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Status Report of Spectrometer-Simulation

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Abstract

In this memo the effects of choosing different target materials is studied together with the implications evolving from different length of the exit beampipe. For the latter scenarios also the background in the CsI-Calorimeter is investigated.

1 Introduction

This memo is the successor of studies on the spectrometer design presented earlier [1,2,3]. The major change w.r.t.the last memo the reconversion target is now embedded in the analyzer magnet. The basic setup for the present memo is shown in Fig. 1. This setup will be called the default setup during this memo.

For the setup of magnetic fields, definition of variables as well the basic input spectra the reader is referred to the previous memos mentioned above.

2 Changing the Aparatus Dimensions

For the following studies

- The length of the exit beampipe is varied. Three options 30 mm, 80 mm and 130 mm (as in Fig. 1) are investigated.
- The distance between the exit beampipe and the gamma beamline is varied. Three options 225 mm, 350 mm and 450.4 mm (as in Fig. 1) are investigated. The 225 mm are chosen because it is the smallest distance allowing for a extent of the dipole field along x and z of 10 cm and for an intermediate collimator with 2.5 cm thickness.

. In all studies the exit beampipe is 'completed' by a 47.5 mm long piece of beampipe ranging into the analyzer magnet and containing the re-conversion target.

For the studies in this section the same input spectra has been used as in the previous studies [1,2,3]. The target material of the conversion target is *Ti* with a thickness of 0.5 X_0.

2.1 Length of Exit Beampipe

Signal

Fig. 3 shows in its upper part the number of positrons hitting the re-conversion target for the three different lengths of the exit beampipe. As expected the number of positrons increases with decreasing length of the exit beampipe. For the shortest option up to 225000 positron hit the reconversion target for a value $B/B_{nom} = 0.7 \longrightarrow 5.6$ MeV. This can be converted into a transmission of roughly 1.1%. All numbers are scaled to $2 \cdot 10^7$ input positrons at the conversion target. However, from the engineering point of view a length of 8 cm seems to be most realistic In this case the transmission is reduced roughly by a factor of two.

As expected, the amount of energy depositions in the CsI-Calorimeter does increase with decreasing length of the exit beampipe. This is demonstrated in the lower part of Fig. 3. The highest values for the 8 cm option are around 600 energy depositions per bunch. With a typical energy deposition of 1.5-2 MeV one would expect roughly 1 GeV energy deposition per bunch.

Background

Fig. 4 shows for the three scenarios the energy spectrum of photons depositing energy in the CsI-Calorimeter which are produced directly by photons present at the re-conversion target or produced by those photons in secondary interactions. The general trend is that the medium position of 8 cm seems to lead to the largest amount of background (See the number of entries in the histograms). This somewhat suprising result is a bit enlightened in Fig. 5. At a length of 8 cm most photons which create a signal in the CsI com directly from the conversion target such at this length the CsI seems to in the line-of-sight of these photons. Another source of background present for all three lengths is the gamma beampipe. Photons which stem from a interaction in the radiation shielding a most probable the result of primary photons undergoing Compton-Scattering.

2.2 Dimensions of Spectrometer

2.2.1 Signal

Three different layouts of the spectrometer itself are tested, *i.e.* varying distances between the two beamlines. The length of the exit beampipe is fixed to 8 cm for this study. In Figure 6 again the number of positrons hitting the re-conversion target (upper part) and the amount of energy depositions in the CsI-Calorimeter are displayed. Again as expected, the number of positrons hitting the re-conversion target increase with decreasing distance between the two beamlines (equivalent to a shorter size of the spectrometer). With respect to the so far assumed distance of 450.4 mm between the beamline a spectrometer which allows a distance reduction to 225 mm would lead to a 3 times larger positron yield at the re-conversion target. This increase can be directly translated into a increase of yield in the CsI-Calorimeter.

2.2.2 Background

Fig. 7 shows for the three different layouts the energy spectrum of photons depositing energy in the CsI-Calorimeter which are produced directly by photons present at the re-conversion target or produced by those photons in secondary interactions. The figure includes a study in which additional shielding is introduced between the spectrometer and the Analyzer magnet (a lead block of roughly 8.5x6x5 cm^3 size).

It is clearly visible that reducing the drift space in the vacuum chamber leads to a sizable increase of background photons. With respect to the default scenario the background increase by factor of 4.4 for the shortest distance between the two beamlines. This increase can be reduced to a factor of only 2.4 if additional shielding is introduced. For the latter scenarion the origin of the background is shown in Fig. 8. The largest source of background are still photons directly produced at the conversion target.

3 Changing the Target Material

As suggested during the collaboration meeting different (conversion) target materials are tested in the following:

a) 0.5 X_0 of Titanium as used so far (X_0(Ti) = 3.56 cm).

b) 0.5 X_0 of Tungsten (X_0(W) = 0.35 cm).

c) 0.1 X_0 of Tungsten.

For the subsequent study 1000 times 1000 undulator photons were simulated such that the results corresponds to what is expected for a bunch of 10^6 undulator photons (in the real experiment we expect to have $4 \cdot 10^9$ undulator photons). The resulting energy spectrum after the conversion target for the particles types for the three material choices is given in Fig. 2. The yield of the different particle types is summarized in Table 1.

Target Material	Particle Yield after the Conversion Target		
	γ	e^+	e^-
0.5 X_0 Ti	913379	5526	24263
0.5 X_0 W	945118	23143	47120
0.1 X_0 W	966896	11336	24975

Table 1: Particle yield after the conversion target for different choices of the target. The numbers are obtained for an amount of 10^6 undulator photons.

The amount of photons varies only by roughly 3-5% for the different choices. On the other hand the number of positrons increase by a factor of 4 when choosing 0.5 X_0 tungsten as target material instead of 0.5 X_0 titanium as have been used so far. Also the number of produced elctrons varies for the different material choices. However, it has been shown in the previous memos that electrons do not constitute a background source for the experiment.

