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Status Report of Spectrometer-Simulation

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Abstract

In this report I will report on my first results obtained by a simulation of a spectrometer according to Kirks proposal.

Status of Spectrometer Simulation

1 Introduction

In January Alexander made a first proposal [1] on the layout of the spectrometer to be used in E166 to filter out the positrons after the undulator photons have been converted into e^+e^- pairs. In the mean time Kirk McDonald *et al.* have revised this proposal substantially. This note is referring to proposal No. 3 sent around by Kirk on the 4th of April.

The geometry shown in Figs. 1 and 2 have been implemented into GEANT3. As a basis the program is used which Ties Behnke has developed for spectrometer studies in 2003. The dimensions of spectrometer are given in Fig. 1.

The vacuum chamber consists basically of a rectangular box. The vacuum part in this volume is enclosed in a 3 mm thick aluminum wall. The vacuum chamber has a total height of 54.9 mm such that roughly 50 mm are left for the aperture. The beampipes at the entrances and exits of the vacuum chamber have a diameter of 41.9 mm.

At the entrance, where the photon beam enters, the spectrometer is equipped with a solenoid. It consists consists of an iron yoke while the copper wires are approximated by a copper ring which is inserted into the iron yoke.

2 Magnetic Fields

The longitudinal component of the magnetic field in the solenoid was indicated in Alexanders note [1] and is approximated by a 4th order polynomial as shown in Fig. 3, *i.e.*

$$B(z) = 11.32 - 0.83z - 0.65z^2 + 0.03z^3 + 0.01z^4. \tag{1}$$

The components of the solenoidal magnetic field are then given by

$$B_r = -\frac{r}{2}\left(\frac{dB}{dz} - \frac{d^3B}{dz^3}\frac{r^2}{8}\right), B_\phi = 0, B_z = B(z) - \frac{r^2}{4}\frac{d^2B}{dz^2}. \tag{2}$$

The field in the bending magnets is approximated by a homogeneous field pointing in $+y$-direction in the upper part and in $-y$-direction in the lower part of the vacuum chamber. The regions in which the bending field is active are indicated in Fig. 1.

3 Simulation Procedure

The simulation is based on the undulator photon spectrum as shown in Fig. 4. In addition the figure presents the energy spectrum of positrons, electrons and photons after the conversion target.

In the next sections results on transportation efficiency and background issues will be presented. For these studies the vertices of the particles are positioned after the conversion target using realistic angular and momentum distributions as input to the simulation. Fig. 5 shows a typical event with a positron spectrum as input to the simulation. In the current setup the re-conversion target is positioned at the exit of the beampipe at the exit of the vacuum chamber.

4 Results

This section presents first results of the simulation studies. Two issues are of interest. Firstly, the transportation efficiency to transport positrons through the spectrometer. Secondly the amount of background which reaches at the re-conversion target is studied[1].

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4.1 Transportation Efficiency

In a first step the transportation efficiency is estimated for different values of the solenoidal magnetic field. The solenoidal magnetic field was increased and decreased w.r.t. its nominal value given in Eqs. 1 and 2. For this study the field in the bending magnets are held constant at a value of ± 1.5 kG. Fig. 6. In this case the highest efficiency of roughly 2% is observed for positron with an energy of $\approx$ 4.5 MeV when the solenoid field 50-75 % of its nominal value. Figure 7 shows the xy-distribution of the positrons at the re-conversion target. The distribution is symmetric around the origin.

In a next step the solenoidal field is kept at its nominal value while the field in the bending magnet is varied. In Fig. 8 the resulting transportation efficiencies are displayed. The highest transportation efficiencies of about 8-10 % are observed for large values of the bending field.

For these values high energetic positrons with an energy between 8 and 10 MeV (with a high degree of polarization) are selected.

4.2 Signal and Background

In this section the background which arrives at the re-conversion target is investigated. For this study 1000 particle bunches comprising 1000 $e^{\pm}$ each are simulated. As before the vertices of the particles are put behind the conversion target. Consequently, the results presented in the following correspond to what is expected for a single bunch containing 10^6 particles [2]. In the experiment we expect to have roughly 10^7 particles per type after the conversion target.

Figure 9 shows in its upper left part the particle composition at the re-conversion target. For this study the field in the bending magnets are set to 1.5 kG and the field in the solenoid is kept to its nominal value. Note, that for this study particles are stopped in the simulation when they reach the air surrounding the spectrometer. The spectrum is dominated by positrons. While the amount of electrons is negligible, roughly 13% of the particles are photons. The energy spectrum of the three particle types is also given in Figure 9. It can be seen that the energy spectra for positrons and photons are entirely different.

[1]To be more precise, the particles hit a scoring plane which is situated directly in front of the re-conversion target.

[2]The reason for not having more statistics is the analysis is only of technical nature. More statistics is easily achievable

From Figure 10 it can be derived that most of the photons are produced in the beampipe at the exit of the vacuum chamber.

In the same manner as positrons, electrons were tracked through the spectrometer. With a statistics of 10^6 primary particles no secondaries are observed at the re-conversion target. Regarding only particles moving within the spectrometer electrons constitute no background source for E166.

Finally, the background produced by a primary positron beam is studied when the secondaries are not stopped in air. Fig. 11 shows the particle composition and the energy spectra of the particle species arriving at the re-conversion target. In this case roughly 40% of the particles are identified as photons. Again the amount of electrons is negligible.

The study has to be repeated for electrons ..., to be done.

5 Conclusion and Outlook

The efficiencies to transport positrons through the E166 vacuum chamber were studied. For high energetic positrons of ≈ 10 MeV transportation efficiencies as high as 10% can be reached.

