High-elevation synoptic radio array for detection of upward moving air-showers, deployed in the Antarctic mountains

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TAROGE and ARIANNA Collaboration

ICRC2019

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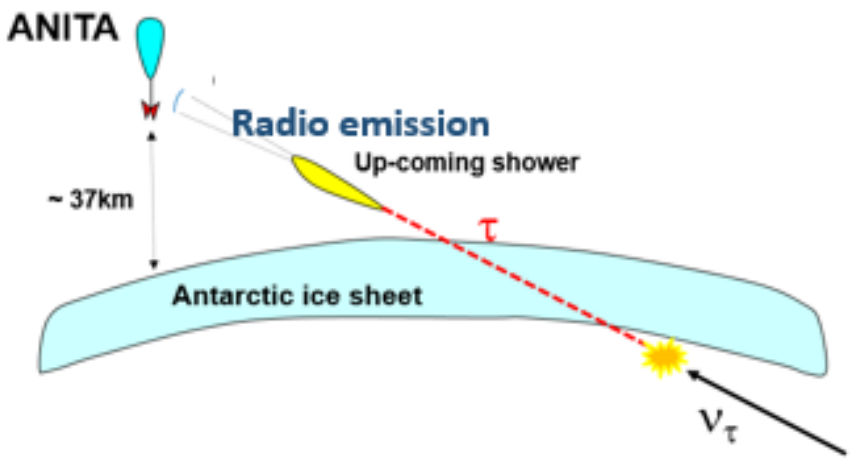
ANITA's anomalous events

Event, flight	3985267, ANITA-I	15717147, ANITA-III
El, Az	-27.4±0.3°, 159.6±0.7°	-35.4±0.3°, 61.41±0.7°
E_{shower}	0.6±0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV
Cord length	~5500 km	~7000 km



- **UHE ν_τ?**

→The arrival directions are too steep to be explained by SM

- **New Physics?**

  Sterile neutrino (Huang 2019, Cherry & Shoemaker 2019, Chuahan & Mohanty 2019)

  Heavy right handed neutrino decay (Anchordoqui et al. 2018)

  Gravitino Decay (Dudas et al. 2018, Collins et al. 2019)

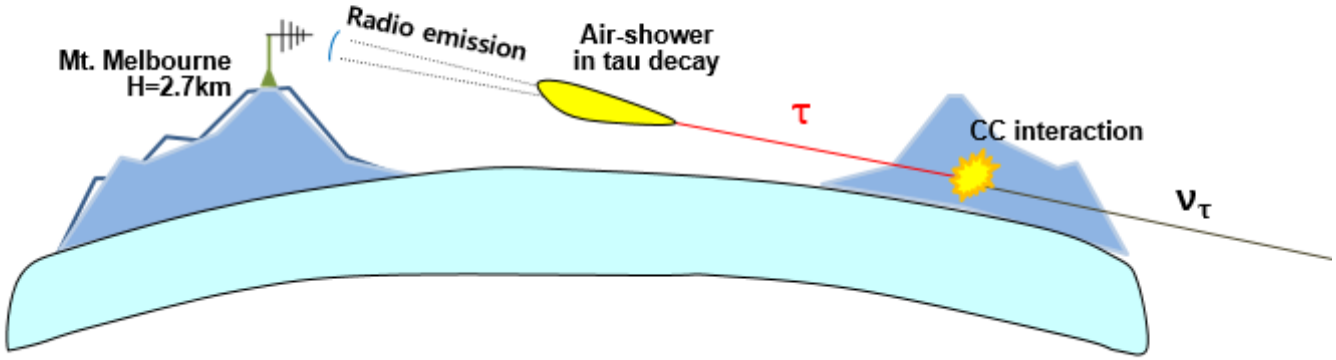
- **Background?**

  Transition radiation (Motloch et al. 2016, de Vries & Prohira 2019)

  Reflection in subsurface layers (Shoemaker et al 2019)

→ Need more events

High-elevation synoptic radio array



- Follows the same detection concept as ANITA,

→ Impulsive RF detection, interferometry technique.

