A GEANT Simulation of Background Rate in Quartz Window of PMT XP4508 in Cerenkov Detector

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A MC simulation based on GEANT-3 has been performed to learn sources of the background in the trarnsversity experiment at Hall A in 2009. The goal of simulation was to verify a feasibility using GEANT to explain background rates measured in real experimental condition and make sure that MC simulation can be used to estimate background rates in the future experiments. As it was expected the MC simulation confirmed that the main source of background is located in the target area where electron beam is crossing the vacuum foils and the windows of the cell target. In considered experiment the electron beam with energy 5.9 GeV has passed through the gas target cell with polarized ^3He. Simulation was making for two runs with measured the background rate: the first for the target cell filled by ^3He with 8 amg density and the second for cell filled by H_2 gas at 132 psi. The experimental set-up of this experiment was described in detail according technical drawings for the target environments including vacuum beam line with flanges and entrance end exit foils , for the BigBite spectrometer with detectors and shield around. The GEANT view from top of the set-up is shown in Figure. 1. The zoomed target area is shown in Figure. 2. The 3D picture of the transversity set-up is shown in Figure. 3. The gas Cerenkov detector was installed between the middle and back drift chambers and Cerenkov light was reflected by mirrors to two sets of PMT. The figure. 4 shows the locations of PMT in the detector system. The GEANT 3 program was used for simulations and includes electromagnetic interactions with material on the beam line. Program calculated

