Hunting for cosmogenic neutrinos with the ARIANNA experiment

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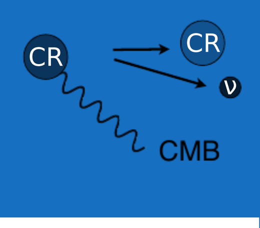
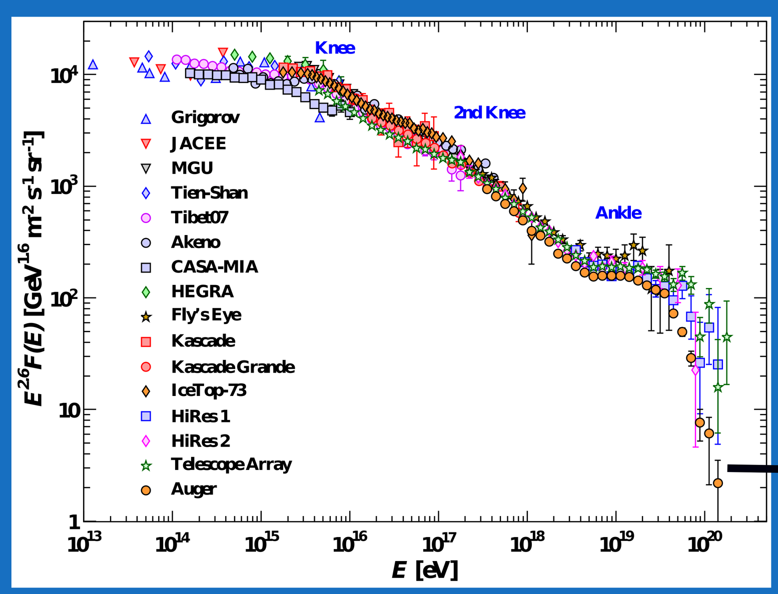
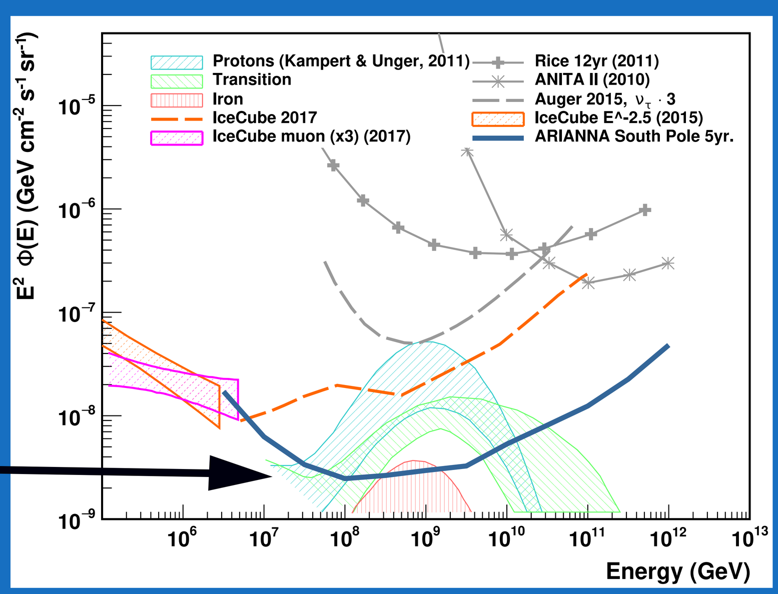
Science goal: Discovery of cosmogenic neutrinos

- Ultra-high energy cosmic rays (CRs) are connected to high energy neutrinos
  → through GZK effect (interaction of CRs with CMB)
  → through interaction of CRs at their source
- Measurement of neutrinos can reveal sources of CRs





