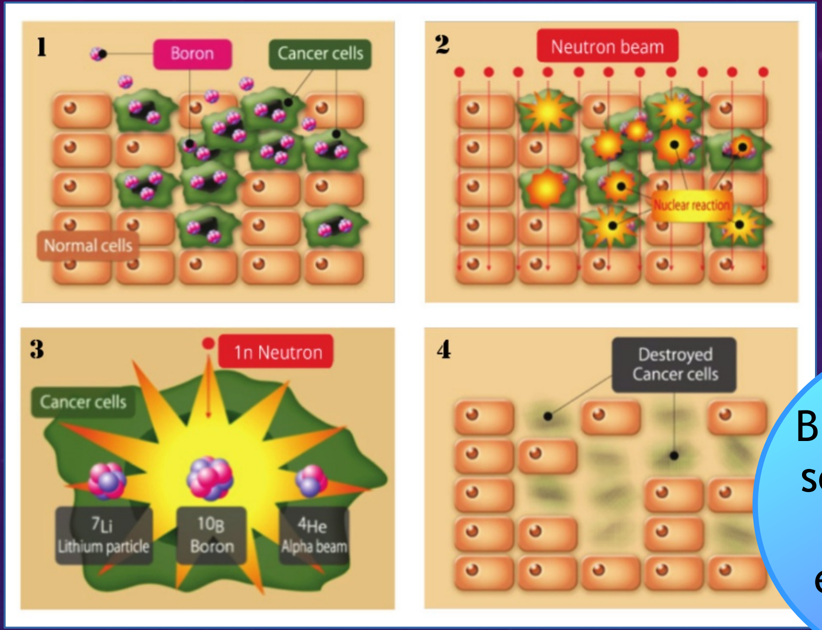
NEXT_AIM KICKOFF MEETING
17-18 FEB 2022

# MACHINE LEARNING ON IMAGING DATA OF B10 UPTAKE TRACKS AND DOSE MONITORING BY COMPTON CAMERA


Nicoletta Protti, UNIPV Dip. Fisica & PV-INFN
Dayron Ramos, UNIBA & BA-INFN
Giuseppe Iaselli, PoliBA & BA-INFN

# GENERAL PROBLEM IN BNCT DOSIMETRY

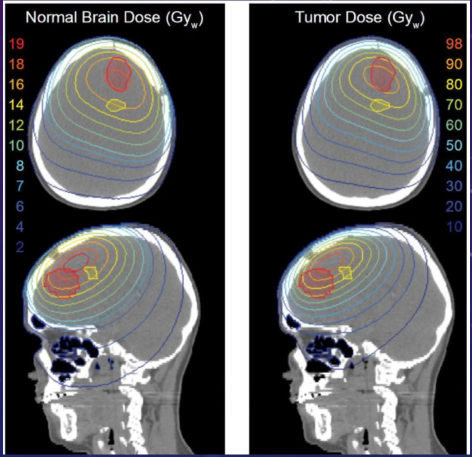
$$dD(x,y,z) \approx n_{B10}(x,y,z) \cdot \Phi(x,y,z)\, dV$$



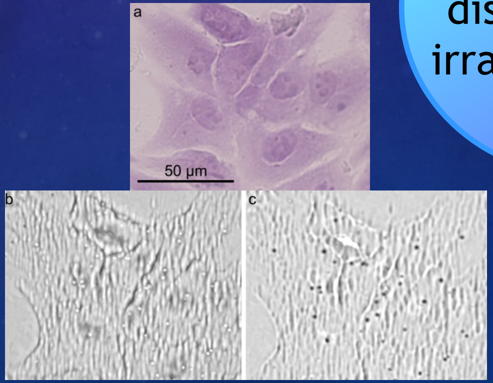

BNCT cell-level selectivity and biological effectiveness

thermal neutron flux distribution @ tumour site

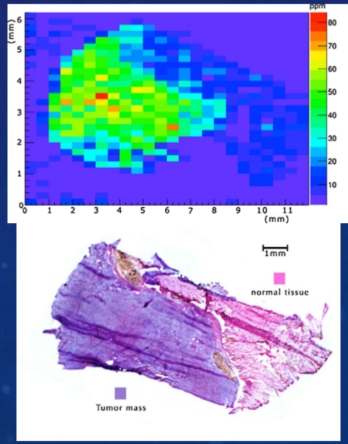
$^{10}$B microscopic distribution @ irradiation time




Monte Carlo-based Treatment Planning Systems (TPS) validated through TE-phantom measurements



