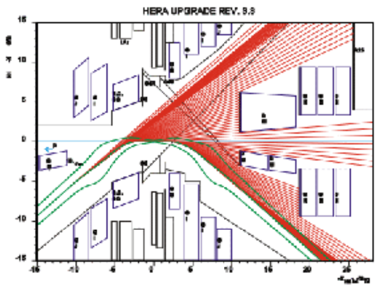
BROOKHAVEN NATIONAL LABORATORY

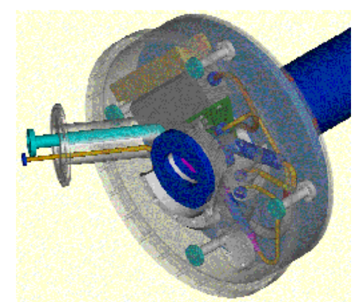
December 11, 2001
Presentation at SLAC

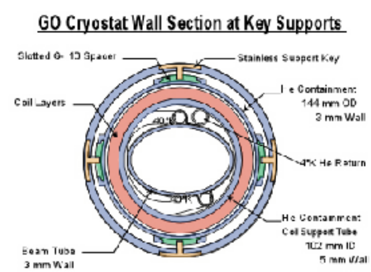
Superconducting Magnet Division

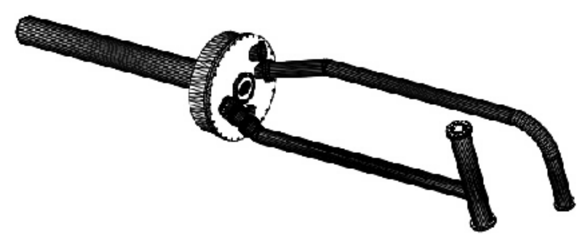
Luminosity Upgrade Magnets for HERA & BEPC-II



Presented by Brett Parker

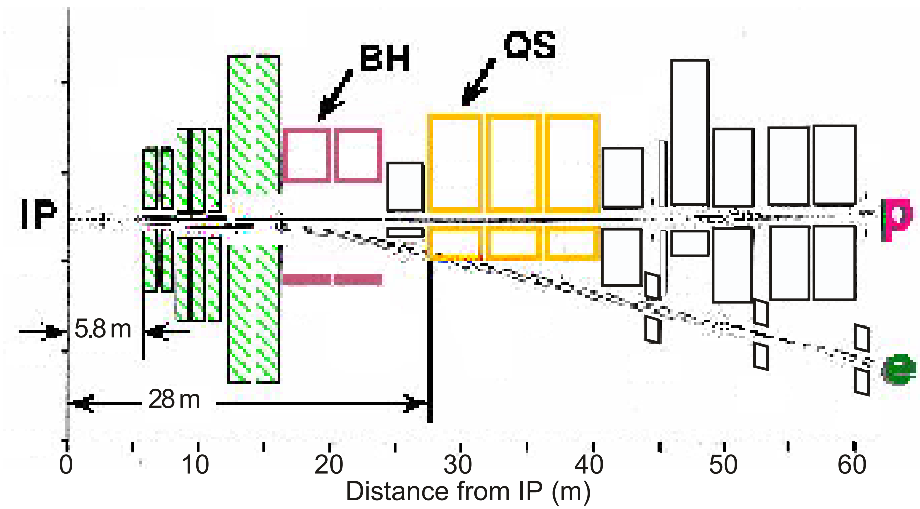


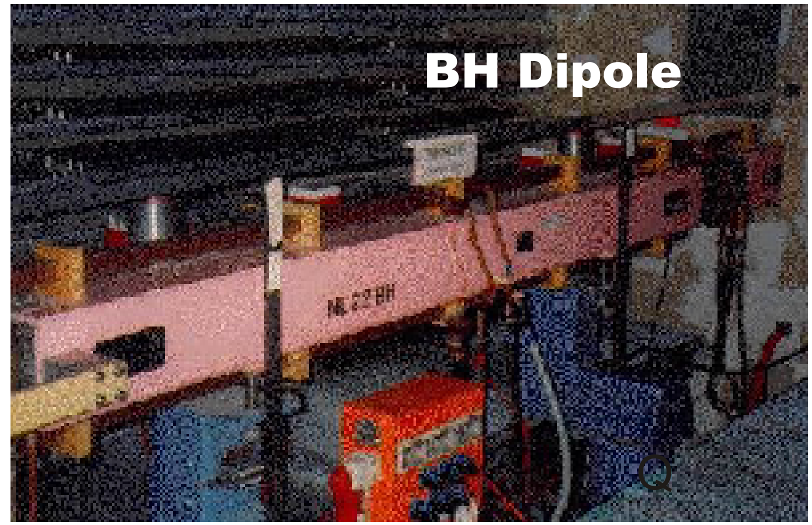




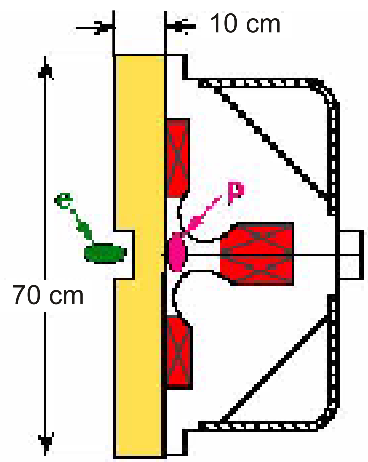
Can you provide background on what has been done in the past?

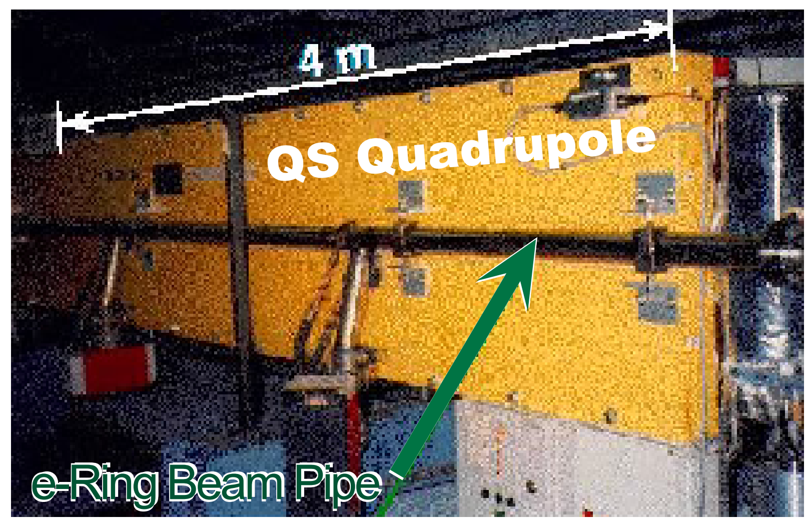
HERA Layout Before Luminosity Upgrade





- Beams "gently" separated.
- Separation < 10 cm at 28 m.
- The first superconducting quadrupole is at 115 m.
- p-ring has vertical bend just beyond region shown.



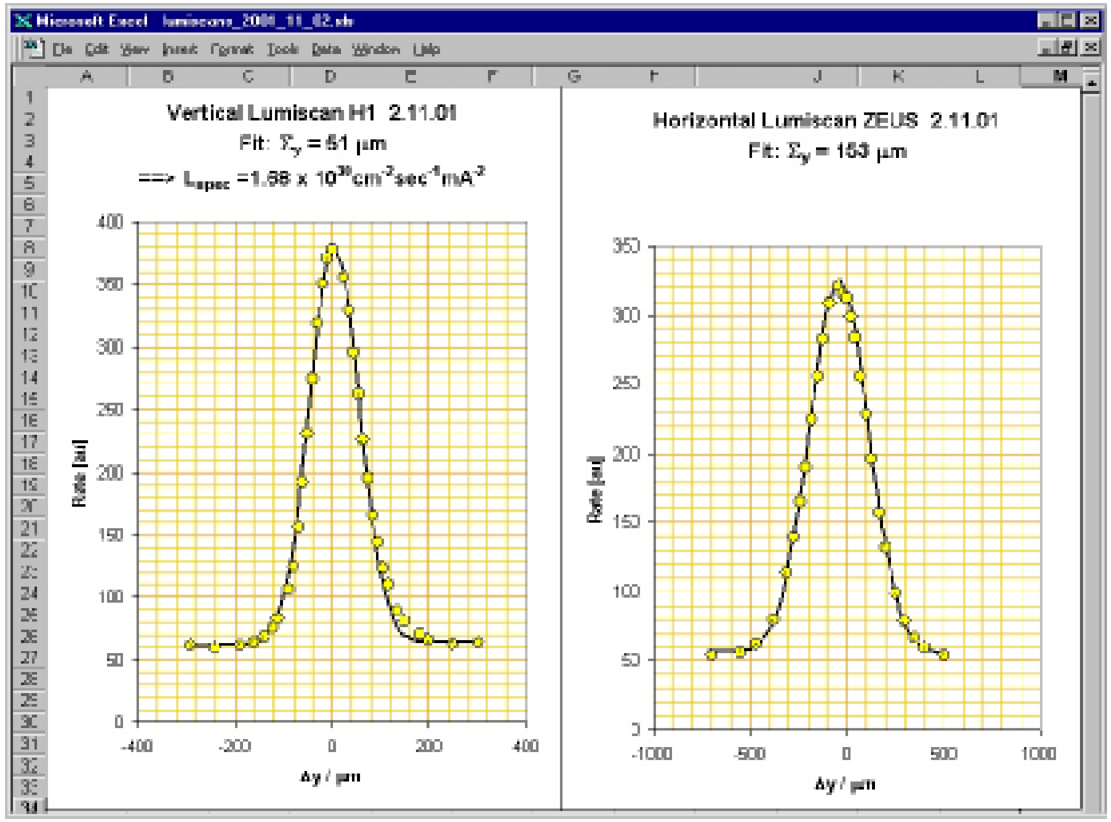


HERA Luminosity Upgrade: Re-commissioning

On November 11, 2001 a specific luminosity of 1.68×10^{30} $cm^{-2} sec^{-1} mA^{-2}$ was measured. This is 94% of the nominal upgrade goal of 1.78×10^{30}.

Optics Parameters

	p	e
β_x^*	2.45	0.60
β_y^*	0.18	0.26



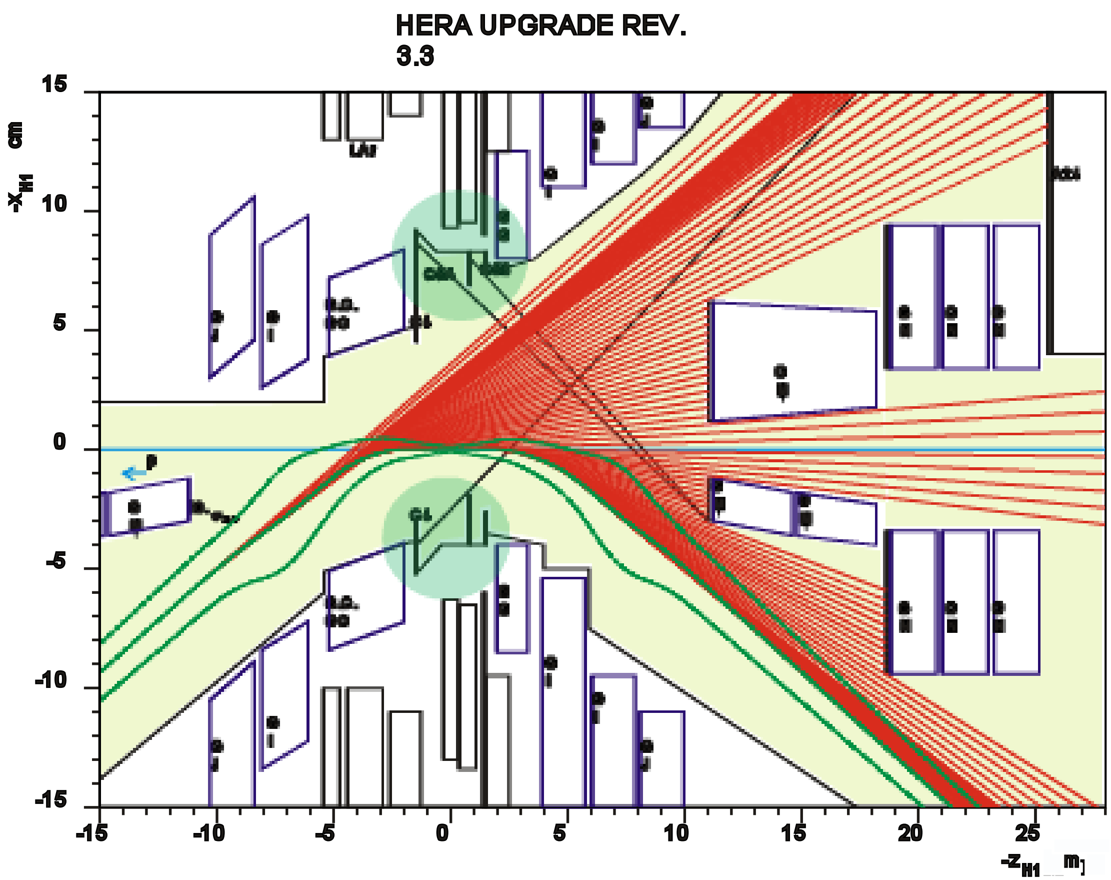
Results from HERA web page: http://desyntwww.desy.de/hera/

To do this took starting beam separation sooner with new magnets that brought e- and p-beam focusing closer to the IP.

eRHIC Workshop at Yale

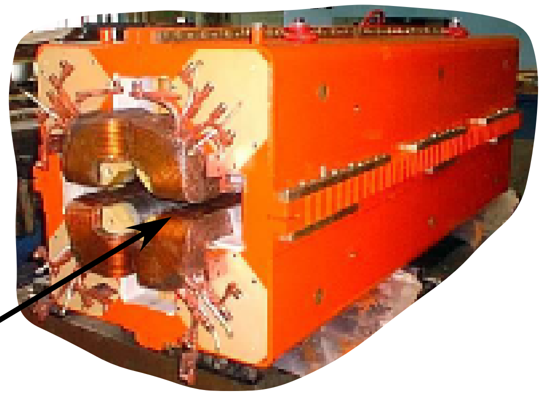
What does it mean to let all the synrad pass through the experiment?

