CERN/ISRC/78-19

MEMORANDUM

23 June 1978

To : ISRC

From : M.M. Block, G.J. Bobbink, M.A.J. Botje, R. Campanini, M.A. van Driel, F.C. Erné, P. Kooyman, W.G.J. Langeveld, H. Ludwig, J.C. Sens, J. Timmer, D. van Wezep. Amsterdam - North Western Collaboration.

Subject : Experiment ISR/R607: Correlations between high p_L mesons produced in pp collisions at the ISR.

I INTRODUCTION

On 9.11.1977 (ISRC/77-29) the ISRC recommended for approval exp. R607 A study of diffractive charm production. On 17.11.77 (RB/21) the experiment was approved by the Research Board. The experiment was to be carried out by a Aachen - CERN - Holland - Munich - North Western - Riverside Collaboration. The major components of the equipment were, at arm 1: 2 septum-magnets equipped with MWPC's, a large aperture ("lamp shade") magnet equipped with (directional) drift chambers, and at arm 2: a septummagnet equipped with drift chambers. The arm 1 equipment is currently in use in exp. R606, the arm 2 equipment is new.

A few weeks before the scheduled start-up date of R607 the Aachen, CERN, Munich and Riverside participants, listed in ISRC/77-28, withdrew from the Collaboration. The reason is, in part, the heavy off-line analysis load which was going to be left at the end of the R606 datataking, as a result of the high rate of triggering by unwanted events in the arm 1 equipment. This withdrawal and the low rejection capability of the arm 1 equipment instigated a reexamination of the R607 project, since it seemed likely that after some 6 to 12 months of running R607 would be sealed with a fate similar to that of R606 today. It was therefore proposed not to pursue the original aim of exp. R607 any further, but, instead, to carry out a more limited programme of measurements in which the already installed arm 2 equipment could be put to use, and which could be ready for installation in the July 1978 4-week shutdown. A vital element in the evaluation of this possibility has been the close collaboration of the ISR division, in particular the vacuum and experimental support groups, who were ready to accomodate the extra work on very short notice.

This new experiment is briefly described below. The equipment consists of 2 identical spectrometers, one of which is a rearranged version of the arm 2 equipment presently installed in I6. The experiment was discussed with and approved by P. Falk-Vairant and J. Perez-Y-Jorba (memo dated 25 may 1978).

II PURPOSE OF THE EXPERIMENT

The purpose of the experiment is to probe for features which might distinguish between gluon exchange and parton exchange as a possible mechanism for high energy hadronic interactions within the context of quantum chromodynamics (QCD), through a measurement of the process

$$p + p \rightarrow \text{meson} + \text{meson} + X \qquad (1)$$

at 31/31 GeV and meson momenta $\geq$ 15 GeV/c, $p_T \geq 1$ GeV/c

Brodsky and Gunion[1)] have pointed out that in the case of gluon exchange the two final state mesons in (1) are expected to be uncorrelated, while in the case of parton exchange, strong long-range correlations are expected to occur. In particular they predict for the production of $\pi^+\pi^+$:

$$\frac{d\sigma}{dx_1 dx_2} (pp \rightarrow \pi_1^+ + \pi_2^+ + X) \sim (1 - x_1)^5 (1 - x_2)^5 \quad \text{gluon exchange} \qquad (2)$$

$$\sim (1 - x_1)^3 (1 - x_2)^7 + (1 - x_1)^7 (1 - x_2)^3 \quad \text{parton exchange} \qquad (3)$$

These predictions are based on dimensional counting, i.e. the notion that the probability for finding a meson with momentum fraction x decreases as the number of spectator partons increases, (as $(1 - x)^{2n - 1}$, where n is the number of spectators in the proton in which the meson is produced). As in the case of gluon exchange no partons are transfered from one proton to the other the momentum distributions in (1) are uncorrelated and are characterised by powers of $(1 - x)$ equal to those observed in the corresponding single particle processes

$$p + p \rightarrow \text{meson} + X \qquad (4)$$

In the case of parton exchange (or annihilation) however, the number of spectators in one proton is decreased by one, and in the other increased by one, resulting in the strongly correlated distributions of eq. 3, with powers $2n_1 - 1 = 3$ and $2n_2 - 1 = 7$.

