Analysis of Pisa method with TUCS

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Overview

- Comparison between different methods to compute *k* constant
- Report on problems found in the *k* stored in ntuples

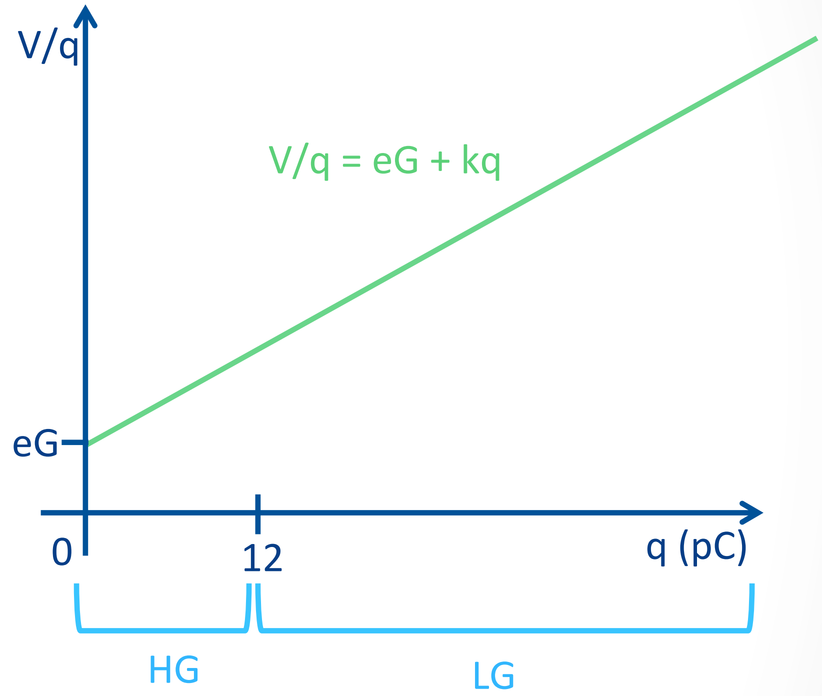
Further plans for qualification task

1. Move to laser gain analysis (in TUCS).
2. Comparison with cesium.

Pisa method: a reminder

- The gain *G* of a PMT can be calculated using the mean collected charge *q* and it's variance *V*.

$$\frac{V}{q} = eG + kq$$



- The Pisa method is applied only for HG: in LG conditions, the uncertainty on the estimation of *k* would be enlarged when extrapolating to zero.

The *kq* correction

- The *kq* correction to the gain is due to time coherence of laser light.

$$G = \frac{1}{e}\left(\frac{V}{q} - kq\right) = \frac{1}{e}\cdot\frac{V}{q}(1-\delta_G)$$

$$\delta_G = \frac{kq}{V/q}$$

In HG conditions: $\frac{V}{q} \sim 0.1\ \mathrm{pC}$ $\quad q \sim 1\ \mathrm{pC}$ $\quad k \sim 10^{-3}$

$$\Rightarrow \delta_G \sim 10^{-2} \rightarrow 4\cdot 10^{-2}$$ (depending on *q*)

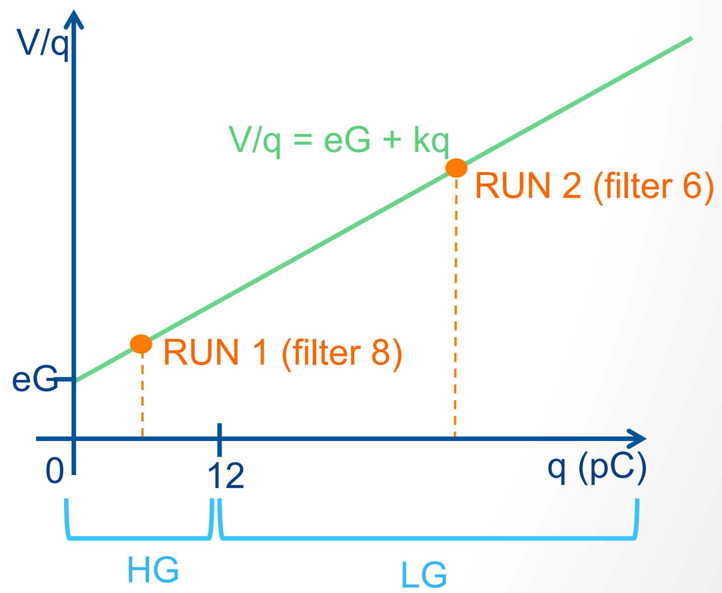
- The *kq* term should be taken into account to reach a precision of the order of percent on the gain.
  - *K* varies in time with Δk/k ~ 1
  - *k* depends on laser conditions (slide 22): could have significant variations if laser parameters are modified for some reason

The *k* constant

- Conventionally, *k* is computed from correlations between PMTs.
  - In ntuples *k* is available only averaged over a fiber. To get *k* for each PMT one should re-analyze the raw data.

- An alternative way is to compute *k* using two runs:
  - One of high gain (filter 8) and one of low gain (filter 6)

$$k = \frac{\frac{V_L}{q_L} - \frac{V_H}{q_H}}{q_L - q_H}$$

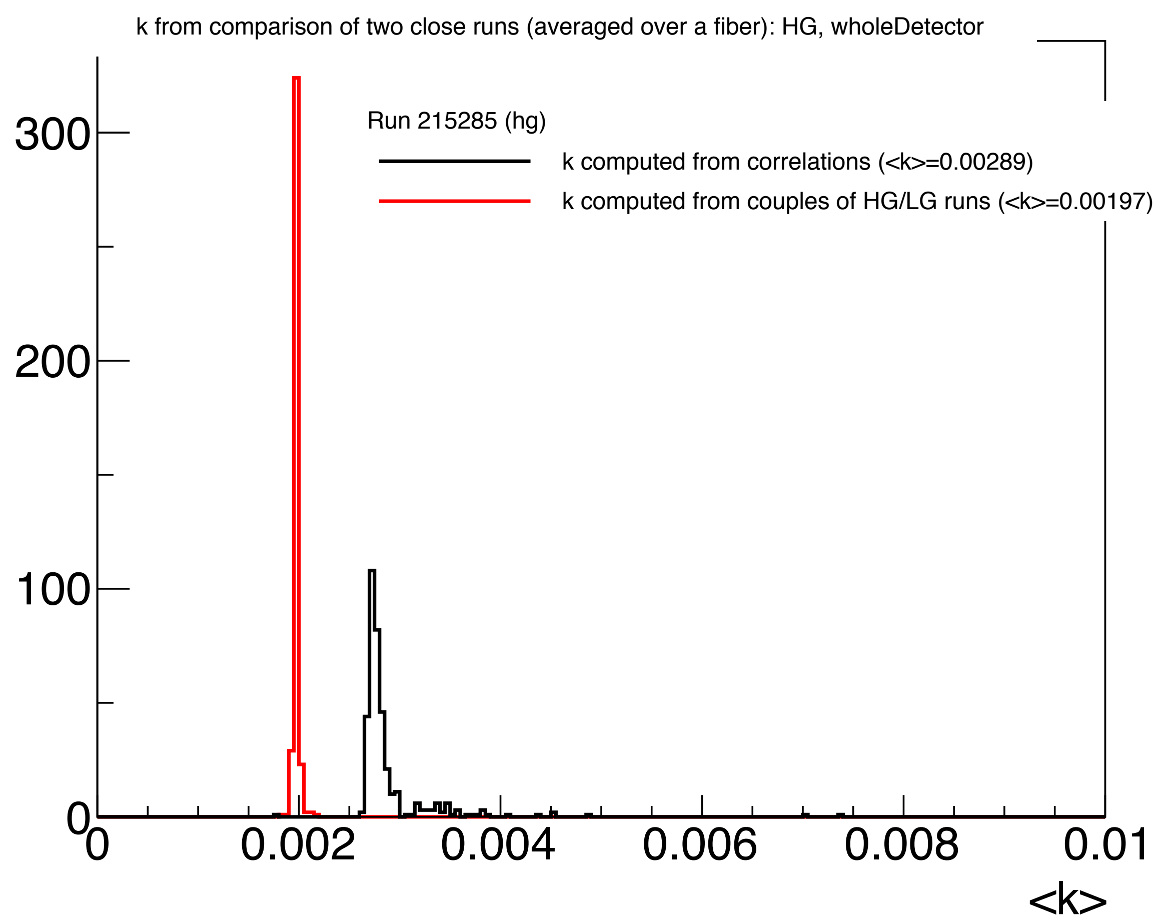


  - The two runs must have been taken at less the two hours from one another

- *K* is then available for each PMT

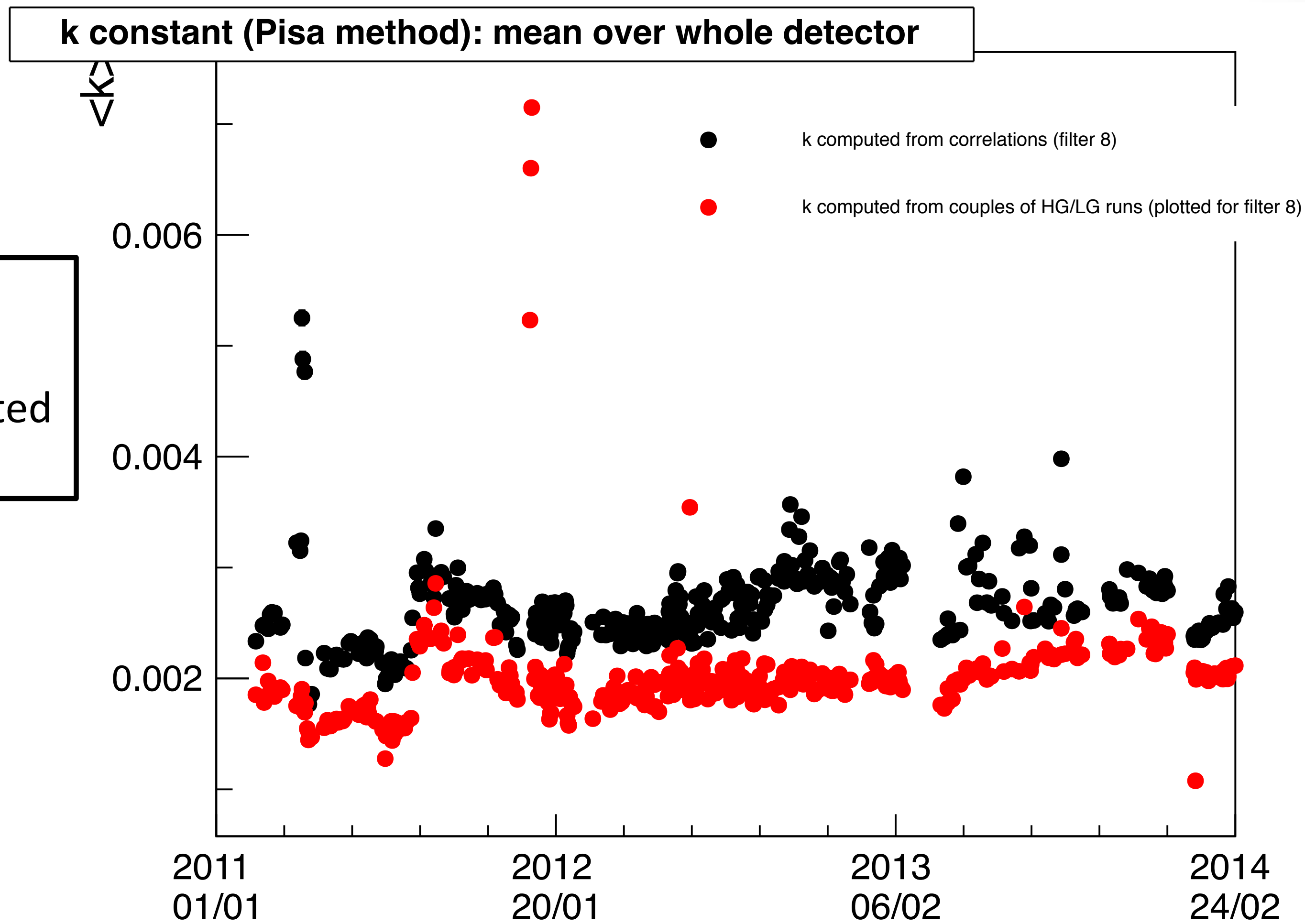
k_{corr} vs k_{2runs}: distribution for one run

- *K* is averaged over each clear fiber.
- Both the distributions have been cut: $k \in [0.001, 0.008]$
  - The cut does not bias the data (check in backup)



k_{corr} - k_{2runs} comparison over time

- There is a systematic difference between the two *k*
- Both the two *k* increase with time, but K_{2runs} appears to be more stable



K_{corr}: statistical uncertainties

K_{2runs}: propagated errors

k_{corr} for LG (filter 6 run)

- Laser runs are made using different light intensities, corresponding to different light filters.
  - Here filter 8 (low intensity) and filter 6 (high intensity) are considered
  - Conventionally, HG (LG) readouts are not used in filter 6 (8) runs.

