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► **To cite this version:**

Giulia Hull, Andrea Fabbri, Michael Josselin, Laurent Menard, Marc-Antoine Verdier. Study of the imaging properties of a SrI2:Eu-based gamma camera. IEEE Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC), Oct 2019, Manchester, United Kingdom. . hal-04227336

HAL Id: hal-04227336

<https://hal.science/hal-04227336>

Submitted on 18 Oct 2023

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Study of the imaging properties of a SrI₂:Eu-based gamma camera



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Introduction: The high light yield of SrI₂:Eu makes this crystal a suitable candidate for possible application in gamma imaging. Furthermore, the observed self-absorption of this material, which determines a performance decrease while increasing the scintillator volume, is not a drawback in medical imaging, for which the scintillator thickness has to remain limited to less than 1 cm for preserving the spatial information. In this work we studied the detection features of a gamma camera based on the use of a disc-shaped SrI₂:Eu coupled to a high quantum efficiency multi anode PMT, in comparison with a similar shaped LaBr₃:Ce crystal.

The tested scintillators and photodetector

The crystals

- LaBr₃:Ce Ø51 mm x 6 mm by Kinheng crystal material Co., Ltd. Diffusive/reflective edges and back plane
- SrI₂:Eu Ø38 mm x 5 mm by RMD. Diffusive/reflective edges and back plane – Larger available disc-shaped crystal at the time of the purchase

Scintillators are sealed in an aluminum housing equipped with a 2 mm-thick quartz windows

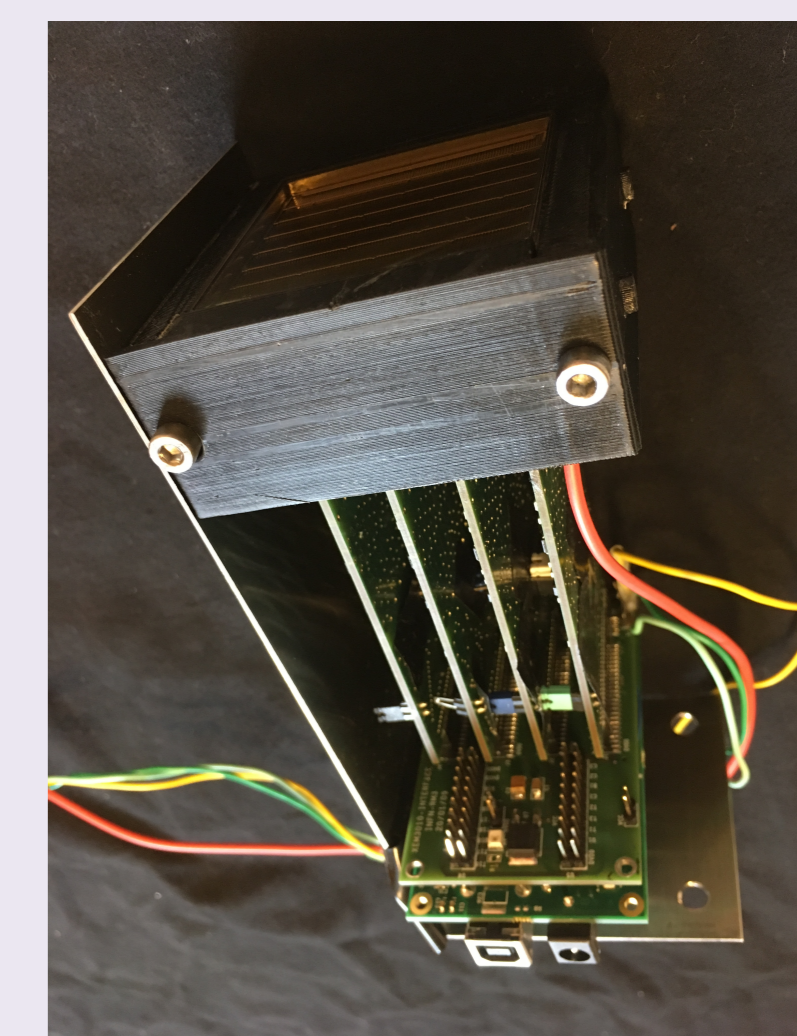
	LaBr ₃ :Ce	SrI ₂ :Eu
Light Yield (ph/MeV)	68 000	80 000 – 120 000
Decay Constant (ns)	16	1200
Wavelength of emission (nm)	380	435
ΔE/E @ 662 keV (%)	3	< 3 - 4
Proportionality	Good	Very good



The MAPMT and read-out system

- Hamamatsu 10966-100: 51mm x 51mm entrance window (49mm x 49mm active area), Q.E. ~ 34% @ 380 nm, 8-stages, 8x8 multianode (5.8mm x 5.8mm anode size)

