Status of RICE and preparations for next generation radio neutrino experiment in Antarctica.

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for RICE/NARC and ARA collaborations

Introduction

RICE (later NARC) experiment:

- designed to measure or limit flux of UHE neutrinos
- sensitive to $E_\nu \sim 10^{17}$-10^{20} eV
- running period 1997 – 2010
- results presented based on data 2000-2010
- previous RICE result published in 2006

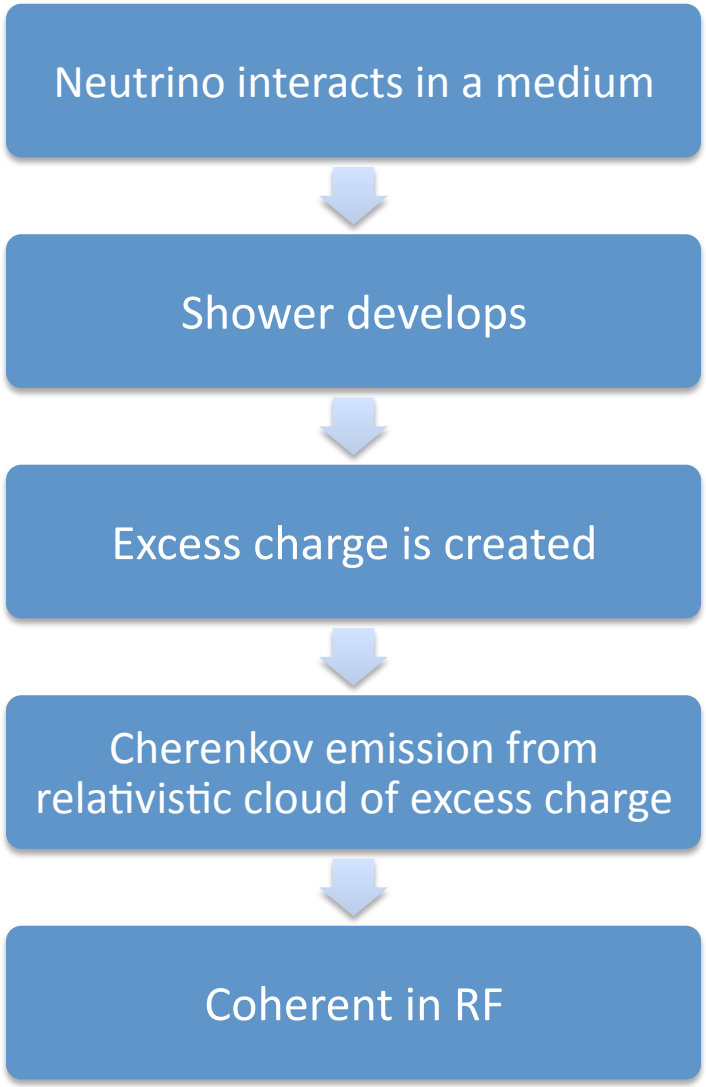
Presently, a larger experiment takes over: Askaryan Radio Array (ARA)

- Precursor studies at the end of this talk

Radio detection mechanism

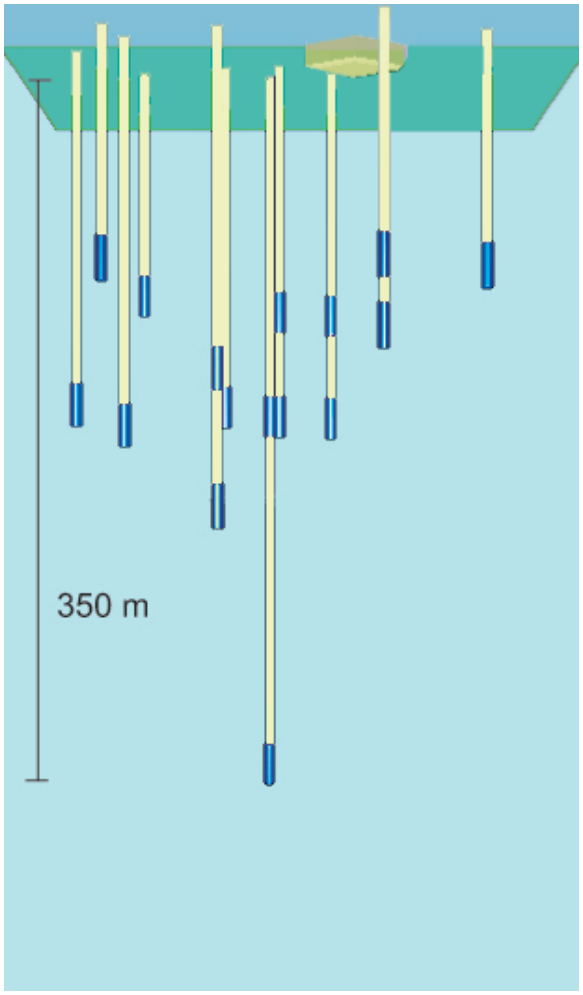
Askaryan effect: coherent radio emission from neutrino interaction in a dense medium.

