Proposals

Proposals are due today!

- Please submit these to me electronically (PDF format preferred)

I will send around a .tar file with all of the proposals for you to read (likely on Friday).

In addition, you will be assigned one proposal on which you will be the primary reviewer.

Before the review on June 6th:

- Read all of the proposals and assign them a preliminary grade
- Prepare a brief report on your primary assignment including a list of strengths and weaknesses

Proposal Grading Guide

4.5 - 5.0	Outstanding. This investigation is among the highest priority investigations for Chandra and must be carried out.
3.5 - 4.5	Very Good. This investigation should be carried out if at all possible.
3.0 - 3.5	Good. This investigation will be of some value to science and may be carried out if resources allow.
2.5 - 3.0	Acceptable. This investigation is less competitive scientifically.
2.0 - 2.5	Fair. It is not clear whether this investigation will yield valuable science results.
1.0 - 2.0	Poor. This investigation should not be carried out for reasons given in the evaluation.
0	This proposal was deemed non-feasible or non-responsive and was not reviewed (discuss with CXC representative first).

Grading shall be via secret ballot. After all grades have been submitted for a proposal, the facilitator will read aloud the individual and/or average grades numbers to confirm all are correctly recorded.

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Typical dividing line for what gets time. Notice there are many proposals thought to be scientifically valuable which don't get time.

Proposal Review

Our last class will be the proposal review. We will:

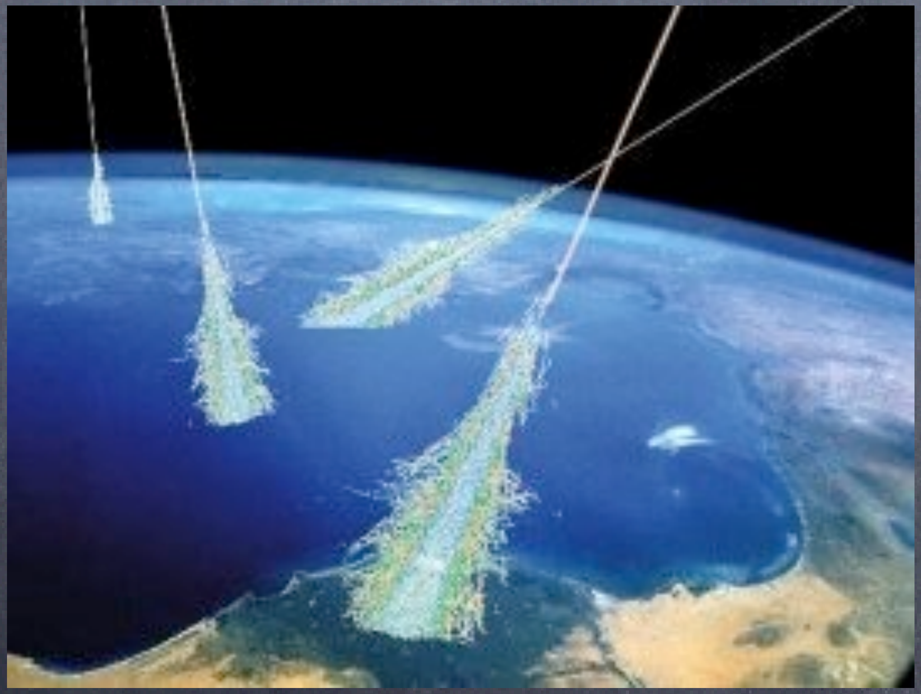
- Discuss each proposal. Discussion is led by the primary, but everyone should participate.
- If your proposal is being discussed, stay quiet until the end. You will then be allowed to briefly comment (obviously not allowed at a real review).
- At the end of the discussion, scores will be submitted by secret ballot (you may not grade your own proposal).

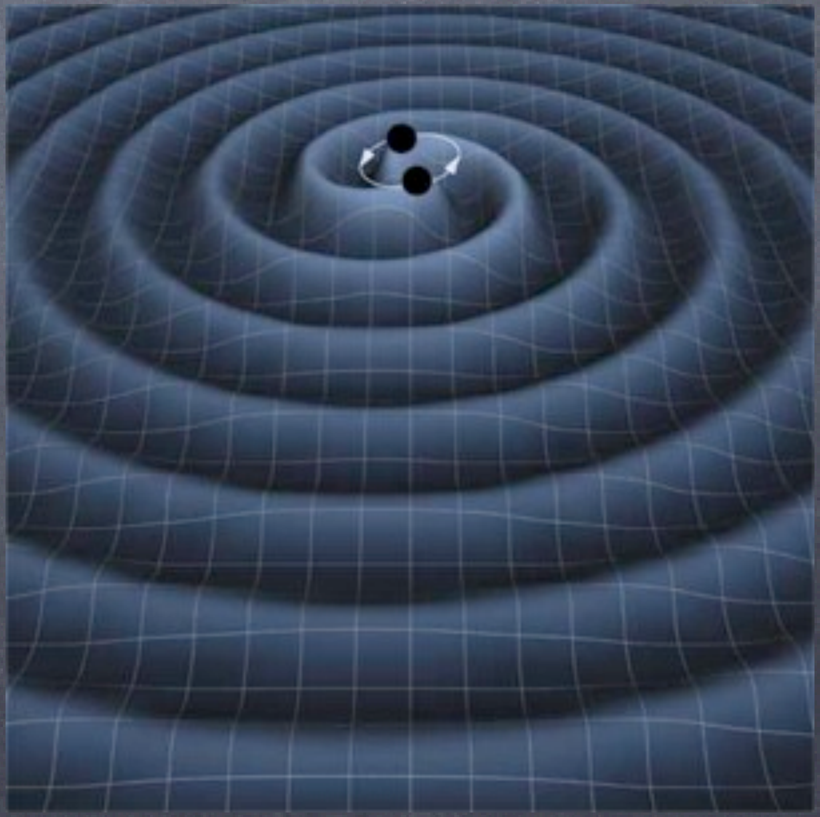
I will tally the scores and present final rankings. The top couple of proposals will be considered "approved".

Your grade will NOT depend on how the class ranks your proposal! This is meant to be fun and educational.

Non-Photon Astronomy:

Cosmic Rays, Neutrinos, and Gravity Waves
(lions and tigers and bears, oh my!)





Cosmic Rays

Cosmic rays were discovered by Victor Hess in 1912 (using a hot air balloon), who showed that ionizing radiation increased as you went higher (i.e. from space not Earth). It wasn't until later that these were shown to be charged particles/nuclei rather than photons.

Before accelerators, the best chance to study high energy particle physics came from studying cosmic rays. The positron and muon were both discovered by studying cosmic rays.

Cosmic Ray Astronomy

Cosmic rays tell us about:

- astrophysical acceleration processes
- energetics and magnetic fields in the Galaxy
- the composition outside our Solar system

Cosmic rays are primarily nuclei, mostly protons and helium, but also elements across the periodic table. Electrons are about 1% of cosmic rays pointing to a less efficient acceleration.

