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Measurement of N* Production in p + p → p + N* between 9 and 300 GeV/c*

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ABSTRACT

We have measured the missing-mass spectrum of p + p → p + MM in the region 1.5 ≤ MM < 7.0 GeV using the acceleration ramp of the NAL machine between 9 and 300 GeV/c and the H_2 jet target. We observe strong N*(1690) and N*(2190) production and are continuing our search for heavier mass resonances.

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We present preliminary results from a nucleon isobar search currently under way at the National Accelerator Laboratory. We are searching for N* resonances in the mass range from 1.5 to 7.0 GeV using the internal hydrogen jet target[1] during the acceleration ramp of the NAL machine. Recoil protons from the reaction

$$p + p \rightarrow p + N^* \tag{1}$$

are detected in a counter-range telescope at a fixed angle near the Jacobian peak. The mass squared of the N* is given by

$$M^2 = (E_1+m-E_3)^2 - p_1^2 - p_3^2 + 2p_1p_3 \cos \theta_3 \tag{2}$$

where m is the proton mass. The dependence of M^2 on the incident momentum p_1 and the recoil momentum p_3 is illustrated in Fig. 1 in which we plot loci of constant M^2 at fixed recoil angle $\theta_3 = 64.4^\circ$. The minima $\partial M^2/\partial p_3 = 0$ (Jacobian peaks) for all M^2 shown occur near $p_3 \simeq 0.43$ GeV/c, i.e., the recoil momentum corresponding to the Jacobian peak is almost independent of the incident momentum over the range $9 < p_1 < 300$ GeV/c. By selecting recoil protons of <u>fixed</u> momentum at a <u>fixed</u> angle the existence of a discrete mass will manifest itself as a peak in the counting rate as a function of the increasing incident proton momentum[2].

Since the mass resolution at the Jacobian peak is insensitive to the resolution in p_3 we select a fairly broad band of recoil momenta as illustrated by the dotted lines in Fig. 1. The incident momentum binning is chosen sufficiently fine (0.2 GeV/c) so that its contribution to the mass resolution is small compared to that of the recoil angle measurement which almost solely determines the mass resolution. Our mass resolution, calculated by a Monte Carlo program, is ±10 MeV at M = 1.5 GeV and ±50 MeV at M = 7.0 GeV.

The experimental set-up is shown in Fig. 2. The hydrogen jet target is essentially a vertical cylinder of approximately 10 mm diameter with a density of $\sim 2 \times 10^{-7}$ g/cm^3. Recoil protons from reaction (1) exit the main accelerator beam pipe through a 3 mil titanium window and are detected in a counter-range telescope. The recoil proton momentum bite is selected by two Al absorbers 1 and 2, the trigger being $C_1C_2C_3C_4C_5\overline{C}_6$. For each proton event, the recoil angle θ_3 is measured by one of three finger counters A, B and C, each 0.25 in. wide, which are located between C_3 and C_4. By taking data at three slightly different angles simultaneously, it is hoped that instrumental effects will be removed. Protons going through the telescope are separated from pions by range, time of flight between C_1 and C_4 and pulse height in C_1 through C_5.

We normalize our proton rates to one of three independent luminosity monitors: 1) Fast charged particles passing through the main spectrometer are selected by means of a third absorber (see Fig. 2) and the trigger logic $C_1C_2C_3C_4C_5C_6C_7$. We estimate that 80% of the particles selected by this trigger are pions. 2) A "backward monitor" at 70° to the beam consisting of four scintillation counters timed for fast particles also measures mostly pions. 3) A solid state detector[3] at 86° measures elastically scattered protons.

In Fig. 3 we show the missing mass spectrum from M = ∿1.5 to ∿4.1 GeV corresponding to a 1 sec jet pulsed from p_1 = 9 to 90 GeV/c. The data have been normalized to fast particles (monitor (1) described above). Normalizations to the backward monitor or elastic monitor give essentially identical spectra. No corrections other than normalization have been applied, thus Fig. 3 represents our raw data. Even though our analysis is in a preliminary stage, we observe the well known structures at M = 1690 and 2190 MeV. The 1690 bump is particularly useful in understanding our mass calibration and resolution. At this stage of the experiment we do not observe any structure comparable to the N*(1690) or N*(2190) in the higher mass region. We are currently improving our statistics and refining our analysis so that we will be sensitive to much smaller structures.

