MUON TELESCOPE : Study of quantum fields generated in an Extensive Air Shower

Kajal Garg, Life and Mathematics Research Division

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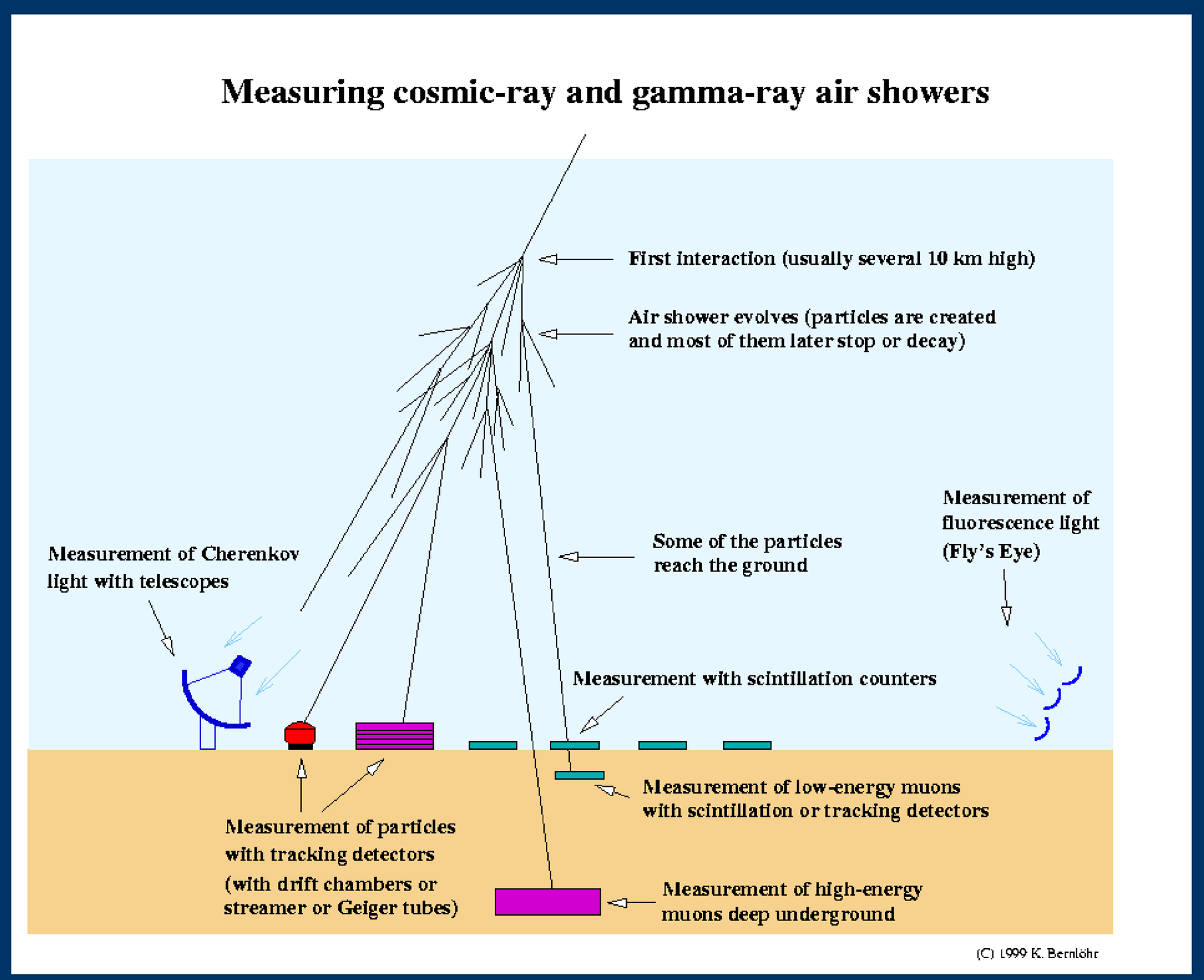
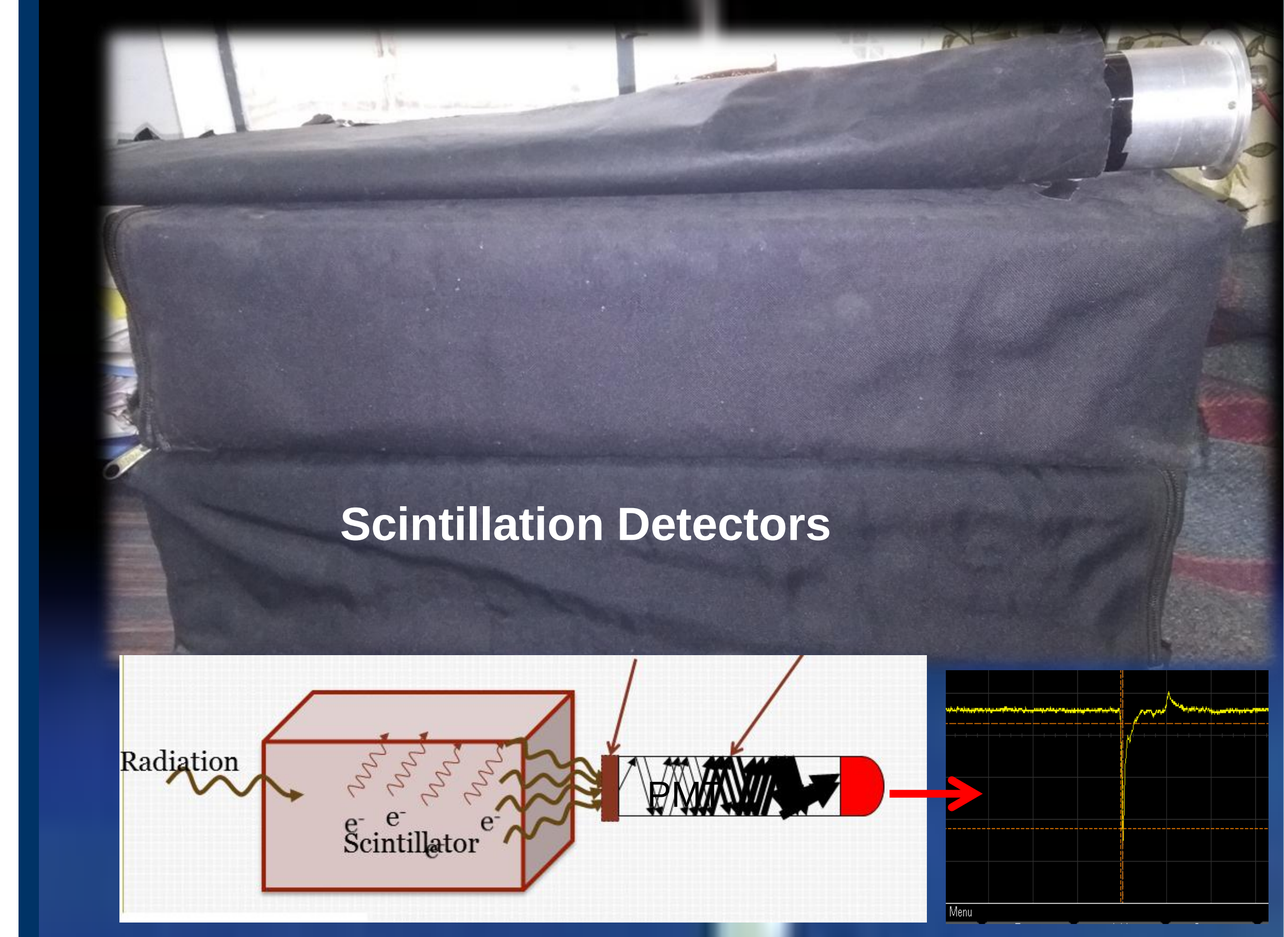
COSMIC RAYS: QUANTUM FIELD



