

Taiwan Astroparticle Radiowave Observatory for Geo-synchrotron Emissions (TAROE)

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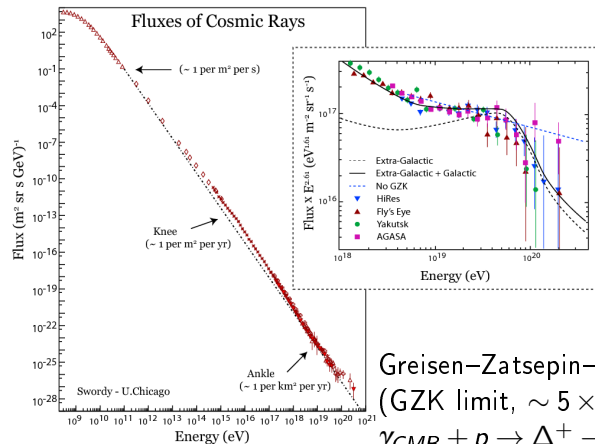


Outline

- 1 Ultra-High Energy Cosmic Ray (UHECR)
 - Cosmic Ray
 - Air Shower
- 2 TAROE Experiment
 - Concept
 - TAROE-1



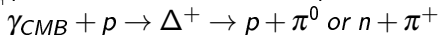
Flux of Cosmic Ray



$$\frac{d\Phi}{dE} \propto E^{-3}$$

Ankle: ~ 1 per km² per yr

Greisen-Zatsepin-Kuzmin limit
(GZK limit, $\sim 5 \times 10^{19}$ eV)



Cronin, J. W., Gaisser, T. K., & Swordy, S. P.
1997, Scientific American, 276, 32
Waxman, E. 2009, Nuclear Physics A, 827, 15

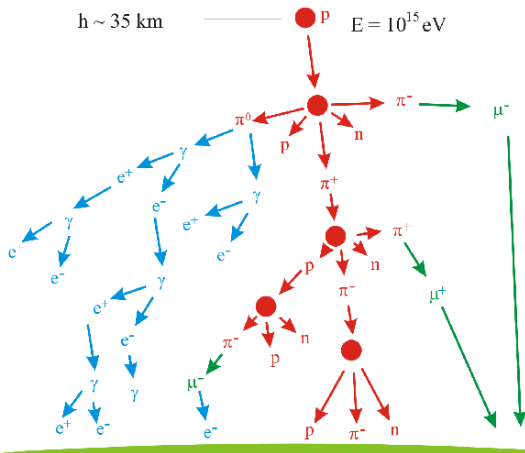


Why studying UHECR?

- Cosmic rays with ultra-high energy ($> 5 \times 10^{19} \text{ eV}$) were detected.
(Fly's Eye, AGASA)
 - Some hot spots near by us?
 - Heavy nuclei?
- Ex. Pierre Auger Observatoy: 100 events / 5 year



Extensive Air Shower



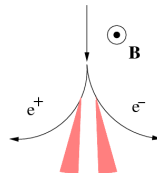
- Ex. A 10^{15} eV proton could induce shower with 10^6 secondary particles.



Radio Emission Mechanisms

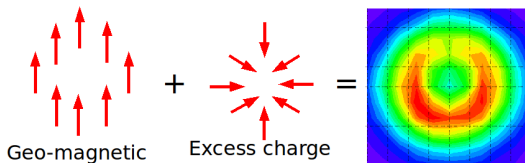
- Geo-magnetic radiation (geo-synchrotron radiation)

- 1 The synchrotron radiation induced from the e^- and e^+ due to the geomagnetic field.
- 2 Linear polarized along Lorentz force direction.



- Excess charge (Askaryan effect)

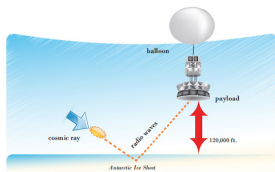
- 1 The coherent cherenkov radiation from excess electrons.
- 2 Radially linear polarized.



- The radio emission induced from air shower is dominated by the geo-magnetic radiation.



Experiment using Radio Frequency



(a) ANITA



(b) LOPES



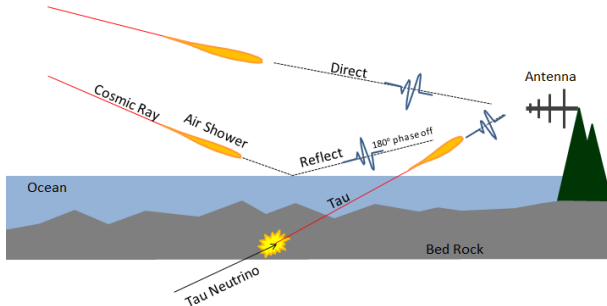
(c) AERA

- Advantage of RF:
 - 1 Signal is stronger at low frequency band.
 - 2 100% duty cycle.
- ANITA: ~16 events within one month



The Idea of TAROE

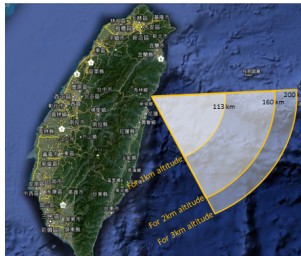
- The advantage of RF is significant.
- Using antennas pointed toward the ocean. not only the direct signal could be detected, but also the ocean-reflected one!



