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ALIGNMENT OF TPC/ITC

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Abstract

A procedure for aligning the two halves of the TPC and the ITC with the help of cosmic rays has been set up. Due to possible imperfections of the TPC the effect of any linear z - dependent distortion of the TPC which may be different in the two halves is taken into account for the alignment. Therefore the TPC is treated as composed of two separate detectors. About 1000 useful cosmic rays should be sufficient to ensure an alignment at the level of 50 - 100 μ.

1. Introduction

The ITC gives a very accurate measurement of the coordinates in the x-y plane (error on one coordinate about 100 - 180 μm) and thus can help to improve the accuracy of the determination of the momentum by the TPC. Furthermore it helps to extrapolate hits into the MVD. Therefore a good relative alignment of TPC/ITC is necessary. The coordinate error due to misalignment clearly should be smaller than the measurement error. A geometrical alignment at the level of 200 μm is ensured by mechanical means (FO88). A higher precission is reached by using cosmic rays crossing TPC and ITC. Furthermore this kind of alignment ensures that some effects which distort a pure mechanical alignment (see e.g. chapter 4) are taken into account properly. Alignment has been studied with the assumption of a perfect TPC (FO87). Aim of this new investigation is to modify the former procedure to study the effect of an imperfect TPC on alignment. Furthermore some of these imperfections may be measured with the help of the ITC.

2. Parameters, basic equations

Essentially the alignment is measured by comparing track parameters fitted independently in ITC and TPC. In this paper the TASSO convention is used (for the mathematical convention see GA88):

- D_0: closest distance of track to beam axis in x-y plane. Positive if origin is encircled negative if not.
- Φ_0: angle of track w.r.t x-axis in the x-y plane at D_0; range 0 to 2π (for cosmics coming from above only π to 2π).
- z_0: z of track at D_0.
- λ: dip angle w.r.t the vertical at D_0; range $-\pi/2$ to $\pi/2$.

The relative position of two rigid bodies can be described by six parameters. These could be chosen to be three offsets along an orthogonal coordinate system and a rotation matrix parametrized by three Euler angles (most general assumption). For alignment purposes only very small deviations from two perfectly aligned bodies are expected (this is ensured by the mechanical alignment). So three rotational angles around fixed axis together with three offsets along these axis are chosen to describe misalignment. The definitions are given in figure 1.

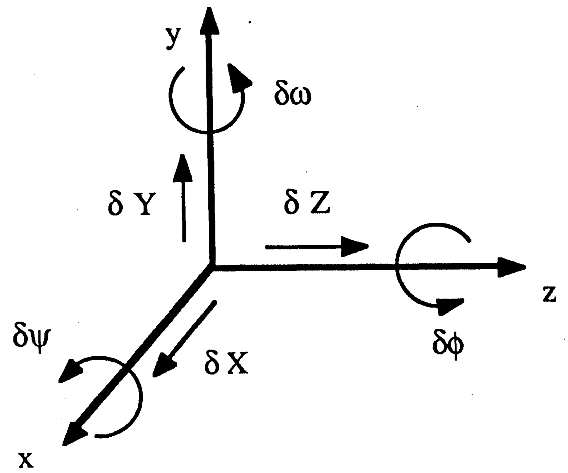

Fig. 1: Definition of alignment constants.

To determine misalignment the track parameters are measured independently in ITC and TPC. Figure 2 shows the effect of misalignment on D_0:

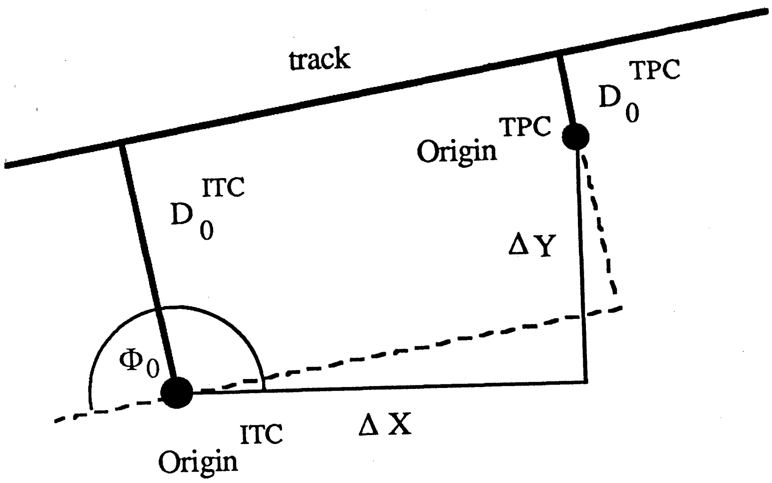

Fig. 2: Effect of misalignment on D_0.

