The ExaVolt Antenna
Mission Concept and Technology Developments

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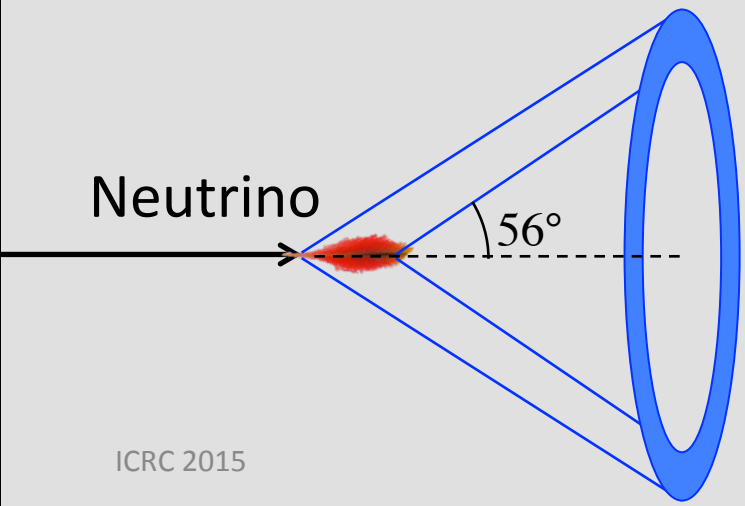
for the EVA Collaboration

ICRC
The Astroparticle Physics Conference
34th International Cosmic Ray Conference
July 30 - August 6, 2015
The Hague, The Netherlands

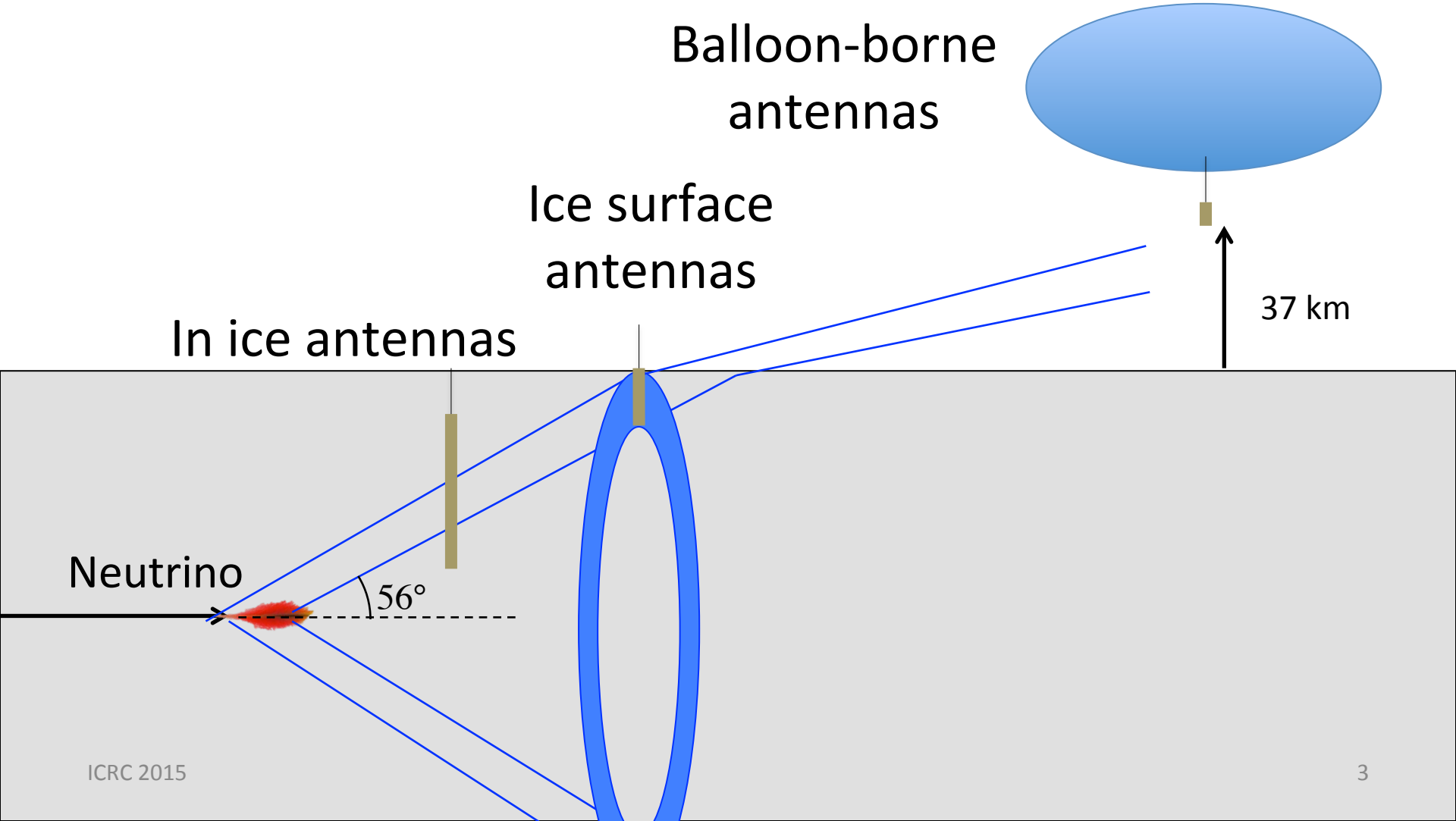
Radio Detection of Ultra-High Energy Neutrinos

