DIRAC NOTE 2002-02

DIRAC Beam Parameters

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Abstract

The impact points and relative errors of tracks at the target provide the mean to determine the different contributions to the experimental uncertainties, in particular the multiple scattering error, the proton beam size and uncertainty on the beam position. The latter turns out 1.0±0.10mm and 1.7±0.09mm in the xz and yz planes, respectively, at the target.

1 Introduction

The analysis is based on a data sample consisting of about 130×10^6 triggers (33 runs) collected during the summer of 2001, using a Ni target. Events were reconstructed using two software packages: the standard Ariane code (hereafter called **standard**) and an improved code which includes independent upstream tracking based on the combined information from MSGC and SFD hit patterns (hereafter called **standard+MSGC**). Reconstructed events were further selected by requiring:

- Q_x, $Q_y < 6$ MeV/c, $Q_L < 45$ MeV/c;
- no muon candidates (10% rejection);
- presence of 2 hits in both x and y plane of SFD (i.e. rejection of events with 2 tracks hitting one fibre column on both planes, or one fibre in one plane and 2 adjacent fibres in the other);
- presence of ADC amplitude in IH (single ionisation).

About 0.3% (376214 events) of the initial statistics matched the above selection criteria. We further considered only events reconstructed by both **standard** and **standard+MSGC** software packages ($\sim$ 44%, or 163880 events). Namely, $\sim$ 56% of events were not reconstructed by the **standard+MSGC** code. An independent analysis was carried out on the subsamples of correlated (36%) and accidental (64%) events from the global 163880 event sample.

Events with e^+ and/or e^- candidates were not rejected.

We considered the standard deviation of the distributions of the difference and sum between the reconstructed x (y) coordinates at the target of the positive and negative tracks, for several momentum interval. An example of such distributions is shown in Fig. 1 for the sample of correlated events, using the **standard+MSGC** reconstruction code, for the momenta of both particles in the range from 2.0 to 2.5 GeV/c.

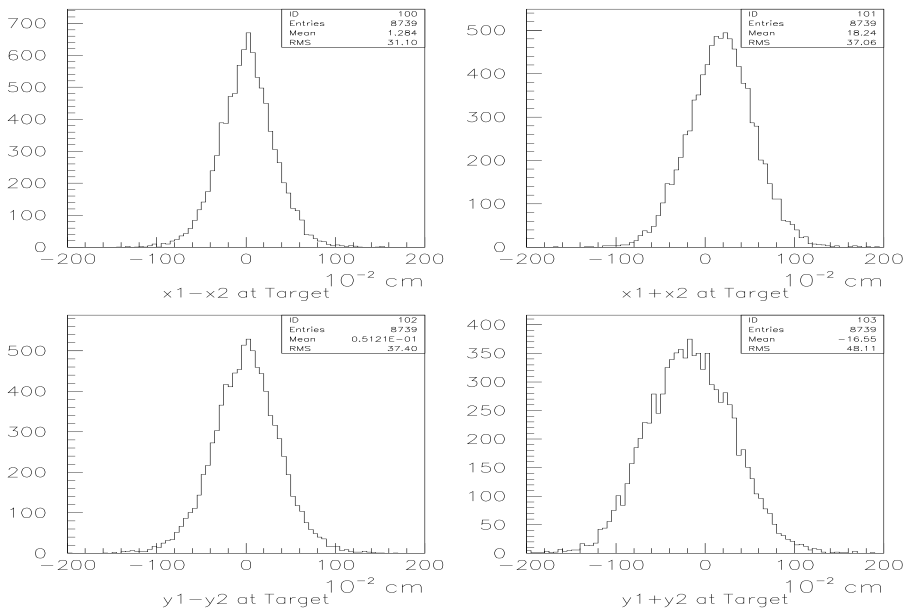

Figure 1: Distributions of difference (left) and sum (right) between reconstructed x (upper) and y (lower) coordinates of negative and positive track, from correlated events, using the **standard+MSGC** code, with both particle momenta in the range from 2.0 to 2.5 GeV/c.

