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Primary Vertex Resolution Measured with Data Driven Two-Vertex Method at $\sqrt{s} = 0.9/2.36$ TeV

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Abstract

This note introduces a data driven algorithm, referred as two-vertex method, to measure primary vertex postion resolution. In two-vertex method, the tracks used in the primary vertex fitter are split into two different sets and used to independently fit the primary vertex. The distribution of the difference in the fitted vertex positions can then be used to extract the resolution. The primary vertex resolution dependence on the number of tracks used in fitting the vertex and the $P_T$of those tracks are presented for the data collected at $\sqrt{s}$ = 0.9 and 2.36 TeV collsion during 2009 in CMS.

Contents

1 Introduction

The event primary vertex resolution is given by the uncertainty reported by the primary vertex algorithm. The reconstruction of the primary interaction vertex in the event starts from the track collection. Tracks are first filtered with cuts on the impact parameter, number of hits, and the χ^2 per degree of freedom. The filtered tracks are then clustered in z. Clusters are split when there is a gap over a thresold. The tracks in the cluster are then fit with an Adaptive Vertex Fit, where tracks in the vertex are assigned a weight between 0 and 1 based on their compatibility with the common vertex.

The resolution on the primary vertex is tightly coupled to the impact parameter resolution of a track. The primary vertex resolution is then a strong function of the number of tracks used in fitting the vertex, and the $P_T$of those tracks. It is not mathematically possible to define a primary vertex resolution for a specific sample since each vertex is independent and has its own uncertainty. Therefore, the best we can do is to try to measure an average resolution of an event ensemble.

In this note, we introduce the data-driven method, referred as two-vertex method, to measure the vertex resolution dependence on the number of tracks used in the primary vertex. In the two-vertex method, the tracks used in primary vertex in an event are split into two different track sets, and then used to independently fit the primary vertex. The distribution of the difference in the fitted vertex positions can then be used to extract the resolution and pulls.

2 Data Samples and Event Selections

This analysis is performed with the data collected at the center-of-mass energy of 900 GeV and 2360 GeV.

2.1 Data Samples

We use *December* $19^{\rm th}$ reprocessing of the collected data and MC datasets:

- /MinimumBias/BeamCommissioning09-BSCNOBEAMHALO-Dec19thSkim_336p3_v1/
- /MinBias/Summer09-STARTUP3X_V8K_900GeV-v1/
- /MinBias/Summer09-STARTUP3X_V8L_2360GeV-v1/

For the collision dataset, the alignment parameters of the silicon tracker were computed with about two million of cosmic ray tracks collected in November 2009 and the nominal values of the alignment parameter errors (APE) have been used in the reconstruction. The simulated events used in this note are minimum-bias events produced with PYTHIA 6.4 [**?**] event generator at center-of-mass energies of 900 GeV and 2360 GeV and processed with a simulation of the CMS detector response based on GEANT 4 [**?**]. The applied misalignment, miscalibration and dead channel map correspond to the expected start-up conditions. The longitudinal distribution of the primary collision vertices has been tuned to match the real data. The signal in the silicon strip tracker was simulated in *peak* mode in agreement with the mode used in the readout chips, during the data taking [**?**].

To select the minimum bias collsion events, the skimmed collision dataset has the following technical trigger bits requirements:

- BSC trigger: technical trigger bit 40 or 41
- Veto BeamHalo: Triggers: 36, 37, 38, 39

In addition, we apply technical trigger bit 0 to pick up the correct bunch crossing for data. Note that this is not simulated in MC.

2.2 Event Selection

To reduce further the background from non-collision events and to select useful events for tracking studies, we have the following event selections:

- At least one real primary vertex reconstructed

- fraction of *highPurity* tracks larger than 20% if the number of reconstructed tracks is larger than 10.

Table 1 shows the selection effcidency and final number of events analysis in each datasets.

