EUCARA23
Astropeiler Stockert Germany

September 15 - 17

Paul Hearn
BAA Radio Section Astronomy Director

Cosmic Radiation detection by muon counting

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A simple scintillation detector is described configured for Cosmic Radiation (CR) detection by muon counting.

The muon production process from CR interaction with upper atmosphere is described.

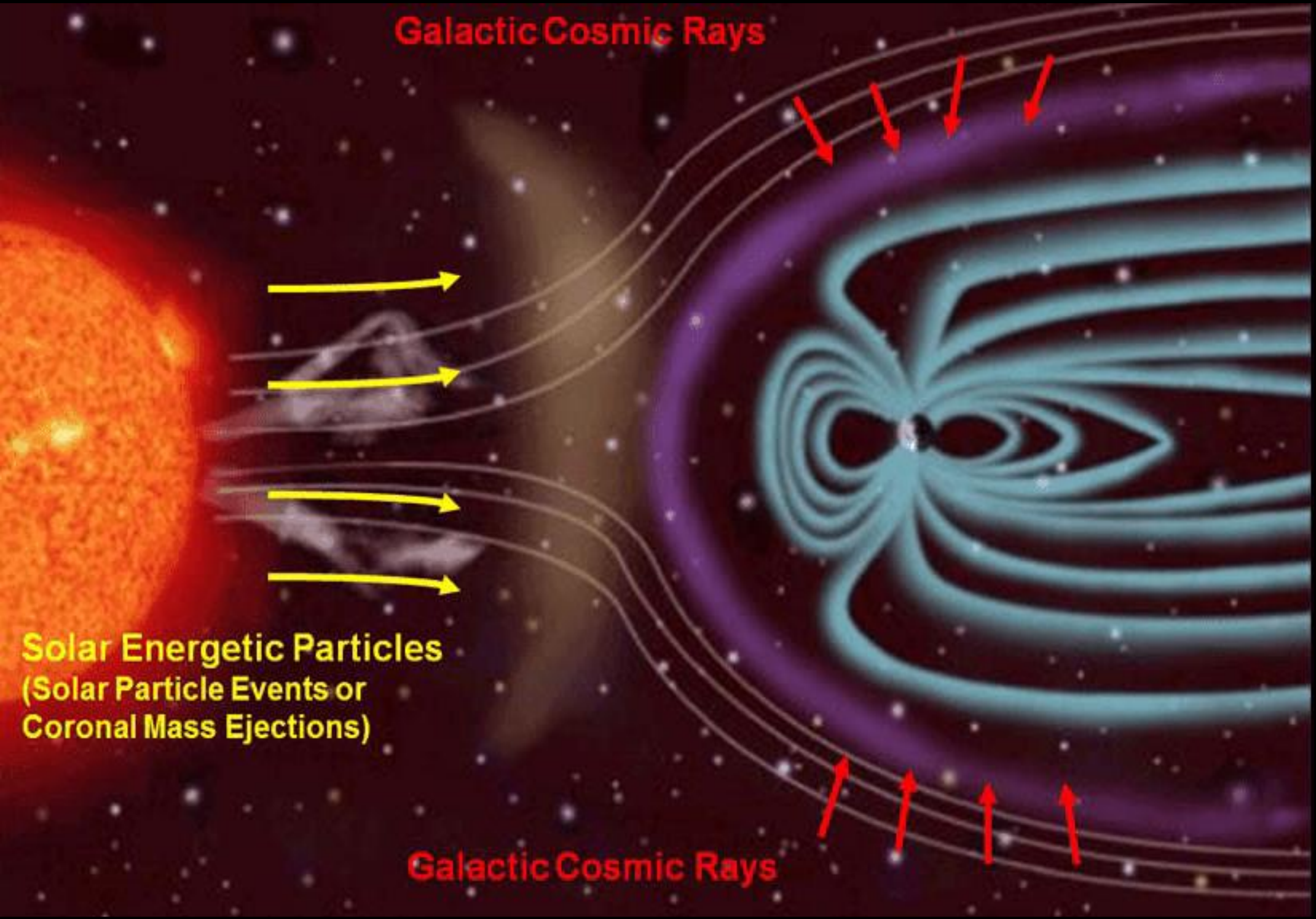
Some initial results will be presented, along with some student work.

Energetic cosmic events produce cosmic radiation. Primarily Protons moving nearly at the speed of light.

e.g., Supernovae — exploding massive stars.

This one: Supernova explosion giving birth to a black hole.
Oct. 2022

More on this event later……



Another source….

