Tunable Universal Filter Frontend

TUFF

Oindree Banerjee

for the ANITA collaboration

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TeVPA 2017

Columbus, Ohio

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THE OHIO STATE UNIVERSITY

ANITA Collaboration

Submitting soon to NIM A

Dynamic tunable notch filters for the Antarctic Impulsive Transient Antenna (ANITA)

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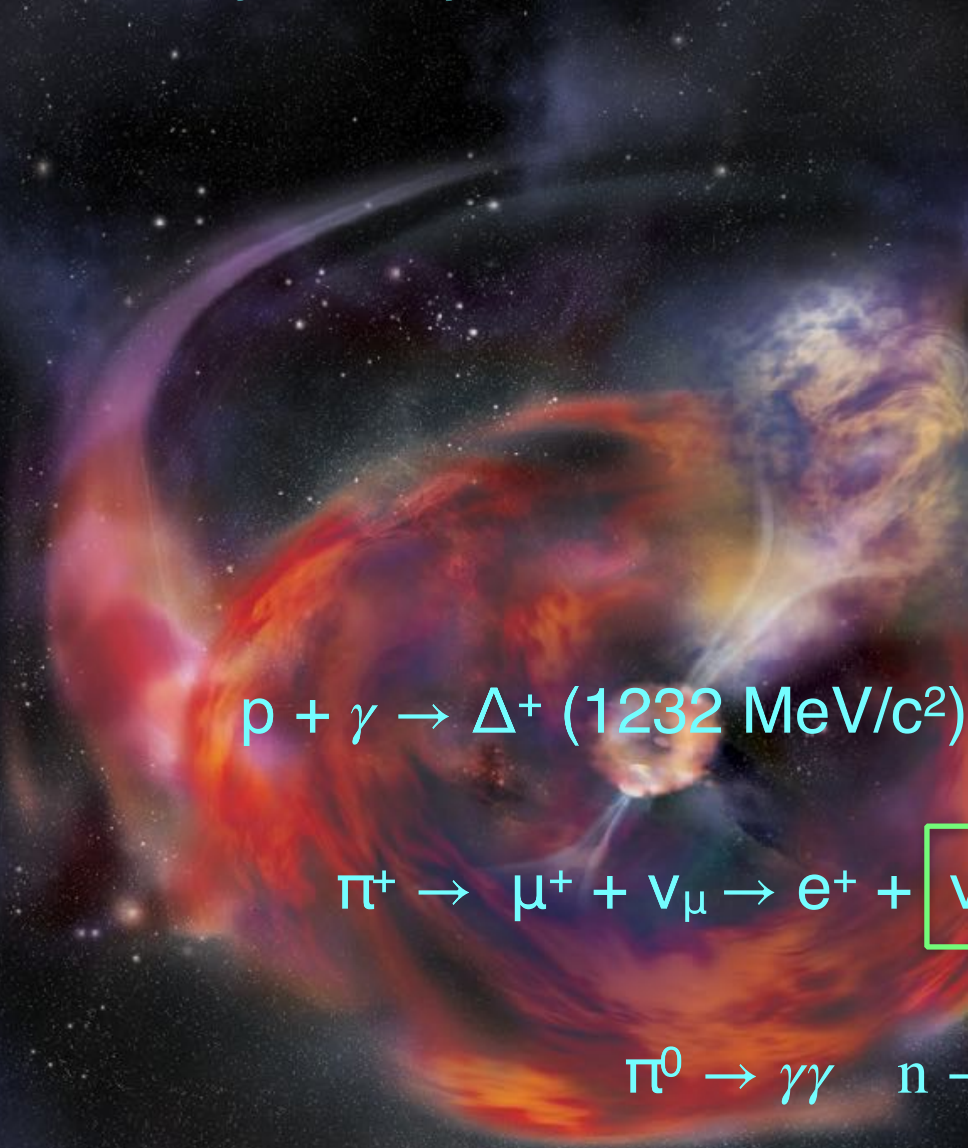
Gamma Ray Burst: My favorite motivation



PC: NASA E/PO, Sonoma State University, Aurore Simonnet

Broad motivation:

- Particle Physics at E > 14 TeV (Large Hadron Collider)
- Astrophysics at Nature's most powerful, remote accelerators

$$p + \gamma \rightarrow \Delta^{+}\ (1232\ \mathrm{MeV}/c^{2}) \rightarrow n + \pi^{+}\ \text{OR}\ p + \pi^{0}$$

$$\pi^{+} \rightarrow \mu^{+} + \nu_{\mu} \rightarrow e^{+} + \boxed{\nu_{e} + \bar{\nu}_{\mu} + \nu_{\mu}}$$

potential ultra-high-energy (UHE) neutrinos

$$\pi^{0} \rightarrow \gamma\gamma \qquad n \rightarrow p\, e^{-}\, \bar{\nu}_{e}$$

