Preliminary Results of Monte-Carlo Simulation of Electron Scattering

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1 Motivation

(1), To study the reliability for establishing a secondary single-electron beam (and a pion beam) at a larger production-angle(about 15^o or 45^o at lab. fram) by means of an electron/positron beam impacting on a fixed target;

(2), To study the performence of the single-electron(pion) beam;

(3), To study the background and to improve the shielding to reduce the background.

The definition of the single-electron beam is: just 1 electron received by the tested module during the time resolution of the module, in order to study the response of the module for 1 electron; but the number of received electrons is of a distribution (Poison distribution), so it is necessary to adjust the intense of the secondary electron beam.

2 Mechanism

We use electron/positron beam fetched from BEPC Linac to impact a fixed target to get secondary particles (γ, electron, positron, pion+, pion-, proton and so on), then use slit, analytic magnet and detectors (TOF, Cherenkov counter and multiwire-chamber and so on) to define the secondary beam.

This is because that we can not make a storage ring specially for the test beam due to economical reason, also can not put a target inside the vacuum pipe of present storage ring in order not to influence the data taking.

A serial interactions is possible to happen between the incident electron/positron and the matter of the target, such as:

(1), Multiple scattering through small angles, the θ distribution of the outgoing electron/positron: $\theta_o = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_o}$ [1+0.038ln(x/X_o)], $\theta^{rms}_{space} = \sqrt{2}\theta_o$

(2), Large angle elastic scattering between the electron/positron and a target particle such as a nucleus or a nucleon, for point-like target particle: 'Rutherford' formula(or 'Mott' formula); but the nucleus (or nucleon) has a volume and therefore a charge distribution, so it is necessary to introduce a 'form facter'(improvement of 'Mott' formula). The momentum of the electron/positron after a large angle elastic scattering: P1 = $\frac{E_o\ M}{E_o+M-P_oCos\theta}$, where M be the mass of the target particle(besides the nucleus/nucleon mentioned above, it is possible to be a cluster of nucleons inside the nucleus).

(3), Hadron production: inelastic scattering and/or deep-inelastic scattering. Inelastic scattering: the electron/positron emits a photon through Bremsstrahlung, then the high energy photon is possible to interact with a nucleon to form an excited state such as Δ(1232), N(1400), (or the electron/positron interacts with a nucleon through a virtual photon), then Δ(1232) or N(1400) decays to nucleon and pions. Deep-inelastic scattering: the electron/positron interacts with the particles inside a nucleon(quark or gluon), it is necessary to introduce 'structure function' to represent the deep-inelastic scattering, experimentally, one can calculate Q^2 = 4E $E_1 Sin^2(\theta/2)$ and x = $\frac{Q^2}{2M\nu}$ then obtain the cross-section simply from experimental curves according to the calculated Q^2 and x.

Besides the interactions mentioned above, there are many other interactions, such as Annihilation, Bremsstrahlung, Compton scattering, δ ray production, energy loss due to ionization and radiation, Decay, Muon nuclear interaction, Pair production, Photo electric effect, Photofission and Rayleigh scattering and so on.

3 Monte-Carlo Simulation: GEANT3.21

At the beginning, we tried to cut off those gammas and electrons/positrons with momentum less than 150MeV/C and ignore some interactions not very important in order to save CPU time, but the rasults are different significantly from those obtained from 'default' setting (cutting off those gammas and electrons/positrons with momentum less than 1 MeV/C and including all interactions but Photofission and Rayleigh scattering), so all results here are obtained from 'default' setting.

For comparison, we use different material to make the target (0.57r.l. tungsten or copper), and different incident particles (electron or positron, both are 1.55GeV, 5 * 10^7.

