Summary and Comments on Machine Detector interface

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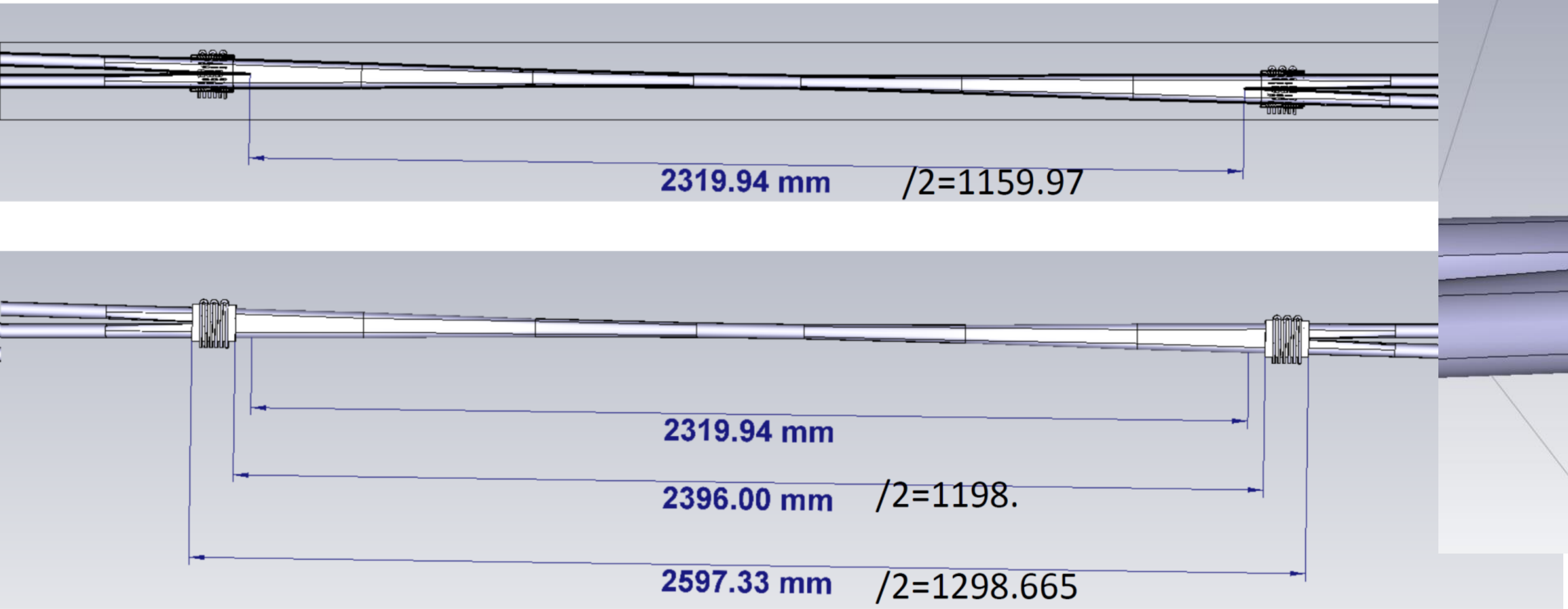
BINP

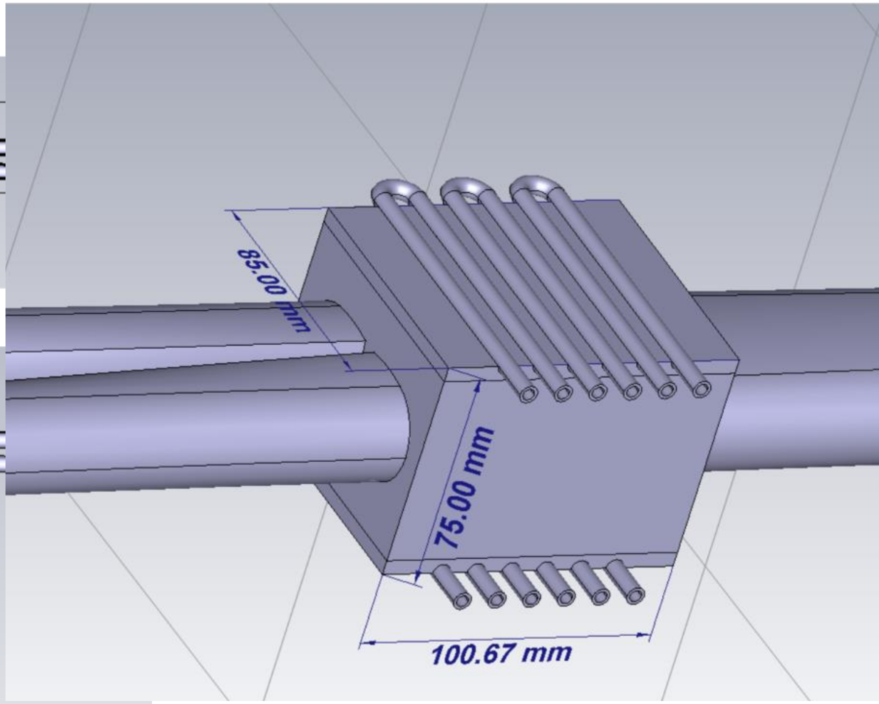
MDI workshop 09-20 September 2019

IR beam chamber (A. Novokhatski, 30.01.18)

