A Simulation of the E949 Collar Detector using GEANT

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Abstract

This note describes the results of a detailed GEANT simulation of the E949 Collar Detectors. I considered the possible upgrade of Collars: the usage of W convertor instead of Pb one.

1 Introduction

One of the main aim of the E949 is to extend the search of the $K^+ \to \pi^+ \nu\bar{\nu}$-decay to the region below $K_{\pi 2}$ peak. To accomplish this it is important to significantly reduce the inefficiency of small angle elements of Photon Veto(PV) system [1]. There is a detailed study of a possible upgrade of the upstream elements of the E949 Detector [2]. As it was mentioned on the October Collaboration Meeting [3], after this and other upgrades of the PV, downstream Collar(CO) will be one of the weakest points of the installation.

Some simulations of E787/E949 detector using GEANT were done in [4, 5]. In these works most of the elements of PV system were simulated as solid cylindrical shells (made of appropriate materials). The main task of this note is to simulate the response of the CO in more details and to study one of the possible ways of the upgrade of CO: the usage of W convertor instead of Pb one.

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2 Geometry of CO

I took the geometry of the downstream CO from the corresponding technical drawing. It includes 24 layers of 1 mm convertor and 25 layes of 5 mm scintillator, as well as aluminized mylar layers and two Al plates. The detector consists of 12 sectors. I did not include mixer blocks and light guides into the simulation. The setup includes also the return iron and active target. No active/passive material between Target and CO was included. It was assumed that the magnetic field is homogeneous with $B_z = 9.6$ kG.

X-view of the detector is presented in Fig. 1. Typical picture of shower development for γ with $E = 200$ MeV is also shown.

Z-view of the detector is presented in Fig. 2. Points 1 and 2 are the entrance points for γ's, used in this simulation.

3 Detector Simulation

The scintillator was simulated as having the properties of BC-408 ($\rho =$ 1.032 g/cm^2, H/C=1.104) [6]. The simulation was done in terms of visible energy in a scintillator. This means that no response of ADC channels were simulated, and they are assumed to be perfectly calibrated. As the main aim was to study the relative inefficiencies for W/Pb options, γ's with descrete energies 10, 20, 40, 60, ..., 240 MeV were generated just upstream of the CO in two points: 1 - in the middle of the sector and 2 - about 2 mm from the sectors boundary. The second point was used to estimate the influence of the discreteness of the detector.

In real life only about 1/2 of γ's, originated near the centre of the fudicial volume of the target and pointing to the face of the downstream CO, pass through the the target without conversion. The estimation of the inefficiency of PV for converted γ's demands the full simulation of E949 detector and offline cuts and goes far beyond the aims of this note.

For the definition of the inefficiency the energy threshold(E_{thr}) of the detector should be specified. In my calculations I used and compared two values for E_{thr} - 1 MeV as a typical threshold energy for E787 detector and 2 MeV as it was used in Mr. Sasaki's thesis (table 4.3 in [7]). It is also important to specify what is the energy threshold - is it a sum of energy in all sectors or a seperate cut in energy should be imposed on each sector. The last way of threshold definition is important for the entrance point 2 (Fig. 2), as in this case the energy is shared between two sectors.

4 Results

I used a relatively low GEANT thresholds (stopping energies,E_{stop}) for e/γ, $E_{stop} = 0.1$ MeV. In order to have a feeling of the influence of GEANT threshold on the inefficiency, I also made some simulations using standard GEANT value $E_{stop} = 1.0$ MeV. The results for Pb option are presented in Fig. 3. It can be seen from the picture, that the the change in the stopping energy has small(if any) influence on the inefficiency, although the distribution of visible energy is shifted.

My main result for the comparison of W/Pb options is presented in Fig. 4. It can be seen from the picture, that the usage of W as a coverter gives the significant improvement of the efficiency for all the energies down to $\approx$ 20 MeV. For the very low energies, on the contrary, the efficiency for Pb option is a little bit better. This is definitely due to the fact, that in this range the inefficiency is dominated by sampling fluctuations and for W option the visible energy is closer to the threshold due to the worse active/passive material ratio. It is not clear now what will be the the influence of the degradation of the efficiency for very low energies if W covertor will be used. The answer to this question again demands a simulation of the whole E949 detector for a real decays.

The influence of the energy threshold is illustrated in Fig. 5 for W option. It is evident that going from 2 Mev to 1 Mev for the energy threshold results in significant (factor of 1.5-2) improvement for low energies($< 30\ MeV$), but gives next to nothing for higher ones.

