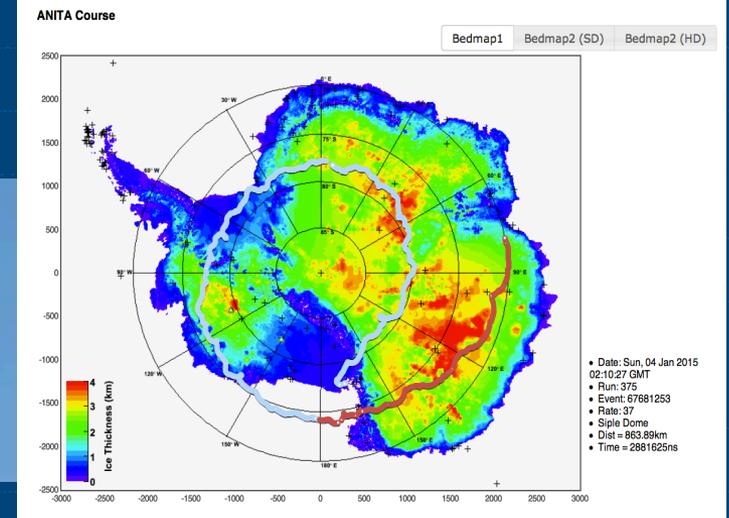


# Suborbital payloads for UHE neutrinos and beyond

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Left: ANITA-3 Launch, Dec. 2014, right, final payload track

# UHE neutrinos probe the the highest energy accelerators in the universe at all epochs

Cosmic rays above  $10^{19}$  eV: neither origin nor acceleration mechanism known, after 45 years!

A paradox:

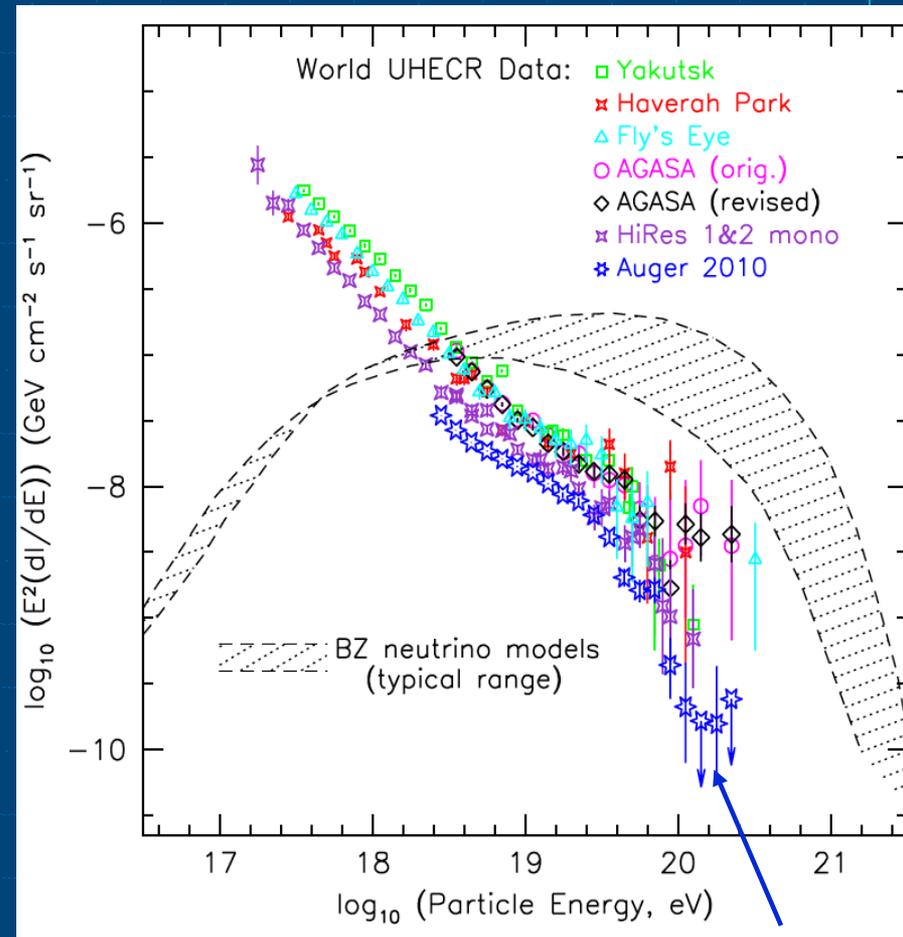
- No nearby cosmic ray sources conclusively observed
- Distant (eg. Gpc) sources excluded due to collisions with microwave background

Neutrinos at  $10^{17-19}$  eV 'guaranteed'\* by standard-model GeV physics:

$p\gamma \rightarrow \Delta^+ \rightarrow \text{pions} \rightarrow \text{neutrinos}$

