Status and perspectives of detector arrays of $LaBr_3$:Ce

F. Camera
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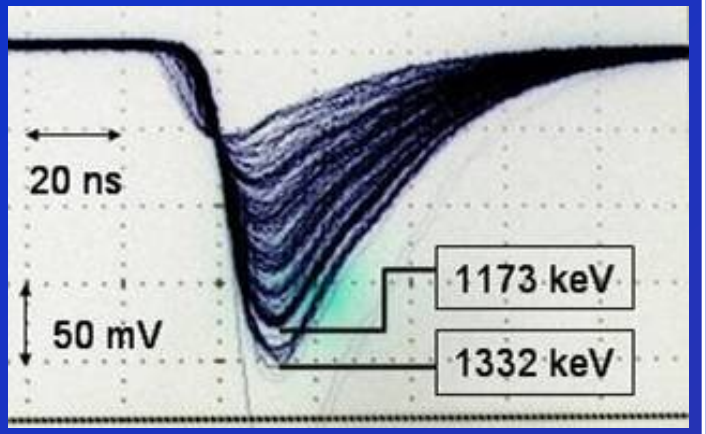
Outline:

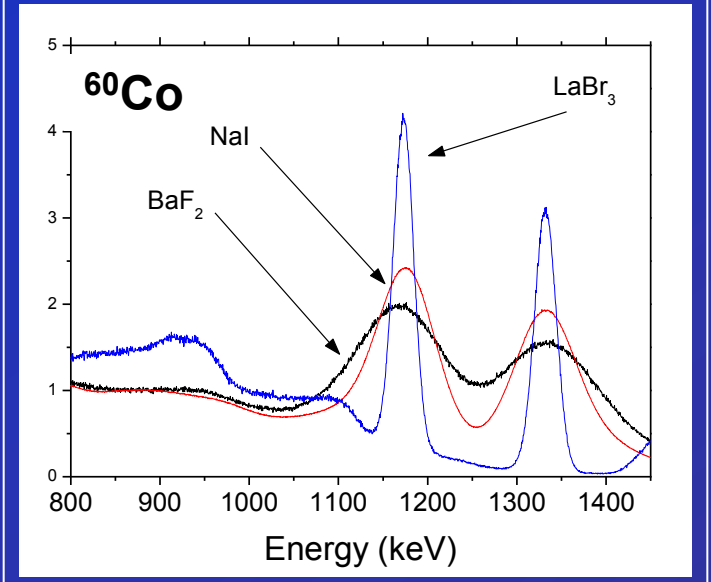
- $LaBr_3$:Ce crystal properties
- R&D on $LaBr_3$:Ce
- The HECTOR$^+$ Array
- Conclusions

$LaBr_3$:Ce Scintillators

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

RL (661 keV) 1.9 cm

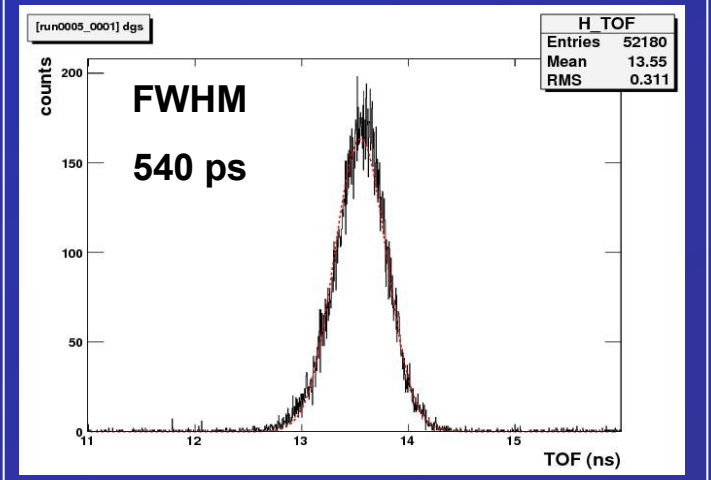




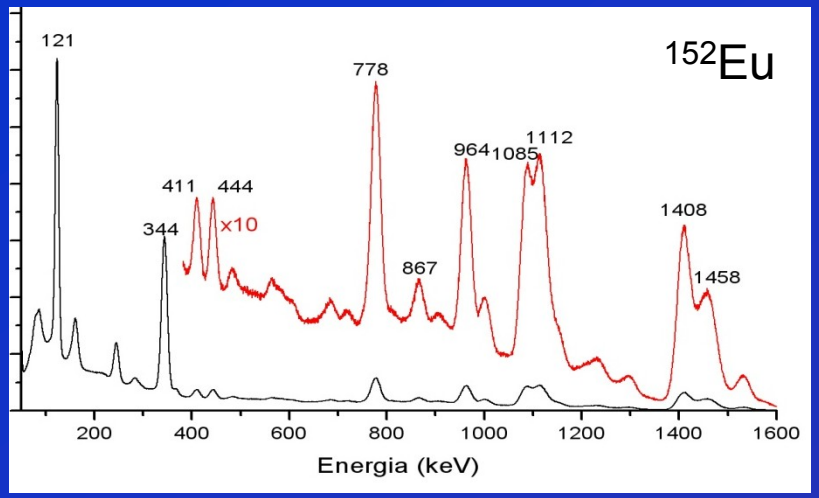
Large Interest in scientific community

- **In 2007 more than 40 papers on $LaBr_3$ / $LaCl_3$ detectors published in IEEE and NIM**

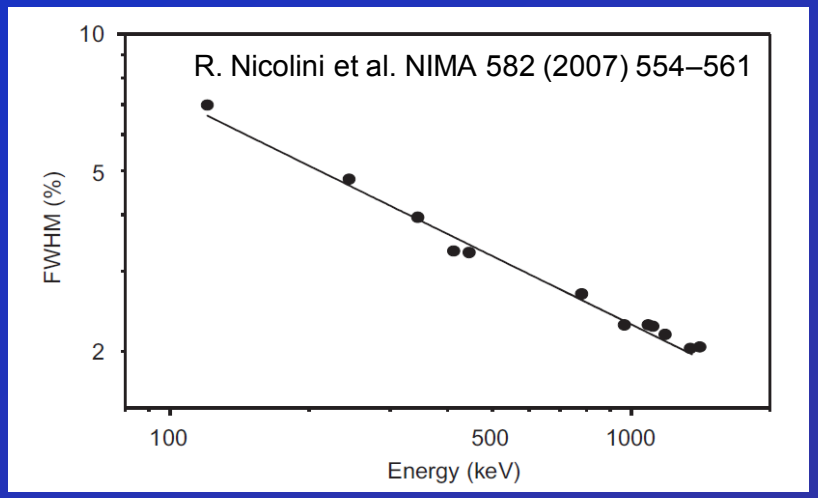
Large Volume crystal 9x20 cm are available



