E1-2002-12

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FAST METHOD FOR GEOMETRIC CALIBRATION OF DETECTORS AND FOR MATCHING TESTING BETWEEN TWO DETECTORS

Submitted to «Nuclear Instruments and Methods»

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To connect tracks from two detectors correctly, it is necessary to determine the values of offsets along the X-, Y-, Z-axes and rotation offsets around these axes. The main idea of this method is to determine offsets by fitting the real data distribution by analytical functions. The method can be applied to offset determination for one detector relative to another detector or for one part of the detector relative to its other part. The detectors should be placed perpendicular to the beam axis. The geometric position of the detector is determined by 6 parameters: X, Y, Z coordinates and rotation matrix around these axes. Z is the beam axis.

A fast method allows one to determine the 6 values: x_{offset}, y_{offset}, z_{offset}, α, β, γ for one detector relative to the other detector. This method is a simultaneous fit by the functions $F1$ and $F2$ for real data dependence $\Delta\phi$ versus ϕ and $\Delta\Theta$ versus ϕ, where

$$\overline{\Delta\phi} = F1(\phi, x_{offset}, y_{offset}, \alpha, \beta, \gamma);$$

$$\overline{\Delta\Theta} = F2(\phi, x_{offset}, y_{offset}, z_{offset}, \alpha, \beta, \gamma);$$

$$\Delta\phi = \phi_{detector1} - \phi_{detector2};$$

$$\Delta\Theta = \Theta_{detector1} - \Theta_{detector2}.$$

ϕ is the azimuthal angle of the track;
Θ is the polar angle of the track;

α is the rotation angle around the X-axis;
β is the rotation angle around the Y-axis;
γ is the rotation angle around the Z-axis.

The fit is simultaneously performed for $\Delta\phi$ and $\Delta\Theta$. $F1$ and $F2$ are analytical functions. Their forms do not depend on the software of a specific experiment. The form of these functions depends on the geometry of experiment and on the direction of the coordinate axes. $F1$ and $F2$ obtained using the rotation matrices and some transformations are the following:

$$\overline{\Delta\phi} = \frac{\int_{R_{min}}^{R_{max}} \arctan \frac{M1 \cdot R + M2}{L1 \cdot R + L2} \cdot dR}{R_{max} - R_{min}}$$

$$\overline{\Delta\Theta} = \frac{\int_{R_{min}}^{R_{max}} [\arctan \frac{R}{Z} - \arctan \frac{\sqrt{N1 \cdot R^2 + N2 \cdot R + N3}}{T1 \cdot R + T2}] \cdot dR}{R_{max} - R_{min}},$$

where

$$M1 = \sin(\phi - \gamma) \cdot E - \cos(\phi - \gamma) \cdot H;$$

$$M2 = Z \cdot F \cdot \sin(\phi - \gamma) + Z \cdot \sin\alpha \cdot \cos(\phi - \gamma) - B_p;$$

$$L1 = \cos(\phi - \gamma) \cdot E + \sin(\phi - \gamma) \cdot H;$$

$$L2 = Z \cdot F \cdot \cos(\phi - \gamma) - Z \cdot \sin\alpha \cdot \sin(\phi - \gamma) - A_p;$$

$$N1 = E^2 + H^2;$$

$$N2 = 2 \cdot E \cdot (Z \cdot F - A_g) - 2 \cdot H \cdot (Z \cdot \sin\alpha - B_g);$$

$$N3 = (Z \cdot F - A_g)^2 + (Z \cdot \sin\alpha - B_g)^2;$$

$$T1 = -\cos\phi \cdot \sin\beta + \sin\phi \cdot \sin\alpha \cdot \cos\beta;$$

$$T2 = Z \cdot \cos\alpha \cdot \cos\beta - z_{offset};$$

$$A_p = x_{offset} \cdot \cos\phi + y_{offset} \cdot \sin\phi;$$

$$B_p = x_{offset} \cdot \sin\phi - y_{offset} \cdot \cos\phi;$$

$$E = \cos\phi \cdot \cos\beta + \sin\phi \cdot \sin\alpha \cdot \sin\beta;$$

$$H = \cos\alpha \cdot \sin\phi;$$

$$F = \cos\alpha \cdot \sin\beta;$$

$$A_g = x_{offset} \cdot \cos\gamma + y_{offset} \cdot \sin\gamma;$$

$$B_g = x_{offset} \cdot \sin\gamma - y_{offset} \cdot \cos\gamma;$$

R_{max} and R_{min} are the maximum and minimum radii of the detector, respectively.

