Portable High Energy Neutron Spectrometer

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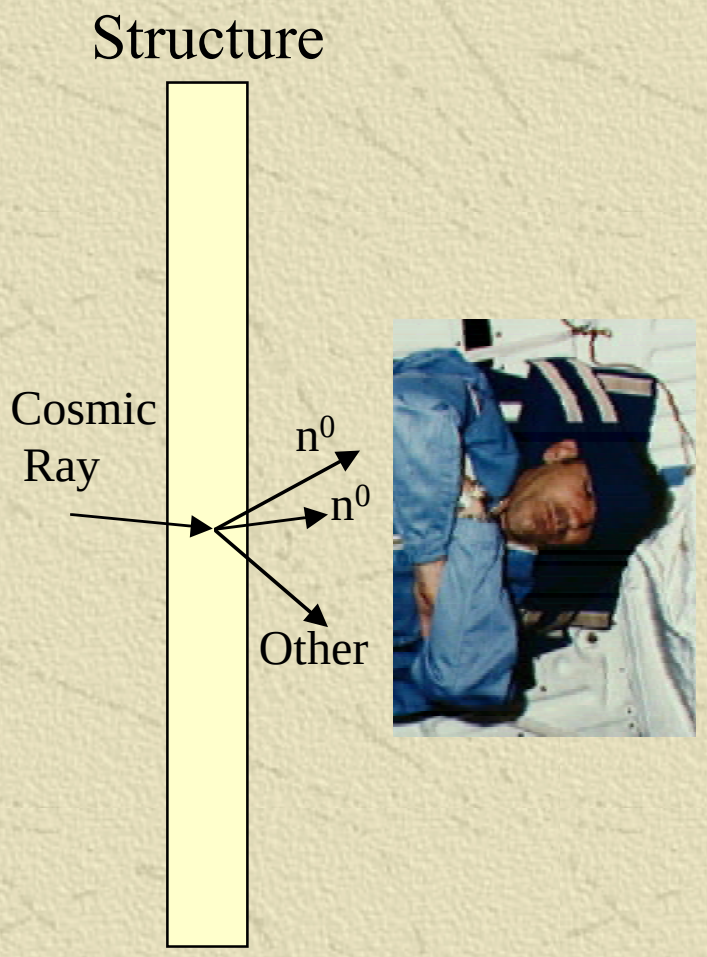
Background

Space Neutron Environment

- Large neutron component inside structure or on planets
  - Interaction of cosmic rays and shielding or atmosphere
- Neutrons are higher energy than those on Earth
  - Deeper tissue penetration
  - More difficult to shield



Background

Effects on Astronauts

- Risk of carcinogenesis from total dose
  - Energetic neutrons penetrate to deeper organs
  - Estimated 30-60% of astronaut dose from neutrons
- DNA double strand breakage
  - Single hit from high energy neutron or heavy ion
  - Latent genetic damage
- Pion production for neutrons > 300 MeV
  - Large amount of energy deposited in a small volume

Dose Equivalence

Radiation Component	Weighting factor ICRP	Weighting Factor NCRP
X-rays, gamma rays, electrons, positrons, muons	1	1
Neutrons with energy of < 10 keV	5	5
10-100 keV	10	10
> 100 keV - 2 MeV	20	20
> 2 MeV - 20 MeV	10	10
> 20 MeV	5	5
Proton with energy of > 2 MeV	5	2
Alpha particles, fission fragments and nonrelativistic heavy nuclei	20	20

Background

Effects on Electronics

- Total Dose/Displacement Damage
  - Cumulative effect of many atomic displacements within a semiconductor or photonic device
- Single Event Effects
  - Charge deposited in memory cells or other sensitive regions can change the logic state of a node or induce a high-current (damaging) condition
  - High energy neutrons are at least as efficient as protons for inducing single event effects

Background

Accelerator Environment

- CERN Large Hadron Collider
  - Intersecting 7 TeV proton beams
  - $> 10^{14}$ n/cm^2 over 10 year lifetime
- Concerns
  - Human exposure and safety
  - Damage to electronics
  - Integrity of data

