Cascades in IceCube and DeepCore

PENNSTATE

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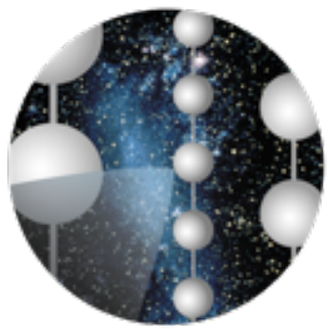


MANTS ’11
Uppsala, Sweden
September 24, 2011

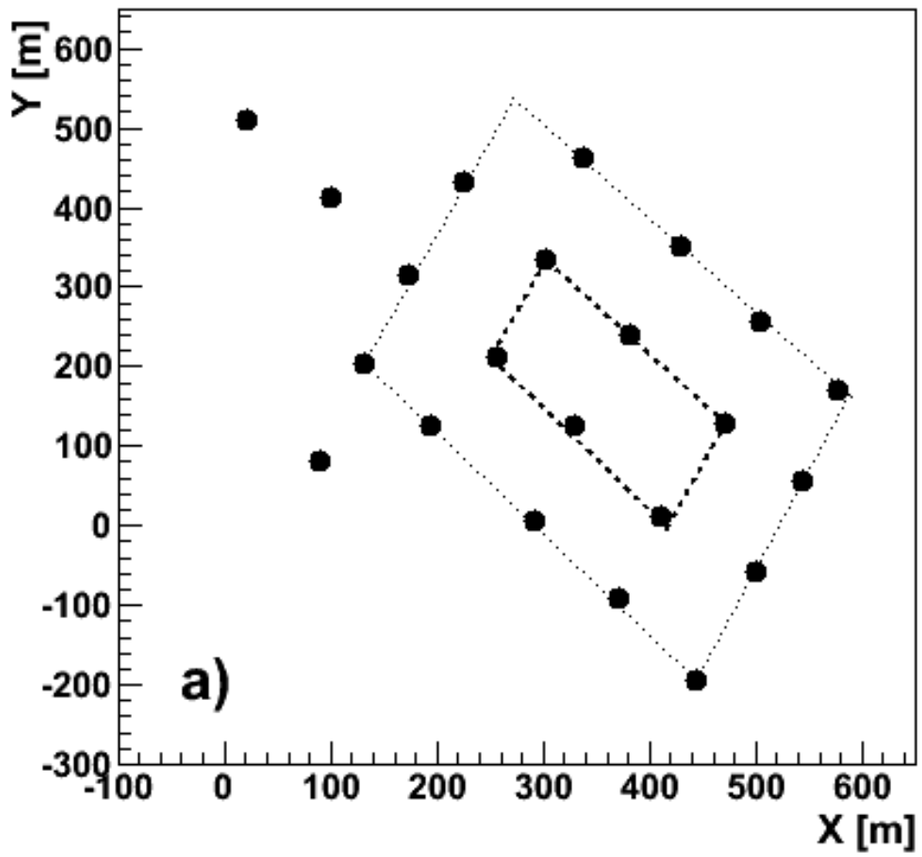
Two Strategies

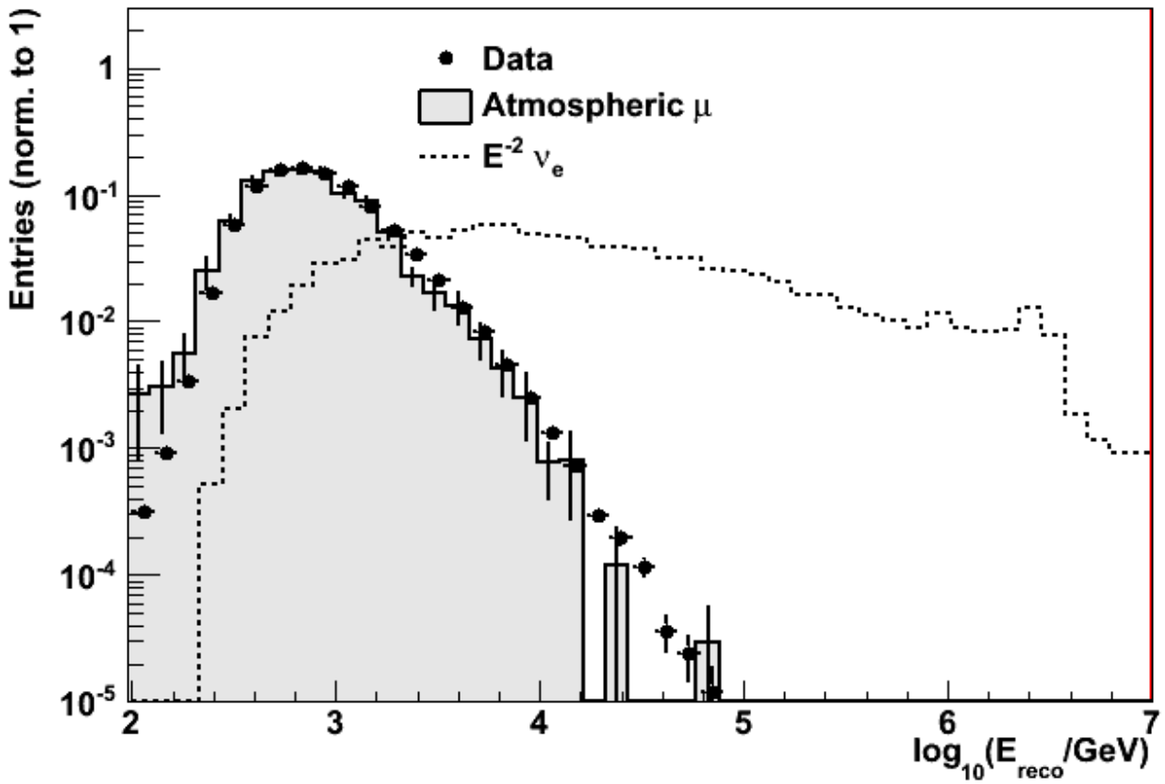
- Searches for Astrophysical Cascades
  - Due to oscillations, expect comparable fluxes of ν_e, ν_τ, and ν_μ (except for muon range effect)
  - Avoid atmospheric backgrounds by demanding high energy events
    - Require cascade-like event topology, weak veto against entering muons
    - Main background is hard bremsstrahlung or other stochastic energy loss from penetrating atmospheric muons
- Searches for Atmospheric Cascades
  - Flux lower than for atmospheric ν_μ, but still copious if energy threshold low
  - Look for cascade-like topology, stringent veto on entering muons
  - Main backgrounds “sneaky” muons, atmospheric ν_μ with short tracks

Astrophysical Searches

arXiv:1101.1692

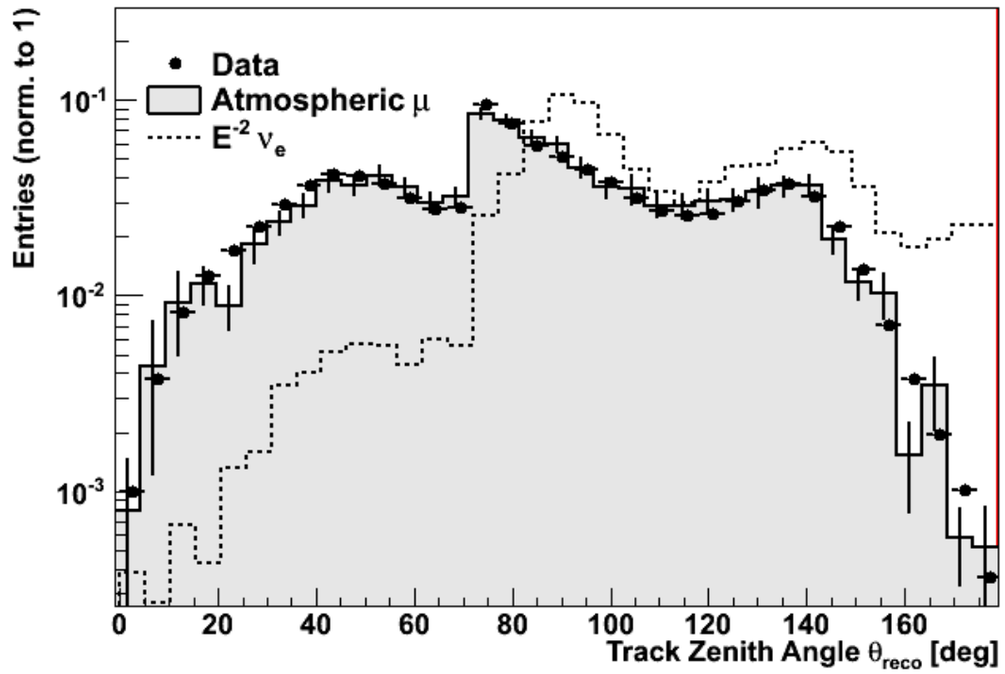
- First published IceCube results based on IceCube 22-string configuration (2007-08)
  - Limited fiducial volume, even with weak veto region
  - Look for signal at high energy