- The electronic readout reads all 64 channels simultaneously.
- Free-run acquisition at a fixed frequency of 100 kHz
- Event-by-event energy selection applied by the digital control implemented in the FPGA
- Threshold is pre-settable by the control software and it is also used to exclude those sampling intervals where no event detection has occurred



Imaging properties and spatial resolution

We used a collimated gamma-ray source in order to evaluate the imaging properties of the crystals:

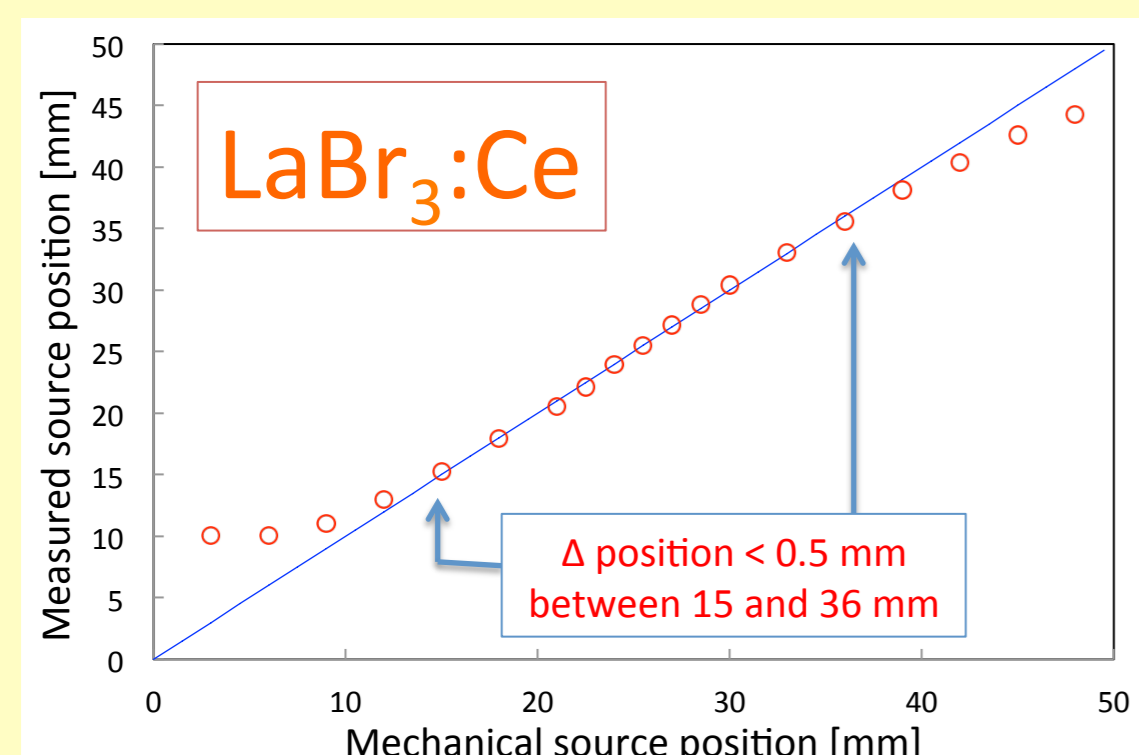
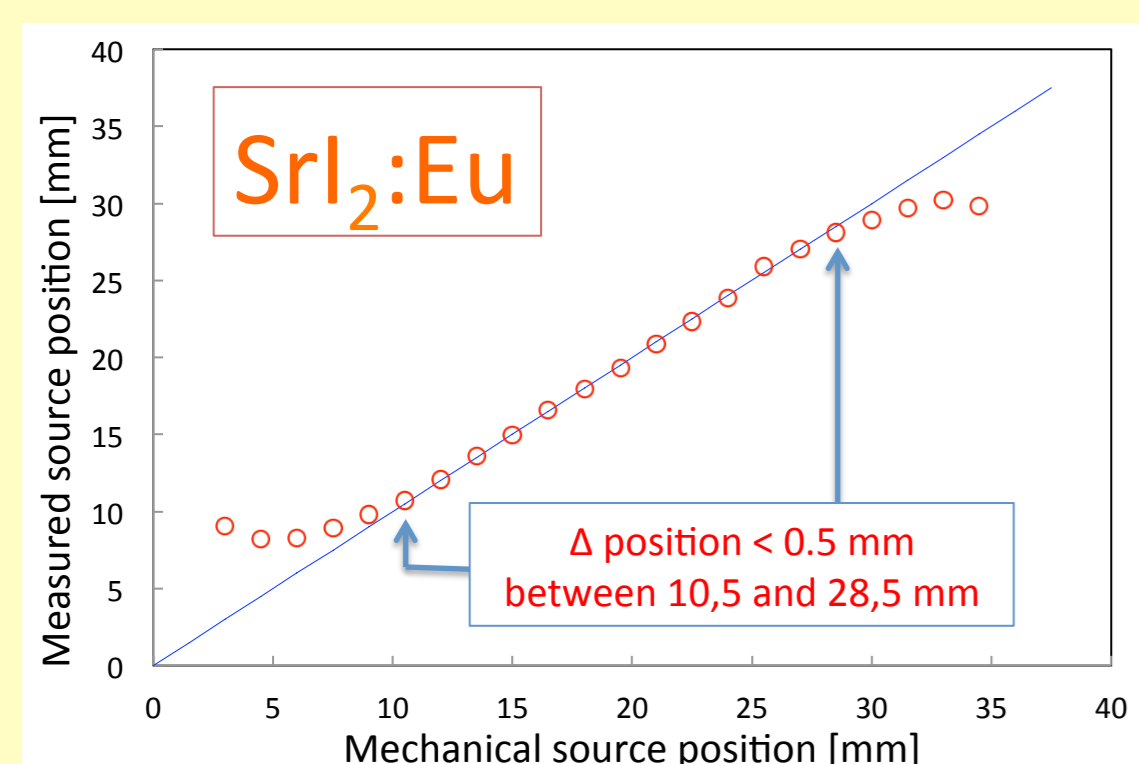
- 1 MBq Co-57 @ 122 keV for the SrI₂:Eu
- 300 MBq Tc-99m @ 140 keV for the LaBr₃:Ce

