Hit Reconstruction Improvements in the Cathode Strip Chambers of the CMS Experiment

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on behalf of CMS Collaboration

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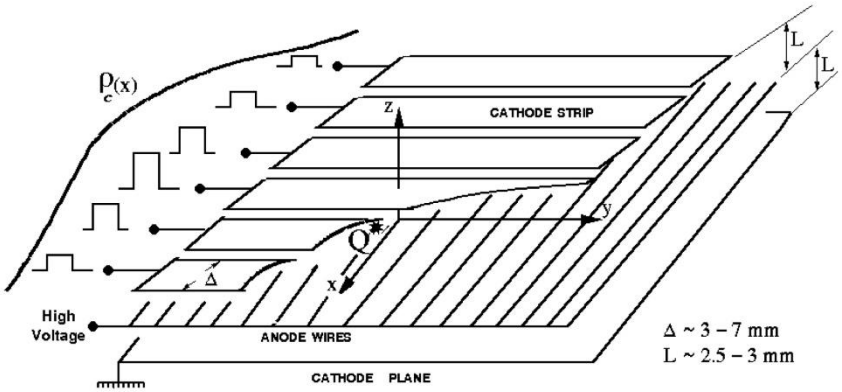
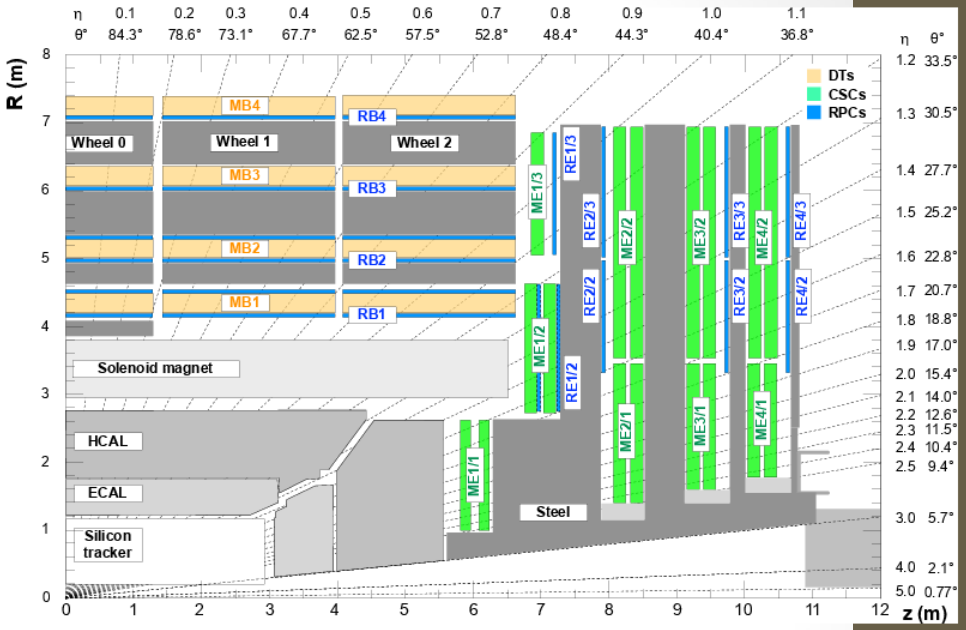
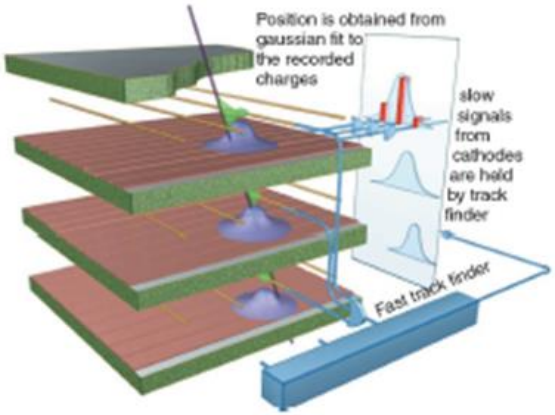
Cathode Strip Chambers @ CMS



The principle of working of cathode strip chambers



CSC placement in the CMS experimental setup



2D points

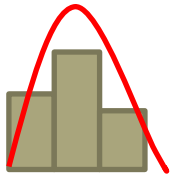
- ϕ coordinate measured by charge distribution on strips (fit with the Gatti function)
- R coordinate measured by wires

3D segments

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

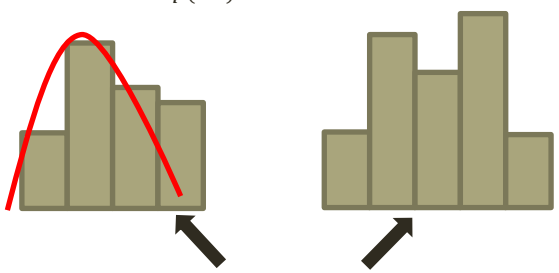
Why the improvement is needed ?

