Vrije Universiteit Brussel

IceCube AGN/GRB searches at the IIHE

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For the Brussels IIHE AGN/GRB group

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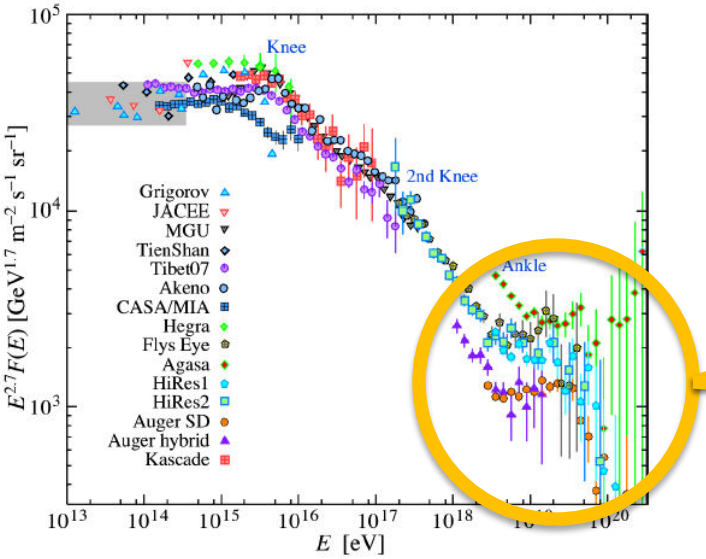
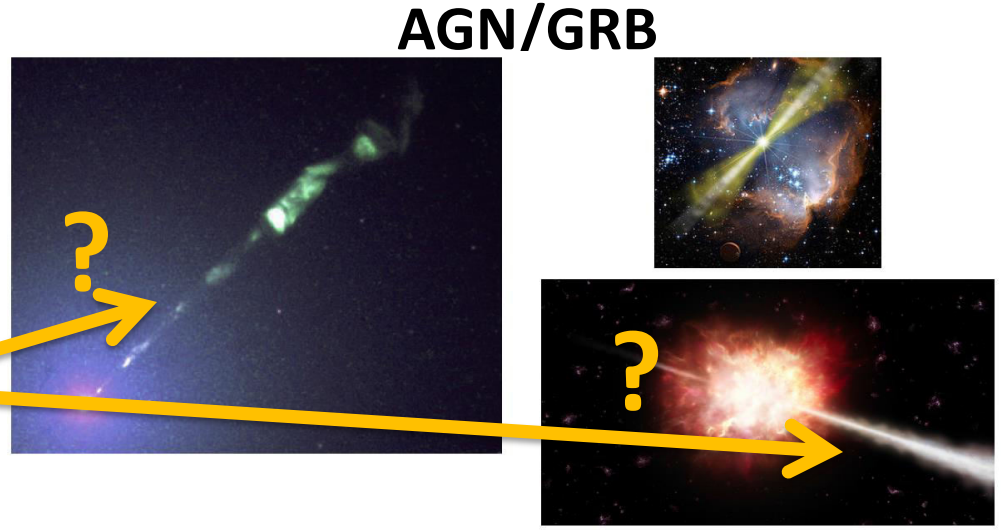
IceCube AGN/GRB searches: Why?

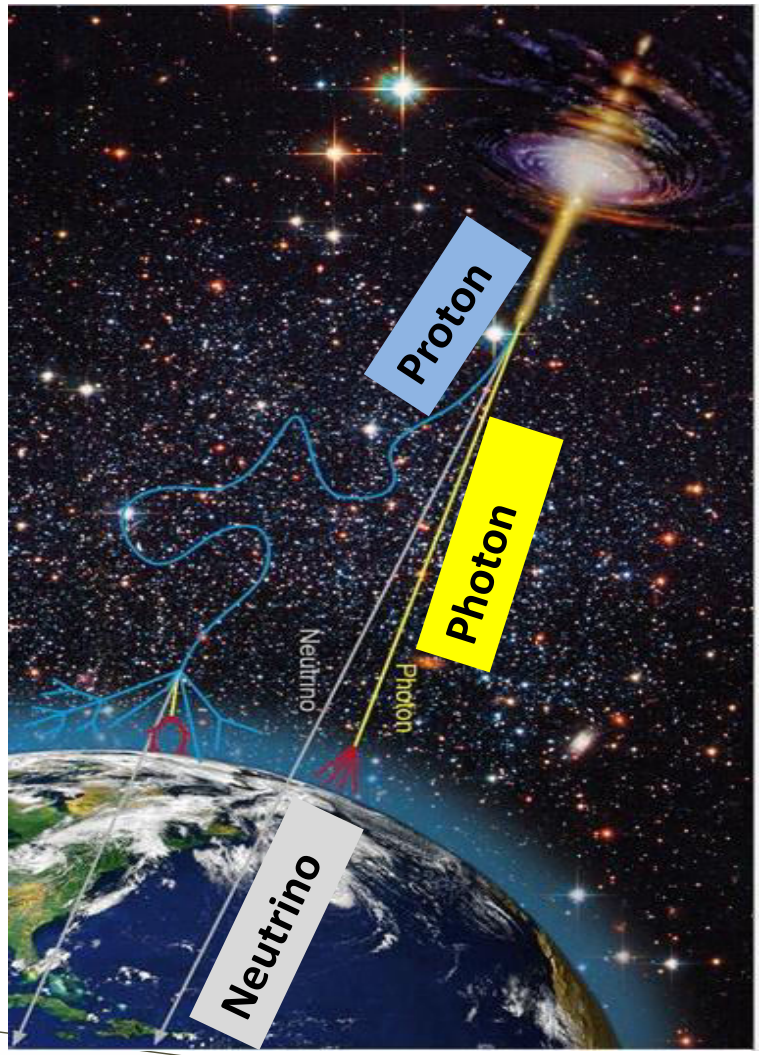
- **What is going on at the most energetic environments in our Universe?**



