Physical Design of the Superferric Dipole for EMuS

Y. Chen[1], H. T. Jing[1], J. Y. Tang[1], Z. L. Hou[1], Z. A. Zhu[1]

1. Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

Thu-Af-Po4.01-12 [12]

Institute of High Energy Physics

Background

The EMuS is an excellent platform for the R&D of the key technologies of the next-generation neutrino beam facility at CSNS (China Spallation Neutron Source), also for the multi-disciplinary applications based on μSR technique. The dipole on the EMuS beamline used for minus/positive particle selection and deflection is designed as a superferric magnet in detail because of its large aperture and high field.
All the calculations are performed with OPERA3D/TOSCA, ANSYS/APDL-STRUCTURAL and ANSYS/APDL-FLOTRAN.

Objectives

- The required field homogeneity should be better than $\pm 5.0\times10^{-4}$ at 1.667 T in a wide aperture of 300 mm × 300 mm.
- Stress and deformation of coil should be less than 100 MPa and 0.5mm respectively.
- Optimization of self-cooled current lead, the ratio of length to diameter, temperature, Helium mass flow rate, heat leak

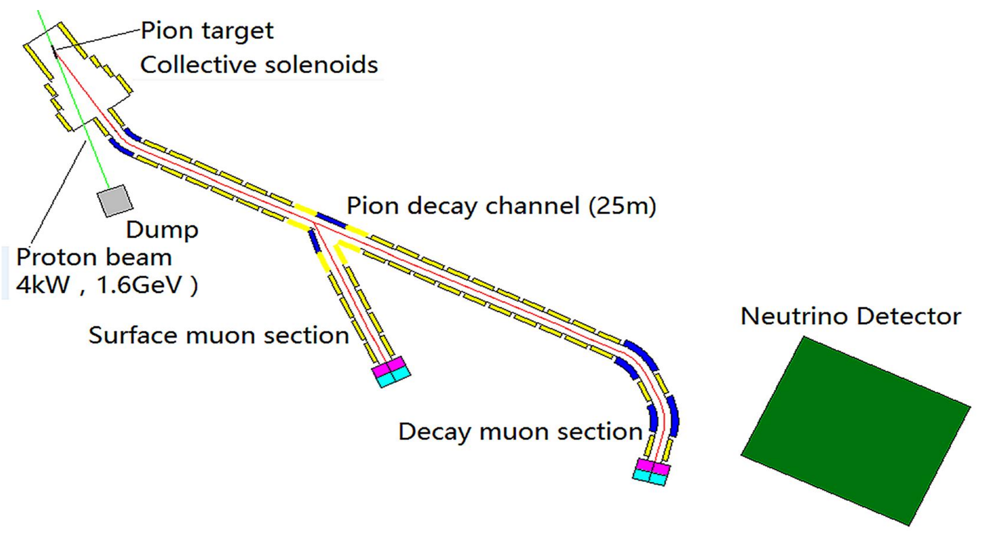
Conclusion

- Three ways are used to improve the field quality of the large aperture EMuS dipole, including trim slots, asymmetrical shims and end chamfering. The integral field uniformity is better than $\pm 5\times10^{-4}$.
- Using coil cases to compact coils, the maximal stress and deformation of coil assembly are 94 MPa and 0.34 mm respectively, which can be accepted, the case also serves as helium containment.
- A self-cooled current lead is designed via fluid analysis, the helium gas passes through the hollow copper tube, the dimensions of length and cross section are optimized, the heat leak of one lead is 0.61 W with 12mg/s helium flow rate @217 A.

These results are all from physical calculations for now, we also consider using HTS current lead instead of self-cooled current leads in further deigns .

EMuS Layout

The present EMuS layout



Experimental Muon Source (EMuS) is planned as the first muon source in China. The roles are as the R&D for the Chinese accelerator neutrino physics. At the same time, the high-intensity muon beam is supplied to carry out multi-disciplinary researches based on the μSR technique.

