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ITBS2005
Innovation in Nuclear and Radiological Imaging:
From Basic Research to Clinical Application
Milos Conference Center, Milos Island, Greece, 25-28 September 2005

special session:

Advances in functional breast imaging by compact and dedicated imagers"

Recent advances and future perspectives of gamma imagers for scintimammography

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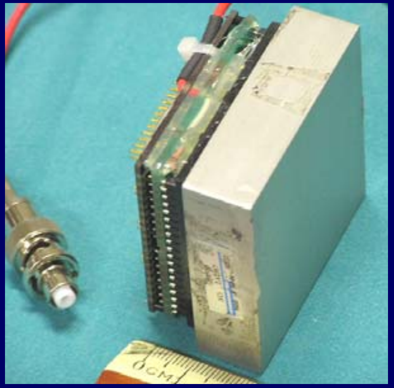
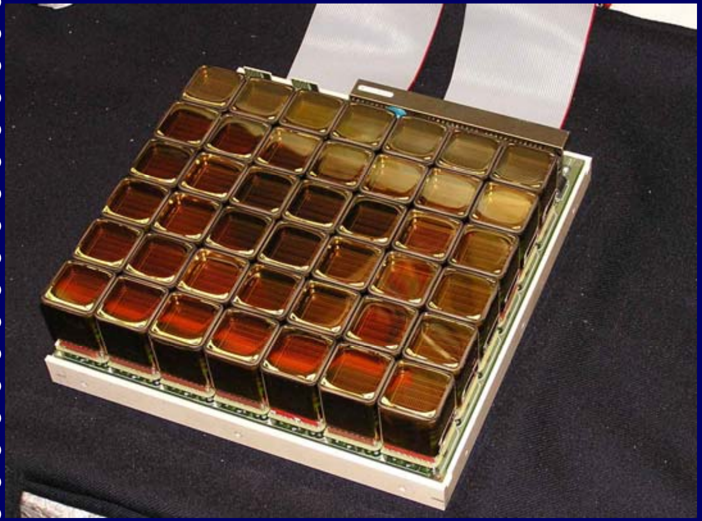
Latest generation gamma cameras for Scintimammography

LaBr3:Ce
gamma camera
Continuous crystal
1st prototype
5x 5 cm² (2005)



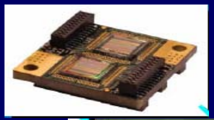
INFN
Scintirad Project

Multi-PSPMT NaI(Tl) pixellated
1° generation gamma camera
18 x 16 cm² (2001)



INFN-IMI project
Pol.Hi.Tech -CAEN

Pixellated CdZnTe 2nd generation
Gamma Camera 12.5 x12.5 cm²
(2005)



Gamma Medica Ideas Inc., Northridge,
California, USA

Some of the most recent Gamma Cameras characteristics

	$LaBr_3$:Ce	Multi-PSPMT	LumaGEM ®	LumaGEM 3200 ®	LumaGem3200S®
	2005	2003	Released 1999	Released 2003	Released 2005
Detector	$LaBr_3$:Ce-H8500 PMT	NaI(Tl) array R8520 PSPMT	NaI(Tl) array - PSPMT	CdZnTe Solid State	CdZnTe Solid State
Field of ®iew	5cm x 5cm	18cm x 16cm	13cmx 13cm	20cmx 16cm	20cmx 16cm
Dead space	< 8 mm from edge	< 8 mm from edge	<10 mm from edge	< 8 mm from edge	< 8 mm from edge
Thickness	< 8 cm	< 9 cm	< 9 cm	< 7.5 cm	< 7.5 cm
Energy Resolution	6% FWHM	12% FWHM	10% FWHM	6% FWHM	4,5% FWHM
Spatial resolution	1 mm	2 mm	2.2mm	2.5 mm	1.6 mm
Space Bandwidth	continuous	6930pixel^2	3,136 pixel^2	5,120 pixel^2	12,288 pixel^2

LumaGEM ® data from Bradley E. Pratt

Solid- State Compact CdZnTe Gamma

Gamma Medica Ideas Inc., Northridge, California, USA

12.5 x 12.5 cm^2 FOV
Pitch: 1.6 mm
Matrix: 80 x 80
high density ASIC readout has been built

CLAIMS

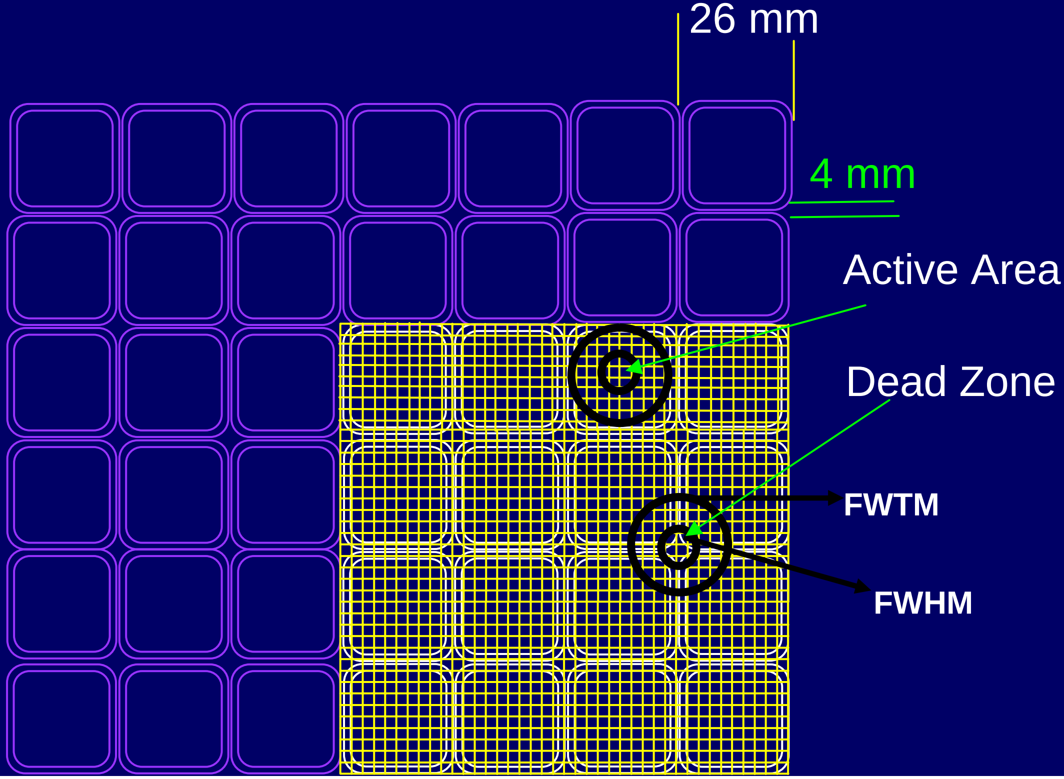
- The energy resolution, sensitivity and spectral shape of the solid state digital gamma camera are each superior to the NaI(Tl)
- The improved energy resolution allows for a smaller energy window to be used.
- Use of narrower energy window could improve scatter rejection while maximizing sensitivity and ultimately lead to improved contrast and resolution in both planar imaging and SPECT