Table 1: List of datasets and selection efficiency. The selection efficiency on n-th colomn is obtained in addition to the cuts in the preceding n-1 columns.

Dataset name	Trigger	primary vertex	track high purity	Events left
900 GeV Dec19thSkim	100%	94%	100%	260,000
900 GeV STARTUP3X_V8K	67%	93%	100%	256,000
2360 GeV Dec19thSkim	100 %	95%	100%	12,959
2360 GeV STARTUP3X_V8L	68%	94%	100%	12,491

3 Primary Vertex Resolution Measured with Two-Vertex Method

3.1 Two-vertex algorithm description

3.1.1 Track splitting

3.1.2 Vertex Fitting

3.1.3 Resolution and pull analyzing

When comparing the two fitted vertices, it is important that the number of tracks used in the final fitted vertices and the ΣP_T and z of the two vertices do not differ by too much. As we sort the tracks according the P_T prior to the splitting step, the difference of the ΣP_T between the two vertices are negligible. We select on the following two variables to ensure the number of tracks and vertex z difference of the two vertex is small:

- Relative difference of the number of tracks used in the two vertices, $|\frac{\mathtt{nTrk(vtx1)}-\mathtt{nTrk(vtx2)}}{\mathtt{nTrk(vtx1)}+\mathtt{nTrk(vtx2)}}| < 0.1$
- The separation signficance in z, defined as $\frac{|z(vtx1)-z(vtx2)|}{\mathtt{max}(\sigma\mathtt{z(vtx1)},\sigma\mathtt{z(vtx2)})} > 5$

Figure 1 shows the distribution of these two variables before applying the cuts. The selection efficiency of the two cuts is found to be 74% in both data and MC.

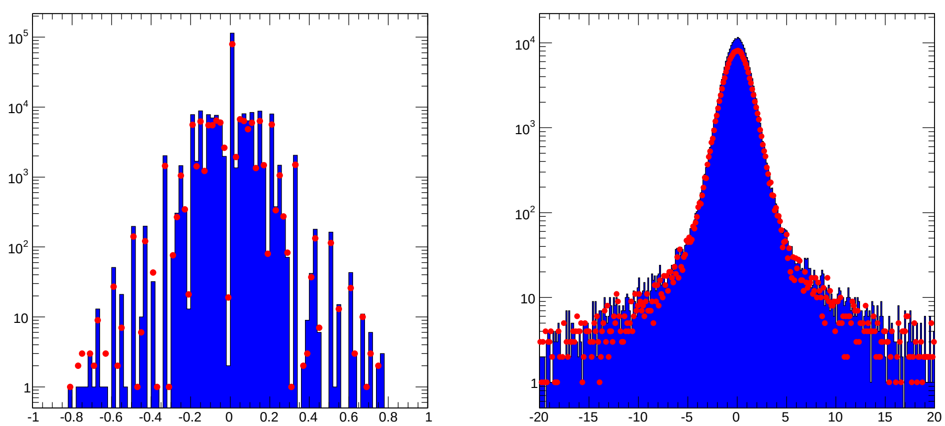

Figure 1: *Left: The relative difference of number of tracks used in the two vertex fit; Right: The z-signficance of the two vertex fit. Please see text for the definition. Data is shown with red dots while MC is shown as histogram filled in blue.*

3.2 Resolution and pulls in different P_T ranges

4 Two-vertex method validation on MC samples

In Monte Carlo, the resolution of the primary vertex positions can be easily evaluated by comparing the reconstructed positions with the simulated positions. This is also referred as MC method later. In the MC method, the residual is defined as $x_{\tt rec} - x_{\tt sim}$.