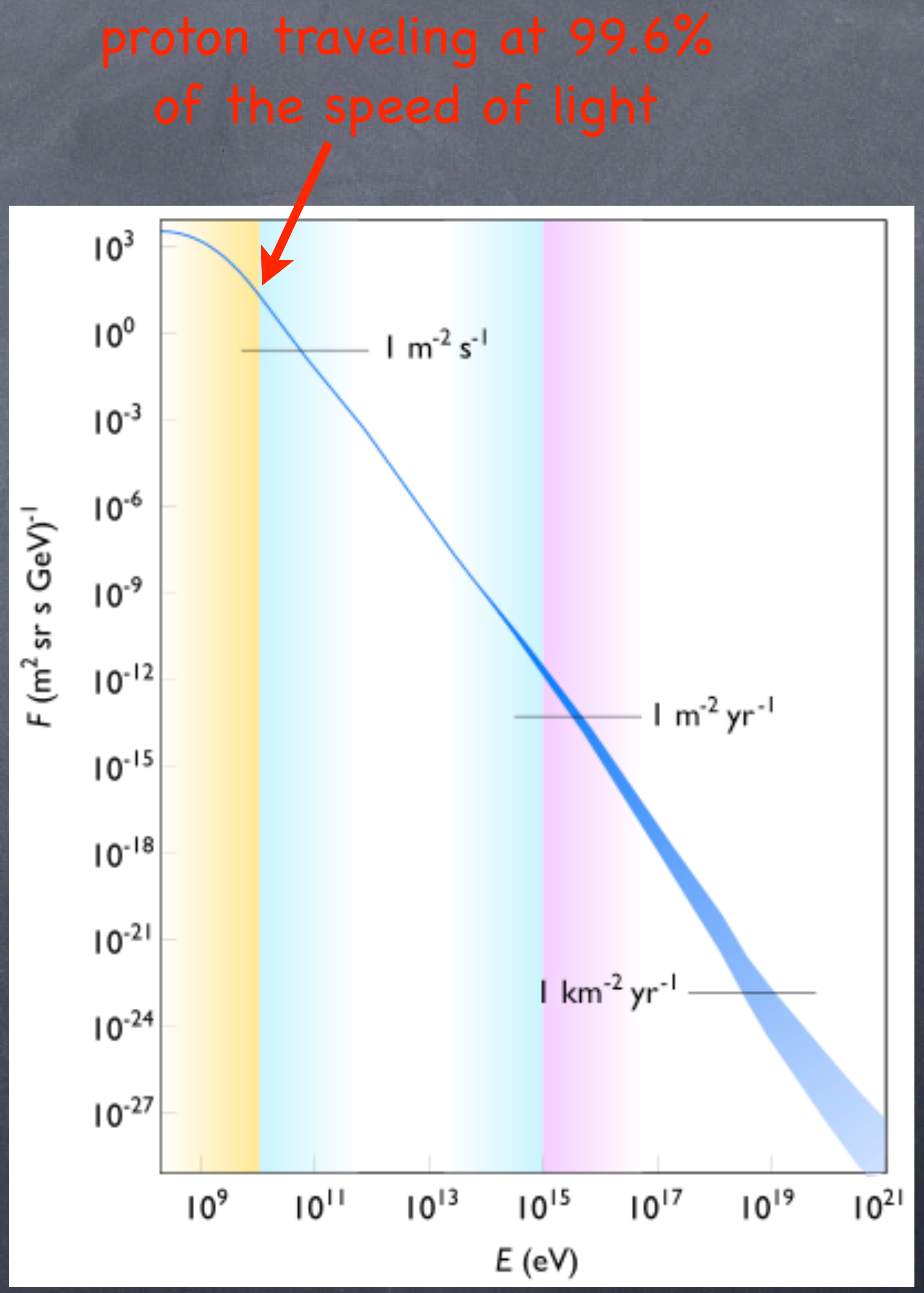
Galactic cosmic rays are thought to be accelerated primarily by supernovae (a few percent of SN energy converted to CRs).

CRs come from the Sun, the Galaxy, and extragalactic sources like AGN, but their arrival directions are obscured/randomized by deflection by magnetic fields.

Cosmic Ray Spectrum

Cosmic rays are detected over a large energy range. At the lowest energies they are primarily from the Sun, at intermediate energies from the Galaxy, and at the highest energies from extragalactic sources.

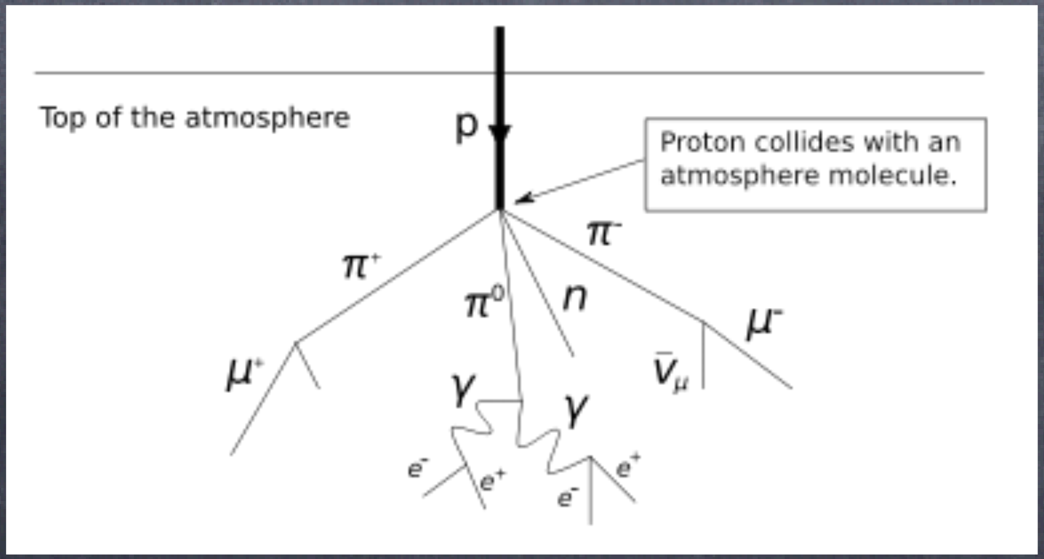
GZK cutoff: upper limit on the energy of CRs from distant sources of 5×10^{19} eV (50 EeV). Above this energy CRs would scatter off of CMB photons. A few dozen events above this energy have been observed. The origin of ultrahigh energy cosmic rays presents a mystery.



Cosmic Rays from the ground

As we have already seen, cosmic rays present a large background for gamma-ray experiments, and they can be detected using similar techniques.

Ground based detectors detect CRs through: Cherenkov radiation in water using water tanks, florescence of atmospheric nitrogen in the UV excited by passing charged particles, and detection of muons created in the air shower with particle detectors.



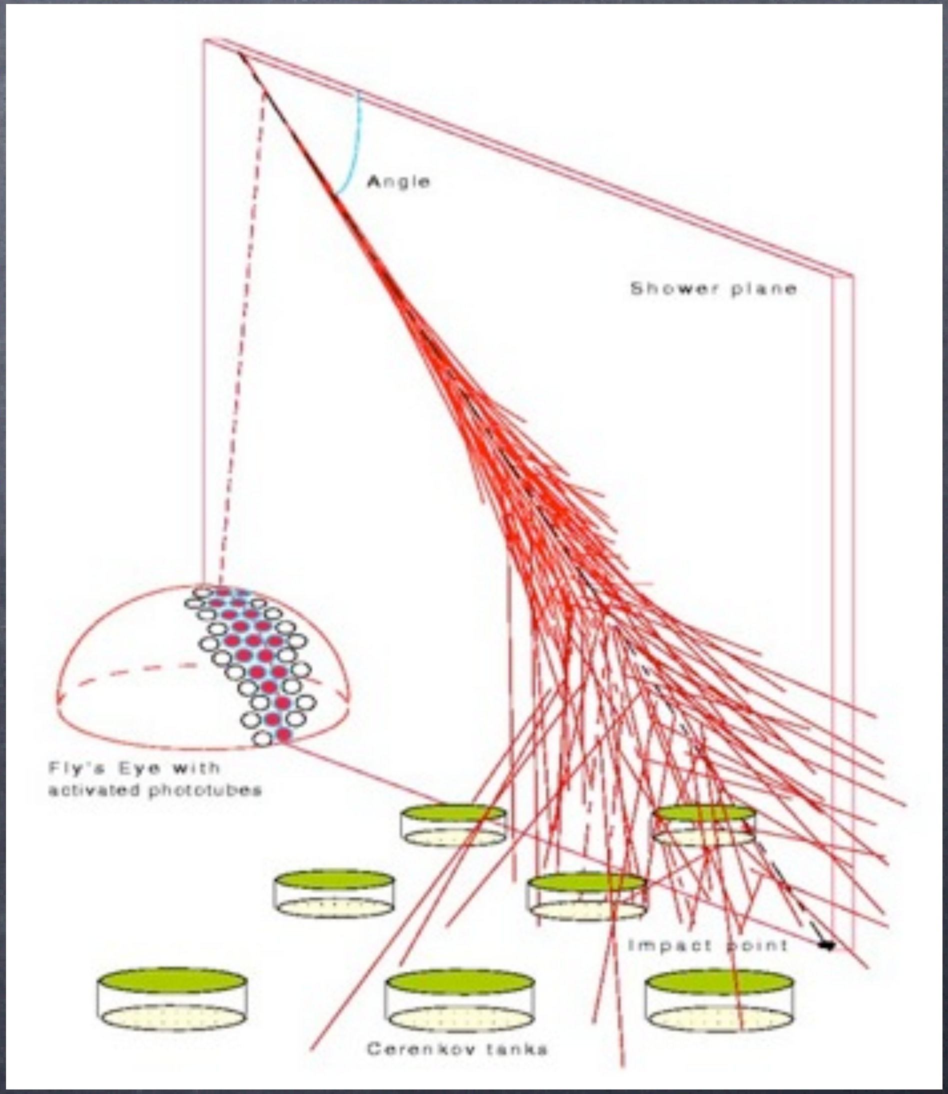
Pierre Auger

Pierre Auger is located in the pampa in western Argentina and was designed to detect high-energy cosmic rays.

It uses a combination of detection techniques:

- 1600 water tanks with photomultiplier tubes spread over 3000 km^2
- 4 atmospheric florescence detectors on the perimeter which can observe the trail left by the developing air shower.

