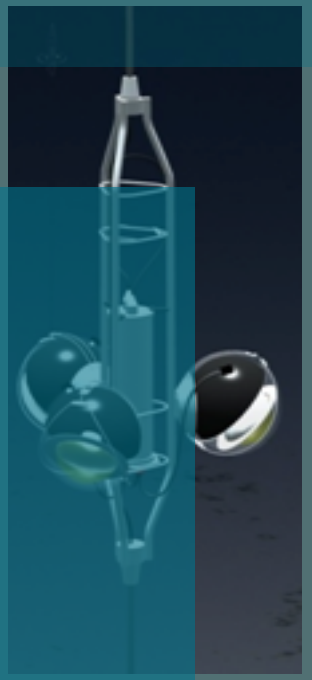
SEARCH FOR POINT SOURCES OF HIGH ENERGY NEUTRINOS WITH ANTARES



TeV PA Conference

August 1-5, 2011
Stockholm

J. P. Gómez-González
on behalf of the ANTARES collaboration

Outline

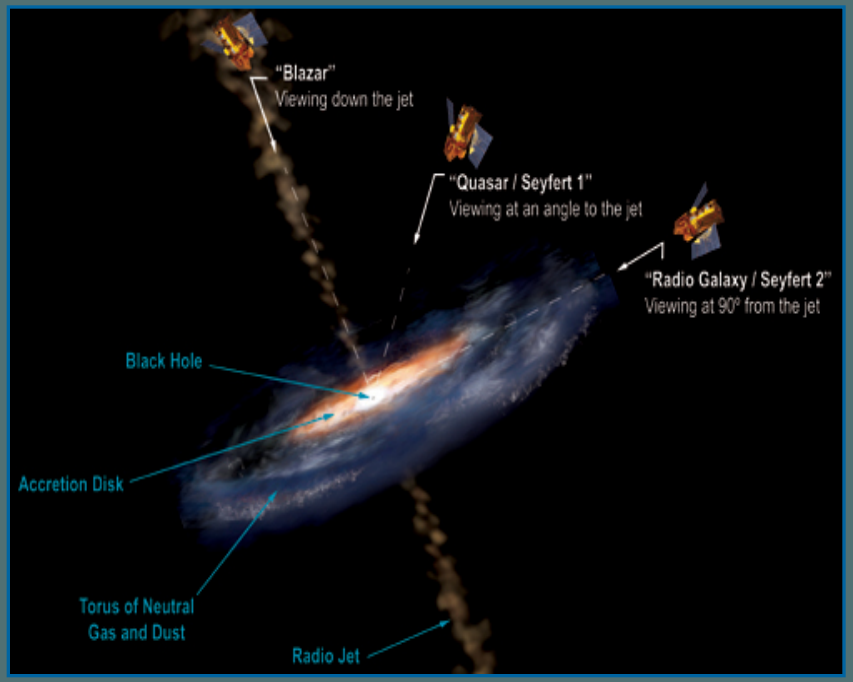
- Introduction
  - High energy neutrino astrophysics
  - Detection principle and detector description:
    - How neutrinos are detected
    - What is measured
- Searching for point-sources of cosmic neutrinos
  - Data sample, search method, skymap, results

Astrophysical candidates

High energy neutrino sources

- Galactic: SNR, Microquasars, Galactic center, …
- Extragalactic: AGNs, GRBs, …

Hadronic models predict the production of high energy neutrinos in the vicinity of the acceleration scenarios

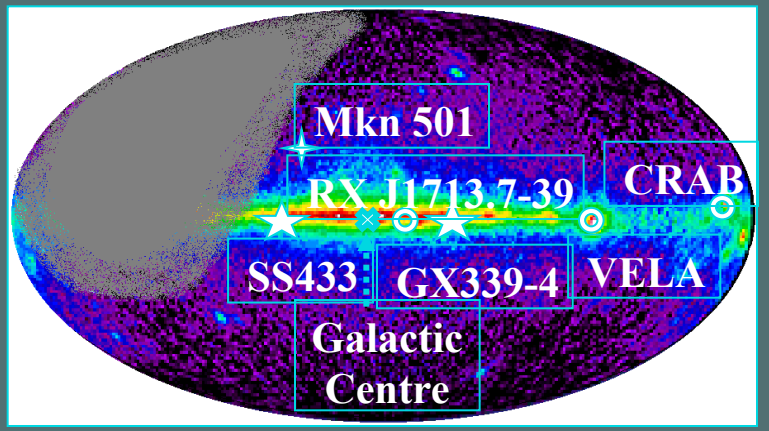


HE ν's are expected together with UHECRs:

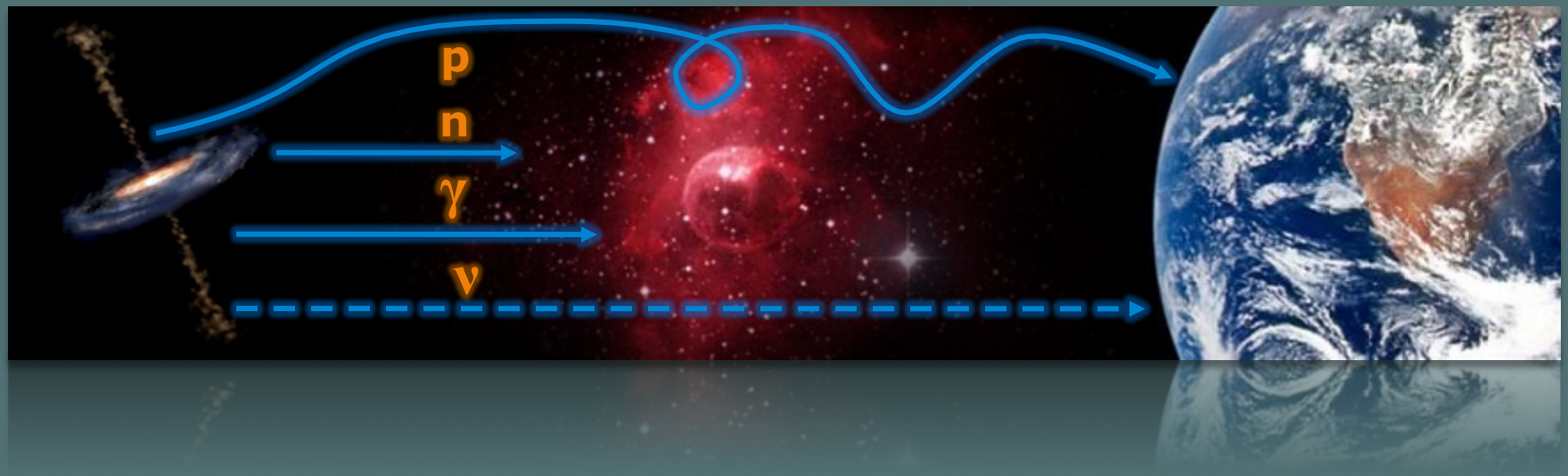
$$p + \gamma \rightarrow \pi^{+} + n \rightarrow UHECRs + \nu' s$$