We are grateful to the USSR-USA collaboration, in particular B. Morozov, S. Olsen and Y. Pilipenko, and the members of the Internal Target Laboratory for providing the H_2 jet target facility and elastic monitor. We also wish to thank D. Jovanovich, J. Sanford and the Accelerator Section for their help and cooperation. The advice and contributions of I. Siotis are warmly acknowledged.

References

1. V. Bartenev et al., Advances in Cryogenic Engineering **18**, (1973).

2. F. Sannes and W. C. Harrison, Nucl. Instr. and Meth. **105**, 541 (1972).

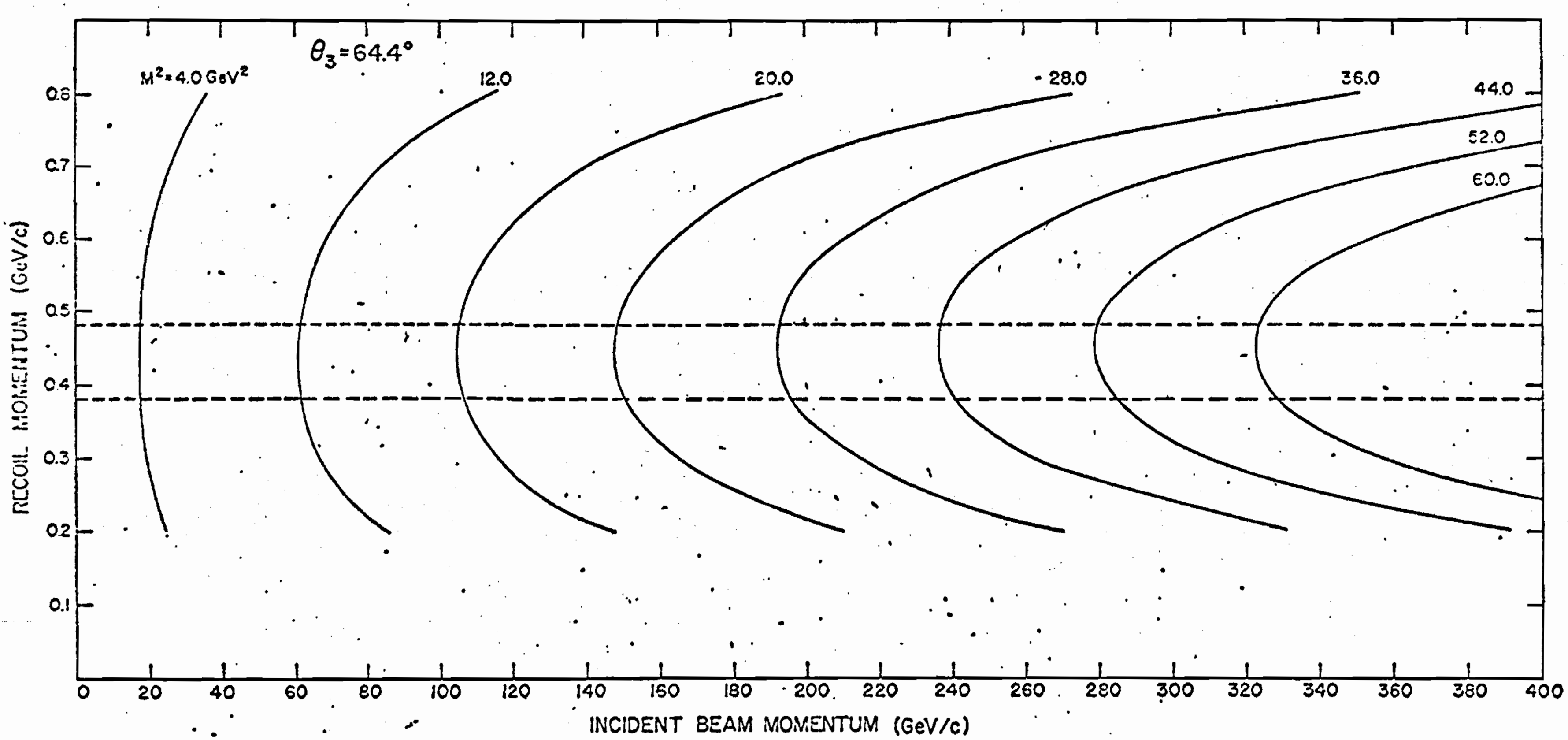
3. The elastic monitor was provided by the USA-USSR collaboration at NAL, authors of Ref. 1.

Figure Captions

Fig. 1 Lines of constant N* masses squared in the reaction $pp \to pN^*$ at fixed recoil proton angle of 64.4° as a function of recoil proton momentum and incident proton momentum.

