The ExaVolt Antenna (EVA)

ULDB (NASA)

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(University of Hawaii, OSU, George Washington University, NASA: JPL and Balloon Program Office)

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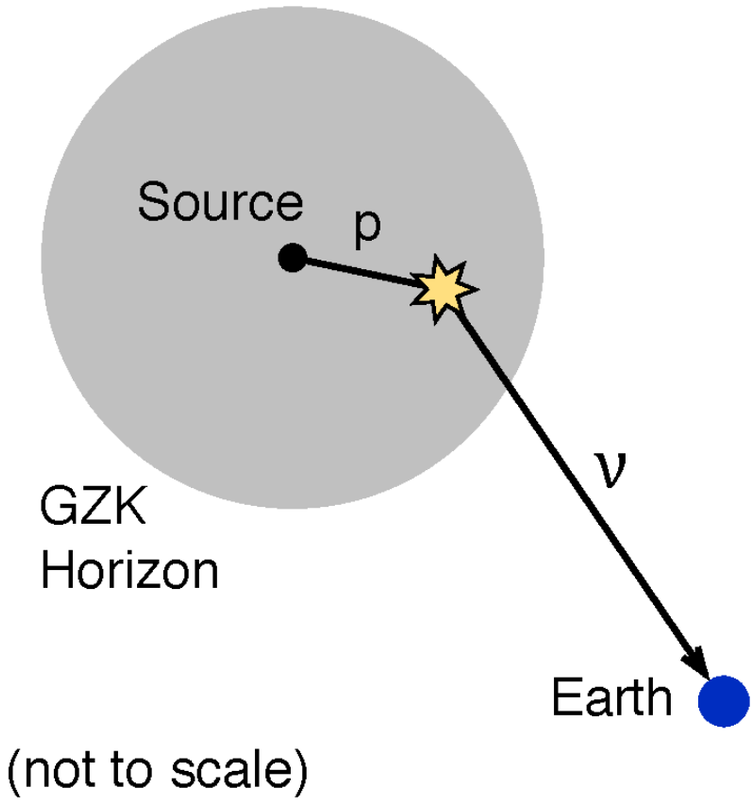
Motivations for ultra-high energy (UHE) neutrinos (>10^{18} eV)

- Greisen-Zatsepin-Kuzmin (GZK): Cosmic rays >$10^{19.5}$ eV slowed by cosmic microwave background (CMB) photons within ~50 Mpc:



$$\mathbf{p} + \gamma_{\mathrm{CMB}} \rightarrow \mathbf{\Delta}^{*} \rightarrow \mathbf{n} + \pi^{+}$$

$$\mathbf{n} \rightarrow \mathbf{p} + \mathbf{e}^{-} + \bar{\nu}_{\mathbf{e}}$$

$$\pi^{+} \rightarrow \mu^{+} \nu_{\mu}$$

$$\mu^{+} \rightarrow \mathbf{e}^{+} \bar{\nu}_{\mu} \nu_{\mathbf{e}}$$

ν's from GZK process first pointed out by Berezinsky and Zatsepin (1969)

- Sources of UHE cosmic rays should also produce UHE neutrinos through photohadronic interactions

Radio Cerenkov Technique (Askaryan Effect)

- Coherent Cerenkov signal from net "current," instead of from individual tracks
- A ~20% charge asymmetry develops (mainly Compton scattering)
- Excess moving with $v > c/n$ in matter

  → Cherenkov Radiation $dP \propto v\, dv$
- If $\lambda >> R_{Moliere}$ → Coherent Emission

