# A software procedure for efficiency measurements

13/02/2019 LECC-02

# Definition

- The efficiency of a detector is given by the fraction of events registered by the detector with respect to the number of events hitting the detector.
- In this analysis efficiency $\varepsilon$ is defined as the ratio between the number of events with a DQM reconstructed track over the number of total events detected by the telescope in a single run

$$\varepsilon = \frac{N\ good\ track\ events}{N\ events}$$

# Measurement aims

1. Checking LECC-02 telescope reliability at ordinary working conditions (MC HV~18000 V).

2. Testing the efficiency of the middle chamber after the transportation of the telescope from the ground floor to the second floor (2017).

3. Introducing a software procedure to compute chambers efficiency.

# The way we worked

The whole measurement was performed in one day, starting on Feb 13th 2019 at 9 a.m. and ending on Feb 14th at 10 p.m.

(5 students and two teachers alternated themselves to take data)

Some preliminary operations had been made on the telescope.

# Preliminary operations (the day before)

- Checking the level of gas bottles and the right working of the telescope (including GPS and weather station).

- Putting the HV in the middle chamber at 19,2 KV.

- Changing the DAQ address from c:\Data to c:\Data\Efficiency.

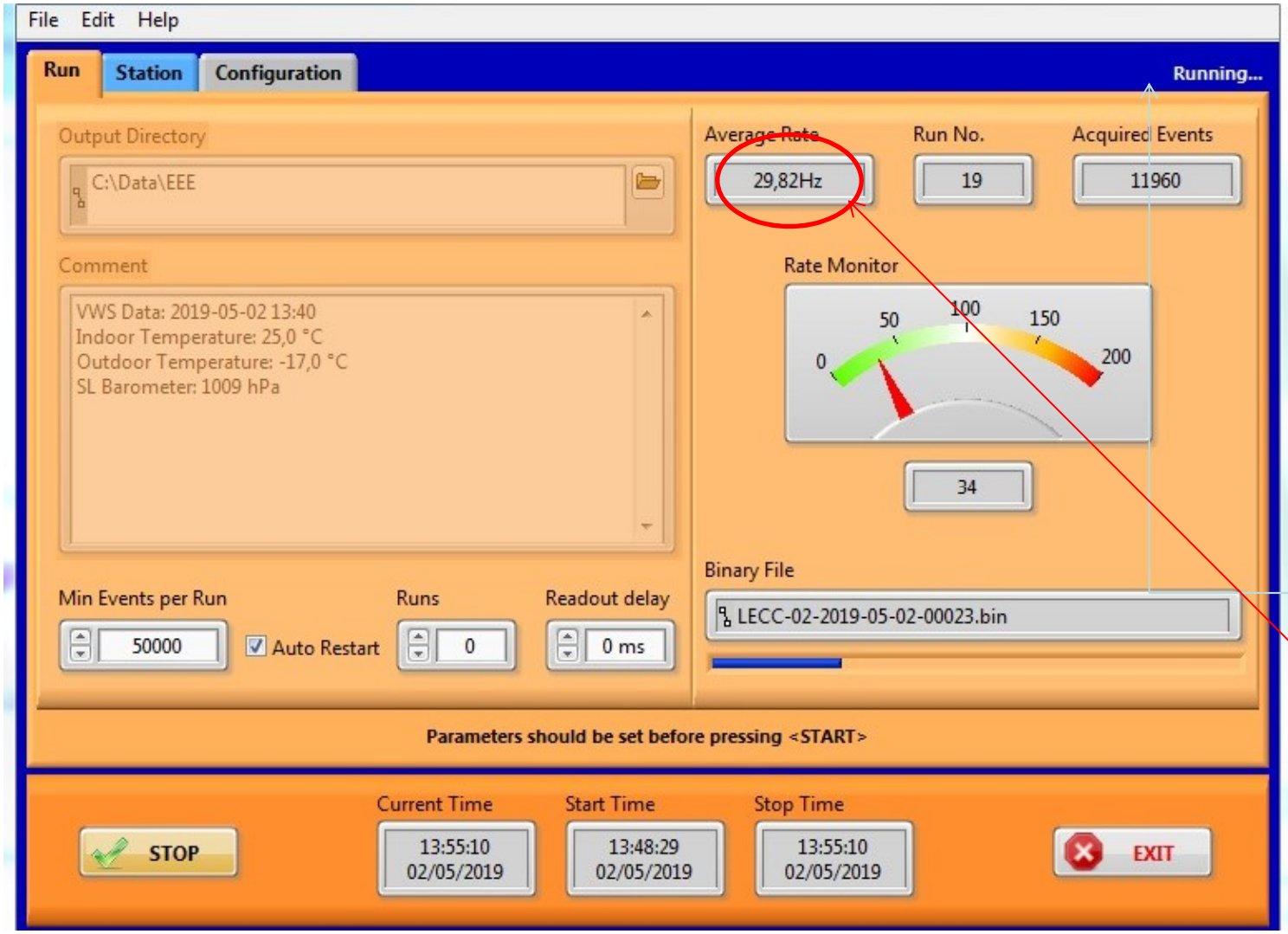
# Preliminary operations (before taking data)

1) Computing the number of events per run through the rate measured by DAQ, using the formula:

$$number\ of\ events\ per\ run\ = average\ rate\ (Hz) * time\ duration(s)$$

2) Excluding the middle chamber from the trigger with EEE GPS Combo VME Tester.

