

# ADVANTAGES AND DISADVANTAGES OF TIMEPIX DETECTOR FOR SPECT/CT

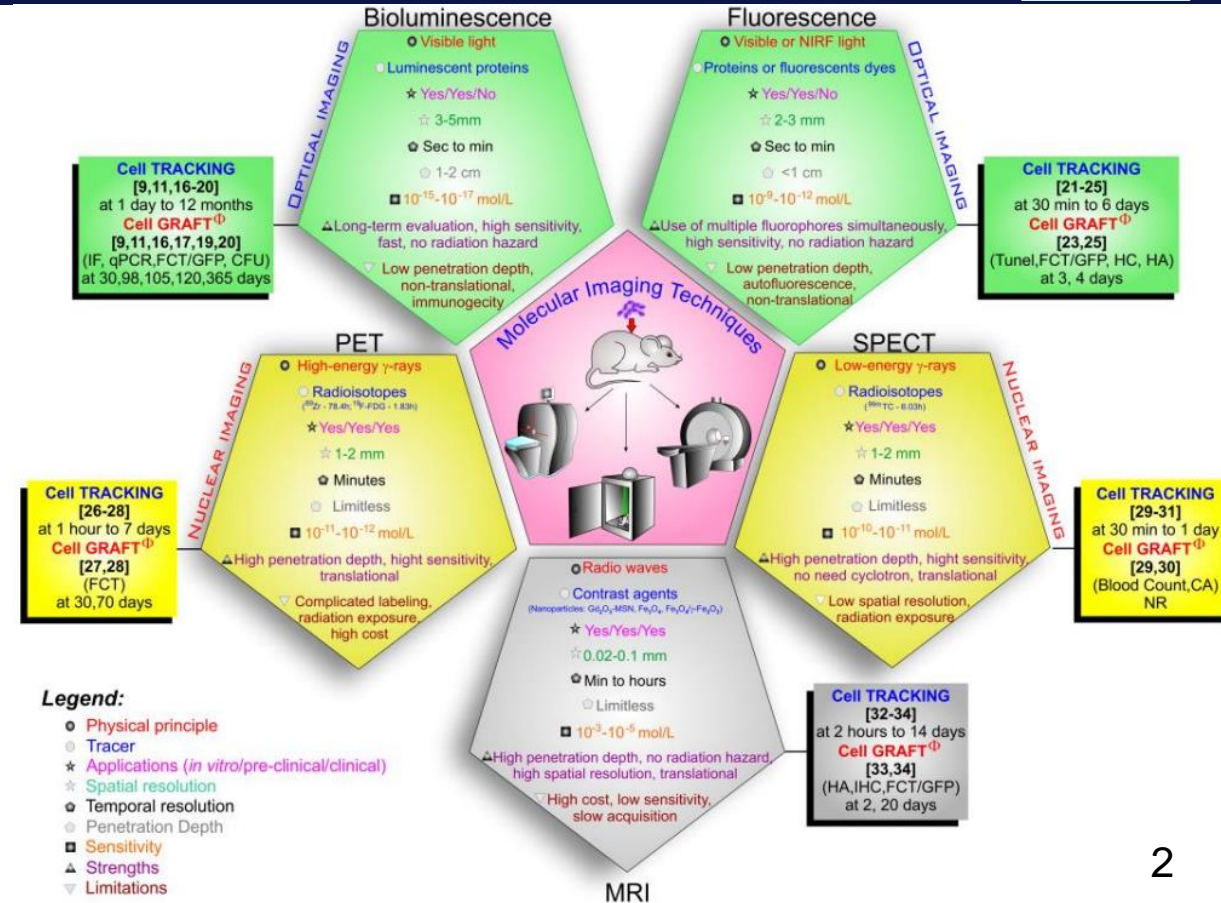
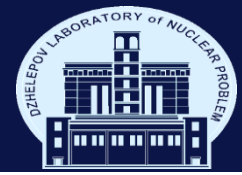
Rozhkov Vladislav  
JINR, DLNP  
rozhkov@jinr.ru

LXXII International conference "Nucleus-2022: Fundamental problems and applications"

15.07.2022

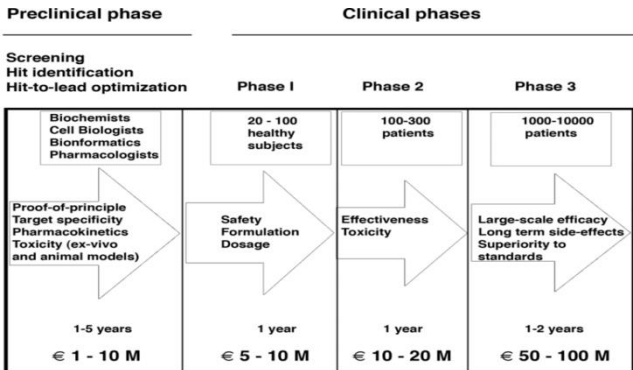


# Molecular Imaging

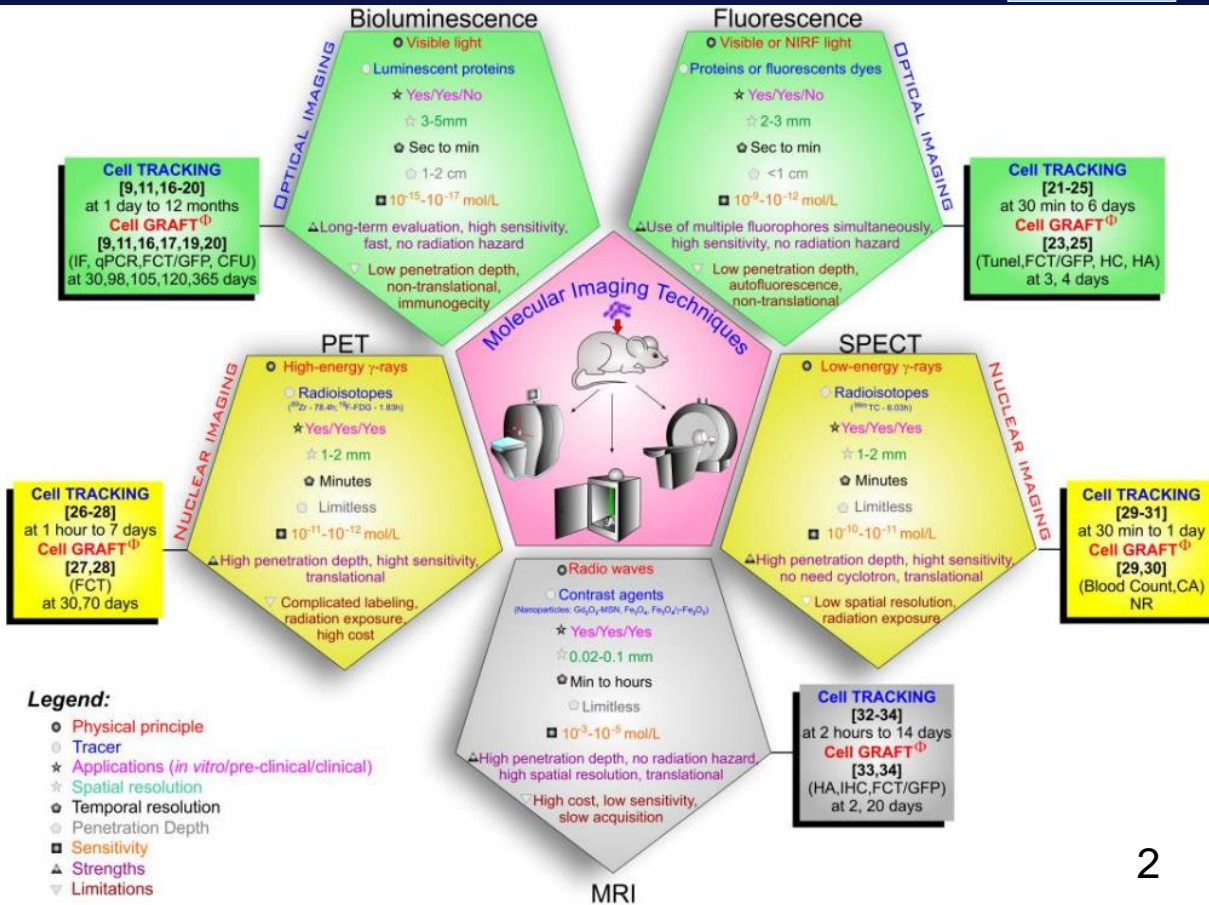




# Molecular Imaging



New Drug



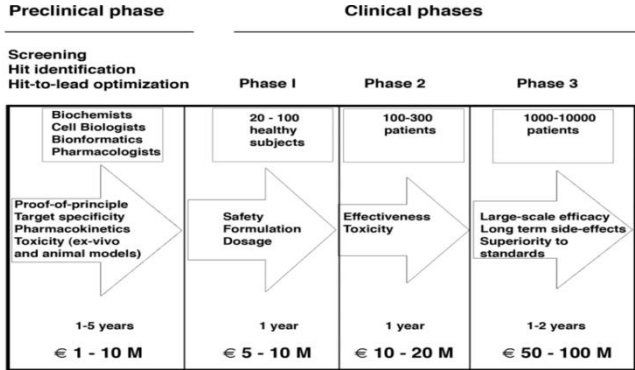
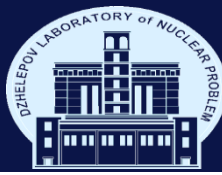
doi: 10.2174/138920101405131111105023

