Mirya μ1 Cosmic Ray Detector; Installation and Features

YEFİST 2023 İstanbul Yüksek Enerji Fiziği Çalıştayı

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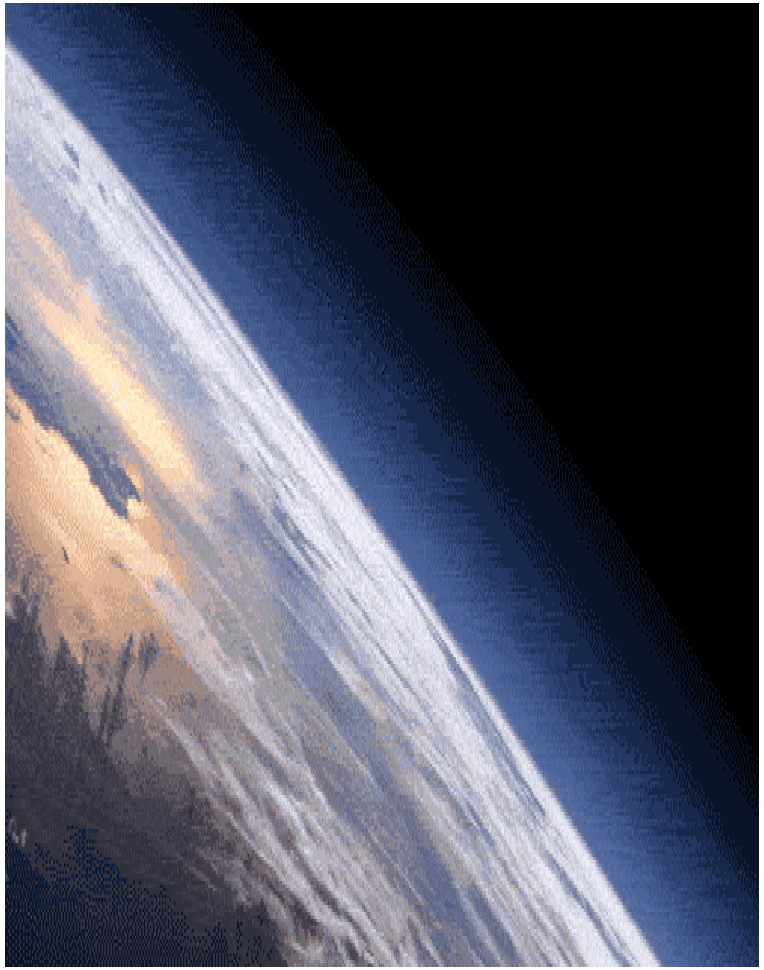
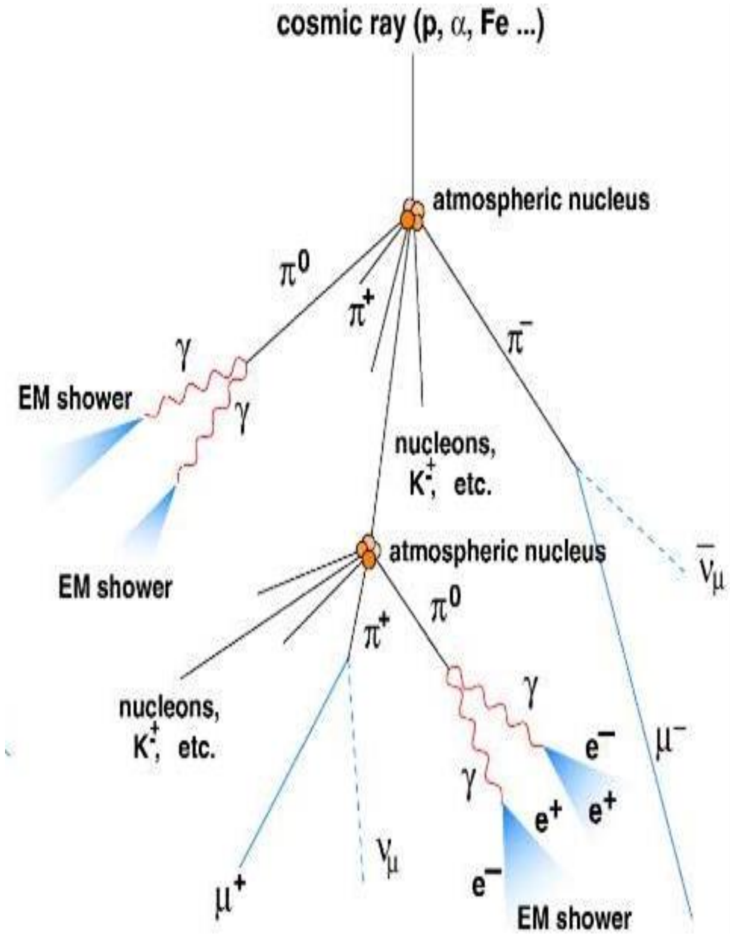
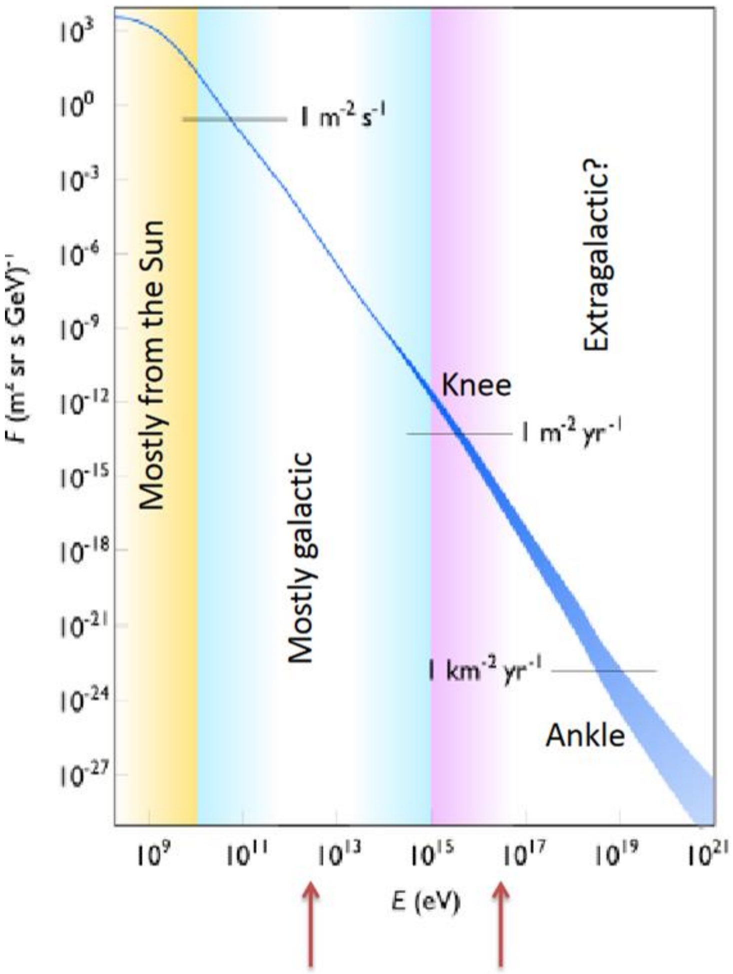
Cosmic Rays



