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High spatial resolution measurement of depth-of-interaction of a PET LSO crystal

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Outline

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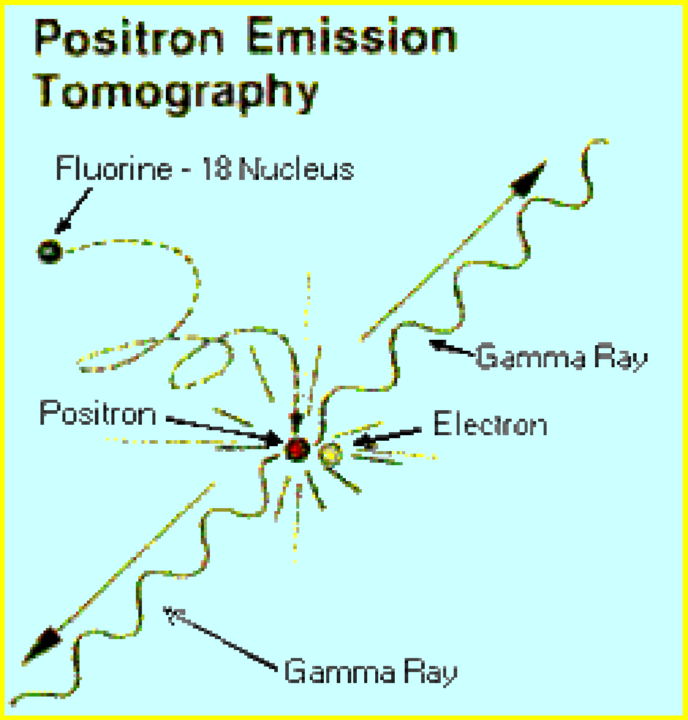
Basic concepts of PET
Challenges in small animal PET
Our motivation

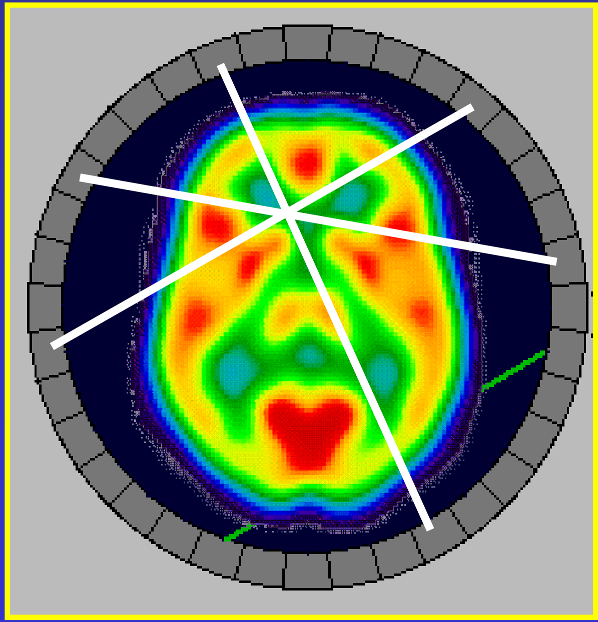
Experimental
Device under study
Nuclear microprobe
Microbeam irradiation of an LSO crystal

Results
Pulse height spectra and maps as a function of position from the detector
Depth of interaction

Conclusions

Basic concept of PET





PET scanner of PET Center, University of Debrecen

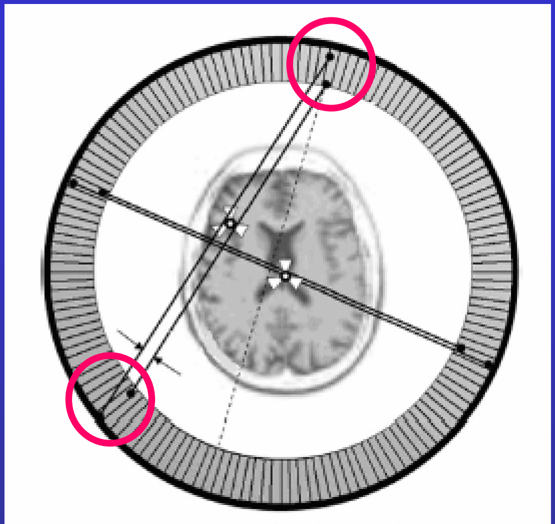
Challenges in small animal PET

Increased Spatial resolution is needed

	Human body PET	Small animal PET
Physical size	Human body:70 kg	Rat:300g, mouse30g
Spatial resolution	**~10 mm** (~1 ml in volume)	<1mm (<1μl in volume) [1]