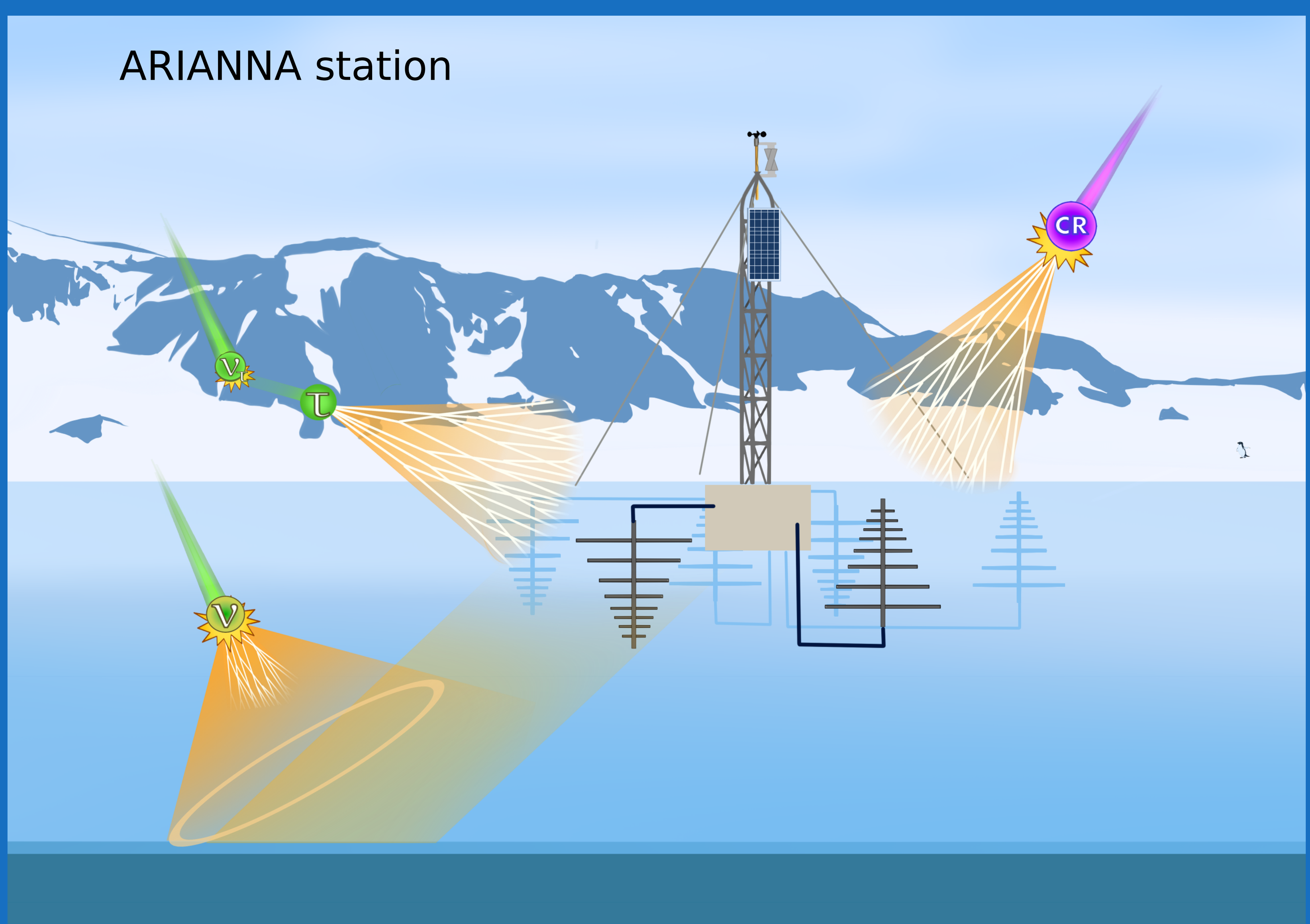


Detection Technique: Radio emission of ν induced in-ice showers

- low event rates require instrumentation of huge volumes
- why radio?
  → attenuation length of radio waves in ice is large (~1km)
  → cost-effective instrumentation of large volumes
  → a single station has $1km^3$ effective volume
  → optical method (e.g. IceCube) are cost-prohibitive
- radio emission generated by Askaryan effect

ARIANNA neutrino detector

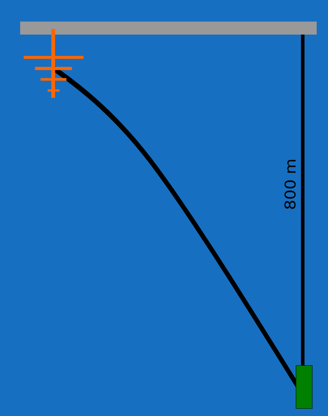
- Pilot stations located on the Ross ice shelf and at the South Pole
- Sensitive to high energy neutrinos $E > 10^{16}$ eV
- Autonomous stations of
  → downward facing antennas → neutrino detection
  → upward facing antennas → cosmic ray detection/veto
- Pilot array operating successfully for 4 years in harsh Antarctic conditions
- Design goal: 300 stations with 1km spacing
  → 10x better sensitivity than IceCube at 10^{18} eV

