Neutrinos Associated With Cosmic Rays of Top-Down Origin

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Prepared For Cosmo 2002, Chicago, IL

- Top-Down Models and Fragmentation
  - -Ultra-High Energy Cosmic Rays
  - -Neutrinos

- Prospects For Detection
  - -High Energy Neutrino Telescopes (AMANDA, RICE, IceCube)
  - -Cosmic Ray Experiments (AGASA, AUGER)

Together with C. Barbot, M. Drees and F. Halzen

Top-Down Origin of the Ultra-High Energy Cosmic Rays

- Top-Down Models

  -Annihilating or Decaying Supermassive Particles

  -Topological Defects

  -Results in UHE Photons, Protons, Neutrinos, etc

- Ultra-High Energy Photons

  -Gamma-Rays Dominate Over Nucleons at UHE's

  -Gamma-Rays NOT UHECRs

  -Radio Background Uncertain

- Ultra-High Energy Protons

  -Sources Within $\sim$100 Mpc

  -Consistent With UHECR Data

- Neutrinos

  -Most Proposed Sources of UHECRs Also Generate Neutrinos

  -Diffuse Flux Limits Placed by Neutrino Telescopes

Nucleons from Ultra-High Energy Jets

- Fragmentation

  -Based On C. Barbot and M. Drees, Phys. Lett. **B 533**, 107 (2002)

