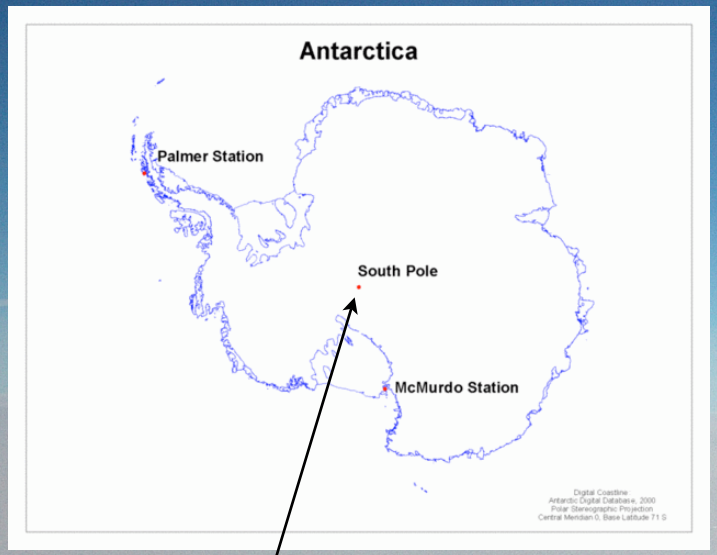
Searching for SUSY with IceCube

Alex Olivas

University of Maryland

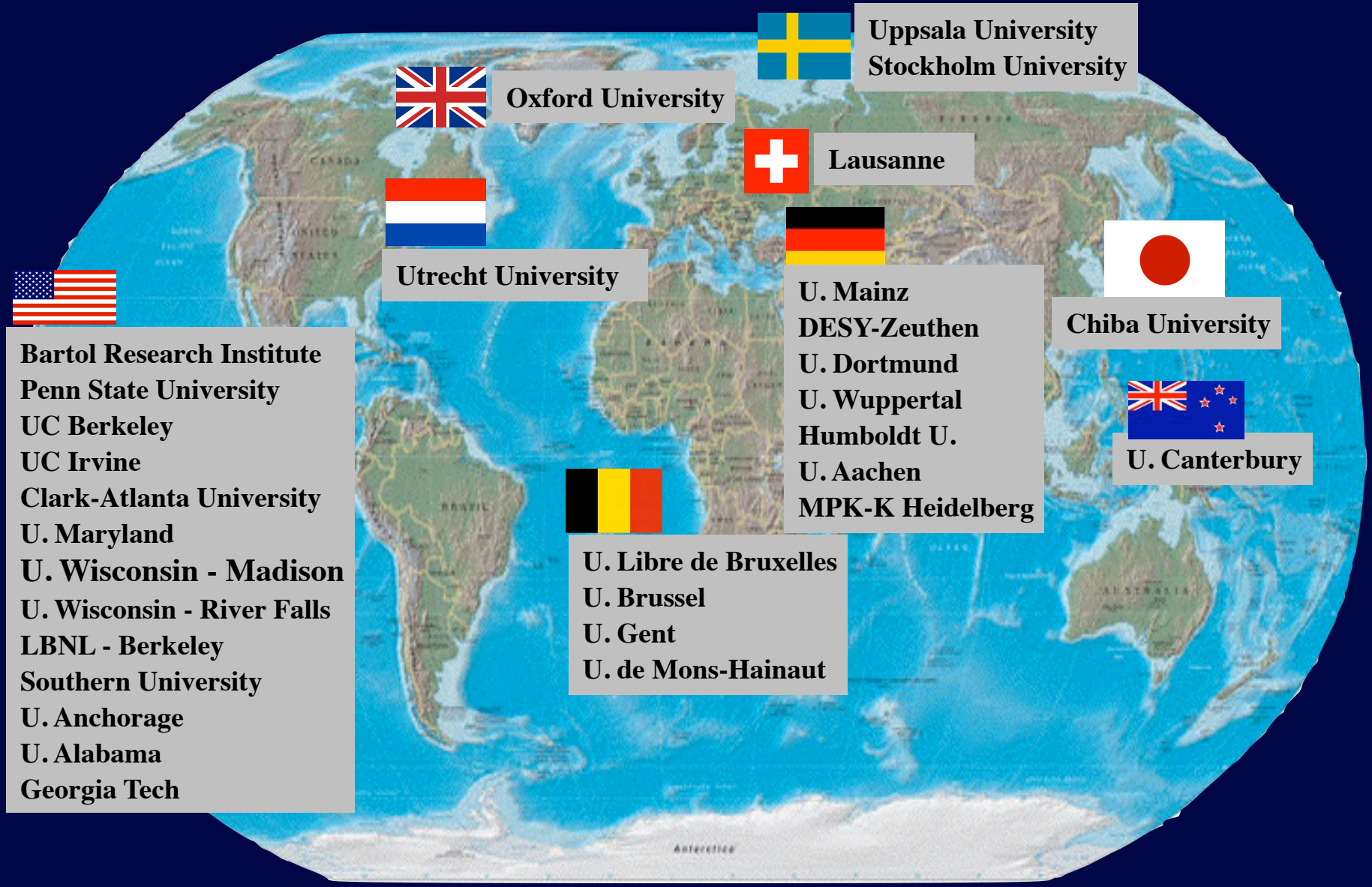
(for the IceCube Collaboration)



Admudsen-Scott
South Pole Station

IceCube

The IceCube Collaboration



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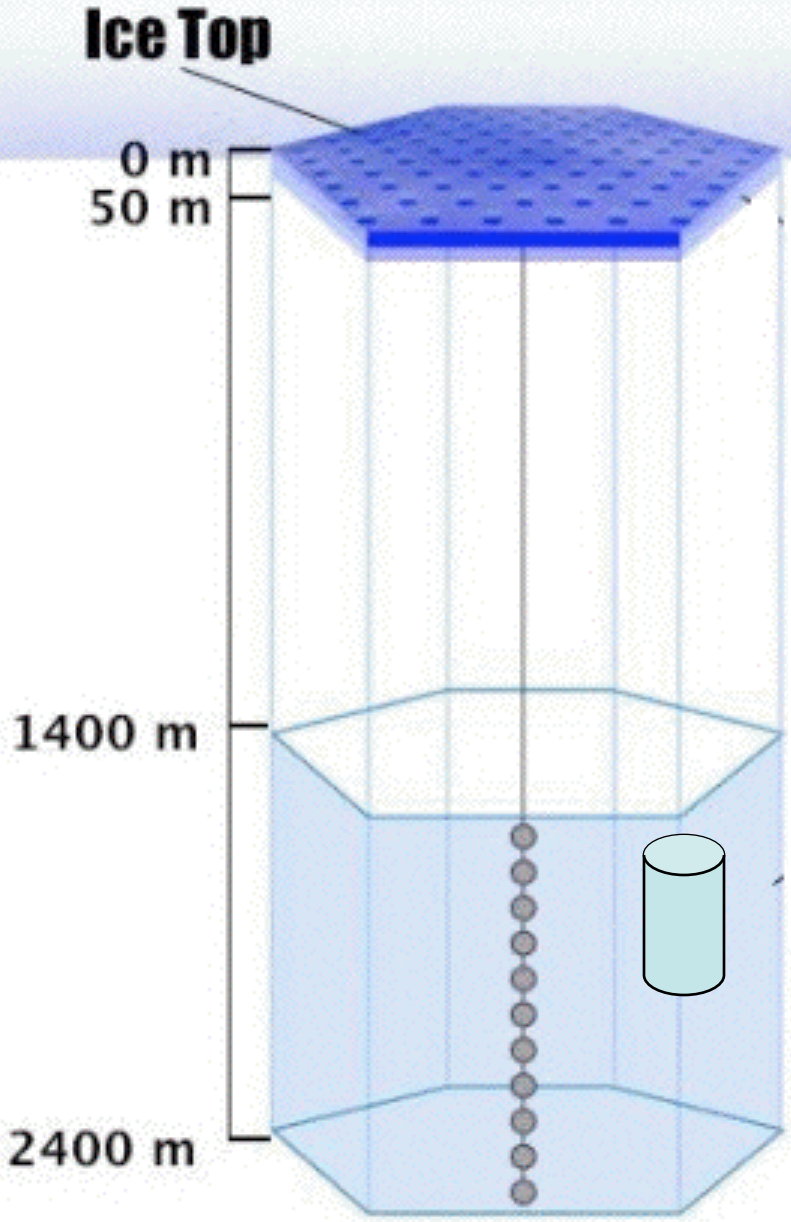


AMANDA

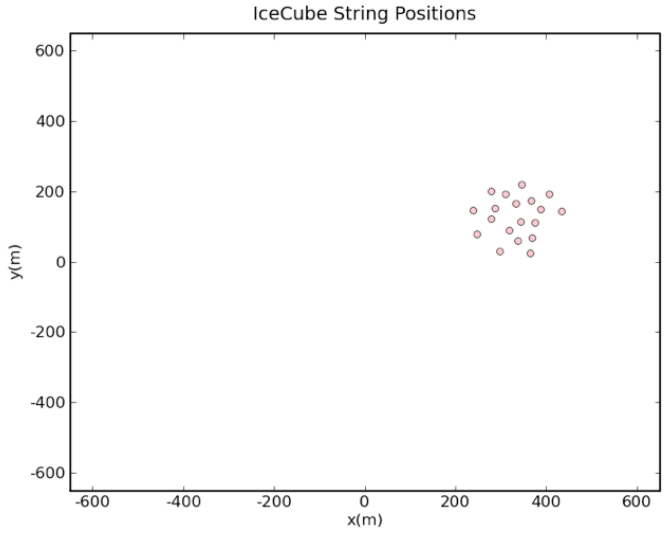
- 19 Strings
- 677 Optical Modules (10-20m spacing)

