

Investigation of pixellated TlBr gamma-ray spectrometers with the depth sensing technique

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Why TlBr?

Advantages of TlBr as a radiation detector material

High photon stopping power

- similar to BGO
- Mean free path for 511 keV: 1 cm

Room temperature operation

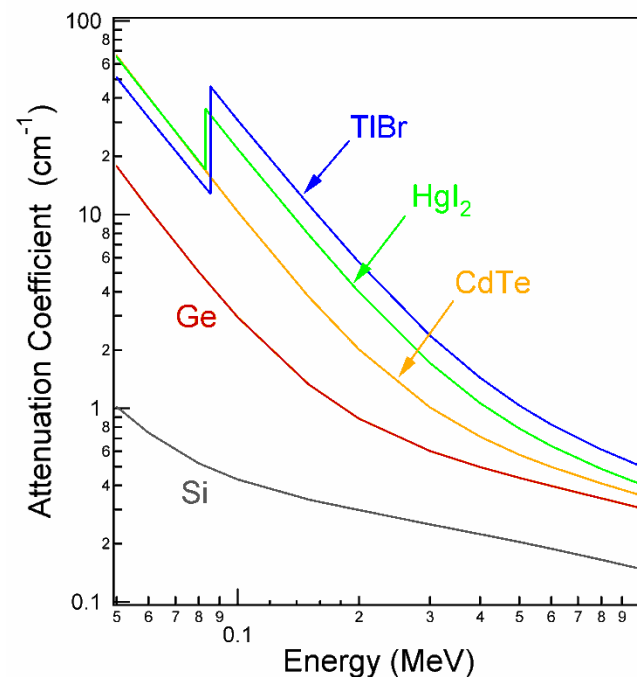
- Resistivity: $10^{10-11} \Omega\text{cm}$

Good charge transport properties

- Similar to CdTe

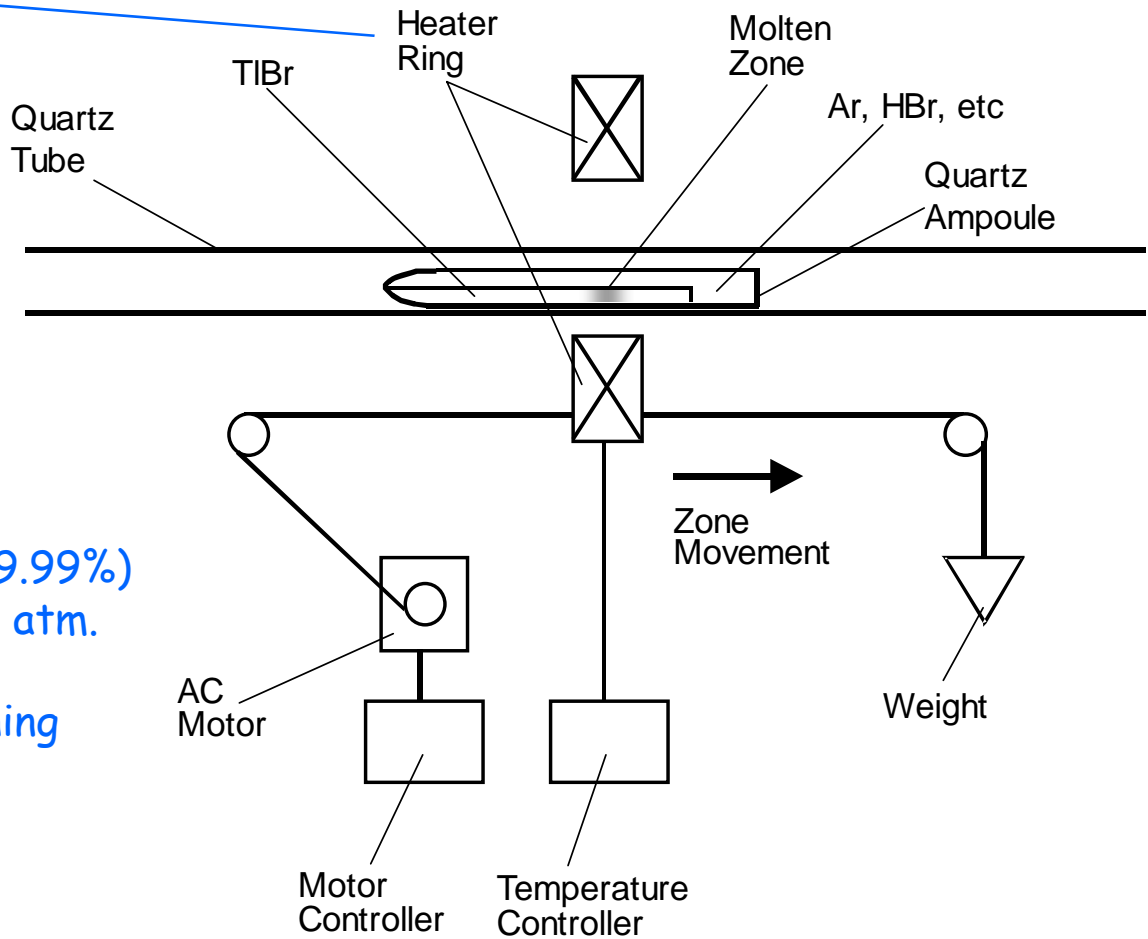
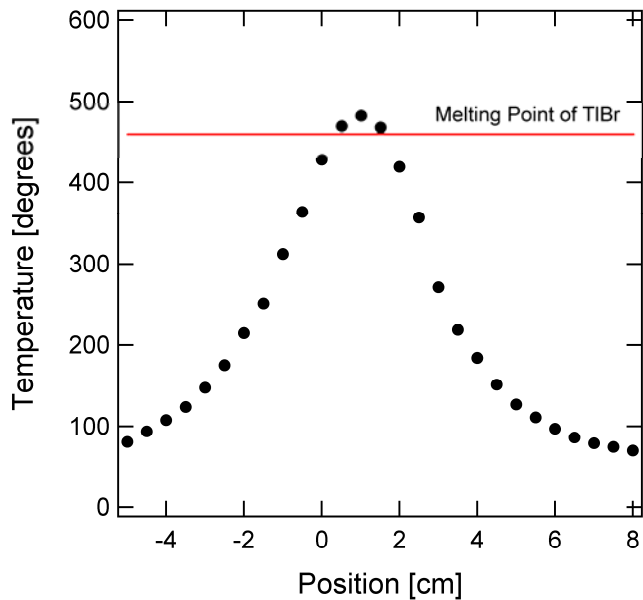
Easy to grow crystals

