SNS RING EXTRACTION SEPTUM MAGNET AND ITS INTERFERENCE WITH ADJACENT QUADRUPOLE*

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Abstract

3D computing simulations have been performed to study magnetic field distributions of the SNS ring extraction Lambertson septum magnet. The magnetic field for extracted beams is fully characterized in all the aspects. The stray field on the circulating beam line and the effect of a shielding box upstream and a shielding cap downstream is investigated. In addition, the magnetic interference between the Lambertson and an adjacent quadrupole has been studied. The simulations have provided valuable information for the SNS ring commissioning and operation. This paper reports our simulation techniques and the major results.

INTRODUCTION

The SNS accumulator ring extraction system is built in one of its four straight sections. Figure 1 shows a part of the straight, containing an Extraction Lambertson Septum (ELS) magnet followed by a quad doublet assembly. During the ring accumulation, the circulating beam passes through a well-shielded aperture in the upper part of ELS. Its effect on the beam should be a minimum. The ring extraction takes place in a single turn and two steps after the beam is fully accumulated. The AC kickers upstream (not shown in figure) are first fired, that pushes the beam down to the dipole entrance of ELS, which in turn bends the beam horizontally out of the ring.

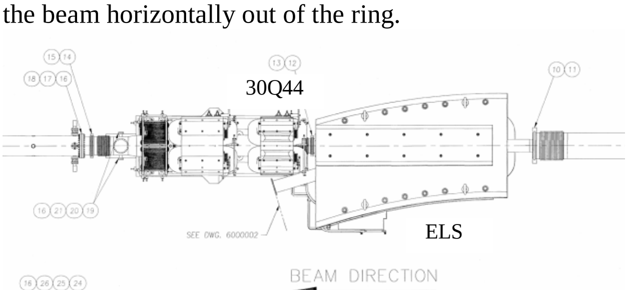

Fig. 1: Extraction septum and quad assembly (Courtesy of BNL/SNS design drawing and specifications)

The ELS was designed by the BNL/SNS team [1, 2]. Its structure is quite complex and its field distributions are very critical to the extracted beam, as well as to the circulating beam. The ELS is closely installed with the downstream quad assembly. Its interference with the quad has been a concern. Therefore, we have performed 3D simulations of ELS, as well as its assembly with a downstream quad 30Q44. In this paper we report our simulation results, including the ELS performances and its effect on the neighboring quad.

3D MODEL OF ELS

The simulation environment is OPERA3D/TOSCA [3]. The model is built with the OPERA package "Modeller" rather than the "Pre-processor". The Modeller makes it easier to simulate two or more magnets together. A single ELS model is shown in Fig. 2, where the top one is the view on the upstream side, while the bottom one downstream side. The circulating beam passes through the upper, round, straight aperture, which is very well shielded. The extracted beam goes through the lower, curved, ELS pole-tips. A shielding box upstream and a shielding cap downstream can also be seen. These parts are critical for shielding the circulating beam from the ELS stray field. In the model, the mechanical dimensions follow exactly the BNL/SNS design drawings and specifications. The coordinate system origin is that z=0 at the magnet entrance face, y=0 at the middle plane, and x=0 at the pole-tip center. The magnet is energized at 1988 A in the model, which is for a 1 GeV proton beam.