  -Includes SUSY Particles In Shower Evolution

  -10^{21} to 10^{25} eV Jets Correspond to $x = 10^{-6}$ to 10^{-10} at 1 PeV

  $\rightarrow$ Color Coherence Effects May Suppress Shower Evolution

  -We Estimate This Effect By Matching to MLLA spectra at small x

- Propagation Effects

  -Scatting Off CMB

  $\rightarrow$ Δ-Resonance

  $\rightarrow$ e^+e^- Pair Production

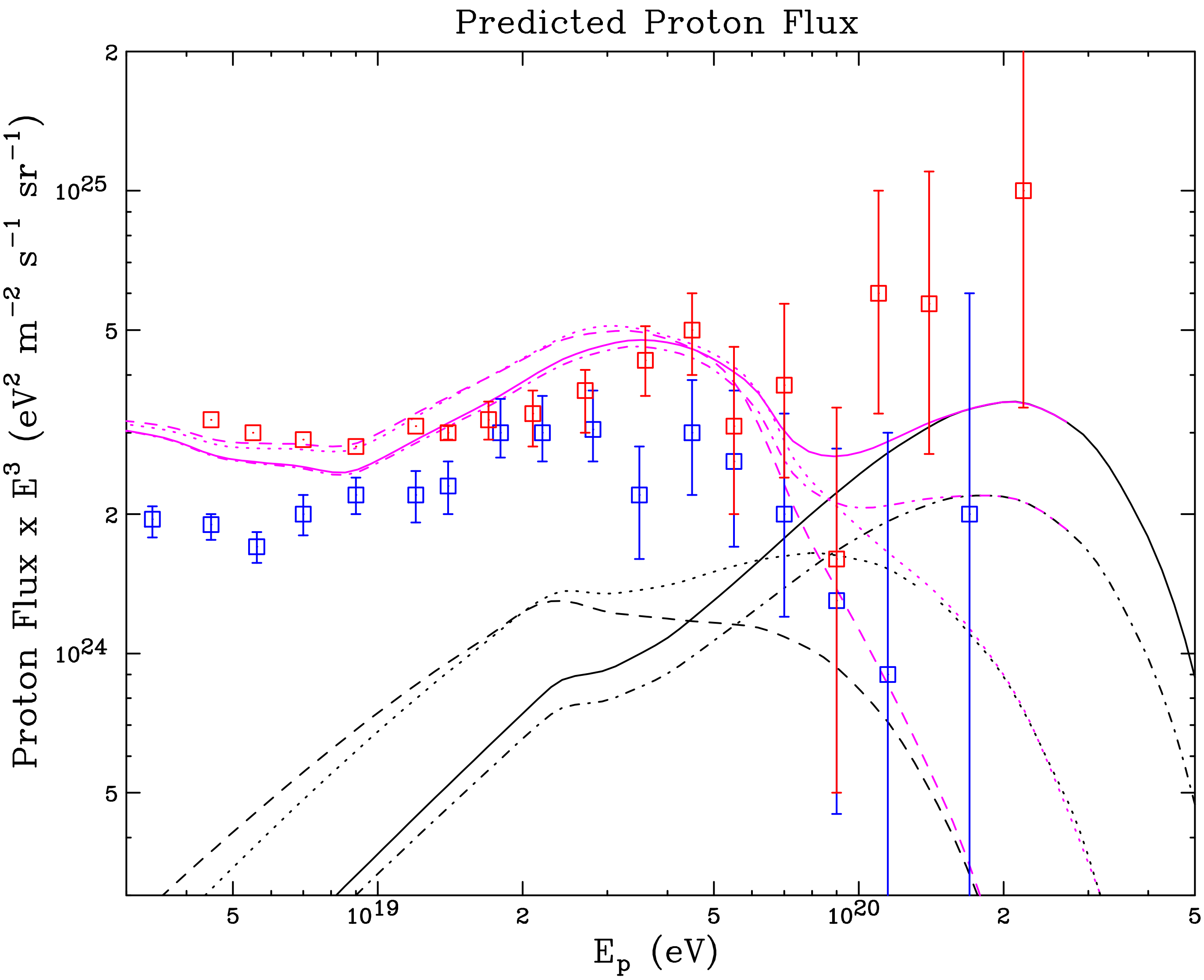
  -Energy Loses Due to Hubble Expansion

- Jet Distributions

  -We Find That to Match the UHECR Data, Galactic Overdensities of 10^3-10^4 or More Are Required

  -Galactic Mass Density Known To be $\sim 10^5$ Times Overdense

  -For Comparison, We Consider a 10^5 Overdensity and a Homogeneous Distributions



Predicted Proton Flux
Proton Flux x E^3 (eV^2 m^{-2} s^{-1} sr^{-1})
E$_p$ (eV)
2
10^{25}
5
2
10^{24}
5
5
10^{19}
2
5
10^{20}
2
5

Figure 1:

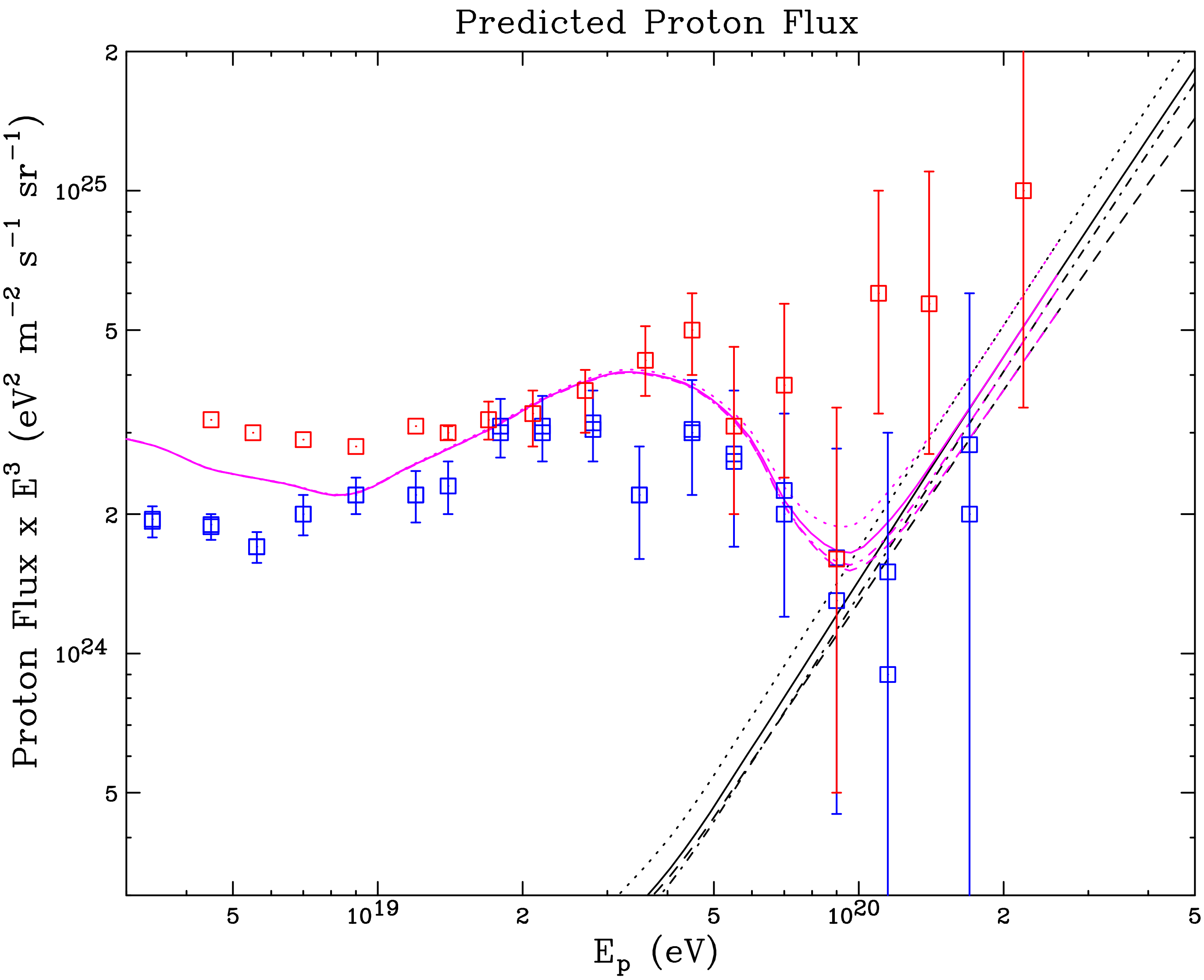

Predicted Proton Flux
Proton Flux x E^3 (eV^2 m^{-2} s^{-1} sr^{-1})
2
10^{25}
5
2
10^{24}
5
5
10^{19}
2
5
10^{20}
2
5
E$_p$ (eV)

Figure 2:

NEUTRINOS FROM ULTRA-HIGH ENERGY JETS

- Propagation

  -Neutrinos Can Travel ~ 30 Times Further Than Protons

  -Neutrinos Only Limited By Hubble Expansion

  -Flux Enhanced Most For More Homogeneous Distributions

- Neutrino Telescopes

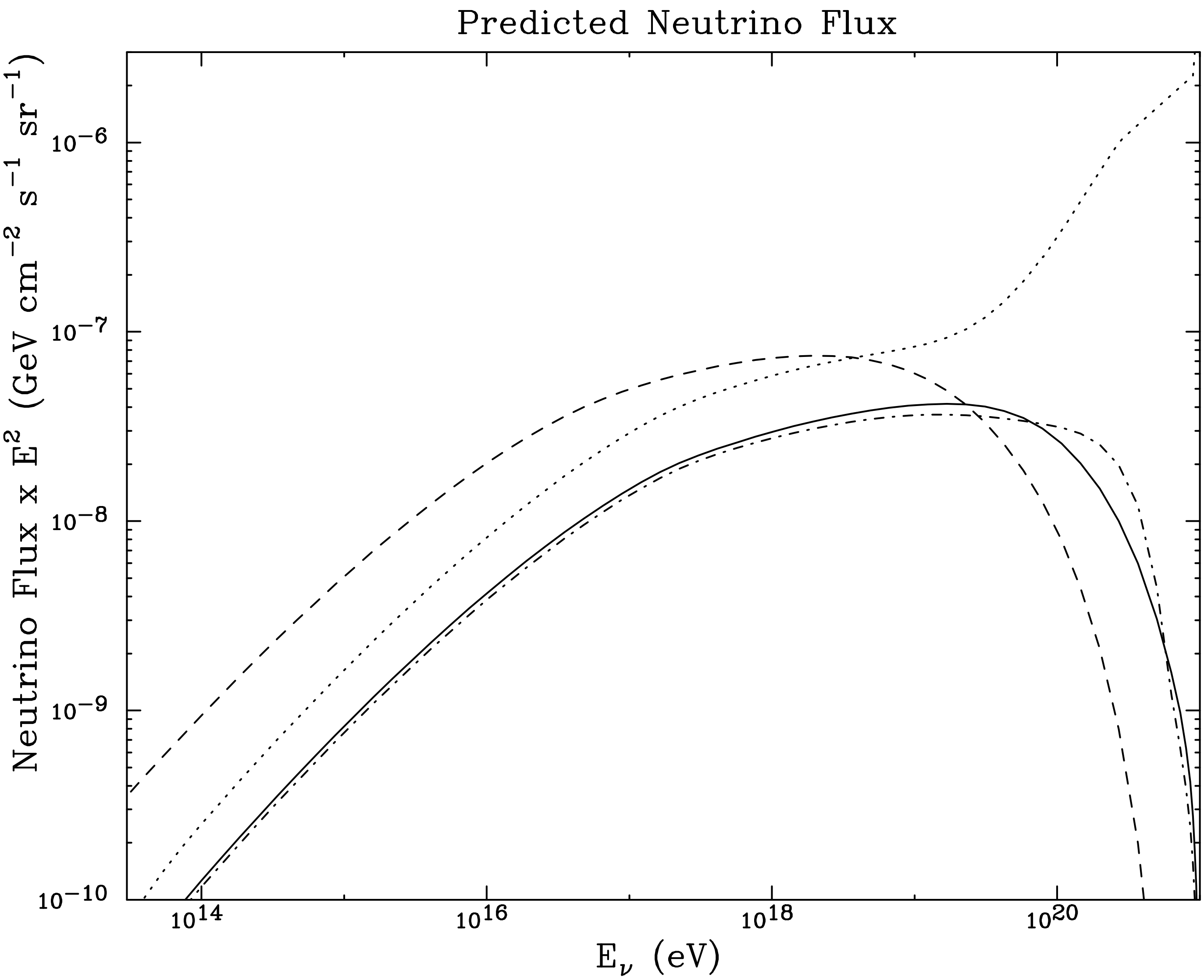
  -Operating Experiments: AMANDA, RICE

  -Future Experiments: IceCube

- Air Shower Experiments

  -Operating Experiments: AGASA

  -Future Experiments: AUGER



Predicted Neutrino Flux
Neutrino Flux x E^2 (GeV cm^{-2} s^{-1} sr^{-1})
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{14}
10^{16}
10^{18}
10^{20}
E$_\nu$ (eV)

Figure 3:

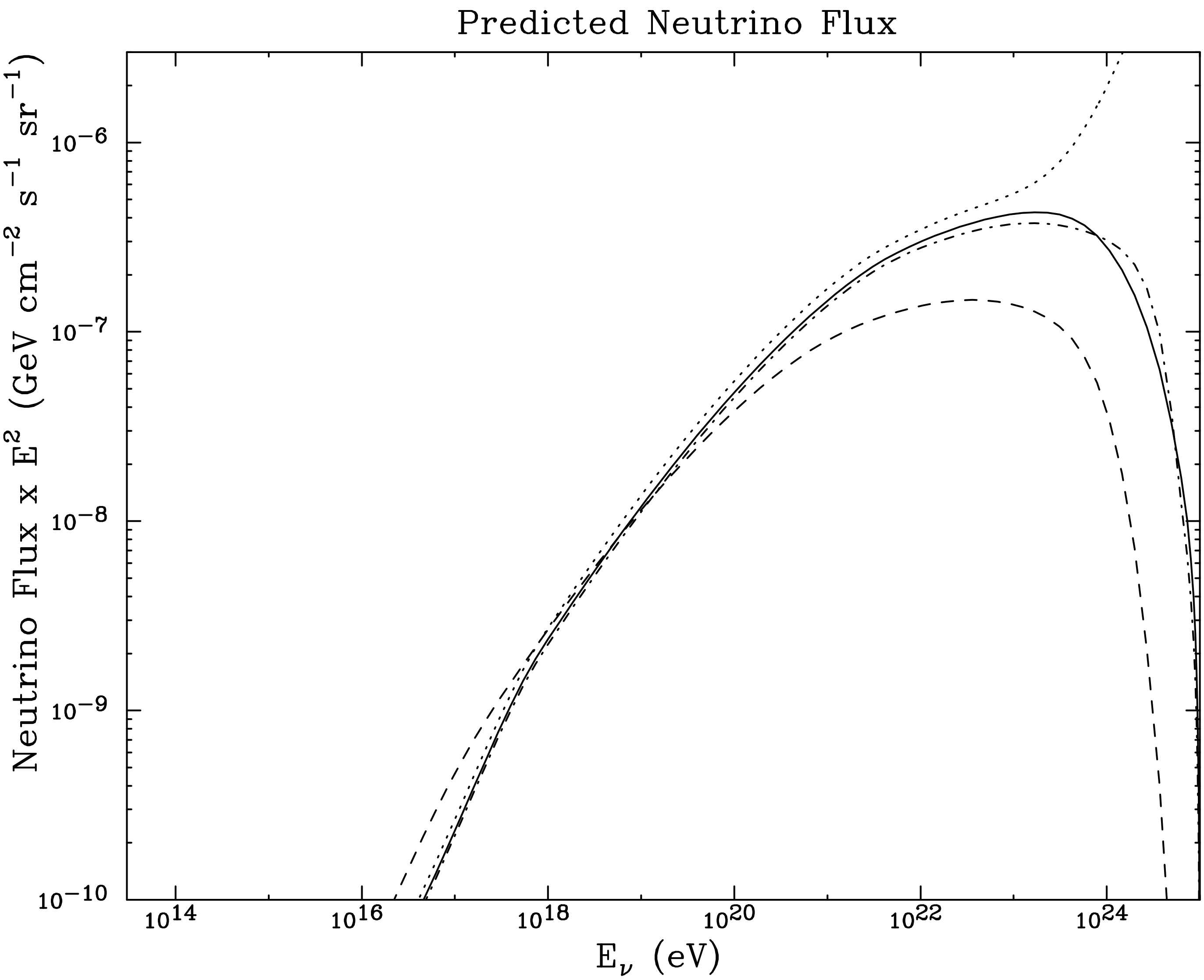

Predicted Neutrino Flux
Neutrino Flux x E^2 (GeV cm^{-2} s^{-1} sr^{-1})
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
10^{24}
E$_\nu$ (eV)

Figure 4:

	AMANDA II	AGASA	RICE	IceCube	AUGER
$q\bar{q}$, 10^{21} eV, Overdensity	0.39	0.056	2.9	12.2	2.3
$q\tilde{q}$, 10^{21} eV, Overdensity	0.36	0.052	2.7	11.4	2.1
$5 \times q\tilde{q}$, 10^{21} eV, Overdensity	1.4	0.11	9.8	44.6	5.0
$l\tilde{l}$, 10^{21} eV, Overdensity	0.96	0.20	6.2	29.8	5.9
$q\bar{q}$, 10^{25} eV, Overdensity	0.041	0.019	0.73	1.2	0.49
$q\tilde{q}$, 10^{25} eV, Overdensity	0.039	0.018	0.69	1.1	0.46
$5 \times q\tilde{q}$, 10^{25} eV, Overdensity	0.039	0.016	0.84	1.1	0.46
$l\tilde{l}$, 10^{25} eV, Overdensity	0.047	0.022	0.64	1.4	0.56
$l\tilde{l}$, no MLLA, 10^{25} eV, Overdensity	0.27	0.041	1.58	8.9	1.0
$q\bar{q}$, 10^{21} eV, Isotropic	3.5	0.50	26.5	110.3	20.5
$q\tilde{q}$, 10^{21} eV, Isotropic	3.2	0.47	24.3	102.2	18.8
$5 \times q\tilde{q}$, 10^{21} eV, Isotropic	6.9	0.57	49.0	223.2	25.0
$l\tilde{l}$, 10^{21} eV, Isotropic	4.8	1.0	31.0	149.2	29.7
$q\bar{q}$, 10^{25} eV, Isotropic	0.62	0.28	10.9	18.0	7.4
$q\tilde{q}$, 10^{25} eV, Isotropic	0.58	0.27	10.3	16.9	6.9
$5 \times q\tilde{q}$, 10^{25} eV, Isotropic	0.58	0.25	12.6	17.1	6.9
$l\tilde{l}$, 10^{25} eV, Isotropic	0.71	0.33	9.6	20.7	8.5
$l\tilde{l}$, no MLLA, 10^{25} eV, Isotropic	4.1	0.61	23.7	133.2	15.3