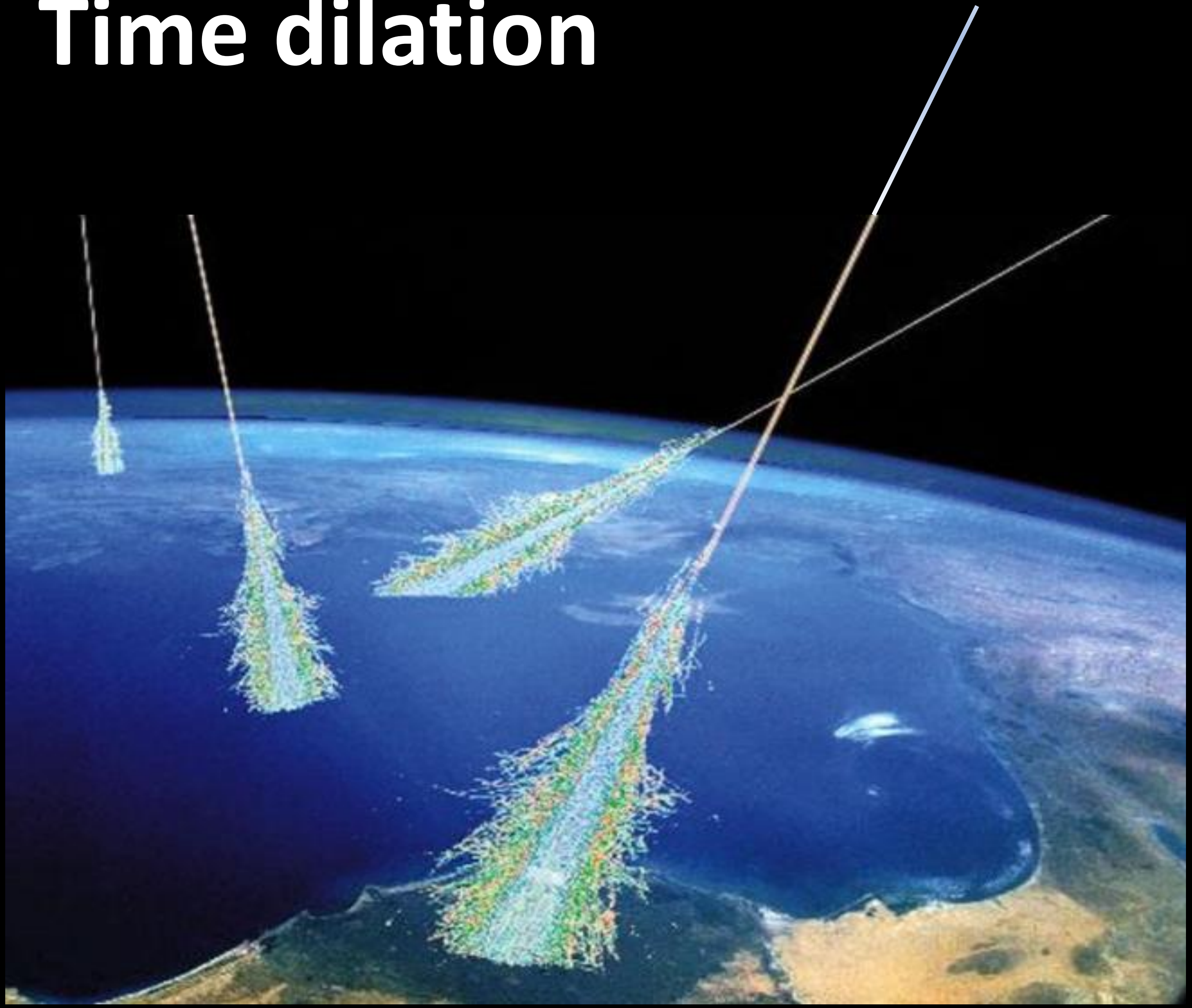
Solar cosmic radiation, high energy particles (predominantly protons) emitted from the sun.

This is particularly interesting as many of us observe other solar phenomena and opens avenues of corelation.

Muons are thought to be generated with the mean energy of 6 GeV (6×10^9 eV) at an altitude of 15km.

One interesting fact about muons

Time dilation



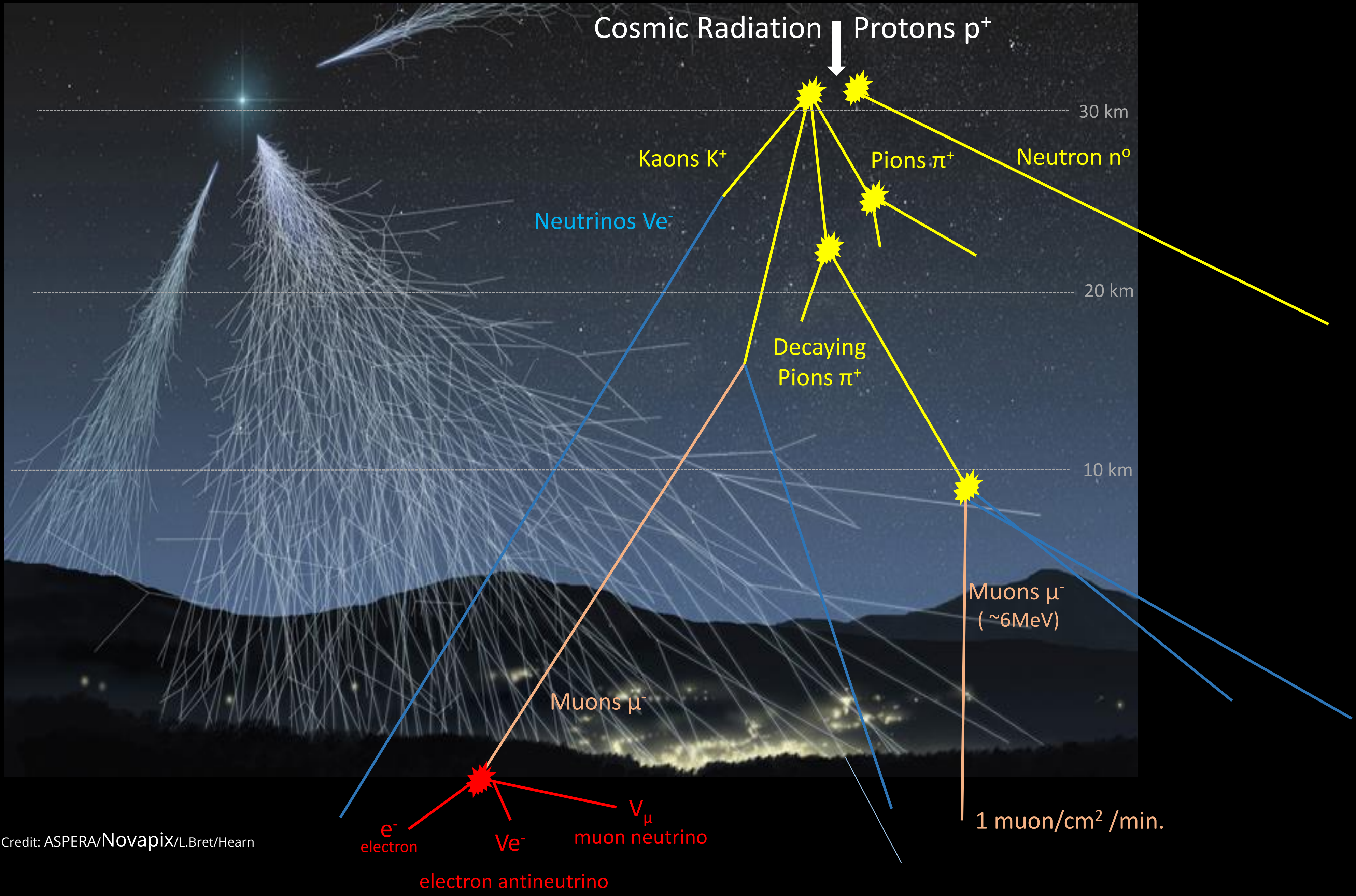
A muon moves at 99.9998c the speed of light, it experiences time dilation. In our time reference it would only get around 700m as the muon lifetime is only 2.2uS.

