EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

PROPOSAL

FOR A JOINT CERN-SERPUKHOV MISSING-MASS EXPERIMENT TO BE PERFORMED AT THE SERPUKHOV PROTON ACCELERATOR

To : The IHEP Scientific Council and the IHEP-CERN Joint Scientific Committee.

From : CERN Boson Spectrometer Group:
R. Baud, H. Benz, G. Damgaard, M.N. Focacci, W. Kienzle, R. Klanner, C. Lechanoine, M. Martin, C. Nef, P. Schübelin, A. Weitsch.

1. INTRODUCTION

We propose a systematic search for heavy bosons X^- in the unexplored mass range $4 < M_X < 8$ GeV with the CERN Boson Spectrometer (Figs. 1, 2 and 5) to be operated by a joint CERN-Serpukhov team in a high-energy pion beam at the Serpukhov Accelerator.

The experiment measures the missing mass M_X of the recoil proton in the reaction $\pi^- + p \to p + X^-$ with a magnetic spectrometer which consists of a big magnet and large wide-gap wire chambers on-line to an IBM 1800 computer.

At present the Boson Spectrometer is operating at CERN to explore the boson mass region of $2.5 < M_X < 4$ GeV. We propose to adapt the spectrometer to the Serpukhov needs during the autumn 1969 shutdown. We could then move to Serpukhov in spring 1970.

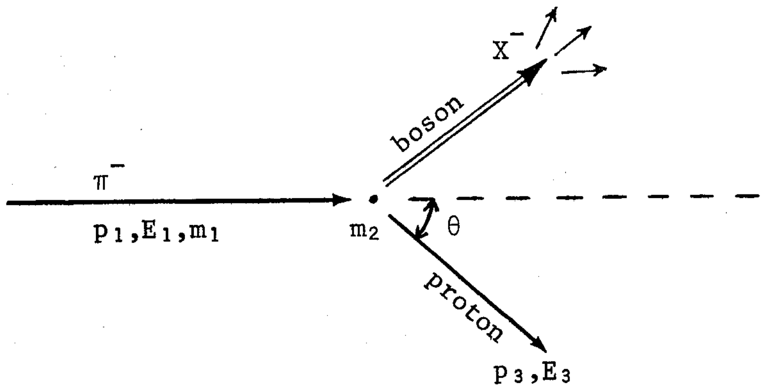
2. METHOD

The mass of bosons produced in the reaction

$$\underset{1}{\pi^-} + \underset{2}{p} \to \underset{3}{p} + \underset{4}{X^-}$$

can be obtained by measuring direction and momentum of the incident pion and the recoil proton. In the lab. system, the angle θ and momentum p_3 of the recoil proton are related, for a given mass of X^- and a given p_1, as shown in Fig. 3, where

$$M_X^2 = (E_1 + m_2 - E_3)^2 - p_1{}^2 - p_3{}^2 + 2p_1p_3 \cos\theta :$$



The method considered here is to measure p_3 and θ in the shaded region of Fig. 3. In the centre-of-mass system, this corresponds to forward production of X^-, i.e. the proton going backwards. In this region, the mass resolution is determined essentially by the accuracy of p_3, whilst the measurement of the angle θ is not critical.

The main features of the method are the following:

- masses from 4 GeV to 8 GeV can be reached with the incident momenta from 20-60 GeV/c available at Serpukhov;
- a given mass is measured for a fixed p_1 at its lowest kinematical possible momentum transfer;
- the mass resolution is $\Delta M_X \approx \pm 15$ MeV and only weakly mass dependent;
- the instrument is designed to accept recoil protons of $500 \leq p_3 \leq 1000$ MeV/c with centre-of-mass angles $178^\circ \leq \theta_{c.m.} \leq 180^\circ$;
- the mass acceptance is typically 800 MeV.

3. APPARATUS

It consists of the following items (see Figs. 1 and 2):

1) A set of beam hodoscopes (H_0, H_1, H_2) together with the beam transport magnets analyse the momenta of the incident pions.

