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# Clusters in RPC and Muon Trigger performance

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**Abstract**

**Influence of clusters in RPC on trigger performance is studied, using experimental data on the cluster size distribution. Simple algorithm is proposed to reduce the effect of clusters. Its behaviour is examined taking into account muon secondaries simulated by Geant.**

## 1 Clusters in RPC

Resistive Plate Chambers (RPC) [1] are proposed to be used for muon trigger in the CMS experiment [2, 3]. Muon trigger efficiencies and rates presented in the CMS Technical Proposal [2] were calculated under assumption that single particle produces a signal only on one readout strips. In reality however, the signal can be observed on several strips. The cluster size distribution depends on the chamber construction and on running conditions like high voltage, discriminator threshold etc. Optimisation of these conditions involves a tradeoff between the cluster size and the chamber efficiency. This note addresses the question what is the impact of the clusters on the trigger performance.

For this study experimental data recently collected by Bari group of the CMS Collaboration [5] were used. The data were obtained with two double-gap RPC's made out of 2 mm thick bakelite plates painted with linseed oil. The gas gaps were 2 mm thick and readout strip pitch was 1.5 cm. The chambers were tested in the so called low gas gain mode [4] using mixture of 85% freon $CF_3Br$ and 15% butane. 10 strips of each chamber were equipped with readout electronics. Discriminator threshold of 40 mV was used for this study.

The measured average cluster size is plotted in Fig. 1. The same data are shown as a function of beam flux and high voltage. The average does not include spark events when the signal was observed on all the strips. This kind of events needs a special treatment which is not discussed here in detail. One can only mention that such an event is for the trigger logic equivalent to a dead area, when the "3 out of 4" algorithm is applied. Hence one can require that the fraction of sparks should not exceed a fraction of dead area per station which is typically a few percent.

The observed average cluster size varies from 1.9 to 3.3 strips. The trigger performance was studied with this two extreme values. For this purpose the two cluster size distributions were parametrised. In order to extrapolate the results to different strip widths an assumption was made that the cluster size expressed in cm does not depend on the strip pitch. This assumption still needs to be checked experimentally.

Distribution functions for the two cases, denoted hereafter "small clusters" and "big clusters", were parametrised with the following formulas respectively:

$$F_{small}(d) = 1 - \exp(-0.2257 \cdot d^2)$$

$$F_{big}(d) = 1 - \exp(-0.04622 \cdot d^2)$$

where $d$ is the cluster size in cm. The curves and the data as well as the resulting distributions are shown in Fig. 2. It is seen that the parametrisations reproduce the experimental data within $2\sigma$ errors.

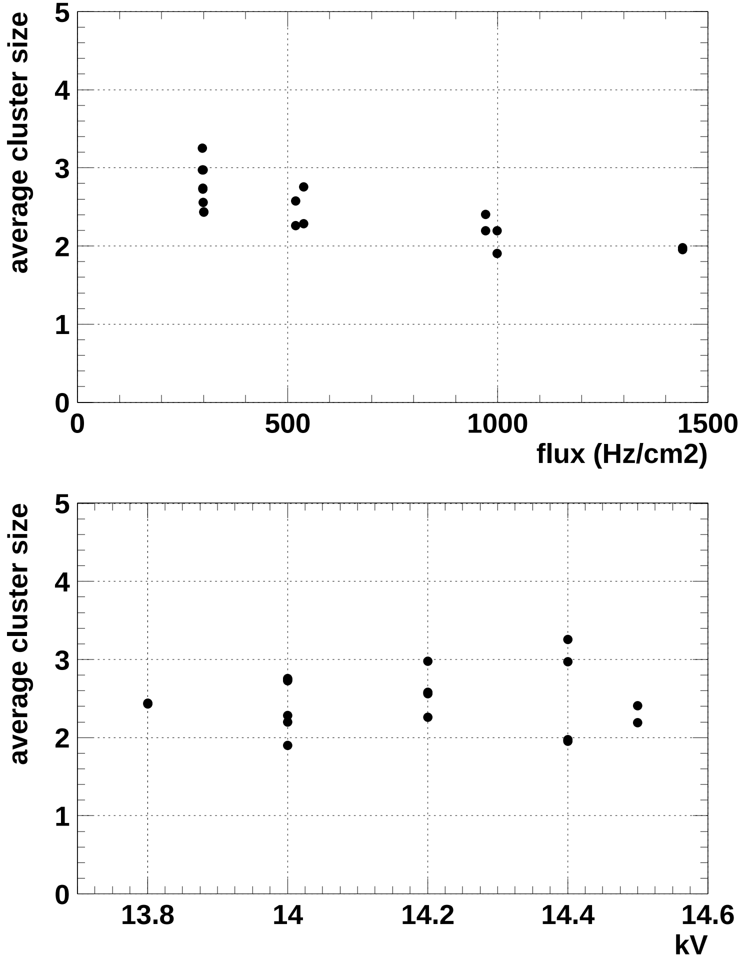


Figure 1: Average cluster size: the same data are plotted vs beam rate and HV.