We can validate the procedure of the two-vertex method by comparing the results using the two-vertex method to the results obtained with MC method. Figure 2- 3 show the resolution and pull as a function of the nubmer of tracks used in the primary vertex for four different methods. In each plot, the results of the following four methods are overlaid:

- Black: MC method applied on the unsplit vertex collection
- Red: MC method applied on the first split vertex collection
- Green: MC method results applied on the second split vertex collection
- Blue: Two-vertex method results

We see good agreement between the resolution obtained using MC method and two-vertex method. There is slight difference at large number of track bins (>10) between the resolutions obtained by applying MC method to the unsplit trackset and the rest of the methods. It is because of the ¡P_T¿ of the split track sets are in general 100 MeV larger than the original *generalTracks*.

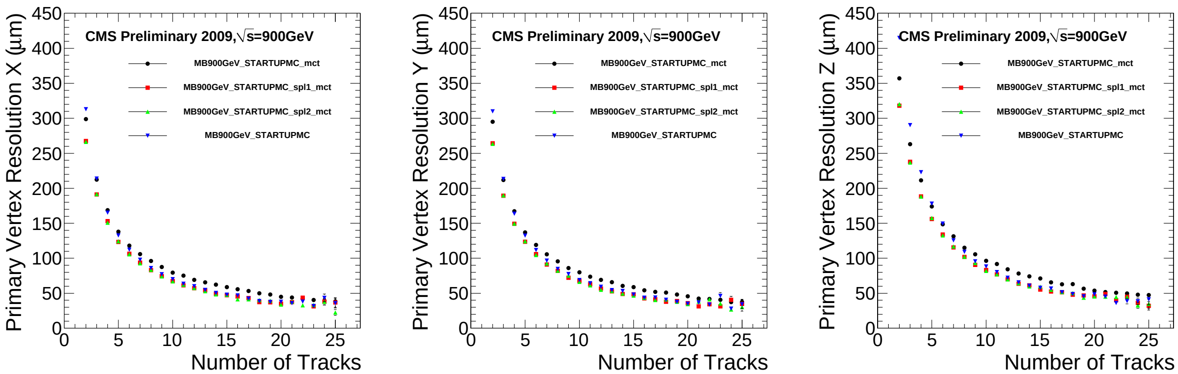

Figure 2: *Primary vertex resolution as a function of the number of tracks used in the fitted vertex.*

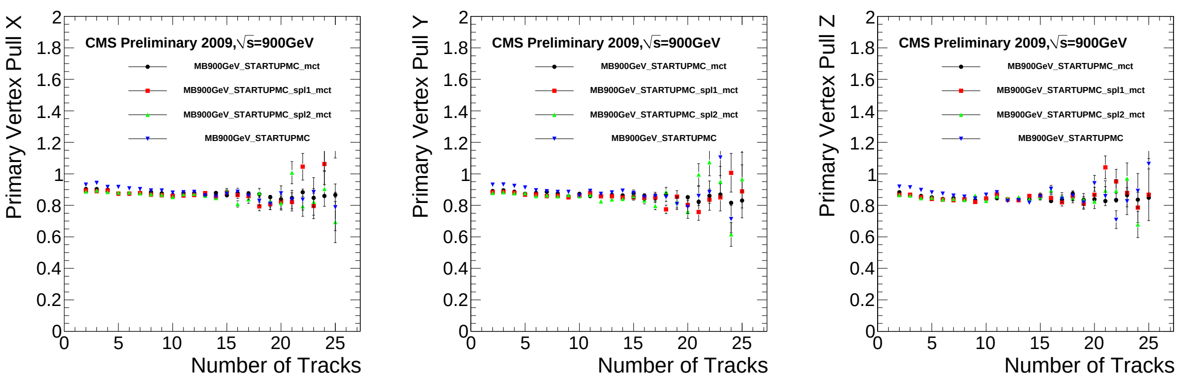

Figure 3: *Fitted pulls from primary vertex distribution as a function of the number of tracks used in the fitted vertex.*

5 Resolution and pull on MB900GeV collision data

5.1 Resolution and pull vs number of tracks

Figure 4 shows the measured primary vertex resolution as a function of the number of tracks in x (left), y (middle), and z (right). Results are shown for both the December data and the MC and a good agreement in the curves is seen. Figure 5 shows the measured pulls on the primary vertex, using the difference in the measured position and uncerntainties reported by the fit. The pulls are roughly flat and close to unity.

