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Alignment Error and Muon Momentum Resolution

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Abstract

The muon momentum resolution of the CMS detector is studied as a function of alignment accuracy in the forward region.

The study presented is a continuation of the work described in [1]-[3]. In those calculations alignment errors were not taken into account. Here we discuss how the previous results are affected by systematic misplacement of the muon stations. We concentrate on the forward region because this area is the most demanding for the chamber resolution and the alignment.

The general CMS detector geometry described in the Status Report [4] was used (see also [3]). The forward muon stations were assumed to contain 6-layer Cathode Strip Chambers having 5 mm thick gas volumes interleaved with 22 mm thick honeycomb plates. Every CSC layer was assumed to be 80 % efficient.

The intrinsic detector resolution was simulated by a gaussian smearing of every measurement point. The following values of σ were assumed:

	$r\varphi$	r, z	
vertex	20 μm	5.3 cm	
Silicon tracker mono-layers	15 μm	12.5 cm	$/\sqrt{12}$
Silicon tracker stereo-layers	15 μm	0.1 cm	
MSGC tracker mono-layers	60 μm	12.5 cm	$/\sqrt{12}$
MSGC tracker stereo-layers	60 μm	0.1 cm	
MS 1-4	200 μm	0.2 cm	
MF 1-4	var.	0.7 cm	$/\sqrt{12}$

Alignment error was simulated by a random displacement of a whole muon station, i.e. all measured point in a given station were moved by the same random number having a gaussian distribution with σ varying from 0 to 200 μm.

The track fitting was done using the GEANE package [6] incorporated into the CMSIM program [7, 5]. Calculated transverse momentum resolution assuming no alignment error is plotted in Fig. 1 as a reference. Multiple scattering limit is denoted as 1 μm resolution. Influence of the alignment accuracy is shown in Fig. 2 and 3 for the constant CSC resolution of 50 and 100 μm respectivly. It is seen that alignment error higher then the chamber resolutions deteriorates the performance of the system and makes the fit unstable. On the other hand one cannot gain much by improving alignment below the chamber resolution level. Fig 4 shows then the dp_t/p_t assuming that the alignment accuracy is equal to the single layer CSC resolution.

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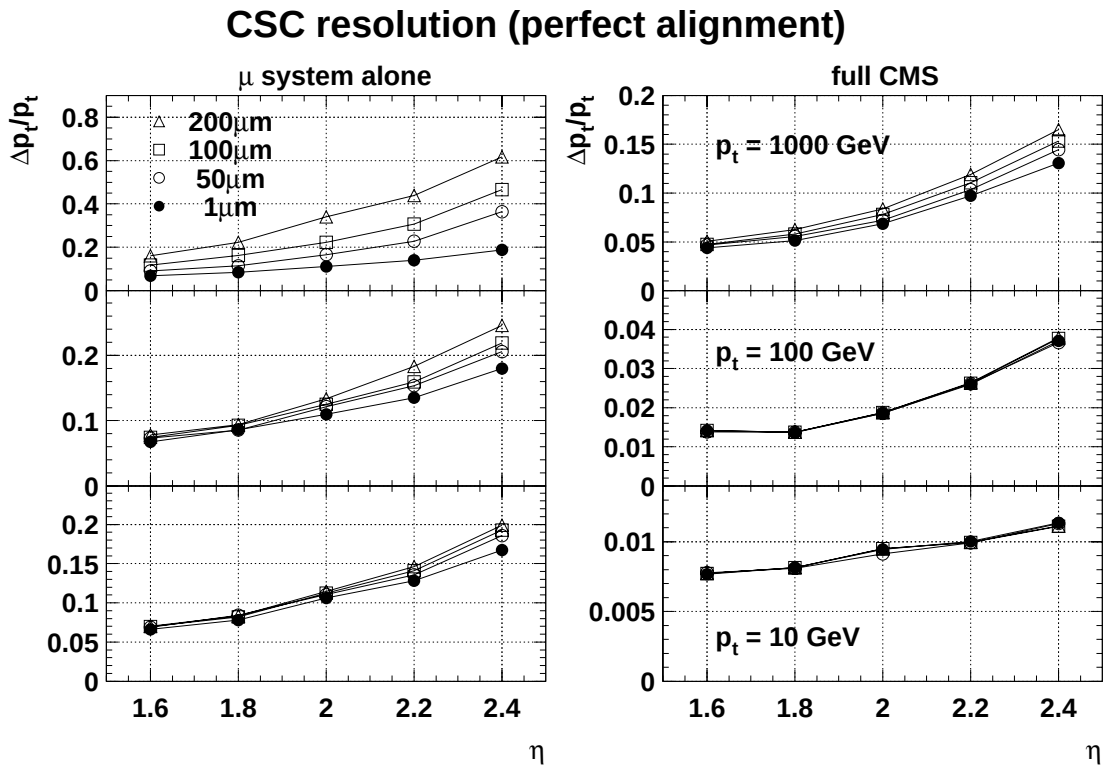

