RESULTS OF THE CERN NA3 EXPERIMENT ON MUON PAIR PRODUCTION IN HADRON COLLISIONS

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ABSTRACT

The present report reviews the results of the NA3 experiment on muon pair production by hadron beams ($\pi^\pm$, $K^\pm$, $\bar{p}$ and p) at 150, 200 and 280 GeV/c. We have obtained ~10^6 events on ψ resonance, the first evidence for Υ production with pion beams and ~30000 $\mu^+\mu^-$ pairs with masses larger than 4.1 GeV/c^2.

We concentrate here on this continuum of massive $\mu^+\mu^-$ pairs (4.1 GeV < $M_{\mu\mu}$ < 8.5 GeV) excluding the resonance region (J/ψ, ψ', Υ). Data are compared with the predictions of the Drell-Yan model. In that framework, we determine nucleon structure functions from our p and $\bar{p}$ data and find very good agreement with the determination from D.I.S experiments. From π and K^- data we extract the pion and kaon functions which cannot be probed directly by lepton scattering.

In all channels studied, the experimental cross-section is significantly larger by a factor ~2.3±0.4 than expected from the Drell-Yan model.

RESUME

Nous présentons les résultats de l'expérience NA3 sur la production de paires de muons par des faisceaux de hadrons ($\pi^\pm$, $K^\pm$, p et $\bar{p}$) à 150, 200, 280 GeV/c. Nous avons obtenu ~10^6 événements au ψ, la première mise en évidence de la production du Υ avec un faiseau de π, et environ 30000 paires $\mu^+\mu^-$ de masse supérieure à 4.1 GeV/c^2.

Nous nous limitons ici aux données sur le continuum de paires de μ de haute masse (4.1 GeV<$M_{\mu\mu}$<8.5 GeV) en excluant la région des résonances (ψ, ψ', Υ). Les données sont comparées aux prédictions du modèle de Drell-Yan. Dans le cadre de ce modèle, nous déterminons de nos données en p et $\bar{p}$, les fonctions de structure du nucléon qui sont en très bon accord avec leur détermination à partir des expériences de diffusion "profondément" inélastique. Des données en π et K^-, nous pouvons extraire les fonctions de structure du π et du K qui ne peuvent pas être mesurées directement dans la diffusion des leptons. Dans toutes les réactions étudiées, la section efficace expérimentale est plus grande (d'un facteur 2.3±0.4) que prévu par le modèle de Drell-Yan.

1. EXPERIMENTAL APPARATUS

The apparatus is shown in fig.1a; this is basically a beam dump experiment using a tagged hadron beam and a large acceptance spectrometer[2]

1.1 Beam, targets and beam dump.

We have been using an unseparated secondary hadron beam produced by 400 GeV protons on a 50 cm Be target. Particles were identified by two differential Cerenkov counters (CEDAR) for $K^{\pm}$ and $\bar{p}$ and by two threshold Cerenkov counters for π^{+}. The intensities used in the experiment were in the range from 1-5 x 10^7 particles/pulse. Table 1 gives the function of different particles in the beam at 200 GeV/c and 150 GeV/c.

Table 1

⊖ beam

Particle	Energy	π^-	K^-	$\bar{p}$
ratio(%)	200 GeV	97.4	2	0.6
	150 GeV	95.5	3.2	1.3

⊕ beam

Particle	Energy	π^+	K^+	p
ratio(%)	200 GeV	36	4.6	59.4
	150 GeV	43	6	51

We used simultaneously a hydrogen target (30 cm) and a platinum target (6 cm for the 150 and 200 GeV/c runs, 11 cm for the 280 GeV/c runs). The hadrons from the interaction and the beam were stopped in a dump consisting of a 1.5 m long stainless steel with a tungsten-uranium conical plug of ±30 mrad aperture in the centre. H_2, Pt targets and the dump were separated by 40 cm, allowing vertex reconstruction and target assignation.

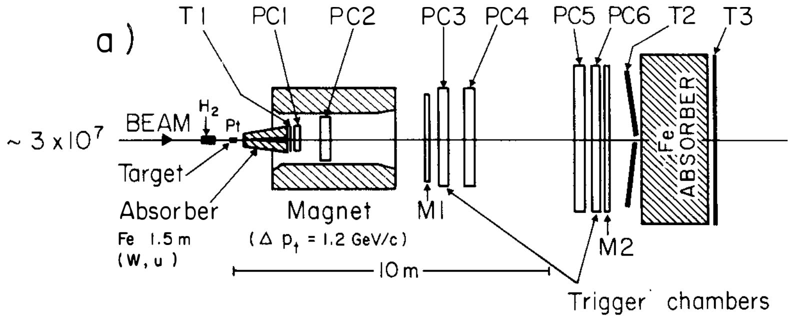
1.2 The spectrometer system (fig.1a) consists of :

- a large superconducting dipole magnet with a circular aperture of 1.6 m in diameter and $\int Bdl = 4.0$ Tm
- a muon filter of 1.8 m of iron, placed in front of the last hodoscope T3
- a set of 6 multiwire proportional chambers (31 planes with a total of ~26000 wires).

The spectrometer is composed of two symmetric telescopes of counters and chambers placed above and below the beam axis and covering vertical angles between ±6 and ±165 mrad.

NA 3 SPECTROMETER

a)

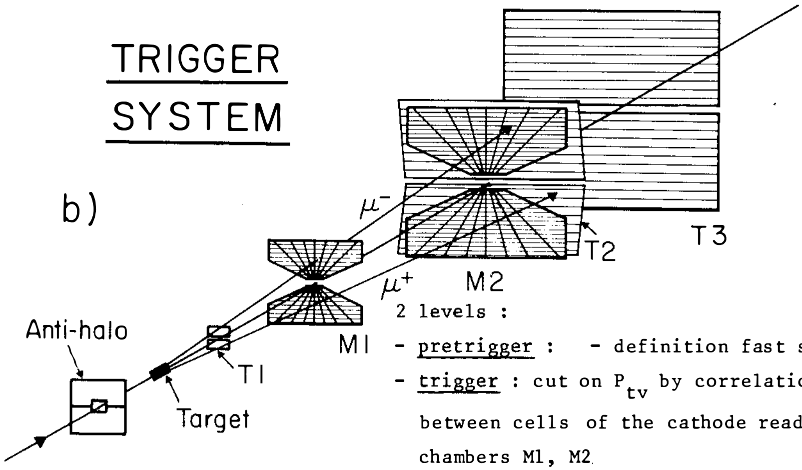


6 MWPC (31 planes, ~ 26 k wires)

T1, T2, T3 Trigger hodoscopes

TRIGGER SYSTEM

b)



2 levels :

- pretrigger : - definition fast strobe
- trigger : cut on P_{tv} by correlations between cells of the cathode read-out chambers M1, M2

$\mathrm{tg}\ \phi_1 - \mathrm{tg}\ \phi_2 = A/P_{tv}$

rough cut on $M_{\mu\mu} > 2$ GeV { one muon : $P_{tv} > 1$ GeV/c; both muons : $P_{tv} > 0.7$ GeV/c

Fig. 1

1.3 Triggering system (fig. 1b)

Due to the high particle flux in the chamber, we used a two level trigger system :

- a "pretrigger" which provides a fast strobe for proportional chambers PC1, PC2, M1 and M2.
  It requires :-at least two particles in the coincidence of hodoscopes T2, T3
  -at least one particle in hodoscope T1
  -no halo particle in the veto counter placed 10 m upstream of the target
- the "trigger" acts on the vertical component p_t^v of the transverse momentum of muons. This selection is obtained by two planes of cathode read-out chambers M1 and M2, divided in 18 separate horizontal bands of 64 cells each. The cells in M1 and M2 correspond to equal intervals of the tangent of the azimuthal angle and the bands define the vertical angle θ_v. Correlation between cells of a given band selects momentum and, θ_v being known, provides a cut off in p_t^v, which in turn, defines a rough cut on the mass of the dimuon.