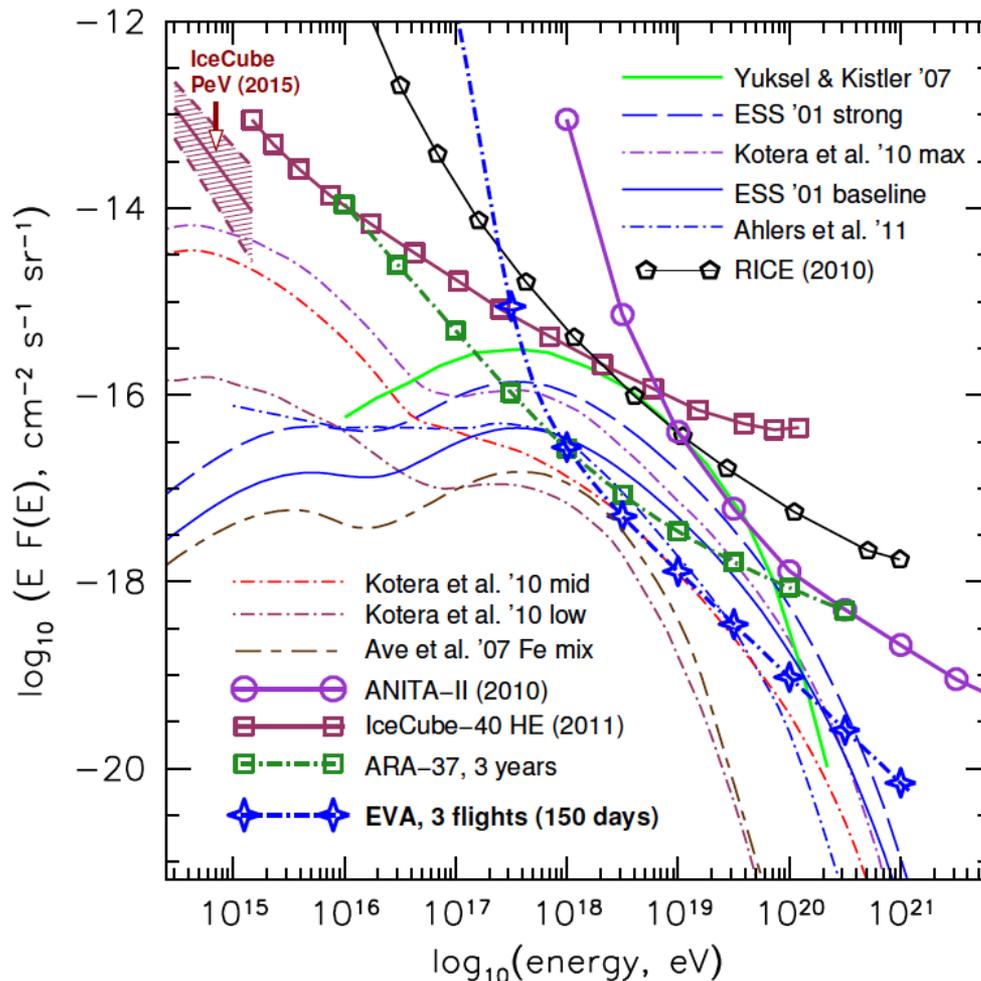
Most sensitive searches for these UHE neutrinos use radio Cherenkov from Antarctic ice: **the most radio-transparent material known**

