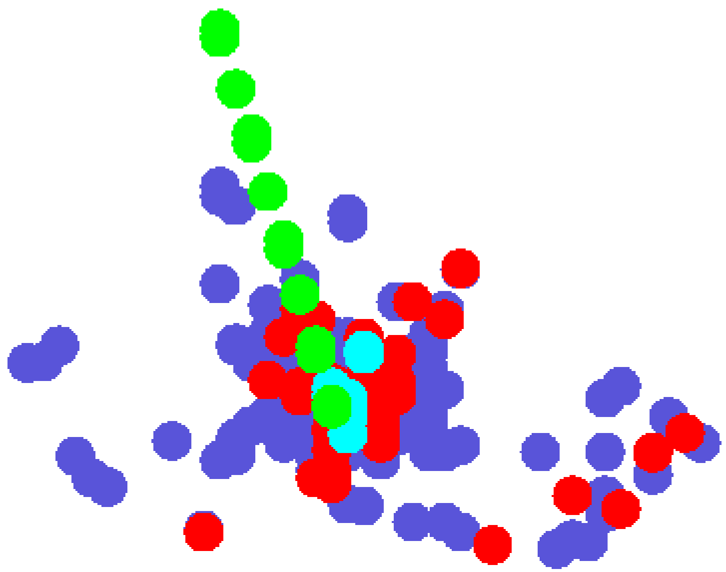
Searching for Atmospheric Neutrino Oscillations at MINOS



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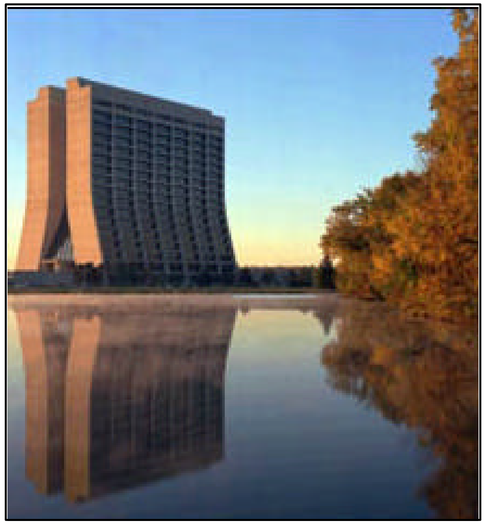
Cambridge University

April 2004

The MINOS Experiment

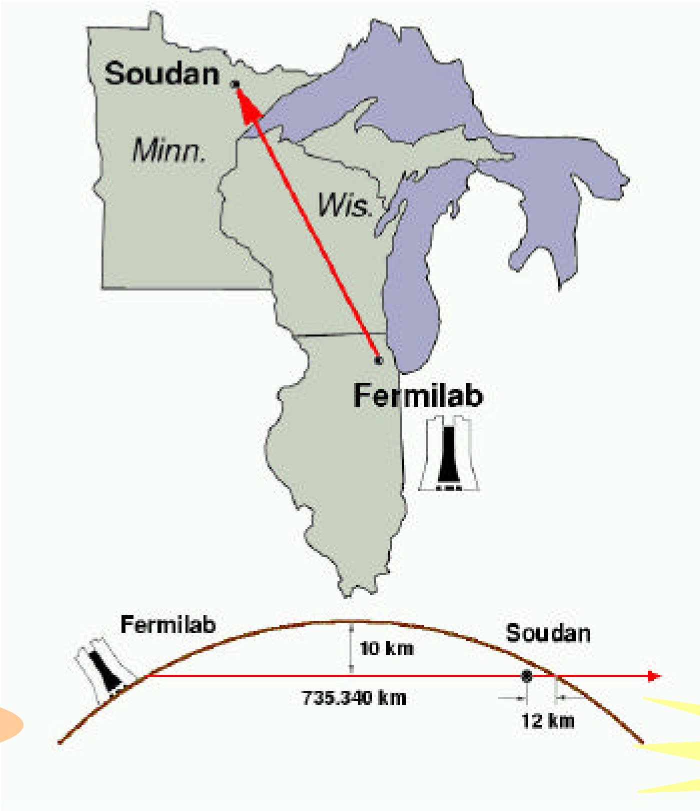
Main Injector Neutrino Oscillation Search

Fermi Laboratory



Near Detector (2004)

Neutrino Beam (2005)