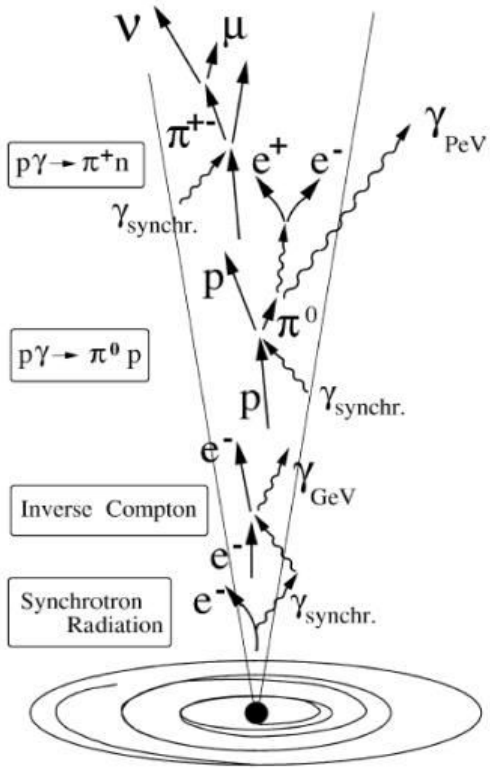


- **Where do our Ultra-High Energy Cosmic Rays come from?**

Probing AGN/GRB
Why Neutrinos??

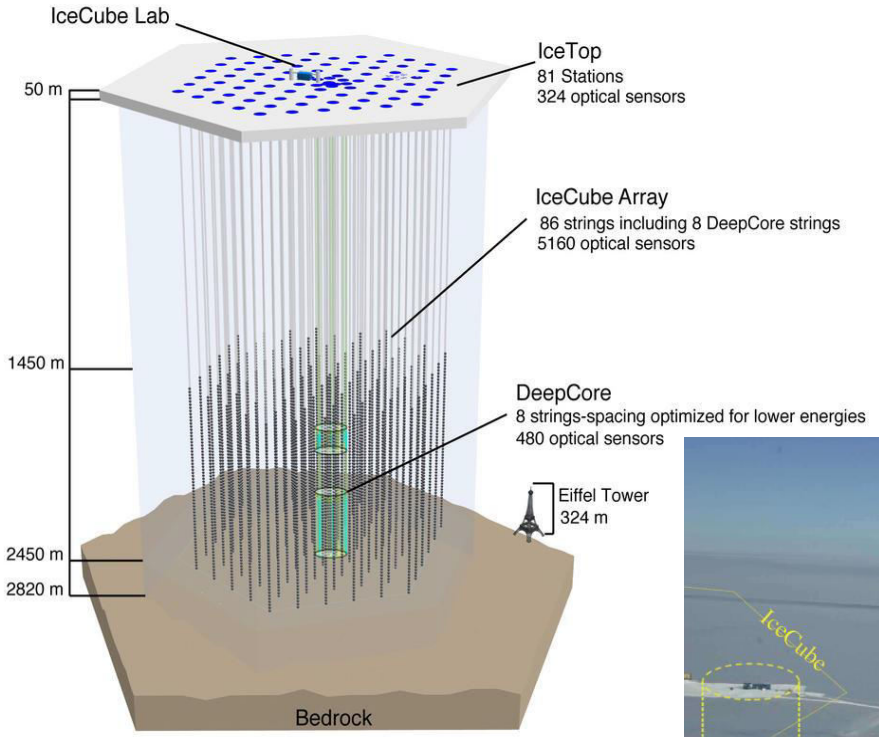


Processes in the jet

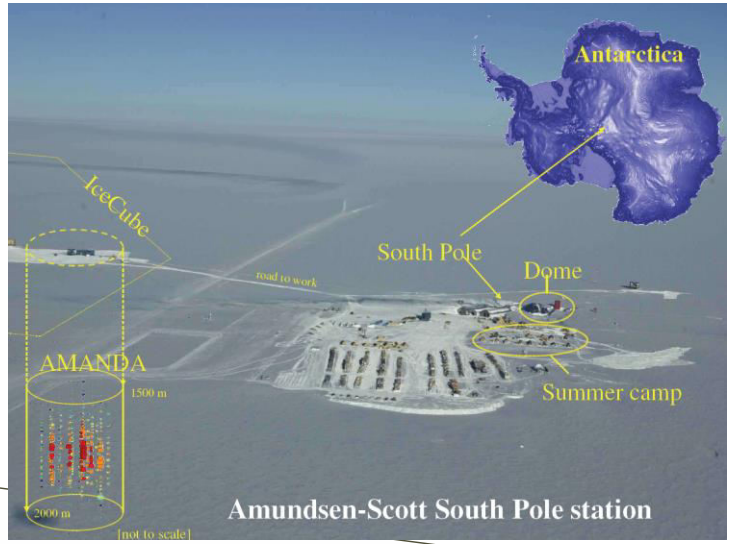


High-energy nuclei, γ and ν

How to detect cosmic neutrinos? The IceCube detector



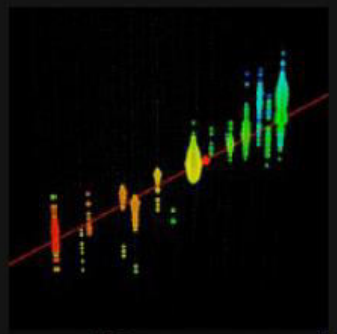
- 1 km^3 volume
- 86 strings
- 5160 DOMs
- 17 m PMT-PMT spacing per string
- 125 m string spacing
- Completed in Dec. 2010