- Coherent Cherenkov radiation up to GHz scale radio frequencies.



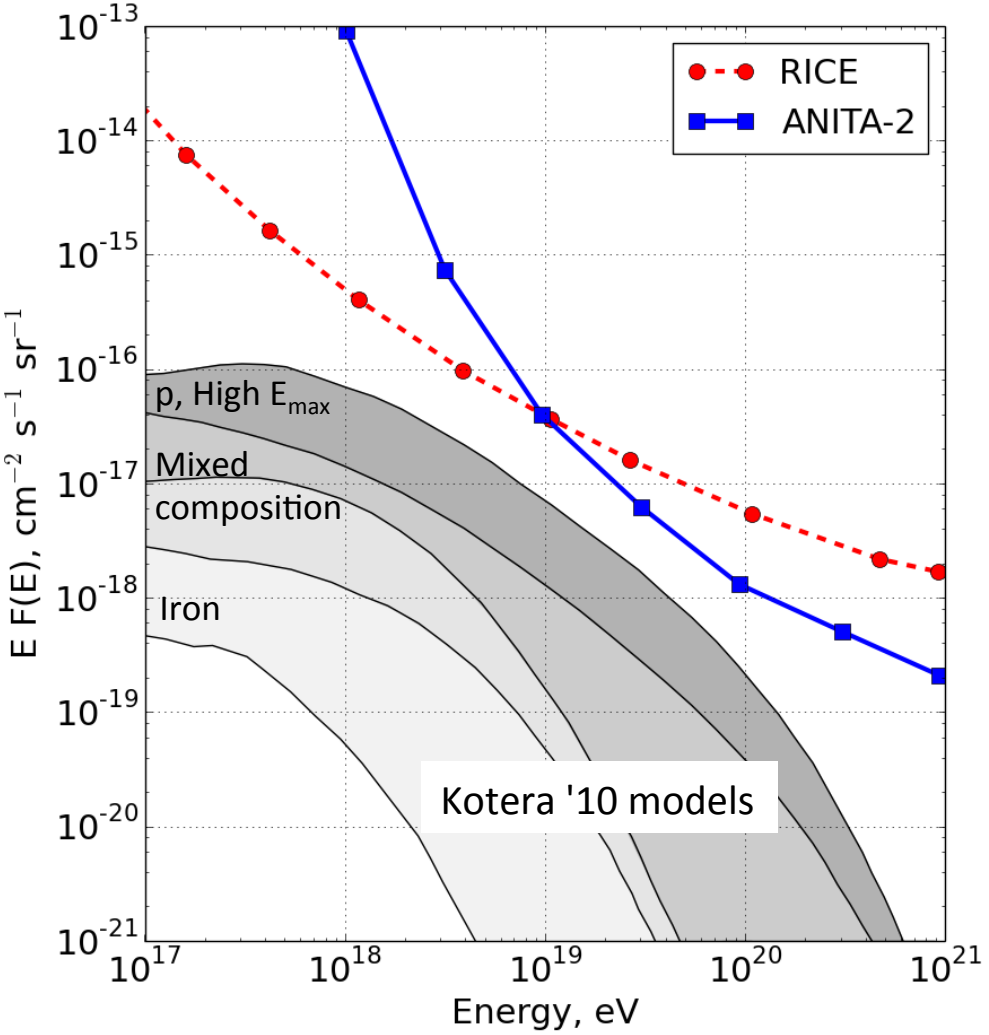
Dense Target (ice)

