MESHCHERYAKOV LABORATORY OF INFORMATION TECHNOLOGIES

Overlapped signals delimitation for HEP experiments

Abstract

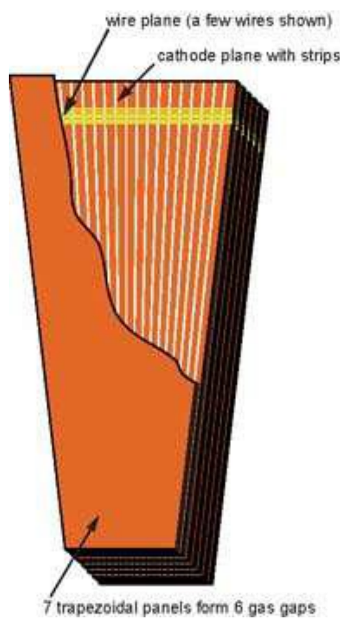
G.A. Ososkov, N.N. Voytishin, D.V. Fomenok

The third phase of the Large Hadron Collider's operation continues, characterized by higher luminosity and an increased multiplicity of overlapping signals. In the cathode-strip chambers of the CMS experiment, when charged particles pass through, electron avalanches are formed, which are registered as clusters (groups of signals from adjacent strips) with charges whose distribution in space can be approximately described by Gauss functions. Often there is an overlap of clusters from closely passing particles, which can lead to significant losses in accuracy in determining their coordinates. The currently used simple center of gravity algorithm does not provide the required accuracy for overlapped signals (the error is up to 40% of the strip width with the required accuracy of up to 5%). To solve this problem, a sequential elimination, spline-based and wavelet analysis algorithms are considered. The results of overlapped signals delimitation for all algorithms are presented and discussed.

Cathode-Strip Chambers [1]

Placement in experimental setup endcaps (0.8 < |η| < 2.4)

- 4 CSC stations
- 6 gaps per station
- per gap:
  - 1 wire plane (*R* coord.)
  - 1 strip plane (φ coord.)



Spatial resolution

100 – 250 μm

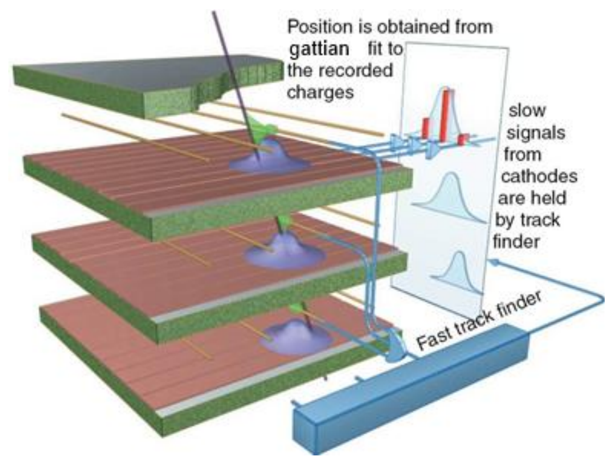
2D points (hits)

➢ φ coordinate measured by charge distribution on strips (fit with the Gatti function)

➢ R coordinate measured by wires

3D segments

Determined by fitting the 2D points from the 6 layers of each chamber.