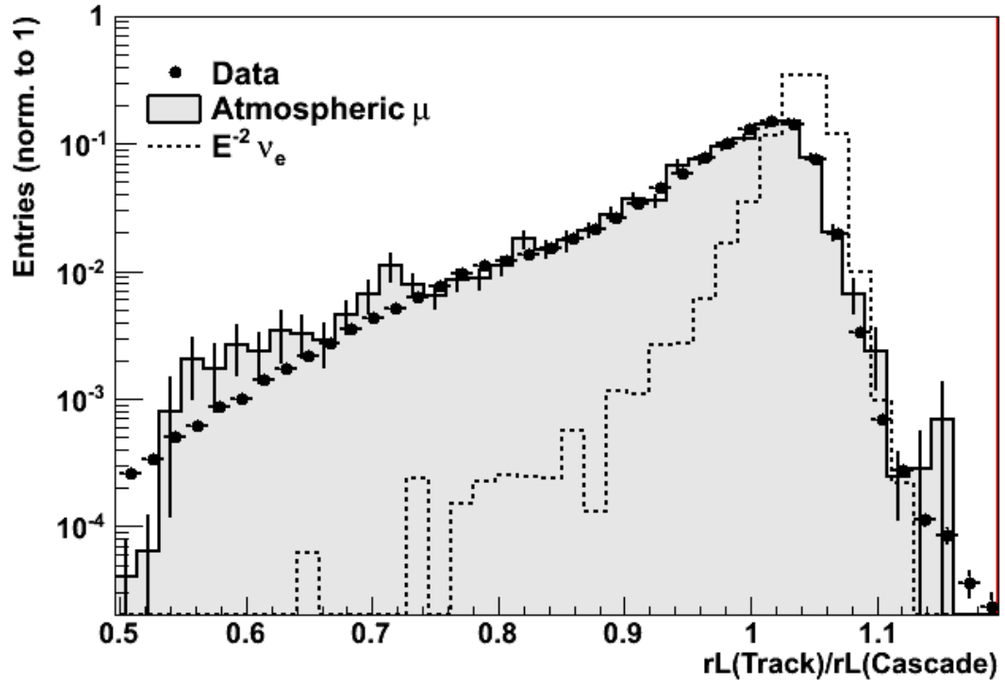




Background Rejection

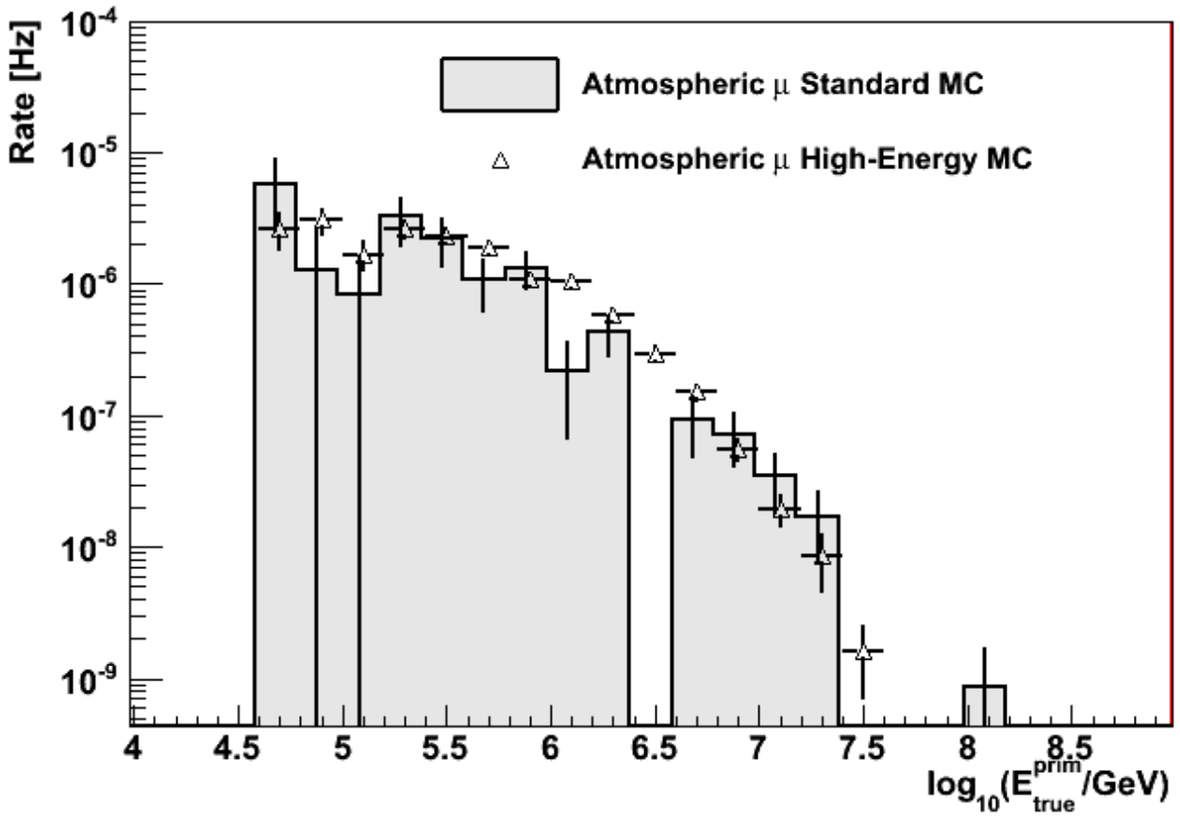
- Reject events with best-fit muon track downgoing
- Demand events reconstruct better under cascade hypothesis than muon hypothesis
- Demand spherical topology
  - Should not have hits distant from the vertex unless most nearby DOMs are also hit





Background Systematics

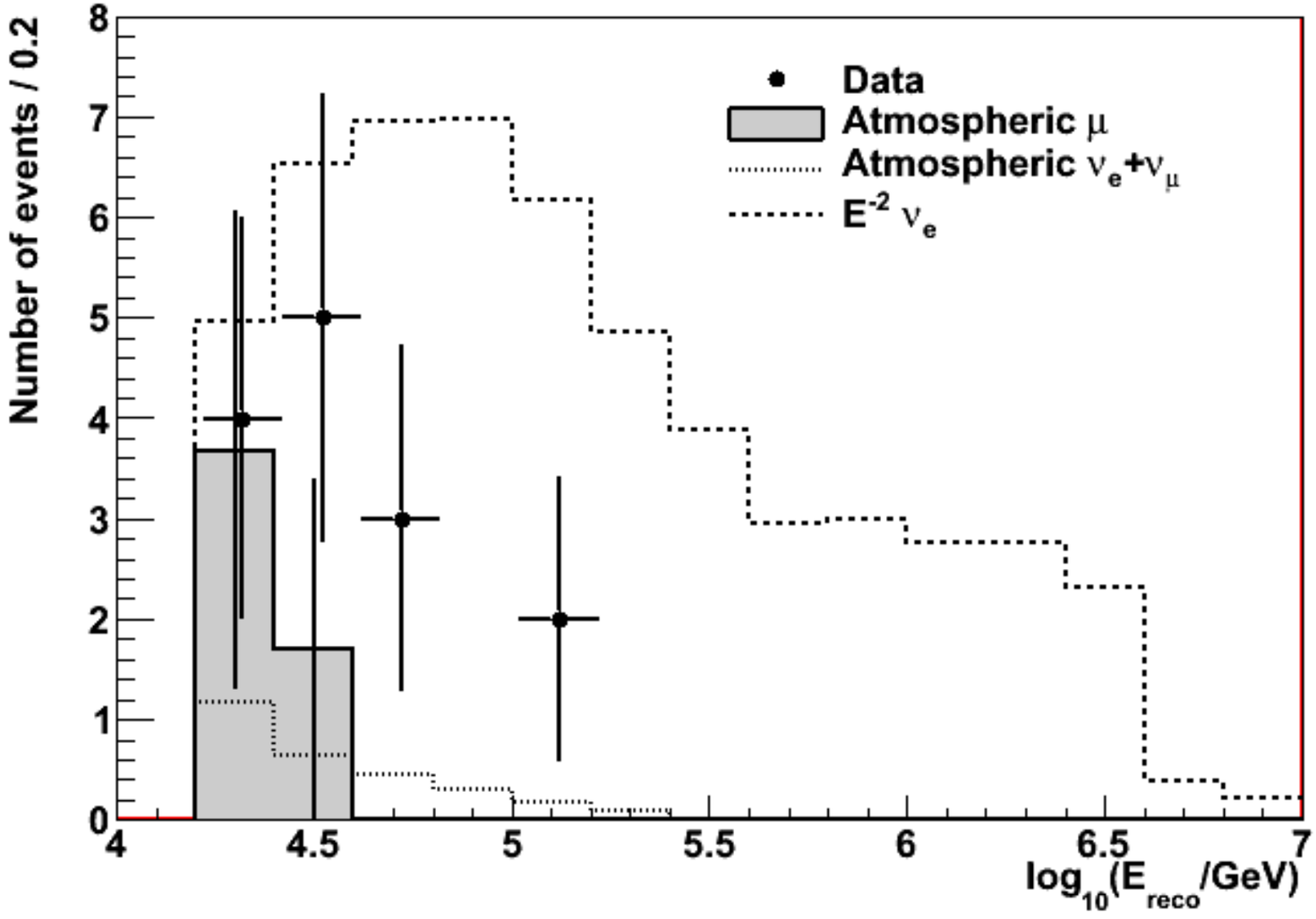
- The most difficult backgrounds are energetic bremsstrahlung from atmospheric muons produced by primaries around the knee
  - Composition important, but not well known
  - Heavy primaries produce bundles, light emission more uniform
- Last four remaining simulated background events are all protons inclined at ~70º, energies of a few PeV