We also study the background and shielding, a beam dump made of iron with size of 0.8 * 0.8 * 0.9 M^3 is arranged about 21 meters downstream of the target, a scintillator of CsI (CsI-1) with the size of 0.8 * 0.8 * 0.2 M^3 is put downstream the beam dump, and several $CaSiO_3$ shielding blocks are arranged around the target and beam dump, a scintillator CsI-2 with the size of 2.0 * 2.0 * 0.2 M^3 is put downstream of that block which is at downstream of the beam dump, a scintillator CsI-3 with the size of 0.8 * 1.0 * 0.2 M^3 is arranged at the place where the tested module will set.

3.1 Preliminary results

Fig.1 shows the Cos(θ) distribution of outgoing electrons or positrons from a 0.2cm thick tungsten target(0.57r.l.) impacted by 5*10^7 1.55 GeV incident electrons.

Fig.2 shows the energy distribution for the same condition.

Fig.3 shows the energy distribution for 5*10^7 1.55 GeV incident positrons.

Fig.4 shows the energy distribution for 0.82cm thick copper target(0.57r.l.) and by 5*10^7 1.55 GeV incident electrons.

Fig.5 shows the shielding arrangement, we arrange a scintillator CsI-3 at a place where the tested module will set.

Fig.6 shows the Cos(θ) and energy distribution of the gamma, electrons and positrons having entered into the scintillator 3(CsI-3) which are obtained from $1 * 10^6$ 1.55GeV incident electrons impacting on a 0.57 r.l. tungsten target.

3.2 Estimation of the Intensity of the Single electron beam

The electron/positron beam from BEPC Linac is of 12.5 pulses a second, each pulse occupys 2.5 ns, pulse current is about 0.6 ampere, so the average intensity is about 1.2 * 10^{11} electrons (or 10^9 positrons) per second.

For 5 * 10^7 1.55GeV incident electrons(positrons), the secondary particles obtained from 0.57 r.l. tungsten or copper target in the θ angle region $10^o \rightarrow 20^o$ is about 250 electrons(positrons) per bin (26MeV) for the energy region from 0.85GeV to 1.45GeV, the θ angle region $10^o \rightarrow 20^o$ corresponds 0.090345 solid angle, so the average intensity is 250.0 / 0.090345 / 50000000.0 = 5.5 * 10^{-5} / Ω * 26MeV, if the tested module occupys 10^{-6} solid angle and receives the electrons(positrons) also in 26 MeV energy region(corresponding to energy resolution about $\pm$ 1.3 %), then the counting rate of the tested module is expected to be about 1.2 * 10^{11} * 5.5 * 10^{-5} * 10^{-6} = 6.6 electrons(positrons) a second.