(1) $$\Delta D_0 = [Q\,D_0]^{ITC} - [Q\,D_0]^{TPC}$$

$$= \Delta X \sin \Phi_0 - \Delta Y \cos \Phi_0,$$

where Q is positive if the track bends clockwise, negative if it bends anticlockwise and ΔX, ΔY are given by

(2) $$\Delta X = \delta X + Z_0\, \delta\omega,$$
$$\Delta Y = \delta Y - Z_0\, \delta\psi.$$

As the resolution in z_0 of the ITC is very poor (around 3 cm), z_0 is taken from the TPC. An alignment in z_0 is furthermore not carried out as z_0 will not be measured for cosmics in the ITC. Φ_0 is measured by the TPC as well because of the longer lever–arm. Combining (1) and (2) leads to

(3) $$\Delta D_0 = (\delta X + Z_0\delta\omega)\sin\Phi_0 - (\delta Y - Z_0\delta\psi)\cos\Phi_0,$$

which is regarded as the basic equation for this procedure. To determine the fifth parameter the Φ_0 information of both detectors with a small dip angle λ dependent correction (see figure 3, there only the effect of one angle - $\delta\omega$ - is regarded) is used:

(4) $$\delta\Phi = \Phi_0^{TPC} - \Phi_0^{ITC} + \tan\lambda\,(\delta\omega\sin\Phi_0 - \delta\psi\cos\Phi_0).$$

So, $\delta\Phi_0$ is completely decoupled from D_0.

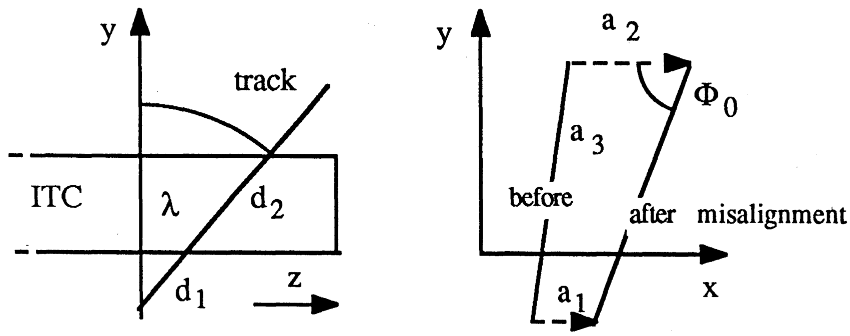

Fig. 3: Correction in Φ_0 due to a nonzero dip angle λ, where
$a_1 = \delta\omega\, d_1 \sin\lambda$,
$a_2 = \delta\omega\,(d_1+d_2)\sin\lambda$,
$a_3 = d_2\cos\lambda$ *and therefore*
$\Delta\Phi_0 = (a_2-a_1)\sin\Phi_0 / a_3 = \delta\omega\, d_2\sin\lambda\sin\Phi_0 / d_2\cos\lambda = \delta\omega\tan\lambda\sin\Phi_0.$

3. Results of former studies

In (FO87) equation (3) is used to apply an iterative procedure which works well if the TPC is regarded as perfect. Results with this procedure adapted for the ALEPH - software environment can be found in table 1.

parameter	measured value	true value
δX	-502 ± 6 µm	500 µm
δY	304 ± 14 µm	300 µm
$\delta\omega$	227 ± 16 µrad	200 µrad
$\delta\psi$	-285 ± 36 µrad	-300 µrad
$\delta\Phi$	486 ± 13 µrad	500 µrad

Table 1: Results of the iterative procedure for a perfect TPC.

4. Imperfections of the TPC

In this note the major known imperfections of the TPC are regarded which are linear dependent on z and may be different in the two halves of the TPC. Examples for these imperfections are (only these are used for the simulation):

- a nonzero angle between the E- and B-field (both are assumed to be homogenous), in this paper called BnpE (B not parallel E),
- a nonzero twist angle between the two TPC - halves.

The question howfar misalignment of sectors of the TPC can be measured is regarded in chapter 12.

To understand the effect of these imperfections the coordinate transformation induced by misalignment of the ITC is regarded:

$$(5) \qquad \vec{r}_{true} \longrightarrow \vec{r}_{true} + \begin{pmatrix} \delta X \\ \delta Y \\ \delta Z \end{pmatrix} + \begin{pmatrix} 0 & -\delta\Phi & \delta\omega \\ \delta\Phi & 0 & -\delta\psi \\ 0 & 0 & 0 \end{pmatrix} \vec{r}_{true}.$$

An angle between E- and B-field introduces nonzero x- and y-components of the drift velocity which are given by

$$(6) \qquad \Psi_x := \frac{v_x^{drift}}{v_z^{drift}} = \frac{(\omega\tau)}{1+(\omega\tau)^2}\{(\omega\tau)\cos\Phi - \sin\Phi\}\Psi,$$

$$\Psi_y := \frac{v_y^{drift}}{v_z^{drift}} = \frac{(\omega\tau)}{1+(\omega\tau)^2}\{(\omega\tau)\sin\Phi + \cos\Phi\}\Psi,$$

where Ψ and Φ are the azimuthal and polar angle of B relative to E. Ψ is expected to be in the order of mrad. $\omega\tau$ is taken from the common block TPCCON in JULIA (variable TOMTAU) which has the default value 4.5. The components Ψ_x and Ψ_y effect the drift in both halves of the TPC in a different way because E changes sign going from one half to the other. Therefore x and y of a hit are shifted by

$$(7) \qquad x/y_{true} \longrightarrow x/y_{true} - \left(\frac{z + s_z z_{end}}{v_z^{drift}} \right) v_{x/y}^{drift},$$

where s_z is the sign of z.