Radio Detection of Ultra-High Energy Neutrinos



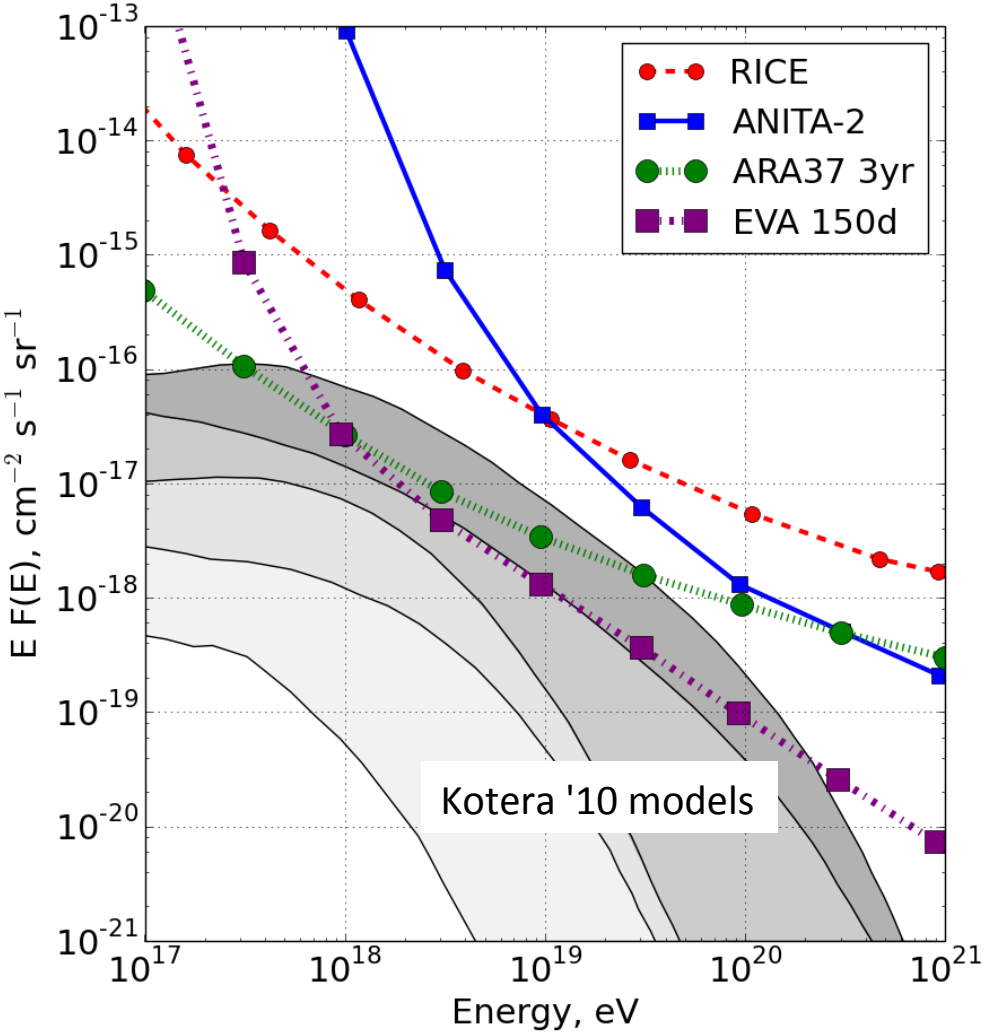
In-ice vs. Balloons

- In-ice antennas:
  - lower energy threshold.
  - Reduced visible volume.
- Balloon-borne antennas:
  - Higher energy threshold.
  - Increased visible volume.

