Accelerator Constraints for the FCC-ee IR

John T. Seeman
SLAC National Accelerator Laboratory
November 17, 2023
FCC-ee MDI Workshop

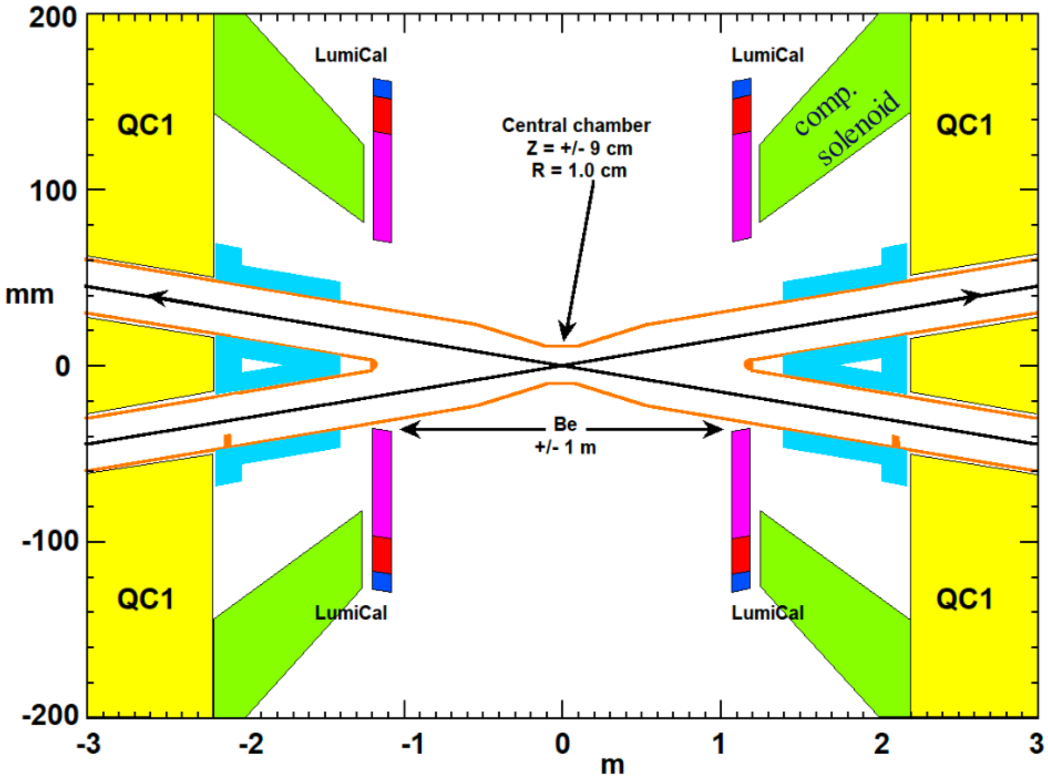
Near Primary MDI IR Issues (Part 1)

1. Cryostat layers, dimensions, and contraction allowances.
2. BPM installed between magnets (e.g. QC1a and QC1b, etc): three per side per ring are “relatively easy”.
3. Magic flanges: remote vacuum connections (FCCee three per side?)
4. Supports for anti-solenoid.
5. Solenoid compensation (anti-solenoid vs. skew quadrupoles).
6. Magnet support and vibration control.
7. Space behind lumi-cal for other utilities (cables, diagnostics).
8. Explicit IP chamber design to divide from one to two chambers.
9. Most efficient quadrupole design (minimal radial space needed).
10. Cables and routing for vertex chamber.

Near Primary MDI IR Issues (Part 2)

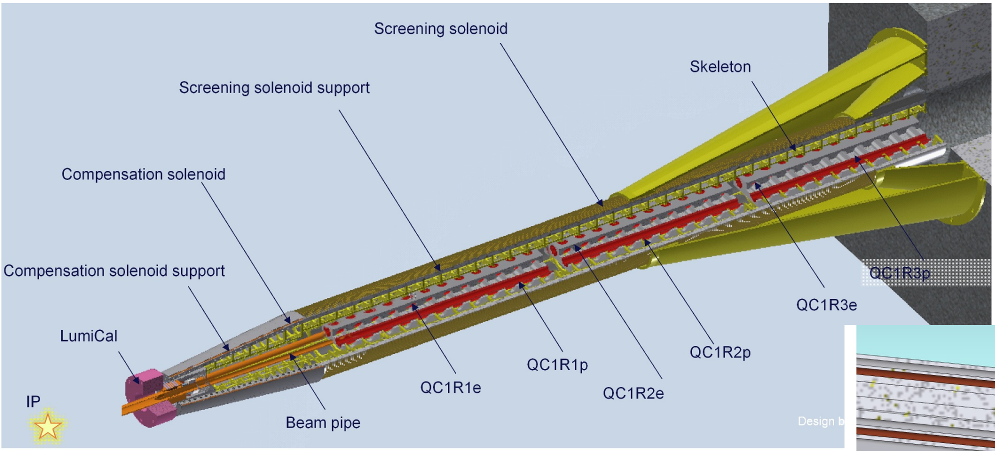
11) Needed magnetic trim coils.
12) Magnetic lengths versus physical lengths of QC1-A-B-C and QC2-A-B.
13) Detector shielding to include in cryostat and cone between 100 and 150 mrad.
14) Deposition of beam energy (~100 W) in magnets, shielding, cryostat.
15) How would the Raimondi lattice affect the IR design.
16) NEG coating: deposition, activation, longevity.
17) IP bellows design (needed compliance, cooling, HOM damping).
18) Assembly of cryostats with all the individual components.

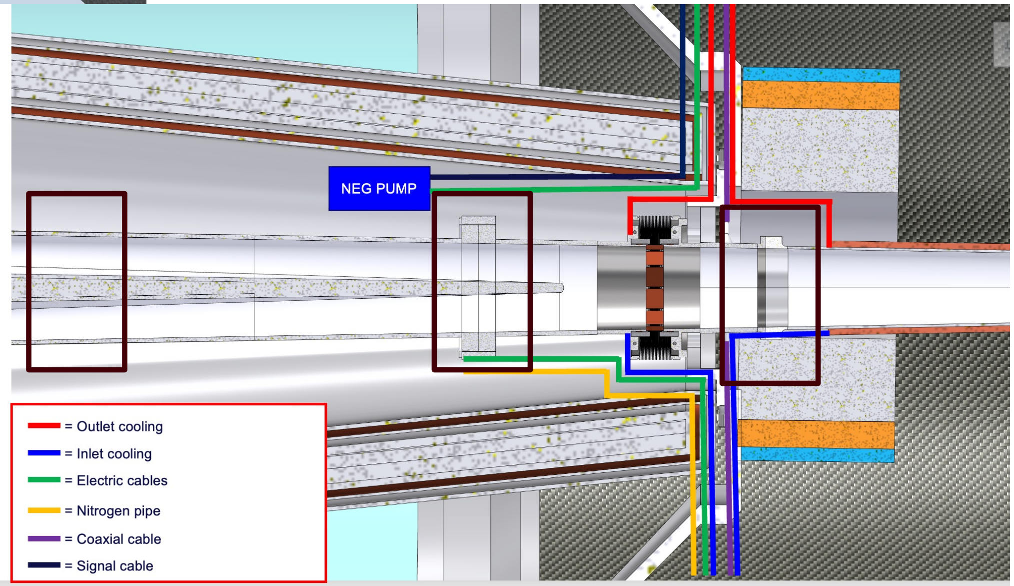
FCCee Interaction Region Layout (Boscolo, Sullivan, …)



- L* is **2.2** m (L* is the face of the first final focus quadrupole QC1, and the free length from the IP).
- Central vacuum chamber has 10 mm radius, 180 mm long.
- Crotch at about 1.2 m, with two symmetric beam pipes with radius of 15 mm.

