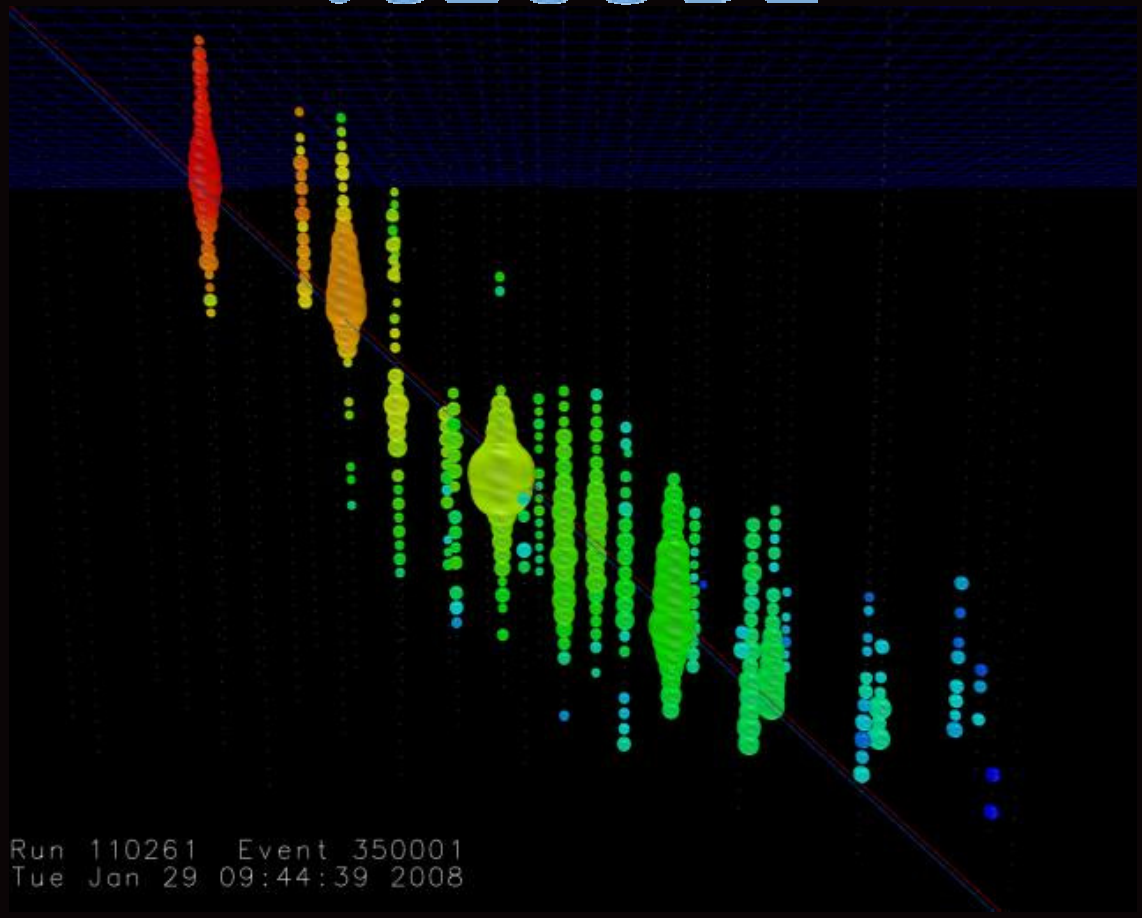
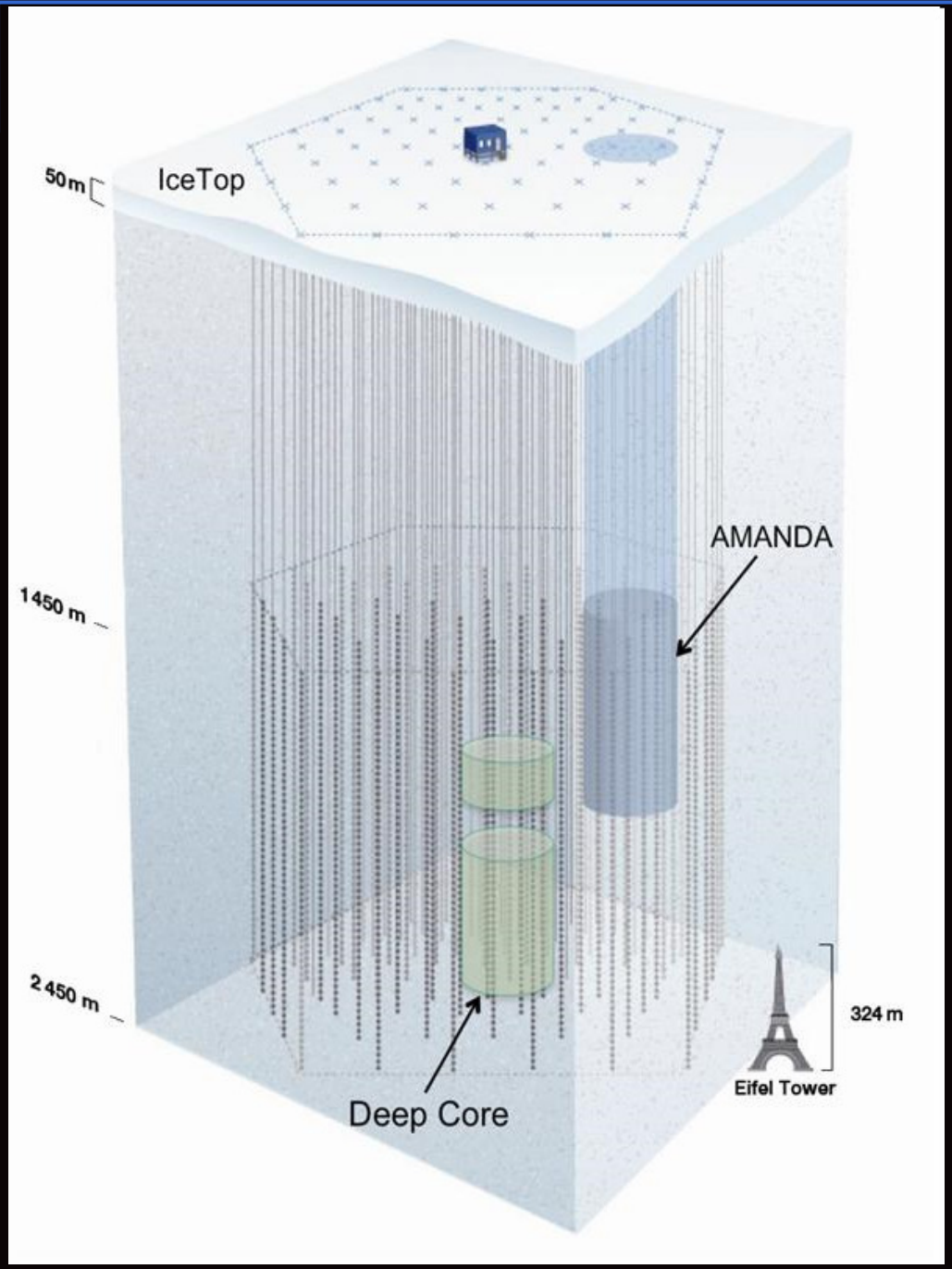
# Cosmic Ray Accelerators with ICECUBE