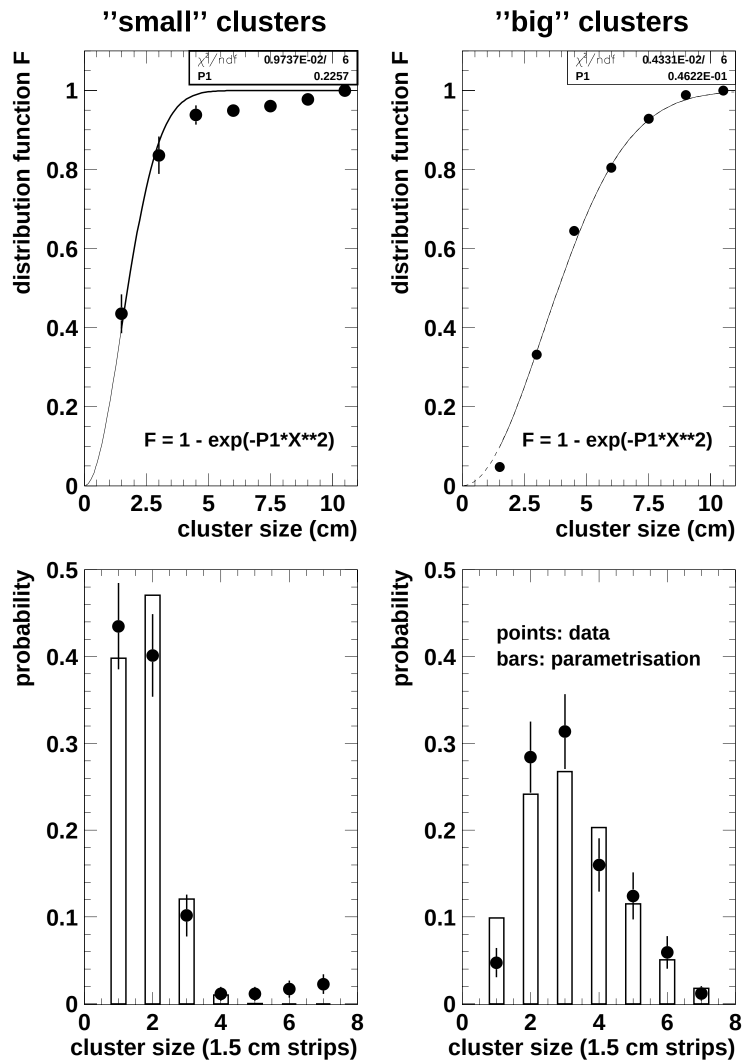


Figure 2: Parametrisation of the best and the worst cluster size distribution.

## 2 Cluster size expected in CMS

A $\phi$-projective RPC geometry is foreseen for CMS. The strip pitch is assumed to be $\Delta\phi = 5/16°$. Therefore the actual strip width will vary with the radius, i.e. with a station number and $\eta$, as shown in the first graph of Fig. 3. From this dependence one can calculate the expected RPC cluster size using above parametrisations. Results are shown in the middle graphs of Fig. 3.

In the case of "small clusters" in the barrel the expected cluster size is close to 1, hence the trigger performance will not be affected. However in the other cases it is significantly higher and the trigger may not function as it is foreseen. Moreover if the clusters are almost always greater than 2 strips it is unreasonable to build chambers with so narrow strips. For example one can consider twice wider strips in the inner part of forward RPC's. Strip widths and expected cluster sizes for this case are shown in Fig. 4.

## 3 Declustering algorithm

The effect of clusters can be reduced by some electronics looking for the cluster center. It could be integrated into the Pattern Comparator Trigger (PACT) ASIC. Developing such an algorithm the following assumptions were made:

1. RPC strip size should not be much smaller than the average cluster size (it is just wasting money).
2. In case of a single muon (no deltas, showers, etc.) the center of the cluster is the best estimate of a real muon position.
3. Therefore in case of a single muon the declustering algorithm should point to only one strip: the one in the center of the cluster.
4. If an observed cluster is much bigger than an average cluster size for single muons this probably means that there were more particles (deltas, shower, etc.). In such a case the declustering algorithm should indicate the larger, "abnormal" size of the cluster.

Two kind of declustering algorithms were proposed:

**"N-2" algorithm**: the number of processor input (logical channels) is equal to the number of RPC strips (physical channels):

```
phys.:   ---X----   ---XX---   --XXX---   --XXXX--  and in general:  N>2
log.:    ...*....   ...*....   ...*....   ...**...                   N-2
```

**"2N-5" algorithm**: the number of processor input (logical channels) is twice larger than the number of RPC strips (physical channels):

```
- - - - X - - - -      - - - X X - - - -      - - - X X X - - -
........*........      .......*.........      ........*........

- - X X X X - - -      - - X X X X X - -  and in general:  N>2
......***........      ......*****......                   2N-5
```

The "2N-5" algorithm might be useful in the forward region if the strip width is much smaller than the typical cluster size. In this case one can use twice wider RPC strips, retaining needed granularity of the trigger logic by the "2N-5" algorithm. Average cluster sizes reduced by the "N-2" and "2N-5" algorithms are presented in the right columns of Fig. 3 and 4 respectively.

