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## USE OF EGS FOR MONTE CARLO CALCULATIONS IN POSITRON IMAGING<sup>(+)</sup>

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We describe the use of the general electromagnetic radiation transport Monte Carlo code EGS for the study of the imaging capabilities of the large area Positron Camera HISPET (1).

### INTRODUCTION

We have proposed a new design: a fully three dimensional Positron Camera, made of six modules arranged to form the lateral surface of a hexagonal prism, and called HISPET (High Spatial resolution Positron Emission Tomograph) (1). Each module consists of two MultiWire Proportional Chambers each sandwiched by 1 cm thick lead-glass tube converters. To study the imaging capabilities of HISPET in detail and to optimize its design, we have made a complete Monte Carlo simulation, by implementing the general purpose electromagnetic radiation transport Monte Carlo code called EGS (Electron Gamma Shower) (2). For the problem at hand we have used an enhanced version of EGS called EGS4 (3), which has the important feature of being able to follow electrons, positrons, and photons down to a kinetic energy as low as 10 keV ( $e^-$  and  $e^+$ ) and 1 keV (photons).

Two separate simulations have been made: the first to calculate the efficiency of the lead glass honeycomb converter as a function of the photon energy (section 2), the second to study the overall performance of HISPET (section 3).

## 2. EFFICIENCY CALCULATIONS

The converter is made of glass capillaries of high lead content, fused to form honeycomb matrices (1). In order to calculate its efficiency versus the photon energy, we have used the EGS code with a special geometry corresponding to a single tube ("unit cell"). Photons randomly irradiate the top face of the cell at  $90^\circ$ , and all particles are transported inside the cell until they reach a cut-off (10 keV and 1 keV for e and  $\gamma$ , respectively), exit the top or bottom, or exit the sides. In the latter case, in order to fully realize the actual converter with a multitude of contiguous holes, the particles are re-transported into the unit cell by making the appropriate coordinate translation while maintaining the direction of motion. If the electron produced by the photon interaction enters the inner diameter of the cell, it is considered to be detected, irrespective of its energy at that point. The probability that an electron will reach a hole depends on its energy, where it is created, and its direction of motion. By throwing photons over the unit cell and scoring the energy released into two histograms (detected and total events) we were able to determine that probability as a function of the electron kinetic energy, averaged over the various positions and directions. This probability table was then used in the second simulation for the study of the general performance of HISPET (see section 3).

Various combinations of inner and outer diameter were chosen with the length of the cell fixed at 1 cm. Various types of lead glass with different percentages of PbO and different densities were also simulated. Figure 1 shows the calculated efficiency of the

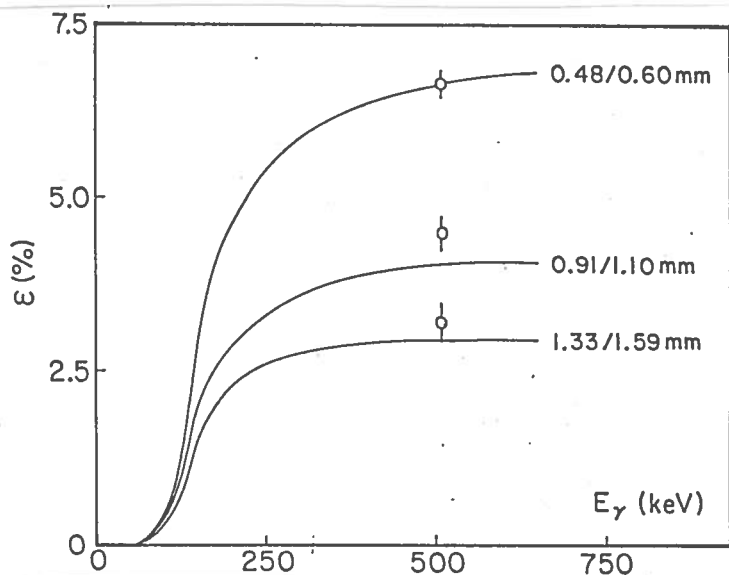


Fig. 1 Calculated efficiency of a 1 cm thick converter as a function of the photon energy (solid lines); o experimental data.

converter as a function of the photon energy for three ID/OD tube converters, compared with our experimental data (6) obtained with 80% PbO lead glass (density  $6.2 \text{ g/cm}^3$ ). Figure 2 shows the calculated efficiency for 511 keV photons versus the diameter of the tube at a fixed OD/ID ratio of 1.2 for the various lead glass types.

