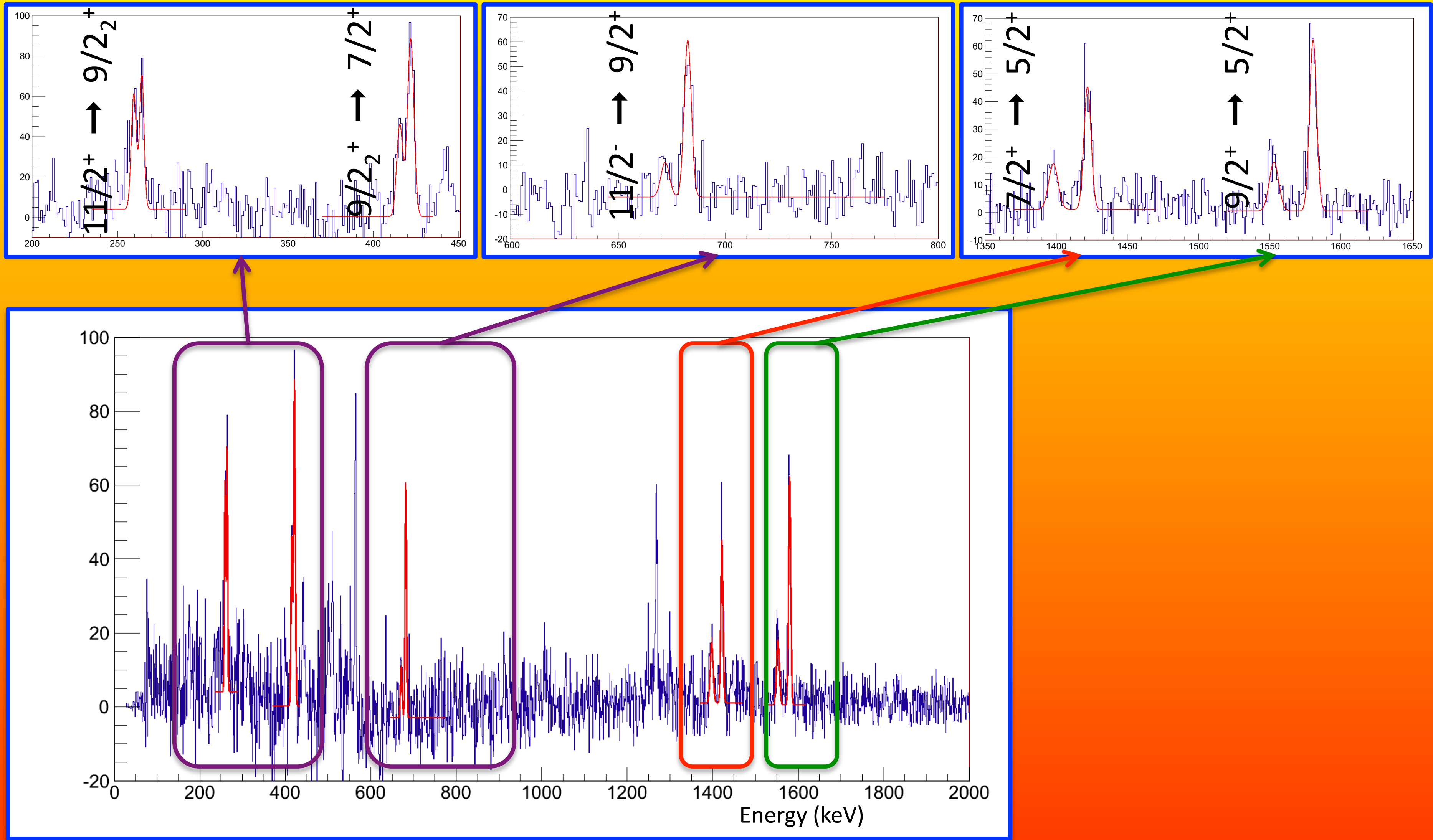
feeding



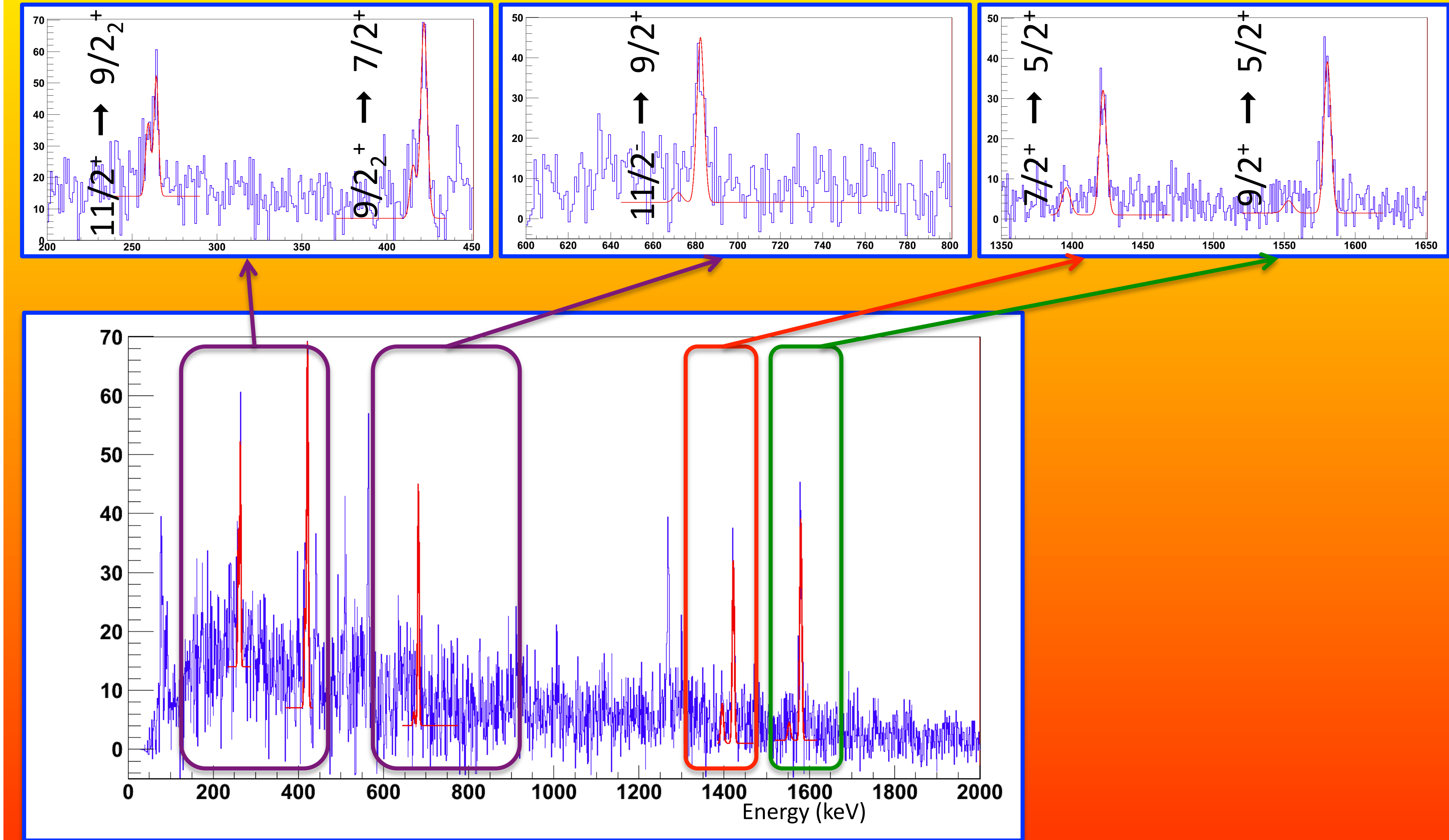
