

Studies of tracking performance in ZEUS

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Abstract

Results of my summerstudent work are presented here. Tests are performed on the quality of tracks with the ZEUS detector in the HERA II data after a new alignment of the Barrel silicon detector (BMVD).

1 Introduction

This work was performed in order to improve the measurements of charm and beauty quark production with the HERA II data. The main production mechanism for the heavy quarks is shown in figure 1. This process allows to obtain direct information on

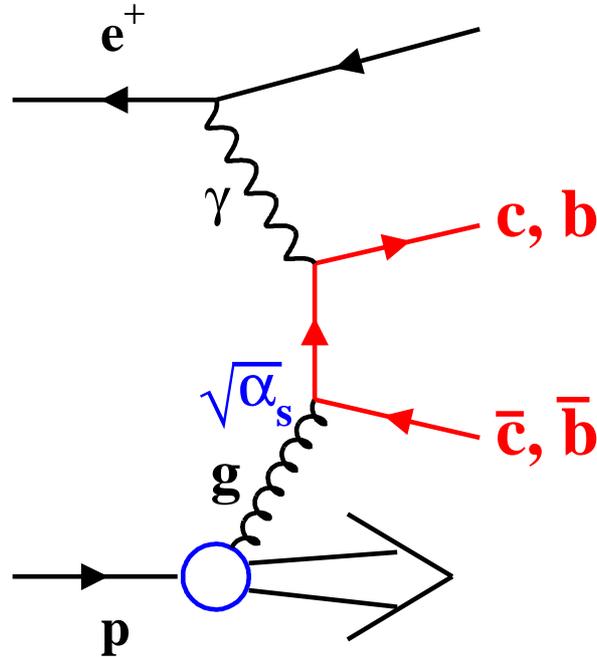
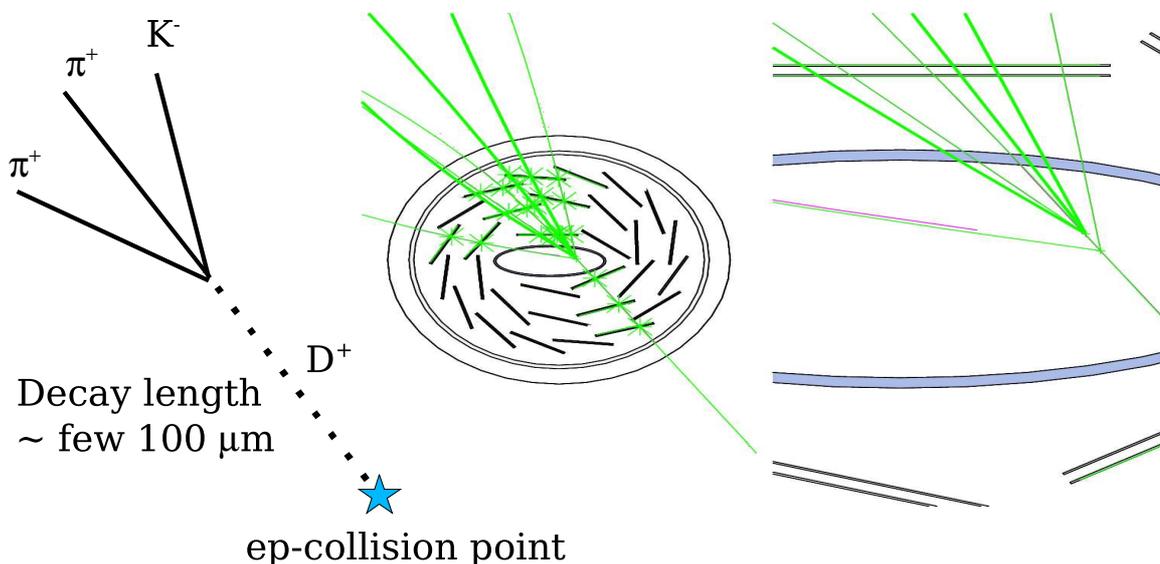


Figure 1: Main production diagram for charm and beauty quarks in ep collisions at HERA.