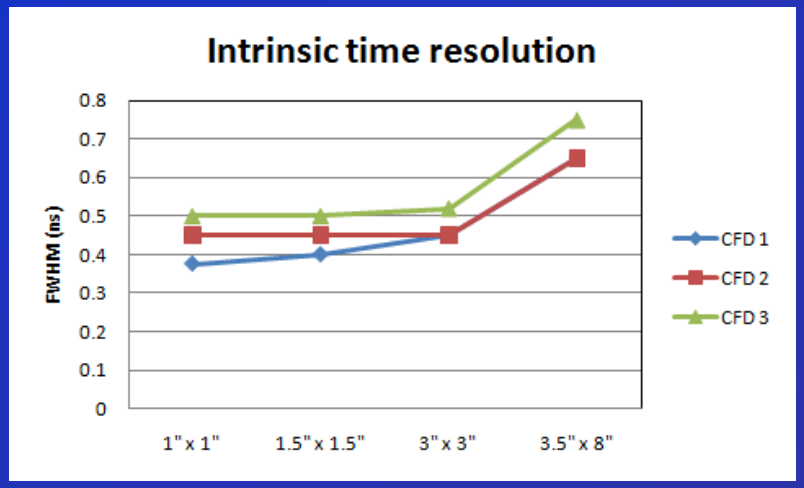
$LaBr_3$ time and energy spectra



Energy resolution: 19 keV at 662 kev



FWHM vs γ-ray energy



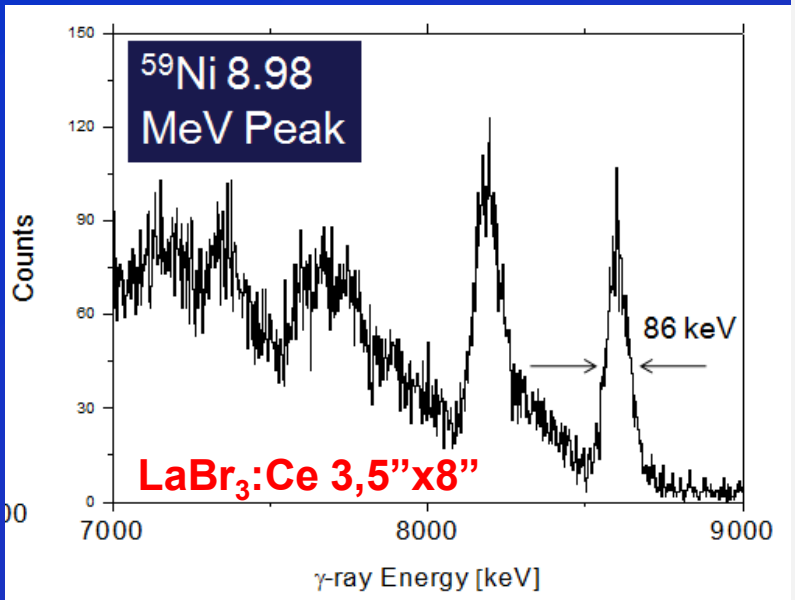
Sub-nanosecond time resolution:

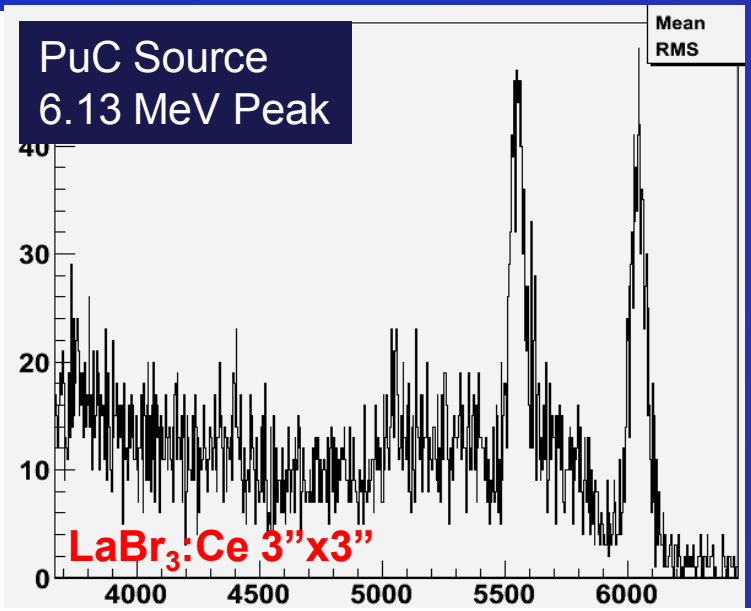
Time resolution slightly degrade as crystal volume increases but :

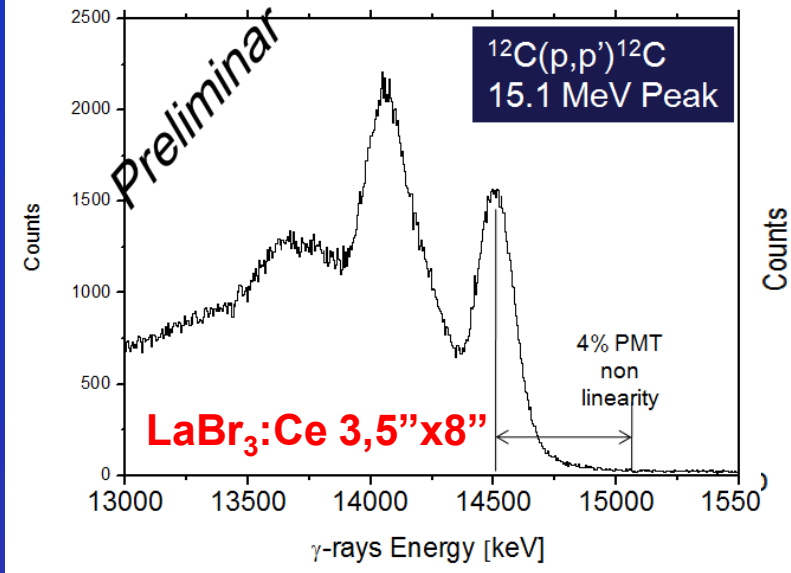
<L(1”x1”> ≈ 10 cm
<L(3”x3”)> ≈ 42 cm
<L(3.5”x8”) ≈ 120 cm

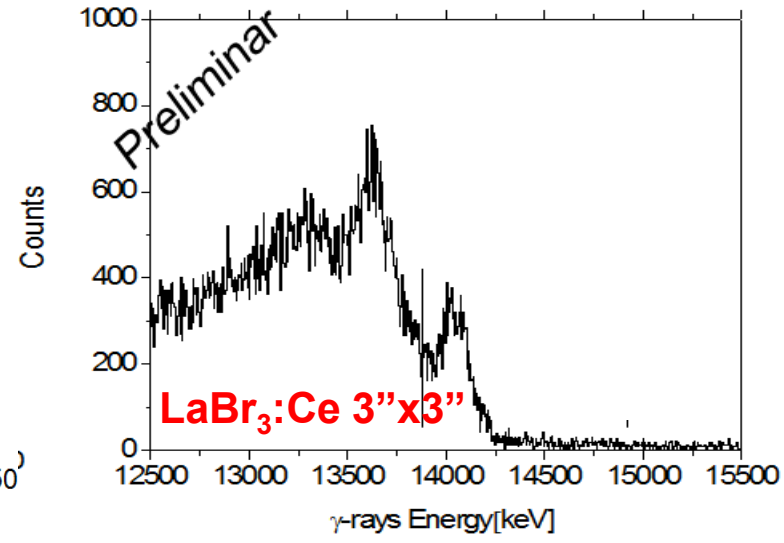
Large volume detectors guarantee efficiency for high energy γ-rays

Measurements of mono-energetic high energy γ-rays
Excellent separation between F.E.P. and 1st E.P.