In considered case, the initial matrices are the following:

$$M_x = \begin{pmatrix} 1 & 0 & 0 \\ 0 & cos\alpha & sin\alpha \\ 0 & -sin\alpha & cos\alpha \end{pmatrix}$$

$$M_y = \begin{pmatrix} cos\beta & 0 & -sin\beta \\ 0 & 1 & 0 \\ sin\beta & 0 & cos\beta \end{pmatrix}$$

$$M_z = \begin{pmatrix} cos\gamma & sin\gamma & 0 \\ -sin\gamma & cos\gamma & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

In case under study, the resulting rotation matrix is the following:

$$A = M_x \cdot M_y \cdot M_z;$$

$$A = \begin{pmatrix} \cos\beta \cdot \cos\gamma & \cos\beta \cdot \sin\gamma & -\sin\beta \\ \sin\alpha \cdot \sin\beta \cdot \cos\gamma - \cos\alpha \cdot \sin\gamma & \sin\alpha \cdot \sin\beta \cdot \sin\gamma + \cos\alpha \cdot \cos\gamma & \sin\alpha \cdot \cos\beta \\ \cos\alpha \cdot \sin\beta \cdot \cos\gamma + \sin\alpha \cdot \sin\gamma & \cos\alpha \cdot \sin\beta \cdot \sin\gamma - \sin\alpha \cdot \cos\gamma & \cos\alpha \cdot \cos\beta \end{pmatrix}$$

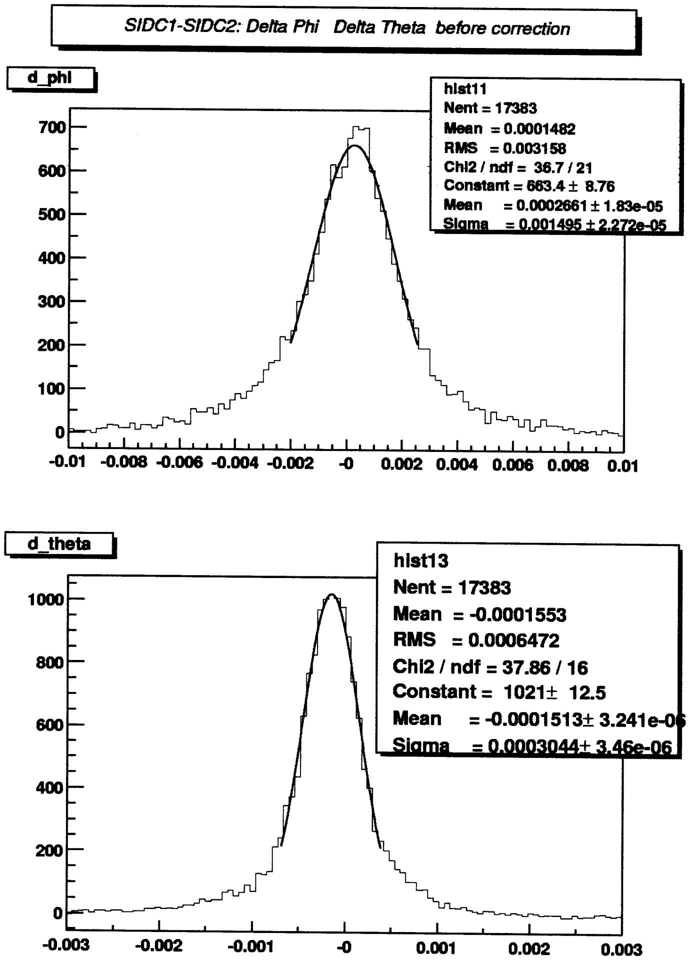

Figure 1: The $\Delta\phi$ and $\Delta\Theta$ distribution before SIDC2 geometric calibration. Matching between the SIDC1 and SIDC2 detectors.