the gluon density in the proton. The events containing charm or beauty quarks can be identified by the signatures resulting from the long lifetimes of these quarks which decay electroweakly. This is shown in figure 2. The D^+ , a charmed meson which is produced at the ep -collision point flies typically a few 100 μm in the detector before it decays. The secondary vertex can be reconstructed from the charged decay tracks if they are precisely enough measured. This is the task of the BMVD (Barrel Microvertex detector) [1]. This detector consists of three layers of silicon strip detectors. There are in total 30 ladders, each containing 10 $r\phi$ and 10 z sensors. For the former ones the strips are parallel to the z -axis (which is parallel to the proton beam) and for the latter one perpendicular. In each sensor the position of a track passing through can be measured with a precision of 20 μm . However, one has to know accurately the position of the sensors. This is the task of the alignment of the detector. It is performed using many (order of 1 Million tracks) tracks originating from the ep collision point. Recently it has been improved by adding also penetrating cosmic muon tracks (order of 200000 tracks), which allow a better relative alignment of the upper and lower parts of the BMVD.

My study consisted of testing the quality of the new alignment and comparing it to the old alignment and to the case of using the nominal BMVD geometry with no alignment

Motivation continued...



**To identify c and b quarks by their decays
-> requires most accurate MVD calibration, check it!**

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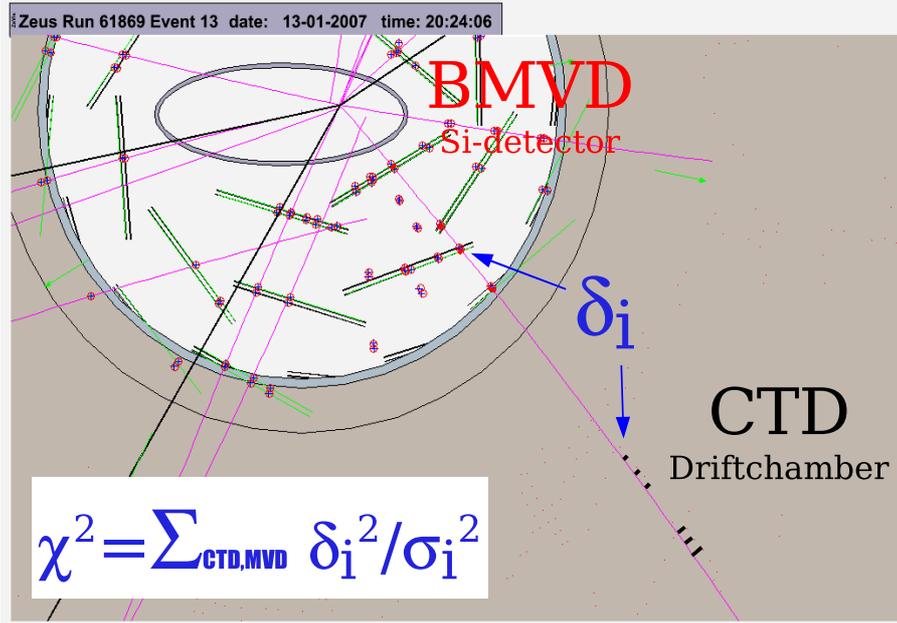
Figure 2: Sketch of D^+ meson production and subsequent decay in three charged particles. In the right the reconstruction of such an candidate event is shown, where one can see (in the transverse plane) the tracks as they are measured in the ZEUS barrel micro vertex detector (BMVD).

corrections at all. Two measures of the quality of the alignment were investigated:

1. Track χ^2 : The standard track χ^2 used in ZEUS so far is depicted in figure 3. It measures the summed quadratic distances of the residuals of the detector hits to the fitted tracks (which parameters have been determined by the minimization of this χ^2). The track is measured not only in the BMVD but also in the central driftchamber, the CTD. The latter provides up to 72 measurement points on a track with a resolution of about 300 μm . This χ^2 has the disadvantage that it is dominated by the many CTD hits and is not so much sensitive to the few BMVD hits. Thus a new χ^2 was defined (by my supervisor Olaf Behnke). Its definition is shown in figure 4.