The layout of the H1 vacuum beam pipe is shown at the right. ZEUS has a similar arrangement. The intent is to have the primary synrad pass cleanly through to absorbers at 11, 19 and 24 m. The central detector region is protected from back scattered radiation by collimators.

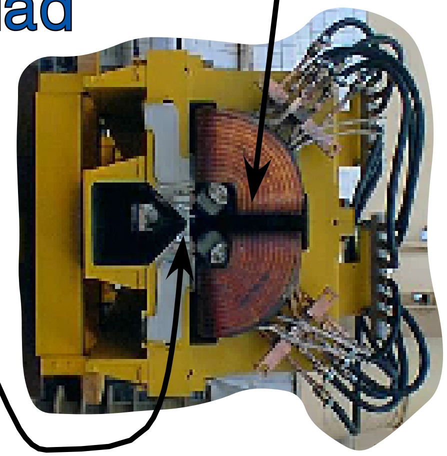


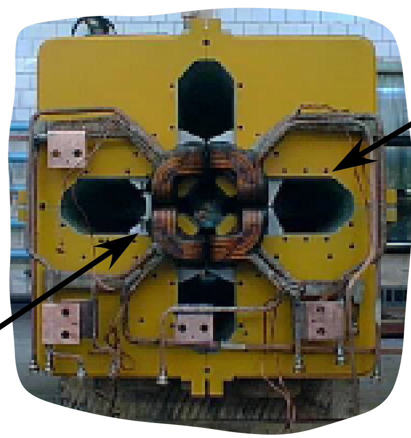
New Normal Conducting Upgrade Magnets

GI & GJ, Normal Quads

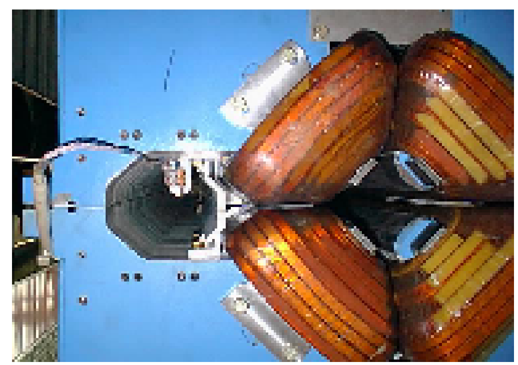


GM, Magnetic Septum Quad



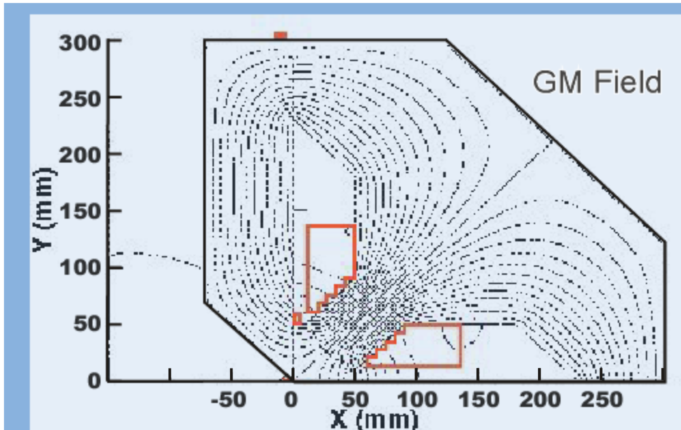


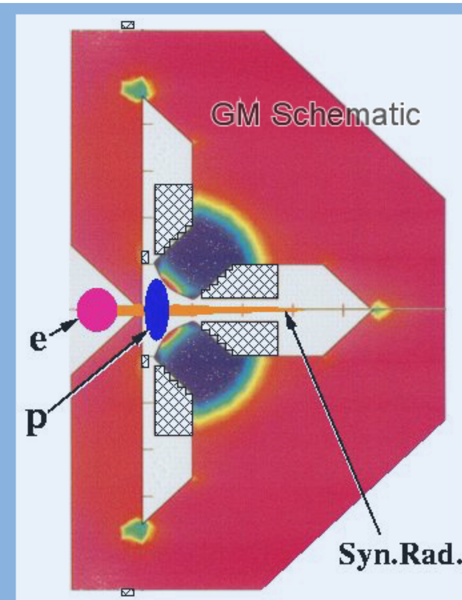
GN, Current Septum Quad



GA & GB, Normal Quads

What else is DESY doing for the HERA luminosity upgrade?

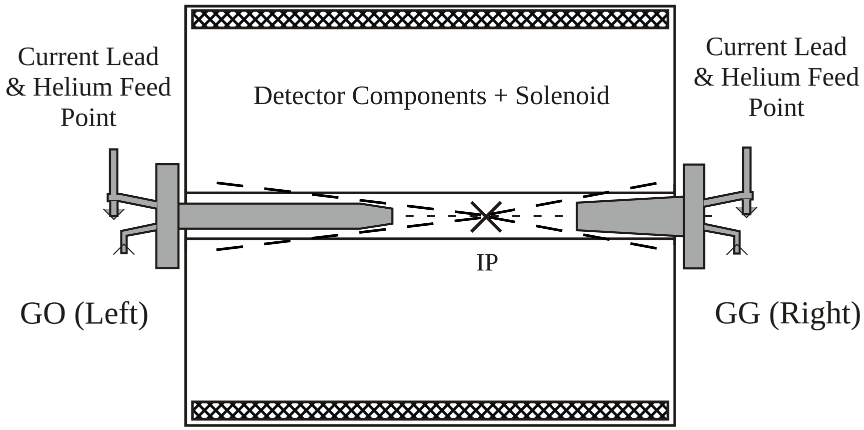




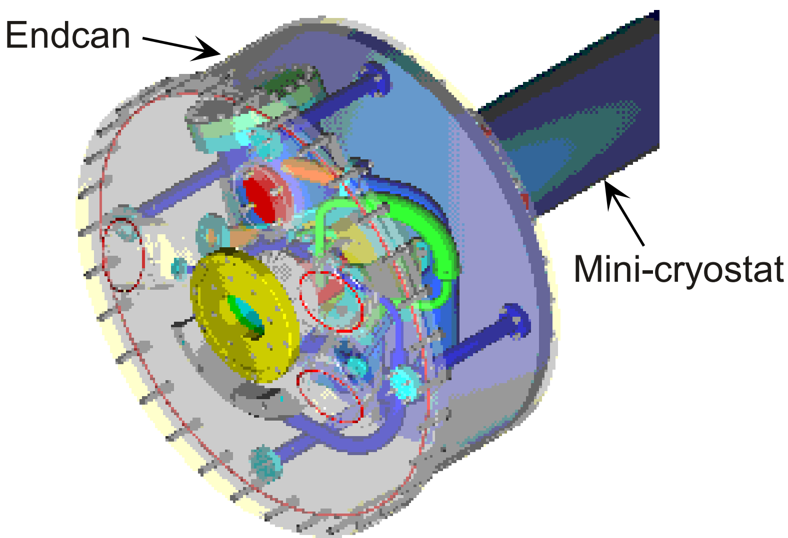
GM, HERA's Magnetic Septum Quadrupole

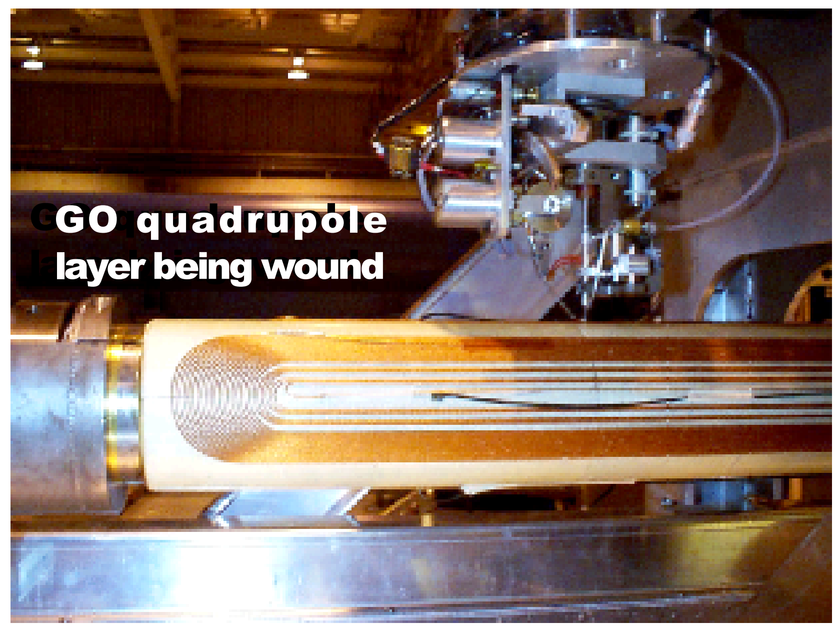
- For luminosity upgrade GM starts proton focusing at 11 m (previously 28 m).
- Inherently a combined function magnet, so is suitable for heavy ions but not e (synrad).

How is the HERA layout changed for the luminosity upgrade?

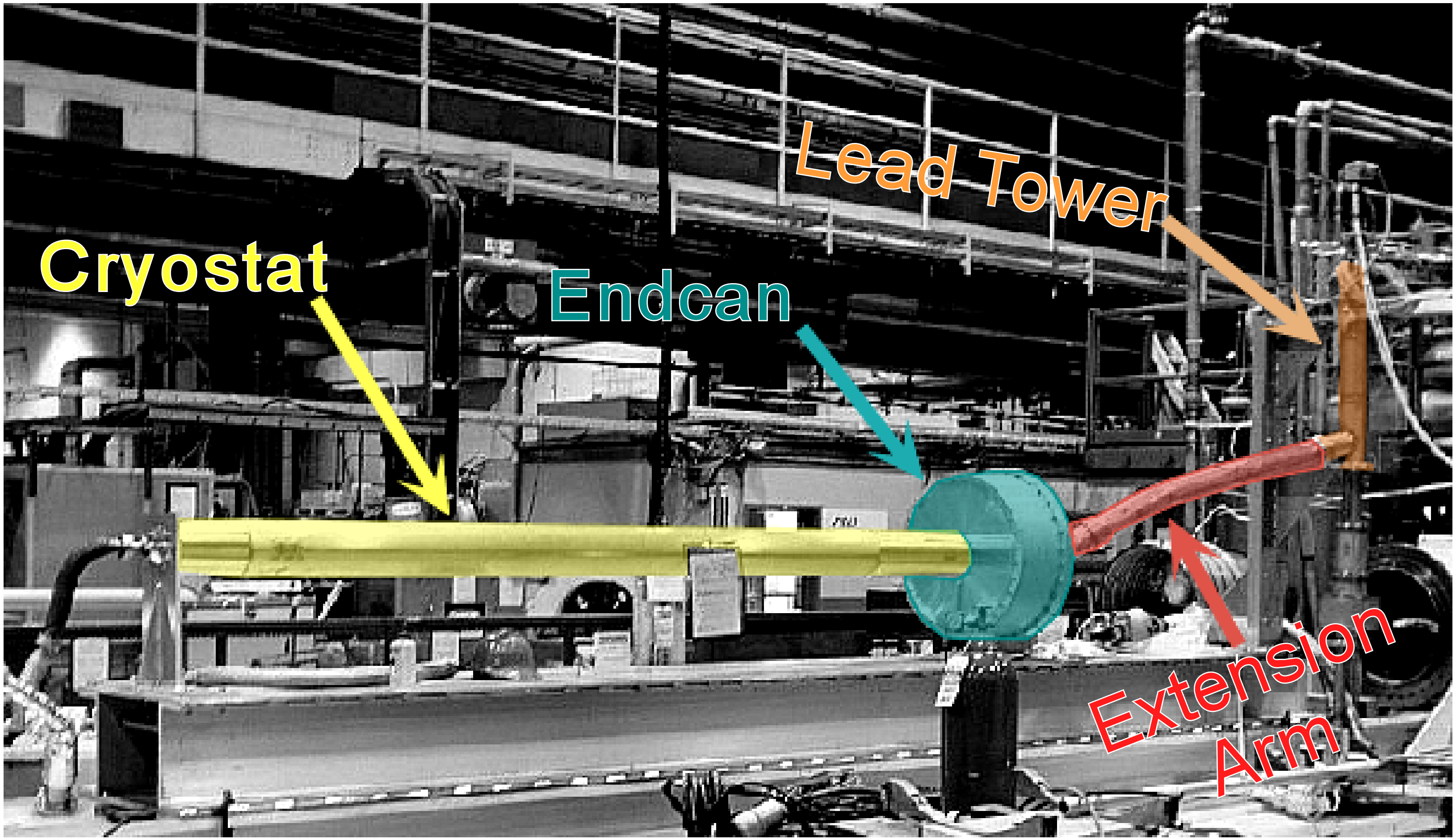


- Magnets go inside HERA experimental detectors.
- Multilayer coils with dipole, quadrupole, skew quadrupole, skew dipole and sextupole windings.
- For GG, a short tapered magnet, we achieved better than 10^{-4} field uniformity at 75% coil radius!

