Developments and future perspectives of coupling HPGe arrays with scintillators

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OUTLINE

HPGe – Scintillator coupling in the past

HPGe – Scintillator coupling in the present days: some example

- $LaBr_3$:Ce detectors
- AGATA and $LaBr_3$:Ce at LNL
- AGATA at PRESPEC at GSI

HPGe – Scintillator coupling in the future

- PARIS array

Scintillators of the future

Conclusion and Perspective

HPGe and inorganic scintillators detectors (up to 2006)

HPGe detectors

Energy Resolution 0.2% at 662 keV
Time Resolution > 10 ns
Linearity 0.05% at 15 MeV

Density 5 g/cm^3
Z(Ge) 32

- Small Crystals (3” x 3”)
- Low efficiency
- Large 1EP
- large 2EP

Very Sensitive to neutron damage
Complex handling
- Cooling
- FET failures

Very high costs

Generic Scintillator (up to 2006)

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Linearity ≅ 2% (PMT)

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Easy handling
PMT non idealities

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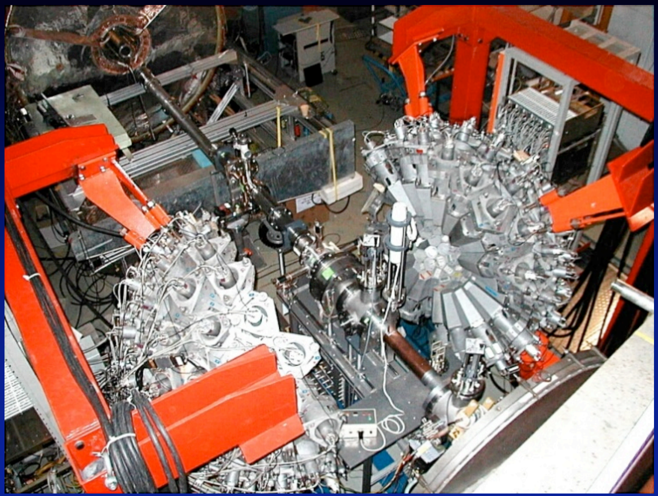
Scintillator Arrays - not for discrete γ spectroscopy -

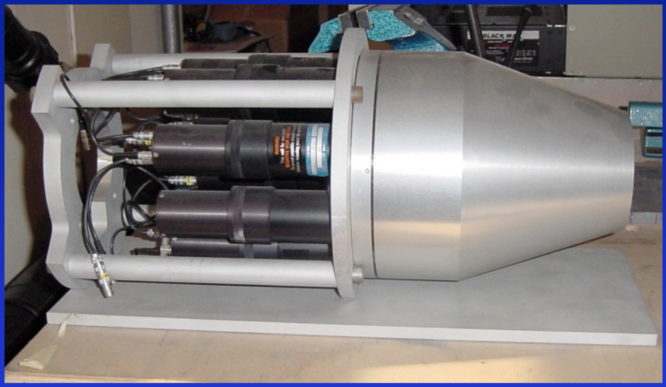
- Crystal Ball, Spin Spectrometer, Medea, Hector, ….



Scintillators as a bulk active volume

Scintillators for Anticompton Shields

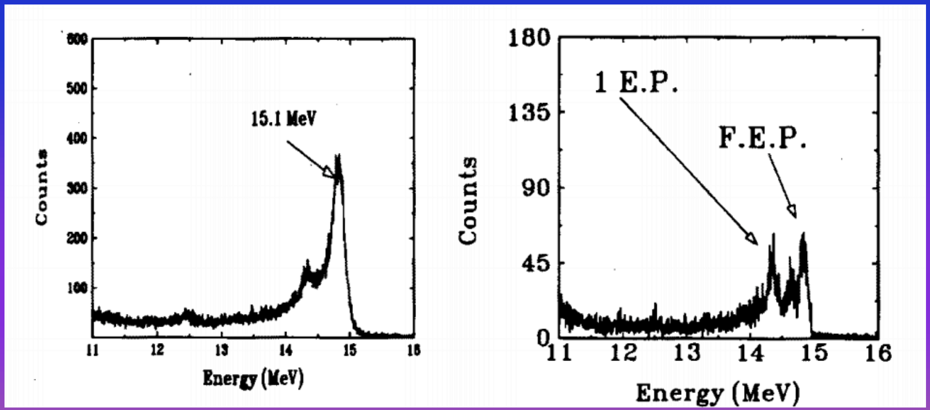
- HPGe ⇒ spectroscopic information
- Scintillators ⇒ yes/no information



Some tests for the Add Back technique

-The excellent resolution of HPGe is not destroied by the poor energy resolution of BGO

F. Camera et al NIM **A351**(1994)401-405



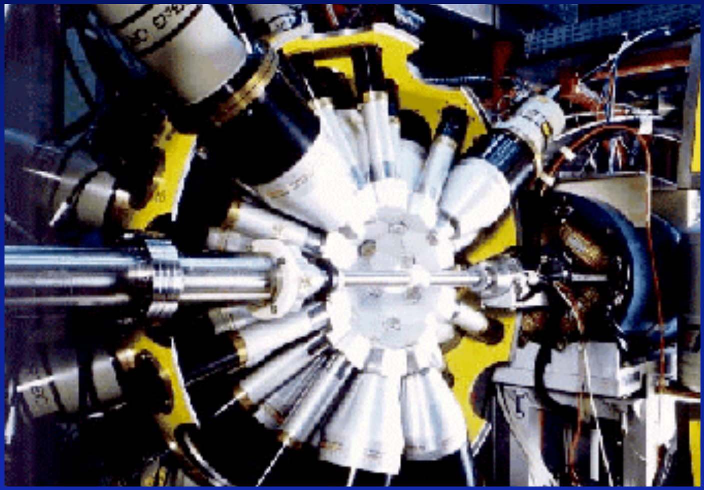
Physics Case ⇒ High Spin physics –

⇒ Very high density of gamma transitions

Scintillator Arrays as multiplicity filters

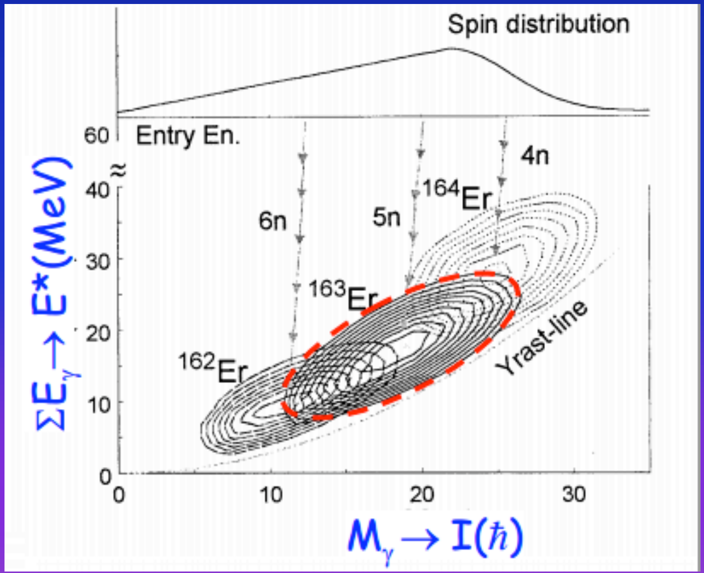
- Nordball ⇒ BaF_2 Ball
- GASP ⇒ BGO Ball
- Euroball ⇒ BGO Ball
- ……………………

' BaF_2 has appeared as a scintillator '



Multiplicity vs Sum-Energy plots

- First generation of ancillary detectors
- First use as:
    - HPGe coupled calorimeter
    - Cheap real 4π array
    - Time reference



Scintillator and HPGe coupled for nuclear structure studies – <u>Specific physics case</u> -

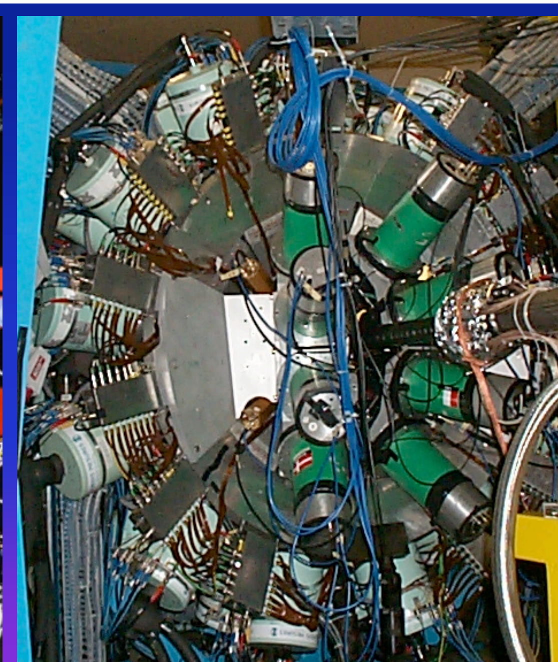
- HPGe provides high energy resolution
- Scintillator provides efficiency and time resolution
  - Measurement of high energy γ-rays
  - Neutrons and background rejection (in scintillator spectra)
  - Some physics cases receive large benefit from this union