used level scheme of ^{87}Kr



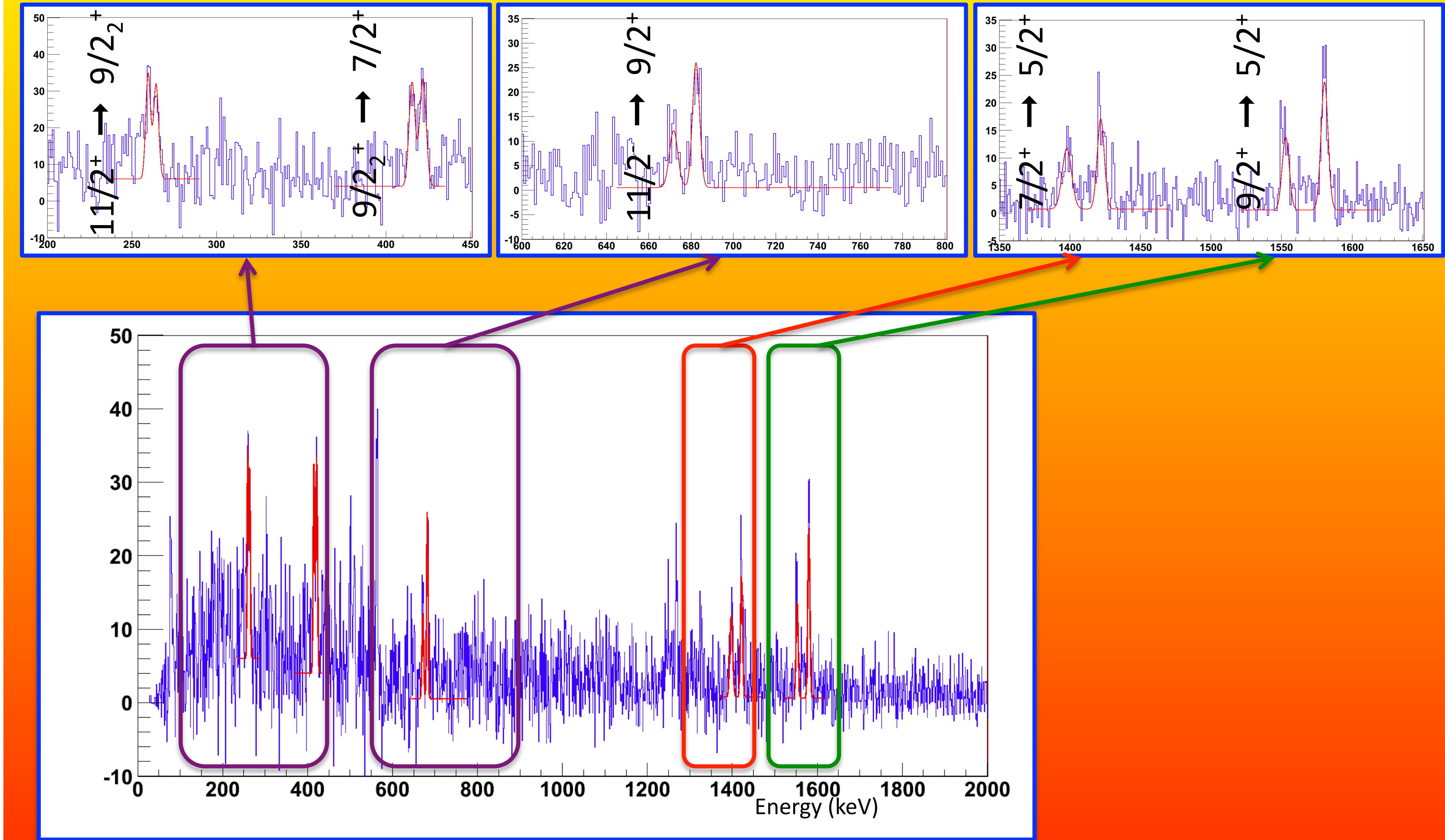
^{87}Kr spectrum : all distances