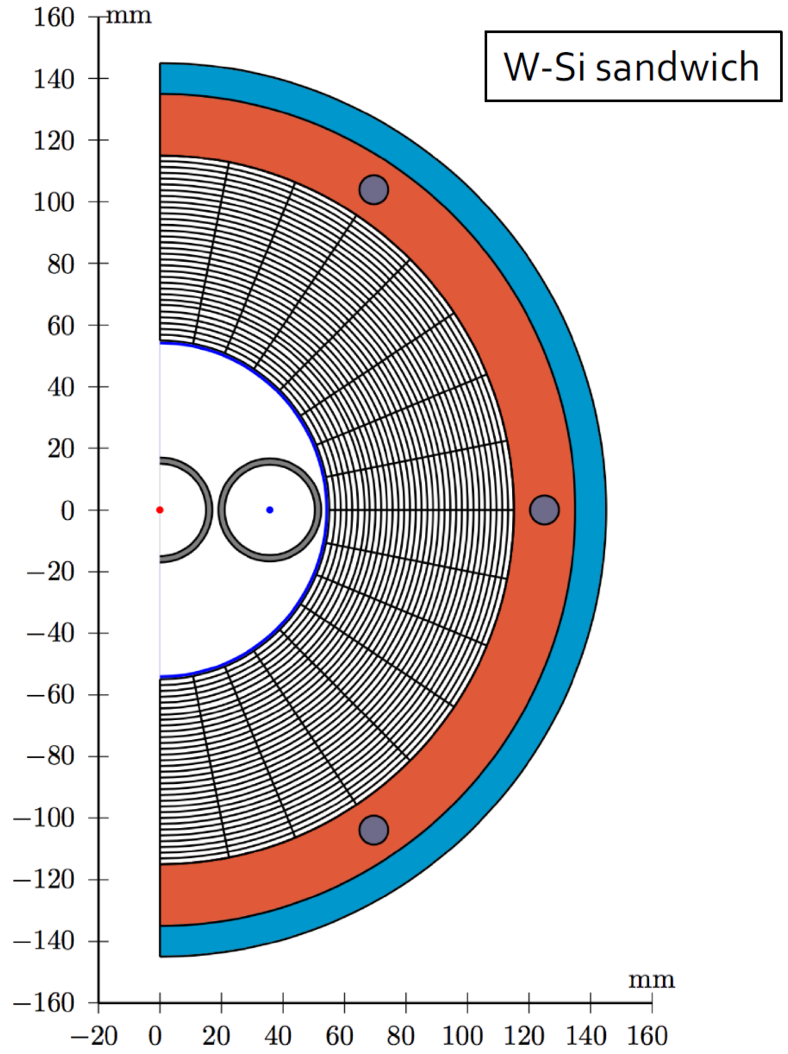
Distance from IP to crotch and absorber

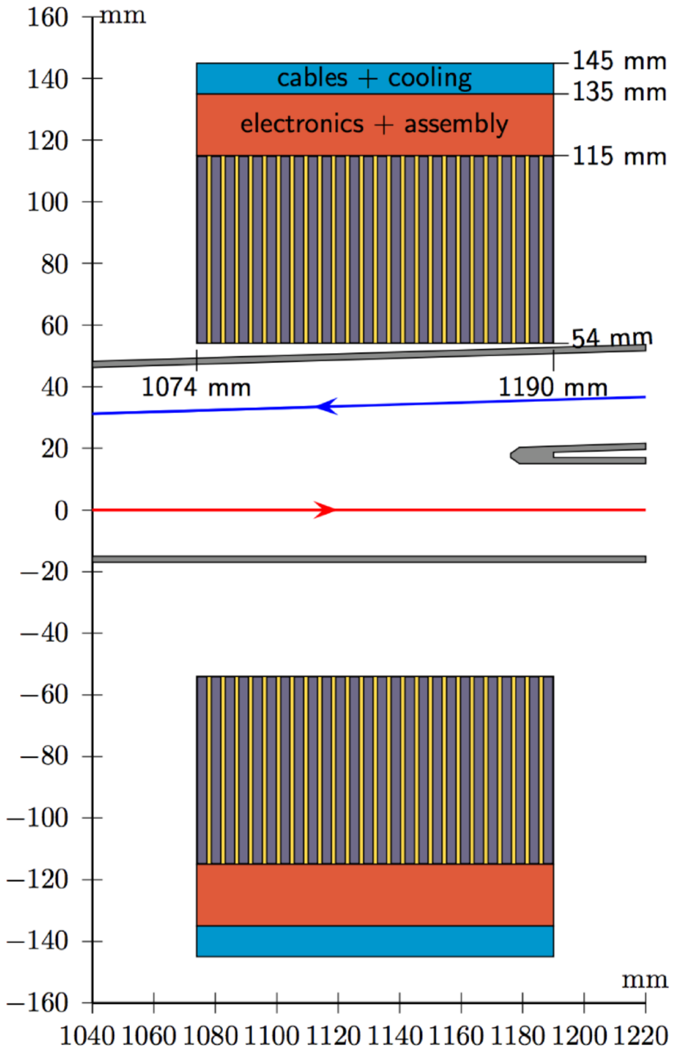


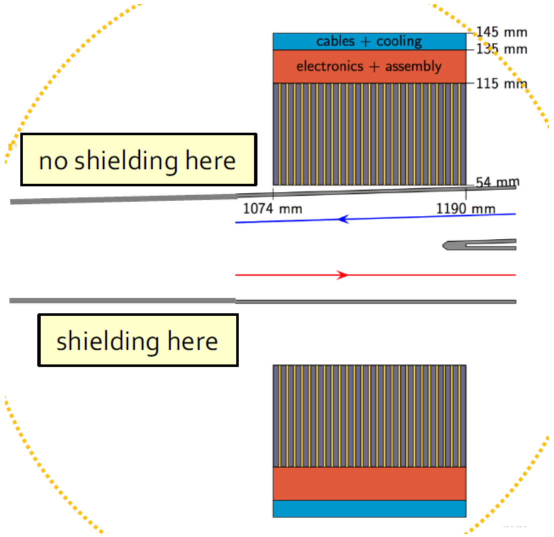
Absorber box dimensions

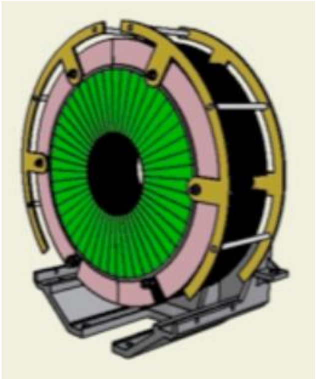


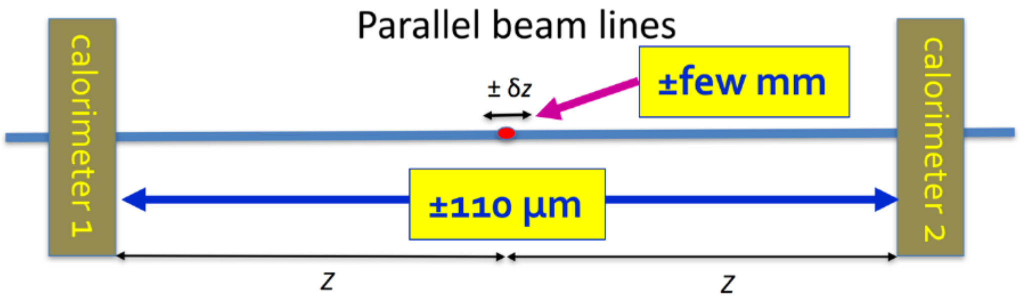
LumiCal (Mogens Dam, FCC week 2018, 2019)

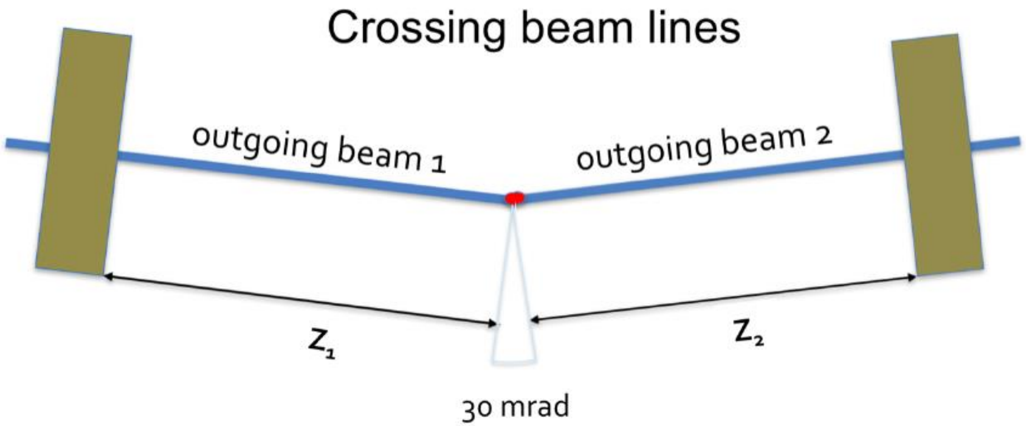






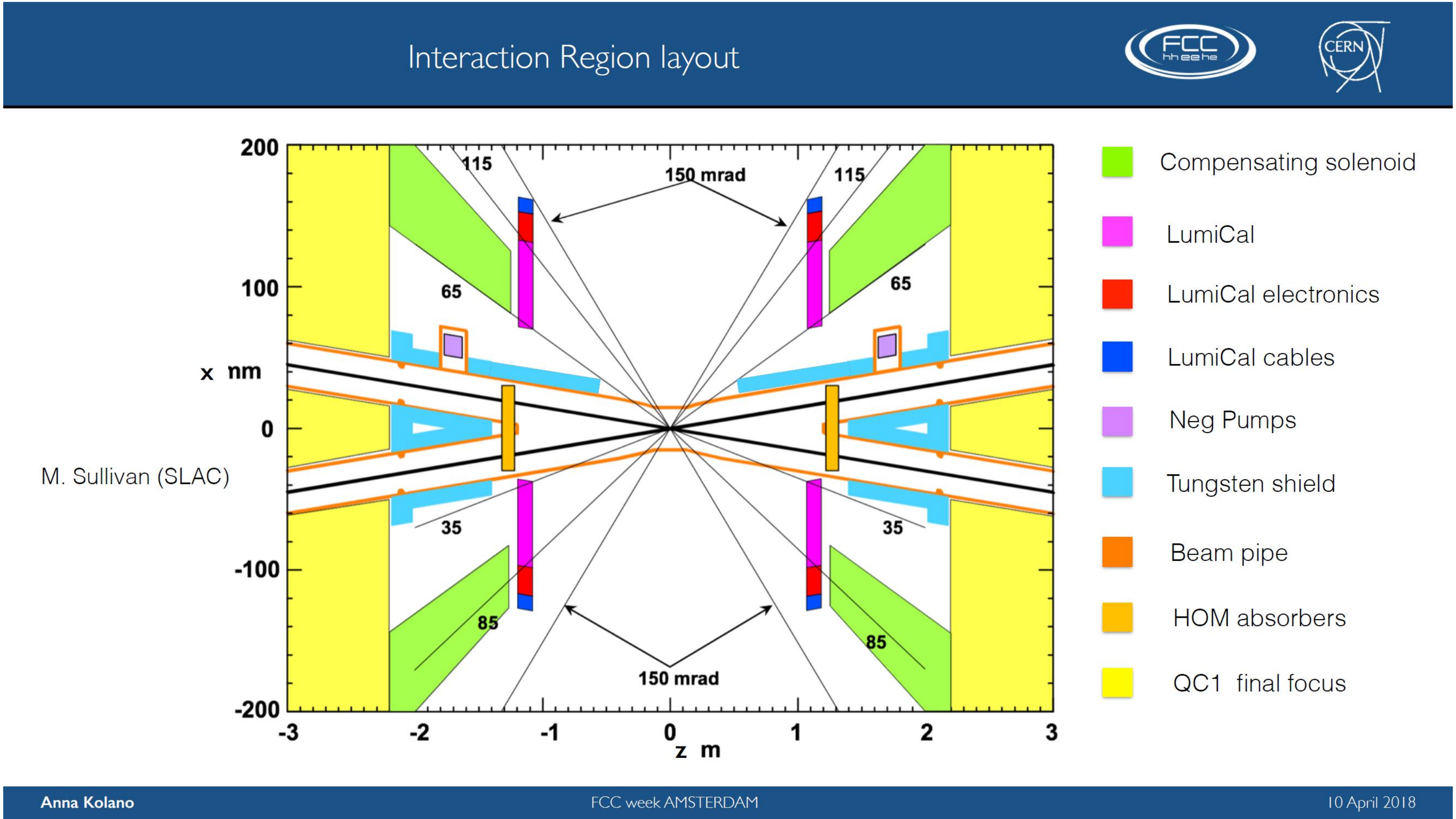






- **Conclusion**: Optimal situation is if interaction point is centered wrt LumiCal coordinate system within the following tolerances:
  - Few hundred microns in radial direction
  - Few mm in longitudinal direction

