Study of SFD Efficiency Using MSGC Detector for 2001 data

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Abstract

The four planes (X,Y,X',Y') of MSGC detector are used in this note as an independent tracking detector to evaluate the two-particle efficiency of Scintillation Fibre Detector (SFD) as function of track pair separation, as well as the single-hit efficiency of this detector. This is done particularly for 2001 data, which were recently used for pionium lifetime determination. Results are compared in detail with Monte Carlo simulations using ARIANE 304-36 version, for specific choices of SFD parameters concerning efficiency, noise and cross-talk.

DIRAC internal note 2005-11 *1 July 2005*

1 Introduction

The DIRAC upstream arm consists of three detectors, using totally different technologies, namely the Microstrip Gas Chambers and GEM (MSGC), the Scintillation Fibre (SFD), and the Ionisation Hodoscope (IH). The first two (MSGC+SFD) provide a tracker to measure accurately the pion pair separation, whereas the IH scintillator measures the double pulse-height expected when the close-angle pair cannot be resolved by the tracker.

The amount of background noise in all three detectors is very high, as we shall see, and this is posing a serious problem for the determination of transverse momentum of the pairs, as well as for the recognition of the true particles coming from the target foil. Of course, this problem translates itself into uncertainty in the determination of pionium lifetime.

The ultimate origin of this strong background is surely the high intensity of the proton beam. However the readout systems of these three detectors have a totally different response in each case [1]. For SFD and IH, the inevitable use of photomultipliers and light-guides so close to the beam aggravates the noise conditions, despite the effective use of TDC's. Discrimination of SFD signals is achieved by Peak Sensing Circuit (PSC). A drawback of this (otherwise very effective) device is that when two pulses arise from adjacent fibre columns, one of them is suppressed with probability in the range 30-40% [1], thus degrading the double-track resolution of SFD. In the case of MSGC, the limited bandwidth in the pipelined readout (built in 1997) originates an affective time gate of approximately 250 ns, which increases significantly the hit multiplicity. The latter agrees perfectly well with the expected performance of this detector when it was designed [2], [3].

It is therefore clear that a precise tracking in the DIRAC experiment cannot be achieved without fully exploiting the redundancy of the upstream detectors in a systematic way. Cross-checking between these detectors is essential, and every atempt to by-pass a real tracking procedure risks leading to doubtful, or even erroneous, results. In any case, both the statistical and systematic errors in the lifetime measurement will clearly reflect the tracking procedure used.

What we present in this note is how the MSGC detectors can be used to perform an unbiased assesment of SFD detector response, in terms of two-particle and single-particle efficiency, as well as cross-talk. A conceptually similar study to the one we present here was done by V. Yazkov [4] using data runs from 2002 on, making use of the U-plane at 45^o of SFD. However such study could never be made with the 2001 data, due to the fact that U-plane was not installed in DIRAC at that time. Our results can certainly be compared with those of reference [5], obtained by means of IH detector and drift chambers only. We believe there is reasonable agreement, despite the intrinsic difficulty of the latter analysis.

2 Tracking procedure and results

In order to evaluate the SFD-X detector we have removed all of its detector hits from the 2001 data sample, and tried to recover the measurement of X-coordinate using only MSGC detectors, together with the Y-coordinate provided by SFD-Y. An identical procedure can of course be applied for SFD-Y (X), reciprocally.