- Place antennas on mountain top

→ Closer to the shower (lower energy threshold)

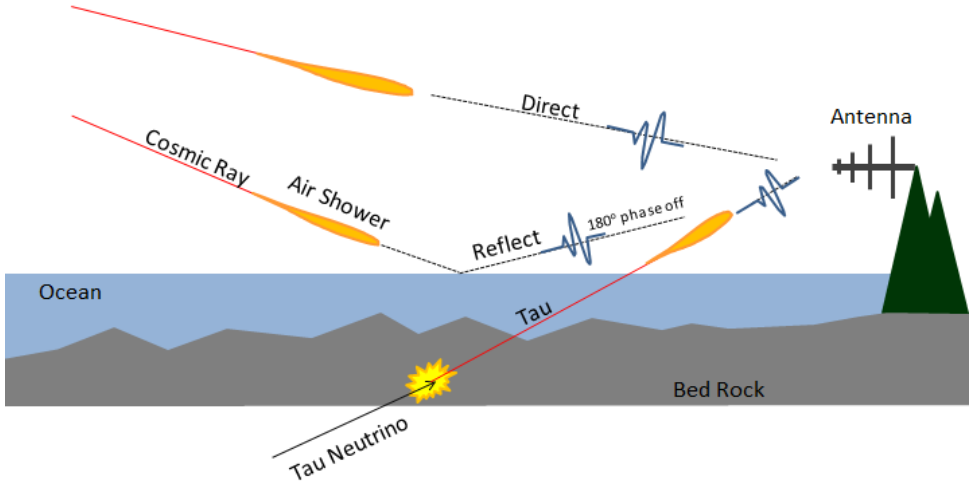
→ Rock target (ANITA uses ice target)

→ Long livetime, 6-12 months / year (ANITA: 30 day flight / 3 years)

→ Easy to extend

Various approaches-1 (TAROGE)

TAROGE

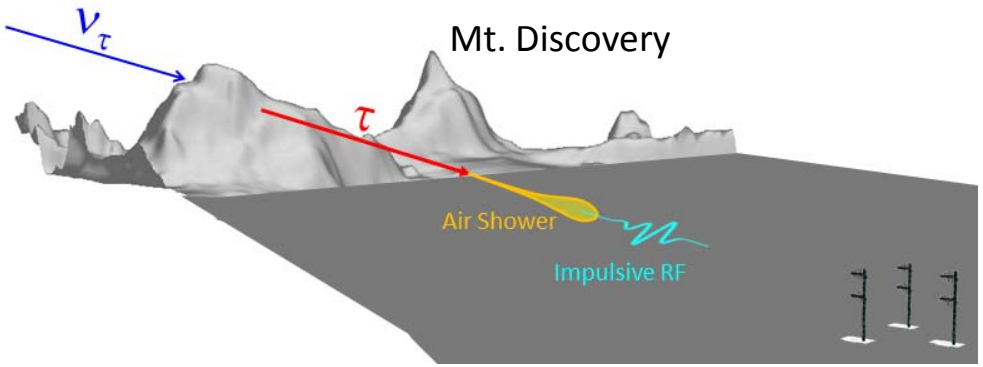


- TAROGE @ high mountains (~1km) in Taiwan
- Higher energy threshold due to anthropogenic noise in Taiwan
- Limited accessibility to higher mountains (2-3km)

See Yaocheng Chen's poster (PS1-153)

Various approaches-2 (ARIANNA-HCR)

ARIANNA HCR



- ARIANNA-HCR @ Moore's bay, Antarctica
- Excellent performance for CR detection
- But systematic uncertainties on low elevation events
  → interference between direct- and reflected- signal

