High Energy γ-ray Observation

Team Blue Daikon

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Contents

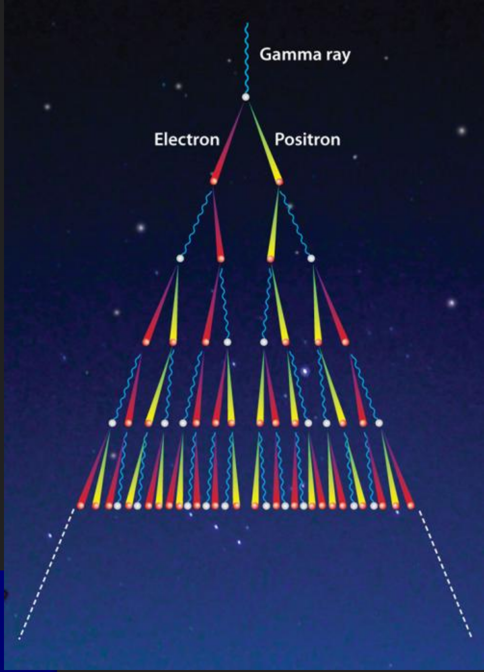
Introduction

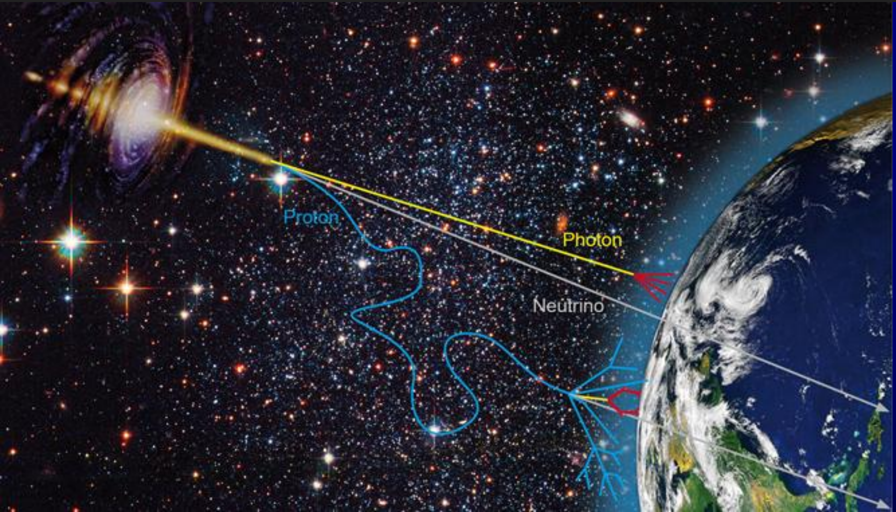
Introduction

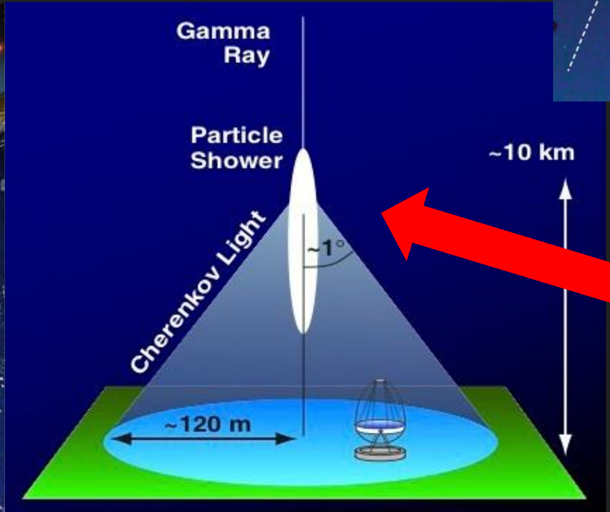
Gamma ray is a wonderful tool to map universe.

High energy gamma ray produces Air shower.

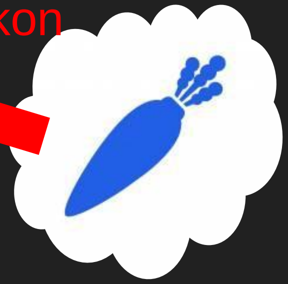
Air shower emits Cherenkov light (Blue Daikon) at ~10km.







Looks like Daikon



Aim

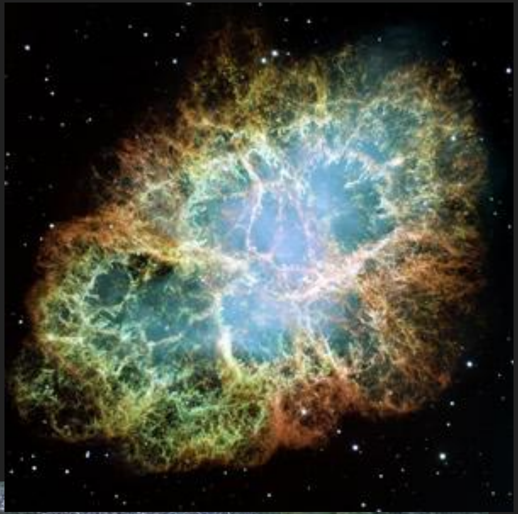
Aim

Detect Cherenkov radiation from extended air showers

With gamma rays we can do astrophysics

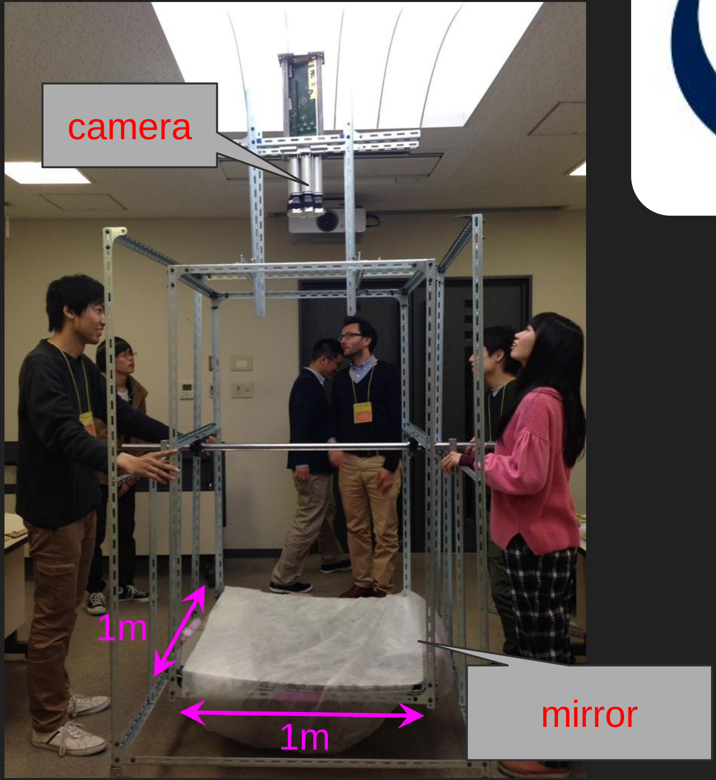
Cosmic rays are our background, BUT:

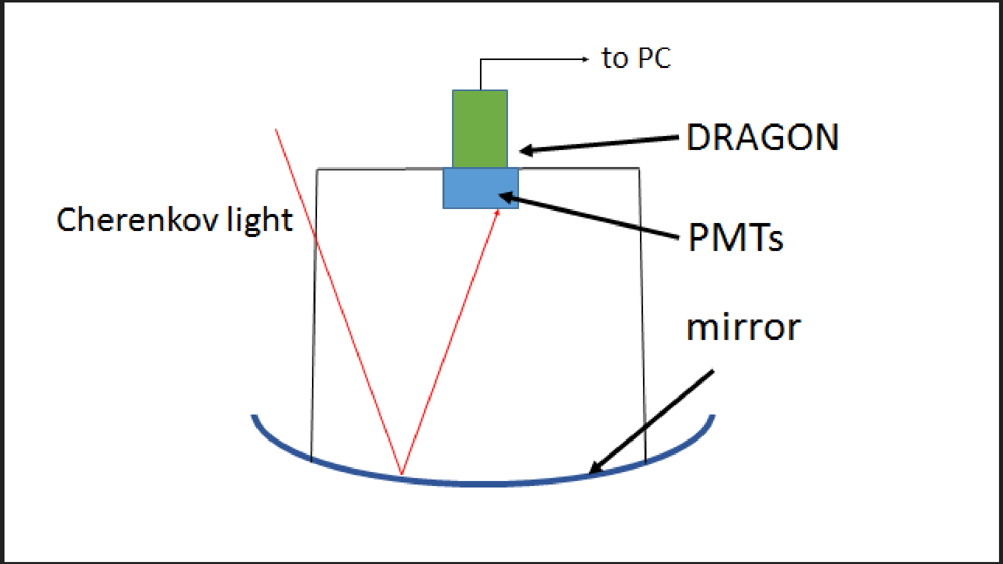
we can estimate the energy threshold by measuring the rate of high energy cosmic-ray at Kashiwa Campus



Set up

Set up


camera
1m
1m
mirror


to PC
DRAGON
Cherenkov light
PMTs
mirror

How PMT works

The light guide is for collecting photons efficiently.

In a PMT, photoelectrons are produced with photoelectric effect.

