Spectroscopy of n-rich nuclei at LNL with CLARA-PRISMA

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• Description of the setup, grazing reactions as mechanism to study the structure of moderately neutron-rich nuclei

• Results on n-rich nuclei from N=28 (A~40) to N=50 (A~80)

• Outlook (AGATA Demonstrator at PRISMA)
PRISMA: Large acceptance tracking Magnetic Spectrometer Q-D
Designed for the HI-beams from XTU-ALPI
\( \Omega = 80 \text{ msr} \)
\( \Delta Z/Z \approx 1/60 \text{ (Measured) IC} \)
\( \Delta A/A \approx 1/190 \text{ (Measured) TOF} \)
Energy acceptance \( \pm 20\% \)
Max. \( B \rho = 1.2 \text{ T.m.} \)
Tracking on PRISMA

A/q

true recoil velocity
trajectory in dipole

\[ \frac{A}{q} \]

\[ \text{true recoil velocity} \]
\[ \text{trajectory in dipole} \]

MCP-MWPPAC

\[ \Delta \text{TOF}=0.5 \text{ ns} \]

S. Beghini et al. NIM A551, 364 (05)
G. Montagnoli et al. NIM A547, 455 (05)
CLARA: Clover Detector array

25 Euroball Clover detectors (EB GammaPool)
Performance at $E_\gamma = 1.3\text{MeV}$
Efficiency $\sim 3\%$
Peak/Total $\sim 45\%$
FWHM $< 10 \text{ keV}$
(at $v/c = 10\%$)
Grazing reactions transferring several nucleons as a tool to study n-rich nuclei

Deep-inelastic reactions used since thick target pioneering work of R.Broda et al. (PLB 251 (90) 245)

Use of Multinucleon-transfer triggered by the LNL reaction mechanism group.

**82\text{Se} + 238\text{U} E=505 \text{ MeV}**

Approximate cross sections [mb]

- **82\text{Ge}**
- **80\text{Zn}**

**Effective Pairing Term**

Grazing calculations

Sequential Transfer

L.Corradi et al., Phys.Rev.C59 (99)261, Theory: G.Pollarolo
Evolution of magic numbers and collectivity in n-rich nuclei

Shell Model States in $^{48}$Ca Region

Island of Inversion. From N=20 to N=28

Evolution of the shell gap N=50

Shell Closures and Collectivity in A~60 nuclei towards N=40
From N=20 to N=28 \( ^{36}\text{S} \) 230 MeV + 208\text{Pb} \( \theta_g=56^\circ \)

R.Chapman,X.Liang (Manchester), M.Stanoiu, F.Azaiez (IPN Orsay)

Effect of the occupancy of the \( \nu 1f_{7/2} \) orbital on the \( \pi d_{3/2} \) and \( \pi s_{1/2} \) single particle energy separation.

“Pseudo-SU(3)” symmetry and quadrupole deformation in n-rich S (N=24,26) isotopes
Harm. vibr. to rotor Si → Mg at N=22

D.O'Donnell et al., LNL Ann.Rep (06)

Parallel work K, Cl, P
A.Gade PRC 74(06)

O. Sorlin EPJA 22(04)173

36Si

41Cl

Deformation (42S)

X.Liang et al., PRC74 (06) 014311

Sdfp SM Strasbourg-Madrid

O. Sorlin EPJA 22(04)173
Shell Model States in the $^{48}$Ca Region

$^{48}$Ca 330MeV + $^{238}$U

Tandem-ALPI

$\theta_g = 52^\circ$

R. Broda, B. Fornal et al.,

$^{48}$Ca(330MeV) + $^{238}$U

48Ca 330MeV + 238U

$\gamma - \gamma$ Coincidences

N=32

$\nu_{3/2}$ $\nu_{1/2}$ $\nu_{5/2}$

$\pi_{1/2}$ $\pi_{3/2}$ $\pi_{5/2}$

CLARA-PRISMA

$\gamma$-product Coincidences

B. Fornal, R. Broda et al., to be published
- Gamma lines identified from CLARA-PRISMA
- Level scheme from GammaSphere coincidence analysis

Energies of the lowest $1/2^+$, $3/2^+$ and $7/2^-$ in odd K isotopes

R. Broda, B. Fornal et al., to be published
Evolution of the N=50 Shell Gap

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<th>Element</th>
<th>Mass Number</th>
<th>Proton Number</th>
<th>Neutron Number</th>
<th>Spin</th>
<th>Parity</th>
<th>Mass (amu)</th>
<th>Width (keV)</th>
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82\text{Se} + 238\text{U} E=505\text{MeV}

Tensor monopole

Major role in OBEP for $\pi$ and $\rho$ mesons

$g_{9/2}$

$f_{5/2}$

$f_{7/2}$

proton

neutron

G.Duchêne, G.deAngelis, E.Sahin, T.Faul
Spectroscopy of the N=50 Isotones

\[\sigma \approx 0.6\text{mb}\]
$^{82}\text{Se} + ^{238}\text{U} \ 505 \text{ MeV} \ 13 \text{ days}$