Neutrino signatures in IceCube

time

CC Muon Neutrino

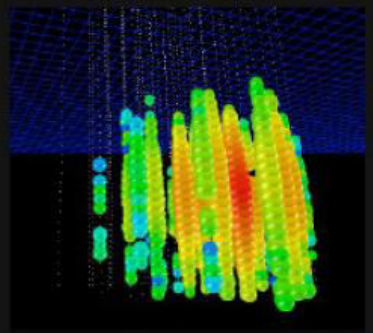


$$\nu_\mu + N \rightarrow \mu + X$$

track (data)

factor of ≈ 2 energy resolution
< 1° angular resolution

Neutral Current /Electron Neutrino



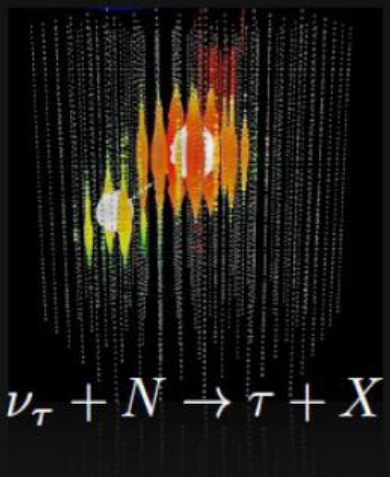
$$\nu_e + N \rightarrow e + X$$

$$\nu_x + N \rightarrow \nu_x + X$$

cascade (data)

≈ ±15% deposited energy resolution
≈ 10° angular resolution
(at energies ≈ 100 TeV)

CC Tau Neutrino



$$\nu_\tau + N \rightarrow \tau + X$$

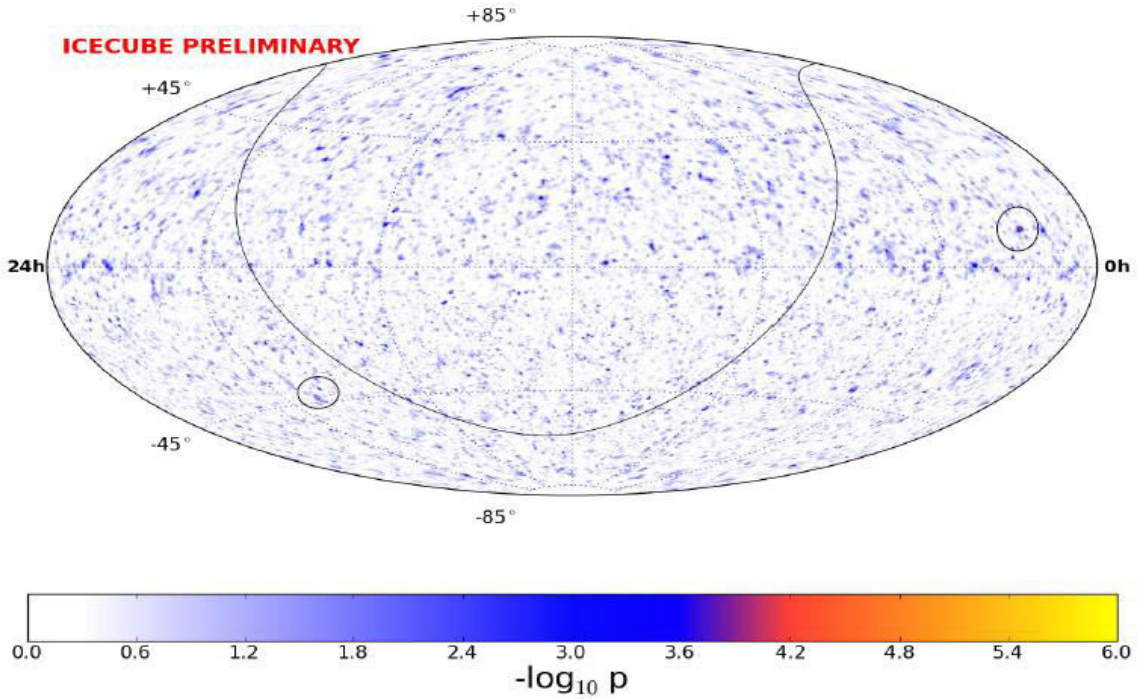
"double-bang" and other signatures
(simulation)

(not observed yet)

(C. Kopper)

IceCube Point Source Analysis

IceCube Preliminary



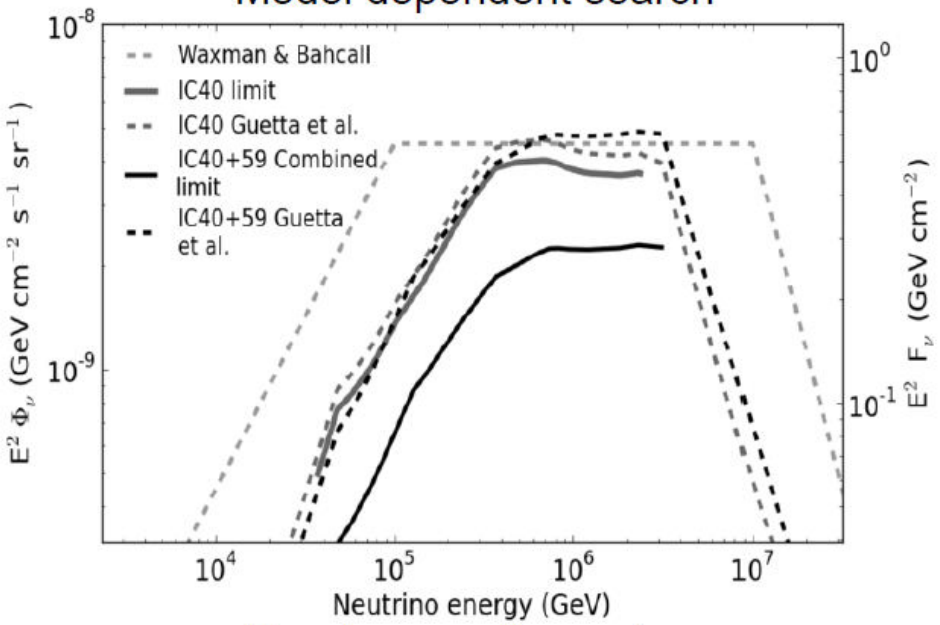
4 years of detector data, no evidence of point sources was found.