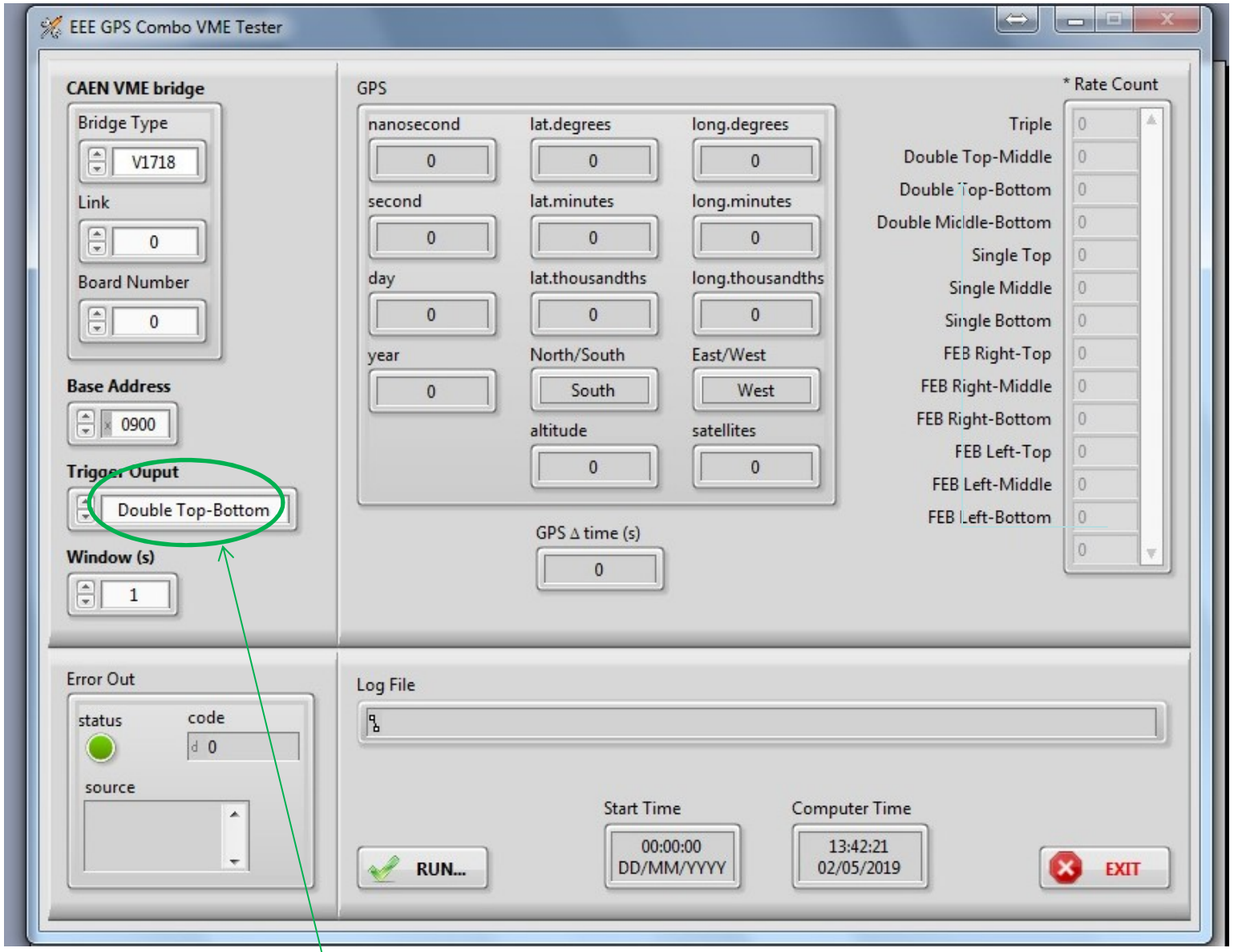
# 1) Computing number of events per run




To get at least 50000 detected events per run we estimated a number of 61500 events per run

This number corresponds to a duration of 25 min at the rate of 41 Hz as measured from DAQ at the first run test.

For lower values of HV we gradually reduced the number of events per run to 10000.

