

Analysis Status of the AGATA Experiments on Collective Excitations

Fabio Crespi

"Inelastic scattering as a tool to search for highly excited states up to the region of the Giant Quadrupole Resonance"

Contact Person: Angela Bracco - University of Milan and INFN

Spokespersons:

R. Nicolini^a, D. Mengoni^{c,h}, A. Bracco^a, G. Benzonia^a, F. Birocchia^a, N. Blasi^a, C. Boiano^a, S. Brambilla^a, F. Camera^a, A. Camplani^a, A. Corsia^a, F.C.L. Crespi^a, A. Giaz^a, S. Leonia^a, B. Million^a, L. Pellegrin^a, S. Riboldi^a, V. Vandone^a, O. Wieland^a, G. De Angelis^b, A. Gadea^{b,d}, P. Molini^b, D. R. Napoli^b, F. Recchia^b, E. Sahin^b, J.J. Valiente-Dobon^b, D. Bazzacco^c, E. Farnea^c, A. Gottardo^c, C. Michelagnoli^c, D. Montanari^c, C. Ur^c, A. Maj^e, M. Kimiecik^e, M. Ciemala^e, R. Kempley^f, A. Bürger^g

^a Università degli Studi e INFN sezione di Milano, Via Celoria 16, 20133, Milano.

^b INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy.

^c Università di Padova e INFN, sezione di Padova, Padova, Italy.

^d IFIC, Valencia, Spain.

^e The Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland

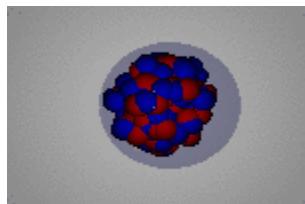
^f University of Surrey, Guildford, UK

^g University of Oslo, Norway

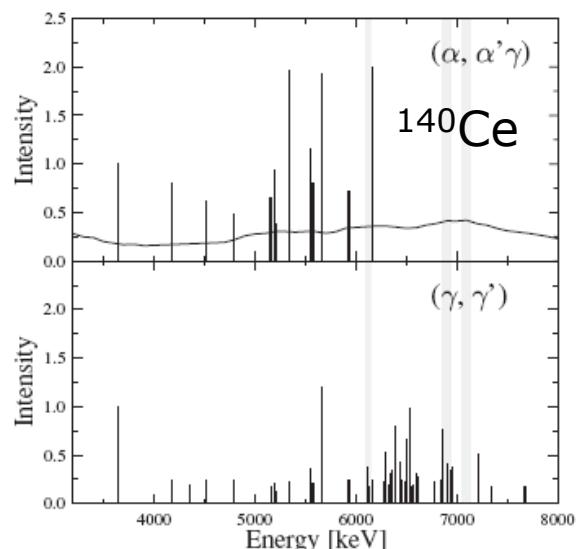
^h School of Engineering and Science, University of the West of Scotland, Paisley, Scotland-U.K.

Physics motivation

Pygmy Dipole Resonance

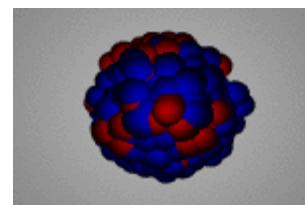


Different population with
 (γ, γ') , $(\alpha, \alpha' \gamma)$

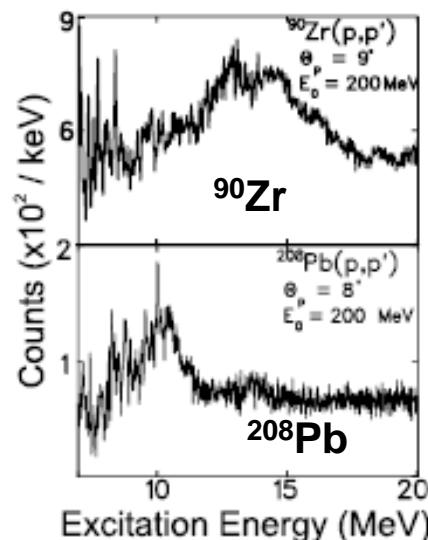


D. Savran et al., PRL97(2006)172502

Giant Quadrupole Resonance

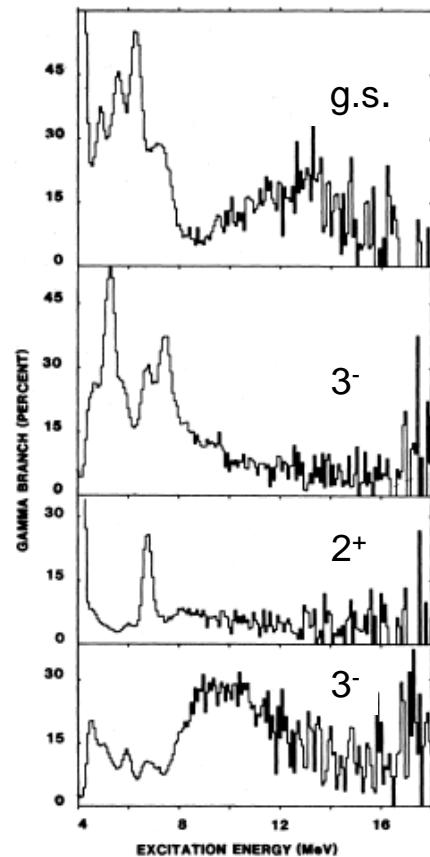


Fine structure



Shevchenko PRL93(2004)

Branching ratios



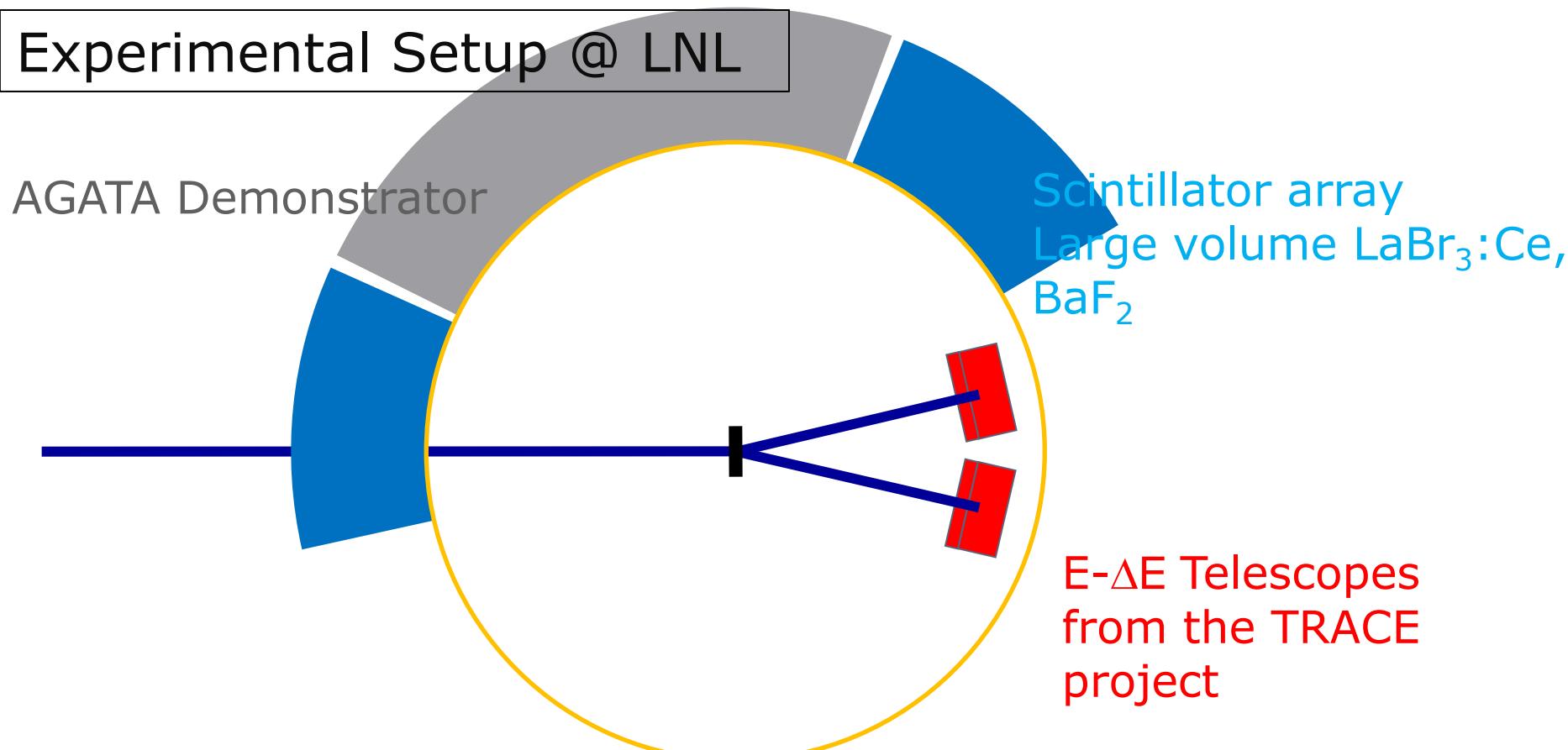
J. Beene et al PRC39(1989)

Experimental technique

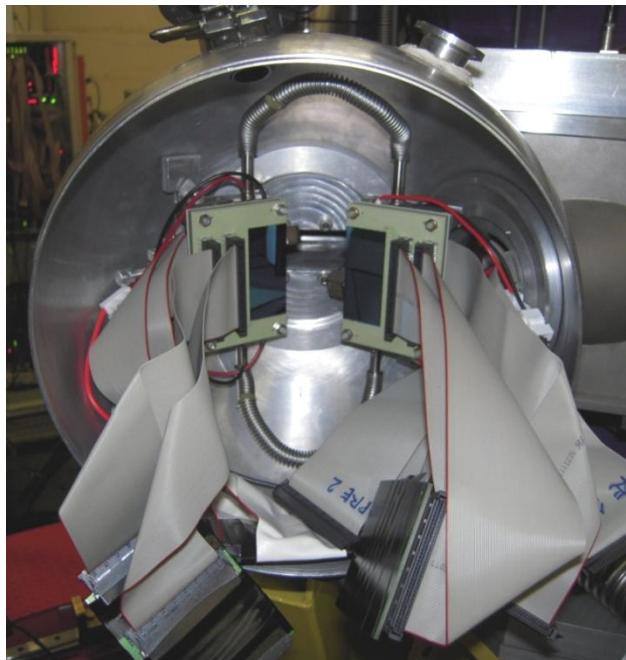
Inelastic scattering ^{17}O @ 20 MeV/u on ^{90}Zr , ^{208}Pb , ^{140}Ce , ^{207}Pb targets
+ γ -ray coincidence measurement