Field of view in galactic coordinates

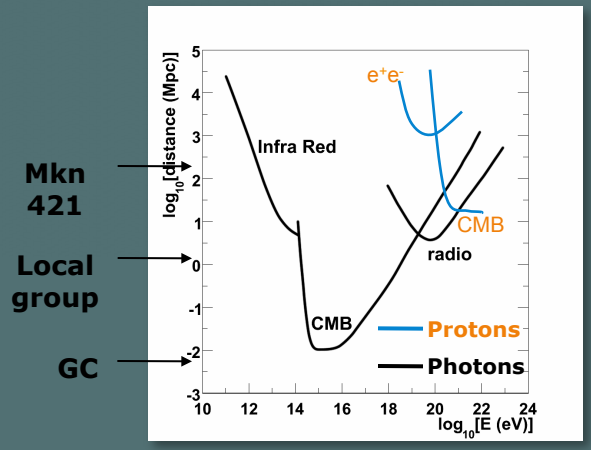
The Galactic Center is visible during the 63 % of the time



Neutrino as a messenger from the deepest universe

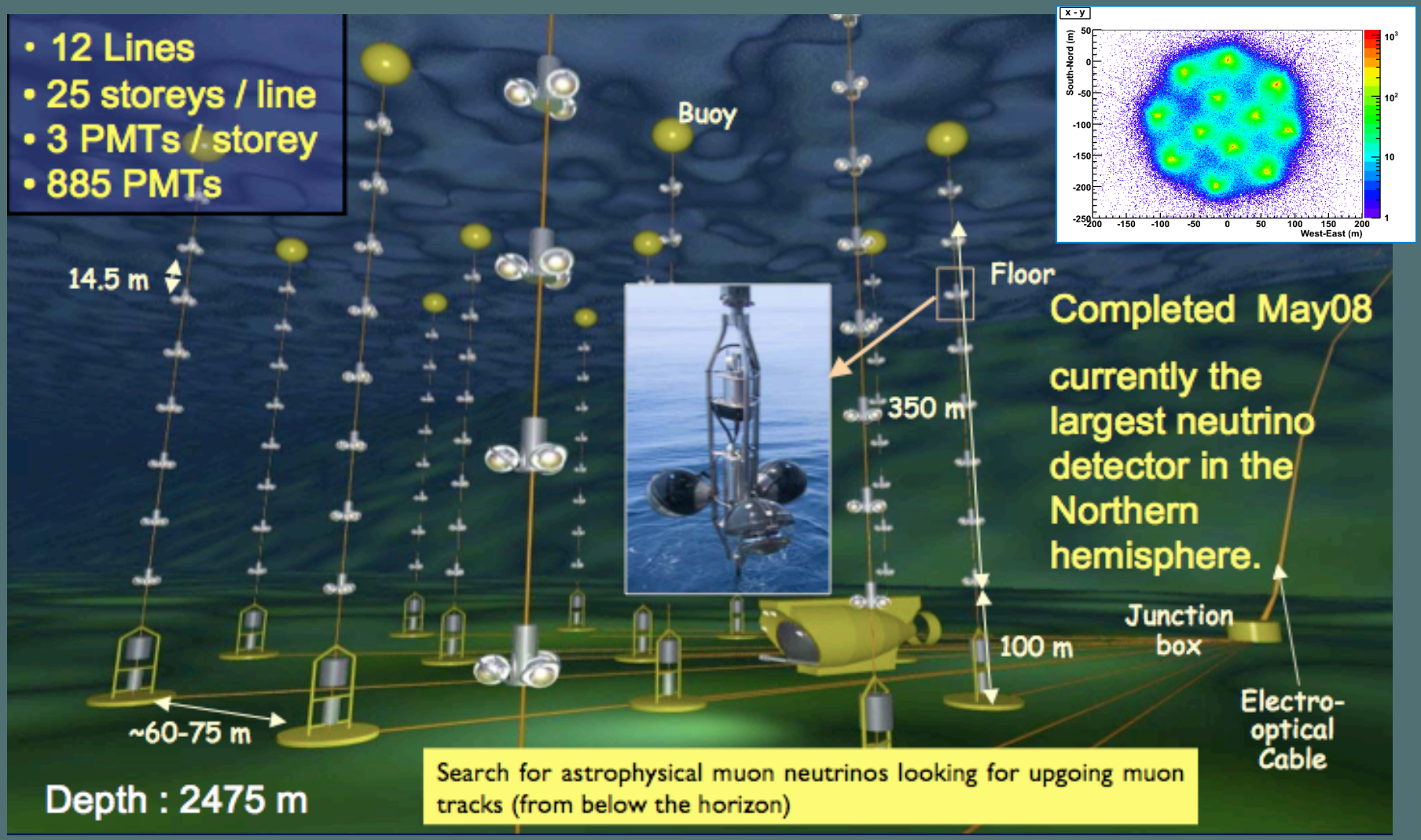


- Protons are deflected by magnetic fields ($E_p < 10^{19}$ eV) UHE protons interact with the CMB ($E_p > 10^{19}$ eV → 30 Mpc)
- Neutrons decay (~10 kpc at E ~ EeV)
- Photons interact with the EBL (~100 Mpc) and CMB (~10 kpc)



