Fermi National Accelerator Laboratory
P.O. Box 500, Batavia IL, 60510

TD-08-009
03/24/2008

Large bore HTS magnet for muon helical cooling channel

V.V. Kashikhin, A.V. Zlobin

Introduction

Parameters of the helical cooling channel (HCC) necessary to achieve the muon cooling factor relevant for the future muon collider have been determined based on the beam simulations [1]. The first (low-field) HCC section, compatible with the MANX experiment, can use either small or large aperture magnets depending on the additional space constraints [2]. This work explores the possibility of using the large bore magnet option for the last (highest field) HCC section.

Magnet design

The 3D magnet model is shown in Fig. 1. It consists of the helical dipole coil placed inside of the straight solenoid. Such configuration was chosen in favor of the MANX type design with the dipole and quadrupole coils placed around the solenoid because of large peak field in the dipole coil.

The flux density distribution calculated at the nominal current is shown in Fig. 2 for each coil. It can be seen that although the helical dipole and solenoid need to produce 4.5 T and 17.4 T respectively, the peak fields in these coils are 34.5 T and 27.5 T that is viable to achieve only with the high temperature superconductors (HTS).

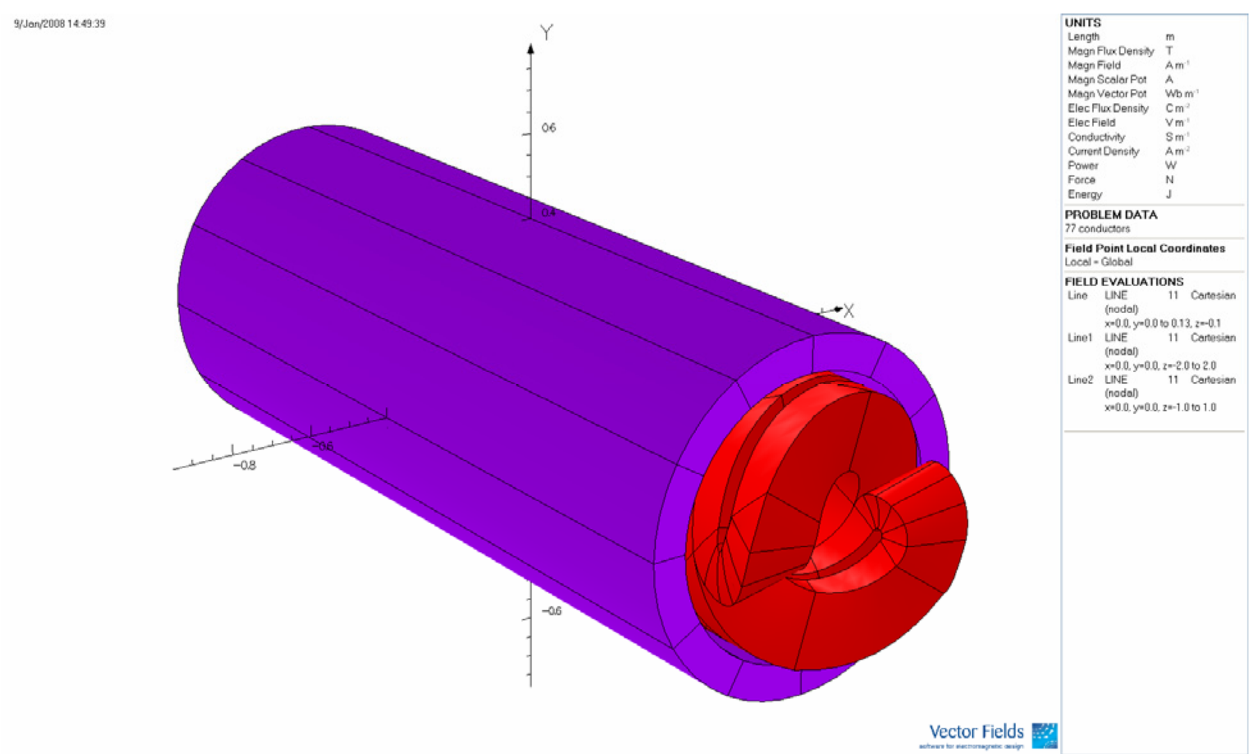

Figure 1. HCC magnet model.