- Charged particle continuously strike with earth's atmosphere.
- This composition is roughly comprises of 89% protons and 10% helium, and the remaining 1% is in the form of heavier nuclei.
- Penetrate and collide with other particle and create a shower of particles.
- The cosmic rays will hardly ever hit the ground but will collide (interact) with a nucleus of the air, usually several ten kilometers high. In such collisions, many new particles are usually created and the colliding nuclei evaporate to a large extent.
- Most of the new particles are pi-mesons (pions).
- Neutral pions very quickly decay, usually into two gamma-rays.
- Charged pions also decay but after a longer time.
- Therefore, some of the pions may collide with yet another nucleus of the air before decaying, which would be into a *muon and a neutrino.*
- The number of particles starts to increase rapidly as this shower or cascade of particles moves downwards in the atmosphere. On their way and in each interaction the particles loose energy, however, and eventually will not be able to create new particles. After some point, the shower maximum, more particles are stopped than created and the number of shower particles declines.
- When a primary cosmic ray produces many secondary particles, we call this an air shower. When many thousand (sometimes millions or even billions) of particles arrive at ground level, perhaps on a mountain, this is called an extensive air shower (EAS).

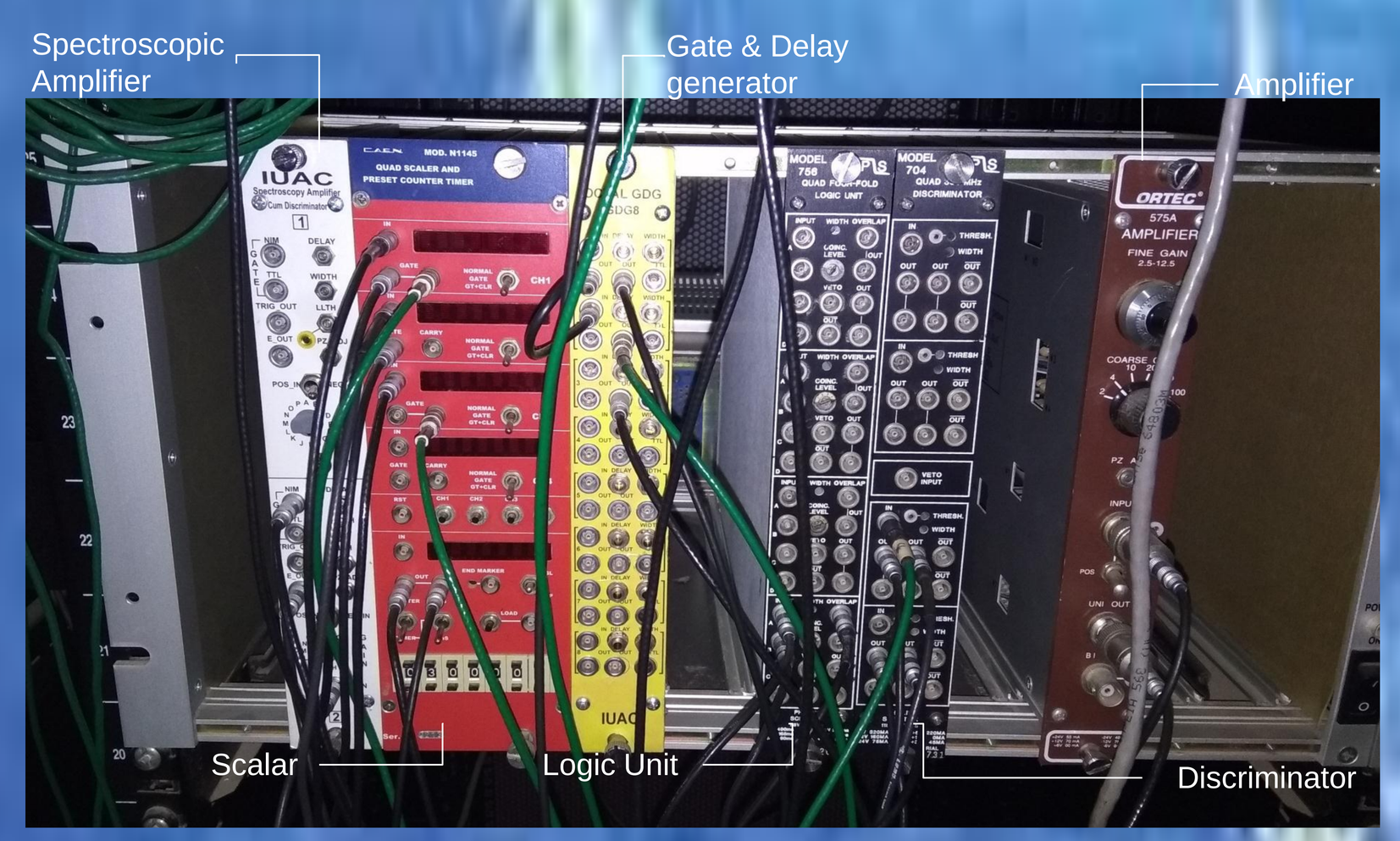
Muon Telescope

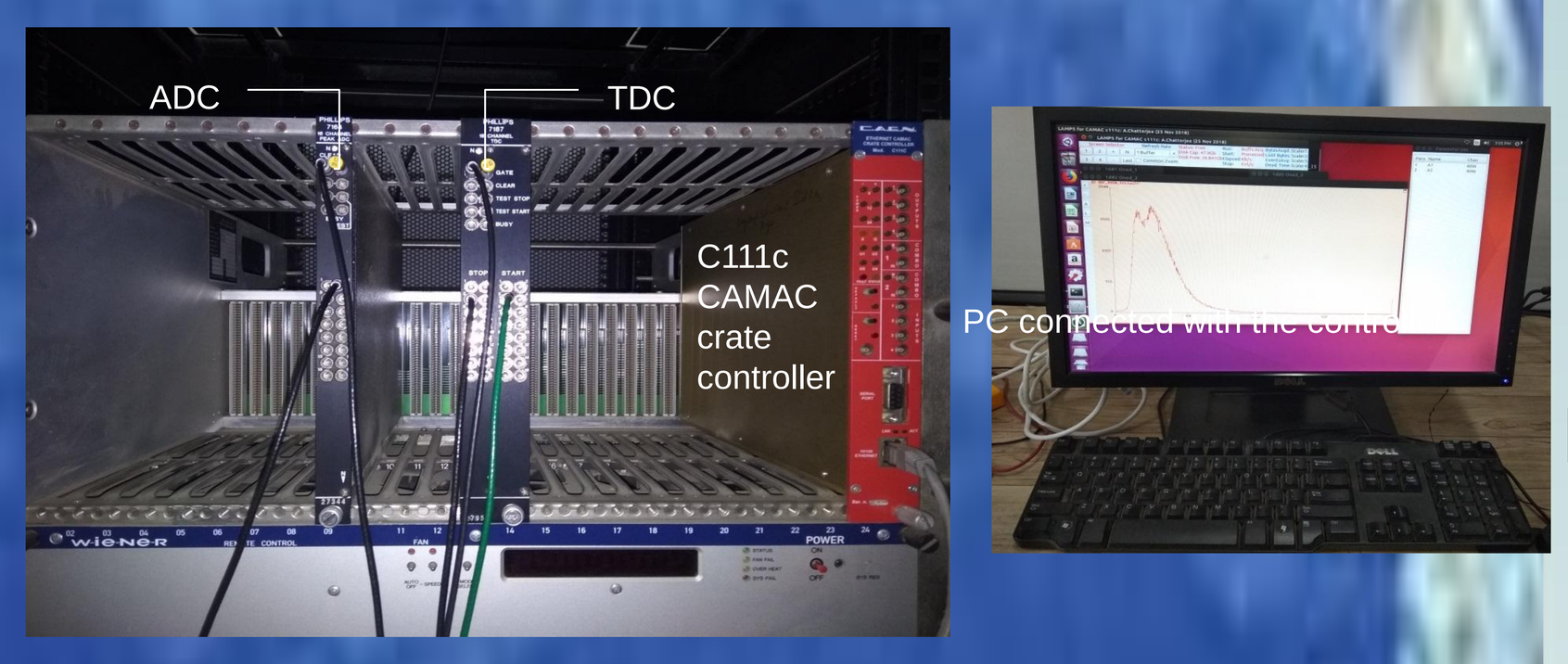
Aim: Study of Quantum Fields generated in an Extensive Air Shower .

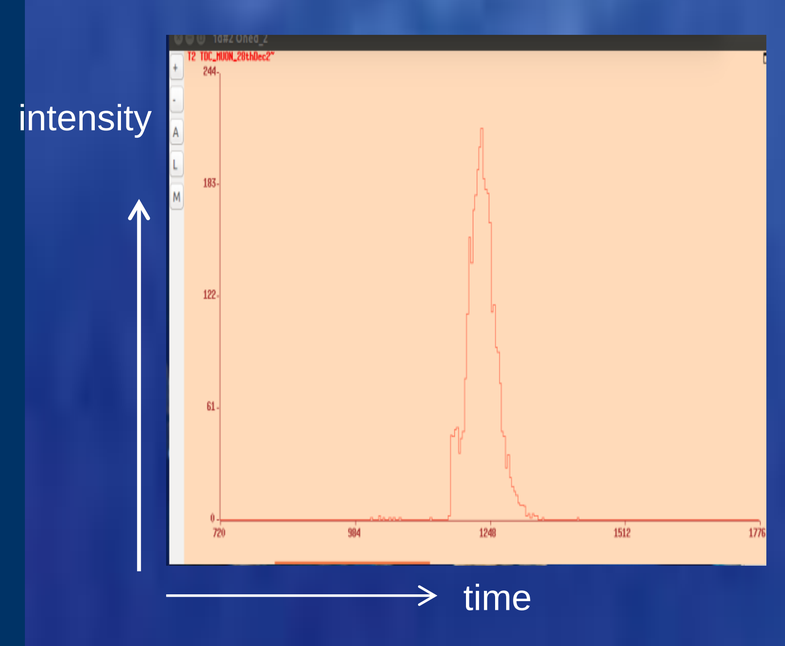


- ❖ Whenever any high energy photon or charge particle hit the scintillator, it converts the energy of the particles to a visible energy.
- ❖ The amount of visible light that is produced by scintillator is proportional to the amount of energy deposited in the scintillator by that particle.