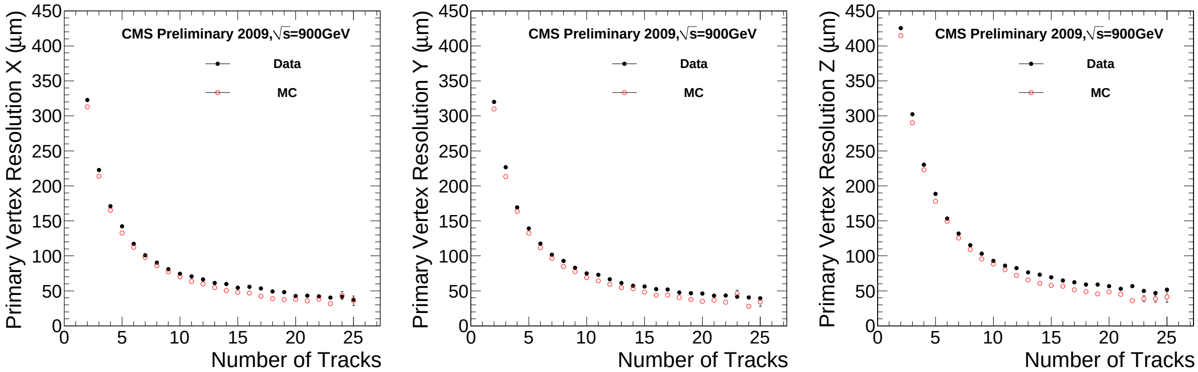

Figure 4: *Primary vertex resolution as a function of the number of tracks used in the fitted vertex.*

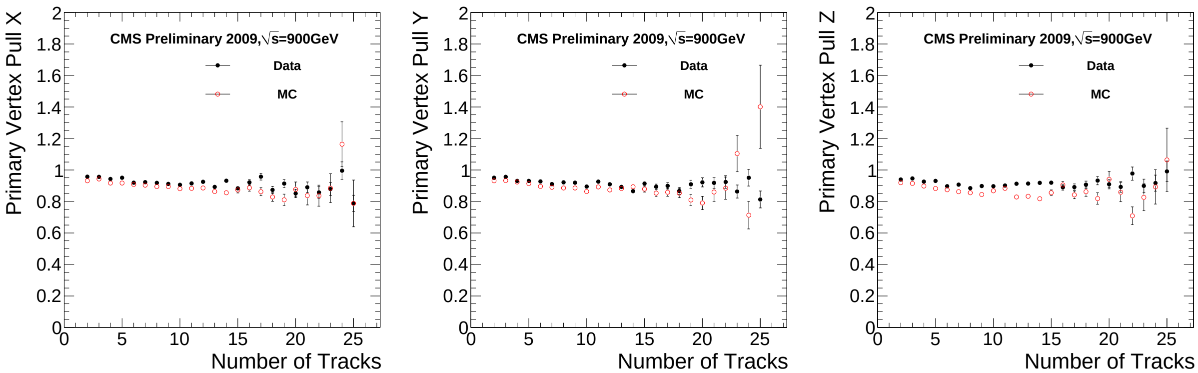

Figure 5: *Fitted pulls from primary vertex distribution as a function of the number of tracks used in the fitted vertex.*

5.2 Resolution and pull vs number of tracks at different P_T ranges

6 Systematic effects and cross checks

6.1 Effect of the alignment scenario

6.2 Effect of the split vertex weight difference

6.3 Compare resolution and pulls at $\sqrt{s}$ 900 GeV and 2360GeV

7 Conclusion

Conclusion

References

[1] Pythia generator package, http://home.thep.lu.se/ torbjorn/Pythia.html