doi: 10.3390/cells9040939

doi: 10.1016/S0167-6296(02)00126-1

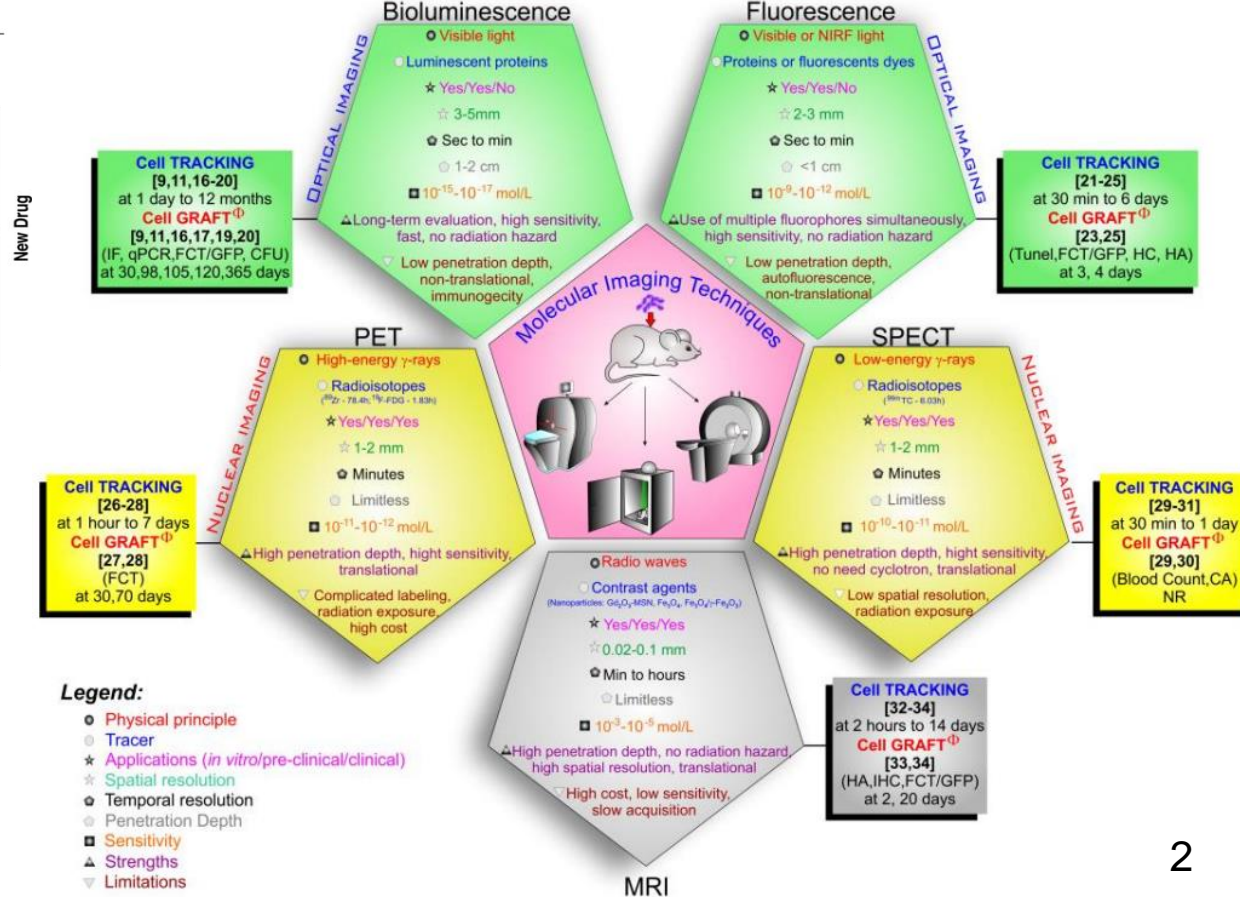


# Molecular Imaging



## SPECT system:

- High resolution
- High SNR
- High contrast
- High sensitivity

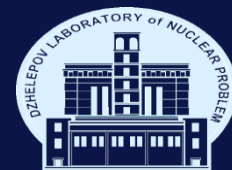


- Legend:**
- ⊙ Physical principle
  - ⊙ Tracer
  - ★ Applications (in vitro/pre-clinical/clinical)
  - ☆ Spatial resolution
  - ⌚ Temporal resolution
  - ⊙ Penetration Depth
  - Sensitivity
  - ▲ Strengths
  - ▼ Limitations

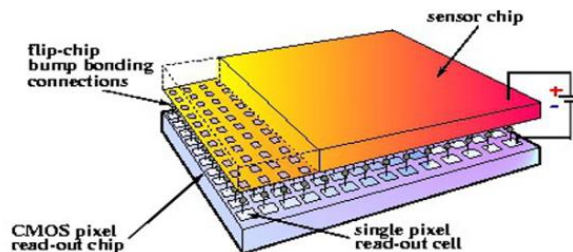
doi: 10.2174/138920101405131111105023  
 doi: 10.3390/cells9040939  
 doi: 10.1016/S0167-6296(02)00126-1



# Timepix detector



Sensor material	CdTe
Sensor size	14.1x14.1 mm
Sensor thickness	2 mm
Matrix size	256x256
Pixel size	55x55 $\mu\text{m}$
Energy resolution 140 KeV	10%
Efficiency 140 KeV	60%



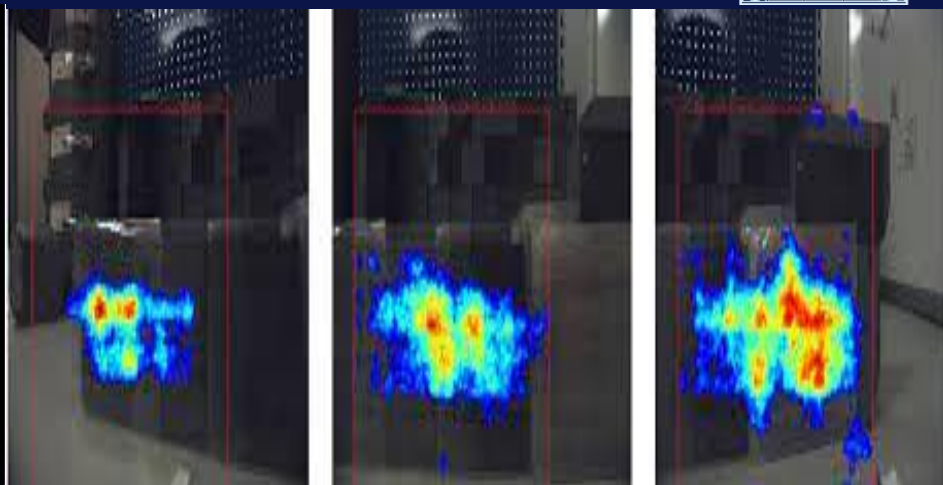
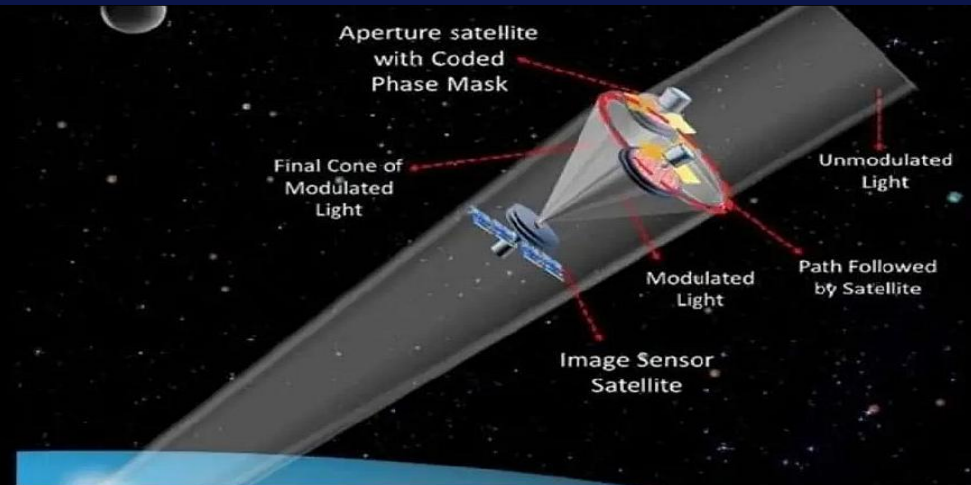
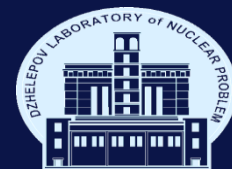
## 1. Medipix – counting mode