σ_{Gatti_fit} ~ 2% of strip width

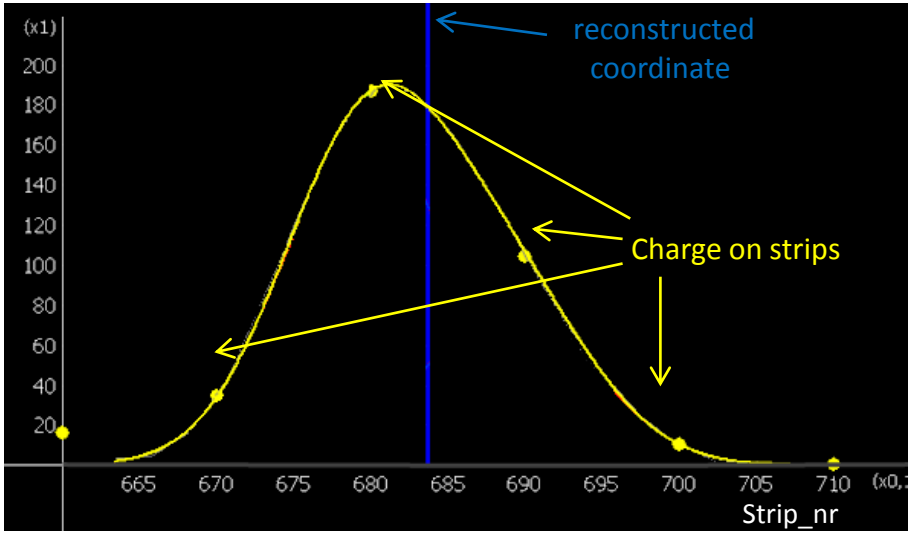


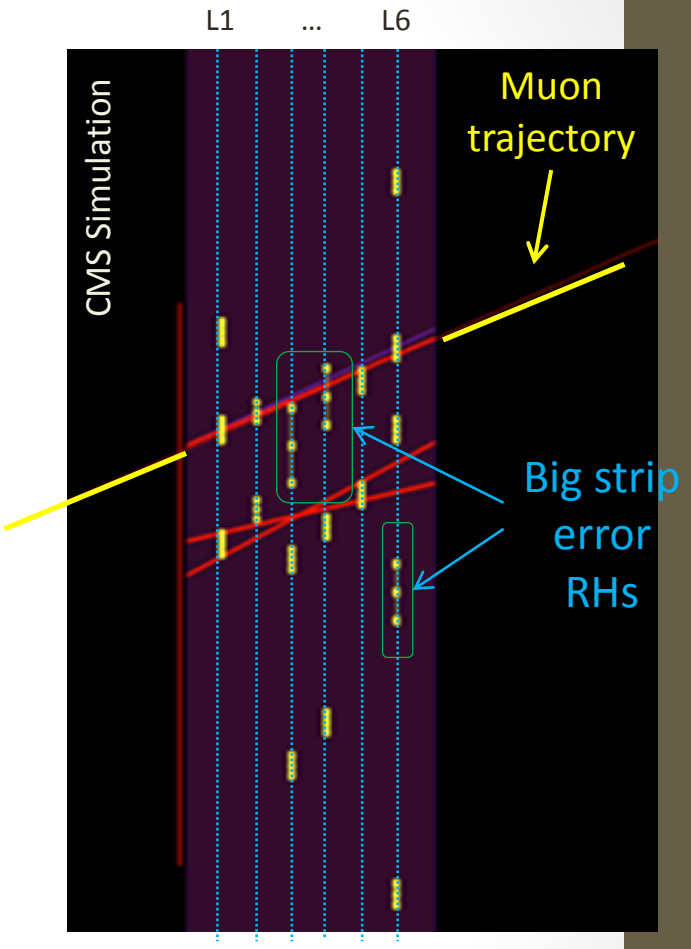
Regular strip charge distribution

$\sigma_{strip(RH)}$ > 30% of strip width



Abnormal strip charge distributions

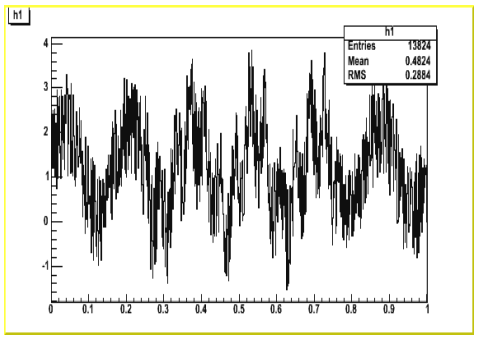




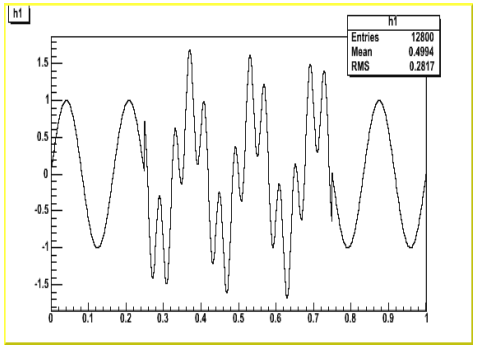
Event display in CSC
Hits with big strip errors fail to be add to the segment.

If $\sigma_{strip(RH)} > \frac{1}{3}\ of\ strip\ width$ =>
the coordinate is calculated using Center of Gravity (CoG) like algorithm

Wavelet analysis for overlapped signals delimitation



Wavelet-filter



The g2-WTS(Wavelet-TranSform method based on the usage of second degree wavelets (g_2))[1] was chosen by us for overlapping signal recognition.

The main function in wavelet analysis is the following double gaussian function

$$G(x; A, x_1; B, x_2) = A\exp\left(-\frac{(x-x_1)^2}{2\sigma^2}\right) + B\exp\left(-\frac{(x-x_2)^2}{2\sigma^2}\right) \quad (1)$$

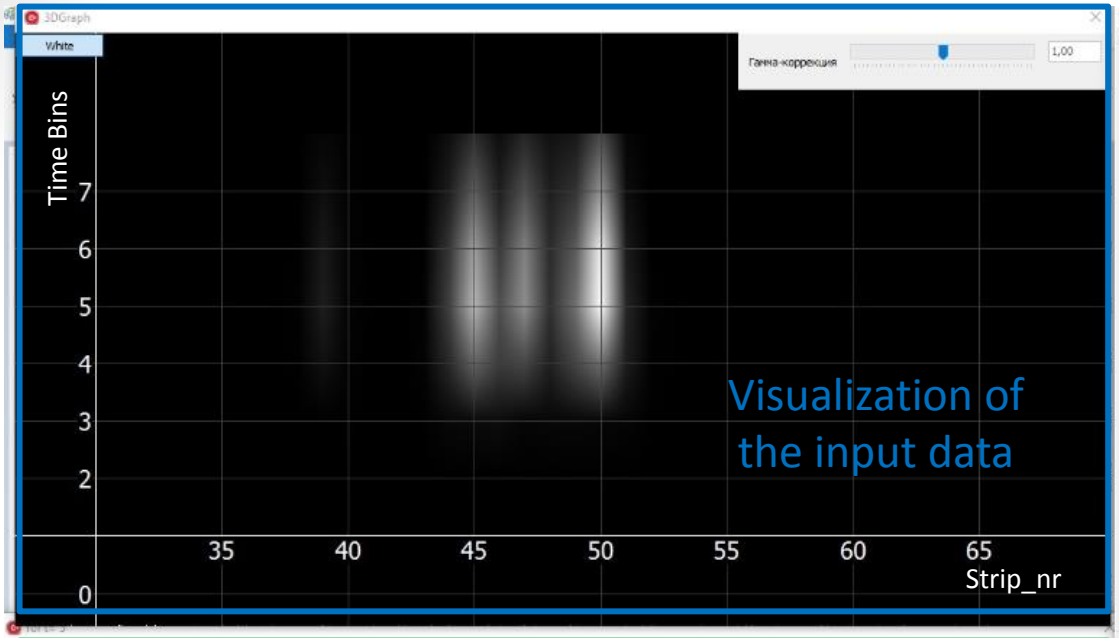
We build 2, 3 or 4 gaussians on a chosen interval of strips with a constant step. For the case of three overlapped signals the formula (1) looks as follows:

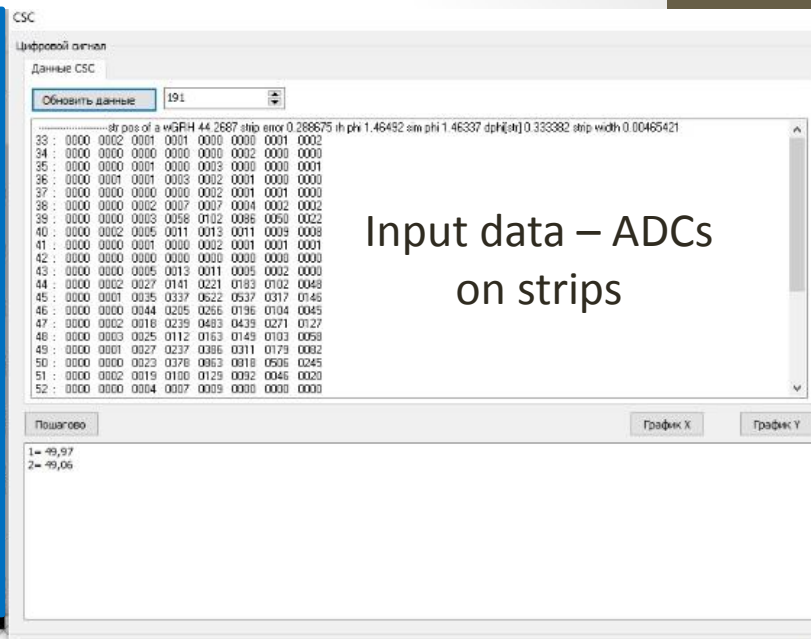
$$G(x, A_1, x_1, A_2, x_2, A_3, x_3) = A_1 e^{-\frac{(x-x_1)^2}{2\sigma_1^2}} + A_2 e^{-\frac{(x-x_2)^2}{2\sigma_2^2}} + A_3 e^{-\frac{(x-x_3)^2}{2\sigma_3^2}}.$$