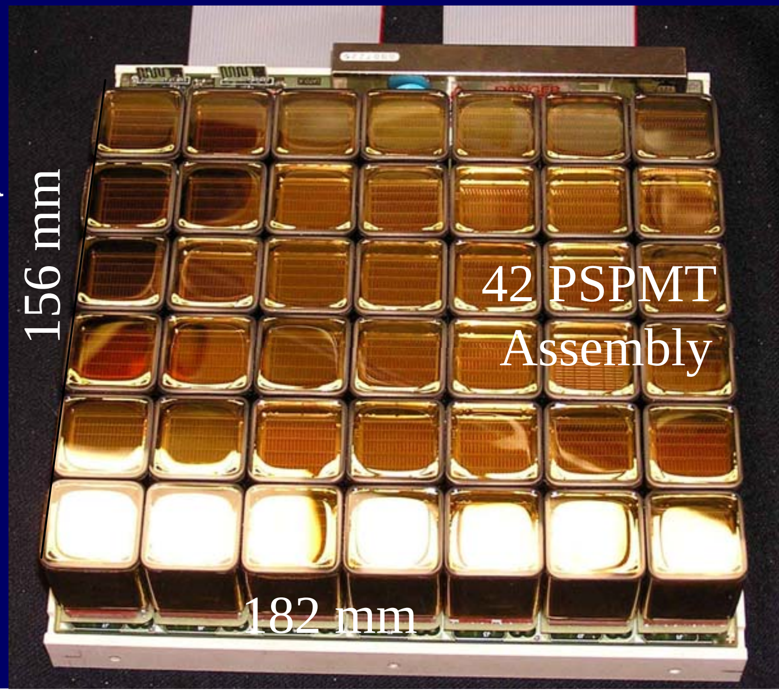
T. Vandehei, K. Parnham, J. Li, Y. Yamaguchi, K. Iwata, , J. B.E. Patt, J. Zhang, H. Zhou, M. Szawlowski, G. Caravaglia, E. Bolle, B. Sundal, S. Mikkelsen, T. Orskaug
Medica Ideas Inc., Northridge, California, USA Gamma
SNMA 2005 presentation

IMI Project: INFN Multi-PSPMT NaI(Tl) pixellated 1° generation scintillation gamma camera 18 x 15 cm2 (2001)

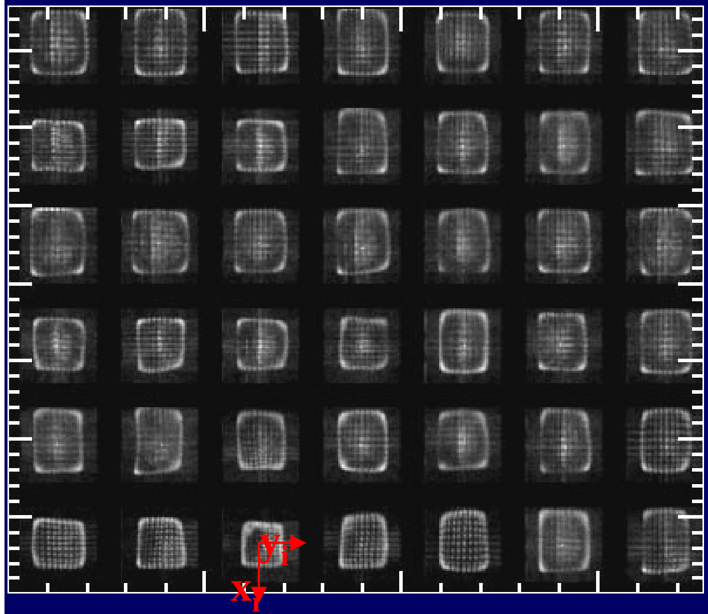
PSPMT array closely packed coupled to a NaI (Tl) scintillation matrix