- Absolute prediction of background rates is difficult, due to CR composition and ice modeling uncertainties

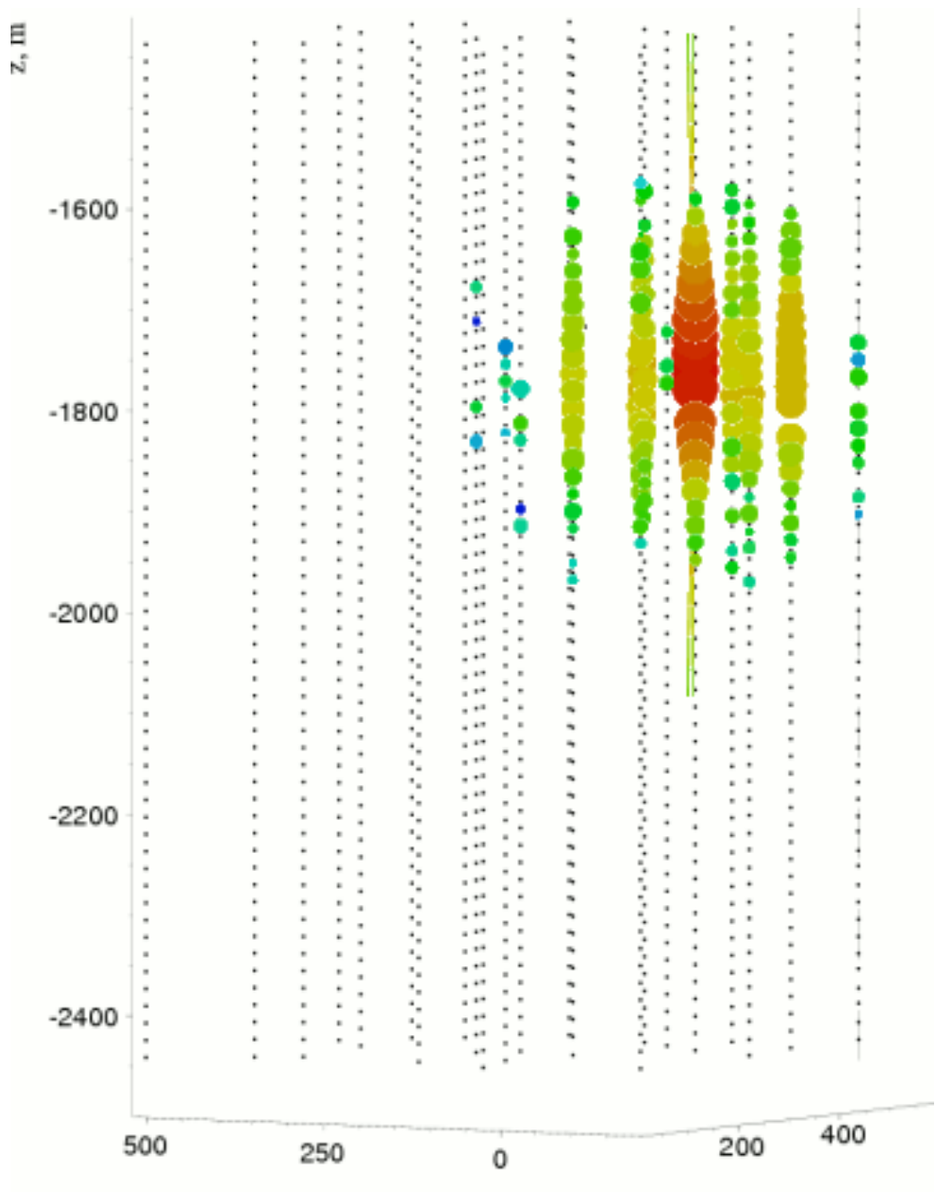
IceCube 22-String Results

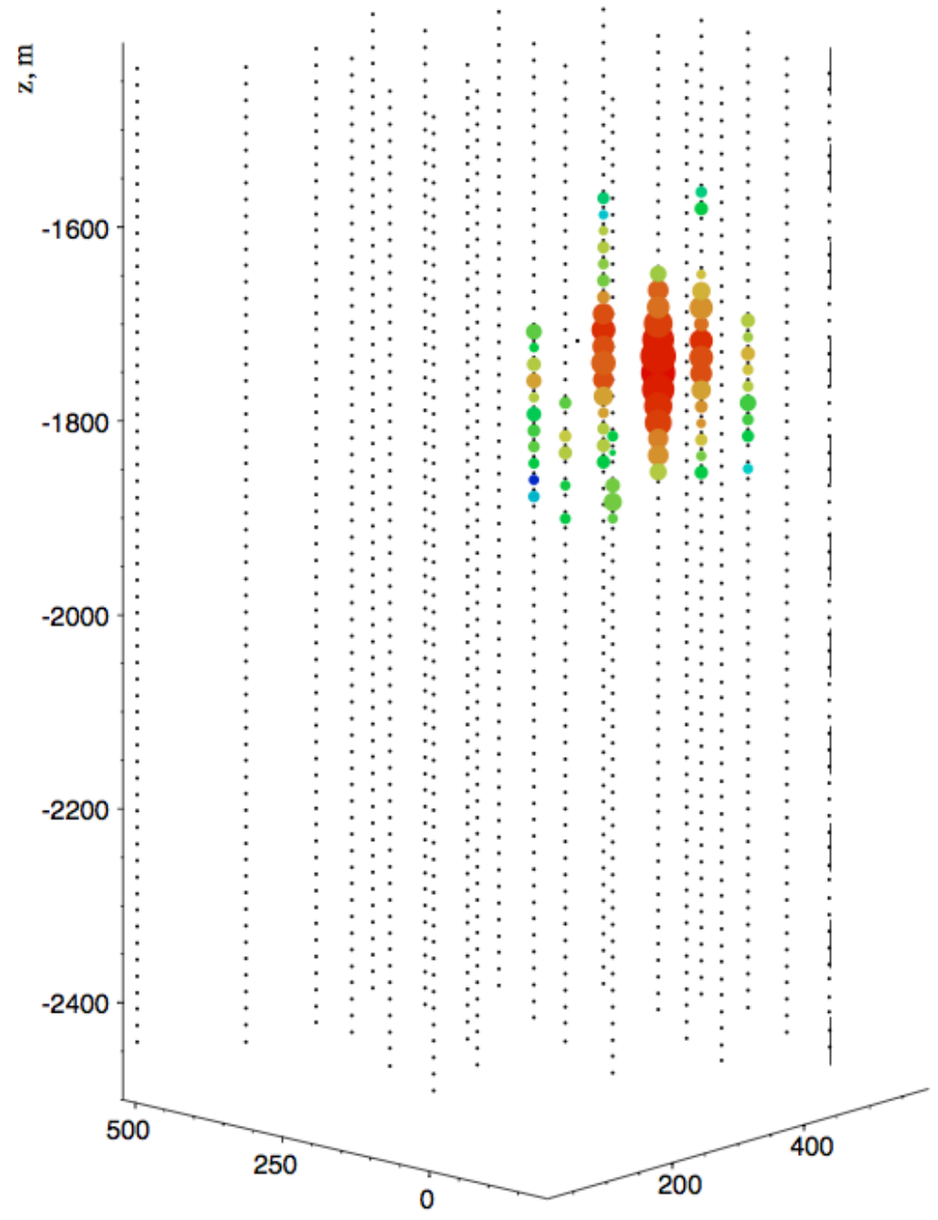
- Observe 14 events in the final sample
- Expect 8.3 ± 3.6 background events
  - 5.4 ± 3.5 atmospheric muons under Hörandel polygonato model with baseline ice properties
  - 2.9 ± 0.9 atmospheric neutrinos (including prompt based on Naumov model)



