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Preliminary Change Request for the Powering of the 21Q40 and 26Q40 Focusing Arc Quadrupoles

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Collider Accelerator Department

Brookhaven National Laboratory

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Abstract

The powering of the 26Q40 arc ring quadrupoles has been reviewed, in order to ensure a good control in the strength of the focusing arc quads with different apertures (21Q40 and 26Q40). For maintaining this good control, for any beam energy the superconducting linac will be able to distribute to the ring, within a wide range (from 1 to 1.3 GeV), the two types of quadrupoles have to be powered individually.

1 The SNS accumulator ring lattice

The SNS accumulator ring has a hybrid type of lattice consisting of four identical arcs and four special function straight sections [1]. The arc has a FODO structure, with four cells (eight quadrupoles and dipoles) plus a quadrupole that matches the arcs with the straight sections. Two quadrupole doublets are placed in the straight sections setting the total number of quadrupoles at 52. The magnetic elements are placed and powered in a way to preserve a four-fold symmetry. The space between the quadrupoles and dipoles is occupied by dipole and multi-pole correctors. A schematic presentation of one super-period is presented in Fig. 1.

2 Justification of change

The optics functions for one super-period for the working point (6.40,6.30) are plotted in Fig. 2. Most of the arc quadrupoles have a 21 cm aperture with a steel-to-steel length of 40cm (21Q40). On the other hand, the physical aperture in the middle of the arc gets wider in order to accommodate the beam size increase, especially close to the horizontal dispersion maxima. This necessitates quadrupoles with different bore diameters in these locations. The