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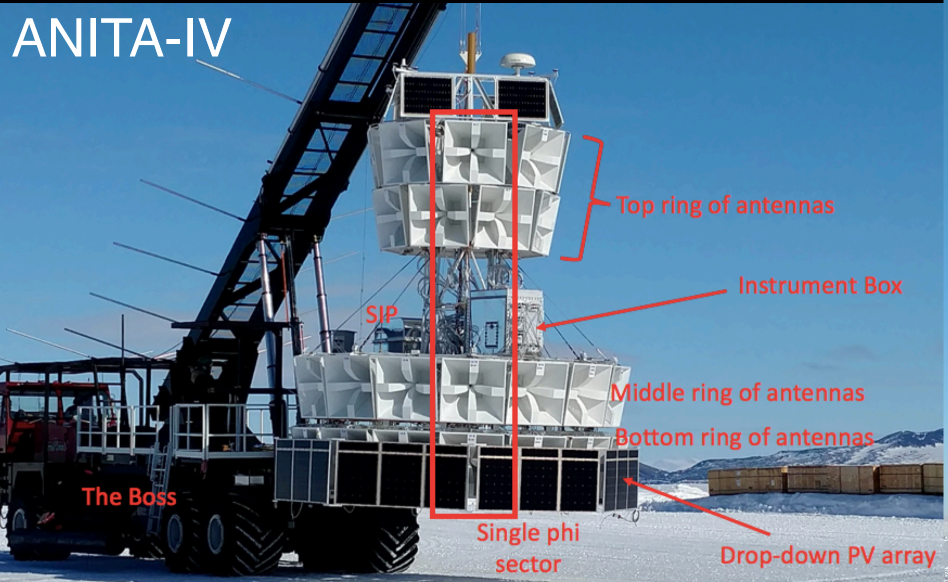
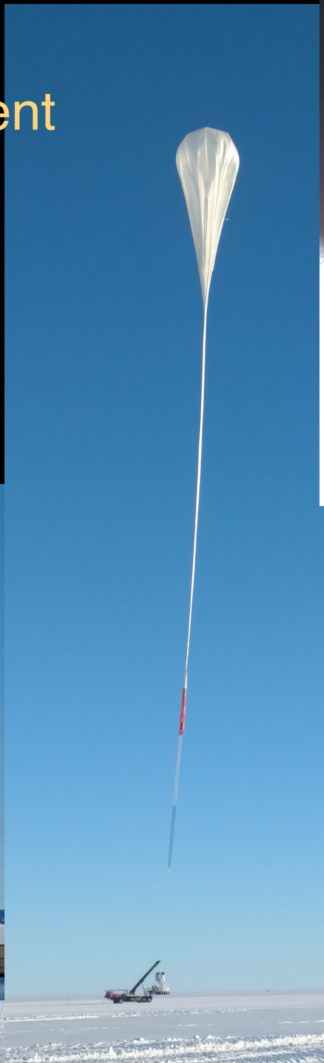
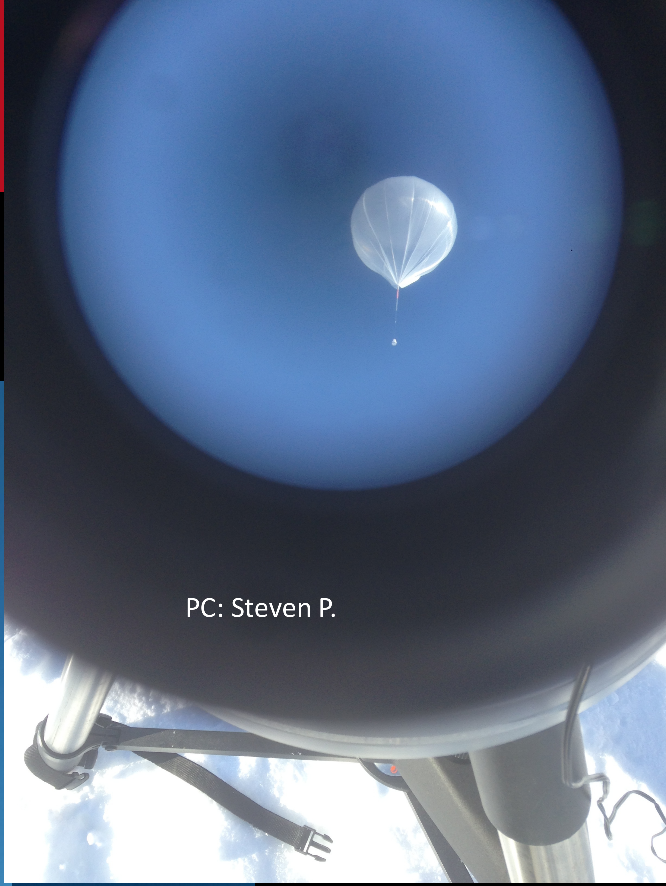
ANtarctic Impulsive Transient Antenna

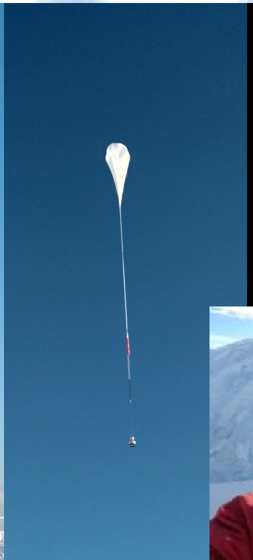
- NASA long-duration balloon experiment
- Ultra-high-energy (>10^{18} eV) neutrino detector
- Looking for radio Cherenkov signal
- Four flights so far
- Recent flight 27.3 days long