- Low melting point
- no phase transition



	Z	Density (g/cm^3)	E_g (eV)	ϵ (eV)	Resistivity (Ωcm)	$\mu\tau_e$ (cm^2/V)	$\mu\tau_h$ (cm^2/V)	M. P. ($^\circ\text{C}$)
Si	14	2.33	1.12	3.6	$\sim 10^4$	0.4	0.2	1412
Ge	32	5.33	0.67	2.9	50	0.8	0.8	958
CdTe	48, 52	6.2	1.44	4.4	10^9	10^{-3}	10^{-4}	1092
CZT	48, 52, 30	6	1.6	4.7	10^{11}	10^{-3}	10^{-5}	
HgI ₂	80, 53	6.4	2.13	4.2	10^{13}	10^{-4}	10^{-5}	250
TlBr	81, 35	7.56	2.68	5.9	10^{10-11}	10^{-3}	10^{-4}	460

Crystal growth

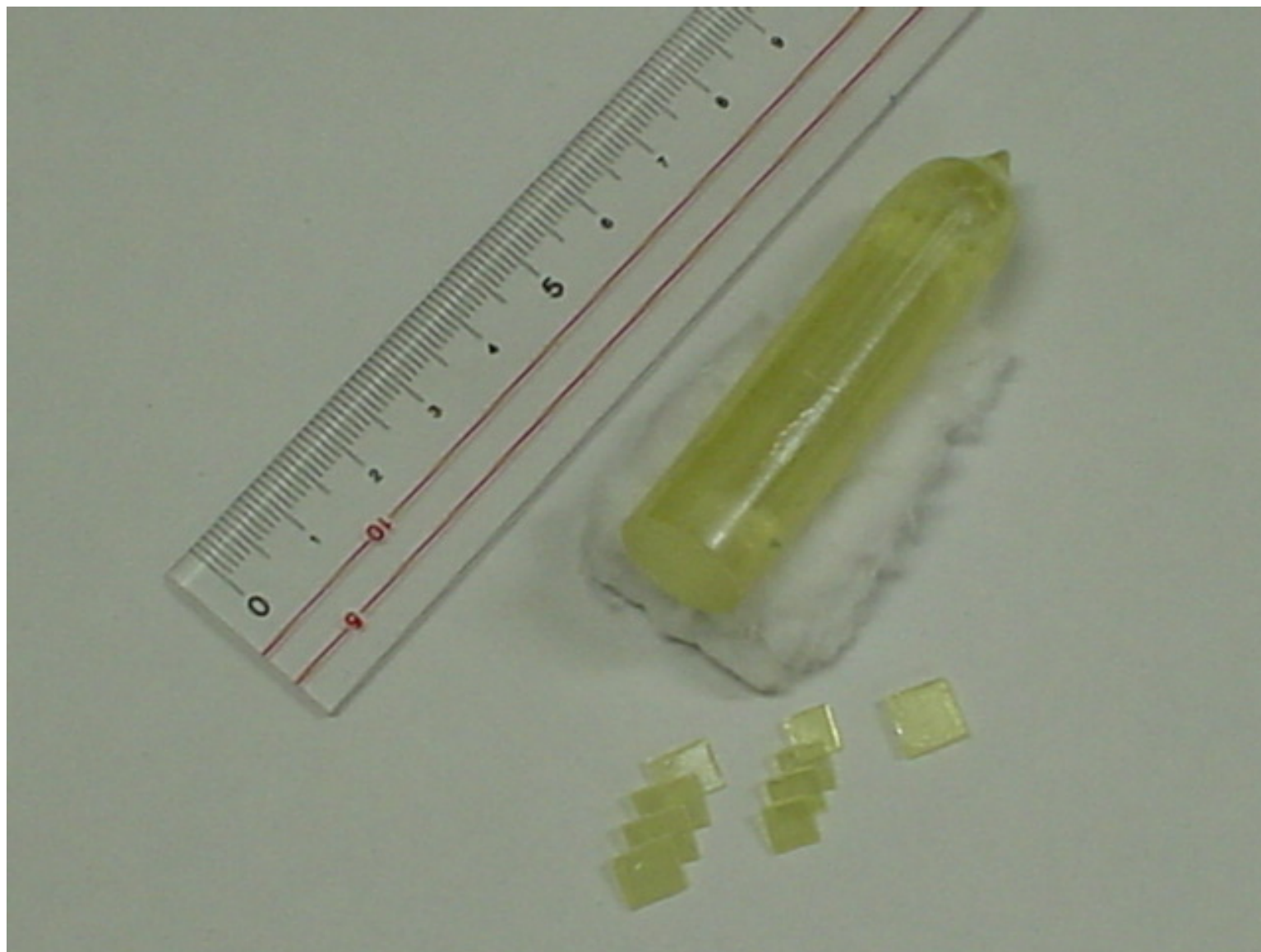


Starting material: TlBr powder (99.99%)