Observable: 1ns pulse picked up by a radio antenna in the Chrerenkov cone.



RICE experiment architecture

- Antarctic ice is neutrino target
- In-ice array of radio antennas
- 20 channels, 200-500 MHz
- Depths 100-300 meters
- Signal digitized at the surface
- Deployed near South Pole Station



Neutrino flux measurement

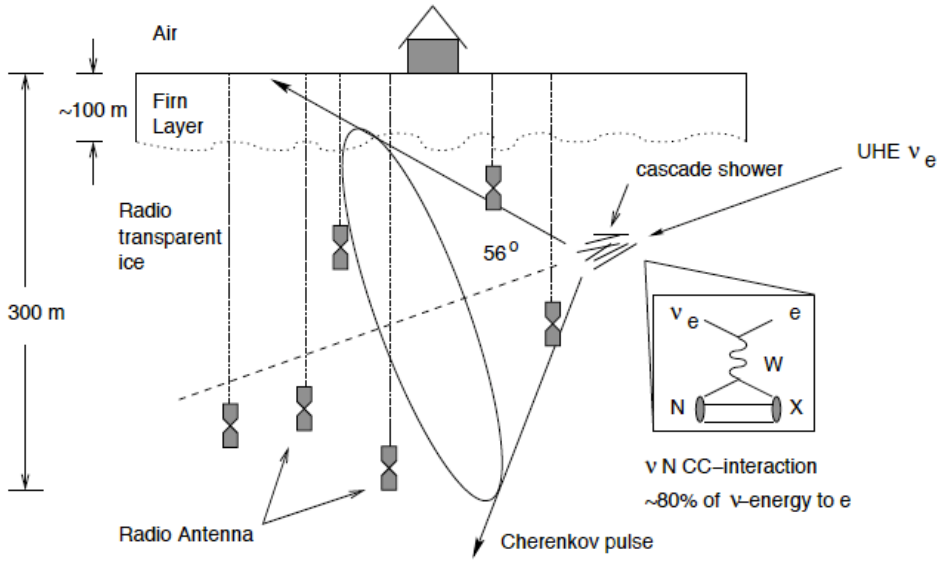
Find flux (or a limit) from observed event rate

$$N = V_{eff}(E)\,\sigma_{\nu N}(E)\,n\,\Phi\,\varepsilon\,L\,\Omega$$

- N - event count
- V - effective volume
- σ - neutrino-nucleon cross-section
- n - target density (nucleons per m^3)
- Φ - neutrino flux (particles per GeV m^2 s sr)
- ε - efficiency to reconstruct an event
- L - livetime in seconds
- Ω - solid angle in steradians

Event definition and reconstruction

- An event: coincidence of a “hit” on ≥4 antennas within 1.25us
- Event source: reconstruct vertex from relative times of the hits
- Vertex reconstruction: grid method or analytic solution method