I found no influence of the absence/presence of the Iron shield on the efficiency within the current accuracy of calculations.

The above results were received applying of energy threshold to the total energy in a detector(summed over all sectors) and for point 1. For this definition of E_{thr} the results for point 2 are the same (as it should be). For the second definition of E_{thr} when the energy cut (1 meV) was emposed on each sector, I saw only a small worsening of the efficiency for point 2 and only for very small energies $<$ 30 MeV.

5 Conclusions

The aim of this study was to understand the advantages and drawbacks of the usage of W instead of Pb as a convertor for CO detectors. The W option is much better for the energies down to $\approx$ 20 MeV. The worsening of the efficiency for very low energies demands a special investigation. As the visible energy for W option is lower, more careful calibration and lower energy threshold for the Collar ADC channels may be needed.

References

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[4] "A Simulation of the E787 beamline/detector using GEANT", E787-TN-339, V. Jain, Oct. 27, 1997.

[5] "A Simulation of the elastic scatter of π^+, produced in $K^+ \to \pi^+\pi^0$ decays, in the target", E787-TN-375, V. Jain, Nov. 3, 1999.

[6] BICRON online catalogue.

[7] T. Sasaki, 1997, Master's thesis, Osaka University.

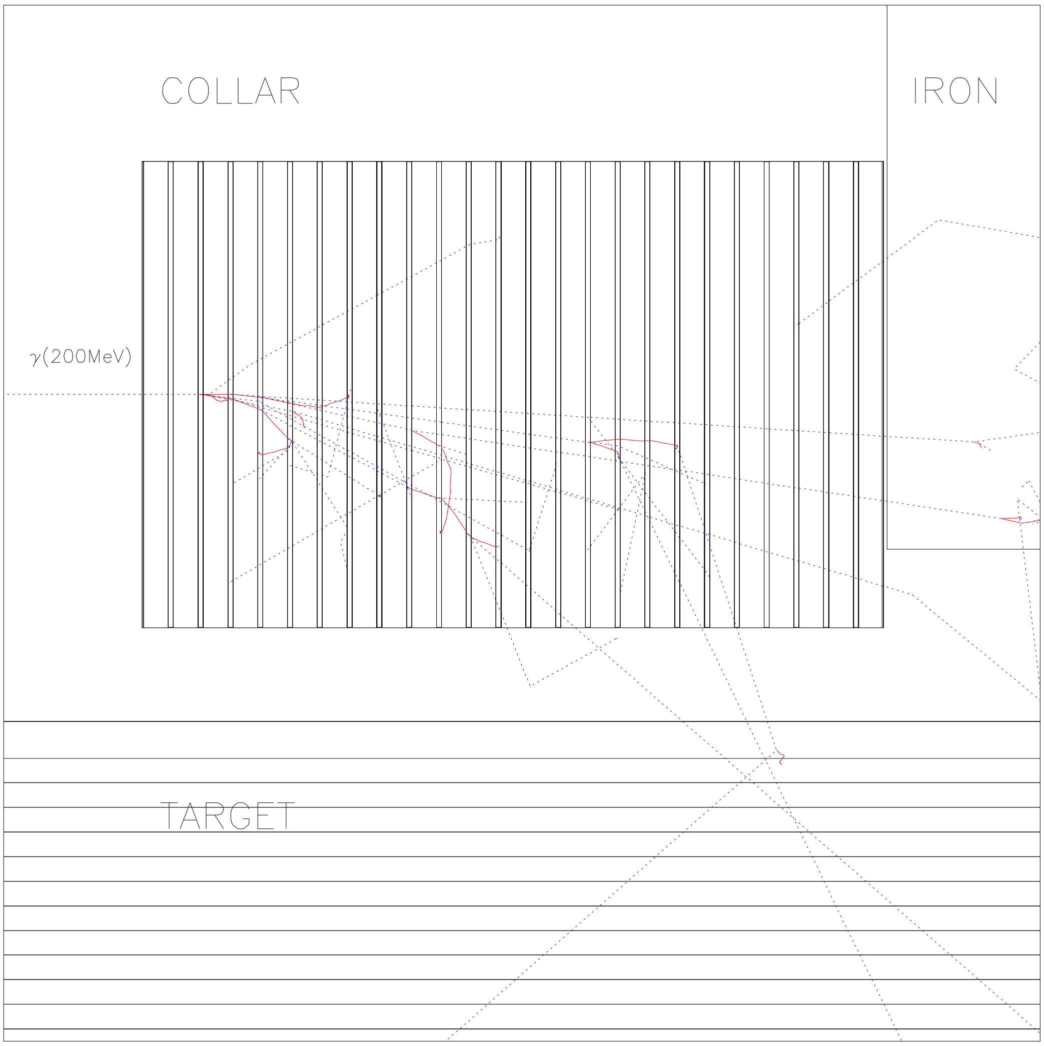

Figure 1: X-view of the downstream CO together with the IRON and active TARGET. Typical picture of shower development for γ with $E = 200$ MeV is also shown.

