

CBETA Magnet and Girder Design Review  
September 20, 2017

Personnel Present

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

Presenters

Steve Trabocchi, Joe Tuozzolo, Stephen Brooks

**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. By default the BPM's will be on or close to the lattice centerline; but, the BPM location is not critical. Knowing the BPM position after installation is critical

Some points related to survey discussed:

- 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 weld points and all in total can distort the beam tube.
- 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.
- 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.
- 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 dimension tolerances for the acceptable range need to be developed. There are two factors:
  1. S. Berg did provide some allowance in his clearance request for the mechanical interference between the magnet ID and the beam tube OD. It must fall within this allowance.

2. George and Steven T. 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 correction it will provide needs to be calculated & analyzed.
- Magnet center survey to be performed by BNL during magnetic measurement and tuning. Magnet location survey on girder plate to be performed at Cornell by Cornell personnel from survey data provided by BNL. The interface to transfer information needs to be developed.
  - The following steps were described for aligning the 4 cell assembly at Cornell, with some modification as a result of the meeting, this is work in progress:
    1. Survey stand to lattice centerline location (this may vary stand to stand and may require a survey fixture), set height, and bolt down to floor.
    2. Place 4 cell assembly plate, check height of the BPM's and re-adjust stand height if needed.
    3. Center end BPM's to lattice centerline; verify that middle BPM's are within acceptable lateral position to lattice centerline.
    4. 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).
    5. Lock plate position.
    6. 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).
    7. Lock Halbach magnets in surveyed position. Survey and save all Halbach magnet and BPM positions.
  - 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.
  - More discussion and a visit by Cornell is needed in order to develop an overall survey plan and procedure.

### **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.

### **FAT**

The present plan is to use the pre-production magnets for the 1<sup>st</sup> girder GFA1 for the FAT. All 8 magnets meet CBETA specifications for this test. The 9<sup>th</sup> magnet, a BDH will be the first production magnet built by BNL. The permanent magnet material will come from the recently awarded production contract.

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.

The fractional arc test girder is expected to be shipped to Cornell by mid-January 2018. Cornell will provide the vacuum chamber and the required water system for the fractional arc test Halbach magnets.

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. It was agreed that thermocouples would not be installed on the rest of the production magnets. If there is a problem with temperature, then thermocouples will be installed later on a few sample magnets.

### **Magnetic Measurement**

Stephen Brooks presented the details of his technical note on magnetic measurement. The time to perform these steps needs to be estimated and tested. Magnetic measurement is on the schedule's critical path for delivering 4 cell assemblies to Cornell.

The magnet measurement system issue (that is, inconsistencies when consecutive measurements are taken) needs to be diagnosed and resolved.

### **Corrector Magnets**

Only horizontal or vertical correction will be provided. There are 2 separate coils so quadrupole correction can be added if operational experience indicated they are needed. For now the quadrupole and dipole coils will be wound in series.

FFAG corrector power supply max current is 3A. Operational needs for the correctors 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. If needed only the dipole coils cutting the number of turns in half, doubling the current required.

The correctors are wired to a terminal block on the plate. The correctors will be tested for resistance at BNL before shipping the 4 cell assembly. The Corrector magnet polarity will be checked at Cornell after installation with the power supply during final pre-beam

checkout. Correcting a polarity or reversed connection of a single leg is fast with the terminal block.

#### **Cover for permanent magnets:**

Cornel (Yulin) requested that the Halbach magnet ends be covered to prevent tools and debris from finding their way on to the magnet ends. There were two options discussed:

- End face covers on the upstream and downstream face of the magnets where the permanent magnet material is exposed. They have to be located at a distance from the permanent magnet material where the field is low. This is TBD. (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 surveyed or during any maintenance.

George and Steven will develop a design for review.

#### **4 Cell Assembly Plate:**

The 4 cell assembly plate is 1 inch aluminum. The distortion of the plate when lifting was shown in Steven T's presentation and is acceptable. The plate will be designed with four lifting points for stability and to further reduce the distortion. Steven will revise the design.

Like the vacuum chamber, the 4 cell (girder) assembly plates will 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 to be different for each girder type to match the lattice centerline radius.

Each plate will also get multiple survey fiducial points on the top and a mounting point for the Faro arm.

#### **Schedule:**

The production schedule for completing and shipping the 4 cell assemblies to Cornell has been completed. It was noted that the schedule is very dependent on 3 critical path items:

1. The delivery of permanent magnet material. This contract has been awarded and the Contractor's production plan is due in 2 weeks (though the contractor indicated they may have it in a week). The schedule presented is based on dates in the BNL Statement of Work.
2. The delivery of the Halbach magnet assemblies. This is out for bid; proposals are due next week. The schedule presented is based on dates in the BNL Statement of Work.
3. The time to do magnetic measurement, tuning, and centerline survey of each Halbach magnet. To meet the production schedule, the BNL magnetic measurement facility must perform at a rate of 2 magnets/day. This gives some margin for system downtime, holidays, and re-measurements.

Minimum acceptable is 8 magnets/week complete. Is this is feasible? If not, need to develop a plan with the resources and equipment needed that accommodates the required schedule. 2 magnets per day for 214 magnets translates to about 6 months.

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 based on the availability of permanent magnet material which will be produced in lots by magnets. Mixing up material batches during material fabrication or magnet fabrication can cause a failed magnet. There is no margin in the schedule for failed magnets.

Delivering magnets in lots causes complications in completing 4 cell plate assemblies in ring order since each girder plate requires mounting of different types of magnets. The specific 4 cell assembly delivery plan to Cornell was presented. The last 4 cell assembly will ship October 23, 2018. As noted above this is based on Contractor delivery schedules in the SOW's. Final confirmation is needed from the Contractor and then they have to meet there own schedule.

The plan requires completing 1 full girder assembly each week. For 24 girders this translates to about 6 months. Girders will be delivered to Cornell as they are completed.

If necessary based on magnet availability, Rob M. proposed to deliver some girders with missing magnets, which will be delivered and installed at Cornell as soon as they are available. Karl S. noted that if the last 4 cell assembly is delivered in October, he could not see a problem with his schedule. Further integration of the schedules is required.

Coordination between BNL and Cornell is required to identify when each girder beam pipe assembly needs to arrive at BNL for the 4 cell assembly to maintain pace. Karl and Yulin estimated that they would be done in March 2018 which meets the schedule requirements. The presentation has the order of 4 cell assembly delivery and details of the chamber delivery requirements are in the schedule.

Rob M. set a goal for all completed Halbach magnet assemblies at BNL by early July 2018. The present schedule shows them arriving several months later. Alternatives should be considered.

Rob M. set a goal 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.

Building 905 at BNL will be used for the girder plate assembly. There are tools or staff in the area at the moment so resource and equipment planning needs to be done.