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J. Kewisch, H. Kreiser, T. Niinikoski, Y. Onel, A. Penzo and and R. Rossmanith:

CONSIDERATIONS ON INSTALLING A STRONG SOLENOID IN A LOW ENERGY STORAGE RING

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CONSIDERATIONS ON INSTALLING A STRONG SOLENOID IN A LOW ENERGY STORAGE RING

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ABSTRACT

Recently a method was proposed to polarize the stored antiprotons in LEAR. Particles with different spins are separated by a device called spin-splitter consisting of skew-quadrupoles and a strong solenoid.

In this paper it is shown in principle that the spin splitter with its strong solenoid field can be integrated into a low energy storage ring such as LEAR, without long changes in the optics.

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1. INTRODUCTION

A method to polarize the stored antiproton beam in LEAR has been recently proposed [1]. In this method spins aiming into different directions are separated by the Stern-Gerlach effect. Two strong skew quadrupoles induce kicks on the particle trajectory. These kicks add over many revolutions until particles with opposite spin directions are separated by macroscopic distances.

In order to achieve a net separation a solenoid in between the skew quadrupoles has to be installed. This unit is called spin splitter (Fig. 1).

The solenoid has to provide a strong field (its integrated field strenght is about 30 percent of the integrated field strenght of all bending magnets). In the following it is shown that it is in principle possible to incorporate such a device in the LEAR ring, using an existing solenoid.

This is a first approach to the problem. The present solution still has to be modified in order to meet the detailed requirements of the existing LEAR straight sections [2].

2. THE MODIFIED OPTICS

The original LEAR optics is shown in Fig. 2. The beta functions are identical for each quadrant and do not exceed 22m. The calculations are performed by the programs COMFORT [2] and PETROS [3]. The results are in good agreement with MAD calculations performed at CERN [4].

The solenoid of the spin-splitter usually couples horizontal beam motion into vertical motion and viceversa. The skew quadrupoles have to be designed in such a way that the coupling is compensated. The compensated spin-splitter disturbes the symmetry of the ring. A series of calculations were performed for a superconductive solenoid (2.5 Tesla) with a length of 1.6 m in order to demonstrate the feasibility of such a compensation scheme.

In the following it is assumed that the strength of the solenoid can be changed within 30 percent. As a consequence it was found that two skew quadrupoles on each side of the solenoid have to be installed (Fig. 3).

Furtheron a solution could only be found when the two LEAR quadrupoles pairs next to the spin-splitter have different K-values compared to rest of the ring (Fig. 4).

Table I shows two possible solutions for a spin-splitter. The calculations for decoupling have been done using the program MINUIT [5]. For two given geometries (D1 and D2) the R-value of the solenoid is varied. The R-value is defined in the following way

$$R = eB / pc = 0.3 B / p \text{ (Tesla / GeV/c)}$$

Note that according to Table I the maximum beta-functions depend on the R-value of the solenoid. Fig. 5 and 6 illustrate this behaviour for a total length of L = 4.2 m. For R = 2.0 (Fig. 5) th optics is not so different compared to the original optics shown in Fig. 1. For R = 1.91 the beta-functions become very high (Fig. 6) and cannot be taken into account for a realistic scheme.

3. SUMMARY

It is shown in principle that a spin splitter consisting of a strong solenoid quadrupoles can be installed in LEAR without disturbing too much the original optics.

The straight section foreseen for the spin splitter in LEAR will be in the near future equipped with a low beta insertion. Therefore the next optical calculations will concentrate on the question if part of the low beta section can be used for the spin splitter, e.g. by rotating two of the low beta quadrupoles by 45 degree. Such a solution has the advantage that existing power supplies can be used.

4. AKNOWLEDGEMENTS

The authors wish to thank S. Baird, P. Lefevre and D Möhl from the LEAR group for advice and discussions.