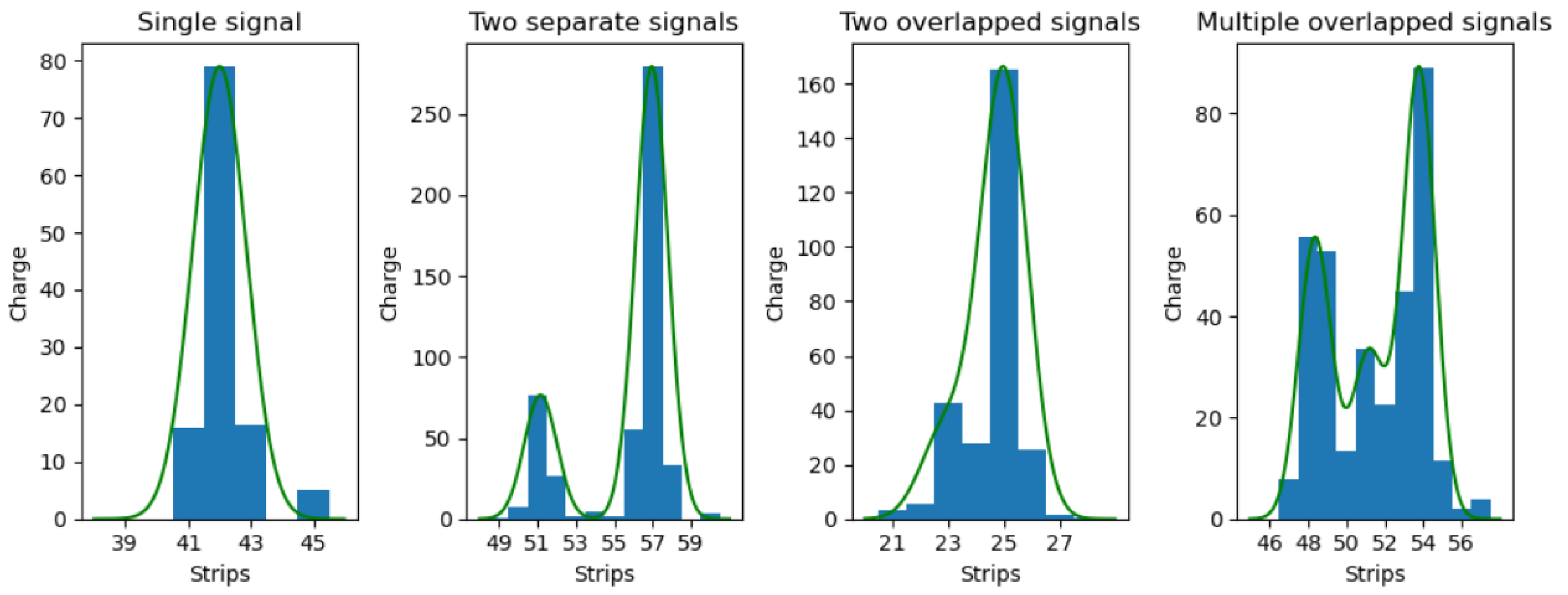
Center of gravity (CoG)

The coordinate calculated using the center-of-gravity algorithm is computed by the formula:

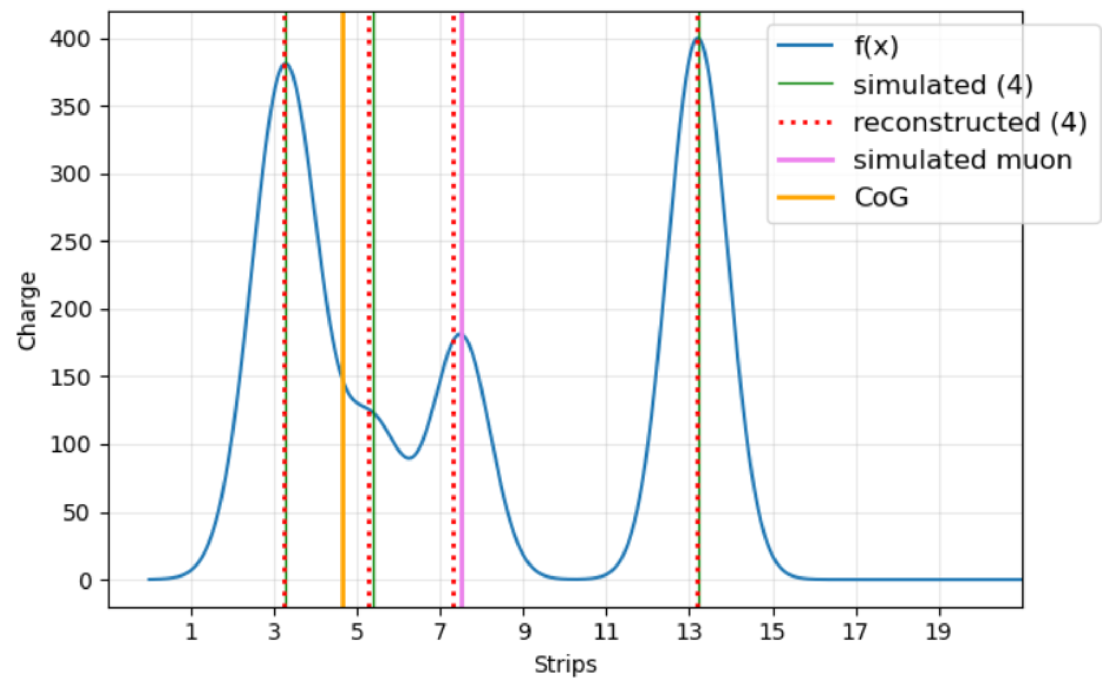
$$x_{CoG} = \frac{\sum_{i=1}^{N} x_i y_i}{\sum_{i=1}^{N} y_i},$$

