BigBite spectrometer Background simulation progress report

X. Qian[1]

[1] *Triangle Universities Nuclear Laboratory, Duke University, Durham, NC 27708*

I MOTIVATION

The Transversity experiment E03-004 is going to use BigBite for electron detection with maximum magnetic field. We used a GEANT3 based simulation to study the background rates on wire chamber, scintillator, pre-shower and shower of BigBite. This study can help us understand the sources of background rates, especially for low energy photon and electrons. Then some shielding can be used to reduce background rates in the real experiment. This study can also help us to understand the detector performance and optimize the experimental settings.

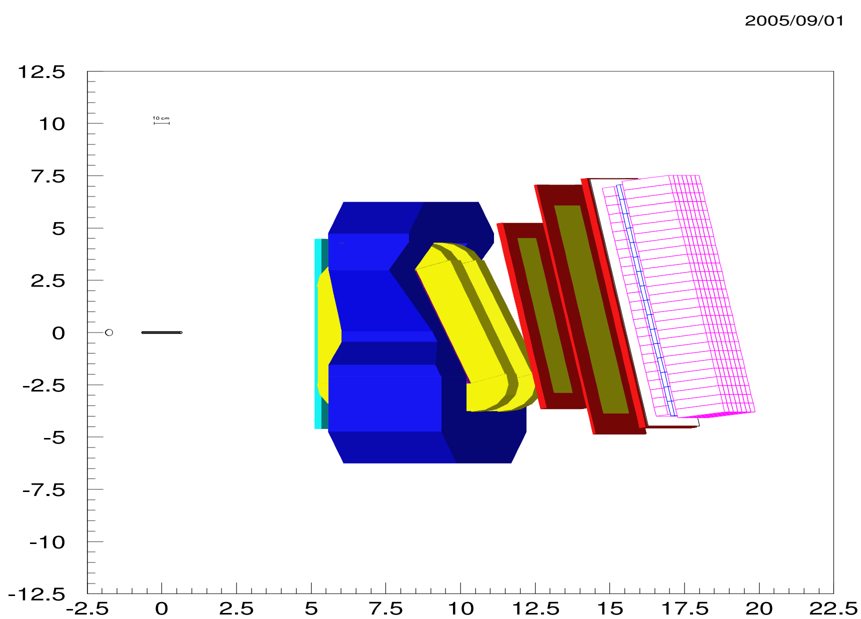

FIGURE 1. BigBite geometry.

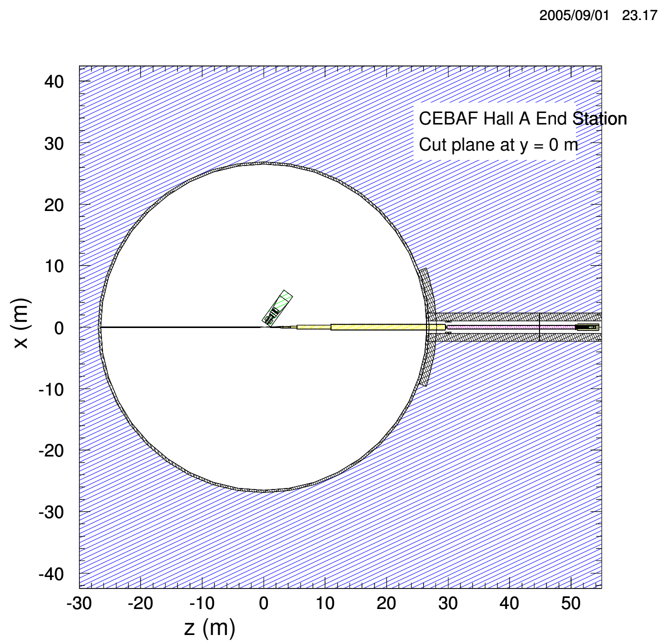

FIGURE 2. Hall geometry with beam pipe, target, beam dump.

II SOURCE CODE

The code describing the BigBite geometry is from Eugene Chudakov's comgeant. The comgeant is a well developed software based on GEANT3. The physics inside comgeant is EM interaction in the target and mott scattering. The output of this code is ntuple with momenta, vertices, hits in the detectors. We extracted and updated the information related to the BigBite geometry from comgeant. The Basic setting of BigBite is presented in Fig. 1. The active area of the wire chambers 35*150 cm, 50*200 cm and 50*200 cm, for the first, second and third wire chamber, respectively. The distance between chamber 1 and chamber 3 is 70 cm. The chamber 2 is just in the middle. The bending angle of the whole detector package is 10 degrees. The distance between the first wire chamber and the center of the magnet is around 95 cm.

The basic hall A geometry and event generator is from Pavel Degtiarenko. Pavel's code is based on GEANT3. He use exclusive event generator which is photon-nuclear fragmentation package DINREG in GEANT substitutes the old 'PFIS' mechanism and the electron-nuclear interactions are modeled using equivalent photon representation of an electron. In the Pavel's original code, the model of the BigBite is relatively simple, we updated it with the latest information of the geometry and the magnetic field. The model of hall is shown in Fig. 2.

With the tools in hand, we also modeled the BigBite geometry of the test run during the SRC experiment. We compared the simulating rates with the data.

2005/09/01 23.40

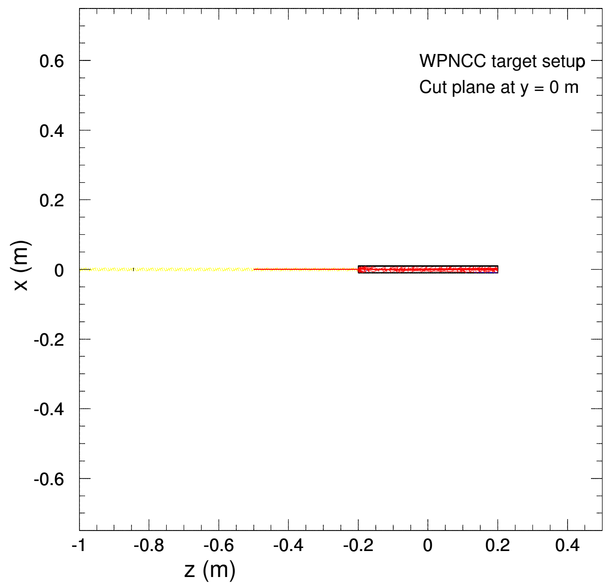

FIGURE 3. Simple geometry model with only target and incoming beam line.