2. Time-over-Threshold (TOT) each pixel records the energy deposit of particles interaction with corresponding sensor segment

3. Time-of-arrival (TOA) - each pixel records the arrival time of particles interaction with corresponding sensor segment

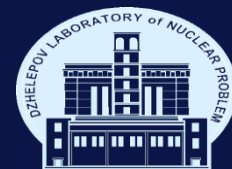


# Coded aperture





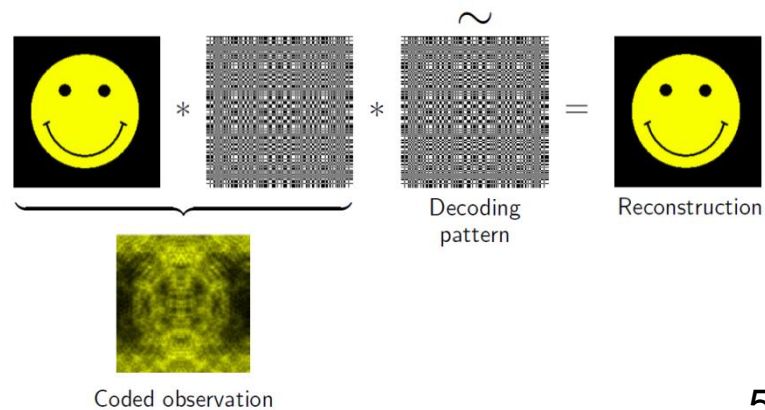
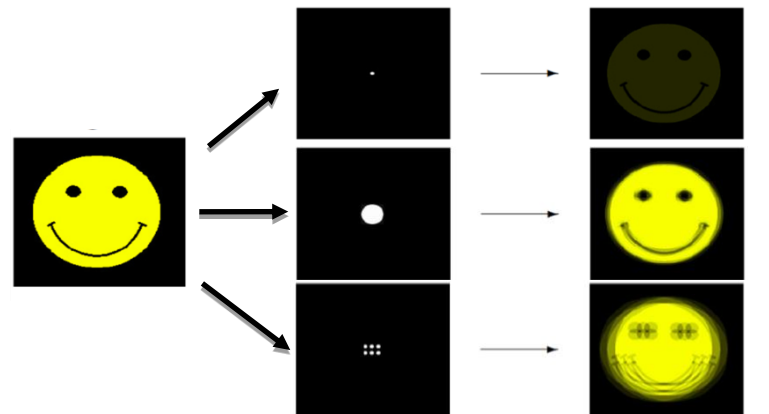
# Setup



Thickness	0.5 mm
Material	Tungsten
Mask type	MURA
Mask rank	31
Hole radius	160-180 $\mu\text{m}$
Work area	22.01 x 22.01 mm

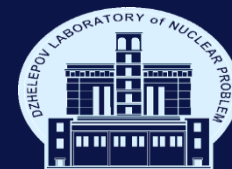


doi: 10.1364/AO.28.004344





# Setup



Thickness	0.5 mm
Material	Tungsten
Mask type	MURA
Mask rank	31
Hole radius	160-180 $\mu\text{m}$
Work area	22.01 x 22.01 mm

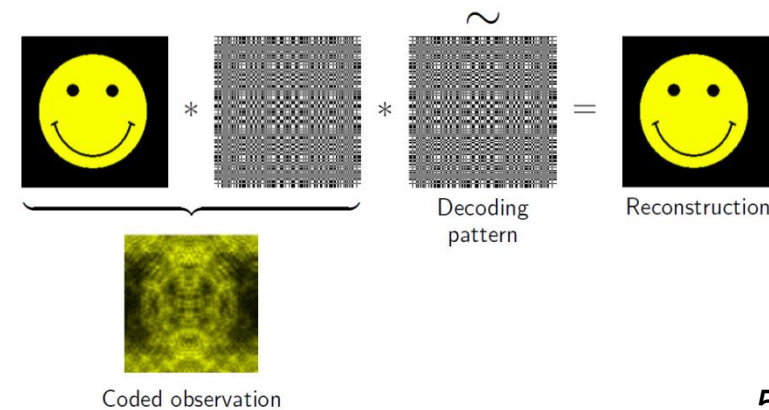
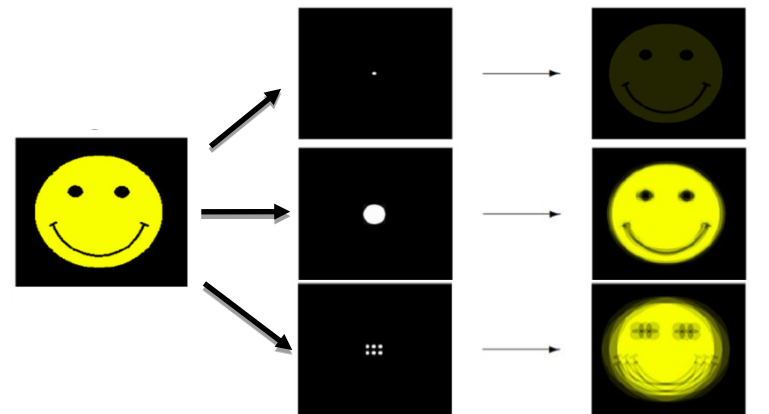


doi: 10.1364/AO.28.004344

Sensor material	CdTe
Sensor size	14.1x14.1 mm
Sensor thickness	2 mm
Matrix size	256x256
Pixel size	55x55 $\mu\text{m}$
Energy resolution 140 KeV	22%
Registration efficiency 140 KeV	60%



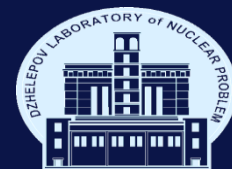
doi: 10.1016/j.nima.2007.08.079







# Setup



Thickness	0.5 mm
Material	Tungsten
Mask type	MURA
Mask rank	31
Hole radius	160-180 $\mu\text{m}$
Work area	22.01 x 22.01 mm

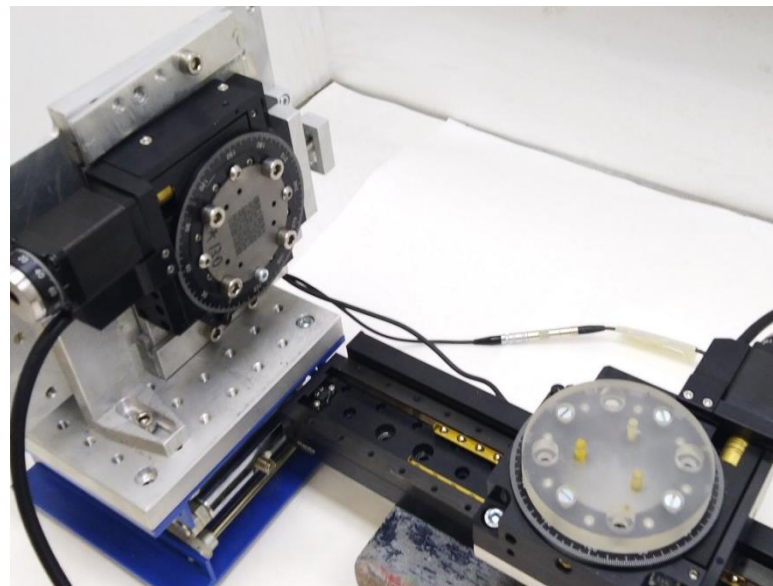


doi: 10.1364/AO.28.004344

Sensor material	CdTe
Sensor size	14.1x14.1 mm
Sensor thickness	2 mm
Matrix size	256x256
Pixel size	55x55 $\mu\text{m}$
Energy resolution 140 KeV	22%
Registration efficiency 140 KeV	60%