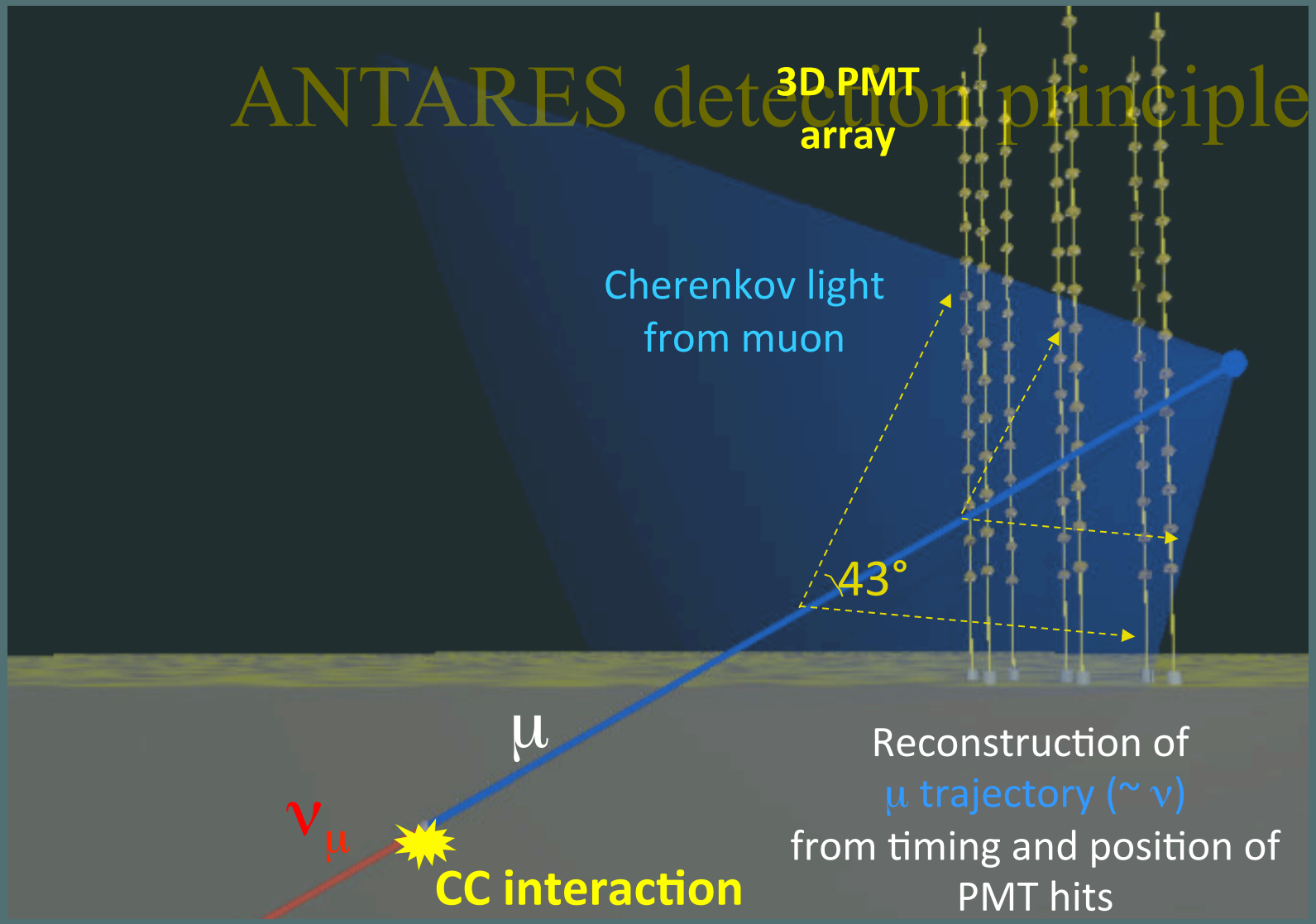
Neutrinos point back to the source of emission

The ANTARES detector

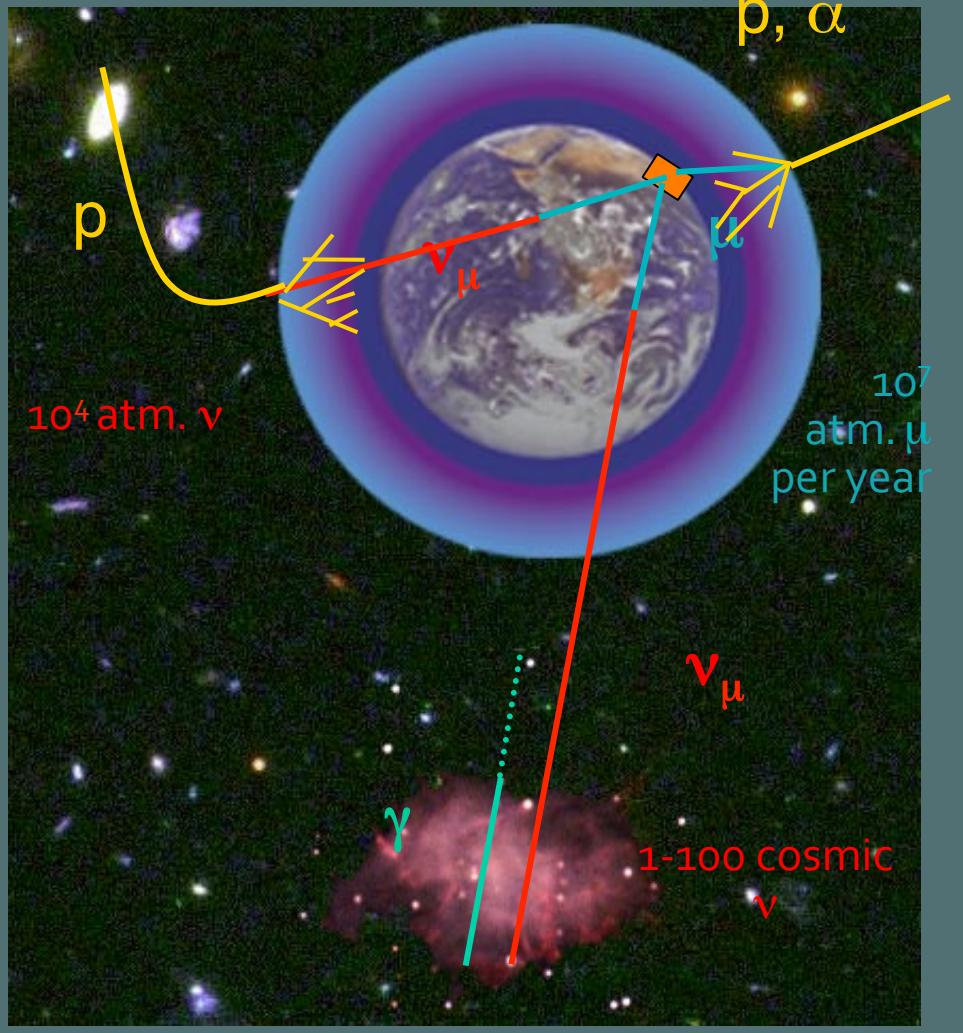


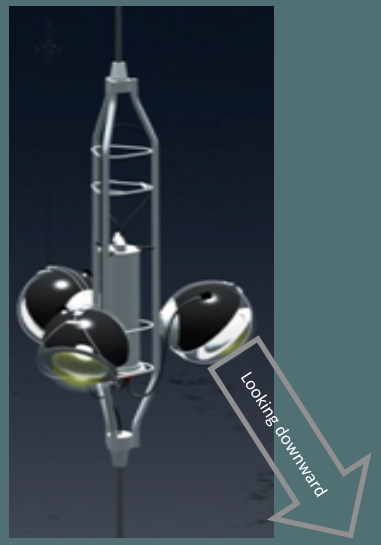
Predominantly sensitive to neutrinos from the Southern hemisphere in the TeV –PeV range

Detection principle



Physical background





Earth shielding rejects atm. muons

upward going muon

↓

neutrino-induced event

Atms. neutrinos can only be separated by looking for clusters of events in the sky
(and unfolding radiation spectra)

Data sample

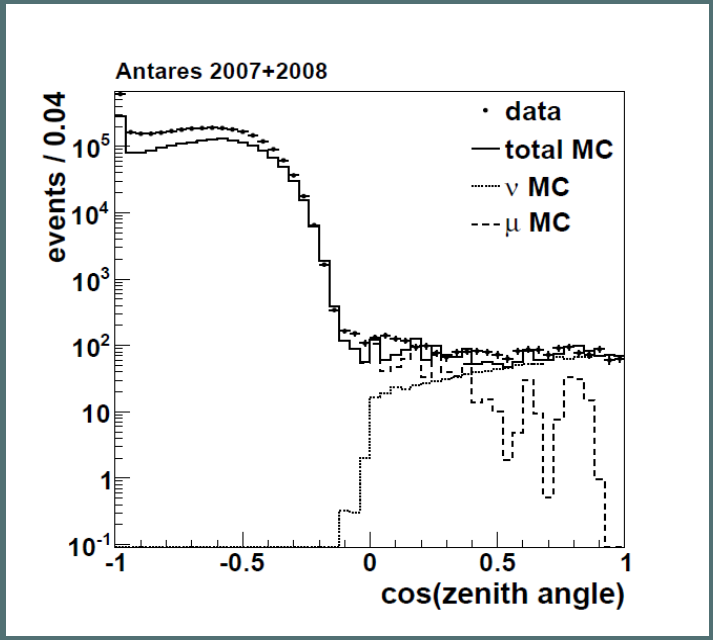
Submitted to 'The Astrophysical Journal Letters'
Preprint available on Arxiv:1108.0292v1 [astro-ph.HE]