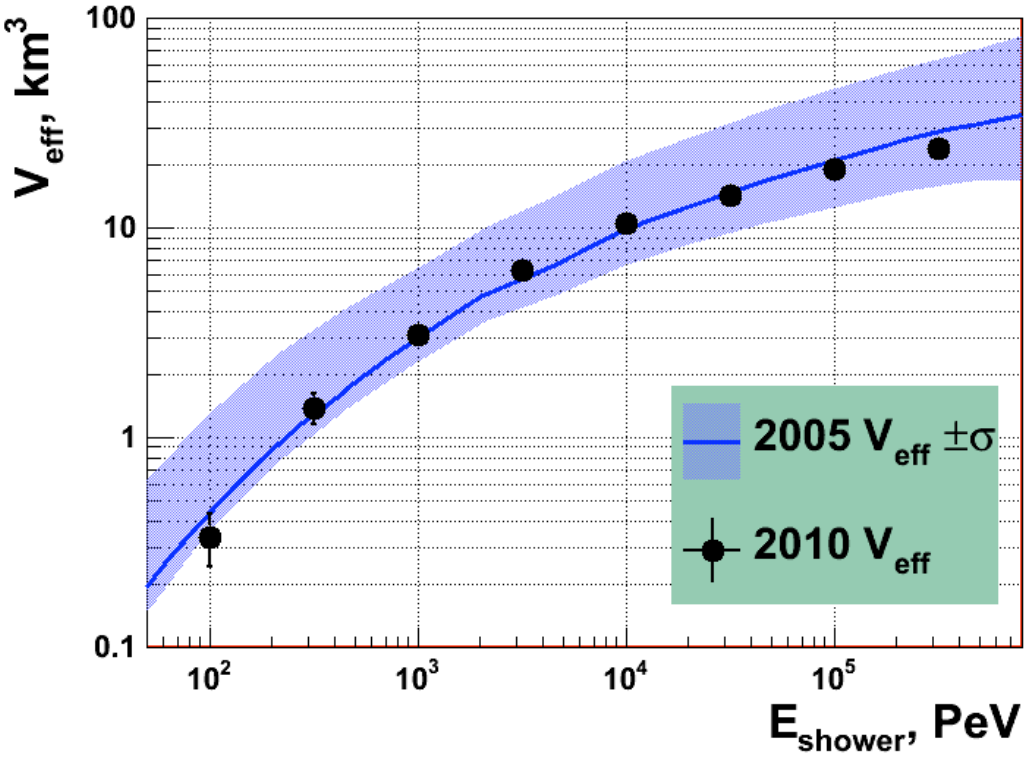
Event selection

- Accumulated 1.78M events on disk
- Select events and reject backgrounds by:
  - Good source vertex: cut on time residuals
  - Consistency of 2 vertex finding algorithms
  - Time over threshold
  - Reconstructed source Z below 150 meters
  - Double pulse rejection

Zero surviving candidates
- upper limit 2.3 events @ 90% C.L.