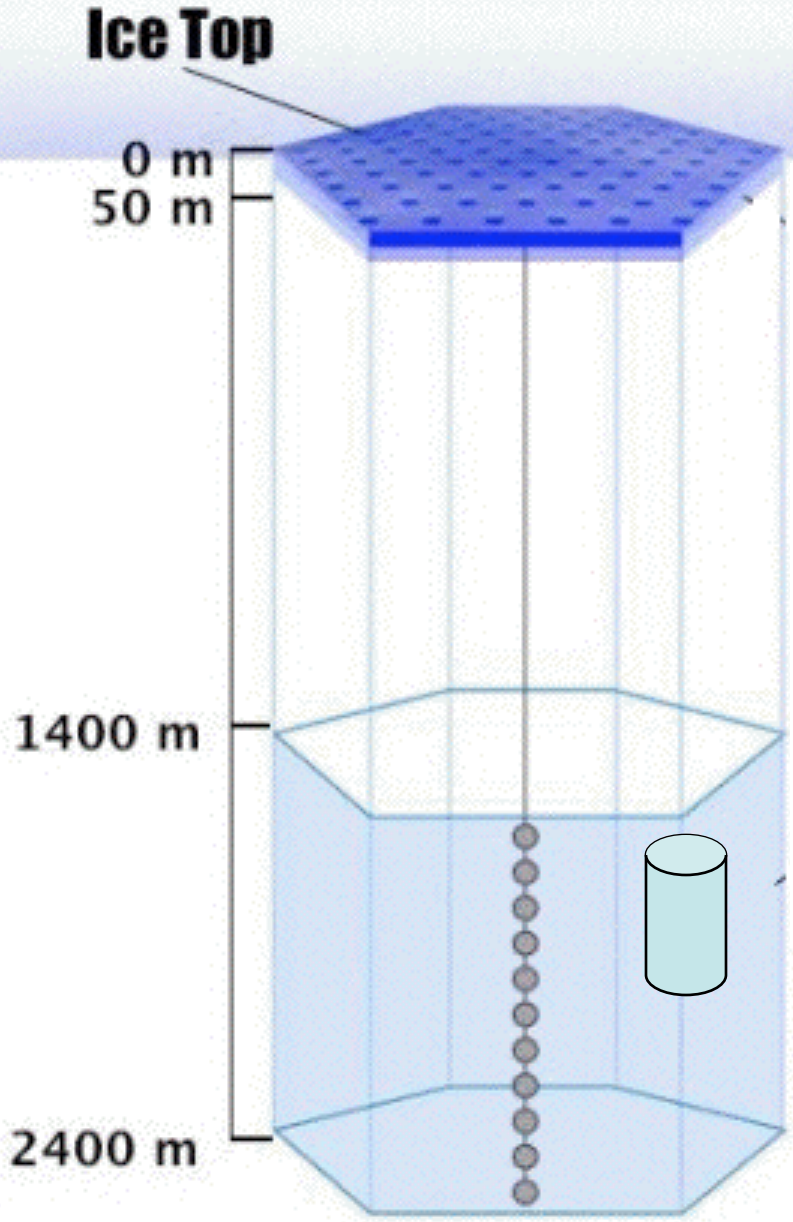
IceCube

- Strings spaced125 m apart on hexagonal grid
- 60 optical modules per string (~17m spacing)
- Cubic kilometer of instrumented ice

IceTop

- Surface array of 80 stations
- 2 ~2.3m^3 surface ice tanks per string
- 2 optical modules per tank (high and low gain)





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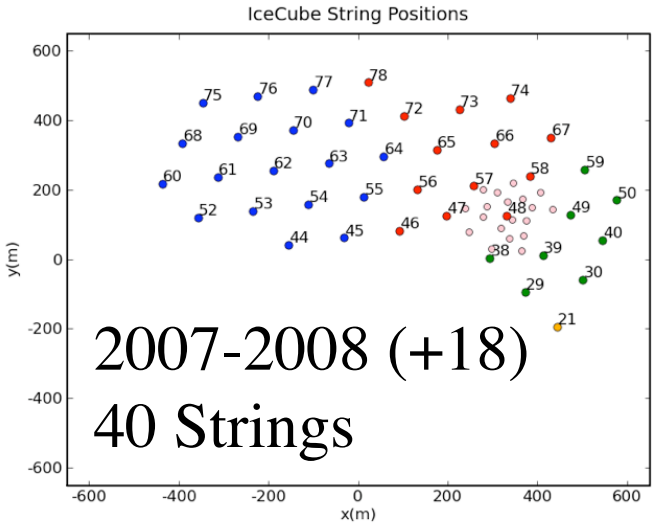

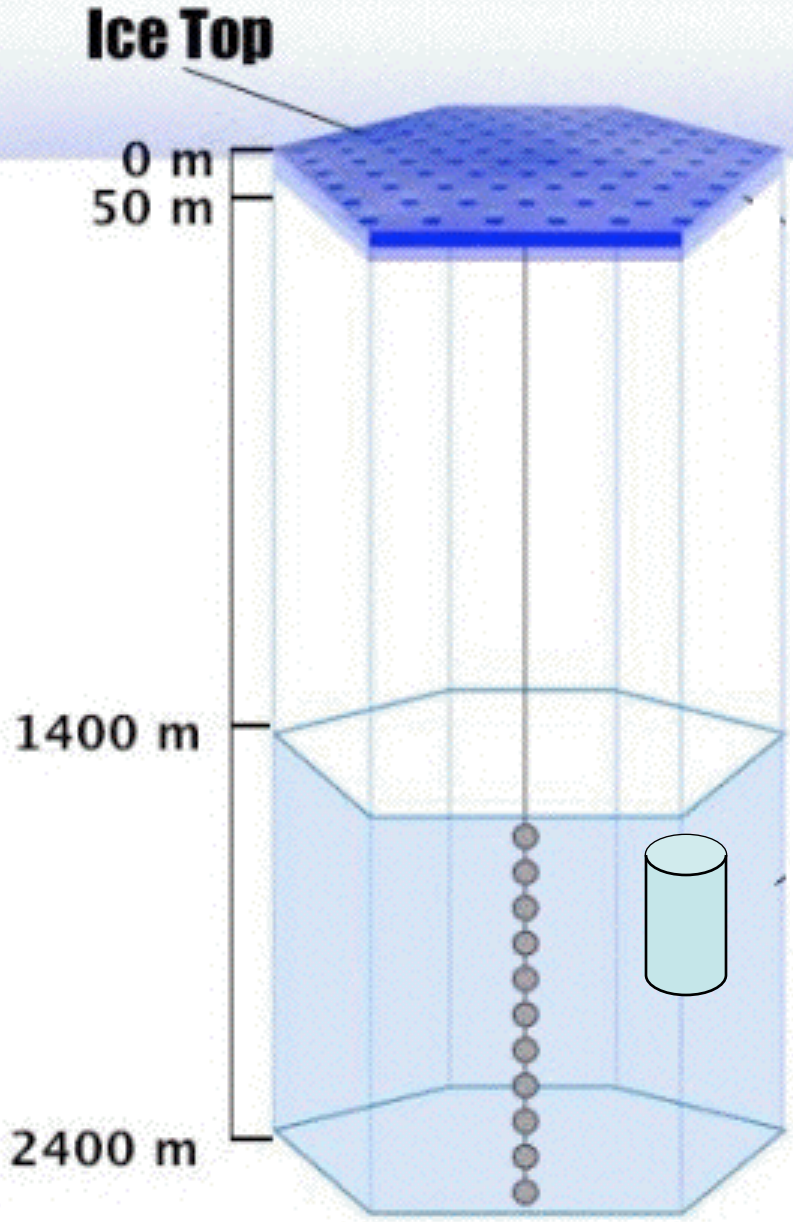

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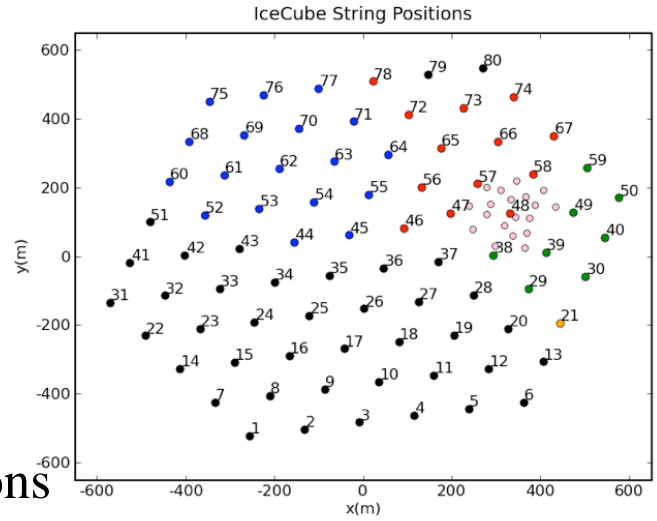
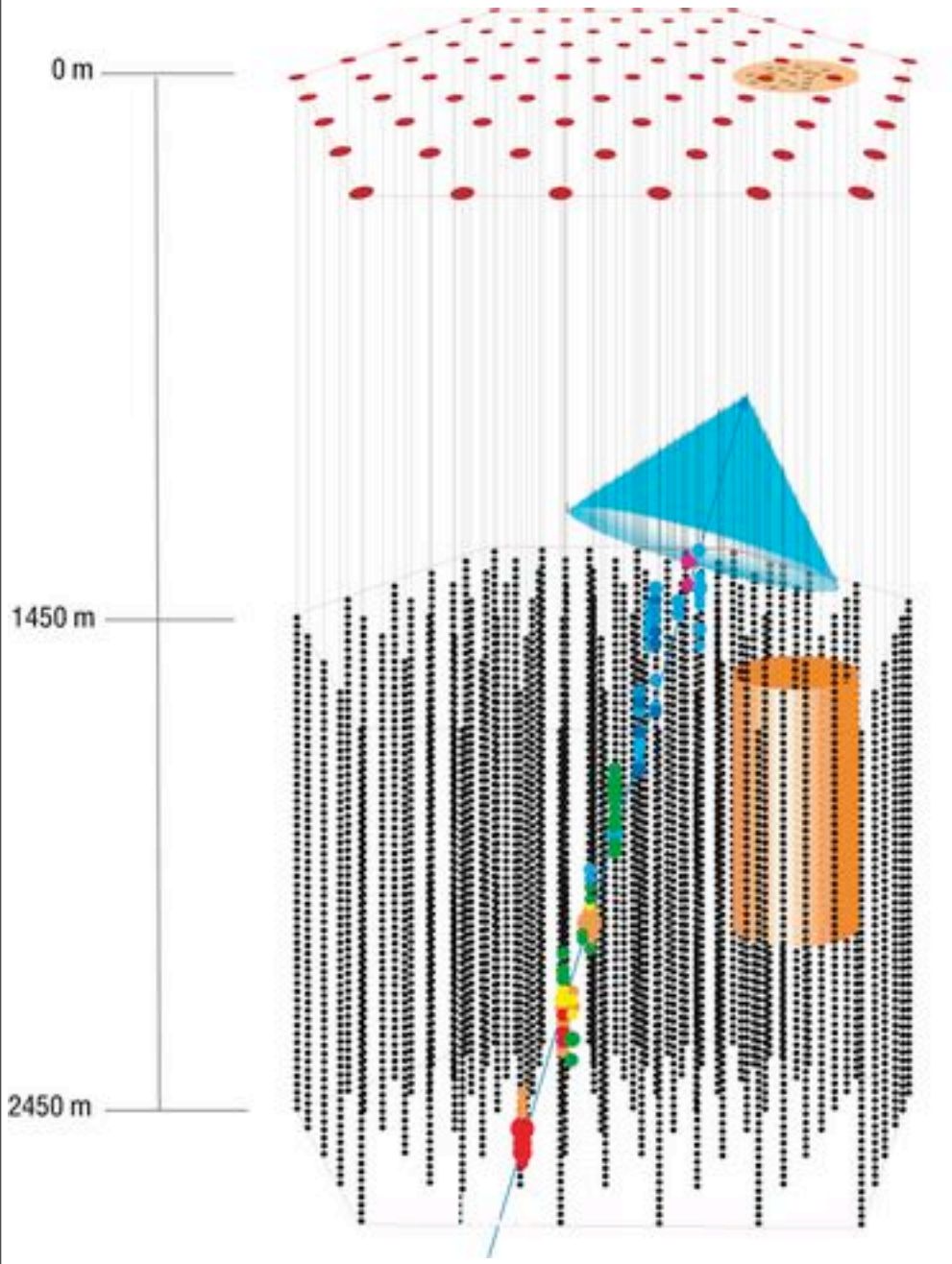
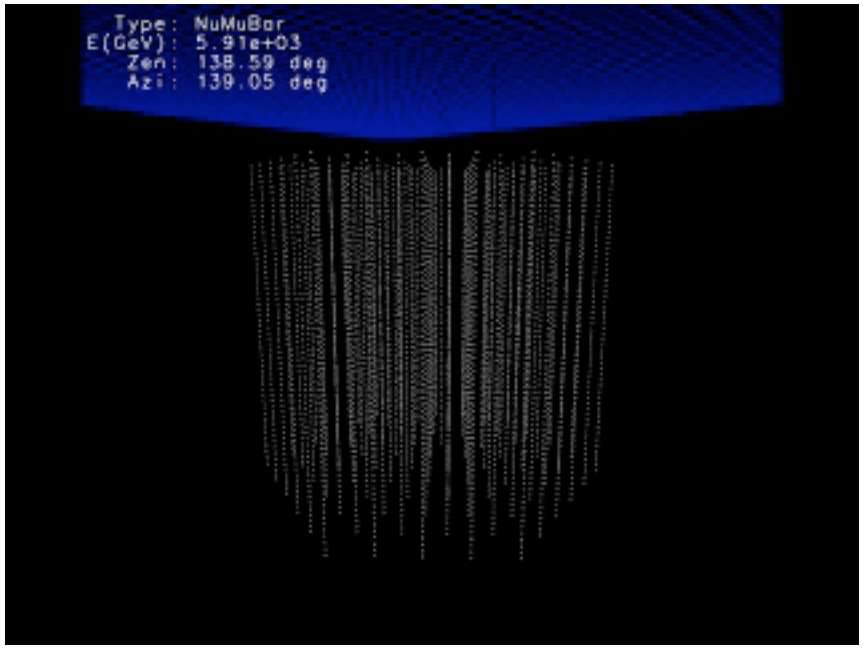