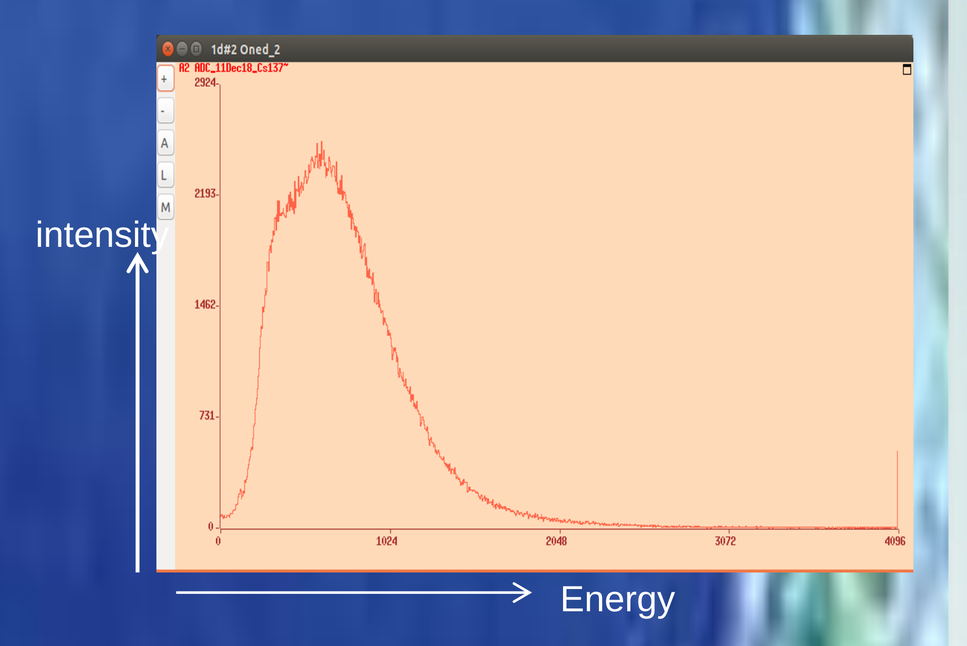
- ❖ Three scintillators are being used in our laboratory in which 2 detectors (embedded with wavelength shifting fibers): 23.4×24×2 cm^3 and third is (light guide): 33.02×10.16×1.5 cm^3.
- ❖ Scintillator Trigger system has been set up with the help of logic unit. It will record the signal only when atleast two detector will get hit within 60 ns.







Time spectrum of Muon



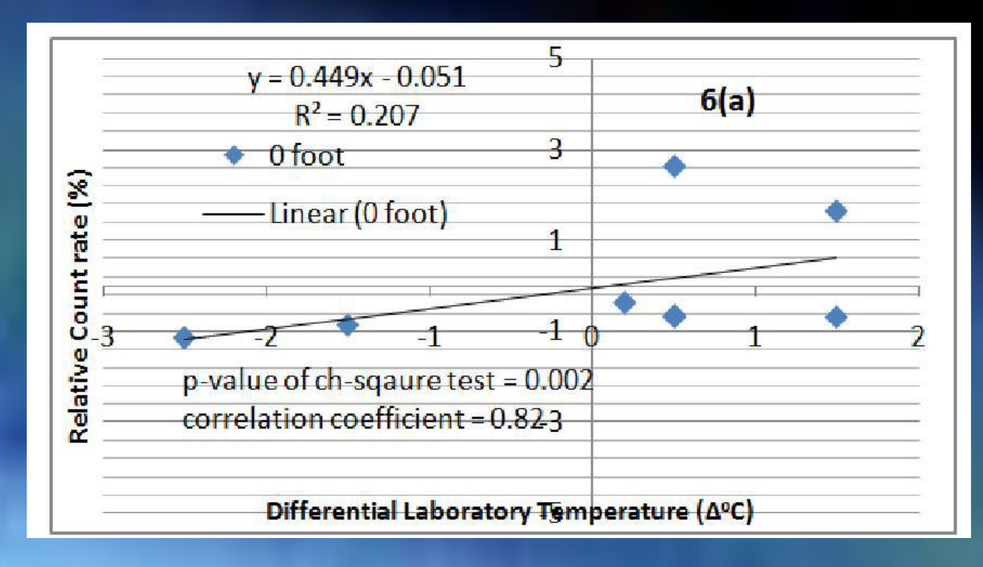
Energy Spectrum of Muon

Muon telescope Consist of::

