Neutron Background Detection for a Hard X-ray Balloon-borne Polarimeter

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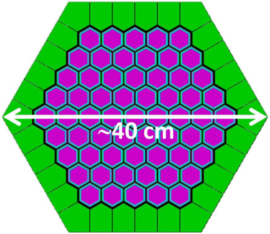
TIPP, June 5th, 2014

Introduction

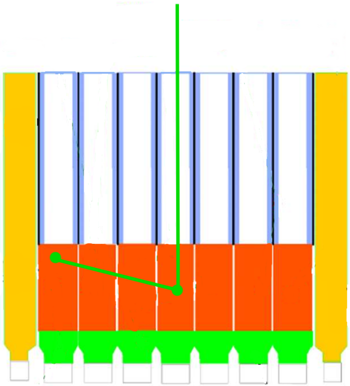
- PoGOLite: balloon-borne hard X-ray polarimeter
- Fast neutrons form main source of irreducible background
- Due to variations of the background rate during flight active monitoring is required
- A small simple scintillator based neutron detector was constructed for this purpose
- Flown on dedicated test flight and near-circumpolar flight of PoGOLite

PoGOLite



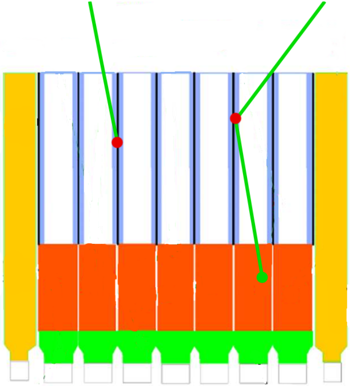
- PoGOLite: balloon-borne hard X-ray polarimeter
- Measures polarisation by measuring the Compton scattering angle.
- Segmented scintillator array
- Plastic scintillators for high Compton scattering cross section in 20-100 keV energy range

Background Reduction Systems



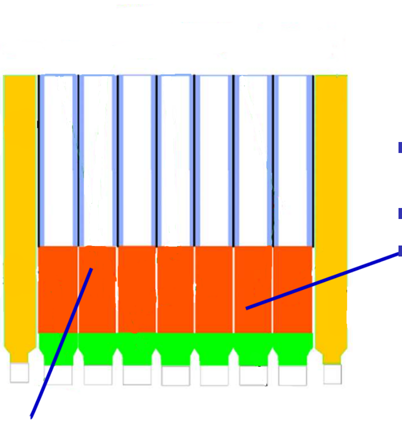
- Signal rate is of order 1 Hz
- Measurements performed in high radiation environment
- Background reduction system required

Background Reduction Systems



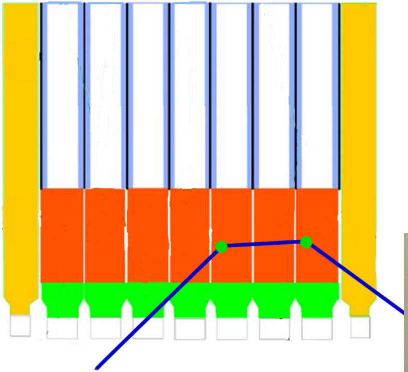
- Active and passive collimators for point-source optimisation

Background Reduction Systems



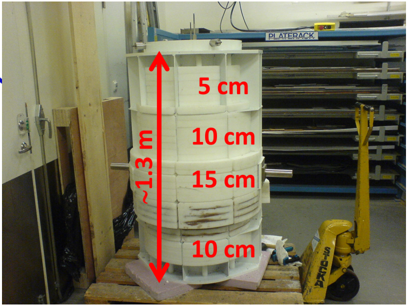
- Bottom and side-anti-coincidence shield from BGO
- Detection of entering charged particles
- Reduction of high energy photons

Background Reduction Systems



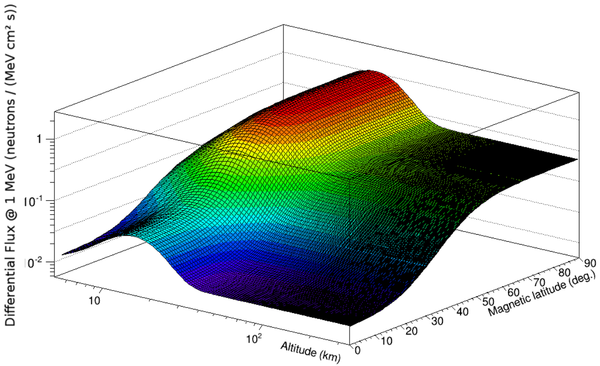
- Neutrons pass through anti-coincidence undetected
- Plastic scintillators have high CS for neutron scattering
- Neutrons with 0.5<E<500 MeV can fake X-rays

- 300 kg polyethylene shield to reduce neutron flux by order of magnitude
- Neutron induced background remains of the same order of magnitude as the signal, active monitoring required



