CBETA Magnet and Girder Design Review
September 20, 2017

<u>Personnel Present</u>
At BNL: Dejan Trbojevic, Steve Trabocchi, Joe Tuozzolo, Thomas Roser, Scott Berg, Stephen Brooks, Nick Tsoupas, George Mahler, Peter Wanderer, Steve Peggs, Rob Michnoff

At Cornell: Karl Smolenski, David Burke, Jim Crittenden, Yulin Li, Dragana Jusic, Tim O'Connell

<u>Presenters</u>
Steve Trabocchi, Joe Tuozzolo, Stephen Brooks

<u>Notes from Rob Michnoff</u>

1. Every other girder-to-girder connection will have bellows with rotatable flanges. (per Yulin Li)
2. Magnets need to be mounted very close to the girder ends, and may make bolting difficult. BNL will confirm that sufficient space will exist to install the bolts.
3. Some protective covering may need to be installed over the permanent magnets to prevent metallic tools or material from being attracted to the magnets. Specifics will need to be determined. (prompted by question from Yulin)
4. Lift points need to be defined on the girder plate.
5. Girder plates are 1" thick.
6. Magnet center survey to be performed by BNL during magnet tuning. Magnet location survey on girder plate to be performed at Cornell by Cornell personnel.
7. The survey location of the magnets is much more critical than the survey location of the BPMs and beam pipe. (per Scott Berg)
8. Several survey targets will be installed on each girder plate.
9. FFAG corrector power supply max current is 3A. Operational needs for some may be in the 0.3 A range. Need to determine that accuracy of power supplies will be sufficient when operated in the low 10% of the full scale operating range.
10. 17 different girder plate designs are required. The basic plate dimensions are expected to be the same for most, but mounting holes will all be different. Each type requires unique drawing.
11. Testing disassembly and reassembly of one of the preproduction Halbach magnets to confirm repeatability of magnetic field has not been performed yet but is expected to be done within about 1 week.
12. The fractional arc test girder is expected to be shipped to Cornell by mid January 2018.

13. Cornell will provide the required water system for the fractional arc test Halbach magnets.
14. Some thermocouples may be installed on Halbach magnets for the fractional arc test, but the installation will likely not occur until temperature measurements are determined to be required – that is, only if and when issues are suspected.
15. Building 905 at BNL will be used for the girder plate assembly.
16. Each magnet will be water leak checked at BNL during magnet measurement and tuning.
17. Corrector magnet polarity will be checked at Cornell after installation during final pre-beam checkout.
18. Coordination between BNL and Cornell is required to identify when each girder beam pipe needs to arrive at BNL for girder assembly.
19. The specific survey plan needs more discussion.
20. The magnet measurement system issue (that is, inconsistencies when consecutive measurements are taken) needs to be diagnosed and resolved.
21. The present plan based on the Halbach assembly Statement of Work is to complete all of one type of Halbach first, then the next, and so on. This causes complications in completing girder plate assemblies in a reasonable order since each girder plate requires mounting of several different types of magnets. The specific girder delivery plan to Cornell needs to be identified. It may be necessary to deliver some girders with missing magnets, which will be delivered and installed at Cornell as soon as they are available.
22. The goal needs to be to receive all completed Halbach magnet assemblies at BNL by early July 2018. The present schedule shows them arriving several months later. Alternatives should be considered.
23. The plan requires 2 Halbach magnets to be tested per day. Need to confirm that this is feasible, and if not, develop a plan that accommodates the required schedule. 2 magnets per day for 214 magnets translates to about 6 months.
24. The plan requires completing 1 full girder assembly each week. For 24 girders this translates to about 6 months.
25. The goal needs to be to complete all girder plate assemblies by the end of October 2018 in order to allow time to complete the full installation at Cornell by the end of December 2018.

Notes from Joe Tuozzolo

Most time was spent on survey issues:
S. Berg made the point that the highest priority is getting each Halbach magnet's magnetic centerline on its proper lattice position. Unlike other accelerators there is not a theoretical single beam centerline. Scott described it as the beam-tube centerline, Joe Tuozzolo called it the lattice centerline in his presentation. (Will use lattice centerline from this point forward because the beam tube centerline can vary from BPM to BPM because the beam tube is a welded assembly.) Scott wants the physical beam tube as

close to the lattice centerline as possible because the lateral position (offset the magnetic center) of the Halbach magnets can be adjusted in either direction laterally to tune the FFAG performance.

