First life time measurement in the $^{78}\text{Ni}$ region with AGATA and VAMOS at GANIL

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Outline

Physics : the $^{78}$Ni 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 $^{78}$Ni region

$N=50$

$Z=28$

$^{78}$Ni: Most exotic spin-orbit doubly magic nuclei neutron orbitals evolution above $N=50$ is still scarce
The $^{78}$Ni region

$N=50$

$Z=28$

$^{78}$Ni: Most exotic spin-orbit doubly magic nuclei

Neutron orbitals evolution above $N=50$ is still scarce
Historical first way to express the nucleon-nucleon interaction as a central one.

A non-central term was added by Otsuka: the tensor mechanism.

Calculation made in order to reproduce energies in $^{87}$Sr.
In order to try to answer this question, we will study the $\nu g_{7/2}$ evolution when removing protons.

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: $B_{\rho_0} = 1.1 \text{ T.m}$

Beam: $^{238}\text{U}$ (25 nA, 6.3 AMeV)

Plunger distances: 100, 250 and 500 $\mu$m
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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\[
\begin{align*}
\text{^{238}U} & \rightarrow \text{^{9}Be} \\
\text{^{247}Cu^*} & \rightarrow \text{^{247-A-n}Y^*} \\
\end{align*}
\]

This reaction populate Yrast states: for a given spin-parity, it is the lowest energy one.
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 correspondence between D and ToF (Time of flight) is given by $\text{ToF} = \frac{D}{V}$ (where $V$ is the velocity of the ion before the degrader).
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A few words about AGATA

AGATA: Advanced GAamma 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

Target Position

X TMW1: 38 ch
Y TMW1: 60 ch

T start

X TMW2: 64 ch
Y TMW2: 92 ch

Dipole

T stop

X,Y DC1
X,Y DC2
X,Y DC3
X,Y DC4

dE E

X,Y DC1
X,Y DC2
X,Y DC3
X,Y DC4

MW_{0-19}

DC_{1,2,3,4}

IC_{0-19}

x=500

x=-500

20 pads

4x160 pads

4x5 pads
<table>
<thead>
<tr>
<th>MWPPAC</th>
<th>T</th>
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<tbody>
<tr>
<td>MWPC</td>
<td>$X_i, Y_i, \theta_i, \varphi_i$</td>
</tr>
<tr>
<td>DC</td>
<td>$X_f, Y_f, \theta_f, \varphi_f$</td>
</tr>
<tr>
<td>IC</td>
<td>\begin{align*} \Delta E_1 \ \Delta E_2 \ \Delta E_3 \ \Delta E_4 \end{align*}</td>
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D and Bρ are reconstructed through the optical matrices of VAMOS knowing the position of the ion in the target plan dans the focal plan.

<table>
<thead>
<tr>
<th>MWPPAC</th>
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<th>X_i, Y_i, θ_i, ϕ_i</th>
<th>D</th>
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<tr>
<td>DC</td>
<td>X_f, Y_f, θ_f, ϕ_f</td>
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<td>Dρ</td>
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<td>ΔE_1</td>
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<td></td>
<td>ΔE_2</td>
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<td>ΔE_4</td>
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\[ B_\rho = \frac{p}{q} = \frac{\gamma \beta A \mu c}{Q e} \]

\[ V = \frac{D}{T} \]

\[ \beta = \frac{V}{c} \]

\[ \gamma = \frac{1}{\sqrt{1 - \beta^2}} \]
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<td>( B \rho )</td>
<td>( V )</td>
</tr>
<tr>
<td>DC</td>
<td>( X_f, Y_f, \theta_f, \varphi_f )</td>
<td>( \Delta E )</td>
<td>( E )</td>
<td>( E_{res} )</td>
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\[
\Delta E_i = \sum_{j=0}^{5} \beta_{ij} \Delta E_{ij}
\]

\[
E = \alpha_1 \Delta E_1 + \alpha_2 \Delta E_2 + \alpha_3 \Delta E_3 + \alpha_4 \Delta E_4
\]
\[ E = (\gamma - 1)Au\epsilon c^2 \]

\[ Q = \frac{A}{\frac{A}{Q}} = \frac{E}{(\gamma - 1)u\epsilon c^2} \]
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<td>( \Delta E_4 )</td>
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\[
A = Q \times \frac{A}{Q}
\]
\[ \frac{\Delta E}{E} \propto Z^2 \]

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**Diagram:**

- The diagram shows a 3D plot of \( \Delta E \) vs. \( E \) with color coding indicating different values of \( E \) and \( Z \).
- The plot includes lines for various elements: Sr (Z=38), Rb (Z=37), Kr (Z=36), Br (Z=35), Se (Z=34), At (Z=33), Ge (Z=32), Ga (Z=31), etc.
- The color scale ranges from 0 to 35 MeV.

**Conclusion:**

The provided data and diagram suggest a relationship between \( \Delta E \), \( E \), and \( Z \) that can be described by the equation \( \frac{\Delta E}{E} \propto Z^2 \). The 3D plot visualizes this relationship with varying \( Z \) values for different elements.
Number of ions identified with VAMOS as a function of the number of proton and neutron
$^{86}\text{Se}$

Sum of all distances $\gamma$-spectrum
Example of life time measurement: $^{86}\text{Se}$

Preliminary Results

$2^+ \rightarrow 0^+$  
$4^+ \rightarrow 2^+$

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

Tracking parameter optimisation

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

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