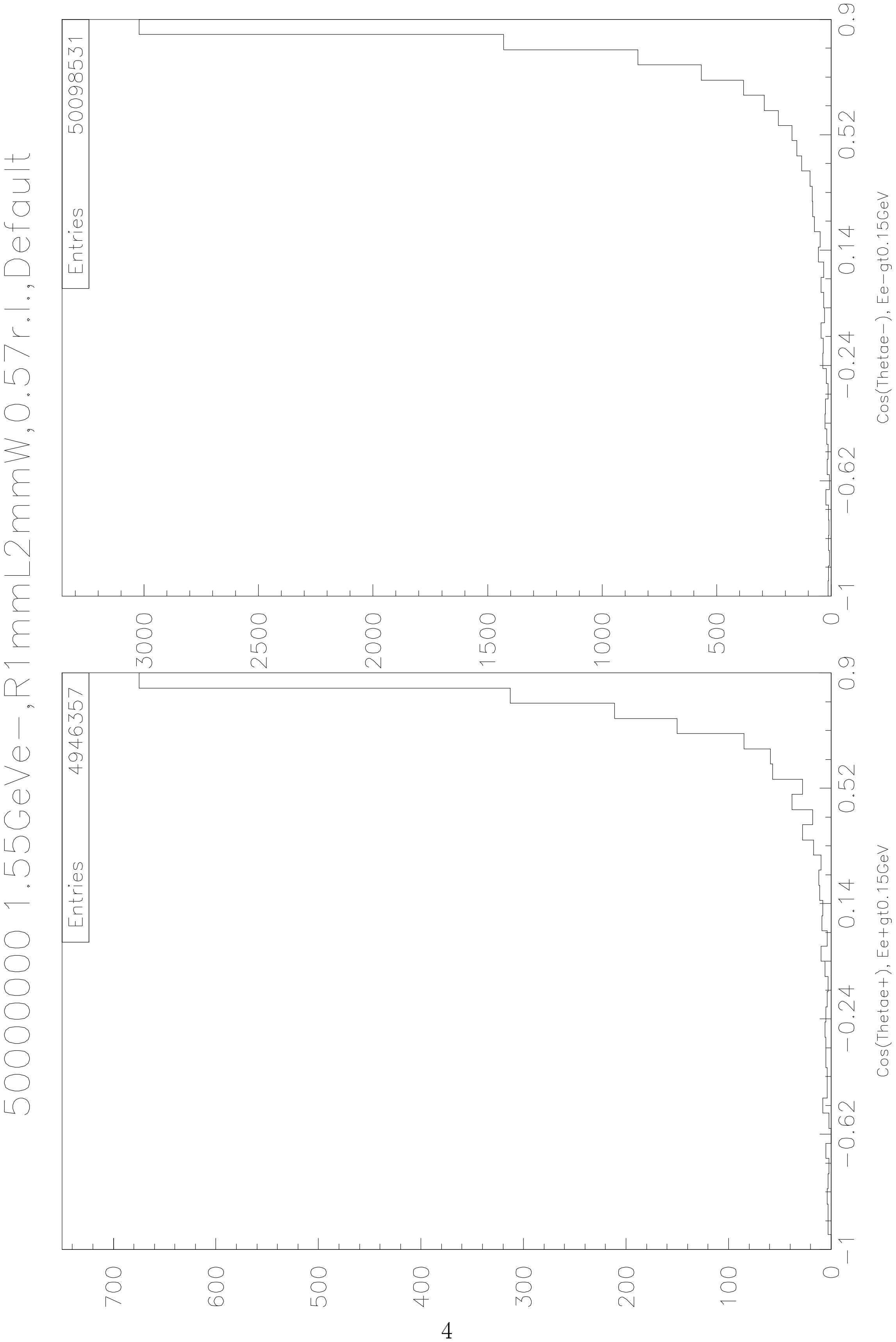

Figure 1: Cos(θ) of secon. e- and e+, 1.55GeV electrons, 2mmW, 0.57r.l.