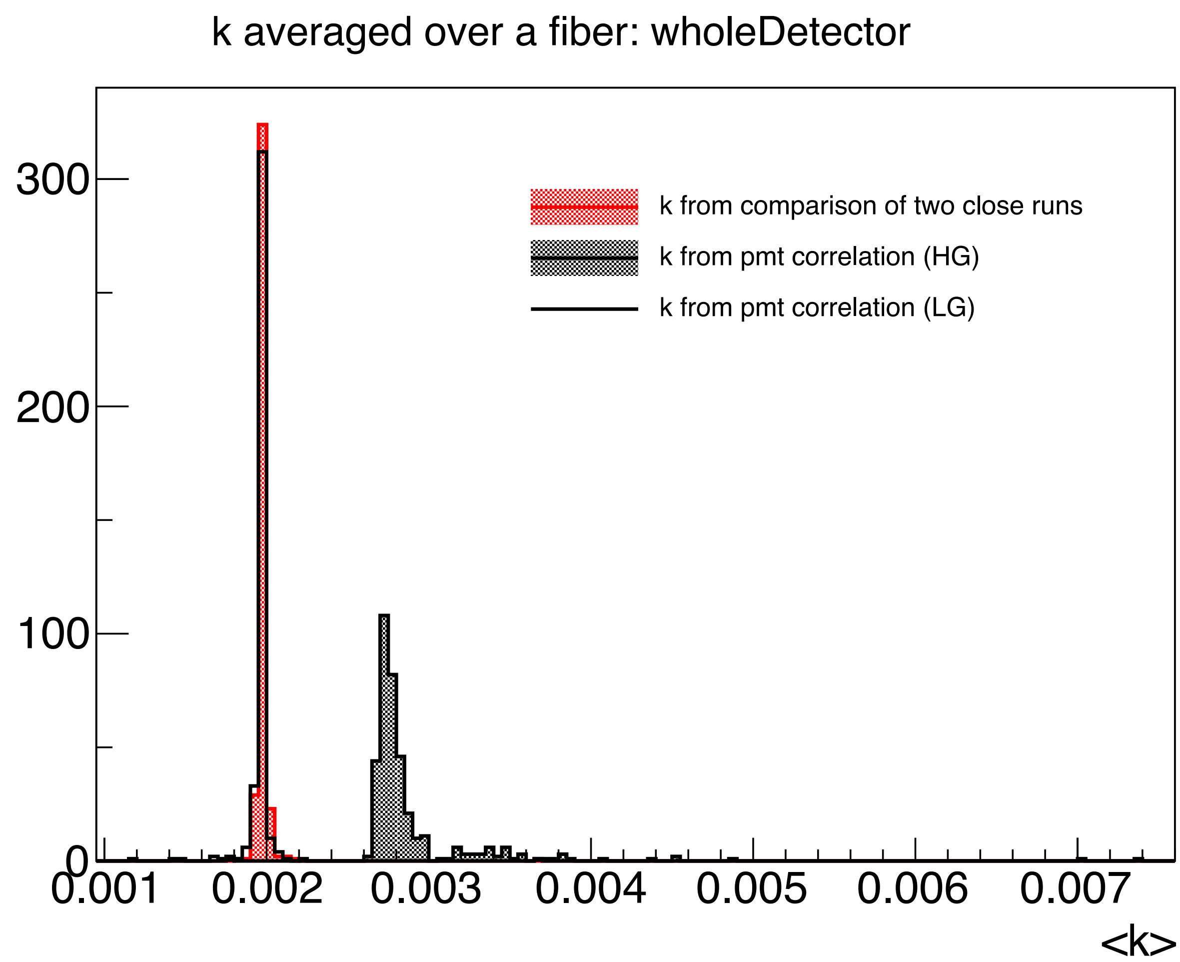
- K_{corr} is computed for both HG and LG, but Pisa method is only applied in HG.

- Then, only k_{corr} from filter 8 runs is really used.

- In the following, k_{corr} computed for a run of filter 6 (the one used to build k_{2runs}) will be compared to previous definitions of k.

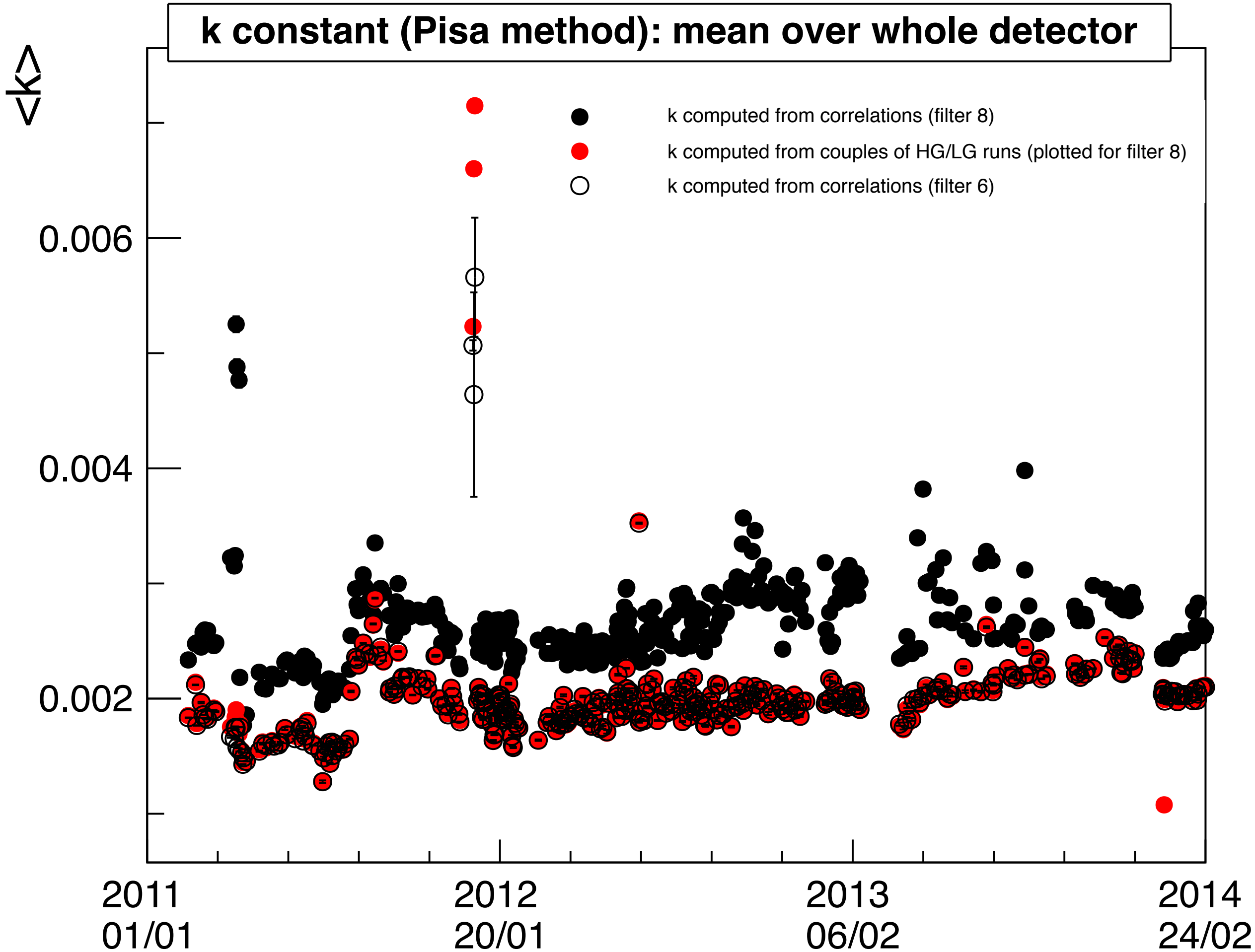
k_{corr}(*filter 8*), k_{corr}(*filter 6*) and k_{2runs}: distribution for one run

- *K* is averaged over each clear fiber.
- All the distributions have been cut: $k \in [0.001, 0.008]$



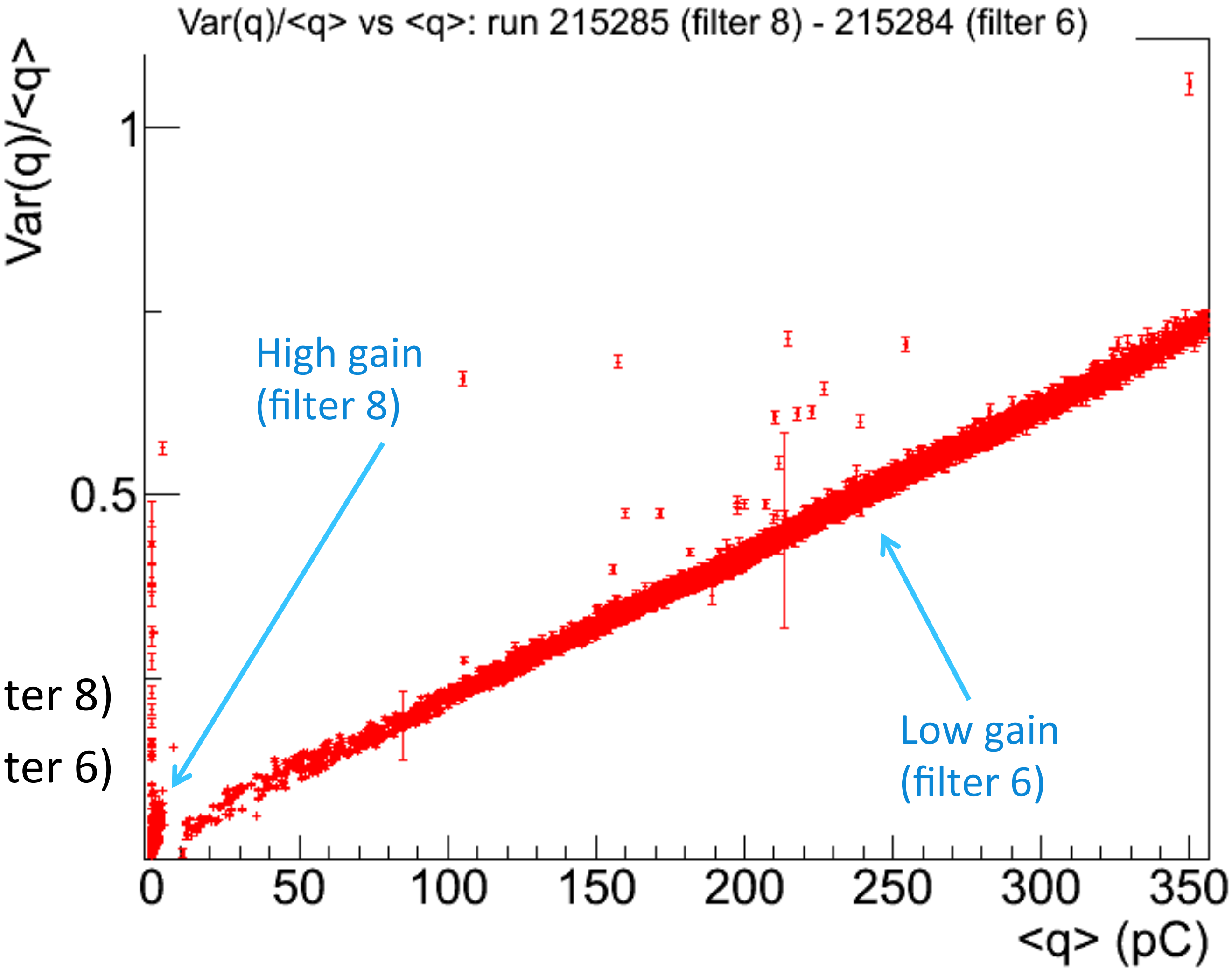
k_{corr}(filter 8), k_{corr}(filter 6) and k_{2runs}: comparison over time

- $k_{corr}(6)$ shows no systematic difference with respect to k_{2runs}



Var(q)/<q> vs <q>

- The slope of such a plot is a further measure of *k*: fitting Var(q)/<q> as a function of <q> could be a cross-check for other computation methods.



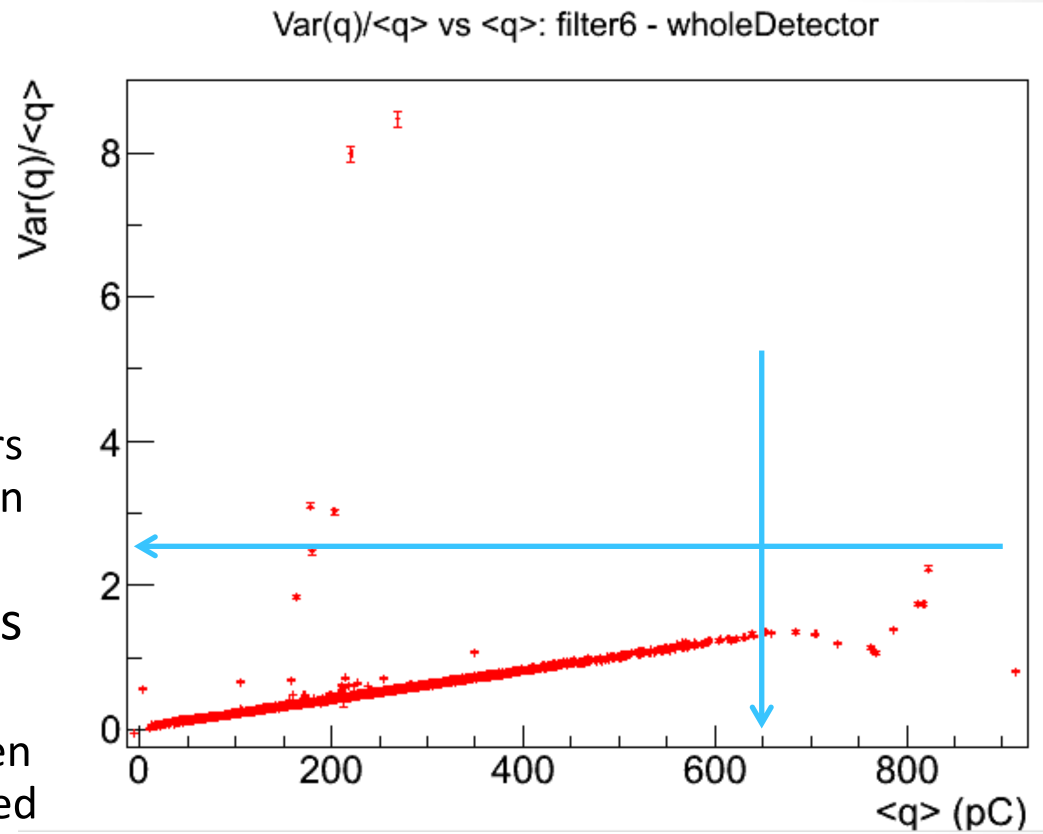
- Data taken on 2012-11-27:

  Run 215285 (filter 8)

  Run 215284 (filter 6)

Var(q)/<q> vs <q>: filter 6 run

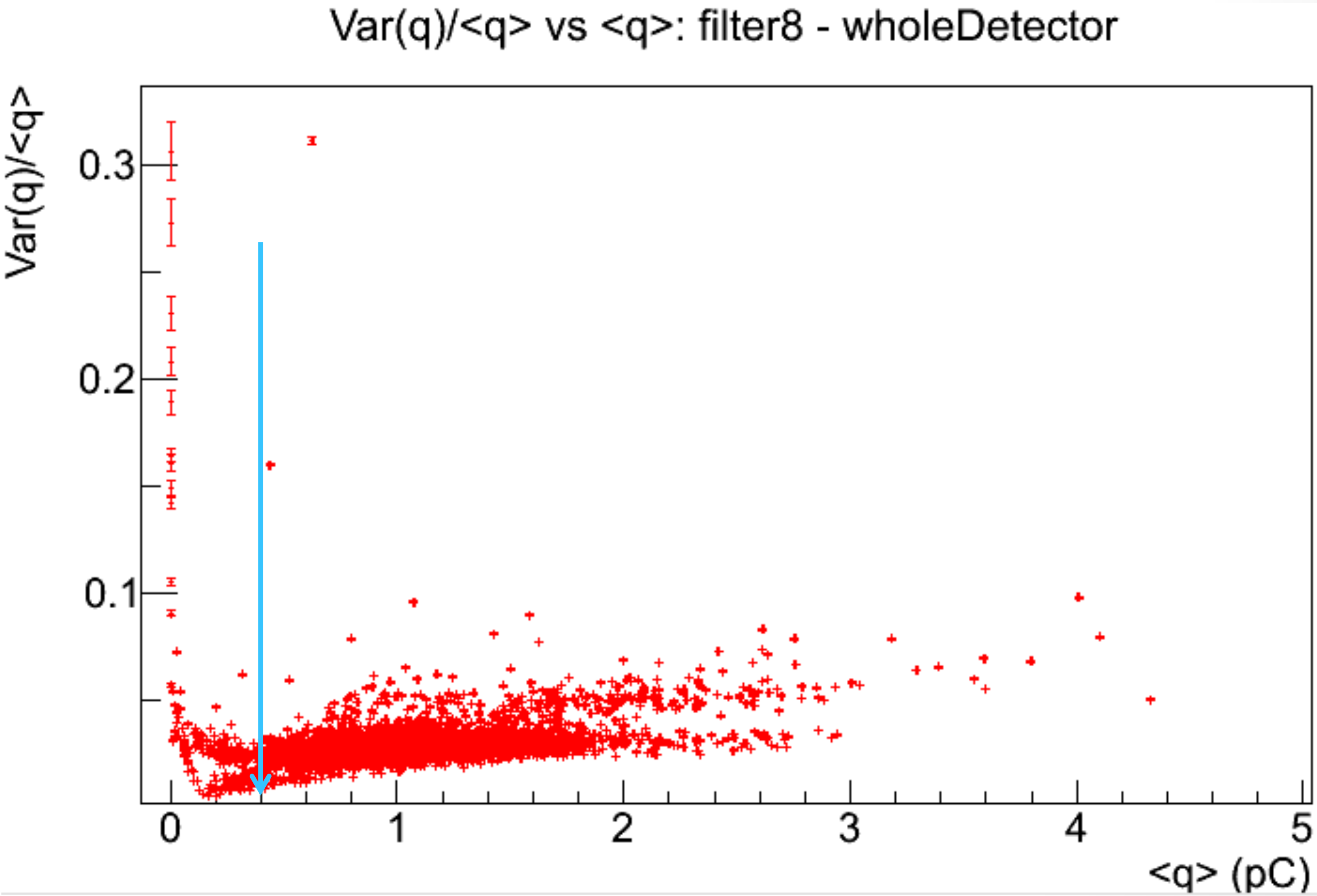
- LG shows clearly a linear behavior.
- It is affected by very far outlayers
  - The amount of outlayers can change between run and run
- At high charge, it deviates from linearity
  - Such an effect have been observed in all the tested runs



- A simple way to obtain a good fit of these data is to reject points with: Var(q)/<q> > 2.5 or <q> > 650 pC

Var(q)/<q> vs <q>: filter 8 run

- HG has a more complicated shape
- Var(q)/<q> increases for <q> $\longrightarrow$ 0 : laser events could be cleaned un by cutting away those with <q> < 0.4 pC



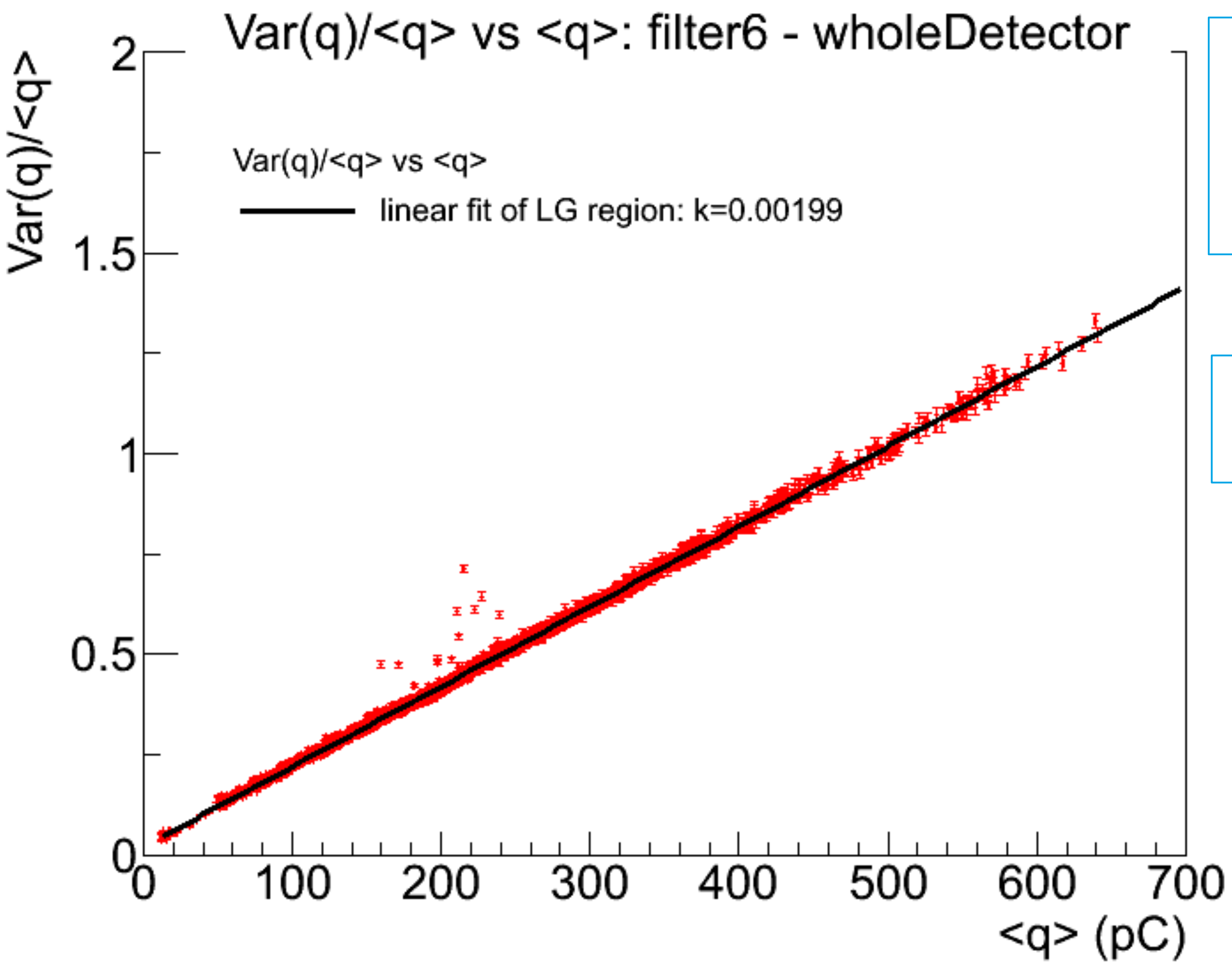
Cleaning cuts

- Adding some cleaning cuts over laser events can eliminate some outlayers in Var(q)/<q> plot.
    - It's then possible to perform an acceptable linear fit.

- Requirements applied to make previous plots:
    - Pump intensity = 23000
    - Do not consider low gain (high gain) events for filter 8 (filter 6) runs
- Cleaning cuts added:
    - Check if the channel is instrumented
    - Require the number of laser entries per run to be larger than an appropriate value (inherited from older TUCS workers)
    - Require 'status'=0
    - Require $0.4\text{ pC} < \langle q\rangle < 650\text{ pC}$
    - Require $0. \leq Var(q)/\langle q\rangle < 2.5$ (this V/q range is large enough not to bias the data.

- These cuts have very small effect on k_{corr} and k_{2runs} distributions (see backup)

Var(q)/<q> vs <q>: fit (LG)



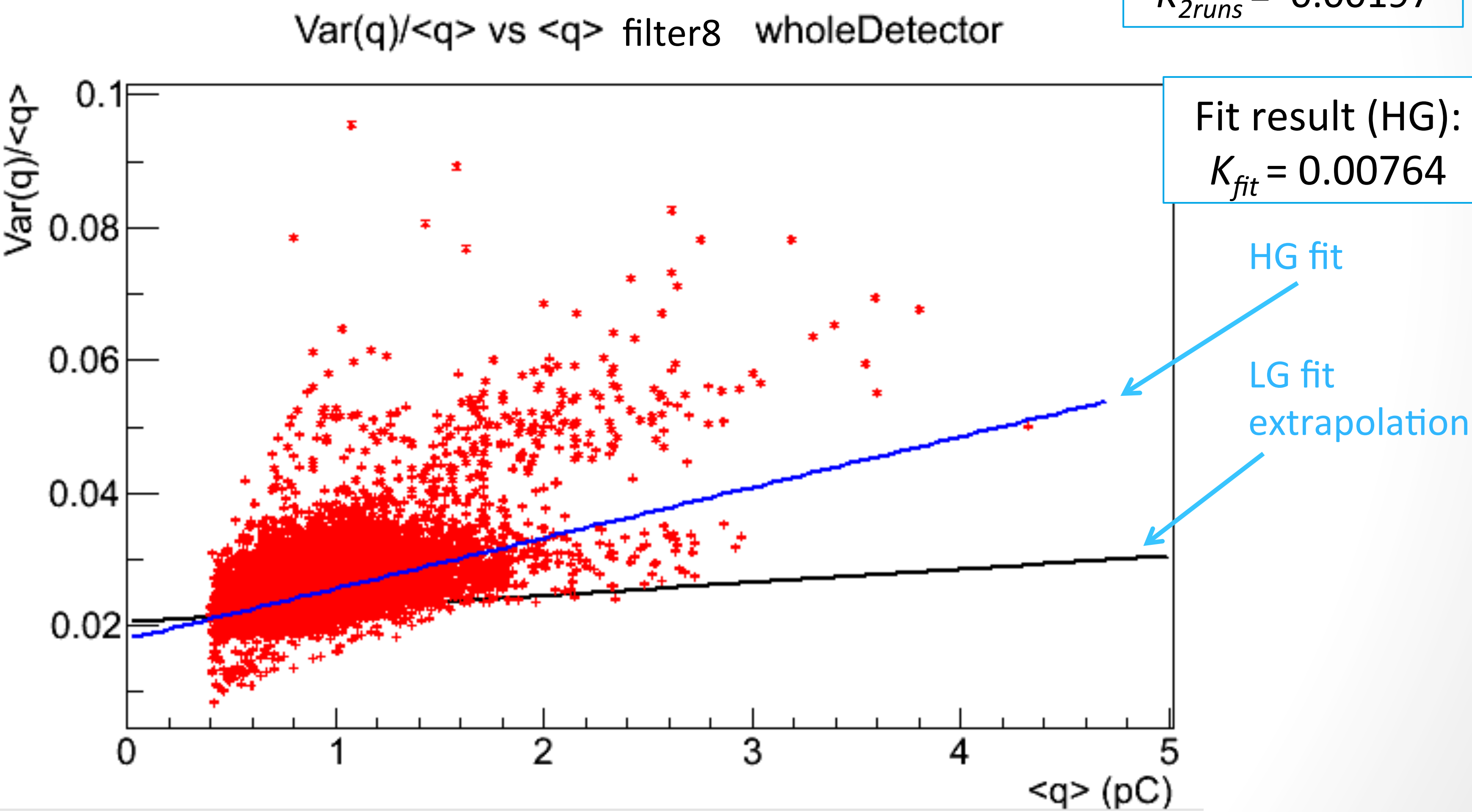
For this run:
$K_{corr}(8) = 0.00288$
$K_{corr}(6) = 0.00196$
$K_{2runs} = 0.00197$

Fit result:
$K_{fit} = 0.00199$

Var(q)/<q> vs <q>: fit (HG)

- The central 'bulk' appears to have a slope quite similar to that of LG
- Fit result is affected by the outlayers

