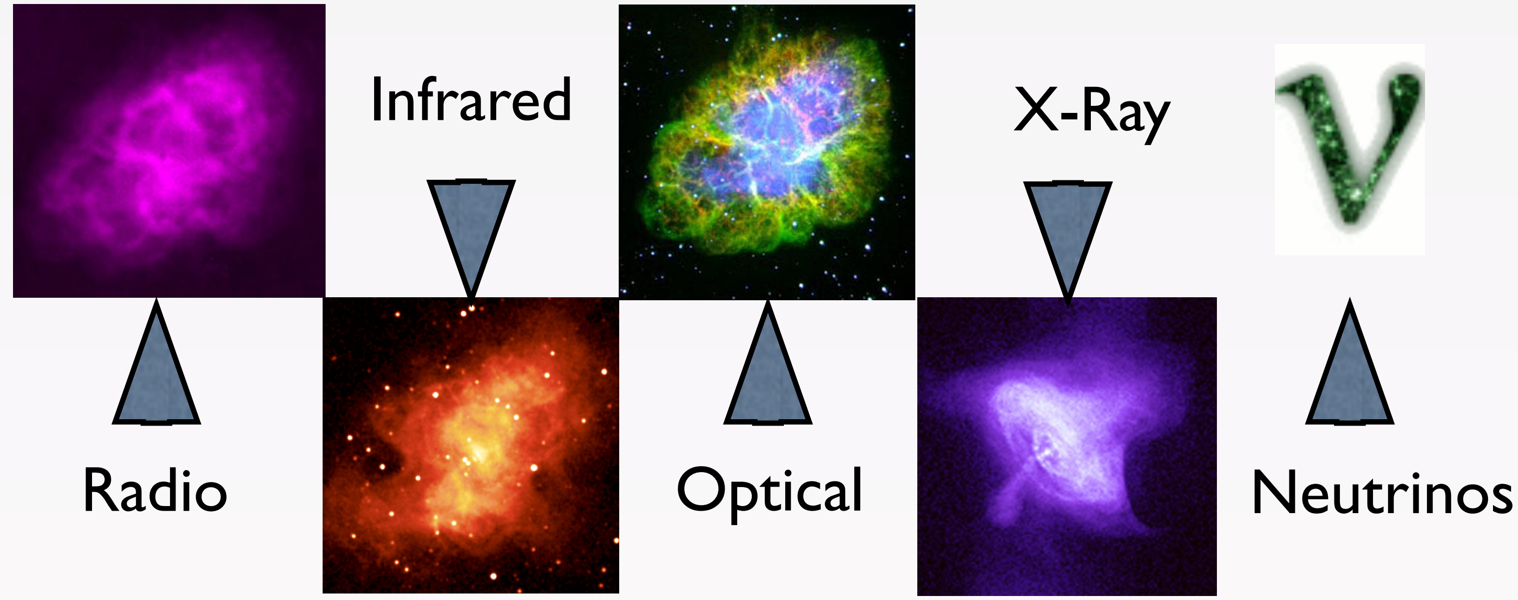
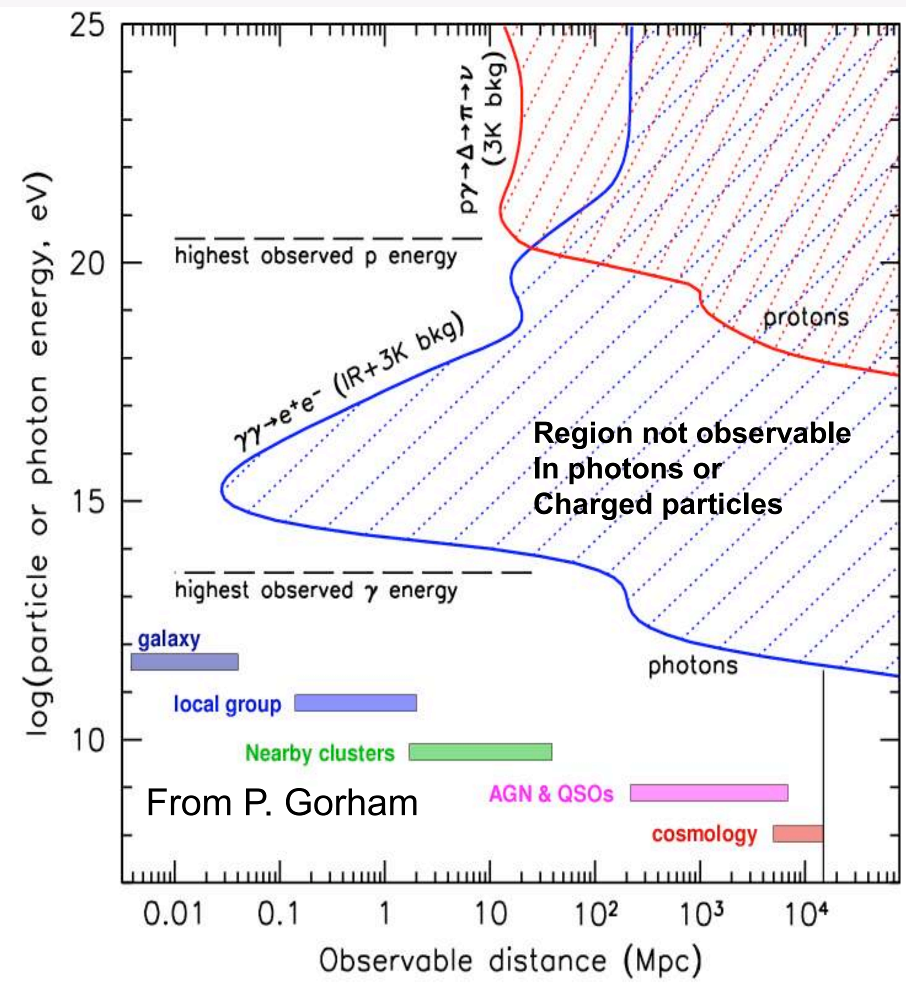
Jonathan Davies
Mark Lancaster
Matthew Mottram
Ryan Nichol
David Waters

ANITA

Why Ultra High Energy Neutrinos?

For Astronomers:
The Pretty Pictures Argument





From P. Gorham

For Astrophysicists:

The Heineken Particle Argument

For Particle Physicists:
The 300 TeV (CoM) Neutrino Beam Argument

Order of magnitude:

type	L/E	$t_{proper} \sim (L/c)(m_\nu/E)$
CERN SpS/WANF	500 m/25 GeV	3 attoseconds
Stopped μ (LAMPF)	30 m/ 40 MeV	130 attoseconds
NUMI	735 km/ 4 GeV	30 femtoseconds
Reactor (KamLAND)	150 km/5 MeV	800 femtoseconds
Atmospheric	10,000 km/1 GeV	2 picoseconds
Sun	150,000,000 km/5 MeV	800 nanoseconds
GZK	1 Gpc/100 PeV	50 milliseconds
SN-1987a	50 kpc/15 MeV	1 hour

How can you detect high energy neutrinos?

- A problem of size
  - Some Numbers:

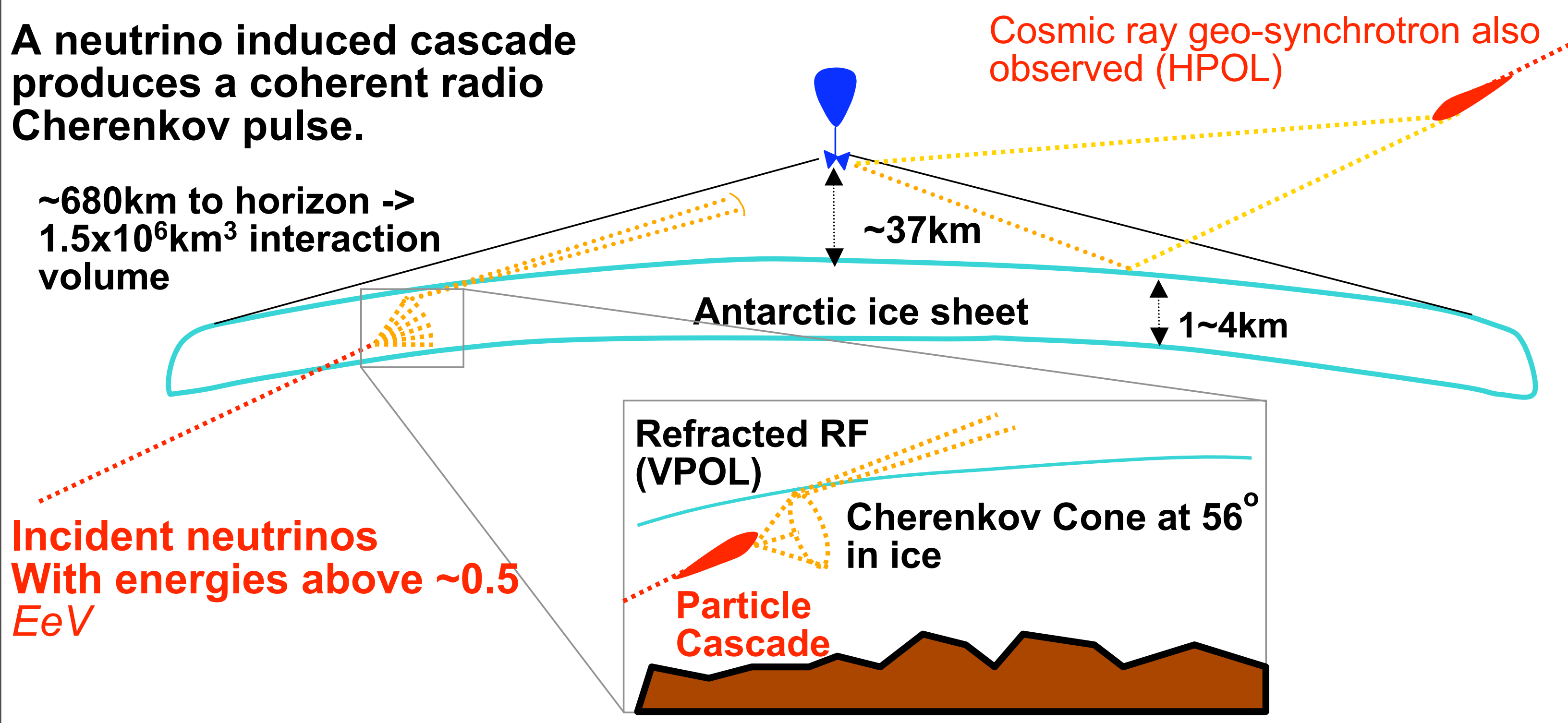
    ~10 GZK neutrinos per km^2 per year

    @ 10^{18} eV the ν-N interaction length ~ 300km w.e.

    $\therefore$ 0.03 neutrino interactions per km^3 per year
- One needs a huge detector volume (>>10 km^3) in order to ensure a neutrino detection.
- Have to use a naturally occurring medium, that is transparent (to some signal). Possibilities,
  - Air, Ice, Salt, Water, The Moon

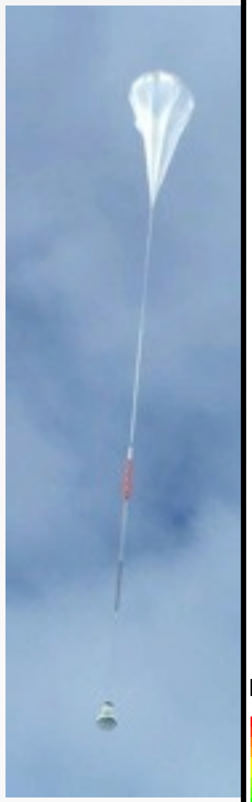
ANtarctic Impulsive Transient Antenna (ANITA)

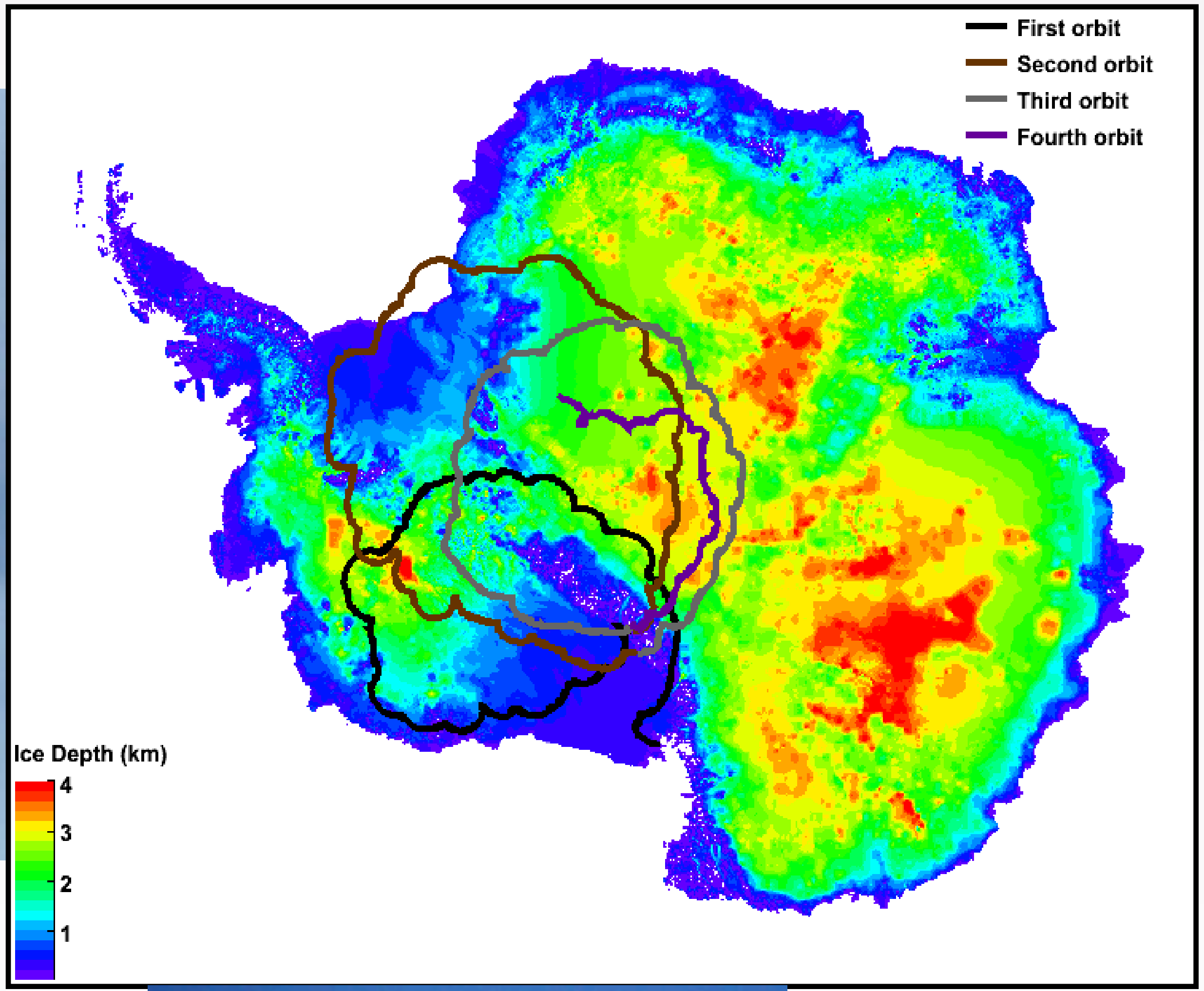
- Balloon borne experiment
  - Views over 1 million km^3 of ice
  - Ice over 4km thick in places
  - Attenuation Length O(km)



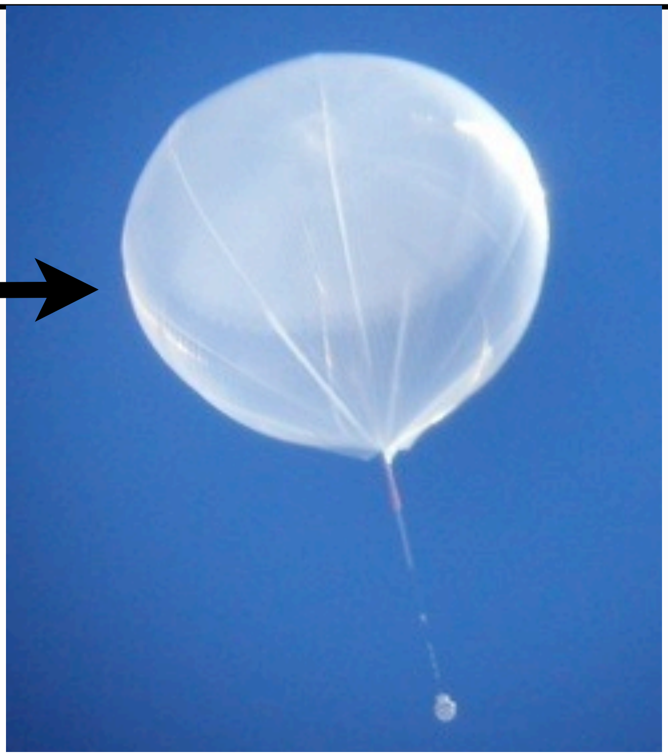
The First Flight

- Launched December 2006
- Lasted 35 days (the record is 42)
  - Three and a half sort of polar orbits
  - Recorded over 8 million triggers