2 Correlated pairs

The left part of Fig. 2 shows the momentum dependence of the standard deviation squared $\sigma_-^2 \equiv \sigma^2(x1 - x2)$ (squares), $\sigma_+^2 \equiv \sigma^2(x1 + x2)$ (triangles) and $\sigma_+^2 - \sigma_-^2$ (circles). Similarly for the right plot of Fig. 2 with x replaced by y. The x and y coordinates were reconstructed using the **standard** (upper) and **standard+MSGC** (lower) software packages.

A fit to the experimental points of Fig. 2 was performed using a function of the type:

$$\sigma^2 = (\alpha/p)^2 + (\beta)^2 \tag{1}$$

with α and β free parameters. The fitting curves are shown on Fig. 2 superimposed to the experimental points.

The dispersion in the 2-track coordinate difference $\sigma(x1-x2)$ (similarly for the y-coordinate) has contribution from two sources: the multiple scattering error (inversely proportional to the

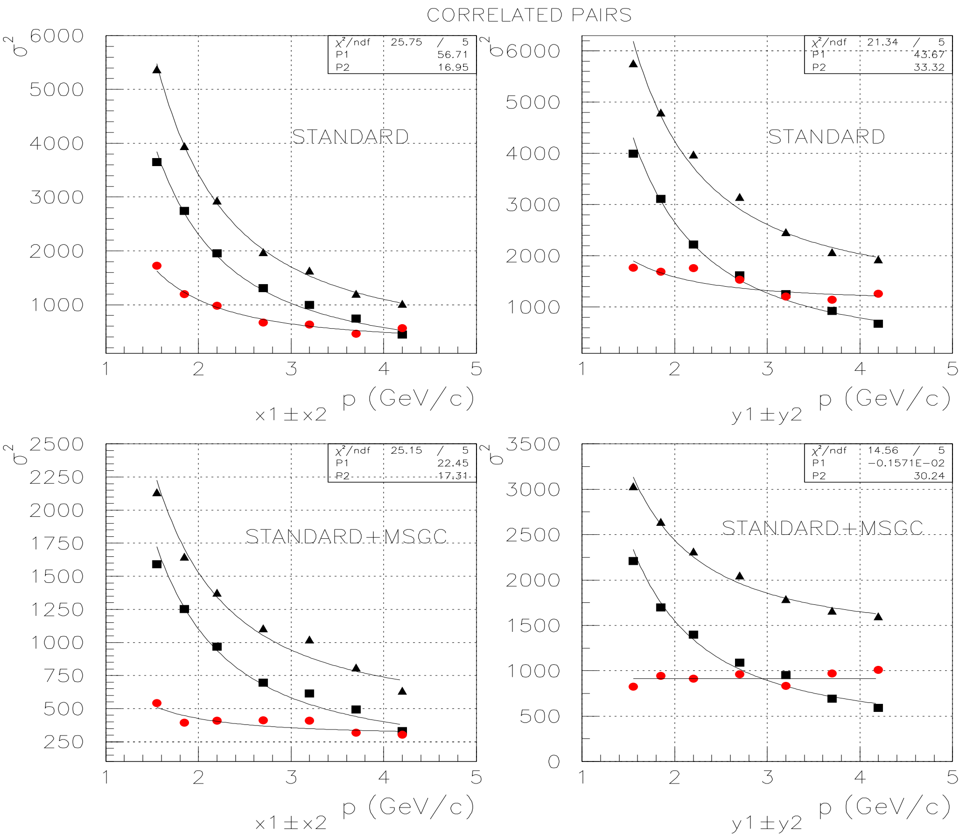

Figure 2: Momentum dependence of the r.m.s. of coordinate distributions of correlated pairs at the target. See text for details.