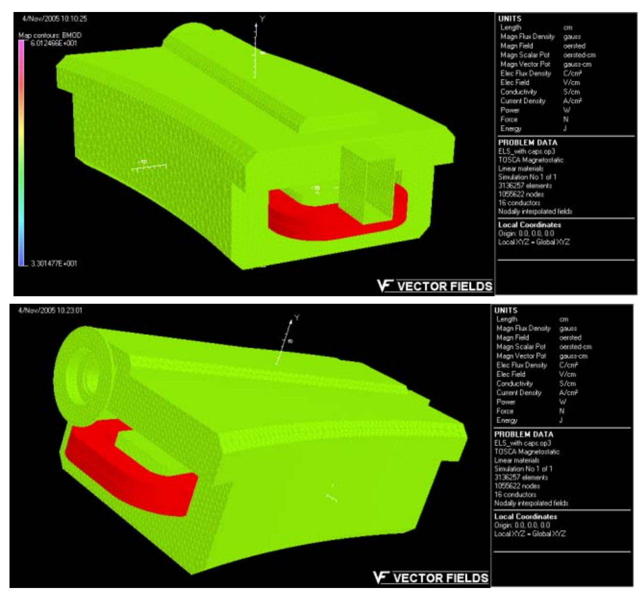

Fig. 2: 3D simulation model for ELS

The post-processor file is employed to obtain field distributions and to analyze other magnet performances. Figure 3 shows the magnetic field across the ELS gap at its longitudinal center (z=-120 cm) and on the middle plane (y=0). The field is quite uniform within the pole-tip region with a magnitude of 7043.5 G. The extracted beam should follow the curved ELS axis inside the magnet, along which the magnetic field is shown in Fig. 4. If we extend the beam trajectory outside ELS for 50 cm along straight lines and take the fringe field into account, we obtain a total integrated dipole field of 1.760 T-m.

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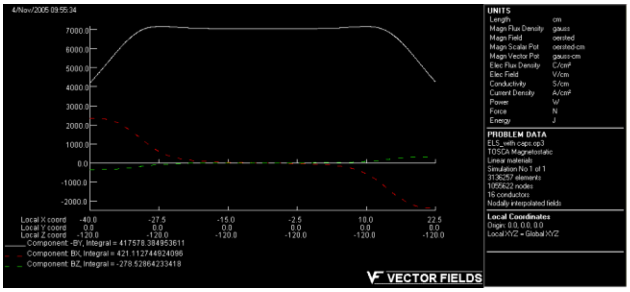

Fig. 3: Field across ELS gap at its center.

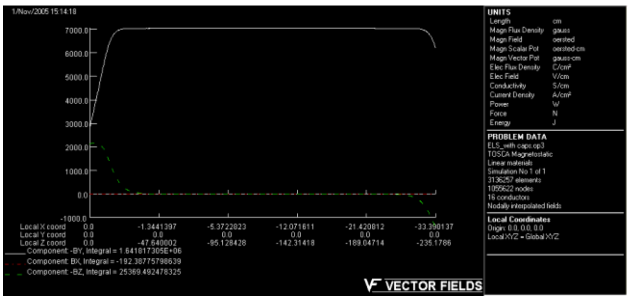

Fig. 4: Field along ELS axis within the magnet.

The square box at the ELS entrance and the round cap attached to its exit are employed to shield the circulating beam from the ELS stray field. Figure 5 shows the field distribution along the circulating beam axis from the ELS entrance extended upstream by 50 cm. The B_y integral is about 101 G-cm, while the B_z integral is about 377 G-cm. Without the shielding box in the model, the B_y integral would be more than 5000 G-cm, while the B_z integral would be more than 1200 G-cm. For the downstream of ELS, the field distribution is shown in Fig. 6. The integrals for the three components are all more than 600 G-cm. These integrals would be quite higher without the round cap. But, the field distribution and amplitude would be changed completely when a quad exists closely in downstream.

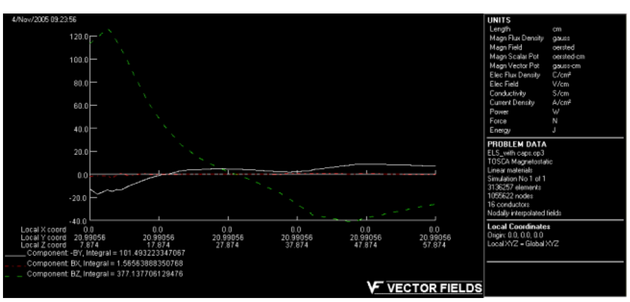

Fig. 5: Field along circulating beam axis upstream.

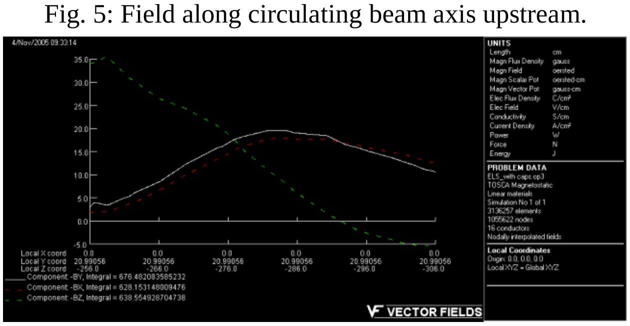

Fig. 6: Field along circulating beam axis downstream.