3.1 Signal

For this scenario the setup as shown in Fig. 1 is used. The number of positrons hitting the reconversion target and the number of events creating a signal in the CsI Calorimeter are displayed in Fig. 9. As expected significantly more positrons are available at the re-conversion target , and subsequently the CsI-Calorimeter, when choosing 0.5 X_0 *W* instead of 0.5 X_0 *Ti*. The increase in yield is roughly a factor of 2. It might be interesting to note that this increase is smaller than the increase observed at the reconversion target. One possible reason for the general trend shown in Fig. 10 where the polar angle w.r.t. the z-axis of the positrons after the conversion target is shown. The high-Z material *W* leads to significantly larger polar angles such that these positrons have a larger risk to hit the beampipe in the solenoid and are lost for the subsequent analysis. Again, the situation is worse in the case of 0.5 X_0 *W* than for 0.1 X_0 *W*.

4 Conclusion and Outlook

In this study different layouts of the spectrometer as well as different choices for the target material have been investigated. From the presented studies the following conclusions can be drawn.

- The analyzer-magnet should be placed as close as possible to to the exit of the vacuum chamber. A length of 8 cm seems technically possible which lead to an increase of 50% of positrons hitting the re-conversion target w.r.t. the default scenario. Shortening the drift space in the vacuum leads to an additional increase of positrons at the re-conversion target w.r.t. the default configuration. At the time, however, the number of background photons registered in the CsI-Calorimeter increases significantly for the scenario. For the shortest possible spectrometer size an increase in signal of a factor 3 which is accompanied by an increase in background by a factor of 4.4 reducable to a factor of 2.4 when introducing dedicated shielding.
- A high-Z material such as tungsten seems to be superior to the titanium target employed so far. In case of 0.5 X_0 as absorber material of tungsten the number of positrons increase by a factor of four compared with 0.5 X_0 of tungsten as material choice. At the same time the increase of photons stays wihtin 5%.

References

[1] R. Pöschl, *Status Report of Spectrometer Simulation* Memo of 21/4/04 `http://www.slac.stanford.edu/exp/e166/internal/doc/2004/2004-04-21-rp-spectr_rp_210404.ps`.

[2] R. Pöschl, *Status Report of Spectrometer Simulation* Memo of 6/5/04 `http://www.slac.stanford.edu/exp/e166/internal/doc/2004/2004-05-06-rp-spectr_rp_070504.ps`.

[3] R. Pöschl, *Status Report of Spectrometer Simulation* Memo of 2/6/04 `http://www.slac.stanford.edu/exp/e166/internal/doc/2004/2004-06-02-rp-spectr_rp_060204.ps`.

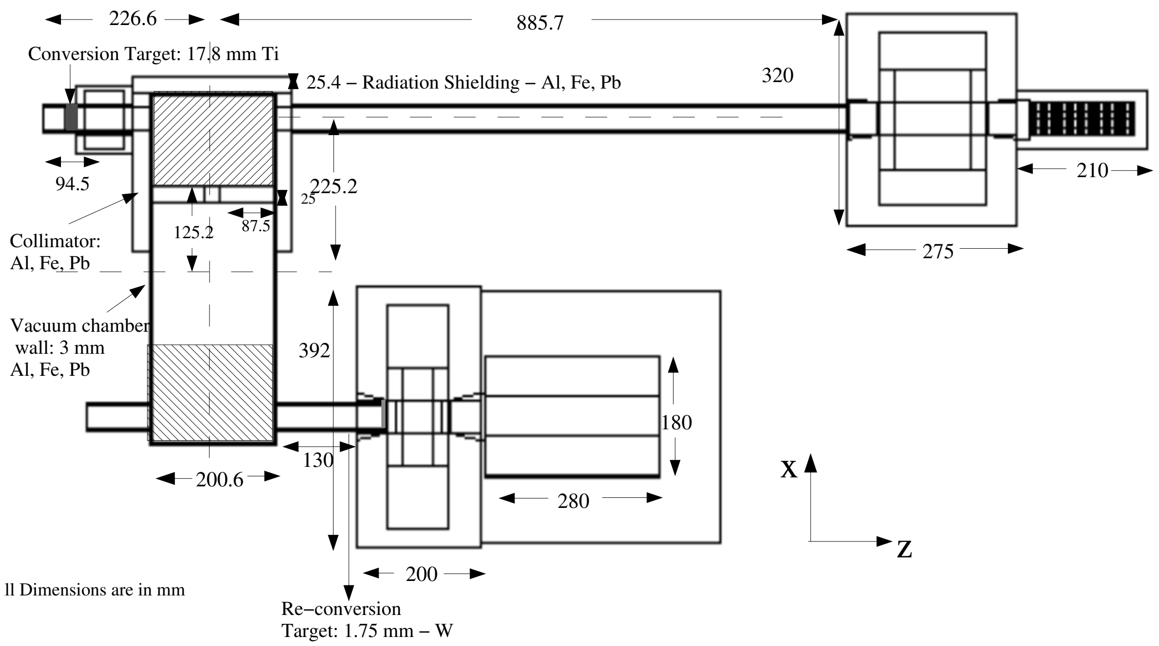

Figure 1: Spectrometer as implemented into the simulation (xz-view, default configuration for this memo). Hatched areas indicate the parts with active bending field.