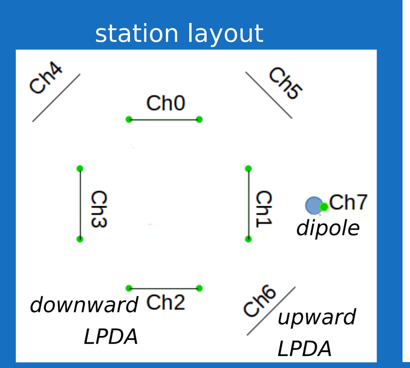


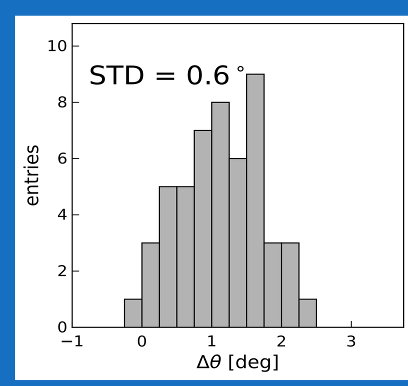
Reconstruction performance

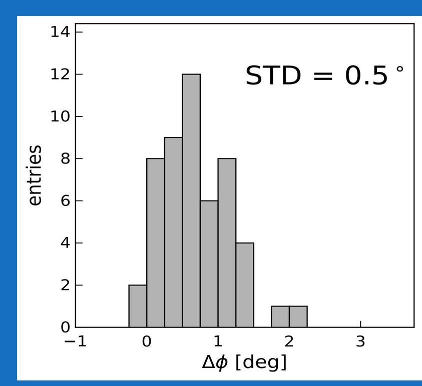
In-Ice Pulser Studies

- A *pulser* that generates short radio pulses was lowered ~800 meters deep into the ice at South Pole
- Radio pulses generated deep in the ice reach a surface station
  → proof of principle of detector technology
- Known location of pulser allows to evaluate directional reconstruction
  → **0.8° resolution** achieved with a lever arm of only 6m
  → systematic offset due to uncertainties in the station geometry