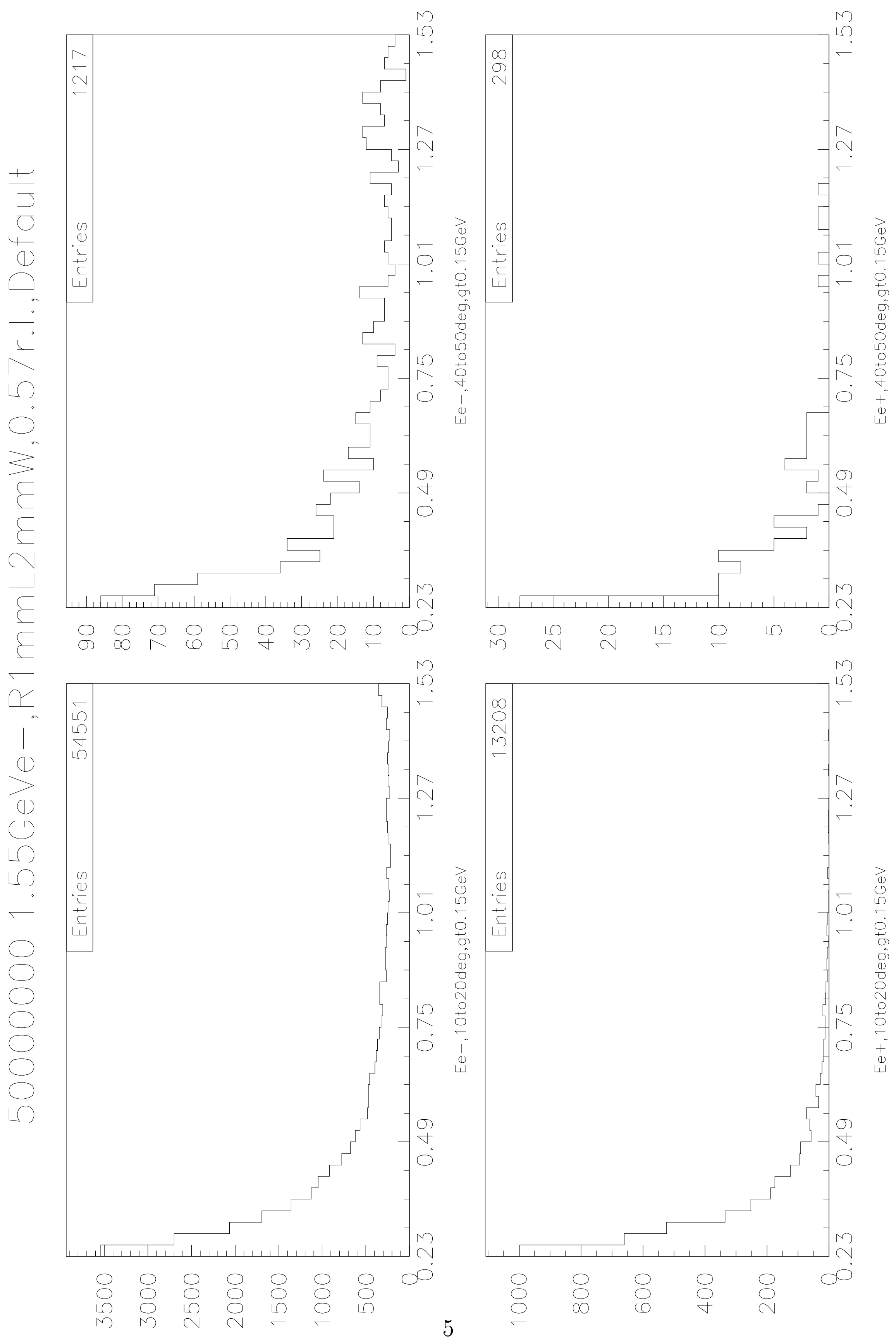

Figure 2: Energy of secon. e- and e+, 1.55GeV electrons, 2mmW, 0.57r.l.

