Coordinate Detector Simulations

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Abstract

Simulations of the Coordinate Detector for the SBS project are presented. The aim of the studies is to estimate the background rates, the detector efficiency and resolution and to optimize the geometry with respect to these parameters.

1 Introduction

The Coordinate Detector was proposed to be used for the GEp experiment in the SBS project to improve the position resolution of the electro-magnetic calorimeter in vertical direction. This is essential for the track reconstruction of the elastic proton.

In the original proposal of the GEp(5) experiment GEM chamber technology was used for the coordinate detector. It consisted of two GEM planes with $1\ mm$ strips oriented horizontally. Later, due to the complexity of building large GEM areas and related to that higher price, scintillator based detector was proposed. It will consist of scintillator plates, few mm thick, with a width of a few cm and the length defined by the horizontal acceptance of the electron arm. The scintillating light is collected by fiber WLS.

2 Simulation parameters

The geometry used for these simulations includes only the GEp target ($40\ cm$ long), the vacuum chamber, and the Coordinate Detector with a $15\ cm$ plastic absorber in front of it (Fig.1. These elements are inserted in an air volume. Two geometry types of the Coordinate Detector have been studied. In one, the scintillators have rectangular cross-section $3\ mm$ or $5\ mm$ thick and a with of $3\ cm$. In the other geometry the cross-section of the scintillators is a trapezoid. The angles and stacking is chosen in such a way so that the top/bottom sides of the scintillator plates always point to the target (Fig.1). All the front sides of the plates are touching the back of the absorber (Fig.1). In this geometry also two scintillator thicknesses, measured at the front, were studied: $3\ mm$ and $5\ mm$. In all the geometries the length of the scintillator planes was $134cm$ corresponding the horizontal size of the elctro-magnetic calorimeter.

Pavel Degtiarenko's version of GEANT3 was used. The energy cut for both the electro-magnetic particles and hadrons was $100keV$. For background rate estimates, $11\ GeV$ electrons are directed to the target. For the other studies, detector efficiency and resolution, ep-elastic reaction was simulated. Only the highest $Q^2 = 12GeV^2$ kinematics was studied with the Coordinate Detector positioned at 28.17^0, $523\ cm$ from the target. All the results presented below are averaged over all the channels.

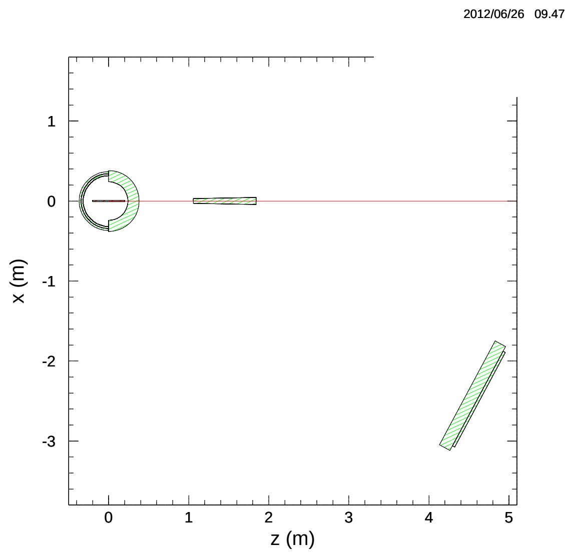

Figure 1: Setup used in the simulation

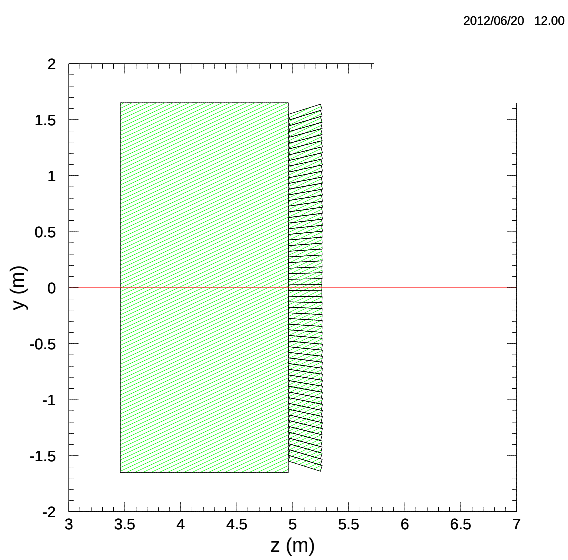

Figure 2: Trapezoid version of the Coordinate Detector: vertical cross-section. To illustrate the geometry the target was placed $50\ cm$ in front of the detector.