We used a 1-mm hole collimator to evaluate the linearity and spatial resolution along the crystals diameter, the source was fixed on a platform that can be moved along the x- and the y-axes via a micrometer screw.

As the dedicated electronic read-out does not support counting rates below 50 Hz, we added a ²²Na source when working with the ⁵⁷Co, to guarantee that the minimum counting rate was achieved. For this reason the linearity, barycenter distribution and spatial resolution of the SrI₂:Eu have been evaluated applying an energy selection on the acquired events.

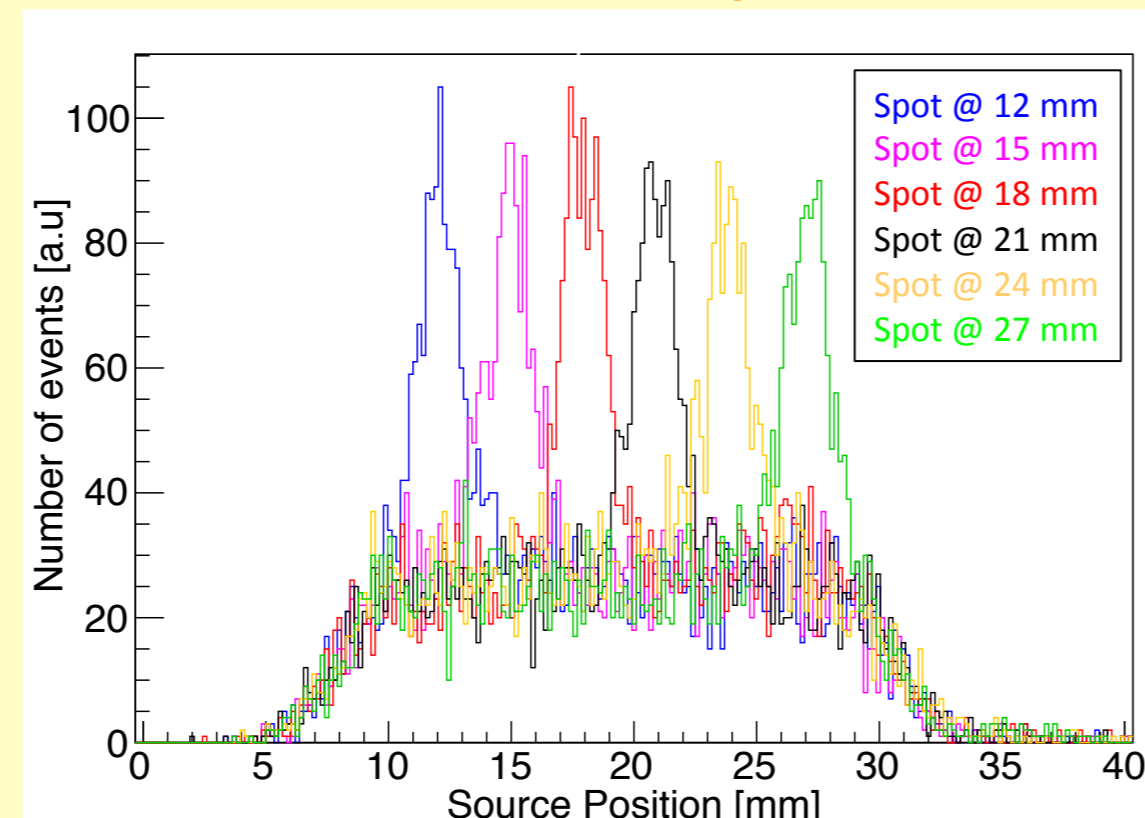
We performed a 1.5 mm-step scan (22 spots) on the SrI₂:Eu crystal and a 1.5 mm-step and and 3 mm-step scan (19 spots) in the center and in the peripheral zone of LaBr₃:Ce, respectively.