ANITA-IV





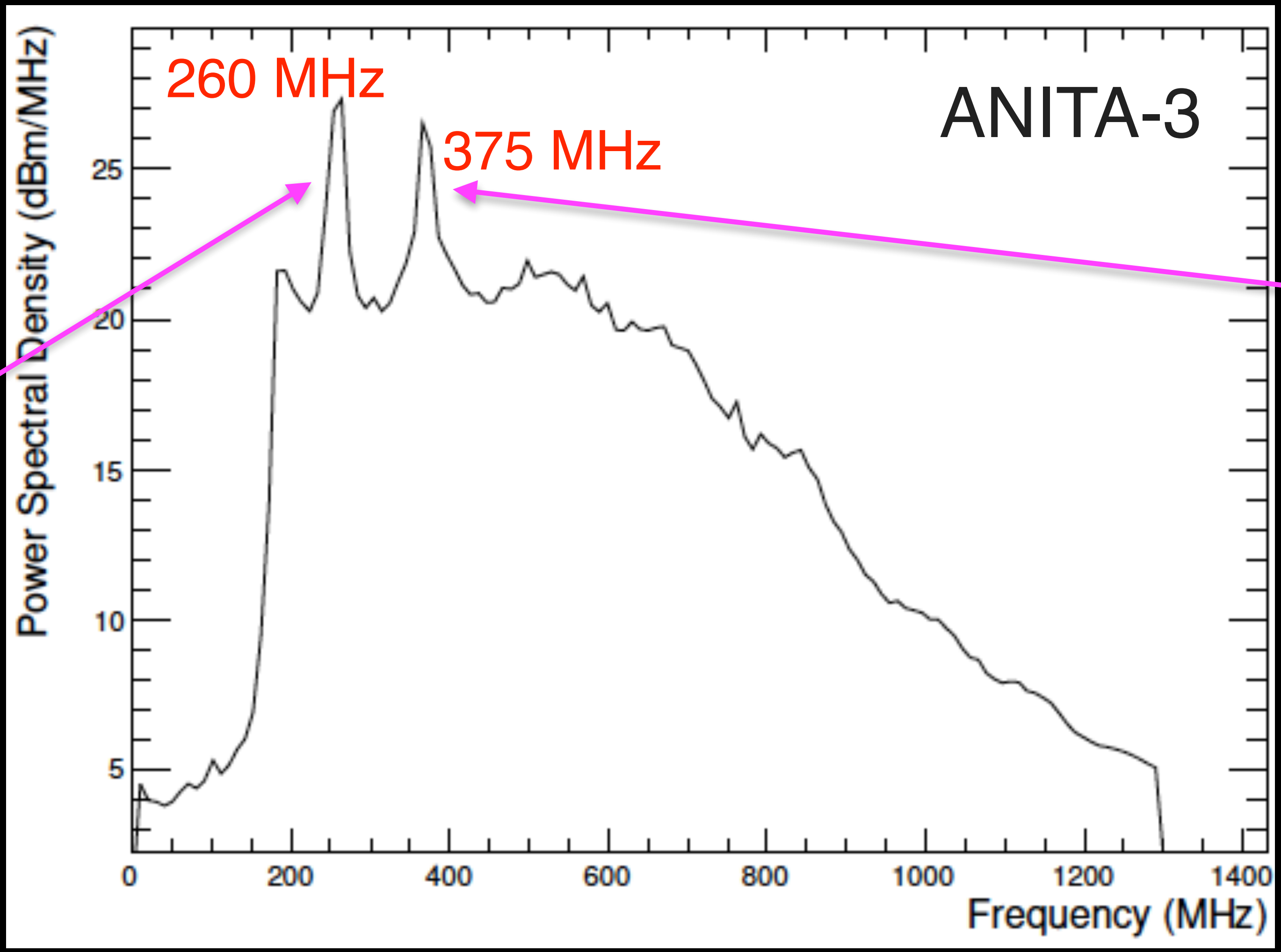




ANITA-IV Flight
2016 Dec 2 - 29

Military satellite noise during ANITA-3

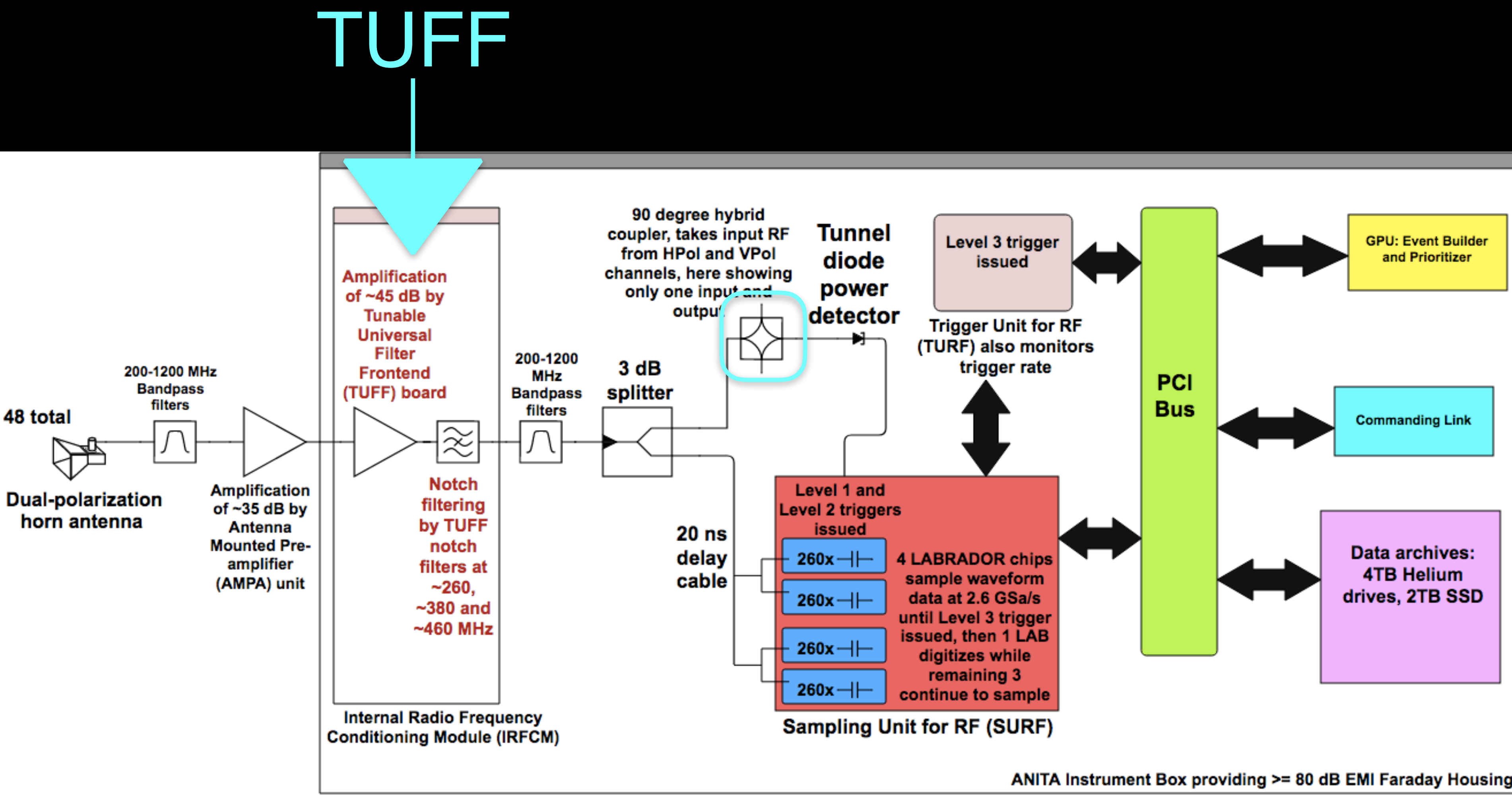
Plot by Ben Strutt



FLTSAT, UFO satellites

MUOS satellites

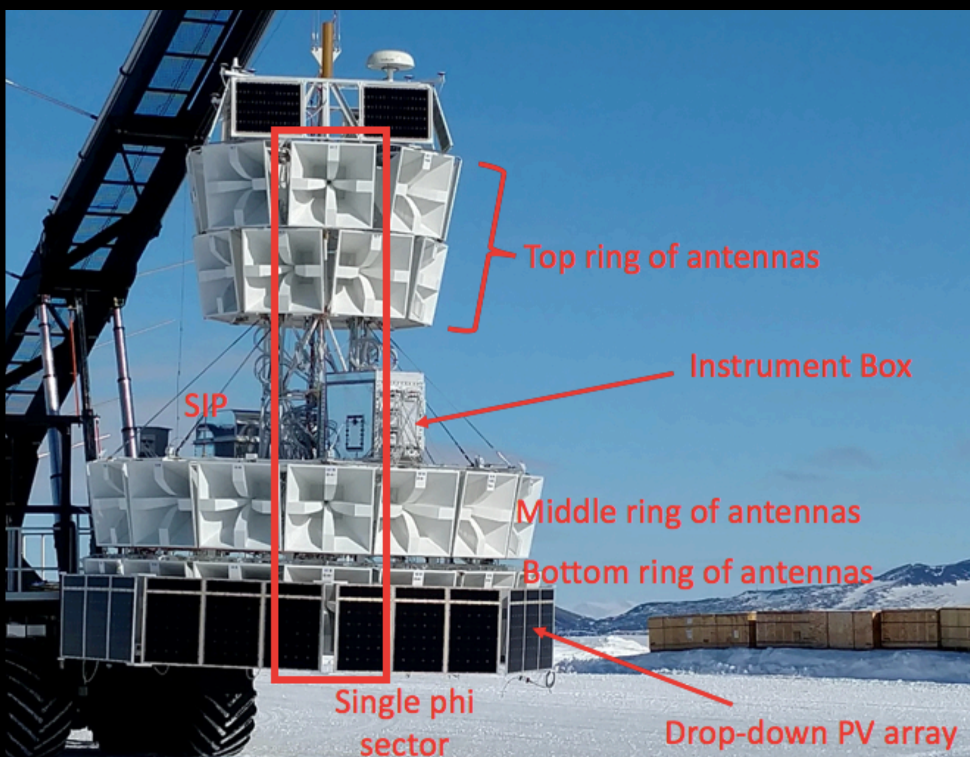
ANITA-4 System Diagram



ANITA-4 Trigger

Trigger Logic:

- Level 1 : LCP and RCP signal from same antenna above threshold
- Level 2 : > 1 antennas in same phi sector have Level 1 trigger
- Level 3 : Adjacent phi sectors have Level 2 trigger



Trigger rate > ~50 Hz

↓

Digitization Deadtime

↓

Phi-masking

↓

"Instrument Deadtime"