At last the twist angle Φ^T of the two TPC halves has to be taken into account. It changes the coordinates according to

$$(8) \qquad x/y_{true} \longrightarrow x/y_{true} \pm \Phi^T a_z z,$$

where $a_z = (1-s_z)/2$. These imperfections therefore lead to the following transformation in the TPC:

$$(9) \qquad \vec{r}_{true} \longrightarrow \vec{r}_{true} + \begin{pmatrix} \Psi_x \\ \Psi_y \\ 0 \end{pmatrix} s_z z_{end} + \begin{pmatrix} 0 & \Phi^T a_z & -\Psi_x \\ -\Phi^T a_z & 0 & -\Psi_y \\ 0 & 0 & 0 \end{pmatrix} \vec{r}_{true}.$$

Comparing (5) and (9) it is clear that both transformations have exactly the same structure looking at one TPC half only. So in half A ($z_0>0$)

$$(10) \qquad \begin{aligned} \delta X_A &= \delta X + \Psi_x z_{end} \\ \delta Y_A &= \delta Y + \Psi_y z_{end} \\ \delta\omega_A &= \delta\omega - \Psi_x \\ \delta\psi_A &= \delta\psi + \Psi_y \\ \delta\Phi_A &= \delta\Phi \end{aligned}$$

and in half B

$$\begin{aligned} \delta X_B &= \delta X - \Psi_x z_{end} \\ \delta Y_B &= \delta Y - \Psi_y z_{end} \\ \delta\omega_B &= \delta\omega - \Psi_x \\ \delta\psi_B &= \delta\psi + \Psi_y \\ \delta\Phi_B &= \delta\Phi - \Phi^T \end{aligned}$$

would be measured. So, by dividing the TPC into two parts during aligning the ITC it is possible to measure any transformation linearly dependent on z and differing in both TPC halves induced by any effect whatsoever.

5. Strategy

As shown in chapter 4 linear z-dependent imperfections in the TPC which may be different in the two halves have to be taken into account. Although some of them will be measured independently and the coordinates will be corrected for before alignment, the accuracy of these corrections may either not be sufficient or unknown imperfections of the above kind will distort alignment. Therefore it is essential for alignment to regard the TPC as two independent detectors. This means 2 * 5 alignment constants are measured. These are the coefficients of two linear transformations which have to be applied in each half. Clearly these 2 * 5 constants are most probably not the same as the geometrical alignment constants but are dominated by distortion effects. So, alignment in this paper means: Find a set of 'alignment' constants which gives you a linear transformation to correct the coordinates so that the relative alignment of TPC/ITC as seen by electronics/reconstruction program is correct. It is shown in chapter 4 that any linear z-dependent distortion is taken into account if the TPC is divided into two halves.

A scheme to incorporate alignment corrections into the offline analysis remains to be defined. Three possible schemes to distribute responsibilities between different groups in ALEPH are: (1) Fix TPC A (B), correct ITC, correct TPC B (A). This alternative means that TPC A (B) defines the ALPEH coordinate system. Coordinates of both detectors have to be corrected which means a shared responsibility between the ITC and TPC group. (2) Fix TPC, divide ITC into two halves and correct ITC A and ITC B. Here the TPC is forced to be a unit - the coordinate system of ALEPH would therefore be some kind of 'mean' of the two systems TPC A & TPC B. Only people of the ITC group would be responsible for alignment. (3) Fix ITC, correct TPC A, correct TPC B. The ALPEH coordinate system would then be defined by the ITC, the TPC group would be responsible for alignment.The last alternative seems to be the most logical one (ITC is a rigid body connecting TPC A & TPC B). Although it somehow inverts the former alignment (ITC relative to TPC), this alternative is proposed in this note.

6. Simulation

Cosmics have been generated with a simple μ - generator (BE87) flat in energy between 2 and 20 GeV. The starting point of the track is distributed flat between -200 cm < z < 200 cm at the upper edge of the TPC. The Φ_0 range stretches (flat) from $-\pi/4$ to $\pi/4$ against the vertical. A second point of the track is then chosen at y = 0, flat between -100 cm < z < 100 cm (ITC) and flat between $-R_{ITC} < x < R_{ITC}$. Samples of 10000 events have been generated with GALEPH V 2.01 with different sets of alignment constants. The track elements in the ITC were modified according to these constants before digitising. Then TPCSIM V 2.04 was used to allow a more reliable study of

TPC effects. TPC imperfections were introduced at the reconstruction level. A description how to use these programs can be found as a separate ALPEH-note (RO88).

7. Reconstruction

In this section the whole reconstruction chain except for the determination of the alignment constants is described.