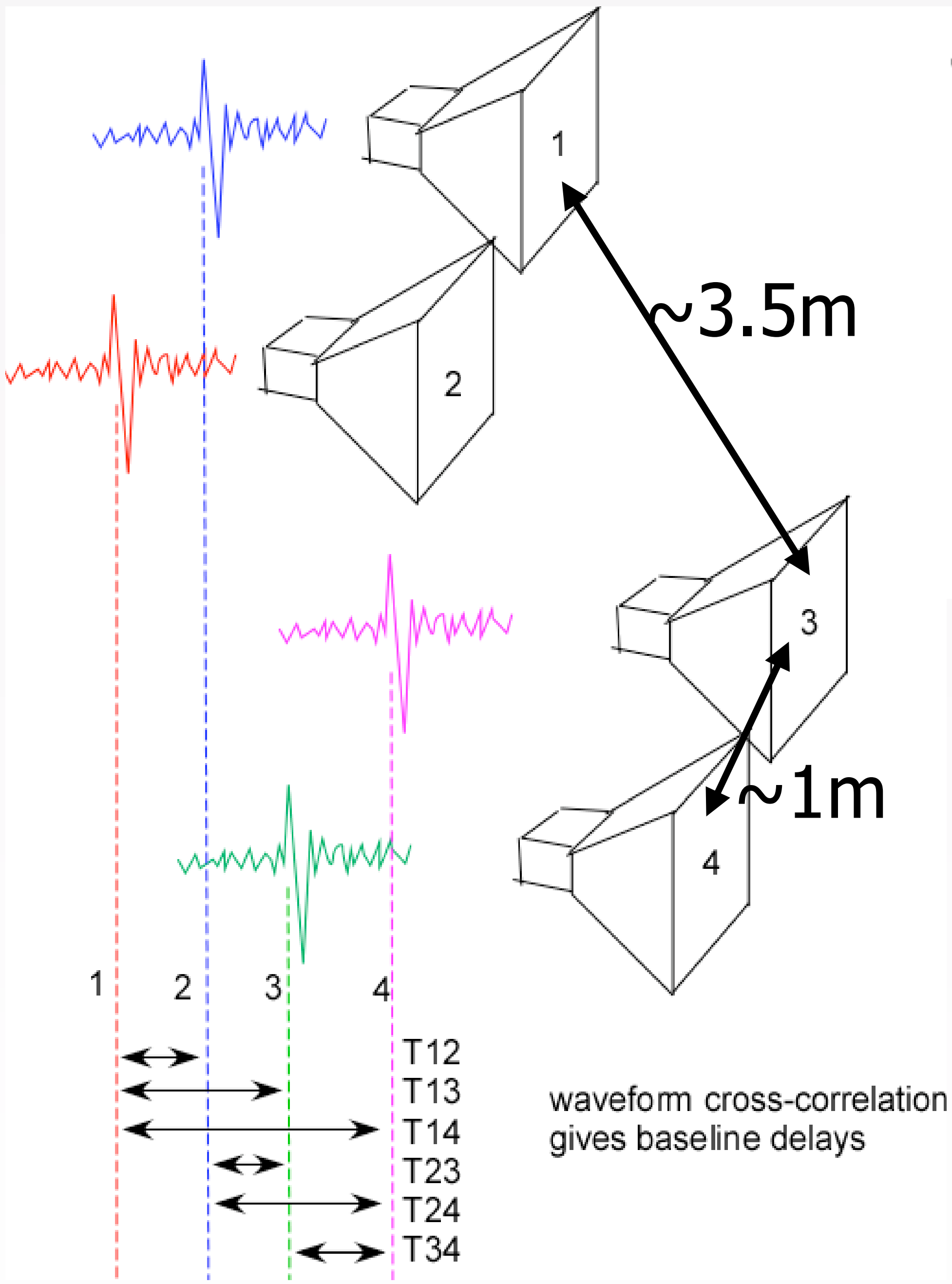


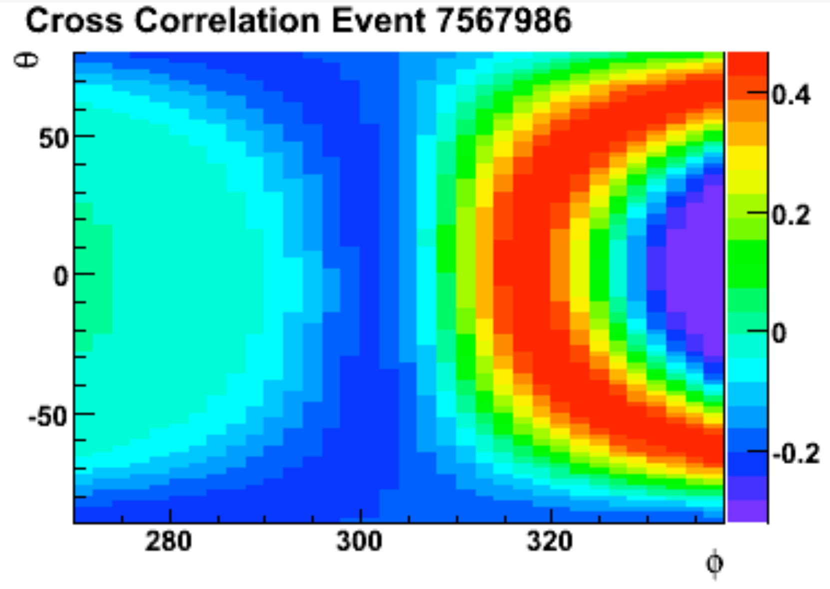


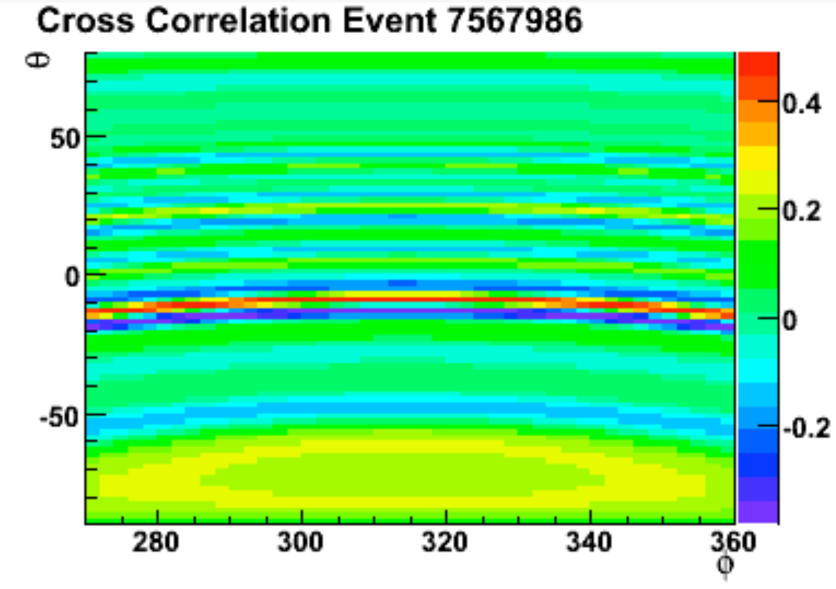
Fits inside the balloon at altitude

