

Search for neutrino emission  
in gamma-ray flaring blazars  
with the ANTARES telescope

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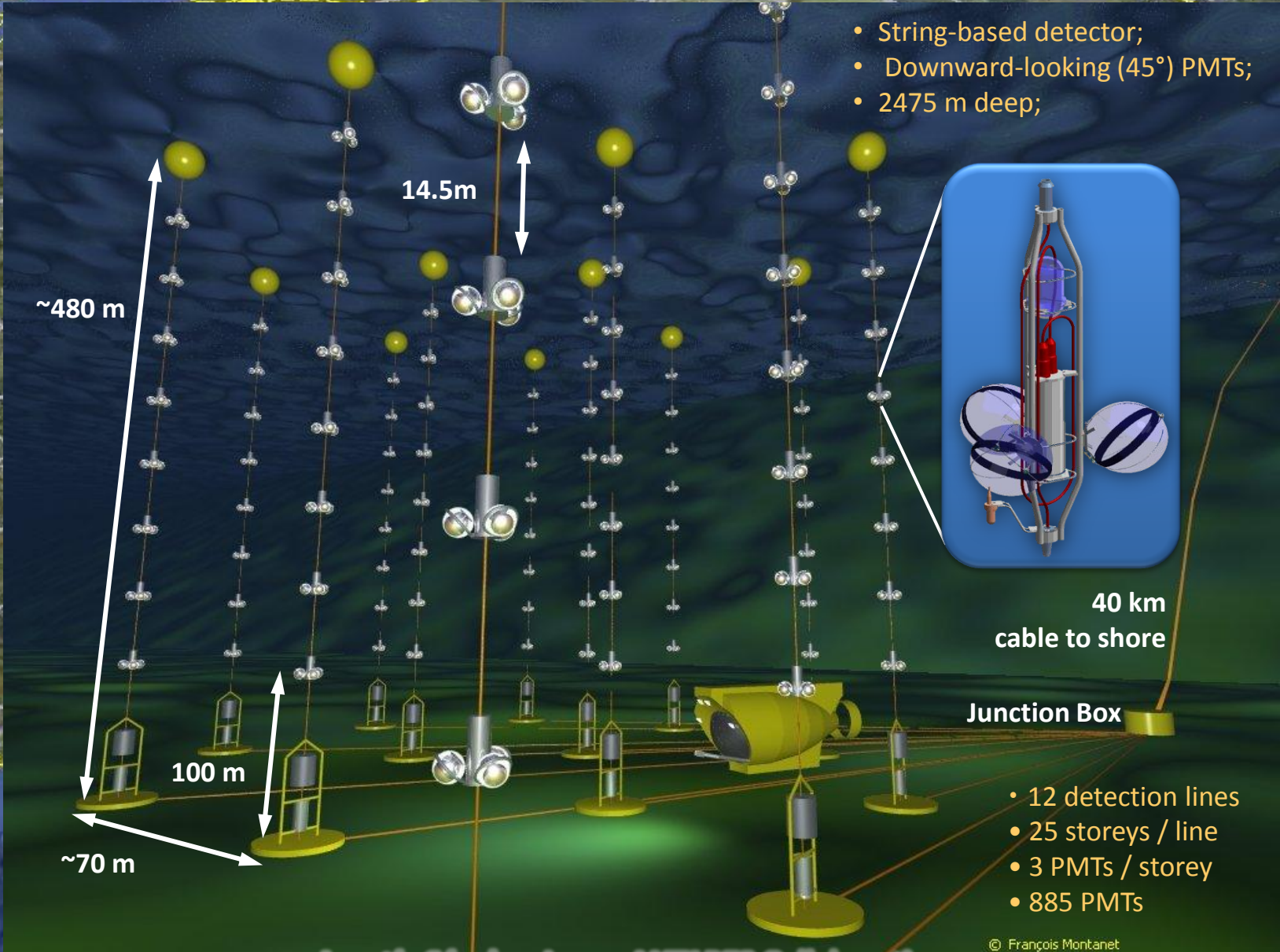
ANTARES Collaboration



