The AGATA CAMPAIGN at LNL

Daniele Mengoni
Università and INFN Padova – ITALY
for the AGATA collaboration

ARIS – Advances in Radioactive Isotope Science 2014
1th-6th June 2014, Tokyo - Japan
Advanced Gamma-ray Tracking Array

- **2009 LNL**
  - 5TC
  - PRISMA
  - EFF~6%

- **~2014 GANIL**
  - 15 TC
  - VAMOS
  - EXOGAM
  - EFF~20%

- **2012 GSI**
  - 8TC
  - FRS
  - EFF>10%
The first implementation of AGATA installed at LNL
PRISMA: Tracking Magnetic Spectrometer

- Large acceptance $\Omega = 80$ msr
- $\Delta Z/Z \approx 1/60$ (Measured) IC
- Energy $\Delta A/A \approx 1/190$ (Measured)
- Acceptance $\pm 20\%$
- Max. $B_\rho = 1.2$ T.m.
DIFFERENTIAL RDDS MEASUREMENTS AT LNL

\[ ^{76}\text{Ge} + ^{238}\text{U} \ 577 \text{ MeV} \]

\[ ^{72}\text{Zn} (-2p-2n) \]

RDDS measurement \( \theta_G = 55^\circ \)

IKP University Köln
TU Darmstadt
PLUNGER

AGATA-PRISMA

Spectra at 50 kHz/capsule counting rate

\[ E' + E_\gamma \]

\[ \beta_{bef} \sim 10\% \]

\[ \beta_{aft} \sim 8.5\% \]
$^{64}$Ni @ 460 MeV (TANDEM+ALPI)
$^{238}$U target of 1.35 mg.cm$^{-2}$ + 4 mg.cm$^{-2}$ Nb Degrader

TKEL gate to reduce side feeding

Inversion of 9/2- and 11/2- in $^{65}$Co agrees with the LSSM LNPS interaction results. Due to the $^{66}$Ni Quadrupole - f7/2 weak coupling

F. Recchia et al., PRC 85, 064305 (2012), V. Modamio et al., PRC 88, 0443265 (2013)
RESULTS ON $^{70,72,74}$Zn

- $^72\text{Zn} \rightarrow Q\text{val gate}$

- $2^+$: maximum collectivity at $N=42$
- Good agreement with previous results

- $4^+$: disagreement with previous results
- Not reproduced by LSSM

- Lowest $B(4/2)<1$
- $B(4/2) \sim$ seniority:

C.Louchart et al., PRC 87, 054302 (2013)
$^{14}\text{N}(p,\gamma)^{15}\text{O}$ REACTION CROSS SECTION

Captures to different excited states in $^{15}\text{O}$ contribute to the cross-section. The one to the gs in $^{15}\text{O}$ is dominated by the tail of the sub-threshold resonance at -507 keV ($6.79 \text{ MeV state in } ^{15}\text{O}$)

C.Angulo et al., NP A690 (2001) 755, M.Marta et al., PR C78 (2008) 022802(R)

$^{14}\text{N}(p,\gamma)^{15}\text{O}$ is the “bottle neck” possible solution for the “solar composition problem” A.M.Serenelli et al., As.J.Lett. 705 (2009)
LIFETIME MEASUREMENT of 6.79 MeV in $^{15}$O

$^{14}$N(2H,n)$^{15}$O and $^{14}$N(2H,p)$^{15}$N reactions @ 32 MeV (XTU LNL Tandem)

Direct lifetime measurement with 4 ATCs at backward angles (close to the beam-line)

C. Michelagnoli et al., EPJ WoC, INPC 2013
BINARY PARTNER
SHAPE TRANSITION IN THE OS ISOTOPES

- Shape transition from prolate to oblate deformed nuclei in the Os isotopes
  - $^{194}$Os suggested to be prolate
  - $^{198}$Os shows oblate character

- Binary Partner Method
  - $^{82}$Se($^{198}$Pt, $^{196}$Os)$^{84}$Kr @ 426 MeV
  - Detect lighter beam-like recoil in PRISMA
  - Reconstruct Spectrum for $^{196}$Os

Diagram:

- AGATA
- Dante Array
- Target $^{198}$Pt (2 mg/cm$^2$)
- $^{82}$Se Beam @ 426 MeV
- $^{84}$Kr
- $^{83}$Br
- $^{198}$Pt
- $^{197}$Ir
- $^{196}$Os

Graph: E(4^+)/E(2^-) vs. N for Z=78 Pt, Z=76 Os, Z=74 W
SHAPE TRANSITION IN THE OS ISOTOPES

- Yrast band measured for the first time
- $E(4^+)/E(2^+)$ close to 2.5 (γ-soft nucleus)

P.R. John et al., submitted to PLB

- State of the art symmetry conserving configuration mixing (SCCM) calculations performed (T.R. Rodriguez)
- $^{196}$Os is a transitional nucleus
HE REGIME
High-Spin Fusion Evaporation
$^{50}$Ti on $^{128}$Te @ 217 MeV, $I \geq 60\hbar$

Goal: populate $^{174}$W at the **highest possible spins** ($\geq 60\hbar$), in order to make the **statistical fluctuation analysis of the ridge-valley structures in the $\gamma$-$\gamma$ matrices**, to estimate the number of low-$K$ and high-$K$ bands and their correlation

V.Vandone et al., PRC 88, 034312 (2013)
The relevant energy window for $(\gamma,n)$ reactions in the stellar photon bath is located in the vicinity of the PDR.

Inelastic scattering of $^{17}$O @ 20 MeV/u on different targets + $\gamma$-rays in coincidence

**TWO EXPERIMENTS PERFORMED:**
- Studied Nuclei: $^{208}$Pb, $^{90}$Zr
  - R. Nicolini (Università di Milano /INFN)
  - D.Mengoni (Università di Padova/INFN)
- Studied nuclei: $^{208}$Pb, $^{124}$Sn, $^{140}$Ce
  - M. Kmiecik (IFJ PAN Kraków)
  - F. Crespi (Univ. di Milano/INFN)

F.C.L. Crespi et al., PRL accepted
PYGMY in $^{208}$Pb

- One group of states with **isoscalar** character, the other with an **isovector** nature.

N. Ryezayeva et al., PRL 89, 27 (2002) – previous NRF Experiment

A. Tamii et al., PRL 107, 062502 (2011)

This experiment

$^{208}$Pb($\gamma$, $\gamma'$)

$^{208}$Pb(p, p$'$)

$^{208}$Pb($^{17}$O, $^{17}$O$'$)$\gamma$
POLARITAZION
I. COULEX TEST $^{104,108}$Pd

II. NON-YRAST OCTUPOLE BAND $^{220}$Ra, $^{222}$Th (J.F. Smith, D. Mengoni)

III. POSITRONIUM ENTANGLEMENT $\beta^+$ source $^{22}$Na (P.G. Bizzeti)
Partially-polarized 555.8-keV and 433.9-keV lines in $^{104}\text{Pd}$ and $^{108}\text{Pd}$ [+unpolarized $^{137}\text{Cs}$ source].

\[ \hat{\sigma}_C(\theta, \varphi) = \frac{r_0^2}{4} \left( \frac{E_{\gamma}'}{E_{\gamma}} \right)^2 \left[ \frac{E_{\gamma}'}{E_{\gamma}} + \frac{E_{\gamma}'}{E_{\gamma}} - \sin^2 \theta \right] (1 + P \cos 2\varphi) \]

GOSIA

\[ \frac{dN}{d\varphi} = a_0 + a_2 \cos(2\varphi) \]

Analyzing power: 0.48

P.G. Bizzeti et al., EPJ WoC, INPC 2013
SUMMARY AND CONCLUSIONS

- SUCCESSFUL TWO-YEAR LONG PHYSICS CAMPAIGN: LIGHT/HEAVY MASSES, HIGH SPINS AND LOW-LYING PROPERTIES, ETC.