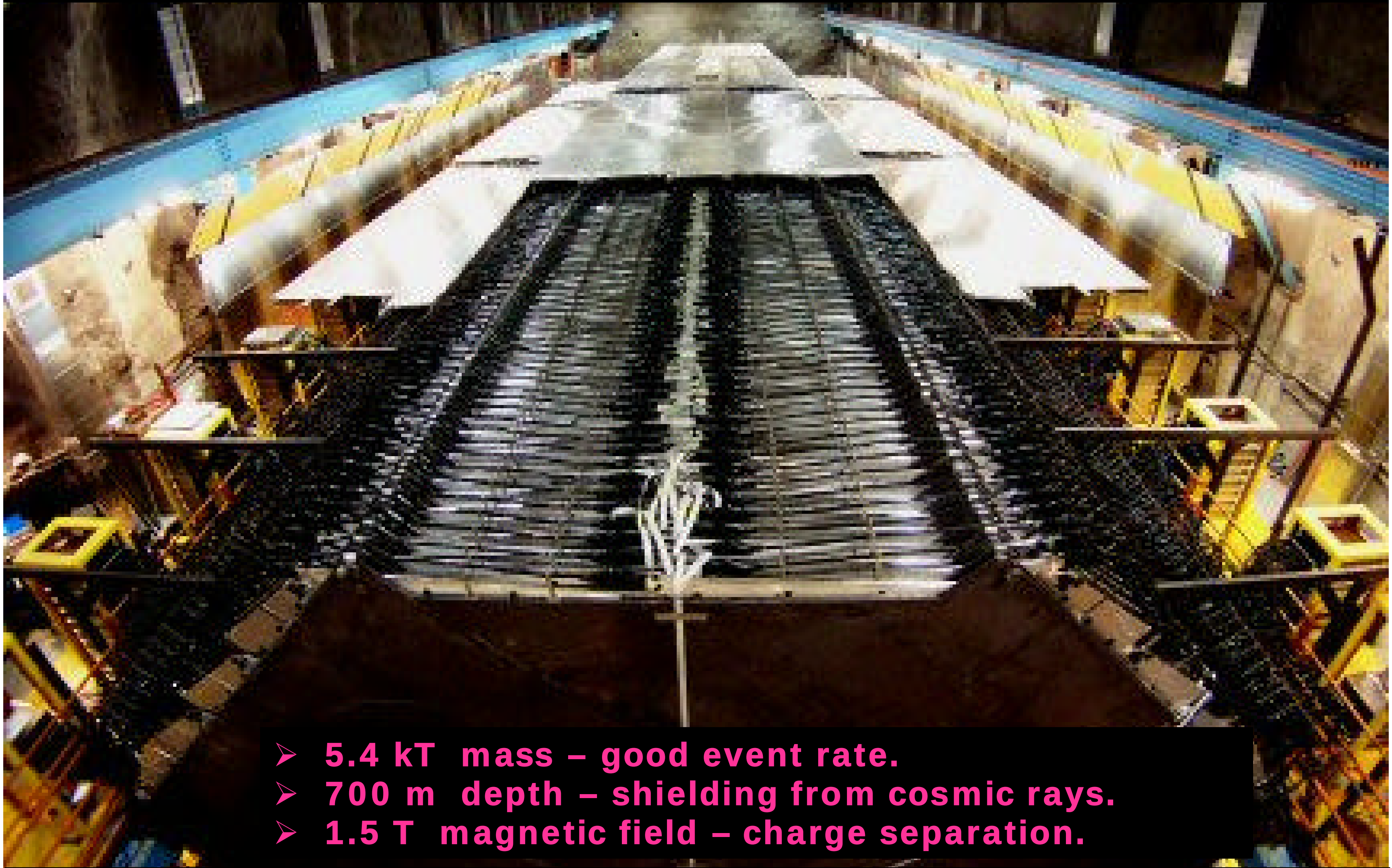


Soudan Mine

Far Detector

COLLECTING DATA!