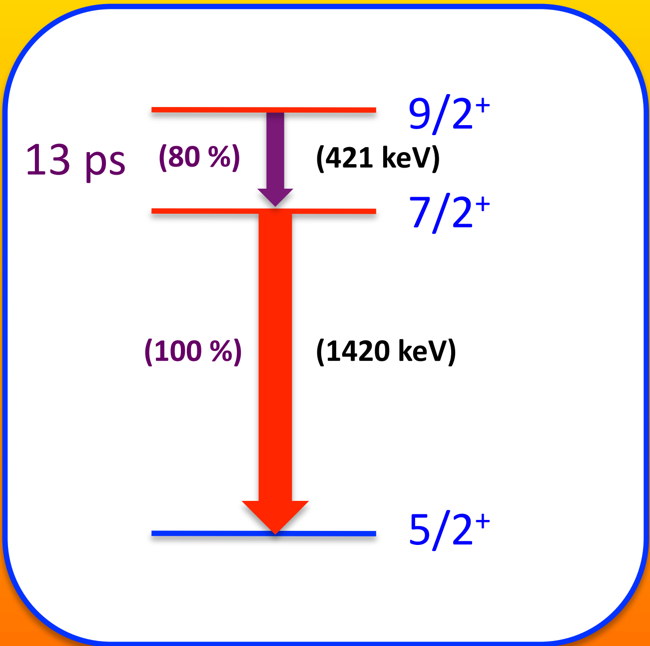
^{87}Kr spectrum : plunger distance of 54µm