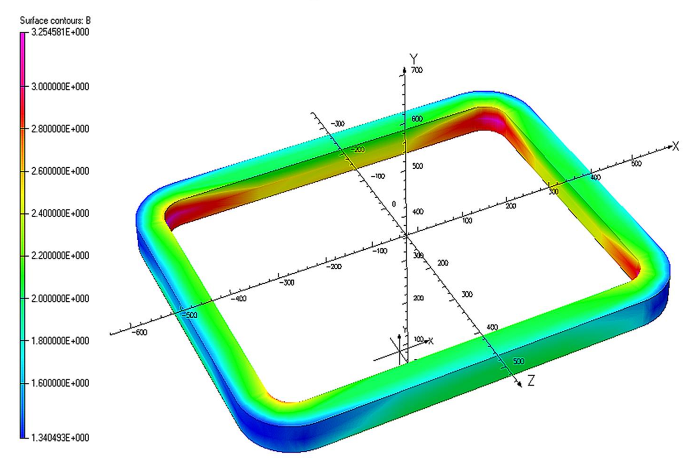
Design parameters of EMUS dipole

Name of the magnet	EMuS-Dipole
Design	superferric C-type, straight
Max. dipole field(T)	1.667
Bending angle(degree)	30
Curvature radius(mm)	1000.68
Pole width(mm)	700
Effective path length(mm)	262
Useable horizontal aperture(mm)	300
Useable vertical gap(mm)	300
Vertical pole gap height(mm)	320
Integral field quality	$\pm5.0\times10^{-4}$

Because the space is very tight at the entrance of large solenoids, the width of pole face is only 600 mm, the superferric C-type dipole with rectangular structure is considered as the best choice for now.

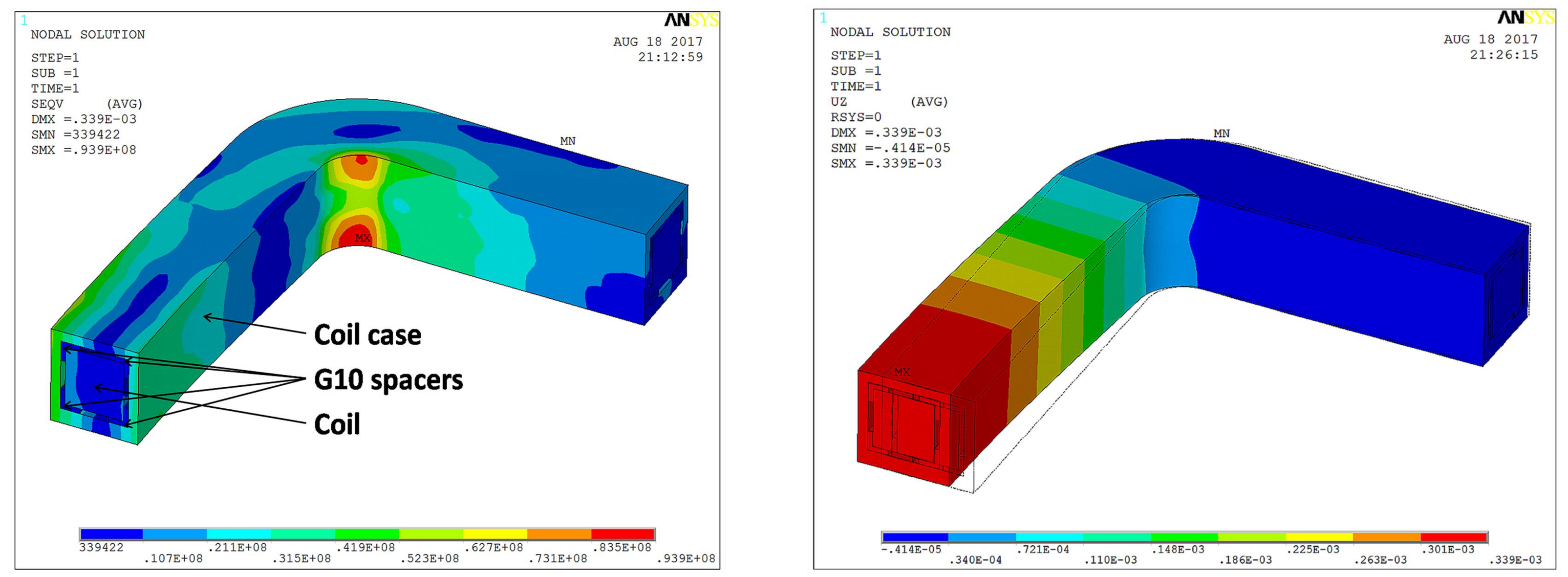
Stress & Deformation of the $Nb_{}$-T_i coil

The field distribution in coil @ 1.667 T



The Nb-Ti/copper wires are used for EMuS dipole coils, the ratio of Cu to Nb-Ti is 4, the dimension of cross section is 1.8 mm×1.2 mm, the current of every wire is 237 A, the Io/Ic is 25%, the maximal arrives at 3.25 T.

