8th International Workshop on Radiation Imaging Detectors
Pisa 2-6 July 2006

$LaBr_3$:Ce scintillation gamma camera prototype for X and gamma ray imaging

Roberto Pani

On behalf of SCINTIRAD Collaboration
INFN University La Sapienza Rome Italy

In 2004, INFN promoted the development of a scintillation camera based on LaBr3:Ce **continuous crystal shape.**

LaBr3:Ce crystals are now available with continuous shape covering up to 10×10 cm2 with a thickness of 1 cm or more. (the high hygroscopicity and fragility of material have introduced serious concerns in pixellated manufacturing).

AIM of the work

- Verify if LaBr3:Ce meets the requirements for SPECT imaging and has the potential to replace NaI:Tl as the material of choice for SPECT.
- Explore the potential of LaBr3:Ce as integrated detector, with sufficient spatial resolution, for SPET/CT co-registration imaging (scintimammography)

Crystal scintillation properties

Crystals	*Density (g cm^{-3})*	*Light yield (ph/keV)*	*Decay time (ns)*	*Maximum Emission (nm)*	*ΔE/E (FWHM) (%) PMT read-out* 662 keV **	140 keV
NaI:Tl	**3.67**	**41**	**230**	**410**	**5.6**	**8.5**
CsI:Na	**4.51**	**40**	**630**	**420**	**7.4**	**9.5**
CsI:Tl	**4.51**	**66**	**800 ÷ 6 x10^3**	**550**	**6.6 (PMT)/ 4.3 (SDD)**	**14**
$LaCl_3$:Ce	**3.79**	**49**	**28**	**350**	**3.8**	**8.0 ***
$LaBr_3$:Ce	**5.0**	**63**	**16**	**380**	**2.8**	**5.8**
$Bi_4Ge_3O_{12}$ (BGO)	**7.1**	**9**	**300**	**480**	**9.0**	
Lu_2SiO_5:Ce (LSO)	**7.4**	**26**	**40**	**420**	**7.9**	**18**
Gd_2SiO_5:Ce (GSO)	**6.7**	**8**	**60**	**440**	**7.8**	**22**
YAl O_3:Ce (YAP)	**5.5**	**21**	**30**	**350**	**4.3 APD**	**20**

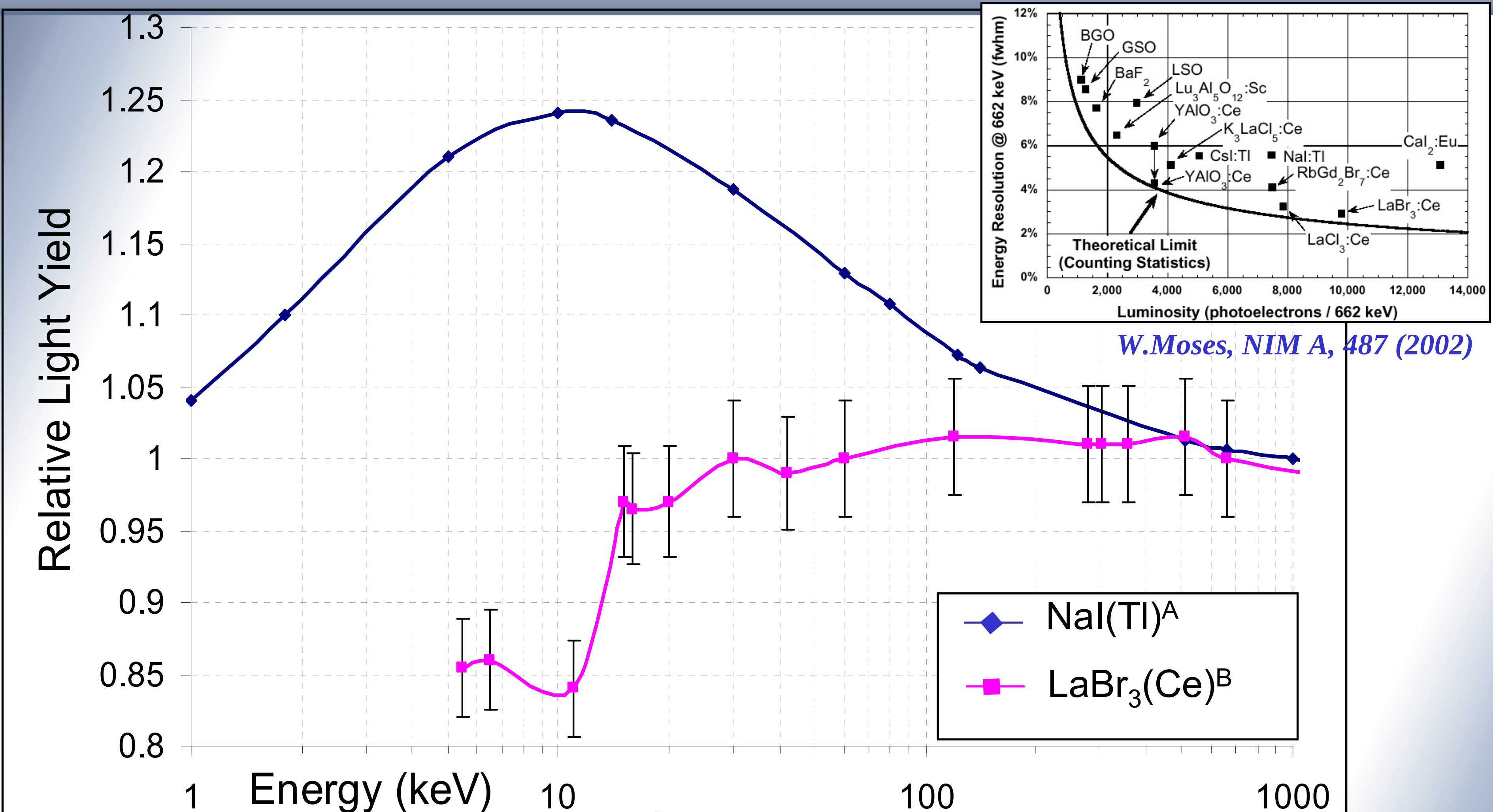
** from C.W.E. van Ejjk Phys. Med. Biol. (2002) 85-106 * Expected values

Radiation absorbtion properties

at 140 keV

Crystals	ρ density (g cm^{-3})	τ (cm^{-1})	μ (cm^{-1})	τ / μ	HVL (cm)	Thick.* 80% eff. (cm)
$LaBr_3$:Ce	5.0	2.2	3.01	0.73	0.23	0.53
$LaCl_3$:Ce	3.79	1.78	2.37	0.75	0.29	0.68
NaI:Tl	3.67	2.07	2.66	0.78	0.26	0.60
CsI:Tl	4.51	3.17	3.92	0.81	0.17	0.41