At the edges, the position linearity is strongly affected by the diffusive surface treatment of the scintillators

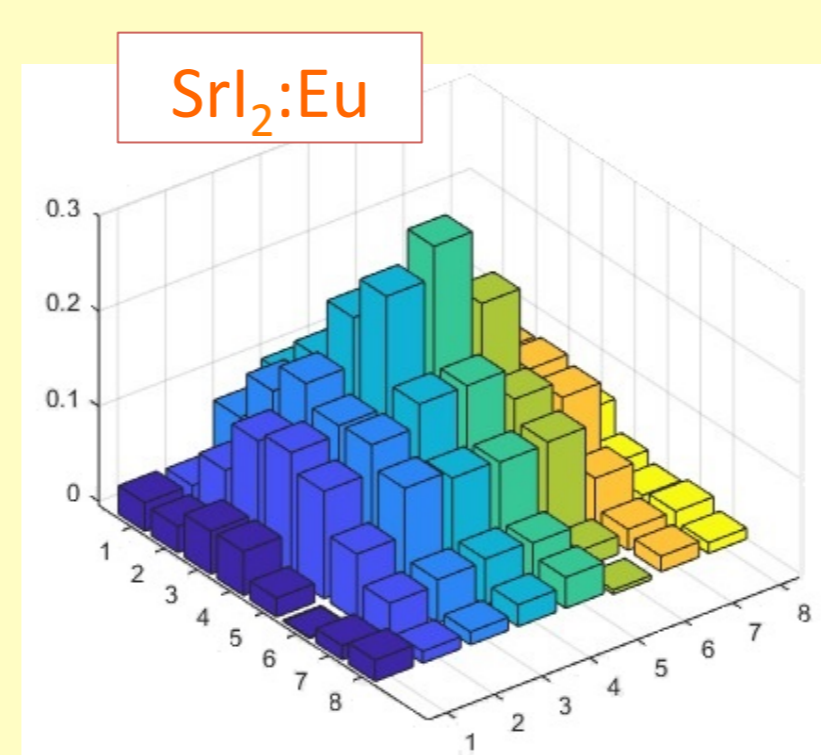
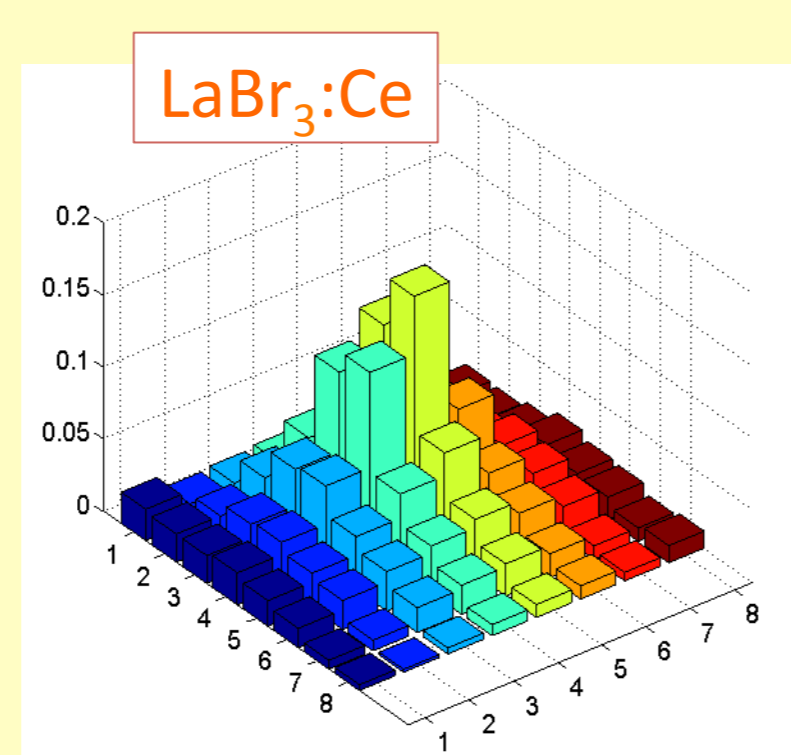
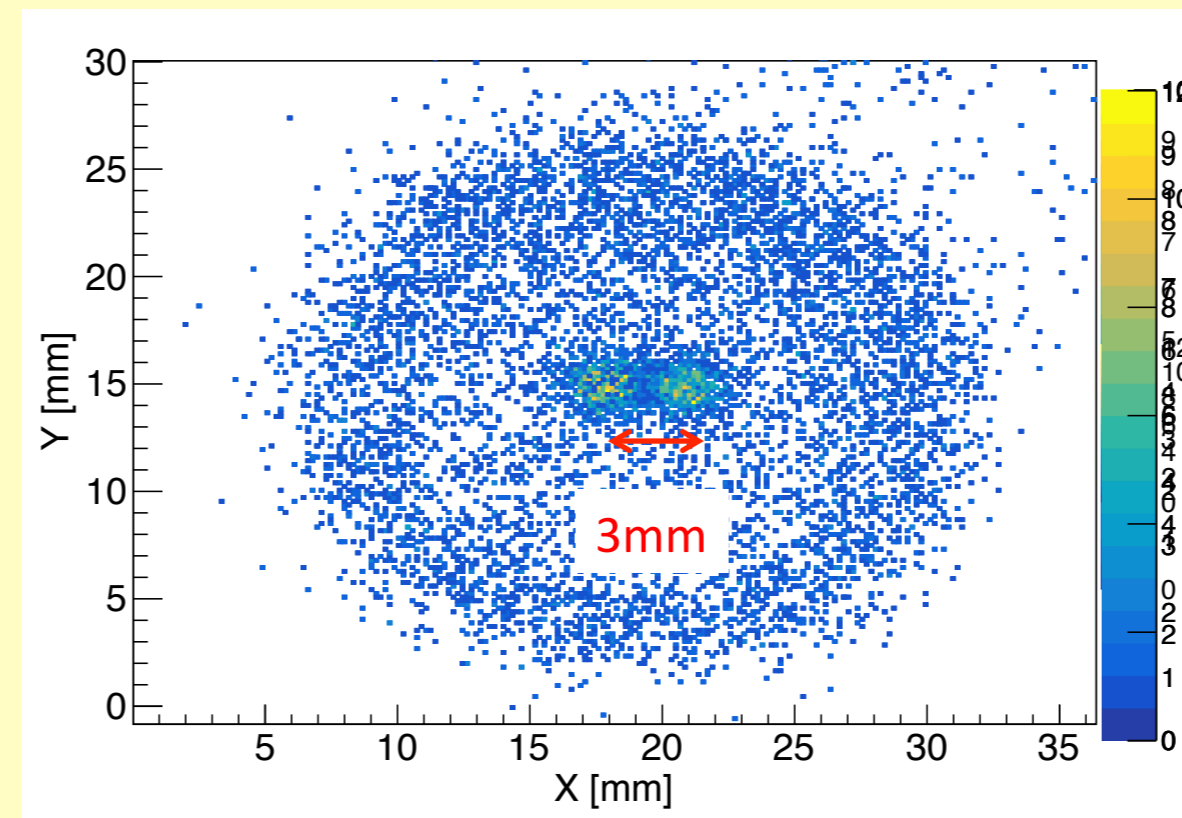