Selected Events from Final Sample

- One is an actual cascade candidate, one is atmospheric muon MC

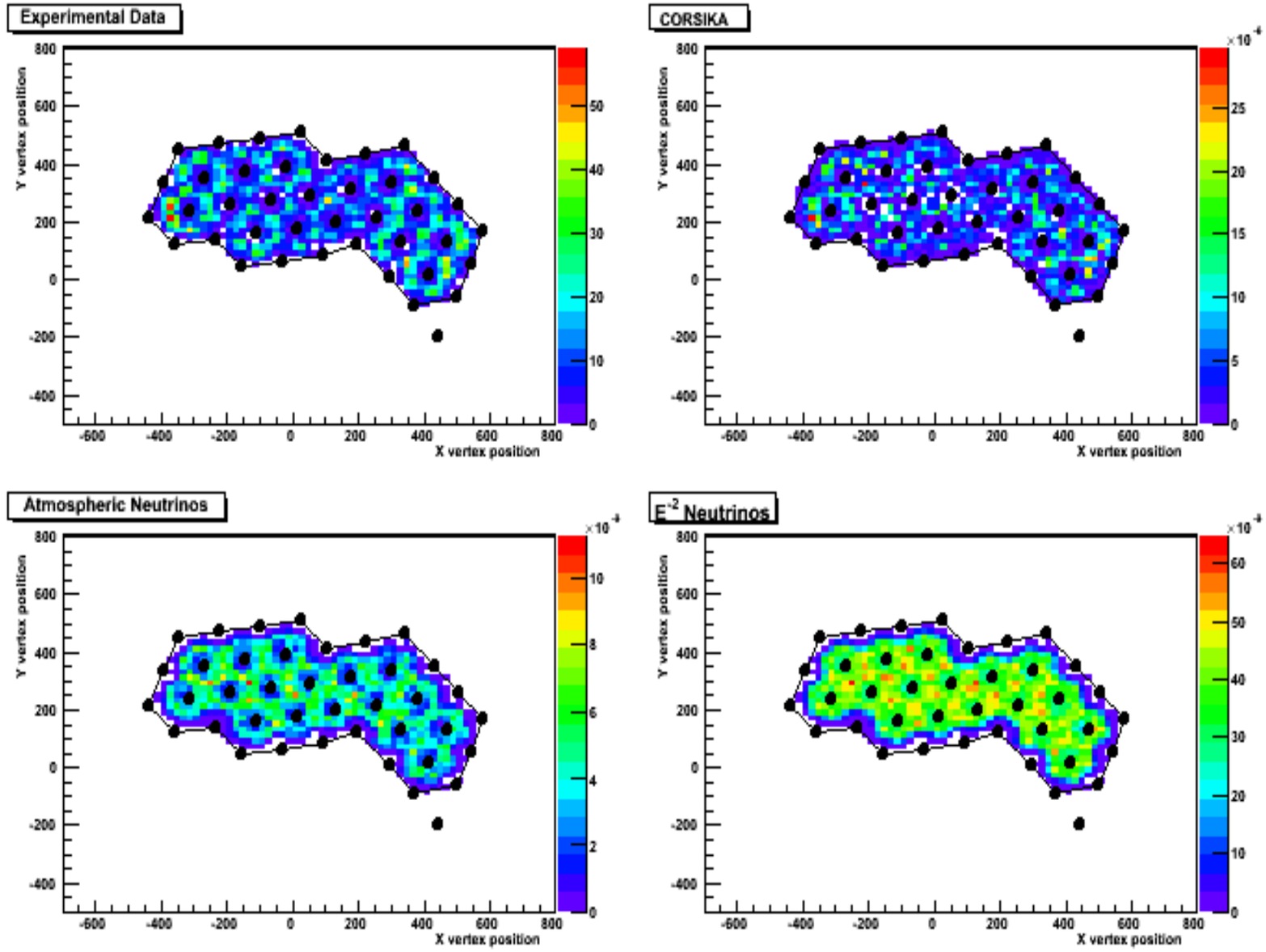




IceCube 40-String Analysis

S. Hickford/S. Panknin, ICRC 2011

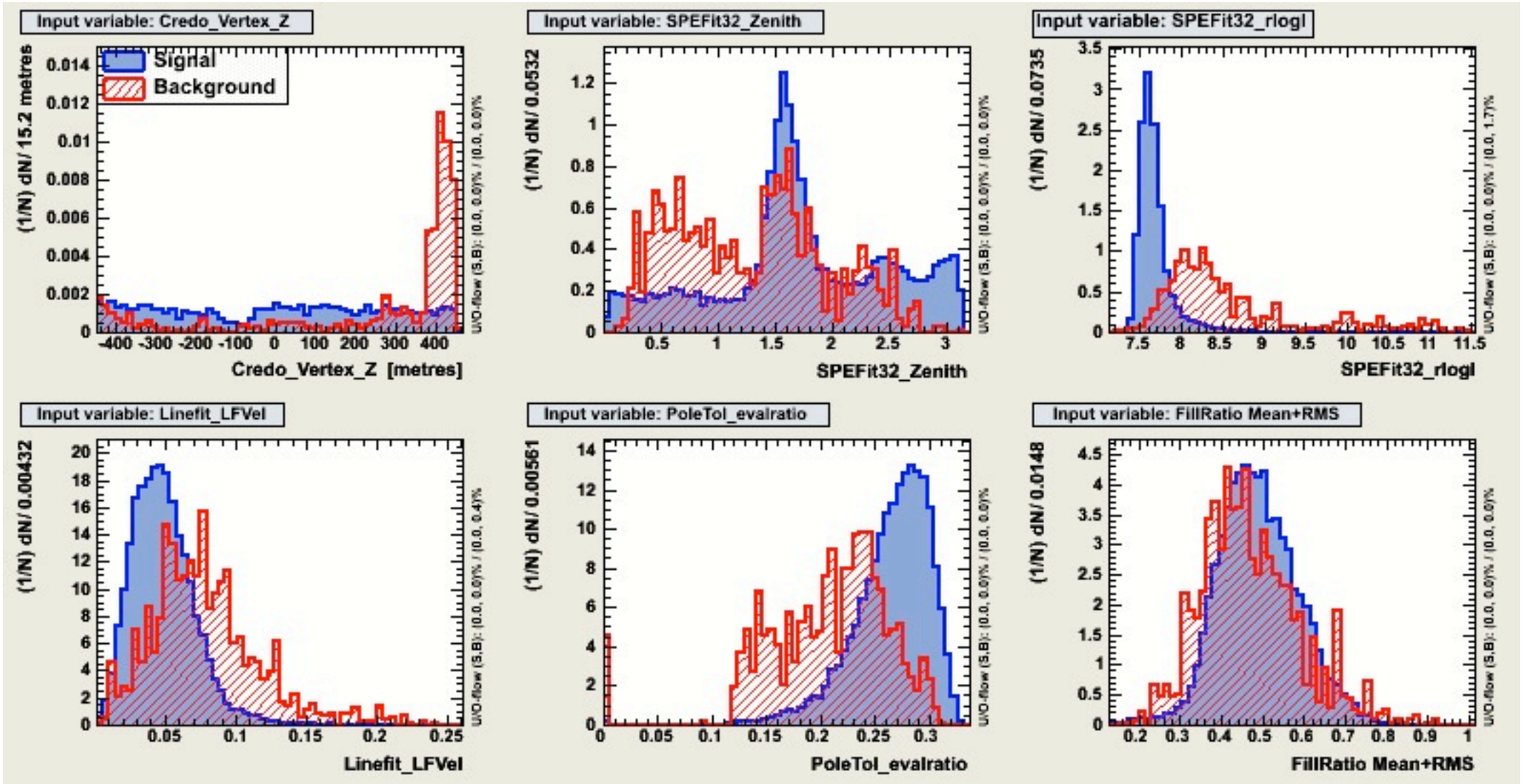
- Larger detector volume
  - More events
  - Better reconstruction, background rejection
- Still large surface-to-area ratio, due to deployment pattern



Background Rejection

Preliminary

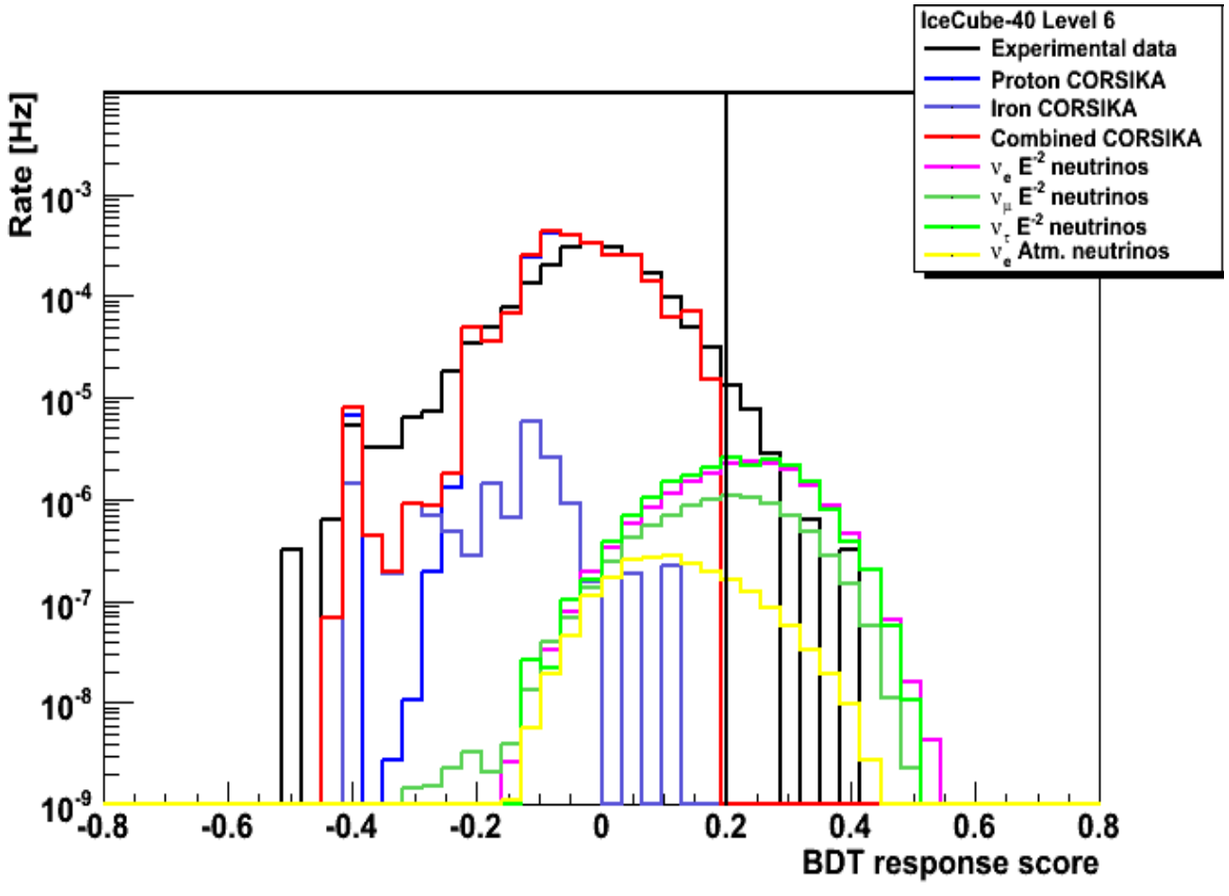
- Use machine learning techniques (Boosted Decision Trees) to incorporate a variety of discriminators
  - Likelihood reconstructions, topological parameters