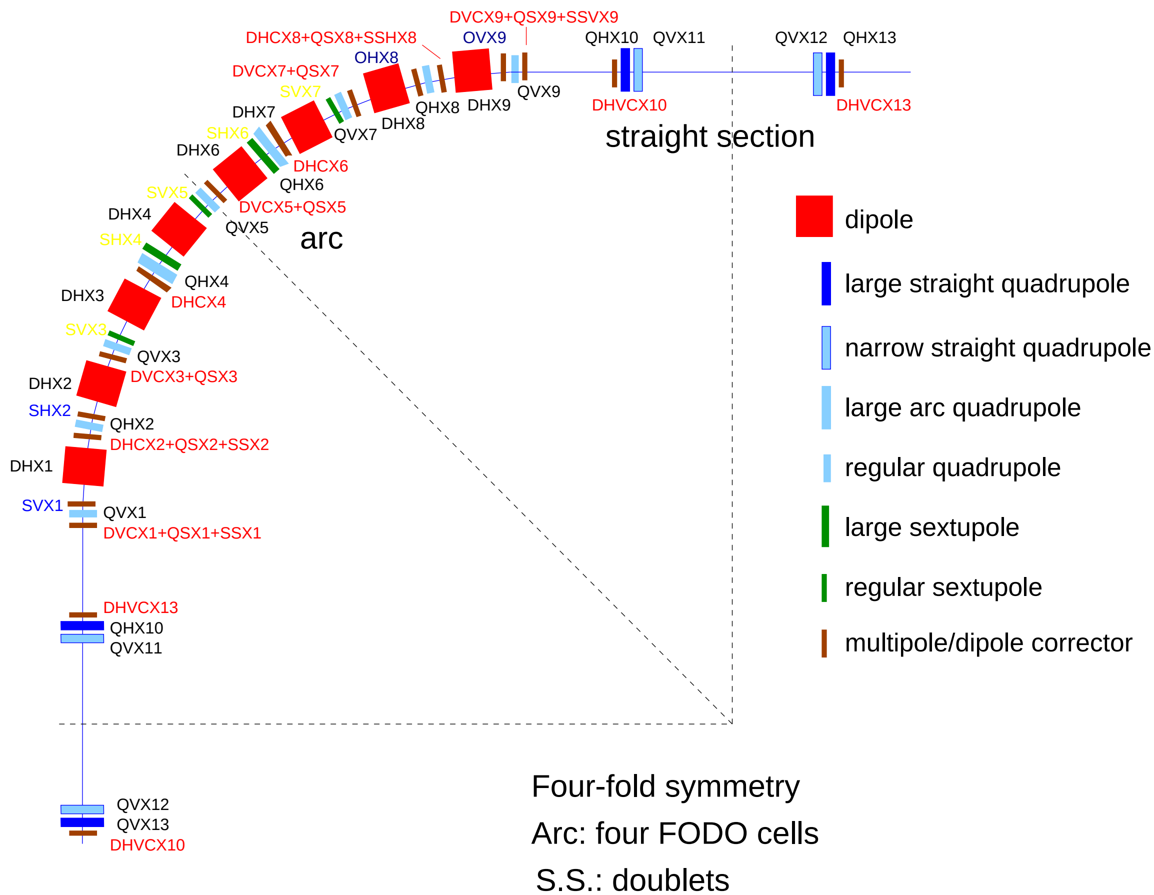

Figure 1: Schematic layout showing dipole, quadrupole, sextupole, and corrector magnets of one lattice super-period. The wide aperture arc quads are upstream and downstream of the quadrupole in the middle of the arc.

corresponding focusing arc quadrupoles have wide apertures of 26 cm with a steel-to-steel length of 40cm (26Q40).

Due to the FODO structure of the arc, all focusing (and defocusing) quadrupoles are powered in series, with the same power supply. The transfer function variation is of the order of 10^{-3} of the quadrupole strength and can be corrected by dedicated quadrupole TRIM windings. On the other hand, the main perturbation in the quadrupole gradient of the wide aperture focusing quadrupoles is attributed to the connection in series with the quadrupoles of smaller aperture. This is apparent in Table 1, where we present the results of TOSCA calculations for two different energies when powering with the same power supply the two types of arc quadrupoles. Especially for the 26Q40 quadrupole, the field difference with respect to the nominal field is of the order of 1 %, for 1GeV.

This systematic error in the quadrupole field can introduce significant optics distortion especially because these quadrupoles are located in areas of maximum dispersion. This can be observed in Fig. 3 where we plot the lattice function for all four super-periods and the associated beta and dispersion perturbation, when a 1 % error is introduced in the gradient

