Muon radiography of the Puy de Dôme: status and prospects

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on behalf of the MURAVES collaboration

INTERNATIONAL WORKSHOP ON MUON & GEO-RADIATION PHYSICS
FOR EARTH STUDIES
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1 INFN-Naples Italy

Summury

- Puy de Dome measurement campaign.
- Analysis status:
  - Statistic;
  - Tracking algorithm.
- Results:
  - Transmission measurement;
  - comparison w.r.t Monte Carlo.

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Puy de Dome

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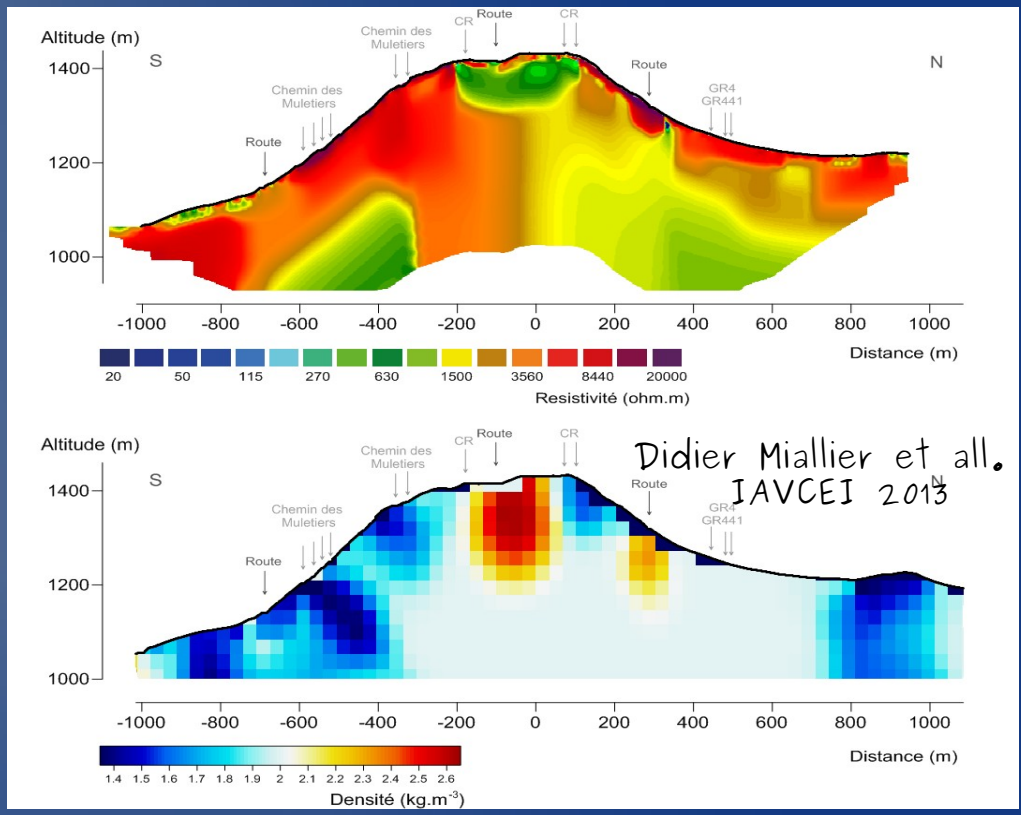
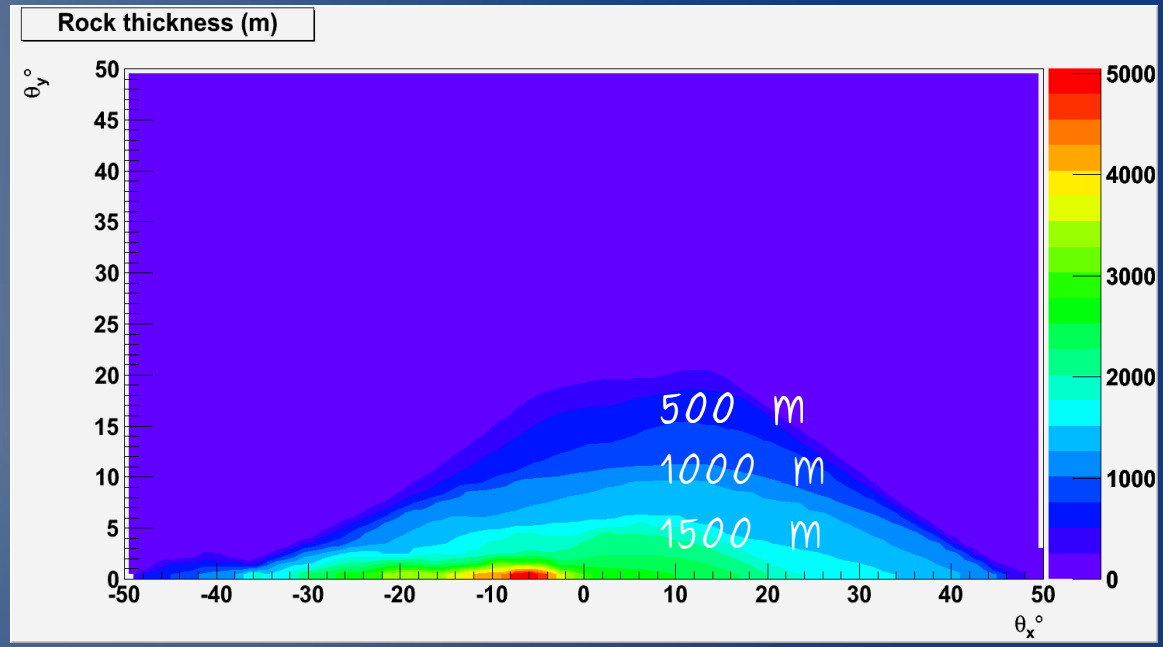


At present, resistive and gravimetry tomography have already been extensively applied on the Puy de Dôme. Both techniques confirm that the dome has a complex internal structure. The presence of large zones of low resistivity agrees with the assumed presence of a significant amount of water in porous altered lava. High resistivity domains fit with older basaltic cones covered by Puy de Dôme products, which existence was already demonstrated by field observation.

Puy de Dome rock thickness



Puy de Dôme volcano offers a good opportunity for developing and testing muon tomography and other methods of geophysical survey.

Some of the advantages are listed below:

- size in the optimal range (500 m – 1000 m);
- complex inner structure but simple external shape;
- easy accessibility and experimental facilities;

The detector Mu-Ray was housed in surface laboratory at Col de Ceyssat (1078 m).

The distance from the Puy de Dome is is of the order of 1 km

Puy de Dome measurement campaign

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The measurement campaign was performed in the frame of a collaboration between the MURAY and TOMUVOL experiments.

Starting from 29 June to 30 November 2013 we acquired:

- 13 days for the calibration, pointing to the free sky(3.5 M triggers):

  29 June → 2 July, 22November → 30 November;

- 92 days pointing to Puy de Dome(24 M triggers):

  4 July → 15 November*

*Due to a black-out at the end of July and summer holidays, we did not acquire during 22July → 3 September.

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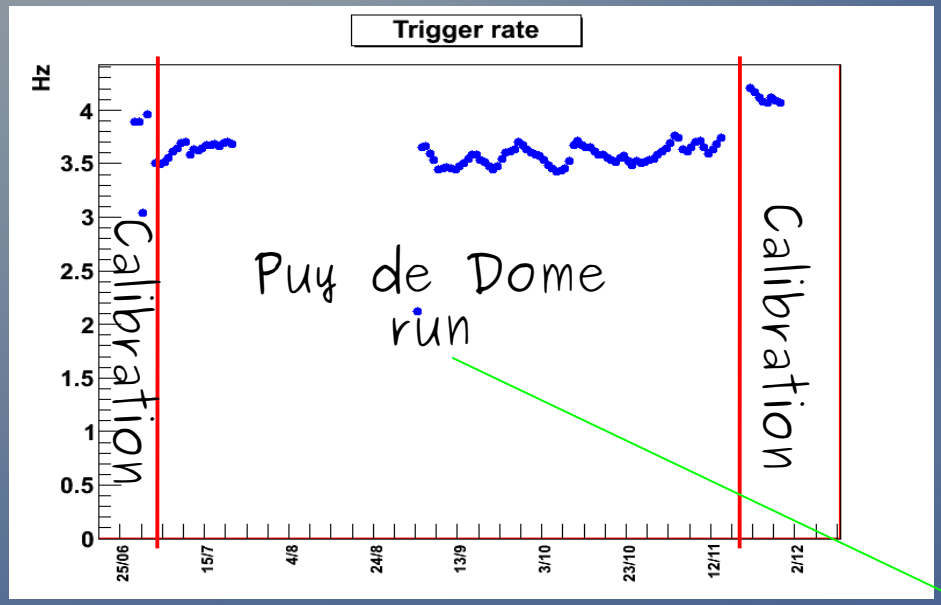
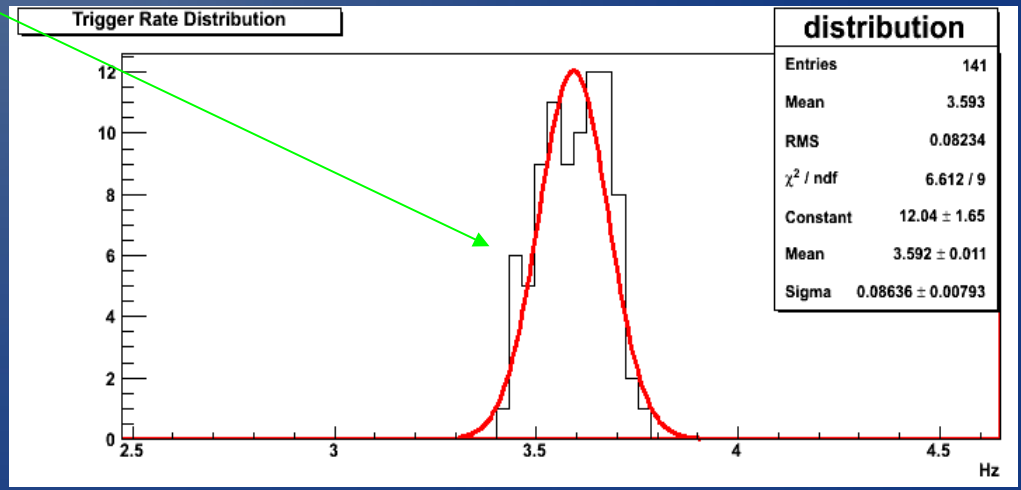
Trigger



Trigger: AND of 6 planes:
Forward XY–Middle XY–Backward XY.
Accidental tracks < 1 event/day

Trigger rate average:
3.6 Hz pointing to Puy de Dome
4.0 Hz pointing to the free sky.