Synchrotron radiation shielding



Beam pipe (FCCweek 2018, 2019)

Vacuum chamber

Geometry of the IR vacuum chamber optimized from the wake fields and trapped modes point of view.

DIMENSION

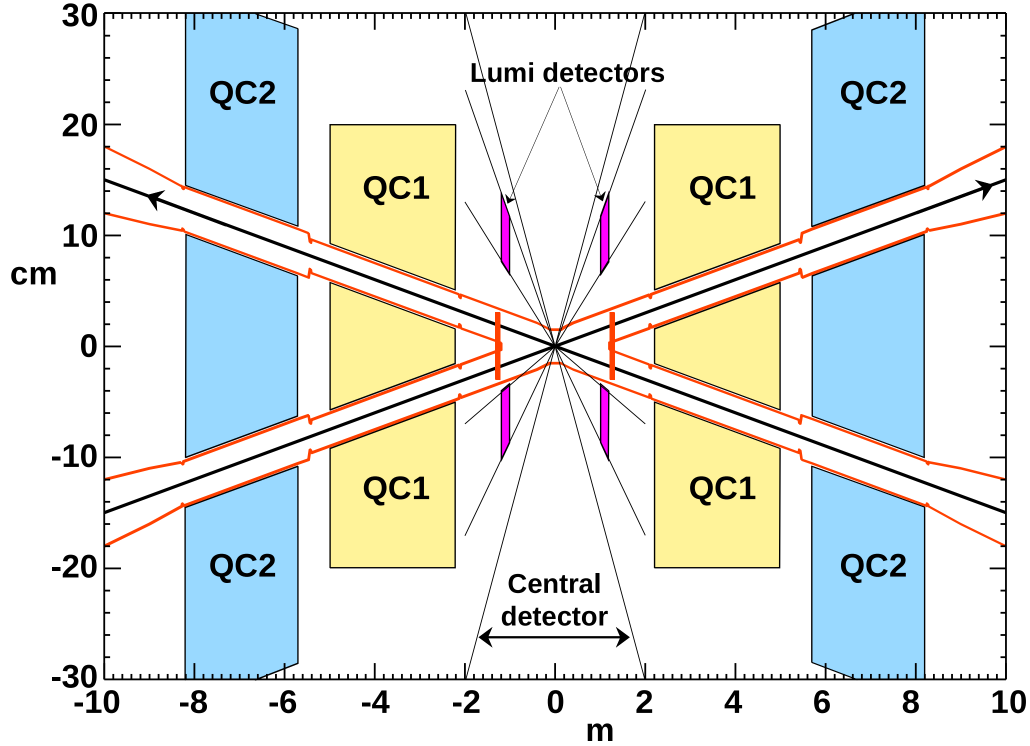
- Central beam pipe has 3 cm diameter
- Entering and exiting beam pipe through QC1 (3cm diameter)
- Pipe size increases to 4cm diameter in QC2
- Size outside QC2 is 7 cm diameter (but 6 cm in plot)

SR MASK TIPS

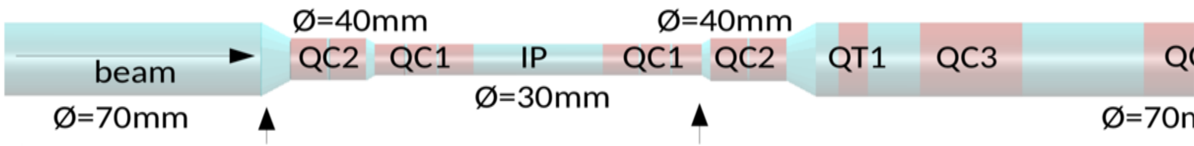
- +/-12 mm radius at Z= +/-2.1 m and +/-5.44 m
- +/-18 mm radius at Z= +/- 8.27 m
- Vert. 10 mm; 5 mm thickness

MATERIAL

- **Be** from about +/-80 cm to accommodate LumiCal
- **Cu** afterwards

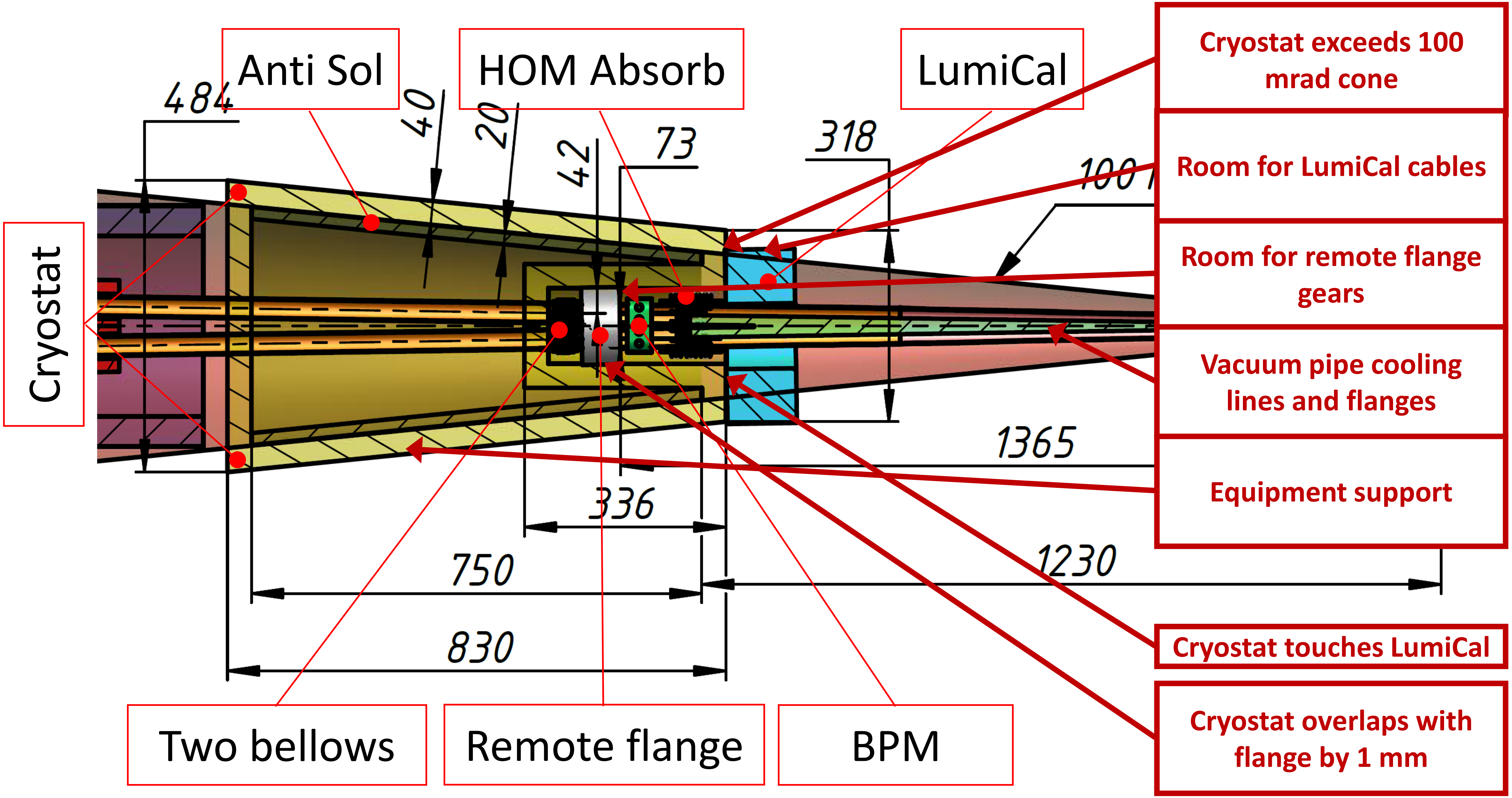


- **warm** beam pipe, liquid cooled (similarly to SuperKEKB) to cope with SR and HOM heating