 -sealed in HBr atmosphere at 1 atm.

Purification: Multi-pass zone refining
 - 5 cm/h, 1, 100 and 300 times

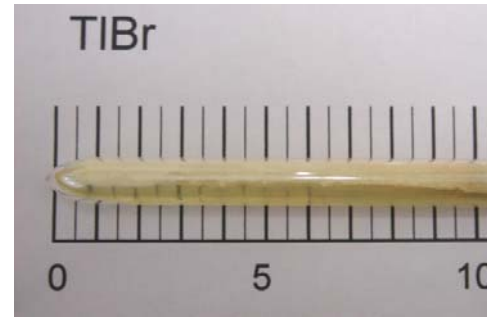
Crystal growth: TMZ method
 - 0.5 cm/h

Single zone horizontal furnace

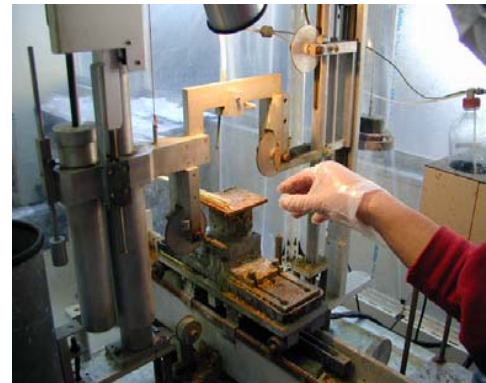


Detector fabrication

As grown crystals



Cut by diamond wire saw



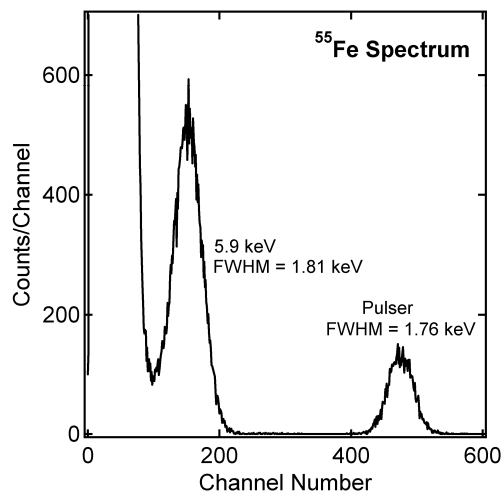
Polishing



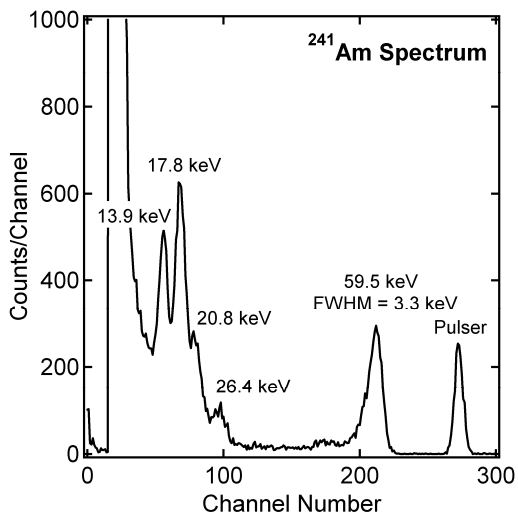
Planar TlBr detectors

Low Energy

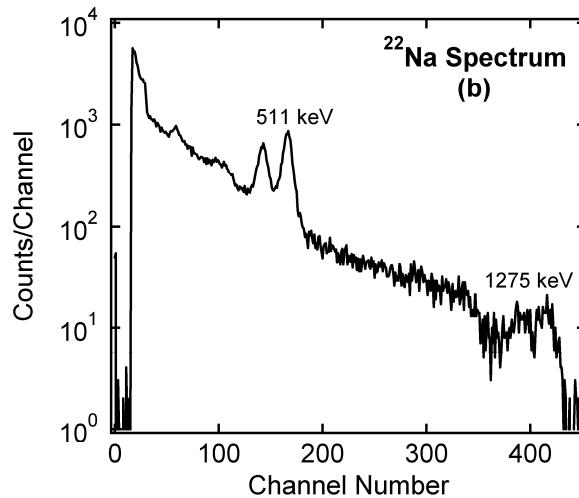
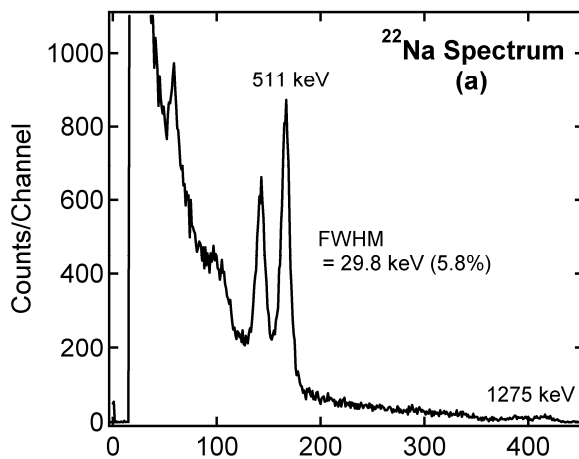
High Energy