However in its time reference it can travel ~15km. It therefore has time to reach ground level and be detected.

SIMON SWORDY (U. CHICAGO), NASA

Particle Physics revision…

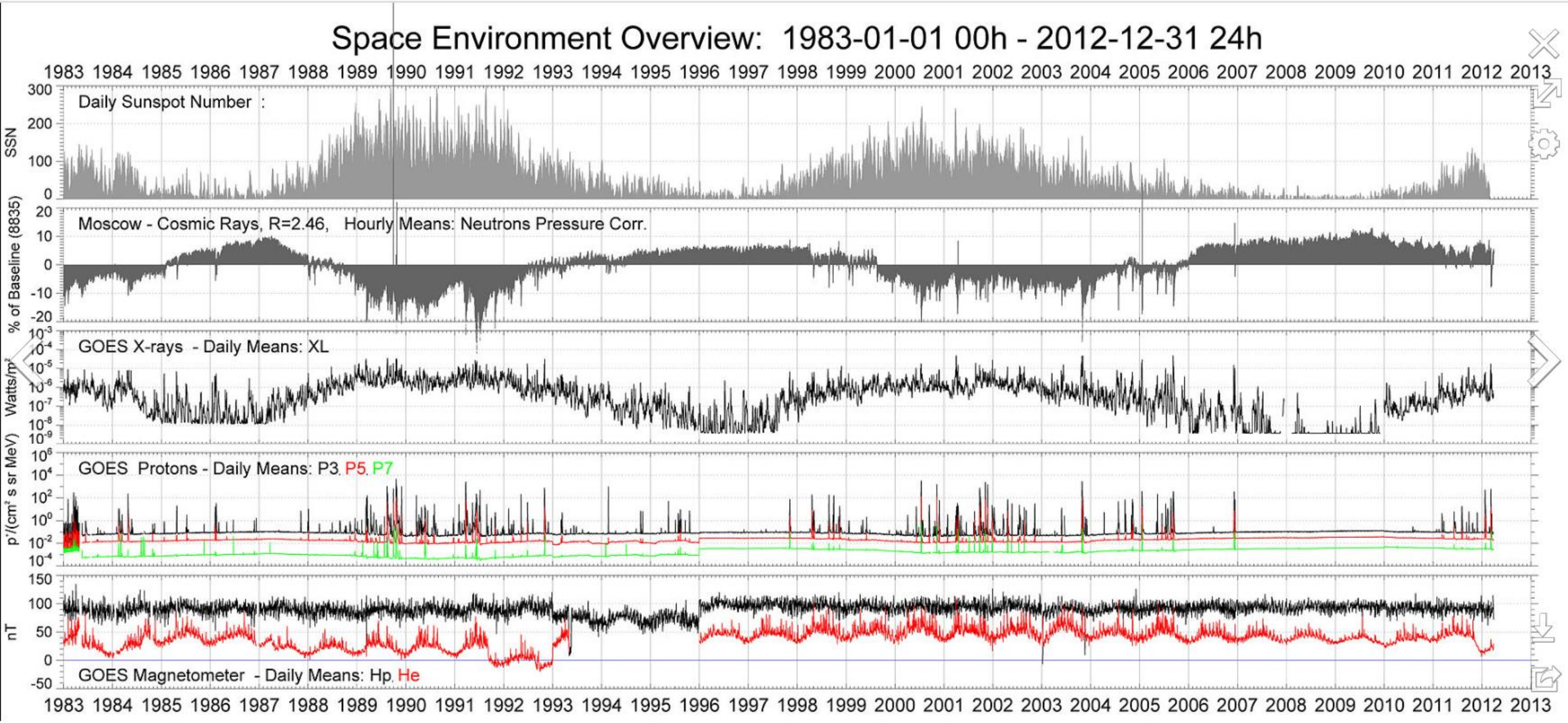
At sea level, the most abundant cosmic ray secondary particles are muons



Artistic view of a cosmic rays shower. Credit: ASPERA/Novapix/L.Bret/Hearn
Brian Resnic vox.com

Solar Cosmic Radiation 1983 – 2013 a 30year context

Daniel Wilkinson



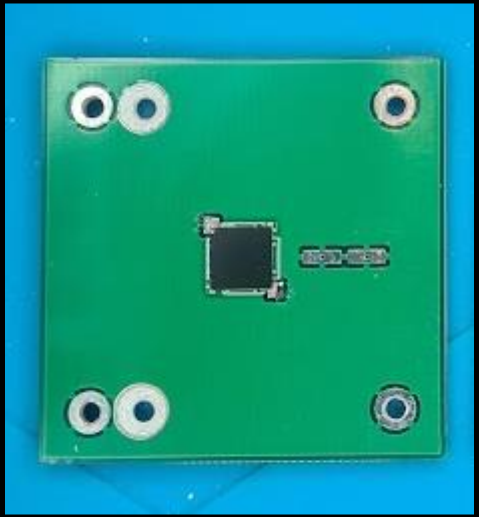
A muon detector will detect background - β, ϒ and μ^- Radiation.