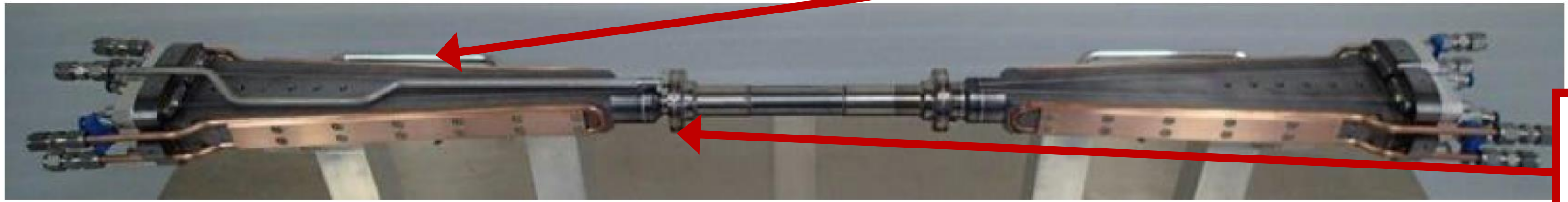
Be and Cu pipes may be welded together but similar solution to SuperKEKB using also Ti being considered

Baseline (with M. Koratzinos' dimensions)



Vacuum chamber, Super KEKB example

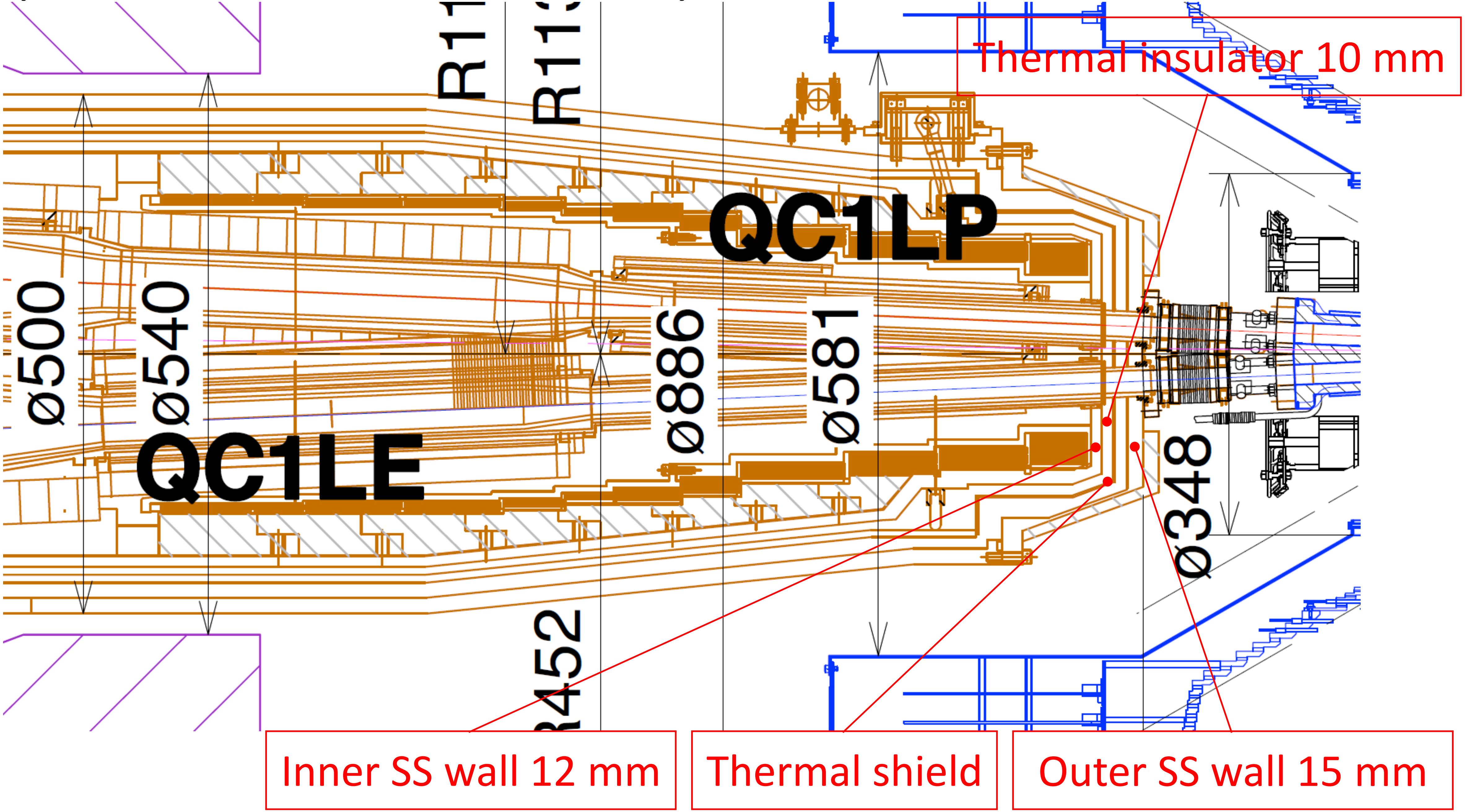
IP chamber



- The central straight part consist double tube. Paraffin runs between them.
  - Outer Be: 0.4 mm thick
  - Inner Be: 0.6 mm thick
  - Gap: 1 mm

The IP chamber for Phase 2 is completed. The IP chamber for Phase 3 is needed before September 2017 when the assembly of VXD starts. Therefore, without feedback from Phase 2 experiences, the next chamber for Phase 3 must be fabricated.

SuperKEKB (the size of cryostat wall)



Quadrupole alignment

SSW measurement summary

- Measured magnetic center shifts to the design values and field angles to the horizontal planes of the 8 main quadrupoles as follows:

	QC1LP	QC2LP	QC1RP	QC2RP
Δx, mm	0.01	-0.34	0.68	0.49
Δy, mm	-0.21	-0.69	-0.30	0.04
$\Delta\theta$, mrad	-1.67	-4.05	2.02	-1.73

	QC1LE	QC2LE	QC1RE	QC2RE
Δx, mm	-0.21	0.13	0.25	0.08
Δy, mm	-0.29	-0.54	-0.37	-0.58
$\Delta\theta$, mrad	-1.60	-1.54	-0.14	-0.73

- Every alignment errors are able to be corrected by the corrector magnets.

N.Ohuchi
IPAC2018

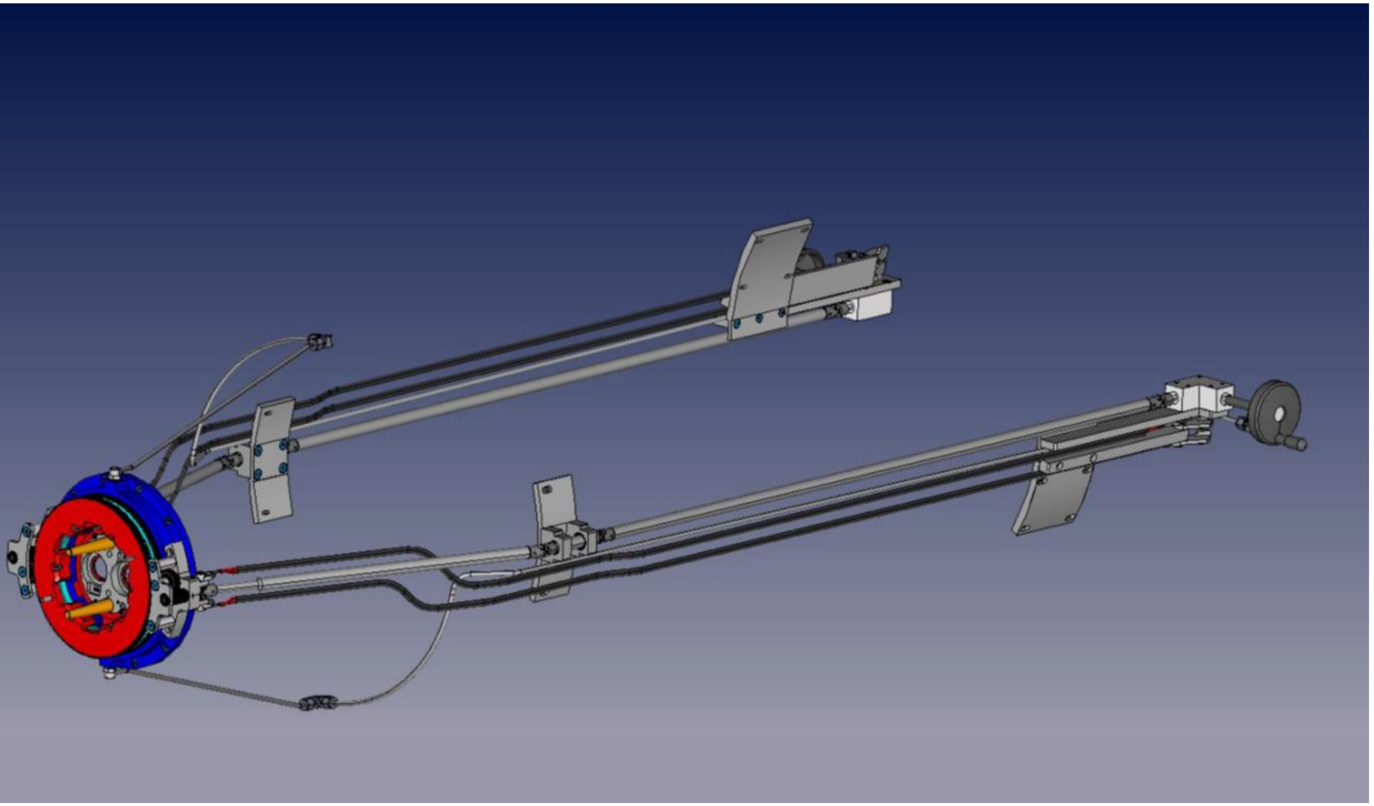
Lessons for FCC-ee:

- Proper steering magnets should be placed at proper places.
- MDI symmetrical to the electromagnet forces is preferable to minimize displacement
- Measurement of the components' position inside the detector is needed
- Measurement of the magnet field inside the detector is needed

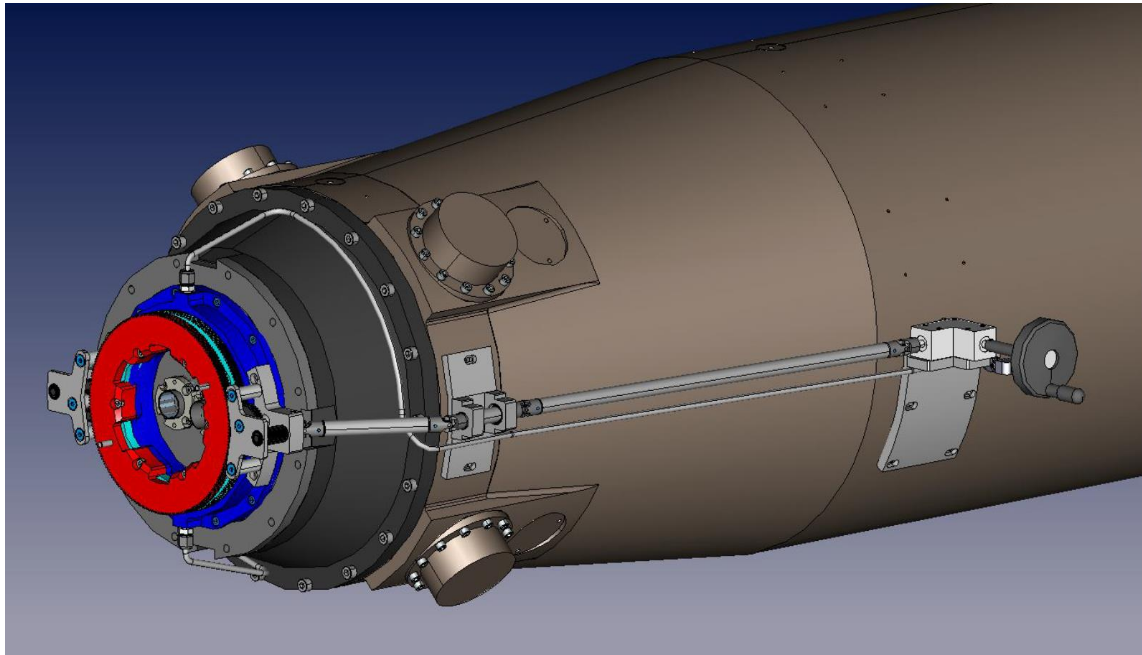
Where to put gears of remote flange?

Remote Flange. DESY design

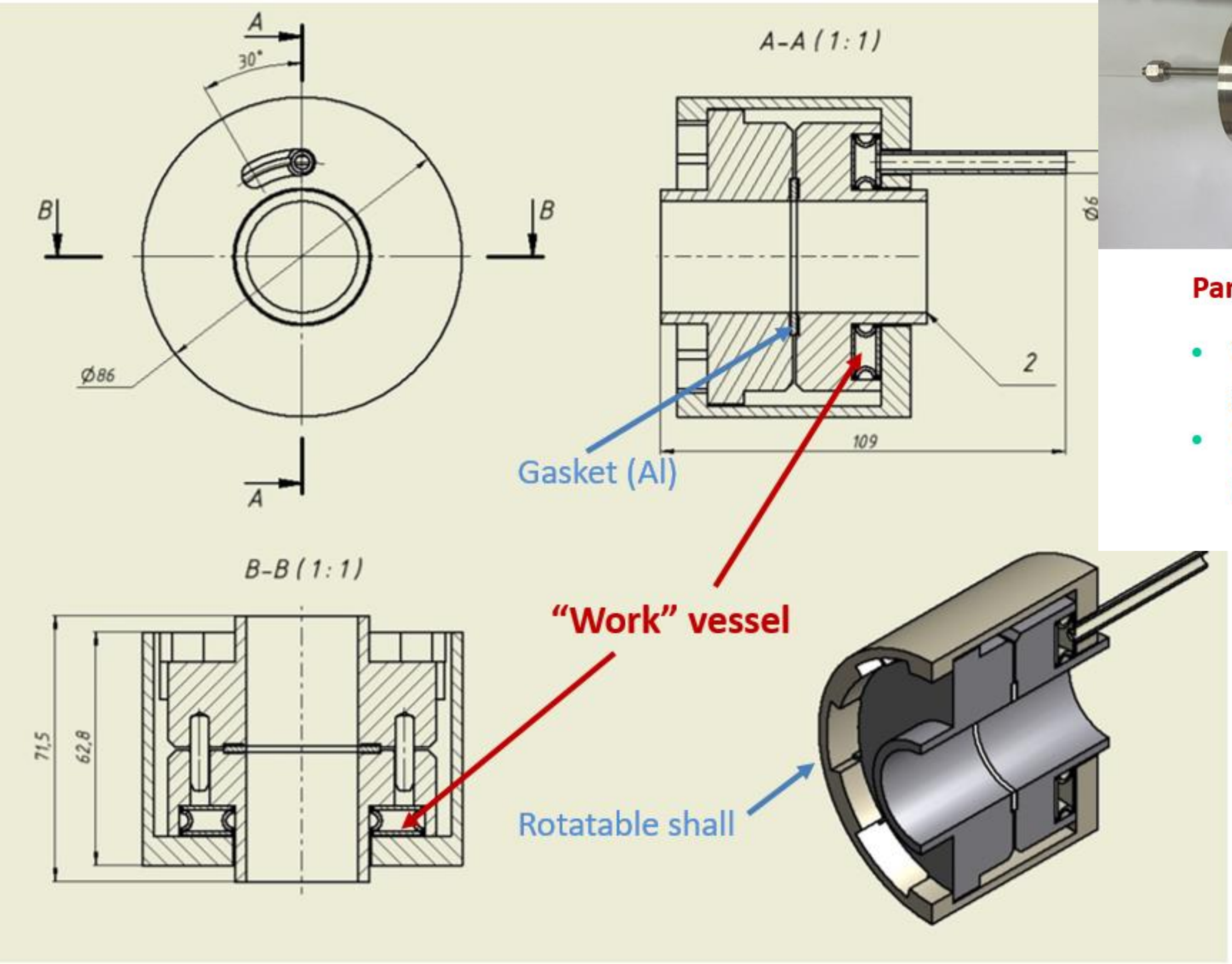
Karsten Gadow | BPAC focused review on VXD | 17.10.2017 |



Remote flange and gears, rods on the cryostat



BINP remote flange prototype



Parts of the flange connection

Assembled connection

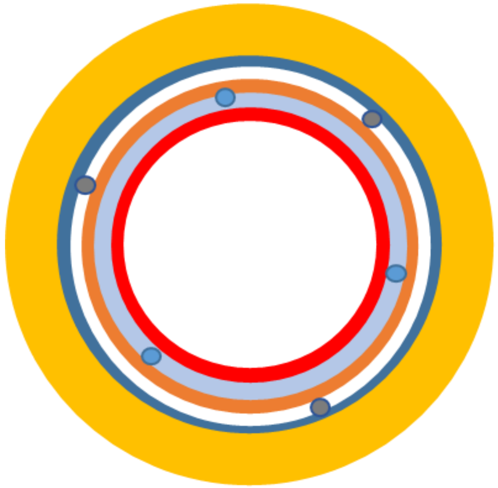
- We've got successful result with Cu and Al gaskets at pressure 150 atmosphere. Leak rate is less than 1E-10 mbar*L/s.
- Note, the connection keeps smoothness of internal surface along beam propagation

Single aperture design works. Double aperture prototype is planned.