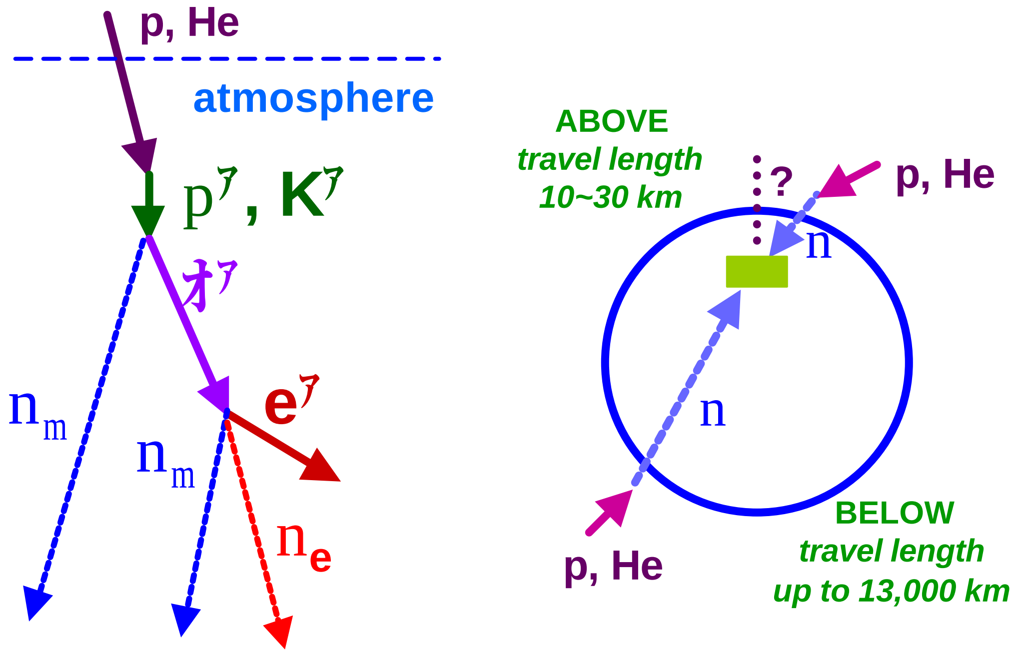
MINOS Far Detector will measure atmospheric neutrino oscillations

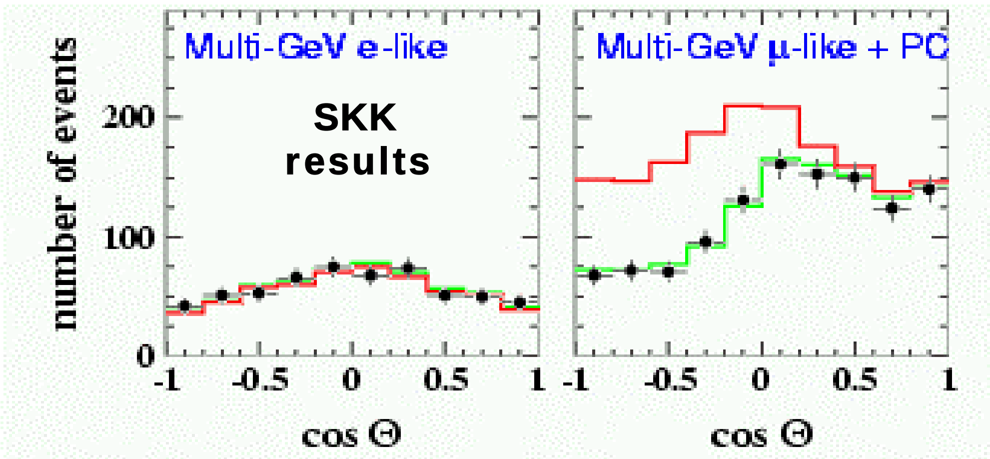


- 5.4 kT mass – good event rate.
- 700 m depth – shielding from cosmic rays.
- 1.5 T magnetic field – charge separation.

Atmospheric Neutrino Oscillations

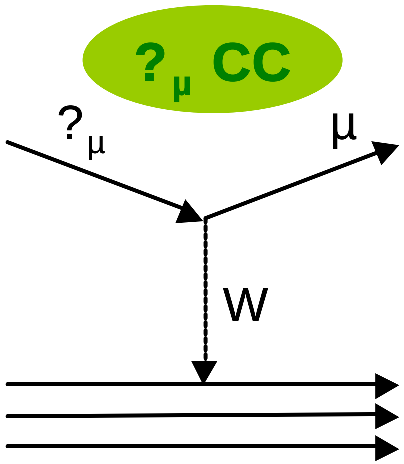
- Compelling evidence for n_m ? n_t oscillations – lots of experiments have measured up/down asymmetry in atmospheric n_m flux.
- MINOS magnetic field can distinguish m^- from m^+, and thus n_m from $\bar{n}_m$.
- MINOS will make separate measurements of n_m ? n_t and $\bar{n}_m$? $\bar{n}_t$ oscillations in atmospheric neutrinos.