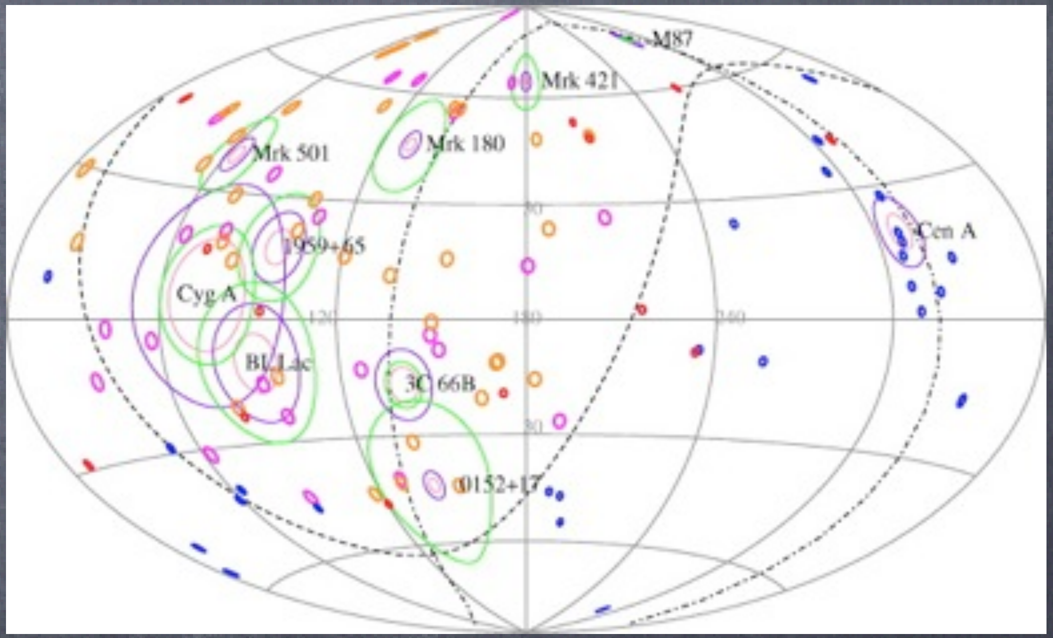
The florescence detectors are composed of 24 3-m mirrors focusing to photomultiplier arrays (10,000 PMTs).



Ultrahigh Energy Cosmic Rays

Correlation with AGN?

In November 2007, the Auger collaboration announced a correlation between 27 events with > 57 EeV energy to nearby AGN.



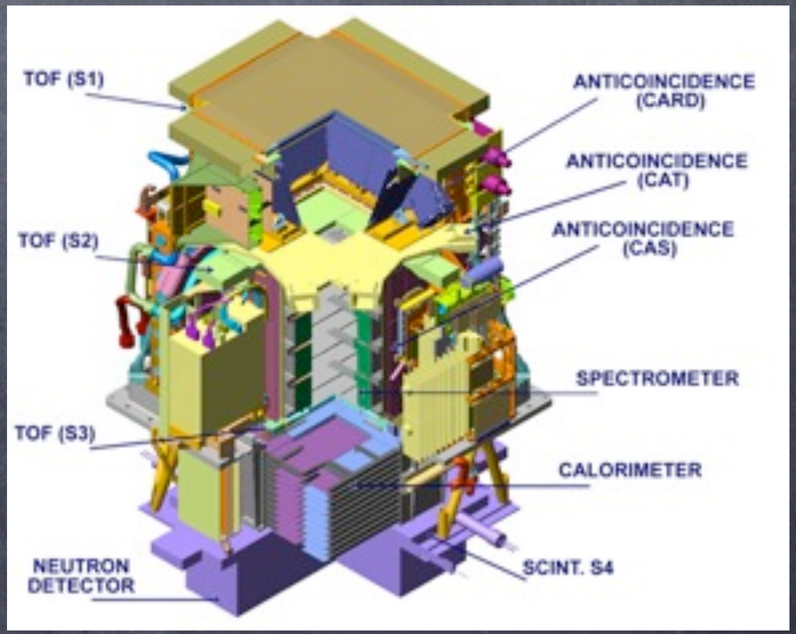
However, the methodology has been debated and a 2010 update with 69 events shows a less strong correlation.

Data may point to some fraction originating from nearby AGN with the rest isotropic. The direction of Cen A does have the largest excess.

From space - PAMELA

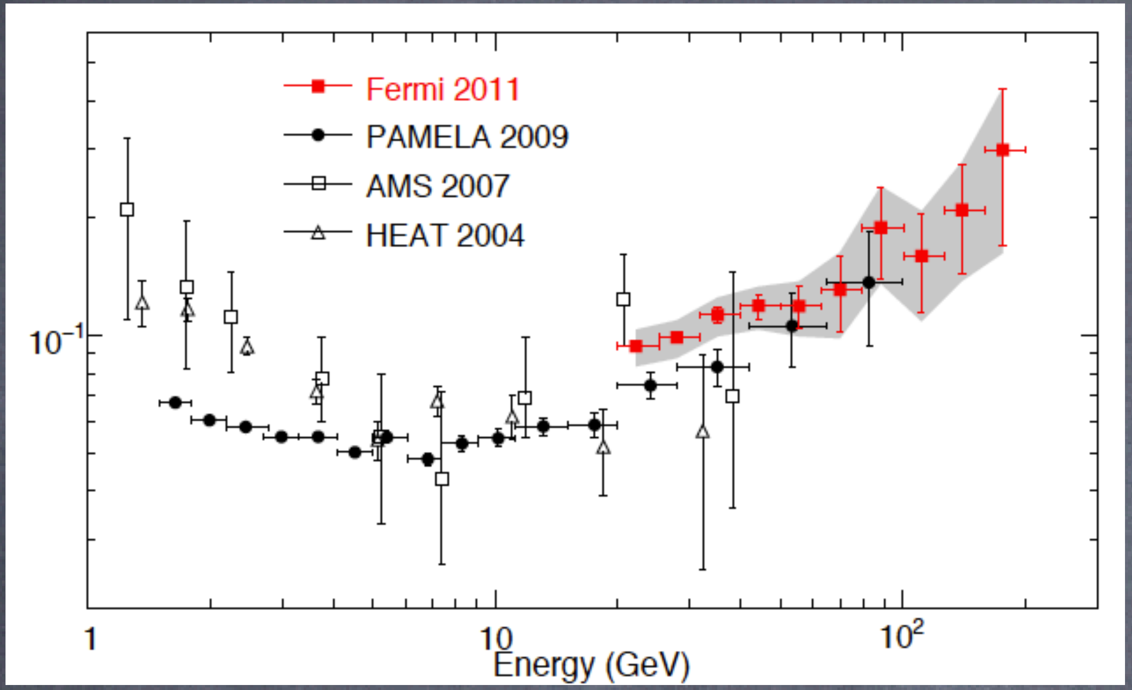
PAMLEA (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) is a space based particle detector launched in 2006.

The instrument module includes a permanent magnet spectrometer, a silicon-tungsten imaging calorimeter, a neutron detector, and a time-of-flight detector made of three plastic scintillators. Leptons and hadrons as well as particles of different charge can be discriminated.

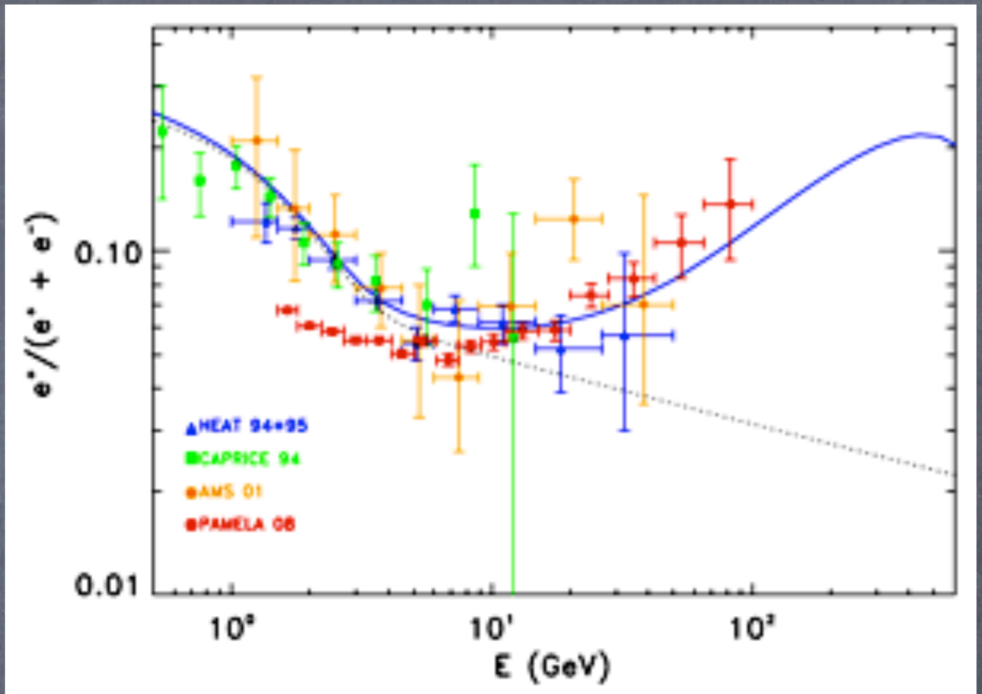


In particular, PAMELA has measured the abundance and spectrum of positrons and anti-protons.