The trigger conditions in the experiment were :

- either one muon $p_t^v > 1$ GeV
- or two muons with each $p_t^v > 0.7$ GeV/c

1.4 Data*)

The data reported have been taken between september 1978 and december 1979 and represent a total of $2 \cdot 10^7$ triggers. The number of events for the different channels are summarized in table 2.

Table 2

Data (septenber 78 - december 79)

			Pt target		H_2 target	
			J/ψ	M>4.1	J/ψ	M>4.1
⊖ beam	280 GeV/c	π^-	130000	4700		
	200 GeV/c	π^-	145000	4996	3000	138
		K^-	2800	80	56	
		$\bar{p}$	1000	30	17	
	150 GeV/c	π^-	703000	21200	18800	541
		K^-	24000	700	550	
		$\bar{p}$	9000	275	250	

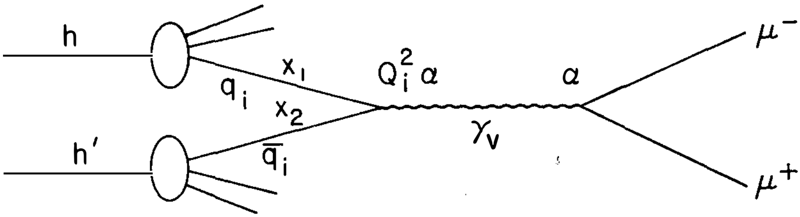
*) The present report has been updated with respect to the talk given at Moriond Conference and presents the status of the analysis at the end of May 1980.

			Pt target		H_2 target	
			J/ψ	M>4.1	J/ψ	M>4.1
⊕ beam	200 GeV/c	π^+	108000	1770	2200	40
		K^+	16000	170	340	
		p	101000	1080	2200	

To study the high mass continuum and the structure functions, are of particular interest the high statistics on π^- at 150 GeV/c and π^+ at 200 GeV/c, π^- induced dimuons on H_2 target (541 events), K^- and $\bar{p}$ induced dimuons at 150 GeV/c.

2. HIGH MASS CONTINUUM ($4.1 \leq M_{\mu\mu} \leq 8.5$) AND DRELL-YAN process

The aim of this experiment has been to test the predictions of the Drell-Yan model and, in the framework of this model, to determine the structure functions of unstable particles (π, K). In the Drell-Yan model(3), the lepton pair production by hadronic reactions is described by an electromagnetic annihilation of a quark and an antiquark of the beam and target particles into a virtual photon which decays into a lepton pair.



The experiment measures the invariant mass $M_{\mu\mu}$ and the longitudinal momentum P_L^* of the muon pair; then, through the relations

$$M^2_{\mu\mu} = x_1 x_2 s \qquad x = 2P_L^*/\sqrt{s} = x_1 - x_2 \text{ (transverse momentum neglected)}$$

we determine the kinematic variables x_1 and x_2 which are the fractional momenta of the quarks in the projectile and target particle.

From the differential cross section :

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{3s}\,\frac{1}{3}\sum_i \frac{Q_i^{\,2}}{x_1^{\,2} x_2^{\,2}}\left[f_i^{\,h}(x_1)\, f_{\bar{i}}^{\,h'}(x_2) + f_{\bar{i}}^{\,h}(x_1)\, f_i^{\,h'}(x_2)\right]$$

we can deduce the structure functions $f(x_1)$, $f(x_2)$.

- in this section, we compare the data to specific predictions of the Drell-Yan model such as :

  a) A-dependence : cross section $\propto$ A

b) charge asymmetry : $\sigma(\pi^+N)/\sigma(\pi^-N) \to 1/4$ for I = 0 target

c) scaling : $M^3\, d\sigma/dM = f(\tau)$ with $\tau = M^2/s$

d) angular distribution $d\sigma/d\cos\theta \propto 1 + \cos^2\theta$

- in section 3, we discuss the determination of the structure functions, the comparison with their determination from D.I.S experiments and another specific prediction of the model of special interest : Absolute cross section.

2.1 A-dependence

In the Drell-Yan model, due to the incoherent nature of the quark annihilation process, the cross section is expected to be linear in A. In order to check this prediction, we parametrize the cross section as A^α (taking into account the isospin asymmetry of the Pt Nucleus) and determine α. This is obtained by comparing H_2 and Pt data and by using the cross section difference $\sigma = \sigma(\pi^-) - \sigma(\pi^+)$ to eliminate sea effects.

We measure

$$A\,\frac{\sigma(H_2)}{\sigma(Pt)} = 1.51 \pm 0.28$$

if u and d are the up and down quark structure function in the proton, this ratio can be written as

$$A^{1-\alpha}\, R(x_2) \quad \text{where} \quad R(x_2) = \frac{4u - d}{u + 2d}$$

$R(x_2)$ is evaluated with the two following hypothesis :

a) $u = 2d \to R(x_2) = 1.75$

b) $2d/u = 1.125(1-x) \to R(x_2) = 1.8$ at the average x_2 the experiment : $< x_2 > = 0.15$

we obtain :

$$A^{1-\alpha} = 0.84 \pm 0.16 \quad \to \quad \alpha_{DY} = \underline{1.03 \pm 0.03}$$

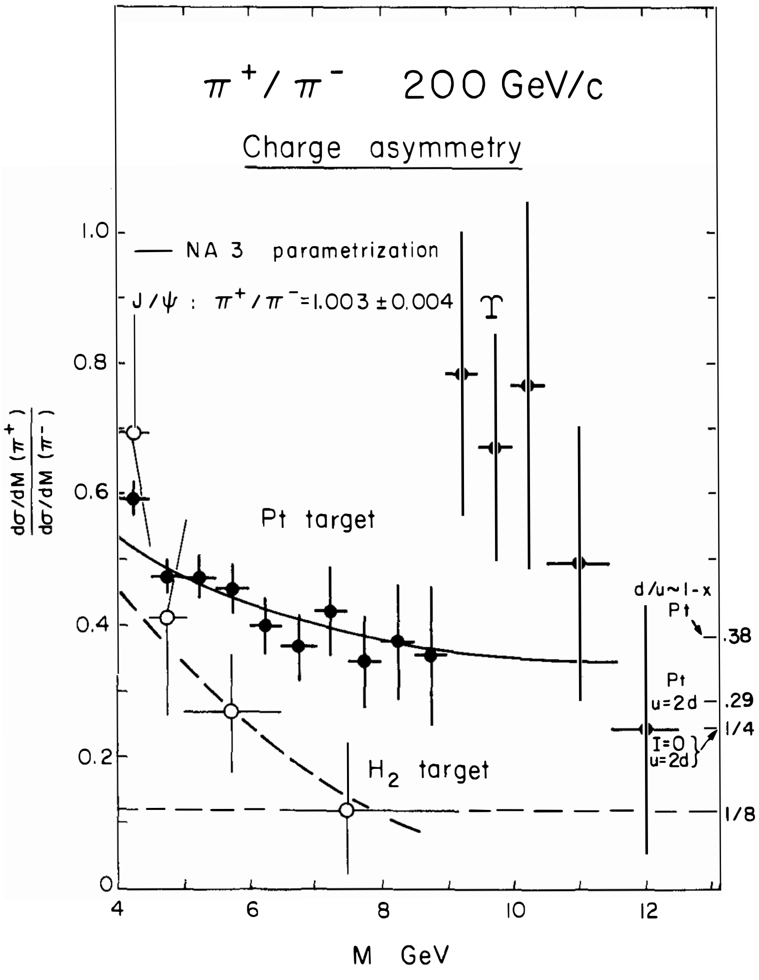
in agreement with the hypothesis of incoherent parton interactions. Other experiments find :