Data were collected during years 2007 and 2008

Integrated livetime of the analyzed data is **304 days**

- 144 with the 5-lines detector configuration
- 160 days with 9, 10 and 12 lines

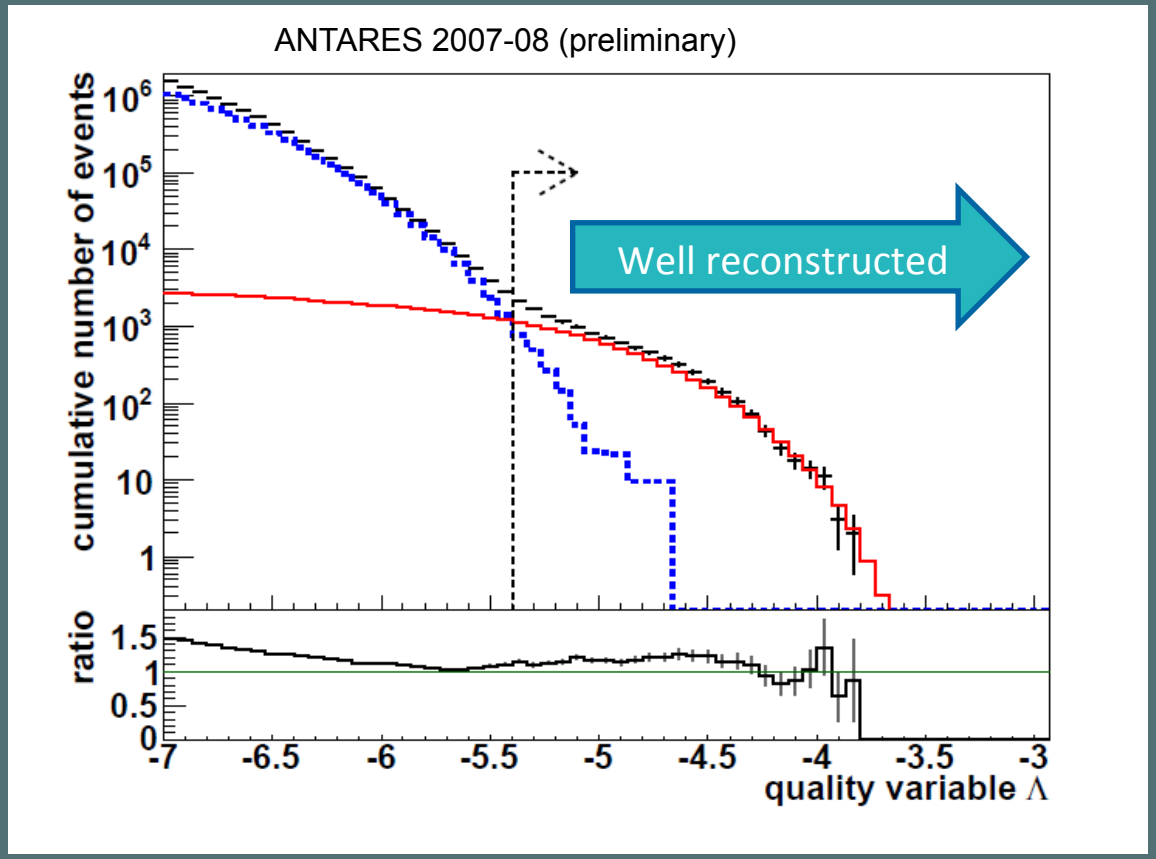
Search for accumulation of events in the Southern sky using directional information



Track reconstruction

Offline Algorithm based on the likelihood maximization of the hit times as a function of the muon direction

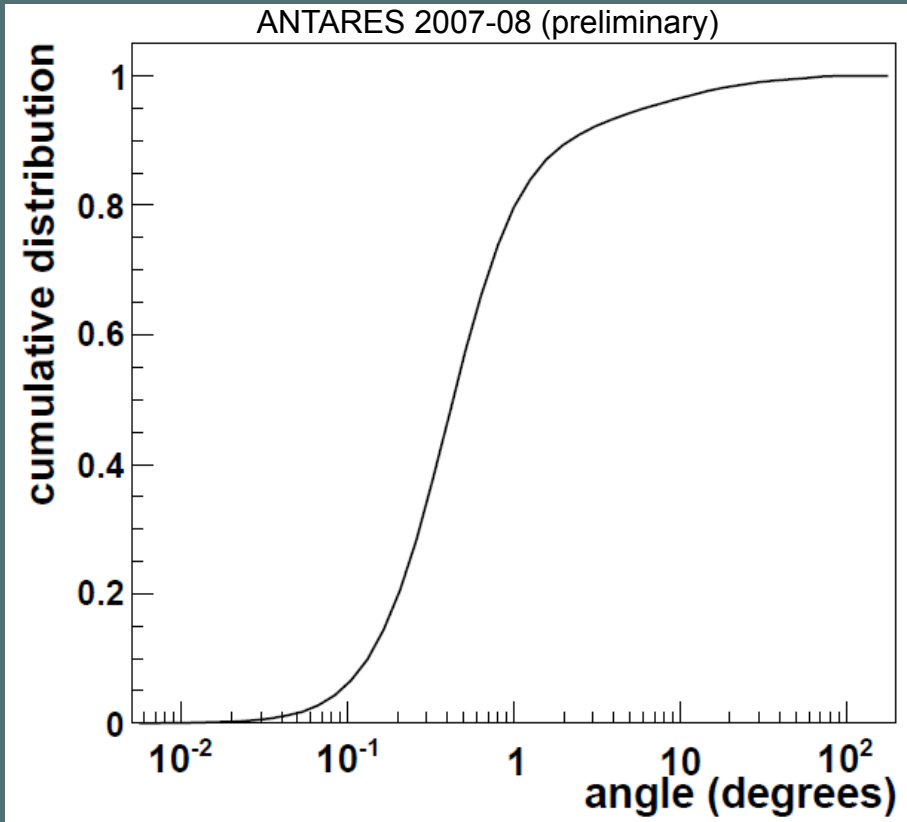
- Uses final alignment
- Loose selection
- Full likelihood fit
- Multiple starting points
- Excellent angular resolution