Heavy-ion scattering can populate giant resonances with large cross-sections ,
 ^{17}O is loosely bound ($S_n = 4.1$ MeV) → we can eliminate projectile excitation above 4 MeV

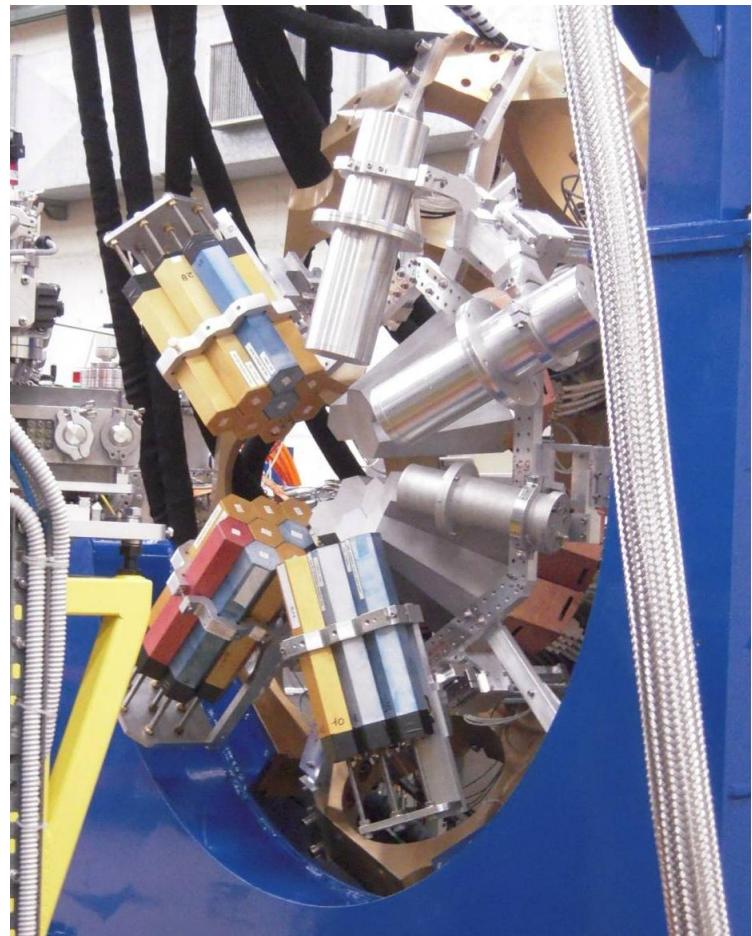
Experimental Setup @ LNL



Silicon Telescopes and Scintillator Array in AGATA



- Si-pad technology: 60 (5x12) pixels
- Active area of 20x50 mm²
- Pixel area of 4x4 mm²
- Cooled to -30 °C
- E detector: 1 mm thick
- ΔE detector: 200 μm thick



- LaBr₃:Ce detectors
- Large volume (up to 9x20 cm)
- 20 Helena BaF₂ clusters

The Experiment @ LNL

- Performed 28 may - 5 june 2010
- 7 Days of ^{17}O beam @ 20 MeV/u
- Targets used: ^{208}Pb , ^{90}Zr , ^{140}Ce , ^{207}Pb

➤ The experiment has run smoothly for the entire beam time period, with an average beam current limited to 1 pnA (in order to keep the single rates in the AGATA Ge detectors not higher than 20 kHz).

3 AGATA Triple Clusters
20 small BaF ₂ crystals
3 Large Volume LaBr
TRIGGER rate (Si + γ) 3 kHz
Single rate in AGATA 20 kHz
7 days , 1pnA
DATA Volume: 20 Tb (non compressed)



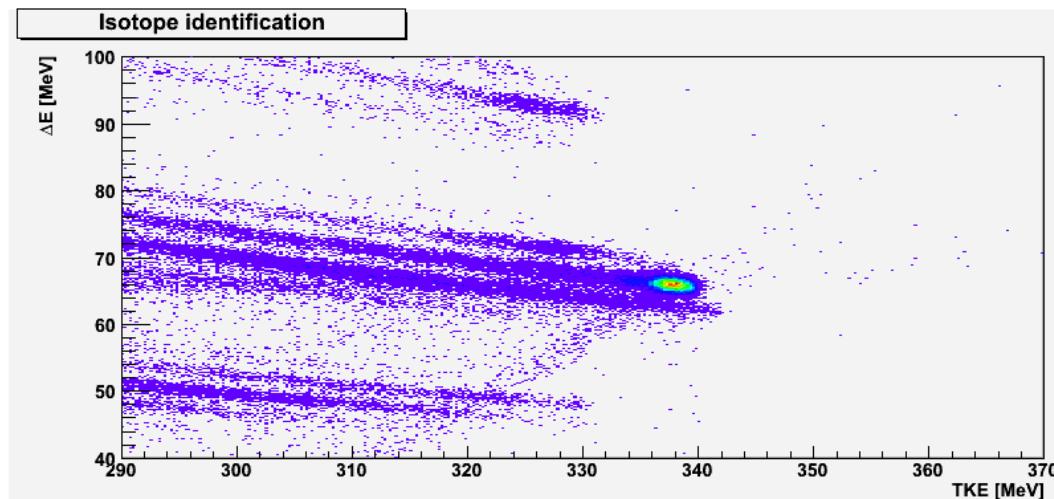
Ejectile detection

Constraints on $E^* - E_{\gamma\text{tot}}$ allow to greatly suppress background and select decay branches to g.s. or excited states

E- Δ E detector must have a high energy resolution for selection of excitation energy (<1%) but also a large solid angle to increase efficiency

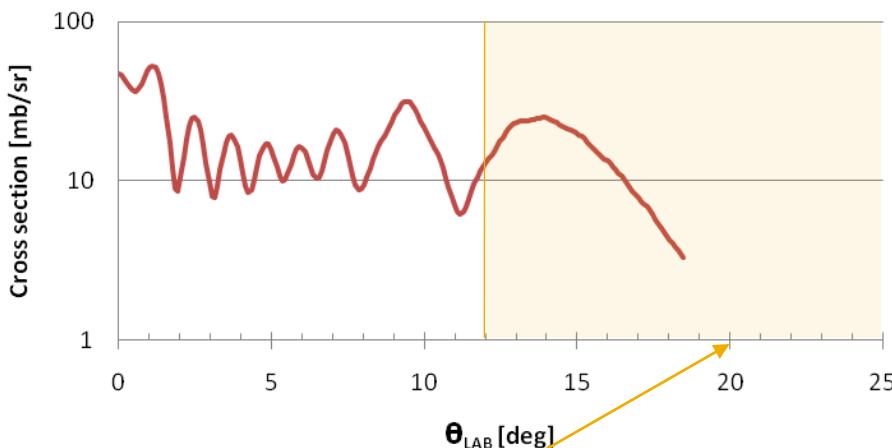
Segmented E- Δ E detector from the TRACE project (--> *D. Mengoni*)

- Si-pad technology,
60 (5x12) pixels
- Large number of channels
- Active area of 20x50 mm²
- Pixel area of 4x4 mm²
- Cooled to -30 °C
- E detector: 1 mm thick
- Δ E detector: 200 μ m thick



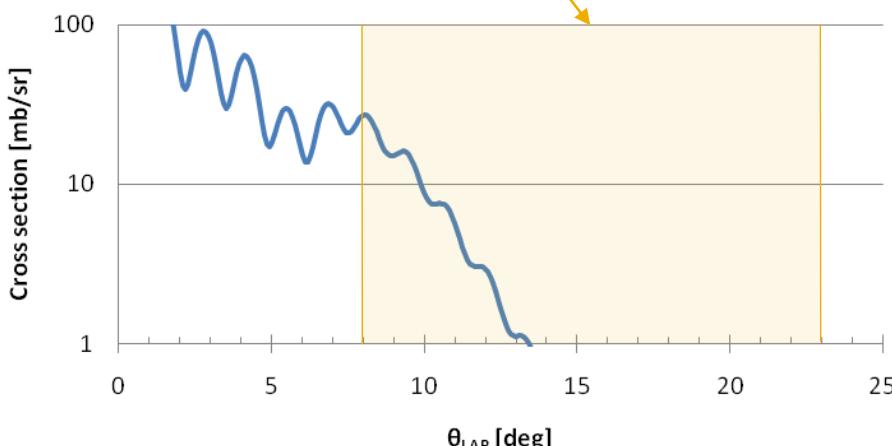
Cross-section estimates

^{208}Pb GQR excitation - DWBA



angular range of the whole telescope

^{90}Zr GQR excitation - DWBA



Sizable cross-section within $\sim 6^\circ$
The detector covers a much larger angle ($\Delta\theta = 15^\circ$)

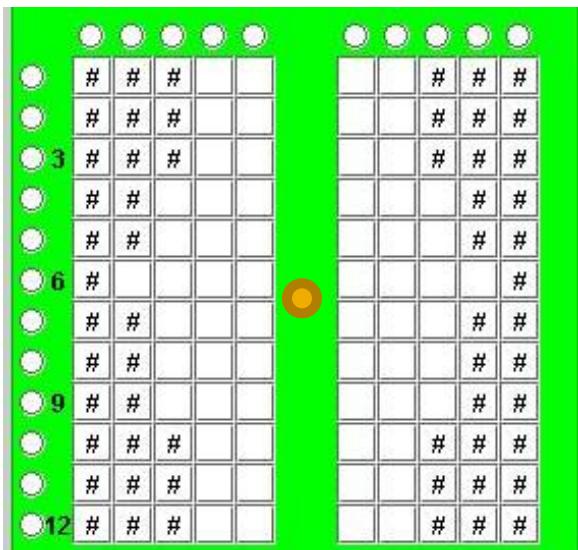
Many pads are too far from the peak of the cross-section

