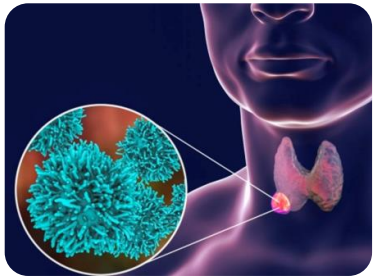
ThyroPIX

Mobile Compton camera based on Timepix3 technology
for monitoring thyroid gland cancer treatment

The current status and its difficulties

diagnostics



diagnosis

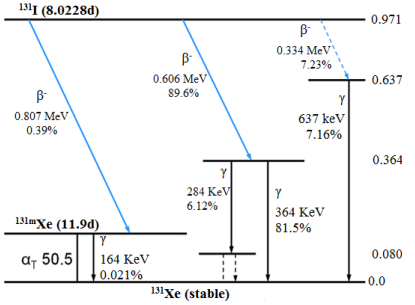
resection

radioteraphy

MONITORING

Difficulties

- **Terapheutic** dose – the high-intensity of radiation (saturation).
  - imaging - decrease of activity in the body.
- Low spatial resolution – small remnants.
- Non-personalized dose – 3 or 7 GBq.



Goal

Development of the mobile robotic gamma camera of new generation for thyroid gland imaging by the nuclear medicine methods.

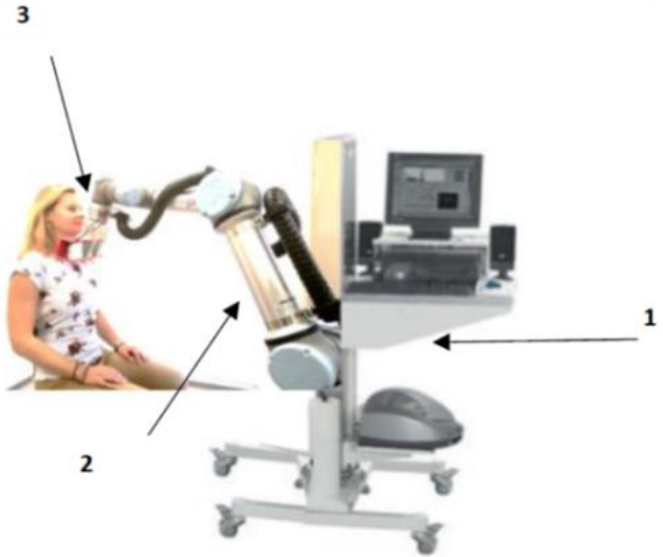
Benefits of our solution

- Imaging of high therapeutic activities of the radiopharmaceutical in the target volume for treatment verification.
- Ability to detect high photon fluxes.
- High spatial resolution imaging that cannot be achieved with current generation gamma cameras that use a collimator.
- Reduction of applied diagnostic activities due to high detection efficiency.
- Reduction of data acquisition time due to high detection efficiency.
- Combination of planar and tomographic scanning (2D and SPECT).
- Mobile camera concept.

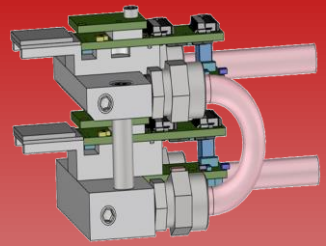
The imaging system

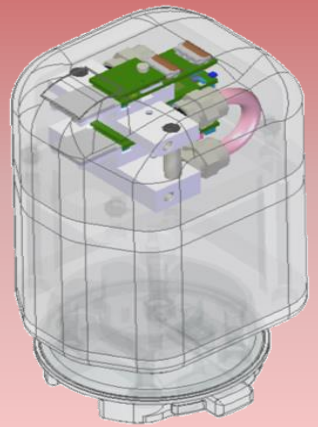
1. **HW** and **SW** for the system control, data colection, reconstruction, and analysis.
2. **Colaborative robotic arm.**
3. **Detection unit** – configuration of two hybrid pixel detectors working in Compton camera mode.

Colaborative robotic arm



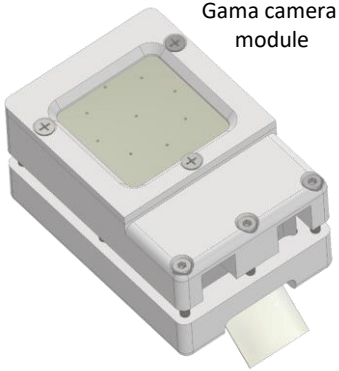
Double-layer Compton camera configuration