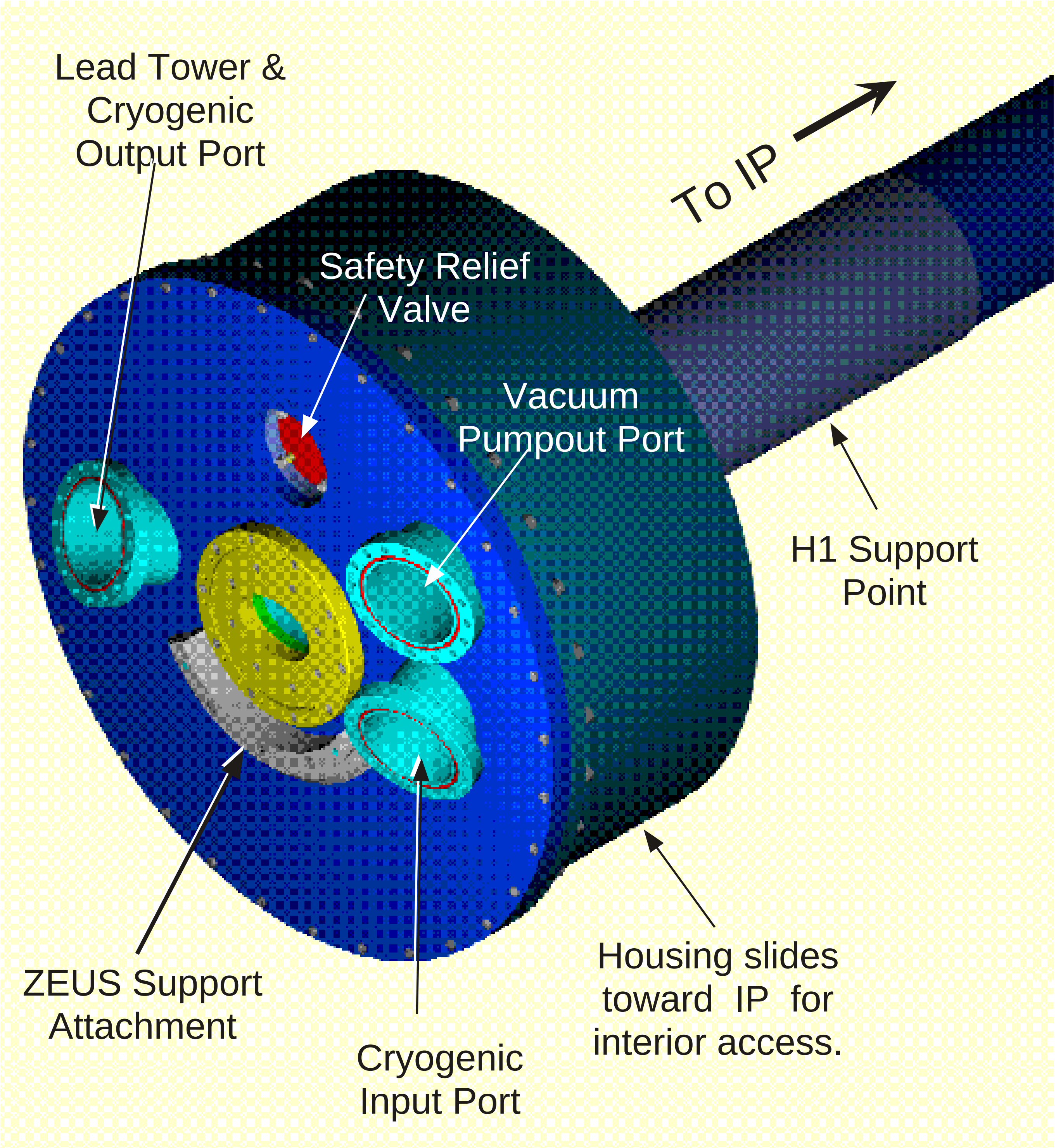




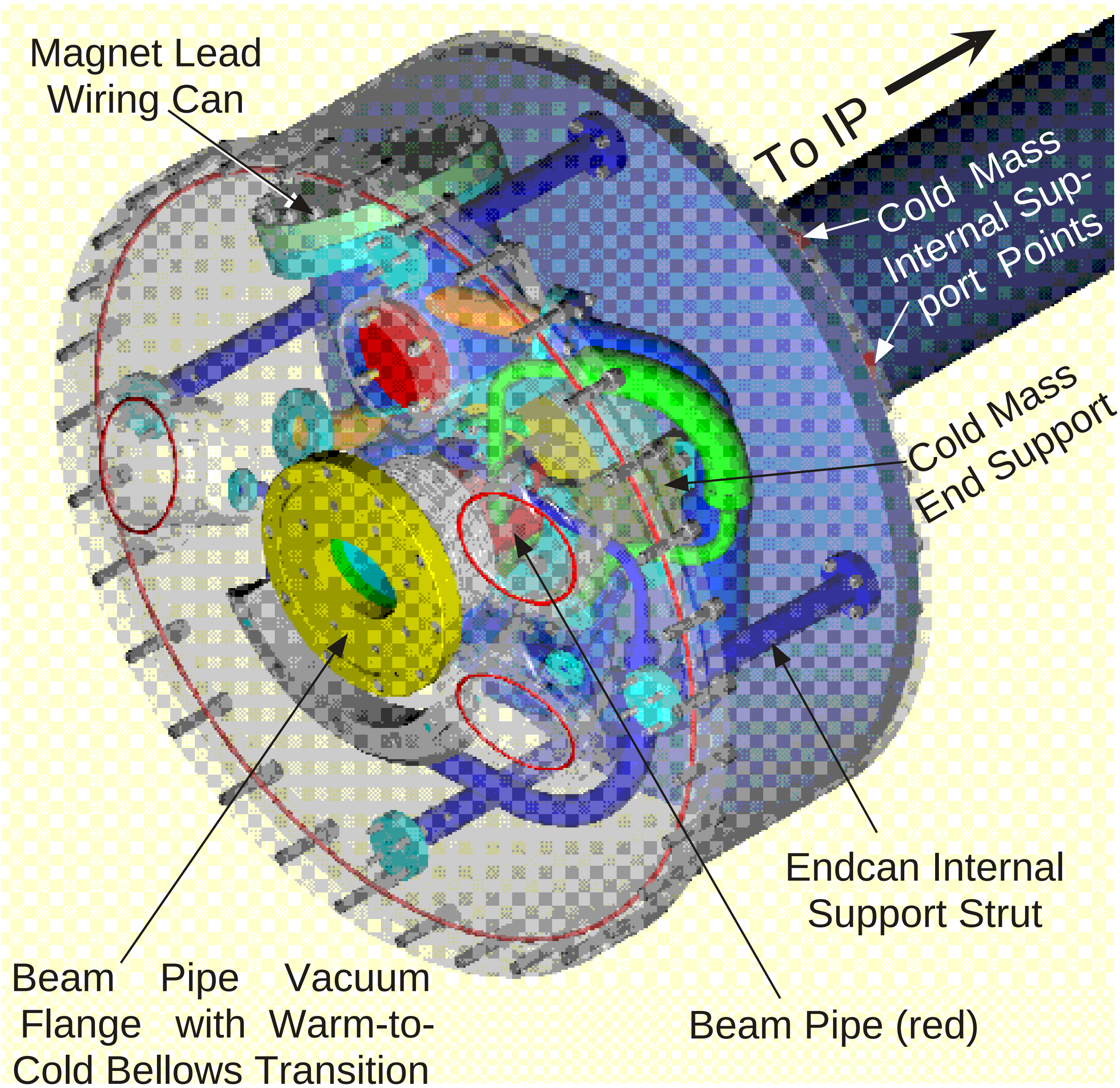
GO Magnet Horizontal Test in Magcool



Extension arms are different for H1 and ZEUS experiments.

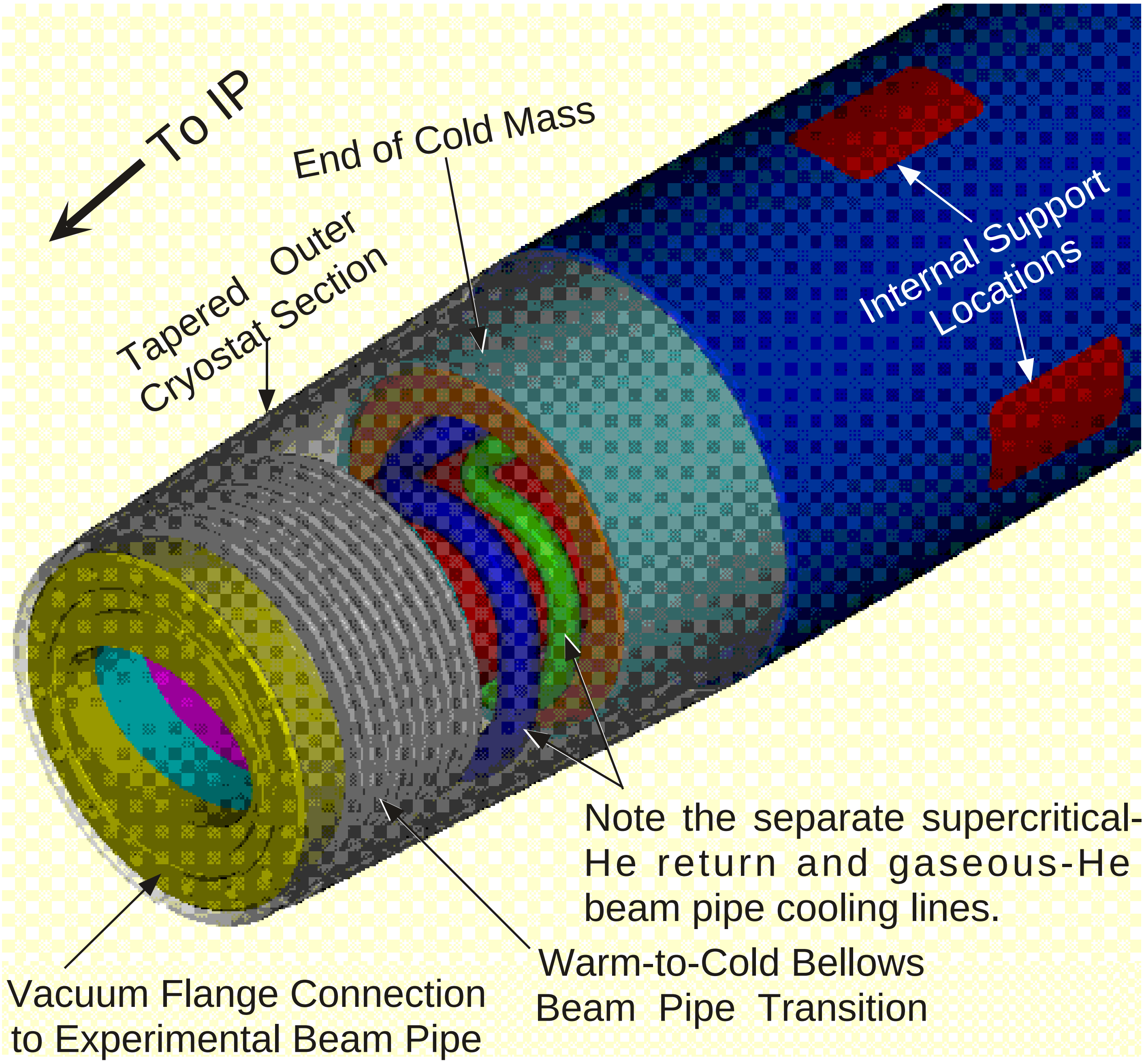


GO Magnet at Endbox: Inside experiment GO cryostat has smallest possible outer diameter. Cryogenic, electrical, vacuum and support connects are made via larger diameter endcan external to ZEUS and H1 detectors. 26.4.1999 B. Parker