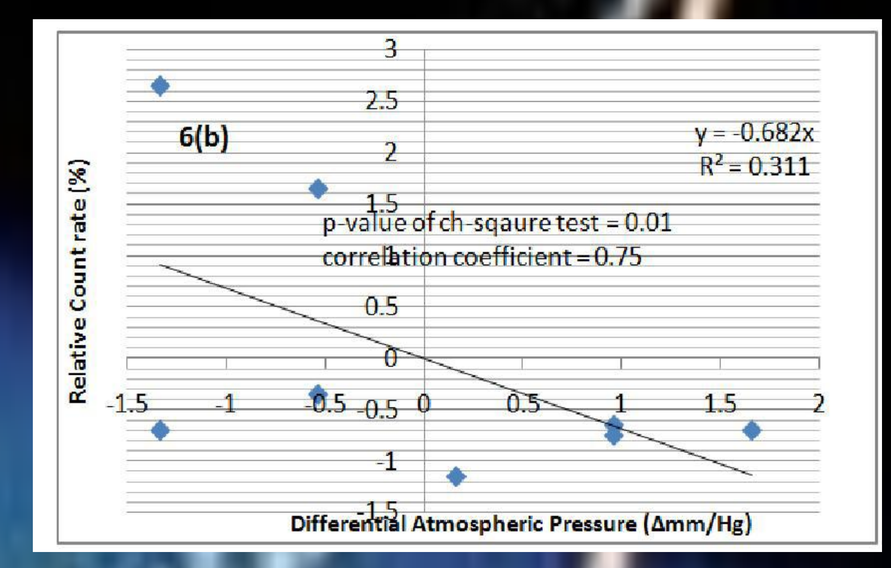
- ❑ Basic electronics:
  - 3 scintillation detectors, Light guide and Photomultiplier tube.
  - High Voltage Power supply
  - 4 channel Discriminator (convert analogue signal to digital)
  - 4 channel Logic Unit (combines signals).
  - 1 Scalar unit (show the number of hits).
- ❑ Data Acquisition:
  - CAMAC (Computer Automated Machine and Control)
  - ADC (observe the energy spectrum)
  - TDC (observe the energy time spectrum)

Results

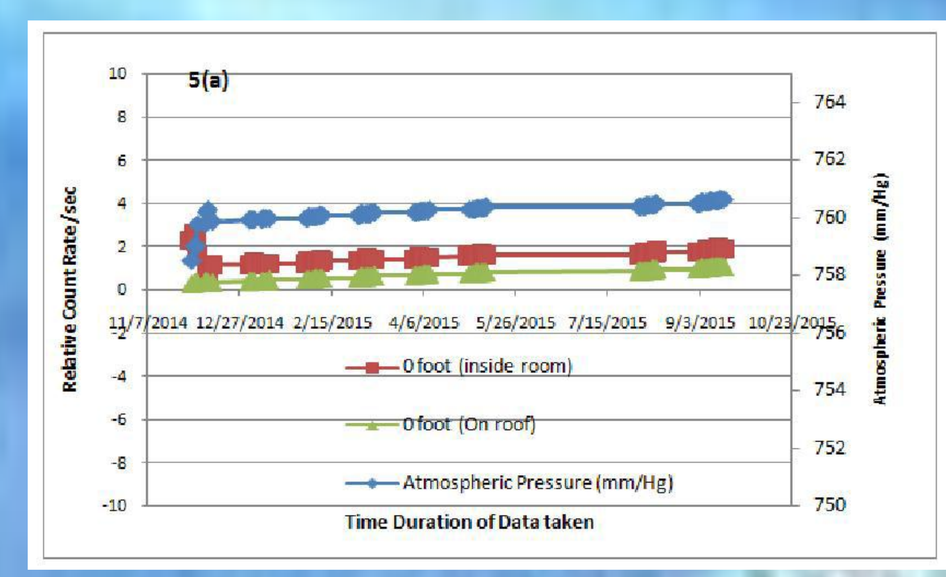
- Muon count rate is correlation with the atmospheric parameters, Solid angle between the detectors and distance between the detectors (vertical as well as horizontal) has been observed.
- The geomagnetic cutoff rigidity i.e. 22 GeV of primary particle is computed for our muon paddle which is located at Agra, India (27.180°N, and 78.02°E.



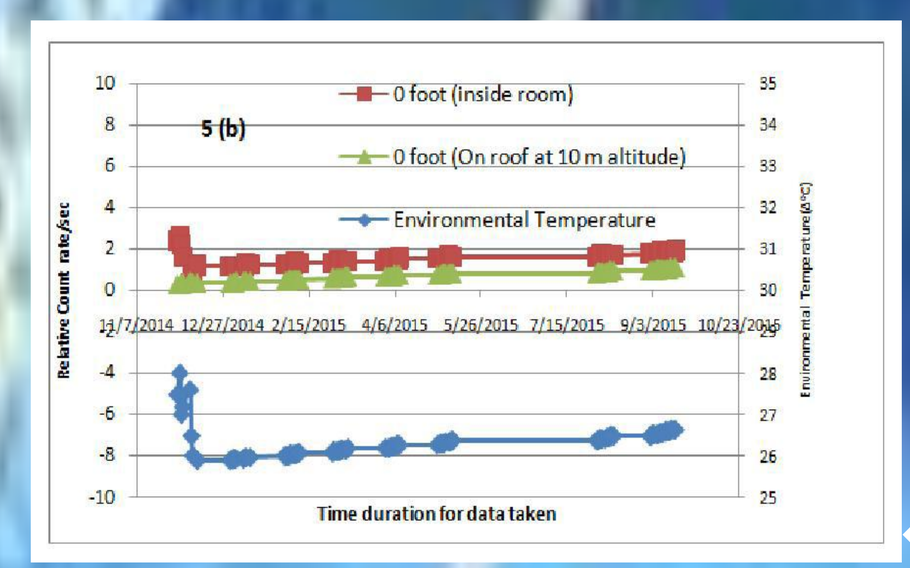
Correlation between relative coincidence rate and differential laboratory temperature