Electrons are multiplied by dynode system applying HV. Typical gain = 40000

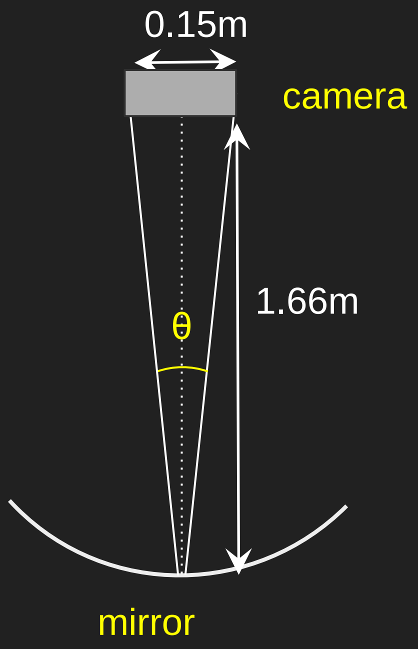
PMTs are covered with Alminium cilynders to shield photoelectrons from geomagnetism.

About telescope

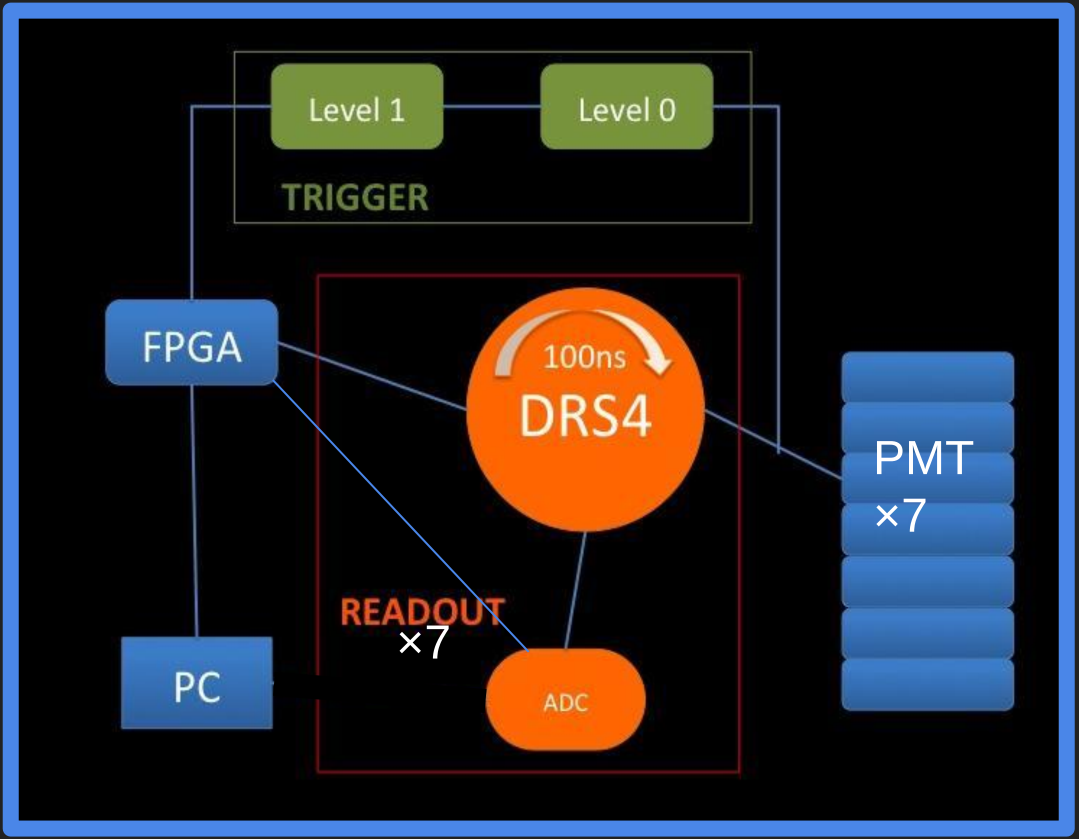
We used a spherical mirror. (Ideally the mirror should be parabollic.)

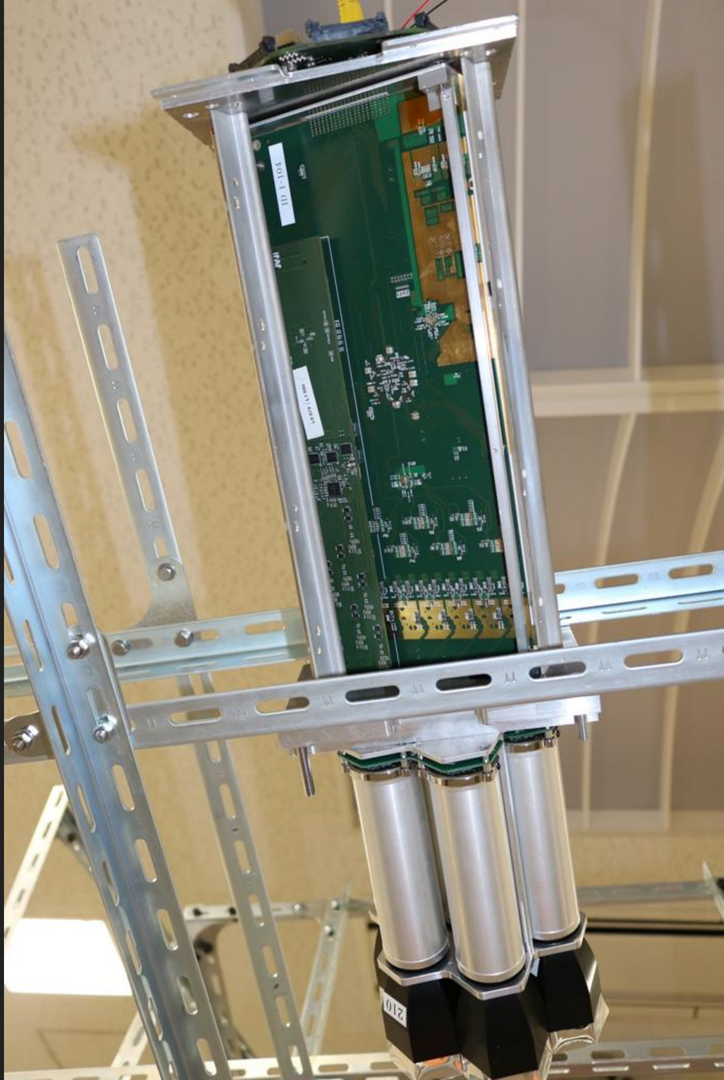
Focal length 1.66m (we measured this ourselves!!)

Field of view θ=5° (this we calculated!)



The Role of Dragon ver.5



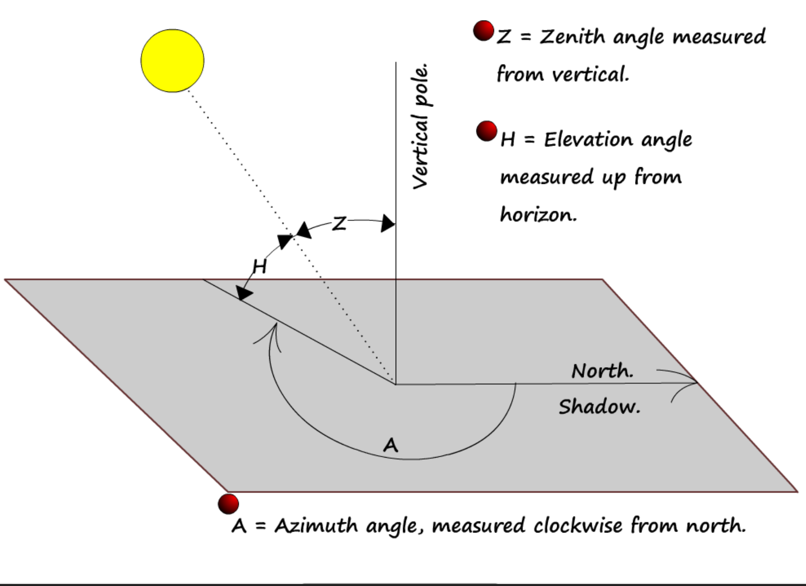


Observation

Observation

We Observed cherenkov light twice

at 3/9 and 3/10. Condition:

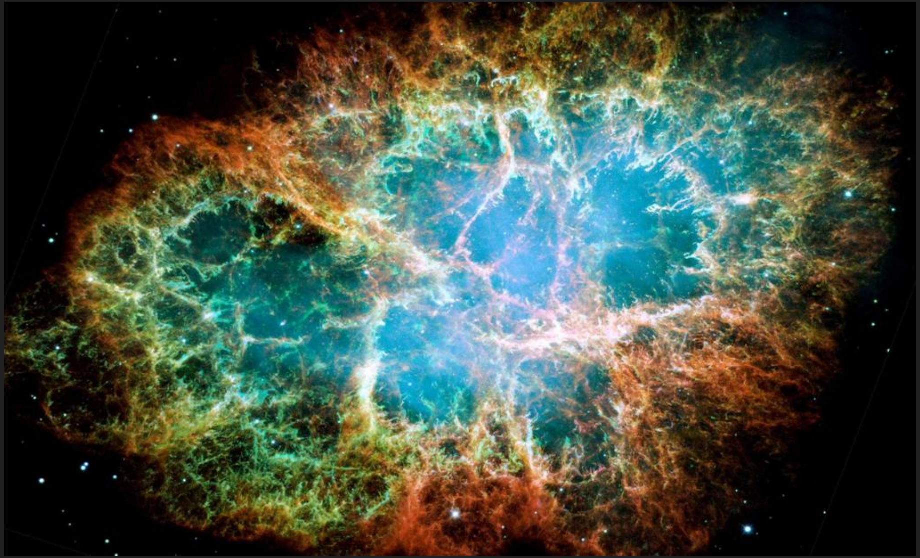


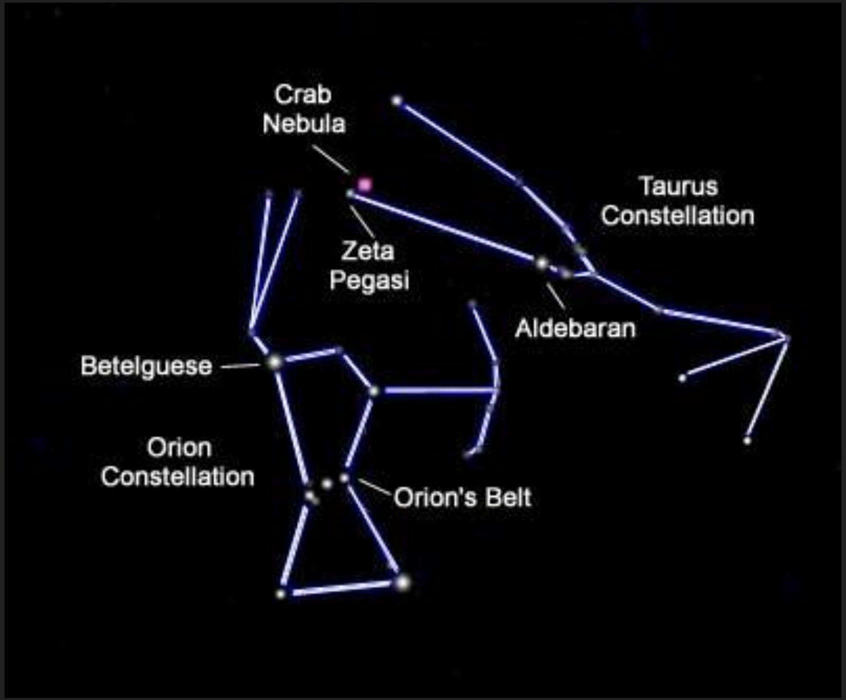
<first observation>
2017 March 9th
PM9:00 ~ PM10:00
moon illumination : 89%
weather : clear sky (no clouds)
azimuth angle : 340°(Orion;north)
zenith angle : about 20°
PMT-mirror distance : 1.72m

<second observation>
2017 March 10th
PM10:30 ~ PM11:00
moon illumination : 95%
weather : clear sky
azimuth angle : 250°(crab nebula;southwest)
zenith angle : about 30°
PMT-mirror distance : 1.66m

Target: Crab Nebula

known as a stable gamma ray source.





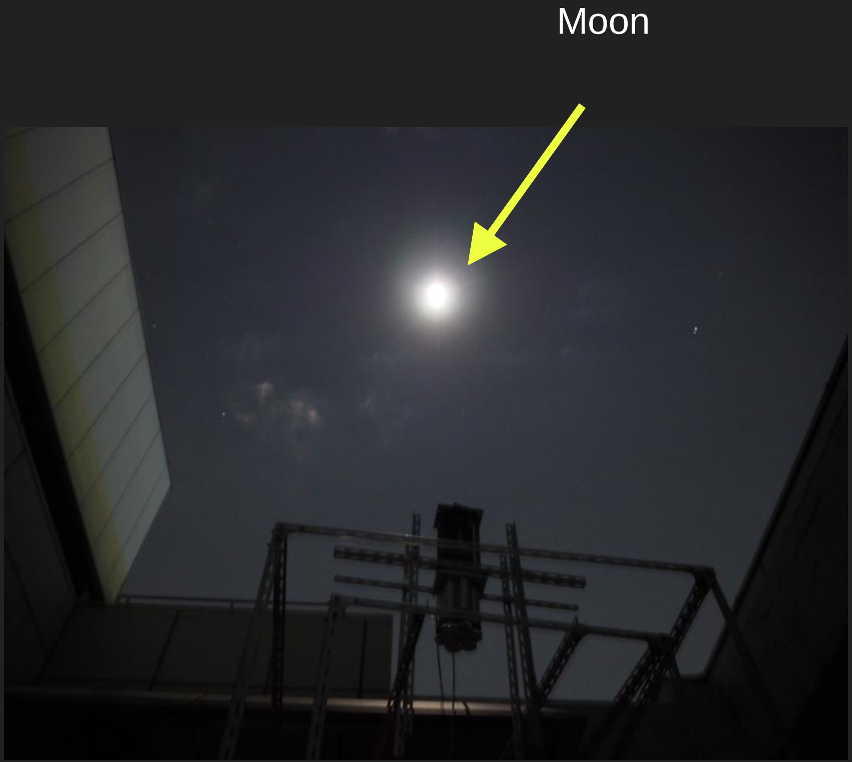
Procedure of the Observation

1) Fix the position of the telescope

2) Calibrate PMTs

3) Decide the Threshold

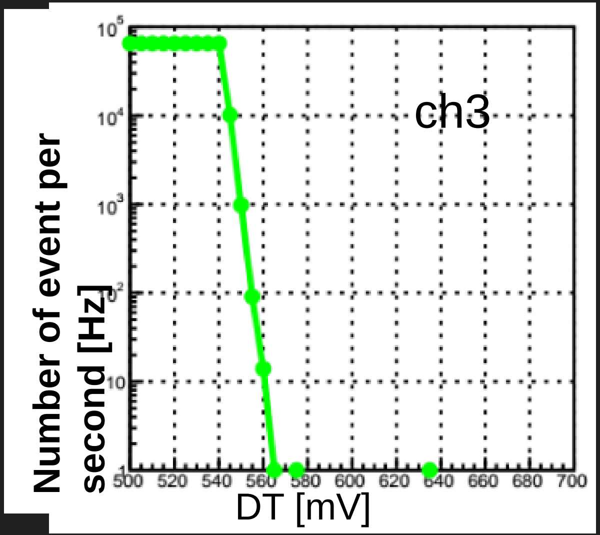
4) Observation

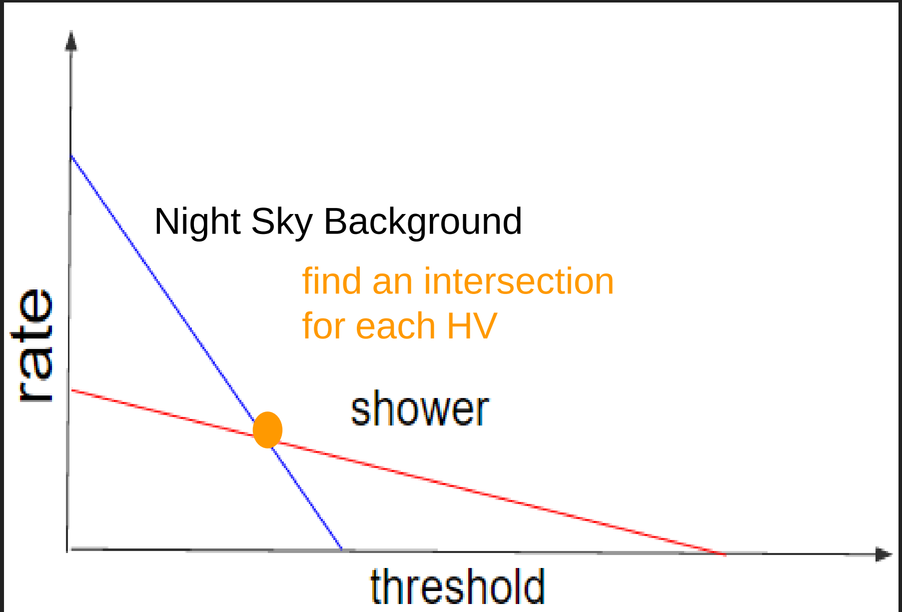


Calibration

Flat Fielding

Equalise the gain of PMTs.