ELS INTERFERENCE WITH QUAD

Along the circulating beam axis the ELS exit face is only about 30 cm away from the downstream quad (30Q44) entrance. The magnetic interference between the two magnets has become a concern. Not only the quad field can be affected by ELS, but also the ELS field for the extracted beam could be affected by the quad. We have built a 3D simulation model, as shown in Fig. 7, to investigate the issue. The coordinate system origin of this model is at the quad center.

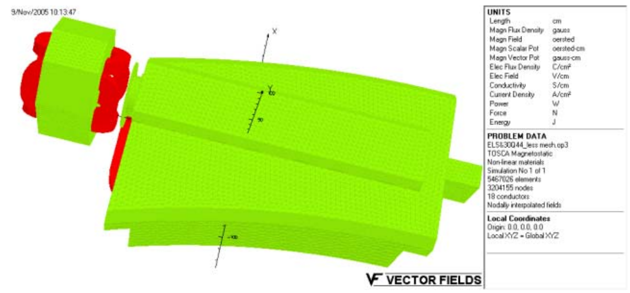

Fig. 7: 3D model for quad and ELS assembly.

The quadrupole 30Q44 has been well studied and its performance data are already available [4]. We then can compare its results with those from Fig. 7. For example, Fig. 8 shows the magnetic field versus z at x=8 cm and y=0. The top one is from a single 30Q44; while the bottom one is from the model of both 30Q44 and ELS. The B_y integral of 30Q44 is reduced by 1.3% in the presence of ELS.

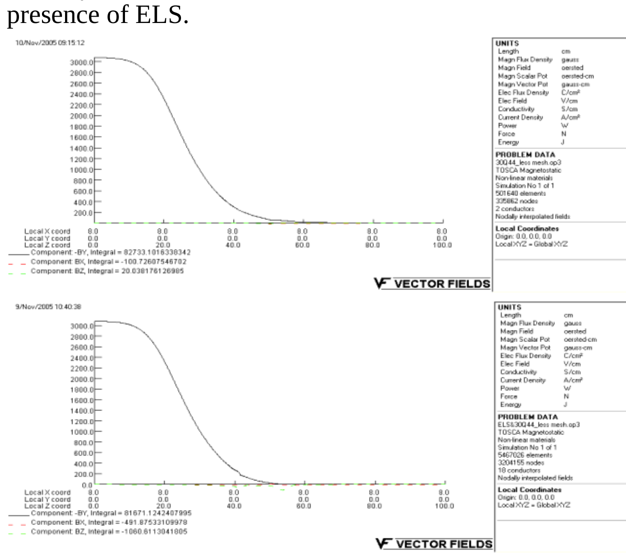

Fig. 8: B vs. z at x=8 and y=0 cm for two cases.

By applying the method of patch rotation [5] to the model in Fig. 7, we can obtain the two dimensional field parameters being compared with those for a single 30Q44, as listed in Table 1. With the presence of ELS, the integrated gradient of 30Q44 is reduced by 1.3%, consistent with that shown in Fig.8. A dipole kick of 51 units (n=1) is exerted on the quad, which accounts for about 840 G-cm. In addition, other higher harmonics are generated for the quad field, such as the sextupole of 9.62 units, etc.

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Table 1: Interference in two dimensional parameters.

	ELS+30Q44	30Q44 alone
Gradient integral (T)	2.0453	2.0725
	Harmonic Amplitude (units)	
n=1	51.48	0.00
2	10000	10000
3	9.62	0.00
5	3.44	0.00
6	1.80	2.85
7	1.43	0.00
Reference radius (cm)	8	
Integral length (cm)	z=-100 to 100	
	* z=0 is at 30Q44 center	

We have also performed 3D multipole expansion [6] to the model in Fig. 7 in order to yield the z-dependent parameters. Figure 9 shows the generalized gradient for m=1 (dipole term). The integral of the normal term is -754 G-cm, while it is -280 G-m for the skew term. Figure 10 shows the generalized gradient for m=3 (sextupole). The integrals are 0.24 and -0.18 G/cm for the normal and skew terms, respectively. For 30Q44 alone, all these terms should not exist in good simulation models.

