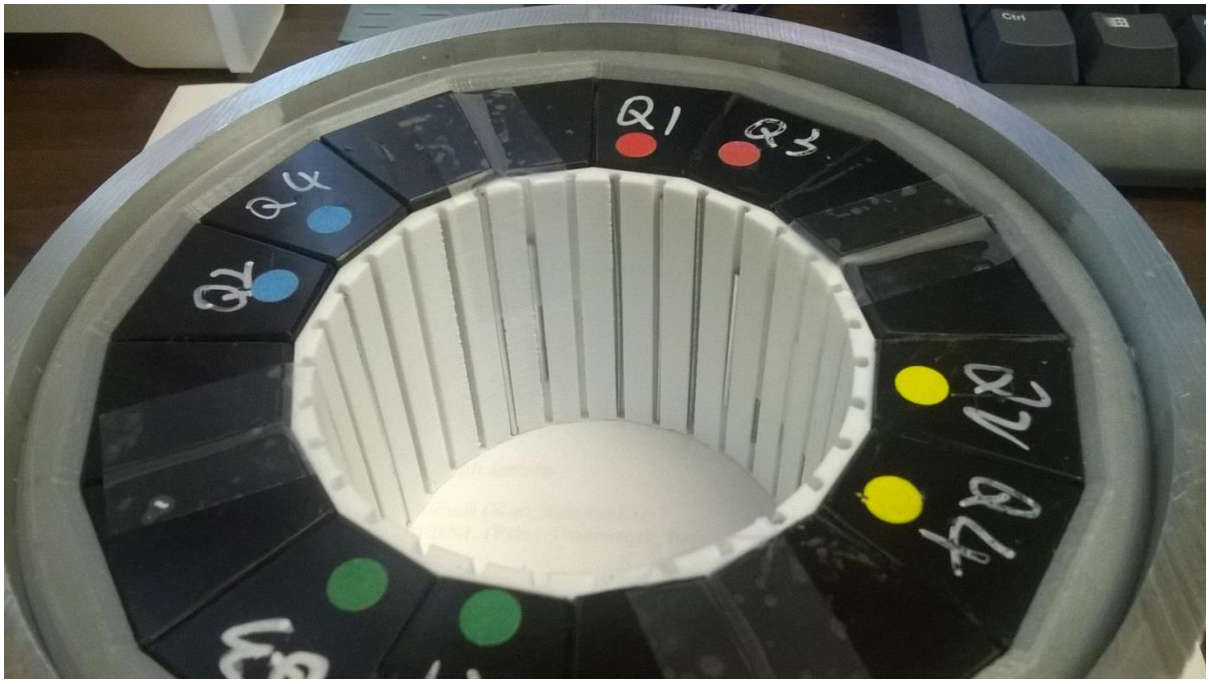
Description of CBETA Magnet Tuning Wire Holders

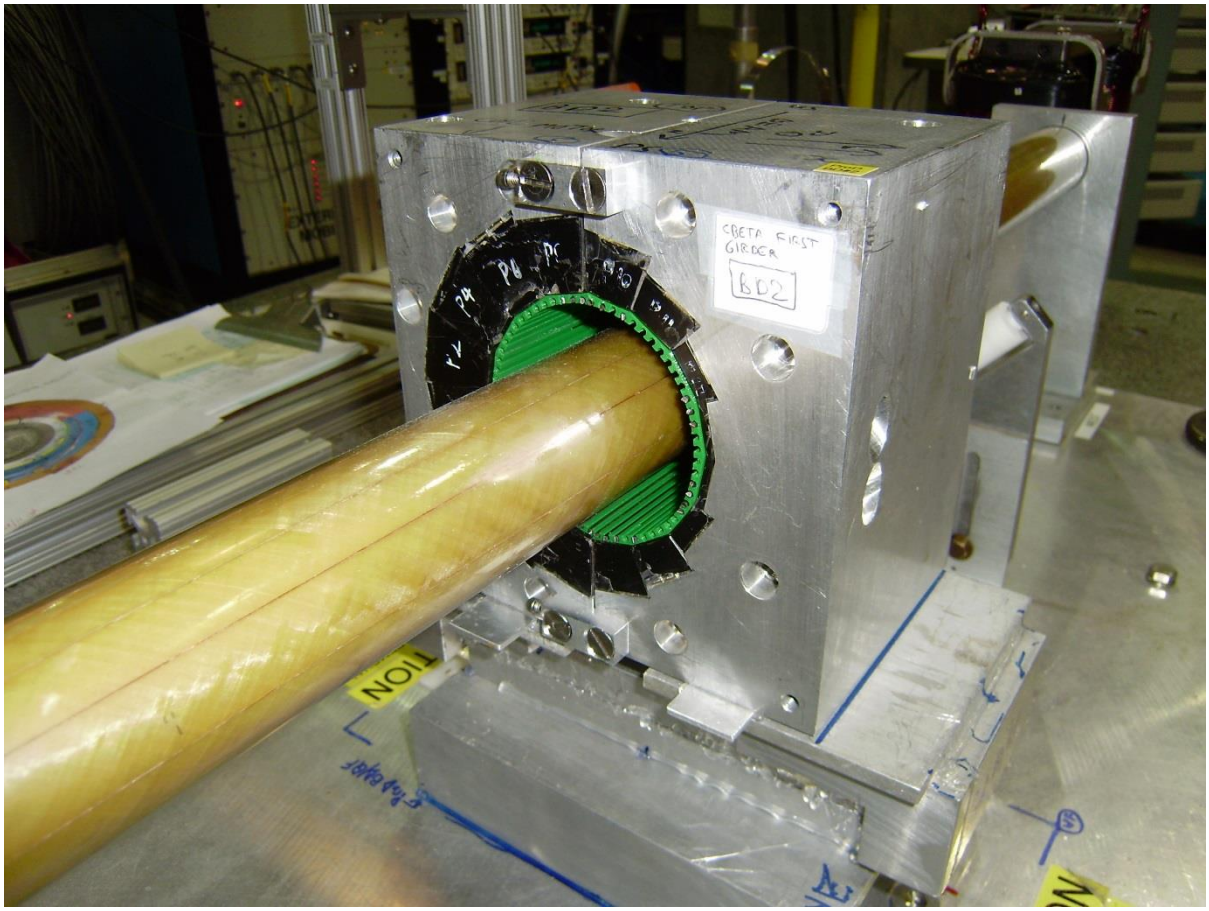
Stephen Brooks 2017-Jul-19 CBETA machine note #018
Revised 2017-Nov-14 by Stephen Brooks