Q. How can we discriminate between random background (β, ϒ) and a cosmic muon evets.

A. Stacked detectors.

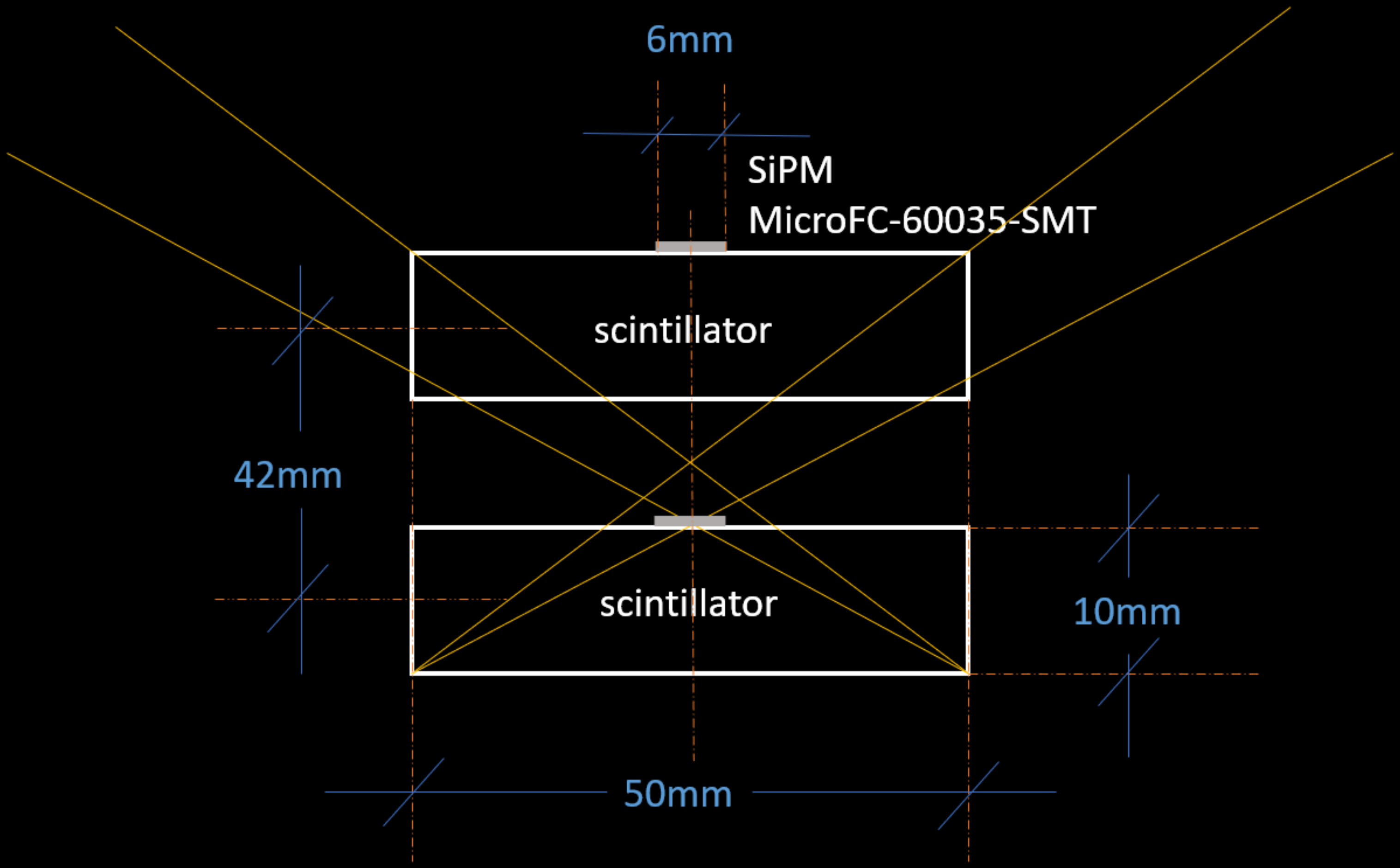
An event registered on both detectors within 30uS will be a muon and not local random background.

Assembled detector, no enclosure



A Silicon Photomultiplier is used as the detection element

UKRAA CosmicWatch detector geometry with two detectors



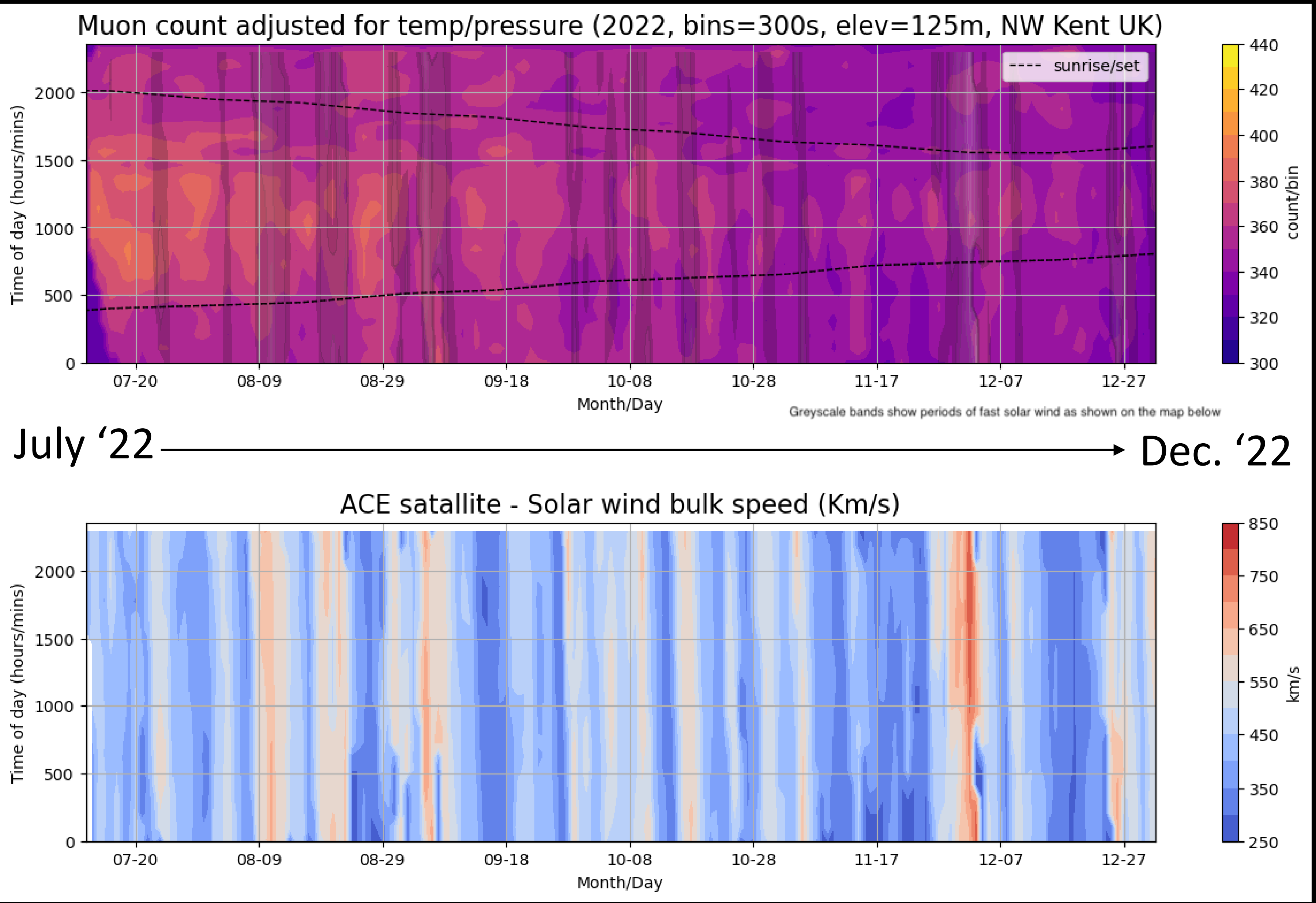
The scintillator is 50x50x10mm
Peak emission at 420nm
Bicron BC408