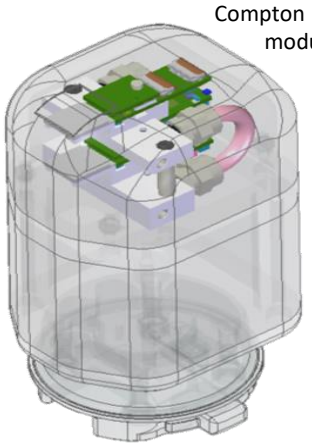




Encapsulated imaging unit

Imaging unit



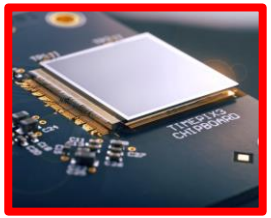


Imaging configuration

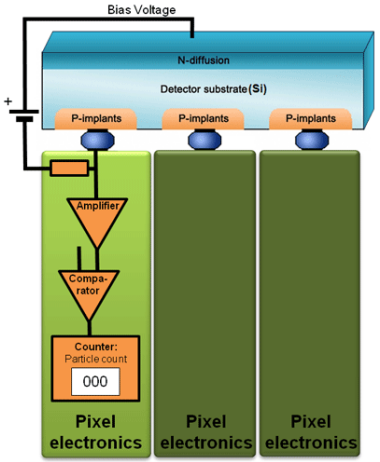
- Gama camera - imaging using collimators
  - (low energy, local diagnostics) – TPX3.
- **Compton camera imaging**
  - (high energy, single or double layer) – TPX3.

Gama camera unit

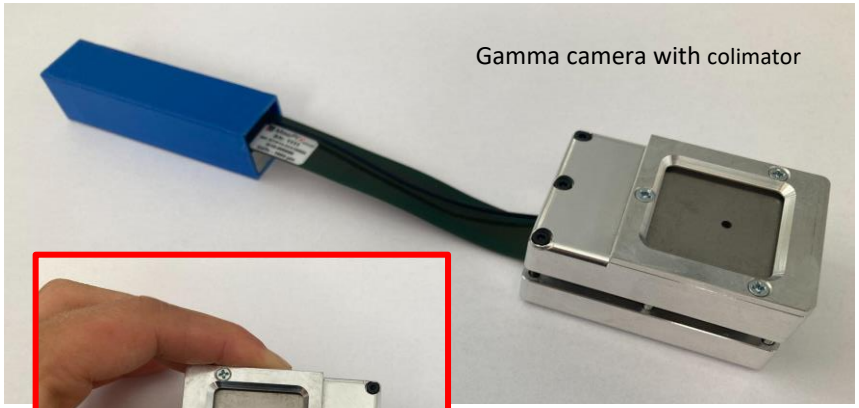
- Small gama camera – close to the patient body (robotic arm).
- Suitable for the examination where current cameras are not usable.
- Low energy, low weight.

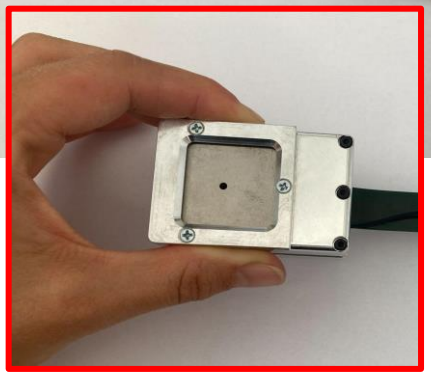


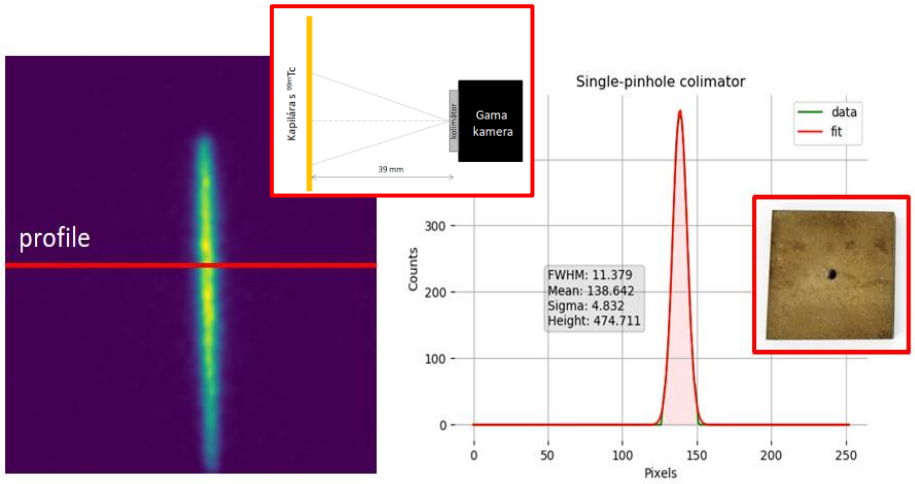
- MiniPIX TPX3 flex version (1mmCdTe).
- Pinhole collimator and sensor config. – low efficiency → long measurement.
- Multipinhole colimator - SW tools for reconstruction.



