EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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PROPOSAL

To : Members of the EEC

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Subject : Proposal to measure Polarisation in $\bar{p}p \rightarrow \pi^+\pi^-$ in the Momentum Range 1.2 $\rightarrow$ 2.4 GeV/c

1. INTRODUCTION

In the study of non-strange mesons of mass $> 2m_p$ the process $\bar{p}p \rightarrow \pi^+\pi^-$ is of particular interest. From parity and angular momentum conservation it follows that for each state of orbital angular momentum L, the reaction is described by two independent amplitudes. This is similar to meson-nucleon elastic scattering and therefore measurements of the differential cross section $d\sigma/d\Omega(\theta^*)$ and polarisation $P(\theta^*)$ in principle permit an essentially unique phase-shift analysis to be made. Further, Bose statistics require that the isospin of the $\pi\pi$ system is zero for even L, one for odd L. Separation of isospin amplitudes from analysis of $\bar{p}p \rightarrow \pi^0\pi^0$ or $\bar{p}n \rightarrow \pi^-\pi^0$ is therefore not necessary.

In the S99 experiment (beam m11)(1) measurements of $d\sigma/d\Omega(\theta^*)$ are being made for the processes $\bar{p}p \rightarrow \bar{p}p$, $\bar{p}p \rightarrow \pi^+\pi^-$ and $\bar{p}p \rightarrow K^+K^-$. By mid-1972 data will have been taken at about 20 incident $\bar{p}$ momenta in the range 0.7 $\rightarrow$ 2.4 GeV/c. It is proposed to supplement these data with polarisation data at incident momenta between 1.2 and 2.4 GeV/c. This reduced momentum range is chosen for three reasons: it contains the T and U resonances (at 1345 and 1840 MeV/c respectively), the $\bar{p}$ flux is adequate(3), allowing for the smaller volume of the target; and the region below 1.2 GeV/c is being investigated by the Yale group at Brookhaven.

2. EXPERIMENTAL METHOD

The experiment would be set up in the m11 beam line, and will make use of most of the S99 equipment. The spark chambers and trigger counters presently in use will be rearranged round the polarised proton target as in Fig. 1, so as to cover the full angular range with fixed geometry. The resultant acceptance is shown in Fig. 4. The target, to be made by the CERN polarised target group, will consist of a cylinder of butanol, 15 cm long x 3.5 cm diameter. It will be placed in the gap of a C-magnet, to be provided by the Rutherford Laboratory, which will have an azimuthal acceptance of $\pm 22.5^{\circ}$. The beam will be steered onto the target by a Rutherford Laboratory type III bending magnet (total length 60 cm). In addition to the large chambers shown, a small chamber will be placed close to the target, to define the trajectories of emerging particles and thus enable a momentum determination to be made. Veto counters will be placed on the magnet pole-tips to reduce the unwanted trigger rate from annihilations.

The trigger requirement will be $B.L_i.R_j.\overline{V}$, where B indicates an incident antiproton, $L_j.R_j$ a coincidence between a left counter "i" and a right counter "j", and V is a logical OR of all the veto-counters The combinations of i and j which give an output will be chosen to correspond to $\pi\pi$ kinematics.

3. EVENT RATE

The expected rate for the detection of $\bar{p}p \rightarrow \pi^+\pi^-$ events has been calculated from the partial cross section values $\sigma_{\pi\pi}$ given by Nicholson et al.(2). This rate, as a function of momentum, is shown in Table 1. Taking 50 hours as a typical figure for the time required to collect 5000 events, the "good data-taking time" required to run 10 momenta is 500 hours. Allowing for contingencies and background runs, we estimate that this would take 1000 hrs or 6 PS weeks of running.

4. TRIGGER RATE

Since no on-line data reduction is done before writing onto tape, and the dead-time of the large spark-chambers is rather long (15 ms), it is important that the spurious trigger rate be kept as low as possible. The rate has been calculated using as input the results of the CERN-Holland group (4) and also our own experience in

S99. Both calculations show that we can expect less than 8 triggers/burst at 2.4 GeV/c, falling to $\sim$ 2/burst at 1.2 GeV/c.

5. EVENT IDENTIFICATION

(i) Elimination of multipion background.

From S99 we know that without momentum resolution the signal to noise ratio between $\bar{p}p \to \pi^-\pi^+$ and $\bar{p}p \to \pi^-\pi^+(n\pi)$ is 3:1 after making coplanarity and angle-angle cuts. For the events studied so far, a crude momentum measurement of 30% on one particle reduces this background to a negligible level. The field of the polarised target will give a momentum resolution of $\pm$ 10% or better on the backward particle.