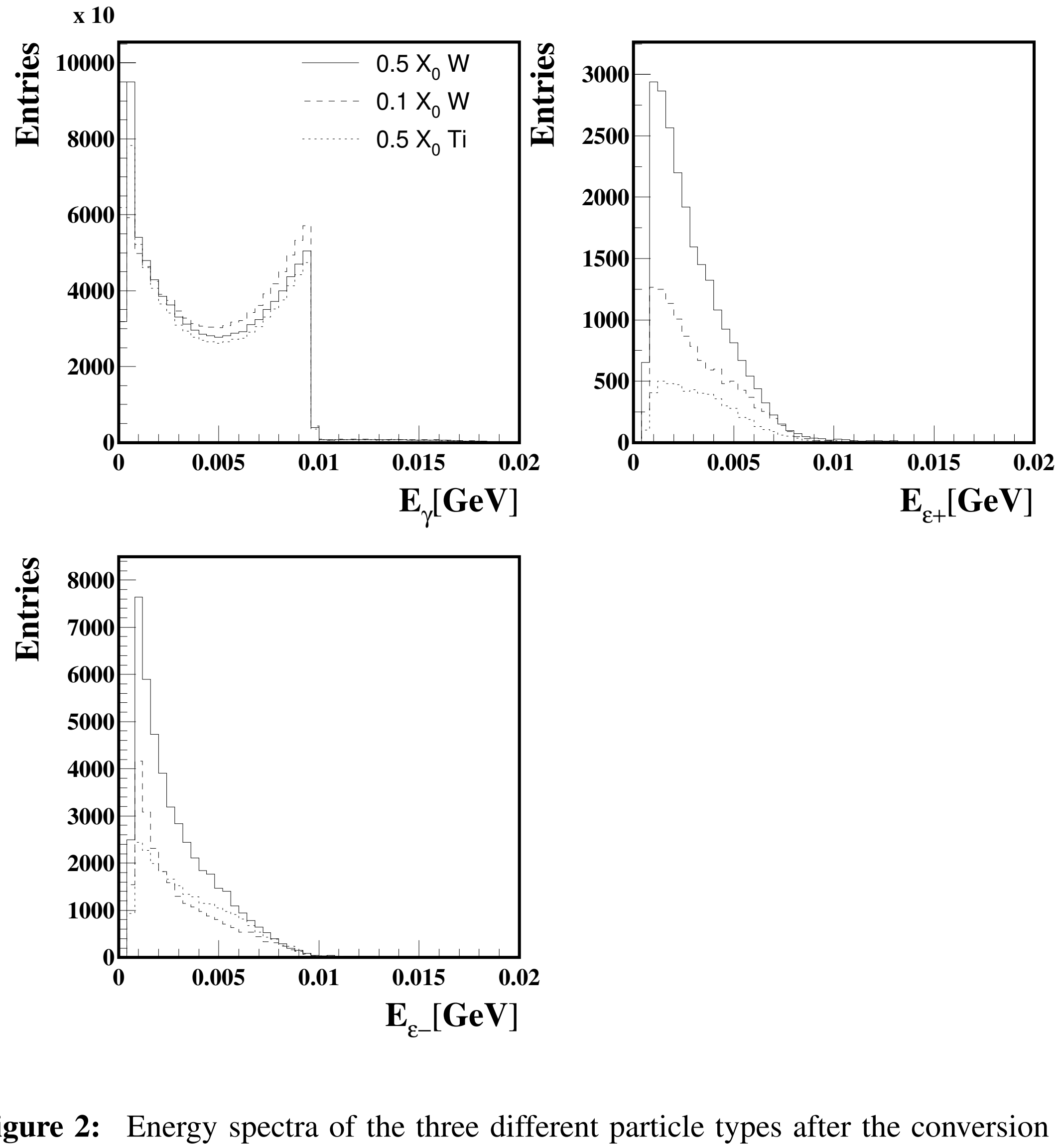

Figure 2: Energy spectra of the three different particle types after the conversion target for three different choices for the target material. The number are obtained for a bunch of 10^6 undulator photons hitting the conversion target.