$\alpha = 1.02 \pm 0.2$ for p on Be, Cu, Pt (CFS Collaboration[4])

$\alpha = 1.12 \pm 0.05$ for π^- on Cu, C, W (CIP Collaboration[5])

2.2 Charge asymmetry

The ratio of π^+/π^- cross sections, as a function of M, for the Pt and hydrogen targets is shown in fig. 2. This ratio is equal to 1.01 ± 0.02 at the ψ mass and falls towards 0.35 at high mass, except in the Υ region. The electromagnetic nature of the Drell-Yan process implies that differently charged quarks produce different annihilation cross sections.



Charge asymmetry of the D.Y. process

Fig. 2

For example :

$$\frac{\pi^+ p}{\pi^- p} = \frac{(1/3)^2}{(2/3)^2} \times \frac{d}{u} = \frac{1}{8} \quad \text{(if u=2d) for } H_2 \text{ target}$$

$$\frac{\pi^+ N}{\pi^- N} = \frac{(1/3)^2}{(2/3)^2} = \frac{1}{4} \quad \text{for I = 0 target}$$

in the limit $\tau \to 1$ i.e. in the approximation that sea contribution is negligible

The exact value depends on the I-spin composition of the target and on the structure function of u and d quarks on the proton. The experimental data reproduce this prediction of the Drell-Yan model.

2.3 Scaling

The Drell-Yan model satisfies the scaling i.e. $M^3 d\sigma/dM = f(M/\sqrt{s})$ if the structure functions are not Q^2 dependent (scaling violations observed in deep inelastic lepton scattering and predicted by QCD produce only very small effects in the M^2 range of our data). Our data at 150, 200 and 280 GeV/c support this hypothesis (fig. 3).

2.4 Angular distribution

A $(1 + \lambda\cos^2\theta)$ distribution with $\lambda = 1$ is expected in the Drell- Yan process because of the annihilation of on-shell spin 1/2 massless quark-antiquark pair. Our experimental data for small p_T values are in agreement with this prediction.

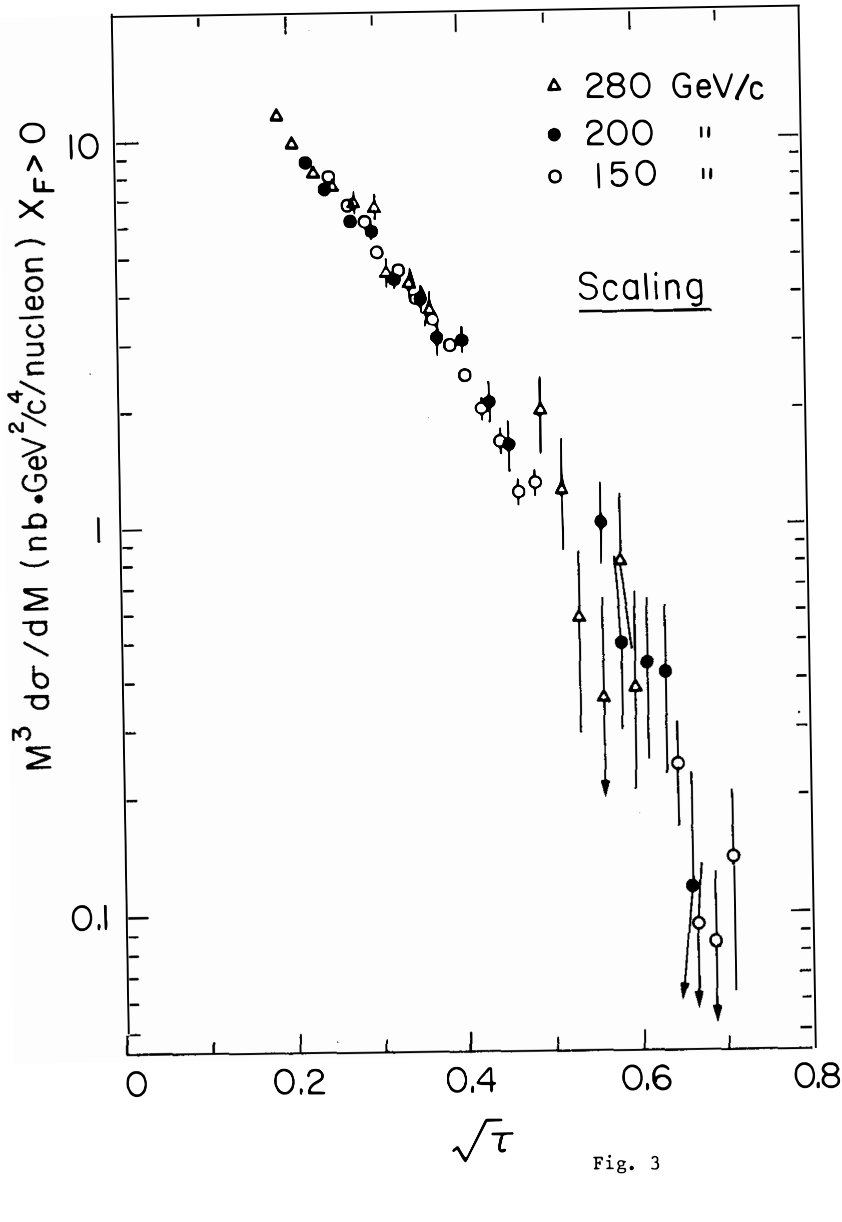
Models including higher twist terms or higher order QCD terms[6] predict deviations of λ from 1 and dependence with x_F and p_T. In particular higher twist contributions[7] lead to $\lambda \to -1$ when $x_F \to 1$. Some evidence for this behaviour has been observed by the C.I.P group[8]. At the Moriond meeting we have shown preliminary data supporting the same conclusion. This result has been withdrawn since the first analysis did not take into account properly the p_T-θ and θ-ϕ correlations to which the acceptance turns out to be highly sensitive. A new and more refined analysis of the angular distribution is now under way.

3. STRUCTURE FUNCTIONS AND ABSOLUTE D-Y CROSS SECTION

The cross section of the D.-Y. process is given by

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{3s} \frac{1}{3} \sum_i \frac{Q_i^2}{x_1^2 x_2^2} \left[f_i^h(x_1)\, f_{\bar{i}}^{h'}(x_2) + f_{\bar{i}}^h(x_1)\, f_i^{h'}(x_2) \right] \qquad (1)$$

where Q_i are the quark charges and $f_i(x_1)$, $f_i(x_2)$ are the structure functions of the projectile and target particle respectively. The model does not contain any free parameter and predicts the absolute value of the cross section if we know the structure functions. This is the case for pN and $\bar{p}$N where the nucleon struc-



280 GeV/c
200 "
150 "
Scaling
10
1
0.1
0
0.2
0.4
0.6
0.8
$M^3\ d\sigma/dM$ (nb•GeV^2/c/c^4/nucleon) $X_F > 0$
$\sqrt{\tau}$

Fig. 3

ture functions are known from deep ineastic scattering experiments.

