Data Selection For The Anisotropy Analysis

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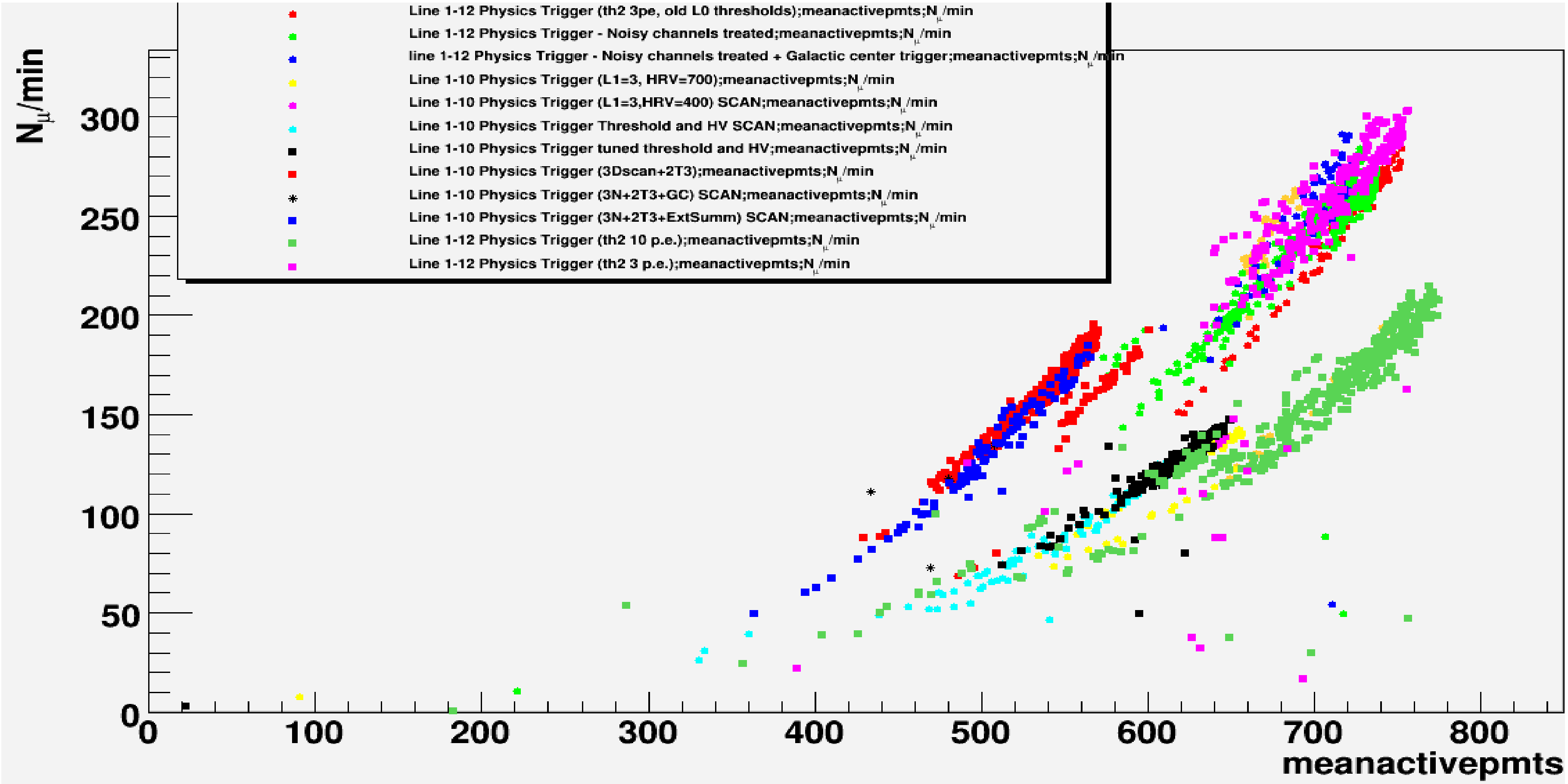
