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PHYSICS I

ELECTRONICS EXPERIMENTS COMMITTEE

SUPERCONDUCTING PARTICLE SEPARATOR

by

Kernforschungszentrum Karlsruhe
(Institut für Experimentelle Kernphysik)

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Letter of Intent

To: Electronics Experiment Committee

From: Kernforschungszentrum Karlsruhe (Institut für Experimentelle Kernphysik)

REF: Superconducting Particle Separator

1. Purpose of the Proposal

Separated particle beams have become of great importance for the operation of bubble chambers. Since bubble chambers can accept only a small number of particles per picture beam pulses with a length of several µsec are adequate. The particle separation for such short pulses has been achieved by D.C. and R.F. separators.

Most of the counter experiments did not need particle separation in the past since the proper kind of particle or event could be singled out by a fast electronic trigger which usually includes threshold cerenkov counters. The situation will change, however, in the near future when higher beam intensities will become available because of the CERN improvement program. The higher particle fluxes will lead to counter saturation, particularly if spark chambers have to be placed in the incident beam. Even without counter saturation some future experiments will require beams enriched in K or π mesons. A CERN study group[1] has investigated the necessity of separated beams in counter experiments in great detail and has come to the conclusion that especially at high momenta and for positive secondary beams a separator would increase the experimental possibilities considerably.

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Gesellschaft für Kernforschung m. b. H., Karlsruhe, Weberstraße 5

Since in counter experiments the full pulse length of a synchrotron can be exploited the separator must be matched to this pulse length which might vary between 100 and 500 msec. At momenta below 5 GeV/c separation could be achieved with D.C. separators whereas at higher momenta R.F. separation has to be used. However, in conventional R.F. separators the necessary deflecting fields cannot be produced for the required long times because of large losses. Therefore a superconducting R.F. particle separator is at present the only device which can provide a long pulse of separated particles at momenta above 8 GeV/c.

At momenta in the 100 GeV/c range such a separator may be the only solution for separated beams even with short pulse lengths[2)].

The development of superconducting deflectors for long pulse separators seems therefore te be of great importance. A procedure is proposed here to achieve this goal in the shortest possible time and the most efficient way by a CERN-Karlsruhe collaboration.

2. Type of Separator

Separators developped for bubble chambers do not represent the best solution for counter beams. Whereas bubble chambers require a high beam purity for counter experiments an enrichment of wanted particles is sufficient. Also the optimization of the superconducting deflectors introduces some new aspects.

Therefore various types of separators have been considered[3)] and an optimization has been carried out. As a result it was found that a properly designed separator with two superconducting deflectors and a central beam stopper will permit particle separation at high momenta for long pulses and it will yield a large solid angle and high beam intensity.

A possible set of parameters for such a separator is given in table 1.

The results obtained so far for superconducting cavities seem to indicate, that no principle difficulties will be met in realizing such a separator. However, introducing this new technique many practical problems will have to be solved, some of which are not yet even knwon. Therefore we propose to install and test a single cavity separator for low particle momenta as an intermediate step towards a two cavity separator. Such a single cavity separator with a momentum range 1.1 to 1.7 GeV/c for Kaons would offer no advantage over conventional D.C. separated beams, but it would make it possible to gain experience with a superconducting deflector in a particle beam. Only after this first step does it seem advisable to proceed to a two cavity separator where the additional problem of phasing the two deflectors has to be solved.

Since the main purpose of installing a single cavity separator would be to establish the R.F. superconducting technique a physics experiment should only be foreseen after the separator has been operated successfully for some time.

3. The Design of a single cavity Separator for Kaons around 1.4 GeV/c

Possible parameters for a single cavity separator are given in table 2. This separator was designed in such a way that the frequency, deflector length, cryostate and refrigerator are the same as for a two cavity separator (see table 1) such that all the instrumentation can later be part of a two cavity separator except for the superconducting structure itself. These requirements and the request for a high Kaon intensity determine the momentum range of the single cavity separator. The resulting beam is comparable to those obtained with D.C. separators and would be interesting for counter experiments.

A preliminary lay-out of the separated beam is shown in figure 1. A final design would have to take into account restrictions imposed by the available space on the floor.