Non-proportionality in light yield

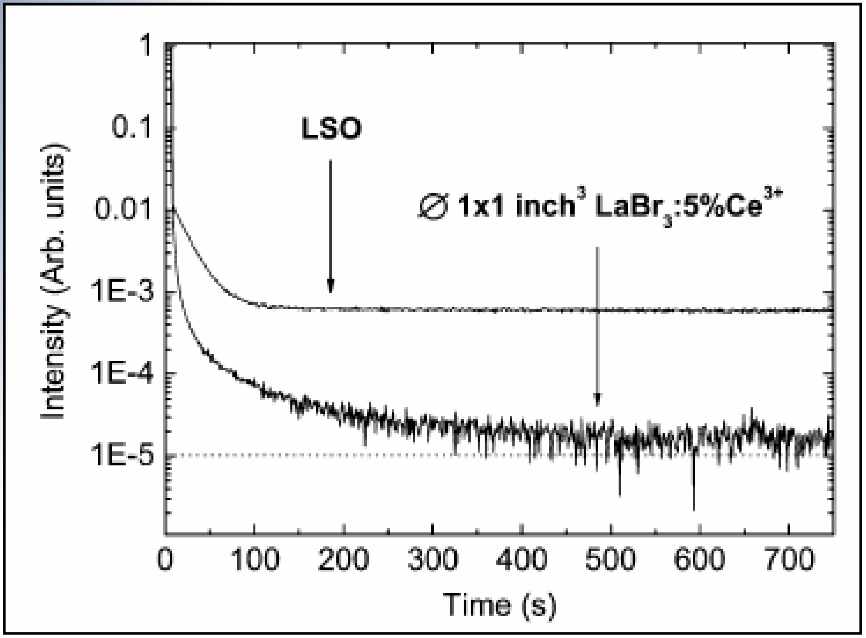


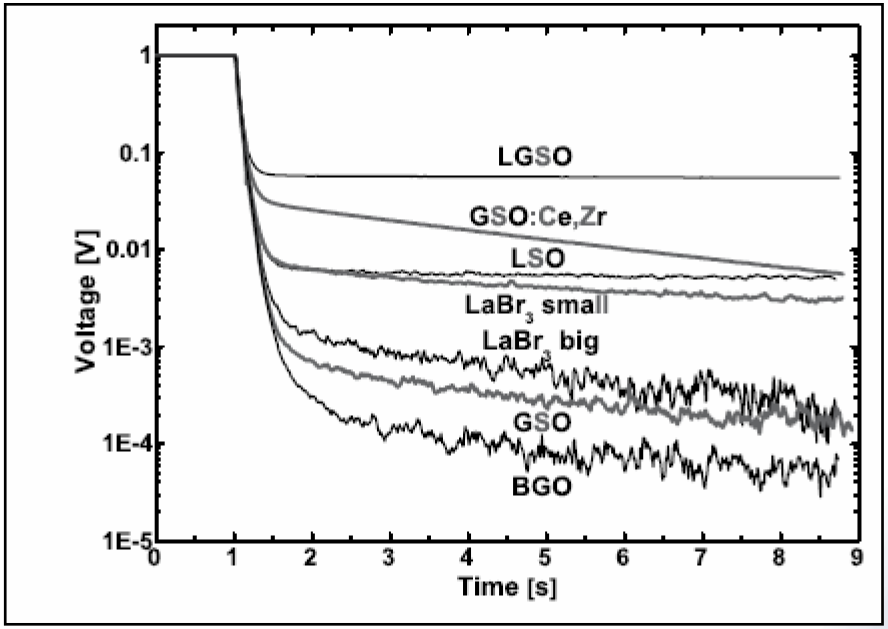
W.Moses, NIM A, 487 (2002)

A – *Prescott and Narayan, Nucl. Instr. And Meth., Vol 75,51 (1969)*

B – *G.Bizarri, W.E.Van Eijk et al., IEEE TNS, Vol 53,02 (2006)*

$LaBr_3$:Ce Afterglow





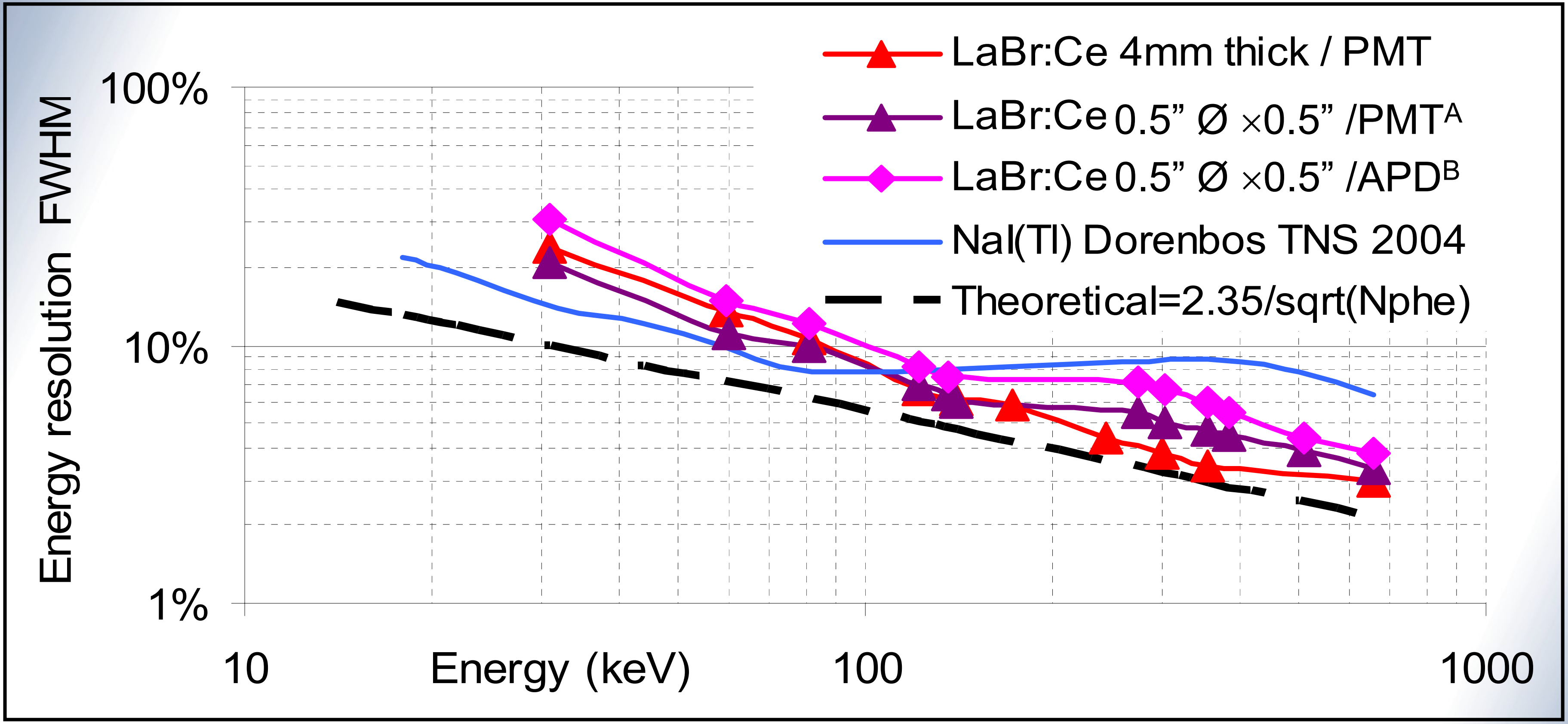
Exp. time: 30 s – Source : X-ray beam

(Bizarri G. et al. IEEE TNS, Vo. 35, 2006)

Exp. time: 300 s – Source : ^{241}Am

(Nassalski A. et al. IEEE NSS_MIC Conf. Rec., 2005)

Energy Resolution

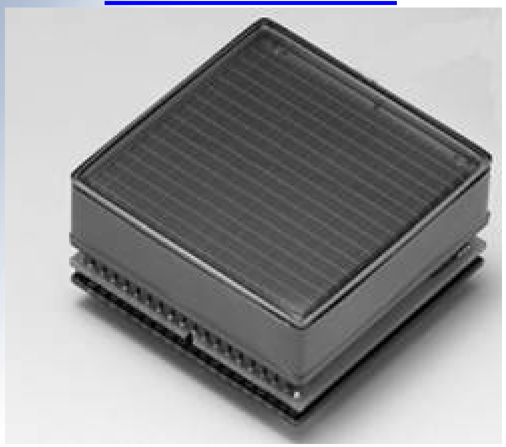


[A] PMT Hamamatsu R3261

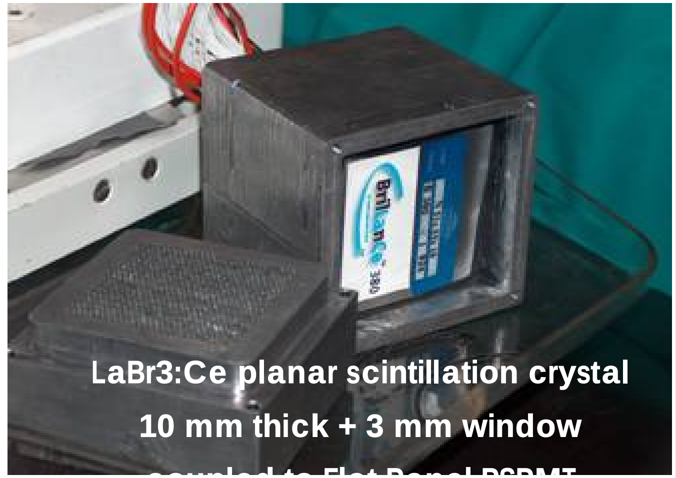
[B] Si-APD Hamamatsu S8664 - Active Area 10 x 10 mm^2

