UNIVERSITY OF DELAWARE
BARTOL RESEARCH INSTITUTE

ICECUBE GEN2

PIERRE AUGER OBSERVATORY

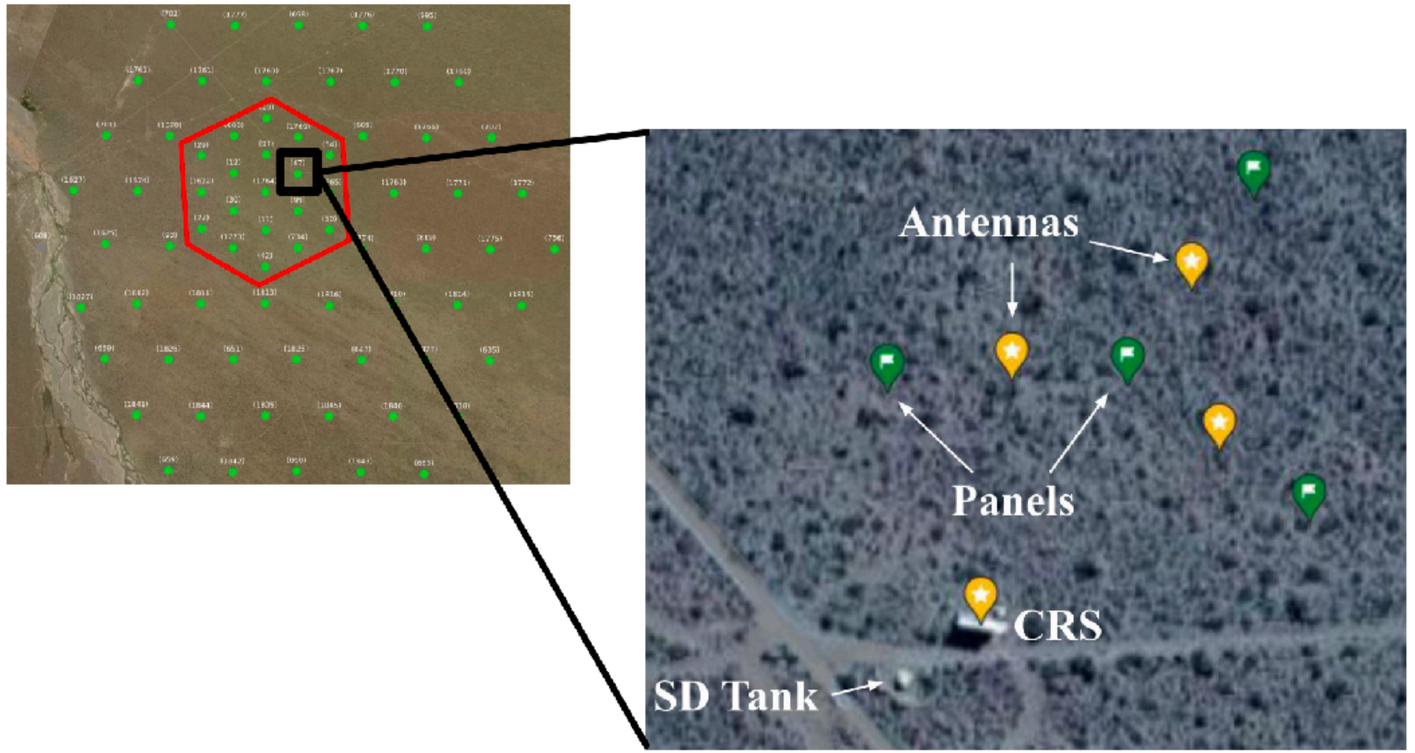
Observation of air showers with an IceCube-Gen2 prototype station at the Pierre Auger Observatory

Stef Verpoest for the IceCube Gen-2 and Pierre Auger collaborations

ARENA 2024, June 13, Chicago

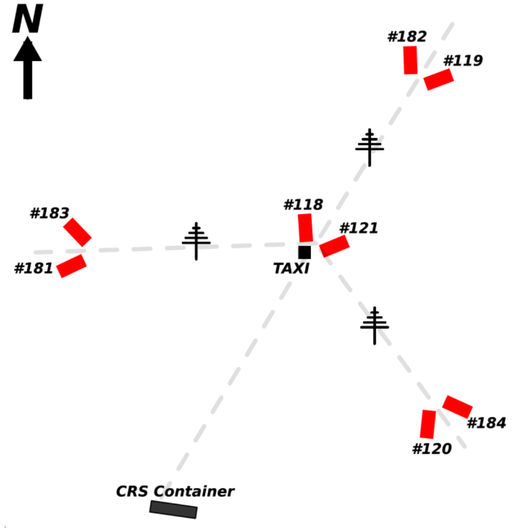
IceCube @ Auger

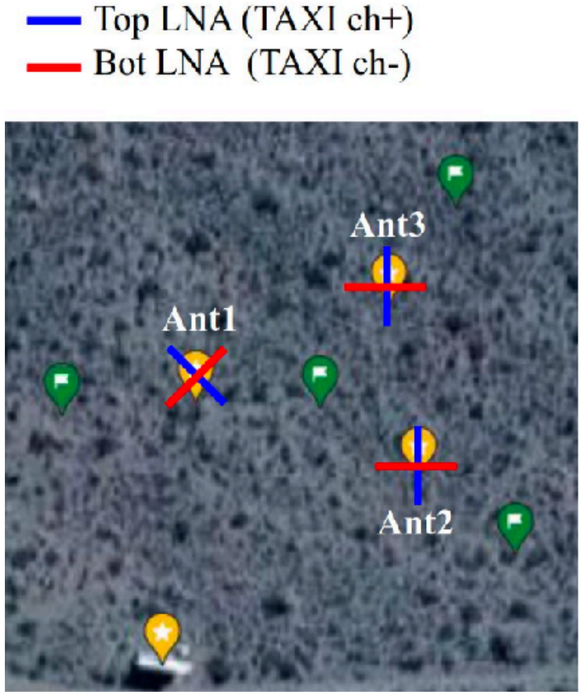
- Surface station deployed at Pierre Auger observatory
  - Prototype station for
    - IceTop Surface Enhancement
    - IceCube Gen-2 surface array
  - Located inside SD-433 infill array
  - Why?
    - More accessible location
    - Cross checks between Auger & IceTop



Prototype station details

- Station layout
  - 2x4 scintillator panels
  - 3 SKALA antennas
  - Central DAQ (TAXI)

