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STATISTICAL PROPERTIES OF THE MULTIPARTICLE FINAL STATE AS A FUNCTION OF THE AVERAGE EVENT p_t IN SOFT $\bar{p}p$ INTERACTIONS AT $\sqrt{s} = 1800$ and 630 GeV

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Abstract

A preliminary analysis of average properties of softly produced events in $\bar{p}p$ interactions at the Tevatron energies is presented. Data have been collected by the Collider Detector at Fermilab using a minimum bias trigger. The average charged event multiplicity, the production of strange particles and the strength of the short range pseudorapidity correlation have been studied as a function of the average transverse momentum of the event. Comparisons have been made between the two center of mass energies 1800 and 630 GeV and also with a sample of selected jet events. Peculiar characteristics in the behaviour of these variables are highlighted.

1. Introduction

A large amount of experimental information on inelastic soft hadron interactions is available, mostly at energies below the Tevatron energy. Many regularities have been recognized such as the $log(s)$ trend of the inclusive distributions and the approximate KNO scaling. Nevertheless, neither QCD, that has to deal with the non perturbative regime, nor any of the attempted theoretical models give an exhaustive and unitary picture of all of the aspects of the low-p_t multibody production. Moreover the known experimental results do not tell us anything about the evolution from soft to hard parton interactions and the production mechanisms still remain unexplained.

In the present work we did a comparative study of some variables describing the average statistical properties of the multibody final state as a function of the same reference variable. The results for a sample of softly produced events selected with a minimum bias trigger are compared at two c.m. energies 1800 and 630 GeV and also with a sample of events selected by a jet trigger. The purpose of this study is to evidentiate some specific characteristics of the soft interactions and their modifications when hard interactions onset.

As a reference variable we chose the average event p_t which is defined as:

$$\langle p_t \rangle_{ev} = \frac{1}{n} \sum_{j=1}^{n} p_{tj} \tag{1}$$

[1] Talk presented at the XXVI International Symposium on Muliparticle Dynamics, Faro, Portugal, September 1st-5th 1996.

n being the event charged multiplicity and p_{t_j} the transverse momentum of the j^{th} track: both are measured in the $\mid \eta \mid \leq 1$ and $p_t \geq$ 0.4 GeV/c intervals as described below.

This variable, involving the transverse momentum and the multiplicity of the event, is significantly connected to the dynamic of the event and to its origin from soft or hard parton interactions.

Three average variables have been analysed as a function of $\langle p_t \rangle_{ev}$:
- the mean event charged multiplicity;
- the strength of the short range pseudorapidity correlation;
- the mean number of K^0_S plus Λ^0 in the event.

The detailed definition of each of these quantities will be given in the following.

2. Data samples

The CDF detector has been described in detail elsewhere [1]. Briefly, the detector components used in this analysis are the Central Tracking Chamber that measures the position and the momentum of the charged particles, and the Beam Beam Counters used to define the minimum bias trigger. The CTC is a drift chamber put in a 1.4 Tesla solenoidal magnetic field. It measures p_t, η, ϕ of each track with high resolution and good efficiency ($\Delta p_t/p_t \simeq 0.002\ p_t$, $\epsilon \simeq 99$ %) in the intervals: $\mid \eta \mid \leq 1$ and $p_t \geq$ 0.4 GeV/c. The BBCs are two sets of scintillator counters located simmetrically along the beam line, covering the η interval $3.2 < \eta < 5.9$. The minimum bias trigger requires at least one hit in both the BBCs in coincidence with the beams crossing signal.

Events and tracks have been selected in order to reject multiple interactions and tracks that do not come from the primary vertex. To ensure a full CTC tracking efficiency, only tracks with $p_t \geq$ 0.4 GeV/c and $\mid \eta \mid \leq 1$ have been accepted [2].

After the selection procedure our data samples consist of about 300,000 events at $\sqrt{s}$ = 1800 GeV and about 250,000 events from a special run at $\sqrt{s}$ = 630 GeV selected with the minimum bias trigger; in addition we used a sample of about 13,500 events at $\sqrt{s}$=1800 GeV selected with an high E_t trigger that required at least one identified jet with energy above 15 GeV [3].

3. Results

3.1. Event charged multiplicity

The scatter plot of fig.1a has on the horizontal axis the $\langle p_t \rangle_{ev}$ as defined in (1) and on the vertical axis the scaled event multiplicity. This quantity is given by the number of tracks counted by the CTC in the above mentioned p_t and η regions, divided by the mean value of the multiplicity distribution. Fig.1b is the profile of the scatter plot, that is the average scaled multiplicity of the events laying in each slice of 0.2 GeV/c size of the $\langle p_t \rangle_{ev}$. The result of fig.1b was already presented [4], but we would like to add a few comments on it.