The trigger rate shows some oscillation.
The period is not constant:
1 week and 2 weeks.
We are studying if there is a correlation with some component of front-end board.

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Trigger vs Board Frequencies

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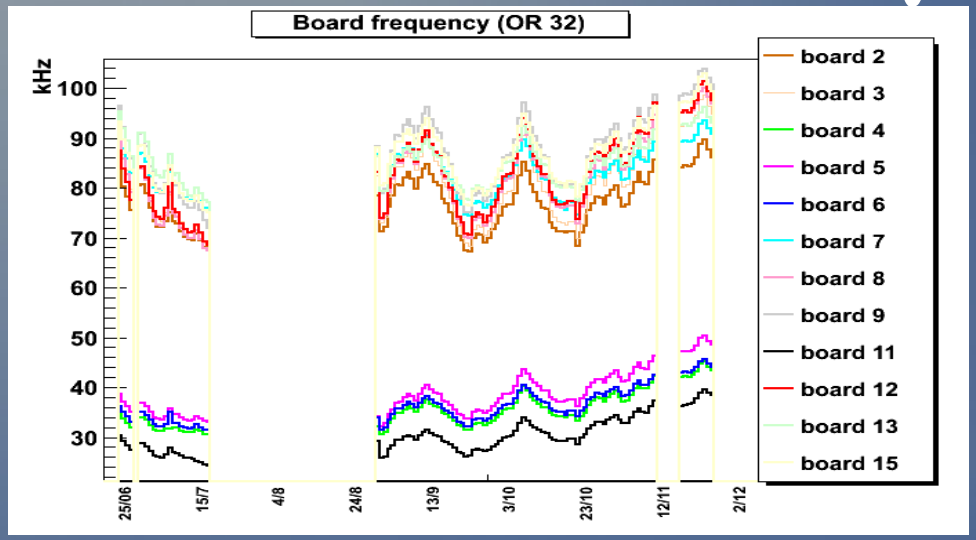
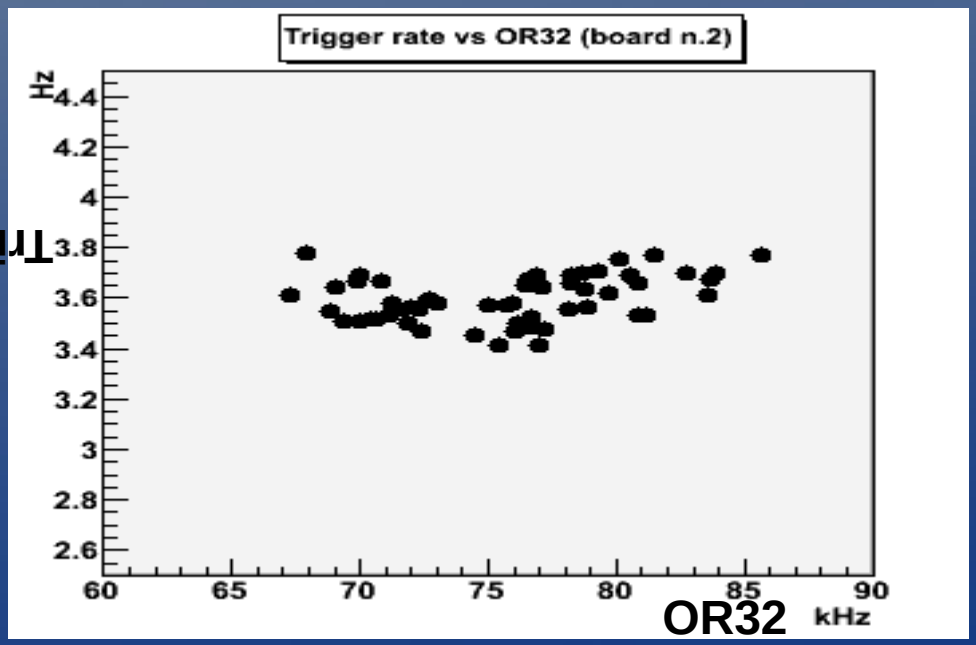


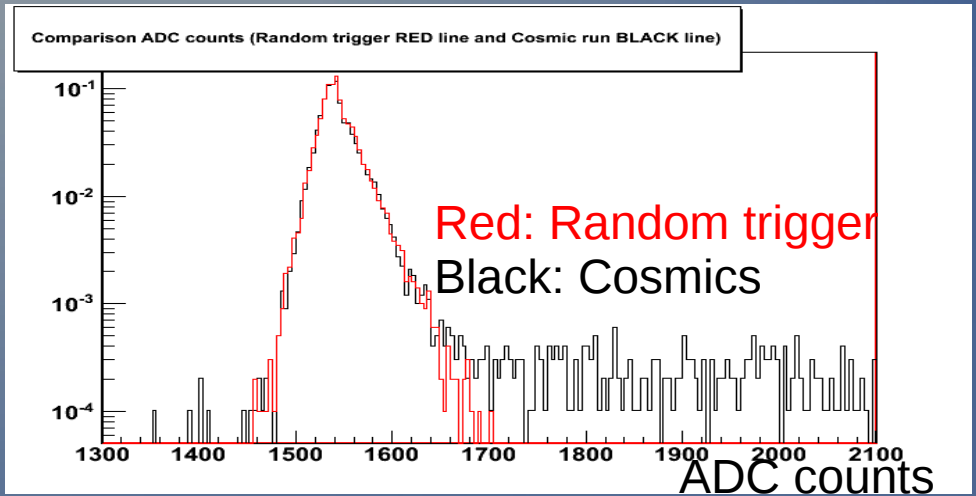
The board activity is related to SiPMs dark rate.
We have two differen groups of SiPMs.
They had different working points.
All board show the some trend.



The trigger rate is not correlated with boards activity (Or32*).

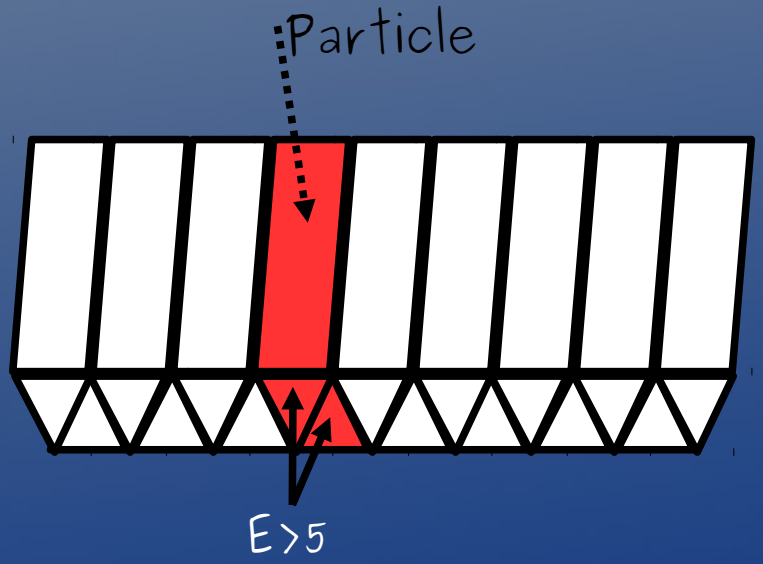
OR32: logic OR of all 32 SiPMs haused in the same connector and read by the same slave board.

Clustering



Define the parameter E related to energy release in the scintillator bar.

$$E = \frac{\text{Adc counts} - \text{Pedestal counts}^*}{\text{Rms pedestal distribution}}$$



Adjacent bars with E>5 form a cluster.
Mean cluster size 1.4 .
The Hit position is the center of the cluster.

* random trigger acquisition with SiPMs ON: Dark rate.

Tracking

X and Y views independent

Sort in descending order the cluster of each plane respect to E variable.

For each couple of Forward and Backward planes cluster we extrapolate a position in the Middle plane.

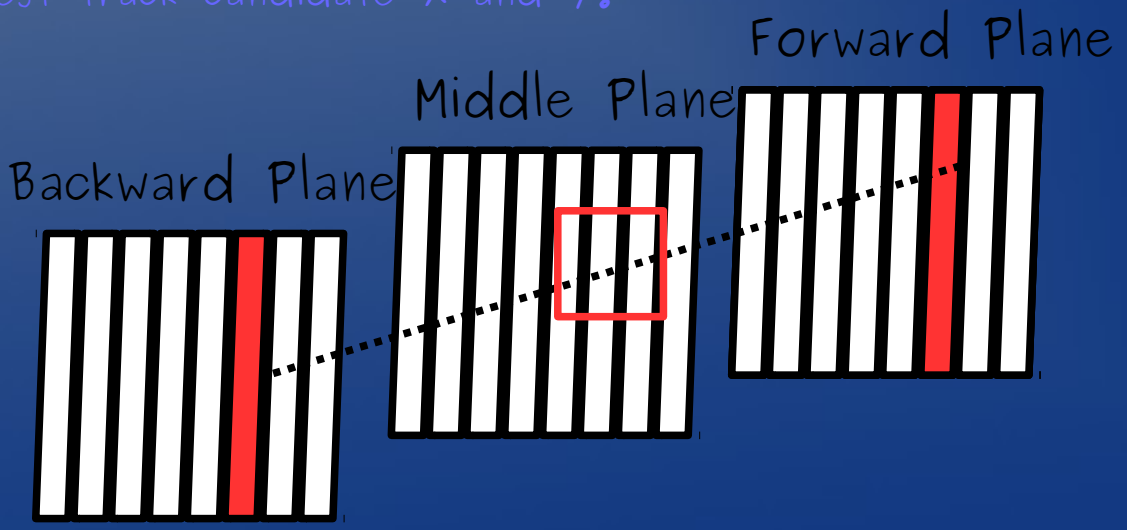
If there is a cluster in a range of 2 strip width, we make a linear fit and we build a track candidate.

We associated at each track candidate the E value of minimum between the three clusters that form it.