L (m)	D_1 (m)	D_2 (m)	R [1/m]	QFN K (1/m²)	QDN K (1/m²)	QFN1 K (1/m²)	QDN1 K (1/m²)	Sk1 K (1/m²)	Sk2 K (1/m²)	max β_x (m)	max β_z (m)	
4.2	0.2	0.1	1.91	-1.15	1.32	-1.97	1.92	-9.17	-0.62	23.8	180	
	0.2	0.1	2.0	-1.36	1.45	-1.93	1.84	-2.87	-1.21	12.6	36	
	0.2	0.1	2.6	-1.52	1.46	-1.9	1.88	+0.25	+7.31	18.2	413.4	
4.6	0.3	0.2	1.8	-1.41	1.58	-2.02	1.88	-6.5	-0.28	16.9	119.5	
			2.0	-1.3	1.38	-1.96	2.03	-1.32	-2.11	12.1	78.6	
			2.5	-1.53	1.63	-1.99	1.82	0.57	9.06	15.4	268.8	
LEAR	-	-	-	-1.4	1.27	-1.4	+1.27	-	-	10.7	21.8	Standard

TABLE I - Optical parameters of LEAR with and without the spin-splitter.

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FIGURE CAPTIONS

Fig. 1: The spin-splitter scheme.

Fig. 2: The original LEAR optics.

Fig. 3: The spin-splitter consisting of two pairs of skew quadrupoles and a solenoid.

Fig. 4: The implementation of the spin-splitter in LEAR.

Fig. 5: LEAR optics with the spin-splitter in one of the straight sections.

Fig. 6: Similar to Fig. 4. The strength of the solenoid is reduced.

SPIN - SPLITTER

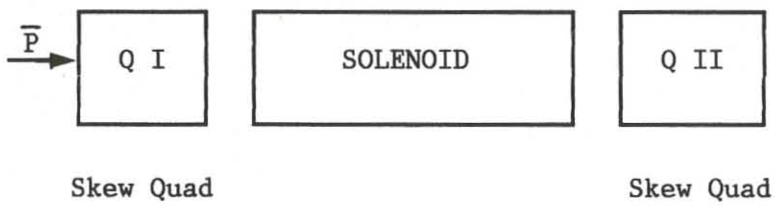
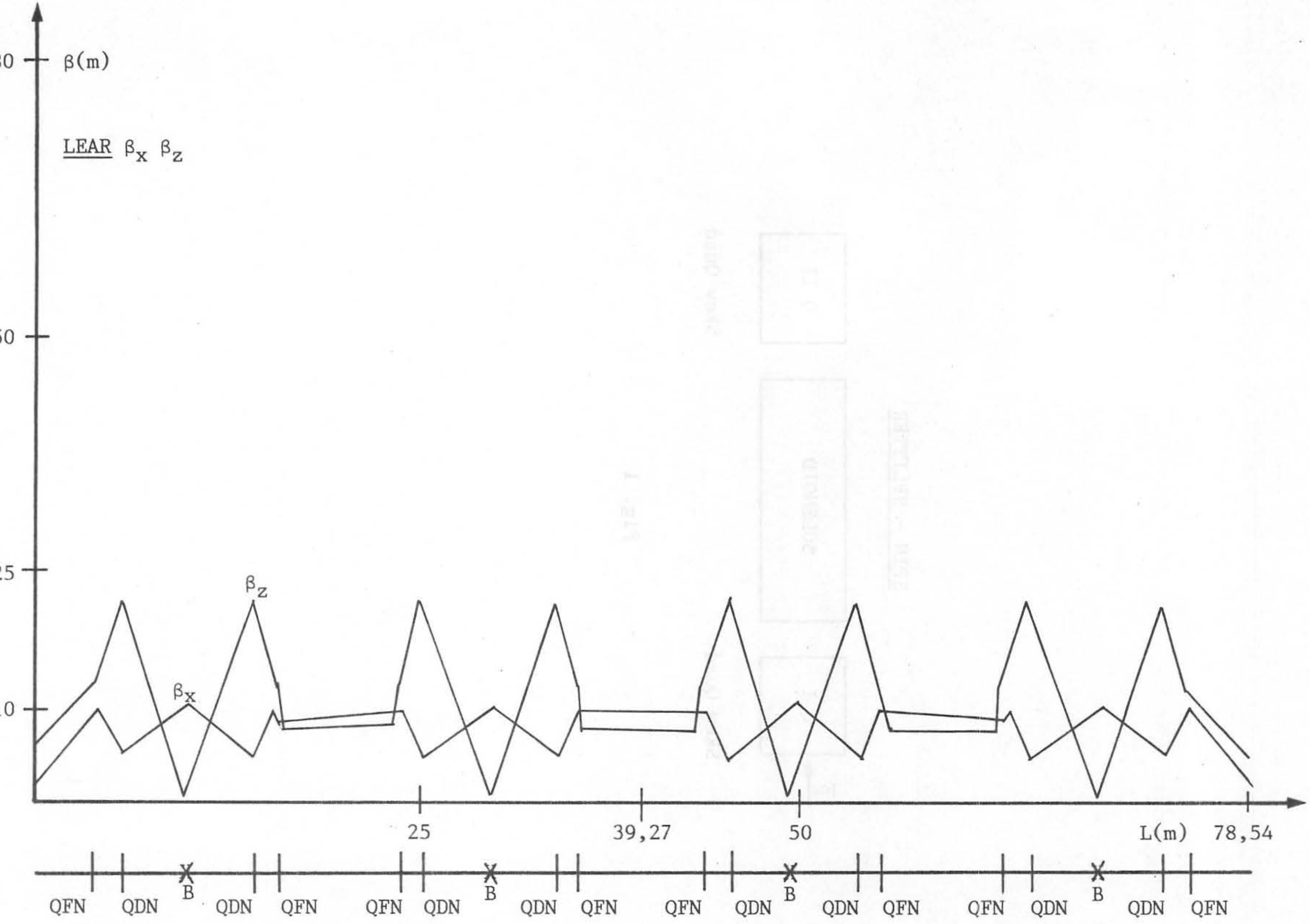