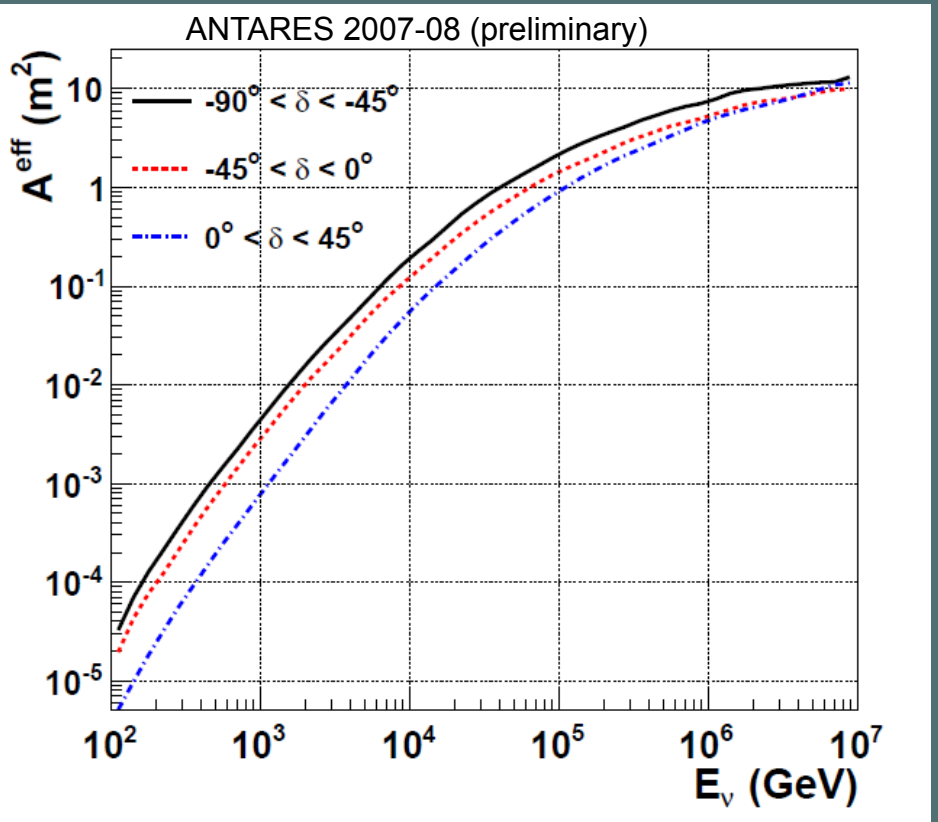


Cumulative distribution of the quality of the reconstruction parameter

Detector performance

Median angular resolution is 0.5 ± 0.1 degrees

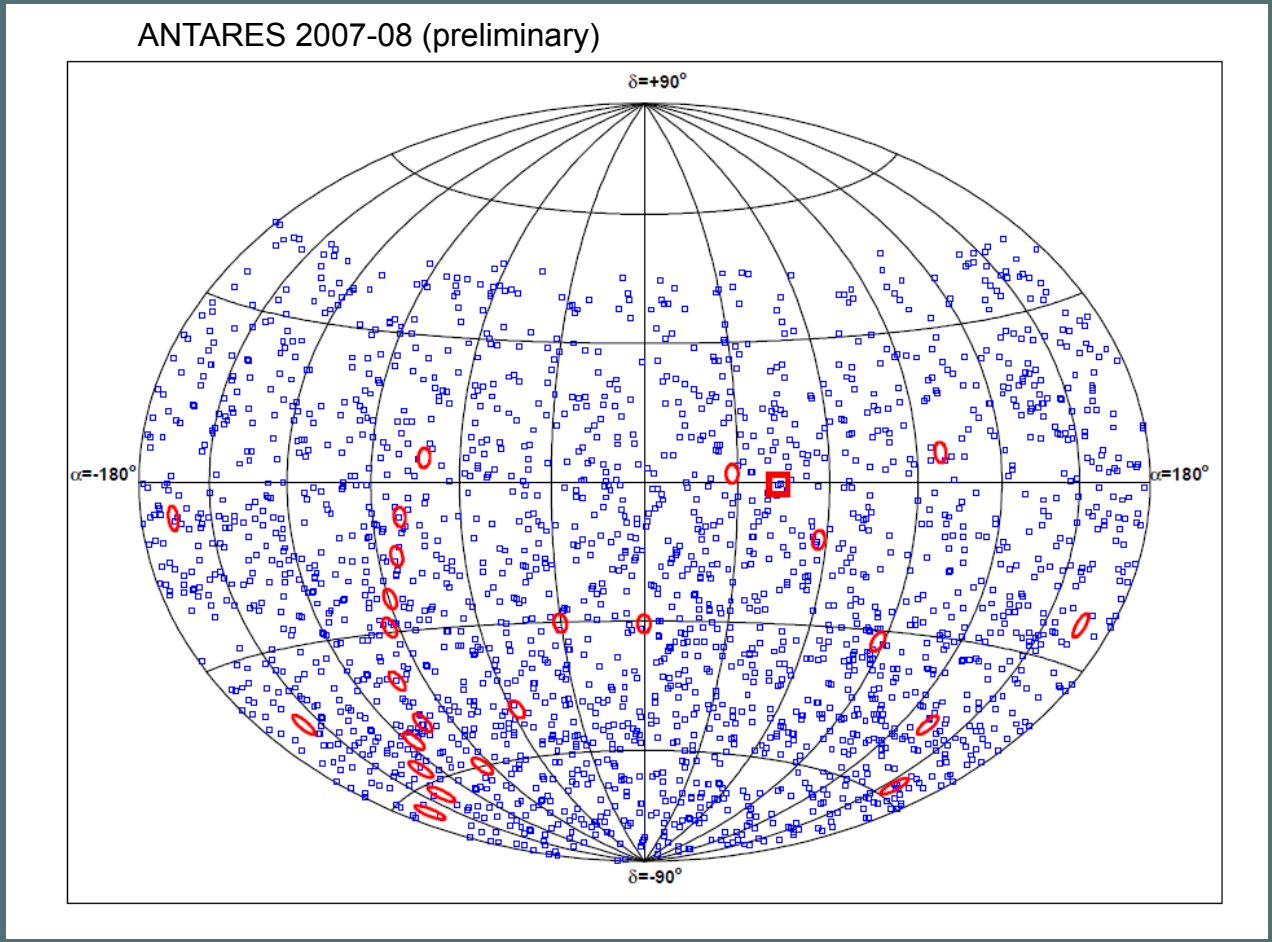




Cumulative distribution of the angle between the reconstructed μ and the true ν direction