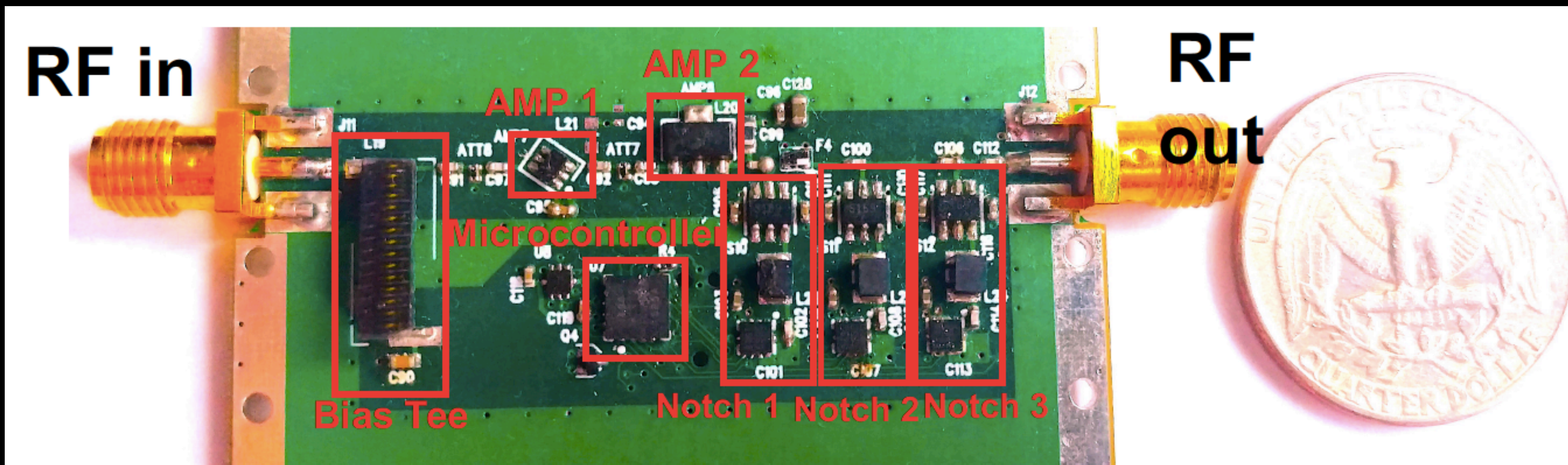
LCP: Left Circular Polarization | RCP: Right Circular Polarization

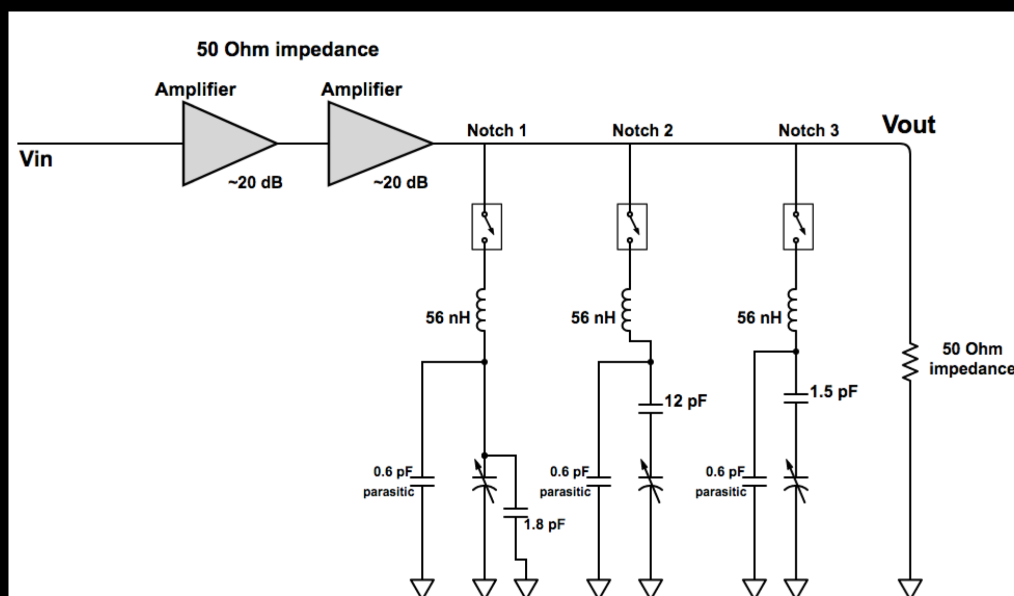
ANITA DATA

- An “event” is a 100 nanosecond snapshot of an incoming plane wave (voltage vs. time) that satisfies our trigger
  - ANITA-1 (06 - 07) — 8 million events
  - ANITA-2 (08 - 09) — 26 million events
  - ANITA-3 (14 - 15) — 77 million events
  - ANITA-4 (2016) — 97 million events
- Most events are noise
  - Thermal radiation by the ice
  - Anthropogenic or Human-made noise
    - Military satellites