Most significant spots post trials P-values:
Northern sky 22.6%
Southern Sky 44.0%

GRB searches in IceCube

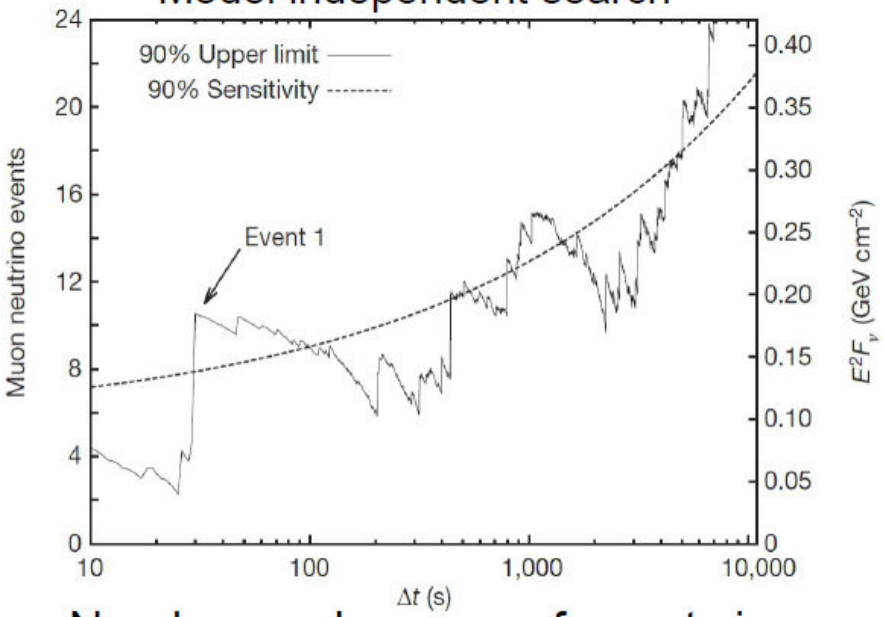
Nature 484 (2012) 351 (IC-40/IC-59 data)

Model dependent search



No observed events

Model independent search



No observed excess of events in coincidence with GRBs (event at Δt = 30 s consistent with bckg cosmic ray event.)

Limits exclude all tested models with standard parameters.
Models are being revisited => Recalculations.
New publication with IC-79/IC-86 data in progress!

The Brussels IIHE AGN/GRB event selection

- No signal seen by IceCube so far.

- Up to now most pre-selections were based on **hard cuts** on certain parameters.

- We try to **retrieve** some of the possible signal events by assigning **weights** to the quality parameters of different track reconstruction algorithms.

- A first pre-selection cut is performed on a **linear sum of these weights:** Hence, *if one reconstruction is bad we do not immediately throw away the event.*

The Brussels IIHE AGN/GRB event selection

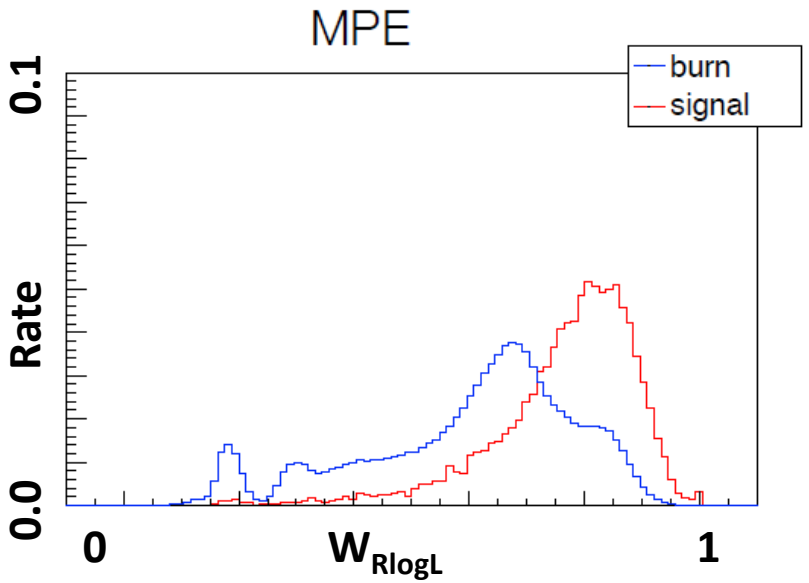
Example:
Log-likelihood quality parameter: RlogL
Causality parameter: Beta=v/c