The best track candidate of view is the one with max of minimum E.

A track is the couple of best track candidate X and Y.

Tracking efficiency : 92%



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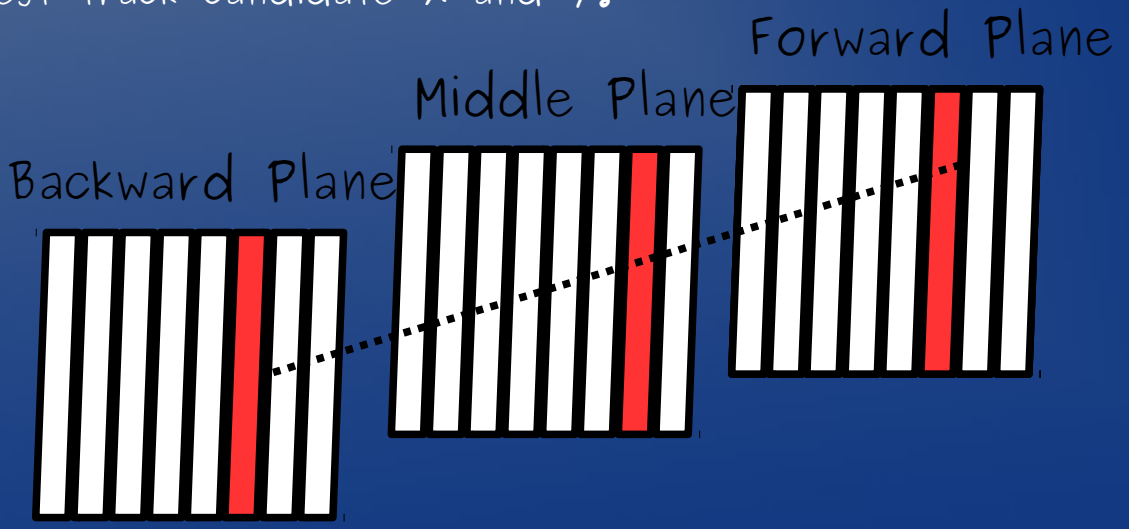

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Golden Track

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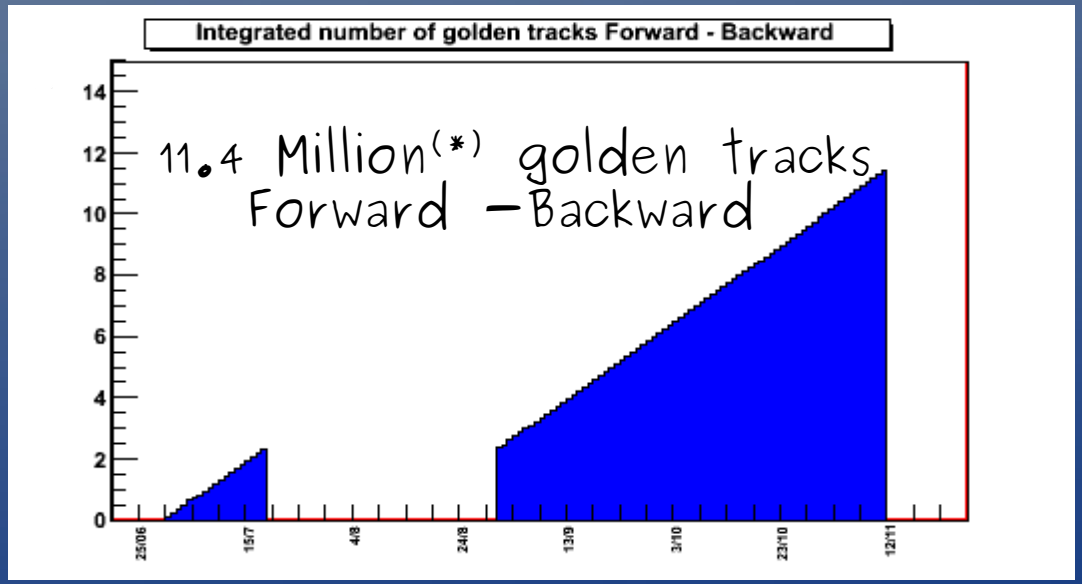
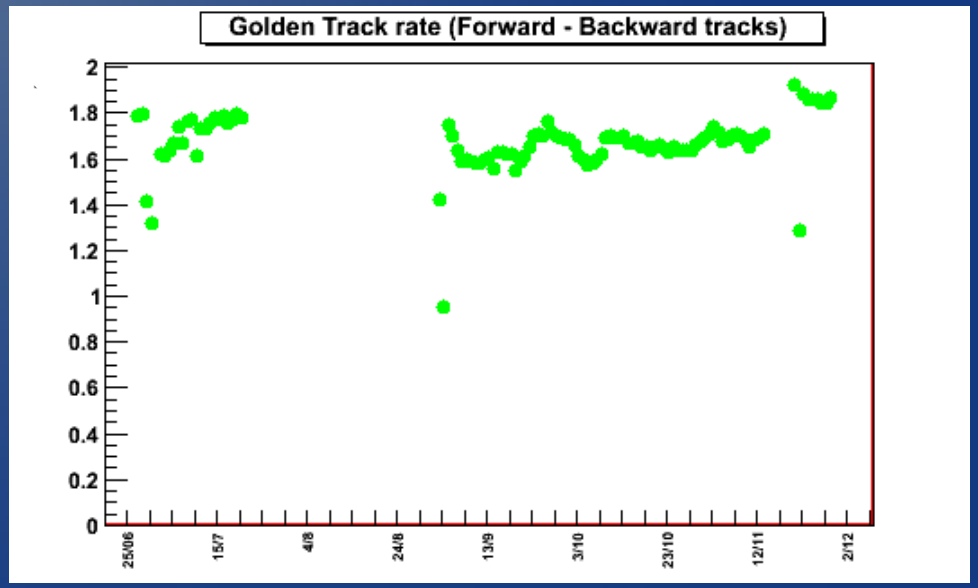
Golden track:

- Isolation: no other cluster not associated to a track with E > 20
- Cluster size < 5
- χ^2 < 5
- E of minimum cluster of track ∈ [20, 120]

Golden track effeciency: 47%





(*) Only Puy de Dome tracks.Calibration 1.7 M. Total 13.1 M tracks

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Golden Track vs Trigger

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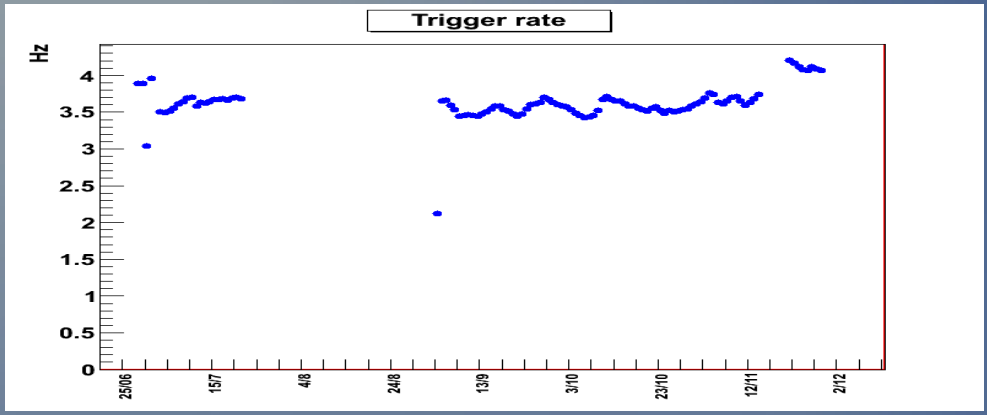
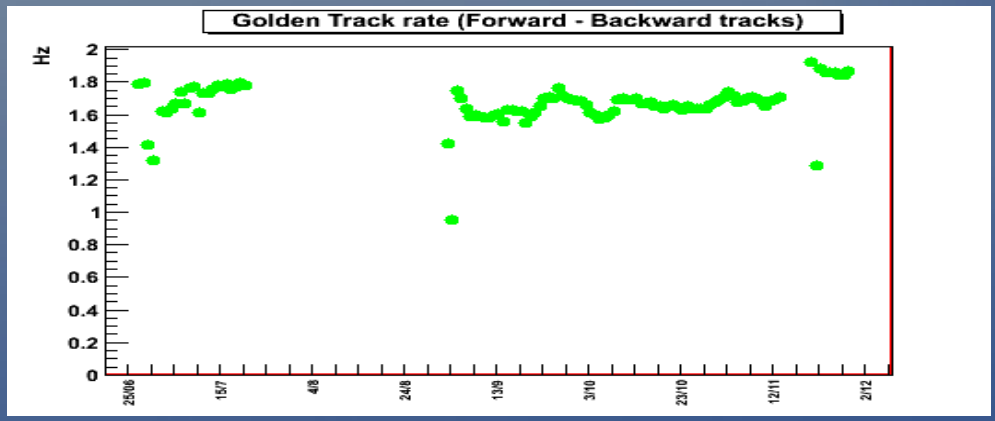
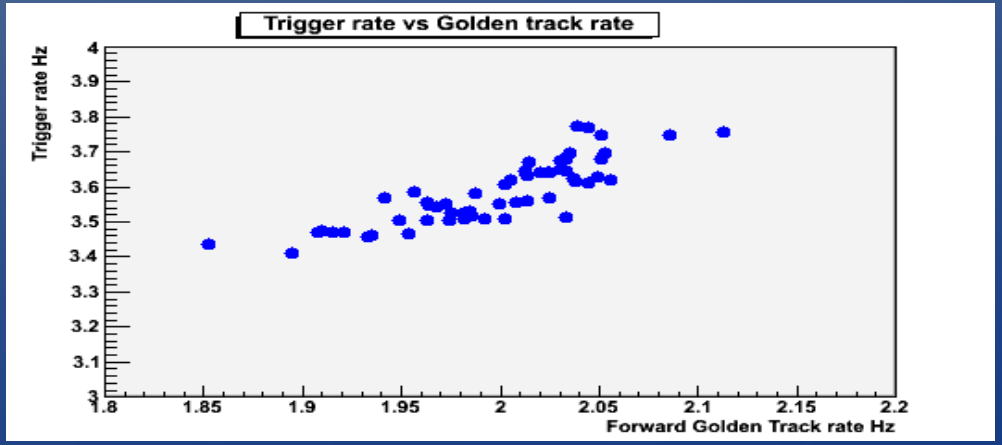






The comparison between Trigger and Golden Tracks rate, shows that we triggered on physical particles.