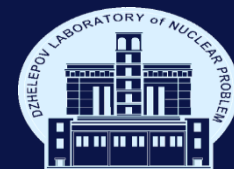
doi: 10.1016/j.nima.2007.08.079



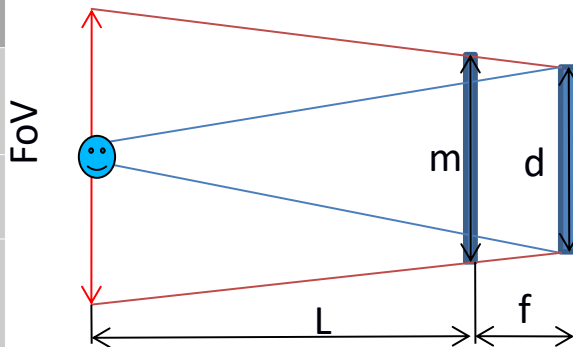
doi:10.1088/1748-0221/15/06/p06028



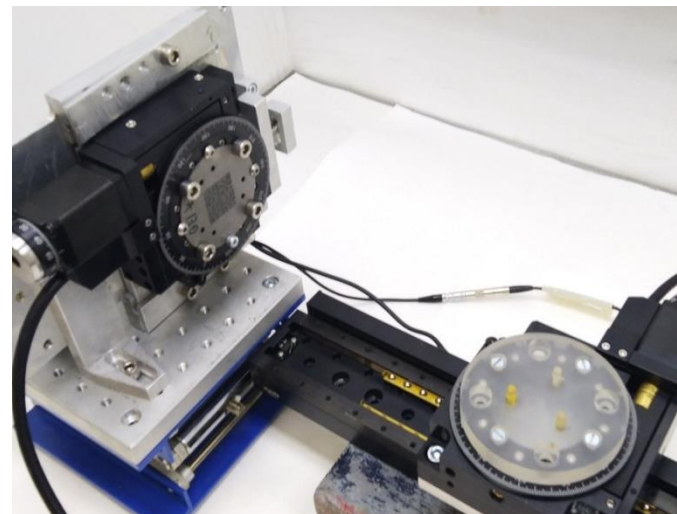
# Setup



Parameter	Contribution to the efficiency
<b>Geometric factor</b>	<b><math>3,4 \cdot 10^{-4}</math></b>
Air attenuation	<b>0,57</b>
<b>System efficiency including:</b>	<b>0,21</b>
Collimator	0,39
Air attenuation	0,88
Detector efficiency	0,6

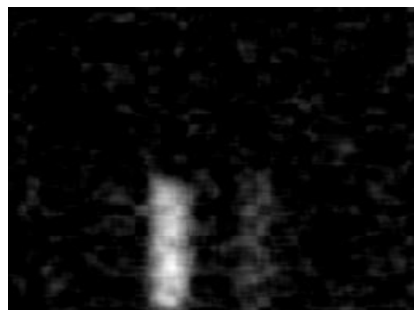
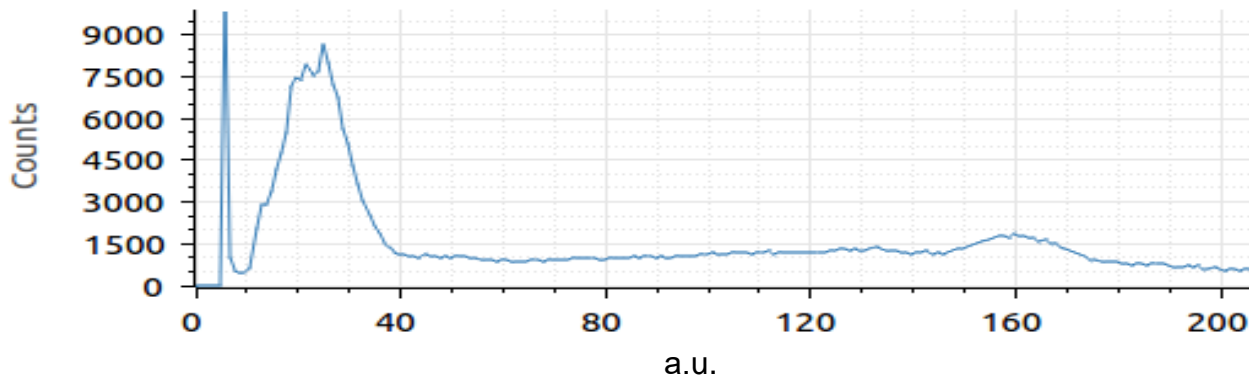
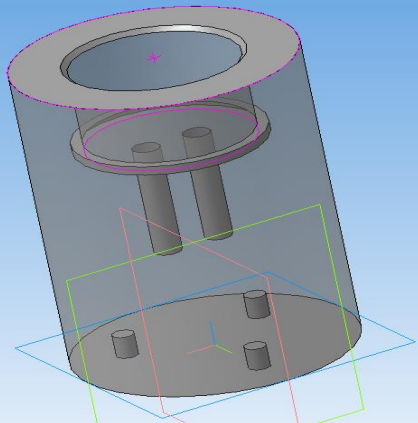


$$FoV = \frac{(m - d)(L - f)}{f}$$

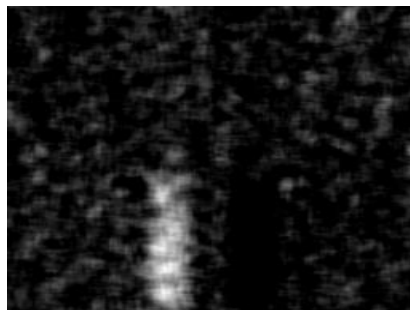




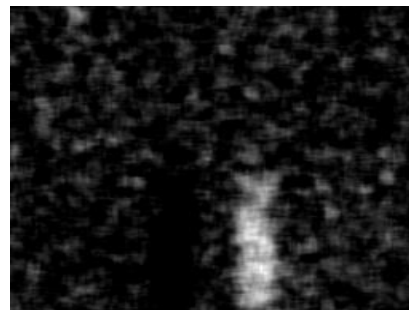
# Contrast Phantom



$^{99m}\text{Tc} + ^{125}\text{I}$



$^{125}\text{I}$  (84 MBq)

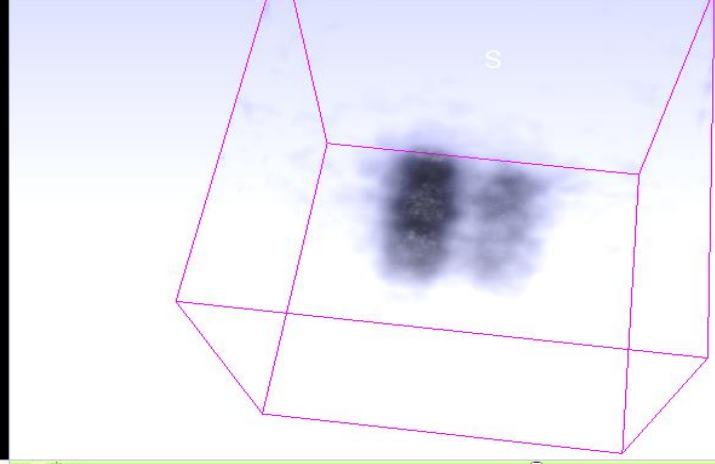
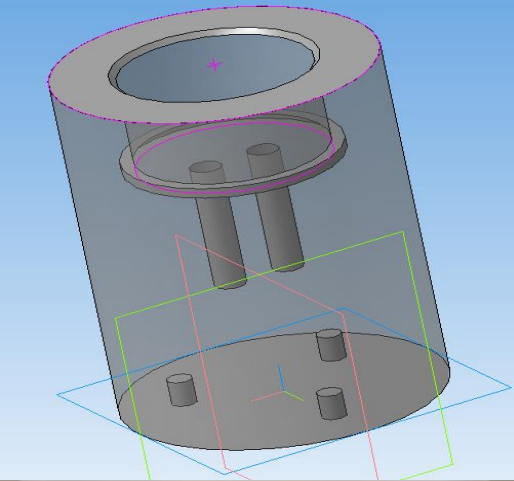


$^{99m}\text{Tc}$  (47 MBq)

$^{99m}\text{Tc}$  activity — 47 MBq  
 $^{125}\text{I}$  — 84.8 MBq  
Acquisition time — 5 min