Table 1:

SUSY In The Sky

- Neutralino LSPs

  -SUSY Particles Generated In Fragmentation

  -LSP Stable by Virtue of R-Parity

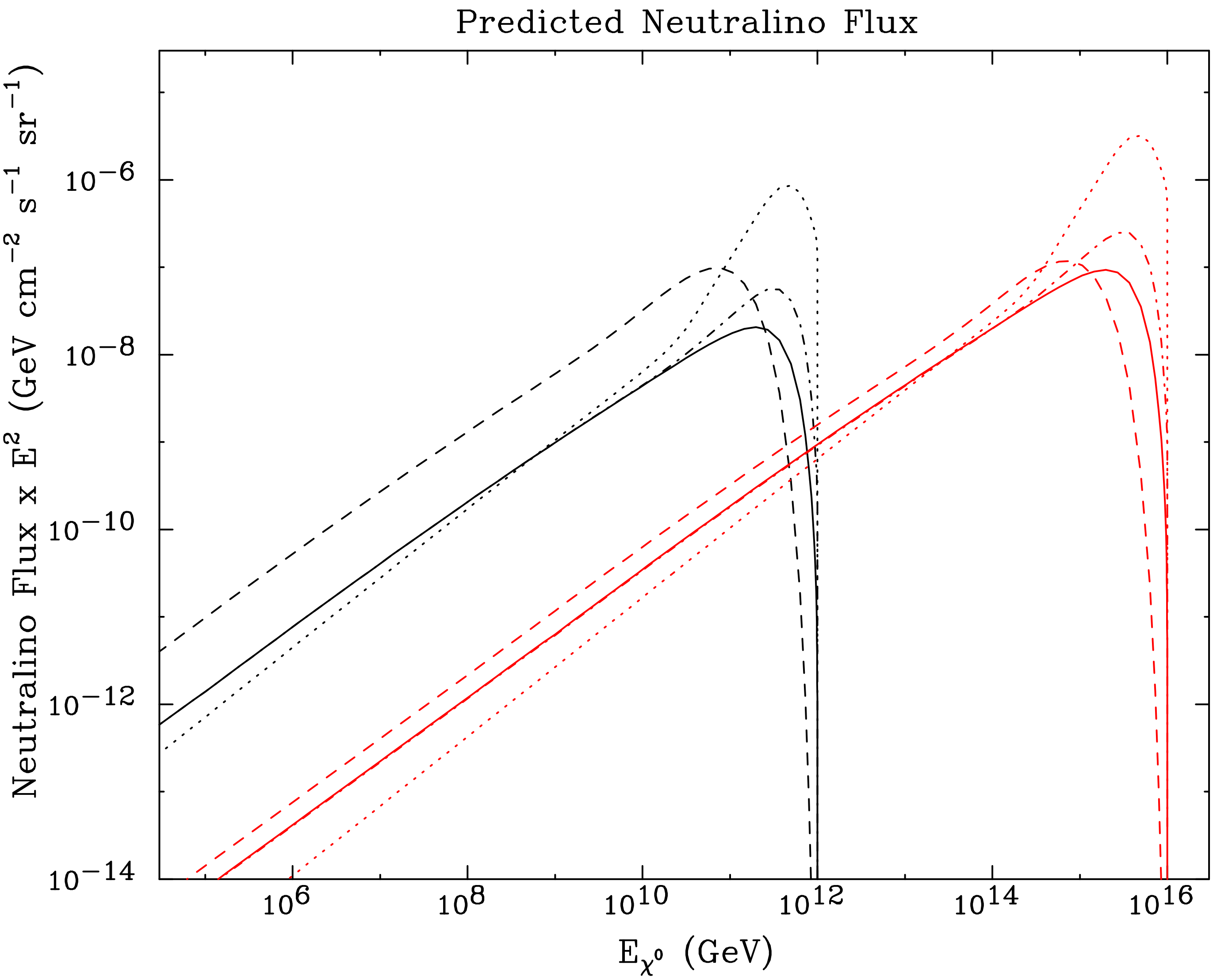
  -The LSP is the Lightest Neutralino in Most Models