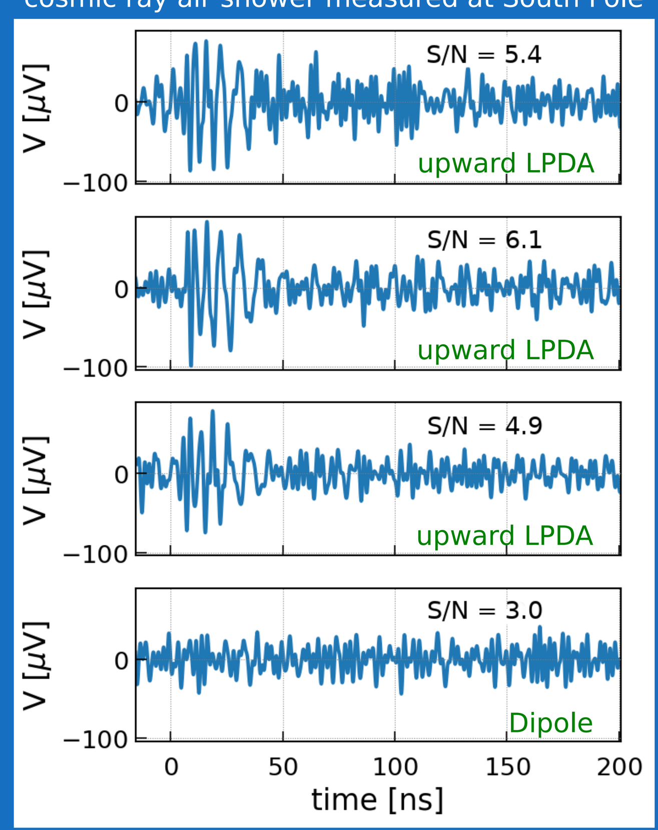




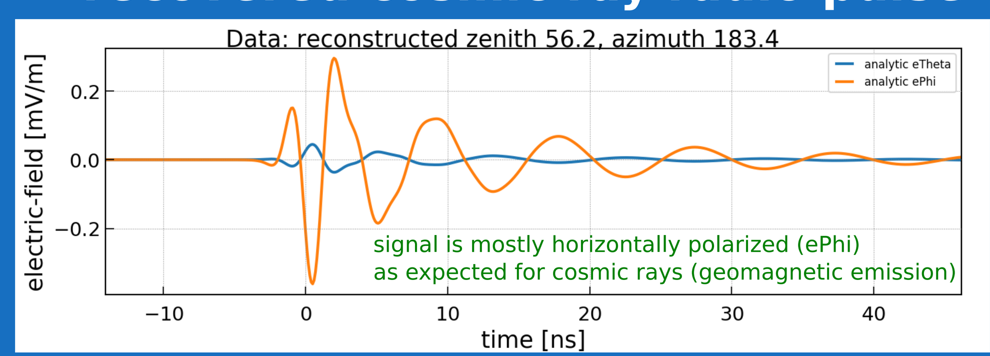
Cosmic ray air shower test beam

- Advantage of a surface array: Sensitive to cosmic ray (CR) radio signals
- CR radio pulse similar to neutrino pulse
  → full test of detector under realistic conditions
- Properties of CR radio pulse well understood
  → reconstruction can be evaluated by comparison with theoretical expectation
- Measurement in multiple antennas with different polarization sensitivity allows for the reconstruction of CR pulse

cosmic ray air shower measured at South Pole

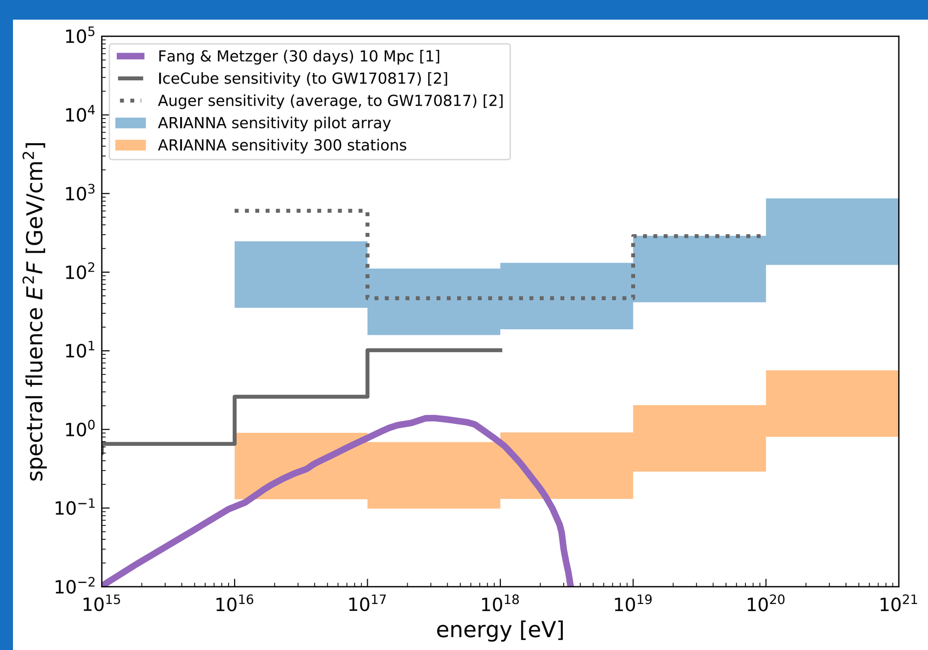


recovered cosmic ray radio pulse



Transient source sensitivity

- ARIANNA's large effective volume results in high sensitivity to transient events
- Coincident detection of neutrinos and gravitational waves from neutron star mergers
  → unique chance to probe a source of cosmic rays
  → neutrinos are produced by cosmic rays at the source
  → no deflection of neutrinos by cosmic magnetic fields
- ARIANNA allows for a basically background free measurement
  → observes the southern sky
  → unprecedented sensitivity for $E > 10^{17}$ eV



References:
[1] K. Fang and B. Metzger, ApJ 849:153 (10pp) 2017
[2] A. Albert et al 2017 ApJL 850 L35

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