Because of decay losses the beam should be as short as possible. On the other hand the deflector must be accessible and should hence not be placed inside the synchrotron ring. This excludes the South Hall for this beam. An external proton beam would offer many advantages and therefore the East Hall should be taken into consideration. There the crane height is also appropriate for the installation of the refrigeration plant. The implications for setting up such a beam have been investigated in a separate note by Munday.

The necessary space for setting up the refrigeration plant (200 to 300 W at $2^{o}K$) can be divided into three parts:

1. The cold box ($7x5\ m^2$) which should be as close to the deflector as possible.
2. The compressors and pumps ($8x15\ m^2$). Their distance from the cold box could be as large as 50 m. They should be installed on a shock absorbing foundation and they should be sound isolated.
3. Space for the storage of He gas ($6x7\ m^2$). The storage tank can be placed anywhere, even outside the hall.

All the dimensions given above are only approximate, since they will depend on the type of refrigerator which is ultimately chosen.

4. Collaboration between CERN and Karlsruhe and time schedule

A common effort in the construction of a superconducting separator would be advantageous to both, CERN and the Kernforschungszentrum. CERN would benefit from the work and the experience at Karlsruhe. On the other hand for Karlsruhe a superconducting separator represents a reasonable intermediate step on the way to a superconducting accelerator. The separator has the advantage that beam loading effects are of no importance.

The present design of the separator is based already on a common effort and the continuation of this collaboration seems quite promising. The various tasks could be shared in the following way:

a) The superconducting deflecting structure, the cryostat and the R.F. system are developped and built at Karlsruhe. The activities at the KFZ would be concentrated at the beginning on the single cavity separator.

b) CERN should provide the standard beam components. General technical support should also be given. Later CERN is expected to help to operate the separator.

c) The refrigerator plant will be installed permanently at the PS and therefore CERN should provide it.

The time schedule is determined by the development of the superconducting deflecting structures and the delivery time of the refrigerators.

The following time schedule appears realistic:

From now to end 68:	Tests with short sections up to 1 m length (plating techniques, superconducting joints, R.F. coupling, cavity tuning etc.). For these tests a 30 W, 2^{o}K-refrigerator is already available
End 68 - autumn 69:	Construction of fullsize deflecting structure (3,25 m) and cryostat.
Autumn 69 - end 70:	Test of fullsize deflector at Karlsruhe. A (300 W, 2^{o}K) refrigerator has been ordered which will be delivered at the end of 1969. This plant will be used to test the deflector.
End 70 - summer 71:	Installation at CERN

Summer 71: Operation of single cavity separator at CERN. The refrigerator (200 to 300 W, $2^{o}K$) should be ordered at the end of 1969 since its delivery time would be approx. 18 months. Work on a two cavity separator could start early in 1971.

This schedule matches quite reasonably the CERN improvement program. Superconducting separators could be available at the time when the increased intensity of the PS will have been achieved.

A. Citron H. Schopper

Table 1: Parameters of a two cavity separator for Kaon and Antiproton separation

<u>Design Momentum</u>	10 GeV/c (K-π)
<u>Deflectors</u>	
deflector length	3.25 m
beam hole diameter	4 cm
frequency	2.856 GHz
phase shift per cell	π/2
shunt-impedance (Cu; 300°K)	12.5 MΩ/m
improvement factor (Pb; 1.8°K)	≈ 105
shunt-impedance (Pb; 1.8°K)	≈ 1.2 . 10^{12} Ω/m
desired equivalent deflecting field	5 MV/m
corresponding cooling power	68 W
<u>Drift Length</u>	47 m
<u>Target Cross Section</u>	2x2 mm^2
<u>Horizontal Plane</u>	
horizontal magnification	6
accepted target half angle	26 mrad
<u>Vertical Plane</u>	
vertical magnification	4.5
beam stopper loss factor	.64

momentum	[GeV/c]	8	10	12	14	17	21
wanted particle		K	K	K	K	$\bar{p}$	$\bar{p}$
accepted target half angle	[mrad]	5.8	7.3	5.4	3.7	3.7	3.4
<u>Angular Acceptance</u>	[msterad]	.47	.60	.44	.30	.30	.28
<u>Kaon Decay Factor</u>	over 120 m	.14	.20	.26	.32		
<u>Momentum Bite</u>					± 1%		

