AMANDA-B10
Limit
on
UHE Muon-Neutrinos

Stephan Hundertmark, Stockholm Universitet

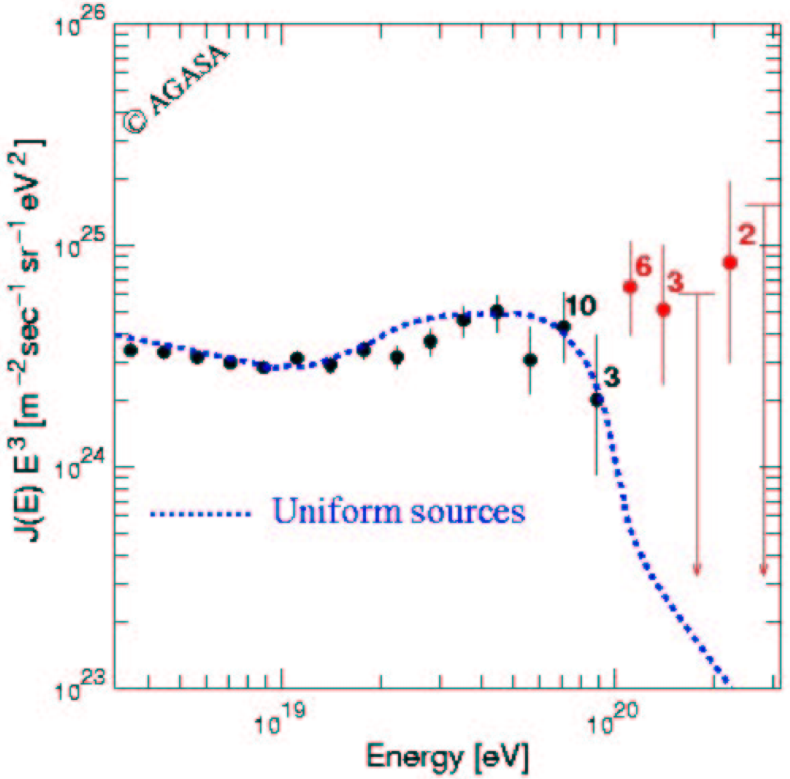
International Workshop on UHE Neutrino Telescopes
Chiba, July 29-30, 2003

Why looking for UHE neutrinos ?

GZK-cutoff @ $5 \cdot 10^{19}$ eV:

$\gamma_{CMB} + CR \rightarrow \pi$

$L_{CR} < 50$ Mpc



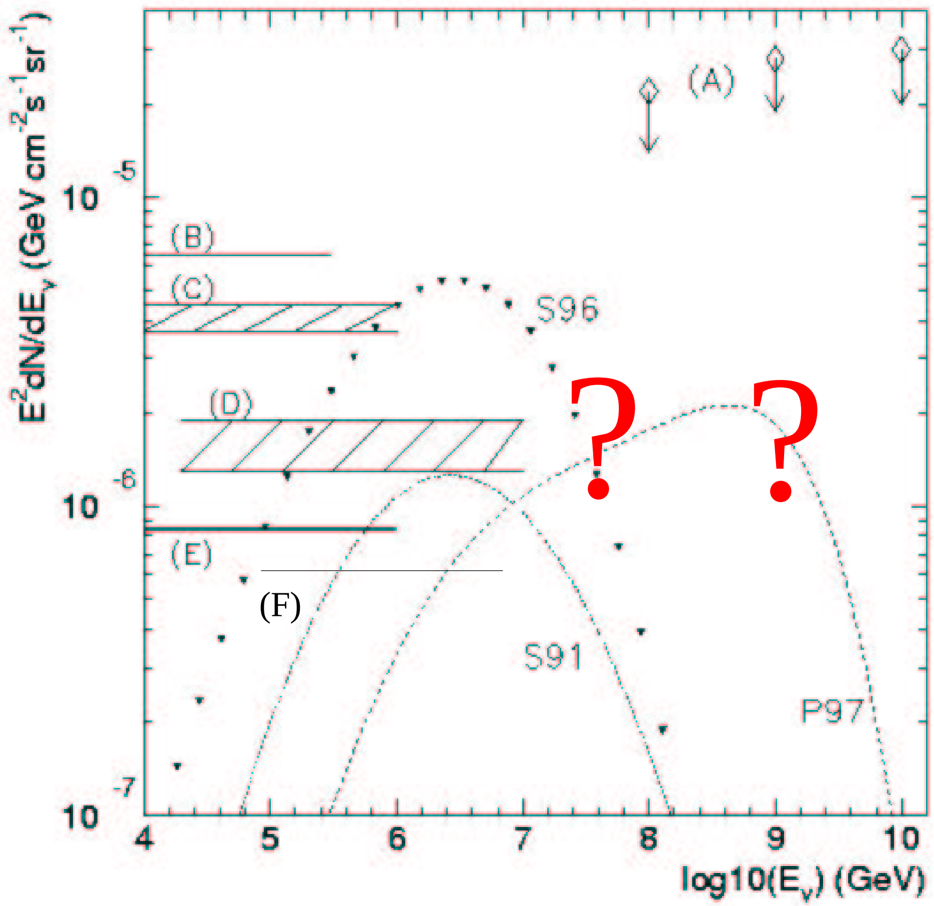
from AGASA web page

- CR above GZK exist
  ⇒ UHE neutrinos exist !
- Where are the sources ?
- CR above GZK produced by neutrinos ?