Predictions such as those of eqs. (2) and (3) are at best indicative of what may be happening in reality. Taken at face value they would imply that the single particle spectra (4) at very high meson momenta are described by a single power in $1 - x$. A recent analysis[2,3] of ISR exp. R201 has shown however that, at $x \geq 0.8$ the meson spectra in (4) do not follow a single power law, but, instead, are well described by the convolution of the $q(x)$ and $\bar{q}(x)$ distributions making up the meson, with $q(x)$ and $\bar{q}(x)$ as derived from the SLAC structure functions (e.g. by Field and Feynman[4]).

The lack of validity of simple power laws, and the emerging consistency in the interpretation of deep inelastic ep, μp and pp $\rightarrow$ high momenta meson data via the structure functions adds considerable interest to a measurement of two meson momentum spectra as proposed here. While the notions of gluon- versus parton-exchange are reflected in the absence, respectively presence of long range correlations, the actual momentum dependence of the meson/meson spectra should be accessible to a quantitative interpretation in terms of double convolution integrals over the appropriate parton x distributions. In this sense the double arm data are a natural follow-up of the single particle (ISR and FNAL) results now available.

Fig. 1 shows typical data of exp. R201 compared to the bare Field-Feynman x distributions of the appropriate flavour, i.e.

$$\pi^+(x) = u(x),\ \pi^-(x) = d(x),\ K^+(x) = u(x),\ K^-(x) = s(x)$$

($\sim$ single power distributions, dashed lines in (Fig. 1)) and to the convoluted distributions ($C(\pi^+ = u\bar{d})$ etc, solid lines). It is seen that while single power laws do not agree with the data at the highest x, the convolution of the q and $\bar{q}$ distributions as derived from ep-scattering describes the ISR data very well indeed.

Fig. 2 shows the predicted behaviour (eqs. 2, 3) of the π^+ momentum distribution in one arm, for fixed, high, π^+ momentum (x = 0.7) in the other. The two distributions have been normalized to the same total integrated yield. In the case of gluon exchange the shape of the coincidence spectrum for fixed momentum in, say arm 1 is the same as that of either single arm; in the parton exchange case the spectra are distinct, as indicated in fig. 2. A comparison between the shape of the momentum distributions of events resulting from one arm and two arm triggers thus provides direct evidence for the presence or absence of long range correlations, relatively free of systematic errors.

III EQUIPMENT AND COUNTING RATES

The equipment is shown in fig. 3. Two identical spectrometers are placed on the pipes at ∿ 5.8 m from the intersection. They are equipped with driftchambers, trigger counters, Cerenkov counters and hodoscopes as indicated. The hodoscopes serve to predetermine the sign of the charge and the accepted range of momenta in the trigger.

We have computed the meson counting rates from the data of exp. R201 assuming no correlations between the two distributions. The single rates in each arm for x > 0.5 is ∿ 1100 particles/sec. The number of pairs ($\pi^+\pi^-$, $\pi^-\pi^-$. etc.) is ∿ 3/sec. The rates/sec. for L = 10^{31}/cm^2/sec. for the different pairs are shown in fig. 4 versus x in one arm, for x > 0.5 in the other arm, and in fig. 5 for fixed x in the other arm. It is clear that rate wise the experiment is entirely feasible, with the currently available high luminosity of the ISR: in a ∿ 100 hour period ∿ 10^6 good events would be collected.

With second priority we have in mind an investigation of the production of K^o's, and Λ's, with parasitic triggers on each arm individually.

Fig. 6 shows the results of the first two minutes of datataking with the septum magnetic field on, taken ∿ 2 weeks after installation of the arm 2 spectrometer. It shows the momentum spectrum of positive and negative secondaries produced at 31.5/31.5 GeV and exhibits the characteristic elastic/quasi elastic peak with good resolution.

IV REQUEST FOR RUNNING AND COMPUTER TIME

The equipment will be installed and run-in in July and August 1978. The intention is to take data for a maximum of 8 months, and review the situation during the January 1979 shutdown, i.e. after $\sim$ 3 months of data-taking. We intend to keep the off line analysis in step with the data-taking, and set our running schedule accordingly.

During 1978 the experiment can run with the beam energies 31/31 and 26/26 GeV as already scheduled. Lower energies may be requested later to verify scaling and to extend the x-range of the particle identification.

The speed of off line tracking is estimated to be approximately 100 events/sec. Including second stage analysis this leads to an estimated 75 hours of CDC 7600 time for 1978 and 150 hours for 1979. We are currently investigating the feasibility of running a fraction of the analysis on a computer outside CERN via the CERN-Amsterdam datalink.