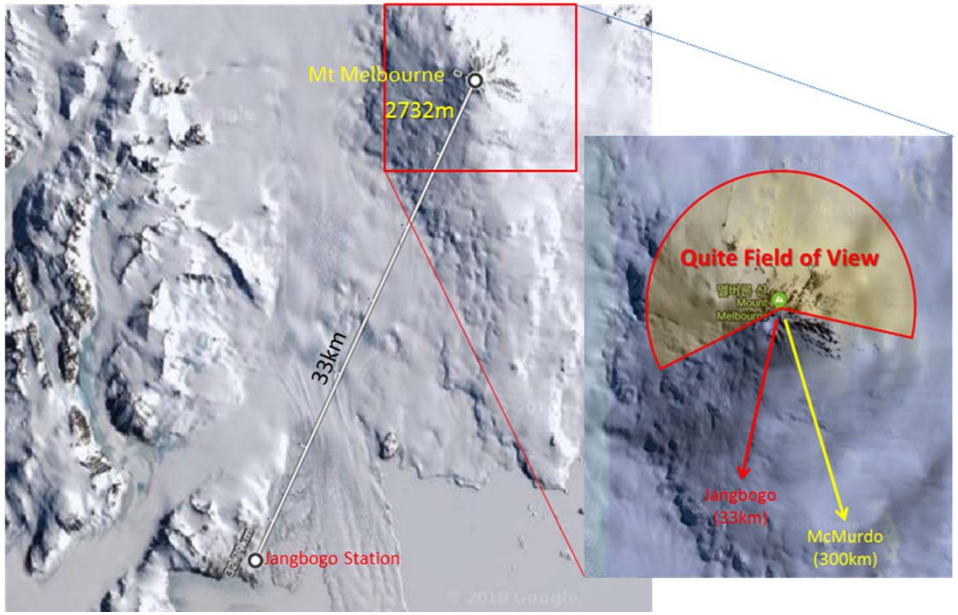
See Shihao Wang's poster (PS3-235)

Why Antarctic Mountain? (TAROGE-Mt. Melbourne)

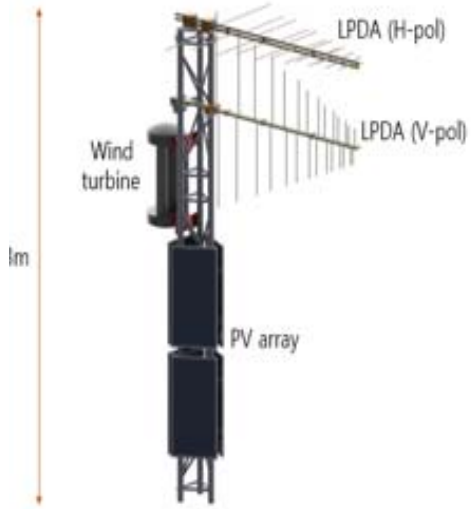
- High Elevation: 2732m
- Lowest anthropogenic noise
- The strongest geo-magnetic field
- Clear view of high mountain ridges (good target)
- No direct-reflect interference
- 33 km away from Jangbogo station (Korean Polar Program)

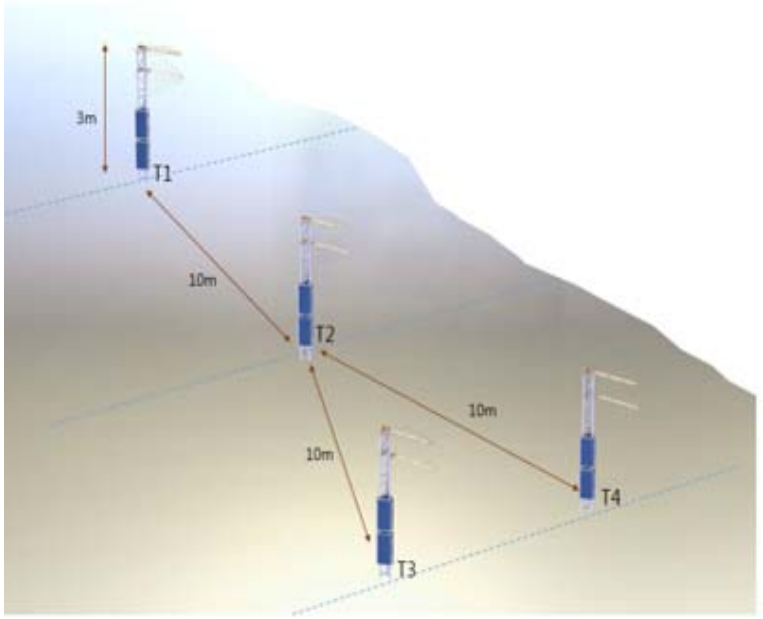
→ Logistics & Infrastructure

→ Good accessibility by helicopter (only 15 min)