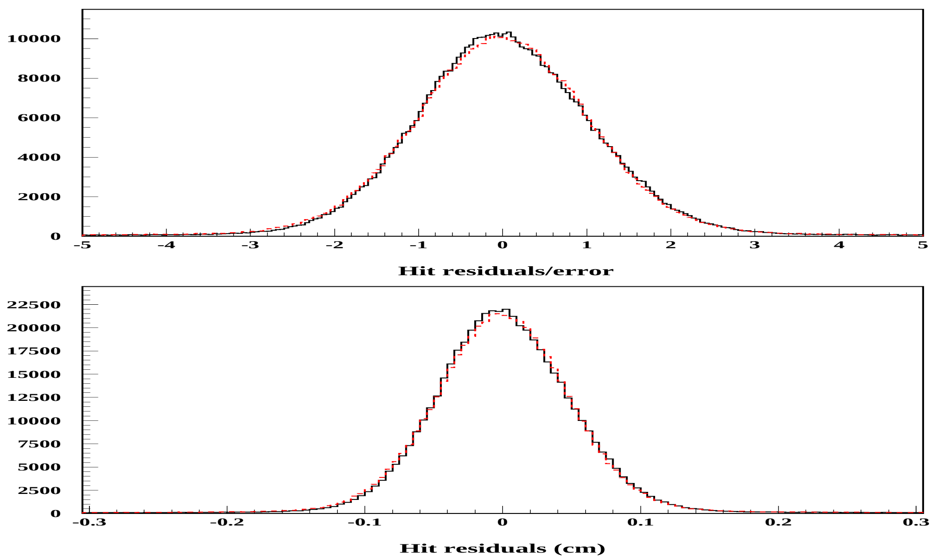

Fig. 1. *Distribution of SFD-X residuals(bottom) and residuals divided by error(top), obtained from extrapolation of 5-hit tracks, fitted with vertex constraint.*

We select 5-hit tracks by requiring signal in MSGC X,Y,X',Y' plus SFD-Y, and extrapolate them to the SFD-X plane. The full upstream tracking procedure is used, taking into account multiple scattering detector correlations and vertex constraint [6]. Track pairs are matched with downstream spectrometer tracks, using the standard procedure for full-tracking (F) in ARIANE. Track pairs are furthermore required to be prompt (strict time coincidence with vertical hodoscope), to have momentum $p > 2$ GeV/c and probability larger than 2%. The distribution of the residuals of the closest SFD-X hit found, is given in figure 1. Track pairs then are divided into three categories, namely:

a) those for which both the positive and the negative tracks contain a SFD-X hit within $\pm 3\sigma$ of track extrapolation. It may be the same hit, when the pion pair is not resolved by SFD-X detector.

b) those for which one of the two tracks contains a hit within $\pm 3\sigma$ window and the other does not.

c) those for which none of the two tracks contains a hit within $\pm 3\sigma$ window.