Silicon Detector System

Theoretical Foundation

- n^0 + Si $\rightarrow$
  - n^0 + Si - elastic collision
  - n^0 + Stuff, p + Stuff, α + Stuff, etc
  - Charged secondaries deposit energy in silicon detector
- Measure energy deposition spectrum
- Deconvolve original neutron spectrum using detector response function

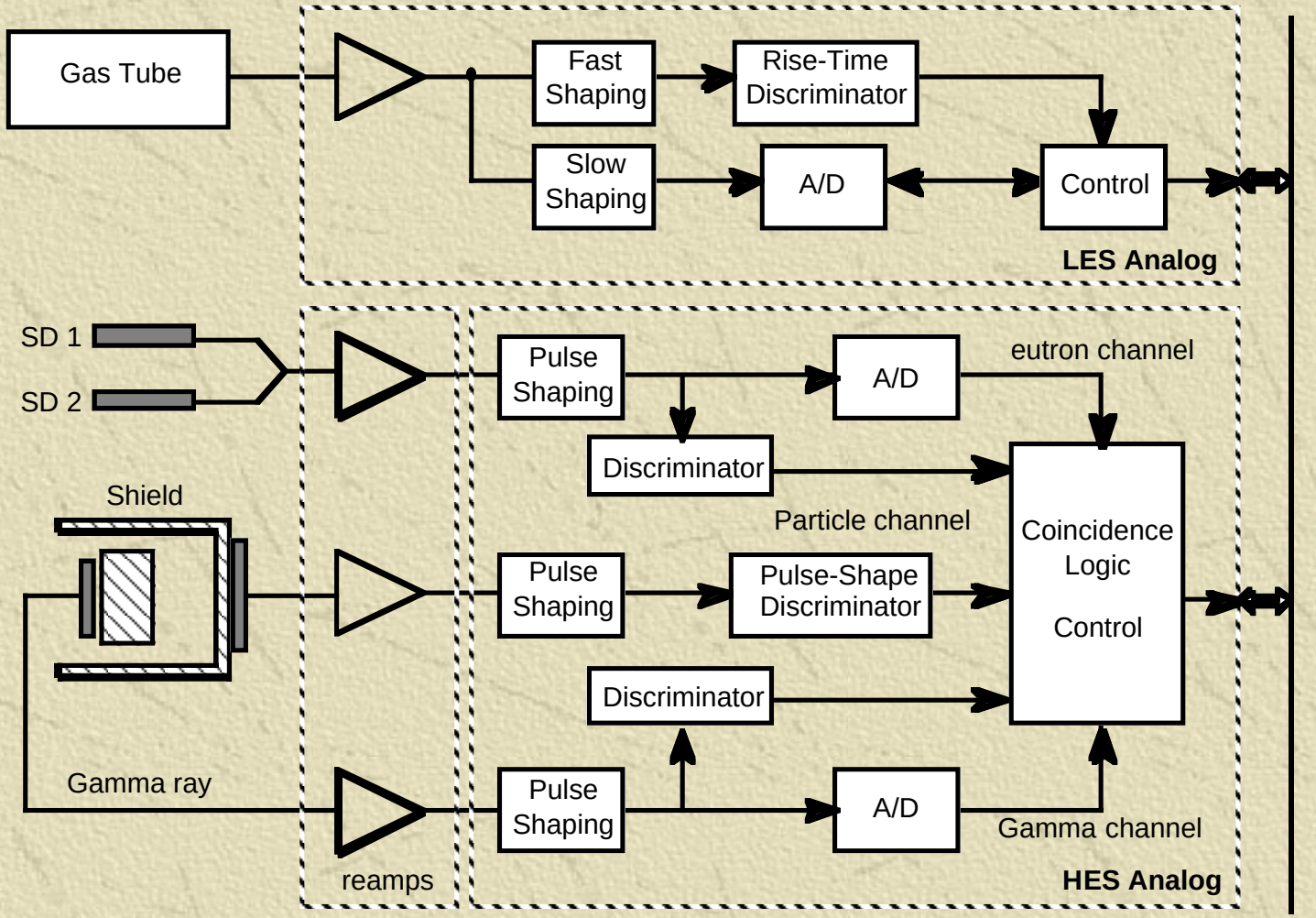
Silicon Detector System

Proto-type Neutron Spectrometer

- Energy Range: <100 keV to ~500 MeV
- Resolution: 10-20%
- Low mass, volume, power
- Near real-time data processing
- Autonomous operation, including data storage