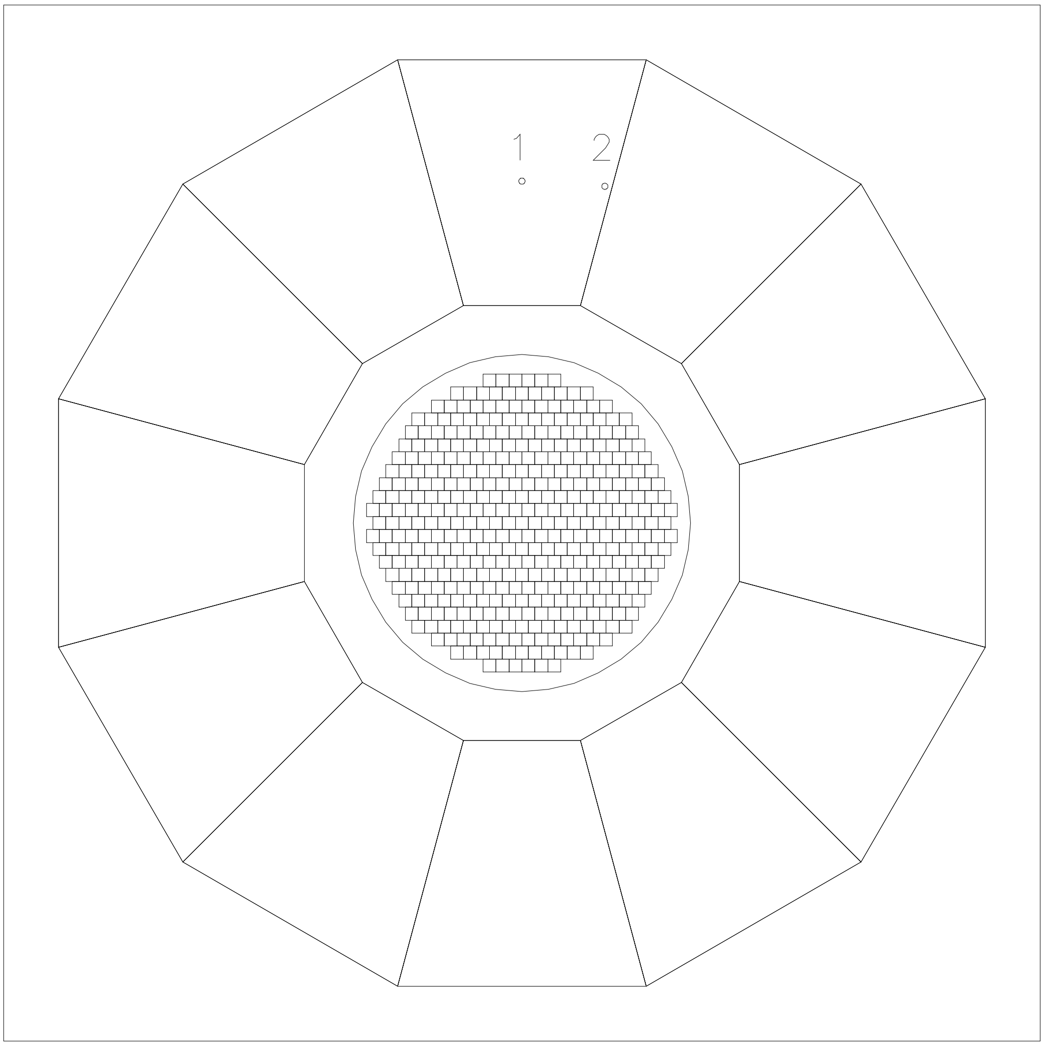

Figure 2: Z-view of the downstream CO together with active TARGET and two entrance points(see text).