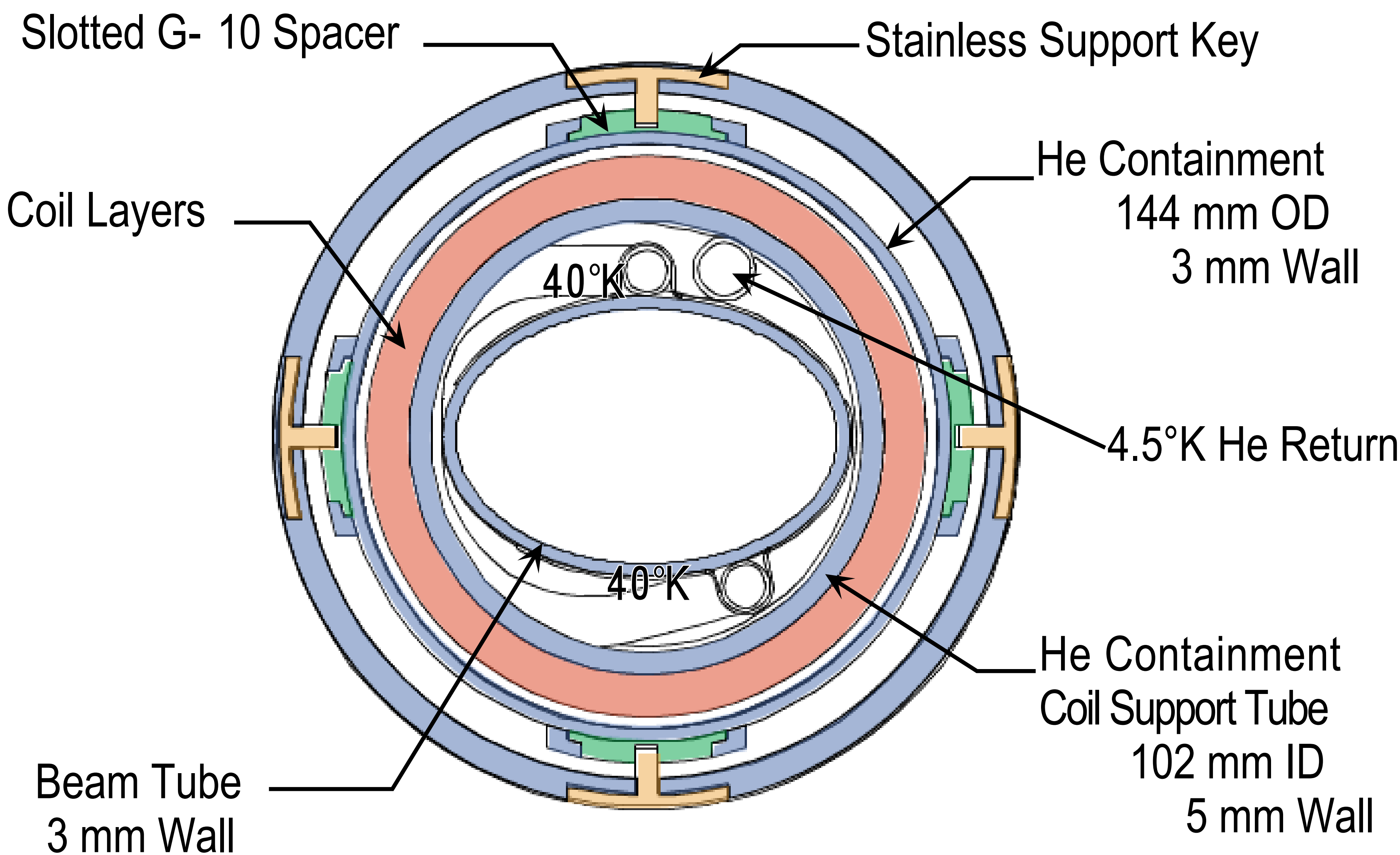
GO Endcan Interior View: This closeup of the GO endcan shows its interior support structure, magnet lead wiring can and flexible cryogenic plumbing. A short length of elliptical beam pipe is visible here between the cold mass end support and the beam pipe bellows warm-to-cold transition.

26.4.1999 B. Parker

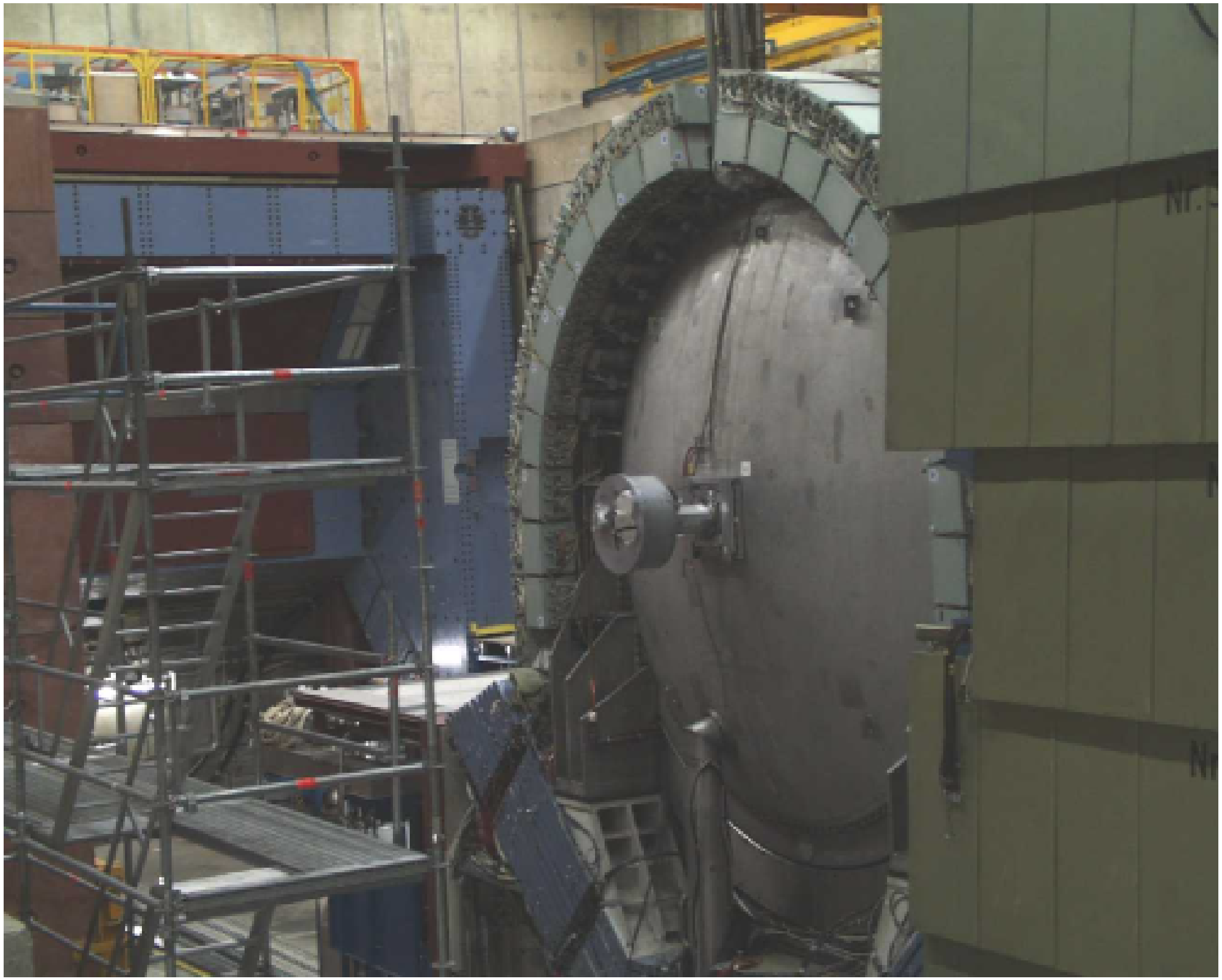


GO IP Side Detail: On IP end GO cryostat is tapered so as not to obstruct ZEUS FCAL IP-sight lines. A cryogenic line returns supercritical helium from cold mass end using vacuum space just outside elliptical beam pipe. Beam pipe cooling is separate. Connection to vacuum flange is via bellows for warm-to-cold transition. 26.4.1999 B. Parker

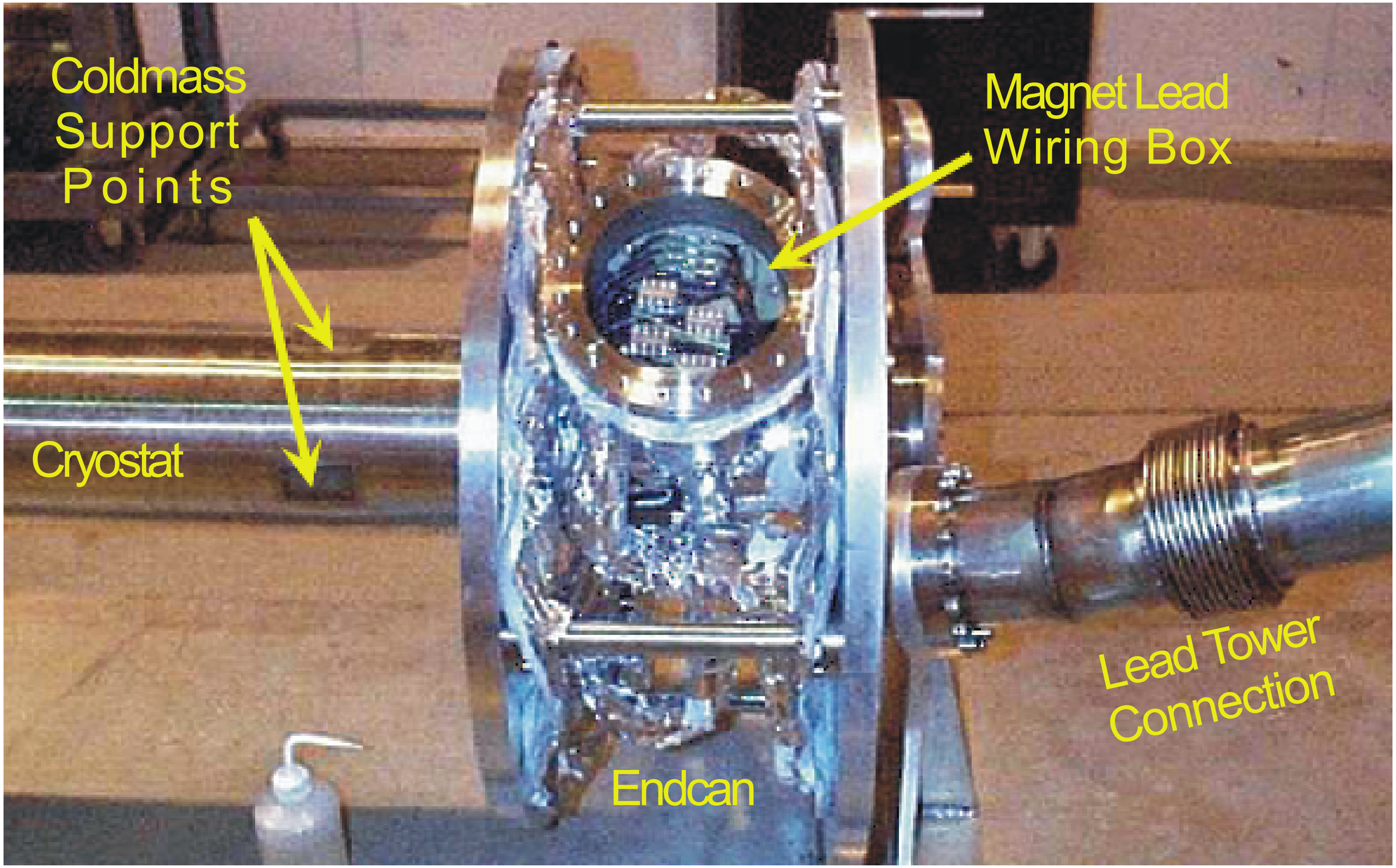
GO Cryostat Wall Section at Key Supports



GO Magnet Installed In H1 Experiment



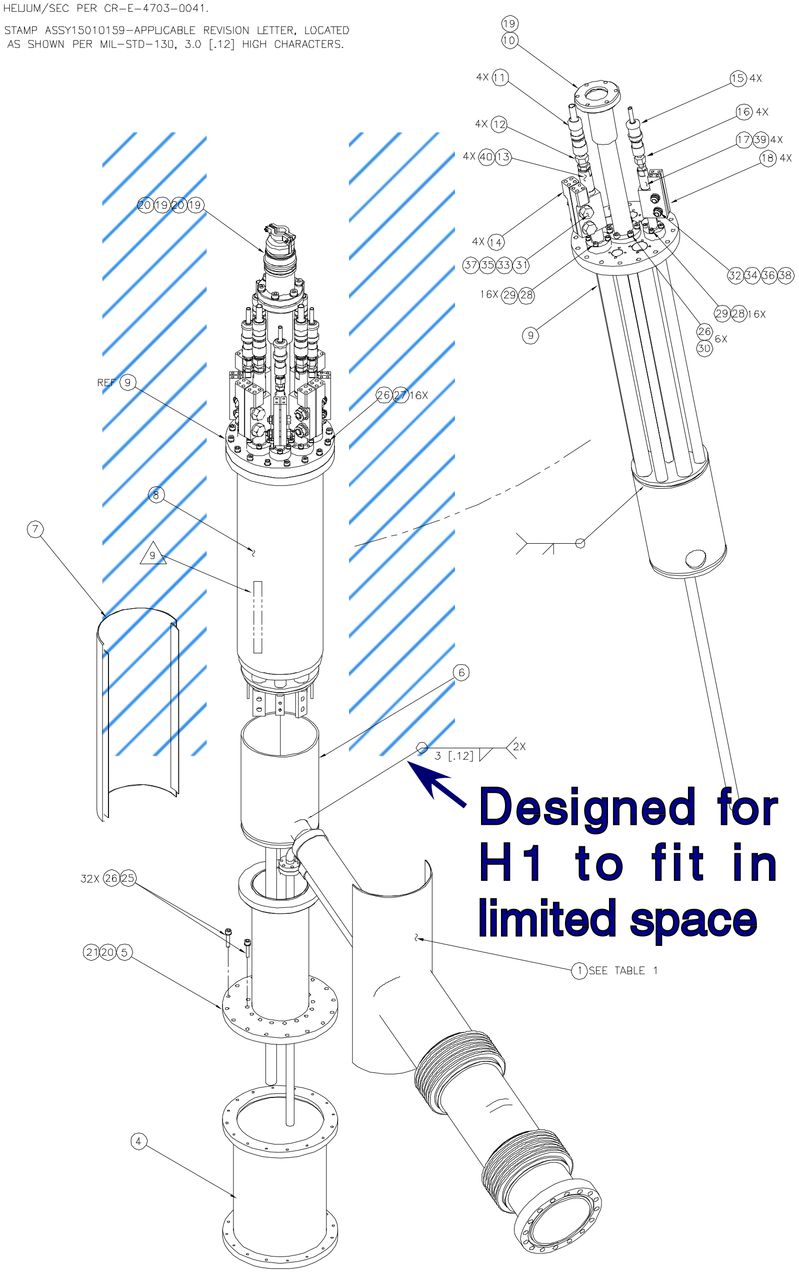
Endcan With Outer & Wiring Box Covers Removed



