Study of Hadronic Events in $pp$ Collisions at $\sqrt{s}=62$ GeV and Comparison with Hadronic Events in $e^+e^-$ Collisions

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Abstract. We present an analysis of minimum bias events from proton-proton collisions at $\sqrt{s}=62$ GeV in the CERN ISR. We remove the effects of both the leading protons and compare the $B=0$ mesonic residue of the events to the hadronic events of similar energy produced in $e^+e^-$ collisions. This comparison is presented in terms of the standard jet-type analyses involving quantities such as sphericity and aplanarity. We find significant differences between these data and the data from $e^+e^-$ annihilations. The data of this experiment are consistent with the predictions of a longitudinal phase space model.

Since the discovery of jets in $e^+e^-$ annihilation into hadrons [1], compelling evidence has been presented for the two-jet structure of $e^+e^-$ annihilation into hadrons [2]. More recently, evidence has been presented for the presence of a three-jet signal in such events, [3] which has been interpreted as evidence for the presence of gluons. By contrast there is very little evidence for the presence of jets from parton scattering in purely hadronic reactions: only one experiment clearly shows the presence of such jets in an unbiased manner, independent of geometric biases due to the limited acceptance of the detectors [4]. The essential difficulty in purely hadronic interactions is the presence of the large flux of forward-backward particles at low $p_T$. These diffractive and other low $p_T$ effects dominate the hadronic cross sections, and thus jet analyses aimed at studying parton interactions must consider high $p_T$ particles which are much rarer than those at low $p_T$.

It is of interest to compare the jet structure observed in $e^+e^-$ annihilations into hadrons with possible jet structure in purely hadronic interactions. Since the quark and gluon fragmentation functions are expected to be identical in the two cases, any differences would probe details of the jet production mechanism. Such a comparison has been performed using $pp$ collision data taken with a minimum bias trigger (as defined below) in the CERN Intersecting Storage Rings (ISR) in which one final-state leading proton has been selected [5]. In that work an attempt has been made to account for the observed difference between $pp$ and $e^+e^-$ interactions through the difference in baryon number. Specifically, a leading proton was selected, and the analysis was performed on only those other hadrons in the same centre-of-mass hemisphere as the leading proton. In the present work on $pp$ interactions we insist on a selection of both leading protons, and perform the jet analysis on the entire $B=0$ mesonic system remaining after the removal of the two leading protons.
The experiment was performed at the CERN ISR at $\sqrt{s} = 62$ GeV, using the Split Field Magnet (SFM) detector, a device which allows one to measure the momenta of charged particles in nearly the full solid angle of $4\pi$ steradians. The detector is built around a magnet with a maximum field strength of 1 Tesla surrounding interaction region I4 of the ISR. The magnetic volume is filled with Multiwire Proportional Chambers (MWPC) divided into three telescopes: two forward telescopes, [6] each consisting of 14 MWPC and a vertex detector, described in [7]. Information about the performance of the detector can be found in previous publications [8].

The MWPC's were used in a self-triggering mode [9]. Wires of the MWPC were associated in groups of 256 to deliver fast signals which were combined to define the event trigger. This experiment used a "minimum bias" trigger, which was defined by a fast majority coincidence of at least three chambers in any of the three telescopes. This trigger essentially required the presence of at least one reconstructible track. After the exclusion of elastic events, the cross section detectable by this trigger amounts to $\sim 95\%$ of the inelastic cross section. In this analysis a sample of 390,000 such minimum-bias events were used.

The raw data were processed through the SFM off-line computer program chain [10] for track finding, track reconstruction, and vertex fitting. Events with probable protons were then selected, using the criteria that the particle in either hemisphere with the largest longitudinal momentum with respect to the beam direction should be positively charged, and should have a value of $x = 2p^*/\sqrt{s}$ between 0.44 and 0.82 in magnitude. The quantity $p^*$ is the component of the particle's momentum along the beam direction in the overall centre-of-mass frame. Since no direct particle identification was available over most of the kinematic region, the lower limit on $x$ was suggested by the inclusive particle distributions. At $x=0.4$ the $\pi^+$ production rate is comparable to that of the protons. As $x$ increases in magnitude, the $p/\pi^+$ ratio increases sharply, and so the assumption that the leading positive particle is a proton becomes more accurate. The upper limit on $x$ was chosen to remove all diffractive events. In addition, a momentum error cut $\Delta p/p < 0.08$ was required for this leading particle. From the inclusive single particle distributions [11] we estimate that the sample of "leading protons" thus chosen is 85\% pure. For this analysis we select only those events in which we detect one leading proton in each of the hemispheres with respect to the beam axis. These form a sample of 3283 events. These data were corrected for geometrical acceptance losses in the detector, losses due to decay and secondary interactions, and inefficiencies of the analysis chain. The average total correction factor applied to the data is about 1.4.

In order to compare properly the $pp$ interaction data with data on $e^+e^-$ annihilations, it is necessary not only to remove the two identified protons so that we are comparing $B=0$ systems, but also to transform all momenta into the rest frame of the mesonic system. This can be done using knowledge of the incident beam momenta and the momenta of the two leading protons. Lack of knowledge of missing neutral particles plays no role as yet. In the rest frame of the mesonic system the event appears as sketched in Fig. 1. The two beam particles, $P_1$ and $P_2$, transfer equal and opposite momenta to the meson system. The dashed lines represent momentum transferred, and not specific particles.

The quantity which corresponds to $\sqrt{s}$ in $e^+e^-$ annihilations is the invariant mass of the mesonic system, $M_0$, and this too can be calculated entirely from the known beam and proton momenta without reference to possible missing neutrals. Due to the finite range of allowed $x$ over which protons are selected, there is a distribution of values for the invariant mass...