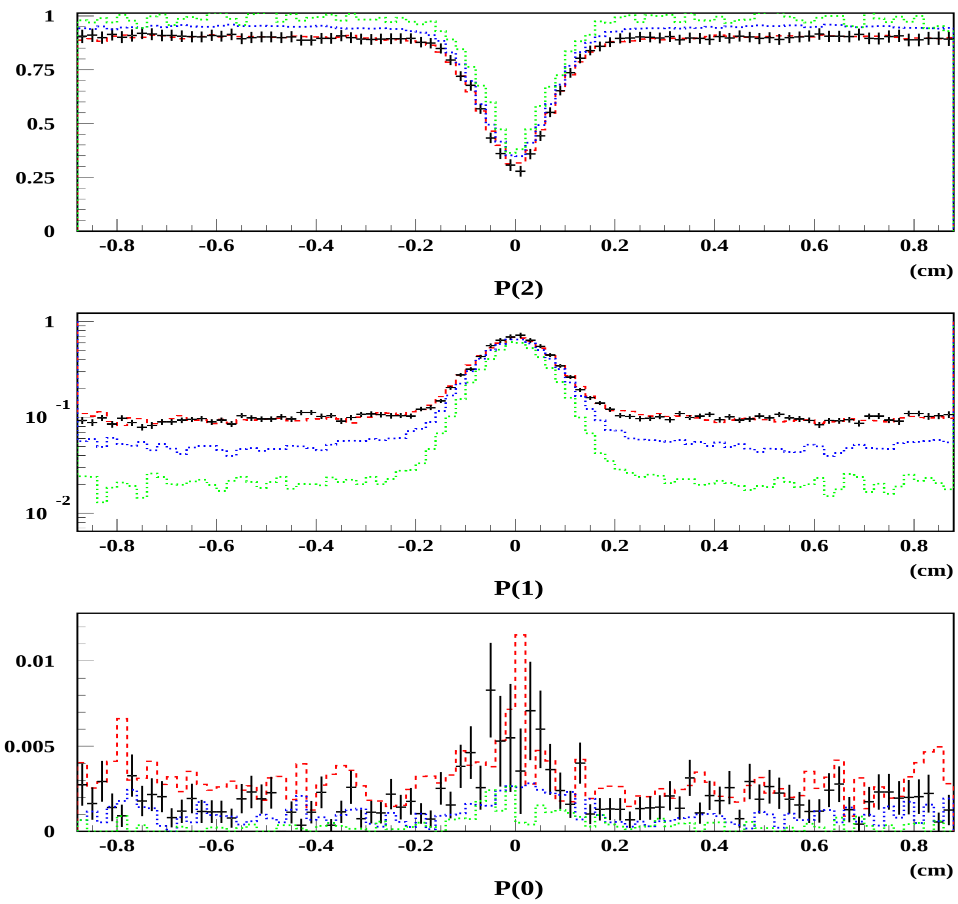

Fig. 2. *Distribution of two-particle ratios P(2) (top), P(1) (central) , and P(0) (bottom), according to the definition given in the text, for SFD-X detector. Prompt data from 2001 are shown by black crosses. Blue dotted line is Monte Carlo with ideal SFD and red dashed line is Monte Carlo with full simulation and optimised PSC threshold. Green dotted line (lowest in P(1)) shows Monte Carlo prediction with null MSGC background and ideal SFD.*

In figure 2 we show the ratio between the number of events in each category divided by the total, as function of the distance between the two hits measured by the MSGC's. We call them probability densities P(2), P(1) and P(0), respectively.

The interpretation of P(2) and P(1) is that they map the double-track efficiency and single-track inefficiency of SFD-X, respectively. This is so because of the mismatch between the space resolution of MSGC and SFD (200μm pitch improved by center-of-gravity determination for the first, digital readout and

430μm pitch for the latter), together with the fact that the stereo angles of X' and Y' ($\pm 5^o$) enable smooth zero-crossing in X, due to track opening in vertical plane.

In order to derive quantitative results about SFD performance, we have compared the experimental data in figure 2 with a Monte Carlo simulation in which the SFD is made 100% efficient, and the PSC malfunction suppressed. This prediction is also shown in figure 2 as a dotted line. The enhancement of P(1) around zero distance indicates the ideal double-track resolution of SFD, essentially determined by fibre pitch, whereas the difference between real data and ideal SFD Monte Carlo in the plateau regions (left and right) shows constant SFD single-hit inefficieny . We define this difference to be $2(1-\epsilon)$, where ϵ is SFD efficiency (likewise, the difference in P(2) is 2ϵ). The non-zero values of P(1) in the plateau region for the ideal SFD Monte Carlo are determined by background noise in MSGC detector and to a lesser extent by far-away hits in SFD that scape the 3σ cut due to tails of multiple scattering. The result for a Monte Carlo with null MSGC background and ideal SFD is also shown in figure 2. Details about this background simulation are given in the next section.