The Positron Excess



Ackermann et al. 2011

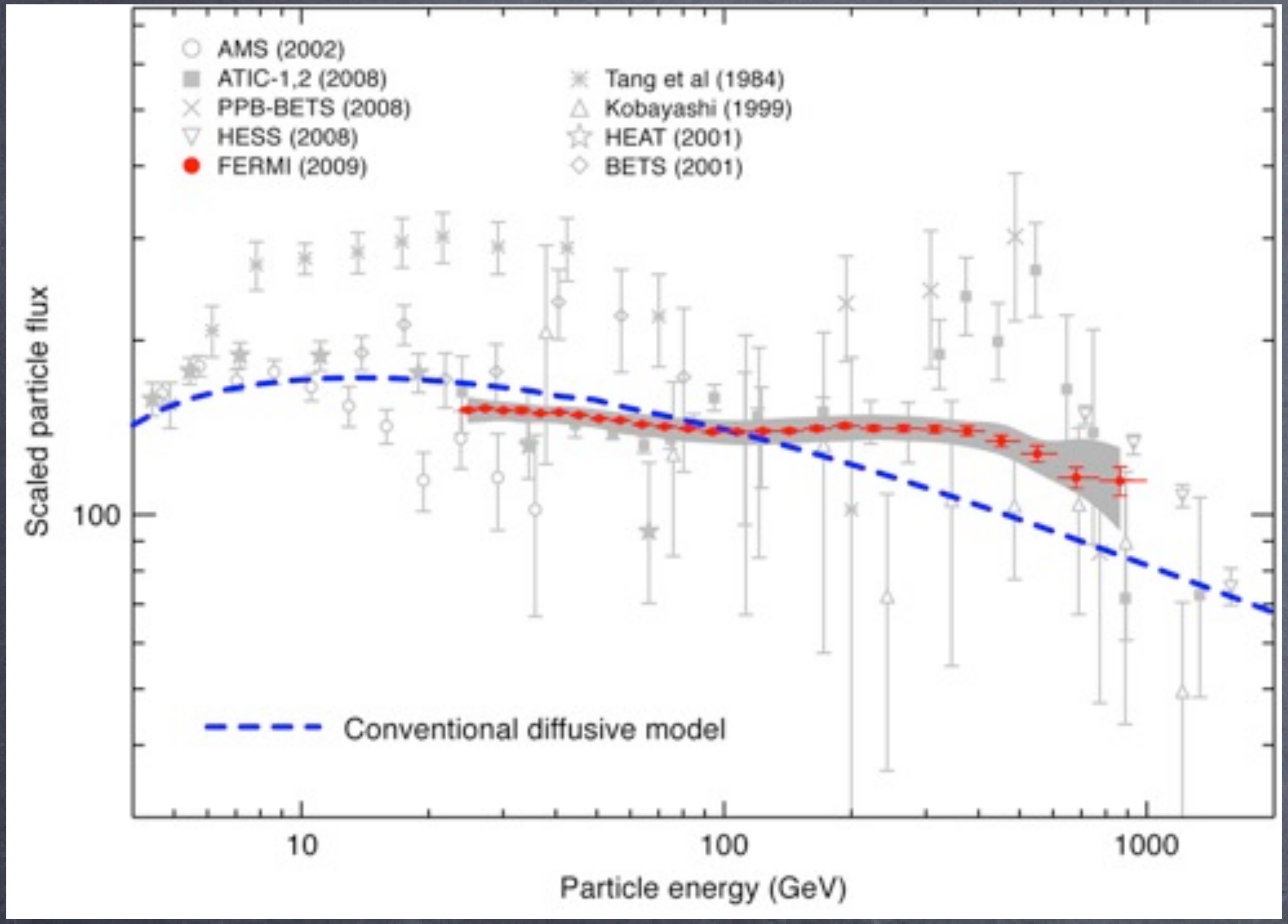


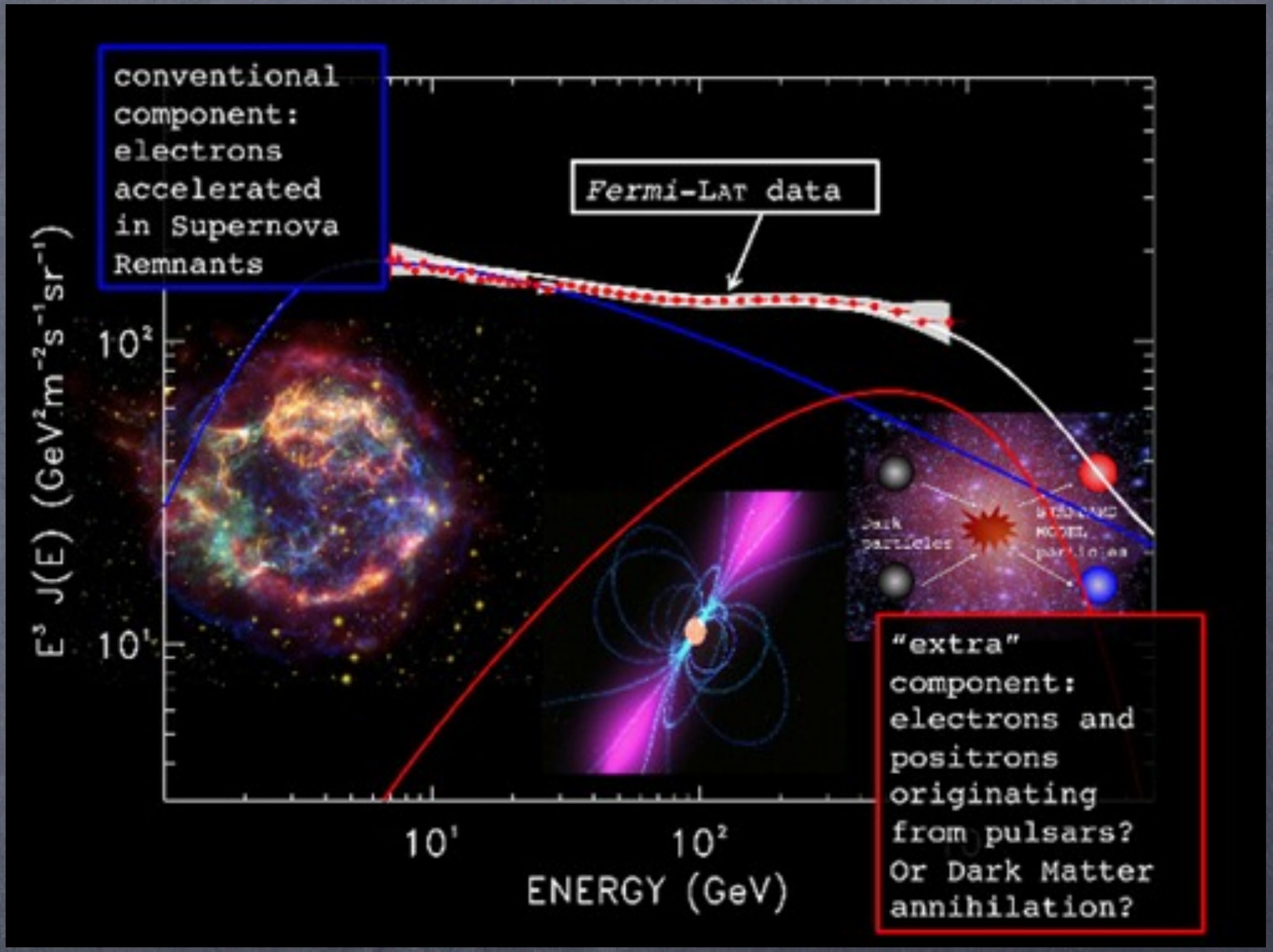
Adriani et al. 2009

Secondary production of positrons in the Milky Way would imply a declining positron fraction with energy. The observed increase above 10 GeV implies a local source of primary positrons.

This source could be nearby pulsars, supernova remnants, or more exotically dark matter annihilation or decay.

Electron Spectrum





Abdo et al. 2009

Fermi-LAT also observes a flatter total electron spectrum than was expected.