E. Resconi, *MPI-K Heidelberg*
*for the IceCube Collaboration*

Max-Planck-Institut für Kernphysik

Emmy Noether-Programm
Deutsche Forschungsgemeinschaft DFG

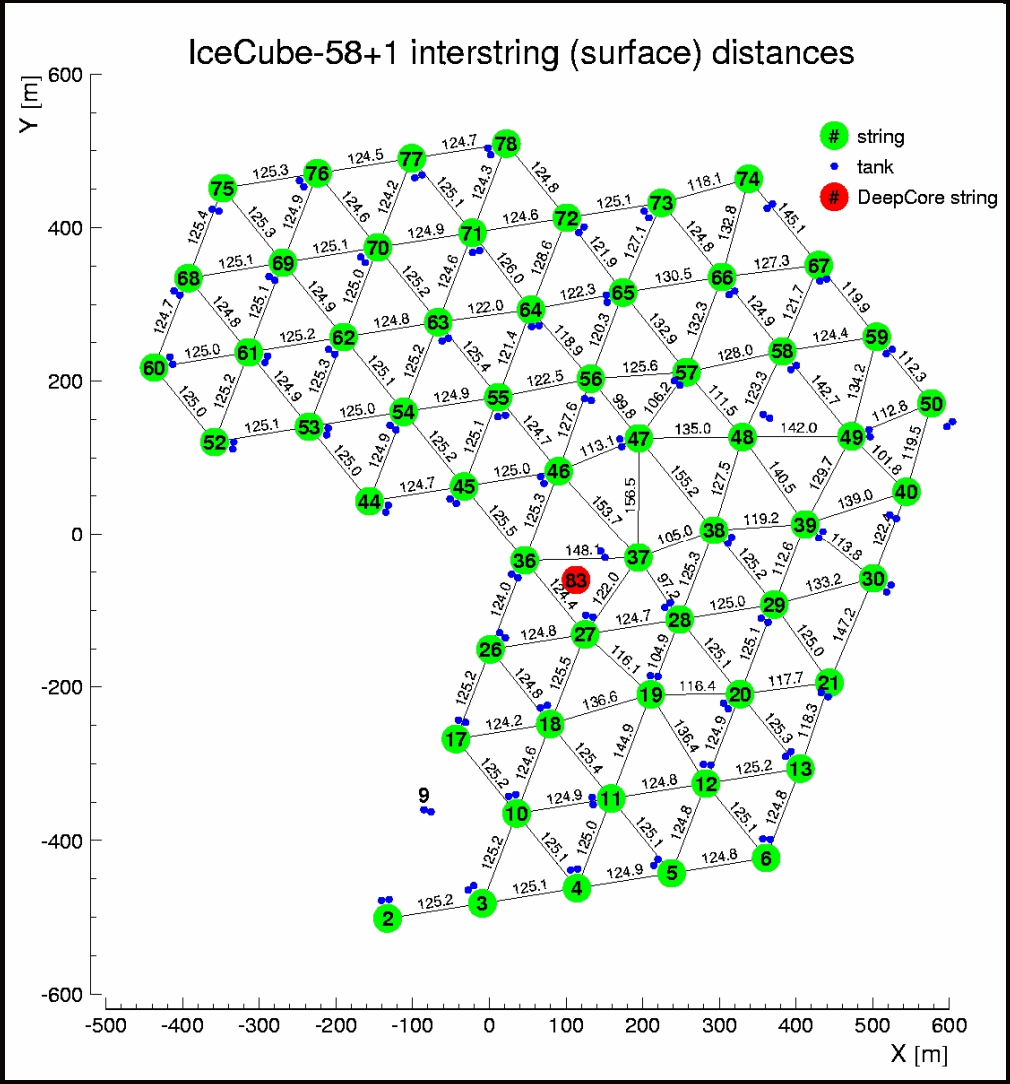



# ICECUBE

2009: 58+1 strings deployed
59 IceTop Stations

2011: 80+6 strings planned
80 IceTop Stations

# ICECUBE




2009: 58+1 strings deployed
59 IceTop Stations

2011: 80+6 strings planned
80 IceTop Stations

# The IceCube Collaboration

**USA:**
Bartol Research Institute, Delaware
University of California, Berkeley
University of California, Irvine
Pennsylvania State University
Clark-Atlanta University
Ohio State University
Georgia Tech
University of Maryland
University of Alabama, Tuscaloosa
University of Wisconsin-Madison
University of Wisconsin-River Falls
Lawrence Berkeley National Lab.
University of Kansas
Southern University and A&M College, Baton Rouge
University of Alaska, Anchorage

**Sweden:**
Uppsala Universitet
Stockholm Universitet

**UK:**
Oxford University

**Netherlands:**
Utrecht University

**Switzerland:**
EPFL

**Germany:**
DESY-Zeuthen
Universität Mainz
Universität Dortmund
Universität Wuppertal
Humboldt Universität
MPI Heidelberg
RWTH Aachen

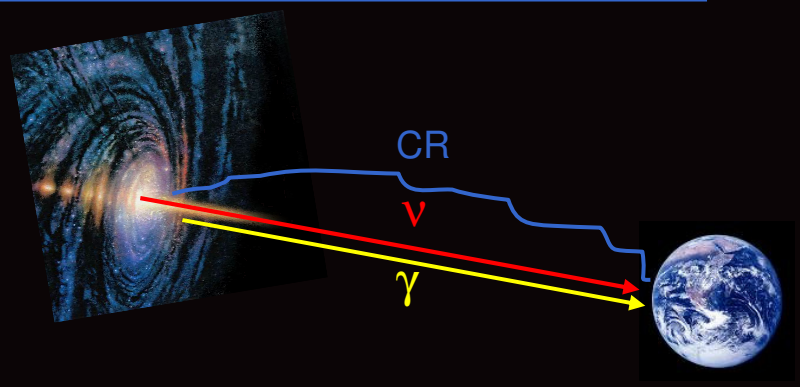
**Belgium:**
Université Libre de Bruxelles
Vrije Universiteit Brussel
Universiteit Gent
Université de Mons-Hainaut

**Japan:**
Chiba University

**New Zealand:**
University of Canterbury

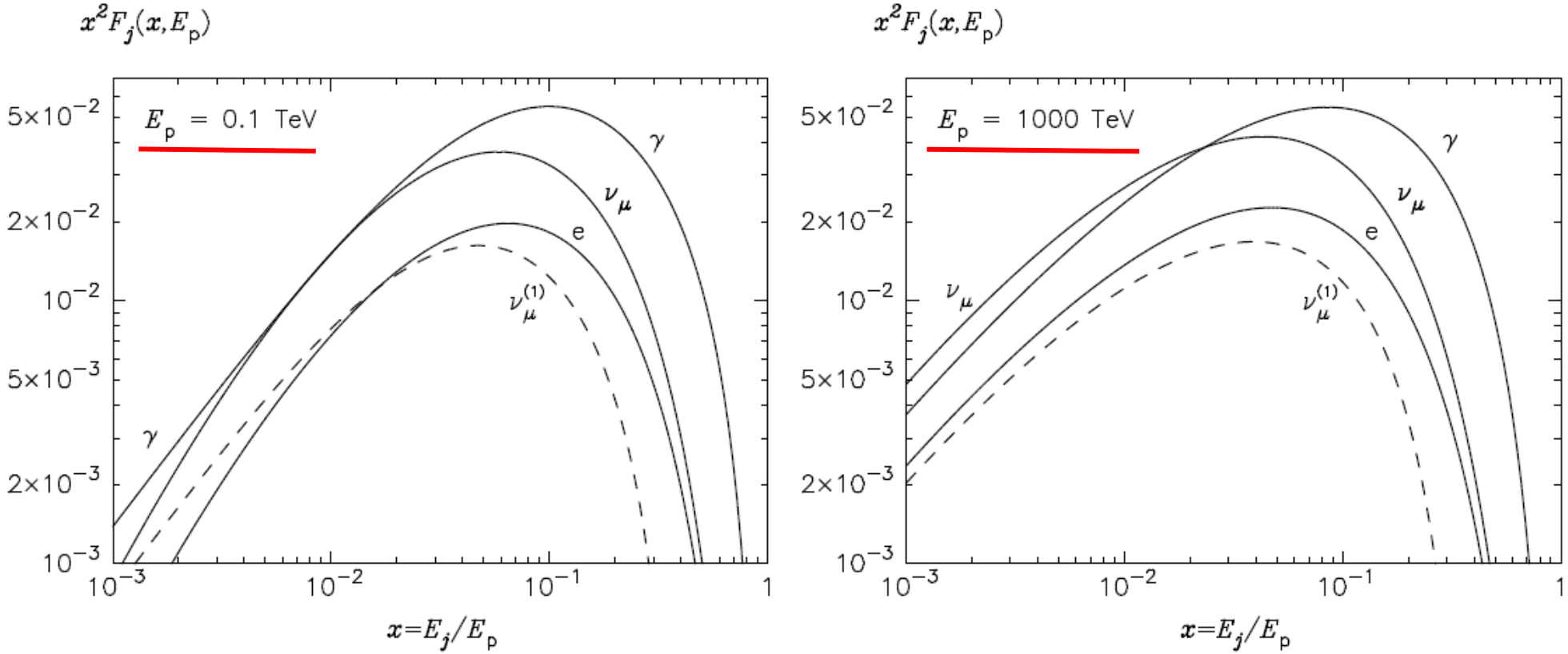
**33 institutions, ~250 members**
**http://icecube.wisc.edu**

