ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ
СО АН СССР

O.V.Zhirov

NONTRIVIAL VARIATIONS OF p_t-SLOPE : A GOOD TOOL FOR SEPARATION OF PRODUCTION MECHANISMS

ПРЕПРИНТ 81 - 31

Новосибирск

NONTRIVIAL VARIATIONS OF p_t-SLOPE: A GOOD TOOL FOR SEPARATION OF PRODUCTION MECHANISMS

O.V.Zhirov

Institute of Nuclear Physics

630090, Novosibirsk-90, USSR

ABSTRACT

The p_t-dependence of p_t-slope demonstrates clearly a plateau at p_t = 2-4 Gev/c, separating low and high p_t regions, where the thermodynamical and parton descriptions make sense.

1. Introduction. The underlying mechanisms of high and low-p_t particle production in high energy hadronic collisions are quite different. The former is dominated by the single hard scattering of pointlike constituents, the latter is rather the multiple soft interactions of newly produced particles. In particular, the constituent interchange model [1] is found to be successful at $p_t \gtrsim 3$-4 Gev/c [2], while at lower p_t a good description [3,4] is provided by the thermodynamical approach [3,5-6]. If both of the approaches make sense, in the region of $p_t \sim 3$-4 Gev/c the experimental spectra should have some irregularity corresponding to the transition from thermal to nonthermal contributions. In this Letter we demonstrate, that such a phenomenon does really exist and naturally fixes the applicability limit of both approaches.

At first sight, the data [7-12] on the p_t-distribution

$$E\,\frac{d\sigma}{d^3p}(\theta_{cm}=90^\circ, p_t, s)\Big|_{pp\to h+\dots} = f_h(m_t, s) \qquad (1)$$

collected up to now demonstrate a smooth, monotonous dependence on m_t ($\equiv (M^2+p_t^{\,2})^{1/2}$, M is the mass of h) [1]. So, the pessimistic opinion that one-particle inclusive spectra are not informative is widespread.

The situation changes completely, if one becomes interested in the behaviour of the <u>local</u> (differential) characteristics of spectra. In view of the parton description such characteristics are the exponents M,N defined by the local (in m_t,s va-

---

1) The use of m_t instead of p_t is advocated, for instance, in refs. [4,13-15].

riations) fit:

$$f(m_t,s) = const\cdot(1 - 2m_t/ s^{1/2})^M m_t^{-N}, \qquad (2)$$

At $m_t \gtrsim$ 3-4 Gev/c M and N are approximately constant [2], being in reasonable agreement with the expectations of the constituent interchange model (CIM) [1], but at lower m_t at variance with CIM N rapidly drops.

In view of the thermodynamical description the corresponding characteristics of spectra are obtained by the local (in m_t) fit

$$f(m_t,s) = \sigma_o\cdot A\cdot\exp(-b\cdot m_t), \qquad (3)$$

where A is the dimensionless normalization constant (σ_o = 1mb$\cdot$Gev$^{-2}\cdot c^3$) and the slope parameter b characterizes the effective production temperature of particles at given m_t [4]:

$$T_{eff} = (b + (2m_t)^{-1})^{-1}$$

Our main observation is that the dependence of T_{eff} on m_t is not monotonous. At $m_t \sim$ 2-4 Gev/c^2 we found a well expressed plateau. An analogous plateau is also found for the normalization factor A.

Fig.1 demonstrates, that the existence of the plateaus is supported by the data [7,8,10] of various experimental groups and can hardly be ascribed to some systematics.

Fig.2 shows, that both the location and height of plateau for T_{eff} are rather insensitive to the quantum numbers of produced particles, as well as to the target [2]. So, one may conclude, that the origin of plateaus, as well as the underlying particle production mechanisms should be universal for any final particle.

---

2) The lower values of T_{eff} for antiprotons reflect presumably the influence of kinematical restrictions.