Limitations of spatial resolution: positron range (~0.7mm tissue equivalent)
non-collinearity of the annihilation photons
parallax error

Parallax error



Schematic drawing of a PET device.
The parallax error, influencing emission points far from the ring centre, is schematically shown.[2]

A photon impinging on the entrance face of a detector with an oblique angle with respect to its axis can be detected not in that detector but in an adjacent one.

[1] A. F. Chatziioannou: Molecular imaging of small animals with dedicated PET tomographs, European Journal of Nuclear Medicine 29 (1): 98-114 JAN 2002
[2] A. Braema, et al., Novel design of a parallax free Compton enhanced PET scanner, NIMA 525 (2004) 268.

The parallax error can be reduced or eliminated by measuring the interaction point of the photon along the detector.

→ Depth of interaction **DOI**

Different approaches to solve the DOI problem

Improved and complex *detector* setup:

(a) Phoswich detector approach
(b) Stack approach
(c) Detection of the light at the opposite bases of the scintillator

Our aim was to investigate the effect of DOI on a LSO scintillator with high resolution

Experimental details

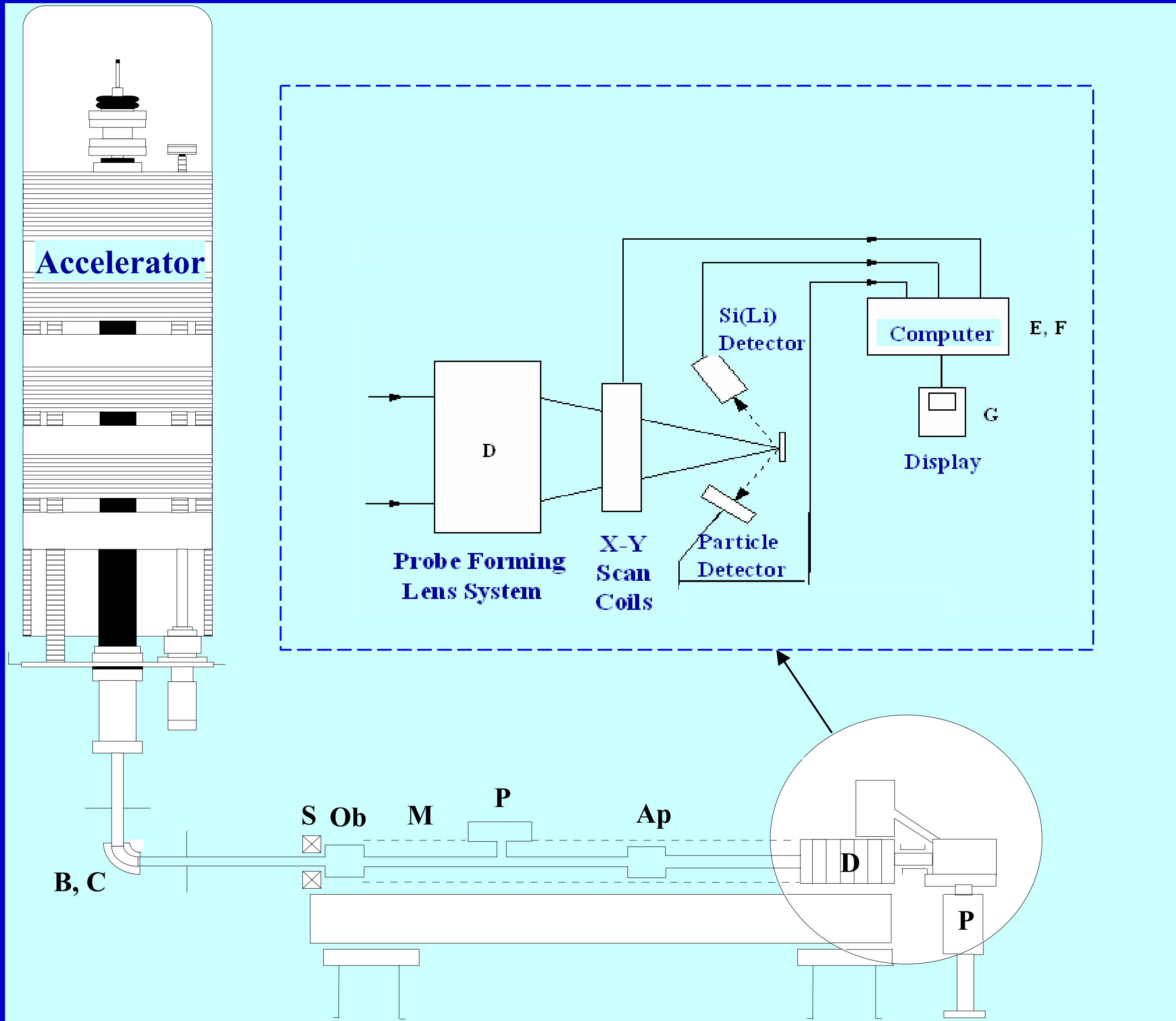
Sample

- Commercially available LSO (Lutetium Oxyorthosilicate) $1x1x10\ mm^3$ crystal wrapped in a Teflon light reflector. A ~0.70 mm wide, vertical cut along the Teflon enabled us to irradiate the crystal itself.

Measurement

- High resolution irradiation with a 2MeV He^{2+} beam at a nuclear microprobe (beam size: $3x3\ \mu m^2$, ion rate: 300Hz)
- Sequential scans of $1x1\ mm^2$ areas along the 10 mm long crystal
- DAQ with standard NIM

Nuclear microprobe components



B: analyzing magnet; C: condenser lens; S: beam steerer; Ob: object collimator; Ap: aperture collimator; P: vacuum pumps.

