Estimation of 511 keV gamma scatter fraction in WLS layer in Total Body J-PET ; A simulation study

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Total Body Jagiellonian Positron Emission Tomograph

- A new generation of Total-Body PET scanners based on plastic scintillators is being developed by the J-PET collaboration [1].
- The total body J-PET scanner comprises of 7 rings with 33 cm length and 89.2 cm diameter.
- Each ring consists of 24 modules.
- Each module is built out of 3 Layers.
- First and third layers build-out of 16 scintillator strips placed next to each other, read out on both ends by SiPM.
- Second layer build of 50 wavelength shifter (WLS) fibers.
- The study has been carried on by Gate software [2] according to NEMA_NU_2 2018 [3].

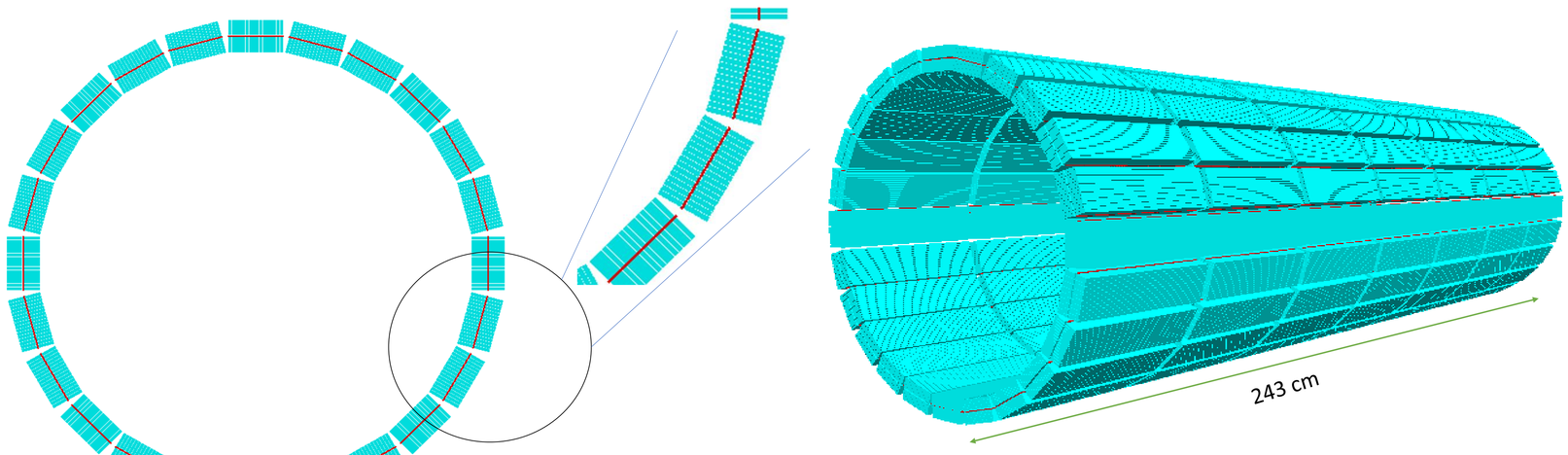

Fig 1. Schematic view of TB-JPET

Single Slice Rebinning (SSRB) algorithm of obtaining the Scatter Fraction

- The space inside the scanner is axially divided into N^2 virtual slices.
- N^2 oblique sinograms are generated for the transformation of the line of response (LOR) into a pair of values.
- SSRB algorithm is used to obtain 2N-1 rebinned sinograms (Fig 2).
- Rebinned sinograms are merged into one sinogram(summed sinogram).

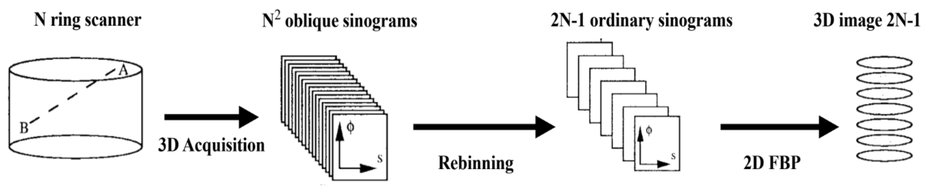

Fig 2. The principle of a rebinning algorithm

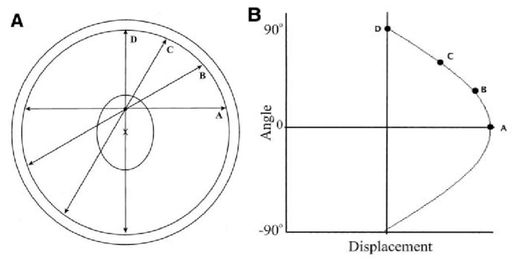

Fig 3. pictorial definition of sinogram [4].