Figure 1: Momentum resolution for various single layer σ assuming perfect alignment.

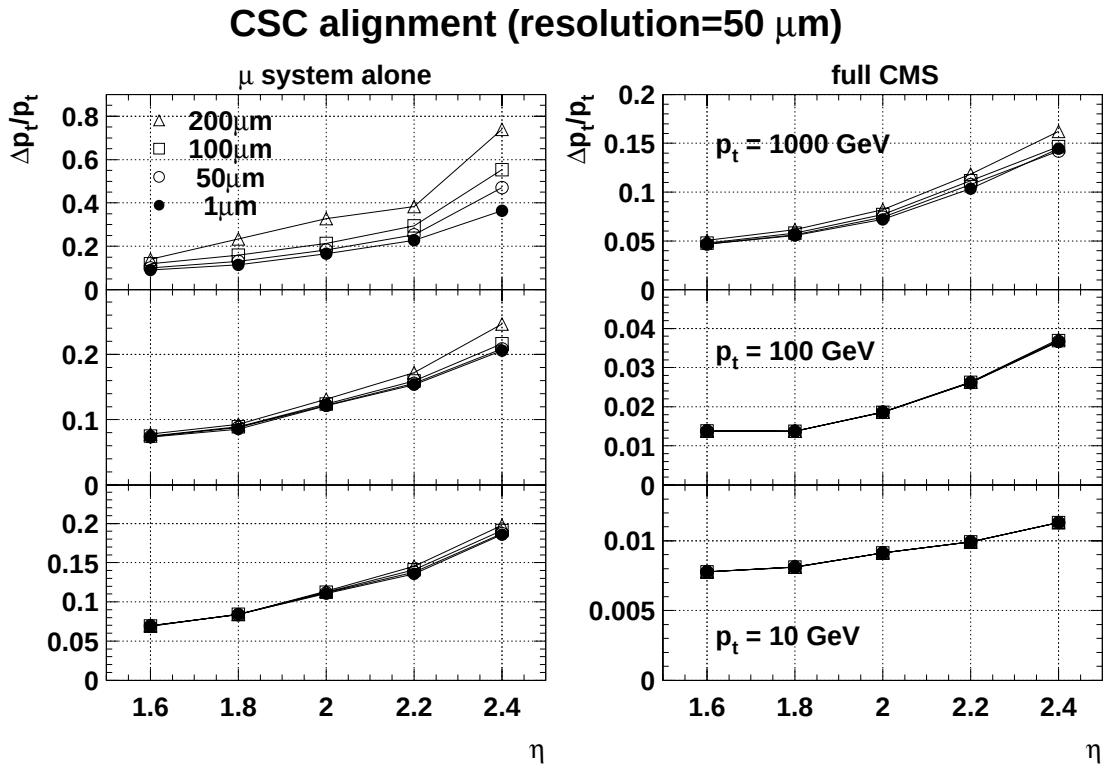

Figure 2: Momentum resolution for various values of alignment error assuming single layer $\sigma = 50\mu$m.

