Gamma-ray Detection, Instrumentation, and Future Prospects

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Contents

- Prompt spectroscopy at Jyväskylä
- Experimental methods

- JUROGAM II
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- Future Developments at Jyväskylä

- Applications: Home and Away

- European Collaboration: AGATA

- Preperations for the next decade
JUROGAM (2003-2008)

- 43 Anti-Compton suppressed HP-Ge detectors ($\varepsilon_{ph} = 4.2\% / 1.3$ MeV)
- JYFL “Host Laboratory” for ex-EUROBALL detectors 2003-2008
- Comprises of all EB Phase I + GASP detectors + France UK loanpool

67 experiments
~30 labs / 14 countries
11000 hours of beamtime
250000l LN$_2$ / year
“Complete Spectroscopy”

Jurogam Array

RITU gas–filled recoil separator

Approx 1 μs

Ge (prompt) Recoil Δt

Ge (delayed) Recoil Δt

Planar

GREAT

PIN Diodes

DSSD

MWPC

α−decay

α−decay

GREAT

ΔtΔt

μs

Ge − Cα

208Pb

T1/2

10−12 s

10−10 s

10−14 s

π

n

234No

rotation

ΔtΔt

10−12 s

10−12 s

ΔtΔt

10−14 s

ΔtΔt

10−10 s

ΔtΔt

10−12 s

ΔtΔt

10−12 s

ΔtΔt

10−10 s

ΔtΔt

10−12 s

ΔtΔt

10−12 s
Tools of the trade

- 2 x 60mm x 40mm DSSD
- 28 x 40mm x 40mm PIN Diodes
- 24 x 12 Segmented Planar Ge
- Compton-Suppressed Segmented Ge Clover
- Position-Sensitive MWPC

- Triggerless Data Acquisition System
- Rates up to 5000 kHz without deadtime
- 380+ channels timestamped data
- 10 ns resolution
- Time-of-Day clock with 32 day rollover
- Successful correlation over 36 hours
- Flexible + Easily Scalable
- Distributable 100MHz Clock
Plunger and selection devices

**Differential plunger** inside JUROGAM

-minded, pised, d-deriever

**Coulex plunger**

Grahn et. al

Harissopulos et. al

E(5) X(5) symmetries in $^{128}\text{Xe}$

- Versatile array design
- Lifetime measurements – new plunger

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JUROGAM Milestone 2007
Fully Instrumented Digital Electronics

IPHC / Orsay
Gabriela Collaboration (CAEN N1728)
L. Arnold et al., 14th IEEE Conf (2005)

V.T. Jordanov NIM A345, 337 (1994)

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Digital Advantages

Throughput

Lineshape (shaping time)

Detection Treshold

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Added Value

Shorter / adaptive shaping time

Pulse Shape Analysis

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Digital Experiments (JUROGAM 2008)

Comparison of TDR and TNT2 Data

$^{208}\text{Pb})^{48}\text{Ca}, 2\text{m})^{55}\text{No}$ @ 219 MeV

- Detection efficiency
- Throughput
JUROGAM II
Summer 2008
CLARA detectors from LNL
JUROGAM II
October 2008

- 24 Clover + 15 Tapered Anti-Compton suppressed HP-Ge detectors
- Increased efficiency ($\varepsilon_{ph} = 4.2\% \rightarrow \sim 6.3\% / 1.3$ MeV)
- Coincidence efficiency
- Digital electronics: Increased count rates (x5), lower thresholds
- Efficient and Versatile
- Gammapool resource approved to end of 2010
New Advances

» LISA: Fast proton decay

» SAGE: Simultaneous Gamma and CE studies

Beamtime

Beam Intensities

» MARA: Vacuum mode
Applications

We need to understand the electron heating mechanism in order to solve the problem with excessive bremsstrahlung

- Simulations
- Time evolution measurements of bremsstrahlung
  - So far this has not been done in the ECR community
Duty Cycle & preglow effects

Gammas timed to 10ns
"Forced preglow effect"

\[ {}_2^6\text{He} \rightarrow {}_3^6\text{Li} \; e^- \bar{\nu} \]
Average \( E_{\text{cms}} = 1.937 \; \text{MeV} \)

\[ {}_{10}^{18}\text{Ne} \rightarrow {}_9^{18}\text{F} \; e^+ \nu \]
Average \( E_{\text{cms}} = 1.86 \; \text{MeV} \)

T. Ropponen et al, JYFL
AGATA
- The Advanced Gamma Tracking Array

$4\pi \gamma$-array for Nuclear Physics Experiments at European accelerators providing radioactive and stable beams

**Main features of AGATA**

- **Efficiency:**
  - Today’s arrays: 43% ($M_\gamma=1$), 28% ($M_\gamma=30$)
  - ~10% (gain ~4), 5% (gain ~1000)