Currently 40 IceTop Stations



Simple case of incoming ν_μ

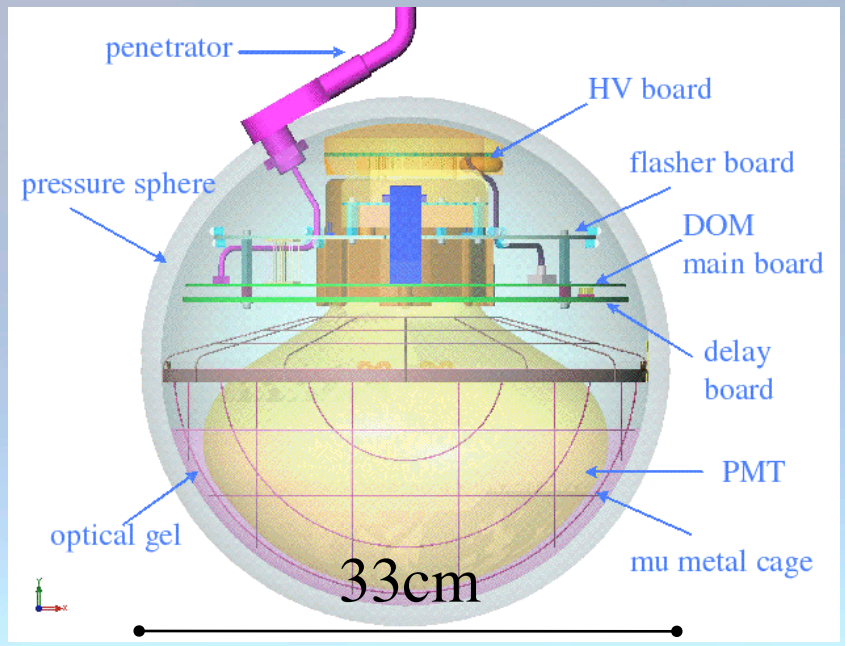
1. Incoming ν interacts with N
2. Muons generate Cherenkov light
3. Cherenkov photons detected in DOM
4. Reconstruct μ from photon arrival times



Simulation - 80 strings

DOM

Digital Optical Module



Measures arrival time of photons

2 ATWD

- **Analog Transient Waveform Digitizers**
- **300MHz for 400ns**
- **3 gain channels each(low, medium, high)**
- **ping-pong to minimize deadtime**

fADC

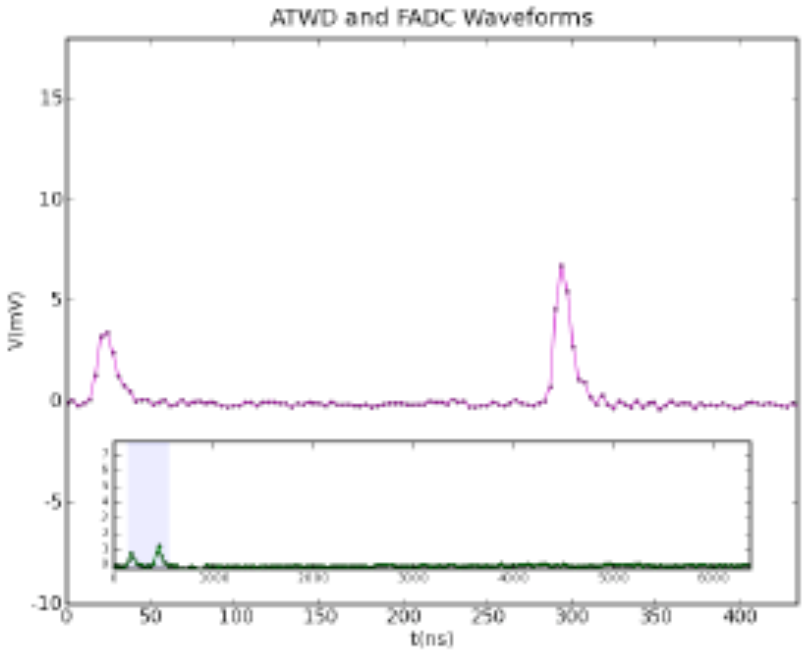
- **fast Analog to Digital Converter**
- **40MHz for 6.4μs**

Local Coincidence triggering

- **Hard Local Coincidence**
- **Soft Local Coincidence (isolated hits)**

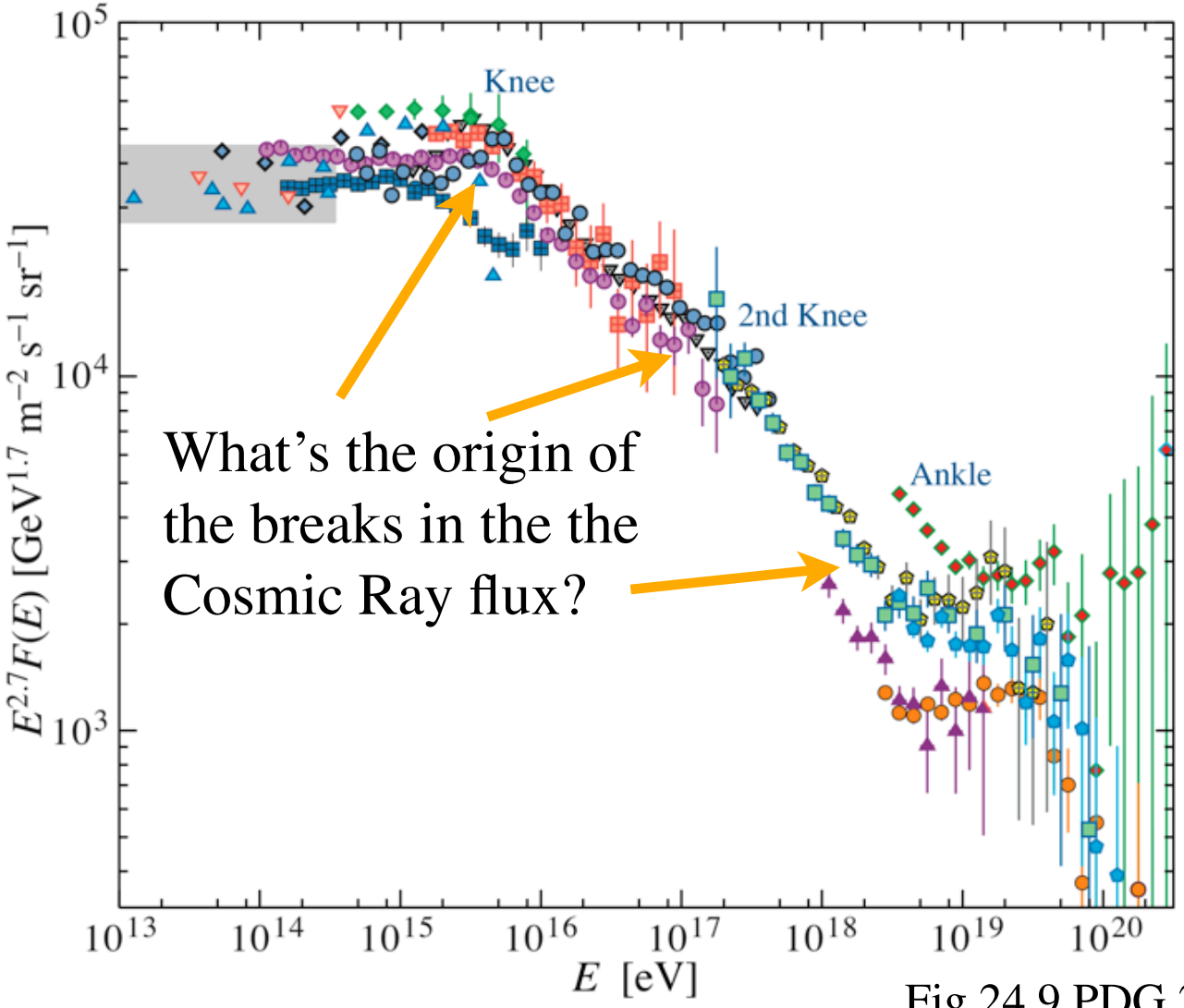
Improvements over AMANDA OMs

- **Digitize waveforms in-ice ⇒ surface**
- **Lower noise ~ 400Hz**



What's the Origin of Cosmic Rays?