REFERENCES

1) S.J. Brodsky and J.F. Gunion, PR D17 (1978) 848.
2) J. Singh et al, preprint.
3) F.C. Erné and J.C. Sens, preprint.
4) R.D. Field and R.P. Feynman PR D15 (1977) 2590.

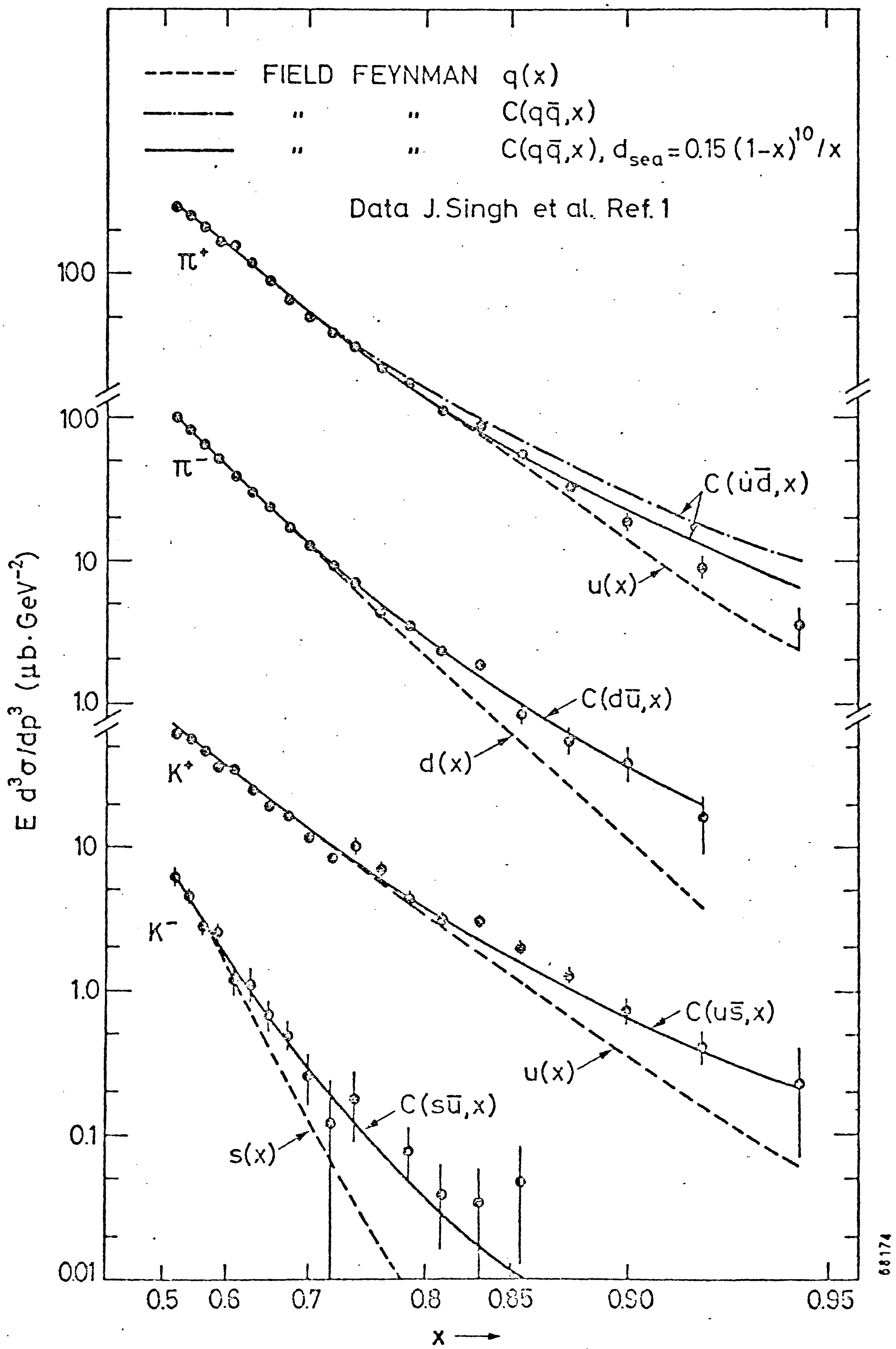
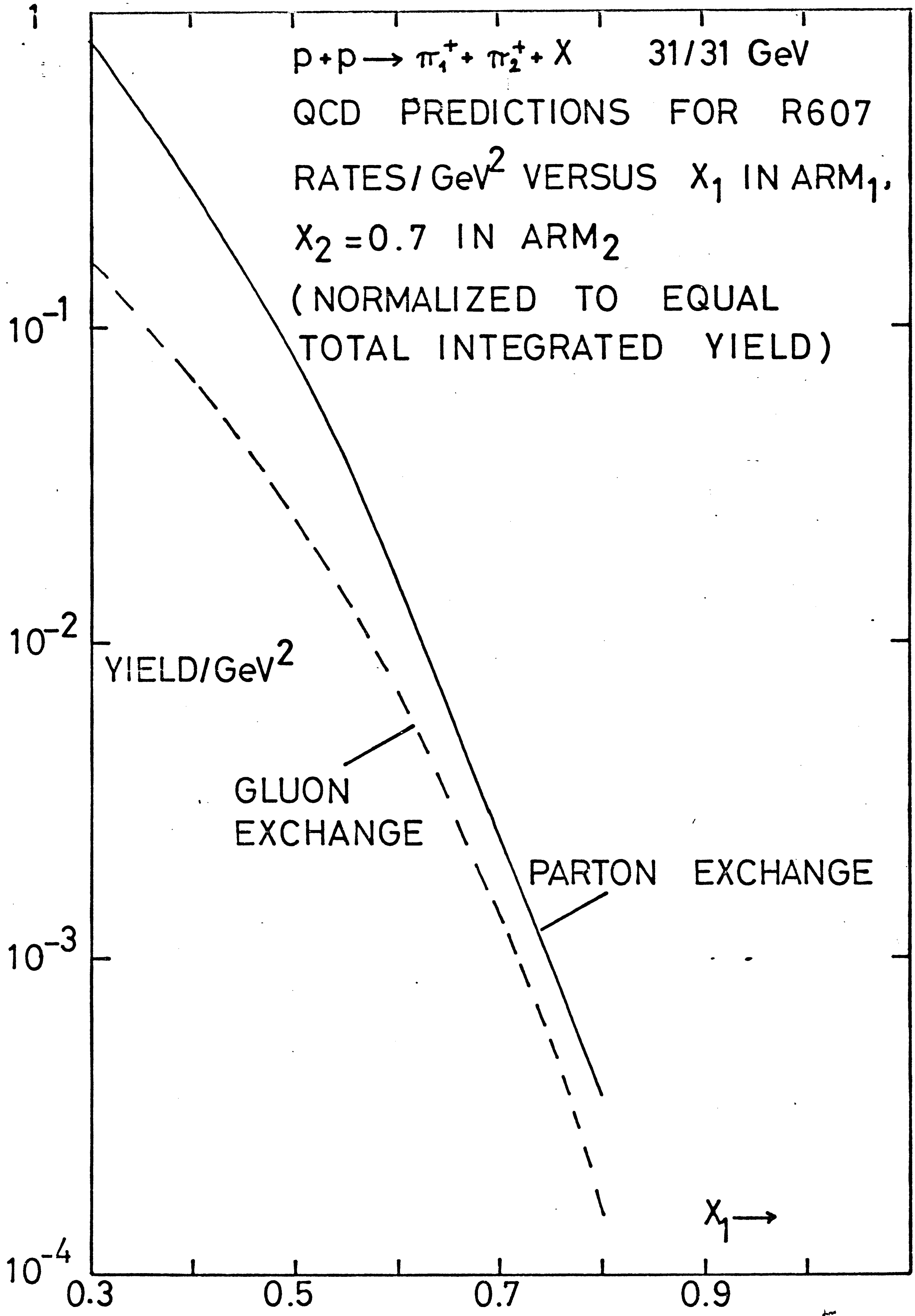