Position is determined by light distribution centroid method





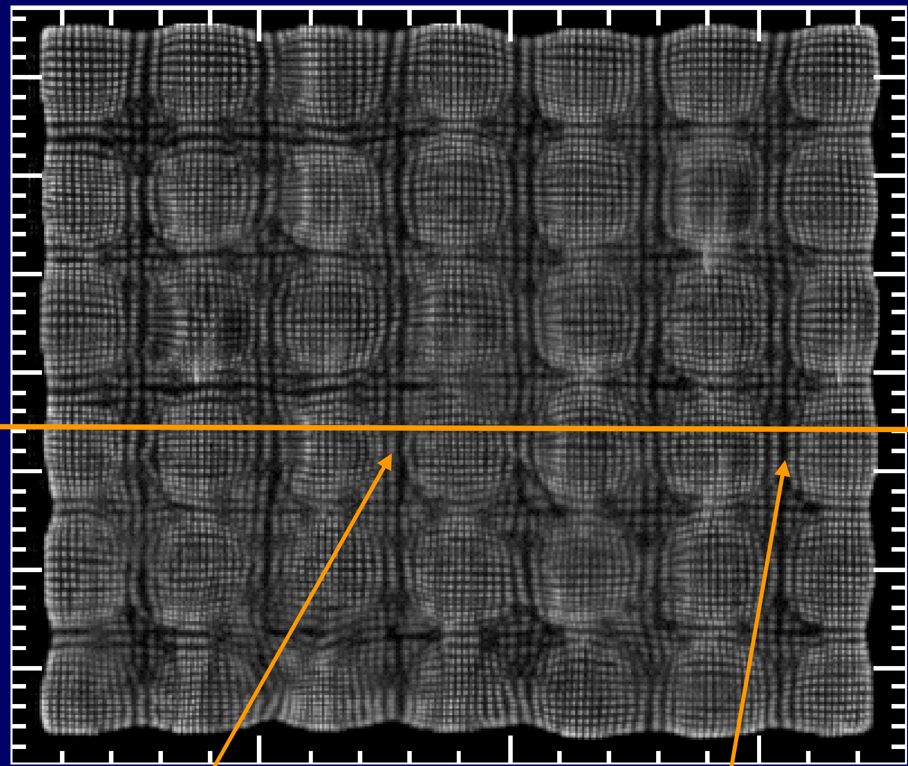
42 PSPMT independent images

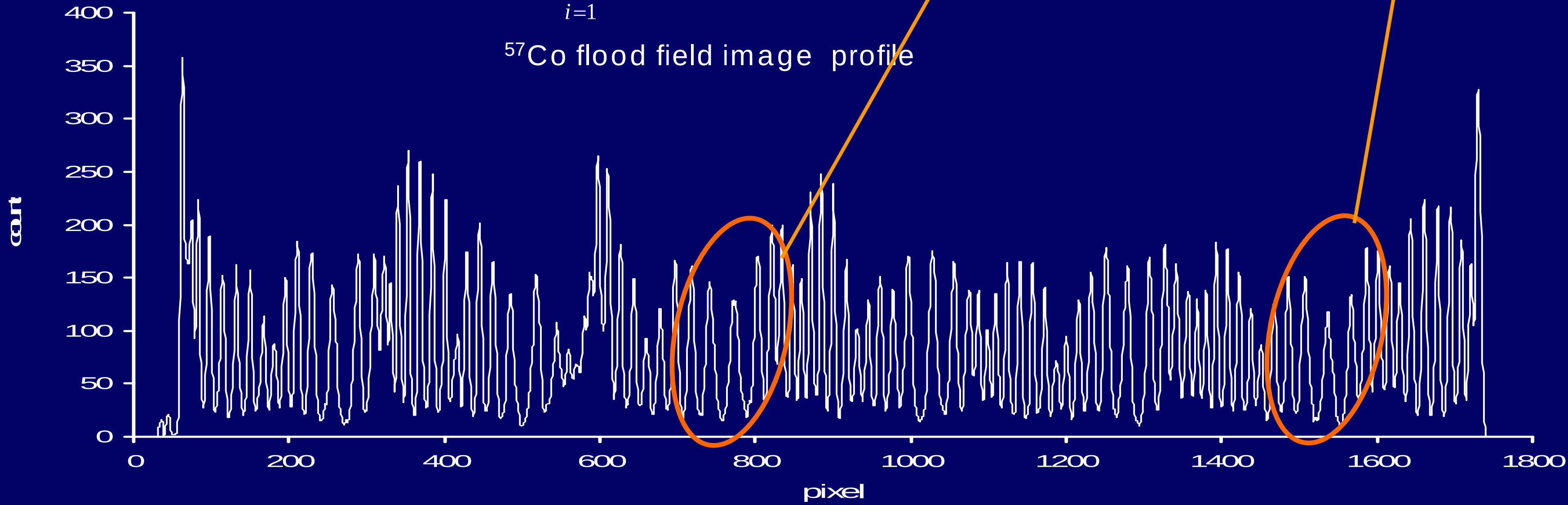


$$Y = \frac{\sum_{i=1}^{16} y_i E_i}{\sum_{i=1}^{16} E_i}$$

$$X = \frac{\sum_{i=1}^{16} x_i E_i}{\sum_{i=1}^{16} E_i}$$

42 PSPMT reconstructed raw image





^{57}Co flood field image profile

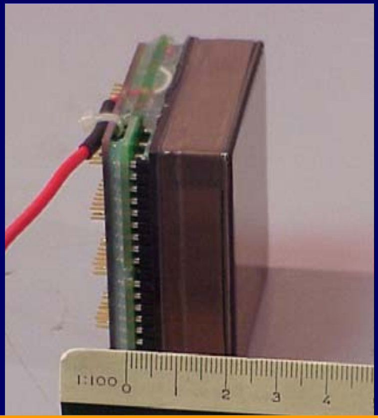
NEW TRENDS IN CRYSTAL GROWING

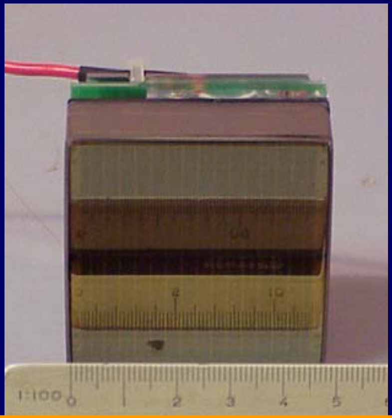
INFN Scintirad Project :
Lanthanum Bromide Gamma Camera Prototype ($LaBr_3$:Ce)

The photodetector: Position sensitive Hamamatsu Flat Panel PMT H8500/9500

- Extreme compactness (15 mm thick)
- Suitable for close packing in matrices(1 mm boundary dead zone) in order to obtain

Very large detection areas





The scintillator : $LaBr_3$:Ce 50x50x5 mm^3

- Fast, efficient, ultra high energy resolution
- Very high light yield (66000 photons/MeV at 350/450 nm)
- Almost a half of NaI(Tl) energy resolution
- Attenuation coefficients higher than NaI(Tl)

$LaBr_3$:Ce Integral assembly with Flat panel

Crystals	Density (g/cm^3)	Light yield (ph/MeV)	Decay time (ns)	Maximum Emission length (nm)	ΔE/E (FWHM) PMT read-out	
					662 keV **	140 keV
NaI:Tl	3.67	41000	230	410	5.6 %	8.5 %
CsI: Na	4.51	40000	630	420	7.4 %	9.5 %
CsI:Tl	4.51	66000	$800 \div 6 \times 10^3$	550	6.6 (PMT)/ 4.3 (SDD)	14 %
$LaCl_3$:Ce	**3.79**	**49000**	**28**	**350**	**3.8 %**	**8.0* %**
$LaBr_3$:Ce	**5.3**	**66000**	**26**	**380**	**2.8 %**	**5.8 %**
$Bi_4Ge_3O_{12}$ (BGO)	7.1	9000	300	480	9.0 %	--
Lu_2SiO_5:Ce (LSO)	7.4	26000	40	420	7.9 %	18 %
Gd_2SiO_5:Ce (GSO)	6.7	8000	60	440	7.8 %	22 %
YAl O_3:Ce (YAP)	5.5	21000	30	350	4.3 % (APD)	20 %

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

* Expected values

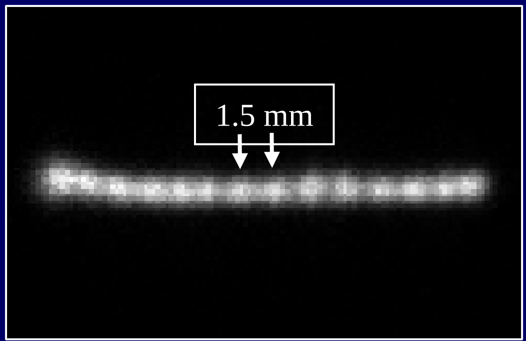
Lanthanum crystals radiation absorption properties

