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A HIGH FLUX MUON CHANNEL INCORPORATING A HIGH QUALITY SPECTROMETER FIELD

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Summary

In a previous paper[1] the author presented properties of a three-coil channel that would have an acceptance > 1 sr within a momentum band of a few percent for muons produced in or near a thick production target. In this paper we present an extension of that design concept: a fourth coil is added in a Helmholz configuration with respect to the third coil to produce a large volume of uniform magnetic field suitable for the incorporation of any spectrometer (such as a time projection chamber) that tracks the paths of particles. Details of an example system are presented.

Introduction

Axially varying axi-symmetric magnetic field can provide a beam transport channel of large acceptance (> 1 sr) suitable for delivering a secondary particle beam into a target volume a few centimeters in diameter. The particles of interest originate in a small source volume on the system axis. Two Larmor periods of motion in the system are necessary. In the first Larmor period, annular slits define a band of transmitted momenta. A degrader then separates the momentum band of the desired particles from that of the undesired particles. In the second Larmor period, annular slits transmit only the desired particles.

Basic properties of these systems have been presented in papers by the author[1,2].

The example system

The example system is presented in fig. 1 and table 1. (Note that the current density is averaged over the entire cross section.) By suitable choice of currents in coils (3) and (4), a small beam spot could be produced at any desired location between coils (3) and (4). Coil (3) with current I_3 and coil (4) with current $I_4' = I_3$ form a Helmholz configuration which has a local maximum in the axial field at z=462.5 cm. The remaining system (coil (1) with current I_1, coil (2) with current I_2, and coil (4) with current ΔI_4) can be adjusted by changing the current ΔI_4 so that a local minimum in the axial field is produced at z = 462.5 cm. The superposition of a local maximum and a local minimum results in an axial field distribution on the symmetry axis which is *better* than the pure Helmholz result.

We have used the program GFUN[3] to calculate the magnetic fields. The desired field would have $B_z = B_0$ = const and $B_r = 0$ everywhere within the volume of interest. If we take B_0 to be the axial field on the axis at z = 462.5 cm (midway between coils (3) and (4)) we shall concern ourselves with the B_z field values 0.990 B_0, 0.995 B_0, B_0, 1.005 B_0, and 1.010 B_0, and the B_r field values -0.010 B_0, -0.005 B_0, 0, +0.005 B_0 and +0.010 B_0.

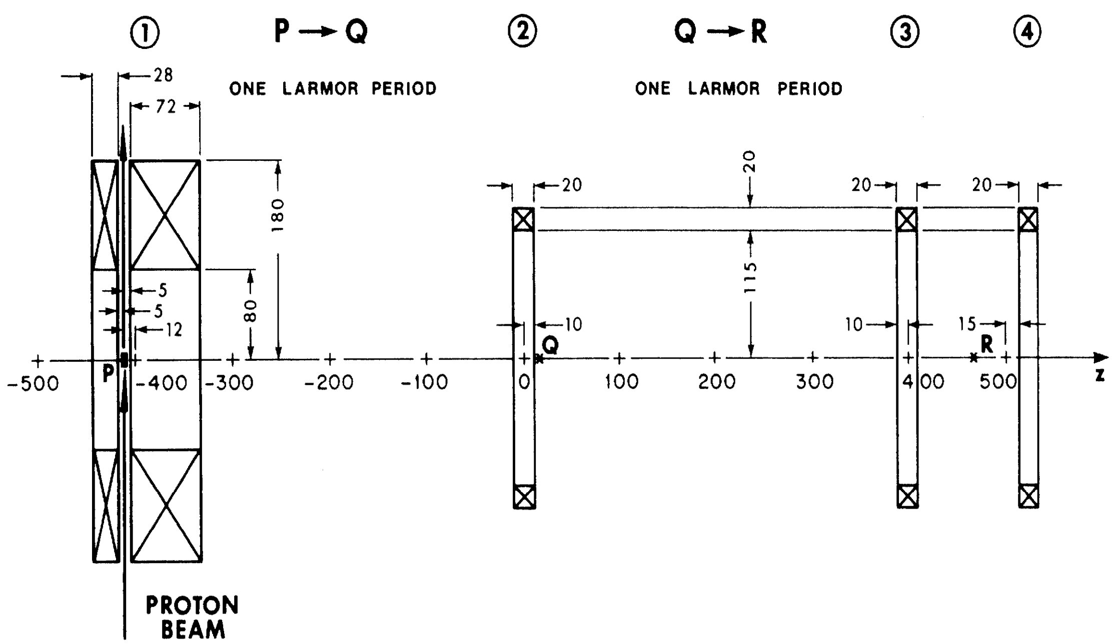

Fig. 1 The example system. The z axis is the axis of symmetry and all dimensions are in centimeters. The production target is located at P(z = -412 cm). The transmitted particles form a small spot at Q(z = 12 cm) where the degrader is located, and the experimental target is located at R(z = 466 cm).