VLVnT11

Erlangen, 12-14 October 2011

# The ANTARES Experiment



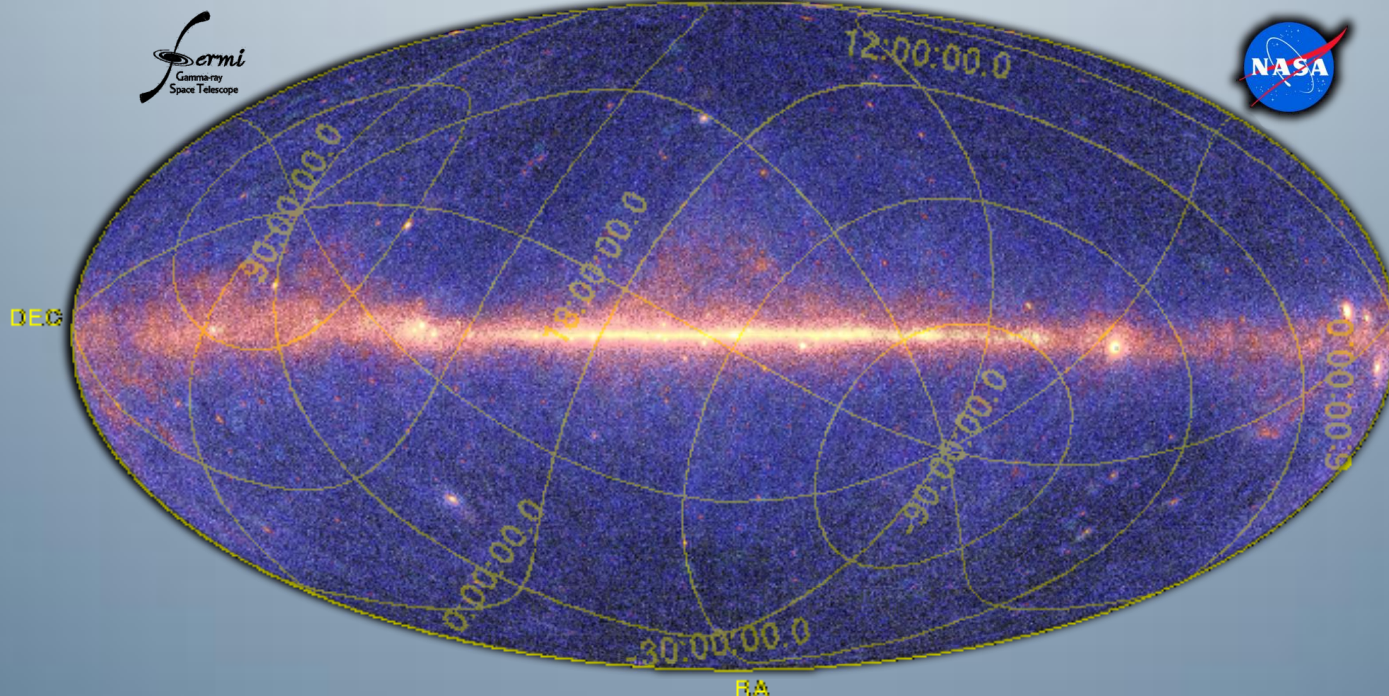


# Gamma Ray Flaring Blazars

- AGN Blazars are good candidates for UHECR:
  - $p-\gamma$  and  $p-p$  interactions in high photon densities offer a strong correlation between gamma rays and neutrinos
- Available gamma-ray data for the end of 2008:
  - No TeV flares found with HESS, MAGIC or VERITAS
  - But many sources monitored by Fermi LAT show important time variability

## Fermi LAT data over the Fermi two-year all sky-map

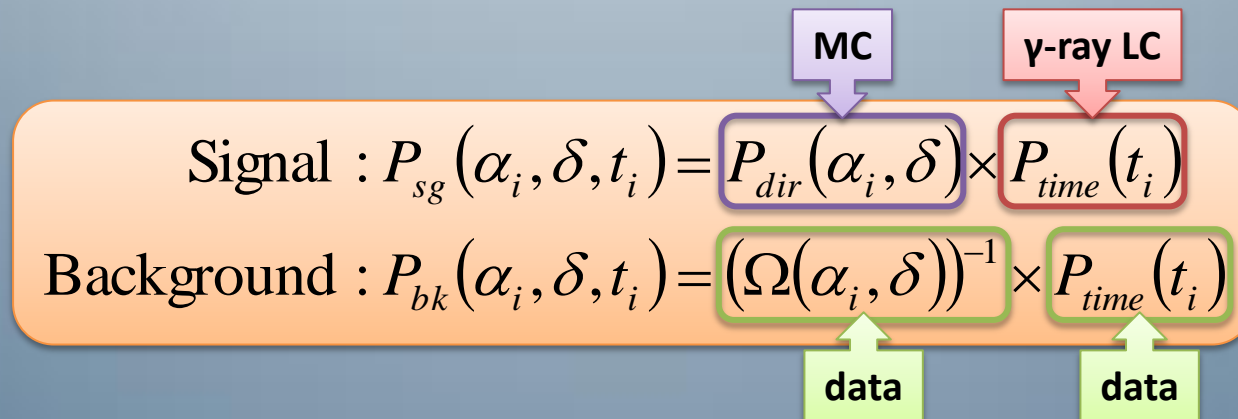
Credit: NASA/DOE/Fermi/LAT Collaboration