Device under study

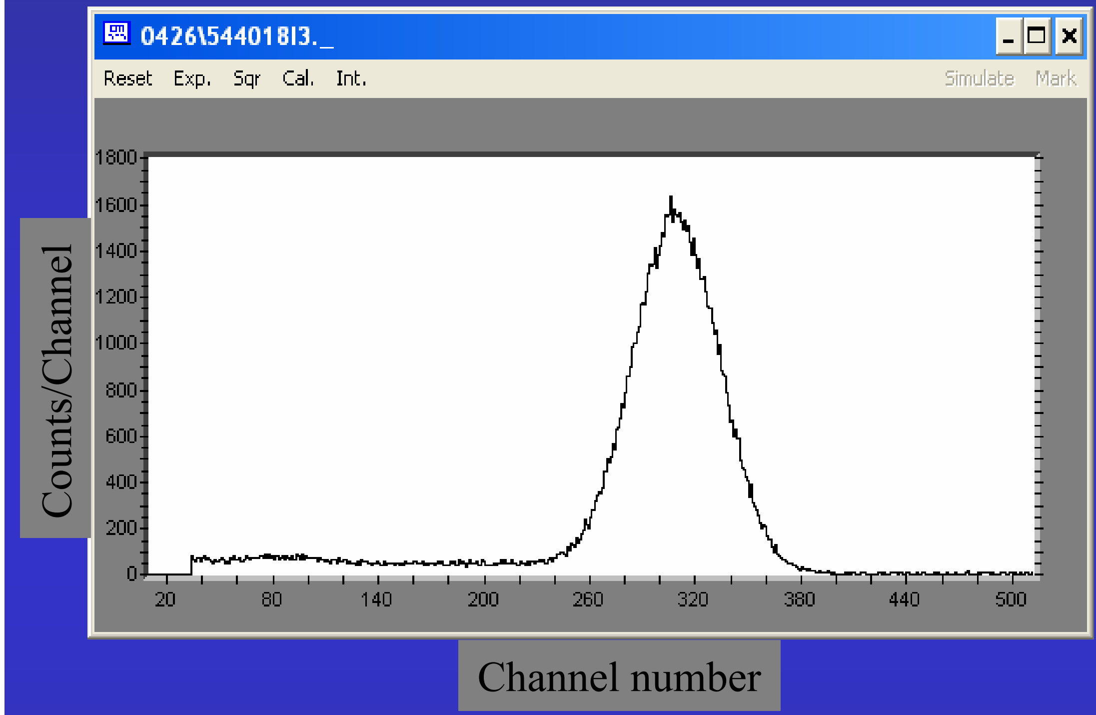
LSO crystal

Tef
wrap