Vacuum chamber: warm to cold (A. Krasnov)

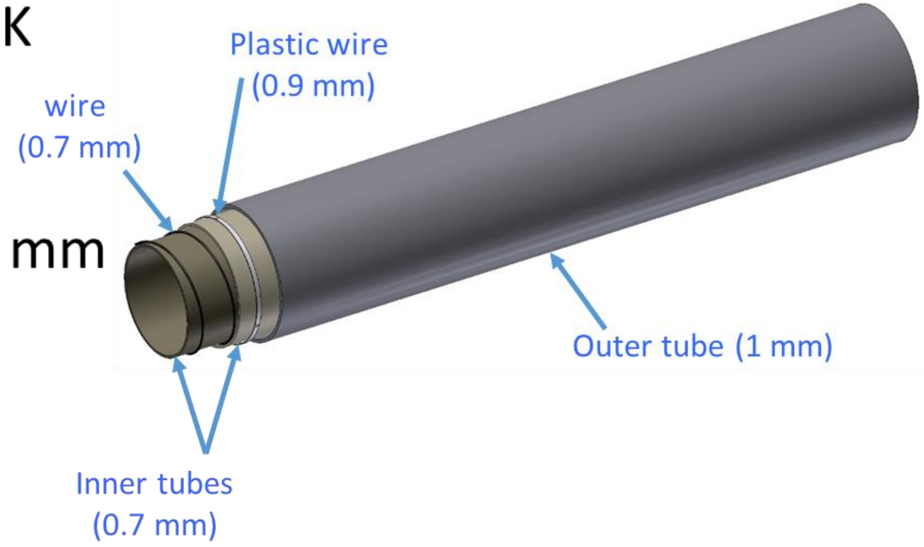
Vacuum chamber inside the cryostate

Rough estimation shows for the SCTF MDI vacuum chamber ~100 W/m thermal load due to HOMs and image currents. The task is to develop, produce and test a prototype for the multilayer vacuum chamber inside the cryostat providing tolerable heating of FF magnets.



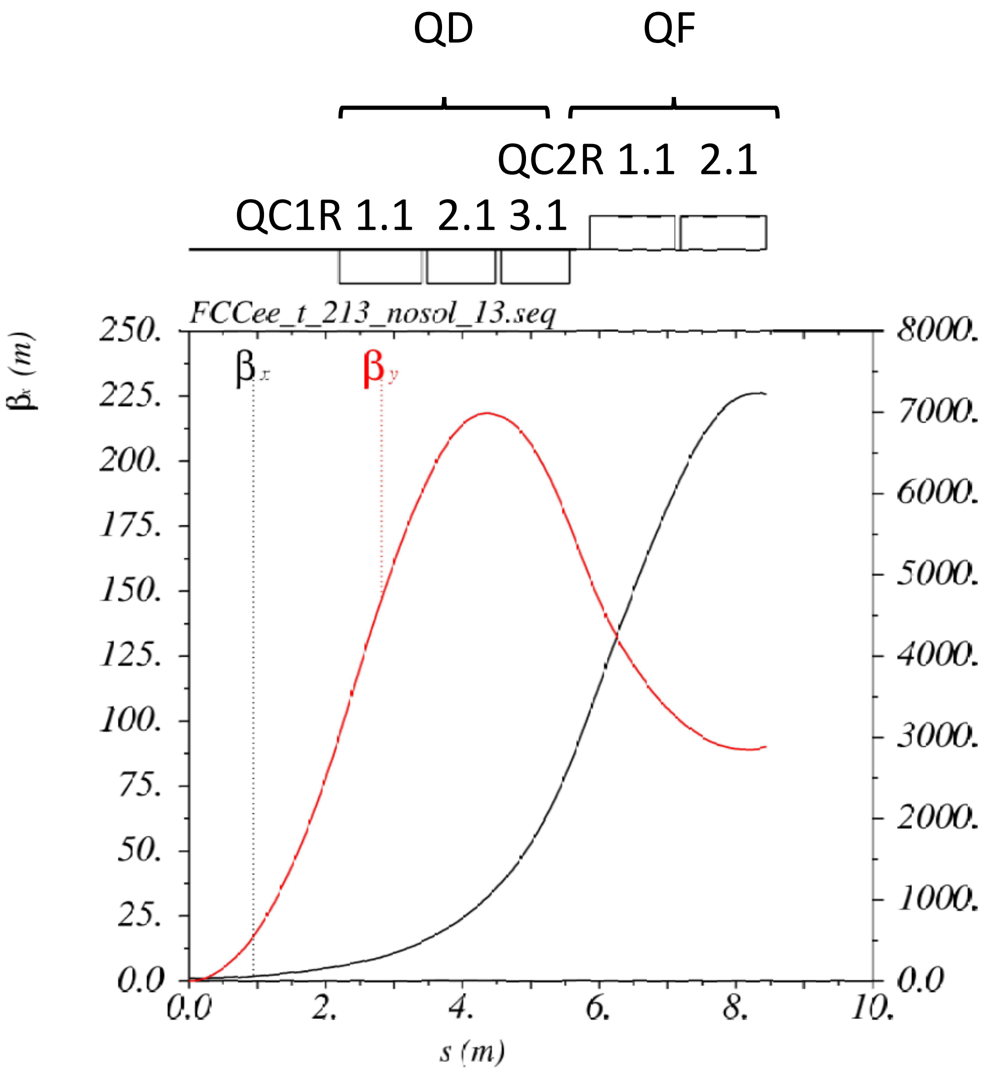
- Inner vessel 0.7 mm thick with copper coating, T=300K
- 0.7 mm cooling water gap against HOM & IC
- Vacuum tube 0.7 mm with mirror-like coating (Cu or Au), T=300K
- 0.9 mm vacuum gap
- Outer 1 mm vessel coated by Cu, T=4.2K
- Superconducting coil on a mandrel

Example: inner ∅=30 mm, outer ∅=38 mm



https://indico.cern.ch/event/803859/contributions/3344818/attachments/1807687/2950964/BINP_MDI_Mar_2019.pptx

FF quadrupole shifts

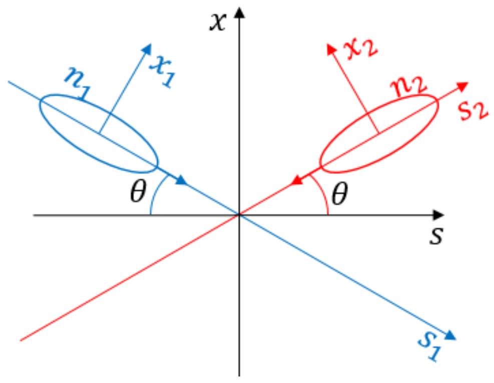


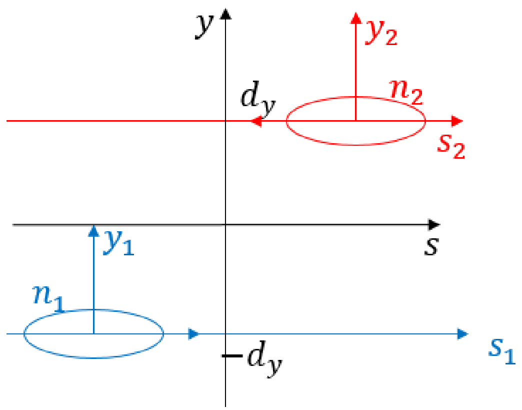
E = 182.5 GeV

β_{ymax}= 6960 m β_{yIP}= 1.6 mm
β_{xmax}= 225 m β_{xIP}= 1 m

$\Delta y(QD) = 1\ \mu m \rightarrow \Delta y(IP) \approx -1\ \mu m$
$\Delta x(QF) = 1\ \mu m \rightarrow \Delta x(IP) \approx -6\ \mu m$

