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LETTER OF INTENTION

A LOW-MOMENTUM MUON BEAM FOR μSR STUDIES

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INTRODUCTION

μSR experiments are presently being carried out at CERN by our groups using a 250 MeV/c muon beam in the Proton Room side of the SC (through the C pipe). The field studied and the future developments have been discussed during the recent Workshop on Low and Intermediate Energy Physics (E. Karlsson, Group 4) and a strong convergence of interests of the two groups towards a very low momentum muon beam brought us to the decision of studying in more detail the possibility of realizing such a beam at CERN.

After general considerations on the opportunity of such a beam, and after studies of the technical and financial aspects of its construction, we decided to present the project to the SCC with the confidence that the output in terms of scientific production will overcompensate the effort put in the preparation of the beam.

The beam's momentum will be near 29 MeV/c, as it will collect the positive muons from pion decay near the surface of a suitable production target. It is expected to allow a good intensity (near 10^4 μ/sec over a 2×2 cm^2 sample area) as well as a very high stopping rate (nearly 100%) either in low-density samples (gases) or in very thin solid samples. Before giving more details of the project, the following points should be made clear:

1) Because of its characteristics, the 29 MeV/c beam will open several new possibilities of investigating local properties in rare materials, in materials that can be obtained in a crystalline state only for very small sizes; it will allow the study of hydrogen interactions and muonium interactions, with surfaces and/or surface layers, along lines that are expected to be unique of low-momentum μSR. Examples of specific problems that we will consider if and when the beam is prepared are given below.

2) The 29 MeV/c beam, even if suitable for new applications, does not represent an alternative to the existing 250 MeV/c beam: complementarity is the real state of the two beams. Perhaps the most obvious examples are a) the comparison between the bulk and surface diffusion of muonium, b) low magnetic field versus high magnetic fields, properties of magnetic systems, etc.

3) Owing to the possibility of efficient acceptance and intensity of muons at wide angles [Pifer*)], the production target can either be a specially designed one (not necessarily useful for simultaneous beams for other groups) or it can be the same target producing the existing muon secondary particle beams in the proton hall. The possibility of switching between "main user" (MU)

*) A.E. Pifer et al., Nuclear Instrum. Methods 135 (1976) 39.

operation to "waste-collecting user" (WCU) is obviously very interesting from the point of view of machine utilisation; the comparison between the two operation modes will be presented when a quantitative study of particular production targets is completed.

4) A similar low-momentum beam is operating at TRIUMF and, with the growing interest in μSR, projects in the same direction are likely to be undertaken in other centres. If the prospect of completing the CERN beam within 1978 is realistic, then the entire scientific community in Europe will have a new, powerful and competitive experimental technique available.

BEAM'S PRELIMINARY CALCULATIONS (R. Tedeschi)

To start this preliminary computation we considered a beam leaving the production target at 90° with an emittance of 40 cm•msr on both X and Y axes following the customary reference set.

The system includes three quadrupolar lenses in the first path which is a couple of metres long. A first bending magnet bends the optical axis 90° to the right, and a block of six quadrupolar lenses transports the beam for six metres to the next bending magnet where the optical axis is then bent 42° to the left. Two quadrupolar lenses after the last bend play an important role inasmuch as they prepare the beam with a small enough divergence to travel for the first 3 metres of the D pipe without adjustments. Regarding the last portion of the D pipe in the concrete wall, we forecast the possibility of inserting lenses in order to carry and focus the beam in the experimental area.

The solution presented here, which is still under study for possible improvements, makes use of small conventional beam elements: the lenses are 30 cm long and generate low magnetic fields at the pole faces (0.3 to 1 kG). Such conditions were chosen because the 29 MeV/c beam, while very easy to bend, is very delicate and subject to strong divergences.

A sketch of the solution we found is given in Fig. 1 together with the layout of the beam elements. As can easily be seen, the half-width along the X-axis has the largest fluctuation, especially after the first bending magnet: optimization in this portion of the beam is believed to bring an improvement also regarding the divergence before the entrance to the D pipe. The transport through the D pipe is presently believed to be optimized with a wide, low-divergence beam.

OTHER DETAILS OF THE BEAM AND PRODUCTION TARGET

The beam line will be under vacuum: this determines two possibilities related to the two operation modes MU or WCU. For MU the vacuum line will include the production target, and a remotely controlled mechanism (operating on the first portion of the line) will insert and remove the target into and from the proton beam.

For WCU the end flange of the vacuum line will approach at 90° the other user's target with the same mechanism; the flange itself can then be considered part of the production target inasmuch as the 29 MeV/c muons are those emitted from the internal surface of the flange.

Magnetic shielding of the beam line in the cyclotron room where the stray field is larger than 10 G (an approximative mapping of the field along the path of the beam) will be needed to establish the extent of the shielding.

