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SPECTRUM OF CHARGED NON-STRANGE BOSONS IN THE MASS REGION 2.5 - 3.0 GeV

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1. INTRODUCTION

We have explored the mass spectrum of charged non-strange bosons X^- in the mass region $2.5 < M_X < 3.0$ GeV, produced in the reaction $\pi^- p \to p X^-$ with the CERN Boson Spectrometer (CBS). Mass spectra at various incident momenta $8 < p_1 < 10$ GeV/c were obtained by measuring the missing-mass of the forward recoil protons. The spectrum shows three significant peaks at masses of 2.62, 2.80, and 2.88 GeV.

2. METHOD

In the reaction $\pi^- p \to pX^-$, the mass M_X of the X^- is given by $M_X^2 = (E_1 + m_p - E_3)^2 - p_1^2 - p_3^2 + 2p_1p_3 \cos\theta_{13}$, where subscripts 1 and 3 refer to the incident pion and the recoil proton, respectively.

The CBS measures p_3 for protons emitted near $\theta_{13} = 0^\circ$, with momenta $0.4 < p_3 < 1.0$ GeV/c, i.e. X^- is produced at minimum momentum transfer. By choosing the appropriate p_1, selected mass regions can be investigated. The momentum p_3 of the proton is measured with a magnetic spectrometer consisting of pairs of wide-gap wire chambers placed before and after a wide-gap magnet and, in addition, by a time-of-flight (TOF) system. The chambers before the magnet also allow one to calculate the interaction point and correct the measured p_3 for energy loss in the H_2 target. The measurement of p_1 is made using the beam magnets and a set of three scintillation hodoscopes. A more detailed description of the system can be found elsewhere[1].

The mass resolution Γ_{exp} for the magnetic measurement is nearly mass independent and amounts to $\Gamma_{exp} = 20$ MeV (FWHM) for the present mass interval. The TOF measurement gives a mass resolution varying from $\Gamma_{exp} = 16$ MeV at the lower end of the spectrum to $\Gamma_{exp} = 24$ MeV at the upper end. The absolute mass scale is known to within $\Delta M_X = \pm 15$ MeV.

3. RESULTS

In order to demonstrate the over-all appearance of the mass spectrum, as directly obtained with the CBS, we shown in Fig. 1a the result of our latest run at $p_1 = 8.9$ GeV/c. M_X is measured by magnetic deflection of the proton. The main features of the spectrum are two enhancements near $M_X = 2.8$ GeV, and $M_X = 2.6$ GeV.

In Fig. 1b we have subtracted a hand-drawn smooth background. This is justified because the acceptance of the spectrometer is a smoothly rising function that cannot produce artificial peaks (Fig. 1c). The better geometrical acceptance at high masses is the reason why the 2.8 enhancement appears stronger than the 2.6 peak.

Additional runs have been made at p_1 = 9.1, 9.5, and 10.2 GeV/c. Since in the last two runs the 2.6 GeV mass region is outside the full efficiency, the two enhancements will be treated separately.

3.1 The 2.8 GeV region

We have compiled the evidence for structure in the 2.8 GeV region in Fig. 2. Figures 2a and 2b contain the sum of the p_1 = 8.9 GeV/c and the 9.1 GeV/c data. In Fig. 2c, also the 9.5 GeV/c and 10.2 GeV/c data are added.

Figures 2a and 2b illustrate the similarity of the spectrum, whether M_X is derived from the TOF or from the magnetic measurement. A shift in the binning by 5 MeV with respect to Fig. 1 does not alter the structure. If the structure were due to a bias in the p_3 measurement, the shift from p_1 = 8.9 GeV/c to 9.1 GeV/c would shift the spectrum by 35 MeV, and adding two samples of almost equal statistics would therefore erase any narrow structure.

Adding the data obtained at 9.5 GeV/c and 10.2 GeV/c in Fig. 2c would wash out even a broad structure. Instead, the enhancement becomes stronger, in the proportion to be expected from the statistics.

In the total sample, the 2.8 GeV enhancement consists of two peaks, one at M_X = 2.80 GeV ($\Gamma \approx$ 45 MeV), the second at M_X = 2.88 GeV ($\Gamma \approx \Gamma_{exp}$). The statistical significance is about 8 standard deviations for the lower peak and about 4.5 standard deviations for the upper, for the background line drawn in Fig. 2c. An estimate of the total cross-section gives σ_t = 14 μb for the lower peak and σ_t = 4 μb for the upper, assuming a $|t|$ dependence of $e^{-8|t|}$. This estimate could, however, be wrong by a factor of 2.