Physics cases: GDR γ-decay

- Exclusive measurements
  - SD states feedings
  - Residue gated GDR

Hector + Nordball
Hector + PEX
Hector + Euroball

Scintillator and HPGe were complementary but substantially different in their use

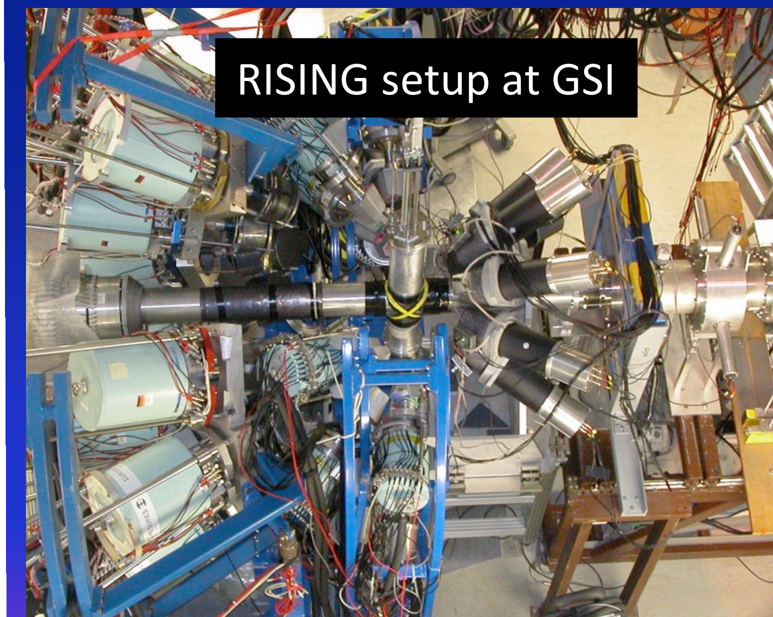


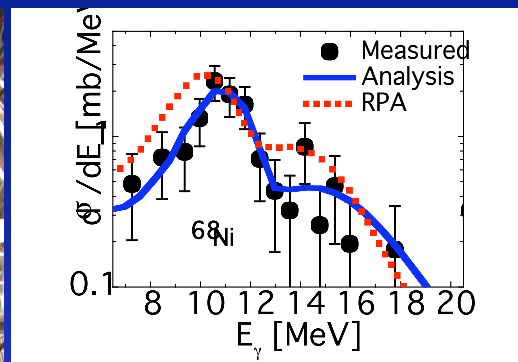
Hector + Euroball (LNL and IRES)

Radioactive Beam facilities

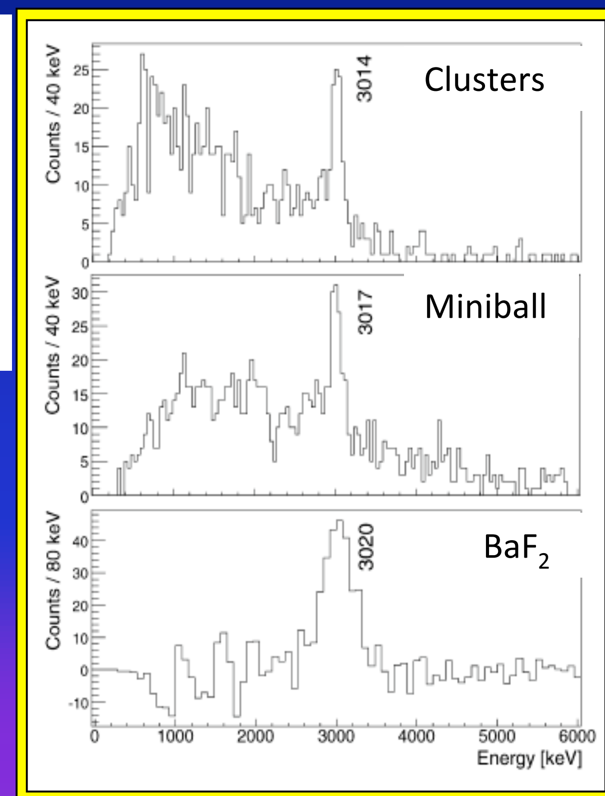
Very High background ⇒ good time resolution required
Low intensity beams ⇒ high efficiency required
Relativistic beams ⇒ high energy γ-rays

Few separated transitions transitions





O.Wieland et al.
PRL 102, 092502 (2009)



P.Doornebal et al Phys. Lett. B647(2007)237

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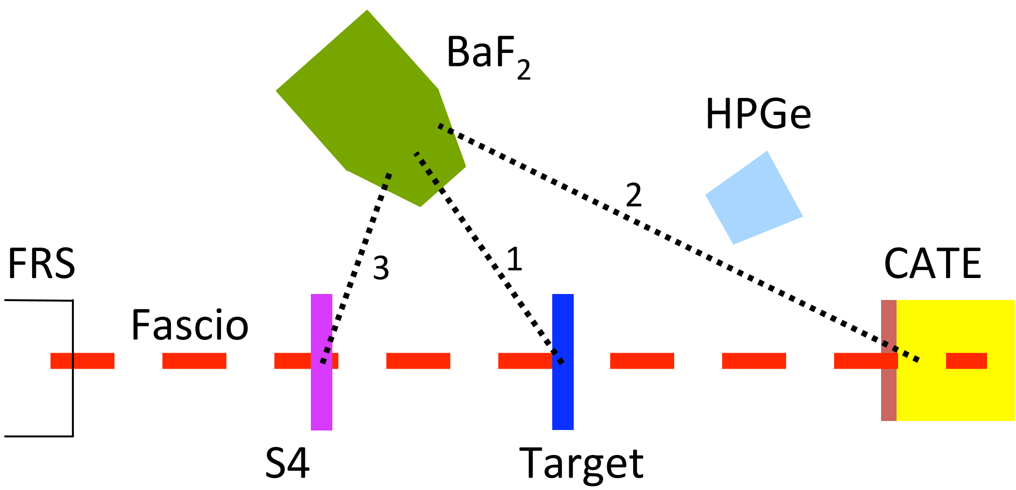
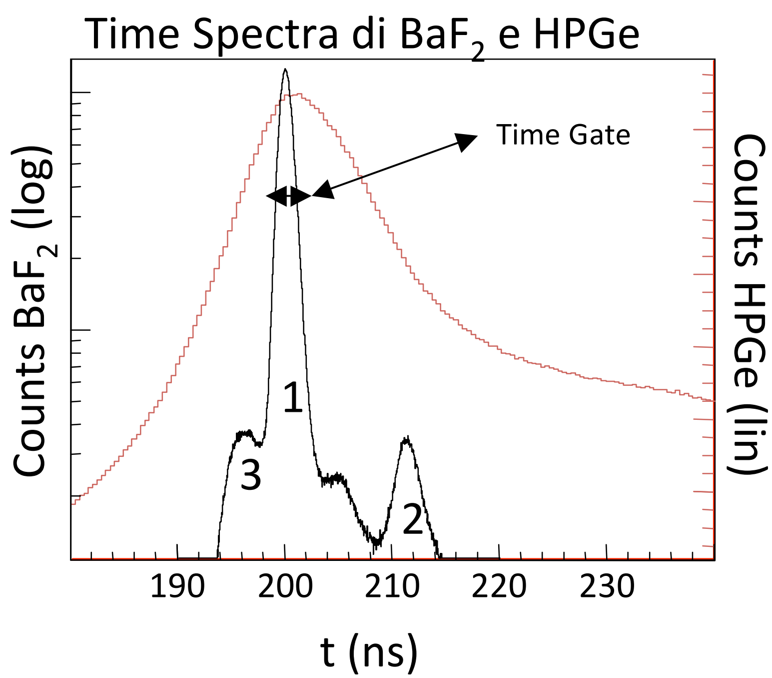