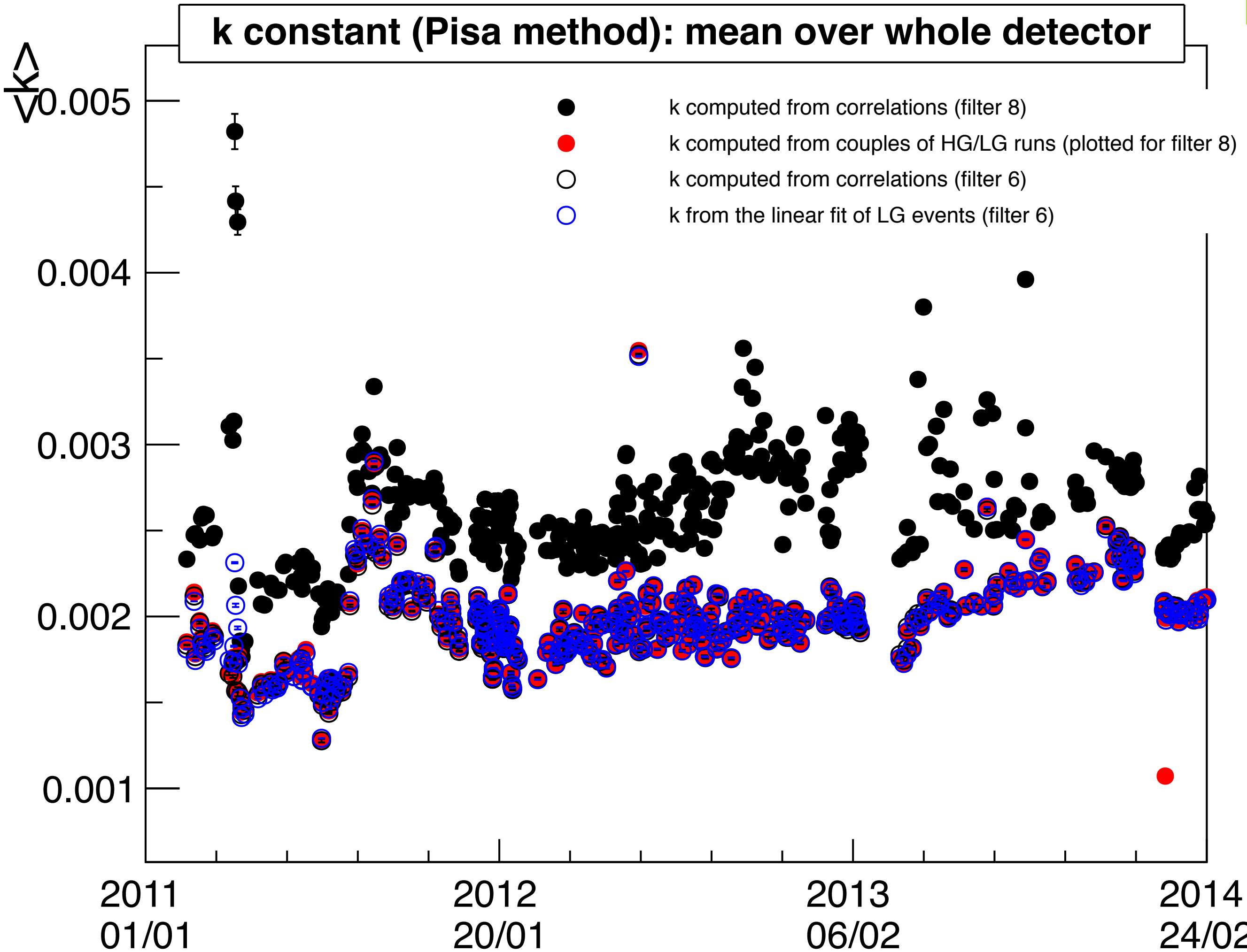
For this run:
$K_{corr}(8)$ = 0.00288
$K_{corr}(6)$ = 0.00196
K_{2runs} = 0.00197



Fit result (HG):
K_{fit} = 0.00764

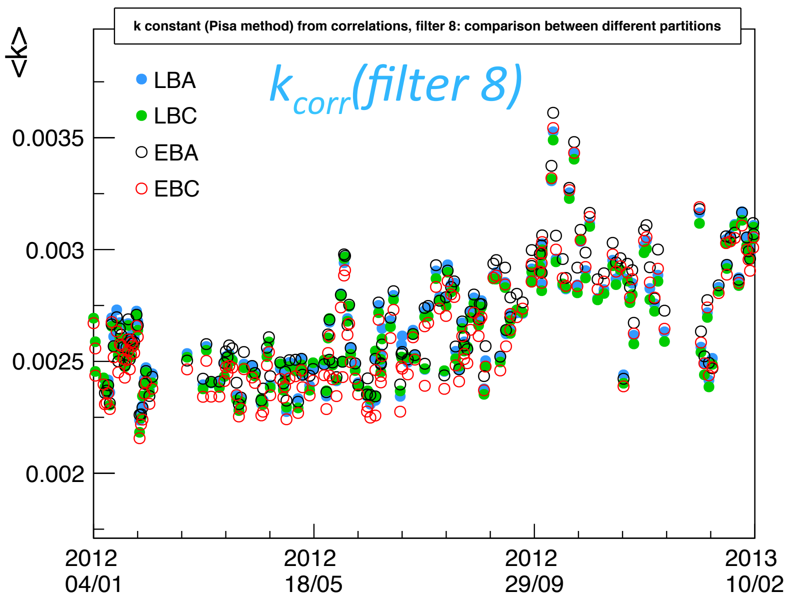
k_{corr}*(filter 8)*, k_{corr}*(filter 6)* and k_{2runs}: comparison with fit over time

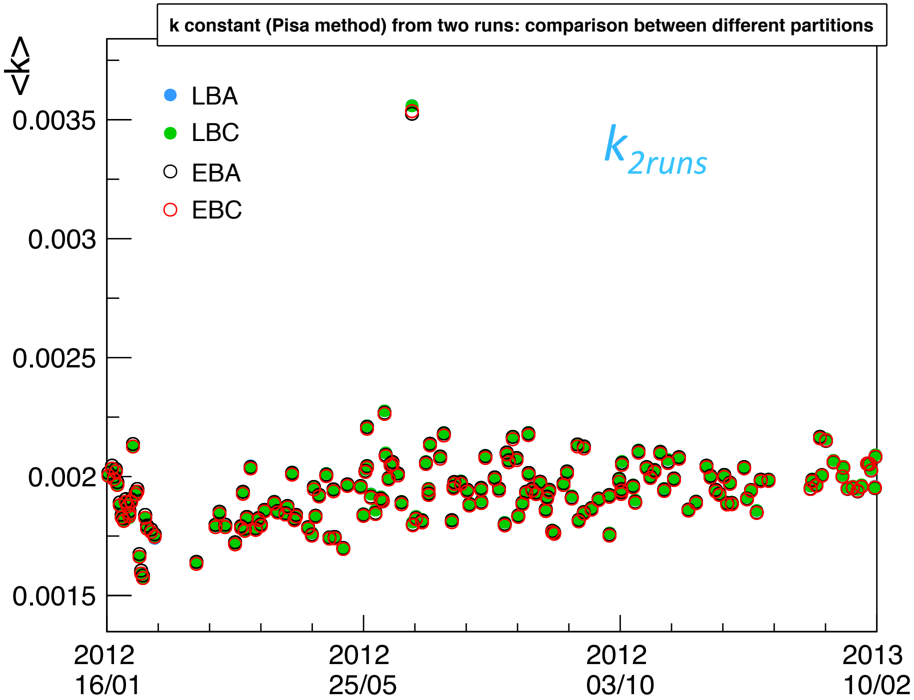
K_{corr}*(8)* (full black dots) is the only one used for calibration

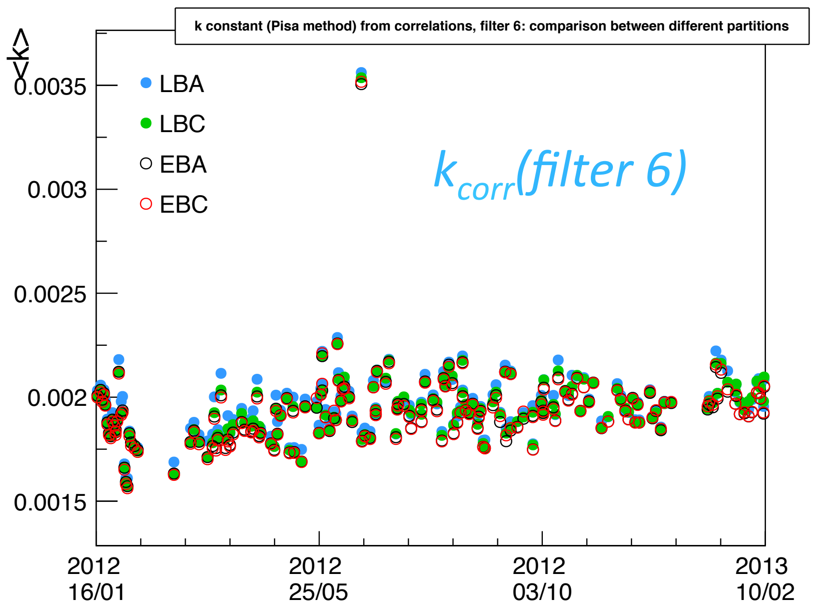


Comparison between different partitions

- K_{2runs} appears to be the more stable varying the partition







Summarizing…

- Starting from an HG (filter 8) laser event, four ways to compute *k* can be considered

  1. Take the *k* computed from light correlations stored in the same run (k_{corr} *filter 8*)
  2. Look for a filter 6 run taken at less than 2 hours from the considered one and compute *k* directly from *V* and *q* PMT per PMT
  3. Take the *k* computed from light correlations stored in this second run (k_{corr} *filter 6*)
  4. Make a linear fit of *V/q vs q* for LG events (k_{fit})

- 3. and 4. have been introduced to check the other methods

Conclusions

- All the values of *k* tends to increase with time, although *k* from method 1. has a sharper increasing

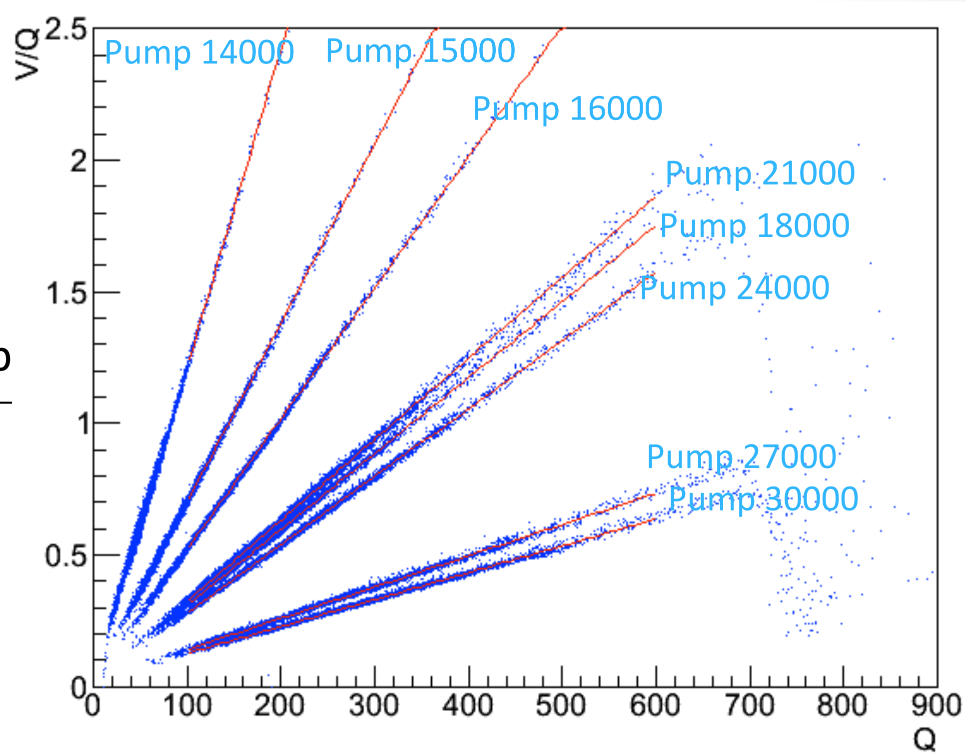
- Methods 2., 3. and 4. return compatible values of *k*
- The values of *k* resulting from method 1. are systematically larger, affected by larger fluctuations and less stable in time.
  - Method 1. is the one currently used for calibration.

- Method 2. :
  - Has the narrowest distribution, less affected by outlayers
  - Has the better stability in time
  - Shows almost no variation moving from a partition to another
  - Provides *k* for each PMT without using ATHENA
- Move to method 2 ?

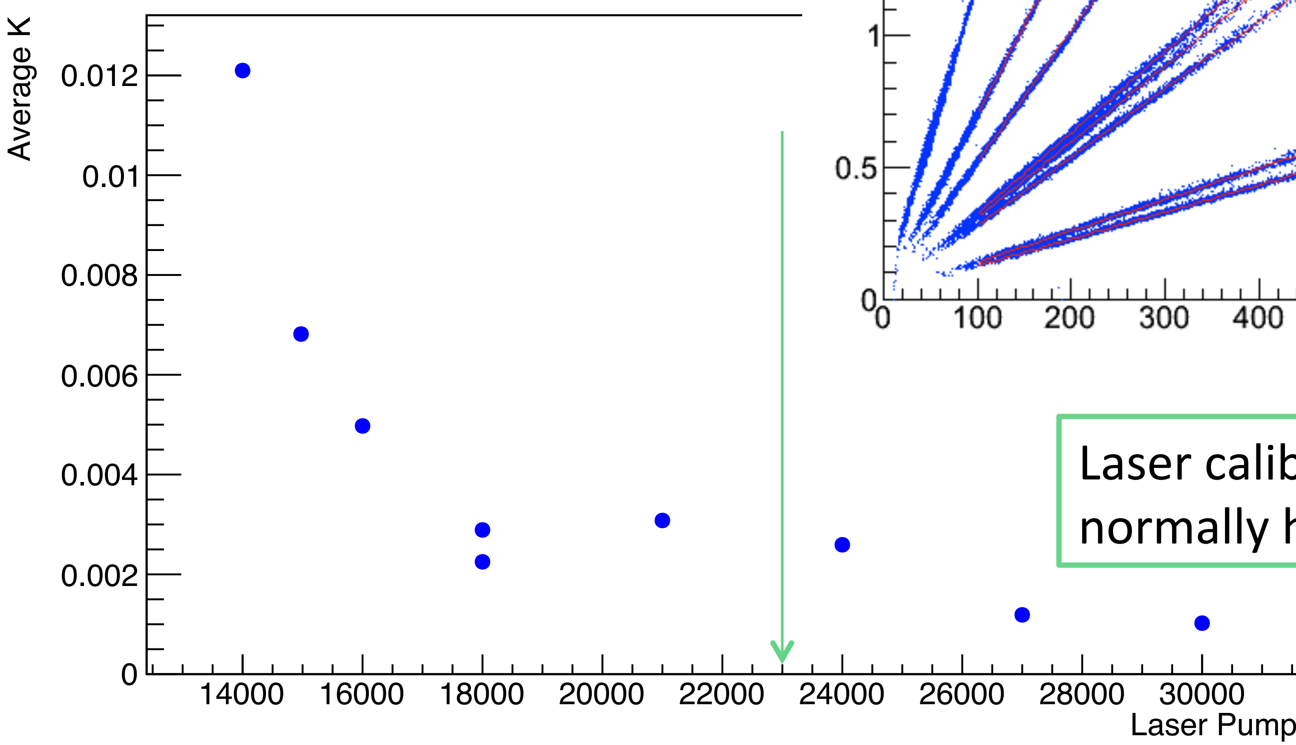
K dependence on laser conditions

- An example: *k* as a function of laser pump.