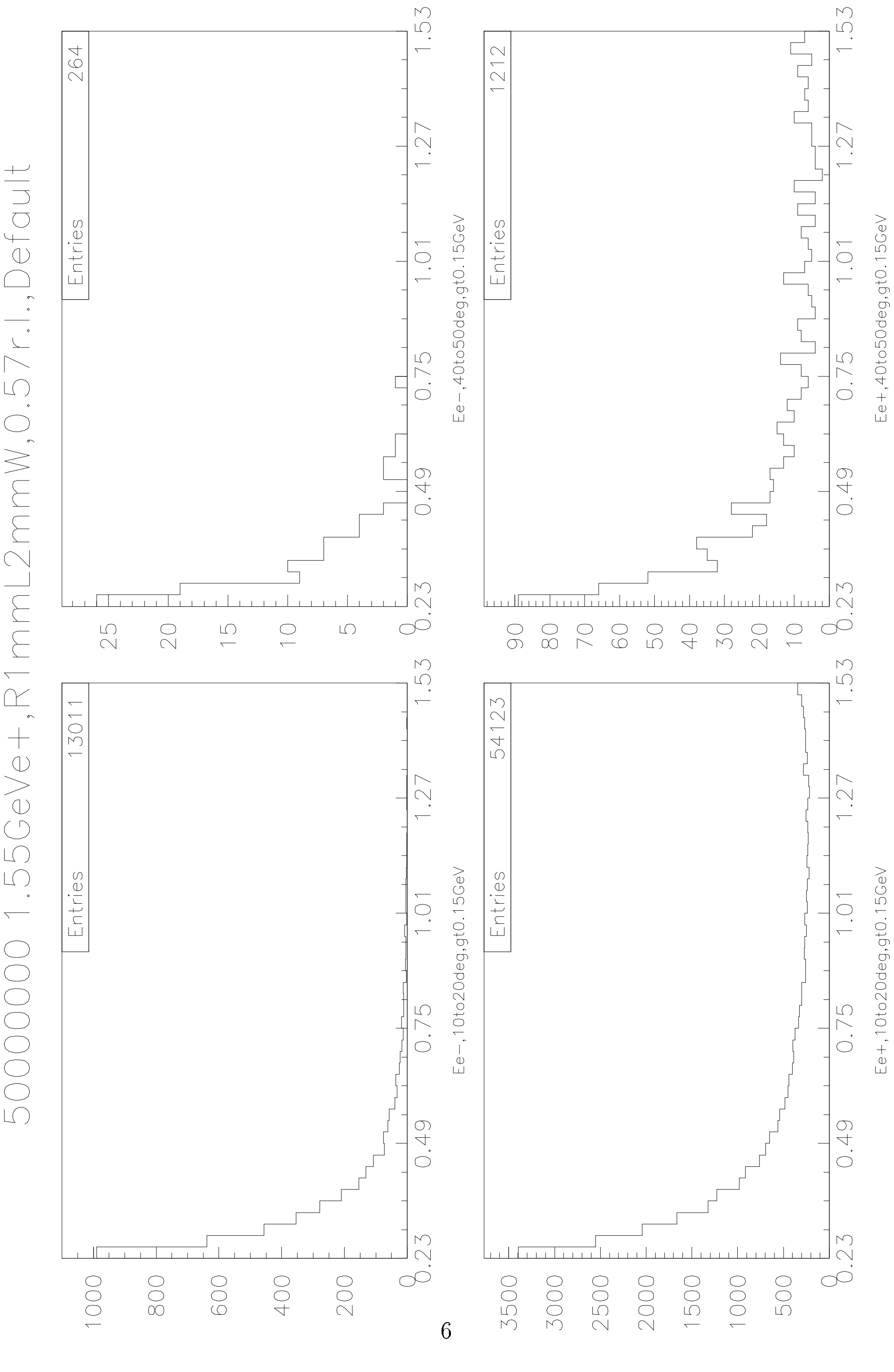

Figure 3: Energy of secon. e- and e+, 1.55GeV positrons, 2mmW, 0.57r.l.