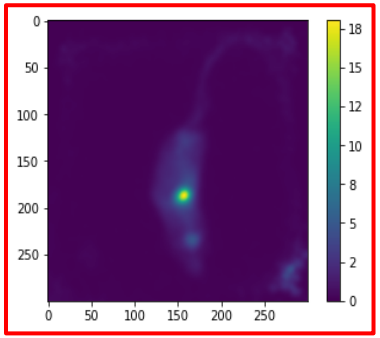
Gama camera unit







Preclinical tests with the gama camera

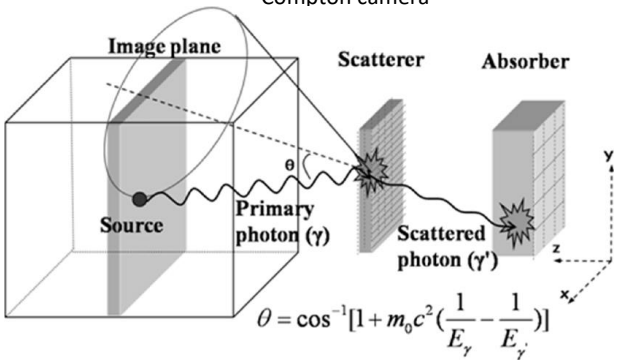


Compton camera unit

Principle

- SPECT method without the use of a collimator → higher detection efficiency
- **Principle:** Utilization of Compt. scattering in the first detector layer (second absorption layer) → information about time and energy → the original direction of the photon can be reconstructed → source localization

Principle of the Double-layer Compton camera



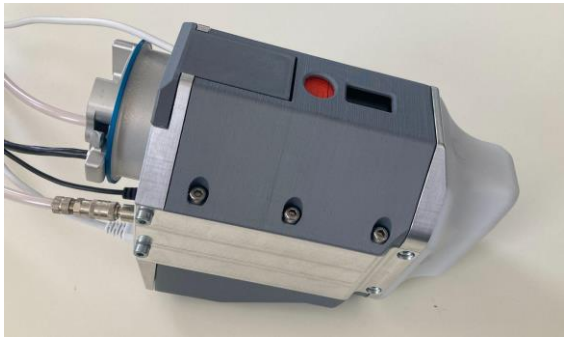
Compton camera unit and its parameters

- AdvaPIX TPX3 Quad Flex
- Quad Electronics – Two modules fully synchronized
- Max hit rate: 10 Mhits/S
- Detectors configuration:
  - First layer: **1 mm Si**
  - Second layer: **1 mm CdTe**

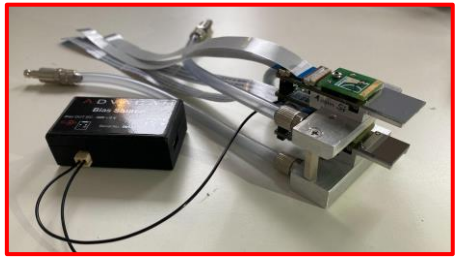
Why we choose the double layer Compton camera?

- Lower detection efficiency – angle, thickness, materiál.
- Better spatial resolution → energy resolution.
- Regulation of the data flux.
- Easier data reconstruction.
- Non random coinc. Events.