Effective volume

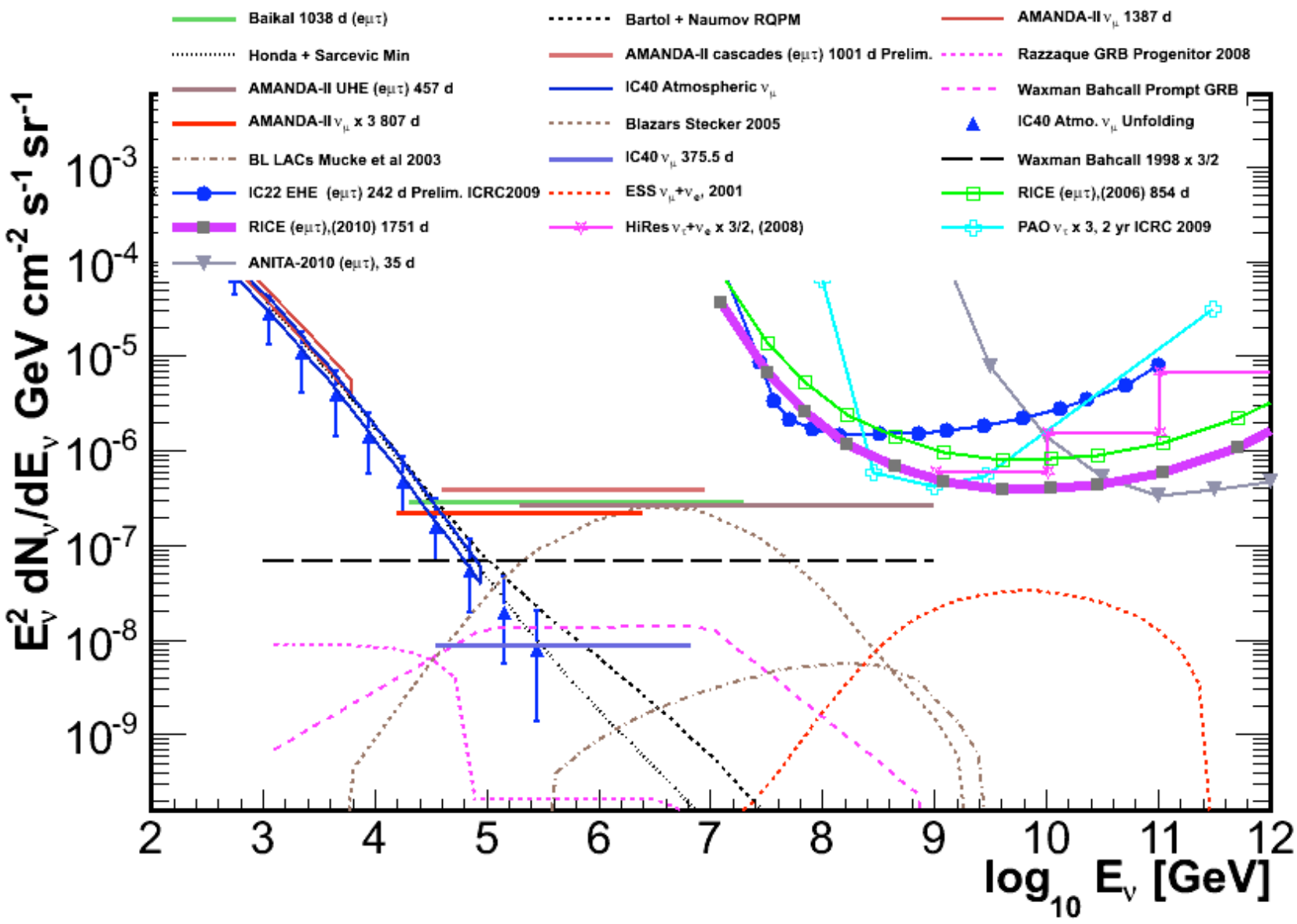
- Indicates the volume in which neutrino events can be detected
- Depends on geometry of antenna array and ice properties
- Estimated from simulation
- Uneven over time: 2006 compromised by installation of 450 MHz Land Mobile Radio system at the Pole



Other event rate pieces

- Livetime: 1751 days over 10 years
  - this is true livetime of the detector
    - detector downtimes are subtracted
    - event readout times are subtracted
  - antenna thresholds are tuned to 90% livetime
  - end of Nov – beginning of Mar too-radio-noisy at the Pole
  - Surface veto board introduced in 2006 caused 7% livetime improvement
- Efficiency to pass selection:
  - 71.4 ± 1.0% from simulation
  - note: trigger efficiency is folded into V_{eff}
- Solid angle covered: ~2π