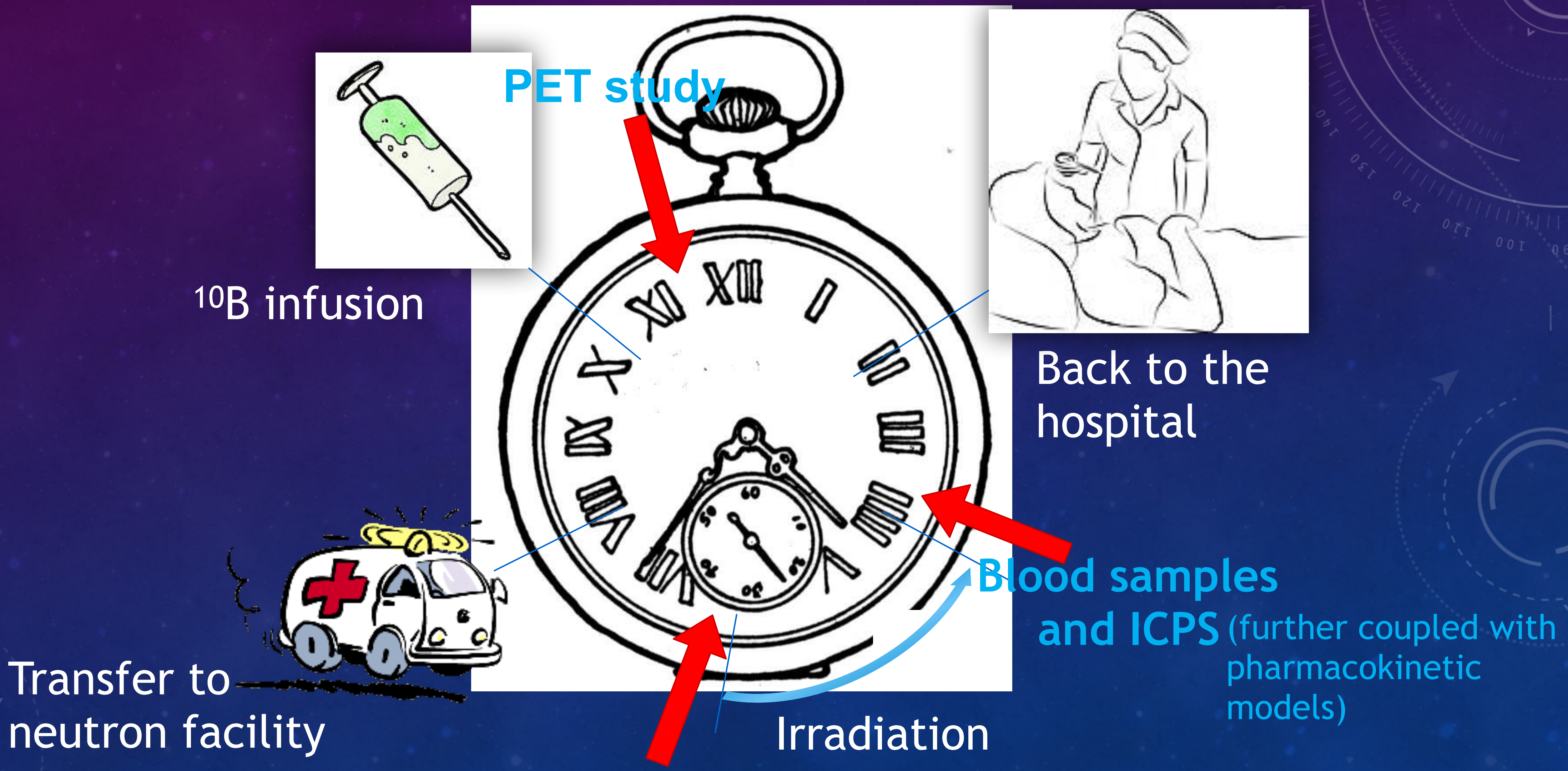

A.Portu et al., Experimental set-up for the irradiation of biological samples and nuclear track detectors with UV C, RPOR 21 (2016) 129-134




I.Postuma et al.,An improved neutron autoradiography set-up for 10B concentration measurements in biological samples, RPOR 21 (2016) 123-128

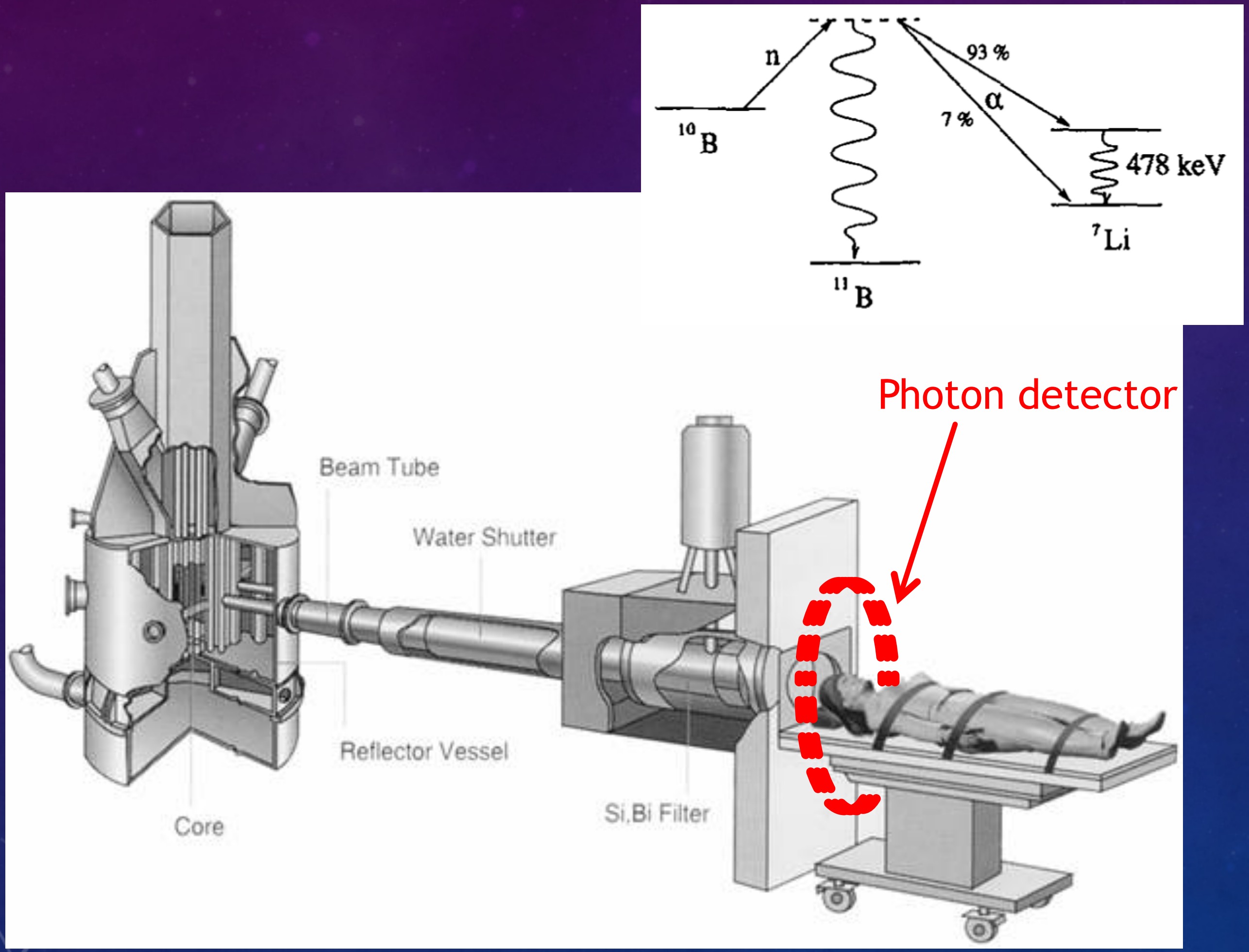
# BNCT CLINICAL PROTOCOL

$$dD(x,y,z) \approx n_{B10}(x,y,z) \cdot \Phi(x,y,z)\, dV$$



# IN VIVO BNCT DOSIMETRY BY SINGLE PHOTON DETECTION

$$dD(x,y,z) \approx \boxed{n_{B10}(x,y,z) \cdot \Phi(x,y,z)}\ dV \approx dI_\gamma(x,y,z)$$




BNCT group in Pavia currently involved in small animal (rats, mice) tumour models irradiation at the thermal neutron facility of Pavia University TRIGA Mark II reactor