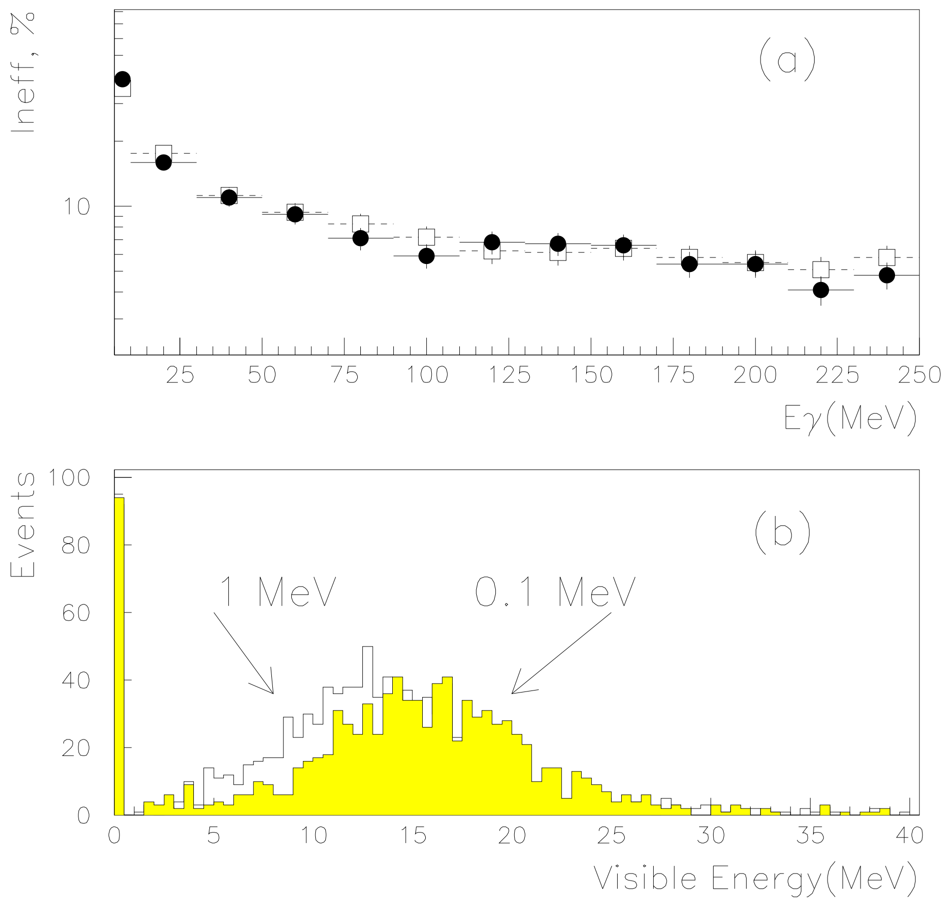

Figure 3: Inefficiency and visible energy for Pb (E_{thr} = 1 MeV), Point 1; (a)-Inefficiency for E_{stop}=1 MeV($\bullet$) and 0.1 MeV($\Box$); (b)-Visible Energy for E_{stop}=1 MeV and 0.1 MeV, $E_\gamma = 60$ MeV.