(ii) Separation of free hydrogen events.

Since the Fermi momentum of the bound nucleons is typically $\sim$200 MeV/c, most elastic and inelastic scattering off these nucleons will be eliminated by coplanarity cuts. As is well known from studies of elastic scattering, the remaining background will be slightly enhanced underneath the $\bar{p}p \to \pi\pi$ peak in, say, an angle-angle plot. The shape of this background must therefore be measured; this will be done using the non-coplanar events, which in principle have the same distribution as the inelastic coplanar ones. This assumption, which is true for elastic scattering, will be checked at some momenta, using a dummy target containing no free protons.

(iii) Separation of $\pi^-\pi^+$ from K^-K^+.

This will be done on the basis of angle-angle correlation over most of the angular range. For angles near 0^o and 180^o, there is a 20% difference in the momenta of the π and the K (Fig. 2) and the field of the target magnet will provide most of the required resolution. Further rejection of KK events will be achieved with water Čerenkov counters.

6. ARE THE STATISTICS ADEQUATE?

Compared with the latest round of πp elastic scattering experiments the statistics are low. However they compare well with the original πp experiments in which a large number of N^* resonances were found.

We have simulated the analysis using a number of trial forms for $d\sigma/d\Omega$ and P. Writing $d\sigma/d\Omega(\theta^*) = \sum_n a_n P_n (\cos\theta^*)$, $P\, d\sigma/d\Omega(\theta^*) = \sum_n b_n P_n^1 (\cos\theta^*)$, we can deduce values of b_n for a given input. The errors on the coefficients b_n which emerge are of course strongly correlated with the assumed shapes. However, the generalisation which emerges as a satisfactory description of any form is that the smallest coefficient which can be determined as a 3 standard deviation effect is around 7% of the largest coefficient. In this momentum range one expects resonant states up to L = 5 (T region) or L = 6 (U region); this is confirmed by our preliminary analysis of the differential cross sections. Inserting folded angular distributions(2) or guesses with appropriate t and u dependence, the a_{10} or a_{12} coefficients are seen as three standard deviation effect if they are $\geqslant$ 7% of the largest coefficient.

More simply, 2500 events for each sign of polarisation, if distributed isotropically into 20 angular bins, give a statistical standard deviation on each point of 10% (assuming a target polarisation of 65%).

We conclude that the proposed statistics are adequate for a first attack on this mass region, and are unlikely to be improved until beams of higher intensity are available, for example from the 300 GeV machine.

7. COMPUTING

On the basis of the trigger rates discussed in section 4, we estimate that about 200 magnetic tapes (1/2", 7 track) will be written. The main data analysis will be done on the Rutherford and Daresbury computers. Monitoring and preliminary scans of data at CERN will require the equivalent of 90 hours CDC 6600 time.

8. TIMESCALE AND MANPOWER

Our present allocated time for S99 provides 4 PS weeks of data collection in 1972, which takes us to early summer. The magnet and mechanical modifications to S99 could be ready 6 months after approval. We envisage a 3 month period between the end of S99 and our first look at the reaction with the polarised target. We should collect some sample data before the 72-73 winter shutdown. Main running would take place during 1973.

The present S99 experiment involves 11 physicists from the U.K., 1 CERN Fellow, 2 research students and 3 technical staff. The group will be enlarged by the addition of 2 physicists. For the polarisation experiment we plan to have about 9 people resident at CERN and an equal number in the U.K. working mainly on the S99 analysis but available if necessary for periods at CERN.

9. <u>SUMMARY</u>

In order to make possible a phase shift analysis of the reaction $\bar{p}p \rightarrow \pi^+\pi^-$ in the region of incident momenta 1.2 – 2.4 GeV/c, we propose to make asymmetry measurements off a polarised target at 10 momenta in this range. Trial data would be taken at the end of 1972, and we would require 6 weeks of data production after the 72/73 winter shutdown of the PS.

REFERENCES

1. S99 EEC documents : PH I/COM-69/33
PH I/COM-69/48
PH I/COM-71/27

Letter of intent concerning this proposal : PH I/COM-71/50.