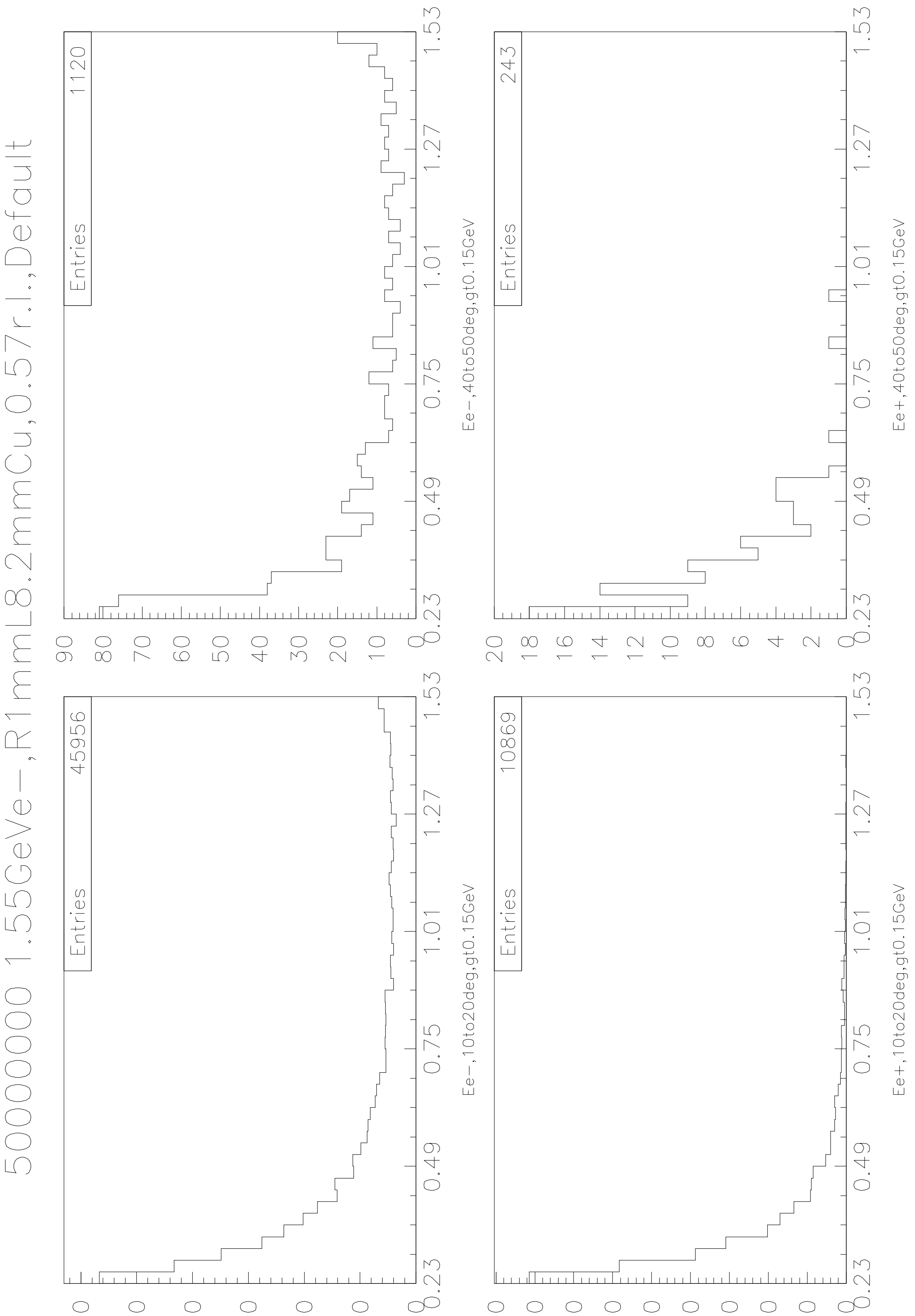

Figure 4: Energy of secon. e- and e+, 1.55GeV electrons, 8.2mmCu, 0.57r.l.

incident particles	*target*	*outgoing particles* $\geq$*150MeV*	*average intensity* *0.85GeV* $\rightarrow$ *1.45GeV*
$5*10^7$ *1.55 GeV* *electrons*	*R1mm* *L2mm* *tungsten* *0.57r.l.*	$10^o \rightarrow 20^o$, *54551 electrons* $10^o \rightarrow 20^o$, *13208 positrons* $40^o \rightarrow 50^o$, *1217 electrons* $40^o \rightarrow 50^o$, *298 positrons*	$5.5*10^{-5}/\Omega*26MeV$
$5*10^7$ *1.55 GeV* *positrons*	*R1mm* *L2mm* *tungsten* *0.57r.l.*	$10^o \rightarrow 20^o$, *13011 electrons* $10^o \rightarrow 20^o$, *54123 positrons* $40^o \rightarrow 50^o$, *264 electrons* $40^o \rightarrow 50^o$, *1212 positrons*	$5.5*10^{-5}/\Omega*26MeV$
$5*10^7$ *1.55 GeV* *electrons*	*R1mm* *L8.2mm* *copper* *0.57r.l.*	$10^o \rightarrow 20^o$, *45956 electrons* $10^o \rightarrow 20^o$, *10869 positrons* $40^o \rightarrow 50^o$, *1120 electrons* $40^o \rightarrow 50^o$, *243 positrons*	*about* $5.*10^{-5}/\Omega*26Mev$