Table 2: Parameters of a single cavity Kaon separator for the momentum range 1.1 - 1.7 GeV/c

Deflector

deflector length	3.25 m
beam hole diameter	4 cm
frequency	2.856 GHz
phase shift per cell	$\pi/2$
shunt impedance (Cu; 300°K)	12.5 MΩ/m
improvement factor (Pb; 1.8°K)	$\approx 10^5$
shunt impedance (Pb; 1.8°K)	$\approx 1.2 \cdot 10^{12}$ Ω/m
required equivalent deflecting field	2.4 .... 3.0 MV/m
corresponding cooling power	$\approx$16 ..... 25 W

Target Cross Section 2x2 mm^2

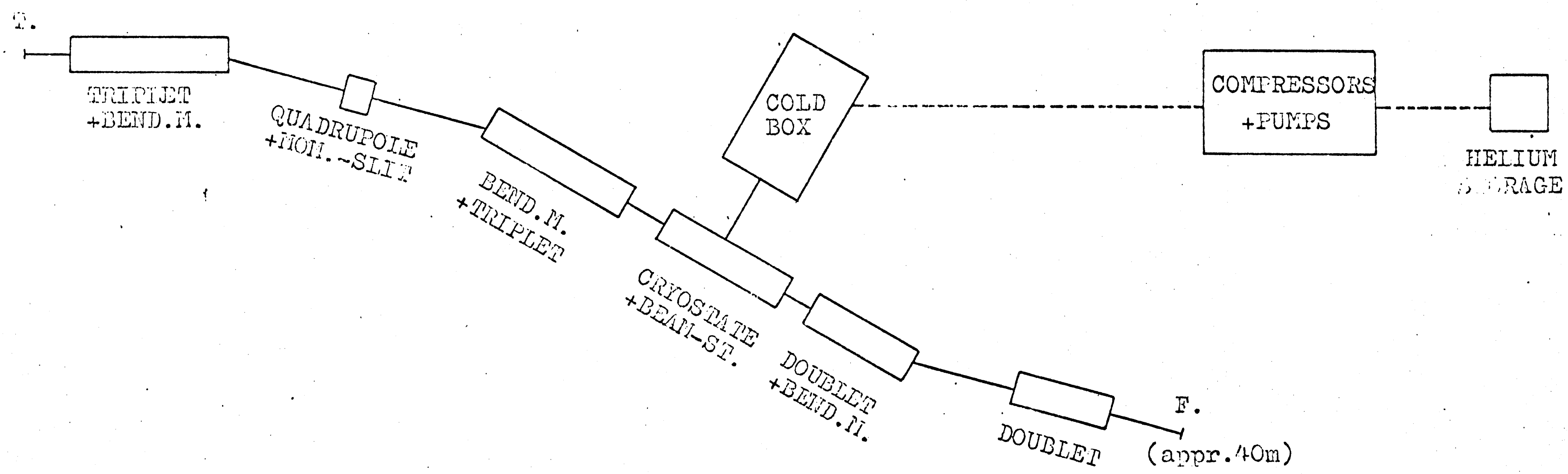
Horizontal Plane

deflector acceptance	> 14 mm x 8.8 mrad
chosen hor. magnification	5.5
accepted target half angle	24 mrad

Vertical Plane

momentum	[GeV/c]	1.15	1.25	1.35	1.45	1.55	1.65
image half height	[mrad]	3.5	3.5	3.5	3.5	3.5	3.5
image half width	[mm]	2.4	3.2	3.2	3.2	2.6	1.8
vertical magnification		2.4	3.2	3.2	3.2	2.6	1.8
accepted target half angle	[mrad]	8	11	11	11	9	6
beam stopper loss factor		.47	.56	.58	.57	.52	.46
Angular Acceptance	[msterad]	.60	.83	.83	.83	.68	.45
Kaon Decay Factor over 40 m		.010	.014	.019	.025	.032	.039

Momentum Bite $\pm$ 1.5 %



SINGLE-CAVITY SEPARATOR 1.1 ÷ 1.7 GeV/c

(Preliminary layout)

SCALE: 1cm/2m