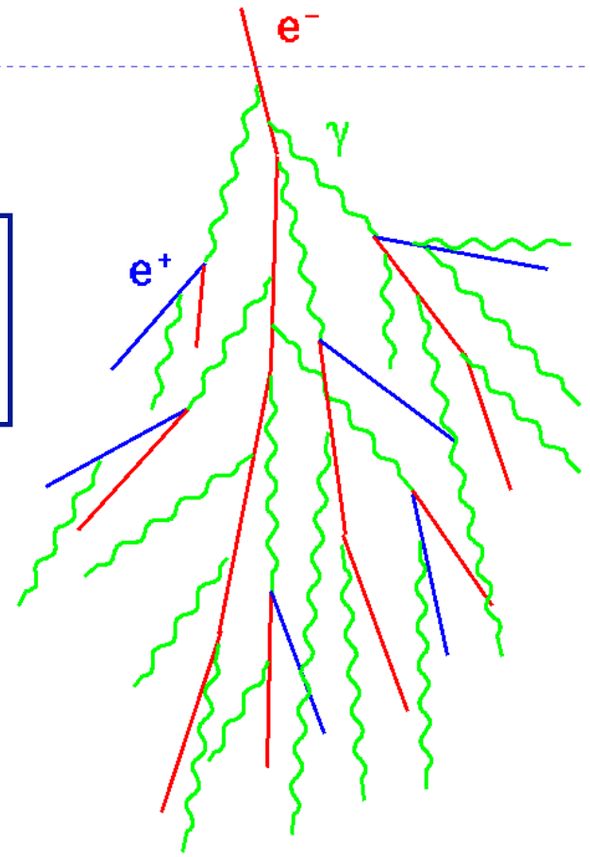
  $P \sim N^2 \sim E^2$

  $\lambda > R_{Moliere}$

  → Radio/Microwave Emission

$R_{Moliere} \approx 10$ cm → Radio!

Idea by Gurgen Askaryan (1962)



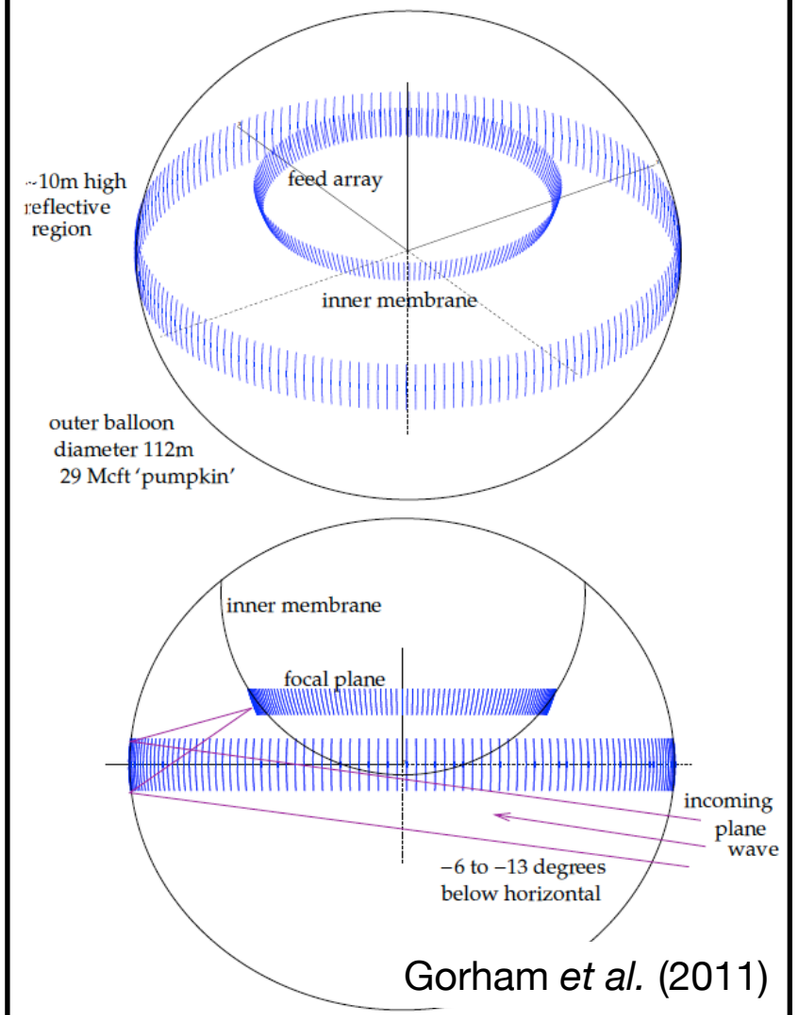
This effect has been confirmed experimentally in sand, salt, ice:

PRL 86, 2802 (2002)
PRD 72, 023002 (2005)
PRD 74, 043002 (2006)
PRL 99, 171101 (2007)

Radio Cerenkov Balloon Experiments

ANITA

proposed ExaVolt Antenna (EVA)