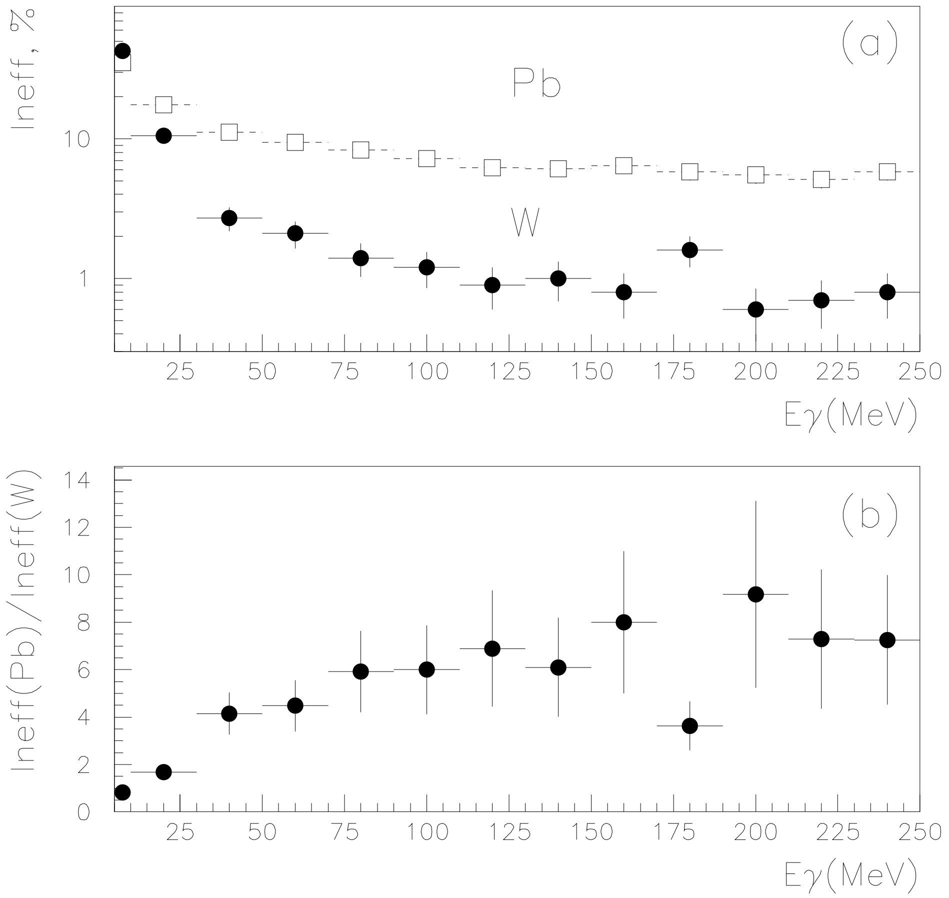

Figure 4: (a)-Inefficiency for Pb and W; (b)-Ratio Pb/W; E_{thr} = 1 MeV, point 1.

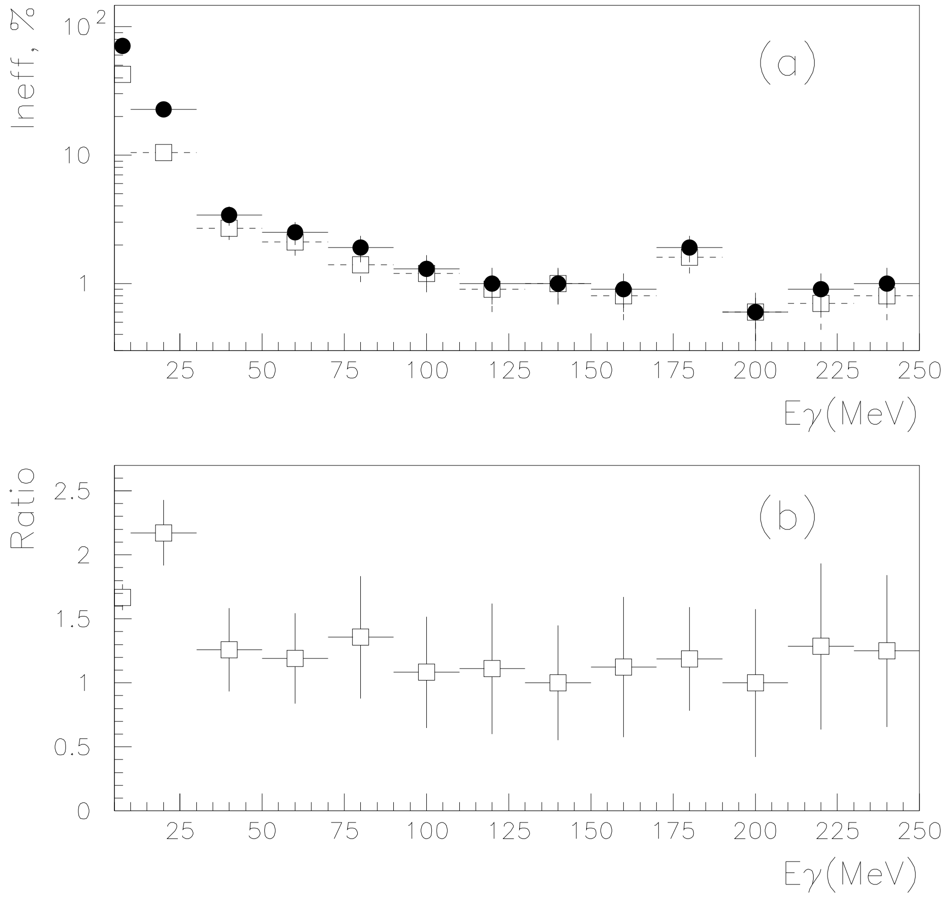

Figure 5: (a)-Inefficiency for W for E_{thr} = 1 MeV (□) and 2 MeV (•); (b)-Ratio 2 MeV/1 MeV.