Calibration

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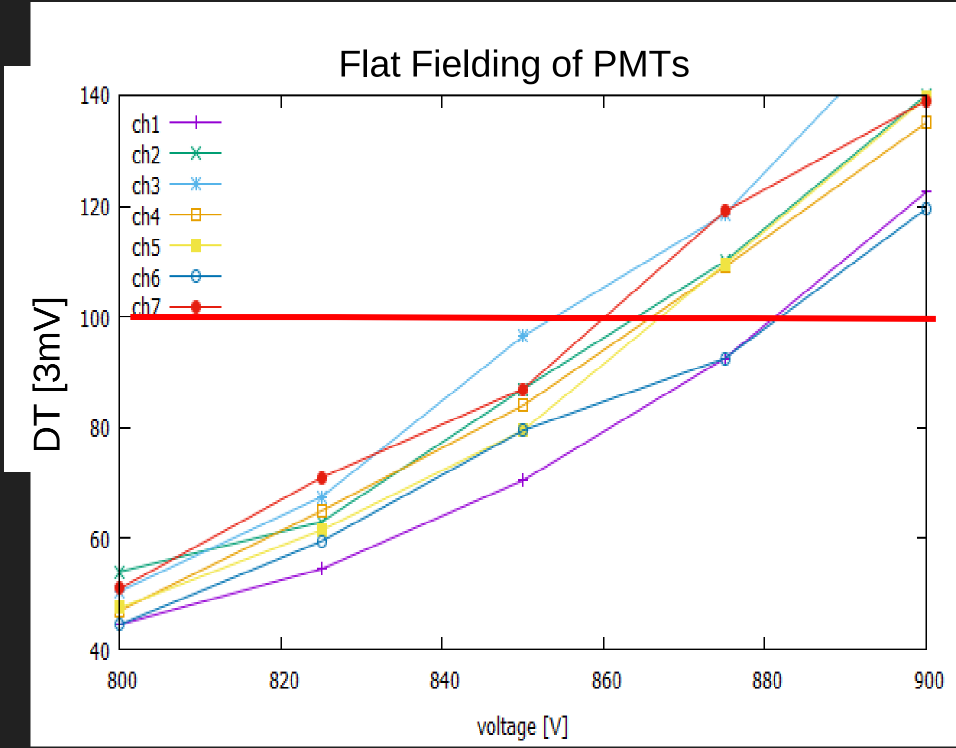
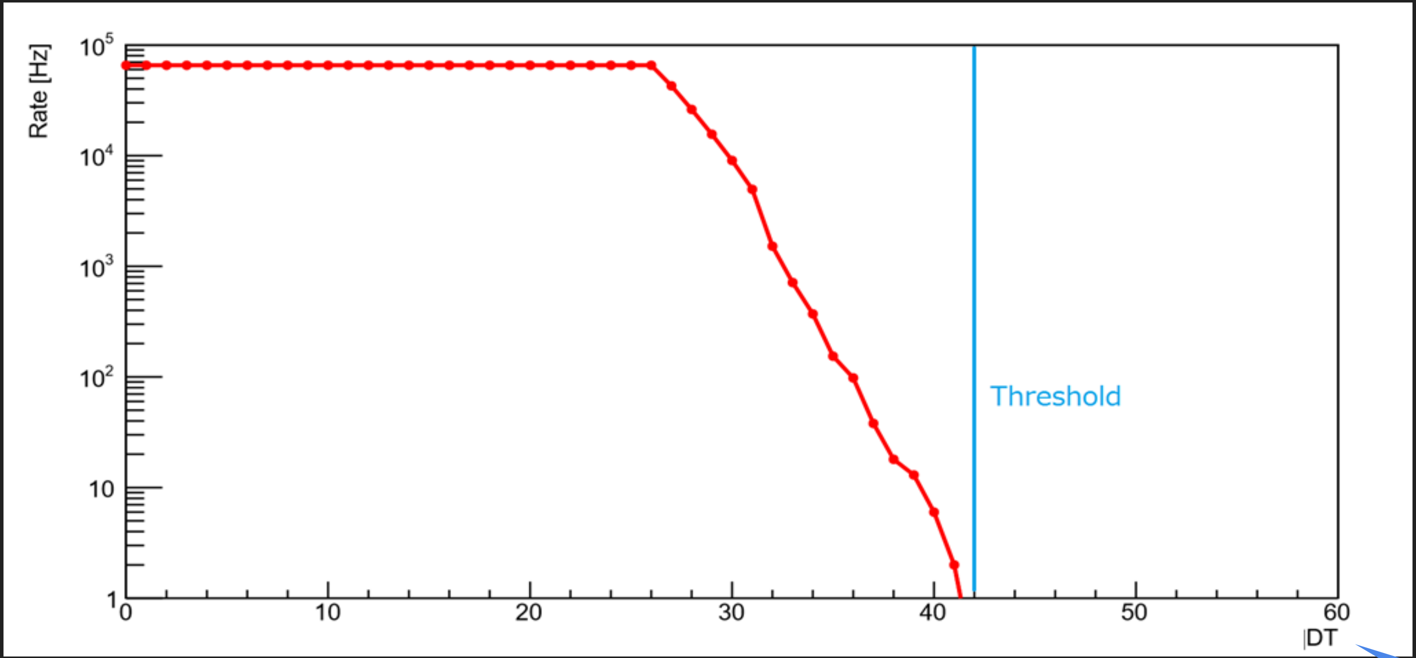
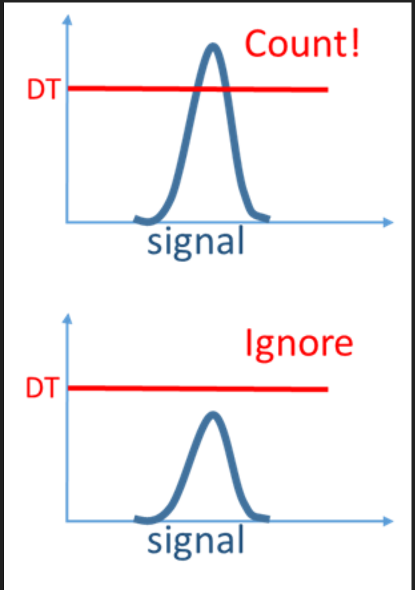
Equalise the gain of PMTs.



Threshold (Camera trigger)





1DT=5mV

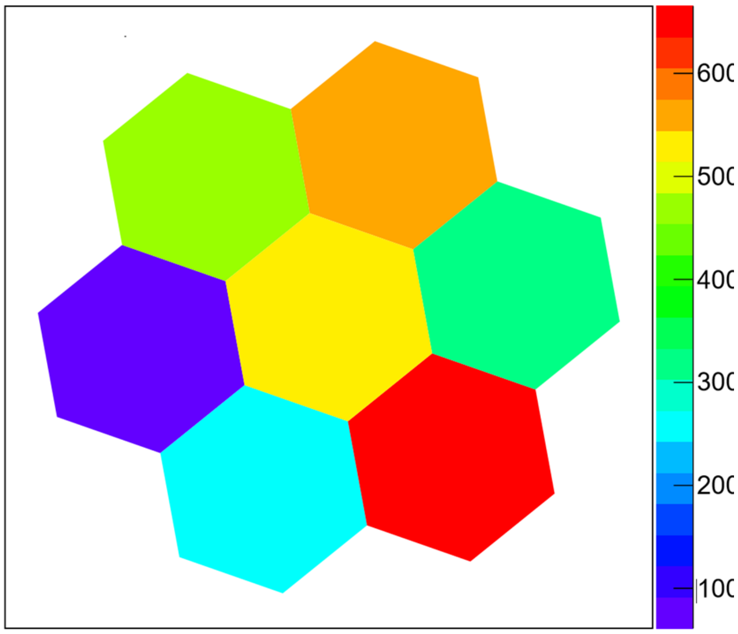
We determined the threshold by L1 scan.

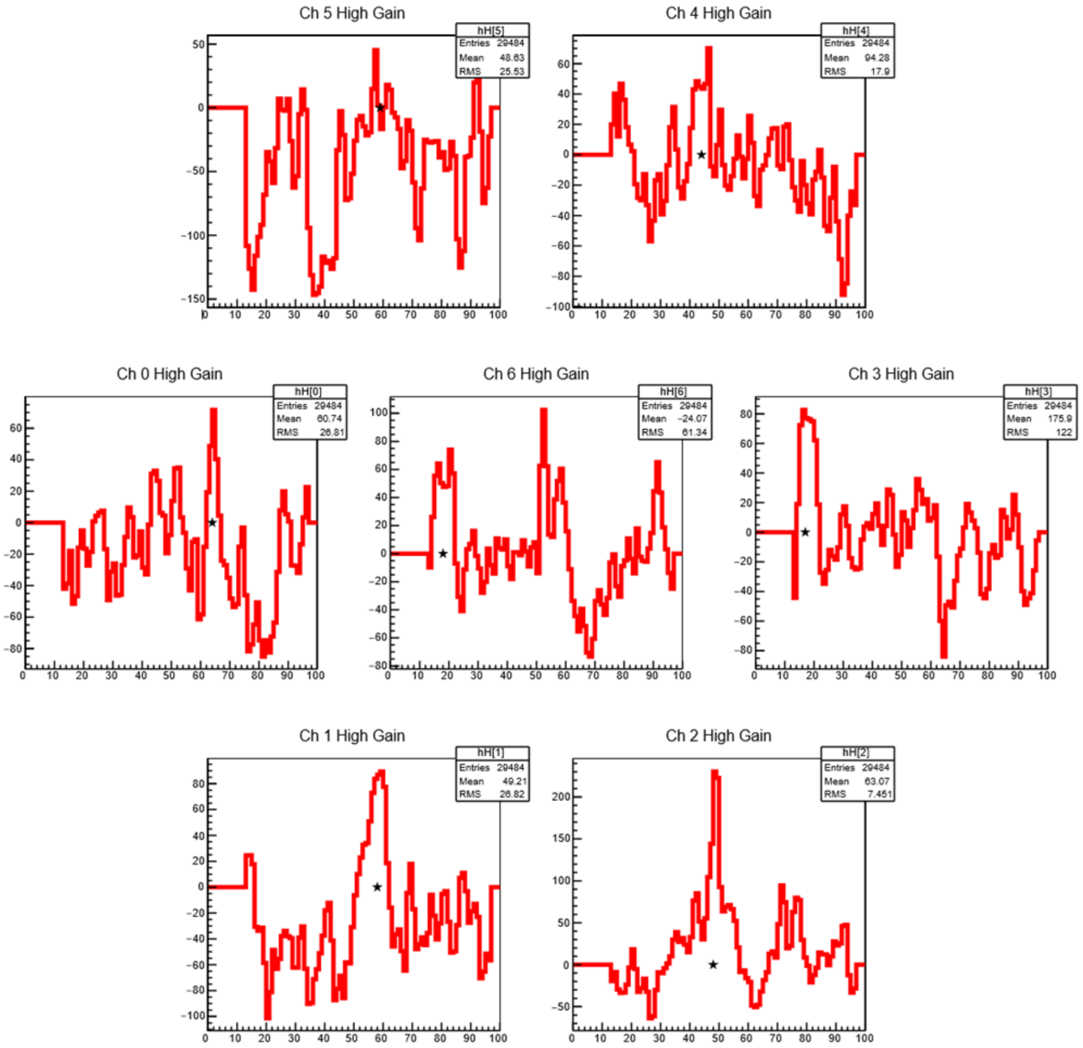
(The threshold correponds to 20 photons.)