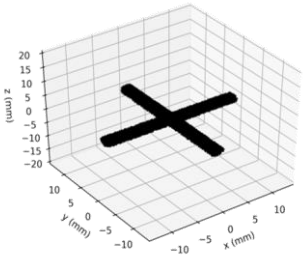
Imging module with the laser sensor

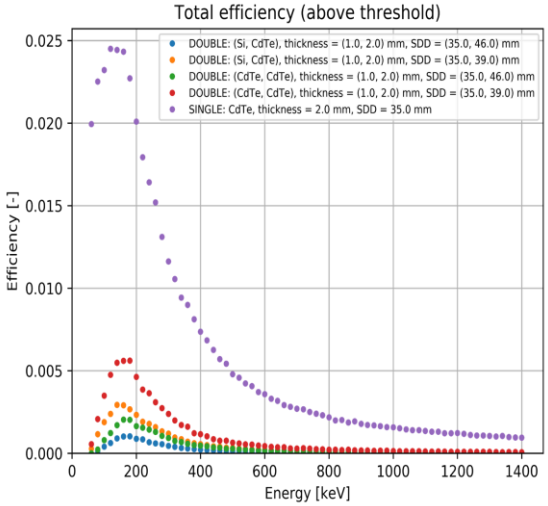


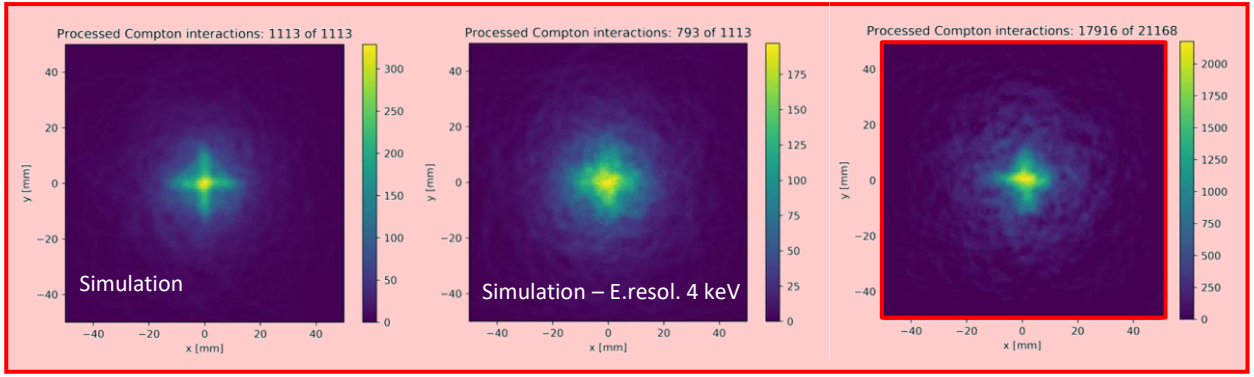
Double-layer Compton camera



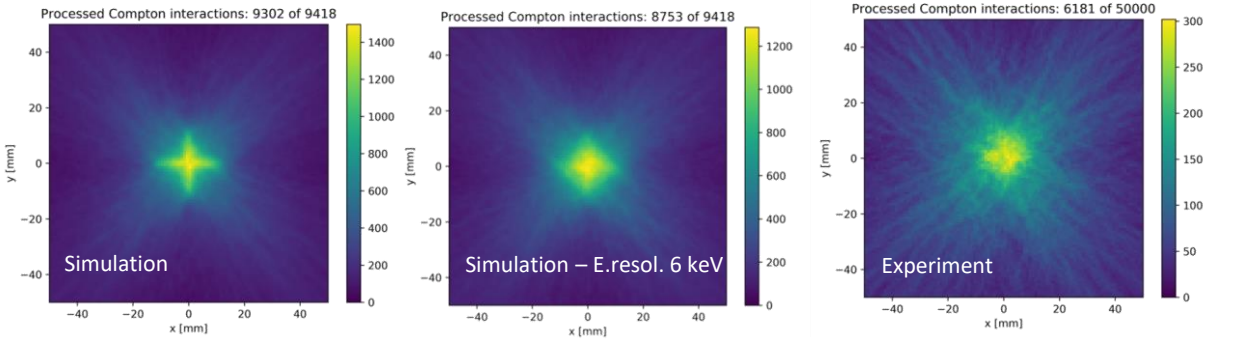
Comparison of imaging properties of SLCC and DL





