The EM/Hadron Calorimeter for High Energy Cosmic Ray Electrons Investigation

G.L.Bashindzhahyan*, **N.A.Korotkova***, **N.B.Sinev**† **and L.G.Tkatchev**‡

*Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
†University of Oregon, Eugene, Oregon, USA
‡Joint Institute for Nuclear Research, Dubna, Russia

***Abstract*. The proposed EM/Hadron Calorimeter is targeted to carefully measure Cosmic Ray electrons energy spectrum in a region 100 - 1000 GeV. It will provide a high level separation between electrons and protons, precise measurements of electron energy and direction, relatively good hadron energy measurements and precise charge measurements for hadron type particles. Presented results on proton-electron separation are based on only longitudinal difference between electron and hadron cascades in the calorimeter. Additional analysis of the transversal shape of the cascade allows the further improvement of the separation.**

***Keywords*: EM/Hadron calorimeter, electron energy spectrum**

I. Introduction

The results obtained by ATIC[1], PAMELA[2] and Fermi collaborations indicate that there is a region in Cosmic Ray electron (positron) energy spectrum with unexpected anomaly. To investigate this interesting area precisely one needs a device which allows exact measurement of electron energy and, what is very important, to distinguish reliably a single electron or positron from another cosmic ray particles. This becomes a serious problem because proton flux at 500 GeV is approximately 250 times higher than electron one. It means that we need to suppress proton ability to be identified as electron in approximately 10^4 times.

Proposed EM/Hadron calorimeter is able to solve a few problems: electron separation, electron energy and direction determination and, as an additional bonus, precise charge measurement of the hadron type particles. Accuracy of hadron energy measurement is not so high because the total thickness of the calorimeter is about 2.5 interaction lengths (λ_{int}). But its still very acceptable for many purposes.

II. Device structure

The calorimeter consists of two sections. The upper section is a pure electromagnetic one (Fig. 1). It includes 5 layers of absorber (tungsten plates) of 50×50 cm^2 size and 0.35 cm thick. It gives $\sim$1 radiation length (X_0) per layer. On the top and between absorber plates there are 6 layers of silicon microstrip detectors. In neighbor layers strips are perpendicularly positioned. The upper section tasks: to detect the point where cascade starts, to register longitudinal and transversal development of the cascade, to determine the secondary particles number and positions. For the hadrons, which passed the upper layers of the absorber without interaction, multilayer silicon system provides precise charge measurement. The upper section plays important role in proton-electron separation.

The second section (Fig. 1) is a catcher. It has 10 layers of steel absorber $2X_0$ thick and 10 layers of scintillators of 1×1 cm^2 size and 50 cm long. Scintillators in neighbor layers are perpendicular to each other.

Relatively good granularity allows to determine electromagnetic or hadron cascade cross-section and direction as well as a number of secondary particles. The steel absorber allows to combine an advantage of rather thick EM calorimeter ($25X_0$) with an ability to measure hadron energy. The second fraction of the calorimeter is also very important for hadron-electron separation because the tail of EM cascade has much lower number of secondary particles comparing to a hadron cascade.

III. Technical data

The calorimeter size (without electronics) $50\times50\times50$ cm^3, weight $\sim$700 kg, geometry factor is $\sim$0.5 m^2 ster, number of electronic channels $\sim$8000.

IV. The concept

EM cascade starts in the first fraction of EM section. Number of secondary particles rises very fast with a maximum between 5 and $9X_0$ depending on energy. After the maximum it goes down. At $25X_0$ the number of particles is about 1/20 of the number in maximum (Fig. 2).

The shape of average proton cascade is very different. It rises slowly and has a maximum at about $21X_0$ and near the same number of secondaries at $25X_0$. For the same energy the total number of secondaries in this calorimeter about 4 times less than for electrons.

But distinguishing between electrons and protons based on a cascade longitudinal shape is not so easy because of a cascade fluctuations. If EM cascade r.m.s. is around 15-30%, proton cascade r.m.s. is about 100%. Taking into account that proton flux is 200-500 times higher than electron flux (depending on energy), one can expect that essential number of protons can imitate EM cascade. To