UHE Neutrino Sources

- Sources of UHE neutrinos are:
  - Active Galactic Nuclei (AGN)
  - Topological Defect Models
  - GZK (CR + CMB)
  - Evaporating Mini-Black Holes
- Neutrinos may carry information from highest energy and most distant phenomena
- Discovery Potential for the unknown

High Energy Limits



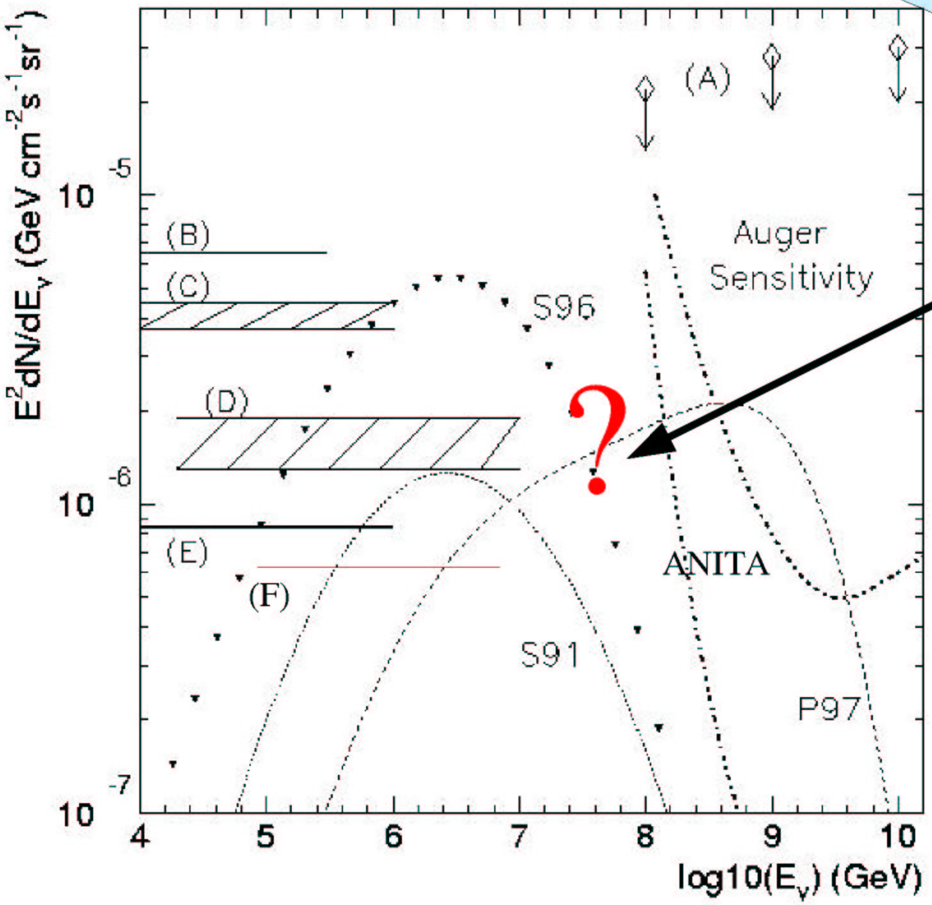
No stringent limits above 10^{16}eV

(A) Flys Eye
(B) AMANDA ν_e (97)
(C) Macro ν_μ
(D) Baikal ν_e
(E) AMANDA ν_μ (97)
(F) AMANDA ν_e (00)

Availible Limits and Future Experiments

There is a 'sensitivity gap' in the existing and planned experiments above 10^{16} eV

What can AMANDA do at energies above 10^{16} eV ?



(A) Flys Eye

(B) AMANDA ν_e (97)

(C) Macro ν_μ

(D) Baikal ν_e

(E) AMANDA ν_μ (97)

(F) AMANDA ν_e (00)

Pros and Cons for UHE

- Raising crossection for $\nu \rightarrow \mu$
- Raising A_{eff}
- Muon range well above ~10 km for $E_{\mu} > 10^{16}$ eV

  $\Rightarrow$ Large volume can be monitored

<u>But:</u>

- Upgoing neutrinos are absorbed by the earth
- Neutrino interaction limited by ice overburden