III INTRODUCTION TO EM BACKGROUND

With the relatively weak BigBite magnet, the target is direct view from the detector. The main sources of the EM background are Moller, Bremsstrahlung, Compton, etc. The main process are that electron go through Moller scattering, then go through Bremsstrahlung, then Compton scattering. The magnetic field can help to bend the low energy charged particles with momentum lower than 200 MeV. However, the low energy charged particle can reach the detector through path outside the magnet. Generally, these charged particles are coming from the the hit of beam particles with the beam pipe and beam dump (sensitive to the beam line structure).

IV SIMPLE MODEL

In this version of simulation, we only model the target and the incoming beam line. All particles are stopped after they come out of the target area. We record the kinetic energy of these particles. This model can help us understand the physical background from the target region. The geometry of the simple model is shown at Fig. 3.

The rates results for different particles are shown from Fig.4 to Fig. 10. Results are after the kinematic energy cuts. Those cuts are related to magnetic field momentum cut 200 MeV momentum of electron, pion and proton. We use standard

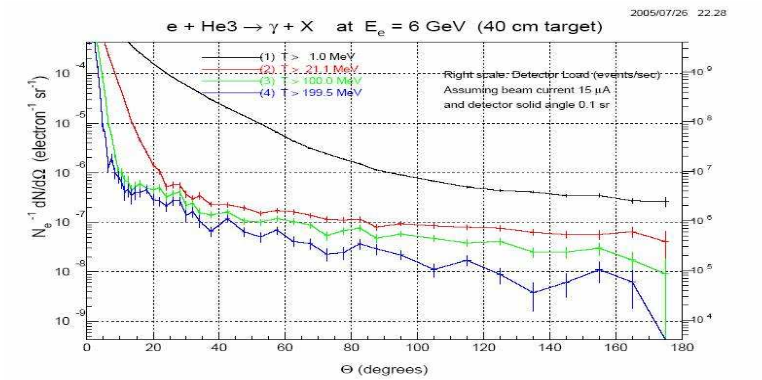

FIGURE 4. γ

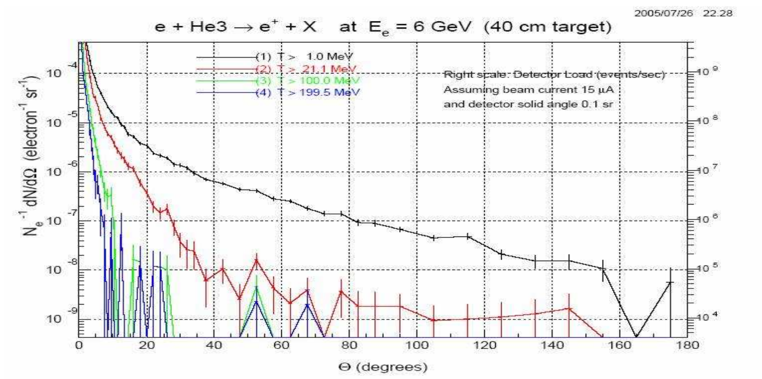

FIGURE 5. e^+

Transversity kinematics: beam energy 6GeV, 40 cm long ^3He target and standard geometry and material of glass wall.

The rates of particle at 30 degrees is shown at Table 1. The rates are in MHz and after 200 MeV momentum cut. The solid angle is 0.1 sr. Beam current is 15 μA. Here * means 0.6% conversion factor of photon. This number come from Eugene's simulation for MAD spectrometer. This conversion factor is the hitting conversion factor. In the simple model case, same study has been done for the GEN highest initial energy kinematics.

particle	γ	γ^*	e^+	e^-	π^+	π^-	p	n
rates (MHz)	600.	3.6	0.1	0.1	1.1	1.0	4.0	8.0

V BIGBITE MAGNET AND CUTOFF MOMENTUM STUDY

The motivation of this study is to confirm the 200 MeV cutoff momentum. The 200 MeV cutoff momentum is coming from the old geant4 simulation for BigBite spectrometer. With the latest magnetic field mapping from SNAKE EMULATION

