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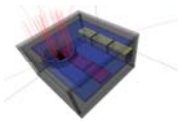
Miniature Low Energy Electron Detector for Particle Environment Studies in Space



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Abstract

Low Energy Electron Detector LEED is a miniature particle monitor for measurements in space. It is based on the MYTHEN Si-microstrip instrument made at PSI for the synchrotron X-ray detection at SLS. The space version will measure electrons with energies from few keV up to few hundred keV at very high fluxes and harsh radiation environments. The device will study hot plasma and particle acceleration, monitor Space Weather and map Radiation Belts of the Earth and in future of the Jupiter. LEED demonstrates high potential of the PSI detector technologies to meet requirements put on space instrumentation: miniaturization, low power consumption, radiation hardness. Its development is supported by the Swiss Space Office and the European Space Agency with possible application in the μSat and Galileo program.

Specifications

- Energy range: 3 to 250 keV and energy resolution: around 3 keV
- Count rate: able to deal with fluxes up to 10^9 /cm^2/s – ca. 1 MHz channel
- Power consumption: about 200 mW
- Size ~ 5 x 5 x 3 cm^3, mass ~ 200 g
- Radiation hardness: ~ 100 krads TID and SEE immunity (MYTHEN ASIC)
- Radiation hard Si-diodes with no surface dead region (threshold 100 eV)
- Effective background reduction

Space Usage Requirements

High level of integration similar to particle physics experimental demands
Radiation hardness: 100 krad – Earth, 1 Mrad – Jupiter (comparable with LHC)
Low mass and low size and minimized power consumption
High flux detection, good energy resolution and background suppression
Cost effective manufacturing/qualification process for serial production (~20 units)

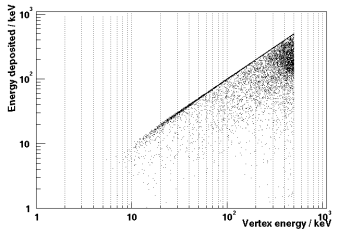
Modeling

Model constructed with GEANT4 (CERN) for 128 Silicon microstrips
Implementation: 5 x 5 x 3 cm^3, m≈170 g; Variable collimator parameters
All basic features implemented: collimator, sensor, PCBs, housing
Different strip sizes: Length=2–8 mm, Width=50–250 μm, Thickness=300 μm
Simulation performed using various particles, directions, energies

Electron Response Matrix

Generated for uniform energies and particles coming from all directions
Tested for various strip L/W ratio, collimator sizes and veto-no veto cases
Matrix semi-diagonal up to 200 keV, low contamination by higher energies
Dead layer thickness crucial for low energy threshold (standard SLS too thick)
Limited role of veto counter, good shielding by collimator and walls

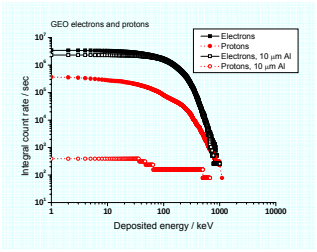
Si microstrip and readout chip on the test-board



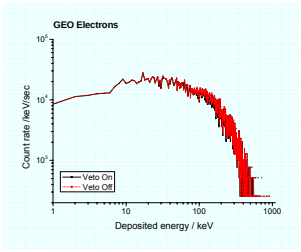
Two-dimensional response matrix generated for electrons coming from all directions toward LEED

In-Orbit Performance

Simulations made for electrons and protons in LEO, Polar and GEO orbits
Model predictions for GEO give the highest counting rates:
$r_e \approx 5 \cdot 10^4$ /strip/sec for electrons and $r_p \approx 10^4$ /strip/sec for protons



Proton and electron integral spectra with and without Al-absorber at GEO orbit



Electron spectra – deposited energy - at GEO orbit with and without veto counter

MYTHEN Detector for PSI SLS

- Microstrip System For Time-resolved Experiment at PSI SLS
- Used at Powder Diffraction Station (Material Science)
- Parameters for X-ray detection:
  1. pitch/length 50 μm / 8mm, thickness 300 μm
  2. low noise (230 e$^-$), room temperature operation
  3. single microstrip block - 128 channels
  4. rad-hard readout chip with discriminators and counters
  5. very fast readout time < 5 μsec

MYTHEN – PSI SLS

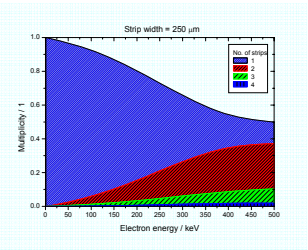
LEED laboratory model for tests with γ and e$^-$ sources

LEED Autocad model for prototype and for response simulations with GEANT4 code

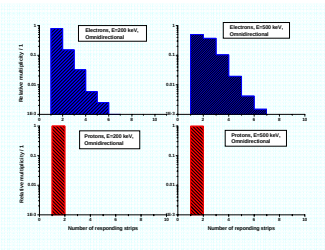
Multi-strip Response

Number of strips responding simultaneously to one electron depends on the electron energy and the strip pitch. Low energy particles are detected in only 1 strip.

For 250 μm pitch and 200 keV electrons, 80% hits is in one strip only



Number of strips responding to single electron vs. initial energy (W=250 μm)



Electron and proton multi-strip response signatures at two energies (W=250 μm)

Summary

LEED is based on the PSI made MYTHEN Si-microstrip applied at SLS
Its response is optimized for electrons (3-250 keV) using MC GEANT4 model
It covers spectroscopy gap between HE plasma and LE particles (ΔE ≈ 3 keV)
Very fast counting (1 MHz) and rad-hard readout are inherited from MYTHEN
Space performance with background analysis were studied for LEO and GEO
Laboratory measurements with sources were performed confirming MC results
Full engineering model is under construction as part of the GSEM instrument
Flight opportunities on the ESA Galileo or μSats are currently investigated