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The use of a decay detector in the search for beauty decays in the WA92 experiment

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Abstract

We present results on the use of a finely segmented silicon microstrip telescope in the search for beauty decay topologies in the WA92 experiment at CERN.

1 Introduction

The main advantage of the fixed target configuration for an experiment aiming at the observation of short lived hadrons containing c or b quarks is the large Lorentz boost: this results in decay paths of several millimeters (at the SPS energy the B mesons travel on average 9 mm before decaying). The decay region therefore can be equipped with detectors which allow the direct observation of the decay vertices. In the past, two experiments (WA75 [1] and E653 [2]) have succeeded in observing several beauty decays in an emulsion target. In this paper we will discuss the use of a finely segmented silicon microstrip telescope in the search for beauty decay topologies in the WA92 [3] experiment. In the first

section we will describe this silicon telescope (decay detector) and its performances. Then we will discuss the problem of hadronic interactions in the material of the detector planes, which is one of the major sources of background. Finally we will describe the status of the search for events with the topology of a beauty decay and how the decay detector is used to significantly increase the signal to noise (S/N) ratio.

2 The decay detector

A detailed description of the WA92 experimental setup can be found elsewhere [4], while the WA92 trigger has been presented at this conference [5]. A 2 mm thick target is followed by a telescope of 17 single-sided silicon microstrip detectors [6] which cover an area of 5 by 5 mm² transverse to the beam and almost the entire decay region (≈ 3 cm along the beam direction) of particles containing heavy quarks. The target and the silicon telescope are placed in a region where the magnetic field is negligible in order to simplify pattern recognition and tracking. The thickness of the first 6 planes was limited to 150 μm in order to minimize multiple scattering and hadronic interactions. The small thickness also results in a smaller cluster size and a better two track resolution. The remaining 11 detectors are 300 μm thick. Most of the planes are closely spaced (the average spacing is 1.2 mm) and with the same strip orientation in order to provide several points along the track in the corresponding projection even for very short track segments (few mm). This configuration allows the visualization of complex topologies and of cascade decays, typical of beauty particles. Moreover, one prong decays of heavy charged particles may be observed. Clearly the resolution and the hit density along the tracks are poorer than what can be obtained with emulsions, but the electronic readout allows us to collect and analyze much larger data samples.

Each silicon plane is segmented in 10 μm pitch strips, individually read out with 8 bit ADCs. To optimize the S/N ratio the amplifier connected to each channel has a long shaping time. This allows us to read the signal at the time of the level 1 trigger of the experiment and thus reduce the dead time. However such a readout scheme has the drawback of increasing the memory time of the detector: one can observe in the telescope out of time beam tracks which, however, are not observed in the downstream detectors equipped with a faster readout. In the experiment the detector was operated with a threshold of 4 times the RMS of the noise distribution giving efficiencies of $\approx 93\%$ and $\approx 97\%$ for the thin and thick planes respectively. Pedestal subtraction is performed independently on each channel resulting in a noise contribution at a level of 10^{-3} for each strip. The measured accuracy was between 2 and 3 μm for the 150 μm planes, a value consistent with the fact that most clusters are constituted by a single strip. The measured accuracy for the 300 μm thick planes was slightly better, as the charge was typically deposited on more than one strip and the charge centroid method could be applied. The full analogue information has been retained for subsequent steps of the analysis such as the rejection of hadronic interactions in the silicon planes (as described in section 3). After an equivalent dose of few 10^{13} particles/cm² we have not observed any degradation of the performance of the silicon detectors due to radiation damage.

The chosen decay detector geometry provides a limited two track resolution (2–3 mrad to be compared with a resolution of 0.5 mrad for the rest of the spectrometer): this implies that clusters belonging to two different tracks may overlap near the vertex. Nevertheless, the decay detector improves considerably the resolution on the tracks impact parameter (2–3 μm) and on vertex coordinates (100–300 μm along the beam direction, depending on the multiplicity and the topology of the vertex). The resolution on the longitudinal position of vertices can be inferred from figure 1 where we show the distribution of the reconstructed position of secondary vertices along the beam.