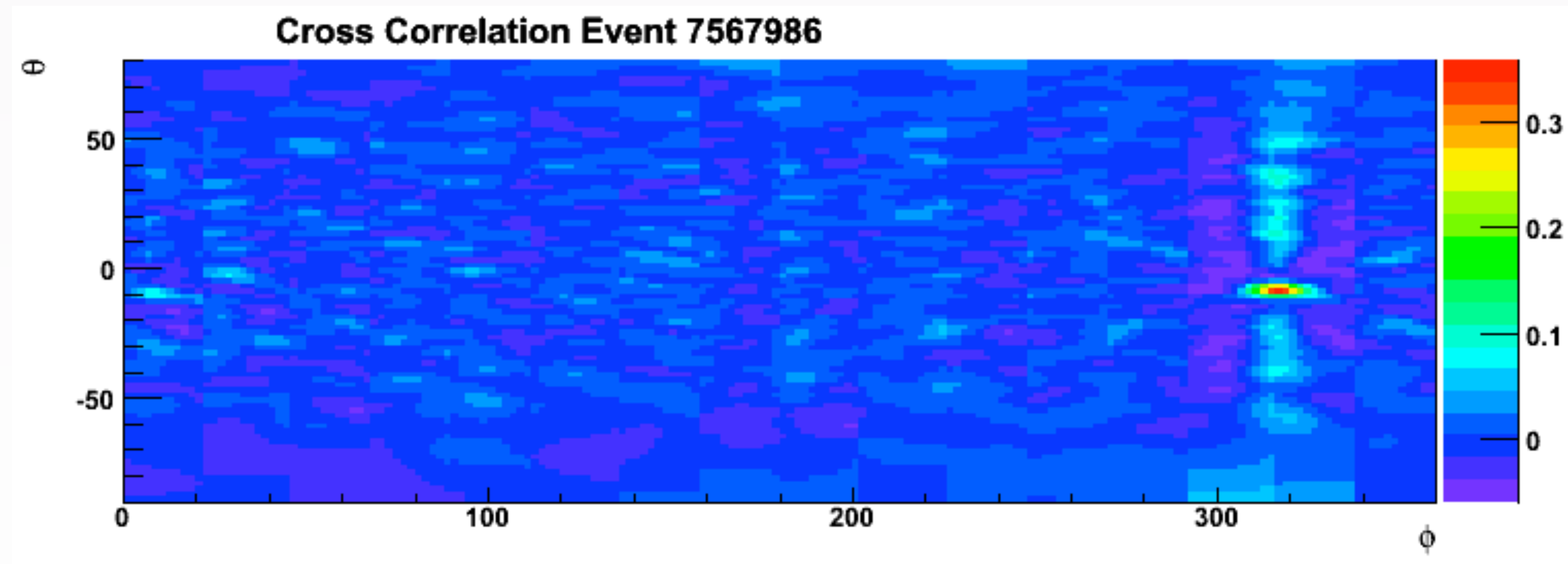


Event Reconstruction

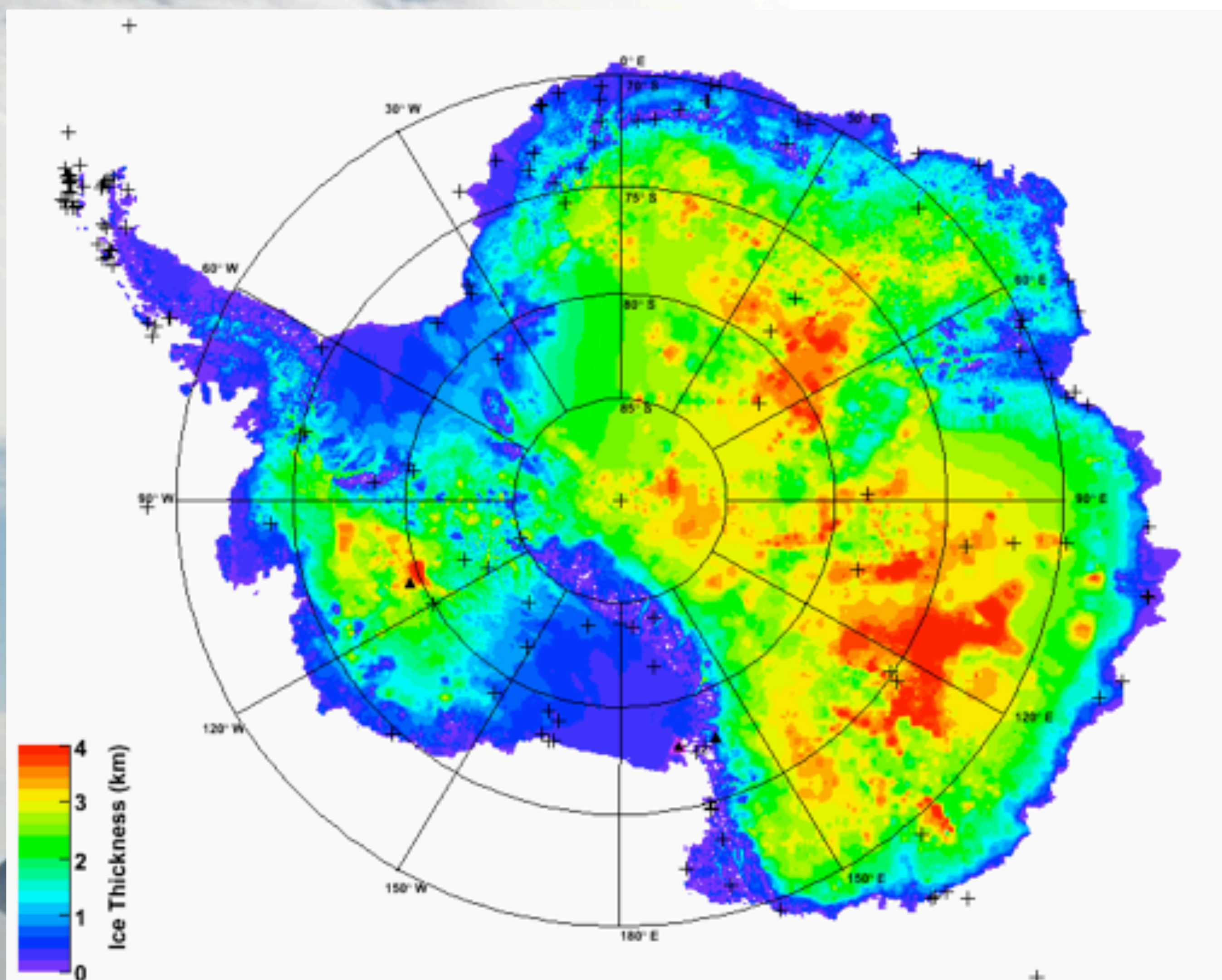




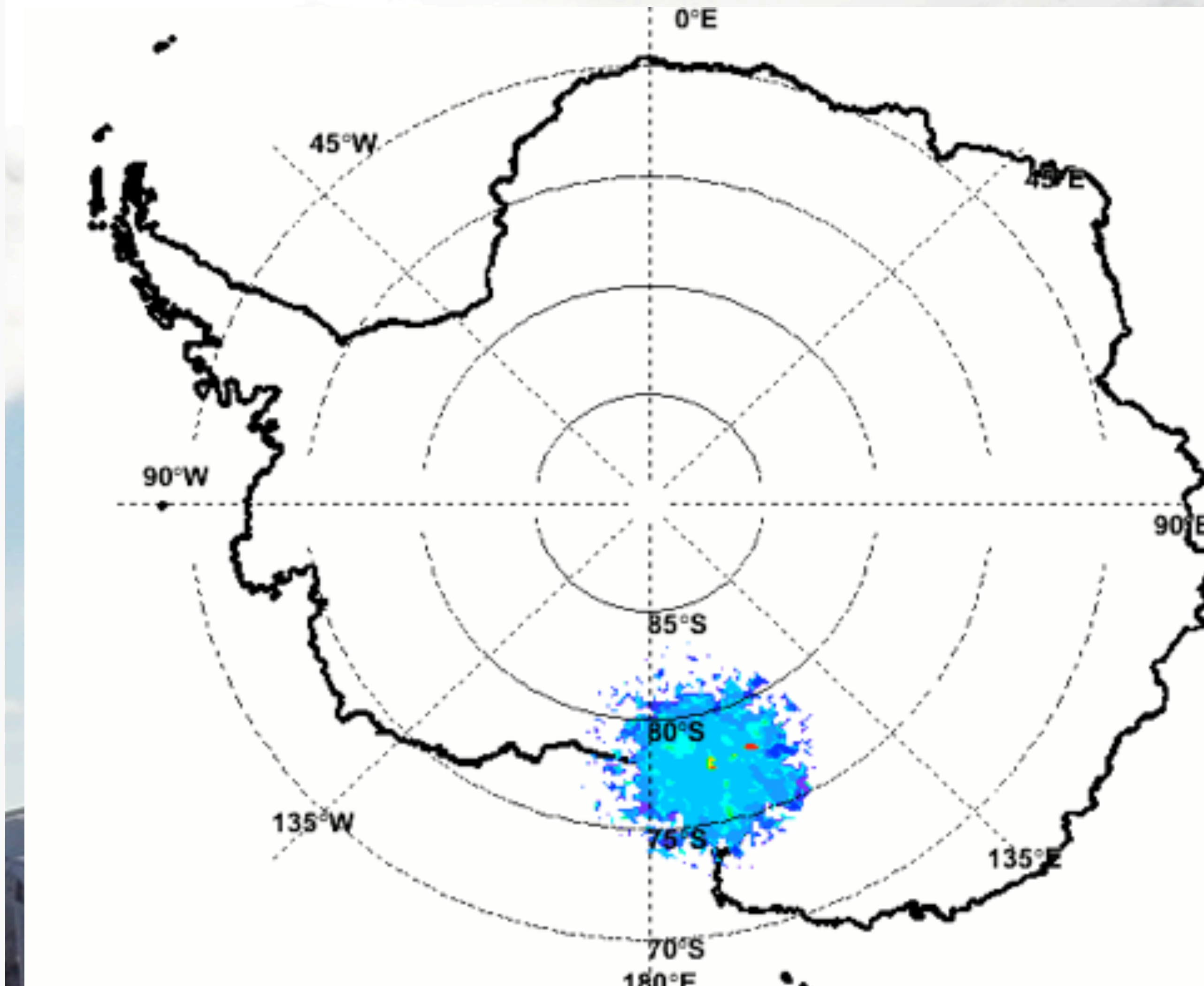




ANITA-II



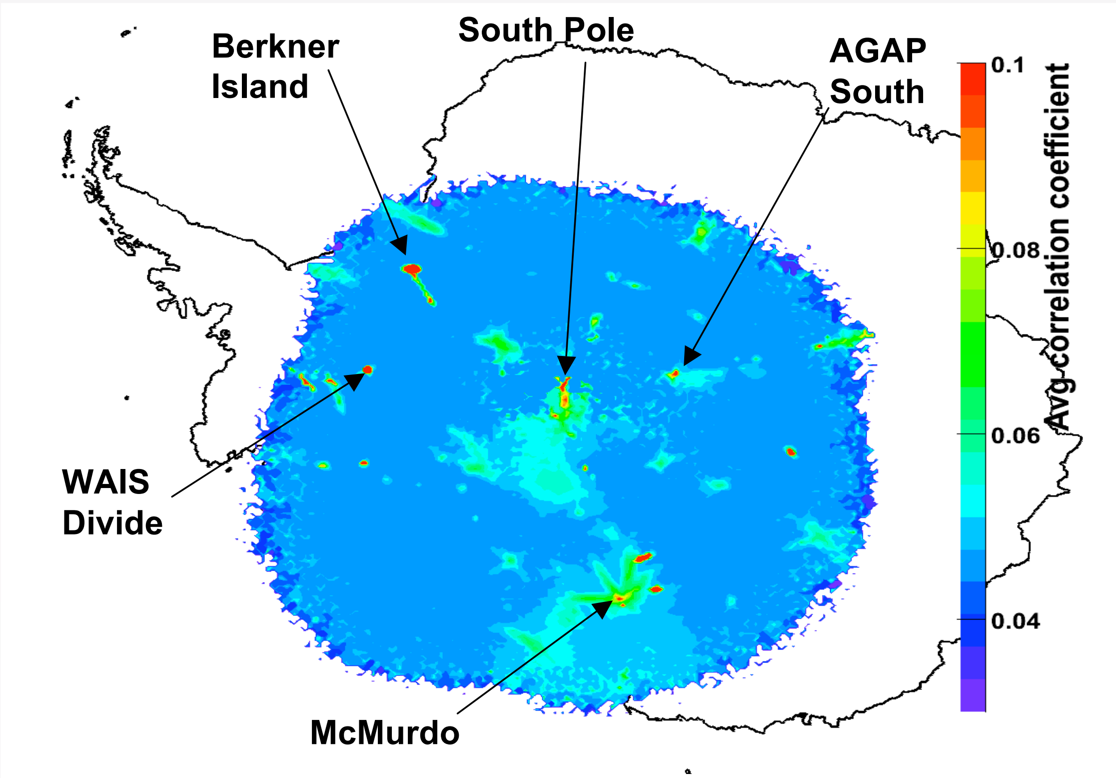