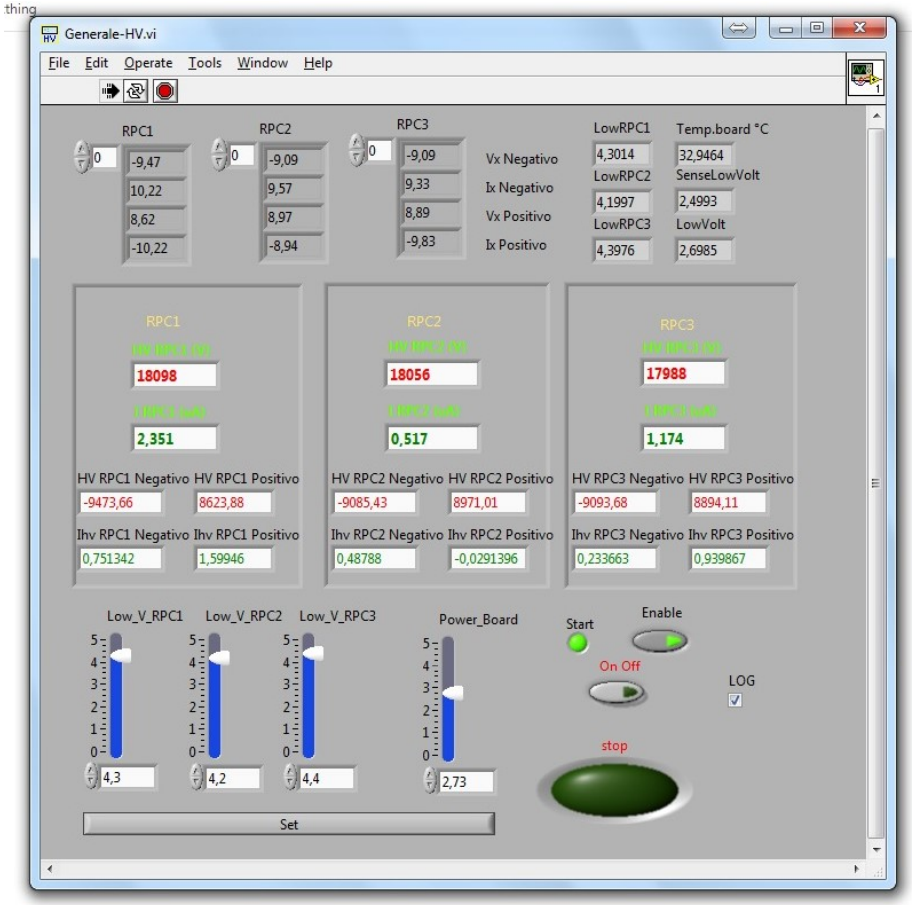


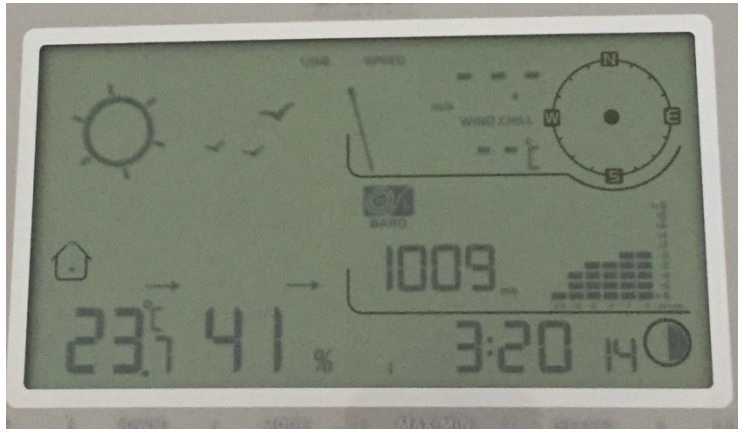

## 2) Excluding the middle chamber

To exclude the middle chamber from the trigger we selected the double top-bottom coincidences in the trigger output menu of Combo VME Tester.

# Taking data

Changing the LV input of the middle chamber, by variable steps, from a maximum value of 4,5 to a minimum of 2,5V, we registered total HV and current in the middle chamber from General HV , pressure and temperature from the weather station.



| Counts per run | LV middle(V) | Total HV middle (V) | Total current (μA) | temperature(K) | Pressure (mbar) |
|---|---|---|---|---|---|
| 61500 | 4,5 | 19225 | 0,82 | 293,7 | 1018 |
| 61500 | 4,4 | 18814 | 0,57 | 293 | 1018 |
| 61500 | 4,35 | 18610 | 0,58 | 293 | 1017 |
| 61500 | 4,3 | 18404 | 0,62 | 293 | 1017 |
| 61500 | 4,25 | 18196 | 0,57 | 293 | 1017 |
| 61500 | 4,2 | 17987 | 0,65 | 293 | 1017 |
| 61500 | 4,15 | 17778 | 0,68 | 293 | 1018 |
| 61500 | 4,1 | 17580 | 1,1 | 293 | 1019 |
| 61500 | 4,05 | 17373 | 0,77 | 293 | 1019 |
| 61500 | 4 | 17168 | 0,72 | 292 | 1019 |
| 61500 | 3,9 | 16758 | 0,75 | 293 | 1020 |
| 61500 | 3,8 | 16335 | 0,86 | 293 | 1020 |
| 61500 | 3,75 | 16124 | 0,85 | 293 | 1020 |
| 40000 | 3,5 | 15066 | 0,83 | 292 | 1020 |
| 40000 | 3,25 | 14028 | 1,04 | 292 | 1020 |
| 20000 | 3 | 12954 | 0,9 | 292 | 1021 |
| 10000 | 2,5 | 10828 | 0,64 | 292 | 1021 |

# Data analysis

- At first we have corrected the working voltage, which depends on environmental parameters such as gas temperature (T) and pressure (P), computing the effective voltage Veff, according to the equation:

$$Veff = V \cdot \frac{P_0}{P} \cdot \frac{T}{T_0}$$

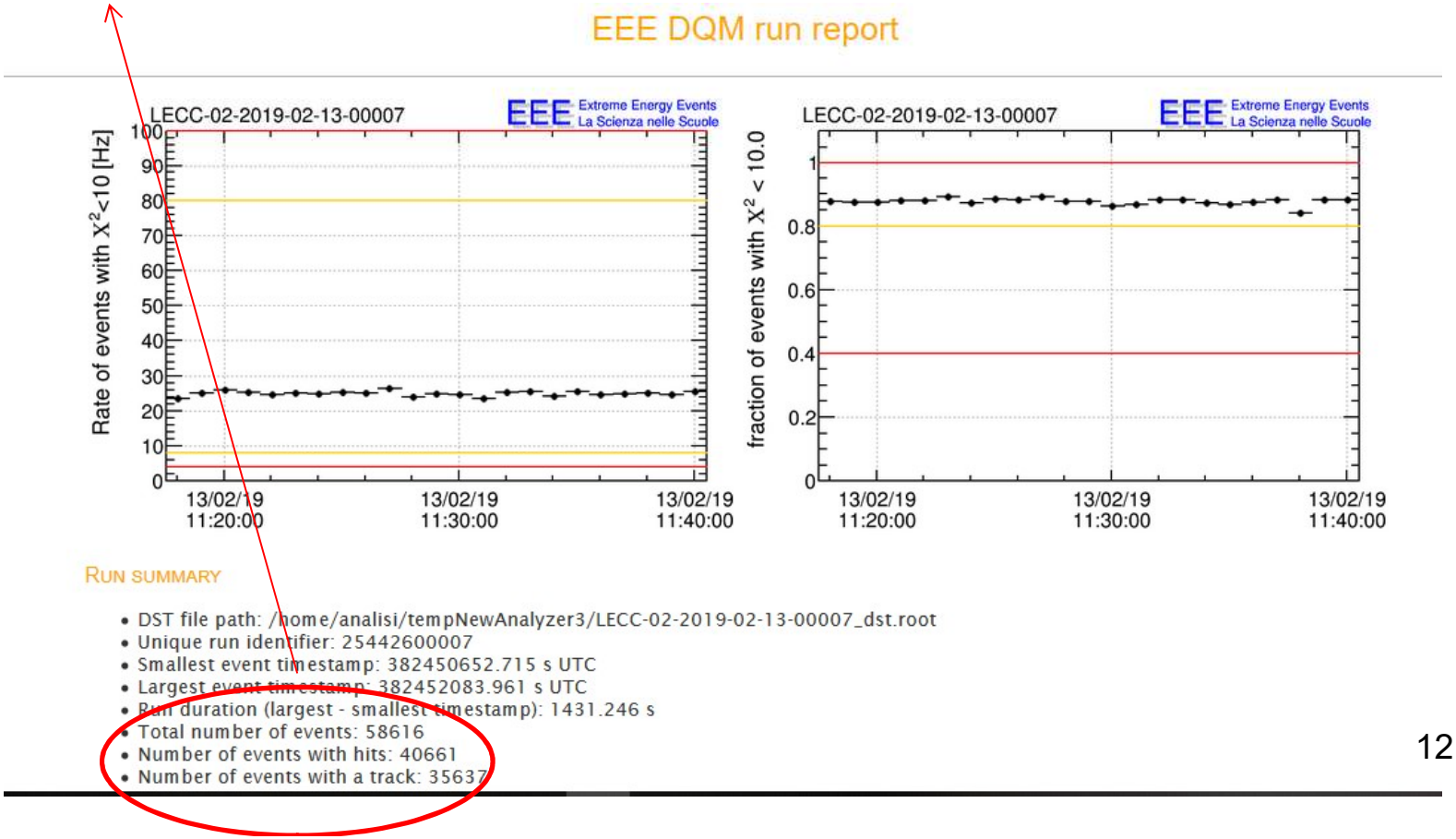
V is the applied voltage $P_0$=1010 mbar $T_0$= 293 K