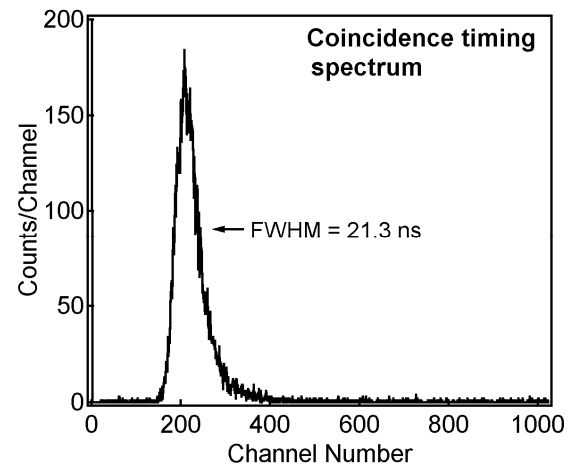
TlBr detector ($0.8 \text{ mm}^2 \times 150 \mu\text{m}$)
Bias = 80 V



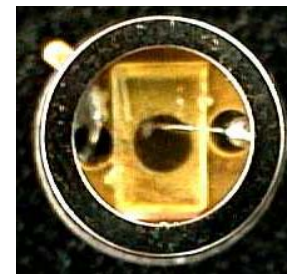
TlBr detector ($0.8 \text{ mm}^2 \times 100 \mu\text{m}$)
Bias = 150 V



TlBr detector ($12 \text{ mm}^2 \times 500 \mu\text{m}$)
Bias = 400 V



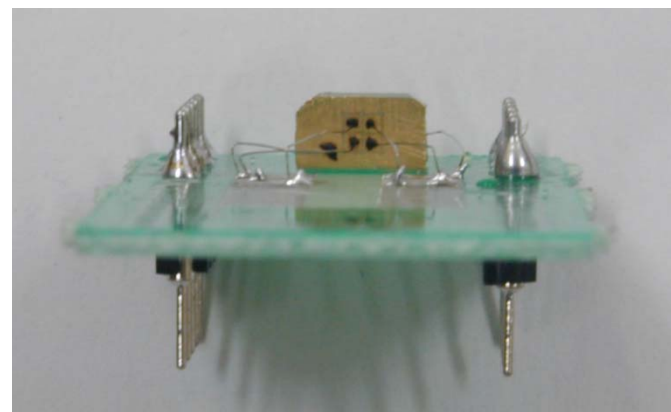
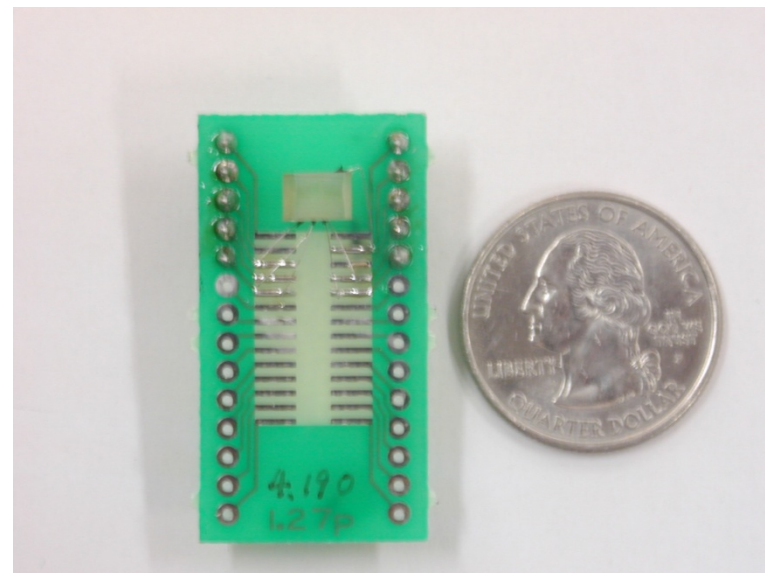
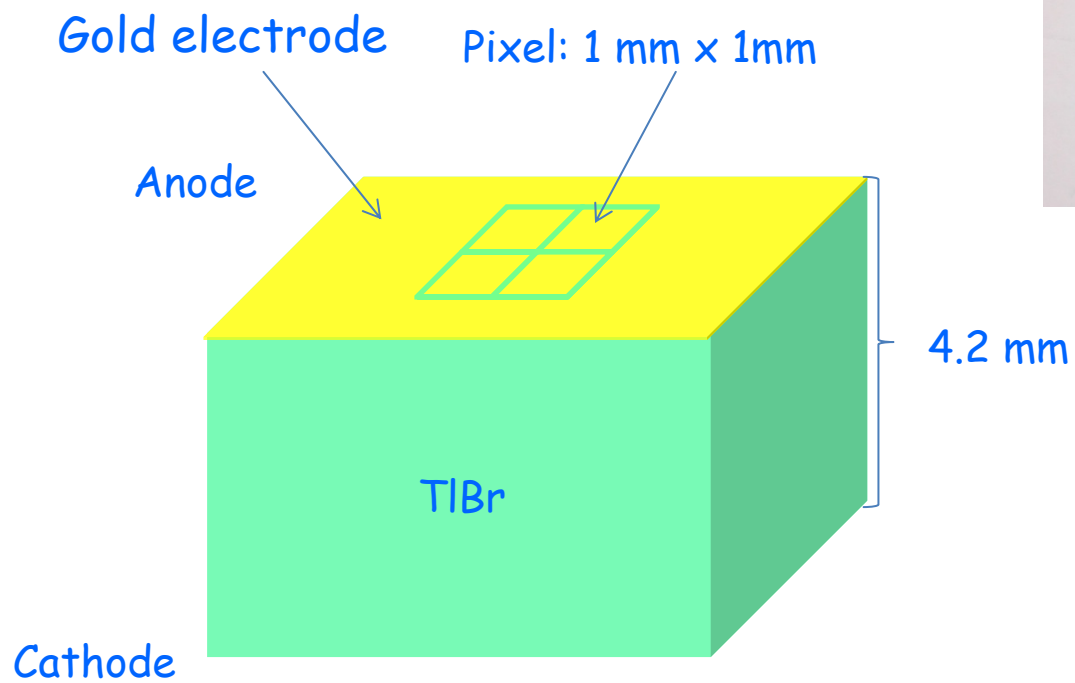
TlBr detector ($12 \text{ mm}^2 \times 450 \mu\text{m}$)
Bias = 400 V v.s. BaF₂/PMT detector



