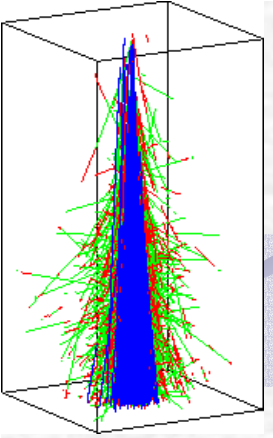
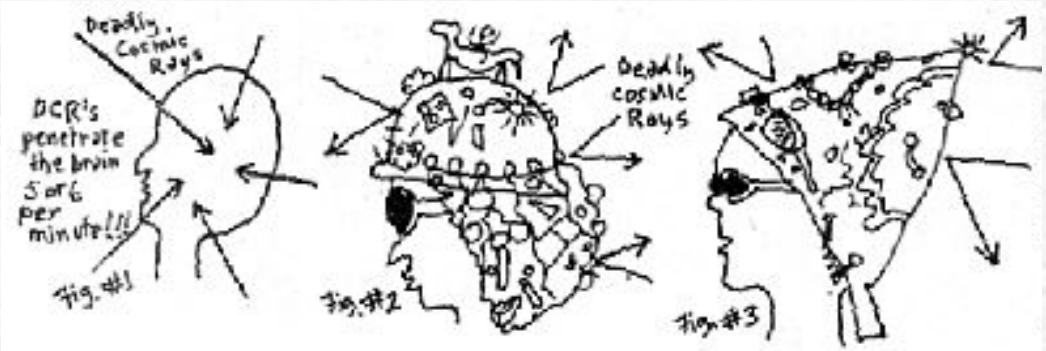


Short-term science with the MINOS Far Detector

Astrophysics: cosmic rays, extraterrestrial neutrinos, etc.

Cosmic rays are a hot topic…



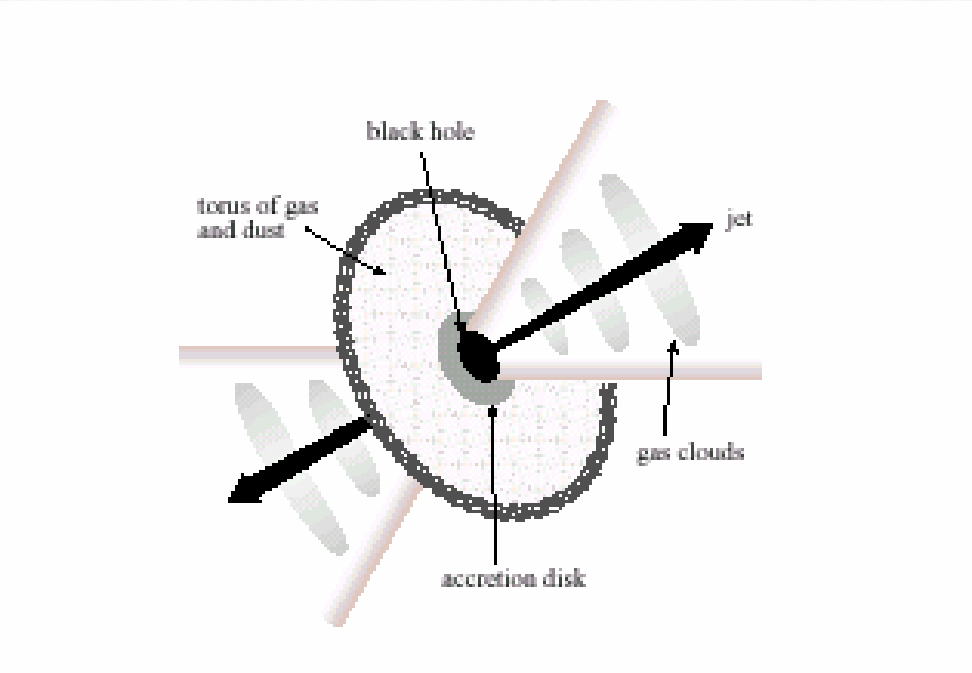
Following on from underground work of Soudan & MACRO, but…