- This correction, relevant to take into account different run conditions, results in an average decreasing of 1% of HV values.

# Efficiency

We computed the efficiency of middle chamber as the ratio between the ***total number of events with a track*** and **the *total number of events*** as reconstructed by CNAF and registered by DQM.

$$\varepsilon = \frac{total\ number\ of\ events\ with\ a\ track}{total\ number\ of\ events}$$

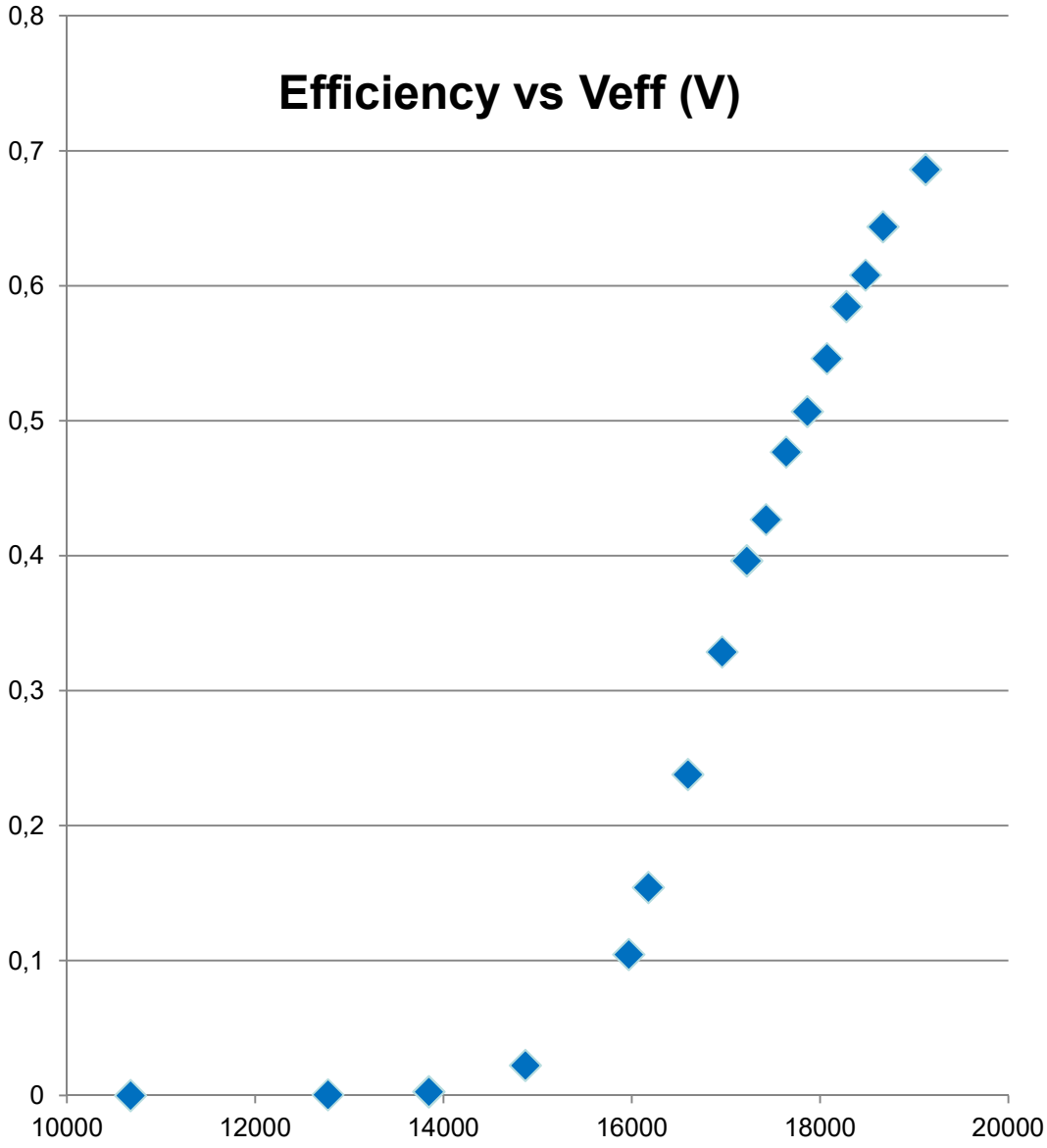


## Where is the plateau?

We plotted this efficiency vs Veff, getting the typical distribution with a knee between 17 kV and 19 kV, the voltage at which we expect a plateau.