Here the information of the CTD internal hit residuals is completely omitted. In-

Observable 1: Standard Track Total Chisquare



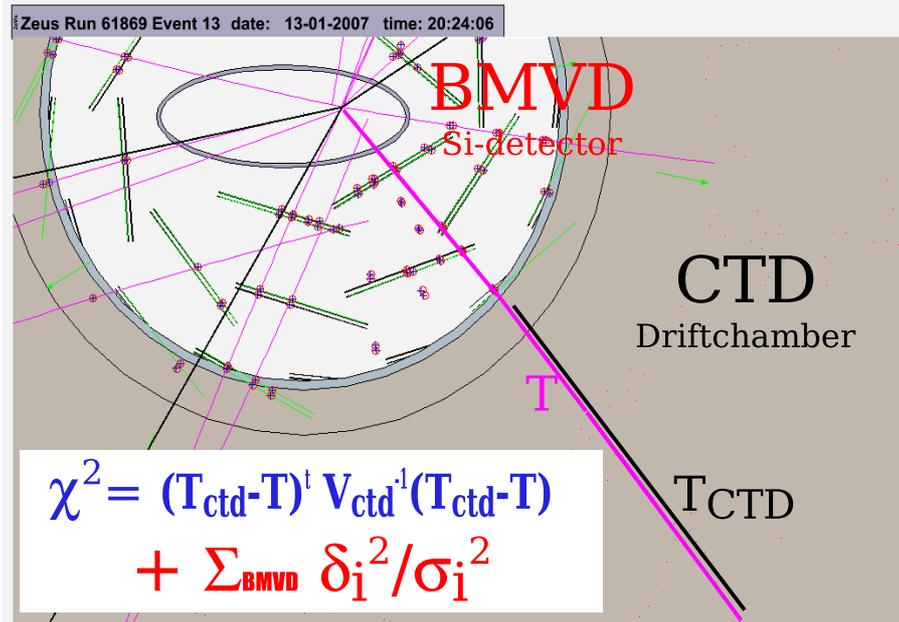
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Figure 3: Sketch of ZEUS standard track χ^2 .

stead the measurement information of the CTD is mapped on a CTD standalone track T_{CTD} (note: tracks are parameterised as a helix with 5 parameters) with covariance matrix V_{CTD} . Then the new χ^2 is defined by the sum over the quadratic distance of these track parameters to the combined track and over the quadratic residuals of the BMVD hits. This χ^2 is a measure of the consistency of the BMVD and the CTD track info and also the internal consistency of the BMVD hits. Both these consistencies are directly dependent on the quality of the BMVD alignment.

2. Track to primary vertex distance: The distance of the track to the primary vertex is called an impact parameter, it is depicted in figure 5. For tracks originating from the primary vertex it should be close to zero. The resolution of the impact parameter depends crucially on the BMVD alignment quality. A new primary vertex fit has recently been installed by Alexander Spiridonov in ZEUS (the software tool is called *rtf_ztverc*). It allows to measure the distance of a selected track to the primary vertex determined by all other tracks. This distance is calculated in the $r\phi$ plane as shown in figure 5. At the point where the track is in the $r\phi$ plane closest to the vertex, the distance of the track in z to the z -position of the primary vertex is also calculated, providing a second independent track to vertex distance which is

Observable 2 (NEW): CTD-MVD-Chisquare



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Figure 4: Sketch of new track χ^2 .

