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Metabolic and Positronium Imaging sensitivity of the Total Body J-PET tomographs

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On behalf of the J-PET Collaboration

J-PET

UNIWERSYTET JAGIELLOŃSKI W KRAKOWIE

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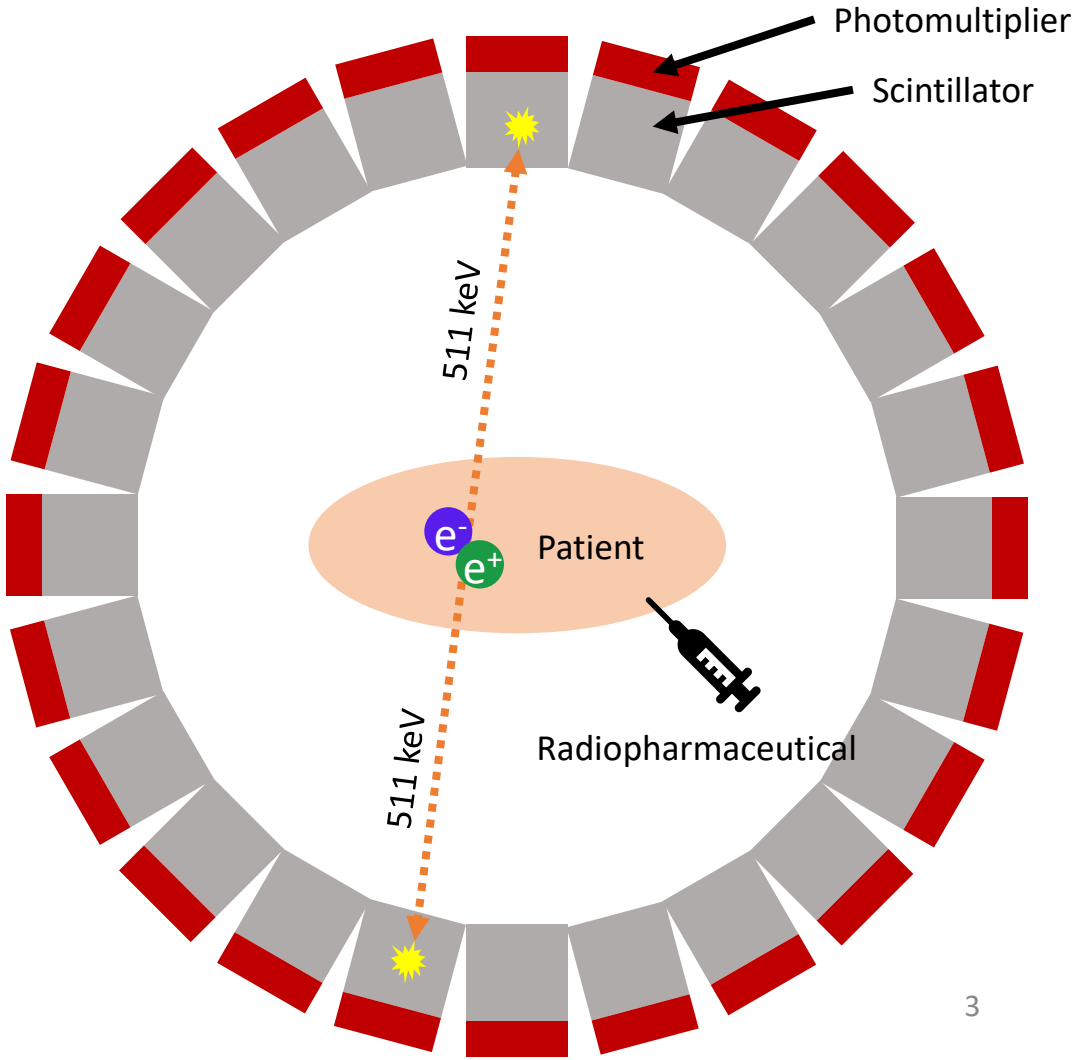
Introduction

Positron Emission Tomography PET

- One of the most technologically advanced diagnostic methods
- Allows for non-invasive study of physiology, metabolism, and molecular pathways in the human body
- The principle of operation is based on the detection of pairs of gamma quanta



Introduction
Metabolic and Positronium Imaging

Metabolic Imaging

- Standard imaging in PET systems
- Based on the back-to-back annihilation photons
- Enables diagnosis of the uptake of radiopharmaceuticals in cells (SUV)