2) A 30 cm long target (containing 1.5 litre of liquid H_2) is cooled by a refrigerator (Philips) and is therefore independent of liquid H_2 or He supply.

3) Two digitized wide-gap wire chambers with magnetostrictive readout (SC1,2, precision ±0.7 mm) measure the direction of the decay products of the X^- to reconstruct the vertex (±8 mm) in the target.

4) A wide-gap magnet (gap $0.5 \times 1.0 \times 1.5$ m^3) together with two more wire chambers (SC3), SC4) and a large-area time-of-flight counter (R) identify and momentum-analyse the recoil proton ($\Delta p_3/p_3$ = ±0.7%).

5) A trigger system consisting of several scintillation counters (T_1, T_2, V_1, V_2, $\bar{B}$, PH) and fast electronics requires that an incident pion should produce secondaries in the target and a slow, more than minimum ionizing proton went through the magnet into the time-of-flight counter (R).

6) A fully automatic data acquisition system consisting of 250 scalers on-line to an IBM 1800 computer, transfers all measured information on magnetic tape and performs a complete technical monitoring of the system.

4. DATA HANDLING

All necessary technical analysis will be done on-line on the IBM 1800. The physics analysis, can be done for a part of the data in a preliminary way also on the IBM 1800. The final analysis requires a larger computer. Therefore a regular exchange of data tapes and computer output from Serpukhov to CERN and back is necessary.

5. MASS RESOLUTION

The mass resolution ΔM_X for different incident momenta p_1 was calculated using the following quantities:

magnetic field	10.0 kG
multiple scattering for 1 wire chamber	±4.0 mrad for protons of p_3 = 500 MeV/c
uncertainty in p_1	±0.3%
vertex reconstruction	±10 mm in beam direction.

The total mass resolution ΔM_X is shown as a function of beam momentum p_1 and missing mass M_X in Fig. 4. A typical value is ΔM_X = ±15 MeV.

6. TRIGGER RATE AND ESTIMATED RUNNING TIME

At present in the region $2.5 < M_X < 4$ GeV, about 10^6 triggers are needed to prove a new resonance with a cross-section of 30 μb and a signal-to-background ratio of ∿ 1:5. If the narrow width and the signal-to-background ratio stay the same also at higher masses, four machine-weeks are required for each mass interval, assuming a trigger rate of 1 trigger/30 000 π, an average beam intensity of 2×10^5/burst, and 70% effective running time. This is to be considered as a lower limit, since cross-section and/or signal-to-background ratio might become worse at higher energy.

7. TIME SCHEDULE AND RUN PROGRAM

In the course of the autumn 1969 PS shutdown, the spectrometer will be adapted at CERN to the Serpukhov requirements. Our experience during the last years shows that after a change of geometry (i.e. exchange of magnet, etc.) a testing and running-in of four PS weeks is needed to reach production conditions again. This means we would be ready to transport the system to Serpukhov in spring 1970.

At Serpukhov the experiment could be done in two parts (see Figs. 4 and 5):

Experimental programme	Run No.	Incident momentum p_1 (GeV/c)	Simultaneously accepted mass bite (GeV)	Estimated running time (weeks)
Part I:	1	20	3.9 - 4.7	4
$4 \leqslant M_X \leqslant 6.5$ GeV	2	26	4.5 - 5.4	4
$20 \leqslant p_1 \leqslant 40$ GeV/c	3	33	5.1 - 6.0	4
(e.g. in channel No. 4)	4	40	5.7 - 6.6	4
Part II:				
$6.5 \leqslant M_X \leqslant 8$ GeV	5	50	6.3 - 7.4	6
$40 \leqslant p_1 \leqslant 60$ GeV/c	6	60	7.0 - 8.2	6
(e.g. in channel No. 2)				

Part I ($4 \leqslant M_X \leqslant 6.5$ GeV) consists of four production runs of four weeks each. In addition, three weeks are needed for running in and testing the equipment at the beginning of the experiment.

Figure captions

Fig. 1 : Boson Spectrometer layout.