We define a scale factor K as the ratio of the measured lepton pair cross section to the one expected from the Drell-Yan model

$$K = \frac{\left[\frac{d^2\sigma}{dx_1 dx_2}\right]_{exp.}}{\left[\frac{d^2\sigma}{dx_1 dx_2}\right]_{D.Y.\ model}}$$

The structure functions are extracted by fitting the (x_1, x_2) data sample to expression (1) with a Buras-Gaemers[9] type of parametrization for the structure functions. Then we compare the obtained nucleon structure function to the one determined in D.I.S experiment and we compute the value of the K factor.

Parametrization

Nucleon

valence

$$\begin{cases} u^p = A^u_{\alpha\beta}\ x^\alpha(1-x)^\beta & \text{with } \int \frac{u^p(x)}{x}dx = 2 \\ d^p = A^d_{\alpha\beta}\ x^\alpha(1-x)^{\beta+1} & \text{with } \int \frac{d^p(x)}{x}dx = 1 \end{cases}$$

$$(u^n = d^p;\ d^n = u^p)$$

sea

$$\begin{cases} \bar{u} = \bar{d} = A_s(1-x)^{\beta s} \equiv s^p \\ \bar{s} = 1/4(\bar{u} + \bar{d}) \quad \text{(from CDHS[10])} \end{cases}$$

Pion

valence $\quad u^\pi(x) = A_\pi x^{\alpha^\pi}(1-x)^{\beta^\pi}$ with $\int \frac{u^\pi(x)}{x}dx = 1$

sea $\quad s^\pi(x) = A_s^{\ \pi}(1-x)^{\beta_s^{\ \pi}}$ (SU3 symmetric)

3.1 Proton nucleon data

The large acceptance of our apparatus (mainly in x_1) allows us to measure the nucleon structure function in the Drell-Yan process and to compare with the D.I.S determination. Our pN data were obtained at 200 GeV/c with a mixed beam on a 6 cm Pt target. We have 1080 proton induced dimuon events in the mass region between 4.1 GeV and 8.5 GeV.

a) Structure function

The parameters left free in the fit were α, β and β_s, while A_s is determined by fixing the total fractional momentum carried by valence and sea quarks to 50%. The results of the fit are shown in Table 3 and are compared with the D.I.S data (CDHS).

Table 3

	NA3	CDHS (Q^2=20)
α	0.5 ± 0.2	0.5 ± 0.02
β	3.2 ± 0.4	2.8 ± 0.1
<u+d>	32%	34%
β_s	9.4 ± 1.0	8.1 ± 0.7
A_s	0.37	0.27
<sea>	18%	15%

On fig. 6 we show the projection onto the x_1 axis of our data together with a curve computed from the CDHS fit. This first determination of the nucleon structure function using μ pairs is in good agreement with the D.I.S determination.

b) Absolute cross section

Since there is agreement between shapes of nucleon structure function deduced from Drell-Yan and D.I.S we can compute the K factor using CDHS parametrization. This leads to K = 2.3 ± 0.4.

3.2 Antiproton nucleon data

The weak point in determining K from pN data is the necessity of fixing the percentage of sea quarks to the value found in D.I.S experiments, since dimuon production in pN reactions comes essentially from valence-sea terms. The cleanest experimental way of obtaining K is using antiprotons since in $\bar{p}$N reactions the valence-sea and sea-sea terms contribute less than 15% to the Drell-Yan cross section in our acceptance region.

We have collected 275 dimuons produced by incident antiprotons at 150 GeV/c. The data sample is obtained by selecting dimuon events with mass between 4.1 and 8.5 GeV, after subtraction of the accidental event background. We have also collected a sample of dimuons produced by 150 GeV/c protons, which consists of 35 events obtained for the same mass cut as for antiproton events and for an integrated luminosity comparable to the antiproton one.

a) Structure functions

We first compare the structure functions obtained in $\bar{p}$ induced dimuon events with their determination from D.I.S experiments. From the expression of the Drell-Yan cross section, we can deduce the difference between antiproton and proton cross sections on a platinum target nucleon (Z/A = 0.4). All contributions from the sea are cancelled in the subtraction :

$$\frac{d^2\sigma}{dx_1dx_2}\Big|_{\bar{p}N} - \frac{d^2\sigma}{dx_1dx_2}\Big|_{pN} = \frac{\sigma_0}{3x_1^{\,2}x_2^{\,2}}\,\frac{1}{9}\Big[(4u(x_1)+d(x_1)\;\;(0.4u(x_2)+0.6d(x_2))$$

$$+\;0.2d(x_1)(u(x_2) - d(x_2))\Big] \quad \text{with} \quad \sigma_0 = \frac{4\pi\alpha^2}{3s}$$

the term $0.2d(x_1)(u(x_2) - d(x_2))$ can be neglected since it contributes less than 2% of the main term and the difference of cross section factorizes :

$$\frac{d^2\sigma}{dx_1dx_2}\Big|_{\bar{p}N-pN} = \frac{\sigma_0}{3x_1^{\,2}x_2^{\,2}}\,\frac{1}{9}\,f(x_1)\;g(x_2) \qquad (2)$$

where $f(x_1) = 4u(x_1) + d(x_1)$

$g(x_2) = 0.4u(x_2) + 0.6d(x_2)$

The functions $f(x_1)$ and $g(x_2)$ can be determined from the data using expression (2). For $f(x_1)$, we have :

$$f(x_1) = \frac{\dfrac{1}{L_{\bar{p}}}\dfrac{dN}{dx_1}\Big|_{\bar{p}N} - \dfrac{1}{L_p}\dfrac{dN}{dx_1}\Big|_{pN}}{\dfrac{\sigma_0}{3x_1^{\,2}}\displaystyle\int\frac{g(x_2)}{9}\,\frac{A(x_1,\,x_2)}{x_2^{\,2}}\,dx_2}$$

where dN/dx_1 is the measured event distribution in x_1

L is the integrated luminosity

$A(x_1,\,x_2)$ is the spectrometer acceptance

the integral of $g(x_2)$ is evaluated using CDHS parametrization of the structure function (at Q^2=20)