→ Signal concentrated at the horizon

Background to UHE Neutrinos

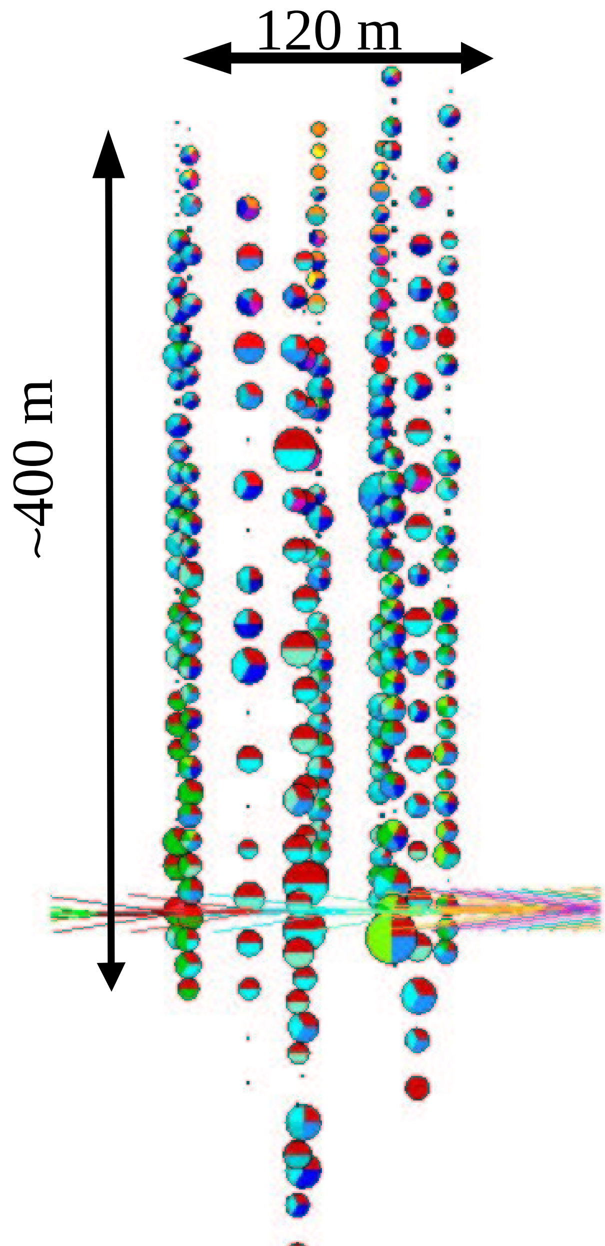
Background to UHE neutrinos are large atmospheric muon bundles

$\Downarrow$

Develop analysis that rejects downgoing muon bundles while retaining efficency for neutrino induced muons from i.e. E^{-2} source

AMANDA-B10 Detector ('97)

- 10 Strings
- 302 OMs
- ~120 m Diameter
- ~400m Height
- Analog Signal
  over ~2 km Cable
- Overburden ~1500 m



Definition of used Variables

1.	NCH	Number of hit channels
2.	NH	Number of hits for all channels
3.	F1H	Fraction of hit channels with exactly one hit
4.	MA	Mean amplitude for hit channels
5.	θ(FG)	Zenith angle for first guess.
6.	θ(LR)	Zenith for likelihood reconstruction
7.	$\mathscr{L}$	Likelihood for LR
8.	S	Smallest moment of tensor of inertia
A.	NN1	Neural Net using 3., 5., 6. and 7.
B.	NN2	Neural Net using 1., 2., 3., 4. and 8.

Analysis Steps

- Start with high multiplicity sample (NCH>100, 131 days)

  $\Rightarrow \sim 4 \cdot 10^6$ events

- Apply F1H <0.65 $\Rightarrow$ 263 k events
- Apply NN1 >0.37 $\Rightarrow$ 3326 events
- Optimal Selection Criterion procedure:
  - Apply NN2 >0.7 $\Rightarrow$ 6 events (8.3 expected)
- Evaluate systematic errors
- Derive limit

Simulation of Background

Two sets are generated with Corsika:

1.) Cosmic Ray spectrum following Wiebel-Sooth

2.) Protons and Iron only, following E^{-2} (→ high energy events)

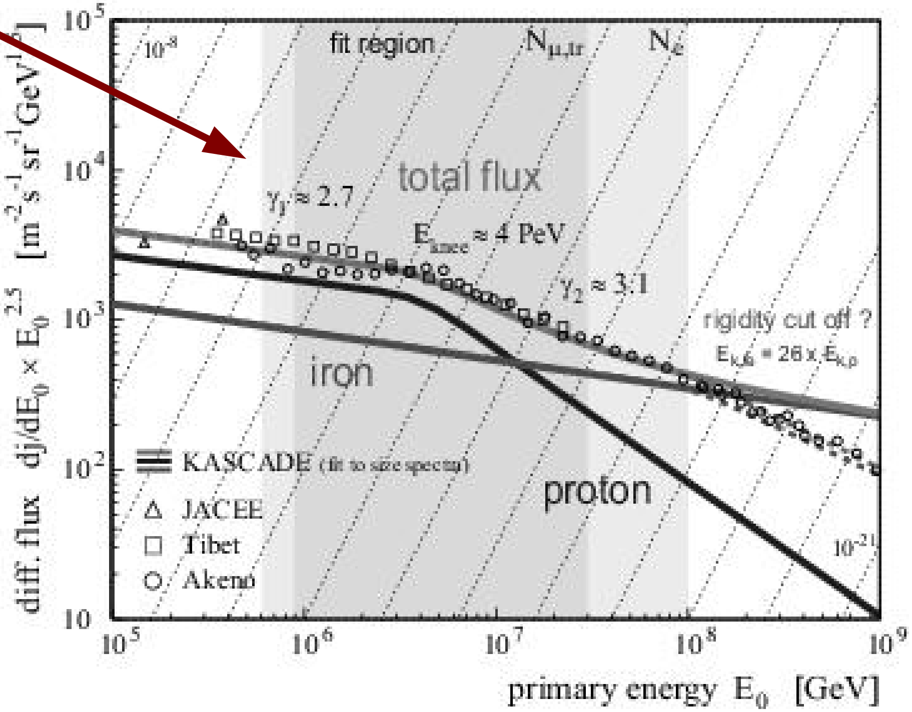
reweighting to:

⇓

Results in over

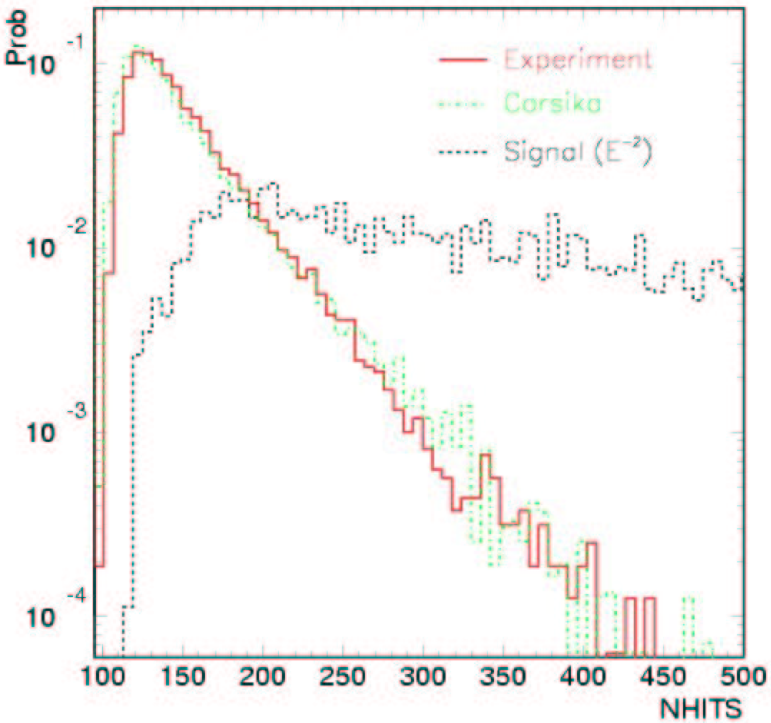
2k BGR events

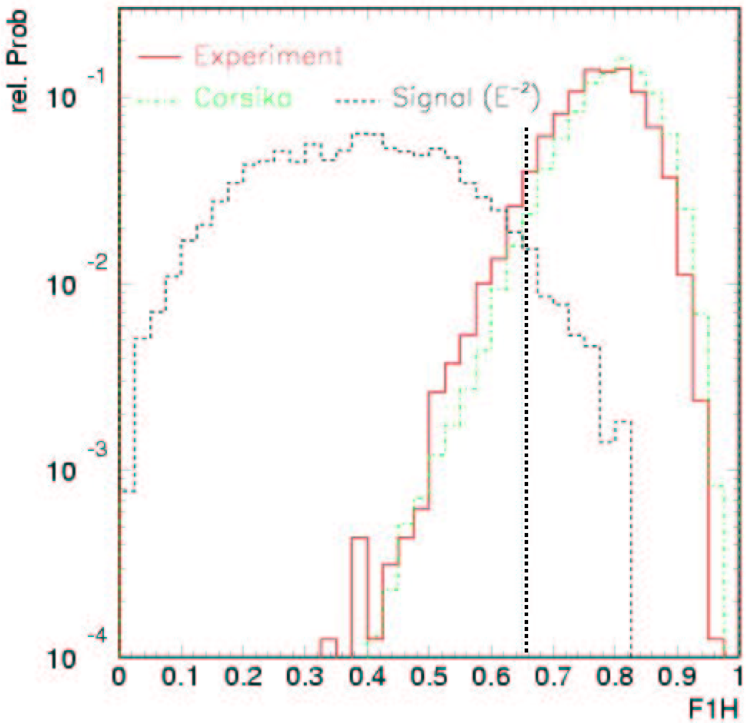
after final cut !