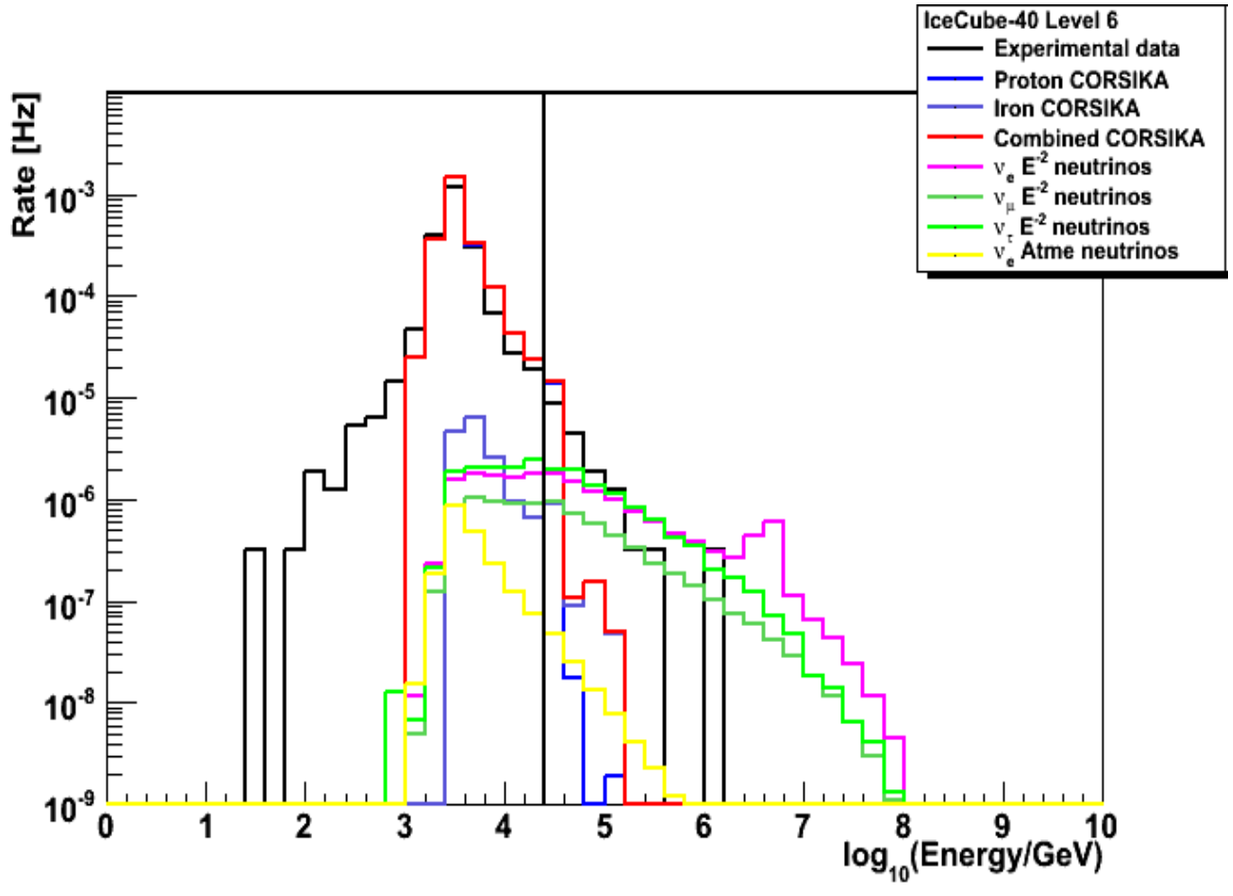


Background Rejection

Preliminary

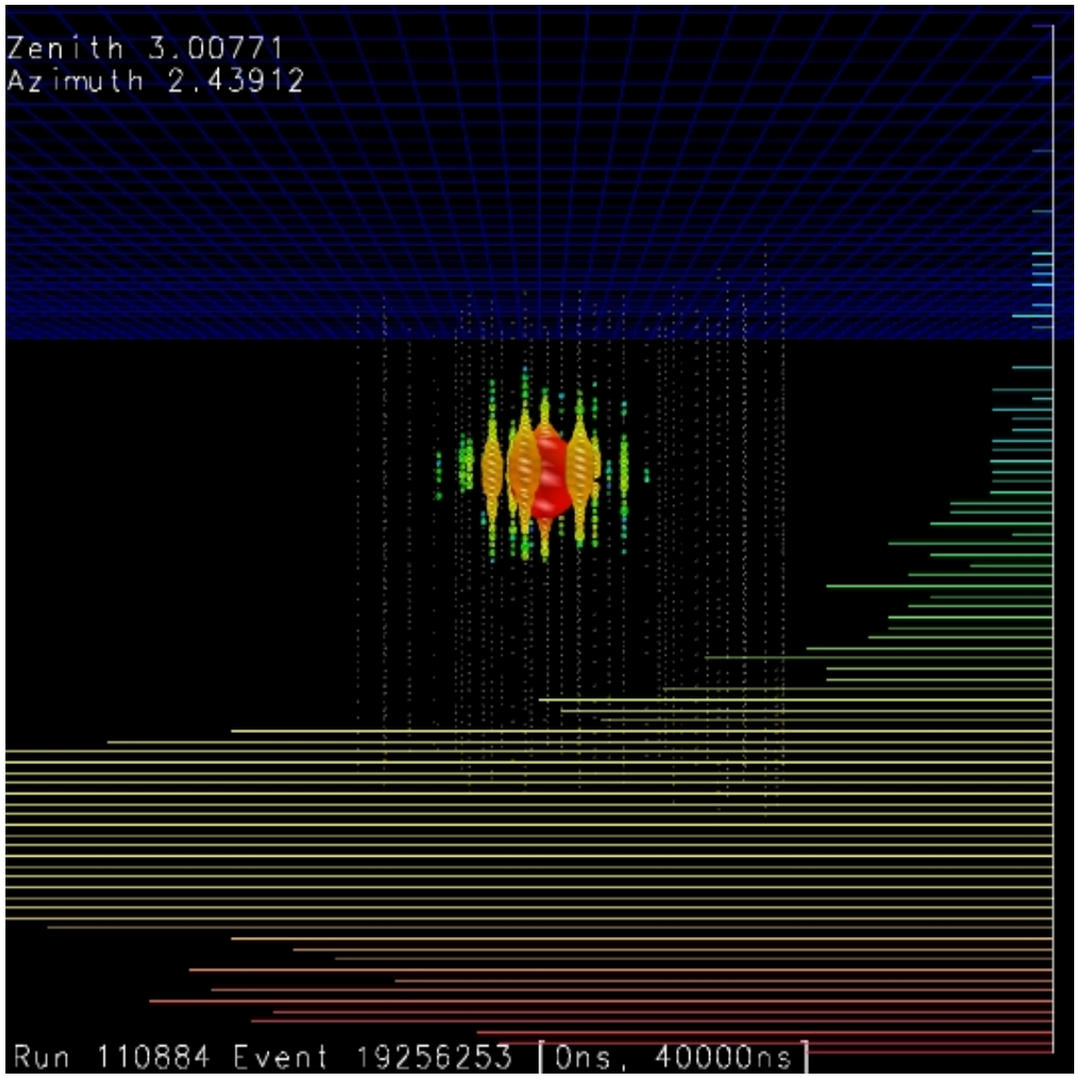
- Apply cut on BDT output score, demand E > 25 TeV
- Fourteen cascade candidate events remain, but assessment of background levels still underway