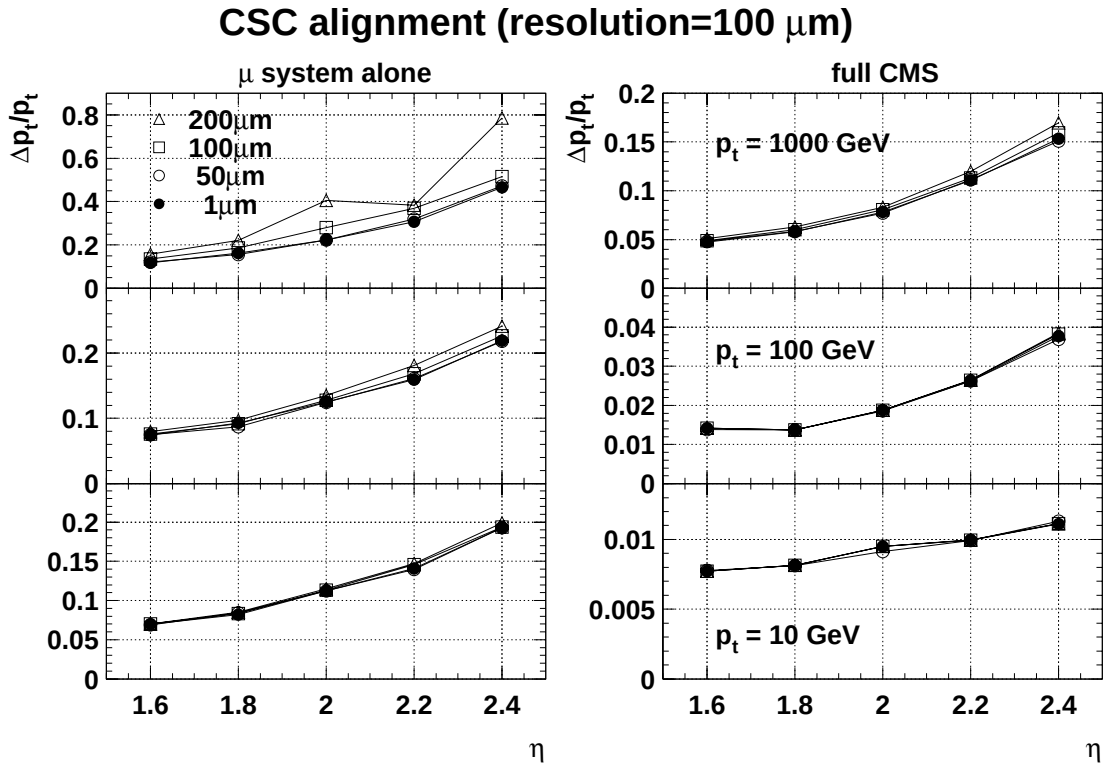

Figure 3: Momentum resolution for various values of alignment error assuming single layer $\sigma = 100\mu$m.