Thanks to R.Nicolini

LaBr$_3$:Ce Scintillators

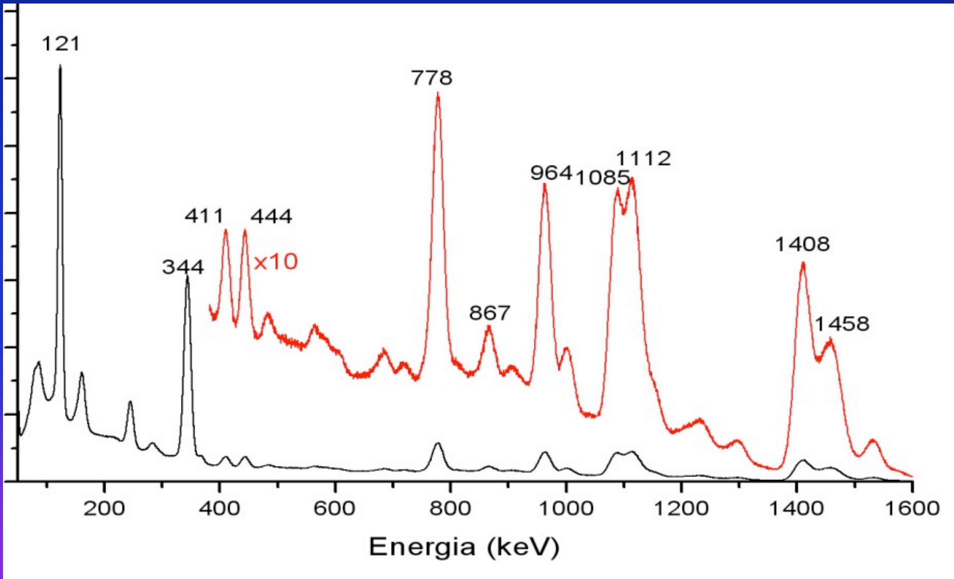
2001 – Discovery - Applied Physics Letter 79(2001)1573

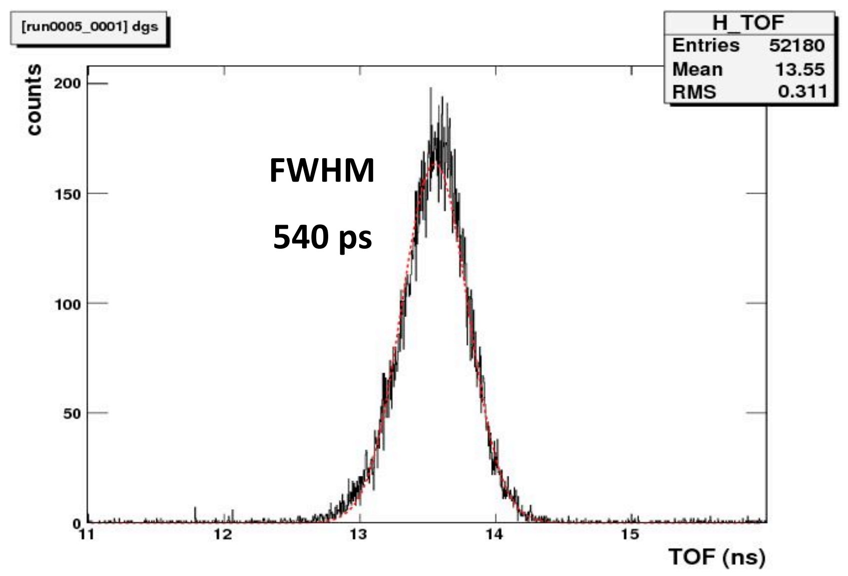
2005 – 1” x 1” Commercially available
2006 – 3” x 3” Commercially available
2007 – 3” x 6” Commercially available
2008 – 3.5” x 8” Commercially available

L.Y. ≈ 63 ph/keV
Decay Time ≈ 16 ns
$\lambda \approx$ 380 nm
N ≈ 1.9
ρ = 5.3 g/cm^3

RL (661 keV) 1.9 cm

History of LaBr$_3$:Ce started 10 years ago
History of large volume LaBr$_3$:Ce started **only** 3-4 years ago