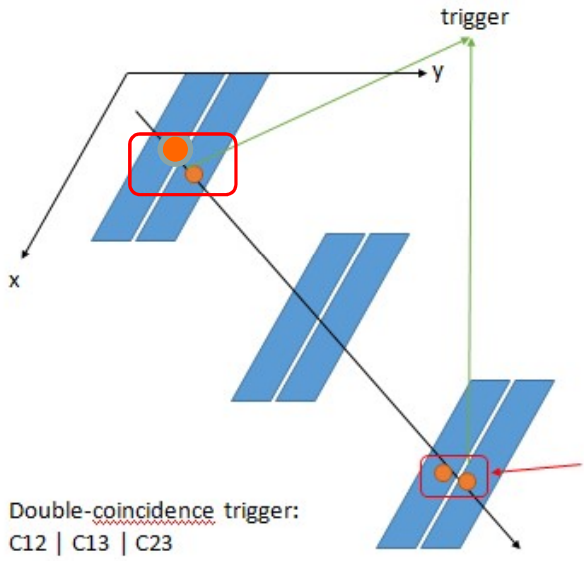
This value of the efficiency is not an absolute value because in our case the count of the double coincidences is overestimated in comparison with the real number of particle tracks in the telescopes.

Infact, in our trigger configuration, without the middle chamber, the track is reconstructed simply matching two hits: this is the reason why the plateau cannot be seen in this plot

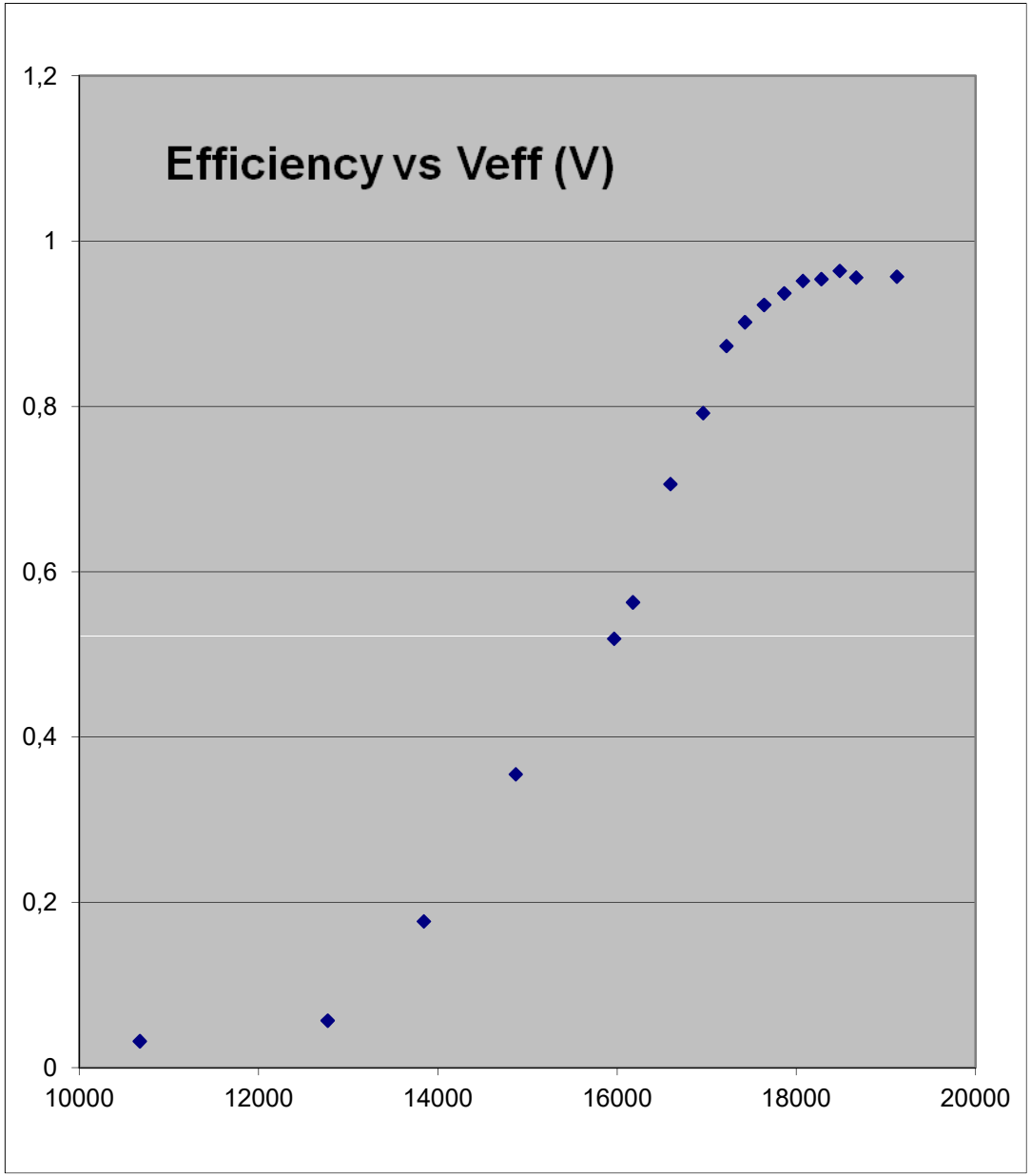


# A better analysis

Dr. Panetta reprocessed our data at CNAF with a different technique, based on the search of double coincidences producing clusterization in two adjacent strips in both chambers




This procedure reduces the total number of reconstructed tracks to the 2% of DQM value, but also reduces the background noise and gives us a better plot, clearly showing a plateau starting from 18 KV.