Results & Discussion

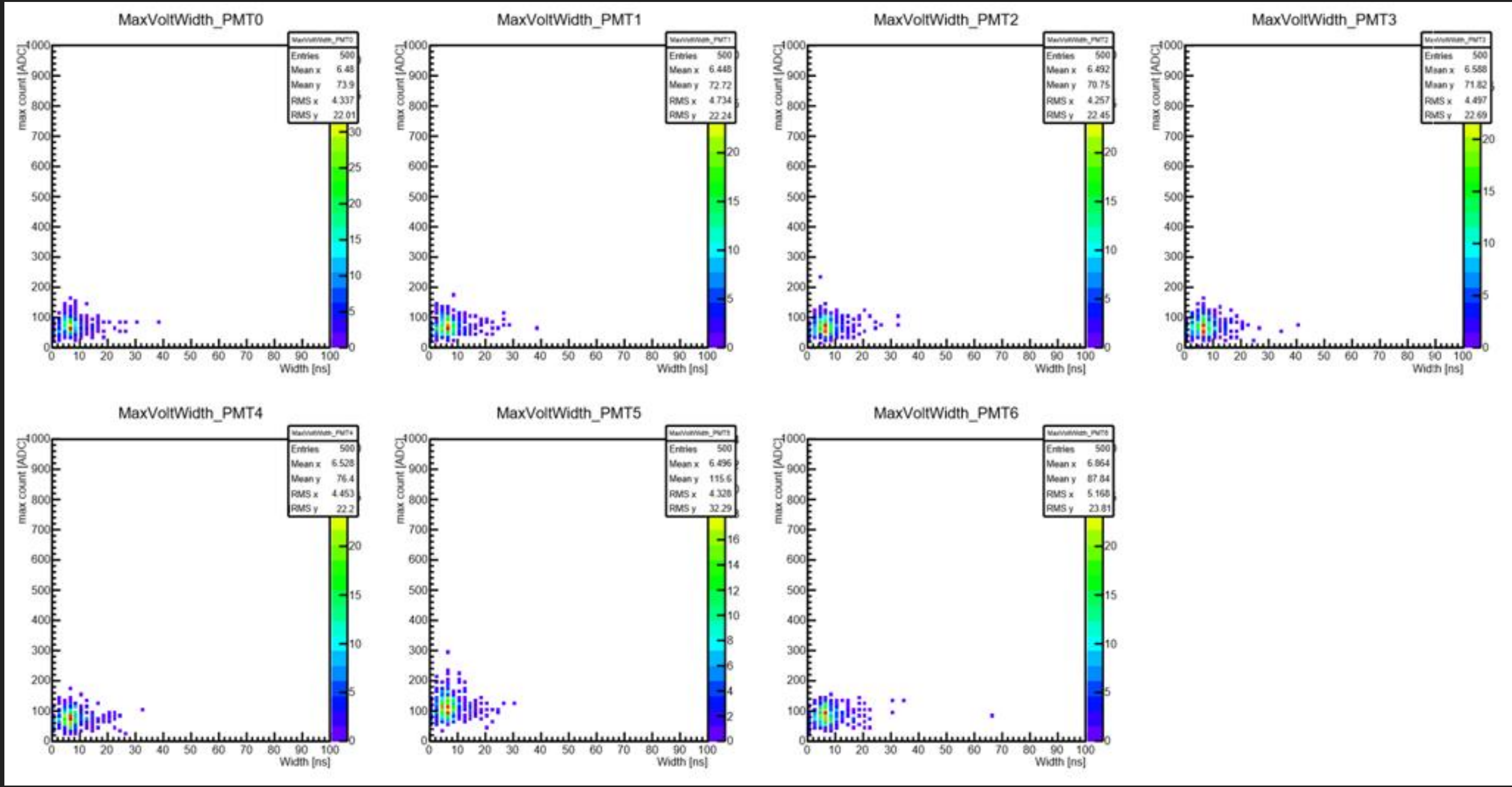
Results

Front View (Charge)