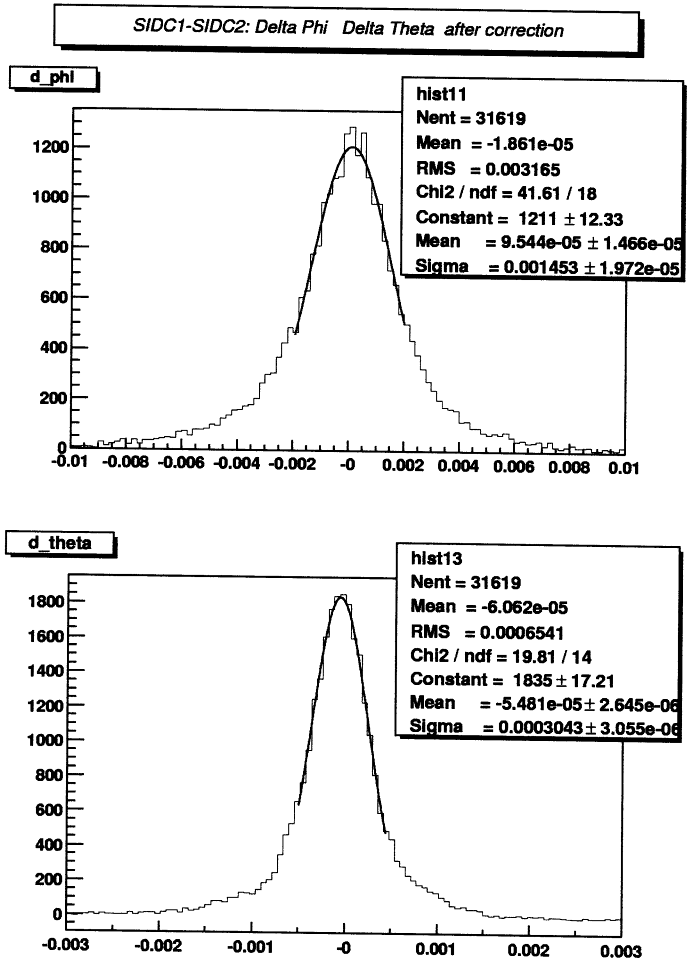

Figure 2: The $\Delta\phi$ and $\Delta\Theta$ distribution after SIDC2 geometric calibration. Matching between the SIDC1 and SIDC2 detectors.

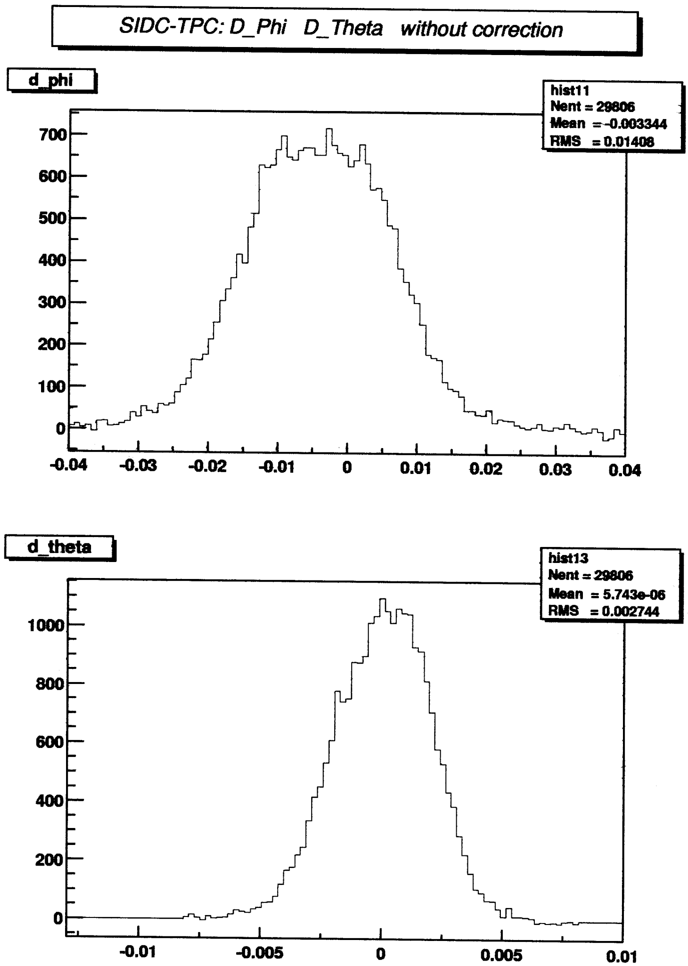

Figure 3: The $\Delta\phi$ and $\Delta\Theta$ distribution before any geometric calibration. Matching between the SIDC and TPC detectors.