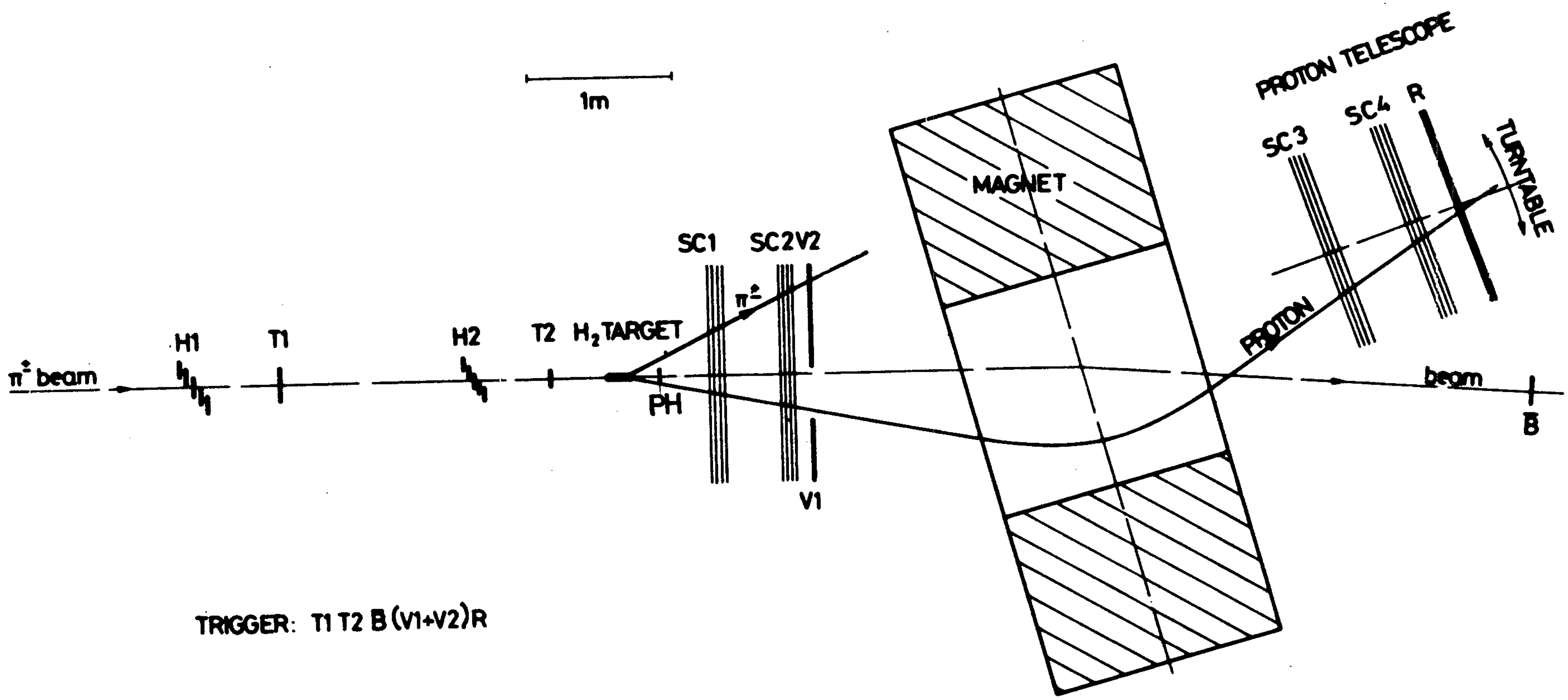
Fig. 2 : Photo of Boson Spectrometer.

Fig. 3 : Kinematics of the reaction $\pi + p \rightarrow p + X$. The shaded area corresponds to the acceptance of the instrument.

Fig. 4 : Mass acceptance and resolution.

Fig. 5 : Mass region accessible with the CERN-Serpukhov Boson Spectrometer.