7.1 ITC reconstruction

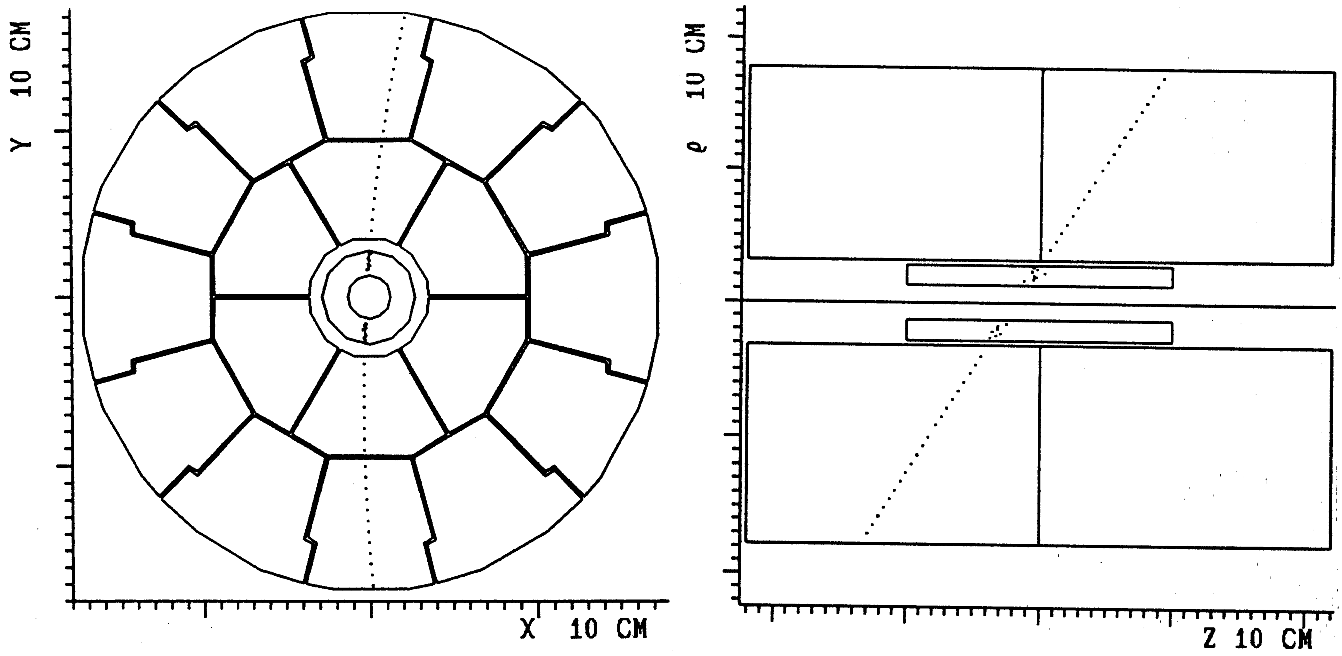

Fig. 4: typical cosmic event displayed by DALI.

In (FO87) merely the influence of ITC digitisation on straight tracks is studied. But approaching reality the reconstruction of curved tracks has to be allowed, as tracks with momentum well below 10 GeV are used. It is also not possible to use the standard JULIA reconstruction, because the ITC gives only drift-time measurement, i.e. the distance from a sense wire which defines a circle in the x-y plane. For e^+e^- data this does not really matter because the knowledge that the tracks are coming from the vertex reduces the circle to two points - a simple ambiguity, easily to be resolved. For alignment with cosmics most of the tracks do not cross the beamline (see figure 4). So a similar procedure as described in (FO87) has to be applied, allowing the reconstruction of curved tracks:

- take position of wires and fit circle giving large weights to short drift times ($w = 1/(d^2+d_0^2)$) to find the position on the drift circles for longer drifts correctly.

- take these position and fit now giving large weights to long drift times ($w = d^2$) to find the positions on the drift circles for shorter drifts.

With these positions the standard fit (UFITMS in JULIA, (GA88)) is performed.