We do not use about 1/2 of the detector

The different kinematics for the ^{208}Pb and ^{90}Zr targets require different detector positions

Setup of the Si detectors

- 2 telescopes, only half of the pads were used
- Adjustable angle from beam direction
- Beam dump at the end of the expansion chamber



telescopes

Data Replay and Presorting

1. Data Replay and Presorting using “Narval Emulator” (C++ program that emulates the AGATA DAQ)

(Same procedure for “Order to Chaos Transitions in warm rotating ^{174}W nuclei”, AGATA experiment @ LNL, spokesperson V. Vandone (University Of Milan), July 2010)

Step 1:

- Data Replay @ LNL using DAQ machines
(performed in September 2010, about a week CPU time)
- Pulse Shape Analysis and Energy calibration (^{60}Co , Am-Be)
- Generation of presorted Data Files:
 - Gamma Hits Position and Energy information
(Data volume reduced by a factor of 20, without traces)

Step 2:

- Fine AGATA energy calibration (check gain stability vs time)
- Time alignment of AGATA crystals
- Event Correlation (AGATA detectors and ancillaries)
- Gamma ray Tracking

ROOT Tree Files

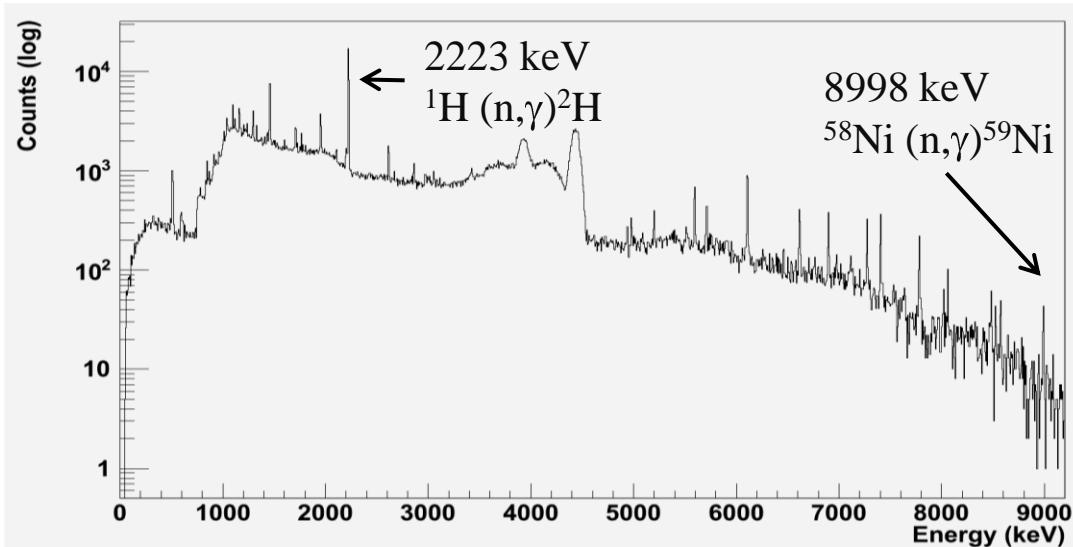


2. Sorting to Extract physical information

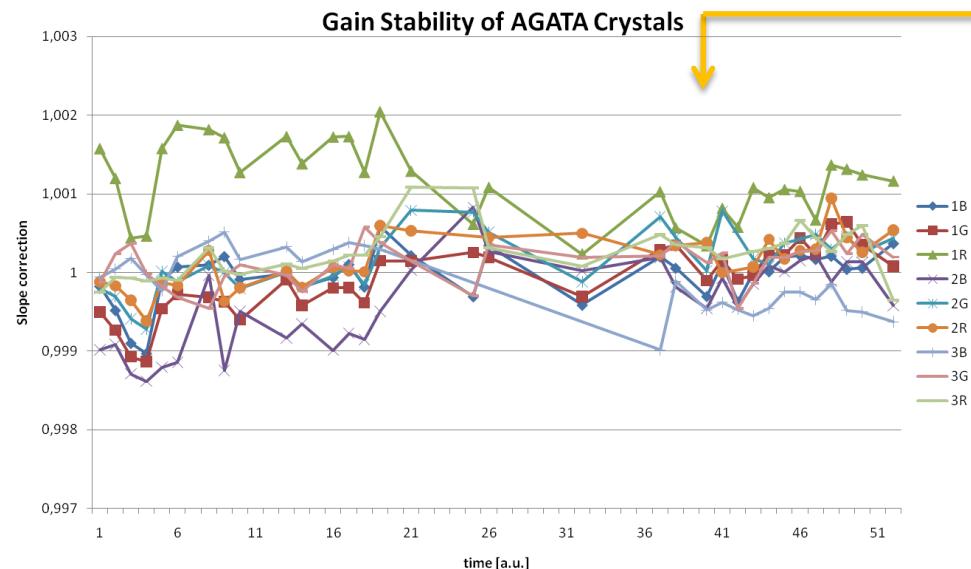
Data Replay and Presorting: calibration and linearity

AGATA calibration

- Energy calibration up to 9 MeV (AmBe(Ni) source)
- Detector linearity tested



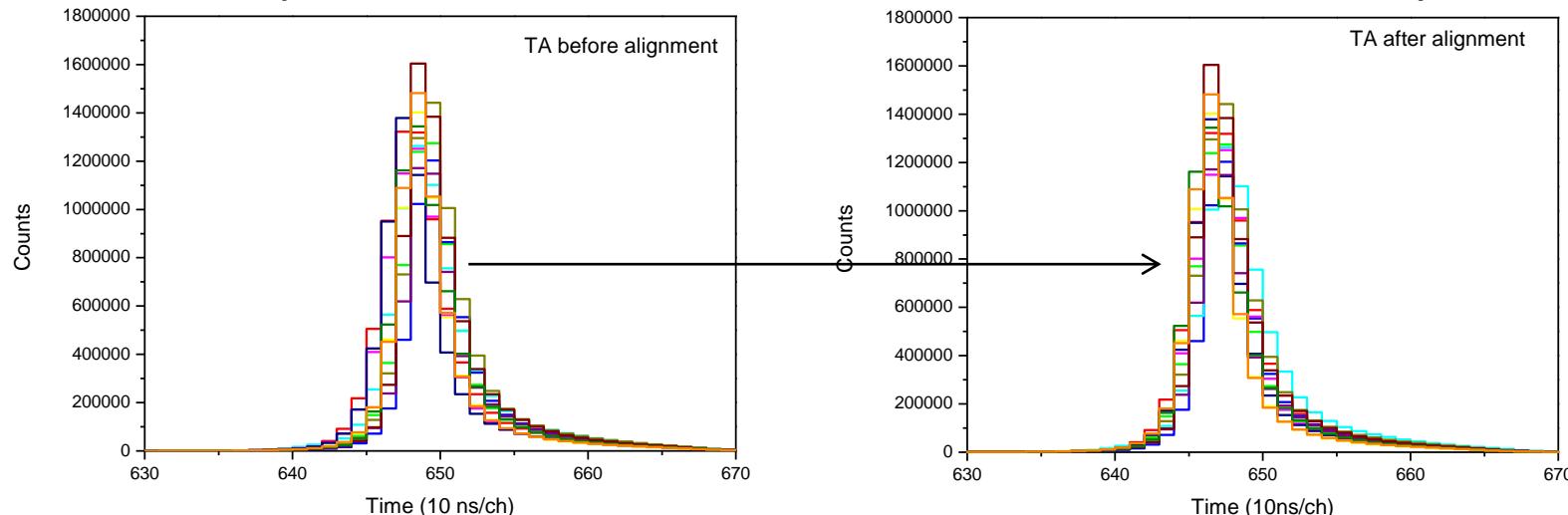
Fine AGATA energy calibration



No significant gain fluctuations (within 3%)
Very stable detectors for all the measurement duration

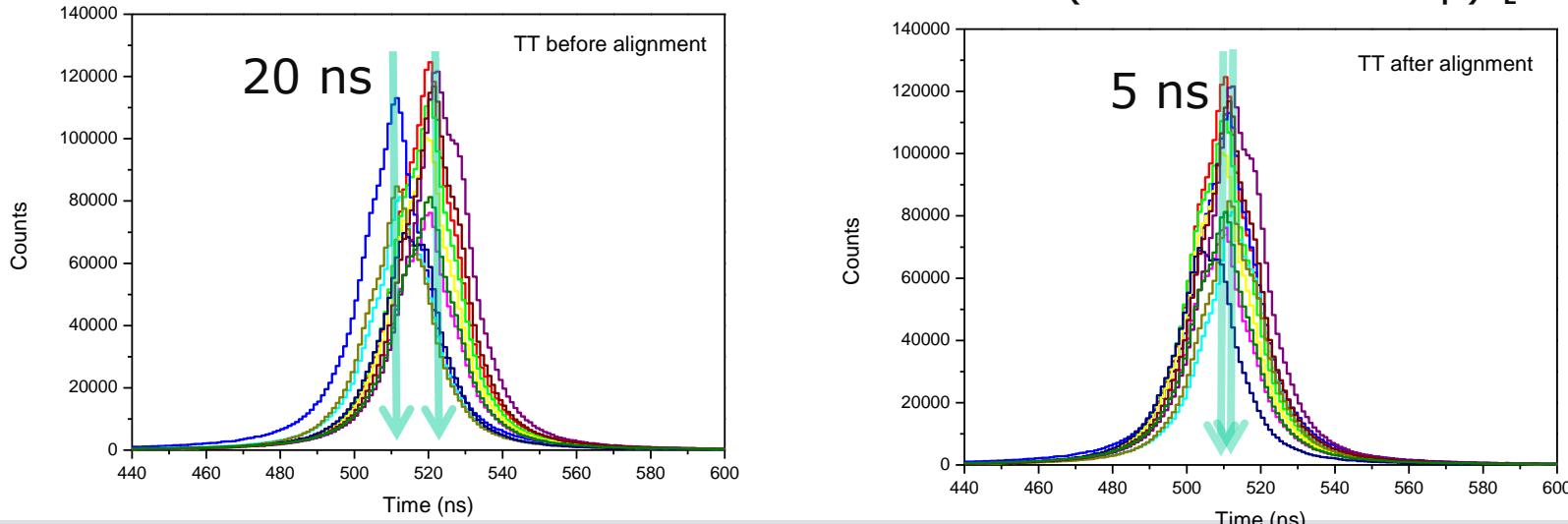
Data Replay and Presorting: Time alignment