The energy dependence of the heights T_i, A_i of plateaus is plotted in Fig.3. At FNAL energies each of the plateaus seems to be sole, while at ISR energies some indications to the second one appear (see again Fig.1c,d).

2. The model. A very elegant explanation follows from the thermodynamical picture, developed in refs. [3-6,17]. In this picture the production of high-m_t particles is ascribed to the "leakage" (or "evaporation") of particles [14,16-17] from the very hot thermodynamical system during its expansion. The higher m_t is produced, the higher temperature (and earlier stage of expansion) dominates in its production. The highest temperature is obviously the initial temperature of expansion. So, the abovementioned plateaus may be attributed to the initial stage of (hydrodynamical) expansion. In this way the further growth of T_{eff} at $m_t \gtrsim$ 3-4 Gev/c^2 should be ascribed to some nonthermal mechanism, e.g. the hard scattering of partons.

The detailed estimates of the "leakage" at the initial stage of expansion are given elsewhere [4,6,17], and here we only summarize them. Following [4,17], we write:

$$E\frac{dN}{d^3p} \sim const\cdot\Delta x_\parallel\cdot\Delta t\cdot\exp(-m_t/T_i) \qquad (4)$$

where $\Delta x_\parallel$ is the longitudinal size of system, $\Delta t \sim \Delta x_\parallel$ is the characteristic "lifetime" of the initial state with the initial temperature T_i. In Landau's hydrodynamical model [18] $\Delta x_\parallel$ is the Lorentz-contracted size of initial hadrons, $\Delta t \sim \Delta x_\parallel \propto s^{-1/2}$. The initial temperature $T_i \propto s^{c^2/(1+c^2)}$, where c is the sound velocity in hadronic matter. Finally, we have:

$$E\frac{dN}{d^3p} \sim const\cdot s^{-1}\cdot\exp(-m_t/T_i(s)) \qquad (5)$$

Let us stress, that the predicted behaviour is universal for any kind of produced particle in agreement with data. Comparing eq.(5) to the above data analysis one can see, that the dependence $A \propto s^{-1}$ has a natural explanation as a consequence of Lorentz contraction of primary hadrons. Fitting the dependence $T_i(s) \propto s^{0.18}$ one finds $c^2 = 0.22$, in very good agreement with the earlier independent estimates (for a review, see [6]).

3. Discussion. The existence of initial state of hydrodynamical system as it is assumed in Landau model [18] is a very nontrivial fact. Let us remind a lot of objections [19] to such a picture and also attempts [3,6] to understand it in QCD framework. So, the detailed study of phenomenon, especially at highest ISR energies is of great importance.

The relevance of thermodynamics is supported by the fact, that the estimates of T_{eff} are rather independent of the kinds of final particles (Fig.2). Its applicability up to $m_t \sim$ 3-4 Gev/c^2 is also verified by the dilepton spectra analysis [4]. Further studies, both theoretical and experimental are very desirable.

At ISR energies an additional step appears at $T_{eff} \sim 0.25$-0.28 Gev, (Figs.1,3), which may characterize an irregularity in hydrodynamical expansion due to the phase transition [4,6] of quark-gluon plasma to hadronic matter. The detailed study of particles composition is crucial [4] in this region.

4. Summary and conclusions. We have analysed data [7-12] on the inclusive hadronic spectra in the region $\theta_{cm} = 90^0$, $m_t =$ 1-5 Gev/c^2 and have found that:

(i) The effective productiom temperature T_{eff} grows with m_t and s. In the region of $m_t \sim$ 2-4 Gev/c^2 its dependence on m_t has some plateau. The location and height of plateau are not sensitive to the quantum numbers of final particle and target. The height of plateau grows with s.

(ii) For the normalization factor A in eq.(3) we observe a similar plateau at the same m_t. Its height A_i decreases with the energy approximately as s^{-1}.

(iii) At ISR energies the plateau seems to be splitted into two steps.

Although the experimental errors quoted are large, the phenomenon is seen in data of different experimental groups. Its more detailed and accurate experimental studies are badly needed.