FIELD FEYNMAN q(x)
" " C(qq̄,x)
" " C(qq̄,x), d_sea = 0.15 (1−x)^10 /x
Data J. Singh et al. Ref. 1
π⁺
π⁻
K⁺
K⁻
C(ud̄,x)
u(x)
C(dū,x)
d(x)
C(us̄,x)
u(x)
C(sū,x)
s(x)
E d³σ/dp³ (μb·GeV⁻²)
100
100
10
1.0
10
1.0
0.1
0.01
0.5
0.6
0.7
0.8
0.85
0.90
0.95
x →
68174

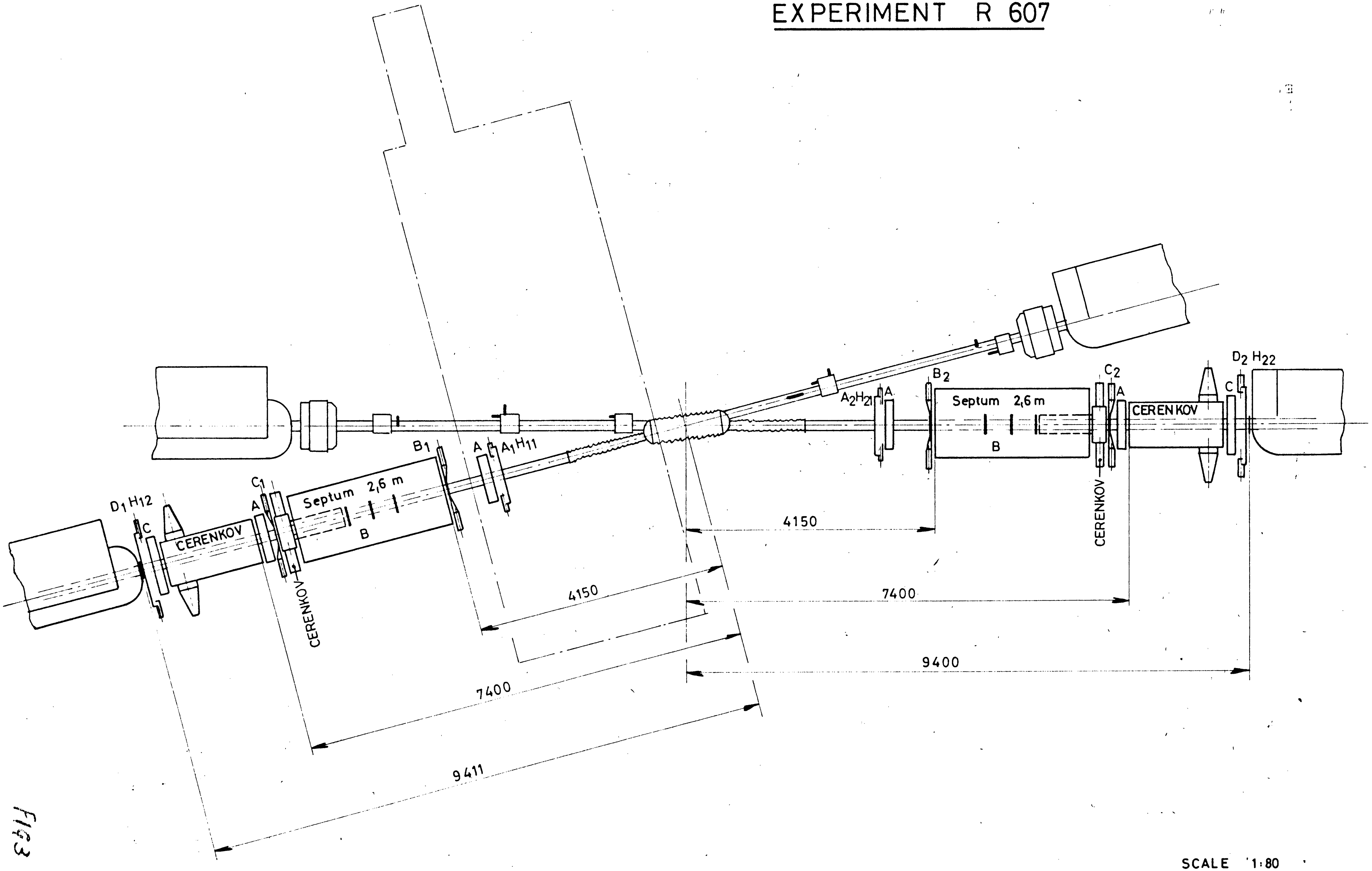
Fig.1



p+p ⟶ π₁⁺ + π₂⁺ + X 31/31 GeV
QCD PREDICTIONS FOR R607
RATES/GeV² VERSUS X₁ IN ARM₁,
X₂ = 0.7 IN ARM₂
(NORMALIZED TO EQUAL TOTAL INTEGRATED YIELD)
YIELD/GeV²
GLUON EXCHANGE
PARTON EXCHANGE
X₁ ⟶
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
0.3
0.5
0.7
0.9