FIG. 1 : BOSONSPECTROMETER LAYOUT



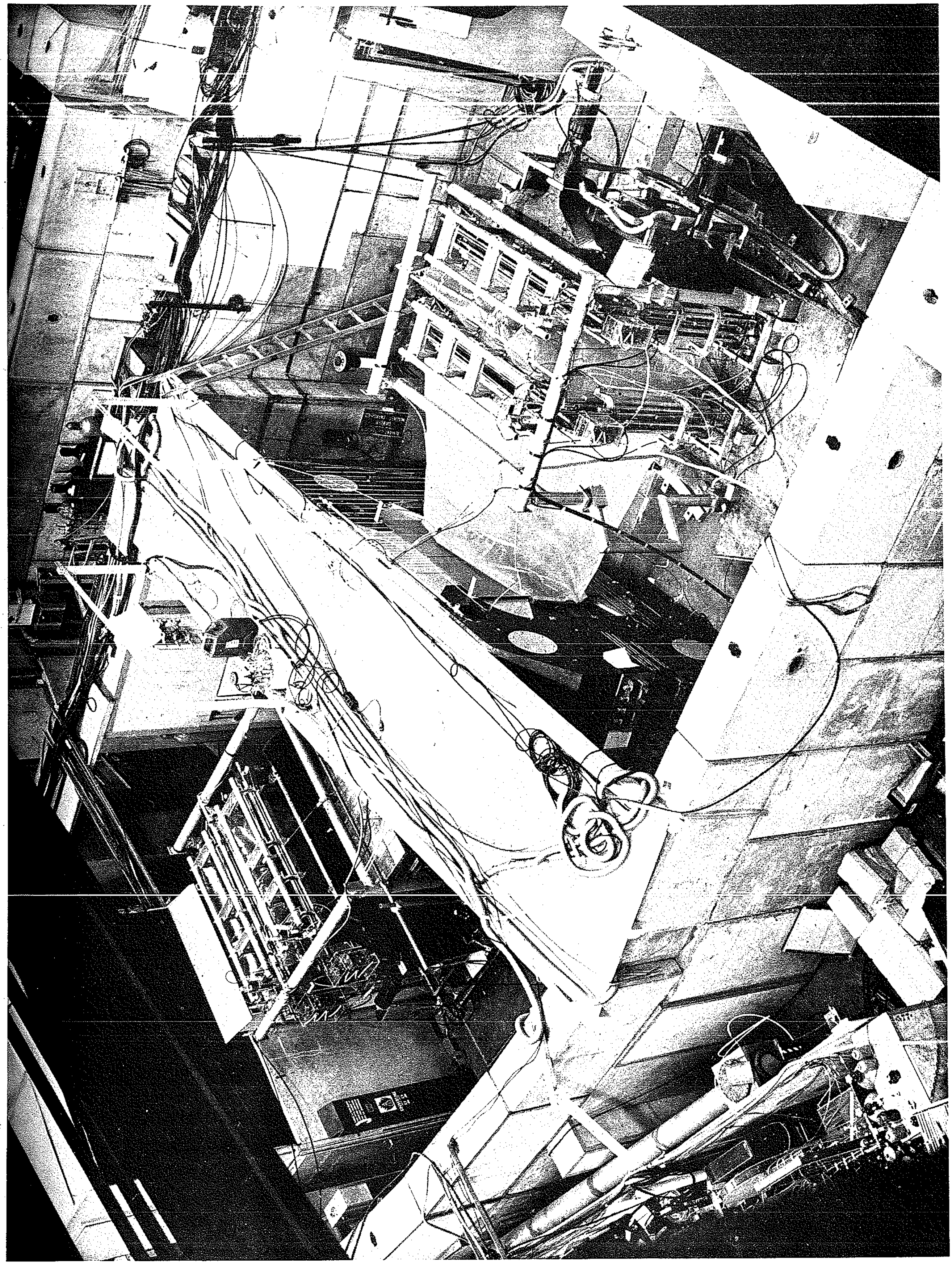


Fig. 2

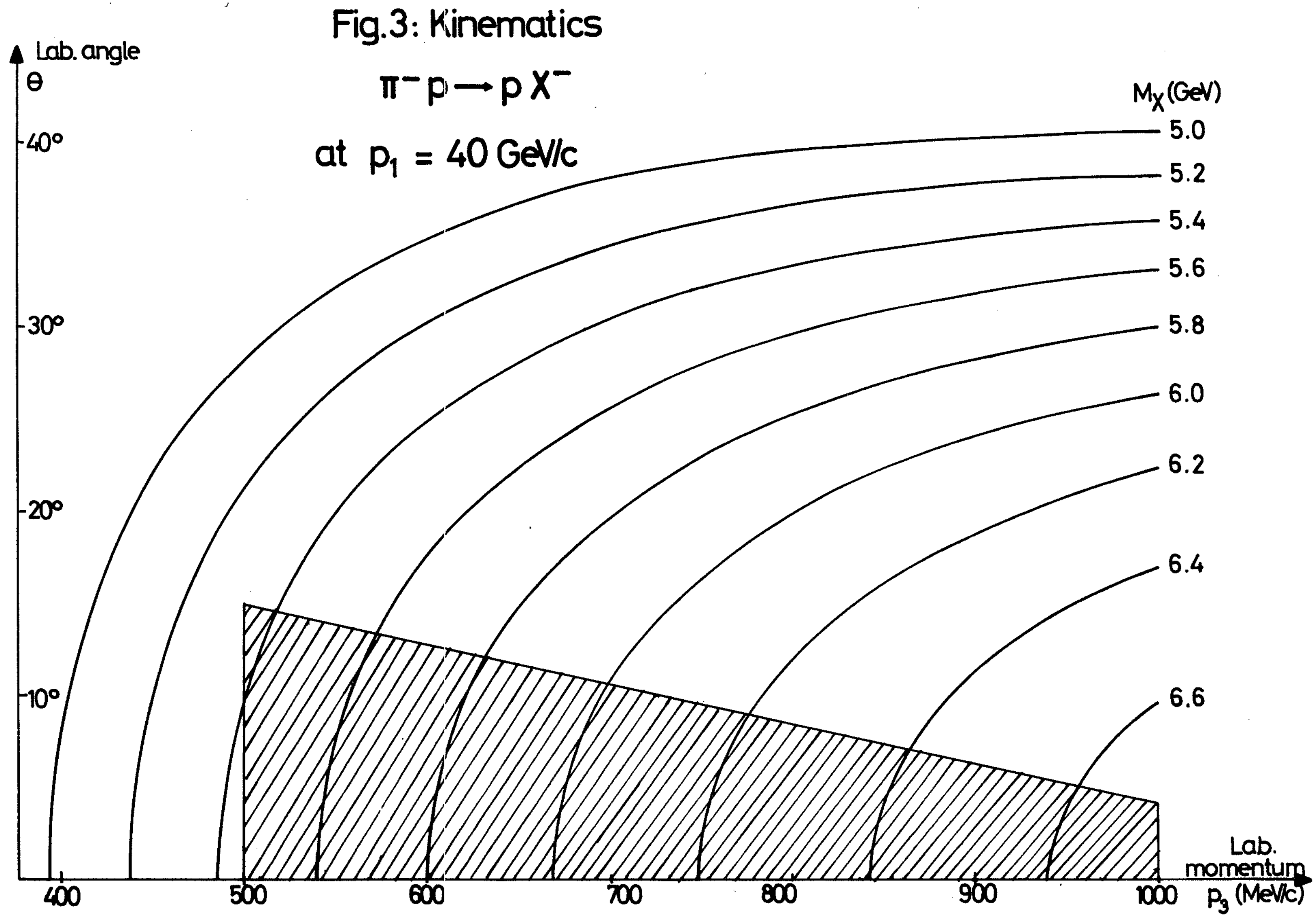


Fig.3: Kinematics
π⁻ p → p X⁻
at p1 = 40 GeV/c
Lab. angle
θ
40°
30°
20°
10°
MX (GeV)
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
400
500
600
700
800
900
1000
Lab. momentum
p3 (MeV/c)