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Contour plots of these field values as a function of r and z are presented in fig. 2. The finite size of coils (3) and (4) plays a negligible role in the field distributions. The field of the complete system differs only very slightly from that produced by a pure Helmholz configuration: in the former case near z = 430 cm, the B_z contours are a couple of cm further upstream and the B_r contours are a couple of cm further downstream.

From fig. 2 it can be seen that a cylindrical region 65 cm long and 80 cm in diameter has a field quality $|B_r| \leq (\frac{1}{2}\%)B_0$. For $|B_z - B_0| \leq (\frac{1}{2}\%)B_0$, we have an oblate spheroidal region with radius 32.5 cm out to the poles, and radius 40 cm out to the equator.

In fig. 3 we present the beam optical properties of the system for point sources at P and Q.

Table 1. PARAMETERS OF THE EXAMPLE SYSTEM

	Coil (1)	Coil (2)	Coil (3)	Coil (4)
(NI) (Ampere Turns)	1.82×10^6	1.93×10^6	0.81×10^6	0.84×10^6
j (amp/cm^2)	182	4816	2018	2101
Maximum Axial Fields				
z location (cm)	- 385.0	- 0.1	452.8	
value (kG)	8.6	10.1	6.1	

Annular Slit Location	Rays Transmitted	Annular Slit Location	Rays Transmitted
- 300	$50.1 \leq r \leq 72.8$	100	$45.6 \leq r \leq 63.7$
- 250	$55.9 \leq r \leq 72.9$	200	$57.1 \leq r \leq 71.8$
- 200	$58.2 \leq r \leq 73.4$	300	$54.7 \leq r \leq 76.6$
- 150	$58.2 \leq r \leq 73.4$	400	$31.9 \leq r \leq 60.0$
- 50	$36.7 \leq r \leq 61.5$		
11	$0 \leq r \leq 3.0$		

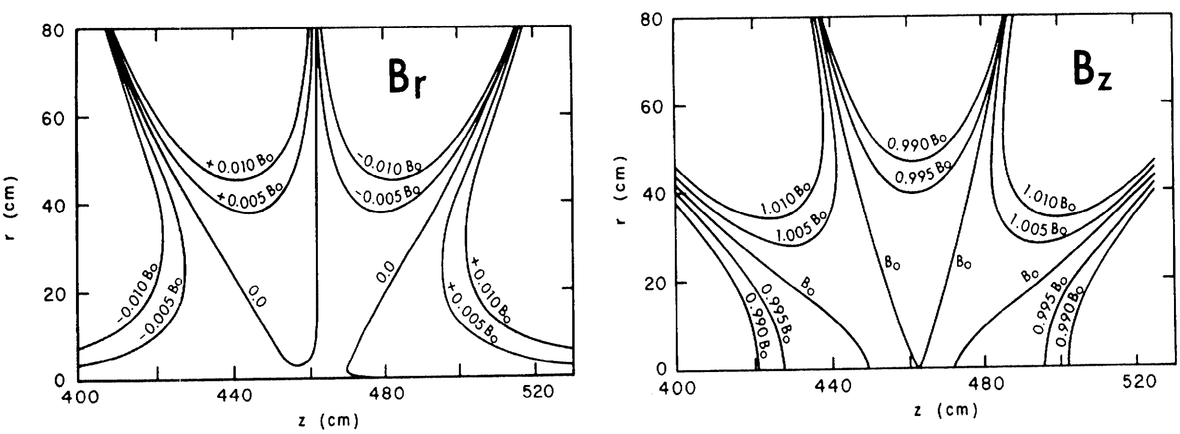

Fig. 2 Contour plots of $B_r(r,z)$ and $B_z(r,z)$ for the field produced by the coils of fig. 1. ($B_0 = B_z(0, 462.5) = 6.1$ kG)