Proto-type ⟶ Aircraft ⟶ Balloon ⟶ ISS

Proposed MANES Instrument

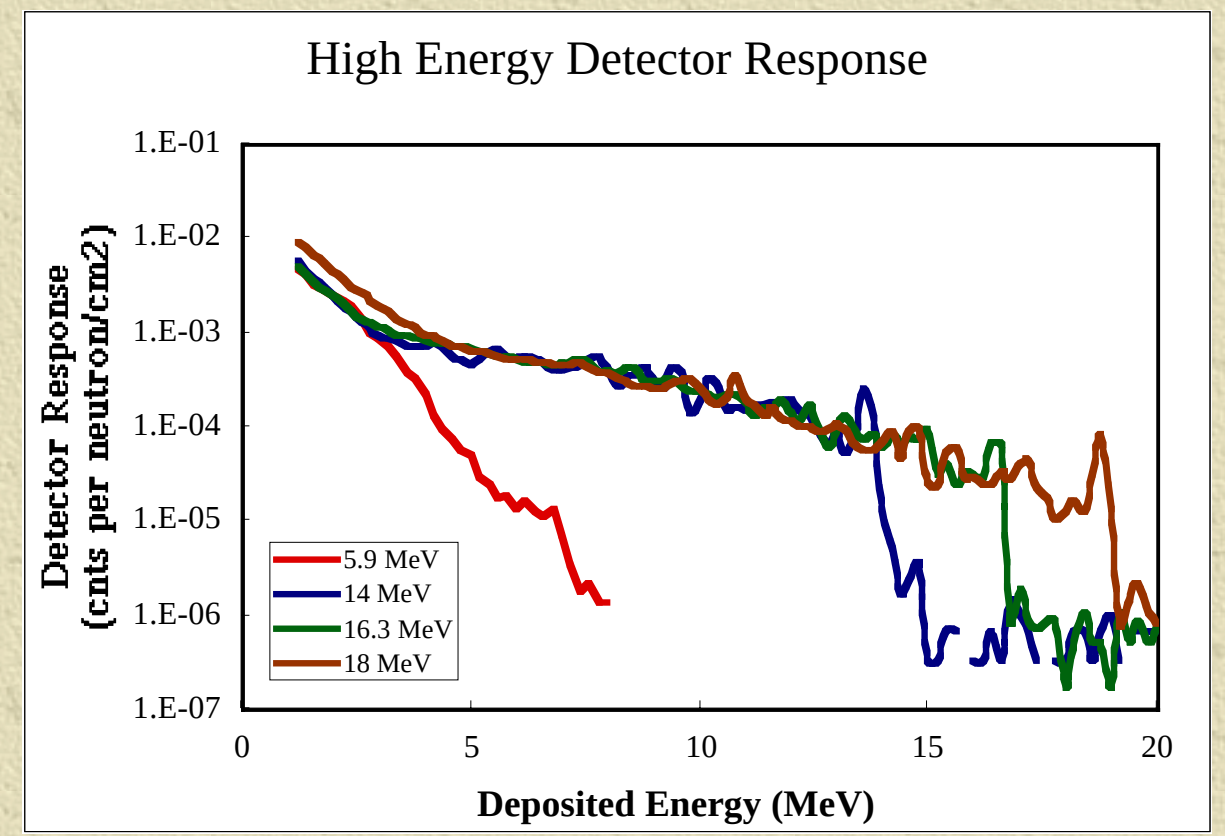


Silicon Detector System

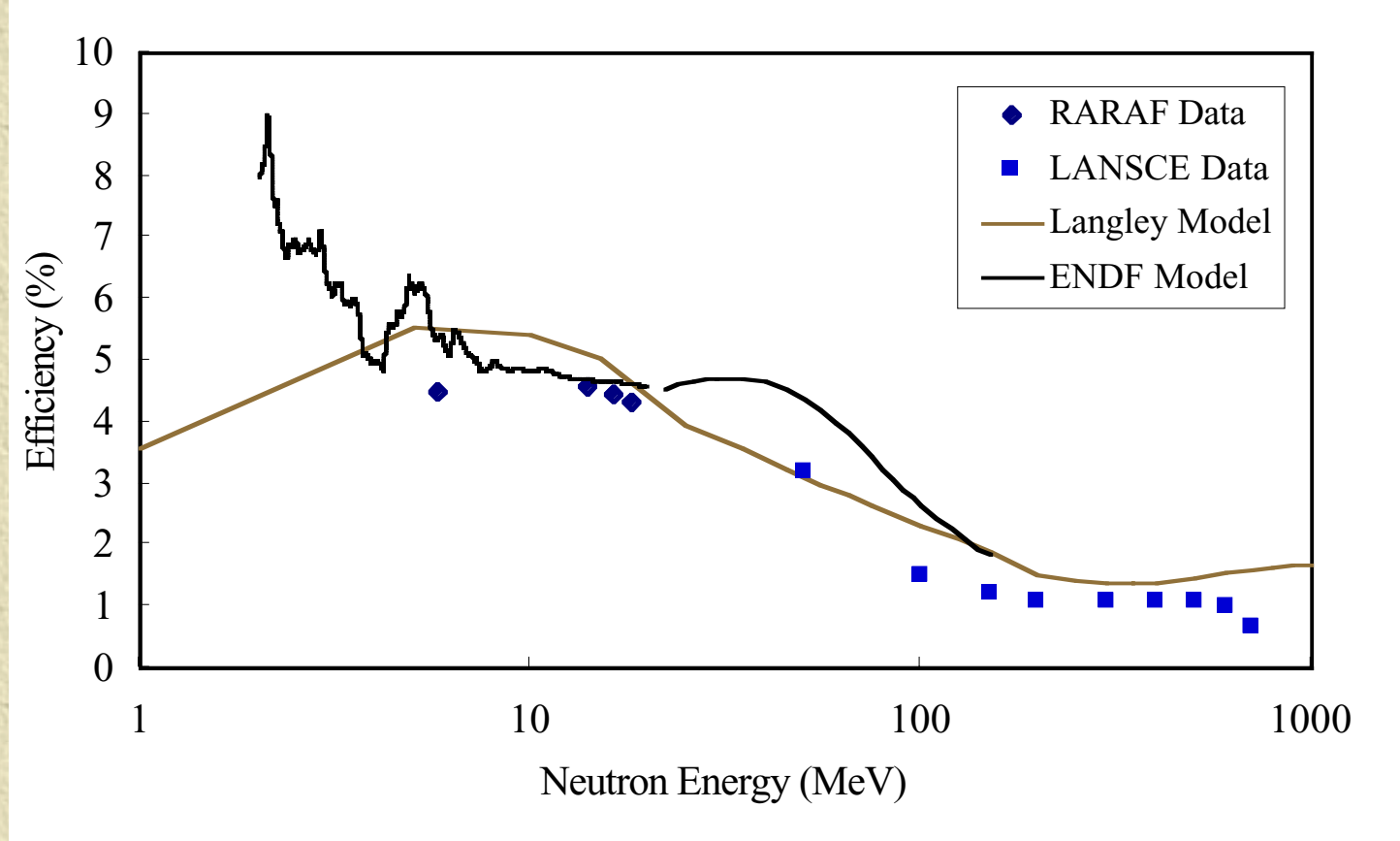
High Energy Channel

- Lithium-drifted silicon solid state detector(s)
- 2 cm^2 by 5 mm thick.
- CsI or BGO scintillator used to veto charged particles passing through silicon detectors
  - Data from scintillator can be used to characterize charged particle and gamma ray spectra