The two distributions show the same trend.

Trigger and Golden Track rate are correlated.

Correlation factor = 0.92

Multiplicity cut

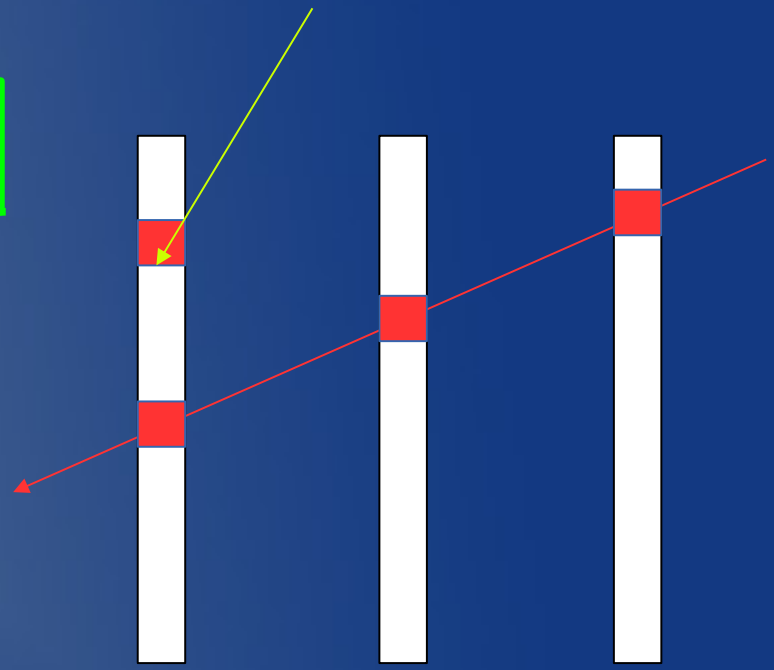
Isolation cut: no other cluster not associated to the track with E>20

+

E minimum of track's clusters >20

=

Multiplicity cut on golden tracks



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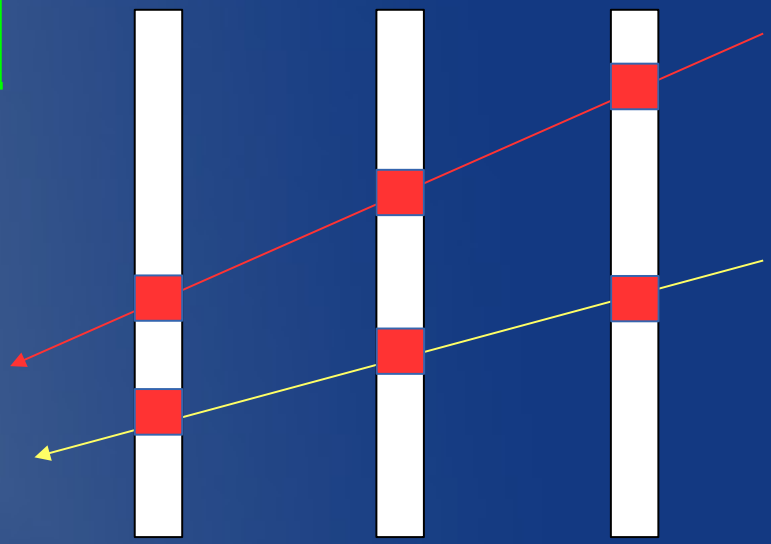

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Multiplicity cut

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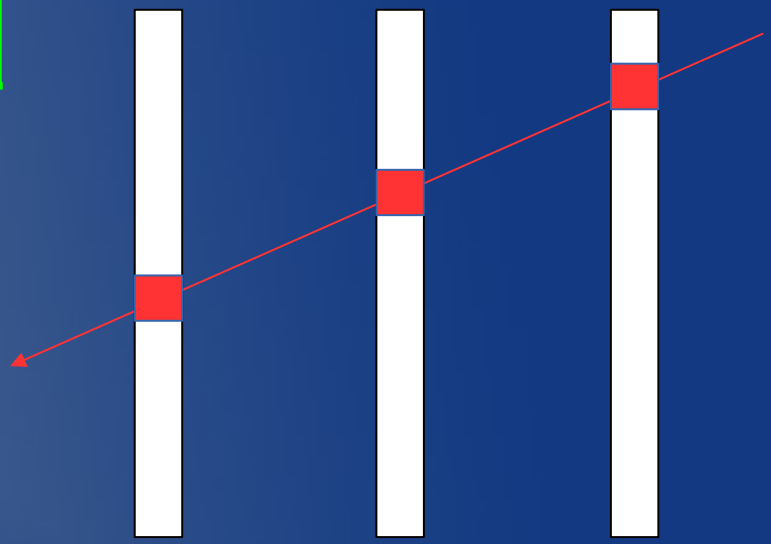

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Analyzed statistic

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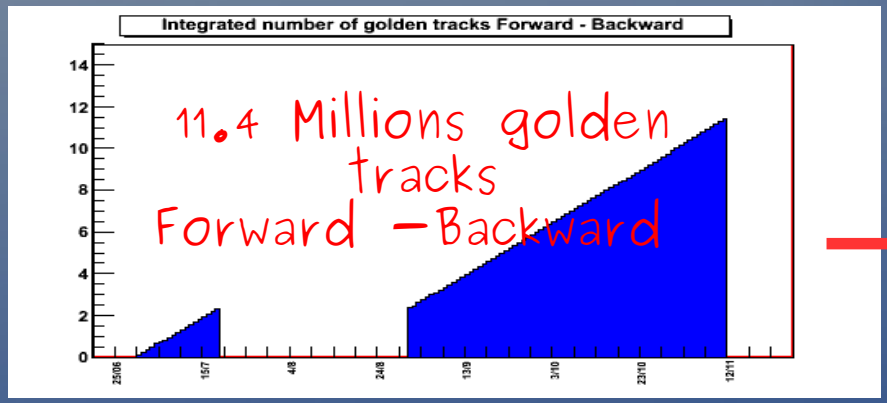
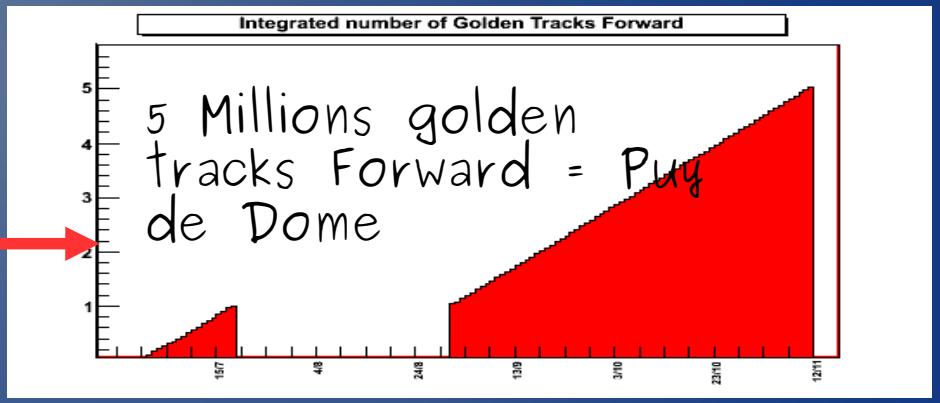
Number of Triggers:

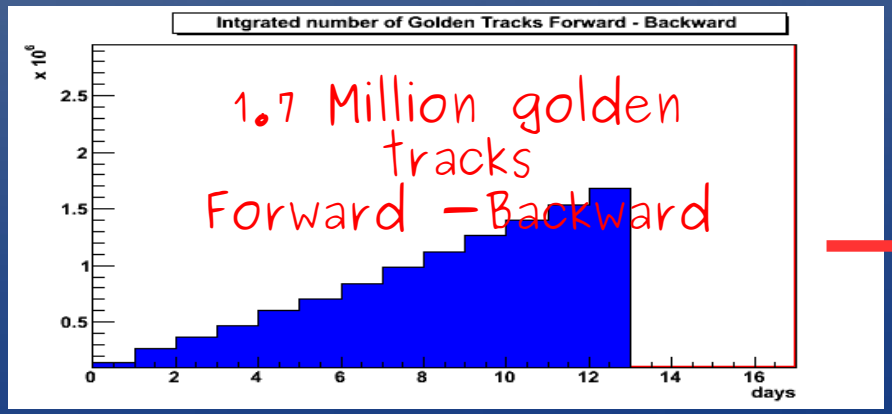
24 Million pointing to Puy de Dome.

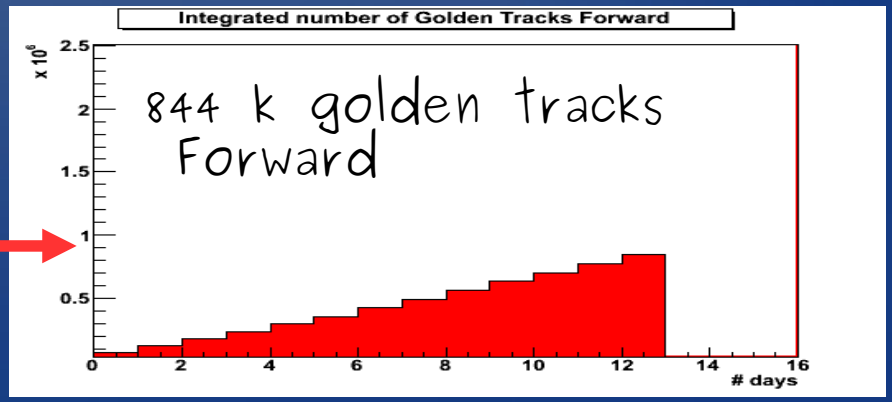
3.5 Millions pointing to free sky. Calibration.