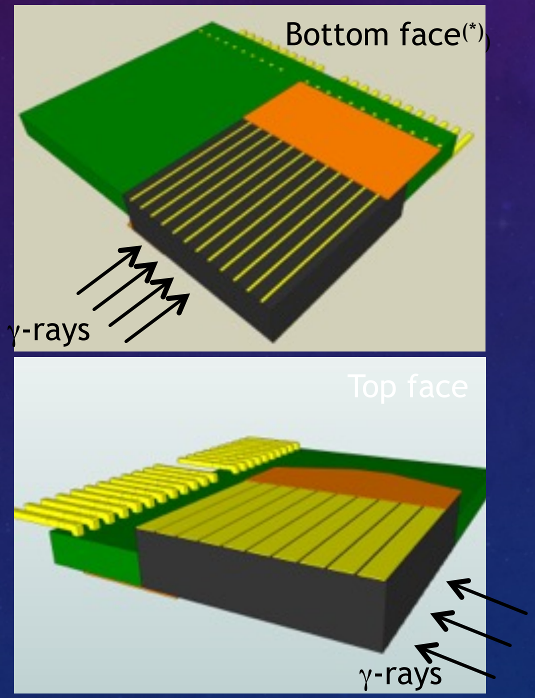
REQUIREMENTS for **SPECT-BNCT**

-high spatial resolution (≤ 1mm)
- good detection efficiency @ 478 keV
- compact and portable system
- **high performance even in presence of mixed (n+g) fields**

# WHY CZT?

- Compact but still highly efficient
- High energy resolution
- Works at room temperature

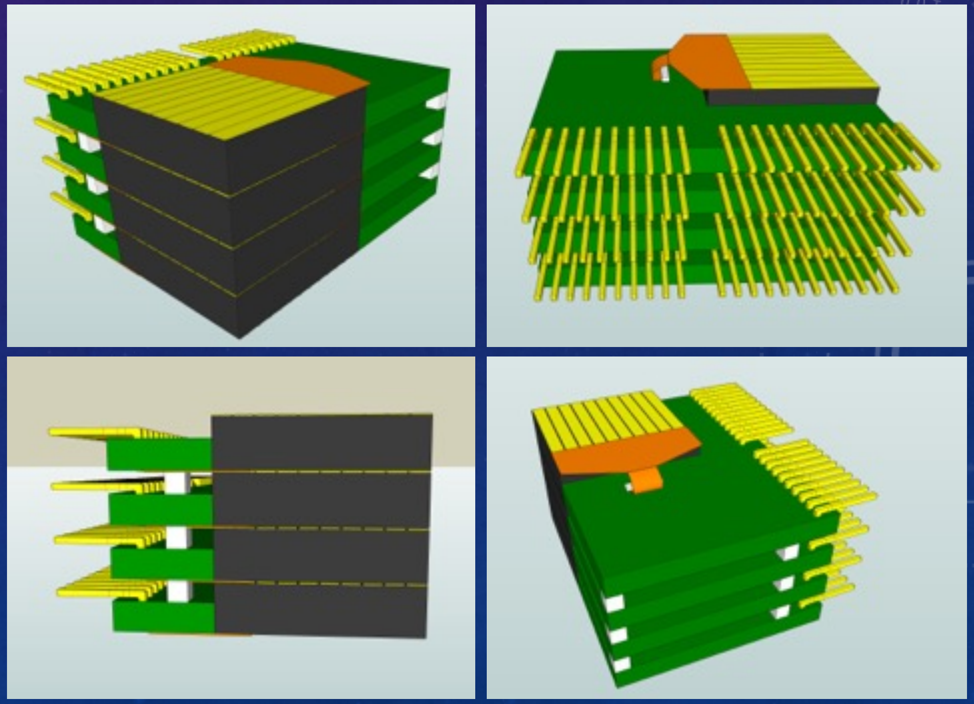
CZT single unit: **20x20x5 mm³**, planar transversal field (PTF), orthogonal drift strip electrodes