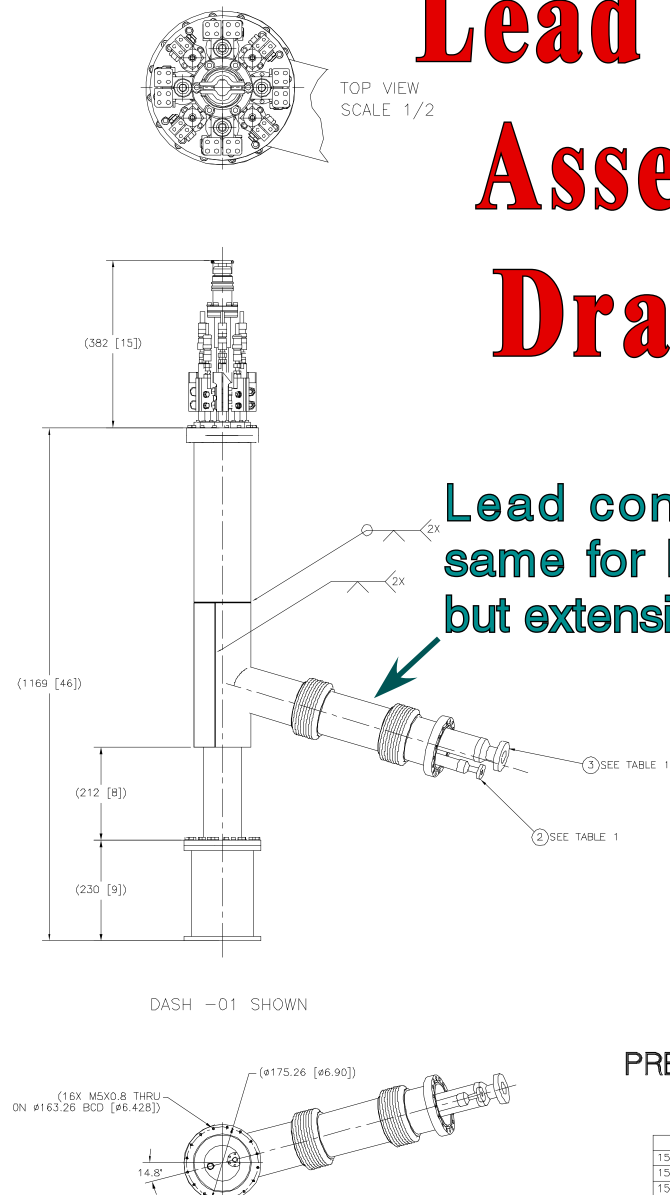
GO endcan is shown. Space for GG endcan was even more restricted.
GG plates are closer together and rectangular wiring box is used.

Lead Tower Assembly Drawing

NOTES:
1. VACUUM LEAK TEST: LEAK RATE NOT TO EXCEED 1x10 −9 STD CC HELIUM/SEC PER CR-E-4703-0041.
2. RUBBER STAMP ASSY15010159-APPLICABLE REVISION LETTER, LOCATED APPROX AS SHOWN PER MIL-STD-130, 3.0 [.12] HIGH CHARACTERS.



Designed for H1 to fit in limited space



Lead configuration is same for H1 and ZEUS but extension arms differ.

PRELIMINARY ONLY

TABLE 1

PART NO.	ITEM 1	ITEM 2	ITEM 3
15010159−01	1501XXXX	1501XXXX	1501XXXX
15010159−02	1501XXXX	1501XXXX	1501XXXX
15010159−03	1501XXXX	1501XXXX	1501XXXX
15010159−04	1501XXXX	1501XXXX	1501XXXX

SEE SEPARATE PARTS LIST PER TABLE 1

INTERPRET IN ACCORDANCE WITH ASME Y14.24M−1989
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS. DIMENSIONS IN [ ] ARE INCHES. ANGULAR TOLERANCE ± 1°

HERA LUMINOSITY UPGRADE

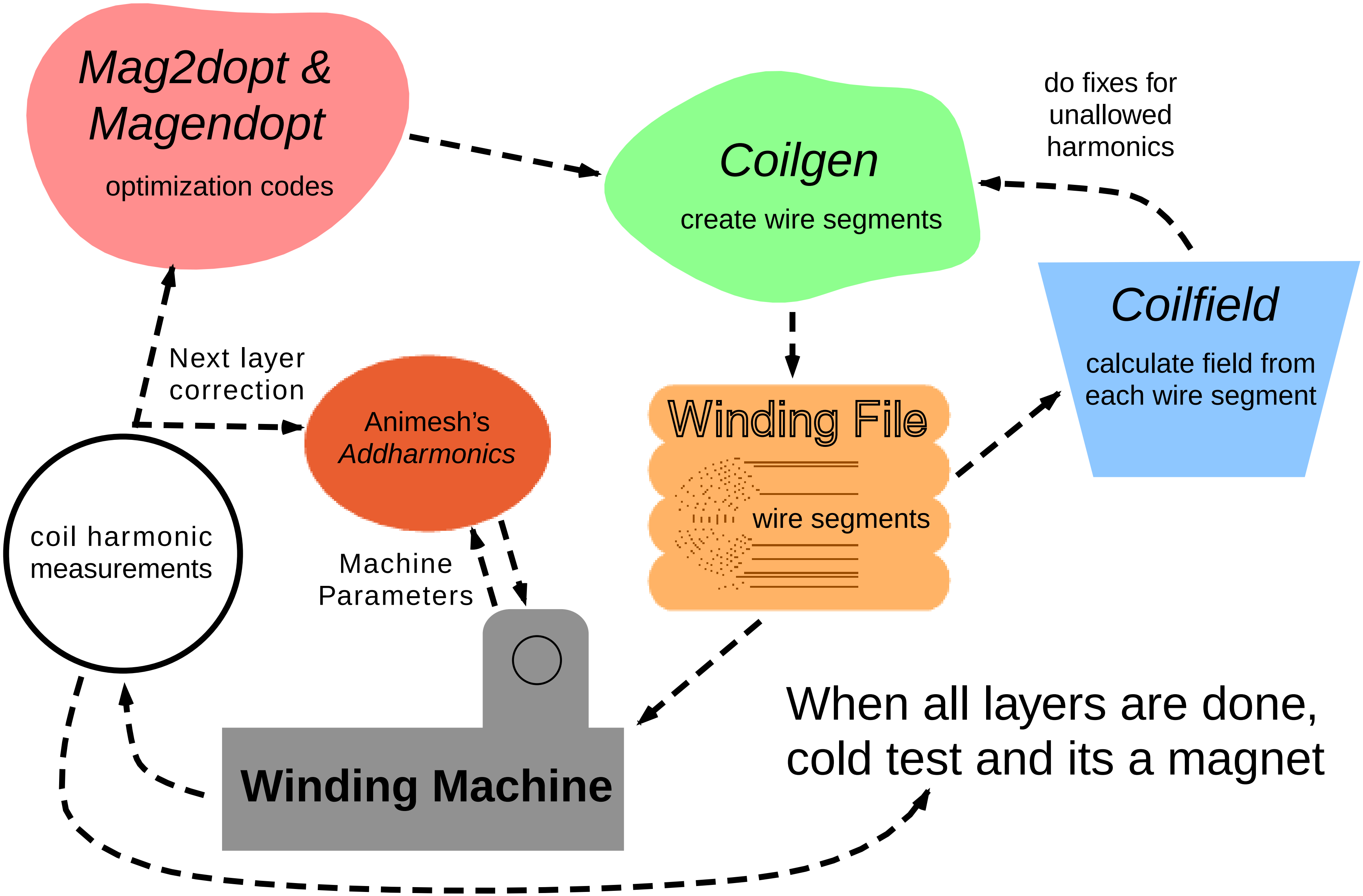
DRAWN BY: G.J.WHITBECK 8/4/99

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES
UPTON, N.Y. 11973

TITLE: GO/GG COMBINED ELEMENT MAGNET TOWER, ASSY

SIZE: E | DRAWING NUMBER: 15010159 | SCALE: 1/4 & NOTED | SHEET 1 OF 1

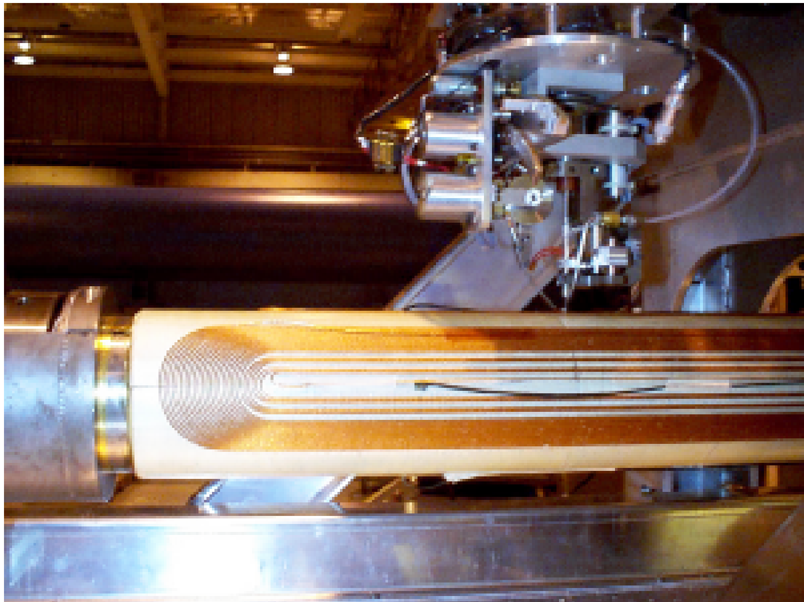
Pat Thompson's Magnet Design Codes



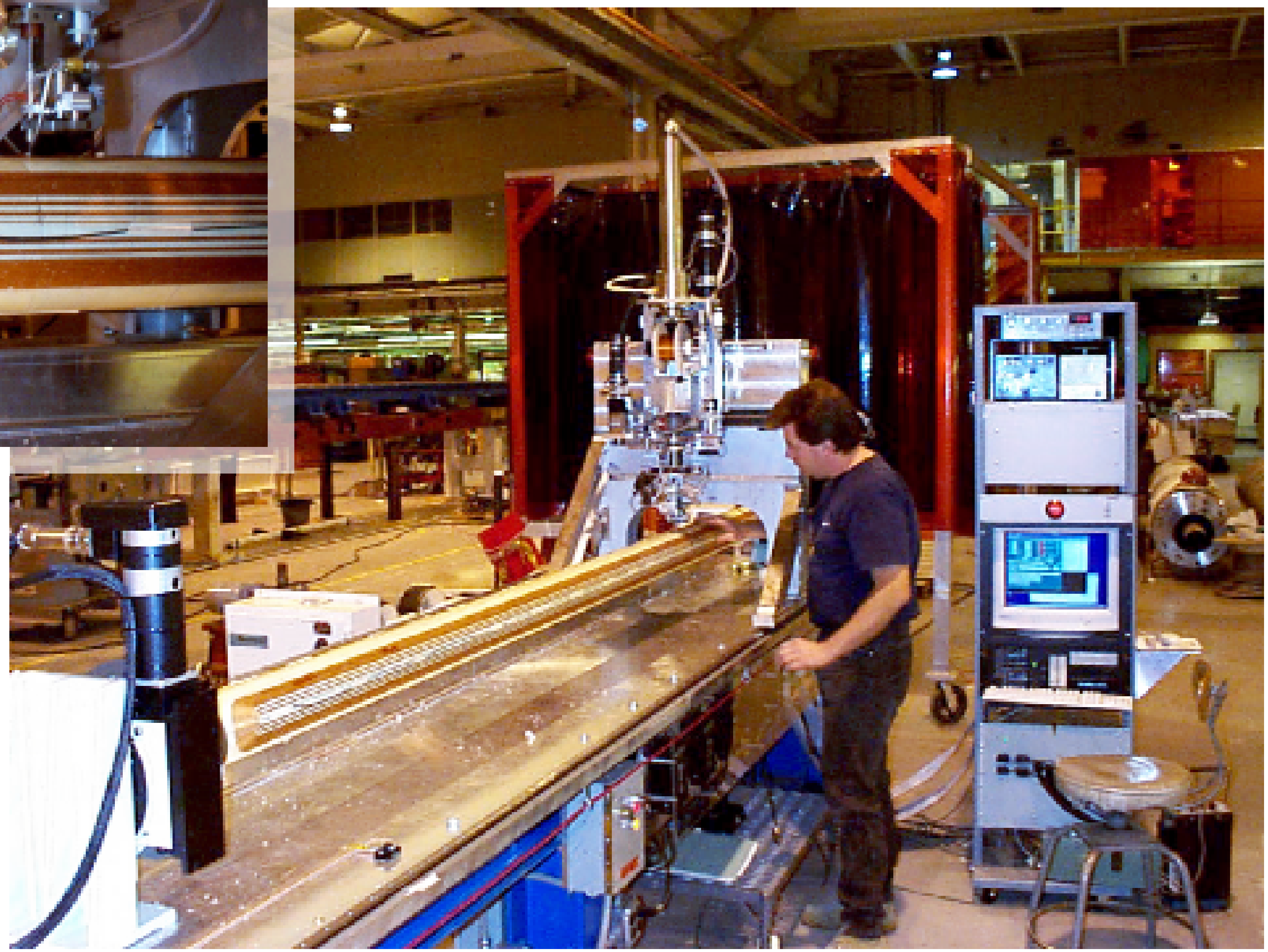
GO Magnet System: Coil Production

- Coated conductor was bonded to prepared surface via localized ultrasonic heating.
- Subcoils wound by spiraling out from pole and then spiraling in to neighboring pole.
- Harmonic spacers and the pole regions are filled in with G-10 and epoxy.
- S-glass fiber used for compression wrap.
- Coil layers cured in clamping fixture with no machining of cured coils.