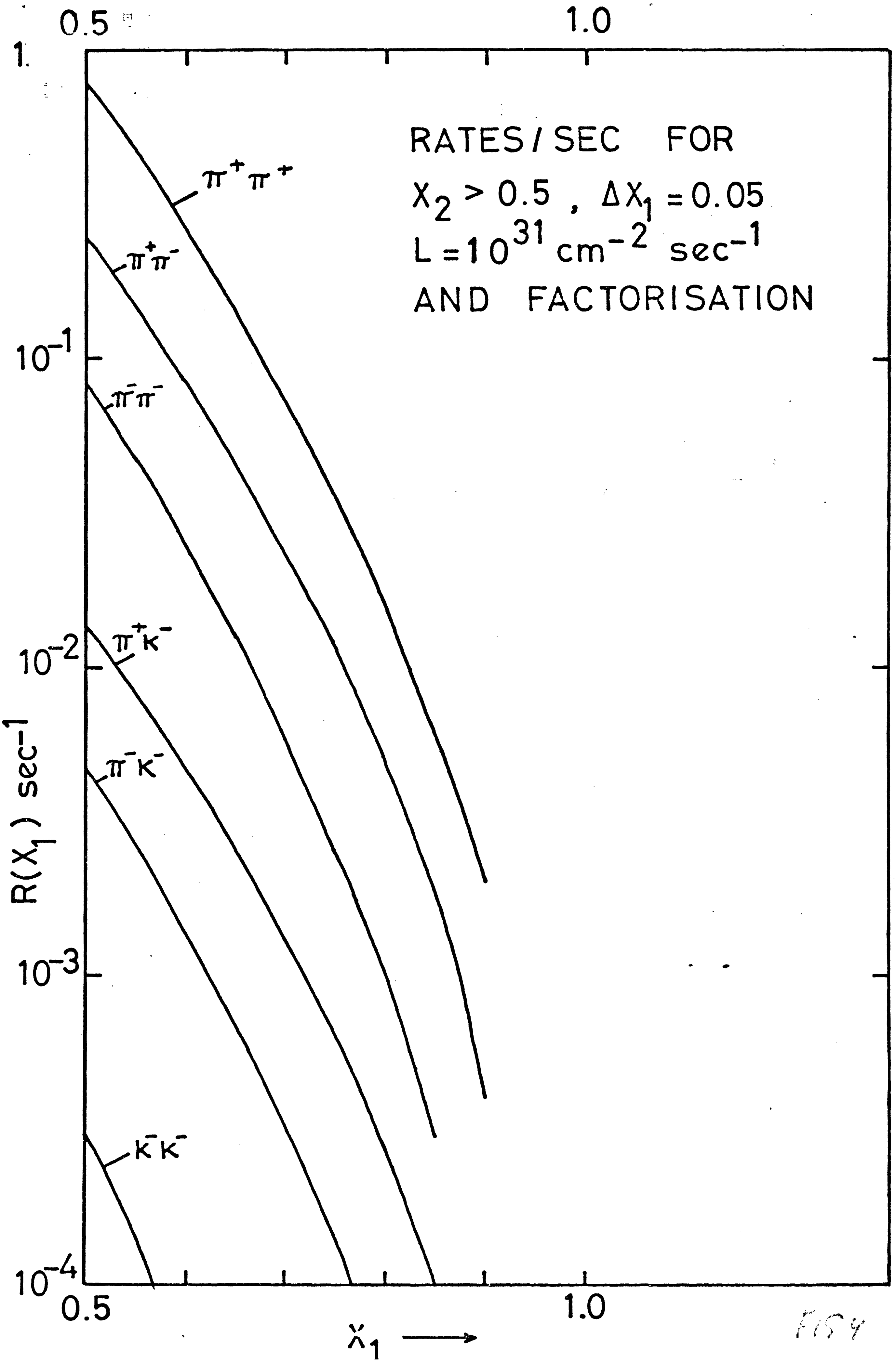
FIG 2

EXPERIMENT R 607



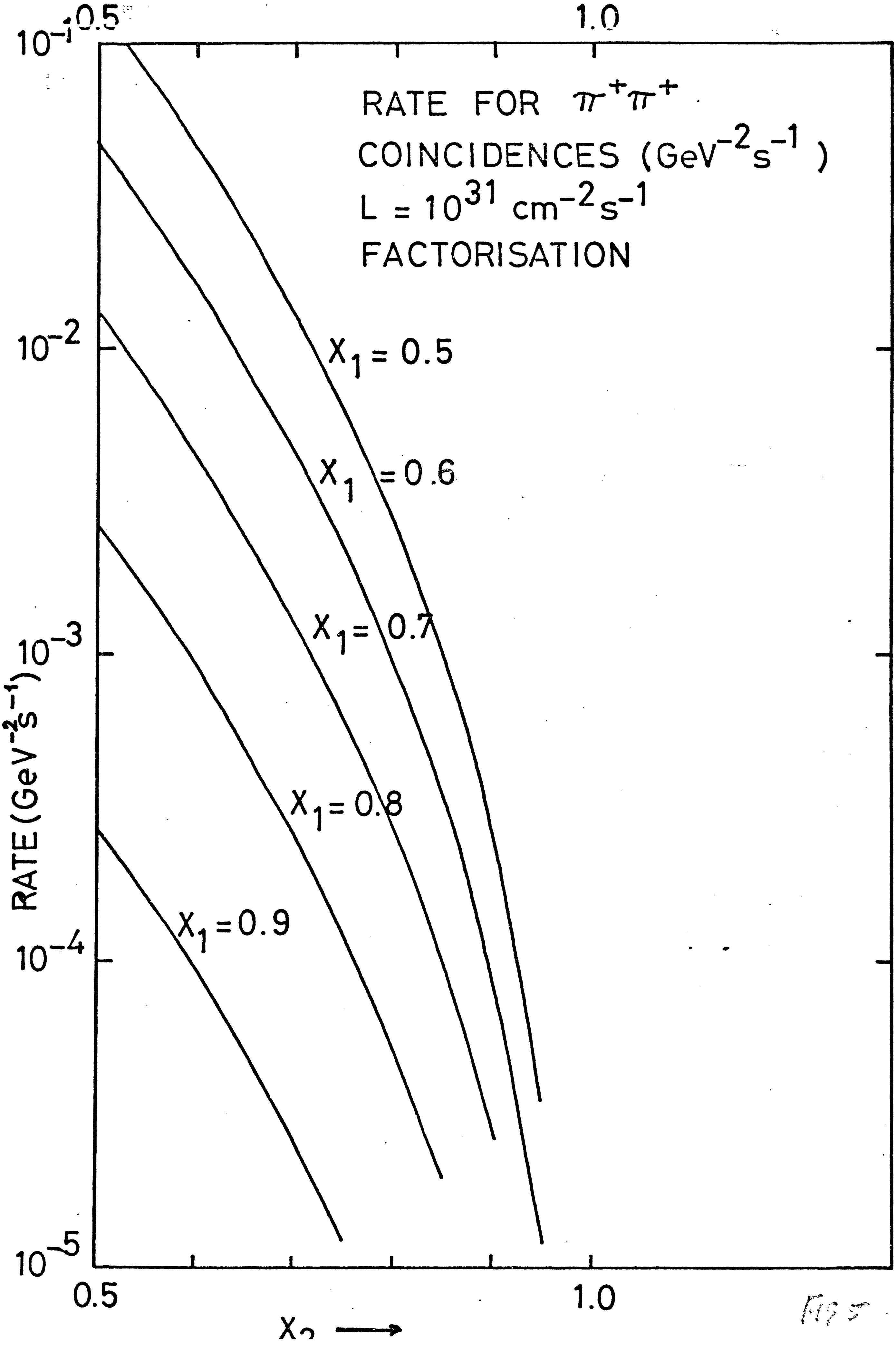
SCALE 1:80

FIG 3



RATES / SEC FOR
X2 > 0.5 , ΔX1 = 0.05
L = 10^31 cm^-2 sec^-1
AND FACTORISATION
π+π+
π+π-
π-π-
π+K-
π-K-
K-K-
0.5
1.0
1.
10^-1
10^-2
10^-3
10^-4
R(X1) sec^-1
X1 →

FIG 4



RATE FOR $\pi^+\pi^+$
COINCIDENCES ($GeV^{-2}s^{-1}$)
$L = 10^{31}$ $cm^{-2}s^{-1}$
FACTORISATION
$X_1 = 0.5$
$X_1 = 0.6$
$X_1 = 0.7$
$X_1 = 0.8$
$X_1 = 0.9$
RATE ($GeV^{-2}s^{-1}$)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.5
1.0
X_2 →