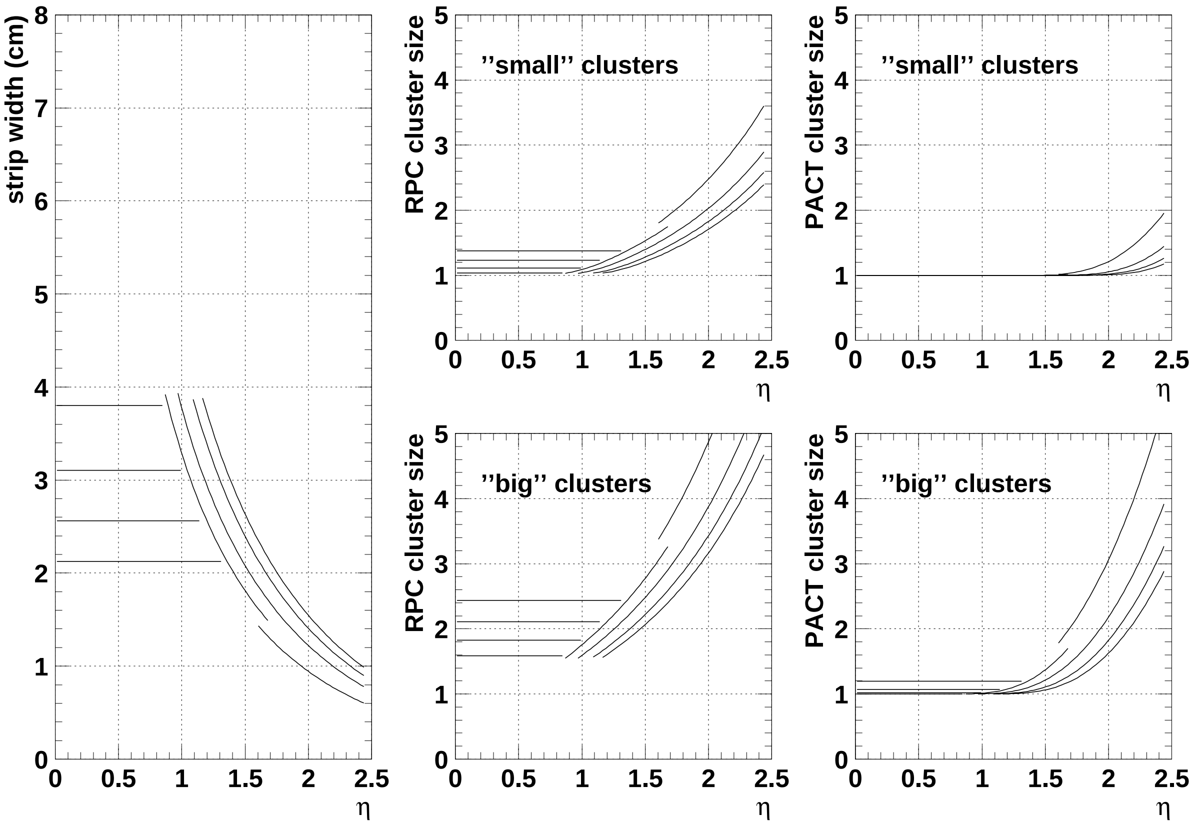


Figure 3: Cluster size with "N-2" algorithm.