A very plausible explanation is suggested by the thermodynamical picture of of multiparticle production, in which particle production in the plateau region is ascribed to the leakage at the initial stage of expansion of thermodynamical system. In particular, the observation $A_i \propto s^{-1}$ has a clear origin and reflects the Lorentz contraction of the colliding primary hadrons. The dependence of $T_i \propto s^{0.18}$ is also consistent with the equation of state for hadronic matter [6]. The further growth of T_{eff} at $m_t \gtrsim$ 3-4 Gev/c^2 is ascribed to the parton mechanism, presumably CIM [1].

The author is very grateful to E.V.Shuryak fͻr numerous considerations and support, and also to E.L.Feinberg, M.I.Gorenstein, N.N.Nikolaev and G.M.Zinovjev for very useful discussions of results.

REFERENCES

1. For a review, see, for instance: D.Sivers,S.J.Brodsky and R.Blankenbecler,Phys.Rep.23C(1976);
   R.Blankenbecler,S.J.Brodsky,J.F.Gunion,Phys.Rev.D18, (1978)900;
2. R.Blankenbecler,S.J.Brodsky and J.F.Gunion,Phys.Rev.D12, (1975)3469.
3. E.V.Shuryak,Phys.Lett.78B(1978)150;Yadern.Fiz.28(1978)796.
4. O.V.Zhirov,Yadern.Fiz.30(1979)1098;Novosibirsk preprint IYaF 79-114(1979).
5. E.L.Feinberg,Nuovo Cim.34A(1976)391.
6. E.V.Shuryak,Phys.Rep.61C(1980)71.
7. D.C.Carey et al,Phys.Rev.D14(1976)1196.
8. D.Antreasyan et al,Phys.Rev.D19(1979)764.
9. C.J.Donaldson et al,Phys.Rev.Lett.36(1976)1110.
10. K.Eggert et al,Nucl.Phys.B98(1975)93.
11. F.W.Büsser et al,Nucl.Phys.B106(1976)1.
12. C.Kourkomelis et al,Preprint CERN-EP/80-07(1980).
13. E.L.Feinberg,Usp.Fiz.Nauk 114(1971)539;Phys.Rep.5C(1972)237
14. E.V.Shuryak,Yadern.Fiz.20(1974)549.
15. J.Bartke et al,Nucl.Phys.B120(1977)14;
    M.Banner et al,Nucl.Phys.B126(1977)61.
16. I.N.Sisakyan,E.L.Feinberg and D.S.Chernavsky,ZhETF,52, (1967)545.
17. M.I.Gorenstein,V.P.Shelest and G.M.Zinovjev,Phys.Lett.60B (1976)283.
18. L.D.Landau,Izv.Akad.Nauk SSSR,ser.fiz.,17(1953)51.
19. D.I.Blokhintzev,ZhETF,32(1957)350;
    J.Novakovsky and F.Cooper,Phys.Rev.D9(1974)771;
    M.J.Morawcsic and M.Teper,Phys.Rev.D16(1977)1593.

FIGURE CAPTIONS

Fig.1 The effective temperature T_{eff} and normalization factor A versus transverse mass m_t.
(a,b) The lines represent interpolations of data [7].
(c,d) The solid and dotted lines are the interpolations of data [10] and [7], respectively. The dashed lines are handdrown through the points, estimated from data [8].

Fig.2 The effective temperature T_{eff} versus transverse mass m_t for hydrogen and deuterium targets. All the points are estimated from data [8]. The dashed line is handdrown through the pion points for hydrogen target.

Fig.3 The heights of plateaus versus the CM collision energy $s^{1/2}$. The points are estimated from: ●,*,■ the FNAL data [7-9] and ○, △, ▽ the ISR data [10-12]. The doubling of some ISR points reflects the splitting of plateaus into pairs of steps.