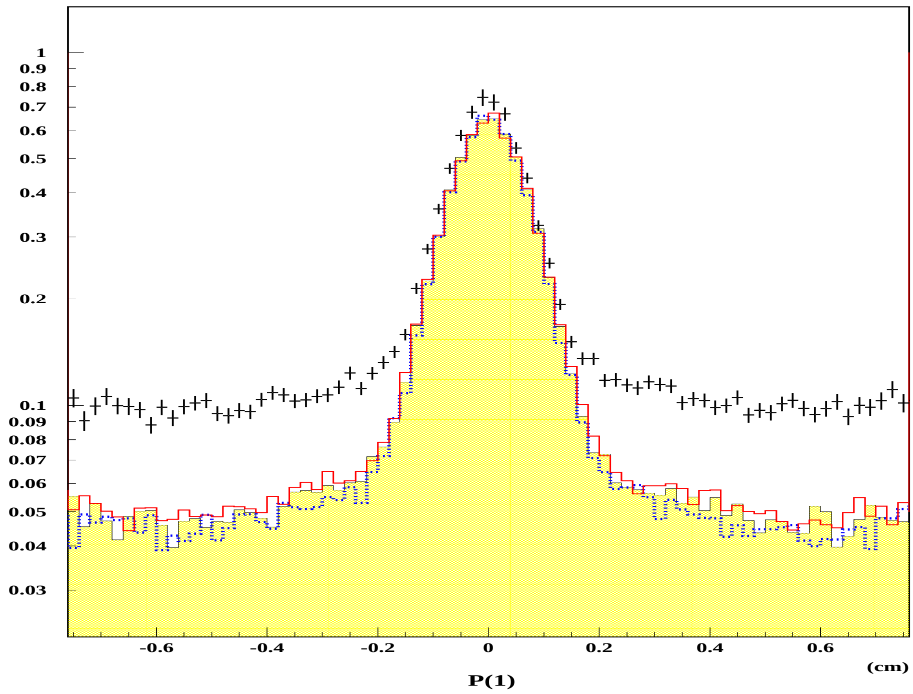

Fig. 3. *Distribution of two-particle ratio P(1) according to the definition provided in the text. The black crosses corresponds to 2001 real data, the filled grey line to ideal SFD Monte Carlo, and the red and blue lines correspond to* $\pm 5\%$ *variation of MSGC background.*

According to our definition, we determine $\epsilon = 97.4 \pm 0.2\%$ to be the average efficiency of SFD-X. All 2001 Ni 24 GeV/c data runs were used for this analysis. Similarly we determine $\epsilon = 97.5 \pm 0.2\%$ for SFD-Y. The main contribution to the error is believed to be systematic, and it is attributed to the precision in the description of MSGC background noise. A conservative $\pm 5\%$ variation of average hit multiplicity has been considered for this purpose, and further enlarged by a factor 2. The corresponding variation of P(1) is illustrated in figure 3.

Now the PSC threshold parameter has been changed in SFD simulation (see FFREAD datacards in ARIANE 304-36) in order to achieve best agreement between Monte Carlo and real data. In fact, the results of figure 2 show that good agreement can be found (with parameter value 1.5) for P(2) and P(1). Variations in the level and shape of SFD cross-talk do not make a visible change in previous figures, neither moderate variations in SFD background noise, although P(0) is more sensitive to the latter. Note that the central enhancement observed in P(0) distribution with real data appears to be described by Monte Carlo. In this respect our results seem to differ slightly from those of reference [4]. Figure 4 shows the corresponding result for SFD-Y.

3 Monte Carlo simulation of MSGC background noise

As we have seen MSGC background is, for this particular study, quantitatively at the same level as SFD inefficiency. Therefore, like in the pionium lifetime measurement, it is important to have control on the accuracy of the simulation procedure, which we describe next.

The source of MSGC background is real particles that cross the detector outside the trigger gating time. Pipeline delay was adjusted at installation time so that maximum pulse-hight is obtained within the experiment trigger gate, and it decreases by approximately a factor two at the borders of the $250ns$ time acceptance.

Clusters (or hits) are defined as a continuous set of strips above threshold. Monte Carlo simulation takes into account the following aspects:

1) cluster strip-multiplicity and pulse-height pattern within a cluster
2) clusterisation code
3) detector-correlated hit multiplicity
4) space correlations within the same detector (pair production, showers)