12.5% of the particles hitting the re-conversion target are identified as photons. These number is valid for particles which move only within the spectrometer.Taking into account also particles which through the air sorrounding the spectrometer the number increases to roughly 40%. The energy of these photons peaks at values below 1 MeV. The main sources of background is the beampipe at the exit of the spectrometer. Electrons produced at the conversion target do not constitute a background source for the experiment.

In a next step of a revised version of the spectrometer comprising *e.g.* the collimator between the bending magnets. In addition the matching between the solenoidal and the bending field will be investigated and optimized.

References

[1] A. Mikhailichenko, *Optics Development for Positron Polarization Analyses* Memo sent around 10/11/2003 and 5/1/2004.

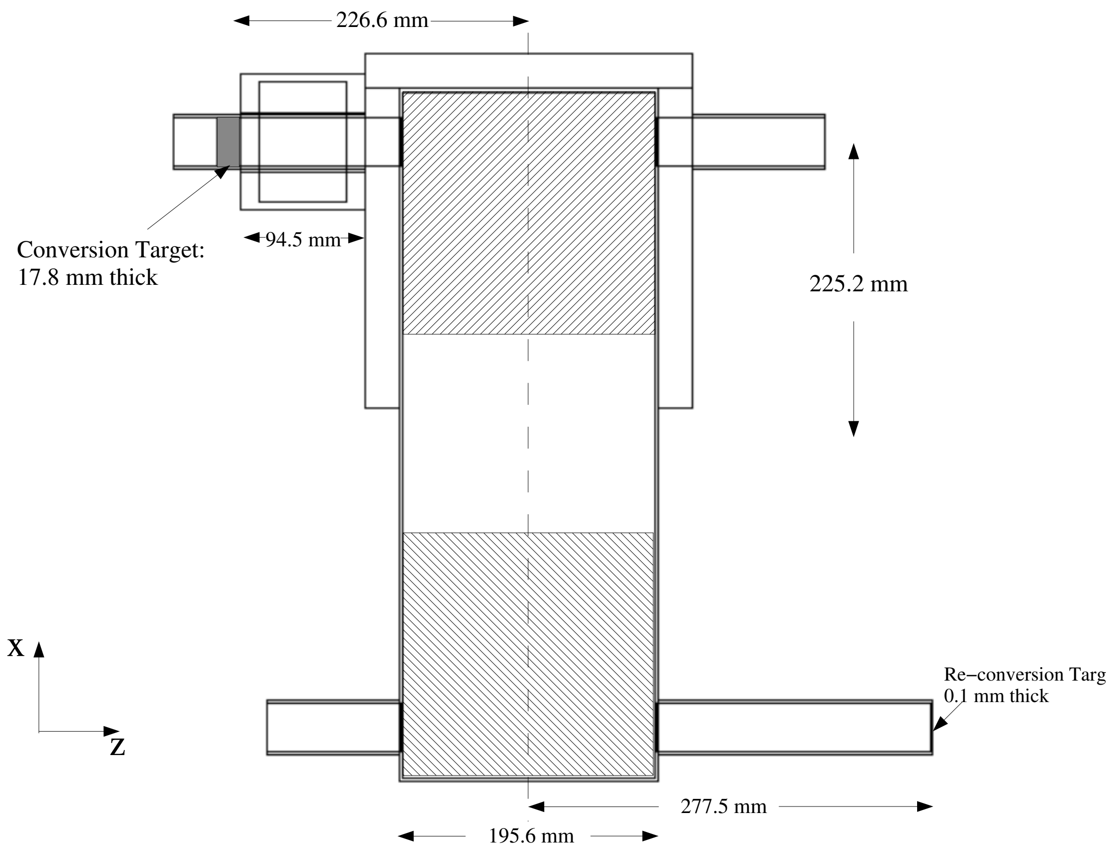

Figure 1: Spectrometer as implemented into the simulation (xz-view). Hatched areas indicate the parts with active bending field.

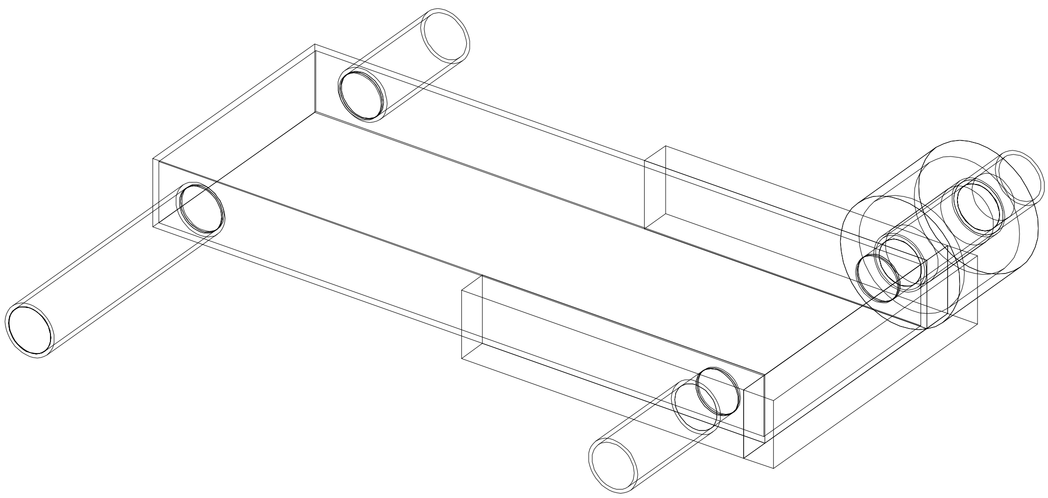

Figure 2: Spectrometer as implemented into the simulation (side-view).