Background Simulation / Experiment

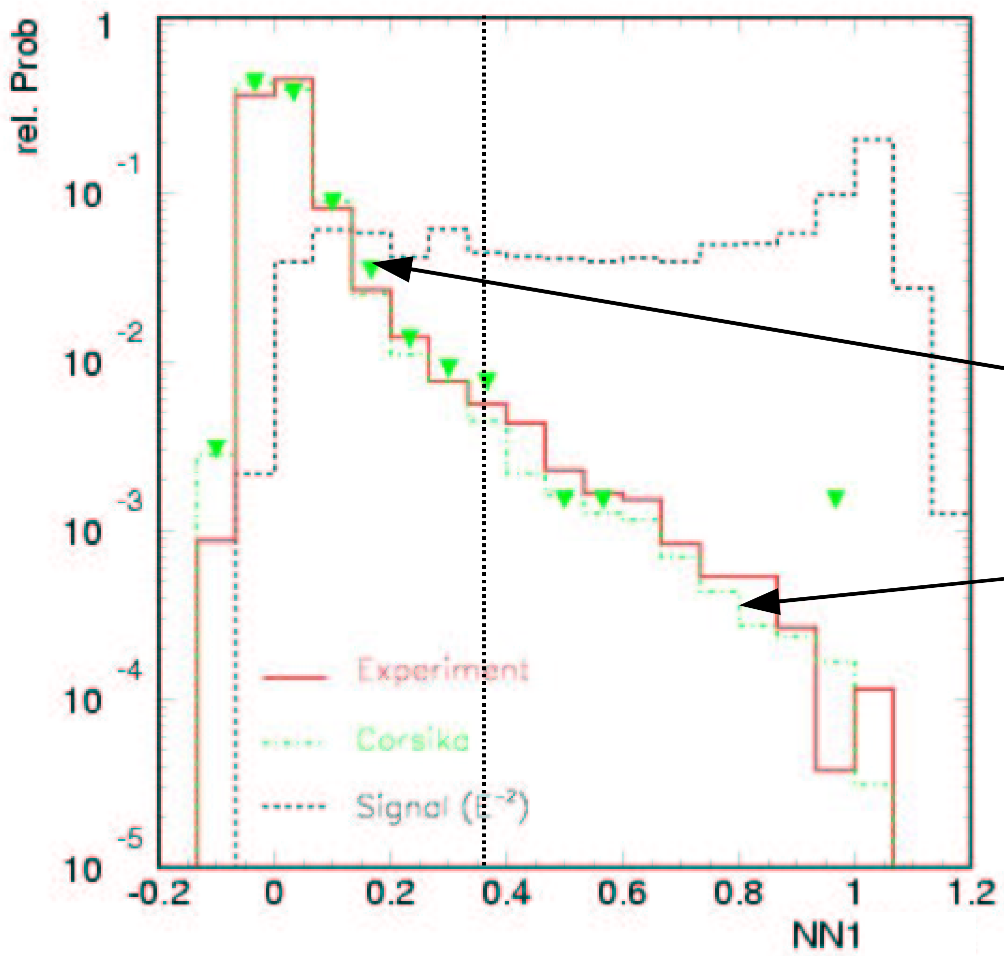
~$4\cdot10^6$ events





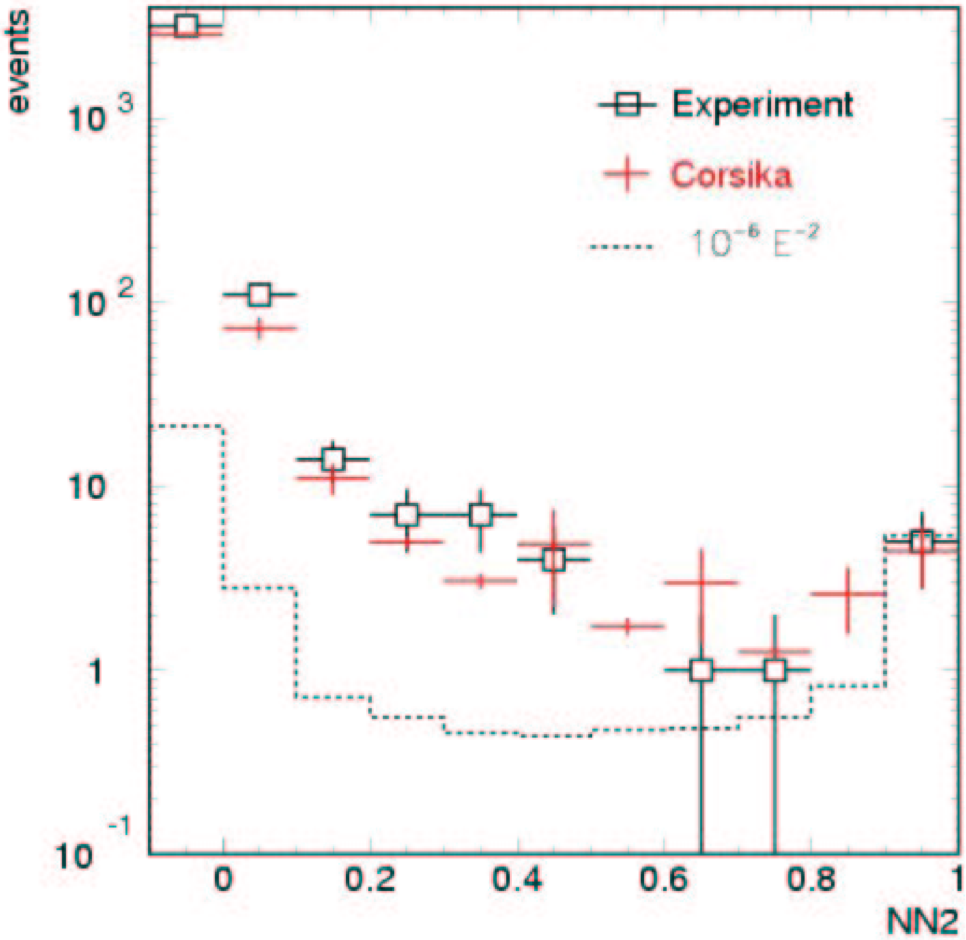
Background Simulation / Experiment

263k events



At this level from 'full' Corsika to reweighted P+Fe simulations