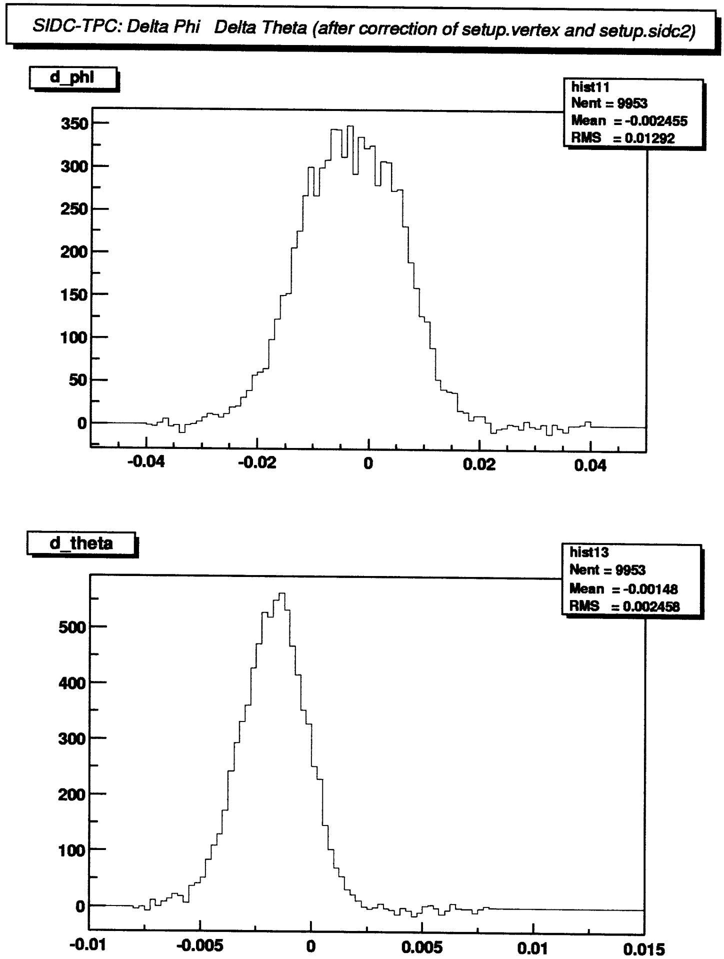

Figure 4: The $\Delta\phi$ and $\Delta\Theta$ distribution after SIDC2 geometric calibration. Matching between the SIDC and TPC detectors.

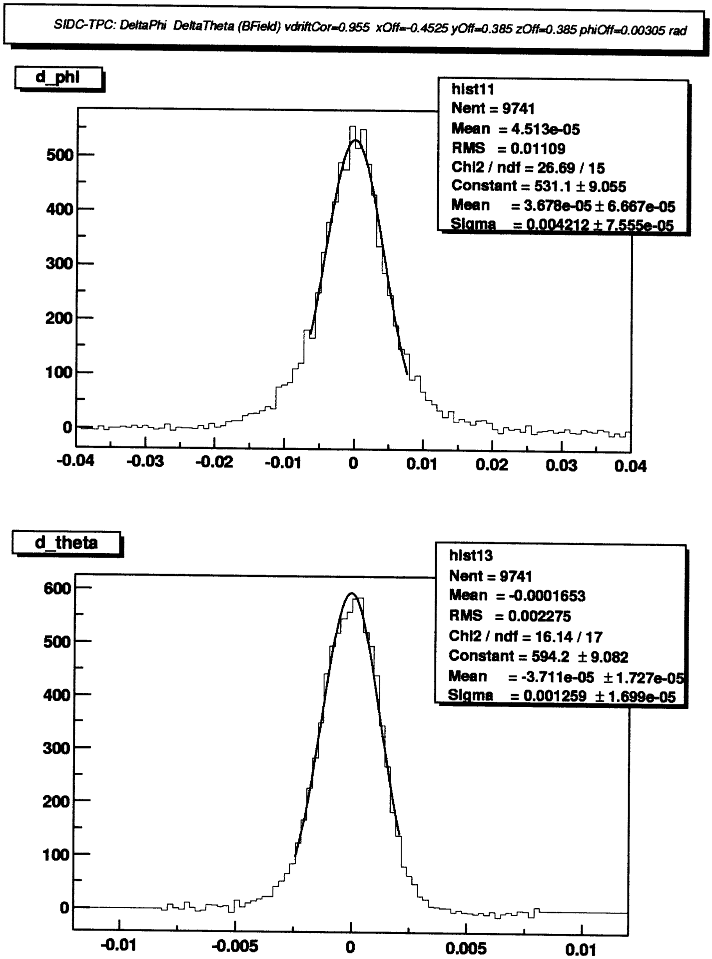

Figure 5: The $\Delta\phi$ and $\Delta\Theta$ distribution after SIDC2 and TPC geometric calibration. Matching between the SIDC and TPC detectors.

