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CDF SILICON VERTEX TRACKER: TEVATRON RUN II PRELIMINARY RESULTS

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The Online Silicon Vertex Tracker (SVT) is the unique new trigger processor dedicated to the 2-D reconstruction of charged particle trajectories at Level 2 of the CDF trigger. The SVT has been successfully built, installed and operated during the 2000 and 2001 CDF data taking runs. The performance of the SVT is already very close to the design. The SVT is able to find tracks and calculate their impact parameter with high precision ($\sigma_d = 35$ μm). It is possible to correct the beam position offset and give the beam position feedback to accelerator in real time. In fact, the beam position is calculated online every few seconds with an accuracy of 1 to 5 μm. The beam position is continuously sent to the accelerator control. By using trigger tracks, parent particles such as K_S's and D^0's are reconstructed, proving that the SVT is ready to be used for physics studies.

Триггер на основе силиконового вершинного детектора (SVT) — новый уникальный триггерный процессор, предназначенный для 2-мерной реконструкции заряженных треков на втором уровне триггера установки CDF, действующей на тэватроне (FNAL). SVT создан, запущен и успешно работал во время набора данных на установке CDF в 2000 и 2001 гг. SVT продемонстрировал характеристики, очень близкие к расчетным. SVT способен находить треки и вычислять их «прицельный параметр» с высокой точностью ($\sigma_d = 35$ мкм). Возможно мониторирование положения пучка. Фактически положение пучка вычисляется с помощью SVT в online-режиме каждые несколько секунд с точностью 1–5 мкм, и полученная информация передается для управления ускорителем. При включении SVT в триггер установки восстановлены инвариантные массы K_S- и D^0-мезонов, что подтверждает готовность SVT для проведения физических исследований.

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INTRODUCTION

The physics motivation for the SVT is triggering on B-decay vertices by selecting tracks with large impact parameter. This is particularly useful in CDF where B hadrons have a decay length of the order of 500 μm and decay into tracks with impact parameter of the order of 100 μm. This characteristic is used to reduce the inclusive $p\bar{p}$ background which is about 1000 times larger at production. Trigger simulation has shown that by triggering on impact parameter it is possible to occupy an acceptable fraction of the CDF trigger bandwidth and to collect significant samples of several kinds of purely hadronic B decays like $B \to \pi\pi$ and $B_s \to D_s\pi$, which are extremely interesting respectively for CP violation and for B_s mixing measurements [1].

The Online Silicon Vertex Tracker (SVT) is the new processor dedicated to the reconstruction of charged particle trajectories at Level 2 of the CDF trigger. The SVT refines the Level 1 tracking information from the eXtremely Fast Tracker (XFT), which reconstructs tracks in the Central Outer Tracker (COT), by linking Silicon Vertex Detector (SVX II) hits. Track reconstruction is performed by the SVT in the plane transverse to the beamline. The Level 2 latency time is about 20 μs, therefore the design of the SVT has been concentrated on performing the various tasks in parallel: hit reconstruction from the single strip pulse height, pattern recognition and final high-precision track fitting.

A typical trigger path will require two tracks with $P_T > 2$ GeV/c at Level 1 from the XFT with an expected accept rate of $\simeq 30$ kHz, which will be reduced to $\simeq 30$ Hz when including impact parameters (d_1 and d_2) in the cuts, typically 100 μm $< |d_1|, |d_2| < 1$ mm.

The core of the SVT is organized as 12 identical systems (sectors) running in parallel independently [2–5]. This architecture derives from the geometry of the SVX II detector which is divided into 12 identical wedges along the azimuthal angle. The SVX II is also segmented into six half-barrels along the beamline [6].

The main functional blocks of each SVT sector are the Hit Finders, the Associative Memory system, the Hit Buffer and the Track Fitter. Every time an event is accepted by the Level 1 trigger, the digitized pulse heights in the silicon vertex detector are sent to the Hit Finders, which calculate hit positions. The hits found by the Hit Finders and the tracks found in the COT are then fed simultaneously to the Associative Memory system and to the Hit Buffer [7]. The Associative Memory system performs pattern recognition by selecting for further processing only combinations of COT tracks and SVX II hits which represent good track candidates.

This is done by comparing the input data with a stored set of precalculated patterns in a completely parallel way [8, 9], using a dedicated custom VLSI chip called AMchip [10]. A pattern is defined as a combination of five bins («SuperStrips») on five different detector layers: four SuperStrips correspond to the position coordinate of particle trajectory on four silicon detector layers; the fifth SuperStrip is a function of the curvature and azimuthal angle of the COT track reconstructed by the XFT, and corresponds to the azimuthal angle of the particle trajectory at a distance of 12 cm from the z axis of the CDF detector. Such a distance is chosen to maximize the pattern efficiency, as determined by simulation studies.