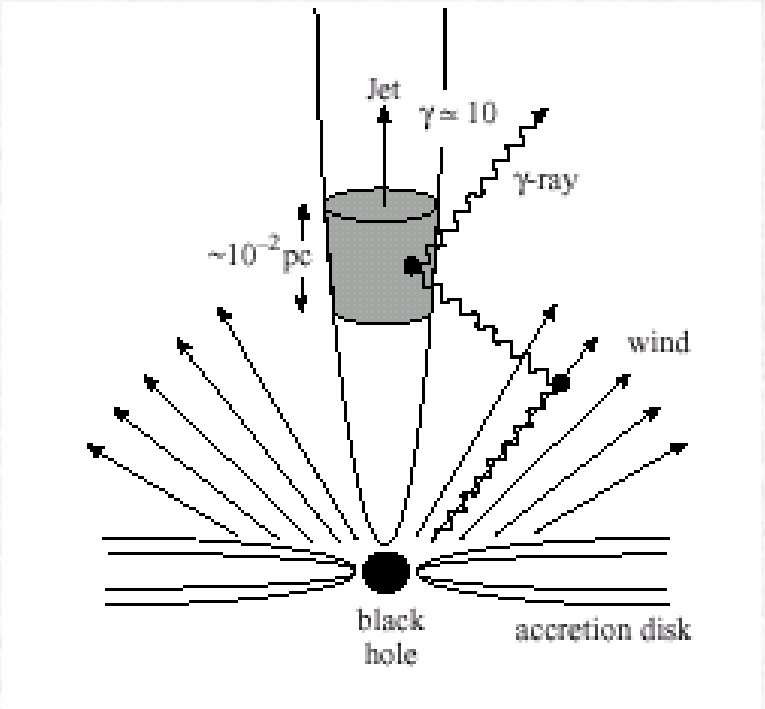
- We have a novel feature, a magnetic field. This offers us new handles on some old problems.
- Student theses over the next few years
- Though no one would fund MINOS for atmospheric neutrinos or cosmics…

What physics are we thinking about?

- Muon and neutrino astronomy
  - Pointing/timing
  - Momentum spectra of charge identified muons
- Cosmic-ray composition
  - Charge-sign of E_{shower} tagged muons
- Sun & moon shadows
- Seasonal, diurnal, etc. variations

Schematic of cosmic neutrino accelerators (NuBH)