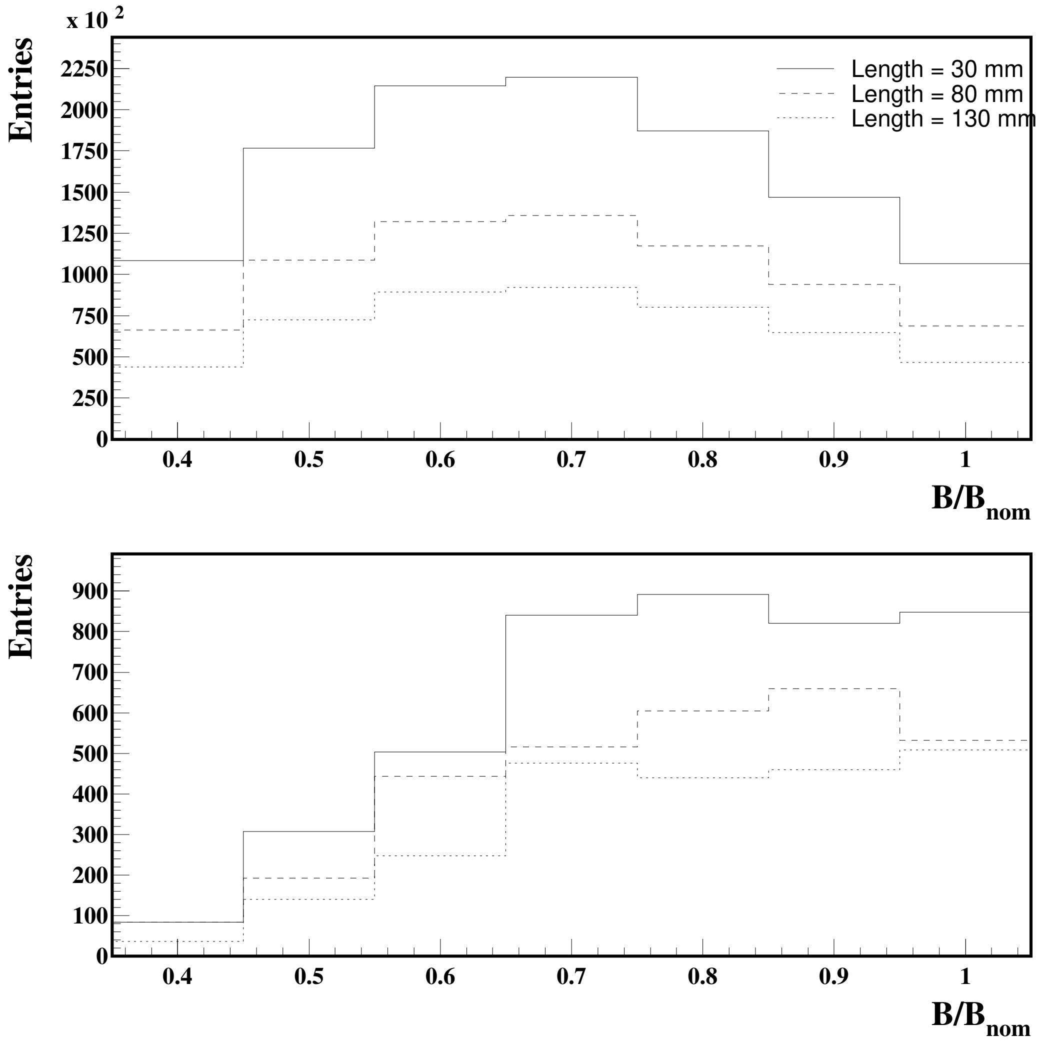

Figure 3: Number of positrons hitting the re-conversion target (upper part) and the number of events with signals in the CsI-Calorimeter. (lower part) for three different lengths of the exit beampipe as descibed in the text. The numbers are scaled to $2 \cdot 10^7$ input positrons

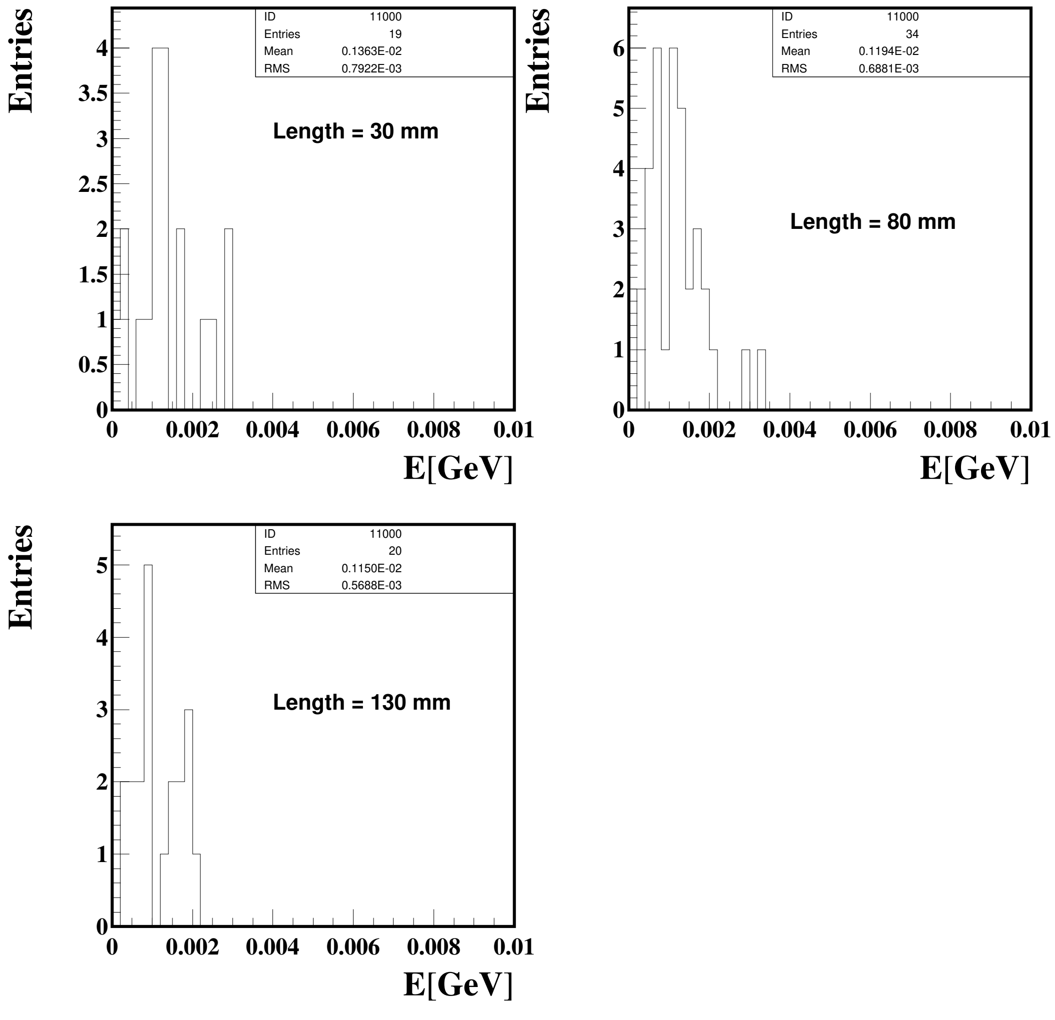

Figure 4: Energy spectra and yield of photons creating signals in the CsI for three different lengths of the exit beampipe. The number are obtained for a bunch of 10^7 photons starting behind the conversion target. They have to be scaled up by 400 corresponding to the number of $4 \cdot 10^9$ photons expected in the real experiment.