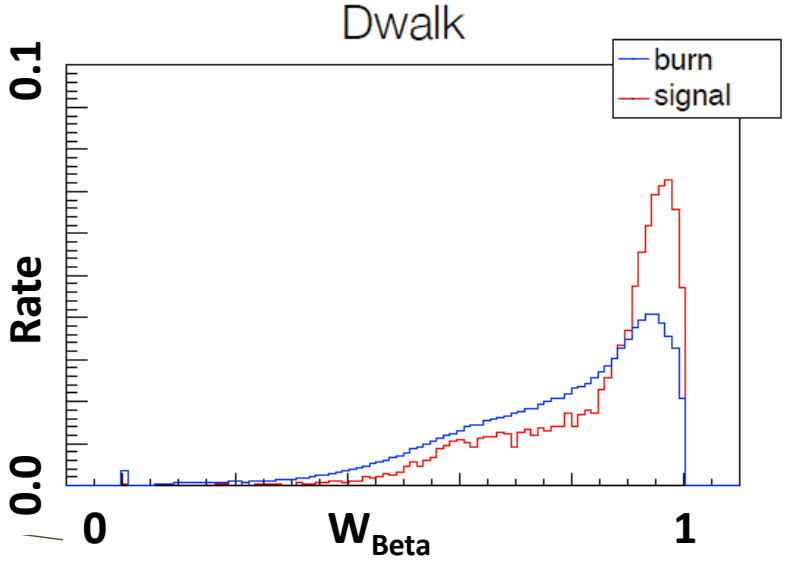
$$w_{R\log L} = \frac{6}{R\log L}$$

$$w_{Beta} = \begin{cases} \beta & (\beta < 1) \\ 2-\beta & (\beta > 1) \end{cases}$$

Burn: 2 hour burn sample in which no signal is expected.

Signal: Nugen simulation





The Brussels IIHE AGN/GRB event selection

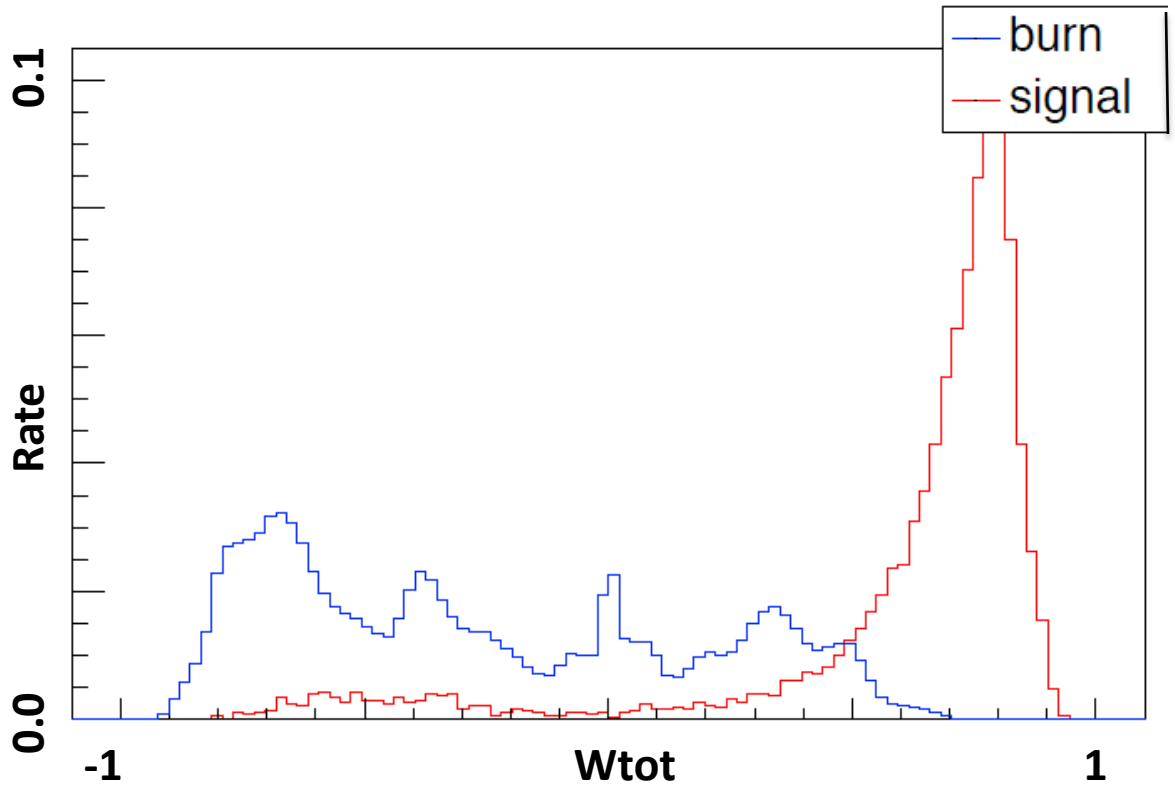
Example: Total weight distribution

Weight: $$w_{Tot} = \sum_{reco,i} \pm a_i w_i$$

$$+ : \theta > 90^\circ$$

$$- : \theta < 90^\circ$$

Cutting at 80% signal leaves only 1% background!!