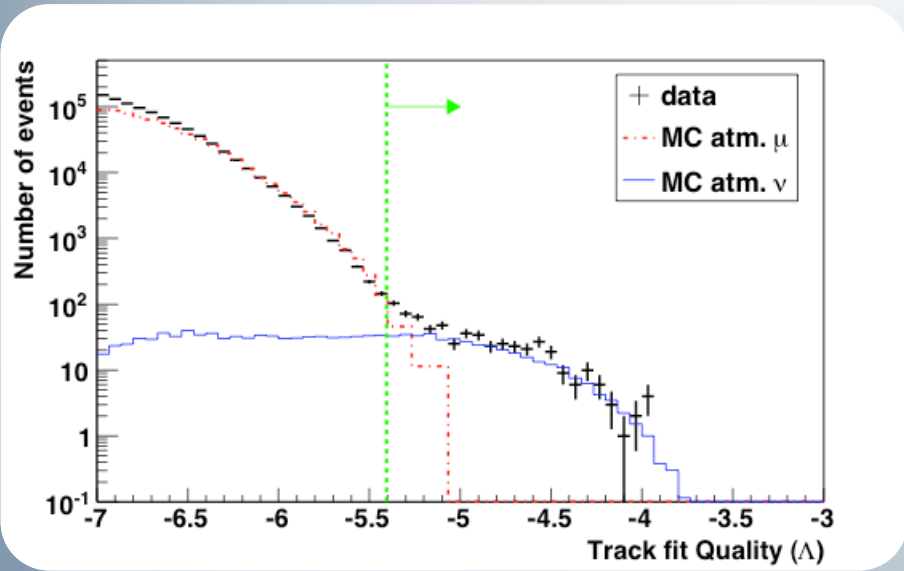
# Time-Dependent Analysis

- Flares time info from gamma ray telescopes
  - Space-Time coincidences reduce significantly the background
  - Discovery potential is improved over a time integrated search
- The method: an unbinned search using likelihood ratio
  - Only one free parameter,  $n_{sg}$ , because of triggered search
  - Optimization: minimum neutrino flux to have a 5 sigma discovery

$$\lambda = \sum_{i=1}^{N_{ev}} \log \frac{P(x_i | H_{sg+bk})}{P(x_i | H_{bk})} = \sum_{i=1}^{N_{ev}} \log \frac{\frac{n_{sg}}{N_{ev}} P_{sg}(\alpha_i, \delta, t_i) + \left(1 - \frac{n_{sg}}{N_{ev}}\right) P_{bk}(\alpha_i, \delta)}{P_{bk}(\alpha_i, \delta)}$$