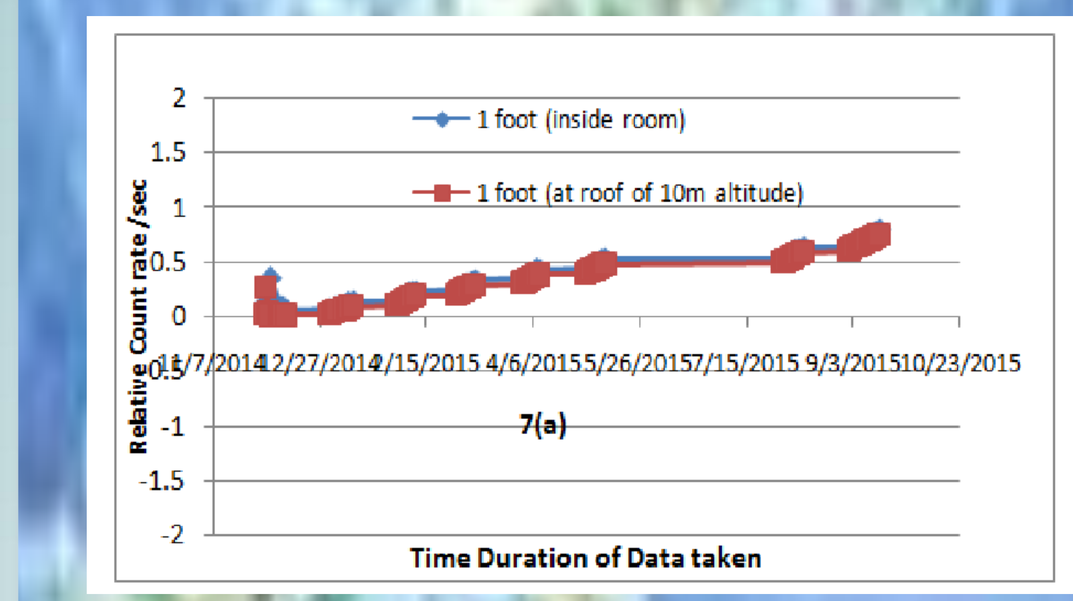
Correlation between relative coincidence rate and differential atmospheric pressure

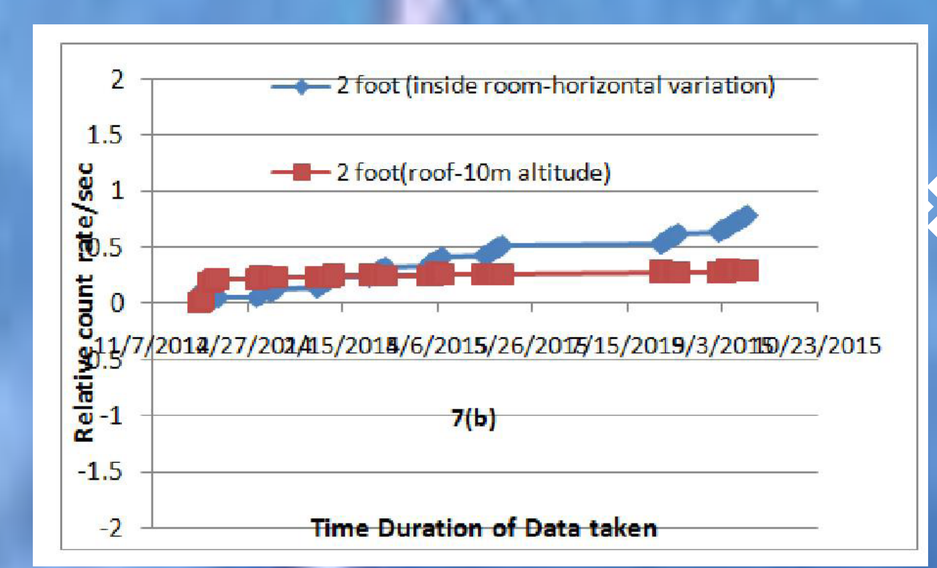


Count Rate dependence of detector coincidence as function of vertical separation among the detectors in a room



Count Rate dependence of detector coincidence as function of vertical separation among the detectors at roof (10m height from room level)





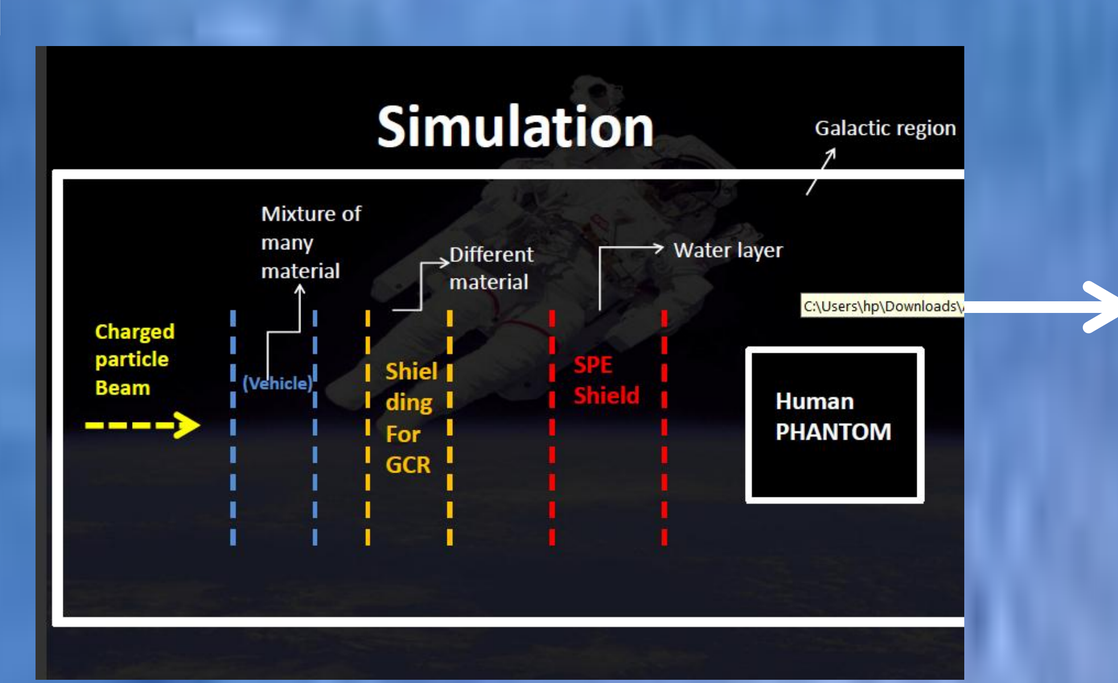
Count rate dependence of detector coincidence as function of horizontal separation among the detectors in a room and at roof (10m height from room level).