Effective area averaged over three declination angles

Event selection

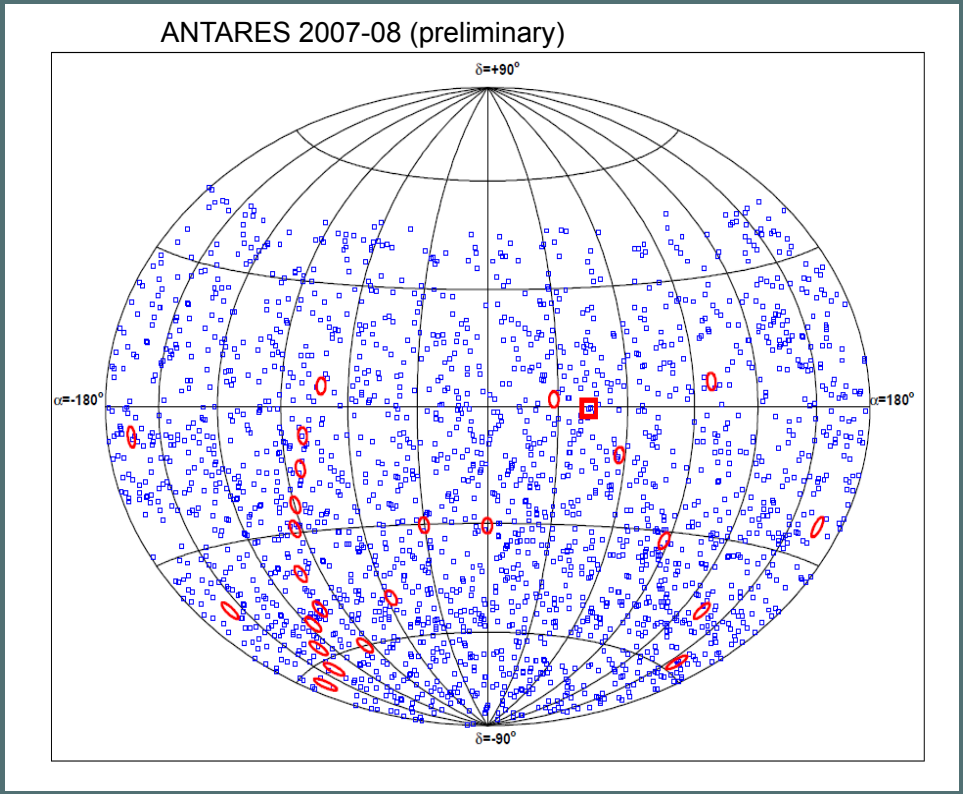


Sample: 2190 events selected from 2007 (5line) and 2008 (12line) data

(Optimal sensitivity → $\theta<90^\circ$ & $\Lambda>-5.4$ & $\beta<1^\circ$)

From which 60% are are atms. Neutrinos while the rest 40% are muons mis-reconstructed as upgoing

Search for point sources



Two searches conducted

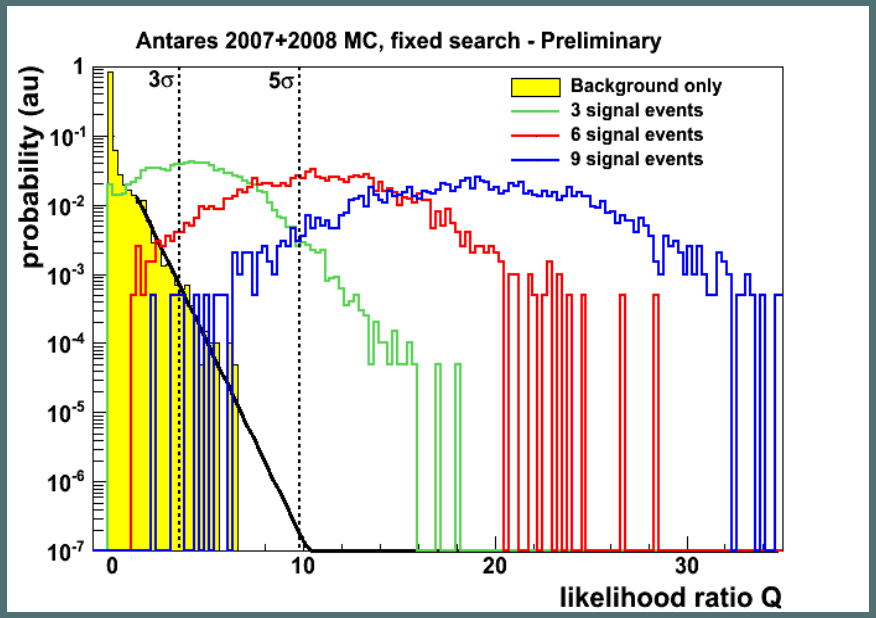
- <u>All sky survey:</u>
  Looking for signal events anywhere in the sky

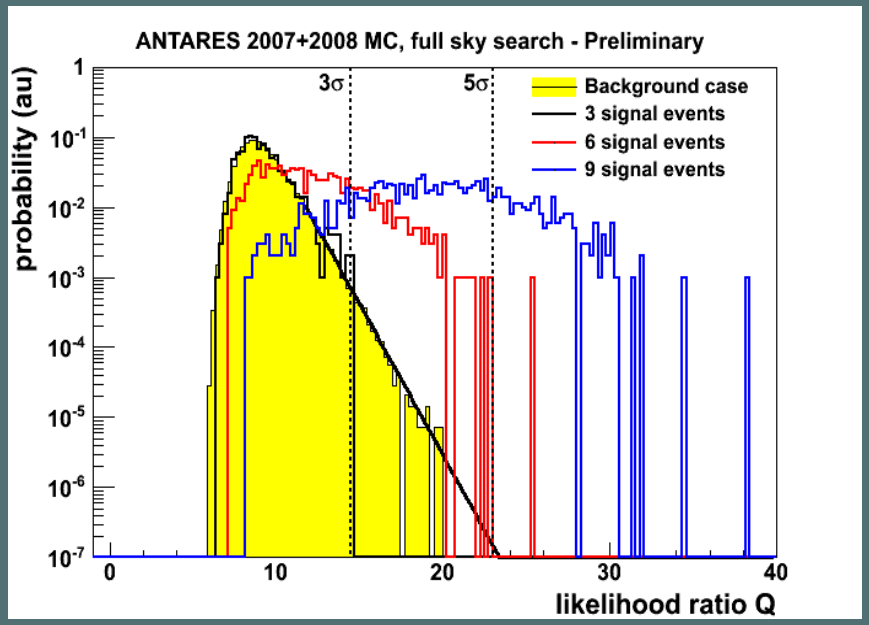
- <u>Candidate list search:</u>
  Search for excess of events at the location of 24 TeV gamma-ray sources

Search for point sources

Unbinned clustering method based on the likelihood of the events

$$\log \mathcal{L}_{\mathrm{s+b}} = \sum_i \log[\mu_{\mathrm{sig}} \times \mathcal{F}(\beta_i(\delta_s, \alpha_s)) + \mathcal{B}(\delta_i)] - \mu_{\mathrm{sig}} - N_{\mathrm{bg}}$$





$$Q = \log \mathcal{L}_{\mathrm{s+b}}^{\mathrm{max}} - \log \mathcal{L}_{\mathrm{b}}$$