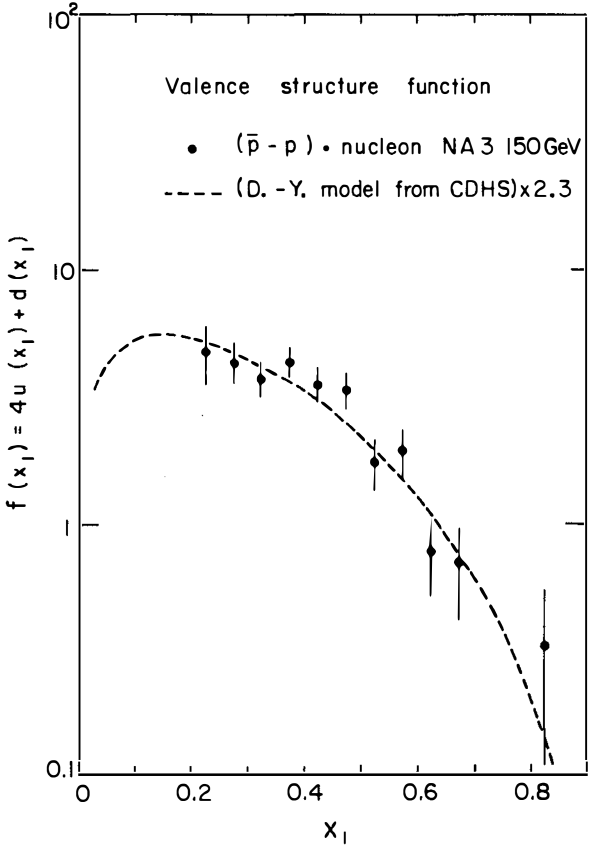
The functions $f(x_1)$ and $g(x_2)$ thus obtained are shown in fig. 4a and 4b where the experimental points are compared to the values of $f(x_1)$ and $g(x_2)$ computed with the CDHS parametrization.

b) Absolute cross section

The measured yield requires a normalisation factor K = 2.3 ± 0.4 in good agreement with our previous experimental determination[11]. The behaviour of $M^3d\sigma/dM$ as a function of $\sqrt{\tau}$ is shown in fig. 5 for our antiproton data at 150 GeV/c and our proton data at 200 GeV/c. In fig. 6, we compare the valence structure function obtained from $\bar{p}$ data to the valence+sea structure function obtained from 200 GeV/c proton data : for $x_1 > 0.4$ the two structure functions superimpose and at lower values of x_1, they separate, showing the sea contribution in the proton data.

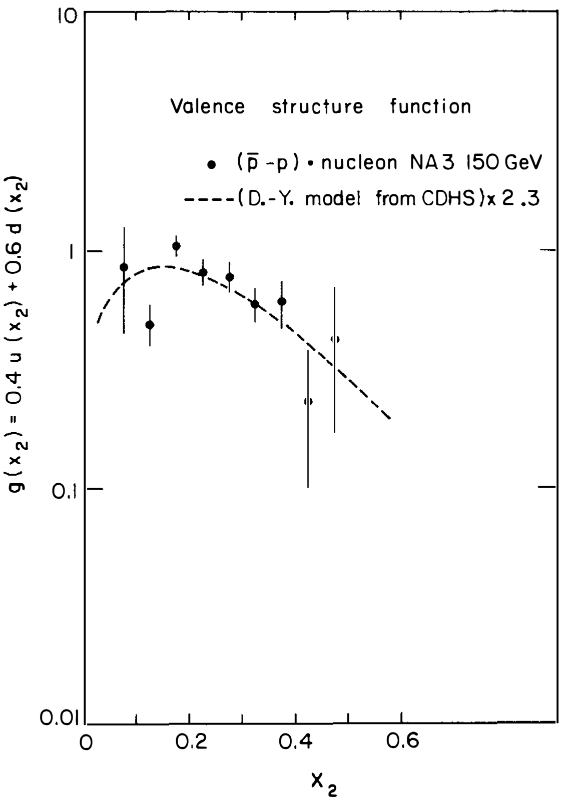
c) Conclusions

1) the determination of nucleon structure functions from $\bar{p}$ induced dimuons shows :



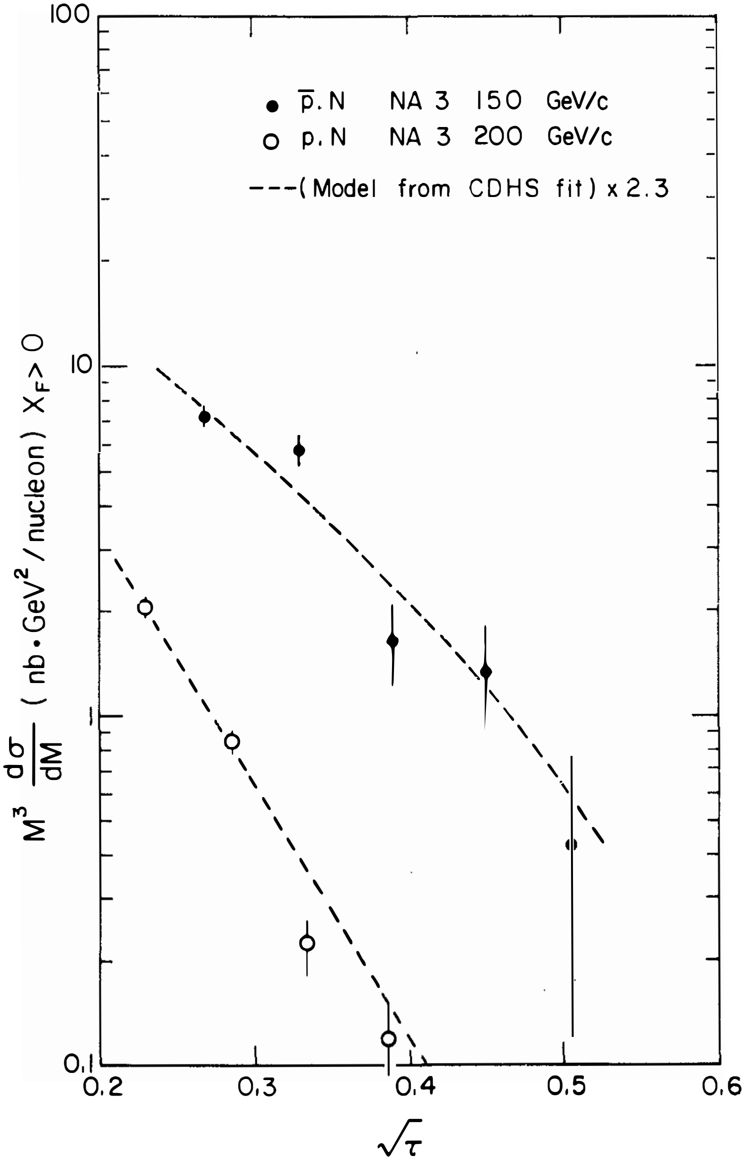
Valence structure function
(p̄ - p) • nucleon NA3 150GeV
(D. -Y. model from CDHS)x2.3
f(x₁) = 4u (x₁) + d(x₁)
x₁
10²
10
1
0.1
0
0.2
0.4
0.6
0.8