momentum) and fluctuations due to incoherent type of errors (momentum independent). The latter include the intrinsic detectors resolution and uncorrelated fluctuations of the pedestal levels and threshold variations of the ADCs. All coherent errors (described later) tend, in fact, to cancel out in the difference. Formally:

$$\sigma_{-}^{2} = 2(\sigma_{ms}^{2} + \sigma_{inc}^{2}) \sim (\alpha/p)^{2} + (\beta)^{2} \tag{2}$$

where the factor 2 takes into account the two independent measurements. Once the parameters α and β are determined from the fit to the data points (squares) of Fig. 2, the uncertainty on the x,y vertex coordinates induced by the multiple scattering error can be determined for both the **standard** and **standard+MSGC** reconstruction methods. For the latter, we expect a better precision due to the additional constraints provided by the MSGC measurement and by the detector location (closer to the target).

On the other end, the distribution that samples the sum $\sigma(x1 + x2)$ is sensitive to contribution from both incoherent and coherent errors. The latter, are caused typically by uncertainties on the beam size and position (momentum independent), and other momentum dependent fluctuations of the detector response, like gain variations, not directly measurable. We can then write formally:

$$\sigma_+^2 = 2(\sigma_{ms}^2 + \sigma_{inc}^2) + 2\sigma_{coh}^2 + 4\sigma_{beam}^2 \sim (\alpha'/p)^2 + (\beta')^2 \tag{3}$$

where

$$\sigma_{beam}^2 = \sigma_{beamsize}^2 + \sigma_{beampos}^2 \tag{4}$$

and the factor 4 means full correlation between the two measurements.

The momentum dependent part of the coherent error $(\propto \alpha'/p) mightreceiveadditionalcontributionsfrompos$

Finally, the difference between dispersions, $\sigma_+^2 - \sigma_-^2$, will be sensitive only to coherent type of errors, namely:

$$\sigma_+^2 - \sigma_-^2 = 2\sigma_{coh}^2 + 4\sigma_{beam}^2 \sim (\alpha''/p)^2 + (\beta'')^2 \tag{5}$$

The parameters α'' and β'', obtained from a fit to the experimental points (circles) of Fig. 2, allow to determine σ_{beam}^2 but not the separate contribution of $\sigma_{beamsize}^2$ and $\sigma_{beampos}^2$.

All different contributions to the experimental uncertainties on the x, y track coordinates at the target have been summarised in Tab. 1, in both approaches using **standard** and **standard+MSGC** reconstruction codes.

	Error	*m.s.*	*incoherent*	*coherent*	*beam*
		mm/(GeV/c)	mm	mm/(GeV/c)	mm
STANDARD	σ_x	6.8(0.05)/p	(0.19)	4.0(0.11)/p	0.9(0.04)
	σ_y	7.1(0.11)/p	0.9(0.09)	3.1(0.20)/p	1.7(0.03)
STANDARD + MSGC	σ_x	4.3(0.06)/p	0.9(0.03)	1.6(0.11)/p	0.9(0.02)
	σ_y	4.9(0.10)/p	1.3(0.04)	(0.41)	1.5(0.01)

Table 1. Different contributions to the vertex position uncertainty of **correlated** events reconstructed with **standard** and **standard+MSGC** software methods. The errors on the fitting parameters are shown in parentheses.

3 Accidental pairs

The study of accidental pairs should in principle provide a mean to cross-check the previous results based on the study of correlated pairs. The main difference consists in the fact that two tracks coming from different proton nucleus interactions sample twice the beam size and not just one like for correlated pairs. One should then take into account such contribution as an additional source of uncorrelated error on the determination of the vertex position.

Fig. 3 shows the momentum dependence of the dispersions squared for accidental pairs. The different experimental distributions are similar to those of Fig. 2, as well as the definition of the fitting functions.