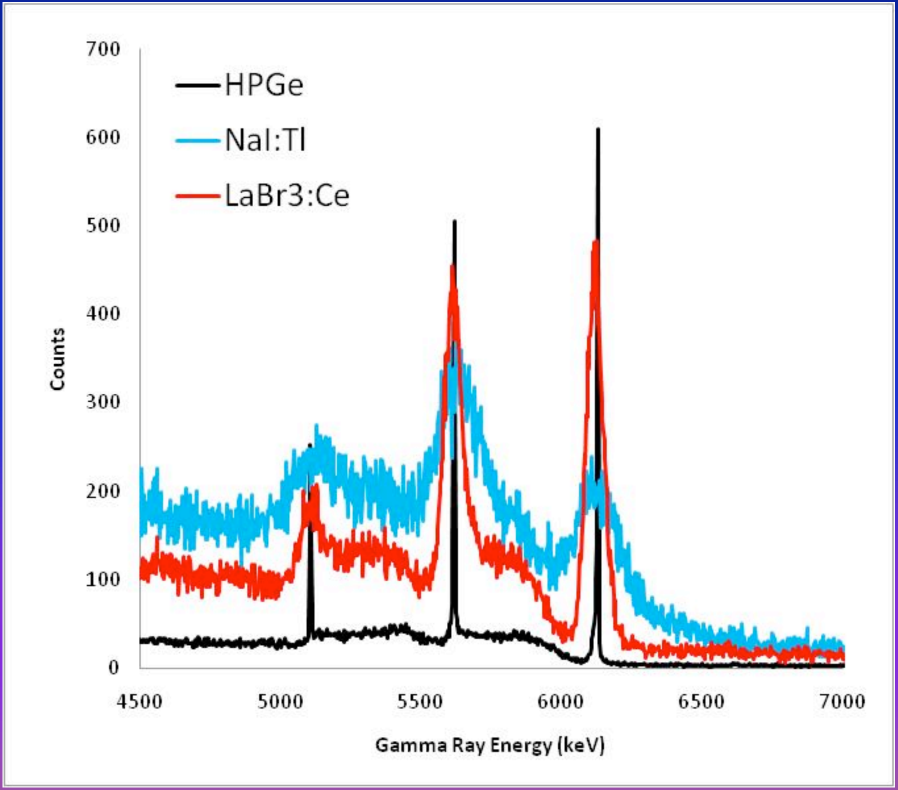


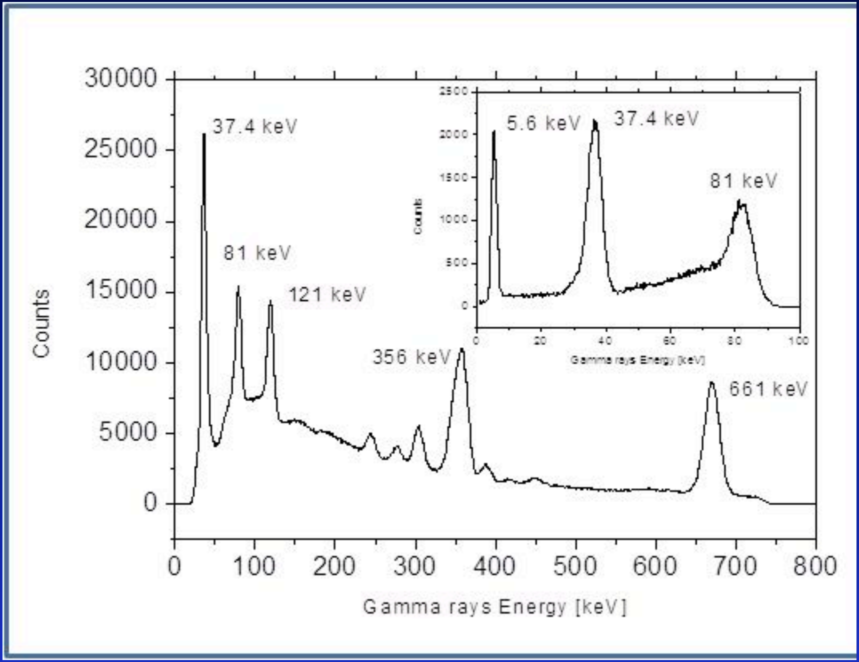


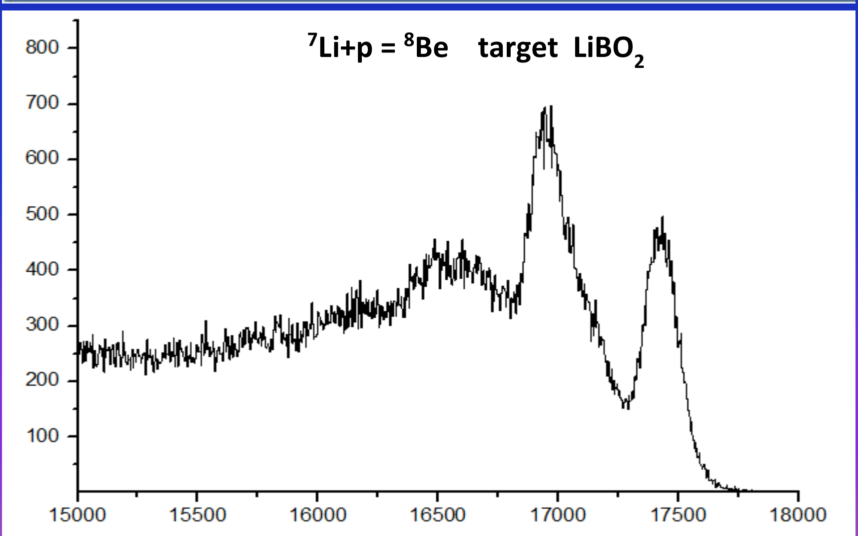
NIM A582(2007)554
NIM A602(2009) 520
NIM A629 (2011)157 … and many others

$LaBr_3$:Ce Scintillators

HPGe still possesses an unmatched energy resolution but $LaBr_3$:Ce has a much better energy resolution if compared to whatever scintillator together with high efficiency and sub-nanosecond time resolution







Thank to S.Riboldi and S.Brambilla

LaBr$_3$:Ce Scintillators

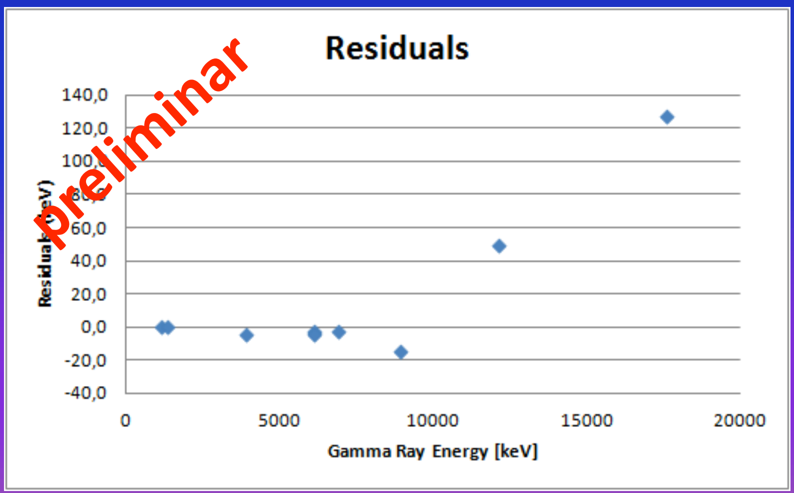
LaBr$_3$:Ce can stand a count rate which is much higher than HPGe without a significative deterioration of the Energy resolution

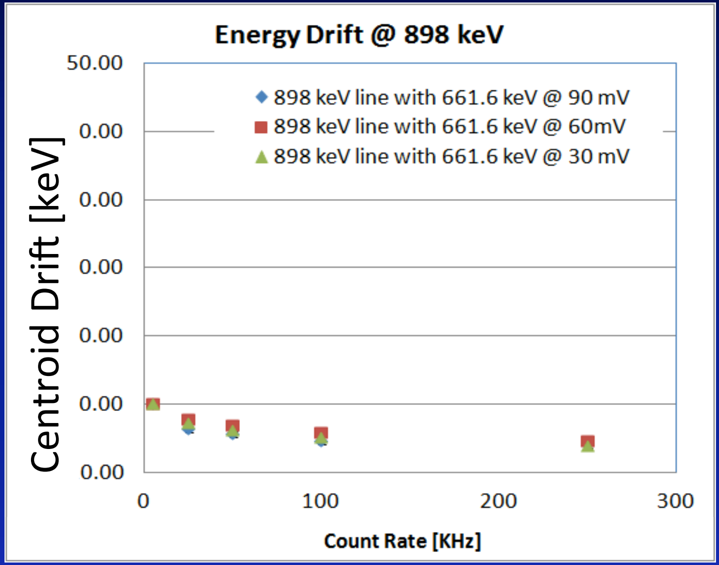
5 - 250 kHz $\Rightarrow$ A.Giaz et al to be submitted

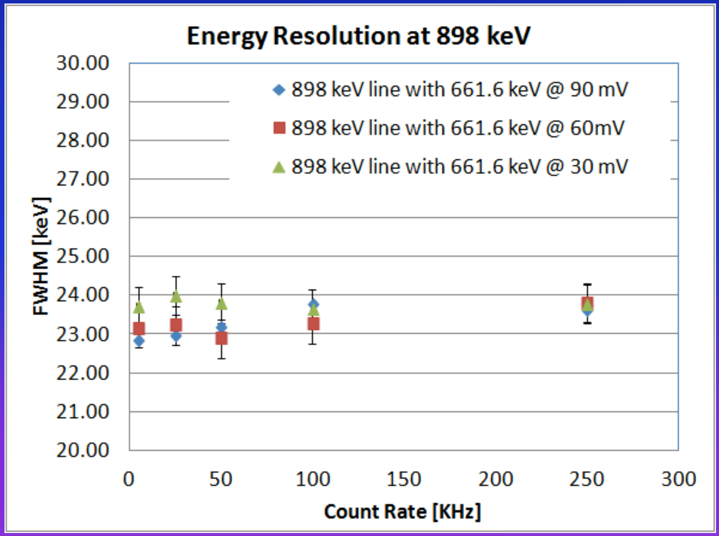
5 – 2.2 MHz $\Rightarrow$ Nocente et al to be submitted

$\Rightarrow$ Nocente et al. Rev. Sci. Inst. 81,10D321 (2010)

In case of very large dinamic range the PMT-VD non linearity if coupled to LaBr$_3$:Ce seems not to be a big issue







Thank to S.Riboldi and S.Brambilla

HPGe, inorganic scintillators and $LaBr_3$:Ce

HPGe detectors

Energy Resolution 0.2% at 662 keV
Time Resolution > 10 ns
Linearity 0.05% at 15 MeV

Density 5 g/cm^3
Z(Ge) 32

- Small Crystals (3" x 3")
- Low efficiency
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- large 2EP

Very Sensitive to neutron damage
Complex handling
- Cooling
- FET failures

Very high costs

Generic Scintillator

Energy Resolution > 6 % at 662 keV
Time Resolution ≅ 1 ns
Linearity ≅ 2% (PMT)

Density high
Z(Ge) high

- Very Large Crystals
- High efficiency
- Small 1EP
- No 2EP

Low Sensitivity to neutron damage
Easy handling
PMT non idealities

Low Costs

Large $LaBr_3$:Ce detectors

Energy Resolution ~ 3 % at 662 keV
Time Resolution ~ 0.5 ns
Linearity good

Density 5.2 g/cm^3
Z(I) 57

- Large Crystals (3.5" x 8")
- high efficiency
- small 1EP (with collimator)
- No 2EP

No Sensitivity to neutron damage
High Count Rates
Easy Handling
PMT non idealities

Medium Costs

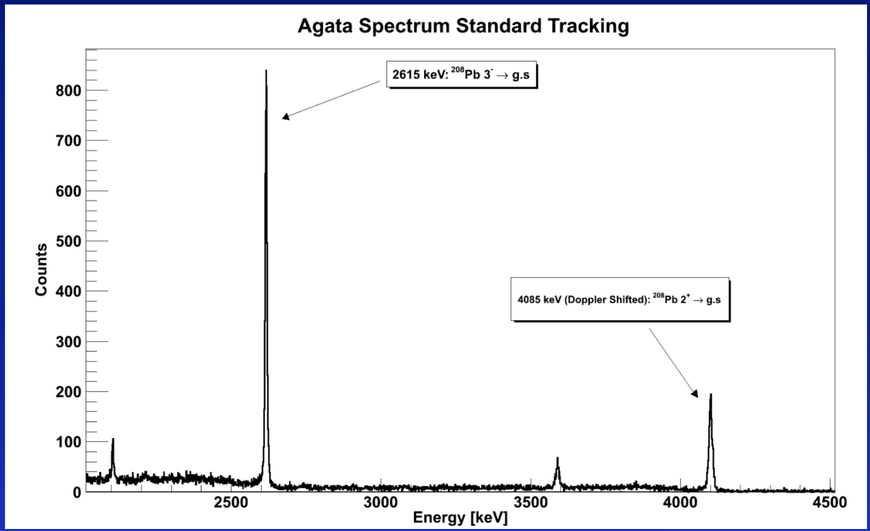
A $LaBr_3$:Ce/scintillator array can increase the efficiency and makes more powerful the physics program of an HPGe Array