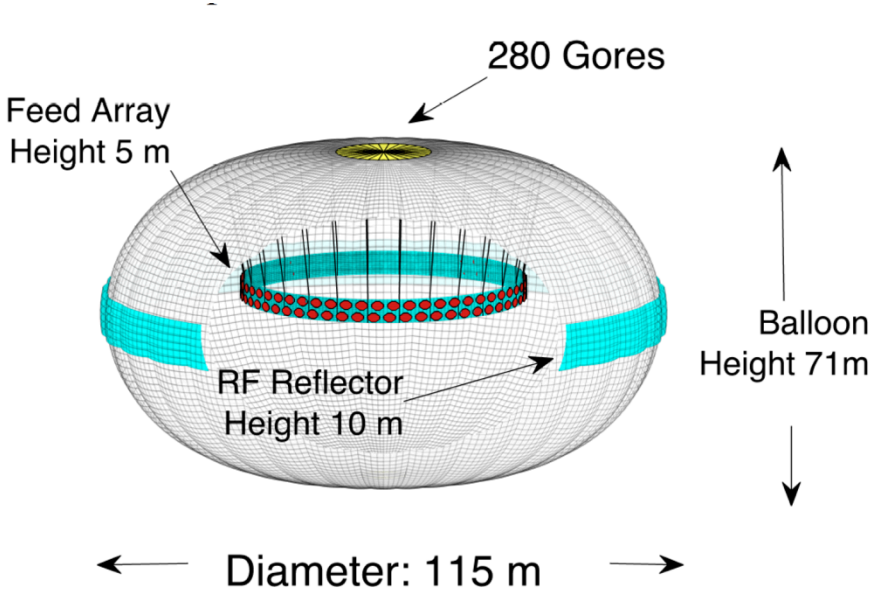


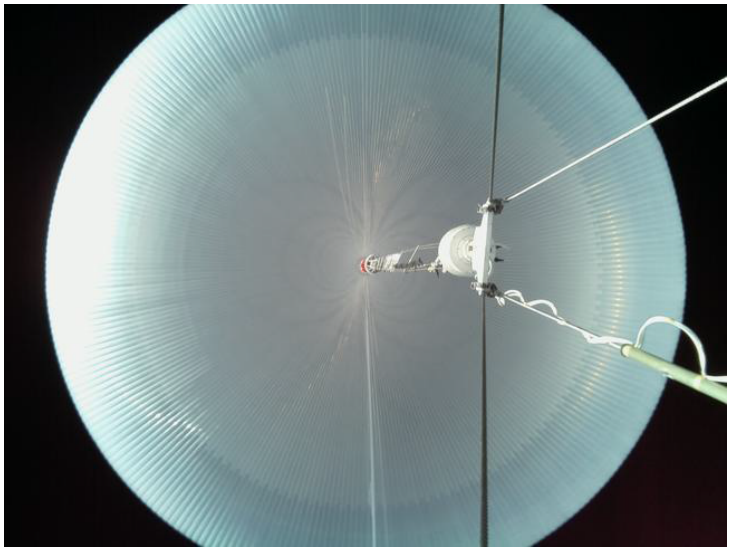
In-ice vs. Balloons

- ARA37:
  - Large number of stations increase the visible volume.
- EVA:
  - High gain antenna reduces the energy threshold while increasing visible volume.
  - EVA antenna gain is 32 dBi compared to 10 dBi for ANITA. This is a factor of 160 improvement.



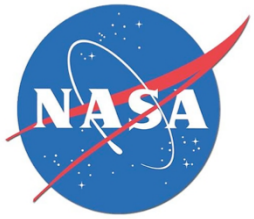
The EVA Concept





Use the surface of a NASA super-pressure balloon as a reflector antenna.

NASA 18.7 Mcft super-pressure balloon.