Timestamp difference distribution: AGATA detectors vs Ancillary [TA]



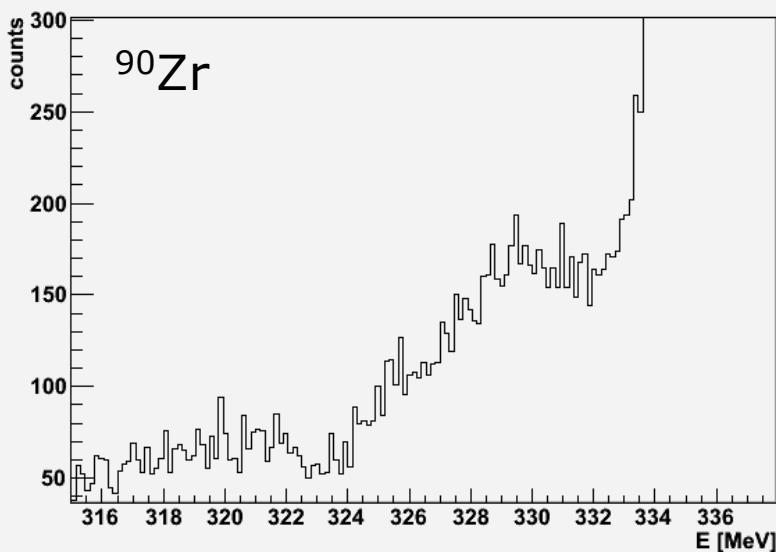
→ Final FWHM < 20 ns (adding phase shift information and CFD)

Time difference between the 12 AGATA detectors (CFD + Timestamp) [TT]

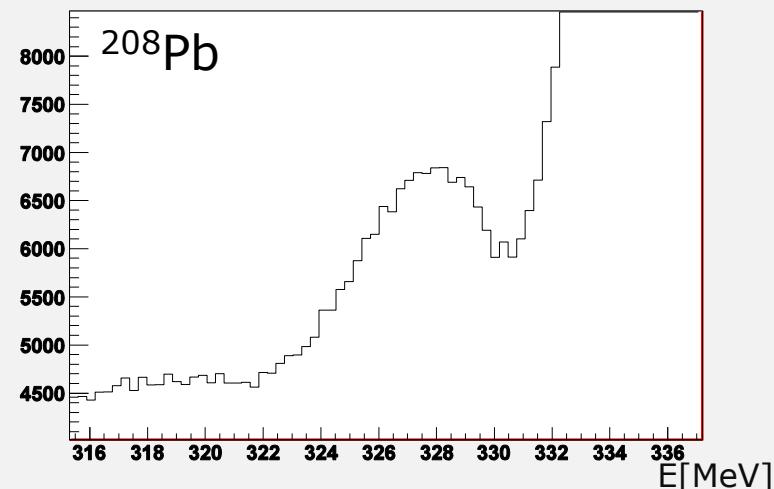


Preliminary results: Si detectors

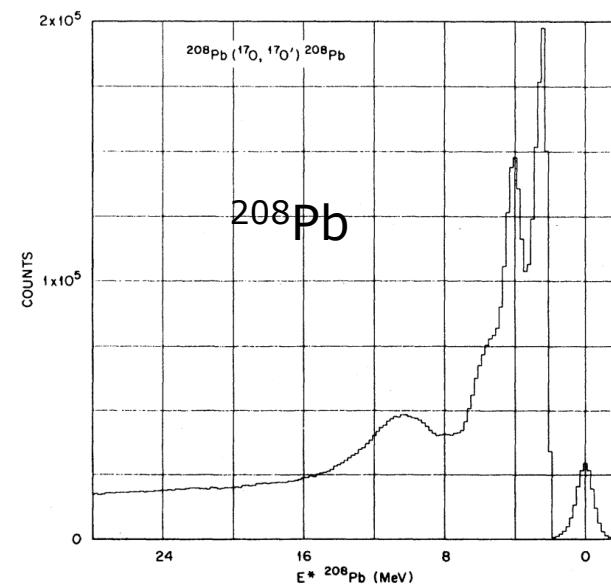
GQR excitation



Silicon detectors - ^{208}Pb GQR



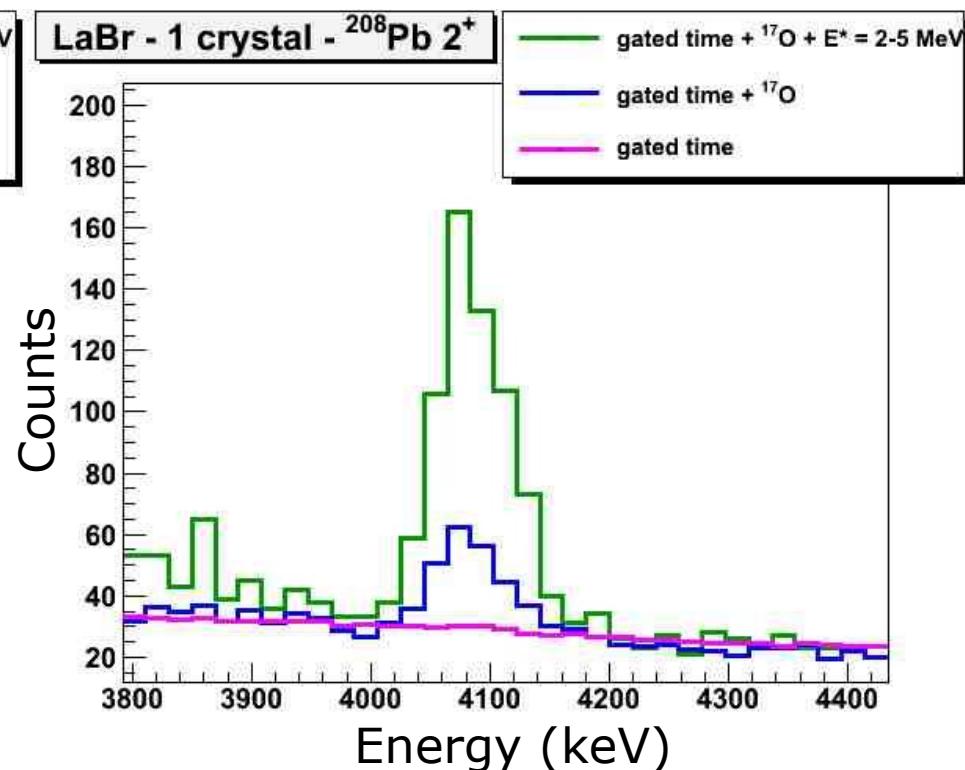
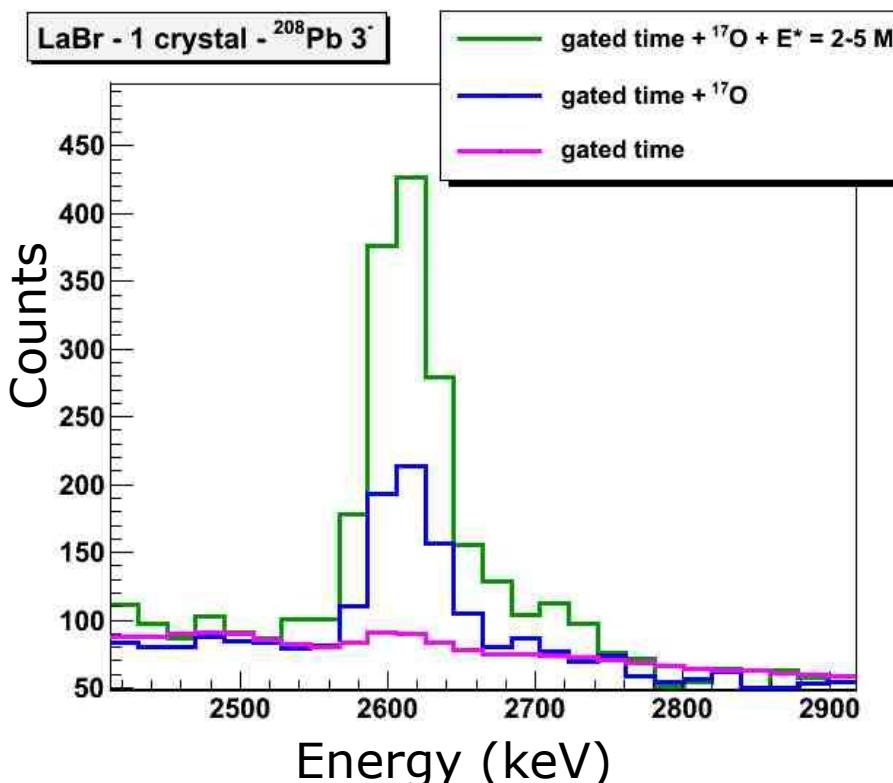
- Giant Resonance structure clearly visible at ~ 10 MeV of excitation energy for ^{90}Zr
- Also observed at ~ 12 MeV of excitation energy for ^{208}Pb



