BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division
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Collider-Accelerator Department

Magnetic Design of a Superconducting AGS Snake*

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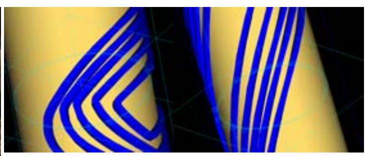
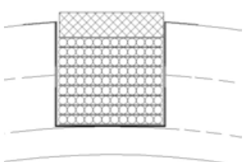
Abstract

- ❑ BNL plans to build a partial helical snake for polarized proton acceleration in the AGS.
- ❑ It will be a 3 Tesla superconducting magnet having a magnetic length of 1.9 meter.
- ❑ AGS needs only one magnet; no plans to build a prototype. The first magnet must function at the design field and provide the required field quality, spin rotation, etc.
- ❑ New software is developed to exchanges input/output between the field design programs, CAD programs and programs that drives the machine to cut the metal.

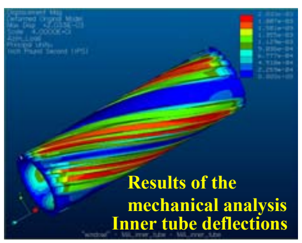
Machined inner coil support tube



CAD Model



Layout of the wires in a current block



Results of the mechanical analysis
Inner tube deflections

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AGS Helical Magnet Design Parameters.

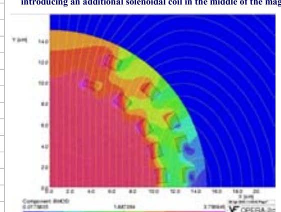
Superconductor Parameters:		
	Filament diameter	10 micron
	Wire diameter	0.33 mm
	Cu to Non-Cu ratio	2.5:1
	Cable type	6-around-1
	Cable diameter, bare	0.99 mm
	Cable diameter, insulated	1.09 mm
	Cable I_c @ 5T, 4.2 K	530 A
Coil Parameters:		
	No. of coil layers	2
	Coil inner radius for inner layer	101.6 mm
	Coil inner radius for outer layer	127.8 mm
	Current blocks per quadrant	10 (5 per layer)
	No. of turns in 9 blocks	12 X 9 = 108
	No. of turns in inner-pole block	12 X 5 = 60
Other Parameters:		
	Design field	3.0 T
	Quench field	~4.1 T
	Operating current	~350 A
	Quench current	~500 A
	Operating temperature	4.5 K
	Stored energy @3T	0.4 MJ
	Inductance	6.5 H
	Pitch in the middle (786 mm)	0.2053 deg/mm
	Pitch in the ends (577 mm each)	0.3920 deg/mm
	Slot size, width/depth	13.6/13.1 mm
	Warm bore tube id/od	152.4/156.5 mm
	Cold bore shield id/od	165.2/167.7 mm
	Cold bore tube id/od	176.5/181.6 mm
	Inner Aluminum tube id/od	195.6/229.6 mm
	Outer Aluminum tube id/od	248/281.8 mm
	Iron yoke id/od	300.4/685.8 mm
	Shell id/od	685.8/687.1 mm
	End plate thickness	12.7 mm

Table 2: Computed values of normal harmonics (b_n) at 1 T in a 2-d model where coils are straight.

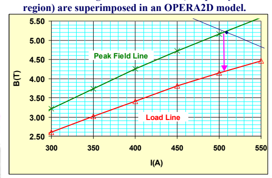
Harmonic No.	2	4	6	8	10
Harmonics@1T	0.0	-0.1	-0.4	-3.1	1.3
Harmonics@3T	2.2	-1.4	-0.5	-3.1	1.3

DESIGN PROCEDURE

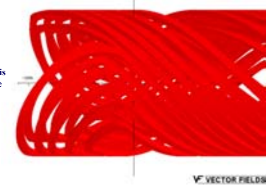
- ➢ The design requires the pitch to be different in the middle of the dipole as compared to that in the two ends.
- ➢ Initial coil cross section is optimized for a good field quality in a straight dipole magnet.
- ➢ In the straight magnet, the physical separation between the blocks is much larger than that it is in the helical magnet, however, the relative angular separation of each block remains the same.
- ➢ The conventional 2-d field harmonics description for a straight magnet is not valid in the case of helical fields. Those harmonics become dependent on integration radius and on helical pitch.
- ➢ Morgan end minimize harmonic content by a judicious choice of angles of the current blocks as they traverse side-to-side in the ends.
- ➢ The actual beam is injected 3 cm off-axis in the horizontal plane to maximize the use of available aperture.
- ➢ The beam must exit the helical magnet with nearly the same position and angle by which it enters the magnet.
- ➢ The beam experiences an axial component of the field when it is away from the magnet axis. One way to compensate this is by introducing an additional solenoidal coil in the middle of the magnet.



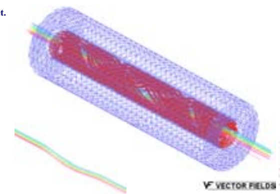
Cross section of the straight magnet with the identical block size as in helical section. The field lines and the magnitude of the field (except in yoke region) are superimposed in an OPERA2D model.



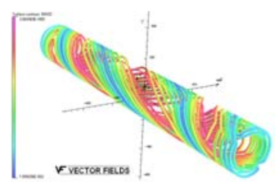
Load line (for central field), peak field line on the conductor and computation of the expected quench field in the helical magnet.



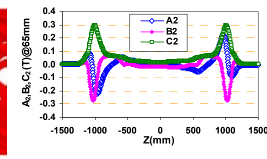
MORGAN ENDS: Minimize harmonic content by a judicious choice of angles of the current blocks as they traverse side-to-side in the ends.



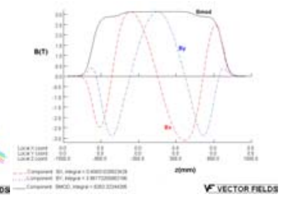
OPERA3d model with coil and iron yoke with the particle tracking superimposed.



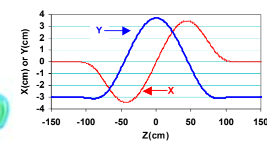
OPERA3d model of the coils with the magnitude of the field superimposed on the conductor for $B_x(0,0,0) = 3.12$ T. The iron yoke is not shown for clarity.



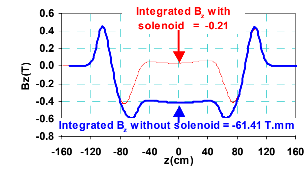
The sextupole harmonic along the magnet axis computed by integrating B_y.



The magnitude and the components of field on the magnet axis.



The nominal horizontal and vertical position of the beam as function of axial position inside the helical magnet.



The axial component of the field along the nominal beam path. The integral value is made zero with the help of a solenoidal winding on the beam tube.

SUMMARY

The design and analysis of a partial helical snake for AGS has been completed. A number of software techniques have been developed to obtain a design that satisfies the basic requirements.

REFERENCES

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[2] E. Willen, et al., "Performance Summary of the Helical Magnets for RHIC", this conference.

[3] M. Anerella, et al., "Engineering of AGS Snake coil Assembly", this conference.

[4] G. Morgan, "Private Communication".

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