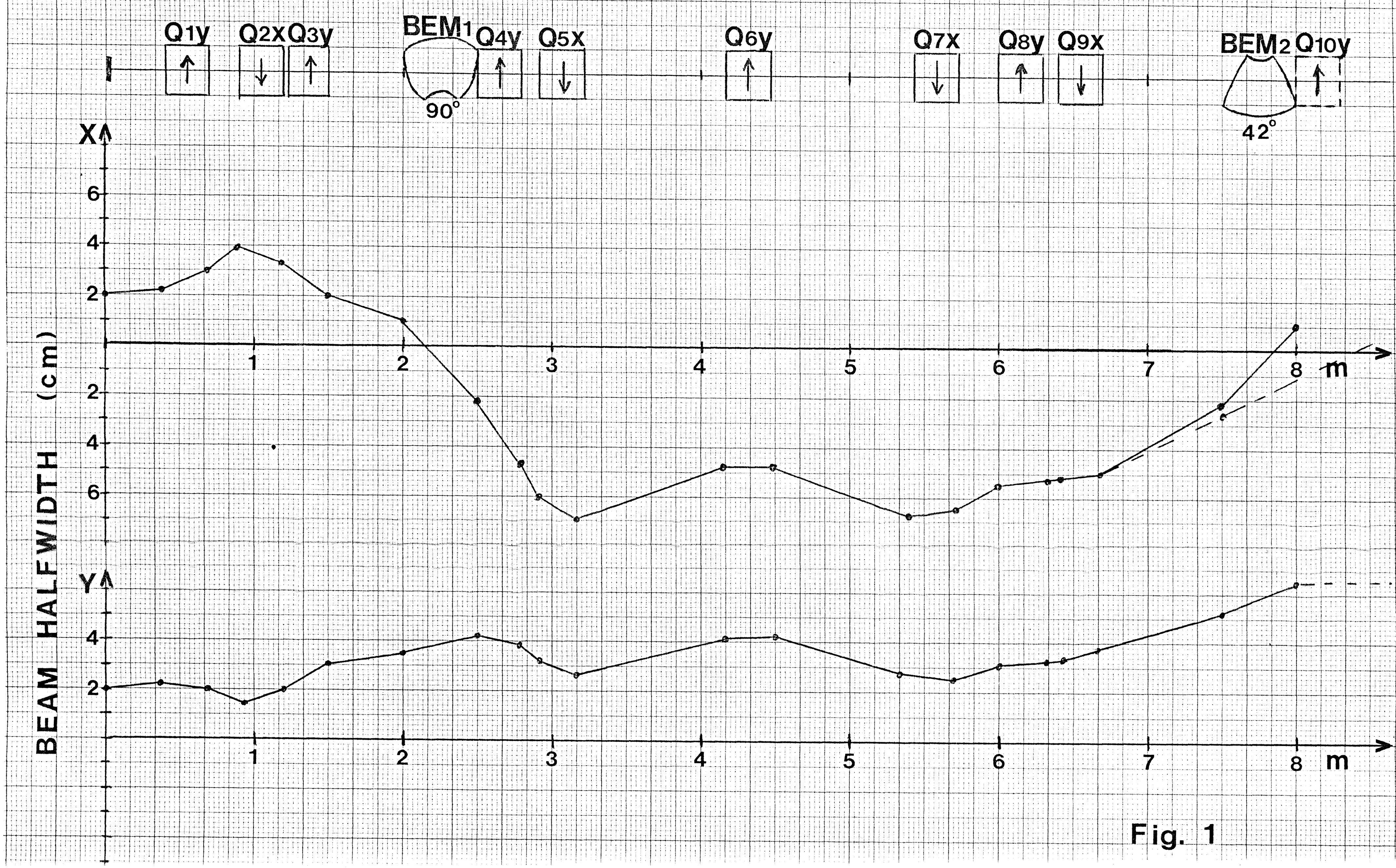
OUTLINE OF EXPERIMENTS FEASIBLE WITH THE LOW-MOMENTUM BEAM

One of the most interesting problems is the behaviour and interactions of muonium in solid surfaces and surface layers as a direct way to know about hydrogen. This is a wide field, and a large number of trends can be envisaged. The choice of some of them also will be determined by the result of preliminary experiments intended to establish to which extend the observable muon and/or muonium signals are correlated to muons at or near the surface of the sample. Less critical, but nevertheless just as interesting, is the study of the influence of the state and nature of the surface on the diffusion of hydrogen. The study of atomic hydrogen, its recombination to a molecular state at the surface at low temperatures; its interaction with impurities and consequent possibility of characterizing the surfaces from the point of view of impurities, including organic molecules, are examples of fields of growing interest in which μSR is likely to contribute greatly with a low-momentum beam. For a recent general view on this and similar problems, see the Proceedings of the 7th International Conference on Vacuum and Solid Surfaces.

In order to approach experimentally some of these fields, we will need, in addition to the more or less standard equipment developed for the present μSR, some specific features that are necessary even at a preliminary stage: the low momentum requires standard vacuum up to the sample but the studies involving surfaces require vacuum in the high to ultra high region and solid experience in surface treatments. Competence in this respect is already available at CERN and, as far as we know, at the best possible level. We intend to take the necessary steps, through Dr. Cristoforo Benvenuti, in order to obtain the technical collaboration of the ISR Division.