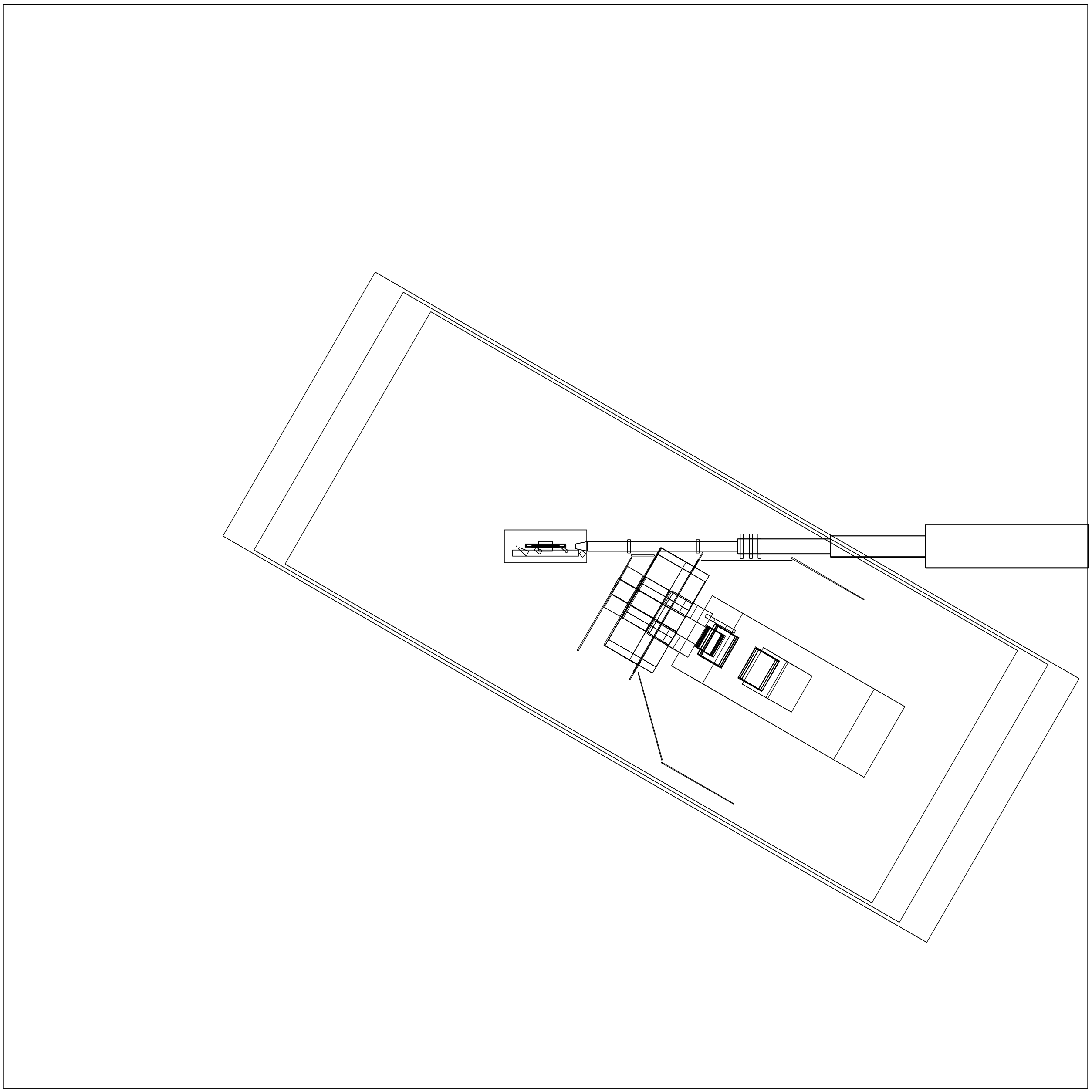

Figure 1: The view from top of the transversity set-up in GEANT simulation.