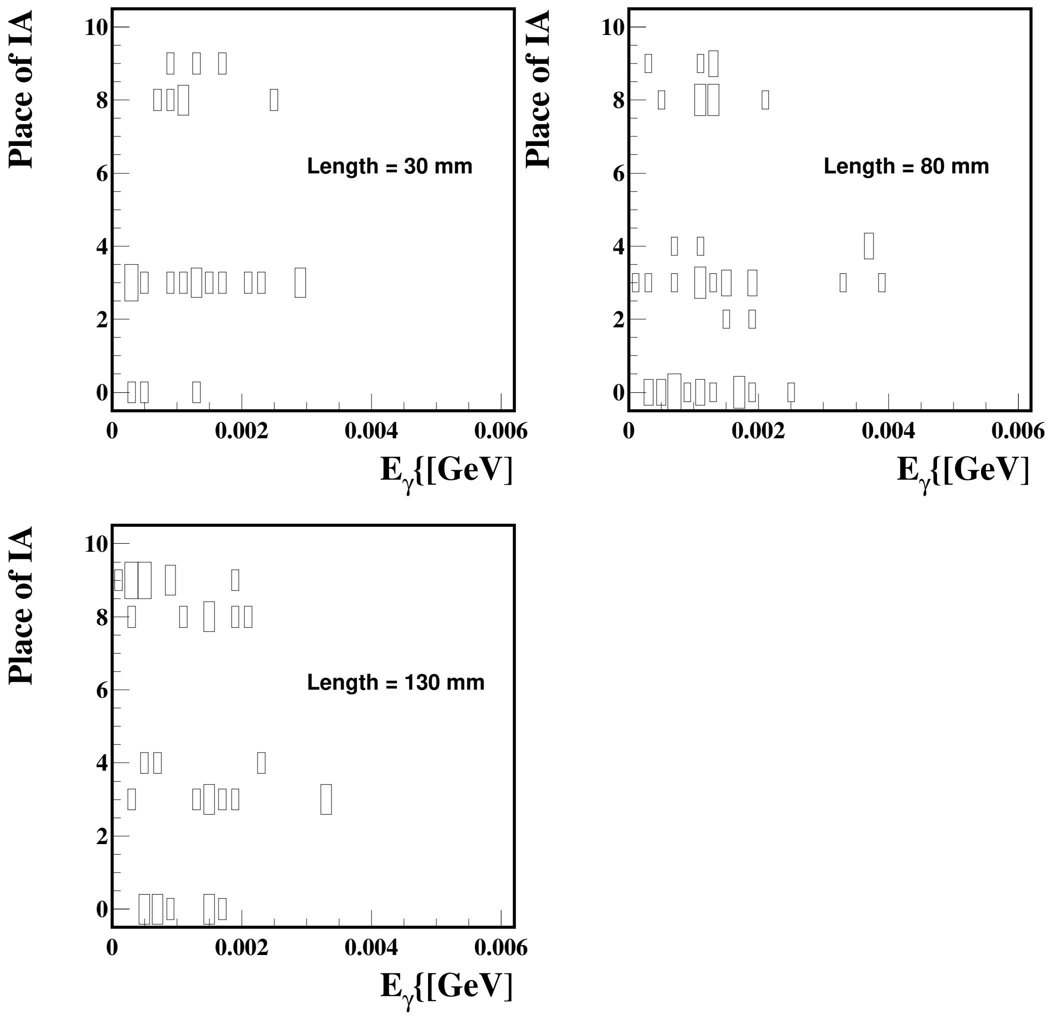

Figure 5: Interaction point versus energy of photons hitting the re-conversion target and produced by primary photons present after the conversion target. The vacuum chamber consists of aluminum. The codes on the y-axis are: 0=No interaction, 1=Solenoid (Copper part, iron part or beampipe piece), 2=Analyzer Magnet, 3=Radiation shielding, 4=Vacuum chamber, 5=Reconversion target, 6=Beampipe at exit of vacuum chamber, 7=Analyzer Iron within Analzer Magnet, 8=Gamma Beampipe, 9=Anything else.