2. Nicholson et al., P.R.L. 23, 603 (1969).

3. Kalmus et al., CERN 71-25 (Yellow Report).

4. M.G. Albrow and J.C. Sens, private communication.

FIGURE CAPTIONS

1. Experimental Layout.
2. Kinematics of $\bar{p}p \to \pi^-\pi^+$ and $\bar{p}p \to K^-K^+$ at 1.8 GeV/c.
3. Antiproton yields in CERN m11 beam.
4. Monte Carlo acceptance curve 1.8 GeV/c $\bar{p}p \to \pi^-\pi^+$.

TABLE 1

CALCULATED EVENT RATE FOR $\bar{p}p \to \pi\pi$

Values of $\sigma_{\pi\pi}$ taken from reference 1.
Beam rates calculated from reference 3; see Fig. 3. $\Delta p/p = \pm 2°$
To obtain the quoted beam rates, it will be necessary to converge the beam in the final triplet more strongly than in S99, and place the polarised target closer to the triplet than the liquid hydrogen target is at present. It is estimated that half the flux can be focussed onto a 3 cm diameter circle at 1.2 GeV/c, and all of it at 2.4 GeV/c.

Incident momentum (GeV/c)	Focussed beam rate (per pulse)	$\sigma_{\pi\pi}$(μb)	events/hour
1.2	0.5×10^4	220	110
1.5	1.4×10^4	130	170
1.8	2.2×10^4	65	120
2.1	2.6×10^4	45	100
2.4	3.0×10^4	30	80