- *K* probably depends also on other factors



Study of *k* as a function of laser pump



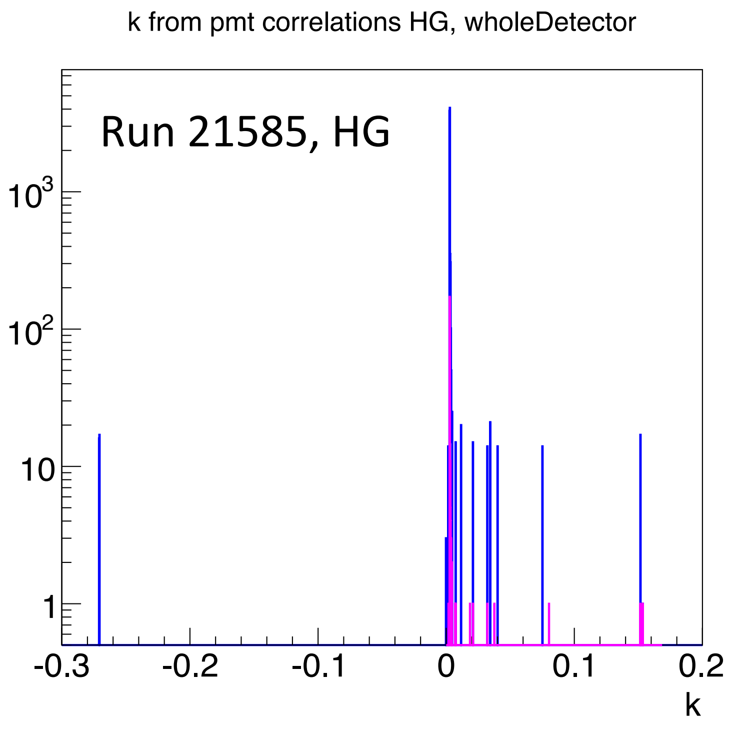
Laser calibration runs normally have pump 23000

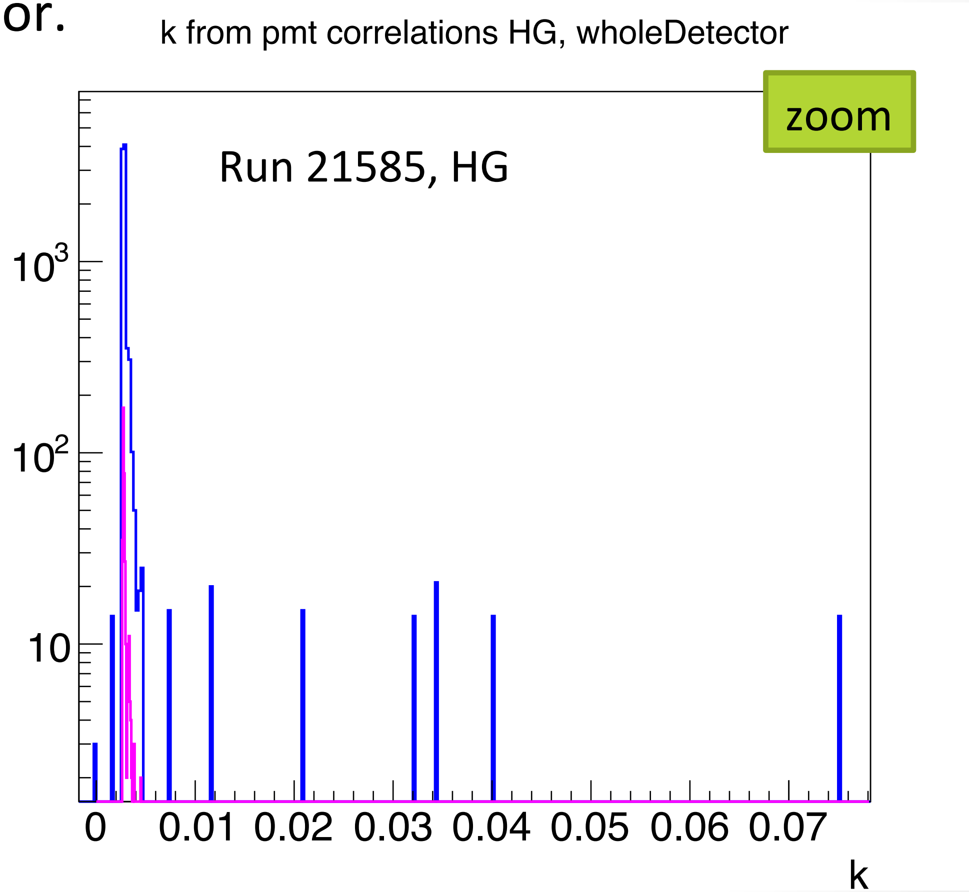
About *k* stored in ntuples

- *K* should be the same for all the PMTs of the same fiber.
- In some cases (we checked 2012 data), there is one PMT over 16 with a different *k*.
  - *K*=-1 or *k*=0: correspond to a non-instrumented PMT
  - $\Delta k/k$ varies from 10^{-2} to ≥ 1: no evidence of problems with the involved PMT
  - The problems seem to appear in groups of close runs
  - The PMT with different *k* often has the same number (30) for different modules and partitions
    - LBC64_pmt46: *k*=-0.27, in the same runs the whole EBA1 has *k*=-0.27. Runs taken in october-december 2012
- Both Sandra and Nino have checked this observation and found similar results
  - We still have to converge on a complete identification of problematic runs and channels

A graphical example

- Blue plot: k PMT per PMT. Magenta plot: k averaged over each fiber. Not normalized.
- If k is the same over each fiber, the two histograms should differ only for a normalization factor.

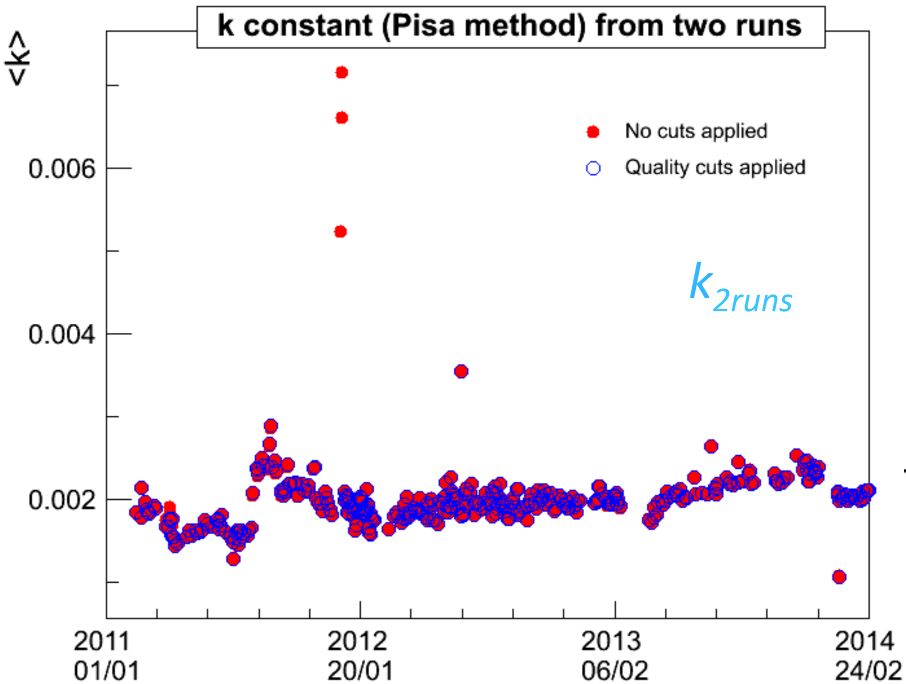


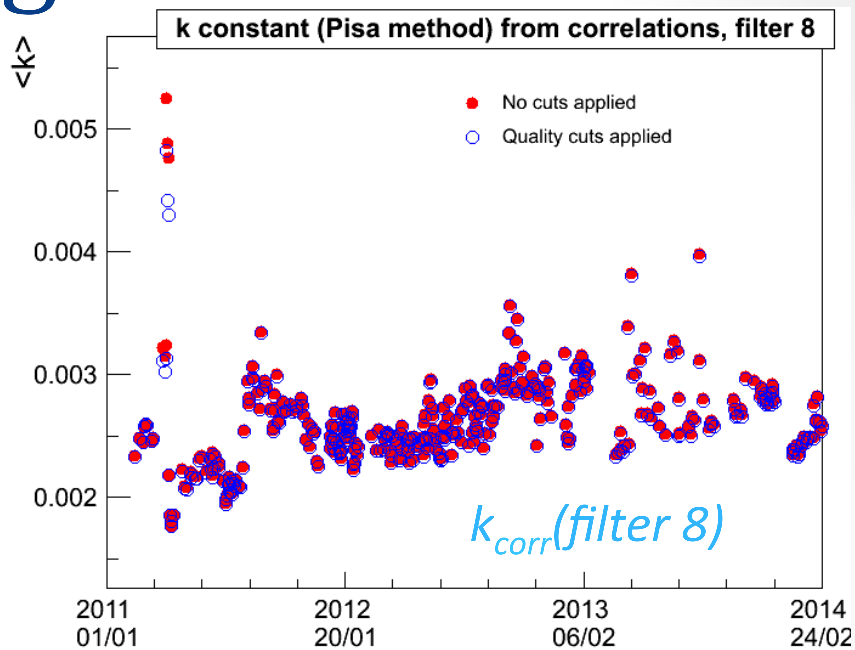


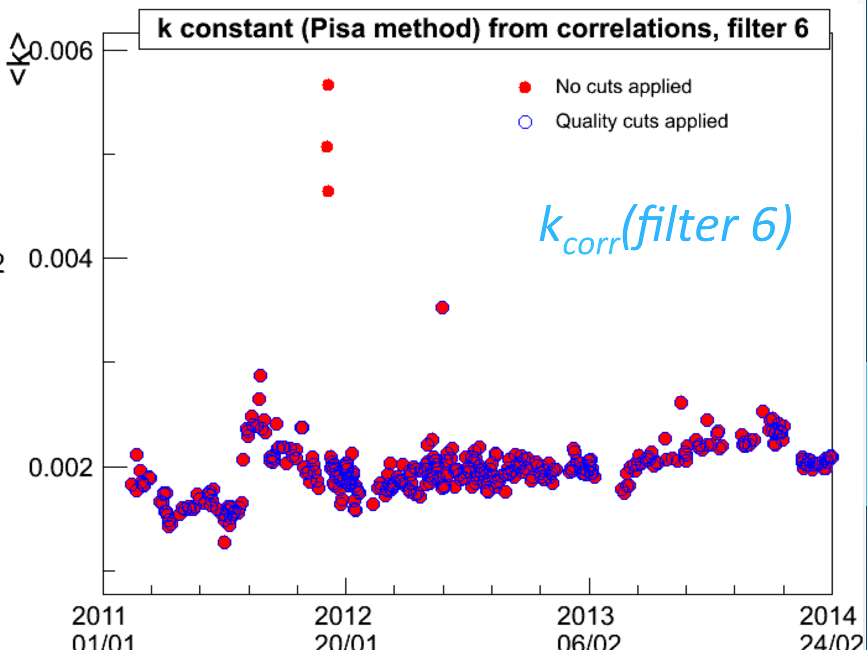
- We do not have an explanation for this: any suggestions?