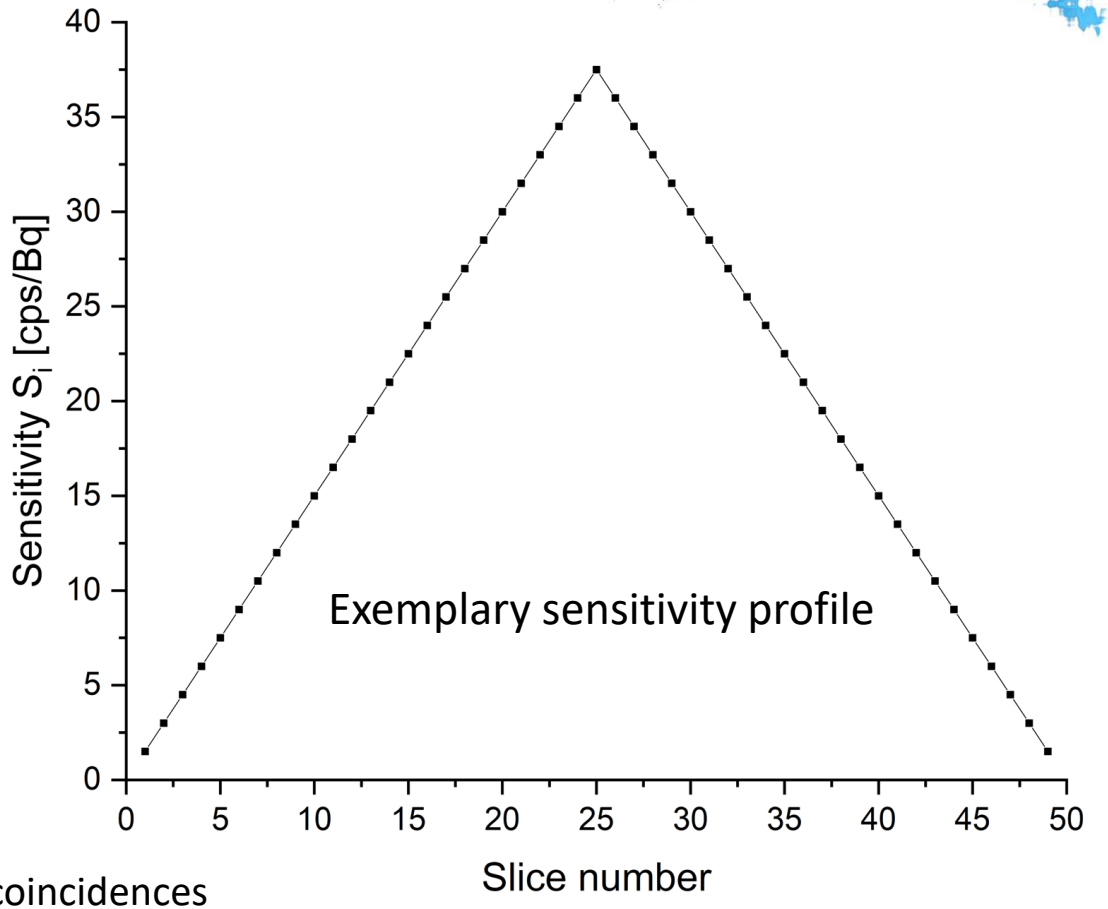
Positronium Imaging

- Complementary to Metabolic
- Based on the back-to-back annihilation photons and deexcitation gamma
- Ortho-Positronium mean lifetime instead of SUV parameter
- Enables imaging of the inner structure of tissues
- Additional diagnostic indicator

Introduction

Sensitivity

- The sensitivity of a PET tomograph is expressed as the true coincidence events rate normalized to the total activity of the source
- According to “NEMA Standards Publication NU 2-2018” guidelines it can be reported as:
  - System (total) sensitivity $S_{tot} = {}^{R}/_{A}$
  - Sensitivity profile, where $S_i = {}^{R_i}/_{A_i}$



R_i - rate of registered true coincidences originating within the i^{th} slice
A_i - fraction of activity located in i^{th} slice

Methods

Tomographs designed with J-PET technology:

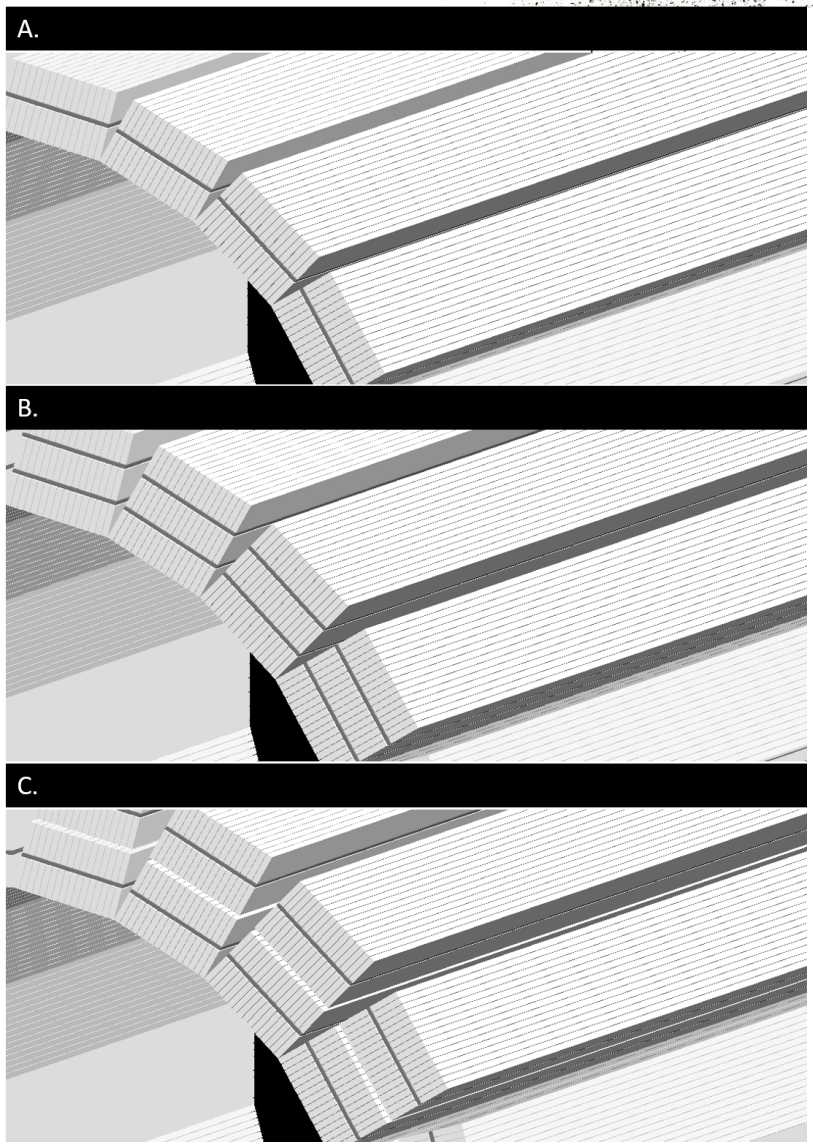
- Scintillator material – plastic (EJ230, Eljen Technology)
- Axial arrangement
- Silicon photomultiplier (SiPM) readout at both ends

