1st Year PhD Talk

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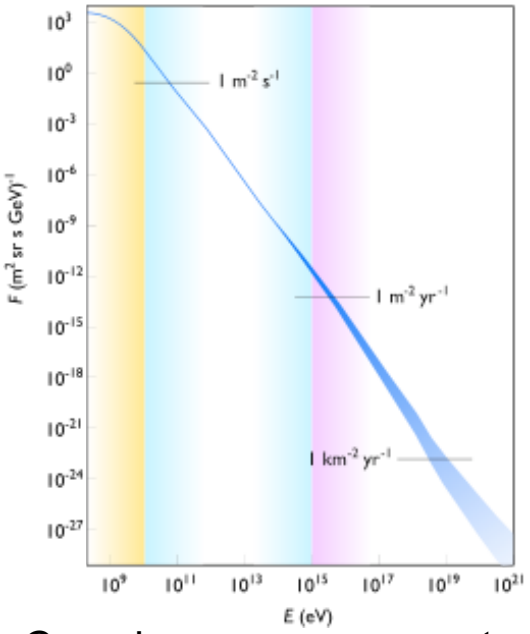
  - Detection
- The ANITA experiment
- ANITA I - II improvements/checks
  - Triggering
  - Prioritizer
- ANITA I Data
  - Power spectra
- Conclusions & Future goals

UHE Physics - Motivation

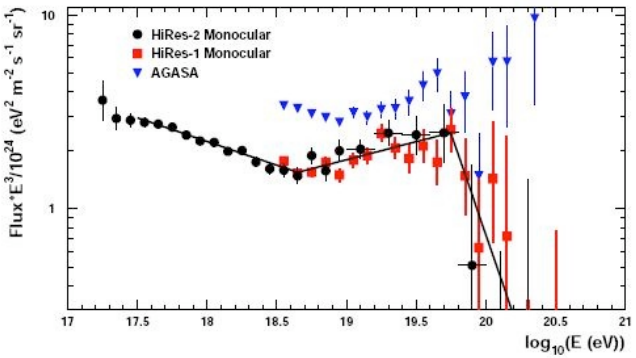


Cosmic ray energy spectrum

- Cosmic rays:
  - Could provide test of physics at highest energies
  - But don't point back to source
- GZK effect:

$$p + \gamma_{CMB} \rightarrow \Delta^+ \rightarrow \pi^+ + n$$
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$n \rightarrow p + e^- + \overline{\nu}_e$$
$$\mu^+ \rightarrow e^+ + \nu_e + \overline{\nu}_\mu$$

- GZK neutrinos:
  - Required by Standard Model
  - Point back to source
  - No horizon



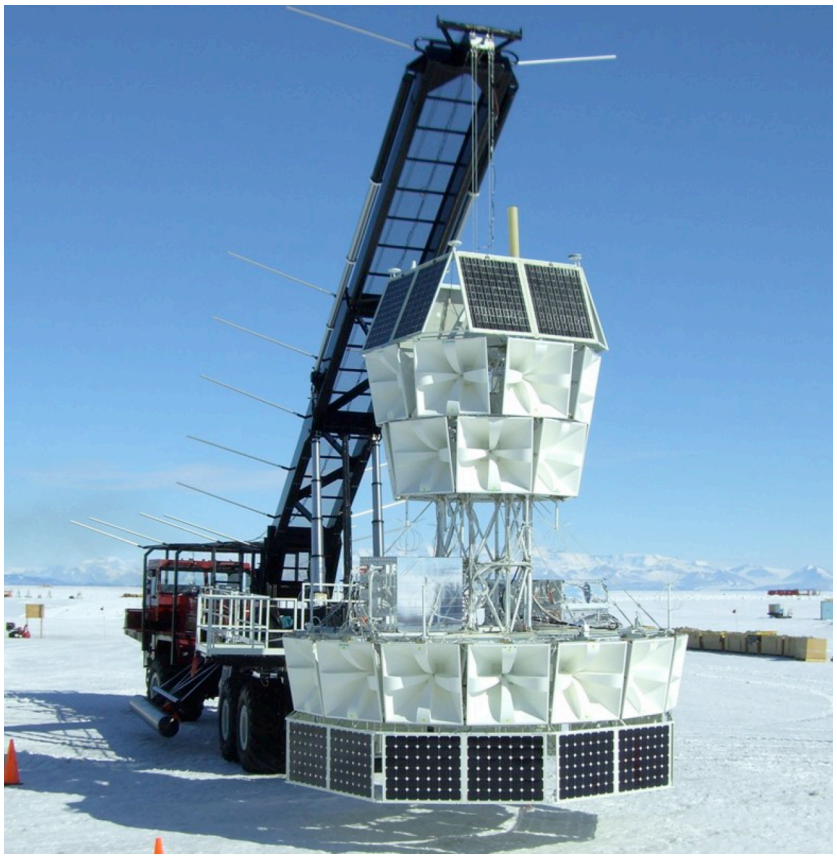
GZK effect

Askaryan Effect

- Neutrino interacts in ice & creates particle shower (NC event), for EeV neutrino:
  - Order of 10^7 e^+e^- pairs at shower max
  - Bunch size ~cm
- Charge imbalance in shower ~ 20% more e^- that e^+
- Cherenkov radiation coherent at λ > shower size
- Radiated power goes as (excess charge)^2
- Radio attenuation length in ice on order of km
- Antarctica provides vast interaction volume