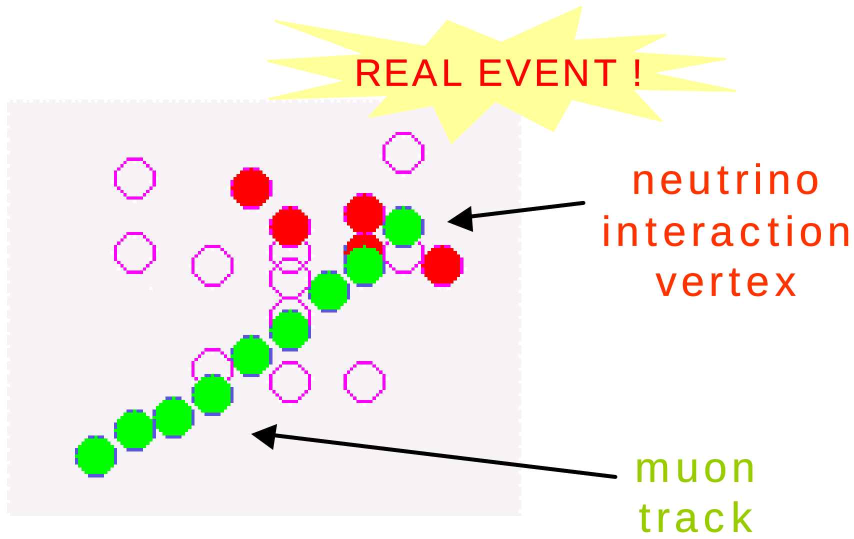




Detecting Atmospheric Neutrinos

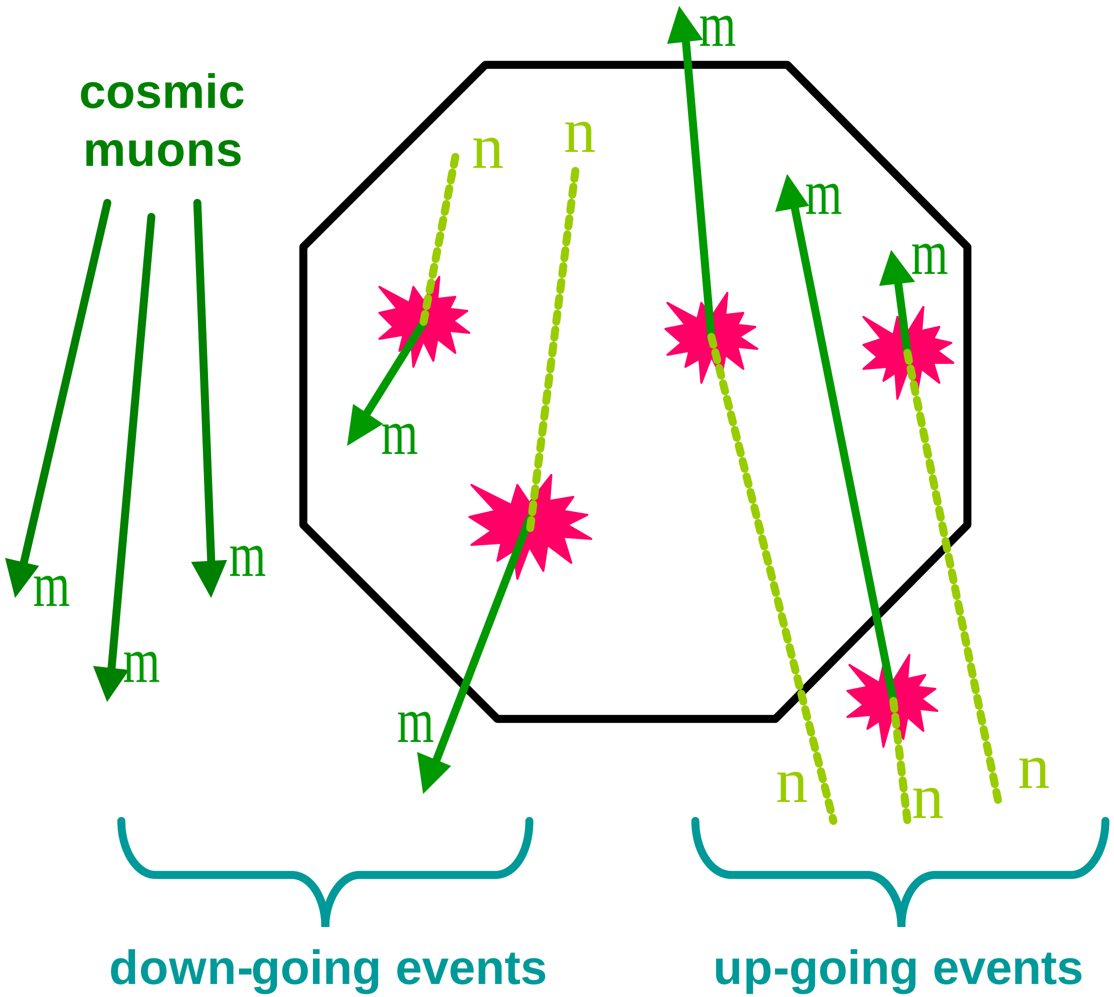
- **The MINOS detectors are sampling calorimeters.**
  - Far Detector comprises ~500 interleaved planes of inch-thick magnetized steel and plastic scintillator.
- **Need clean sample of n_m CC events to measure oscillations.**
  - select events with muon track and contained interaction vertex.
- **Cambridge is developing event reconstruction software.**
  - reconstruct particle tracks + showers.
  - measure particle direction + charge + energy.