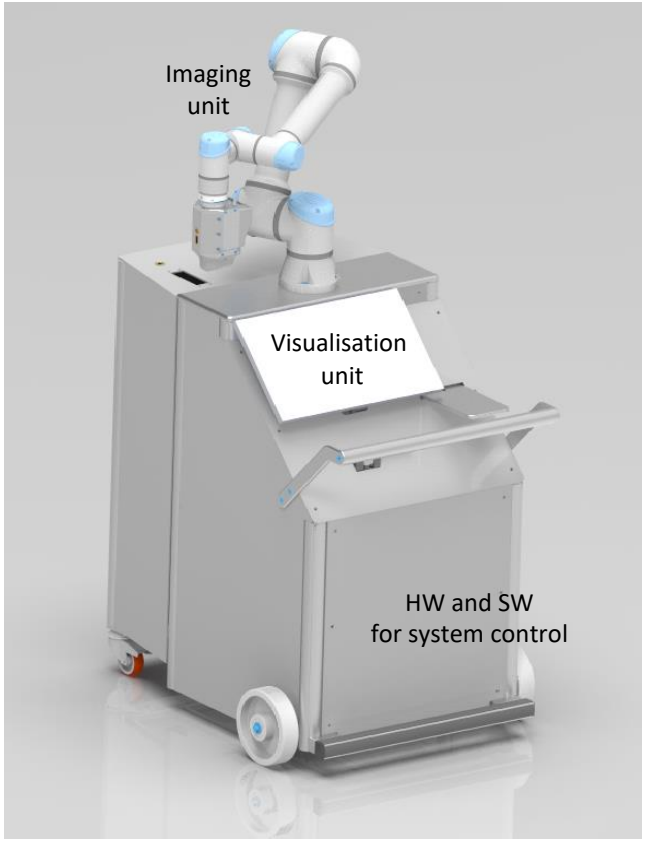


Double-layer Compton camera

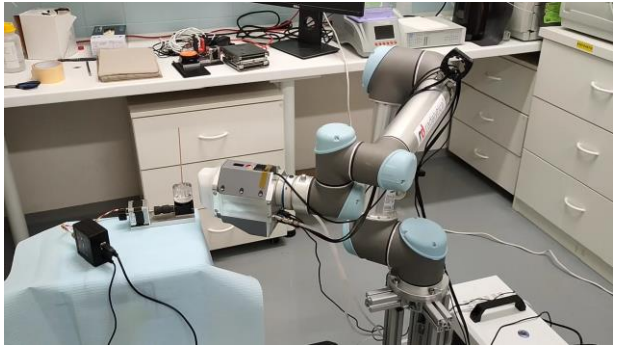


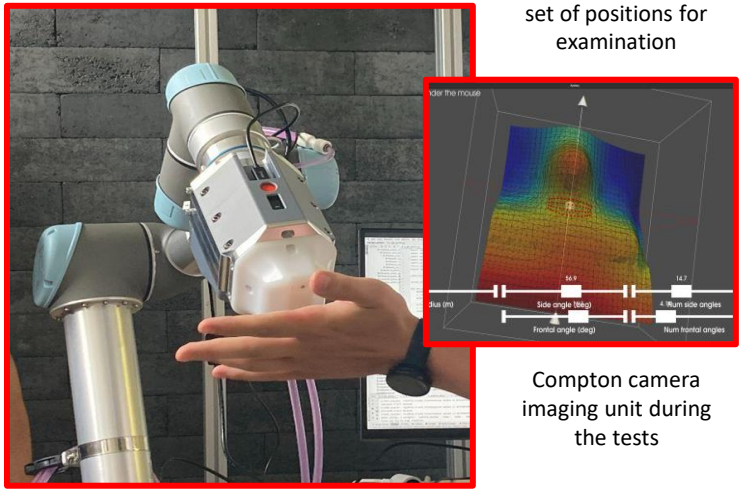
Single-layer Compton camera

Imaging system



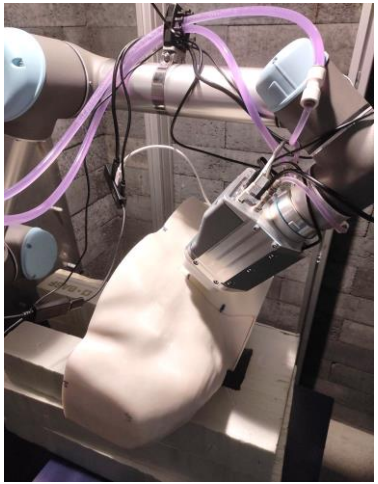
- Imaging unit
  - Compton camera
- Software unit
  - Acqusition software
  - User software
  - Reconstruction software
- Safety features – distance laser sensor
  - Robot positioning
  - Trajectory planning





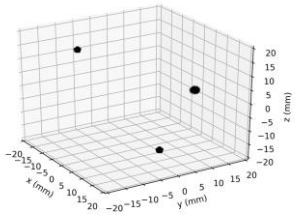
set of positions for examination

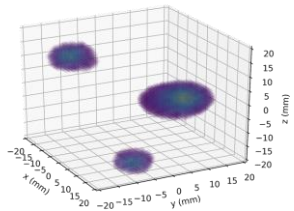
Compton camera imaging unit during the tests