- **Peak/Total:**
  - Today: 58% ($M_\gamma=1$), 49% ($M_\gamma=30$)
  - ~55%, 40%

- **Angular Resolution:**
  - ~1º $\rightarrow$ FWHM (1 MeV, v/c=50%) ~ 6 keV !!!
  - Today: ~40 keV

- **Rates:**
  - Today: 3 MHz ($M_\gamma=1$), 300 kHz ($M_\gamma=30$)
  - 1 MHz, 20 kHz

- 180 large volume 36-fold segmented Ge crystals in 60 triple-clusters
- Digital electronics and sophisticated Pulse Shape Analysis algorithms allow
- Operation of Ge detectors in position sensitive mode $\rightarrow$ $\gamma$-ray tracking

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The First Step:
The AGATA Demonstrator
Objective of the final R&D phase 2003-2008

1 symmetric triple-cluster
5 asymmetric triple-clusters
36-fold segmented crystals
540 segments
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
Technical proposal for full array

Cost ~ 6 M € Capital
Ingredients of $\gamma$-Tracking

1. Highly segmented HPGe detectors

2. Digital electronics to record and process segment signals

3. Pulse Shape Analysis to decompose recorded waves

4. Reconstruction of tracks e.g. by evaluation of permutations of interaction points

Identified interaction points $(x,y,z,E,t)_i$
AGATA triple-detector module

Hexagonal Ge crystals
90 mm long
80 mm max diameter
36 segments
Al encapsulation
0.6 mm spacing
0.8 mm thickness
37 vacuum feedthroughs

3 encapsulated Ge crystals in one cryostat
111 preamplifiers with cold FET
~230 vacuum feedthroughs
LN₂ dewar, 3 litre, cooling power ~8 watts
Without Crosstalk

\[
\begin{pmatrix}
E_{\text{core}} \\
E_{\text{seg}_1} \\
E_{\text{seg}_2} \\
\vdots \\
E_{\text{seg}_n}\end{pmatrix}_{\text{meas}} = \begin{pmatrix}
1 & 1 & \cdots & 1 \\
1 & 0 & \cdots & 0 \\
0 & 1 & \cdots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \cdots & 1
\end{pmatrix} \begin{pmatrix}
E_{\text{seg}_1} \\
E_{\text{seg}_2} \\
\vdots \\
E_{\text{seg}_n}\end{pmatrix}_{\text{true}}
\]

With Crosstalk

\[
\begin{pmatrix}
E_{\text{core}} \\
E_{\text{seg}_1} \\
E_{\text{seg}_2} \\
\vdots \\
E_{\text{seg}_n}\end{pmatrix}_{\text{meas}} = \begin{pmatrix}
1 + \delta_{01} & 1 + \delta_{02} & \cdots & 1 + \delta_{0n} \\
1 & \delta_{12} & \cdots & \delta_{1n} \\
\delta_{21} & 1 & \cdots & \delta_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\delta_{n1} & \delta_{n2} & \cdots & 1
\end{pmatrix} \begin{pmatrix}
E_{\text{seg}_1} \\
E_{\text{seg}_2} \\
\vdots \\
E_{\text{seg}_n}\end{pmatrix}_{\text{true}}
\]

D. Birkenbach, IKP

Bruynell et al., NIM A 599 (2009) 196–208
AGATA Demonstrator at Legnaro

From CLARA to AGATA

March 2008

Present day

E. Farnea, INFN

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FIRST AGATA Demonstrator
In-Beam Test Results

“Standard” experiment: Doppler correction capabilities exploited to measure the position sensitivity

- No ancillaries have been used
- Measurement performed at 2 target-detector distances

F. Recchia, INFN

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Near future for AGATA Demonstrator

Delivery of ATC2 & 3 to LNL Electronics in autumn 2009
Start of physics by end 2009

Second Workshop on the Physics with the AGATA Demonstrator and PRISMA

18th – 20th May 2009, Legnaro, Italy

AGATA Steering Committee:

Legnaro operation will continue to ensure excellent physics output
At least until end 2010

Currently in negotiation with GSI concerning next host laboratory
Decision expected by May/June 2009

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Next Decade

New facilities.
New challenges..
New physics...

The Phases of AGATA

15 Clusters

1π

The first “real” tracking array
Used at FAIR-HISPEC, SPIRAL 1,2, SPES, ECOS
Coupled to spectrometer, beam tracker, LCP arrays...
Spectroscopy at the N=Z (^{100}Sn), n-drip line nuclei, ...

Accelerator Planning
Summary

- JUROGAM upgraded to JUROGAM II
- Experiments started
- Flexible array with many options for spectroscopy and tagging

- Applications important for JYFL

- AGATA Demonstrating and physics campaign 2009-2010

- Next decade holds many challenges both at JYFL in Europe
Thanks…