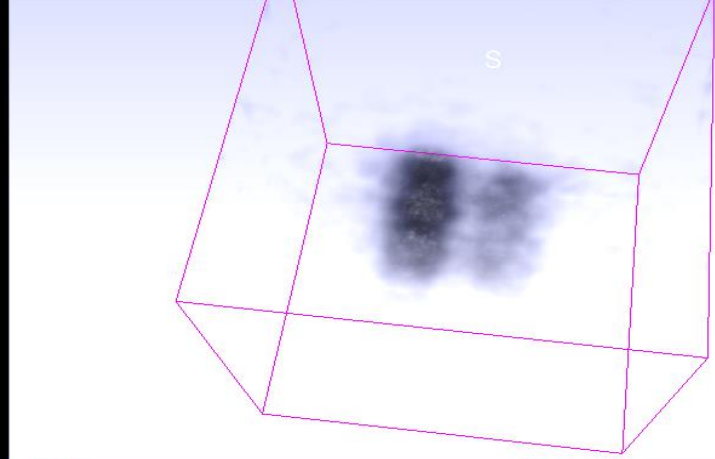
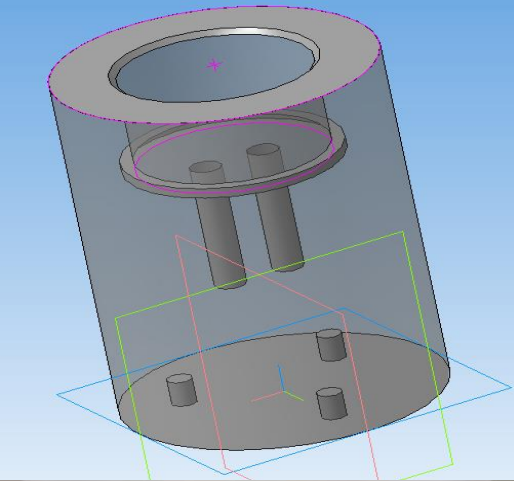


# Contrast Phantom



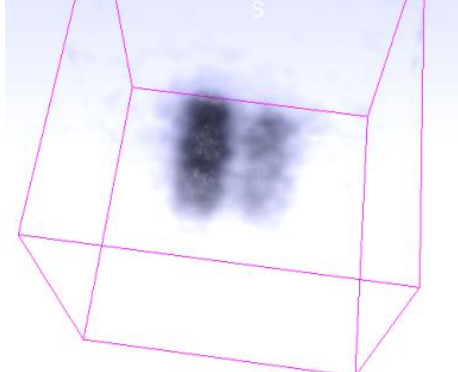
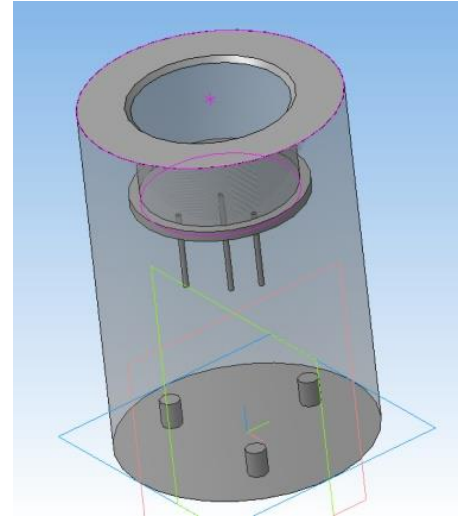
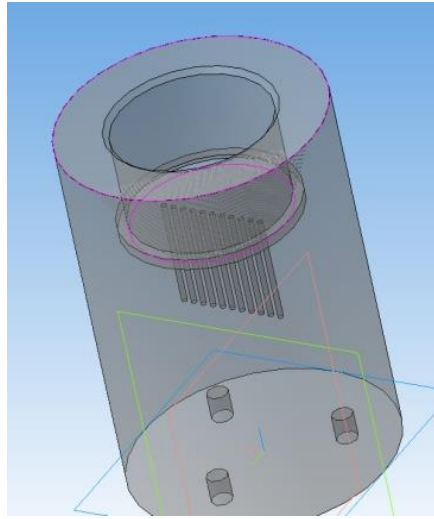
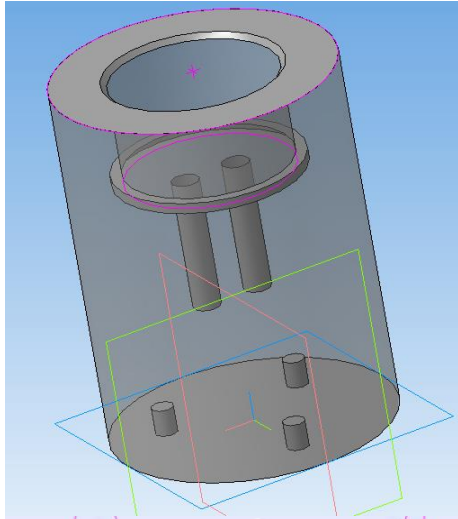


# Contrast Phantom



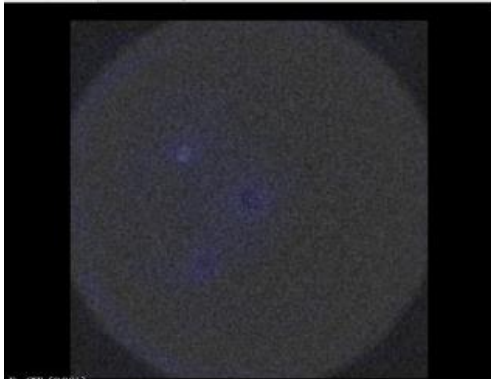
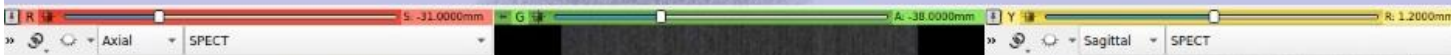
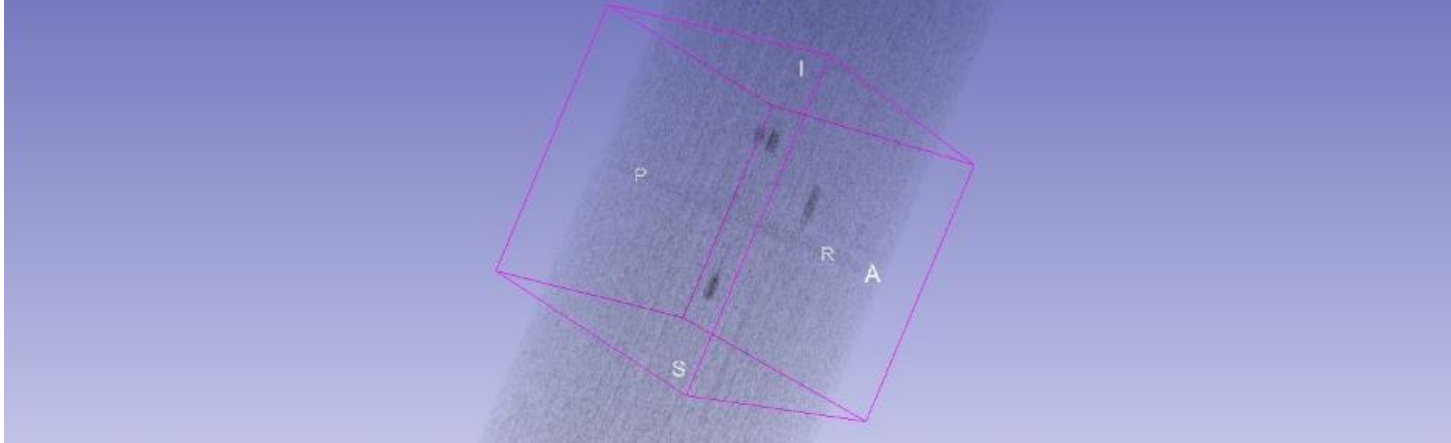