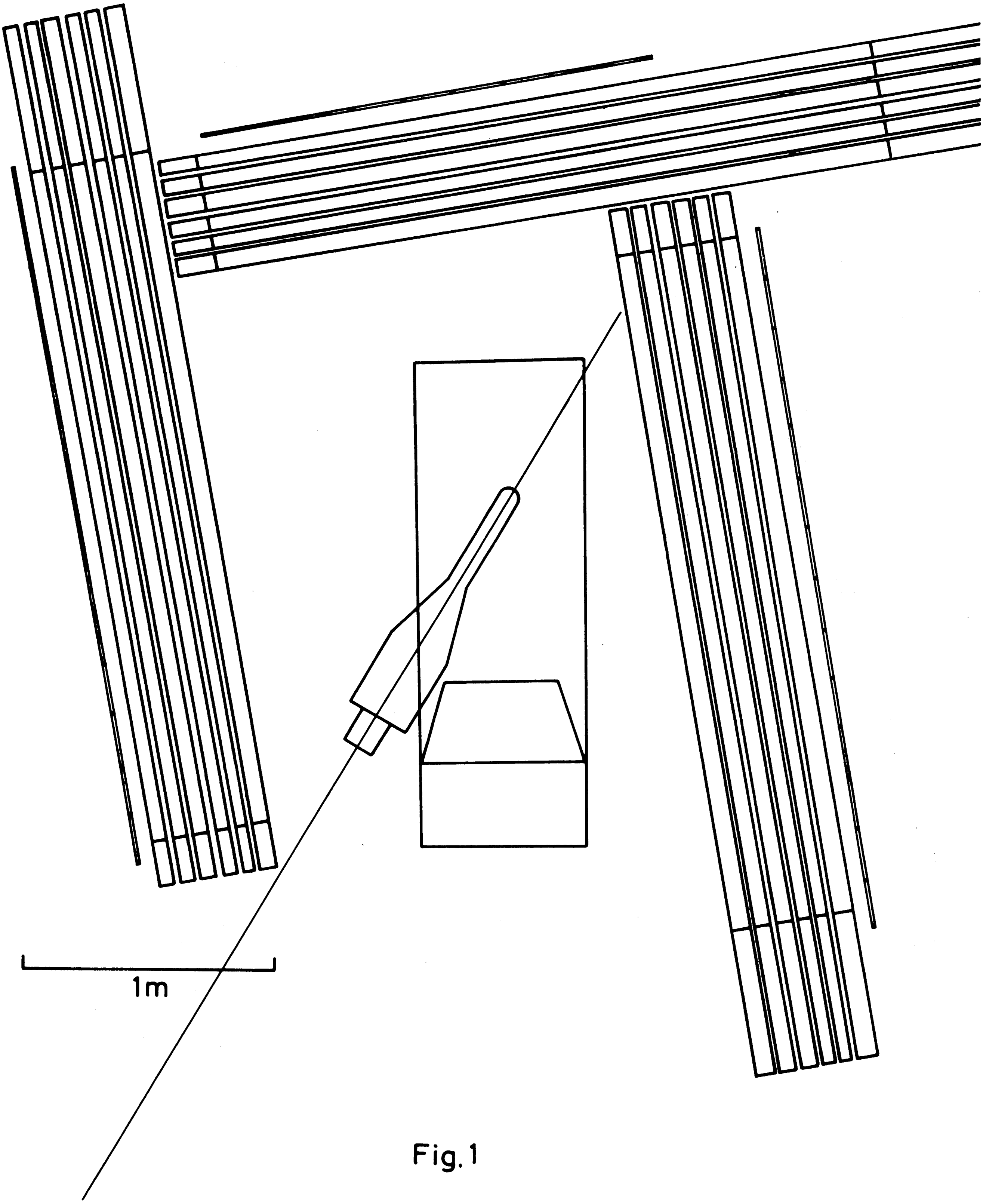


Fig. 1

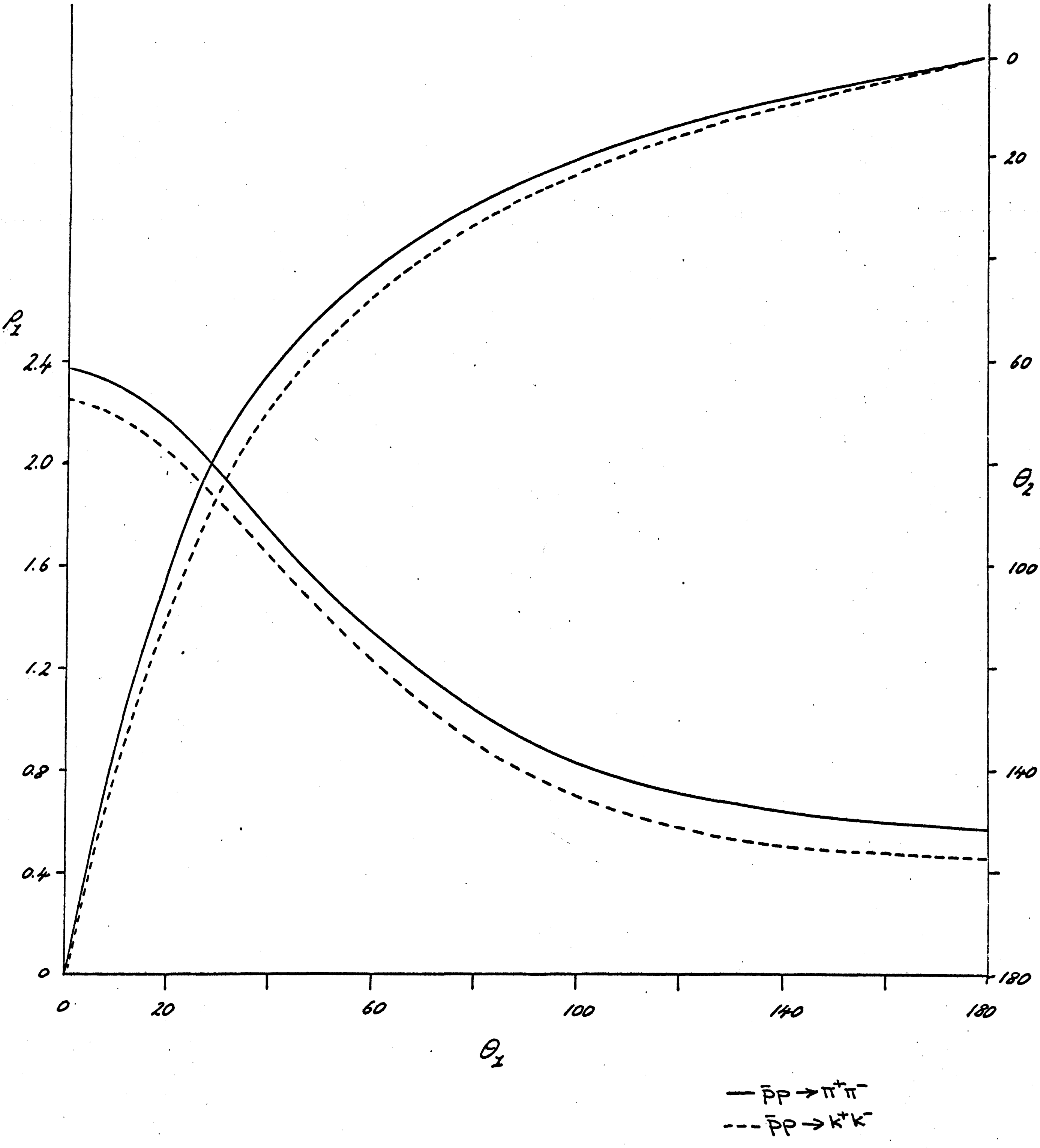

ρ_1
2.4
2.0
1.6
1.2
0.8
0.4
0
0
20
60
100
140
180
θ_1
0
20
60
θ_2
100
140
180
$\bar{p}p \to \pi^+\pi^-$
$\bar{p}p \to K^+K^-$

FIGURE 2.