$LaBr_3$:Ce X and γ imager

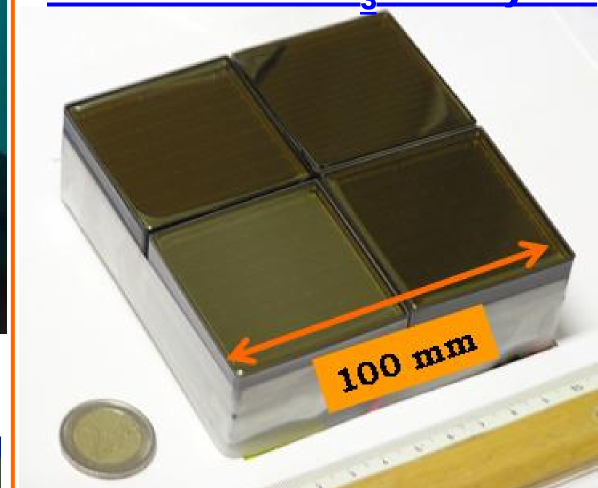
Hamamatsu H8500 Flat Panel PMT



- external size 52 x 52 mm^2
- 49 × 49 mm^2 active area
- 1.5 mm glass window
- metal channel dynodes
- 8×8 matrix 6.0 mm anodes

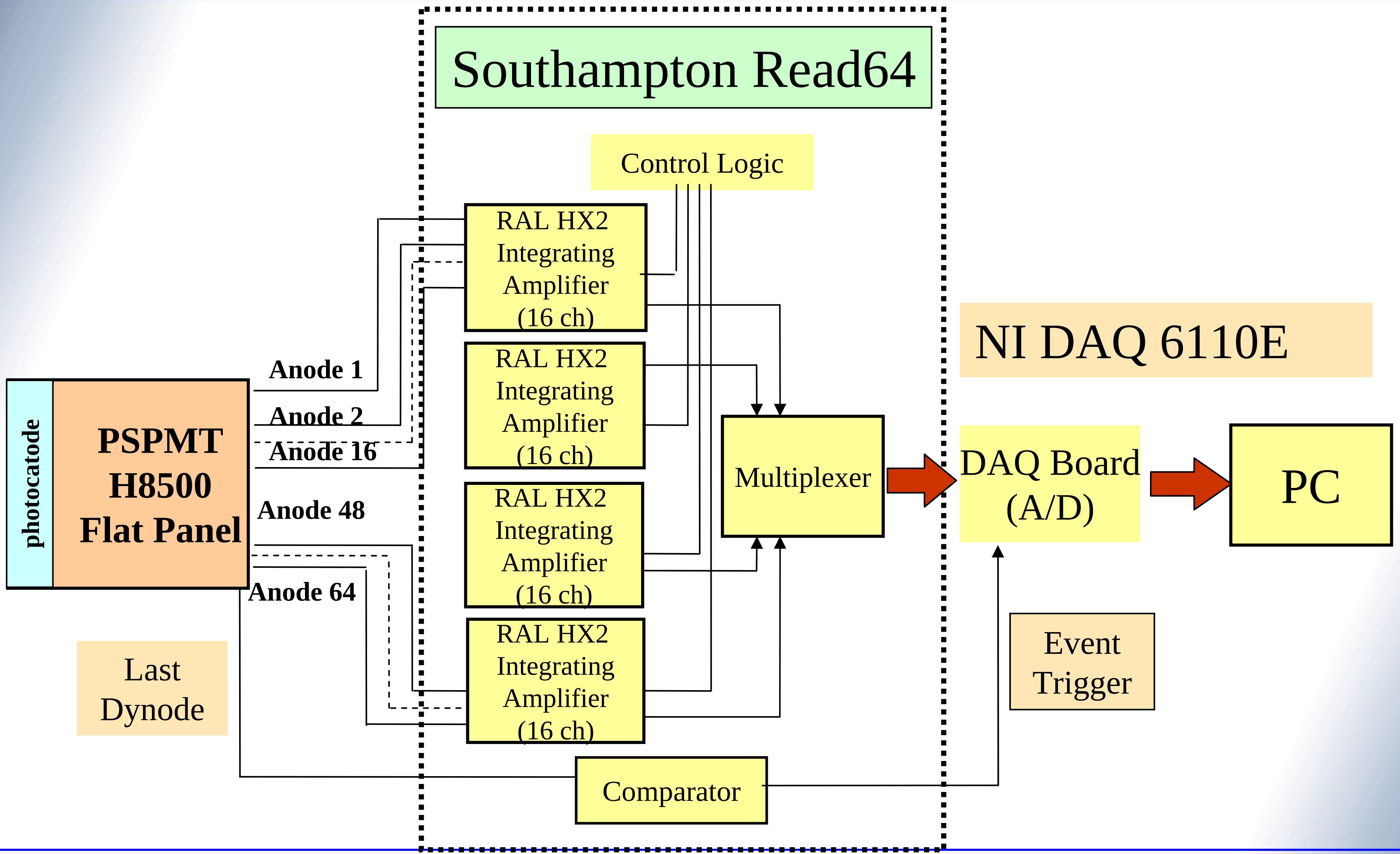


Photodetector assembly for 10x10 cm^2 $LaBr_3$:Ce crystal

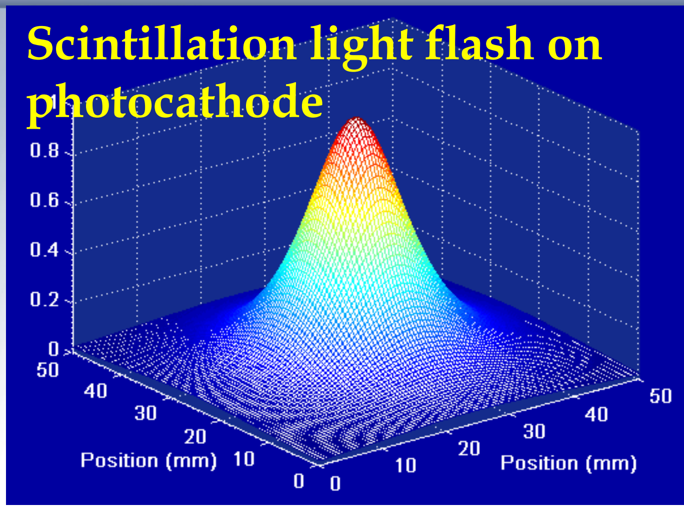


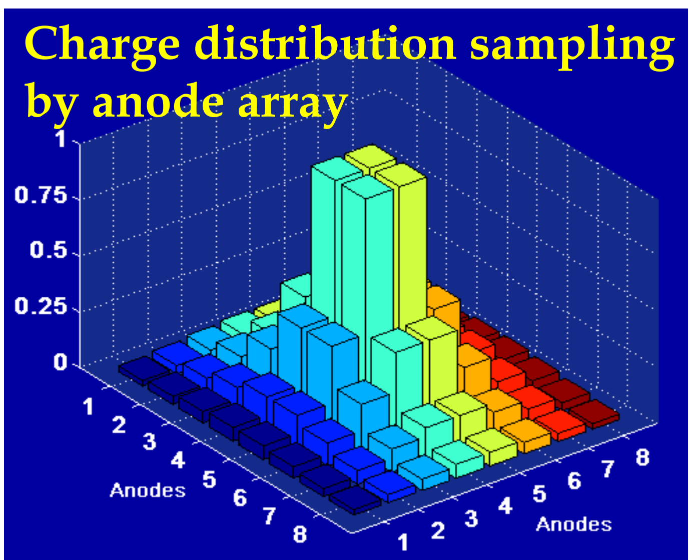
- Extremely compact (15 mm of thickness)
- Ideal for closely packing in array (1.5 mm edge dead zone)
- Intrinsic spatial resolution better than 0.5 mm

Flat Panel Electronic Readout:
Multi-anode 64 channels



Position Arithmetic for continuous scintillator in single photon counting



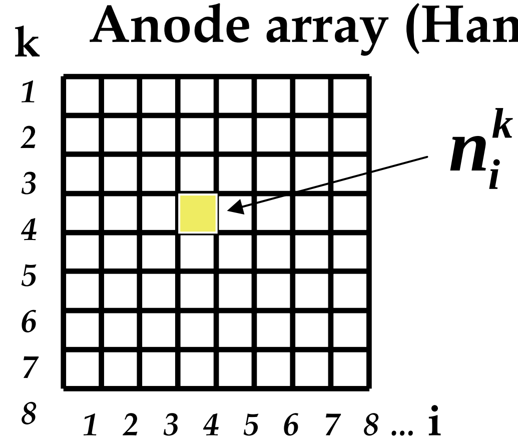


X & Y Position Centroid Algorithm

Position: $X = \dfrac{\Sigma_i \, i \, n_i}{\Sigma_i \, n_i}$

Energy: $E = \Sigma_i \, n_i$

Anode array (Hamamatsu H8500)