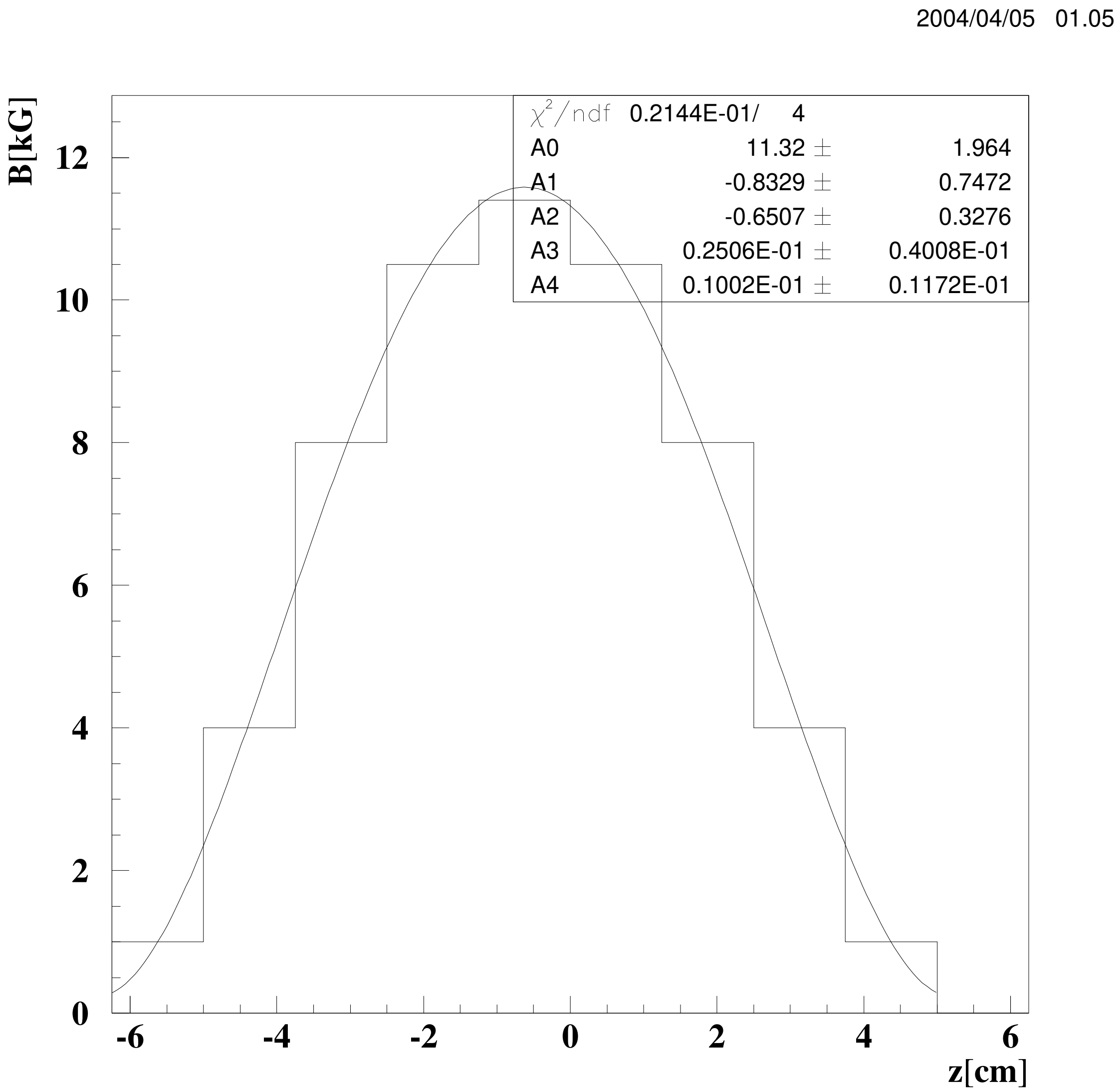

Figure 3: Longitudinal component of solenoidal field.