Some points discussed:

1. Making a beam tube that follows the lattice radius is difficult. Each tube has four BPM's with 2 welds + 2 welded end flanges + 2 locations with diagnostic ports and a center welded assembly for vacuum pumping. Any of these and all in total can distort the beam tube.
2. Yulin and Karl have been working on the weld design and fixture design to reduce this distortion and will know how tightly the beam pipe position can be controlled in November.
3. There are 17 different 4 cell assembly configurations with a different lattice centerline radius. The welding fixture and beam tube dimensions will vary for each. The welding fixture and beam tube components must be adjustable to meet this requirement.
4. The 4 cell (girder) assembly plates will also have to come in 17 different configurations. The goal of the design is that the stands and the outside plate dimensions are all the same. The threaded holes for mounting the vacuum chamber and magnets will have be different for each girder type to match the lattice centerline radius.
5. The vacuum chamber will be inspected at Cornell after welding to verify that any distortion is within an acceptable range before shipping it to BNL for final assembly. The dimensions for the acceptable range need to be developed. There are two factors:
   a) S. Berg did provide some allowance in his clearance request for this type of mechanical interference. It must fall within this allowance.
   b) George and Stephen designed the 4 cell assembly base plate with the thought that it can pull the chamber into alignment or at least reduce the error. The amount of force it can put on the chamber and how much deflection it will provide needs to be calculated or analyzed.
6. The following steps were described for aligning the 4 cell assembly, with some modification as a result of the meeting, this is work in progress:
   a) Survey stand to lattice centerline & set height and bolt down to floor.
   b) Place 4 cell assembly plate, check height of the BPM's and re-adjust stand height if needed.
   c) Center end BPM's to lattice centerline; verify that middle BPM's are within acceptable lateral position to lattice centerline.
   d) If one or both of the middle BPM's lateral position does not meet specification, adjust to lateral position specification for all four BPM's to the lattice centerline. Have survey locate the beam tube to this position. (If that can't be done, stop install and 4 cell assembly production, the vacuum chamber or plate assembly is out of specification).
   e) Lock plate position.
   f) Survey/adjust Halbachs to lattice centerline specifications. Inspect all Halbachs for proper inner clearance to beam tube for specified lateral adjustment range. If the Halbachs do not have proper clearance, recalculate all four BPM positions to lattice centerline positions and repeat steps d, e, and f. (relocate plate and BPM positions, then resurvey the magnets, then check clearance again).
   g) Lock Halbach magnets in surveyed position. Survey and save all Halbach magnet and BPM positions.

7. Cornell is meeting with the Faro arm vendor. An arm is needed for the survey steps above. The Faro arm is also needed to transfer the laser tracker position of the 4 cell assembly plate to the individual 4 cell assembly components. How this is done is TBD.

Vacuum Chamber:
The present plan is that the every other vacuum chamber connection will have a bellows. The concern is that any end flange distortion or accumulation of distortions in the 2 vacuum chamber will reduce the amount of Halbach magnet adjustment needed. It could also add multiple survey steps if one 4 cell assembly is installed and the flange alignment forces the adjacent 4 cell assembly beam tube location too far out of specification. Having a bellows between each chamber (and 4 cell assembly) should be investigated further by Yulin and Karl.
It was noted that installing the bolts in the flanges between chambers would be difficult. 2 options discussed: installing the bolts at BNL before installing the Halbach magnets; this is acceptable to BNL or using studs on those flanges. This decision can be made soon; when the second cell assembly and vacuum chamber is modeled by Steven T.

Cover for permanent magnets:
Cornel requested that the Halbach magnet ends be covered to prevent tools and debris from finding their way on to the magnet ends. Again there were two options discussed:

- End face covers at located at a safe distance from the face to be determined (It was noted that such a cover would make survey difficult and may take space away from the flange bolts (for example).
- A continuous overall Plexiglas cover covering all the Halbachs and vacuum chambers. (It would not provide protection while the plate is being survey or during any maintenance.

George and Steven will develop a design for review.

4 Cell Assembly Plate:
The distortion of the plate when lifting was shown in Steven T's presentation and is acceptable. The plate should be designed with four lifting points for stability and to further reduce the distortion. Steven will revise the design.
The plate will also get multiple survey fiducial points on the top and a mounting point for the Faro arm.