- Observation

  -Can Use Earth as a “Neutrino Filter”

  -Future Air Shower Experiments: EUSO, OWL

  -Detect Upgoing Showers From Neutralinos Interacting In Shallow Earth



Predicted Neutralino Flux
Neutralino Flux x E^2 (GeV cm^{-2} s^{-1} sr^{-1})
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}
10^{16}
E_{χ^0} (GeV)

Figure 5:

$E_{\chi^0} \geq 1\,\mathrm{EeV}$	$\sigma_{\chi^0} = \sigma_\nu/10$	$\sigma_{\chi^0} = \sigma_\nu/100$
$q\bar{q}$, 10^{21} eV, Galactic	1.86	0.196
$q\tilde{q}$, 10^{21} eV, Galactic	2.96	0.306
$5 \times q\tilde{q}$, 10^{21} eV, Galactic	4.05	0.436
$l\tilde{l}$, 10^{21} eV, Galactic	28.0	2.81
$q\bar{q}$, 10^{25} eV, Galactic	0.187	0.0189
$q\tilde{q}$, 10^{25} eV, Galactic	0.213	0.0216
$5 \times q\tilde{q}$, 10^{25} eV, Galactic	0.213	0.0216
$l\tilde{l}$, 10^{25} eV, Galactic	0.615	0.0617
$q\bar{q}$, 10^{21} eV, Homogeneous	27.9	2.94
$q\tilde{q}$, 10^{21} eV, Homogeneous	44.4	4.56
$5 \times q\tilde{q}$, 10^{21} eV, Homogeneous	60.8	6.54
$l\tilde{l}$, 10^{21} eV, Homogeneous	420.0	42.15
$q\bar{q}$, 10^{25} eV, Homogeneous	2.81	0.284
$q\tilde{q}$, 10^{25} eV, Homogeneous	3.20	0.324
$5 \times q\tilde{q}$, 10^{25} eV, Homogeneous	3.20	0.324
$l\tilde{l}$, 10^{25} eV, Homogeneous	9.23	0.926
$E_{\chi^0} \geq 100\,\mathrm{EeV}$	$\sigma_{\chi^0} = \sigma_\nu/10$	$\sigma_{\chi^0} = \sigma_\nu/100$
$q\bar{q}$, 10^{21} eV, Galactic	0.0976	0.0344
$q\tilde{q}$, 10^{21} eV, Galactic	0.391	0.122
$5 \times q\tilde{q}$, 10^{21} eV, Galactic	0.0161	0.00716
$l\tilde{l}$, 10^{21} eV, Galactic	10.1	2.38
$q\bar{q}$, 10^{25} eV, Galactic	0.0946	0.0143
$q\tilde{q}$, 10^{25} eV, Galactic	0.116	0.0169
$5 \times q\tilde{q}$, 10^{25} eV, Galactic	0.103	0.0159
$l\tilde{l}$, 10^{25} eV, Galactic	0.435	0.0576
$q\bar{q}$, 10^{21} eV, Homogeneous	1.46	0.516
$q\tilde{q}$, 10^{21} eV, Homogeneous	5.87	1.83
$5 \times q\tilde{q}$, 10^{21} eV, Homogeneous	0.242	0.107
$l\tilde{l}$, 10^{21} eV, Homogeneous	151.5	35.7
$q\bar{q}$, 10^{25} eV, Homogeneous	1.42	0.215
$q\tilde{q}$, 10^{25} eV, Homogeneous	1.74	0.254
$5 \times q\tilde{q}$, 10^{25} eV, Homogeneous	1.55	0.239
$l\tilde{l}$, 10^{25} eV, Homogeneous	6.53	0.864

Table 2:

CONCLUSIONS

- Neutrinos Are Associated With UHECRs In Top-Down Scenarios

  -More Numerous Than Photons or Protons

  -Important Distinguishing Feature of Top-Down Models

- Within Reach of Present or Next Generation Experiments

  -AMANDA and RICE Can Begin to Probe Now

  -IceCube and AUGER Can Test All Models

- Future Air Shower Experiments Can Probe Supersymmetry

  -LSP Neutralino: Stable, Weakly Interacting

  -Uses Earth as “Neutrino Filter”