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MULTIPLICITY DEPENDENCE OF TRANSVERSE MOMENTUM SPECTRA

AT ISR ENERGIES

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ABSTRACT

We observe an increase of the average transverse momentum with the multiplicity of the charged particles produced in the central rapidity region of proton-proton collisions at ISR energies. The increase is smaller than that observed at the CERN proton-antiproton collider. The magnitude of the effect is the same for negative and positive particles.

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1. INTRODUCTION Studies of the distributions of transverse momenta of particles produced in hadron-hadron collisions have shown that at low p_T they depend only weakly on energy and on the type of the initial particles. The mean value of the transverse momentum is therefore considered as one of only a few variables commonly used for the description of hadronic reactions. Recently an experiment at the CERN proton-antiproton collider at a c.m. energy $\sqrt{s} = 540$ GeV has shown that there is a clear dependence of the p_T spectrum on the charged particle multiplicity, n_c , in the central region of rapidity. The spectrum becomes less steep as n_c increases. This corresponds to an increase of the mean transverse momentum $\langle p_T \rangle$ with the number of charged particles produced in the central region of rapidity [1]. A number of possible explanations of this observation has been proposed [2-4].

It is interesting to study whether such an effect exists also at lower energies, in particular in the ISR energy range. A recent ISR experiment has given rather low upper limit for this effect [5]. Such studies require high statistics, good acceptance and good momentum resolution.

2. EXPERIMENT In this paper we present the results of an analysis of charged particle production in proton-proton collisions at c.m. energies $\sqrt{s} = 31$ GeV and 63 GeV. About 40 000 events and 230 000 events were analyzed at 31 GeV and 63 GeV respectively. The experiment was performed at the CERN Intersecting Storage Rings (ISR) using the Split Field Magnet (SFM) detector. The magnetic volume of the detector (with a maximum field strength of 1 T) was filled with Multiwire Proportional Chambers. The momenta of charged particles were measured in nearly the full solid angle of 4π steradians. The performance of the detector is described in previous publications [6]. The experiment used a "minimum bias" trigger, which essentially required the presence of at least one charged track in the detector. This trigger accepts $\sim 95\%$ of the inelastic cross section. About 80% of the charged tracks were measured with a relative momentum precision $\Delta p/p$ better than 10%. Careful analysis of the data has shown that we can accept tracks with $\Delta p/p < 0.8$ without a significant change in the presented results.

3. ANALYSIS In fig. 1(a) the mean transverse momentum is plotted as a function of the charged multiplicity in the central rapidity region $|y| < 2$ of proton-proton collisions at c.m. energy $\sqrt{s} = 63$ GeV. The mean transverse momentum was calculated as

$$\langle p_T \rangle = \frac{1}{n_c} \sum_{i=1}^{n_c} |p_{Ti}|$$

separately for each event, where n_c is the number of charged particles in the central region of rapidity, and then these values were averaged over all events. Low multiplicity events ($n_c < 4$) which could be contaminated by diffraction dissociation were removed from the data of fig. 1(a). The figure shows that the mean p_T increases with n_c and then appears to flatten out at the highest multiplicities. The proton-proton data for $\sqrt{s} = 31$ GeV analysed with the same cuts are presented in fig. 1(b). In this case no increase of $\langle p_T \rangle$ with n_c is observed within the present statistical uncertainties. It is thus clear that the effect increases with c.m. energy over the ISR energy range. The detailed comparison of the p_T spectra at $\sqrt{s} = 63$ GeV plotted for low and high multiplicities grouped separately is shown in fig. 2. These data show that the main contribution to the observed increase of $\langle p_T \rangle$ comes from particles with $p_T > 0.3$ GeV/c. There is no bigger loss of very low p_T particles ($p_T < 0.2$ GeV/c) at higher multiplicities than at low multiplicities due to the detector or track finding program inefficiency.

From fig. 2 we can conclude that the effect will be enhanced if we plot $\langle p_T \rangle$ only for particles with $p_T > 0.3$ GeV/c. Indeed in fig. 3(a) we observe that the increase of $\langle p_T \rangle$ for the sample with the p_T cut is larger than that for the whole sample. It is almost as large as the increase of $\langle p_T \rangle$ observed at $\sqrt{s} = 540$ GeV. Fig. 3(b) shows that the magnitude of the increase in $\langle p_T \rangle$ is the same for positive and negative particles with $p_T > 0.3$ GeV/c.

To exclude the possibility that the increase in $\langle p_T \rangle$ with multiplicity results from biases in the detector and in the event reconstruction program or by the cuts used in the analysis we have

studied also Monte-Carlo generated events. No $\langle p_T \rangle$ dependence on n_c is found when simulating events in the detector and analyzing them with the same cuts as for the real events.

The magnitude of the effect is sensitive neither to the choice of the range in rapidity nor to a $\Delta p/p$ cut-off. It is the same for all four quadrants of azimuthal angle so a possible bias resulting from the non-symmetrical configuration of the SFM detector can be excluded. The mean value of $\Delta p/p$ shows a negligible increase with multiplicity so the possibility of generating the increase of $\langle p_T \rangle$ by different momentum resolution smearing of the steeply falling transverse momentum spectra can be also excluded. Our studies show, however, that there is a systematic uncertainty in the $\langle p_T \rangle$ scale of $\sim 5\%$ and multiplicities are measured with an average error of ± 1 unit. Due to the cuts applied to our data the average values of p_T are slightly different from those of the previous measurements.

In fig. 4 the $\langle p_T \rangle$ increase observed at the highest ISR energy is compared with that reported at the CERN $p\bar{p}$ collider. Although there is a large difference in magnitude, the trends are similar: the rise of $\langle p_T \rangle$ is followed by a kind of plateau at the highest available multiplicities per unit rapidity. The similarity could suggest a kinematical origin of the plateau.

4. CONCLUSIONS We observe the increase of the mean p_T with charged multiplicity in the central rapidity region at the highest ISR energy. The effect comes mainly from medium p_T particles and is enhanced if only particles with $p_T > 0.3$ GeV/c are taken for the calculation of $\langle p_T \rangle$. The magnitude of the effect is smaller for $\sqrt{s} = 63$ GeV than for $\sqrt{s} = 540$ GeV at the CERN $p\bar{p}$ collider but both data sets show that $\langle p_T \rangle$ flattens after an initial increase with particle multiplicity per unit rapidity.

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FIGURE CAPTIONS

Fig. 1 The average transverse momentum for charged particles produced in the central region of rapidity of proton-proton collisions plotted versus charged multiplicities at the c.m. energies:

(a) $\sqrt{s} = 63$ GeV,

(b) $\sqrt{s} = 31$ GeV.

The cuts applied to the data are described in the text.

Fig. 2 Transverse momentum distributions for low ($3 < n_c < 8$) and high ($n_c > 12$) multiplicities of particles produced in the central region of rapidity, $|y| < 2$, of proton-proton collisions.

Fig. 3 (a) The average transverse momentum of charged particles with $p_T > 0.3$ GeV/c at $\sqrt{s} = 63$ GeV as a function of the multiplicity of all charged particles in the central region of rapidity ($|y| < 2$).

(b) Same as (a), but here plotted separately for negative and positive particles.

Fig. 4 The average transverse momentum as a function of charged particle density in the central rapidity region of proton-(anti)proton collisions at ISR and CERN $p\bar{p}$ collider energies.

Fig. 1

Fig. 2

Fig. 3

Fig. 4