# Cosmic Ray & Gamma & Neutrinos



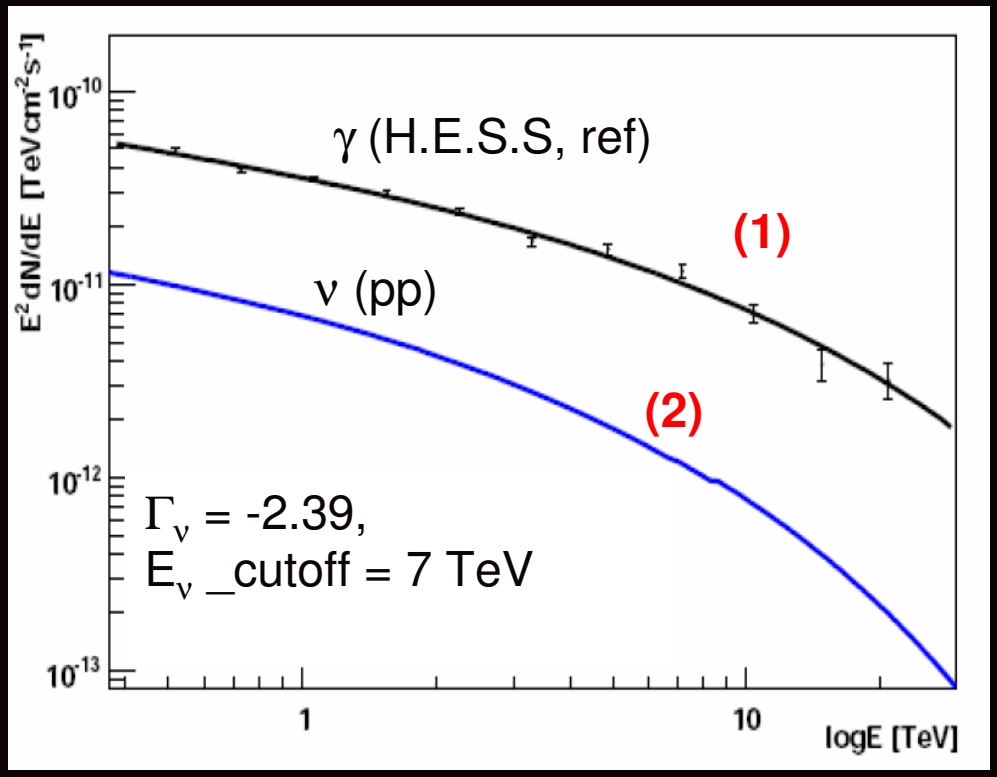

Proton-Proton Interaction: All-Products Energy Spectrum

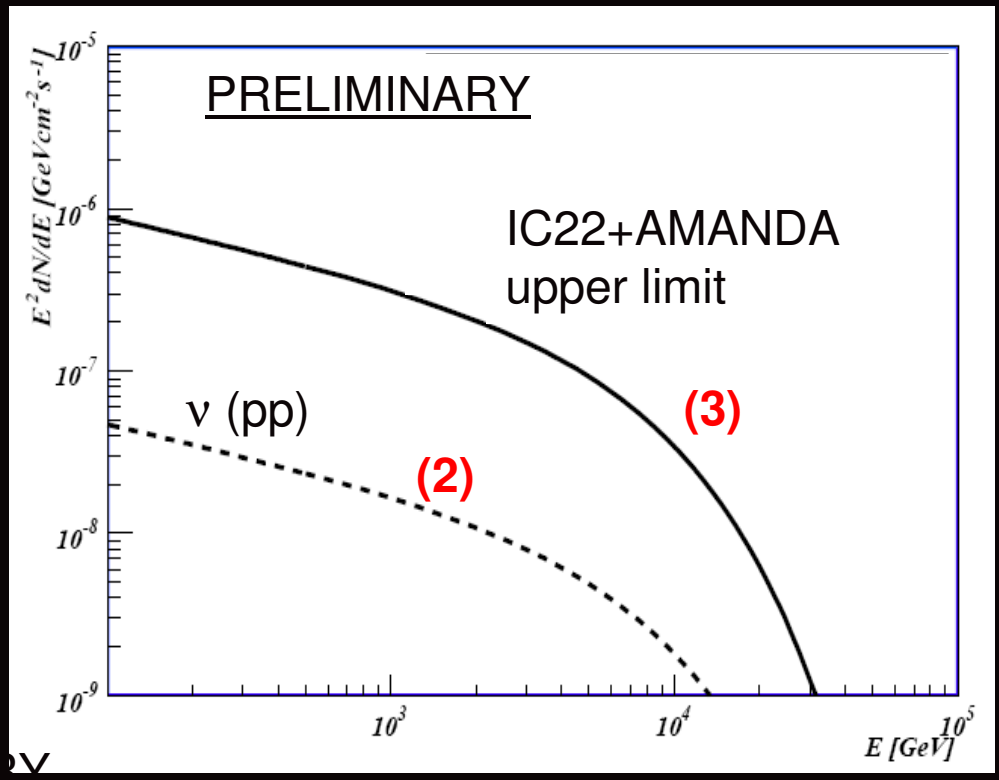
S.R. Kelner et al., Phys.Rev.D74:034018,2006



# Search in our Galaxy: The Crab a "low" energy source

Crab Upper Limit (IceCube 22 + AMANDA)
A. Gross, C. Roucelle et al., for the IceCube Coll., ICRC 2009

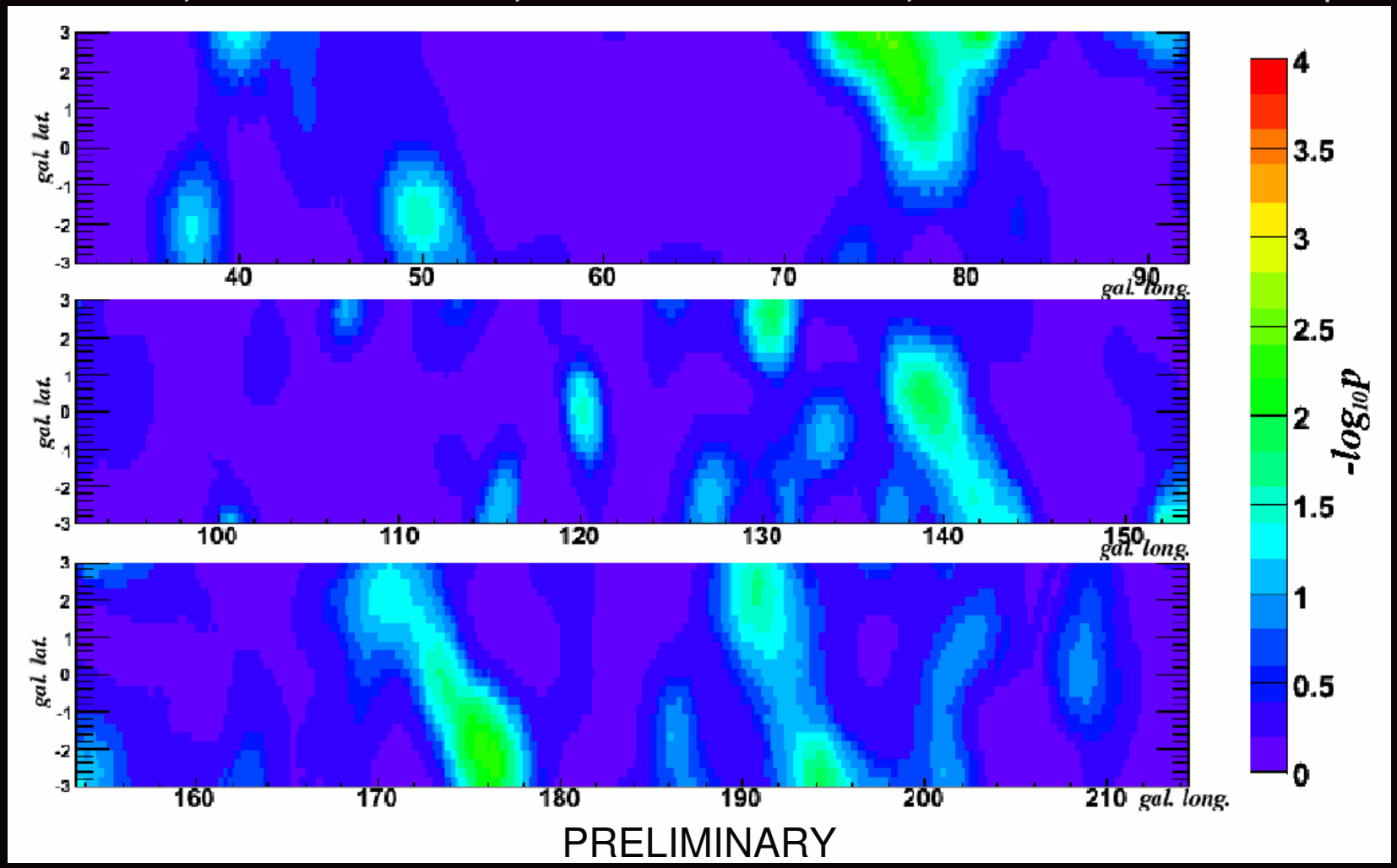


# The "Knee": Search in our Galaxy

Galactic Plane Scan: IceCube 22 + AMANDA

A. Gross, C. Roucelle et al., for the IceCube Coll., ICRC 2009 Pre-trial p-values

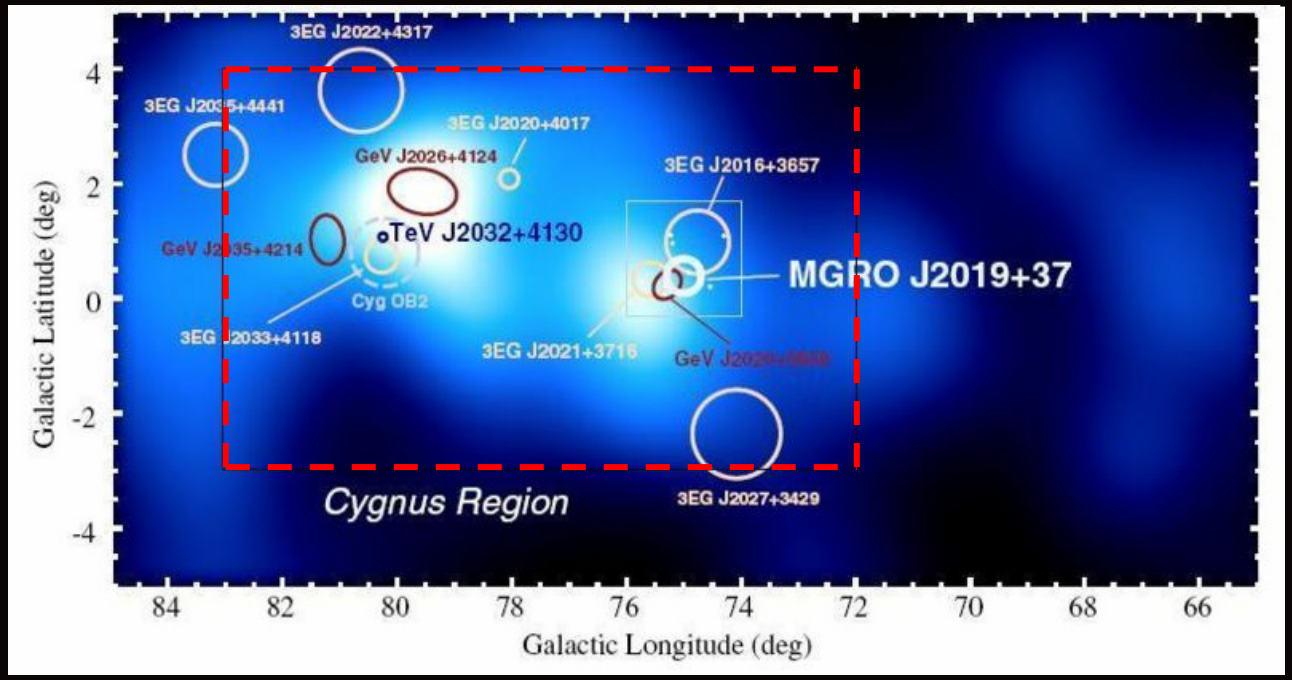



**NO SIGNIFICANT STRUCTURE OBSERVED**

# The "Knee": Search in our Galaxy

PROSPECTS for Soft Spectra Sources:

- Dedicated Search for Extended Cygnus Region
  ($\gamma$-rays Point Sources + Diffuse Emission)




- IceCube40 + AMANDA under processing

# Above the "Knee": extra-galactic
# Or … everything we don't know

- Point Source Search
  - Northern Hemisphere
  - Southern Hemisphere
  - Flaring Sources

- GRBs
- Diffuse Flux Search

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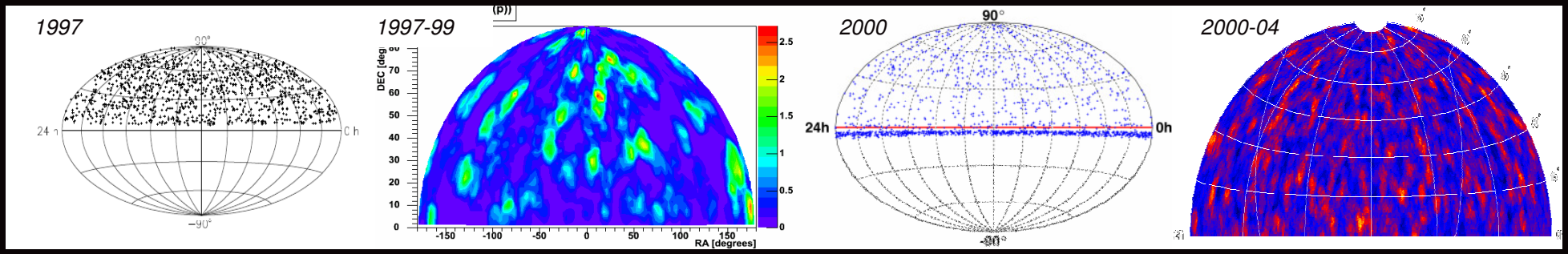
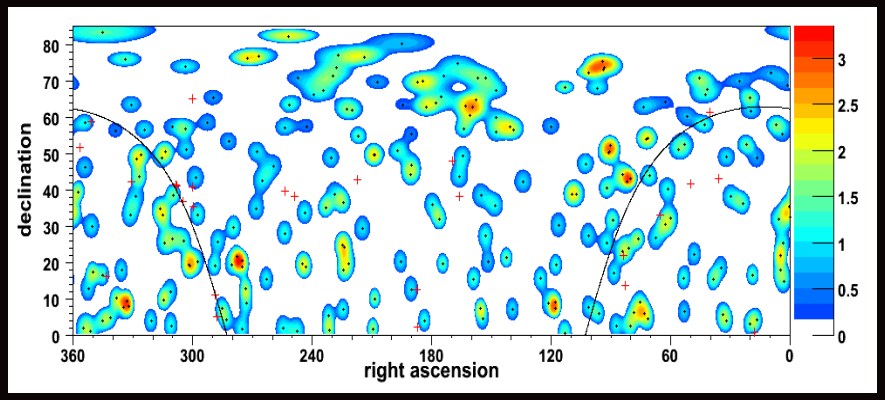
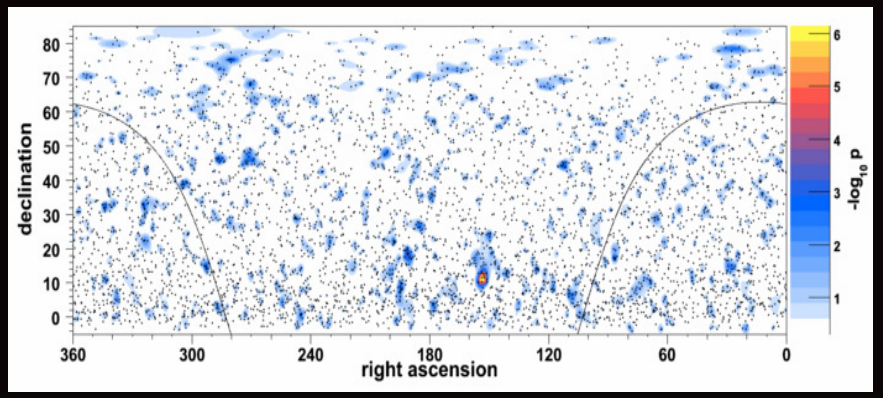



1997 — 2000 — 2004

AMANDA B10 — AMANDA II

| Detector | Energy Window (TeV) | Exposure Time (days) | Limit ($TeV^{-1}\ cm^{-2}\ s^{-1}$) |
|---|---|---|---|
| AMANDA-B10 (1997-99) | ~1 – 1000 | 623 | $4.0 \cdot 10^{-10}$ |
| AMANDA-II (2000-04) | 1.6 - 2600 Phys.Rev.D75:102001,2007 | 1001 | $5.5 \cdot 10^{-11}$ |
| AMANDA-II (2005-06) | | | $7.0 \cdot 10^{-11}$ |



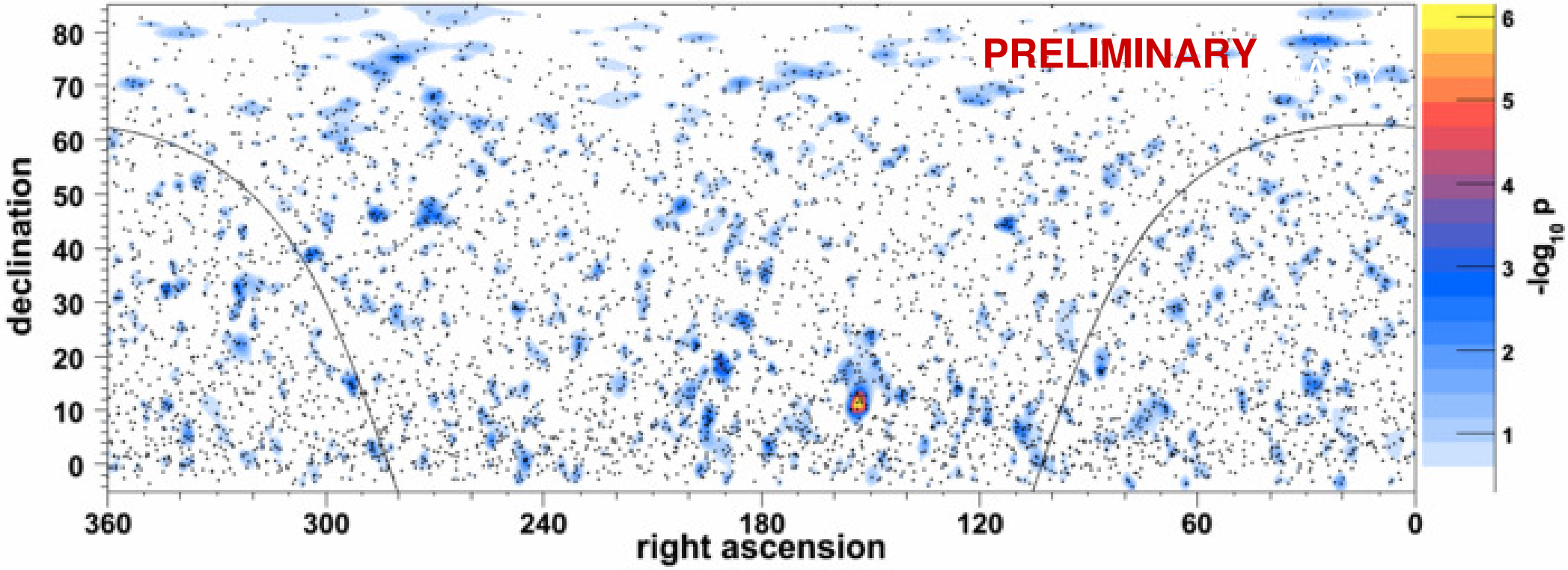



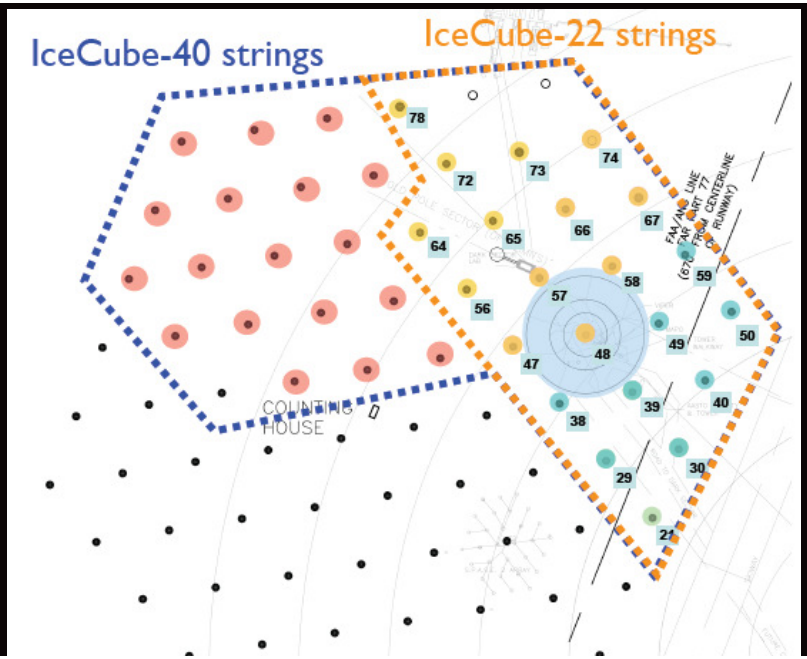

2006 — 2007

IceCube 9 strings — IceCube 22 strings

| Detector | Energy Window (TeV) | Exposure Time (days) | Limit (L) Sensitivity (S) ($TeV^{-1}\ cm^{-2}\ s^{-1}$) |
|---|---|---|---|
| IC9 (2006) | ~ 5 - 1000 | 137 | $1.2 \cdot 10^{-10}$ (L) |
| IC22 (2007)<br>IC22 + AMANDA | ~ 5 – 5000<br>~ 0.5 - 10 | 240 | $\sim 10^{-11}$ (S)<br>Only for specific |
| IC80 | ~ 5 - 5000 | 3 years | $2 \cdot 10^{-12}$ (S) |