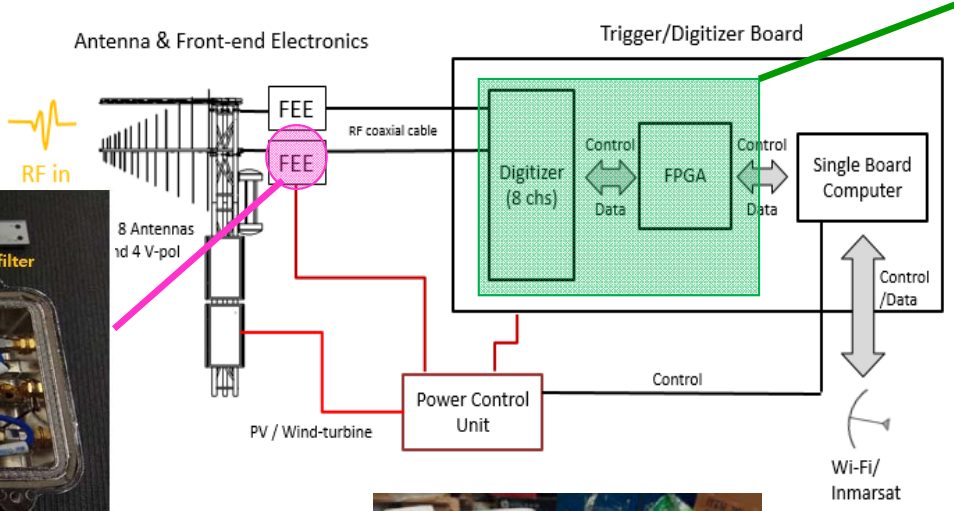
TAROGE-M Receiver Antennas

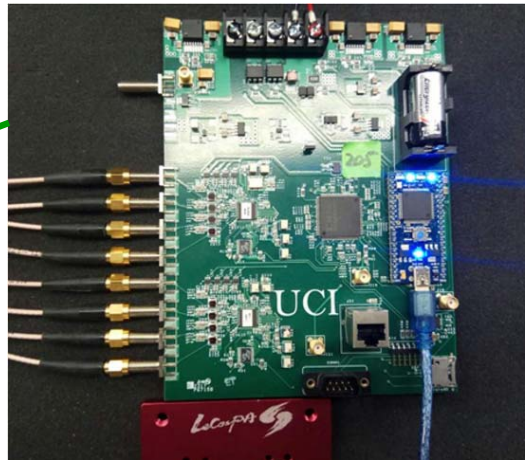




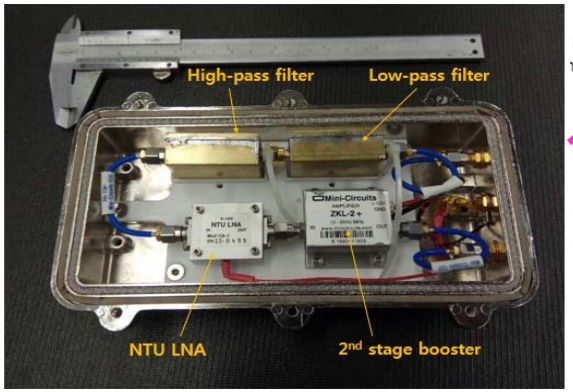
- LPDA Antennas (7dBi, 150-500MHz): Excellent endurance against high wind
- Horizontal- & vertical-polarization channels for polarization angle measurement
- Forming a triangular array (4-5 towers): Interferometry
- Designed to be light-weighted and for fast&easy installation

TAROGE-M System





Front-end



- NTU LNA (<60K noise temp)
  → used in ANITA, ARA, and TAROGE
- Band-pass filters

- All in a portable Faraday cage!

Trigger/Digitizer board

- ARIANNA SST Board

>Digitizer

8 Channels

1GHz analog band width

2GS/s, 12bit ADC, 256 samples

>Trigger

Double threshold

Multi channel coincidence (5ns)

TAROGE-M System (cont.)

- **Data rate**

Level 0: Double threshold & Coincidence → 20 mHz @ 4σ (V_{rms})

Level 1: CW filtering & thermal event rejection (X-corl) → ~ mHz

Forced trigger: 1 mHz

→Data save in local flash-disk and transferred via satellite

- **Power**

20W (prototype) → to be less than 10W in upgraded system

Hybrid (Solar + wind)