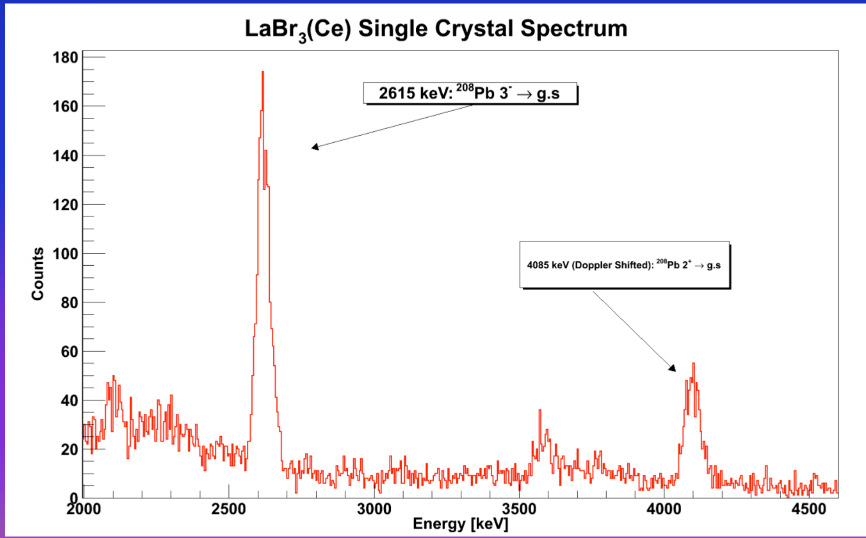
Scintillators not only for
- Anticompton shields
- Multiplicity filter
- ancillary

Scintillators as spectroscopic detectors

γ decay of the GDR-GQR in inelastic scatterinc reactions
$^{208}Pb(^{17}O,^{17}O')^{208}Pb$ @ 20 MeV/u

Low density of γ lines and high energy γ-rays





Thank to F.Crespi and L.Pellegri

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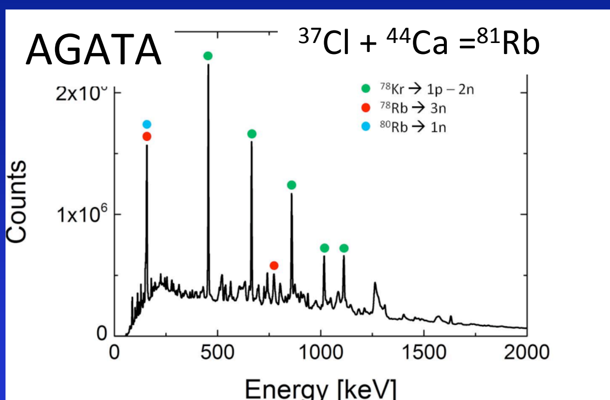
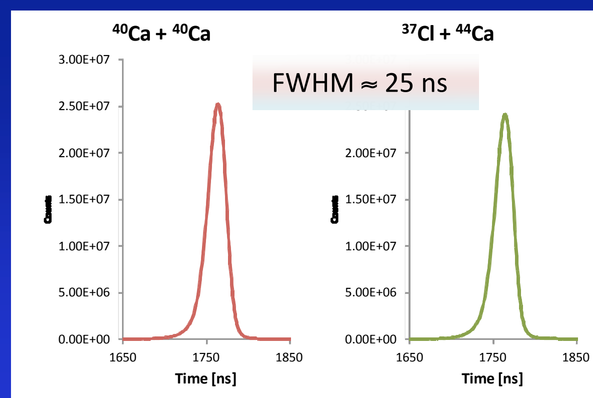
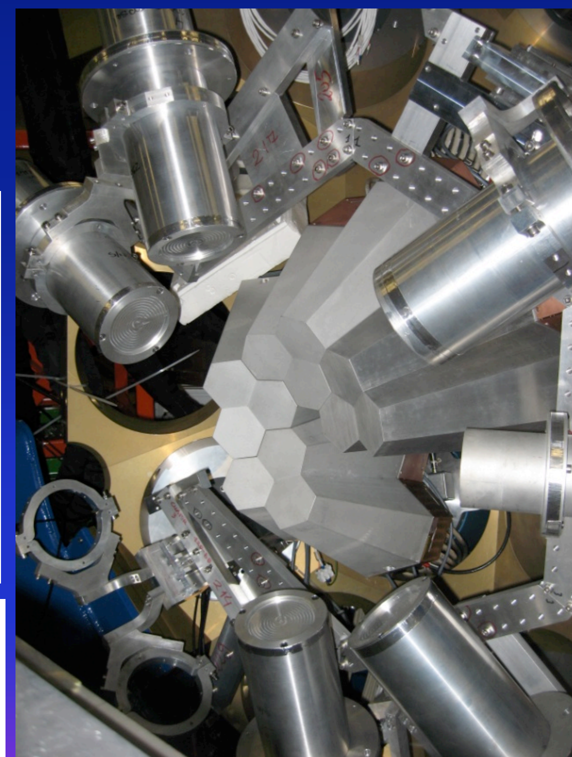
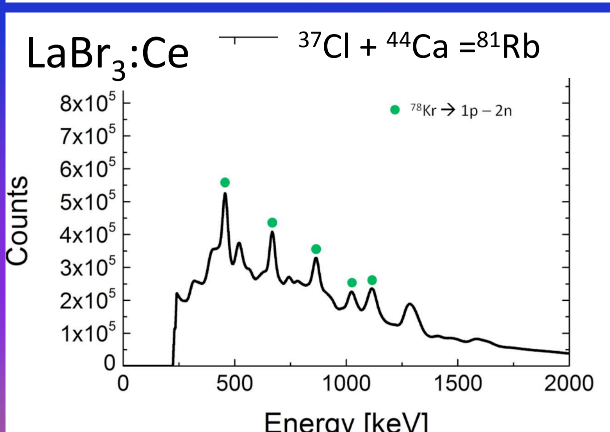
Scintillators as spectroscopic detectors

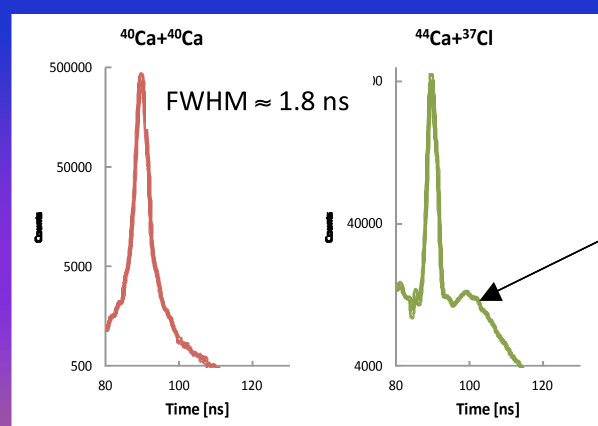
Isospin Mixing in the N=Z Nucleus ^{80}Zr at Medium Temperature