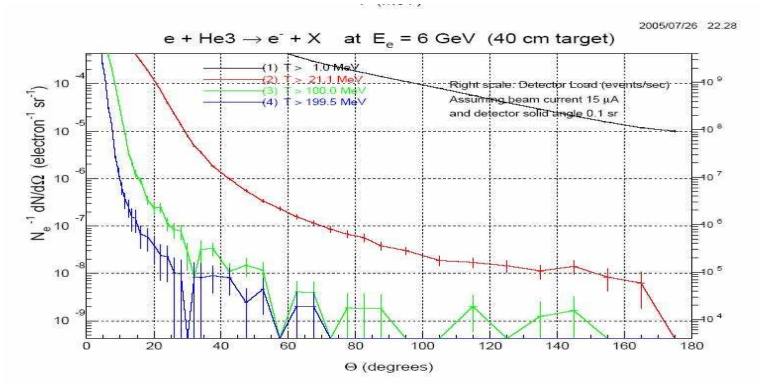

FIGURE 6. e^{-}

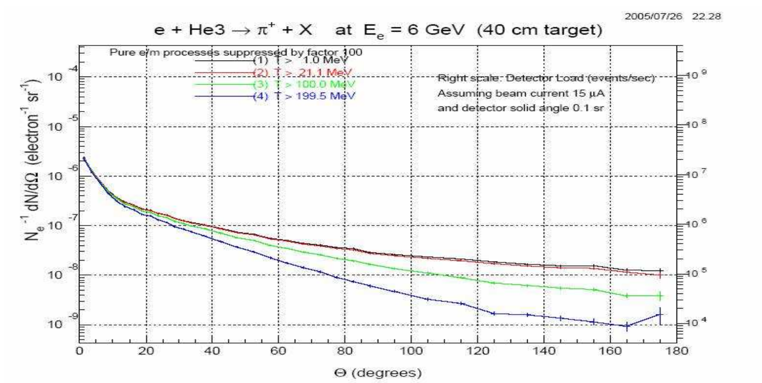

FIGURE 7. π^{+}

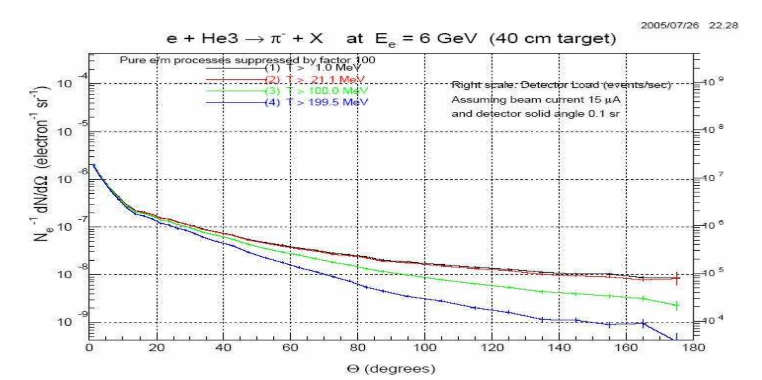

FIGURE 8. π^{-}

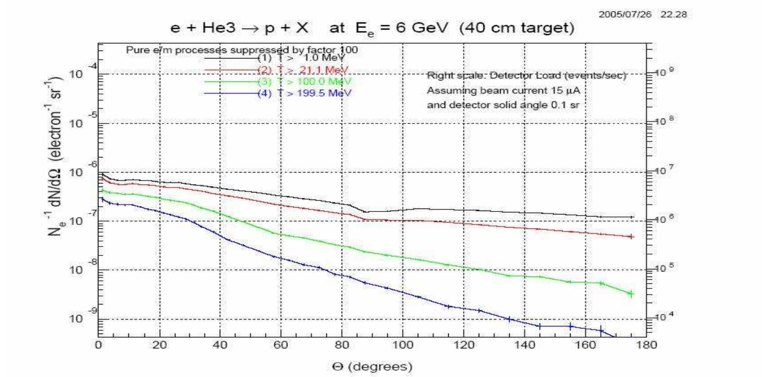

FIGURE 9. proton

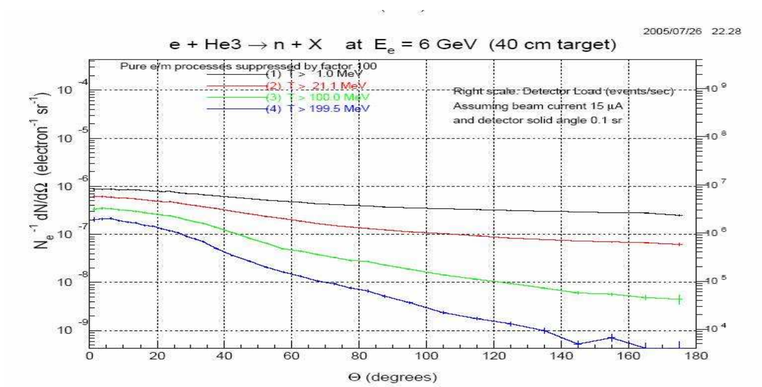

FIGURE 10. neutron

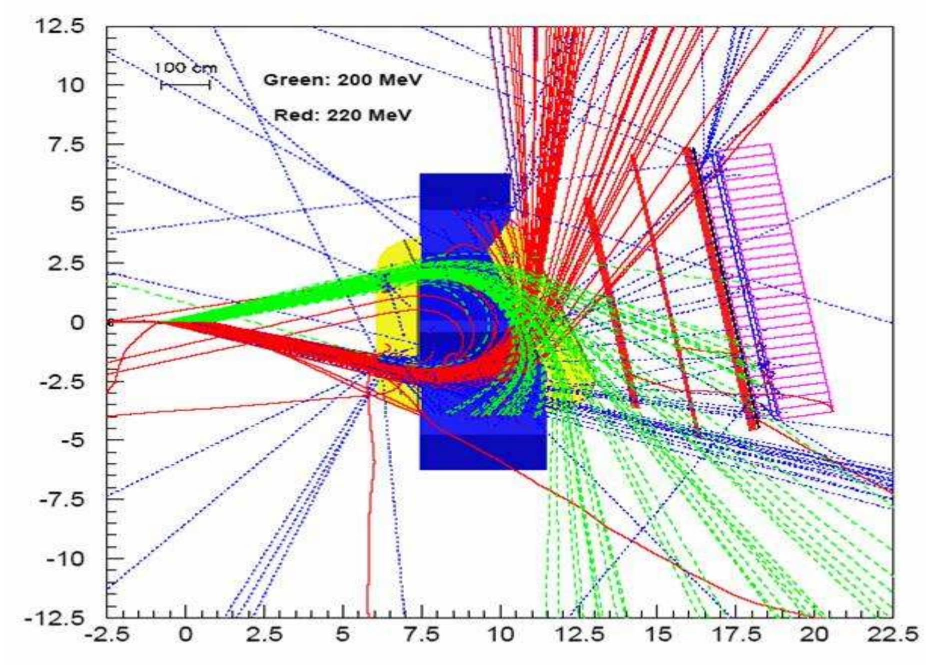

FIGURE 11. The momentum cut without the lead shielding in the gap.

from MAFIA by V. Nelyubin. we want to confirm this momentum cutoff. Meanwhile, we discovered that there were two gap with weak magnetic field inside the BigBite magnet. They allows low momentum charged particle passing through. In the real experiment, we may want to fill them with lead shielding. The result with lead shielding and without lead shielding are shown in Fig. 11 and Fig.12. The gap can be seen clearly from Fig. 13. The lead shielding with larger size are shown in Fig. 14.