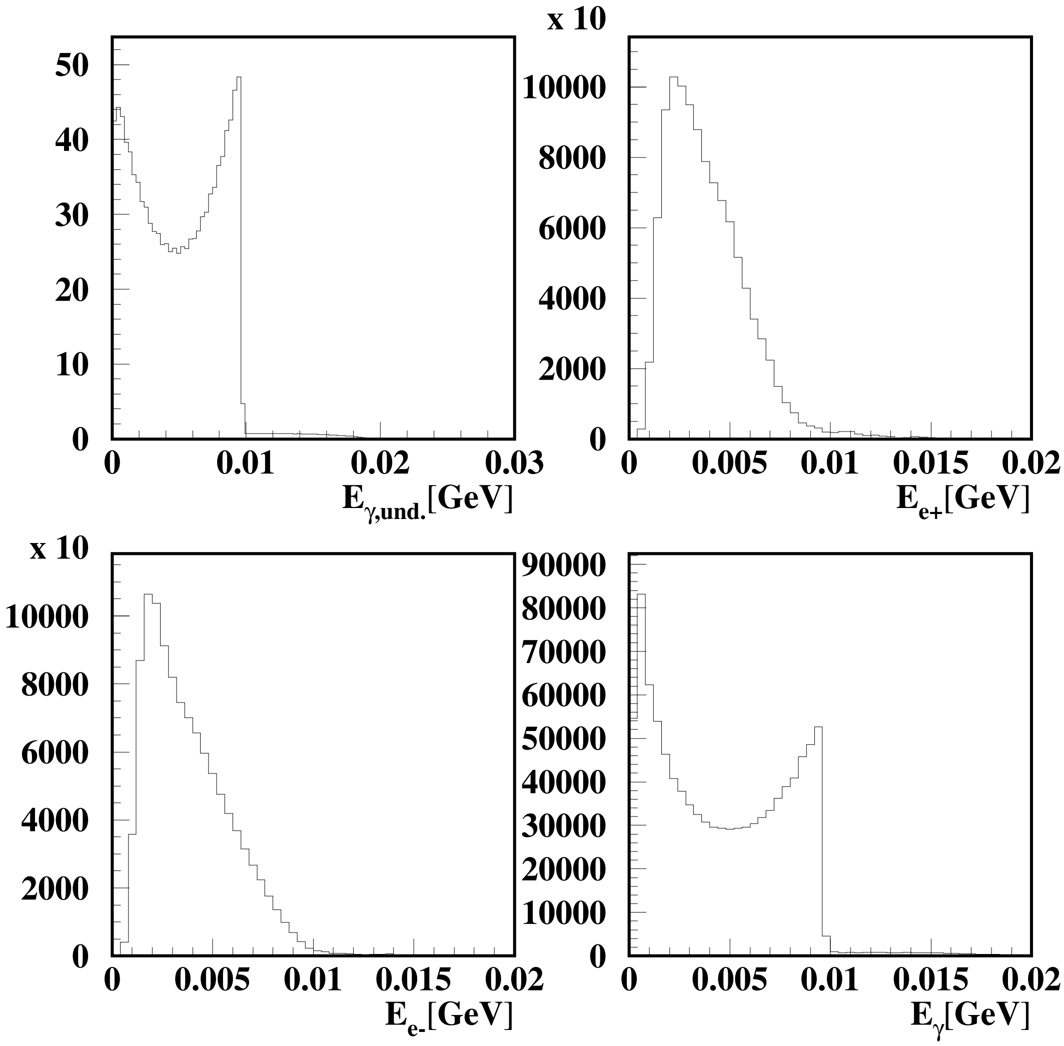

Figure 4: Undulator photon spectrum (upper left) and energy spectra for different particle species after the conversion target.

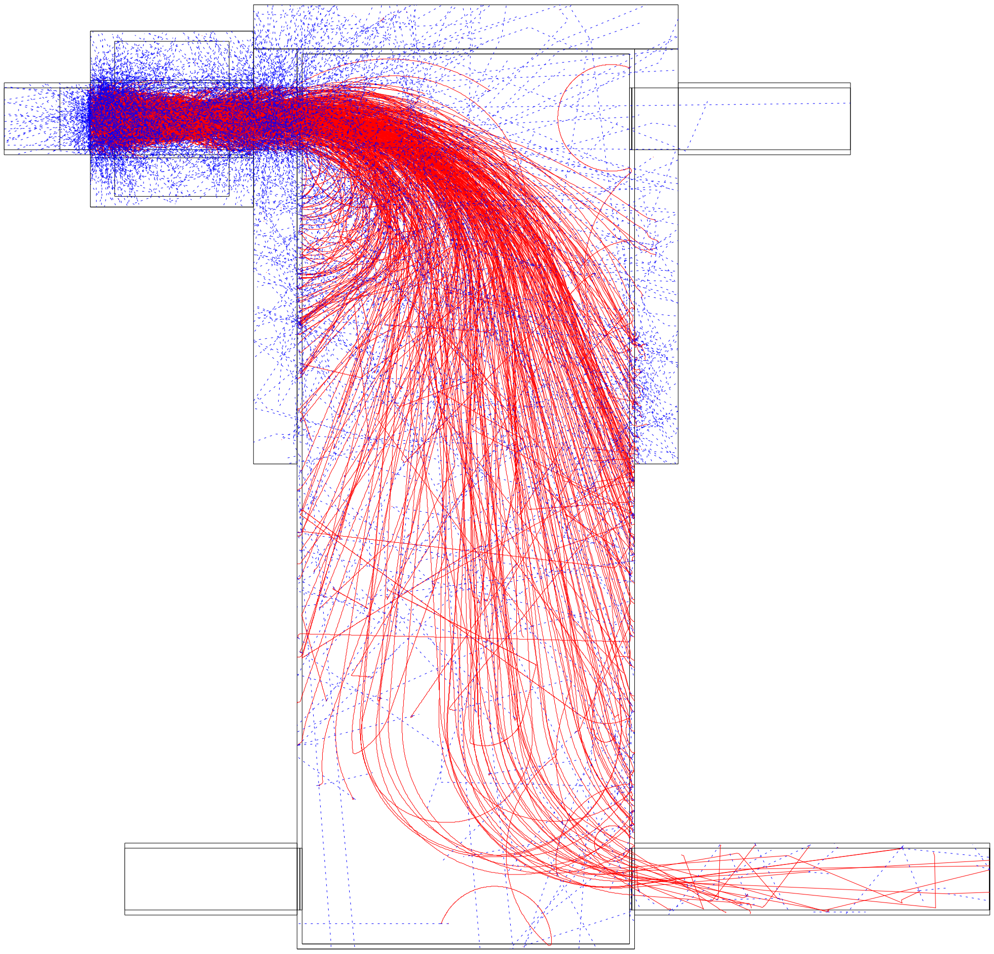

Figure 5: A typical event in the spectrometer (Blue lines = Photons, Red lines = Positrons or electrons). A realistic positron spectrum is used as an input. The particles start behind the conversion target.