neutrons

Thank to S.Ceruti and A.Giaz

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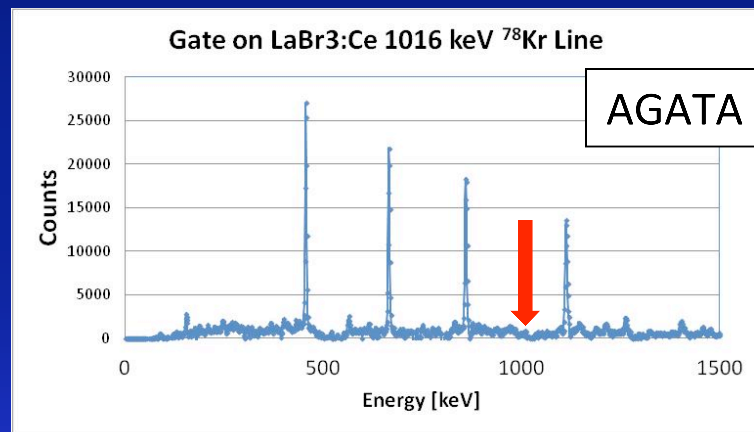
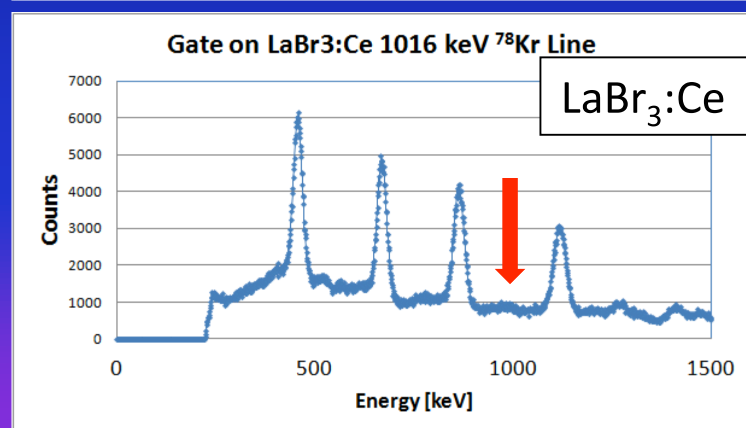
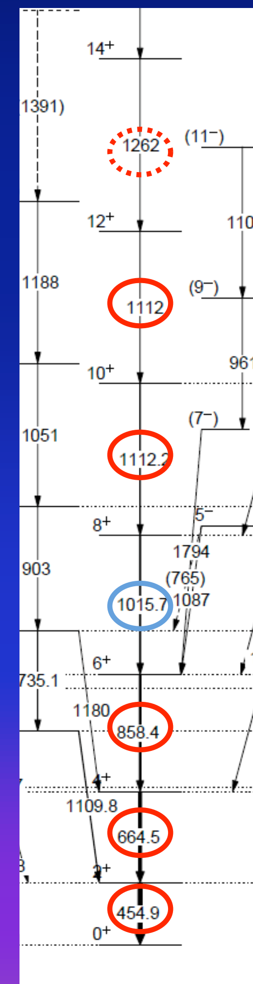
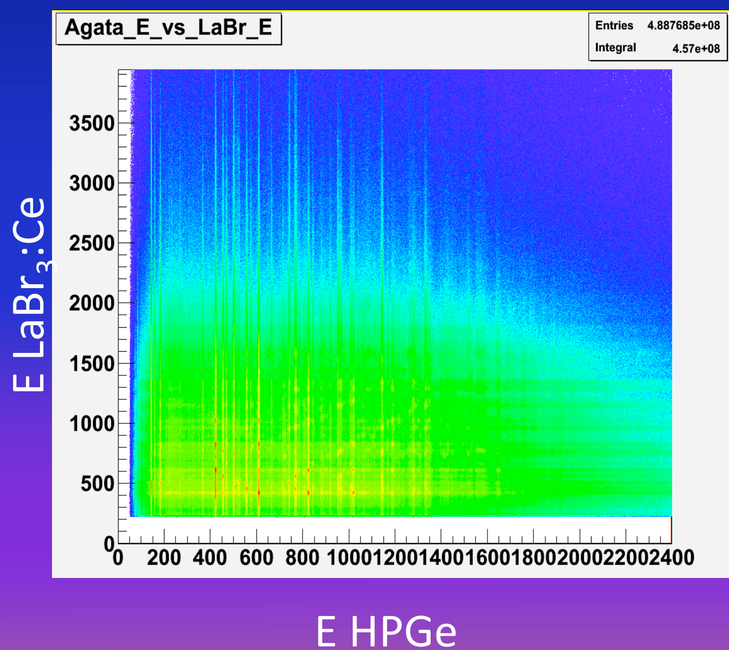
Scintillators as spectroscopic detectors









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Scintillators as spectroscopic detectors

-5 Agata TC subtend a solid angle which is approximately twice that of 6 large volume LaBr3:Ce

By coupling HPGe and scintillators it was possible a 50% increase in the solid angle with spectroscopic detectors capable to totally reject background

Trigger	Events
AGATA & $LaBr_3$:Ce	82%
$LaBr_3$:Ce $M_\gamma \geq 2$	21%
Singles $LaBr_3$:Ce	2%
Singles AGATA	5%

Net Gain (subset of data):

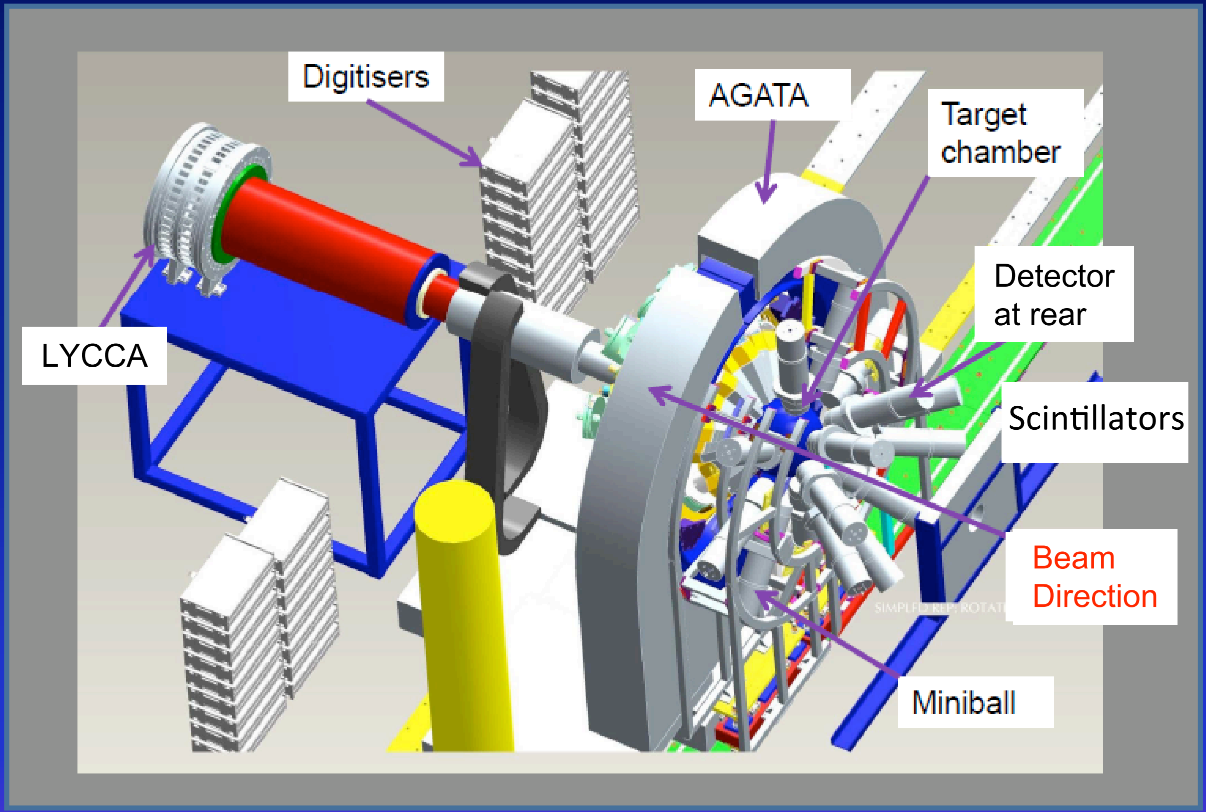
AGATA $M_\gamma \geq 2$ Events = 0.4 10^7 events

$LaBr_3$:Ce $M_\gamma \geq 2$ Events = 0.3 10^7 events
AGATA & $LaBr_3$:Ce Events = 1.1 10^7 events

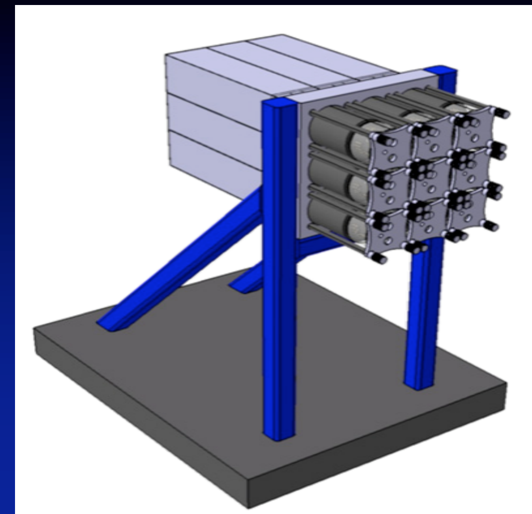
The presence of $LaBr_3$:Ce produces three times more statistics usefull for the physics case