(*) drift strips not reported

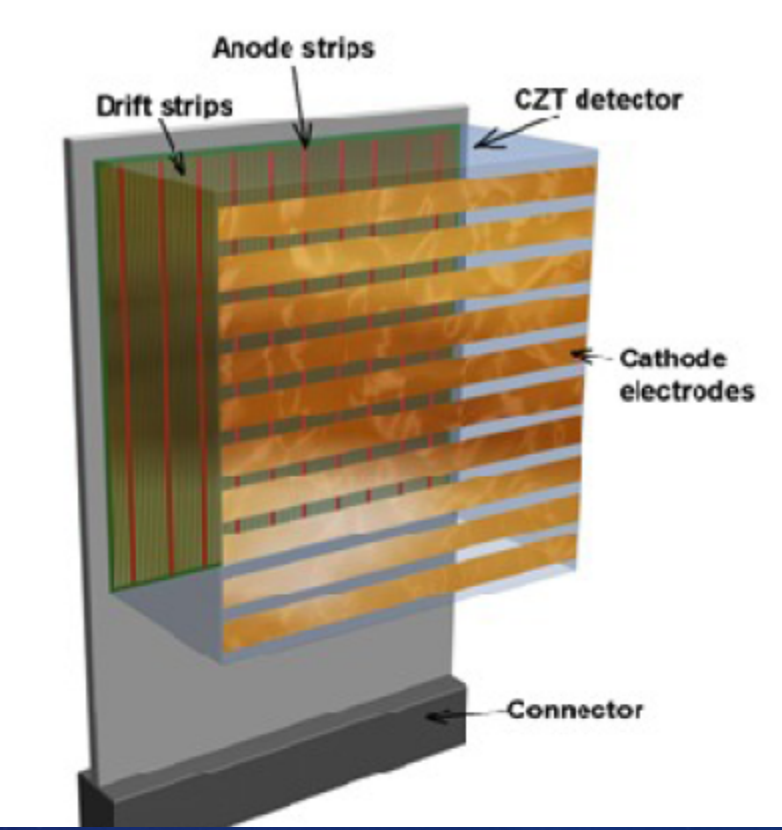
x4

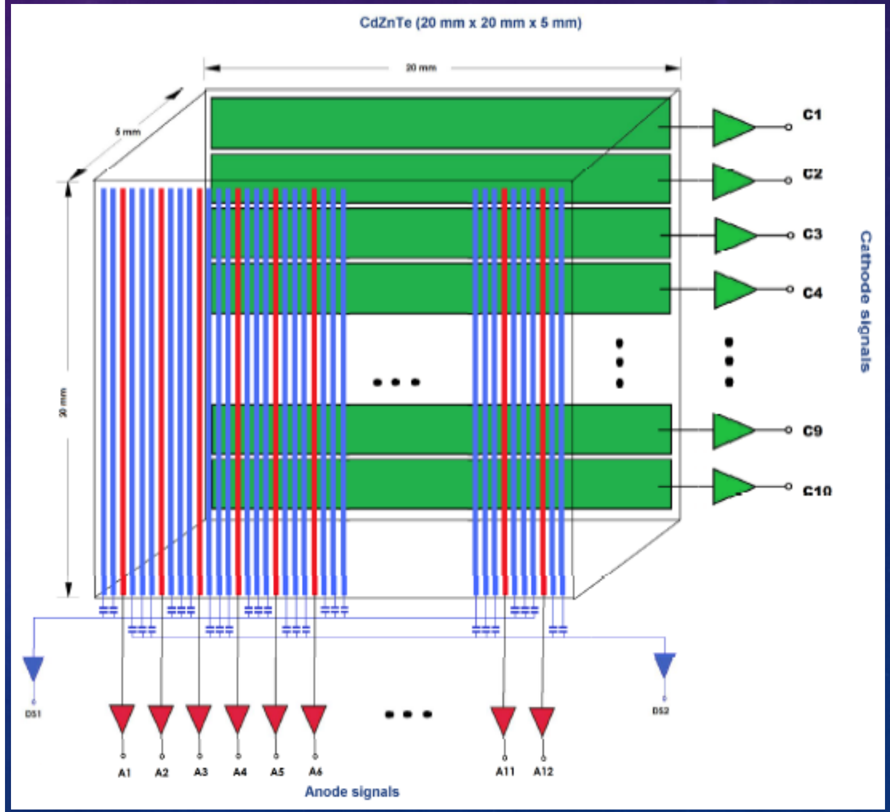
3D-CZT prototype, 20x20x20 mm³



# DRIFT STRIP DETS.

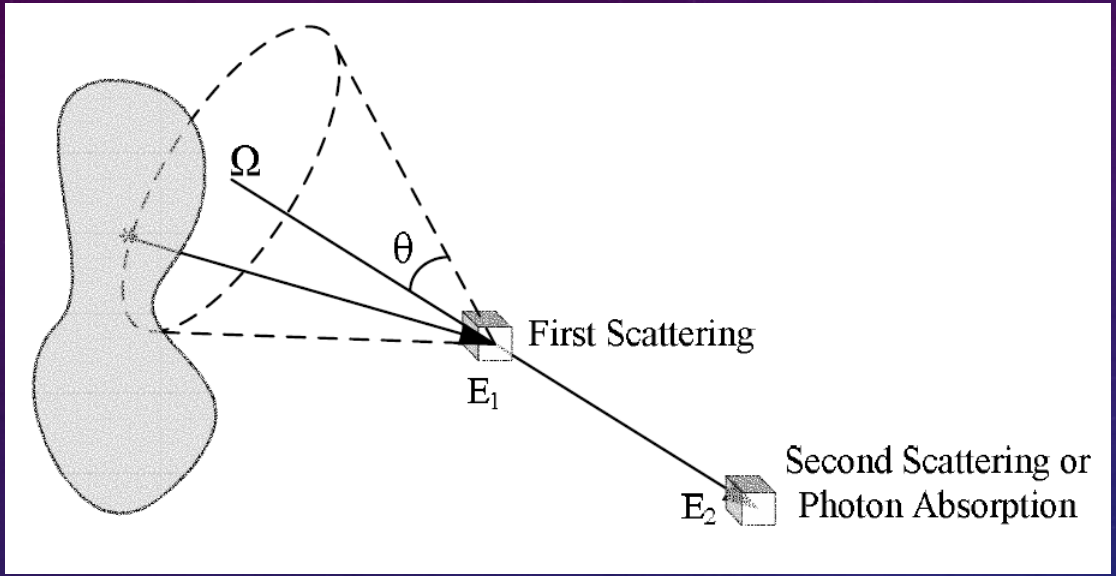
High resolution 3D position sensitive CZT detector based on CZT DRIFT STRIP DETECTOR PRINCIPLE for 2D sensing and the DOI TECHNIQUE based on cathode and anode signal for depth sensing -> SPECTRO-IMAGER: i-th event = ($E_i$, $x_i$, $y_i$, $z_i$)




taken from I.Kuvvetli et al., Proc of SPIE vol. 9154, 9154OX, 2014 (doi: 10.1117/12.2055119)

# COMPTON IMAGING: 2-STAGE (STANDARD) DETECTOR




2 stage system:
front plane SCATTER det.
+ back plane ABSORBER det.

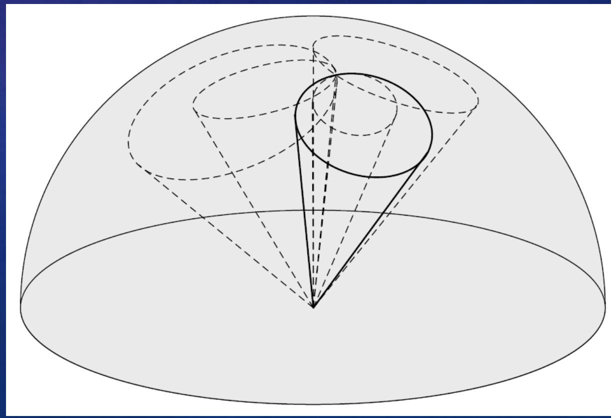
Nuclear medicine: well know energy line!

