PROCEEDINGS OF SCIENCE

Study of Number of photons at axis Shower with different dE/dx and Fluorescence Yield

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The particles deposit part or all their energy by ionization of air molecules and produce fluorescence radiation leaving a track of fluorescent light as the shower develops. A study on the number of electrons of the shower development in several atmospheric layers is addressed. We take into account parameterizations for density, temperature and composition of each layer and we used different formulations for the energy deposit and different measurements for fluorescence yield to evaluate their influence on the total number of photons in the shower axis as a function of the slant depth.

4th School on Cosmic Rays and Astrophysics,
August 25- September 04, 2010
Sao Paulo Brazil

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PoS(CRA School)018

1. Introduction

Studies on the production of photons in the atmosphere by ionization processes caused by charged particles from EAS (Extensive Air Showers) are strongly dependent on the parameterized forms of the Fluorescence Yield (FlY). Kakimoto *et al.* and Nagano *et al.* [1, 2] are some of the most used. The energy deposit (dE/dx) is callculated using Bethe-Bloch formula [3, 4] and further corrections due to the polarization effects of the medium density (parameter δ). The calculation of the number of photons emitted per charged particled at the shower axis along the longitudinal development can be expressed as the dependence of the fluorescence yield, thus:

$$N_\gamma(h) = FlY(dE/dx(\rho),\lambda,T)\Delta X(h), \tag{1.1}$$

and these calculations are dependent on the total number and average energy of electrons produced by the shower development along of the atmosphere.

This work presents a study of the development of the electrons along the atmosphere and an analysis on the dependence of the number of the photons produced at the EAS axis calculated for two forms of dE/dx and some of FlY [5]. The showers were simulated with the CORSIKA[6] program version 6617 using the hadronic model Sibyll 2.1 [7]. The chemical composition of the primaries were chosen to be proton and iron with the energies fixed in 10^{18}, 10^{19}, and 10^{20} eV, where 1000 events were simulated for each energy. The thinning factor used was of 10^{-5} and the zenith angles were sorted between 0^o and 60^o.

2. Number of electrons

The colors identify the chemical composition, blue for iron and red for proton, and the thickness corresponds to the energy of the primary.

In figure 1 we compare the number of electrons by depth for proton and iron. We can see the similarity in the number for each energy. The interesting is the figure 2, relative error to the number of electrons in function of depth, where the minimum of the curves are close to the maximum of the shower reflecting the total number of the electrons in this level, and the shape of the curves are significantly dependent of the energy and yet can be related to the model of particle generation.

3. Average energy per electron

The average energy per particle is decreasing as a function of atmospheric depth, as we can see in the figure 3. This is expected during the development of the shower. But the fluctuation of this number is larger for showers initiated by proton, and this is related to the superposition model and the interaction mean free path. The relative errors, shown in Figure 4, are all dependent on the primary energy and decreasing with respect to atmospheric depth.

4. Results - No of Photons

Taking the number of electrons and the average energy per electron at each level of $5g/cm^2$ in atmospheric depth, we calculated the energy deposition using dE/dx by Leo [8] and NIST [10, 9]

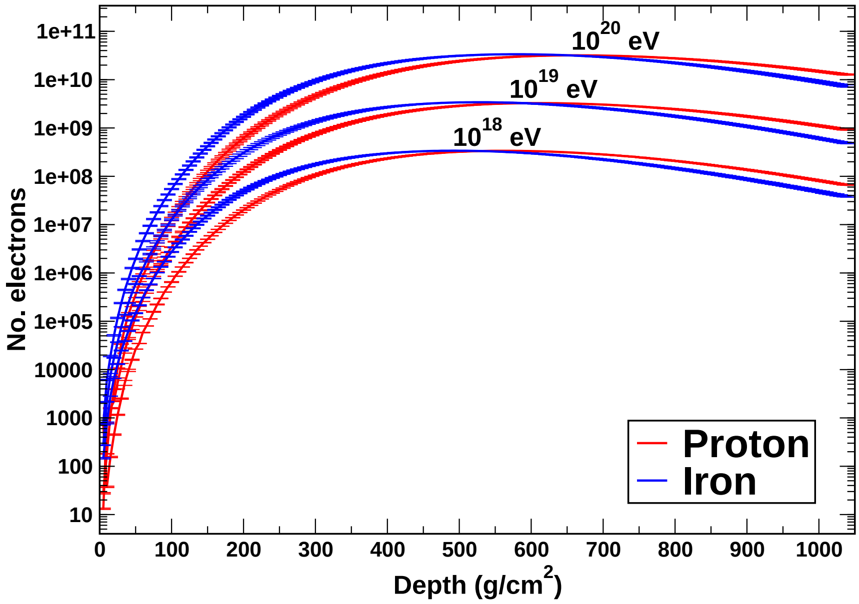

Figure 1: Number of eletrons by level of $5g/cm^2$ in atmospheric depth for energies 10^{18}, 10^{19}, and 10^{20} eV.