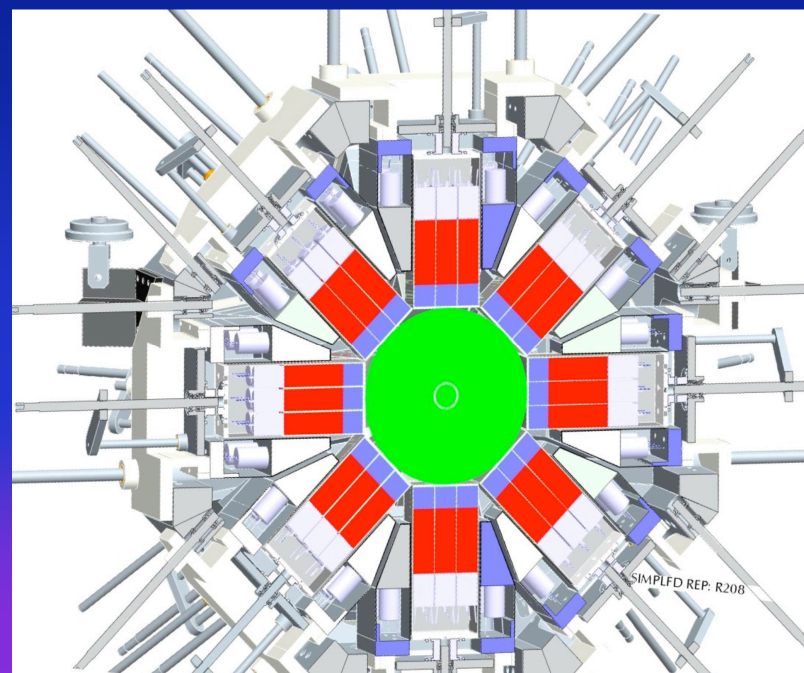
Thank to S.Ceruti and A.Giaz

AGATA at PRESPEC (GSI)



PARIS

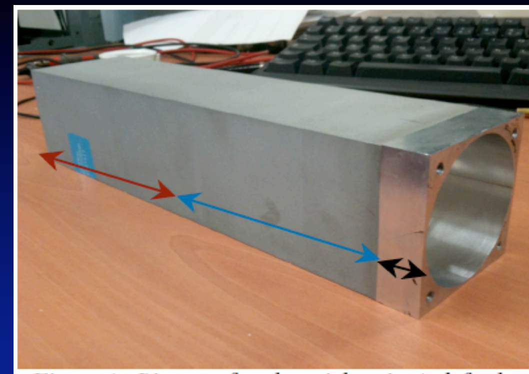




Thanks to A. Maj

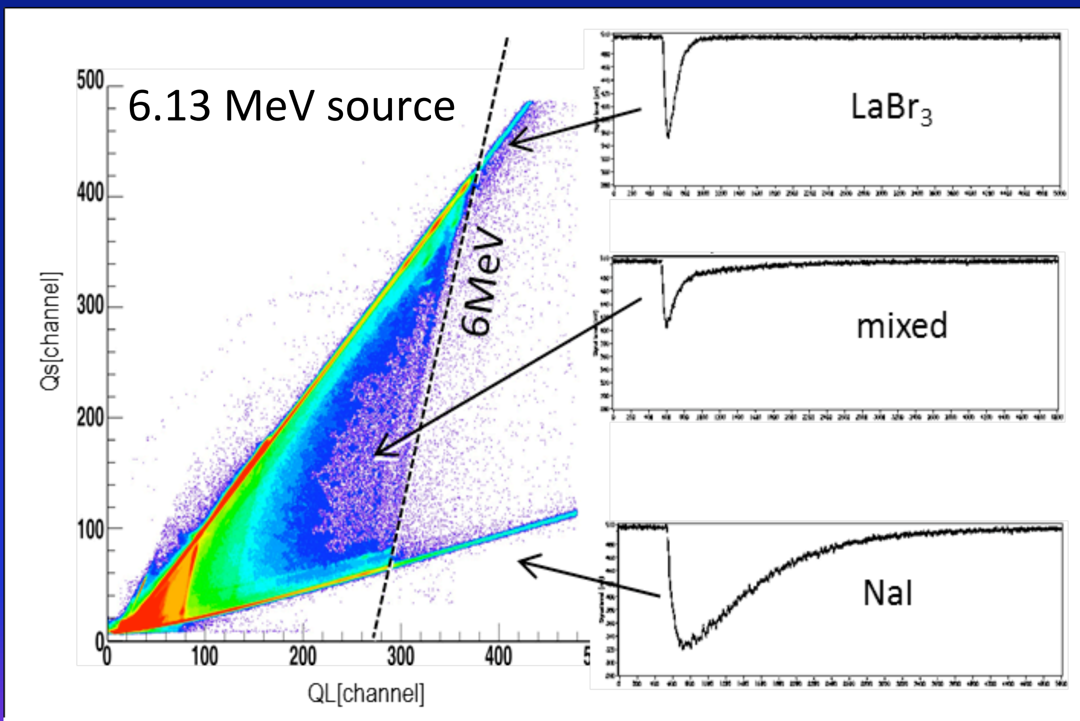
The Phoswich geometry is a tradeoff between performance and costs.

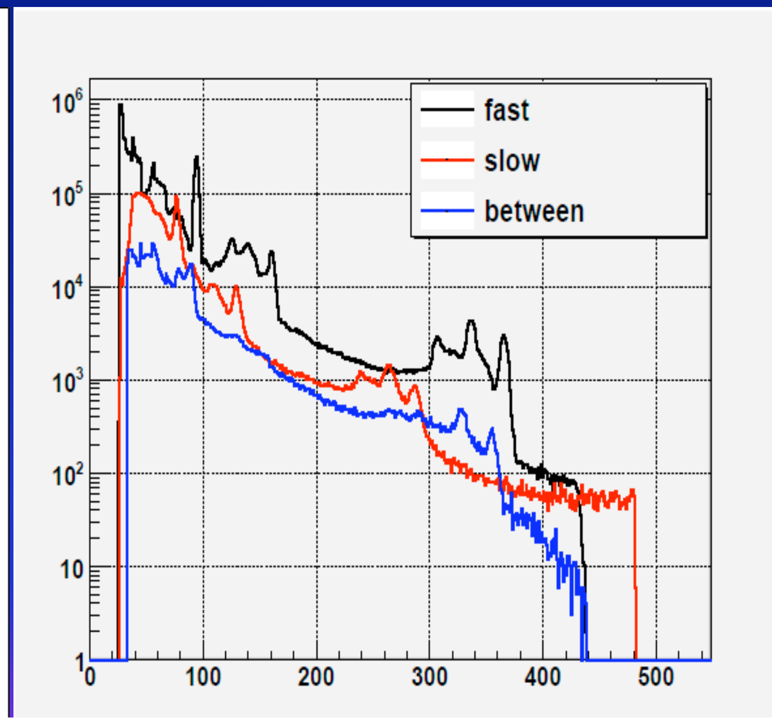
- A. Maj et al., Acta Phys.Pol. B40, 565 (2009)
- http://paris.ifj.edu.pl



NaI (2”x2”x6”)

LaBr3 2”x2”x2”





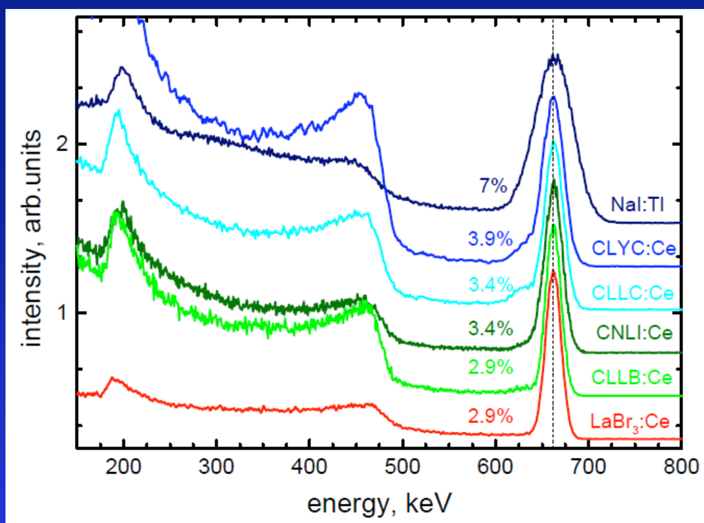
plot for a phoswich detector obtained for a 6MeV gamma source unsing simple analog electronic