Signature of Askaryan radiation is impulsive event broad radio frequency range

ANITA

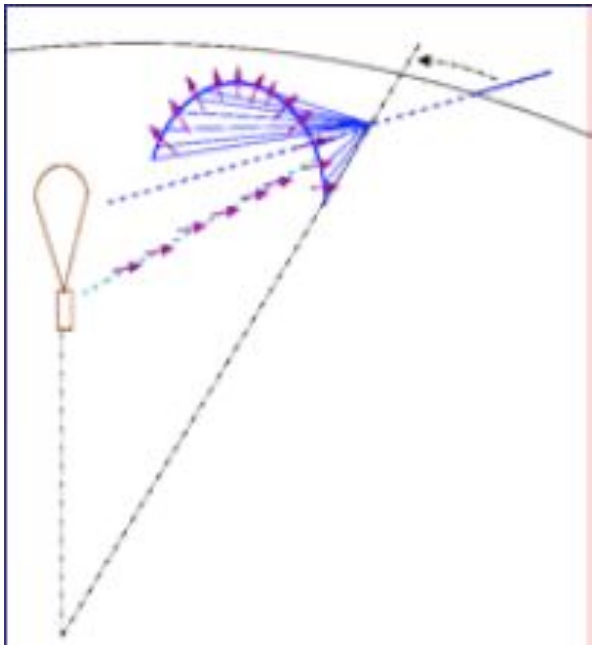


- 32 Quad ridge horn antennas
- Downward cant of 10°
- 200-1200MHz operating range
- 36km altitude - 1.5million km^3 interaction volume
- Source location from split level antenna distribution
- Main noise (when not near base station) is thermal:
  - 180K average, 50K fluctuations for ANITA I

Is most sensitive UHE neutrino experiment to date

Triggering

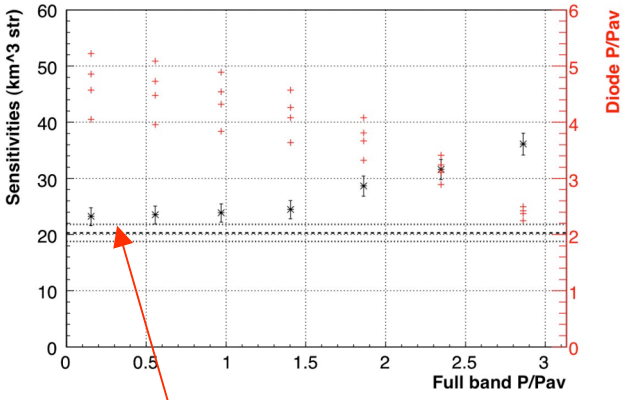
- 3 levels to hardware trigger
  - L1: single antenna, N of M channels, M = polarizations x freq bands
  - L2: antenna cluster, 2 of 3 adjacent antennas
  - L3: phi sectors, both antenna rings in same angular sector
- ANITA I level 1 trigger:
  - 4 frequency sub bands
  - LCP & RCP trigger
  - Trigger on 3 of 8
- Test trigger alterations using ANITA MC (10,000,000 events)