Analysis cut efficiency 47%









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Not Isolated and Isolated tracks

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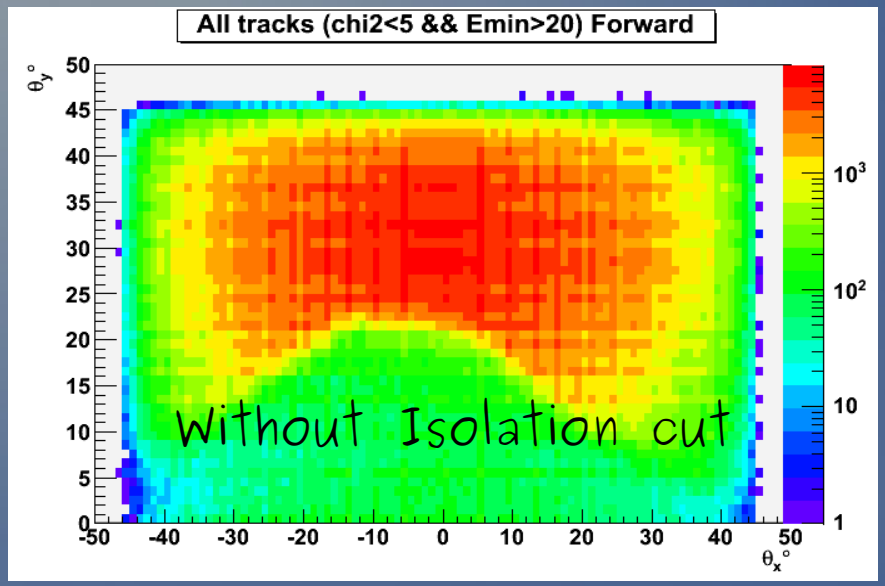
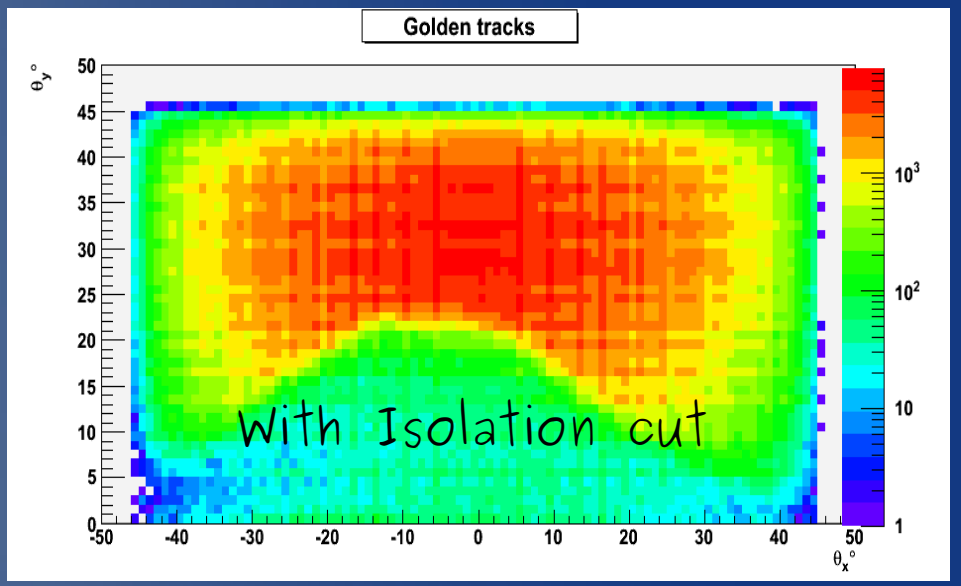
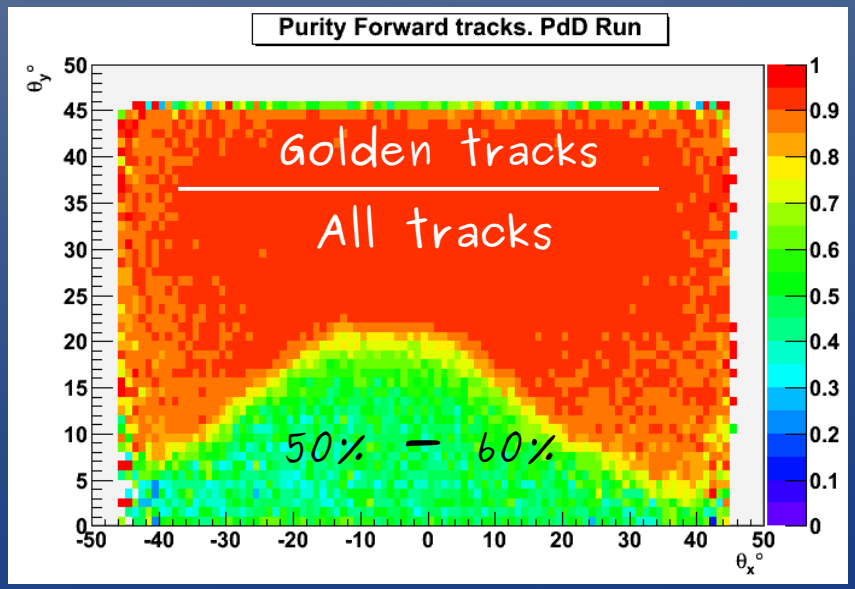
1) $\chi^2 < 5$
2) E of minimum cluster of track >2.0 a.u.







The isolation appears more important in the mountain region.
The ratio decreases to about 50– 60%.

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Calibration run: Not Isolated and Isolated tracks.

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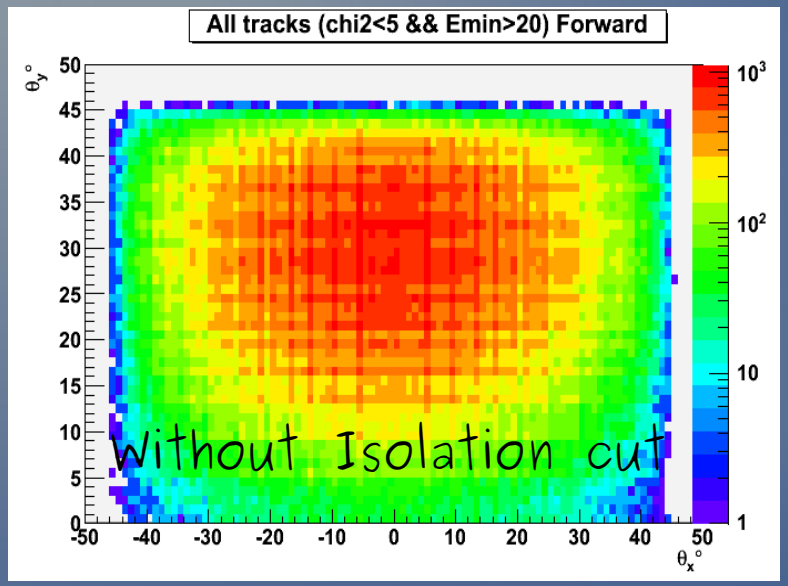
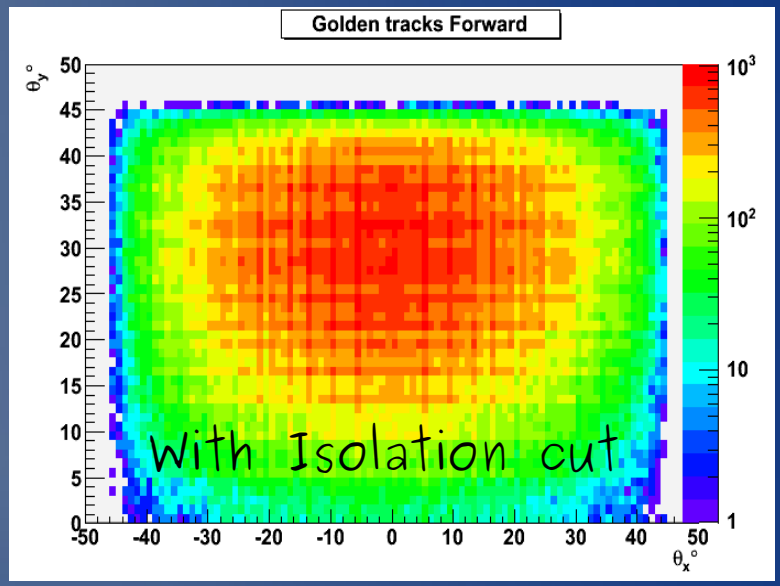
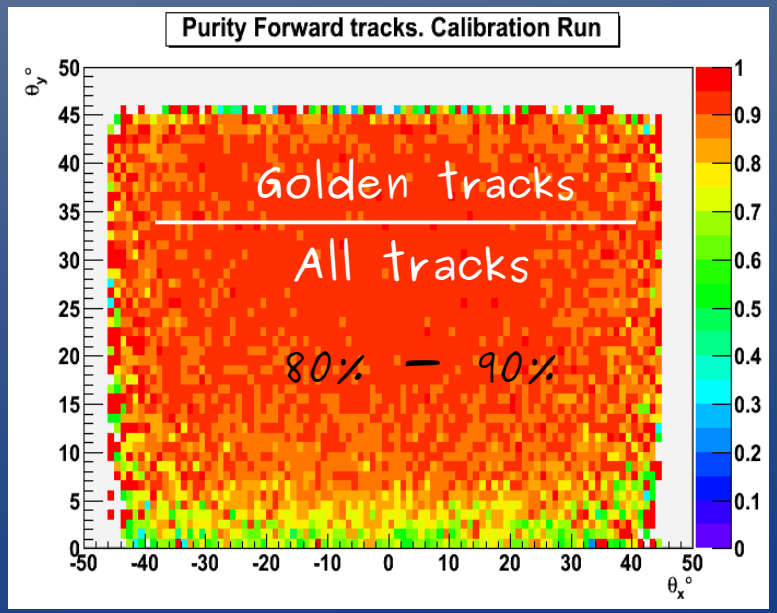
1) $\chi^2 < 5$
2) E of minimum cluster of track >2.0 a.u.







In this case the ratio is of the order 80–90 %.

Flat Background?
The mountain is a huge absorber and a flat background becomes more important in the mountain shadow respect to free sky.

The mountain region has multi-tracks events?

Other?