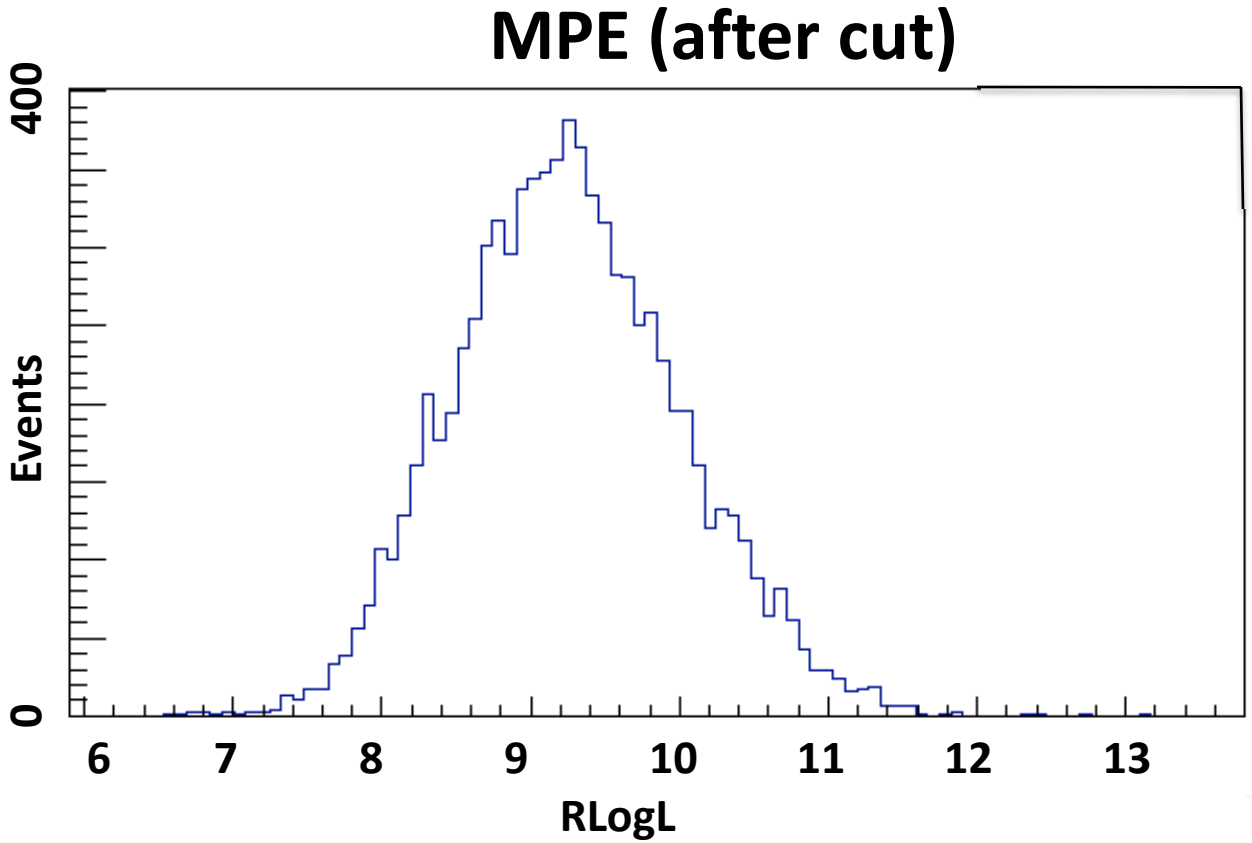
Lionel Brayeur

The Brussels IIHE AGN/GRB event selection

Many events which would not survive a typical IceCube pre-cut

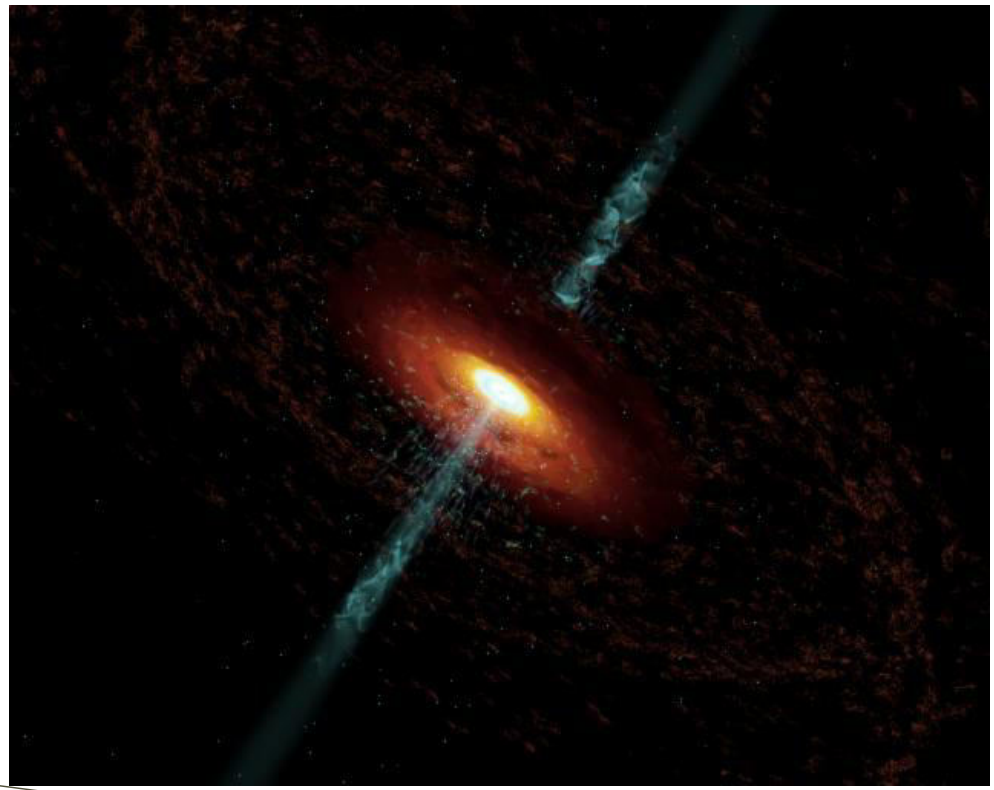
RLogL < 8 - 10

are still maintained with a very good efficiency!!