Table 1: average intensity of outgoing particles

scintillator	*secondary particles*	*energy*	*average intensity per an incident electron*
CsI-1 *0.8 * 0.8* m^2	γ *5005* *positron 8160* *electron 16594*	$\leq$ *20MeV* $\leq$ *0.1 GeV* $\leq$ *0.08GeV*	$7.8 * 10^{-3} / m^2$ $1.2 * 10^{-2} / m^2$ $2.6 * 10^{-2} / m^2$
CsI-2 *2.0 * 2.0* m^2	γ *66384* *positron 83745* *electron 154006*	$\leq$ *20MeV* $\leq$ *0.1 GeV* $\leq$ *0.08GeV*	$1.6 * 10^{-2} / m^2$ $2.1 * 10^{-2} / m^2$ $3.9 * 10^{-2} / m^2$
CsI-3 *0.8 * 1.0* m^2	γ *1* *positron 6* *electron 21*	$\leq$ *20MeV* $\leq$ *20 MeV* $\leq$ *20 MeV*	$1.25 * 10^{-6} / m^2$ $7.5 * 10^{-6} / m^2$ $2.6 * 10^{-5} / m^2$

Table 2: average intensity of outgoing particles

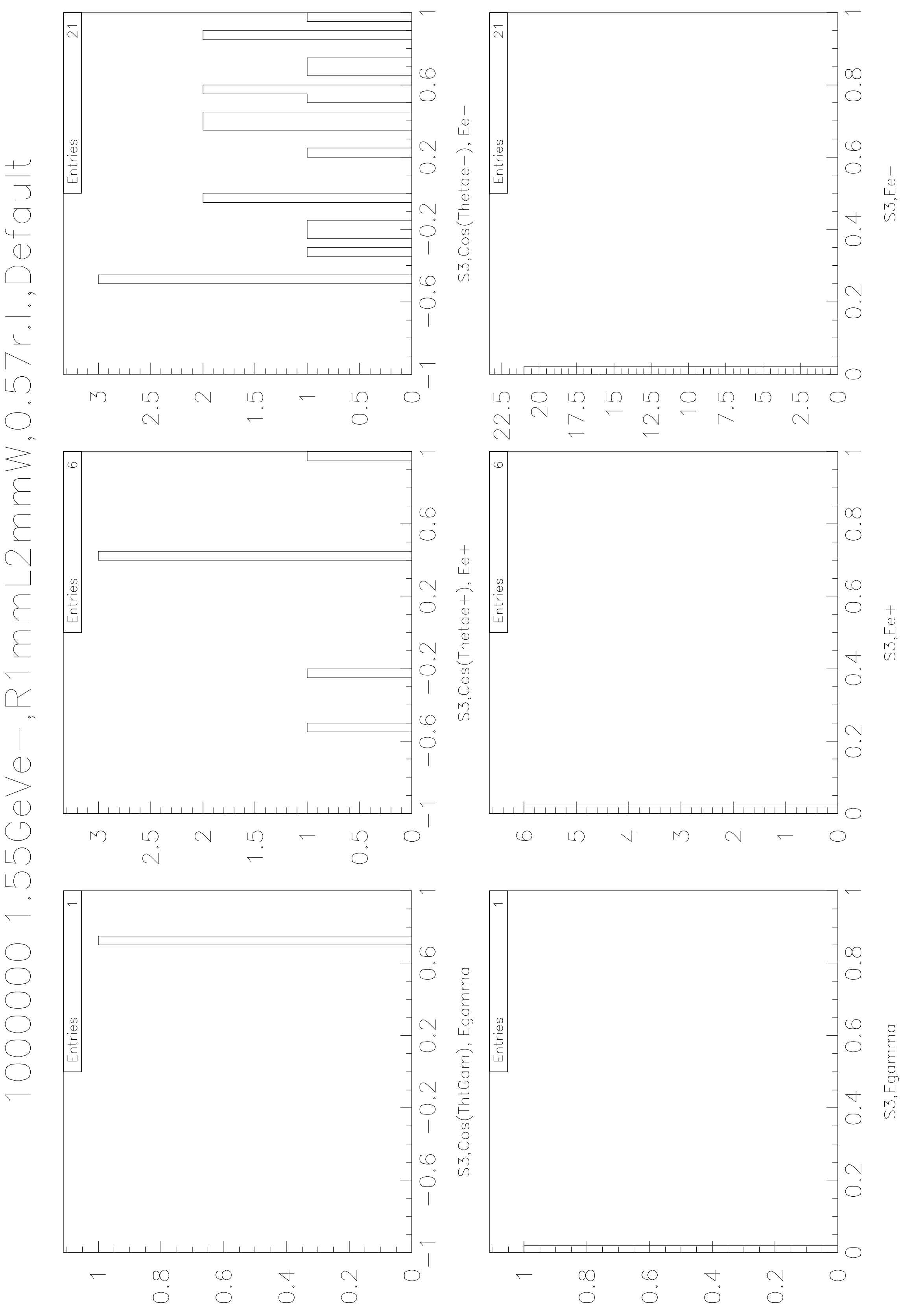

Figure 5: Cos and Energy of secon. γ, e+ and e-, Shielding, 2mmW, 0.57r.l.

It is possible to get roughly the same counting rate for θ about 45^o by adjusting the incident intensity, the target material and thickness and the effective solid angle of the tested module.

As having discussed above, the number of received electrons during the time resolution is of a distribution: P(n, μ) = $\frac{\mu^n \ e^{-\mu}}{n!}$, where μ be the average counting rate for time resolution, and n be the actual rate for a certain time resolution. Now the pulse duration (2.5ns) is much much narrower than time resolution of tested module(about 1 $\rightarrow$ 2 μs), so μ should be the average counting rate for pulse duration here, 6.6 electrons(positrons) a second means about 0.5 