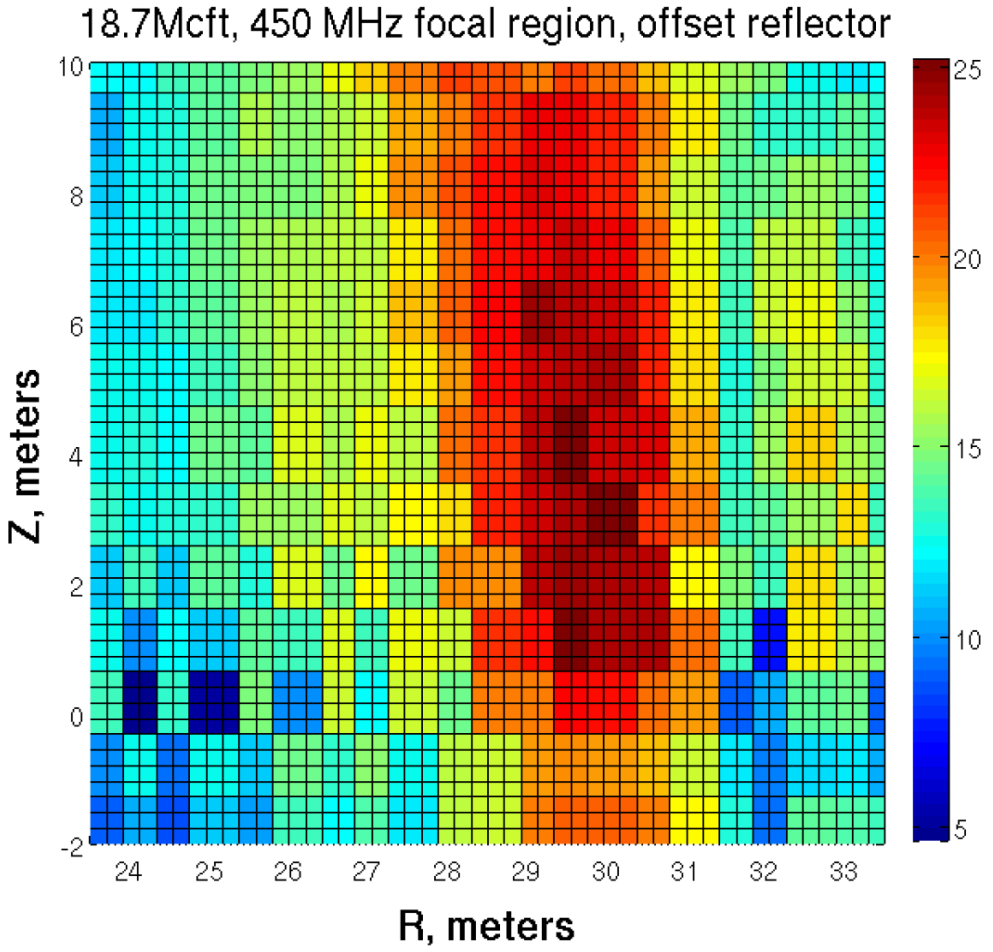
Simulations of EVA Antenna Gain

JPL

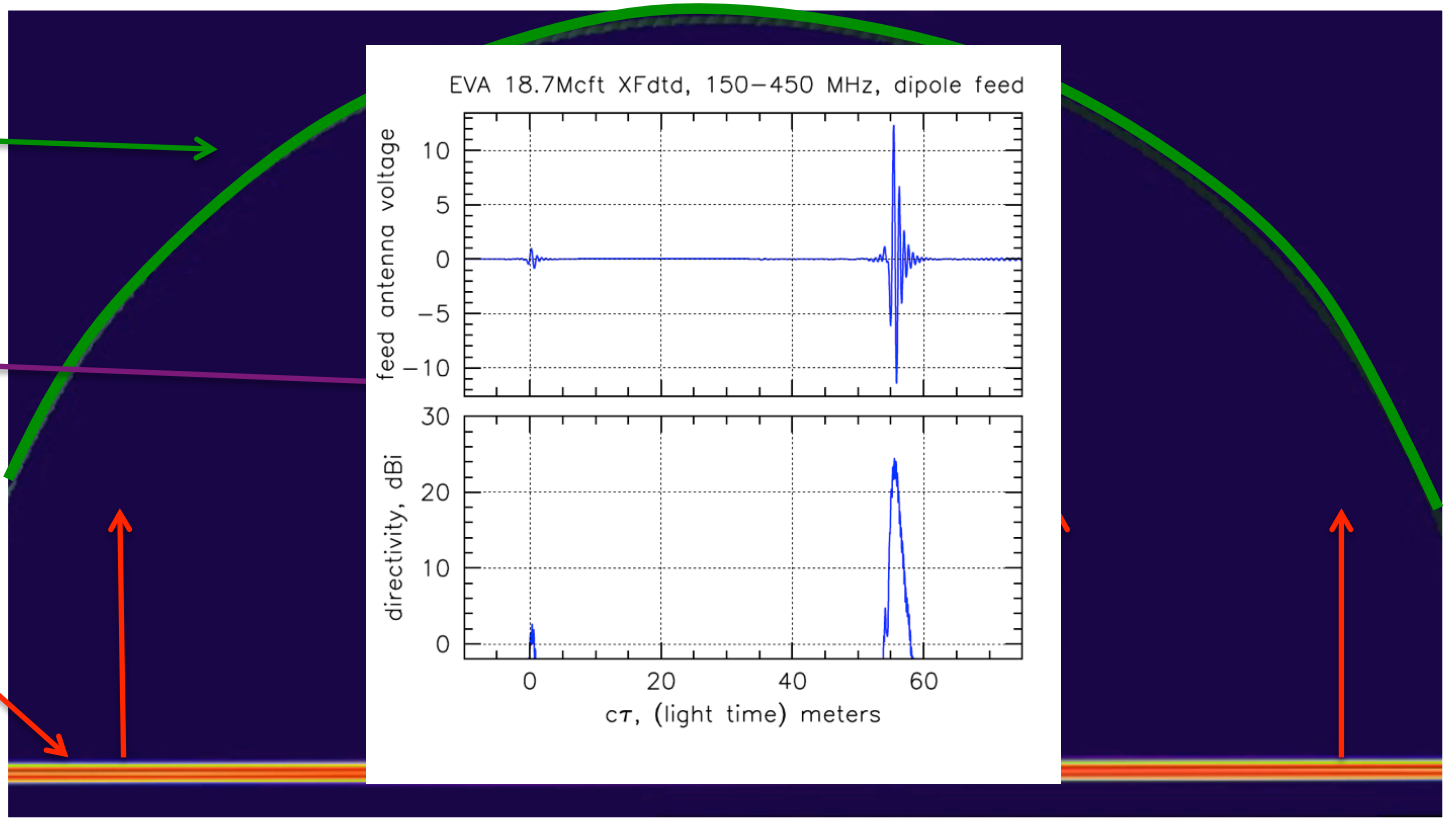
- Three independent simulations with of the EVA antenna gain have been performed.
  - Numerical Electromagnetics Code (NEC) using method of moments.
  - XF7 using Finite difference in the time-domain (FDTD).
  - General Reflector Antenna Software Package (GRASP) using physical optics.
- Each simulation uses a different computational electromagnetics technique.