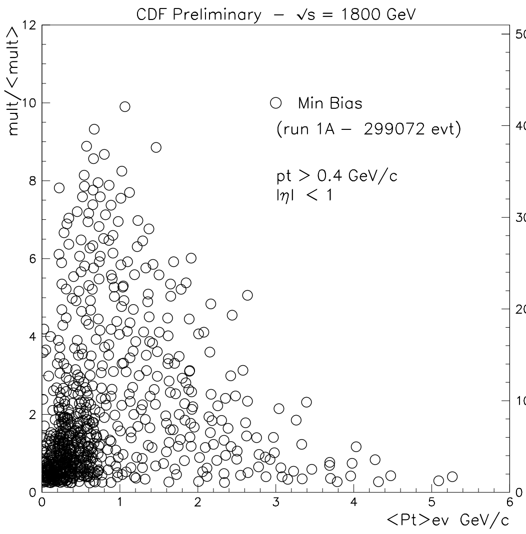

Fig.1 (a)

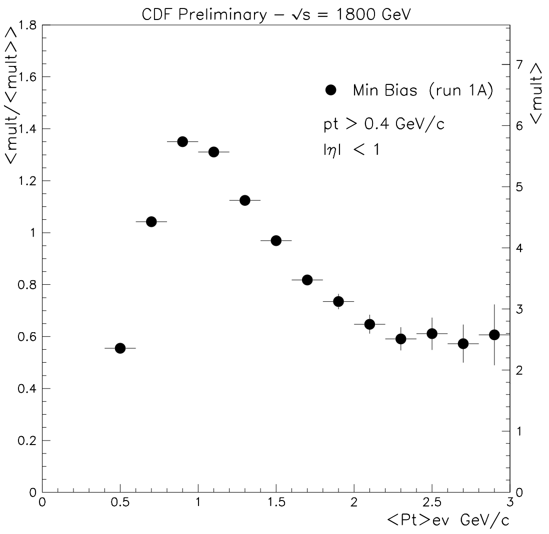

Fig.1 (b)

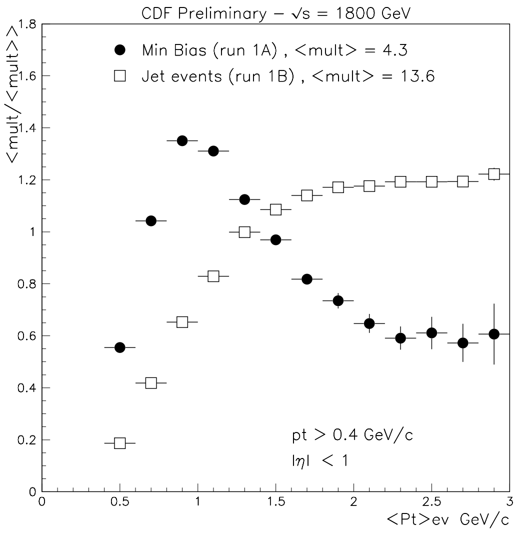

Fig.2 (a)

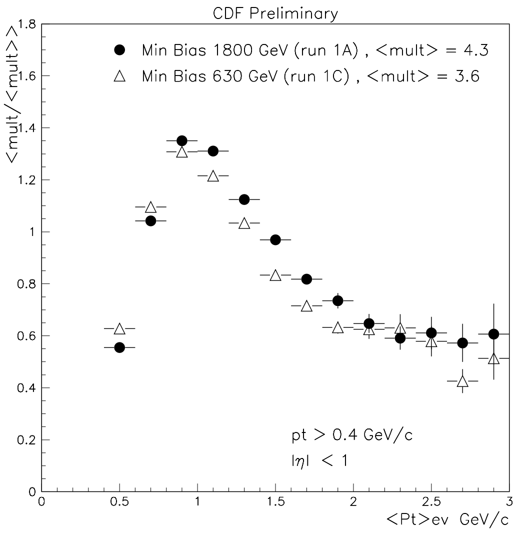

Fig.2 (b)

We note the peculiar shape of this plot: a steep rise, a peak at about 1 GeV/c and then a decrease with a flat down at higher $\langle p_t \rangle_{ev}$. The major part of the softly produced events lay around the peak position: 31% of the events are in the $\langle p_t \rangle_{ev}$ interval between 0.8 and 1.1 GeV.

The low mean multiplicity tail above 1.5 GeV/c does not mean that high $\langle p_t \rangle_{ev}$ events all have lower multiplicities than at lower $\langle p_t \rangle_{ev}$, but it is merely a consequence of the steeply decreasing population of the scatter plot of fig.1a with increasing $\langle p_t \rangle_{ev}$. In other words, events with high $\langle p_t \rangle_{ev}$ and high multiplicity, which would rise the tail to higher values, have too low cross section to be recorded by the minimum bias trigger.