Askaryan pulse totally linearly polarized
- equal LCP and RCP amplitudes

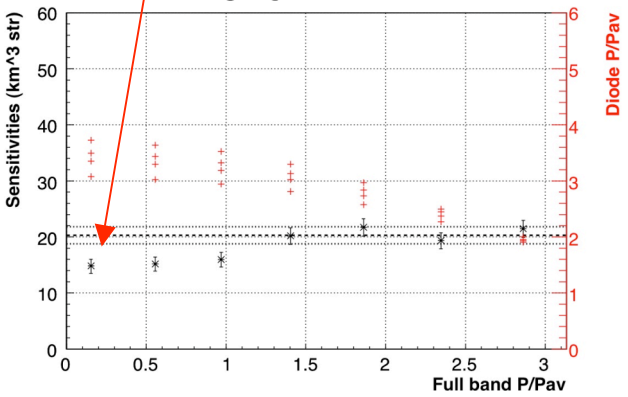
Triggering

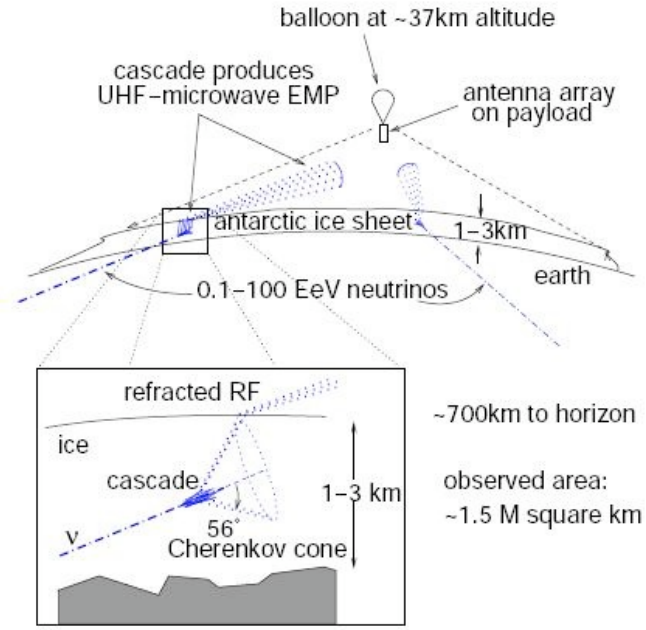
2 of 4



3 of 8 sensitivity

3 of 4

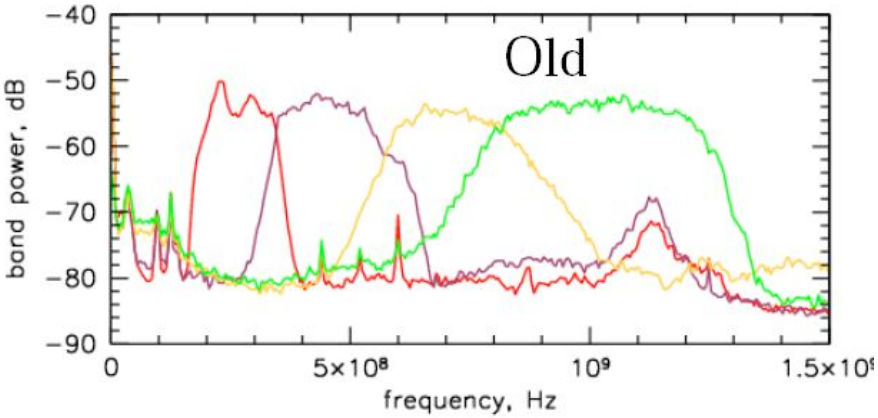


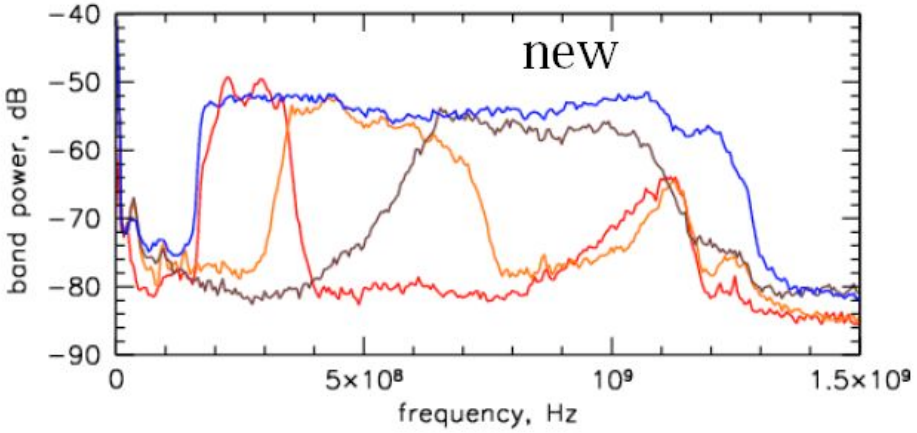


Signal must have some VPOL component

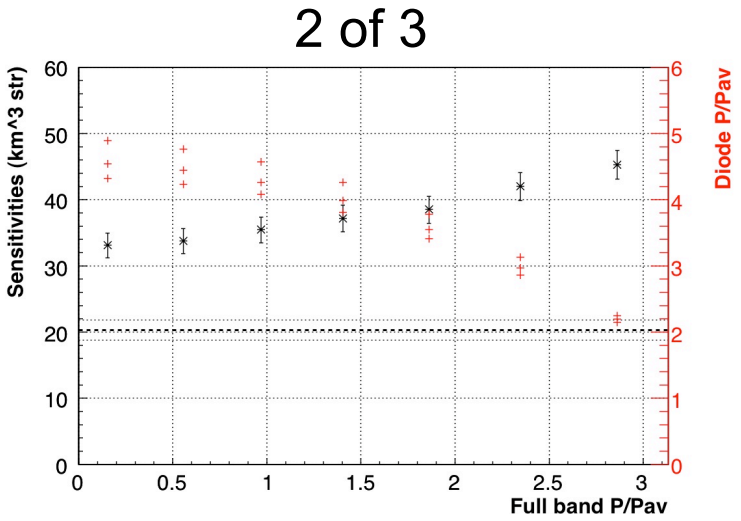
- Try with separate full band trigger
- VPOL + FB more effective than LCP & RCP

Triggering





- Change to 3 sub bands
- Best sensitivity so far
- ANITA II will pass L1 trigger when at least 2 of 3 VPOL + FB triggers are recorded



Prioritizer

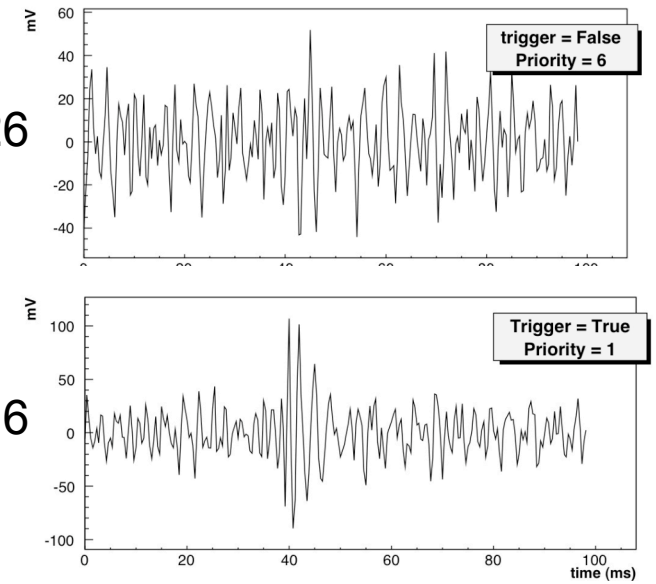
- Event data etc stored on board ANITA
- Need to check data being recorded & have backup in case of loss of on board data
- Satellite link
  - 6kbit/s link max, ~15kbyte/event @ 5Hz
  - Less that 1 in 100 events can be transmitted
  - Need to select events
- Prioritizer
  - Assigns priority value of 1 (high) to 9 (low)
  - Is it working as intended?

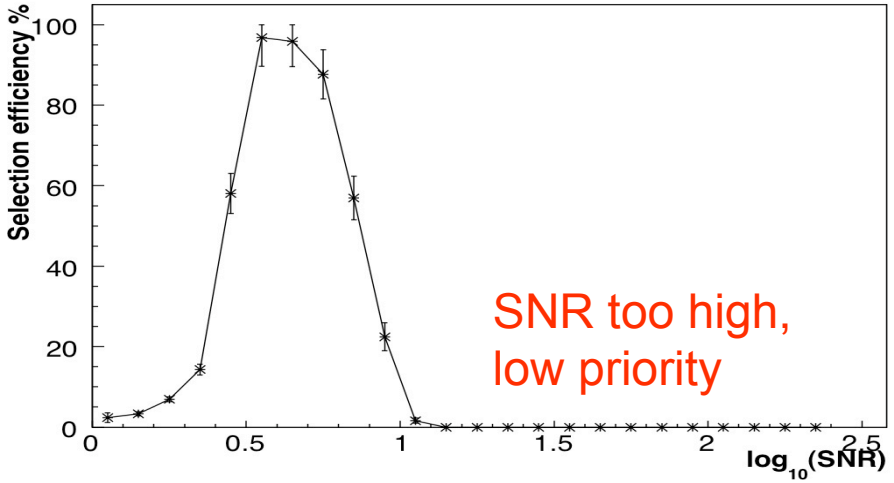
Prioritizer

- Use event generator, defining:
  - Event energy
  - Thermal noise
  - Neutrino interaction point etc.
- Created volt-time waveforms, send to prioritizer

