CERN/EP 84-22
27 February 1984

HIGH p_T BARYONS EMITTED AT $\theta = 10^\circ, 20^\circ$ AND 45°
IN pp COLLISIONS AT $\sqrt{s} = 62$ GeV

Ames-Bologna-CERN-Dortmund-Heidelberg-Warsaw Collaboration

A. Breakstone¹, C.D. Buchanan^{3(*)}, R. Campanini², H.B. Crawley¹,
G.M. Dallavalle², K. Doroba⁶, D. Drijard³, F. Fabbri³, A. Firestone¹,
H.G. Fischer³, H. Frehse^{3(**)}, W. Geist³, G. Giacomelli², R. Gokieli⁶,
M. Gorbics¹, P. Hanke⁵, M. Heiden³, W. Herr⁵, E.E. Kluge⁵, J.W. Lamsa¹,
T. Lohse⁴, W. T. Meyer¹, G. Mornacchi³, T. Nakada⁵, M. Panter³,
A. Putzer⁵, K. Rauschnabel⁴, F. Rimondi², R. Sosnowski⁶, M. Szczekowski³,
O. Ullaland³ and D. Wegener⁴

- ¹ Ames Laboratory and Physics Department, Iowa State University, Ames, USA
- ² Istituto di Fisica dell'Università and INFN, Bologna, Italy
- ³ CERN, European Organization for Nuclear Research, Geneva, Switzerland
- ⁴ Institut für Physik der Universität Dortmund, Germany
- ⁵ Institut für Hochenergiephysik der Universität Heidelberg, Germany
- ⁶ University and Institute for Nuclear Studies, Warsaw, Poland

ABSTRACT

The composition of high p_T particles is determined for pp collisions at a c.m.s. energy $\sqrt{s} = 62$ GeV and at three c.m.s. polar angles $\theta \approx 10^\circ, 20^\circ$, and 45° . The fractions of protons and antiprotons are given as functions of transverse momentum p_T . The fractional yield of high p_T protons depends strongly on θ , whereas the one for antiprotons is constant.

Submitted to Physical Review Letters

(*) UCLA.

(**) Now at BBC, Turgi (Baden), Switzerland.

In recent years a detailed understanding of the processes yielding high transverse momentum mesons in deep inelastic proton proton collisions has been achieved both experimentally and theoretically [1-7]. Many observed features were successfully described quantitatively on the basis of the parton picture of the proton [8], lowest order perturbative QCD predictions for the parton-parton scattering [9] and phenomenological schemes for the hadronization of coloured partons [10]. It is now known that a high transverse momentum meson is a leading particle in a jet [2,11,12] and provides a tag for the flavour of the fragmenting parton [4]. There is, however, still one essential aspect, which has not been studied in detail up to now, namely the production of baryons at very high transverse momenta. The results published concern medium p_T at ISR energies [13] or high p_T at lower energies for only one centre of mass polar angle $\theta \approx 90^\circ$ [14,15]. In this paper the inclusive cross sections for baryon production at a centre of mass energy of $\sqrt{s} = 62$ GeV are presented for different polar c.m.s. angles ($\theta \approx 10^\circ, 20^\circ$ and 45°); these data are compared with those for meson production. The study will be completed in forthcoming publications with an analysis of the event structure.

The experiment was performed at the CERN-ISR using the Split Field Magnet detector (SFM), which is schematically sketched in fig. 1. The detector consists of a system of multiwire proportional chambers and an array of scintillation counters for time-of-flight measurements. A trigger logic selects events with a high p_T track at $\theta \approx 10^\circ, 20^\circ$ or 45° . Five threshold Cerenkov counters (four of them filled with freon 114 at atmospheric pressure ($\theta \approx 10^\circ, 20^\circ, 45^\circ$) and one (at 45°) with freon 13 at 7.5 atm.) are used to separate high transverse momentum pions, kaons and protons. Thresholds and efficiencies of the counters are given in table 1. Details of the set-up, of the acceptance and of the trigger scheme have been described in ref. [3].

In this paper ratios of invariant cross sections for equally charged high transverse momentum particles are presented. They are essentially free of systematic errors, since all acceptance corrections cancel. The data were corrected for Cerenkov inefficiencies, decay in flight, absorption and production of knock-on electrons in the Cerenkov counters and for nuclear interaction in the chambers of the trigger telescope. The remaining systematic uncertainties are given in table 2.

