Evolution of some Correlations with Transverse Momentum in Minimum Bias Events at CDF

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We analyze the structure of the event as described by some average variables like the mean charged multiplicity and the mean multiplicity of the V° ($K_s^\circ + \Lambda^\circ$) as well as the strength of the intermittency like correlation as a function of the average event p_t. Multibody final state from minimum bias and jet trigger events are examined for the two available center of mass energies 1800 and 630 GeV.

1. Introduction

The basic phenomena and detailed dynamics which produce the hadronic multibody final state are still essentially unknown. In soft hadronic production several aspects of particle correlations are unclear and their evolution with the center of mass energy, event tranverse energy and multiplicity are unexplained and require more extensive studies. Nor QCD can help us since at such low momentum transfer we are definitely in the nonperturbative regime.

Moreover we do not know how and where to set a boundary (if there is one) between soft and hard parton interactions.

In this note we describe a comparative study of some of the statistical properties of the multibody final state as a function of the same reference variable. Our goal is to describe the general features of the event so to characterize soft interactions and investigate the transition toward harder parton production.

2. Analysis Guideline

For the purpose of describing the general properties of the event we analize some final state global variables as a function of the same reference variable which we chose to be, alternatively, the charged multiplicity and the average event p_t, defined as:

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

where n is the event charged multiplicity and $p_{t\,j}$ the transverse momentum of the j^{th} track.

This latter variable, involving the transverse momentum and the multiplicity of the event is significantly related to the dynamic of the event and to its origin from soft or hard interaction.

The global variables that have been analized are:
– charged strange particle multiplicity versus $\langle p_t \rangle_{ev}$
– mean p_t versus charged multiplicity
– strength of correlation versus both multiplicity and $\langle p_t \rangle_{ev}$.

A detailed description of these quantities will be given in section 4.

3. Experimental data and selection procedure

The details of the CDF apparatus and the triggers are published elsewhere ([1]). Here we shortly describe only some features relevant for the present analysis.

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The momentum and position of tracks are measured by a drift chamber (CTC) located in a 1.4 Tesla solenoidal magnetic field. The CTC measures p_t, η and ϕ of each track with good resolution and efficiency ($\Delta p_t/p_t \simeq 0.002$, $\varepsilon \simeq 99\%$) in the interval: $|\eta| < 1$ and $p_t > 0.4$ GeV/c.

Two sets of scintillator counters (BBC) located simmetrically along the beamline (5.82 m from the nominal interaction point) and covering the interval $3.2 < \eta < 5.9$ are used for the minimum bias trigger.

The results preliminarly presented here come from minimum bias triggers recorded during run 1A (about 1.2 Mtriggers at 1800 GeV) and run 1C (about 1.5 Mtriggers at 630 GeV). We have also analized smaller samples from jet triggers at both energies.

The minimum bias trigger requires at least one hit in both the BBCs in coincidence with the beam crossing signal. The jet trigger requires the presence of at least one jet with minimum 20 GeV energy in the central calorimeter. No finer jet-clustering algorithm is emplojed but the one runned for the level 2 trigger. In Fig. 1 is shown a tranverse energy spectrum for a subsample of the 630 GeV jet-trigger events.

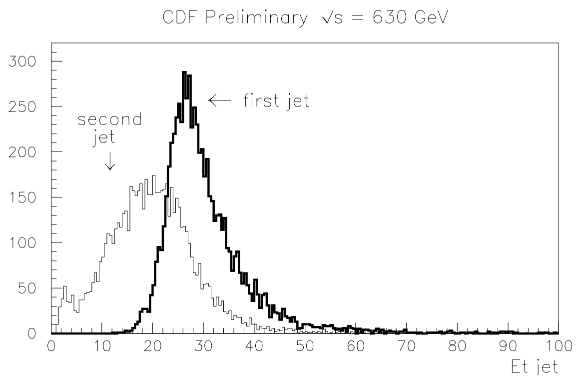


Figure 1. E_t spectrum of JET 20 trigger selected events.

Only tracks measured in the CTC were used.

In order to reject multiple interactions, events with two or more primary vertices within a 60 cm interval have been rejected. The event primary vertex is required to be in $\pm$ 60 cm from the origin of the coordinate system to ensure good event acceptance in the CTC.

Our data samples after these selections are shown in table 1.