SNR = 1.26 (10^{18}eV)

SNR = 3.16 (10^{20}eV)

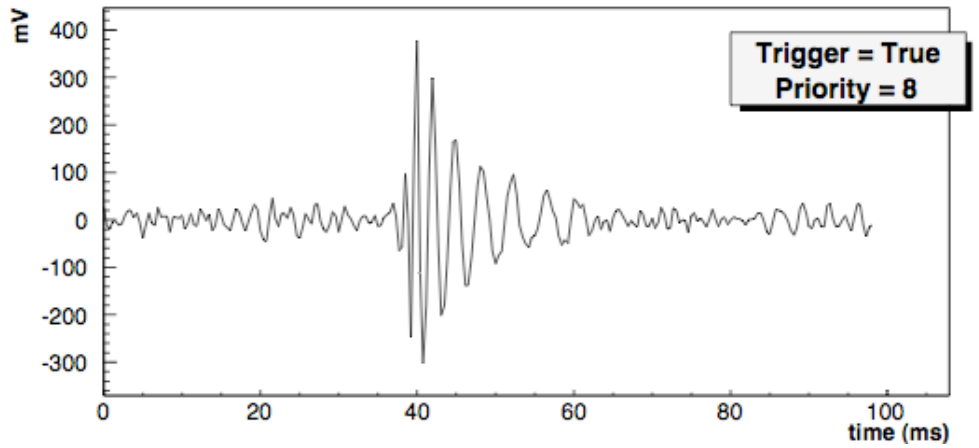




SNR too high, low priority

Events with priority < 5

Prioritizer

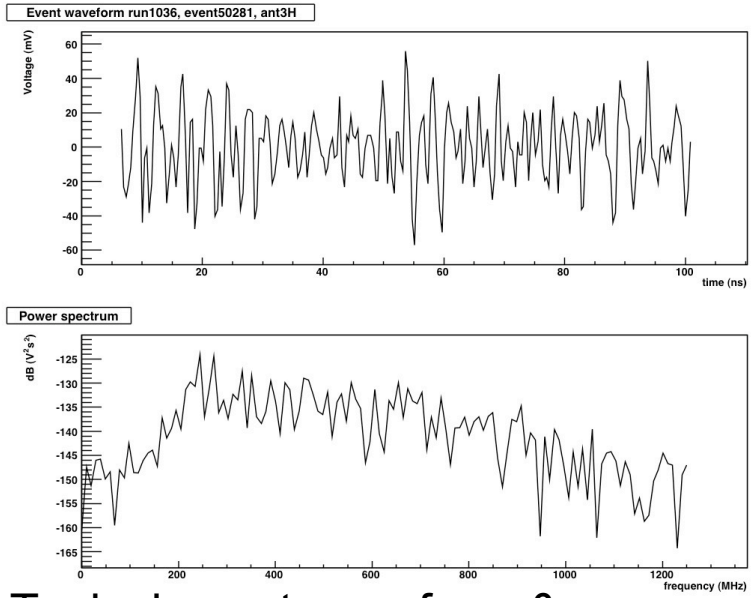


10^{20}eV event was assigned low priority

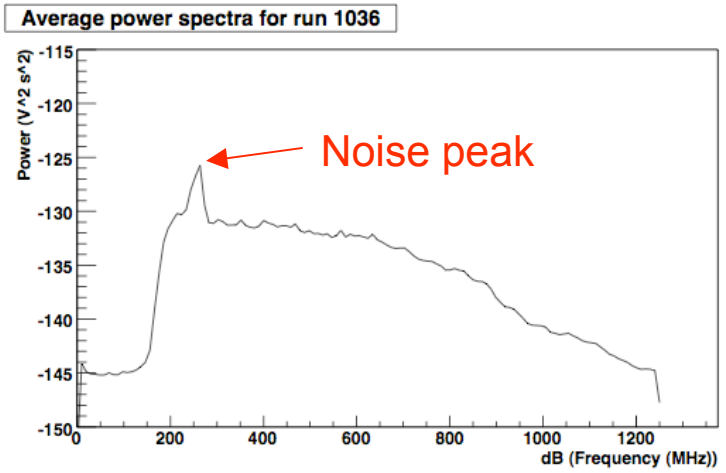
- Priority of 8 is a flag for 'bad' events
  - Too many horns peak simultaneously
  - Value must be too low
- Need to change this flag
  - Just increase number peaking?
  - Multiple antennas on opposite sides of payload?

