29th International Cosmic Ray Conference Pune (2005) **00**, 101–104

The Performance of the Corrector Lenses for the Auger Fluorescence Detector

Ricardo Sato[a], Carlos O. Escobar[a],
for the Pierre Auger Collaboration
(a)Instituto de Física Universidade Estadual de Campinas, Campinas, Brasil
Presenter: C. O. Escobar (escobar@ifi.unicamp.br), bra-escobar-co-bas1-he15-poster

We present an analysis of the effect that the corrector lenses (Schmidt Optics) have on the overall performance of the Auger Fluorescence Detector. The analysis uses real data from the telescopes. Figures of merit for the corrector lenses performance include shower trigger rate and the distribution of the distance of closest approach to the shower axis. As a result of this analysis we may say that the effective light collection area of a telescope nearly doubles with the use of a corrector lens at its aperture.

1. Introduction

The Auger Observatory fluorescence detector design is based on Schmidt optics with a spherical mirror of 3.4 m radius of curvature and a circular diaphragm positioned at the center of curvature of the mirror. The traditional design (f/1 optics) calls for a diaphragm with an aperture (diameter) which is one half of the mirror radius of curvature, which, in the Auger design, corresponds to 1.7 m aperture. The Schmidt optics has the advantage of eliminating the coma aberration at the price of having to introduce a large radius of curvature mirror so as to keep a reasonable spot size at the camera placed at the focal surface of the system. The design of the Auger fluorescence detector aims at a spot size (circle of least confusion) less than 15 mm diameter (0.5 degrees) while the pixel size is 45 mm in diameter (1.5 degrees) [1].

Early in the design phase, after deciding for a Schmidt optics telescope, it was envisaged to complete the Schmidt optics with a corrector plate placed at the aperture, not for the purpose of reducing the spot size but rather of increasing the signal to noise ratio, effectively enlarging the light collection area of the telescopes. Pratical considerations led to a corrector plate of aspherical profile, having the shape of an annulus, segmented in 24 pieces, with an inner radius of 0.85 m and an outer one of 1.10 m [2] (we will refer to this corrector plate as corrector lenses or just lenses in the rest of this article). Ray tracing simulations indicated that with such a corrector lens the effective aperture of the telescope would double while maintaining the spot size within the design requirements, as mentioned in the paragraph before.

In this contribution we show that the data collected so far by the Auger Observatory fluorescence detectors confirm the design studies and support an effective light collection area which is twice that without the corrector lens, with the diaphragm at nominal aperture (1.7 m diameter).

2. Event Selection

Our analysis uses data collected from January 2004 to March 2005. Two eyes are used, known as Los Leones and Coihueco. Each eye has six telescopes covering a total of 180 degrees in azimuth and 28.6 degrees in elevation, at Los Leones we consider telescopes 3, 4 and 5 and at Coihueco 2, 3 and 4. We compare the performance of telescopes with and without corrector lenses as detailed below.

The events were reconstructed using the standard Auger offline reconstruction and simulation chain. All selected events had a zenith angle less than 60^0 degrees and were well reconstructed geometrically, with reduced χ^2 less than 5.

3. Results

Figure 1 shows the ratio of the total number of events collected by telescopes with corrector lenses to those without lenses, over the same period of time (exposure) for telescopes at Los Leones (left) and at Coihueco (right). Notice that the denominator is an average over all events detected by the telescopes without lenses. The data is divided in intervals of distance of closest approach of the showers to the telescopes (R_p): black, R_p < 4.2 km; blue, 4.2 < R_p < 6.0 km and red, 6.0 km < R_p . Notice that the areas of these two rings are approximately the same. One notices a clear pattern of increase in the number of detected events once a given telescope has a corrector lens installed. The start of operation with corrector lenses were as follows:

Los Leones: number 3, end of July 2004; number 4, from the start of the data selection period and number 5, end of February 2005.

Coihueco: number 2, end of February 2005; number 3 start of the data selection period and number 4, end of July 2004.

The plots for each telescope are ordered vertically according to the sequence above (Los Leones: 3, 4 and 5. Coihueco: 2, 3 and 4).

The plot at the bottom of Fig. 1 shows the same ratio but now with all distances put together.