values @ 140 KeV photon energy

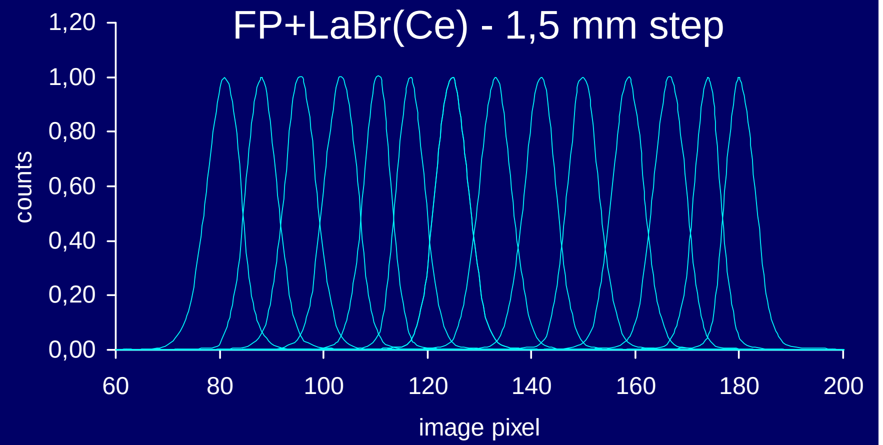
Crystal	ρ (density) ($g\ cm^{-3}$)	τ (cm^{-1})	μ (cm^{-1})	τ/ μ	HVL (cm)	Thick. (80% eff.) (cm)
$LaBr_3$:Ce	**5.29**	**2.2**	**3.01**	**0.73**	**0.23**	**0.53**
$LaCl_3$:Ce	3.79	1.78	2.37	0.75	0.29	0.68
NaI:Tl	3.67	2.07	2.66	0.78	0.26	0.60
CsI:Tl	4.51	3.17	3.92	0.81	0.17	0.41

LaBr$_3$:Ce detection performance

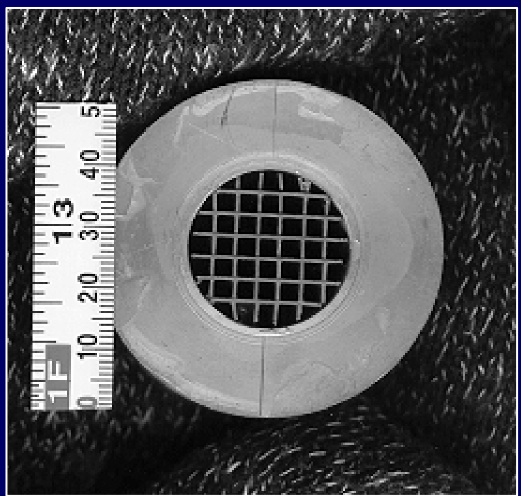
Co57 Spot scanning with 1 mm collimation aperture