electrons(positrons) a pulse(μ = 0.5), therefore about 60 % pulses are empty: P(0,0.5) = 0.6065, 30 % pulses have 1 electron(positron): P(1,0.5) = 0.3033, 9 % pulses have 2 or more than 2 electrons(positrons): P(n $\geq$ 2,0.5) = 0.09023. It is easier to prove that when μ = 1, the percentage of 1 electron pulses is the largestt: P(1,1) = 0.37, and P(n $\geq$ 2,1) = 24 %. Therefore, it is necessary to adjust the incident intensity and the target thickness to reach the best condition.

Acorrding to P = eB ρ, where e be the electron charge, B the field intensity of the analytic magnet, ρ the radius of the secondary electron(positron) moving in the magnetic field. The accurecy of B is possible to reach $\pm$ 1 % via careful calibration, ρ is possible to reach $\pm$ 1 % via careful measurement, so the momentum resolution Δ P / P is possible to reach $\pm$ 2 %.

Acorrding to the experimental results obtained by us in 1990, it is possible to establish the secondary pion beam at roughly the same momentum region which has roughly the same momentum resolution.

4 Conclusion and Discussion

It is possible to establish a secondary single-electron beam at a larger production-angle(about 15^o or 45^o at lab. fram) by means of an electron/positron beam fetched from BEPC Linac impacting on a fixed target;

The momentum region is from 150 MeV/C to 1.5 GeV/C, and the momentum resolution Δ P / P is about $\pm$ 2 %;

It is necessary to do careful work to establish pion beam;

It is necessary to do more to improve shielding to reduce background.