Figure 1: *Distribution of secondary vertices in the decay detector region. The shaded area corresponds to vertices which are rejected as hadronic interactions in the silicon planes. Also shown are the distributions of real decay vertices (the depletion at small decay paths for K^0 and Λ^0 decays is an effect of the impact parameter trigger).*

3 Rejection of secondary interactions

As shown in figure 1, most secondary vertices reconstructed in the decay detector region are hadronic interactions in the silicon planes. The decay detector represents 0.6% of an interaction length and 4.5% of a radiation length. Given the small beauty production cross section, the ratio between the number of secondary vertices due to beauty cascade decays and of those coming from secondary interactions in minimum bias events is of the order of 10^{-5} . Thus in order to isolate beauty events using topological and kinematical criteria we need a powerful method to reject secondary interactions in the decay detector material. Photon conversions do not represent a serious background since the e^+e^- pair is not reconstructed as two separate tracks in the silicon telescope and the conversion point cannot be misidentified as a secondary vertex. For rejecting hadronic interactions we have developed a method based on the large energy release (due to nuclear fragments and slow tracks) which accompanies most of the interactions in the active silicon layers. A simple cut on the vertex position cannot be used due to the small spacing between the decay detector planes. We used a cut which depends on the distance between the reconstructed vertices and the centroid of the large energy deposits. This cut has been tuned on primary interactions of the 350 GeV/c π^- beam in the silicon planes and has been found to reject 97% of them. For secondary hadronic interactions the efficiency of this cut is slightly worse (91%) since the vertex multiplicity is lower and the vertex definition poorer. In figure 1, we show the effect of the cut: the shaded region corresponds to the vertices which are rejected by the algorithm. Of all the secondary vertices identified by the reconstruction program 84% are recognized as interactions and very few of them (as shown in the plot) are identified as fully reconstructed strange or charmed decays. It should be stressed that the distribution of these identified decays shows no enhancement corresponding to the silicon planes. The remaining fraction of secondary vertices is mostly due to coherent hadronic interactions and to badly reconstructed vertices. In both cases the cut based on the distance and the energy deposit cannot work

properly. The losses of real decays caused by this method have been evaluated using K^0 , Λ^0 and charm decays and are of the order of 5%.

4 The search for beauty decay topologies

In the 1992 run the WA92 experiment has collected $8 \cdot 10^7$ events on tape, half of them were obtained with a copper target and half using a tungsten target. The reconstruction program has selected a sample of $1.2 \cdot 10^7$ events with a reconstructed secondary vertex, containing an estimated sample of approximately 750 beauty events (assuming a cross section of 5 nb/nucleon and a linear dependence on the atomic number). The cut on hadronic interactions has reduced the data sample to $2 \cdot 10^6$ events. The following

Figure 2: Display of an event reconstructed in the decay detector where the decay chain $B^+ \rightarrow \bar{D}^0 \mu^+ \nu_\mu X$ is clearly visible, together with additional secondary activity (two tracks not pointing to the primary vertex). Both the $\bar{D}^0$ and the μ^+ have a large transverse momentum relative to the line of flight p_{Tv} . The hits left by the B^+ meson itself are visible in 5 layers of the decay detector (the B^+ and $\bar{D}^0$ lines of flight are shown as thin lines).

step of the analysis has been the selection of 3 separate streams of events to be analyzed with a graphical display program, in order to exploit the pictorial character of the decay detector. We have selected:

- events with at least 3 secondary vertices in the decay detector region,
- events with a fully reconstructed charm meson not pointing to the primary vertex and accompanied by additional secondary activity,
- events containing a high transverse momentum muon not associated with the primary vertex and accompanied by additional secondary activity.

These selection criteria give, for the Cu target sample, a sample of ≈ 5000 events amongst which we expect to observe 20 beauty decays. The interactive graphical analysis allows us to check the reconstruction of

the tracks and of the vertices in the decay detector region, to correctly measure the transverse momenta relative to the line of flight (using the precise reconstruction of vertices or the first measured point along a track for single prong decays in the decay detector) and to search for additional secondary activity and kinks. It is therefore possible to improve the selection performed using the kinematical information alone (transverse momentum of the track in the laboratory reference frame, invariant mass of tracks attached to a secondary vertex, presence of leptons attached to a secondary vertex), and thus to obtain a large background reduction. The use of the decay detector information in the graphical analysis of these events has significantly enhanced the S/N ratio and has led to the identification of events with cascade decays such as the one shown in figure 2. The background evaluation in the final sample is still in progress, but the presence of events with very strong signatures characteristic of beauty decays gives us confidence that we are observing beauty events and that only a small fraction of them may be ascribed to background.

5 Conclusions

In the WA92 experiment we have operated for the first time a high precision silicon microstrip telescope and used it to observe directly the cascade decays of beauty particles. The secondary hadronic interactions can be rejected with high efficiency with a cut which correlates the position of the reconstructed vertices and the large energy deposit in the silicon detectors due to nuclear fragments. The combined use of kinematical cuts and of the pictorial character of this decay detector yields a strong background suppression and allows the detection of beauty decays.

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