Table 1
Event samples after selection

events	cms energy	trigger
$\sim$ 0.8 M	1800 GeV	Min-Bias
$\sim$ 1.3 M	630 GeV	Min-Bias
$\sim$ 30000	1800 GeV	Jet 20
$\sim$ 100000	630 GeV	Jet 20

Track selection requires three-dimensionally recontructed tracks with an impact parameter smaller than 0.5 cm and a distance between the event vertex and the extrapolated Z0 of the track smaller than 5.0 cm.

Finally, to ensure full tracking efficiency, only tracks with $p_t > 0.4$ GeV/c and $|\ \eta\ | < 1.0$ have been accepted.

4. Analysis

4.1. Charged Multiplicity

In Fig. 2 are shown four contour plots where, for each event, the event charged multiplicity is plotted versus the event average p_t as defined in equation 1. The charged multiplicity is given by the number of tracks counted by the CTC in the limited phase space region mentioned before. For both energies are shown the minimum bias and the jet trigger samples: the regions occupied in the plots are different and, what is more, a three-dimensional plot would show a minimum bias distribution far more peaked than the other one. That is to say, the minimum bias events tend to be gathered together in the low p_t low multiplicity region while the jet events spread in a larger interval.

A more significant inspection to the same data can be done with a look to the profile of the pre-