Three designs were taken into account:

A. 2 panels × 16 scintillators

B. 3 panels × 16 scintillators

C. 4 panels × 16 scintillators



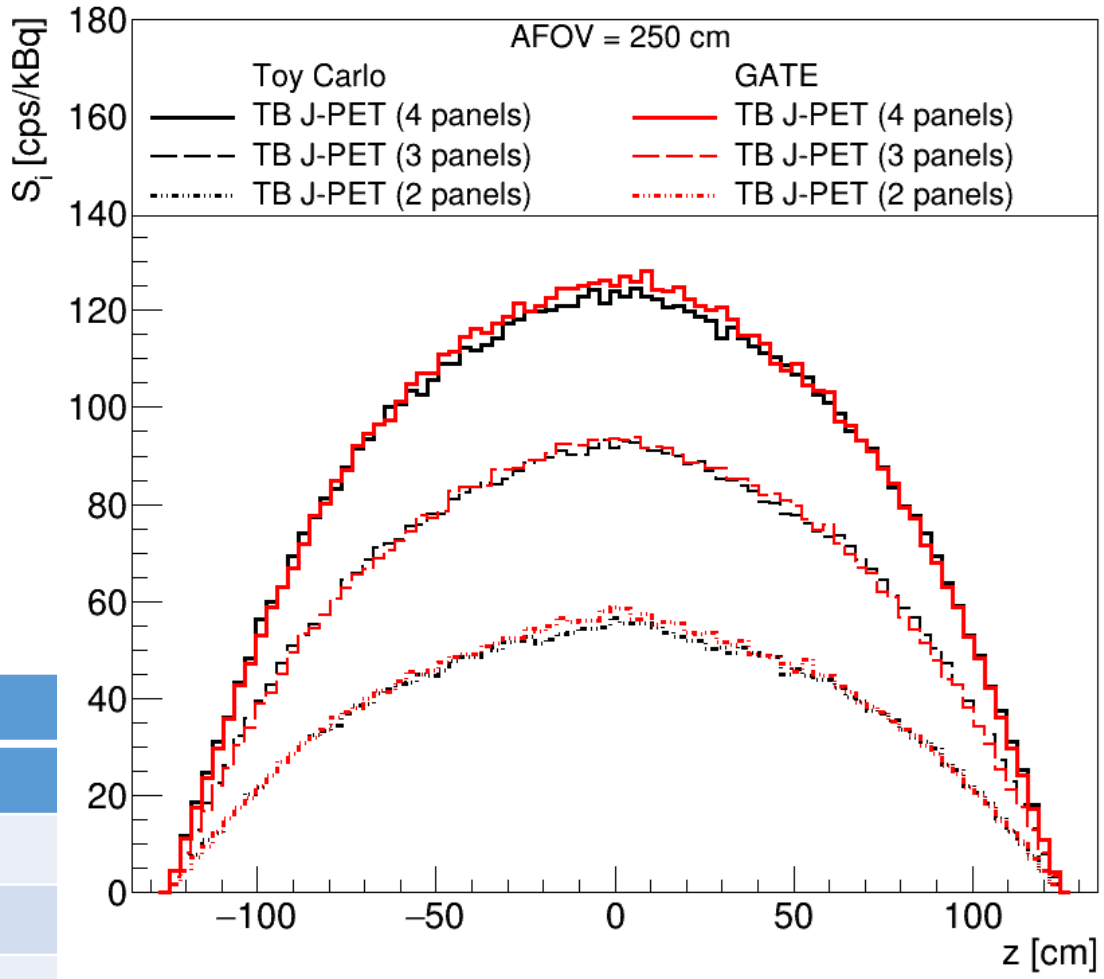
Methods

Presented study was conducted with a use of a dedicated Toy Monte-Carlo model:

- event-by-event basis
- true coincidence registration
- Metabolic and Positronium Imaging

Validation was performed as a comparison with the standard GATE software

Design	S_{tot} [cps/kBq]	
	Toy Carlo	GATE
A.	37.14(06)	36.46(06±07)
B.	62.12(08)	62.21(08±08)
C.	85.47(09)	84.7(0.9±1.1)