The output of the Associative Memory system is the list of patterns («Roads») where at least one hit has been found on all layers. To reduce the amount of required memory, this pattern recognition process is performed at a coarser resolution than the full available detector resolution. Simulation studies show that the performance is optimized by choosing a SuperStrip size of 250 μm in the silicon layers and 5° for the azimuthal angle measured by the XFT. Each Road may contain several hits and therefore several hit combinations, which are considered as independent track candidates. The number of patterns is about 32 000 for each detector sector and corresponds to a 95 % track finding efficiency.

In principle it is possible to generate a bank of pattern which is 100 % efficient, but in practice one should also consider effects which make particles deviate from the ideal trajectory, such as detector resolution smearing, multiple scattering, etc. Those effects generate a huge number of extremely improbable patterns, which blow up the bank size. Therefore it is necessary to use a bank which is partially inefficient. The list of Roads found by the Associative Memory system is sent to the Hit Buffer, which retrieves the original full-resolution silicon hit coordinates and the XFT track associated with each Road and delivers them to the Track Fitter. The Track Fitters check all the hit combinations in each Road and calculate the track parameters with full detector precision.

In the following we review the tracking algorithm implemented in the SVT and report on the results of the analysis of the data taken during the commissioning run of CDF and the early phase of Run II (April–October 2001 data taking).

1. OVERVIEW OF THE TRACK FITTING METHOD

The track fitting method is based on linear approximations and principal component analysis [11, 12]. In the following we describe the basic principles of the method.

The SVT reconstructs 2-D tracks in the plane transverse to the beamline. This means measuring the following three parameters:

- the impact parameter, i. e., the closest distance of approach of the particle trajectory to the z axis of the CDF detector, d;
- the azimuthal angle in the transverse plane of the particle direction at the point of closest approach, ϕ;
- the curvature, $c = 1/2R$, where R is the radius of the circle of the particle trajectory.

Each detector layer measures one hit position along the track. There is an analytical relationship between the parameters of the track and the hit coordinates. This relationship can be expressed in terms of n equations (n is the number of detector layers):

$$x_i = x_i(d, \phi, c). \tag{1}$$

By eliminating the three track parameters (d, ϕ, c) from equations (1), one can obtain a set of $n-3$ independent constraints which all real tracks must satisfy within detector resolution effects. We assume that the constraints are linear functions of the hit coordinates:

$$\hat{f}_k = f_k(\mathbf{x}) = \mathbf{v}_k \cdot \mathbf{x} + c_k = \sum_{i=1}^{n} v_{ki} x_i + c_k \simeq 0 \tag{2}$$

($k = 1, ..., n-3$), where $\mathbf{x} = (x_1, ..., x_n)$, and the vectors $\mathbf{v}_k$ and $\mathbf{c}_k$ are constants which depend only on the detector geometry and the magnetic field. It can be shown [12] that the vectors $\mathbf{v}_k$ are eigenvectors of the ($n \times n$) covariance matrix of the hit coordinates:

$$M_{il} = \langle x_i x_l \rangle - \langle x_i \rangle \langle x_l \rangle \tag{3}$$

with $\langle\rangle$ defined as the average over a sample of tracks that correspond to null eigenvalues. A simple way to get this result is to find the vectors $\mathbf{v}_f$ that minimize the variance of the constraints, $\langle(\hat{f}_k - \langle\hat{f}_k\rangle)^2\rangle$. Also, we find

$$c_k = -\mathbf{v}_k \cdot \langle \mathbf{x} \rangle. \tag{4}$$

In case of perfect detector resolution there are exactly $n-3$ null eigenvalues. Since the detector has finite resolution, the $n-3$ eigenvalues are «almost null», i. e., much smaller than the other eigenvalues. Therefore, a combination of hits forms a track if the value of all constraints is only approximately zero. The χ^2 is the sum of the $n-3$ constraints squared, with a proper normalization. If λ_i are the eigenvalues, then

$$\chi^2 = \sum_{i=1}^{n-3} \frac{\hat{f}_i^2}{\lambda_i}. \tag{5}$$

This procedure has a simple geometrical interpretation. The $n-3$ constraints represent an ($n-3$)-dimension hypersurface in the n-dimension space. The linear approximation means that we consider the hyperplane that locally approximates the hypersurface. Finding the constraints as the eigenvector of the covariance matrix means performing a rotation so that $n-3$ axes of the new reference frame are on the hyperplane. A combination of hits forms a track if the corresponding point in the n-dimensional space lies on the hyperplane. The χ^2 is the distance squared of the point from the hyperplane. In the new reference frame the constraints are the coordinates orthogonal to the hyperplane. The other expressions, $\hat{f}_{n-2}$ to $\hat{f}_n$, which are calculated using the eigenvectors of M_{ij} corresponding to the nonnull eigenvectors, are the coordinates along the hyperplane (the «significant» coordinates).