The Brussels IIHE AGN selection

A specific type of AGN will be considered for the IIHE analysis



General Blazar properties:

- **Very strongly polarized variable emission over a wide range of frequencies**
- **Neutrino production:**

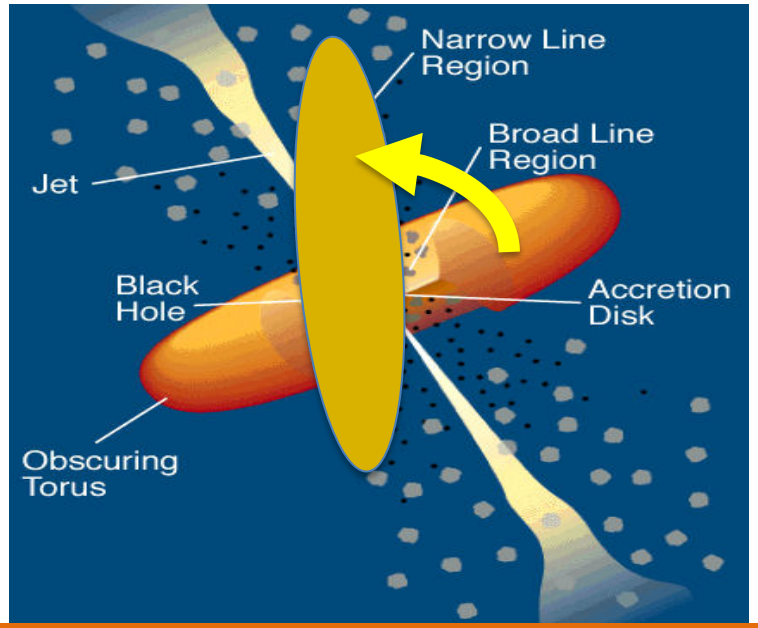
$$p^{+}_{jet} + \gamma \rightarrow \pi^{+} + n$$

$$\pi^{+} \rightarrow \mu^{+} + \nu_{\mu}$$

$$\rightarrow e^{+} + \nu_{e} + \nu_{\mu} + \bar{\nu}_{\mu}$$

The Brussels IIHE AGN selection

The Brussels selection: Search for a specific type of Blazar



- At a distance of a few parsec a dust torus is formed.

- This torus does not have to be perpendicular to the jet!

- Enhanced neutrino production can occur through the jet- torus interaction:

$$p^{+}_{jet} + p^{+}_{torus} \rightarrow X$$

$$X \rightarrow \pi^{+} \rightarrow \mu^{+} + \nu_{\mu}$$

$$\rightarrow e^{+} + \nu_{e} + \nu_{\mu} + \bar{\nu}_{\mu}$$

- Radio waves will pass through the torus without interaction.
- Emission at higher frequencies will be obscured

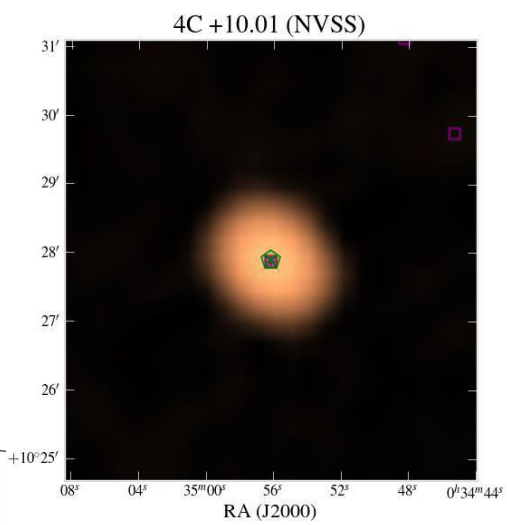
Search for AGN with high radio luminosity and low luminosities at higher frequencies!!