All Particle Cosmic Ray Flux x $E^{2.7}$



Particle Data Group 2007
http://pdg.lbl.gov/

Fig 24.9 PDG 2007

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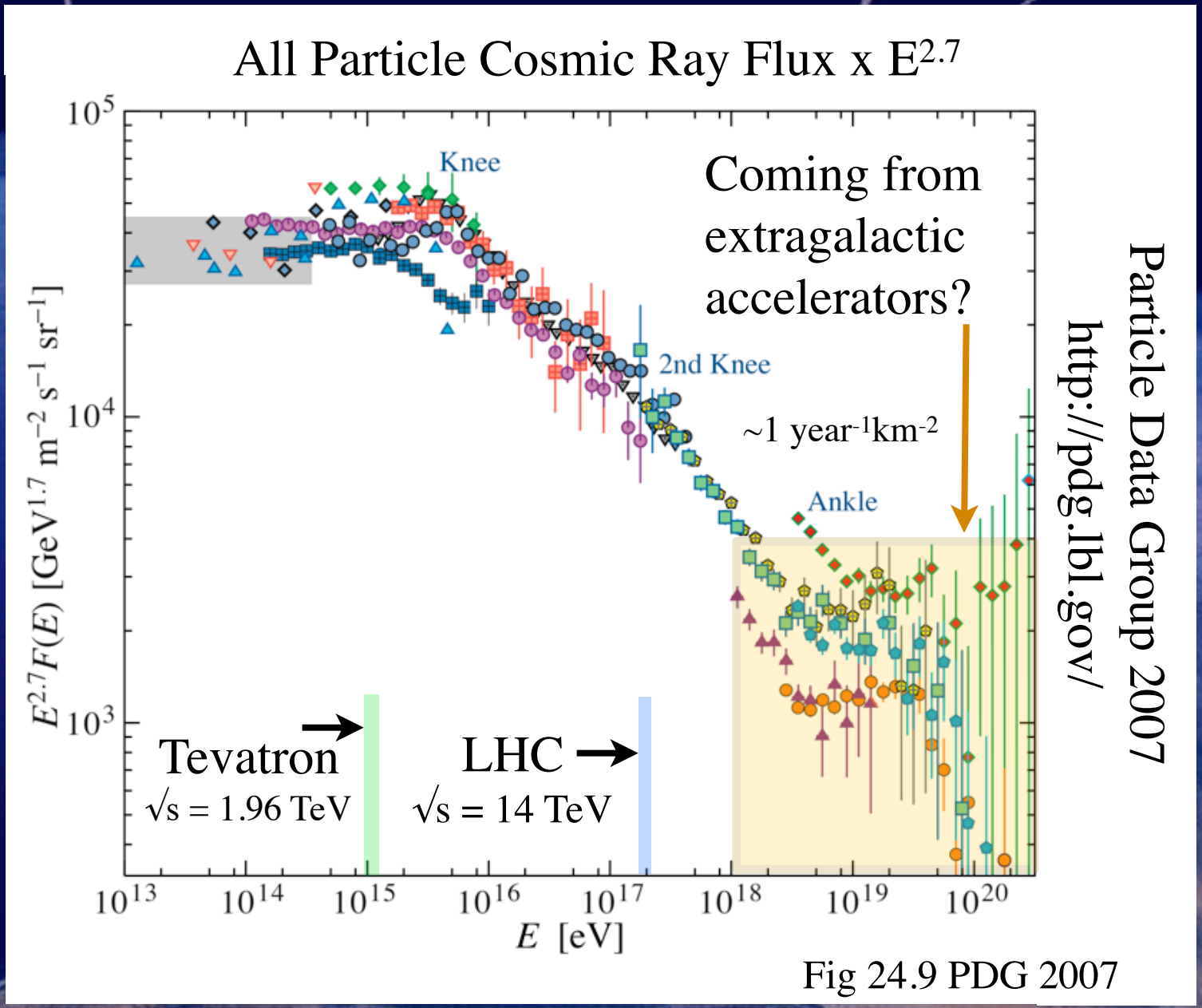


SUSY on IceCube

All Particle Cosmic Ray Flux x $E^{2.7}$

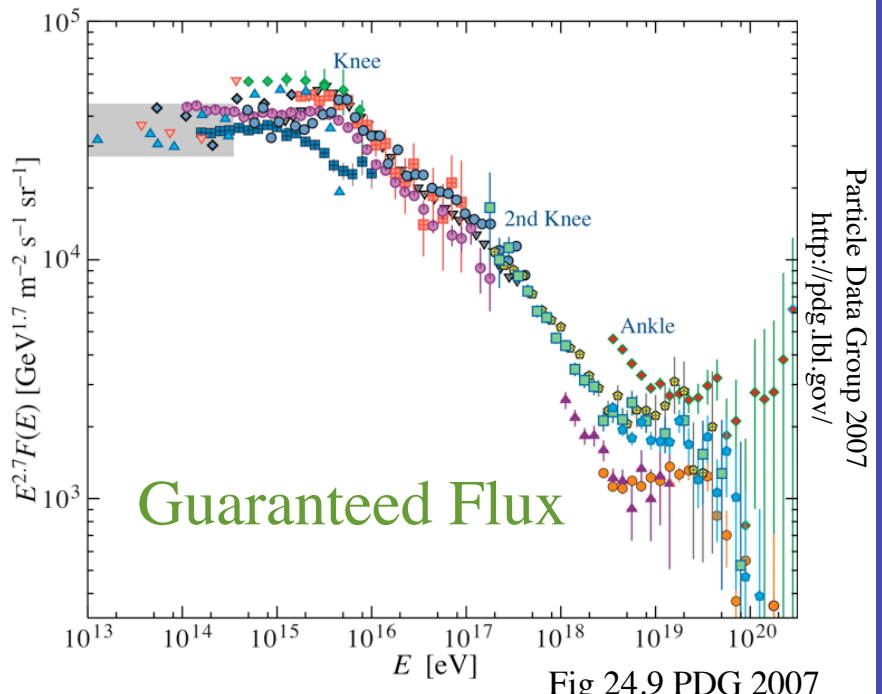
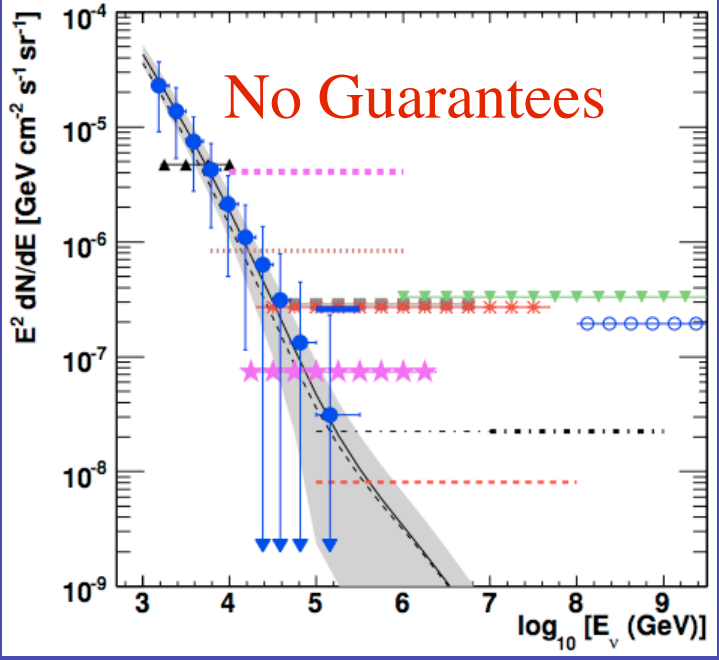
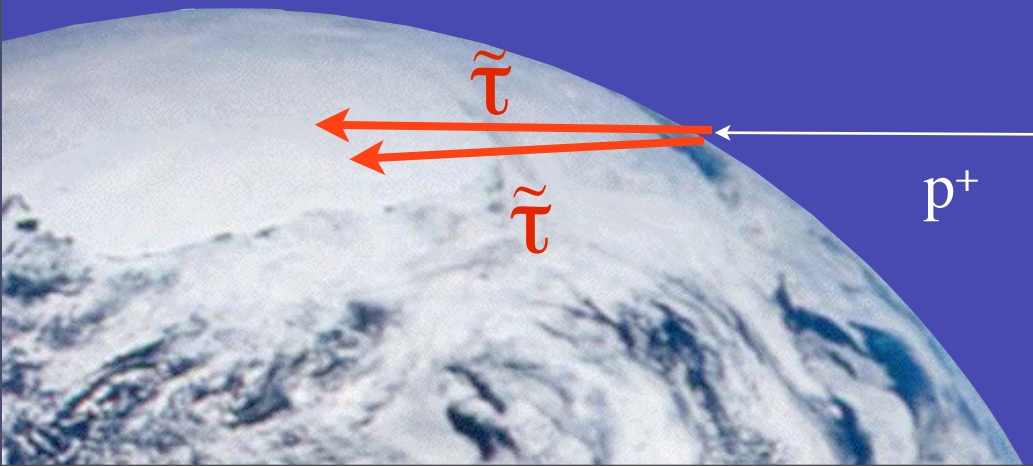


Fig 24.9 PDG 2007

vs.