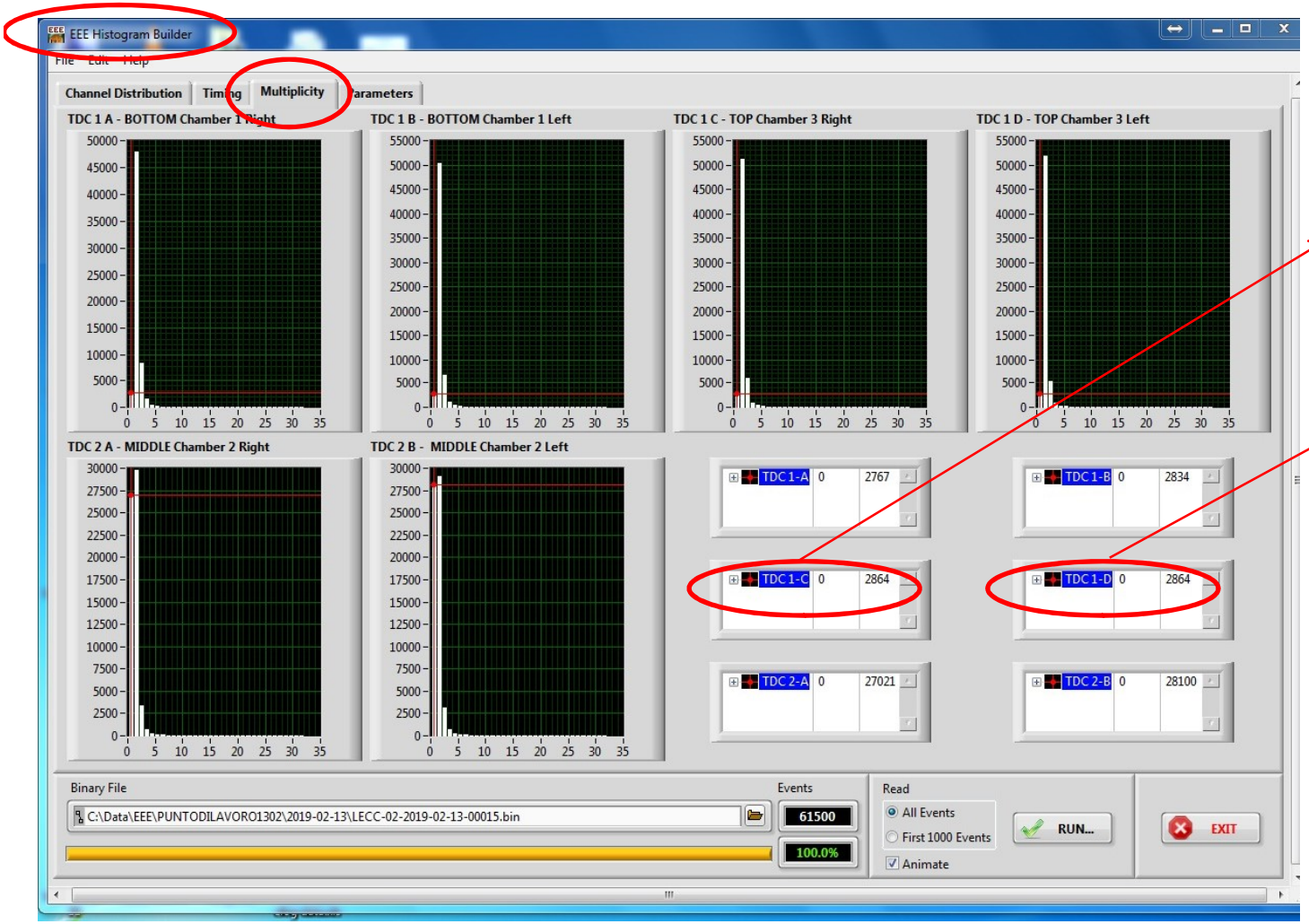


# More measurements

Collecting more data, we also analyzed an estimate of the dark rate, here defined as the ratio of the difference, between number the TDC bin 0 counts in the middle chamber and the number of TDC bin 0 counts in the other chambers, over the total number of events

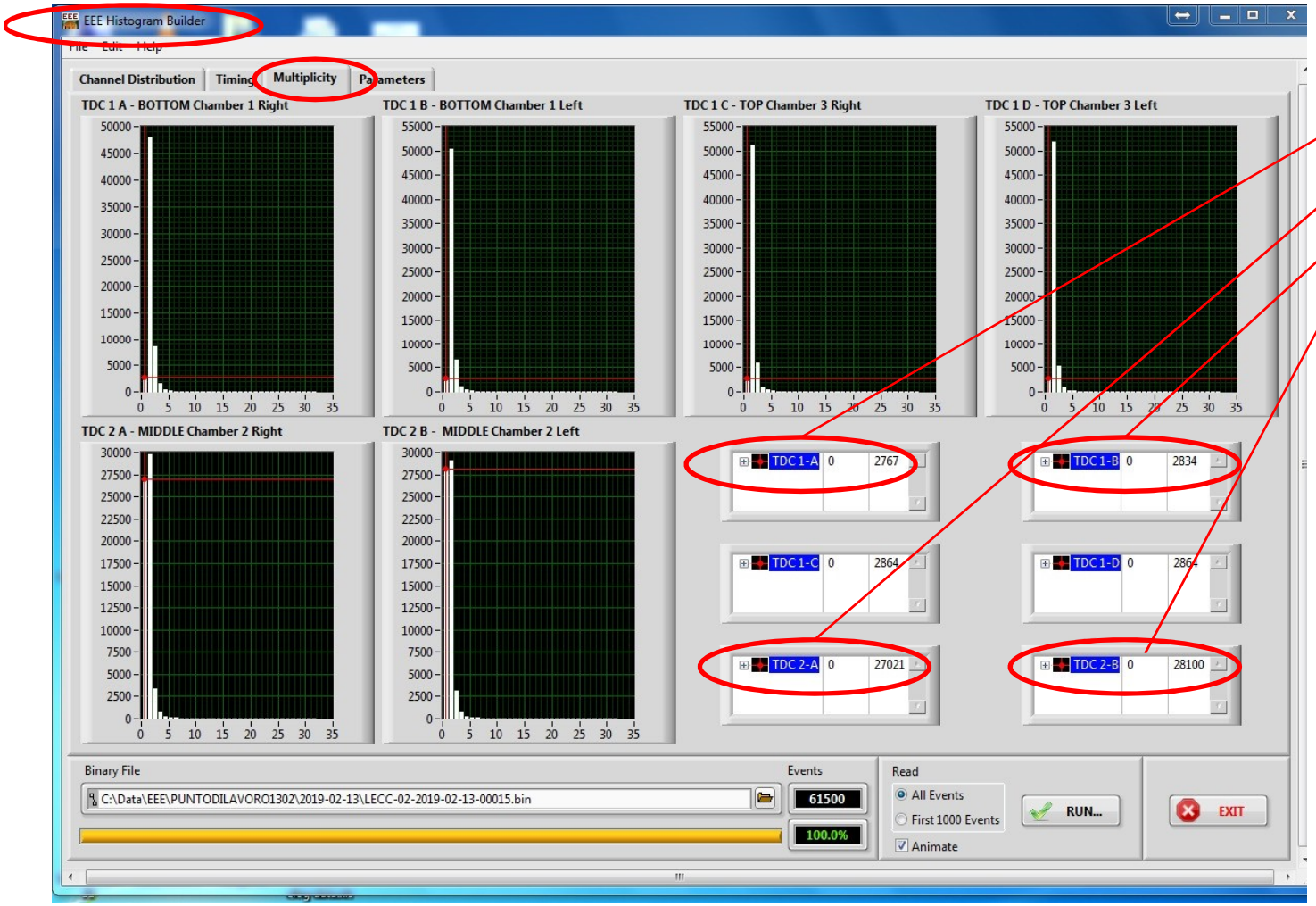
$$dark\ rate = \frac{TDC\ MC\ 0\ counts - TDC\ TCor\ BC\ 0\ counts}{total\ number\ of\ events}$$

