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MAGNETS FOR THE GERMAN SPALLATION SOURCE SNQ

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Abstract

For the SNQ high energy linac 320 quadrupoles with a gradient of up to 6 T/m and a bore of 80 mm will be used. The design and mechanical layout of a cheap prototype are presented. The coils with a low resistivity and a high filling factor are produced by simply sawing from a forged hollow copper block.

Due to radiation exposure no organic materials are used and insulation is established by spacers and distance. Design criteria and layout of the beam line and the tolerances are discussed.

The Quadrupole in the HELA section

In the high energy part of the Linear Accelerator (HELA) for the SNQ an array of 320 identical quadrupoles are used to transport the beam from 100 MeV to 1100 MeV (1).

The parameters of this type of quadrupole are given in table 1.

Table 1: Parameters of the HELA Quadrupoles

Effective length	200	mm
Aperture diameter	80	mm
Maximum flux at pole tip	0.26	T
Maximum flux inside the iron	0.8	T
Maximum field gradient	6	T/m
Overall dimension	580*640*200	mm 3
Length of the iron body	120	mm
Total weight .	600	kg
Ampere turns per pole	3800	A
Number of turns per pole	7.5	
Coil material	copper type SE-CU DIN1787 material number 2.0070.1	
Spacers	Aluminum oxid	
Filling factor	0.87	
Power consumption per quadrupole	160	W
Resistivity at 50 centi degrees	0.56	mOhm

The basic requirements on this quadrupole are:

- low power consumption and high reliability because of the rather large number of 320 quadrupoles located in the HELA tunnel,
- air cooling because water cooled equipment is not so easy for remote handling,
- ceramic insulation because of the high radiation level,
- the mechanical parameters are optimized in terms of costs using the program MAGBER (2),
- the magnetic design was done using the Poisson Group Programs (3),
- the higher harmonics of the field should be below 5*10**-4 in relative units at the radius of 10 mm because the particle loss had to be minimized.

The design is given in Fig. 1. Fig. 2 shows the first prototype.

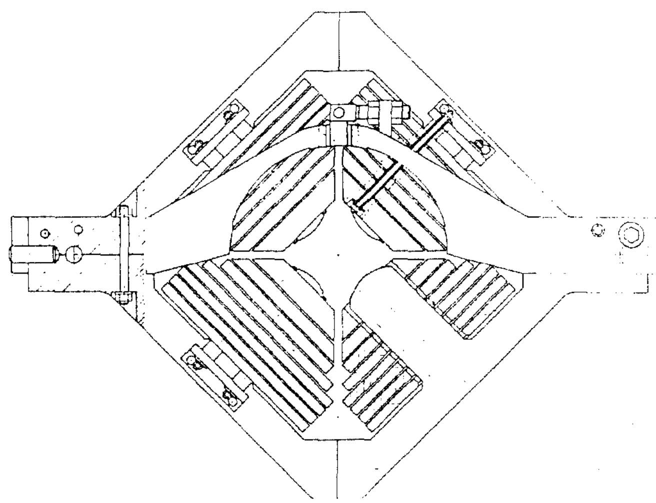

Fig. 1 Schematic view of HELA quadrupole

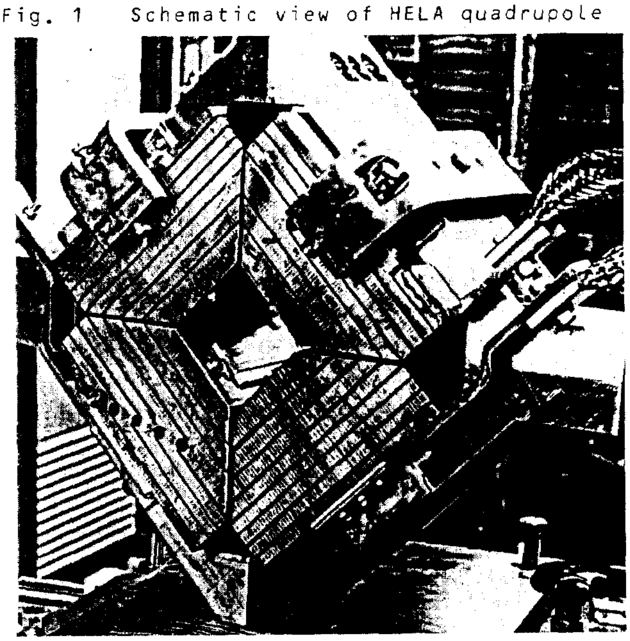

Fig. 2 Picture of prototype

The poles have a stepping profile for easy machining and for practise of mechanical corrections caused as a result of field measurements (4). The coils are made from a hollow copper block with a bore for the poles by simply cutting the coil layers with a saw and drilling holes in the appropriate positions to separate the different layers.

All quadrupoles are connected to one power supply in series resulting in a total power consumption of approximate 50 KW for the HELA section.

The measured harmonics of the first prototype are given in Fig. 3.

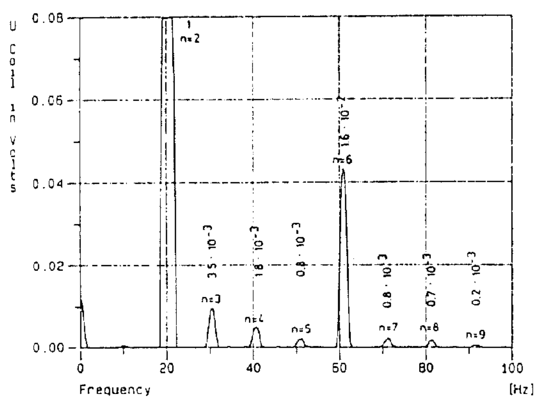

Fig. 3 Fourier-analysis of rotating coil measurement at 540A; normalised to the main component; radius 36 mm.