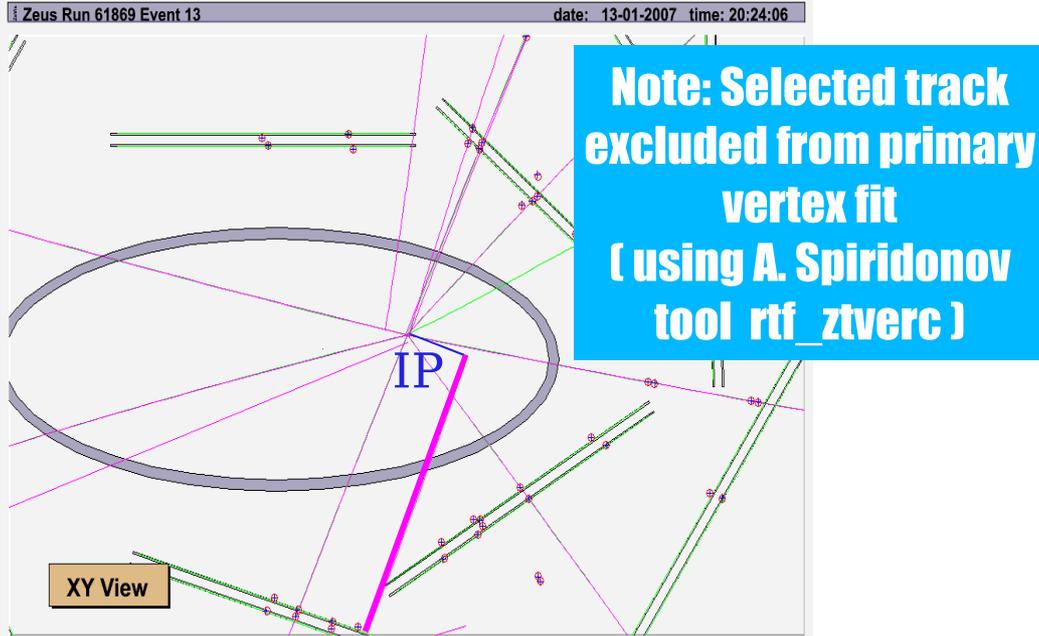
especially sensitive to the alignment of the z-sensors in the BMVD. Such a study of the width of the z-distance is performed here for the first time.

2 Data selection

The following points characterize the data analysis chain:

- ep events are analysed from a period corresponding to run numbers 61800-61850, a part from the e^+p running in 2006. The data correspond to an integrated luminosity of 10 pb^{-1} .
- ZEUS standard non vertex fitted tracks from ep events are used (stored in ZTTRHL bank)
- Only tracks which could be successfully fitted to the primary vertex are analysed (so have an associated primary vertex fitted track).
- Very high quality cuts are applied, each track has to fulfill:
 - transverse momentum $p_T > 5 \text{ GeV}$

Observable 3: track to primary vertex distance



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Figure 5: Sketch of track impact parameter to the primary vertex from other tracks.

- polar angle $60^\circ < \theta < 120^\circ$
- At least to have 3 associated BMVD hits in each ($r\phi$ and z projection)
- Further event cuts are applied: The z -coordinate of the primary vertex must be within ± 20 cm from zero, at least 10 tracks must have been used for the primary vertex.

3 Results

Here the results of the track quality checks are presented for the three cases of the BMVD alignment as discussed in the introduction. Figure 6 shows the distribution for the selected tracks of the ZEUS standard track χ^2 (see figure 3) for the three alignment cases. With using no alignment this χ^2 has the largest mean value, however the difference of the old and the new alignment are small. The reason for this is, as said above, that the χ^2 is dominated by the CTD hit residuals and does not say much about the BMVD quality. Figure 7 presents the distribution of the new track χ^2 (see figure 4). divided by the number of $r\phi$ plus z BMVD-hits associated to the track. Here much larger differences are seen for the three alignment cases. In the case of no alignment the χ^2 values are clearly

much too large. With the new alignment the best results (smallest mean value of the distribution) are achieved, but only slightly better than with the old calibration.

Figure 8 shows the results of the selected tracks impact parameter in $r\phi$ to the primary vertex from the other track. Here again, the results are clearly bad for the case of no alignment and there is only a very slight improvement for the new over old alignment. This changes for the corresponding impact parameter in z , which is shown in figure 9. Here clearly the new alignment provides the highest peak and smallest width, not dramatic, but still considerably better than for the old alignment case.

All the studies mentioned above have been also performed differentially in bins of p_T , ϕ and θ of the track (not shown here) The results with the new calibration are the most homogenous one, while for the old calibration in some phase space corners some tendency for degradation of quality is observed(e.g. at $\phi = 180^0$, where the BMVD has only two layers).