where x_{CoG} – the coordinate of the muon, N – number of strips in the cluster, x_i – the number of the i-th strip, y_i – charge on the i-th strip.

Strip cluster distribution cases



Sequential elimination algorithm [2]



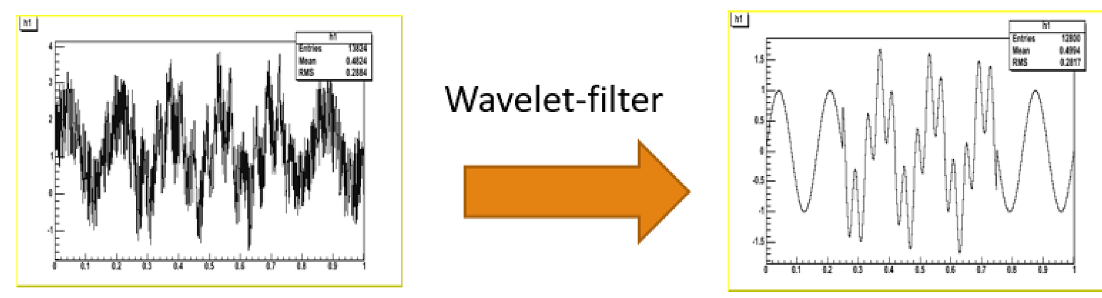
Model

The signal is a sum of gaussians and is described by formula:

$$f(x) = \sum_{i=1}^{n} A_i \exp\left(\frac{(x - x_{0i})^2}{2\sigma_i^2}\right),$$

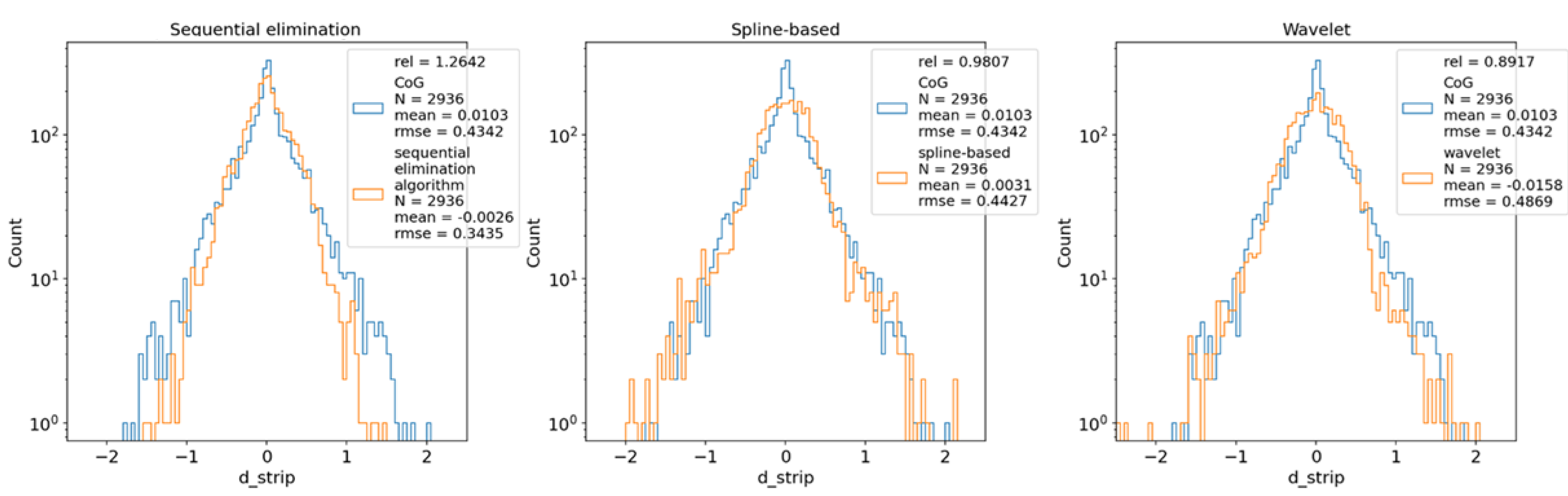
where n – number of particles, A_i – the amplitude of the i-th gaussian, σ_i – the half-width of the i-th gaussian, x_{i0} – the center of the i-th gaussian.