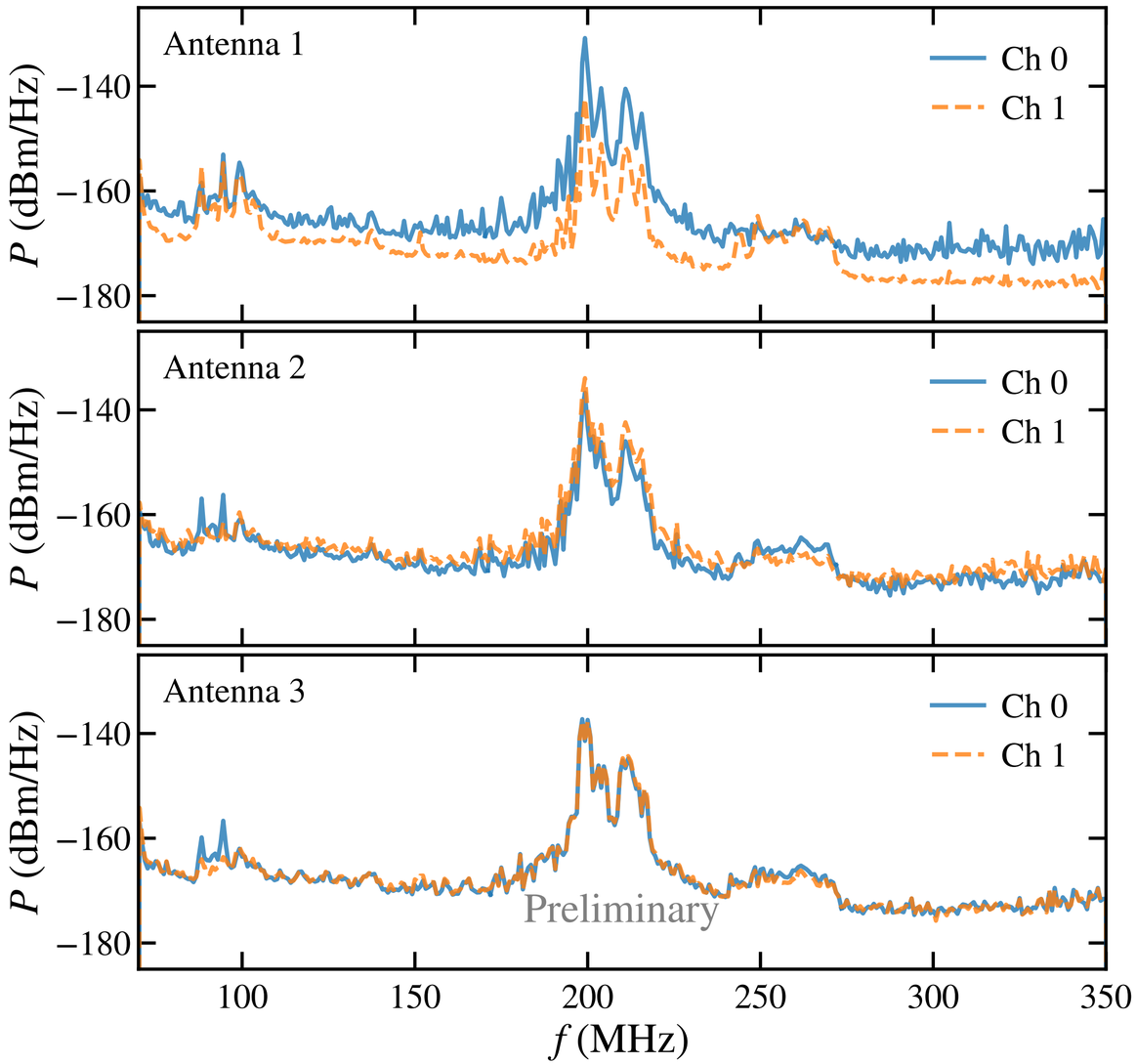




- Triggers for radio readout
  - Scintillator trigger
  - Fixed-rate software trigger (background waveforms)

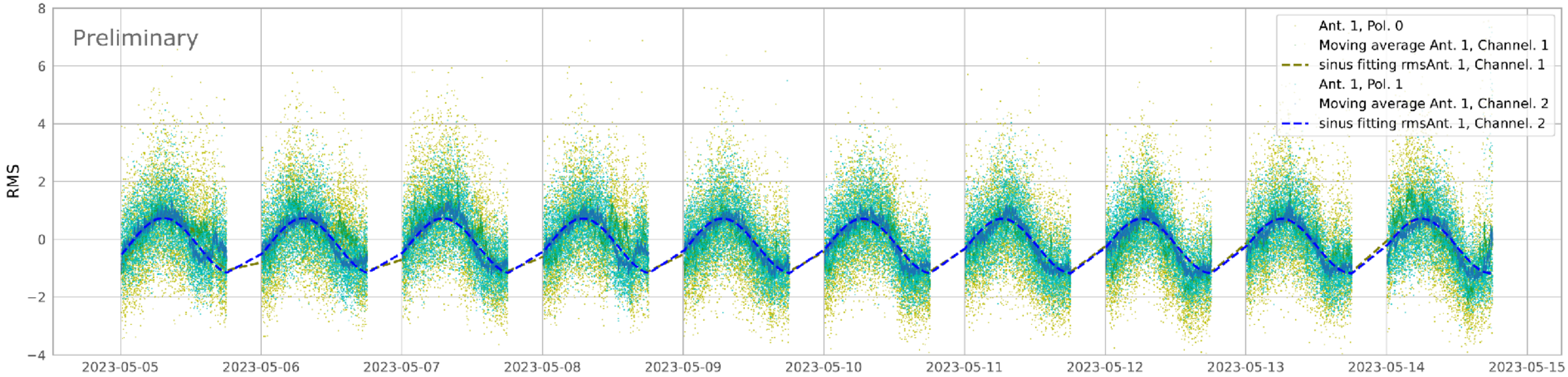
Background spectrum

- Background waveforms
- Frequency spectrum
  - Nominal band 70 - 350 MHz
  - Large RFI
    - FM radio ~100 MHz
    - TV ~200 MHz
  - Relatively clean band in between



Galactic noise

- Time evolution of RMS
  - Background waveforms
  - 110 MHz - 130 MHz
  - Sidereal modulation observed



Air shower search

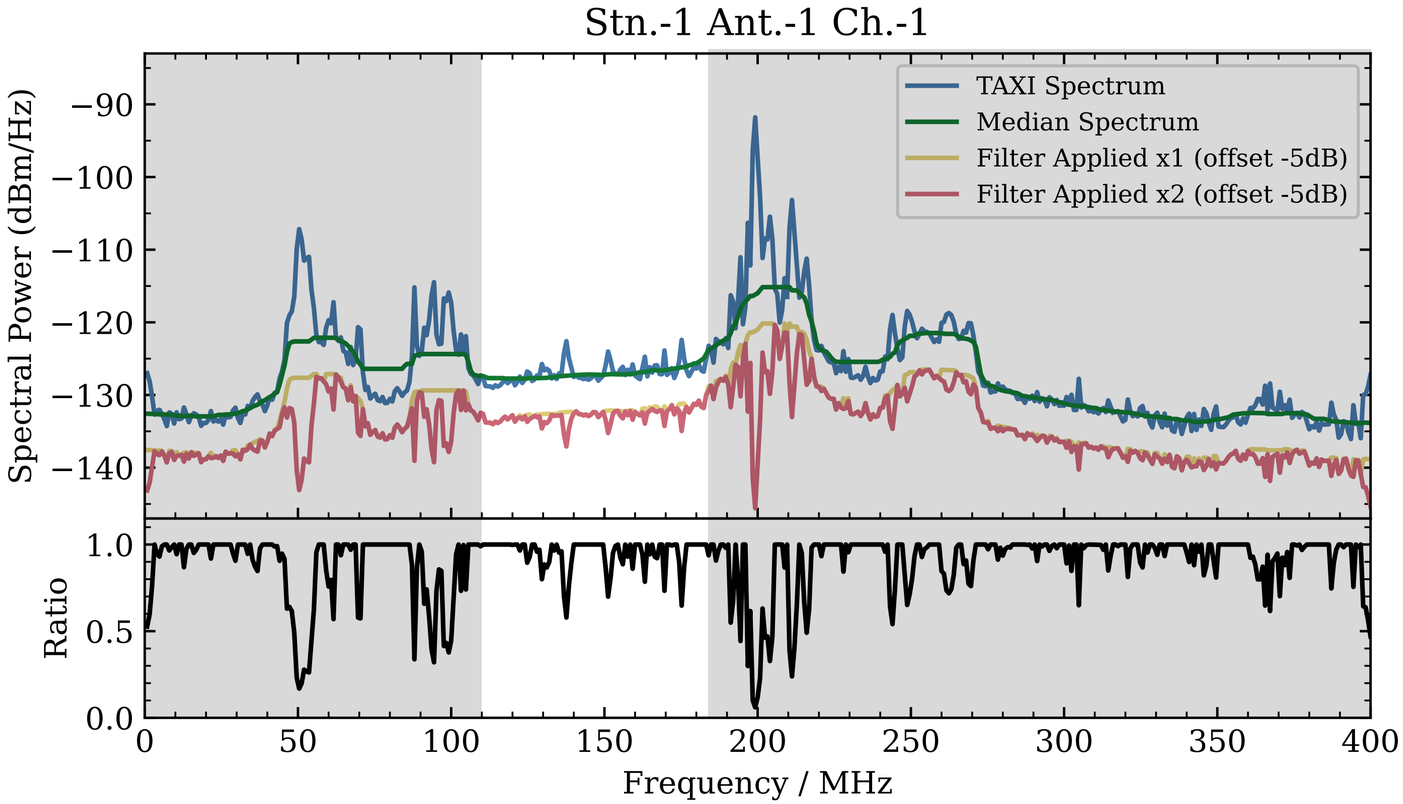
- Dataset selected for first analysis
  - Radio data from prototype station
    - May 2023 (1000 MSps), November 2023 (800 MSps), January 2023 (800 MSps)
  - SD-433 data
    - Preliminary reconstructions of shower core, direction, energy