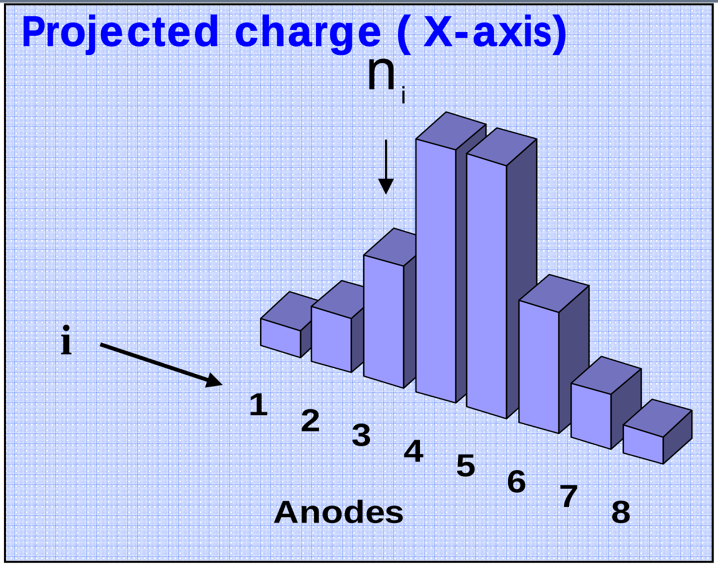
$$n_i = \sum_k n_i^k$$

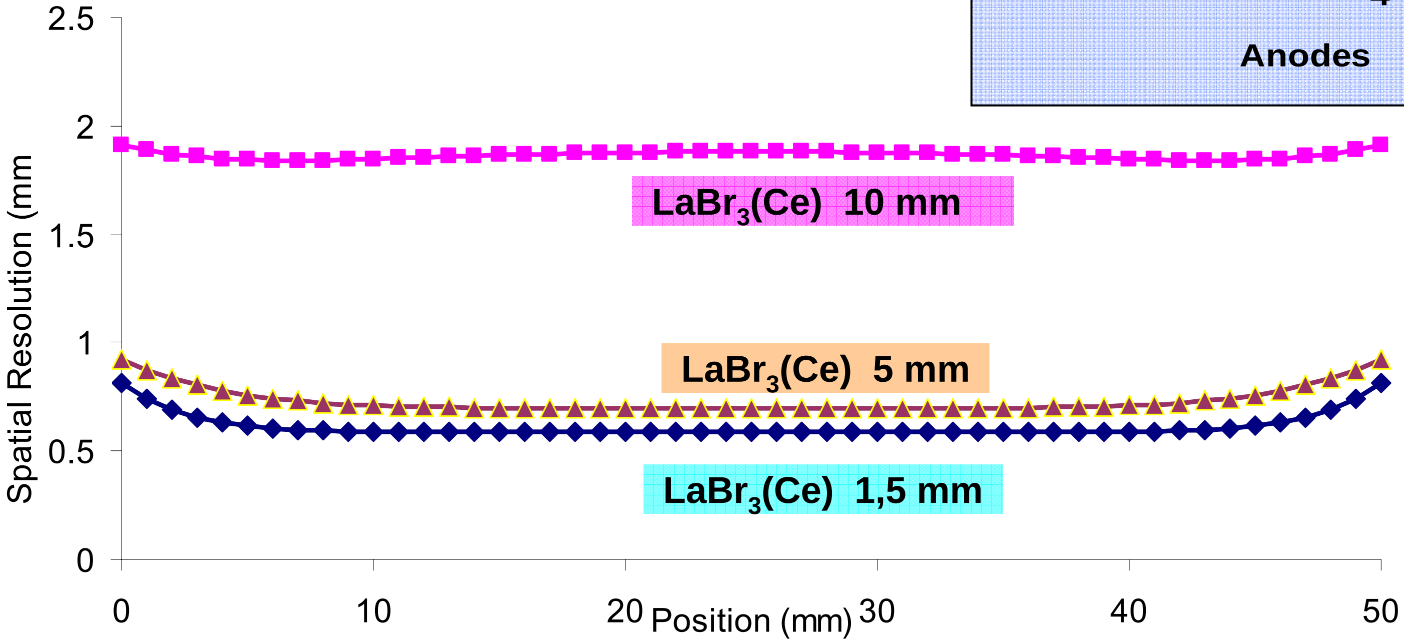
Expected Spatial Resolution

$$\sigma_{x_c} = \frac{1}{\sqrt{n_{phe}}}\sqrt{\sum_i (i - \langle i \rangle)^2 f_i}$$