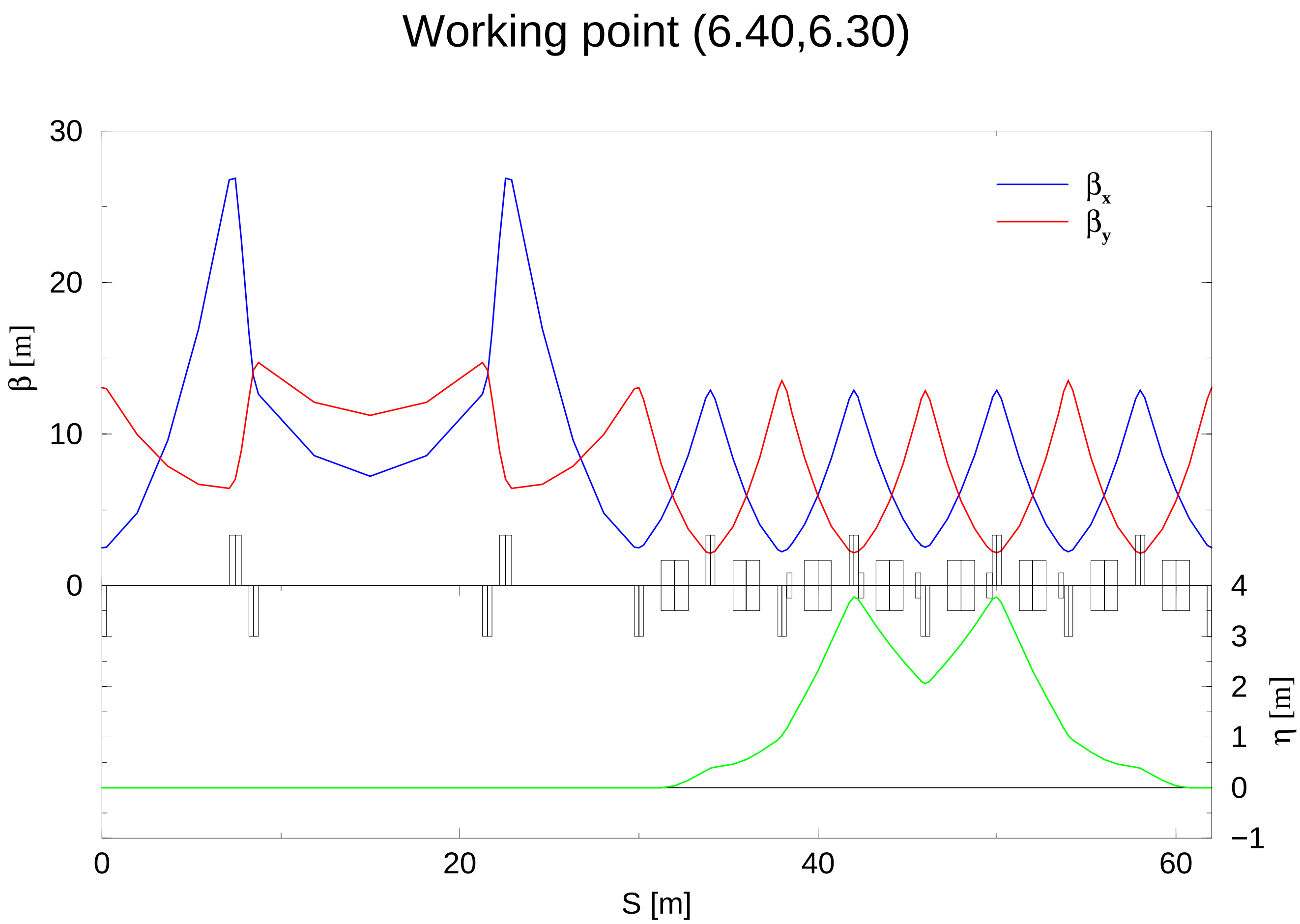

Figure 2: Optics functions for one super-period of the SNS ring. The lattice is matched to the tunes (6.40,6.30).

of the high-dispersion large bore quadrupoles. Even after re-matching the lattice, there is a variation of the horizontal beta function of up to ±3%, especially in the straight sections. The dispersion has a variation of up to ±10%. Especially the straight sections are not dispersion free due to this error. One can note also that the super-periodicity of the lattice is broken. This is mostly pronounced in the horizontal beta function of the straight sections and the dispersion in the middle of the arc.

Since the approval of the modified hybrid design of the accumulator ring [1], it was foreseen to correct the detrimental effect of the systematic quadrupole error of the large bore quadrupoles by including dedicated TRIM windings on the core of both the 21Q40 and 26Q40 quadrupoles and connecting them in series in a single small power supply in addition to the high power supply distributing current to the main windings of the two magnets. In order to achieve the 1 % gradient which will balance out the error a small power supply of 65 Volts and 20 Amps is needed. This power supply was included in the purchase package of the TRIM

Table 1: Quadrupole magnetic parameters extracted by 3DTosca calculations for 1 and 1.3GeV operation

Kinetic Energy (GeV)		1	1.3
Current/Turn (Amp)		729.02	911.31
21Q40	Tip Field (T)	0.4767	0.5753
	Tip Field Integral (T m)	0.2451	0.2956
	Requirement (T m)	0.245	0.295
	Error (%)	0.04	0.20
26Q40	Tip Field (Tesla)	0.5908	0.6981
	Tip Field Integral (T m)	0.308	0.3637
	Requirement (T m)	0.305	0.365
	Error (%)	0.98	-0.36

windings power supplies and a PCR was submitted on May 2000 [3], which was not finally approved.