# IceCube-22 sky-map, 275.70 days, 5114 events



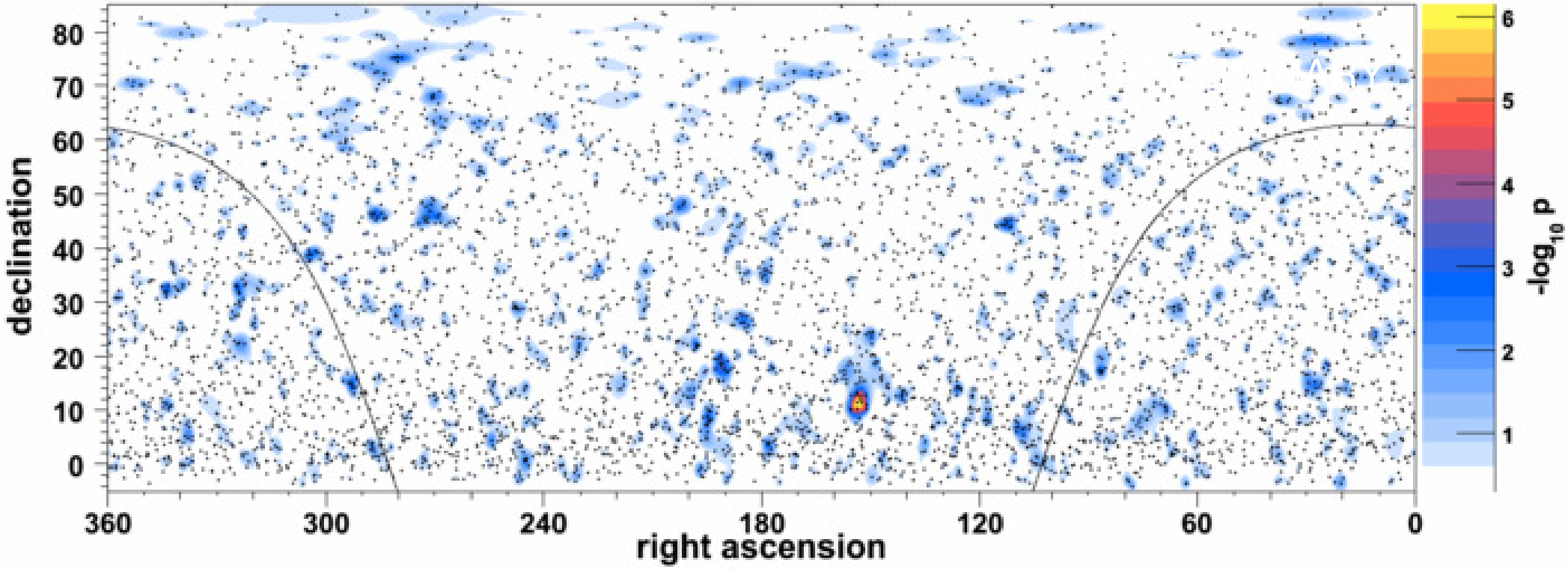




Location: <u>equatorial coordinates</u>
RA: 153.375° = HA: 10h13m30s (J2000.0)
Dec: +11.375° = 11d22m30s

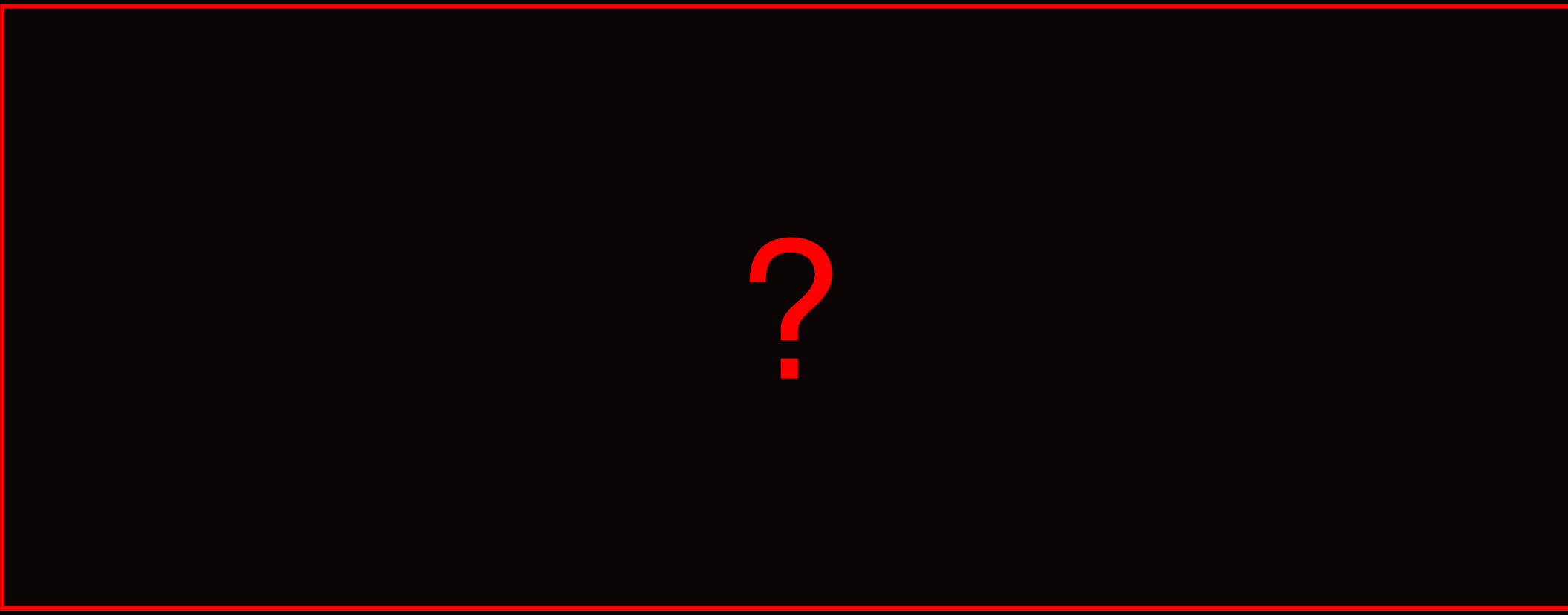
Pre-trial: p-value = $7 \cdot 10^{-7}$
Post-trial: p-value = 1.3%

C. Finley for the IceCube Coll.,
4th TeVPA Workshop Beijing, *China*. 2008

IceCube-22 sky-map, 275.70 days, 5114 events




- This can happen in 1.3% of random cases
- Compatible with a fluctuation of the background
- No evidence of specific time behaviour



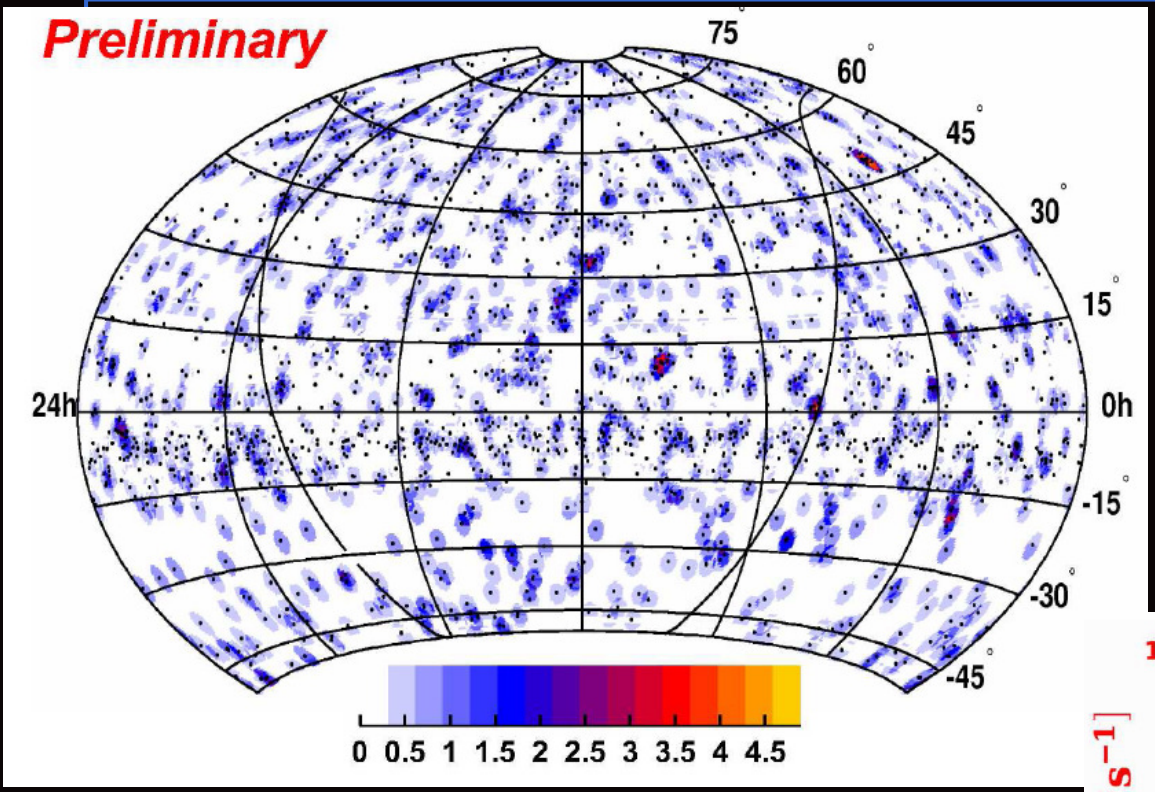

IceCube 40 new analysis
… and
IceCube 59 is taking data

IceCube 40 preliminary results based on 6 months ~ ready for ICRC09

# Above the "Knee": extra-galactic
# Or … everything we don't know

- Point Source Search
  - Northern Hemisphere ($E_\nu$~ TeV – PeV)
  - Southern Hemisphere ($E_\nu$ ~ 100 TeV – EeV)
  - Flaring Sources