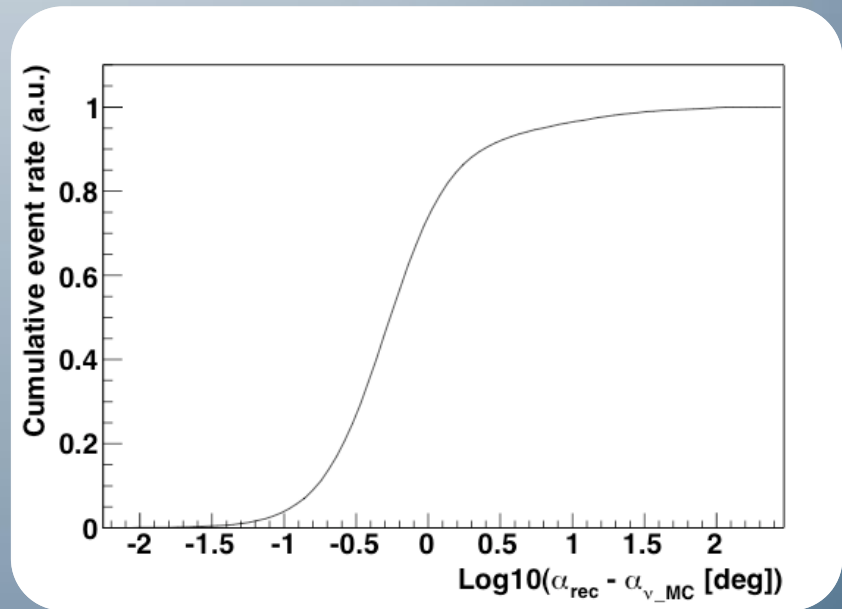
# Selection of events



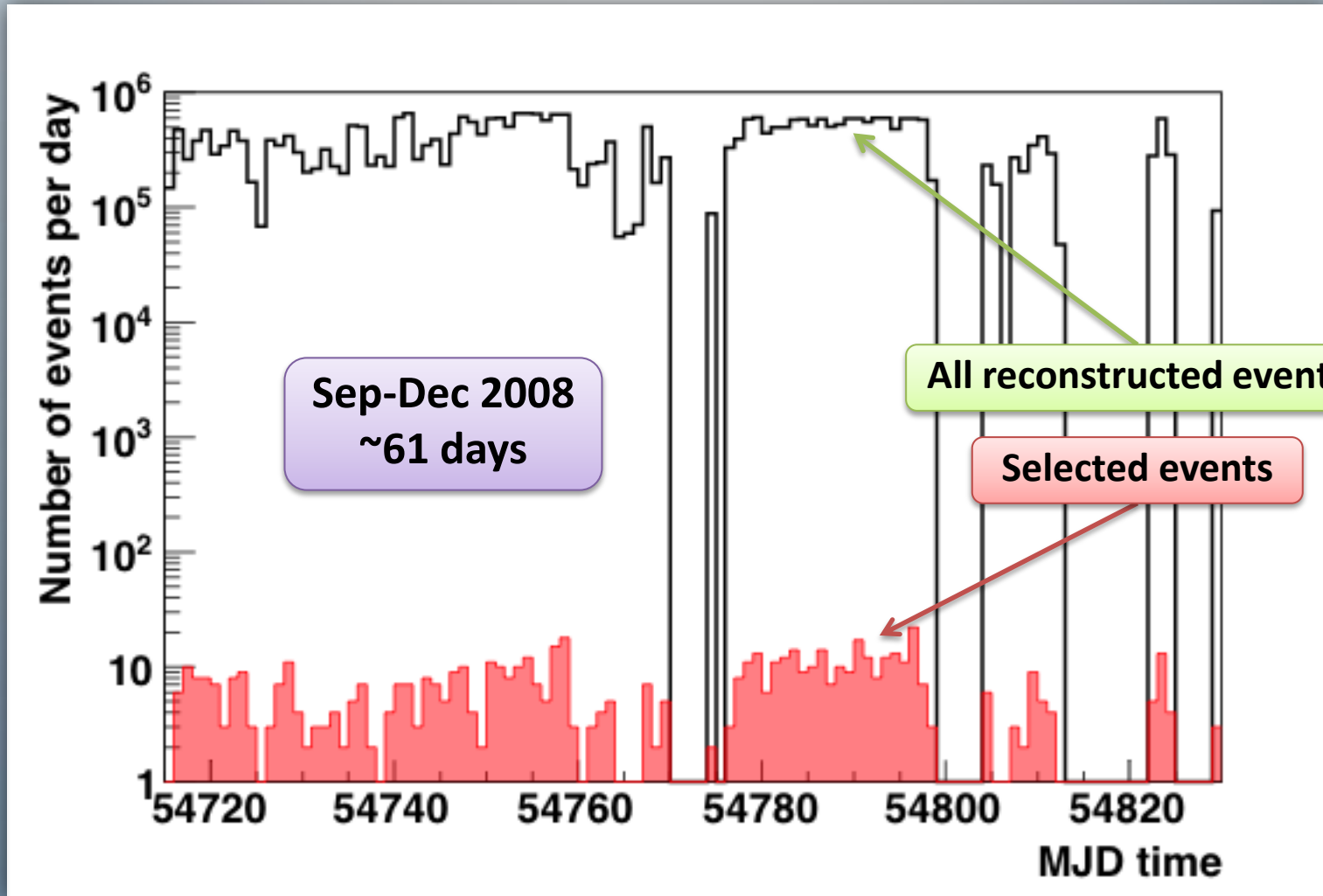
Neutrino events selection:

- $\Lambda > -5.4$  (track's fit quality parameter)
- $\beta < 1^\circ$  (track's error estimate)
- $\theta > 90^\circ$  (only upgoing events)

- Angular resolution:  $0.4 \pm 0.1$  degree
  - Estimated from MC
  - Constrained using data
  - Comparable to IceCube besides size difference (advantage of water over ice)