If there is deviation from linearity there are additional contributions to the variance of the constraints. This effect can be reduced by choosing a finer segmentation of the detector, and the natural choice is the segmentation that makes the effect of nonlinearity negligible with respect to the resolution. The criterion can be translated into a simple recipe: in each region, if $\mathbf{v}_k$ ($k = 1, 2, 3$) are the eigenvectors of M_{ij} corresponding to the smallest eigenvalues, nonlinearities are negligible if $\mathbf{v}_k \cdot \mathbf{M} \cdot \mathbf{v}_k \simeq \mathbf{v}_k \cdot \mathbf{S} \cdot \mathbf{v}_k$, where $\mathbf{S} = \mathbf{M} - \mathbf{M}_0$ is the covariance matrix due to the resolution smearing, and $\mathbf{M}_0$ is the covariance matrix for the «perfect resolution» case.

For the calculation of track parameters (p_j) the relationship between hit coordinates and track parameters is also assumed to be linear:

$$p_j(\mathbf{x}) = \mathbf{w}_j \cdot \mathbf{x} + q_j. \tag{6}$$

A sample of tracks with known parameters is needed to determine the constants $\mathbf{w}_j$ and q_j by inverting (6). This sample is generated using a Monte-Carlo program and a simulation of the CDF detector. Equations (6) can be inverted by minimizing the sum over the tracks of $(p_j - p_j(\mathbf{x}))^2$ [13]. The result is the following:

$$\mathbf{w}_j = \mathbf{M}^{-1} \cdot \gamma, \quad \gamma_j = \langle \hat{p}_j \mathbf{x} \rangle - \langle \hat{p}_j \rangle \langle \mathbf{x} \rangle, \quad q_j = \langle \hat{p}_j \rangle - \langle \mathbf{w}_j \cdot \mathbf{x} \rangle$$

($\langle\rangle$ is defined as the average over the sample of tracks).

In the SVT implementation the vector containing track hits has six components: four components correspond to four hits measured on the SVX II silicon layers and two components correspond to the curvature and azimuthal angle measured by the XFT. The azimuthal angle is measured at a distance of 106 cm from the center of the CDF detector. The curvature and the azimuthal angle are measured by the XFT with a resolution of $0.25 \cdot 10^{-4}$ cm^{-1} (i. e., $0.012 \cdot P_T^2$ GeV/c in transverse momentum P_T) and 4 mrad respectively.

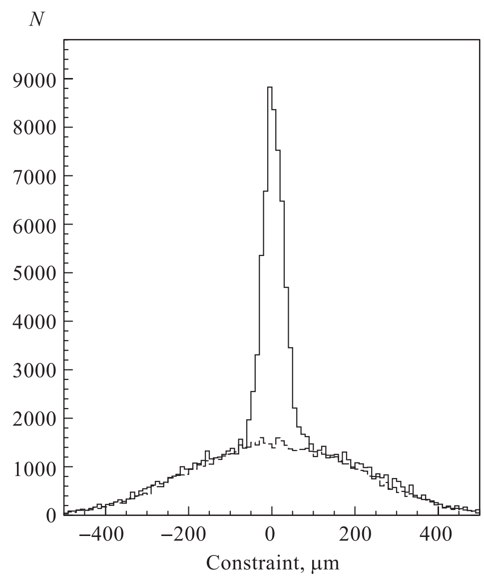
Each SVX II sector has five silicon layers which measure a coordinate in the ϕ direction with a resolution of $\simeq 15$ μm. Only four layers are used by the SVT. In each SVX II sector the linear relationships (2) and (6) are satisfied with good approximation and nonlinearities are found to be negligible. A different set of geometrical constants is used in every sector.

The expected SVT resolutions for the parameters are $\sigma_\phi \simeq 1$ mrad for the azimuthal angle, $\sigma_d \simeq 35$ μm for the impact parameter, and $\sigma_{P_T} \simeq 0.003 \cdot P_T^2$ GeV/c for the transverse momentum ($\sigma_c \simeq 0.6 \cdot 10^{-5}$ cm^{-1} for the curvature). This performance is very close to the offline tracking algorithm, with the advantage that calculation is very fast.

2. DATA ANALYSIS

CDF II has taken the first data using the SVT in the October 2000 Commissioning Run. Run II began in the spring of 2001. Some results concerning the performance of the system, obtained from the analysis of these data, are reported in the following.

2.1. The «Silicon-only» Mode. There is a reduced functionality mode for the SVT. In this special mode, called «silicon-only», the system uses only silicon hit information. The two components which correspond to the parameters measured by the XFT are not used. Since the track hit vector has four components, there is only one constraint. Compared to the standard configuration, the «silicon-only» configuration has reduced performance. There is more combinatorial background and the parameter resolution is worse. In particular, we have found that the impact parameter resolution is $\simeq 50$ μm and the P_T resolution is poor, since all the SVX II layers are very close to the vertex (between 2.5 and 8.7 cm).