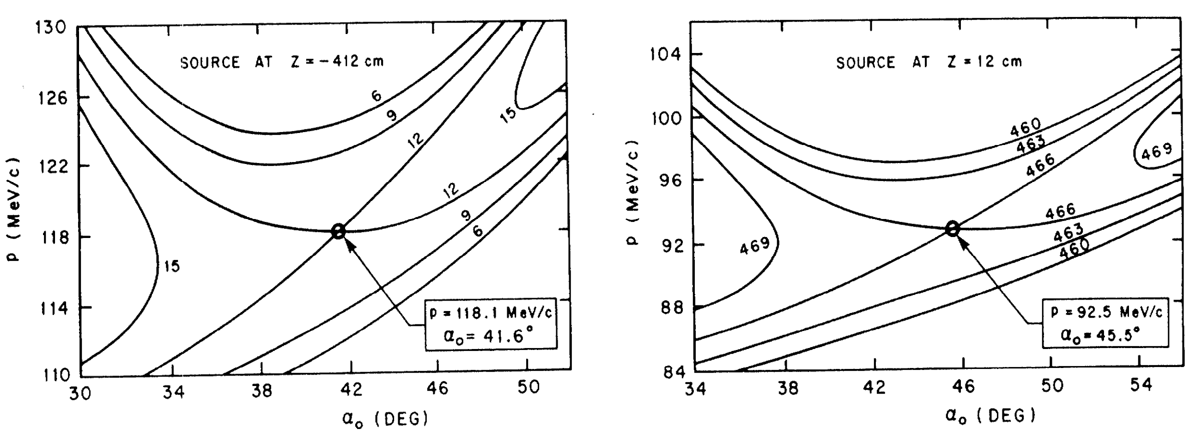

Fig. 3 Phase space contour plots for point sources on the axis at z = -412 cm and z = 12 cm. The contours are the values of z at which the next axis intersection occurs. The axes are p, the momentum, and α_0, the angle with respect to the z axis that the trajectory makes at the source location. The intersection of the phase space loci determine the parameters of the operating point of that part of the channel.

In figs. 4 and 5 we present the solid angle of acceptance for transmitted trajectories from disc sources at P and Q. Incident on the degrader at Q is a beam containing particles in the momentum range $112.75 \leq p \leq 123.25$ MeV/c. The channel downstream of Q will accept particles in the momentum range $84.75 \leq p \leq 99.75$ MeV/c. An 8.6 g/cm^2 Al degrader at Q will reduce the pion and electron momenta to below the accepted range ($65.4 \leq p_\mu \leq 84.2$ MeV/c; $65.8 \leq p_e \leq 73.4$ MeV/c), while most of the muon beam will be transmitted to R ($83.8 \leq p_\mu \leq 97.6$ MeV/c). At R, 50% of the muons will lie within a radius of 2.6 cm; 90% within a radius of 4.2 cm. The range of angles with respect to the system axis will be $28° \leq \alpha \leq 48°$.

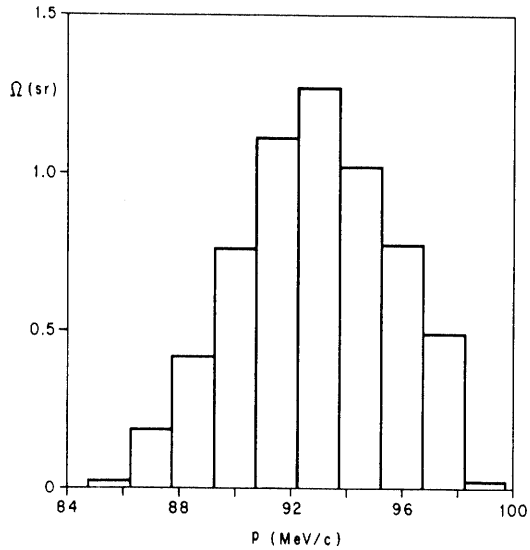

Fig. 4 The solid angle of acceptance for trajectories that leave a 1 cm disc source at z = -412 cm and are transmitted through the annular slits to z = 12 cm. ($\int \Omega dp = 7.7$ sr · MeV/c)

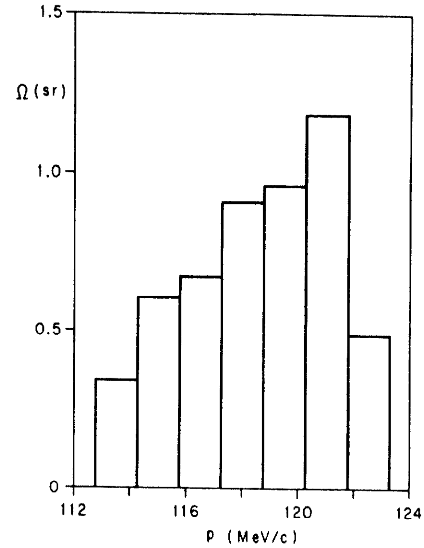

Fig. 5 The solid angle of acceptance for trajectories that leave a 3 cm radius disc source at z = 12 cm and are transmitted through the annular slits downstream. ($\int \Omega dp = 9.2$ sr · MeV/c)

References

1 D.E. Lobb. An Axi-Symmetric High Flux Muon Channel, presented at the Eighth International Conference on Cyclotrons and their Applications (1978)

2 D.E. Lobb. An Axi-Symmetric High Flux Secondary Particle Channel, accepted for publication in Nucl. Instr. and Meth. (1978)

3 A.M. Armstrong, C.J. Collie, N.J. Diserens, M.J. Newman, J. Simken and C.W. Trowbridge. Proc. Int. Conf. on Magnet Technology (Rome 1975) 168

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