Ice Thickness (km)
0
1
2
3
4

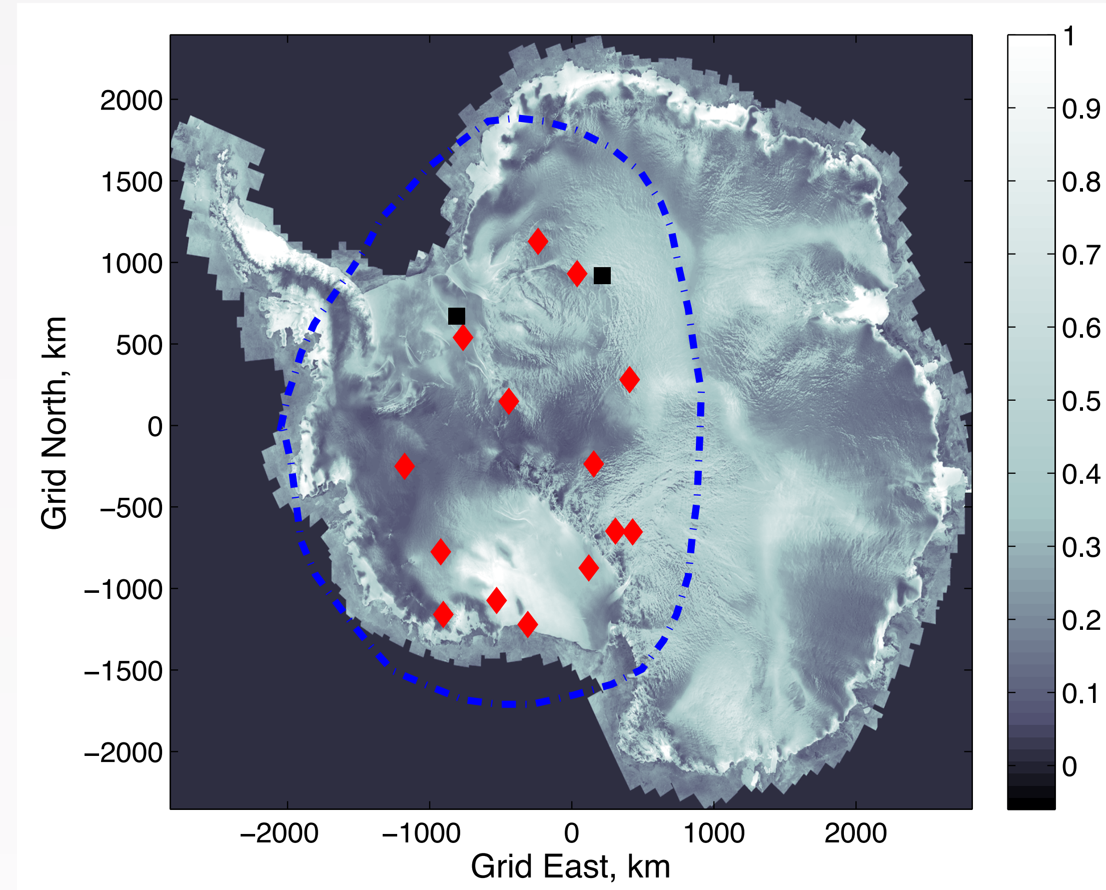


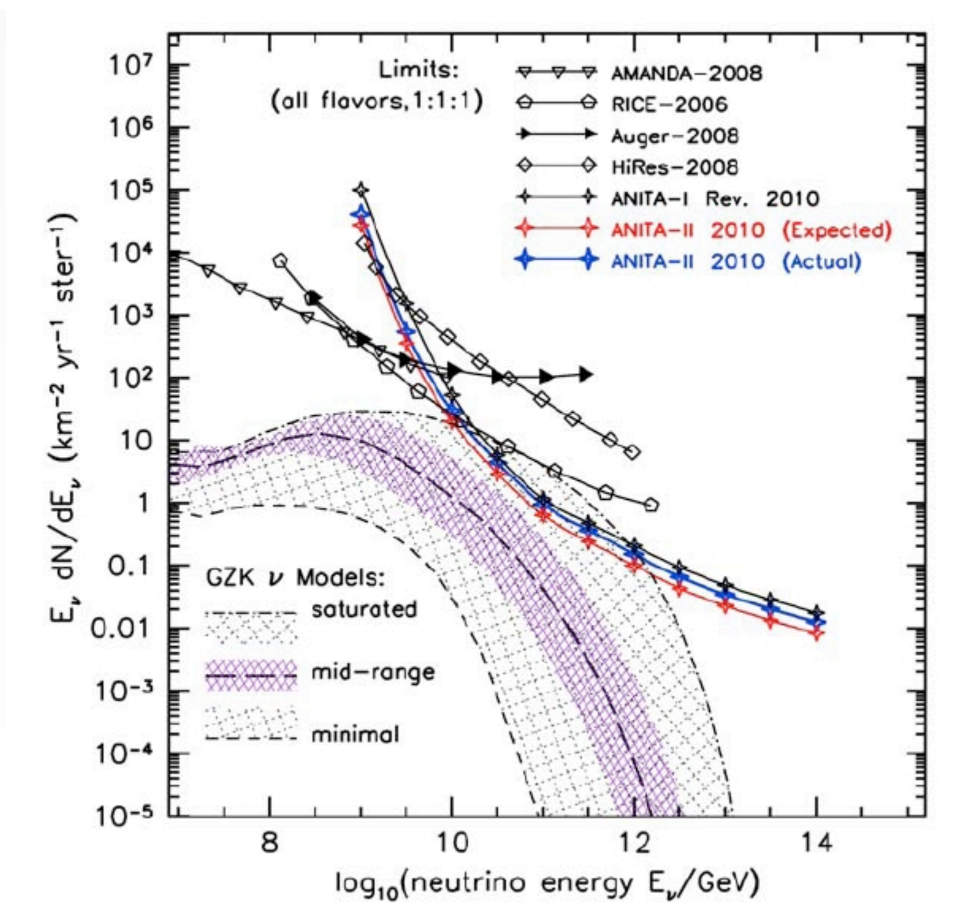
0°E
45°W
45°E
90°W
90°E
85°S
80°S
75°S
135°W
135°E
70°S
180°E