Detecting Atmospheric Neutrinos

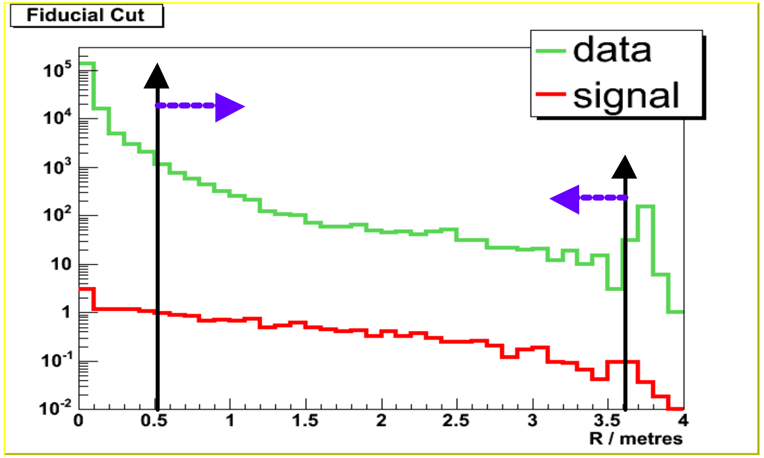
- **Neutrino event signatures:**
  - contained interaction vertex.
  - upward-going muons.
- **Dominant background from cosmic muons**
  - sneak between detector planes, appear contained (? containment cuts)
  - mis-reconstructed as upward-going muons (? direction cuts)
- **Need to achieve ~10^5 cosmic muon rejection to separate neutrino signal.**



