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- Photons are absorbed
- Protons (>10^{19} \text{ eV}) experience GZK cutoff
- "Visible" UHE universe is small
- Neutrinos travel unaffected
Most models assume a central black-hole and accretion disk.

Particle acceleration occurs either near the black hole or in the jet.

AGNs
Background: South Pole Station and Runway

Foreground: Amanda deployment site

Photo by Robert Schwarz
Amanda Deployment Site

Photo by Robert Schwarz

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- Absorption length is big!
- Varies with depth from 85 m to 225 m
Accumulated detailed knowledge about scattering length

Average eff. scattering length $\sim 24\text{m}$

Included in the Monte Carlo
Effects on Arrival Time

\[ \chi^2 = \sum_{i=1}^{N} \frac{(t_i - t_{i0})^2}{\sigma_i^2} \]

\[ L = f(t_i, t_{i0}, \sigma_i, dist, \lambda_{abs}, \lambda_{scatt}) \]
Results

- Muon Flux
- Monopoles
- WIMPs
- Atmospheric Neutrinos
- Diffuse Flux
- Point Sources
- Supernova Monitor
• Atm. muons $\rightarrow$ high statistics
• To moderate depths $\rightarrow$ well known characteristics
• Energy spectra comparable to atm. neutrinos
• Depths $>7$ kmwe $\rightarrow$ prompt muon
• Water / Ice homogeneous $\leftarrow$ Rock

Good tool for detector investigation
AMANDA

Atm. Muon Flux

- Convert angle to depth
- Compare with theoretical models and other measurements
- Good agreement, but few data points...

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Introducing magnetic charge in Maxwell equations

Light output follows

\[ n^2 \left( \frac{g}{e} \right) \sim 8300 \]

\[
\frac{d^2 N}{d\lambda dx} = \frac{2\pi \alpha n^2(\lambda) (g/e)^2}{\lambda^2} \left( 1 - \frac{1}{\beta^2 n^2(\lambda)} \right)
\]
Event
Simulated Monopole
• Galactic mag. field exist $\Rightarrow$ Parker bound
• No monopoles have been observed
• Very similar to Baikal limit

AMANDA

Atmospheric Neutrinos

- Two analyses performed on 97 data
- Preliminary results
- $\sim 140$ atm. Neutrinos per year
- Systematic studies under way

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- Timeflow from red to blue
- Event clearly travels upward
- Track length ~400 m
- Size of OM corresponds to amplitude
- Shape agreement with MC expectation
- Normalization?
- Atm. $\nu$ Flux (30%), Ice Properties, PMT Coll. Efficiency, Obscuration by Cables... adds up to $+/− 50\%$
Combined plot of the atm. Neutrino events for two analyses

No indication of clustering

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Continuous emission from sources with hard spectra (\(\sim E^{-2}\))

- Cuts are more "relaxed" than in atm. Neutrino analysis
- Optimize search on Signal to Noise Ratio
  - \(A_{\text{eff}}\) depends on rejection requirement

Background for this search
- Poorly reconstructed atmospheric muons
- Atmospheric neutrinos
Sky Plot of Events

- 1097 events
- No sources visible
- Sample consist of atm.ν and atm.μ
Due to geometry the eff. Area is a strong function of the zenith angle.

Typical areas are of the order of \(~10000m^2\)
Flux limits calculated with power law neutrino source for declination >30 degrees

Preliminary

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AMANDA

Markarian 501 (1997)

- Time averaged spectrum of $\gamma$ and corrected for absorption with infrared background
- Neutrino flux = $\gamma$ flux
EeV in AMANDA

$R_\mu \sim 25 \text{ km}$
If $E_\mu \sim 10^{20} \text{ eV}$
• Horizontal Triggerarea
• Vertical ~ half the size
• Loose Area by further selection
• 4800 Optical Modules
• 80 Strings
• String spacing ~125 m
• OM spacing 16 m
• Threshold well below 1 TeV
• Proposal submitted
• Start deploying in 2003 — finish 2010
### Diffuse Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Rate ((\text{km}^2\text{yr sr}))</th>
<th>(E &gt; 1 \text{ TeV})</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGN</td>
<td>400-800</td>
<td></td>
</tr>
<tr>
<td>AGN jets</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>GRB</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Atm (\nu)</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

### Point Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Rate ((\text{km}^2\text{yr}))</th>
<th>(E_{\mu} &gt; 1 \text{ TeV})</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNa Remnant</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AGN (3C273)</td>
<td>1-100</td>
<td></td>
</tr>
<tr>
<td>Mk421, Mk501</td>
<td>1-10 from (\gamma) flux</td>
<td></td>
</tr>
<tr>
<td>GRB</td>
<td>(\sim 3)/burst</td>
<td></td>
</tr>
</tbody>
</table>
Particle Physics:

- Topological defects
- Relativistic magnetic monopoles
- Prompt muon flux
- Cold dark matter — Neutralinos (> 0.5 TeV)
- $\nu_\tau$ discovery
OMs that detect Cherenkov photons are colored circles.

Earliest photons are red, latest photons are blue.
OMs that detect Cherenkov photons are colored circles.

Earliest photons are red, latest photons are blue.
**Summary**

- **Analysis of ’97 data**
  - Rel. Monopole limit well below Parker bound
  - WIMP sensitivity with ~140 days reached sensitivity of other experiments
  - Atm. $\nu$ seen with expected angular distribution. Normalization is within the errors
  - Point sources $\rightarrow$ None found, limit set
  - GRB $\rightarrow$ None found, limit set

- **Detector understood $\rightarrow$ physics output**
Summary

- More data on tape with "growing" detector
- EeV analysis has started
- ICE$^3$ will start soon (if funding is available)
- Neutrino Astrophysic has started
Telescopes

overwhelmingly motivated by the
cosmic potential

- astronomy (multi-wavelength)
- particle physics
- multi-disciplinary science