Results – reconstruction methods SIMULATION

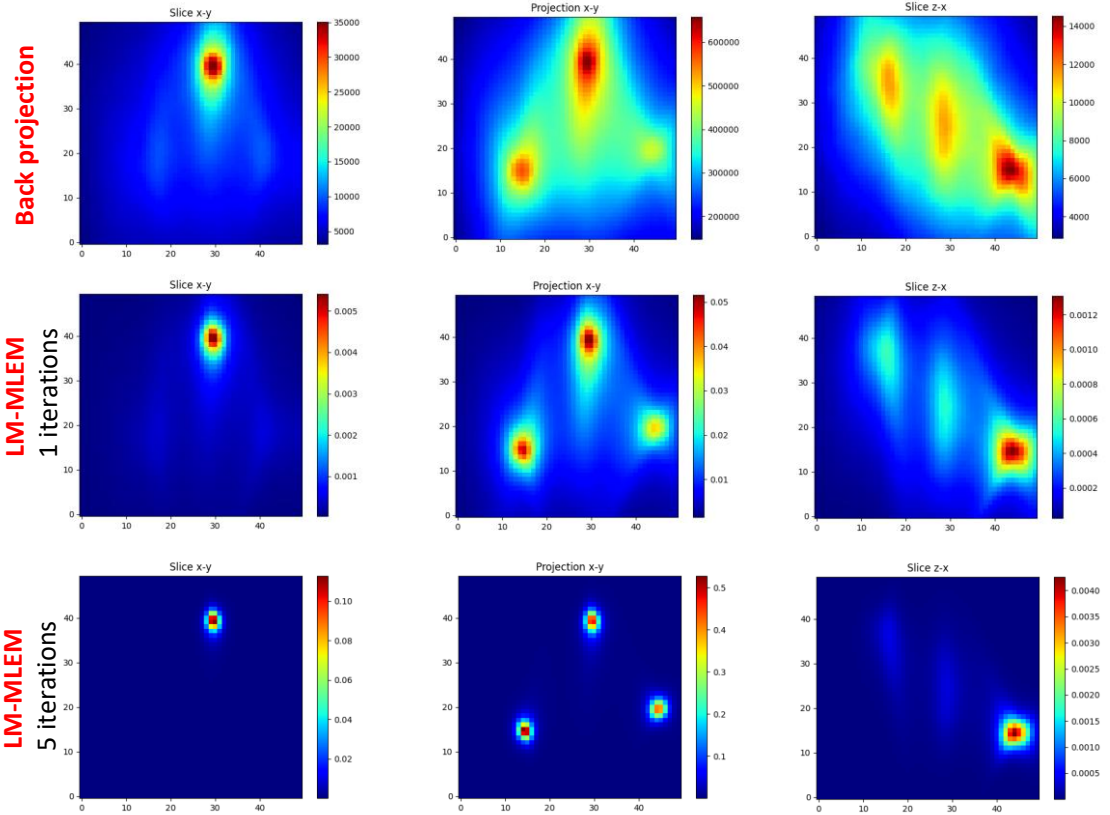
- **Imaging** - based on the reconstruction
- → development and optimization
- Optimization of the reconstruction
  - **Simple back projection** - projection of the cones into the space
  - **LM-MLEM** - iterative reconstruction, easier implementation, more accurate





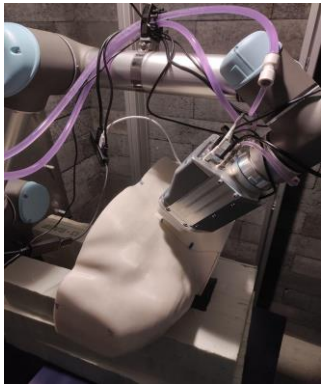
SIMULATION

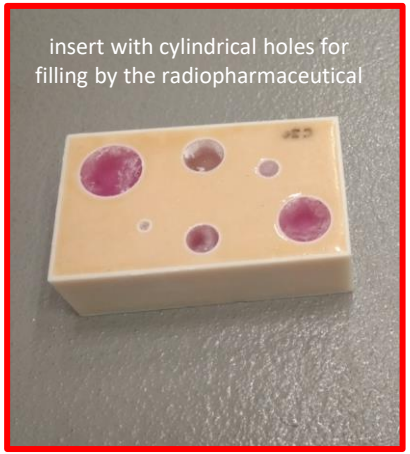
- ^{131}I in the form of 3 balls – 1mm, 1mm and 2mm
- Scanning parameters: 360°, 72 projections
- 1200 coinc. events
- reconstruction volume is 50x50x50mm
- No postprocessing (filter, gamma correction atc.).
- **Reconstruction duration**
  - 13,1 s - Back projection
  - 43,6 s - LM-MLEM



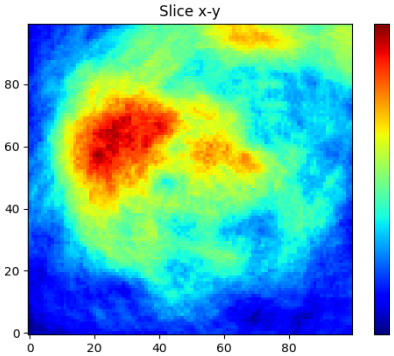
Results – reconstruction methods EXPERIMENT

- Amorphotropic phantom – ELVIS with inserts.
- Insert with cylindrical focus.
- ^{133}Ba .
- One projection processed - one measuring position.



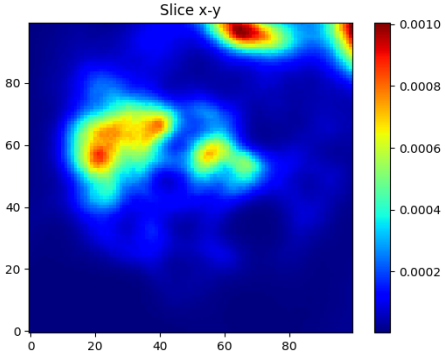


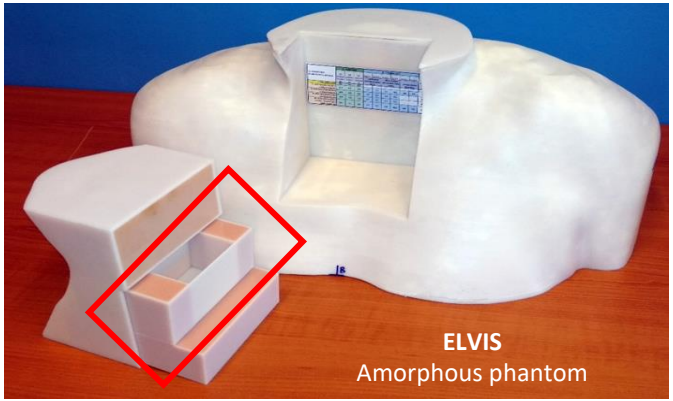
Back projection



Vs.

