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Electron identification and energy measurement with Emulsion Cloud Chamber

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Abstract

Charged particles undergo the Multiple Coulomb Scattering (MCS) when passing through a material. Their momentum can be estimated from the distribution of the scattering angle directly. Angle of electrons (or positrons) largely changes because of the energy loss in bremsstrahlung, and they are distinguished from other charged particles by making use of its feature. Electron energy is generally measured by counting of electromagnetic shower (e.m. shower) tracks in Emulsion Cloud Chamber (ECC), so enough absorber material is needed to develop the shower. In the range from sub-GeV to a few GeV, electrons don't develop noticeable showers. In order to estimate the energy of electrons in this range with a limited material, we established the new method which is based on the scattering angle considering the energy loss in bremsstrahlung. From the Monte Carlo simulation (MC) data, which is generated by electron beam (0.5 GeV, 1 GeV, 2 GeV) exposure to ECC, we derived the correlation between energy and scattering angle in each emulsion layer. We fixed the function and some parameters which 1 GeV MC sample would return 1 GeV as the center value, and then applied to 0.5 GeV and 2 GeV sample and confirmed the energy resolution about 50% within two radiation length.

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Keywords: energy measurement, radiation;

1. Electron detection in Emulsion Cloud Chamber

Emulsion Could Chamber (ECC) is made of a target material plates interspaced with nuclear emulsion films acting as high-resolution 3D tracking devices. Nuclear emulsion is successfully used for detection of the decay of

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short-lived particles: tau and charm particles. It also allows to distinguish some kinds of particle (proton/pion, electron/pion, electron/gamma, etc…).

Recently ECCs, where the emulsion layers are interleaved with 1mm-thick lead plates, has been used for neutrino experiments (i.e. OPERA (<Eν>=17 GeV) and PEANUT (<Eν>=3 GeV)). Electrons (positrons) generated in neutrino interaction or gamma conversion develop electromagnetic shower (e.m. shower) passing through ECCs. Then the particles are identified as electrons and are measured their energy by counting the number of shower tracks. To develop a noticeable e.m. shower, enough particle energy and absorber material (generally needed more than 3 radiation length (X_0)) are needed. The new method aims to estimate electron energy in the range from sub-GeV to a few GeV or in the case when ECC material is not sufficient for development of the noticeable e.m. shower.

2. Distinction between electron and pion

Electrons can be also identified by the change of angle, since they lose their energy in the bremsstrahlung process. The energy of electrons after passing through material decreases as $E(x) = E_0 \times \exp(-x/X_0)$ (E_0: initial energy, x : particle path in the material, X_0: radiation length (for lead = 5.6 mm)), while the energy of pions (π) (or muons (μ)) is almost constant: $E(x) = E_0$ (see Fig.1).

Basing on a difference of behavior between electron and π (μ), the method of separating electron from π (μ) by the evaluation of difference of angle between two films has been already developed, and the availability of this method was confirmed by 2 GeV and 4 GeV electron beams (Kodama et al., 2003).

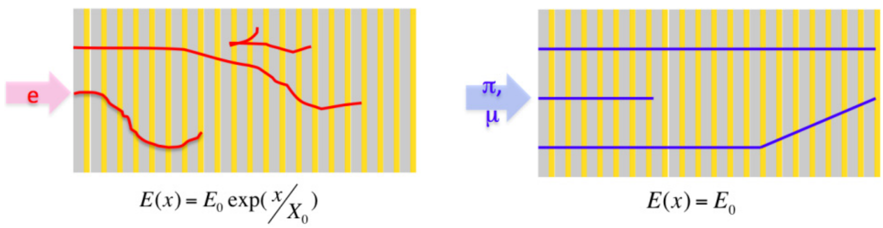

Fig. 1. (Left) A picture of the behavior of electrons passing through an ECC: grey area shows metal plates and yellow one shows emulsion films. (Right) A picture of the behavior of pions and muons.

3. Energy measurement by Multiple Coulomb Scattering

In measuring the energy (momentum) by Multiple Coulomb Scattering (MCS), the estimated error decreases as the number of the data increases, since the error is mainly originated from the statistical error ($\mathrm{sqrt}(N_{data})/N_{data}$). However in case of an electron, the error increases since the energy fluctuation becomes larger because of the energy loss in the bremsstrahlung. So it is important to determine the effective number of data. In this study, the correction parameter is given by MC sample for 1 GeV so that it gives the center value of 1 GeV. Considering behavior in case of 0.5 GeV and 2 GeV being similar to 1 GeV until $2X_0$, 0.5 GeV and 2 GeV MC samples are calculated after applying the same correction parameter. We estimated the energy resolution about 50% within $2X_0$ and best number of data minimized it is seven data (See Fig.2).

4. Conclusion

Electron identification and energy measurement with ECC have been used in the past and are being used in current experiments in high-energy region (Ee> a few GeV) with high efficiency and a few tens of percent energy

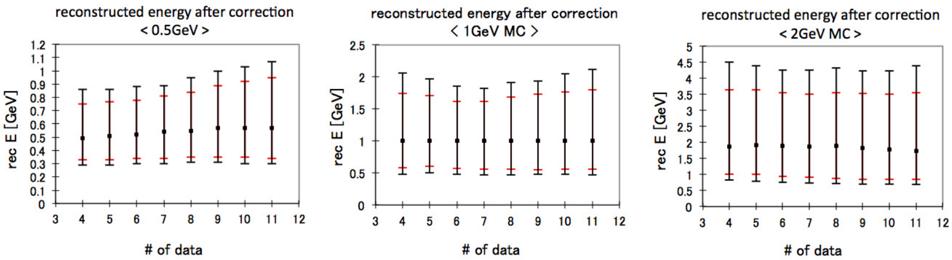

Fig. 2. Results of electron energy measurement by simulated by Geant4 (Left: 0.5 GeV, Center: 1 GeV, Right: 2 GeV). In each plot, vertical axis shows reconstructed energy, horizontal one shows number of data which are angle differences calculated from each adjacent emulsion films. Black squares show center values and black (Red) bars show measurement errors in 90% (68%) C.L.

resolution. While the study in low-energy (sub-GeV ~ multi-GeV) region is not so advanced. In this study, the method based on MCS in limited material ($<2X_0$) is discussed. It also proved to be effective to the electron energy determination same as momentum measurement of π and μ, while even statistics of less than 10 data is enough. However some problems have revealed such as a mathematical treatment of the fitting function, a low energy resolution. We intend to evaluate this method by data from test beam exposure.

References

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