Fig. 4a



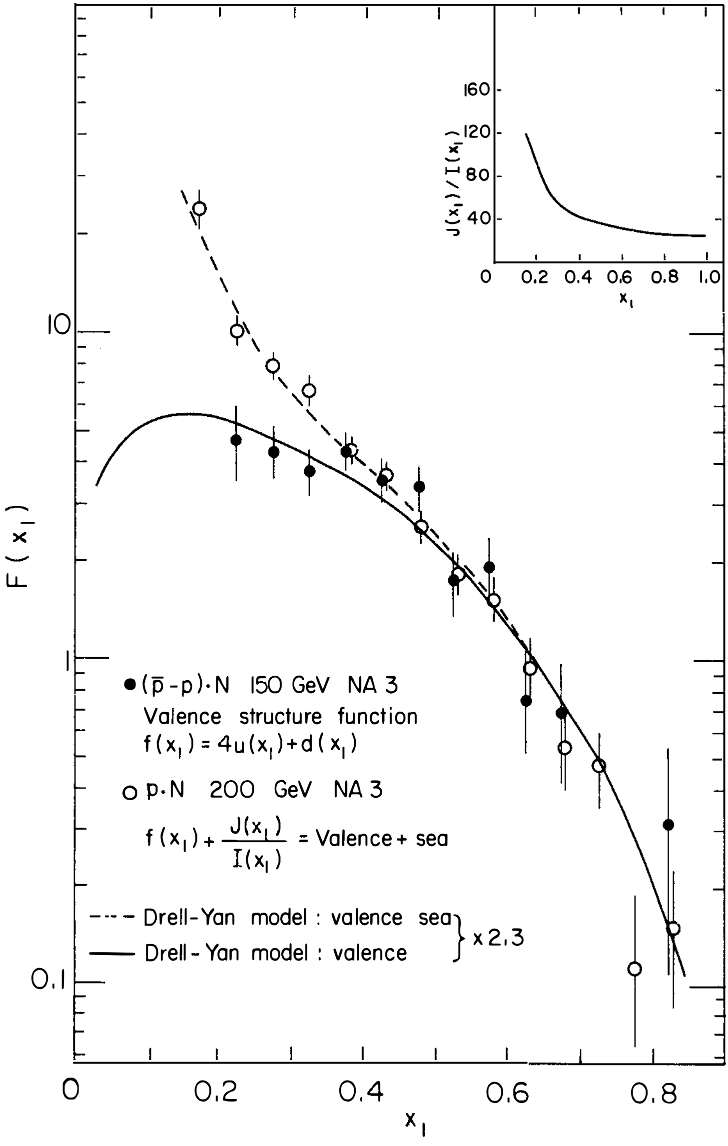
Valence structure function
(p̄ -p) • nucleon NA3 150 GeV
(D.-Y. model from CDHS)x 2.3
g(x₂) = 0.4 u (x₂) + 0.6 d (x₂)
x₂
10
1
0.1
0.01
0
0.2
0.4
0.6

Fig. 4b



100
10
1
0.1
0.2
0.3
0.4
0.5
0.6
p̄.N NA 3 150 GeV/c
p.N NA 3 200 GeV/c
---(Model from CDHS fit) x 2.3
$M^3 \frac{d\sigma}{dM}$ (nb·GeV^2/nucleon) $X_F > 0$
$\sqrt{\tau}$

Fig. 5



160
120
80
40
0
0.2
0.4
0.6
0.8
1.0
$J(x_1)/I(x_1)$
x_1
10
1
0.1
0
0.2
0.4
0.6
0.8
$F(x_1)$
x_1
● $(\bar{p}-p)\cdot N$ 150 GeV NA 3
Valence structure function
$f(x_1) = 4u(x_1)+d(x_1)$
○ p·N 200 GeV NA 3
$f(x_1) + \frac{J(x_1)}{I(x_1)}$ = Valence + sea
Drell-Yan model : valence sea
Drell - Yan model : valence
x 2.3

Fig. 6

- good agreement with the results from proton induced dimuons
- good agreement with nucleon structure functions from D.I.S

2) scaling factor K = 2.3 ± 0.4, in $\bar{p}N$ data this factor cannot be explained by an increased sea compared to D.I.S experiments.

3.3 π-Nucleon data

We have collected 4996 dimuons produced by π^- and 1770 dimuons produced by π^+ at 200 GeV/c. In our high statistics run at 150 GeV/c we have 21200 π^- induced dimuons. A mass selection was applied in the range 4.1 to 8.5 GeV. The relative π^+/π^- luminosity was monitored by the J/ψ events collected simultaneously with the dimuon continuum. The J/ψ production cross sections by π^+ and π^- beams on Platinum target were measured to be equal within 1%. The π^+/π^- relative luminosity is thus known to ±2%.

Using the cross section of the Drell-Yan process (1) and the parametrization defined in the introduction of sect. 3, we can express the cross section for pions as follows :

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{3s}\,\frac{1}{3}\,\frac{1}{x_1{}^2 x_2{}^2}\left[\underbrace{u^\pi(x_1)}_{\text{beam}}\ G(x_2) + \underbrace{s^\pi(x_1)}_{\text{beam}}\ \underbrace{H(x_2)}_{\text{target}}\right] \qquad (3)$$

where $G(x_2)$ and $H(x_2)$, for platinum target (Z/A = 0.4), take the following forms :

$$G(x_2) = 1/9(1.6u^P + 2.4d^P + 5S^P) \quad \text{for } \pi^-$$
$$G(x_2) = 1/9(0.6u^P + 0.4d^P + 5S^P) \quad \text{for } \pi^+$$
$$H(x_2) = 1/9(2.2u^P + 2.8d^P + 11S^P) \quad \text{for } \pi^+,\pi^-$$

a) Parametrization method

A global fit of the 200 GeV π^+ and π^- data allows a determination of both the valence and the sea structure functions. The result of this fit is given in table 4.

Table 4

Pion	Nucleon
α^π = 0.4 ± 0.15	α = 0.49 ± 0.2
β^π = 1.07 ± 0.12	β = 3.3 ± 0.5
A_s^π = 0.32 ± 0.2	A_s = 0.25 ± 0.1
β_s^π = 6.9 ± 2.9	β_s = 7.7 ± 1.4

As in $\bar{p}N$ and pN data, the nucleon structure functions obtained are in good agreement with the results of the ν deep inelastic scattering experiment[10]. To improve the accuracy of the pion structure function we fix the nucleon parameters

$\alpha = 0.5$ and $\beta = 2.8$ compatible to the values given by the CDHS fit, we obtain the results given in Table 5a). Table 5b) shows the results of the fit of the 150 GeV π^- data where we impose the π sea from our 200 GeV π^+-π^- fit and we use the nucleon valence and sea from the CDHS fit.

Table 5

a) 200 GeV	b) 150 GeV
$\alpha^\pi = 0.45 \pm 0.1$	$\alpha^\pi = 0.4 \pm 0.1$
$\beta^\pi = 1.04 \pm 0.1$	$\beta^\pi = 0.9 \pm 0.1$
$A_s^\pi = 0.25 \pm 0.15$	A_s^π } fixed from 200 GeV
$\beta_s^\pi = 5.4 \pm 2.0$	β_s^π } $\pi^+\pi^-$ fit

b) Projection method

By projecting the content of the x_1, x_2 arrray on the two axes, we get the distribution dN/dx_1 and dN/dx_2. We can get from equation (3) an expression depending only on x_1 :

$$F_\pi(x_1) = \frac{dN/dx_1}{\frac{\sigma_0}{3}\frac{L}{x_1^2} I(x_1)} = K\left[u^\pi(x_1) + \frac{J(x_1)}{I(x_1)} S^\pi(x_1)\right] \qquad (4)$$

where : L is the integrated luminosity

$\sigma_0 = 4\pi\alpha^2/3s$

K is the cross section normalization factor

$J(x_1)$ and $I(x_1)$ are integrals involving the nucleon structure function $G(x_2)$ and $H(x_2)$ and the calculated acceptance of the apparatus $A(x_1,x_2)$

$$I(x_1) = \int \frac{G(x_2)}{x_2^2} A(x_1, x_2)\, dx_2 \qquad J(x_1) = \int \frac{H(x_2)}{x_2^2} A(x_1, x_2)\, dx_2$$

We use for u and d the results of ν DIS parametrization. In fig. 7a we present the values of $F_\pi(x_1)$ obtained at 150 GeV with the curves calculated from our fit of the pion structure function.