Thin TlBr detector

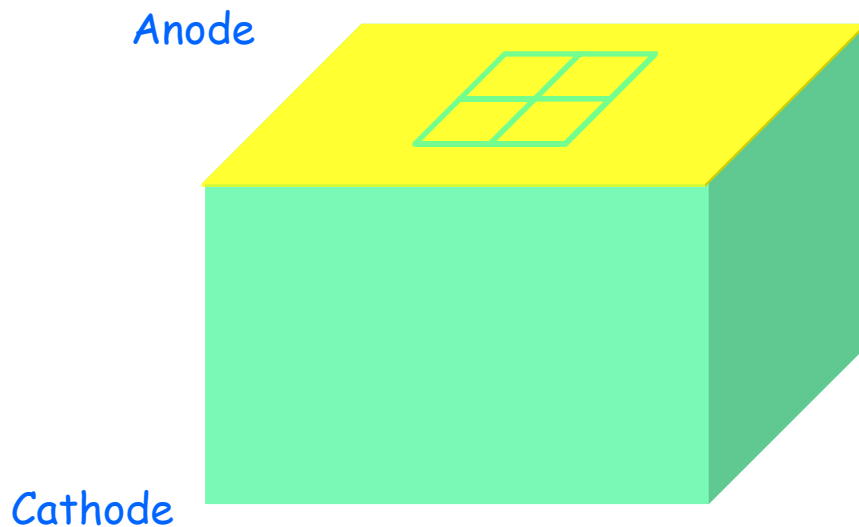
3D position sensitive TlBr detectors

Pixellated TlBr detector



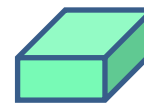
Three-dimensional position-sensitive single polarity charge sensing technique