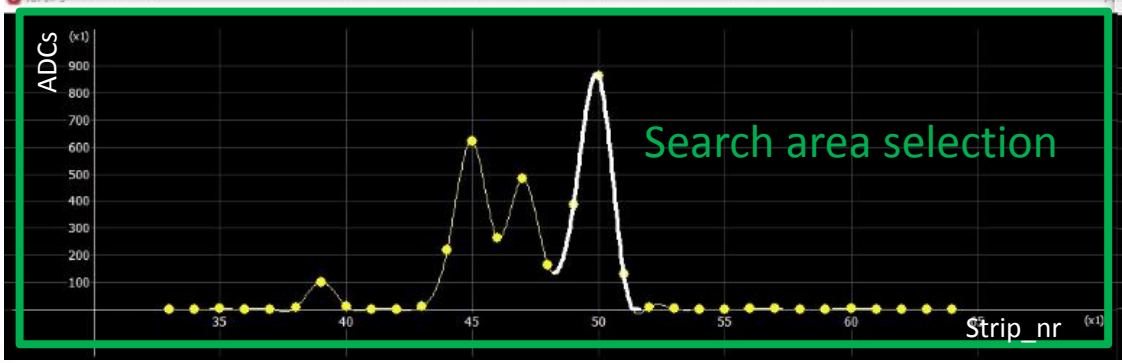
The parameters $A_1, x_1, A_2, x_2, A_3, x_3, \sigma_1, \sigma_2, \sigma_3$ of the overlapped signals are obtained by summation of the values of these gaussians in each coordinate x.

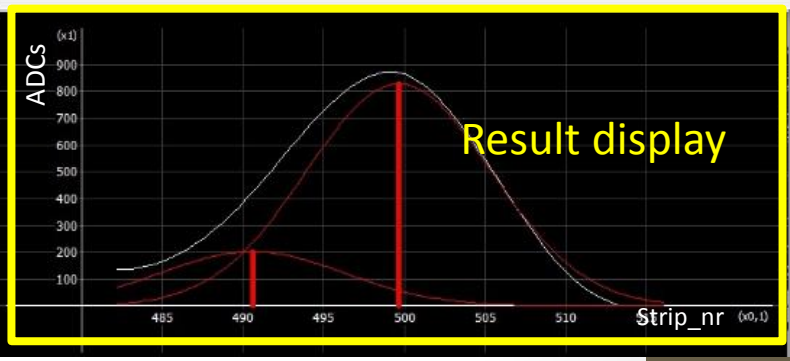
G.Ososkov, A.Shitov Gaussian Wavelet Features and Their Applications for Analysis of Discretized Signals // Comp.Phys.Comm, v.126/1-2, 149-157, (2000)

What has been done ?









Universal tool for overlapping signal recognition

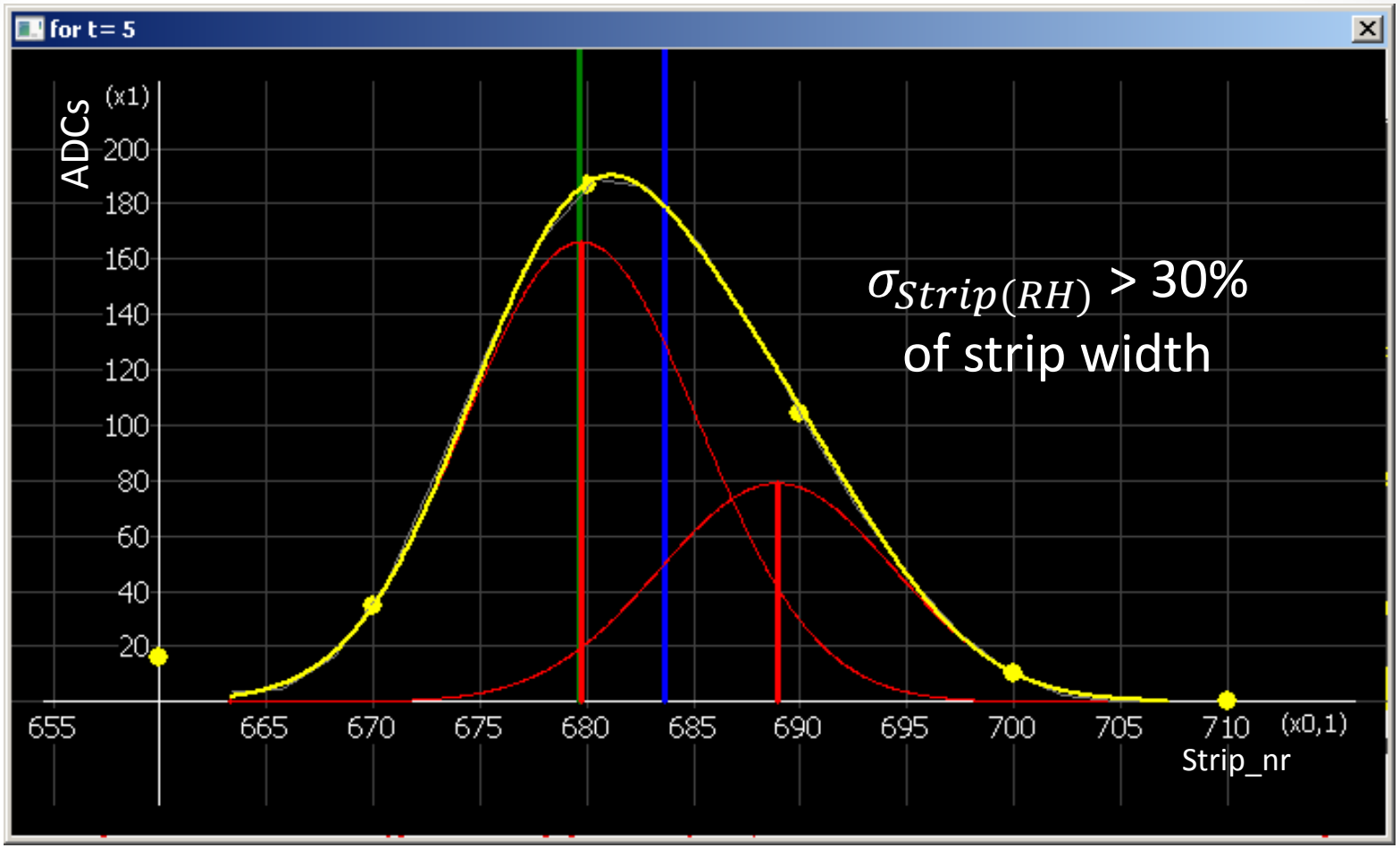
Good case example

The coordinate is well reconstructed by both methods.

Yellow line – initial charge distribution;
Green line – simulated muon coordinate;
Red line – wavelet analysis;
Blue line – standard approach (Gatti fit).