Diffuse Neutrino Flux x E^{-2}



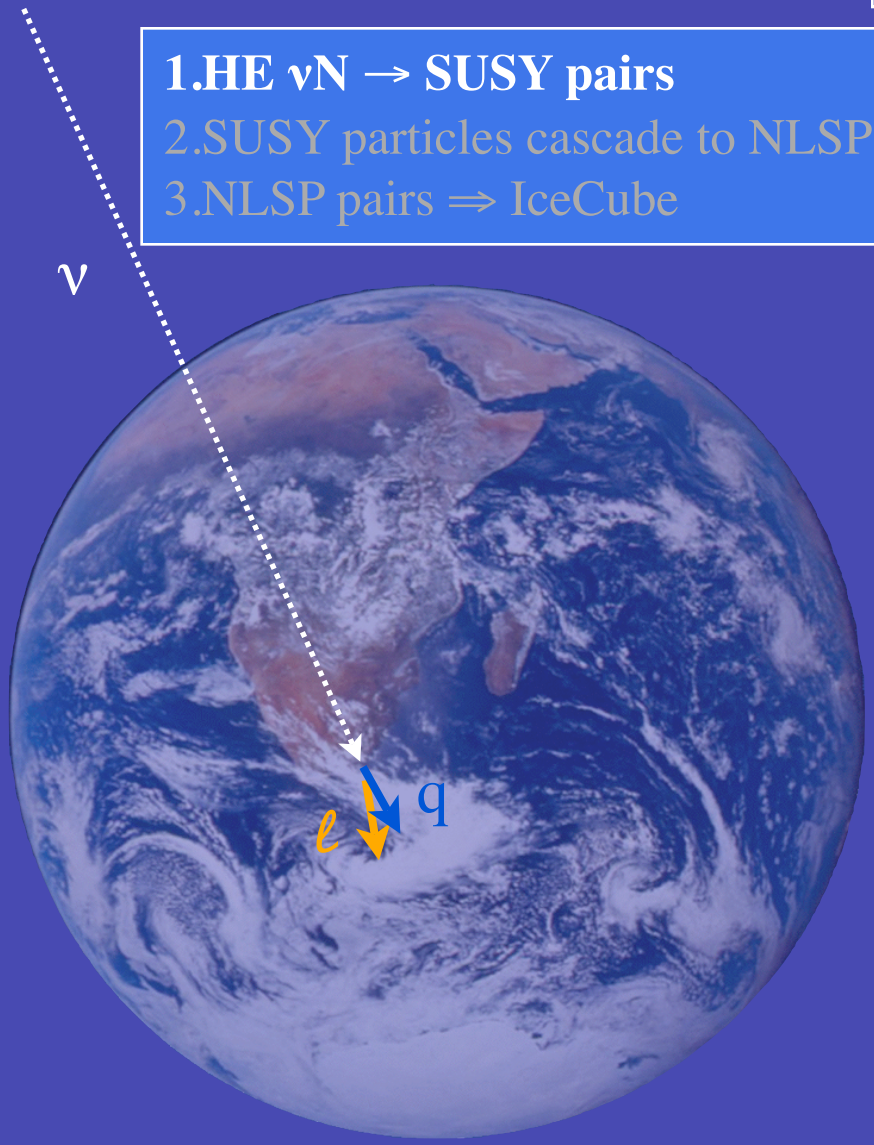


Neutrino Flux uncertain above 100 TeV

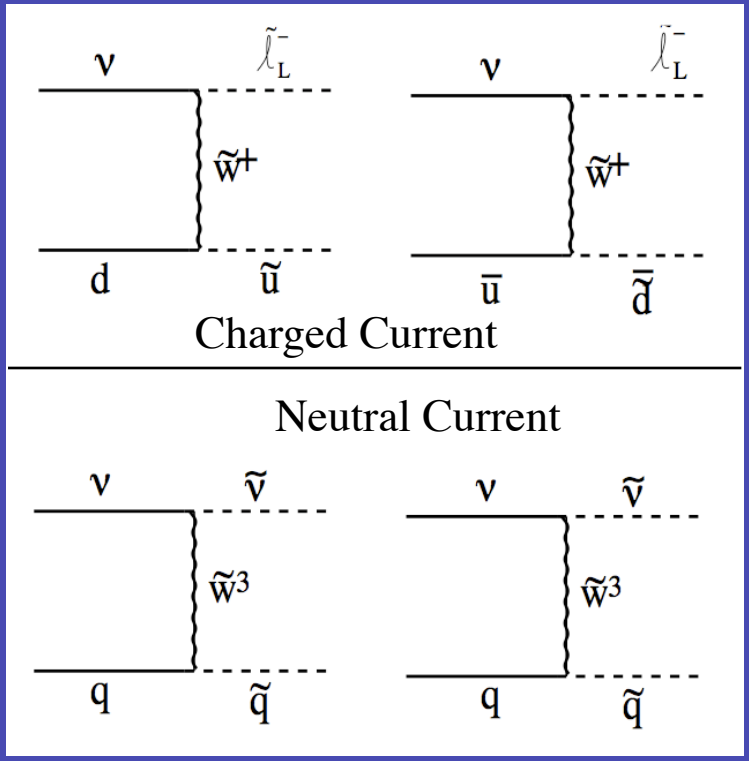
SUSY Pair Production in ν-N Collisions

I.F.M. Albuquerque, G. Burdman,
Z. Chacko
arXiv:hep-ph/0605120v2

1.HE νN → SUSY pairs
2.SUSY particles cascade to NLSP
3.NLSP pairs ⇒ IceCube



$$\nu + N \rightarrow \ell_L + q$$



Every final state contains a slepton and a squark

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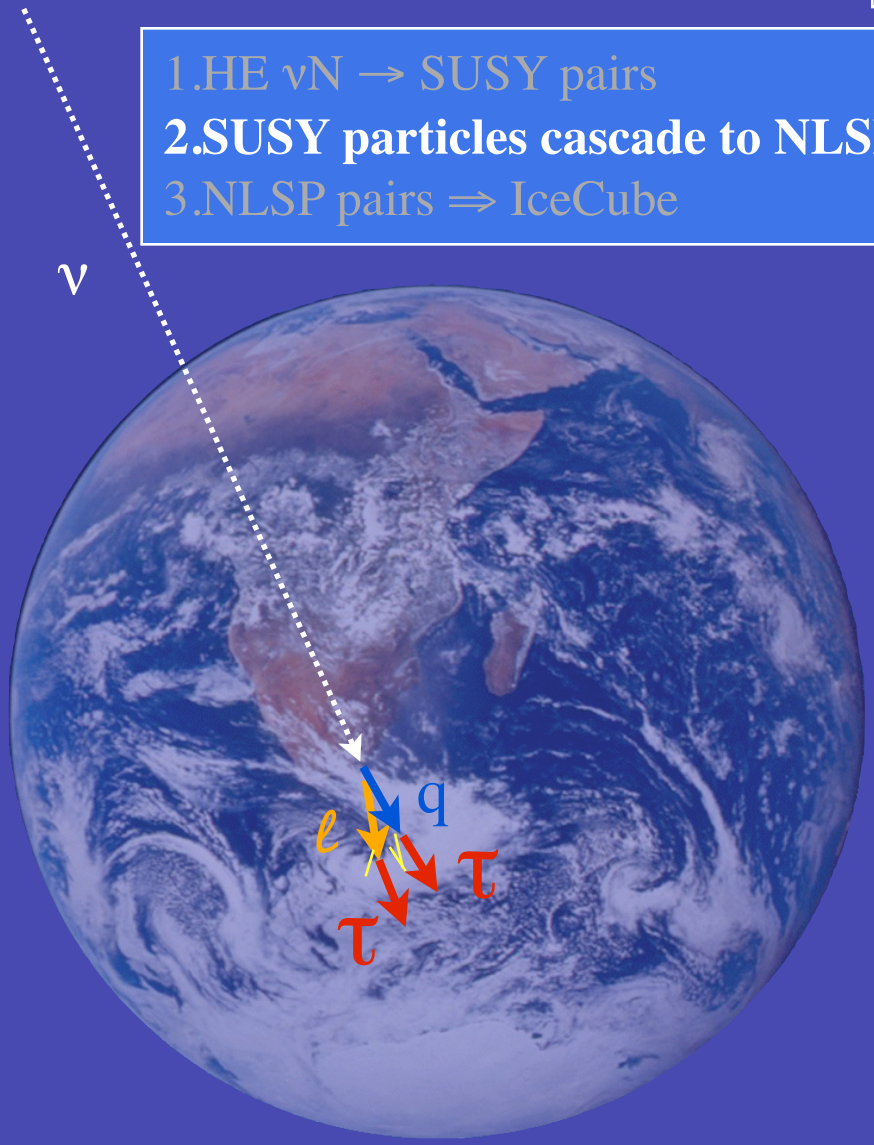

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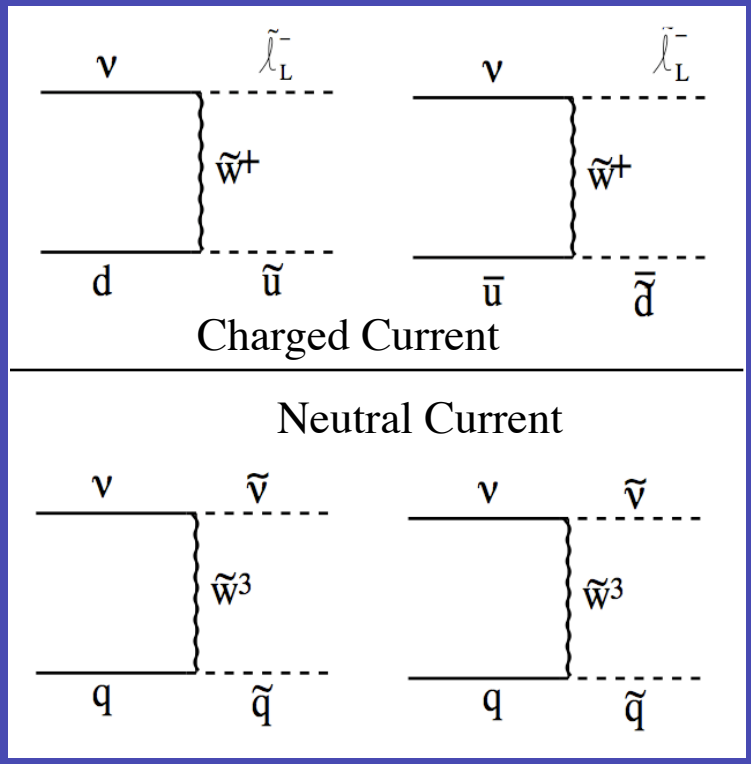

