POSITRON COLLECTION AND BACKGROUND STUDY

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In this study, I looked at the positron collection efficiency and related background improvements when certain parameters changed.

1 Positrons at the Tungsten target

Positron energy distributions in the upstream and downstream directions are shown in Fig. 1. In this figure only e+ is shown. The total number of events in the forward direction is 30463 e+ from 10^8 e-. In all these studies the incident electron kinetic energy is 6.5 MeV on a 1 mm Tungsten converter.

The total efficiency (created positrons per INCIDENT electron) is $\sim 3.1 \times 10^{-4}$ e+/e-. If we make an artificial cut in the forward angle of positrons for Fig. 1, we see that the number of positrons decrease by a factor of ~ 9 as seen in Fig. 2. So the efficiency (e+/e-) within 300 mrad hard cut in the forward direction is $\sim 3.4 \times 10^{-5}$ e+/e-. By looking at the figure we see that the most efficient collectible bin of positrons lies between 0.5 and 1.5 MeV kinetic energy.

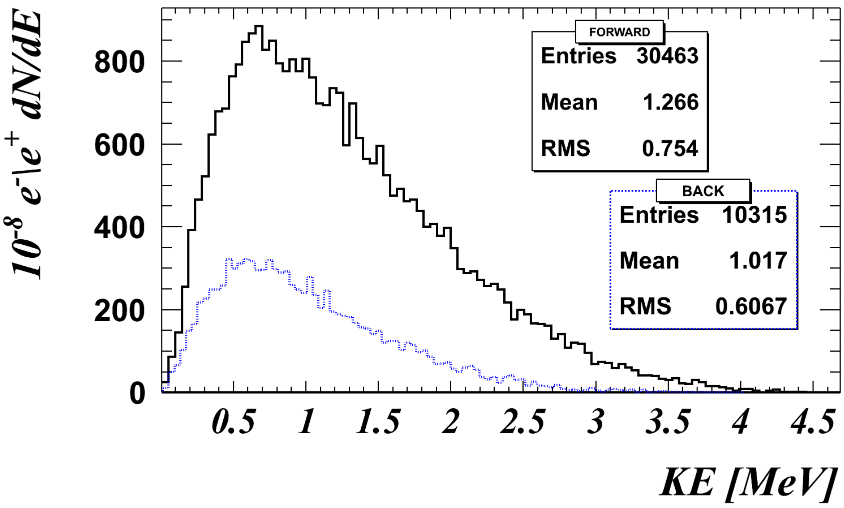

Figure 1: Positrons emitted from 1 mm tungsten. Number of incident electrons is 10^8.

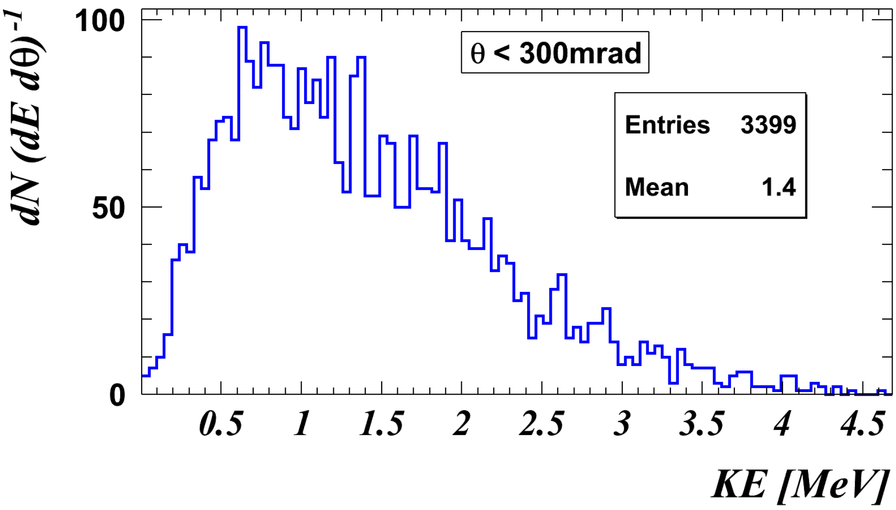

Figure 2: Positrons emitted from 1 mm Tungsten with angular cut $\theta < 300$ mrad. Number of incident electrons is 10^8.