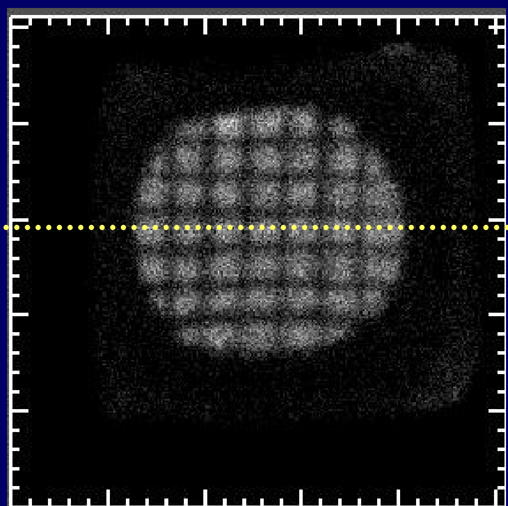


Overall SR = 1.23 mm
Intrinsic SR = 0.9 mm

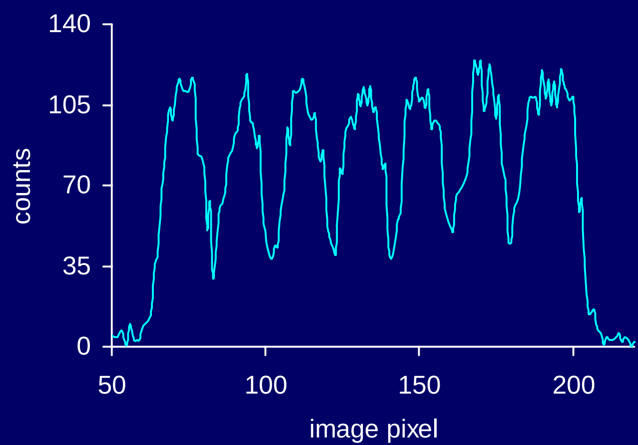


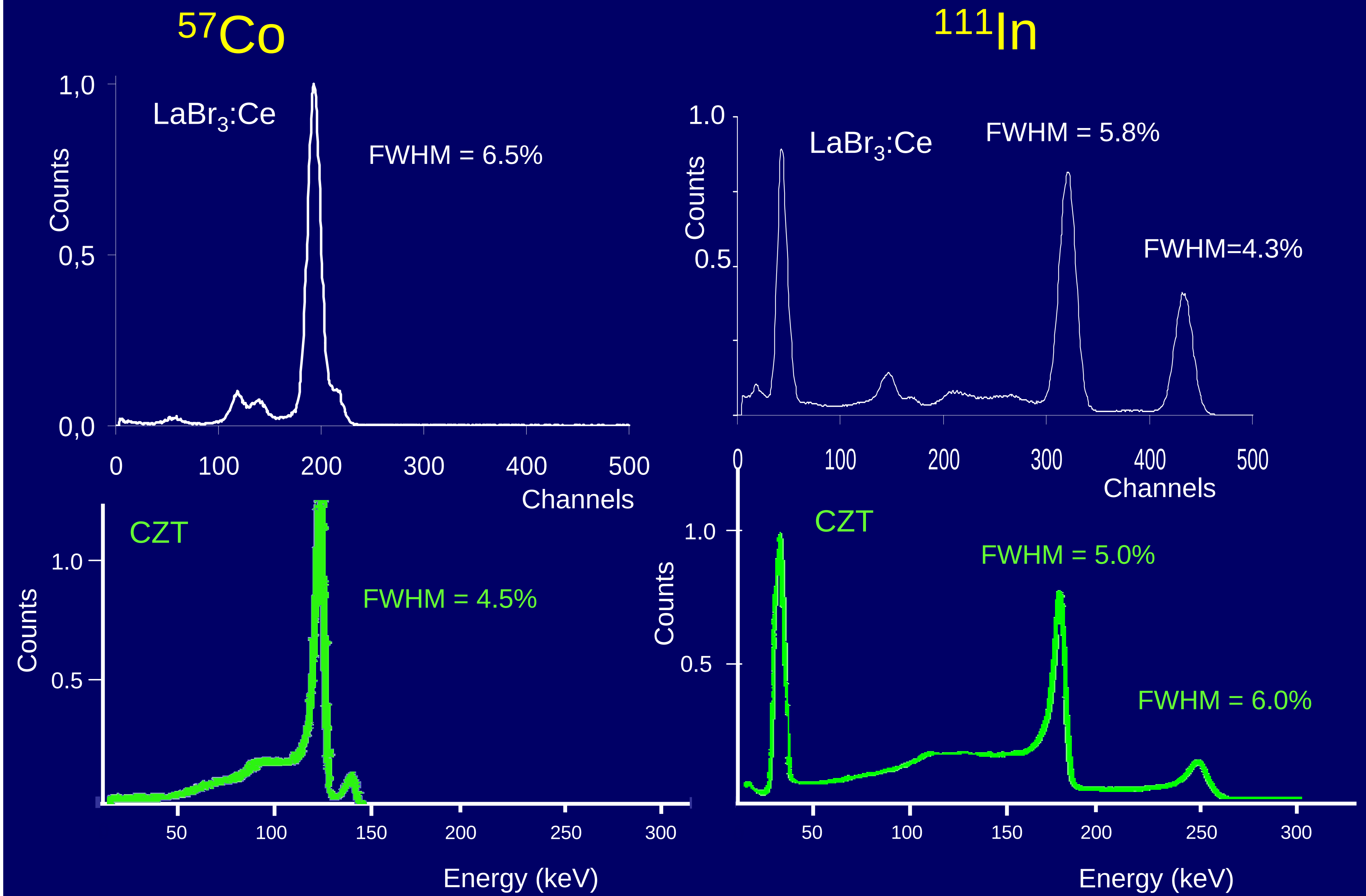
Flood field with Co57 source





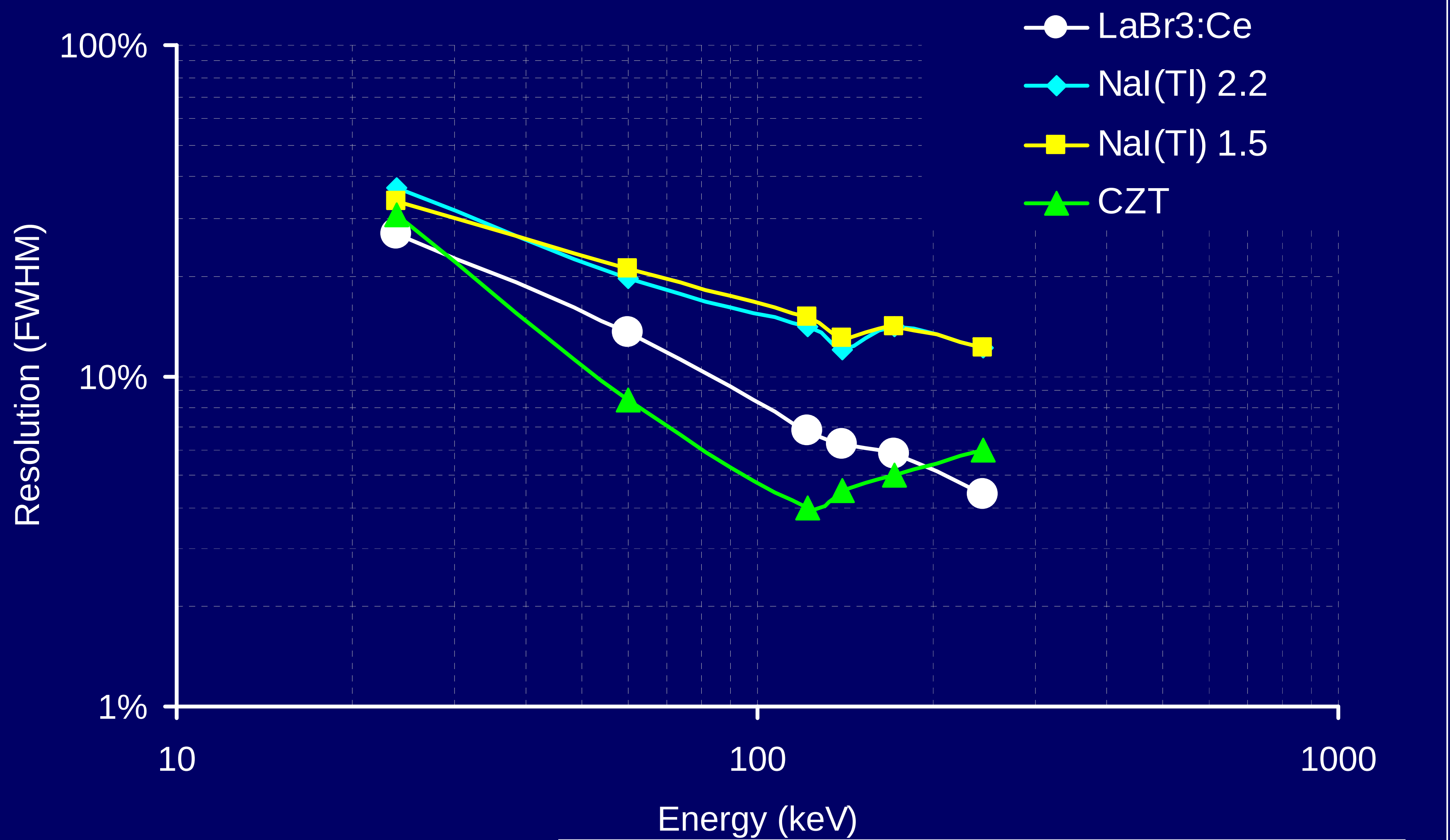
Collimator: 3.0 mm hole
0.5 mm septum





LumaGEM ® data from Bradley E. Pratt © Gamma Medica Instruments

Energy Resolution



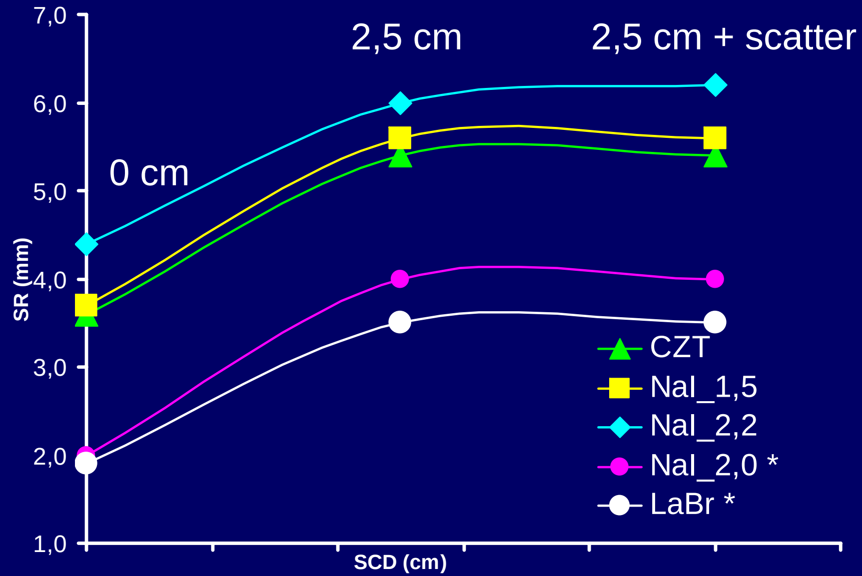
LumaGEM ® data from Bradley E. Pratt © Gamma Medica Instruments CZT NaI_1.5 NaI_2.2

