Combined Ion and Neutron Spectrometer for Space Applications (CINS)

D. K. Haggerty\textsuperscript{1}, R. H. Maurer\textsuperscript{1}, Cary Zeitlin\textsuperscript{2},
D. R. Roth\textsuperscript{1}, J. O. Goldsten\textsuperscript{1},

\textsuperscript{1}Space Department, The Johns Hopkins Applied Physics Laboratory
Laurel MD
\textsuperscript{2}Lawrence Berkeley National Laboratory, Berkeley, CA
Dennis.haggerty@jhuapl.edu

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CINS concept

Combine a charged particle telescope and neutron spectrometer into a single unit with common electronics.

Charged particle telescope: silicon + plastic scintillators + BGO scintillator.
  • MARIE/IVCPDS design w/many improvements.

Neutron spectrometer: Low, medium, and high-energy detectors.

Funded by the National Space Biomedical Research Institute (NSBRI).

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Project Goals I

• CINS will monitor the complete particle radiation environment

• After instrument detector procurement, fabrication and calibration are complete, CINS will be used in ground based accelerator experiments using heavy ions, protons and neutrons to determine energy spectra
  • The dose or dose equivalent calculated from the CINS energy spectra will be compared with the measured LET or dose of TEPCs or dosimeters to ascertain the limitations in response of the latter devices.

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Project Goals II

Demonstrate feasibility without regard to flight requirements.
Extensive testing at accelerator facilities.
  • Emphasis on heavy ion beams and thick targets.
In second generation instrument, reduce size, mass, power.
Technical Approach

1. Create a charged particle telescope system that improves the MARIE instrument flying on the Mars Odyssey mission.
   a) eliminate the gain saturation for heavy ions with LET > 35 keV/μm;
   b) increase the dynamic range of the MARIE instrument by a factor of 10-20 (up to 1000:1) to include protons with energies above 100 MeV;
   c) increase the maximum event rate of MARIE by at least a factor of 10 above the current limit of 3 Hz.

2. Fabricate, evaluate and calibrate the Eljen 454 scintillator detector system for medium energy neutrons from 1-15 MeV.

3. Develop the instrument electronics design based on the Gamma Ray Neutron Spectrometer (GRNS) instrument for the MESSENGER mission.

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CINS Tasks and Milestones

The main initial tasks in 2005

- Refurbish 4cm diameter X 5mm thick silicon detectors by redrifiting and applying guard rings
- Design and procure an Eljen 454 scintillator sized to detect up to 15 MeV neutrons producing a cross over region with the higher energy thick silicon neutron detector
- Use modeling with GEANT 4 to design the charged particle telescope
Refurbished Thick Silicon Detectors

Refurbished thick silicon detector (4 cm X 5 mm) re-drifted with lithium to reduce noise (30 keV) and with guard ring added to define active diameter (3.7 cm).
Charged Particle Telescope I

Conceptual design of 7 detector charged particle telescope determined by modeling; BGO detector is 3 cm thick.
Charged Particle Telescope II

Similar to MARIE in that 4 thick Si detectors provide particle identification and LET spectra.

- MARIE dynamic range problem fixed.

BGO adds mass, stops protons up to energy of 150 MeV, makes stack asymmetric for directionality.

Plastic scintillators used as triggers & simple counters; helpful in high-rate environments.

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Charged Particle Telescope Simulations

A shows the energy deposition in the thick BGO detector on the abscissa with the energy deposition in the last Si SSD on the ordinate. The vast majority of the protons can be separated from the electrons. With the BGO this simulation shows that protons up to ~300 MeV can be uniquely identified.

B and C show that a proton depositing ~80 MeV in the BGO yields primary and penetrating depositions in SSD4 of 1 MeV resolution.
Neutron Spectrometer

Three components:

- $^{3}$He tube for low energy (thermal to 1 MeV)
- Boron-loaded plastic scintillator (Eljen) for medium energy (1-15 MeV)
- Thick Si(Li) detector with anti-coincidence shield for high energy (12-600 MeV)

- Unfolding to get incident neutron energy spectrum from deposited energy spectrum is maximum likelihood method.
Comparison of the measured high energy neutron spectrum >20 MeV (red) from the 5mm thick silicon detector with the Los Alamos calculation for the beam-target configuration.
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Typical (1-15 MeV) Neutron Waveforms from Bicron 454 Scintillator

![Waveforms Graph]

- Neutron Recoil + Capture
- Neutron Recoil
Heritage

• Low- and medium-energy neutron sensors used on Mars Odyssey, Mercury MESSENGER.
• JHU-APL built electronics for MESSENGER Gamma Ray/Neutron Spectrometer (GRNS).
• High-energy sensor used on balloon flights and thick target accelerator experiments.
• Charged-particle detectors from LBNL SSDL which built detectors for Voyager, ACE/CRIS, MARIE, etc.
Progress and Schedule

• Eight silicon detectors from LBNL group have been re-drifted by SSDL and guard rings added to 4.

• Boron-loaded scintillator has been procured.
• In 2006 procure BGO, complete mechanical design and begin assembly.
• Aiming for Spring 06 NSRL run for individual detectors, Fall 06 first test of telescope.

• Continue GEANT4 modeling
References