- PERFORMANCE OF THE AGATA DEMONSTRATOR IS PROMISING, MOSTLY IN COMBINATION WITH SEVERAL ANCILLARY DETECTORS
ACKNOWLEDGMENTS

Jose Javier Valiente Dobon
Francesco Recchia
Daniele Mengoni

for the GALILEO Collaboration
Galileo: The New Installation

- High efficiency and P/T
- High sustainable counting rate
- Holding structure
- LN$_2$ filling system
- Beam line and beam dump
- Detectors tapered and triple
A fast low-noise charge sensitive preamplifier based on the core-type AGATA preamplifier
used for both tapered and triple cluster detectors
80 preamplifiers already available

Digi-opt12: 12-channel 14/16-bit 100/125-MS/s digitizer with optical output for GALILEO/AGATA power consumption < 10 W/board
Prototypes under test

New low-power and low-cost readout and preprocessing PCI-express boards developed for GALILEO and AGATA
Prototypes under test
ANCILLARY DETECTORS

- Light charged particles detectors
- Binary reactions fragment detectors
- Neutron detectors
- Lifetime measurement
- Fast timing detectors
- High-energy γ-ray detectors
- Recoil detectors

EUCLIDES LuSiA TRACE
n-Ring N-Wall NEDA
RFD SPIDER
DANTE MW-PPAC
Cologne Plunger
LaBr₃
HECTOR HECTOR+ PARIS
ABOUT PHYSICS: CALL FOR LoIs ...

- STRUCTURE OF N~Z NUCLEI
- ISOSPIN SYMMETRY
- STUDY OF NEUTRON–RICH NUCLEI
- EXOTIC DECAY OF HIGH–SPIN STATES
- NUCLEAR STRUCTURE CLOSE TO 100SN
- CLUSTER AND HIGHLY DEFORMED STATES IN SD–SHELL NUCLEI
- GIANT RESONANCES AND WARM ROTATIONS
- SYMMETRIES AND SHAPE–PHASE TRANSITIONS IN NUCLEI
- SHAPE COEXISTENCE IN NEUTRON–DEFICIENT NUCLEI
- g – FACTOR MEASUREMENTS
- MEASUREMENT OF ASTROPHYSICAL INTEREST CROSS SECTIONS – SURROGATE NR METHOD

GALILEO 0.0: GASP-TYPE DETs, DIGITAL ELECTRONICS
TADEM XTU – PIAVE – ALPI

2nd workshop @ LNL
26-28 May 2014
### (ALMOST) COMPLETE LIST OF EXPERIMENTS

<table>
<thead>
<tr>
<th>Week</th>
<th>Size (MB) 07.12.2011</th>
<th>Size (MB) 06.01.2012</th>
<th>Spokesperson(s)</th>
<th>Copied to Grid</th>
<th>Raw Data Deleted</th>
<th>Experiment</th>
<th>Goal</th>
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<tr>
<td>2009</td>
<td>2009_wk49</td>
<td>426.180</td>
<td>81.927</td>
<td>test</td>
<td>XX</td>
<td>AGATA+DANTE+PRISMA</td>
<td>Trial of the PRISMA detector to grid</td>
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<td>1,869</td>
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<td>1,233.943</td>
<td>26.285</td>
<td>A.Maj,F.Azari, P.Napiorkowski</td>
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<td>AGATA+DANTE+PRISMA</td>
<td>Coulomb excitation of the presumably deformed band in 42Ca</td>
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<td>2010</td>
<td>2010_wk09</td>
<td>109.475</td>
<td>14.014</td>
<td>J.Leske</td>
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<td>Coulomb excitation of the presumably deformed band in 42Ca</td>
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<td>885.033</td>
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<td>Zs.Podolyak</td>
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<td>2010</td>
<td>2010_wk21</td>
<td>311.444</td>
<td>180.501</td>
<td>R.Nicolini, R.Mengoni</td>
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<td>Coulomb excitation of the presumably deformed band in 42Ca</td>
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<td>M.Doncel,A.Goergen,E.Sahn</td>
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<td>196.429</td>
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<td>R.Moreno,A.C.Ur</td>
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<td>Coulomb excitation of the presumably deformed band in 42Ca</td>
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<td>2,115.231</td>
<td>466.036</td>
<td>P.G.Bizet</td>
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<td>C.Weldon</td>
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<td>141.589</td>
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<td>2010</td>
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<td>432.839</td>
<td>252.433</td>
<td>R.Chapman,F.Haas</td>
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<td>402.214</td>
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<td>9,571.161</td>
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<td>AGATA+DANTE+PRISMA</td>
<td>Coulomb excitation of the presumably deformed band in 42Ca</td>
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</table>
Position Resolution from in-beam tests

- $^{30}\text{Si}@70\text{MeV} + ^{12}\text{C}$

Position of first interactions at AGATA nominal distance

$\Delta \theta$  $\gamma$ ray  $\theta$  Beam  Recoil

Overall position resolution for three detectors and two distances

4 - 4.5 mm for $E_\gamma$ above 1 MeV ($\sigma = 2$ mm).