Contained Events

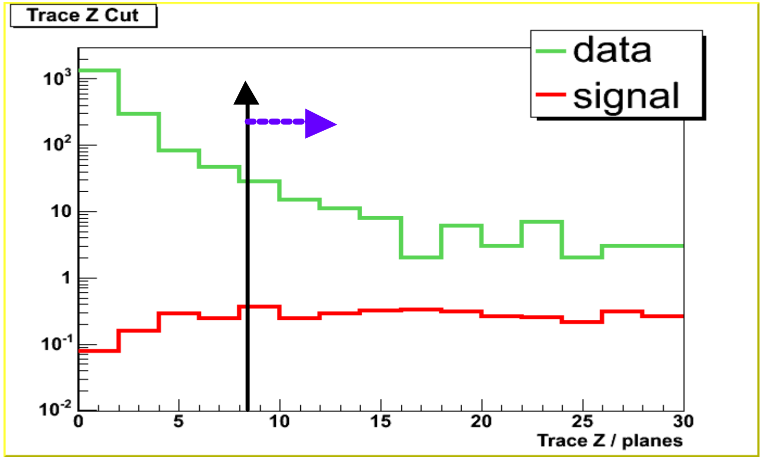
(1) Fiducial Cuts

- consider top track vertex
- must be >50 cm from detector edge



(2) Trace Cuts

- trace track back to detector edge
- must cross >50 cm steel

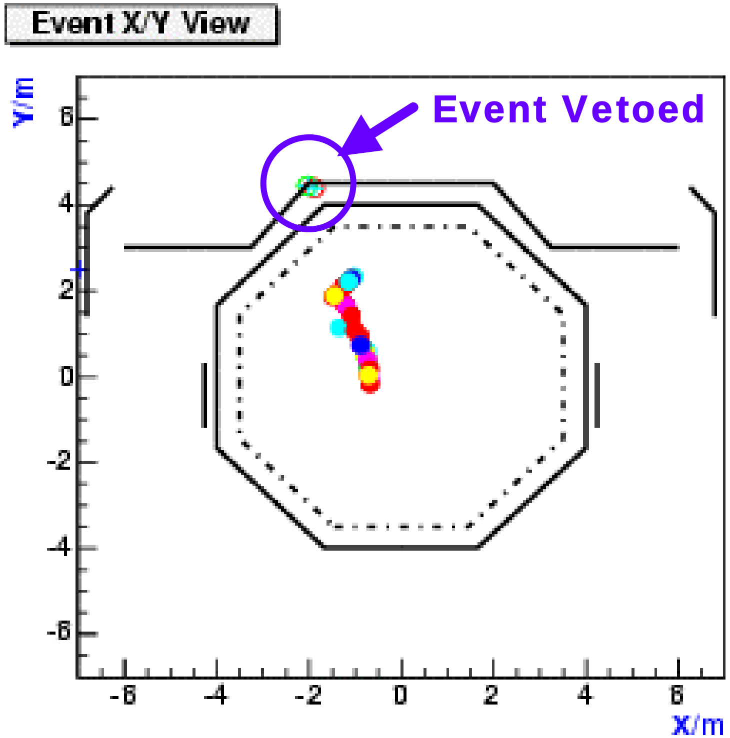


(3) Topology Cuts

- Cut on steep muon topologies
- 1:1 signal-to-background achieved.

(4) Veto Shield Cuts

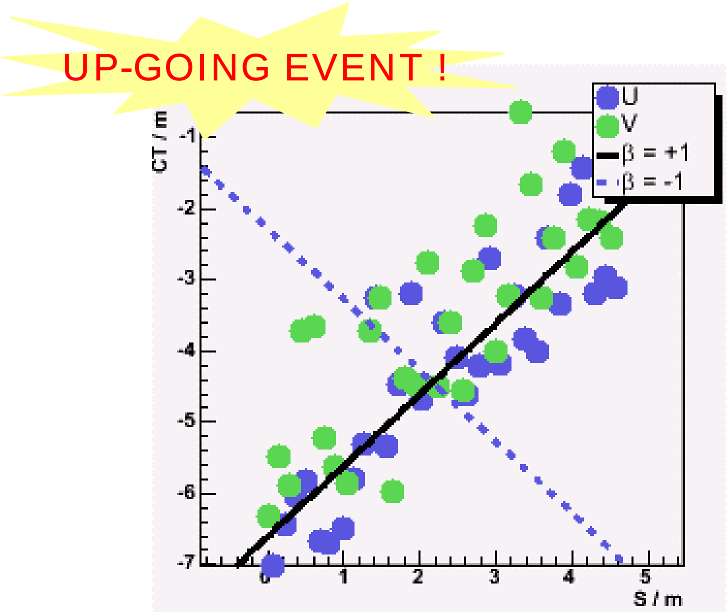
- planes of scintillator positioned above detector to tag cosmic muons
- >95% rejection rate.