^{87}Kr spectrum : plunger distance of 277μm



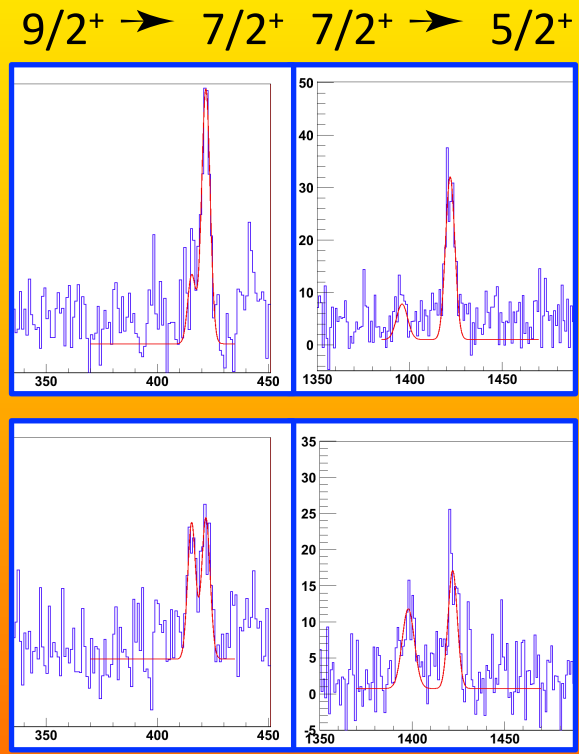
Measurement of the lifetime of the first 7/2$^+$ in ^{87}Kr



plunger :