4 Conclusion

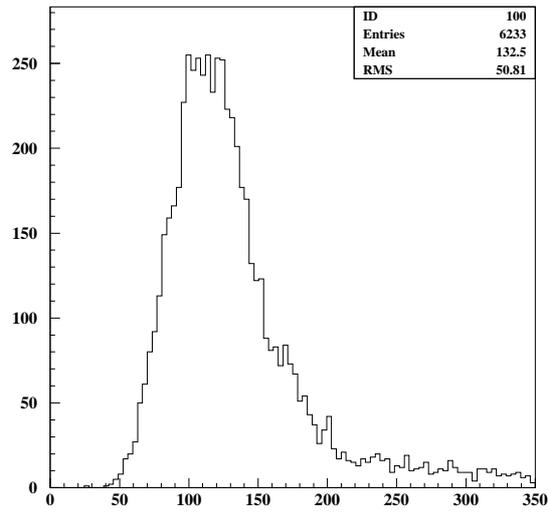
Several studies of the track quality in the HERA II data have been performed checking the improvements from the recent new alignment of the ZEUS barrel silicon tracker (BMVD). A new track χ^2 has been introduced and studied which is more sensitive to the BMVD alignment than the ZEUS standard track χ^2 . The track impact parameters to the primary vertex of the other tracks have been studied separately in the transverse plane $r\phi$ and in z . All the studies using high p_T tracks in the central θ regions from a subsample of 10 million ER events from 2006 indicate that the new alignment improves the tracks and their spatial resolution close to the primary vertex mainly in z and to a lesser/small extent in $r\phi$.

5 Acknowledgement

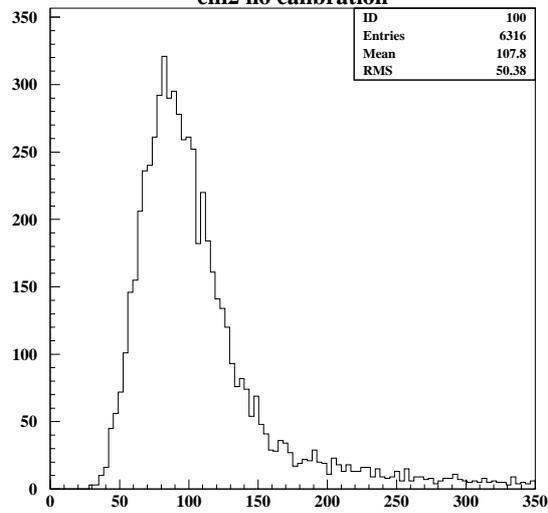
Many thanks to my supervisor Olaf Behnke for his patience and support. He helped me to perform the work and preparing the talk and this writeup. Also thanks to the organizers for such a nice summer program.

References

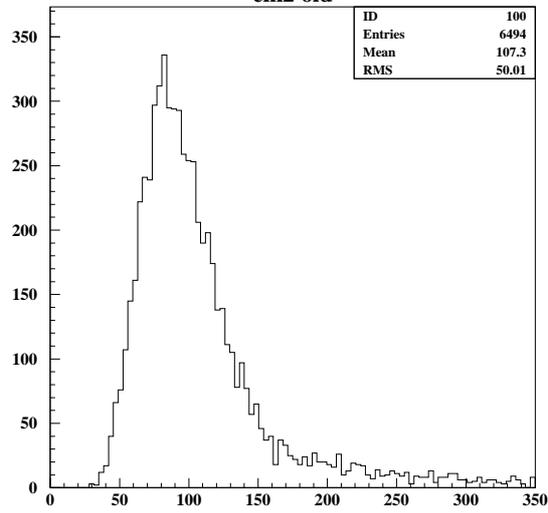
- [1] T. Haas, Nucl. Instrum. Meth. A **549**, 37 (2005).



chi2 no calibration



chi2 old



chi2 new

Figure 6: ZEUS standard ZTTRHL track χ^2 distribution for the selected high transverse momentum tracks from e^+p events in 2006 for three different BMVD alignments: Top with no alignment using the nominal geometry; middle with the old alignment using ep tracks only; bottom with the new alignment using in addition cosmic muon tracks.