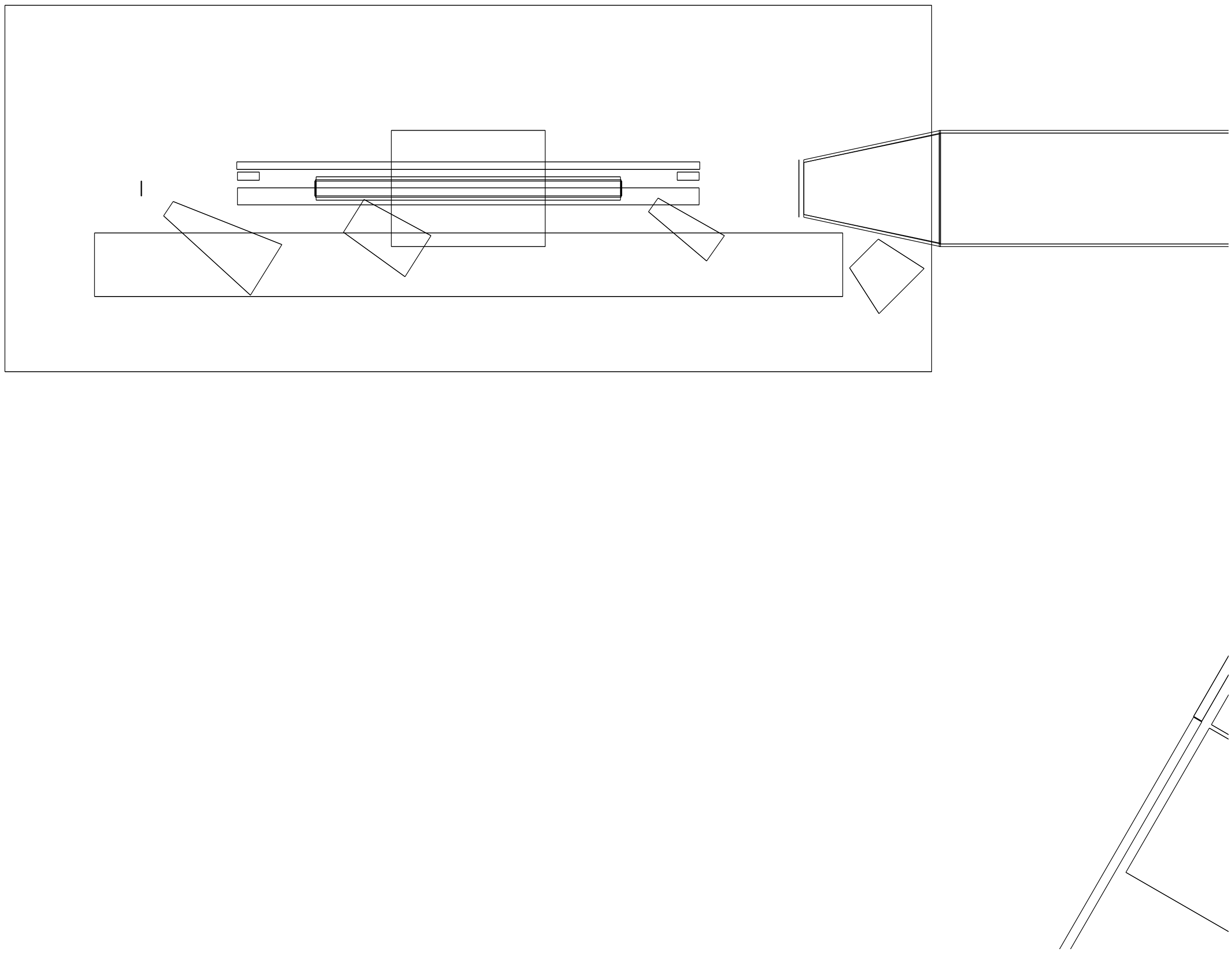

Figure 2: The view from top of the target area described in GEANT. One can see the tungsten collimator attenuated radiation from beam interaction with material of windows to the BigBite aperture. There are visible the parts of the target ladder nearest to the beam line.