Position and Time Dependency

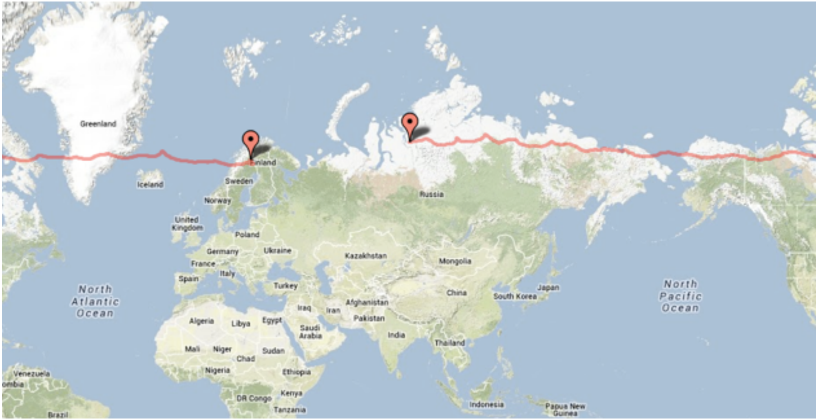
- PoGOLite float altitude between 35 and 40 km
- Neutron flux varies by $\sim 50\%$ between these altitudes
- Production comes from cosmic rays $\rightarrow$ dependency on geomagnetic latitudes
- Further dependency on solar activity
- Highest and most variable flux found at the poles



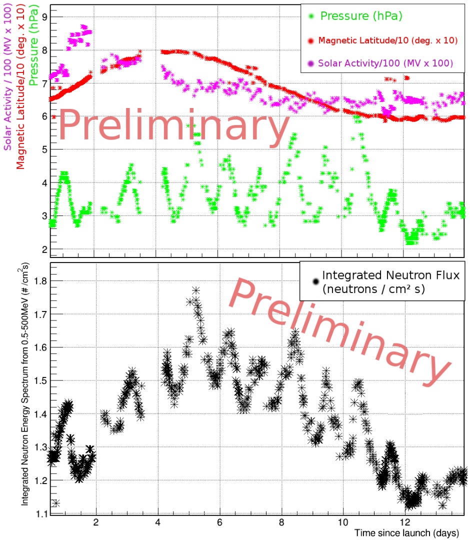
M. Kole et al. 'A Model for the Cosmic Ray induced Atmsopheric Neutron Spectra', to be sub. Astroparticle Physics

Long Duration Balloon Flights

- Highest and most variable flux at high latitudes
- Long duration flights only possible at the poles
- PoGOLite flight was 14 days from Northern Sweden to Russia
- Altitude, latitude and solar activity vary during the flight
- Neutron induced background varies during measurements



PoGOLite Flight



- The altitude and mag. latitude were measured during the flight, solar activity is known for this period
- Can be used to calculate the expected neutron flux
- Using model from M. Kole et al. 'A model of the Cosmic Ray Induced Atmospheric Neutron Spectra' to be submitted to Astroparticle Physics

LiCAF

- Dedicated neutron detector required
- Balloon → light weight and mechanically simple
- Neutron detection using Eu:LiCAF scintillators.
- LiCAF provided by Tokuyama Corp. Japan
- $n + {}^{6}\mathrm{Li} \rightarrow {}^{3}\mathrm{T}$ (2.7 MeV) $+\alpha$ (2.1 MeV)
- 95% ${}^{6}\mathrm{Li} \rightarrow$ high efficiency

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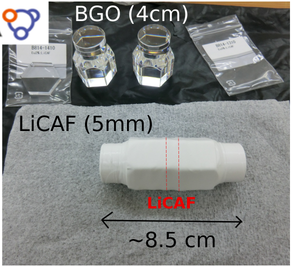
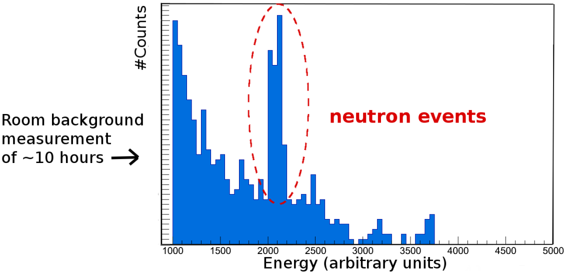
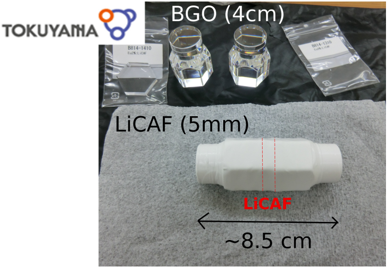
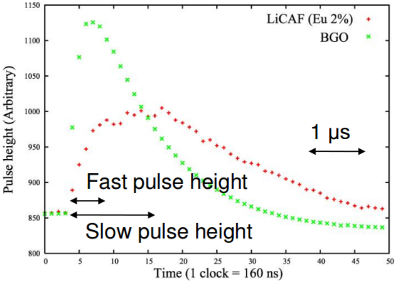