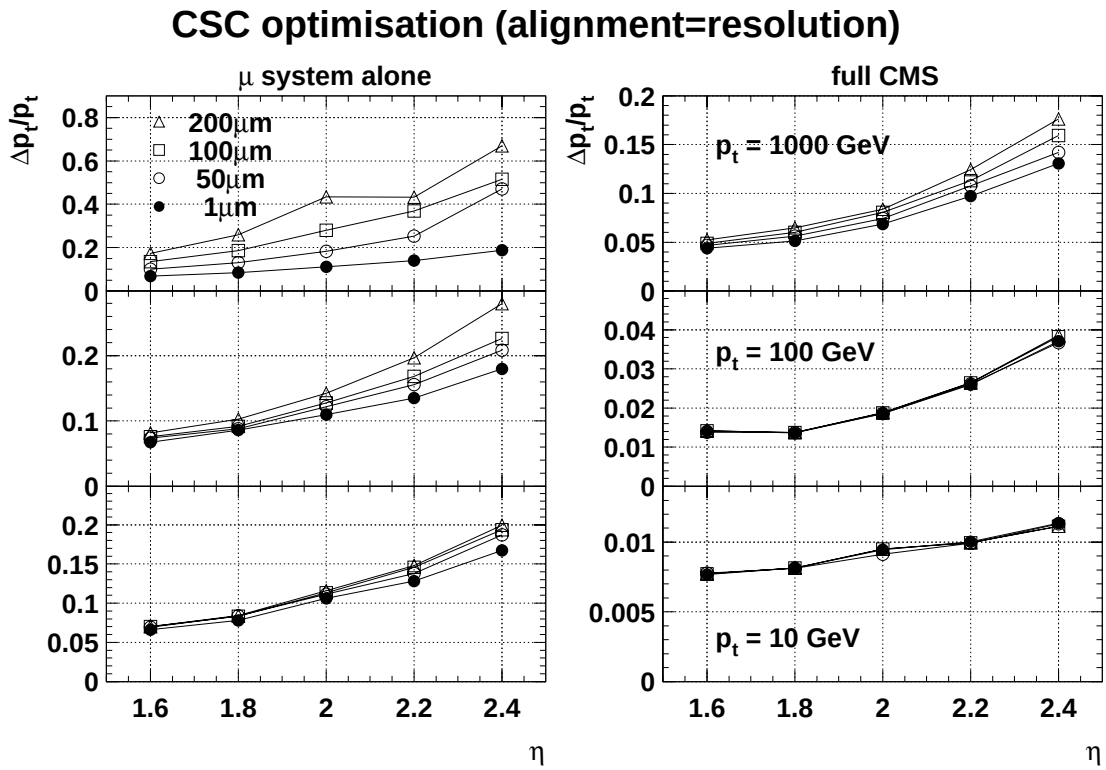

Figure 4: Momentum resolution for various values of alignment error and single layer σ assuming they are equal.

Another way to compare the results is to look for the dp_t/p_t values at fix p_t and η. The table below shows the example of $p_t = 1$ TeV and $\eta = 2$.

dp_t/p_t [%] at $p_t = 1$ TeV and $\eta = 2$

CSC σ [μm]	alignment error [μm]			
	1	50	100	200
1	12			
50	16	17	20	27
100	21	21	23	30
200	30			37

Summarising the study one can conclude:

- single layer CSC resolution should be in the range 50 - 200 μm,
- alignment accuracy should be in the range 50 - 200 μm,
- in this range variation of the stand alone muon momentum resolution is slower then linear,
- variation of the overall momentum resolution is visible only for highest p_t and it is very slow.

Reducing errors below 50 μm one cannot gain anything more because of the multiple scattering limit. Above 200 μm the performance of the system is degraded significantly and the fitting procedure became unstable. However in the range of 50 - 200 μm the performance of the system varries rather slowly, leaving room for optimisation. A possible gain in the performance has to be traded off against an increase of the cost. Since the chamber resolution is "more expensive" than the alignment one, the 200 μm CSC resolution and 100 μm alignment error can be considered as target numbers.

At the end it should be pointed out that in this study a perfect pattern recognition was assumed. What is an impact of the discussed errors on the track finding efficiency is not yet known and should be studied.

References

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[4] CERN/LHCC 93-48, *"CMS Status Report and Milestones"*.

[5] CMS TN/93-63, C.Charlot et al., *"CMSIM-CMANA, CMS Simulation Facilities"*.

[6] V. Innocente, M. Maire and E. Nagy, *"GEANE: Average Tracking and Error Propagation Package"*, CERN Program Library W5013-E (1991).

[7] CMS TN/94-151, V.Karimäki, *"Overall muon momentum fit in the CMS detector"*.