J. Beene et al PRC39(1989)1307

Preliminary results: Scintillators

- 1 $\text{LaBr}_3:\text{Ce}$ detector
- **Pink line histograms** : gated time
- **Blue line histograms** : gated time + ^{17}O detected in the Si telescopes (scaled)
- **Green line histograms** : g. t. + ^{17}O detected in Si + $E^* = 2 - 5 \text{ MeV}$



Preliminary results: AGATA Demonstrator

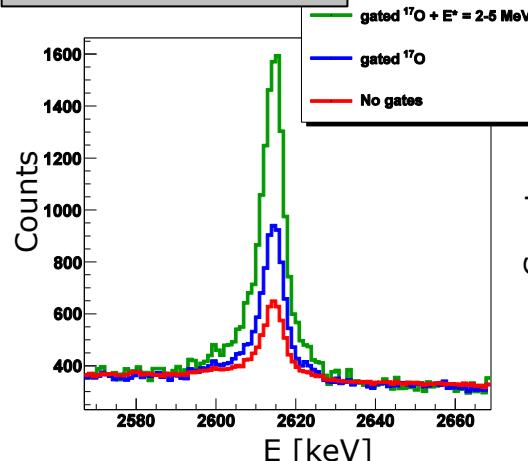
Outgoing ^{17}O + E^* Condition

Outgoing ^{17}O

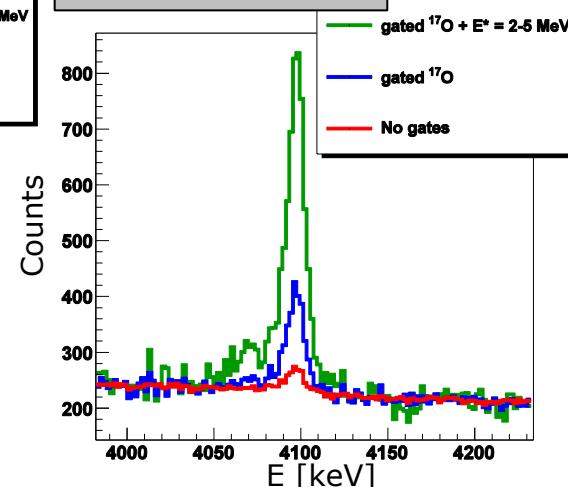
No Gate

Structures appear in gamma spectrum
after gating on ^{17}O With $E^* = 5\text{-}10 \text{ MeV}$.

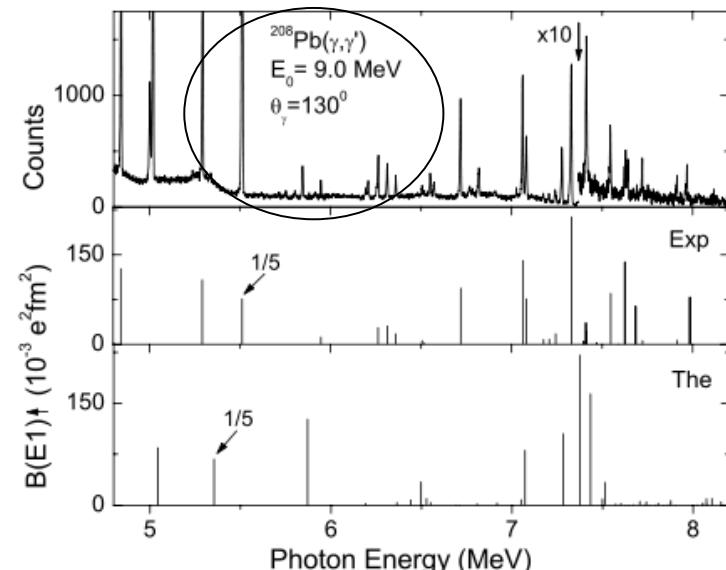
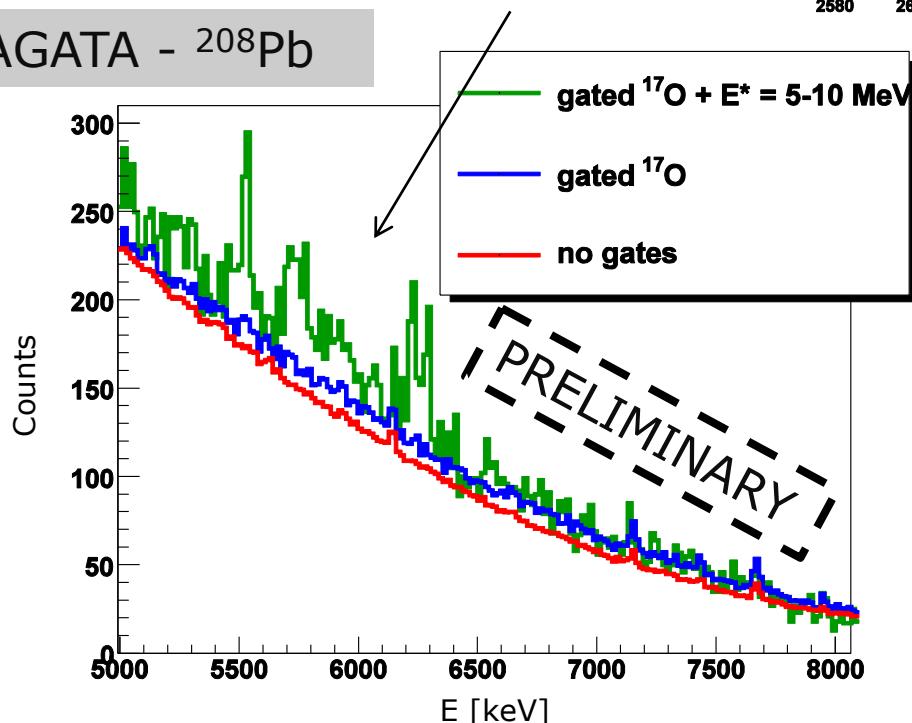
AGATA - $^{208}\text{Pb } 3^-$



AGATA - $^{208}\text{Pb } 2^+$



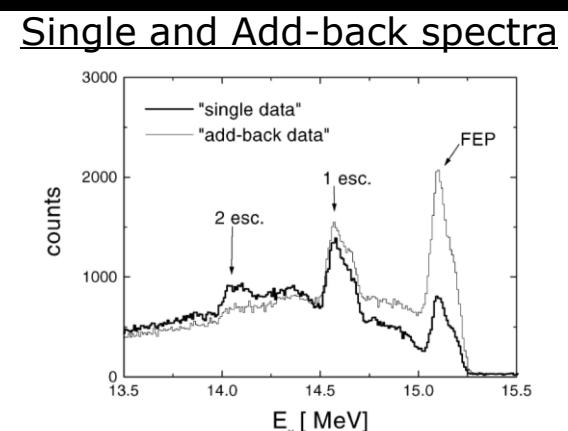
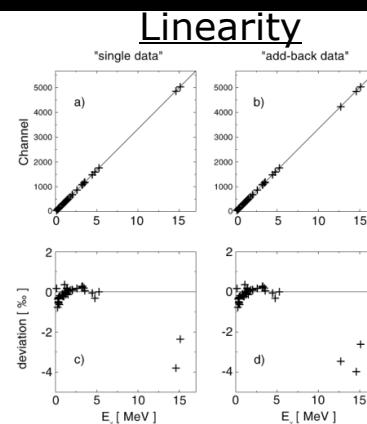
AGATA - ^{208}Pb



N. Ryezayeva et al., PRL 89, 27 (2002)

CALIBRATION Measurement with 15 MeV γ -rays and the AGATA cluster detectors (to be performed Dec. 2010 @ LNL, spokesperson F. Crespi)

Response of the EUROBALL cluster detectors to high energy gamma-rays
(B. Million et al., NIMA 452 (2000) 422)



AGATA cluster detectors:

- No characterization performed with gamma rays up to 15 MeV
- Need for tests in this energy range of:
 - PSA (*different algorithm needed?*)
 - Tracking ("The performance of gamma-ray spectrometers at high energies (several MeV) can be greatly improved through intelligent spectroscopic analysis...")*
 - Linearity
- Test the impact on Doppler correction capabilities
- Relativistic Beams (GSI)
- Data useful to further test neutron gamma discrimination methods developed for AGATA**



* "Intelligent Gamma-Ray Spectroscopy Using 3-D Position-Sensitive Detectors", C. E. Lehner, Z. He, G. F. Knoll, IEEE Trans. Nucl. Sci. 50, NO. 4 (2003) ** A. Ataç et al., Nucl. Instr. and Meth. A 607 (2009) 554

CALIBRATION Measurement with 15 MeV γ -rays and the AGATA cluster detectors (to be performed Dec. 2010 @ LNL, spokesperson F. Crespi)

The proposed test is intended to measure the AGATA detectors response to 15.1 MeV gamma rays that are emitted by the $1^+ \rightarrow 0^+$ M1 transition in $^{12}\text{C}^*$ produced in the **reaction:**



- 45 MeV ^{11}B XTU Tandem beam degraded to 19.1 MeV using gold foil in front of the target
- Target made of $\text{C}_{32}\text{D}_{66}$ with thickness of $490 \mu\text{g}/\text{cm}^2$ deposited on a 0.1 mm tantalum backing
- Both the recoiling nuclei and the beam are stopped in the target backing
 - This beam and reaction have been successfully used several times at LNL for calibration runs, during experimental campaigns with scintillation detector arrays (HECTOR) and in the EUROBALL campaign.