The pulse hight from the SiPM is a function of the muon energy and the path length in the scintillator block.

Max path ~20mm
Min ~2mm
Solid angle ~135°

We can assume that muons deposit 2-3MeV/cm (density 1g/cm^2

Observations

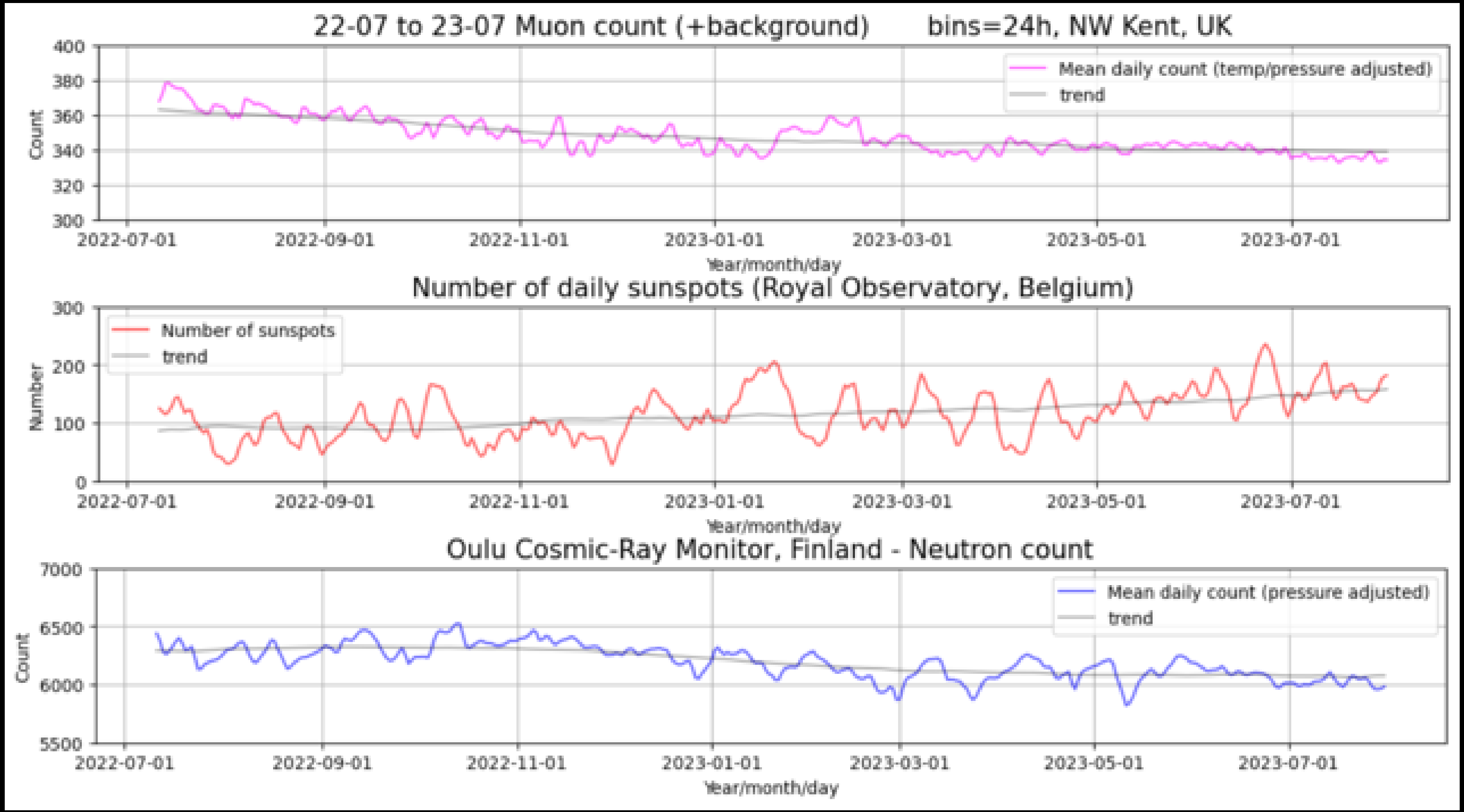


Muon count July – Dec. 2022

Note the higher mid-day and summer count rate.