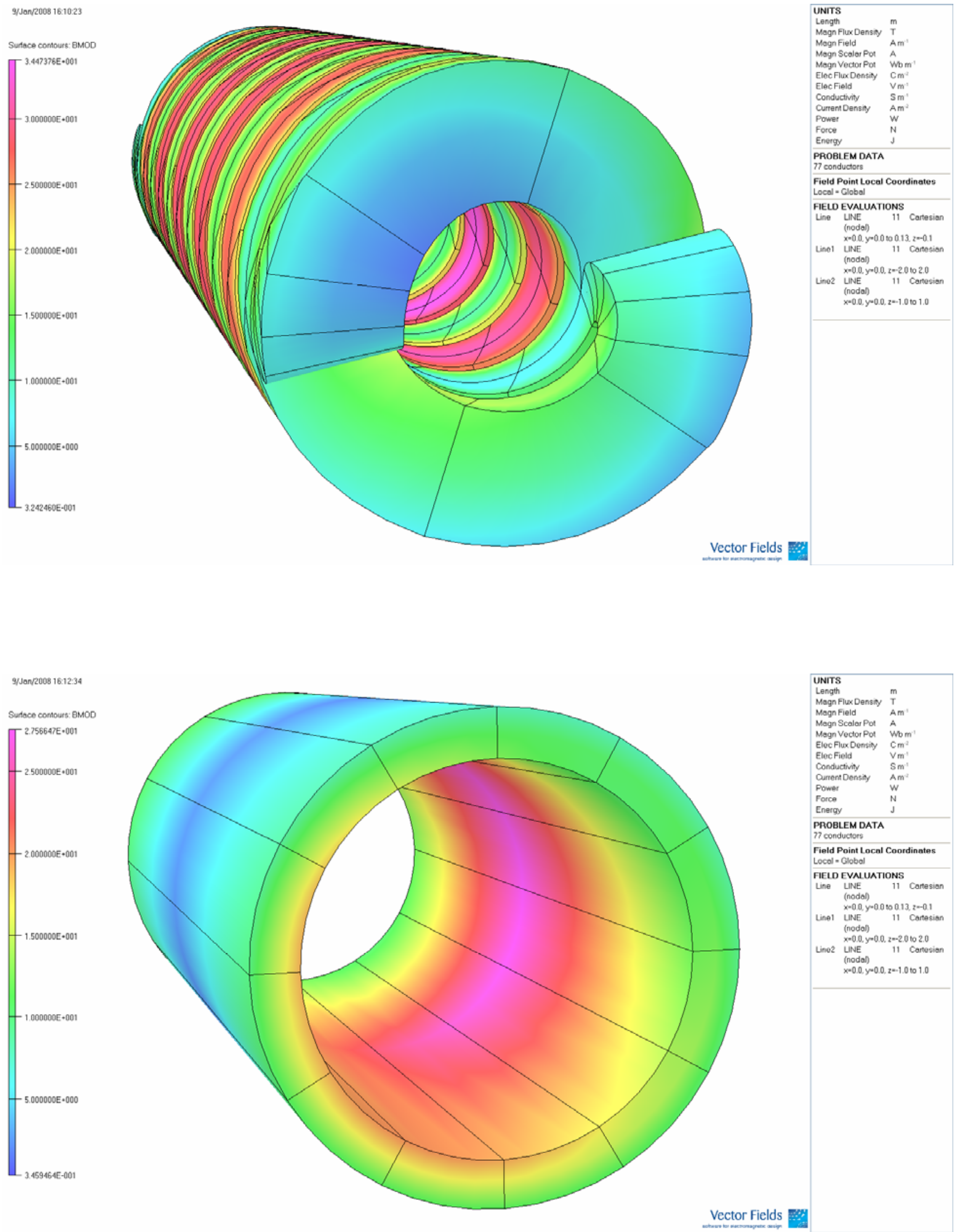

Figure 2. Flux density distribution in the helical dipole (top) and solenoid (bottom) coils. The field was calculated with both coils in place; for clarity each coil is shown separately.