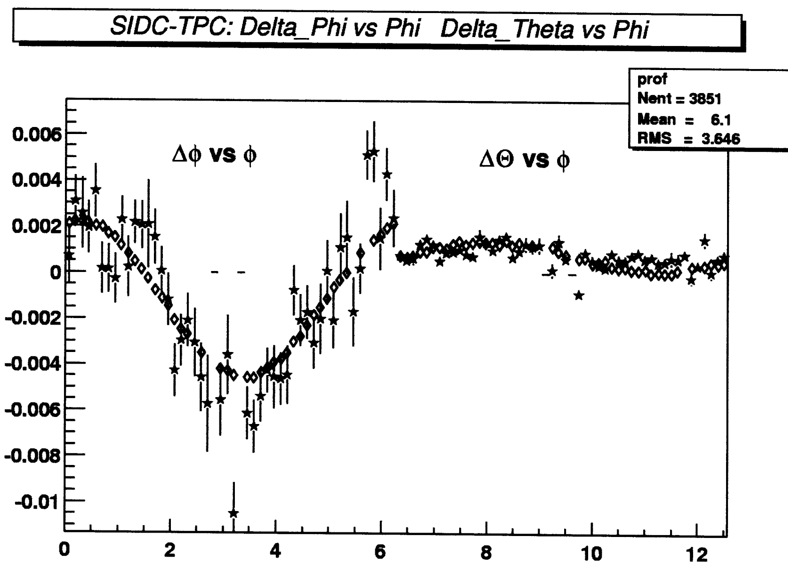

Figure 6: Fit of real data distribution by the functions $F1$ and $F2$. The plot of $\Delta\phi$ versus ϕ (an interval of 0.-6.28 rad) and $\Delta\Theta$ versus ϕ (6.28-12.56 rad). Black stars are the real data dependence and empty rhombuses the fitting functions.

The flow of particles at angle Θ (along the detector radius) is the same. Having the real data plot of $\Delta\phi$ versus ϕ and $\Delta\Theta$ versus ϕ and performing a simultaneous fit of this dependence by the functions $F1$ and $F2$, we can obtain 6 parameters: x_{offset}, y_{offset}, z_{offset}, α, β, γ. This method can be applied to any two detectors or to any two parts of the detector (placed perpendicular to the beam axis). This method used to determine 4 parameters (x_{offset}, y_{offset}, z_{offset}, γ), was tested for the experimental data. The values of α and β were equal to 0. The geometric calibration of SIDC2 relative to SIDC1 (Silicon Drift Camera) and TPC relative to SIDC was carried out. It is necessary that the systematic errors in the mean values of experimental data should be negligible in comparison with the statistical ones.

After the offsets for SIDC2 had been determined relative to SIDC1, matching between SIDC1 and SIDC2 changed slightly, in error bounders, (figs.1 and 2), but the matching between SIDC and TPC changed greatly (figs.3 and 4). Then, after offset determination for TPC relative to SIDC, matching between SIDC and TPC was additionally improved (fig.5).

Figure 6 shows the plot of $\Delta\phi$ versus ϕ (an interval of 0.-6.28 rad) and $\Delta\Theta$ versus ϕ (6.28-12.56 rad). The real data dependence is denoted by black stars and the fitting functions by empty rhombuses. The rhombuses do not coincide with the black stars because there are other reasons of mismatching, not only a geometric shift reason.

This method can be applicable to matching testing between two detectors.

Received on January 30, 2002.

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Быстрый метод геометрической калибровки детекторов
и проверки мэтчинга между двумя детекторами

Предложен быстрый метод геометрической калибровки детекторов. Основная идея этого метода — определение смещений одного детектора относительно другого (или одной части детектора относительно другой) с помощью фитирования зависимостей, полученных на основе экспериментальных данных, аналитическими функциями, которые описывают перемещение в пространстве одного детектора относительно другого. Аналитические функции получены на основе использования матриц вращения. Этот метод может быть использован для проверки качества мэтчинга между двумя детекторами. Детекторы расположены перпендикулярно к оси пучка. (Мэтчинг — соответствие друг другу двух частей трека, зарегистрированных двумя разными детекторами.)

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2002

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Fast Method for Geometric Calibration of Detectors
and for Matching Testing between Two Detectors

A fast method of geometric calibration of detectors has been proposed. The main idea of this method is to determine offsets by fitting the real data distribution by analytical functions which describe the motion of one detector relative to another one. This method can be applicable to offset determination for one detector relative to the other detector or for one part of the detector relative to its other part. The detectors should be placed perpendicular to the beam axis. The form of analytical functions depends on the geometry of experiment and on the direction of the coordinate axes. The analytical functions have been obtained using the rotation matrices. This method can be applied to matching testing between two detectors.

The investigation has been performed at the Laboratory of High Energies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2002

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ЛР № 020579 от 23.06.97.
Подписано в печать 22.02.2002.
Формат 60 × 90/16. Бумага офсетная. Печать офсетная.
Усл. печ. л. 0,94. Уч.-изд. л. 1,12. Тираж 375 экз. Заказ № 53145.

Издательский отдел Объединенного института ядерных исследований
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