The ratios of the inclusive cross sections $\sigma(p)/\sigma(K^+)$, $\sigma(p)/\sigma(\pi^+)$, $\sigma(\bar{p})/\sigma(K^-)$ and $\sigma(\bar{p})/\sigma(\pi^-)$ at a centre of mass angle of $\theta \approx 45^\circ$ are shown as functions of transverse momentum p_T of the trigger particle in figs 2(a,b) and listed in tables 3(a,b). The ratios for positive and negative particles are clearly different in magnitude and show a different slope in p_T . Both, $\sigma(p)/\sigma(K^+)$ and $\sigma(p)/\sigma(\pi^+)$, decrease by a factor of about 2.5 between $p_T = 3.6$ and 6 GeV/c. By contrast, the ratios for negative particles are constant or only slowly decreasing in this p_T range. The ratio $\sigma(p)/\sigma(K^+)$ tends to approach $\sigma(\bar{p})/\sigma(K^-)$ for $p_T \gtrsim 6$ GeV/c. If one combines $\sigma(\bar{p})/\sigma(\pi^-)$ with the measurement of $\sigma(\pi^-)/\sigma(K^-)$ [3] one finds again, but with higher significance, that $\sigma(\bar{p})/\sigma(K^-)$ is almost constant. Only one other measurement of baryon production at $p_T \gtrsim 4$ GeV/c, with a precision comparable to ours, has been performed so far [15]. The data were taken at $\sqrt{s} = 19.4$ GeV and at a c.m.s. polar angle of $\theta \approx 90^\circ$. While the antiproton ratios compare well to those presented above, the relative proton yield in [15] is a factor of 2 larger, but shows the same p_T -dependence.

Similarly, the ratios $R(p) = \sigma(p)/\sigma(\text{positive particles})$ and $R(\bar{p}) = \sigma(\bar{p})/\sigma(\text{negative particles})$ are shown in fig. 3 (a,b) and listed in table 4(a,b) for $\theta \approx 10^\circ$, 20° and 45° . (For $\theta \approx 10^\circ$ only an upper limit for $R(\bar{p})$ is obtained). The θ dependence is further exhibited in fig. 4 at $p_T \approx 3.8$ and 4.4 GeV/c for $R(p)$ and $R(\bar{p})$ respectively^(*). The strong p_T -dependence of $R(p)$ for $\theta \approx 45^\circ$ is also observed for $\theta \approx 10^\circ$ and $\theta \approx 20^\circ$. In addition $R(p)$ decreases strongly with θ . On the contrary, $R(\bar{p})$ shows no significant θ -dependence for $p_T \gtrsim 4$ GeV/c and seems to decrease only slightly with transverse momentum for $\theta \approx 20^\circ$ and 45° .

In order to interpret these results in the context of parton models a somewhat simplified framework is adopted here, in which all but the dominant hard scattering and fragmentation processes of quarks and gluons are neglected. Also, eventual effects in the fragmentation process due to the masses of (heavy) fragments are not taken into account in the following.

(*) Note that the angular regions covered by the trigger telescopes are slightly different for positive and negative particles.

In most of the cases π^+ - and K^+ -triggers stem from scattered u-quarks [4]. Protons should, in analogy, be predominantly created via u-quark scattering. Under this hypothesis the main difference between π^+ , K^+ and proton production would be due to the fragmentation mechanisms. In phenomenological models [16] π^+ -triggers would be produced by the creation of $d\bar{d}$ -pairs in the colour-field of the scattered u-quark, K^+ -triggers by the creation of $s\bar{s}$ -pairs, and protons by the creation of $(ud)(\bar{u}\bar{d})$ -diquark pairs. In this simple framework the ratios $\sigma(\pi^+)/\sigma(K^+)/\sigma(p)$ would then reflect essentially the relative probabilities to create $d\bar{d}$ -pairs, $s\bar{s}$ -pairs and $(ud)(\bar{u}\bar{d})$ -pairs in the fragmentation chain, and thus be expected to depend only a little on p_T and θ . This is in clear disagreement with the experimental observations, hence this valence-quark source of protons is probably not dominant. For negative trigger-particles the model predictions are more involved. While a π^- can be created via valence-d-quark scattering [4], such a scheme is excluded for K^- and $\bar{p}$ which have no valence-quark in common with the incoming protons and are therefore believed to originate predominantly from gluon scattering for $p_T \approx 4$ GeV/c [4]. Again K^- and $\bar{p}$ are produced in the fragmentation chain by the creation of a quark- or diquark-pair in the colour field. In this picture the hard scattering mechanism would be the same for $\bar{p}$ and K^- production, though different for π^- production, but again the ratio $\sigma(\bar{p})/\sigma(K^-)$ should essentially reflect the ratio of probabilities for s-quark- and diquark-pair production in the fragmentation scheme. It is therefore expected to show no strong variation with θ and p_T - which is compatible with the data - and to be of approximately the same magnitude as $\sigma(p)/\sigma(K^+)$. It was shown above that experimentally this may only be the case asymptotically in p_T .