Upper limit on neutrino flux



Toward next generation experiment

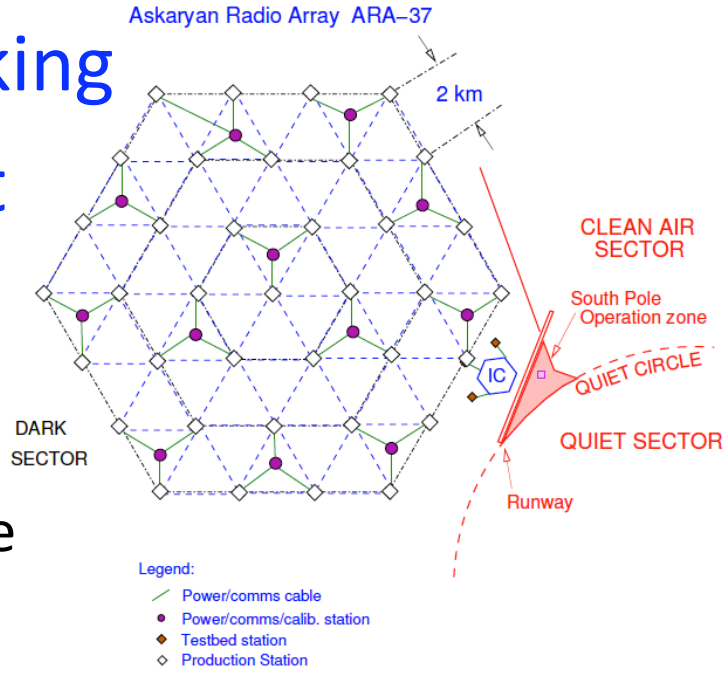
RICE is at limit of useful data-taking

The next generation experiment

Askaryan Radio Array (ARA)

presently under construction:

- people/tech from Rice/Anita/Icecube
- same detection mechanism: radio
- same location: next to Icecube
- similar architecture: antennas submerged in ice
- larger than RICE, ×100 more sensitive
- now preparing for 2d deployment season



Present ARA focus

Since the first deployment in Jan 2011:

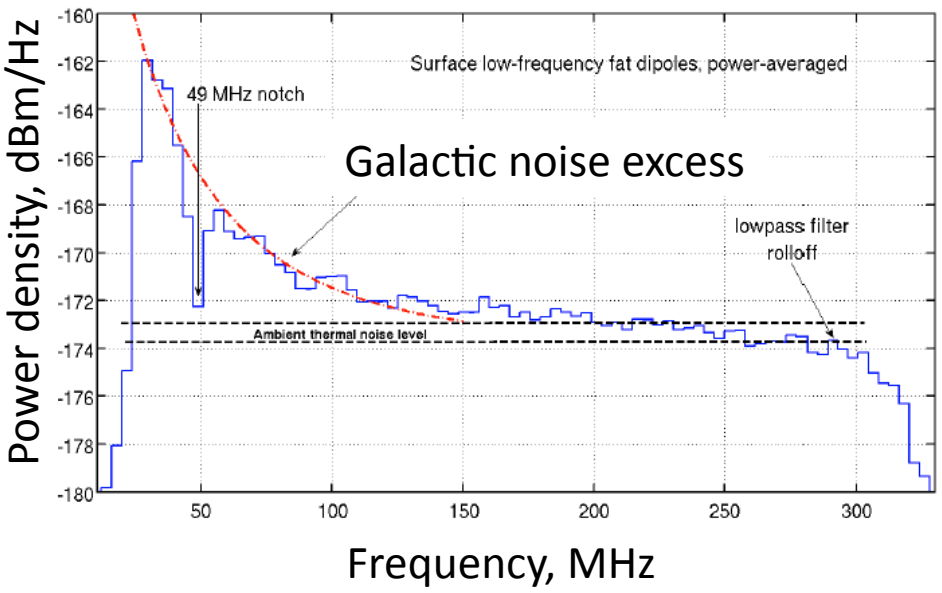
- tests of radio receivers and readout
- studies of radio backgrounds
- measurements of ice properties
- tests of autonomous power systems
- event reconstruction with a known source (transmitter)
- … and other work …

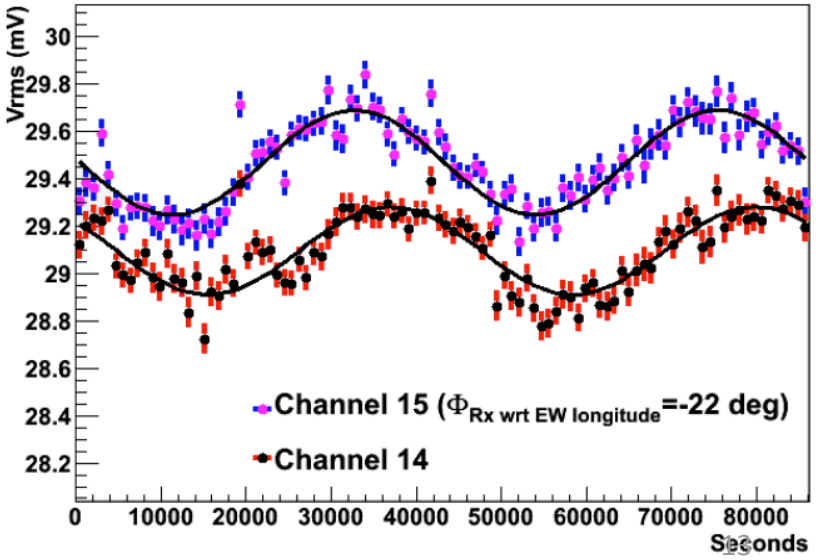
first report in arXiv 1105.2854 [astro-ph]