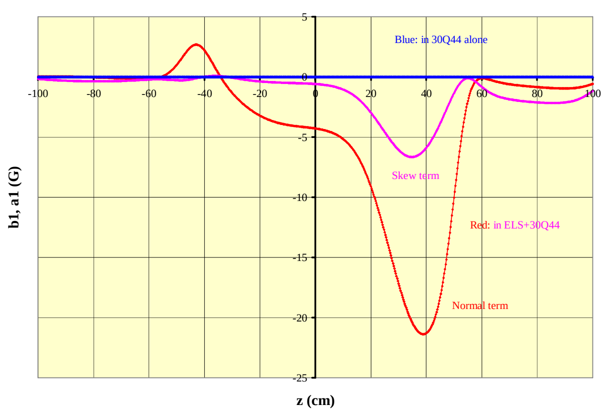

Fig. 9: Generalized gradient for m=1.

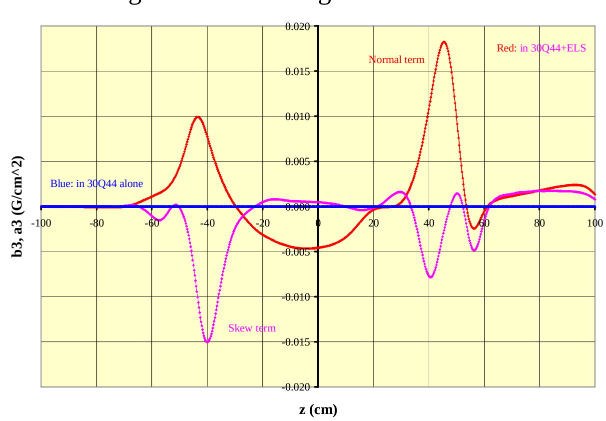

Fig. 10: Generalized gradient for m=3.

The ELS field for the extracted beam is also affected by the quadrupole. Figure 11 shows the magnetic field along the extracted beam axis from the ELS exit face extended 50 cm downstream. The top view is for ELS alone as calculated from the model in Fig. 2; while the bottom view is for ELS plus 30Q44 as in the model of Fig. 7. Since the two models use different coordinated system, the two plots appear differently, but they give the field on the same line. A comparison indicates that the B_y integral of the ELS field is reduced by 3.5% with the presence of 30Q44.

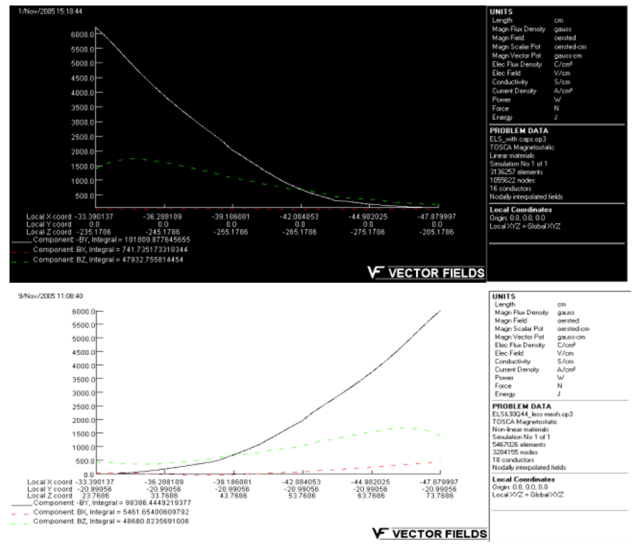

Fig. 11: ELS field affected by 30Q44.

SUMMARY

3D modeling of SNS ring extraction septum has provided the magnetic field distributions and performance characteristics of the magnet. The shielding box upstream and the cap downstream are very important to reduce the effect of the ELS stray field on the circulating beam. The magnetic interference between ELS and an adjacent quad appears to be moderate and can be compensated or corrected by other devices in the beam lines.

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