Characterization of a scintillator tile equipped with SiPMs for future cosmic-ray space experiments

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Motivations

- Plastic scintillators are used for anti-coincidence systems in gamma-ray detectors on satellite experiments (Fermi-LAT, DAMPE,...)
- The detector is often segmented in small tiles to enhance gamma-ray selection efficiency against back-splash
- In most cases scintillators are read-out with PMTs
  - High voltage is required: unpractical on satellites
- SiPMs are suitable to replace PMTs
  - Lower voltages required
  - Better sensitivity to low light yields
- Plastic scintillators coupled to SiPMs are being tested in recent years for future missions, such as HERD, AMEGO, e-Astrogam
Tile assembly

• Plastic scintillator BC-404:
  • Tile of 15 cm side and 1 cm thickness with two cut edges
  • CAVEAT: the light yield of the scintillator might be deteriorated due to the scintillator age

• Readout:
  • 12 NUV SiPMs produced by FBK
    • 6 small area SiPMs: 1×1mm^2
    • 6 large area SiPMs: 4×4mm^2
  • 40µm cell pitch
  • Peak PDE @400nm: 43%

• Preamplifier:
  • Trans-impedance amplifier
  • Tail cancellation with a RC filter

• Signals integrated with a Caen V792 QDC
Beam test at CERN PS and SPS

• PS - T10: 2-5 GeV/c particles (e/π)
  • Scintillator irradiated in different positions
  • beam spot diameter = 3cm

• SPS – H8: 20 GeV/c particles (e/π)
  • Scintillator irradiated only in the central position
Analysis method

• Small SiPMs (1×1mm$^2$ area):
  • Charge distributions fitted with multi-gaussian functions
  • Areas of individual peaks fitted with Poisson distributions

• Large SiPMs (4×4mm$^2$ area):
  • Individual peaks still visible in charge distributions, but difficult to fit due to low statistics
  • Re-binning of histograms and fit with a Landau distribution folded with a gaussian
Examples of the fit procedure

Channel 3

Channel 4

ADC channel

# photons
Yield at fixed positions

- Values represent the number of detected photons by each SiPM
- The beam position is indicated by the black circle
Yield at fixed positions

- Values represent the number of detected photons by each SiPM
- The beam position is indicated by the black circle
Yield for each SiPM

- Values represent the detected photons by the selected SiPM in all positions tested
SPS data

• Scintillator irradiated in the central position with 20 GeV particles

Channel 2 - Central position

• Good separation of signal and pedestal
• Individual peaks visible up to 40-50 photons
Efficiency (for a large SiPM)

- Efficiency is evaluated as the area of the histogram as a function of the threshold.
- The visible steps are due to the individual peaks in the distribution.
Conclusions

• Small SiPMs detect too few photons
  • Useful to extend the dynamic range to detect/reject ions
• Response is almost uniform in the tile, with peaks in the points closer to the SiPMs
• Efficiency reached with this configuration is close to the requirements of ACD detectors for satellites
  • Improvements can be obtained by summing the signals from individual SiPMs or by implementing coincidences among multiple SiPMs
• Future plans:
  • Repeat tests with a new scintillator and SiPMs
  • Test with cosmic rays or a radioactive source in lab
  • New beam tests
Backup
FBK NUV SiPM photon detection efficiency perfectly match the yield spectrum of the plastic scintillator.
Example channels
Energy dependence

- Photons detected vs energy of the beam
- Central position
- Runs taken with different trigger configurations: different particles

- No energy dependence is observed