Calibration of a Position-Sensitive Scintillation Detector for Secondary Cosmic Ray Measurements

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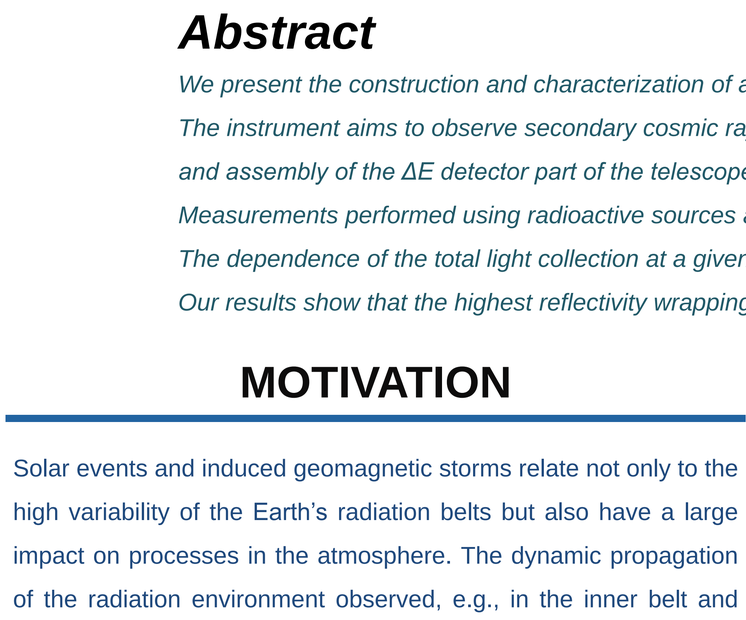
Abstract

We present the construction and characterization of a thin, large-area scintillation detector used for a particle telescope project, AMORE - Airspace Measurement of Radiation Environment. The instrument aims to observe secondary cosmic rays during geomagnetic storms, detecting energies and directions of various incoming particles. In this work, we optimized the design and assembly of the ΔE detector part of the telescope. Our study demonstrates how different reflective wrappings affect the signal amplitude and position sensitivity of detected electrons and protons. Measurements performed using radioactive sources and monoenergetic protons from the EMON and PIF facilities at PSI determined detector responses at different particle hit positions. The dependence of the total light collection at a given energy deposition on the reflective quality of the wrapping material is also studied. Our results show that the highest reflectivity wrappings correlate with the lowest accuracy of the particle hit position.

MOTIVATION

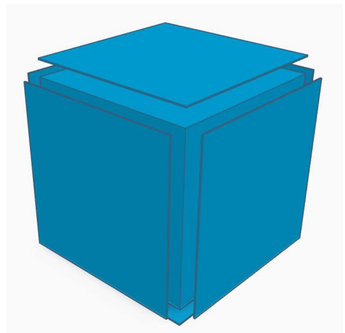
Solar events and induced geomagnetic storms relate not only to the high variability of the Earth's radiation belts but also have a large impact on processes in the atmosphere. The dynamic propagation of the radiation environment observed, e.g., in the inner belt and around magnetic poles toward the Earth's surface, strongly correlates with measurements from the global neutron monitor network on the ground. The intermediate region is studied less systematically using either bulky or simplified instrumentation placed as a payload on the high-altitude balloons.



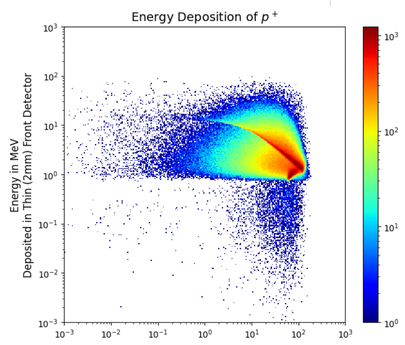
Dynamic radiation background in the upper magnetosphere during calm and stormy geomagnetic conditions – POLAR trigger rate

The AMORE detector aims to fill the void in measurements at cruising and balloon altitudes.

- Novel airspace radiation environment monitor
- Energy measurement from fractions to hundreds MeV
- Full solid angle sensitivity; directional sensitivity
- Telescope with scintillators, SiPM and ASIC
- Particle identification and separation
  - Electron spectra with threshold ~ 0.35 MeV
  - Proton spectra with threshold ~ 9 MeV
  - Neutrons and gamma rays via PSD
  - Pions, muons, and cosmogenic isotopes …
- Compact, low-power design, autonomous operation.



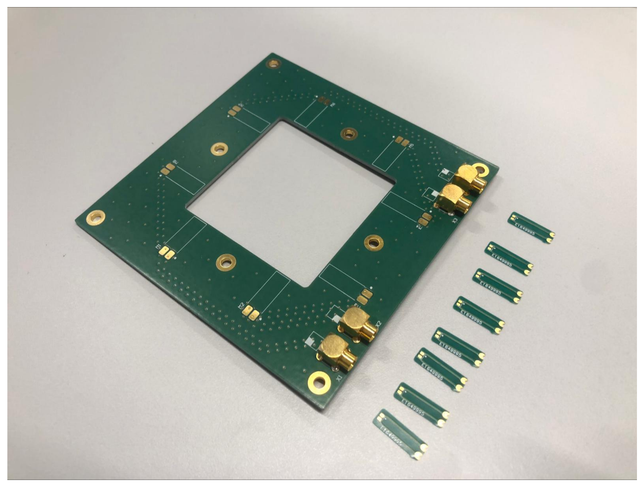
Simplified geometry of the detector. Thin dE detectors are placed on each side of the large E-detector



The ΔE-E energy depositions from Geant4 simulation of protons shot at random directions with a flat spectrum up to 200MeV..