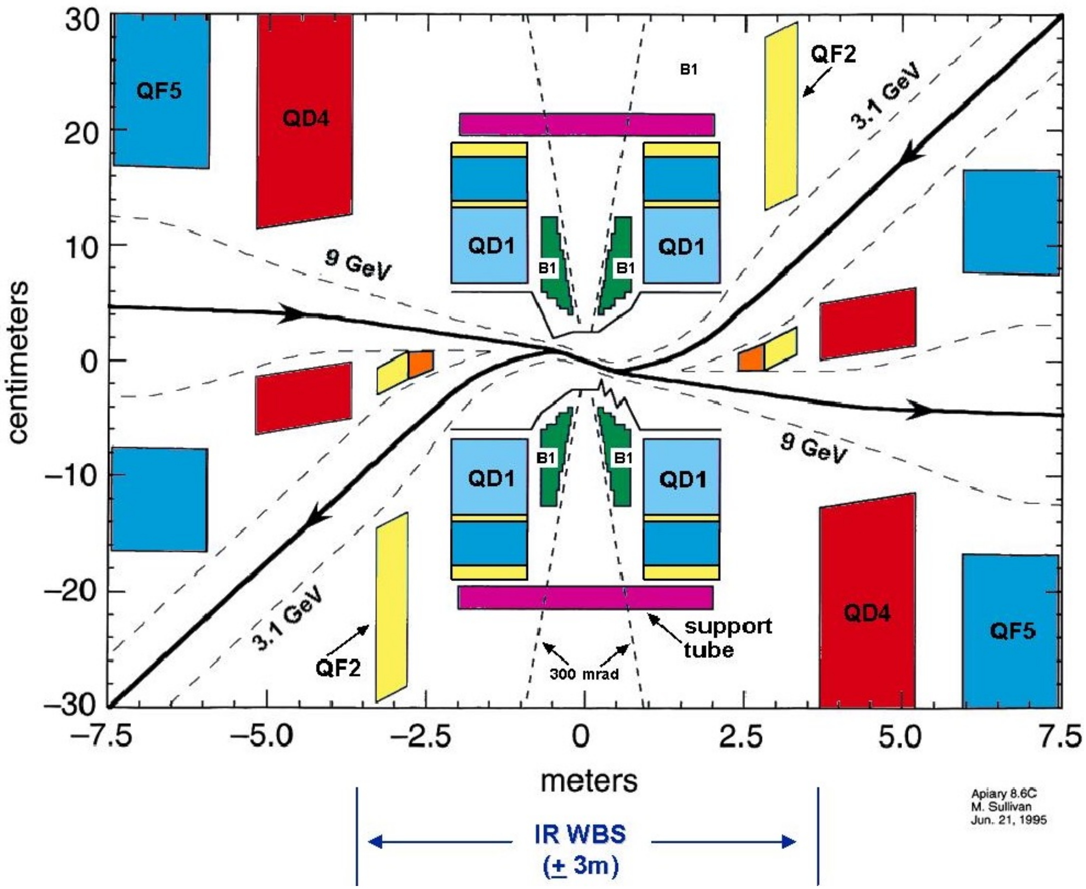
Full QC1 cryostat (from M. Koratzinos, F. Fransesini, …)





Cryostat "skeleton" strengthened to support longitudinal and transverse loads
Additional supports at outer end for stability.
Three remote flanges per side?

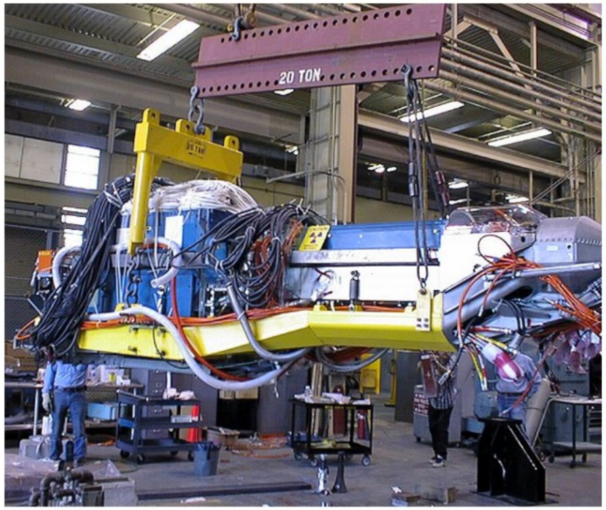
PEP-II IR Layout (S. Ecklund, M. Sullivan, …)



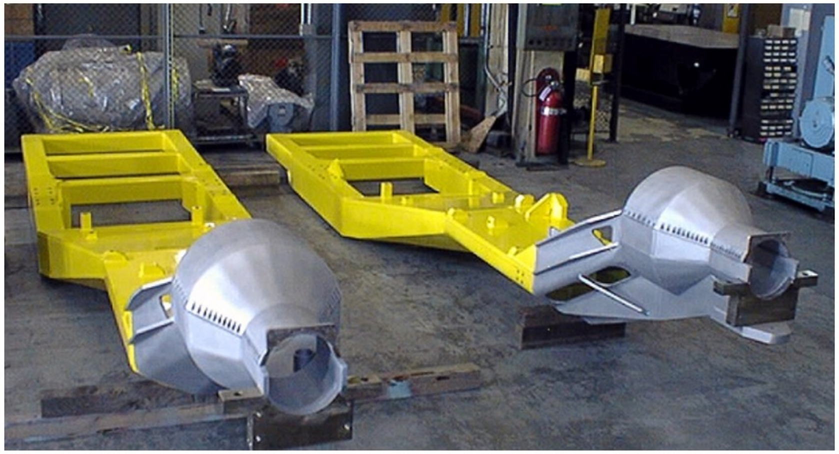
Head on collisions (crossing angle = 0).
First magnet from IP is a dipole (permanent magnet).
Accelerator passage through detector solenoid endcap:
Affected detector solenoid compensation and shielding.

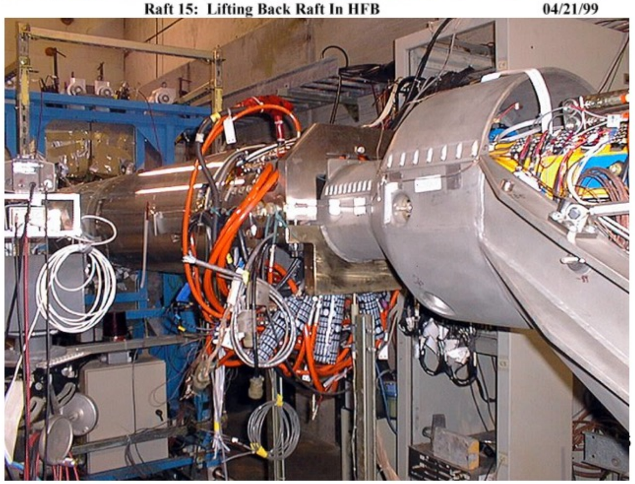
PEP-II Magnet Rafts near to BaBar (S. DeBarger, M. Sullivan)

Q2, Q4, Q5 rafts were assembled in the shop and then installed by the overhead crane in the IR hall. These cantilevered supports were vibration sensitive and much work was invested in damping them.



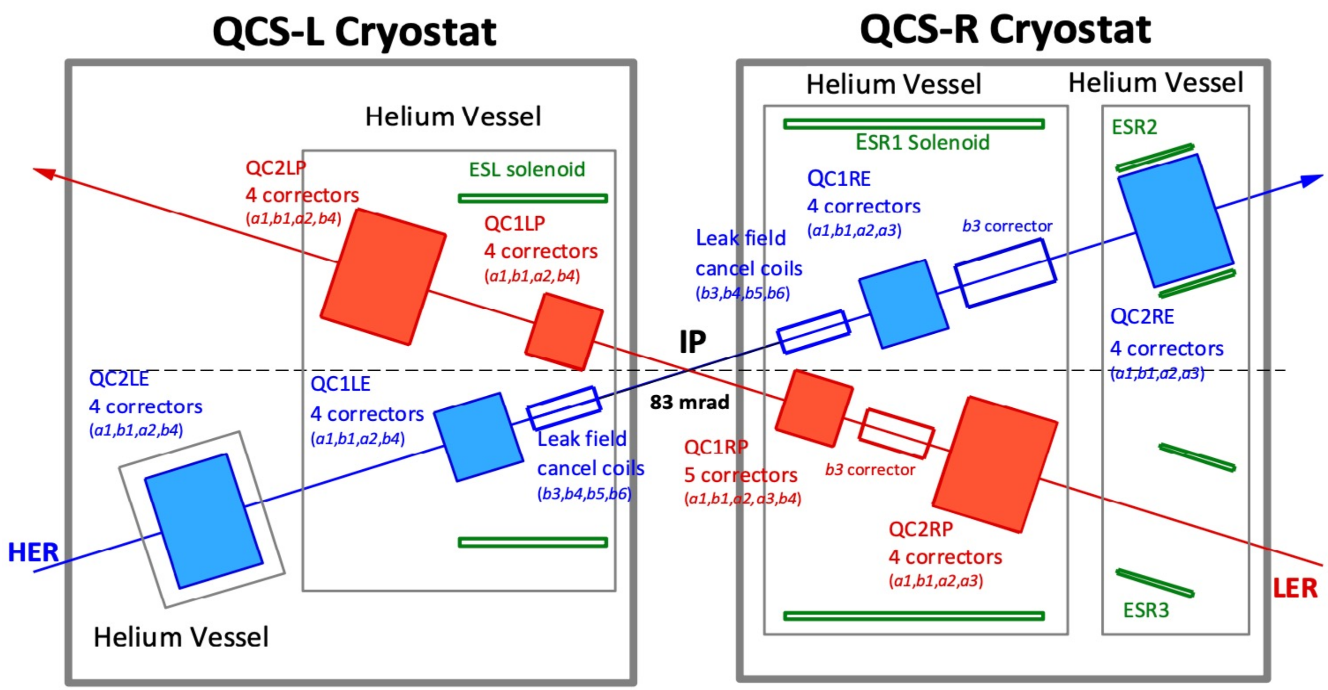
Raft 15: Lifting Back Raft In HFB 04/21/99





Babar's end cap opened transversely.