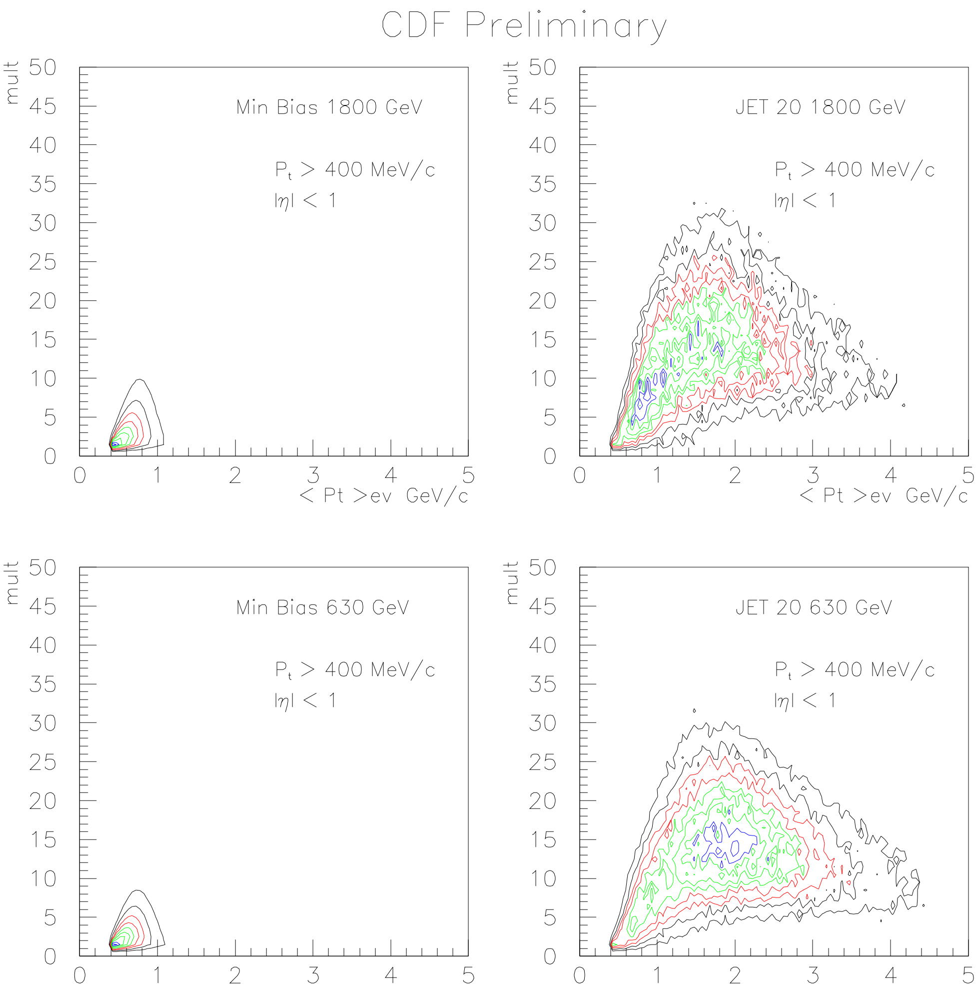


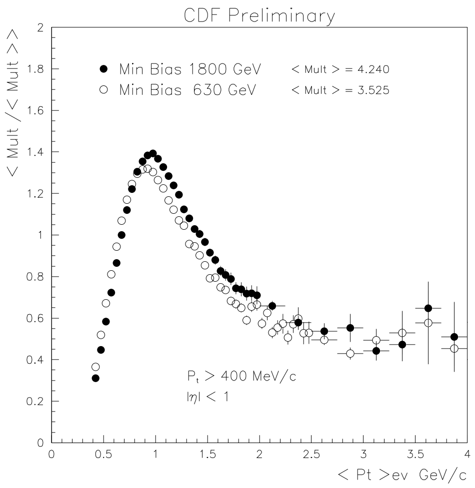
Figure 2. Contour plots of multiplicity versus the mean event p_t (spacing between contours is linear).

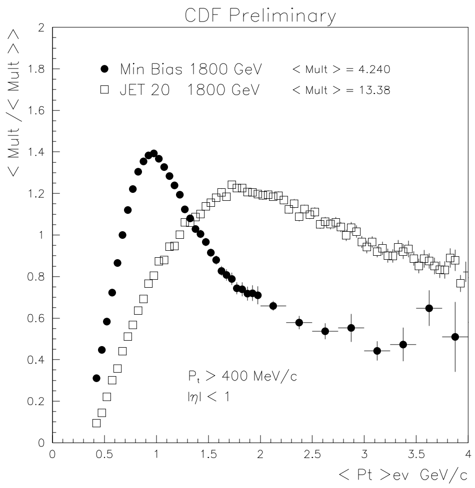
vious plots: see Fig. 3. On the vertical scale we are now plotting the charged CTC multiplicity divided by the overall mean value of the multiplicity distribution (each sample divided by its mean). This allows a comparison at the two energies.

Minimum bias data show a peculiar shape with a peak around 1 GeV/c which is not observable in the jet data. Most part of the inelastic cross section is located in the region of this peak. It is interesting to notice that the minimum bias high p_t tail has a multiplicity lower than that of the jet sample; a feature which is still not understood since we would expect this tail to be shaped by those jet events that are present in the minimum bias sample.

4.2. Production of strange particles

The same analysis is done with the multiplicity of strange particles. K_s^0 and Λ^0, decaying before entering the CTC, can be detected looking for couples of opposite sign CTC tracks converging to a secondary vertex. Selection of V^0 was





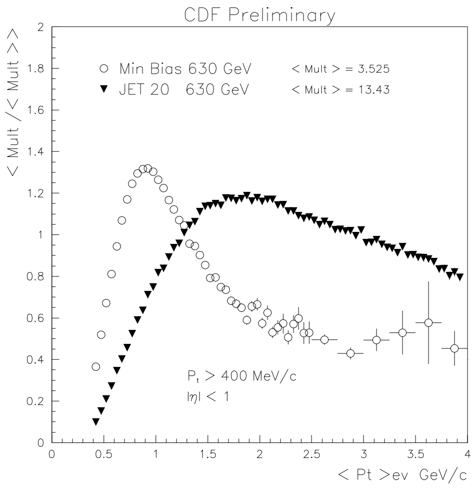


Figure 3.
Profile plots of multiplicity versus the mean event p_t.
Upper left: comparison of minimum bias at two energies. Upper right: minimum bias and jet sample at 1800 GeV. Lower right: minimum bias and jet sample at 630 GeV.

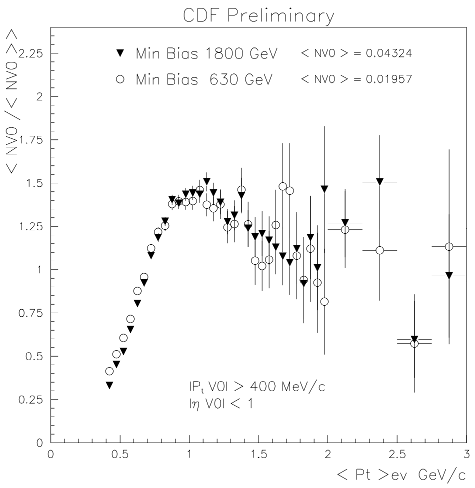
obtained requiring them to be in the $|\eta| < 1$ and $p_t > 0.4$ GeV/c interval, and their decay products in $|\eta| < 1.5$ and $p_t > 0.2$ GeV/c.