Upward-going MACRO muons

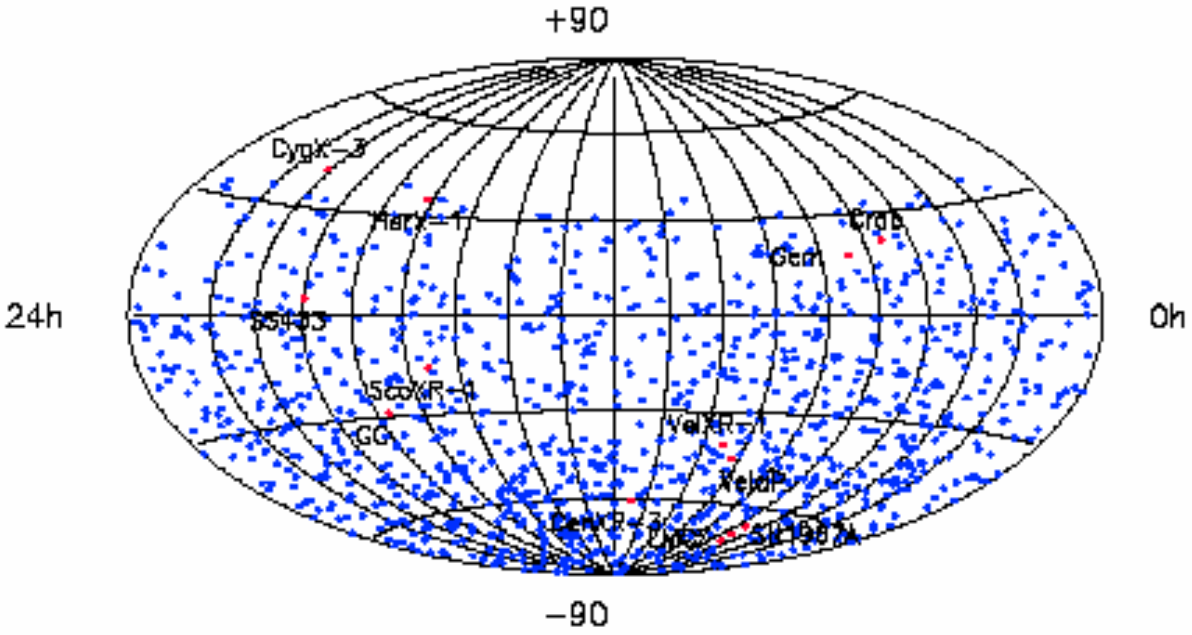
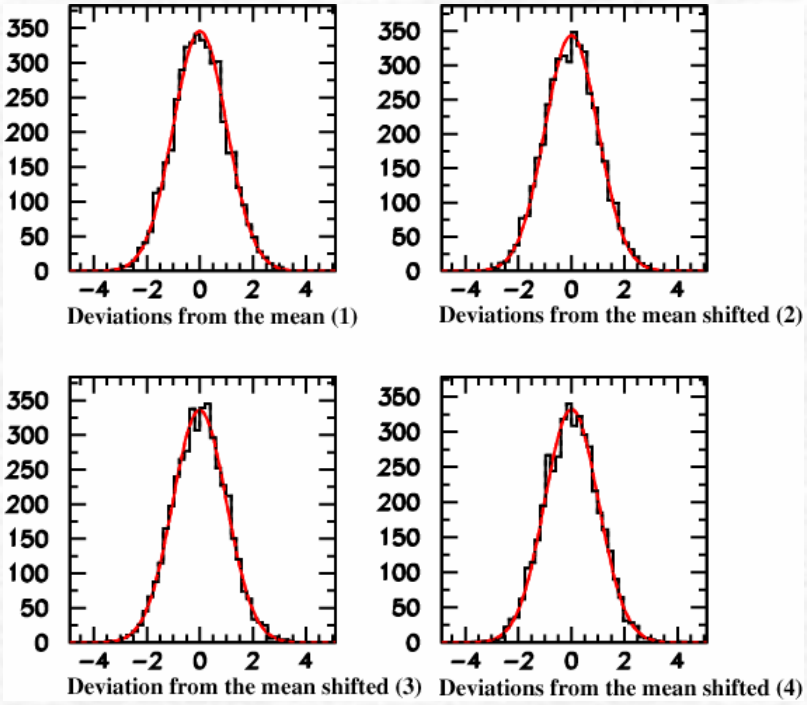
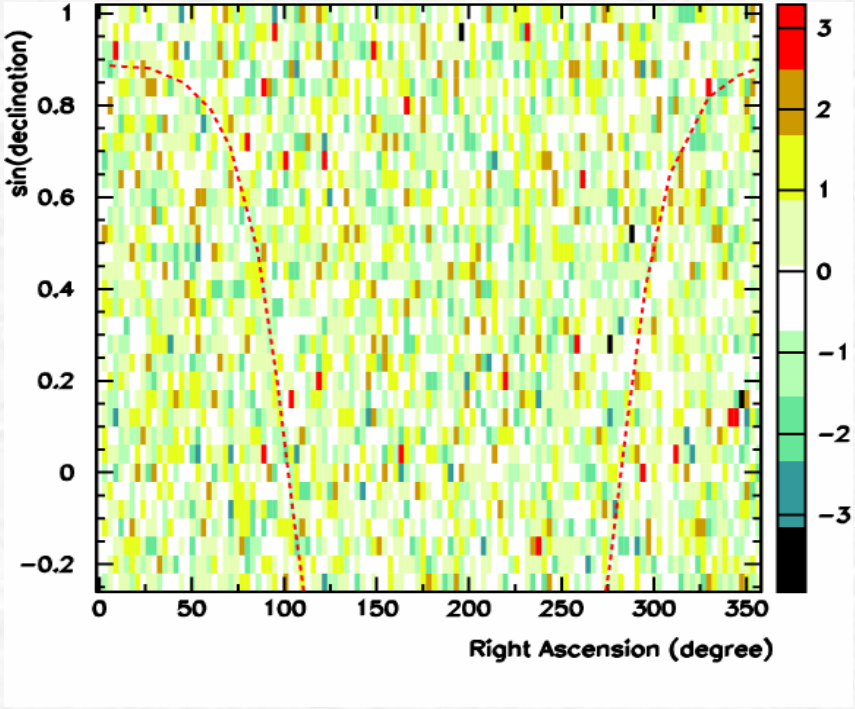


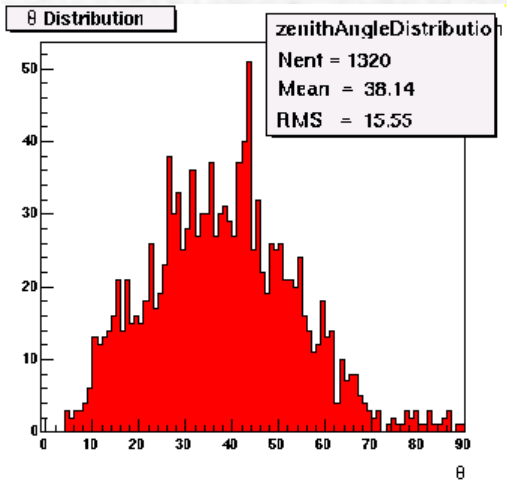
Fig. 9.— Upward-going muon distribution in equatorial coordinates (1100 events).