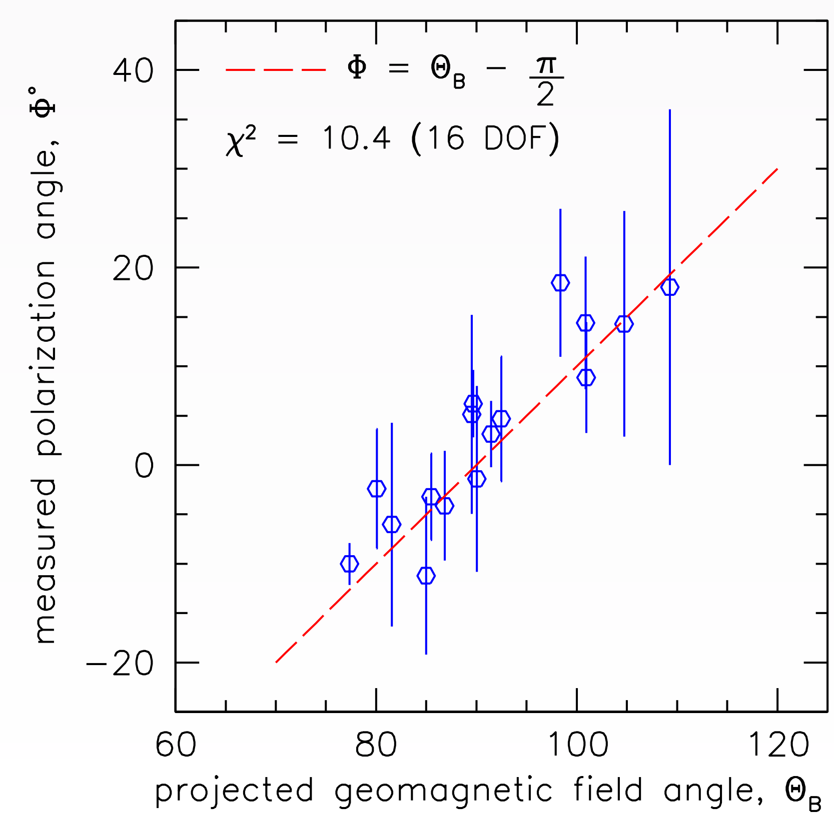
ANITA-II Recovery

New Neutrino Limits & UHECR Detection









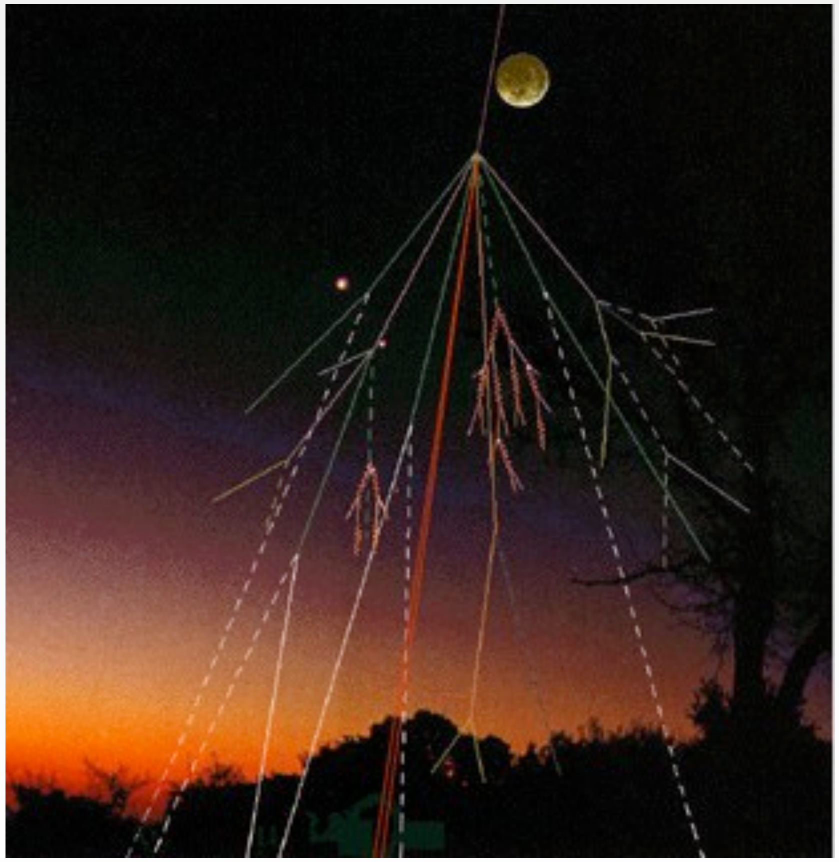
Summary

- Ultra-high energy neutrino research is an exciting new field at the crossroads of particle physics, astrophysics, cosmology and astronomy.
- The UCL group is very active in the field with leading roles in ANITA, the most advanced radio detection experiment.
  - And involvement with ARA and ARIANNA the future in-ice experiments
- The first sight (or whatever the radio equivalent of sight is) of UHE neutrinos is likely come in the next few years.
- Now is an excellent time to start working in the field.

CREAM TEA

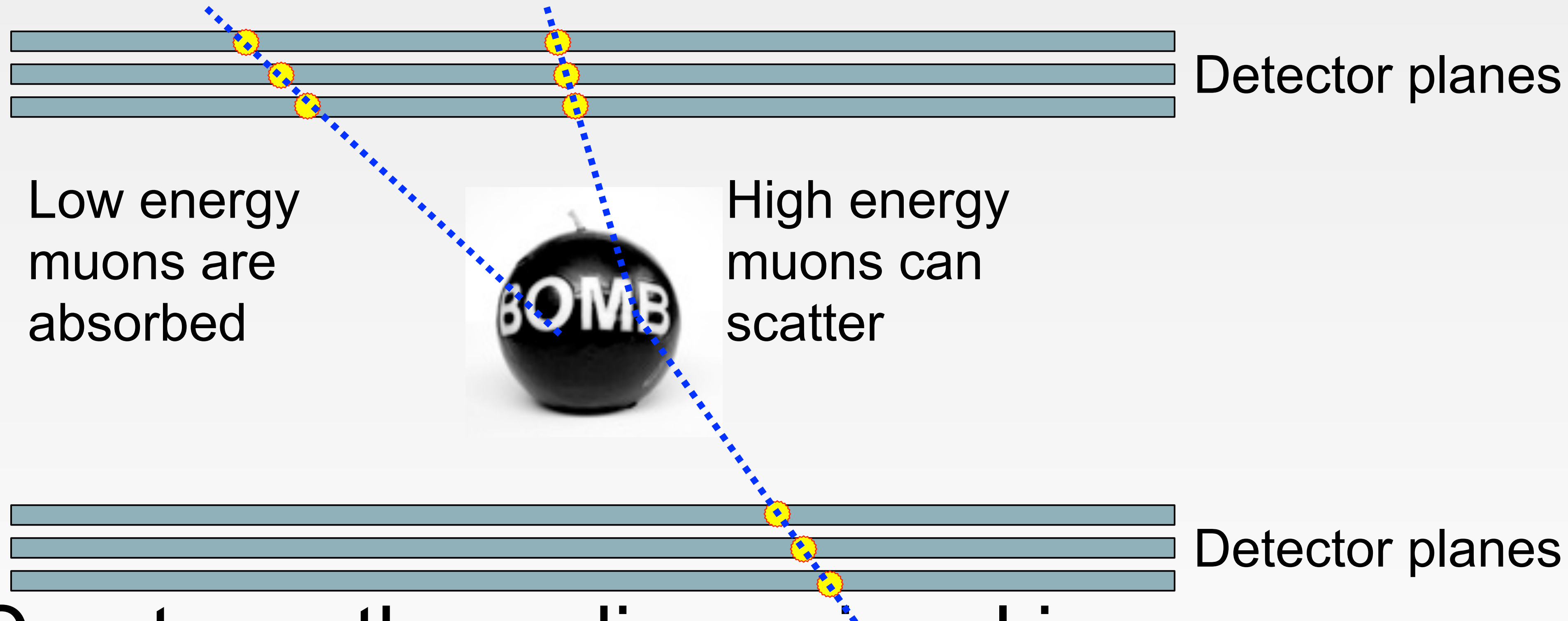
Cosmic Ray Extensive Area Mapping for Terrorism Evasion Application

Justin Evans, Anna Holin, Ryan Nichol, Jenny Thomas



The Idea - Cosmic Ray Muon Tomography

- Over 10,000 cosmic ray muons a minute stream through each square metre of the Earth's surface.
- These particles either scatter (high energy) or are absorbed (low energy) as they pass through matter.