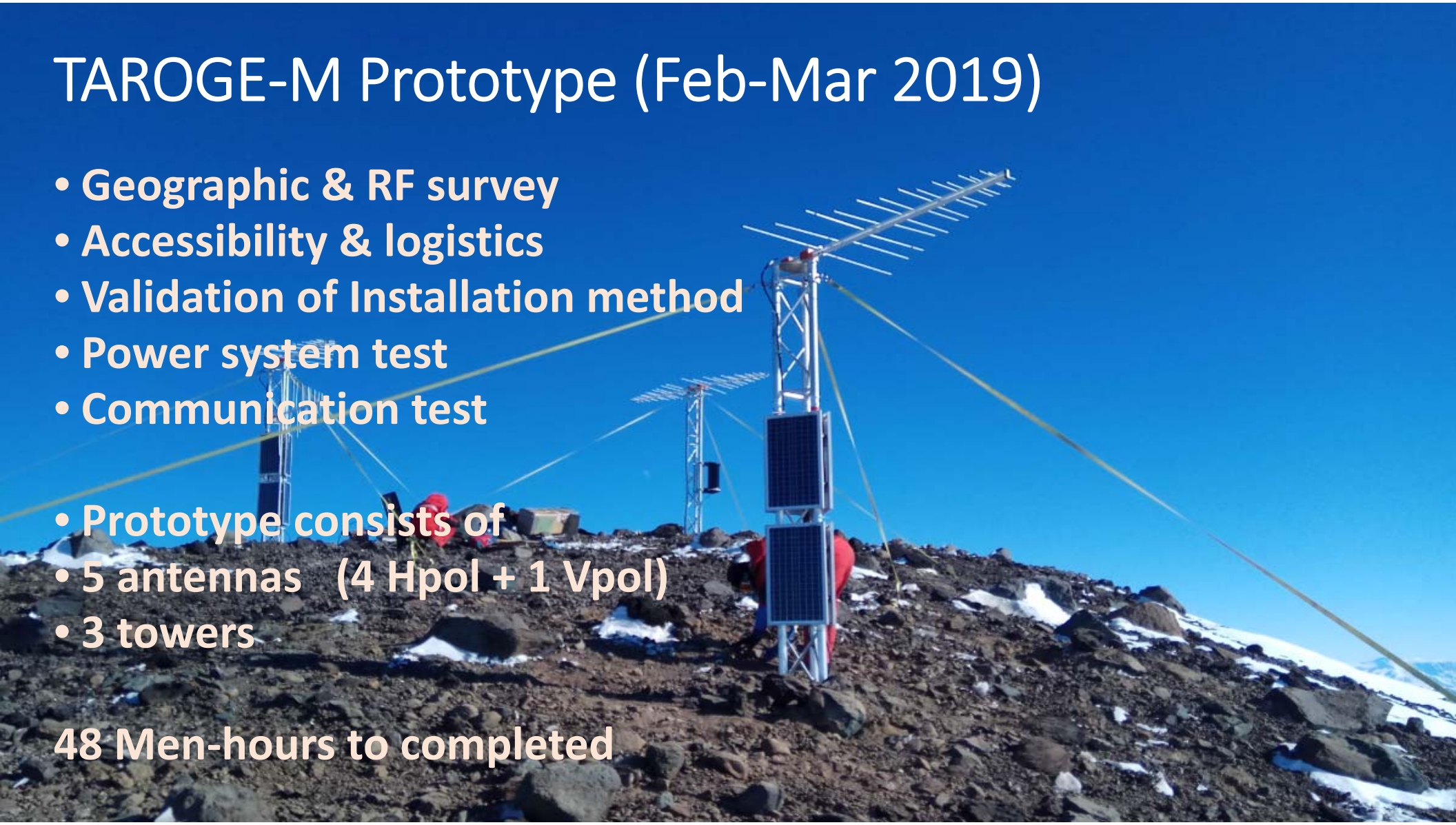
Solar: guaranteed for summer (6 month) operation

Wind: need more R&D → 2x livetime when succeed!

- **Aerial cal-pulser**

Drone + solid state pulser (See Chungyun Kuo's poster PS3-120)

TAROGE-M Prototype (Feb-Mar 2019)



- **Geographic & RF survey**
- **Accessibility & logistics**
- **Validation of Installation method**
- **Power system test**
- **Communication test**

- **Prototype consists of**
- **5 antennas (4 Hpol + 1 Vpol)**
- **3 towers**

48 Men-hours to completed

TAROGE-M Prototype (cont.)