Z. He, W. Li, G.F. Knoll, D.K. Wehe, J. Berry and C.M. Stahle
Nucl. Instr. and Meth. **A422**, 173 (1999).



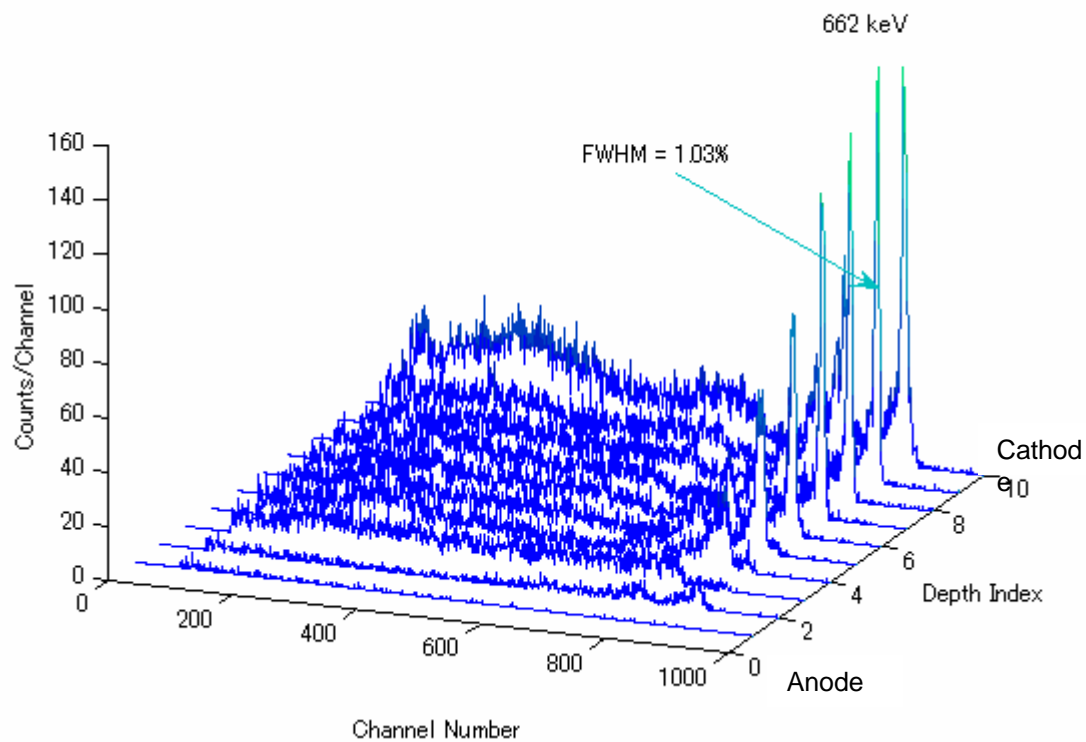
X - Y position: position of the pixel

Z position: Cathode to Anode ratio

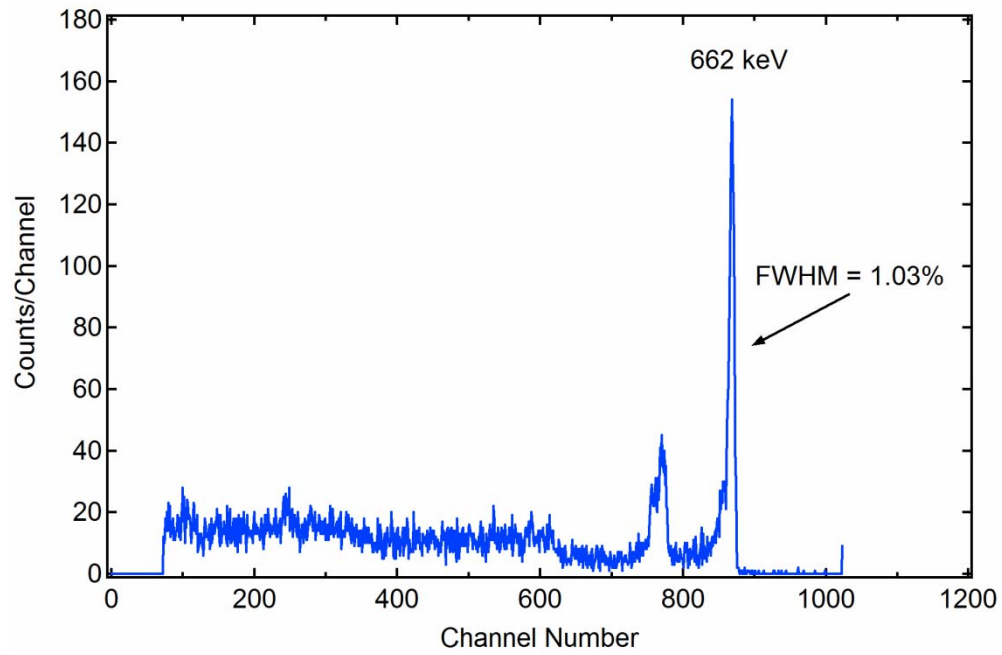


Voxel: $1 \times 1 \times 0.4$ mm

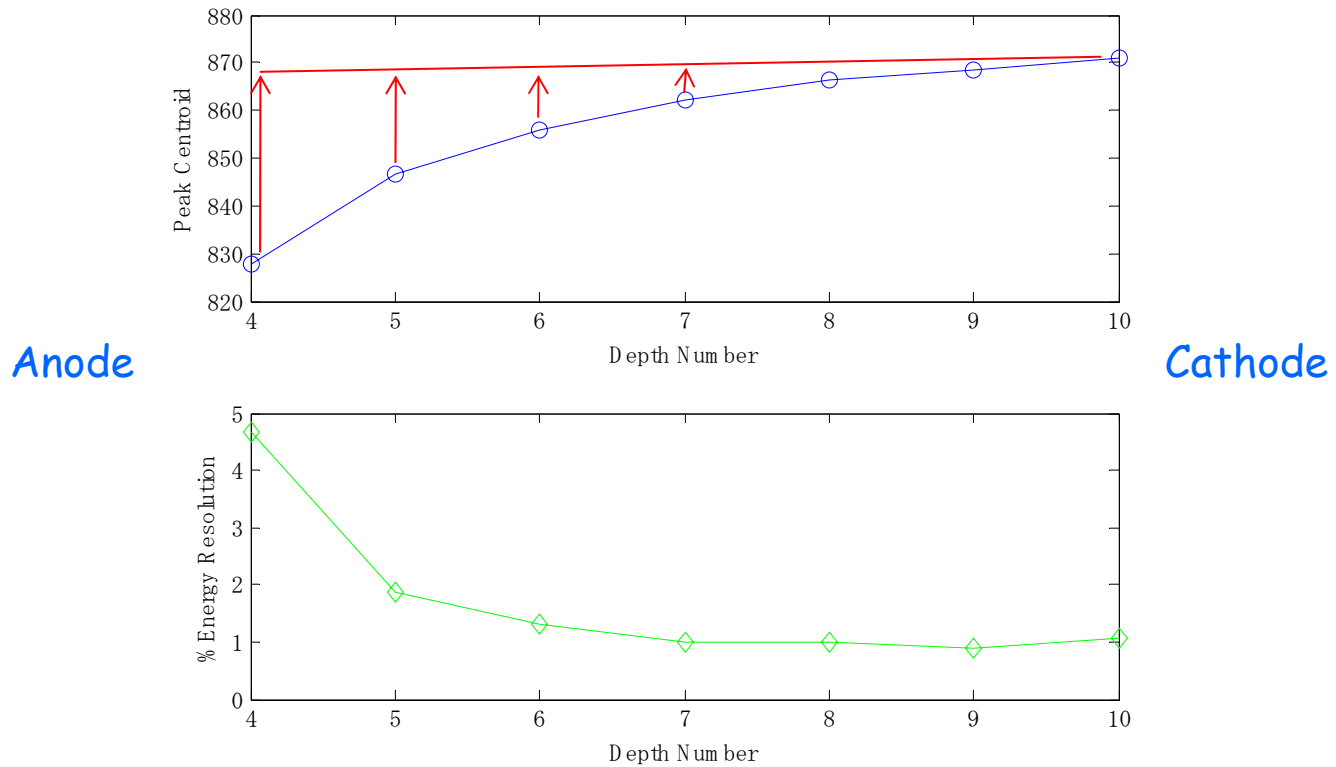
^{137}Cs spectra obtained from pixel #1