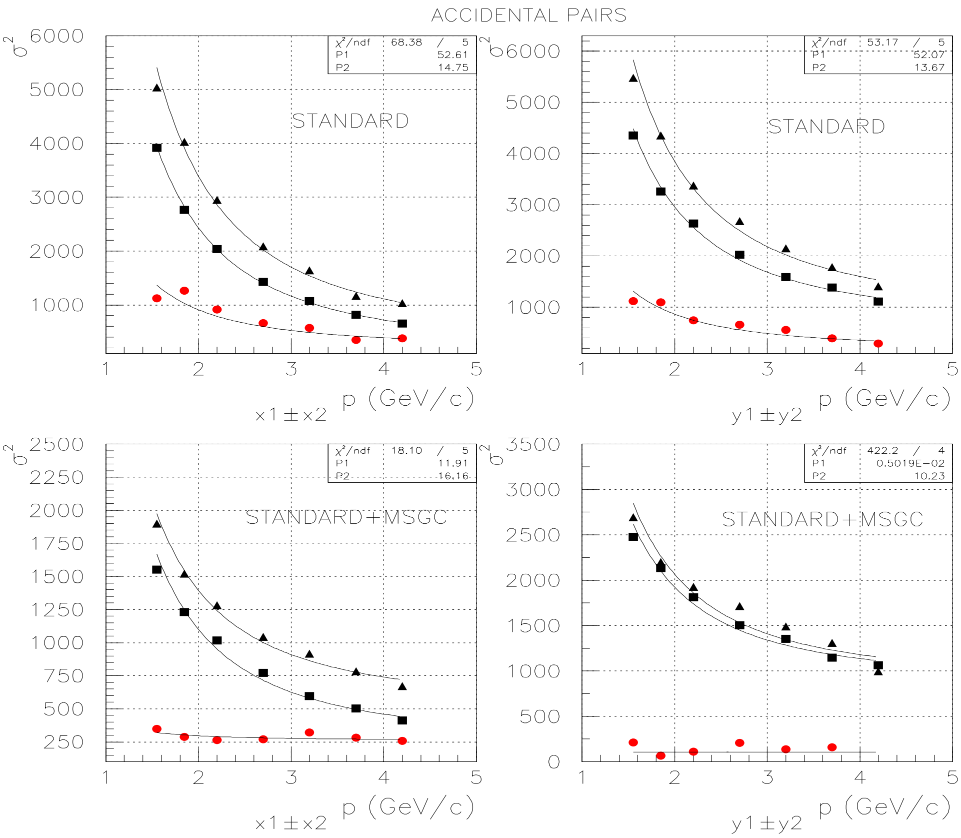

Figure 3: Momentum dependence of the r.m.s. of coordinate distributions of accidental pairs at the target. See text for details.

The dispersion in the 2-track coordinate difference $\sigma(x1-x2)$ senses all sources of incoherent error:

$$\sigma_-^2 = 2(\sigma_{ms}^2 + \sigma_{inc}^2 + \sigma_{beamsize}^2) \sim (\alpha/p)^2 + (\beta)^2 \qquad (6)$$

where now the additional factor $2\sigma_{beamsize}^2$ takes into account the two independent measurements of the beam size. If one assumes that the contribution of σ_{inc}^2 is the same for correlated and accidental pairs, then the fitting parameter β provide a determination of the uncertainty on the beam size.

In a similar way, the dispersion of the sum can be written as:

$$\sigma_+^2 = 2(\sigma_{ms}^2 + \sigma_{inc}^2) + 2\sigma_{coh}^2 + 2\sigma_{beamsize}^2 + 4\sigma_{beampos}^2 \sim (\alpha'/p)^2 + (\beta')^2 \qquad (7)$$

where the factor 4 means full correlation between the two measurements of the beam position.

Finally, the difference between dispersions, $\sigma_+^2 - \sigma_-^2$, will sense only coherent type of errors, namely:

$$\sigma_+^2 - \sigma_-^2 = 2\sigma_{coh}^2 + 4\sigma_{beampos}^2 \sim (\alpha''/p)^2 + (\beta'')^2 \tag{8}$$

The parameter β'' provides therefore an independent measurement of the uncertainty on the beam position, which can be added in quadrature to the error due to the beam size, allowing to determine the overall uncertainty σ_{beam}^2. Its value can then be compared to the one obtained from the analysis of correlated pairs.