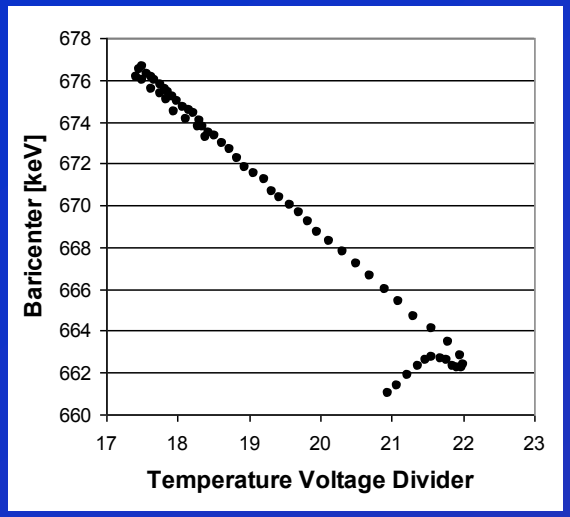


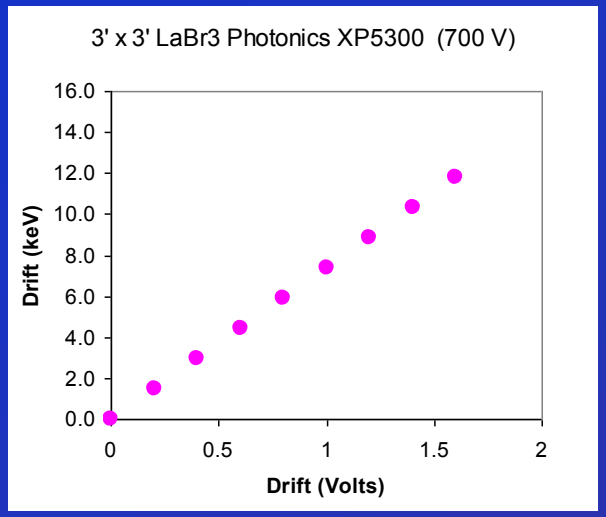


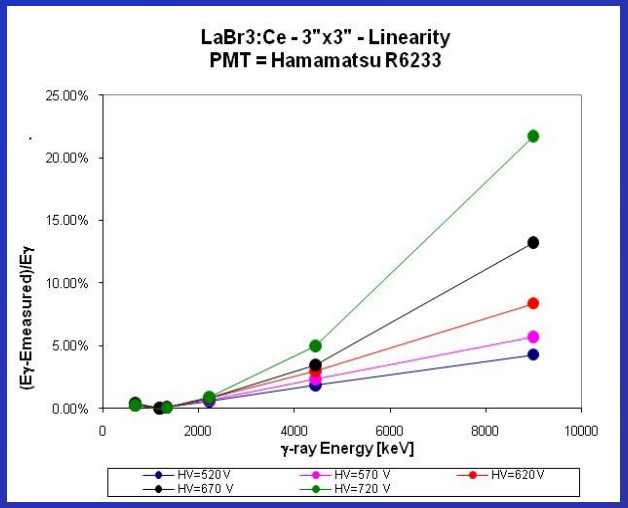




PMT non idealities might affect $LaBr_3$:Ce performances







A $LaBr_3$:Ce (crystal + commercial PMT and VD) detector suffers of non linearity for high energy gamma rays and gain drift due to temperature, HV drift, and count-rate,

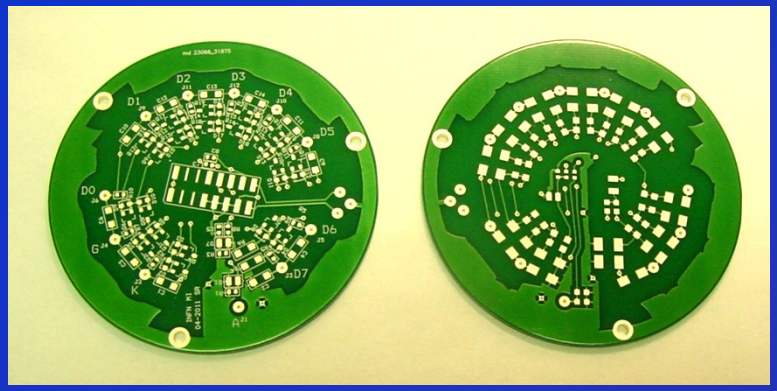
$\Delta T = 1° \quad \Rightarrow \quad \Delta E \sim 2$ keV (@ 661 keV)
$\Delta V = 0.25$ V $\quad \Rightarrow \quad \Delta E \sim 2$ keV (@ 661 keV)

Non linearity and gain drift due to temperature, HV drift, and count-rate can be monitored, minimized/corrected with a proper design for voltage divider

- using PMT at low voltage is not the optimal solution.

A Voltage divider for $LaBr_3$:Ce

New Voltage Divider design
Active Design

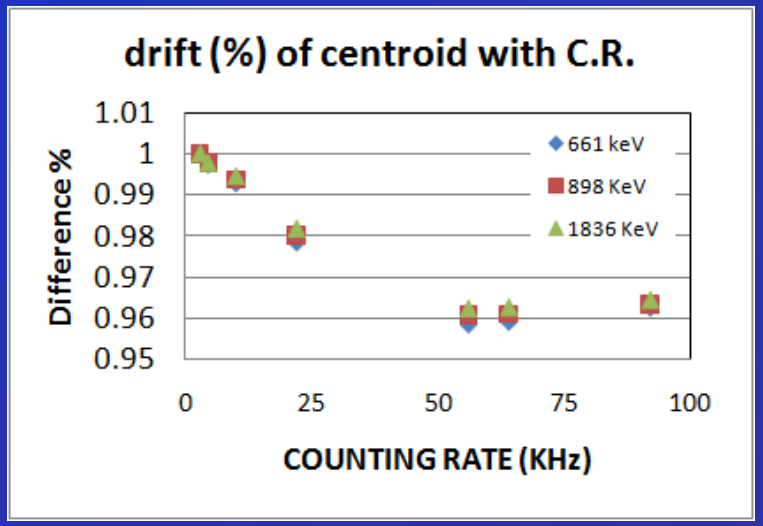


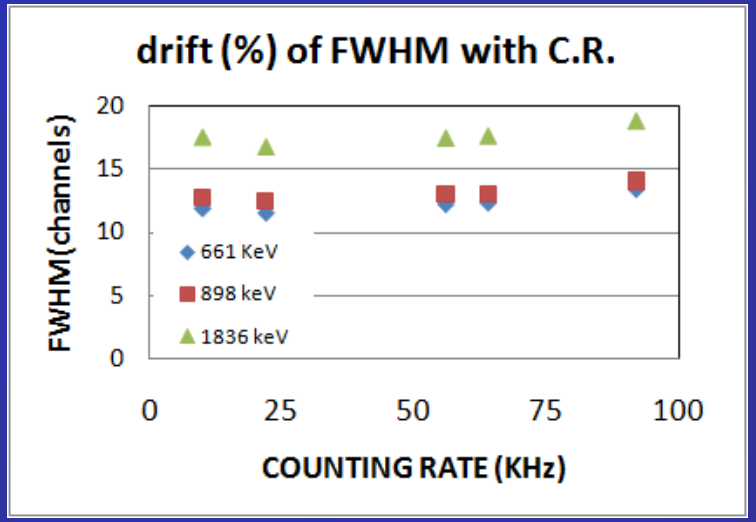
- **High Linearity ⇒ 1.8% at 9 MeV**
- **High Stablility vs Count Rate**
- **Compact Geometry**