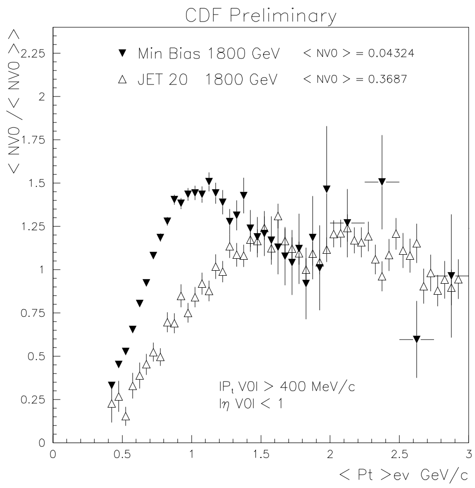
Fig. 4 shows the average number of V^0 (K_s^0 and Λ^0) per event divided by the average number of V^0 in the sample as a function of the $\langle p_t \rangle_{ev}$. The normalization helps in minimizing V^0 finding inefficiencies and make the distributions scale with energy.

The shape of the plot is quite similar to that of charged multiplicity with a maximum in the same region of $\langle p_t \rangle_{ev}$; the tail seems to be higher, with respect to the maximum, than for charged tracks. The agreement at the two energies is pretty good within the statistical errors. The behaviour of the jet sample is as for the charged multiplicity.

4.3. The mean P_t versus multiplicity

The dependence of the average p_t on the event multiplicity (or particle density) has been measured at various energies and for different reactions [2–4] since its first observation by UA1[5]. CDF has presented the same analysis based on 1988/89 data at 1800 GeV ([6]). Here we extend the statisics to run 1A (1800 GeV) and 1C (630 GeV) (Fig. 6): the rise of the average p_t with the





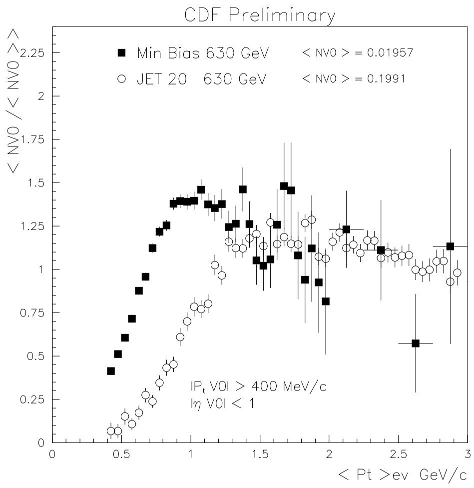


Figure 4.
Profile plots of number of V^0 versus the mean event p_t.
Upper left: comparison of minimum bias at two energies. Upper right: minimum bias and jet sample at 1800 GeV. Lower right: minimum bias and jet sample at 630 GeV.

multiplicity is not linear. The same study has been done on the jet sample and shows a completely different behaviour.

It is convenient to stress out that this kind of plot, obtained computing the mean p_t of all the tracks pertaining to events of the same multiplicity, implies a different event classification than the one obtained when computing the multiplicity of all the events having an average p_t in a given interval. Nevertheless the region of the peak of Fig. 3 roughly corresponds to the multiplicity interval 5-9 in the latter plot (Fig. 5).

4.4. Intermittency

Investigation of correlations among hadrons produced in high energy collisions have been done since several years ago through the study of the so called factorial moments computed in small pseudorapidity bins of decreasing size δ. The power-like increase of the factorial moments as a function of the bin size is referred to as *intermittency.* Intermittency has been observed in a very wide variety of multiparticle final state, although the effect changes with the different initial and/or final states analysed. We refer to reference [7] and references therein for the definition of the facto-