$$f_i = n_i / n_{phe}$$

$$SR = ER \times \sigma_{charge\_distrib}$$

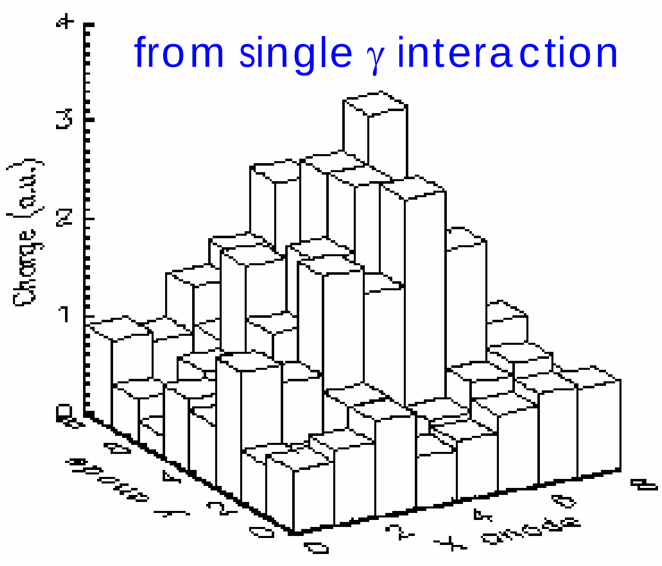




Charge distribution treatment for position linearity correction

Original charge distribution

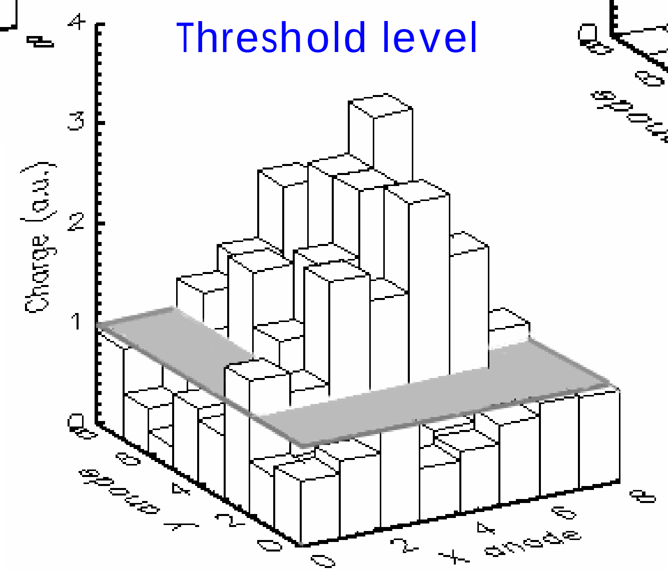
from single γ interaction



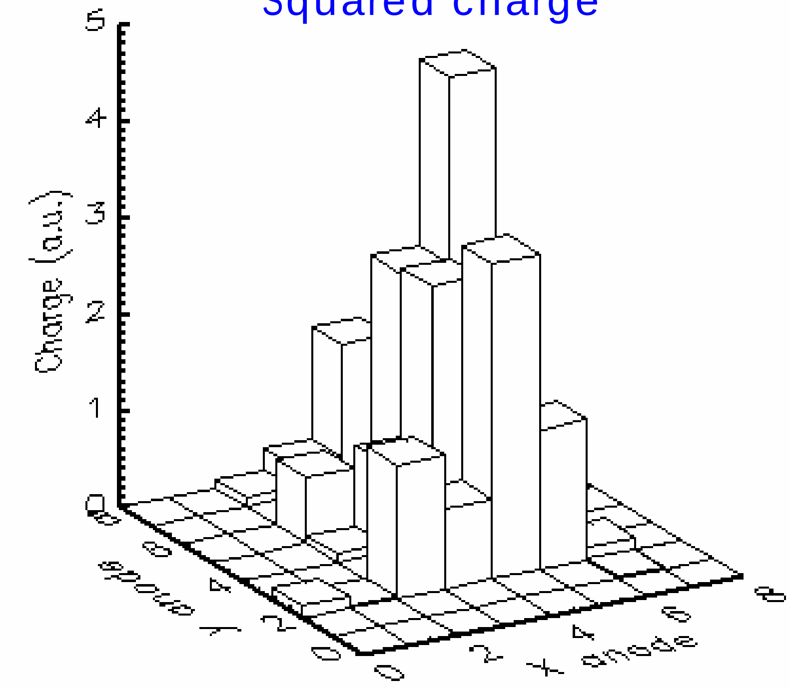
LaBr$_3$:Ce

10 mm thick

Threshold level



Squared charge



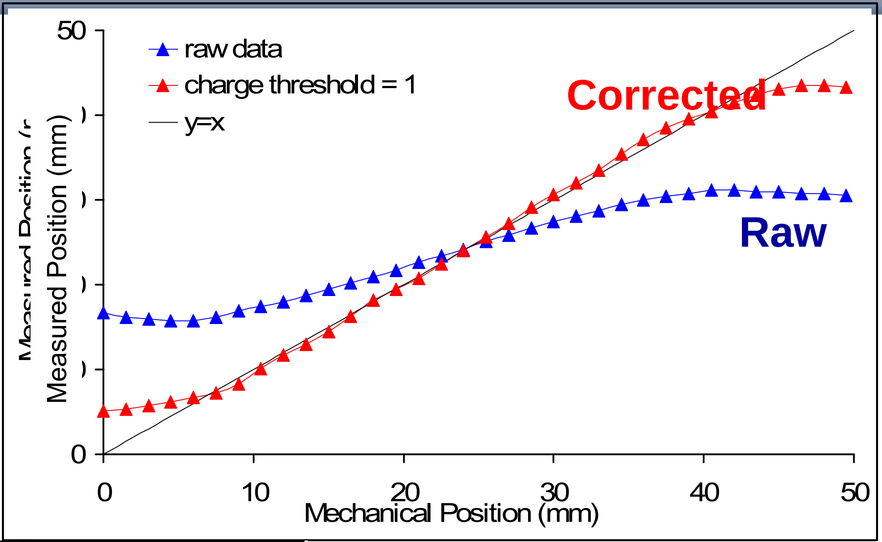
Position linearity correction

LaBr$_3$:Ce

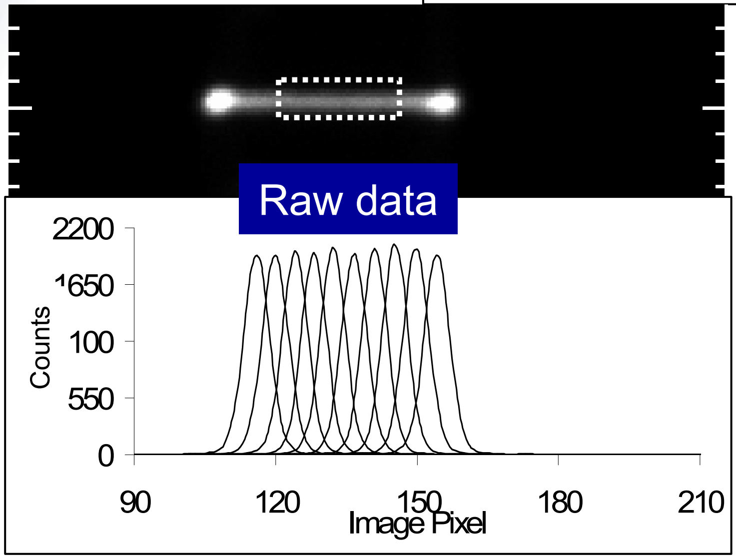
integral assembly

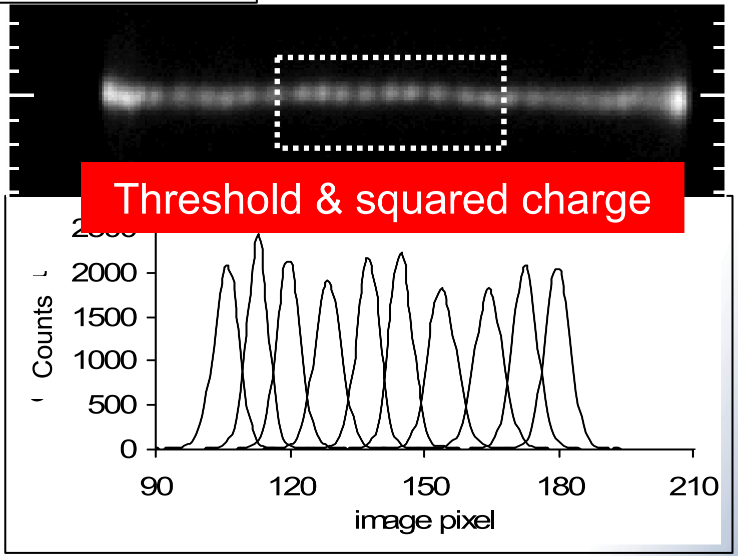
Co57 Spot scanning,

1.5 mm step

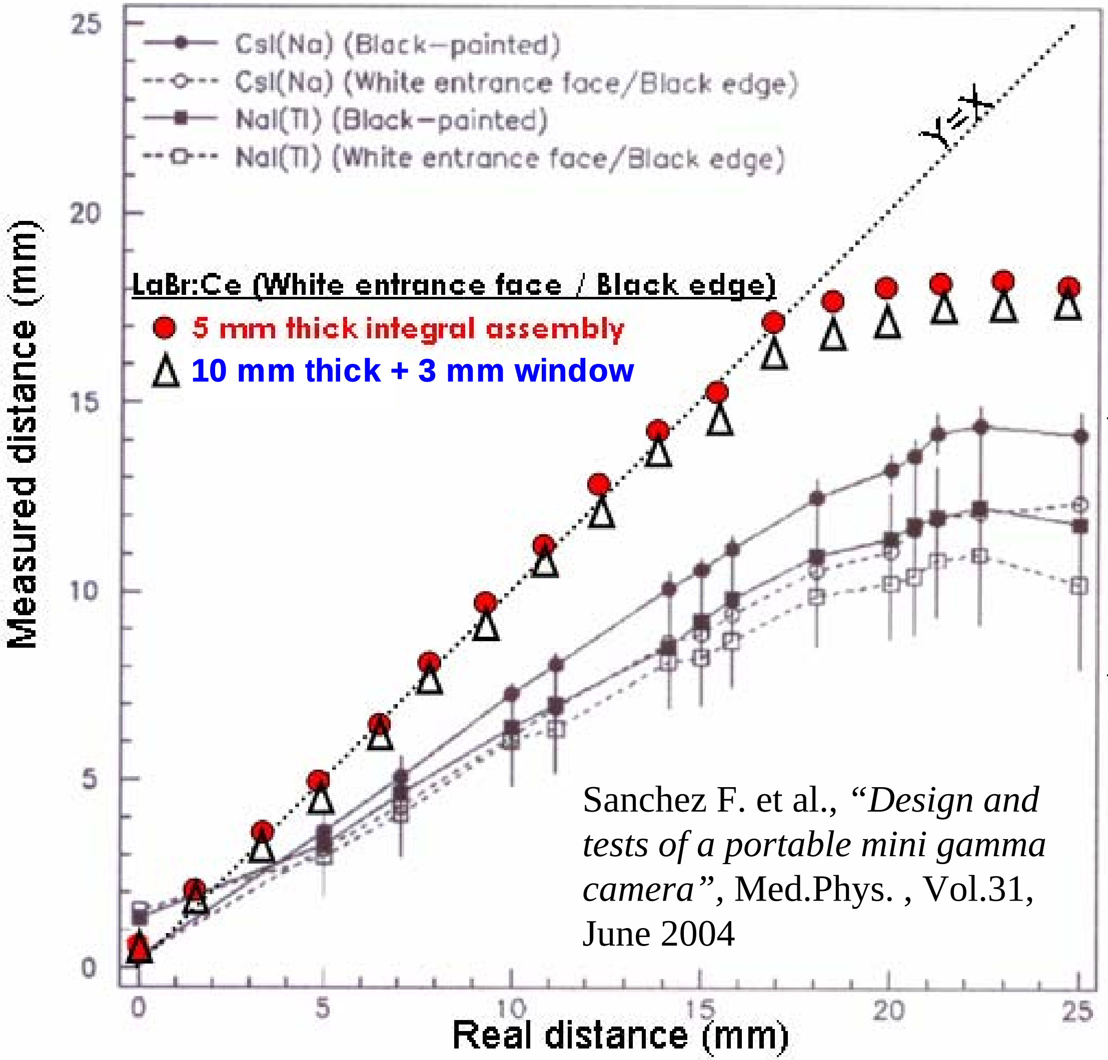


The correct position linearity relation enables to carry out the true intrinsic spatial resolution