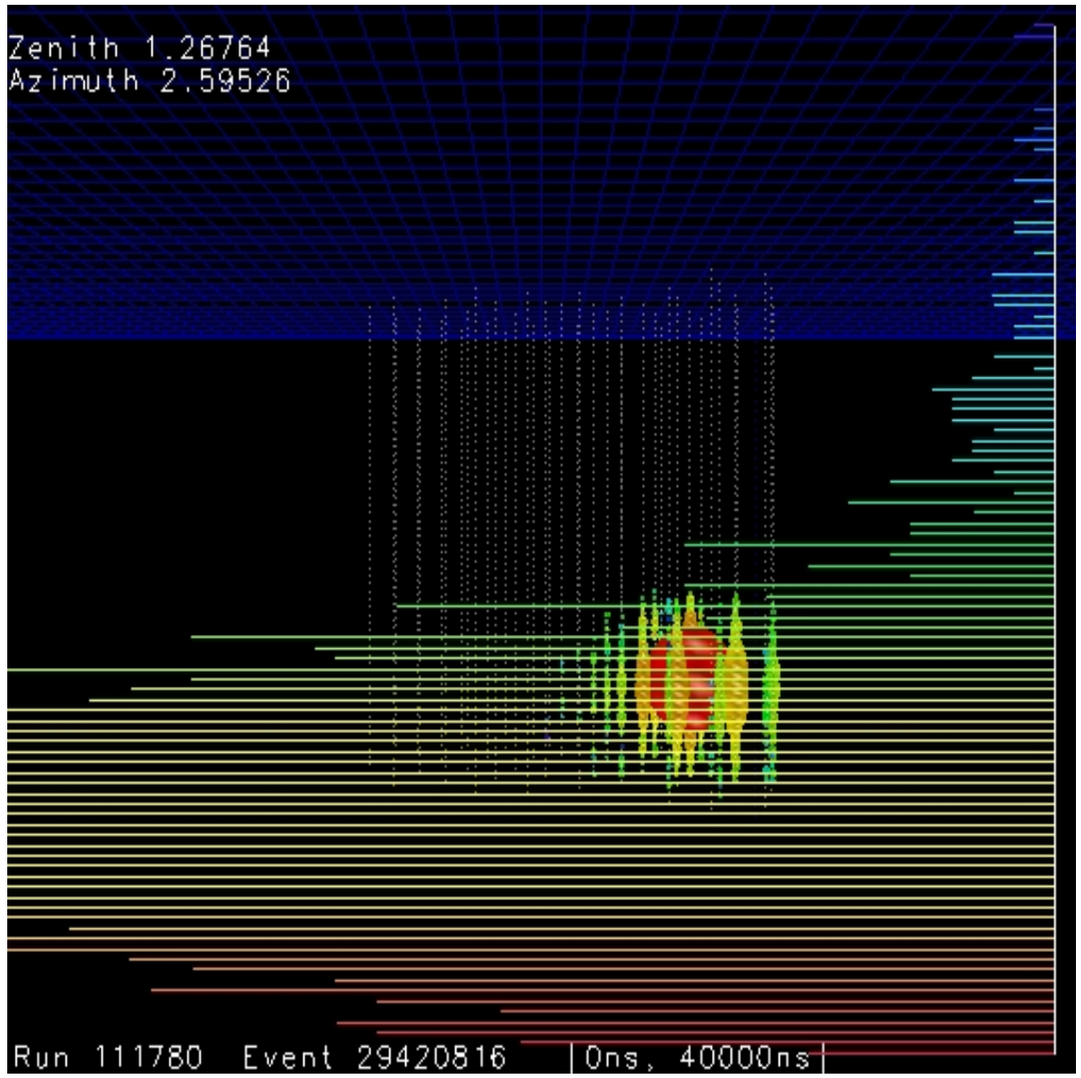


Two Cascade Candidates

Preliminary



- Run 110884
- 23rd April 2008, 1:23:14
- 175 TeV

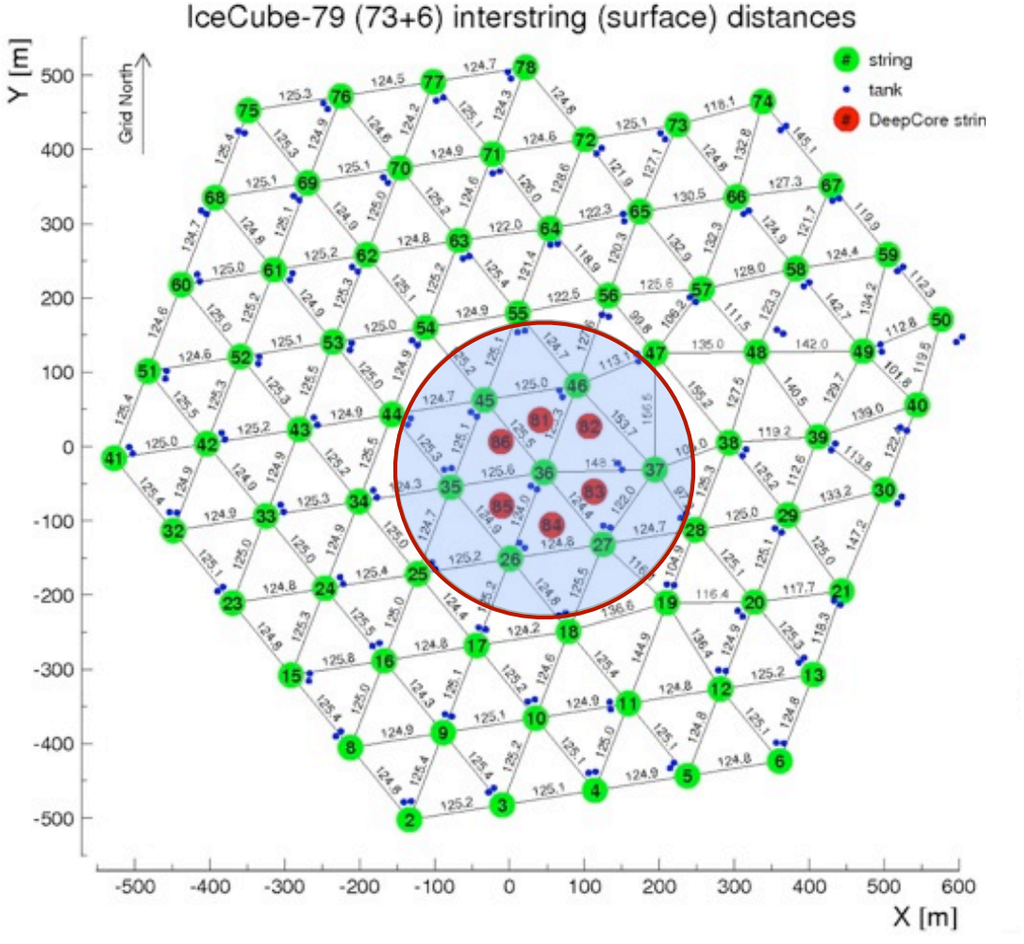


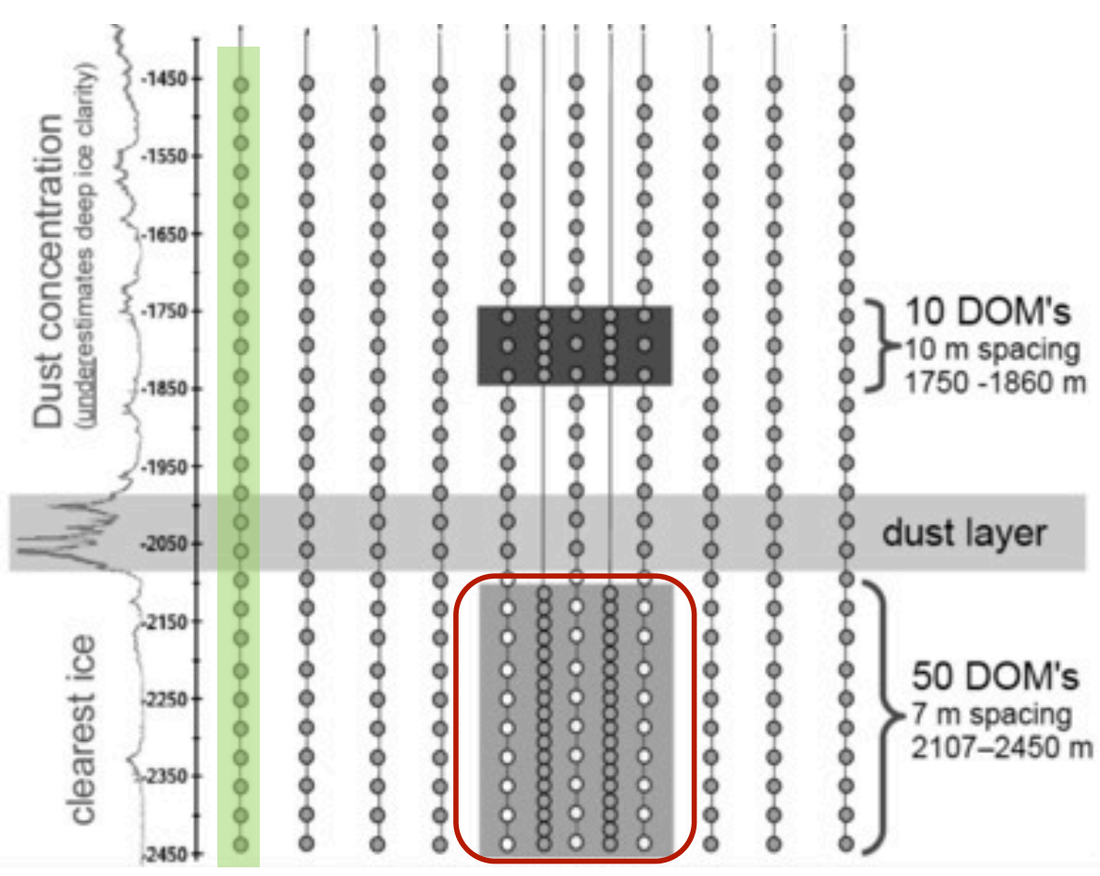
- Run 111780
- 16th October 2008, 11:32:47
- 144 TeV