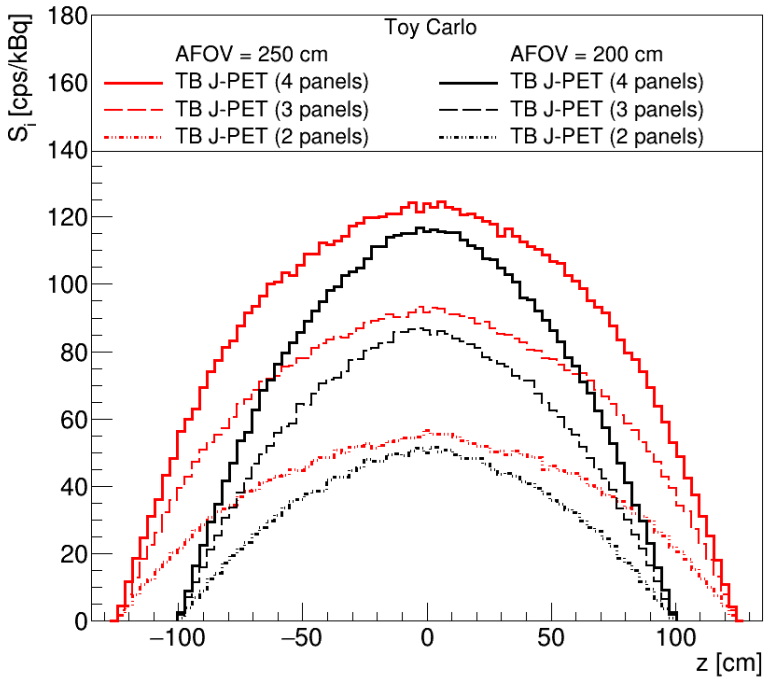
Results

Metabolic Imaging sensitivity

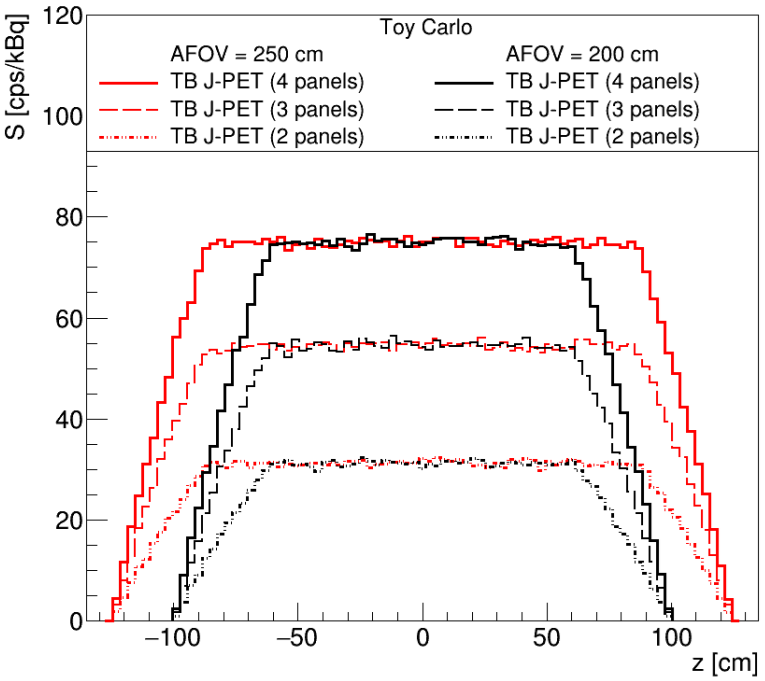
Sensitivity profiles of the 200 cm and 250 cm long (AFOV) Total Body J-PET tomographs:

a. without any conditions

b. with imposed angular acceptance criterion on 45° angle



a.

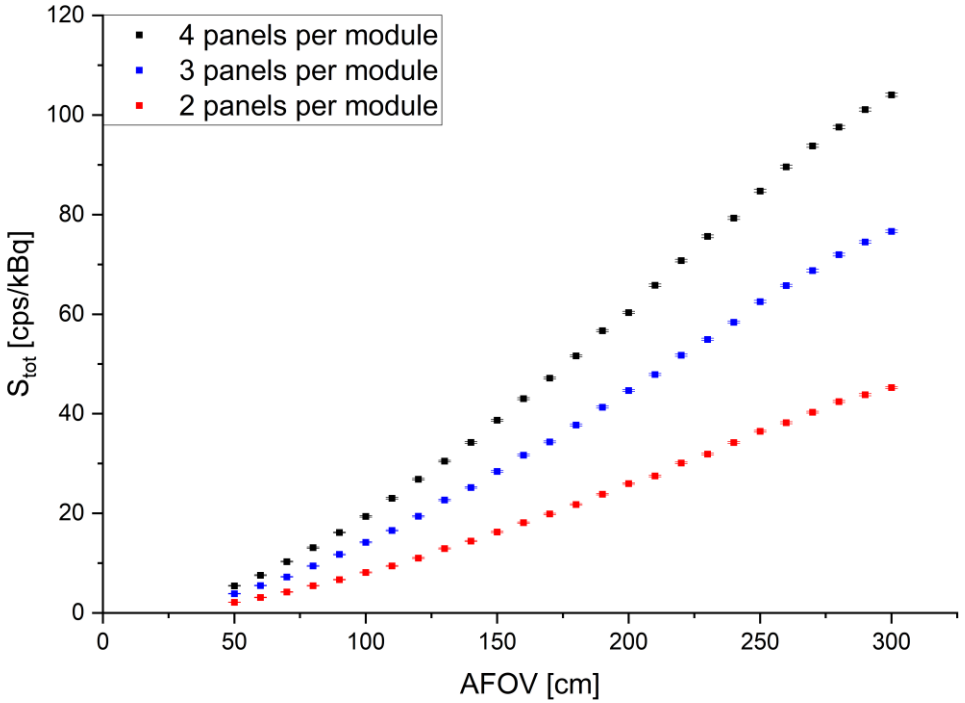


b.