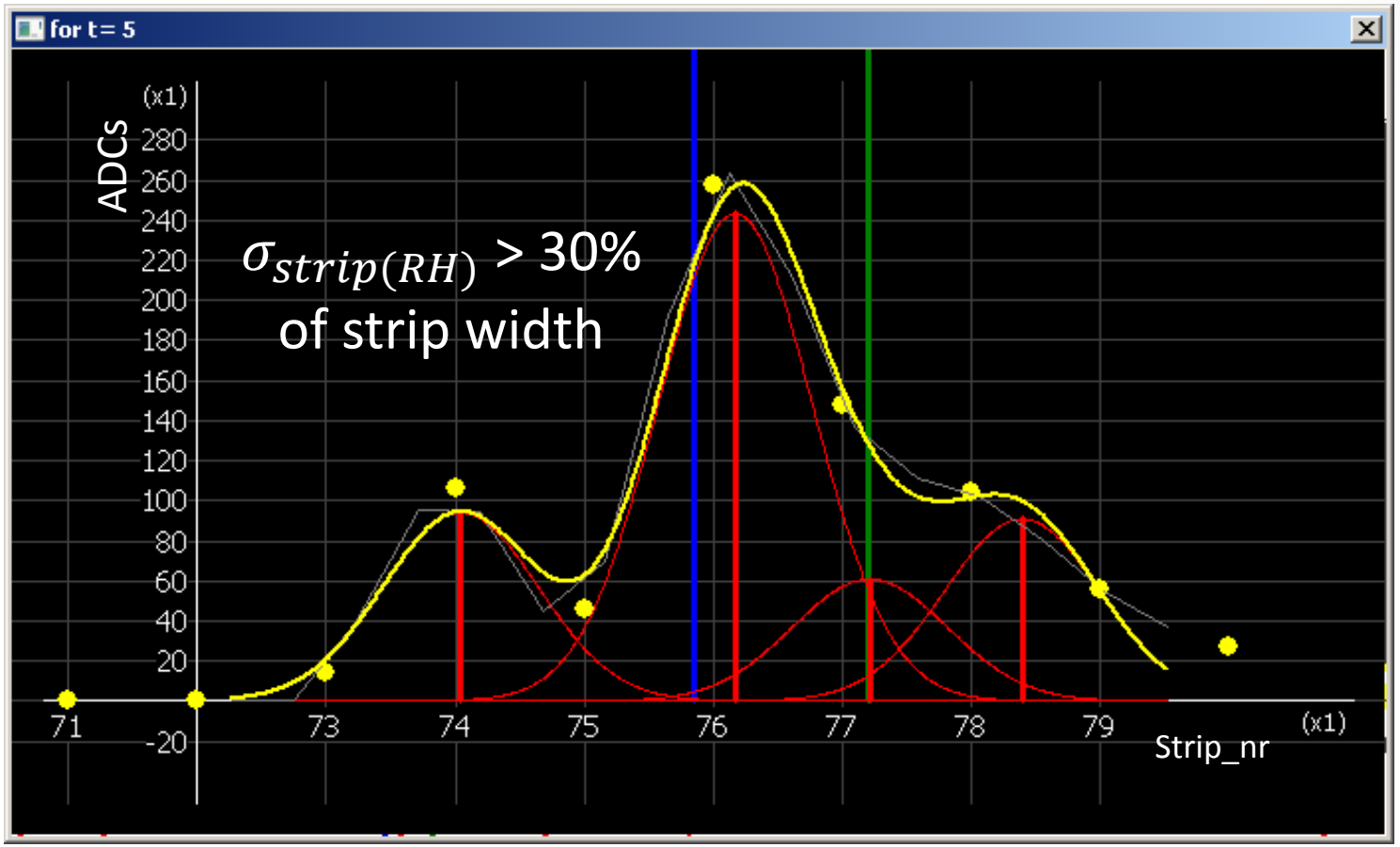
All three coordinates coincide

Two overlapped signals recognition



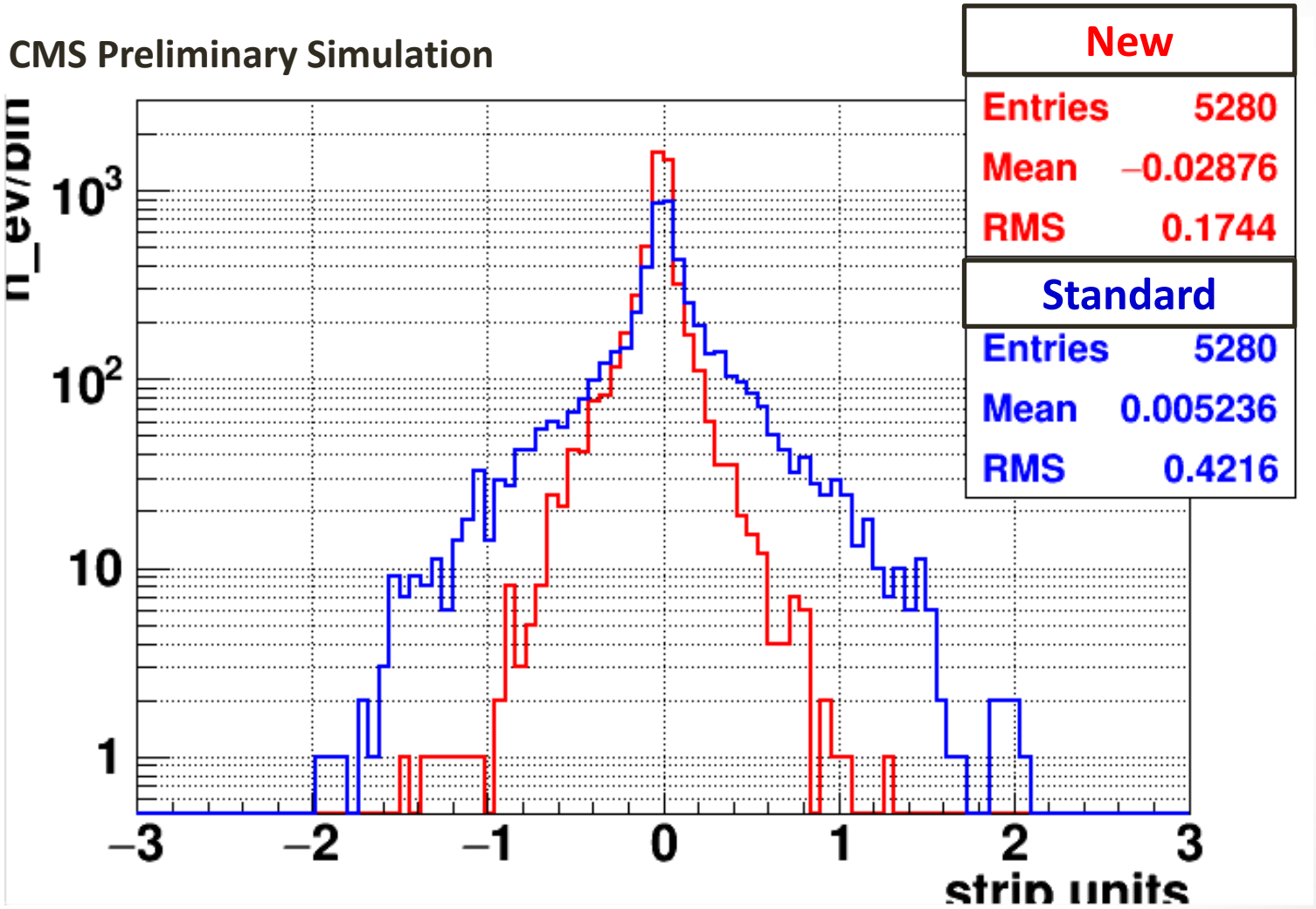
Yellow line – initial charge distribution;
Green line – simulated muon coordinate;
Red line – wavelet analysis;
Blue line – standard approach (CoG like).