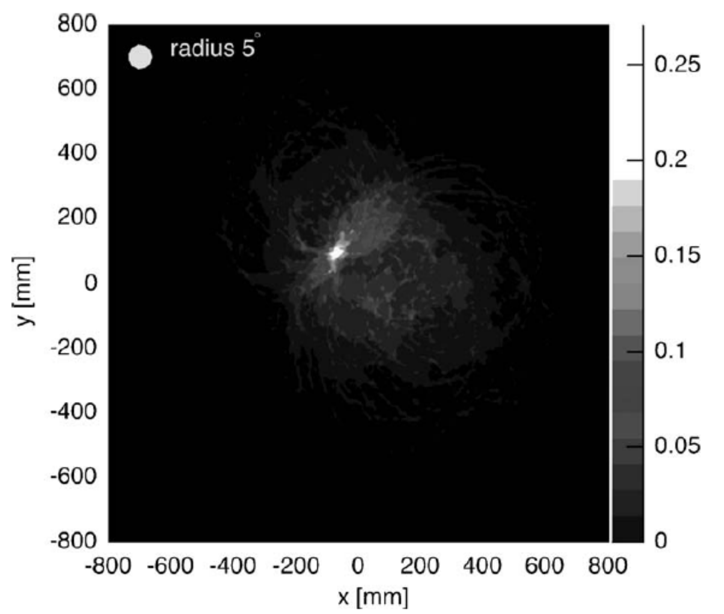
$h\nu_{emiss} = E_1 + E_2$

$\cos\vartheta = 1 - (m_e c^2 E_1) / (E_1+E_2)E_2$

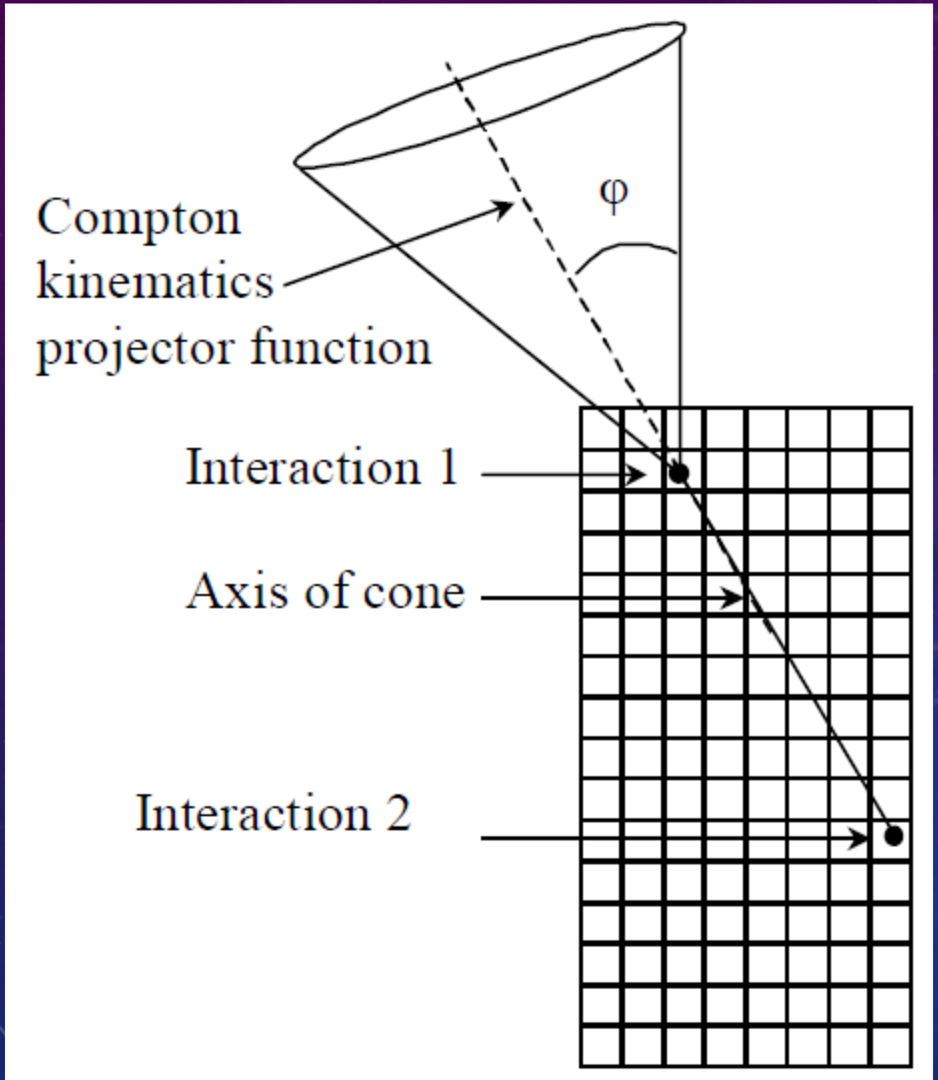
axes Ω from segment
(interaction-point2 – interaction-point1)

backprojection cone





# COMPACT COMPTON IMAGING




single stage Compton imager exploing 3D position sensing CZT

- Energy range of SPECT-BNCT peaked around 500 keV: Compton interaction probability in CZT crystal 4 times > that of photoelectric effect
- Development of an image reconstruction software based on Compton imaging thanks to the 3D detecting capabilities of CZT (co-registration of interaction position and deposited energy *per hit*)

# COMPTON CAMERA RECONSTRUCTION ALGORITHM

- Maximum Likelihood expectation Maximisation (MLEM) is an iterative statistical algorithm to reconstruct most probable source distribution of a given dataset

$$\lambda_j^n = \frac{\lambda_j^{n-1}}{s_j} \sum_{i=1}^{N} \frac{t_{ij}}{\sum_k t_{ik} \lambda_k^{n-1}}$$

where:

$\lambda_j^n$ = calculated amplitude of pixel j at the nth iteration

$s_j$ = sensitivity, i.e. the probability that a gamma ray originating from pixel j is detected anywhere

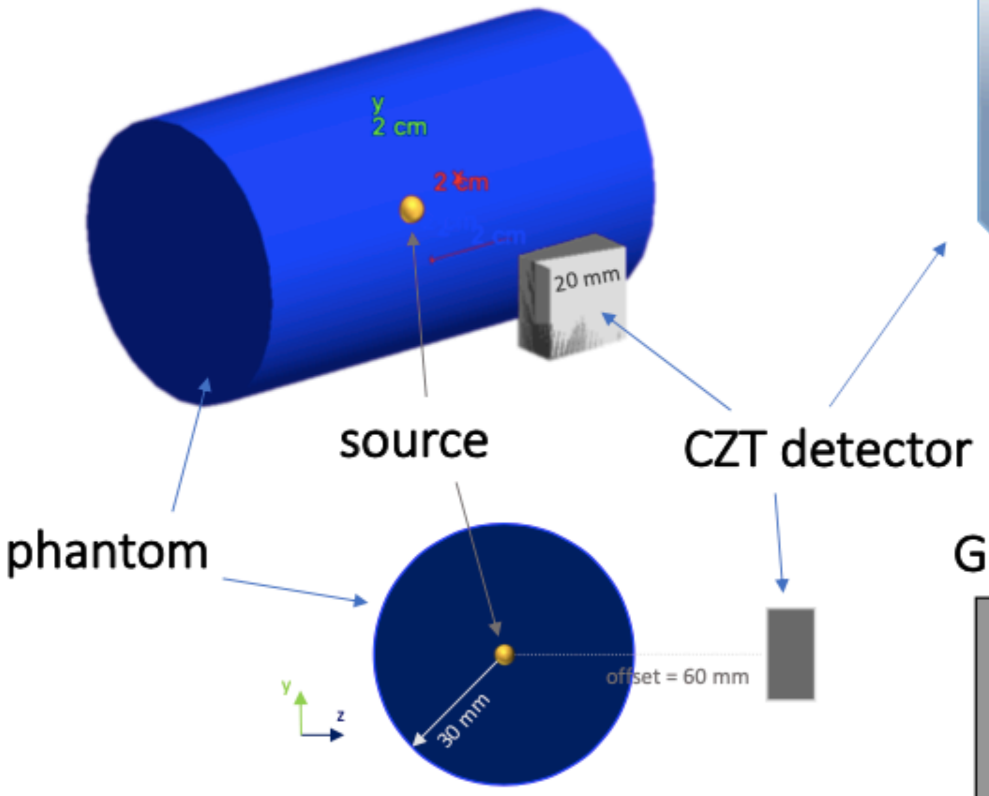
$t_{ij}$ = imaging response matrix, i.e. the transition probabilities generated by the measured events