Larger Q values indicate that data is more compatible with the signal

Search for point sources

source	α_s (deg)	δ_s (deg)	μ_{sig}^{fit}	Q	p-value	$\phi^{90\%CL}$
HESS J1023-575	155.83	-57.76	2.7	2.5	0.17	2.0
GX 339	-104.30	-48.79	2.2	2.1	0.26	1.9
RX J1713.7-3946	-101.75	-39.75	1.0	1.7	0.46	2.2
HESS J1837-069	-80.59	-6.95	1.1	1.5	0.55	2.6
1ES 0347-121	57.35	-11.99	1.4	1.1	0.70	2.5
3C 279	-165.95	-5.79	0.91	0.74	0.83	2.4
Cir X-1	-129.83	-57.17	0.82	0.65	0.85	1.5
PKS 2005-489	-57.63	-48.82	0	0	1	1.1
Galactic Center	-93.58	-29.01	0	0	1	1.2
LS 5039	-83.44	-14.83	0	0	1	1.4
H 2356-309	-0.22	-30.63	0	0	1	1.1
RX J0852.0-4622	133.00	-46.37	0	0	1	0.76
PKS 0548-322	87.67	-32.27	0	0	1	1.1
PSR B1259-63	-164.30	-63.83	0	0	1	0.76
PKS 2155-304	-30.28	-30.22	0	0	1	1.0
HESS J1614-518	-116.42	-51.82	0	0	1	0.59
SS 433	-72.04	4.98	0	0	1	1.1
HESS J0632+057	98.24	5.81	0	0	1	1.2
RCW 86	-139.32	-62.48	0	0	1	0.47
RGB J0152+017	28.17	1.79	0	0	1	0.89
Centaurus A	-158.64	-43.02	0	0	1	0.49
ESO 139-G12	-95.59	-59.94	0	0	1	0.36
W28	-89.57	-23.34	0	0	1	0.61
1ES 1101-232	165.91	-23.49	0	0	1	0.61

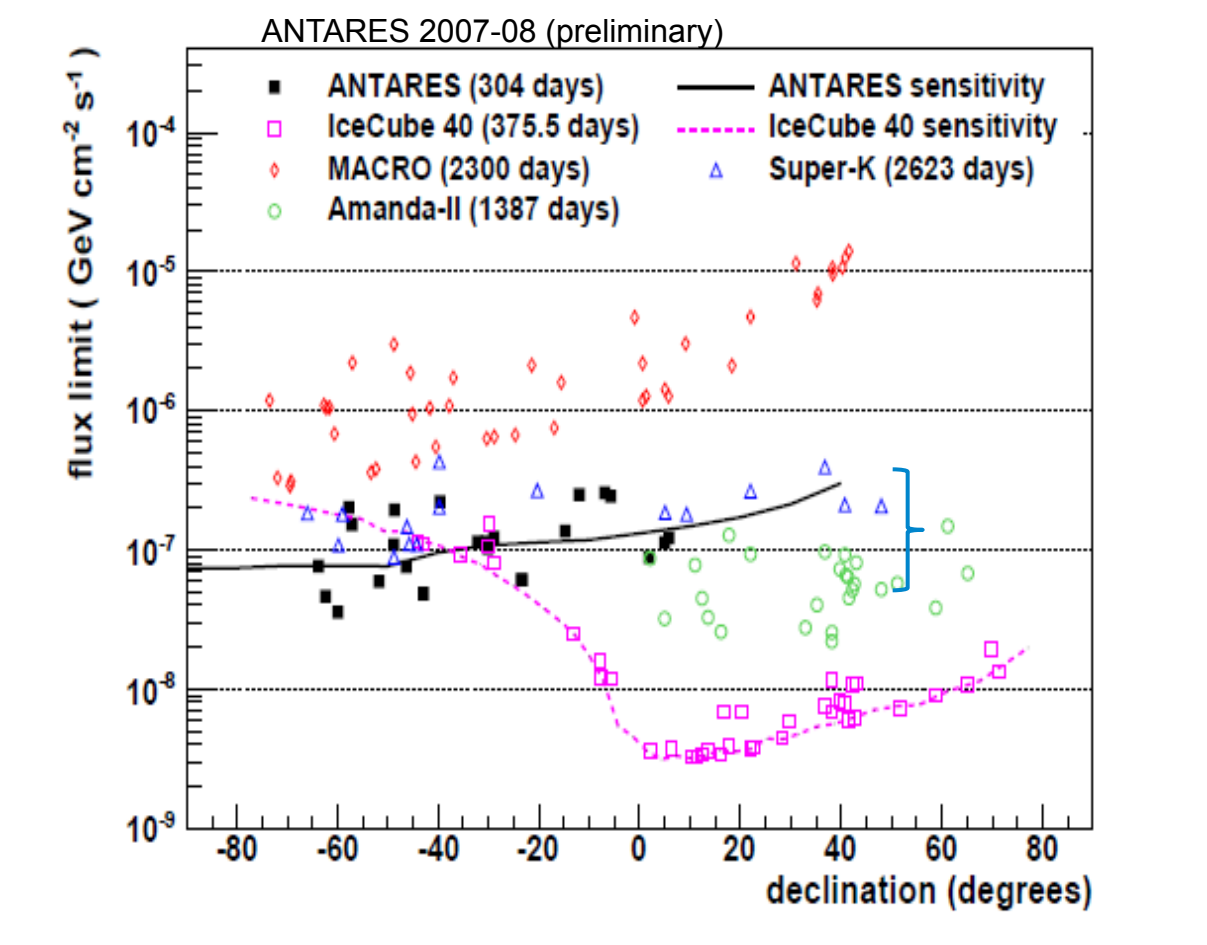
Not statistically significant excess of events observed

- **All sky search:**
  - $(\alpha,\delta) = (43.21°, -0.50°)$
  - Q= 6.8, Nsig = 3.4
  - p=88% in bg only exp.

- **Candidate list search:**
  - HESS J1023-575
  - Q = 2.5, 3 events within 1°
  - p = 17% (post-trial)

Search for point sources

Upper limits on the flux normalization of an E^-2 spectrum of high energy neutrinos