To check what we would see appearing if we were able to attenuate in the minimum

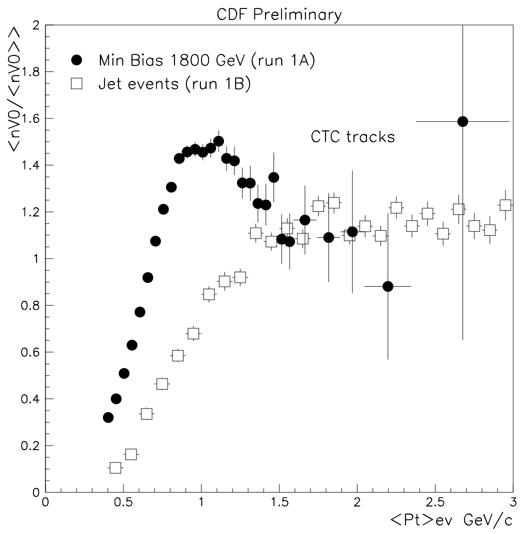

Fig.3 (a)

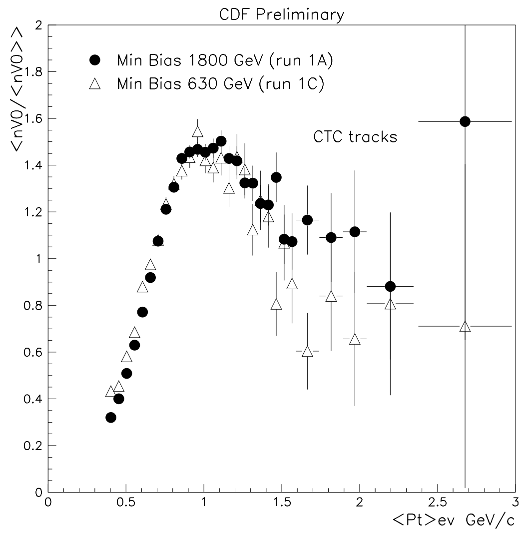

Fig.3 (b)

bias sample the sovrasting number of low-p_t events, we produced the same plot for the events of the jet sample. The profile is shown in fig.2a (open squares), the behaviour of the two data samples is clearly different in this variables plane: jet data do not show a peak and the *plateau* sets at an higher level than the minimum bias data.

Fig.2b shows the superposition of the same plot for minimum bias events at two different energies $\sqrt{s} = 1800$ GeV and $\sqrt{s} = 630$ GeV. It is remarkable that, with the normalized multiplicity scale used, the two curves are almost equal. In particular there is a good overlapping of the peak values.

3.2. Production of strange particles

K^0_S and Λ^0 particles, decaying before entering the CTC volume, can be detected looking for couples of opposite sign off-vertex CTC tracks converging to a secondary vertex.

We looked at the multiplicity of this subsample of strange particles produced in the event in a way analogous to what we did for the event charged multiplicity.

Fig.3a shows, as a function of $\langle p_t \rangle_{ev}$, the number of V^0 (K^0_S plus Λ^0) per event divided by the overall average number of V^0 and averaged on the events belonging to each slice in $\langle p_t \rangle_{ev}$.

The shape of the curve for the minimum bias data is clearly similar to that of fig.1b, apart for the flat tail that, for the V^0, seems to start at a lower $\langle p_t \rangle_{ev}$ and to be at an higher level, with respect to the maximum, than for charged tracks. What we note, and is not expected *a priori*, is that the peak of the curve for the V^0 is in the same position as for the charged tracks: at $\langle p_t \rangle_{ev} \simeq 1$ GeV/c. The curve for the jet sample agrees very well with the correspondent for the charged tracks. Again there is a quite good agreement between 1800 and 630 GeV data (fig.3b).

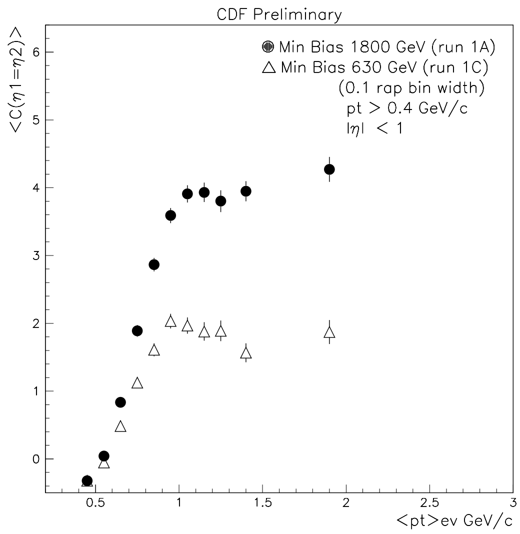

Fig.4 (a)