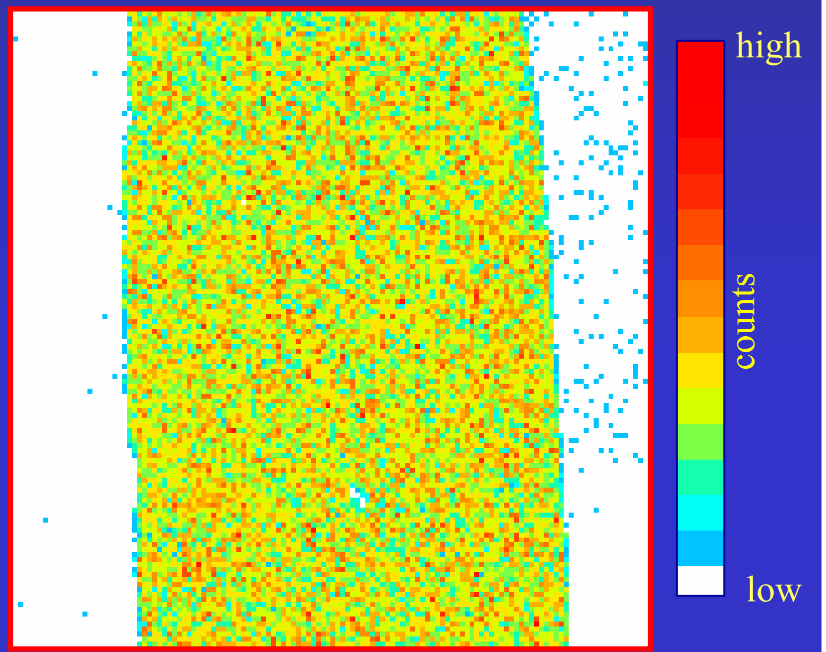
LSO c

Ha

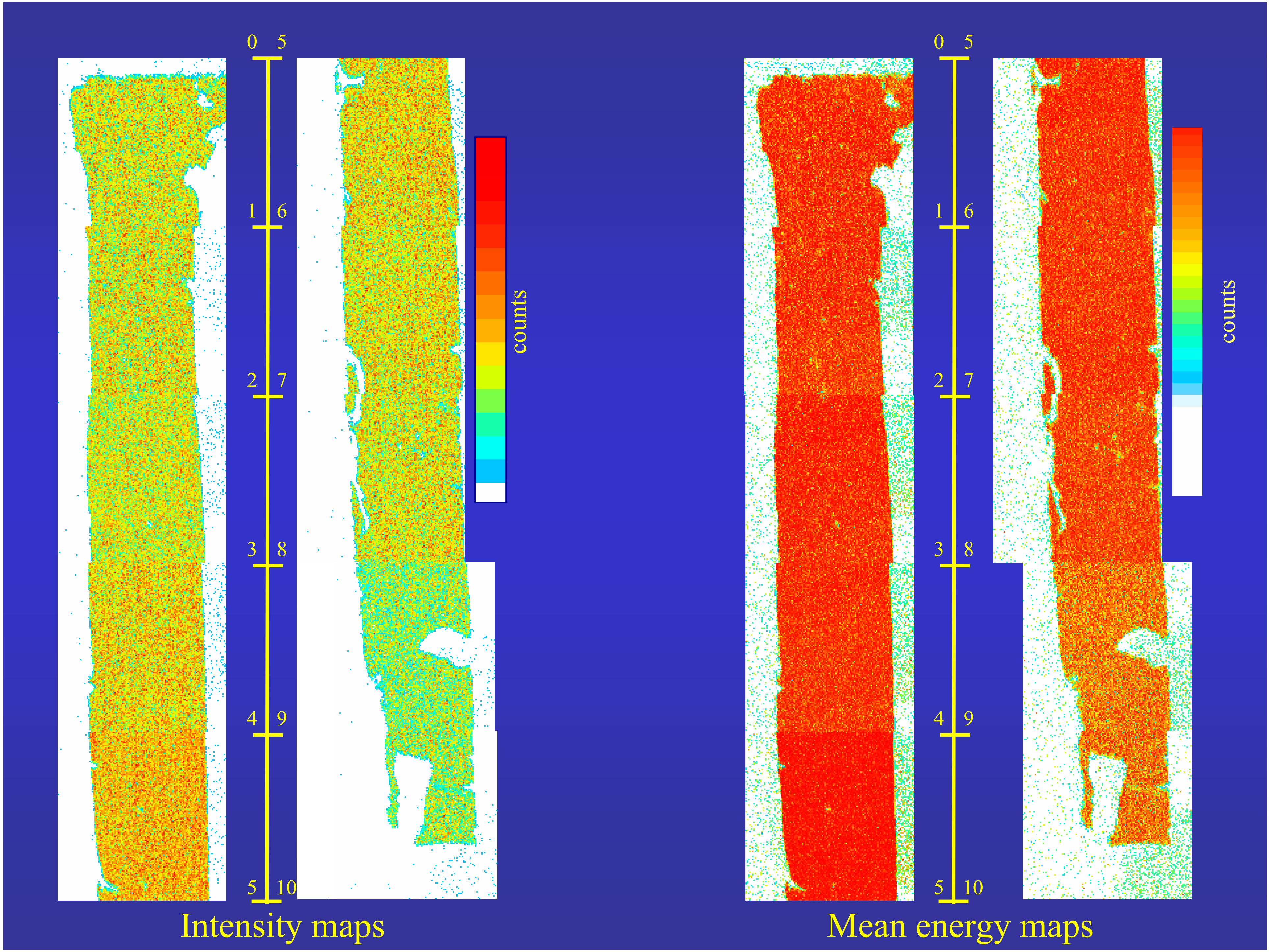
Results