Only a sampling of the present results are shown in the next slides

Thermal background and galactic noise

- Understanding noise floor is necessary for setting lowest possible thresholds
  - thermal noise is measured after deployment
- Galactic noise is clearly seen
  - starts to dominate over thermal below 100 MHz



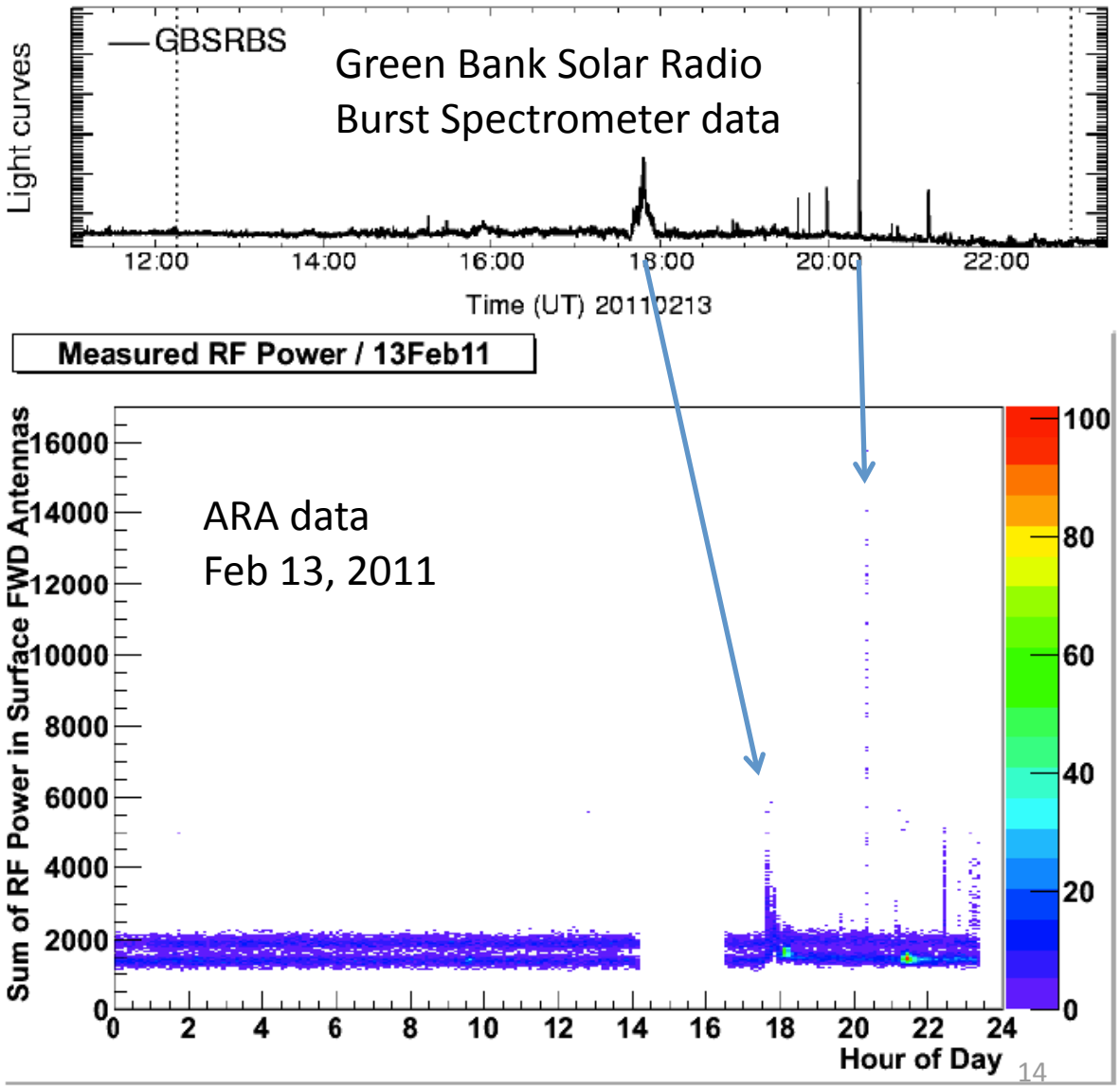


Response to solar flares

ARA detects the solar flare of Feb 13, 2011.