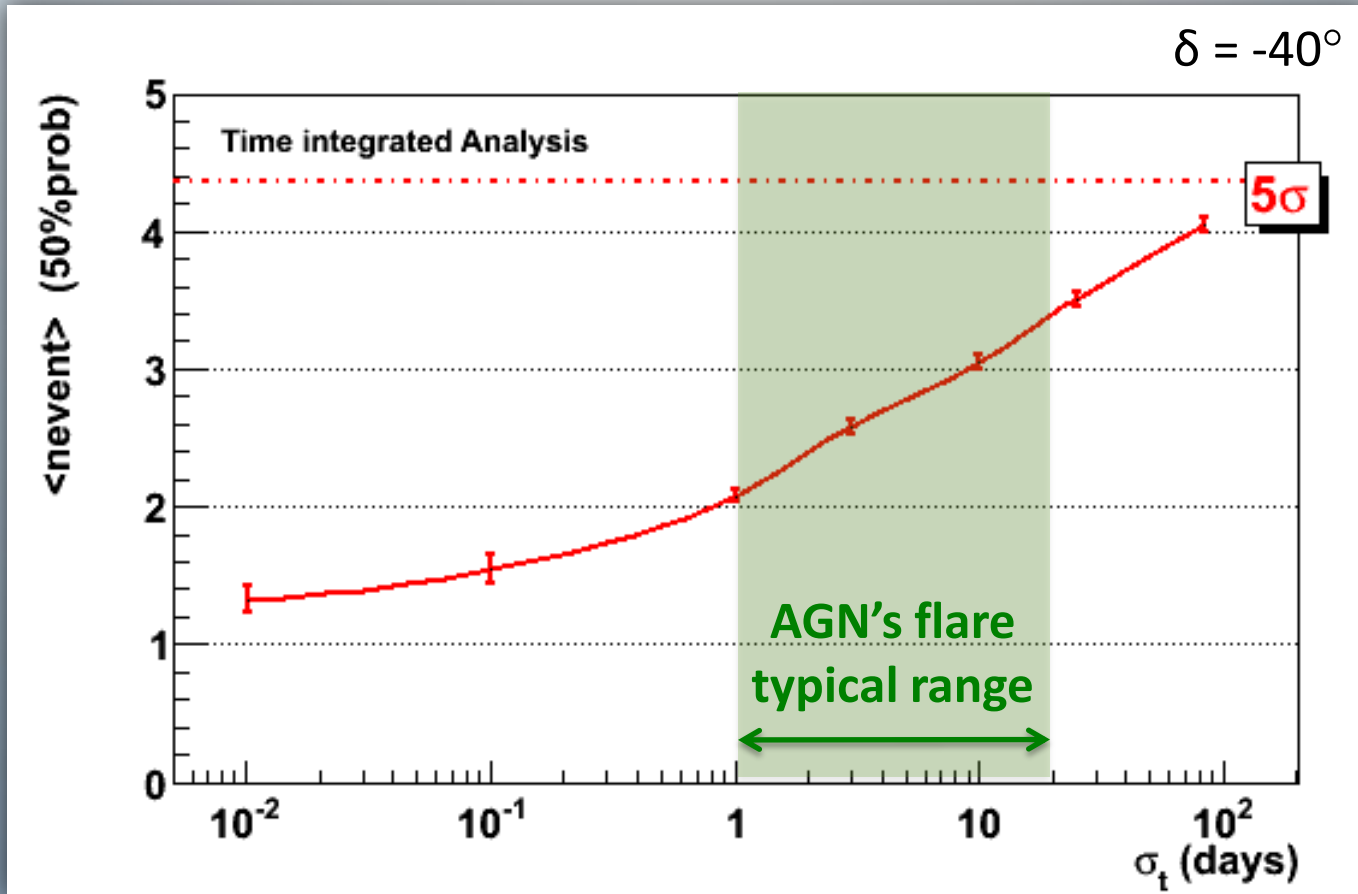
# Data sample of events



Distribution used as time PDF for background once normalized



# Performance

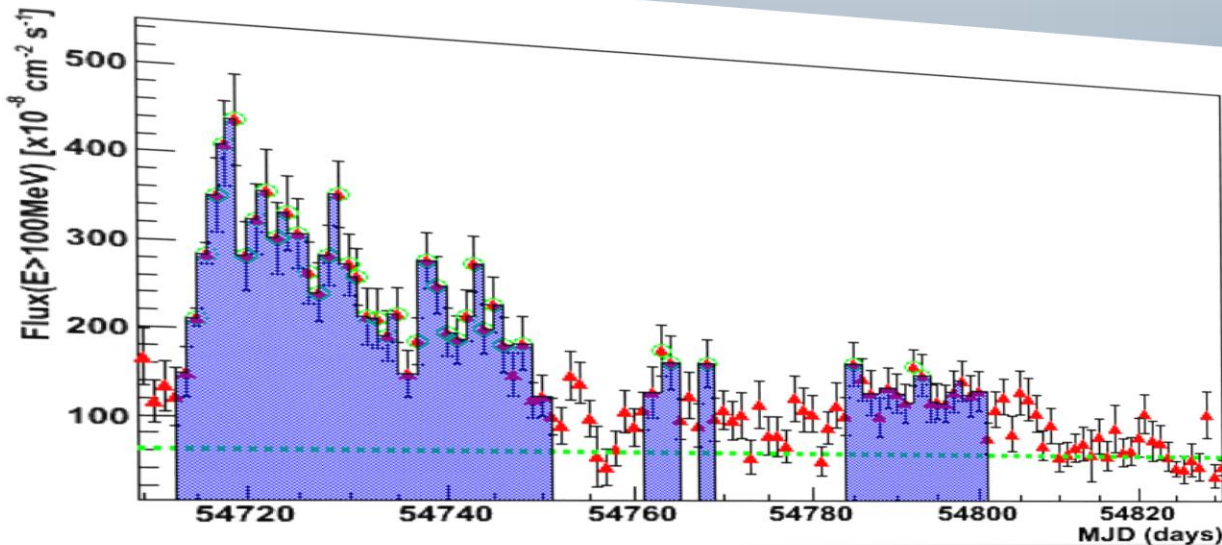


Averaged number of events required for a  $5\sigma$  discovery (50% prob) produced in one source as a function of the width of one flare period:

**Improvement by a factor 2-3 with respect to a time integrated analysis**

# Flare identification

- Identification of the flare periods on AGNs from Fermi LAT data:
  1. Gamma Ray sources: selection of variable and energetic blazars (10 sources)
  2. 1-day binned light curved (`fit` files from Fermi website)
  3. Flares as the high emission states periods: robust and simple method
    - Light curve baseline & sigma:  
(linear fit and Gaussian fit  $\rightarrow$  remove points above baseline + sigma) x 3  $\rightarrow$  Gaussian fit
    - Flare prior:  
(flux - error\_flux) > (baseline + 2\*sigma) && flux > (baseline + 3\*sigma)
    - Flare duration:  
Add all consecutive points to prior for which (flux - error\_flux) > (baseline + sigma)  
Add  $\pm 0.5$  days to each flare (due to 1-day binned LC and uncertainties in models)