TUFF board

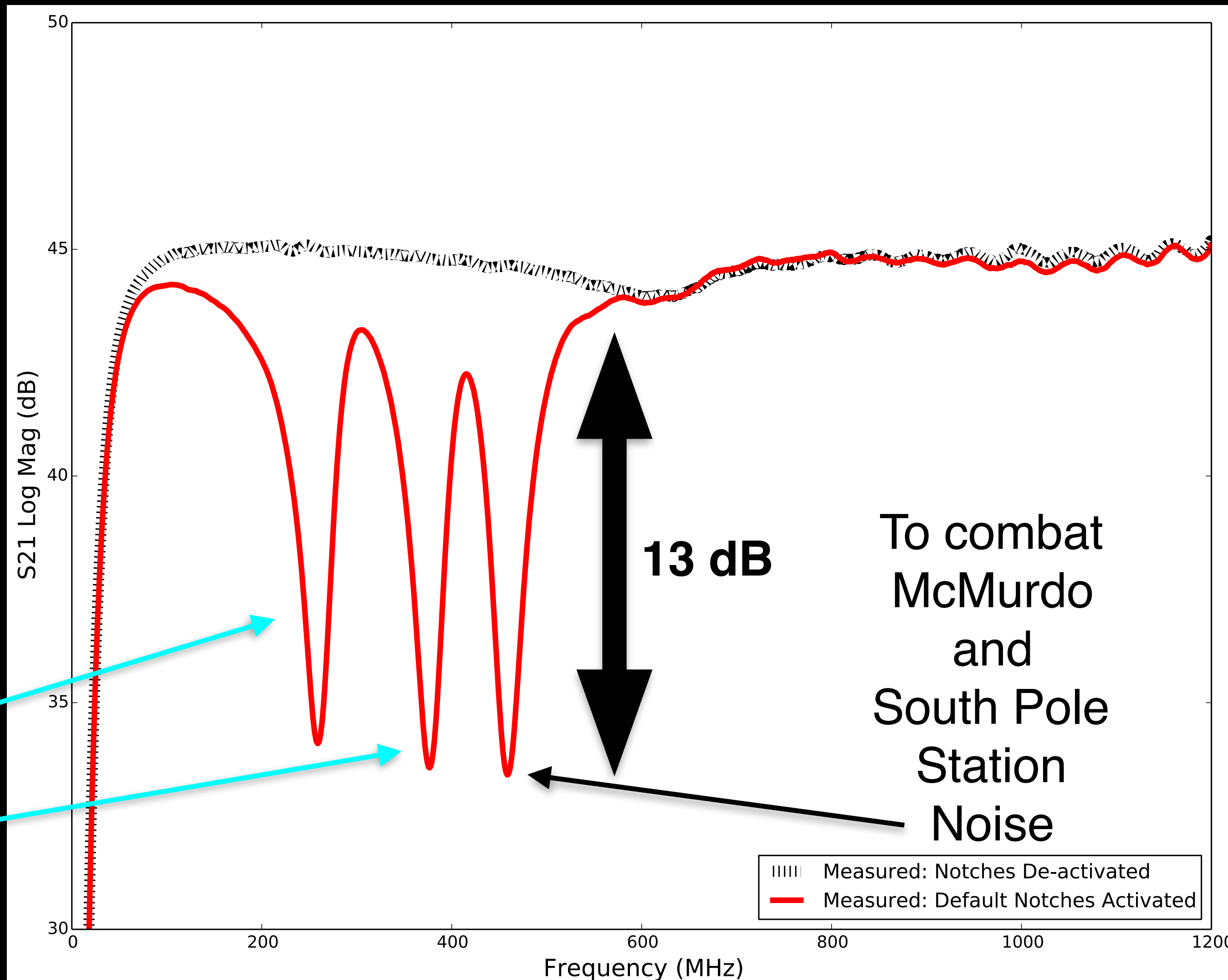
Single TUFF channel





Circuit diagram

TUFF response

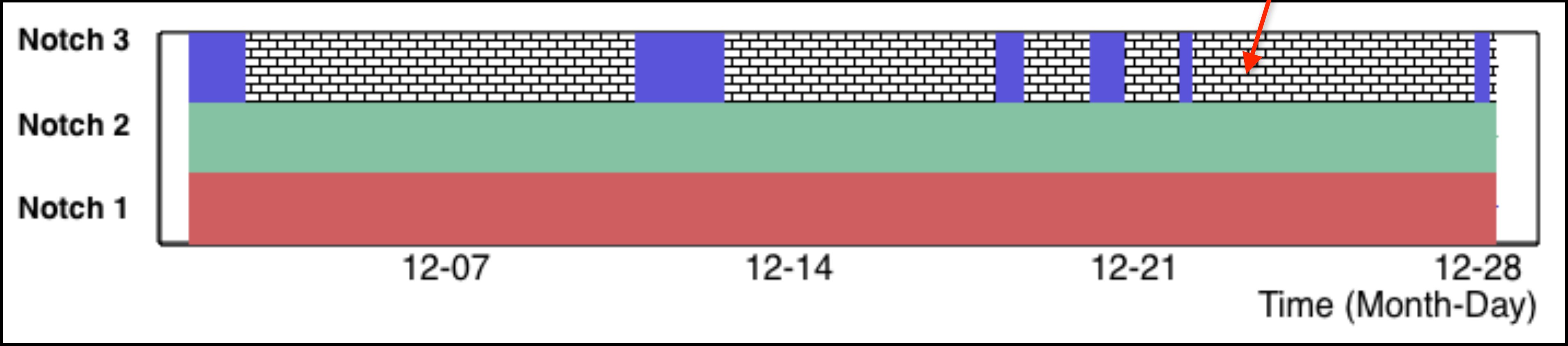


To combat Military Satellite Noise

TUFF notch operations during ANITA-4

Notch 3 off

Notch activation status vs. time



Notch 1: 260 MHz

Military Satellite

Notch 2: 375 MHz

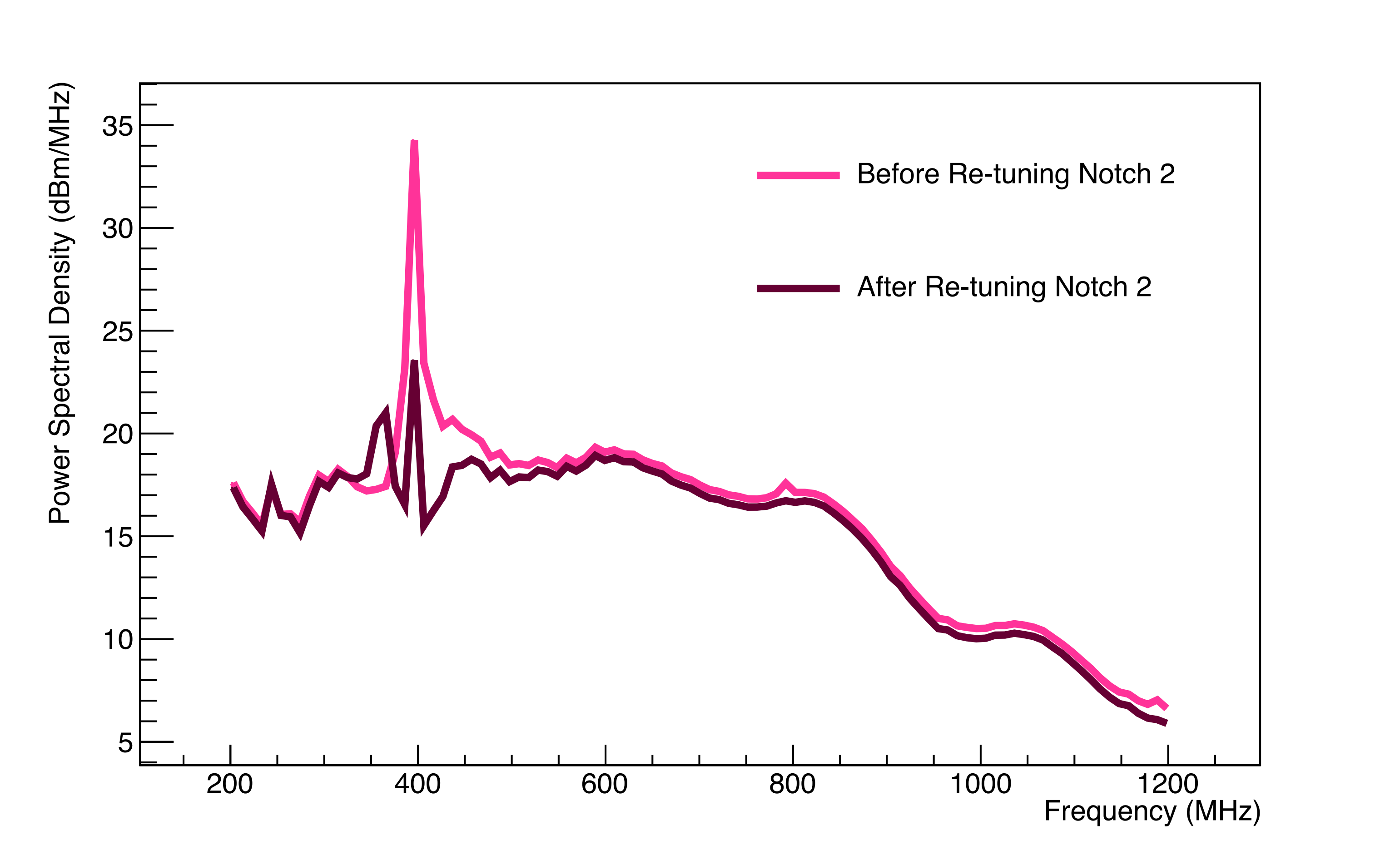