- **Operated 8 hours**
- Then lost communication

→no chance to repair (summer station closing)

→System possibly being alive without communication. (Data on sd-card)

- **RF noise data (forced trigger)**

>Noise floor as low as ARIANNA site

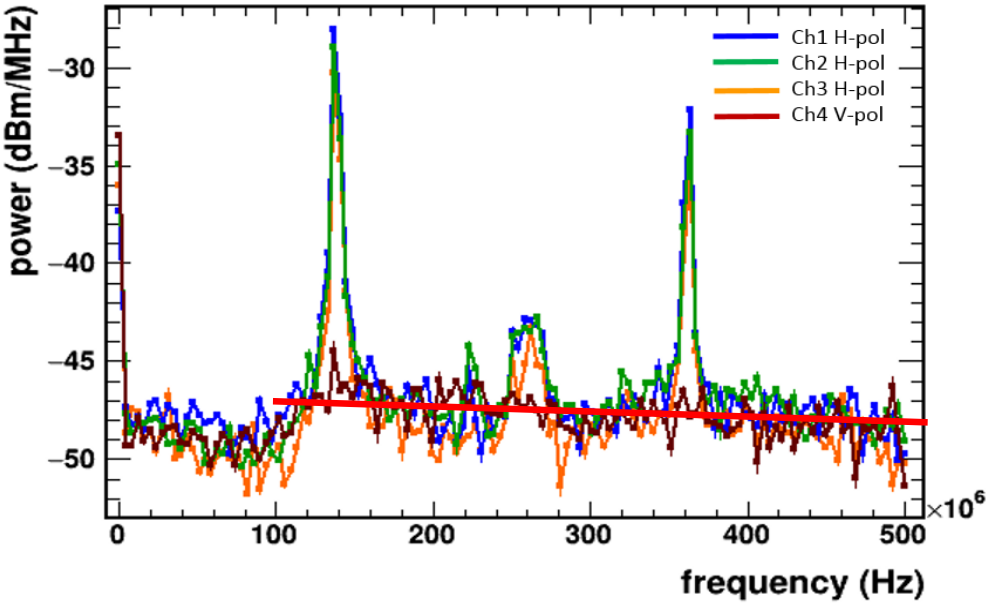
>Two CW peaks

140 MHz: to be removed by HP filter

360 MHz: to be removed by notch filter

240-280MHz (satellite): minimal effect

>No impulsive noise observed in 8 hours



Plan

- Dec-Nov 2019

  System upgrade to 6 channels
  Antenna upgrade (for 160-500MHz) & new RF filters
  New LNAs for low power consumption
  Online-filtering upgrade
  →Data taking during summer + winter test
  →System validation with 100 UHE CR event detection