Four overlapped signals recognition



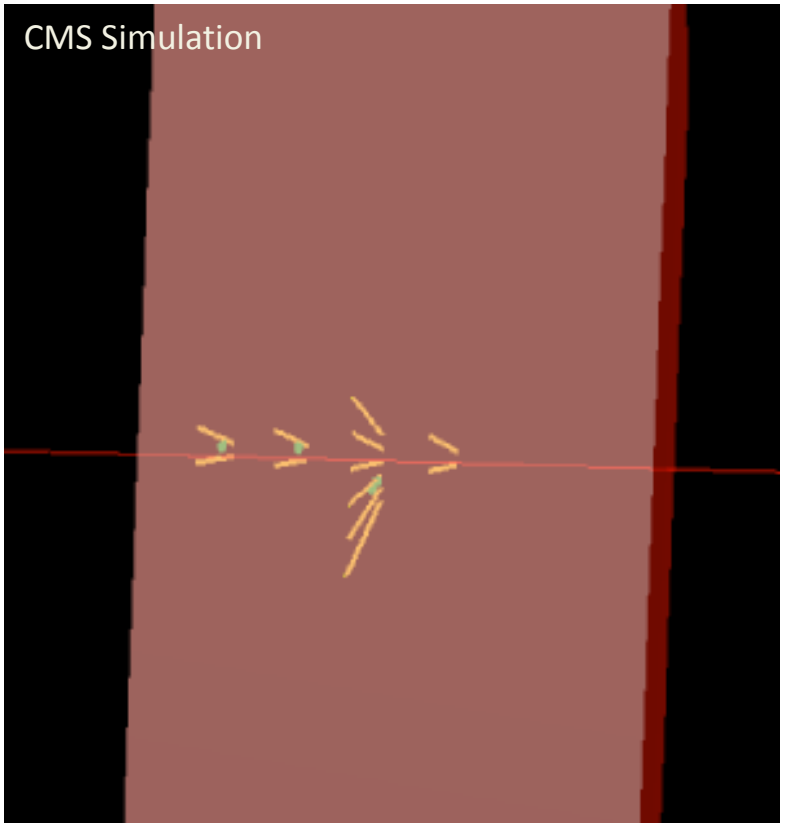
Yellow line – initial charge distribution;
Green line – simulated muon coordinate;
Red line – wavelet analysis;
Blue line – standard approach (CoG like).

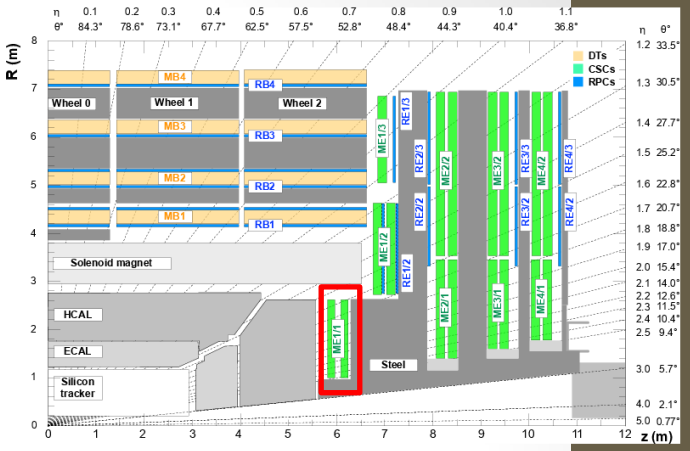
Difference in the φ coordinate between simulated and reconstructed hit



BLUE – standard approach; **RED** – wavelet analysis.

Particular event improvements





- First 4 layers with strip and wire information;
- The Segment Builder failed to reconstruct a 3-hit segment because of a very bad χ^2 caused by big differences in strip coordinates of the reconstructed hits

	L1	L2	L3
strip coordinate:	14.37	14.32	16.20

Yellow – "fired" strips;
Green – reconstructed hit;
Red – muon.

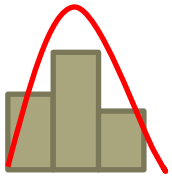
What's wrong?

- The hit on layer 3 must be on the same or neighboring strip as the two hits from the previous layers;
- There should be a hit on layer 4.

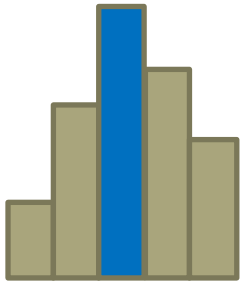
3rd layer problem

simple two overlapped signals recognition

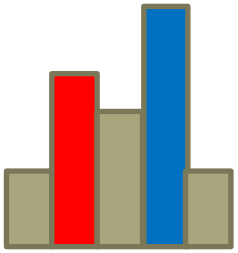
σ_{Gatti_fit} ~ 2% of strip width



Regular strip charge distribution

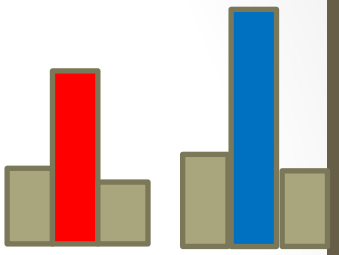


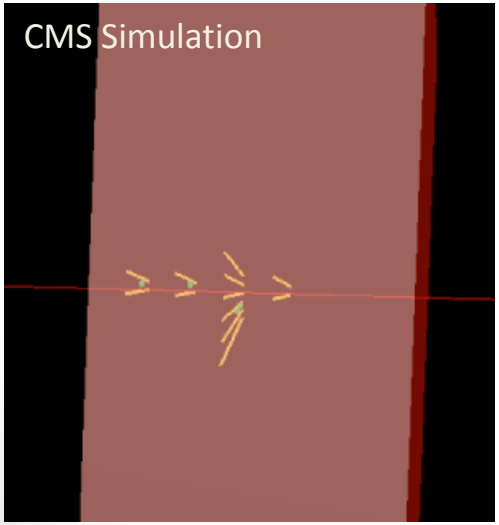
Regular wide cluster strip charge distribution

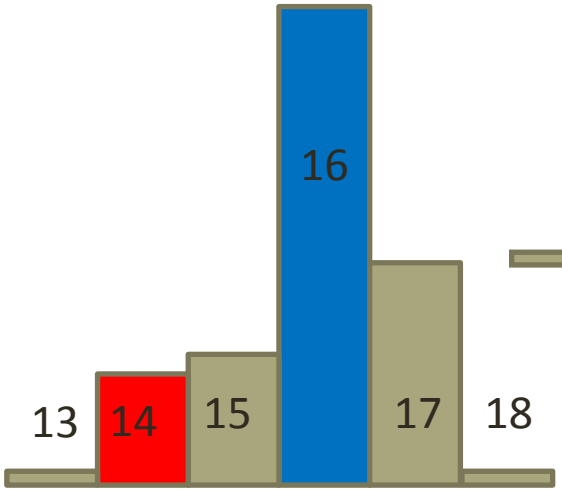


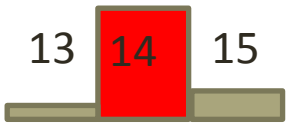
Abnormal strip charge distributions

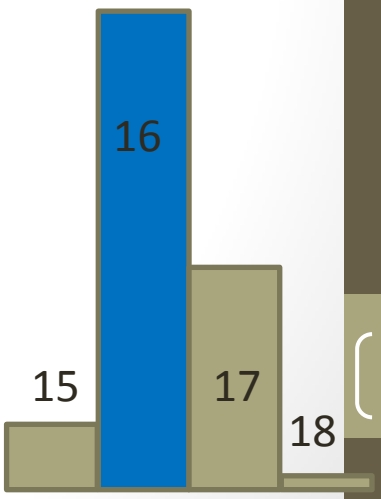
Make two maxima and share the charge of common strip proportionally