1. Introduction

A non-magnetic insert will be placed directly inside the permanent magnet blocks in every CBETA Halbach magnet in order to hold a set of iron “tuning wires”. These wires have various lengths around the perimeter of the aperture in order to cancel multipole field errors from the permanent magnet blocks. An example of such a wire holder made of 3D printed plastic is shown below.

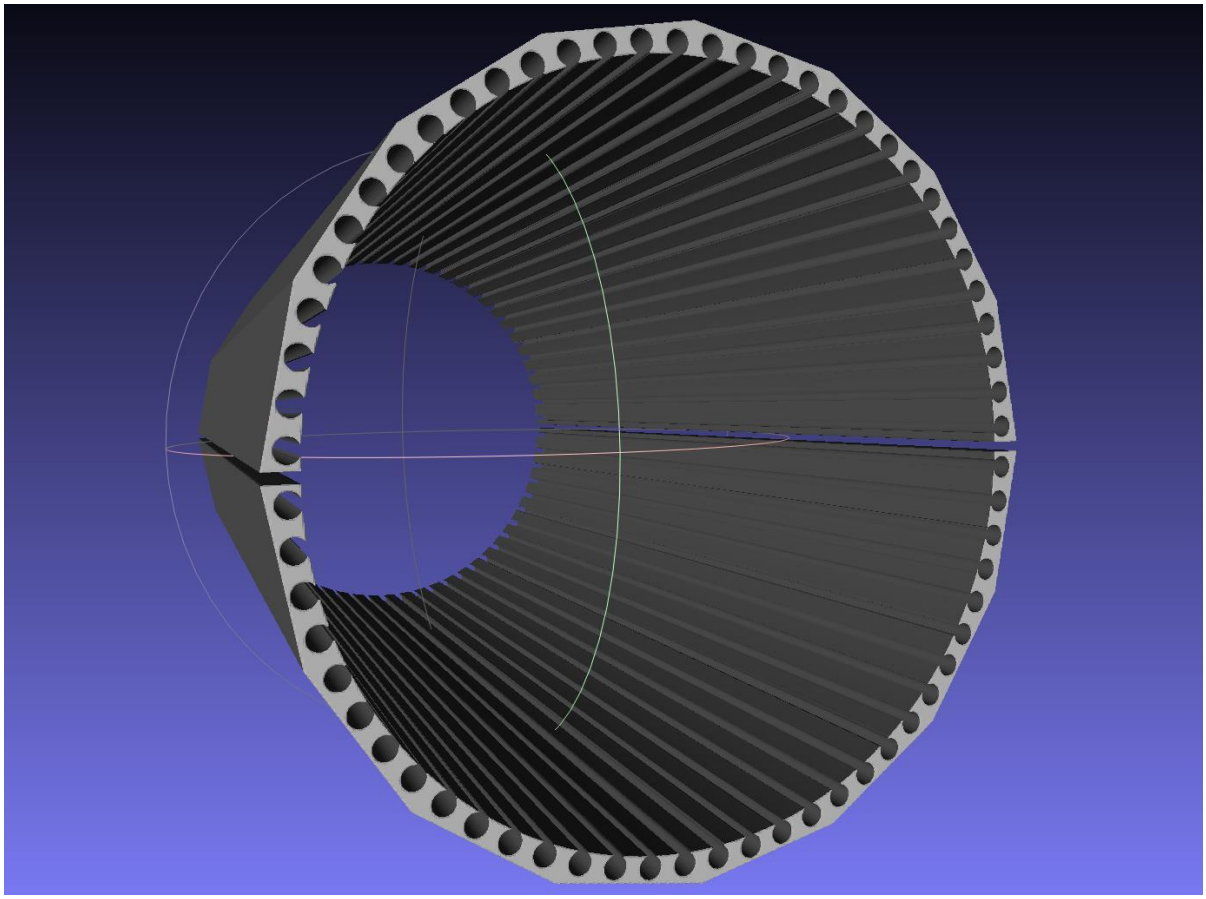


Note that the holder can be made of any non-magnetic material and that the holder pictured above has only 32 slots for wires, fewer than in the final version. The picture below shows a CBETA “first girder” magnet undergoing rotating coil measurement while containing a plastic wire holder.



2. Geometry Description and Dimensions

The interior of each Halbach magnet is a 16-sided regular polygon in cross-section. The CBETA magnets split into two halves, so the shim holders will be made in halves too (both halves are shown in the 3D model below). Each shim holder half has a large circle removed from the centre of the polygon, which becomes the final usable magnet bore, as well as 64 equal-sized, equally-spaced holes all at the same radius. The holes are offset by half of a gap so a hole does not interfere with the place the two holder halves join. The holes are placed so that the holder is continuous on the outside but the wires can be seen on the inside (this will help with removing wires if needed). However, the holes must be sufficiently indented into the plastic so that the wires do not fall out.



There are several types of Halbach magnet bore in CBETA. Their dimensions and number of each are shown in the table overleaf, consistent with v6/v6.5 of the CBETA Halbach magnet designs.

Parameter	QF wire holder	BD-type wire holder	BDT1 wire holder	BDT2 wire holder	QFH wire holder	BDH wire holder
Associated magnet types	QF	BD, QD	BDT1	BDT2	QFH[1]	BDH[1]
Number of magnets	107	32, 27 (59 total)	28	20	1	1
Magnet length	133.0mm	122.0mm	122.0mm	122.0mm	66.5mm	61.0mm
Radius to corner of 16-gon	~47.105112mm	~44.046339mm	~53.207452mm	~48.979246mm	~47.105112mm	~44.046339mm
Radius to side of 16-gon	46.2mm	43.2mm	52.185mm	48.038mm	46.2mm	43.2mm