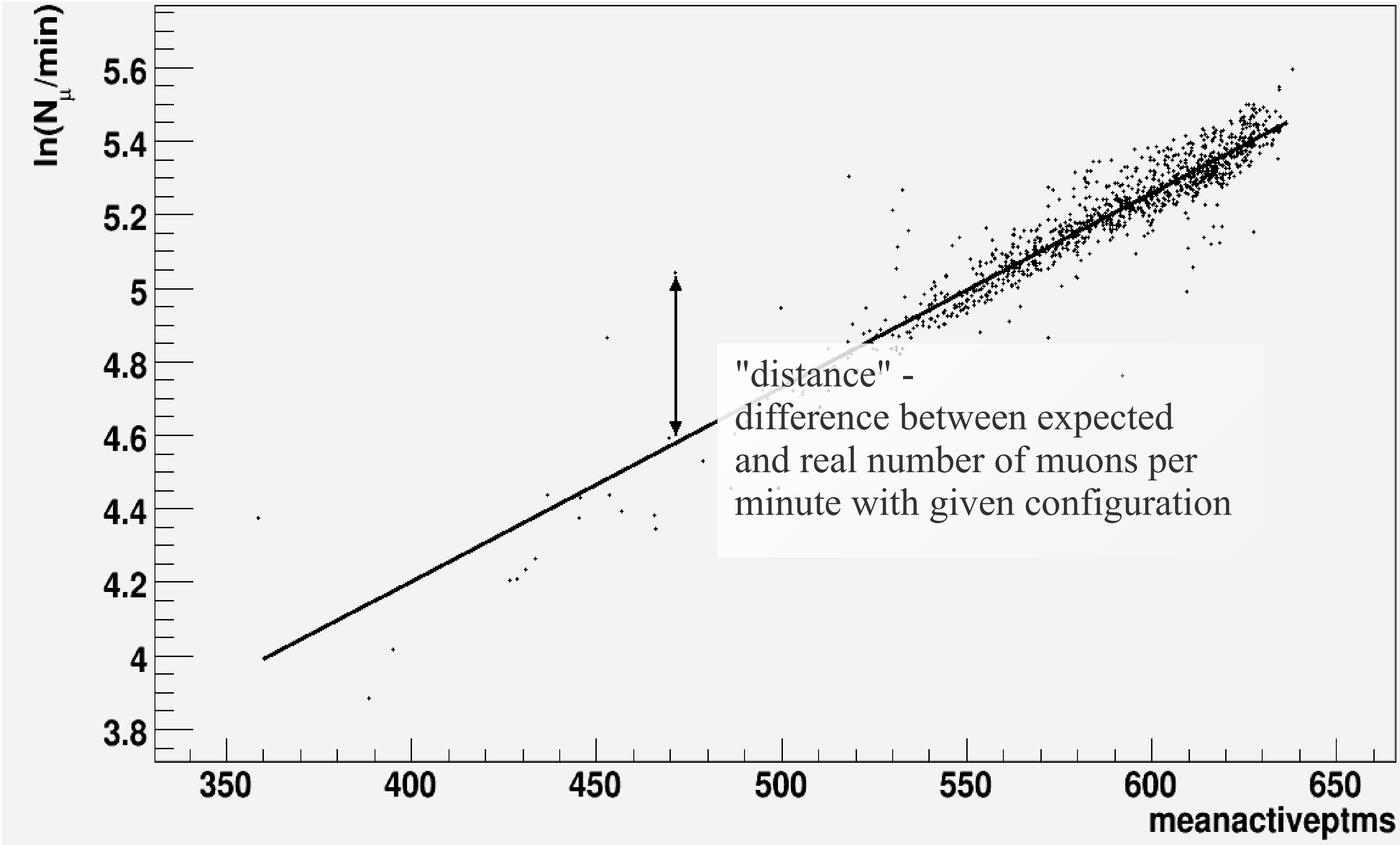
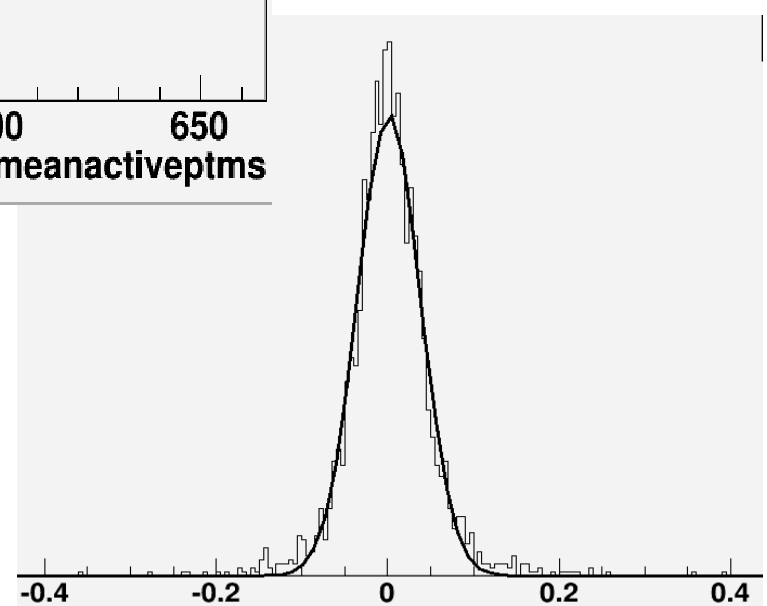
Short reminder of previous analysis