LM-MLEM - iterative



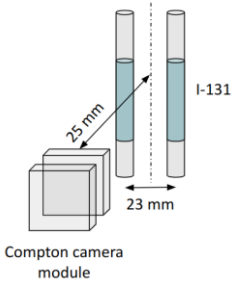


Measuremnents with ^{131}I

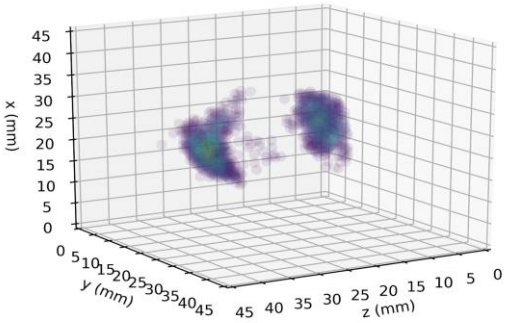
- Department of Nuclear Medicine and Endocrinology at Motol Faculty of Medicine.
- Liquid ^{131}I and iodine capsules.

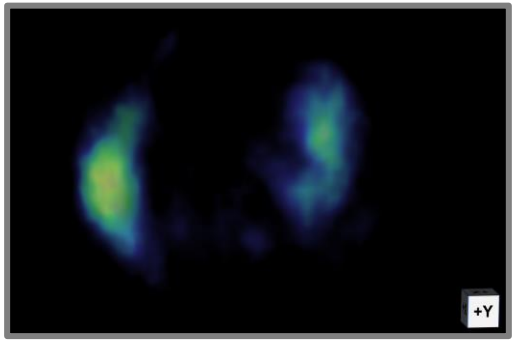
EXPERIMENT I.

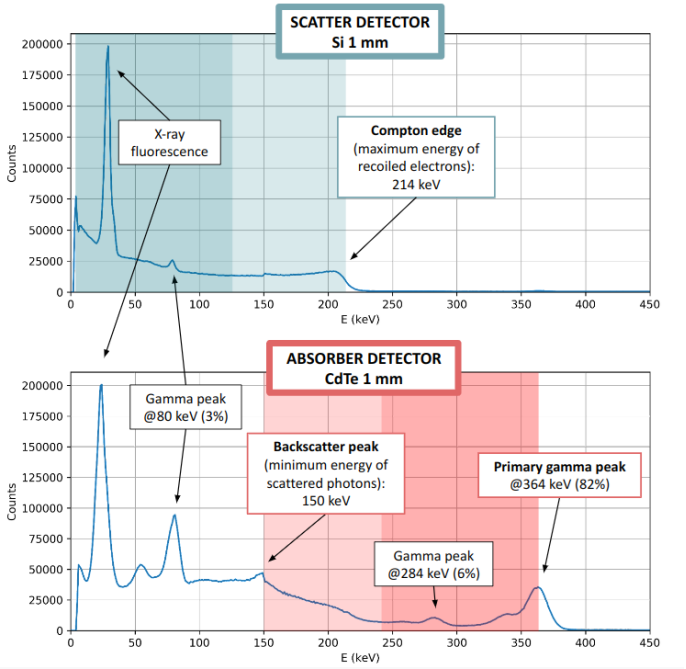
- 2 capilars of inner diameter 5mm.
- Liquid iodine.
- Filled to high 20 mm.
- Distance between capilars was 23 mm.
- Measurement at different angles.
- Fixed distance of Com.Cam was 25 mm from the center of sample.
- **Scanning parameters:** 360° , 72 projections, 60 s – one projection.
- **Activity:** 35 MBq.