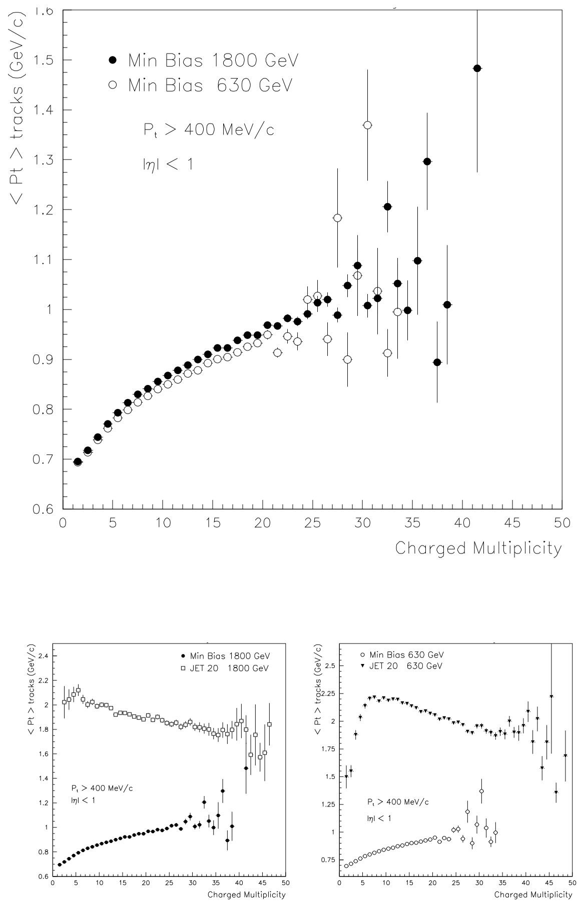


Figure 5. The mean p_t versus the event charged multiplicity at 1800 and 630 geV for the minimum bias sample. The jet sample is shown for a qualitative comparison.

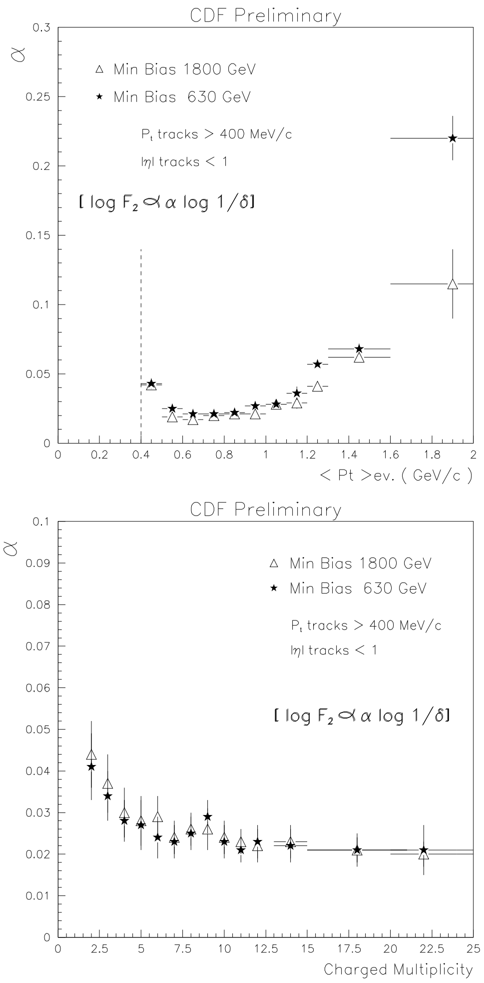


Figure 6. The strength of the factorial moment of order 2 plotted against the mean event p_t (upper) and against the charged multiplicity (lower).

rial moments and for a more detailed discussion about intermittency.

In more recent years considerable improvements in the investigation of intermittency have been obtained with the introduction of more sophisticated techniques like the so called *correlation integrals* and the *star integrals* [8] and also with the use of three-dimensional bins in p_t, η and ϕ space instead of the original one-dimensional pseudorapidity bins. As a preliminary approach we have used factorial moments F_q (q is the order of the moment) in one-dimensional pseudorapidity space [9]. This quantities have been studied, as for the charged and V^0 multiplicities, as a function of the average event p_t. Specifically factorial moments of order 2 have been calculated as a function of decreasing pseudorapidity bin size for different bins of the average event p_t. The *strength* of the effect for each bin of $\langle p_t \rangle_{ev}$ has been obtained taking the slope of the straight line fitted, in the limited region of pseudorapidity bin size in which linearity is observed, to the experimental points of the factorial moments (or factorial cumulants) versus the bin size dependence. In Fig. 6 this slope, the strength of the correlation, is shown as a function of the $\langle p_t \rangle_{ev}$ and of the charged multiplicity.

5. Summary and Outlook

1. In minimum bias samples both charged multiplicity and multiplicity of strange particles show a similar behaviour as a function of $\langle p_t \rangle_{ev}$ with a peak around 1 GeV/c in our limited phase space.

2. In the region of the peack there is most part of the inelastic Cross Section.

3. The position of the peak is roughly the same at 1800 and 630 GeV.

4. The analized jet sample shows a completely different behaviour.

5. The strength of the correlation has a shallow minumum in the region where we find the multiplicity peak.

We are still unable to draw any final conclusion on this analysis; several aspects require further investigation, including the need of isolating jet events inside the minimum bias sample and understanding the behaviour of the high p_t region. Correlations, which may be more sensible to the evolution of the event structure, should be more deeply studied.

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