Strip ADC's

10 106 119 374 178 12

3rd layer problem solved

L1 L2 L3

14.37 14.32 16.20

χ^2 = 203.17

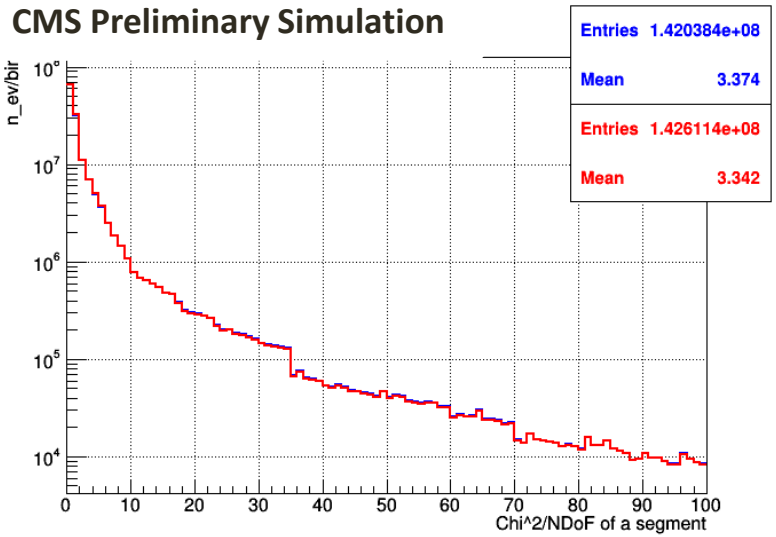
Abnormal charge distribution handling

L1 L2 L3

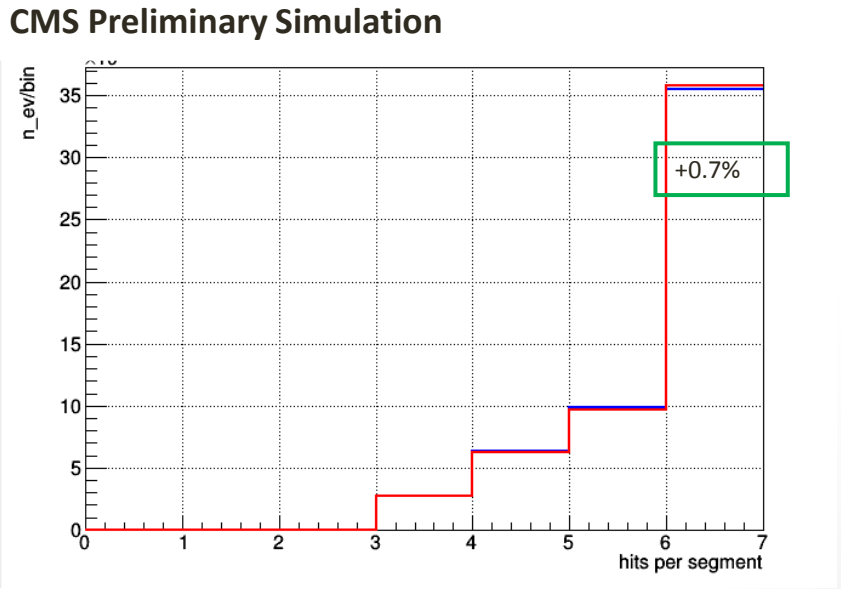
14.37 14.32 14.16

16.23

χ^2 = 2.82



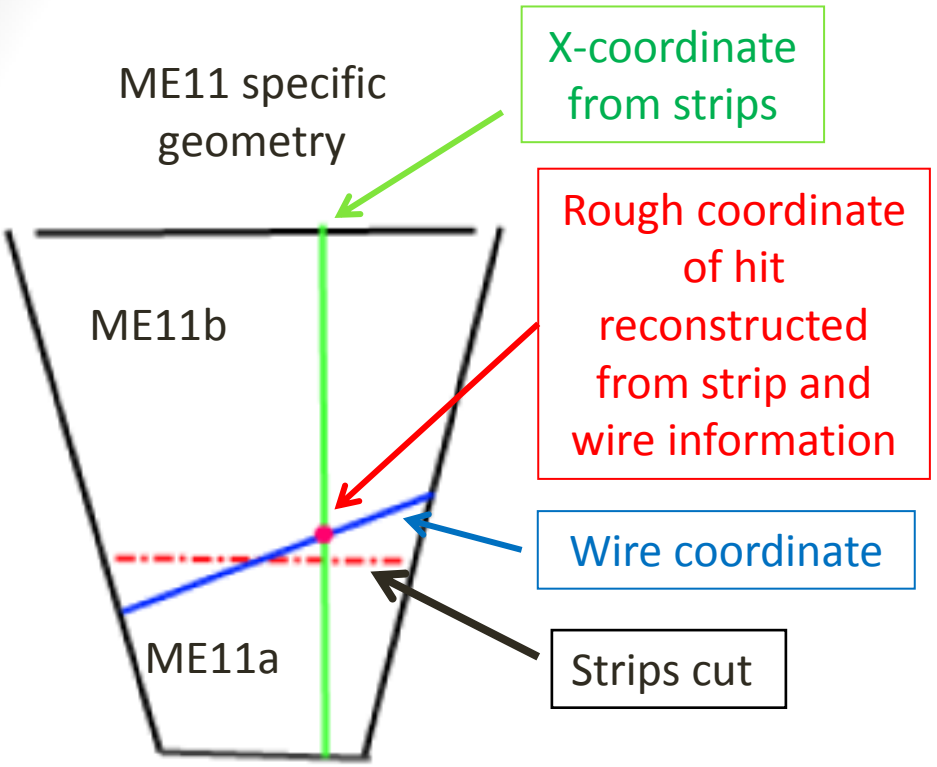
χ^2/NDoF of a segment

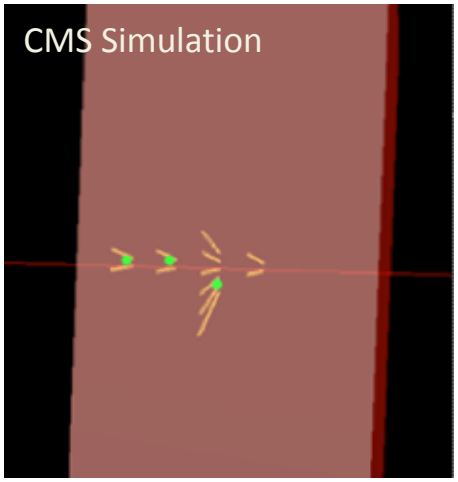


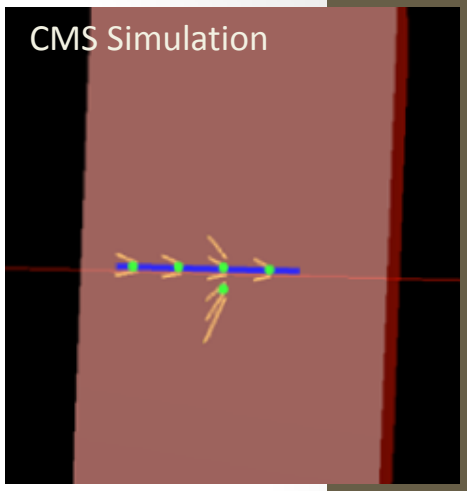
Number of hits per segment

BLUE – standard RH Builder; **RED** – abnormal strip distribution division

4th layer problem solving







Problem: Hit on layer 4 not reconstructed.
Cause: Old hardware required a preliminary check (at the software level) on whether the rough coordinate fitted into the chamber geometry.
Solution: After the hardware updates the check had to be modified.