- Method
  1. Processing & filtering of radio data
  2. Select high-SNR, scintillator-triggered events
  3. Match with SD event based on time & direction
  4. Re-simulate event for validation

Air shower search

Filtering

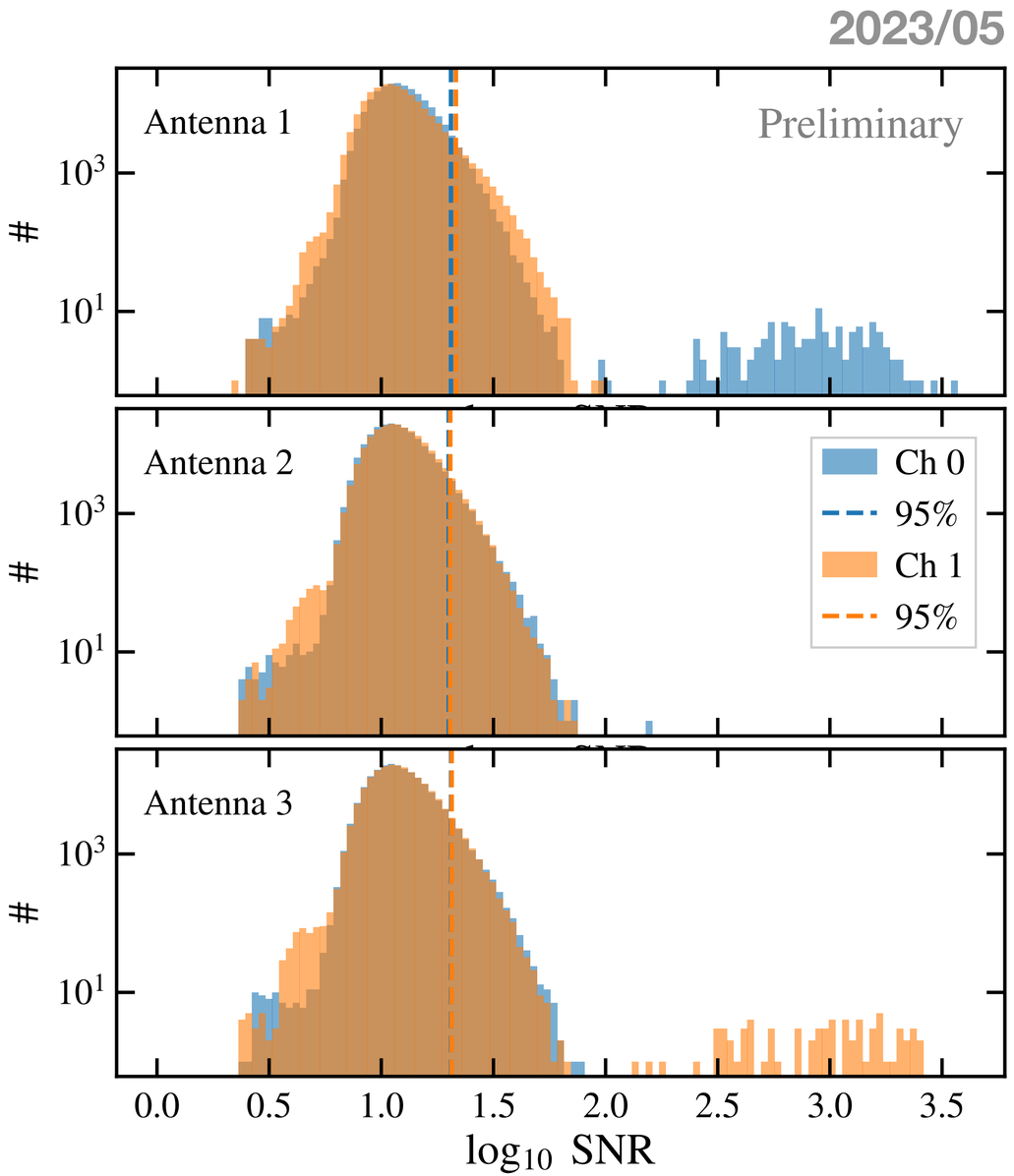
- Bandpass & RFI suppression
  - 110 MHz - 185 MHz
  - Frequency weighting to suppress RFI



Air shower search

Noise SNR distribution

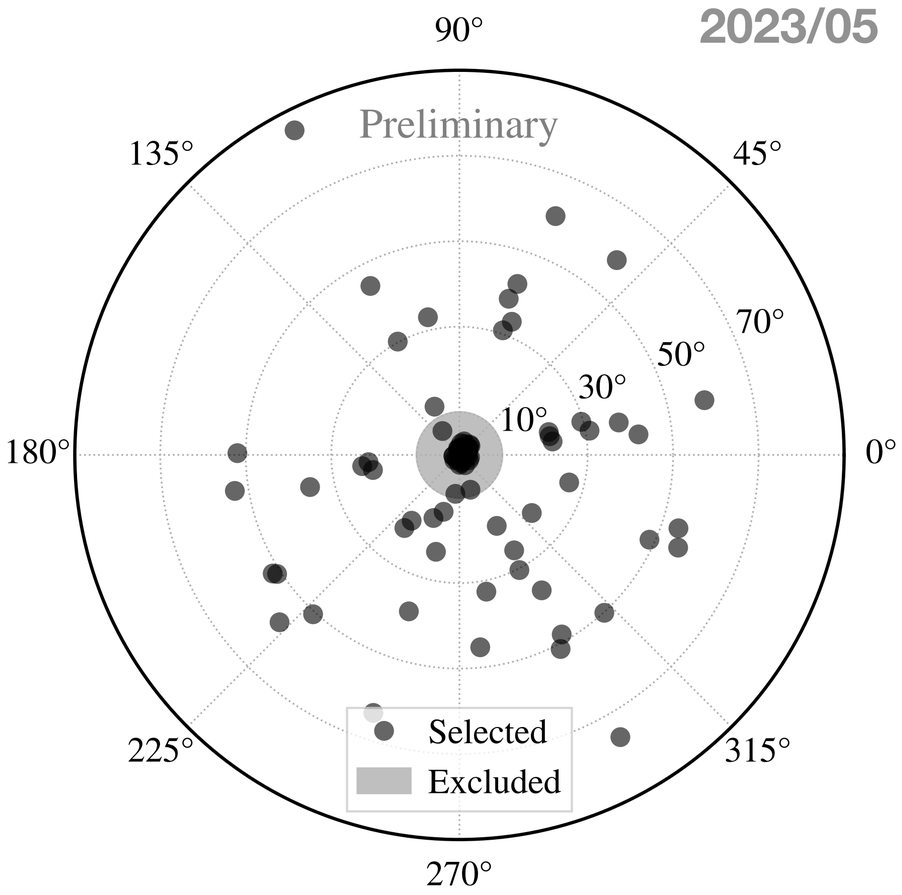
- Background SNR
  - Background waveforms
  - Find 95% percentile value