Luminosity and vertical separation





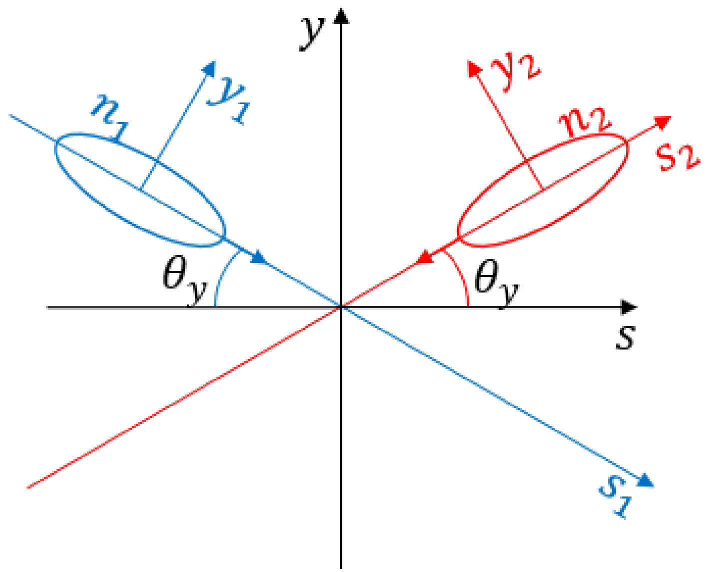
$$\mathcal{L} = \mathcal{L}_0 \exp\left(-\frac{d_y^2}{\sigma_y^2}\right)$$

	Z	W	H	tt	ttH
E, GeV	45.6	80	120	175	182.5
$\mathcal{L}_0, 10^{34}\text{cm}^{-2}\text{s}^{-1}$	230	34	8.5	1.9	1.7
σ_y, nm	28	41	36	76	82
d_y, nm	60	60	60	60	60
$\frac{\Delta\mathcal{L}}{\mathcal{L}_0}$, %	-99	-88	-94	-46	-41

For 10% luminosity loss, the vertical separation at IP should be $d_y < 10$ nm

Active beam adjusting feedback is needed.

Luminosity and vertical crossing angle



$$\mathcal{L} = \mathcal{L}_0 - \mathcal{L}_0 \frac{\sigma_s^2}{8\sigma_y^2(1+\varphi^2)} \frac{3+\cos 4\theta}{(\cos\theta)^4} \theta_y^2$$

For 10% luminosity loss, the vertical crossing angle at the IP θ_y < 10-20 μrad

	Z	W	H	tt	ttH
E, GeV	45.6	80	120	175	182.5
$\mathcal{L}_0, 10^{34}\text{cm}^{-2}\text{s}^{-1}$	230	34	8.5	1.9	1.7
$\sigma_{py}, \mu\text{rad}$	35	41	36	48	51
$\theta_y, \mu\text{rad}$	25	25	25	25	25
$\frac{\Delta\mathcal{L}}{\mathcal{L}_0}$, %	-7	-14	-20	-23	-20

In horizontal plane
d_x < 20-60 μm
θ_x < 1-2 mrad

But still active beam adjusting feedback is needed.

Comments

- The cryostat is out of 100-mrad-cone.
- No space for flange (RVC) mechanics: gears, rods.
- The cryostat wall of SuperKEKB is very complicated, the width is 41 mm. The width of the outer stainless steel is 15 mm. The lever arm of FF in FCC is about 4 m, which is larger than SuperKEKB’s 3.2 m. The rigidity is defined by cryostat.
- The 40 mm wall overlaps by 1 mm with flange.
- Superconducting coils of quadrupoles, anti-solenoid will heat up in case of quench. The size of the cable should prevent this.
- No room for central vacuum chamber cooling pipes and flanges.
- Assembling/disassembling procedure is unclear.
- Stray field from large diameter anti-solenoid defines large gap before the first quad.
- Reduction of anti-sol diameter degrades the vertical emittance due to the strong horizontal field at the beams orbit.

Possible tasks and responsibilities

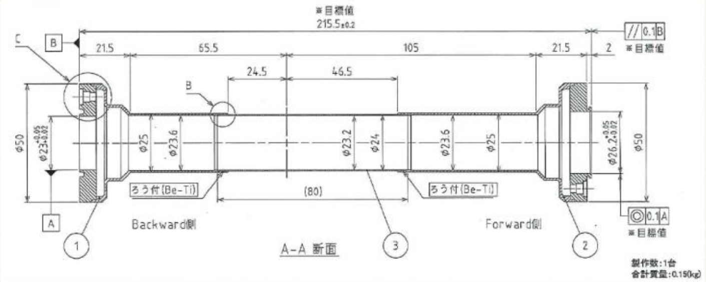
- Beam dynamics (ε_y, $\Delta x, \Delta y, \ldots$) in realistic fields (BINP+?)
- FF magnets, 3d fields, forces (including nonlinear correctors) (?+BINP)
- Vacuum system (joints, flanges, bellows, BPMs, material) (?+BINP)
- Beam diagnostics and feed back (dithering) system (who?)
- HOM and wake fields (Novokhatsky+?)
- Cryogenics, heat loads (who?)
- Detector protection (who?)
- Alignment system (who?)
- Water cooling system including Be pipe (who?)
- Mechanical supports (BINP+?)

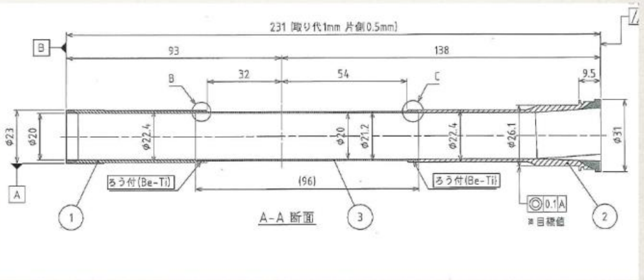
SuperKEKB (Be beam pipe)

Be beam pipe at IP for SuperKEKB

Outer pipe

Inner pipe





	Outer	Inner
Thickness (Be) [mm]	0.4	0.6
Thickness (Ti) [mm]	0.7	1.2

- The beam pipe at the IP of SuperKEKB is a double pipe, each consists of middle (Be) and side (Ti) parts, brazed to each other.
- The inside of inner pipe is Au coated (10 μm thick via 0.3 μm Ti), by magnetron-sputtering.

MTC Metal Technology Co.Ltd.

K. Kanazawa (KEK)

Paraffin for the cooling media

- Normal 10-decan ($C_{10}H_{22}$).
- N=10 is chosen to avoid freezing due to an additional gas cooling.
- ...her N is usable otherwise for higher flash point.

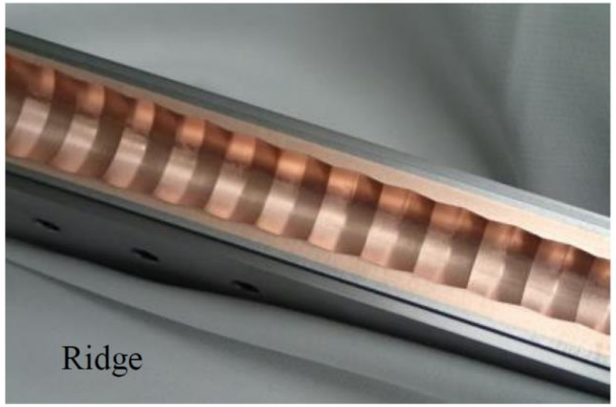
N	10	11	12
Melting point (°C)	-30	-25	-7.5
Flash point(°C)	46	68	85

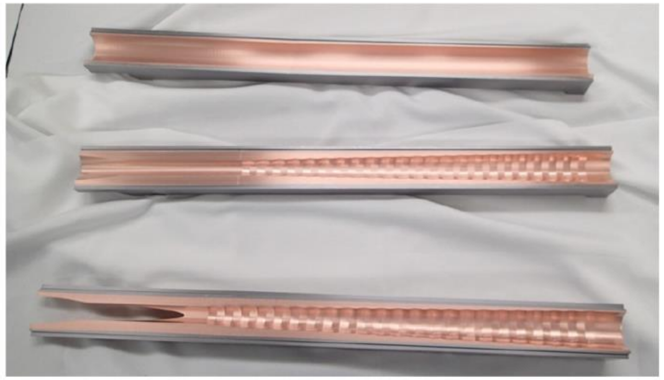
H. Nakayama (KEK, Belle II)

https://indico.cern.ch/event/803859/contributions/3343825/attachments/1807047/2949675/Bepipe_190307_Oide.pdf

SuperKEKB

IP chamber (Ta part manufacturing)