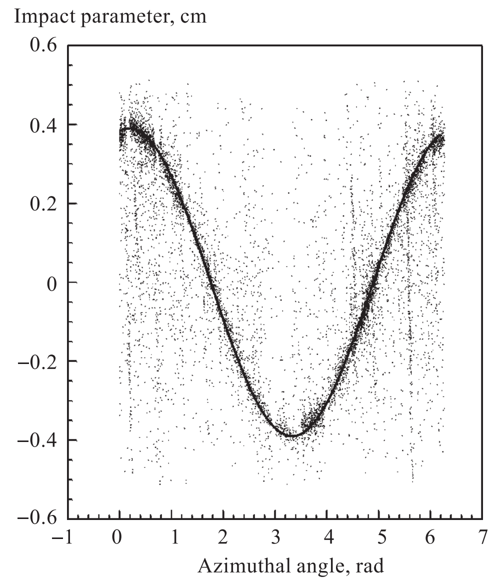


Fig. 1. Constraint distribution in the «silicon-only» configuration. The solid line is for real SVT data, while the dashed line is generated by random hit combinations within the Roads

Fig. 2. Impact parameter versus azimuthal angle for candidate tracks with $\chi^2 < 40$ in the «silicon-only» configuration

The «silicon-only» mode has proven to be particularly useful for the early tests of the SVT. In particular, the capability of the SVT to find tracks has been checked and understood.

An example of the capability to find tracks by the SVT in the «silicon-only» configuration is shown in Fig. 1. The value of the constraint $f_1(\mathbf{x})$ calculated for the real SVT data using the covariance matrix of the hit coordinates is shown (solid line). Also shown is the value of $f_1(\mathbf{x})$ for a sample of hit coordinates randomly distributed within the Roads (dashed line), which simulate the combinatorial background. The presence of a narrow peak in the SVT data shows that a large fraction of the hit combinations actually originated from real tracks.

The most critical parameter provided by the SVT is the impact parameter with respect to the beam axis. The SVT is supposed to work with the beam in its nominal position, i.e., parallel to the z axis of the CDF detector, and at $x = 0$ and $y = 0$. In practice, some misalignment and time variations of the beam position are possible, thus corrections are needed. The beam position in the transverse plane can be calculated using the correlation between the impact parameter d and the azimuthal angle ϕ. If the beam spot position in the transverse plane is (x_0, y_0), different from the nominal one (0, 0), the relationship between d and ϕ for primary tracks is

$$d = -x_0 \sin(\phi) + y_0 \cos(\phi). \tag{7}$$

The beam position calculation and the impact parameter correction are performed online by fitting data with (7) and measuring the average beam position (x_0, y_0).

Figure 2 shows the d–ϕ correlation for track candidates which satisfy a cut $\chi^2 < 40$ in the «silicon-only» configuration. The solid curve superimposed is the expected relationship for primary tracks for a beam position in the transverse plane at $x = 0.0153$ cm and $y = -0.3872$ cm. The coordinates x_0 and y_0 are determined with an accuracy of few micrometers. The impact parameter with respect to the position of the beam can be calculated by subtracting (7) from the impact parameter calculated by the Track Fitter with respect to the nominal beam position:

$$d' = d + x_0 \sin(\phi) - y_0 \cos(\phi). \quad (8)$$

If the beam is not parallel to the z axis, but has a tilt in x and y, the relationship (7) becomes

$$d = -(x_0 + m_x z_0) \sin(\phi) + + (y_0 + m_y z_0) \cos(\phi), \quad (9)$$

where z_0 is the value of z for which the distance of the particle trajectory from the z axis is minimum. Such a quantity is not available to the SVT. Therefore, a beam tilt along z results in a smearing for the impact parameter. The consequence is a higher trigger rate for a given impact parameter cut and a higher background contamination in the selected sample. To make the spread of the beam profile small compared to the beam width, the SVT requires each SVX II strip and the beamline to be all parallel within 100 μrad.

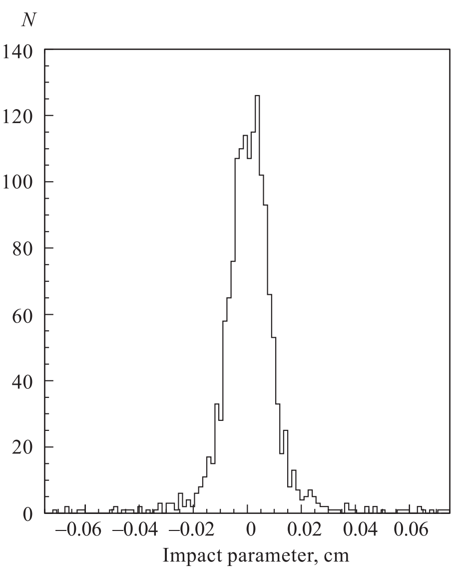


Fig. 3. Impact parameter distribution in the «silicon-only» configuration

Figure 3 shows the impact parameter distribution, after correction for the beam offset, in the «silicon-only» configuration. The Gaussian shape and the width of this distribution originated from the convolution of the actual beam profile with the impact parameter resolution. A Gaussian fit gives $\sigma = 66$ μm.