\* Berezhinsky & Zatsepin (BZ) 1970, many others since



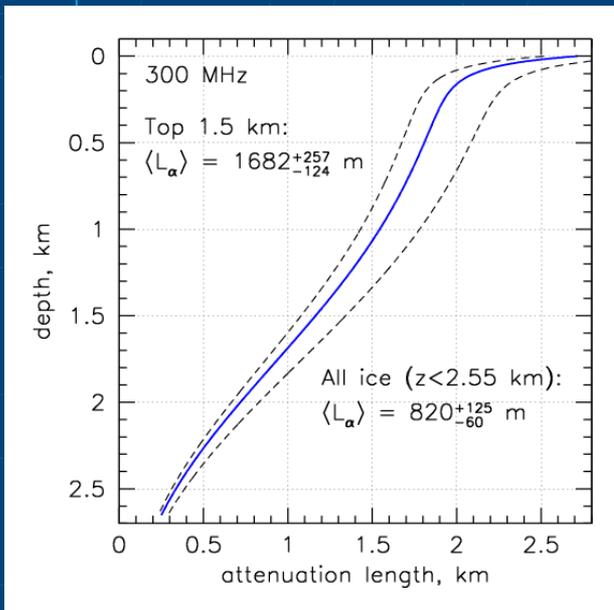
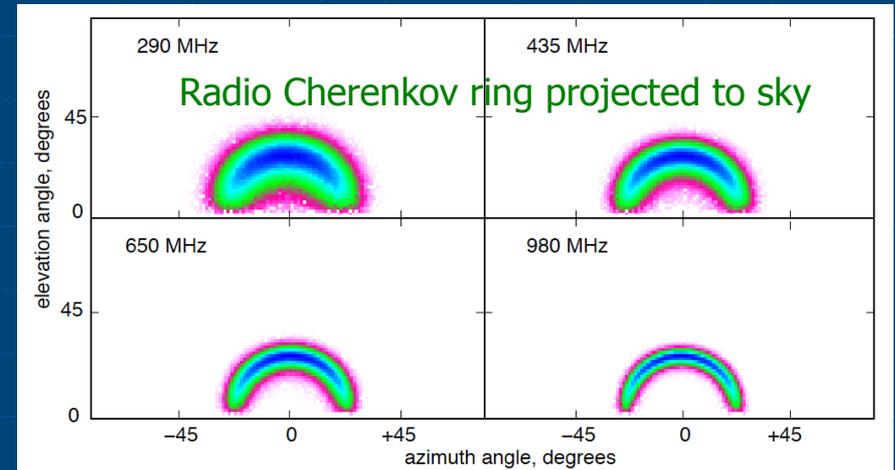
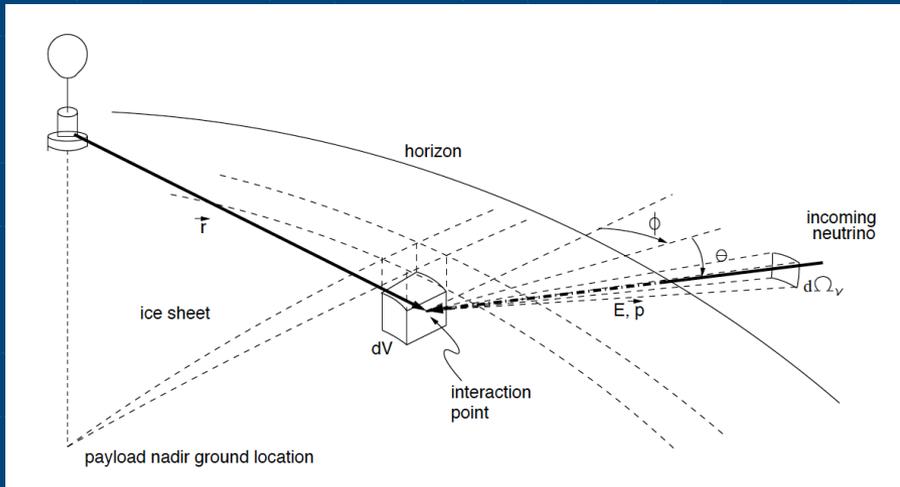
**$10^{20}$  times energy of visible light!**

# HE+UHE neutrino fluxes/limits



- ⊕ HE fluxes ( $\sim$ PeV): IceCube sees a signal!
  - Unrelated to cosmogenic UHE neutrino flux? Probably.
  - But: this is an Unexpected & unpredicted flux  $\rightarrow$  it is crucial to continue the search for UHE fluxes!
- ⊕ Highest UHE flux predictions now constrained by radio methods, both embedded (eg. RICE/ARA) & balloon-based (ANITA)
  - RICE completed, ARA in development through end-of-decade
- ⊕ Above  $\sim 3e18$  eV, balloon-based methods are currently the only viable approach
  - Need ultra-large target volume
  - To go deeper than ANITA requires new technology  $\rightarrow$  EVA
- ⊕ **Orbital detectors such as EUSO would extend this to  $\sim$ ZeV neutrino energies ( $>10^{20}$  eV)**

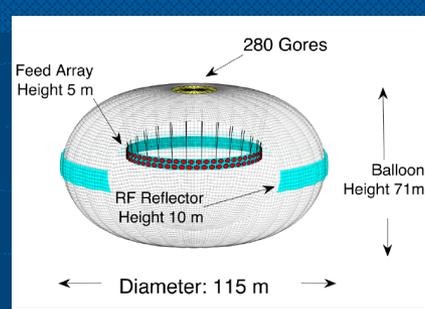
# Balloon-based neutrino radio telescopes



- ⊕ Payload sees  $\sim 1.5$  M km<sup>2</sup> ice at alt. of 36km
  - Ice RF attenuation length  $\sim 1.7$  km in upper 1.5km →
  - → **Effective neutrino target volume  $\sim 3$  M km<sup>3</sup>**

- ⊕ But over this large an area other processes – atmospheric, anthropogenic, electrostatic – may produce radio impulses
  - events are analyzed for radio polarization and direction
  - V-pol, isolated → **neutrino candidate**
  - H-pol or Vpol, non-isolated → anthropogenic
  - H-pol, isolated: UHE cosmic rays radio impulse
    - ◆ Seen in reflection from ice surface, UHECRs provide real-time validation channel for payload sensitivity

# ExaVolt antenna (EVA)



662NT 2015, still up:  
18Mcf is reality!

Wallops: successful 1/20<sup>th</sup> scale model test, 2014



- ⊕ Based on “super-pressure” NASA balloon technology
- ⊕ Gives balloon with stable shape and altitude
- ⊕ Reflective band near equator = toroidal radio dish
- ⊕ Focus is in balloon interior, requires an inner membrane for patch-antenna feed array
- ⊕ Gain estimates give 25-33 dBi using 3 independent methods (50-300x ANITA)
- ⊕ Will require MIDEX-class Explorer Mission-of-opportunity at full scale

XFDTD simulation of 18Mcf EVA system: validated!