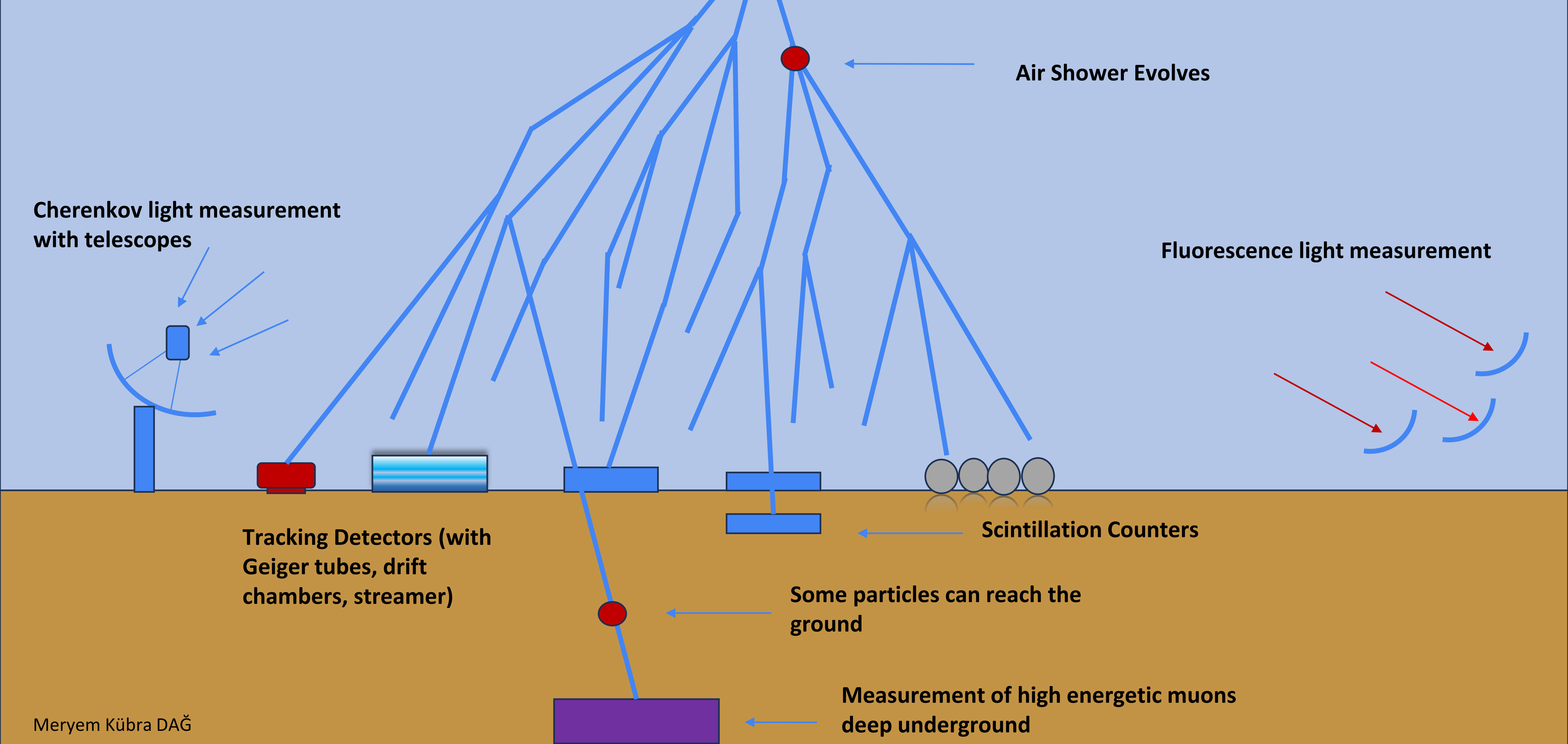




http://dx.doi.org/10.13140/RG.2.1.4140.4969

https://en.wikipedia.org/wiki/Cosmic_ray

Cosmic Rays and Detection Methods



Worldwide use of cosmic ray detectors

- Geophysical and atmospheric surveys

(Roberta Colalillo & The Pierre Auger Collab. (2023), //doi.org/10.1051/epjconf/202328306014)