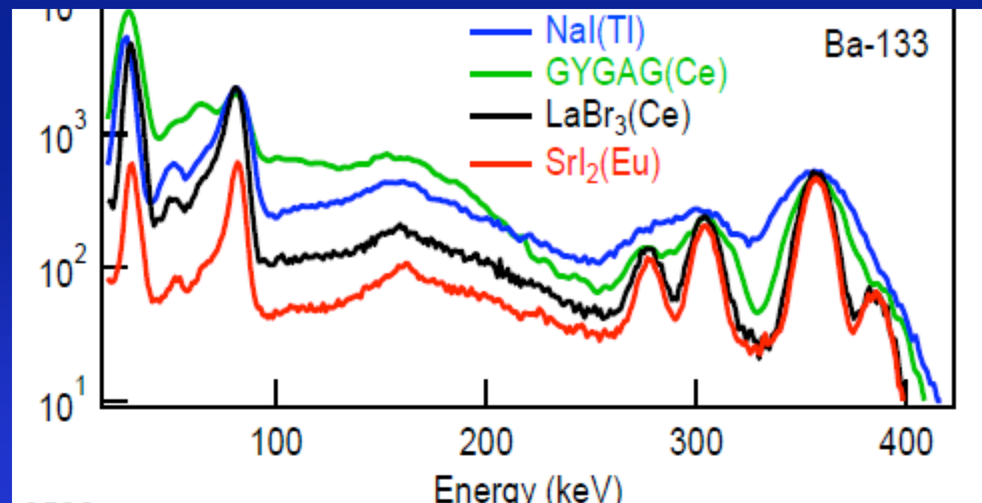
PARIS+ HPGE will be an extremely high performing instrument

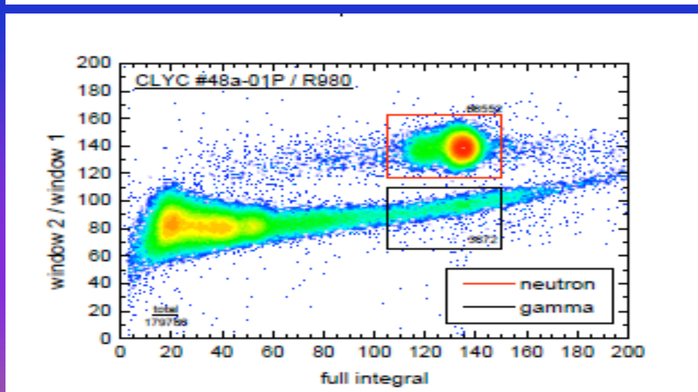
Thanks to A. Maj

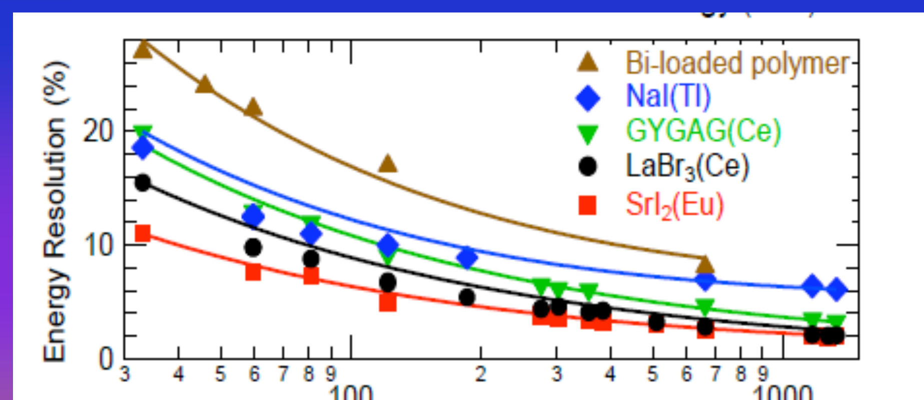
New Scintillators in the future ?

CLYC, CLLB, CLLC, $CeBr_3$, GYGAG, SrI_3









Thanks to N. Cherepy

Conclusions

Before 2008 scintillator performances prevent them to be largely used as spectroscopic detectors. They provided:

- Active volume for anticompton shields
- A cheap almost full 4π coverage at high granularity
- main detectors for only specific physics cases (i.e. GDR)

After 2008 large volume $LaBr_3$:Ce became available

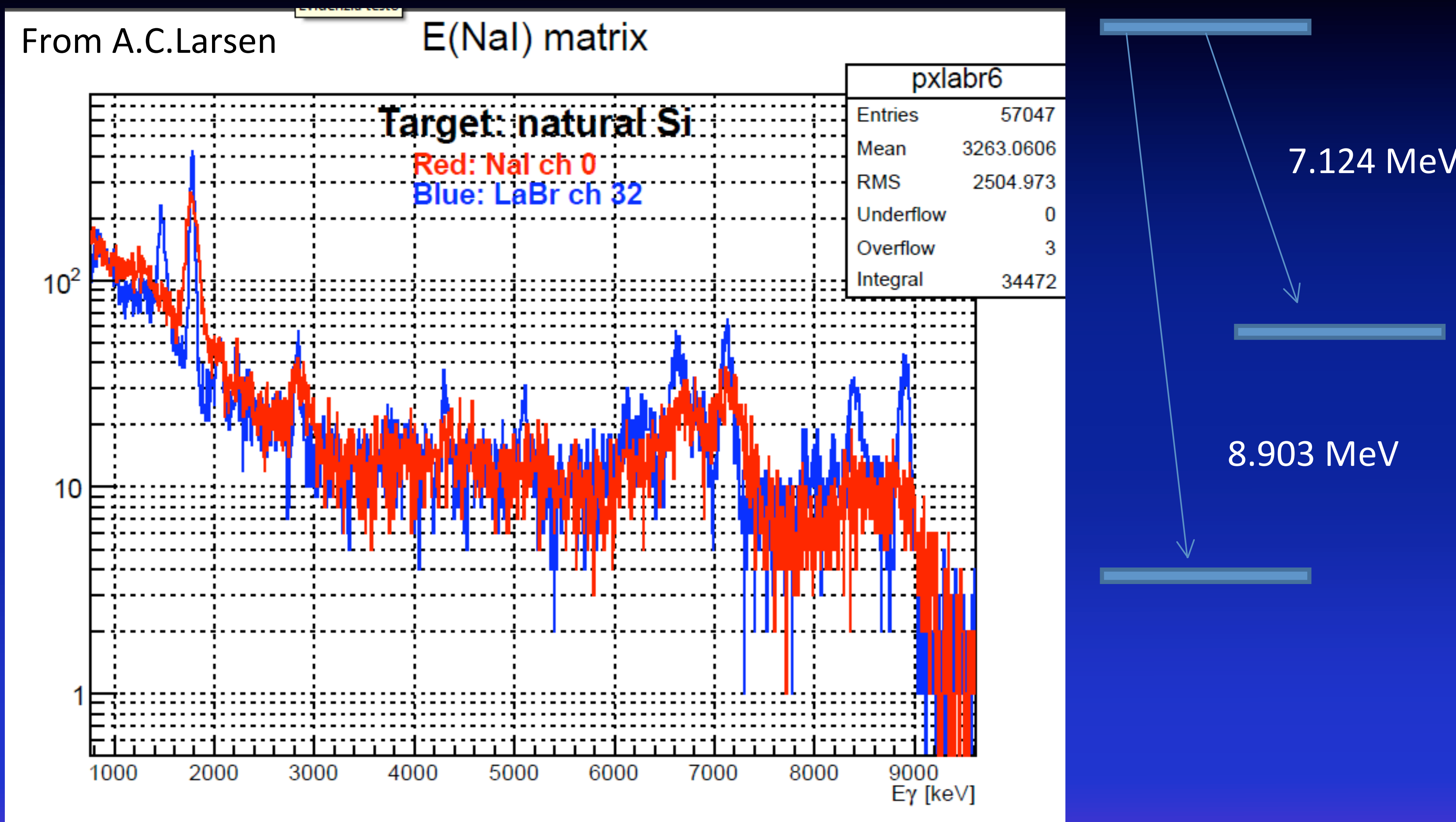
- $LaBr_3$:Ce are a breakthrough in scintillator tecnology

A $LaBr_3$:Ce/scintillators array can increase the efficiency and makes more powerful the physics program of an HPGe Array

- some examples

The story is not yet ended, R&D for $LaBr_3$:Ce is not finished and new performing scintillator material might be available in the future

Thank you



γ-ray spectrum of ^{28}Si, gated in silicon on the 1st excited state at 8905 keV, (FWHM = 90-100 keV) with no time gate.

Selection of excitation energy at 8.9 MeV made by gating with Si detector

"The difference between NaI and $LaBr_3$:Ce is really striking."