$LaBr_3$:Ce Position Linearity Enhancement
continuous crystals

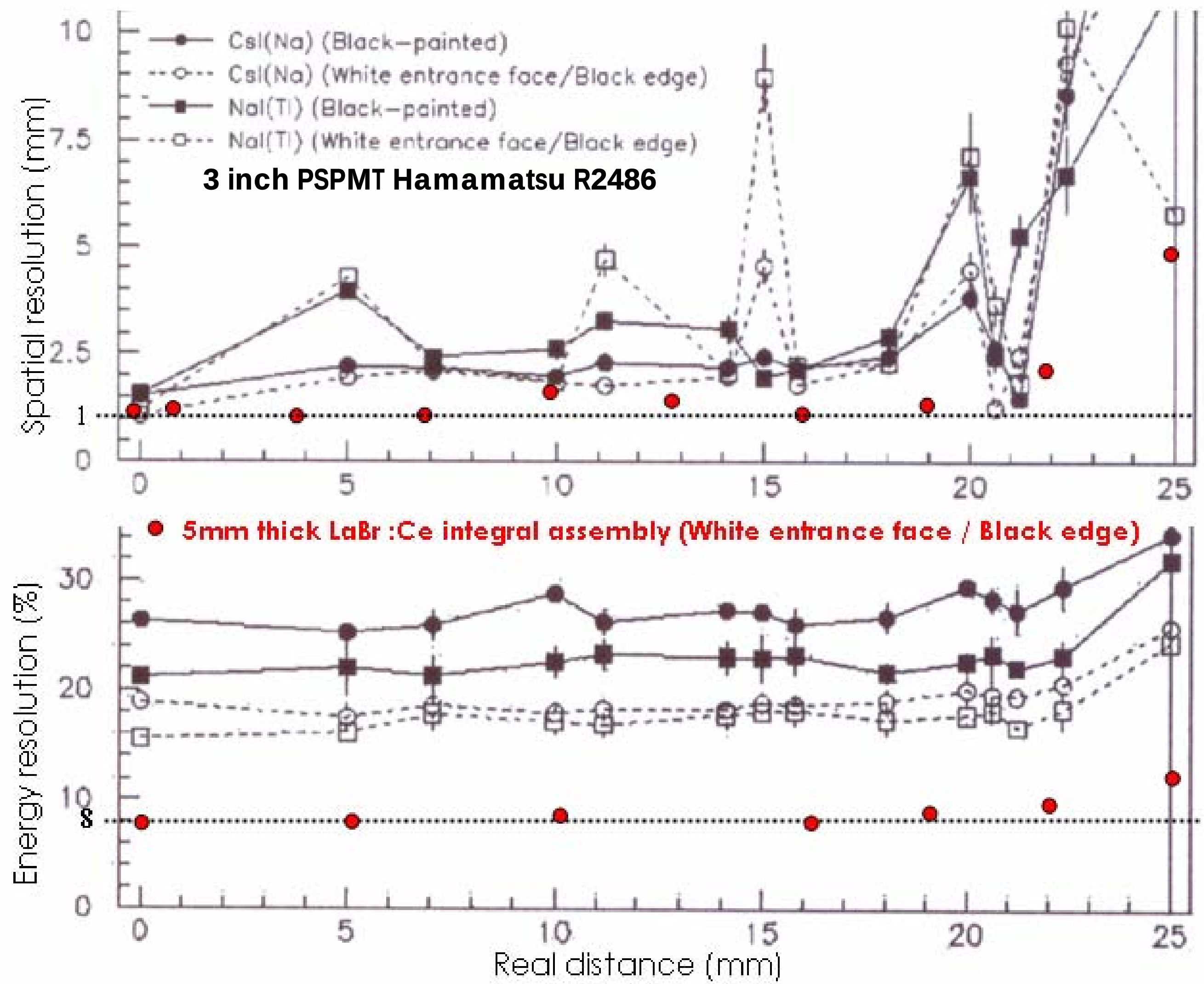


3 inch PSPMT

Hamamatsu R2486

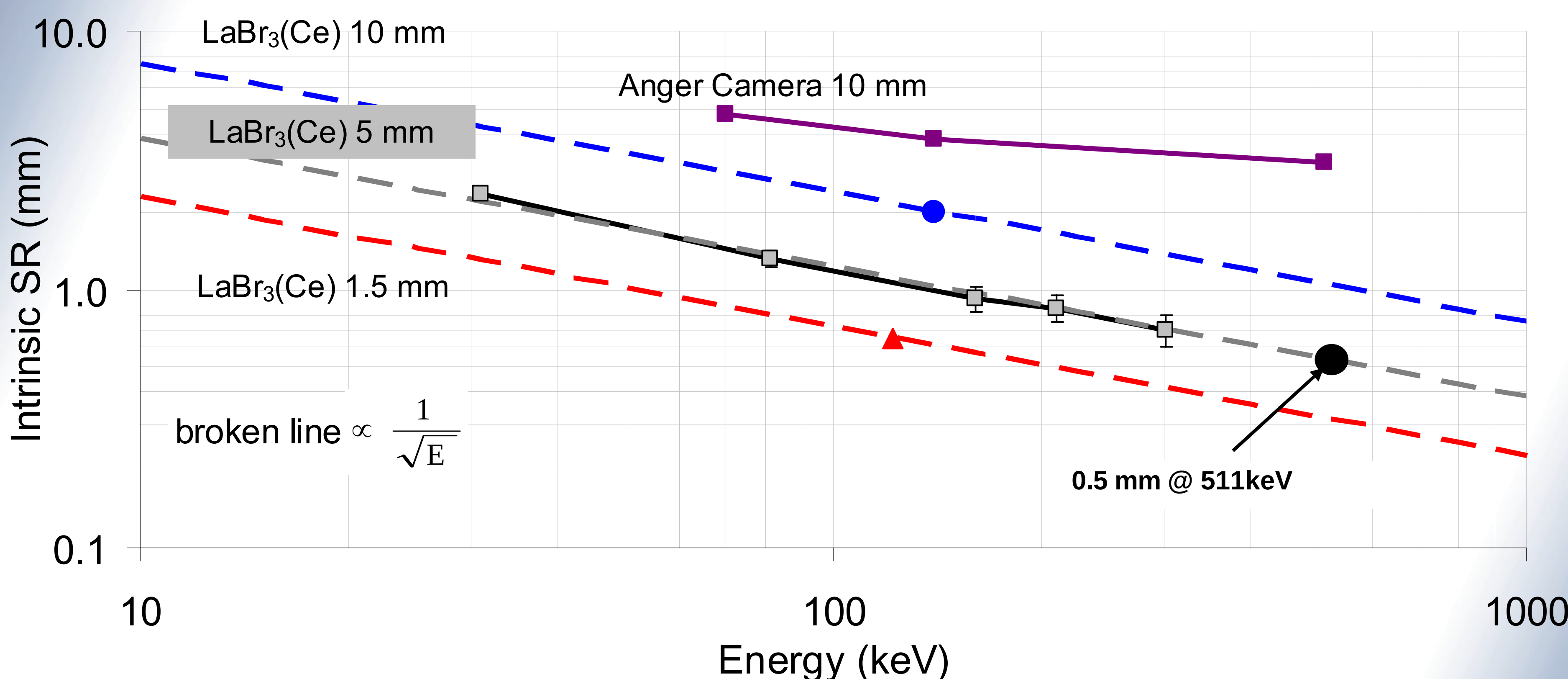
Sanchez F. et al., *"Design and tests of a portable mini gamma camera"*, Med.Phys. , Vol.31, June 2004

$LaBr_3$:Ce Energy and Spatial Resolution Enhancement
continuous crystals



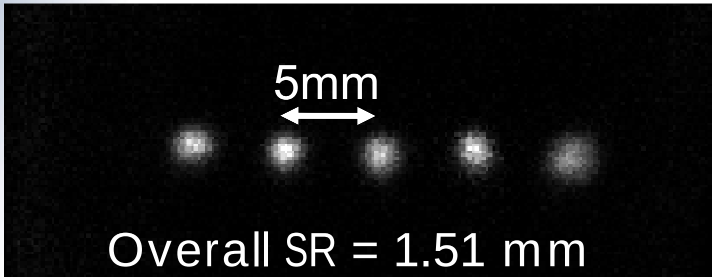
Sanchez F. et al., Medical Physics, Vol.31, June 2004