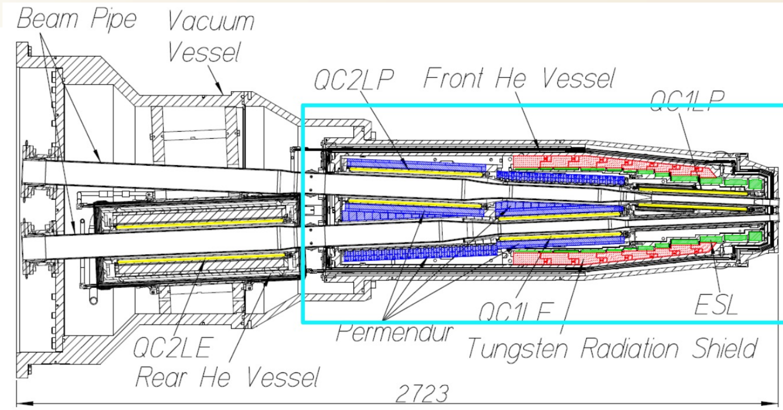
SuperKEKB IP crossing angle and quadrupole placement

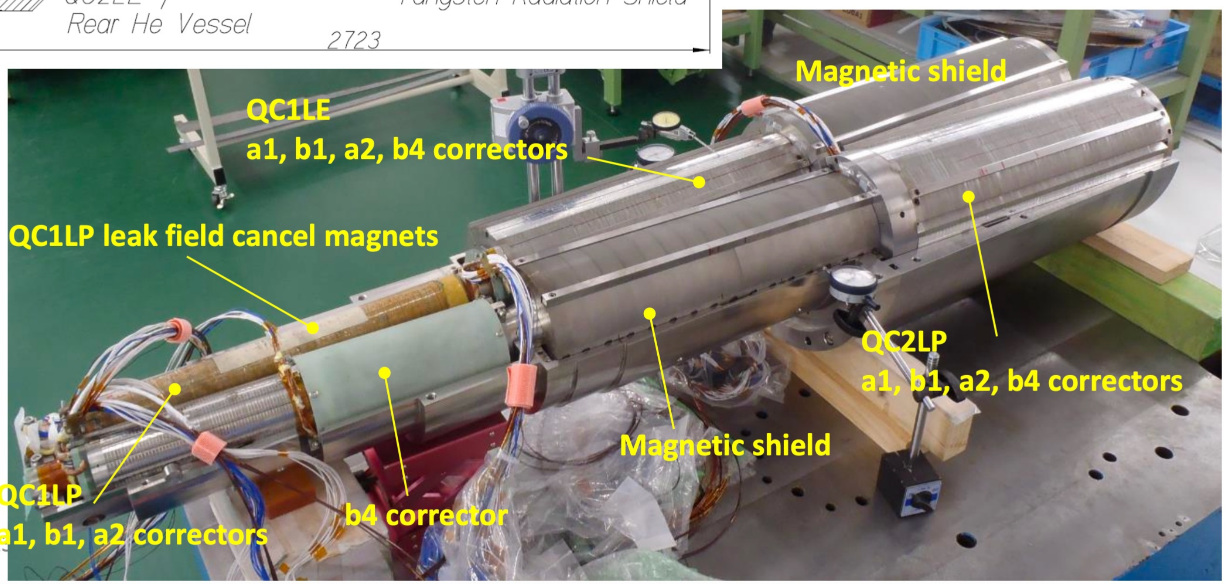


Crossing angle is 83 mrad. (FCCee is 30 mrad.)
No primary magnets side by side.
Cryostat: Each vacuum vessel has two He vessels inside.

N. Ohuchi

SuperKEKB cryostat magnet layout (N. Ohuchi, …)

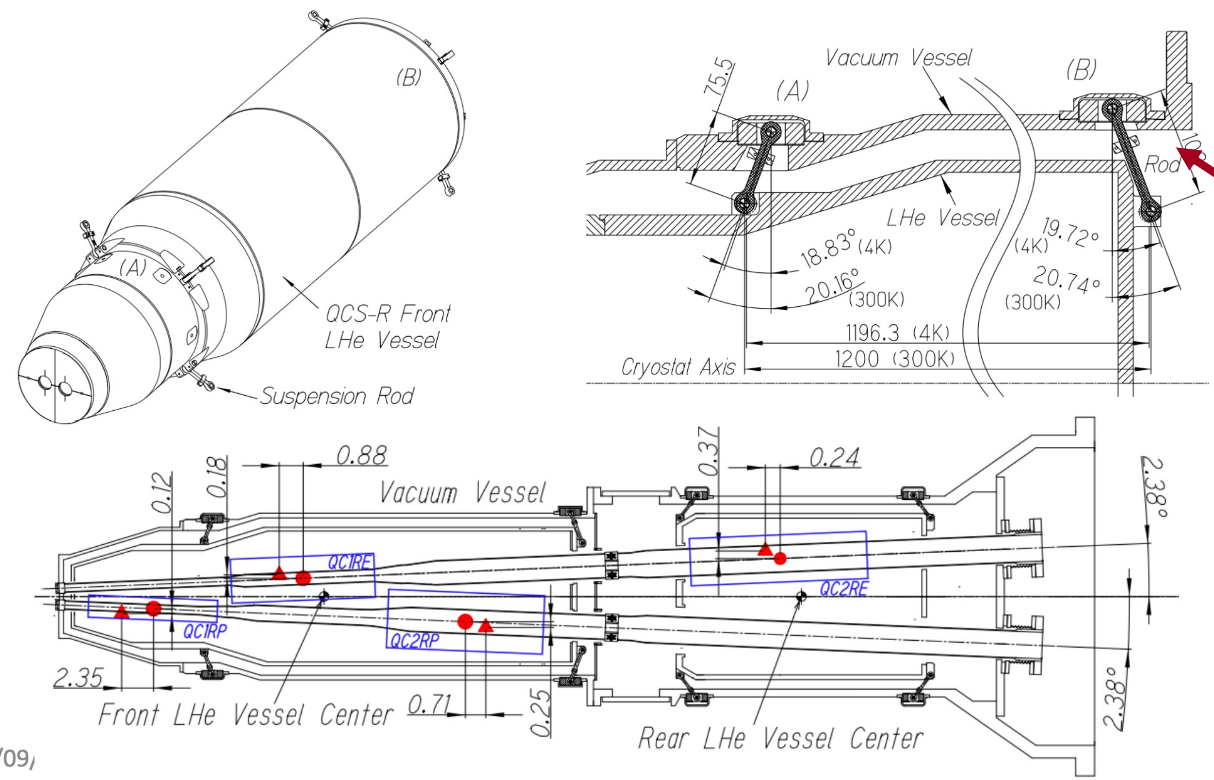




SuperKEKB: forces must be transmitted through the vacuum and He vessels.
Magnets must be shimmed carefully to the He vessel.
All magnet trims and background shielding must be attached.
Cold He flow must be ensured.

SuperKEKB support of He wall from Vacuum wall

Magnets are mechanically supported by the cryostat components in the helium vessel.
Helium vessels are supported by the rods (Ti alloy) from vacuum vessel.