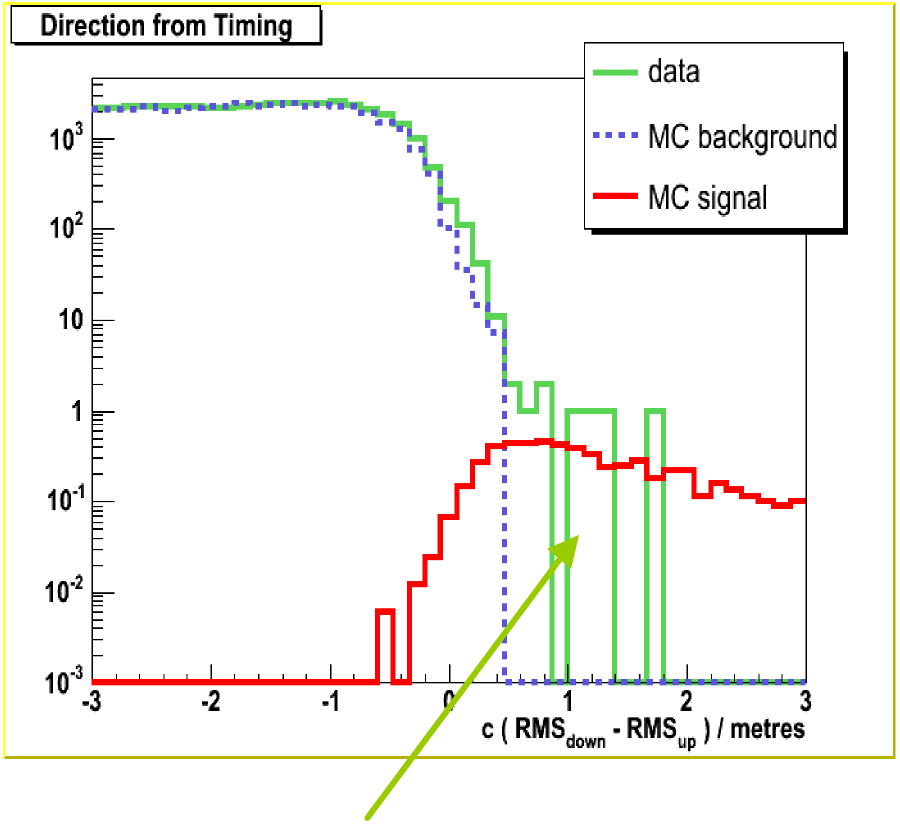


Up-Going Events

MINOS Far Detector Timing Resolution ~ 2.5 ns

- **Direction-Finding Algorithm:**
  - consider distance *vs* time for track
  - force fits with ß = ± 1
  - calculate RMS about each fit
  - RMS_{down}-RMS_{up} > 0 for up-going tracks.





up-going
neutrinos

Charge Reconstruction

MINOS Far Detector Magnetic Field ~ 1.5 T

- **Charge-Finding Algorithm:**

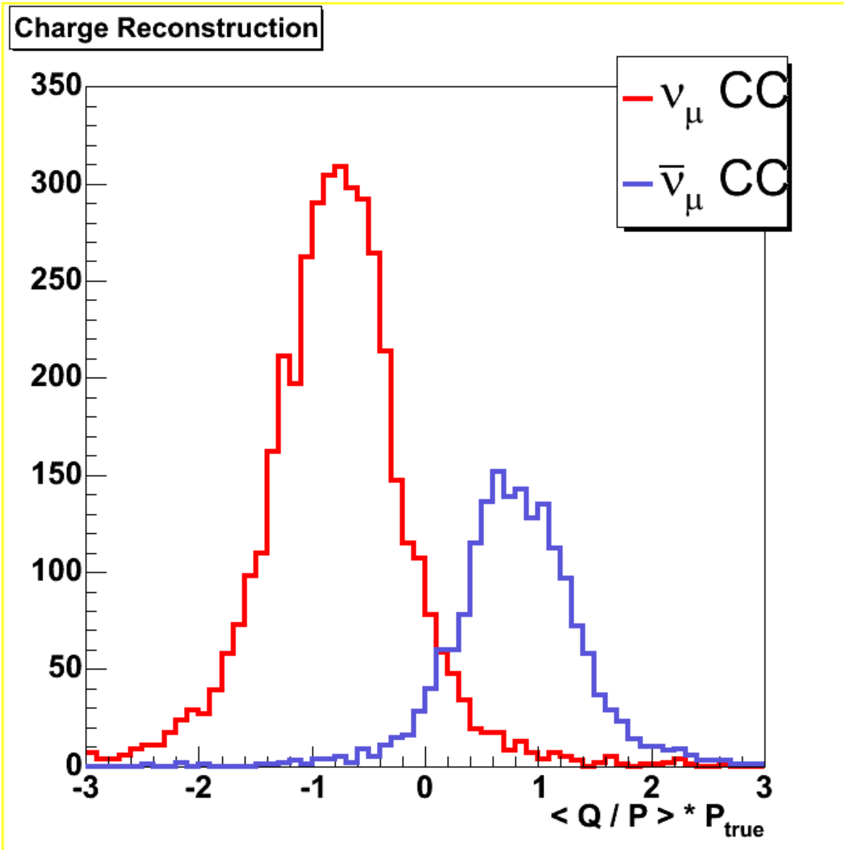
changing momentum given by :

$$\frac{d\underline{p}}{ds} = 0.3Q\,\underline{p} \times \underline{B} + \hat{\underline{p}}\,\frac{dp_{loss}}{ds}$$

$$\therefore \frac{Q}{p} = \frac{\frac{d\hat{\underline{p}}}{ds} \cdot \hat{\underline{p}} \times \underline{B}}{0.3\,|\hat{\underline{p}} \times \underline{B}|^2}$$