Intrinsic Spatial Resolution vs Energy

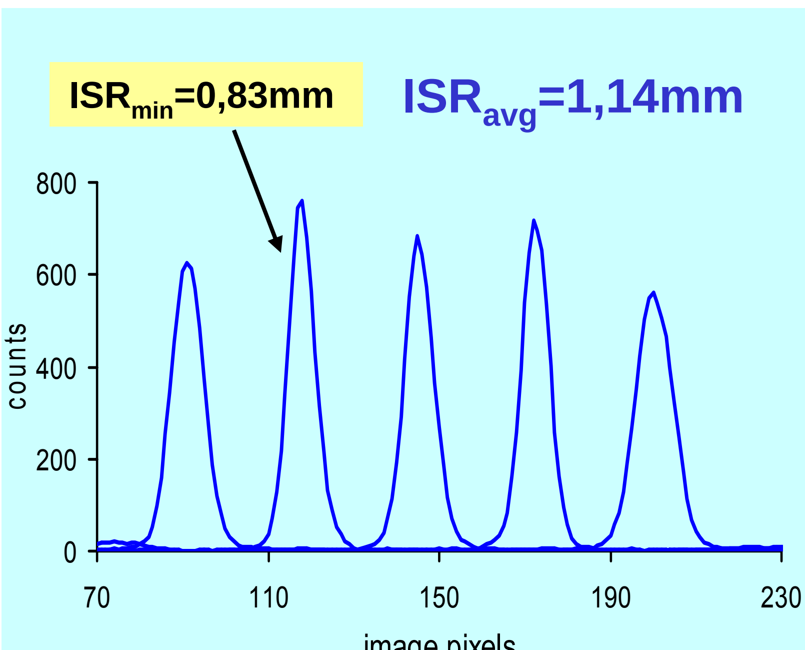


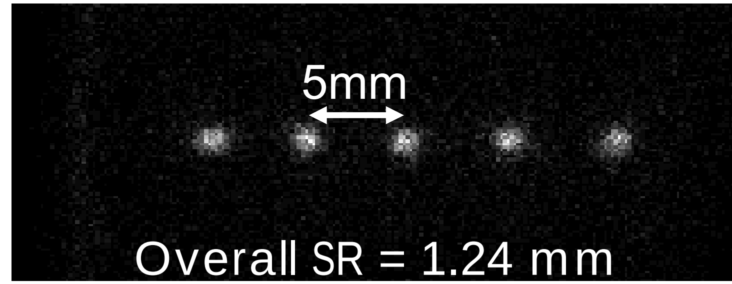
Intrinsic Spatial Resolution vs γ energy