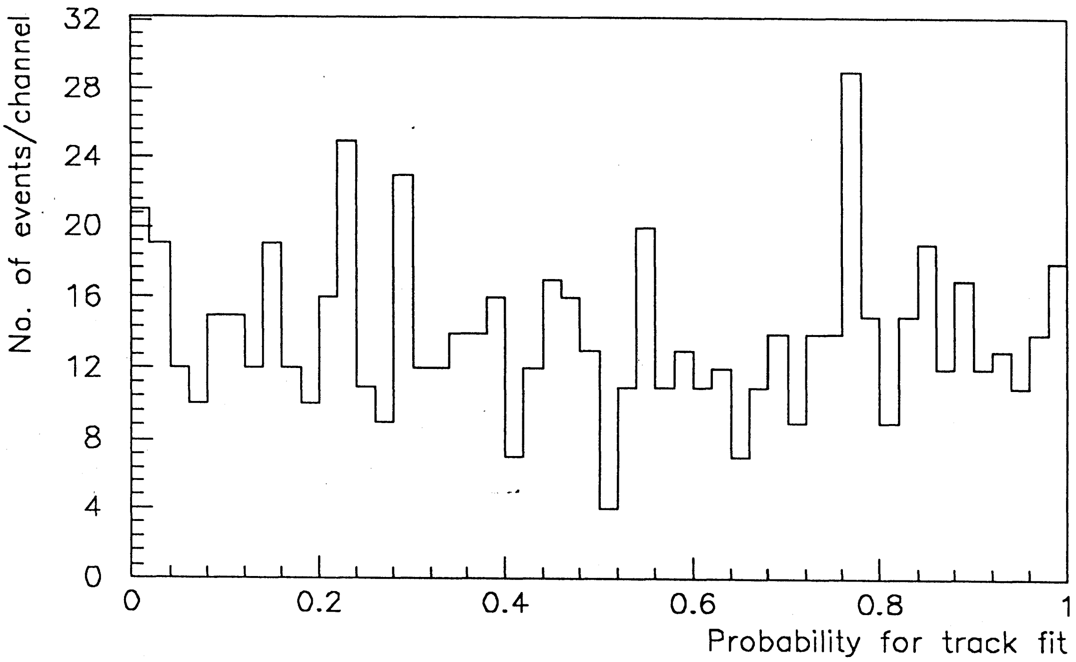

Fig. 5: probability distribution for ITC track fit.

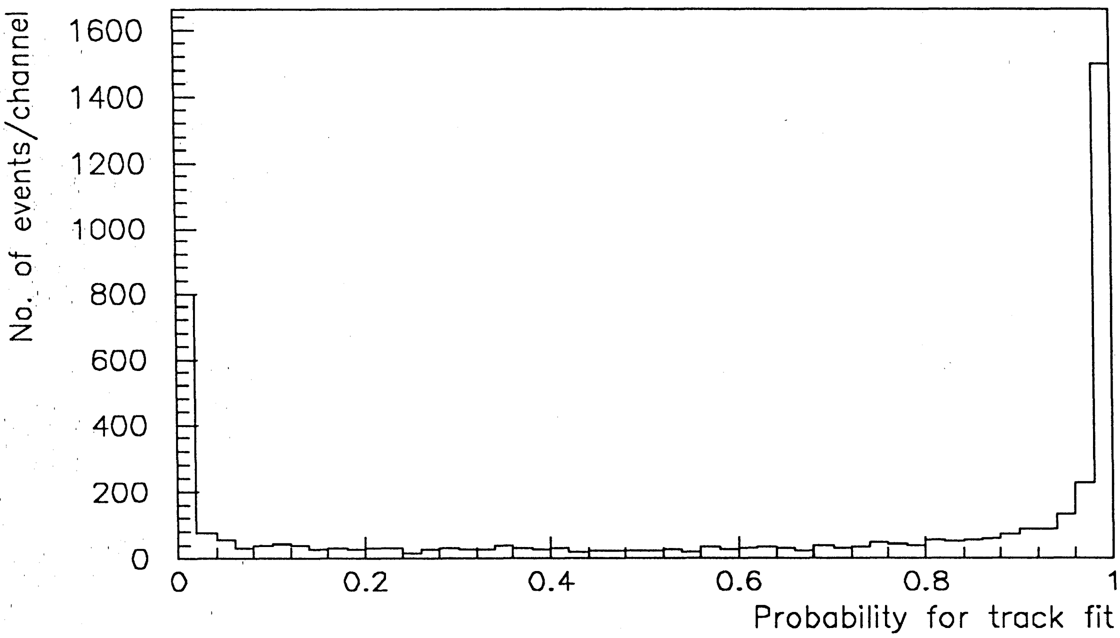

Fig. 6: probability distribution for TPC track fit.

Due to the curvature of tracks some constellations are causing problems, e.g.: Only long drifts in the upper half of the ITC, only short drifts in the lower half sometimes leads to a wrong fit result which is clearly visible by looking at the maximum residual.

So a cut at 500 μm for the largest residual is applied which cures the problem and kills only 1% of all good events. The probability distribution for the track fit is shown in figure 5. The spike at low probabilities is due to effects like bremsstrahlung or multiple scattering and is cut away with a χ^2/d.o.f. cut at 2.

7.2 TPC reconstruction

For reasons mentioned in chapter 4 it is necessary to use information coming from one TPC half only. One way would be to use only tracks which cross only one half at all. But clearly this reduces statistics too much. So the hits of one track on each side are counted and the half in which more hits are found is chosen whereas the other hits are thrown away. Then the standard fit (UFITMS) without multiple scattering is performed. For TPCSIM the probability distribution for the track fit shows a peak at 1 which gives a hint to a problem concerning coordinate errors in JULIA (see figure 6).

7.3 Cuts

Cuts are listed here for completeness although some of them will be explained later.

- $22 \leq$ # hits in TPC ≤ 42	(explanation in chapter 8)
- # hits in ITC = 16	for best quality of tracks,
- maximum residual in ITC < 500 μm	(see above),
- χ^2/d.o.f. for TPC fit ≤ 2	track quality, excluding e.g.
- χ^2/d.o.f. for ITC fit ≤ 2	Bremsstrahlung,
- $\lvert D_0 \rvert < 5$ cm	see chapter 8,
- $p > 6$ GeV	see chapter 8.