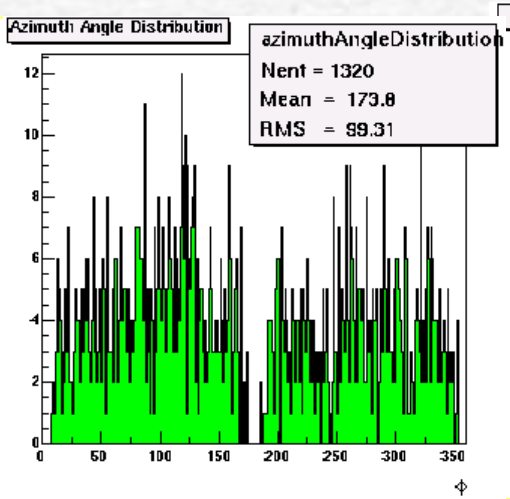
Astronomical search for point sources (MACRO data)

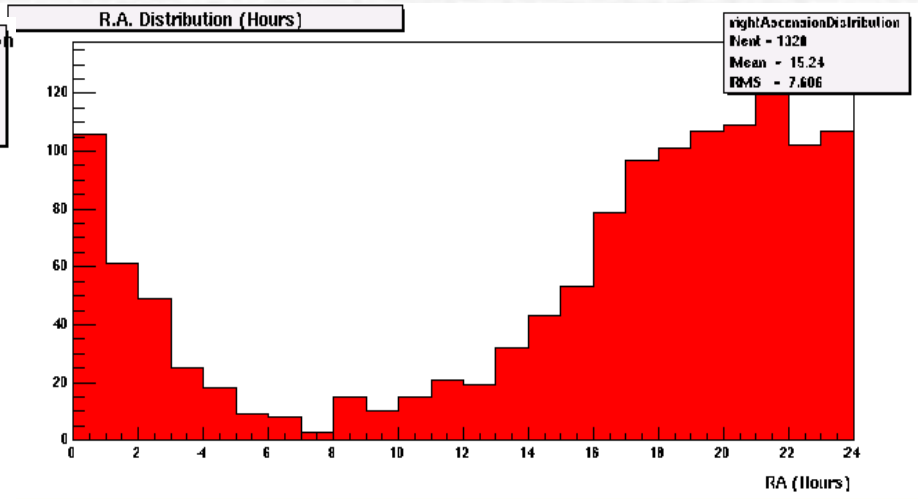


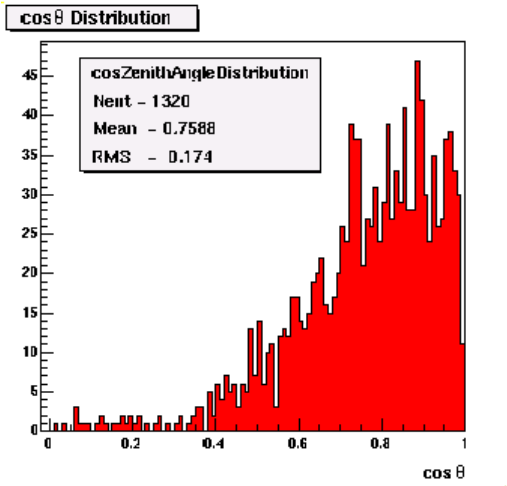


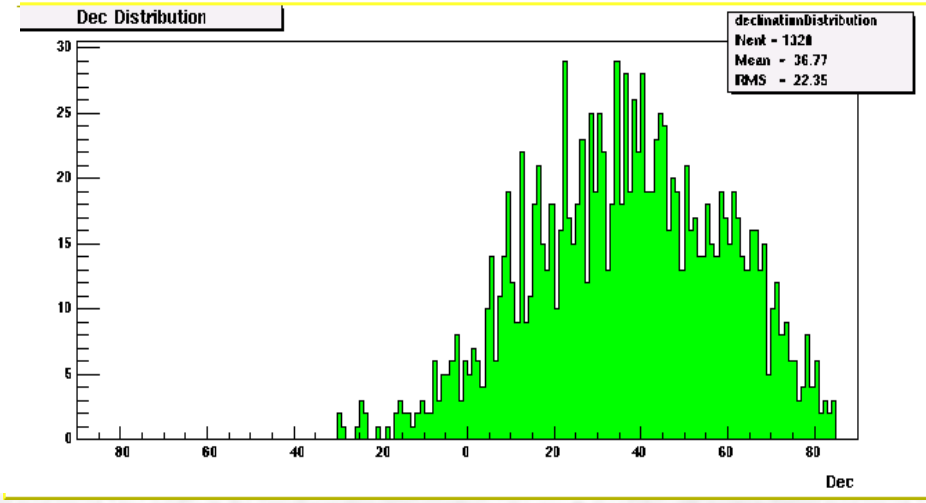
First MINOS far detector cosmics (5 hour run)