# Counting TDC MC 0 bin events




We chose the maximum value between these two counts

# Counting GPS events

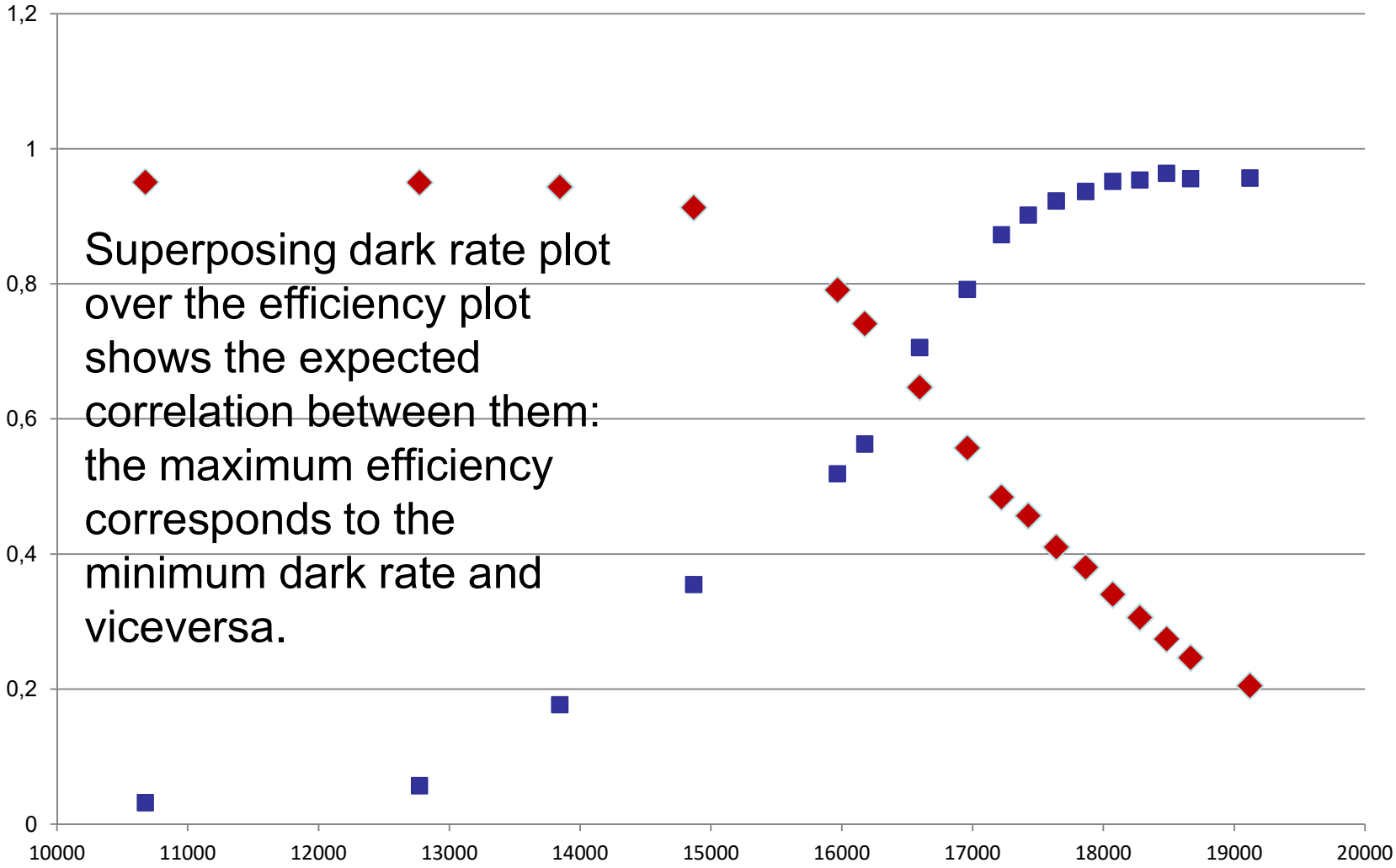



The maximum number of events counted in multiplicity TDC distribution in top and bottom chambers is a good estimate of the number of GPS events