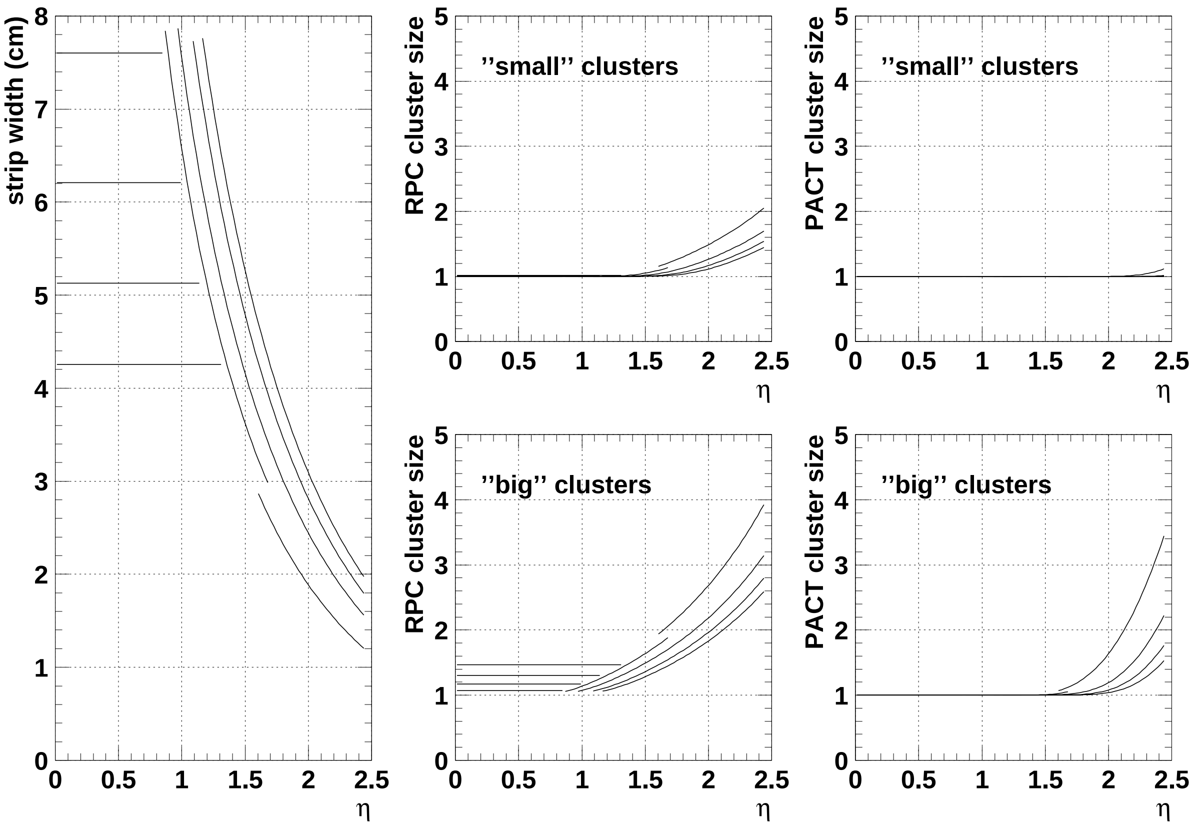


Figure 4: Cluster size with "2N-5" algorithm.

# 4 Simulation of muon secondaries

Presence of muon secondaries can disturb a declustering algorithm if e.g. muon and delta produce two overlapping clusters (Fig. 5). In such a case the declustering algorithm will see only one big cluster and its center might be displaced from the real muon position. In order to estimate this effect a simulation with GEANT was performed. The simulated setup (Fig. 6) consists of a 35.5 cm thick iron block and one RPC separated by a 5 cm air gap. The following cuts were used:

| | | |
|---|---|---|
| first 30 cm of iron | 100 | MeV |
| next 5 cm of iron | 10 | MeV |
| last 0.5 cm of iron | 1 | MeV |
| 2 mm RPC bakelite | 100 | keV |
| 2 mm RPC gas | 100 | keV |

Three samples of muons with momenta of 10 GeV, 100 GeV and 1 TeV were generated, 10 000 events each. Four example events are shown in Fig. 6. Cluster formation and declustering results for several example events are presented in the Appendix.

Results of the simulation are shown in Fig. 7, 8, and 9. Fig. 7 shows the number of particles entering the RPC gas (number of geometrical hits) and the distance of a secondary hit from the muon. Fig. 8 and 9 shows errors made by declustering algorithms caused by muon secondaries. The error is defined as a distance between the muon and the edge of the closest strip pointed by the algorithm (see Fig. 5). It is seen that the displacement never exceeds one strip width and is concentrated close to the real muon.

# 5 Trigger rates

Finally overall trigger performance was examined by calculating trigger rates taking into account clusters in RPC and declustering algorithms. A sample of 1.5 million muons was generated according to the $p_t$ spectrum expected at LHC from 2 to 150 GeV for $|\eta| < 2.45$. Muons were tracked through the CMS detector using CMSIM program v.008 with IMVERS=921 and IMFLOW=3. Clusters in RPC were generated according to the parametrisations described above. Finally the data were passed through the program MTRIG simulating PACT processor including declustering algorithm. The "N-2" algorithm was used at $|\eta| < 1.5$ and the "2N-5" one – above this value, assuming twice wider strips.

Results for "big" and "small" clusters are compared to the results of ideal case simulation (no clusters) in Fig. 10. It is seen that the curves for "small" clusters almost coincide with the curves for the ideal case whereas the curves for "big" clusters only slightly deviate at high $p_t$, especially for very high $|\eta|$. This means the trigger performance is not significantly degraded by the clusters after applying proposed declustering algorithms.

# 6 Conclusions

Presented study can be summarised as follows:

- Test beam data shows the cluster size of 3.5 – 6.5 cm.
- Simple logic is proposed to reduce the cluster size.
- "Declustering" do not introduce errors greater than one strip.
- 3.5 cm clusters do not affect trigger performance.
- 6.5 cm clusters slightly reduce the purity of trigger cuts for large $|\eta|$ and high $p_t$.

However one should not draw a conclusion that there is no need to reduce the cluster size at the chamber level. Big clusters increase occupancy in RPC. Large fluctuations in the cluster size probably reflects fluctuations of the detected charge. This may mean that a very low discriminator threshold is required in order to achieve high efficiency. That may in turn increase the noise and thus further increase the occupancy. On the other hand large pulse high fluctuations may affect the time resolution.