Computer Controlled Winding Machine

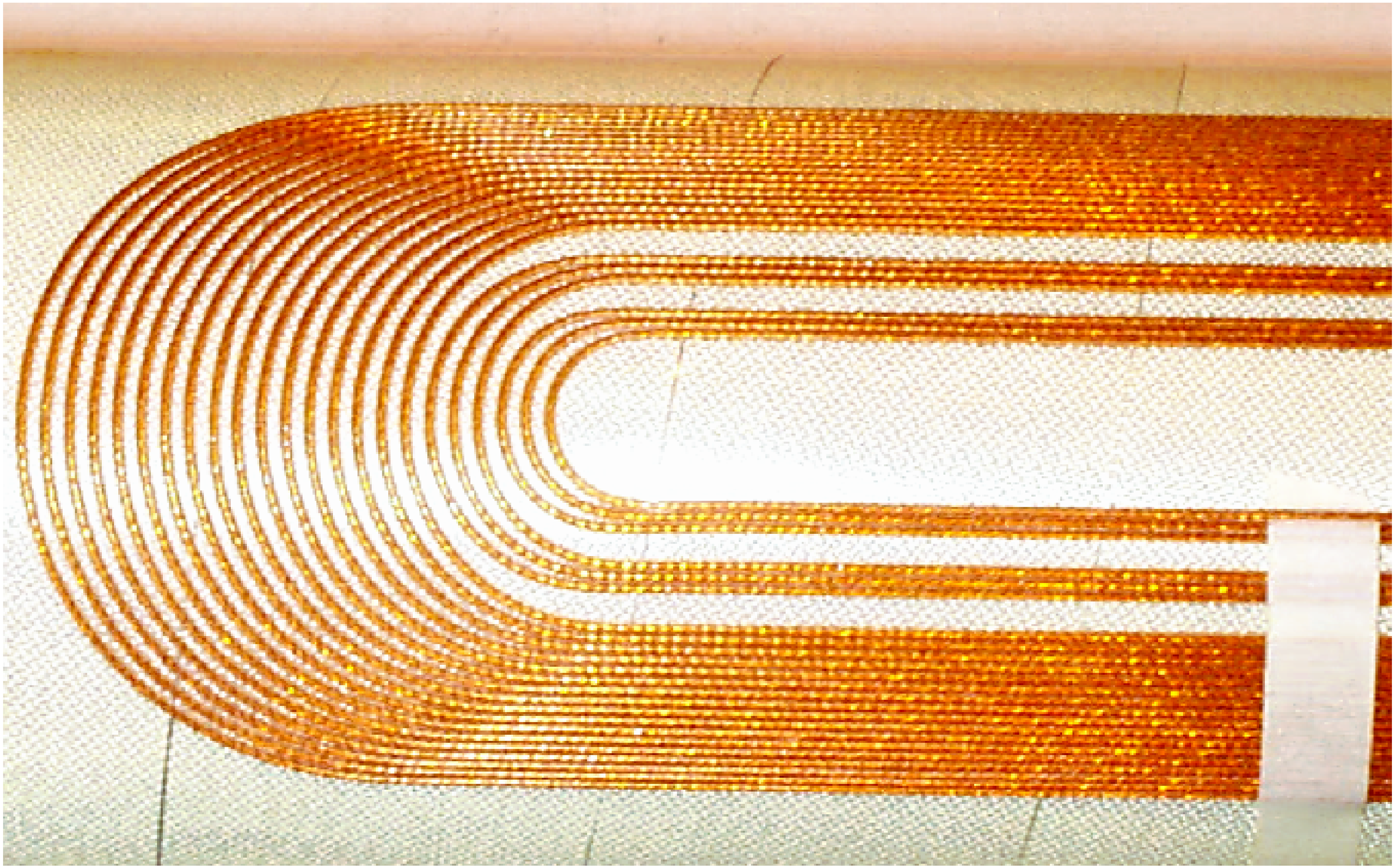


File used for field harmonics gives winding machine the path in space for the conductor.

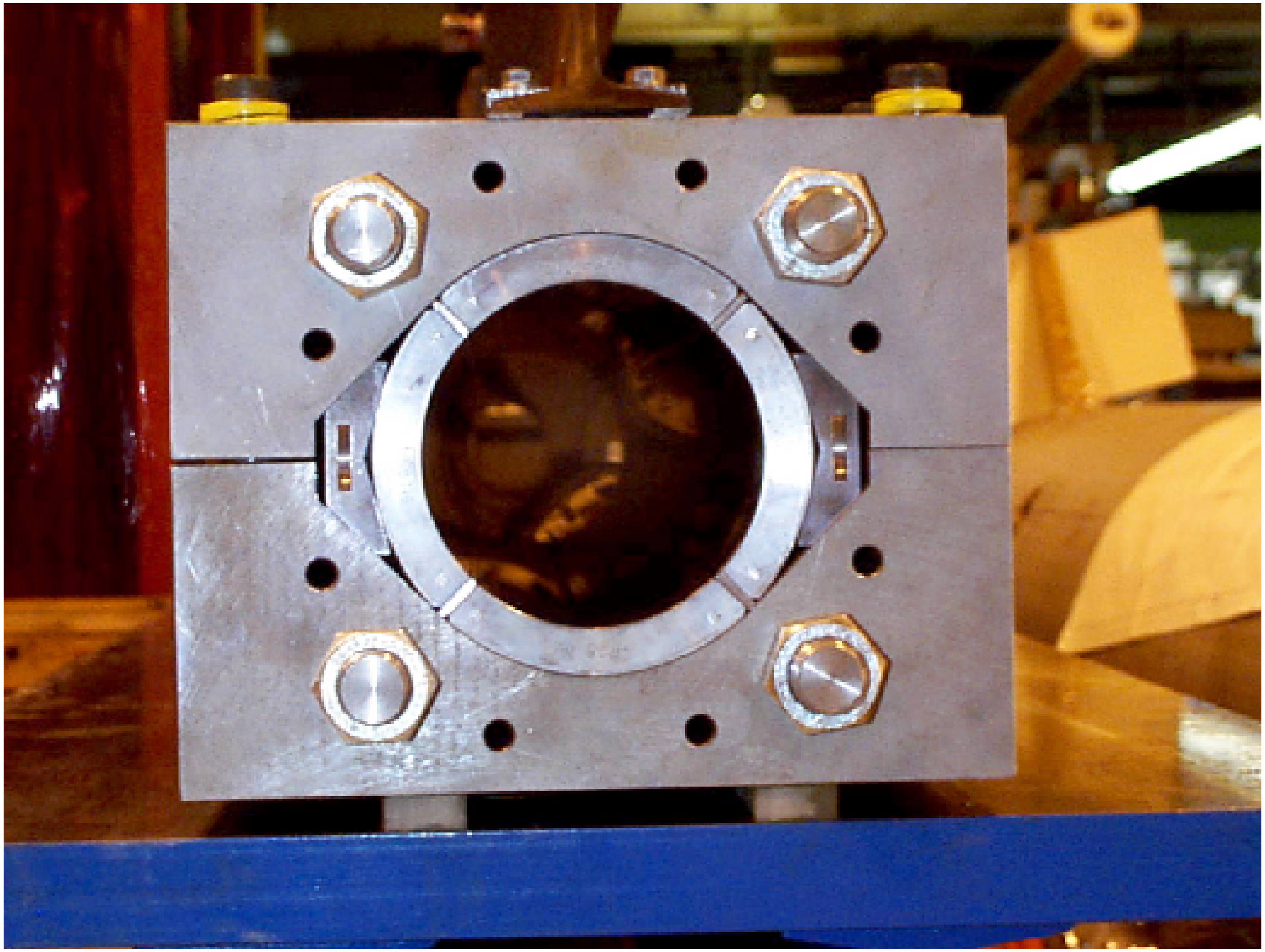


Insulated conductor with b-stage epoxy coating is payed out under hollow stylus. Ultrasonic heating and rapid cooling leaves conductor bonded to substrate. Typically a coil goes next to magnetic measurements.

GO Quadrupole Layer Winding



HERA Coil Curing Fixture



HERA Upgrade Magnets: Coil Production

- Coils wound from either 7-strand cable or 0.33 mm single strand wire.
- Coil spacer gaps and variable conductor spacing provide field harmonic knobs.
- Tune both integral and body harmonics.
- Magnetic measurement results are used to fine tune multi-layer coil harmonics.

HERA Upgrade Magnets: Field Harmonics

GO Harmonics at R=31 mm, Centered

Untapered Magnet, Dipole Inner Radius = 56 mm

	Dipole	Quadrupole	Skew Dipole	Skew Quad.	Sextupole
I.T.F.	1.5620	81.1609	0.7056	11.5601	711.5599
Fld. Ang.	0.0	0.8	0.7	2.2	0.2
Leff(m)	3.094	3.106	--	--	--
b1	10000.00	0.00	0.00	0.00	19.81
b2	0.71	10000.00	-1.01	0.00	0.00
b3	3.52	0.79	0.14	-1.19	10000.00
b4	0.24	0.67	0.43	-0.38	1.24
b5	-0.50	0.42	0.22	0.11	1.73
b6	-0.13	-0.16	0.00	0.37	0.68
b7	-0.55	-0.01	0.00	0.01	0.20
b8	0.00	-0.02	0.00	0.17	-0.04
b9	-0.15	0.00	0.00	0.00	-0.09
b10	0.02	-0.06	0.00	0.00	-0.06
b11	0.45	-0.01	0.00	0.00	-0.02
b12	0.00	0.00	-0.01	-0.01	0.00
b13	-1.57	0.00	0.00	0.01	-0.01
b14	0.00	-0.38	0.01	0.00	0.00
b15	0.33	0.00	0.00	0.00	-0.31
a1	0.00	0.00	10000.00	0.00	1.29
a2	-4.97	0.00	-1.03	10000.00	0.00
a3	0.67	0.87	0.88	7.27	0.00
a4	0.33	-1.26	0.52	-3.32	0.70
a5	0.21	0.03	-0.42	-0.22	-0.48
a6	0.15	0.08	0.26	0.25	-1.19
a7	-0.04	0.07	0.82	0.04	-0.59
a8	0.09	0.09	0.00	0.19	0.04
a9	0.00	-0.02	-0.16	-0.03	0.07
a10	0.02	-0.01	-0.01	-0.06	0.03
a11	0.00	0.00	0.05	-0.02	0.05
a12	0.00	0.00	0.00	0.01	0.01
a13	0.01	0.01	0.00	0.00	0.01
a14	0.00	0.00	-0.01	0.14	0.00
a15	-0.01	0.00	0.03	0.00	0.01

