National Centre for Nuclear Research Świerk

ŚWIERK COMPUTING CENTRE

Simulations of the J-PET detector response with the GATE package

Author: Paweł Kowalski

pawel.kowalski@ncbj.gov.pl

22nd to 24th September 2014
II Symposium on Positron Emission Tomography

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

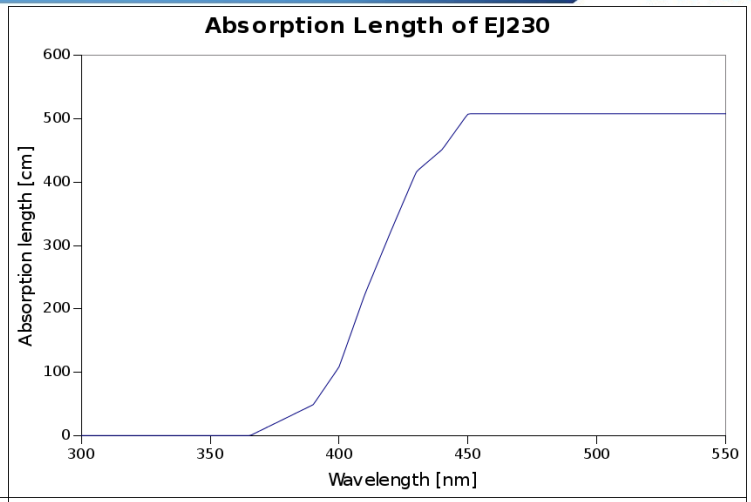
Project co-financed by the European Regional Development Fund under the Operational Programme Innovative Economy

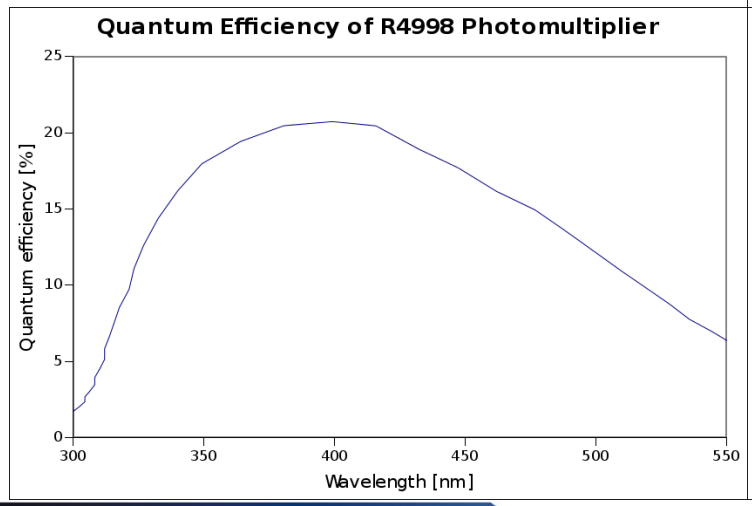
Outline

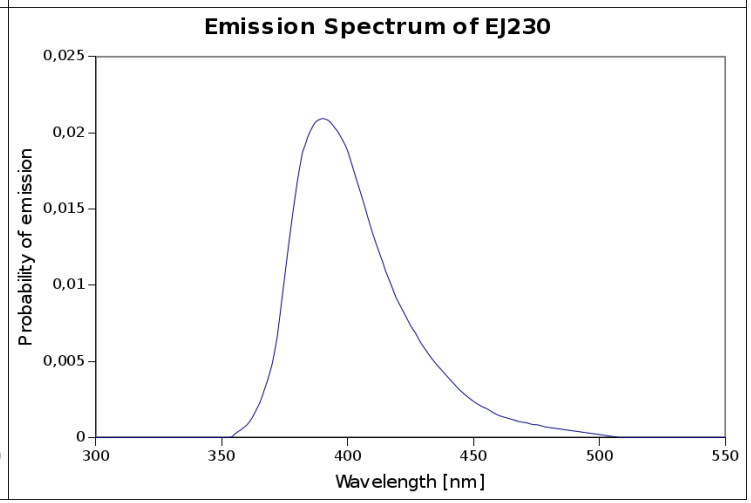
1. Introduction
2. Simulation of the single EJ230 scintillator strip and comparison with the experiment
3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors
4. Summary