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Transmission

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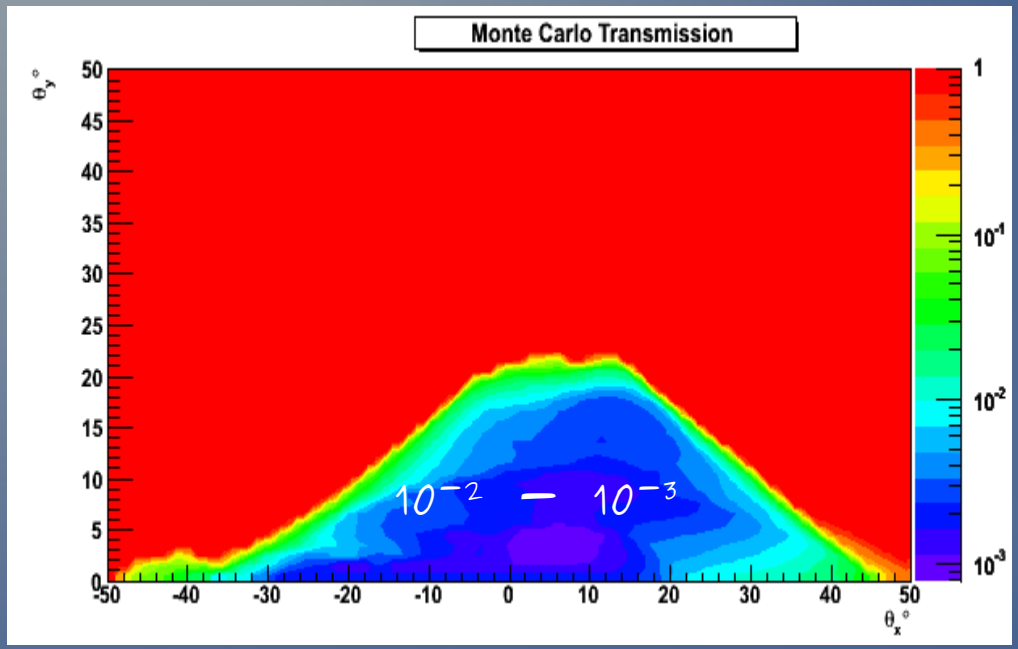

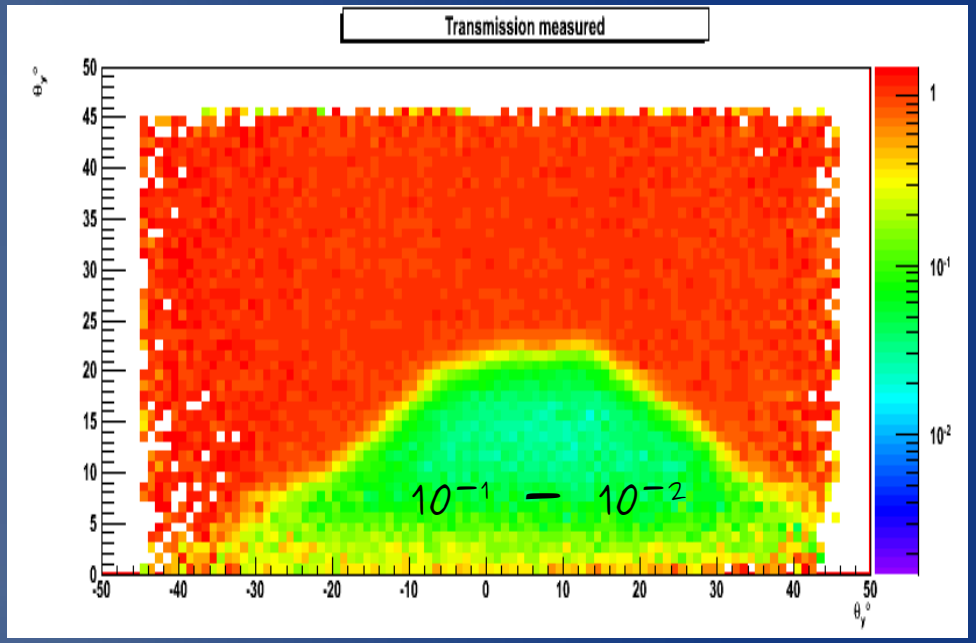

The Monte Carlo Transmission is in average one order of magnitude smaller respect to the measured.
This plot shows that measure is dominated by residual Background.

Very important: in this measurement campaign the detector was on surface (no Shield).

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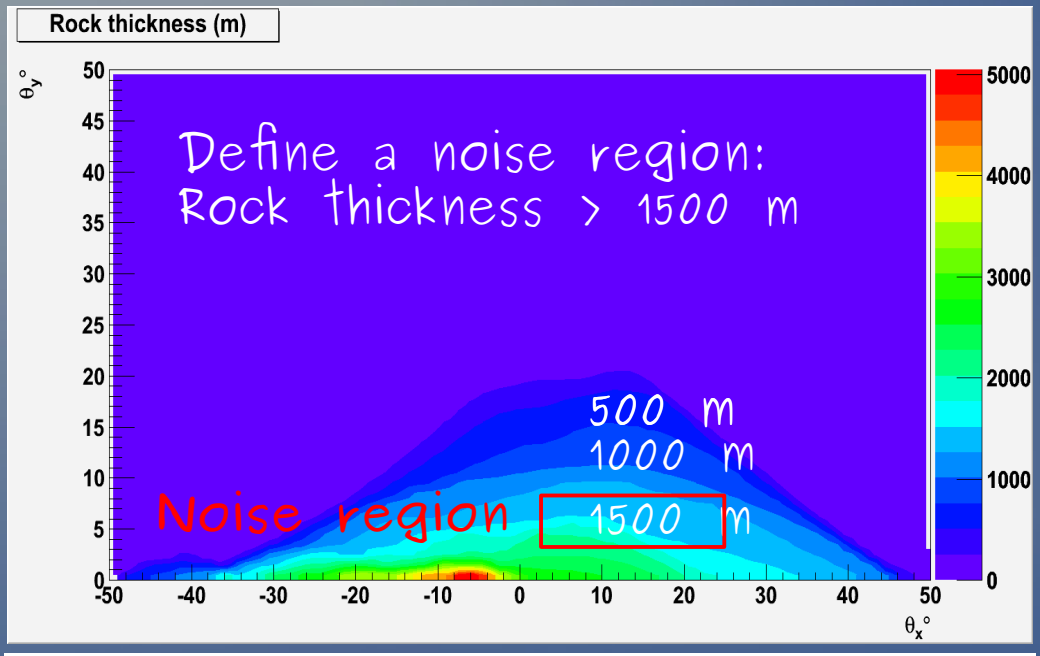
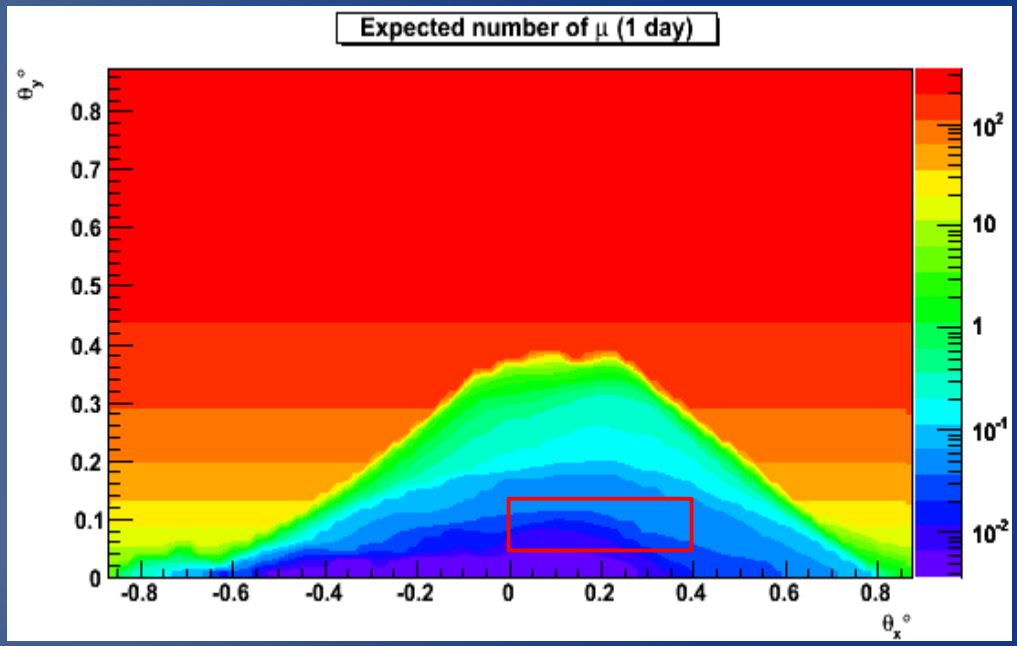
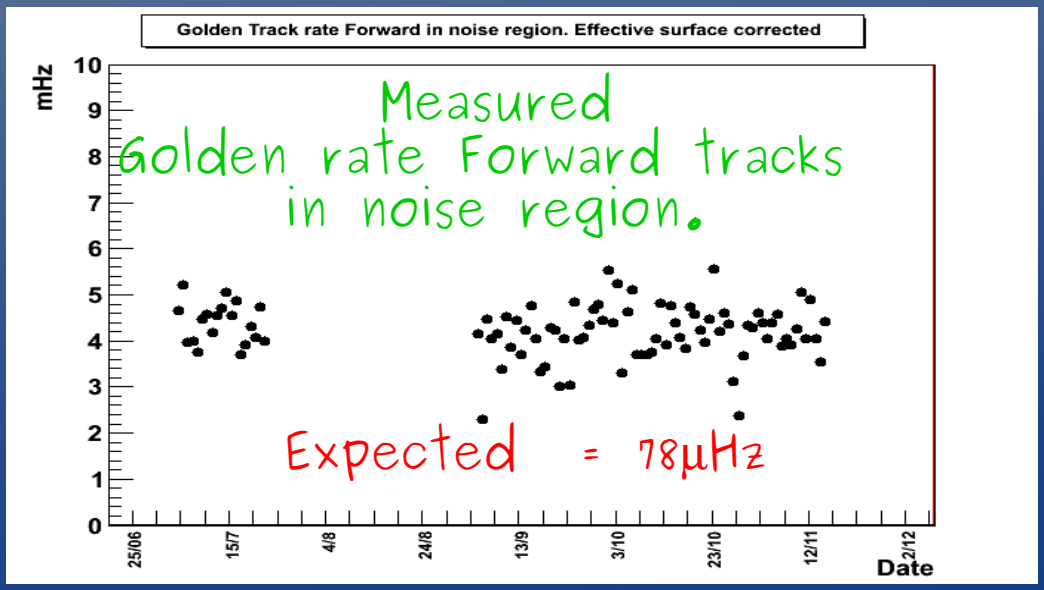
Noise region. Comparison w.r.t. Mone Carlo







The integral of Monte Carlo rate in the is 2 order of magnitude smaller respect to the measured. There is a residual background to subtract.