Military Satellite

Notch 3: 460 MHz

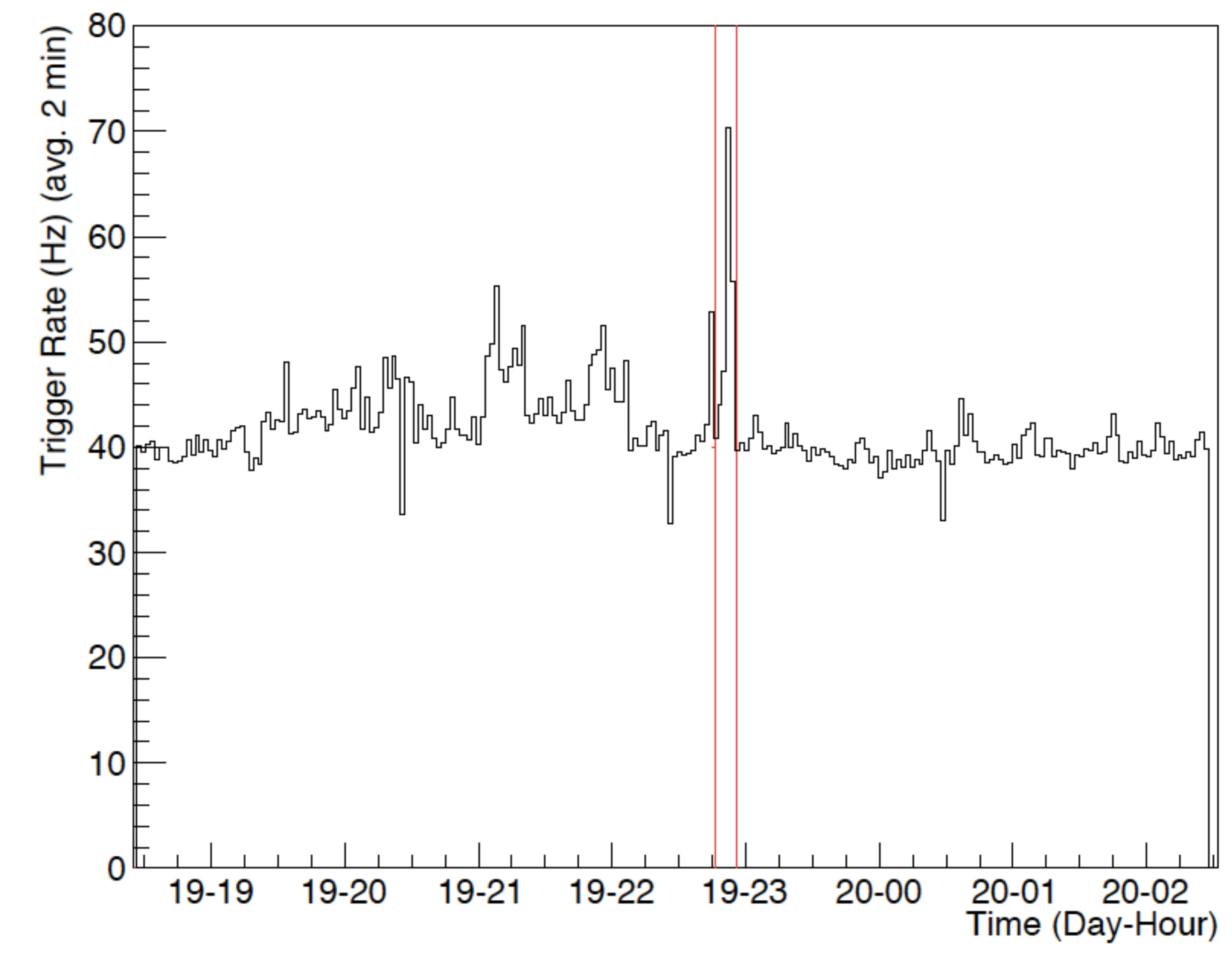
Base

TUFF notch operations during ANITA-4

Realtime notch tuning



Turning Notch 2 off… ouch



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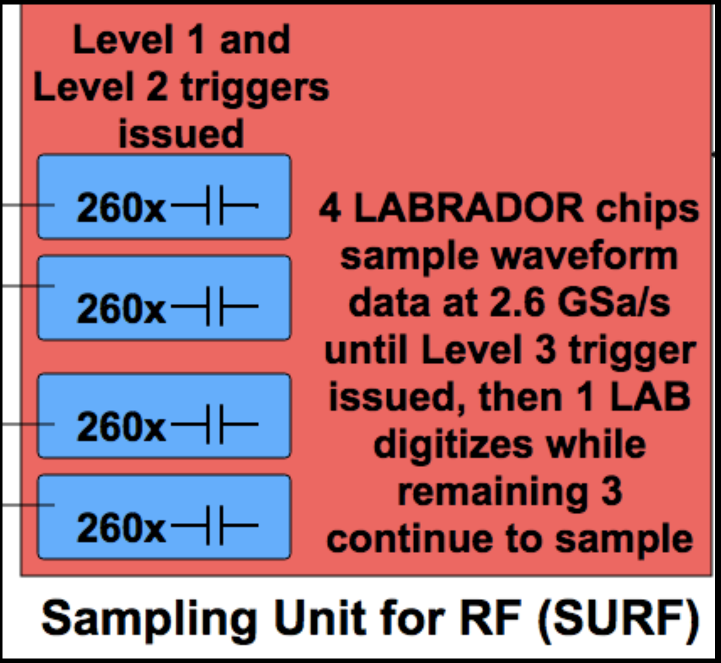
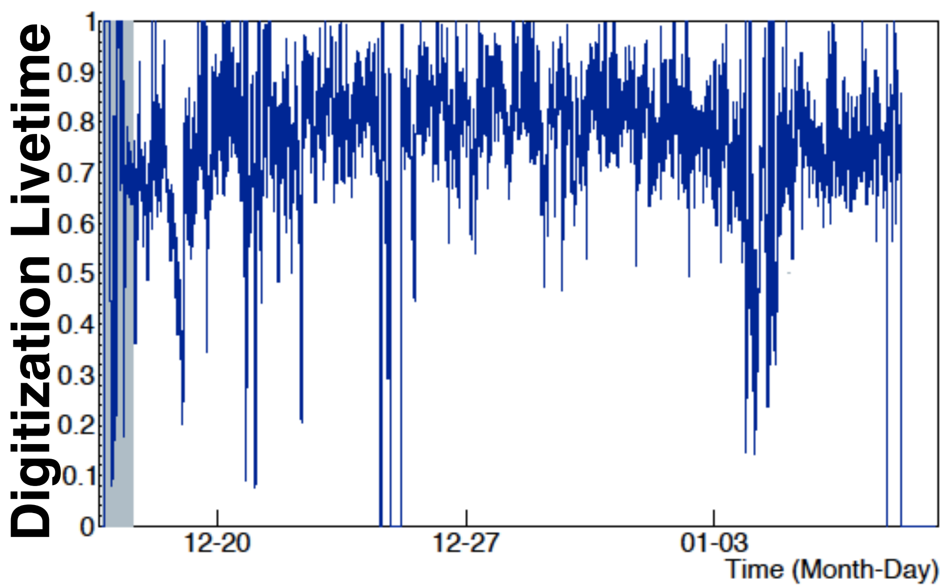
Digitization livetime