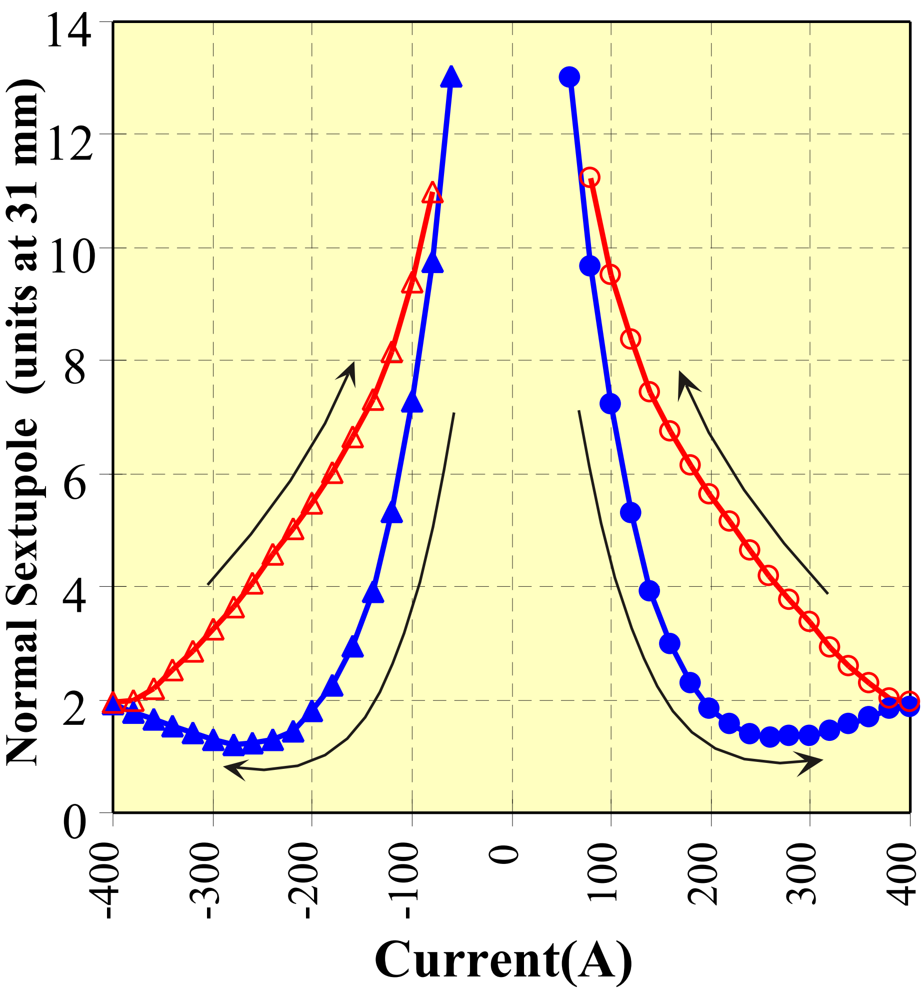
GG Harmonics at R=45 mm, Centered

Tapered Magnet, Quad Inner Radius = 65 to 70 mm

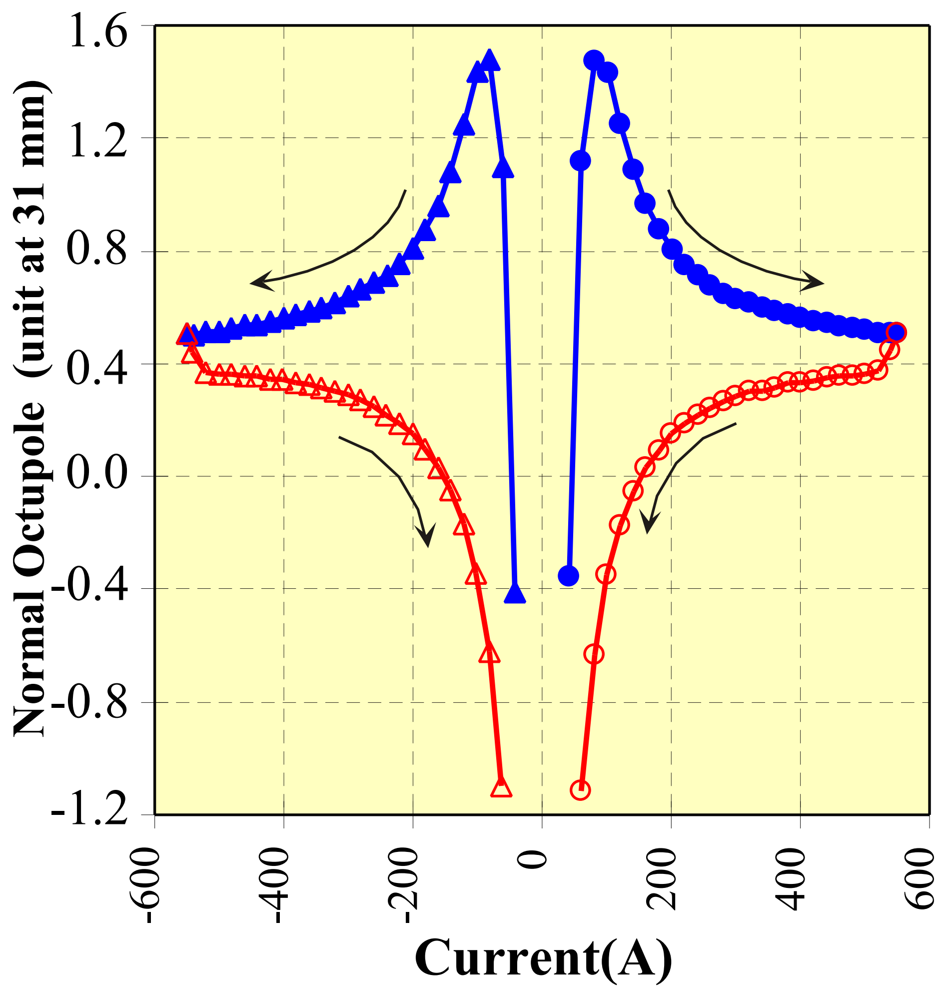
	Quadrupole	Dipole	Skew Dipole	Skew Quad.	Sextupole
I.T.F.	9.423	1.1593	1.0398	15.307	162.51
Fld. Ang.	0.0	-0.4	-2.3	0.0	-1.2
Leff(m)	Not meas.	Not meas.	Not meas.	Not meas.	Not meas.
b1	0.00	10000.00	0.00	0.00	-8.57
b2	10000.00	-2.23	-1.99	0.00	0.00
b3	-2.23	-0.04	0.21	-1.09	10000.00
b4	1.49	-0.07	-0.31	-1.01	-1.95
b5	-1.10	-0.12	-0.58	1.31	-3.27
b6	1.11	0.03	0.43	0.45	0.72
b7	-1.48	0.33	-0.38	0.53	-2.22
b8	0.73	-0.11	-0.34	0.51	0.73
b9	-0.34	0.09	0.04	0.08	-1.57
b10	0.63	-0.03	0.00	0.10	-0.28
b11	-0.08	0.06	0.05	-0.13	-1.19
b12	0.13	0.01	-0.06	-0.17	-0.08
b13	-0.07	-0.04	0.00	0.04	-0.63
b14	0.02	0.06	0.10	0.09	0.04
b15	0.01	-0.08	0.04	0.06	-0.25
a1	0.00	0.00	10000.00	0.00	13.99
a2	0.00	-3.02	5.22	10000.00	0.00
a3	-1.51	0.08	2.95	-3.53	0.00
a4	1.18	-0.43	0.09	5.12	-0.93
a5	1.81	-0.31	-3.25	-0.53	0.55
a6	-0.64	-0.18	-0.37	0.10	-1.61
a7	-0.96	-0.36	0.13	0.51	0.70
a8	0.52	0.14	0.07	0.65	0.44
a9	-0.45	-0.05	0.08	0.12	0.12
a10	-0.11	0.03	-0.11	-0.17	0.32
a11	0.23	0.02	-0.22	0.32	0.42
a12	0.12	-0.02	-0.06	0.02	0.49
a13	-0.03	-0.01	-0.14	-0.08	0.09
a14	0.13	0.00	0.04	-0.16	-0.43
a15	0.02	0.07	0.19	0.02	-0.18

Integral Transfer Function (I.T.F.) in T·m for dipole; T/kA for quadrupole and T/m/kA for sextupole. Field angle in mrad, relative to center of dipole layer.

HERA Upgrade Magnets: Magnetization

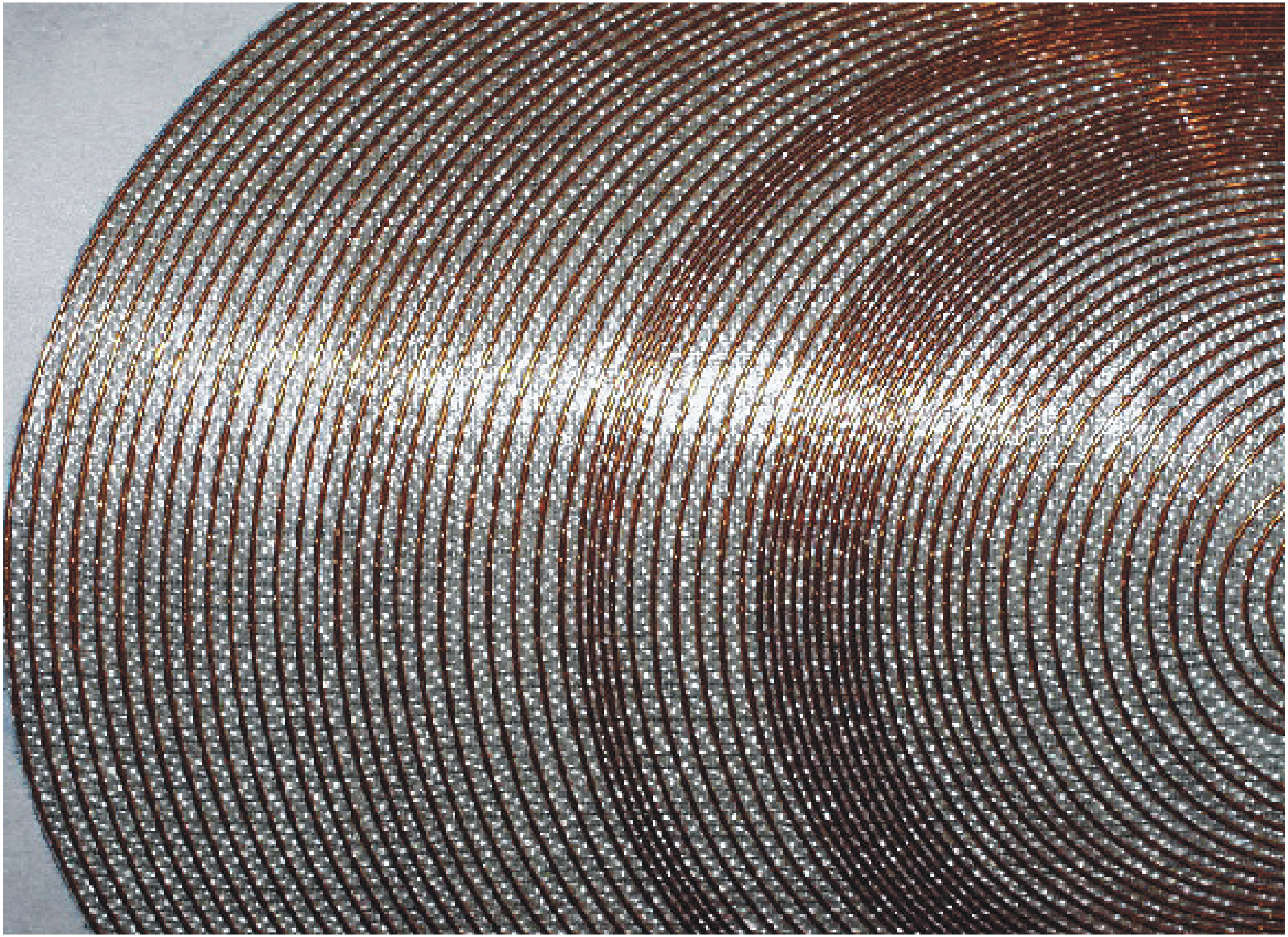


GO Dipole Coil: Allowed Sextupole



GO Quad Coil: Unallowed Octupole

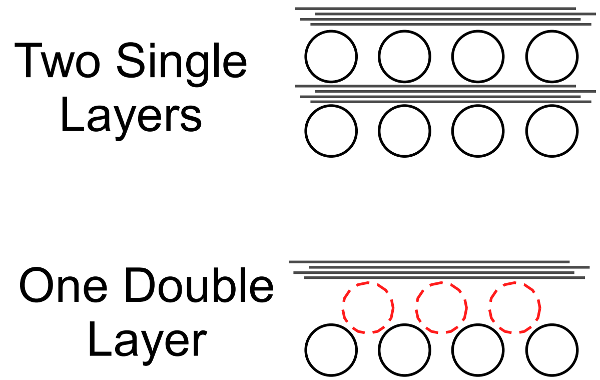
GG Coil Production with 0.33 mm Wire

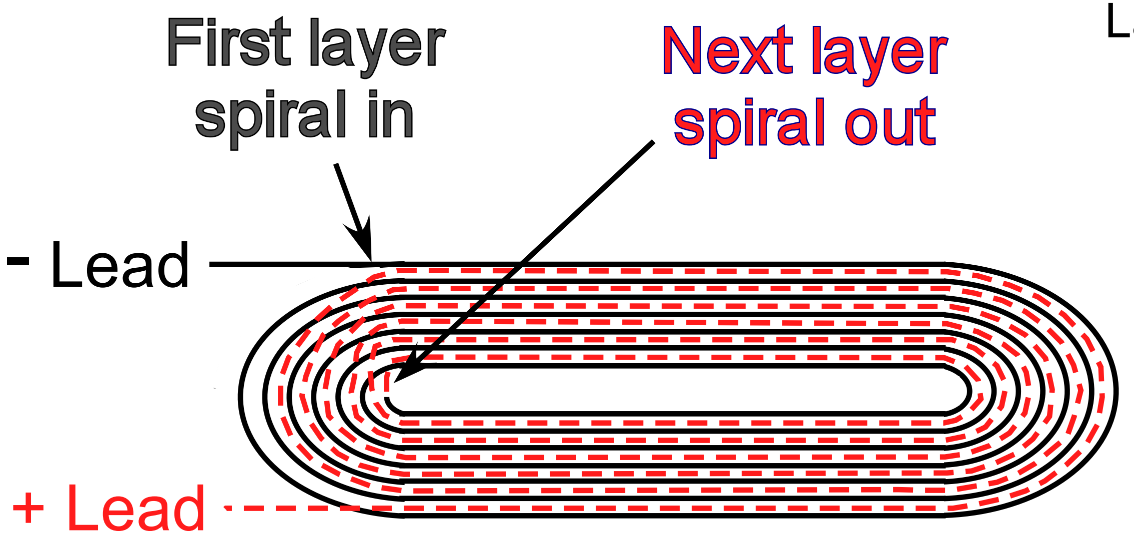


Closeup of GG coil end showing variable wire spacing

Next Step: Make Double Layer Windings*

- Double layer winding moves leads from pole region to the midplane.
- Fewer wrapping and curing steps.