LiCAF

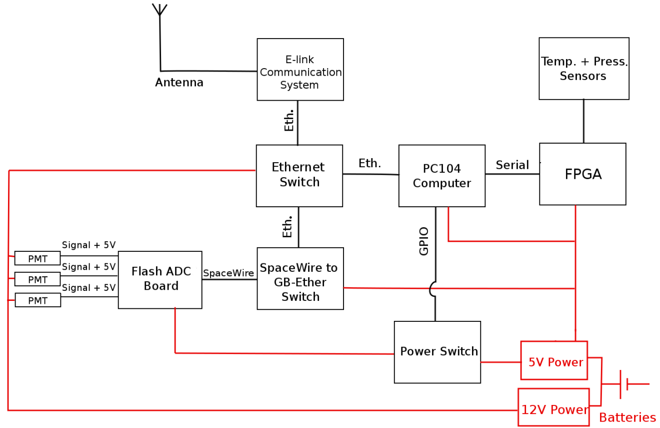
- Further background reduction by sandwiching between 2 BGO crystals
- Pulse shape discrimination between BGO (300 ns) and LICAF (1600 ns)
- Read out using Hamamatsu PMT





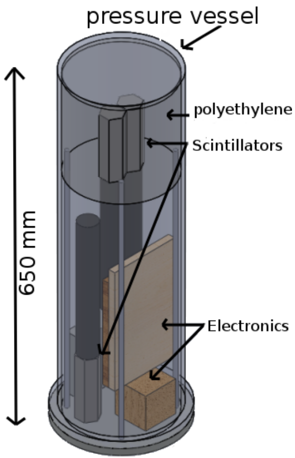
Test Instrument

- Separate test instrument built and launched in March 2013 from Northern Sweden
- 2 LiCAF detectors read out using FPGA with 12.5 MHz pulse shape sampling
- FPGA controlled using PC-104 computer through SpaceWire

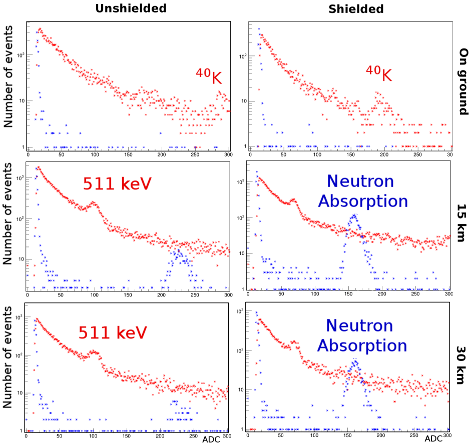


Test Flight in March 2013

- Two LiCAF-BGO scintillators flown, different energy ranges
- Total mass 13 kg
- 8kg is pressure vessel needed for thermal management
- One of the main challenges is thermal management due to BGO performance dependency



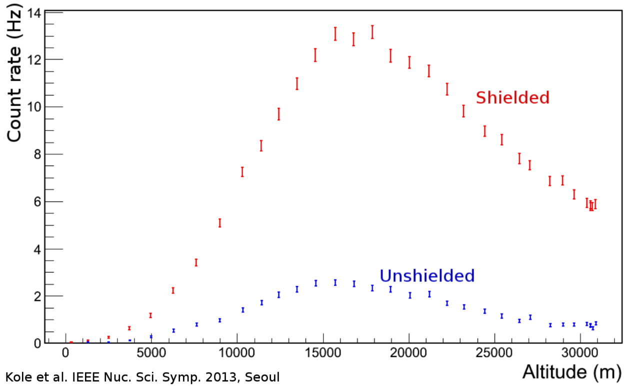
Test Flight in March 2013



M. Kole et al. "PoGOLino: a scintillator-based balloon-borne neutron detector", submitted to NIMA 2014

Clear uncontaminated neutron absorption peak.

Test Flight in March 2013



M. Kole et al. IEEE Nuc. Sci. Symp. 2013, Seoul

With 5 mm thick scintillator 300 second measurements suffice for a statistically significant measurement

Conclusions

- Neutrons may form an irreducible background for balloon-borne experiments with low Z materials
- Background rate varies with altitude, location and time, active monitoring is required
- LiCAF + BGO can be used for efficient, mechanically simple and light weight detection
- For technical details Test Instrument see: M. Kole et al. 'PoGOLino: a scintillator-based balloon-borne neutron detector', submitted to NIMA 2014
- For details on the atmospheric neutron model see: M. Kole et al. 'A Model of the Cosmic Ray Induced Atmospheric Neutron Environment', submitted to Astroparticle Physics 2014