Summary

- Two Experiments were performed by the University of Milan group with the AGATA Demonstrator @ LNL (*R. Nicolini, D. Mengoni, May 2010 and V. Vandone July 2010*).
 - For both experiments (~30 TB (compressed) of data on disk) the data “replay” and presorting has been performed producing the root files that are used for the final sorting (→ data volume reduced by a factor of 20).
 - Preliminary results were shown for the R. Nicolini, D. Mengoni experiment:
Measurement of gamma decay from highly excited states (GQR, PDR), populated with inelastic scattering of heavy ions: fine structure, branching to low-lying states
 - Carefully verify the effect of gamma tracking algorithms response, especially at several MeV energy. Check ancillary detectors performance (Helena, LaBr, Si) to optimize gates.
 - CALIBRATION Measurement with 15 MeV γ -rays and the AGATA cluster detectors (to be performed 30 Nov. - 2 Dec. 2010 @ LNL)
- **Final Sorting to Extract Physics Results**

Thank you for the attention

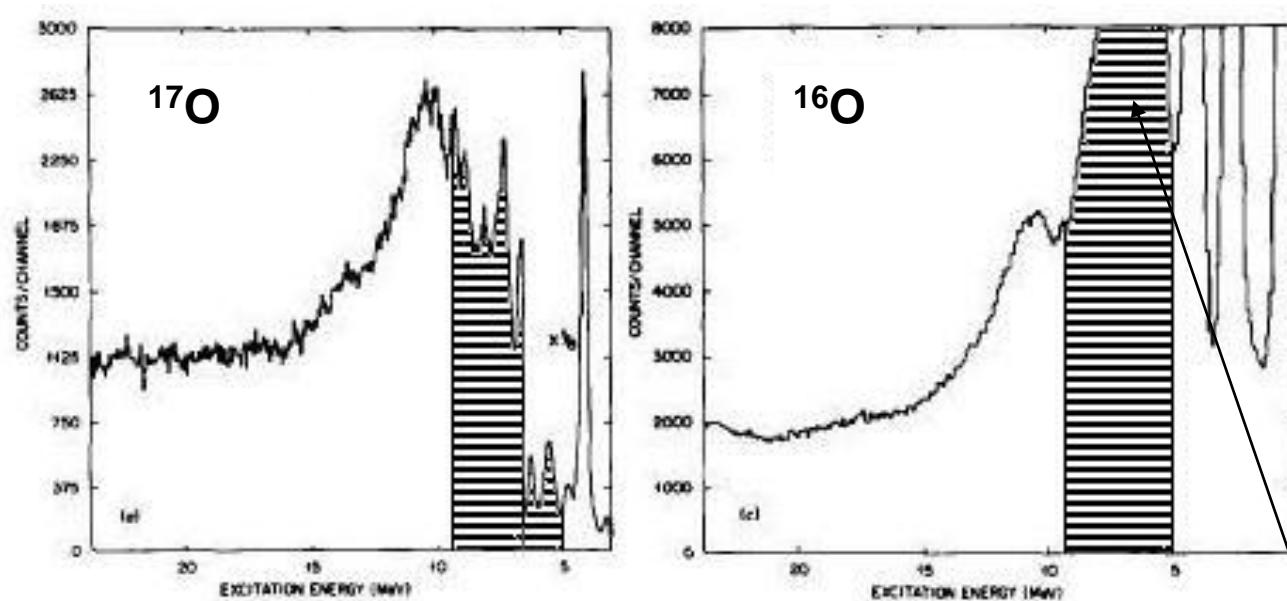
Experimental technique

Inelastic scattering ^{17}O @ 20 MeV/u on ^{90}Zr , ^{208}Pb , ... targets
+ γ -ray coincidence measurement

Heavy-ion scattering can populate giant resonances with large cross-sections

^{17}O is loosely bound ($S_n = 4.1$ MeV)