2.2. The Standard Mode. The standard SVT configuration uses both the SVX II hits and the XFT parameters and has the following advantages compared to the «silicon-only» configuration:

- there are more constraints, therefore we have more cuts available to reduce the combinatorial background;
- since we use more information, we have better resolution on the useful quantities (constraints and parameters);
- a better resolution allows tighter cuts and therefore a better background rejection.

The most critical item is the correction of the impact parameter for the beam offset. Figure 4 shows the correlation plot of d versus ϕ for candidate tracks with $\chi^2 < 10$, before the correction (a) and after the correction (b). The regions without points around $\phi = 2.2$ and 4.2 rad are due to missing SVX II sectors. The calculated beam position in the transverse plane was $x = 0.0995$ cm and $y = -0.3895$ cm, with a precision of $\simeq 3$ μm on both x and y.

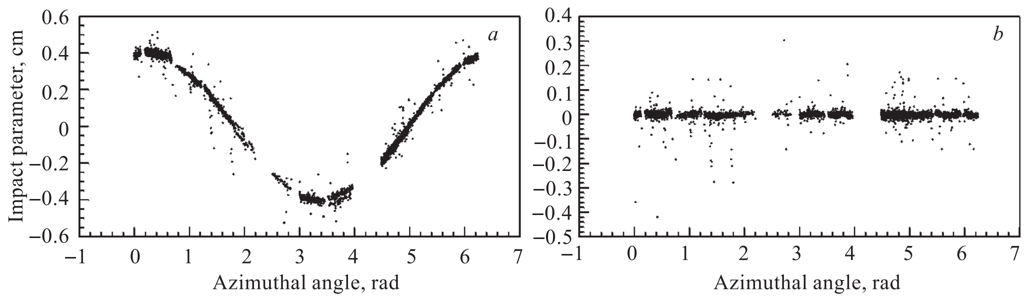


Fig. 4. Impact parameter versus azimuthal angle for candidate tracks with $\chi^2 < 10$ in the standard configuration before (*a*) and after beam offset correction (*b*)

The resolution of the corrected impact parameter, due to the contribution of different factors, has been studied in detail. It was possible to study the effect of the beam tilt by using the z_0 position measured by the COT and available in the offline reconstructed tracks and subtracting (8) from the impact parameter. This is done by matching the SVT tracks with the COT offline reconstructed tracks. In each event in which at least one track was found by the SVT and in the COT, combinations between all the SVT tracks and all the COT tracks were formed. The parameters ϕ and c calculated by the SVT and by the COT reconstruction program running in Level 3 trigger were compared. Matching tracks were defined to have ϕ consistent within 10 mrad and c within 10^{-4} cm^{-1}.

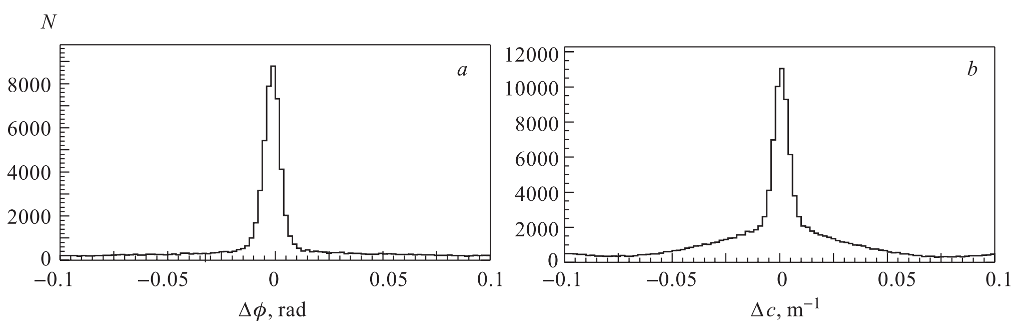


Fig. 5. Difference of the track azimuthal angle (*a*) and of the track curvature (*b*), both calculated by the SVT and by the COT reconstruction program for all the possible combinations of the SVT and COT tracks

Figure 5 reports the correlation between the SVT tracks and the COT tracks. Plot a shows the difference of the azimuthal angles calculated by the SVT and by the COT reconstruction program for all the possible combinations of the SVT and the COT tracks. Plot b shows the difference of the curvature calculated by the SVT and by the COT reconstruction program for the same combinations.

In addition to the beam tilt, there are two more major contributions to the impact parameter resolution. One is the relative misalignment of the SVX II wedges. This misalignment has the consequence that different wedges «see» the beam in different positions. The effect can be compensated for easily by doing a beam position fit and the impact parameter correction in each wedge independently. The relative misalignment of the five silicon layers in the SVX II wedges has been found to be negligible.

