CERN-TCC/69-29
NPA-GAR/69-5
28.5.69

THE PROPOSED GARGAMELLE TEST BEAM (G 4)

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1. INTRODUCTION

This report describes the high momentum unseparated beam which has been designed for the engineering test runs in the Gargamelle Heavy Liquid Bubble Chamber. The beam is called G 4 in the nomenclature of the Gargamelle Beam Studies Group (and in this report) but is labelled p6 in the conventional PS notation.

At a recent Gargamelle Users Meeting (19.3.69) many groups expressed a strong interest in possible π^- and p experiments using G 4 and it was therefore decided to write this full report. It describes in detail the version which will be used for the Gargamelle tests and outlines how the beam might be modified. A construction programme has been drawn up by Mr. B. Langeseth and the beam is expected to be ready for operation in the Spring of 1970.

2. GENERAL DESCRIPTION

G 4 has been designed to be rapidly interchangeable with the ν-beam. It uses the same extracted proton beam and the same target position. The secondary beam is constructed entirely within the ν-beam. tunnel and passes through the central pipe in the ν-shielding. Because of the small dimensions of the tunnel the beam uses no separators and employs pulsed quadrupoles and bending magnets. Being unseparated G 4 is envisaged as a π^- beam and maybe as a p beam if the problem of obtaining a low intensity can be solved. Particles with momenta up to 25 GeV/c can be transported; at high momenta the operation is therefore limited by the π^- flux obtainable. At low momenta several factors limit the performance of the beam. Firstly the magnet power supplies have been selected for operation at 20 - 25 GeV/c and they become less stable when operated at a small fraction of their normal power output. If the beam is required to operate at a low momentum, say less than 8 GeV/c, some power supplies may have to be replaced. Secondly the contamination due to μ^- becomes large at low momenta and finally, at very low momenta, the injection of the beam into Gargamelle may present problems.

3. BEAM OPTICS

The schematic layout of the beam area is shown in Fig. 1; a more detailed plan is to be found on the NPA drawing 224-244-0B. The beam consists of 3 parts, a stage about 50 m long in which the momentum is selected and the target redefined, a stage which shapes the beam for passage through the pipe in the ν-shielding and a final stage before entry into the chamber. The profile of the complete beam is given in Fig. 2.

3.1 Target and Momentum Selection

A Cu target of dimensions 2 x 2 x 100 mm is positioned at T. Two quadrupoles are used to form an image in the horizontal plane at A where a collimator (HC 2) selects the momentum. Two previous collimators (HC 1 and VC1) limit the angular acceptances in the horizontal and vertical planes. The section contains two bending magnets of equal strength but opposite polarity so that the beam axis at A is parallel to the proton beam axis but is displaced 34.2 cm from it. At A the full image width is 1.3 mm and the dispersion is 3.4 mm/%. Allowing for chromatic aberrations and scattering the momentum resolution is a little better than $\pm$ 0.5 %. The reflector R 2 of the ν-beam provides a serious obstruction in this section of the G 4 beam. Due to the small diameter of its inner conductor the first bending magnet of G 4 has to be placed very close to R 2 and the maximum bending angle is limited by R 2. The next section of the beam is a mirror image of the first and the target is re-defined at H with no dispersion. The reflector R 3 presents no problems since its position is not critical and its inner conductor has a large diameter.

3.2 Passage through the ν-shielding and entry into Gargamelle

G 4 passes through the 6 cm diameter pipe which pierces the ν-shielding. Two quadrupoles are placed in the 12 m length between B and the start of the 22 m long shielding. Two vertical bending magnets are provided before the shielding in case the pipe through it is not horizontal or is not at beam level. Immediately after the ν-shielding a pulsed, vertically defocussing quadrupole is placed to give a beam which has a focus in the horizontal plane at the centre of Gargamelle but which diverges in the vertical plane from a full width of 12 cm at entry to 17 cm at its exit from Gargamelle. This beam profile is considered to be adequate for the test run. If a particular experiment requires a different beam shape this could be obtained using an additional standard quadrupole and bending magnet and would perhaps necessitate the removal of the last 1 or 2 m of the ν-shielding. A standard 2 m long vertical bending magnet is also shown on the plan just before Gargamelle. This is not needed at high momenta but will be used to aid injection if the beam is run at a lower momentum. However at present the fringe field of the Gargamelle magnet is not known and the calculation of exact trajectories must await its measurement.