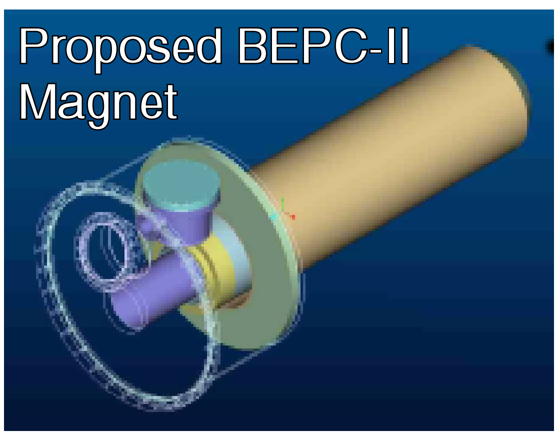
Then continue winding the next subcoil

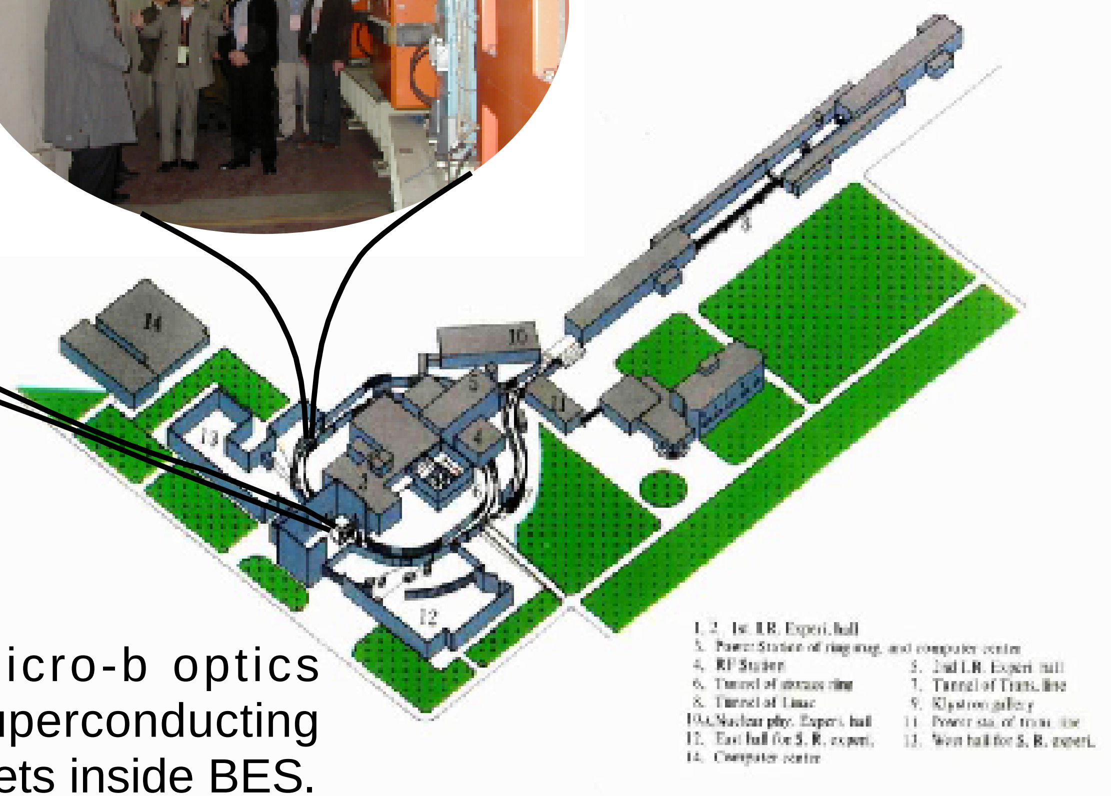
*RHIC corrector flat patterns were routinely wound in double layers.

BEPC-II Luminosity Upgrade at IHEP Beijing

Add a second ring in the existing tunnel.

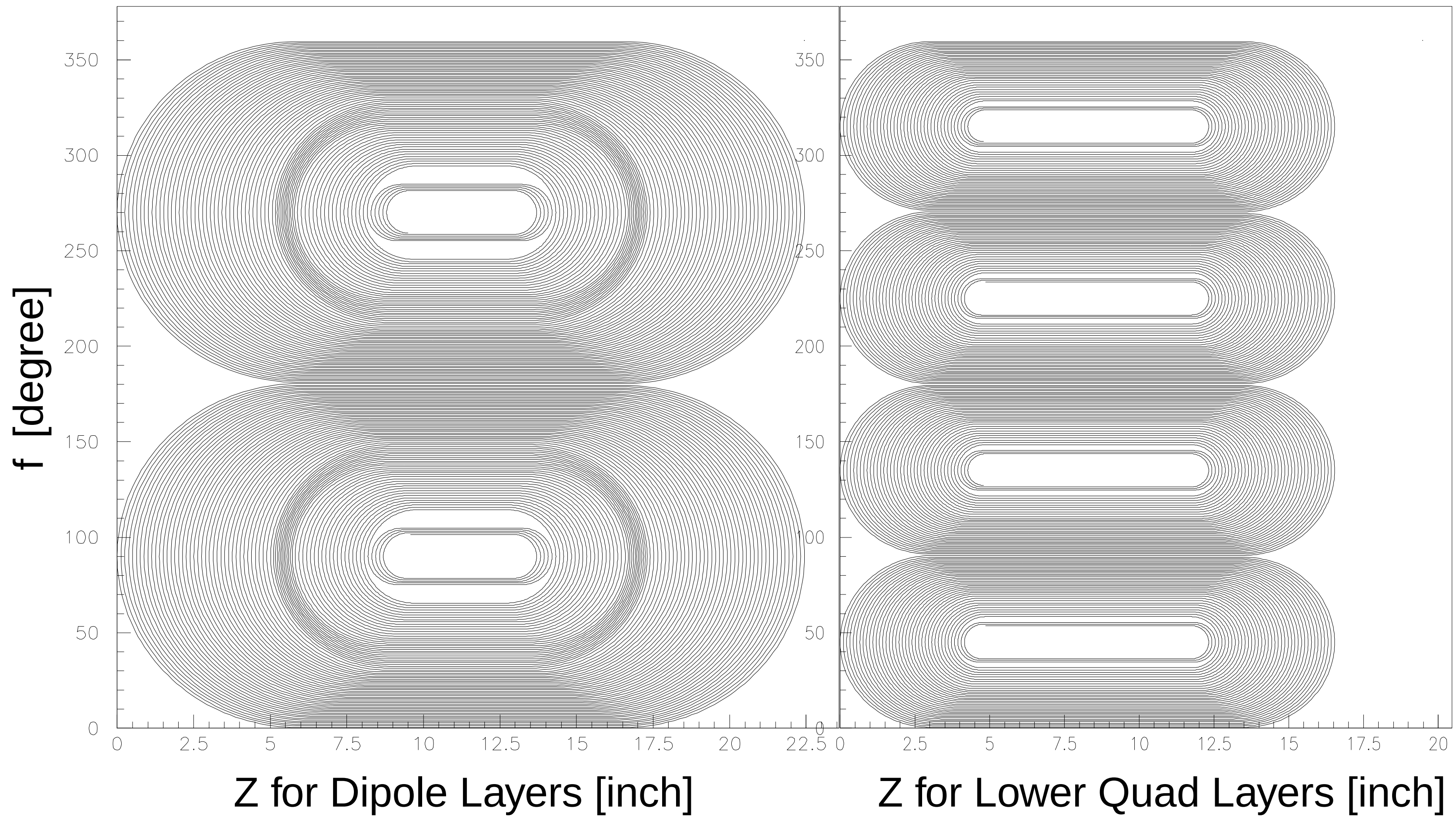
Upgrade the full energy linac injector and add ring superconducting rf.





Do micro-b optics via superconducting magnets inside BES.

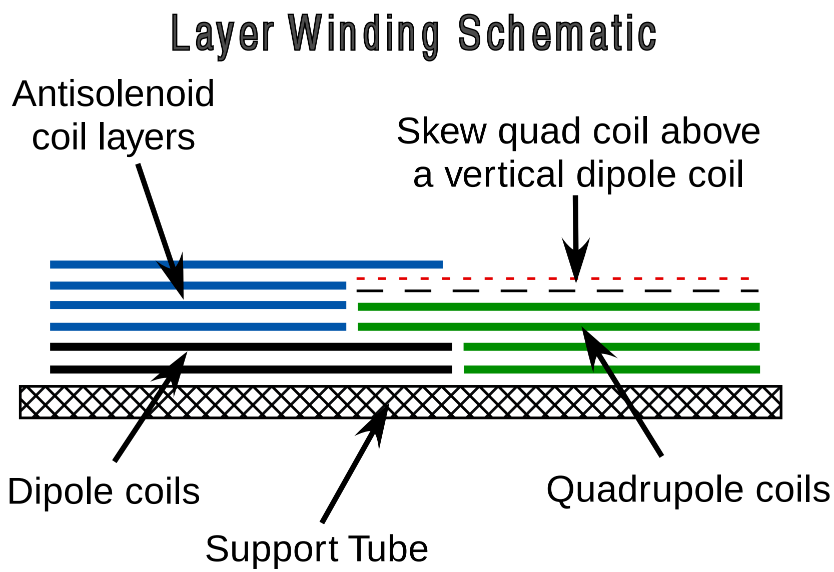
Bottom Coil Layout For BEPC-II Magnets

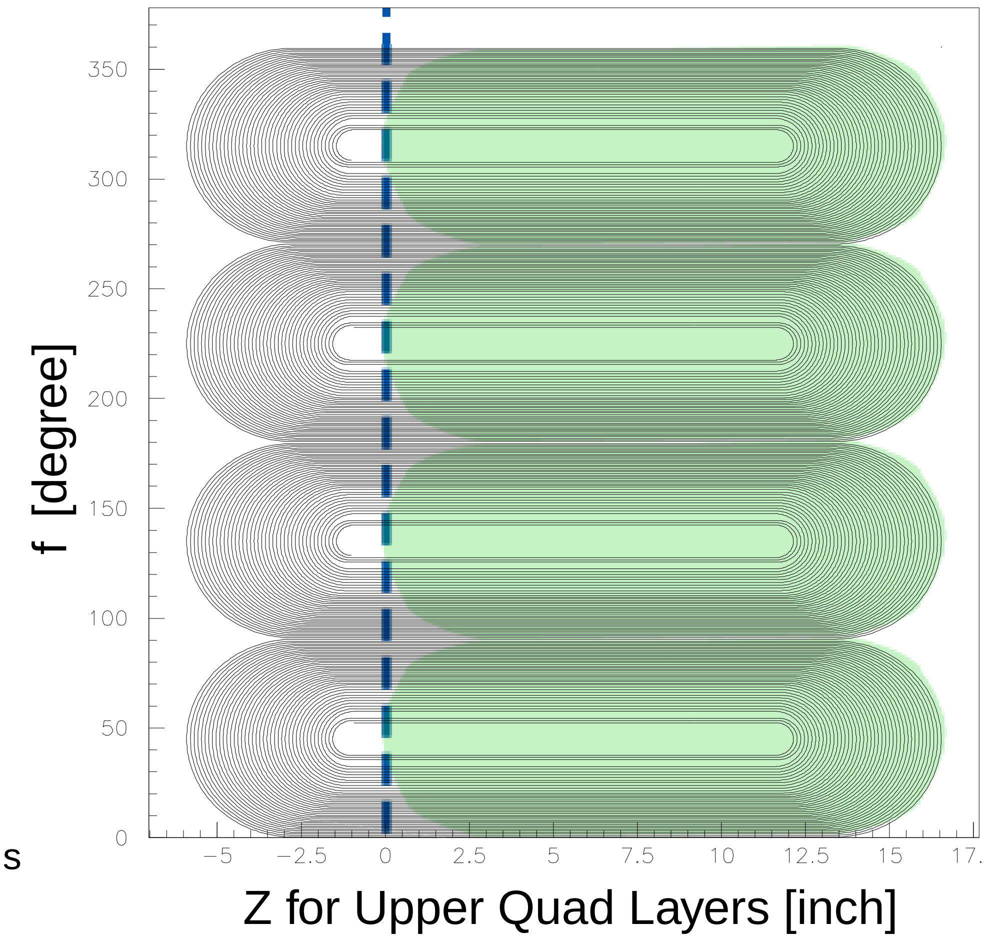


If quadrupole coil is made full length, then dipole coil has essentially no straight section. But we cheat and make first quadrupoles layers shorter...

Upper Coil Layout For BEPC-II Magnets

Upper quadrupole layers can be extended to recover loss in quadrupole transfer function. Center of focusing of combined coil is then adjusted to be at desired location.





The antisolenoid then shares layer space with the upper quadrupole coils.

A single layer skew quadrupole corrector can be wound over a dipole corrector. Both coils can use thin single strand wire.