AMS-02

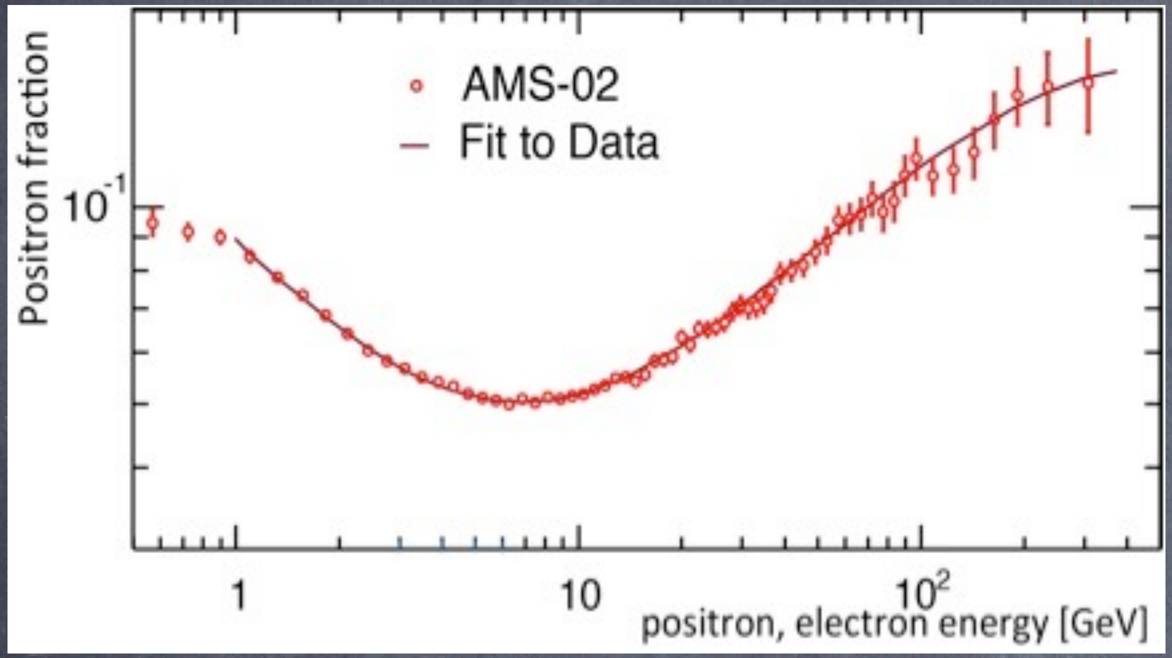
(a long story)

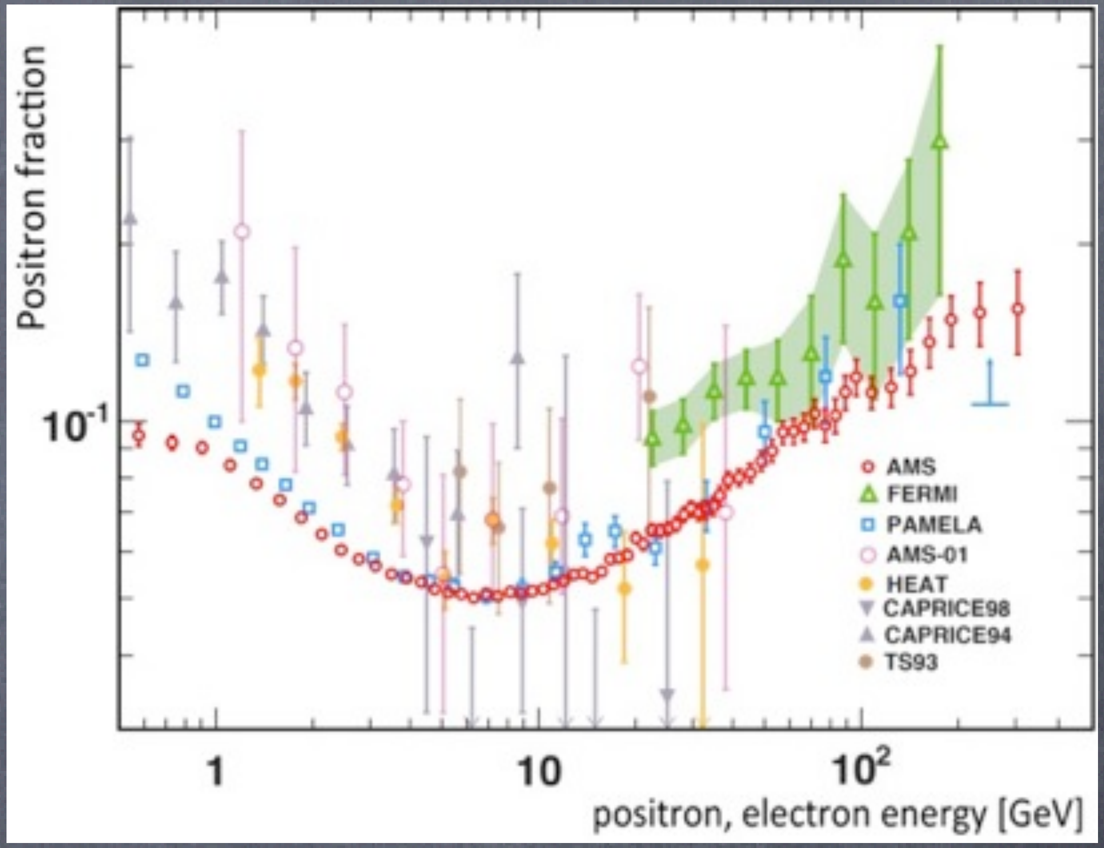
Mounted on the International Space Station in May 2011. Originally not scheduled for a shuttle launch before the shuttle was retired, but PI Ting lobbied to get it launched via a special congressional bill. Technical problems with the planned cryogenic, superconducting magnet led to a down scope to a permanent magnet system.
Cost of $1.5 billion.

Will give large improvements in sensitivity over PAMELA including measuring the positron excess to higher energies.

AMS-02

First Results



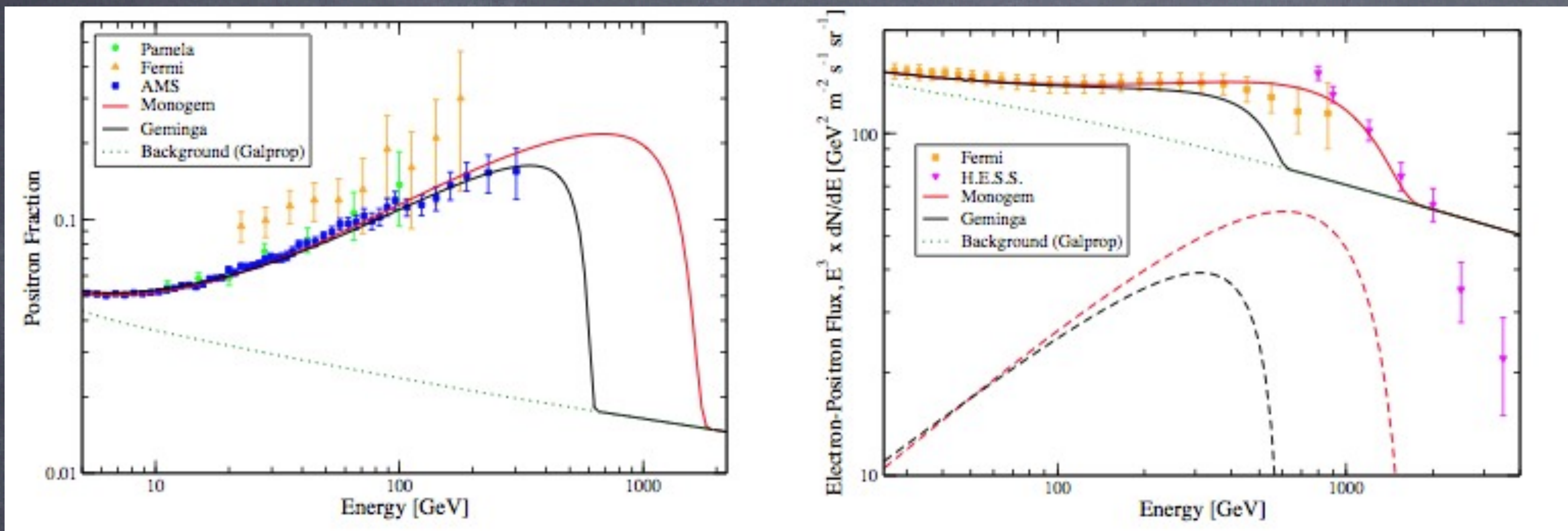


Positron fraction results extended to higher energies with indications of a flattening/turn-over.