Power Spectra

- Power spectra plots
  - 1 average spectra per pol per ant per run
  - 1 time histogram per pol per ant per time period per run
  - + average histo & graph over all ant & pol per run

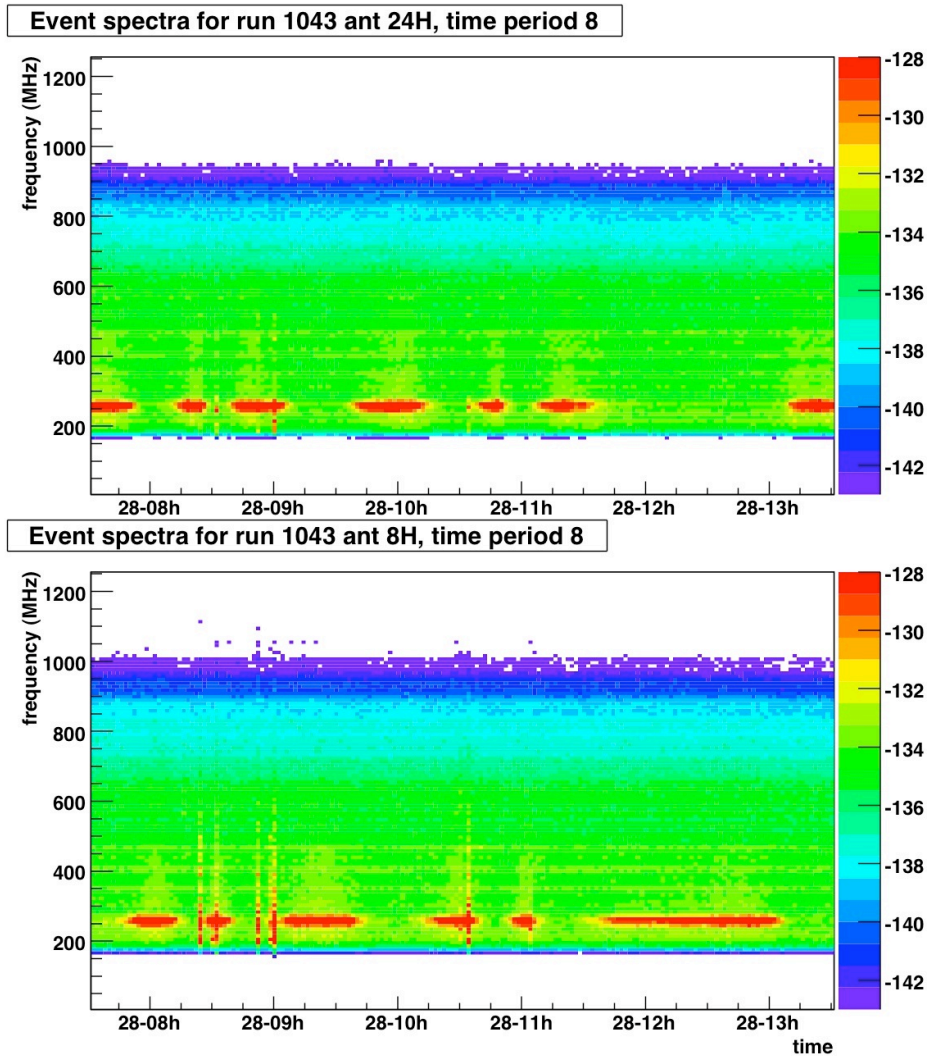


Typical event waveform & power spectrum



Average power spectrum for a data run

Power Spectra

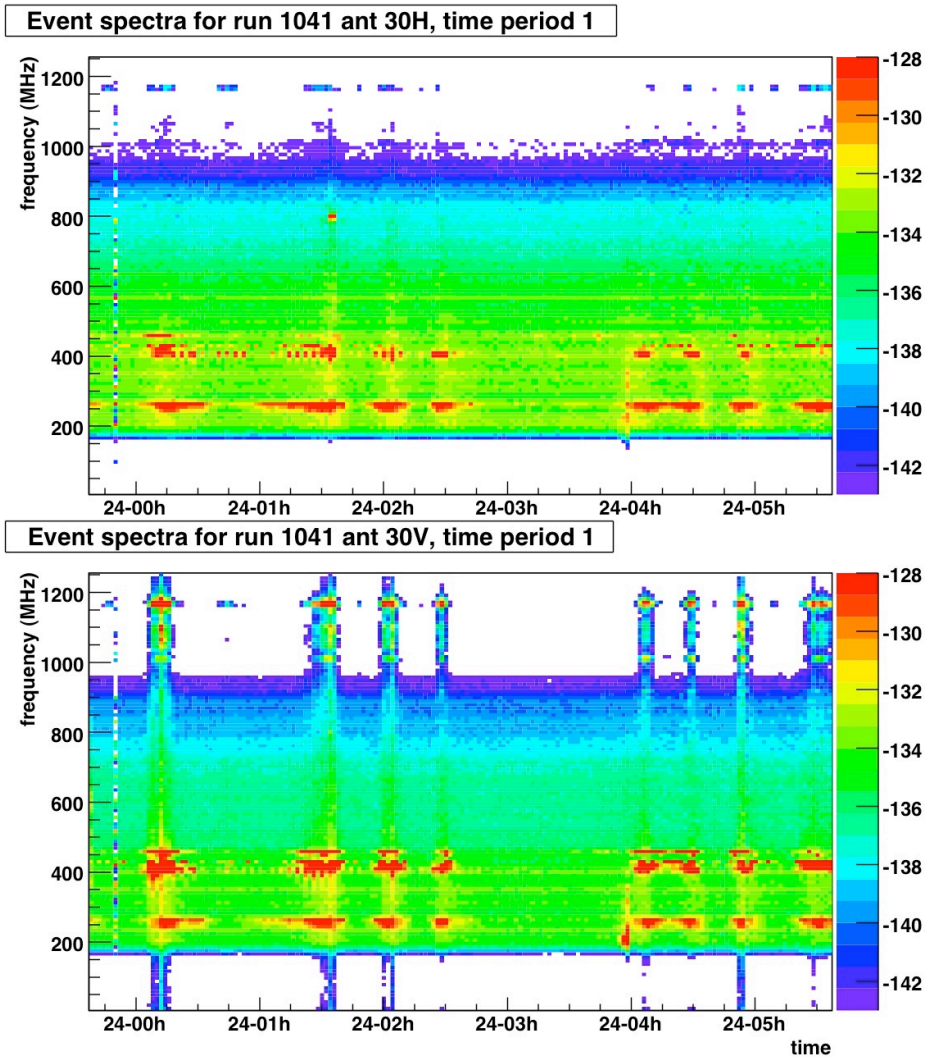


- Periodic noise at 260MHz (in synch with ANITA rotation)
- Opposite antennas see this directly out of phase
- Apparent throughout flight

→ Satellite noise (circularly polarized - observed in both V & HPOL)

- Notch filtering would be too detrimental to neutrino sensitivity

Power Spectra



- Signals at 420 & 1200MHz
- Again periodic, only present for portions of flight

→ Ground based radio noise

Conclusions & Future Work

- ANITA hardware trigger will be improved for next flight
- Prioritizer is largely effective, issues with high energy events
- Satellite noise observed is irritating but unavoidable

- Short term:
  - Complete work with prioritizer
  - Systems testing & integration in Texas
- Long term:
  - ANITA flight Winter 08/09
  - Develop code for data analysis

Any questions?