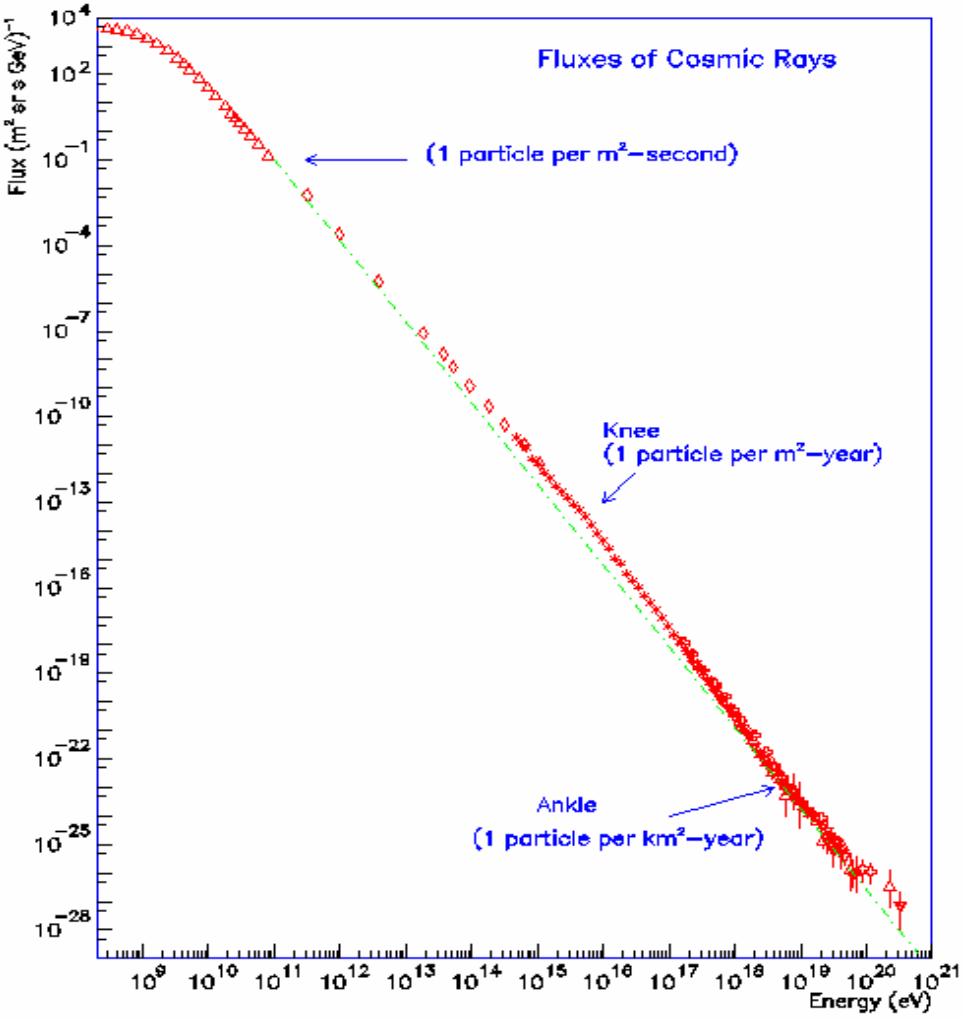








Cosmic ray spectrum Features—knee & ankle



Composition confusion at the knee of the CR spectrum

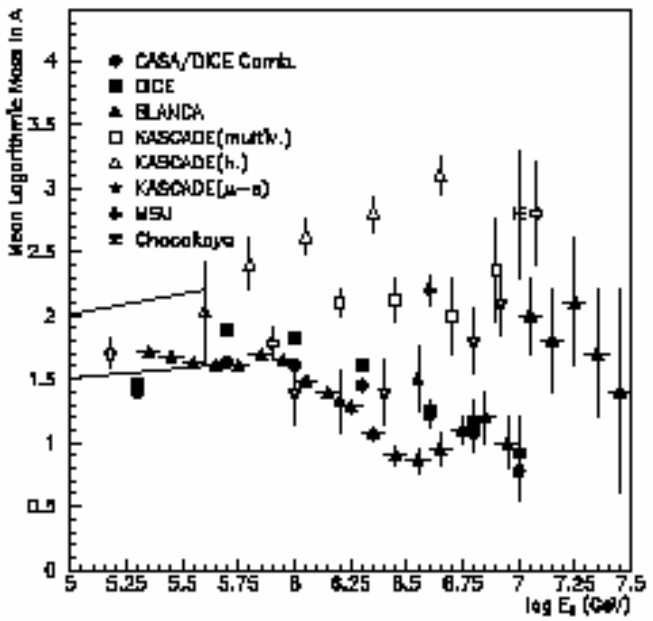


Figure 18. *Mean logarithmic mass vs primary energy. The box represents the region of direct measurements [52]. MSU data from [51], Chacaltaya data from [53].*