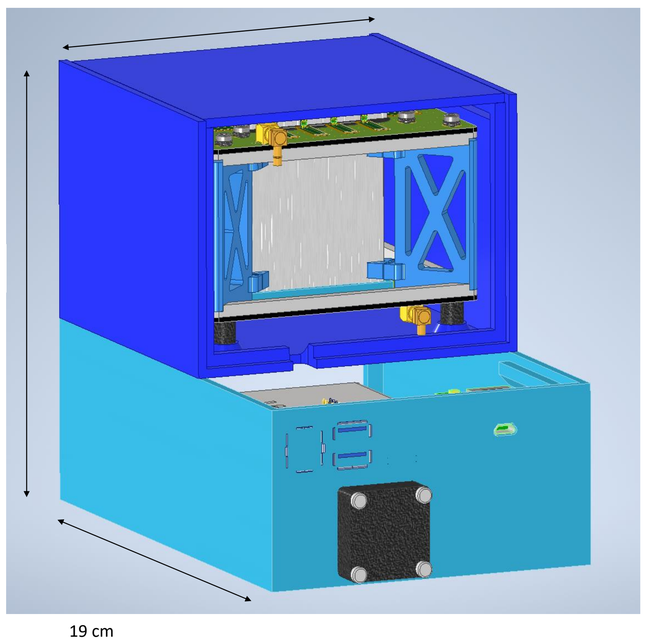
DETECTOR

The AMORE Demo Model uses a two mm-thin square plastic BC400 connected to eight Silicon photomultipliers SiPM.. For distributed readout, the SiPMs are grouped in pairs at the corners.



Large PCB for four-channel readout And small flex PCB for SiPMs.

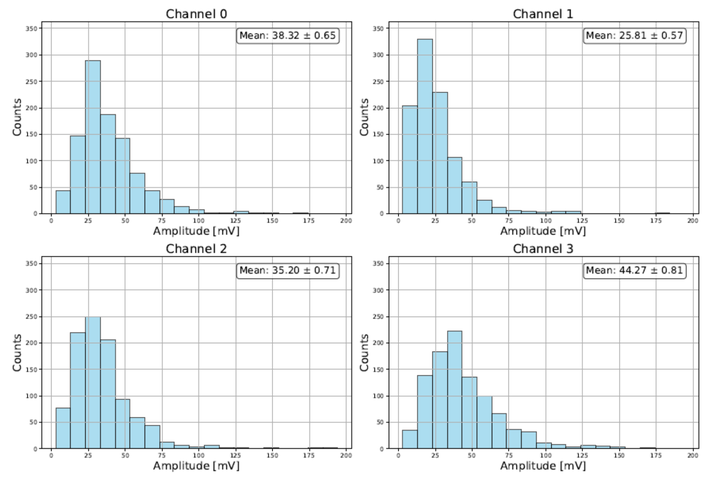
Proton tests at PIF with detector on the XY-table



CAD Version of AMORE DM
Upper part: ΔE-E Telescope Detector head
Lower part: Readout Electronics:
- WaveDREAM DAQ
- Health Status Subsystem
- SBC (or Laptop)

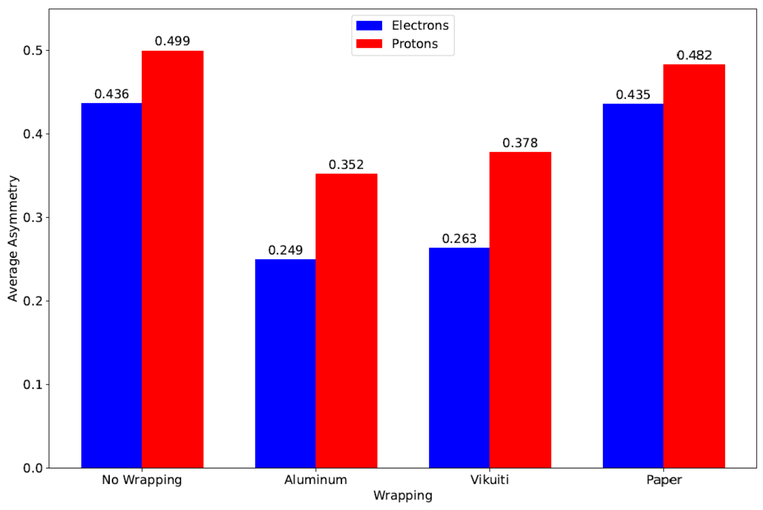
CALIBRATION

AMORE was tested using narrow collimated beams of electrons and protons at the PIF and EMON facilities in PSI. A matrix of 5x5 equally spaced points was used to study position sensitivity.



Example of histograms with signal amplitudes Case for the no-wrapping detector.

Example of the two-dimensional amplitude maps Case for the white milky paper wrapped detector



Comparison of asymmetry values for electrons and protons and for each type of the scintillator wrapping material

SUMMARY AND NEXT STEPS

The particle monitor AMORE for Space Weather studies was developed

It will measure secondary cosmic rays at airplane and balloon altitudes

The instrument has a 4π FOV and enables particle identification

Several studies with particle beams have been performed to date:

distributed readout, particle identification, and quenching

This work presents results for the particle hit localization method

DM tests during flights with airplanes are scheduled for September

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