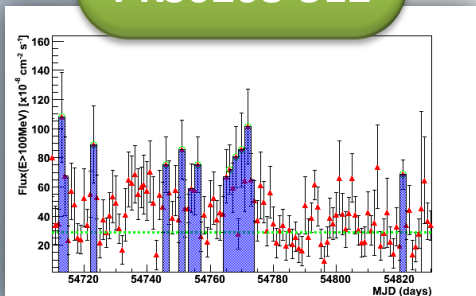


Sample for  
source 3C454.3

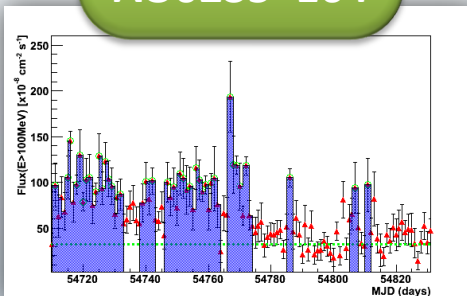


# Flaring Periods

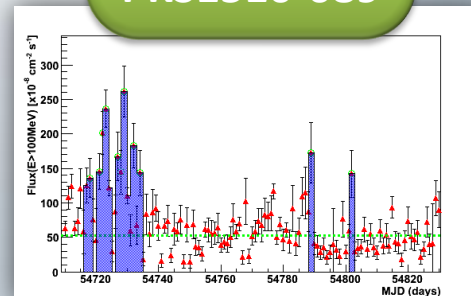
PKS0208-512



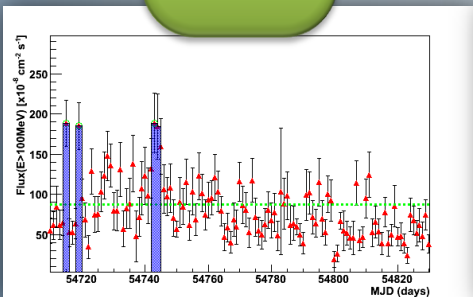
AO0235+164



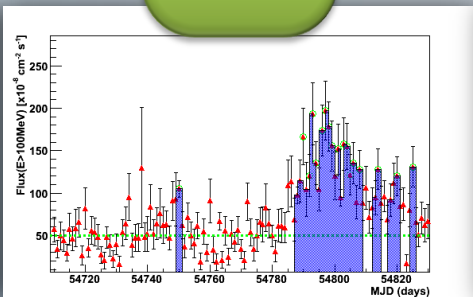
PKS1510-089



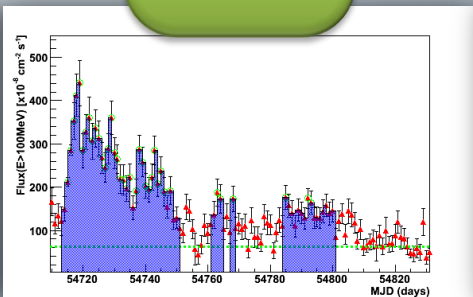
3C273



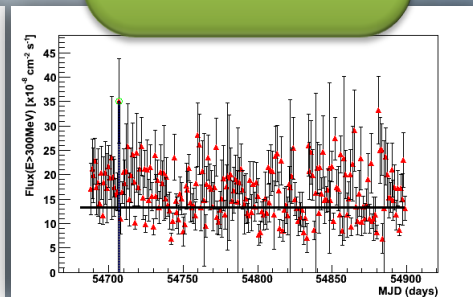
3C279



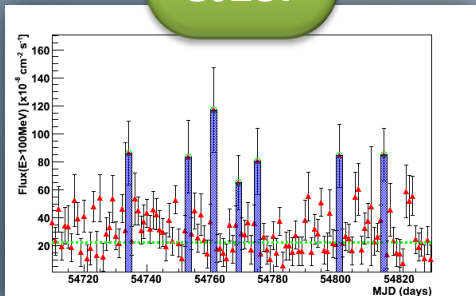
3C454.3



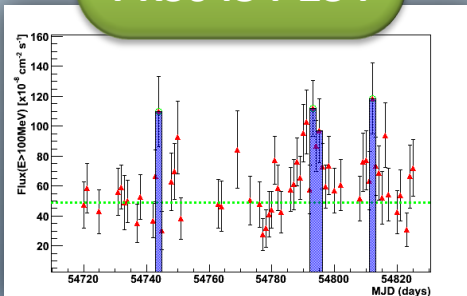
PKS2155-304



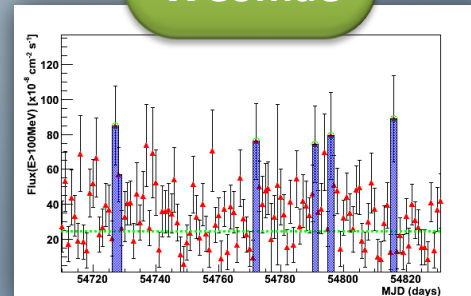
OJ287



PKS0454-234



WComae



# Results for 2008 data (\*)

source name	ANTARES visibility	time PDF (MJD+54000)	Live time (days)	N(5 $\sigma$ )	N <sub>obs</sub>	Fluence U. L. GeV/cm <sup>2</sup> (**)