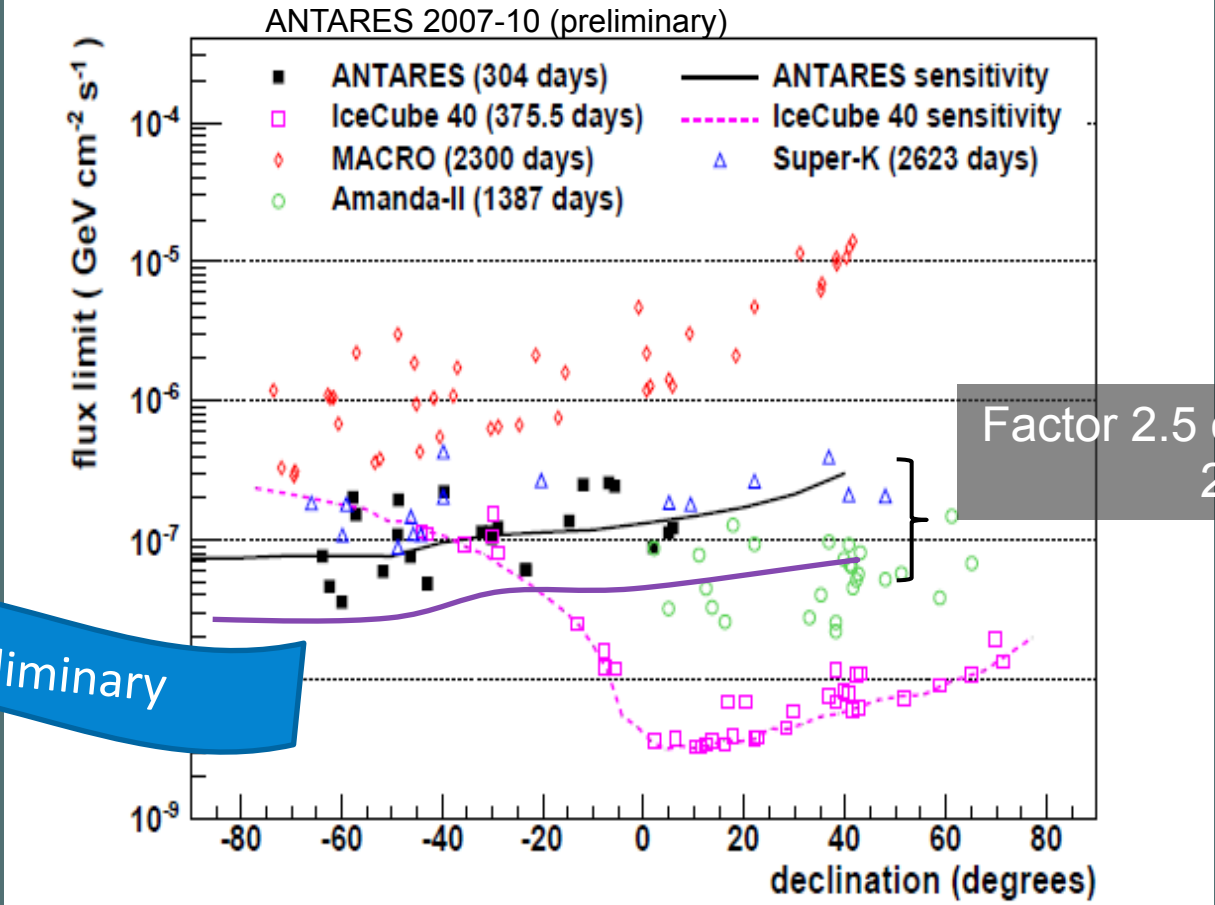


90% C.L.
Feldman-Cousins

Most stringent limits (than previous multi-year neutrino experiments) for many sources

Search for point sources

Analysis with data collected in 4 years of detector operation
(803 days of livetime) ongoing



preliminary

Factor 2.5 of gain using 2007-10 data

With about 2.5 times longer exposure

Selection with a stringent Qcut (only 14% of muon contamination)

Expected sensitivity on the E^-2 neutrino flux

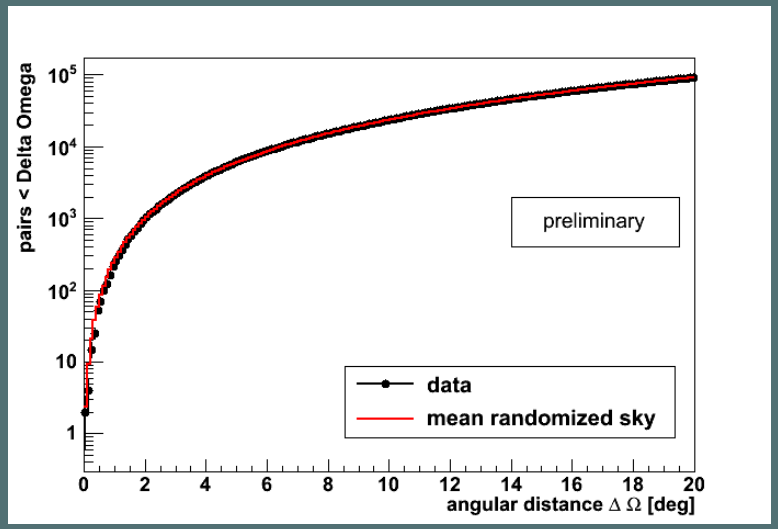
Autocorrelation analysis

Same data sample as point source search (2007-2008)

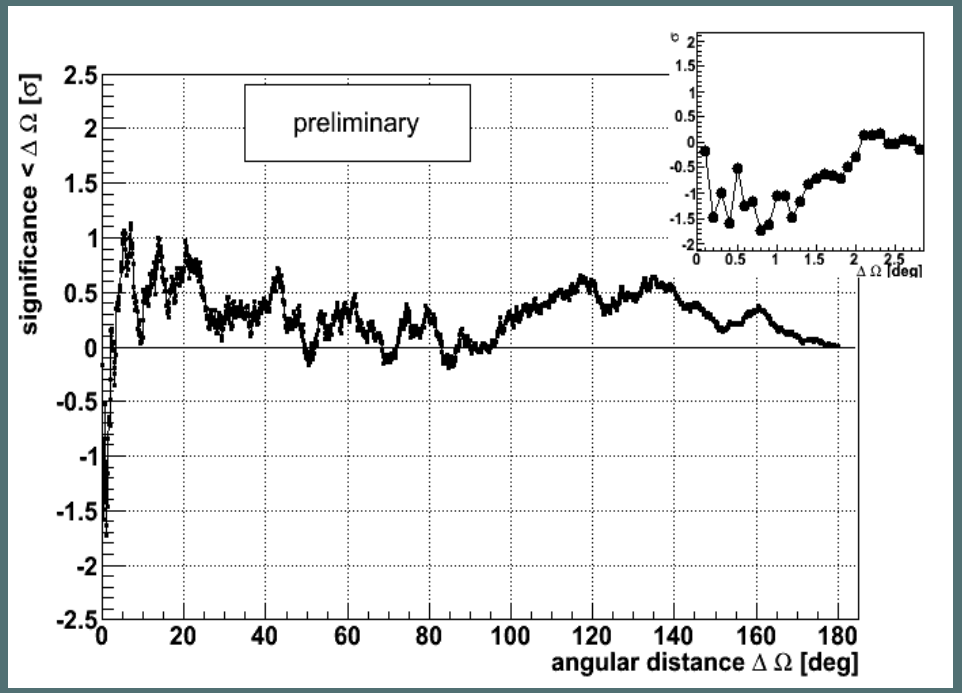
Event selection and search method cross-checked:

Results using the Expectation-Maximization algorithm are consistent

Number of pairs in a given angular bin



No significant excess found



Summary

ANTARES is taking data since 2007 **(infrastructure complete in May 2008)**

- Largest neutrino telescope in the northern hemisphere, the first
- Data analysis ongoing, first results published

Search for point-sources

- Integrated livetime 304 days

  Final sample of 2190 events (60% atms. neutrinos)

- No significant excess found neither in the candidate list search, nor in the full sky survey

  Best limits for point sources for the Southern sky
  Independent search method and data selection agree
  No structures in the autocorrelation analysis

- Analysis of 2007-10 data almost ready (stay tuned!)