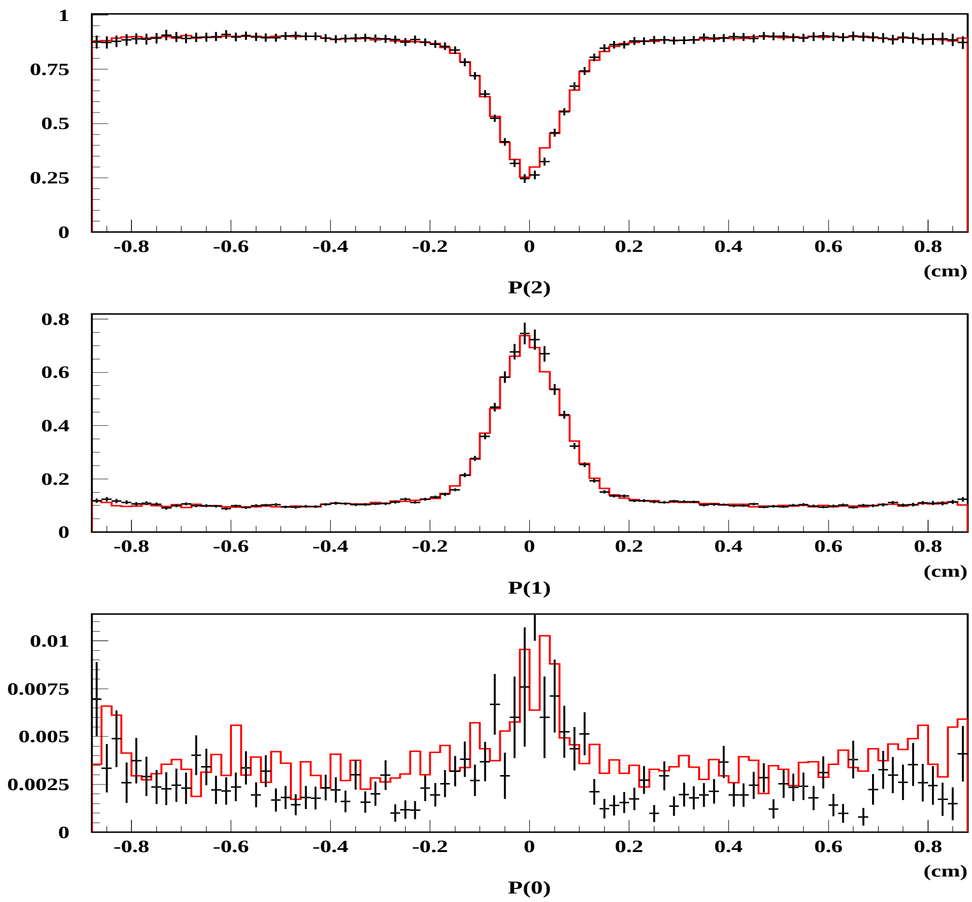

Fig. 4. *Distribution of two-particle ratios P(2) (top), P(1) (central) , and P(0) (bottom), according to the definition provided in the text, for SFD-Y detector. Prompt data from 2001 are shown in black continuous line, whereas red dotted line indicates full Monte Carlo simulation, as in figure 2.*

5) absence of space correlations between different detectors (when trigger particles are removed)

In all cases mentioned, an average of all Ni data spectrometer runs from 2001 has been used as input for the simulation code. For the first item, all information is encoded from real data under the form of dedicated input histograms initialised by ARIANE. For the second, the same clusterisation routine is used as in ARIANE reconstruction. Concerning the third item, hit multiplicities are also input from experimental data, but under the form of 4-fold correlation matrices, so that 4 multiplicities for X,Y,X',Y' detectors are generated jointly.

As far as item 4 is concerned, it is observed that a fraction of close-hit pairs are produced near the detector frames, outside the acceptance of the drift chambers. Therefore we focus our simulation for those MSGC hits that actually lie on the path of the extrapolated drift chamber tracks. So we define a hit multiplicity N_h as the sum of all hits found within a 3σ cut around the extrapolated coordinates of positive and negative tracks to all MSGC detectors. The same momentum-dependent σ is used here as for the matching procedure in ARIANE reconstruction [6].

The observation mentioned in item 5 was demonstrated by showing that events with one-sided activity in X-coordinate did not have corresponding activity in X' (likewise for Y and Y'), when hits from real trigger tracks were removed. Therefore simulation of space correlations appeared to be unnecessary.

We should mention that, because of the non-linear response of the clusterisation routine, which combines near-by particles together at large particle densities, the simulation procedure generally requires several iterations to converge. The final results for simulated MSGC hit multiplicities are illustrated in figure 5.