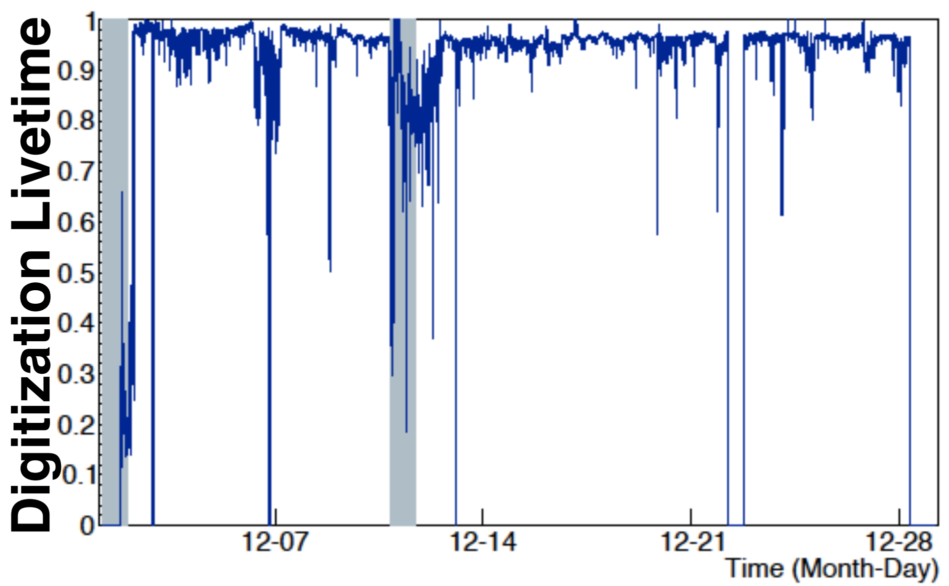
ANITA-3

74%



ANITA-4

92%



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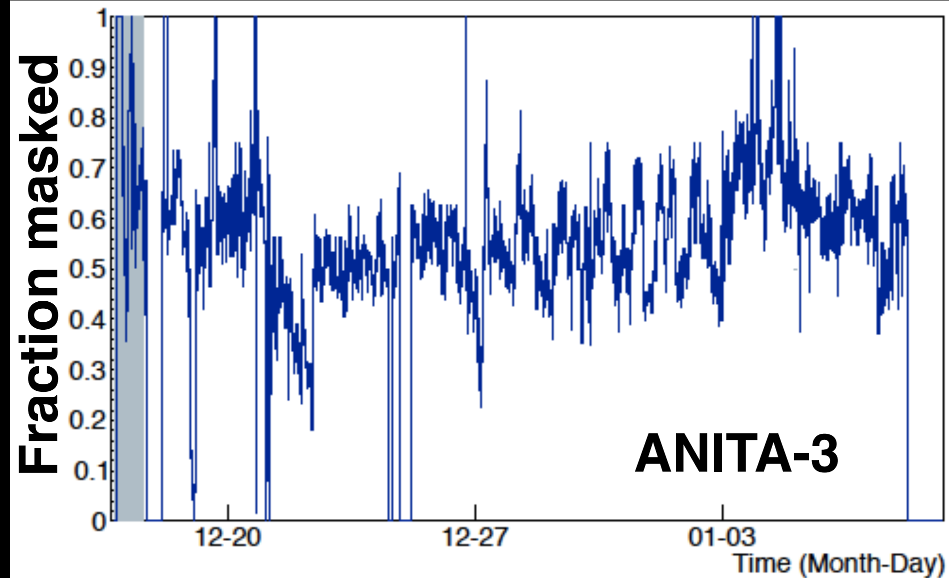
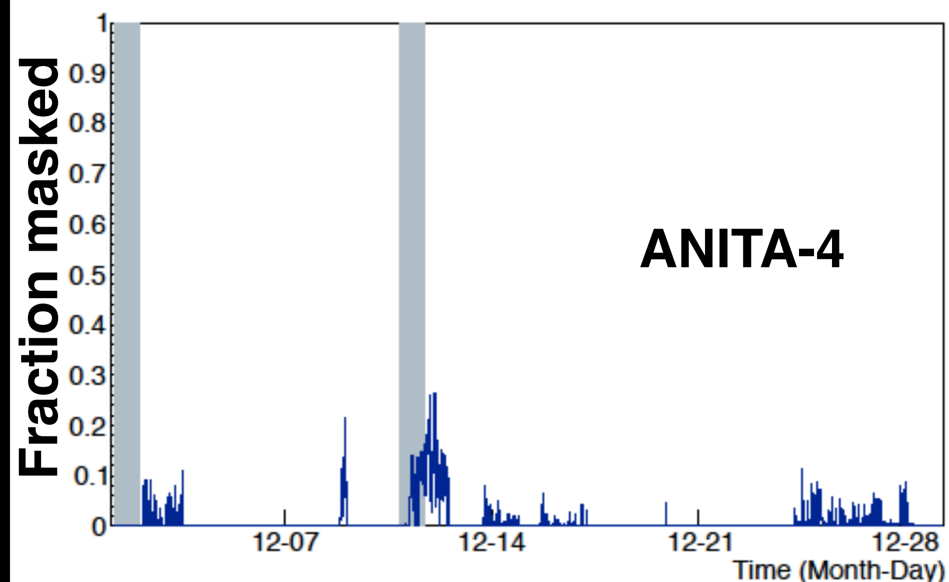
Phi-masking


Fraction masked
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
12-20
12-27
01-03
Time (Month-Day)
ANITA-3


Fraction masked
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
12-07
12-14
12-21
12-28
Time (Month-Day)
ANITA-4