54 µm

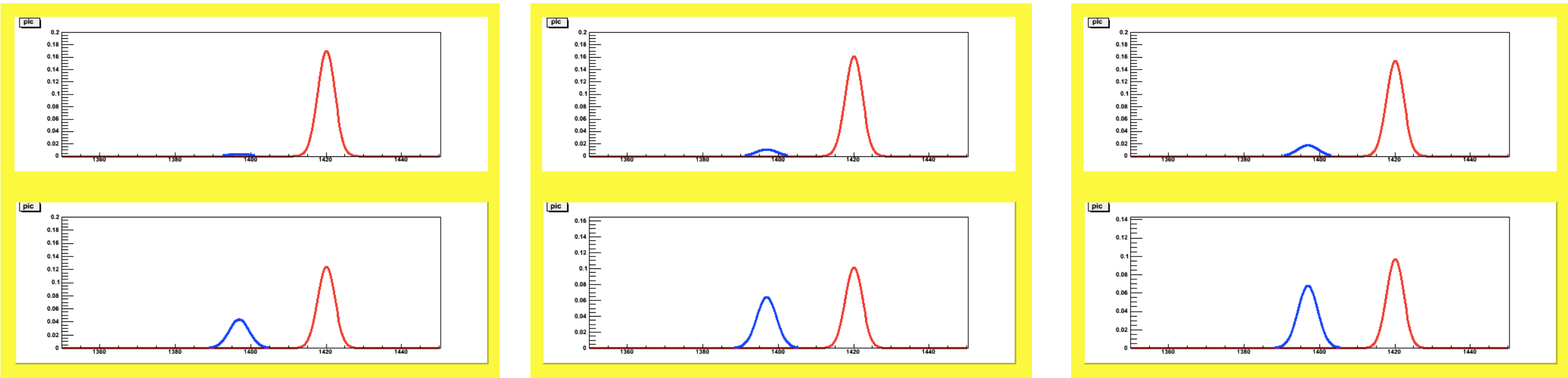
277 µm

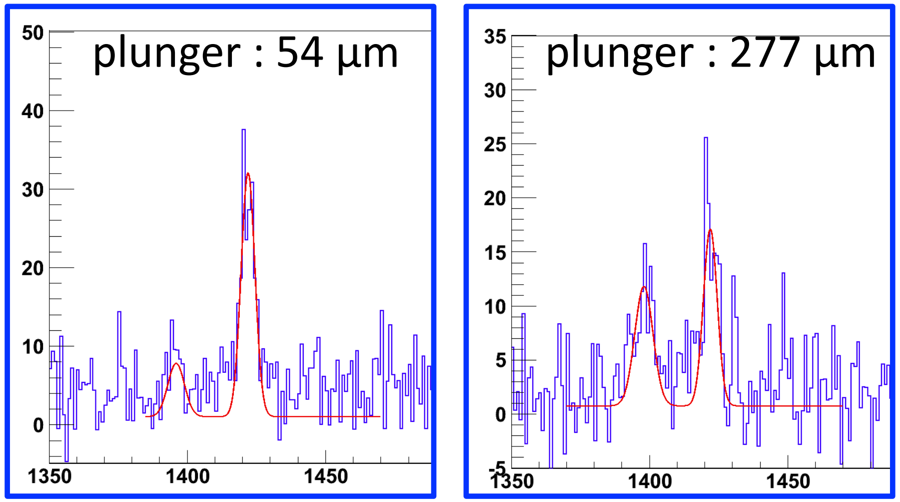


$$\tau_i = -\frac{d}{v \,.\, Ln(R_i)} = 13ps$$

Measurement of the lifetime of the first 7/2$^+$ in ^{87}Kr

7/2$^+$ at 5 ps | 7/2$^+$ at 1 ps | 7/2$^+$ at 0.1 ps





$\Rightarrow \tau < 1\,ps$

$\Downarrow$

collective configuration

Conclusion

-- We measured lifetimes of low-lying states in N=51 nuclei to determine their single particle (T~10 ps) or core+particle (collective with T~0.1 ps) character .

-- N= 51 nuclei have been produced at LNL via the $^{82}Se+^{238}U$ multi-nucleon transfer reaction; the gamma-ray emitted by the light products were detected in AGATA demonstrator (5 ATC) and the fragments identified in PRISMA.

-- Lifetime were measured with the RDDS technique using the Cologne plunger; a Nb degrader was used.

-- the goal is to determine the order of magnitude of the lifetime and only plunger positions were selected 54µm and 277µm.

-- Using Bateman equations, very preliminary results in 87Kr indicate that the first $7/2^+$ state is short lived and compatible with the collective core +particle coupling.

-- Further work will be to use the Cologne technique to cross check this conclusion and to extend the analysis to the first and second $9/2^+$states; than the study of the low-lying states in ^{85}Se will be performed.

10.41 LNL-AGATA Collaboration

F. Didierjean, G. Duchêne, D. Verney, G. de Angelis, R. Lozeva, A. Dewald, C. Fransen, J. Litzinger, S. Aydin, D. Bazzacco, A. Bracco, S. Bottoni, L. Corradi, F. Crespi, E. Ellinger, E. Farnea, E. Fioretto, S. Franchoo, A. Goasduff, A. Gottardo, L. Grocutt, M. Hackstein, F. Ibrahim, K. Kolos, S. Leoni, S. Lenzi, S. Lunardi, R. Menegazzo, D. Mengoni, C. Michelagnoli, T. Mijatovic, V. Modamio, O. Möller, G. Montagnoli, D. Montanari, A. Morales, D.R. Napoli, M. Niikura, F. Nowacki, F. Recchia, E. Sahin, F. Scarlassara, L. Sengele, K. Sieja, J.F. Smith, A. Stefanini, C. Ur, J.J. Valiente-Dobon, V. Vandone.

IPHC - University of Strasbourg, France.
IPNO - University Paris Sud – 11, France.
LNL - INFN Legnaro, Italy.
University of Padova, Italy.
University of Milano, Italy.
IKP - University of Cologne, Germany.
Technical University of Darmstadt, Germany.
Ruder Boskovic Institute of Zagreb, Croatia.