2 Simulation of positron capture by S1 solenoid

The following configuration as shown in Fig. 3 consists of a target ladder, tungsten target (1 mm thick) inside the pipe, collimator (thickness is ~ 3.1 mm) with various aperture diameters and finally S1 solenoid (ID = 1.5 inch , Length=3.5 inch as provided). The Poisson field map was used for this solenoid. 100 A current excitation is used. This current is equal to about 2.8 kG at the center of the S1 solenoid. The collimator is located 10 mm away from the Tungsten. The face of the S1 solenoid is located 120 mm away from the Tungsten.

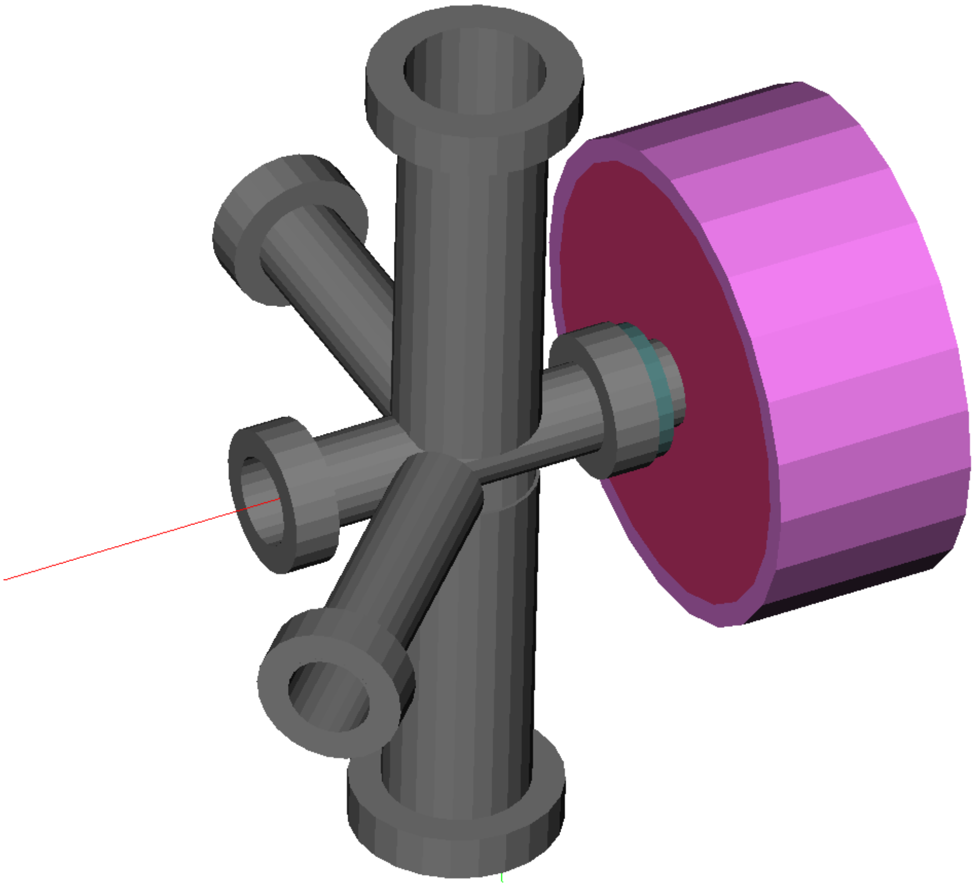

Figure 3: G4beamline snapshot for configuration of target ladder with solenoid. The collimator and tungsten target is inside the ladder. The electron beam is coming from the left.