Whereas the above discussion presents a qualitative explanation for $R(\bar{p})$, one concludes that there must exist a substantial contribution to high p_T proton production from processes beyond these simple models. One possible explanation for the observed features may be the hard scattering of bound diquark systems which will mainly enhance the relative contribution of proton production and will die out with increasing p_T and θ because of the suppression by a diquark form factor [17].

We are grateful to the British Scandinavian Collaboration and the Science and Engineering Research Council (UK) for making the high pressure Cerenkov counter available to us. This experiment was greatly helped by contributions from the SFM detector group. We are indebted to the ISR Experimental Support group. The Dortmund and Heidelberg groups were supported by a grant from the Bundesministerium für Wissenschaft und Forschung of the Federal Republic of Germany. The Dortmund group was also supported by the Ministerium für Wissenschaft und Forschung des Landes Nordrhein - Westfalen. The Ames group was supported by the U.S. Department of Energy under contract W-7405-eng-82.

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TABLE CAPTIONS

- Table 1 Description of the Cerenkov counters used in the analysis.
- Table 2 Estimation of the systematic uncertainty on the particle ratios.
- Table 3 Particle ratios for protons (a) and antiprotons (b) at a centre of mass polar angle of $\theta \approx 45^\circ$. Only statistical errors are listed.
- Table 4 Particle ratios at a centre of mass polar angle of $\theta \approx 10^\circ$ (a) and $\theta \approx 20^\circ$ (b). Only statistical errors are listed.

TABLE 1

Trigger region, polar angle		Gas	Threshold [GeV/c]	Efficiency in the momentum range under consideration
10°		Freon 114 at atmospheric pressure	π : 2.7 K: 9.5 $(\frac{-}{p})$: 18.1	98% for pions 82%–99% for K^+ at $p_{lab} > 14$ GeV/c 95%–98% for K^- at $p_{lab} > 14$ GeV/c
20° (second counter)				100% for pions 100% for kaons at $p_{lab} > 13$ GeV/c
45°	First counter			100% for pions
	Second counter	Freon 13 7.5 atm.	π : 1.4 K: 4.7 $(\frac{-}{p})$: 9.0 100% for pions > 50% for kaons at $p_{lab} = 4.9$ GeV/c $\geq 99.5\%$ for kaons at $p_{lab} = 5.2$ GeV/c 100% for kaons at $p_{lab} \geq 6$ GeV/c	

TABLE 2

θ	$\frac{\sigma(p)}{\sigma(\pi^+)}$	$\frac{\sigma(p)}{\sigma(K^+)}$	$\frac{\sigma(p)}{\sigma(pos)}$	$\frac{\sigma(\bar{p})}{\sigma(\pi^-)}$	$\frac{\sigma(\bar{p})}{\sigma(K^-)}$	$\frac{\sigma(\bar{p})}{\sigma(neg)}$
10°	-	-	± 0.025	-	-	-
20°	-	-	± 0.015	-	-	± 0.010
45°	± 0.006	± 0.015	± 0.004	± 0.005	± 0.012	± 0.003

TABLE 3(a)