Air shower search

Selection & reconstruction

- Radio event selection
  - Scintillator triggered events
  - At least 1 polarization in each antenna passes 95% SNR cut
- Reconstruction
  - Plane front reconstruction on signal peak times
  - DAQ artifacts: exclude 10° around zenith

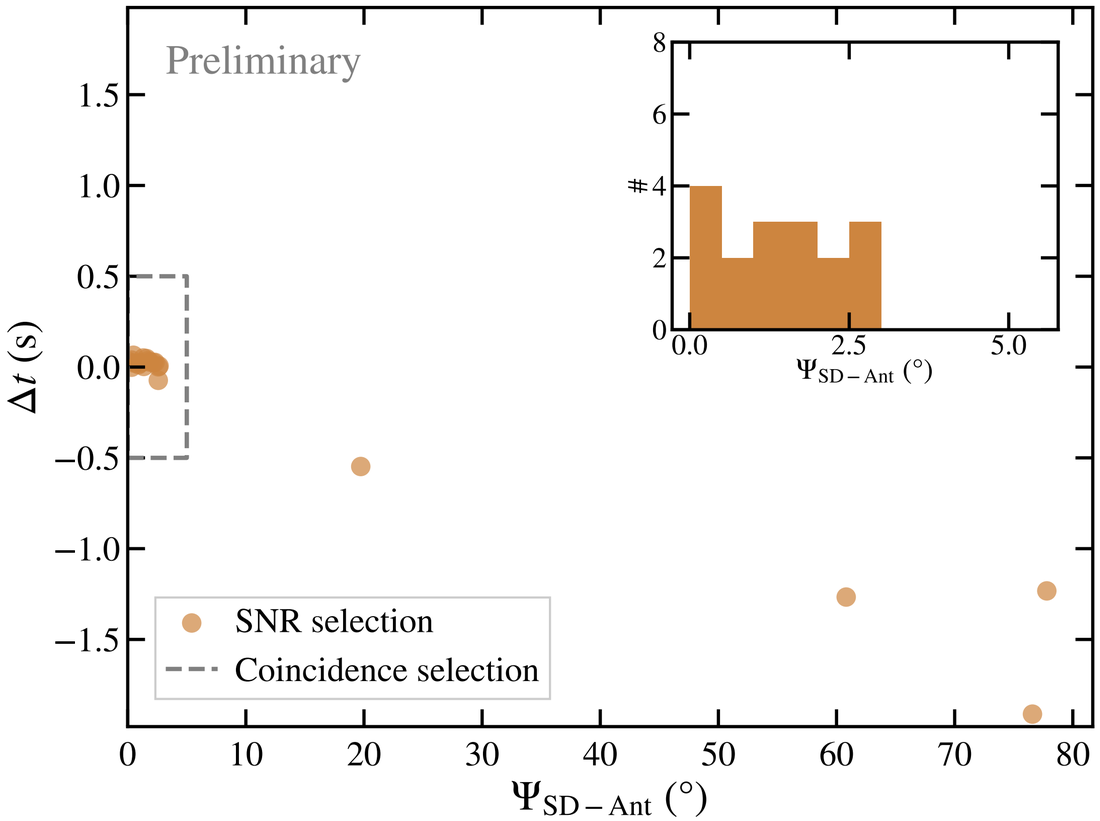


Air shower search

Matching with Auger SD-433 events

2023/05

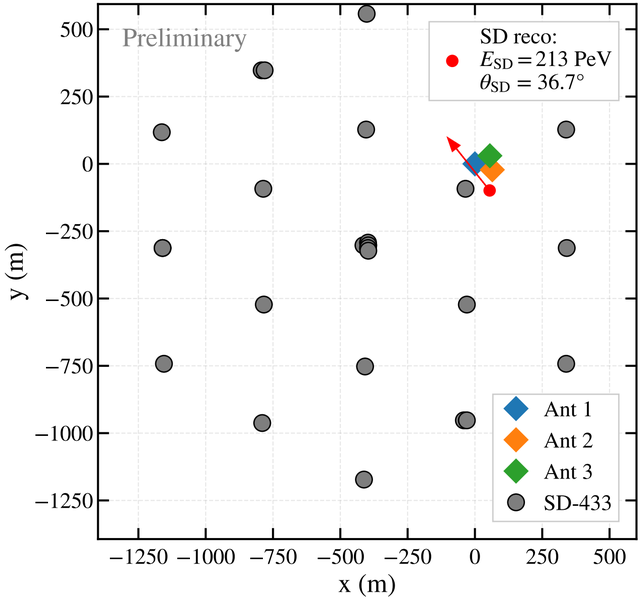
- Time offset
  - Statistically determine offset between station and SD
  - Synchronization issues: drifts in time → derive daily
- Event matching
  - [-0.5s, +0.5s] window around station trigger
    - SD-433 dataset rate is ~0.01 Hz
  - If opening angle < 5°, consider as coincident event

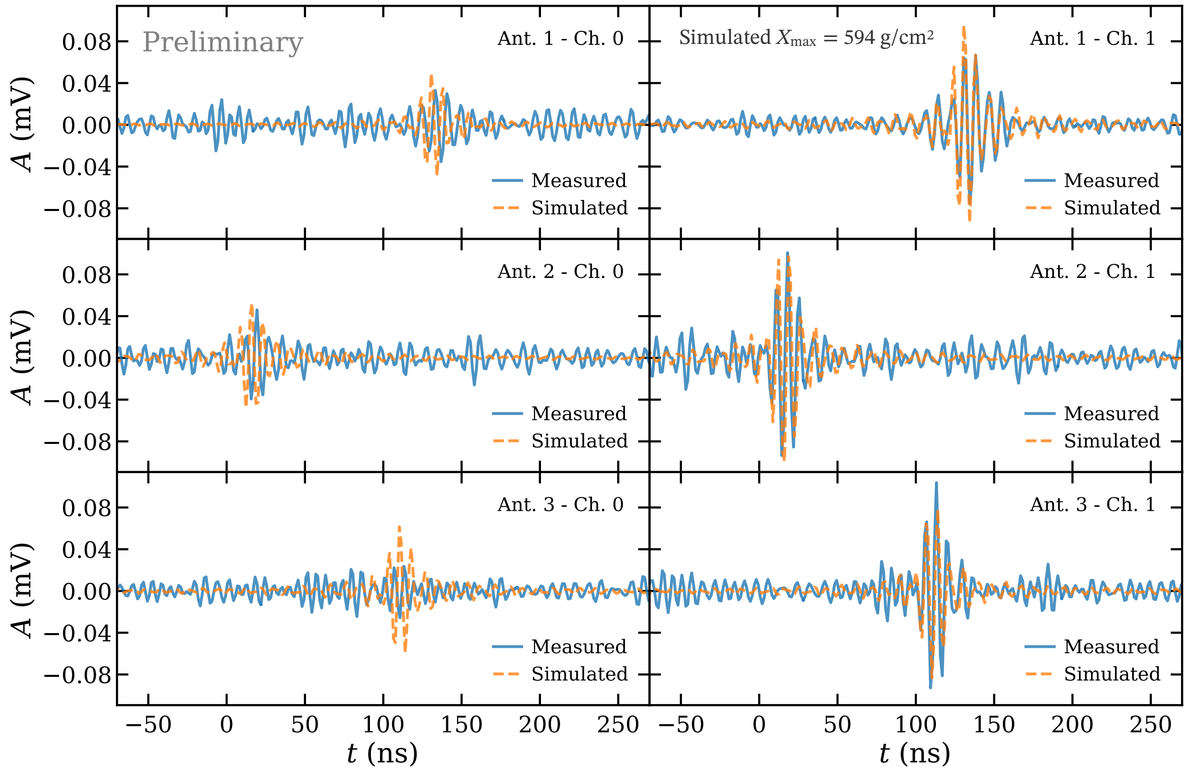


Air shower search

Validation of identified events

- CoREAS simulation
  - Fixed properties from SD reconstruction
    - Core position
    - Direction
    - Energy
- Processing
  - Frequency response of DAQ
  - Processing chain identical to data
  - No noise added