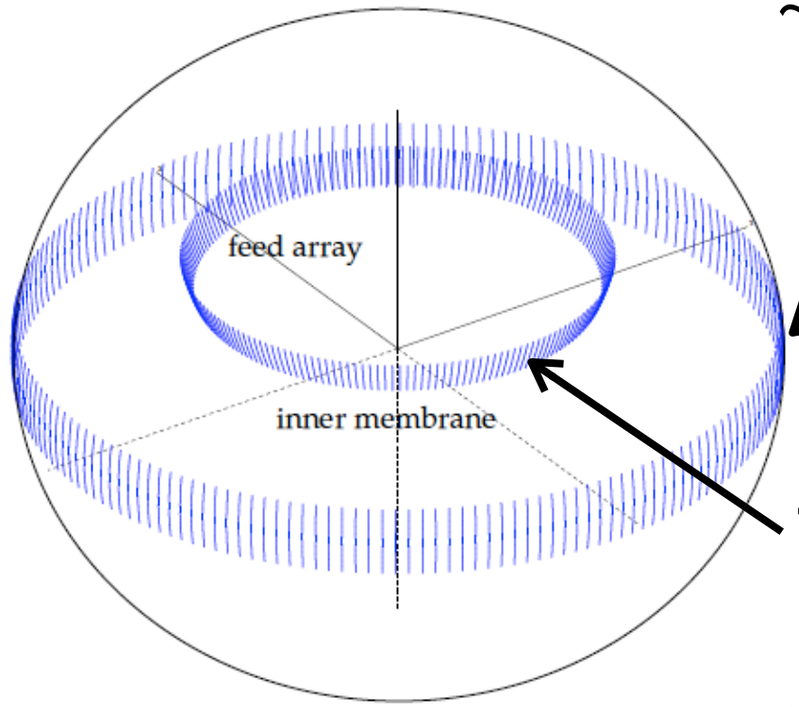
Gorham *et al.* (2011)

ExaVolt Antenna (EVA) concept

P. W. Gorham et al., *The ExaVolt Antenna: A Large-Aperture, Balloon-embedded Antenna for Ultra-high Energy Particle Detection,* Astroparticle Physics, **35** No. 5 (2011) 242-256.

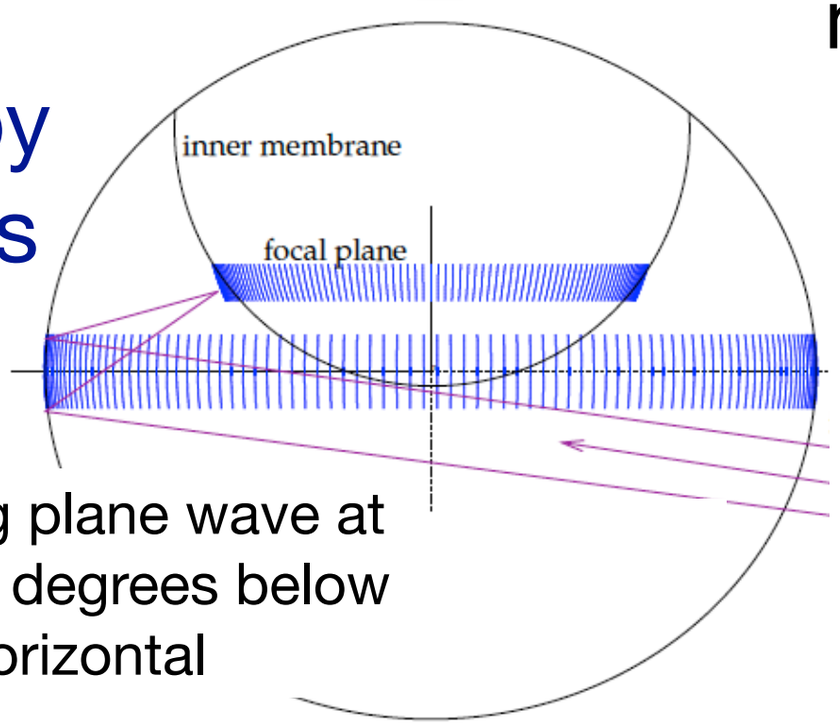
- Would be the world's largest aperture airborne telescope
  - 1000's of square meters
  - 150-600 MHz ($\lambda_{air} \approx 0.5$-2 m)
- Increase in sensitivity to radio frequency neutrino impulses by factor of 100 over any previous experiment

3 year feasibility study funded by NASA



~10 m high reflective region

feed array on inner membrane



incoming plane wave at -6 to -13 degrees below horizontal

outer balloon diameter 112 m, 29 Mft^3

Zero Pressure Balloons (ZPB) vs. Super Pressure Balloons (SPB)