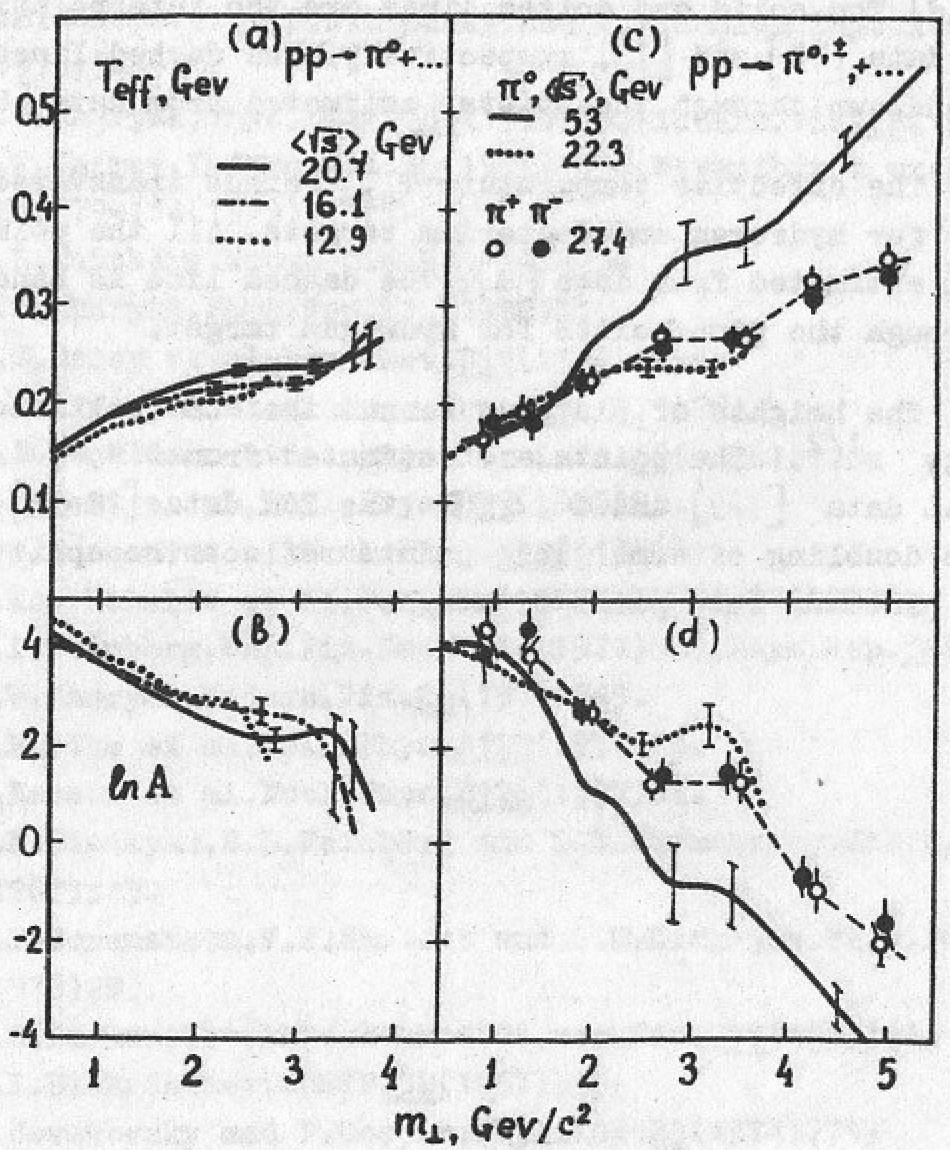
(a) pp → π°+...
T_{eff}, Gev
⟨√s⟩, Gev
20.7
16.1
12.9
(c) pp → π°,±+...
π°, ⟨√s⟩, Gev
53
22.3
π+ π−
27.4
(B)
ln A
(d)
$m_\perp$, Gev/c²