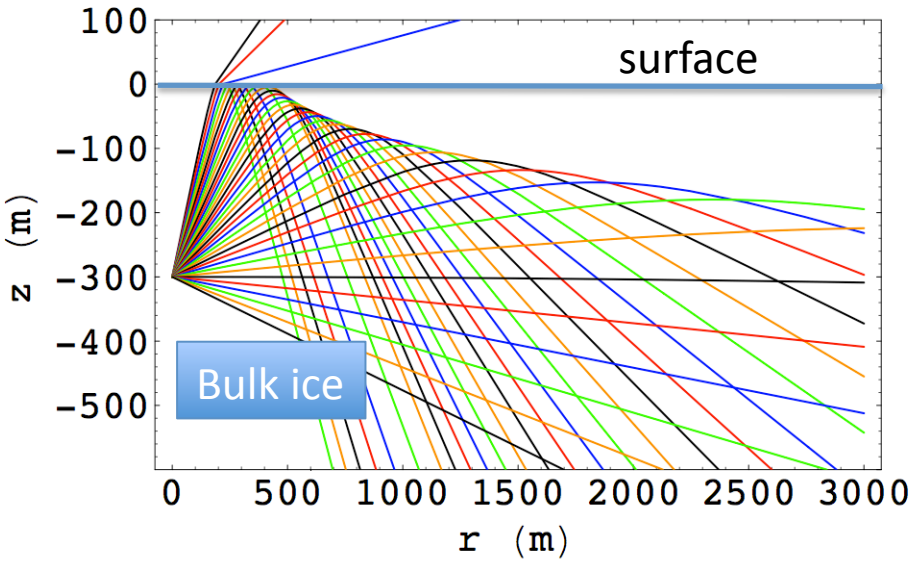
Major features match between ARA and GBSRBS

Quantitative analysis of RF power for this event is underway



Ice properties at experiment site

- Needed for ARA: full characterization of complex permittivity at all polarizations for propagation in both Z and azimuth.
- Ice studies performed by combined efforts of RICE, radio group of Icecube, ARA collaborators.



Shown: pathways for propagating radio waves emitted from a point at 300 m depth in ice.

Understanding ice properties is critical to event reconstruction and effective volume estimates.

Ice properties are location specific: temperature, purity, reflective layers, ice flow, …

Studies at S.P. by RICE/ARA/Icecube

- Attenuation length:
  - measured by ARA for deep RF pulse source (Z=-2500m) over 3.2 km baseline (depth, temperature dependent)
- Permittivity constant:
  - depth profile already known to 0.5-1.0% at the site
- Dispersion:
  - found limited at $<10^{-4}$ for 100-1000 MHz
- Birefringence:
  - found $(\Delta c/c) \approx 0.3\%$ for RF polarization parallel vs perpendicular to local ice flow