Background Simulation / Experiment



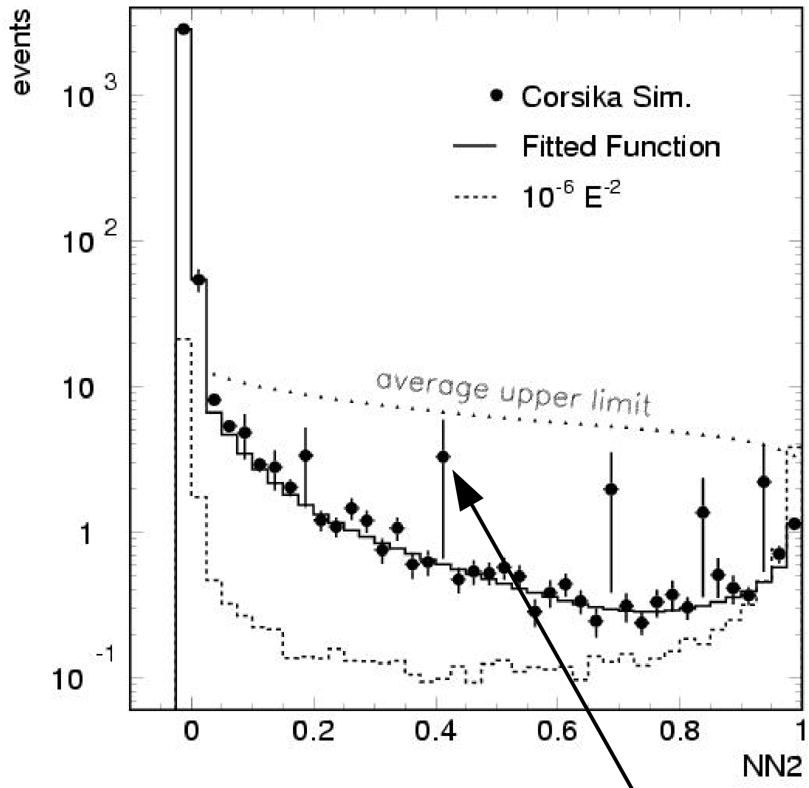
Experiment: 3326
Corsika: 2938

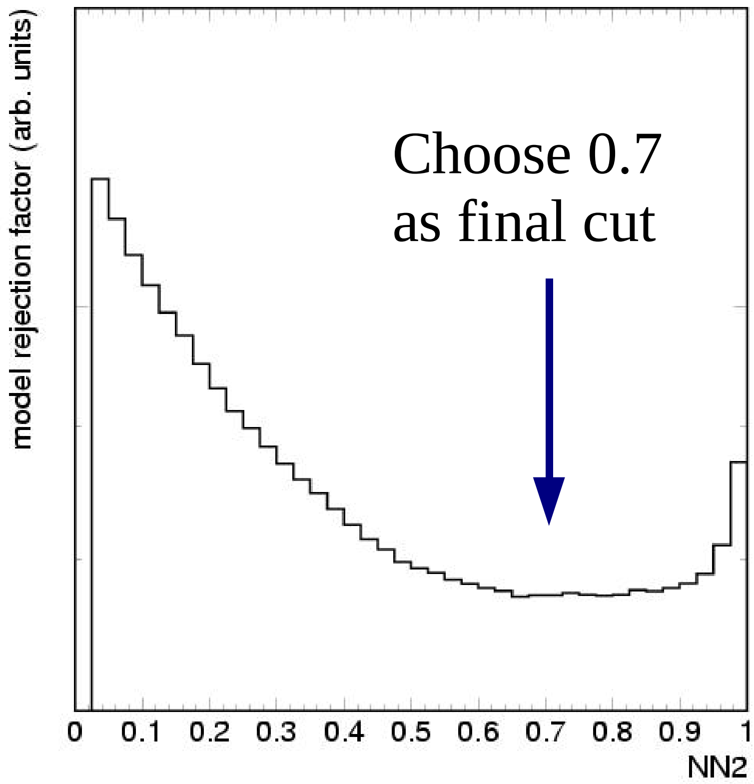
→ apply optimal cut

Optimal Cut

Uses simulated background expactation n_b to calculate average event upper limit μ_{90}