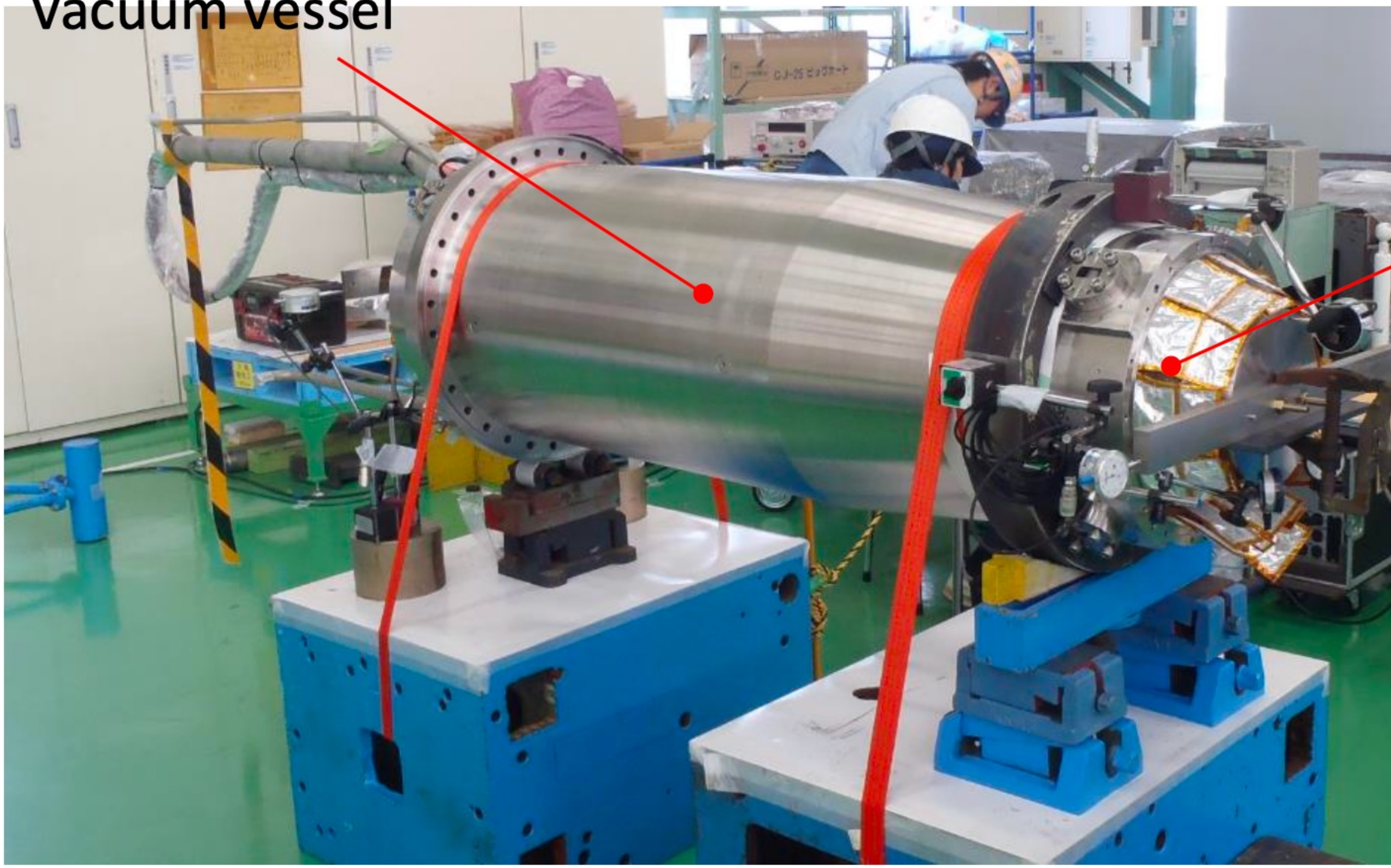
Vacuum tight joints

2023/09/

Eight rods per cryostat

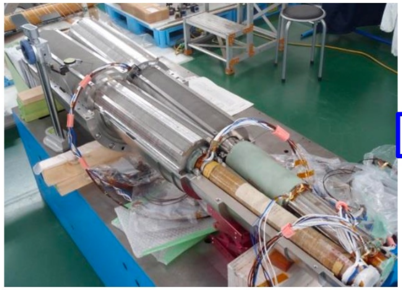
(N. Ohuchi)

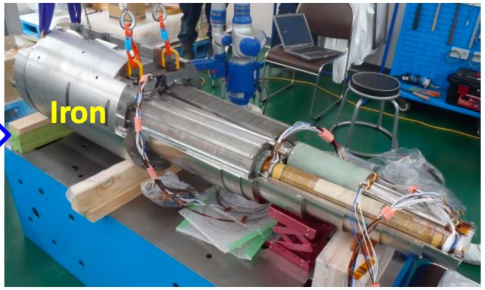
SuperKEKB first half of vacuum vessel (N. Ohuchi, …)



Superinsulation and flexible supports extend from warm to cold.

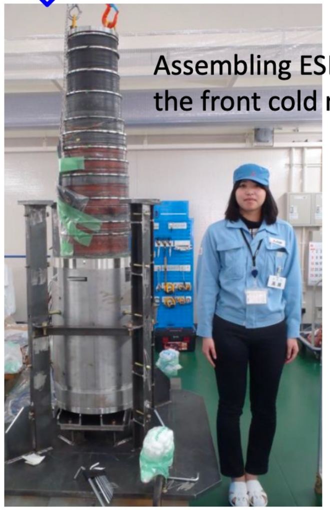
SuperKEKB cryostat assembly (N. Ohuchi)



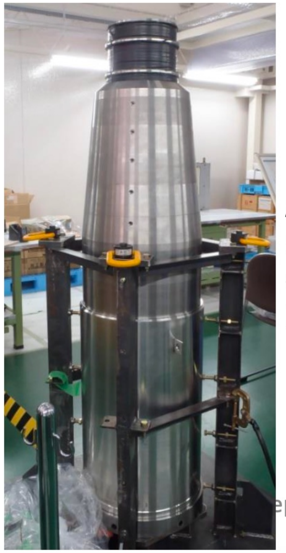


Fixing the magnets with the support components

Measurement of quadrupole alignment in the cold mass with the stationary harmonic coil at room temperature



Assembling ESL on the front cold mass



Assembling the radiation shield of W alloy on ESL

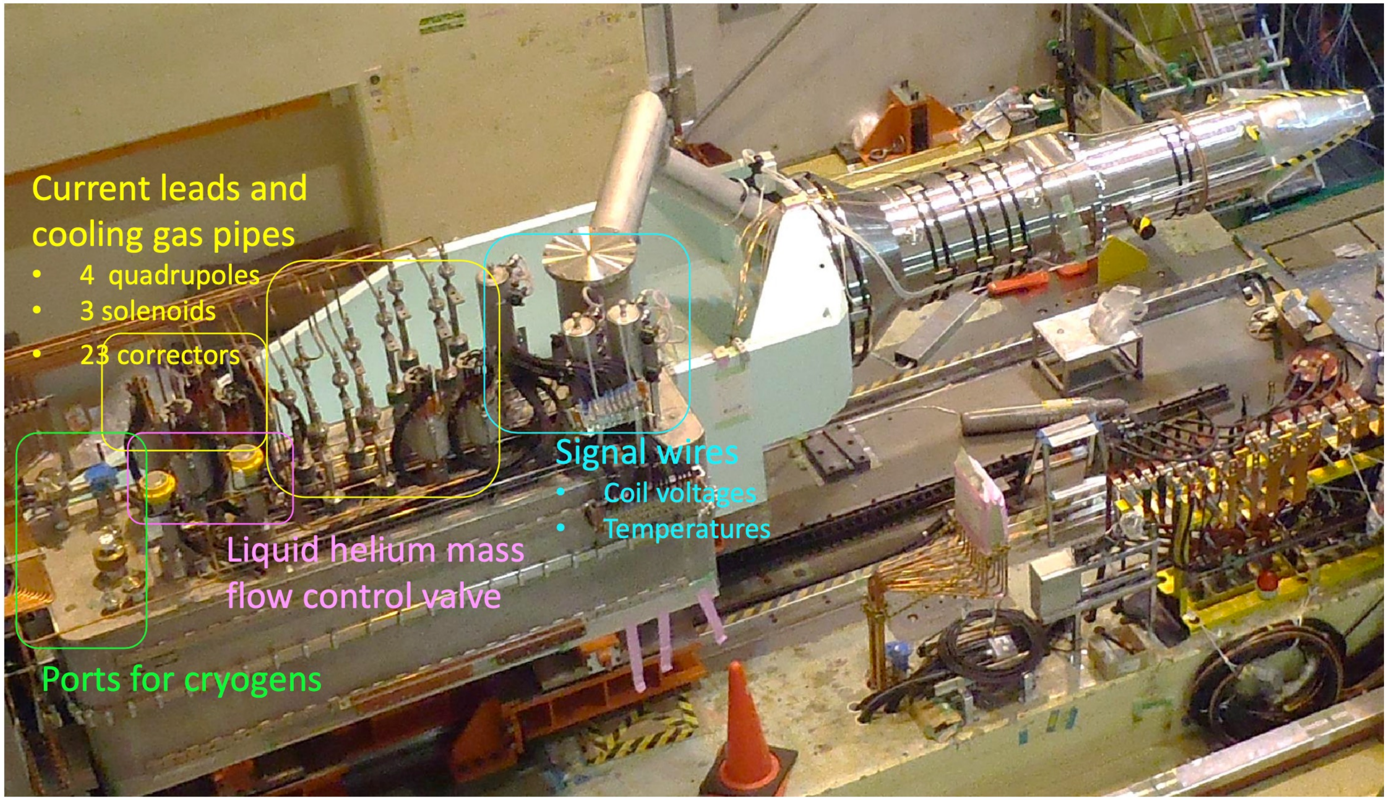
Covering the cold mass with the helium vessel and welding the vessels