By using the configuration provided in Fig. 3 I looked at positron collection efficiency for collimator aperture diameters 2,4 and 6 mm. In Fig. 4, only positrons are recorded in the virtual detector which is located right after the S1 solenoid. Electromagnetic shower is turned ON in all objects so it is possible to collect positrons not only from the Tungsten but also from others. As it can be seen from Fig. 4 with 2 mm aperture we get a factor of 3 less positrons at the end of S1 when compared to 6 mm aperture. Any aperture larger than 6 mm does not affect the captured positron efficiency. In the next study I looked at the background suppression with the same configuration.

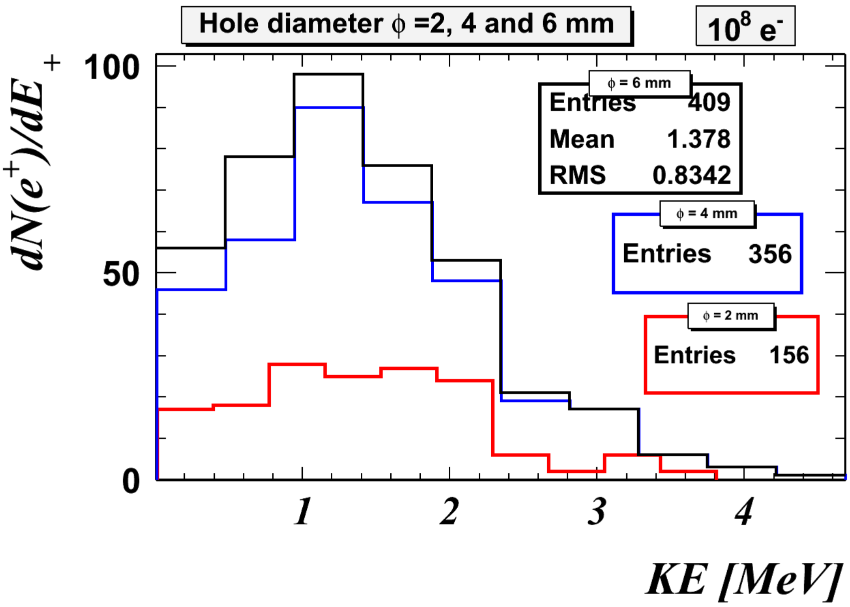

Figure 4: Positrons recorded at the end of S1 for collimator apertures 2, 4 and 6 mm size. 10^8 e- is used as incident electron.

3 Background for various collimator aperture diameters

In the previous section we looked at how different aperture sizes change the capture efficiency as recorded at the end of S1 solenoid. Now let's look at if using a collimator suppresses the background or not. In Fig. 5, secondary particles emitted from tungsten in the forward direction is shown. No collimator is used. The number of incident electrons used for this background study is 10^6 e-.