Fig.1

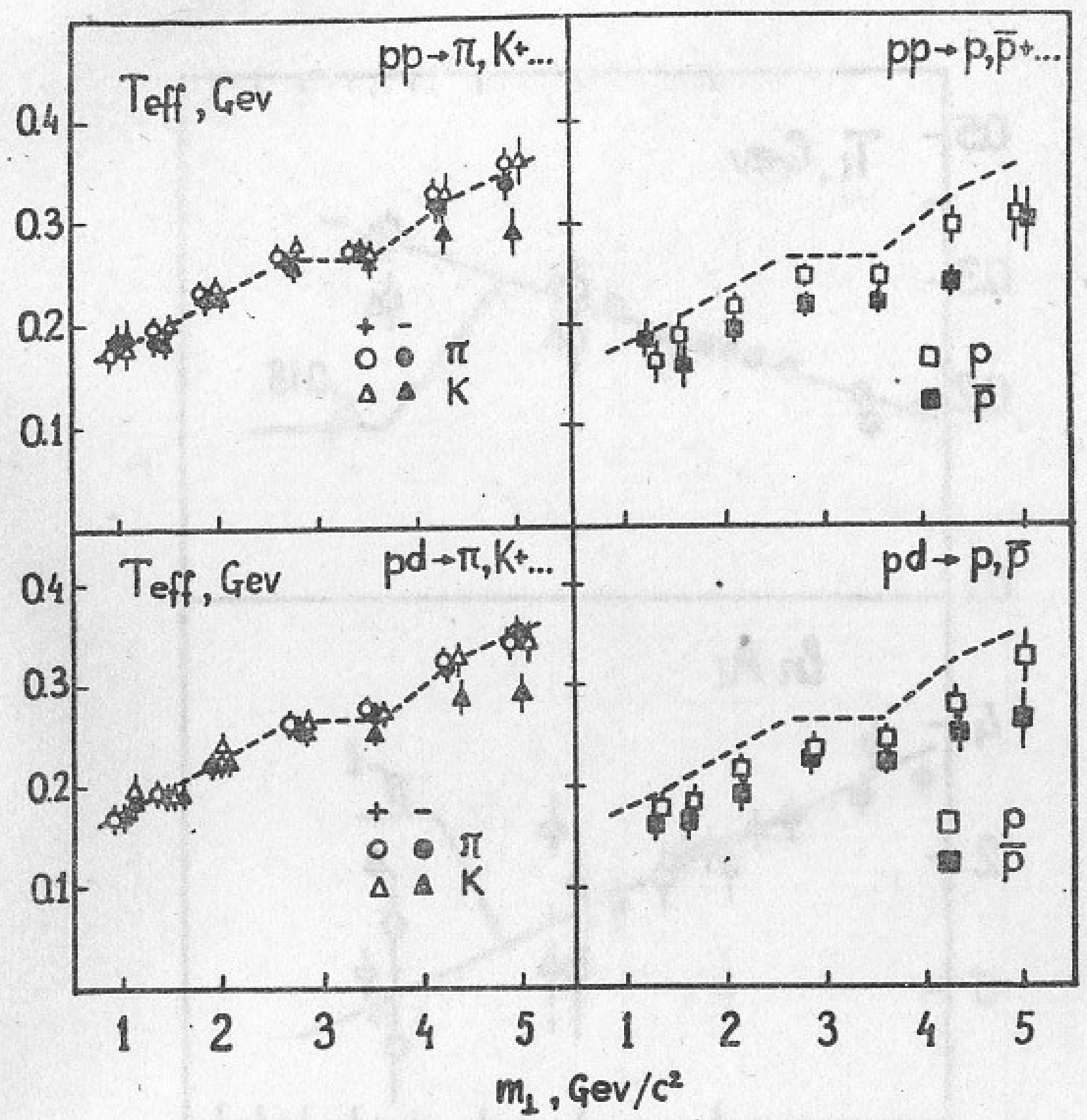
Teff, Gev
pp→π, K+...
pp→p, p̄+...
+ −
π
K
p
p̄
Teff, Gev
pd→π, K+...
pd→p, p̄
$m_\perp$, Gev/c²