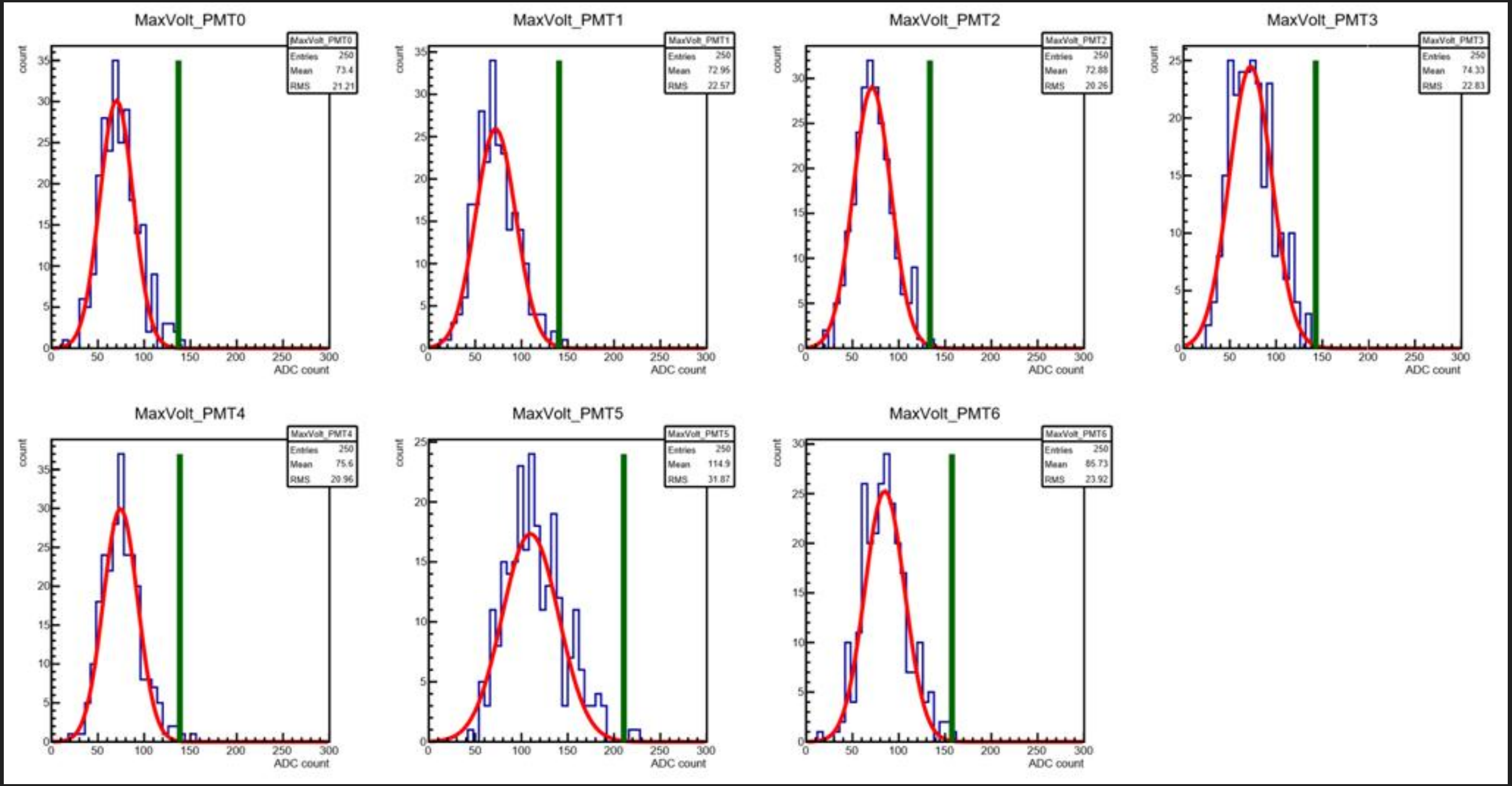




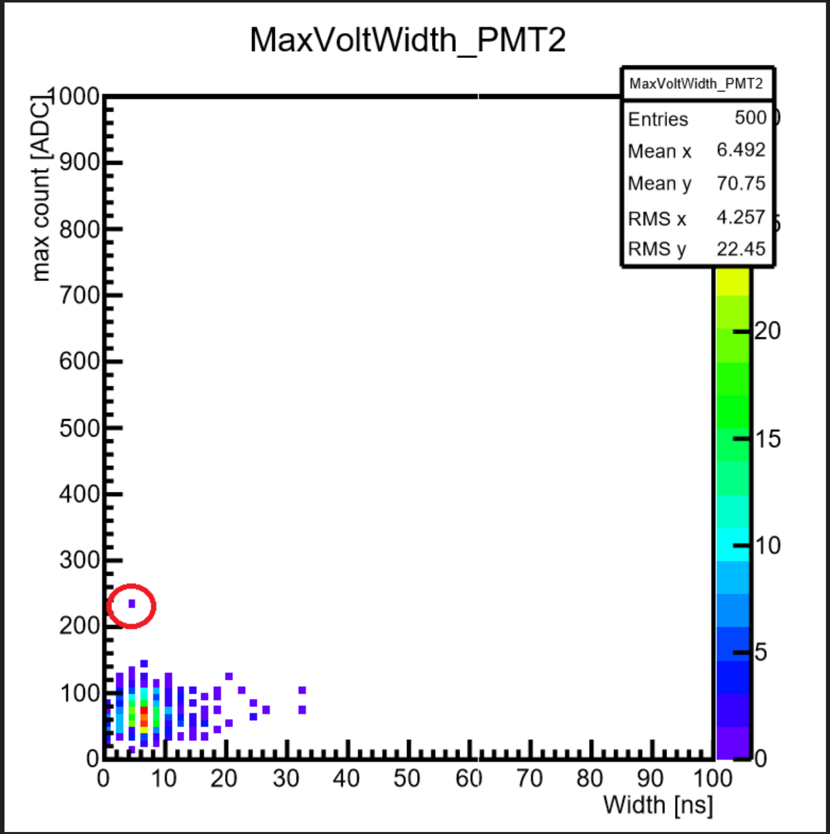
Beautifulness



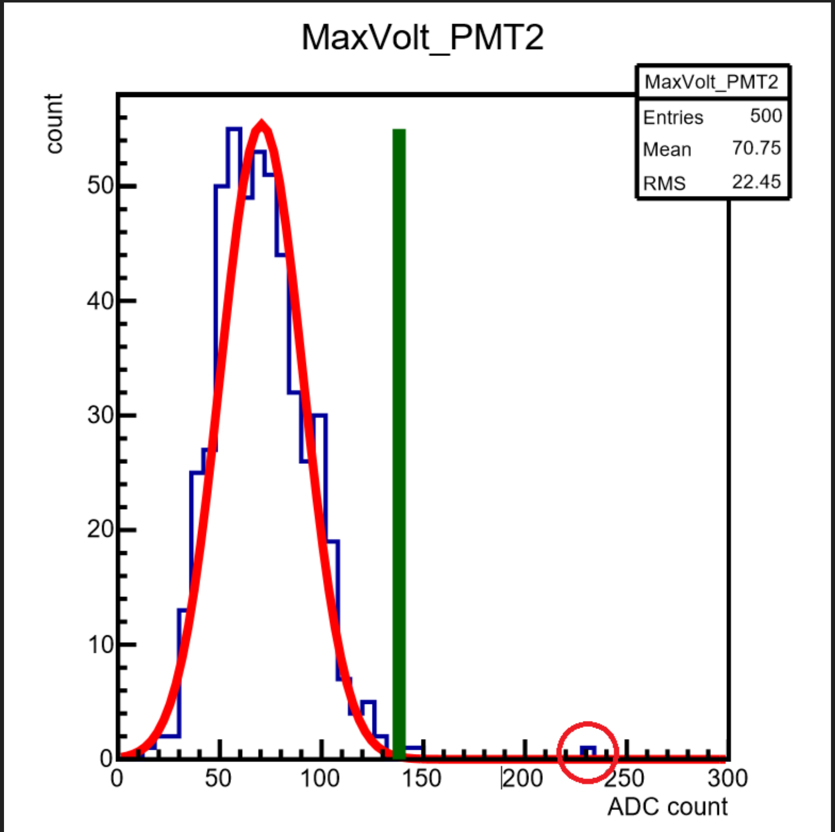
Histogram of events



Detection

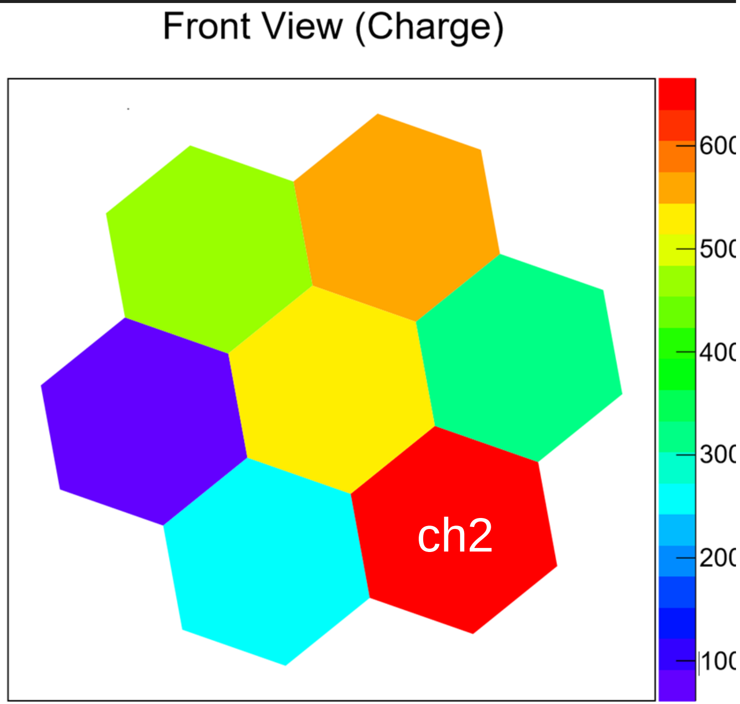


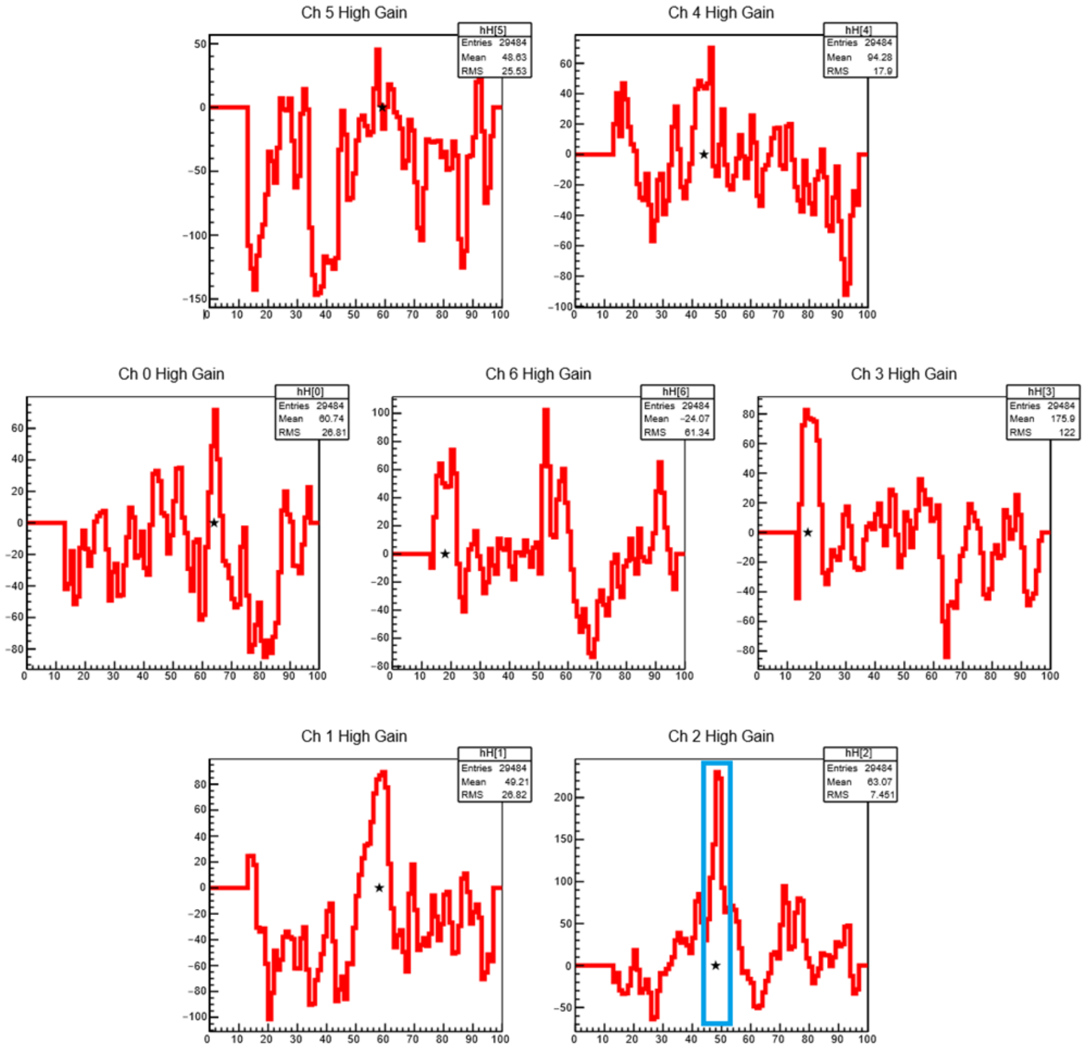
MaxVoltWidth_PMT2
MaxVoltWidth_PMT2
Entries 500
Mean x 6.492
Mean y 70.75
RMS x 4.257
RMS y 22.45
max count [ADC]
Width [ns]



MaxVolt_PMT2
MaxVolt_PMT2
Entries 500
Mean 70.75
RMS 22.45
count
ADC count

Detection


Front View (Charge)
ch2
600
500
400
300
200
100


Ch 5 High Gain
hH[5]
Entries 29484
Mean 48.63
RMS 25.53
Ch 4 High Gain
hH[4]
Entries 29484
Mean 94.28
RMS 17.9
Ch 0 High Gain
hH[0]
Entries 29484
Mean 60.74
RMS 26.81
Ch 6 High Gain
hH[6]
Entries 29484
Mean -24.07
RMS 61.34
Ch 3 High Gain
hH[3]
Entries 29484
Mean 175.9
RMS 122
Ch 1 High Gain
hH[1]
Entries 29484
Mean 49.21
RMS 26.82
Ch 2 High Gain
hH[2]
Entries 29484
Mean 63.07
RMS 7.451

Detection

Day 1

Observed for 50 minutes

Counted 950 events

Detected 7 showers!