Radius of bore circle removed	43.1mm	40.1mm	49.085mm	44.938mm	43.1mm	40.1mm
Radius to centre of wire holes	44.484mm	41.484mm	50.469mm	46.322mm	44.484mm	41.484mm
Number of wire circles	64	64	64	64	64	64
Radius of wire[2]	0.080”	0.080”	0.080”	0.080”	0.080”	0.080”

The “first girder” is constructed out of older series magnets that had slightly different aperture dimensions, so the shim holders for that are in the table below.

Parameter	QF wire holder	BD wire holder
Associated magnet types	First girder QF	First girder BD
Number of magnets	4	4
Magnet length	133.3mm	121.7mm
Radius to corner of 16-gon	~43.332624mm	~43.332624mm
Radius to side of 16-gon	42.5mm	42.5mm
Radius of bore circle removed	39.4mm	39.4mm
Radius to centre of wire holes	40.784mm	40.784mm
Number of wire circles	64	64
Radius of wire[2]	0.080”	0.080”

[1] The QFH and BDH magnets are one-off half-length magnets, so their shim holders may be 3D printed at BNL.
[2] It is possible a larger radius e.g. 0.105” may be used depending on magnet quality, which would probably also thicken the holder and reduce the overall bore circle.

3. Fits

The shim holder should fit within the magnet bore ideally with a small amount of friction; it can be glued in place once the wires are inserted correctly. For 3D printed plastic, the radius was reduced by 0.2mm to account for plastic roughness (3D printer layers) and any magnet construction errors.

The wires should fit within the holes so that they can slide in longitudinally with a small applied force, but ideally with enough friction so that they do not fall out of place if the holder containing wires is picked up and turned over. Again, 0.2mm was added to the wire radius to give the hole radius in the case of 3D printed plastic (fast print on Ultimaker 2).

Wires may be glued in place to prevent them moving when the holders are being placed in the magnet (the magnet will strongly attract the wires).

4. Automated Wire Placement

The wires may be inserted robotically in the future, in which case the ends of the wire holes facing the robot should be flanged outwards – for instance growing by 1mm in radius over 5-10mm length – to better guide the wires into the holes.