The spatial resolution has been estimated using an iterative fit algorithm for determination of the gamma interaction point

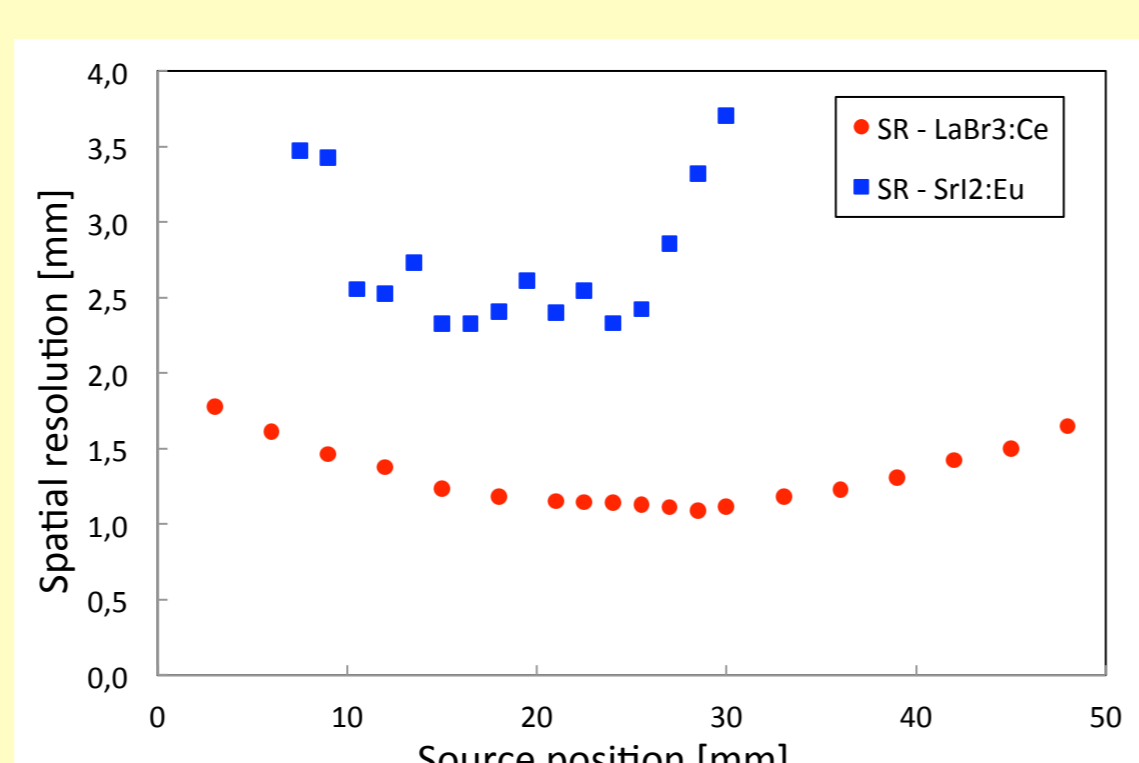
x-axis projections of the barycenter distribution for the central spots



Barycenter distribution for two 3-mm-distant spots



Mean light distribution from a 1 mm-collimated source for the two tested crystals



Mean spatial resolution in the central region of the crystals:

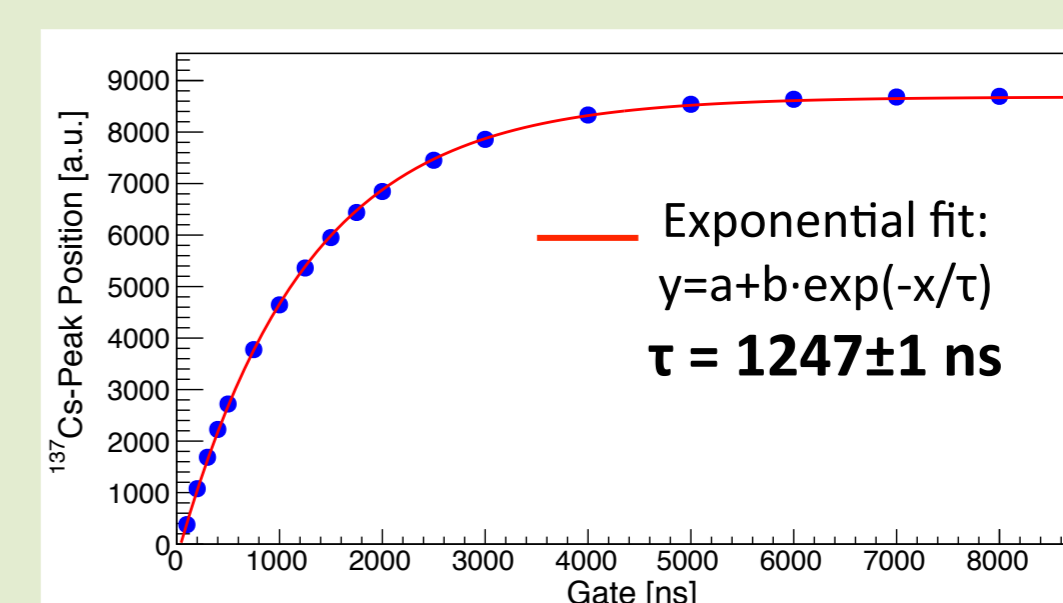
LaBr₃:Ce – between 12 mm and 39 mm
 SR = 1.14 mm ± 0.05 mm