- Understanding the nature and composition of the universe in elementary particle physics and cosmology

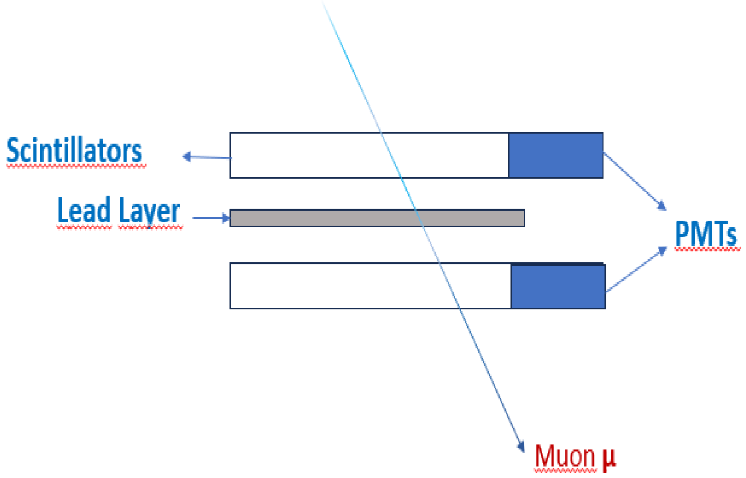
(Soldin Dennis (2023), arXiv:2302.07111v1)

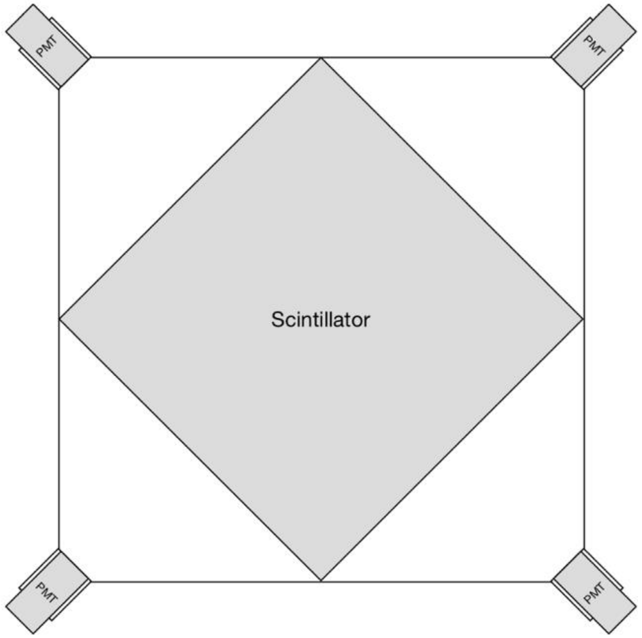
- Solar Activity Forecast and Space Weather

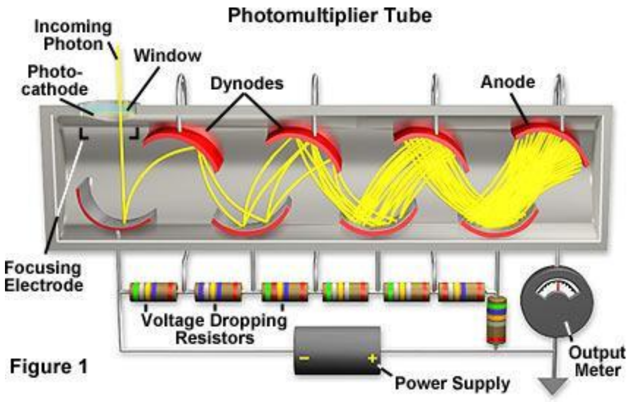
(Maghrabi A.& Aldosari A. & Almutairi M.,(2021)), https://doi.org/10.1016/j.asr.2021.05.016)

Scintillation Detectors

- Operating based on the principle of scintillation (emitting flashes light)
- Interaction between ionizing radiation and scintillating materials.
- Typically use photomultiplier tubes (PMTs) or silicon photomultipliers (SiPMs) as photodetectors.