Backup

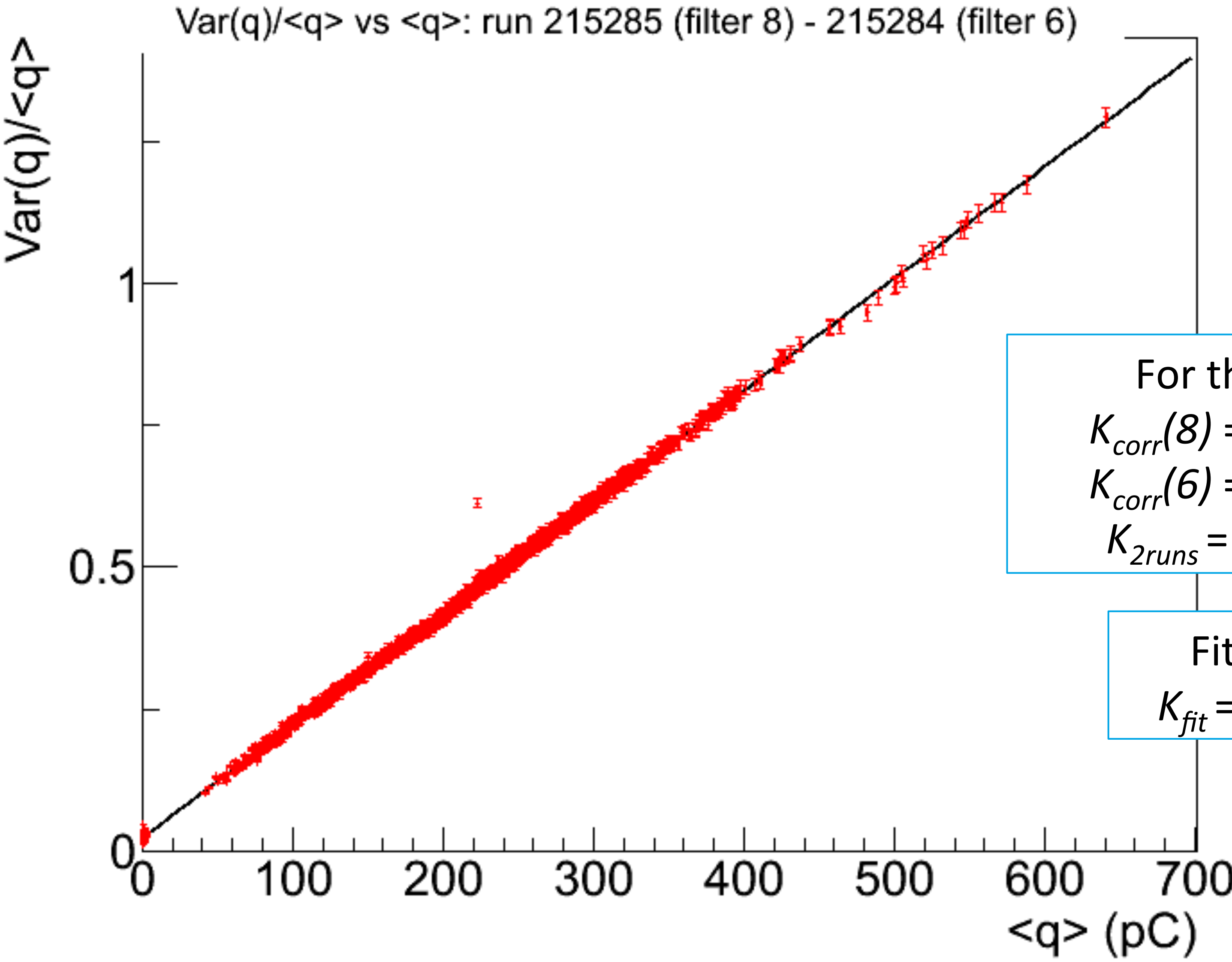
Effects of cleaning cuts on *k* distribution







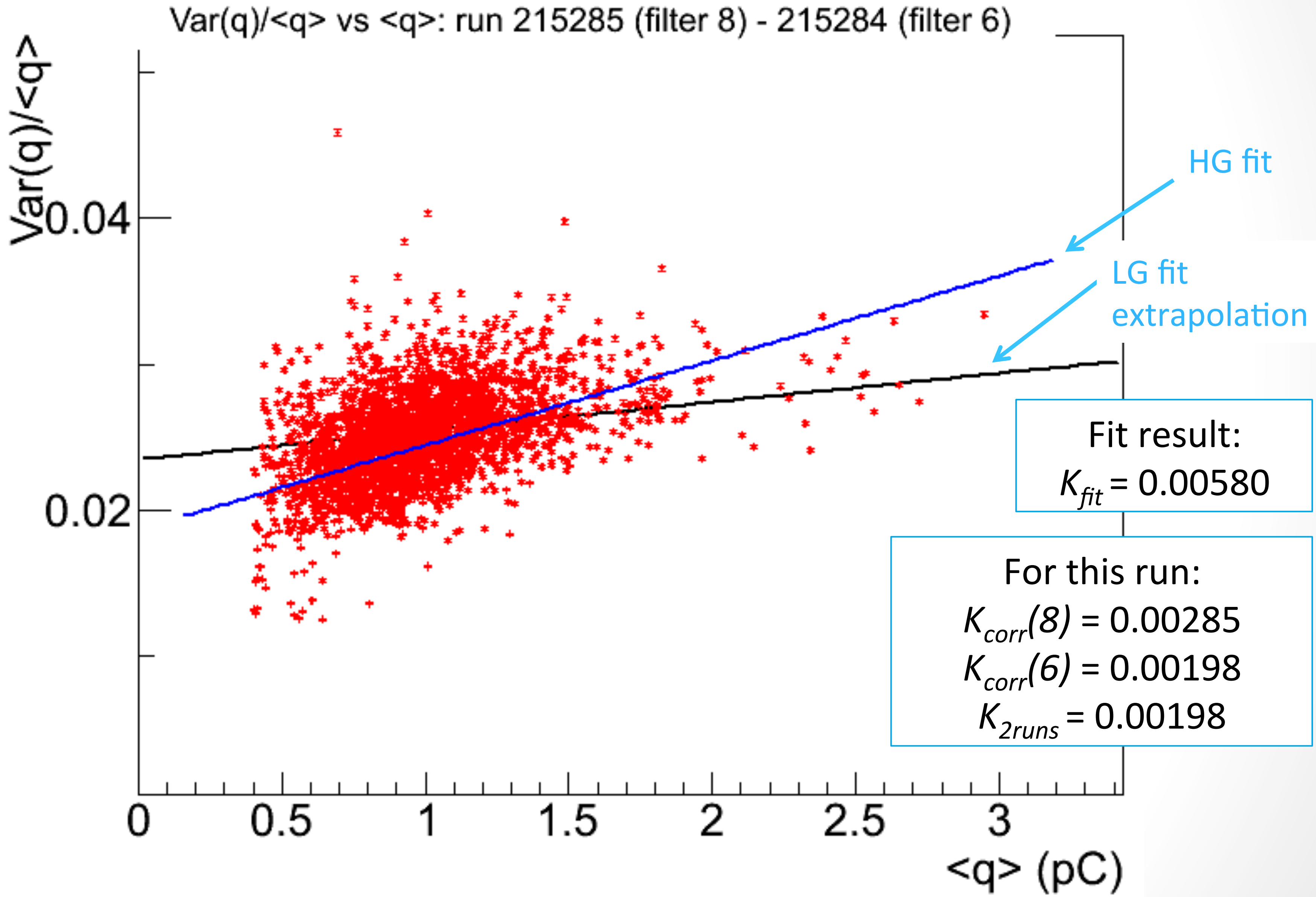
Var(q)/<q> vs <q>: LBA (LG)



For this run:
$K_{corr}(8)$ = 0.00285
$K_{corr}(6)$ = 0.00198
K_{2runs} = 0.00198

Fit result:
K_{fit} = 0.00197

Var(q)/<q> vs <q>: LBA (HG)



Fit result:

K_{fit} = 0.00580

For this run:

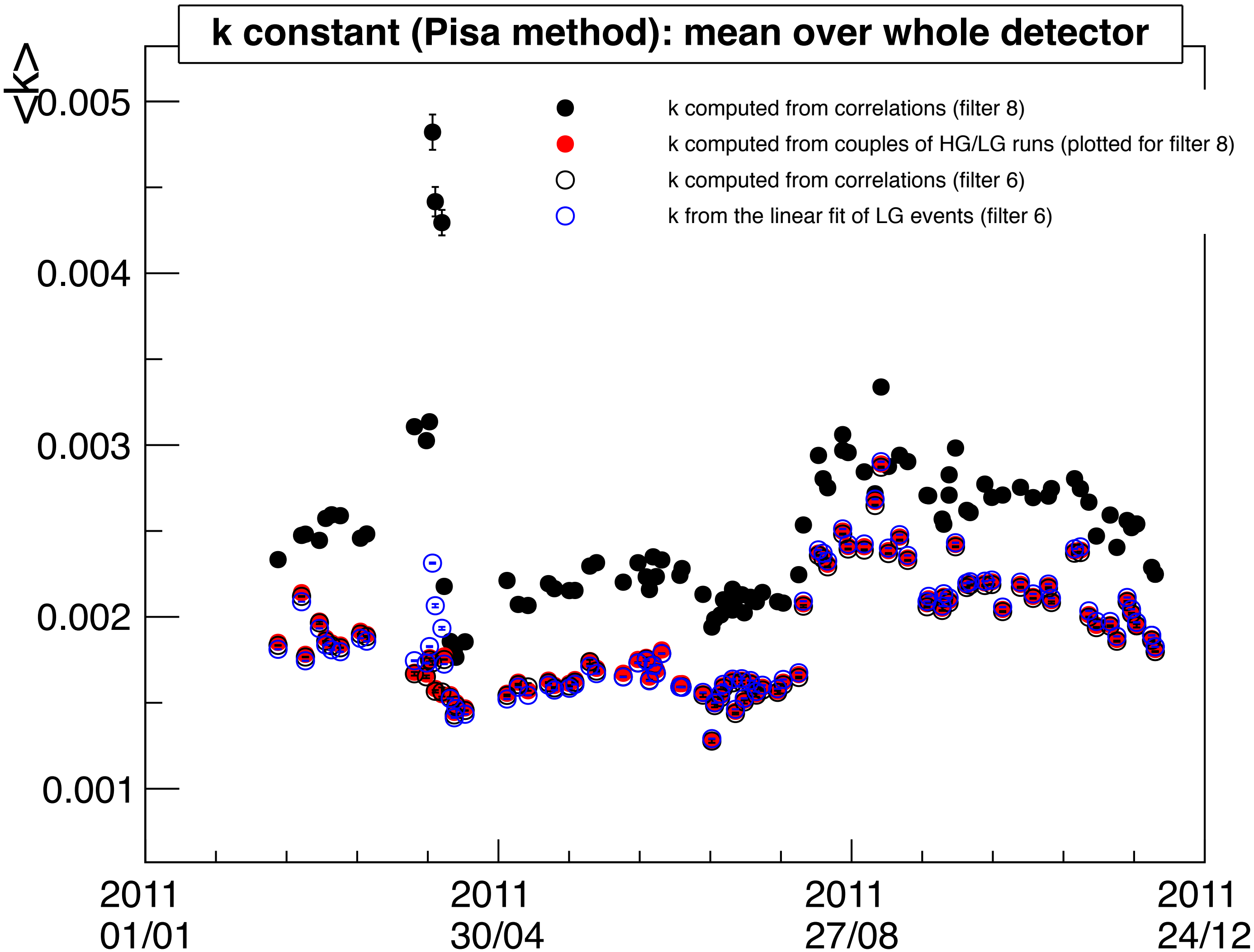
$K_{corr}(8)$ = 0.00285

$K_{corr}(6)$ = 0.00198

K_{2runs} = 0.00198

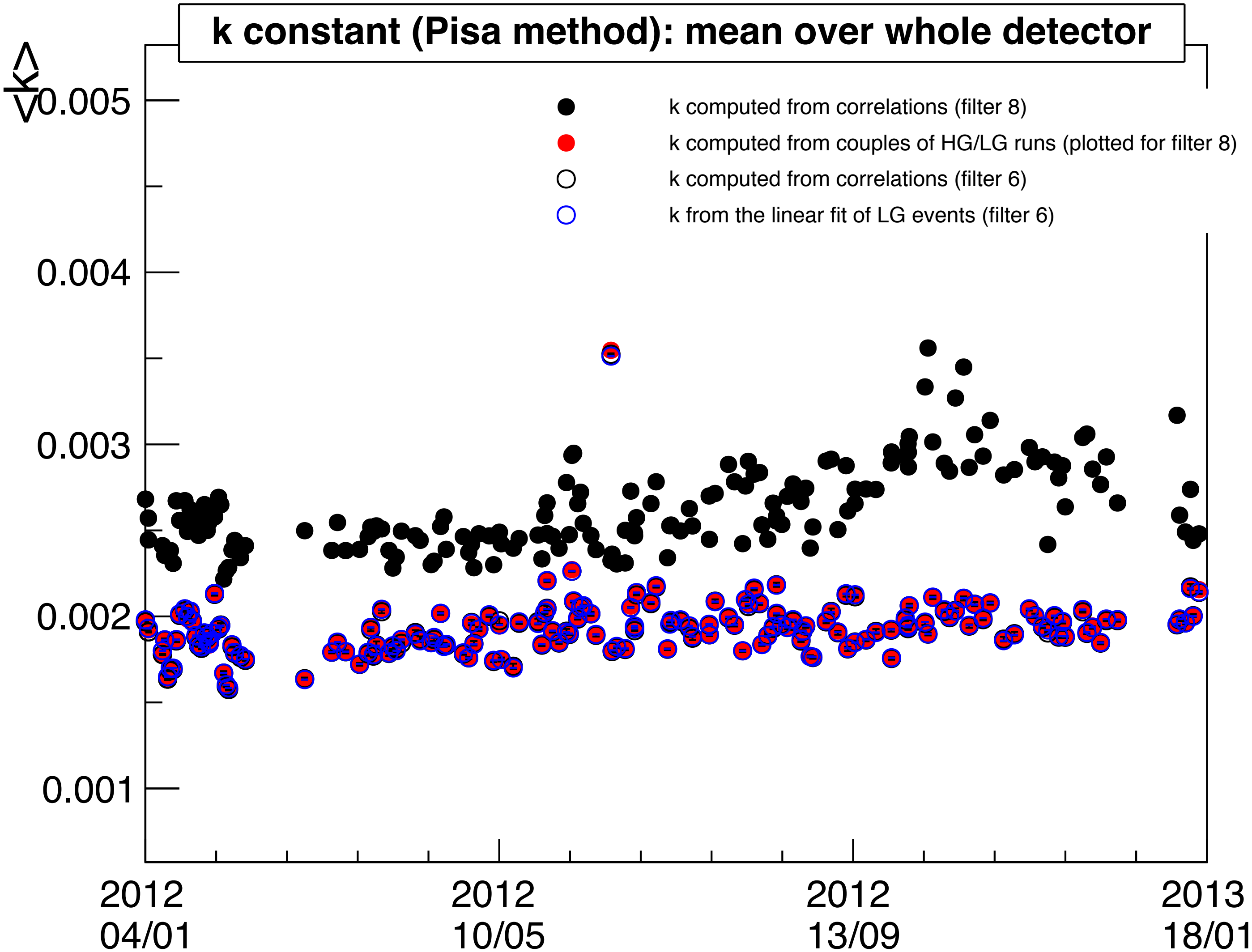
k_{corr}*(filter 8)*, k_{corr}*(filter 6)* and k_{2runs}: comparison with fit over time