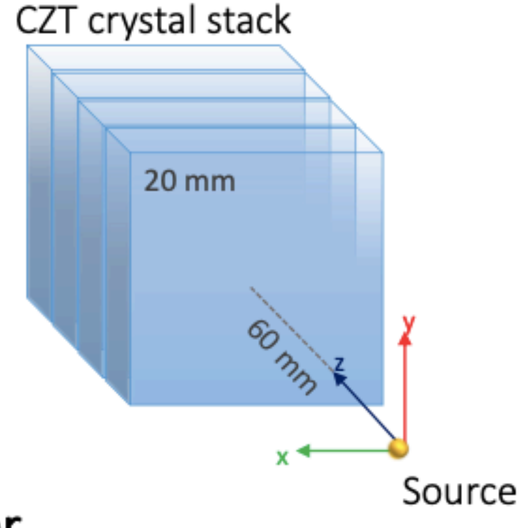
(first estimation: based on back-projection, $\lambda_0$ )

-Images are created by overlapping cones from many interactions

# GEANT4 SIMULATION OF 3D-CZT CC

## Geometry details



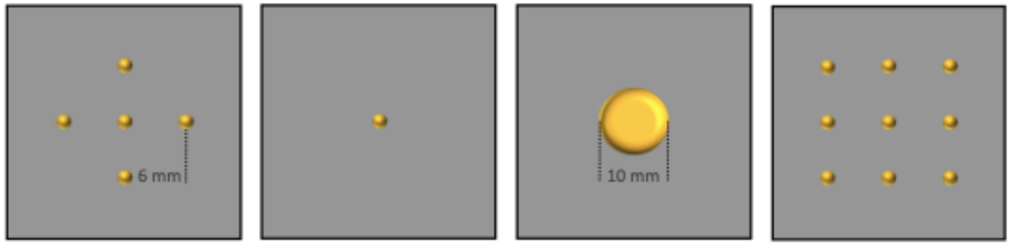




G4_TISSUE_SOFT_ICRP

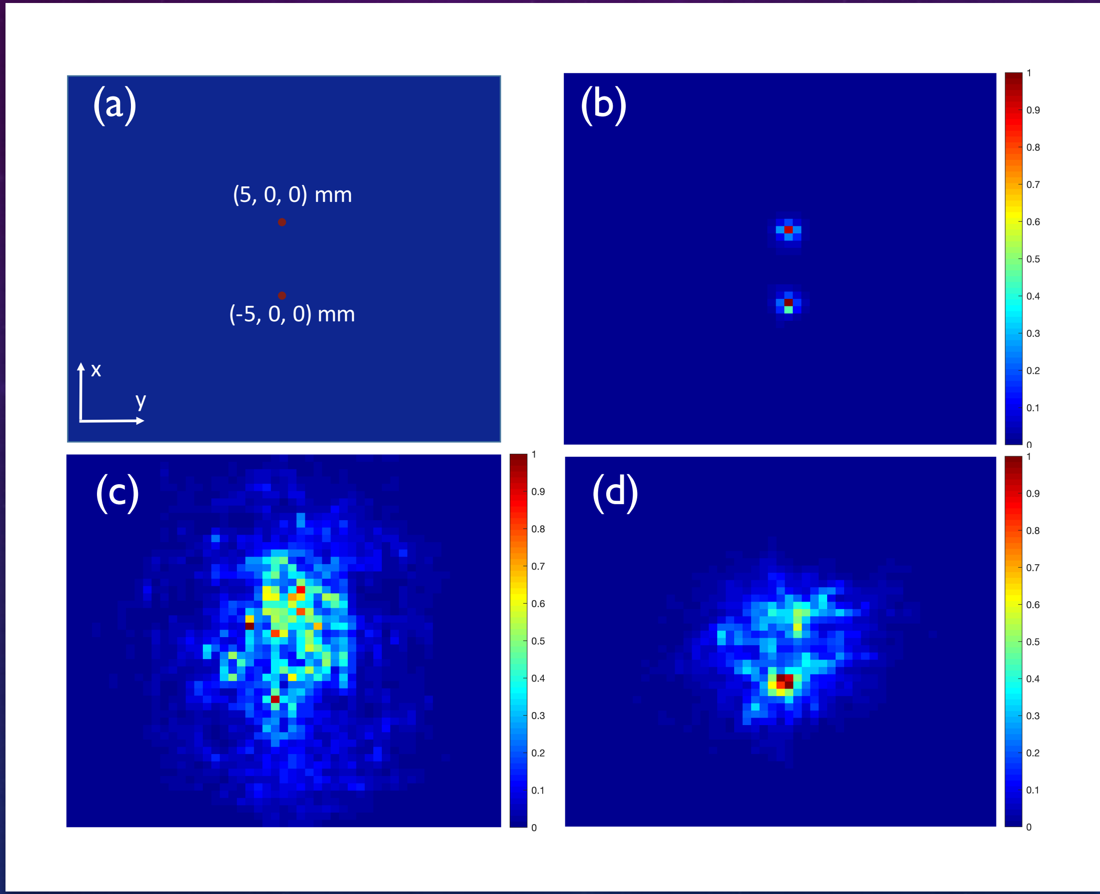
| Element | Ratio |
|---|---|
| H | 0.105 |
| C | 0.256 |
| N | 0.027 |
| O | 0.602 |
| Na | 0.001 |
| P | 0.002 |
| S | 0.003 |
| Cl | 0.002 |
| K | 0.002 |

density: 1.030 $g/cm^3$

GunAction:

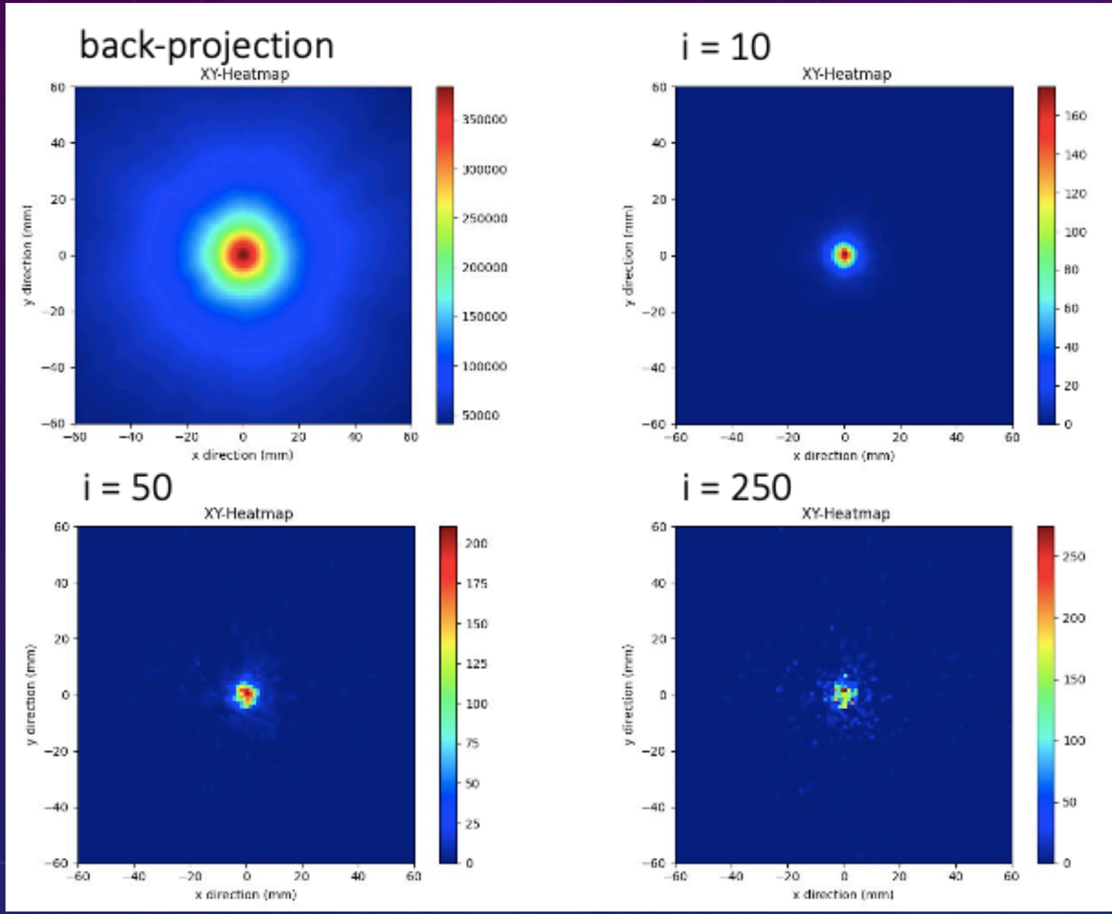


# GEANT4 SIMULATION OF 3D-CZT CC

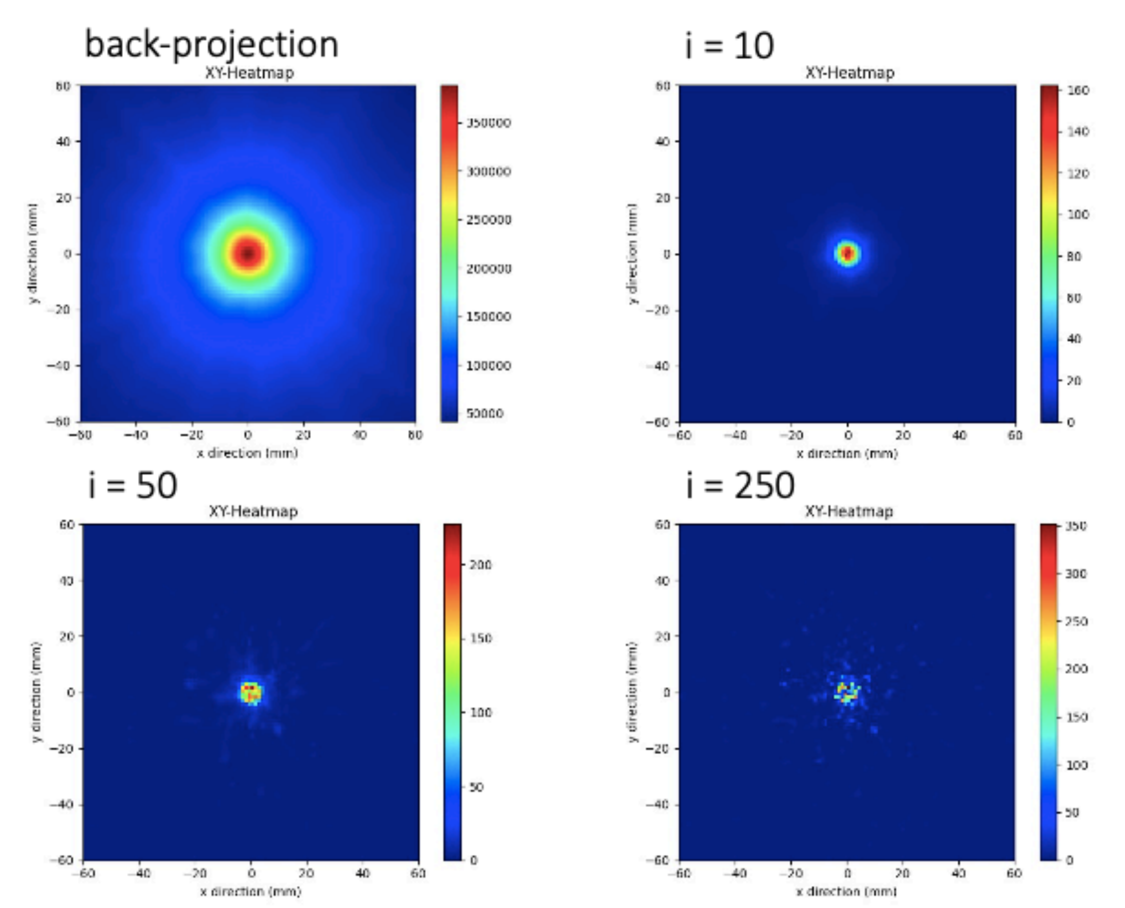



two 478 keV point-like sources, 6cm apart, in air

# GEANT4 SIMULATION OF 3D-CZT CC

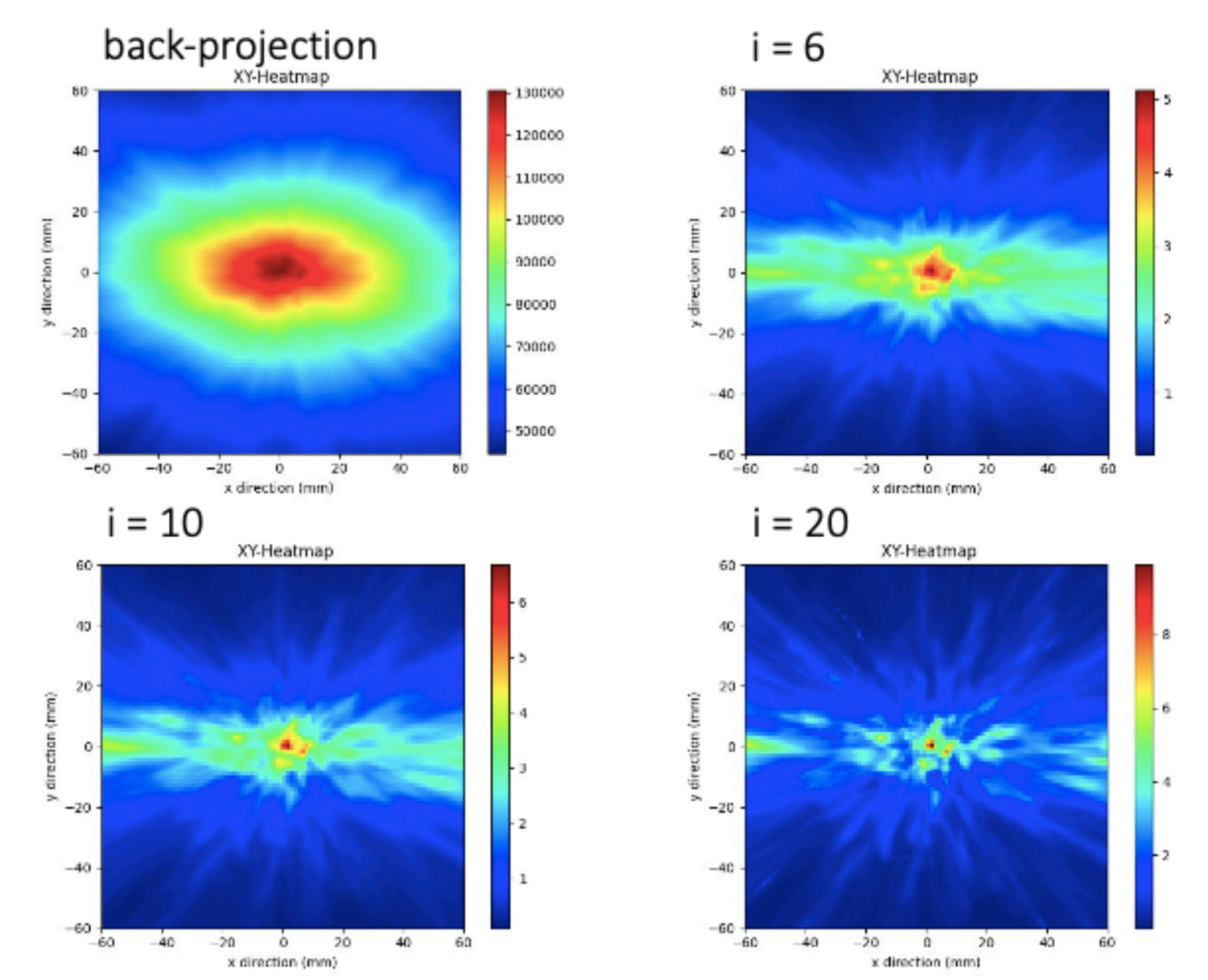



spheric source, 1 cm diameter, in air




spheric source, 1 cm diameter, soft tissue phantom (scatterer)

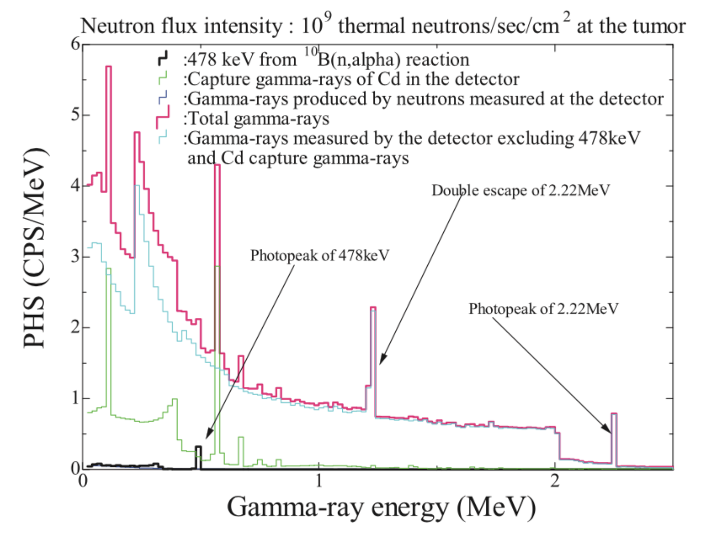
# GEANT4 SIMULATION OF 3D-CZT CC



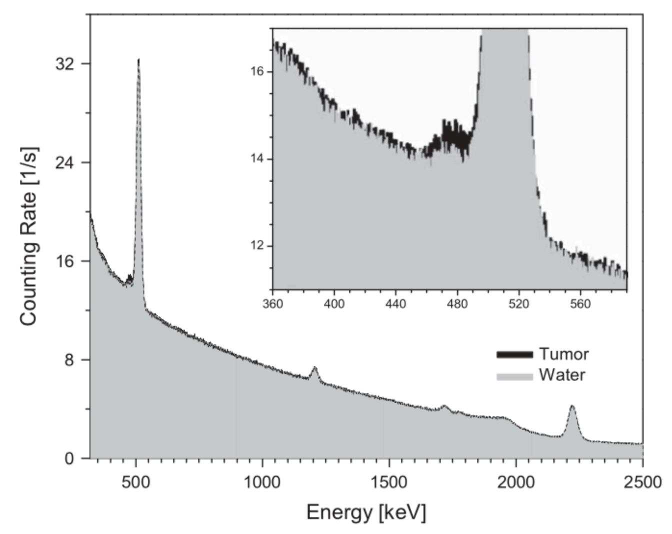

Spherical source, 1 cm diameter, phantom loaded by B10 (scatterer + emitter) 5:1

# AI FOR SUCH COMPTON CAMERA IMAGES?

- Optimisation of reconstruction algorithm: ?
- Help in signal discrimination from the background: ?
- Improvement in image quality: ?




Manabe et al., Rep Pract Onc Radioth 21(2) (2016). 102-107




Minsky et al., ARI 67 (2009) S179-S182

Presently we are still on MC SIMULATED DATA -> NECESSITY OF CC IMAGES DATASET!!!!

# THANKS!!!!

dayron.ramos@ba.infn.it
nicoletta.protti@unipv.it