Day 2

Observed for 24 minutes

Counted 1250 events

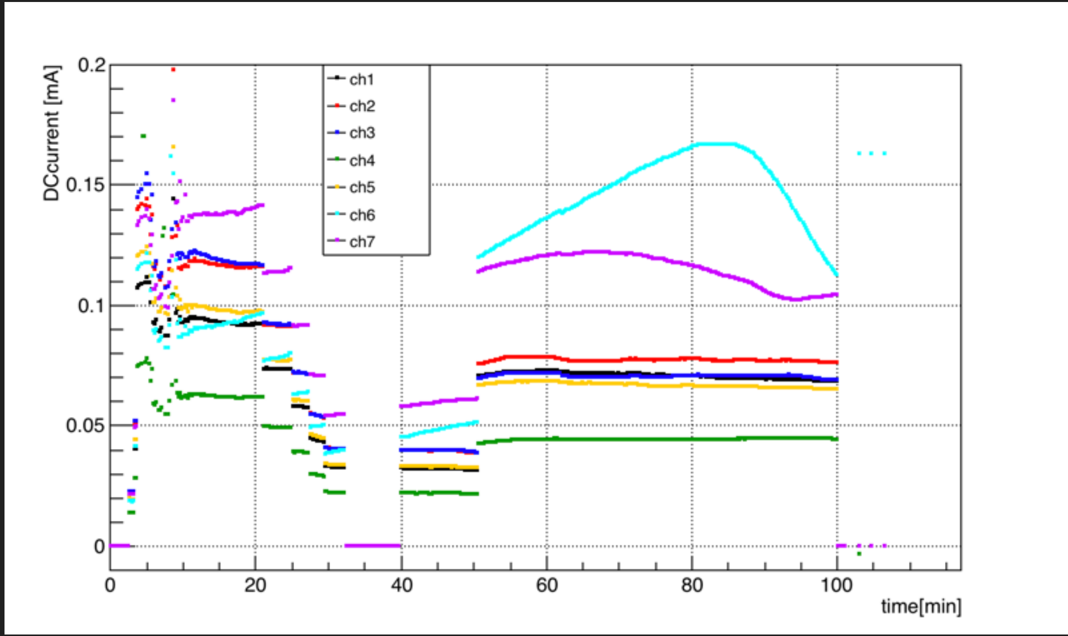
Detected 15 showers!

DC light curve day1

DC light curves of 5 PMT were constant.

2 of them were changing gradually.

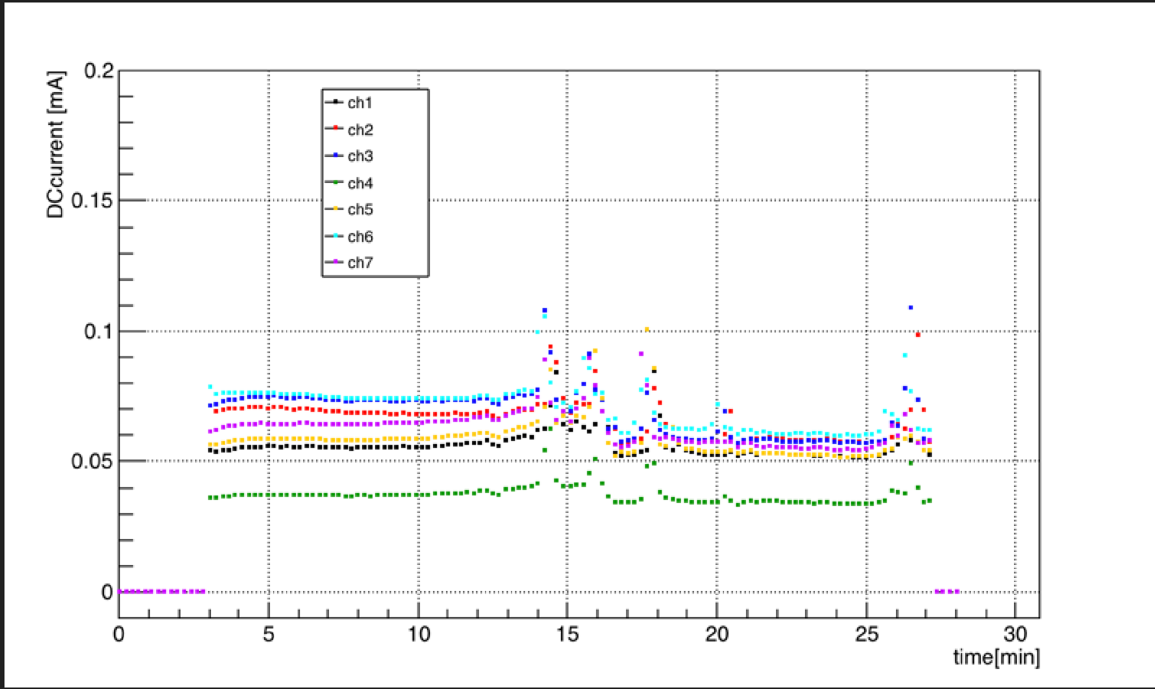
Moon light and the power can be the cause of the change.



DC light curve day2

DC current is stable.

at T = 15 min, moon came into the field of view, so we moved the telescope and the DC current fluctuated.



Detection of air shower

Most of the air shower were in only one pixel.

Field of view angle for air shower is just 0.2°, it’s reasonable.

Moon light and power light were huge background.

Because of low pixels, we could not distinguish gamma shower from hadronic shower.

We could not determine the direction of air shower.

Minimum Energy Corresponds to Threshold

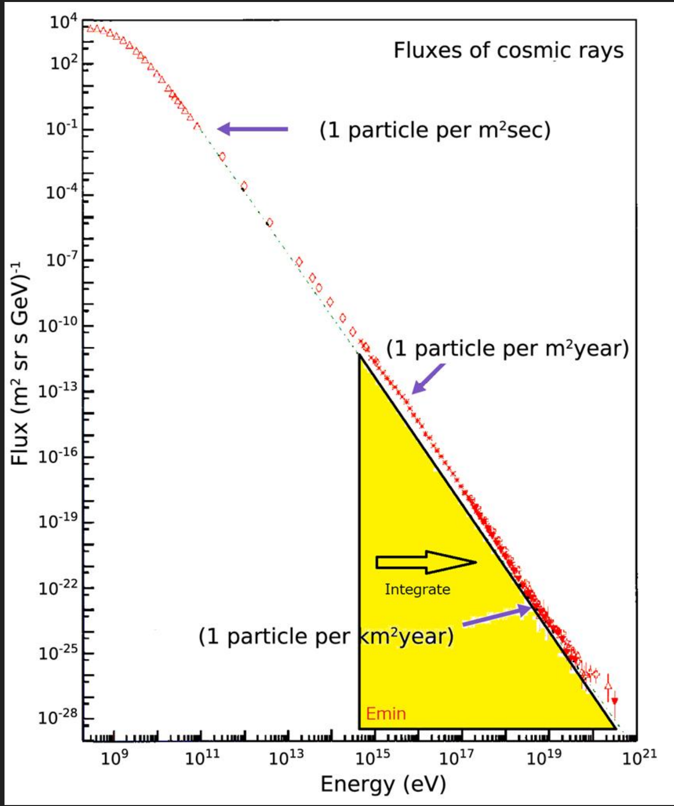
Compare the data of cosmic ray flux and our observation.

Effective area is 3×10^3 [m^2 sr]

We detected 22 showers.

We observed for 24 minutes.

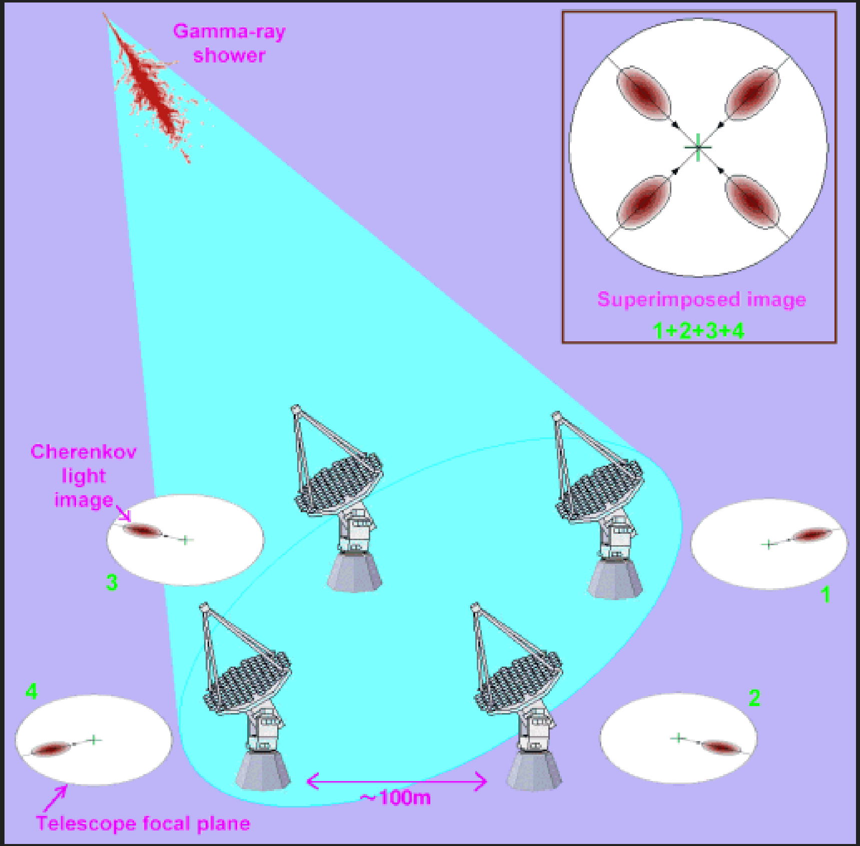
Corresponding Energy was 200TeV !