Additional board for Temperature, and High Voltage monitor and LED source

Full test on schedule

At PMT voltage of 800-900 V the Dynamic range is 0-23 MeV





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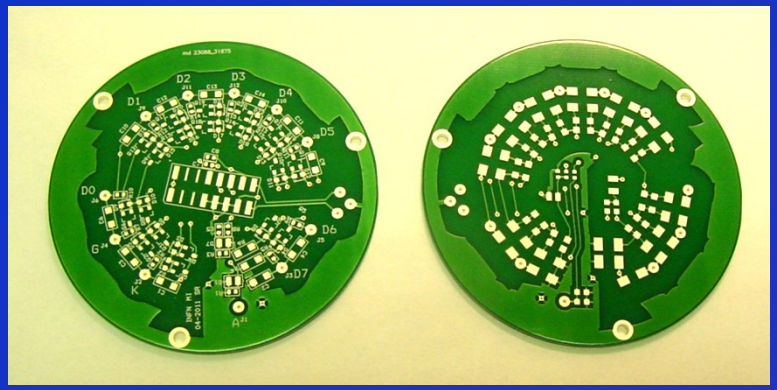

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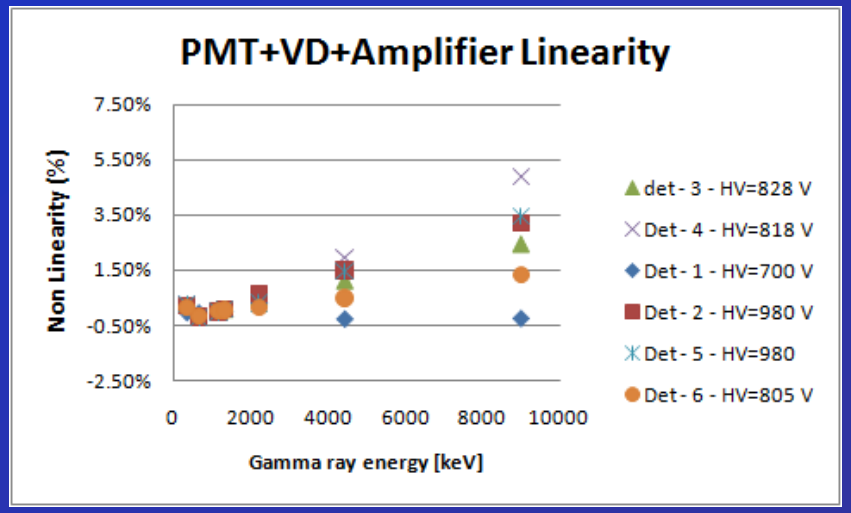
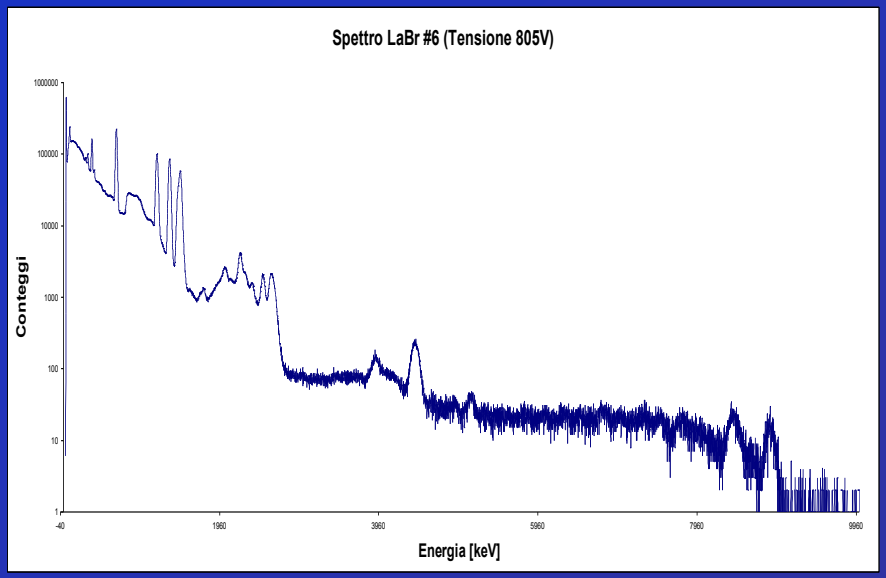
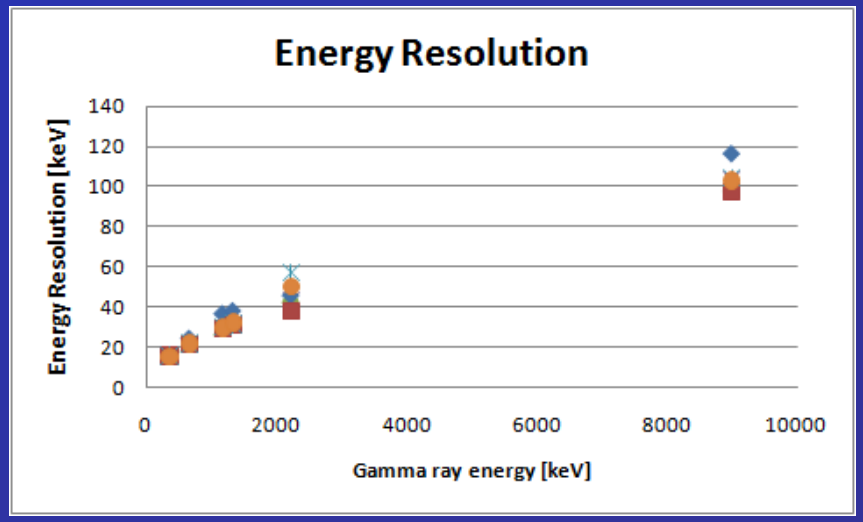
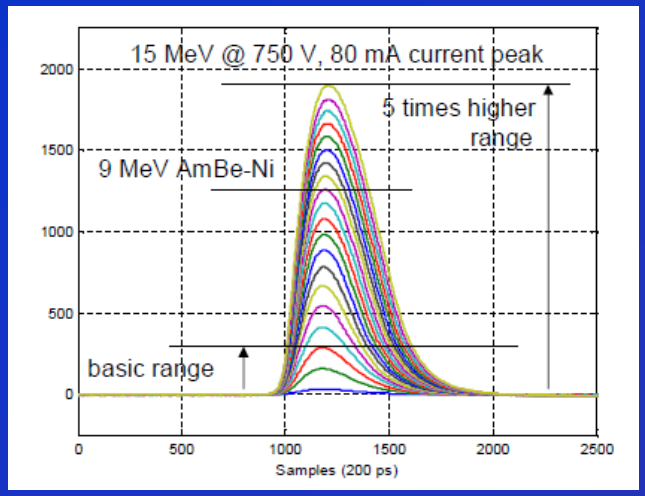
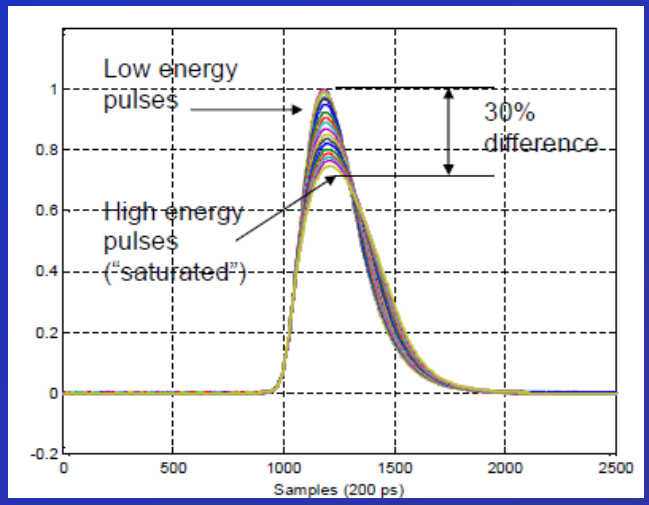