The reason of large difference between the field required on the beam orbit and the peak field in the coils is illustrated in Fig. 3. The necessary for muon cooling relationship between the solenoidal and dipole field components is achieved in the beam envelope location shown. Due to the high field gradient across the aperture, the peak field occurs at the opposite side of the aperture. Thus, it essentially doubles the coil peak field with respect to the maximum field on the beam orbit.

The magnet load lines and critical current density in HTS superconductor are shown in Fig. 4. The assumption made for the superconductor properties and insulation were the same as in the design of the 50 T solenoid [3]. Either the Bi-2223 tape or Bi-2212 round strand, that have similar engineering critical current densities, can be used. The helical dipole coil has virtually no quench margin at the operating field and the solenoid has a small (10 %) margin. Further increasing of the coil thickness in order to gain the extra margin is very inefficient in a coil with the thickness comparable to its aperture. Therefore, the operating field has to be reduced by 20-30 % in order to obtain the necessary quench margin.

The combined magnetic field components produced by the helical dipole and solenoid coils are presented in Fig. 5-6. One can see that the required solenoidal and dipole component are precisely reproduced. However, the field gradient of 16 T/m is off by an order of magnitude. A dedicated quadrupole coil of a reasonable thickness would be able to correct only 1-2 T/m that would still leave a much than necessary larger gradient. Its impact on the muon cooling performance needs to be evaluated in the beam simulations.