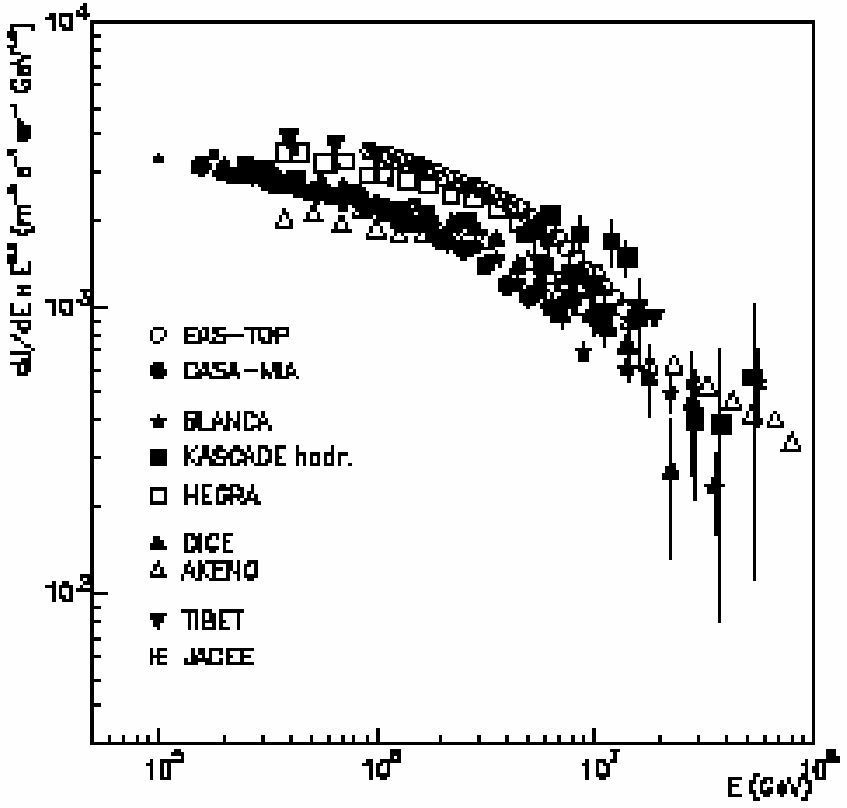


Figure 13. *All-particle primary energy spectrum from the various experiments as described in the text.*

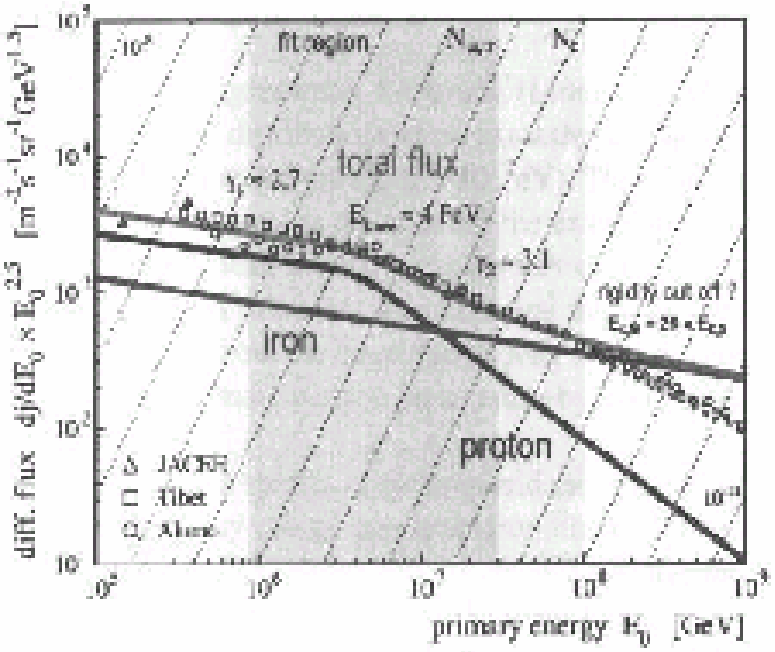
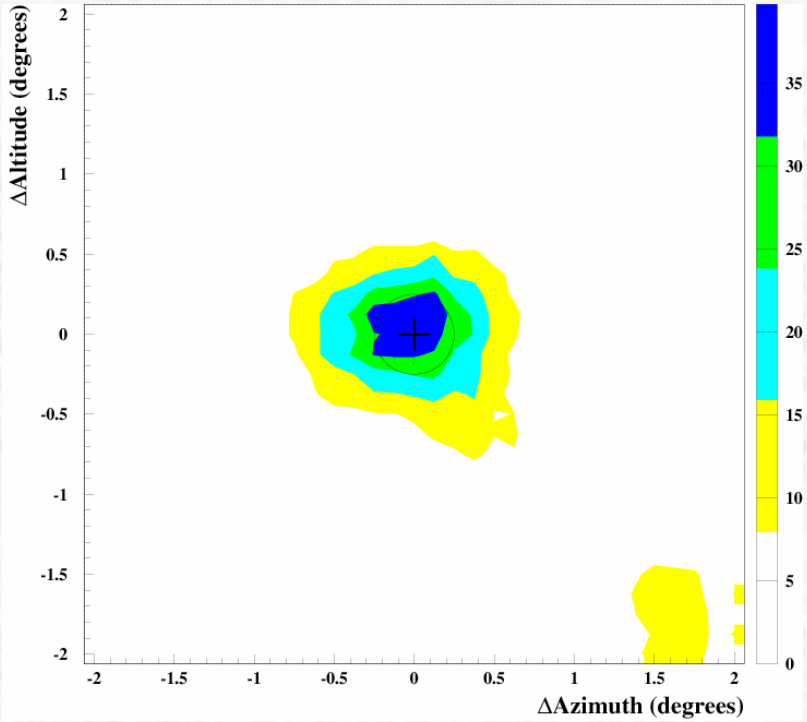