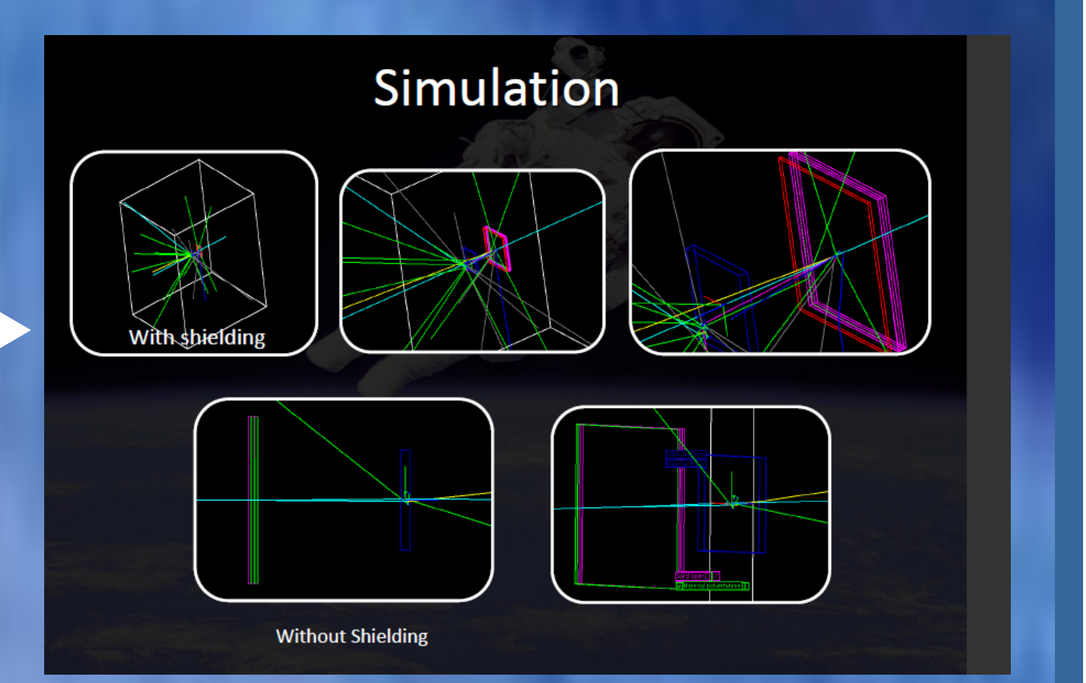
- The variation of muon flux with respect to temperature, pressure and humidity possibly direct us to a new path to understand the global climate warming trend.
- It could also indirectly impact the solar irradiance at ground level. This may leads to catastrophic weather, crop failures, disease outbreak and impact on plants, wild life and humans.

- Measurement of muon flux at different heights with change of distance in detectors helps to find the primary particle source information form the obtained Decohorence curve.
- The factors influencing the detector sensitivity such as cross-section and surrounding material of the sensitive region of muon telescope are studied.

Simulation

- ❖ Earth is protected from this space radiation by it's magnetic field so once the astronauts leave the orbit, they are exposed to constant shower of various radioactive and high energy particles
- ❖ Space radiation may place the crew at significant risk for radiation sickness, and increased lifetime risk for cancer, central nervous system effects, and degenerative diseases.
- ❖ Astronauts are exposed to ionizing radiation with effective doses in the range from 50 to 2000 mSv (milli-Sievert).
- ❖ Space radiation is of three types which are identified by their origin;
  - ➢ GCR which is produced by the acceleration of solar plasma by strong electromotive force on solar surface,
  - ➢ SEP which are produced by acceleration across the transition shock boundary of propagating coronal mass ejection
  - ➢ Trapped radiation which is produced near the magnetic field lines of earth.
- ❖ SEP has always been the primary concern for operation outside the earths protective magnetic shield but after space flights begin it was realized that GCR are much more harmful then SEP when astronaut leave earths protecting shield.
- ❖ Energy of SEP ranges from 10 MeV to 100 MeV and GCR ranges from 100s of MeV to 10 GeV.





- ❖ Different material (shielding) has been used to find the suitable material to protect the astronauts.
- ❖ The primary proton obeying GCR energy spectrum defined in has been incident on the vehicle in the galactic atmosphere.
- ❖ The primary and secondaries reaching to the phantom after passing through vehicle and shielding is given in table 1.
- ❖ Secondary particles are produced from the nuclear reaction that happen in shielding, this includes neutron, proton, mesons, gamma rays etc.

Table: 1

Result	Al	Polyethylene	Polystyrene	Water	No Shielding
Initial energy in shielding	981(MeV), 392(Counts)	991(MeV), 380(Counts)	991(MeV), 379(Counts)	1004(MeV), 375(Counts)	995(MeV), 1007(Counts)
Energy of primary reaching Phantom	762(MeV), 184(Counts)	774(MeV), 197(Counts)	789(MeV), 227(Counts)	796(MeV), 237(Counts)	970(MeV), 999(Counts)
Secondary particles reaching phantom	1572(Counts)	1955(Counts)	1902(Counts)	1858(Counts)	14(Counts)

Table: 2

Dose Calculation

Equivalent Dose:

H = Q D (Q = Quality factor, D = absorbed Dose)

Q = 10 (for proton)

Absorbed Dose :

$$D = \frac{\int_0^\infty f(E)dE}{\rho V}$$

ρ is detector density and V is the volume.