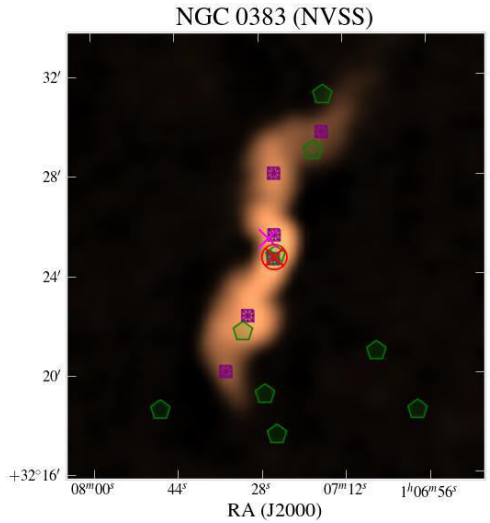
The Brussels IIHE AGN selection

Nijmegen AGN radio catalogue

S. van Velzen, et al., Astronomy & Astrophysics 544 (2012) A18 "Radio Galaxies of the Local Universe", arxiv:1206.0031

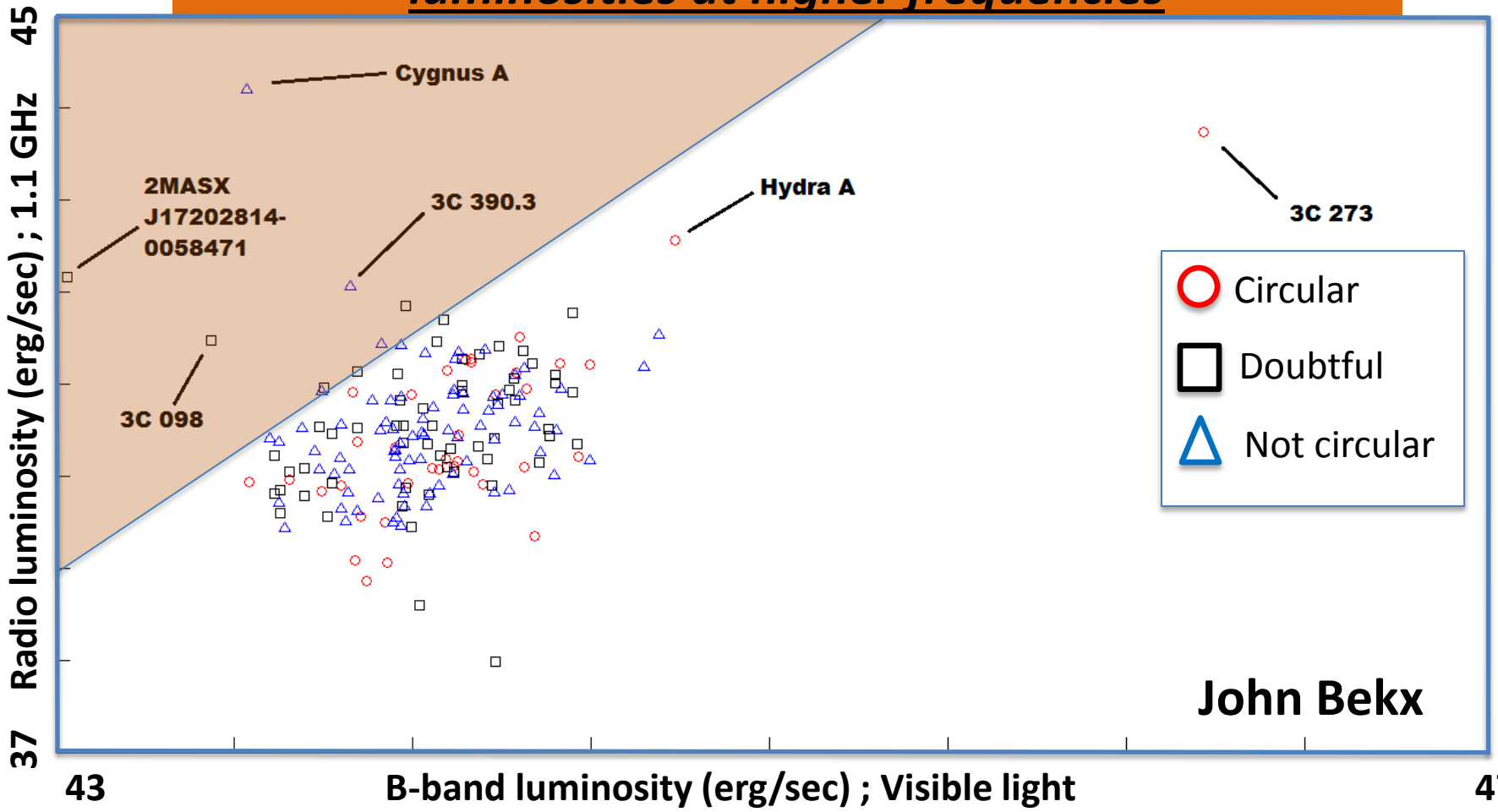
- **Goal: Select AGN within 100 Mpc which could be responsible for UHECRs**
- **407 entries in "Jets & Lobes" are investigated**
- **First categorization: Radio morphology**





The Brussels IIHE AGN selection

Search for AGN with High radio luminosity and low luminosities at higher frequencies



The Brussels IIHE AGN selection

Conclusion:

407 entries in "Jets & Lobes" are investigated

First categorization: Circular Radio morphology

-> 94 Candidates left

Select high radio luminosity and low luminosity at high frequencies

-> No candidates left

Outlook:

Include AGN from larger distances

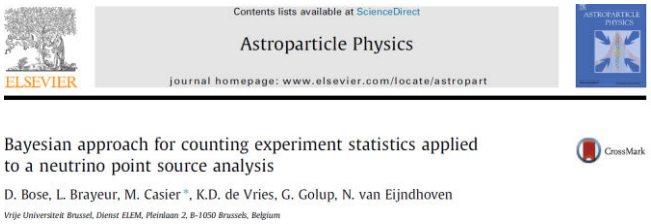
Refine selection by:

1) **More quantitative morphology selection**
2) **More detailed inspection of emission spectrum**
3) **Develop new AGN selection criteria**

Event selection + AGN selection
There is more:

- **Combined point-source analysis with the Auger and TA collaborations**

- **Developing new statistical methods: *Astropart.Phys. 50-52 (2013) 57-64 (ArXiv:1212.2008)***


Contents lists available at ScienceDirect
Astroparticle Physics
journal homepage: www.elsevier.com/locate/astropart

Bayesian approach for counting experiment statistics applied to a neutrino point source analysis

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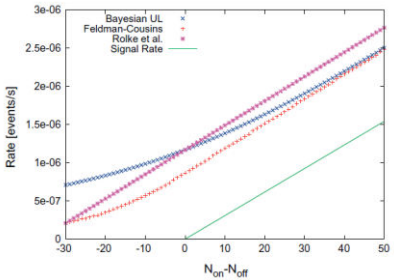
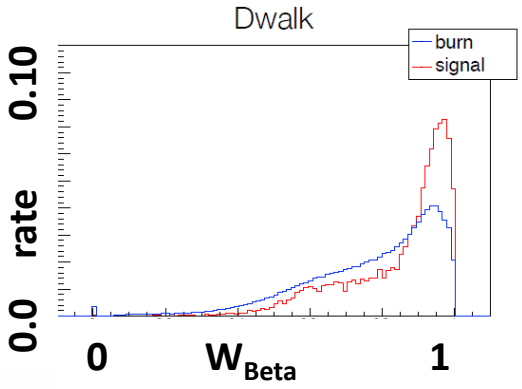
Vrije Universiteit Brussel, Dienst ELEM, Pleinlaan 2, B-1050 Brussels, Belgium



- **Developing and implementing new IceCube track reconstruction algorithms**



Summary

- So far IceCube did not see point sources: Strong constraints have been put on existing GRB models!
- At the Brussels IIHE AGN/GRB group a new IceCube event selection method is under development showing very promising initial results.
- A specific type of AGN (obscured Blazar) will be considered for the Brussels AGN analysis. A selection method for this specific type of AGN is currently under investigation
- Next to these subjects, the Brussels IIHE AGN/GRB group is also involved in:
  - Combined point-source analysis with the Auger and TA collaborations
  - Developing new statistical methods: *Astropart.Phys. 50-52 (2013) 57-64 (ArXiv:1212.2008)*
  - Developing and implementing new IceCube track reconstruction algorithms