Method of Moments Simulations with NEC

- Simulates the reflector using a wire mesh.
- Reflector is dipole fed.
- Optimization of feed position provides 25 dBi of gain.
- Likely an under-estimate due to sparseness of wire model reflector and it does not account for the non-dipole feed gain.



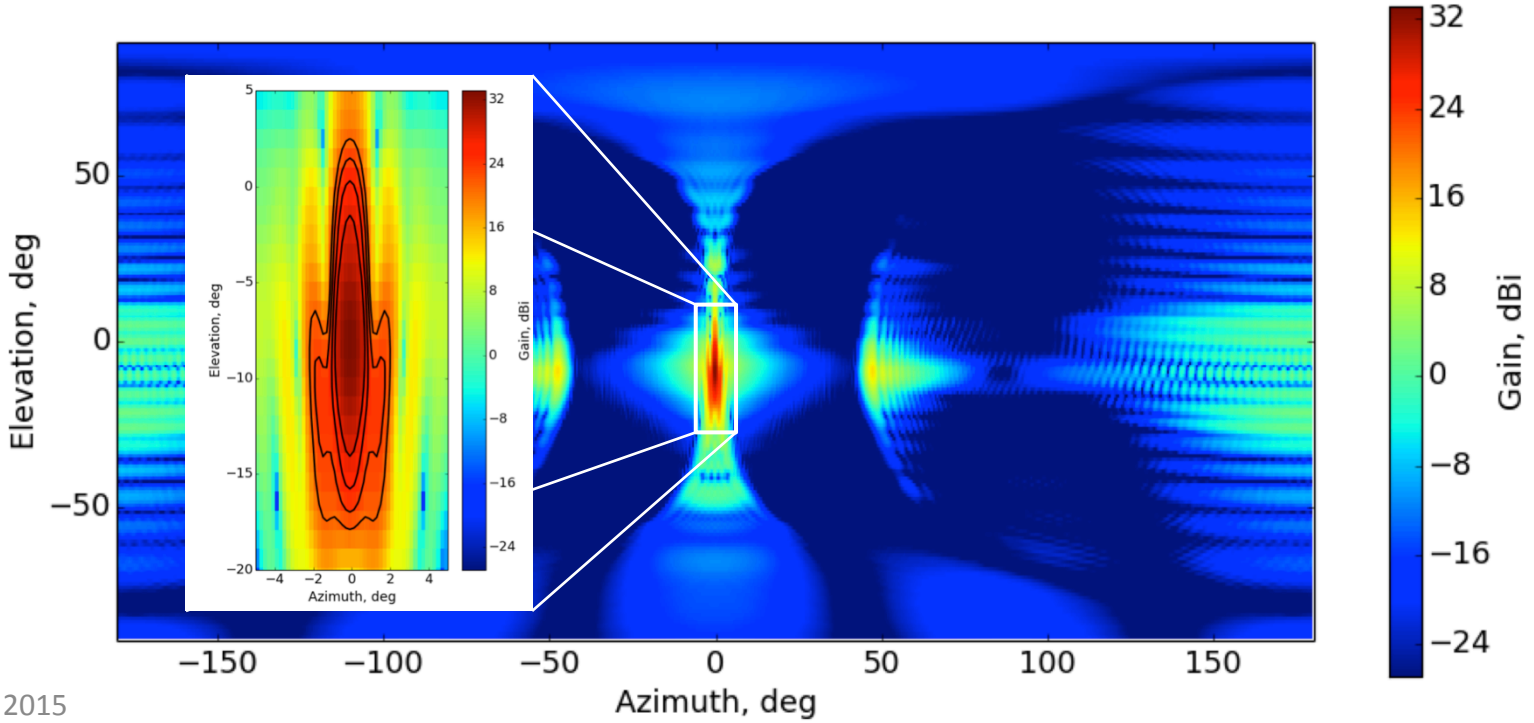
XFdtd Reflection Simulation



- FDTD discretizes a volume and applies Maxwell's equations on each cell.
- A plane wave illuminates the surface of the balloon and its reflection is propagated to find the focal point.
- A gain of 24 dBi is achieved at the focal point.