Conclusions

We integrated about 27 M of triggers.

The detector acquired for a long period without problems.

The trigger rate shows some oscillations but they are not correlated with the dark rate of SiPMs.

The golden rate tracks is correlated with trigger rate.

The Transmission measure is not available.

There is a residual background that have to be understood.

In this campaign the electronic didn't allow the Time Of Flight measurement.

The MURAVES detector will allow the time of flight measurement.

Thank you
for the attention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SPARE

Tracking and analysis cut efficiencies

		Free sky			Puy de dome		
Cut	#	N entries	Eff	Eff rel	N entries	Eff	Eff rel
Trigger	1	1000000	-	-	6252584	-	-
Not corrupetd	2	999142	99.91 %	-	6240210	99.80 %	-
Traccia x&y	3	923917	92.39 %	92.24 %	5770902	92.29 %	92.47 %
Not Ass E >20*	4	758596	75.85 %	82.10 %	4768603	76.22 %	82.63 %
20 <Emin < 120**	5	599973	59.99 %	79.10 %	3830314	61.25 %	80.03 %
Chi2< 5 && ClusterSize	6	463406	46.34 %	72.38 %	2974669	47.58 %	76.62 %

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Trigger vs all paramenters

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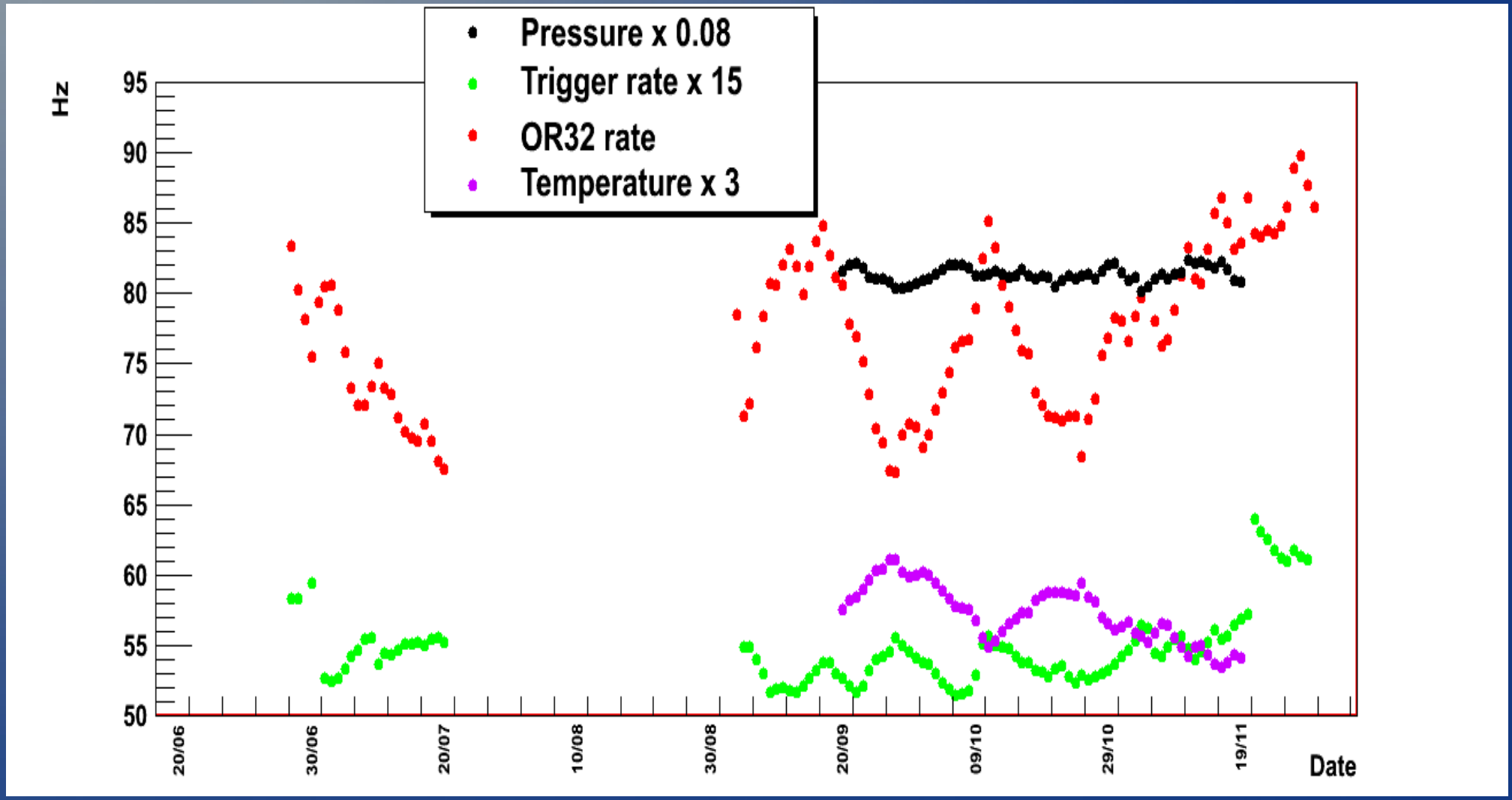
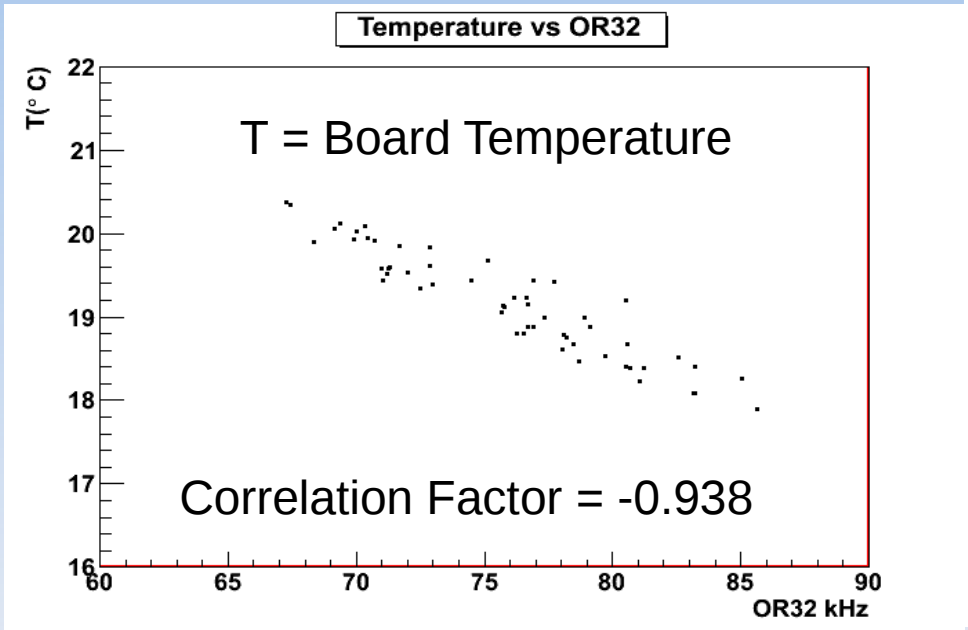
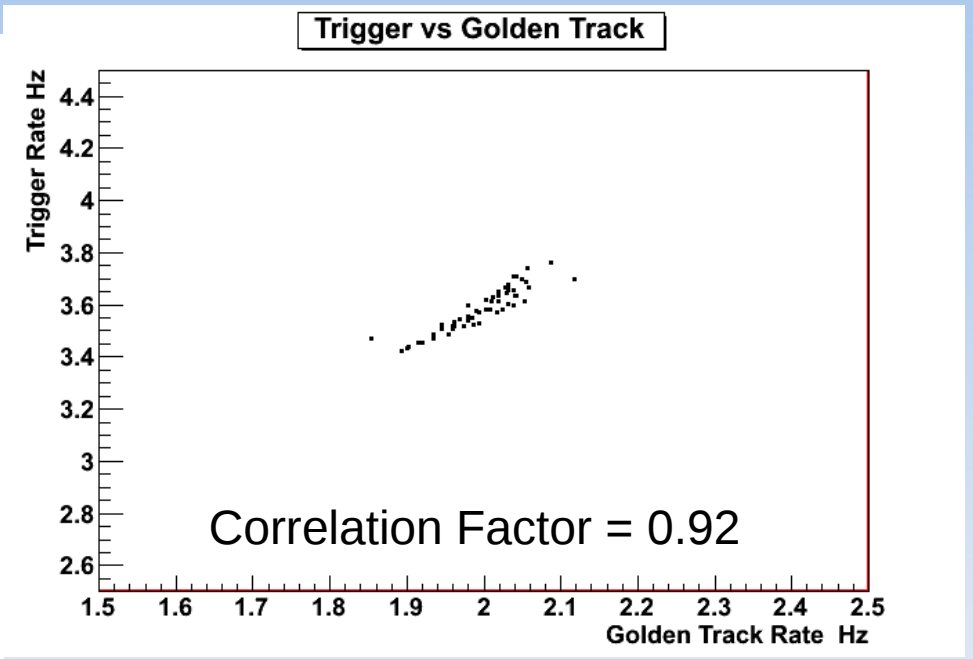
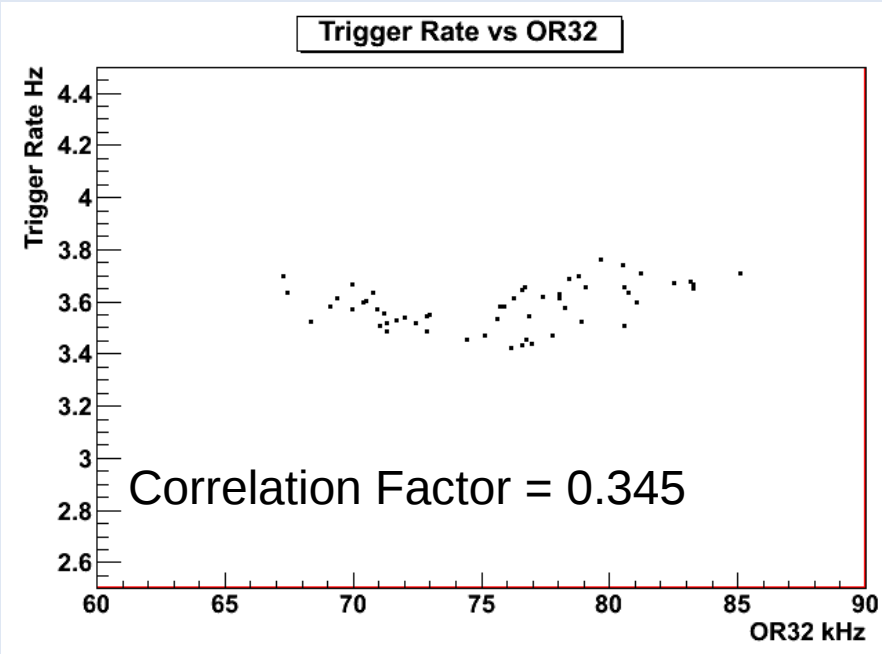
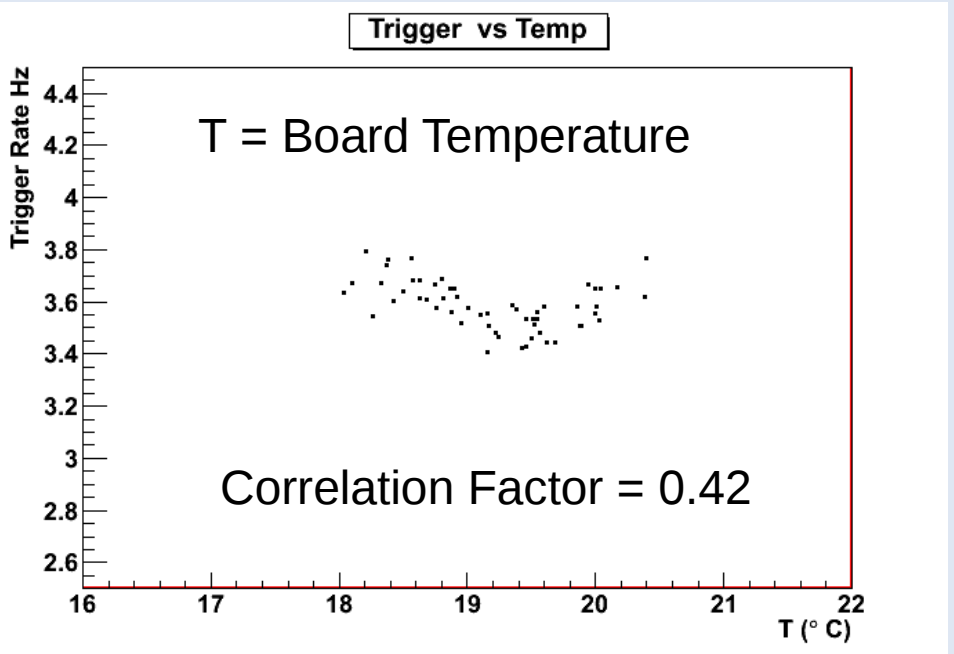
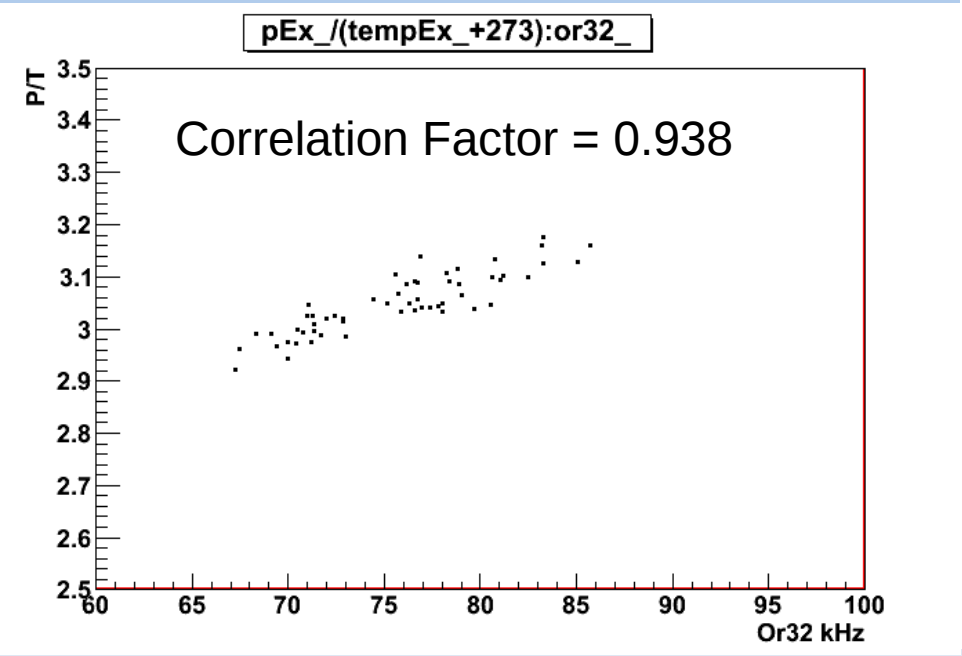