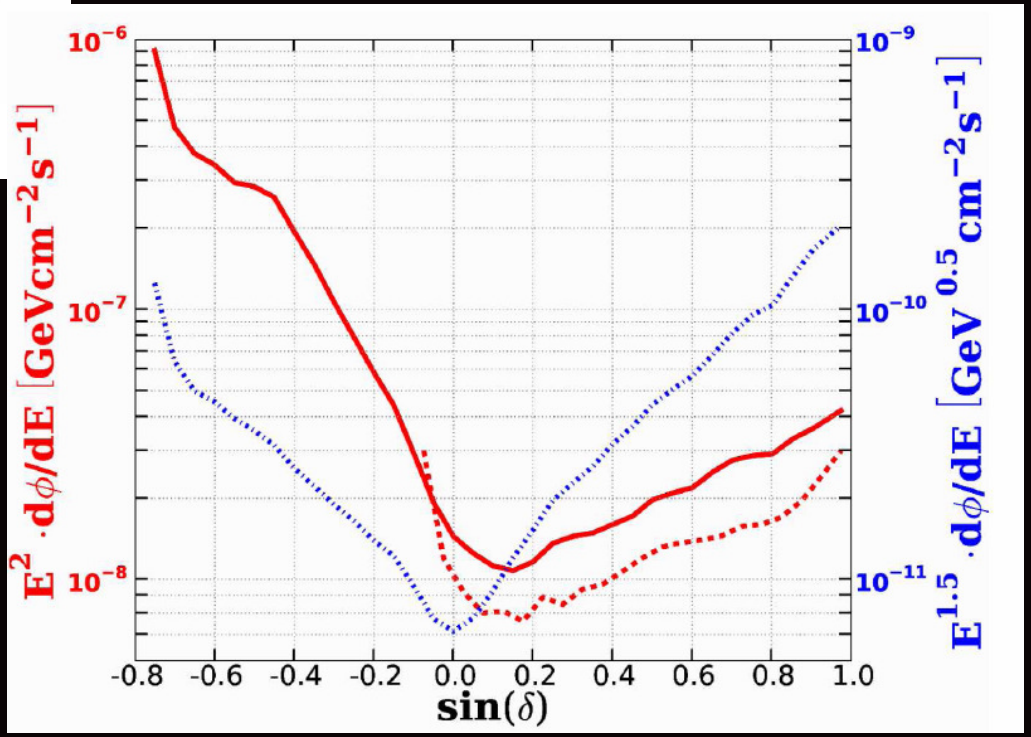
- GRBs
- Diffuse Flux Search




Pre-trial p-values

**NO SIGNIFICANT STRUCTURE OBSERVED**

R. Lauer for the IceCube Coll.,
2nd Heidelberg Workshop,
**"High-Energy Gamma-rays and Neutrinos from Extra-Galactic Sources"**



# Above the "Knee": extra-galactic
# Or … everything we don't know

- Point Source Search
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  - Southern Hemisphere
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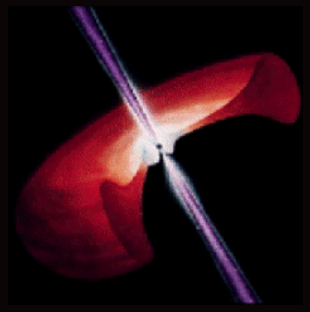
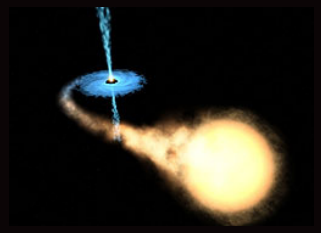
# Flaring/Periodic Sources: Multi-wavelength

**Active Galactic Nuclei**



- Mkn 421, Mkn 501, 1ES1959+650 → **X- and γ-rays**
- 3C273, 3C454, S5 0716+71 → **GeV γ -rays**

**X-ray Binary Systems**



- SS433, LSI +61 303, Cyg X-1, Cyg X-3, ….. → **Radio Periodicity**

# Flaring/Periodic Sources: Multi-wavelength

Flares Tested in IceCube 22:
M. Baker et al., for the IceCube Coll, ICRC 2009

3C 454.3: July 24-30, 2007; Nov. 11-21, 2007

1ES 1959+650: Nov 25-28, 2007; **Dec 2-7, 2007 (1 event)**

Cygnus X-1: August 8, 2007

S5 0716+71: September 7-12, 2007; **October 19-28 2007 (1 event)**

**In ~ 10% random cases: 2 coincidences**

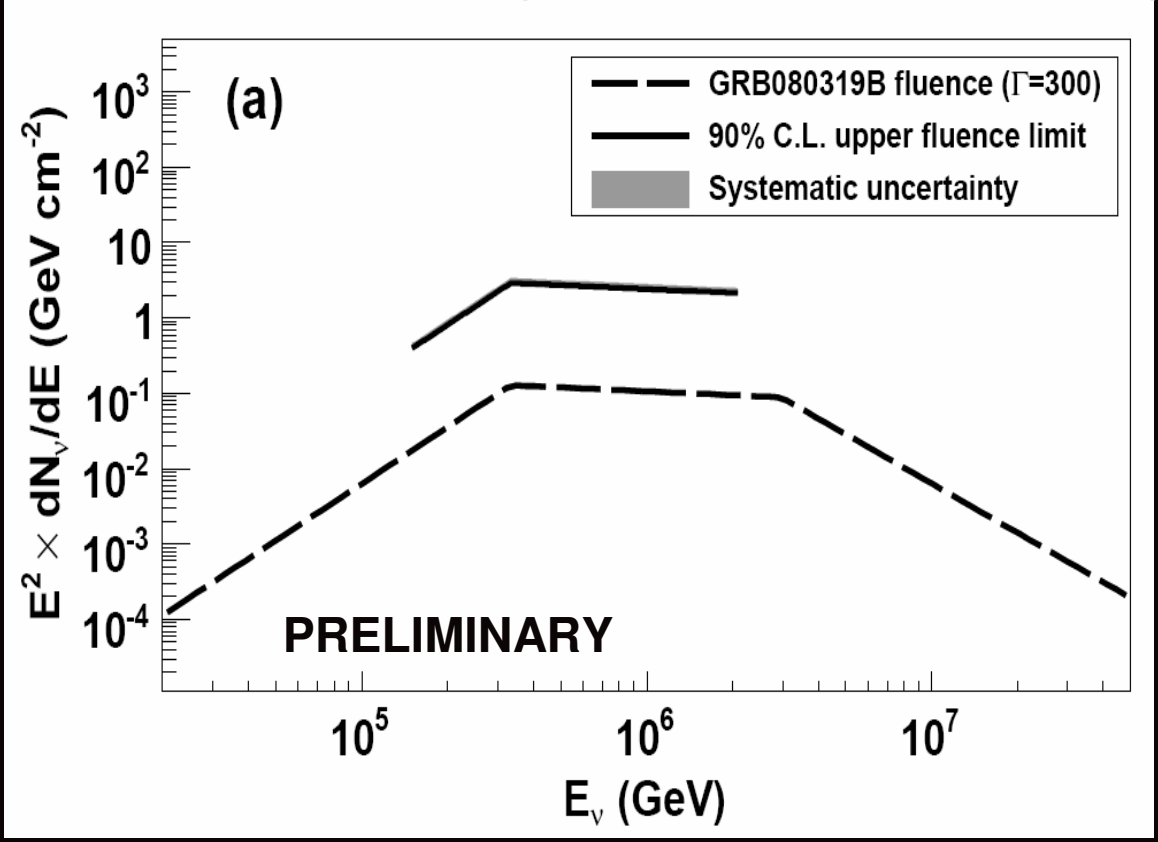
# Above the "Knee": extra-galactic

- Point Source Search
  - Northern Hemisphere ($E_\nu$~ TeV – PeV)
  - Southern Hemisphere ($E_\nu$ ~ 100 TeV – EeV)
  - Flaring Sources

