Seniority isomeric in nuclei around the N=82 shell closure

- Shape coexistence (triaxial – spherical)
- Constraints for matrix elements of effective residual interactions used in the shell-model calculations and to improve the predictive power of such interactions
- Variation of the pairing interaction with seniority and with Z (50<Z<64) from comparison of the excitation energy and of the B(E2) for simple isomeric states with shell model calculations in nuclei with 50<Z<64, N<82
why searching for isomers?

- Around closed shells nuclei are spherical or oblate
  => yrast "spins" traps with optimal configurations
  => allow the study "SIMPLE" states at high spin

- A “gate-way” or “tool” to acces excited states in very exotic nuclei

- Why isomeric states in isotones around N=80 close to the stability line?
  => Extract $\Delta p$ in the Z=50-64 sub-shell ($\pi d_{5/2} g_{7/2}$)
Where to measure isomers?

- Where a pulsed beam is available - many labs
- Where a spectrometer is available - no so many
- Where specific instrumentation is available (high efficiency detectors for $\gamma$-rays, fast timing available) – not so many
- Suitable beam (radioactive, neutrons,...) - no so many

Jyväskylä, Osaka, Orsay, GANIL, GSI, Argonne, RIKEN
Ground state deformations

Moller Chart of Nuclides
Quadrupole Deformation

Prolate

Oblate

> 0    prolate
< 0    oblate

Möller and Nix, Atomic Data and Nuclear Data Tables 59, 185-381(1995)
Potential energy surfaces for $^{140}$Nd

Shape coexistence

$I=31$

$I=41$

$I=51$

$I=61$
Which beam?

- \( ^{154}\text{Hf}^* \), N/Z=1.14
- \( ^{150}\text{Yb}^* \), N/Z=1.14
- \( ^{96}\text{Ru} \), N/Z=1.18
- \( ^{92}\text{Mo} \), N/Z=1.19
- \( ^{58}\text{Ni} \), N/Z=1.07
- \( ^{124}\text{Sn} \), N/Z=1.48
- \( ^{48}\text{Ca} \), N/Z=1.40
- \( ^{17}\text{N} \), N/Z=1.43 - RI
- \( ^{14}\text{C} \), N/Z=1.33
- \( ^{141}\text{La} \), N/Z=1.47
Systematics of N=80 nuclei

- $^{17}\text{N} + ^{124}\text{Sn}$ (p4n)
- $^{14}\text{C} + ^{130}\text{Te}$ ($\alpha$4n)
- $^{18}\text{O} + ^{126}\text{Te}$ (4n)
- $^{238}\text{U} + ^{12}\text{C}$ (fission)
- $^{24}\text{Mg} + ^{124}\text{Sn}$ (6n)
- $^{58}\text{Ni} + ^{96}\text{Ru}$ (p3n) + p emission
Tilted Fermi surfaces for $^{140}$Nd

\[ [0,200] \pi (g_{7/2})^2 (d_{5/2})^2 \nu (h_{11/2})^2 \]

\[ I = 3.5 + 2.5 + 2.5 + 1.5 + 5.5 + 4.5 = 20^+ \]
Comparison of CNS calculations for $^{136}$Ba and $^{140}$Nd

$\pi(h_{11/2})^{10+}$

$\left(\pi(d_{5/2}g_{7/2})^{-2} \otimes \nu(h_{11/2})^{10+}\right)_{14+}$

$\left(\pi(d_{5/2}g_{7/2})^{-8} \otimes \nu(h_{11/2})^{-10+}\right)_{22+}$
Six-quasiparticle isomer in $^{140}\text{Nd}_{80}$

$\pi(d_{5/2}g_{7/2})^{-4}_{10+} \nu(h_{11/2})^{-2}_{10+}$

$\pi(d_{5/2}g_{7/2})^{-4}_{10+} \nu(h_{11/2}d_{3/2})^{-1}_{7-}$

$\pi(d_{5/2}g_{7/2})_{6+} \nu(h_{11/2}g_{7/2})^{-9}_{10+}$

$\pi(d_{5/2}g_{7/2})_{6+} \nu(h_{11/2}d_{3/2})^{-7}_{7-}$

$\nu(h_{11/2})^{-1}(d_{5/2}/g_{7/2})^{-1}_{7-8-9-}$

$\nu(h_{11/2})^{-1}(d_{3/2}/s_{1/2})^{-1}_{5-6-7-}$

$\nu(d_{3/2}h_{11/2})_{7-}$

$\nu(s_{1/2}h_{11/2})_{5-}$

C.P. et al., PR C74 (2006) 034304
Level scheme of $^{139}$Nd

$T_{1/2} = 272(4)$ ns

M. Ferraton et al., EPJ A35 (2008) 167
JUROGAM+RITU at Jyväskylä ($^{48}\text{Ca} + ^{96}\text{Zr}$)
PRELIMINARY RESULTS

$^{139}\text{Nd}$

$\Delta E = 45$ keV

$T_{1/2} = 272(4)$ ns
Level scheme of $^{139}$Nd

$\pi(d_{5/2}g_{7/2})^2 \otimes \nu(s_{1/2}/d_{3/2})h_{11/2}^3$
$^{140}\text{Nd}$

PRELIMINARY RESULTS
• Accelerator: ONLY AVF cyclotron; Primary beam $^{18}$O, E=9.2 MeV/u, I=3 $\mu$A
• Production target: 50 $\mu$m $^9$Be; Degrader: 52 $\mu$m Aluminium at F1
• Identification of $^{17}$N RI-beam $\rightarrow$ $\Delta E-E$ at F2
• $^{17}$N RI-beam: E=80 MeV (4.7 MeV/u), I=1.5x10$^5$ pps $^{17}$N + $^{124}$Sn
Detection system – Ge array

Ge array: - 10 HPGe detectors from French-UK pool
- large volume (80%)
- 13.5% total efficiency at 0.5 MeV

Mechanical supports for Ge – designed at RCNP
Level scheme of $^{136}$Ba from multinucleon transfer reaction $^{136}$Xe+$^{198}$Pt

$^{14}$C+$^{130}$Te @ 80 MeV
$\sigma(I=24) = 6\% \sigma_{\text{tot}}$

$(\pi(d_{5/2}g_{7/2})^2_{6+} \otimes \nu(h_{11/2})^2_{10+})_{14+}$

$(\pi(d_{5/2}g_{7/2})^2_{4+} \otimes \nu(h_{11/2})^2_{10+})_{14+}$

$\pi(g_{7/2}d_{5/2})^2_{6+}$

$\pi(d_{3/2}h_{11/2})^2_{7-}$

$\nu(h_{11/2})^2_{10+}$

$\sigma_{\text{tot}}$
The EXOGAM Array

16 Clovers

Each Clover has 4 Ge crystals

Each Crystal has 4 segments
FIG. 5. Experimental and calculated level schemes of $^{134}$Xe above the $7^-$ and the $10^+$ isomers (see text).
The $^{132}\text{Te}$ states are calculated at energies of 4.7 and 6.0 MeV, respectively, which are higher by more than 1 MeV than the simple estimates based on unchanged building blocks. This shows how important it is to have experimental information of medium and high-spin states to get confidence on the shell-model calculations which describe well the low-lying states, but could have a poor agreement for higher spin states.
Search for isomeric states in nuclei with few holes in N=82

Collaboration

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