https://hamamatsu.magnet.fsu.edu/articles/photomultipliers.html

Scintillator of Mirya µ1

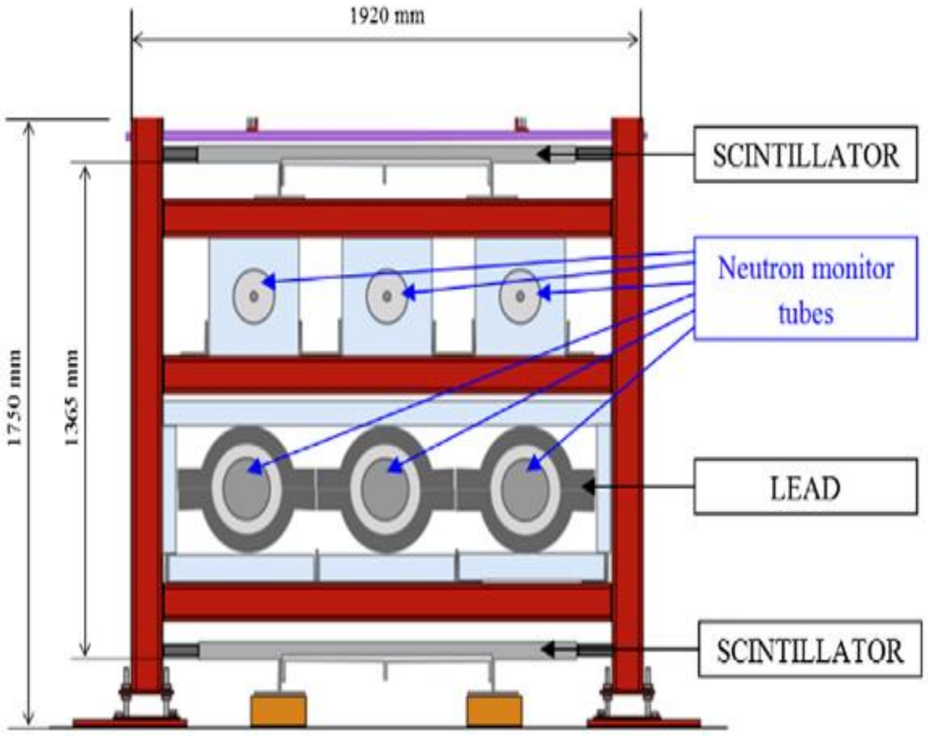
Mirya µ1 Cosmic Rays Detector

Starting Point of The Project; MITO Cosmic Rays Detector

- Two stacked scintillators ($1m^2$) with an optional lead layer that allows the filtering of unwanted particles.
- Eight photomultipliers (PMTs) gather the light emerging from the four lateral sides of the scintillators

WHY MITO?

- Low number of scintillators and electronic components
- Simplicity of design
- Volume, weight, power consumption, and cost
- A reasonable performance-cost ratio



S. Ayuso et al.: J. Space Weather Space Clim. 2021, 11, 13

Mirya µ1 Cosmic Rays Detector

Introduction

- Optical Design of Mirya

  -ELJEN Scintillator EJ 200

  -H1411 Hamamatsu PMT

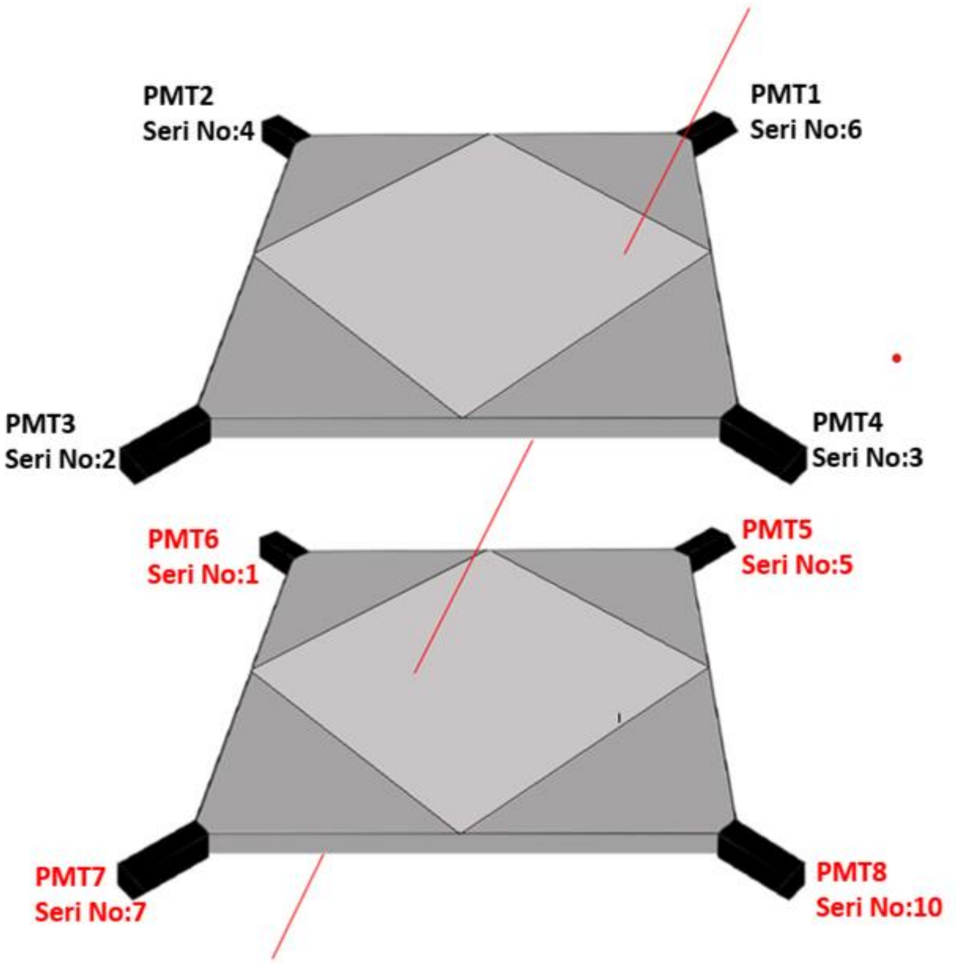
  -C7319 Hamamatsu Amplifier

- Mechanical Design of Mirya
- Electronic Design of Mirya

General Structure of Mirya µ1

- 8 PMT H11411 Hamamatsu
- 8 Amplifier C7319 Hamamatsu
- 2 Plastic Scintillators (ELJEN Tech. EJ 200)