eport

4

SuperKEKB completed QCS-R raft and cryo-junction box

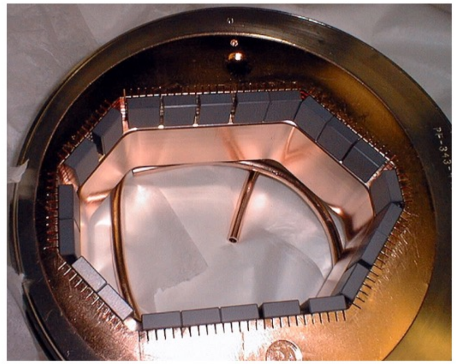
QCS-R cryostat

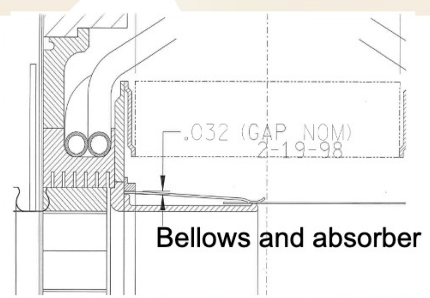


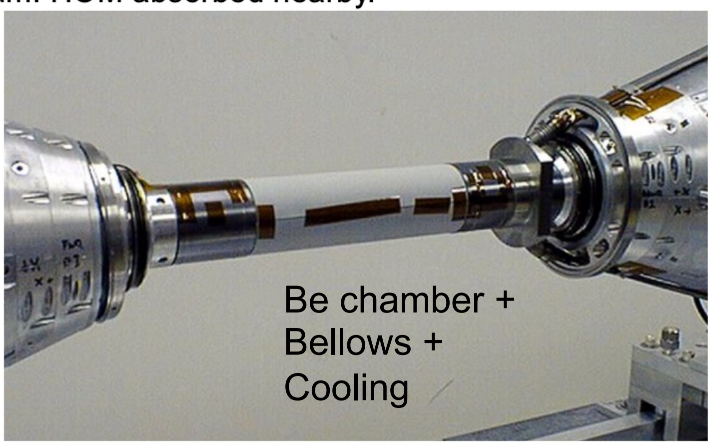
SuperKEKB cryostat with cantilevered support (white) and cryo-connection box on the side.
All the cryogens and magnet cables (with no magnet wire slices) go through one stainless outer tube. (N. Ohuchi)

PEP-II IR Be chamber, bellows and HOM absorber

Be chamber was ~40 cm long.
Two layers: 0.8 mm and 0.4 mm wall Be tubes with 1.5 mm gap for de-ionized water cooling with ~1 gpm. Negative H2O pressure to prevent leak problems.
Be material protected by aircraft BR-27 epoxy (K. Scarpass-VIII).
Background protection layers on Be: 4 microns Au, 7 microns Ni, 7 microns Ni, 75 micron, tantalum. HOM absorbed nearby.







3D vacuum chamber shapes

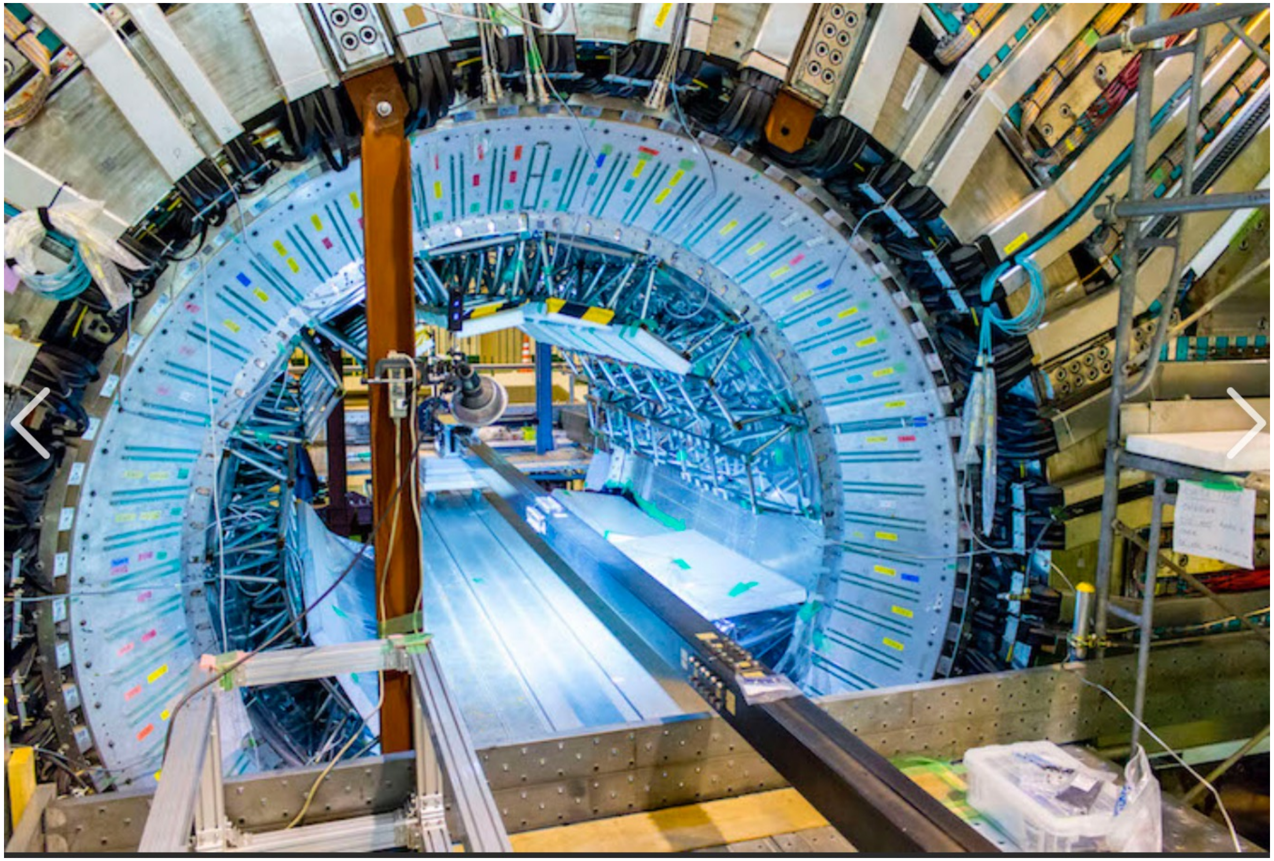
Ecklund, Sullivan, Novokhatski, Kurita, Nordby)

Babar's vertex chamber cables cover most of circumference of PEP-II IR

BaBar's vertex chamber mounted on Be chamber.
Vertex cables are mounted over the PM IR magnets together with accelerator cables, cooling, and diagnostics.