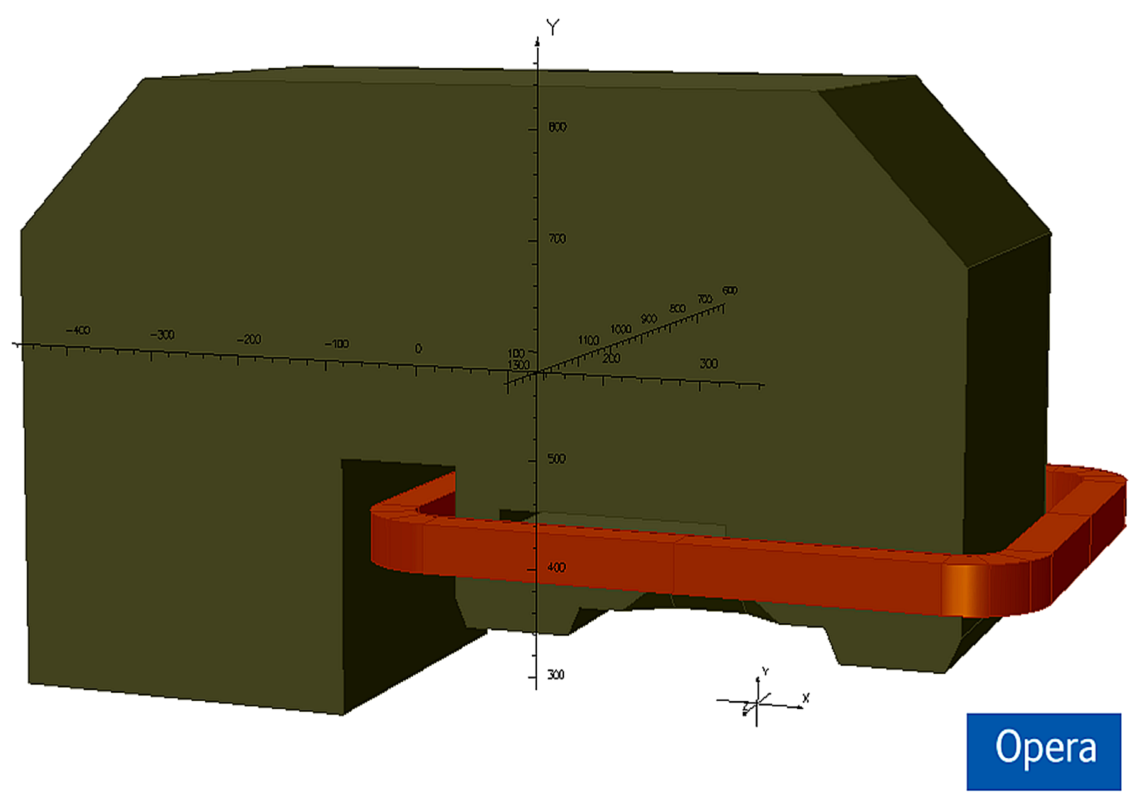
Stress and deformation analysis



the maximal von Mises stress is reduced to 94 MPa, the maximal displacement is only 0.34 mm, which is located at the middle of the long side of the coil assembly, these results can be accepted.