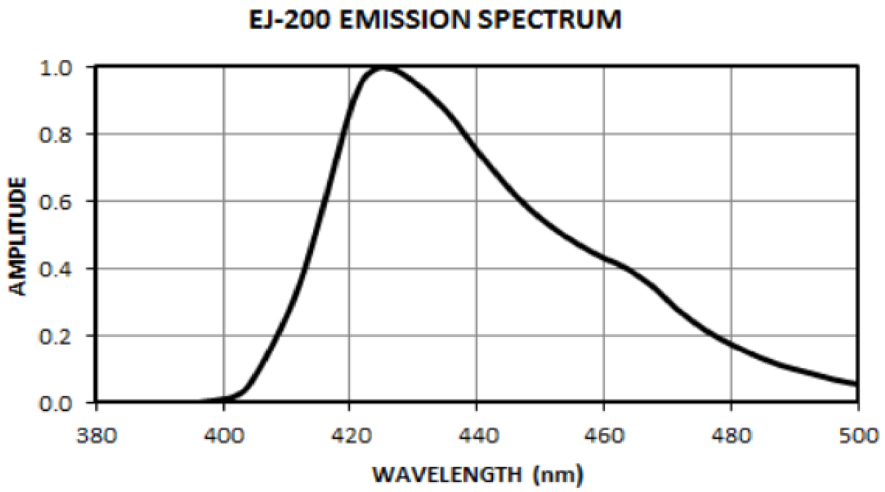
- 10 cm Lead Layer



Optical Design

Scintillator (ELJEN Tech. EJ 200)

PROPERTIES	EJ-200	EJ-204	EJ-208	EJ-212
Light Output (% Anthracene)	64	68	60	65
Scintillation Efficiency (photons/1 MeV e^-)	10,000	10,400	9,200	10,000
Wavelength of Maximum Emission (nm)	425	408	435	423
Light Attenuation Length (cm)	380	160	400	250
Rise Time (ns)	0.9	0.7	1.0	0.9
Decay Time (ns)	2.1	1.8	3.3	2.4
Pulse Width, FWHM (ns)	2.5	2.2	4.2	2.7
H Atoms per cm^3 ($\times 10^{22}$)	5.17	5.15	5.17	5.17
C Atoms per cm^3 ($\times 10^{22}$)	4.69	4.68	4.69	4.69
Electrons per cm^3 ($\times 10^{23}$)	3.33	3.33	3.33	3.33
Density (g/cm^3)	1.023	1.023	1.023	1.023
Polymer Base	Polyvinyltoluene			
Refractive Index	1.58			
Softening Point	75°C			
Vapor Pressure	Vacuum-compatible			
Coefficient of Linear Expansion	7.8×10^{-5} below 67°C			
Temperature Range	-60°C to 60°C			
Light Output (L.O.) vs. Temperature	At 60°C, L.O. = 95% of that at 20°C No change from -60°C to 20°C			



Optical Design
Scintillator

"EJ-200 combines the two important properties of long optical attenuation length and fast timing which make it particularly useful for time-of-flight systems using scintillators greater than one meter long."

Optical Design

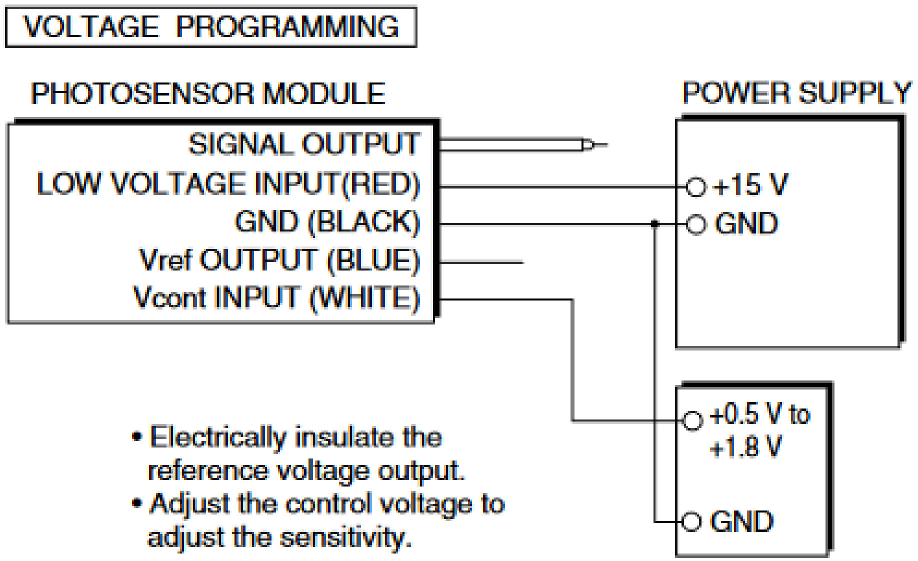
Photomultiplier Tubes (PMTs) - H11411 Hamamatsu

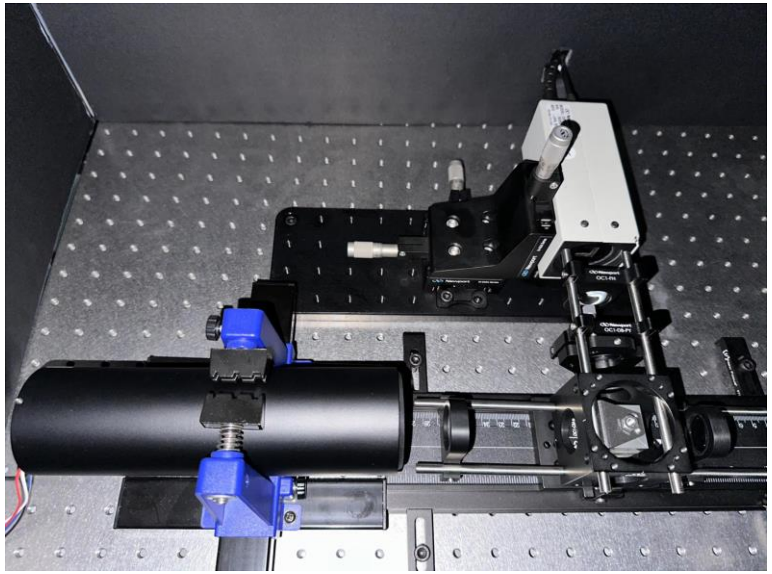
-The H11411 is a photomultiplier module that integrates a 51-mm (2") diameter head-on photomultiplier tube with a high-voltage power supply circuit.