In the following discussion, we have put the lead shielding in the magnet gap.

VI GEN EXPERIMENT BACKGROUND RATES SIMULATION

The motivation of this study is to confirm the BigBite wire chamber background rate which is given by Pavel with the simplified version of BigBite geometry, simplified version of magnetic field and old beam line structure. By this comparison, we can check our new modified version of code, obtain the correct input and finding analyzing method in order to obtain reliable rates.

In Pavel's old simulation, the BigBite geometry is shown in Fig. 15 and the magnetic field is a stable 12 kG with no detail structure. He used standard GEANT3 energy cutoff 10 keV; the reliability of the low energy cross sections are unknown. There is no interaction chamber included in the model. Material around the target may have significant effects on the background rates.

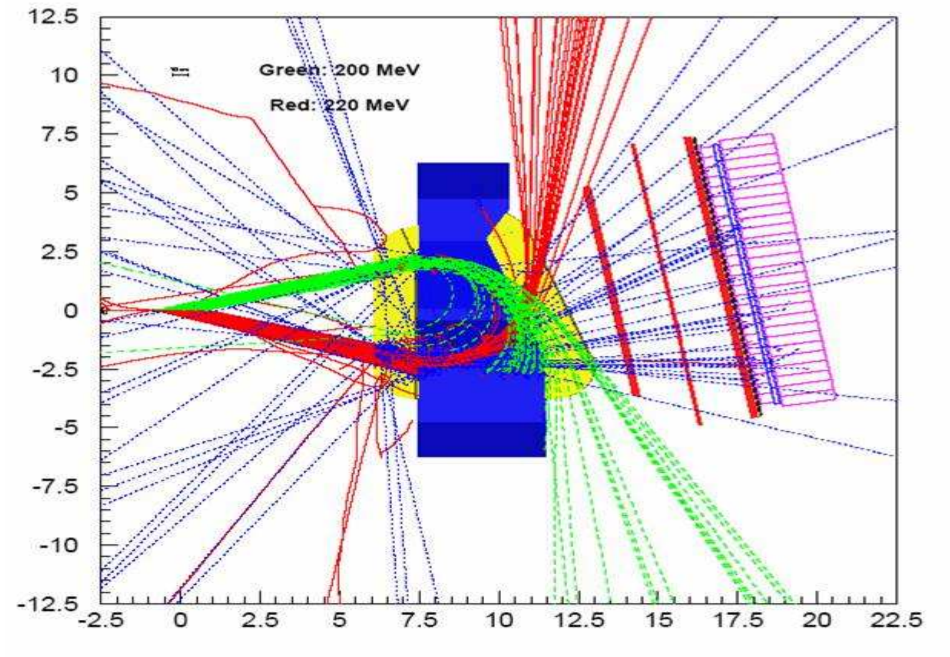

FIGURE 12. The momentum cut with the lead shielding in the gap.

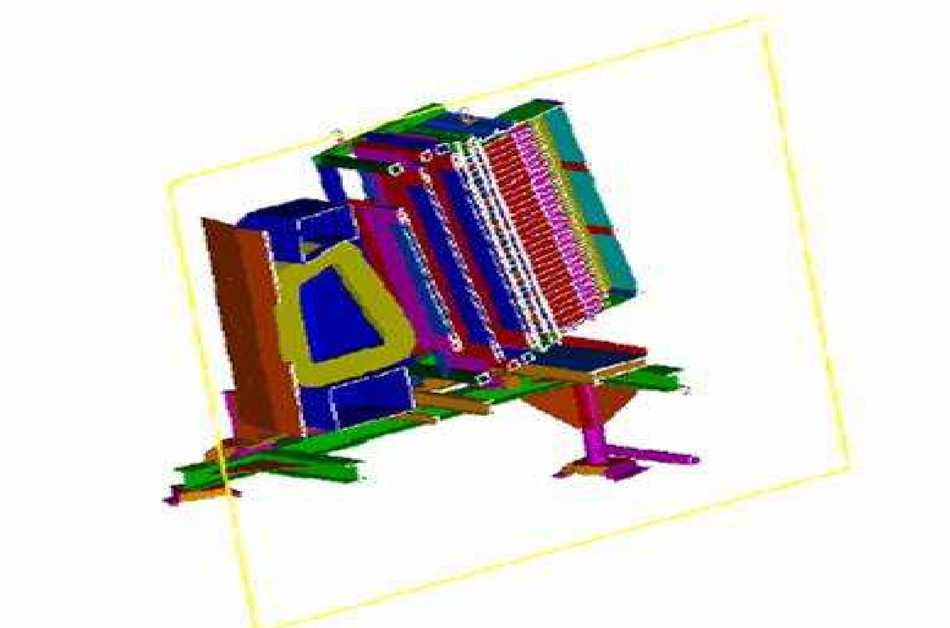

FIGURE 13. The gap is shown clearly from 3-D view of BigBite. (engineering picture)