$LaBr_3$:Ce 5 mm thickness- 1mm collimated Ba^{133} source

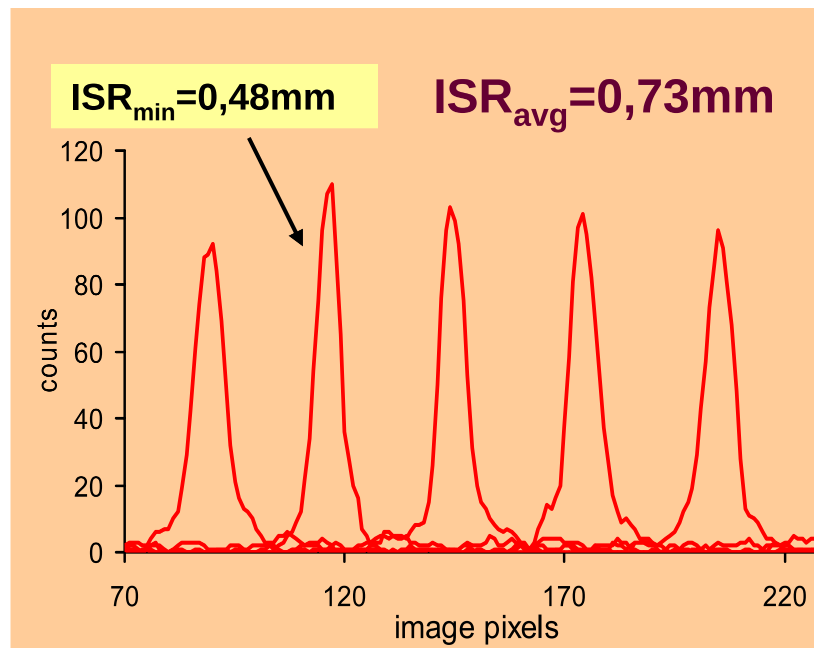


80 keV





302 keV

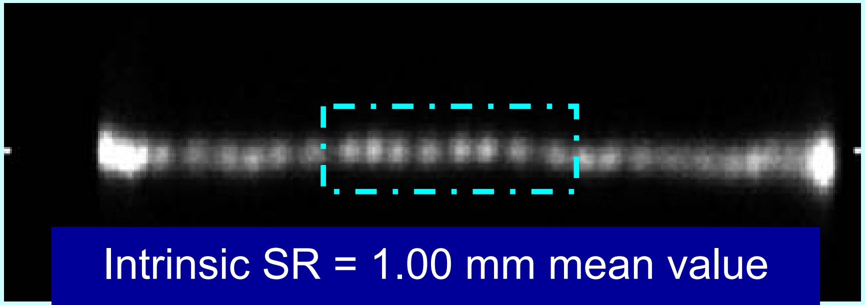


Spatial resolution vs crystal thickness

Co^{57} 1 mm collimated source - Detector Scanning @ 1.5 mm step

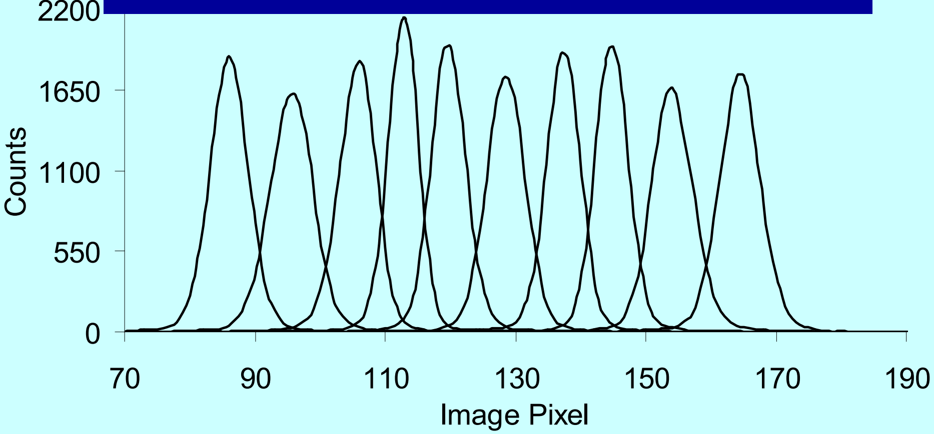
LaBr3:Ce 5 mm thick

Integral assembly



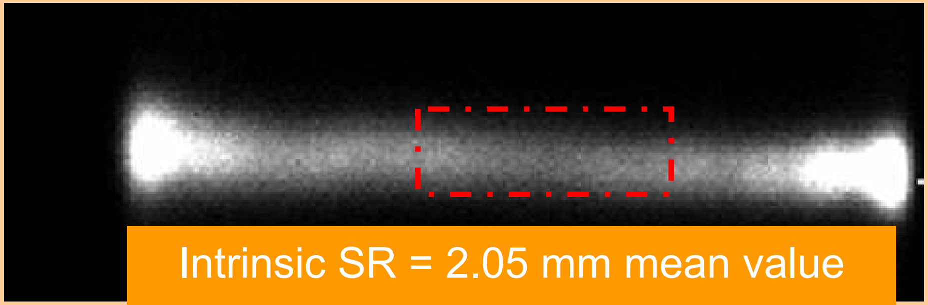
Intrinsic SR = 1.00 mm mean value

0.90 mm best value



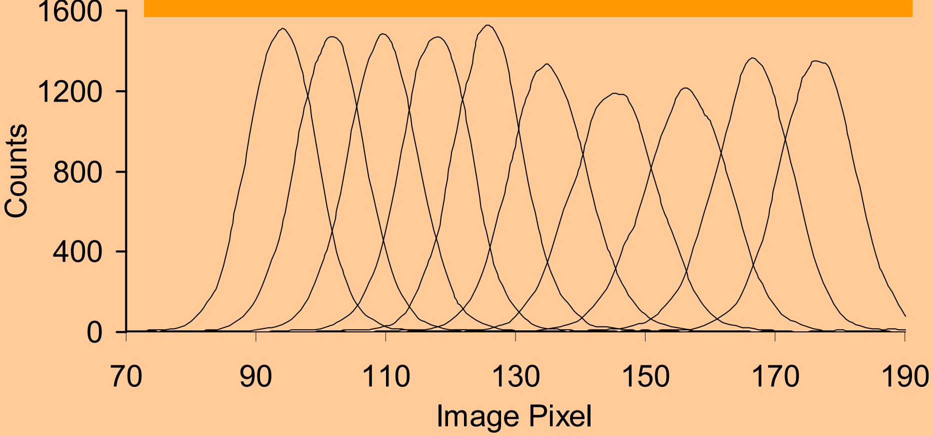
LaBr3:Ce 10 mm thick

3 mm window



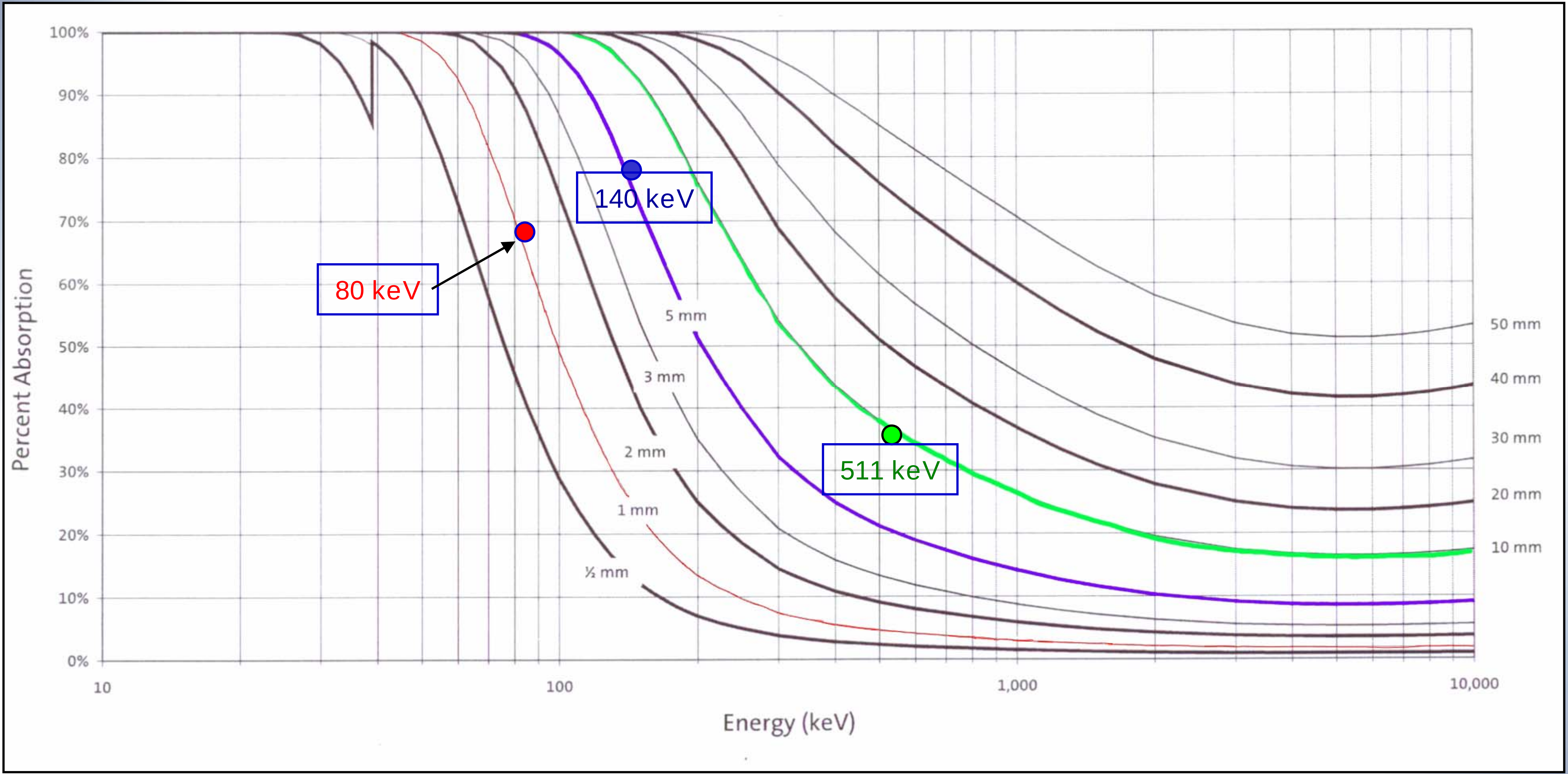
Intrinsic SR = 2.05 mm mean value

1.85 mm best value



Absorption efficiency of BrilLianCe ™ 380

$(LaBr_3:Ce)$

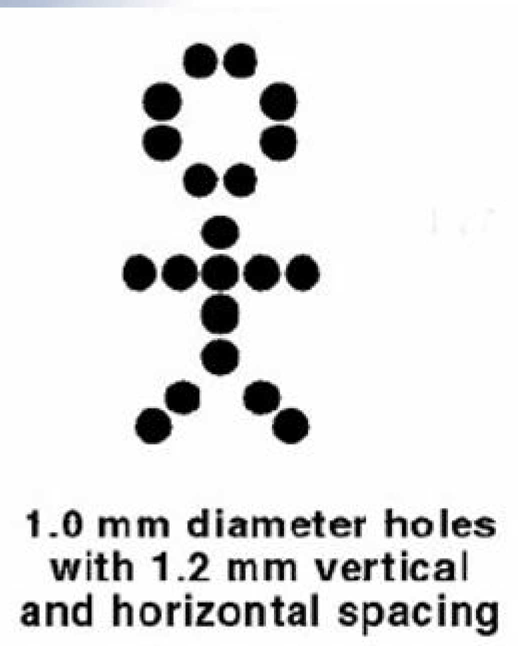


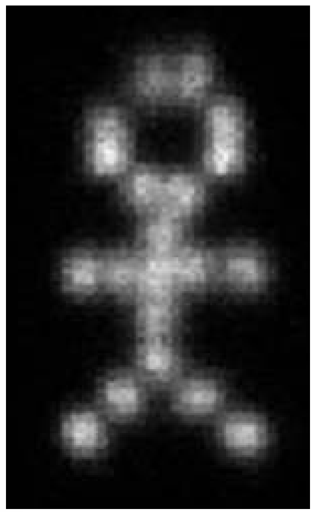
Courtesy of Saint Gobain Crystals

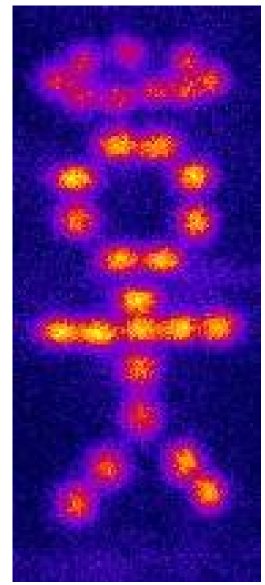
“Mario” transmission Pb mask

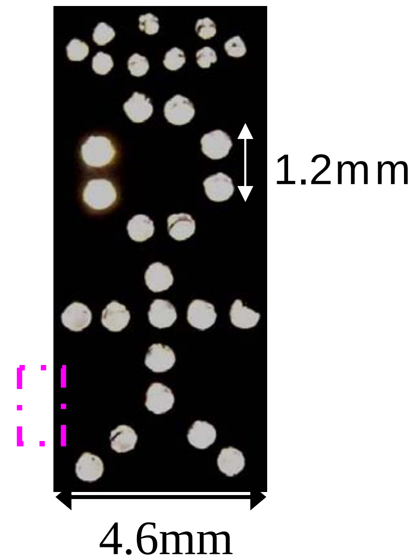
Co57 flood field irradiation

(S. Majewsky, Jlab, Va, USA)









$LaBr_3$:Ce 5 mm thickness -Integral assembly

Spatial Resolution = 0.90 mm – Efficiency: 80%

$LaBr_3$:Ce 1.5 mm thickness -Integral assembly

Spatial Resolution = 0.65 mm – Efficiency: 35%

Conclusion

- This work confirms the expected high potential of the LaBr3:Ce gamma camera for single photon Imaging.
- Continuous LaBr3:Ce crystal shows superior spatial and energy resolution performances than previous generation scintillators
- It shows interesting features as integrated detector for SPET/CT imaging though the wide charge distribution detection in pulse mode is the major limitation for high count rate X-ray imaging