Taking all this into account one can conclude that clusters as they are observed in the current prototypes [5] do not degrade the trigger performance but they may reduce significantly important safety margins of the design.

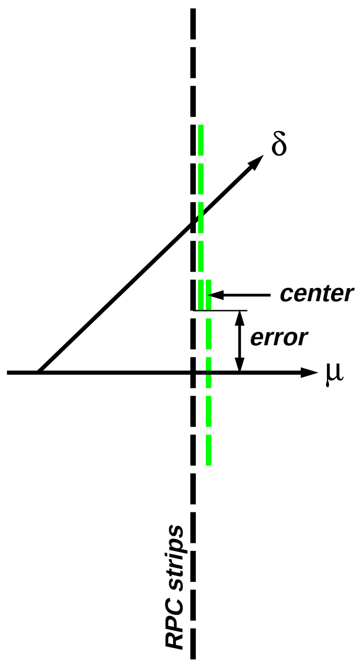


Figure 5: Possible error of declustering algorithm.

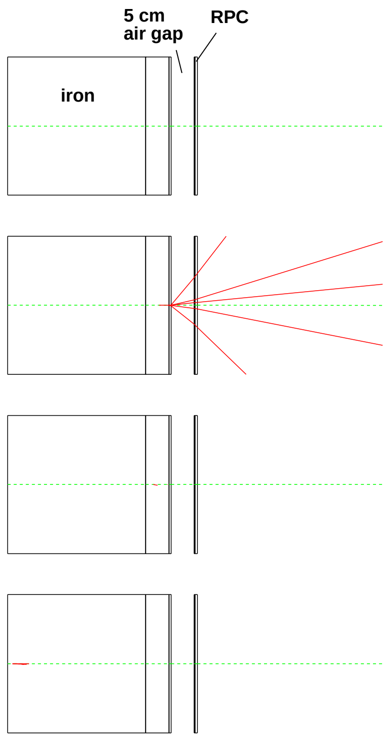


Figure 6: Four simulated events with 1 TeV muons.

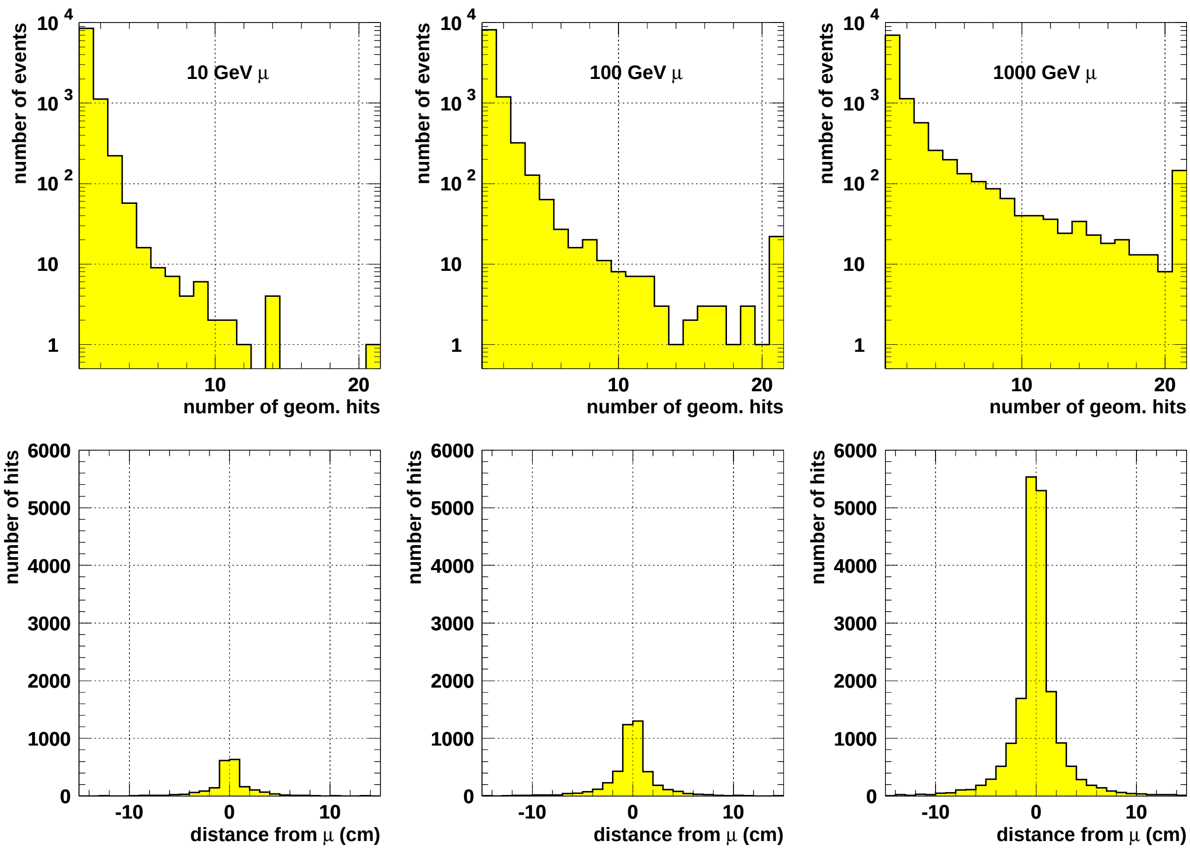


Figure 7: Number of secondaries crossing the RPC and their distance from the muon.