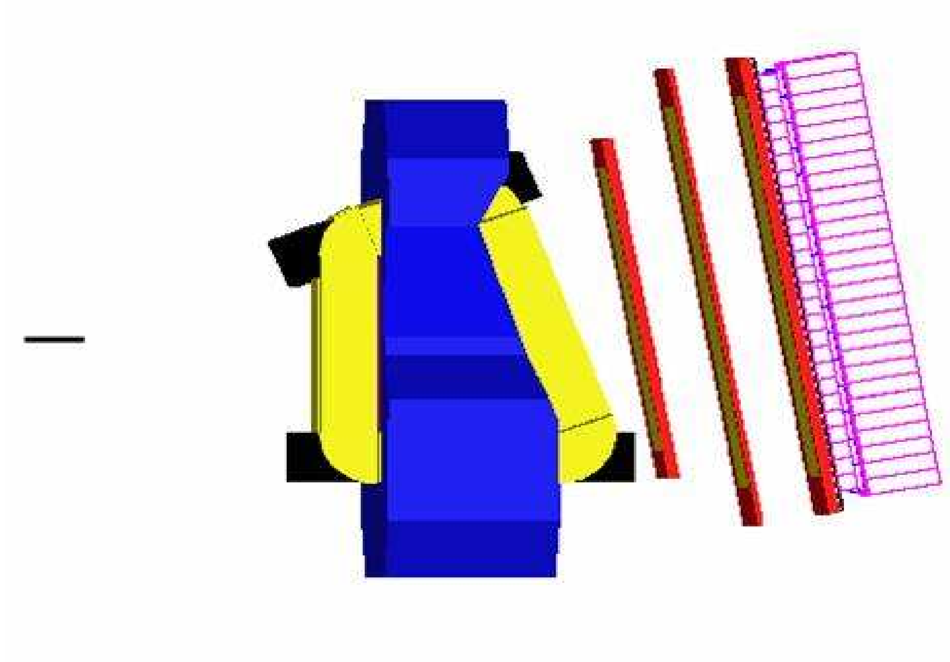

FIGURE 14. The Lead shielding are shown.

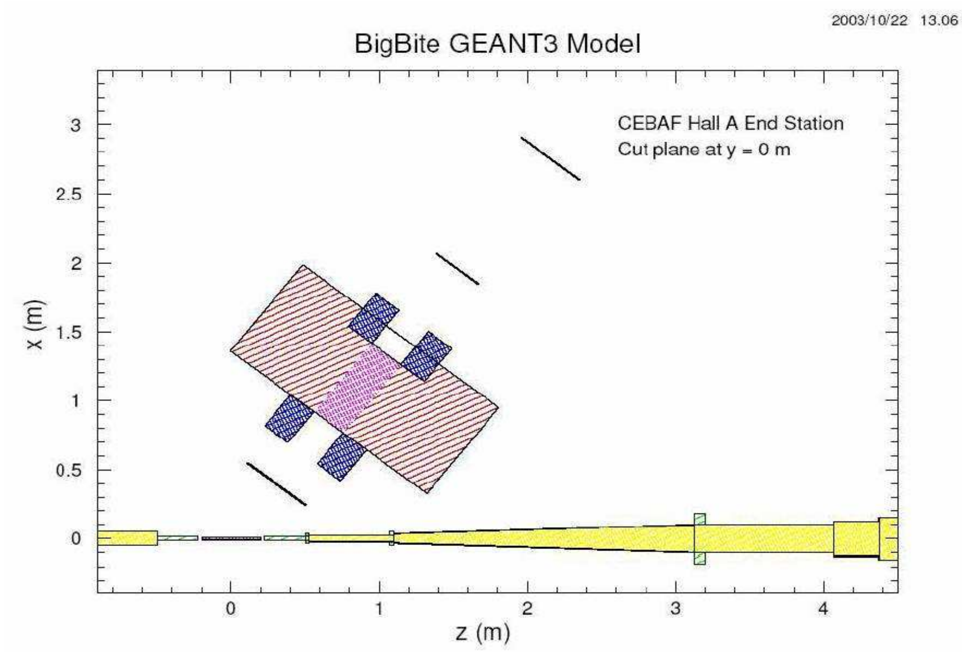

FIGURE 15. The simplified BigBite geometry in Pavel's original code.

The condition used in the Pavel's simulation are: $E_e = 3.2GeV$, I= 12 μA, drift distance 107 cm, BigBite magnetic field is 12 kGs, MWDC gas $ArCO_2$ 20 % mixture and $E_{threshold} = 0.6keV$. In this case, he count the total energy loss in the wire chamber by each initial electron, then by adding a 0.6 keV energy loss cut to cut off the low energy loss particles. In the real situation, although the possibilities are small, there might be situation when one initial electron can generate more than one signals in the wire chamber. We also studied the rates using the "black box" model in which we count every particle which enter the wire chamber and count photon with the conversion factor.

The estimated rate for DC1 from Pavel's old simulation is $31 \pm 6MHz$ and rate for DC2 is $119 \pm 12MHz$. After obtained this number, Pavel updated the beam structure. We used the new beam structure in our simulation. We use several different settings to estimate the rates, results are summarized in the following table. * means black box model. Rates are in MHz.

settings	DC1	DC2	DC3
Pavel's simulation	31 ± 6	119 ± 12	-
with new beam line	38.4 ± 9.6	168 ± 20.08	-
new BigBite model	149.8 ± 23.7	296 ± 33	288 ± 32.8
settings	DC1*	DC2*	DC3*
new BigBite model	181.75 ± 28.7	364.4 ± 39.8	408.821 ± 47.2

The following table shows the rates for different particles from the black box model. Here we assume that the photon conversion factor is 0.6%. Rates are in MHz.

particle	layer	γ	e^+	e^-	π^+
rates	BD1	19.5 ± 0.66	3.7 ± 3.7	157 ± 24.3	0.11 ± 0.000779
particle	layer	π^-	n	p	-
rates	BD1	0.0551 ± 0.000551	19.55 ± 0.0103	1.43 ± 0.00281	-
particle	layer	γ	e^+	e^-	π^+
rates	BD2	25.55 ± 0.75	3.74 ± 3.74	333.3 ± 35.3	0.165 ± 0.00095
particle	layer	π^-	n	p	-
rates	BD2	0.0551 ± 0.00055	26.9 ± 0.012	1.702 ± 0.00306	-
particle	layer	γ	e^+	e^-	π^+
rates	BD3	21.8 ± 0.7	26.2 ± 9.9	359.5 ± 36.6	0.11 ± 0.0007788
particle	layer	π^-	n	p	-
rates	BD3	0 ± 0	23.9 ± 0.011	1.211 ± 0.000258	-

The rates with the new beam line is slightly larger than the rates with old beam line. The difference can be seen in Fig. 16 and Fig. 17. The new version is closer to the real situation.