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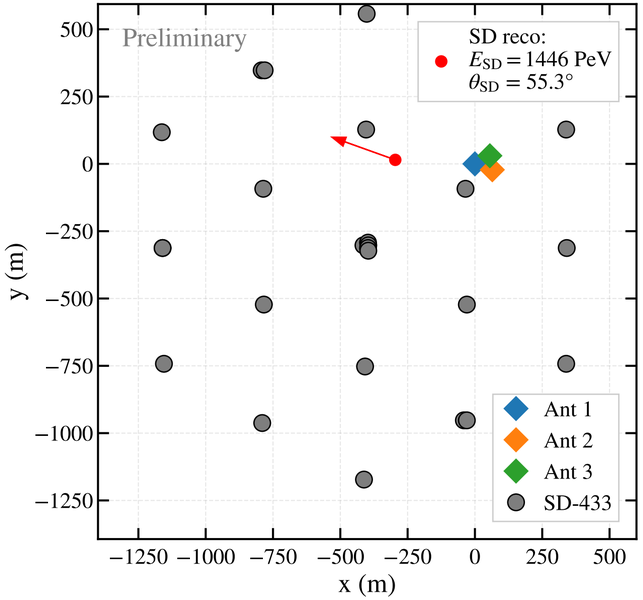

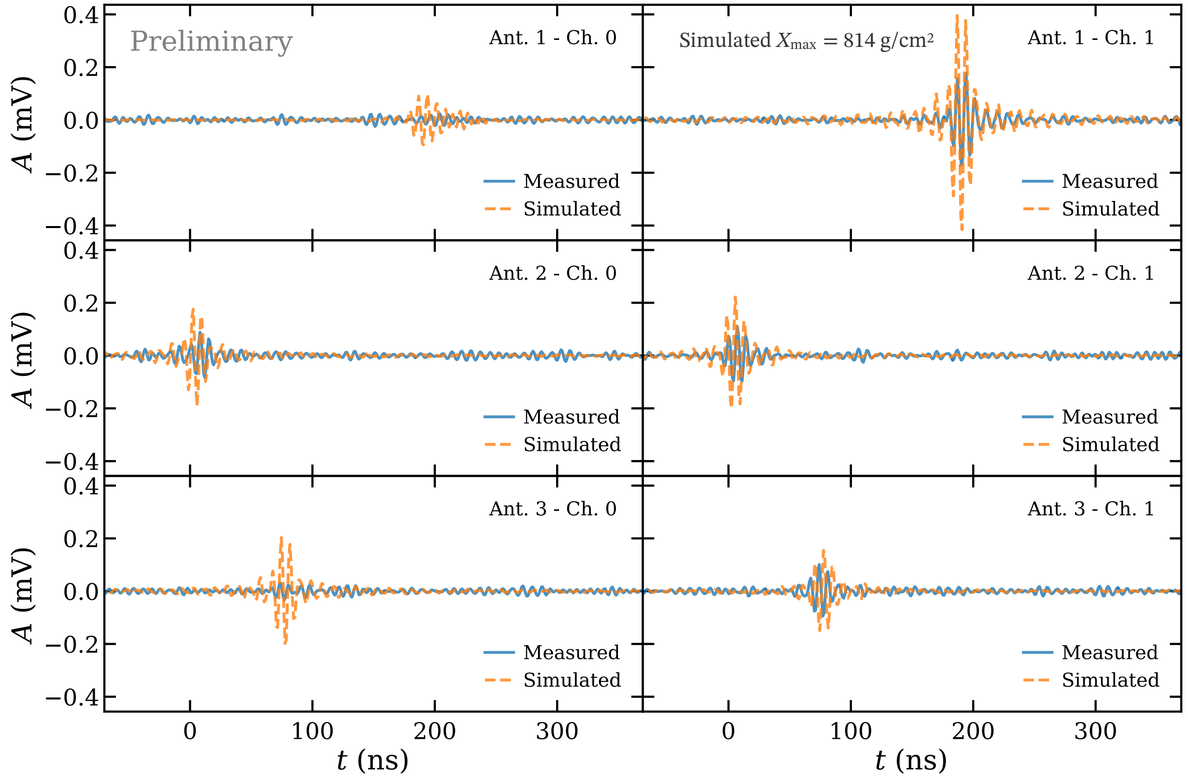

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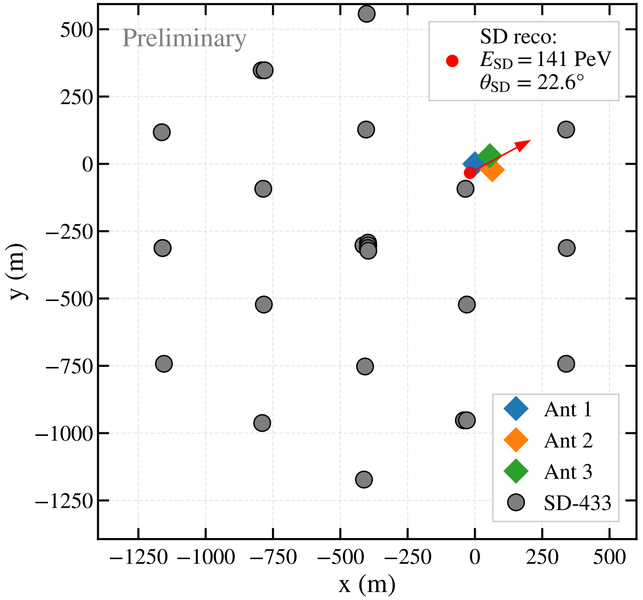
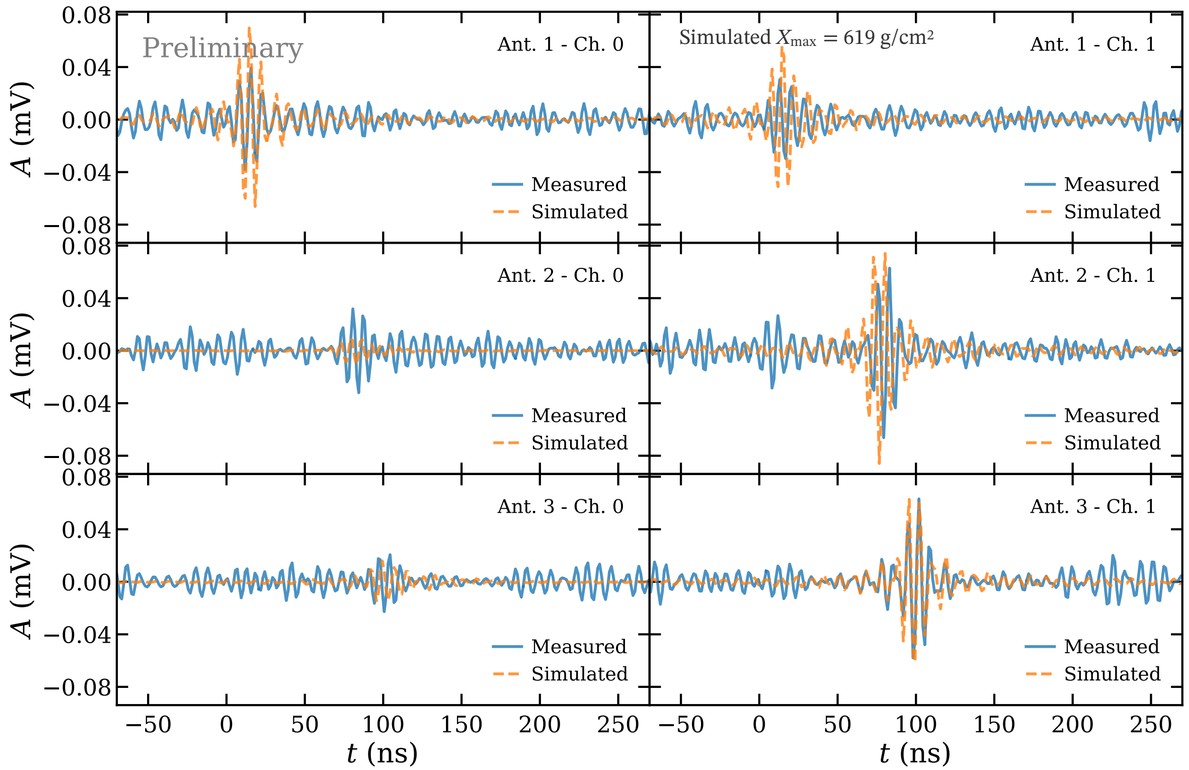
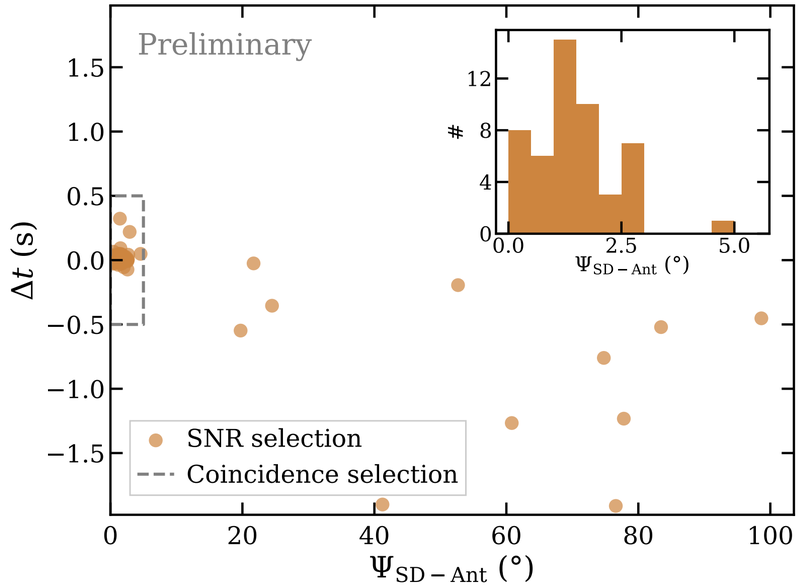