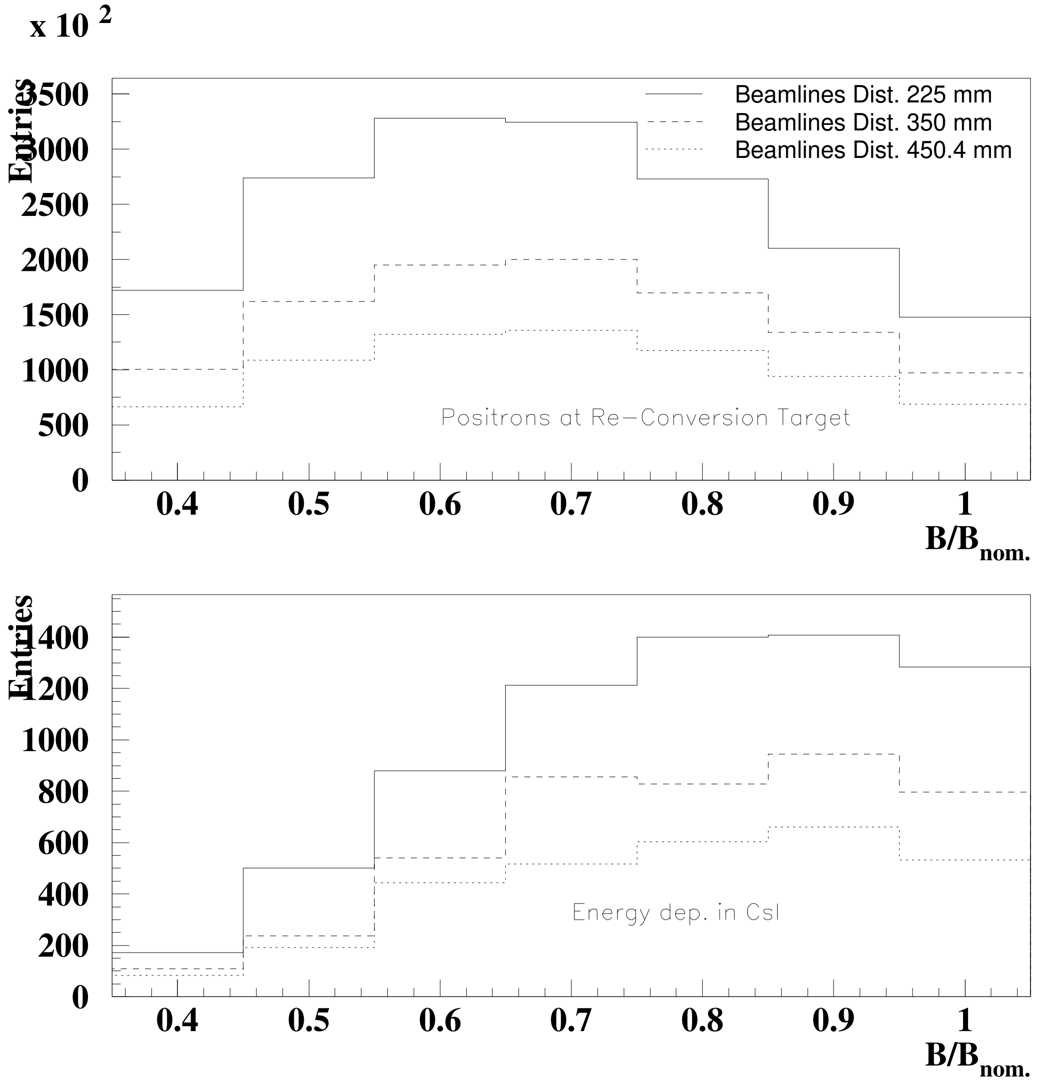

Figure 6: Number of positrons hitting the re-conversion target (upper part) and the number of events with signals in the CsI-Calorimeter. (lower part) for three different distances between the beamlines as descibed in the text. The numbers are scaled to $2 \cdot 10^7$ input positrons

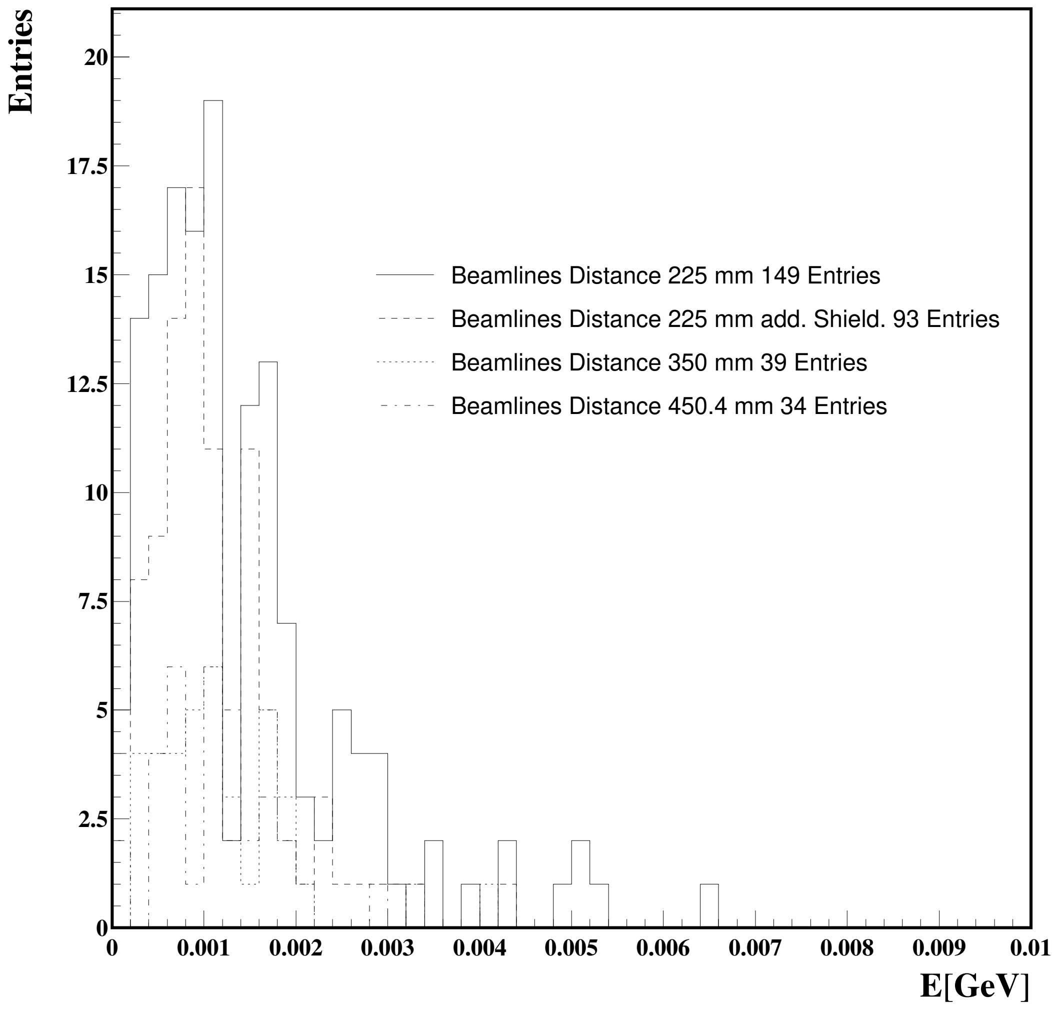

Figure 7: Energy spectra and energy depositions photons in the CsI for three distances between the beamlines (equivalent to three different layouts of the spectrometer). For the '225 mm'-scenario the reults after the implementation of additional shielding is given. The number are obtained for a bunch of 10^7 photons starting behind the conversion. They have to be scaled up by 400 corresponding to the number of $4 \cdot 10^9$ photons expected in the real experiment.