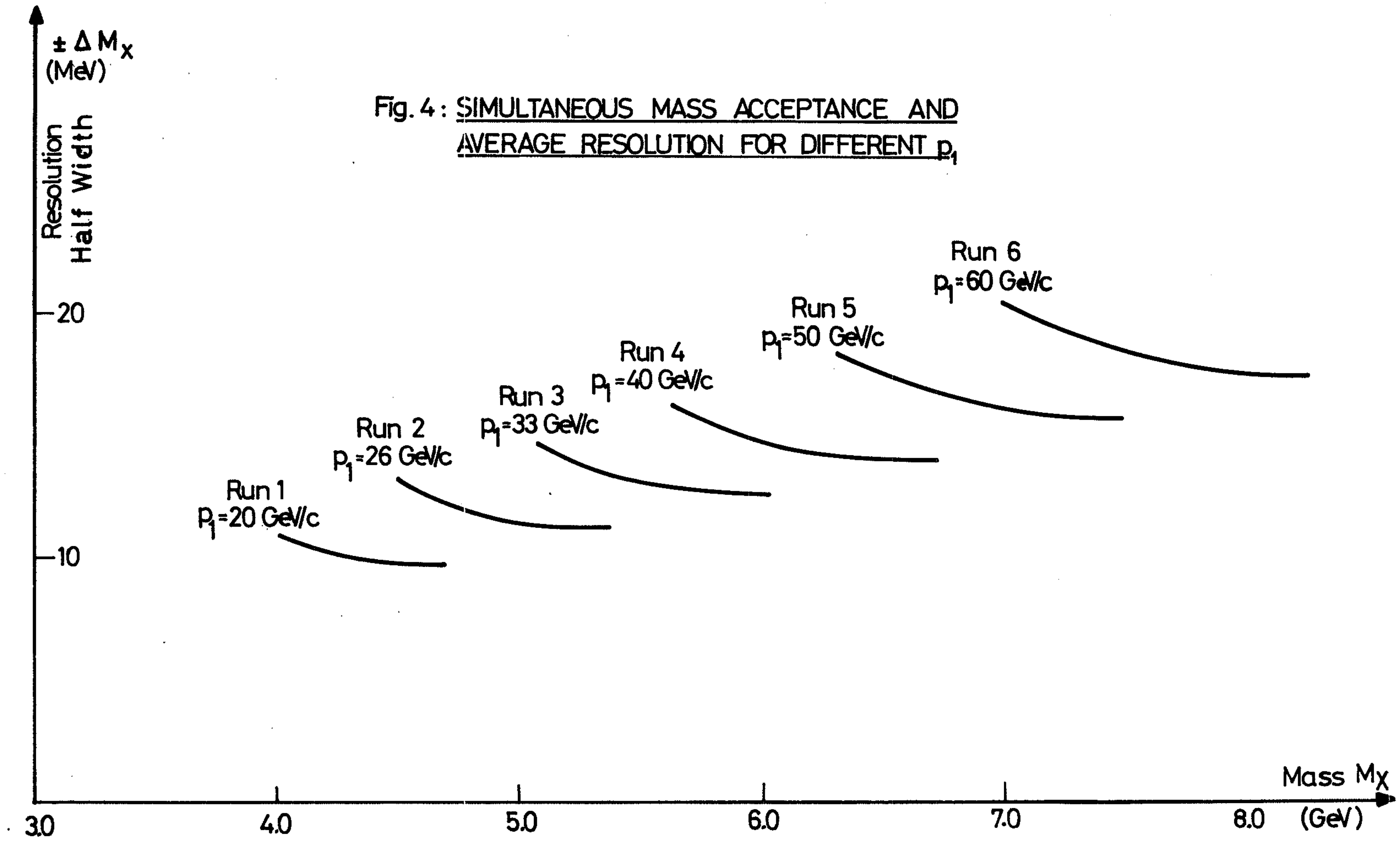


Fig. 4: SIMULTANEOUS MASS ACCEPTANCE AND AVERAGE RESOLUTION FOR DIFFERENT p_1