Extra Slides

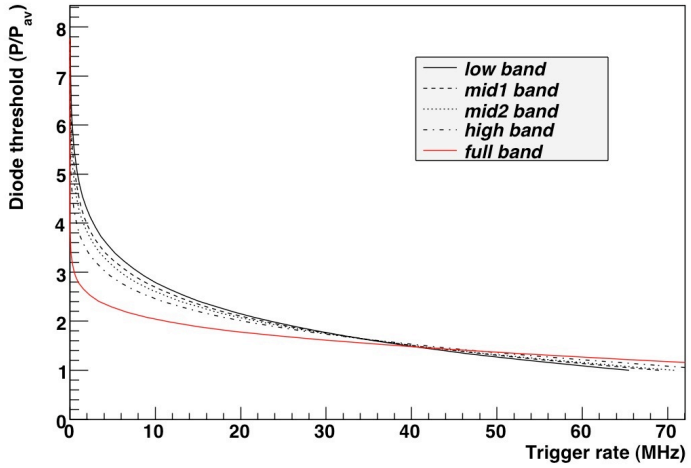
Rate Calculation

- Max write event to disk speed 5Hz
- Get global trigger rate from:

$$R_{N,M,\Delta t,r} = \sum_{i=N}^{M}\left[\sum_{j=0}^{i-N}(-1)^{j} C_{i}^{j}\right] i C_{M}^{i} r^{i} \Delta t^{i-1} \qquad C_{M}^{N} = \frac{M!}{N!(M-N)!}$$

assumes $r\Delta t < 1$

- Have a set L2 trigger rate for the global rate, but sub band and full band rates differ (as sub is N of M, full is 1 of 1)
- Used theoretical diode response curves to get threshold (really need experimental)