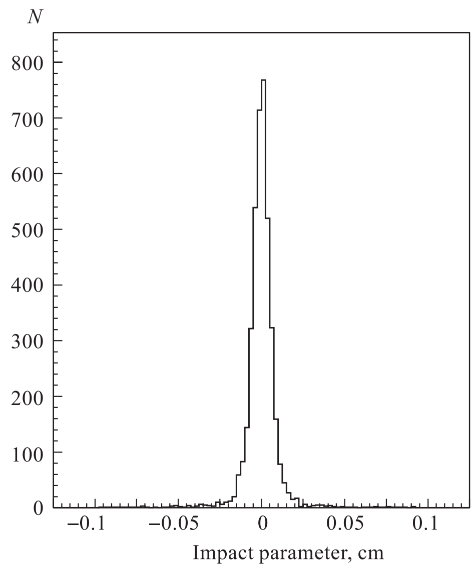


Fig. 6. Impact parameter distribution for data taken in October, 2001, for track candidates with $\chi^2 < 10$ and $P_T > 2$ GeV/c, after correction for beam position offset, relative misalignment of the wedges and nonlinearity. In this case the correction for the beam tilt was not necessary since the tilt was $\simeq 0$. The Gaussian fit gives $\sigma = 48$ μm

The other major effect is the nonlinearity. Since the beam position was far from its nominal position ($\simeq 4$ mm away) the effect of nonlinearity was larger than expected. The reason is that the linear approximations in the track fitting assume a first-order power expansion centered at the nominal beam position. This was corrected in two steps. First, the constants for (2) and (6) were recalculated assuming the beam to be in its measured position instead of the nominal position. Second, the beam position fit was done using a linear relationship between d and ϕ. This is, in fact, in each wedge, the real relationship between the SVT estimates of the parameters, because of the linear approximations in (2) and (6). After these steps, there is a residual nonlinearity, which can be corrected by multiplying d by $\cos(\phi - \phi_0)$ (where ϕ_0 is the azimuthal angle of the center of the wedge). Its effect on the impact parameter resolution is however small, less than 0.4 μm.

After the corrections for these effects, the impact parameter distribution was found to have a Gaussian shape with a σ of 48 μm. The Gaussian shape and the width of this distribution originated from the convolution of the actual beam profile with the impact parameter resolution. Figure 6 shows such a distribution for data taken in October, 2001, for a particular run in which the beam tilt was $\simeq 0$, so no correction for the tilt was necessary. Without the corrections for nonlinearity and the relative misalignment of the wedges, and with the effect of the beam tilt, which was $\simeq 0.8$ mrad for most of the data taking period, the σ is as large as 69 μm. The best σ when the beam tilt is $\simeq$ 0.8 mrad, after all the other corrections are done, is 58 μm. The additional contributions can be quantified approximately as follows: 10 μm for the beam tilt, 6 μm for misalignment, 5 μm for the nonlinearity.

The best result was obtained from the October 2000 Commissioning Run, when all the possible corrections were used, including the internal alignment, and ϕ and c from the offline reconstructed tracks were used instead of the XFT (so the resolution was slightly better). The distribution of the corrected impact parameter is shown in Fig. 7. A Gaussian fit gives a σ of 45 μm. This is in agreement with results of early simulations of the SVT performance using CDF Run I data.

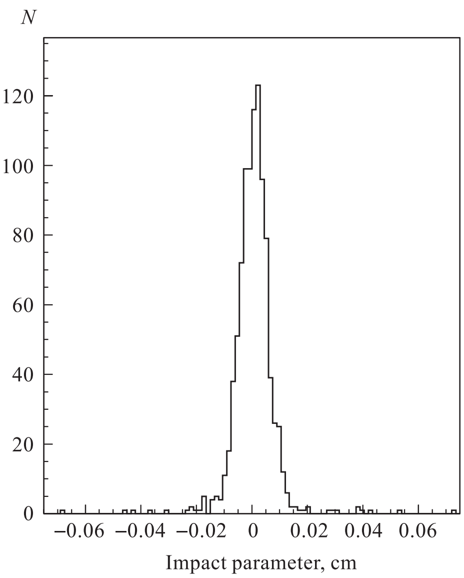


Fig. 7. Impact parameter distribution for the October, 2000 Commissioning Run data, after all the cuts and correction. The Gaussian fit gives $\sigma = 45$ μm

2.3. Disentangling the Beam Width and the d Resolution. Using a sample of events in which two good tracks are found, we were able to calculate the true transverse beam size (σ_B) without the effect of the resolution. It can be shown using (7) that the covariance of the impact parameters of the two tracks is proportional to the cosine of the difference of the azimuthal angles of the two tracks, $\Delta\phi$:

$$\sigma_{d_1 d_2} = \langle d_1 \cdot d_2 \rangle = \sigma_B^2 \cos \Delta\phi \tag{10}$$

under the assumption that the two tracks originate from the same point and the measurement errors on d_1 and d_2 are uncorrelated to each other.