Zero Pressure Balloons (e.g., ANITA)

- Balloon pressure at equilibrium with ambient pressure at float altitude
- Shape can change dramatically with thermal environment
  - ANITA: 40% drop in volume while over east Antarctica

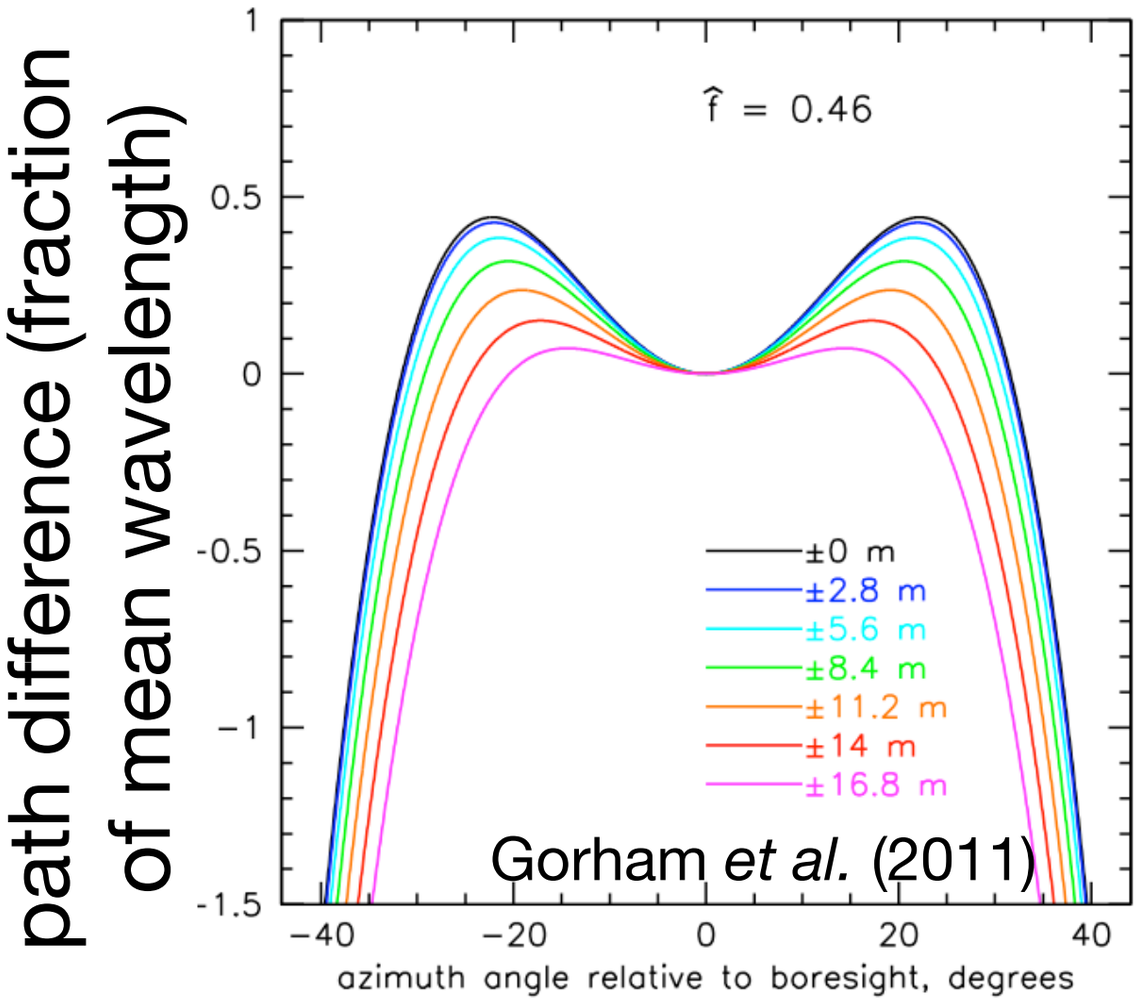
Super Pressure Balloons (under development, proposed for EVA)

- Balloon pressure higher than outside pressure
- Height, diameter changed by 1% in 54 day flight 591NT (December 2008) 7Mft^3 over Antarctica
- SPB launches continue with larger balloons of long duration flights. Early 2011: Antarctic flight 616NT 14 Mft^3