Fig. 1



80
β(m)
LEAR βx βz
50
25
10
βz
βx
25
39,27
50
L(m)
78,54
QFN
QDN
B
QDN
QFN
QFN
QDN
B
QDN
QFN
QFN
QDN
B
QDN
QFN
QFN
QDN
B
QDN
QFN

Fig. 2

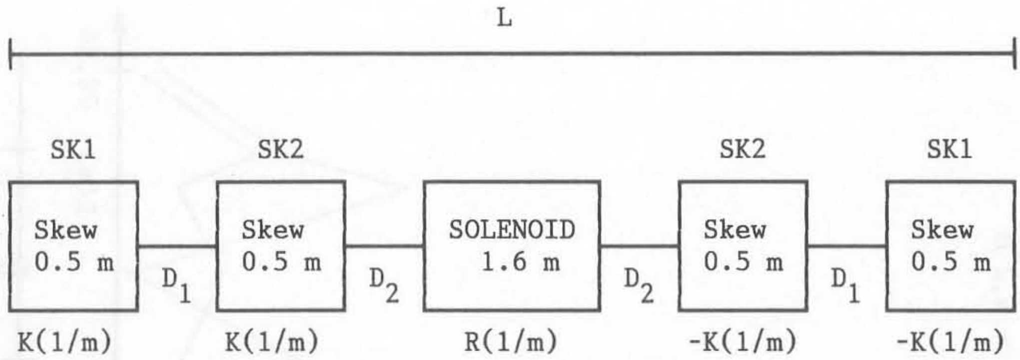

L
SK1
SK2
SK2
SK1
Skew 0.5 m
Skew 0.5 m
SOLENOID 1.6 m
Skew 0.5 m
Skew 0.5 m
D1
D2
D2
D1
K(1/m)
K(1/m)
R(1/m)
-K(1/m)
-K(1/m)