We can eliminate projectile excitation above 4 MeV



F. E. Bertrand et al NPA 482(1988)287c

Projectile excitation

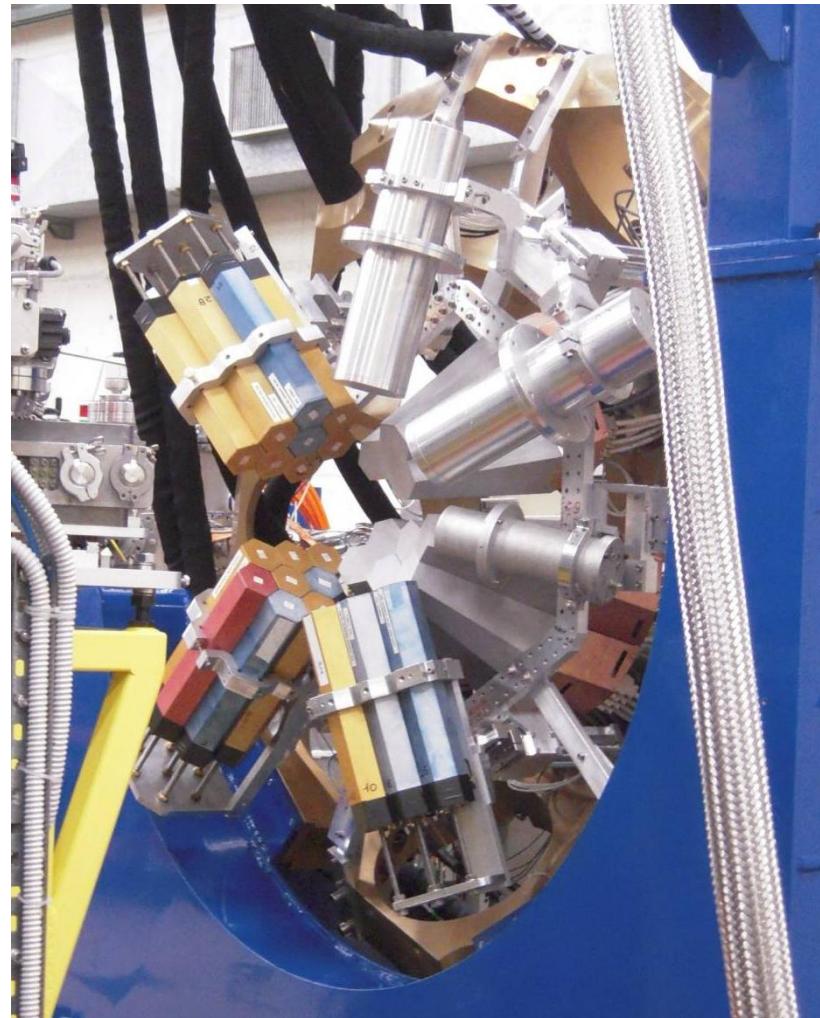
Scintillator array

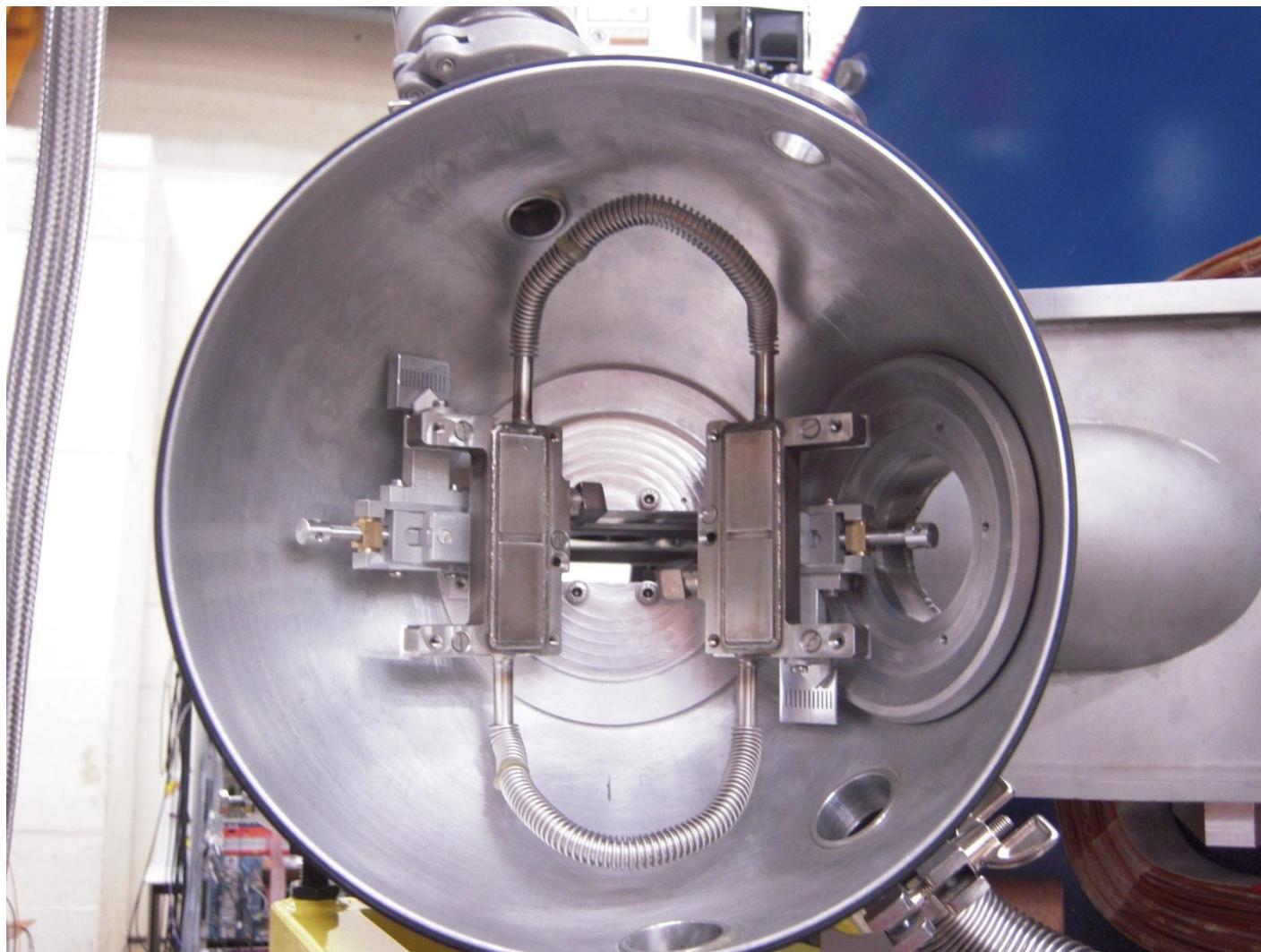
3 LaBr₃:Ce detectors

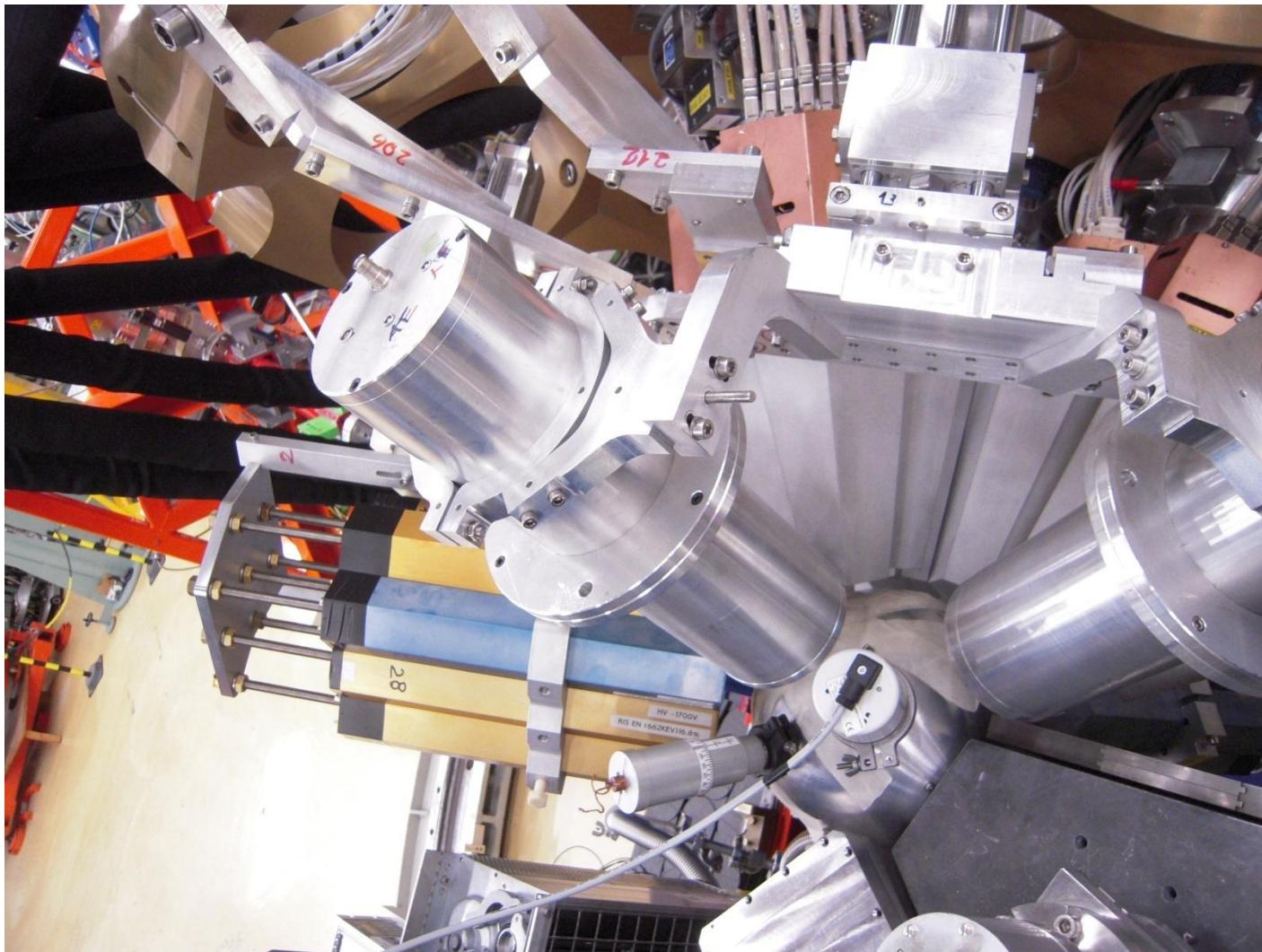
- High efficiency
(30% higher than HPGe)
- Large volume
(up to 9x20 cm)
- Good time resolution
(< 1ns)
- Good energy resolution
(the best of all scintillators,
20 keV FWHM at 662 keV)

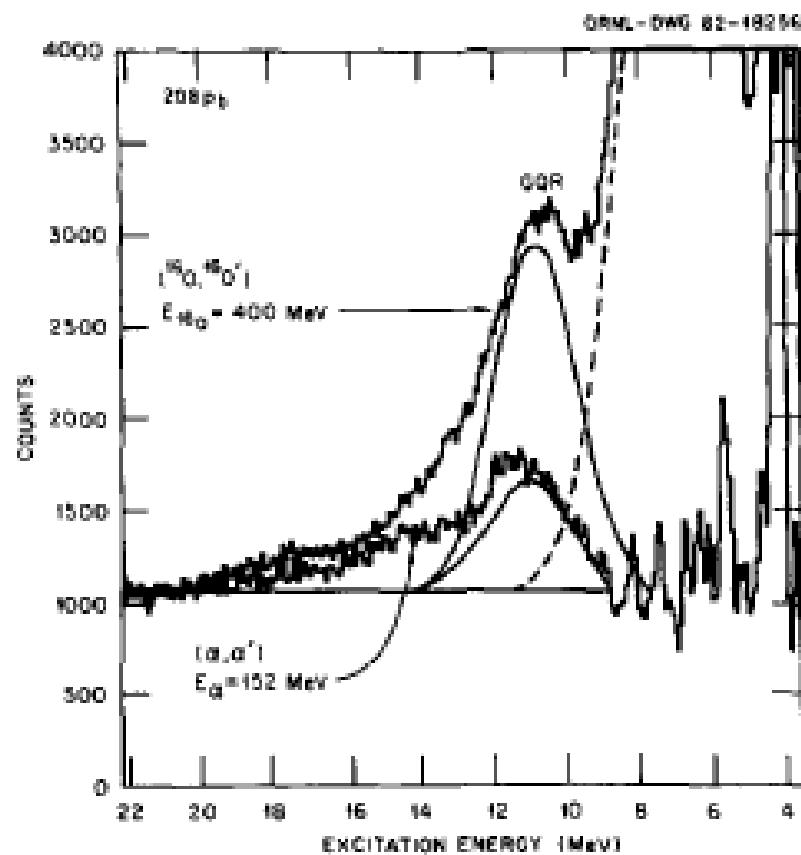
Helena BaF₂ clusters

- Large number of detectors
(20 crystals)
- Large solid angle
(30%)
- Good time resolution
(500 ps)