We would like to call attention to the results from telescope 4 at Coihueco which shows a clear jump in the rate of events after the introduction of the lenses but then returns, in the period between October 2004 and February 2005, to a level compatible with having no lenses, jumping back to the higher level in March 2005. This behavior is now under investigation. Notice that in November 2004 there is data point with a very large error, this being due to a lower rate of events detected in this period due to bad weather conditions.

Figure 2 shows the distribution of the distance of closest approach of showers, R_p, that is, the distance from the shower axis to a given telescope, including all the data from June 2004 to March 2005. It is clearly seen from Fig. 2 that both at Los Leones and Coihueco, telescopes 3 , and 4, with lenses for a longer period of time, detected at least twice as many events than the telescopes without lenses. Since telescope number 5, at Los Leones, and 2 at Coihuecos started operating with corrector lenses at the end of February 2005, no significant effect is observed for them in Fig. 2.

4. Conclusions

Our preliminary analysis of real data collected by the Auger fluorescence detector clearly indicates that the use of corrector lenses at the aperture of the telescopes increases the effective aperture by a factor of roughly 2, following the expectations we had at the design phase of the telescopes.

References

[1] G. Matthiae, for the Auger Observatory Collaboration, *Optics and Mechanics of the Auger Fluorescence Detector* in Proceedings of the ICRC 2001, Hamburg.

[2] M. A. L. de Oliveira et al., *Manufacturing the Schmidt Corrector Lenses for the Pierre Auger Observatory*, Nucl. Instr.and Meth. **A 522**, 360-370 (2004).