On the other hand, additional studies were carried out with respect to the magnetic design of the quadrupoles. More specifically, in order to have the two types of quadrupoles operate at the same current but at different field points, their degrees of saturation has to be brought as close as possible. Since the 21Q40 had an optimized design, it was necessary to reduce the saturation on 26Q40 quadrupole. It was finally found out that it would be difficult to reduce the field saturation level at the bottom of the poles of the 26Q40 for 1GeV and 1.3GeV, without changing drastically the mechanical design (tapering the poles or adding neck chamfers).

Thus, a different option was considered, where the 26Q40 quadrupoles are powered independently of the 21Q40 quads. The latter would necessitate the purchase of two same size medium power supplies. This option is much more robust than the previous one as it would solve both the gradient perturbation and the magnetic field quality problems. It would also simplify the mechanical design of the magnet by removing the additional TRIM winding. Finally, the number of cables for connecting the TRIM windings will be further reduced.

A third option would be to use dissipative shunts, which are optimum for warm magnets and are extensively used in RHIC and CEBAF and are proposed for the SNS LINAC. These devices are used to divert the current but they cannot supply any power. It is not possible, however, to shunt all four super-periods with a single shunt supply and this means that four shunt supplies will be required. For a 1% correction, a 1% change in current is required. The 26Q40 magnets operate at a maximum of 1100A, so the shunts need to operate at 11A. A minimum compliance voltage of about 3V is needed. Considering that the resistance of the 26Q40 is 26.6 ohm, the two magnets in series at 1000A is over 50V. Thus the required units have to be rated at 15A/75V for 1125W. note that the shunts in the LINAC are much smaller: 20A/5V for 100W, and cannot be used in the ring.

The last option presents several potential problems and was finally dropped. The first has to do with controls: the set-point to the shunt supply is not the magnet current, but its difference from the preceding magnet. This caused a fair amount of problems in the control system for RHIC. The second has to do with the supply protection: in a shunt system, the shunt supply must be protected from the amount of energy the main supply can make available. The worst case is often where the large supply trips and the shunts are still active. The stored energy in the magnets must not go into the shunts. Finally, care needs to be taken so that the various regulation loops do not interact. Due to all the technical issues mentioned above in addition to non-negligible cost and schedule impact, the shunt supplies options was finally dropped.

3 Impact in Schedule and Budget

There will be no impact in schedule if we choose the separate medium power supplies connection scheme for the focusing arc quadrupoles. In fact, the mechanical design proceeded under this assumption. On the other hand, going back from the present (medium+medium) PS scheme to the previous (high+trim) scheme carries high risk in schedule of about 2 months and performance, in addition to a marginal reduction in cost, considering the redesign and measurement efforts of around $ 40,000 and probably the purchase of spare power supplies. The actual cost impact of the separate power supply scheme would be $ 74,277.

4 Summary

The powering scheme of the focusing arc quadrupoles with different bore radius was reviewed. It was found that the prefereble scheme for physics, cost and schedule issues would be to connect the different type of quadrupoles with 2 medium power supplies instead of the initial connection scheme with one high power supply and an additional TRIM winding,

5 Acknowledgments

Nuria Catalan-Lasheras provided the code for studying the optics function comparison between two lattices. Many thanks to George Mahler and John Smith for their help on engineering and control issues and Kerry Mirabella for her assistance in the cost estimates.

References

[1] J. Wei, *et al.*, BNL/SNS Technical Note 76, 2000.

[2] N. Catalan-Lasheras, BetaBeat script.

[3] Y. Papaphilippou and N. Tsoupas (eds.), BNL/SNS Technical Note 75, 2000.