Compton camera module





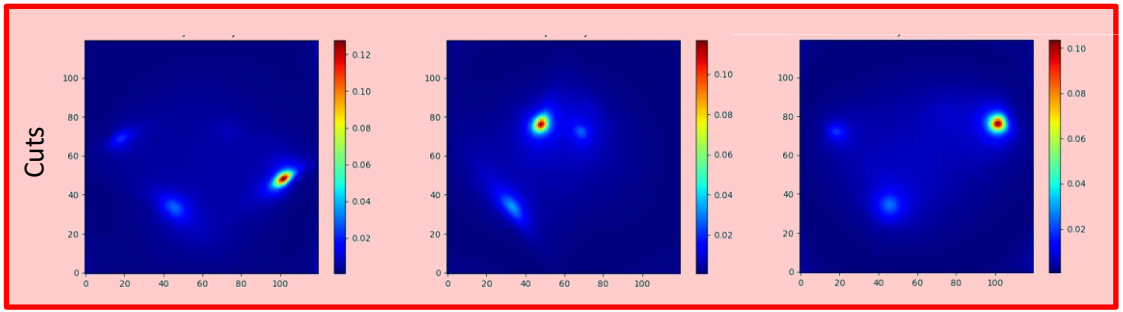


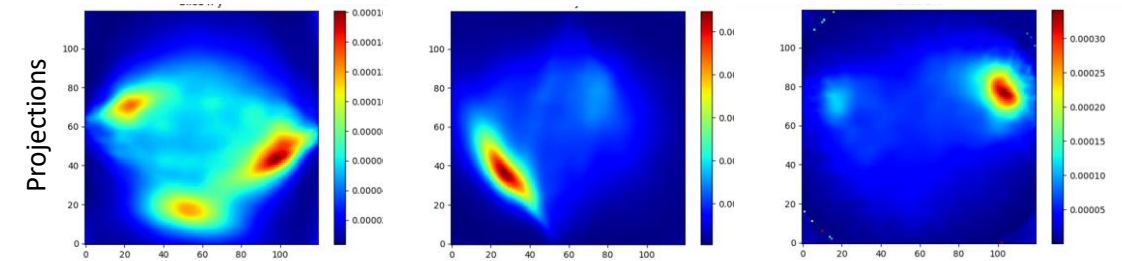
The energy intervals marked with light color correspond to the emerging Compton products. The intervals marked with a darker color represent the energy applied during the reconstruction

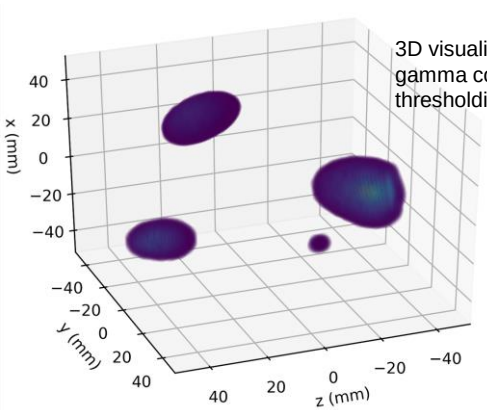
Measuremnents with ^{131}I

EXPERIMENT II.

- 4 capsules of different aktivity - 2x 25 MBq, 1x 10 MBq, 1x 7.5 MBq.
- Glued to plastic cylinders to cover the real scanning volume.
- **Dimensions:** Inner cylinder: **50mm**, External cylinder: **90 mm .**
- Duration of the acqusition: 100 s 360 dg po 5 st.
- Reconstruced volume: 10x10X10 cm.



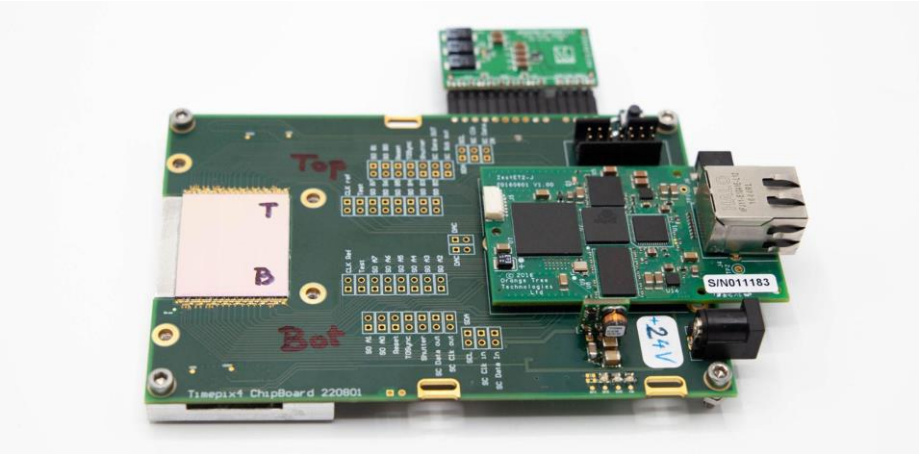




3D visualization using gamma correction and thresholding.

Next steps

- Evaluation of performer test – Elvis with remnants simulated insert.
- Clinical tests on patients.
- Comparative tests with the current modalities.
- Certification of the ThyroPIX as a medical device.
- AdvaPIX TPX4 evaluation – Timepix3 replacement.
- Optimization of reconstruction time.



Thank you for your attention.

Questions?