From the point of view of optimizing the positron detection efficiency we will make an effort for the 29 MeV/c beam (with a useful fall out also for the present set-up) involving the use of wire chambers as "logical" selectors for the standard telescopes. In this direction we will profit from the collaboration of Dr. Jeavons of DD Division.

Finally, we would like to point out that, in our opinion, some of the suggested fields of investigation are likely to provide information of direct interest for CERN's technical development (specifically ISR Division).


Q1y
Q2x
Q3y
BEM1
90°
Q4y
Q5X
Q6y
Q7X
Q8y
Q9x
BEM2
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Q10y
X
6
4
2
2
4
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Y
4
2
1
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4
5
6
7
8
m
BEAM HALFWIDTH (cm)

Fig. 1

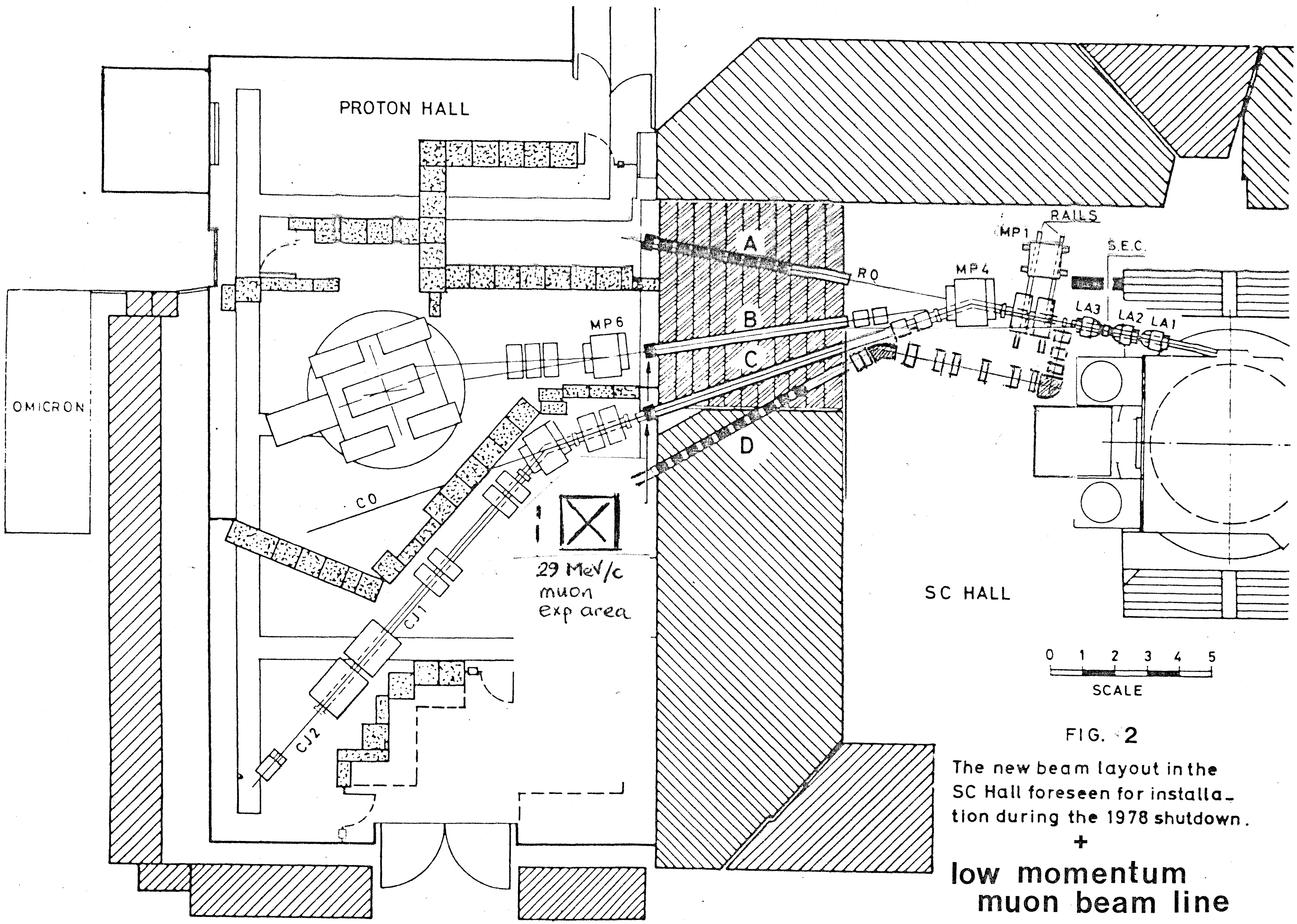

FIG. 2

The new beam layout in the SC Hall foreseen for installation during the 1978 shutdown.

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low momentum muon beam line