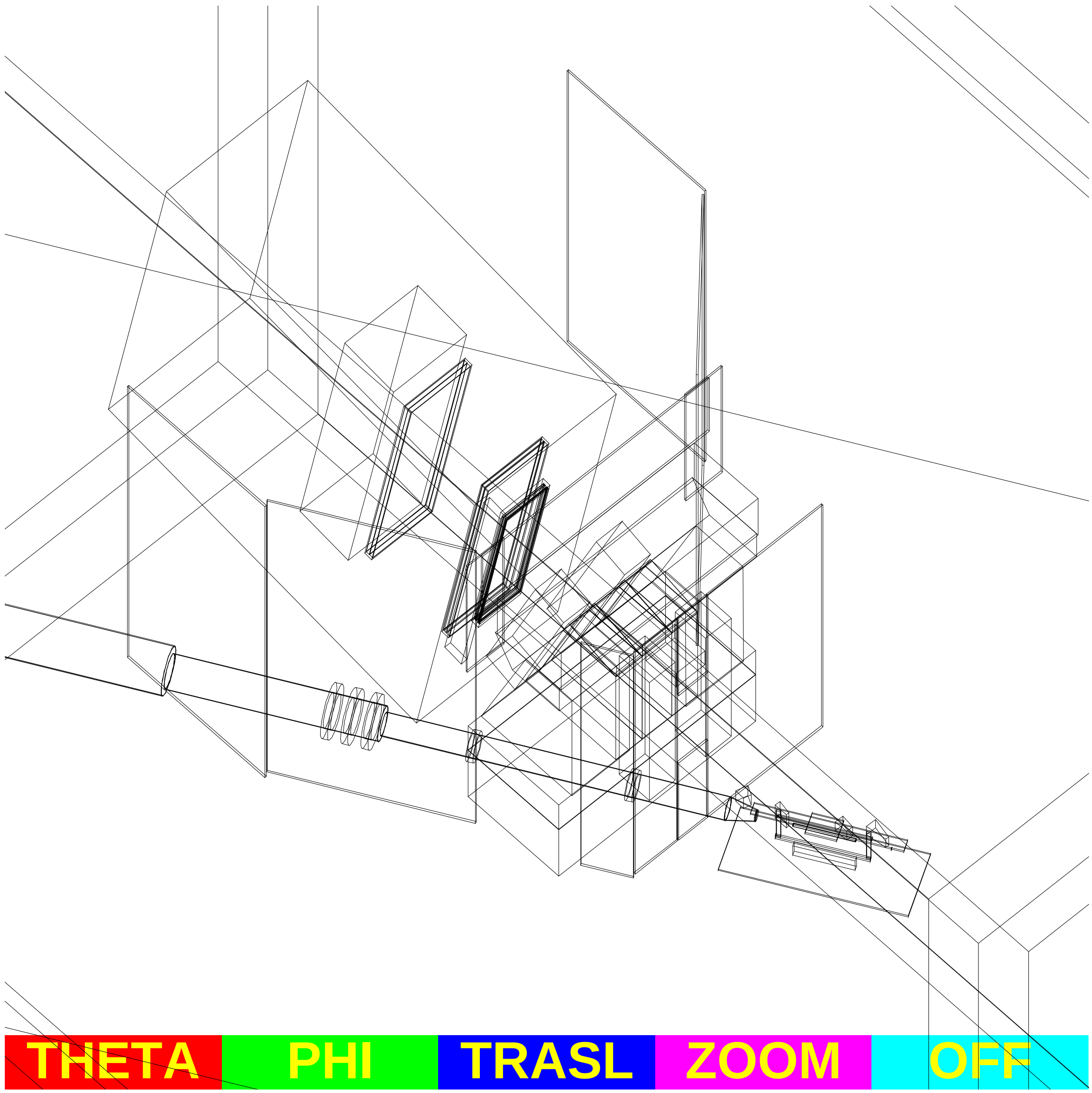

Figure 3: The 3D wire plot of view of the transversity set-up included in GEANT simulation. There are visible the shield around BigBite spectrometer and active planes of the drift chambers.