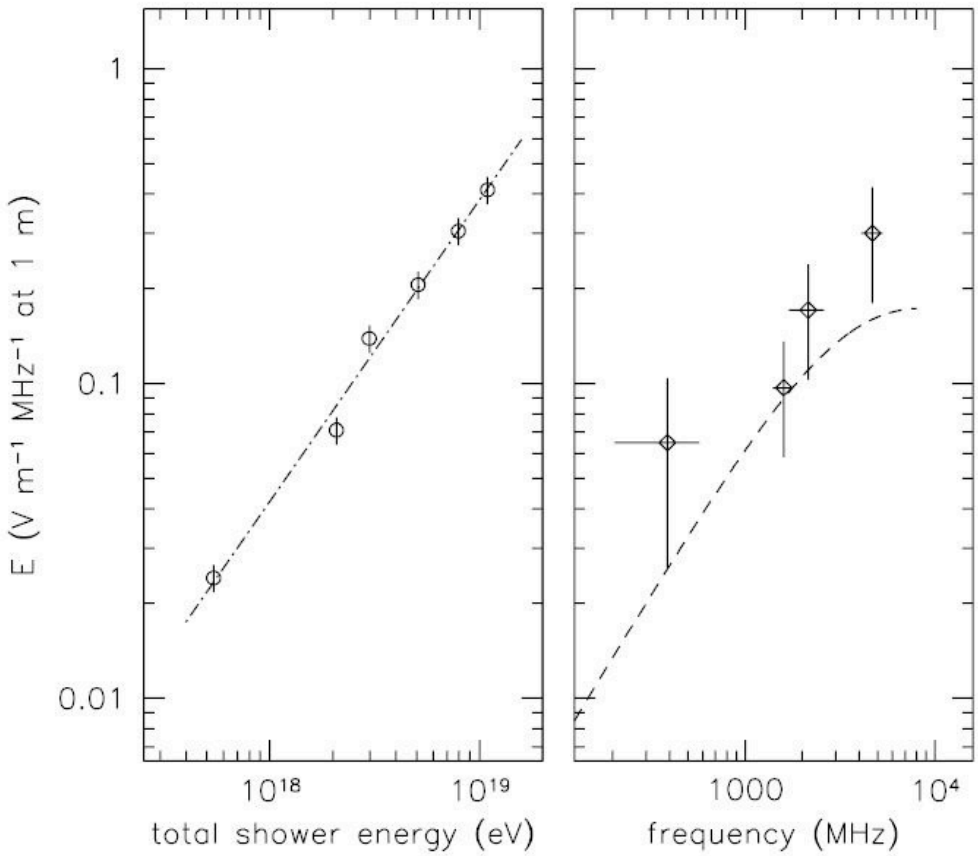


Askaryan Pulse Strength

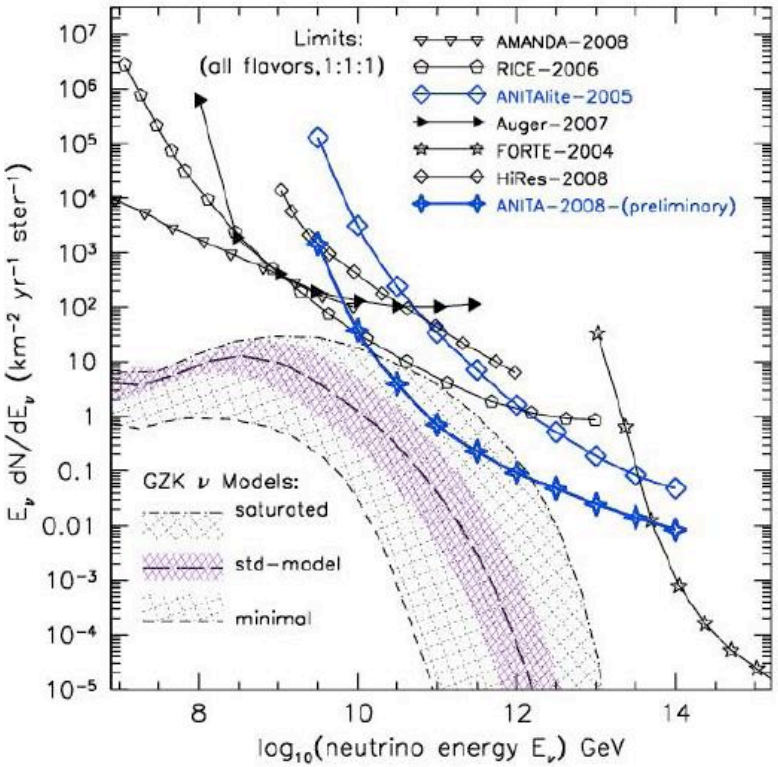
$$\omega = \left(\frac{\pi h \alpha}{c}\right) L \left(1 - \frac{1}{n^2 \beta^2}\right) \left(\nu_{\max}^2 - \nu_{\min}^2\right)$$