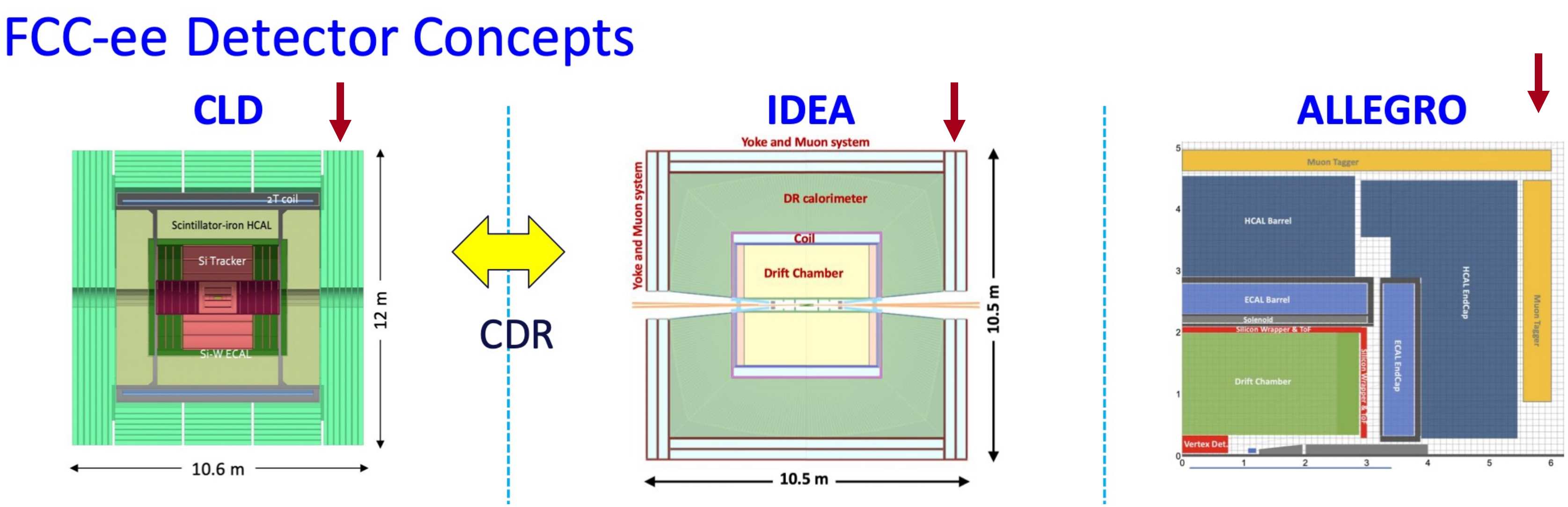
Ecklund, Sullivan, BaBar

Belle-2 TOP counter installation and cable layout



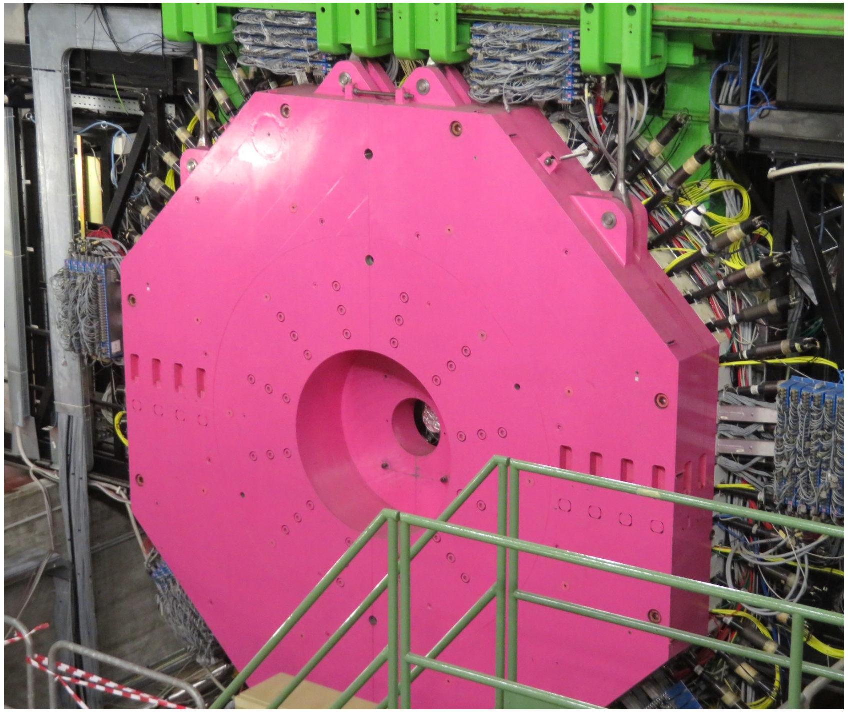
TOP chamber being installed in Belle-2.
Cable routing for TOP and other detectors seen on the outer radius.
Belle-2 assembled off to the side and then rolled in on rails.

Detector Layout and End Cap Withdrawal



Radial removal of detector end chambers is much easier. In and out in ~day. Longitudinal end chamber removal will take ~weeks with poor vacuum for perhaps another week.

FINUDA end cap



Daphne (e+e-) Hall with rainbow.

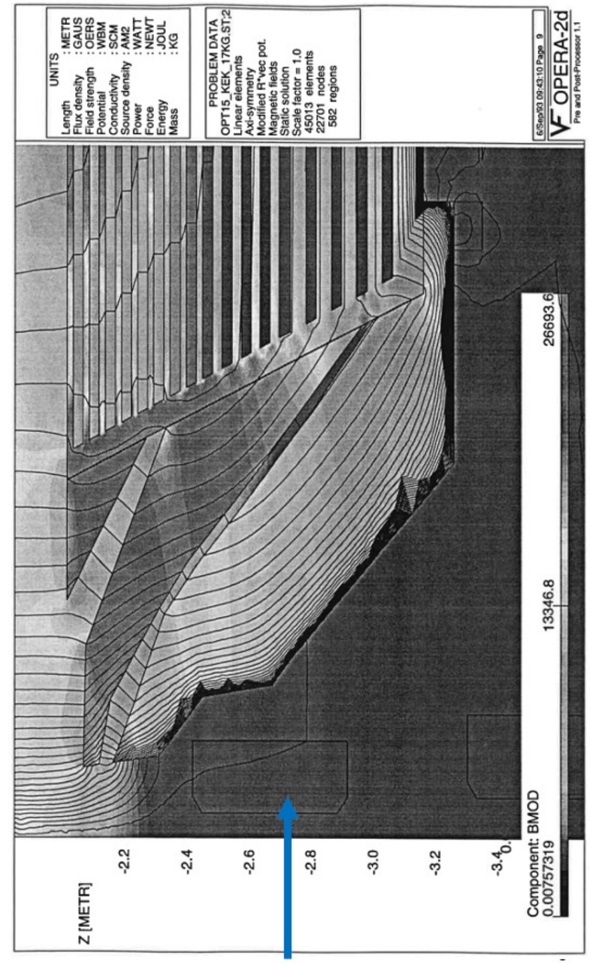
FINUDA detector with horizontal separation and sliding supports from above.

BaBar end cap solenoid field on PEP-II magnets (SLAC + LLNL)

SLAC

Permanent magnets were used inside of BaBar.
Outside quadrupoles were steel magnets.
We calculated the solenoid field escaping outside the central hole using OPERA-2d to see if the near steel magnets would saturate. OK in end.
Measured fields in the hole were measured.

OPERA-2d field calculations.



Q2

BaBar's end caps removed radially.

Belle-2 detector end caps are removed radially

Belle-2 end chambers

Issues with Detector End Cap motion direction

Several detector designs want the Endcaps moved transversely for access.

Easy for the accelerator →

No accelerator changes for one day access

Operate the next day.

Several detector designs want the endcap removed longitudinally for access.

Hard for the accelerator →

Remove IR quadrupole rafts for access

One month down for accelerator removal/reinstallation for one day access

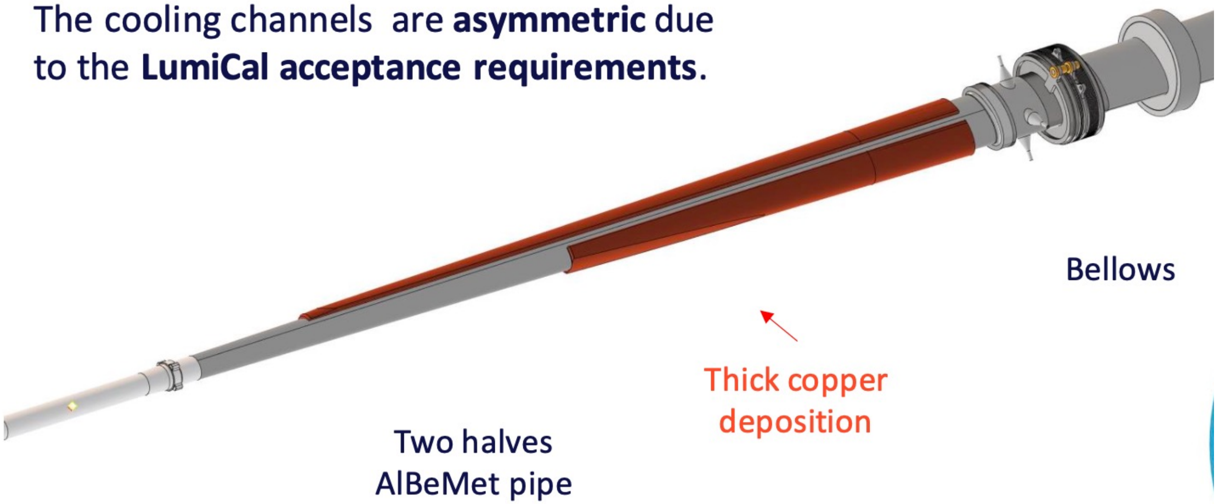
Need to scrub IR vacuum with beam for about a week.

Operate again about one month to six weeks after down starts.

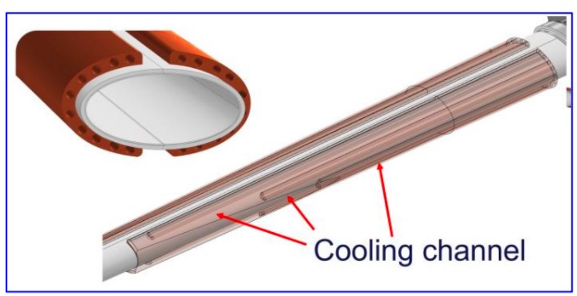
FCCee Near-IR Vacuum Chamber Layout (A. Ciarma, M. Boscolo, …)

Prototyping planned with the IR mockup

The cooling channels are **asymmetric** due to the **LumiCal acceptance requirements**.