We can see that the rates of the new BigBite model is larger than a factor 4 comparing to the old BigBite model. The original reason might be that the size of the BigBite spectrometer's magnet in the Pavel simulation (Fig. 15) is much larger

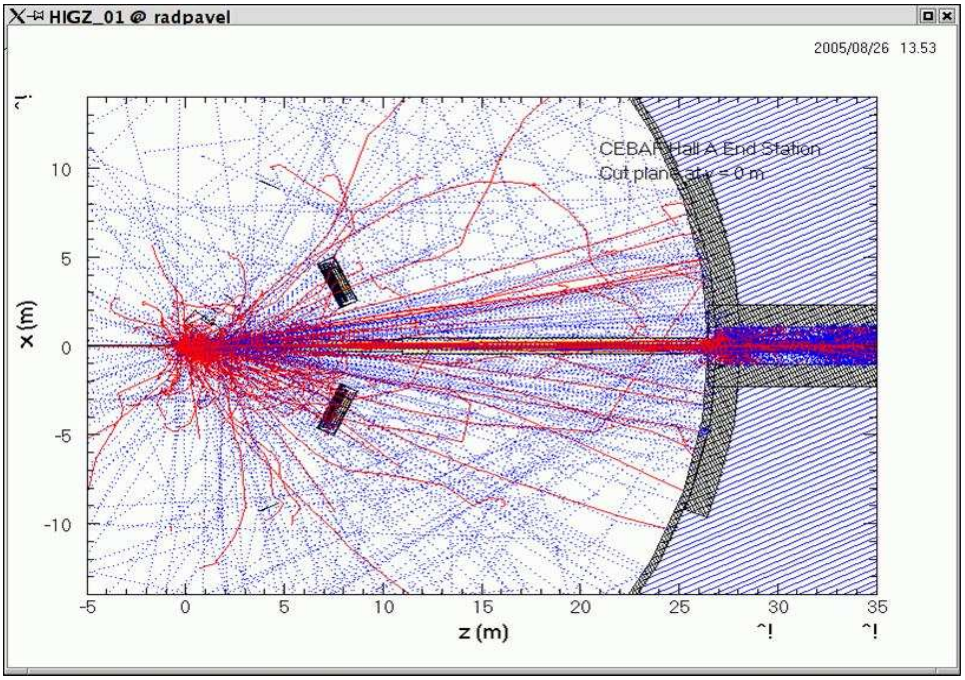

FIGURE 16. Old beam line.

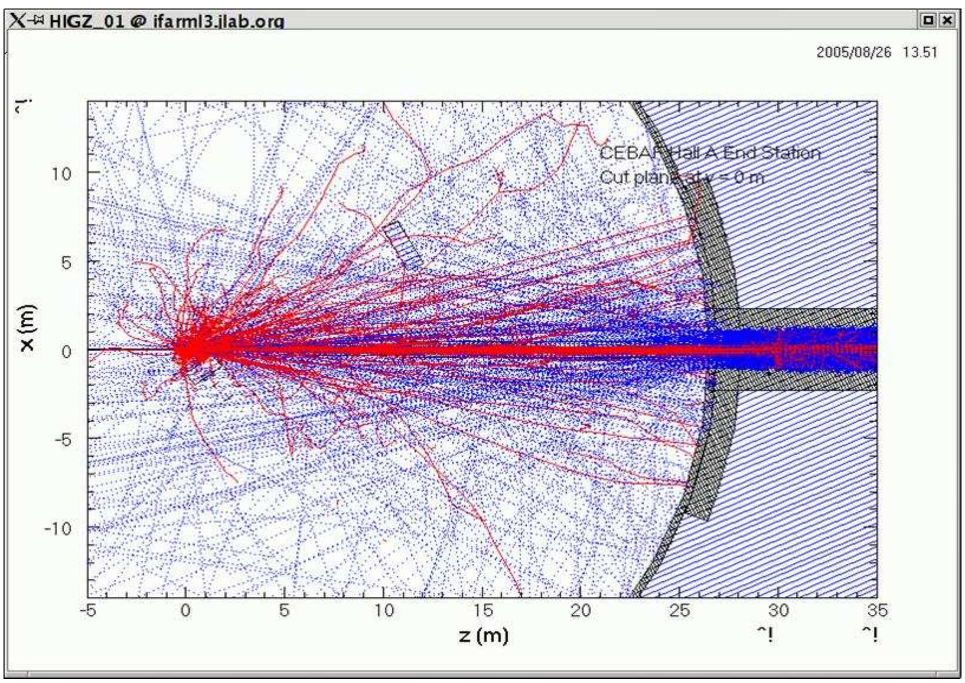

FIGURE 17. New beam line.

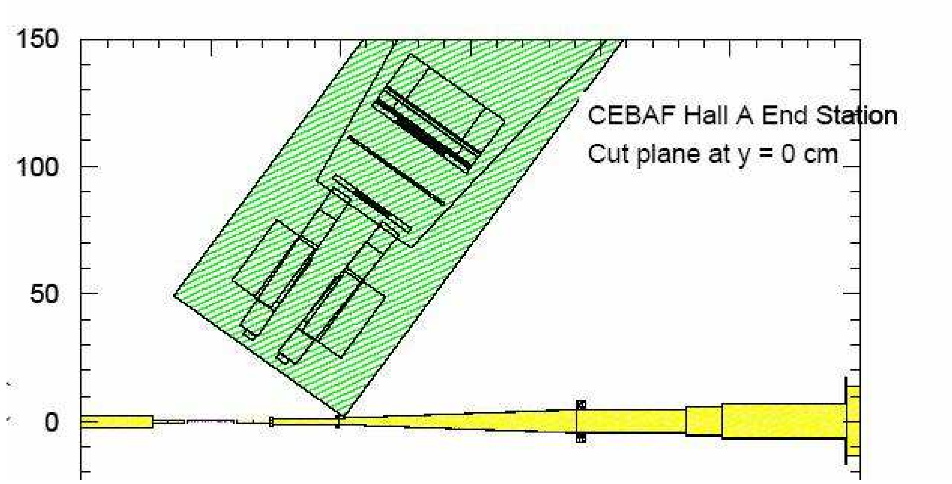

FIGURE 18. Updated version of BigBite in the new simulation.

than the the normal size (updated version Fig. 16). The larger magnet near the target and beam line can block some background particles which is coming from the hitting of the initial beam and beam pipe. When the initial electron pass through the windows in the beam line. It can change the angle a little bit and then the the electron can hit the beam pipe and generate a lot of final state particles. If we can put some shielding to block the particles coming from the beam pipe and beam dump in the new BigBite geometry model, we can reduce the rates significantly. We also study several shielding possibilities with the updated BigBite model. Results are not summarized here.