Fig. 3

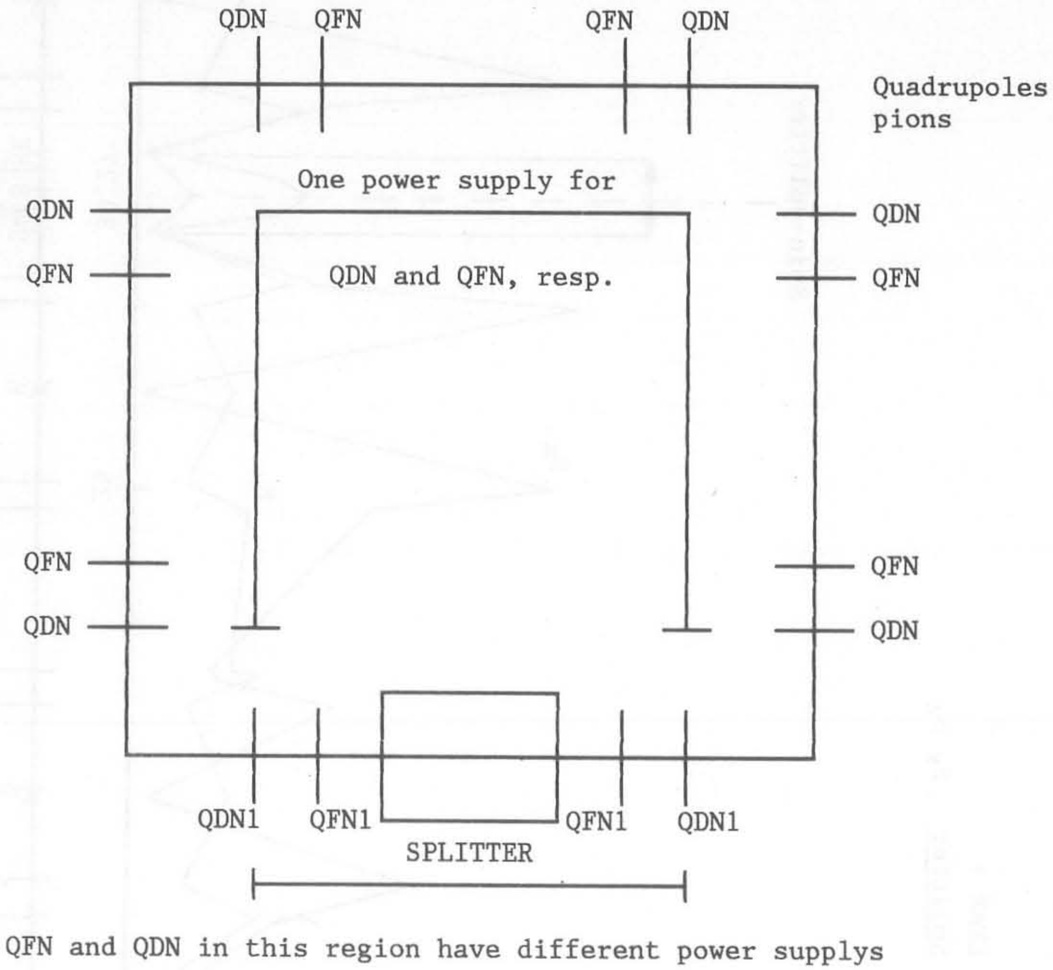