Atmospheric Cascades with IceCube 79

C. H. Ha,
TAUP 2011

- DeepCore reduces energy threshold, increases yield
- IC79 provides much thicker veto
  - Reduced fiducial volume acceptable due to high atmospheric flux



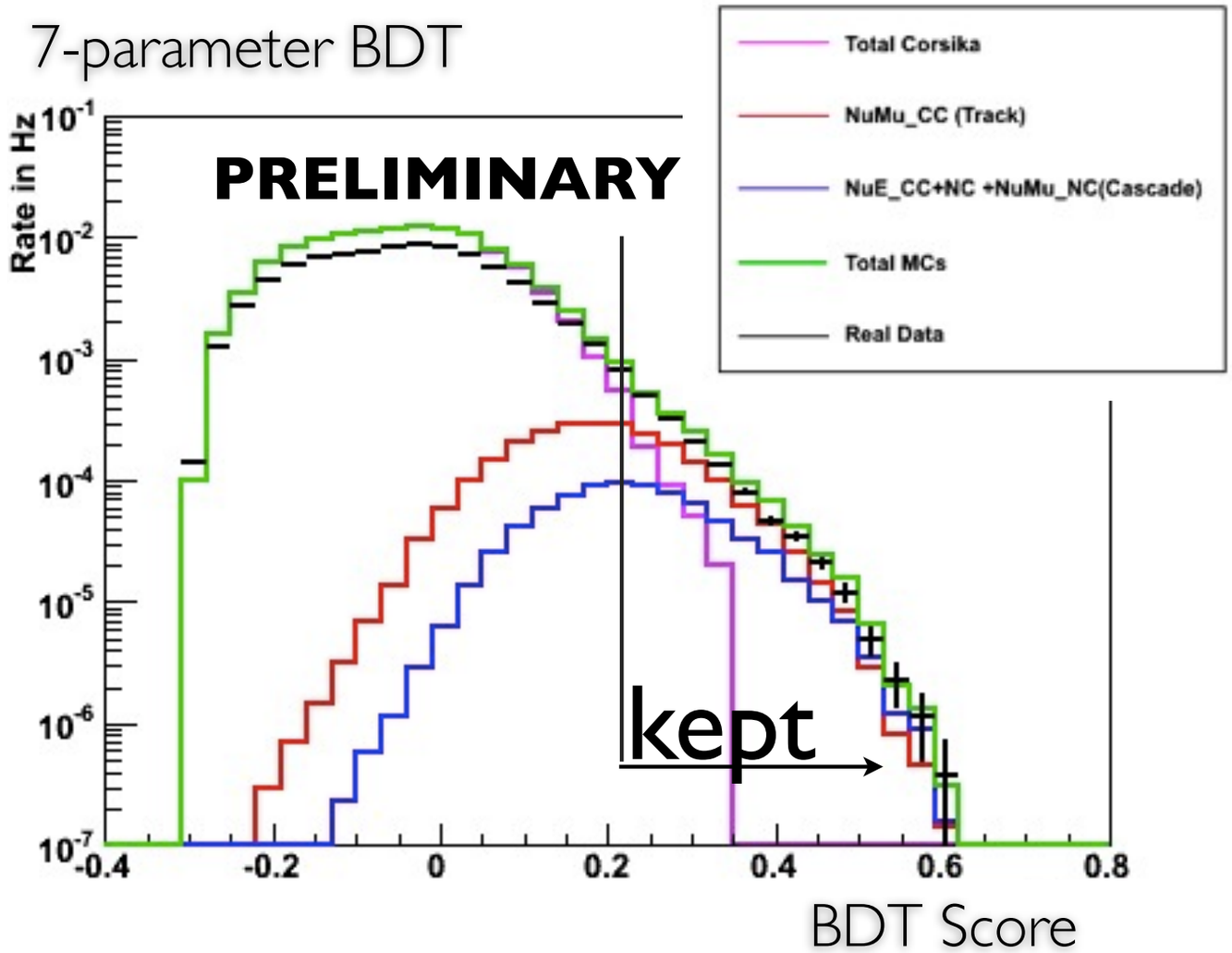


Background Rejection

- Reduce atmospheric muon background with two BDTs
  - One based on topological parameters, one on slower likelihood fits
  - Atmospheric muons can be almost completely removed due to thick veto region

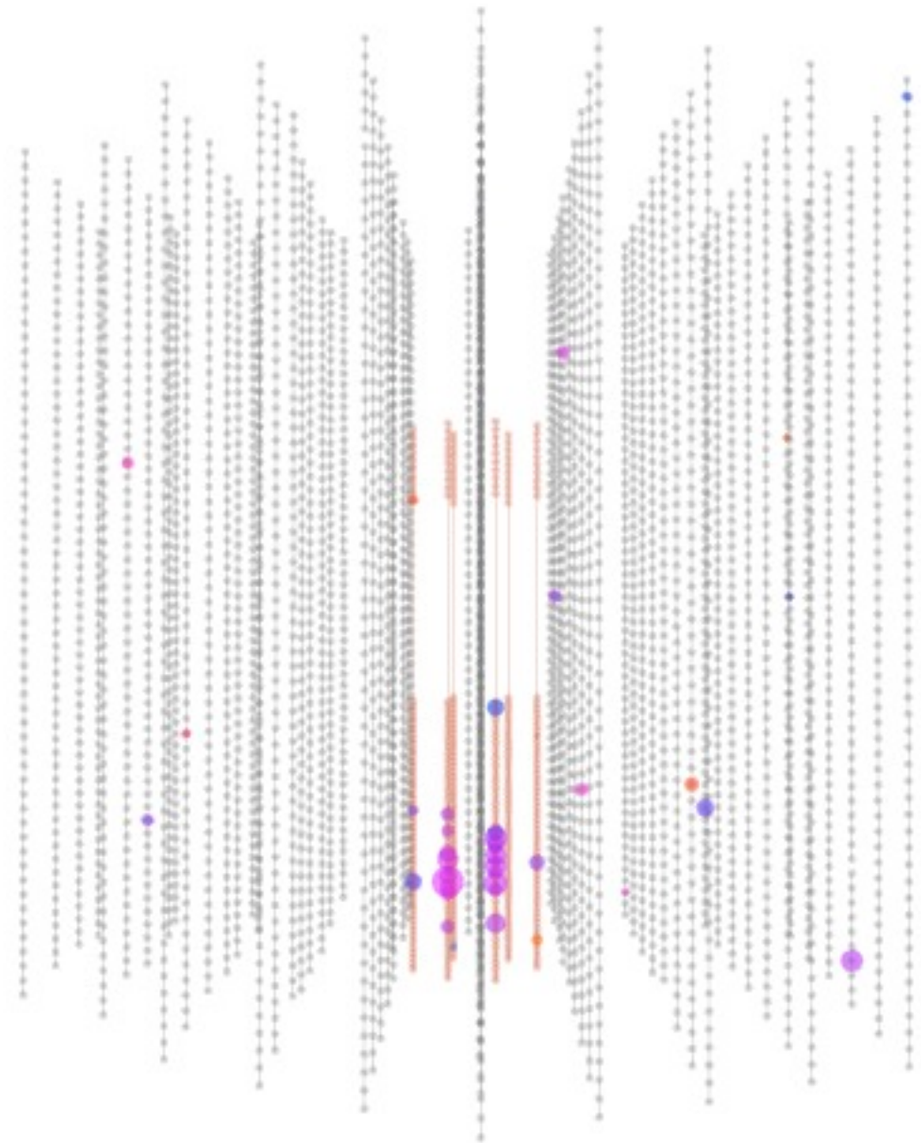
- Dominant background to cascades is atmospheric ν_μ CC with short muon tracks
  - NC ν_μ irreducible, counted as cascade signal