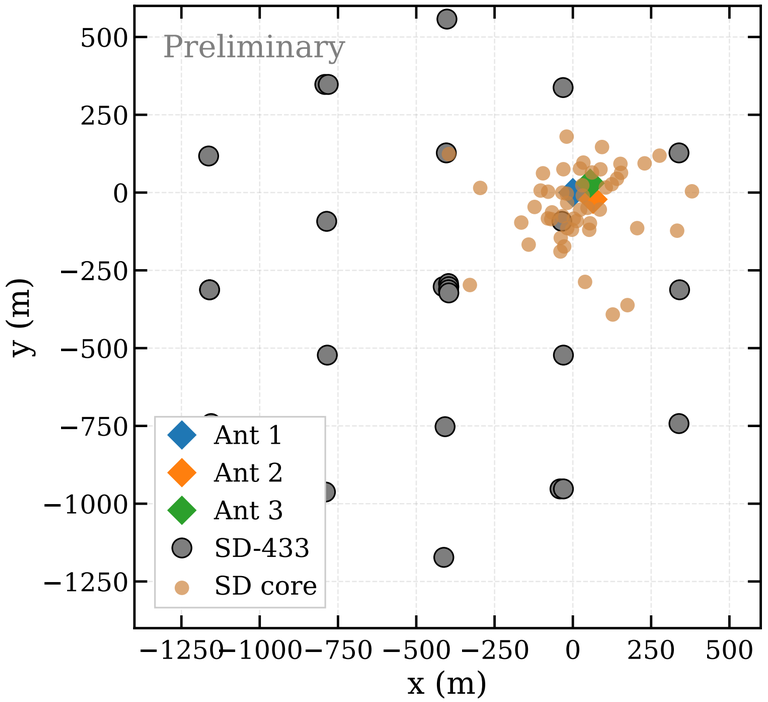


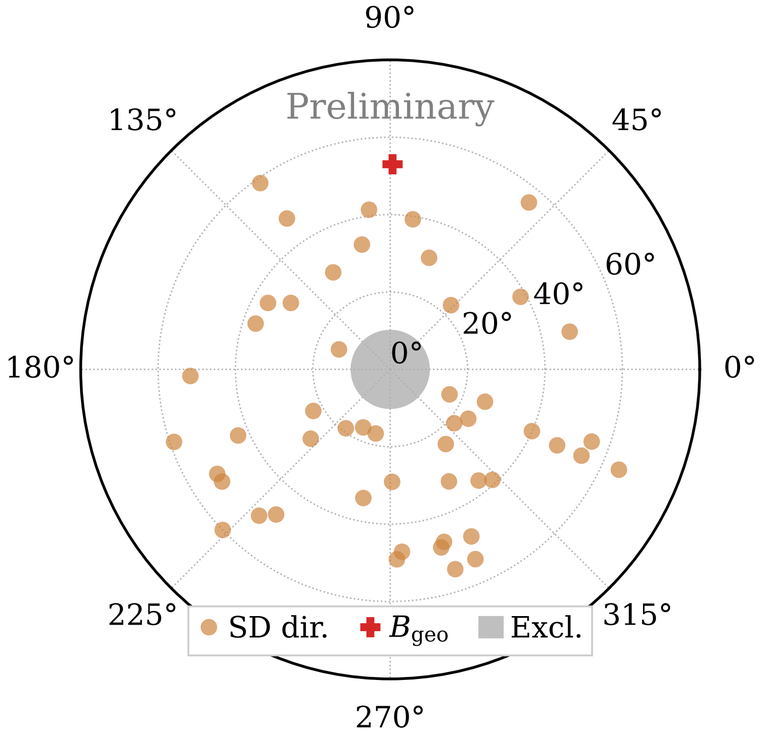
Air shower search

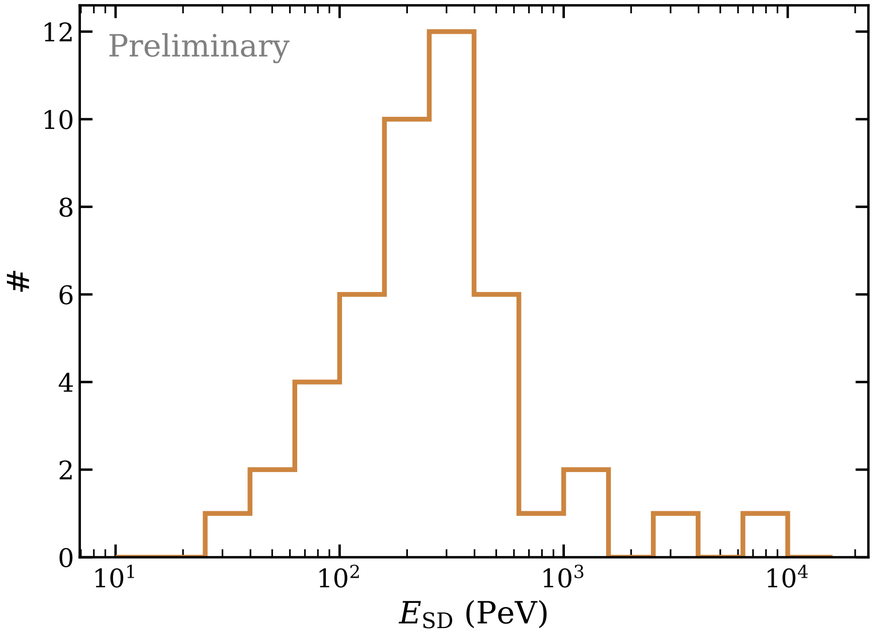
Full shower sample

- Identified 50 events in ~3 months







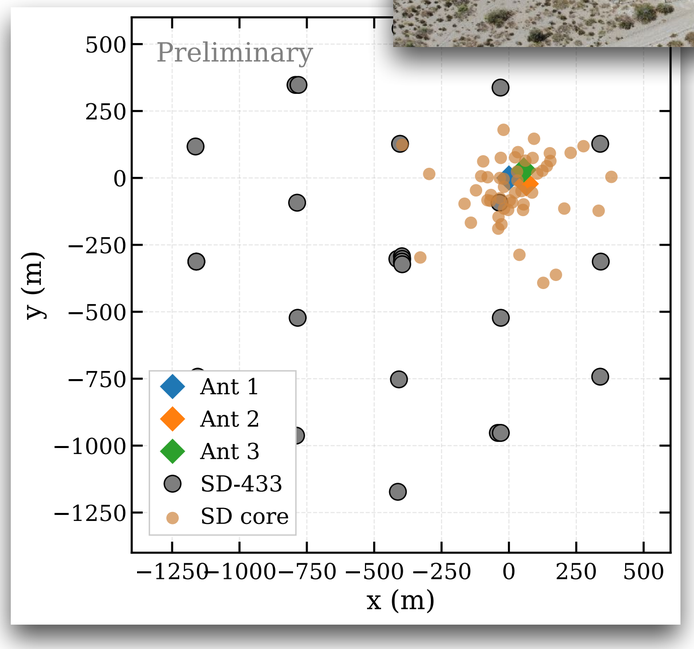


Summary & Outlook

- Scintillation detectors & SKALA antennas @ Auger SD-433
  - Prototype for IceTop Surface Enhancement / IceCube-Gen2 surface array