Strongest constraint for minimum of μ_{90} / n_s

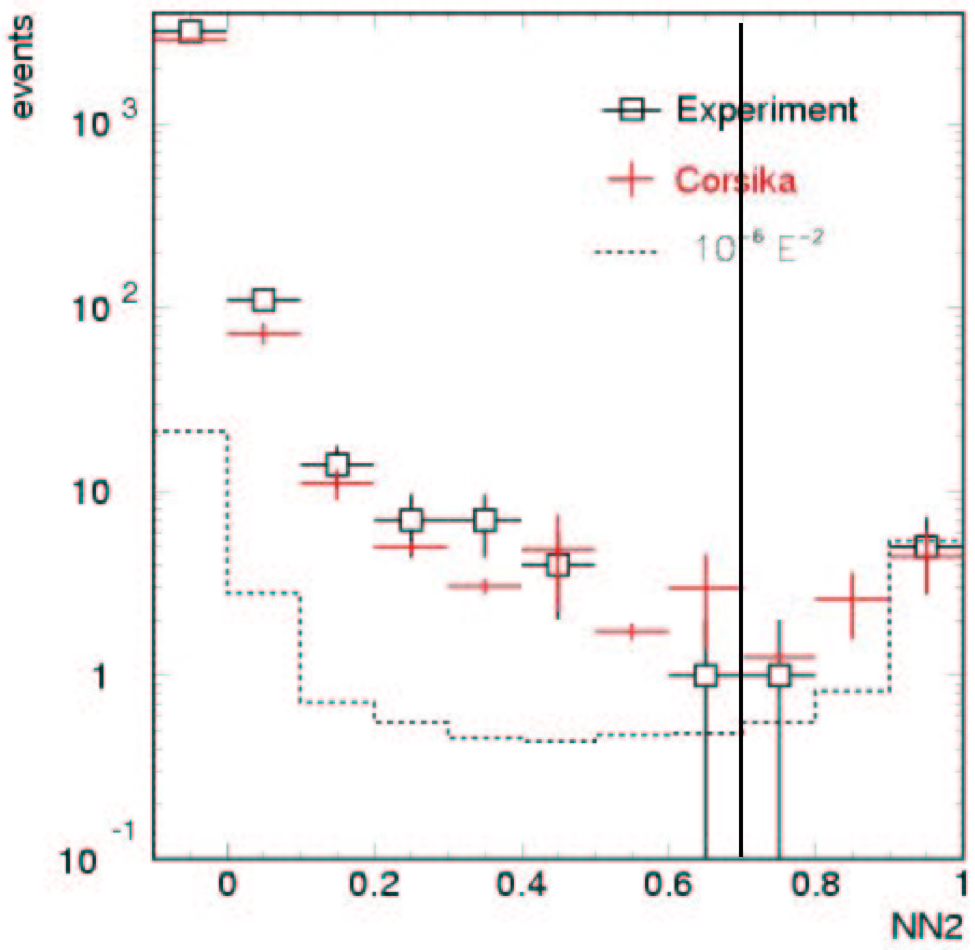




high weight events from reweighting

Applying the Final Cut

Sensitivity: $E^2\phi_{90} = 9.3 \cdot 10^{-7}\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}\,GeV}$