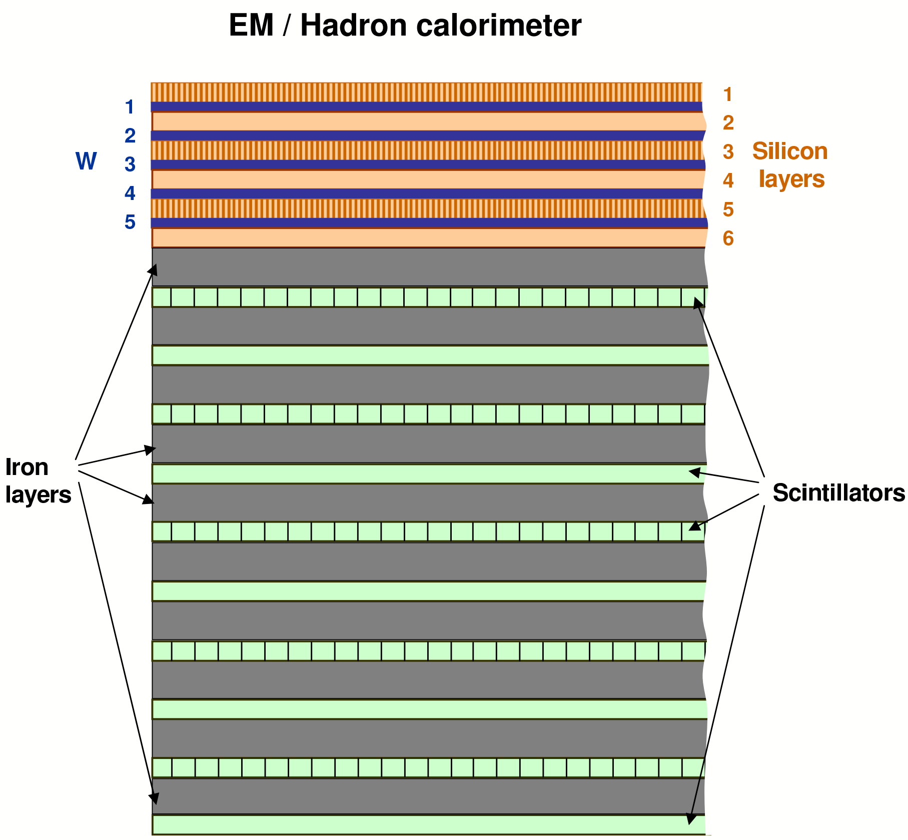

Fig. 1: The EM/hadron calorimeter

provide good proton-electron separation we created a set of filters based on a number of secondary particles at practically each layer of the calorimeter. This number was fixed as a certain percent of the total number of particles at the whole calorimeter. The filters have been tuned to miss about 10% of electrons for any energy in the region E_e=100-1000 GeV. It does not mean that 10% of electron flux will be really missing, because offline analysis will be used. All the events will be recorded and additional filters based on transversal cascade shape analysis will be applied to recover missed electron events.

The filters practically exclude the possibility to identify a proton as an electron. We estimate that only one fake electron imitated by proton will be among 100 identified electrons.

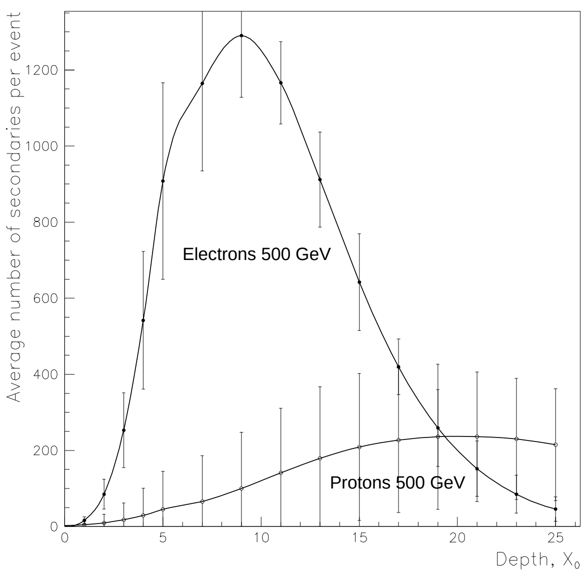

Fig. 2: Comparison of average electron and proton cascades in the calorimeter

V. The results of simulations

Table I shows the proton energies used for simulations, number of simulated events for each energy, number of protons passed the filters, calculated probability to pass the filters, average number of secondary particles for the protons, which passed the filters (quasi electron events) and the electron energy, which corresponds this number of secondaries. Table II shows the same data for simulated electrons.

From the tables one can see that average probability to pass the filters for electrons within 100-1000 GeV energy range is about 0.9. The same probability for protons from energy range 100-2000 GeV is about 0.00028. But average number of secondary particles

TABLE I:

Proton energy, GeV	Number of events	Number of protons passed the filters	Probability to pass the filters	Average number of secondaries for passed protons	Corresponding ellectron energy, GeV
100	75000	0	0.0	-	-
200	25000	8	0.00032	2032	120
300	89000	35	0.00039	2859	175
500	60000	34	0.00057	4915	300
700	56000	13	0.00023	6358	390
900	40000	12	0.00030	6517	400
1200	25000	3	0.00012	4108	250
2000	63000	18	0.00029	13970	900

TABLE II:

Electron energy, GeV	Number of events	Number of electrons passed the filters	Probability to pass the filters
100	2419	2312	0.956
200	1000	929	0.929
300	3000	2755	0.918
500	1000	903	0.903
700	1000	899	0.899
900	9500	8458	0.890

for the quasi electron events (the protons passed all the filters) is only a half of corresponding number for regular electrons of the same energy. It means that filtered protons imitate electrons with two times smaller energy. In other words, to imitate electron with energy E_e we need a proton with energy $2E_e$. Because of proton energy spectrum decrease the flux of $2E_e$ energy protons will be about 7 times less than flux for protons with energy E_e, and final probability to imitate electron with energy E_e will be 0.00028/7=0.00004. But we know that proton flux is approximately 250 times higher than electron one (at 500 GeV). Therefore, probability to pick up a false electron imitated by proton is approximately 0.00004·250=0.01.

VI. Conclusion

Much more simulations are needed to carefully analyze all the properties of the proposed calorimeter. However our preliminary results show that the calorimeter allows reliable electron separation from other cosmic ray particles and their precise energy and direction determination. It can appear as a relatively simple and reliable device for successful electron flux and energy spectrum measurements.

References

[1] J. Chang et al. [ATIC Collaboration], *An excess of cosmic ray electrons at energies of 300-800 GeV*, Nature 456, 362 (2008)

[2] O. Adriani et al. [PAMELA Collaboration], *An anomalous positron abundance in cosmic rays with energies 1.5-100 GeV*, Nature 458, 607 (2009)