L1 L2 L3

14.37 14.32 16.20

χ^2 = **203.17**

Make the check thresholds looser

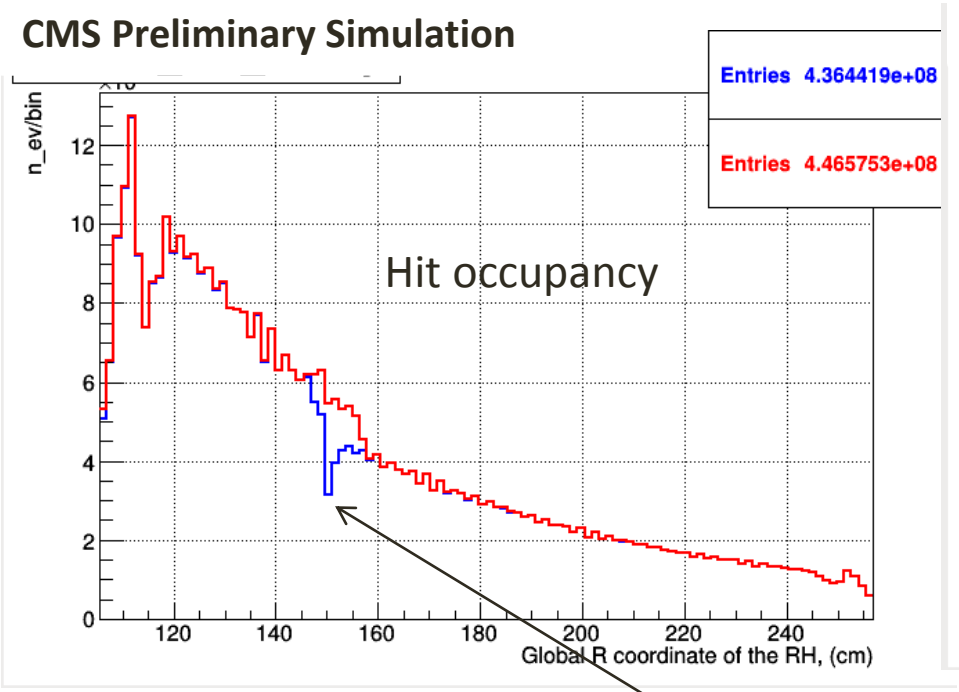
L1 L2 L3 L4

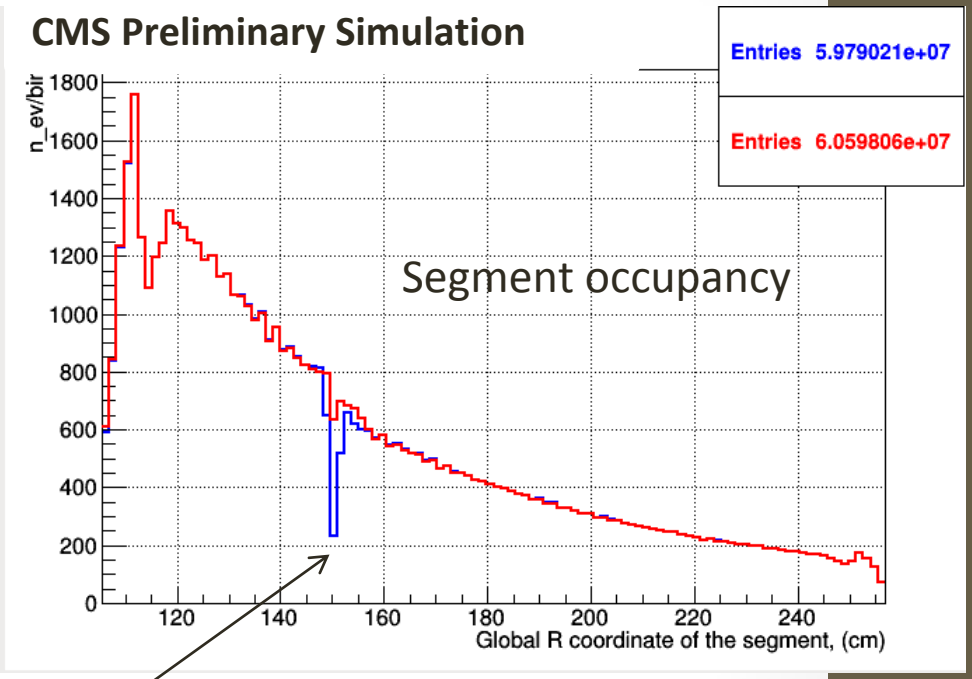
14.37 14.32 14.16 14.28

16.23

χ^2 = **1.01**

Hit and Segment occupancy in ME11



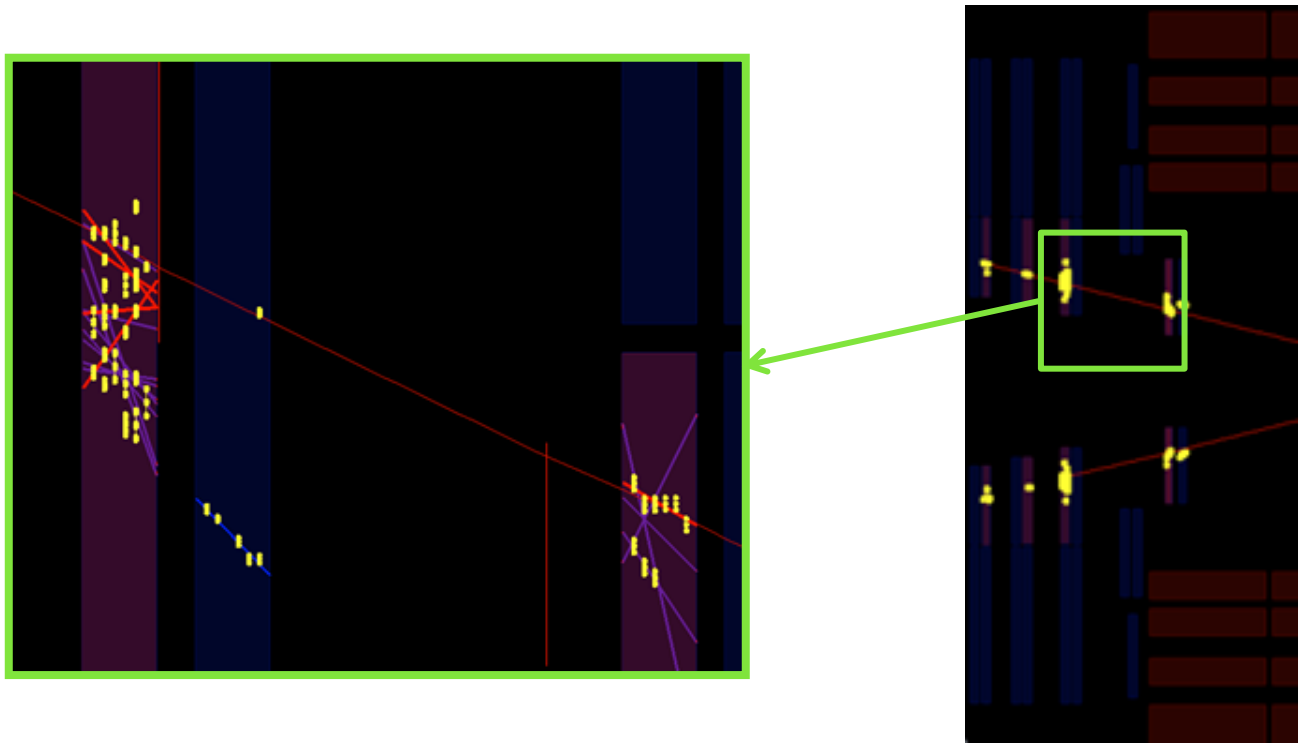


ME11 strip cut region

BLUE – standard RH Builder;

RED – thresholds made looser for strip cut region ± 5cm.