- Additional, strict cuts on containment, cascade likelihood, number of hits

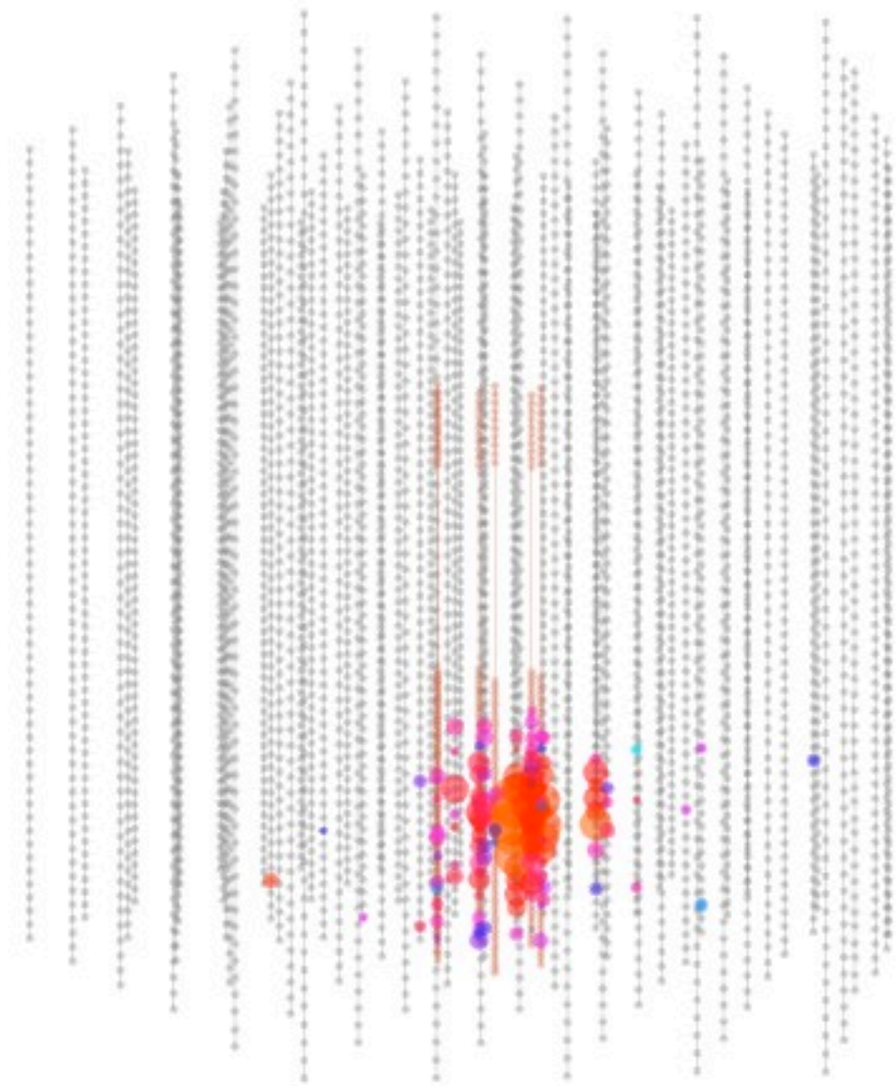


Selected Events

Preliminary



Run = 116020
Event ID = 20788565
2010/06/06



Run = 116100
Event ID = 13022869
2010/06/28

Atmospheric Cascades

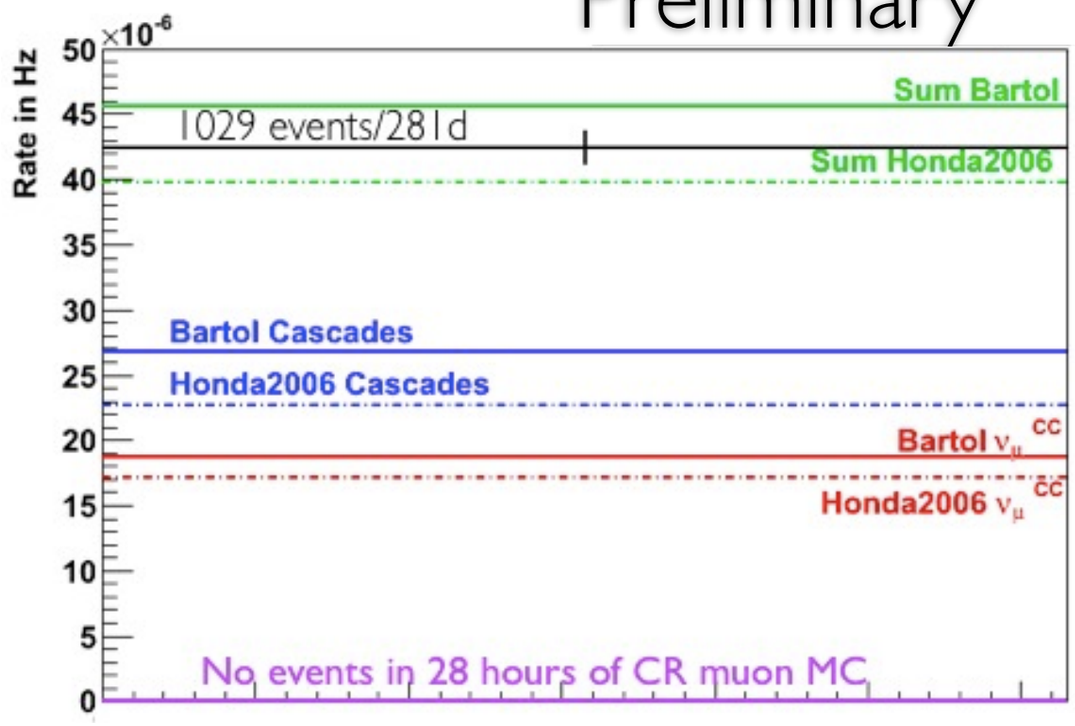
Preliminary

- Remaining data sample consists of 1029 events over 281 days
  - Significant efficiency losses to particle ID cut – improvements expected
  - Additional simulation needed to assess residual atmospheric muon background, systematic uncertainties

- Appear sensitive to differences in atmospheric neutrino models
  - Energy range roughly 30 GeV – 1 TeV

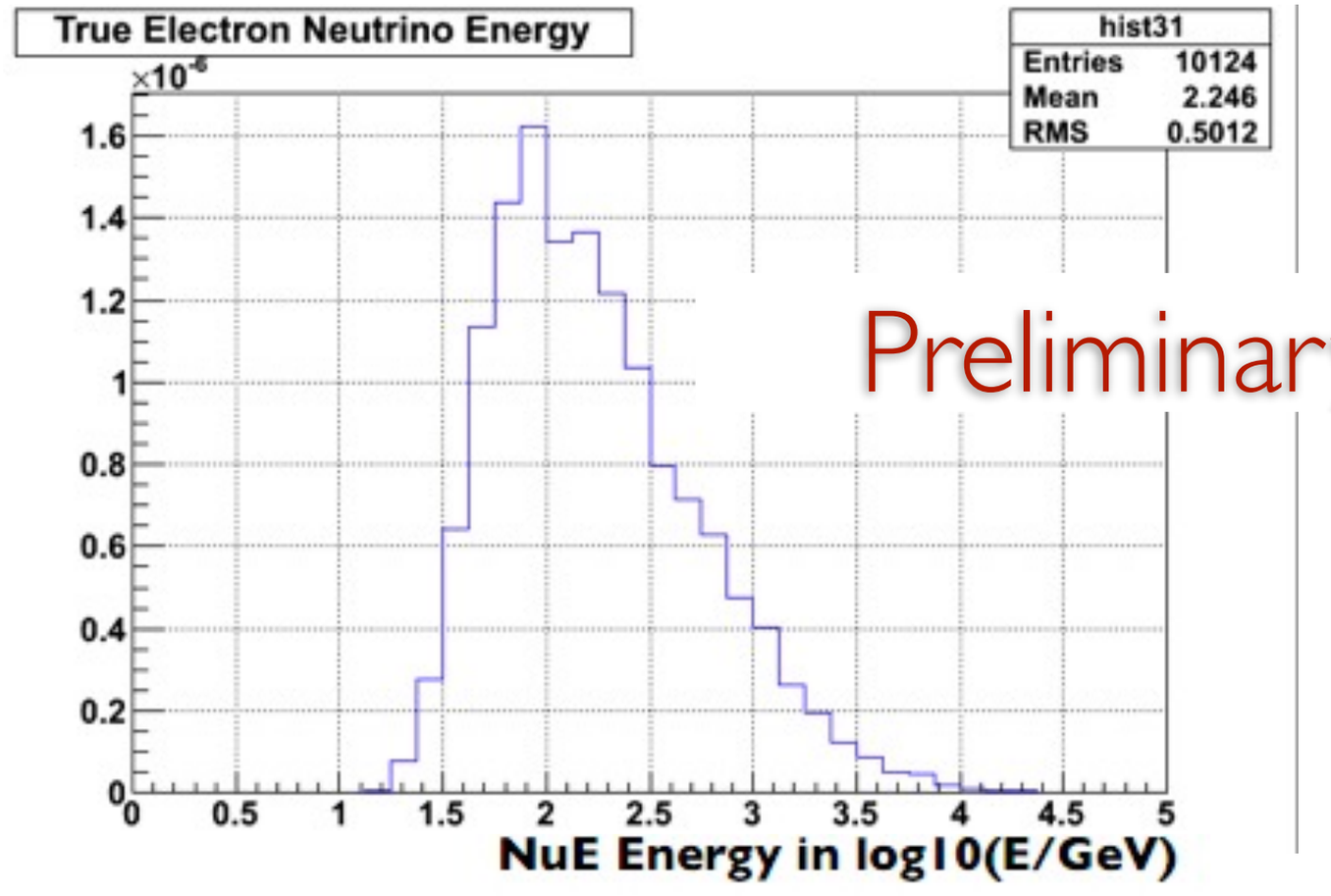
	Cascades	CC ν_μ	Total
Bartol	650	454	1104
Honda	551	415	966
Data			1029

Preliminary



Atmospheric Energy Distribution

- Energy threshold raised significantly by final event quality (particle ID) cuts
- Work to produce lower energy sample in progress
  - Sensitivity to neutrino oscillations (tau appearance) seems possible
  - Requires detailed understanding of systematics, better reconstructions, or both



<NuE> ~180 GeV

Conclusions

- Cascade searches rely on both event quality and containment to identify neutrino-induced cascades
  - Balance between the two depends on energy scale of interest – at lower energies fluxes allow smaller fiducial volumes, at higher energies events are less idiosyncratic and backgrounds are lower
- Searches for diffuse astrophysical ν_e / ν_τ fluxes underway
  - Additional background systematics due to CR composition uncertainties
  - Better containment possible with more recent data: higher signal yields?
- Clear observation of atmospheric cascades (still preliminary result)
  - Still lots to do – better particle ID needed, working toward lower energy threshold, need to understand systematics better to extract physics