Recent results from the AGATA Demonstrator Array at LNL

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On behalf of the AGATA Collaboration

1. The AGATA Demonstrator at Legnaro
2. Highlights from the performed experiments
5 asymmetric triple-clusters
36-fold segmented crystals
555 digital-channels
Eff. 3 - 8 % @ $M_\gamma = 1$
Eff. 2 - 4 % @ $M_\gamma = 30$
Full EDAQ with on line PSA and $\gamma$-ray tracking
In beam Commissioning
First installation site: LNL

Main issue is Doppler correction capability
→ coupling to beam and recoil tracking devices
From CLARA to AGATA

March 2008

May 2011
Doppler correction capabilities

Inelastic scattering

\(^{17}\text{O} \@ \text{20 MeV/u on } {^{208}\text{Pb}}\)

\[\beta \approx 20\%\]

D.Mengoni, R.Nicolini, F.Crespi

No Dopp Corr
Crystal Centers
Segment Centers
PSA+Tracking

\(\text{TKE (MeV)} - \text{dE (MeV)}\)

4500 5000 5500 6000 6500

Energy (keV)

Counts (A.U.)
Resolution vs rate

Two independent sources of dead-time: pile-up rejector and GTS

$^{60}$Co - fixed

$^{137}$Cs - 6 positions

6 different rates x 4 trapezoid risetime x 6 blr length
The Experimental Campaign at LNL

- Neutron-rich nuclei in the vicinity of $^{208}\text{Pb}$
- N=51 nuclei
- Molecular structure of $^{21}\text{Ne}$
- Coulex of $^{42}\text{Ca}$
- Octupole-deformed Ra and Th nuclei
- Shape transition in $^{196}\text{Os}$
- g.s. rotation in Dy, Er, Yb
- The lifetime of the 6.792 MeV state in $^{15}\text{O}$
- Lifetimes near the island of inversion
- N=84 isotone
- n-rich Th and U
- Order-to-chaos transition in $^{174}\text{W}$
- Lifetimes in n-rich Ni, Cu and Zn isotopes
- Lifetimes of the n-rich Cr isotopes
- 20(+3) exp. 148 days

- Isospin Mixing in $^{80}\text{Zr}$
- Proton drip-line
- Pygmy and GQR states
- Neutron-rich nuclei populated by fission
- g.s. rotation in Dy, Er, Yb
- Neutron-rich nuclei in the vicinity of $^{208}\text{Pb}$
- n-rich Th and U
Around the island of inversion

Transition from harmonic vibrator to rotor between Si and Mg at N=22?

X. Liang et al., PRC 74, 014311 (2006)
Shell model calculations (Antoine+PSDPF) reproduce fairly the observed level energies (CLARA-PRISMA data), transition probabilities are needed to provide more stringent test of the model!

AGATA+PRISMA +plunger experiment

$^{36}\text{S} + ^{208}\text{Pb}$
Preliminary γ spectra

$^{36}$S

$3^- \rightarrow 2^+ \ 902 \text{ keV transition}$

Predicted lifetime: 0.25 ps
Stellar burning rates and $^{14}\text{N}(p,\gamma)^{15}\text{O}$ reaction

Precise knowledge of nuclear x-sections

$C,N$ abundances in the solar core can be obtained by measuring the neutrino fluxes

[W.C.Haxton et al., As.J.687(2008)678]

possible solution for the “solar composition problem”


$^{14}\text{N}(p,\gamma)^{15}\text{O}$ is the “bottle neck” determining the overall rate
Captures to different excited states in $^{15}$O contribute to the x-section. The one to the gs in $^{15}$O is dominated by the tail of the sub-threshold resonance at -507 keV (6.79 MeV state in $^{15}$O).

\[ \text{[C. Angulo et al., NP A690 (2001) 755, M. Marta et al., PR C78 (2008) 022802(R), ...]} \]
$^{14}\text{N}(p,\gamma)^{15}\text{O}$ reaction cross section

M. Marta / Progress in Particle and Nuclear Physics 66 (2011) 303–308

$Q$  $E_p^{\text{cm}}$  $E_x$  $J^\pi$

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<tr>
<td>$987$</td>
<td>8284</td>
<td>$3/2^+$</td>
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<td>7536</td>
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<td>6292</td>
<td>$3/2^-$</td>
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<td>$5241$</td>
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</tr>
<tr>
<td>$5181$</td>
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<td>$1/2^+$</td>
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Adopted $\Gamma_\gamma(6792\text{ keV}) = 0.9 \pm 0.2\text{ eV}$

$S_{gs}(0) = 0.20 \pm 0.05\text{ keV} \cdot \text{b}$


$\Gamma_\gamma(6792\text{ keV}) = 0.8\text{ eV}$

$0.6\text{ eV}$

$\frac{\hbar}{\tau}$

Change of $\approx 20\%$ in $\Gamma = \frac{\hbar}{\tau} \rightarrow$ change of $\approx 30\%$ in $S_{gs}(0)$