- Dec-Nov 2020

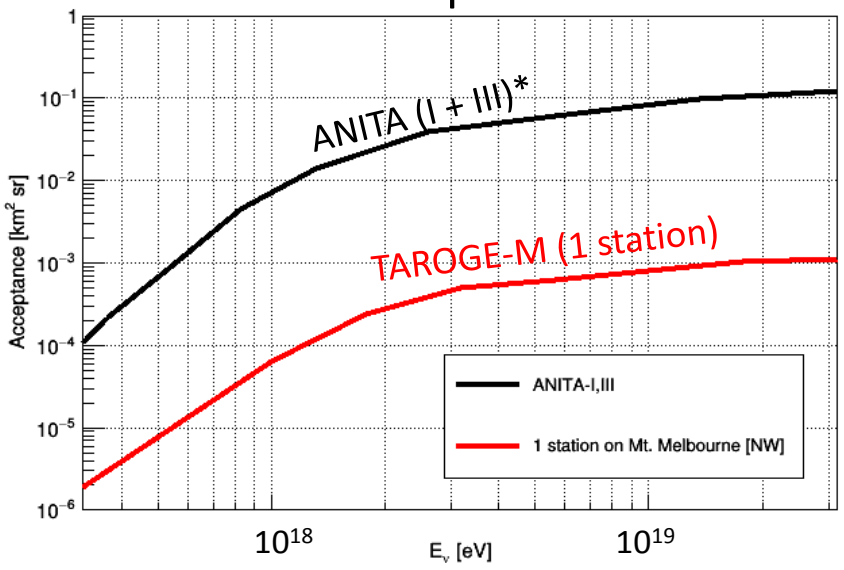
  Complete +3 stations

- Dec-Nov 2021

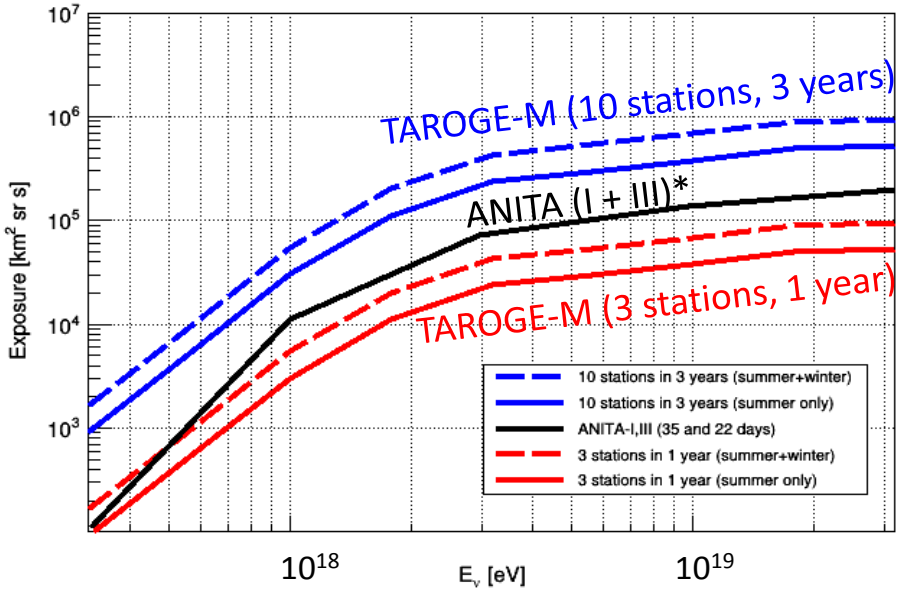
  Complete +6 stations (10 station total)

TAROGE-M Capability for ν_τ detection

Acceptance



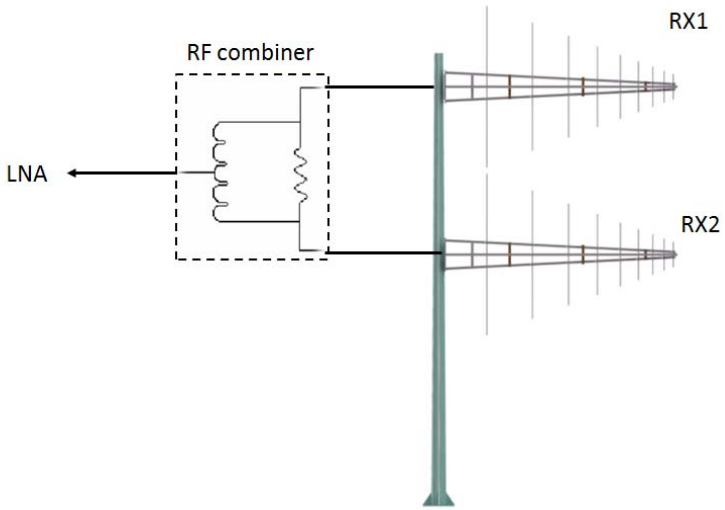
Exposure

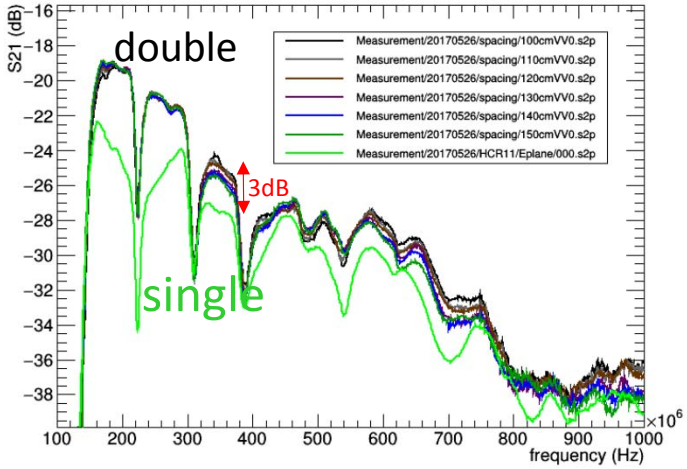


- A detailed simulation study includes;
  neutrino / tau propagation, air-shower development, radio emission, system response

*Romero-Wolf et. al (2019)