Fig 5

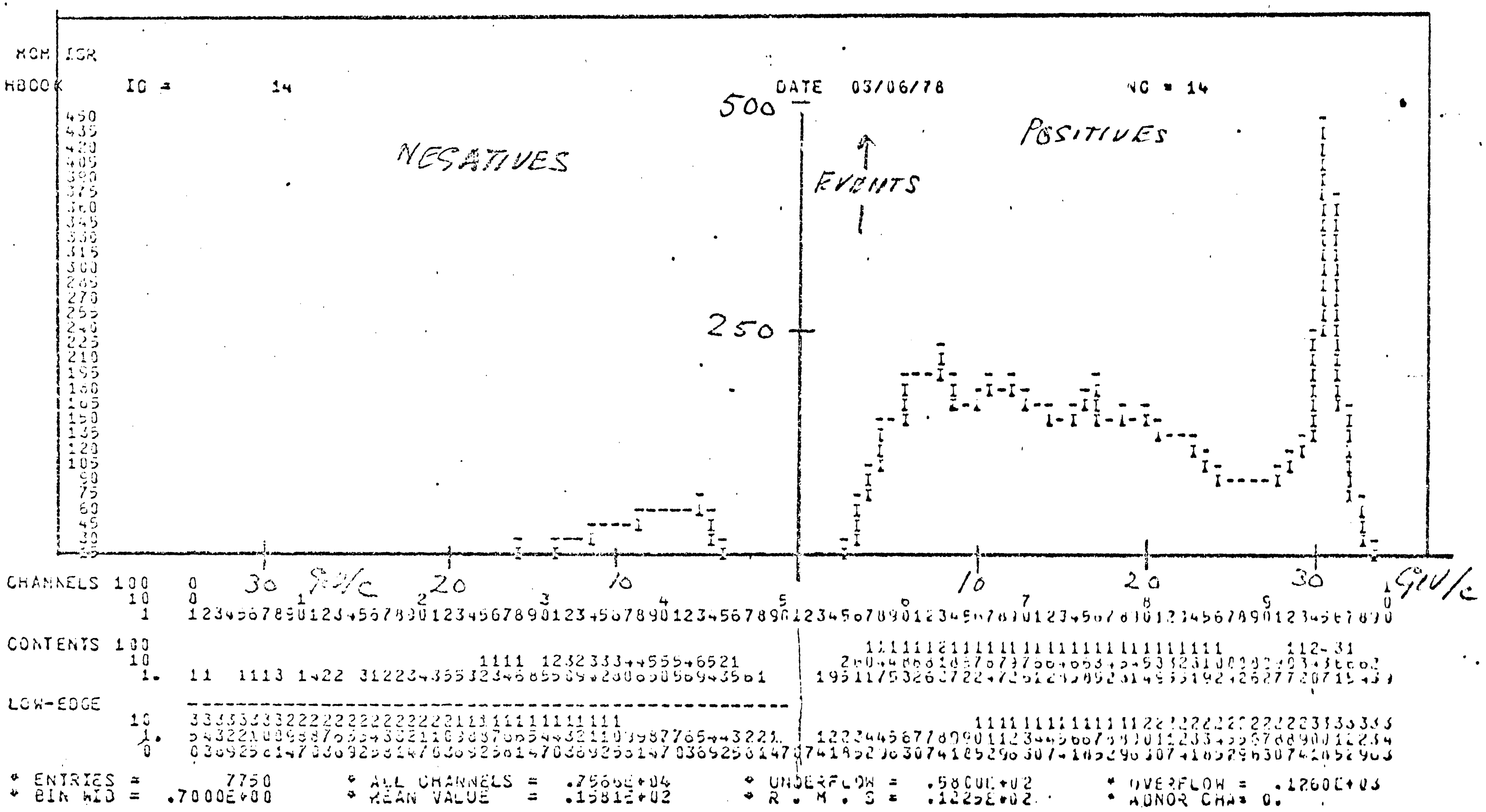

HBOOK
ID = 14
DATE 03/06/78
NO = 14
500
250
NEGATIVES
POSITIVES
EVENTS
GeV/c
CHANNELS
CONTENTS
LOW-EDGE
* ENTRIES = 7750
* BIN WID = .7000E+00
* ALL CHANNELS = .7566E+04
* MEAN VALUE = .1581E+02
* UNDERFLOW = .580UE+02
* R . M . S = .1225E+02
* OVERFLOW = .1260E+03
* ABNOR CHA= 0.

FIG 6