SPB flight 591NT

Reflectors on outer balloon

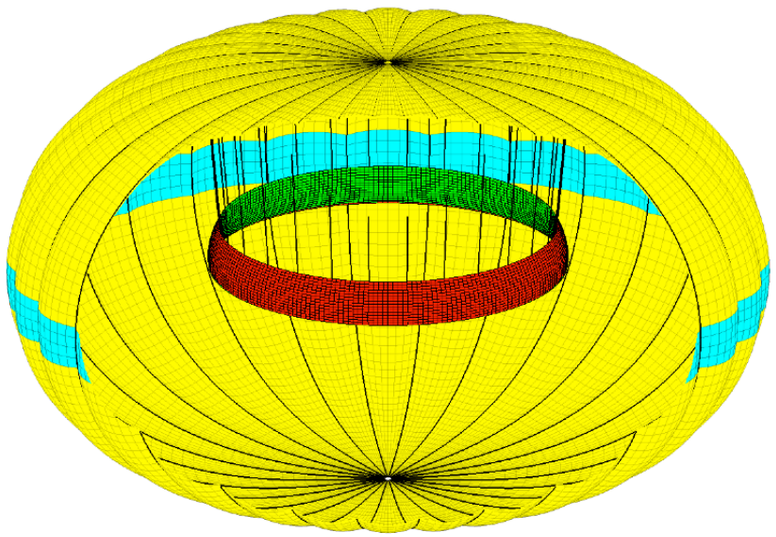
- To find reasonable size for reflector region:
  - Want reflected signals across reflector region to have small path length differences



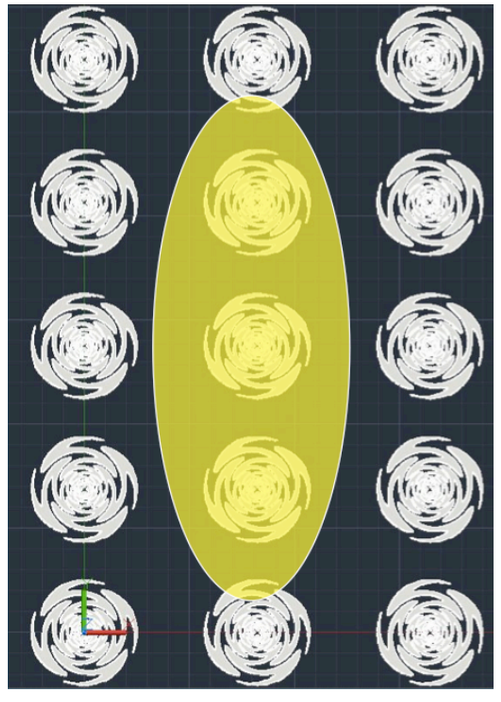
- Path difference less than 1/4 wavelength for a reflector band ± 30°, 20 m high
  - ± 25°, 11 m high more conservative
- 1000 m^2 of coherent surface area

Feed array on inner balloon

- Reflected signals received by feed array on inner membrane
  - NEC2 simulations show surface of best focus is convex (same sign of curvature as balloon)
- Planar patch antennas (flat, inexpensive) with dipole-like response (size ~$\lambda/2$)
- Focal plane is ~3m high
  - 5 rows of patch antennas
- 1200 patch antennas cover surface area of feed region