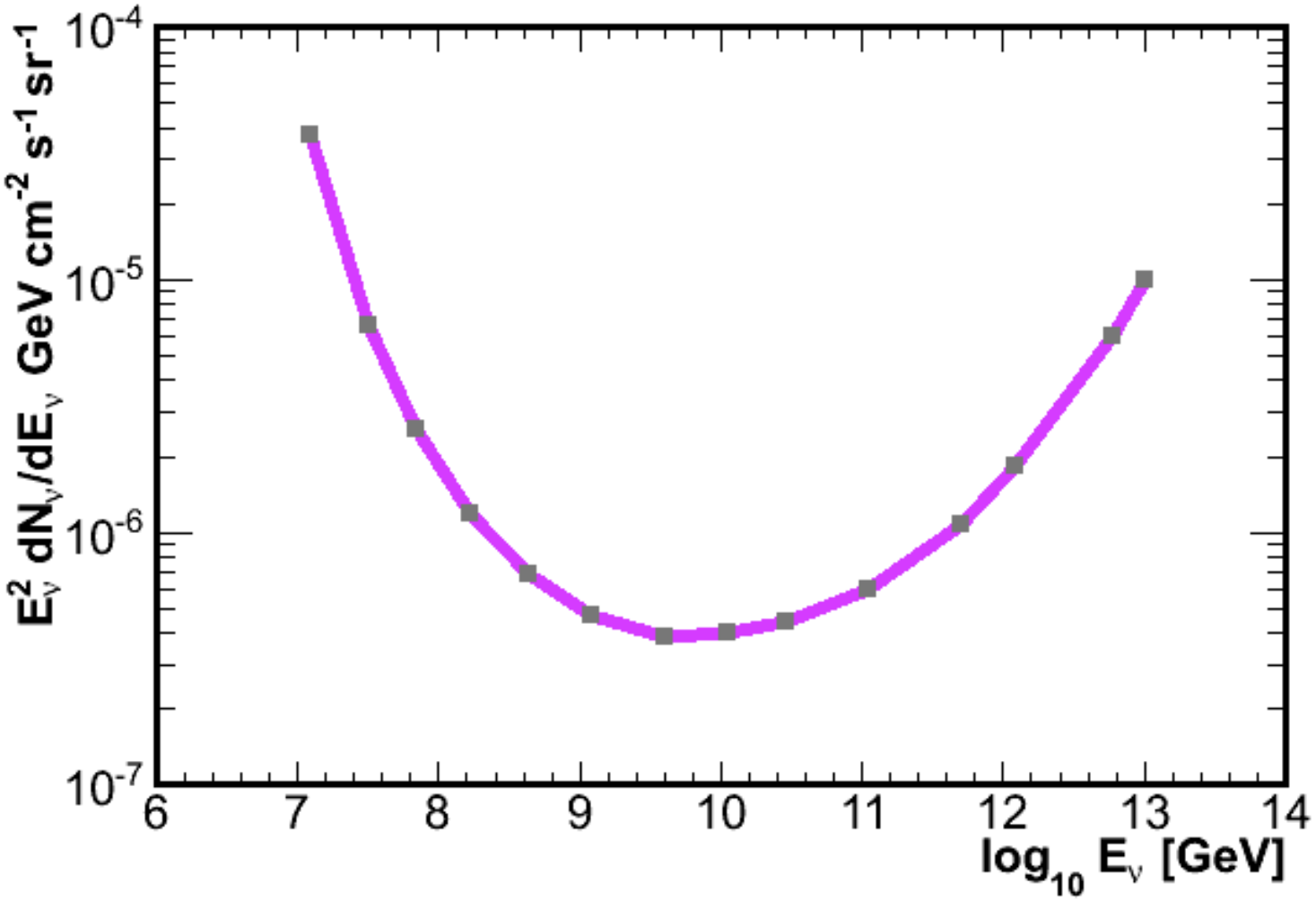
Summary

- Present RICE limits on neutrino flux based on 10 years of data
  - ultimate flux limits paper in preparation
  - the limit is among the best at covered energies
- Building next generation experiment – ARA – is well underway at the South Pole site

Backup slides

Upper limit on neutrino flux

RICE 2010 limits for all neutrino flavors, 1751 days



Attenuation and index of refraction

- Attenuation length:
  - measured in the past at South Pole for vertical propagation reflecting RF from the bottom
  - Measured by ARA for deep RF pulse source (Z=-2500m) over 3.2 km baseline
    - average 760 $^{+60}_{-40}$ meters for 150-350 MHz
    - Depends on temperature and other parameters, over 1km at larger depth

- Permittivity constant:
  - depth profile already known to 0.5-1.0% at the site

Dispersion and birefringence

- Direct time-domain measurement
  - reflection from the bottom
- Dispersive effects:
  - different frequencies return simultaneous within 4 ns
  - limits dispersion $<10^{-4}$ for 10^{2}-10^{3} MHz
- Birefringence
  - compare propagation parallel vs. perpendicular to local ice flow
  - detect difference $(\Delta c/c) \approx 0.3\%$