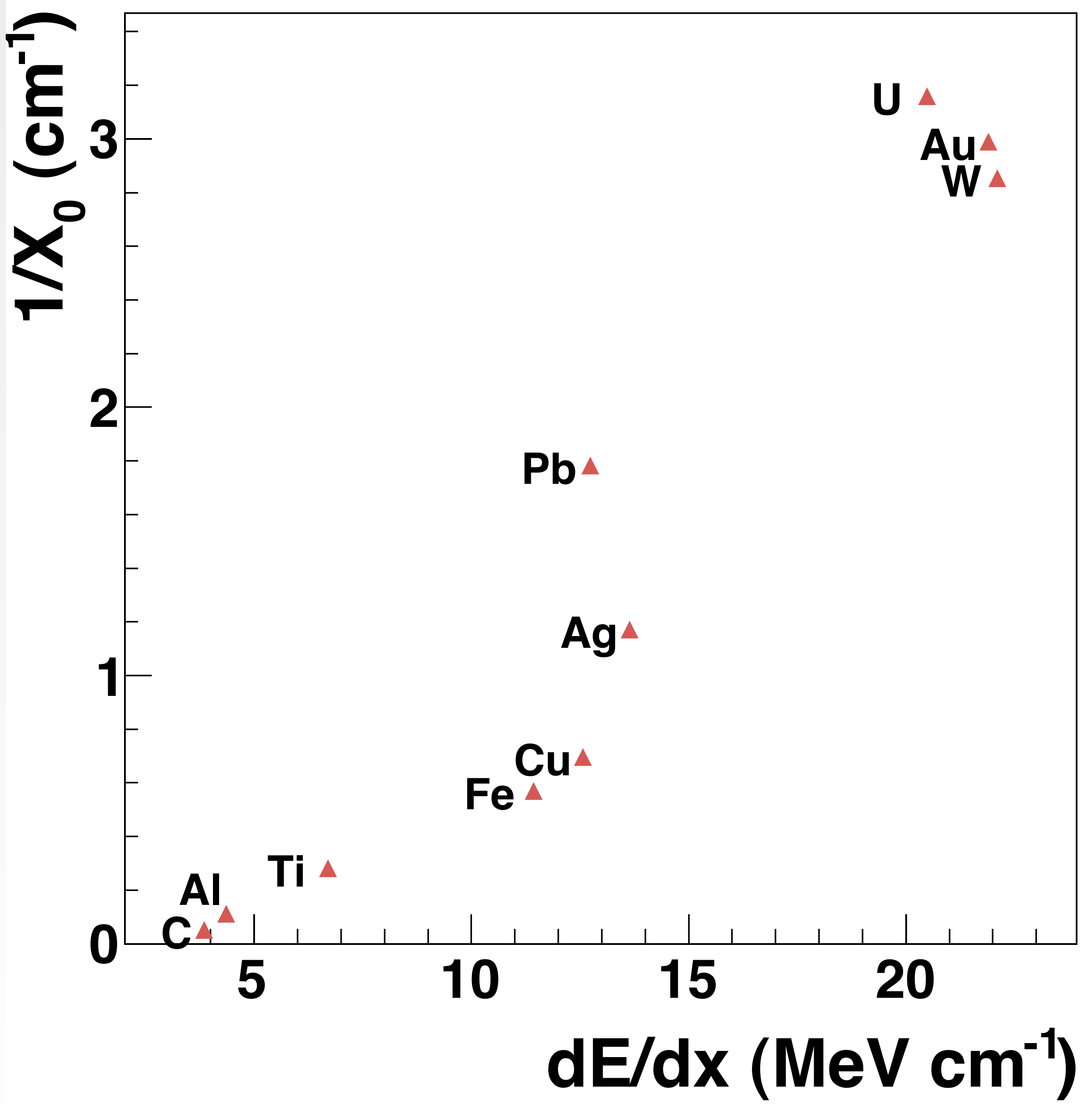


- Creates a three dimensional image.
  - Cosmic ray imaging is an old idea (1950's) and has been used to image: pyramids, volcanoes, mines, ...

Muon Tomography Capabilities

- The scattered and absorbed muons can be used to make two independent measures of the target material

Radiation Length (Scattering)



Energy Loss (Absorption)