$\langle P_T \rangle$ [GeV/c]	$\sigma(p)/\sigma(\pi^+)$	$\sigma(p)/\sigma(K^+)$	$\frac{\sigma(p)}{\sigma(\text{all pos.})}$
3.66	0.241 ± 0.017	0.518 ± 0.042	0.141 ± 0.008
3.88	0.228 ± 0.012	0.506 ± 0.031	0.136 ± 0.006
4.12	0.204 ± 0.013	0.486 ± 0.035	0.126 ± 0.007
4.37	0.207 ± 0.016	0.436 ± 0.038	0.123 ± 0.008
4.62	0.158 ± 0.016	0.303 ± 0.034	0.094 ± 0.009
4.87	0.166 ± 0.019	0.421 ± 0.055	0.106 ± 0.011
5.22	0.159 ± 0.019	0.316 ± 0.041	0.096 ± 0.010
5.72	0.087 ± 0.020	0.239 ± 0.060	0.060 ± 0.013
6.22	0.115 ± 0.035	0.217 ± 0.071	0.070 ± 0.020

TABLE 3(b)

$\langle P_T \rangle$ [GeV/c]	$\sigma(\bar{p})/\sigma(\pi^-)$	$\sigma(\bar{p})/\sigma(K^-)$	$\frac{\sigma(\bar{p})}{\sigma(\text{all pos.})}$
4.20	0.0881 ± 0.0365	0.191 ± 0.086	0.0569 ± 0.0225
4.37	0.0326 ± 0.0080	0.105 ± 0.028	0.0243 ± 0.0059
4.62	0.0364 ± 0.0094	0.193 ± 0.055	0.0297 ± 0.0075
4.87	0.0222 ± 0.0102	0.082 ± 0.040	0.0171 ± 0.0079
5.20	0.0329 ± 0.0107	0.151 ± 0.053	0.0263 ± 0.0084
5.87	0.0143 ± 0.0099	0.086 ± 0.064	0.0121 ± 0.0084

TABLE 4(a)

P_T [GeV/c]	$\sigma(p)/\sigma(\text{all pos})$
1.91	0.547 ± 0.026
2.11	0.522 ± 0.008
2.30	0.502 ± 0.006
2.49	0.468 ± 0.006
2.69	0.447 ± 0.008
2.89	0.413 ± 0.010
3.09	0.382 ± 0.013
3.29	0.366 ± 0.017
3.49	0.304 ± 0.025
3.69	0.276 ± 0.039
3.91	0.332 ± 0.062

TABLE 4(b)

P_T [GeV/c]	$\frac{\sigma(p)}{\sigma(\text{all pos})}$	P_T [GeV/c]	$\frac{\sigma(\bar{p})}{\sigma(\text{all neg})}$
3.74	0.246 ± 0.036	2.53	0.030 ± 0.012
3.91	0.247 ± 0.021	2.71	0.048 ± 0.004
4.10	0.240 ± 0.017	2.90	0.046 ± 0.004
4.30	0.220 ± 0.017	3.10	0.043 ± 0.004
4.49	0.176 ± 0.018	3.29	0.024 ± 0.004
4.70	0.196 ± 0.023	3.50	0.024 ± 0.004
4.90	0.171 ± 0.027	3.69	0.017 ± 0.004
5.09	0.180 ± 0.031	3.89	0.021 ± 0.005
5.29	0.188 ± 0.041	4.09	0.015 ± 0.005
5.48	0.139 ± 0.052	4.29	0.024 ± 0.008
5.79	0.192 ± 0.060	4.49	0.014 ± 0.009

FIGURE CAPTIONS

Fig. 1 Top view of the SFM detector.

Fig. 2 Particle ratios $\sigma(p)/\sigma(K^+)$, $\sigma(\bar{p})/\sigma(K^-)$ (a) and $\sigma(p)/\sigma(\pi^+)$, $\sigma(\bar{p})/\sigma(\pi^-)$ (b) at a c.m.s. polar angle of $\theta \approx 45^\circ$.

Fig. 3 Particle ratios $R(p)$ (a) and $R(\bar{p})$ (b) for the three different c.m.s. polar angles ($\theta \approx 10^\circ$, 20° and 45°).

Fig. 4 Angular dependence of $R(p)$ and $R(\bar{p})$ at fixed p_T .

SFM Detector (1983)

Fig.1

Fig. 2

Fig.3

P_T [GeV/c]

Fig. 4