Mark Prescot
(Kent UK)

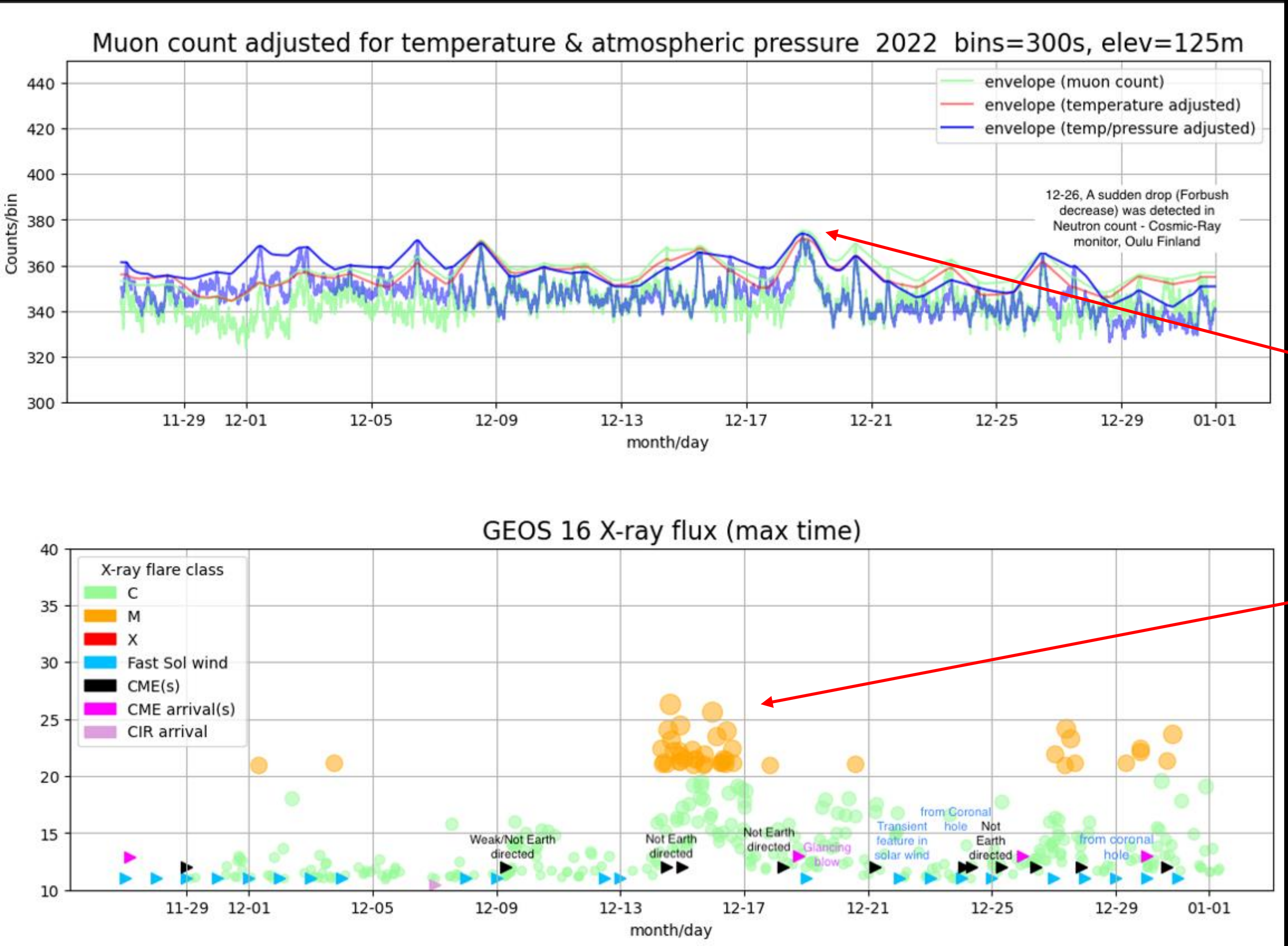
One year muon count data



Muon count decreasing

Sunspot count increasing

Neutron count decreasing



Muon data for December 2022 corelated with GEOS x-ray flux.

Possible corelation with C class glancing blow event on 18th

The M class on the 14th and 15th was not earth directed.