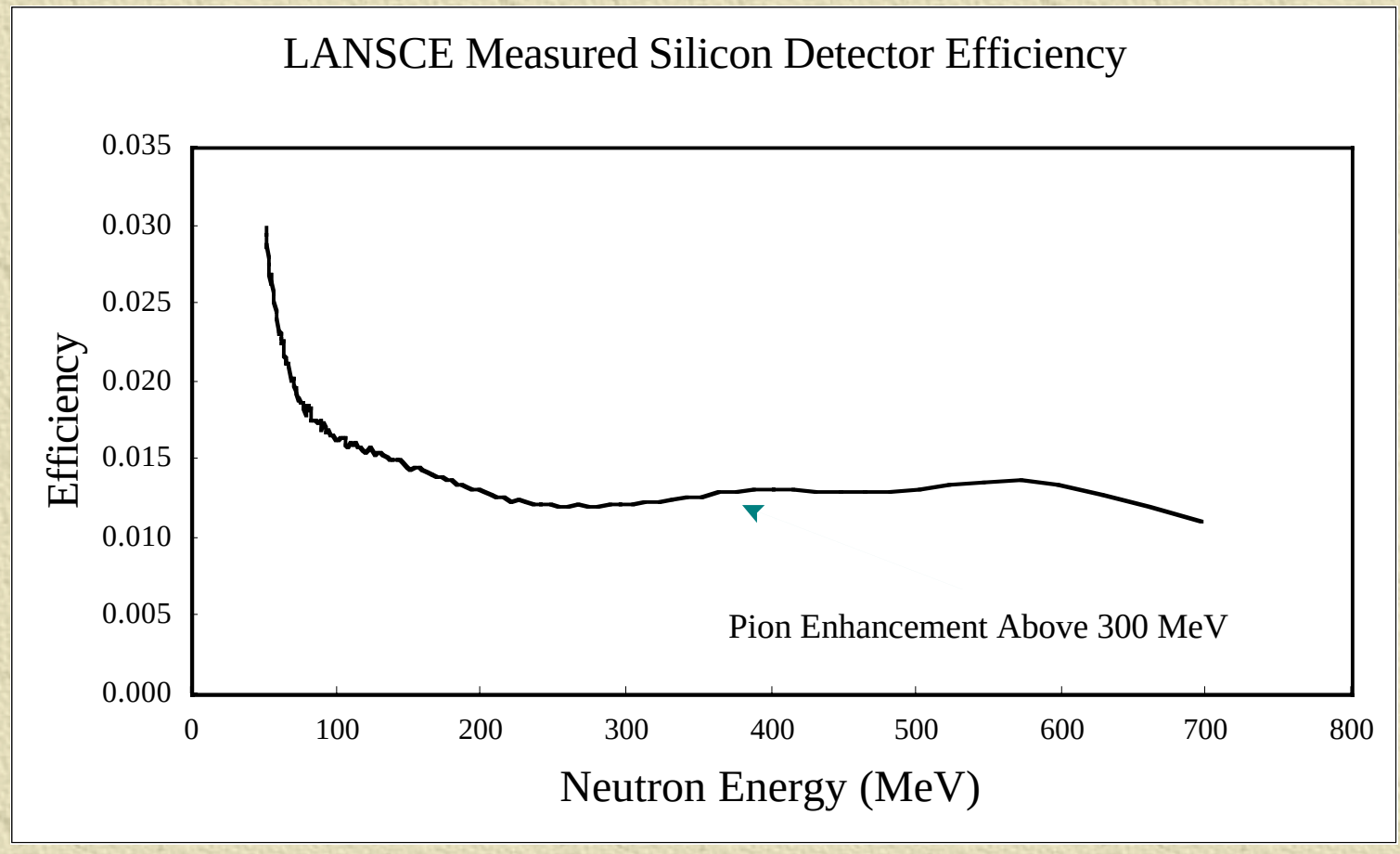
Silicon Detector System



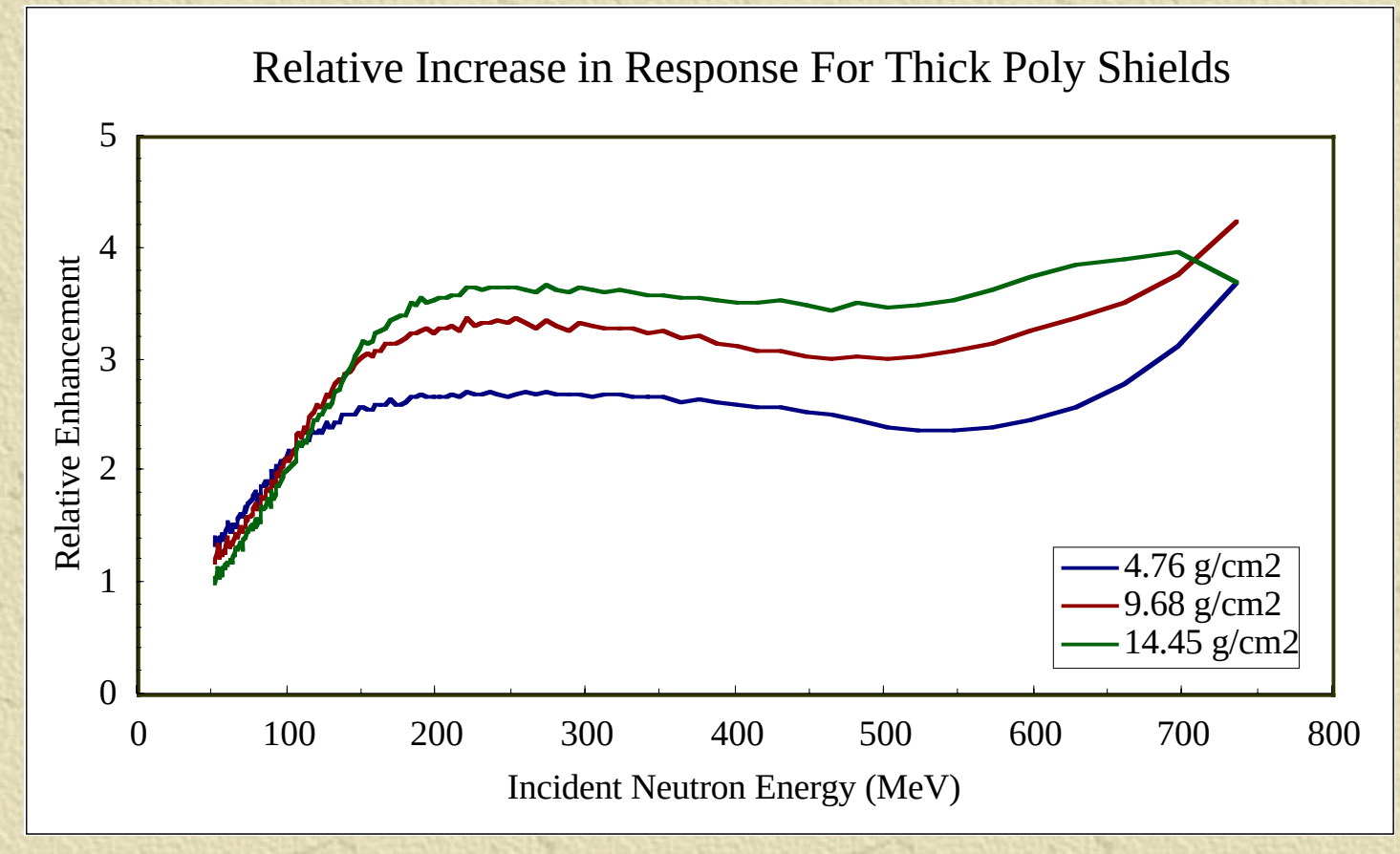
Silicon Detector System



Silicon Detector Efficiency



Polyethylene Enhancement



Response Function

Methodology

- Measure energy deposition spectra using known neutron beams
  - LANSCE 90-meter beamline with fission chamber
  - Time-of-flight spectrometer tags neutron energy for each pulse in silicon detector
  - Matrix equation: $D = R\Psi$
  - Neutron energy beyond range for which resonance is of concern, so response matrix is well-behaved