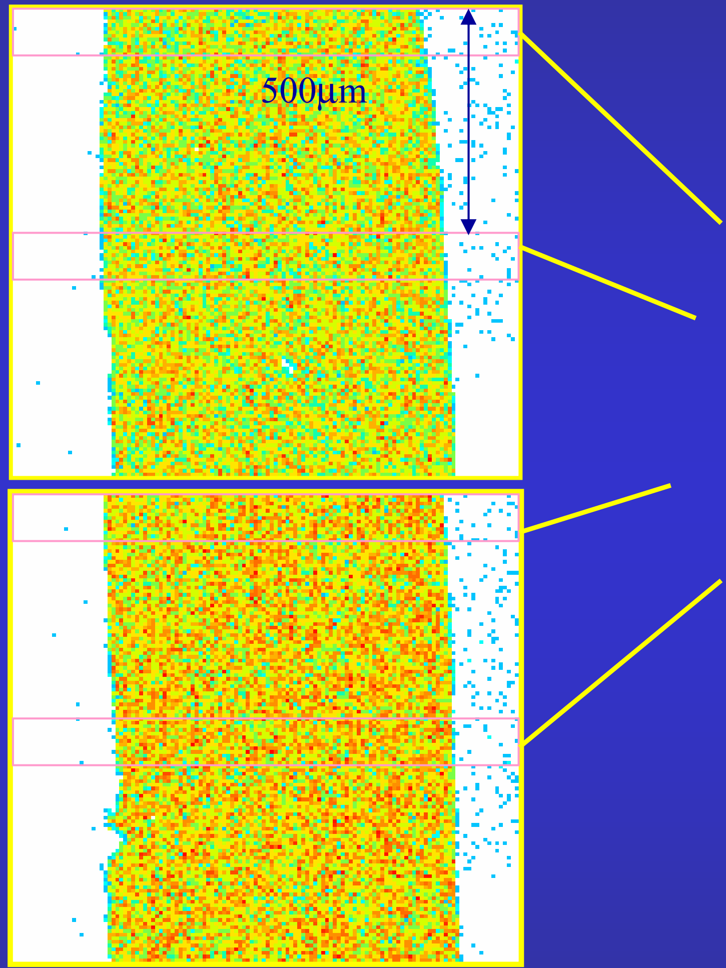
Pulse height spectrum of an 1x1mm^2 area
(512 channel)