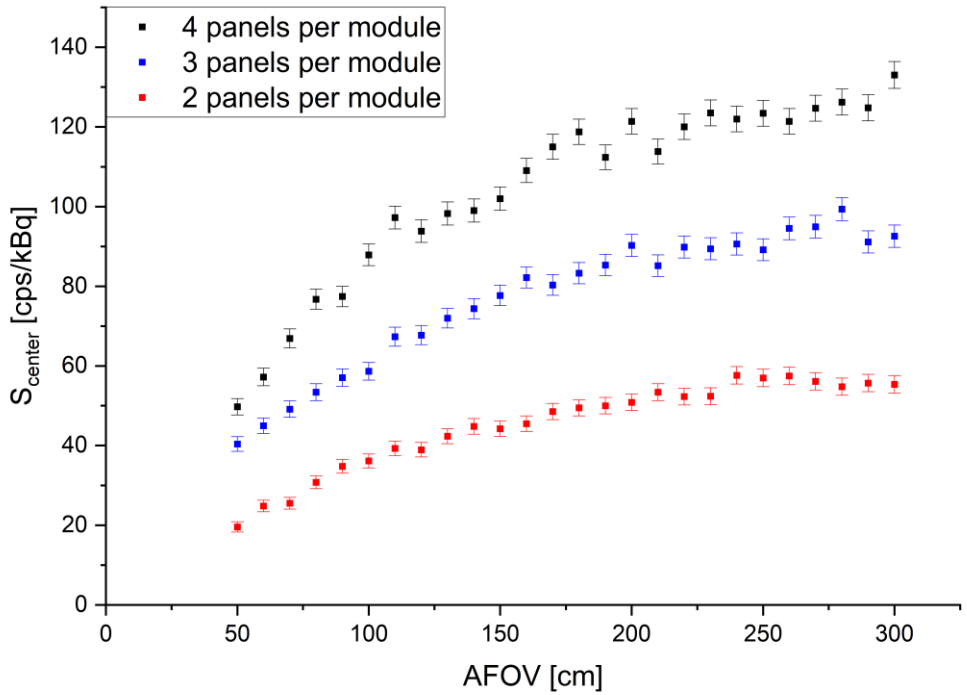
Results

Metabolic Imaging sensitivity

Dependence of the sensitivity on the PET scanner's length



System (total) sensitivity

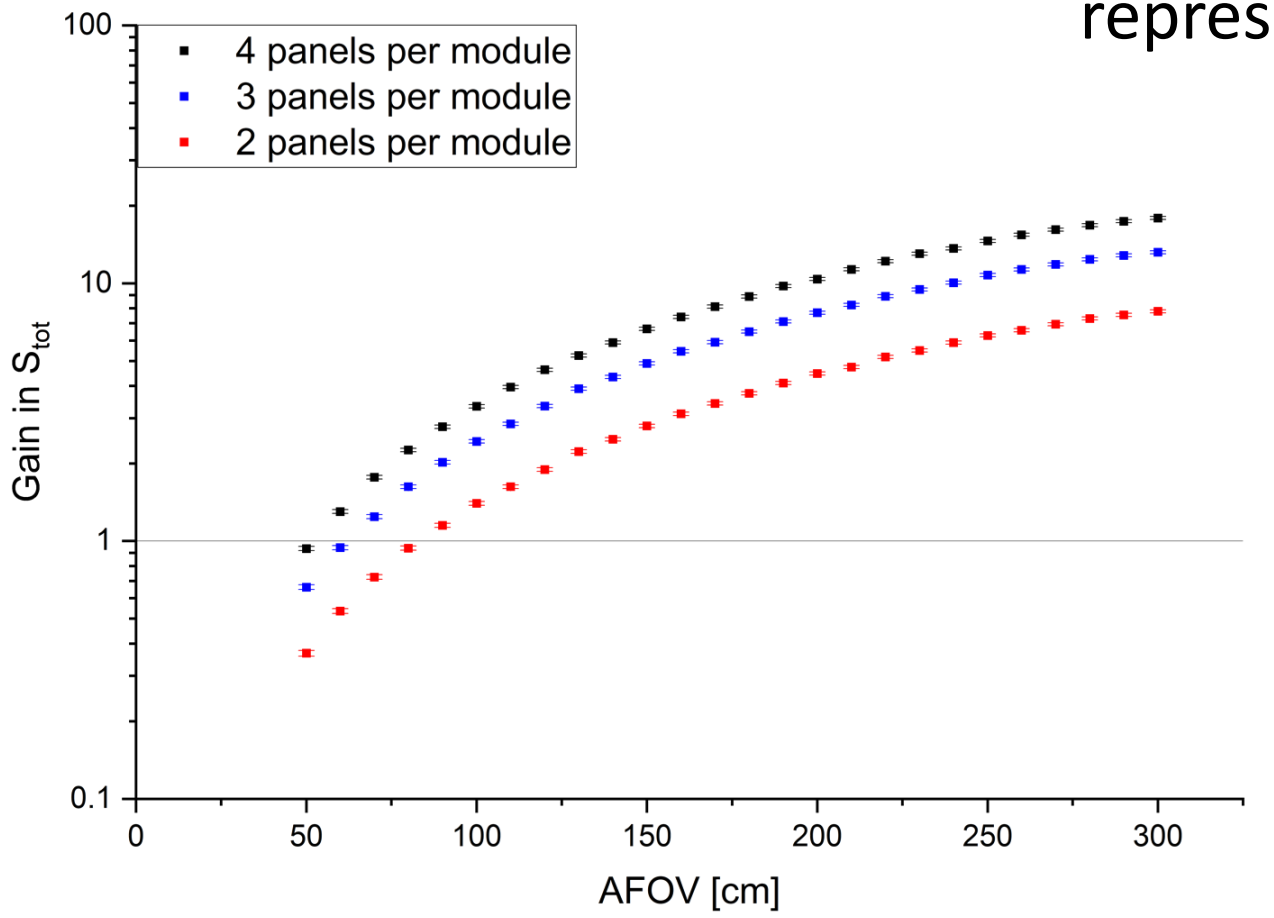


Sensitivity in the center of PET scanner

Results

Metabolic Imaging sensitivity

J-PET technology vs. state-of-the-art conventional short AFOV PET represented by the Biograph Vision



Gain is defined as a ratio:

$$S_{tot}^{J-PET}(AFOV) \Big/ S_{tot}^{Biograph\ Vision}$$

Value of the $S_{tot}^{Biograph\ Vision}$ was estimated to 5.81(08) [cps/kBq]

Results

Positronium Imaging sensitivity

For the study of Positronium Imaging a ^{44}Sc isotope was chosen as a radioisotope. A corresponding reaction chain of β^+ decay:

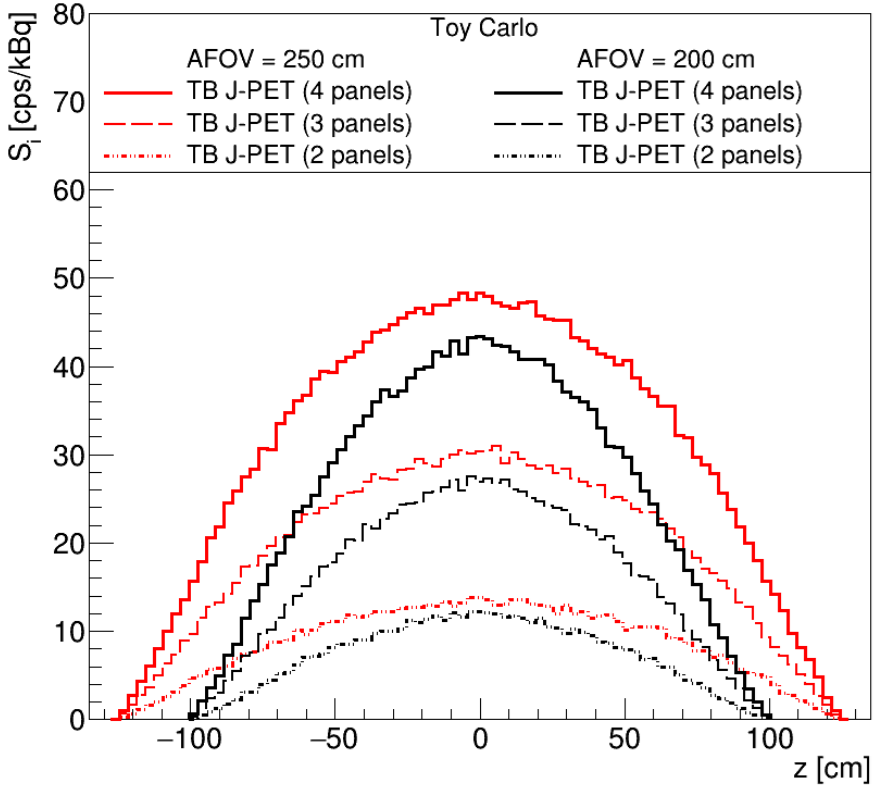
$$^{44}Sc \rightarrow {}^{44}Ca^{*} + e^{+} + \nu \rightarrow {}^{44}Ca + \gamma + e^{+} + \nu$$

creates excited ^{44}Ca* nucleus, which during the deexcitation process emits prompt photon of 1160 keV energy

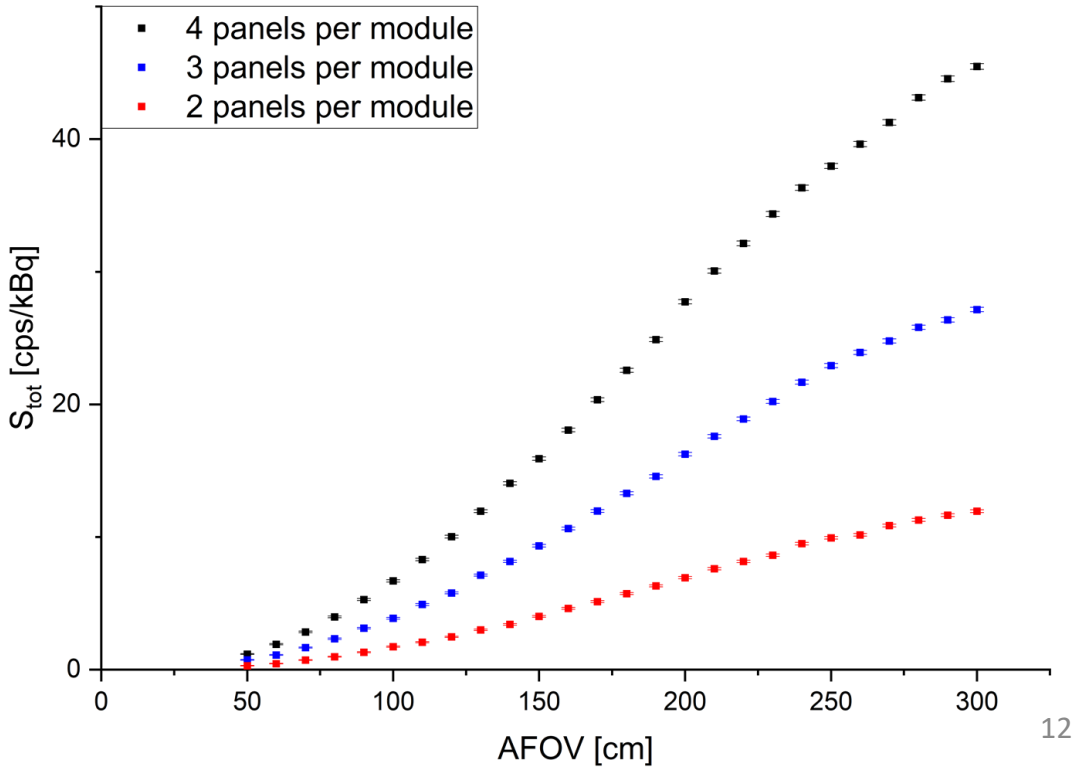
Results

Positronium Imaging sensitivity

Sensitivity profiles of the 200 cm and 250 cm long (AFOV) Total Body J-PET tomographs