Detector Modeling

Purpose

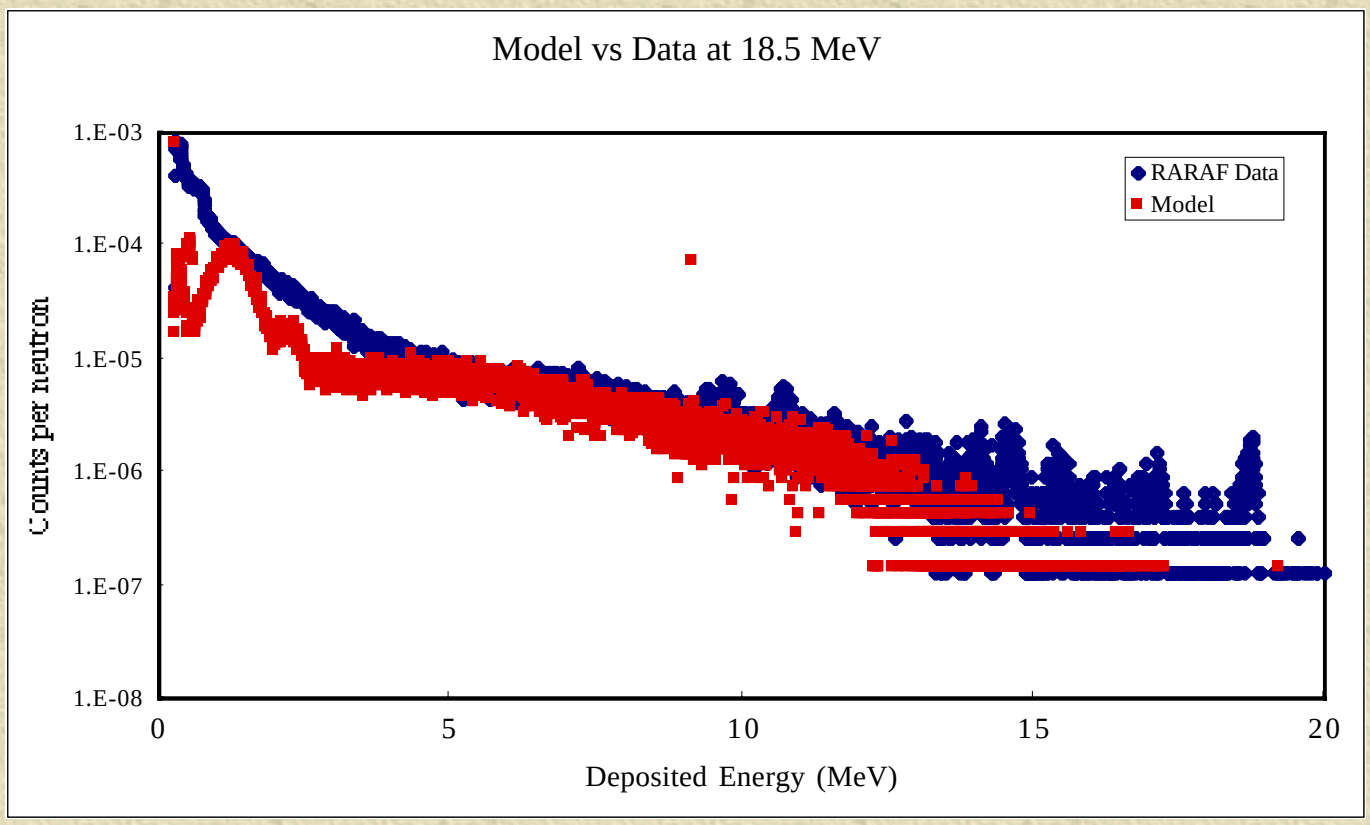
- Understand at a fundamental level neutron-silicon interactions and products
- Track secondaries and predict energy deposition
- Estimate the effect of detector structure and packaging on instrument response

Detector Modeling

Approach

- Base model on GEANT4 from CERN
  - Theoretical models, some neutron cross-sections
- Tasks:
  - Expand GEANT4 framework to include recent cross-section measurements to 120 MeV
  - Validate theoretical models of cross-sections
  - Build model to simulate energy depositions in our geometry
  - Explore contributions from various interaction channels to energy deposition spectra
  - Calculate the effect of detector packaging on incident spectrum and develop correction to account for spectral changes

Detector Modeling



Environment Measurements

Ground-Level Environment

- Baseline environment for comparison with previous measurements

Materials Research Support

- Measure neutron spectra from charged particle irradiation on shielding materials

NASA Aircraft

- Several hours at ~45,000 ft per flight
- Typical of commercial/military aircraft