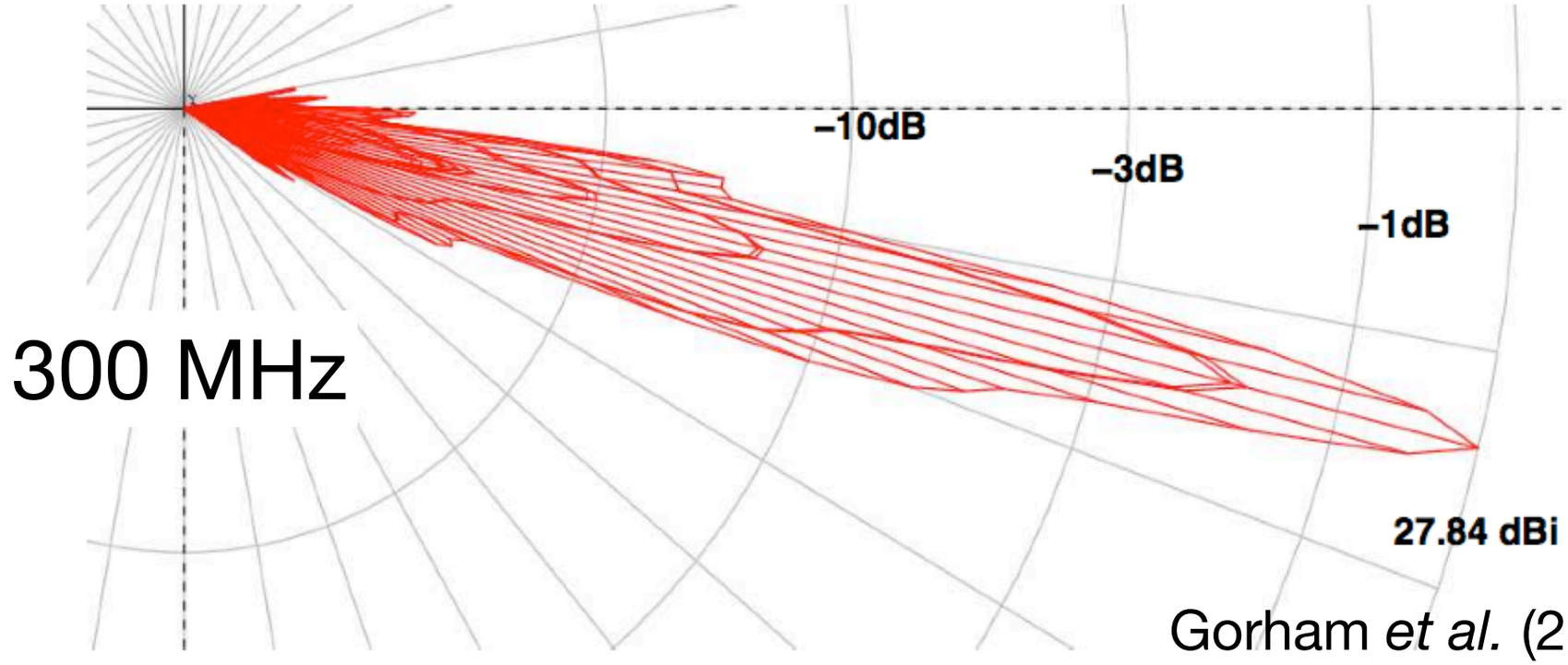


Dual linear polarization sinuous antenna



Gains

- Nec2 simulation of ± 25°, 11 m high reflector region
- For vertical polarization 200-500 MHz, gain exceeds ~500 times isotropic = 27 dBi



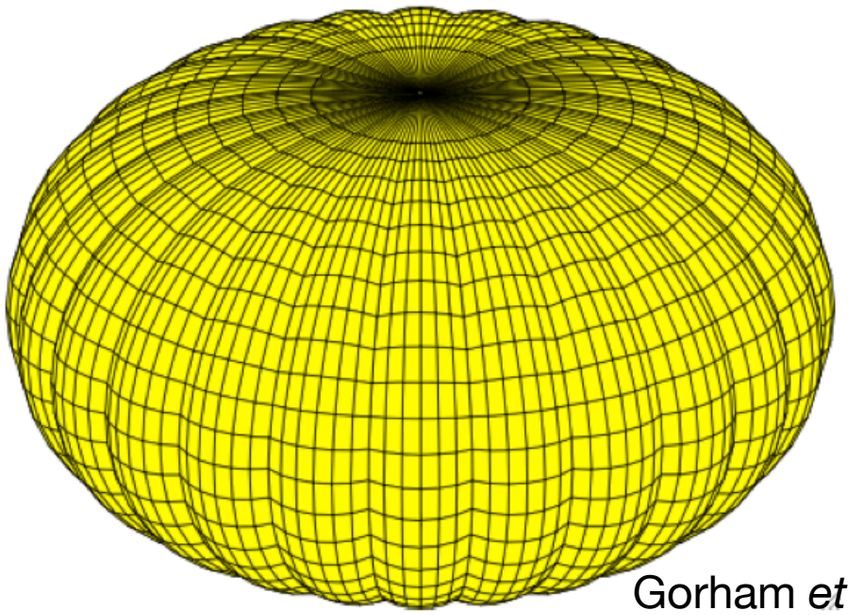
300 MHz

Gorham *et al.* (2011)

- x 100 in gain → ÷ 100 in power threshold → ÷ 10 in E field threshold → ÷ 10 in ν energy threshold