Future Study

Future Study

- Weather, Moon phase
- Set the angle of telescope correctly
- More pixels to distinguish gamma shower from hadronic shower, and to determine the direction of air shower
- More telescopes, Stereo Imaging



Conclusion

Conclusion

We

Detected 18 showers / h

By the Telescope we built!

CTA is Great!!!

ct

cherenkov telescope ~~array~~

≪

cta

cherenkov telescope array

Acknowledgement

Masahito Teshima

Daniel Mazin

Takayuki Saito

Satoshi Fukami

Tomohiro Inada

Hayato Kuroda

Taku Kumon

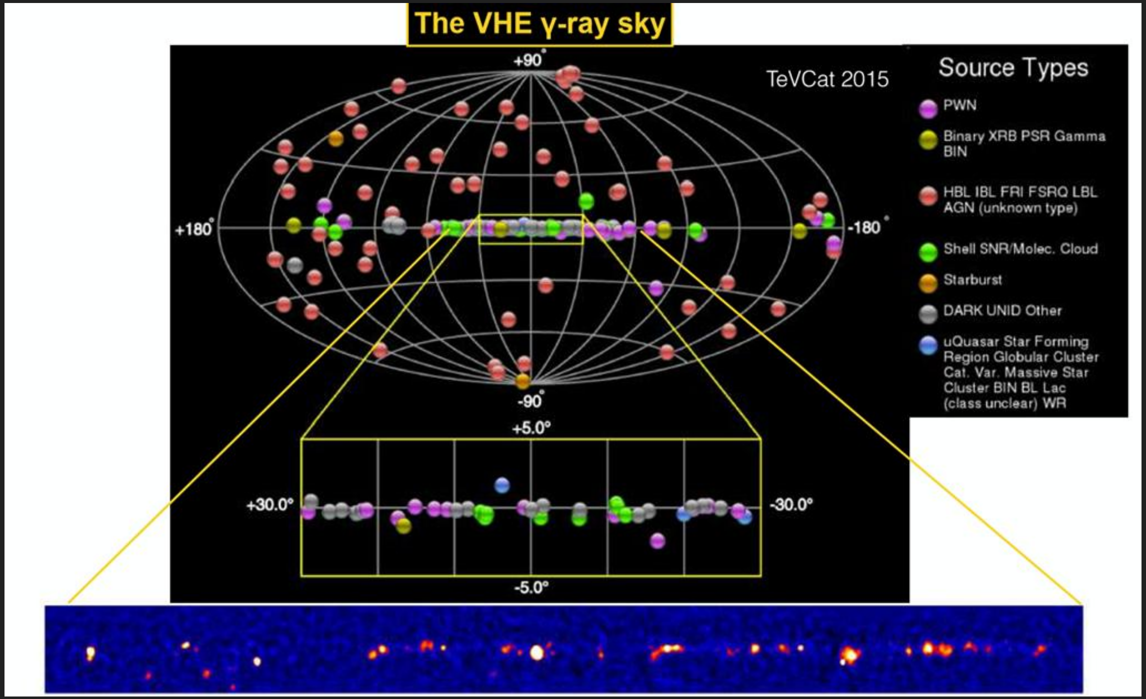
Appendix

Origin of gamma ray

- Gamma ray burst
- Super nova remnant
- DM + DM $\rightarrow \gamma\,\gamma$

Inverse Compton

Fermi acceleration

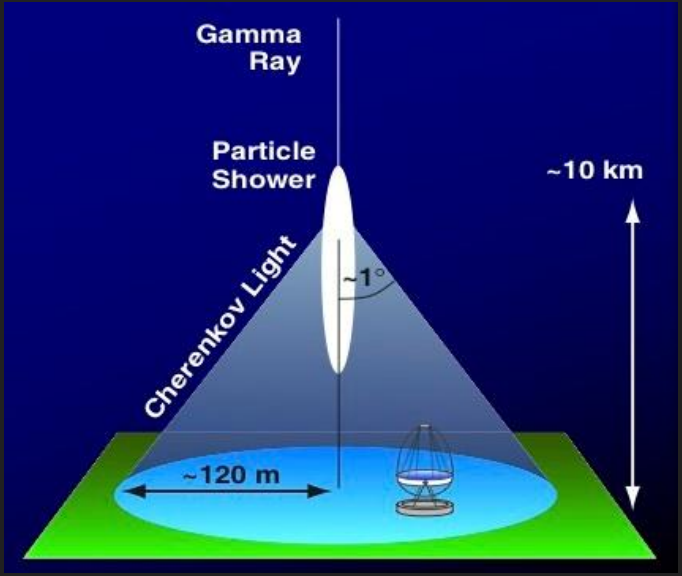


Cherenkov light

assume that the speed of shower is c

length of air shower is 1 km

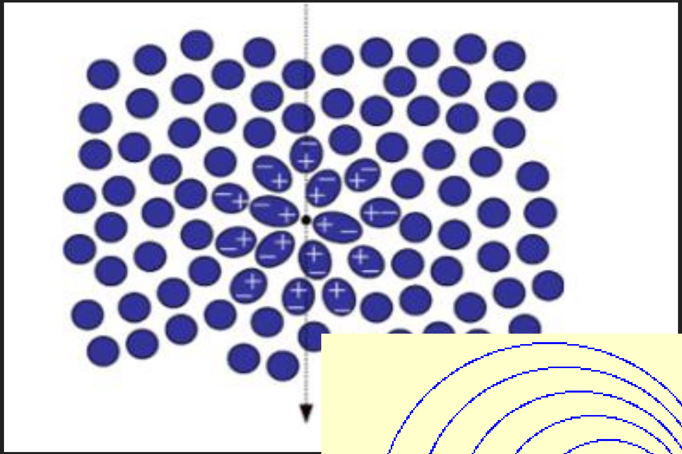
Atmospheric refractivity: n = 1.000292

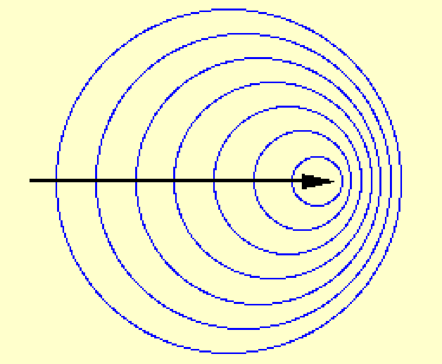


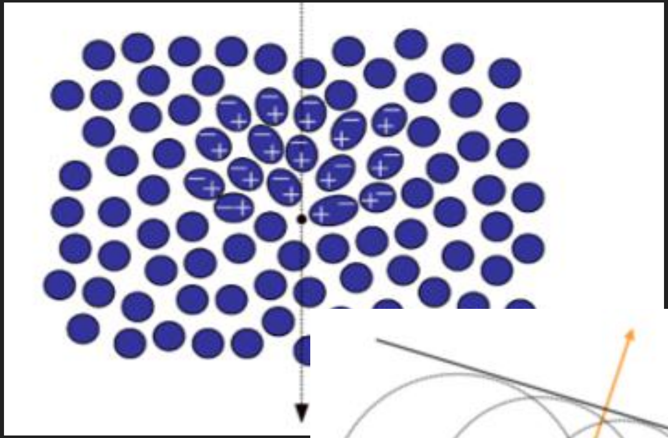
δt = 1 km / c - 1km /(c/n) =1km × (n - 1) / c ~ 1 ns

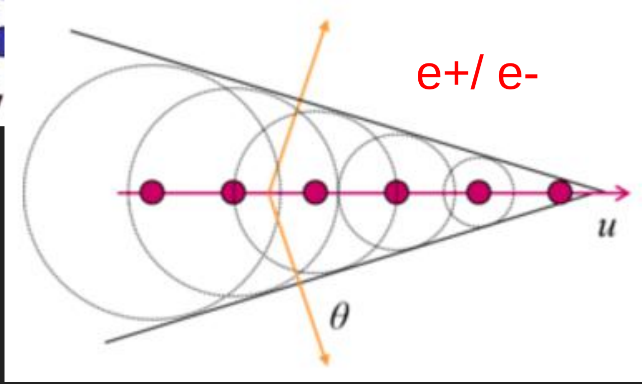
Cherenkov angle θ: $\cos\theta = 1 / (n\beta) \sim 1/1.000292$ $\therefore$ $\theta \sim 1°$

Atmospheric cherenkov radiation









Dead Time

Dead time ~ 4 μs(ring buffer) + 3μs(ADC Time)

Dead time (~10 μs) is at most 10 % (events 10 k Hz)

1/10kHz = 0.1 ms ∴10 μs/0.1ms ~ 10%

I this experiment, event rate was only 10 Hz ∴ 0.01%

You can ignore the effect of Dead time.

Gamma shower and Hadronic shower