Dependence of the sensitivity on the PET scanner's length



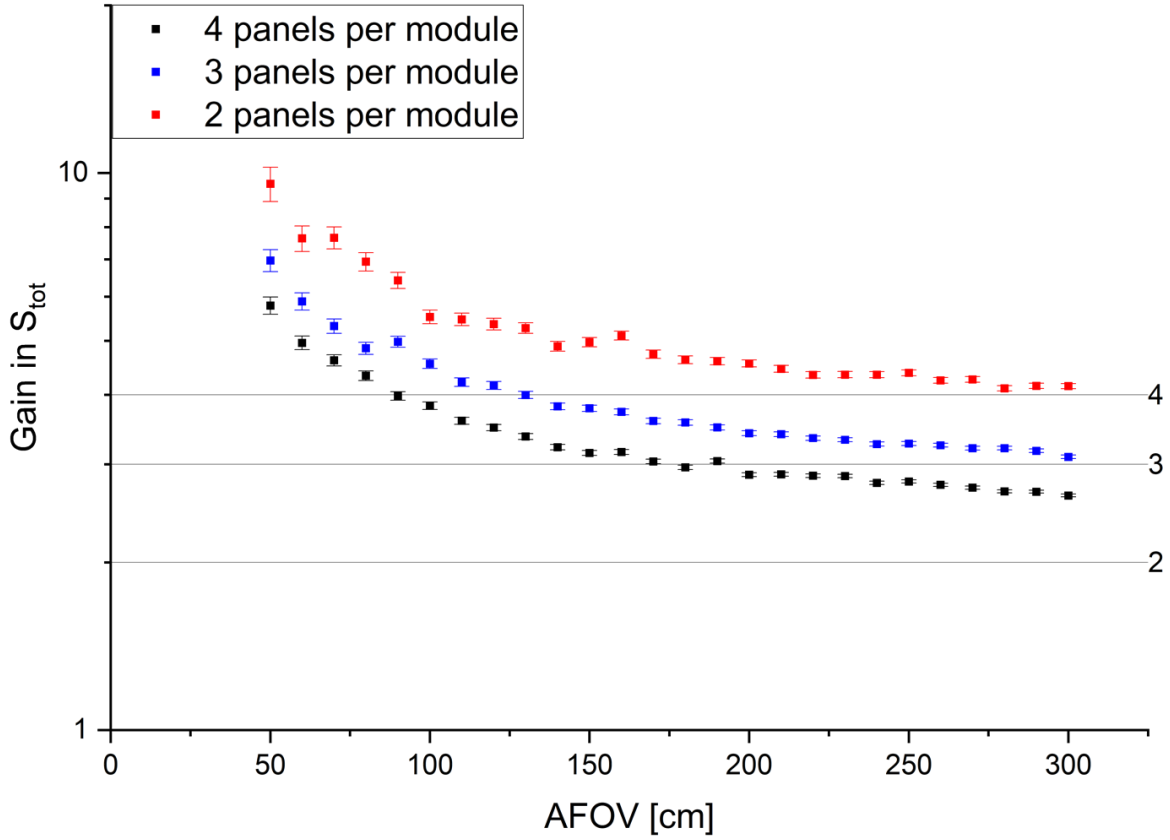
Results

Positronium Imaging sensitivity

Metabolic Imaging with J-PET technology

vs.

Positronium Imaging with J-PET technology



Gain is defined as a ratio:

$$S_{tot}^{Metabolic}(AFOV) \Big/ S_{tot}^{Positronium}(AFOV)$$

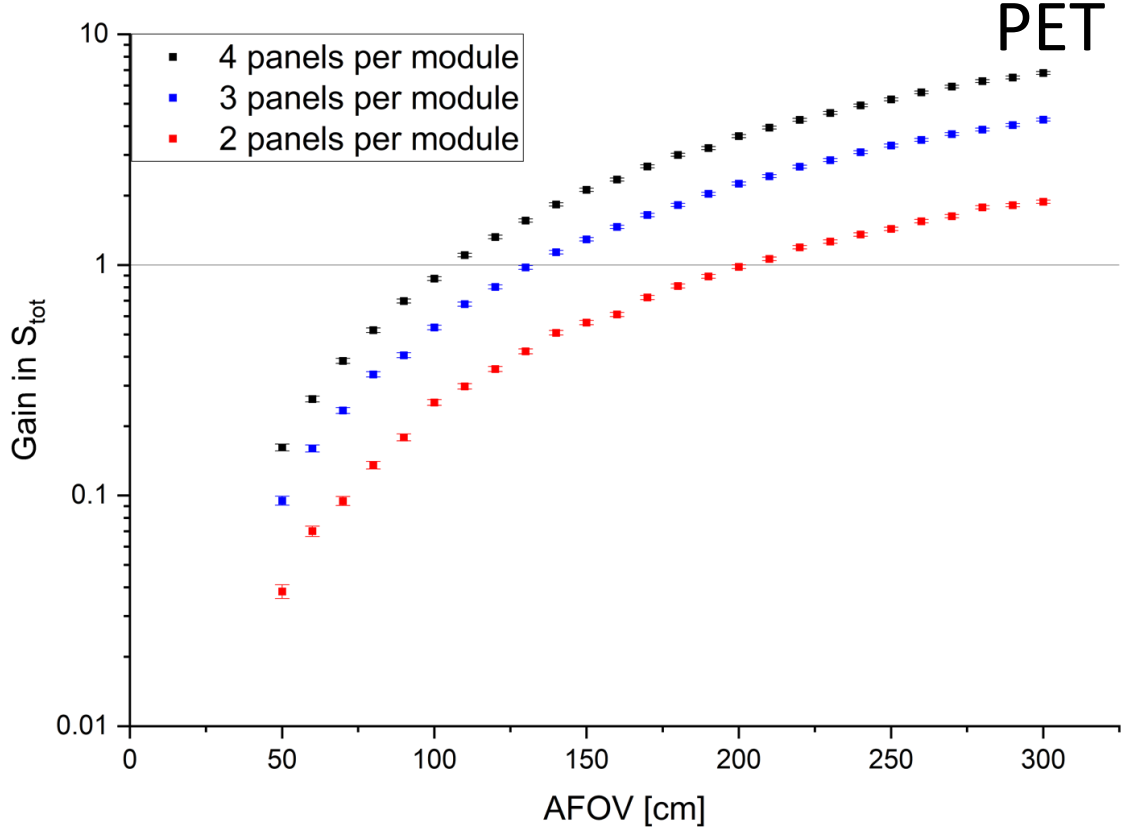
Results

Positronium Imaging sensitivity

Positronium Imaging with J-PET technology

vs.