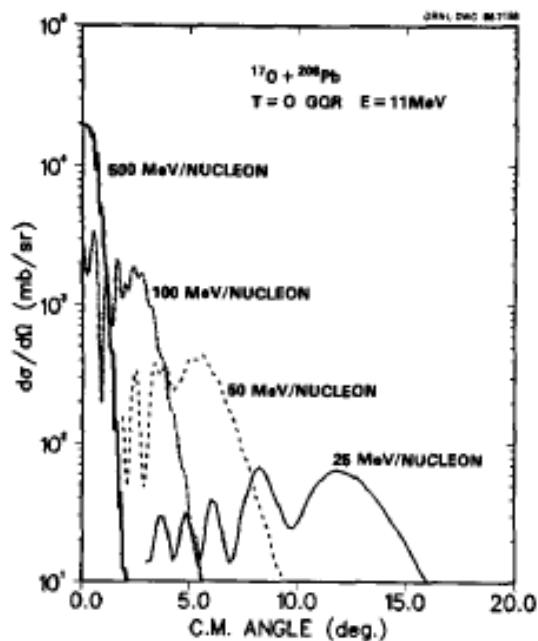




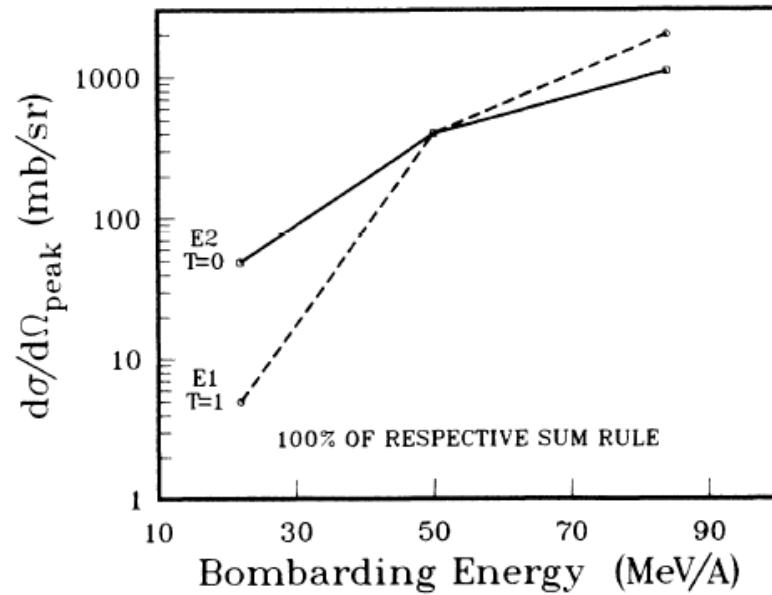




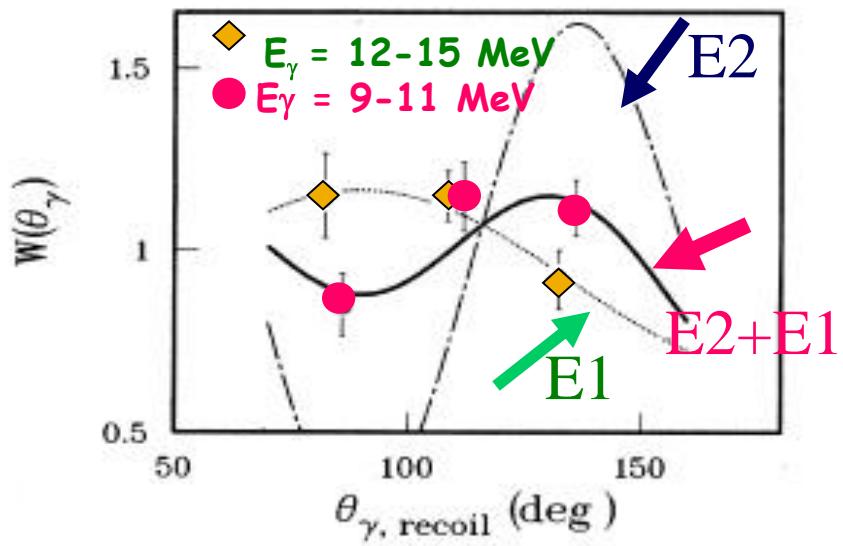
F.E.Bertrand et al NPA 482(1988)287c



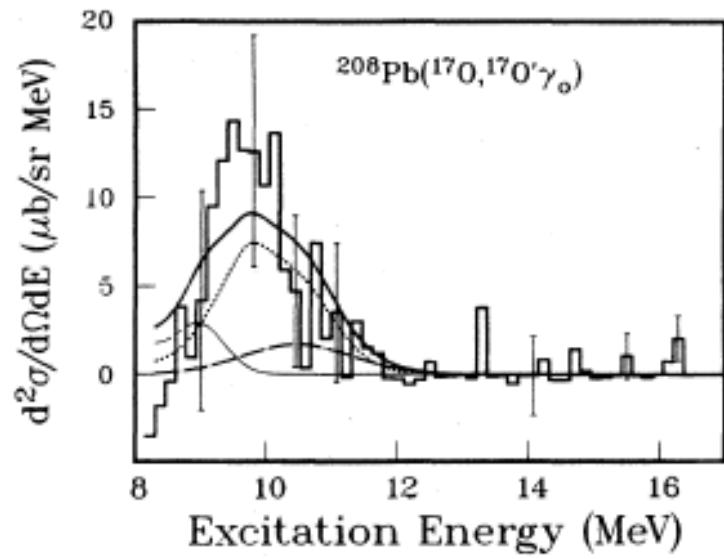
F.E.Bertrand et al NPA 482(1988)287c



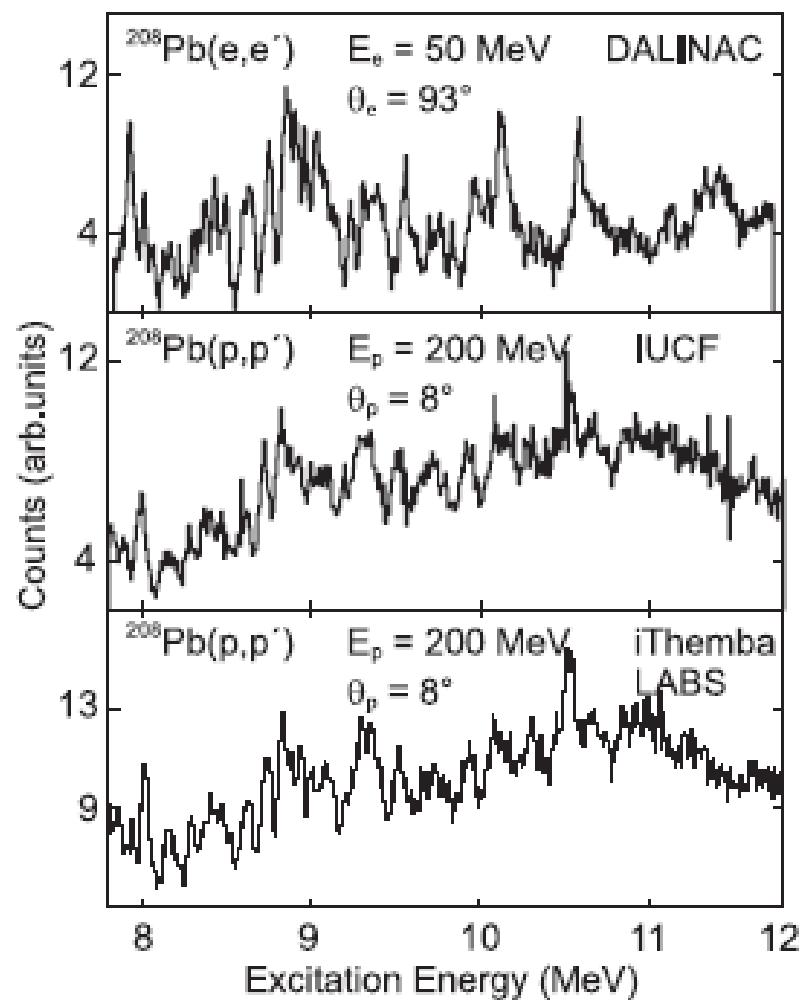
J. Beene et al. PRC41(1990)929

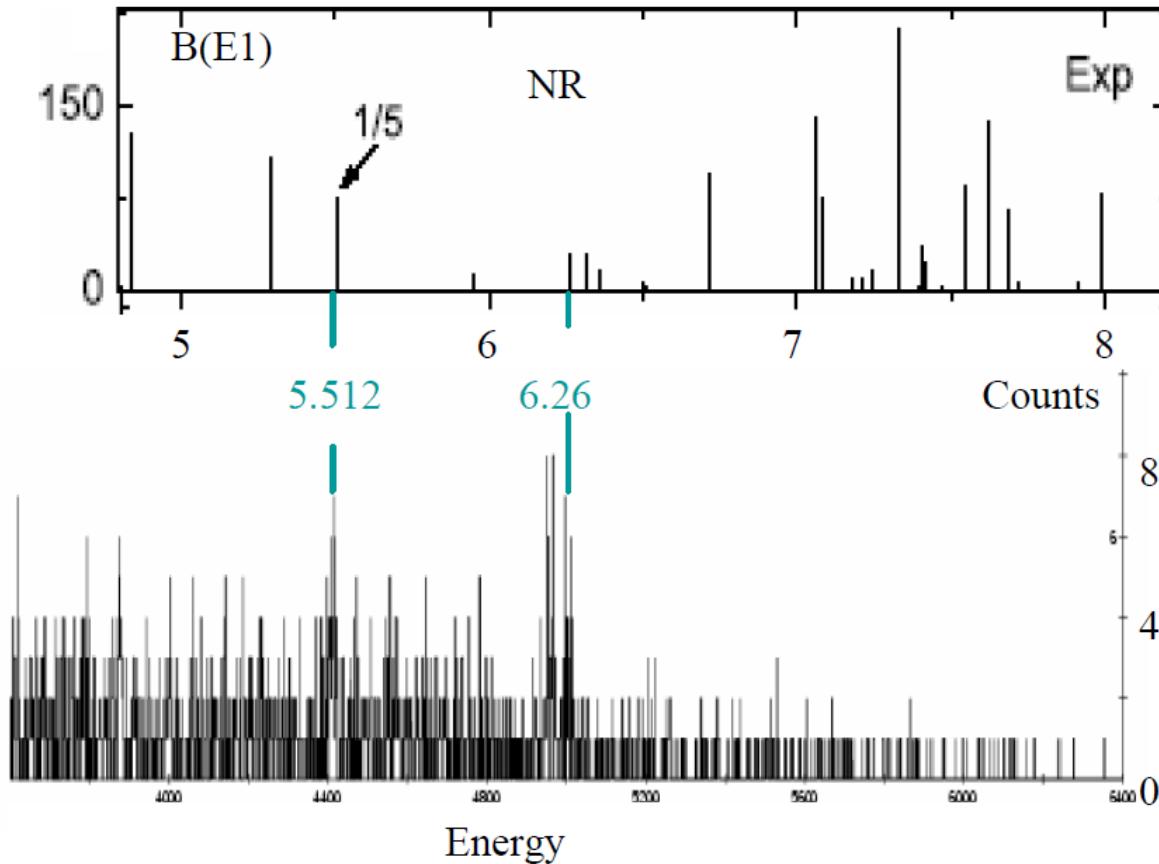


J. Beene et al PRC39(1989)1307



J. Beene et al PRC39(1989)1307





Pygmy Dipole Resonance in ^{208}Pb

M.A. Deleplanque¹, L.W. Phair¹, P. Fallon¹, M. Wiedeking¹, F.S. Stephens¹, I.Y. Lee¹, A.O. Macchiavelli¹, R.M. Clark¹, M. Cromaz¹, L. Moretto¹, S. Sinha¹, M. Descovich¹, E. Rodriguez-Vieitez¹, L. Bernstein², J. Burke², J. Church², E.B. Norman²

¹ Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720

² Lawrence Livermore National Laboratory, Livermore, California 94551

Inelastic scattering as a tool to search for highly excited states up to the region of the Giant Quadrupole Resonance: ^{208}Pb and ^{90}Zr

R. Nicolinia^a, D. Mengonici^{c,h}, A. Bracco^a, G. Benzonia^a, F. Birocchia^a, N. Blasi^a, C. Boiano^a, S. Brambillia^a, F. Camera^a, Á. Camplani^a, A. Corsia^a, F.C.L. Crespi^a, A. Giaz^a, S. Leonia^a, B. Million^a, L. Pellegrin^a, S. Riboldi^a, V. Vandone^a, O. Wieland^a, G. De Angelis^b, A. Gadea^{b,d}, P. Molini^b, D. R. Napoli^b, F. Recchia^b, E. Sahin^b, J.J. Valiente-Dobon^b, D. Bazzacco^c, E. Farnea^c, A. Gottardo^c, C. Michelagnoli^c, D. Montanari^c, C. Ur^c, A. Maj^e, M. Kimiecik^e, M. Ciemala^e, R. Kempley^f, A. Bürger^g

^a Università degli Studi e INFN sezione di Milano, Via Celoria 16, 20133, Milano.

^b INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy.

^c Università di Padova e INFN, sezione di Padova, Padova, Italy.

^d IFIC, Valencia, Spain.

^e The Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland

^f University of Surrey, Guildford, UK

^g University of Oslo, Norway

^h School of Engineering and Science, University of the West of Scotland, Paisley, Scotland-U.K.