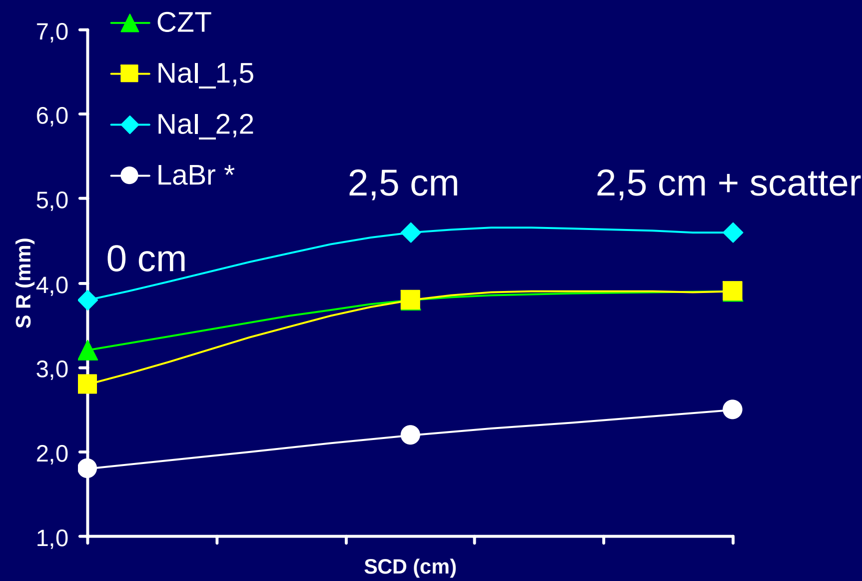
Spatial Resolution

LEAP

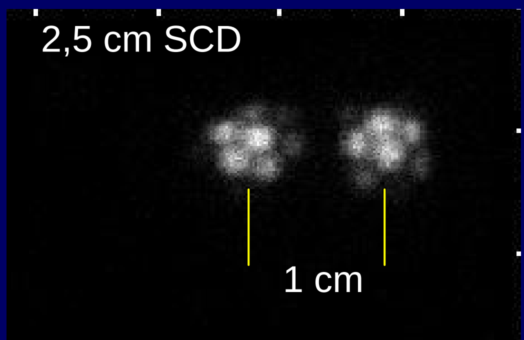
LEHR

LumaGEM ® data from Bradley E. Pratt © Gamma Medica Instruments CZT NaI_1.5 NaI_2.2

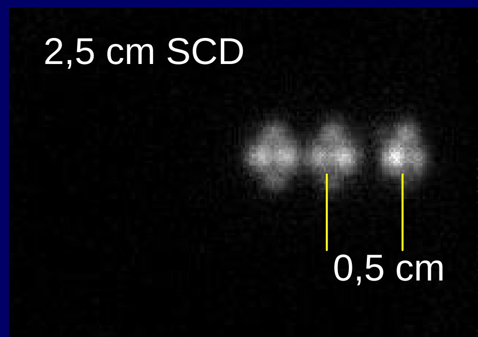




- LEAP parallel hexagonal collimator, 1.5 mm hole 0.2 mm septum and 22 mm length
- LEHR parallel hexagonal collimator, 1.3 mm hole 0.2 mm septum and 35 mm length