VII COMPARISON BETWEEN TEST RUN AND SIMULATION

The target we used in the simulation is 15 cm Liquid deuterium target. The beam current is 2 μA. The BigBite spectrometer is placed at 99 degrees. The BigBite magnet is 0.986 T. The initial electron energy is 4.6 GeV. The drift distance between the target and the BigBite spectrometer is 1 m. There are three scintillator planes in the detector package. They are auxiliary plane, dE plan and E plane. The scintillators are made of standard plastic scintillator. Density is 1.032 g/cm^3, with an effective composition C_9H_{10}. The auxiliary plane sits just at the position of first wire chamber in the BigBite setting of the TRANSVERSITY experiment and the distance between the E and auxiliary planes is 900 mm. dE plane is right in front of E plane.

The sizes of the auxiliary plane, dE plane and E plan are 350*500*2.5 mm, 500*2064*3 mm and 500*2064*30 mm, respectively. The bending angle of the detector package is 25 degrees instead of 10 degrees in the BigBite settings in TRANSVERSITY experiment. There are 56 bars in the auxiliary plane, 24 bars

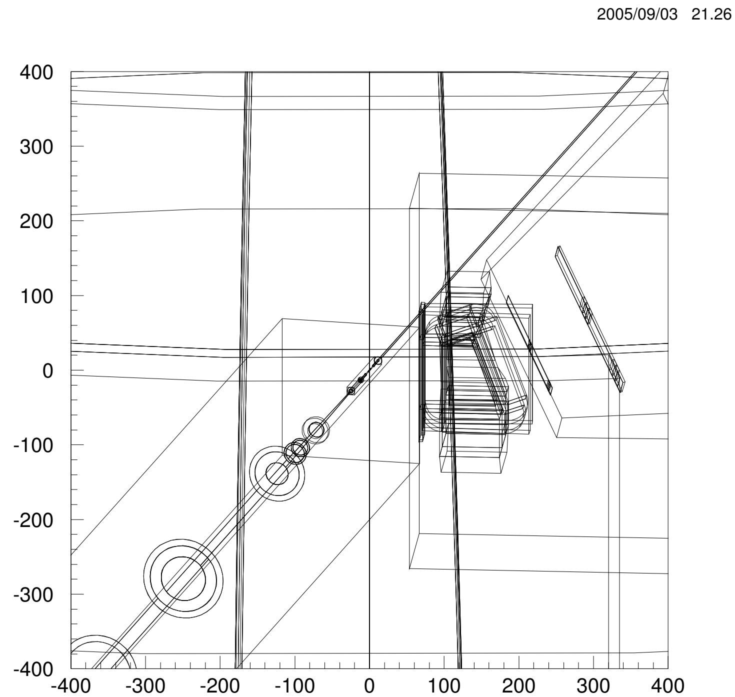

FIGURE 19. The geometry and detector setting of BigBite during the SRC experiment.

in dE plane and 24 bars in E plane. The basic geometry of the BigBite setting is shown in Fig. 17. The energy cut that we used in the simulation for three planes are same with the one derived from the data analysis of the test run (from Lingyan Zhu). The cuts are 0.07 MeV, 0.4 MeV and 1.2 MeV for auxiliary plane, dE plane and E plane, respectively.

The comparison between the simulation and test run are shown in the following tables. Here we simply scaled the experimental data to the same condition in the simulation, since the simulation is quite slow in collecting statistics. Rates are in kHz.

detector	field	Aux28	Aux29	Aux30	Aux52	Aux53
simulation	yes	913 ± 527	2131±805	1826±743	913±527	304±304
data	yes	697.5	382.5	405	637.5	528.5
detector	field	Aux54	dE11	dE12	dE22	E10
simulation	yes	913±527	3349±1009	3044±962	3957±1098	608±430
data	yes	746.2	1252.5	1740	1635	210
detector	field	E11	E12	E13	E22	-
simulation	yes	0±0	0±0	0±0	608±430	-
data	yes	213.75	251.25	213.75	213.75	-

detector	field	Aux28	Aux29	Aux30	Aux52	Aux53
simulation	no	2547±805	1273±569	2547±805	2038±720	3057±882
data	no	1813.5	994.5	1053	1275	1162.7
detector	field	Aux54	dE11	dE12	dE22	E10
simulation	no	2547±805	5604±1194.9	5234±1167	4840±1110	1273.77±569.647
data	no	1492.4	1252.5	1740	1635	420
detector	field	E11	E12	E13	E22	-
simulation	no	509±509	509±509	509±509	1274±569	-
data	no	427.5	502.5	427.5	427.5	-

Standing on the poor statistics in the simulation, we can see that the rates estimation of the simulation are basically consistent with the data. The difference is smaller than a factor of three in some situation. The relation with open magnetic field and close magnetic field are consistent with the data. In the data, the conclusion of the magnetic field is that turning off magnetic field will lead to the increment of rate of a factor of 2 in some situation. We will keep collecting the statistics in the simulation.

VIII TRANSVERSITY EXPERIMENT BACKGROUND SIMULATION

We also used the updated BigBite model to estimate the background rates in the TRANSVERSITY experiment conditions. The comparison of the condition of Transversity experiment and the condition of the highest energy GEN experiment is shown in the following table.

EXPERIMENT	Energy	BigBite angle	Drift distance	Bending angle
TRANSVERSIT	6.0 GeV	30 degrees	1.1 m	10 degrees
GEN	3.244 GeV	54 degrees	1.5 m	10 degrees

The standard geometry for the TRANSVERSITY experiment is shown in Fig. 18.