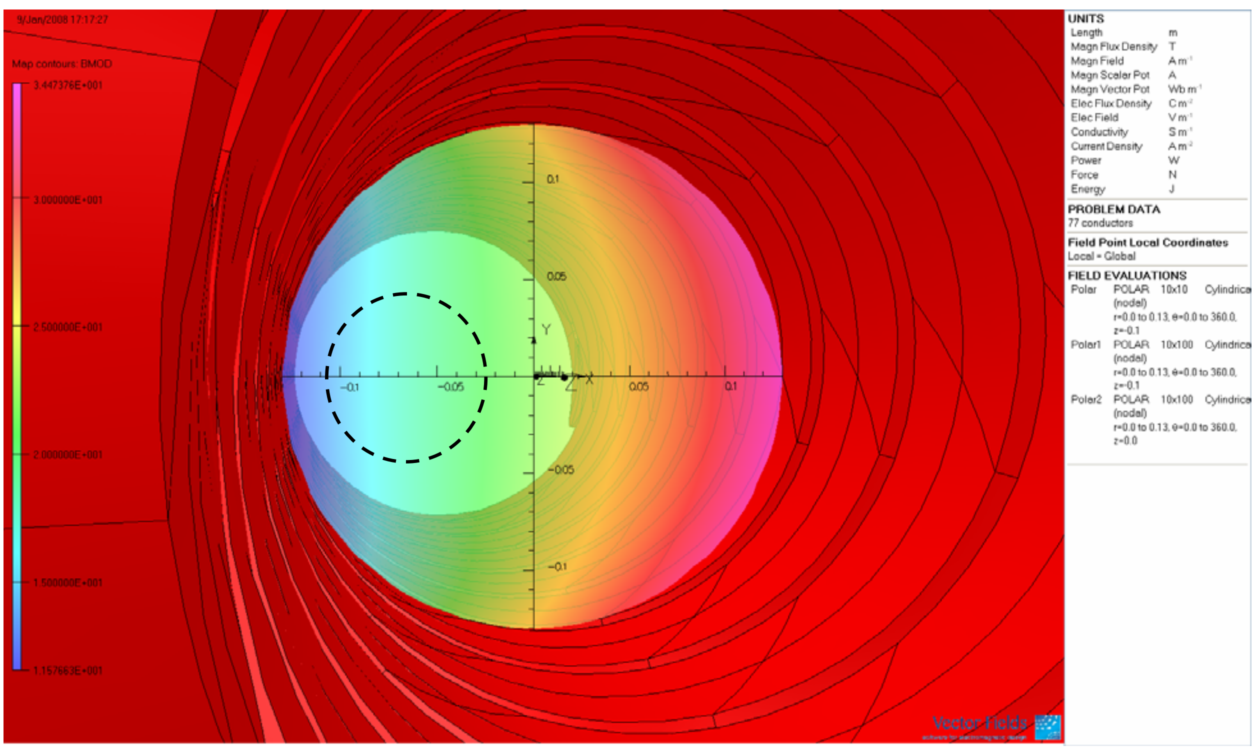

Figure 3. Flux density distribution in the magnet aperture with the relative position of the beam envelope (dashed line).

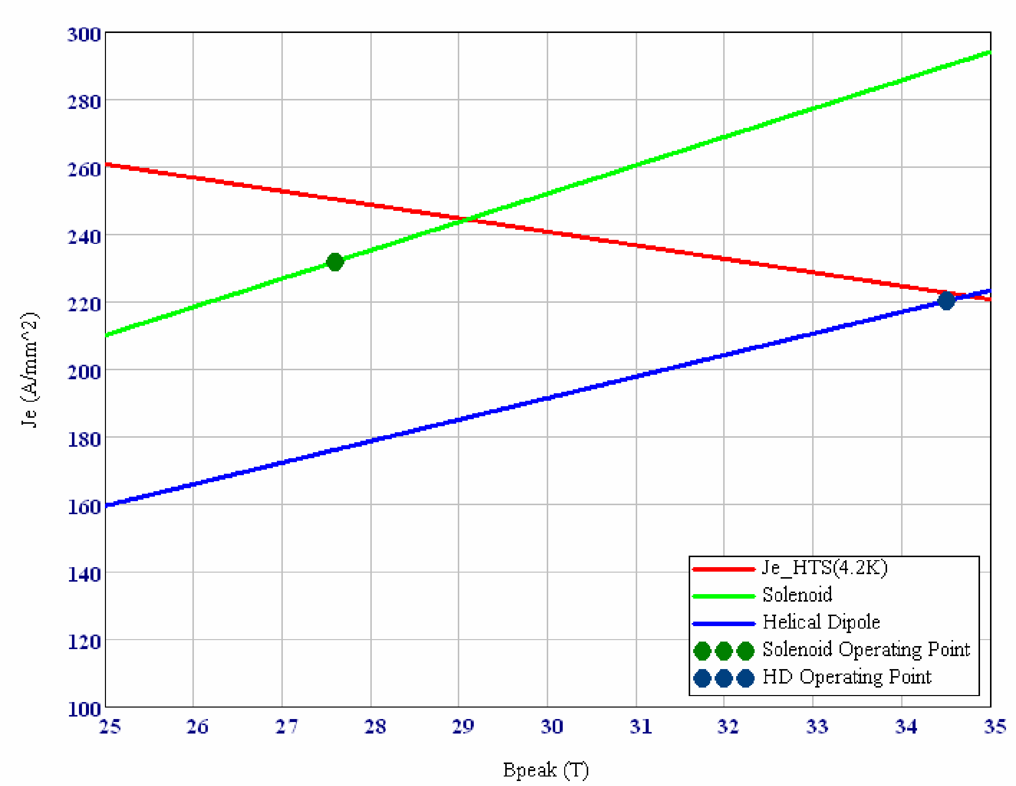

Figure 4. Engineering critical current density in the HTS material and the solenoid and helical dipole load lines.