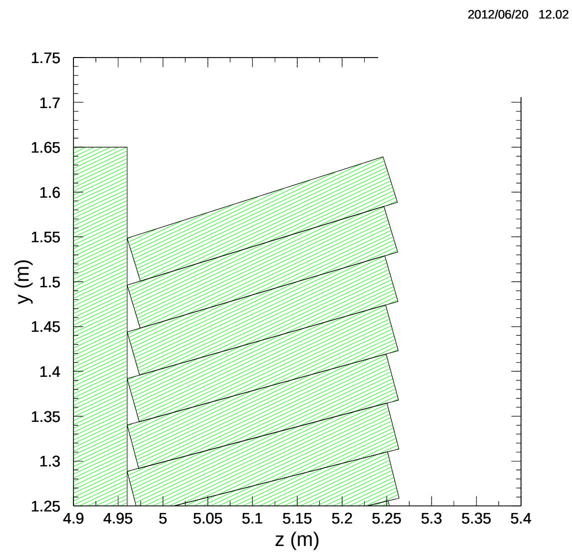

Figure 3: Fig.1, zoomed at the top edge.

3 Results

The distribution of the energy deposited in one channel is shown for the two types of geometry with $3\ mm$ thick scintillators in Fig.3, and Fig.3. The higher energies in the spectra come from the direct electrons while the lower energy part represents energy losses from δ-electrons and Bremstrahlung photons created mostly in the absorber. If the elastic electron goes through the whole scintillator depth it deposits energy at least of $4.5\ MeV$ which is mostly the case for the trapezoidal geometry, where the direct peak is visible. For the rectangular geometry, due to the inclined tracks, the energy deposition from the direct electron is similar to the energy depositions of the secondary particles. Therefore, there's a significant difference in the efficiencies of these two types of geometry. As shown at the top of Fig.4 the drop of the efficiency for the rectangular geometry happens at much lower thresholds. Remarkably, the efficiency for the trapezoidal geometry behaves in the same way for the 3 and $5\ mm$ thicknesses. The multiplicity distributions, number of channels above a threshold, also are very different for the two geometries (Fig.3,Fig.3): much higher multiplicity in case of rectangular geometry.

The coordinate is reconstructed using the center of gravity of the channels above the threshold. Weighting by the corresponding channel energy improves the resolution only slightly; the results presented here are without weighting. As it is common for such block detectors, the reconstructed in this way coordinate deviates from the real hit position in a standard way (for the corresponding geometry) as show for the two detector types at Fig.3 and Fig.3. The Coordinate Detector resolutions, after applying such

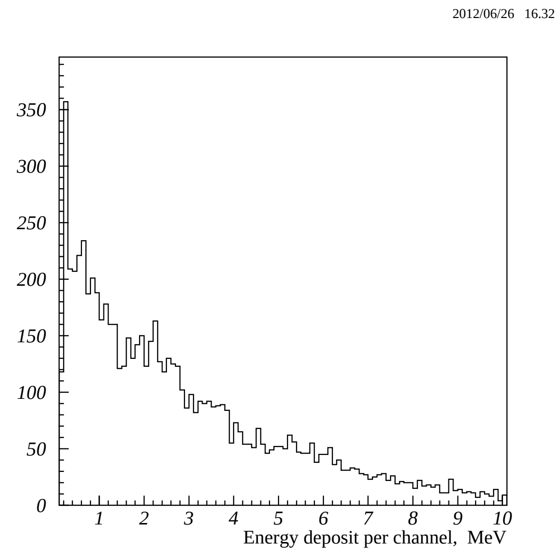

Figure 4: Averaged energy deposition in one channel for $3\ mm$ rectangular scintillators.

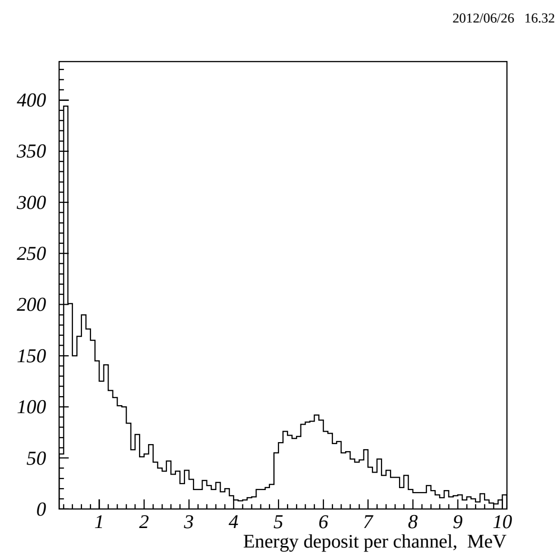

Figure 5: Averaged energy deposition in one channel for $3\ mm$ trapezoidal scintillators.