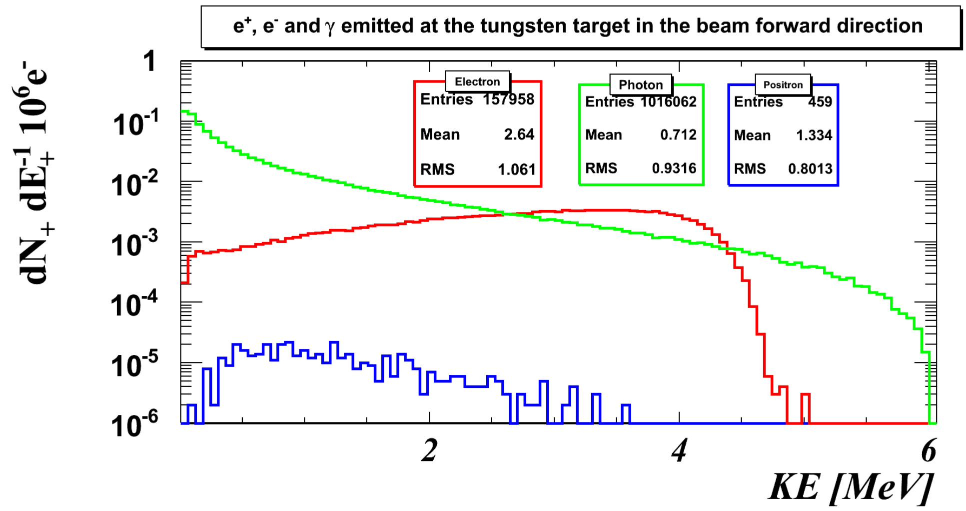

Figure 5: The emitted e-, e+ and γ from 1 mm tungsten in the forward direction. There is no collimator. 10^6 e- incident electron used in the simulation. Y axis is plotted in log scale. Blue is positron, green photon and red is electron.

If we compare the total number of (electrons + photons) produced for cases where no collimator exist, $\phi = 2$ mm and $\phi = 6$ mm we see that only $\sim 10\%$ of the background is suppressed with the collimator. While suppression of background stays only at 10% the signal loss is by a factor of 3 when no collimator is used and 2 mm aperture is used.

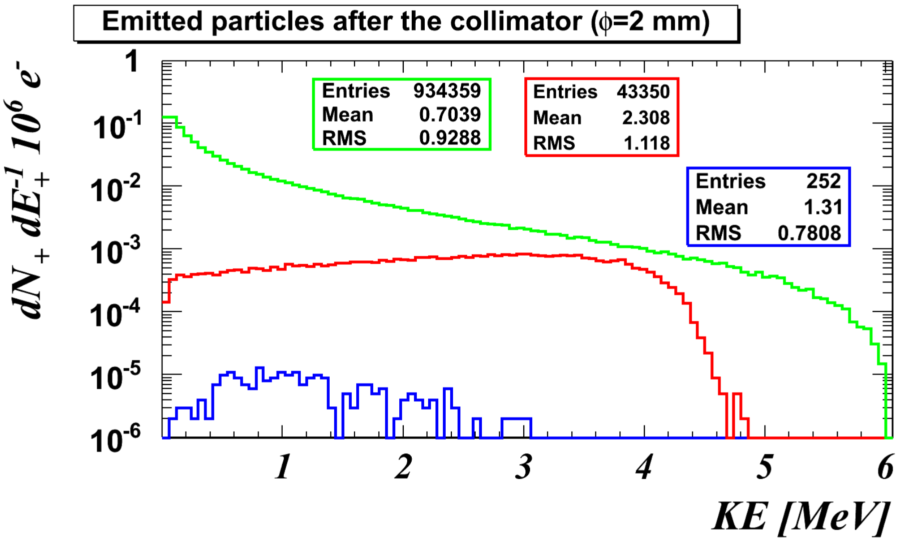

Figure 6: The emitted e-, e+ and γ from 1 mm tungsten in the forward direction. The collimator aperture is 2 mm. It is located 10 mm away from the Tungsten. 10^6 e- incident electron used in the simulation. Y axis is plotted in log scale. Blue is positron, green photon and red is electron.