2011



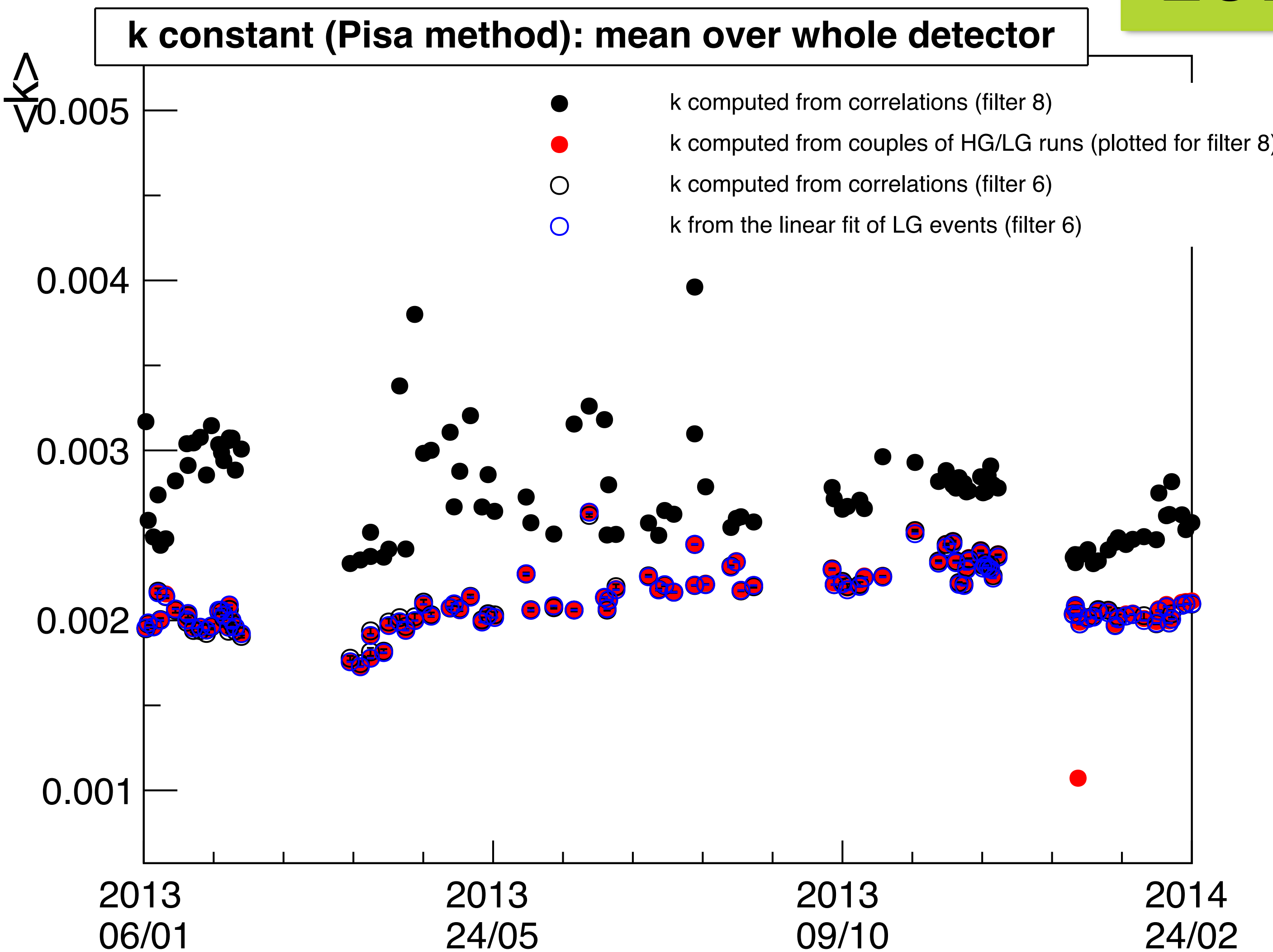
k_{corr}(filter 8), k_{corr}(filter 6) and k_{2runs}: comparison with fit over time

2012

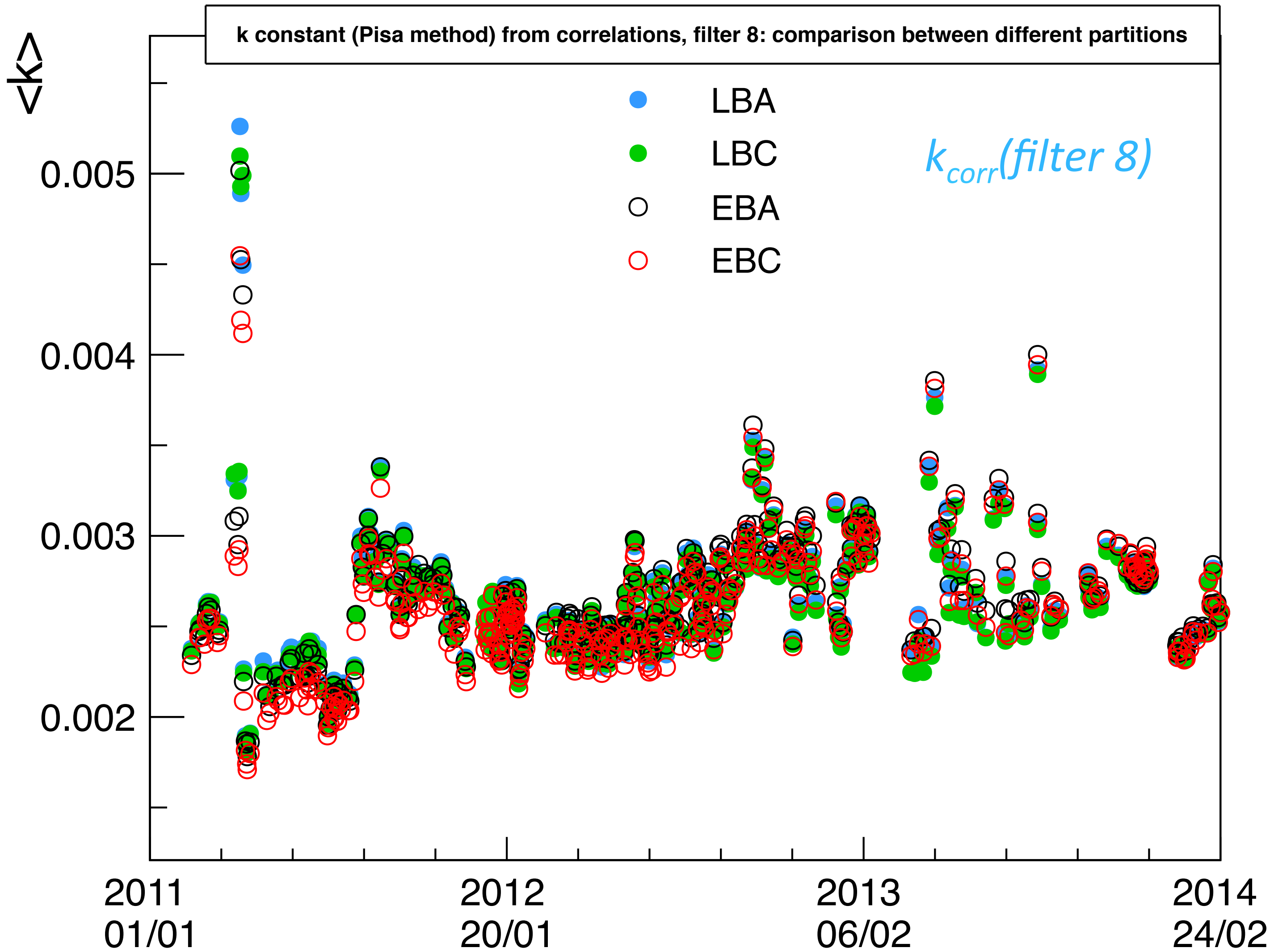


k_{corr}(filter 8), k_{corr}(filter 6) and k_{2runs}: comparison with fit over time