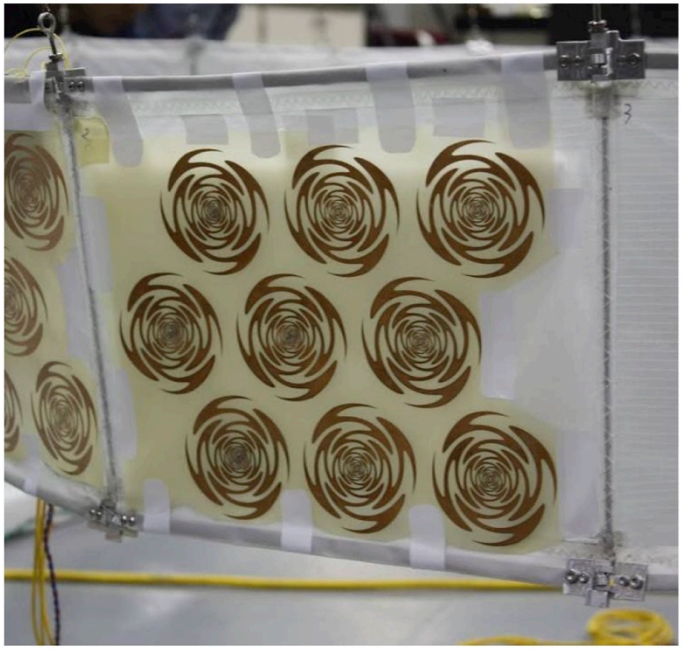
Simulations with GRASP

- GRASP is the tool of choice for reflector antenna designers.
- Physical optics simulator fully accounts for the surface shape and the feed antenna gain pattern.
- Surface simulations using an optimized feed illumination pattern results in a peak of 32 dBi.



1/20th Scale Model Test at Wallops Flight Facility

1/20th scale model balloon. This balloon has 28 gores compared to the 280 gores of the full scale balloon.



Dual-polarized sinuous antenna feeds.

Balloon and feed system.

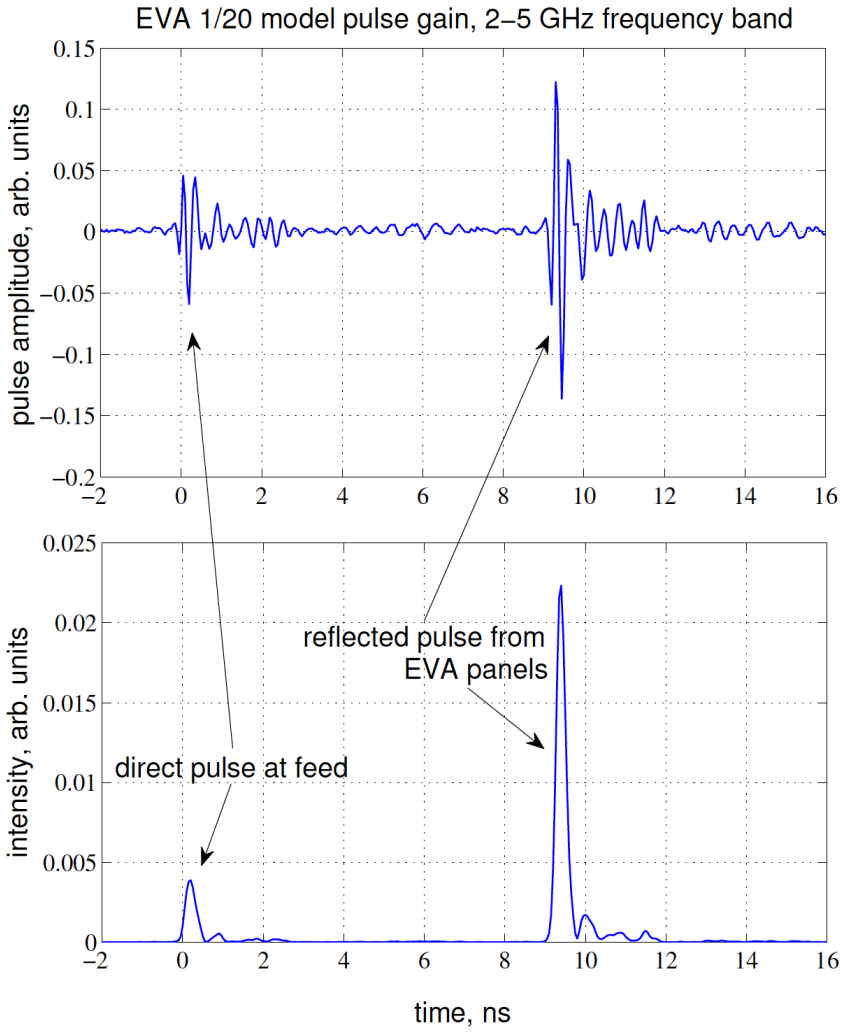
Scale Model Results

Data from scaled model test shows increased gain is achieved with pulse coherence is maintained upon reflection.

The gain estimated from this measurements is ~11.4 dBi.

GRASP simulations of the scaled model antenna predict 11.5 dBi while XF7 predicts 10.0 dBi.

Results are consistent within ~2 dBi lending credibility to the EVA concept.