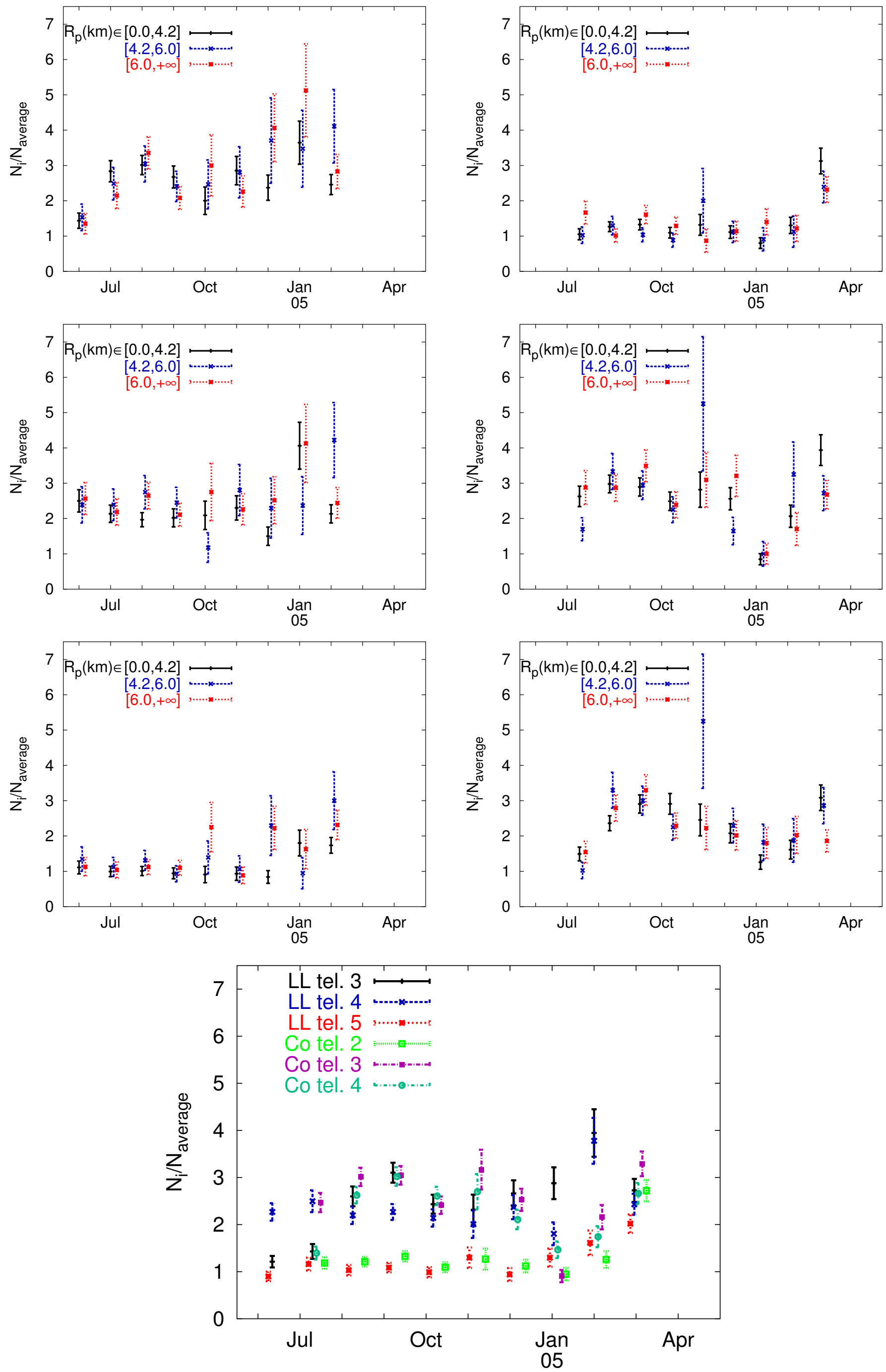

Figure 1. The ratio of the number of events for telescopes with lenses to the average number of events for telescopes without lenses, whence the factor 3 (see text). On the left the eye at Los Leones and at the right the Coihueco eye. The ratio is shown for selected ranges of the distance of closest approach, R_p. The plot at the bottom includes all R_p.

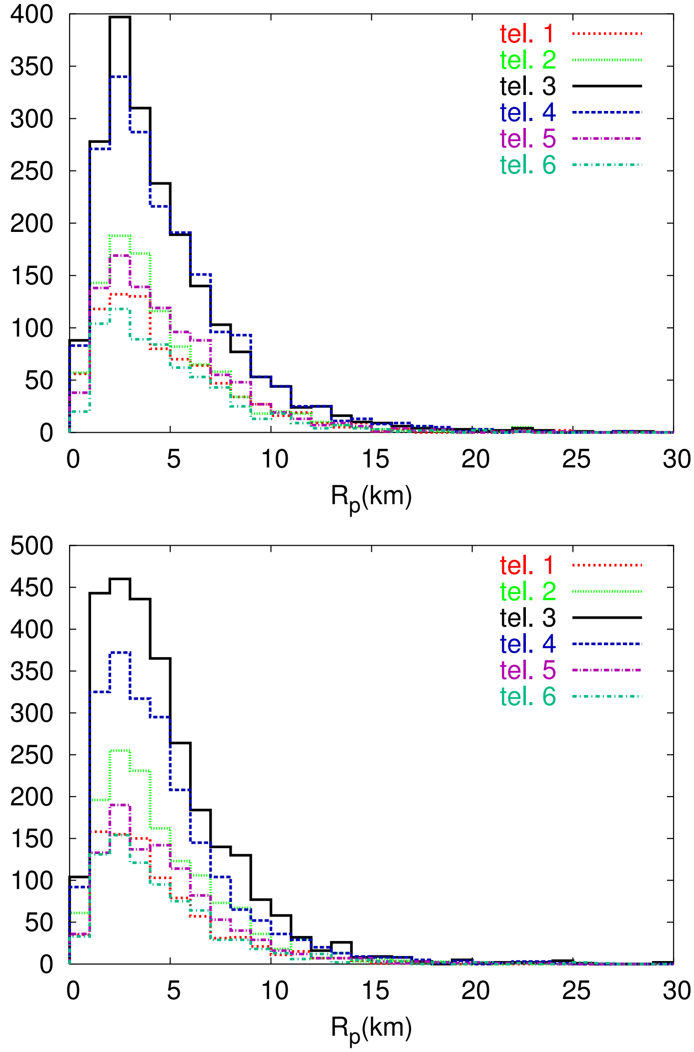

Figure 2. Number of events as a function of R_p. On the top data from Los Leones and on the bottom Coihueco