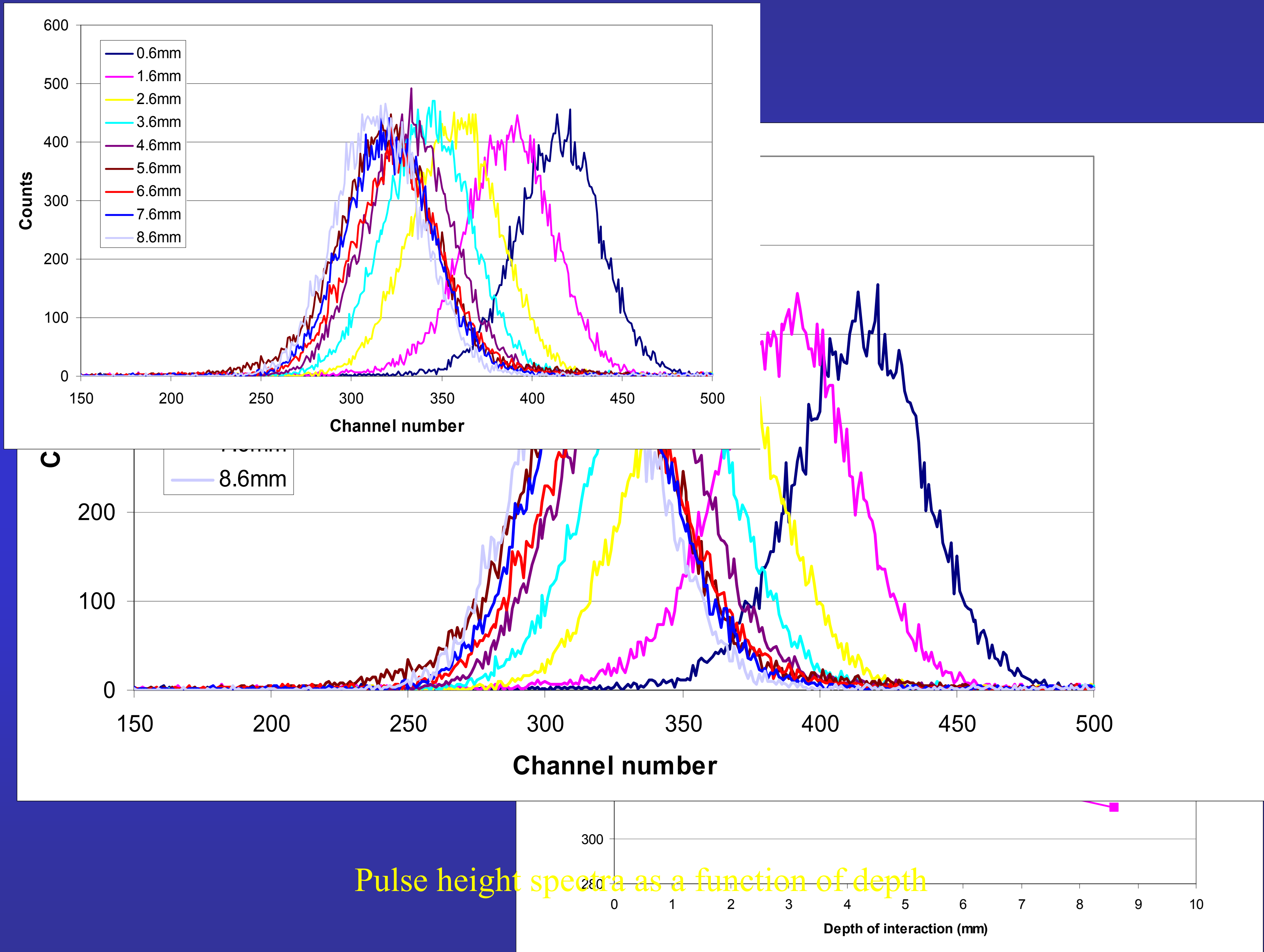
Intensity map
1x1mm^2 scan area, full energy window
128x128 pixel