Wavelet analysis [3]

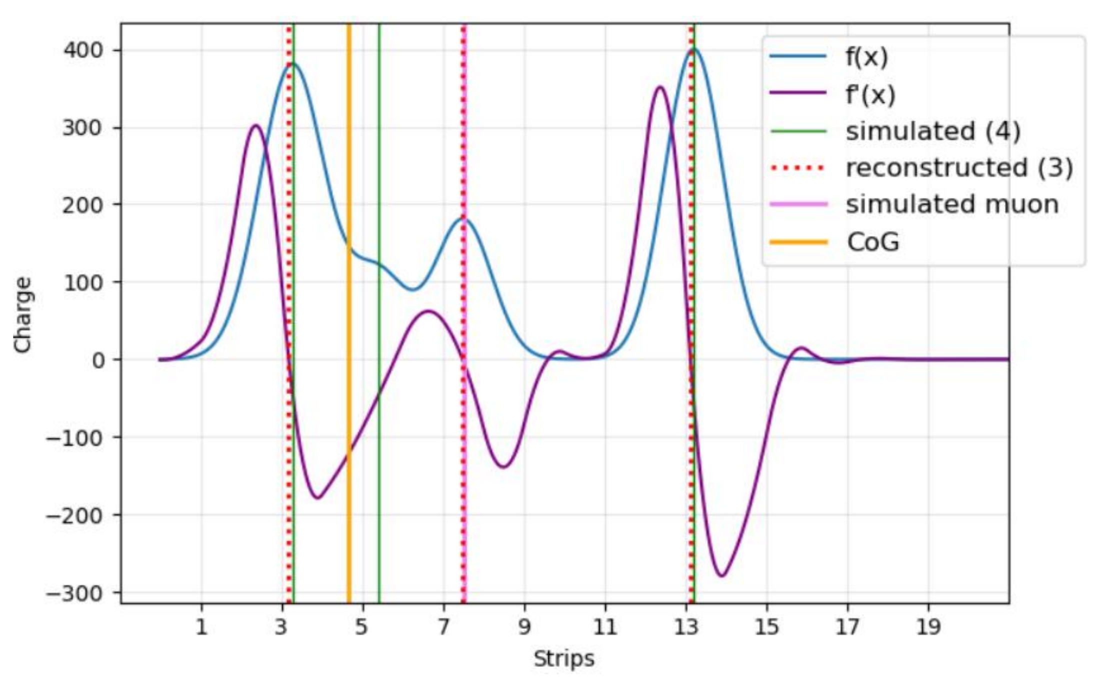


$$Wf = W_{g_2}(a,b)f = \sum_{i=1}^{n} A_i g_2\left(\frac{b - x_{0i}}{s}\right)$$

Difference between simulated and reconstructed muon coordinate



Spline-based algorithm



Conclusions

Sequential exclusion demonstrates the best result out of the considered algorithms. For CMS data with muon at 1 TeV transverse momentum, it reconstructs the muon coordinate 1.26 times closer to the true trajectory than the center-of-mass method, confirming its effectiveness for overlapping signal delimitation. The method can be applied for reconstruction of signals in similar detectors (BM@N, ATLAS, etc.)

References

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2. Agakishiev, H. Effective pulse resolution algorithms for detectors with gaussian-like shape / H. Agakishiev [et al.] // Community on JINR. – 1997.
3. Ososkov, G.A. Gaussian wavelet features and their applications for analysis of discretized signals / G.A. Ososkov, A.B. Shitov // Computer Physics Communications. – 2000. – Vol. 126. – P. 149-157.