AIRFLY: Air Fluorescence Induced by Electrons in a Wide Energy Range

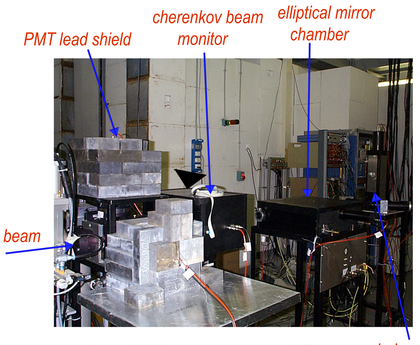
INTRODUCTION

Fluorescence detection of ultra high energy cosmic rays is a well established technique. It is based on atmospheric nitrogen excitation by charged particles of the air shower, mainly electrons and positrons, followed by emission of photons in the 300-400 nm range. The yield is about 4 photons/e-/m of air. A precise measurement of the fluorescence yield is essential for the absolute calibration of cosmic ray detectors like Hires, AUGER and EUSO.

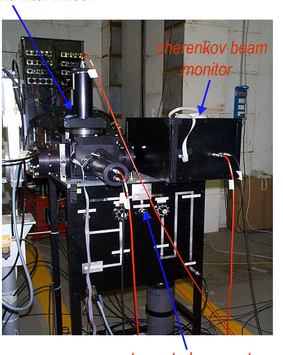
The AIRFLY experimental programme foresees:

- *a precise measurement of the energy dependence of the fluorescence yield over a wide energy range (1 MeV-800 MeV) ;*
- *the absolute measurement of the fluorescence yield spectrum ;*
- *the dependence of the fluorescence yield on gas pressure, temperature and humidity.*

AIRFLY will measure the yield in the region close to the critical energy in air, where most of the shower particles are found.



The AIRFLY experiment at the BTF



AIRFLY TEST AT THE BTF

AIRFLY has performed a prototype run in 2003 at the Beam Test Facility (BTF) of the INFN Laboratori Nazionali di Frascati. The BTF provides electron and positron beams in a range 25-800 MeV, with intensity from single particle up to 10^{10} particles/bunch. The repetition rate is 25 Hz and a bunch length as short as 1 ns is available.

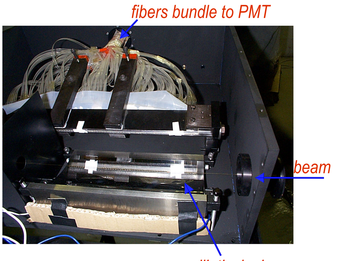
The main objectives of this first test were the characterization of the beam and related background and the operation of the AIRFLY chamber, in preparation for more extensive measurements.

The experimental apparatus consisted of a 6-way cross aluminum chamber. Three fused silica viewports are placed orthogonally to the beam direction, equipped with 2 inch diameter Photonis XP2262 photomultipliers, selected for low noise. A filter wheel was associated to each PMT. The filter wheels hosted interference filters of central wavelength corresponding to the main emission lines , a M-UG6 band pass filter (300 to 400 nm) and a shutter for background measurements.

Measurements with dry air and pure nitrogen gas were performed.

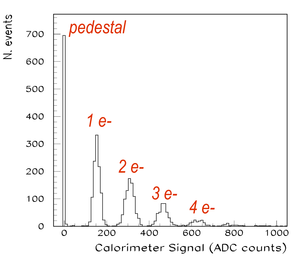
The possibility of increasing the light collection with an elliptical mirror was also tested.

The beam passed along one focus of the mirror. Fluorescence photons emitted from the beam were collected by optical fibers positioned in the other focus along the mirror length. A factor 10 increase in the light collection was measured.

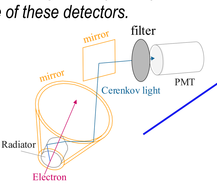


BEAM INTENSITY CALIBRATION

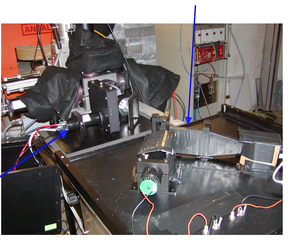
In order to measure the fluorescence yield, the number of electrons/bunch must be known. The beam intensity was measured by a lead-scintillating fibers calorimeter placed at the end of the BTF line. The calorimeter was calibrated by the single electron peak measured at low beam intensity, and allowed a beam intensity measurement up to 1000 e/bunch. For higher multiplicity, where the calorimeter saturated, beam monitors based on Cherenkov light produced by the beam particles were developed. The use of calibrated attenuating filters in front of the PMTs increases significantly the dynamic range of these detectors.



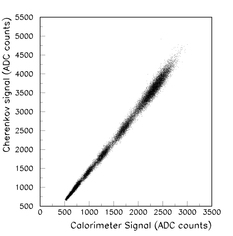
Calorimeter signal at low beam intensity



Two crossed plexiglass light guides used as radiator and light collectors



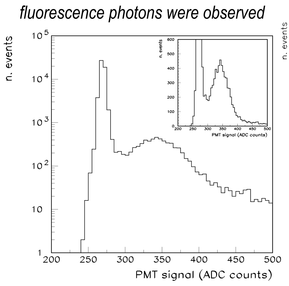
Cherenkov beam monitors



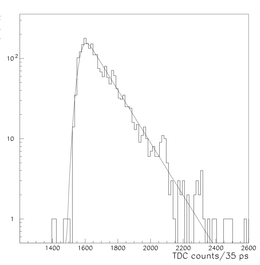
Cross-calibration of Cherenkov monitor and calorimeter

PRELIMINARY RESULTS

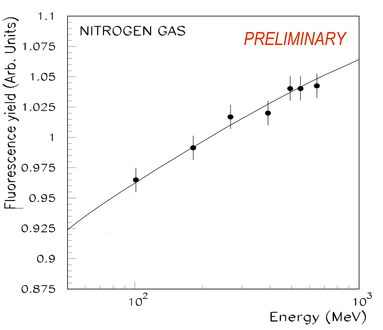
Measurements of the fluorescence yield were performed at a moderate beam intensity of 200 e-/bunch with single photon counting. The PMT signal was integrated at each bunch passage, and a splitted signal was discrimitated for time measurement with a TDC. Clear signals associated to the emission of fluorescence photons were observed



PMT signal spectrum with the beam trigger, with a clear single p.e. peak



TDC spectrum showing the exponential decay associated to fluorescence

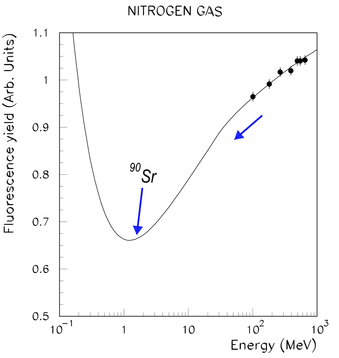


Measured energy dependence of the fluorescence yield. The solid line is the theoretical dE/dX dependence

Relative fluorescence yields as a function of the electron energy were measured from 100 to 650 MeV in pure nitrogen with a M-UG6 band filter. These preliminary measurements confirm the proportionality between the fluorescence yield and the electron energy deposit in the gas.

OUTLOOK

A measurement of the fluorescence yield at MeV energy with a ^{90}Sr source is being prepared. AIRFLY will take data in 2004 at the BTF with several improvements on the detector and beam. We expect to perform measurements at energies down to at least 50 MeV, thanks to a new thin beam exit window which will limit the multiple scattering. High beam intensities (>10^6 particles/bunch) will allow a measurement of the fluorescence spectrum with a spectrophotometer.



The AIRFLY Collaboration

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