- A large effective photocathode area of 46 mm diameter and suited for scintillation counting application.

Optical Design

Photomultiplier Tubes (PMTs) - H11411 Hamamatsu





https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/etd/H11411_TPMO1070E.pdf

Parameter				Value	Unit
Spectral response				300 to 650	nm
Input voltage				+11.5 to +15.5	V
Max. input voltage				+18	V
Max. input current *1				5.0	mA
Max. output signal current *2				200	µA
Max. control voltage				+1.9 (Input impedance 1 MΩ)	V
Recommended control voltage adjustment range				+0.5 to +1.8 (Input impedance 1 MΩ)	V
Effective area				ϕ46	mm
Peak sensitivity wavelength				420	nm
Cathode	Luminous sensitivity		Min.	60	µA/lm
			Typ.	90	
	Blue sensitivity index (CS 5-58)		Typ.	10.5	—
	Red / White ratio		Typ.	—	—
	Radiant sensitivity *3		Typ.	85	mA/W
Anode	Standard type	Luminous sensitivity *2	Min.	30	A/lm
			Typ.	300	
		Radiant sensitivity *2 *3	Typ.	2.8×10^5	A/W
		Dark current *2 *4	Typ.	6	nA
			Max.	40	
Rise time *2				2.0	ns
Ripple noise *2 *5 (peak to peak)			Max.	1	mV
Settling time *6			Max.	10	s
Operating ambient temperature *7				+5 to +50	°C
Storage temperature *7				-20 to +50	°C
Weight				560	g