We can express in a similar form the function $F_N(x_2)$ by using as input the pion structure functions $u^\pi(x_1)$ and $S^\pi(x_1)$ taken from our fit. $F_N(x_2)$ is shown in fig. 7b together with the effective nucleon structure function calculated using the valence and sea parametrization given by CDHS.

By assuming in equation (4) the K factor to be independent of x_1, we can derive its value after integration of $F_\pi(x_1)$ over x_1 :

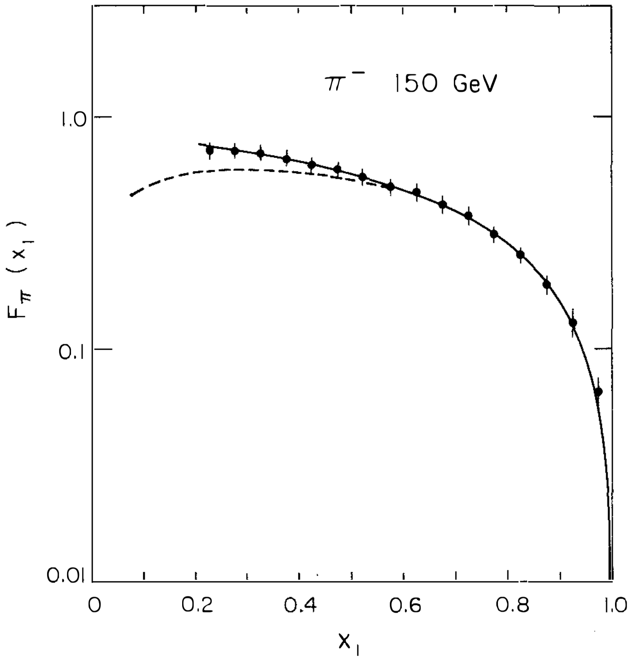

π⁻ 150 GeV
$F_\pi(x_1)$
1.0
0.1
0.01
0
0.2
0.4
0.6
0.8
1.0
x_1

Fig. 7a

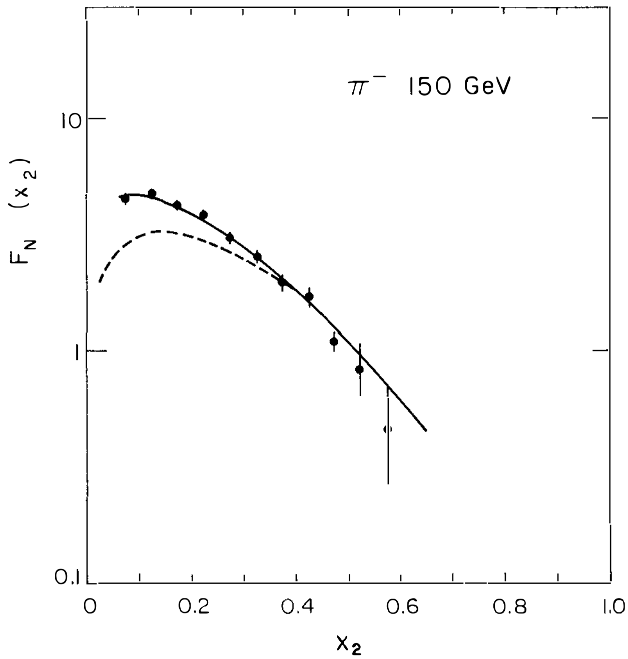

π⁻ 150 GeV
$F_N(x_2)$
10
1
0.1
0
0.2
0.4
0.6
0.8
1.0
x_2

Fig. 7b

$$K = \frac{\int F_{\pi}(x_1)\, dx_1}{\int \left(u^{\pi}(x_1) + \frac{J(x_1)}{I(x_1)}\, dx_1 \right)}$$

At 150 GeV we obtain K = 2.4 ± 0.4. Thus, also in the πN data, the experimental cross section for massive dimuons production is larger than the prediction of the simple Drell-Yan model. We recall that in the case of pN and $\bar{p}N$ data, we found K = 2.3 ± 0.4.

We also analysed the $\pi^- - \pi^+$ difference which has the advantage that effects of decay of high mass resonances or simultaneous leptonic decays of heavy mesons cancel out; this analysis leads to K = 2.2 ± 0.4.

A more direct way of measuring K with pions is to use a H_2 target. This has the advantage that A = 1 and therefore no A-dependence is involved. From our 540 events with M > 4.1 GeV, we obtained K = 2.4 ± 0.4. The data are shown in fig. 8.

It is therefore probable that the K factor implies a fundamental correction to the leading log Drell-Yan calculation. The next to leading log first order(12) in QCD has been calculated to give K~1.8 in the τ interval 0.2 to 0.4 where our experimental data are available.

3.4 K nucleon data

At 150 GeV/c we have collected simultaneously dimuons produced by K^- and π^- and we have obtained 700 $\mu^+\mu^-$ pairs with mass between 4.1 and 8.5 produced by K^-. The K^- are identified by a CEDAR and the only background left is due to random coincidences (~20%) which were subtracted out in the data analysis.

Using a formalism similar to the projection method described above we can obtain a $F_K(x_1)$ and $F_{\pi}(x_1)$, since the K^- data are at values of $x_1 > 0.2$ and their statistical accuracy is limited, we neglected contributions of the meson sea. Up to an accuracy of ~10% in the ratio $\bar{u}^K(x_1)/\bar{u}^{\pi}(x_1)$, we can also neglect terms corresponding to $d^{\pi}\bar{d}^p$ and $s^K\bar{s}^p$ annihilations.

The events distribution $dN/dx_1 \,|_{K,\pi}$ can be written as :

$$\frac{dN}{dx_1}\Big|_{\pi} = K_{\pi} \frac{\sigma_0 L_{\pi}}{3x_1^2}\, \bar{u}^{\pi}(x_1)\; I(x_1)$$

$$\frac{dN}{dx_1}\Big|_{K} = K_{K} \frac{\sigma_0 L_{K}}{3x_1^2}\, \bar{u}^{K}(x_1)\; I(x_1)$$

