The Plunger Setup for AGATA at PRESPEC

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• Motivation: lifetime measurements in exotic nuclei
• Example: investigation of n-rich Fe at NSCL, MSU
• Construction of a new plunger for PRESPEC
• AGATA@PRISMA with the Plunger
Studies of Exotic Nuclei

Many-body problems for strongly-interacting system with protons and neutrons

Stable nuclei
Shell structure
magic number (2,8,20…)

Exotic nuclei
Drastic change of shell structure
disappearance (N=8,20,..) and appearance of magic numbers N=16,34

What is the driving force responsible for the shell evolution?
Can we characterize the structure changes in a simple manner?
The recoil distance Doppler-shift method (RDDS): lifetimes, absolute transition strengths

\[ E_{\text{obs}} = E_0 \cdot \left( \frac{\nu}{c} \cos(\theta) \right) \]

\[ \tau(t_k) = \frac{I^{us}(t_k)}{\frac{d}{dt} I^{sh}(t_k)} \]

- \( I^{us} \) = Intensity of the unshifted \( \gamma \)-ray line
- \( I^{sh} \) = Intensity of the Doppler-shifted component

Use degrader instead of stopper to allow identification of recoils

Particle ident.: LYCCA S800 (MSU)
Example (NSCL, MSU): Neutron-rich Fe isotopes

In the vicinity of $N=40$, only Ni isotopes show a typical signature of magicity with high $E(2^+)$ and small $B(E2)$.

Low $E(2^+)$ for other isotopes indicate a fragility of the $N=40$ (sub) shell closure.

Collectivity at $N=40$ seems to be increased toward lighter isotopes ($\text{Ni} \rightarrow \text{Fe} \rightarrow \text{Cr}$).

(E(2+) $^{66}\text{Fe}$ : M.Hannawald et al., PRL82(99)1391 $^{64}\text{Cr}$ : A.Gade et al., PRC81(10)051304R)

But, $B(E2)$ data are still scarce.

Recent $B(E2)$ data on $^{62,64}\text{Fe}$ (J.Ljungvall et al., PRC81(10)061301R) suggest an increase of collectivity towards $N=40$. How about $^{66}\text{Fe}$?
$^{62,64,66}\text{Fe}: \ 2_1^+ \ \text{lifetime measurement at NSCL}$

NSCL coupled cyclotron facility + A1900; MSU

$^{76}\text{Ge} \quad 130 \text{ AMeV}$

RDDS applied to projectile ($^{62,64,66}\text{Fe}$) Coulomb excitation reactions at intermediate energies (88-98 AMeV)
Comparison with shell model in the $fpgd$ space

Symmetry with respect to $Z \approx 30$, and shell evolution at $N=40$

$Z \leq 26$ (Fe) \hspace{1cm} $\nu(1g_{9/2}) \uparrow_{40}$ \hspace{1cm} $34 \leq Z$ (Se) \hspace{1cm} $\nu(1g_{9/2}) \downarrow_{40}$

$\pi(1f_{7/2})$ \hspace{1cm} $\nu(1f_{5/2})$ \hspace{1cm} $\pi(1f_{5/2}) \nu(1f_{5/2})$

proton-neutron monopole tensor int.

Recent shell model calculations with new effective LNPS interaction (by S.M.Lenzi, F.Nowacki, A.Poves, K.Sieja) well explain the trends of $B(E2)$ for $^{62,64,66}$Fe at $N=40$

Construction of a new plunger for PRESPEC

Requirements:

• No material in front of plunger target due to beam halo: avoid scattering on plunger structure

• Inner target/degrader diameter: 80 mm

• Thick, massive targets and degraders: thickness in mm range, weight up to 50-100 g: need stable construction

• Recoil velocities: typically around 100 MeV/u corresponding to v/c = 0.5 or v = 1.5 mm/ns = 1.5 μm/ps
  Need precision of a few 10 μm for short lifetimes in ps range for long lifetimes up to few 100 ps: large distances up to cm range

• Mount DSSD detector close to plunger
New plunger for PRESPEC

Flat spring

Piezo crystal for feedback system

Inchworm motor (Piezo Instruments)

Construction: S. Thiel, IKP, Cologne

Open questions:

• Construction warp resistant?
• If not: further inchworm needed to make construction precise enough?
• In that case: need to run inchworm motors in parallel: teststand under development
New PRESPEC plunger mounted in chamber

- Commissioning run already in April 2011 (probably)
- New PRESPEC chamber will not be finished till this run
- Construct own chamber for plunger for existing setup: with smaller diameter of 30 cm.
- Thus can be made in Cologne
New chamber will have lid that can be removed for aligning and adjusting plunger
Possibility to mount Si-detector up- or downstream from plunger: where?