Figure 8 shows the covariance of the impact parameters of the two tracks versus $\cos \Delta\phi$ for data taken in October, 2001, in a run in which the beam tilt was $\simeq 800$ μrad (*a*) and for the same data as Fig. 6 still taken in October, 2001, in which the beam tilt was $\simeq 0$ (*b*). The tracks were required to pass the cuts $\chi^2 < 10$, $P_T > 2$ GeV/c, $d < 0.1$ cm, and events were selected in which the number of tracks ≥ 2. A linear fit gives $\sigma_B = (40 \pm 1)$ μm for plot a and $\sigma_B = (33 \pm 1)$ μm for plot b. In the case of large beam tilt, as in plot a, the projection of the beam spot on the transverse plane is not a circle, but σ_B is the average of two different values, $\sigma_{\min}$ and $\sigma_{\max}$. In the case of negligible beam tilt, as in plot b, $\sigma_{\min} = \sigma_{\max} = \sigma_B$. Assuming, then, that $\sigma_{\min} = (33 \pm 1)$ μm yields $\sigma_{\max} = (47 \pm 2)$ μm for plot a.

Since the fitted $\sigma = 48$ μm of the impact parameter distribution in Fig. 6 is the convolution of the beam transverse size $\sigma_B = 33$ μm and the d resolution σ_d, we find $\sigma_d = 35$ μm, as expected.

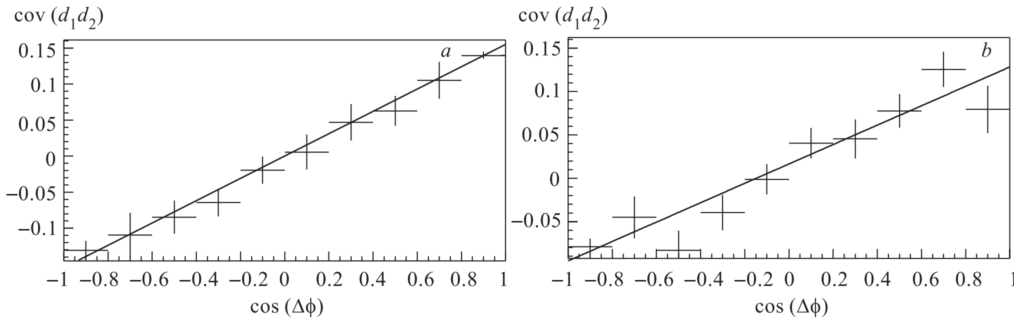


Fig. 8. Covariance of the two impact parameters of track pair versus the cosine of the difference of the two azimuthal angles: when the beam tilt is $\simeq 800$ μrad (*a*) and $\simeq 0$ (*b*)

2.4. First Search for Physics Signals in SVT Data. In October, 2001, the first trigger tests using the SVT have been done. The SVT was used to impose a set of cuts to select track pairs: a cut on $\chi^2 < 25$, on the transverse momentum $P_T > 2$ GeV/c, on the impact parameter with respect to the beam position (50 $\mu\text{m} < |d| < 0.1$ cm, 100 $\mu\text{m} < |d| < 0.1$ cm, or $|d| < 0.1$ cm; the lower cut is released when the beam position is studied) and on the number of selected tracks ≥ 2.

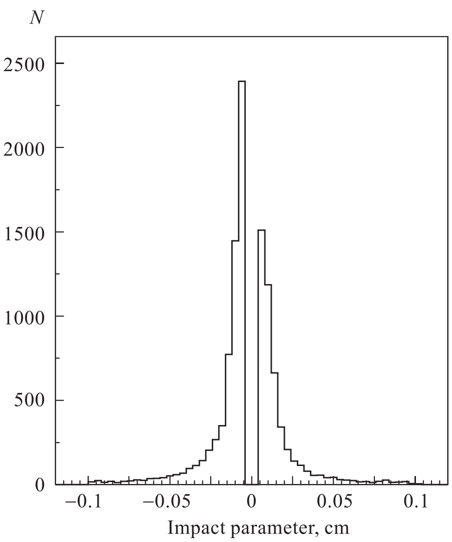


Fig. 9. Impact parameter distribution for tracks which pass the online cuts (number of tracks ≥ 2, $\chi^2 < 25$, $P_T > 2$ GeV/c, and 50 $\mu\text{m} < d < 0.1$ cm)

Figure 9 shows the d distribution when an online cut at 50 μm is done.