Logistics

- After the antennas, the RF chain will build on ANITA heritage
- In close proximity to patch antennas:
  - bandpass filter, low noise amplifier ~36 dB
  - second stage amplifier ~20 dB to analog optical driver onto optical fiber
- Optical fiber to payload at the bottom
- 0.8W per channel x 1200 patch antennas supplied by 1.2 kW photovoltaic array

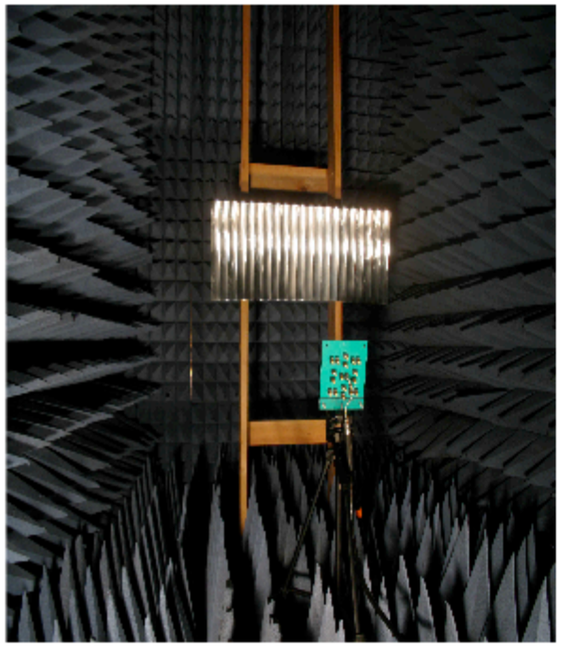


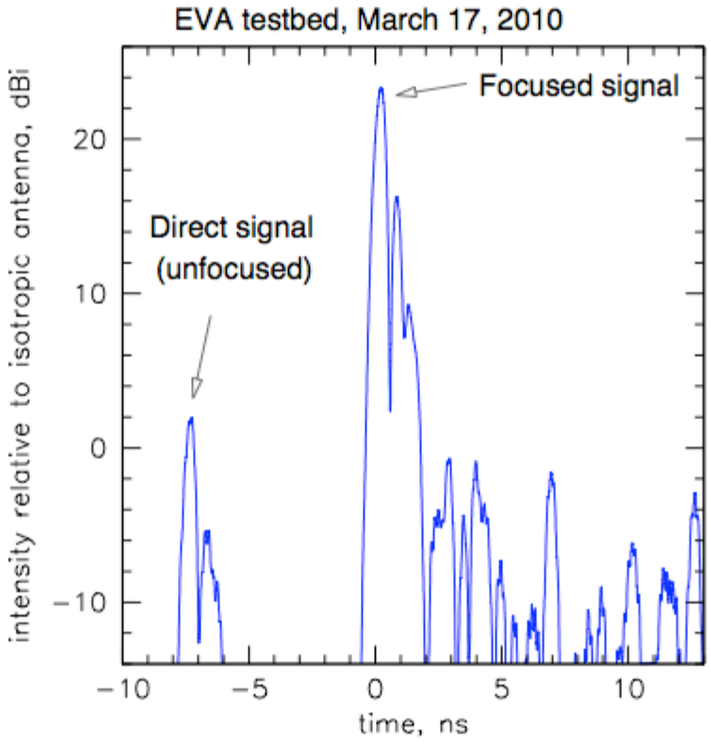
Gorham *et al.* 2011)

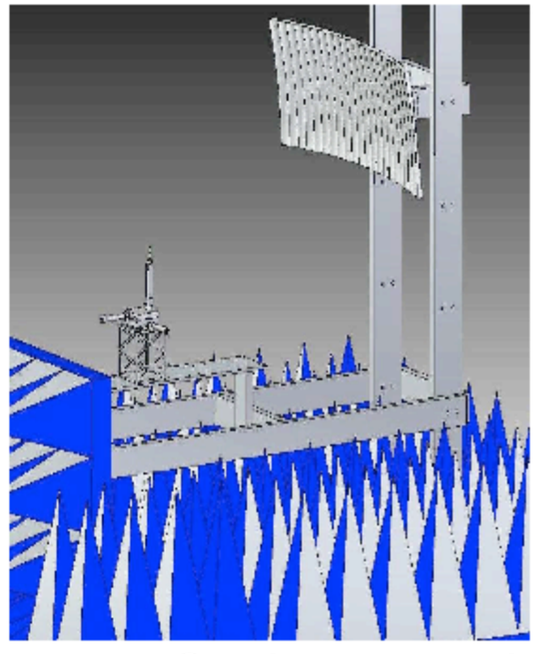
Pumpkin shape with lobes provides structural stability