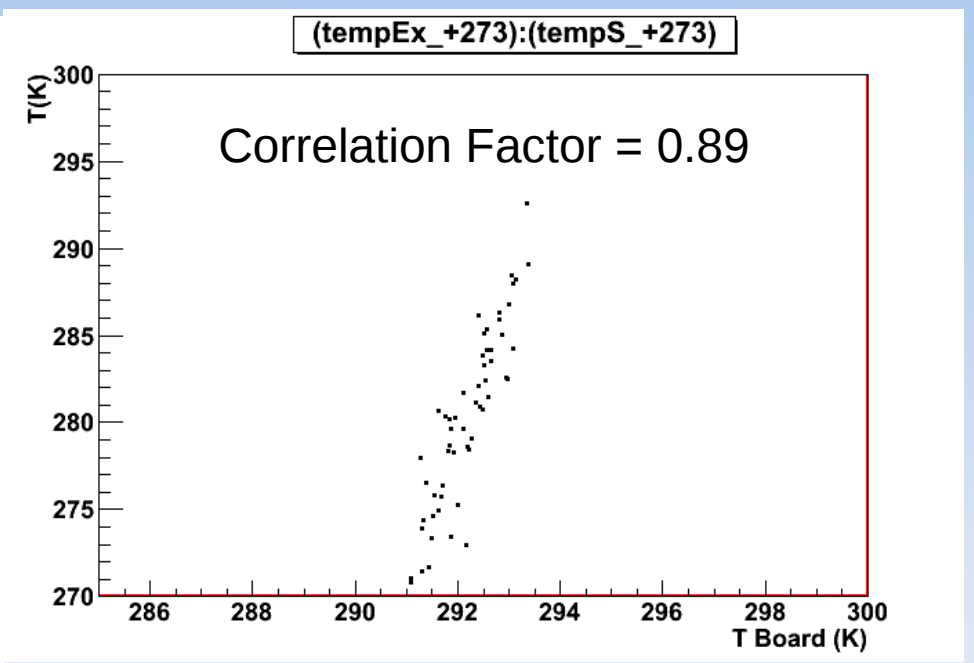

Temperature vs OR32
T(° C)
T = Board Temperature
Correlation Factor = -0.938
OR32 kHz


Trigger vs Golden Track
Trigger Rate Hz
Correlation Factor = 0.92
Golden Track Rate Hz

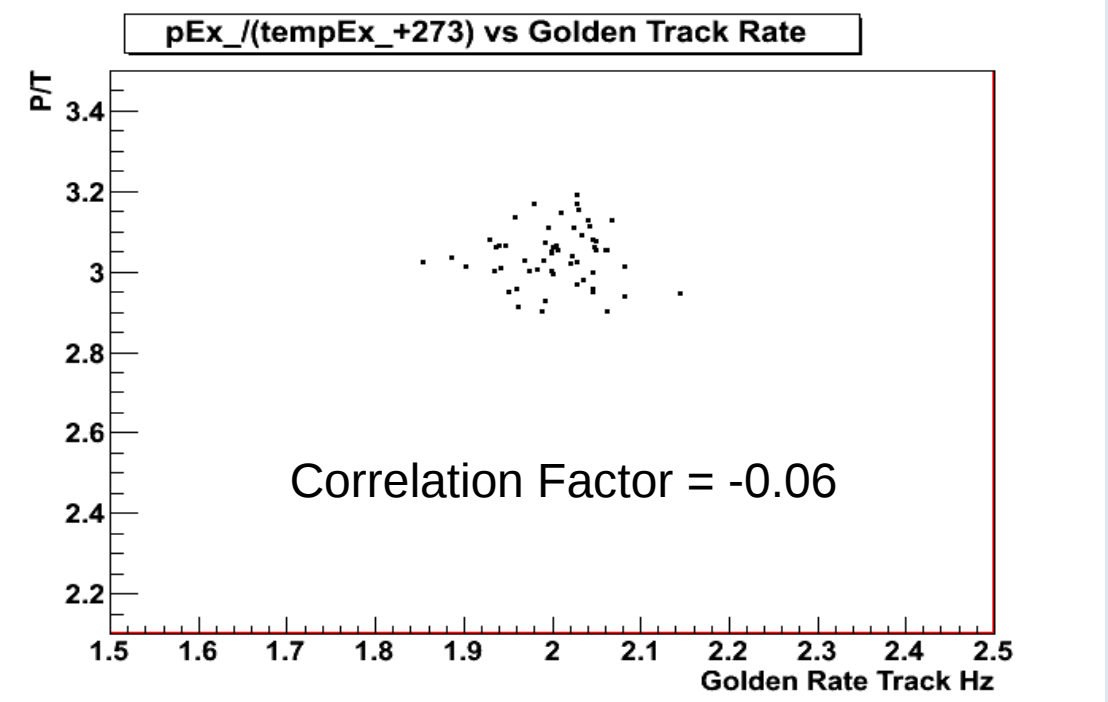

Trigger Rate vs OR32
Trigger Rate Hz
Correlation Factor = 0.345
OR32 kHz


Trigger vs Temp
Trigger Rate Hz
T = Board Temperature
Correlation Factor = 0.42
T (° C)





TempEx = External Temperature
TempS = Board Temperature



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Effective surface

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