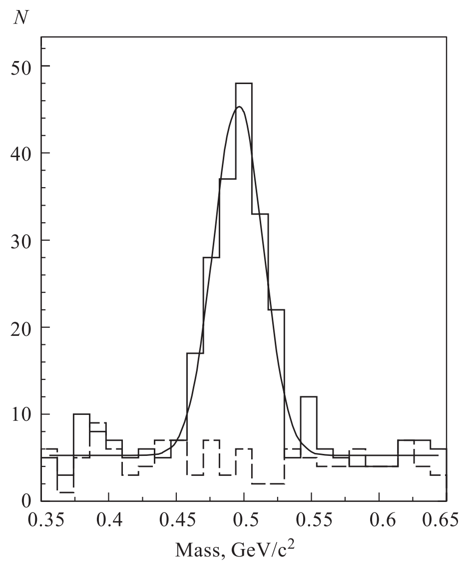
Using the two additional longitudinal parameters for selected SVT tracks made it possible to calculate the invariant mass for track pairs. Events were selected in which at least two tracks passed the following cuts:

- $\chi^2 < 10$;
- $P_T > 2$ GeV/c;
- 100 $\mu\text{m} < |d_1|, |d_2| < 1$ mm;
- $|\phi - \phi_{\text{COT}}| < 10$ mrad, where ϕ_{COT} is the track azimuthal angle calculated by the COT reconstruction program at Level 3;
- $|c - c_{\text{COT}}| < 10^{-4}$ cm^{-1}, where c_{COT} is the track curvature calculated by the COT reconstruction program at Level 3;
- impact parameter of the decaying particle > 100 μm.

The SVX II reconstruction was not performed at Level 3, because it was very time-consuming, and the impact parameter resolution using the COT only was too poor. So no matching between the impact parameter calculated by the SVT and the impact parameter calculated by the COT reconstruction program was required. The invariant mass for each combination of two tracks was calculated assuming a decay into $\pi^+\pi^-$; i.e., the two tracks were assumed to correspond to particles which have the mass of the π^+ or π^-.

Figure 10 shows the invariant mass distribution for track pairs with opposite charge for data taken in October, 2001, in several runs, in the mass window 0.35 to 0.65 GeV/c^2, with a clear peak at the value of the mass of the K_S. The dashed line shows the same distribution for track pairs with same sign charges, to give an idea of the combinatorial background.

Figure 11 shows the invariant mass distribution for track pairs with opposite charge, using the same cuts as Fig. 10, but assuming the two tracks to correspond to a π^+ and a K^-. A peak at the value of the mass of the D^0 is clearly visible. Since the D^0-decay length is of the order of 100 μm (the K_S-decay length is much larger, 2.6 cm), this is a more challenging test for a track selection based on impact parameter cut.



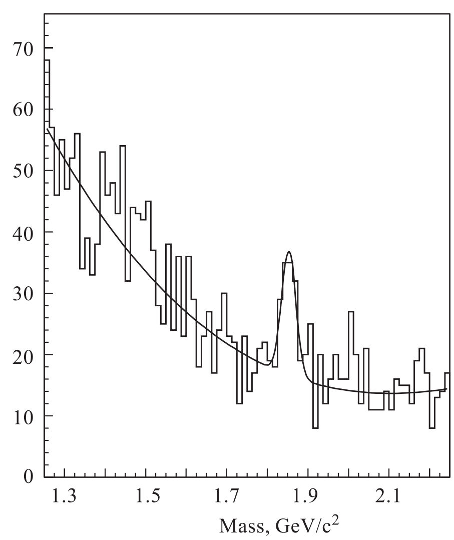


Fig. 10. Invariant mass distribution for track pairs, assuming the two tracks to be π^+ and π^-

Fig. 11. Invariant mass distribution for track pairs, assuming the two tracks to be π^+ and K^-

CONCLUSION

The Silicon Vertex Tracker has been successfully built, installed and operated during real CDF data collection. During the 2000 and 2001 data taking runs, the performance of the SVT was already very close to the design. The SVT is able to find tracks and to calculate the parameters with the expected precision. It is possible to correct the beam position offset and give the beam position feedback to accelerator in real time. In fact, the beam position is calculated online in each of the six half-barrels every few seconds with an accuracy of 1 to 5 μm. The beam positions (12 parameters) are continuously sent to the accelerator control.

The impact parameter resolution meets expectations for a successful operation of the trigger, provided that the beam tilt is not larger than 100 μrad. The SVT has shown the capability to select tracks and track pairs from secondary vertices. Using trigger tracks, parent particles such as K_S's and D^0's can be reconstructed, proving that the SVT is ready to be used for physics studies. Improvements of the SVT performance are expected in the near future as the operating conditions will evolve from the test to the operation phase. Pedestal adjustment, dead/hot channel corrections and a better tuning of the clustering algorithm are expected for SVX II. The beam is expected to be closer to its nominal position and parallel to the SVX II strips. Also, some SVT improvements, such as the corrections for the nonlinearities and the relative misalignment of the wedges, and the use of real geometry constants instead of nominal constants, will be implemented online.

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