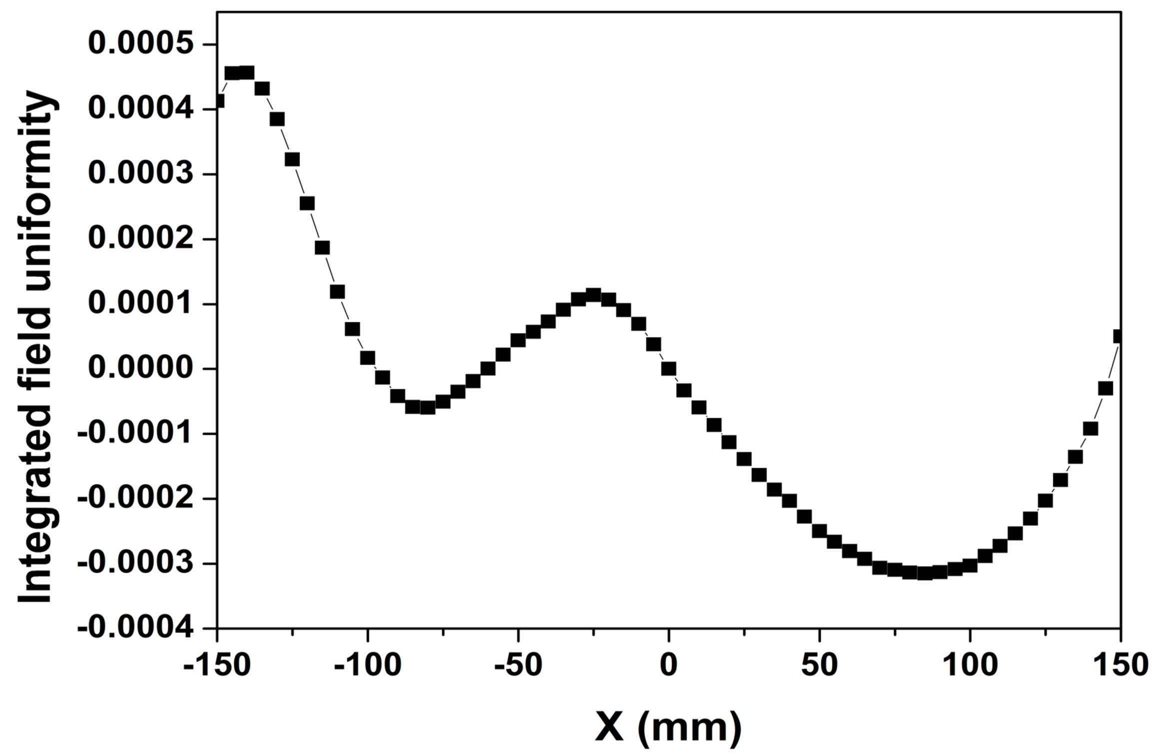
Field Design

3D model for EMuS dipole (half)



The uniformity of the integrated field arrives at 5.3×10^{-2} for this C-type magnet without any end chamfering, to improve field quality greatly, the air shim slots is used, other than shimming and chamfering.