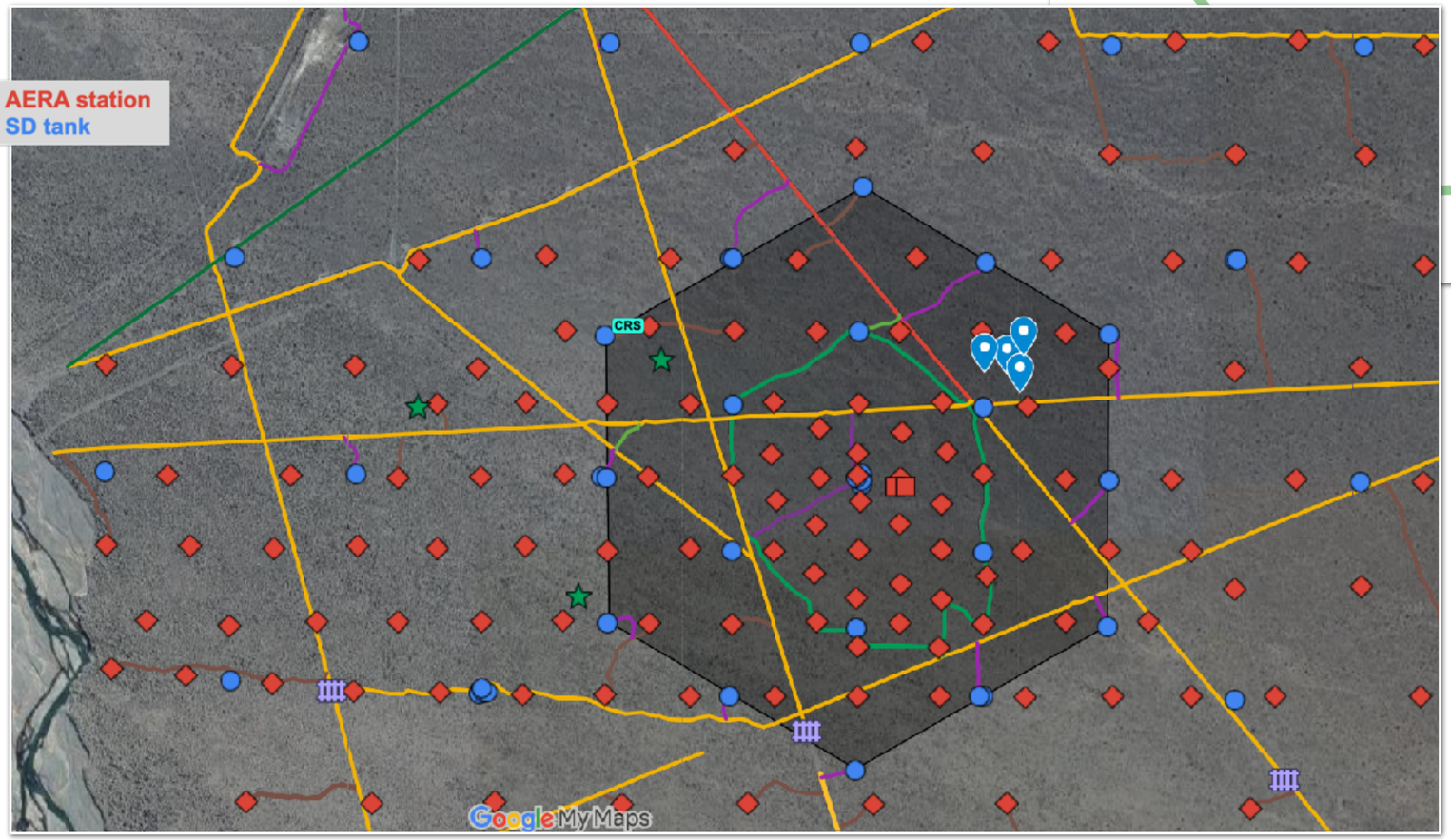
- First analysis of radio data
  - Observation of Galactic noise modulation
  - Detection of air showers coincident with SD-433
    - 50 events in ~3 months
    - 110 MHz - 185 MHz band
    - Starting at several 10s of PeV

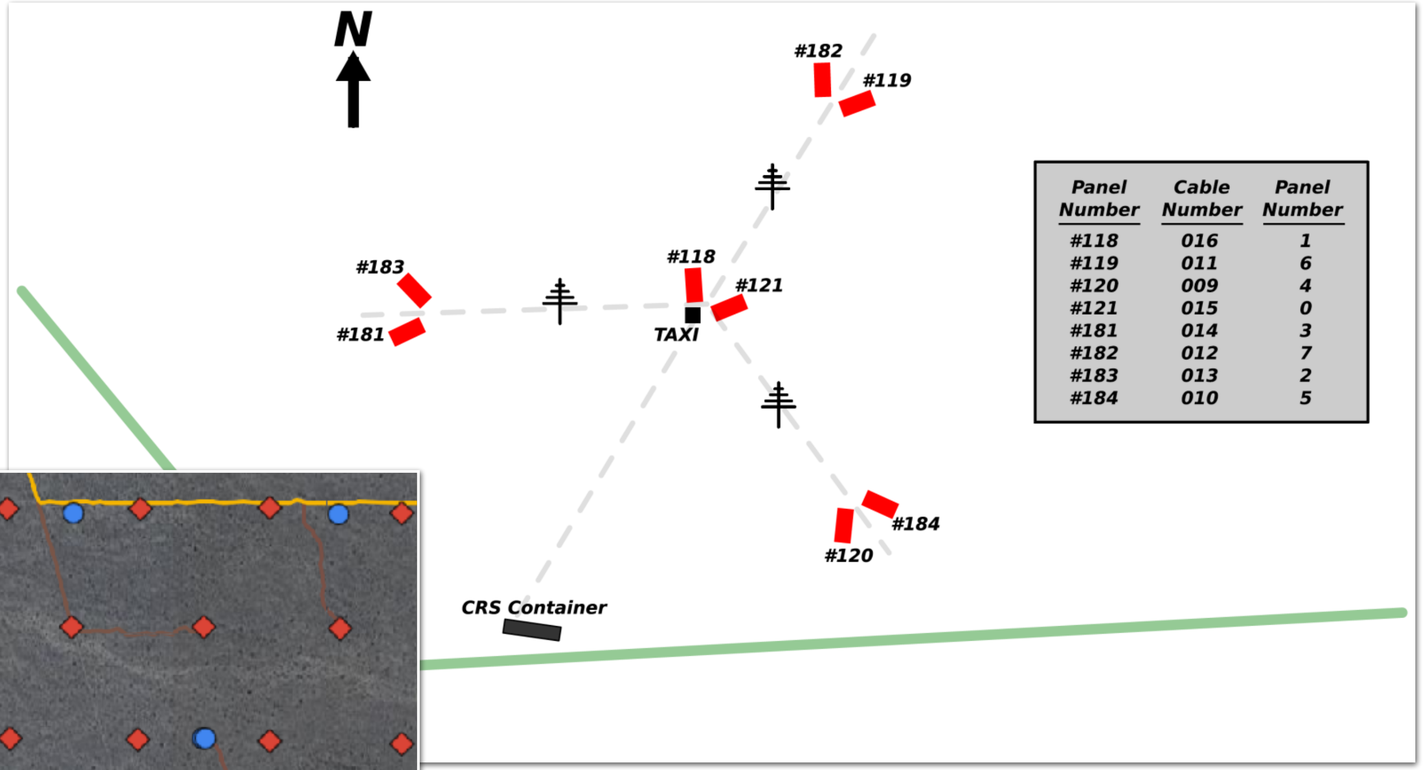
- Future deployment
  - Preparing deployment of additional SKALAs in SD-433
    - Will be triggered by nearby SD detector