# Measurements with Phantom





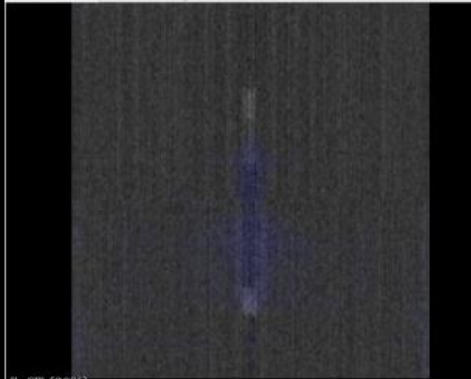
# SPECT/CT



F: CT (90%)  
B: SPECT



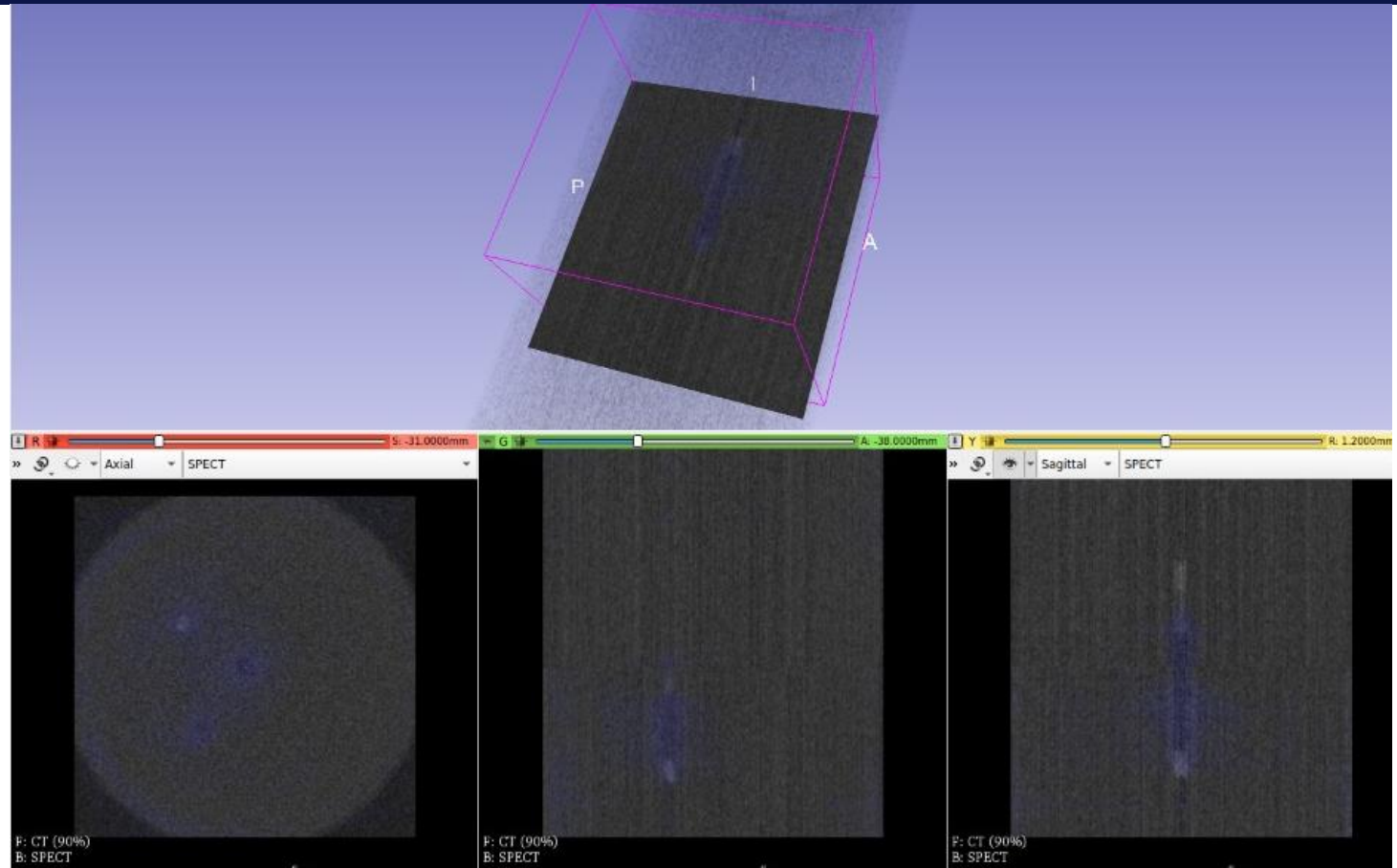
F: CT (90%)  
B: SPECT



F: CT (90%)  
B: SPECT



# SPECT/CT



F: CT (90%)  
B: SPECT

F: CT (90%)  
B: SPECT

F: CT (90%)  
B: SPECT





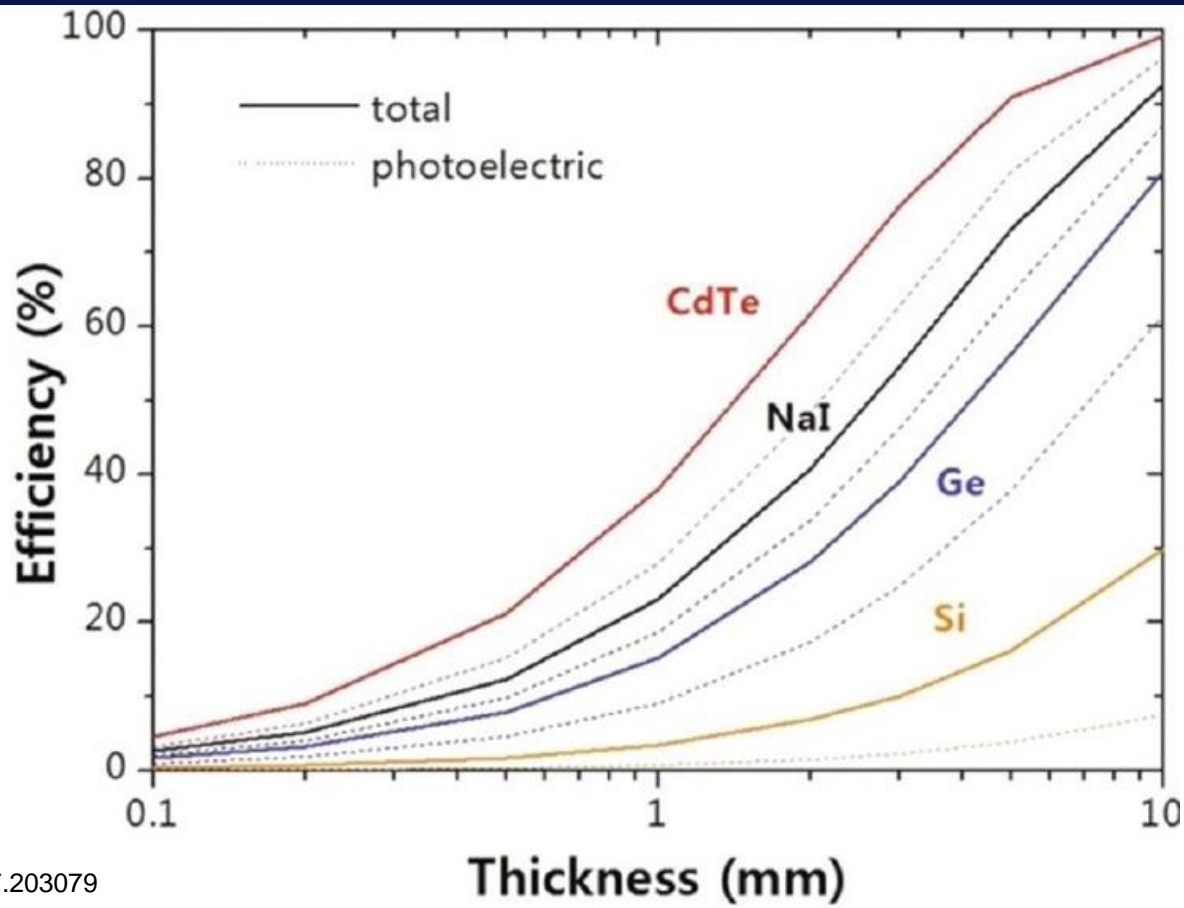
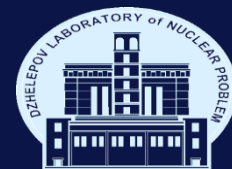
# System parameters



Detector	Timepix CdTe 2 mm
Tomography spatial resolution	2.5 mm (FoV 57 mm x 57 mm)
Spatial resolution	0.8 mm (FoV 30 mm x 30 mm)
Energy resolution	22% (140keV)
Sensitivity	35 cps/MBq
Linearity	99,9%
Scanning time	<2 min/projection
Radiopharmacy energy	30 – 300 keV
SNR	>70%