- The average number of muons Nμ per minute for each run depends on number of active OMs (Npmts) during this run as $\ln N_\mu \approx A + B \cdot Npmts$.
- For different detector configuration and different triggers used during the run, parameters A and B vary → it's necessary to split data on several general groups and process them separately.
- Splitting made by number of active lines and type of triggers (including or not GC, TQ, T2, SCAN&PRELIMS and reduced gains).

"Distance": the quality cut for run selection





In order to calculate optimal value of distance one should summarize in one axis all distance-histograms from each group, make a Gaussian approximation of total histogram and calculate the 3σ value.

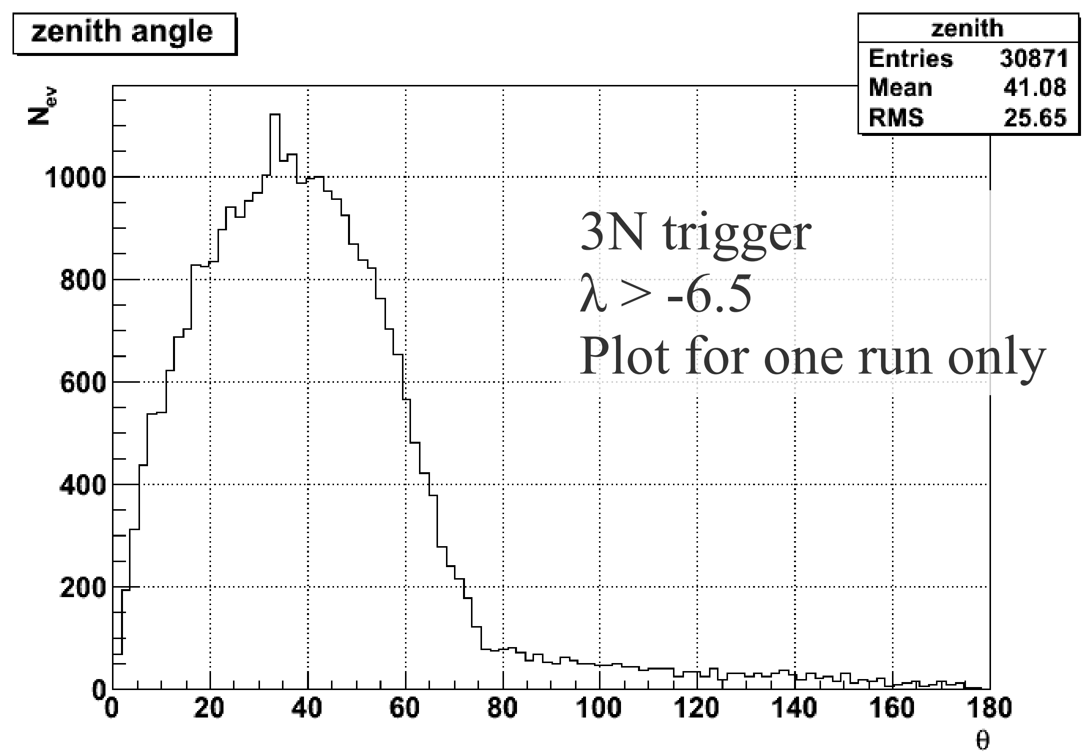
Further processing

Only 3N events of «good» runs of previous analysis are selected:
- 3N triggered events exist in every run
- Better accordance with MC for rates <150kHz (see elog 548 by Colas)
- GC triggered events excluded

AaFit:
- $\lambda > -6.5$ (Vladimir's presentation explains reason)
- Zenith angle < 20° (in order to look only at events with vertical tracks)

After all filtres:
2008 year — $0.83 \cdot 10^7$
2009 year — $0.77 \cdot 10^7$
2010 year — $1.04 \cdot 10^7$
} μ-events

Total:
$2.6 \cdot 10^7$ μ-events
(comparing to $3 \cdot 10^8$ for all triggers before filtering)