3.3 Summary of the Beam Performance

The angular acceptance of the beam is 1.5×10^{-5} ster and its momentum resolution is $\pm$ 0.5 %. Assuming a 10 cm Cu target and one incident bunch of 3.5×10^{10} protons at 25 GeV/c then we compute the following π^- fluxes. The production data used is that compiled by Sanford and Wang [1)] from protons with momenta between 21 and 27 GeV/c incident on a Be target.

p_π (GeV/c)	Flux π^-	Contamination μ^- (%)
2	400	11
6	2700	7
10	2600	5.5
14	1500	4
18	500	3.5
22	70	3

The figures for the μ^- contamination are very approximate but are probably underestimated. The π^- flux at very high momenta is not very reliable and depends strongly on the incident proton momentum.

3.4 Additional Remarks

The fraction of the proton beam which does not interact in the target presents a problem in that, although it is deflected in the opposite direction to the π^- beam by the first bending magnet, it passes close to the collimator at A. Therefore background flux at this point may make it difficult to tune the beam to a focus. This situation is worse at low π^- momenta when the field in the bending magnet is reduced. Consequently an additional bending magnet is used, see fig. 1 to further deflect the excess protons away from G4. The lateral position of this magnet will depend both on the primary proton momentum and the secondary π^- momentum.

If G 4 is to be used to provide a proton beam for Gargamelle the main problem is to obtain the correct intensity. One solution would be to extract one bunch of PS protons in the normal manner, to remove the G 4 target and to use the G 4 beam line to transmit positive particles with the same momentum as the primary beam. The difficulty lies in reducing the proton flux by a factor of about 10^{10} which could probably be achieved by successively defocussing the beam and dumping it into collimators upstream of G 4. A more elegant solution would be to deflect the PS internal beam rapidly across a thin target. A small fraction of the diffraction scattered protons would commence betatron oscillations of the correct amplitude so that they enter the septum magnet and are deflected down the extracted proton beam line. Tests made by PS division have shown that several thousand protons can be scattered from the machine by this method in a time of about 200 μsec. During this time the currents in the pulsed beam elements may change by up to 5 % and so only a fraction of these protons will be transmitted by the primary proton beam line and by G 4. The size of this fraction is difficult to estimate but we can reasonably hope to obtain a low intensity, high momentum p beam in this manner.

4. EQUIPMENT REQUIRED

4.1 Magnets and Collimators

G 4 uses the following elements :

- 7 pulsed quadrupoles of length 0.46 m, diameter 60 mm
- 5 pulsed bending magnets of length 1.10 m, aperture 66 x 39 mm
- 2 pulsed bending magnets of length 0.32 m, aperture 66 x 39 mm
- 1 standard PS bending magnet of length 2 m
- 3 horizontal collimators
- 1 vertical collimator.

4.2 Vacuum Pipe

Because of the small image sizes, scattering in air at atmospheric pressure is important even at 20 GeV/c. For this reason vacuum has been requested up to the collimator HC 3.

5. COMPATIBILITY OF THE G 4 AND ν-BEAMS

The times estimated here are necessarily approximate since they depend partly on the available manpower and on other unknowns such as the level of radioactivity in the tunnel after a long ν-run. When changing from G 4 to ν-beam or vice-versa the limiting time is that needed to remove or replace the G 4 magnets, collimators and vacuum pipe. This is estimated to be about 2 weeks for the dismantling of G 4 and 3 weeks for replacing and aligning it. In addition some time must be allowed in the latter case for the retuning of G 4, say half a week. Other jobs, such as the retuning of the extracted proton beam, the change of target and, if necessary, the removal of the last few metres of ν-shield are much shorter and can be absorbed into these periods.

6. ACKNOWLEDGEMENTS

We should like to thank the many people who have helped us in this work. In particular we have benefited from many discussions with the other members of the Gargamelle Beam Studies Group and with members of the Pulsed Beam Transport Group headed by B. Langeseth.