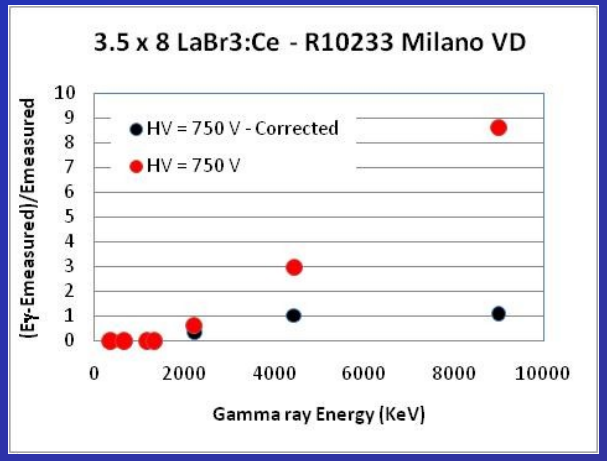


NON Linearity correction using PSA techniques





$LaBr_3$:Ce non linearity can be corrected using clever PSA algorithm



New optimized electronics for $LaBr_3$:Ce

- Digital board especially optimized for $LaBr_3$:Ce-

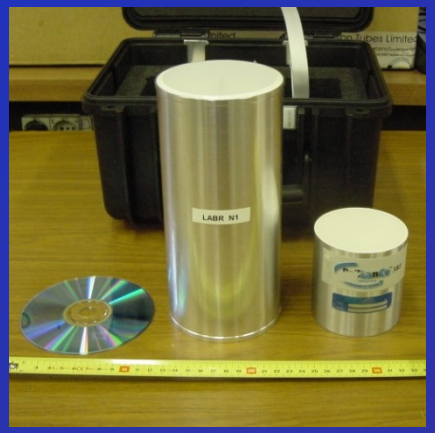
Preliminary results:

- Digital board prototype for BaF_2

- Sampling of $LaBr_3$:Ce signals (1"x1" and 3"x3") with CAEN VME 2Gs 12 bit board
- Data elaboration in MatLab environment of "direct" signals
  - 540 ps timing resolution FWHM
  - 2,3 % energy resolution at 1332 keV
- Factor 16 decimation (one sample every 8ns: 125 Ms/sec)
- Optimum FIR Filter
- On-line correction of PMT non linearity & saturation
  - 630 ps time resolution FWHM
  - 2,3 % energy resolution at 1332 KeV
- Similar results with Struck 100Ms 16 bit

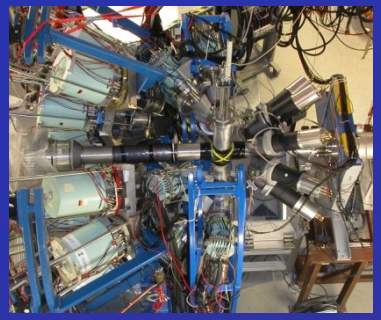
HECTOR+ Array

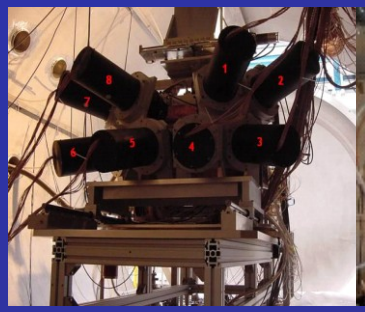
- High efficiency portable scintillator detector array



- 8 Large Volume BaF_2 Detectors (14 x 17 cm)
- 36 Small Volume BaF_2 Detectors
- 10 large Volume $LaBr_3$:Ce detectors (9 x 20 cm)
  - 8 ready and 2 almost ordered

- It was/will be coupled with
  - HPGe arrays - RISING/PRESPEC (GSI) , AGATA (LNL,GSI) …
  - Scintillator array – DALI (RIKEN)
  - Fragment separators FRS (GSI), BigRIBS (RIKEN), ...
  - Charged particle detectors arrays GARFIELD and TRACE (LNL), Si (RIKEN)

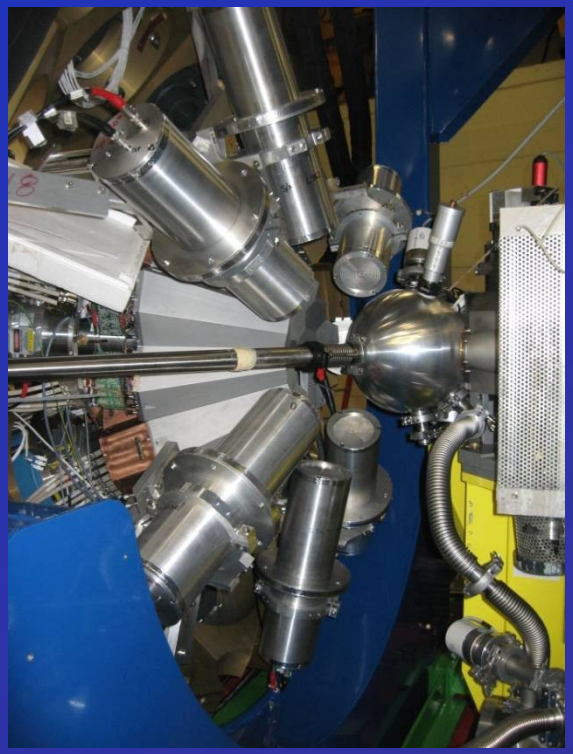




A $LaBr_3$:Ce array, when coupled to a radiation detection system, increases the efficiency and makes much more powerful the physics program

- Very high background
- Few γ transitions
- Extremely rare events
- High energy γ-rays