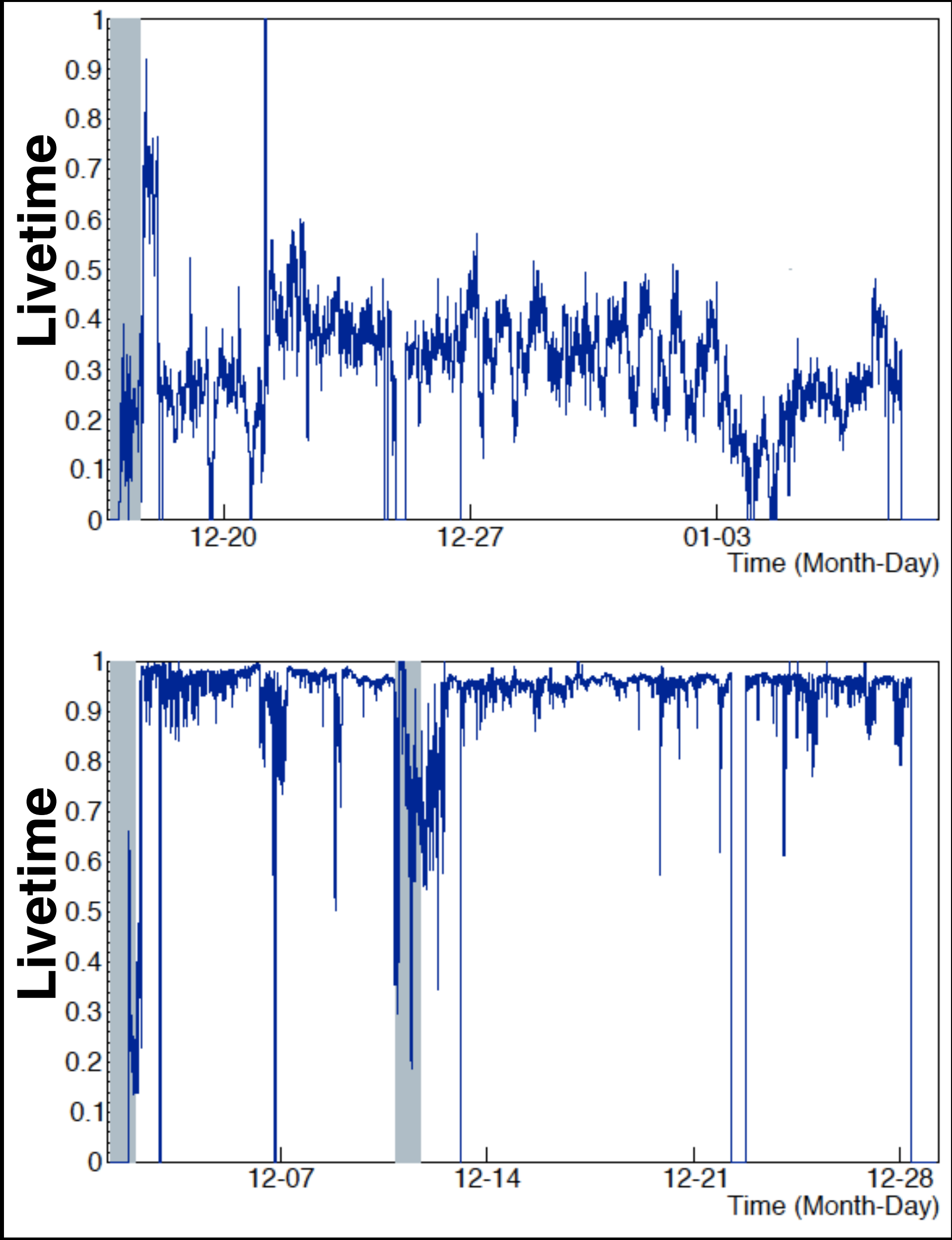
"Instrument Livetime"

ANITA-3
32%

Digitization livetime X Fraction of unmasked phi sectors

ANITA-4
91%

2.8x live acceptance



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Conclusions

- New tunable dynamic notch filters were successfully operated during ANITA-4
- Helped to increase per day “instrument livetime” by 2.8x
- With satellite noise under control, we can focus on improving other parts of signal processing
  - ANITA-5 trigger: continuous, low-resolution digitization to perform interferometry in realtime
- ANITA-4 flight is promising and data analysis is underway
  - Planned analysis includes
    - Diffuse search for UHE neutrinos
    - Search for UHE neutrinos from Gamma Ray Bursts
    - Evaluating sensitivity to Fast Radio Bursts

Backup slides

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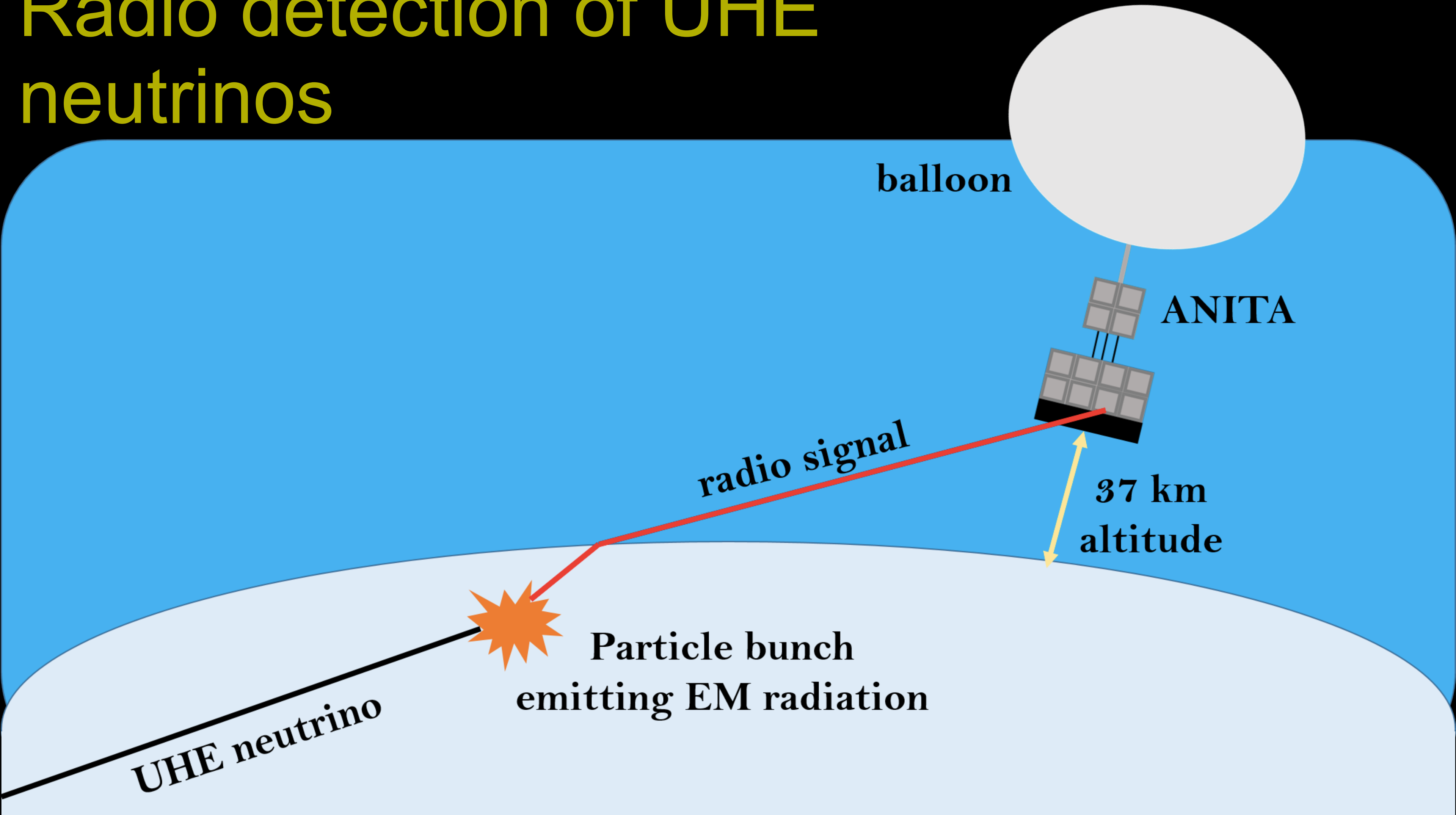
Radio detection of UHE neutrinos



Antarctic ice sheet is lots of ice and it is radio transparent!

Threshold

Changing thresholds during the flight is a secondary method of reducing digitization deadtime

ANITA-3

ANITA-4