Metabolic Imaging with state-of-the-art conventional short AFOV PET represented by the Biograph Vision



Gain is defined as a ratio:

$$S_{tot}^{J-PET}(AFOV) \Big/ S_{tot}^{Biograph\ Vision}$$

Value of the $S_{tot}^{Biograph\ Vision}$ was estimated to 5.81(08) [cps/kBq]

Summary

Metabolic Imaging

- System sensitivity up to 84.7(0.9±1.1) [cps/kBq]
- Sensitivity at scanner's center up to 124.1(1.0±1.1) [cps/kBq]
- Uniform simultaneous sensitivity over the patient's body
- Up to ~15 times improvement with respect to conventional short AFOV tomographs

Positronium Imaging

- System sensitivity up to 30.63(06±31) [cps/kBq]
- Sensitivity at scanner's center up to 48.37(64±60) [cps/kBq]
- Only ~3 times worse than Metabolic Imaging
- Up to ~5 times improvement with respect to conventional short AFOV tomographs with Metabolic Imaging

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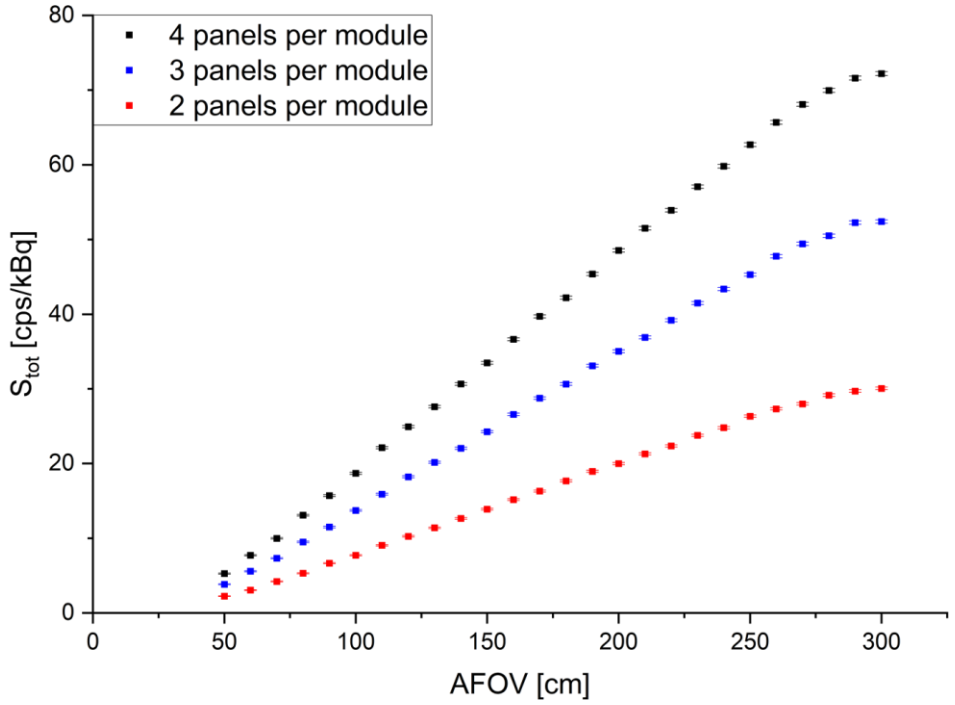
Thank you for your attention

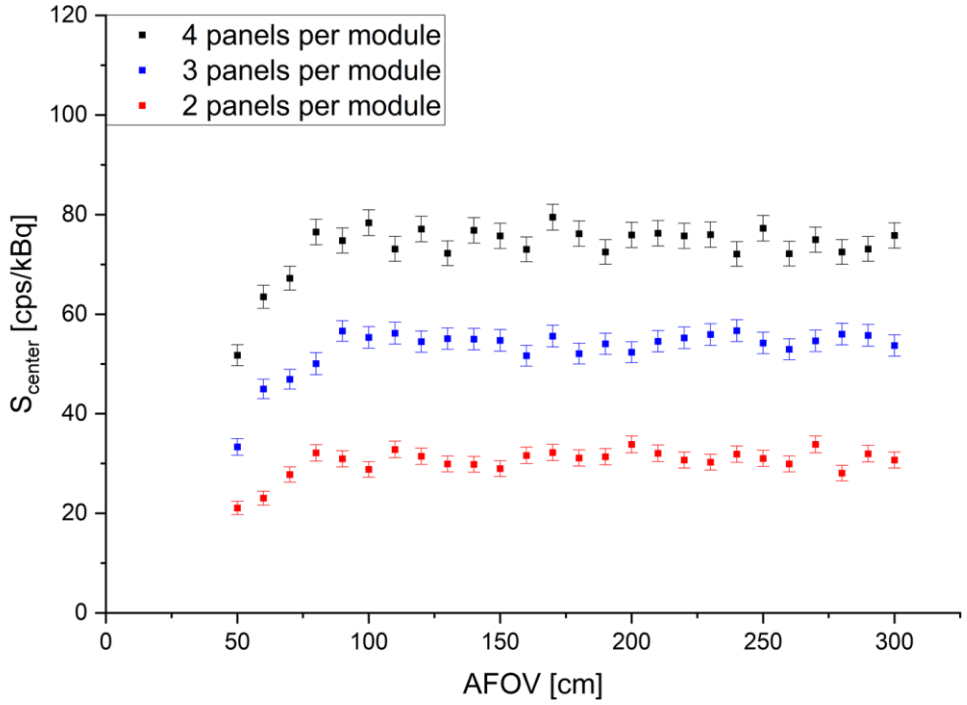
Results

Metabolic Imaging sensitivity

Dependence of the sensitivity on the PET scanner's length after angular acceptance cut



System (total) sensitivity



Sensitivity in the center of PET scanner