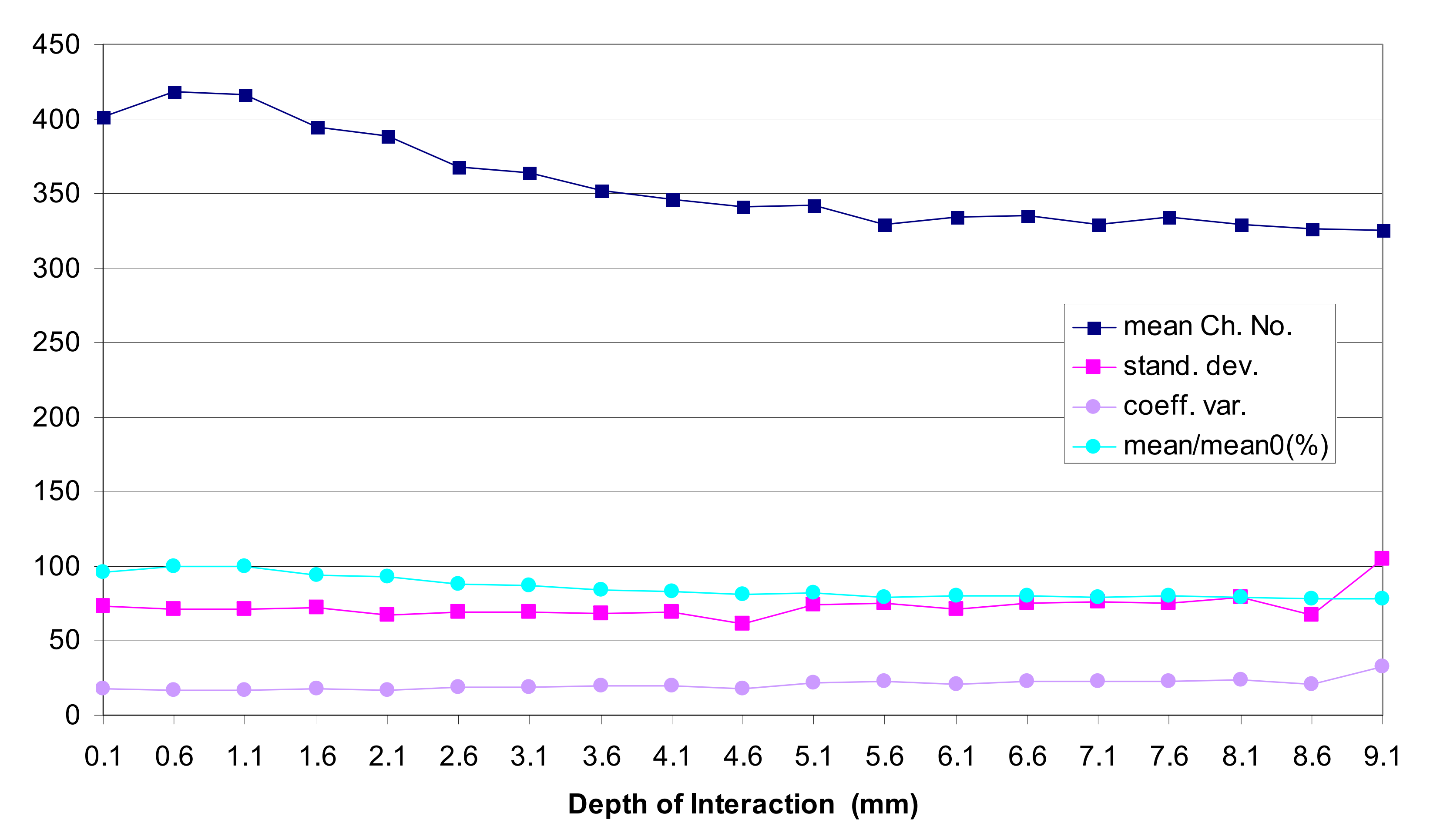
0
5
1
6
2
7
3
8
4
9
5
10
counts
counts
Intensity maps
Mean energy maps