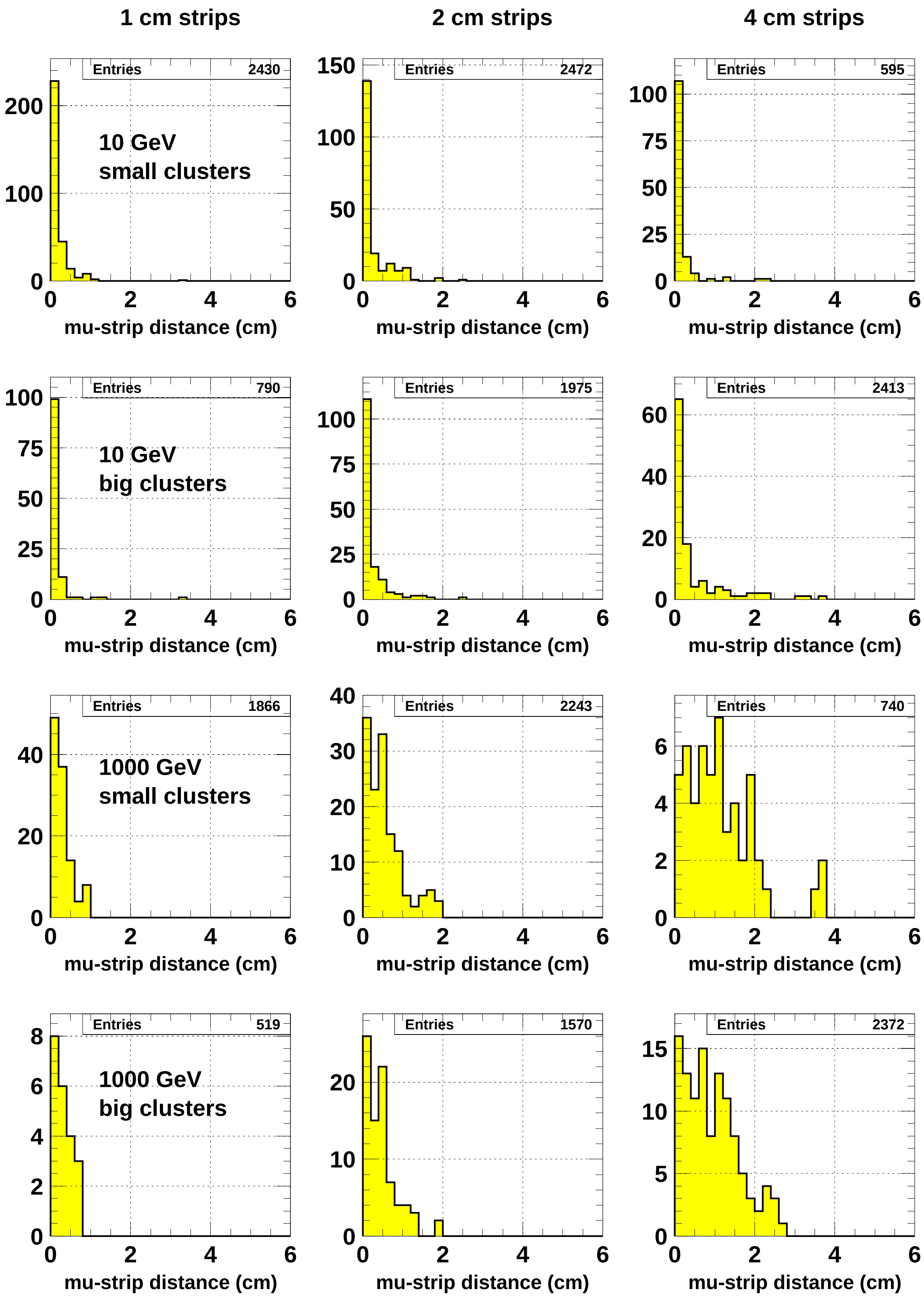


Figure 8: Distribution of the "N-2" declustering algorithm error. Note that the number of entries is smaller than 10000. Remaining events have no error, because muon crossed the central strip of the cluster.