The rates estimation is presented in the following table. Here * means black box model. Rates are in MHz. The energy cut is also 0.6 keV.

settings	DC1	DC2	DC3
new BigBite model	55.4±9.8	83.2 ± 12	79.7±11
settings	DC1*	DC2 *	DC3 *
new BigBite model	98.1±11.145	120.4±12.8	119.7±12.9

We can see that the rates estimation from this simulation in TRANSVERSITY experiment is smaller than the GEN experiment. The reason might be that the magnet block some background rates from the beam pipe and the relative solid angle of the wire chamber is smaller, since the drift distance is 1.5 m in TRANSVERSITY experiment. Placing some shielding can reduce the background rates. The rates

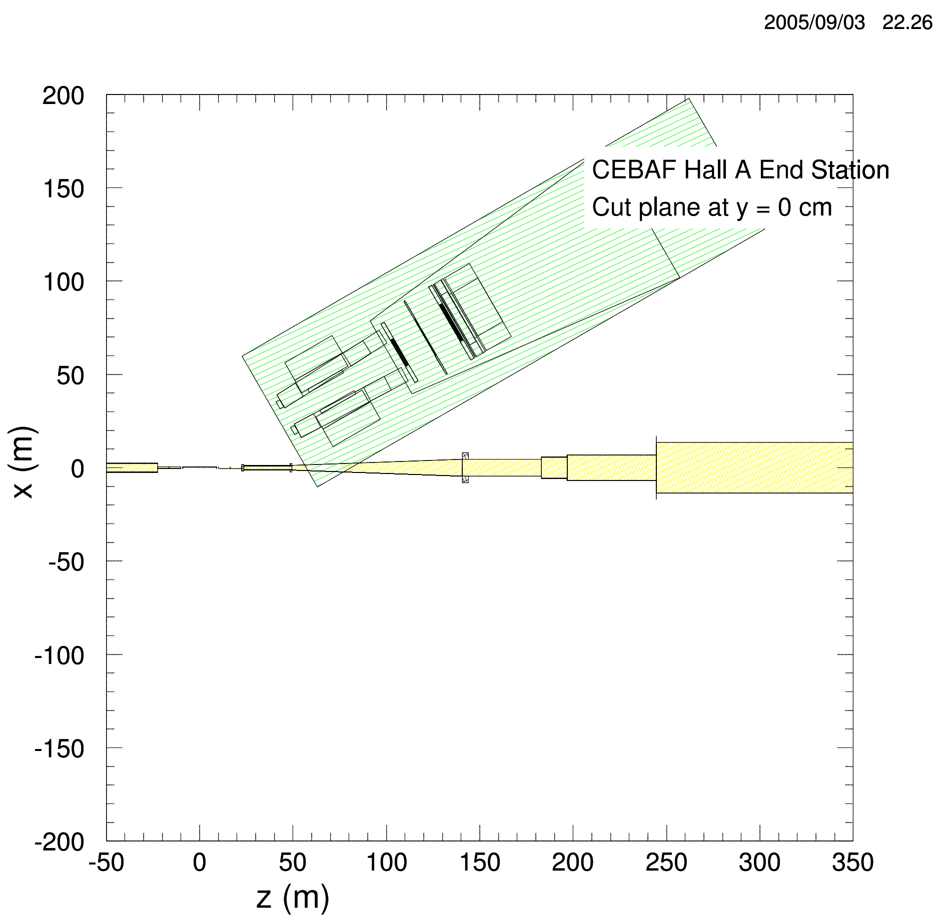

FIGURE 20. The geometry and detector package of BigBite in the TRANSVERSITY experiment.

of different particles from the black box model is shown in the following table, we compared this rates with the one that we obtained in the simple geometry model. Rates are in MHz.

particle	Rates at BD1	Rates at BD2	Rates at BD3	Rates (simple)
γ	28.6±0.54	30.13±0.56	28.2±0.54	2.16
e^+	0	0	0	0.06
e^-	65.88±10.6	86.68±12.2	88.4±12.4	0.06
π^+	0.51±0.0012	0.534±0.0012	0.455±0.0011	0.66
π^-	0.588±0.0012	0.588±0.0012	0.588±0.0012	0.6
p	2.54±0.0026	2.54±0.0026	2.09±0.0023	2.4
n	28.64±0.0081	40.5±0.01	42.58±0.01	6.8

From this table, we can see that the rates of the charged hadron from both models are consistent. This is expected, since most of the charged hadron are coming from the target and the charged hadron with low momentum is bended by the magnetic field. The neutron rates in the first model is larger than the simple model, since the charged hadron can hit the magnet and then generate some more neutrons. Some neutrons can also be generated from the beam dump. The rates of proton, positron and electron from the first model are much larger than the simple model. The reason is that when charged particle travel in the space, there are some possibility to generate some more photon by Bremsstrahlung. These photons can then generate electrons and positrons by pair production, Compton scattering, and ionization, etc. Most of these photons and electrons are in the low energy region. The electrons can generate signals in the wire chamber. We have to put some shielding to reduce the low energy background.

IX DISCUSSION AND FUTURE WORK

From this progress report, we can see that the model that we obtained from Pavel can describe the data from test run in SRC within statistics. However, the rates of low energy particles in estimating the TRANSVERSITY and GEN cases are far from our expected values. The rates especially the low energy particle rates are very sensitive to the beam structure (beam line, window, beam dump, etc.) and also very sensitive to the structure near the target. In this study, we used an old geometry for the beam line, we may want to improve it when we have some real data from GEN experiment. We also want to improve our model of the geometry near the target region. Our motivation is to understand the low energy background in GEN experiment, then extend the result to the TRANSVERSITY experiment. After confirming the validity and reliability of this model, we want study the shielding step by step.

Our current step of work is to study the optics of the BigBite magnet by using the field mapping in this model. We want to obtain some idea about the optics before running GEN. Meanwhile, we will also collect some statistics in the comparison of the SRC test run data and the simulation.

The results from the comparison of the SRC test run and simulation are encouraging. However the reliability of this model should be confirmed by comparing more data with simulation in the future.