Spectrum analysis, Lomb method

- Lomb method was elaborated for cases of unevenly sampled data
- Weights the data on «per point» basis instead of «per time interval»

and cosines, only at times t_i that are actually measured. Suppose that there are N data points $h_i \equiv h(t_i)$, $i = 1, \ldots, N$. Then first find the mean and variance of the data by the usual formulas,

$$\bar{h} \equiv \frac{1}{N}\sum_{1}^{N} h_i \qquad \sigma^2 \equiv \frac{1}{N-1}\sum_{1}^{N}(h_i - \bar{h})^2 \tag{13.8.3}$$

Now, the Lomb *normalized periodogram* (spectral power as a function of angular frequency $\omega \equiv 2\pi f > 0$) is defined by

$$P_N(\omega) \equiv \frac{1}{2\sigma^2}\left\{ \frac{\left[\sum_j (h_j - \bar{h})\cos\omega(t_j - \tau)\right]^2}{\sum_j \cos^2\omega(t_j - \tau)} + \frac{\left[\sum_j (h_j - \bar{h})\sin\omega(t_j - \tau)\right]^2}{\sum_j \sin^2\omega(t_j - \tau)} \right\} \tag{13.8.4}$$

Here τ is defined by the relation

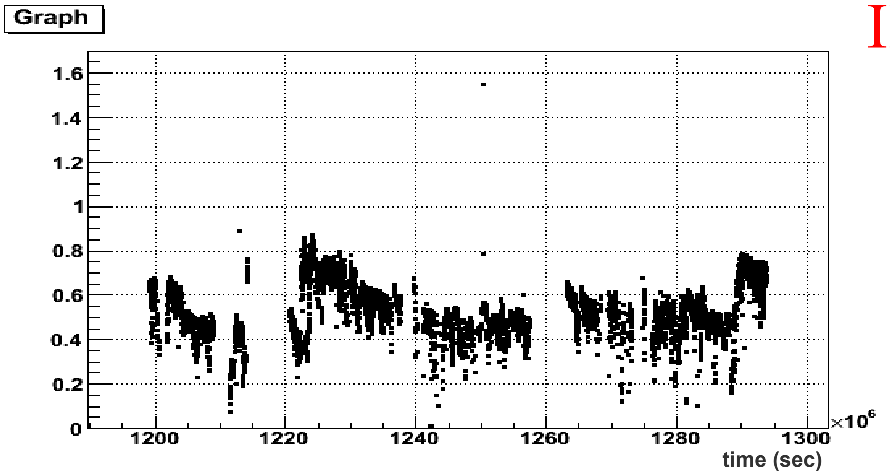
$$\tan(2\omega\tau) = \frac{\sum_j \sin 2\omega t_j}{\sum_j \cos 2\omega t_j} \tag{13.8.5}$$

NUMERICAL RECIPES IN C: THE ART OF SCIENTIFIC COMPUTING (ISBN 0-521-43108-5, p. 575)

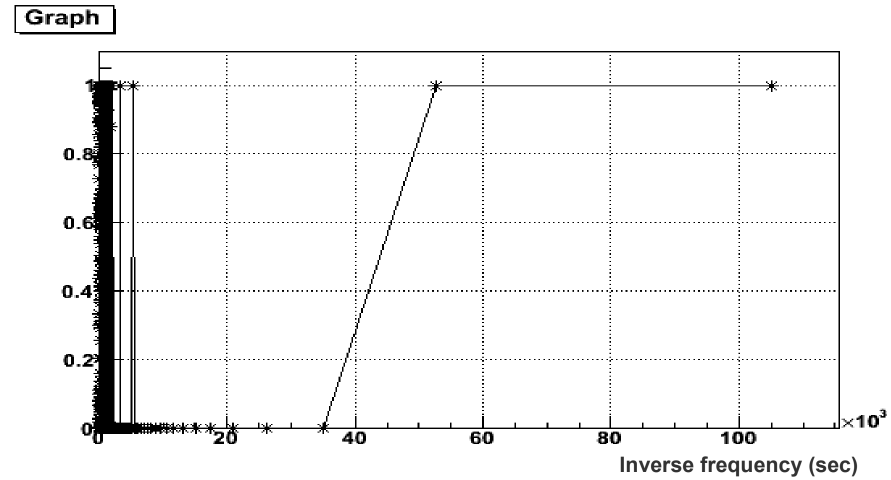
Example of the FastLomb output

(zenith < 20°, λ > -6.5, GC excluded, artificial added anisotropy)