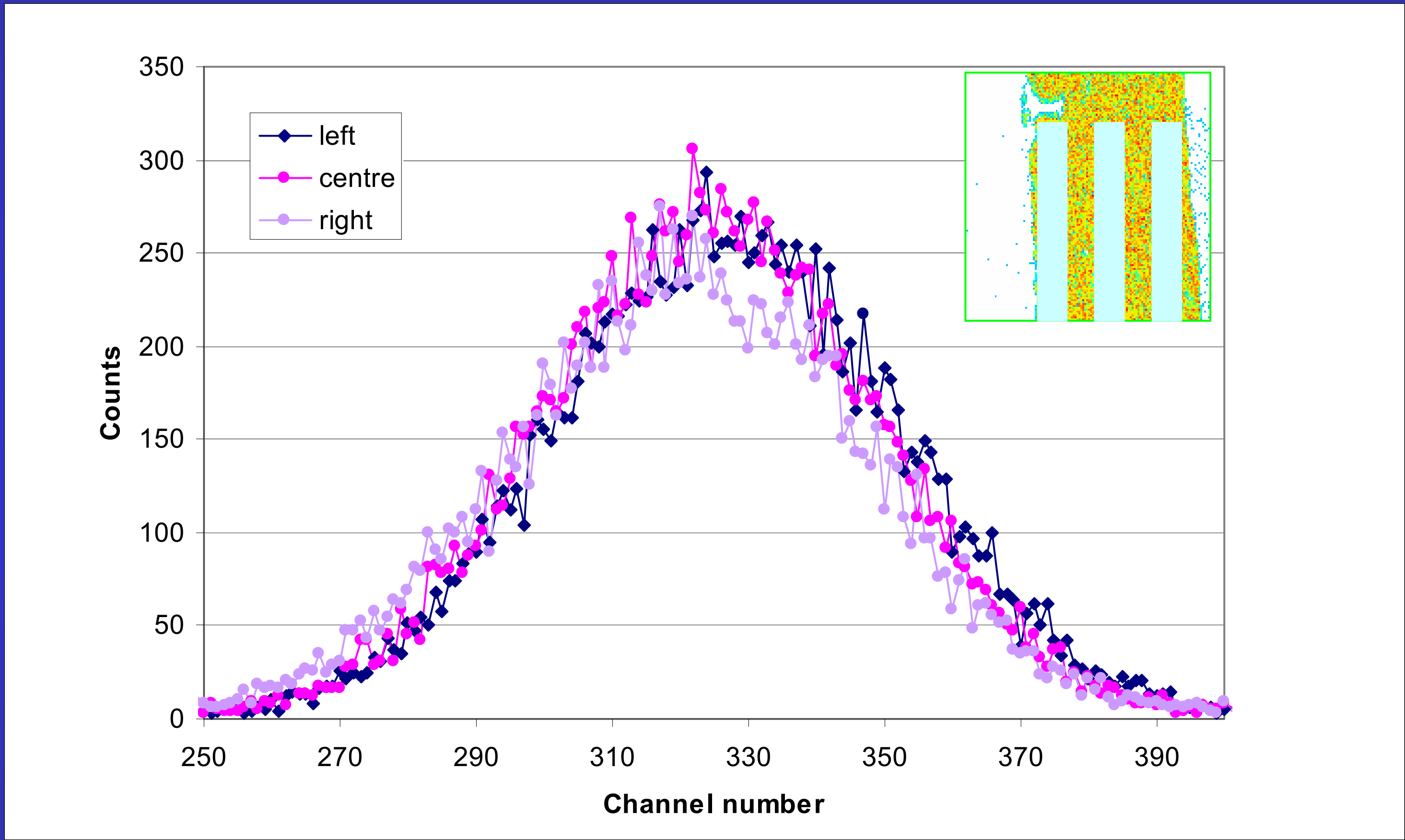


Selected area spectra of 100µmx1mm areas are extracted



Pulse height spectra as a function of depth


450
400
350
300
250
200
150
100
50
0
0.1
0.6
1.1
1.6
2.1
2.6
3.1
3.6
4.1
4.6
5.1
5.6
6.1
6.6
7.1
7.6
8.1
8.6
9.1
Depth of Interaction (mm)
mean Ch. No.
stand. dev.
coeff. var.
mean/mean0(%)



Pulse height spectra of vertical areas (left centre and right) between 5mm and 6 mm

Conclusions

- Focused micro-ionbeam irradiation is a perspective technique to study the position sensitive characterisics of a PET detector.

- We have demonstrated that the interaction between the generated light and detector can be studied with high lateral resolution (from µm up to mm).

- The mean value of the pulse height spectrum (~ position of the full energy peak) is characteristic to the DOI.
  Our results confirm previous gamma measurements on LSO crystal with similar geometry and wrapping.

- There is no difference between spectra collected from the left and right region of the crystal.

- Further advantage of the ion beam irradiation that there is no Compton-scattering
  ⇒ there is no Compton-background in the spectrum.

- By varying the beam energy the penetration depth of the ions can be changed giving opportunity for the real 3D light collection mapping.
  (2mm projected range for 20 MeV protons)

Acknowledgements

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