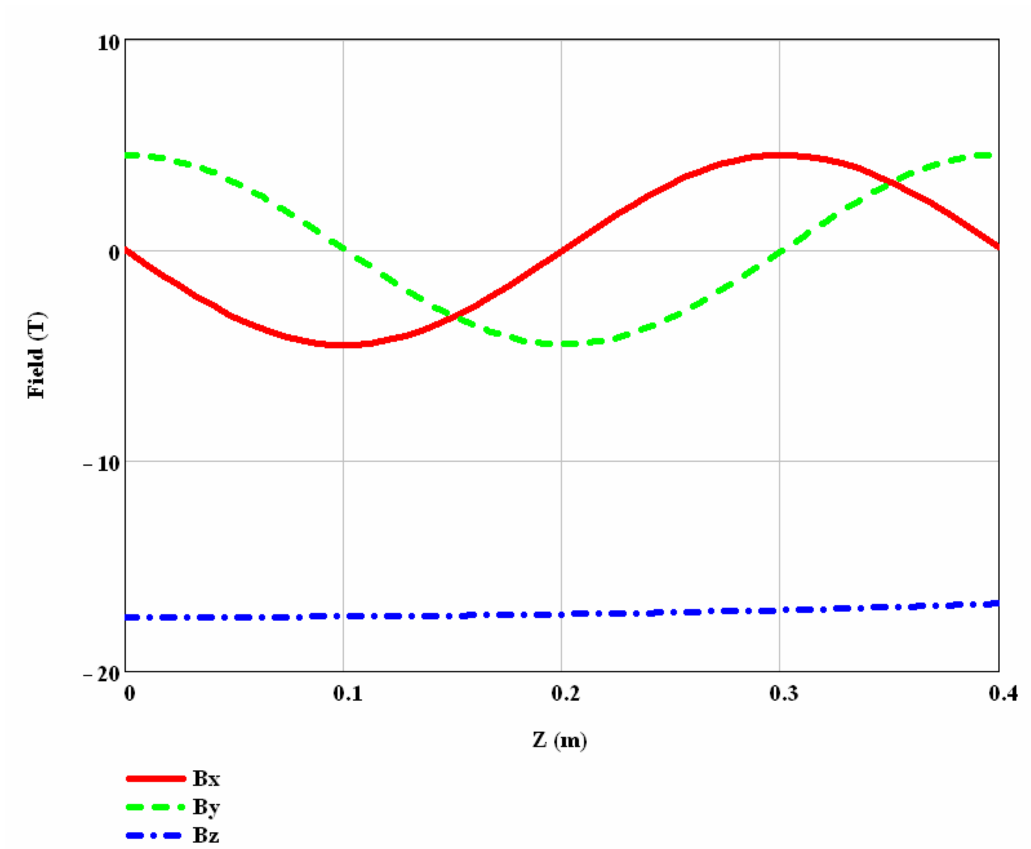

Figure 5. Magnetic field components produced on the beam orbit in the global coordinate system.