0208-512	1.0	712-5, 722-4, 745-7, 750-2, 753-7, 764-74, 820-2	8.8	4.5	0	2.8
0235+164	0.41	710-33, 738-43, 746-64, 766-74, 785-7, 805-8, 810-2	24.5	4.3	0	18.7
1510-089	0.55	716-9, 720-5, 726-35, 788-90, 801-3	4.9	3.8	0	2.8
3C273	0.49	714-6, 716-8, 742-5	2.4	2.5	0	1.1
3C279	0.53	749-51, 787-809, 812-5, 817-21, 824-6	13.8	5.0	1	8.2
3C454.3	0.41	713-51, 761-5, 767-9, 784-801	30.8	4.4	0	23.5
OJ287	0.39	733-5, 752-4, 760-2, 768-70, 774-6, 800-2, 814-6	4.3	3.9	0	3.4
0454-234	0.63	743-5, 792-6, 811-3	6.0	3.3	0	2.9
WComae	0.33	726-9, 771-3, 790-2, 795-7, 815-7	3.9	3.8	0	3.6
2155-304	0.68	753-5, 766-8, 799-801, 828-30	3.1	3.7	0	1.6

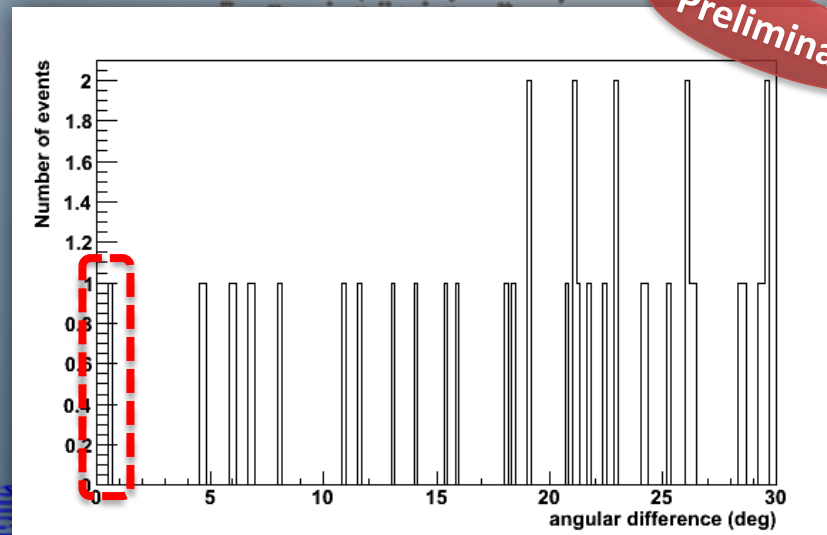
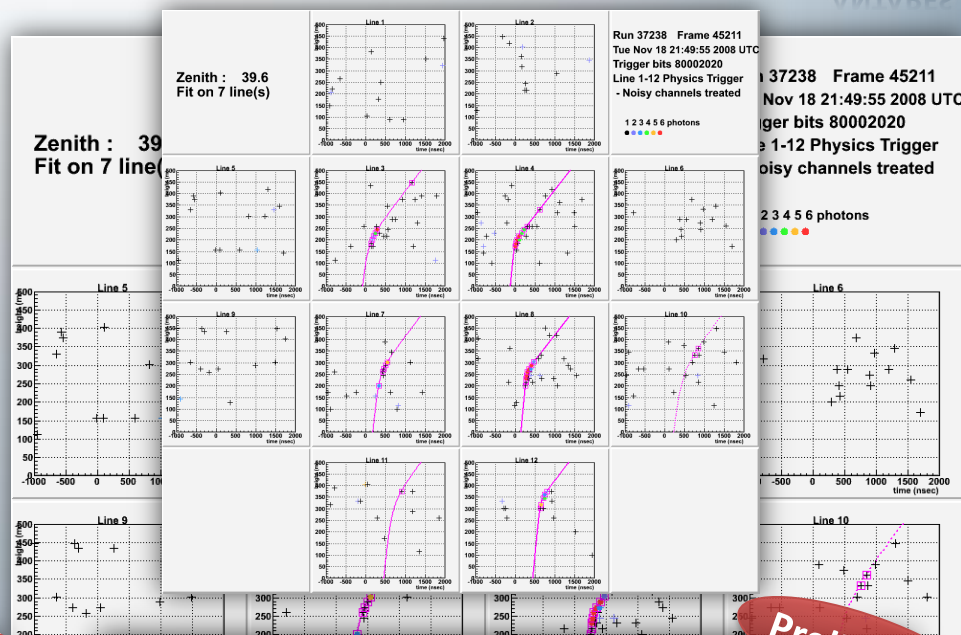
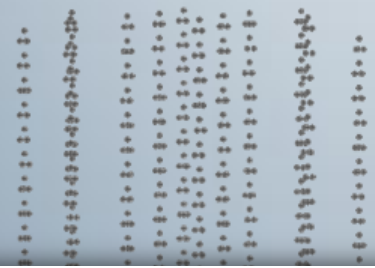
(\*) 61 days