H. P. Trautvetter et al., JGP 35 (2008) 014019 and courtesy of M. Marta
Lifetime measurement of the 6.79 MeV state in $^{15}$O

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

Direct lifetime measurement with 4 ATCs at backward angles (close to the beam-line)
Lifetime measurement of the 6.79 MeV state in $^{15}\text{O}$

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

Detected gamma-rays can be sorted in few degrees $\theta$ “slices” with a continuous distribution

C. Michelagnoli
Reaction kinematics

Due to the short lifetimes, the lineshapes strongly reflect the reaction kinematics. Both $^{15}$O and $^{15}$N excited levels are mainly populated via nucleon (proton and neutron, respectively) transfer reactions.

CDCC** calculations of the nucleon transfer process by N. Keeley

**Continuum-Discretized Coupled Channels

but also the fusion-evaporation channel is open

ratio between the two different mechanism and (energy) spectrum of the evaporated particle not much help in the literature....
The 8.31MeV level in $^{15}\text{N}$

$\tau = (2\pm3) \text{ fs}^*$

*from $\Gamma=(0.3\pm0.2) \text{ eV}$
[R. Mareh et al., *PRC* 23 (1981) 988]
The 6.79MeV level in $^{15}$O

chi-square analysis on all the “theta-slices” ongoing...
Order-to-chaos in $^{174}$W

High-Spin Fusion Evaporation
$^{50}$Ti on $^{128}$Te @ 217 MeV, I $\geq 60\hbar$

Loss of selection rules on K with temperature

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.

4 Triple Clusters
2 and 3 folds:
$\varepsilon_2\gamma=30\%$, $\varepsilon_3\gamma=10\%$
($M_\gamma = 30$)

27 detectors: 5 clusters of BaF$_2$
(3”x3”, exagonal)
Total solid angle: 25% of 4$\pi$
Total efficiency: 16% @ 500keV

V. Vandone
Helena: selection of high-K bands

$^{174}\text{W selection}$

$K = 12$

$K = 8$

Gate on ENERGY:

- delayed $\gamma$
- prompt $\gamma$

Gate on $\gamma$-isomer → enhanced delayed bump

AGATA vs Helena time-spectrum

Gate on DELAYED time:

Isomeric gammas

- $1000$ keV
- $965$ keV
- $1314$ keV
- $1328$ keV
- $1349$ keV
- $1879$ keV

$\star$ background

Helena: selection of high-K bands

- $K = 12$
- $K = 8$

Band 16

Band 15

Band 8

Band 7

$686$ keV

$1328$ keV

$1879$ keV

$128$ ns

$158$ ns

$174\text{W selection}$
Quasi-Continuum $\gamma-\gamma$ matrices

**Statistical fluctuation analysis of ridges:**
Number of bands below 1 MeV

**Covariance analysis of ridges**
Covariance = similarity of different cascades & test of the selection rules

- $2\times4\hbar^2/\gamma^2 \approx 120$ keV
- $880$ keV
- $820$ keV
- $780$ keV

K quantum number is conserved up to 1 MeV
AGATA Demonstrator/1π Experimental Program

2010-2011 → LNL
   5TC

2012 → GSI/FRS
   ≥5DC+5TC

2014 → GANIL/SPIRAL2
   ~15TC

AGATA D. + PRISMA
Total Eff. ~6%

AGATA @ FRS
Total Eff. > 10%

AGATA + VAMOS + EXOGAM
Total Eff. > 20%
AGATA at PreSPECC

- 5 double Cluster
- 10 triple Cluster
- AGATA + Miniball

\[ \gamma\text{-efficiency} = 17.5\% \]
\[ \gamma\gamma\text{-efficiency} = 2.5\% \]

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<th>Resolution (FWHM)</th>
<th>Intrinsic Spatial Resolution</th>
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<tr>
<td>8.5 keV</td>
<td>5 mm</td>
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<tr>
<td>4 keV</td>
<td>2 mm</td>
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Aim for AGATA@GSI:

- 5 double Cluster
- 10 triple Cluster
- AGATA + Miniball

Start spring 2013

Beam pipe diameter = 12 cm
Chamber diameter = 46 cm

\[ \gamma\text{-efficiency} = 17.5\% \]
\[ \gamma\gamma\text{-efficiency} = 2.5\% \]
Outlook

• Following the commissioning campaign, the physics campaign has started in February 2010
• Performance of the array is satisfactory, in close coupling with several ancillary devices
• Analysis of the experiments performed so far is ongoing, more results soon
• Good luck to the GSI colleagues with the upcoming AGATA@PreSPEC campaign!