Scaled down model at University of Hawaii

- At UH, Gorham *et al.* constructed microwave scale model testbed to test a reflector section
- 1/35 and 1/26 scale models of a 25 Mft^3 SPB







Gorham *et al.* (2011)

- Measure directivity gain of 220 relative to isotropic at 6.6 GHz corresponding to 260 MHz for full scale
- Measured focal region (scaled to full size balloon) ~1.14m (Φ) x 3-4m (θ) x >3m

EVA event rates for neutrinos from GZK process

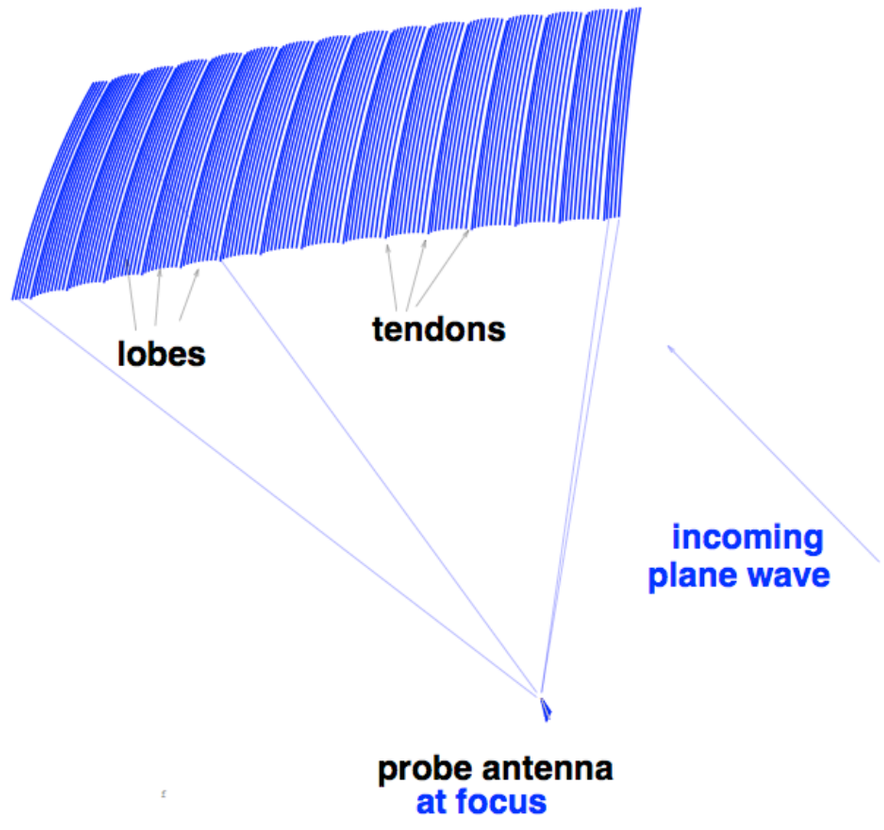
BZ neutrino models	*Events, ANITA-II,28d*	*Events, EVA,50d*	*ratio, EVA/ANITA*
Mixed UHECR composition [30]	0.05	5.0	100
Minimal, no evolution [3, 32, 33]	0.3-0.9	9.2-38	~ 40
$\Omega_m = 0.3, \Omega_\Lambda = 0.7$, Standard model [3]	0.7	29	41
Waxman-Bahcall E^{-2} flux (minimal) [34]	0.49	6.5	13
GRB UHECR-sources [46]	1.44	66	46
Strong source z-evolution [3, 31, 33]	2.2-5.3	40-60	11-18
Maximal, saturate all bounds [31, 33]	16-25	180-220	~ 10

Gorham *et al.* (2011)

- For a standard model, a factor of 40 increase in event rate over ANITA-II
- Can even reach extremely scarce neutrinos from mixed UHECR composition models
- Also expect ~300 CR events/day from geomagnetic

Plans and Summary

- Planning a 1/20 scale model inflation and deployment test in a ~20m highbay at NASA's Wallops Flight Facility in Virginia, USA
- Stayed tuned for the full EVA!



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