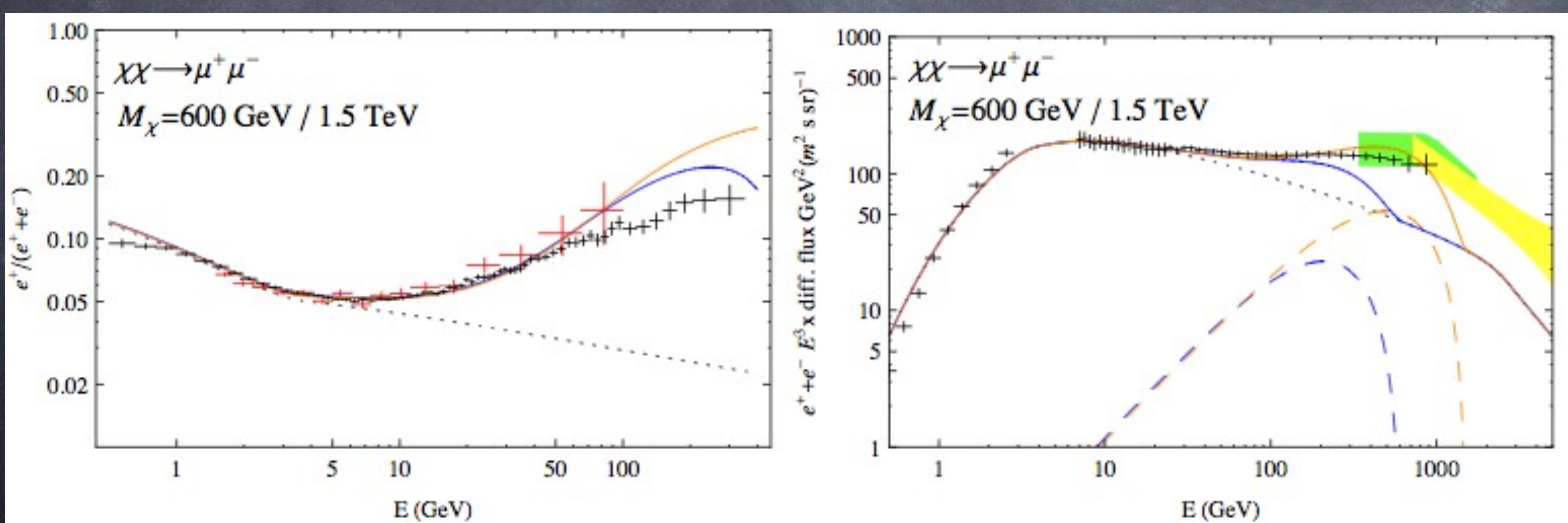
You expect a cut-off for both a pulsar origin and a dark matter origin, but (some) dark matter models have a harder time fitting both the positron spectrum and the total electron spectrum.

AMS-02

Implications of First Results

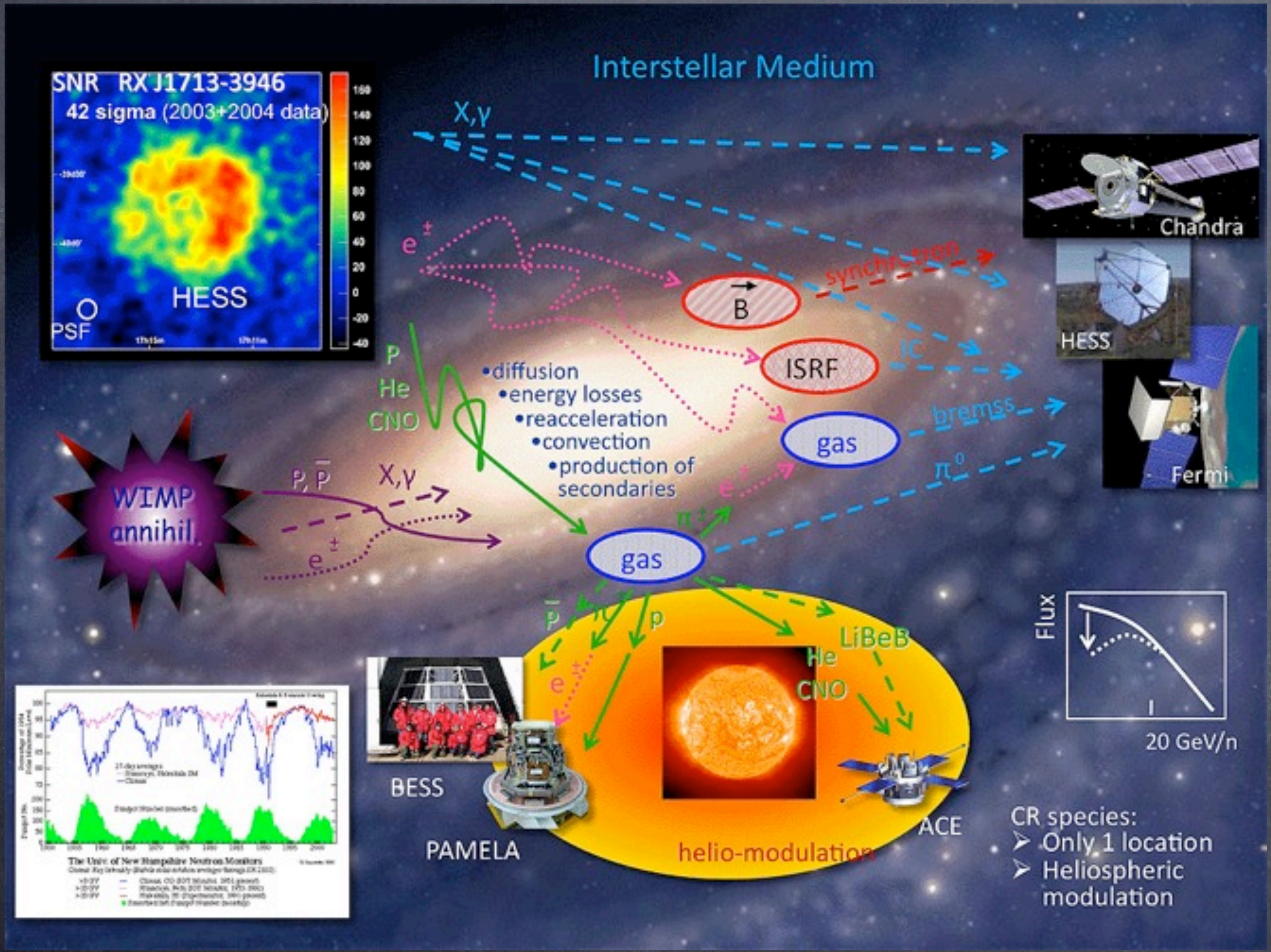


example pulsars fits (Linden & Profumo)



example dark matter fits (Cholis & Hooper)

Cosmic Ray Propagation and Interaction in the Galaxy



Strong, Moskalenko & Reimer, Science Watch

Additional common diagnostics include:

- B/C ratio (and other secondary/primary ratios)

- antiproton/proton ratio

Neutrino Astronomy

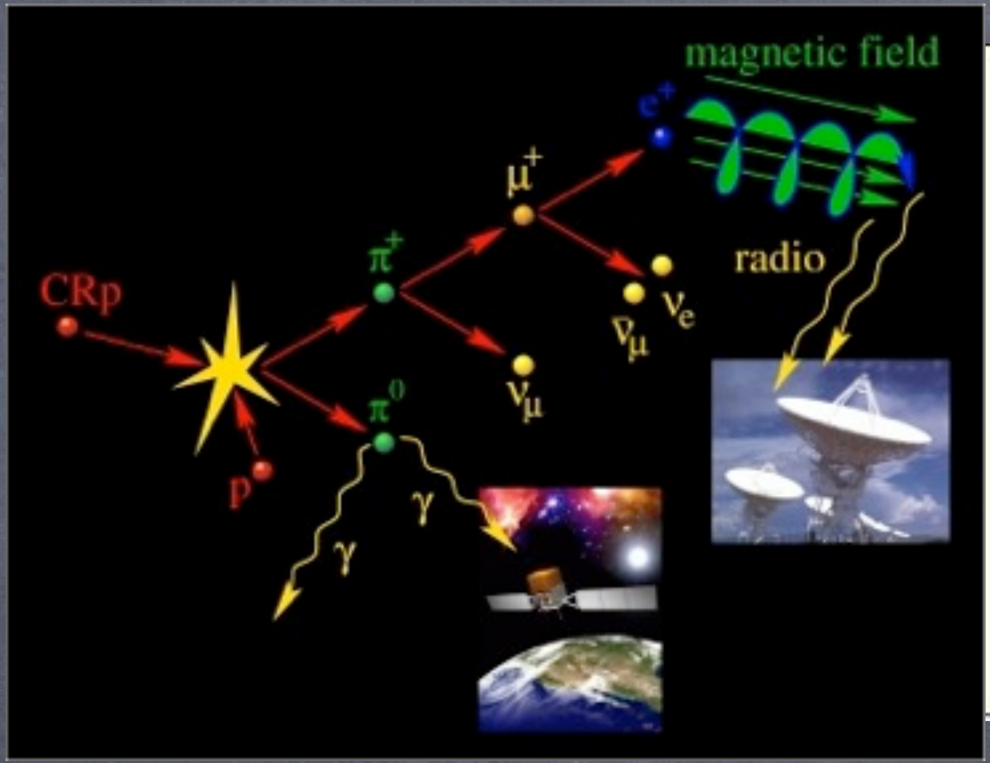
Neutrinos have a distinct advantage over light in that they interact very little, and are therefore not obscured. Unlike charged particles, they are not deflected by magnetic fields.