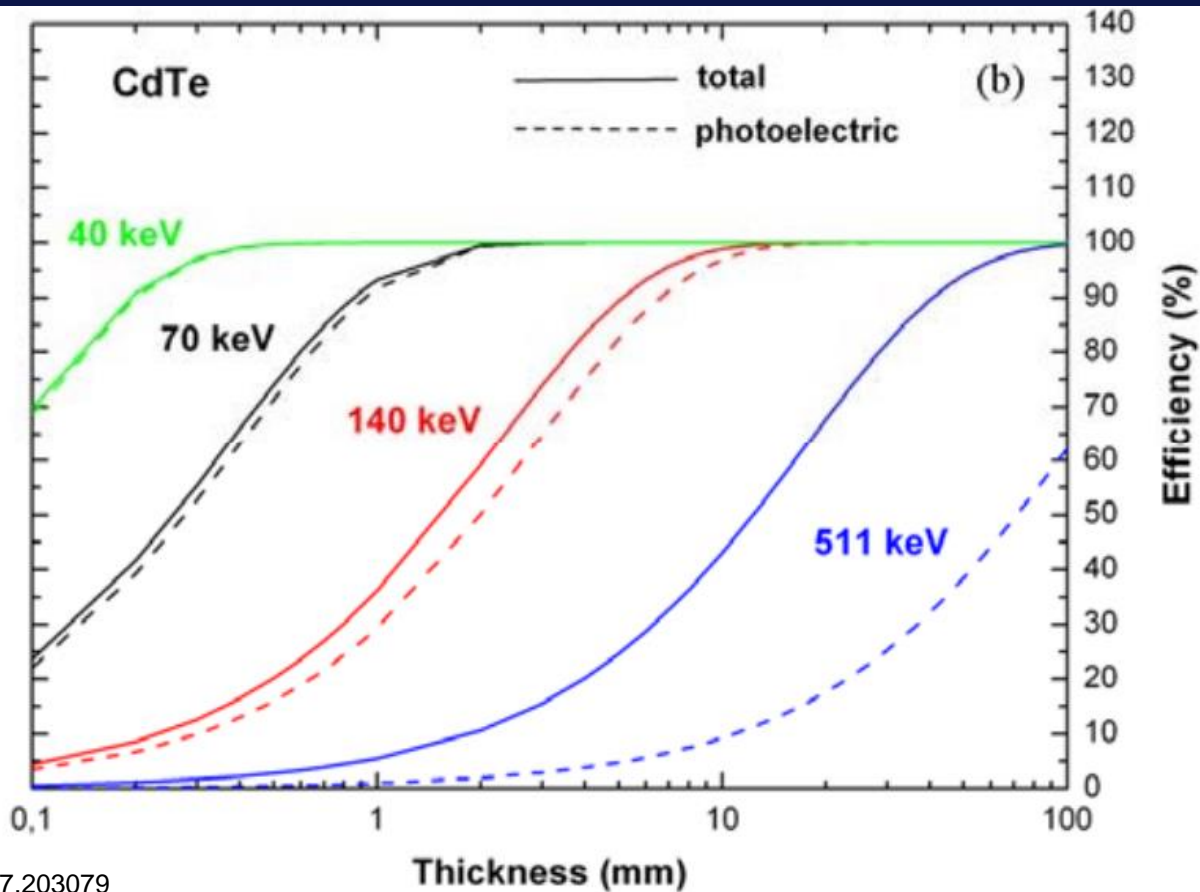
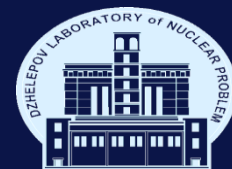


# CdTe sensor



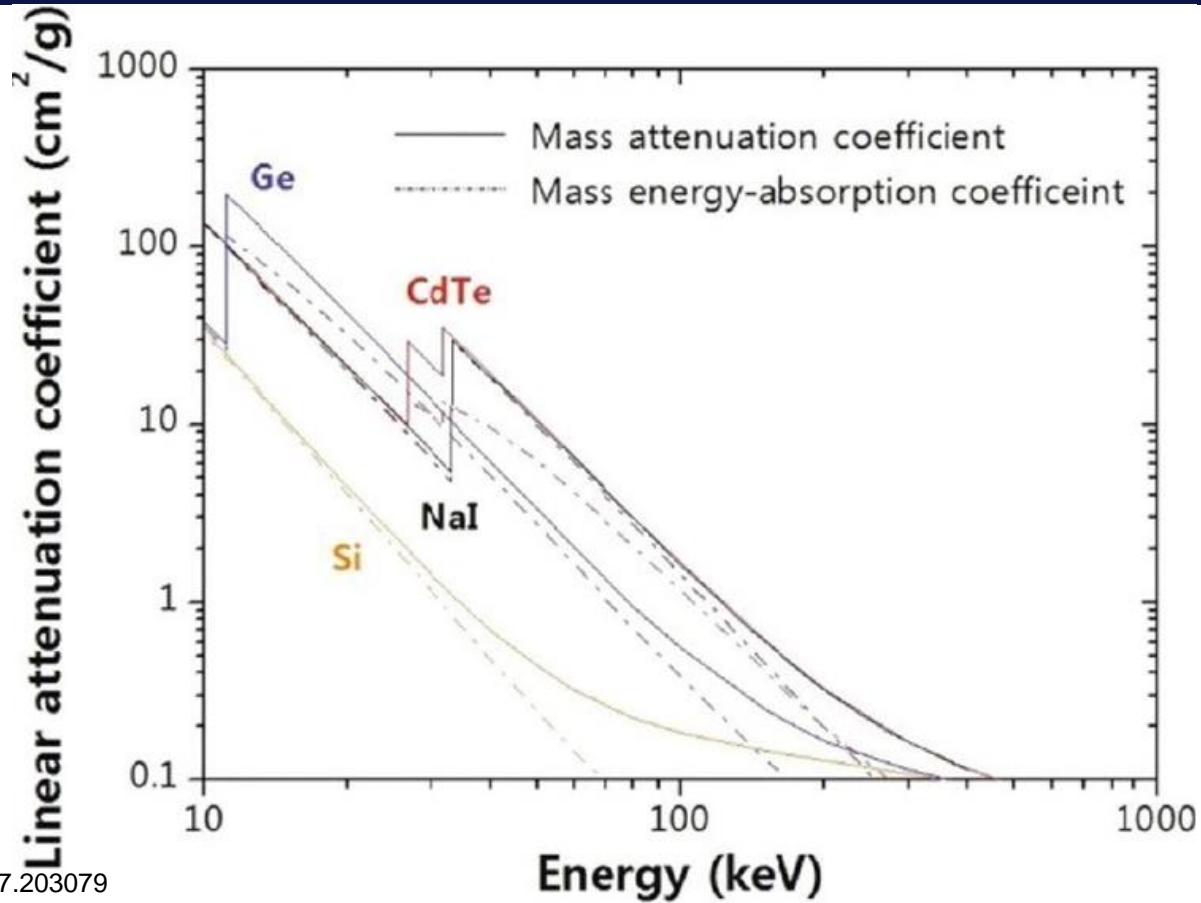
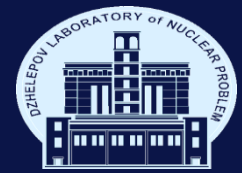


# CdTe sensor



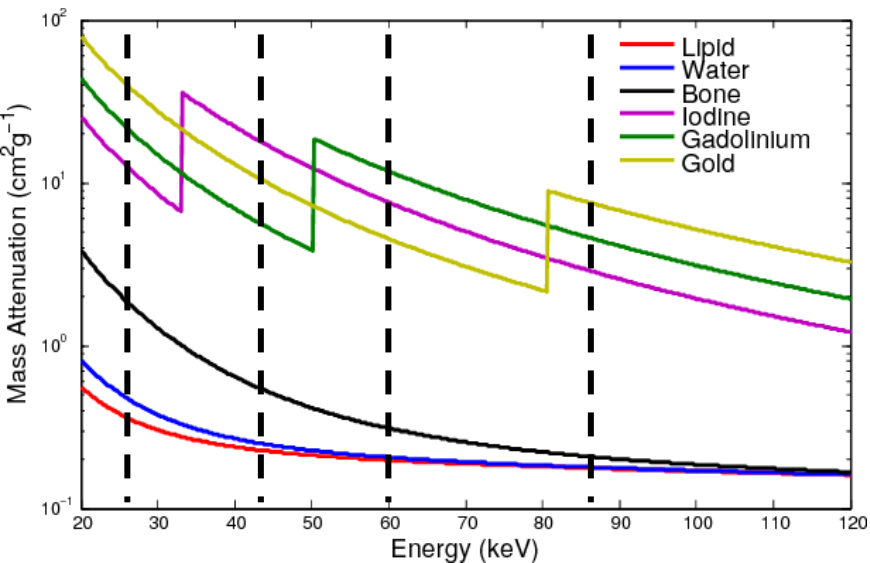


# CdTe sensor

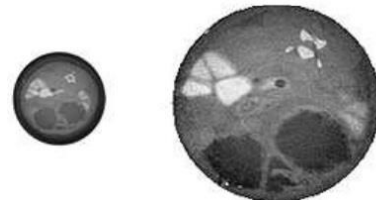
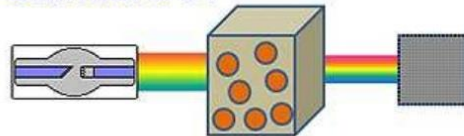