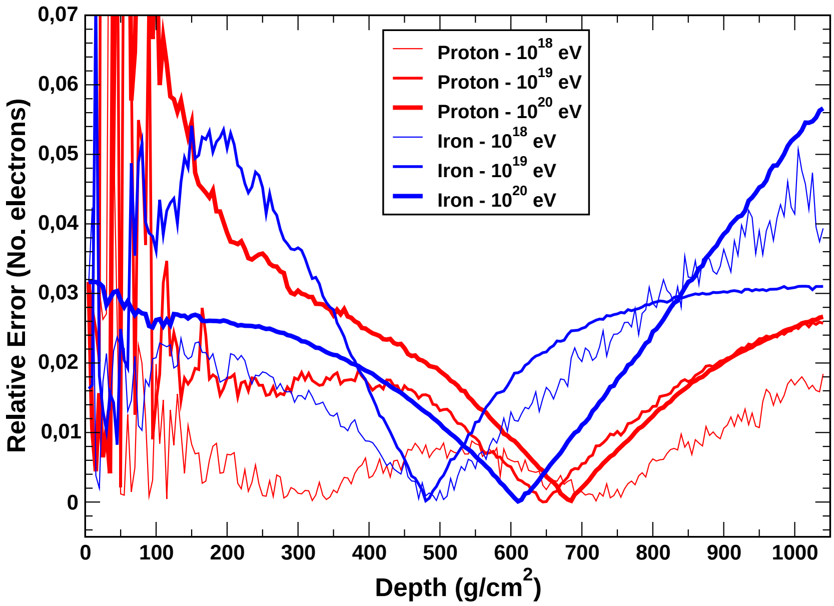

Figure 2: The Relative Error for the number of eletrons.

and hence the fluorescence yield for each particle from Kakimoto and Nagano, and FlY Kakimoto, Nagano, Keilhauer and Airfly extracted directly from Offline[11]. The result is the number of photons generated by each shower level in atmospheric depth. In the figures 5 and 6, the width of the line is related with the standard deviation of the average (σ) in each step of the atmospheric depth. The values of σ are around 0.5% for proton and 1% for iron. The difference on the number of photons between the curve of Leo-Kakimoto and NIST-Nagano for proton at $495g/cm^2$ and for iron at $425g/cm^2$ is about 30%.

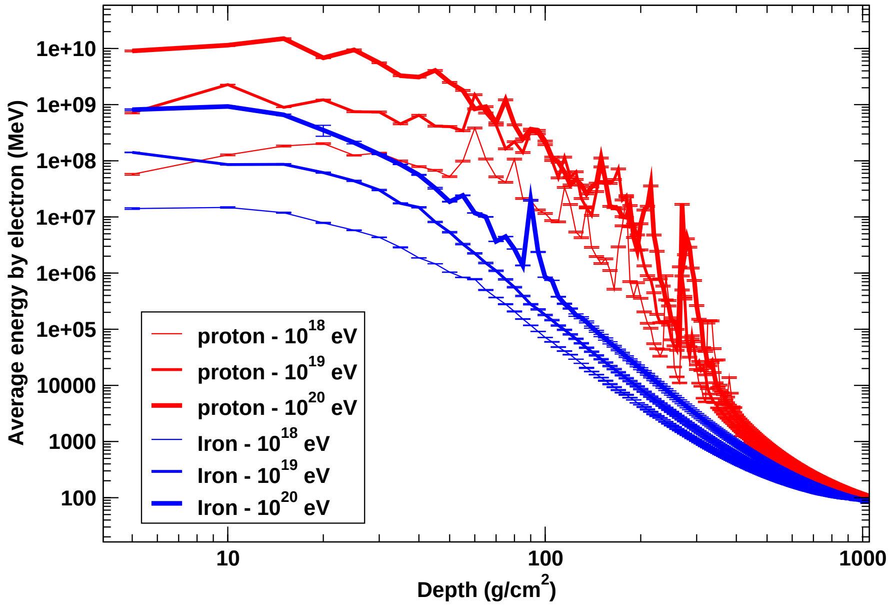

Figure 3: The average energy per electron in atmospheric depth by levels of $5g/cm^2$.