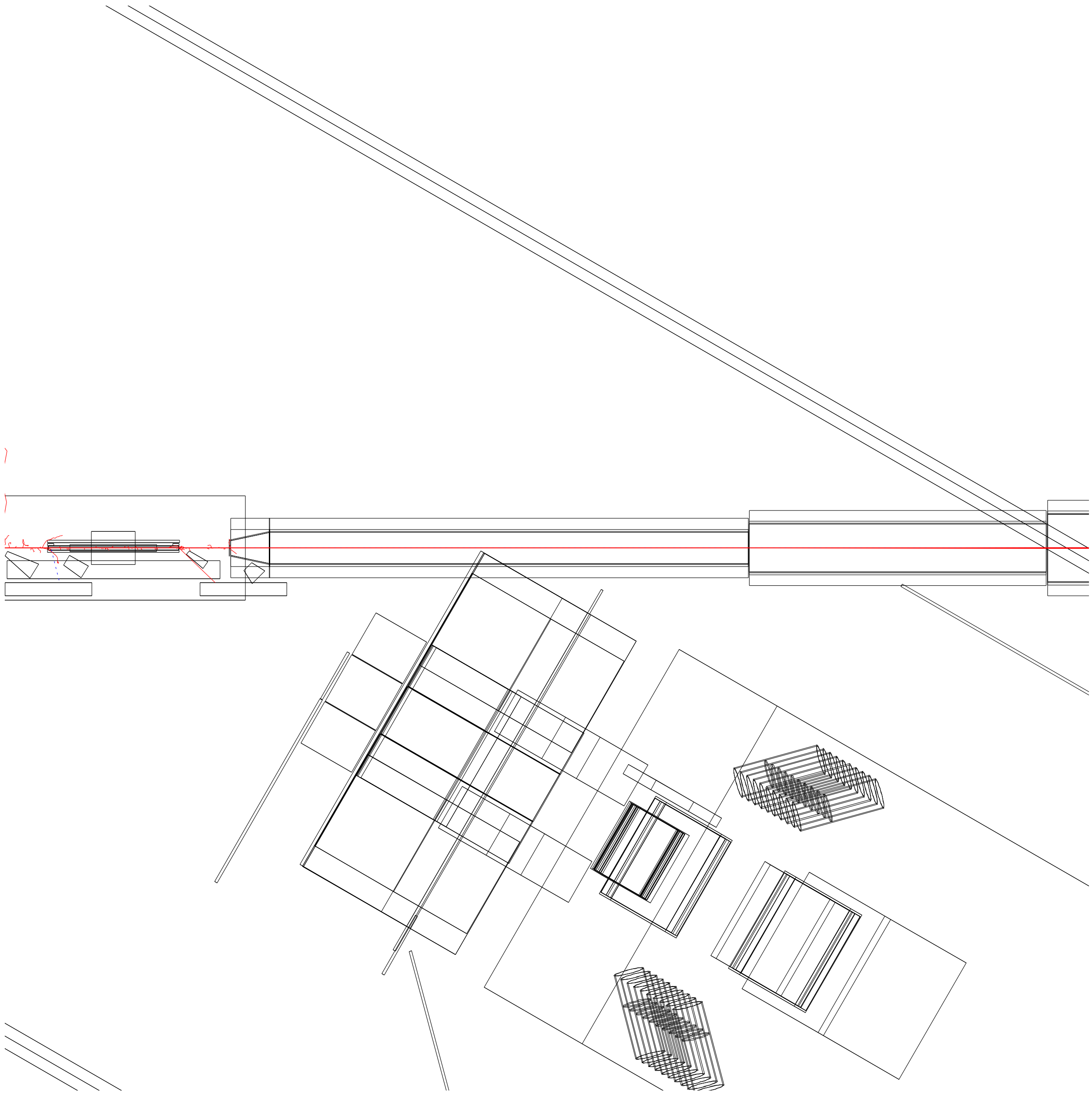

Figure 4: View from top of BigBite spectrometer with twenty steel housing of PMT and quartz photocatodes inside. The beam tracks are drawing by red lines. There are visible a lead shield around the beam line which was considered in simulation to reduce background rate in the photocatodes of PMTs

Table 1:

Name	material	density g/cm^3	thickness cm	thickness g/cm^2
vacuum foil	Be	1.848	0.0254	0.0464
air gap	air	0.0012	23.	0.028
cell window	glass GE180	2.75	0.013	0.036
target gas (8 amg)	^{3}He	0.00107	40.0	0.043
cell window	glass GE180	2.75	0.013	0.036
air gap	air	0.0012	23.5	0.028
vacuum foil	Be	1.848	0.0508	0.093
				total: 0.31

tracking and interactions all secondaries particles with all volumes included in in simulation. Note: the electro-nuclear interactions were not included in this simulation. When any particle hits the sensitive gas volume of the front chamber or the quartz window of PMT the program stored the particle ID, coordinates, momentum and energy deposit. The minimum energy for tracking was taken 10 keV. The program stored events with electrons or positrons passing the quartz window of PMT and having energy higher than 180 keV. In case electrons or positrons with energy higher than 180 keV the Cerenkov light may be produced in the quartz window sufficient to be registered by the PMT. The Cerenkov detector includes 20 PMT installed in two vertical columns with step of 200 mm and distances between lines 122 cm. The PMTs were housed in a iron tubes of the magnetic schield with wall thickness of 5 mm. Diameter of the quartz window is of 130 mm. Thickness of the windows is taken equal to 5 mm. The 5.9 GeV electron beam had intensity 11.5μA. The BigBite spectrometer was installed at 30^o. The Table 1 presents a material thickness on the beam line in the transversity experiment at 5.9 GeV.

The luminosity with 11.5 μA beam was 1.34×10^{37}cm^{-2}.

The simulated count rate was summarized for each column of PMT.

The column nearest the beam has count rate of 9$\pm$1.8 MHz or an average rate 0.9 MHz per one PMT.

The count rate for column far from the beam was obtained equal to 2.2$\pm$0.9 MHz or an average value of rate is of 0.22 MHz per one PMT.

The plot 5 shows the count rates of electrons and positrons with energy higher than 180 keV in each quartz window of PMT simulated for the transversity set-up. These particle may produce Cerenkov light sufficient to be registered. Bogdan estimated an efficiency of such process order $\sim$0.3. In the transver-

Table 2:

Name	material	density g/cm^3	thickness cm	thickness g/cm^2
vacuum foil	Be	1.848	0.0254	0.0464
air gap	air	0.0012	23.	0.028
cell window	glass GE180	2.75	0.013	0.036
target gas (8 amg)	^{3}He	0.00107	60.0	0.064
cell window	glass GE180	2.75	0.013	0.036
air gap	air	0.0012	23.5	0.028
vacuum foil	Be	1.848	0.0508	0.093
				total: 0.33

sity experiment the count rate was ∼3 MHz at threshold of ∼100mV and ∼0.5 MHz at threshold of ∼700 mV. Comparison at low threshold with simulation results and estimated efficiency ∼0.3 gives difference ∼6 times less in simulation. In additional by simulation the background rate in PMTs was estimated from neutrons created in target by electron beam from electron-nuclear interactions. For this the neutron output was taken from MC simulation by Pavel Degtyarenko. The contribution in in the background rate from these neutrons was obtaned ∼2% from total amount.

A1n experiment

In future experiment the A1n at 11 GeV in Hall A after upgrade a simulation has been doing for the same set-up with only one change: the target cell has been taken with length of 60 cm instead of 40 cm. The Table 2 presents a material thickness on the beam line for 11 GeV electrons.