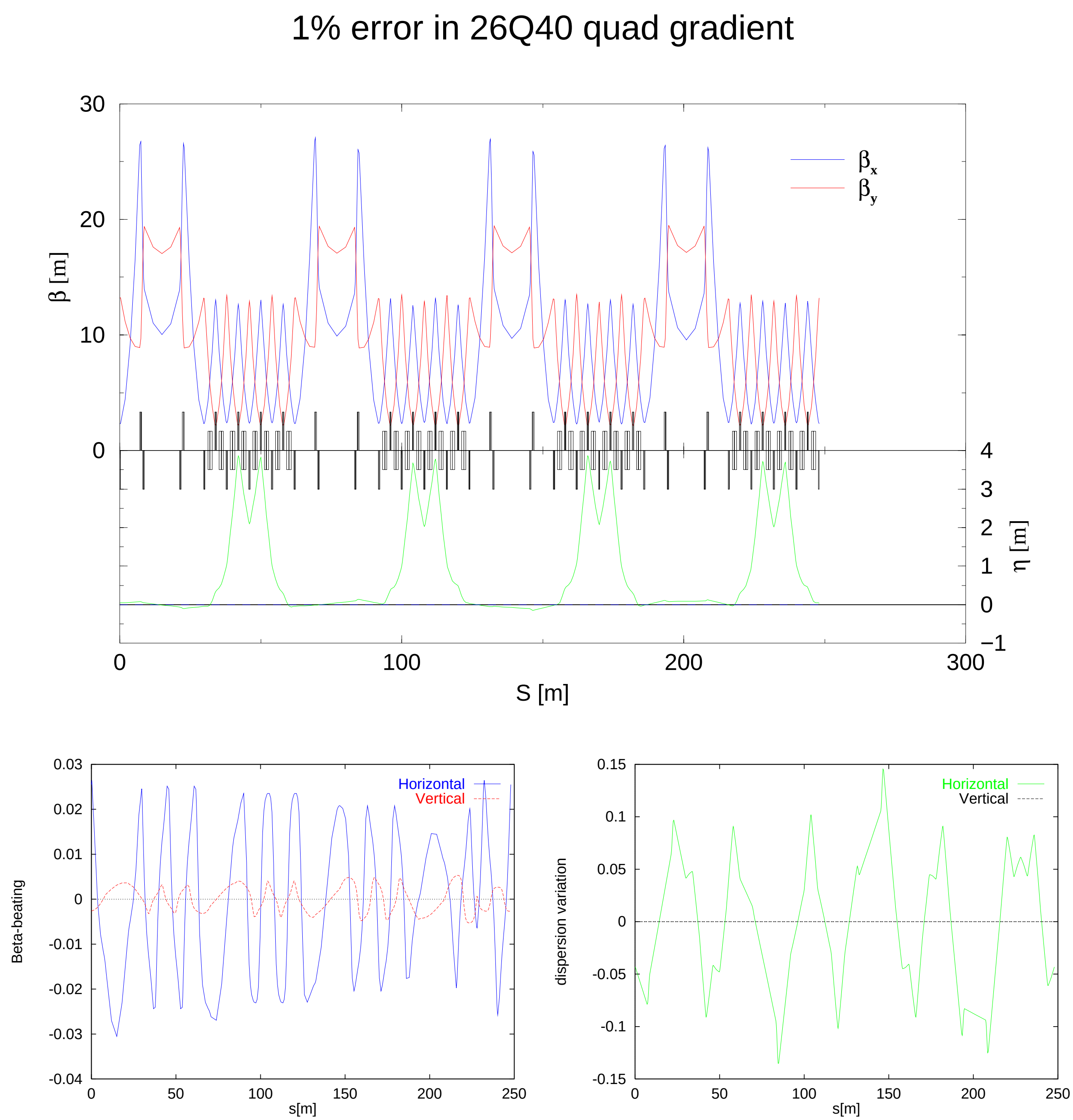

Figure 3: Optics functions (top) and beta and dispersion beating [2] (bottom) after including a 1 % systematic error in the quadrupole strengths of the large bore arc quadrupoles, for a lattice matched to the working point (6.40,6.30).