SrI₂:Eu – between 12 mm and 25.5 mm
 SR = 2.25 mm ± 0.14 mm

Gamma spectroscopy

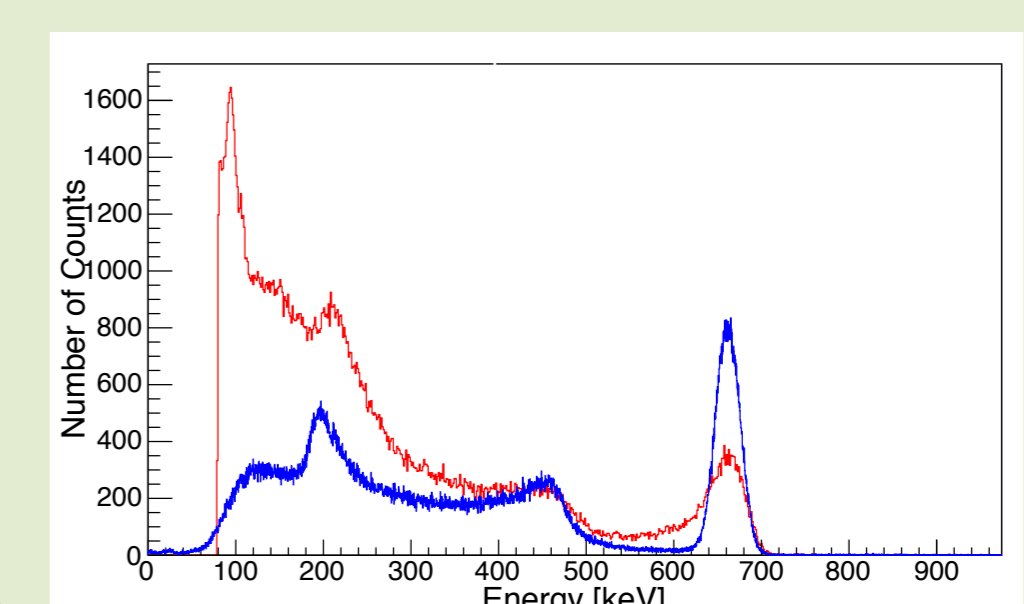
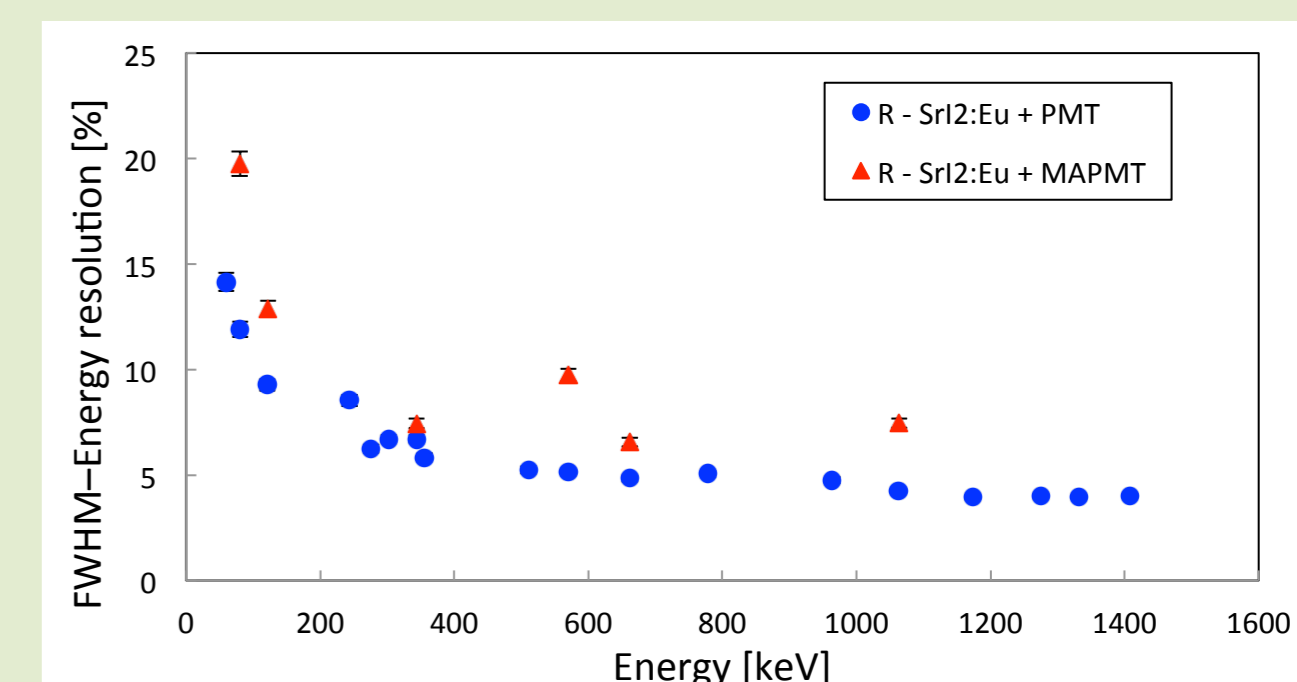
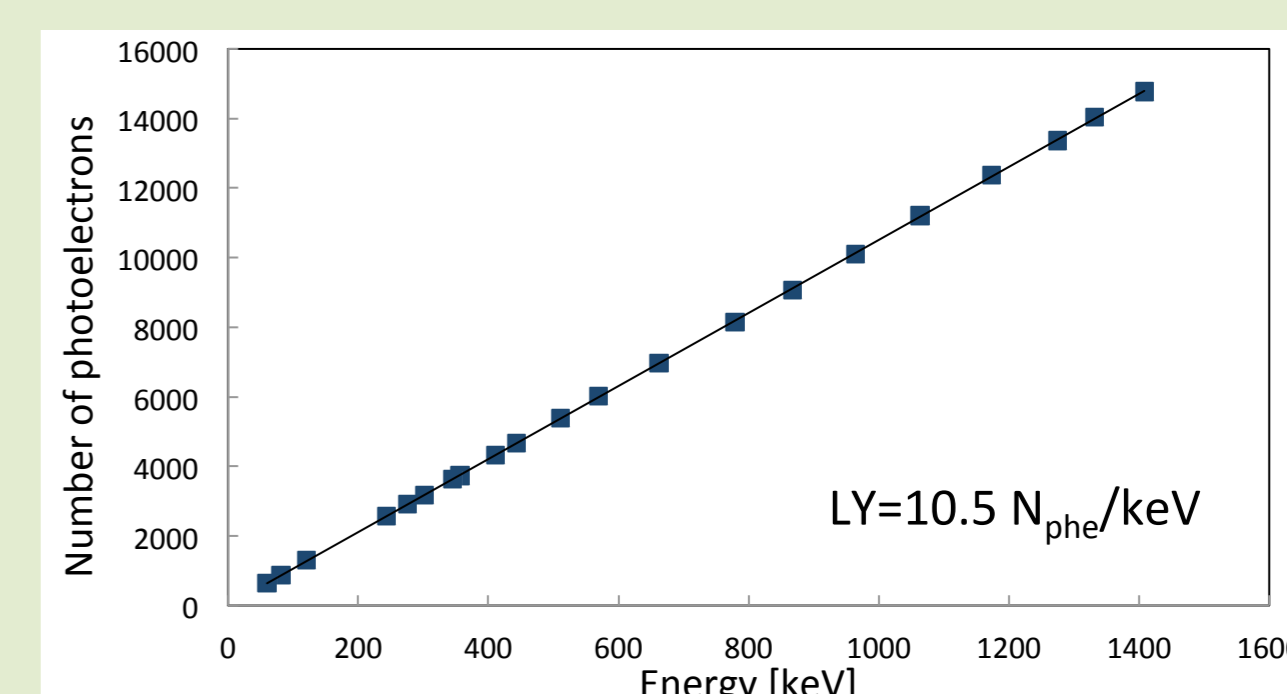
For this study we coupled the SrI₂:Eu crystal to a 2"-diameter, low-gain, high quantum efficiency PMT (Hamamatsu R6231-100), and we acquired the signals with a waveform digitizer (CAEN DT5730)

