



First life time measurement in the ⁷⁸Ni region with AGATA and VAMOS at GANIL

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Outline

Physics : the ⁷⁸Ni region, monopole drift and life time measurement

Setup : AGATA, VAMOS and OUPS

Analysis : Identification with VAMOS

Analysis : Life time measurement : an example

What is the next step?

The ⁷⁸Ni region

Ν	=50
IN	= 00

z	79Kr	80Kr	81Kr	82Kr	83Kr	84Kr	85Kr	86K1	87Kr	88Kr	89Kr	90Kr	91Kr	92Kr	93Kr	94Kr	95Kr
	78Br	79Br	80Br	81Br	82Br	83Br	84Br	85Br	86Br	87Br	88Br	89Br	90Br	91Br	92Br	93Br	94Br
34	77Se	785 e	79Se	80Se	81 Se	825 c	835 e	84 Se	85Se	865e	87.Se	885e	895e	905e	91Se	925e	935e
	76As	77 As	78As	79As	80As	81As	82As	83As	84 As	85As	86As	87 As	88As	89As	90As	91As	92As
32	750e	760e	77Ge	78Ge	79Ge	80G e	81G e	82Ge	83Ge	84G e	85G e	86Ge	87G e	88G e	89Ge	90Ge	
	74Ga	75Ga	760a	77Ga	78Ga	79Ga	80Ga	81Ga	82Ga	83Ga	84Ga	85Ga	860a	87Ga			
30	73Zn	74Zn	75Zn	76Zn	77Zn	78Zn	79Zn	80Zn	81Zn	82Zn	83Zn	84Zn	85Zn				
	72Cu	73Cu	74Cu	75Cu	76Cu	77Cu	78Cu	79Cu	80Cu	81Cu	82Cu						
28	71 N i	72Ni	7 3Ni	74Ni	75Ni	76Ni	77Ni	78 N i	79Ni	80 N i				Z	=2	8	
	43		45		47		49		51		53		55		57		N

⁷⁸Ni : Most exotic spin-orbit doubly magic nuclei neutron orbitals evolution above N=50 is still scarce

The ⁷⁸Ni region

Ν	=50
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z	79Kr	80Kr	81Kr	82Kr	83Kr	84Kr	85Kr	86Kr	87Kr	88Kr	89Kr	90Kr	91Kr	92Kr	93Kr	94Kr	95Kr
ľ	78Br	79Br	80Br	81Br	82Br	83Br	84Br	85Br	86Br	87Br	88Br	89Br	90Br	91Br	92Br	93Br	94Br
4	775 e	785 e	795e	805 c	81 Se	825 c	835e	84.Se	855e	865e	87.Se	885 e	895e	905e	915e	925e	935e
	76As	77As	78As	79As	80As	81 As	82As	83As	84As	85As	86As	87As	88As	89As	90As	91 As	92As
2	750e	760 c	110e	78Ge	790e	80G e	81Ge	820 c	83Ge	84G c	85G e	86G e	87Ge	88G e	89Ge	90Ge	
	74Ga	75Ga	76Ga	77Ga	78Ga	79Ga	80Ga	81Ga	82Ga	83Ga	84Ga	85Ga	860a	87Ga			-
)	73Zn	74Zn	75Zn	76Zn	77Zn	78Zn	79Zn	80Zn	81Zn	82Zn	83Zn	84Zn	85Zn		-		
ľ	72Cu	73Cu	74Cu	75Cu	76Cu	77Cu	78Cu	79Cu	80Cu	81Cu	82Cu						
8	71Ni	72Ni	73Ni	74Ni	75Ni	76Ni	77Ni	78 N i	79 N i	80 N i				Z	=2	8	
	43		45		47		49		51		53		55		57		N

⁷⁸Ni : Most exotic spin-orbit doubly magic nuclei neutron orbitals evolution above N=50 is still scarce

$$\widetilde{\epsilon}_{j_
u} = \epsilon_{j_
u} + \sum_{j_\pi} E(j_\pi j_{pi}) n_{j_\pi}$$

$$E(j_{\pi}j_{pi}) = \frac{\sum_{J}(2J+1)\langle j_{\pi}j_{\nu}, J|V_{\pi\nu}|j_{\pi}j_{\nu}, J\rangle}{\sum_{J}(2J+1)}$$



Calculation made in order to reproduce energies in ⁸⁷Sr

$$ilde{\epsilon}_{j_
u} = \epsilon_{j_
u} + \sum_{j_\pi} E(j_\pi j_{pi}) n_{j_\pi}$$



In order to try to answer this question, we will study the vg_{7/2} evolution when removing protons.

$$E(j_{\pi}j_{pi}) = \frac{\sum_{J}(2J+1)\langle j_{\pi}j_{\nu}, J|V_{\pi\nu}|j_{\pi}j_{\nu}, J\rangle}{\sum_{J}(2J+1)}$$

The question is : what is the real importance of the tensor term in the nuclear interaction ?



Life time measurement : why ?