Fig.2

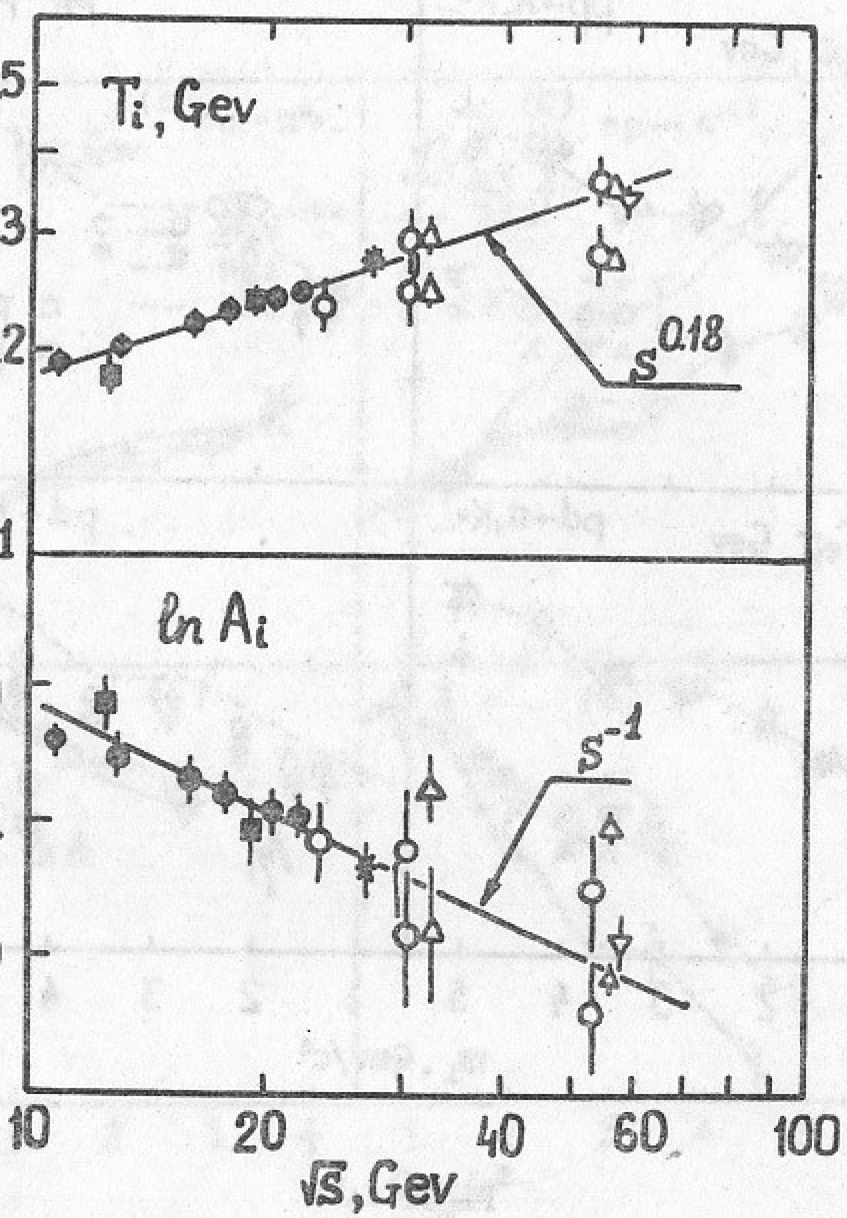

Fig.3

Работа поступила - 25 февраля 1981 г.

Ответственный за выпуск - С.Г.Попов
Подписано к печати 9.3-1981 г. МН 06149
Усл. 0,6 печ.л., 0,5 учетно-изд.л.
Тираж 200 экз. Бесплатно
Заказ № 31.

Отпечатано на ротапринте ИЯФ СО АН СССР