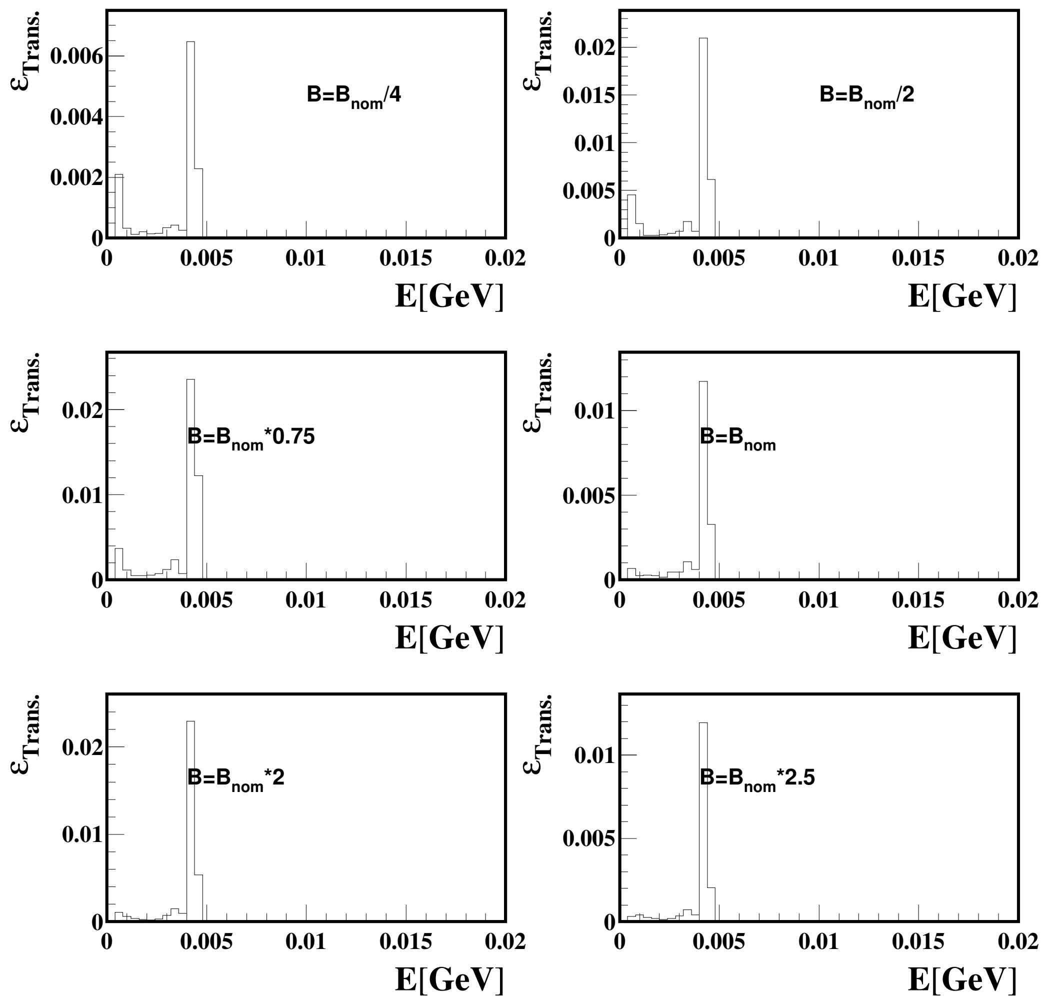

Figure 6: Transportation efficiency as function of the positron energy for different values of the magnetic field in the solenoids. The field within the bending magnets is kept constant to ± 1.5 kG.