Expected EVA Results

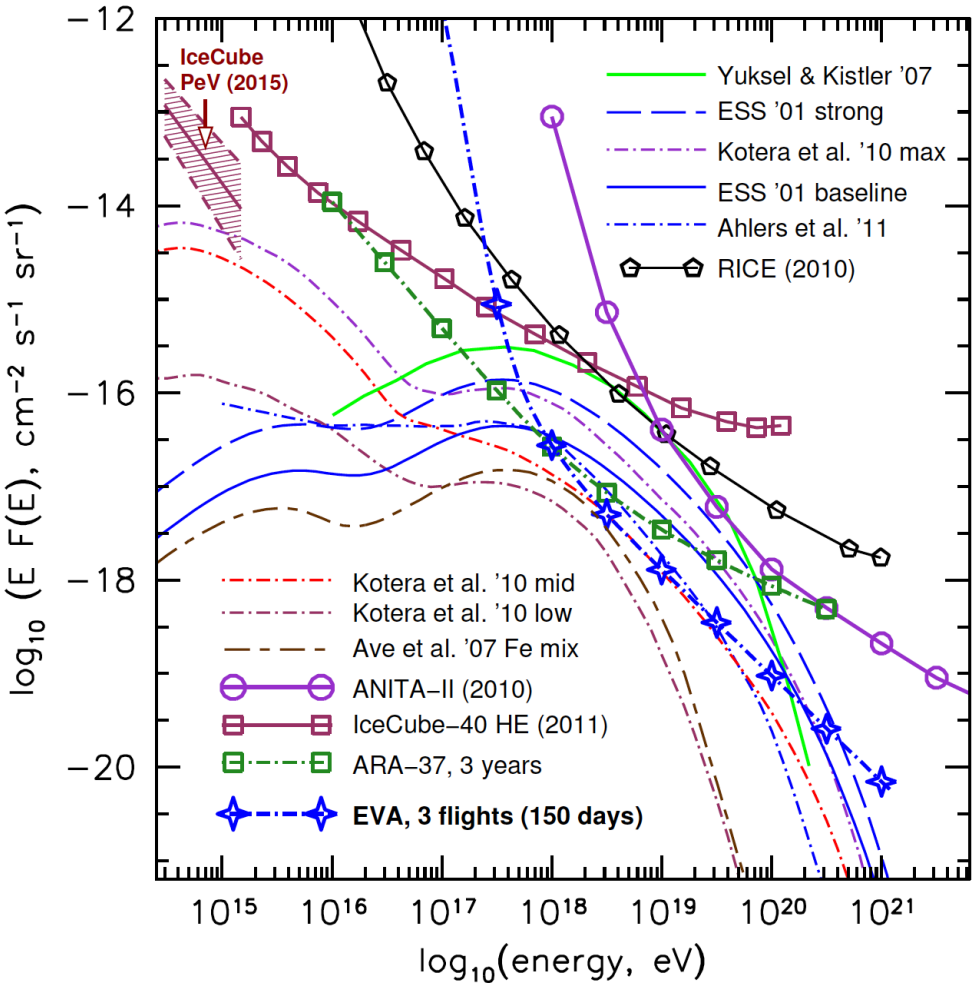


Table 1: *Expected numbers of events N_ν for published values of ANITA-II, 3 years of ARA-37, and 150 days of EVA with 80% analysis efficiency.*

Model & references N_ν:	ANITA-II (2008)	ARA 3yr	EVA 150d
Baseline cosmogenic models:			
Protheroe *et al.* 1996[11]	0.6	13	44
Engel *et al.* 2001[3]	0.33	11	38
Kotera *et al.* 2010[12]	0.5	13	38
Strong evolution models:			
Engel *et al.* 2001[3]	1.0	34	120
Kalashev *et al.* 2002[13]	5.8	41	312
Barger *et al.* 2006[14]	3.5	32	91
Yuksel *et al.* 2007[15]	1.7	50	156
Mixed-Iron-Composition:			
Ave *et al.* 2005[16]	0.01	1.3	2.5
Stanev 2008[17]	0.0002	0.23	0.3
Kotera *et al.* 2010[12] high	0.08	2.4	6.4
Kotera *et al.* 2010[12] low	0.005	0.76	1.4
Waxman-Bahcall (WB) fluxes:			
WB 1999, evolved[18]	1.5	17	98
WB 1999, standard[18]	0.5	5.9	35
IceCube PeV E^{-2} power-law			
IceCube 2015 [19]	...	2.9	6.10

Conclusions

- The EVA high gain balloon antenna has been estimated by three independent electromagnetic simulations.

- The scaled model test provides a first proof of concept for the balloon mechanics and validation of electromagnetic simulations.

Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Government sponsorship acknowledged.