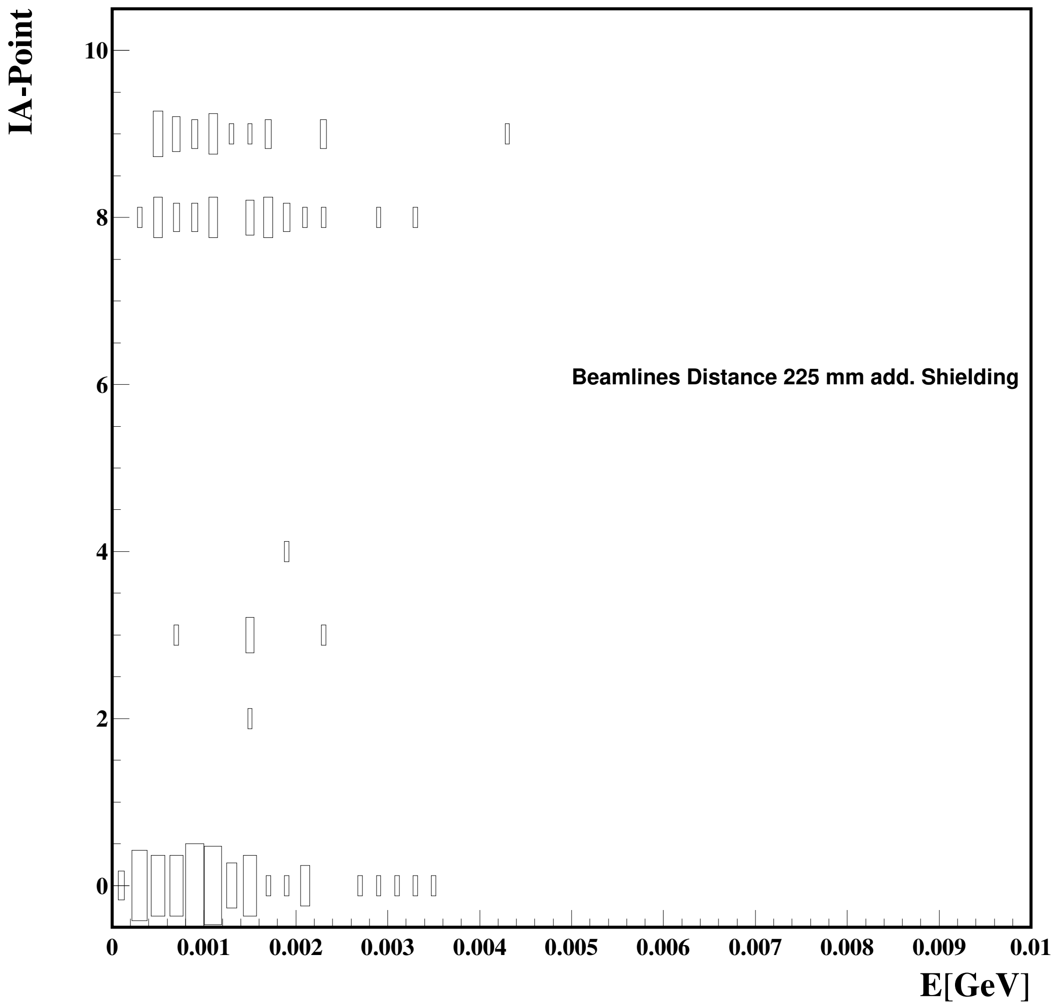

Figure 8: Interaction point versus energy of photons hitting the re-conversion target and produced by primary photons present after the conversion target. The vacuum chamber consists of aluminum. The codes on the y-axis are: 0=No interaction, 1=Solenoid (Copper part, iron part or beampipe piece), 2=Analyzer Magnet, 3=Radiation shielding, 4=Vacuum chamber, 5=Re-conversion target, 6=Beampipe at exit of vacuum chamber, 7=Analyzer Iron within Analzer Magnet, 8=Gamma Beampipe, 9=Anything else.