Scope for further data analysis

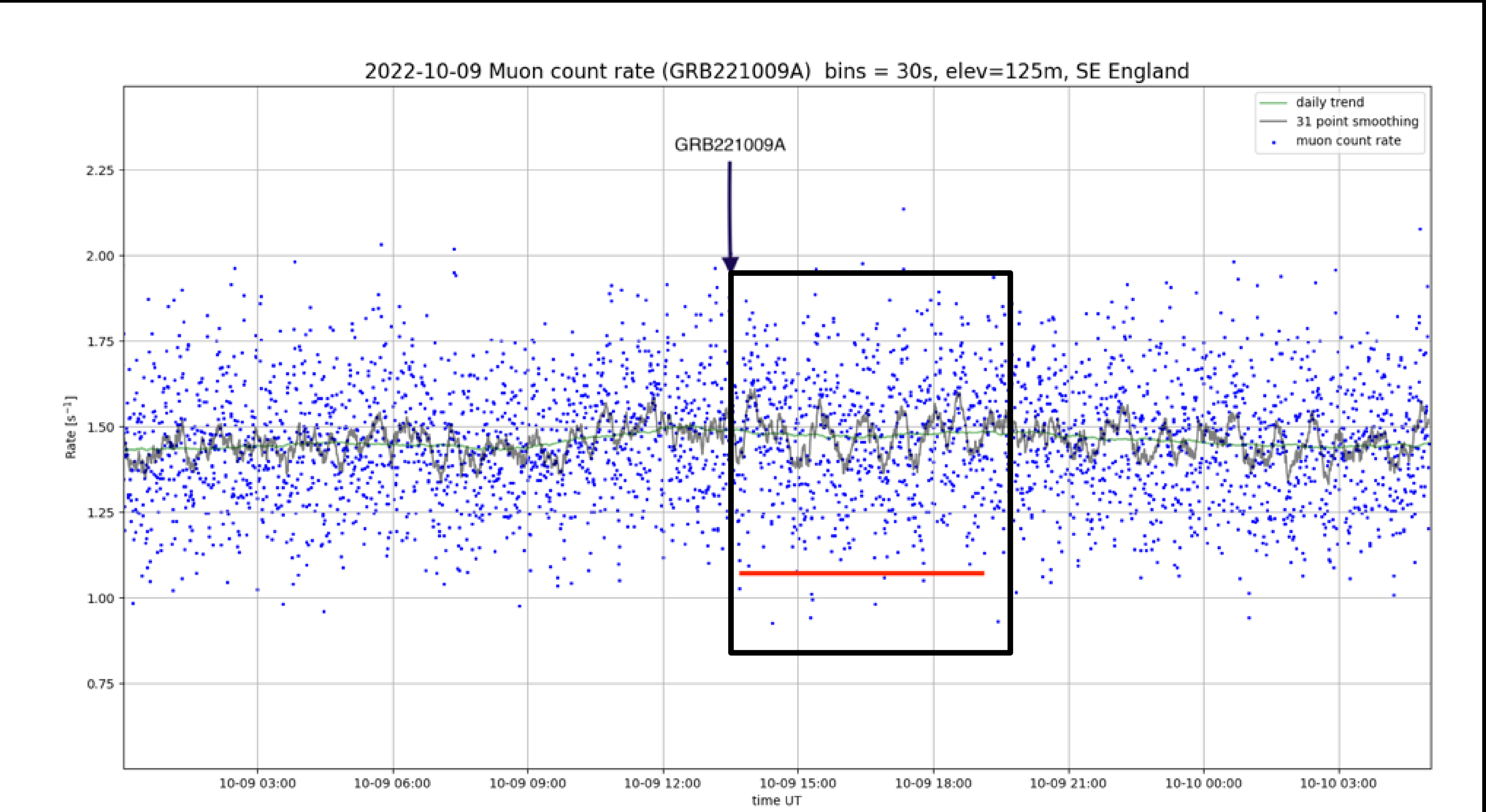
Mark Prescot (Kent UK)

PHYS.ORG

Record-breaking gamma-ray burst possibly most powerful explosion ever recorded

In the early-morning hours of today, 14 October 2022, astronomers using the Gemini South telescope in Chile operated by NSF's NOIRLab observed the unprecedented aftermath of one of the most powerful explosions ever recorded, Gamma-Ray Burst GRB221009A. This record-shattering event, which was first detected on 9 October 2022 by orbiting X-ray and gamma-ray telescopes, occurred 2.4 billion light-years from Earth and was likely triggered by a supernova explosion giving birth to a black hole.

Data from an dependant researcher using a muon Detector (9th & 10th Oct. ’22)



Note a change in character from the point at which the GRB arrived. Lower frequency with a much clearer oscillation and a slight reduction to the count

Mark Prescot (Kent UK)

A Novel Method of Determining Air Shower Muon Half-Life Using Time-of-Flight

Introduction and Objectives

Air showers are events in Earth's atmosphere caused by incident cosmic rays created by events such as supernova of distant stars.

One of the main decay products of air showers and the particles created are muons. Muons have a half-life of about 1.56μs and are created predominantly at an altitude of 15km, assuming a speed of 0.994c, they would not be able to travel to the ground before almost all particles decay.

The muon's high speed causes this half-life to be dilated to an outside observer to 14.26μs. This brings the count rate from a miniscule non-zero value to around 1 count/minute/cm^2.

Objective: Gather data at varying altitudes and use the collected data to accurately determine the half-life of muons.

Materials and Methods

Determine a method of creating simple, cost-effective particle detectors that exclude background radiation.

↓

Source most efficient parts for this task and construct detectors with said parts.

↓

Ensuring proper functionality by comparing results to established values of count rate and hardware efficiency.

↓

Derive method and equation to directly calculate the half-life of the muon using large changes in altitude.

↓

Run detectors over the course of a commercial plane flight, and record the data collected across altitude.

↓

Process raw data from detectors and apply the derived equation to the processed data.

↓

Use Poisson statistics to ensure that count rate discrepancies are not caused by random gamma events.

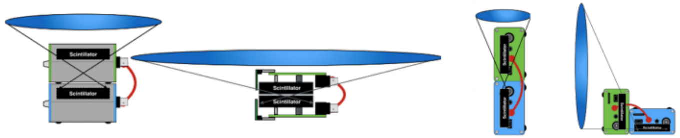
↓

Determine cause of calculated half-life discrepancy and apply theoretical correction to demonstrate viability.

Assumptions & Limitations

- Pressure and temperature differential at high altitudes attenuates muon count due to atmospheric density.
- Due to limited resources, atmospheric noise has a larger effect on results due to small detector size and amateur quality equipment.
- Processors become more inefficient as count rate increases due to processing inefficiencies.
- Particles that decay faster in external reference frame due to speed loss cannot be accounted for with limited sophistication of detectors.

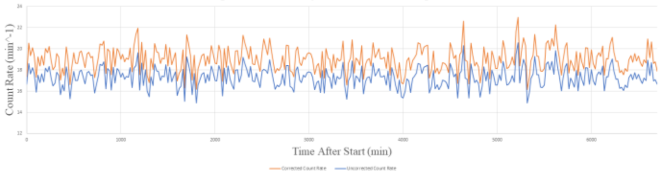
1.)