8. Determination of alignment constants

As shown in chapter 2, $\delta\Phi_0$ is decoupled from the other four parameters. So it is sufficient to determine four parameters (δX, δY, $\delta\omega$, $\delta\psi$) independently per half. But it was not possible to use the old alignment procedure (FO87) for this purpose. This was because the $\langle z \rangle$ (mean over z for one half) does not vanish as it is the case for the whole TPC. This fact introduces strong correlations between each offset and the corresponding tilt angle. The former procedure could not handle these correlations and lead to wrong results w.r.t the errors. To get things right a χ^2 - fit (using MINUIT) for the four parameters has to be performed. For the fifth parameter the term on the right hand side of equation (4) is calculated for each track. This value is filled into a histogram to measure mean and error. As $\delta\Phi_0$ is (nearly) decoupled from any other parameter this leads to the right result. The basic equation for the χ^2 - fit is equation (3) which leads to

$$(11) \qquad \chi^2_{fit} = \sum_{i=1}^{n} \frac{f^2(\Delta D_{0,i},\Phi_{0,i},z_{0,i})}{\sigma^2(D_{0,i},\Phi_{0,i},z_{0,i})},$$

with $f(\Delta D_0,\Phi_0,z_0) =$

$$\Delta D_0 - \{(\delta X \sin\Phi_0 - \delta Y \cos\Phi_0) + z_0\,(\delta\omega \sin\Phi_0 + \delta\psi \cos\Phi_0)\},$$

and $$\sigma^2(D_0,\Phi_0,z_0) = \sum_{k\,l=1}^{4} \frac{\partial f}{\partial x_k} C_{kl} \frac{\partial f}{\partial x_l} + \sigma^2_{D_0^{ITC}},$$

where n = # of tracks, $x = (\delta X,\delta Y,\delta\omega,\delta\psi)$ and C_{kl} is the covariance matrix coming from the track fit.

This fit is performed independently in each half and a comparison with the true values is made. Results for two different sets of alignment constants are shown in table 2 which gives an impression how well the procedure works.

Set I

(ITC misalignment: δX = -200μm, δY = 400μm, $\delta\omega$ = 300μrad, $\delta\psi$ = -200μrad, $\delta\Phi_0$ = -600μrad, TPC imperfections: Φ^T = 200μrad, Ψ=2000μrad, Φ = 1.3rad)

parameter	TPC (z_0<0) measured	true	TPC (z_0>0) measured	true
$\delta X_{B/A}$[μm]	-432 ± 22	-445	71 ± 20	45
$\delta Y_{B/A}$[μm]	-4231 ± 49	-4280	5125 ± 43	5080
$\delta\omega_{B/A}$[μrad]	231 ± 38	198	139 ± 35	198
$\delta\psi_{B/A}$[μrad]	1680 ± 83	1750	1868 ± 75	1750
$\delta\Phi_{B/A}$[μrad]	-812 ± 39	-800	-617 ± 42	-600
χ^2_{fit}	437/313 = 1.40		555/332 = 1.67	
$\chi^2_{deviation}$	2.31/5		6.78/5	

Set II

(ITC misalignment: δX = -400μm, δY = -500μm, $\delta\omega$ = -400μrad, $\delta\psi$ = 100μrad, $\delta\Phi_0$ = 1000μrad, TPC imperfections: Φ^T = -400μrad, Ψ=1500μrad, Φ = 0.8rad)

$\delta X_{B/A}$[μm]	1425 ± 22	1443	-2215 ± 19	-2243
$\delta Y_{B/A}$[μm]	2437 ± 43	2493	-3552 ± 39	-3493
$\delta\omega_{B/A}$[μrad]	340 ± 38	368	341 ± 33	368
$\delta\psi_{B/A}$[μrad]	-1025 ± 74	-1147	-1245 ± 65	-1147
$\delta\Phi_{B/A}$[μrad]	1446 ± 24	1400	974 ± 26	1000
χ^2_{fit}	462/340 = 1.35		547/353 = 1.55	
$\chi^2_{deviation}$	7.62/5		6.65/5	

Table 2: Two sets of measured alignment constants (χ^2_{fit} gives the χ^2/d.o.f for the fit over all tracks, $\chi^2_{deviation}$ gives the χ^2 for the deviation from the input parameters including correlations).

Now some problems and cuts which have to be applied are discussed:

- *Multiple scattering*

The multiple scattering angle is not fitted as it is rather difficult to use this information for alignment. This clearly causes a rise in χ^2 for the fit. To reduce the influence a momentum cut is applied (see table 3 for the influence of multiple scattering and this cut). For all results given in this note a cut at 6 GeV is applied which is a compromise between loss in statistics and gain in quality. Furthermore there is one fact which helps to suppress the effect of multiple scattering: If the track fit in the TPC includes hits before and after traversing the ITC it measures some kind of 'mean' for the track parameters. But the ITC is measuring as well some kind of 'mean' w.r.t. multiple scattering as it lies inbetween the TPC. Therefore it is essential to demand at least one hit in the TPC after traversing the ITC for the track fit. This means the number of hits in the TPC must be at least 22 and not more than 42. But even after switching off multiple scattering some distortions are left which can be seen from table 4. While $\chi^2_{deviation}$ decreases substantially χ^2_{fit} does not change very much. This hints to an additional different problem, which is discussed next.