- 'Low' Budget
- Simple experimental setup
- Easy to transport

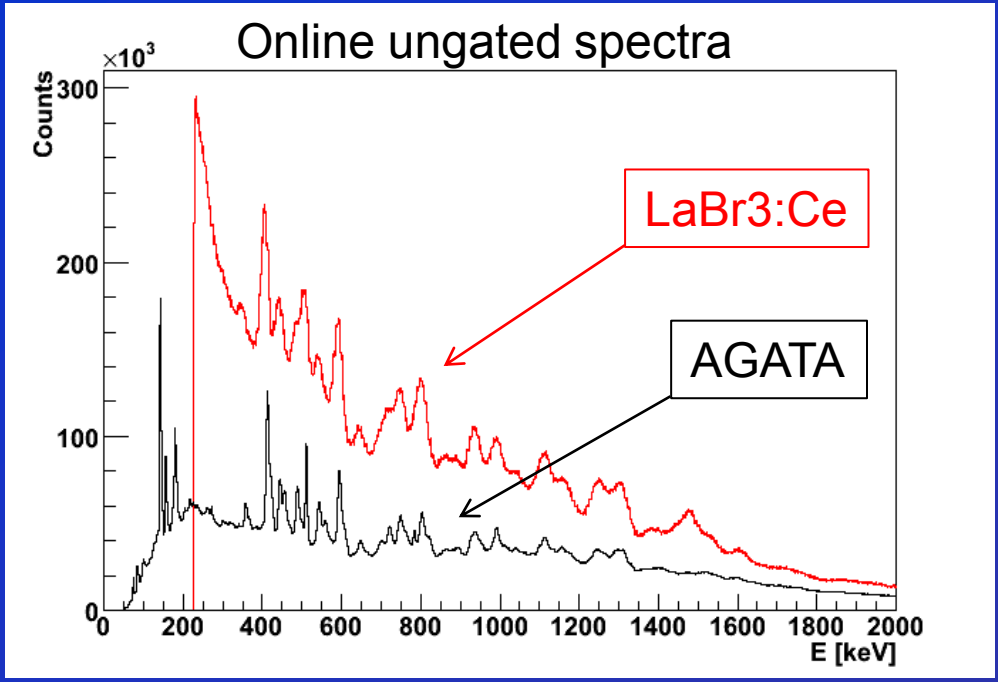


Large volume $LaBr_3$:Ce detectors are specific and unique for the measurement of high energy γ-rays.

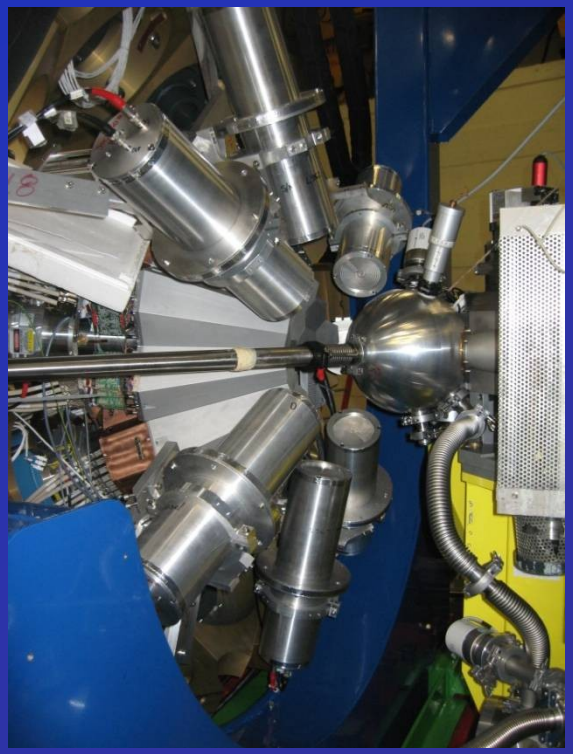
Performed experiments

- Measurement of γ-decay of GQR in inelastic scattering reactions (LNL)
- Measurement of isospin mixing in ^{90}Zr (LNL)
- Measurement if isomer decay in exotic nuclei (RIKEN)

A $LaBr_3$:Ce array, when coupled to a radiation detection system, increases the efficiency and makes much more powerful the physics program

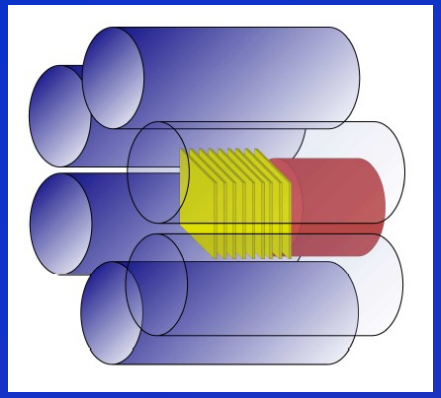


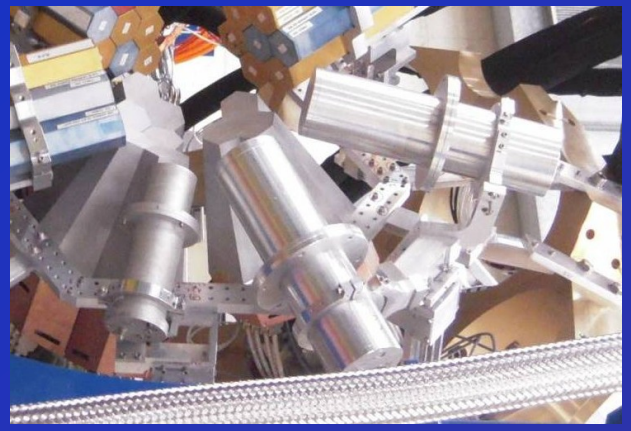
Isospin mixing AGATA+$LaBr_3$:Ce LNL experiment

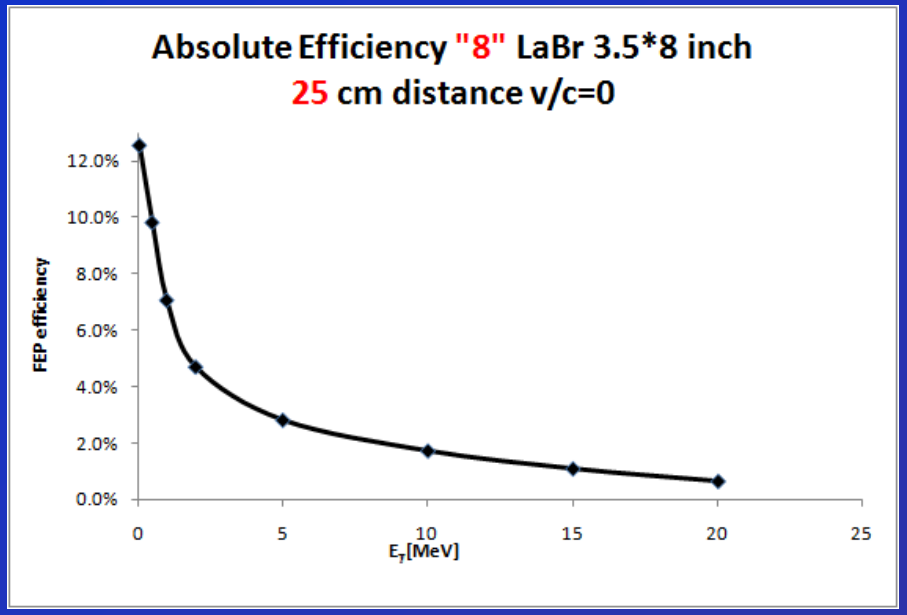


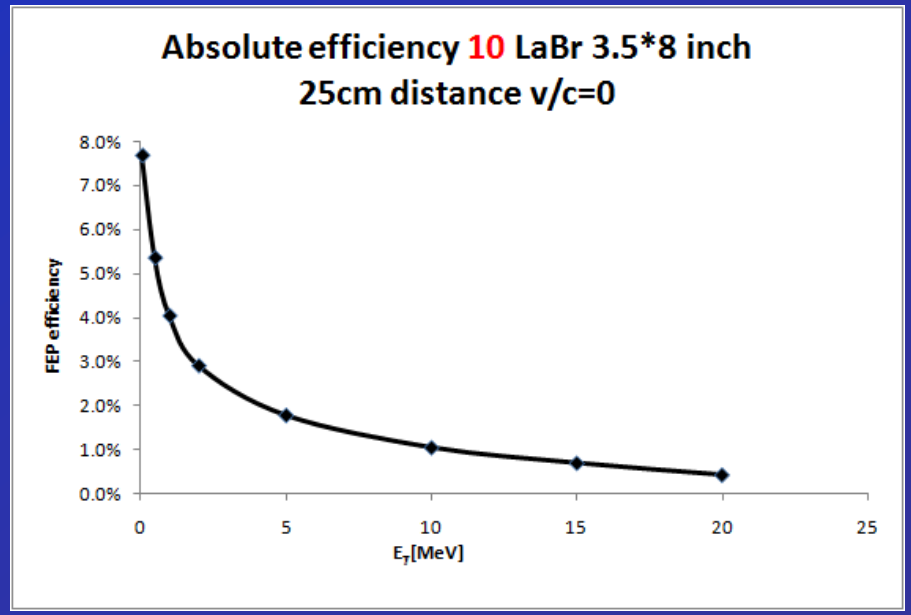
Planned experiments:

- **October GSI – LAND setup**
- **November Debrecen (tests)**
- **December LNL – Agata setup**
- **2012 – Riken and GSI (Agata)**









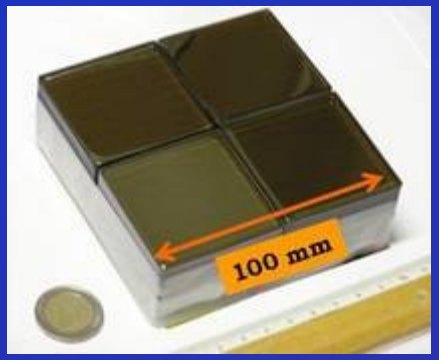
8 $LaBr_3$:Ce in barrel configuration
Solid angle covered ≈ 12.5 %
Absolute F.E.P. efficiency at 2 MeV ⇒ 5 %
Absolute F.E.P. efficiency at 10 MeV ⇒ 1.7 %

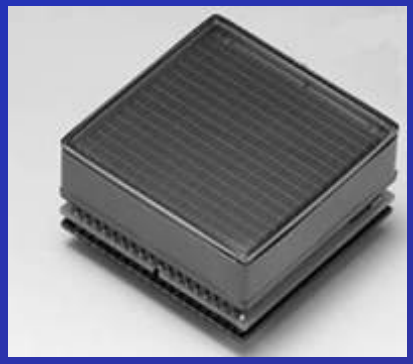
10 $_{LaBr3:Ce}$ in standard configuration
Solid angle covered ≈ 7.7 %
Absolute F.E.P. efficiency at 2 MeV ⇒ 3 %
Absolute F.E.P. efficiency at 10 MeV ⇒ 1 %

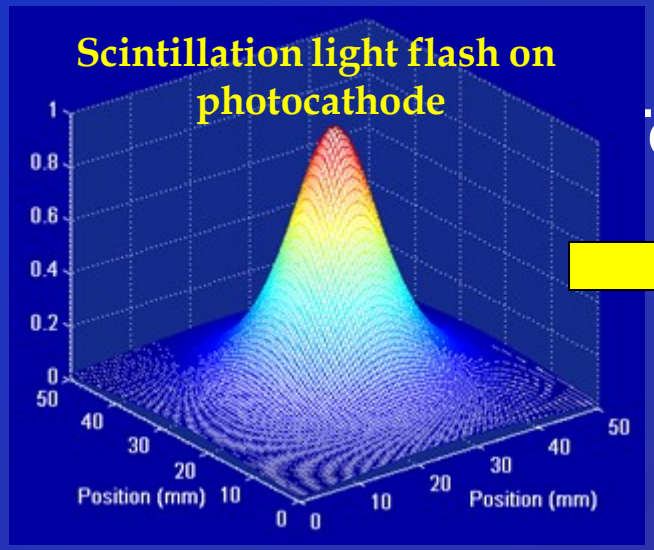
Doppler Broadening Correction
– Position Sensitivity -