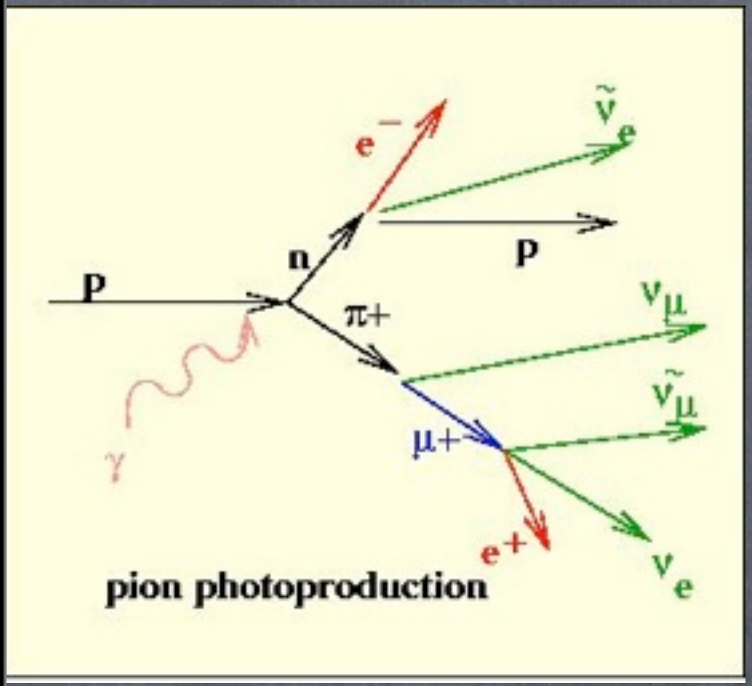
Neutrino sources:

- hydrogen fusion in the Sun
- supernova: still waiting for the next SN in the Galaxy
- AGN: hadronic or leptonic?
- gamma-ray bursts
- origin of ultrahigh energy CRs (should be associated to pion production leading to neutrinos and gamma-rays)
- relic neutrino background equivalent to CMB at effective temperature of 1.9 K (difficult to observe)
- dark matter? (dark matter captured in the Sun which annihilates)

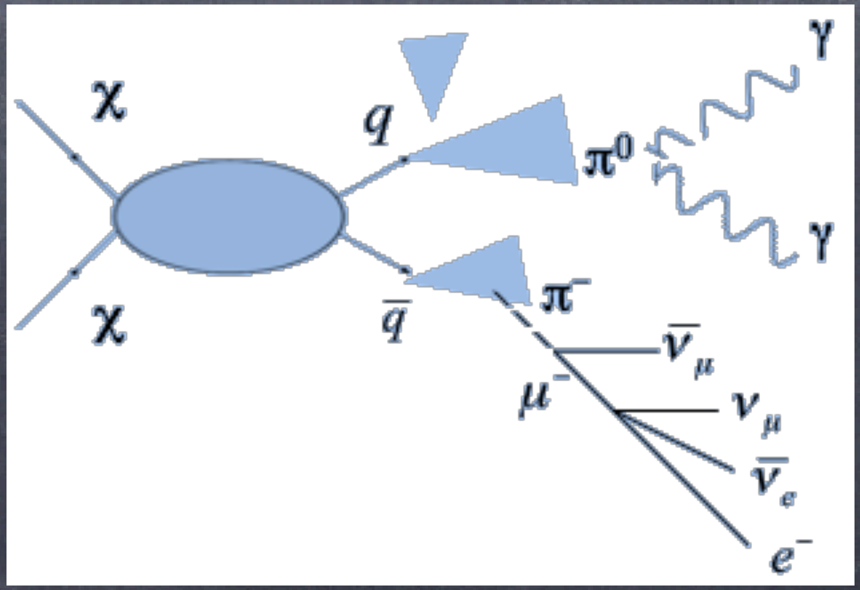
Neutrino Production

proton-proton and proton-photon collisions





Plus fusion and radioactive decay



dark matter annihilation

SN 1987A -

the birth of neutrino astronomy

1987A was a supernova in the LMC, the closest and first visible to the naked eye since SN 1604 in the Milky Way. It is the only extrasolar neutrino source that has been detected.

A total of 24 neutrinos from the supernova were observed by three neutrino experiments about 3 hours before the optical light.

The Solar Neutrino Story

There was an observed deficit of neutrinos from the Sun compared to theory, which posed a problem from the 1960s until 2002.

The resolution to this problem is that neutrinos can oscillate (i.e. change flavor between electron, muon, or tau neutrinos). The Sun produces electron neutrinos which were the only ones which could be detected at the time. Evidence for neutrino oscillations came from Super-K in 1998, and in 2001 SNO, which detected all types of neutrinos, found the total from the Sun to agree with theory.

neutrinos have mass!

Another example of astronomy telling us about fundamental particle physics.

Searching for Extrasolar Neutrino Sources

So far the Sun and SN1987A are the only detected extraterrestrial neutrino sources.

Neutrino detection:

- Neutrinos only interact very weakly with matter, so detectors must be large.
- Neutrino detectors must contend with large backgrounds from cosmic ray produced muons and radioactive decays

➜ put them underground and shield them

Neutrino Detectors

Cherenkov Radiation: detected when an incoming neutrino produces an electron or a muon.

- Super Kamiokande: used large water tank surrounded by phototubes
- SNO: used heavy water (deuterium enriched). Here mu and tau neutrinos can also be detected through the dissociation of deuterium. When the neutrons are recaptured, gamma-ray emission is released.
- IceCube: Cherenkov in ice with photomultipliers
- ANTARES: Cherenkov in water in the Mediterranean Sea

Chlorine or Gallium: large volumes. Argon or germanium are produced in interactions with neutrinos, tank is periodically checked.

IceCube

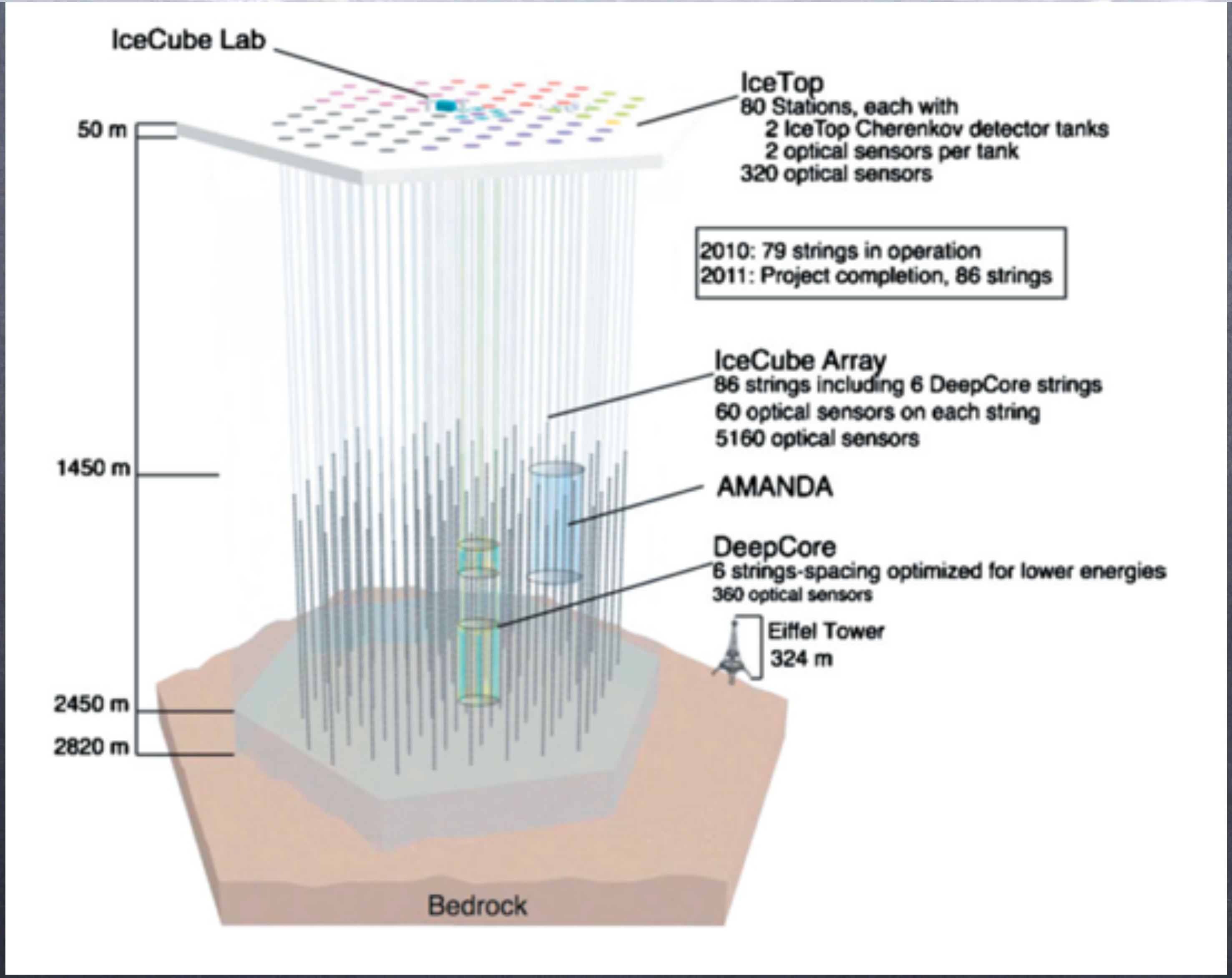
(formerly AMANDA)

Detects Cherenkov radiation created by leptons (primarily muons) created in neutrino interactions with the ice.