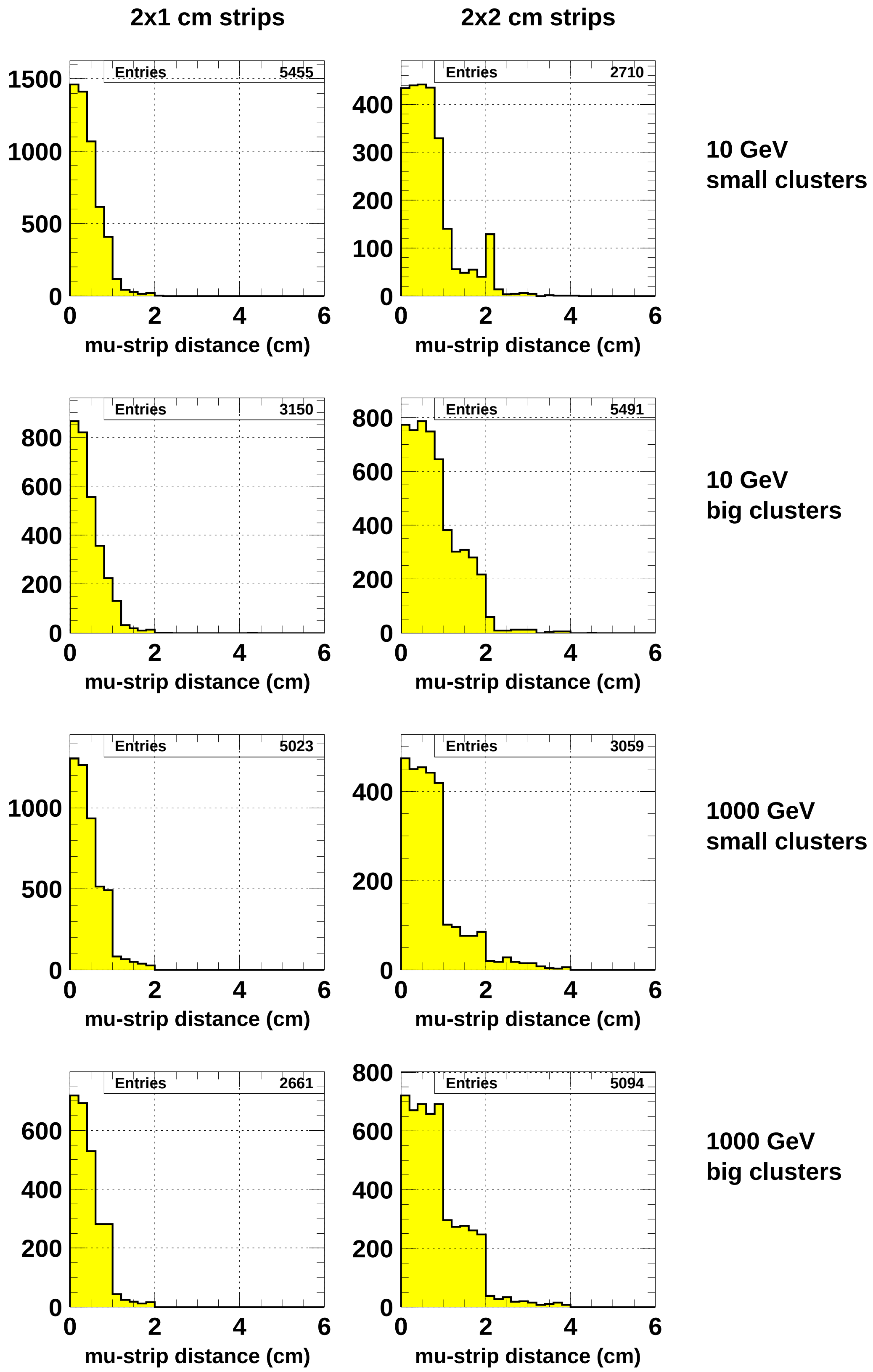


Figure 9: Distribution of the "2N-5" declustering algorithm error. Note that the number of entries is smaller than 10000. Remaining events have no error, because muon crossed the central strip of the cluster.