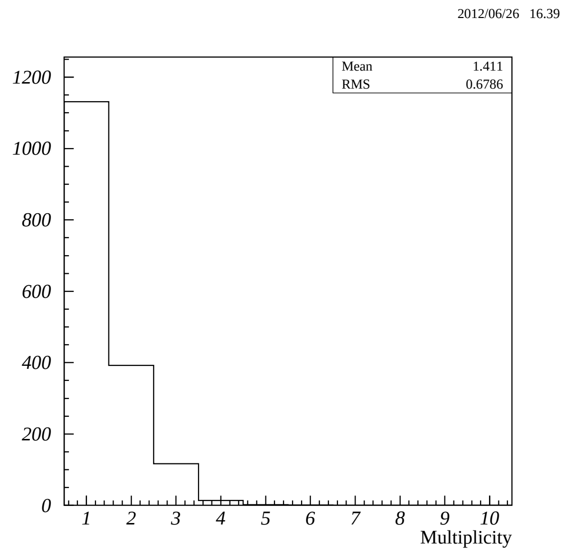

Figure 6: Multiplicity distributions for $3\ mm$ rectangular scintillators with a threshold of $4\ MeV$.

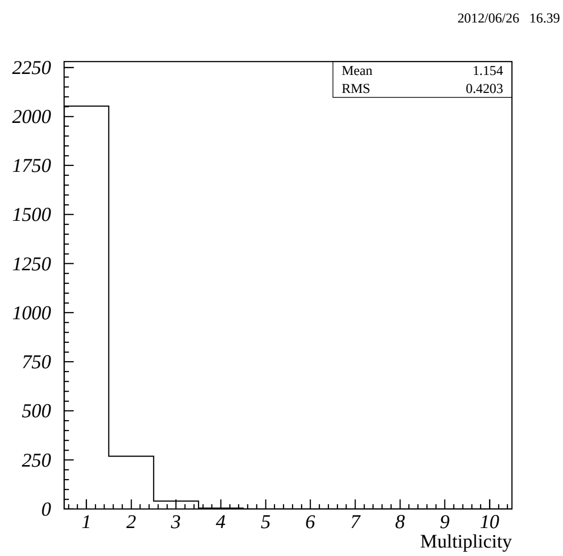

Figure 7: Multiplicity distributions for $3\ mm$ trapezoidal scintillators with a threshold of $4\ MeV$.

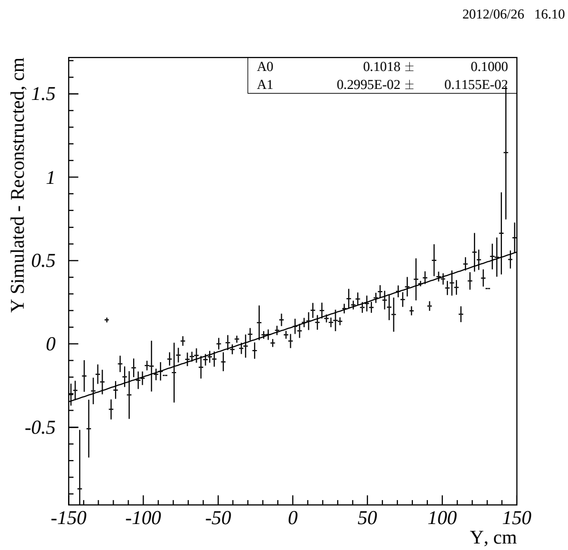

Figure 8: "S-shape" correction in case of $3\ mm$ rectangular geometry.

corrections, are plotted in the middle panel of Fig.4 as a function of the threshold. The resolutions for the rectangular geometries at a fixed thickness, are slightly better than those for the trapezoidal geometries that can be explained by the lower multiplicities in the latter case. Certainly there's an improvement of $30-40$ % going from $5\ mm$ to $3\ mm$ thickness.

4 Recommendations for the conceptual design of the Coordinate Detector

Fig.4 summarizes all the results. The background rates per channel are plotted at the bottom panel. As expected, they are roughly proportional to the thickness of the scintillator. On the other hand, the independence of the efficiency on the scintillator thickness (3 to $5\ mm$) in case of the trapezoidal geometry, gives a opportunity to reduce the load on the strips without affecting the working threshold and the amplitude of the signal. Based on these simulations, we propose to use $3\ mm$ trapezoidal strips. Additional studies are needed to further define the number of vertical detector planes needed. To reduce the attenuation in the WLS and the loads on the strips, splitting of the scintillator plates in half is an advantage. In case it turns out that the loads on the strips are well below the acceptable level, thinner absorber is recommended which will further improve the coordinate resolution.