The luminosity was taken $\sim 5\times 10^{37}$cm^{-2} for 40 μA beam current. The simulated count rate for Cerenkov spectrometer was obtained for each column of PMTs. The figure 6 shows the rates of electrons and positrons with energy higher than 180 keV in quartz windows of each PMT in Cerenkov spectrometer. For column nearest to the beam the count rate is expected of ∼32±6 MHz or an average rate 3.2 MHz per one PMT.
For the column far from the beam the count rate is expected of ∼9±3.3 MHz or an average rate 0.9 MHz per one PMT.

Moreover the simulation for 11 GeV beam was performed to study how may be reduce this rate. For this purpose a shield tube from lead was included to screen the vacuum beam pipe downstream of the target. See figure 4. The

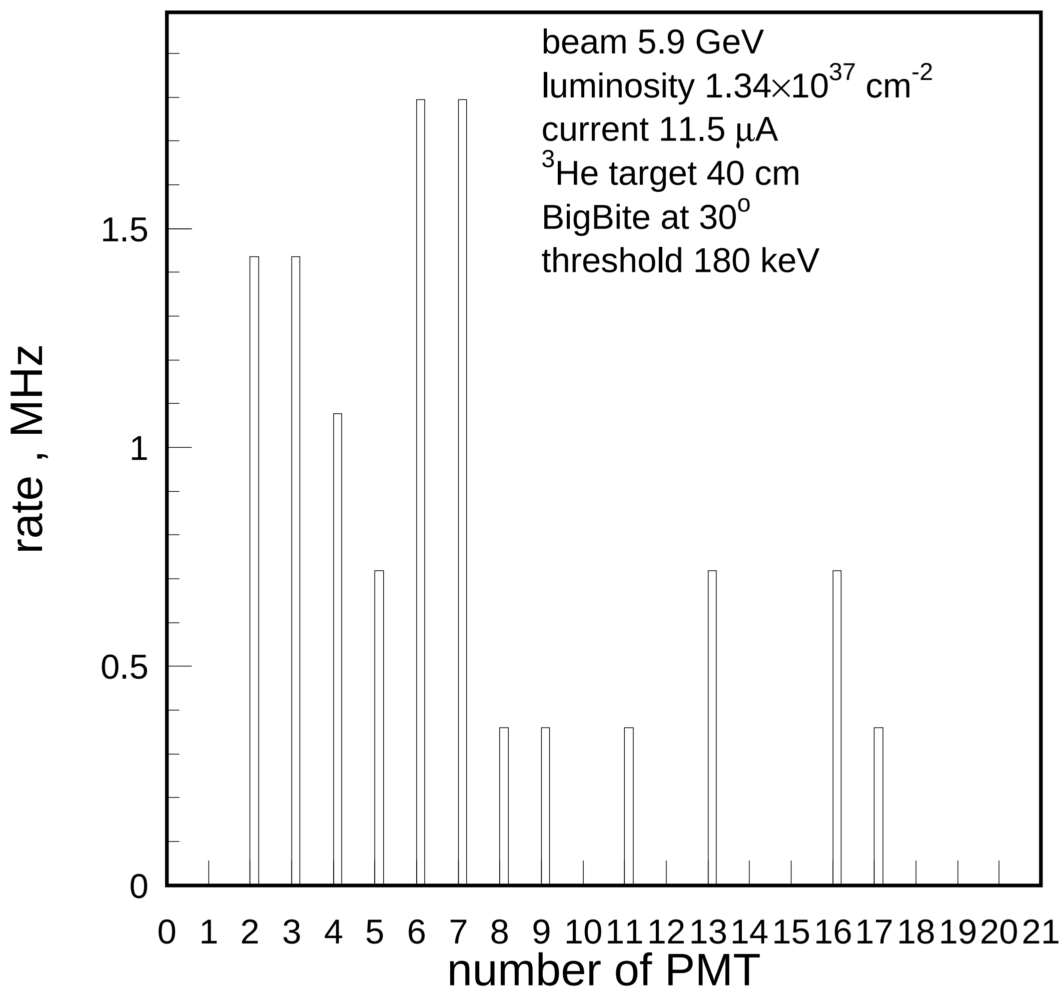

Figure 5: Simulated count rates for each PMT in the transversity experiment. The PMT column nearest the beam line is enumerated from 1 to 10 and PMT column far from the beam line is from 11 to 20.