Tab. 2 shows the results obtained from the analysis of reconstructed accidental pairs using both the **standard** and **standard+MSGC** reconstruction codes.

	Error	*m.s.* mm/(GeV/c)	*incoherent* mm	*coherent* mm/(GeV/c)	*beam* size - pos mm
STANDARD	σ_x	6.7(0.11)/p	(0.19)	3.7(0.09)/p	1.1(0.09) 0.8(0.08) - 0.8(0.03)
	σ_y	6.8(0.13)/p	0.9(0.09)	3.7(0.09)/p	1.7(0.07) 1.6(0.06) - 0.7(0.03)
STANDARD + MSGC	σ_x	4.1(0.06)/p	0.9(0.03)	0.9(0.15)/p	1.1(0.03) 0.8(0.02) - 0.8(0.02)
	σ_y	4.6(0.13)/p	1.3(0.04)	(0.08)	1.7(0.04) 1.6(0.04) - 0.5(0.01)

Table 2. Different contributions to the vertex position uncertainty of **accidental** events reconstructed with **standard** and **standard+MSGC** software methods. The errors on the fitting parameters are shown in parentheses.

4 Conclusion

From a comparison of the results presented in Tab. 1 and Tab. 2, we gather that the uncertainty induced by the multiple scattering error on the measurement of track coordinates at the target is ∼3.4mm for a 2 GeV/c pion (average between σ_x and σ_y) when using the **standard** reconstruction code, that is, when the first measured points are at the level of SFD detector. A better precision (∼2.2mm on average) is achieved when the information from the MSGC detector is used in addition (**standard+MSGC** code). This is true on average for both correlated (Tab. 1) and accidental (Tab. 2) events. From an analytic calculation based on a statistical treatment of the multiple scattering and intrinsic detector errors induced on the upstream tracking it was derived (ref.[1]) an uncertainty on the vertex position:

$$\sigma_{xy}^{vertex} = \sqrt{\sigma_x^2 + \sigma_y^2} \simeq 2.6mm \tag{9}$$

to be compared with the value $\sigma_{xy}^{vertex} = \sqrt{2.1^2 + 2.4^2} \simeq 3.2mm$ (average between correlated and accidental) obtained from the analysis of **standard+MSGC** reconstructed tracks. We mention the fact that the analytic calculation [1] does not include any uncertainty caused by the 2-track vertex fit whereas our reconstruction algorithm does.

The contribution to the y-coordinate measurement uncertainty arising from coherent-type of errors is negligible, as expected, when using the **standard+MSGC** reconstruction code. On the contrary, a positive contribution to the x-coordinate measurement error remains, probably due to the effects of magnetic field.

The momentum independent incoherent errors add at most $\sim 1.5mm$ to σ_{xy}^{vertex}. The source of such errors arises probably from uncorrelated fluctuations in the detectors response (pedestal fluctuations, etc.). The use of MSGC information in addition to SFD might justify the larger size of such type of error in the case of **standard+MSGC** tracking.

Finally, the error induced by the uncertainty on the beam position and size is of the order of $1mm$ on the x-coordinate and $1.7mm$ on the y-coordinate, for both correlated and accidental pairs, and both tracking methods. From the study of the sample of accidental pairs one is capable of disentangling the relative contributions of beam size and beam position to the overall beam uncertainty. Tab 3 summarizes the final values of the beam parameters after averaging among the values and relative errors obtained with the **standard** and **standard+MSGC** reconstruction of correlated and accidental pairs. These values will be used as input to the DIRAC Monte Carlo program.

Error	*beam* mm	*beam size* mm	*beam pos* mm
σ_x	1.00±0.10	0.80±0.08	0.80±0.04
σ_y	1.70±0.09	1.60±0.07	0.60±0.03

Table 3. Uncertainty to the particle tracking induced by the beam-spot size and by fluctuations of the beam position at the target. The values have been obtained by averaging the results presented in Tab. 1 and Tab. 2.

References

[1] M. Pentia and S. Constantinescu, *DIRAC Note 00-07* 21 August 2000.