P-A Söderström (Uppsala)
F. Recchia (INFN-PD)
NIM A 638 (2011) 96
Performance from Commissioning Run

LSSM
Interaction from
E. Caurier et al.
PRC 75, 054317

(AGATA Collaboration)
SHELL EVOLUTION IN Cu AND Zn ISOTOPES

- Systematic variation of effective single-particle energies due to the tensor interaction
  
  T. Otsuka et al. PRL 95, 232502 (2005)

  \[ \pi p_{5/2} \times 2^+ (^{A-1}\text{Ni}) \quad 7/2 \]
  \[ \pi p_{3/2} \times 2^+ (^{A-1}\text{Ni}) \quad 7/2 \]
  \[ (\pi f_{7/2})^{-1} \quad 7/2 \]
  \[ \pi f_{5/2} \quad 5/2 \]
  \[ \pi p_{3/2} \quad 3/2 \]

  LNL

  ISOLDE

  \[ 71^{\text{Cu}}_{42} \]
  \[ 73^{\text{Cu}}_{44} \]
  \[ 75^{\text{Cu}}_{46} \]
  \[ 77^{\text{Cu}}_{48} \]

  ISOLDE

  COULEX ISOLDE

  Inversion of the f_{5/2} with the p_{3/2} in \(^{75}\text{Cu}\)

- Presence of both single-particle and collective states at low energy

Spokespersons: E. Sahin, M. Doncel, A. Goergen

CHARACTER OF THE $7/2^-$ STATE IN $^{71}\text{Cu}$

- RDDS measurement: $^{76}\text{Ge}$ (577 MeV) + $^{238}\text{U}$ (1.5 mg/cm$^2$), Degrader Nb 4.17 mg/cm$^2$

- New approach for lifetime: normalization done with the number of ions (PRISMA)

- **LNPS interaction**: shell-model calculations using an enlarged valence space: pf-shell orbitals for protons and f$^{5/2}$, p$_{1/2}$, p$_{3/2}$, g$_{9/2}$ and d$_{5/2}$ orbitals for neutrons.

-\[ \pi p_{3/2} \times 2^+ (\text{Ni})_{7/2}^- \text{Ni} \quad \text{1190 keV} \]
-\[ (\pi f_{7/2})^{-1} \text{Ni} \quad 7/2^- \text{Ni} \quad 981 \text{ keV} \]

- Complex wavefunctions small changes in $\pi p_{3/2}$ & p$_{1/2}$ occupancies

- $\pi p_{3/2} \quad 3/2^-$

- $^{71}\text{Cu}_{42}$

- Analysis by M. Doncel, E. Sahin, C.Louchart

- LSSM by K. Sieja *et al.*
SHAPE TRANSITIONS IN Os ISOTOPES

Ph. R. John, V. Modamio, Zs. Podolyak, C. Wheldon, W. Korten

Energy Density Functionals – D. Vretenar (Priv. Comm.)

Binding energy map $\beta\gamma$ plane

P. D. Bond Phys. Lett. 130B, 167
Zs. Podolyak et al. PRC79, 31305(R)
C. Wheldon et al. PRC63, 11304
FIRST EVIDENCE OF $^{196}$Os

$^{82}$Se + $^{198}$Pt (2mg/cm$^2$) at 426 MeV

BLF: $\beta \sim 10\%$ FWHM: 0.5%
TLF: $\beta \sim 3\%$ FWHM: 1.8%

Analysis by P.R. John
K. Hadyńska-Kłęń et al., (accepted in Acta Phys. Pol B)
Zakopane Conference on Nuclear Physics 2012

$Q^2$ nuclear shape invariants determined by using the Quadrupole Sum Rules method

$$\langle Q^2 \rangle = \left[ \frac{3}{4\pi} Z (\frac{3}{A} r_0^3) \right]^2 \langle \beta^2 \rangle$$