- GRBs
- Diffuse Flux Search

# GRB080319B (Naked eye)

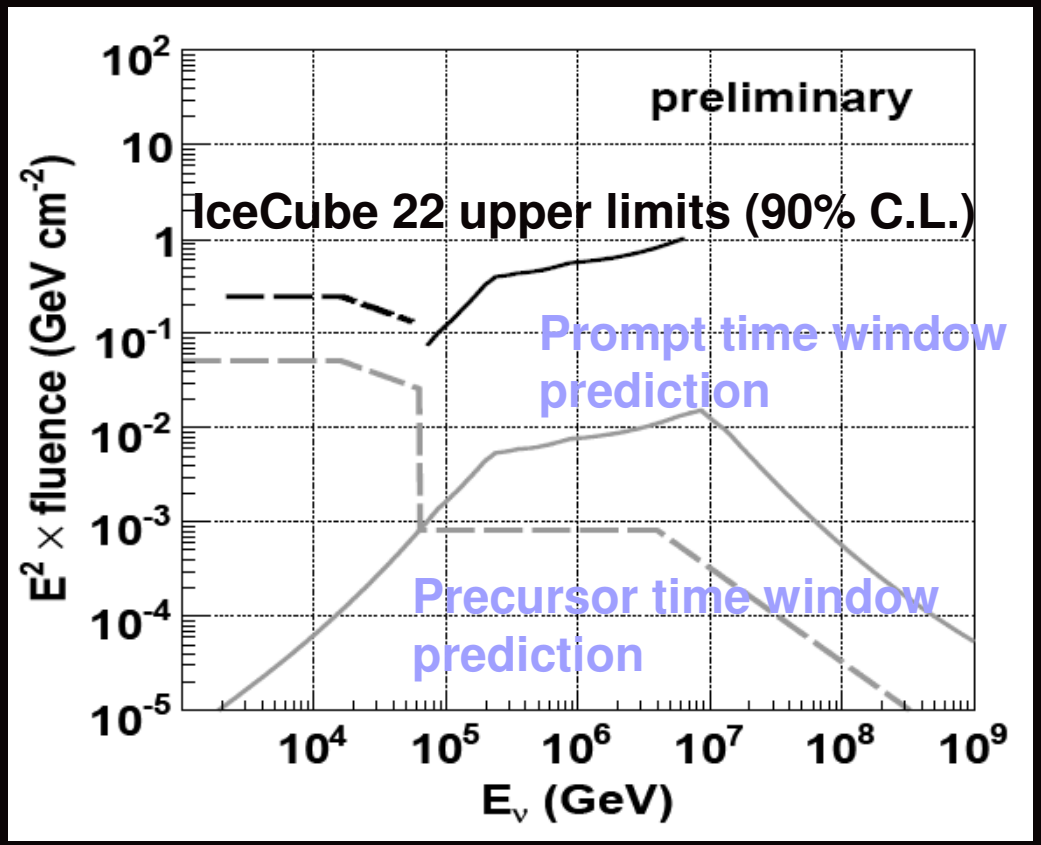
The IceCube Coll, astro-ph 0902.0131, submitted to ApJ




0 events on-time with 9 strings. In IceCube: ~ 1 event

# IceCube 22, Northern Hemisphere Search

A. Kappes et al., for the IceCube Coll, ICRC 2009




41 GRBs (Swift) stacked

- Prompt time window: $\gamma$ time
- Precursor time window: -100s
- Extended time window: -1h +3h

Waxman-Bahcall model
PRL 78, 2292 (1997)

# Above the "Knee": extra-galactic

- Point Source Search
  - Northern Hemisphere ($E_\nu$~ TeV – PeV)
  - Southern Hemisphere ($E_\nu$ ~ 100 TeV – EeV)
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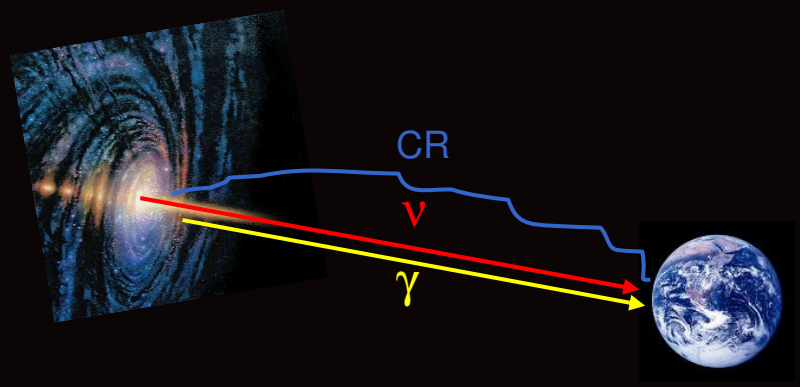
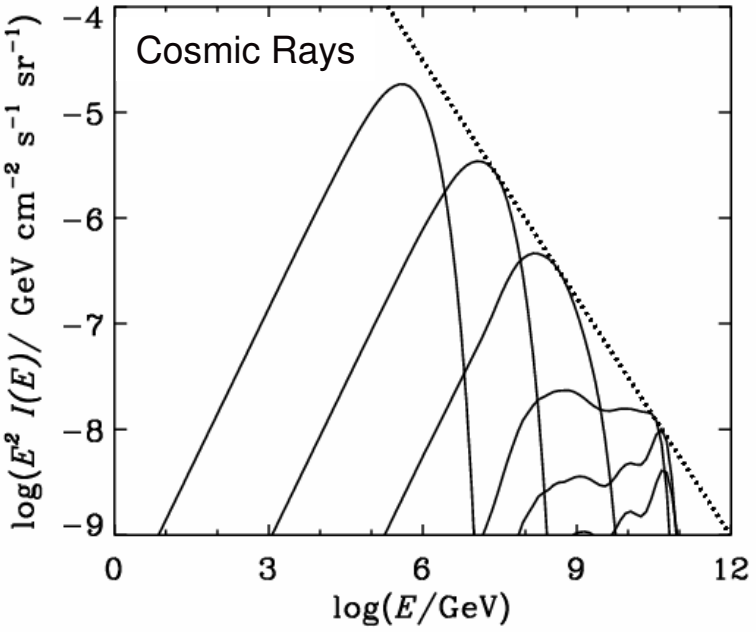
- GRBs
- Diffuse Flux Search