Heavy sleptons and squarks decay eventually to NLSP + SM

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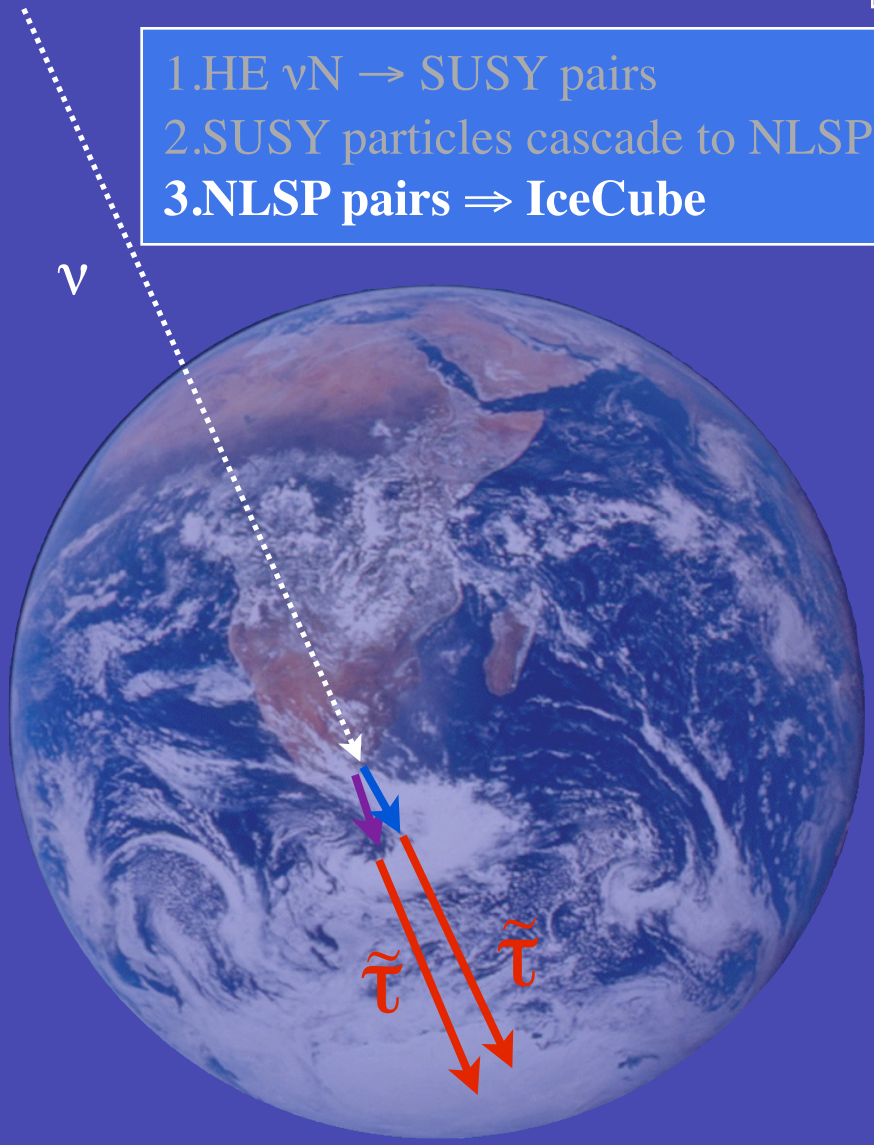
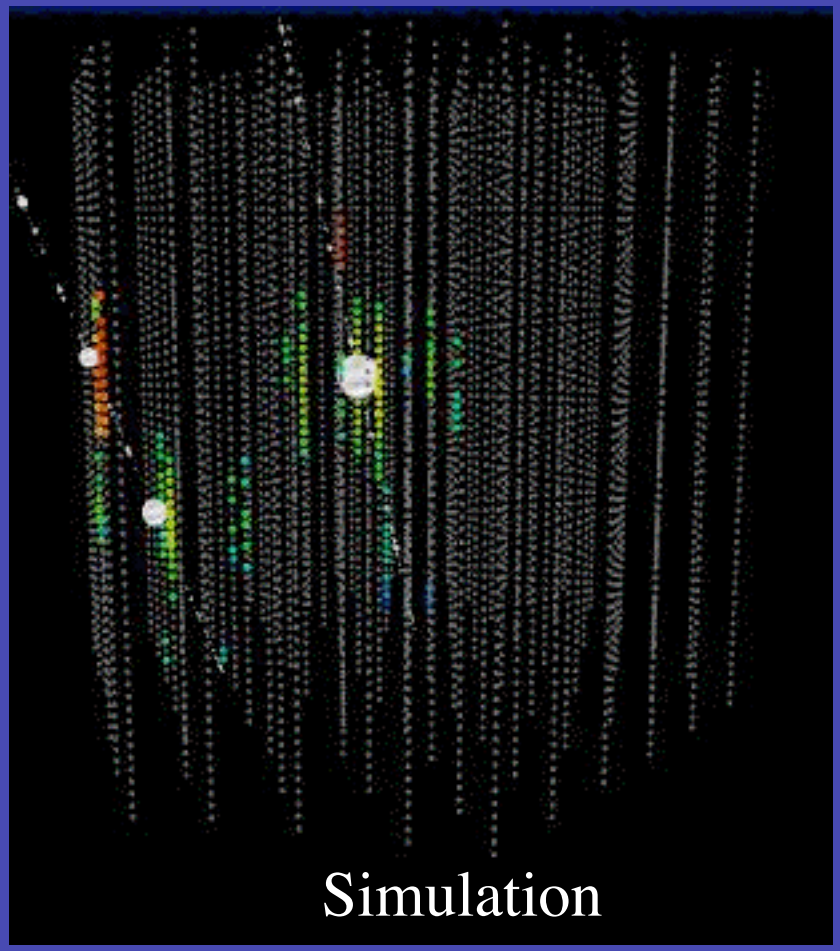