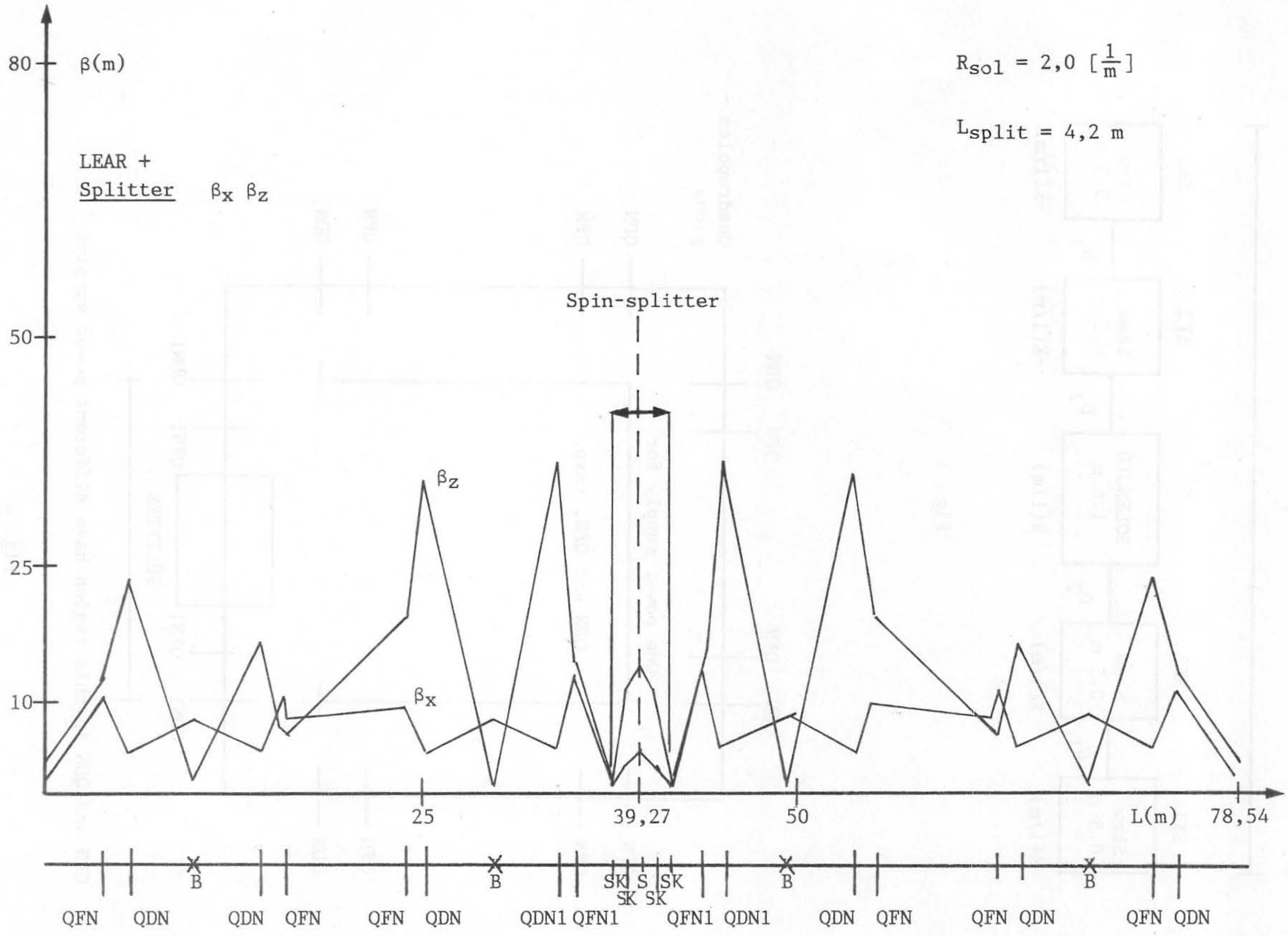