High Altitude Balloon

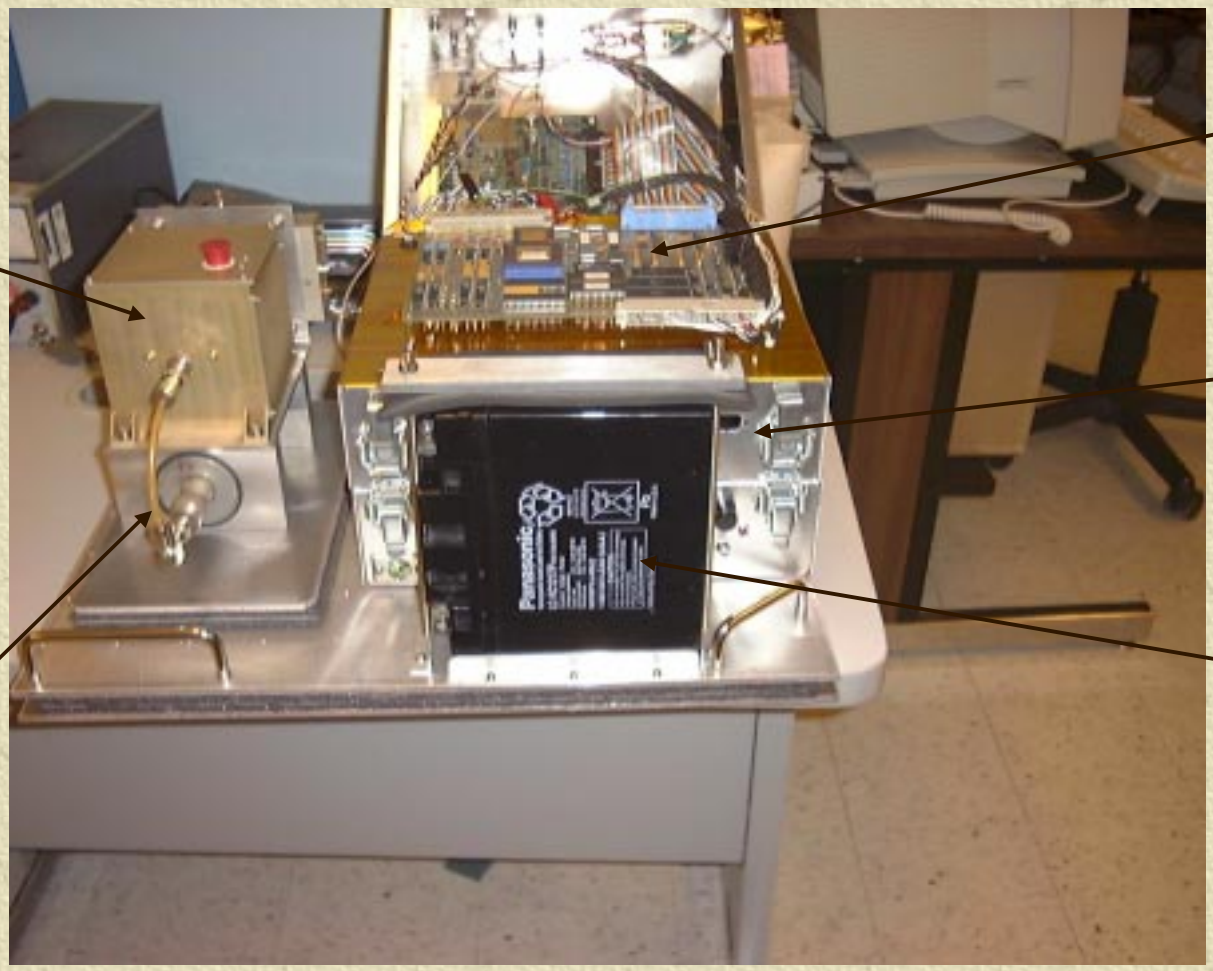
- Longer periods near 100,000 ft
- Simulates environment at Martian surface

Aircraft Flight Hardware

- Have designed and fabricated version of spectrometer for F18 aircraft flights
  - Flown up to 45,000 feet from NASA Dryden
  - 10 x ISS average shield depth
  - Balloon flights planned to approach ISS environment in FY 02
- Successfully completed environmental qualification tests
- First flight - April 2000
  - Corona discharge at 39,000 feet damaged instrument

Aircraft Flight Hardware

Aircraft Flight Hardware



Aircraft Flight Hardware