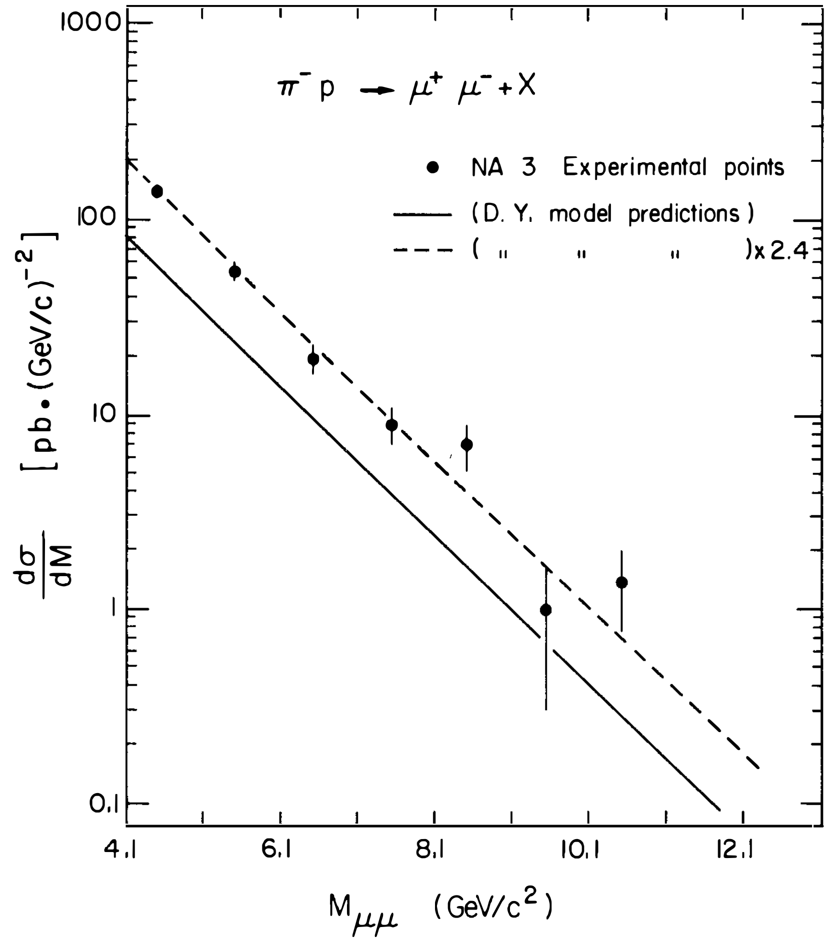

1000
100
10
1
0.1
$\pi^- p \rightarrow \mu^+ \mu^- + X$
NA 3 Experimental points
(D. Y. model predictions)
(" " ")x 2.4
$\frac{d\sigma}{dM}$ [pb•(GeV/c)$^{-2}$]
4.1
6.1
8.1
10.1
12.1
$M_{\mu\mu}$ (GeV/c^2)

Fig. 8

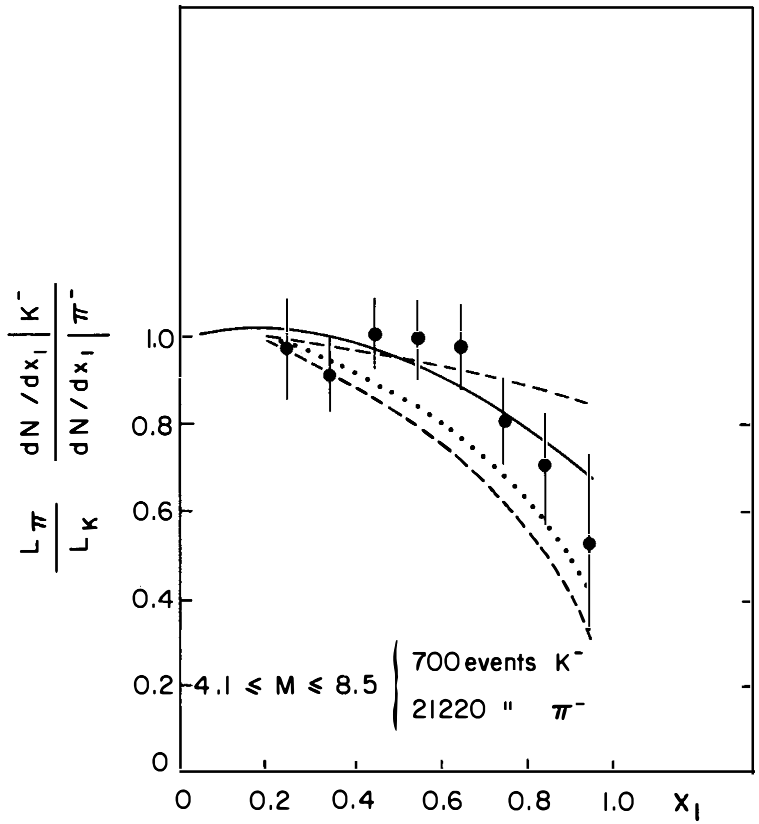


Fig. 9 Dashed curves : limits of $\bar{u}_K/\bar{u}_\pi$ ratio from ref.(13); the upper (lower) curve corresponds to A=1/8 (A=1/2) dotted ans solid curves represent $\bar{u}_K/\bar{u}_\pi$ from ref.(14) and (15) respectively.

where : - $\sigma_0 = 4\pi\alpha^2/3s$, s being the total c.m.s energy squared

- $L_\pi (L_K)$ is the integrated luminosity for pions (kaons)
- K_π, K_K are the ratios of the measured cross section of KN and πN reaction to its predicted value by the Drell-Yan model (they are assumed to be identical in value).
- $I(x_1)$ is an effective nucleon structure function integrated over experimental acceptance. For a Pt target

$$(Z/A = 0.4) \quad I(x_1)=\int(1/9x_2{}^2)(1.6u^P(x_2) + 2.4d^P(x_2) + 4s^P(x_2)) \; A(x_1,x_2) \; dx_2$$

We thus obtain the result (fig.9) :

$$\frac{\bar{u}^K(x_1)}{\bar{u}^\pi(x_1)} = \frac{L_\pi}{L_K} \frac{(dN/dx_1)_K}{(dN/dx_1)_\pi}$$

This ratio is independent of experimental acceptance and trigger efficiency due to simultaneous K and π data collection in our experiment.

From fig.9 it appears that for values of $x > 0.7$ the momentum spectrum of the $\bar{u}$ quark in the kaon decreases faster than the corresponding one for the $\bar{u}$ in the pion. This can be expressed by parametrizing the data with the analytic form $R(1-x)^A$, giving $A = 0.18 \pm 0.07$.

In fig.9, we compare our data with the theoretical model based on Regge considerations, proposed by P.V. Chliapnikov et al.(13) and A. El Hassouni et al.(14). These models limit the value of A in the range 1/8 to 1/2. Recently a non relativistic calculation(15) of the pion and kaon structure function in the framework of QCD has been performed assuming for the quark mass ratio m_s/m_u the value : 540/336. The corresponding $\bar{u}_K/\bar{u}_\pi$ ratio can be deduced from this model and be compared to our experimental data. This is shown in fig. 9 by the solid curve which seems to agree satisfactorily with the data.

4. CONCLUSIONS

a) Drell-Yan predictions :

- A-dependence
- charge asymmetry
- scaling

} classical Drell-Yan model works

- angular distribution : $(1 + \lambda\cos^2\theta;\ \lambda = 1)$

  Data at small p_T agree with $\lambda = 1$. The question of λ dependence with x_F and p_T has to be settled (analysis of our 150 GeV and 280 GeV data under way).

b) structure functions :

i) pN and $\bar{p}$N data

- determination of the nucleon valence structure function
- good agreement of the shape with the ν DIS determination of the nucleon structure function

ii) πN data : $u^{\pi}(x) \propto x^{0.4\pm0.1}(1-x)^{0.9\pm0.1}$

iii) KN data : for $x_1 > 0.7$ $\bar{u}^K$ decreases faster than $\bar{u}^{\pi}$: $\bar{u}^K/\bar{u}^{\pi} \propto (1-x)^{0.18\pm0.07}$

c) absolute cross section :

In all channels, the experimental cross section is larger than the Drell-Yan model prediction by factor K ≃ 2.3 ± 0.4. This is consistent with next to leading log first order QCD calculations, but the question of higher orders (possible exponentiation?) is still open.

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