(this hypothesis has been tested by comparing this number the same number got from EEE viewer results)

| countsTDC right | counts TDC left | counts bin 0 | max TDC-GPS | dark rate | veff |
|---|---|---|---|---|---|
| 14976 | 15613 | 3000 | 12613 | 0,20509 | 19119,5 |
| 17324 | 18120 | 2951 | 15169 | 0,24665 | 18666,1 |
| 18911 | 19737 | 2864 | 16873 | 0,27436 | 18481,9 |
| 20813 | 21718 | 2890 | 18828 | 0,30615 | 18277,3 |
| 22870 | 23797 | 2868 | 20929 | 0,34031 | 18070,8 |
| 25132 | 26238 | 2836 | 23402 | 0,38052 | 17863,2 |
| 27021 | 28100 | 2864 | 25236 | 0,41034 | 17638,3 |
| 29737 | 30942 | 2846 | 28096 | 0,45685 | 17424,7 |
| 31348 | 32725 | 2932 | 29793 | 0,48444 | 17219,6 |
| 34400 | 37219 | 2945 | 34274 | 0,5573 | 16958,3 |
| 40649 | 42740 | 2944 | 39796 | 0,64709 | 16593,7 |
| 47383 | 48532 | 2946 | 45586 | 0,74124 | 16174,9 |
| 50269 | 51629 | 2968 | 48661 | 0,79124 | 15965,9 |
| 38331 | 38491 | 1960 | 36531 | 0,91328 | 14867,4 |
| 39666 | 39706 | 1954 | 37752 | 0,9438 | 13843,1 |
| 19996 | 19971 | 990 | 19006 | 0,9503 | 12770,7 |
| 10004 | 10004 | 496 | 9508 | 0,9508 | 10674,8 |

# Dark rate and efficiency vs $V_{eff}$



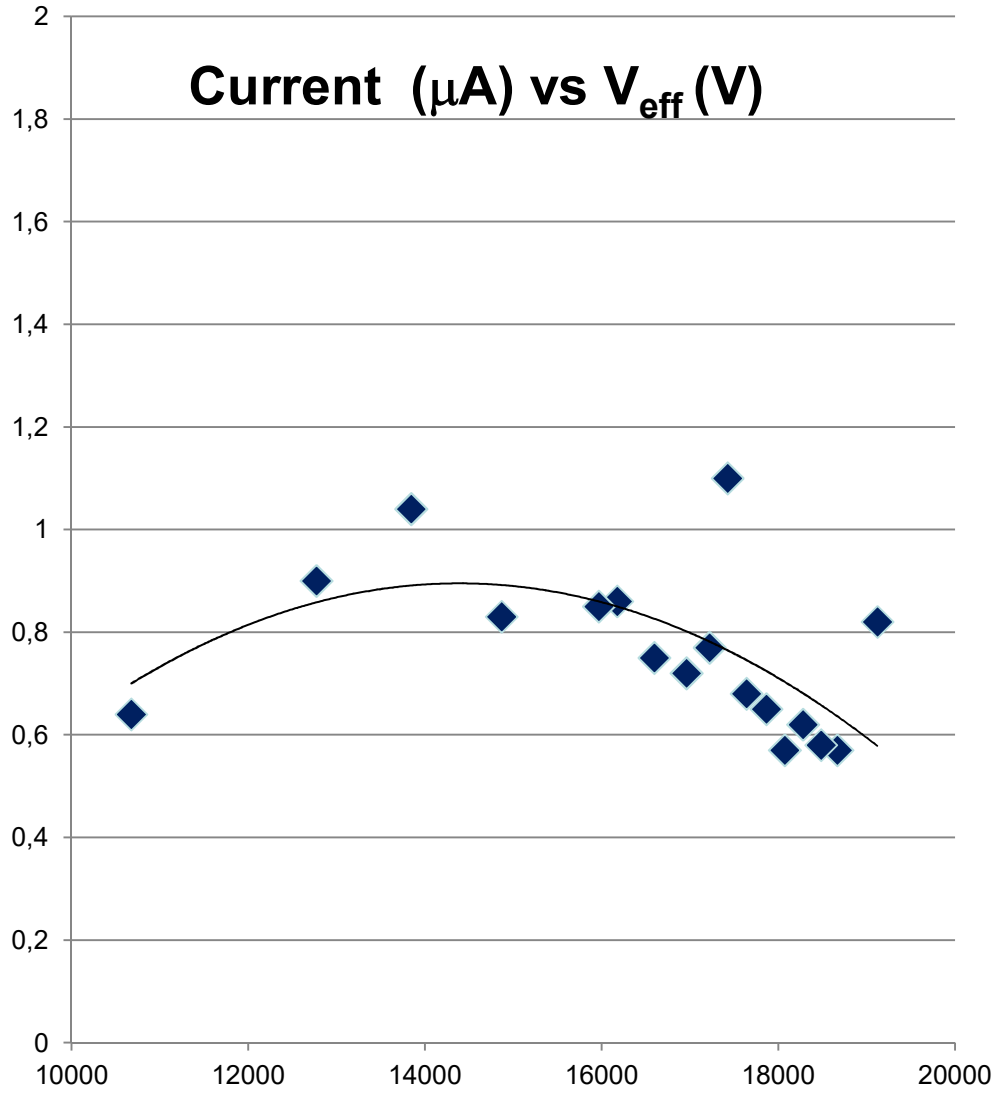

Superposing dark rate plot over the efficiency plot shows the expected correlation between them: the maximum efficiency corresponds to the minimum dark rate and viceversa.

## Current checking

We also plotted the total current as a function of the effective voltage.

The plot shows as the current (more or less) decreases when the voltage increases.

But there are big fluctuations in its value, maybe because of the quick fluctuations of the current values during the data taking.



# Measurement conclusions

1. The ordinary working point of LECC-02 is well chosen if compared with the plateau in the plot at slide 14.
2. The efficiency of the middle chamber is good at the working point (more than 90% from 18KV of HV value in MC).
3. This software procedure can be replicated, for both efficiency and dark rate measurements, by most of the telescopes installed after 2017.