Cut value (GeV)	χ^2_{fit} half A and B		$\chi^2_{deviation}$ half A and B	
2	718/439 = 1.64	802/439 = 1.83	10.08/5	5.55/5
6	462/340 = 1.35	547/353 = 1.55	7.62/5	6.65/5
10	270/220 = 1.23	365/237 = 1.54	6.81/5	5.37/5

Table 3: Influence of MS and momentum cut.

	χ^2_{fit} half A and B		$\chi^2_{deviation}$ half A and B	
multiple scatt.	437/313 = 1.40	555/332 = 1.67	2.31/5	6.78/5
no multiple sc.	454/333 = 1.36	507/352 = 1.44	1.63/5	4.03/5
20k gen. events	1733/636 = 2.72	1858/656 = 2.83	10.90/5	11.99/5

Table 4: comparison multiple scattering - no multtiple scattering and higher statistics.

- *Coordinate reconstruction problems*

After switching from simple coordinate smearing à la GALEPH to (fast) TPCSIM the quality of the fit became very poor. Looking at figure 7 it can be seen that for large $|D_0|$ the distribution of $D_0^{GALEPH} - D_0^{TPCSIM}$ becomes broader (see figure 7) and has longer tails. This is most probably due to the fact that the coordinate finding algorithm(s) in JULIA is built to handle tracks coming from the vertex. But tracks with large $|D_0|$ for example do not look like coming from the vertex as they cross the padrow not under 90^o which is assumed by the coordinate finding algorithms. Therefore tracks with

$|D_0| > 5$ cm are excluded from the analysis. Examples for data reduction due to cuts are shown in table 5.

Cut	loss in	Set I (all: 6927)	Set II (all: 6961)
TPC rec. failure		91	80
$22 \leq$ # hits TPC ≤ 42		2451	2415
χ^2/d.o.f. trackfit TPC < 2		527	469
$p \geq 6$ GeV		805	845
$|D_0| < 5$ cm		2294	2368
# hits ITC = 16		103	79
ITC residual cut		7	8
χ^2/d.o.f. trackfit ITC < 2		4	4

Table 5: Data reduction.

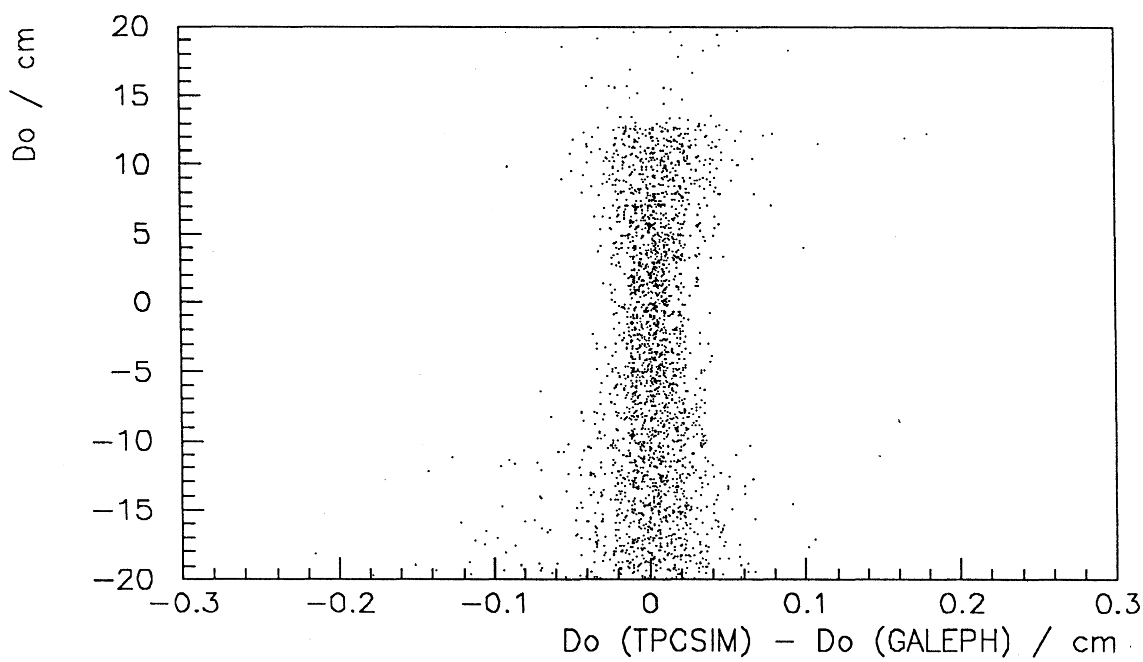

Fig. 7: D_0^{GALEPH} - D_0^{TPCSIM} versus D_0.