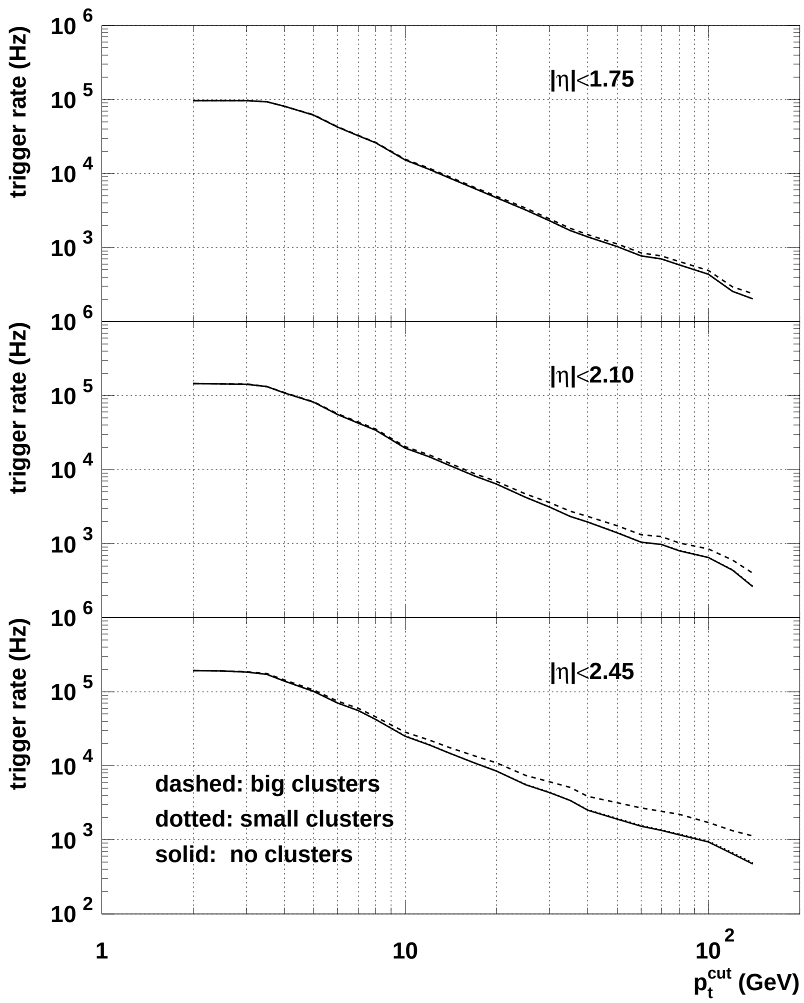


Figure 10: RPC trigger rate with and without clusters.

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# Appendix

Below several example events are presented with the following convention:

```
      v        hit position
-----XXXX----- RPC physical strips
......**...... PACT logical channels
```

10 GeV, small clusters, "N-2" declustering

```
                              v
-----------------------------XX------------------------------
..............................*..............................

                              v
----------------------------XXXX-----------------------------
.............................**..............................

                               v
------------------------------XX-----------------------------
...............................*.............................

                              v
------------------------------XX-----------------------------
...............................*.............................
```

10 GeV, big clusters, "N-2" declustering

```
                             v
-----------------------------XXX-----------------------------
..............................*..............................

                              v
--------------------------XXXXXXXX---------------------------
...........................******............................

                               v
-----------------------------XXXX----------------------------
..............................**.............................

                              v
----------------------------XXXXX----------------------------
.............................***.............................
```

1000 GeV, small clusters, "N-2" declustering

```
                              v
------------------------------XX------------------------------
...............................*..............................

                          v  vvv    v
-------------------------XX-XXXXX---X-------------------------
..........................*..***....*.........................

                              v
-----------------------------XX-------------------------------
..............................*...............................

                              v
------------------------------XX------------------------------
...............................*..............................
```

1000 GeV, big clusters, "N-2" declustering

```
                              v
-----------------------------XXX------------------------------
..............................*...............................

                          v  vvv    v
------------------------XXXXXXXXXXX-XX------------------------
.........................*********...*........................

                              v
-----------------------------XXX------------------------------
..............................*...............................

                              v
-----------------------------XXXX-----------------------------
..............................**..............................
```

10 GeV, small clusters, "2N-5" declustering

```
                              v
- - - - - - - - - - - - - - X X - - - - - - - - - - - - - - -
.............................*...............................

                              v
- - - - - - - - - - - - - - X X - - - - - - - - - - - - - - -
.............................*...............................

                               v
- - - - - - - - - - - - - - - X - - - - - - - - - - - - - - -
..............................*..............................

                              v
- - - - - - - - - - - - - - - X - - - - - - - - - - - - - - -
..............................*..............................
```

10 GeV, big clusters, "2N-5" declustering

```
                              v
- - - - - - - - - - - - - - X X - - - - - - - - - - - - - - -
.............................*...............................

                              v
- - - - - - - - - - - - - X X X X - - - - - - - - - - - - - -
............................***..............................

                               v
- - - - - - - - - - - - - - X X X - - - - - - - - - - - - - -
..............................*..............................

                              v
- - - - - - - - - - - - - - X X X - - - - - - - - - - - - - -
..............................*..............................
```

1000 GeV, small clusters, "2N-5" declustering

```
                              v
- - - - - - - - - - - - - - - X - - - - - - - - - - - - - - -
..............................*..............................

                          v  vvv    v
- - - - - - - - - - - - X X X X X - X - - - - - - - - - - - -
..........................*****.....*........................

                              v
- - - - - - - - - - - - - - X X - - - - - - - - - - - - - - -
.............................*...............................

                              v
- - - - - - - - - - - - - - - X - - - - - - - - - - - - - - -
..............................*..............................
```

1000 GeV, big clusters, "2N-5" declustering

```
                              v
- - - - - - - - - - - - - - X X - - - - - - - - - - - - - - -
.............................*...............................

                          v  vvv    v
- - - - - - - - - - - - X X X X X X X - - - - - - - - - - - -
..........................*********..........................

                              v
- - - - - - - - - - - - - - X X - - - - - - - - - - - - - - -
.............................*...............................

                              v
- - - - - - - - - - - - - - X X X - - - - - - - - - - - - - -
..............................*..............................
```