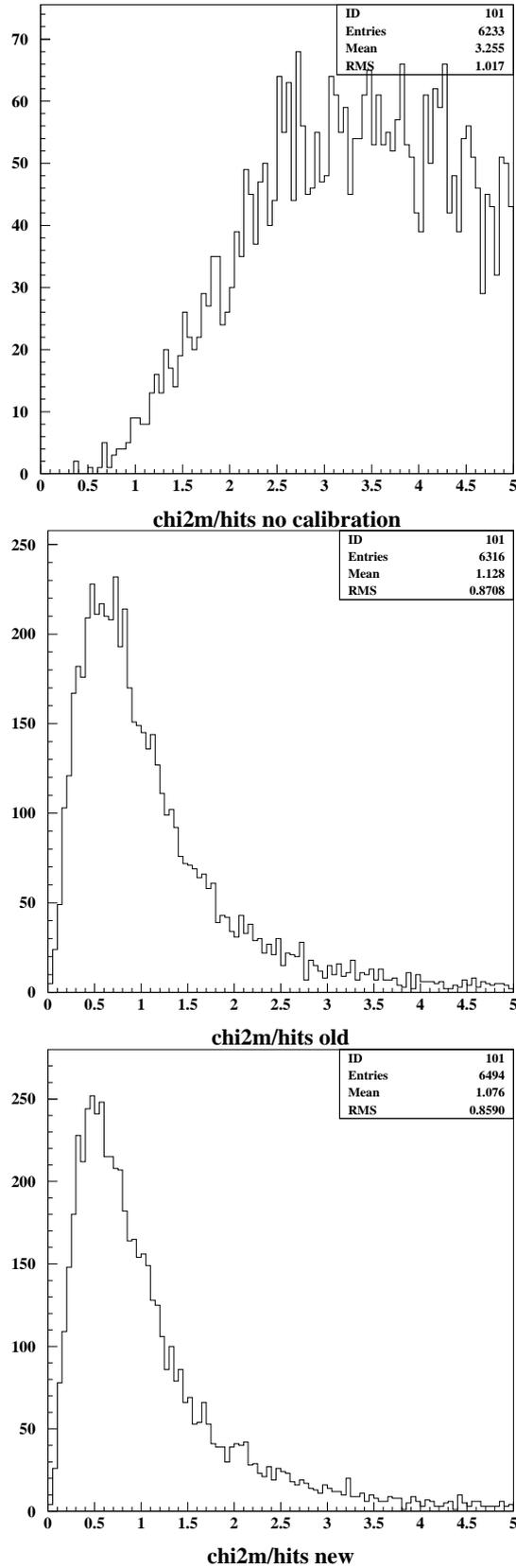


Figure 7: New track $\chi^2/\#\text{BMVD-hits}$ distribution for the selected high transverse momentum tracks from e^+p events in 2006 for three different BMVD alignments: Top with no alignment using the nominal geometry; middle with the old alignment using ep tracks only; bottom with the new alignment using in addition cosmic muon tracks.