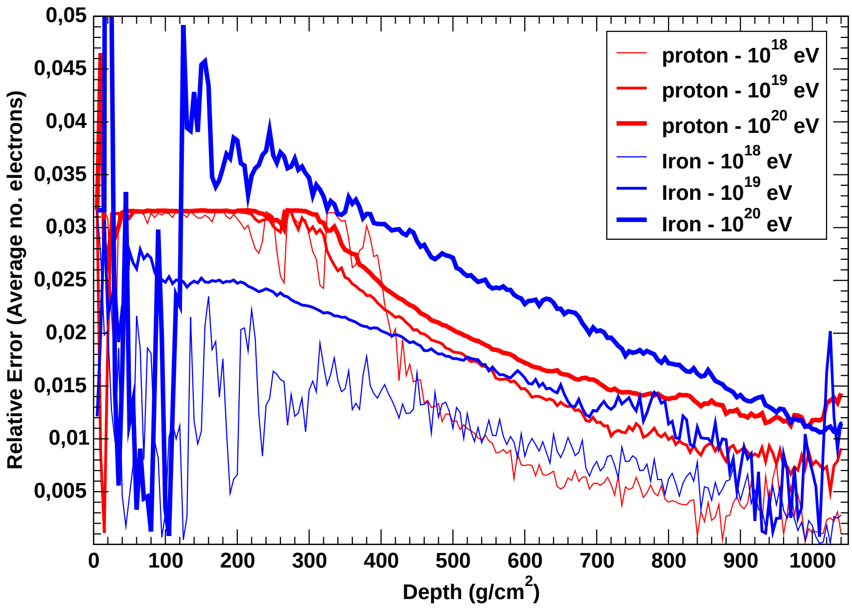

Figure 4: The Relative Error for the average energy.

5. Conclusions

We propagate all errors related to the number of electrons and the average energy per electron and found an error related to the number of photons of about 0.5% up to 1%. But the number of photons in the shower axis has a fluctuation of around 30% depending on the combination of the form of dE/dx and FlY. So this models has a very important influence in the reconstruction chain for extensive air showers experiments.

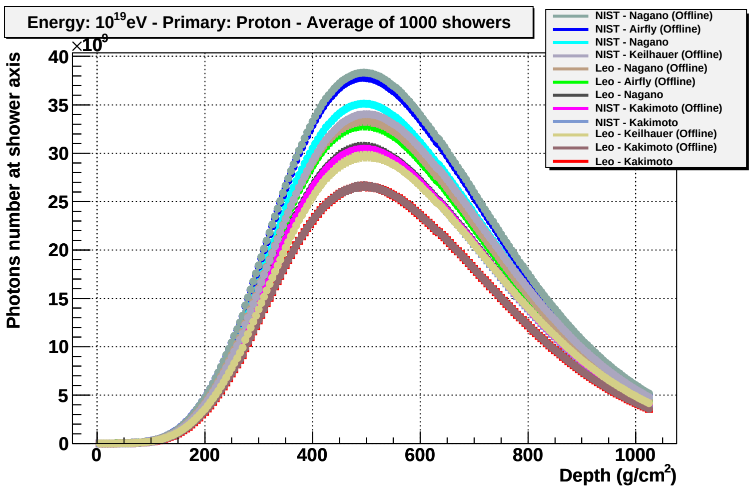

Figure 5: Number of photons calculated by different FlY for **proton** primaries.

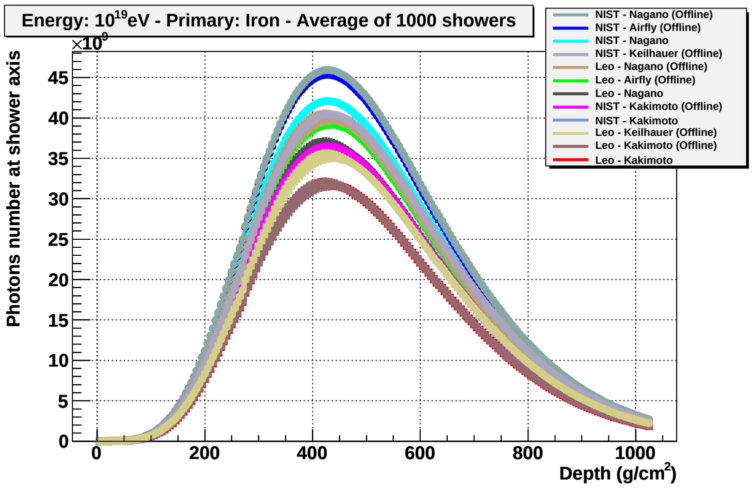

Figure 6: Number of photons calculated by different FlY for **iron** primaries.

6. Acknowledgments

We thank the financial support given by Universidade Federal do ABC. To CENAPAD (Centro Nacional de Processamento de Alto Desempenho), NTI (Núcleo de Tecnologia e Informática - UFABC) where the simulations and calculations for this work has been performed.

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