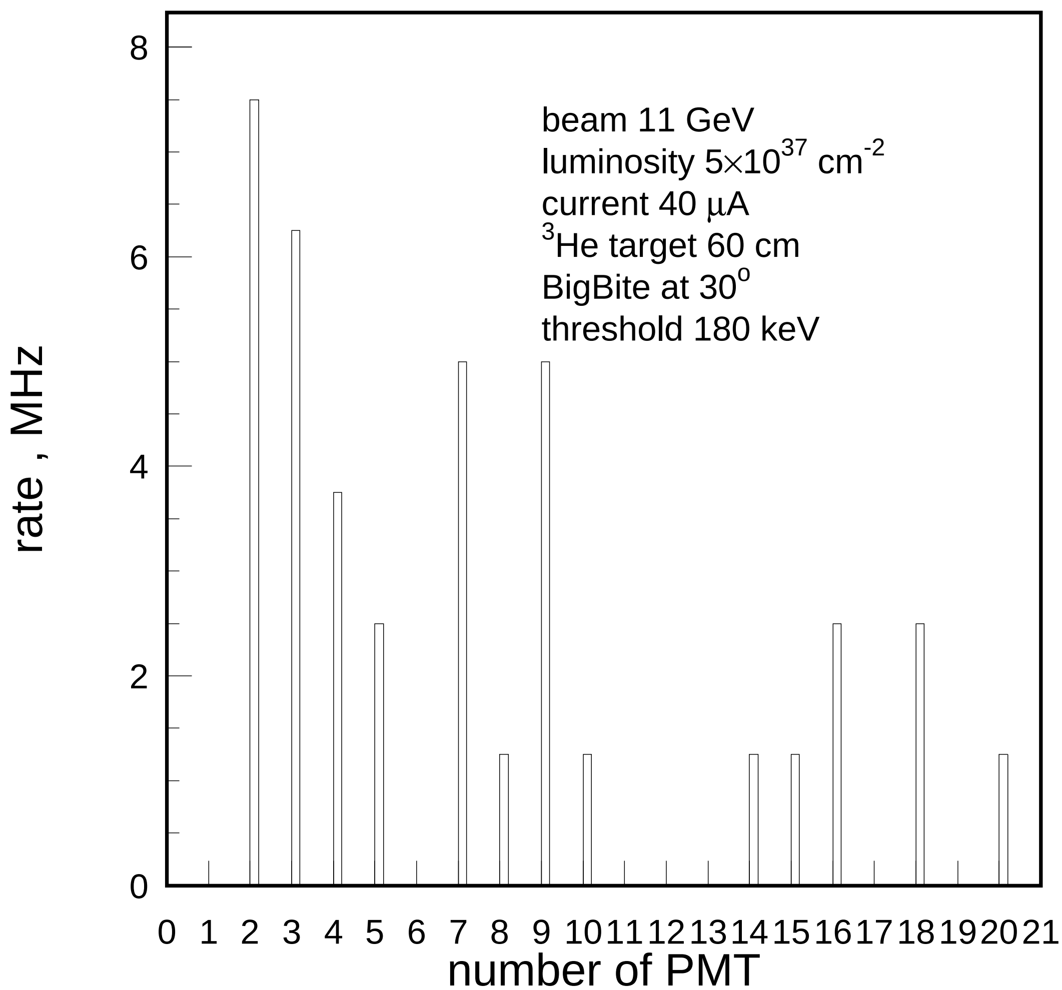

Figure 6: Simulated background count rates for each PMT expected in the A1n experiment at 11 GeV. The PMT column nearest the beam line is enumerated from 1 to 10 and PMT column far from the beam line is from 11 to 20.

wall thickness of lead tubes were taken 5 cm. Moreover two pieces of the shield from the tungsten compound in shape of box 30×40×6 cm^3 were installed close to the target to shade visibility the vacuum channel and cell windows from the BigBite aperture. In result the background rate in PMTs windows was reduced about ∼3 times.

Conclusion: The GEANT simulation is very useful for planing experiments and reducing background rate by appropriated shield.