FIG. 3.

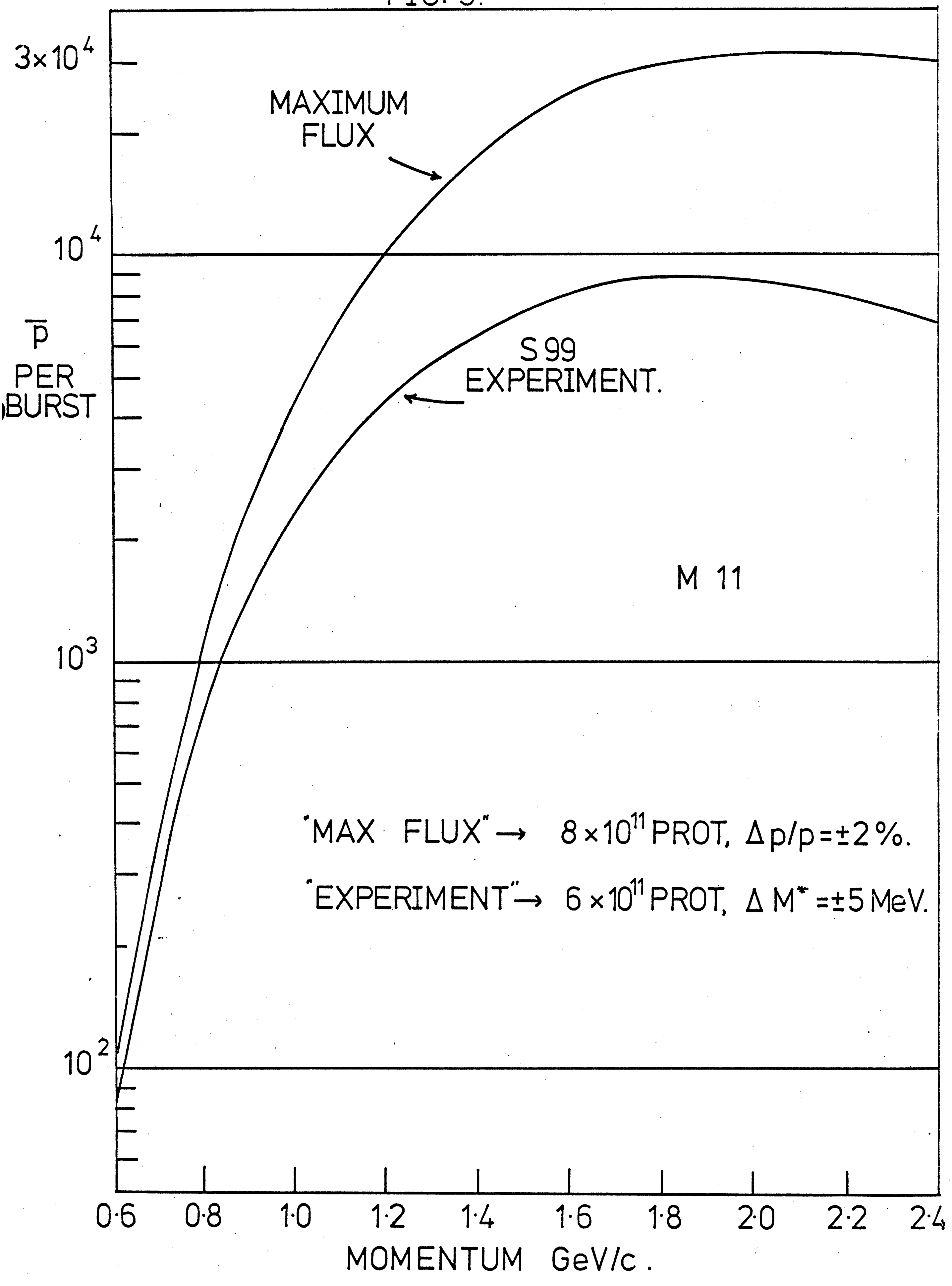
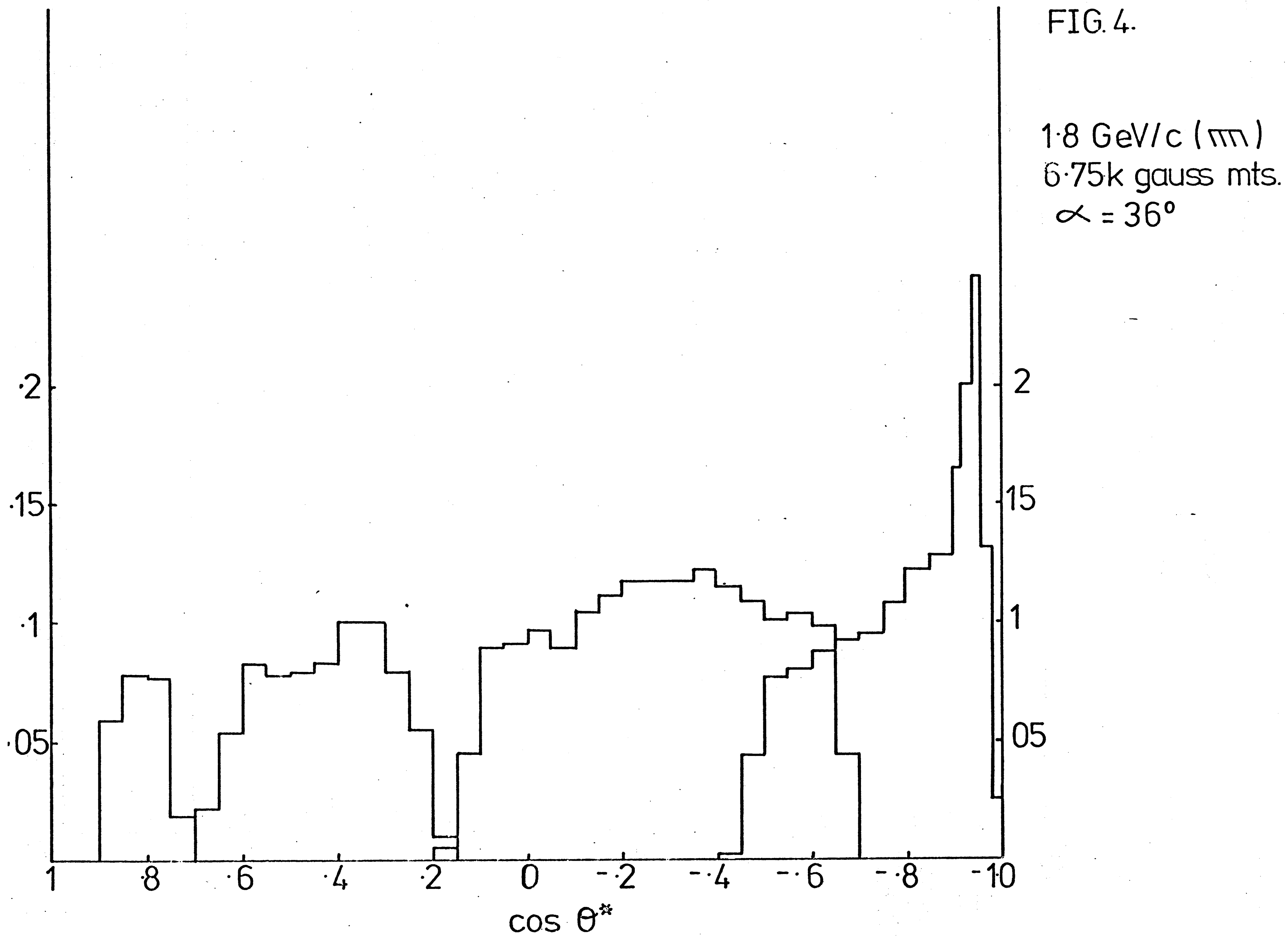

3×10^4
10^4
10^3
10^2
p̄
PER
BURST
MAXIMUM
FLUX
S 99
EXPERIMENT.
M 11
"MAX FLUX" → 8×10^11 PROT, Δp/p=±2%.
"EXPERIMENT" → 6×10^11 PROT, ΔM* =±5 MeV.
0·6
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
MOMENTUM GeV/c.

FIG. 4.


1·8 GeV/c (πn)
6·75k gauss mts.
α = 36°
·2
·15
·1
·05
2
15
1
05
1
·8
·6
·4
·2
0
-·2
-·4
-·6
-·8
-1·0
cos θ*