Optical Design

Amplifiers - C7319 Hamamatsu

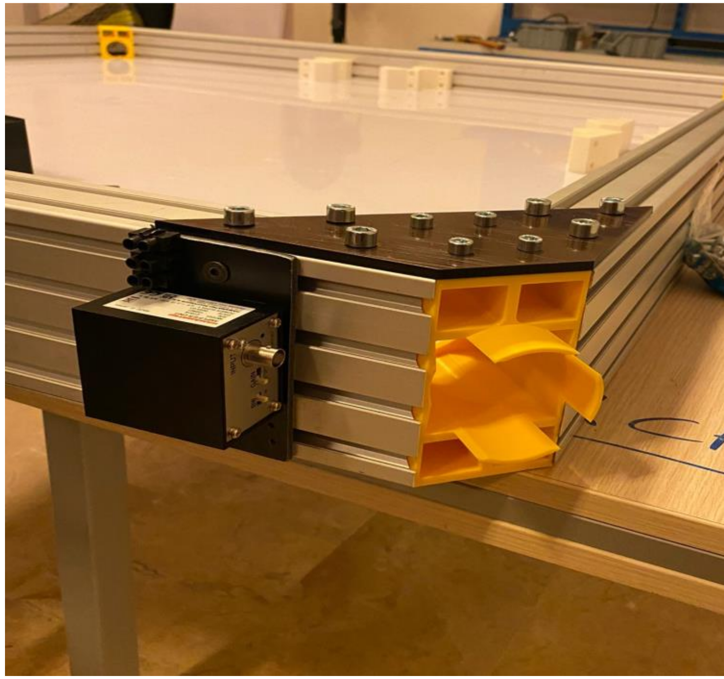
-0.1, 1 and 10 V/µA conversion ratios

-20 kHz and 200 kHz bandwidth

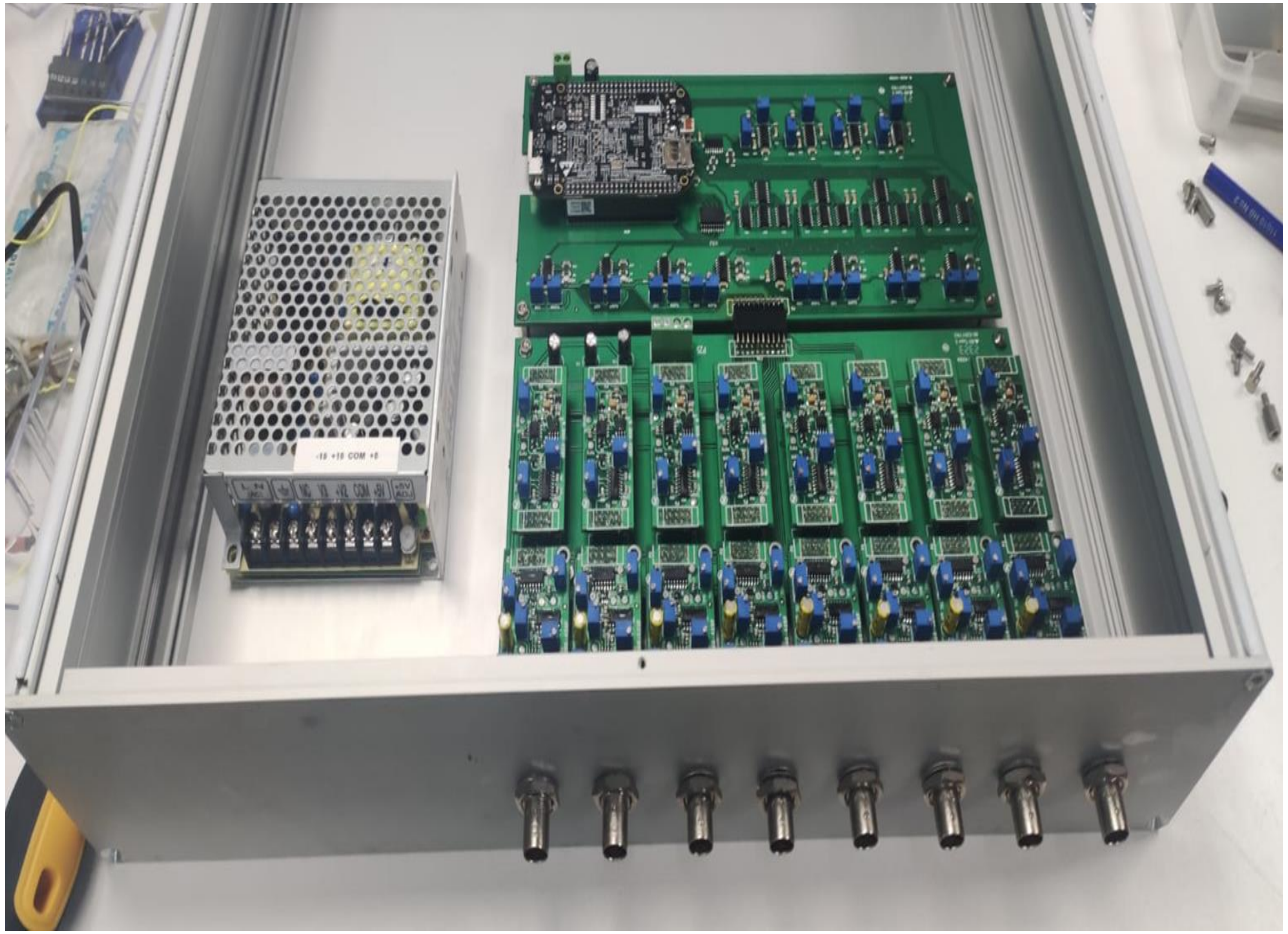
-Adjustable offset level with VR included

-Low noise and high gain

-Inverting output



Electronical Design

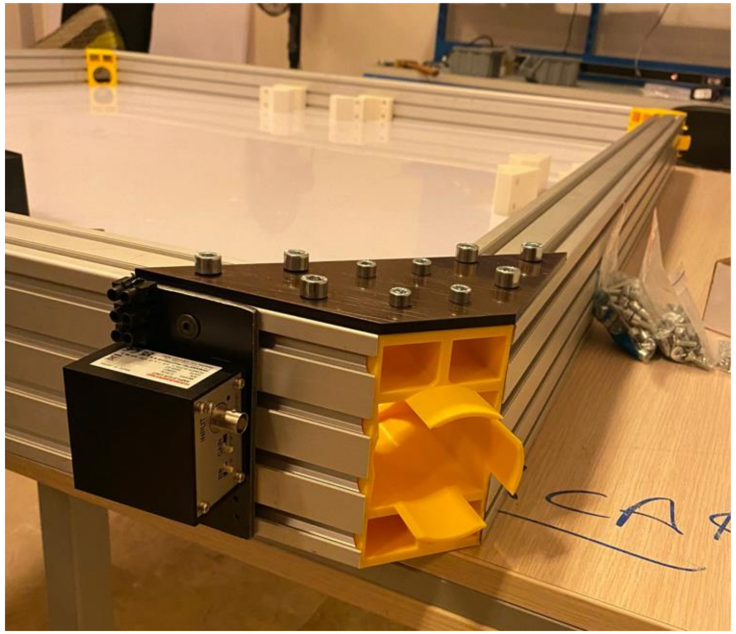


Mirya Data Acquisition Unit

MITO ARACNE

Mechanical Design

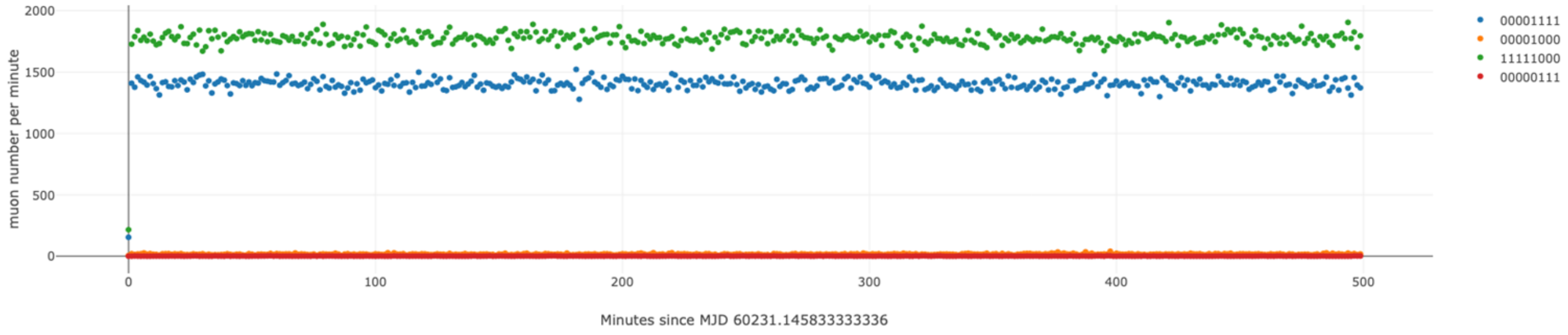
- A 3 layers contractor exoskeleton
- Two $2m^2$ profile frames for both scintillators
- 16 Scintillator support
- 8 Pmt holders
- Lots of tape! :)