Due to a misalignment of the pole surfaces the harmonic content can be understood.

The Radiation Hard Bending Magnet (RHB) near the Spallation Target

In the High Energy Beam transport line (HEBL) which transports the beam from the linac to the spallation target the last bending magnet is the most critical component in terms of radiation hardness handling and reliability because this magnet defines the position of the beam on the target wheel.

The basic design requirements are given in table 2.

Table 2: Design requirements for the magnet

emittance of the linac beam at 1100 MeV (both planes)	$\mathcal{E}\cdot\beta\cdot\gamma$ = 7	mm·mrad
emittance with compressor ring	350	mm·mrad
acceptance of the bending magnets	450	mm·mrad
acceptance in momentum		+/- 1 %
lattice function	achromat corrected in 2nd order (5)	
structure	O-F-D-O-B-O-F-D-O-O-D-F-O-B-O	
target spot (10 m behind the last bending magnet)	2x = 2y = 80 +/- 2 mm	
pole tip field at 1100 MeV		0.6 T
accuracy of the field setting	dB/B	2*10**-4
sextupole strength in dipole field	$dB''/(dx)^2$	0.006 T/m**2
radiation power load on last magnet (estimation)		50 KW (6)

Due to the radiation safety a C-type dipole magnet with the coils on the yoke was preferred (Fig. 4). The gap height of 270 mm enables the transport of the larger emittance of the compressor beam. The width of 800 mm is necessary to separate the backstreaming charged particles from backstreaming fast neutrons. This allows an experimental area for fast neutrons under 180 degree to the incident proton beam.

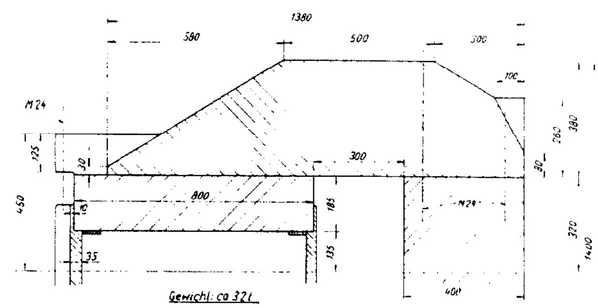

Fig. 4 Schematic view of HEBL-dipole (dimensions in mm)

The coils consists of a solid copper conductor with a MgO insulation and an outer copper shield (7). Two coils with one cooling pipe each of stainless steel are used. The cooling water is isolated from the copper conductor to prevent corrosion and to avoid critical components like ceramic insulators in the cooling circuits. To achieve sufficient heat conductance the coils are sealed with a lead-tin solder.

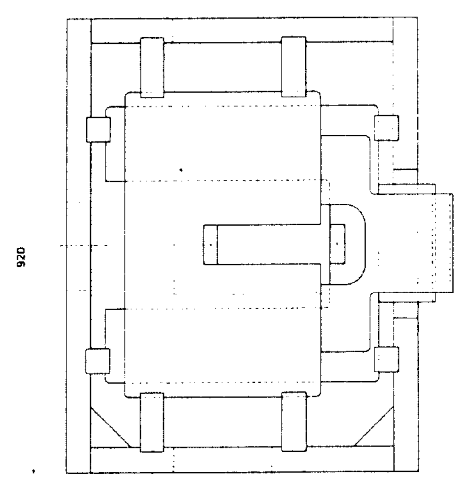

Fig. 5 Front view of kickersegment (dimensions in mm)

Table 3:

Data HEBL-Dipol		
maximum field	0.62	T
bending radius	10.0	m
deflecting angle	15	deg.
gapheight	270	mm
gapwidth	800	mm
outer dimensions incl. coils	3200*1400*1500	mm
weight	app. 38	t
Coils		
mineral insulated conductor area	80	mm^2
no. of turns	880	
resist. at 35 deg.C	1.76	Ohm
current	153	A
power	41.3	KW
cooling water	50	l/min
pressure-drop	6	bar
temperature-rise	13	K

Kicker Magnet

For several experimental areas which share the SNQ-linac beam, only a short fraction of one pulse is required. Kicker magnets are needed to switch this beam fraction to the experiments in order to keep the intensity of the beam at the spallation target as high as possible.

Two magnet systems are discussed. A 230 ns solution with a fast kicker is under construction (Fig. 5).

First a structure of 12 magnets are planned, consisting of 10 kickers and 2 antikickers to correct malfunction of the switch circuit. The characteristic rise time is about 230 ns. A magnetic field of up to 0.03 Tesla will result in a 10 mrad kick. This needs a power supply of about 100 KV and 75 - 100 A/ns switched by thyratrons.

Second a structure of 4 magnets are planned with a characteristic rise time of 20 us. With a magnetic field of 0.06 T a total kick of 18 mrad can be achieved. This needs a power supply with 50 KV and 30 - 70 A/ns also switched by thyratrons.

A prototype magnet will be built for both concepts in order to make frequency and time domain analysis measurements. These measurements will act as a check on the transient response analysis models of the magnets which are investigated using the Spice (8) computer code.

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