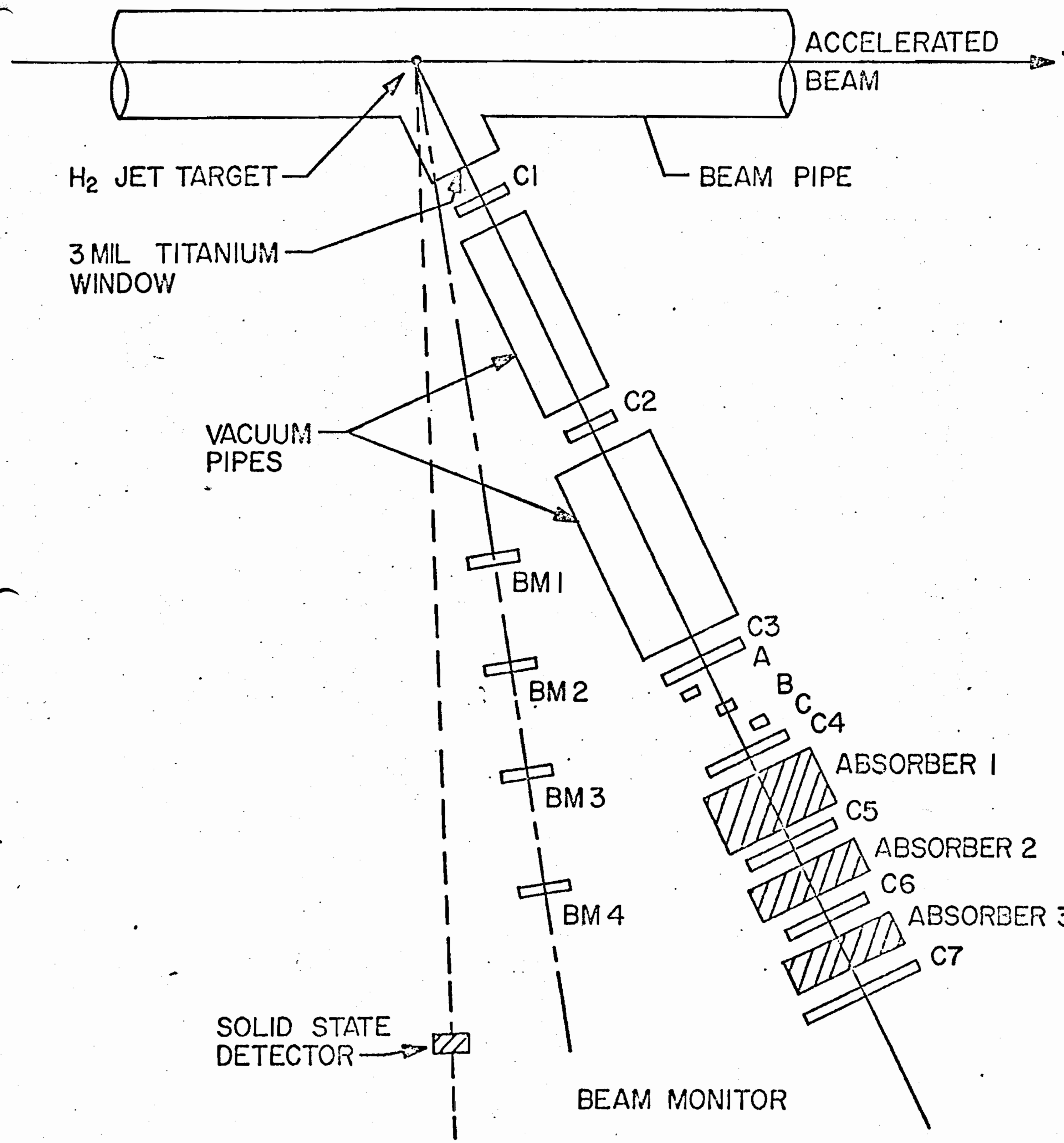
Fig. 2 Experimental set-up inside NAL main ring. The defining counter C_4 is 2.5 m from the target and subtends $\sim 5 \times 10^{-4}$ sr. The hodoscope elements A, B and C are 0.6 cm wide by 10.0 cm high.

Fig. 3 Our raw missing mass spectrum taken with a 1 sec. long jet during acceleration of the incident proton beam from 9 to 90 GeV/c. The proton rate has been normalized to fast particles in the same spectrometer in which the slow protons are measured (see text).