Completed December 2010

- 86 strings with 60 detectors at 1450-2450 meters in depth. Placed using a hot water drill.
- IceTop array of Cherenkov detectors to study CR showers
- Deep Core array of closely packed detectors to extend sensitivity to lower energies
- Sensitive to neutrinos from 10^{11} - 10^{21} eV
- Very large CR background, primarily use upgoing events

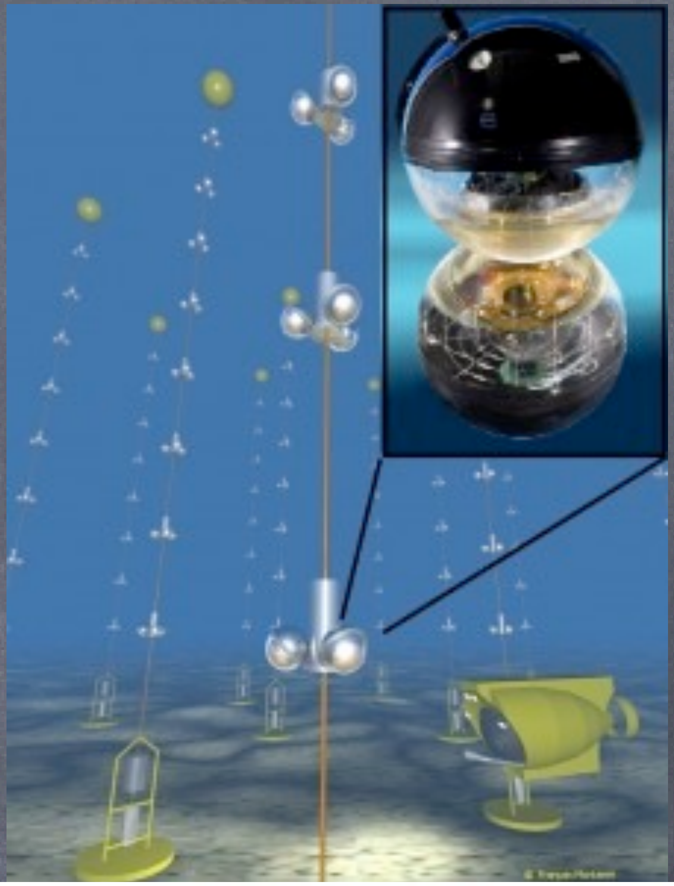
IceCube


IceCube Lab
IceTop
80 Stations, each with
2 IceTop Cherenkov detector tanks
2 optical sensors per tank
320 optical sensors
50 m
2010: 79 strings in operation
2011: Project completion, 86 strings
IceCube Array
86 strings including 6 DeepCore strings
60 optical sensors on each string
5160 optical sensors
1450 m
AMANDA
DeepCore
6 strings-spacing optimized for lower energies
360 optical sensors
Eiffel Tower
324 m
2450 m
2820 m
Bedrock

ANTARES

ANTARES is 2.5 km below the Mediterranean Sea and detects Cherenkov in the water.

- 12 strings with 75 modules, each 350 m long
- More sensitive to southern hemisphere compared to IceCube which probes northern hemisphere.
- Light in water is less scattered than in ice giving higher resolution.
- Additional backgrounds from radioactive elements in sea salt and bioluminescent organisms leading to higher energy thresholds



Neutrino Detection in Radio

(today's colloquium)

Ultrahigh energy neutrinos (10^{18} eV) can potentially be detected through the Askaryan effect (theorized in 1962, experimentally verified in 2001).

A high energy particle traveling through a dense medium (here ice) produces a particle shower with a charge asymmetry (more e^- than e^+) leading to coherent radio Cherenkov emission. The radio pulse lasts about a nanosecond.

High energy neutrino science: Neutrinos pass unattenuated and can probe very high energy AGN emission (here high-energy photons interact with the EBL) and high energy cosmic ray interactions (neutrinos produced in the GZK process).

Neutrino Detection in Radio

(today's colloquium)

Antarctic Impulsive Transient Antenna: ANITA is a balloon-borne array of 32 antennas flown over the Antarctic ice in 2006-07 and 2008-09. No neutrinos found, but did detect ultrahigh energy CRs.

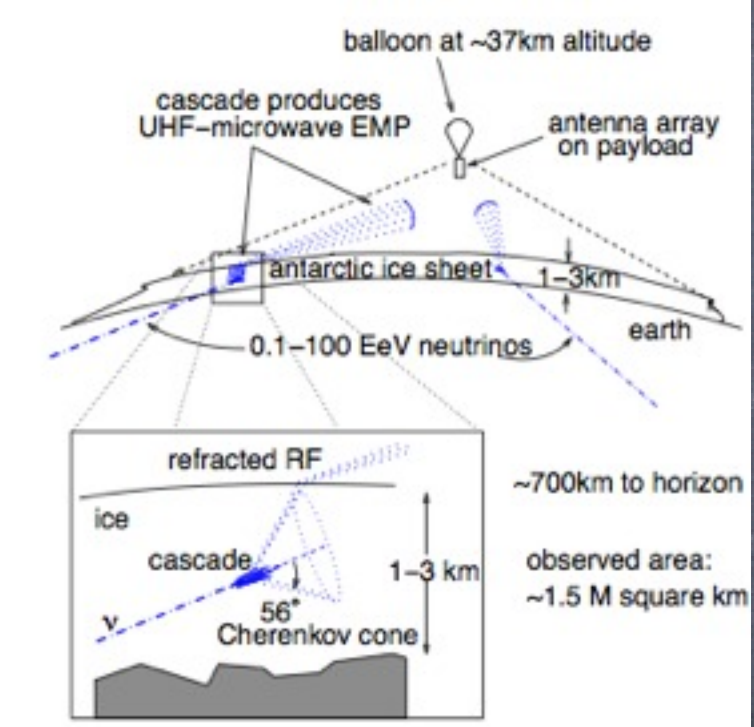


Figure 1: A schematic of ANITA detection concept.

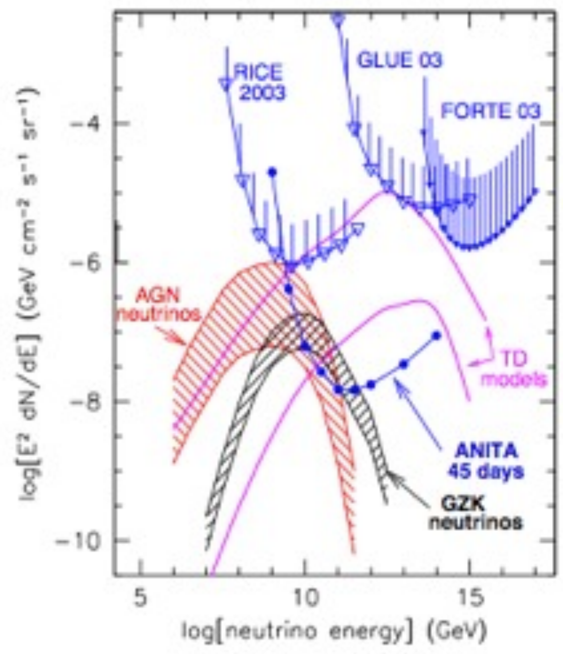


Figure 9: Published RICE, GLUE, and FORTE neutrino flux limits, and the expected sensitivity of ANITA. The models of neutrino sources are given as bands, spanning the range from optimistic to conservative ones.

Miocinovic, for the ANITA Collaboration 2004

Askaryan Radio Array: designed to detect GZK neutrinos. Will be an 200 km^2 radio array (2 km spacing) in the ice near the South Pole. Testbed run done, three stations (of 37) in place.

Future Neutrino Observatories: KM3NeT

KM3NeT stands for the Cubic Kilometer Neutrino Telescope. It is actually planned to cover more than 5 cubic kilometers.

- Water Cherenkov detectors in the Mediterranean Sea
- Array of tens of thousands of optical detectors
- Also will have instrumentation for marine biology, oceanography, and geophysics