LaBr detects collimator lattice

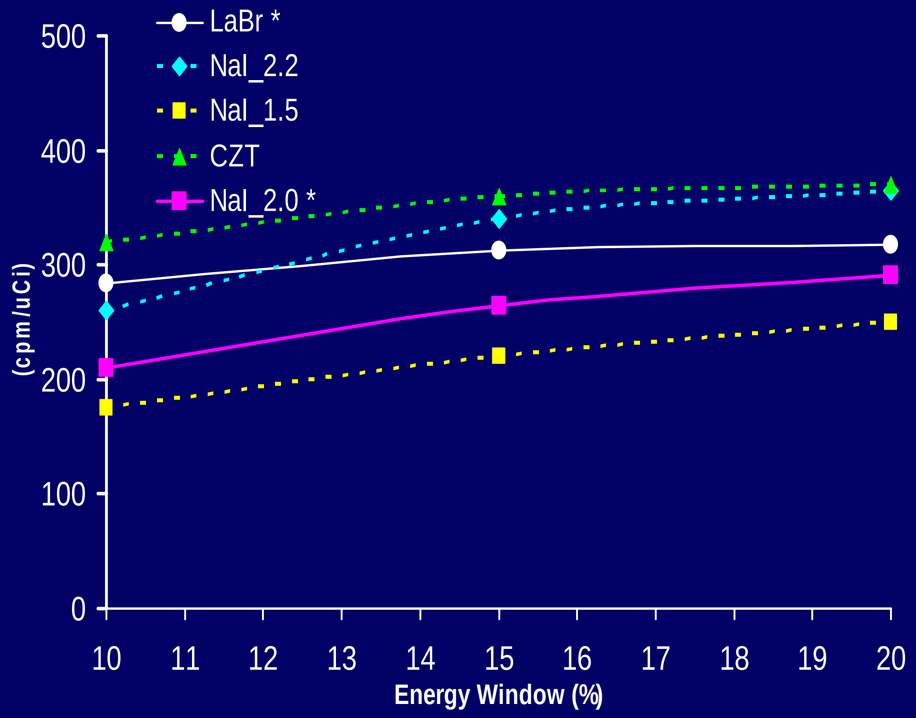


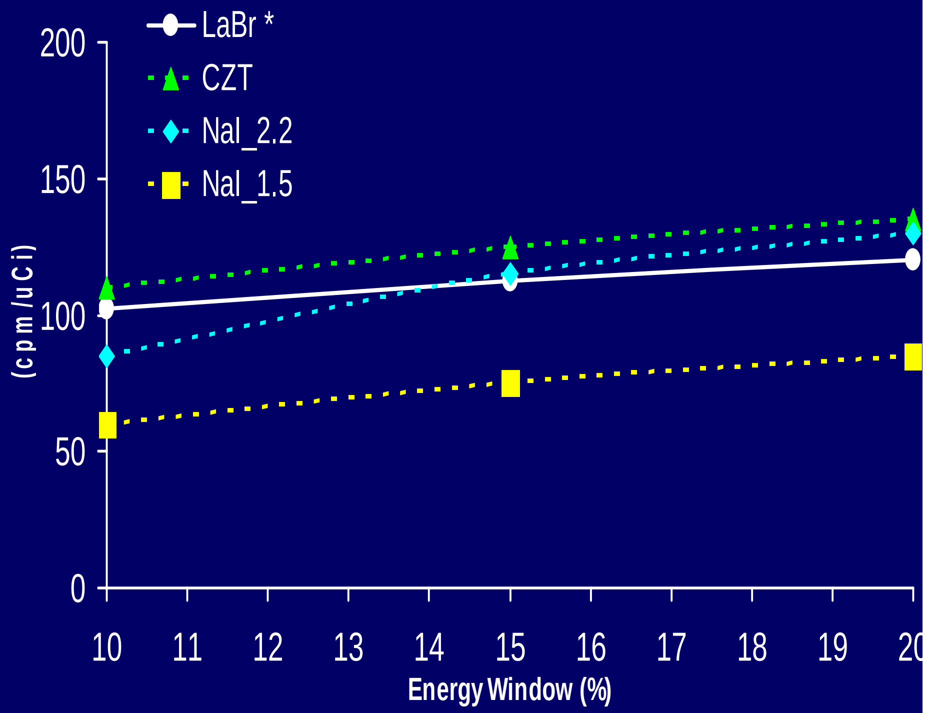
Sensitivity

LEAP

LEHR

LumaGEM ® data from Bradley E. Pratt © Gamma Medica Instruments CZT NaI_1.5 NaI_2.2





- LEAP parallel hexagonal collimator, 1.5 mm hole 0.2 mm septum and 22 mm length
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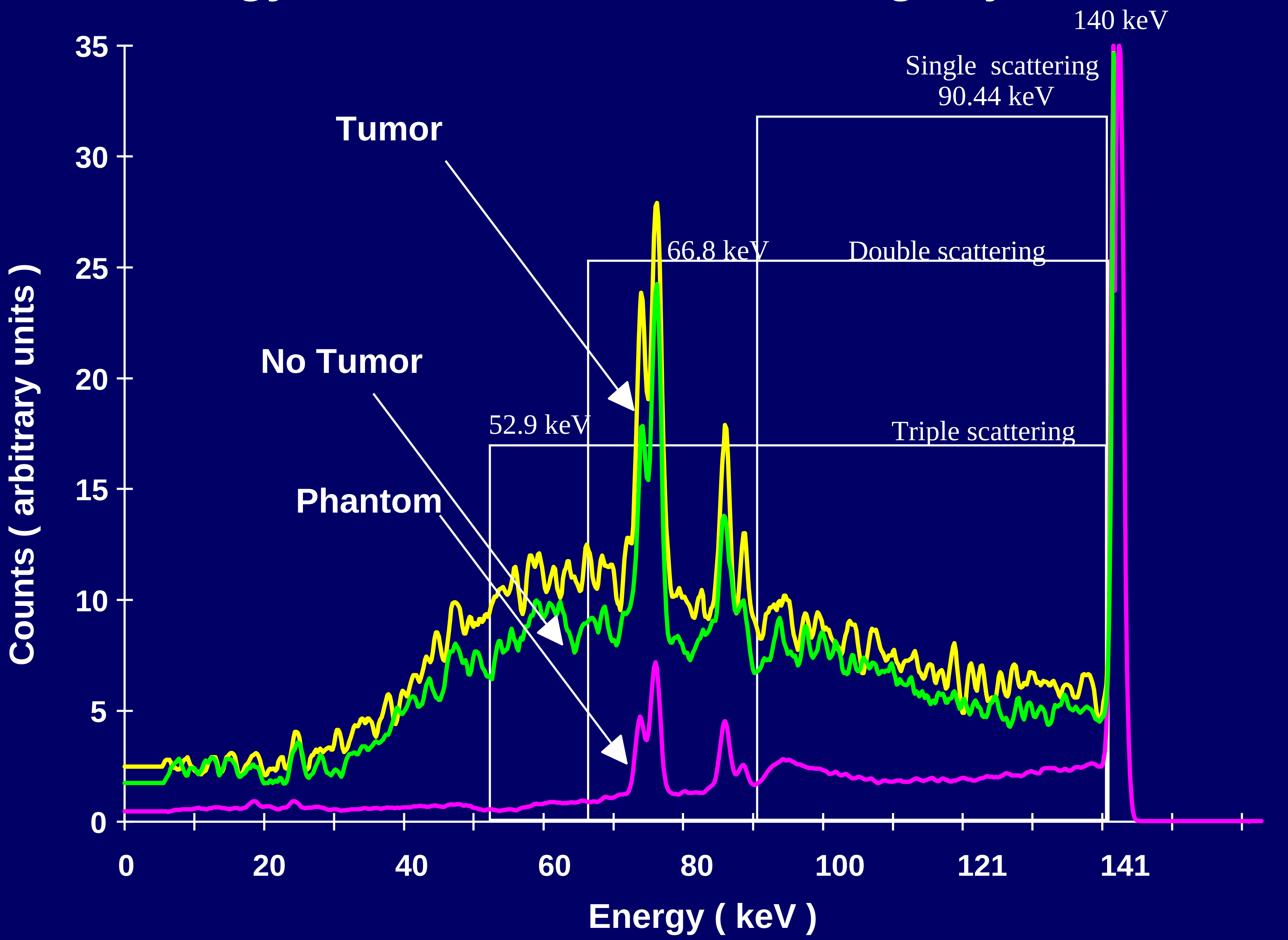
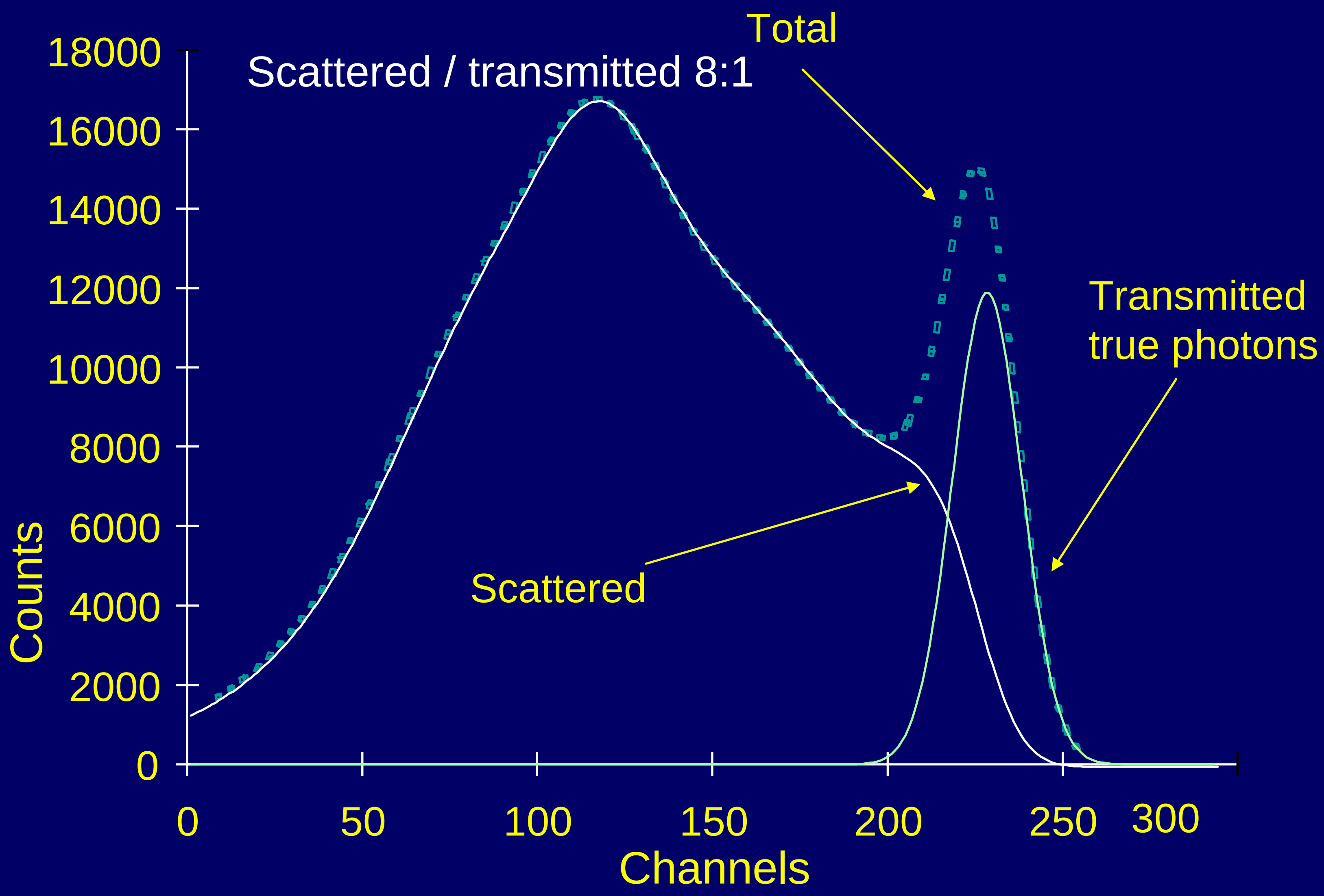
Role of energy resolution in scattering rejection