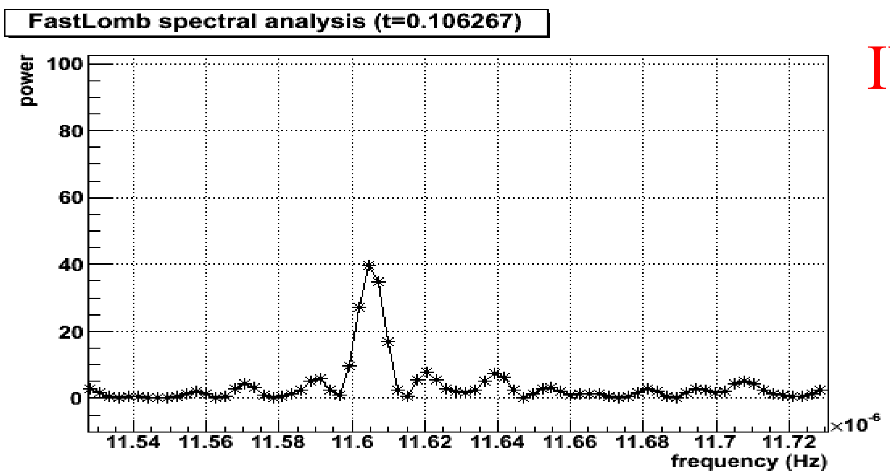
I



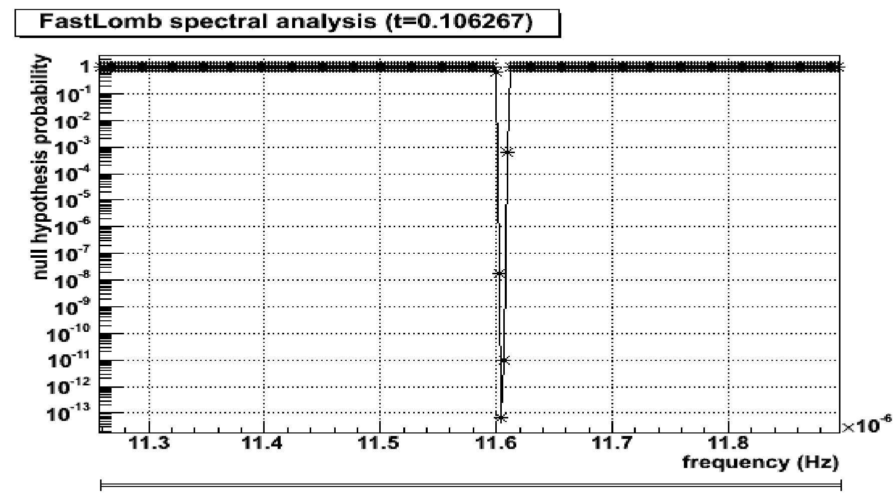
II



III



IV



I — input muon rate

II — null hypothesis probability vs inverse frequency

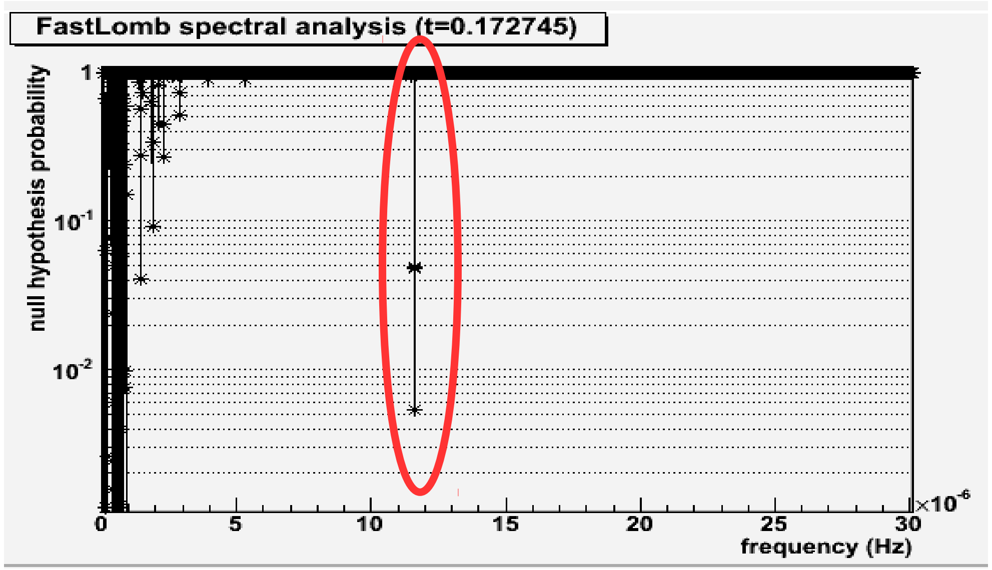
III — spectral power vs frequency

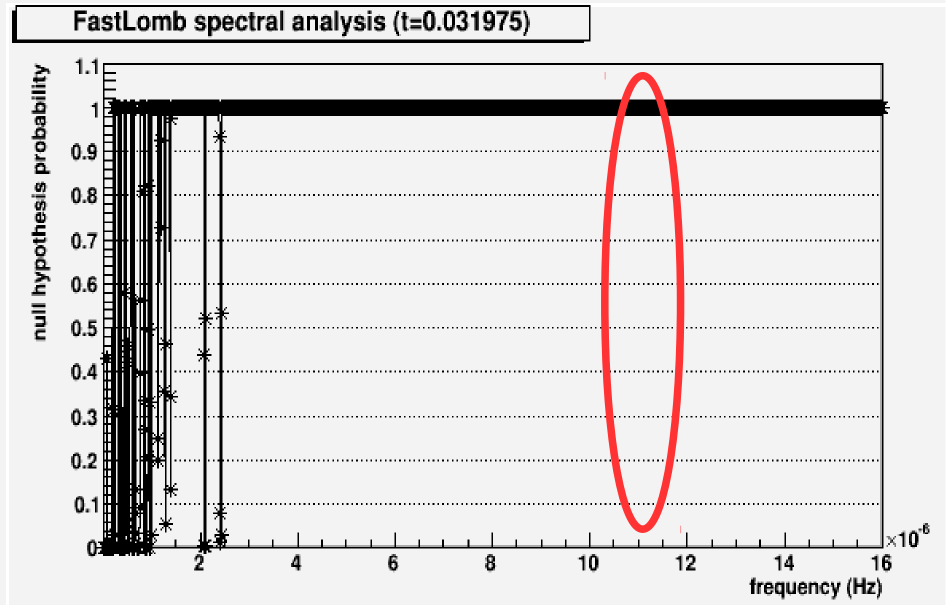
IV — null hypothesis probability vs frequency

Comparison of the Lomb analysis perfomed on the μ-rate with and without GC trigger after angle and lambda cuts