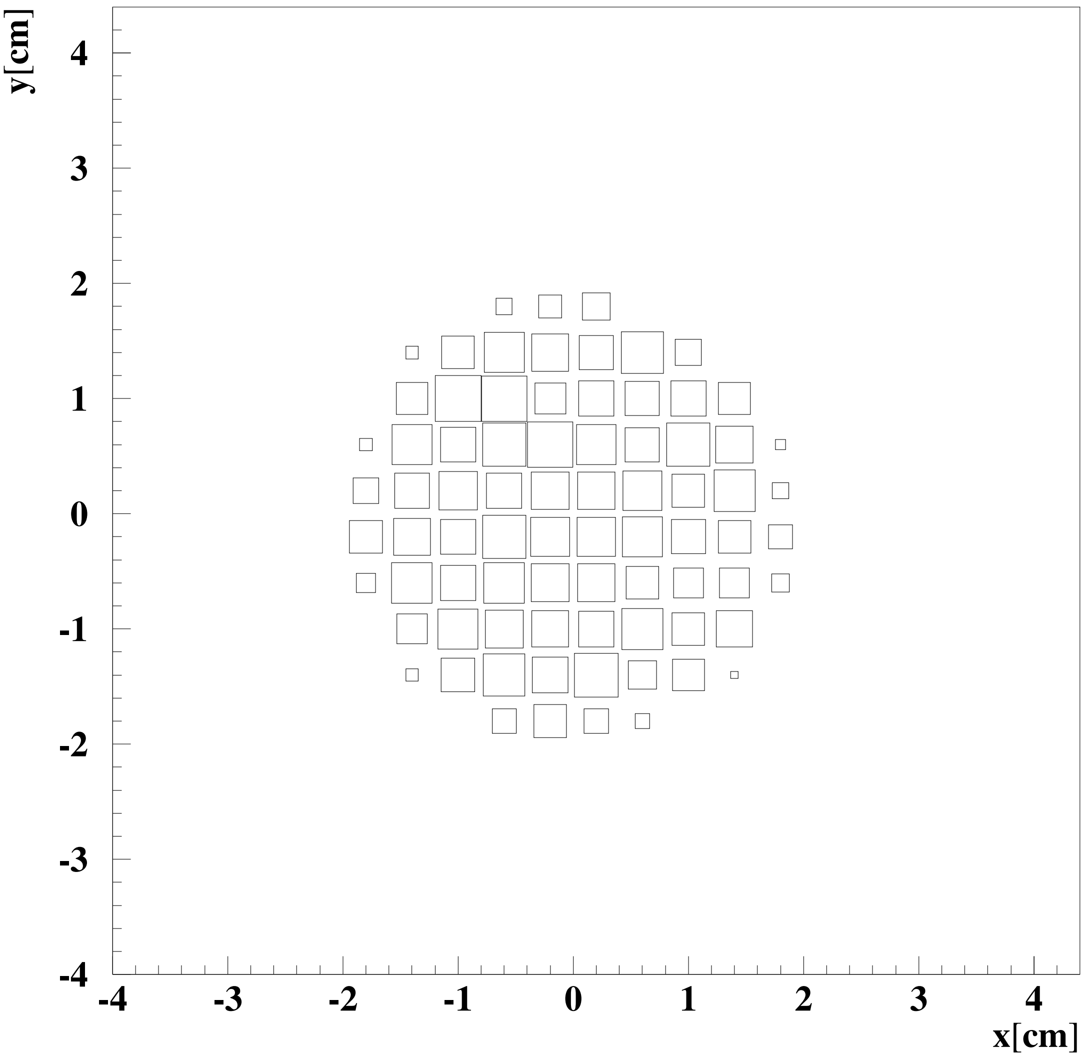

Figure 7: Spatial distribution of positrons arriving at the re-conversion target.

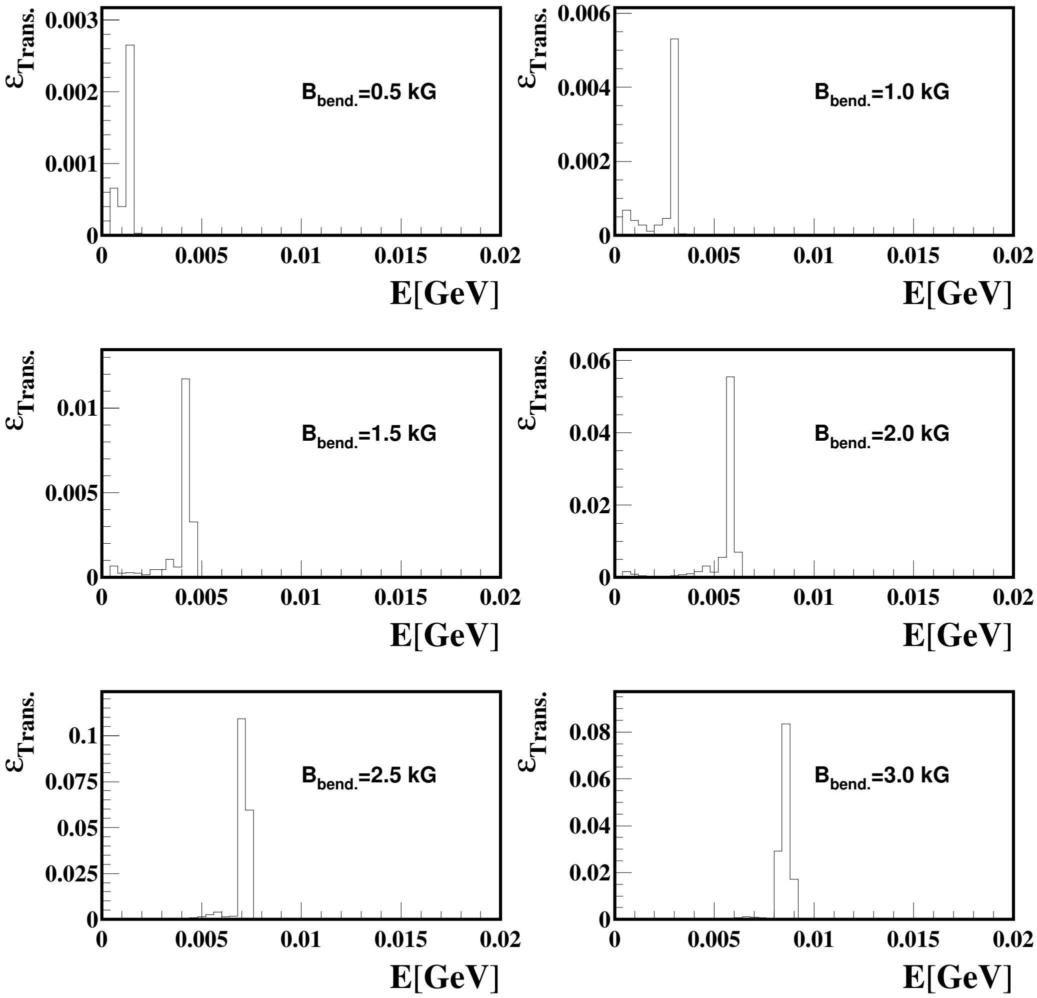

Figure 8: Transportation efficiency as function of the positron energy for different values of the magnetic field in the bending magnets. The field within the solenoidal magnets is kept constant to its nominal value.