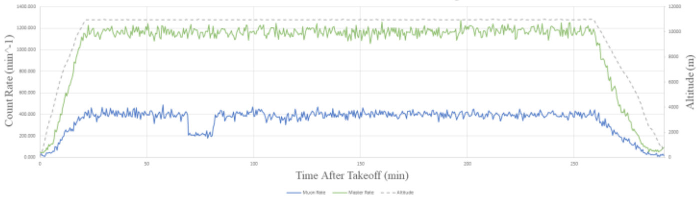
Derived Time of Flight Halving Equation

$$t_{1/2} = \left(\frac{h_{j\mu}}{u_{j\mu}} * \frac{1}{\gamma_{j\mu}}\right) - \left(\frac{h_{1/2j\mu}}{u_{1/2j\mu}} * \frac{1}{\gamma_{1/2j\mu}}\right)$$

Long Term Stability Correction Comparison



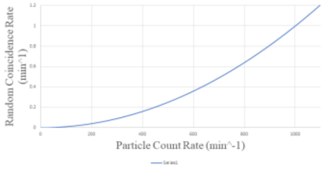
Corrected Count Rate Over Plane Flight



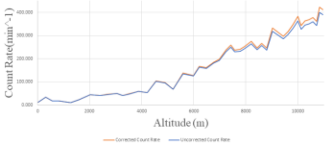
$$f(n,u) = \frac{u^n e^{-\mu}}{n!}$$

$$R_p(q) = \binom{q}{p} p N^p \tau^{p-1}$$

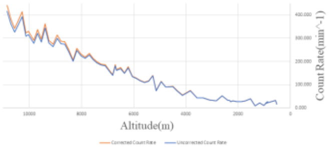
Poisson Random Coincidence Rate



Correction Comparison of Muon Count Rate Over Ascent



Correction Comparison of Muon Count Rate Over Descent



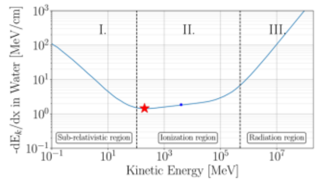
Results

Grouping #	Upper Altitude (m)	Upper Speed (c)	Lower Altitude (m)	Lower Speed (c)
1	7799	0.99300	5564	0.99370
2	8201	0.99285	5714	0.99350
3	9492	0.99275	6243	0.99325
4	10397	0.99269	6765	0.99315

Grouping #	Expected Half Life (μs)	Uncorrected Half Life (.994c, μs)	Corrected Half Life(μs)
1	1.560	0.820	1.001
2	1.560	0.913	1.105
3	1.560	1.193	1.402
4	1.560	1.333	1.560
P-Value		0.012	0.065

This shows that muon speed is most likely inconsistent across altitude, and that a theoretical calculated half-life scenario with changing muon speed has a p-value over 0.05, showing statistical significance over the original fixed speed calculation.

1.)



Conclusions

- Coincident, SiPM based scintillating detectors can detect muons with high purity of sample.
- At higher altitudes, half-life can be measured with reasonable accuracy, but as altitude decreases, so does the observed half-life.
- This inconsistency is likely due to the anisotropic nature of muon energy at a given altitude, and the mode of which high energy particles lose energy at different energy levels.
- This anisotropic nature of decay causes lower energy particles to almost immediately come to a stop at a certain energy level, causing lower energy particles to decay at much greater rates.
- The large effect that speed has on the half-life of the particles demonstrates the theory of special relativity, as well as showing that the slightly lower half-life measured at maximum altitudes is very likely to be the half-life of the muon.

References

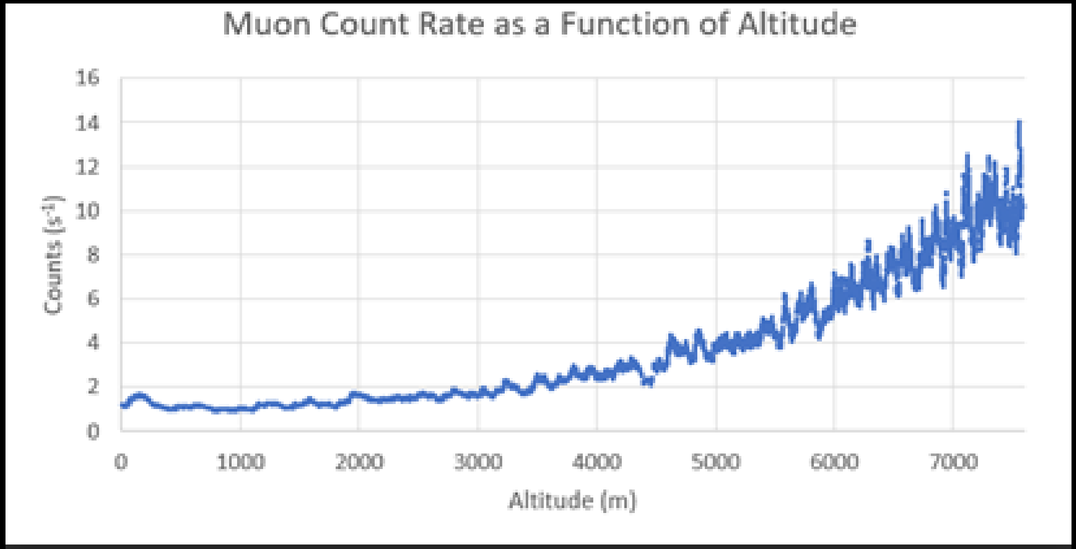
1.) Axani, Spencer. "The Physics Behind the CosmicWatch Desktop Muon Detectors." *Arxiv*, July 2019. *Michigan Institute of Technology*, https://arxiv.org/pdf/1908.00146.pdf.

Unless otherwise noted all graphics created by researcher.

Dillen Scott
Satalite High School FL

Objective:
To gather data at varying altitudes and use the collected data to accurately determine the half-life of muons.


University of
Central Lancashire


Muon Count Rate as a Function of Altitude
Counts (s⁻¹)
16
14
12
10
8
6
4
2
0
0
1000
2000
3000
4000
5000
6000
7000
Altitude (m)

A great project for:

- UTC/undergraduate teaching.

  We already have a number of universities using the MIT/UKRAA muon detector.

- Academic/Amateur collaboration, this has already started.

- For developing data processing skills.

End

thanks for your attention