Lomb analysis of the μ-rate for the 2009 data with GC:

Sharp peak in the null probability function with frequency ≈11.6·10-6 Hz corresponding to one sidereal day (23 h 56 min 4 sec)



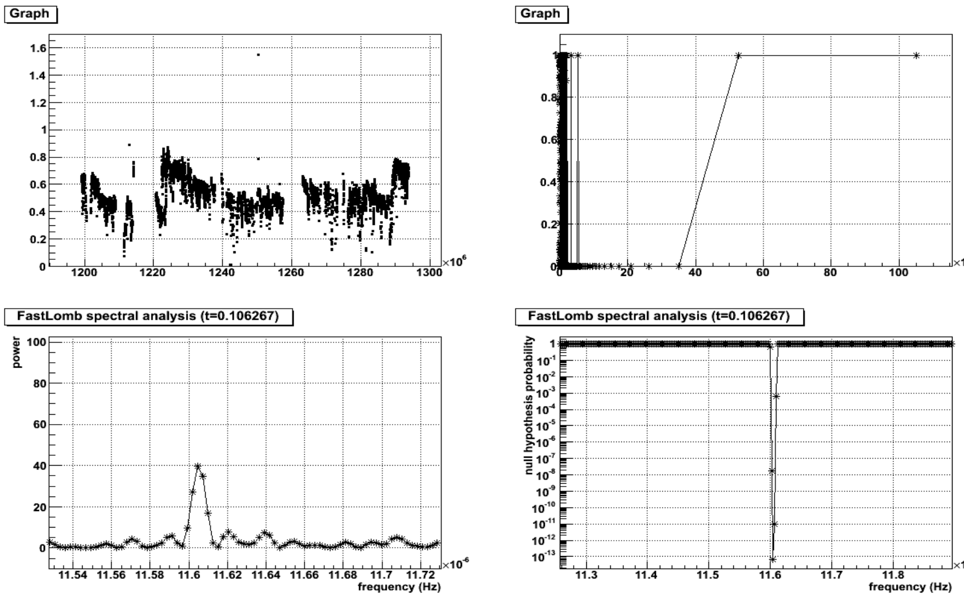


Lomb analysis of the μ-rate for the 2009 data without GC:

As soon as GC evens are filtred no peak is seen. No evidence of possible anisotropy either. But can it be observed this way?