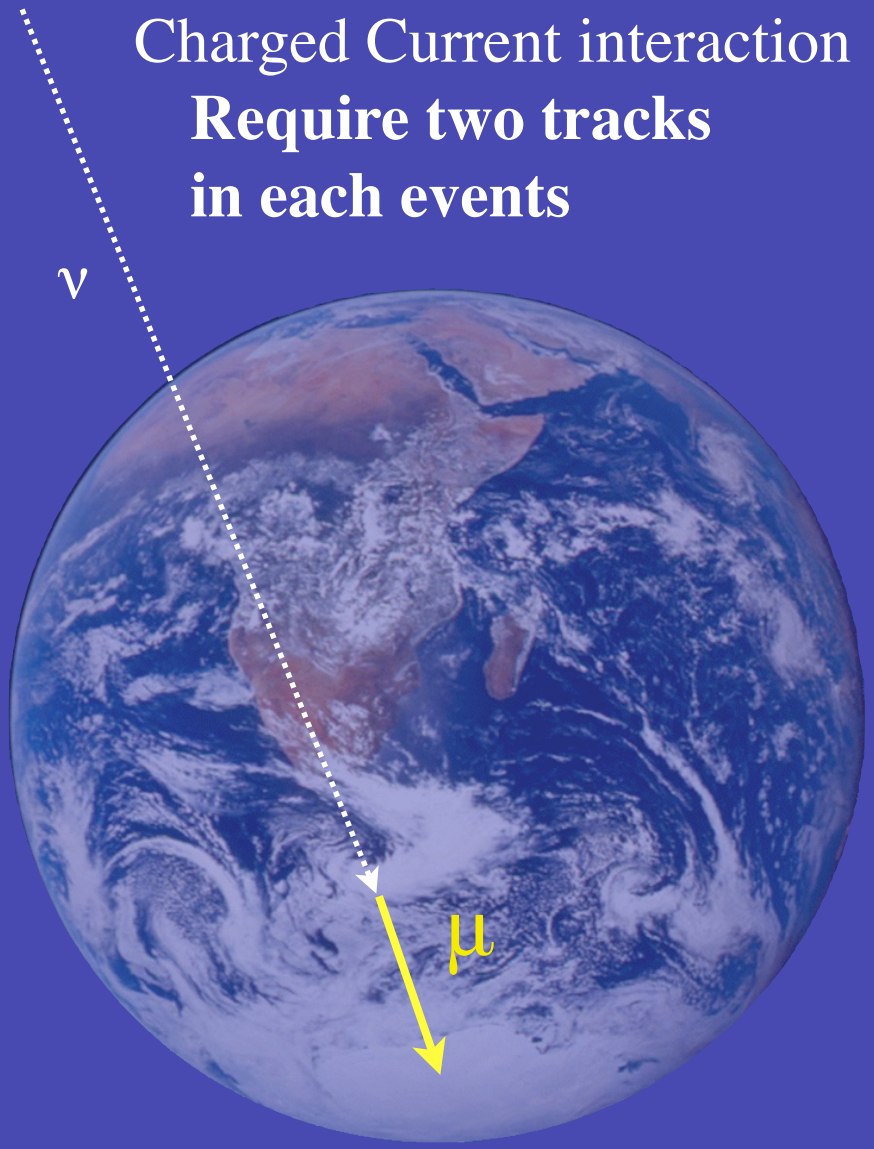


SUSY Pairs

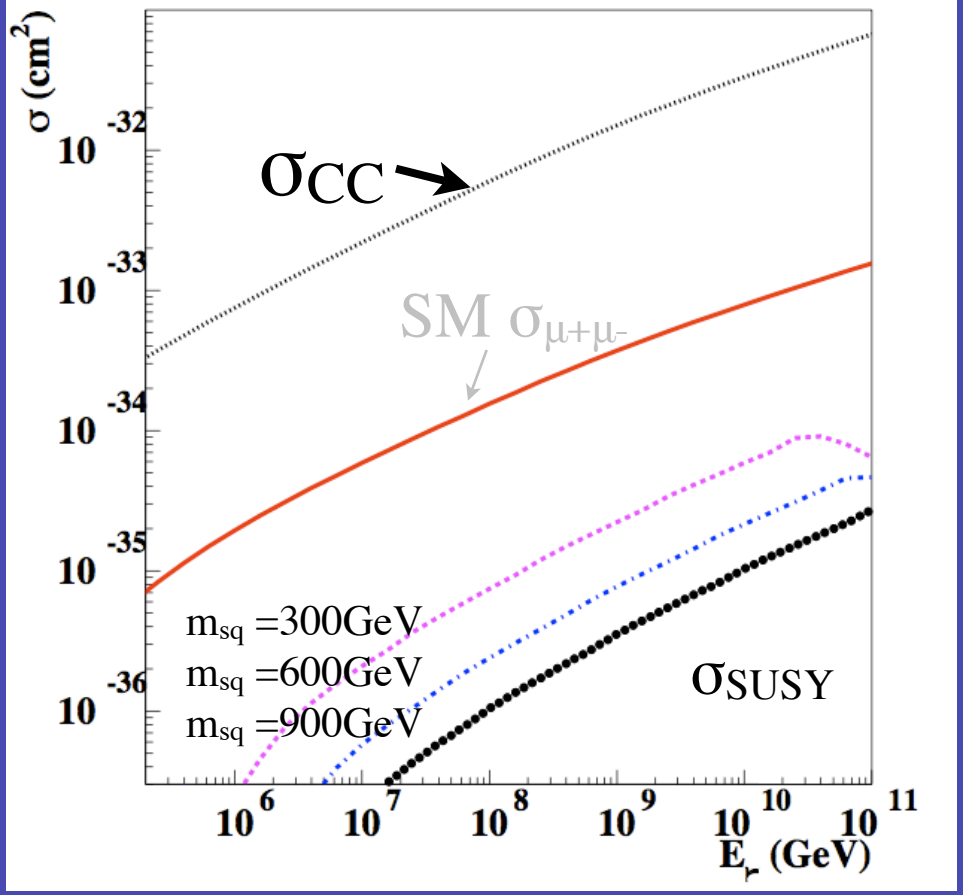
Standard Model Background

Dominant background
is single muons from SM
Charged Current interaction

Require two tracks
in each events



Production Cross Sections



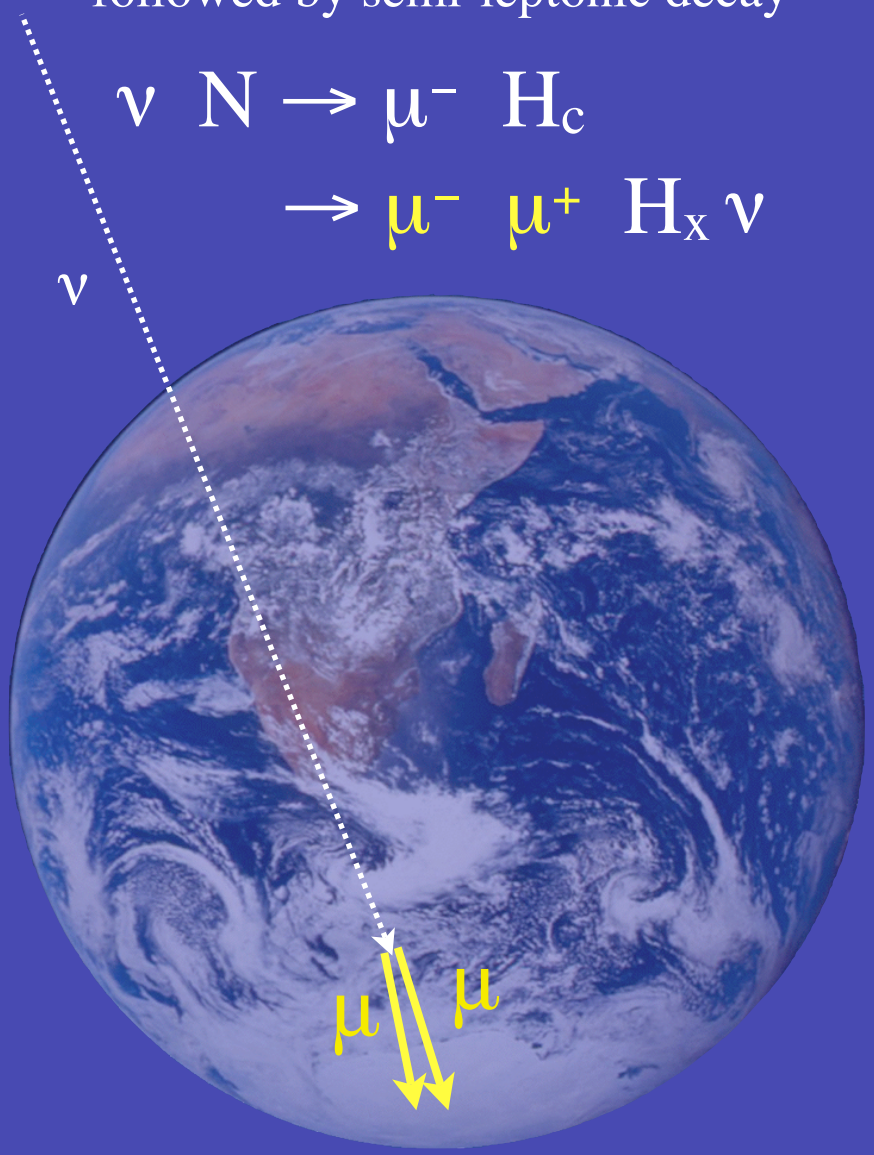
I.F.M. Albuquerque, G. Burdman,
Z. Chacko
arXiv:hep-ph/0605120v2

SUSY Pairs

Standard Model Background

Di-muon background from charm hadron production followed by semi-leptonic decay

$$\nu\ N \rightarrow \mu^-\ H_c$$
$$\rightarrow \mu^-\ \mu^+\ H_x\ \nu$$



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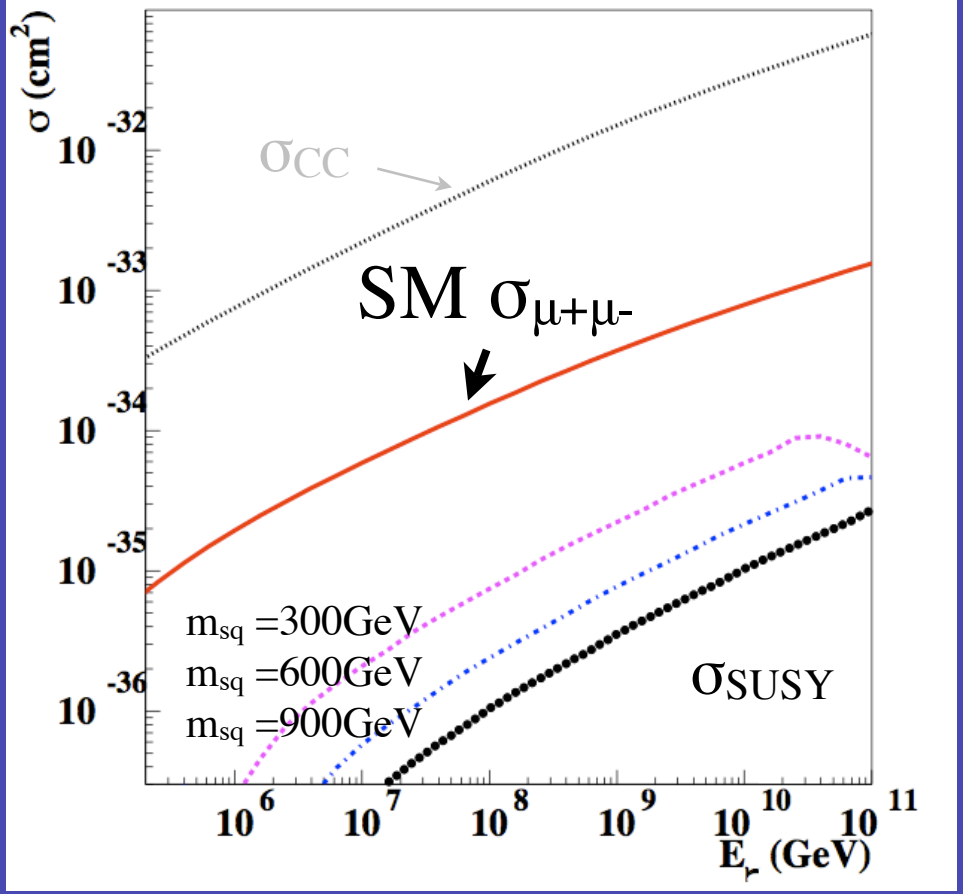

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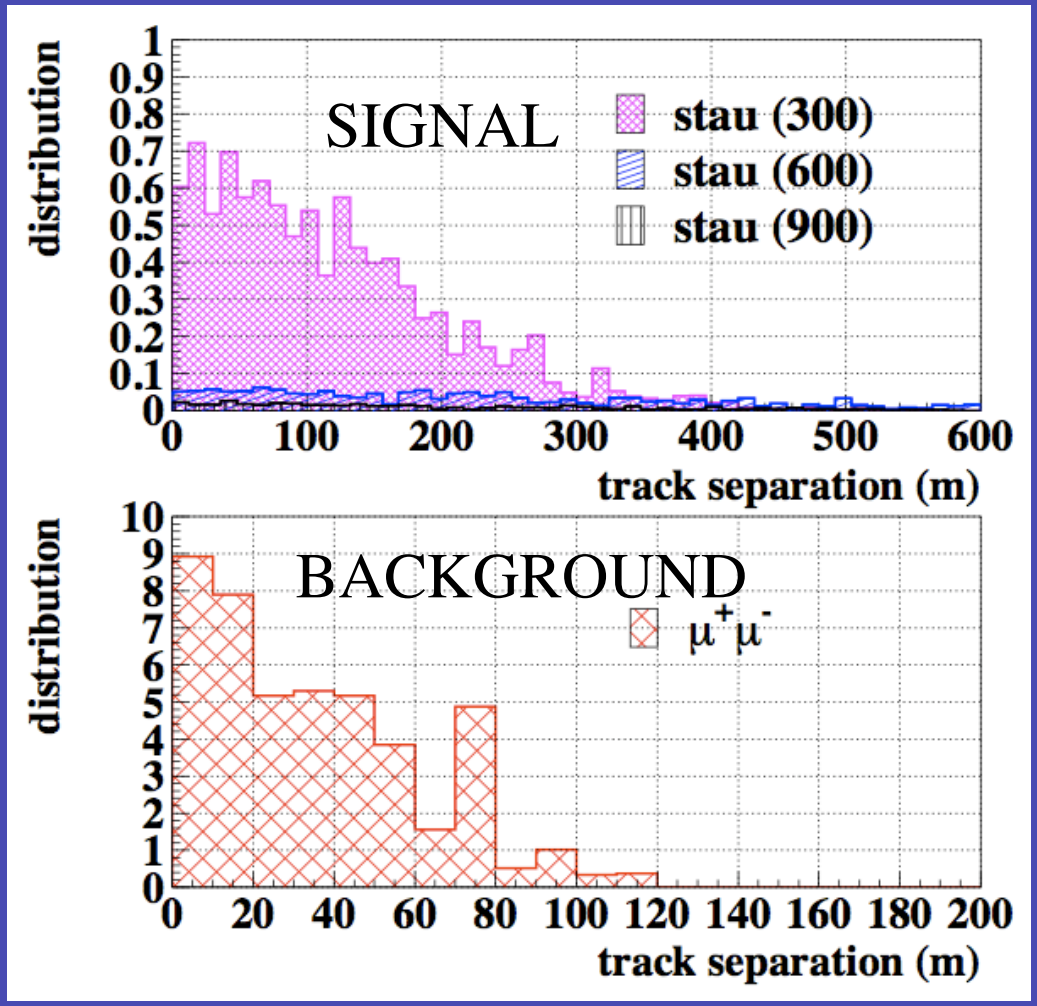
Stau Signal and Background



stau separations on the order of 100s m.

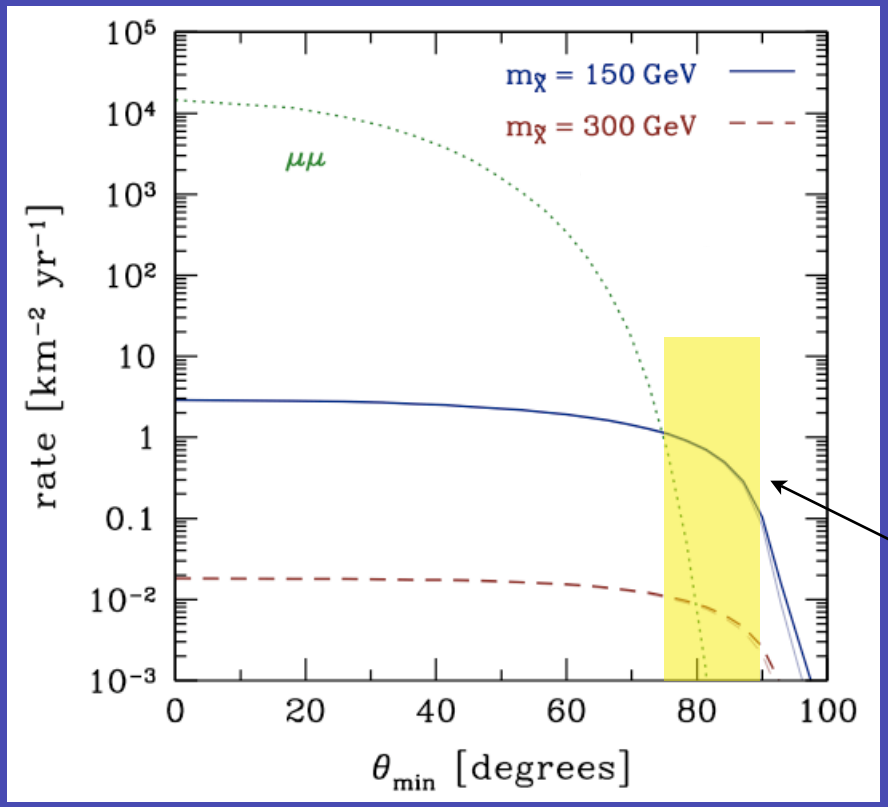
Not a significant background from $\mu^+\mu^-$ for track separations above 100m.