PRELIMINARY

$^{82}\text{Ge}$

$(6^+) \rightarrow 4^+$

$4^+ \rightarrow 2^+$

$2^+ \rightarrow 0^+$

G.Duchêne, G.deAngelis, E.Sahin, T.Faul

keV
Fix effective SPE and TBME for $\pi$

Even-even N=50 isotones

\[ \varepsilon(\nu d_{5/2}) - \varepsilon(\nu g_{9/2}) \]

N=50

\[ ^{82}\text{Ge} \]

Neutron energy Gap reduced of \(~ 20\%\)

N~40: Neutron-rich Fe isotopes

$^{64}\text{Ni}$ (400 MeV )$^+$ $^{238}\text{U}$

CLARA-PRISMA

$\theta_G = 64^\circ$

Doubly magic character

R. Broda et al., PRL 74 (95) 868

Yrast states: evolution of the collectivity towards N=40 in the Fe (Z=26) isotopes

First indication of N=32 shell gap in Cr isotopes

J. I. Prisciandaro et al PLB510(01)17

Present in the in the $1\pi f7/2$ band in $^{55,57}\text{V}$

S. Lunardi, S. M. Lenzi, S. Freeman
$^{64}\text{Ni} \ (400 \text{ MeV}) + ^{238}\text{U} \ (\theta_{\text{grazing}} = 64^\circ)$
Spectroscopy around the N=32 shell closure

First identification of yrast states in $^{55}$V and $^{57}$V

$^{64}$Ni(400 MeV) + $^{238}$U

N=32 shell closure as previously observed in $^{54}$Ti and $^{56}$Cr, N=34 could not be confirmed.
SM calculations for Fe nuclei
- Core $^{48}$Ca
- fp for protons
- $p_{3/2}, f_{5/2}, p_{1/2}, g_{9/2}$ for neutrons

S. Lunardi, S. Lenzi et al. to be submitted

also in $\beta$-decay
M. Hannawald et al., PRL 82 (99)
Differential RDDS Measurements with CLARA-PRISMA

A. Dewald, N. Marginean, A. Gadea

Differential Plunger for angles $\neq 0^\circ$

Beam: $^{64}\text{Ni}$ at 400MeV
Target: $^{93}\text{Nb}$ 1mg/cm$^2$ + $^{208}\text{Pb}$ 1mg/cm$^2$
Degrader: $^{24}\text{Mg}$ 2mg/cm$^2$
$^64\text{Ni}$ Inelastic Scattering

\[ T_{1/2} (4^+) = 4.2^{+14} \text{ ps} \]

\[ T_{1/2} (4^+) = 4.7^{+13} \text{ ps} \]

\[ T_{1/2} (4^+) = 4.8^{+15} \text{ ps} \]

\[ \bar{\nu} = 1.7 \]

\[ \bar{\nu} = 5.7 \]

\[ \bar{\nu} = 7.5 \]
Preliminary Results for 150μm Target-Degraded Distance

Test case $^{60}$Fe

$(2^+ \text{ at } 824 \text{ keV})$

$T_{1/2} = 8.2(15) \text{ ps}$

(known $8.0(15) \text{ ps}$)

$B(E2)=0.018 \text{ e}^2\text{b}^2$

(13 W.u.)

Sign of "longer" lifetime in $^{62}$Fe

$(2^+ \text{ at } 877 \text{ keV})$

$T_{1/2} \approx 9.5(20) \text{ ps}$

$B(E2) \approx 0.012 \text{ e}^2\text{b}^2$

(8 W.u.)
Outlook:

- CLARA will be dismounted on Spring 2008 after 3 years providing valuable structure information on moderately n-rich nuclei.
- During 2008 the AGATA Demonstrator will be mounted and commissioned at the PRISMA target position.

- The AGATA Demonstrator will improve the efficiency (x2) and resolution (x3) of the setup.
- The experimental campaign with the new setup will start in 2009.
- The new research program will extend to heavier beams and will also cover RDDS measurements with the plunger device.
The CLARA-PRISMA collaboration

- France
  IReS Strasbourg
  GANIL Caen

- U.K.
  University of Manchester
  Daresbury Laboratory
  University of Surrey
  University of Paisley

- Germany
  HMI Berlin
  GSI Darmstadt

- Poland
  IFJ-PAN Kraków

- Italy
  INFN LNL-Legnaro
  INFN and University Padova
  INFN and University Milano
  INFN and University Genova
  INFN and University Torino
  INFN and University Napoli
  INFN and University Firenze
  University of Camerino

- Spain
  University of Salamanca

- Romania
  Horia Hulubei NIPNE Bucharest