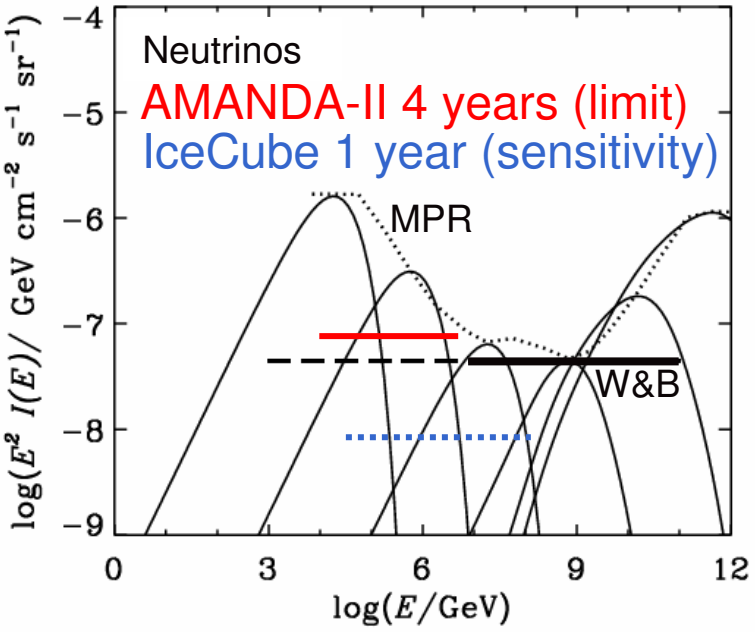
# Cosmic Ray & Gamma & Neutrinos



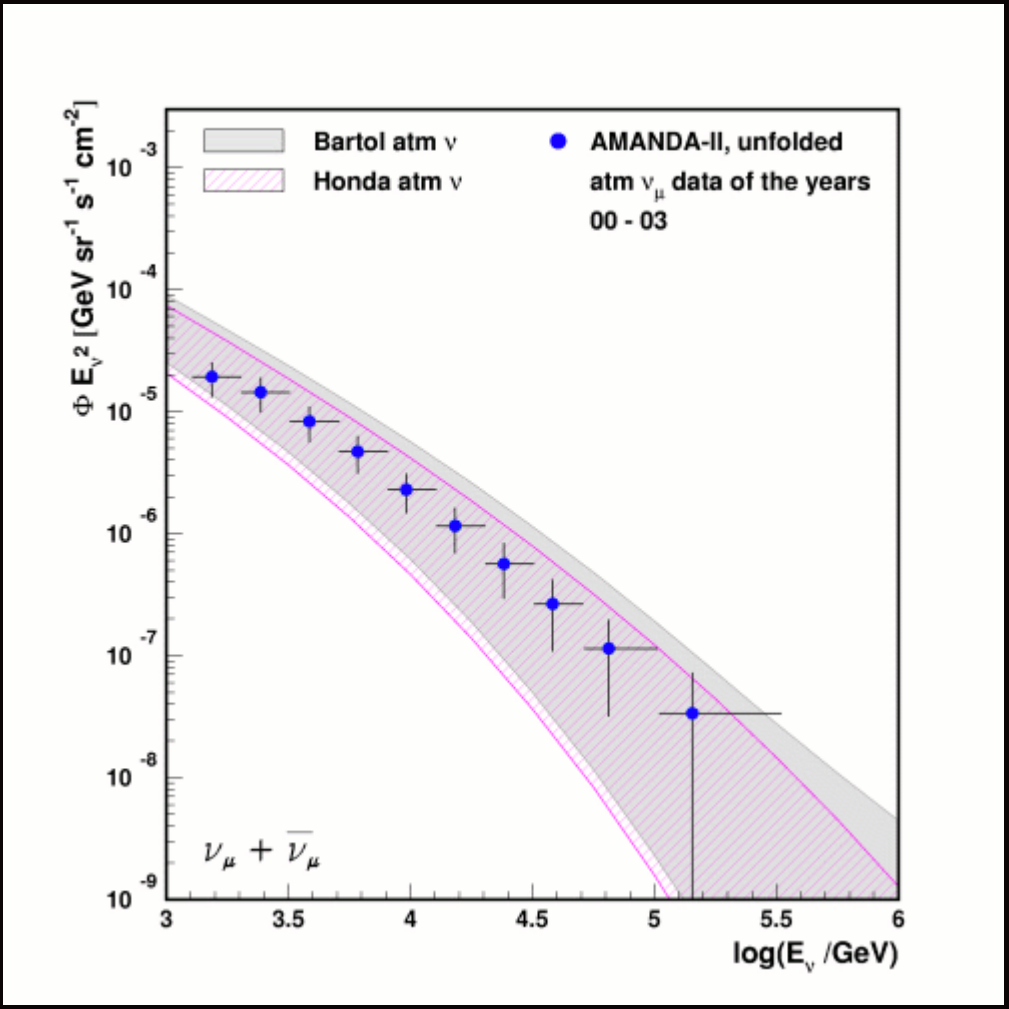

Proton luminosity ⟶ Upper bound HE ν flux

K. Mannheim et al., Phys.Rev. D63 (2001) 023003



# Diffuse Flux Searches: Deviation from Atmospheric Neutrinos




IceCube Collaboration, astro-ph/0711.0353

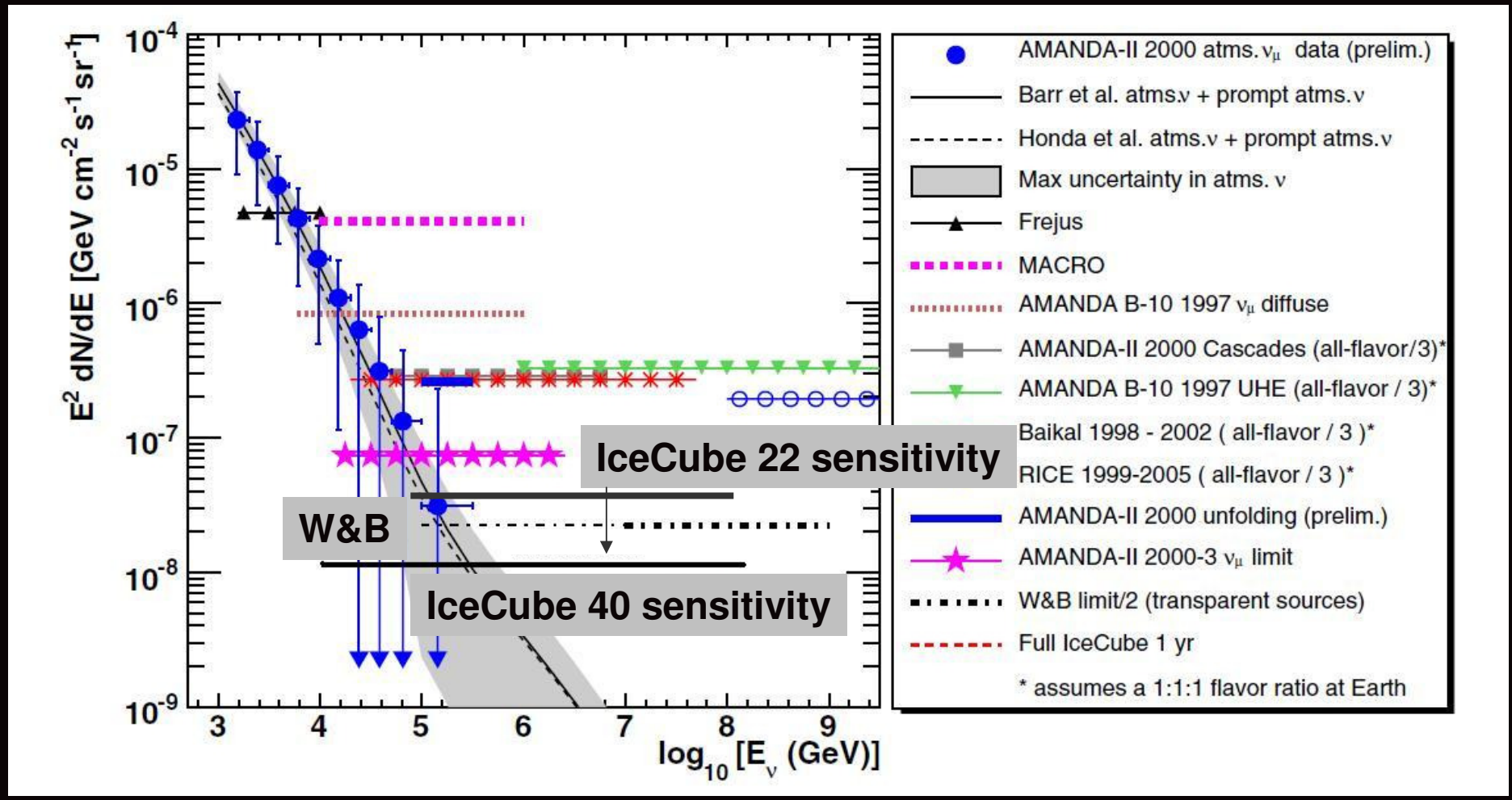
Searches for a Diffuse Flux challanges:

- Theoretical models: uncertainties
- Detector systematic effects

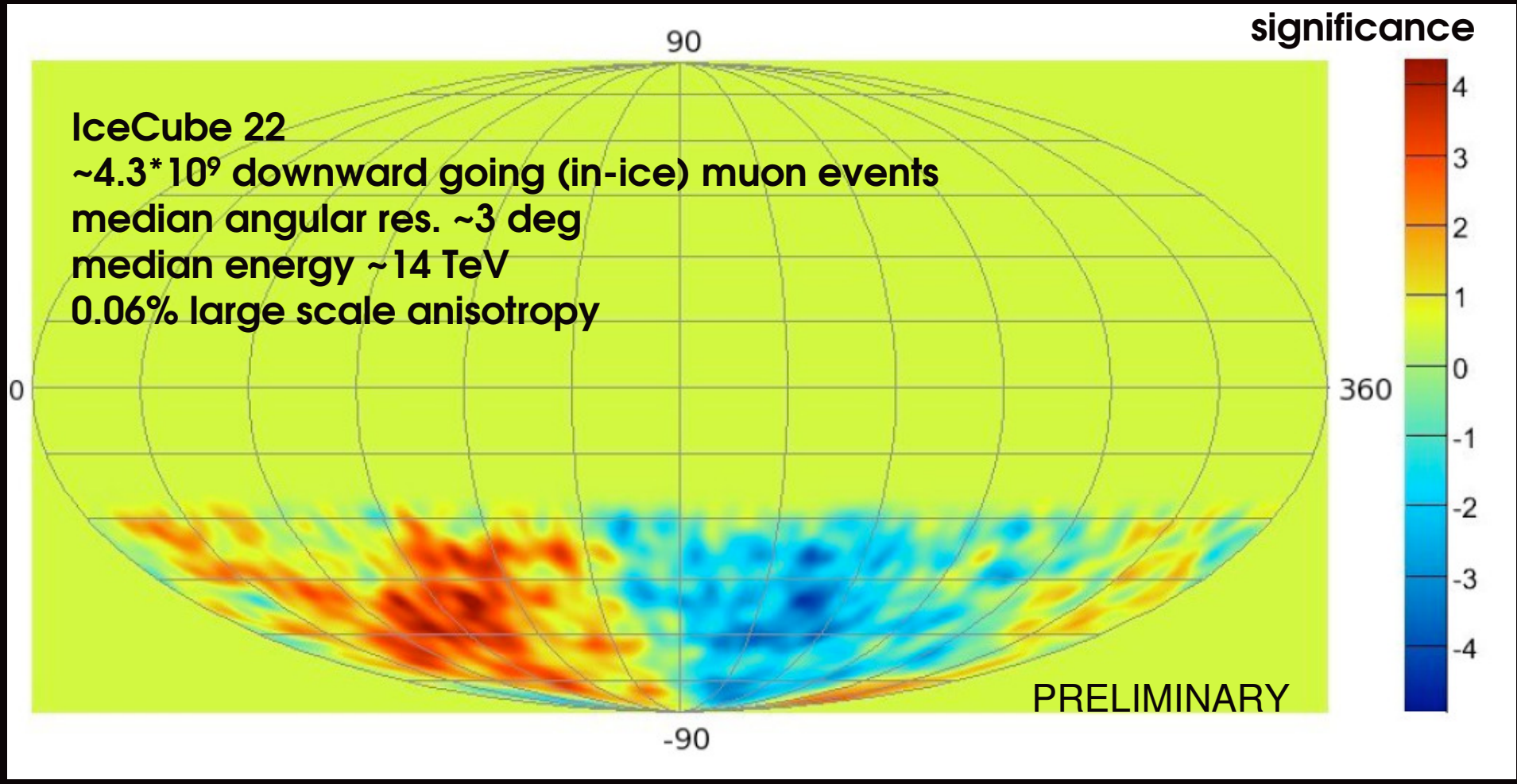
Kotoyo Hoshina et al, for the IceCube Coll, ICRC 2009

# IceCube 22 ⇒ IceCube 40: Crossing W&B

The IceCube Collaboration, arXiv:0705:1315.



# And … IceCube measures the Large Scale Anysotropy




R. U. Abbasi, P. Desiati et al., for the IceCube Coll, ICRC 2009

# Conclusions

IceCube construction: in 2 seasons done

IceCube data taking and analysis on-going

IceCube is searching for cosmic accelerators in the entire sky

Not mentioned:
- Shadow of the Moon (more then 5$\sigma$)
- Search for GZK neutrinos
- Search for Dark Matter, Exotics
- IceTop