It goes from 90 mm to 1190 mm from IP.



Long welds may cause straightness Issues.

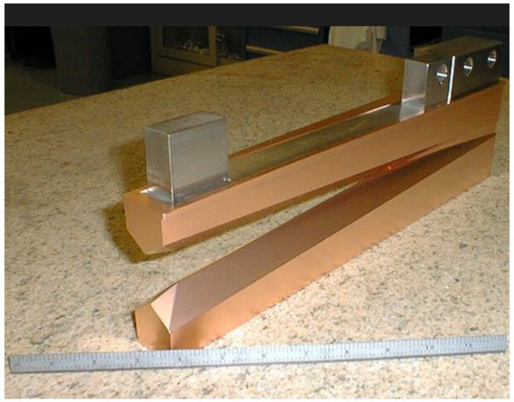
Make a Ni layer before Cu deposition.

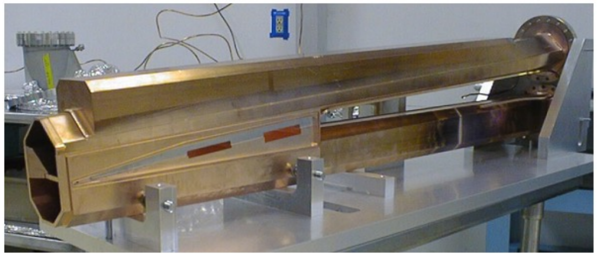
Will need to machine after Cu deposition.

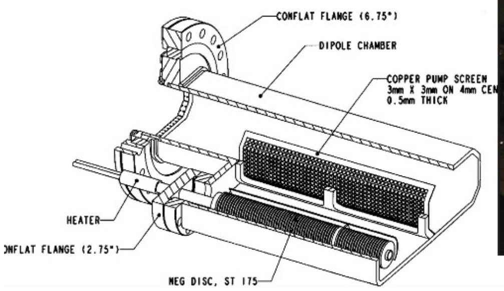
PEP-II interaction region vacuum chambers: 3D (Eklund, Sullivan)

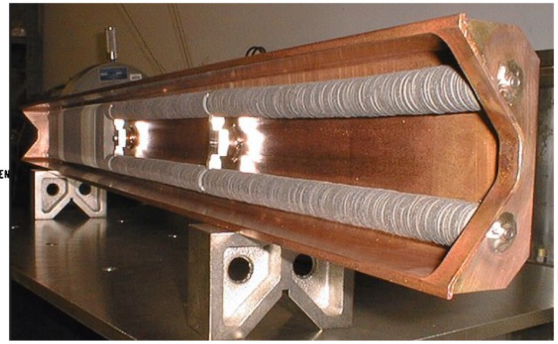
IR chambers made of GlidCop for strength. Special NEG and radial ion pumping. 3-D surfaces for synchrotron power absorption and to reduce HOM generation.

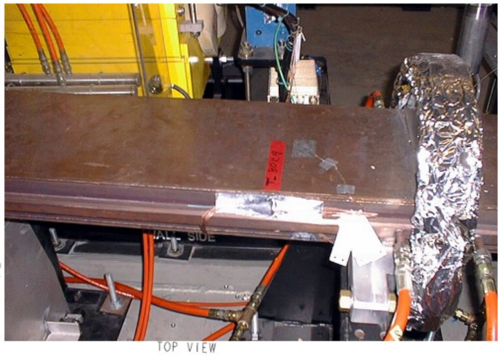
HER downstream high power dump was ~4 m long tapered copper, absorbing 90 kW at 1.8 A.

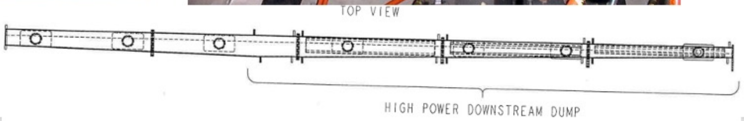






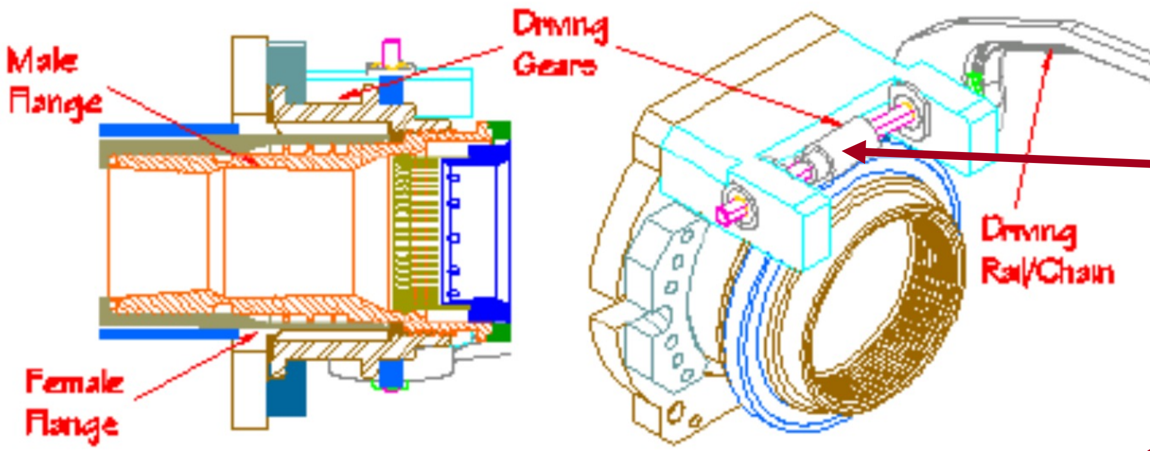






Extra (special) work can be put into the IR chambers as only a few are made.

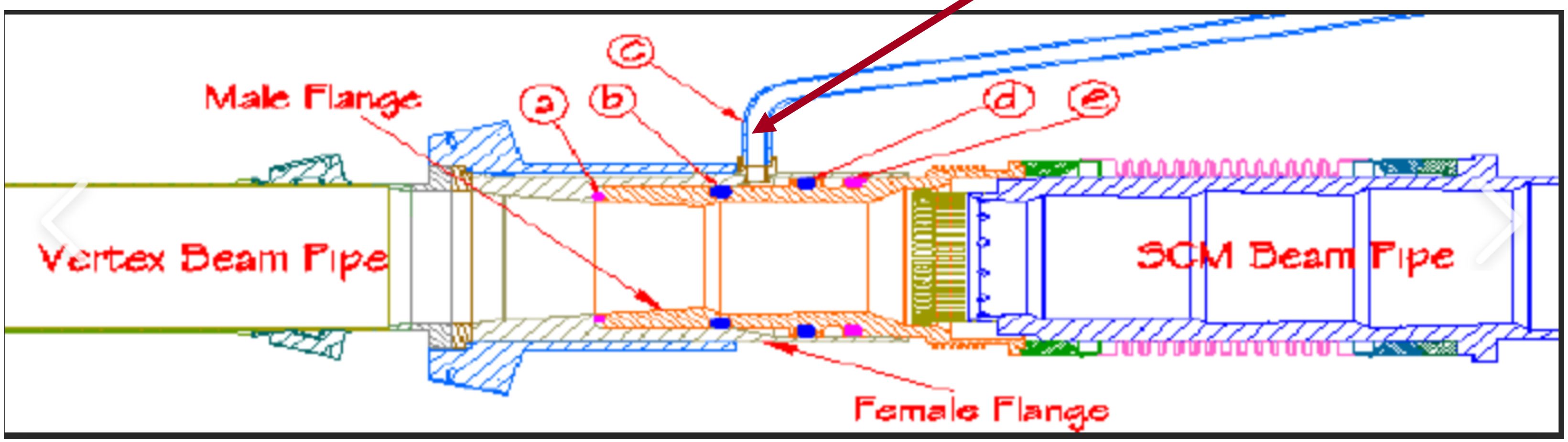
Cornell CESR Magic Flange (D. Rice, et al)