1. Introduction

GATE – GEANT4 Application for Tomographic Emission







2. Simulation of the single EJ230 scintillator strip and comparison with the experiment

Goals of the simulations of the single strip:

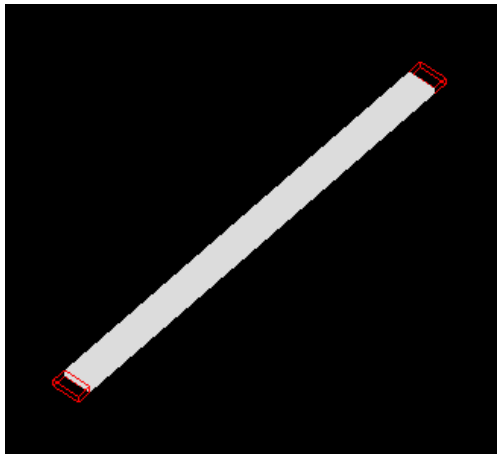
- better understanding of the phenomena in the scintillating strip
- fitting parameters of the simulation to obtain results consistent with the experiment
- preparation of input for hit position reconstruction methods development

...etc.

2. Simulation of the single EJ230 scintillator strip and comparison with the experiment

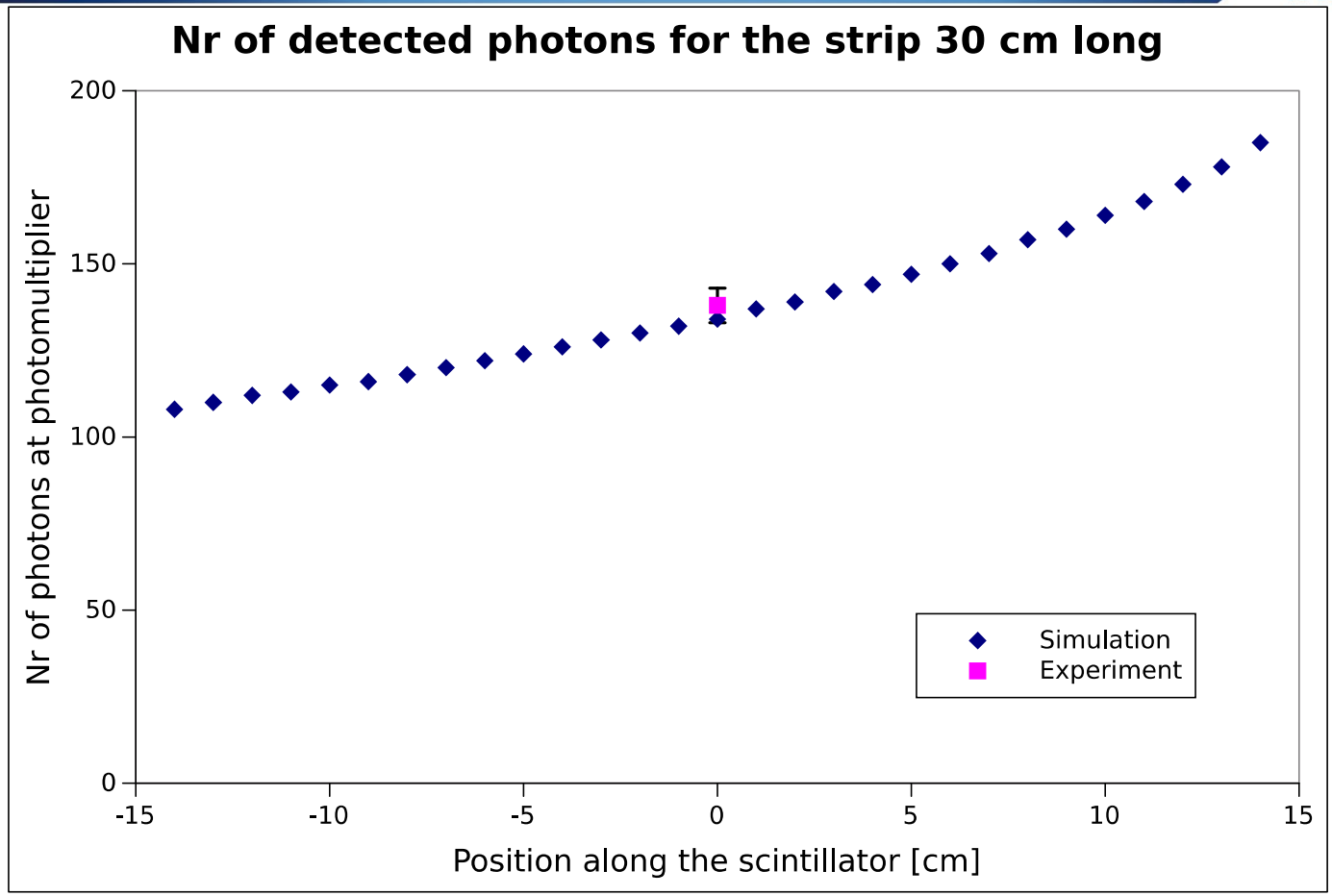
Description of the simulation:

- geometry: single scintillator EJ230 with size 30 cm x 19 mm x 5 mm with two photomultipliers R4998 attached at its ends
- source: point source of optical photons with emission spectrum equal to emission EJ230 moved along and inside the scintillator
    - nr of generated gamma quanta per simulation: 3492 (10,000 simulations for each position)
    - positions of the source along the scintillator:
        - from -14 to 14 cm with step 1 cm



Visualization of the single strip from the GATE software

2. Simulation of the single EJ230 scintillator strip and comparison with the experiment



Results of the experiment are described in the publication: *Test of a single module of the J-PET scanner based on plastic scintillators*, P. Moskal et al.

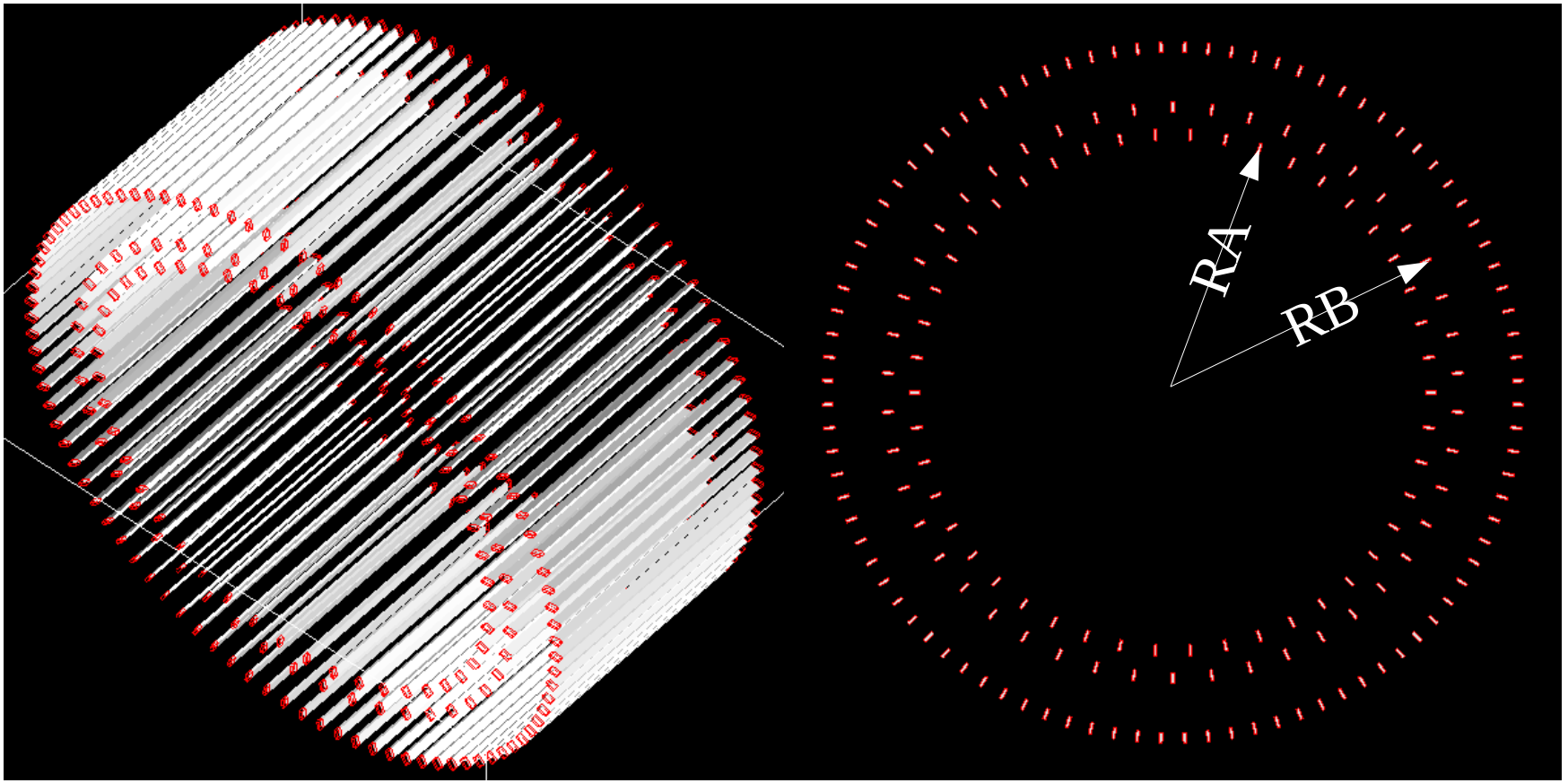
3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors

Goals of the simulations of the full geometry Strip-PET scanner:

- optimization of the radiuses of the inside and the middle layers of the Strip-PET scanner for number of true and false coincidences (the outside layer has fixed radius)
- optimization of the level of energy (energy deposited in single strip) threshold for number of true and false coincidences

...etc.

3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors



RA – radius of the inside layer,
RB – radius of the middle layer

3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors

Description of the simulation:

- geometry: 192 scintillators EJ230 with size 50 cm x 18 mm x 7 mm with two photomultipliers R4998 attached to the ends of each scintillator
  - radius of outside layer – 585 mm
  - radiuses of the middle (RB) and the inside (RA) layers – 15 different combinations were tested

- source: point source of back-to-back gamma quanta with energy 511 keV
  - position of source - the center of the Strip-PET scanner
  - number of generated back-to-back gamma quanta – 1,000,000
  - directions of flights of quanta - perpendicular to the axis of the Strip-PET scanner

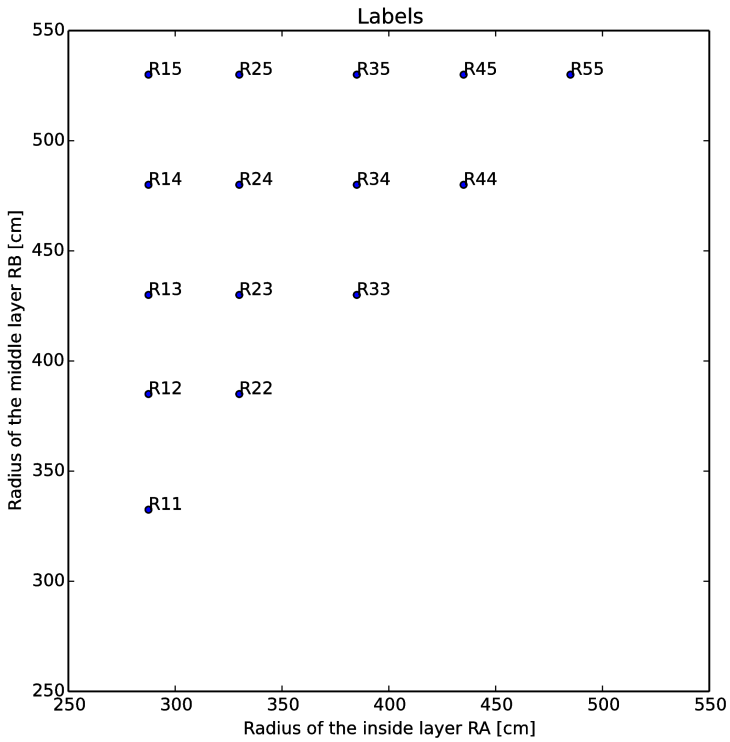
3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors

Optimization task:

What are the most optimal radiuses of the inside and the middle layers?

- minimal distance between two layers 4.5 cm
- minimal distance between detectors in each layer ~ 3.8 cm

-> minimal radius of inside layer: 287.5 mm
-> maximum radius of middle layer: 530 mm



Simulations were performed for 15 pairs of the radius of the middle layer (RB) and the radius of the inside layer (RA).

3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors

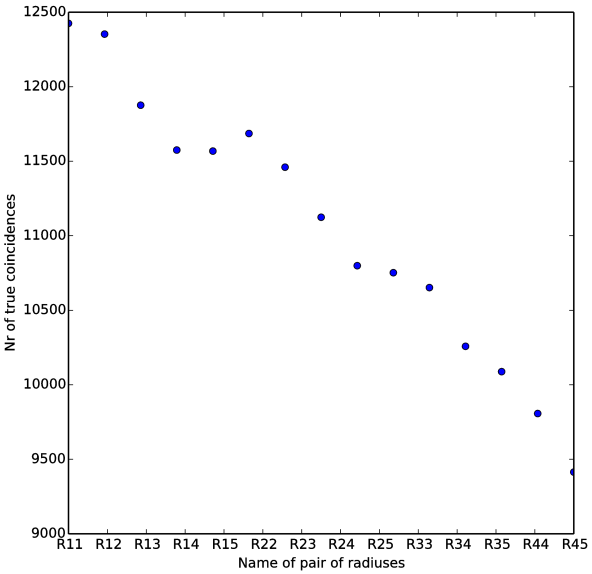
What should be the criterion?

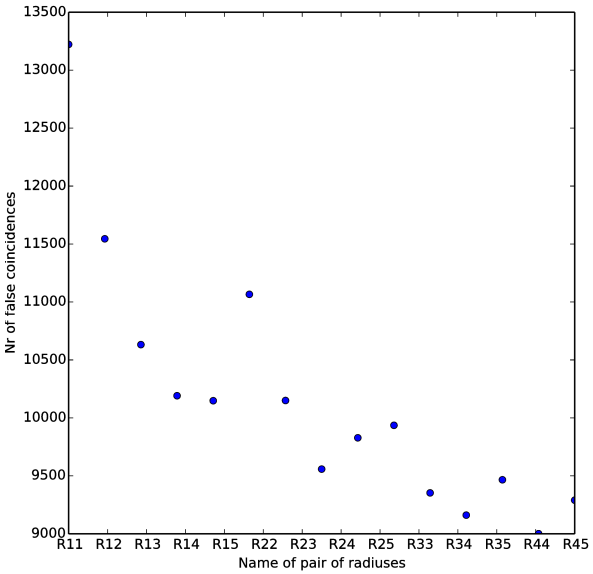
-> the biggest number of true coincidences and the smallest number of false coincidences

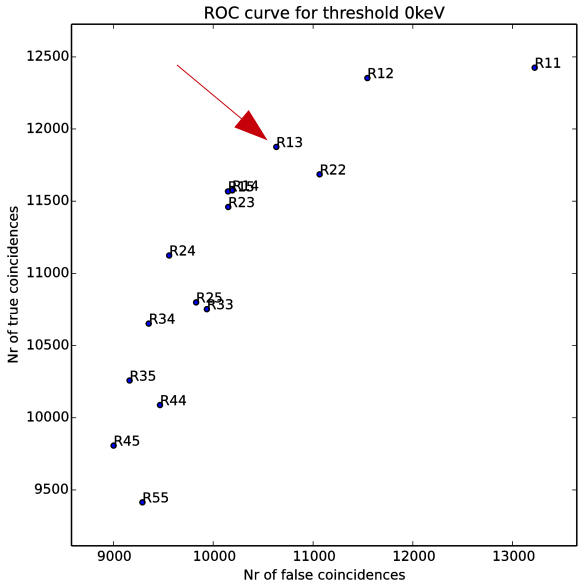
True coincidence:
- two different gamma quanta cause depositions of energy bigger than fixed energy threshold in two different strips