Charge collected vs the digitizer gate length to estimate the SrI₂:Eu decay time



Any acquisition frequency lower than 250 kHz will assure complete charge collection

Linearity and energy resolution are evaluated using gamma-rays emitting sources in the energy range between 60 keV and 1.4 MeV



SrI₂:Eu + PMT:
 R = 4.8 ± 0.1 % @ 662 keV
 R = 9.3 ± 0.2 % @ 122 keV

SrI₂:Eu + MAPMT:
 R = 6.6 ± 0.2 % @ 662 keV
 R = 12.9 ± 0.3 % @ 122 keV

Conclusions and future work

We tested the detection properties of a SrI₂:Eu disc-shaped prototype crystal coupled to a multi-anode PMT for possible applications in a gamma camera. The crystal was the largest sample available at the time of the purchase and the shape and surface treatment were not optimized for imaging.

- ★ The crystal provided an energy resolution of 4.8% and 6.6%, at 662 keV, when coupled to a standard PMT and a MAPMT, respectively;
- ★ Despite the smaller surface area of SrI₂:Eu, we observed for this scintillator good position linearity over a relatively larger field of view compared to LaBr₃:Ce;
- ★ For the SrI₂:Eu crystal we measured a spatial resolution equal to 2.25 mm ± 0.14 mm in the central region of the scintillator.

The crystal production is improving and larger SrI₂:Eu samples with better optical properties will be available soon, so we expect that in the near future better spatial resolution can be easily achieved. Furthermore, despite the long decay time constant of this scintillator material, we are interested in pursuing this activity with the study of the imaging properties of a SrI₂:Eu coupled to a matrix of SiPMs.

Acknowledgements: This work was supported by IN2P3-CNRS