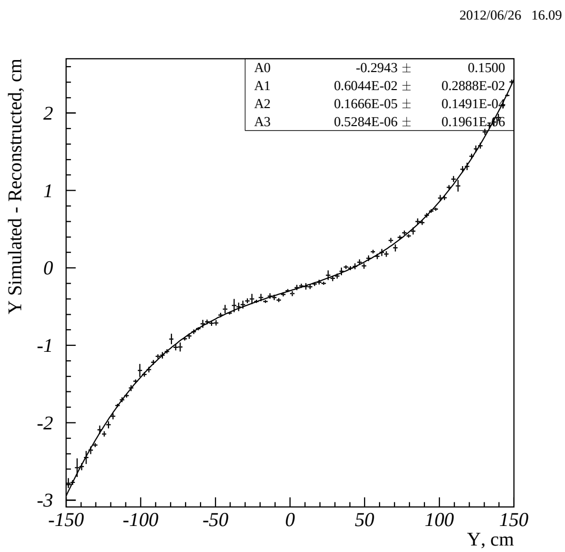

Figure 9: "S-shape" correction in case of $3\ mm$ trapezoidal geometry.

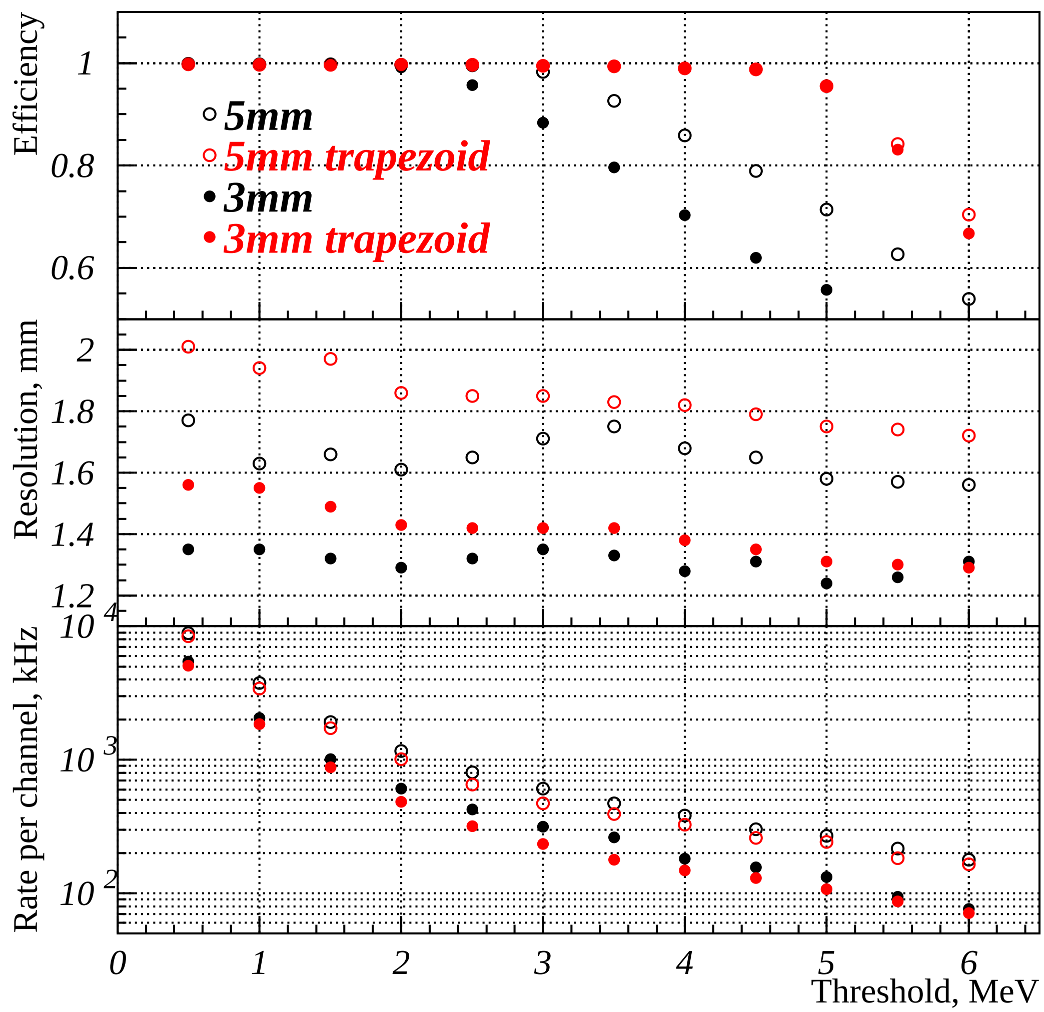

Figure 10: Efficiency (top), coordinate resolution (middle), and background rate (bottom) averaged aver all the channels for different thresholds and geometries as indicated.