Sensitivity of the Lomb method on possible muon anisotropy

I



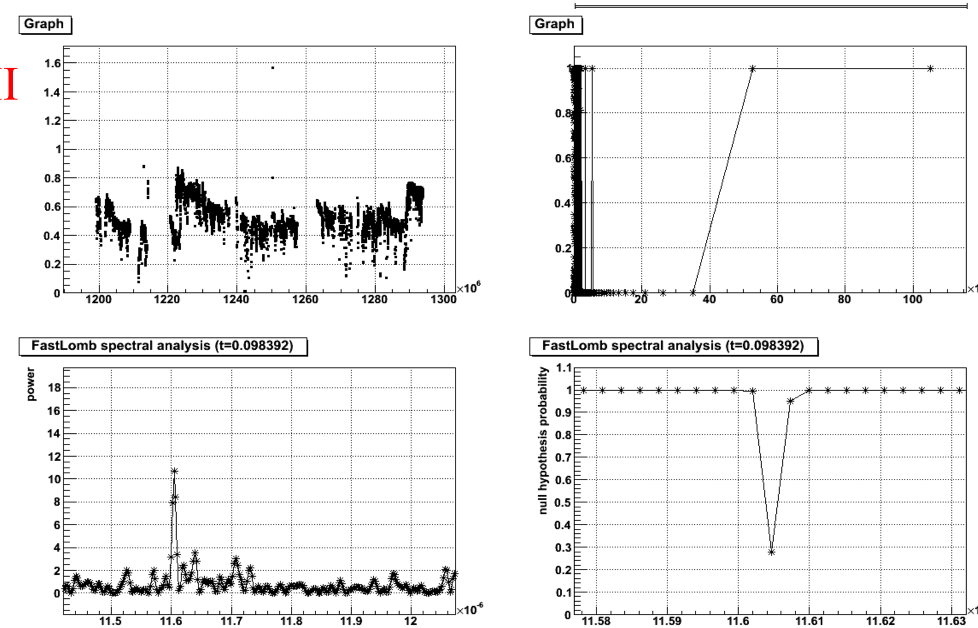
I — artificially added anisotropy 4%, peak is well-seen

II — artificiallly added anisotropy 2%, peak still seen

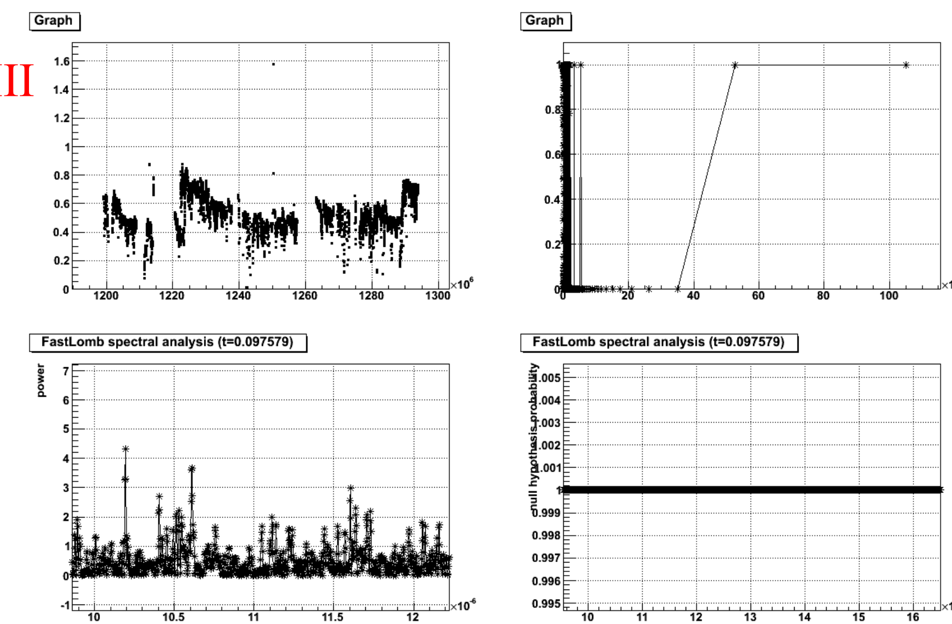
III — artificially added anisotropy 1%, no peak can be seen