3.2 The 2.6 GeV region

Figure 3 shows the 2.6 GeV enhancement as it appears in the sum of the p_1 = 8.9 GeV/c and the 9.1 GeV/c data. In Fig. 3a the spectrum is derived from the TOF measurement, and in Fig. 3b from the magnetic measurement. In both figures the spectra have been corrected for the geometrical acceptance (Fig. 1c) in order to have a flatter background shape where it is easier to judge the significance of the enhancement. The structure is nearly equal in both spectra and is clearly significant (> 8 st. dev.). The mass and width of the peak are M_X = 2.62 GeV and $\Gamma \simeq$ 80 MeV. In addition, we show in Fig. 3c an uncorrected spectrum obtained by requiring that the c.m. angle θ^* of the proton > 178°. In this case the acceptance is flat down to the centre of the peak, and drops by less than 5% at its lower edge. The same over-all shape of the peak is apparent.

An indication that this enhancement may contain more than one peak can be seen in Fig. 3c, where the resolution, due to the angular cut, is somewhat better than in the other samples. However, this structure cannot be proved with the present data, since its significance is at best 3 standard deviations.

4. SUMMARY AND CONCLUSIONS

In conclusion, our present boson mass spectra in the 2.5-3.0 GeV region show evidence for three resonances at masses M_X = 2.62, 2.80, and 2.88 GeV. Detailed parameters are compiled in the table. A structure is indicated in the broadest peak (2.62 GeV); however, no definite conclusions can be drawn at present.

It is interesting to note that a straight line extrapolation of the $\rho - A_2 - R - S - T - U$ trajectory[2] passes through the mass values M_X = 2.62 ($\pm$0.02) GeV and 2.82 ($\pm$0.02) GeV. A broad peak at 2.8 GeV is also indicated in bubble chamber data from $\bar{p}p$ annihilations[3].

Acknowledgements

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Name	Mass (GeV)	Width (GeV)	Statistical significance st. dev.	Events in peak	Signal to background ratio	$\|t\|$ $(GeV/c)^2$	$d\sigma/d\|t\|$ *) $[\mu b/(GeV/c)^2]$	Estimated*) σ_{tot} (μb)
$X^-(2.6)$	2.62 ± 0.02	0.085 ± 0.03	8	550 ± 70	1 : 6	0.29	135	17
$X^-(2.8)$	2.80 ± 0.02	0.046 ± 0.010	8	640 ± 80	1 : 8	0.46	110	14
$X^-(2.9)$	2.88 ± 0.02	< 0.015	4.5	230 ± 50	1 : 8	0.46	30	4

*) These values are estimated and could be wrong by a factor of 2.
The last three columns refer to the 8.9 GeV/c data.

REFERENCES

1) Confirmation of the two peak structure in the A_2 meson in $\pi^- p$ at 2.6 GeV/c, H. Benz, G.E. Chikovani, G. Damgaard, M.N. Focacci, W. Kienzle, C. Lechanoine, M. Martin, C. Nef, P. Schübelin, R. Baud, B. Bošnjaković, J. Cotteron, R. Klanner and A. Weitsch, Phys. Letters 28 B, 233 (1968).

2) M.N. Focacci, W. Kienzle, B. Levrat, B.C. Maglić, M. Martin, Phys. Rev. Letters 17, 890 (1966).

3) B. French, Proc. Int. Conf. on High-Energy Physics, Vienna (1968) (CERN, Geneva, 1968), p. 91.

Figure captions

Fig. 1 : a) Example of over-all missing-mass spectrum in $\pi^- p \to X^- p$ at 8.9 GeV/c with M_X measured by magnetic deflection.

b) Same data, but with the hand-drawn background subtracted.

c) The mass-dependent acceptance of the spectrometer.

Fig. 2 : Evidence for structure in the 2.8 GeV region:

a) Sum of all 8.9 and 9.1 GeV/c data with missing mass measured by time-of-flight.

b) Same data, but with M_X measured by magnetic deflection.

c) Sum of data at 8.9, 9.1, 9.5 and 10.2 GeV/c (magnetic measurement).