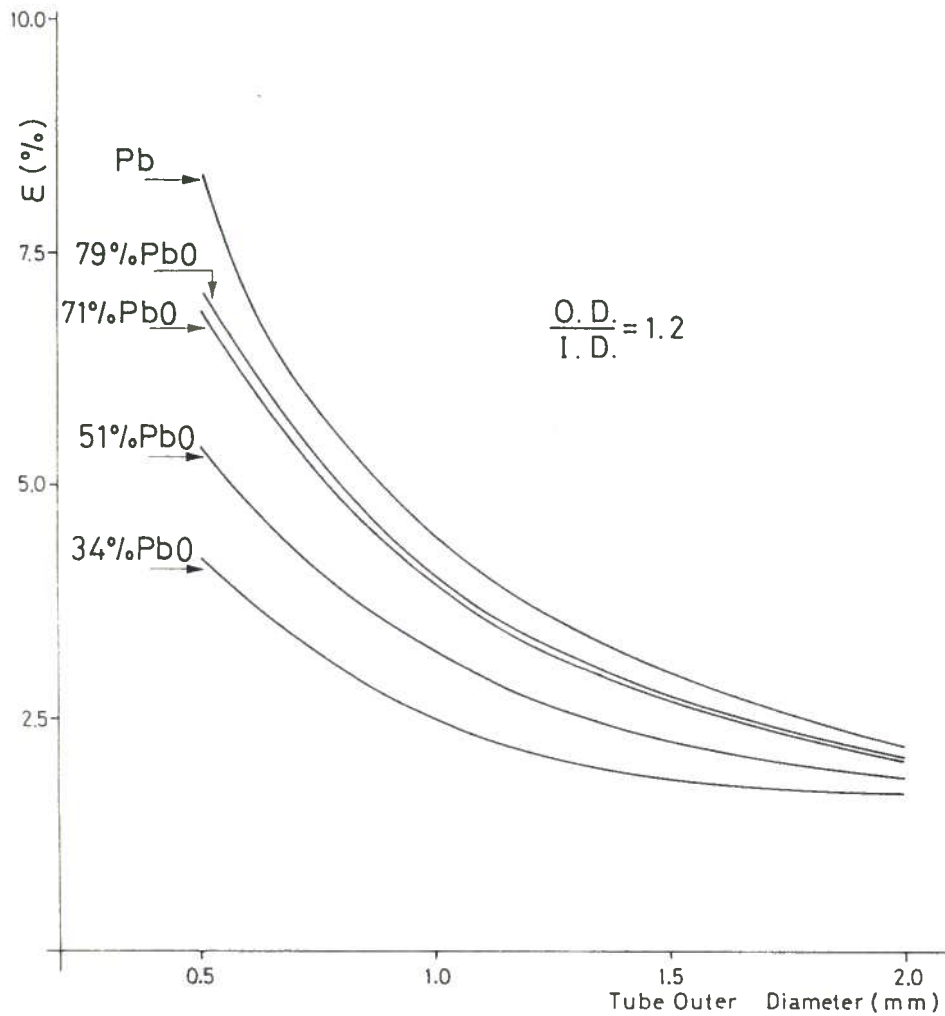


Fig. 2 Calculated efficiency of a 1 cm thick converter as a function of the tube outer diameter. The various proportions of PbO correspond to commercial glasses we have used. The efficiency curve for pure lead is also drawn for comparison.

### 3. STUDY OF HISPET PERFORMANCE

This simulation, which is completely three dimensional, may be subdivided into the following sections:

- i) Generation of the positron coordinates, direction, and energy, the latter sampled

according to the energy spectrum of the selected radioisotope. The theoretical beta spectra corrected for the screening effect were introduced into EGS in the form of look-up tables. The following isotopes were considered:

$^{11}\text{C}$ ,  $^{13}\text{N}$ ,  $^{15}\text{O}$ ,  $^{18}\text{F}$ ,  $^{19}\text{Ne}$ ,  $^{38}\text{K}$ ,  $^{68}\text{Ga}$ , and  $^{82}\text{Rb}$ .

- ii) Transport and annihilation of the positron in the simulated phantom. Due to the structure of EGS itself it is in principle possible to simulate any type of phantom. However, only the cylindrical and spherical geometries have been implemented in the simulation. The positron is followed within the phantom until it reaches the lower energy cut-off of 10 KeV, when it is forced to annihilate at rest. In addition to Bhabha scattering and continuous energy loss, EGS also considers annihilation in-flight as a discrete Monte Carlo process. Once the annihilation takes place, the proper angular distribution is considered for the two photons, both for annihilation at rest (4) and in flight (5), the latter probability being at most a few per cent for the highest energy radioisotope.
- iii) Transport and interaction of the annihilation quanta from within the phantom to the detector. During this step of the program all charged particles that are generated are immediately discarded. If the photon emerges from the phantom with an energy greater than the cut-off energy it is further transported to the detector.
- iv) Simulation of the three-dimensional geometry of the detector. It is left to the user of EGS to construct the geometry of his detector, with any number of planes, cylinders and spheres. In our case the hexagonal prism geometry of HISPET was exactly simulated, including the four planes of converters and the two MWPC sensitive regions for each module.
- v) Interaction of the photon within the detector. To simulate the interaction of the  $\gamma$  within the detector the real lead-glass honeycomb geometry was approximated by a solid converter whose density was reduced by the appropriate area ratio. Following an interaction in the pseudo converter, the Compton or photo-electron was assumed to be detected with a probability as given by the appropriate probability table calculated from the "unit cell" simulation (see section 2). If one photon produces more than one detected electron in the same module, only the earliest electron (that nearest to the anode plane of the MWPC) is retained. The real coordinate along the thickness of the converter is substituted by half the thickness so as to introduce parallax error. The x and y finite resolution of the MWPC are also simulated under Gaussian distributions and the final position is checked against spatial cut-offs.



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