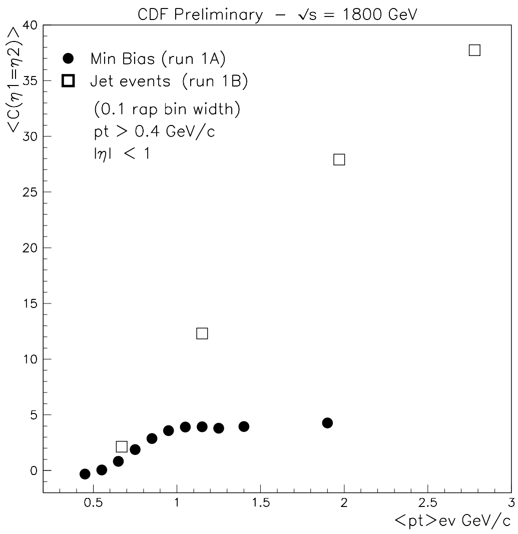

Fig.4 (b)

3.3. Two particle pseudorapidity correlations

The two particle pseudorapidity correlation measures the tendency of pairs of particles in a multiparticle final state to be emitted close in rapidity.

The correlation function $C(\eta_1, \eta_2)$ is defined as described in reference [5]. It differs from zero if the joint production of a pair of particles with pseudorapidity values η_1 and η_2 differs from the independent production of the two particles with those pseudorapidity values.

The correlation effect appears as a peak in the correlation function at $\eta_1 \simeq \eta_2$. The height of the peak results to be almost independent from η_2, at least when η_2 moves in the -0.5 to +0.5 range. For each subsample of events laying in each $\langle p_t \rangle_{ev}$ slice 0.2 GeV/c wide we measured the correlation strength by averaging the peak values of the correlation function at $\eta_1 = \eta_2$ for various values of η_2.

Results are shown in fig.4a where the mean strength of the correlation is plotted as a function of the $\langle p_t \rangle_{ev}$. Both data at $\sqrt{s} = 1800$ GeV (black points) and at 630 GeV (open triangles) are shown.

The correlation exhibits a steep rise up to a $\langle p_t \rangle_{ev}$ of about 1 GeV/c, then it has a clear change in slope and stays flat for higher $\langle p_t \rangle_{ev}$. The 630 GeV data have the same behaviour with a flattening point at the same value of $\langle p_t \rangle_{ev}$, then the correlation reaches a higher plateau level.

It is remarkable that the change of slope of these curves happens at the same $\langle p_t \rangle_{ev}$ value where there is a peak in both the average charged multiplicity and the average number of V^0.

The comparison of 1800 GeV minimum bias data with the jet sample (fig.4b) again shows that jetty events behave in a complete different way: having a steady rise with $\langle p_t \rangle_{ev}$ up to much higher values than those reached by minimum bias events.

We are aware that, with the definition we used [5], the correlation function is normalized to $\langle n(n-1)\rangle$ - $\langle n\rangle^2$, $\langle n\rangle$ being the average multiplicity of the event subsample. This means that the computed value of the correlation strength shown in fig.4 has an implicit multiplicity dependence, so its behaviour as a function of $\langle p_t\rangle_{ev}$ is not totally independent from the behaviour of the normalized multiplicity shown in figures 1-2. Previous preliminary measurements of this correlation were done at CDF [6].

4. Conclusions

The average event variables we examined as a function of the mean event p_t for the minimum bias data sample clearly show a similar behaviour, which is a peak or a change of slope at a $\langle p_t\rangle_{ev}$ value that, in our limited η-p_t space, is around 1 GeV/c.

These correlation plots, when compared at different energies, show a scaling property; in particular the position of the peak or the change of slope is the same at 630 and 1800 GeV.

The behaviour of events with jets is clearly different, the plots being flat or having a steep rise with increasing $\langle p_t\rangle_{ev}$.

About 31% of the inelastic cross section lays in the $\langle p_t\rangle_{ev}$ region between 0.8 and 1.1 GeV/c around the peak position (this percentage becomes the 99% if the interval is extended from 0.4 to 1.5 GeV/c).

To conclude, we have observed that the major part of the $\bar{p}p$ cross section collects at a well defined value of the average p_t independently of the c.m. energy, and that different average properties show a clear change at this $\langle p_t\rangle_{ev}$ value. This might suggest that the production mechanism of the soft interactions proceedes through a specific condition characterized by this value of $\langle p_t\rangle_{ev}$. When hard interactions onsets $\langle p_t\rangle_{ev}$ evolves to higher values and the events show average properties which stay flat or increase as a function of $\langle p_t\rangle_{ev}$. The characterization of the transition between the two production mechanisms still needs further investigation.

References

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