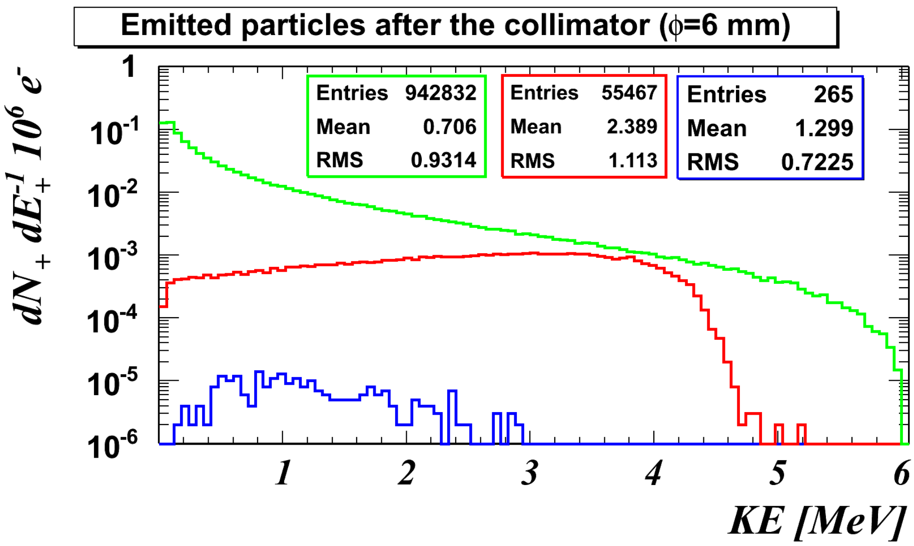

Figure 7: The emitted e-, e+ and γ from 1 mm tungsten in the forward direction. The collimator aperture is 6 mm. It is located 10 mm away from the Tungsten. 10^6 e- incident electron used in the simulation. Y axis is plotted in log scale. Blue is positron, green photon and red is electron.

4 Where is the best location for S1 solenoid ?

In this study, I removed the collimator and looked how changing the location of the S1 improves the capture efficiency. I looked at 2 different locations where the tungsten is 10 mm away from the face of S1 and 50 mm away from S1. As seen in Fig. 8, when the S1 face is as close as 10 mm to the tunsten we collect almost 80% of the positrons we calculated in Fig. 2. If we locate the face of the S1 solenoid 50 mm away from the tungsten there is a factor of 2.5 more loss when compared to 10 mm distance.

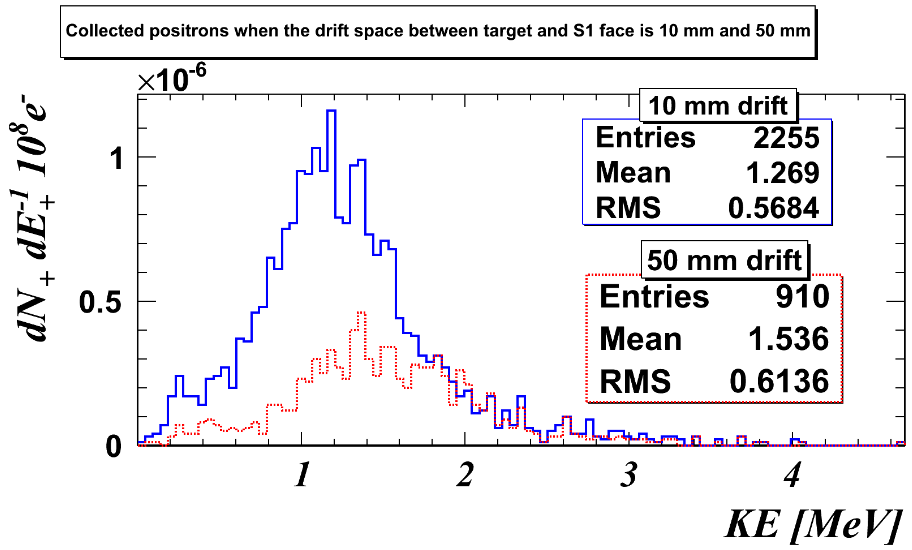

Figure 8: The collimator is removed and S1 solenoid is located closer to the tungsten target. The drift space between tungsten and S1 face is 10 mm and 50 mm.

5 Summary

The efficiency of emitted positrons in the forward direction without any type of cuts is $\sim 3.1 \times 10^{-4}$ (e+ / incident e^-). If we look at the positrons emitted within 300 mrad hard cut the efficiency drops down by order of magnitude $\sim 3.4 \times 10^{-5}$. It can be said that around 1 MeV it is the most efficient energy bin. Although S1 by being positioned 10 mm away from the tungsten does a great job by collecting most of these positrons, clearly in the spectrometer most of them will be lost.

From the collection and background simulations, placing a collimator right next to the tungsten target does not suppress the background drastically nor it improves the positron collection. I believe it is best not to use a collimator instead locate the S1 as close as possible to the target.