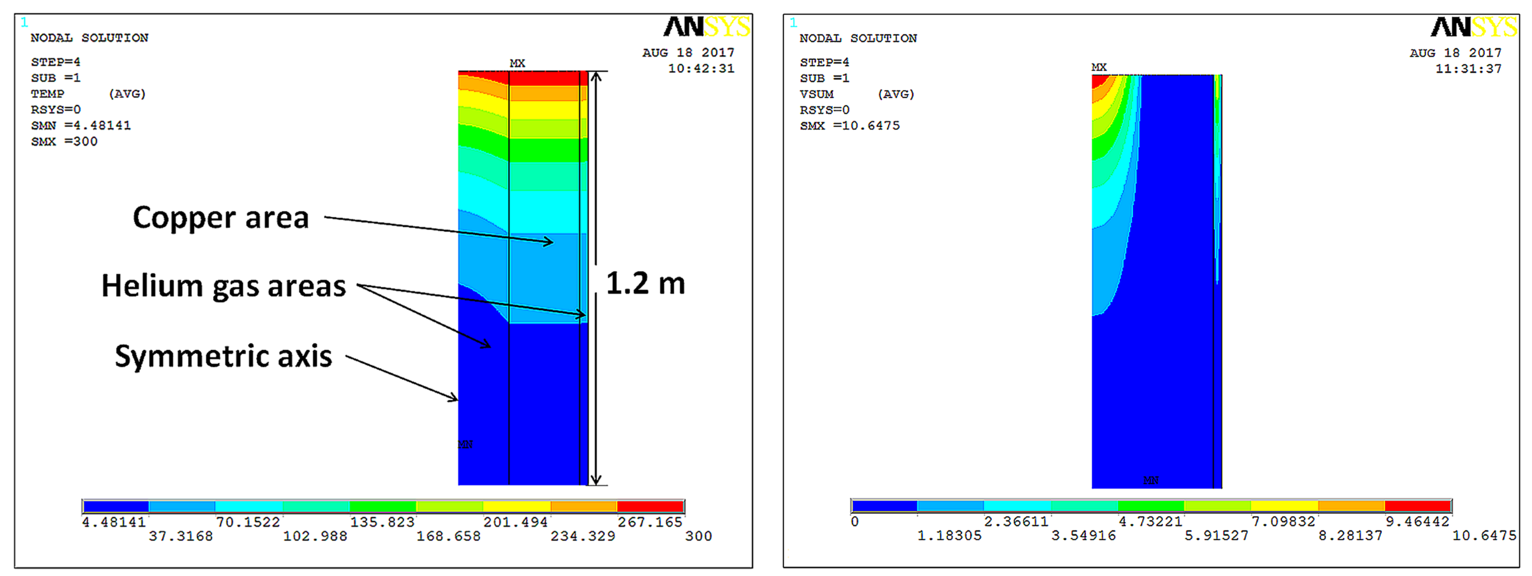
Uniformity of the integrated field

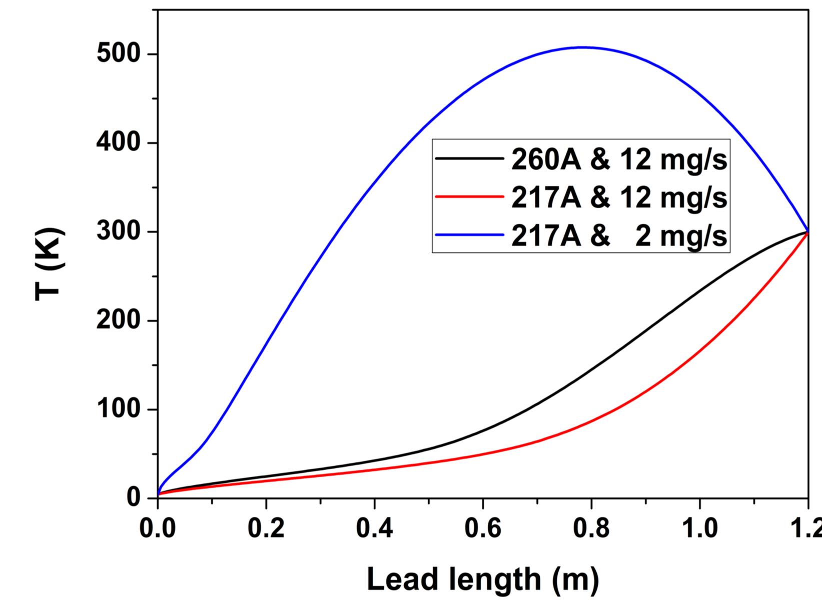


The uniformity of the integrated field arrives at $\pm5\times10^{-4}$ within $\pm$150 mm along x-axis. The air trim slots are shifted to the left of the poles to reduce the field distortion due to C-type iron. The asymmetrical shims on the two sides of pole faces are also used.

Optimizations of a self-cooled current lead

Optimization of a Self-cooled current lead





we performed the simulations of temperature and flow field of this current lead with ANSYS/APDL-FLOTRAN, CFD. The diameter of the inner helium gas is 3 mm, the thickness of the copper tube is 2 mm, the thickness of outer thin layer of helium gas between copper and stainless steel is 0.25 mm. The result is preliminary, the HTS is also under consideration. For now, the temperature and heat leak are accepted.

Current & Helium gas flow rate	Heat leak (W)
217 A &12 mg/s	0.61
260 A &12 mg/s	0.94
217 A & 2 mg/s	5.6

Presented at the MT-25 Conference , 2017 Aug. 27 – Sep.1, Netherlands, Amsterdam; Session: Thu-Af-Po4.01; Program I.D. number: 12