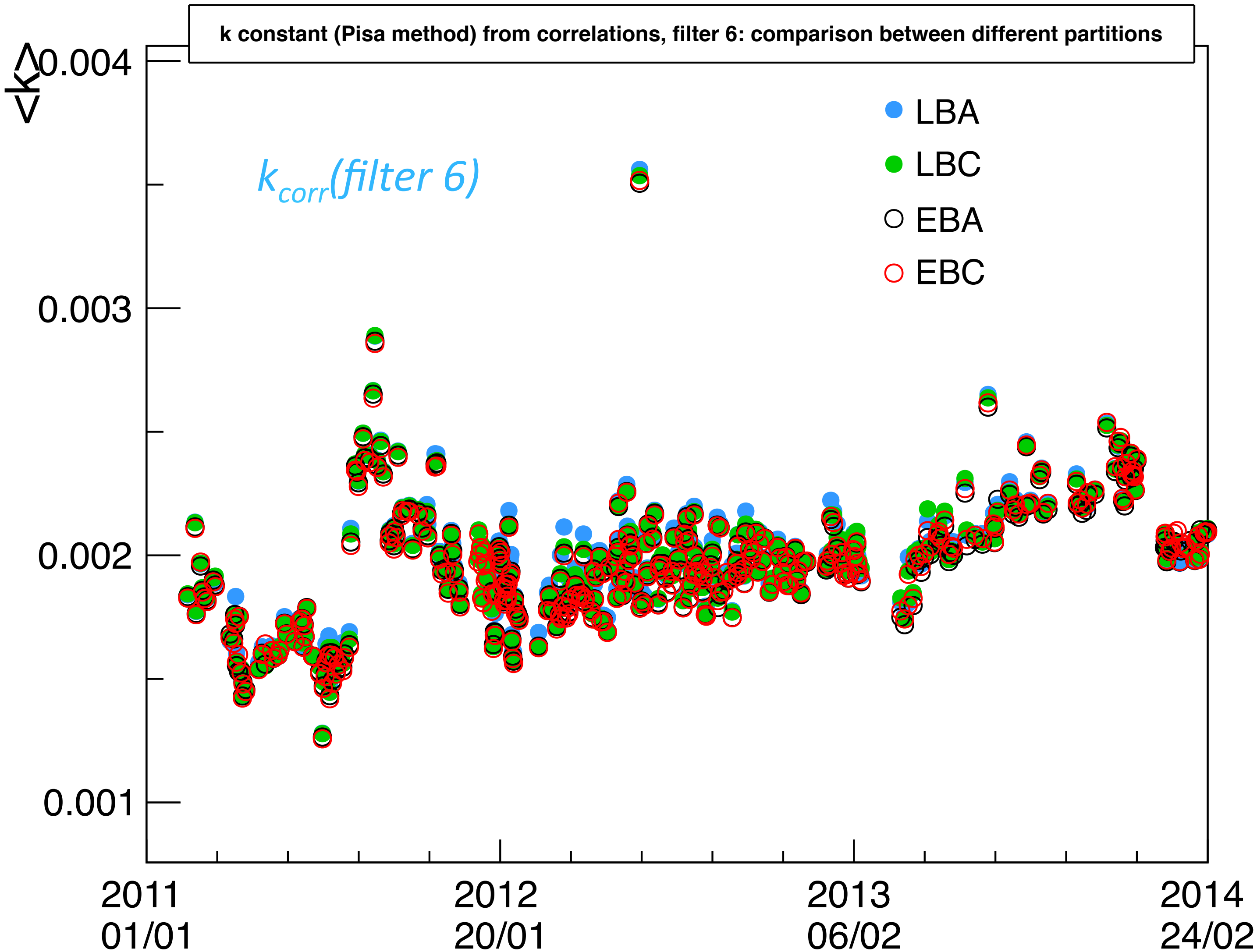
2013-14



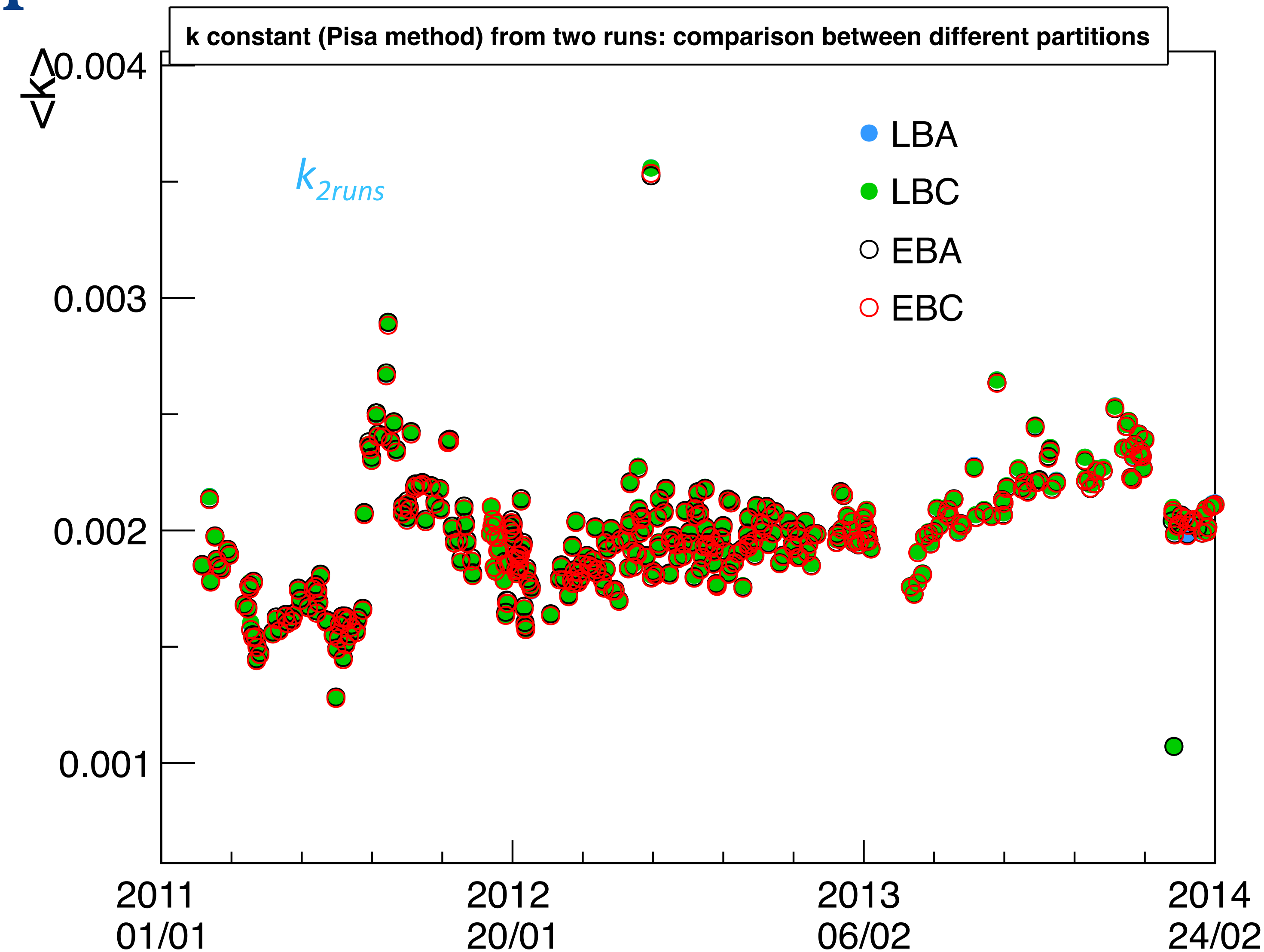
Comparison between different partitions



Comparison between different partitions

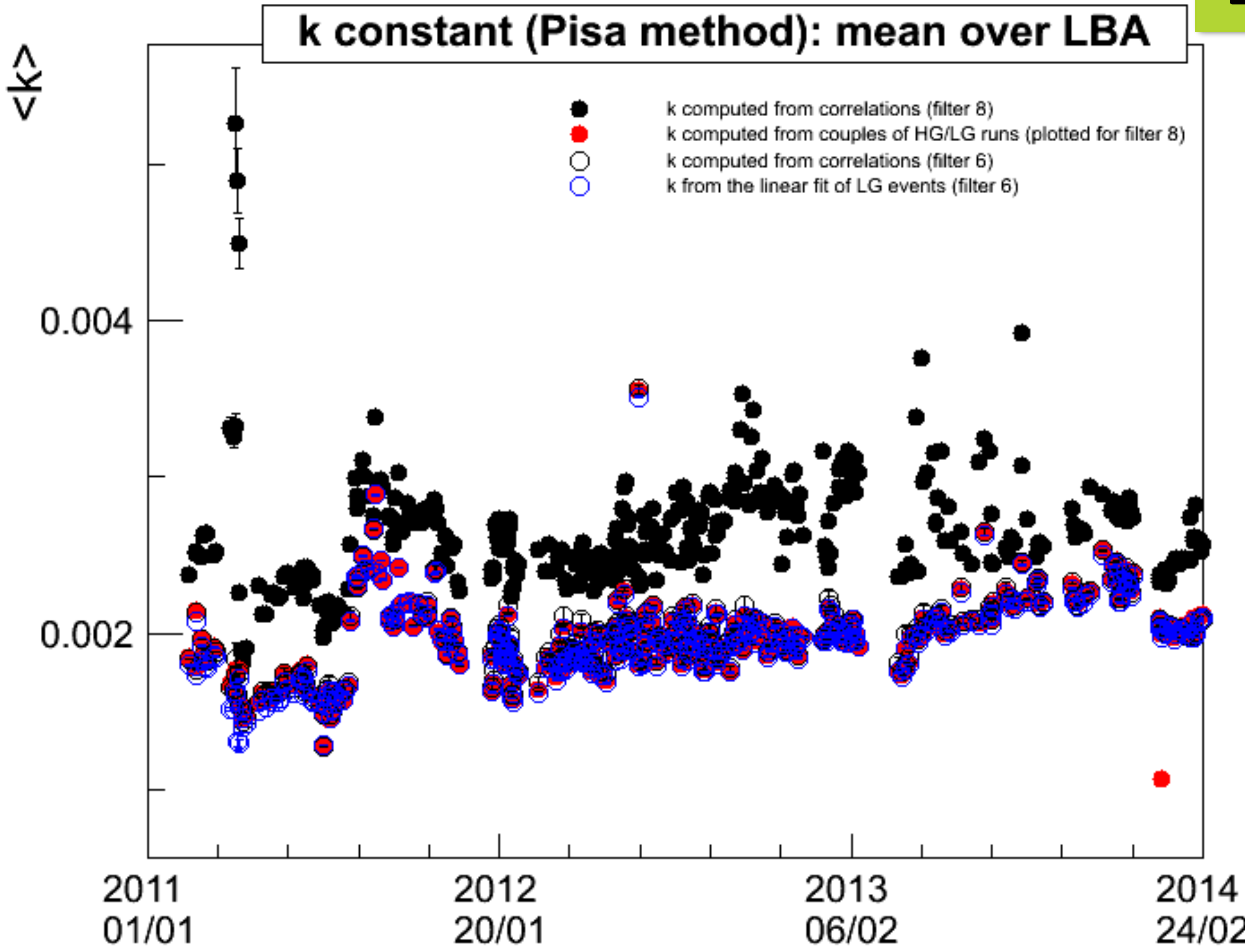


Comparison between different partitions



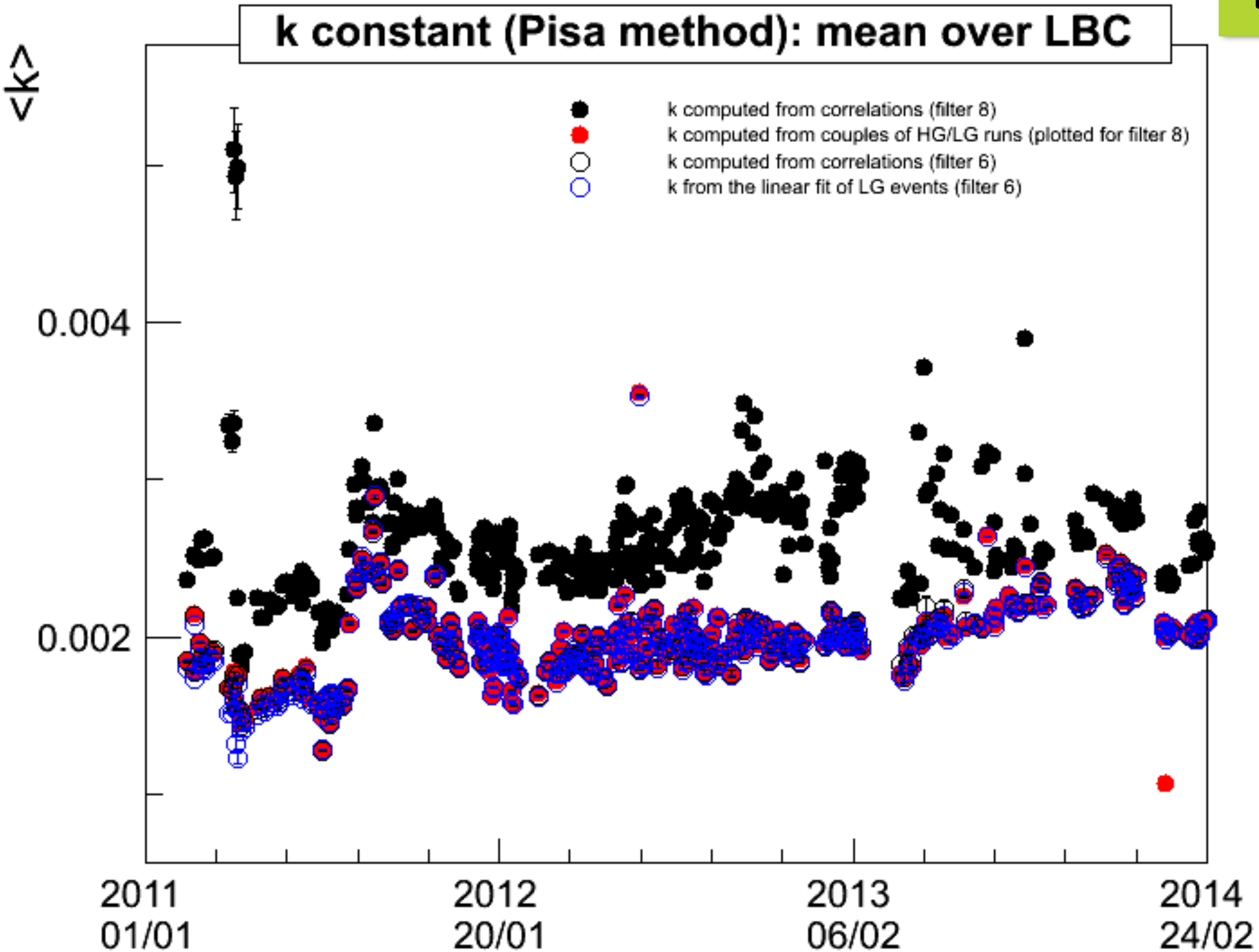
k_{corr}(*filter 8*), k_{corr}(*filter 6*) and k_{2runs}: comparison with fit over time

LBA



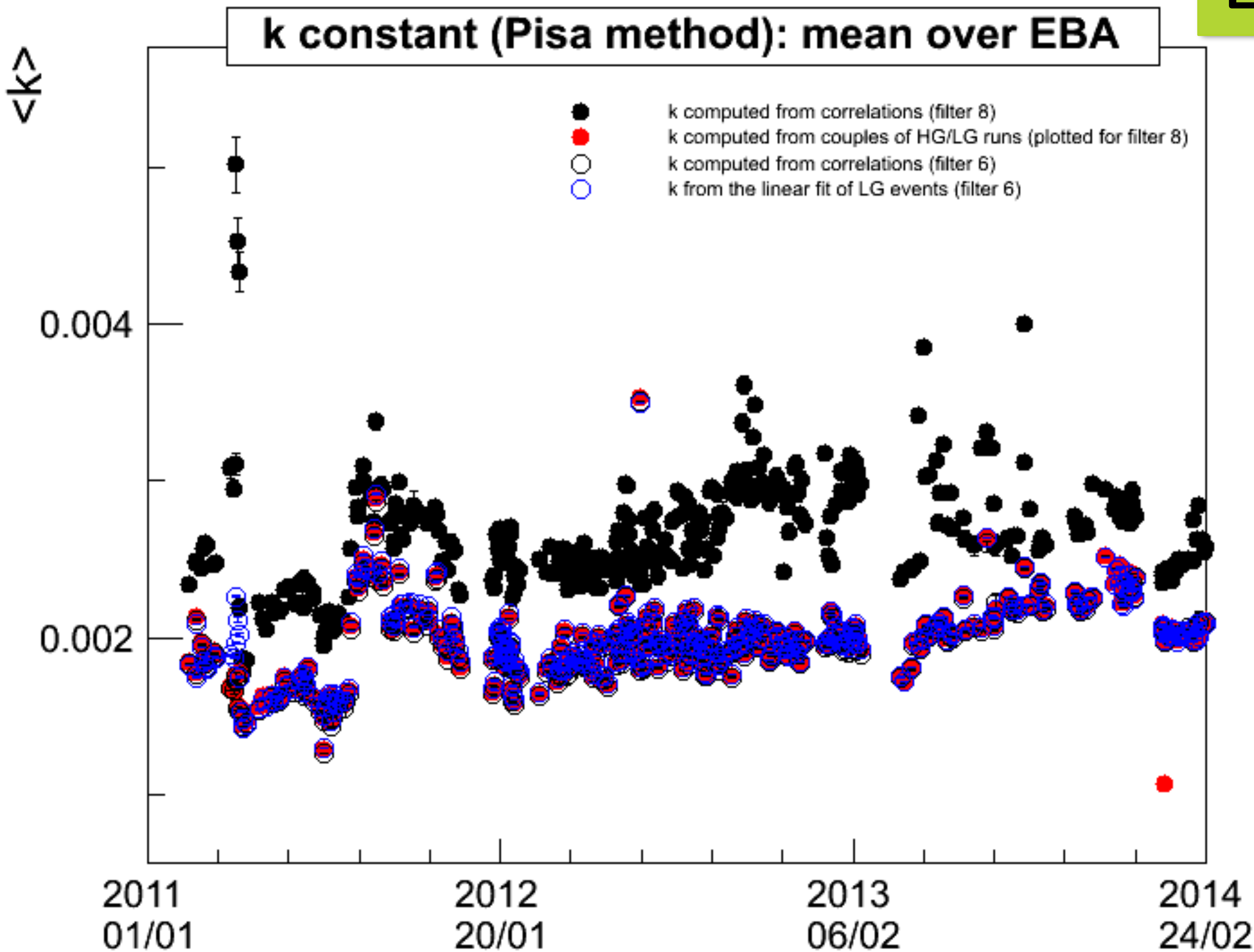
k_{corr}(filter 8), k_{corr}(filter 6) and k_{2runs}: comparison with fit over time

LBC



k_{corr}(*filter 8*), k_{corr}(*filter 6*) and k_{2runs}: comparison with fit over time

EBA



k_{corr}(filter 8), k_{corr}(filter 6) and k_{2runs}: comparison with fit over time

EBC