θ3=64.4°
M²=4.0 GeV²
12.0
20.0
28.0
36.0
44.0
52.0
60.0
RECOIL MOMENTUM (GeV/c)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
INCIDENT BEAM MOMENTUM (GeV/c)

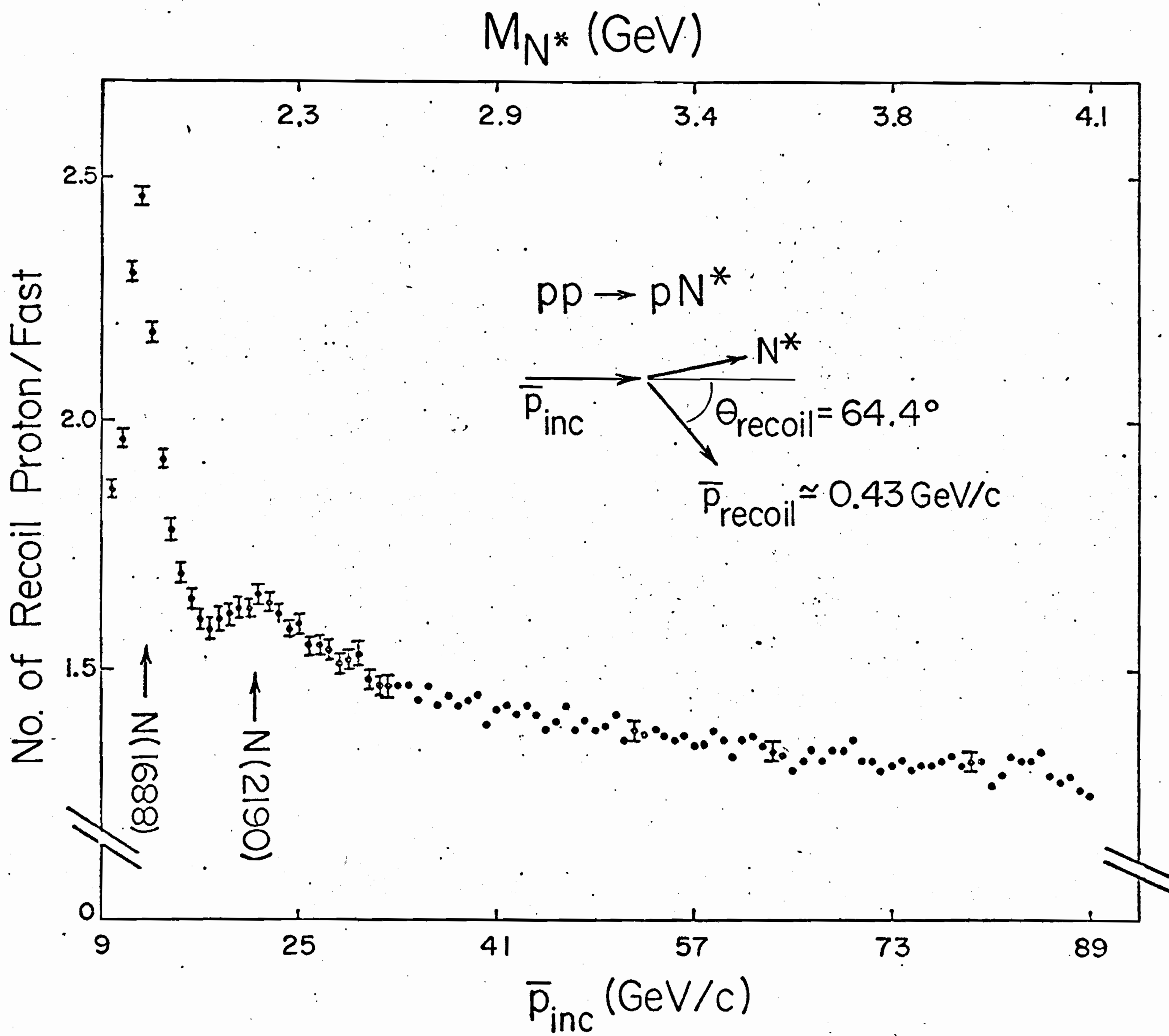
Fig. 1



EXPERIMENTAL APPARATUS

(NOT TO SCALE)

Fig. 2



M_N* (GeV)
2.3
2.9
3.4
3.8
4.1
2.5
2.0
1.5
0
No. of Recoil Proton/Fast
pp → pN*
N*
p_inc
θ_recoil = 64.4°
p_recoil ≃ 0.43 GeV/c
N(1688)
N(2190)
9
25
41
57
73
89
p_inc (GeV/c)

Fig. 3