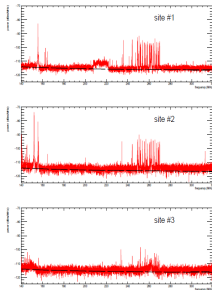
- In addition to the cosmic ray, it also has possibility to detect the Earth-skimming tau neutrino.



TAROE Field of View



(d) TAROE FOV.



(e) Noise survey.

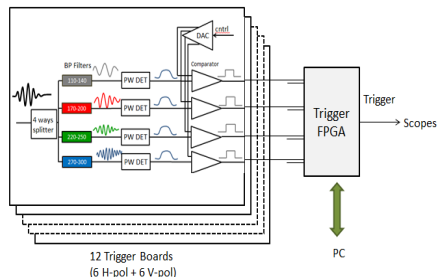
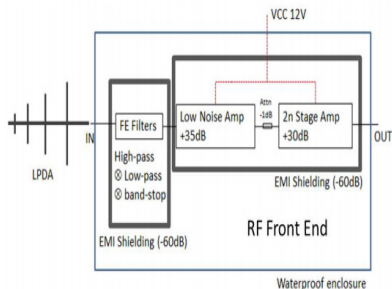


(f) TAROE-1 Site.

- To build the antenna on the high mountain at the east of Taiwan.
- Quiet RF band.
- TAROE-1: A prototype station.
 - Mt. Young-Shih, 1 km elevation near the ocean.



System Architecture



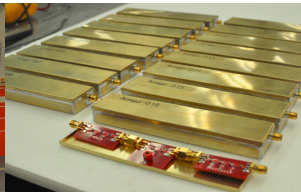
LPDA -> Filter -> Amplifier -> Sub-Band Filter



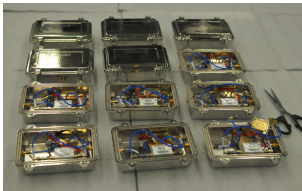
Hardware



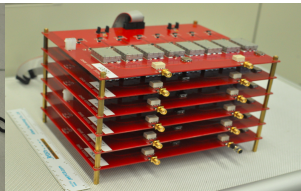
(g) 12 LPDAs



(h) Filters



(i) LNAs



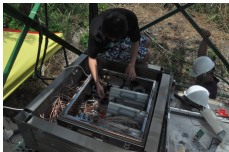
(j) Trigger boards



Installation



Hang test.



DAQ box.



Installation



Tower

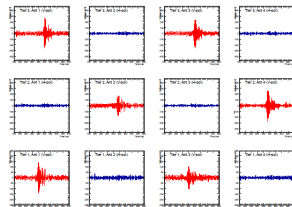


Calibration

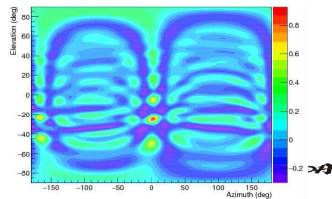
- The system was calibrated with the man-made pulse.



(k) Calibration system

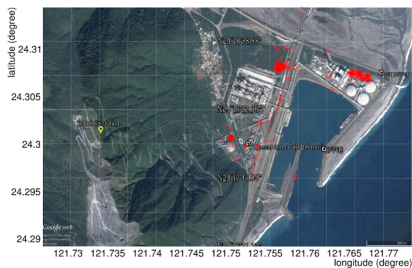


(l) Result in oscilloscope

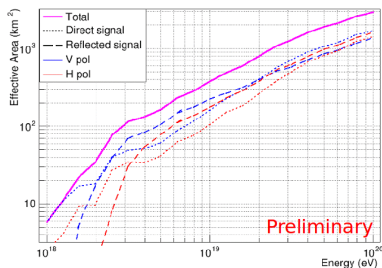


(m) Interferometry image

TAROE-1 Result



(n) Noise pulse measurement.

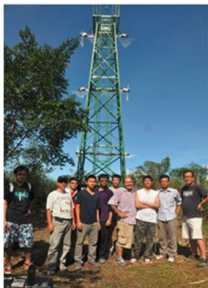


(o) Expected effective area.

- Noise sources are well identified, mostly came from the town.



Summary



- A detection system made by ourselves only!
- The detection concept of TAROG is well-demonstrated in TAROG-1.
- The TAROG-2 will be built on October.
- Thanks for all of our members!

C.-C. Chen, C.-H. Chen, C.-W. Chen, P. Chen, S.-Y. Hsu, J.-J. Huang, M.-H. A. Huang, T.-C. Liu, J.W. Nam, Y.-S. Shiao, M.-Z. Wang, S.-H. Wang, T.-L. Zhou