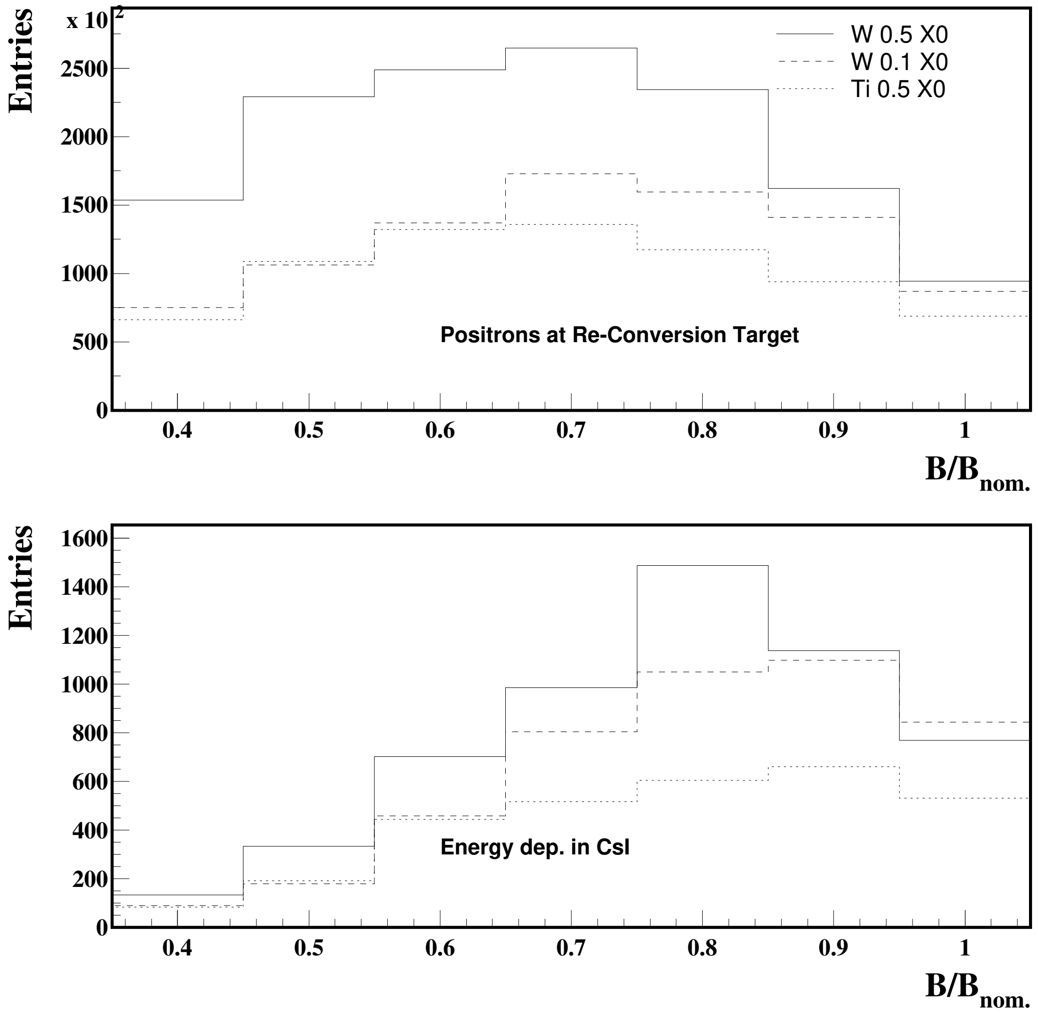

Figure 9: Number of positrons hitting the re-conversion target (upper part) and the number of events with signals in the CsI-Calorimeter. (lower part) for three different configurations of the spectrometer as descibed in the text. The numbers are scaled to the correct number of input positrons at the conversion target.

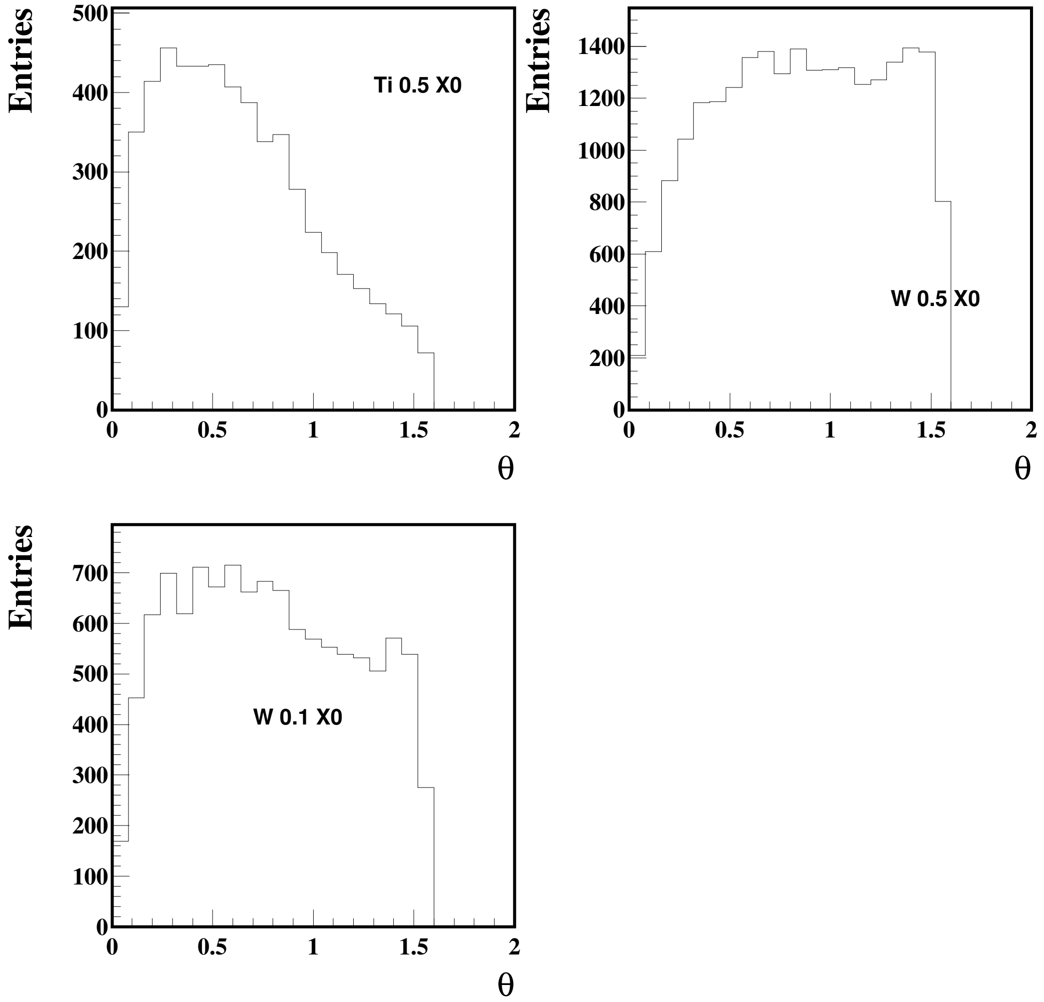

Figure 10: Polar angle measured w.r.t the z-axis of positrons after the conversion target for three different options of the conversion-target material.