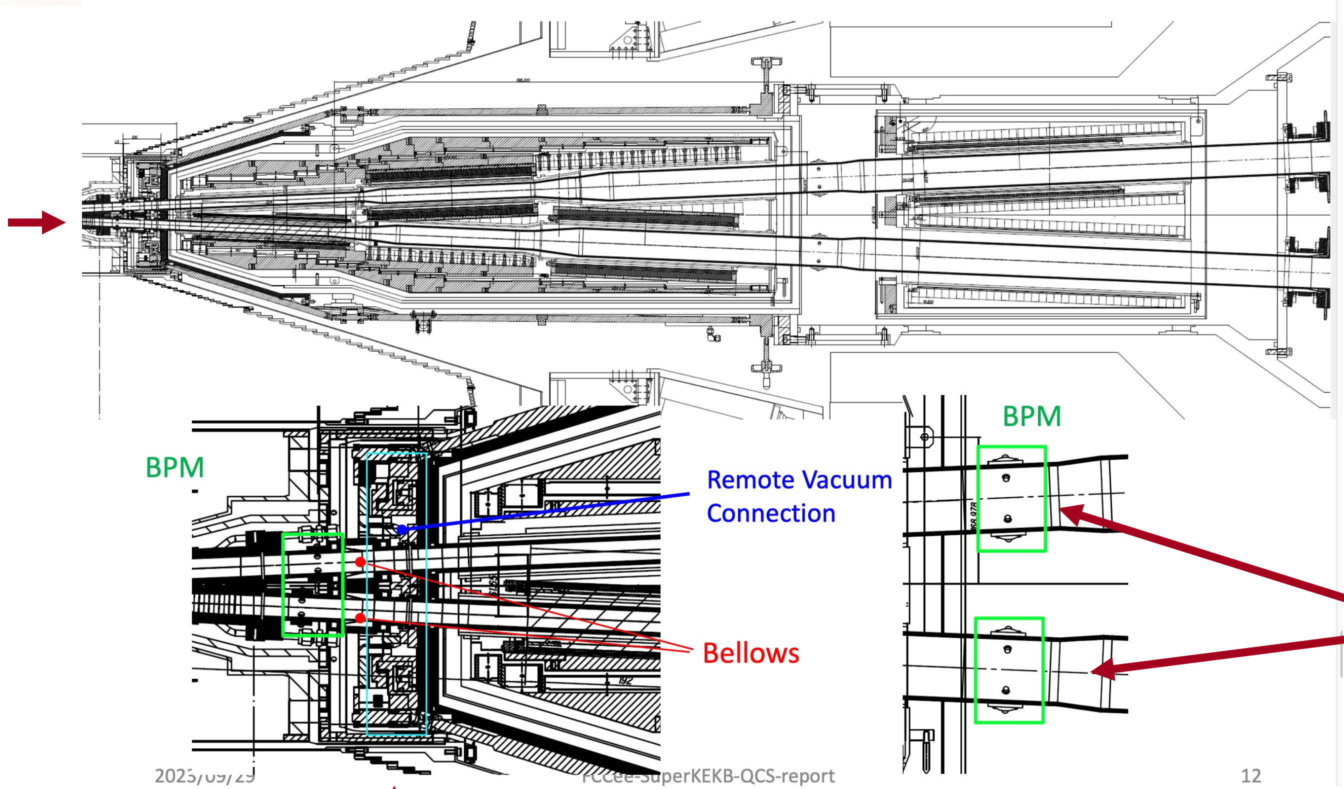
Remotely driven Gears for flange Tightening.

Extra pumping volume for leak mitigation, if needed.

Magic flange engage and disengage mechanism.



SuperKEKB BPM, Remote Flange, and Bellows (C. Niebuhr et al)



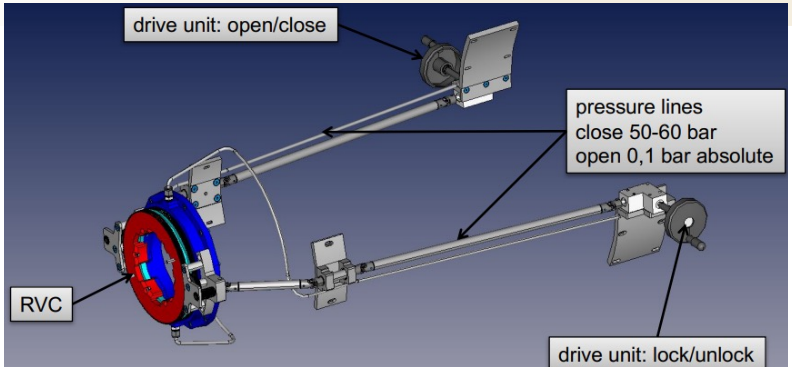
Warm vacuum chambers and beam bellows

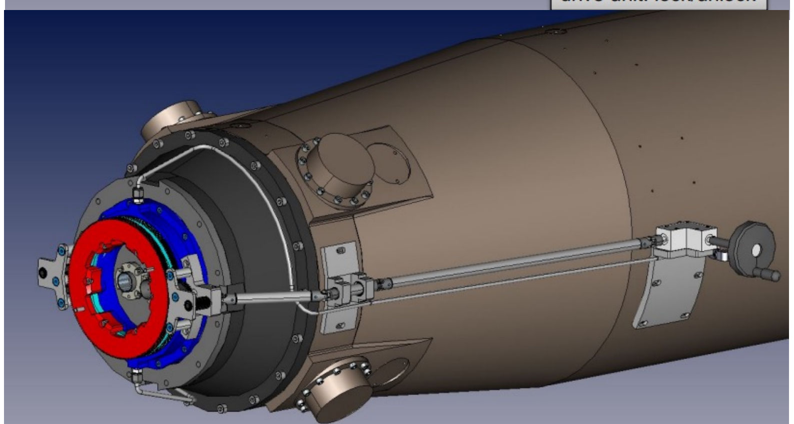
BPMs

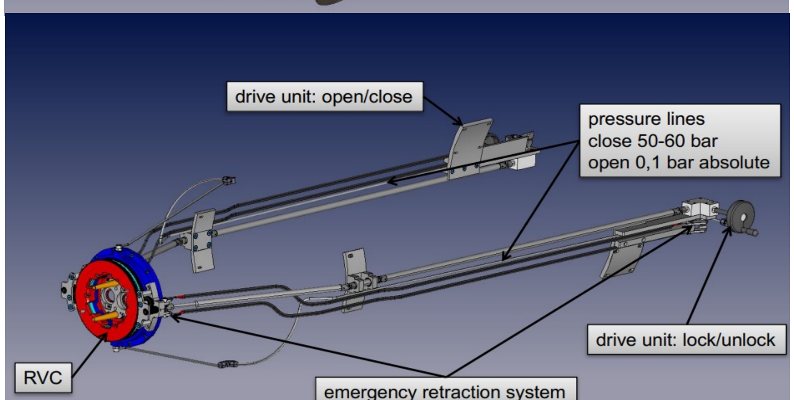
Remote magic flange

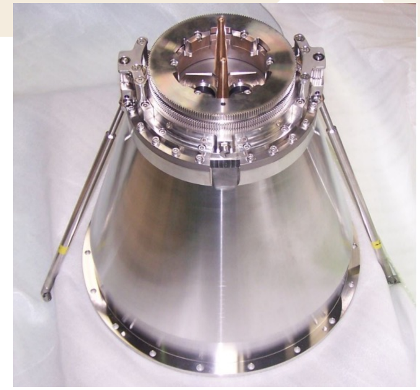
Remote flange mounted in front of the cryostat with remote controls radially outside.

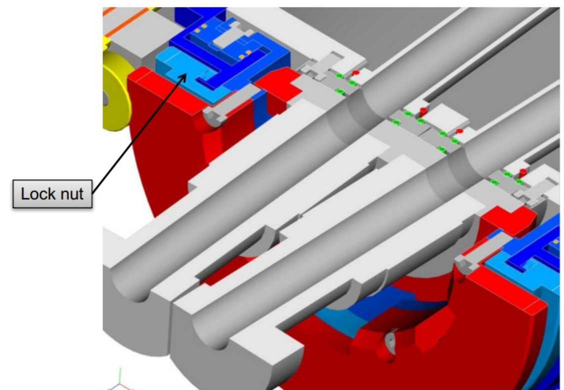
2) SuperKEKB Magic Flange (DESY, Helmholtz Association, KEK)



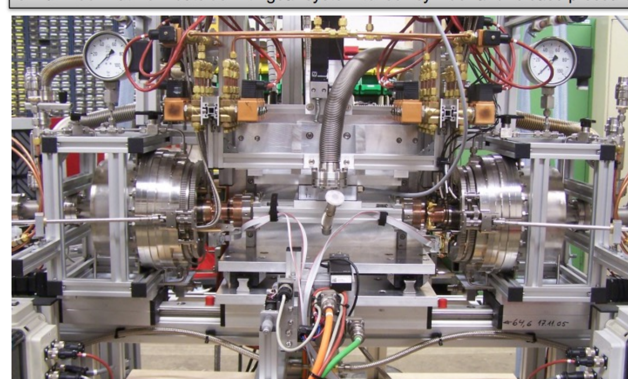








5. Turn lock nut from outside with gear system to lock cylinder and release pressure



Conclusion: Many issues to accommodate near the IP.

Thanks to many people for inputs!