TAROGE-M Capability with double-stacked LPDA





Double-stacked antenna makes +3dB higher gain of antenna
Vertically narrow & horizontally wide beam pattern (perfect for us)
→improve sensitivity by factor 2 at 10^{18} eV
→need more R&D for pointing capability

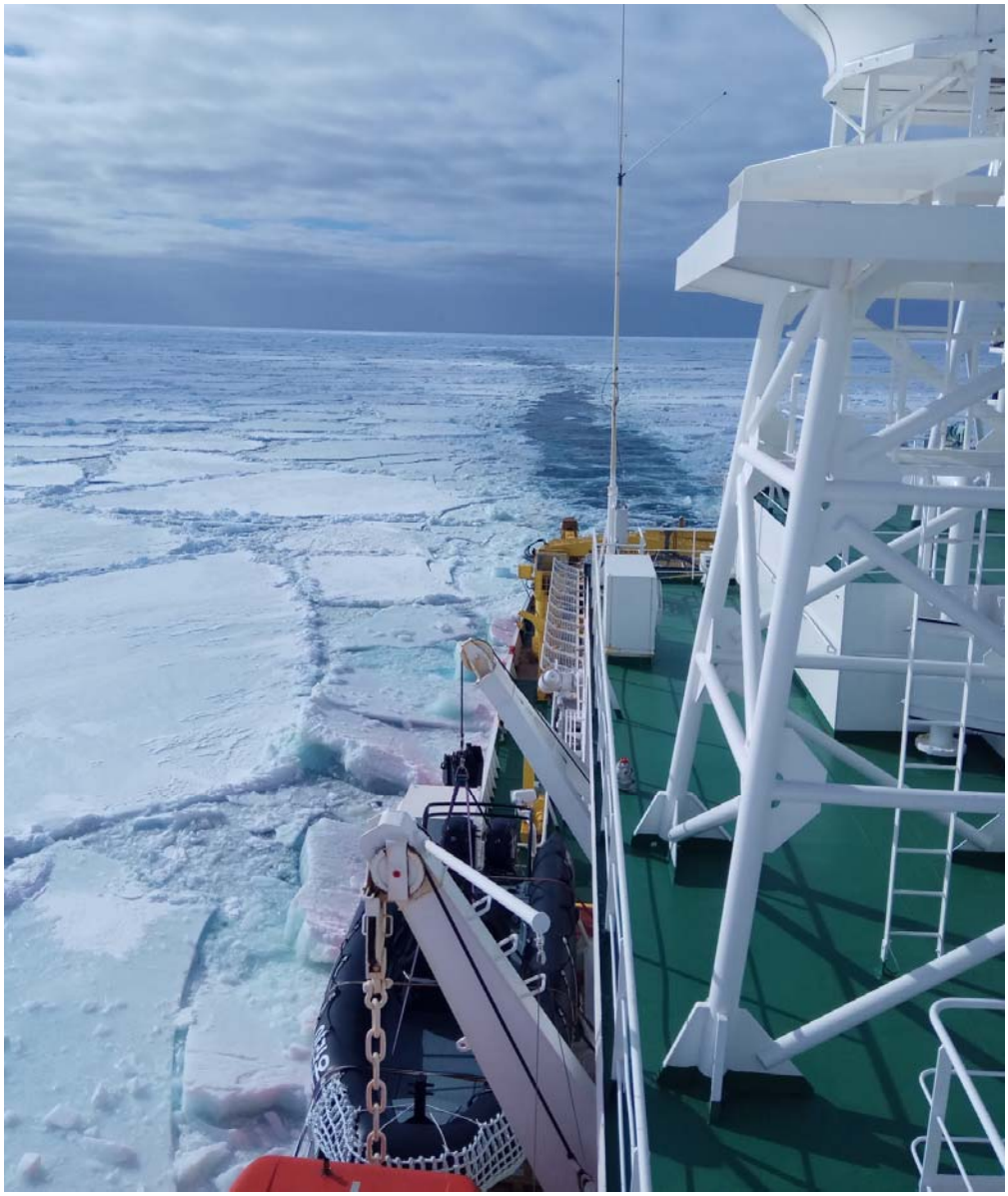
Conclusion

TAROGE-M provides a promising and rapid method to unveil ANITA's mystery events

How to reach to Jangbogo Station

ARAON (Ice breaker)

7-12 days (one way)



Free Antarctic cruise / Helicopter tour / Korean BBQ every day

Your participation will be welcomed