False coincidence:
- single gamma quantum causes depositions of energy bigger than fixed energy threshold in two (or more) different strips
- two different gamma quanta cause depositions of energy bigger than fixed energy threshold in more than two strips

3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors

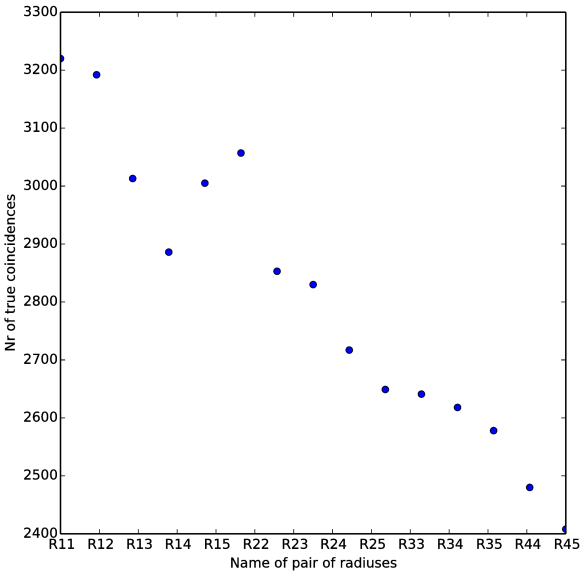


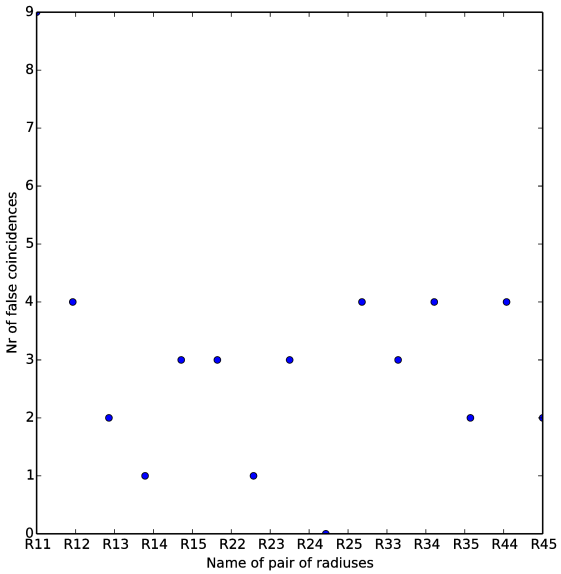


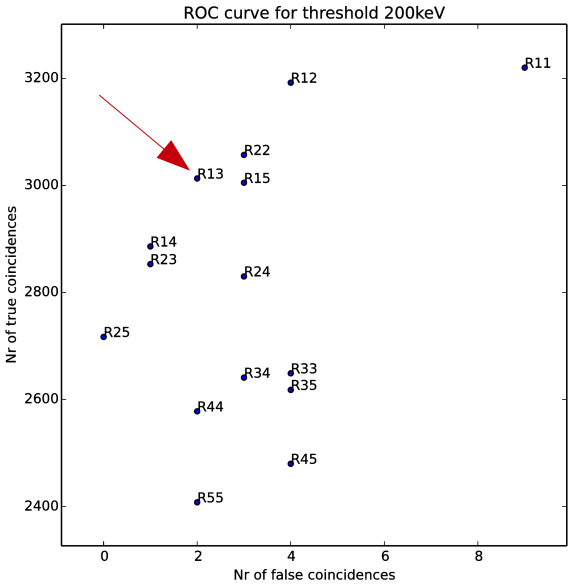


True and false coincidences for energy threshold 0 keV

3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors

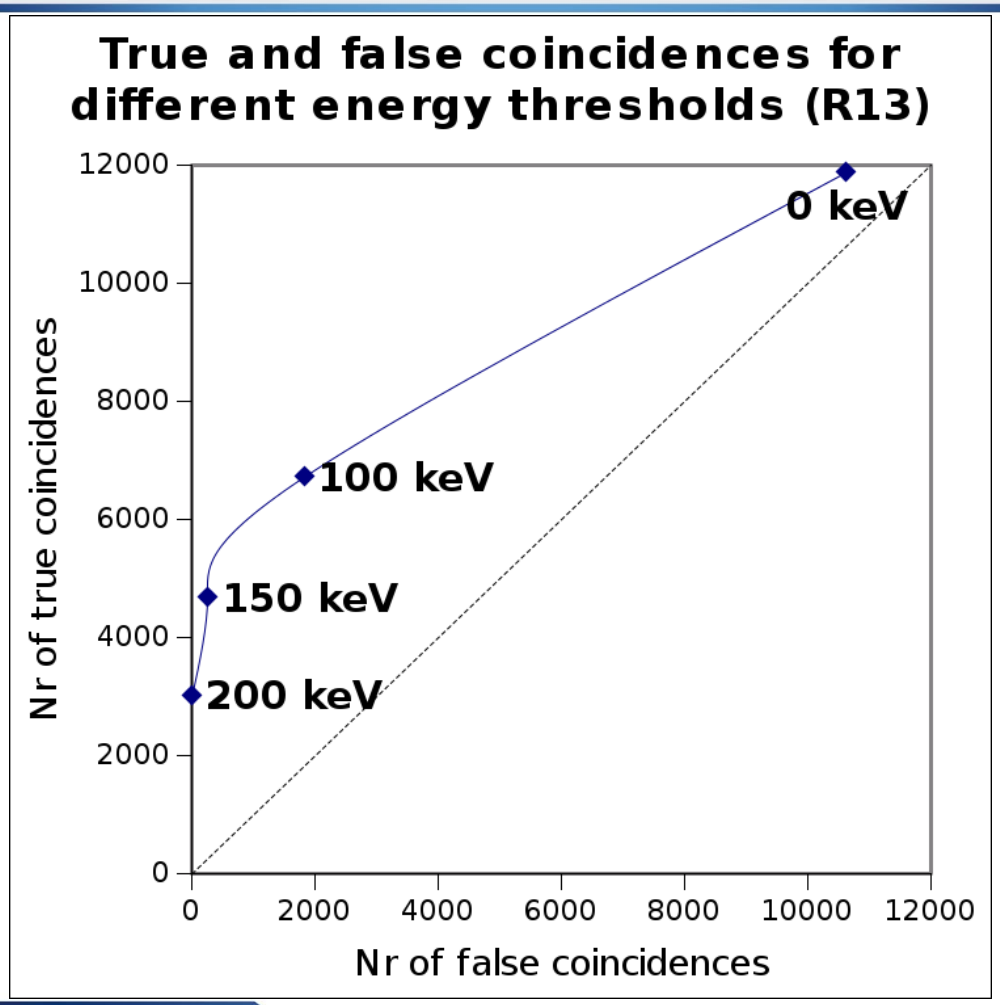






True and false coincidences for energy threshold 200 keV

3. Simulations of the Strip-PET scanner with 3 layers and 192 detectors



4. Summary

1. Thanks to the implementation of real properties of EJ230 scitnillator and R4998 photomultiplier, it is possible to simulate realistic response of the single detecting module and subsequently the response of a whole Strip-PET scanner.

2. Simulations of the 3-layer scanner shows, that the best configuration of radiuses is the configuration R13. Energy threshold will be optimized in next steps.

National Centre for Nuclear Research Świerk

ŚWIERK COMPUTING CENTRE

Thank you for your attention

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Regional Development Fund under the Operational Programme Innovative Economy