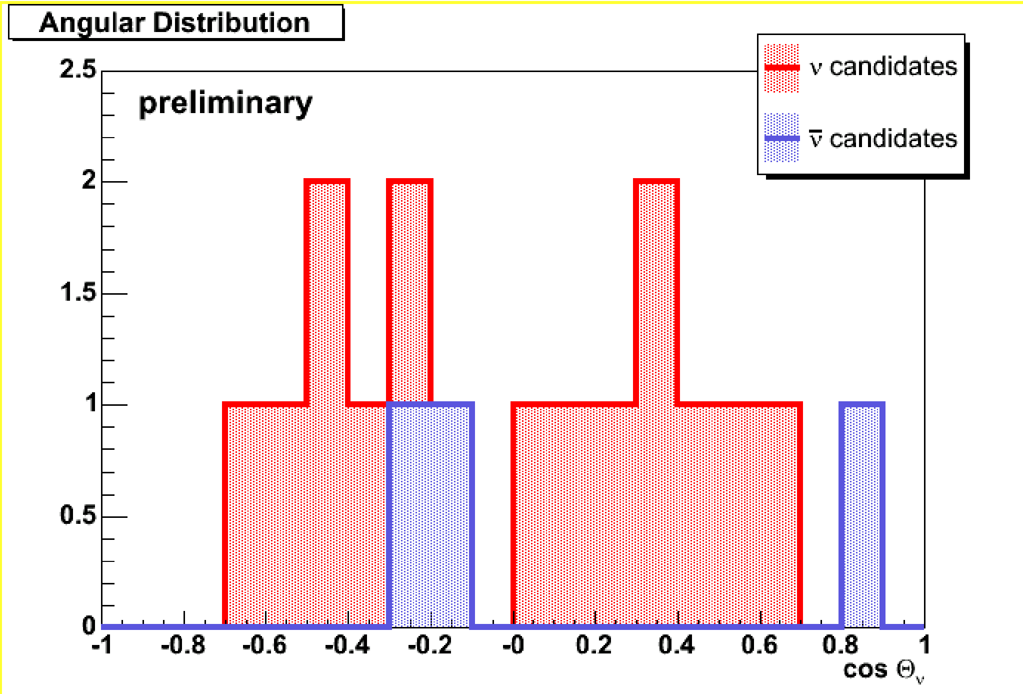
- need to measure curvature of muon track in magnetic field.
- parametrize track segments using polynomial fits.
- calculate <Q/p> along track.

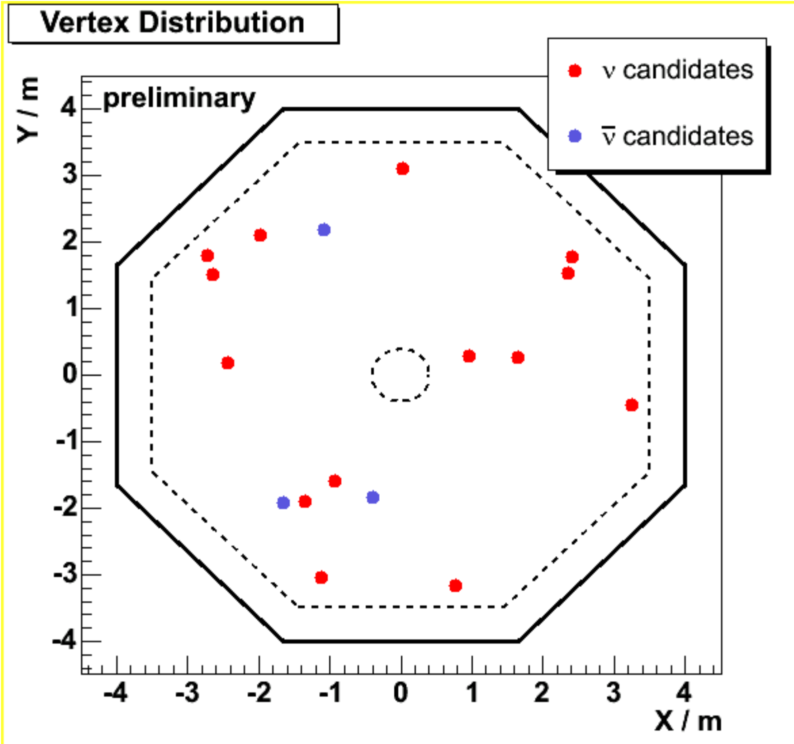
> 90% charge separation



Current Status

- **Currently analysing subset of data – 17 candidate events so far!**
  - selecting events with contained interaction vertices.
  - 14 neutrinos + 3 anti-neutrinos (consistent with expected ratio of ~3:1).
- **Distributions of zenith angle + interaction vertex look sensible.**
- **Expect >100 contained events per year.**





Conclusion

- MINOS Far Detector is able to identify atmospheric neutrino events.
- MINOS will carry out charge-separated atmospheric neutrino oscillation analysis.
- Data is now accumulating – first physics results expected soon!