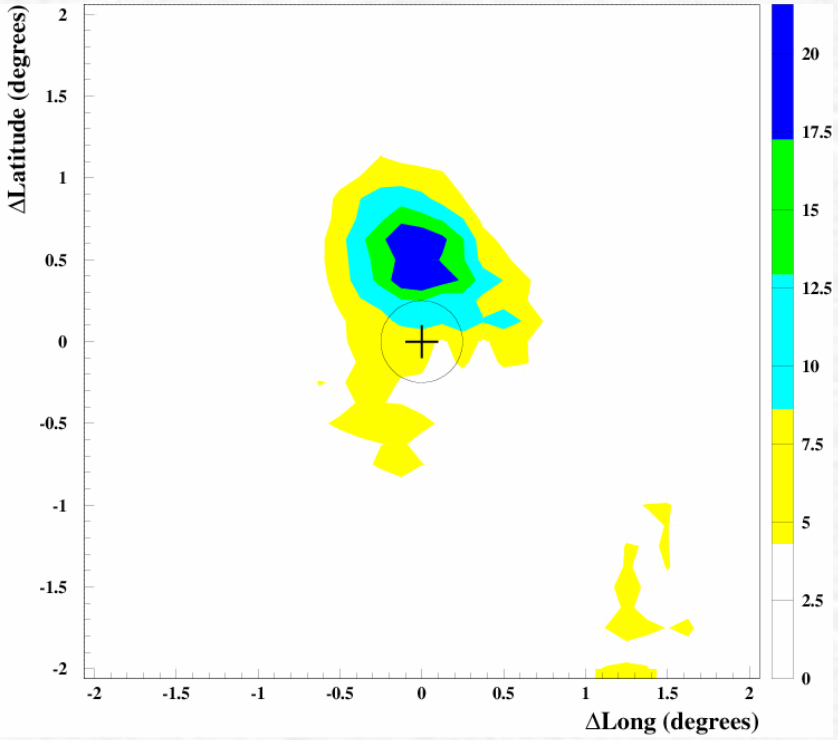
Figure 9. *Primary energy spectrum by KASCADE from electron and muon size spectra [28].*

Composition with MINOS FD

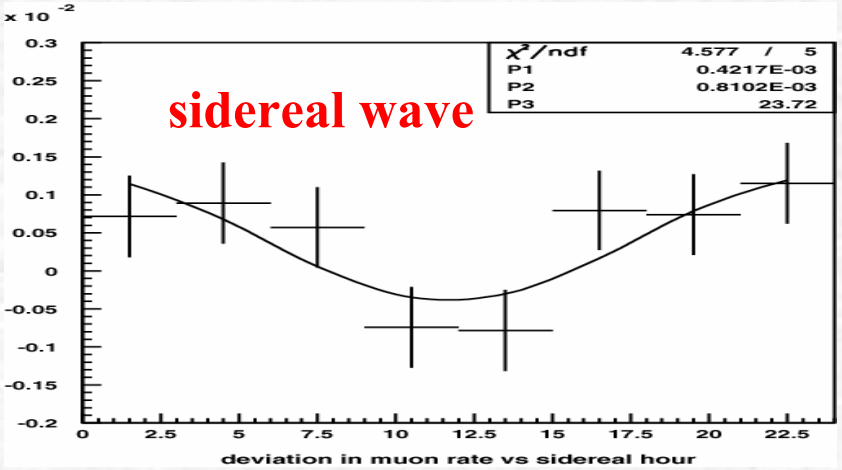
- Two basic approaches
  - Muon charge ratio as a function of zenith angle (links to shower energy)
  - Tag shower energies at the surface, and find muon ratio vs. shower energy
- At a few GeV $\mu^+/\ \mu^- = 1.2$ …
- At a few TeV (on the surface)?
  - Increasing ratio => composition heavier