(S.N.L Sirisha http://dx.doi.org/10.14257/ijbsbt.2015.7.5.23)

Shielding dimensions: 1500*1500*50 cm³	Shielding Material	Density (g/cm3)	Expected dose (Sv)	Calculated dose (sV)
	Al	2.7 g/cm3	130	140
	Polyethylene	0.94	113	117
	Polystyrene	1.04	--	107
	Water	1	--	113

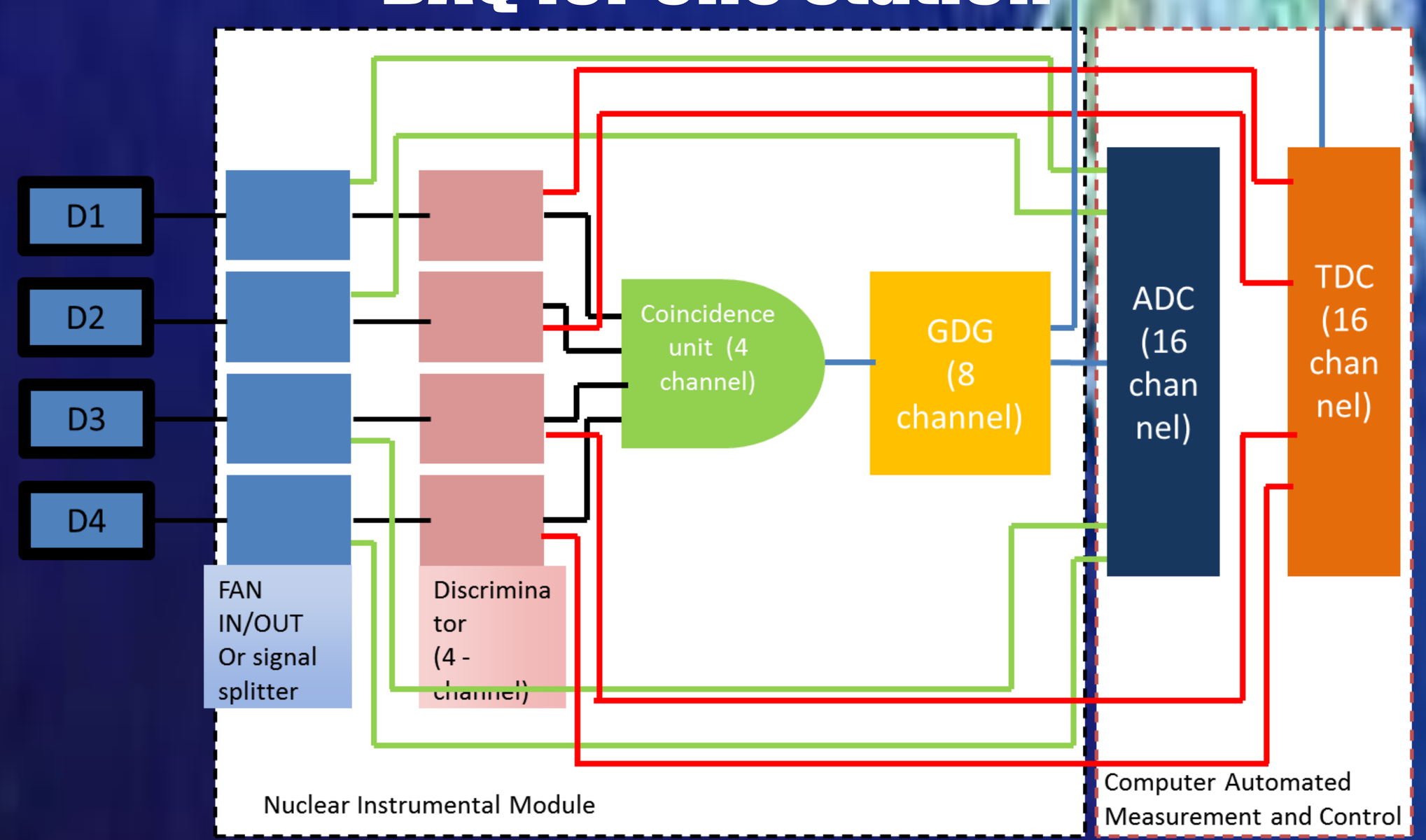
CONCLUSIONS

- ❖ Aluminium structure attenuate radiation effects over most of the range of depth used in human vehicles and Poly materials are material with high hydrogen (H) which is efficient to break GCR particles into small fragments and low atomic number (Z) which produce more secondary particles.
- ❖ From this study Aluminium (Al) is found to be a poor shielding material as far as dose equivalent is concerned.
- ❖ Polyethylene, Polystyrene are examined as potentially useful material and demonstrates important advantages as an alternative to Al.
- ❖ It is observed that equivalent dose is minimum in Polystyrene as compared to the other material.(table 2)

FUTURE REARCH

To setup a Quantum Field Array under the MoU between Tata Institute of Fundamental Research, Mumbai and Dayalbagh Educational Institute, Dayalbagh.

DAQ for one station



Objectives:

1. To design the user interface of detector station, data analysis techniques and simulations of Extensive Air Shower at our location.
2. Study the cosmic ray energy spectrum and its composition using the muon multiplicity distribution.
3. Variation in count rate related to temperature, pressure, time and angle.
4. Studying energy threshold, angular and energy resolution and sensitivity

References

1. Francis A.Cucinotta et al.: Space radiation risks to the central nervous system. Life Sciences in Space Research 2 (2014) 5469.
2. L. Narici 1 et al.: ALTEA: Anomalous Long Term Effects in Astronauts. A probe on the influence of cosmic radiation and microgravity non central nervous system during long flights. Adv. Space Res. Vol. 31, No. 1, pp. 141-146, 2003
3. Tatsumi Koi, Dennis H. Wright, Gunter Folger: Validation of Hadronic Models in Geant4 Hadronic Shower Simulations Workshop 2006, Batavia.EARCH

CONTACT

Kajal Garg
Research Scholar
Department of Physics and Computer Science,
Faculty of science
Dayalbagh Educational Institute
Email: kajalgarg.dei@gmail.com