Place a cut on the track separation at 100m

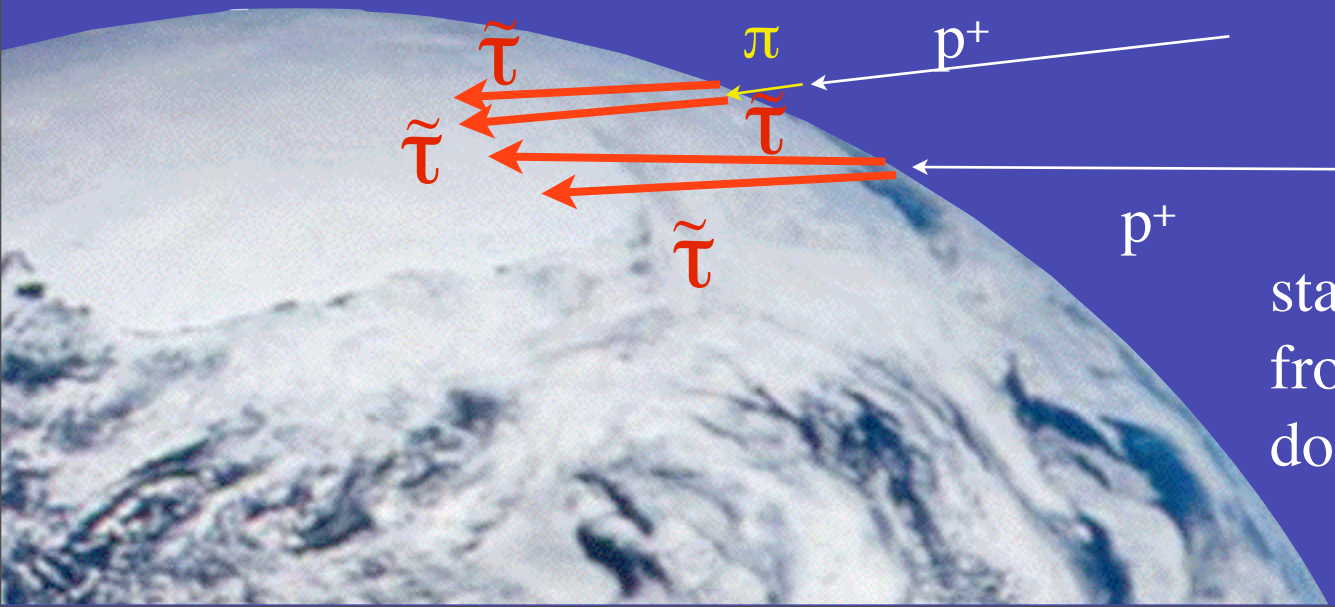
If we see 3 NLSP pairs on a background of 0.25 Significance of 5σ

SUSY in High Energy p-N Collisions

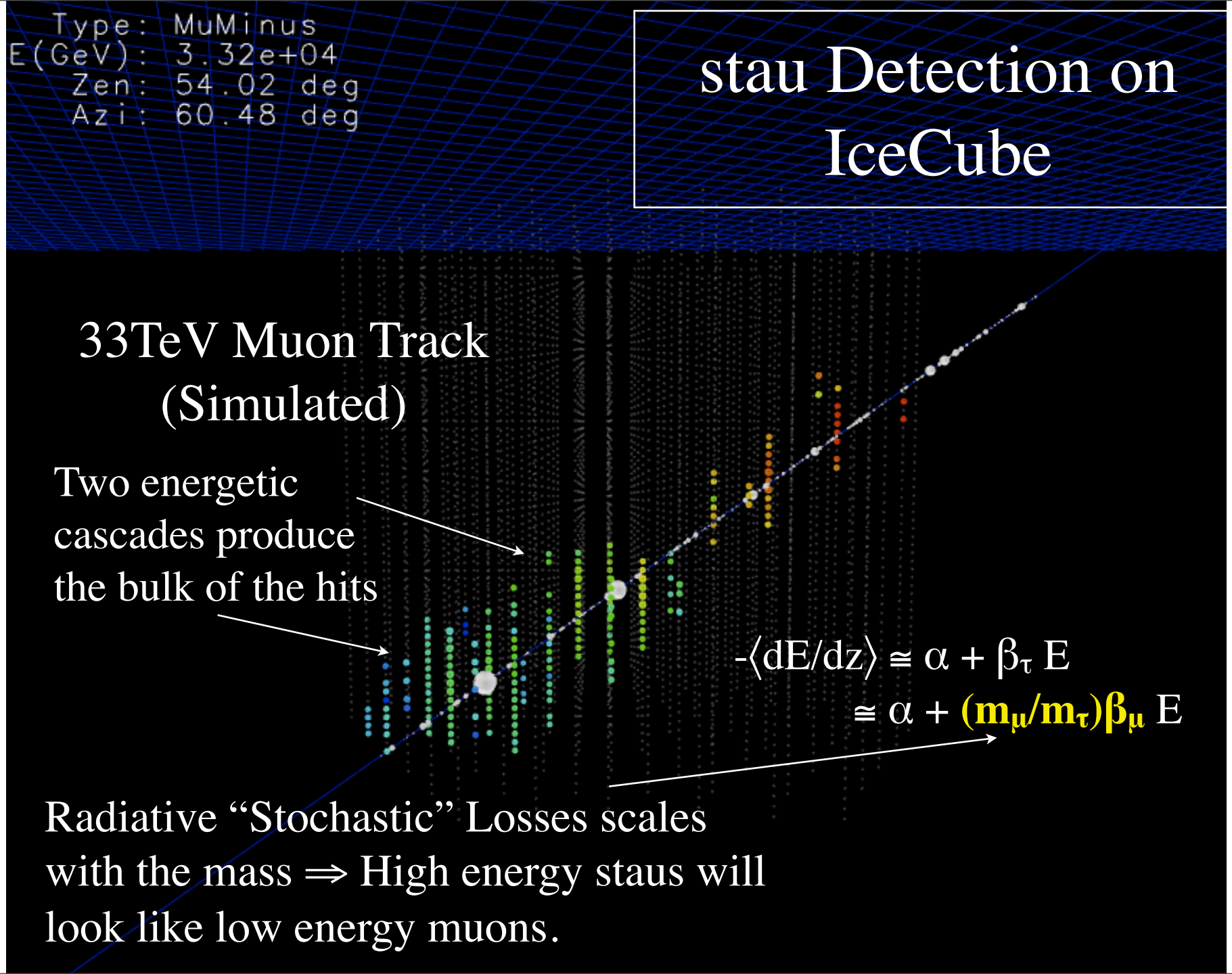
M.Ahlers, J.I. Illana, M. Masip, D. Meloni
arXiv:0705.3782v1 [hep-ph]



SM $\mu^+\mu^-$ background $\theta<75^o$
Low background $\theta>75^o$
Signal Region : $75^o<\theta<90^o$



stau production
from secondary hadrons
dominate prompt



stau Detection on IceCube

33TeV Muon Track (Simulated)

Two energetic cascades produce the bulk of the hits

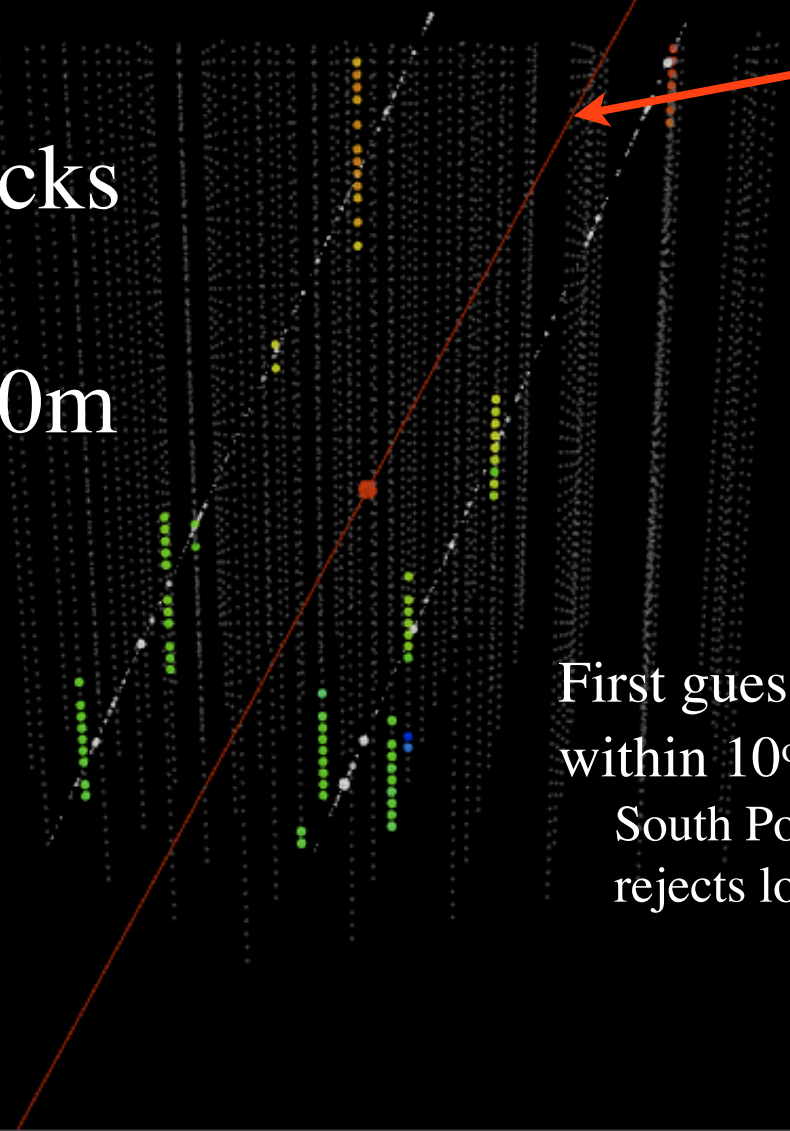
$$-\langle dE/dz \rangle \cong \alpha + \beta_\tau E$$
$$\cong \alpha + (m_\mu/m_\tau)\beta_\mu E$$

Radiative "Stochastic" Losses scales with the mass ⇒ High energy staus will look like low energy muons.

Type: STauMinus
E(GeV): 7.17e+06
Zen: 29.88 deg
Azi: 23.47 deg

SUSY double stau

Two parallel muon-like tracks separated by **more** than 100m



First guess reconstruction used in filters at the South Pole

First guess reconstruction within 10° for ~66% of tracks

South Pole Filter for muons rejects low energy tracks < 70°

Conclusion

IceCube currently the largest neutrino observatory
- 40 IceCube strings + 19 AMANDA + 40 surface stations
- Full detector (80 strings and stations + 6 Deep Core) in 2011

IceCube offers the possibility to discover hints of SUSY in ν-N and p-N cosmic ray collisions

Current run ends in April 1st, 2009
- ~1 km^2 year for 3 seasons
- First analysis results in Summer 2009