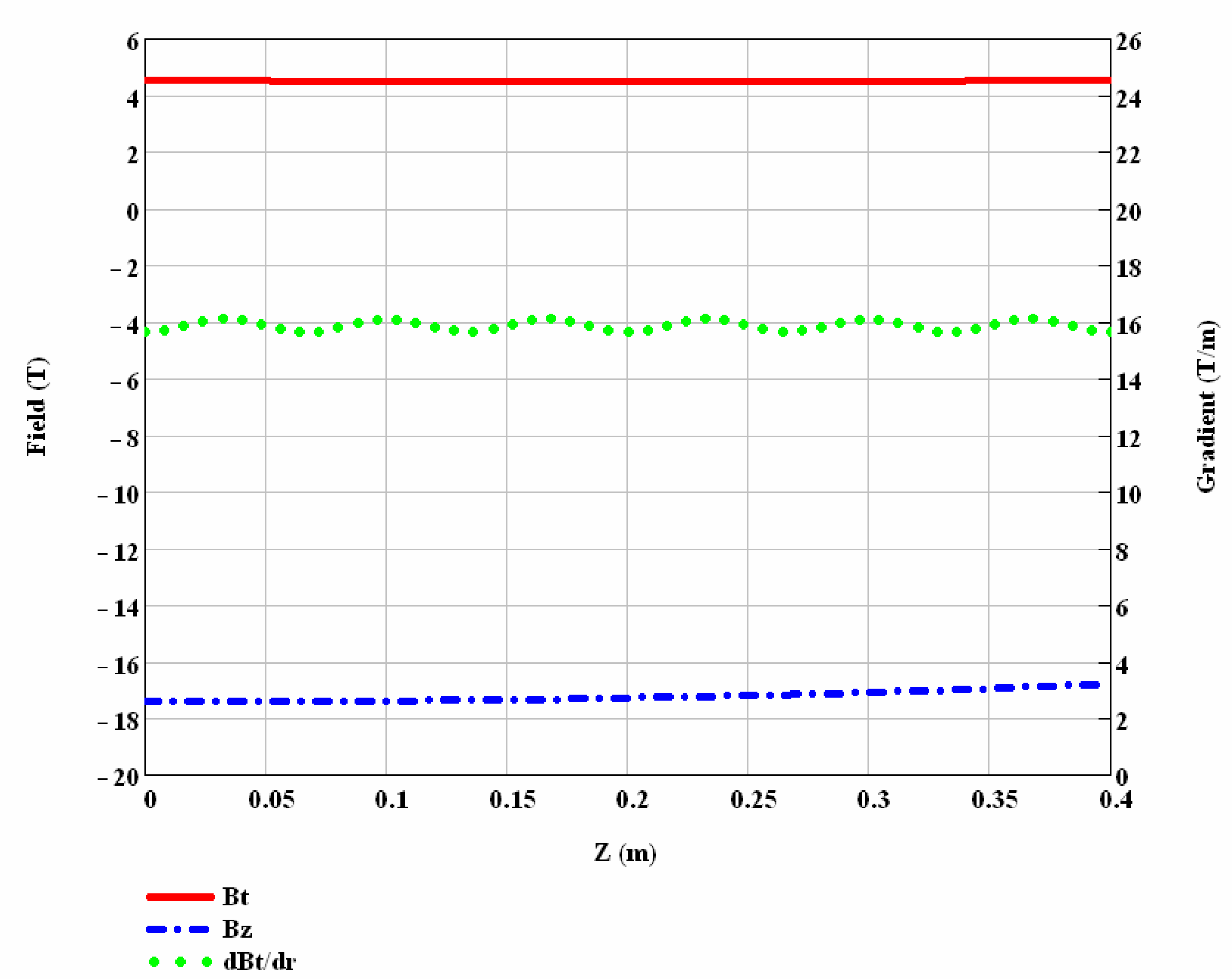

Figure 6. Magnetic field components produced on the beam orbit in the local (beam-linked) coordinate system.

References:

1. S.A. Kahn, M. Alsharo'a, R.P. Johnson, V.S. Kashikhin, V.V. Kashikhin, K. Yonehara, A.V. Zlobin, **Magnet System for Helical Muon Cooling Channels**, *Proceedings of PAC07*, Albuquerque, New Mexico, USA, pp.443-445.
2. V.S. Kashikhin, V.V. Kashikhin, K. Yonehara, R.P. Johnson, N. Andreev, I. Novitski, A.V. Zlobin, **Superconducting Magnet System for Muon Beam Cooling**, *IEEE Transactions on Applied Superconductivity*, Vol. 17, No. 2, June 2007, pp.1055-1058.
3. V. V. Kashikhin, E. Barzi, V. S. Kashikhin, M. Lamm, Y. Sadovskiy, and A. V. Zlobin, **Study of High Field Superconducting Solenoids for Muon Beam Cooling**, to be published in MT-20 conference proceedings.