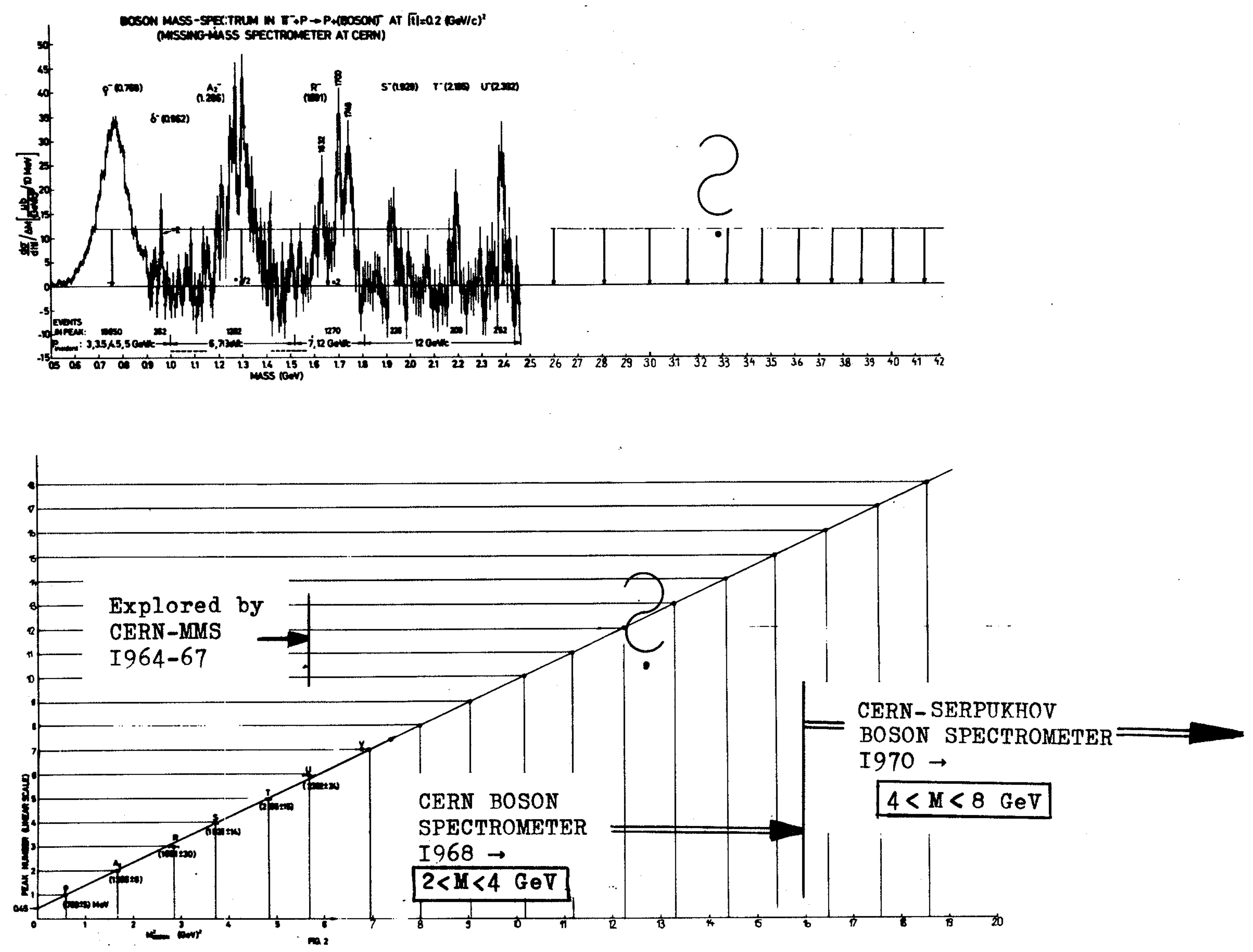


Fig.5: Accessable Boson-mass Region for a CERN-SERPUKHOV Missing-mass Spectrometer