9. Measuring imperfections

The procedure outlined above results in 2 * 5 constants for a linear transformation. If it is guaranteed (e.g. by independent measurements) that no distortions but the one described in chapter 4 are present in the TPC, equation (10) can be inverted to get the geometrical alignment constants and the parameters describing the distortions. For the two samples given in table 2 this has been done and the results can be found in table 6. It should be stressed that under the assumptions given in this paragraph these imperfections are measurable to a remarkably high degree of accuracy (v^x_{drift}/v^y_{drift} to about 10^{-5}) compared e.g. to the measurements of the laser calibration system. But clearly it will be very difficult to show that no other distortions are present which is essential to interpret these constants in this way.

parameters	measured value set I	true	measured value set II	true
δX [µm]	-181 ± 15	-200	-395 ± 15	-400
δY [µm]	447 ± 32	400	-557 ± 29	-500
$\delta\omega$ [µrad]	290 ± 27	300	-418 ± 26	-400
$\delta\psi$ [µrad]	-176 ± 57	-200	113 ± 51	100
$\delta\Phi$[µrad]	-617 ± 42	-600	974 ± 26	1000
Φ^T [µrad]	195 ± 58	200	-472 ± 36	-400
Ψ_x [10^{-6}]	105 ± 6	102	-758 ± 6	768
Ψ_y [10^{-6}]	1949 ± 14	1950	-1248 ± 12	-1247
$\chi^2_{deviation}$	4.5/8		12.2/8	

Table 6: Interpretation of alignment constants in terms of imperfections and geometrical alignment constants.

10. Systematic effects

	TPCSIM	NO TPCSIM
multiple scatt.	<x> = 0.47 ± 0.06 σ = 1.8	<x> = 0.17 ± 0.06 σ = 2.4
no multiple sc	<x> = 0.44 ± 0.04 σ = 1.1	<x> = -0.06 ± 0.03 σ = 1.0

Table 7: $x = (D_0 - D_0^{TRUE})/\sigma_{D_o}$: mean value and width ($|D_0| < 5$ cm, $p > 6$ GeV).

To check the error given by UFITMS the expectation value of mean and rms-width of the distribution $(D_0 - D_0^{TRUE})/\sigma_{D_0}$ have been calculated with and without multiple scattering (MS & NMS) and with and without TPCSIM. Numbers are given in table 6. For 'perfect' errors a gaussian distribution with mean 0 and width 1 is expected. There exists a bias using TPCSIM - the origin of this bias may be related to the coordinate reconstruction problem. Using NMS the width becomes more realistic and thus gives some confidence in these alignment measurements (MS only broadens but does not bias distributions). On the other hand the width of about 2 shows that the systematic error due to MS and coordinate reconstruction problems (and other possible distortions) is not negligible. To check its influence a sample of 20000 events has been generated. The χ^2 values are shown in table 4. It is clear that the error is more and more dominated by systematics not taken into account for the fit and thus the χ^2 increases. Therefore the errors given for this special sample may give an estimate of 50% for the systematic error. For the moment this leads to an estimate of 25% systematic error relative to the error given by the sets with the usual amount of data (about 700 useful events). This as well reduces the χ^2 of the MINUIT fit to roughly 1 for these samples.

11. Data taking

The values given for data reduction are somehow misleading. The rather high loss of events is explained by the way they are generated. Therefore it is proposed to take only data which

- is rather high energetic to mimise the influence of multiple scattering,
- has values for $|D_0| < 5$ cm.

Then the cuts now killing most of the events have no large effect anymore. It has to be discussed and decided how to arrange the trigger to fulfill the requirements quoted above. If a very pessimistic acceptance of 10% for the cosmics is assumed and the number 0.35 $m^{-2}s^{-1}$ for the μ flux/horizontal area for $p_\mu > 10$ GeV (WA87) is taken, about 2 days of running is needed to collect about 1000 useful events assuming a D_0 range of [-5 cm, 5 cm]. Reducing this range may become necessary which would increase the duration of the cosmics run. It appears to be very useful to have a cosmic trigger during normal data taking of e^+e^- interactions.

12. Further studies

Concerning misalignment of sectors of the TPC at least two alternatives w.r.t the procedure developed in this note are possible. Cosmics may simply be used to align each sector relative to the ITC which is then regarded as the reference system. But surely statistics is a problem which would require a cosmic trigger during normal data taking. In principle this alignment seems to be possible although no work has been done so far. The priority of such investigations currently is anyhow regarded as rather low due to dedicated measurements of misalignment with the MOPA-laser.

One way to avoid the problem of statistics would be to take e.g. μ-pairs from e^+e^- interactions to align single sectors relative to the ITC. This is possible in principle but the procedure outlined in this note has to be modified because it needs a rather large lever-arm in z_0. As tracks coming from the vertex have a rather sharply peaked z_0 distribution at values around 0 they are of little use for this procedure.

13. Conclusions

A procedure used to align ITC, TPC A and TPC B relative to each other has been set up. A twist angle between half A and B and every linear z-dependent distortion (which may be different in the two halves) are taken into account and are measured. The general scheme consists of measuring the five coefficents of two linear transformations to be applied for z>0 and z<0. The accuracy to which each of this coefficient is measured with about 1000 useful events ensures a relative alignment of TPC A / ITC / TPC B to better than 100 µm. The systematic error due to multiple scattering and coordinate reconstruction problems in the TPC is estimated to be about 25% of the statistical error for this amount of data. It is proposed that both halves of the TPC are aligned relative to the ITC which then defines the ALEPH coordinate frame. This remains to be discussed by people from the ITC and TPC group. Concerning cosmic trigger some requirements are quoted which should be taken into account for designing the trigger.

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