Fig. 3 : Evidence for the 2.6 GeV enhancement:

a) Sum of 8.9 and 9.1 GeV/c data corrected for the acceptance of the spectrometer, with missing-mass measured by time-of-flight.

b) Same data, but with M_X measured by magnetic deflection.

c) Subsample of (a) with a centre-of-mass angular cut $\theta^* > 178°$ (no correction).

EXAMPLE OF OVER- ALL MASS SPECTRUM (p_1 = 8.9 GeV/c)

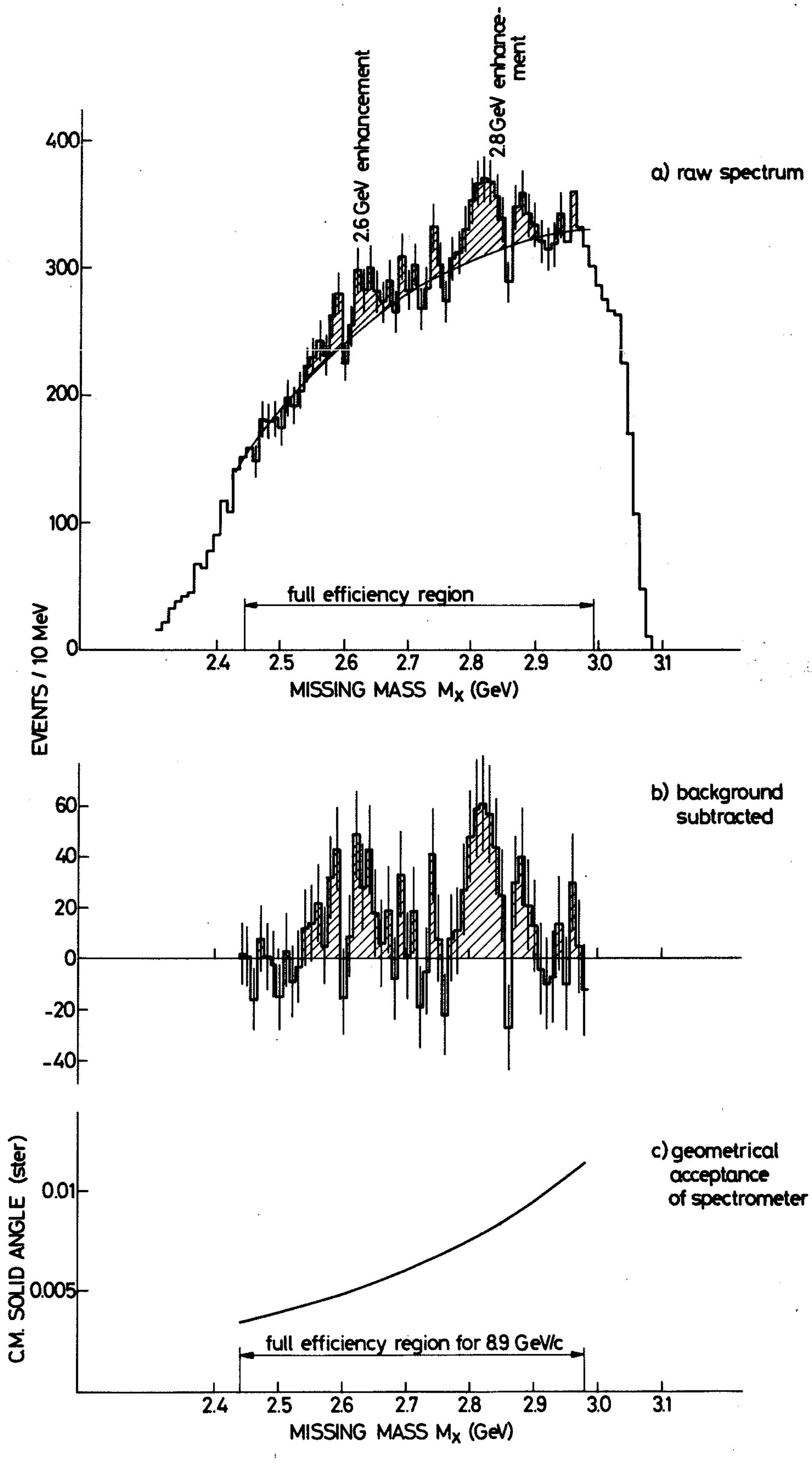

Fig. 1

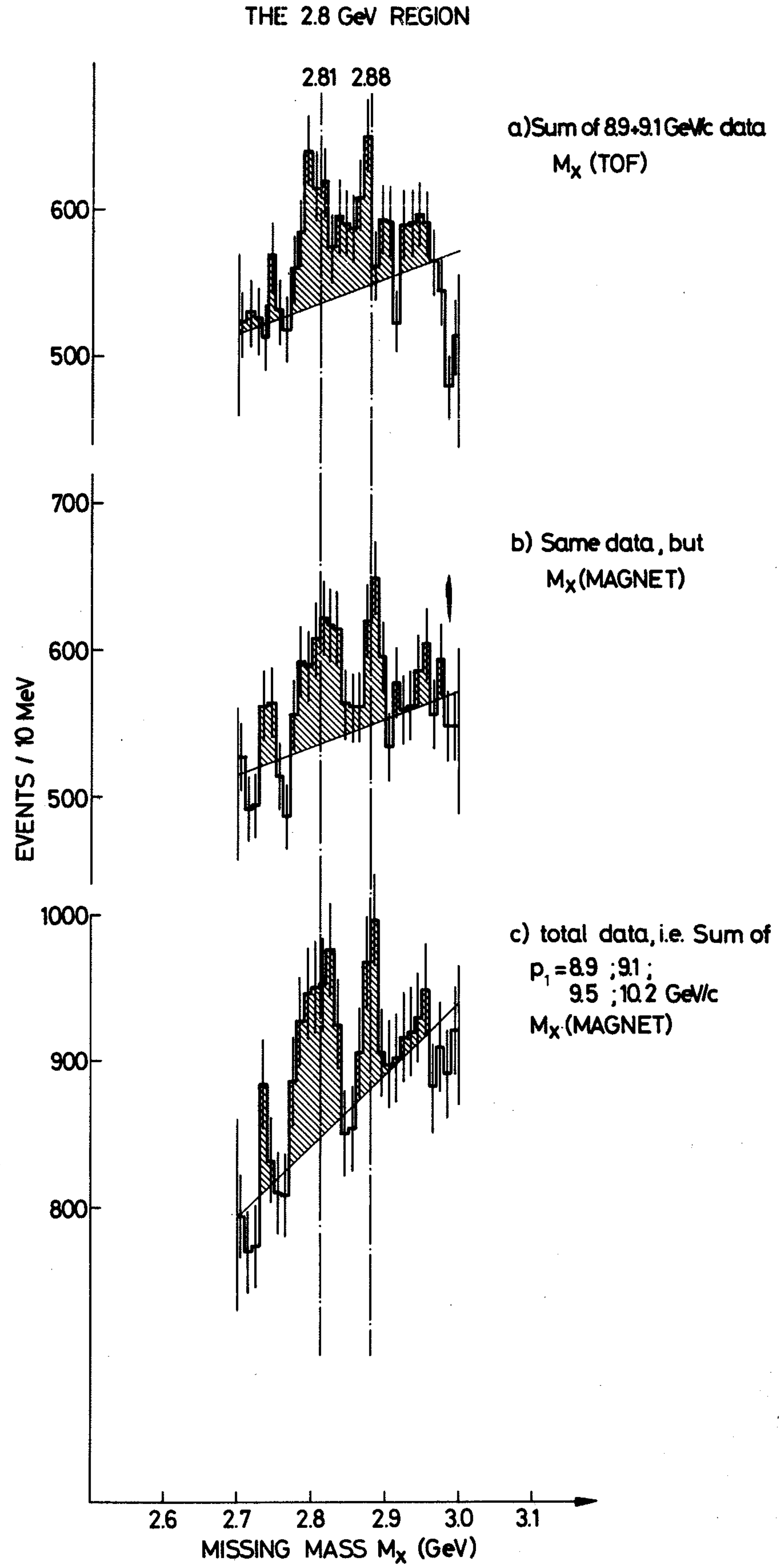
THE 2.8 GeV REGION
2.81 2.88
a) Sum of 8.9+9.1 GeV/c data
M_X (TOF)
b) Same data, but
M_X (MAGNET)
c) total data, i.e. Sum of
p_1 = 8.9 ; 9.1 ;
9.5 ; 10.2 GeV/c
M_X (MAGNET)
EVENTS / 10 MeV
600
500
700
600
500
1000
900
800
2.6
2.7
2.8
2.9
3.0
3.1
MISSING MASS M_X (GeV)