Expected level of natural anisotropy is ~ 0.1% → The method is helpless

II



III



Conlusions

- 3 years of data are analysed and put into DB (2008-2010)
- Events with 3N trigger only are filtred
- Lambda cut ($\lambda > -6.5$) for vertical downgoing muons is applied
- Lomb method is used to perform spectrum analysis for μ-rate during 2008-2010 years
- Analysis has shown it's impossible to see anisotropy using Lomb method (level of possible anisotropy is too low)

What's going on when the gain of PMTs changes? (Colas' question from Moscow)

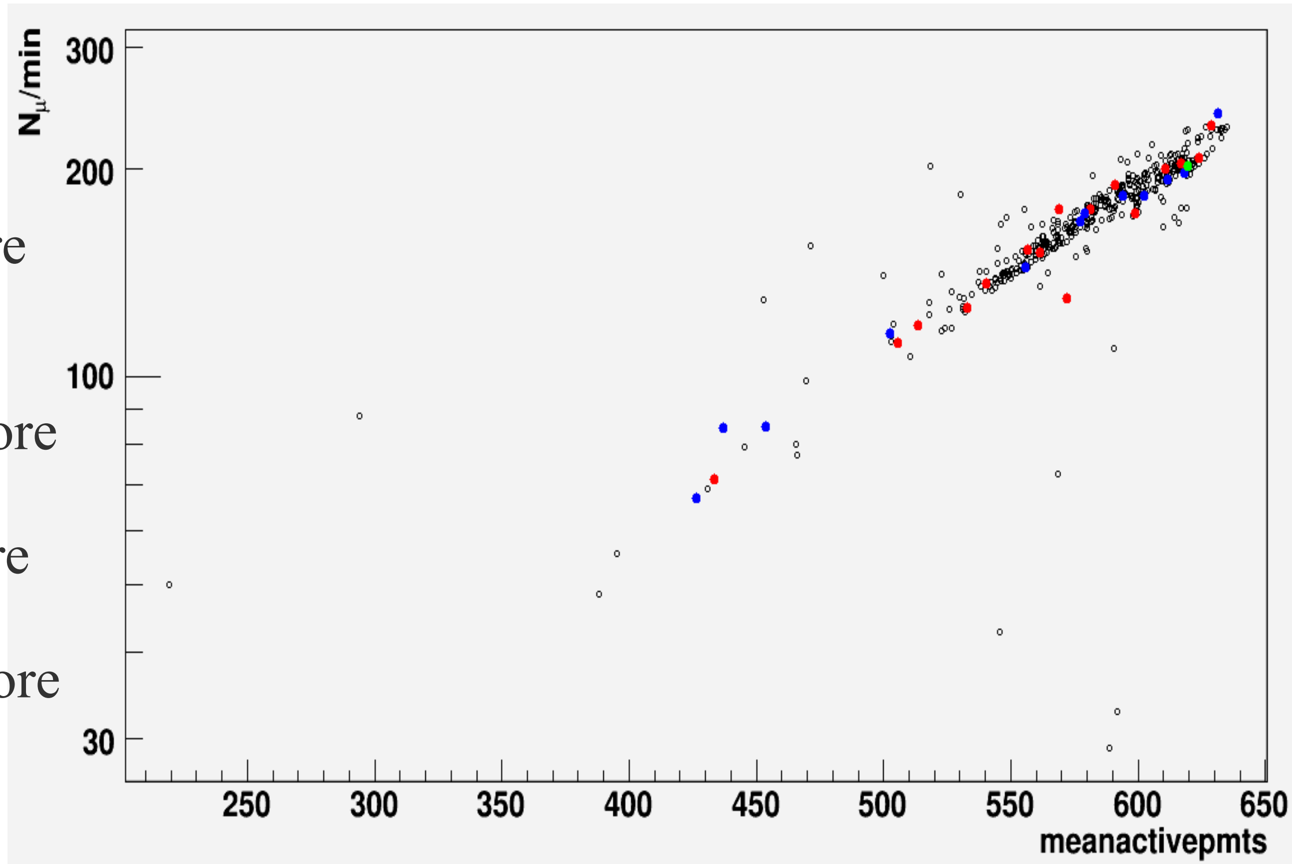
3N+2T3 trigger, normal gain

Black — normal gain runs were before

Red — halfgain runs were before

Blue — gain/4 runs were before

Green — gain/8 runs were before



Colored runs in this plot possibly coud have another number of detected muons if calibration sets were not downloaded in time from the DB. But, apperantly, this effect is not seen in this analysis (even runs after switching between gain/8 or gain/4 and normal are lying in main group).