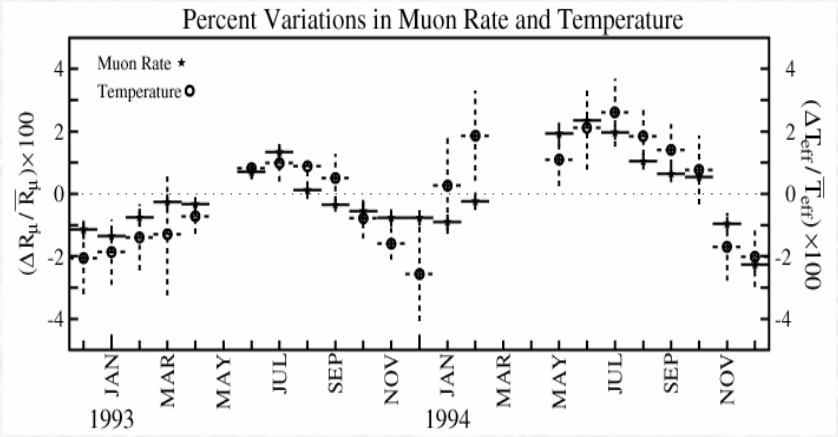
Moon & sun shadows from MACRO

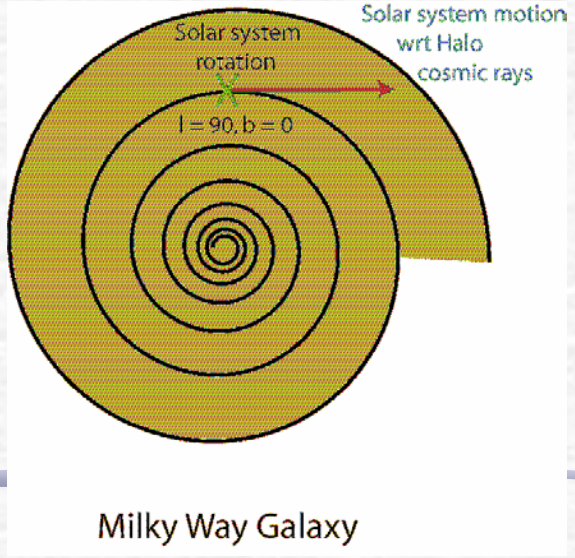


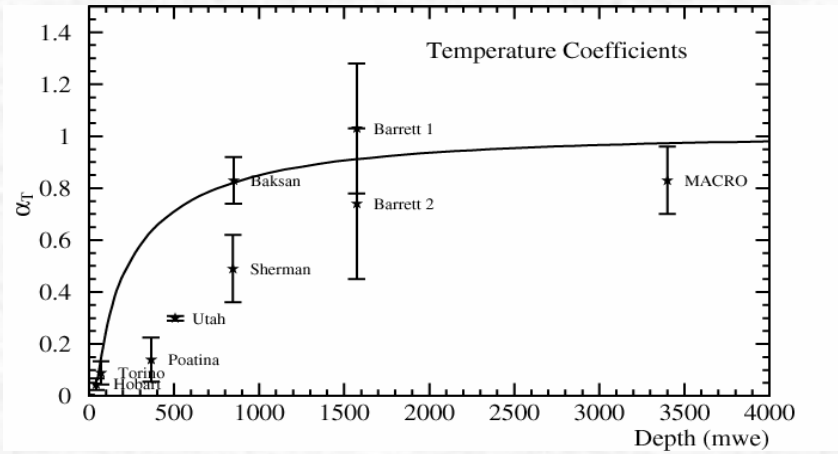


Sidereal (Compton-Getting) & Seasonal (Temp) Variations









Additional detectors

- Surface array
  - As per Soudan experiments, tag shower energies
  - Likely to be built by Minnesota
- Top/bottom shield
  - Most important for atmospheric neutrinos
  - Some interest within the collaboration
- Outriders underground
  - Mostly useful for cosmic ray measurements using shower lateral extents