7. REFERENCES

1) AGS Internal Report, Brookhaven National Lab., May 1967.

Distribution : (open)
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FIG. 1 Schematic Layout

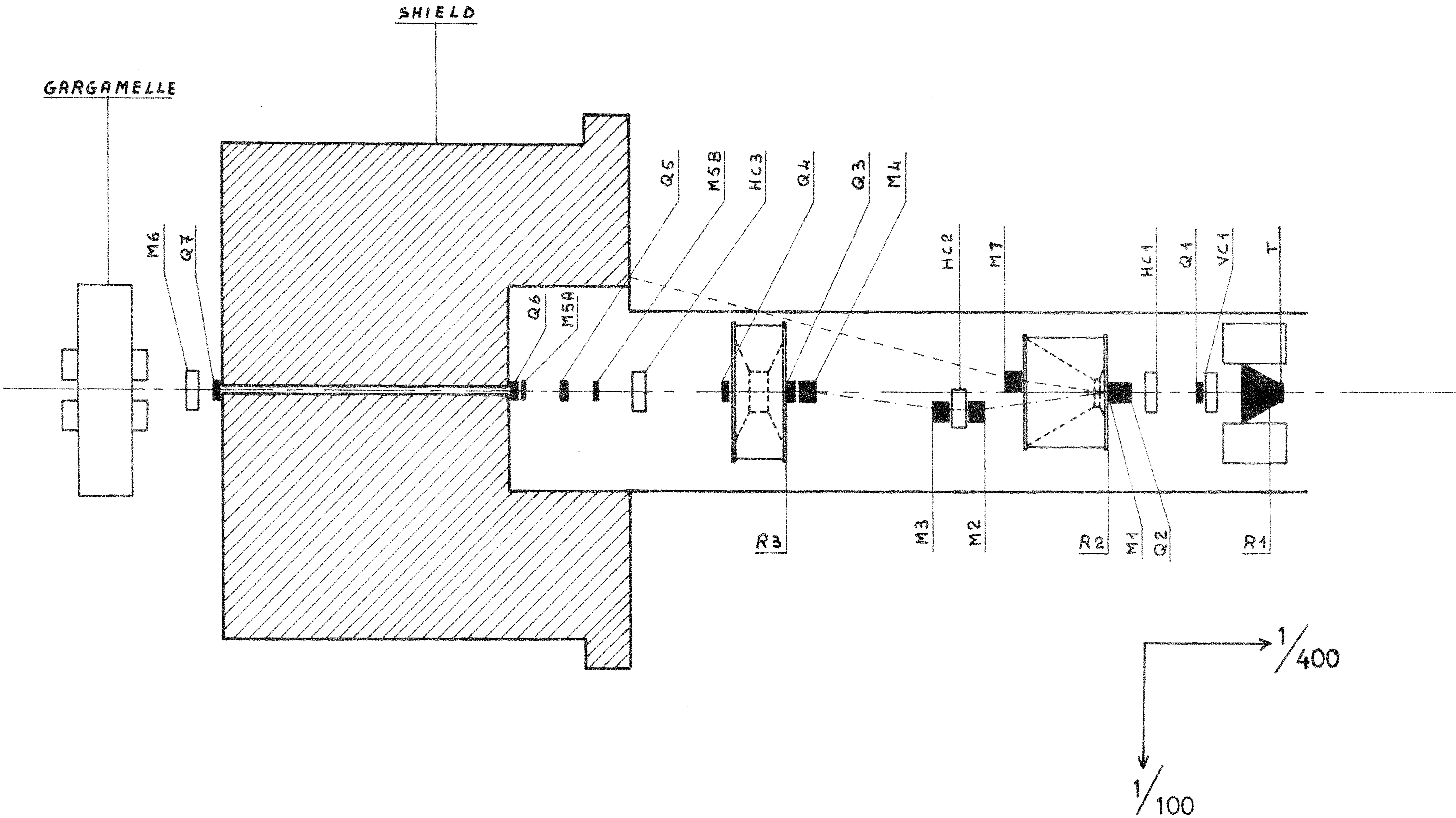

FIG. 2 G_4 Ray Traces