LARGE SCALE RADIO DETECTORS IN ICE.

Dave Seckel @ RADHEP 2000
10^4 Radio Antennas @ 1 km spacing

(similar in scale to Pierre Auger project)
1. Confession

2. UHE CR + G7K >

3. Event Rates + Detector Mass

4. RICE $\rightarrow$ X-RICE

5. Alternate Technologies
   - ICECUBE
   - Air showers - ground
   - Air fluorescence - ground/space
   - LUNAR

6. Feasibility
Source -> GtK

\[ p \rightarrow n \rightarrow r \rightarrow \bar{\nu} \rightarrow \nu \]

- Protons primary
- \( \nu \)'s secondary
- \( \bar{\nu} \)

\[ \text{Cosmic String} \]

\[ 3 \rightarrow \bar{\nu} \text{ from "k" or jet} \]

- \( \bar{\nu} \)'s primary
- Protons suppressed
- GZK $\Rightarrow$ 1 proton $E_p > 10^{18}$ eV

$$\Rightarrow 1 \nu \ \text{w/} \ E > 10^{18} \text{eV}$$

- $R = \frac{\int_{10^{16}}^{10^{19}} \phi_\nu \ dE_\nu}{\int_{10^{19}}^{10^{20}} \phi_{cR} \ dE_{cR}} = 1 + \alpha$

- If $\alpha \approx 1$ \hspace{1cm} Astrophysical Source
  \hspace{1cm} $\nu\gamma$ production
  \hspace{1cm} (AGN, GRB...)

$\alpha \ll 1$ \hspace{1cm} Astrophysical Source
\hspace{1cm} with NO $\gamma\gamma$
\hspace{1cm} (Hot spots)

$\alpha \gg 1$ \hspace{1cm} Top Down (Defects)
In 2 km Ice, for VT models
All Events above Threshold

Differential Event Rate for VT Model 2

N(E > E) (10^6 km^-2 s^-1)

Log10(E)
Array of receivers is detected by a bursted radio pulse (100 MHz - 1 GHz) resulting in radio emission being coherent Cherenkov

At wavelengths longer than the shower, an EM shower

Antarctic Ice producing a UHE * interacts in

RICE Concept
3 Versions of RICE

- **RICE**
  - **Feasibility**
  - Background Survey
  - ~20 Antennas (Rx)
    - (100 m)$^3$ 10-100 PeV
  - Limits

- **RICE$^3$**
  - Few hundred Rx
  - (km)$^3$ 1-10 PeV
  - Limits
  - Test models
  - Events
  - Calibrate

- **X-RICE**
  - $10^3$-$10^4$ Rx
  - $10^3$-$10^4$ km$^3$ 1 EeV
  - 100 GZK $\gamma$'s per yr
  - "Guaranteed"
A "small" array of antennas, $V_{\text{threshold}} = 30\, \mu V$

11x11, 2 km spacing, 300 m depth

$E = 10^{16}\, \text{GeV}$
Array efficiency:

\( \text{central array efficiency} \)

\( (N=4, R=4) \)

\( 0.5 \)

\( 1.0, 1 \)

\( 1.0, 4 \)

\( 1.5, 1 \)

\( 2.0, 1 \)

\( 10^{17} \) to \( 10^{21} \) cascade energy (eV)

\[ \text{Horizontal spacing} = \text{# of antennas/ hole} \]
Experiments

Technique

Optical \( \gamma \)  \( \text{AMANDA, ANTARES} \)
\( \text{NEVOTIR, BAIKAL} \)
\( \text{ICE}^3 \)

Radio  \( \text{RICE, RICE}^3, \text{X-RICE} \)
\( \text{LUNAR, REMOTE} \)
\( \text{ORBIT} \)
\( \text{VENUS} \)

Air Fluorescence  \( \text{FLY\textprime S\textprime GYE, Hi Res I, II} \)
\( \text{Telescope Array Project} \)
\( \text{AUGER, OWL/AIRMAK} \)

Ground  \( \text{AGASA, AUGER} \)
G2K at ICECUBE

- CONTAINED EVENTS \( 1 \text{ km}^3, 2 \pi \text{ sV} \)
  \( R \sim 0.01 - 0.1 \text{ /yr} \)
  \( \Delta E \text{ good} \)

- External \( \mu \)'s (\( \Delta E \text{ not so good} \))
  \( R \sim 1-2 \text{ /yr} \) (private comm. Francis)

\( \text{contained} = 6 \text{ km}^3 \text{ sV} \)
\( \text{Horizontal} = 10 \text{ km}^3 \text{ sV} \) ? 6x Contained
\( \text{Down} = \) ? 15
\( \text{Vertical} = 2 \)
AIR TARGET

GROUND ARRAY
water tanks
scintillator

N. FLUORESCENCE DETECTOR
(fly's eye e.g.)

- PROVEN TECHNOLOGY
- COS Rayz Background
- HIGH THRESHOLD
- LOW TARGET MASS/AREA
equiv. 10 cm H$_2$O
\[ \log [\text{km}^3 \text{ sv}] \]
Neutrino Detector Characteristics

Lower E Limit: Detector Threshold (Sensitivity)
Upper E Limit: Detector Size (Flux)
Feasibility

• All the problems of ICERCUBE

• All the problems of AUGER

• But the real problem is convincing people that it works