Depth index 9



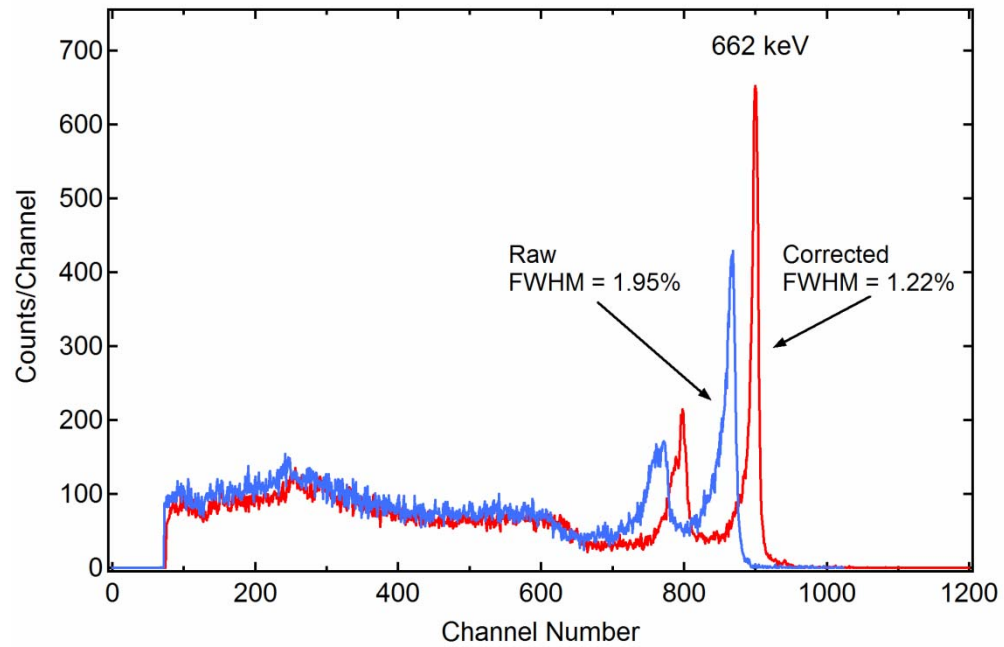
Peak centroid and % energy resolution



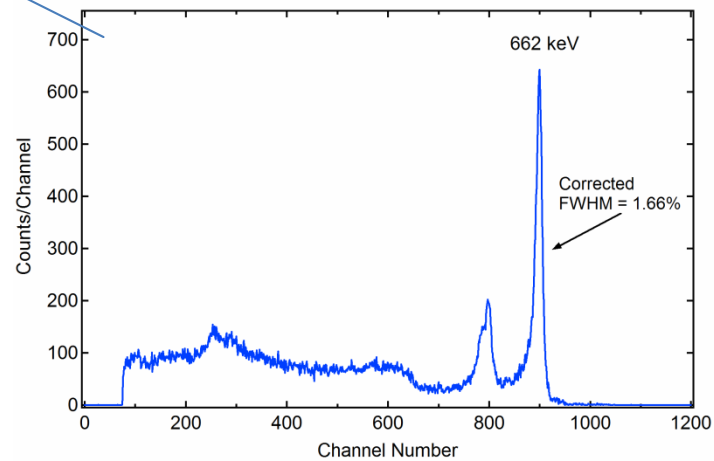
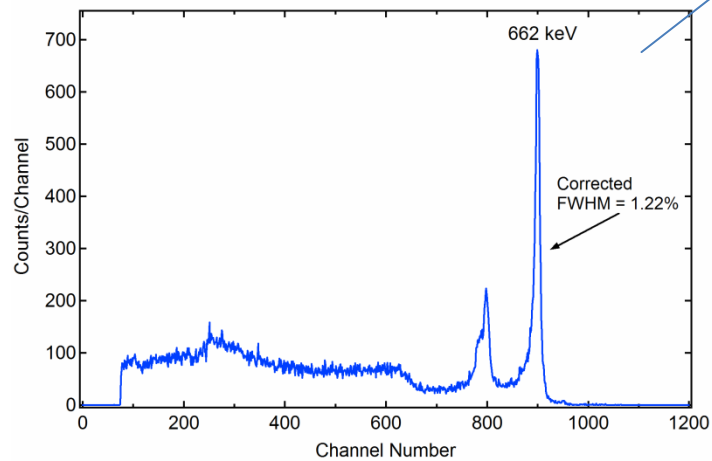
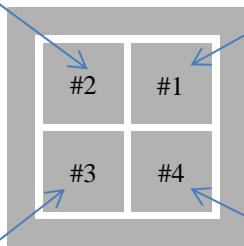
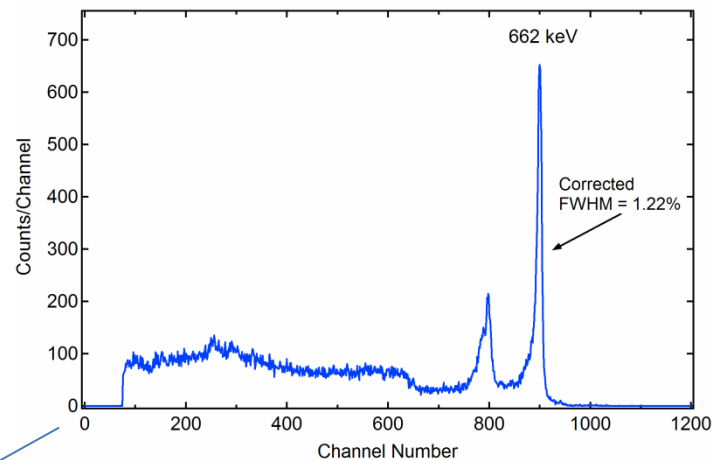
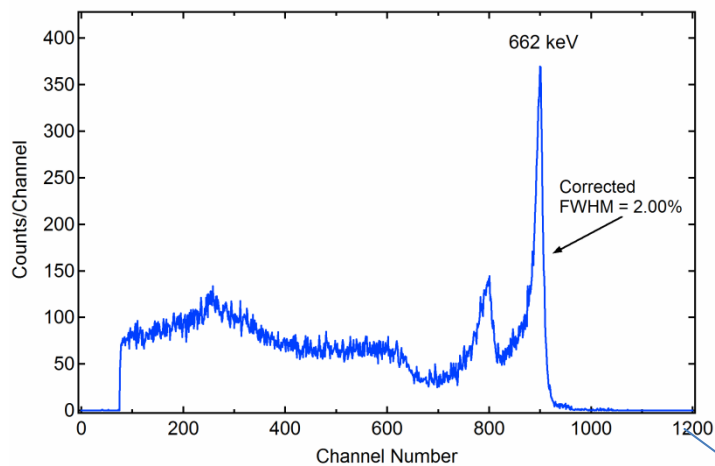
Anode

Cathode

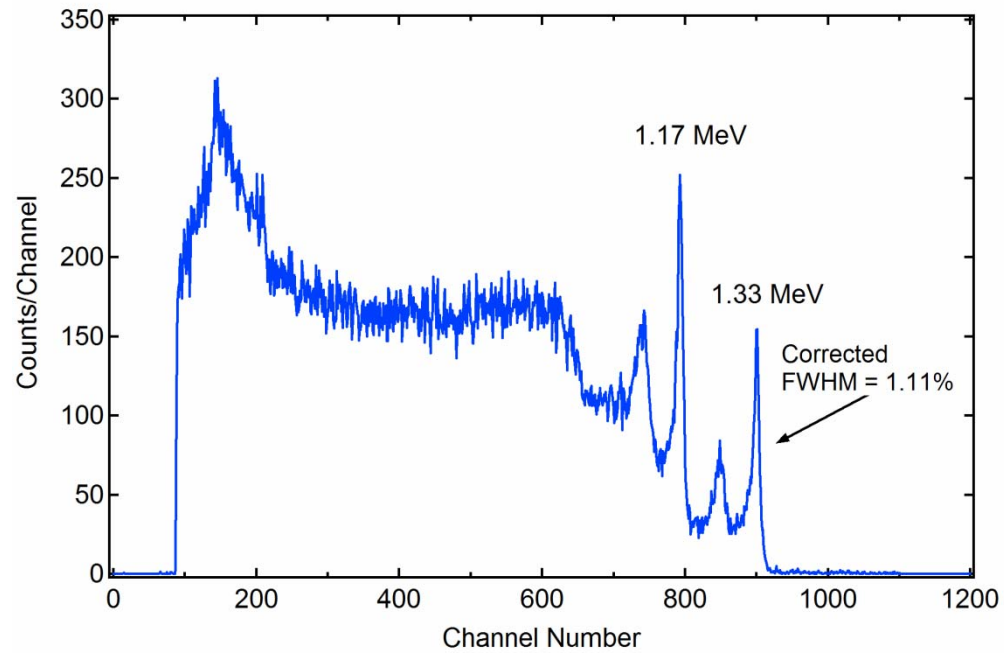
Depth correction and rejection (DI4 to DI10)



Depth corrected spectra for each pixel



^{60}Co spectrum obtained from pixel #1



Conclusion

3D position sensitive TlBr detector exhibited good energy resolutions!
(less than 2% for all pixels)

Due to its high efficiency and high energy resolutions, TlBr is a promising material for various applications!