Propose: construct holding structure to support Si detector from beam pipe
Missing so far: support structure for plunger. Will be done similar to LNL/GANIL plunger. Modification: possibility to move plunger upstream to increase angular resolution.
LNL/GANIL plunger

Adjustable ring for plunger
New inchworm motor: performance

New type of inchworm motor was tested manufactured by PI Piezo Instruments, type N381 K001

- Accuracy: \( \leq 0.5\mu m \) (reproducible)
- Accordance between motor and micrometer distance measurement: \( \leq 0.5\mu m \)
- Maximum driving distance: 30mm
- Dimensions:
  - diameter: 25 mm
  - length: 119 mm (only motor)
Software written by T. Pissulla was used already in different experiments. Performance: running stable and reliable.
Approved commissioning experiment:
Investigation of $^{122}\text{Cd}$ with the RDDS method and new Cologne differential plunger at PRESPEC

Aim: application of Cologne differential plunger for lifetime measurements at HISPEC/PRESPEC with Coulex in inverse kinematics

Measure $B(E2,0^+ \rightarrow 2^+_1)$ in $^{122}\text{Cd}$:
Determine from lifetimes measured with plunger
Compare to $B(E2,2^+_1 \rightarrow 0^+_1)$ from Coulex

Incoming Beam cocktail
93% $^{122}\text{Cd}$, ...

E - 220 MeV/u
E' ~ 120 MeV/u
E'' ~ 100 MeV/u

$\beta = 0.59$

Gold 2000 mg/cm$^2$

$\beta' = 0.46$

$\gamma'$

$\beta'' = 0.43$

$\gamma''$

LYCCA

to the $\gamma$-ray detector

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Lifetime $\tau$ [ps]</td>
<td>14.4</td>
</tr>
<tr>
<td>Doppler-shifted $\gamma$-ray energy after plunger-target at $15^\circ$ [keV]</td>
<td>914.2</td>
</tr>
<tr>
<td>PRESPEC $\gamma$-ray energy resolution [%]</td>
<td>4</td>
</tr>
<tr>
<td>Averaged cross section for Coulex in target [mb]</td>
<td>300</td>
</tr>
<tr>
<td>Cross section for Coulex in degrader [mb]</td>
<td>140</td>
</tr>
<tr>
<td>Number of detected good PRESPEC-LYCCA coincidences/h</td>
<td>172</td>
</tr>
<tr>
<td>Shifts per single target-degrader data point</td>
<td>1</td>
</tr>
<tr>
<td>Estimated number of shifts</td>
<td>3</td>
</tr>
</tbody>
</table>

Approved parasitic experiment
21 parasitic shifts (Spring 2011)
A new plunger at PRESPEC: conclusion

• New plunger for PRESPEC under development

• PRESPEC plunger will allow precise lifetimes measurements of excited 2+ state in very exotic nuclei: knockout reactions, Coulex(?)

• New inchworm motors will be used: testing finished

• Software for operating plunger existing and performing well.

Compact plunger for proposed experiments already successfully used at GANIL and at LNL in last campaign in June 2010 (E. Sahin, J.J. Valiente-Dobon).

Modifications for large grazing angles up to 60 deg.

Proof of principle with fixed Plunger with PRISMA/CLARA (J.J. Valiente-Dobon et al., PRL 102, 242502 (2009))

(from A. Stefanini et al., Nucl. Phys. A 701, 217c (2002))
Compact plunger at PRISMA
Several experiments performed with this new plunger at LNL (see, e.g., talk by E. Farnea)

A. Gadea, et al., to be submitted to NIM (will contain section on plunger by A. Dewald, T. Pissulla)