Life time of states is a signature of its degree of collectivity !

Acquisition system are not fast enough for measuring such a life time (from 0.1 ps to 10 ps) !

Experimental setup



VAMOS field : $B\rho_0 = 1.1$ T.m Beam : ²³⁸U (25 nA, 6.3 AMeV) Plunger distances : 100,250 and 500 μ m

Be target

Mg degrader

VAMOS

AGATA

)UPS



Grand Accélérateur National d'Ions Lourds

Exotic nuclei production

« In flight » production : a heavy projectile on a thin target so the reaction product are emitted in the forward direction



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RDDS : plunger device

RDDS : Recoil Distance Doppler Shift



If a photon is emitted before or after the degrader, the Doppler shift is different because the velocity is different

The distance D is retro-controlled by computer The correspondance between D and ToF (Time of flight) is given by ToF = D/V (where V is the velocity of the ion before the degrader)

RDDS : plunger device

RDDS : Recoil Distance Doppler Shift



A few words about AGATA

AGATA : Advanced GAmma Tracking Array



Highly segmented Ge detector in order to have access to the interaction point with a good precision (<5mm)



Reconstruction of incident γ energy through tracking algorithm Knowledge of the first interaction point : good Doppler correction

Identification in VAMOS

VAMOS : VAriable MOde Spectrometer Target Target MW X TMW1: 38 ch Y TMW1: 60 ch T start X,Y DC1 X, Y DC2X,Y DC3 Dipole X,Y DC4 dE E T stop X TMW2: 64 ch $DC_{1,2,3,4}$ IC_{0-19} MW_{0-19} Y TMW2: 92 ch x=500 10 15 0 52 3 4 5 11 16 1 6 6 7 8 9 \mathbf{Z} 27 12 17 \frown 10 11 12 13 3 13 18 8 14 1516 179 14 19 4 18 19 x = -50020 pads4x5 pads 4x160 pads

MWPPAC	Т				
MWPC	$X_i, Y_i, \theta_i, \varphi_i$				
DC	$\frac{X_{f}, Y_{f}, \theta_{f}, \varphi_{f}}{X_{f}, Y_{f}, \theta_{f}, \varphi_{f}}$	-			
	ΔE_1				
IC	ΔE_2				
	ΔE_3				
	ΔE_4				



D and Bp are reconstructed through the optical matrices of VAMOS knowing the position of the ion in the target plan dans the focal plan.

MWPPAC	. Т			A	A	
MWPC			V	Q	Q	
	$X_i,Y_i, heta_i,arphi_i$	D		V		
DC	$X_f,Y_f, heta_f,arphi_f$	B ho)	V		
	ΔE_1					
IC	ΔE_2					
	ΔE_3					
	ΔE_4					

$$B\rho = \frac{p}{q} = \frac{\gamma\beta Auc}{Qe}$$





 $\gamma = \frac{1}{\sqrt{1-\beta^2}}$





$$\Delta E_i = \sum_{j=0}^5 \beta_{ij} \Delta E_{ij}$$

$$E = \alpha_1 \Delta E_1 + \alpha_2 \Delta E_2 + \alpha_3 \Delta E_3 + \alpha_4 \Delta E_4$$



MWPPAC	Т			A	A		
MWPC	_		V	Q	Q	Q	
	$X_i,Y_i, heta_i,arphi_i$	D		V			
DC	$X_f,Y_f, heta_f,arphi_f$	B ho)	V			
	ΔE_1	ΔE					
IC	ΔE_2		E				
	ΔE_3	E_{res}					
	ΔE_4		Δ	E			

$$E = (\gamma - 1)Auc^2$$



MWPPAC	Т			A			
MWPC	_		V	Q	Q	Q	
	$X_i,Y_i, heta_i,arphi_i$	D		V			
DC	$X_f,Y_f, heta_f,arphi_f$	Bμ)	V	A		
	ΔE_1	ΔE					
IC	ΔE_2			Ŧ			
	ΔE_3	E_{res}					
	ΔE_4		Δ	E			

 $A = Q \times \frac{A}{Q}$



MWPPAC	Т			A	A		0
MWPC	_		V	Q	Q	Q	¥
	$X_i, Y_i, heta_i, arphi_i$	D		V			A
DC	$X_f,Y_f, heta_f,arphi_f$	Bρ)	v	A		
	ΔE_1	ΔE					\boldsymbol{E}
IC	ΔE_2		l	Ŧ			
IU	ΔE_3	E_{res}			2	Z	7
	ΔE_4		Δ	E			

 $\frac{\Delta E}{E} \propto Z^2$





Number of ions identified with VAMOS as a function of the number of proton and neutron



Example of life time measurement : ⁸⁶Se



R=I_U/(I_U+I_S) evolution as a function of ToF is given by Bateman equation



Perspectives

Tracking parameter optimisation

Life time measurement in ⁸⁷Kr, ⁸⁵Se, ⁸³Ge (N=51 odd isotones)

Life time measurement in other nuclei of the region (N=52 & N=54)