(\*\*) Neyman

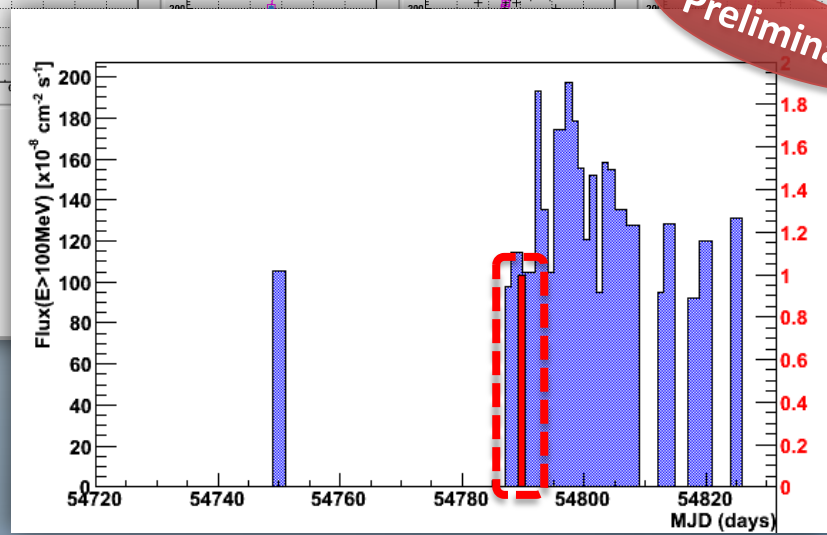
# Results for 3C279

1 neutrino compatible with the time-space distribution ( $\Delta\alpha = 0.56^\circ$ ) of 3C279 with probability 10% after trials

Compatible with background fluctuations



Preliminary



Preliminary



# Summary and future

## SUMMARY: Flare analysis of ANTARES 2008 data

- Transient sources analysis more sensitive than a standard point source search
- Study of a selection of 10 very bright and variable Fermi LAT blazars
- First time-dependent search for cosmic neutrinos using ANTARES data (end 2008)
- Most significant correlation of a flare with 3C279 (10% probability)

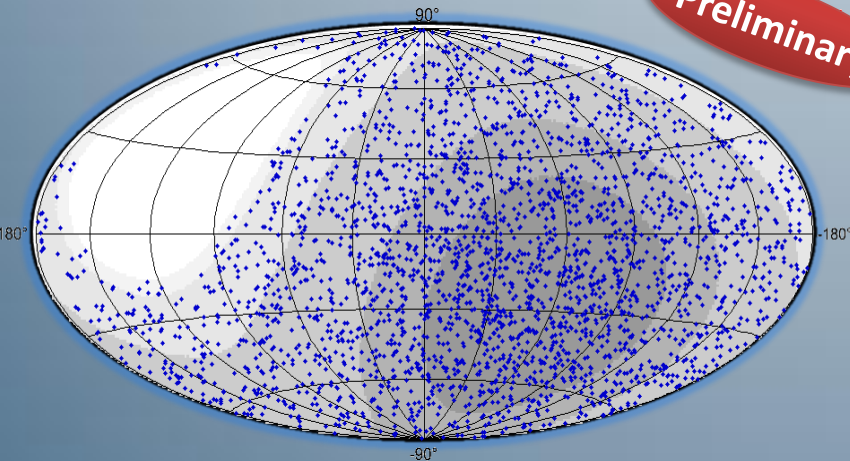
## FUTURE: Data analysis in progress

- More than 3000 neutrino candidates detected by ANTARES since 2008
- Very important flares detected by Fermi the last 2 years
- Ongoing analysis of the most important flares (around 40 flares)
- Application of a maximum likelihood blocks algorithm for light curve denoising in future analysis

## ANTARES events since 2008

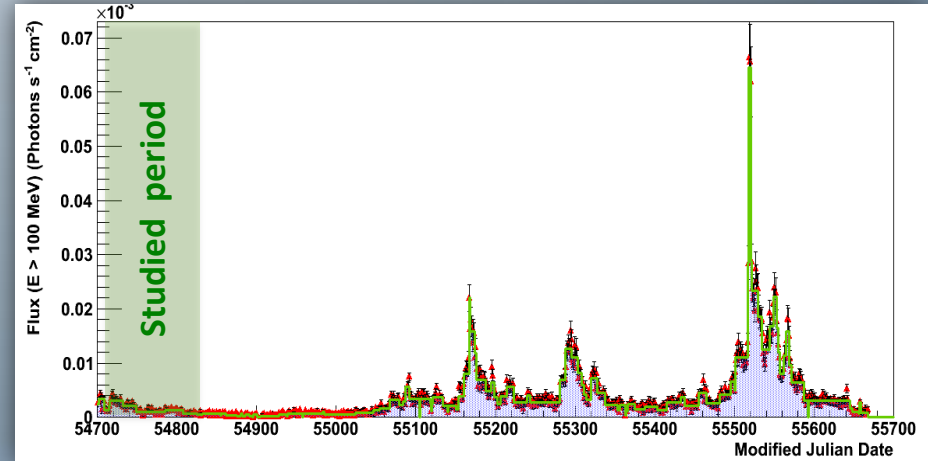
Credit: ANTARES Collaboration

Preliminary



## 1000 days of 3C454.3 denoised light curve

Plot: Agustín Sánchez Losa (IFIC-Spain)





Thank you  
for your attention