Breast spectrometry of two patients by Ge detector

Role of energy resolution in scattering rejection



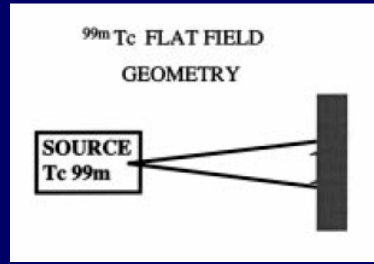
10% relative energy resolution

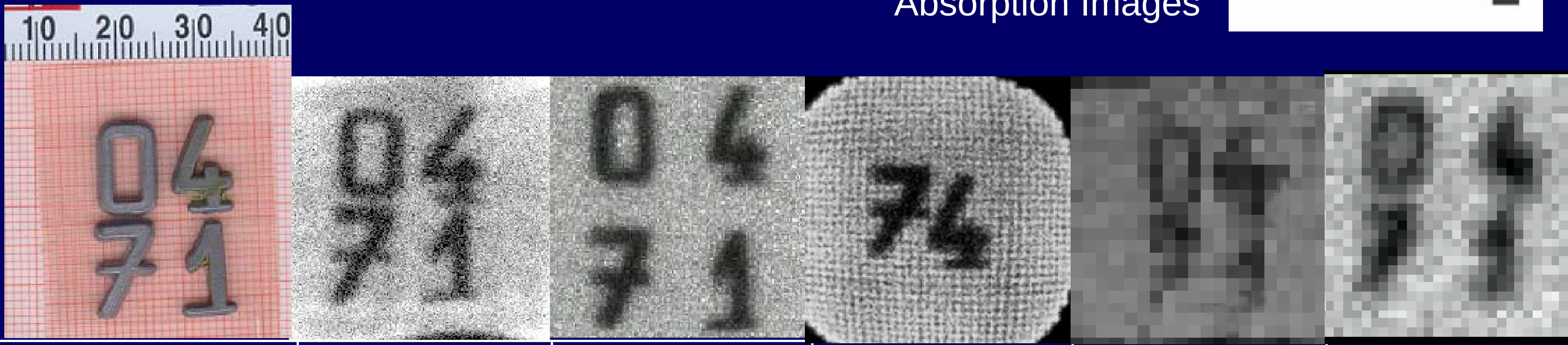
Role of energy resolution in scattering rejection

Energy Resolution @140 KeV	10%			20%			30%		
	Scattered/Transmitted ratio								
	8:1	5:1	2:1	8:1	5:1	2:1	8:1	5:1	2:1
Energy Windows	Percentage of false events (Scattering)/true events								
50%	13	8	3	36	23	9	66	42	17
84%	26	16	6	66	40	16	125	77	30
98%	45	29	12	110	71	29	-	-	-

Continuous Crystals vs pixellated Crystals

Lead test objects
Absorption Images





Gamma Camera & Crystals	H8500 PSPMT $LaBr_3$: Ce continuous (5 mm thick)	R2486 PSPMT YAP(Ce) array 0.6 mm pixel	R2486 PSPMT CsI(Tl) array 1.2 mm pitch	42 PSPMT HAMAMATSU R8520-C12 NaI(Tl) 1,8 mm pixel	<u>ANGER Camera</u> NaI(Tl) continuous (6 mm thick)
Intrinsic Spatial Resolution*	0.9 mm	1.1 mm	1.3 mm	2.0 mm	3.5 mm
Energy Resolution*	6.0%	50%	23%	15%	10%
Efficiency*	80%	45%	40%	70%	80%

* @ 140 KeV

Conclusions :

LaBr and CZT gamma cameras show superior spatial and energy resolution than previous generation based on NaI(Tl) scintillation array

LaBr continuous crystal shows better imaging performance than pixelated detectors

Both CZT and LaBr gamma cameras show similar efficiencies for the same energy window

CZT has the best energy resolution @ 140 keV

Energy resolution better than 10% could help scintimammography by improving scatter rejection while maximizing sensitivity.

Large area LaBr continuous crystals are not available yet (10 x10 cm^2 in June 2006)