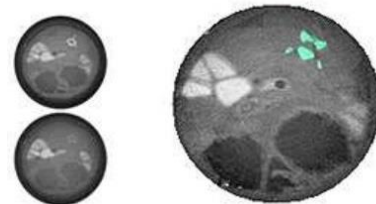
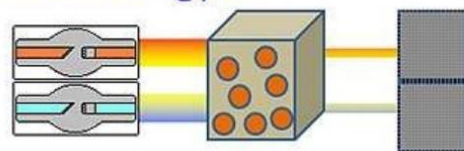
# Multi-energy tomography



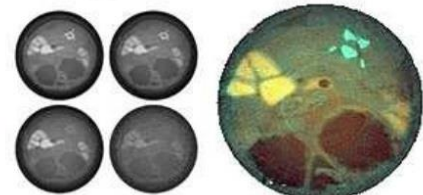
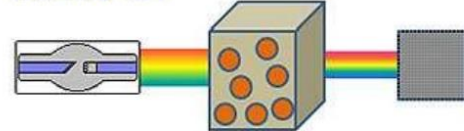
Standard CT



Dual energy CT



MARS-CT



Source

Subject

Detector

Data

Result

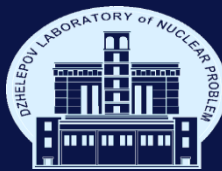
## 1. Medipix – counting mode

2. Time-over-Threshold (TOT) each pixel records the energy deposit of particles interaction with corresponding sensor segment

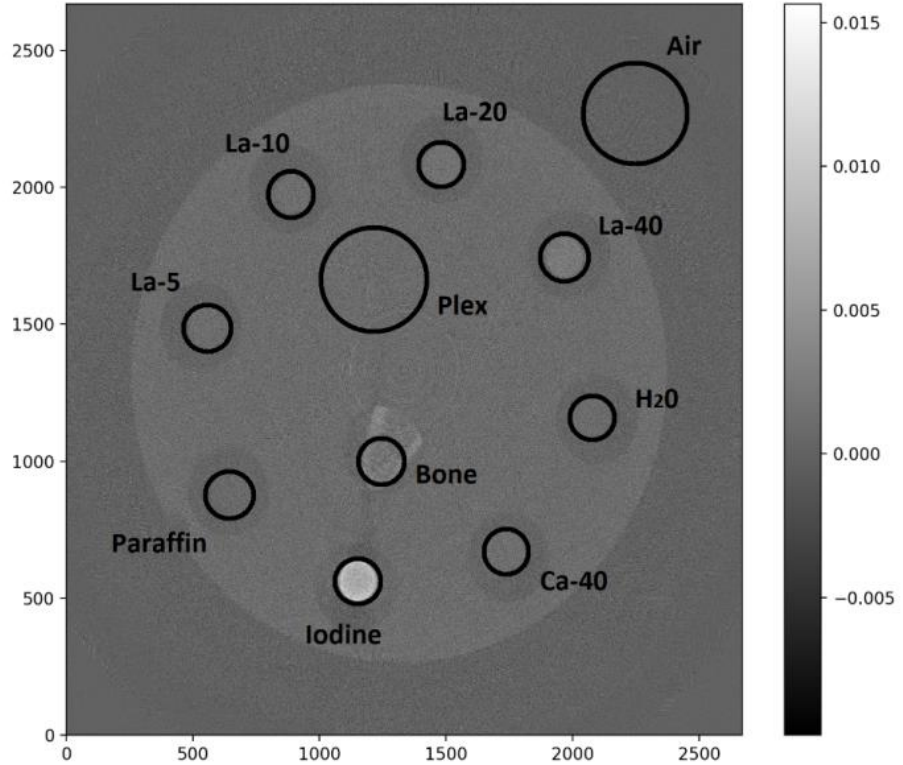
3. Time-of-arrival (TOA) - each pixel records the arrival time of particles interaction with corresponding sensor segment



# Multi-energy tomography



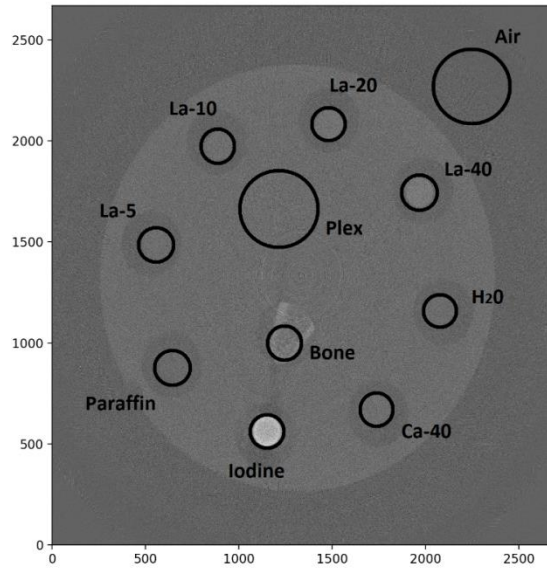
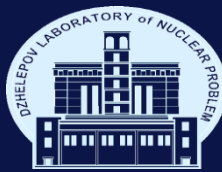
Phantom "Eva"  $\varnothing$  70 mm



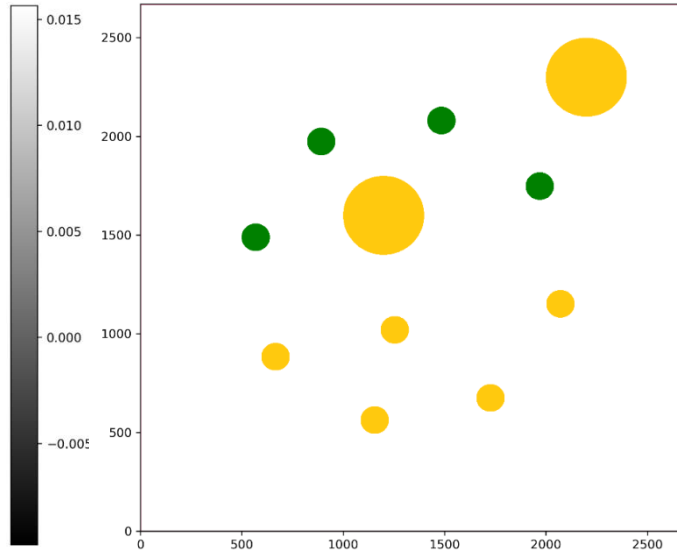
Phantom slice



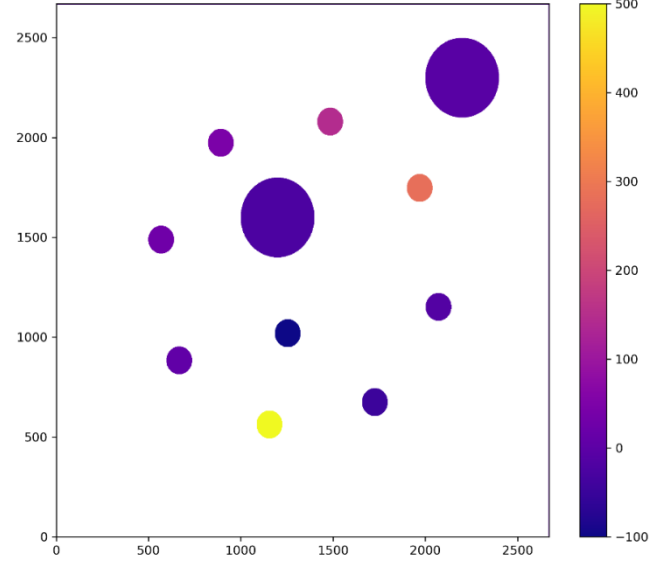
# Multi-energy tomography



Phantom slice



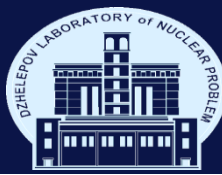
Green color - samples with La.  
Yellow color - samples without La/



La concentration



# Summary



- Spatial resolution  $\sim 0.8$  mm for the field of view 30 mm x 30 mm
  - Sensor with CdTe significantly increase registration efficiency
- Developed system can be modify by changing mask type and geometric parameters
- Micro-SPECT system can used for preclinical studies for small animals
- Multimodal system based on pixelated detector with counting mode can significantly increase obtained information





Thank you for attention!

rozhkov@jinr.ru