Test Stand Construction Progress

‘Test Stand’ Stand

Scintillator Modules

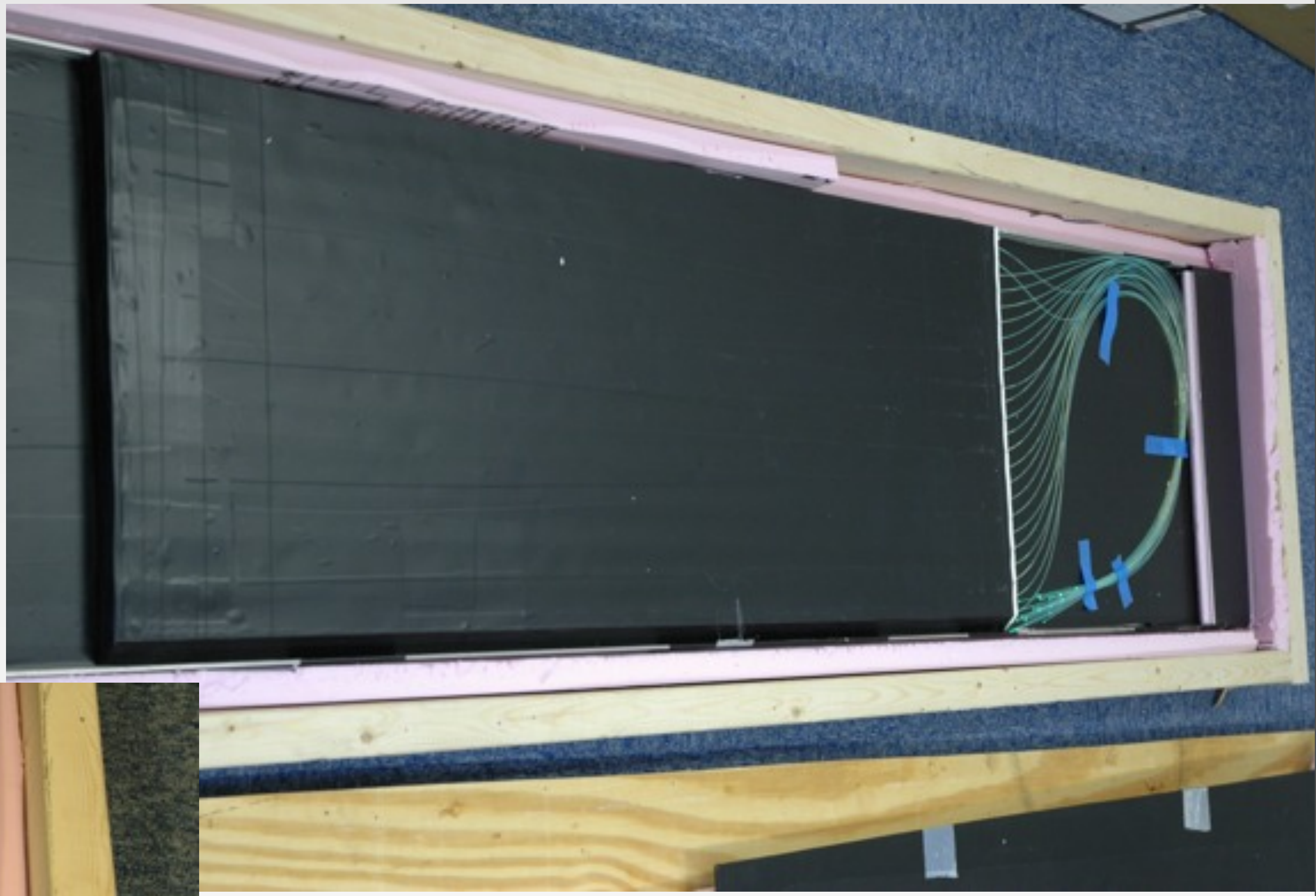
4xTARGET Digitiser

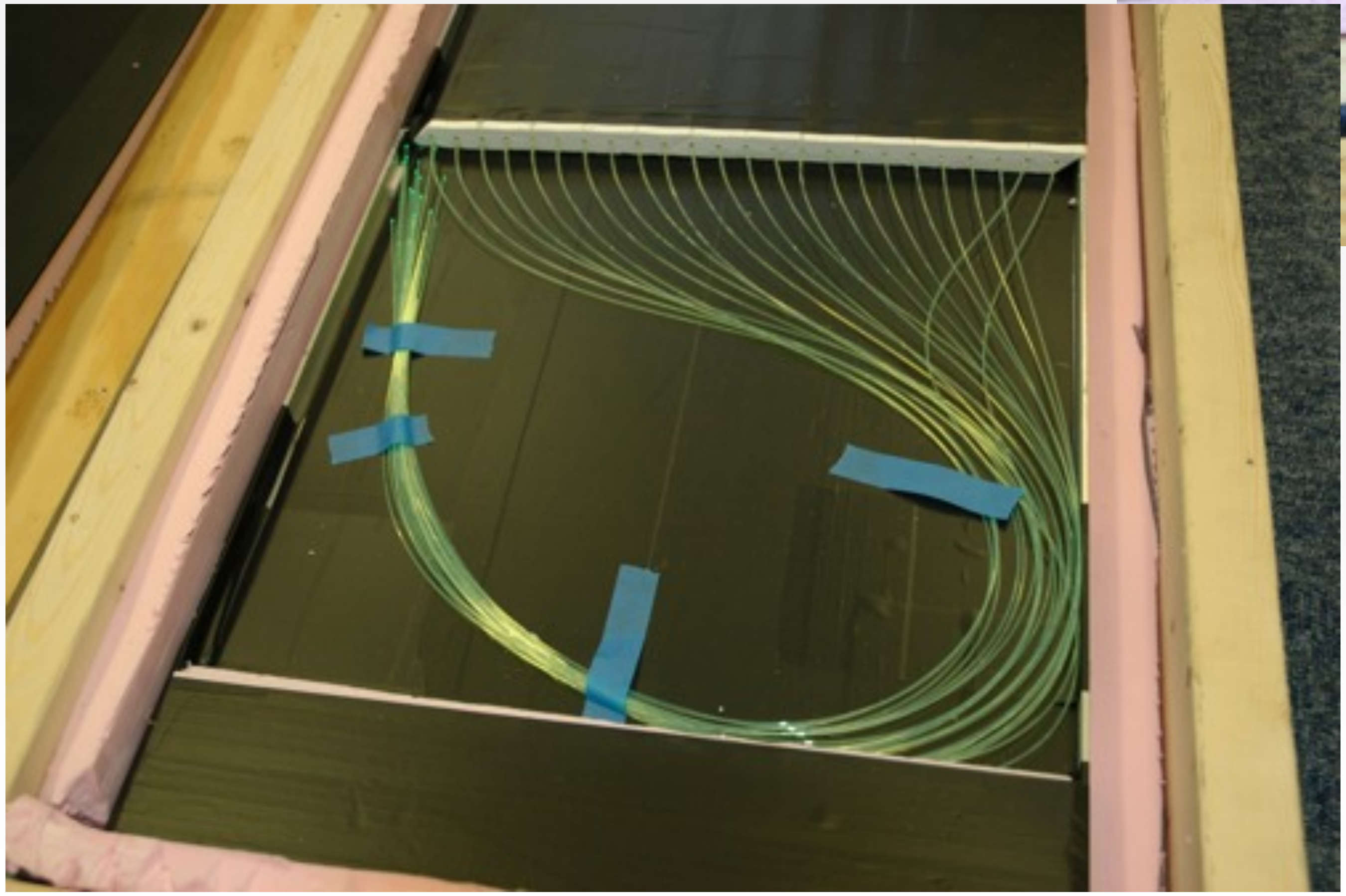
64 Channel PMT

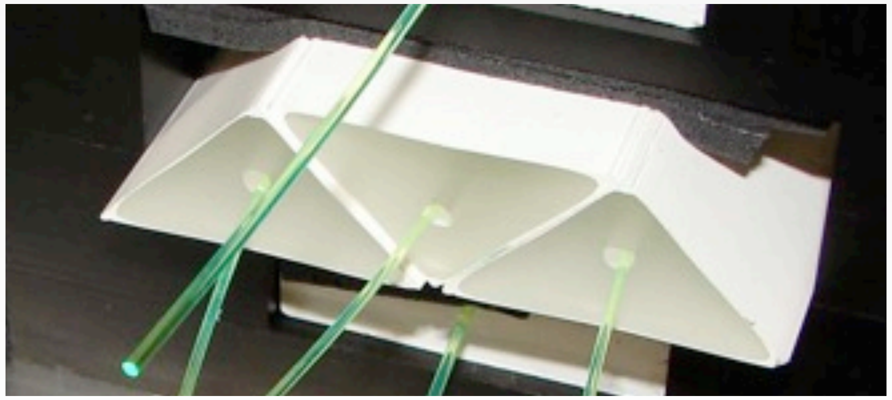
Readout Cables

New Scintillator Planes

- First evaluation models are in the laboratory in MSSL







UCL Muon Tomography Summary

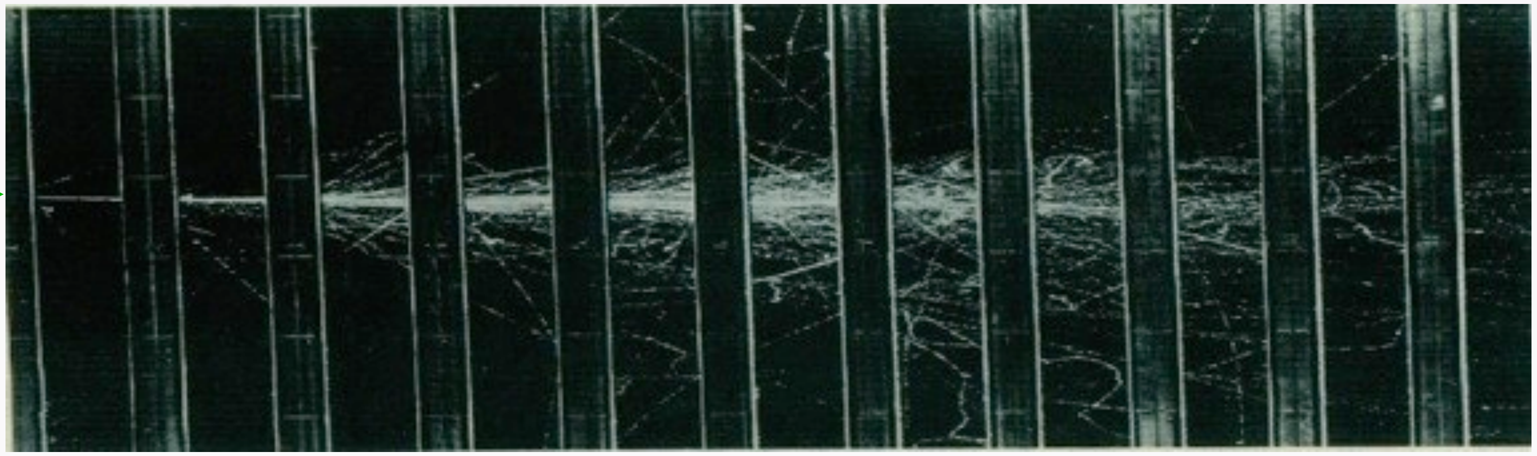
- Preliminary studies have shown that muon tomography techniques can be applied to security areas
- We have moved from a feasibility stage to a detector optimisation stage
- Test stand under-construction at the ν-lab at MSSL
- Seeking extra funds for CRμMPET
  - construction and testing of higher resolution scintillator planes
  - the addition of a muon spectrometer below the test stand
  - an increase on the 256 PMT/electronics channels currently in testing

Backup Slides

Radio Cherenkov

- In 1962 Gurgen Askaryan hypothesised coherent radio transmission from EM cascades in a dielectric:

e± or ϒ

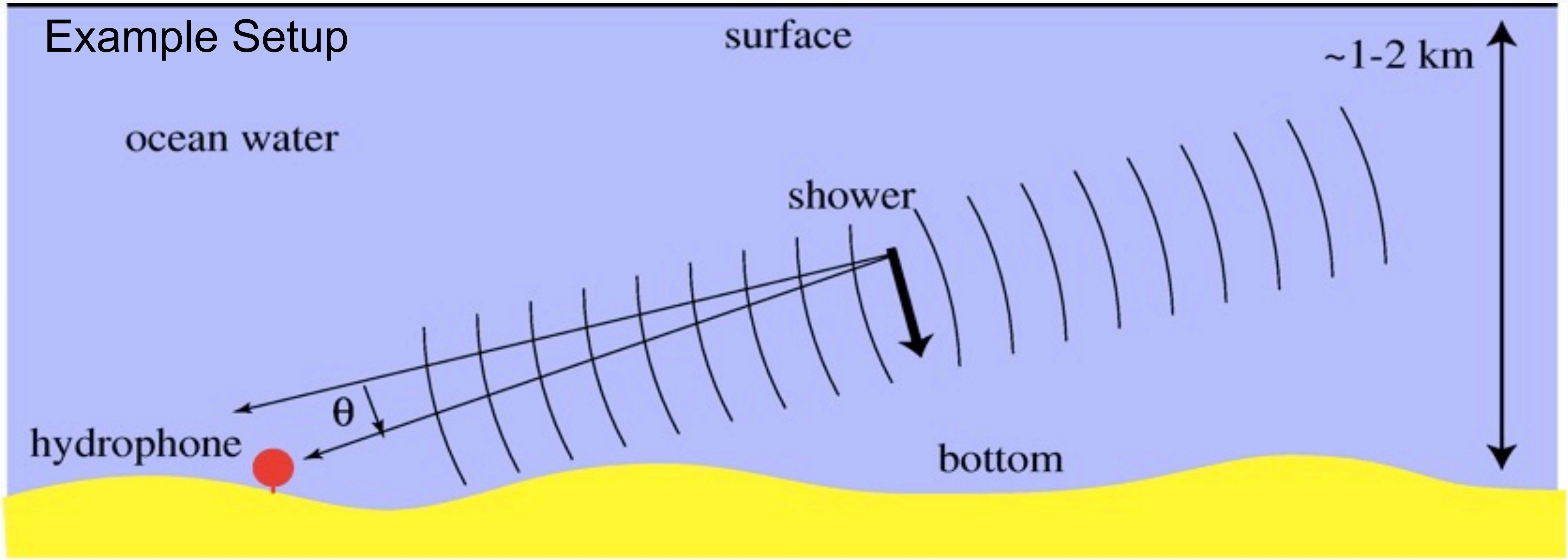


Typical Dimensions:
$L \approx 10$ m
$R_{Moliere} \approx 10$ cm

  - 20% Negative charge excess:
    - Compton Scattering: $\Upsilon + e^-_{(rest)} \Rightarrow \Upsilon + e^-$
    - Positron Annihilation: $e^+ + e^-_{(rest)} \Rightarrow \Upsilon$
  - Excess travelling with, $v > c/n$
    - Cherenkov Radiation: $dP \propto v\, dv$
  - For $\lambda > R$ emission is coherent, so $P \propto E^2_{shower}$

Acoustic Detection

- Mechanism first described by Askaryan (1957) “Hydrodynamical emission of tracks of ionising particles in stable liquids”
- Emission is coherent & broadband (peak at ~20 kHz)
- Easily detected by commercially available hydrophones.



The ANITA Collaboration

- University of Hawaii at Manoa
  Honolulu, Hawaii, USA
- University of California at Irvine
  Irvine, California, USA
- University of California at Los Angeles
  Los Angeles, California, USA
- University College London
  London, UK
- University of Delaware
  Newark, Delaware
- Jet Propulsion Laboratory
  Pasadena, California, USA
- University of Kansas
  Lawrence, Kansas, USA
- University of Minnesota
  Minneapolis, Minnesota, USA
- The Ohio State University
  Columbus, Ohio, USA
- Stanford Linear Accelerator Center
  Menlo Park, California, USA
- National Taiwan University
  Taipei, Taiwan
- Washington University in St. Louis
  St. Louis, Missouri, USA