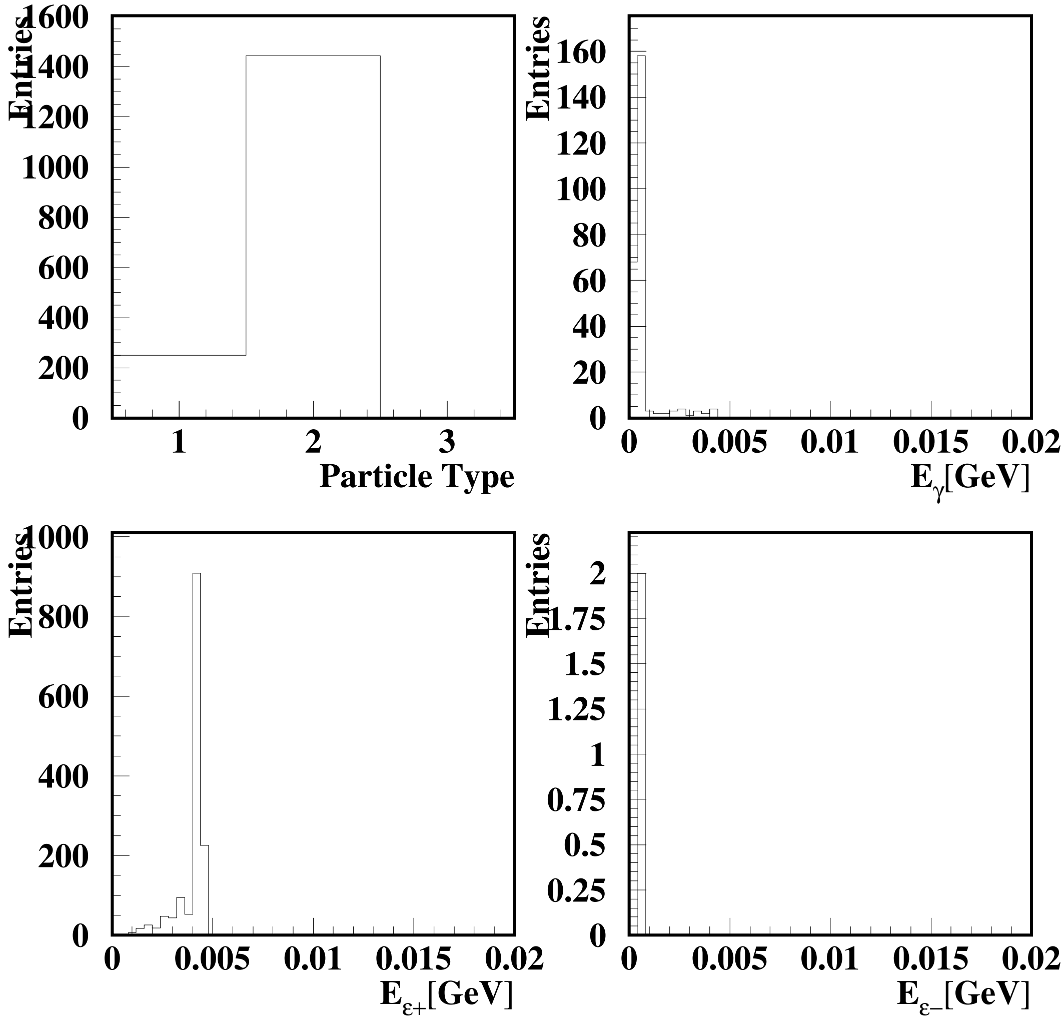

Figure 9: Particle composition (upper left, 1=Photons, 2=Positrons, 3=Electrons) and energy composition of photons, positrons and electrons hitting the re-conversion target. Particles are stopped in the simulation when they reach air