- Using this summed sinogram, all projections are aligned with maximum value to zero and summed in order to get a one-dimensional profile.
- After summing up, the values of such obtained profiles at distances ±2 cm from zero are calculated.
- The area of the profile over the line crossing two points at ±2 cm: true coincidences.
- The area below this line: scattered (Random) coincidences.

Scatter fraction

The Scatter fraction of the PET scanner quantifies the sensitivity of the detector to scattered radiation. It is expressed as a ratio between the scattered coincidences and the sum of scattered and true coincidences. The Scatter Fraction was calculated based on SSRB algorithms.

Phantom simulation:

- Cylinder phantom is composed of polyethylene with the specific gravity of 0.96 ± 0.01 g/cm3
- The diameter of source 203 ± 3 mm
- The length of source 700 ± 5 mm
- Position of source is (0, -45, 0) mm

Source Distribution:

- line source
- The activity of source is 1 MBq
- Back to back gamma photons

To evaluate the effect of the WLS in the Total-Body J-PET configuration, two simulations have been performed, once Total-Body J-PET including WLS layers, then without the presence of it. For the case of this comparison study, the GATE simulation toolkit has been utilized. The percentage share of the coincidences and scatter fraction have been used as metrics to evaluate the effect of the WLS in the Total-Body J-PET scanner.

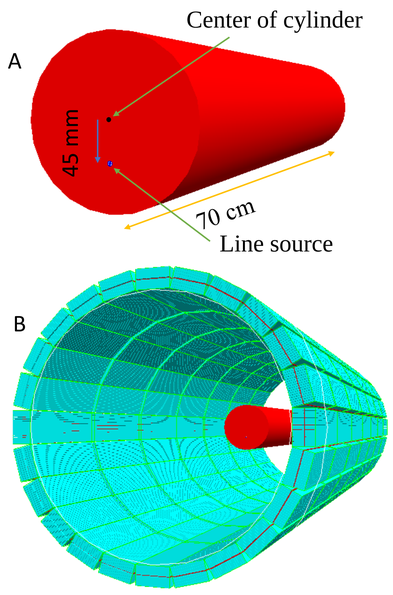

Fig 4. Schematic view A) simulated phantom model and B) position in the center of the scanner.

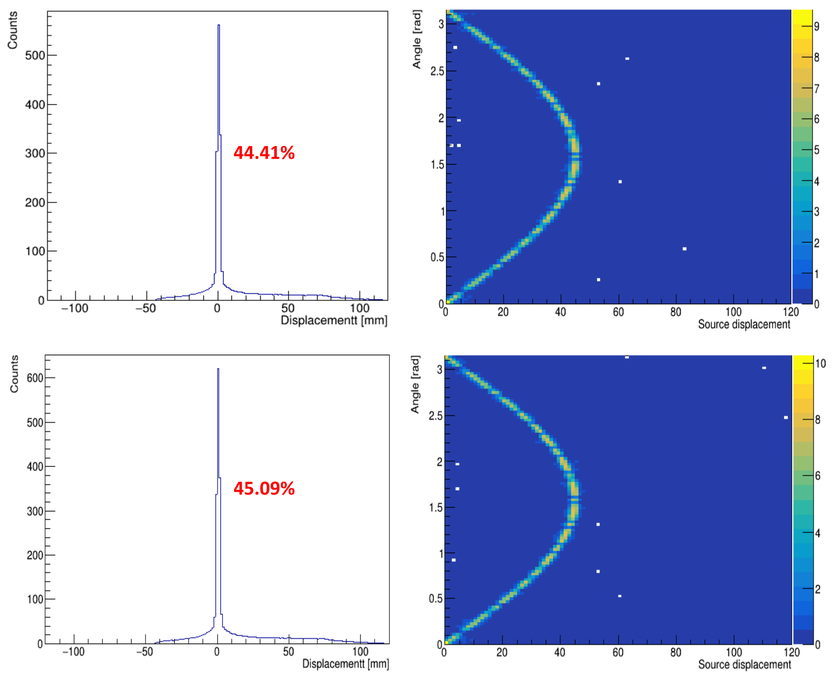

Fig 5. simulations result for 243 cm long prototype with the 70 cm long source with 1MBq total activity (left) aligned to zero and summed sinogram (right) sinogram for a whole scanner.

Conclusion

	TB-JPET with WLS layer (3 layer)	TB-JPET without WLS layer (2 layer)	uExplorer [5]	PennPET explorer [6]
Scintillator	EJ-230	EJ-230	LYSO	LYSO
Number of modules	24	24	24	18
Number of rings	7	7	8	3
Ring diameter(cm)	89.2	89.2	78.6	76.4
AFOV (cm)	243	243	194	64
Time window (ns)	3	3	4.5	4
Energy window (KeV)	> 200	> 200	430-645	440-660
Scatter Fraction (%)	45.09	44.41	36.3	32
Activity (MBq)	1	1	1100	-

Table 1. Result of crystal-based Total Body PET scan in comparision with traditional PET scan

Simulation is done with Gate V9

Acknowledgments

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