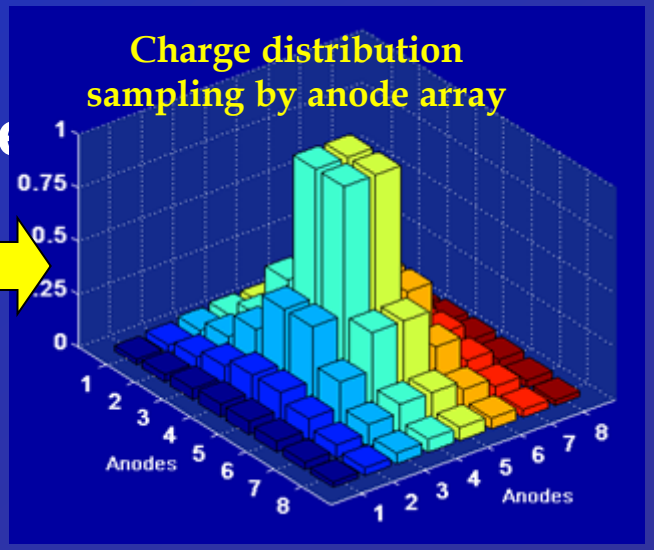
- **Segmented Photosensor**

  PSPMT H8500
  Silicon Drift Detector pad







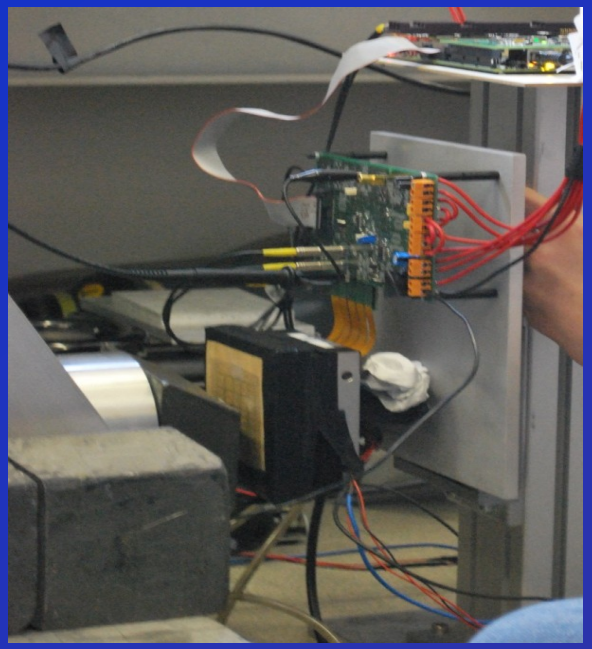


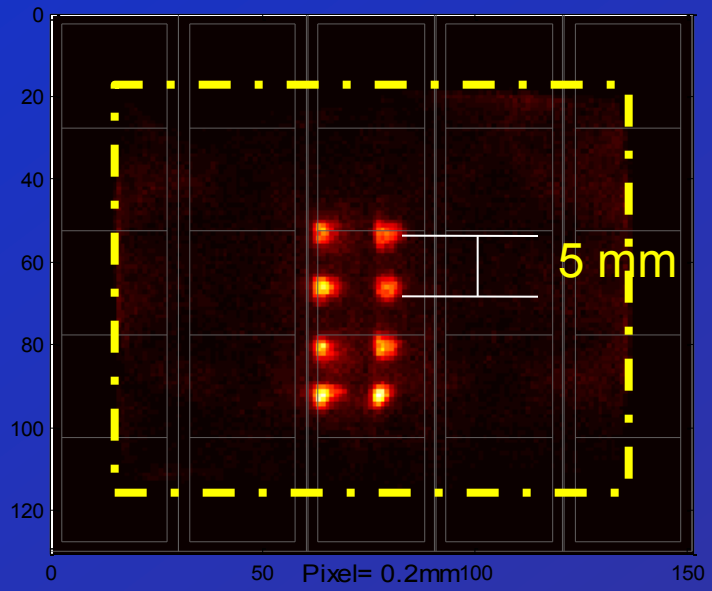
- **Charge PSF**
- **Image PSF**

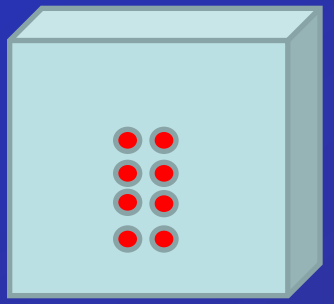
  - Spatial Resolution

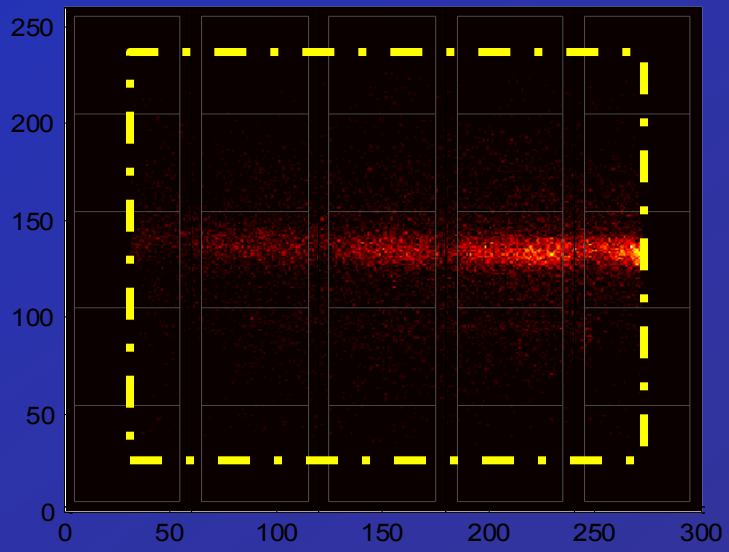
  - Spatial Linearity

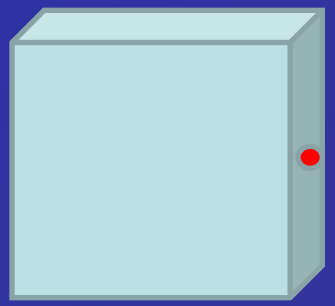
Measurement in Milano using a collimated source of ^{137}Cs and a square 5cm x 5cm 1 cm thick CsI + pads of SDD



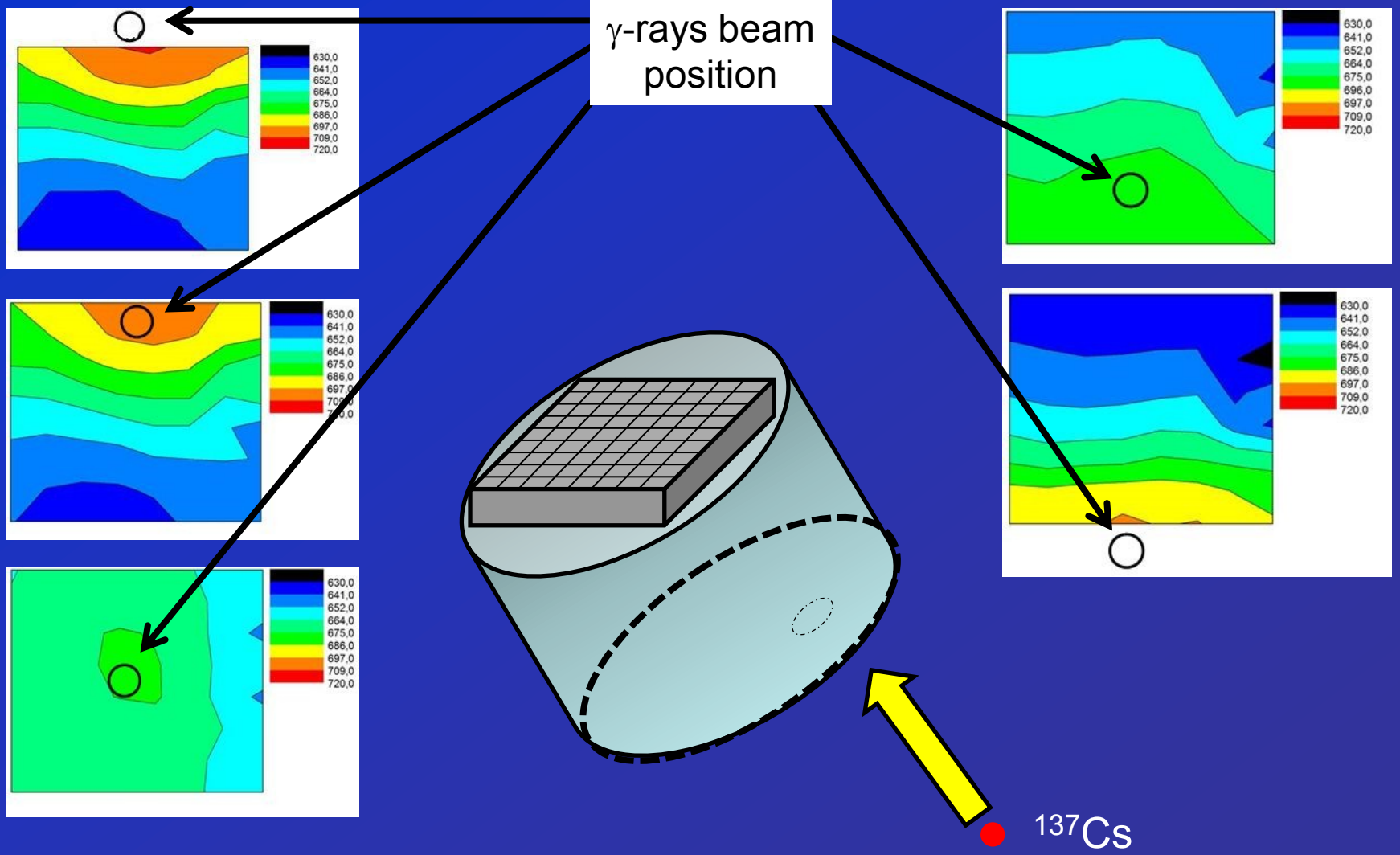








Measurement in Milano using a collimated source of ^{137}Cs and a cylindrical $LaBr_3$:Ce 3”x3” and a PSPMT



Conclusions

- We have started an R&D project concerning $LaBr_3$:Ce for gamma spectroscopy
- The project points to the construction of a trasportable array ($HECTOR^+$) which is composed of 10 large volume $LaBr_3$:Ce
- The array has already been used in LNL coupled with AGATA and in RIKEN coupled with CAITEN and clover detectors
- The array has already a tight schedule of experiments in several laboratories
- Even though there are still several technical aspects which remain to be optimized, $LaBr_3$:Ce gives a fantastic opportunity for all those experiments where efficiency, time and energy resolution are a key factor
- <u>There are several projects based on $LaBr_3$:Ce detector arrays</u>

  - Paris array (Spiral2) $\Rightarrow$ See Next Talk
  - Shogun (Riken)
  - Califa (GSI)
  - Darmstadt
  - OSLO

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