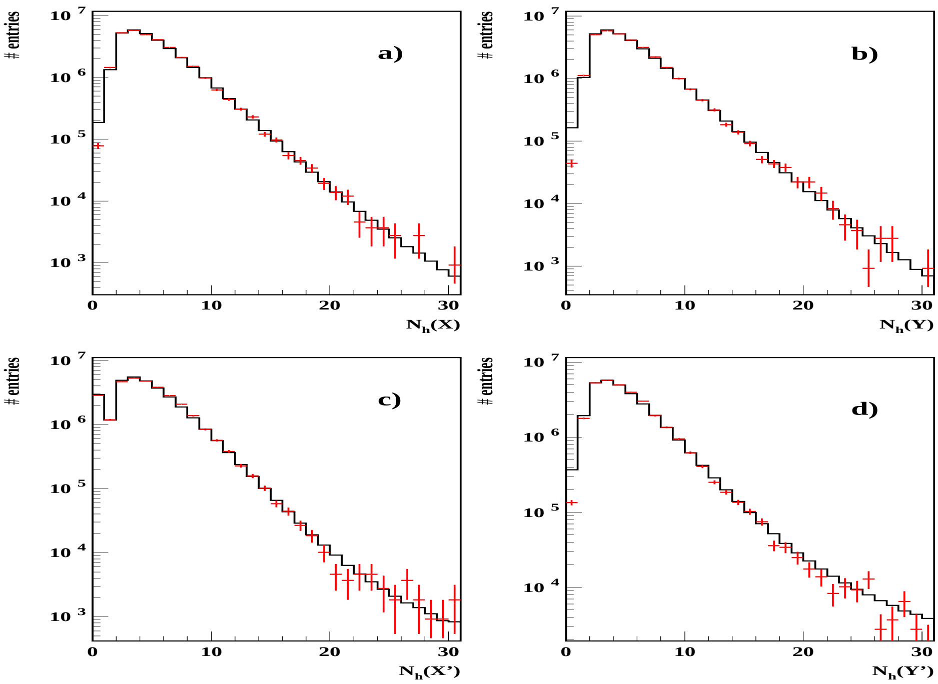

Fig. 5. *Continuous lines represent observed hit multiplicity in MSGC X (a) ,Y (b) , X' (c) and Y' (d) detectors for 2001 data runs, as described in the text. Coloured crosses are the Monte Carlo simulations described in the text, for each detector.*

4 Conclusions

We have determined the single-hit average efficiency of SFD-X and SFD-Y detectors for Ni 2001 data runs, and also evaluated the double-track resolution of these detectors, using MSGC planes X,Y,X', and Y'. The results obtained demonstrate that, despite the strong noise conditions in DIRAC upstream arm (IH, SFD and MSGC), pion pairs can be unambiguously measured provided full tracking information is used.

The following points have been demonstrated:

- DIRAC spectrometer double-track resolution is basically determined by MSGC detector
- PSC malfunction is totally circumvented by the use of MSGC's
- ARIANE F-tracking performs well both at long and short distances
- GEANT-DIRAC Monte Carlo simulation performs rather accurately for all critical functions, such as MSGC background, PSC simulation, as well as SFD and MSGC digitisations

It is shown in particular that the problem originated by SFD single-hit ineffícency at large angles (fake close pairs) can be effectively reduced by use of MSGC's. Overall tracking resolution for critical kinematic variables for lifetime measurement will be reviewed elsewhere.

5 Acknowledgements

We would like to thank fruitful e-mail exchange with Valery Yazkov.

References

[1] B. Adeva et al. DIRAC : A High Resolution Spectrometer for Pionium Detection, Nucl. Inst. and Meth. A515 (2003) 467-496.

[2] T. Núñez-Pardo, *Desarrollo de un detector de micropistas de gas para el experimento DIRAC*, doctoral thesis presented at University of Santiago de Compostela, May 1999.

[3] P. Vázquez, *Development and Construction of Electronics for Microstrip Detector Readout* , doctoral thesis presented at University of Santiago de Compostela, June 2000.

[4] DIRAC note 2005-04, V.V. Yazkov, *Experimental and simulated response of ScFi detector*

[5] DIRAC note 2003-02, D. Goldin and L. Tauscher, *Scintillating Fiber Detector Efficiency Study*

[6] DIRAC note 03-08: A Tracking System for Upstream Detectors in DIRAC, B. Adeva, A. Romero and O. Vázquez Doce.