Fig. 2

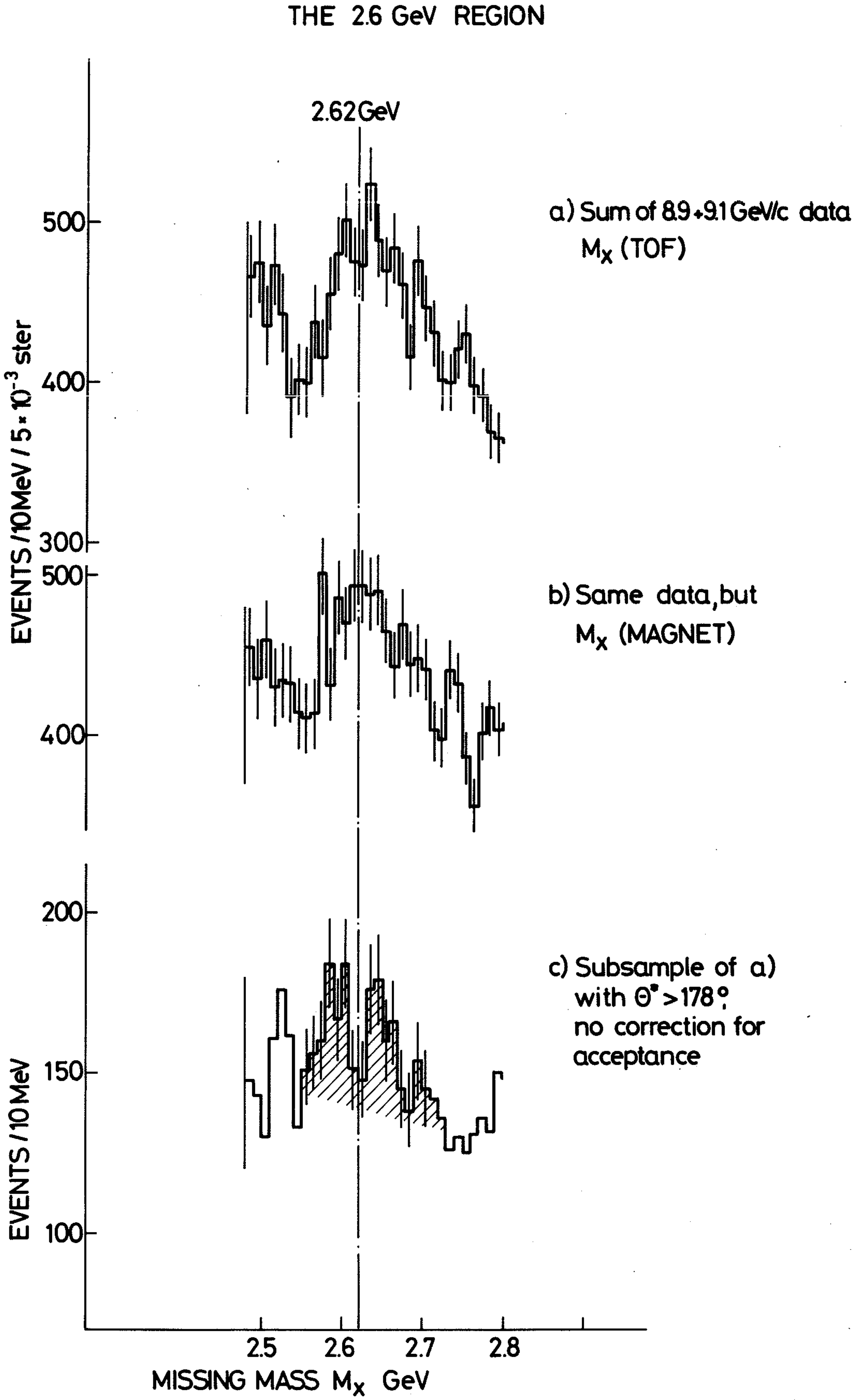
THE 2.6 GeV REGION
2.62 GeV
a) Sum of 8.9+9.1 GeV/c data
M_X (TOF)
b) Same data, but
M_X (MAGNET)
c) Subsample of a)
with Θ* > 178°,
no correction for
acceptance
EVENTS / 10 MeV / 5 × 10^-3 ster
EVENTS / 10 MeV
500
400
300
200
150
100
2.5
2.6
2.7
2.8
MISSING MASS M_X GeV

Fig. 3