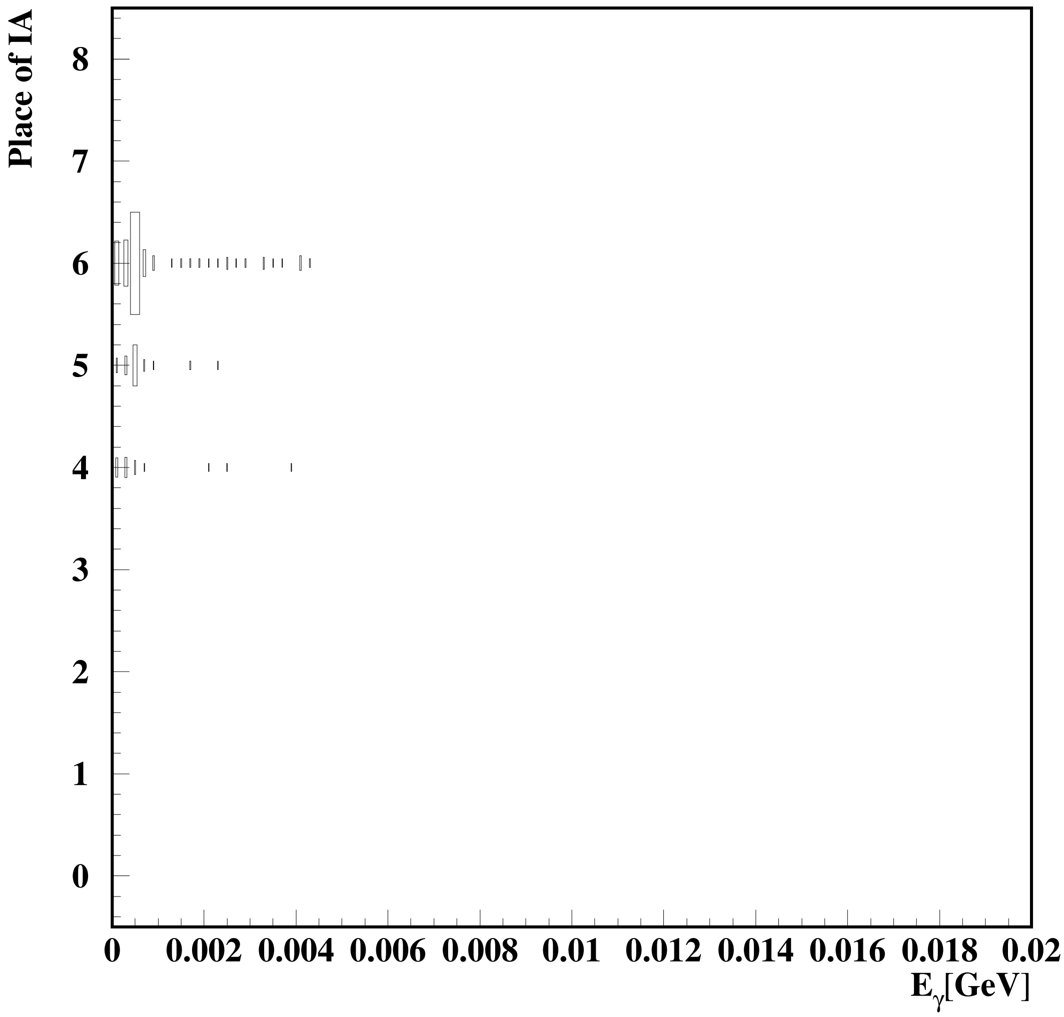

Figure 10: Photons hitting the re-conversion target. Shown is the position of the interaction where the photons are produced versus the energy. The codes on the y-axis are: 1=Solenoid (Copper or iron part), 2=Beampipe within solenoid, 3=Radiation shielding, 4=Vacuum chamber, 5=re-conversion target 6=Beampipe at exit of vacuum chamber.

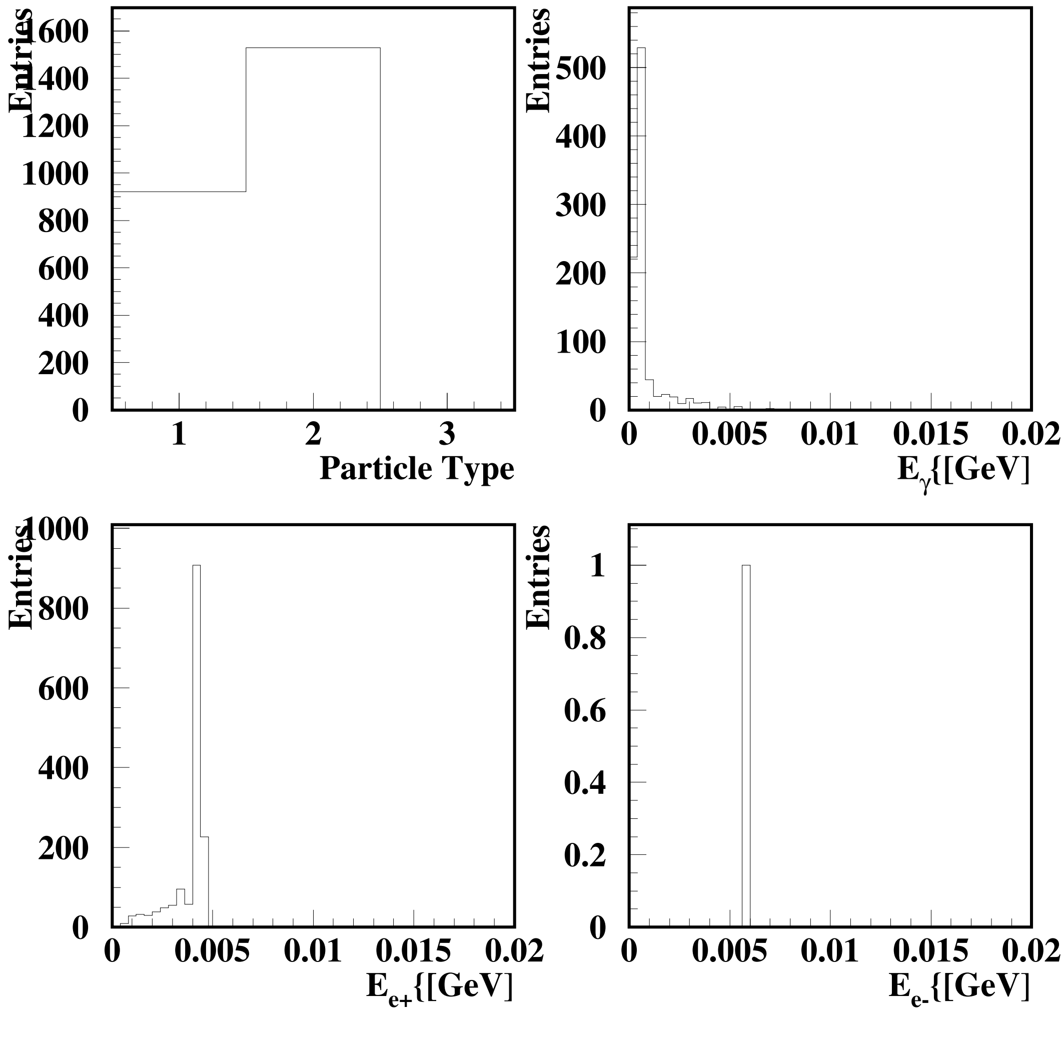

Figure 11: Particle composition (upper left, 1=Photons, 2=Positrons, 3=Electrons) and energy composition of photons, positrons and electrons hitting the re-conversion target. Particles are not stopped when they reach air