Road towards HL-LHC

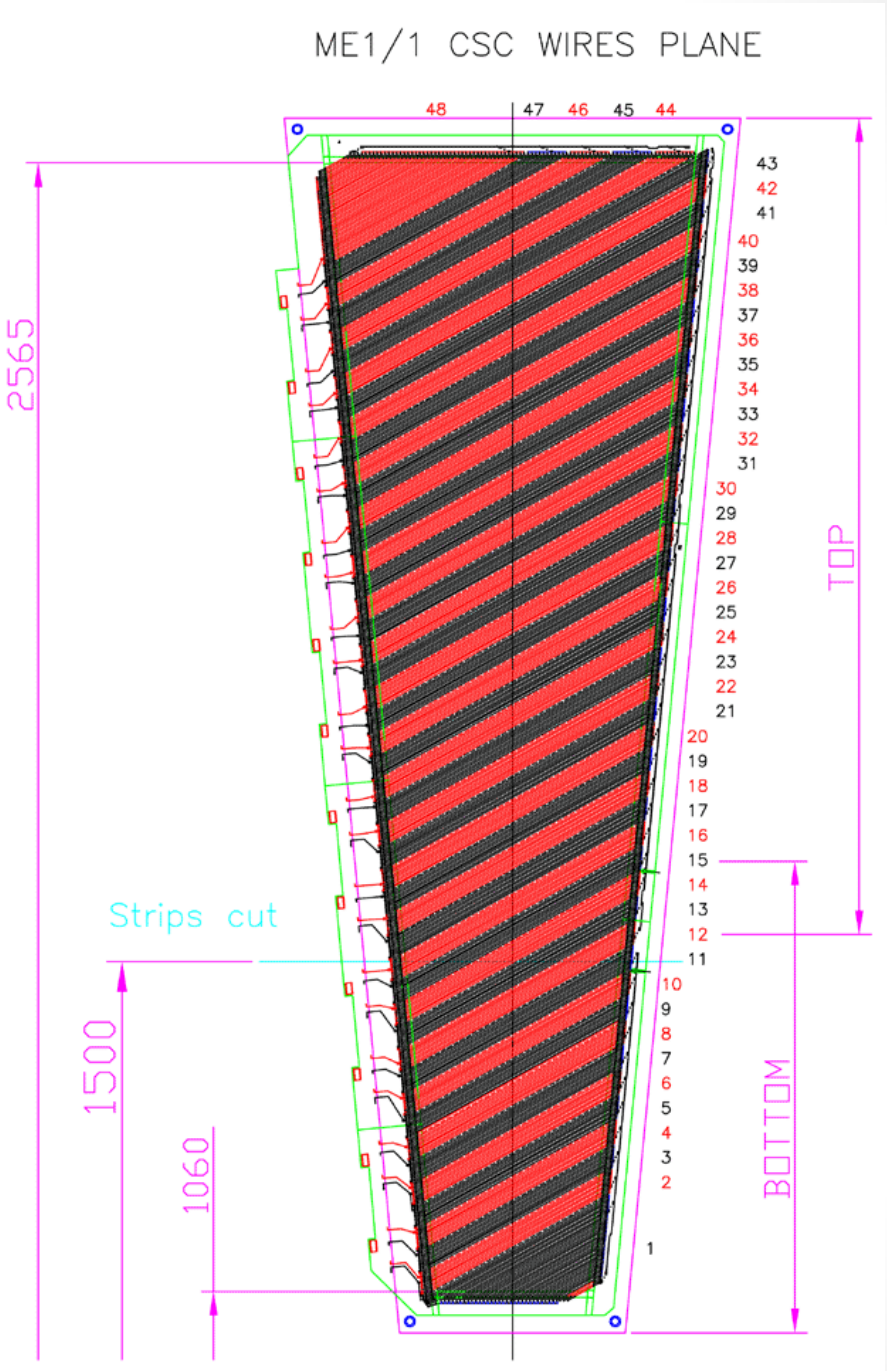


- Multiple places for improvements in terms of hit and segment reconstruction in CSCs;
- Different approaches can be used for solving the same problem.

Main goal: Get as much, and as accurate, information as possible for further steps of the particle trajectory reconstruction.

Back up slides

ME11


ME1/1 CSC WIRES PLANE
48
47
46
45
44
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33
32
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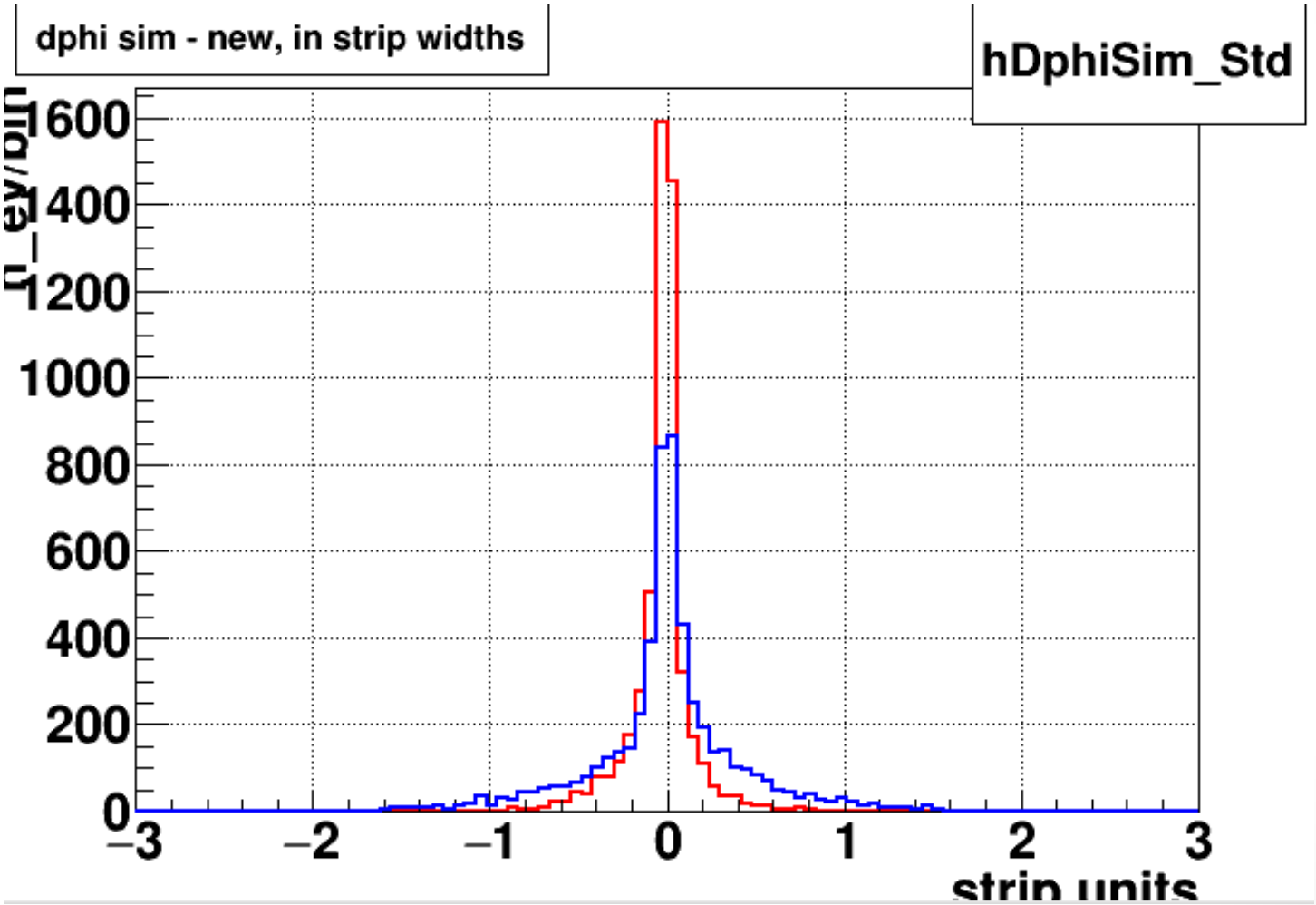
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
2565
TOP
Strips cut
1500
1060
BOTTOM

Same distribution of dphi for wavelets in linear scale



BLUE – standard approach; **RED** – wavelet analysis.