QDN
QFN
QFN
QDN
Quadrupoles pions
One power supply for
QDN and QFN, resp.
QDN
QFN
QDN
QFN
QFN
QDN
QFN
QDN
QDN1
QFN1
QFN1
QDN1
SPLITTER
QFN and QDN in this region have different power supplys

Fig. 4



80
β(m)
50
25
10
LEAR +
Splitter βx βz
Rsol = 2,0 [1/m]
Lsplit = 4,2 m
Spin-splitter
βz
βx
25
39,27
50
L(m)
78,54
B
B
B
B
SK S SK
SK SK
QFN QDN QDN QFN QFN QDN QDN1 QFN1 QFN1 QDN1 QDN QFN QFN QDN QFN QDN

Fig. 5

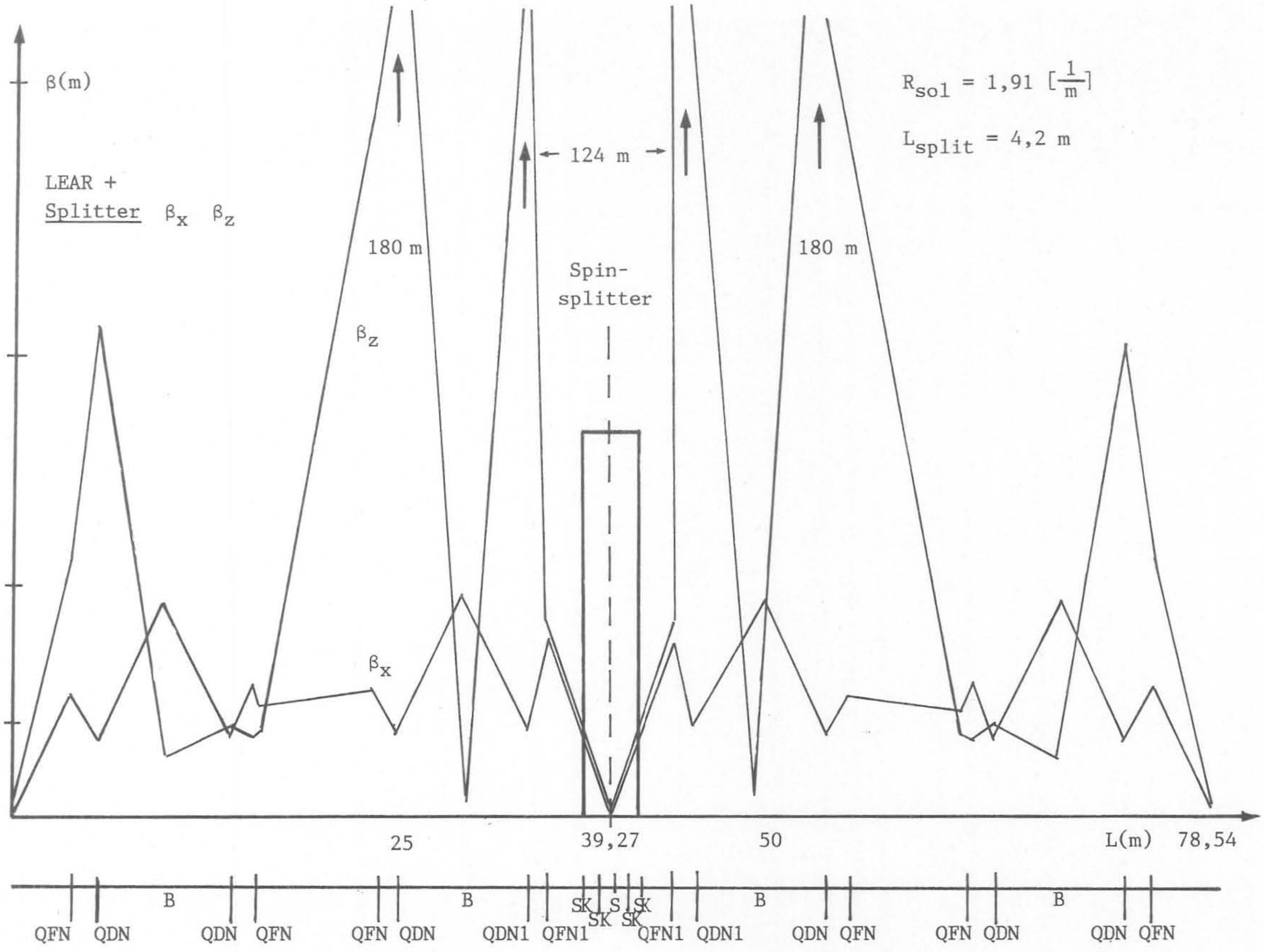

80
50
25
10
β(m)
LEAR +
Splitter βx βz
180 m
124 m
Spin-
splitter
180 m
$R_{sol} = 1,91 \left[\frac{1}{m}\right]$
$L_{split} = 4,2$ m
β_z
β_x
25
39,27
50
L(m) 78,54
B
B
B
B
SK
SK
S
SK
SK
QFN QDN QDN QFN QFN QDN QDN1 QFN1 QFN1 QDN1 QDN QFN QFN QDN QDN QFN

Fig. 6