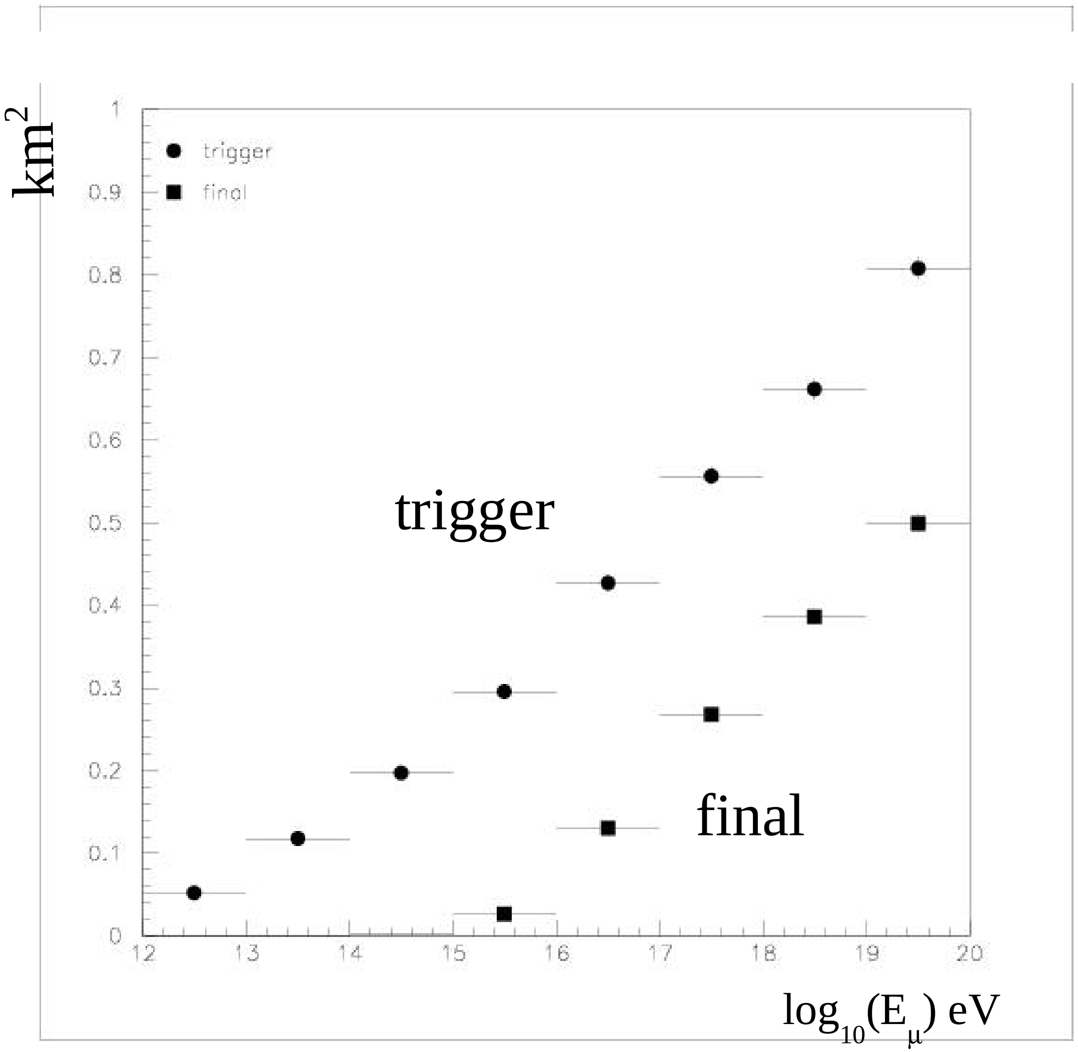


Experiment: 6
Corsika: 8.3

→ Feldman, Cousin event upper limit is 3.6 (90% C.L.) or

$E^2\phi_{90} = 5.3 \cdot 10^{-7}\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}\,GeV}$
(preliminary)

Effective Area



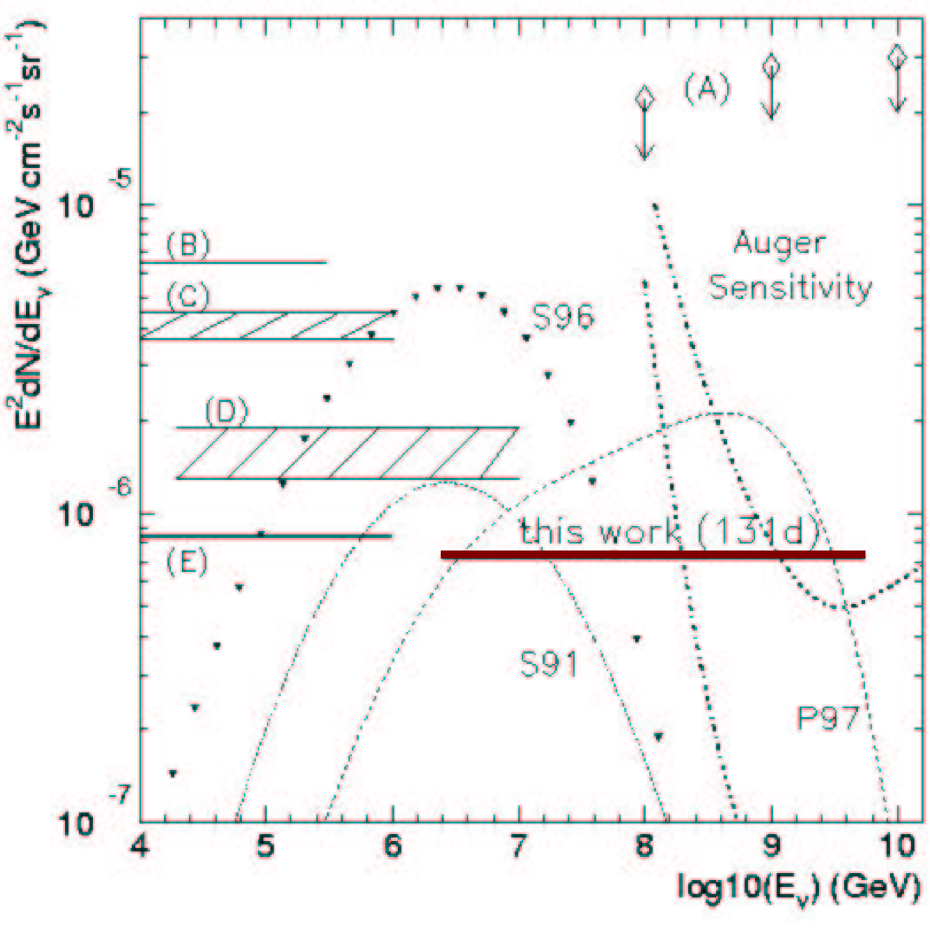
Including Systematics

Absolute detector sensitivity	12%
Optical Ice Parameters	34%
Muon Propagation	6%
Neutrino Cross Section	8%
Primary CR Flux	20%
Composition	16%

$$\Downarrow$$

$$E^2\phi_{90} = 7.2\cdot10^{-7}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}\,\mathrm{GeV}$$

The Limit on UHE Muon-Neutrinos



(A) Flys Eye
(B) AMANDA ν_e (97)
(C) Macro ν_μ
(D) Baikal ν_e
(E) AMANDA ν_μ (97)

Limits on UHE Source-Models

model	n_s(NN2>0.7)	mrf	act. limit (no sys + osc)
S91	2.1	3	1.7
S96	8	0.8	0.45
P97	7	0.9	0.51
TD	0.4	16.6	9

Remarks to Limits

- No oscillation effects are included, they will cut the expected signal from muon-neutrions to 50%
- Currently the sensitivity to electron-neutrinos is evaluated
- Some of the lost muon-neutrinos can be compensated by detecting tau-neutrinos
- Limits are preliminary

Summary

- InIce detectors are usefull tools to search for UHE neutrinos (now !)
- This analysis extends the energy reach of AMANDA to a very interesting physics region
- The current best limit at UHE energies already with AMANDA-B10 !
- AMANDA-B10 is limited to even higher energies due to saturation

  -> does not apply to AMANDA-II and IceCube
- Important information comes from F1H -> TWR will help a lot