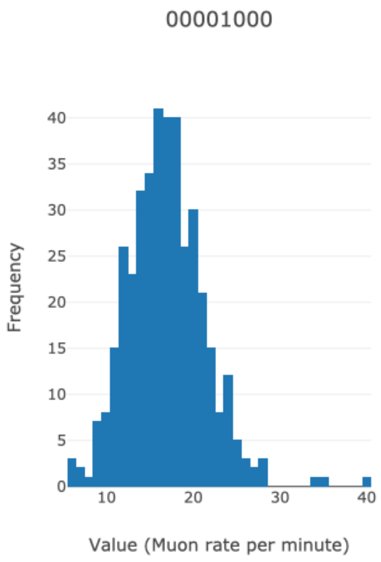


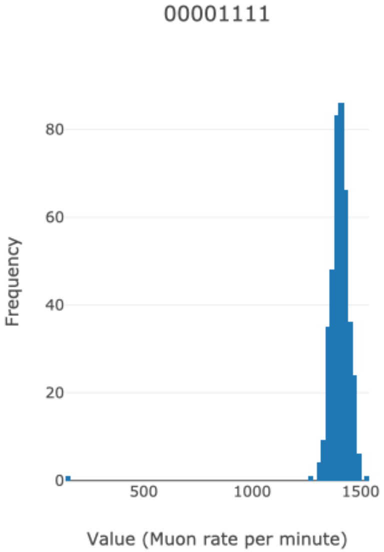
Packaging

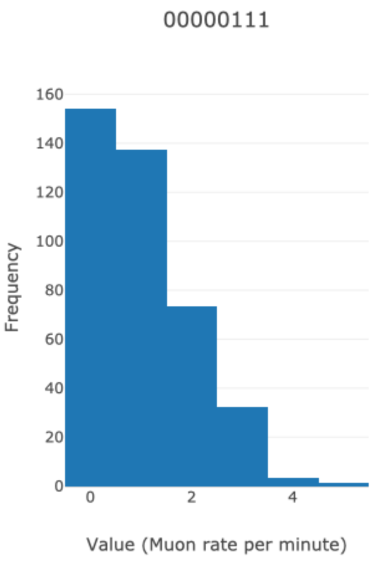
First Measurements

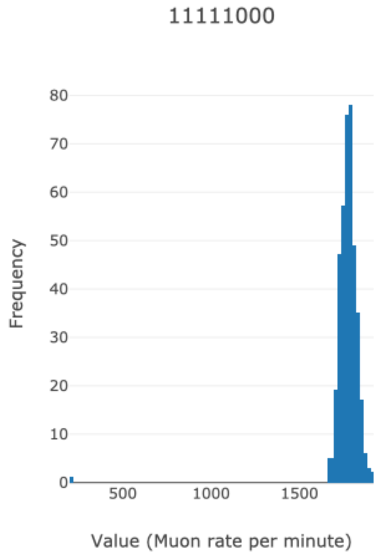
http://ist60.istanbul.edu.tr/mirya











What is the next step?

- Space weather tracking by measuring rates of change in Cosmic Ray rate;

    - ❖ Forbush Decreases

(Forbush SE. SOLAR INFLUENCES ON COSMIC RAYS,1957)

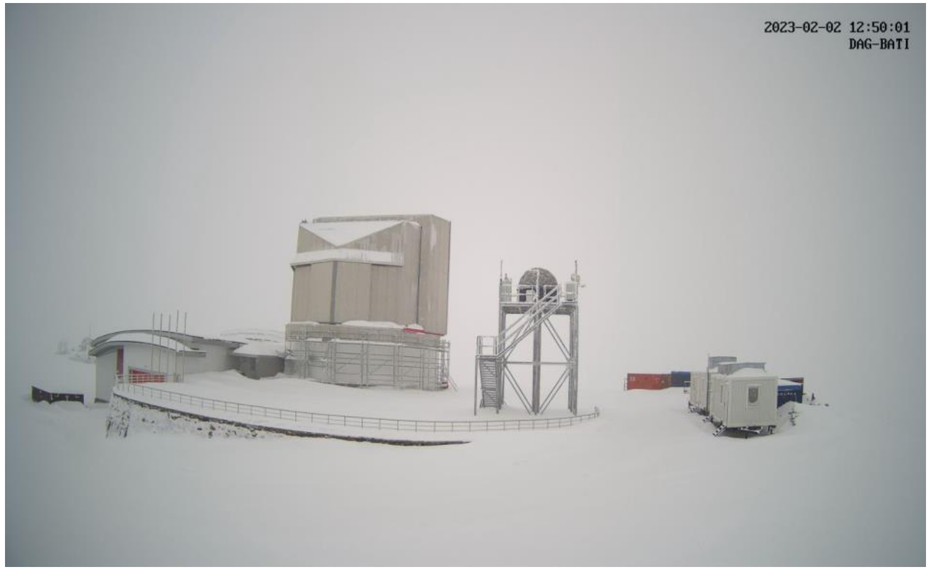
    - ❖ Ground Level Enhancements

(J. A. Lockwood ve G. A. Dulk, 1979)

    - ❖ Long-term correlation between Cosmic Rays and Solar Activity

(A. Maghrabi, A. Aldosari, M. Almutairi, Advances in Space Research Volume 68, Issue 7,2021)

- Early warning to prevent damage as a result of solar activity



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