Backup

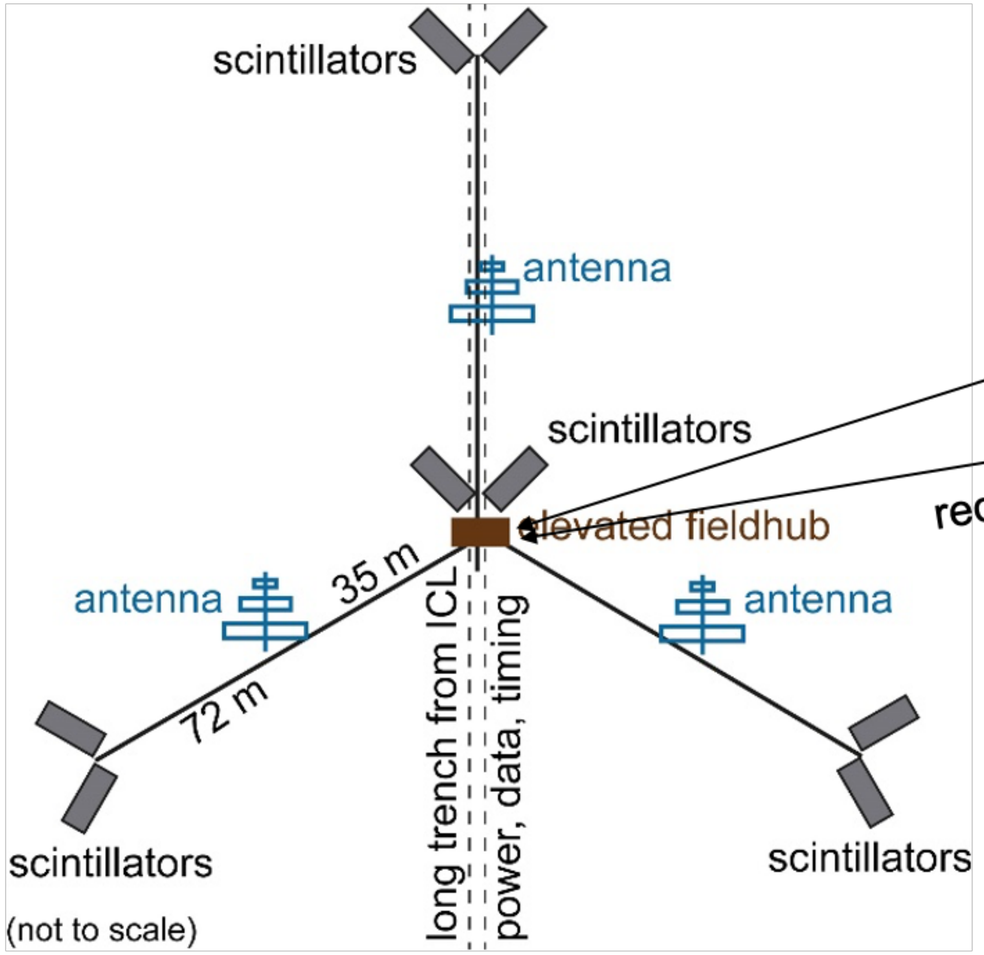
Map of station





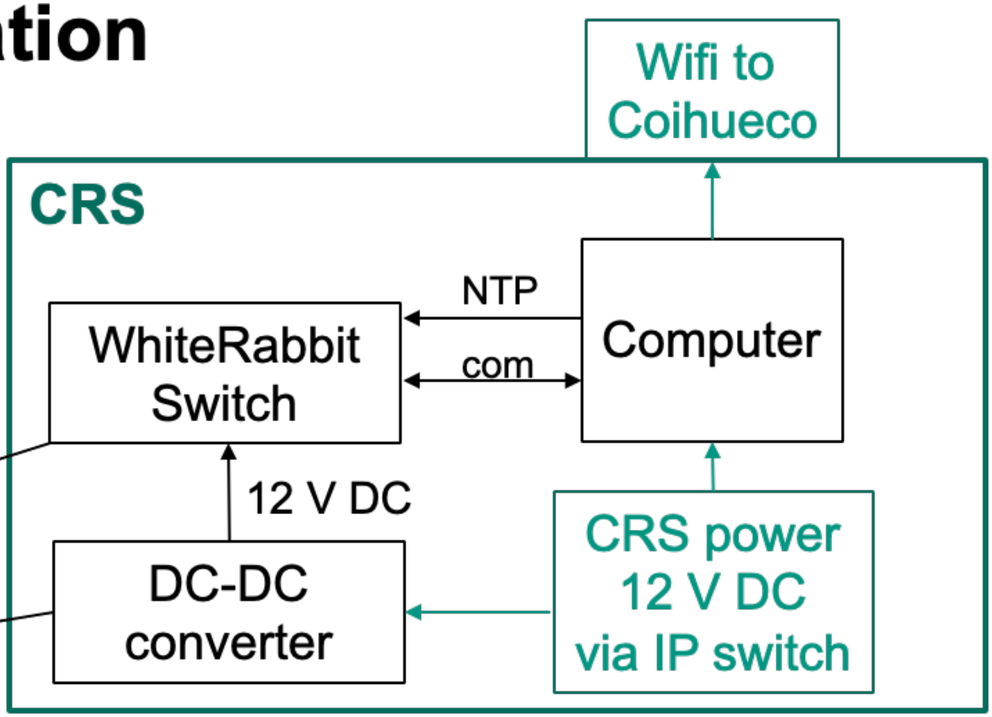
Panel Number	Cable Number	Panel Number
#118	016	1
#119	011	6
#120	009	4
#121	015	0
#181	014	3
#182	012	7
#183	013	2
#184	010	5

Deployment Sketch at CRS of existing station



buried optical fiber

redundant 24 V DC, 2.5 A
(buried + lightning protection)
max distance: 100m



*second bullet link to Coihueco kept as spare
(AERA would get priority if the spare is needed)

Power Budget:

- Station: 60 W
- WR Switch: < 60 W
- Computer: < 80 W

Total < 200 W
(corresponds to free power bank in CRS)