$$\Omega = N^2 \omega^2$$

- Above GHz level radiation no longer coherent
- Results for silica sand



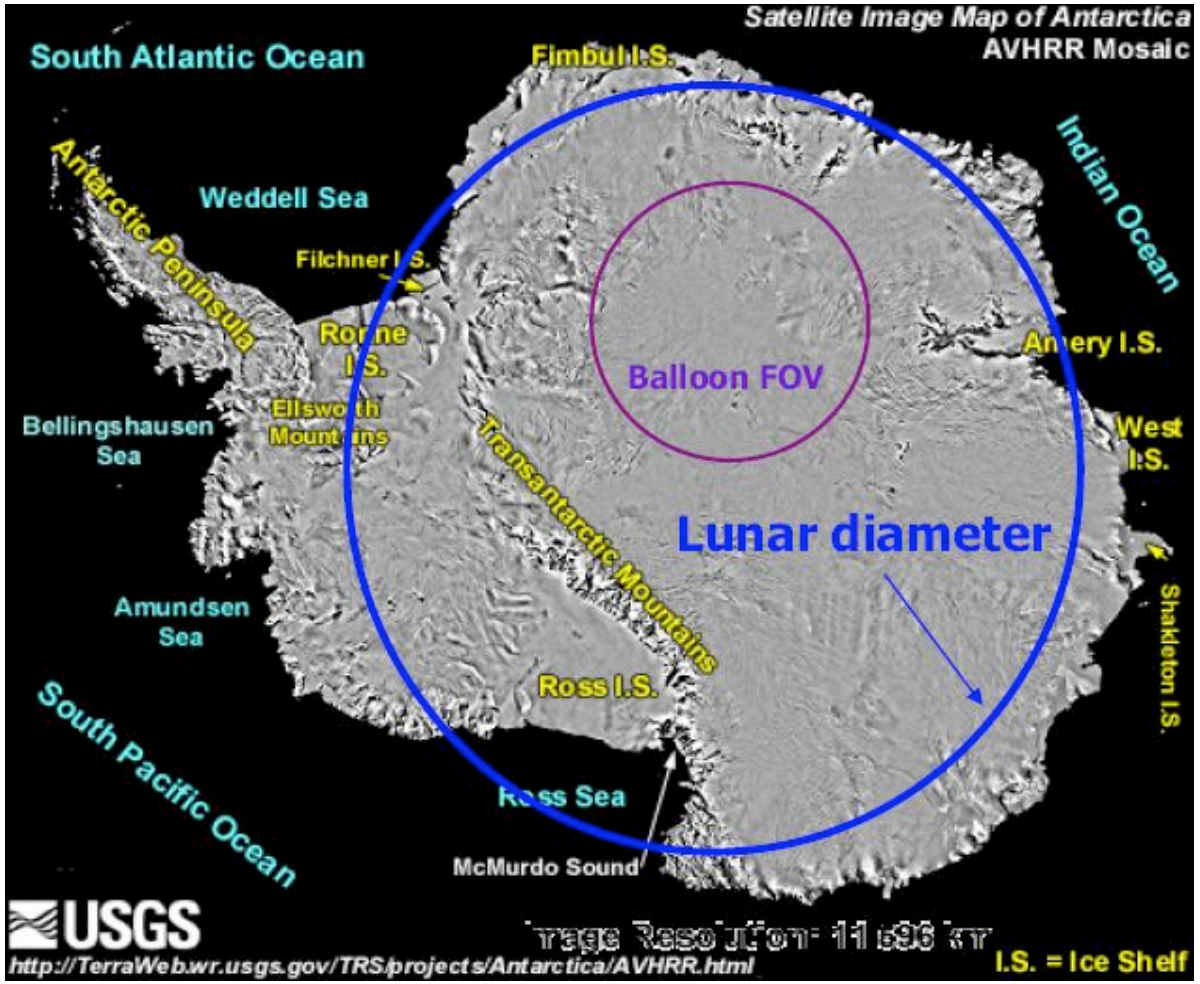
ANITA I info



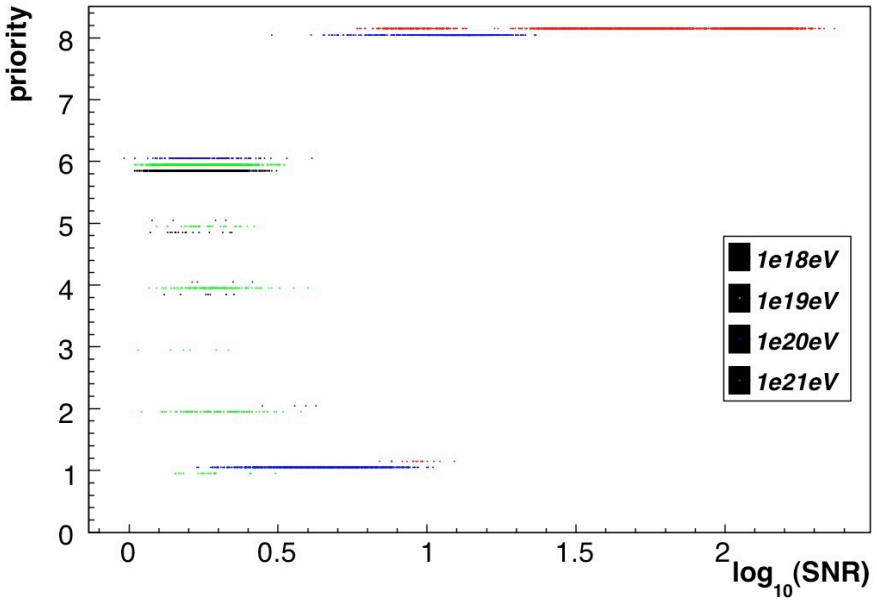
- ANITA I had 18 days live-time
- Base stations in view 50% time
- Location resolution:
  - Elevation:
    - 3.5m antenna separation
    - 0.3º resolution on pulse direction (pulse timing)
    - 1º resolution on neutrino direction (polarization angle)
  - Azimuthal:
    - 1m antenna separation
    - 0.8º resolution on pulse direction (relative amplitudes)
    - 3-5º resolution on neutrino direction

Antarctic vs Moon

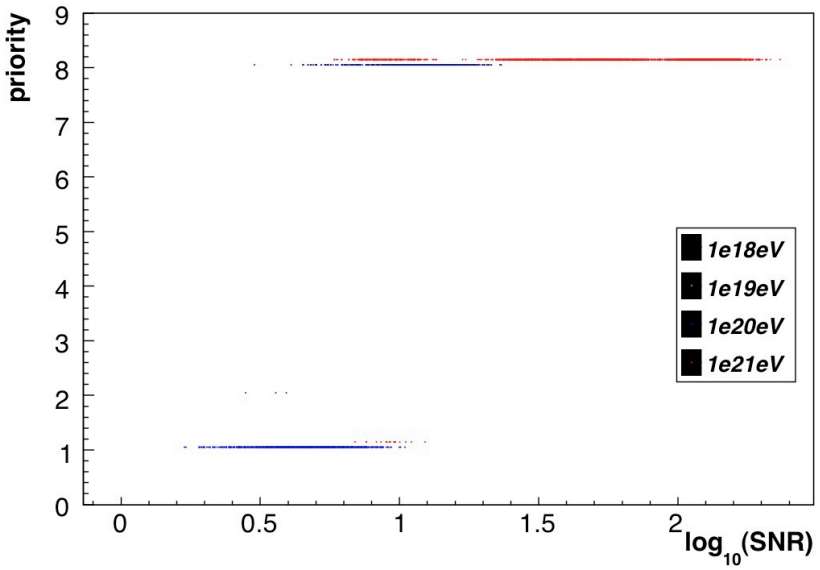
- Antarctic
  - 1-3km ice depth
- Moon
  - Regolith ~30m, then bedrock



Priority vs SNR



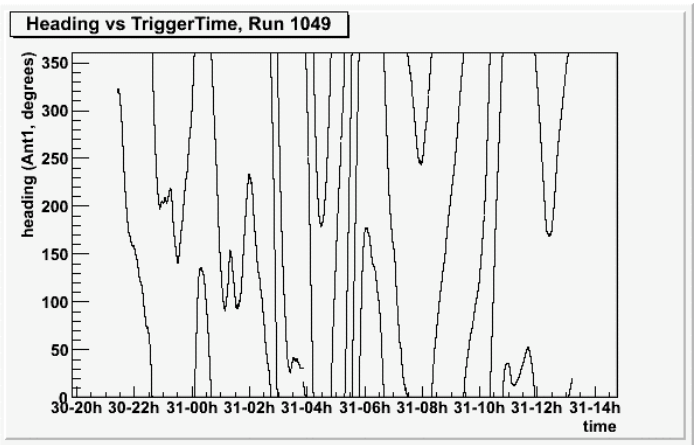
All events (8000 total)

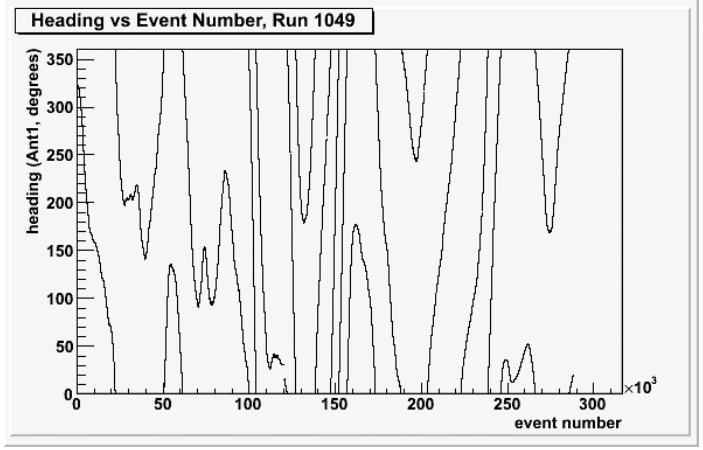


Triggered events

Rotation Time & DAC values

- Time of rotation from minutes to hours





- DAC value - higher DAC, lower threshold