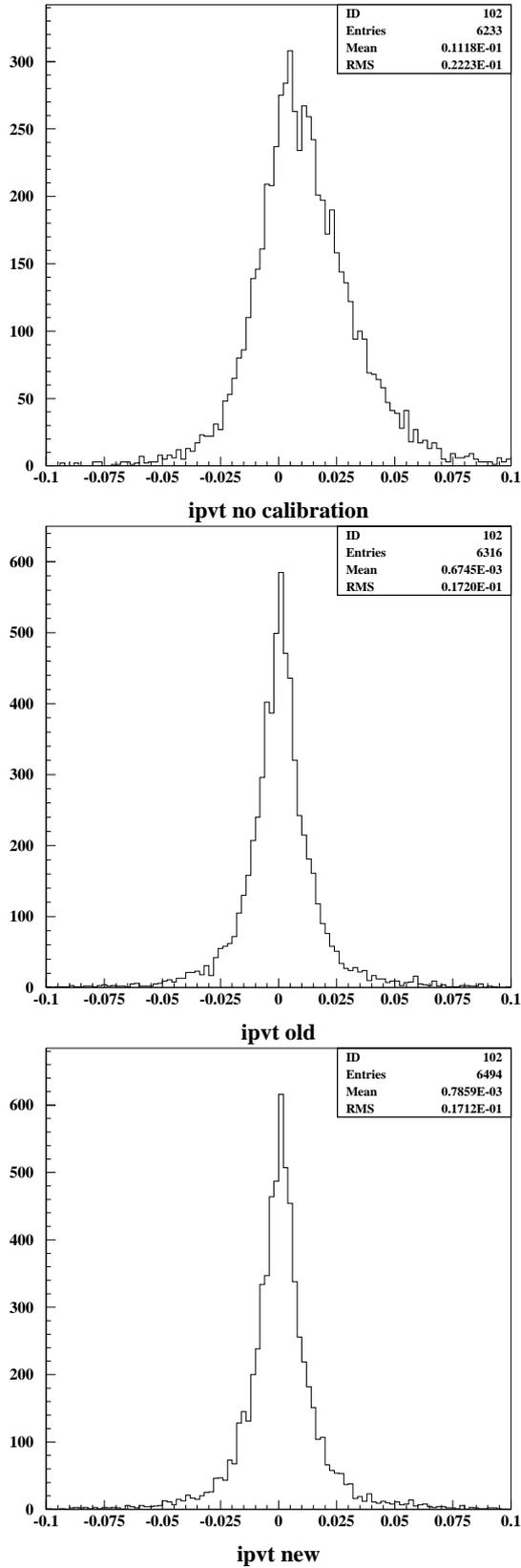


Figure 8: Distribution of the track impact parameters (in $r\phi$) of the selected tracks to the primary vertex from the other tracks. Top with no alignment using the nominal geometry; middle with the old alignment using ep tracks only; bottom with the new alignment using in addition cosmic muon tracks.

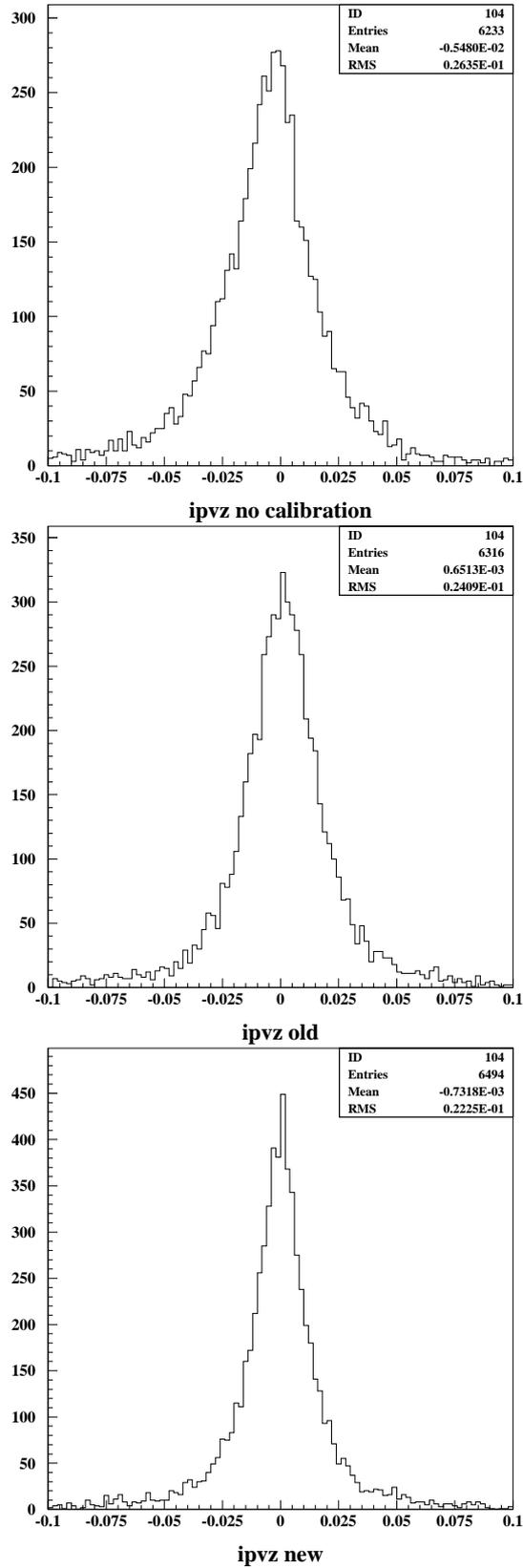


Figure 9: Distribution of the track impact parameters (in z) of the selected tracks to the primary vertex from the other tracks. Top with no alignment using the nominal geometry; middle with the old alignment using *ep* tracks only; bottom with the new alignment using in addition cosmic muon tracks.