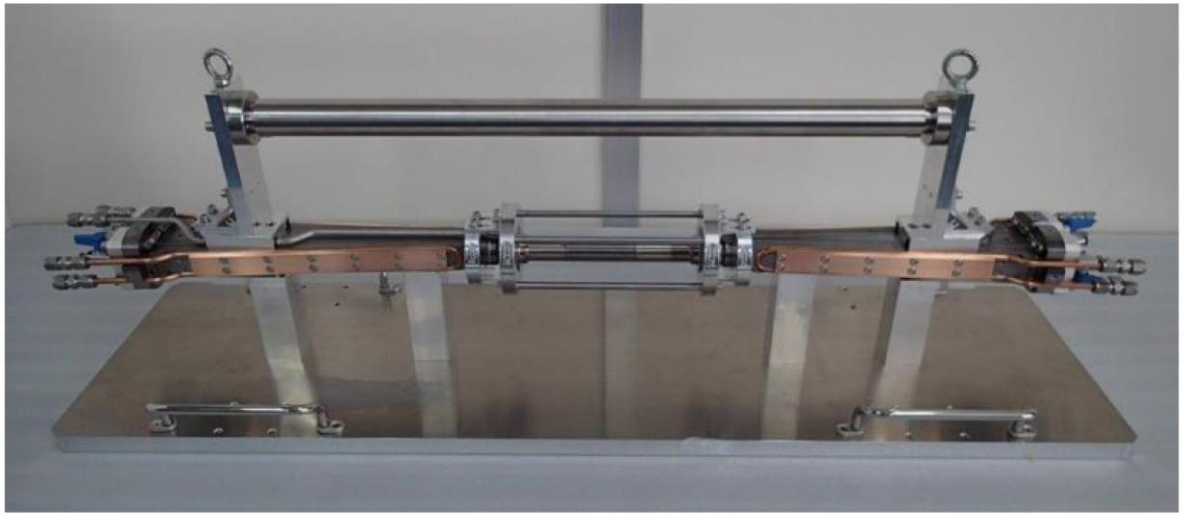




End flange

Metal Technology Co., Ltd

IP chamber with a handling tool



SuperKEKB

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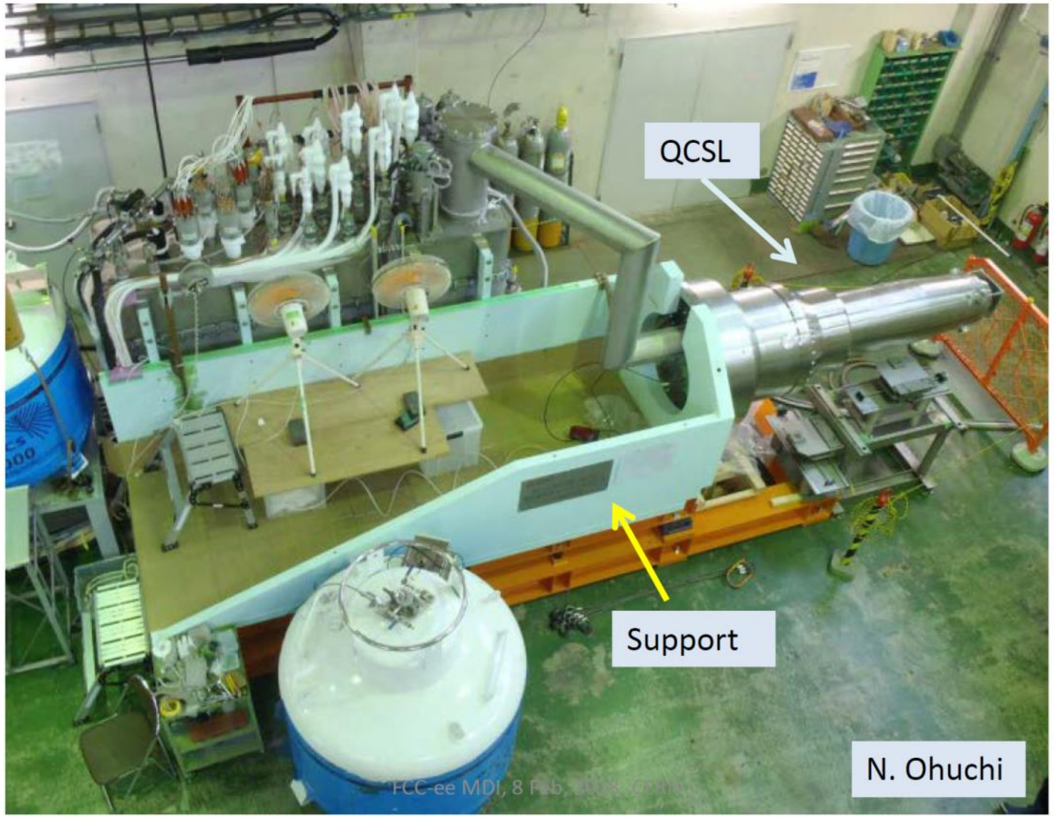
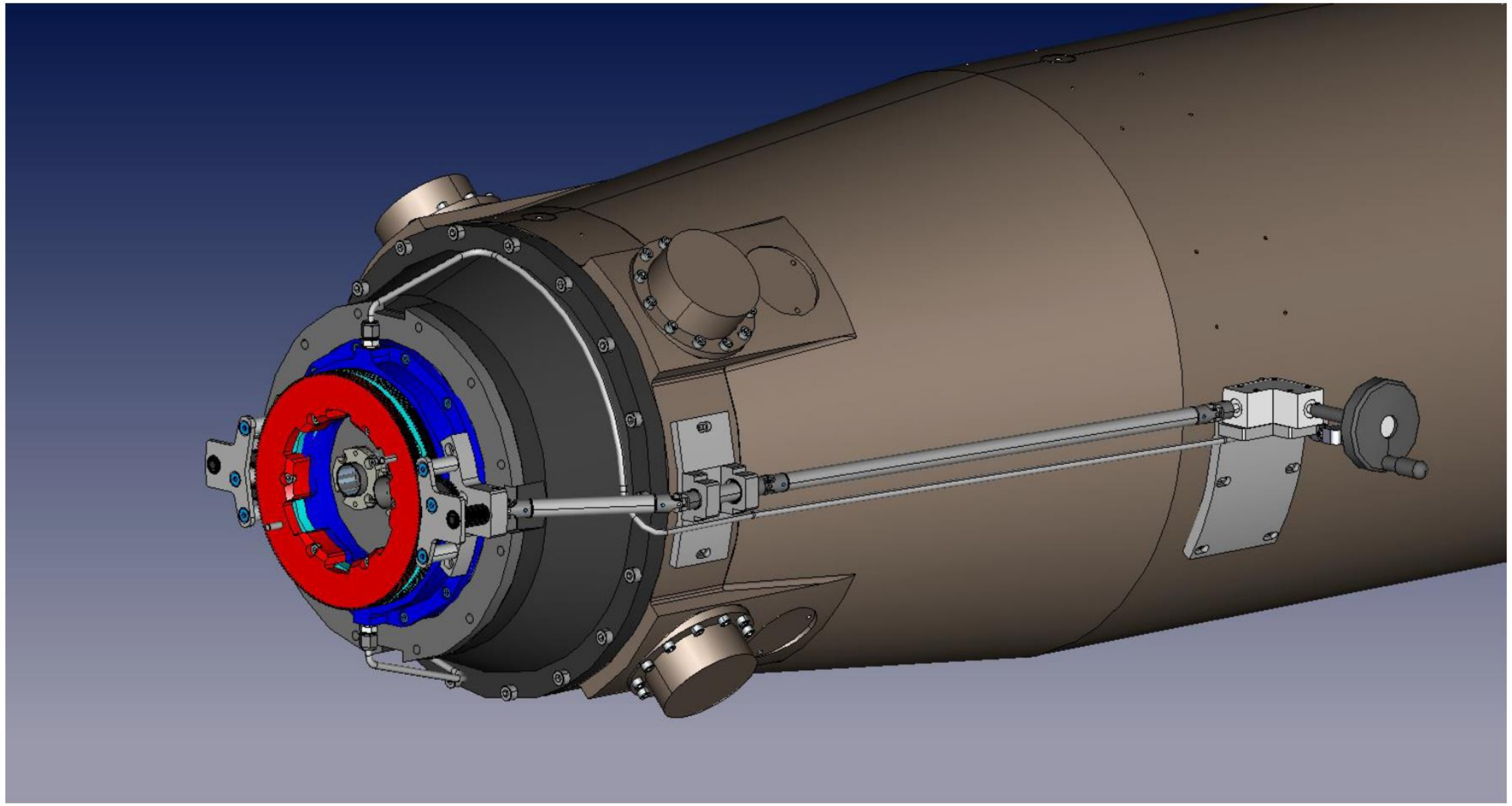
QCSL in the test facility

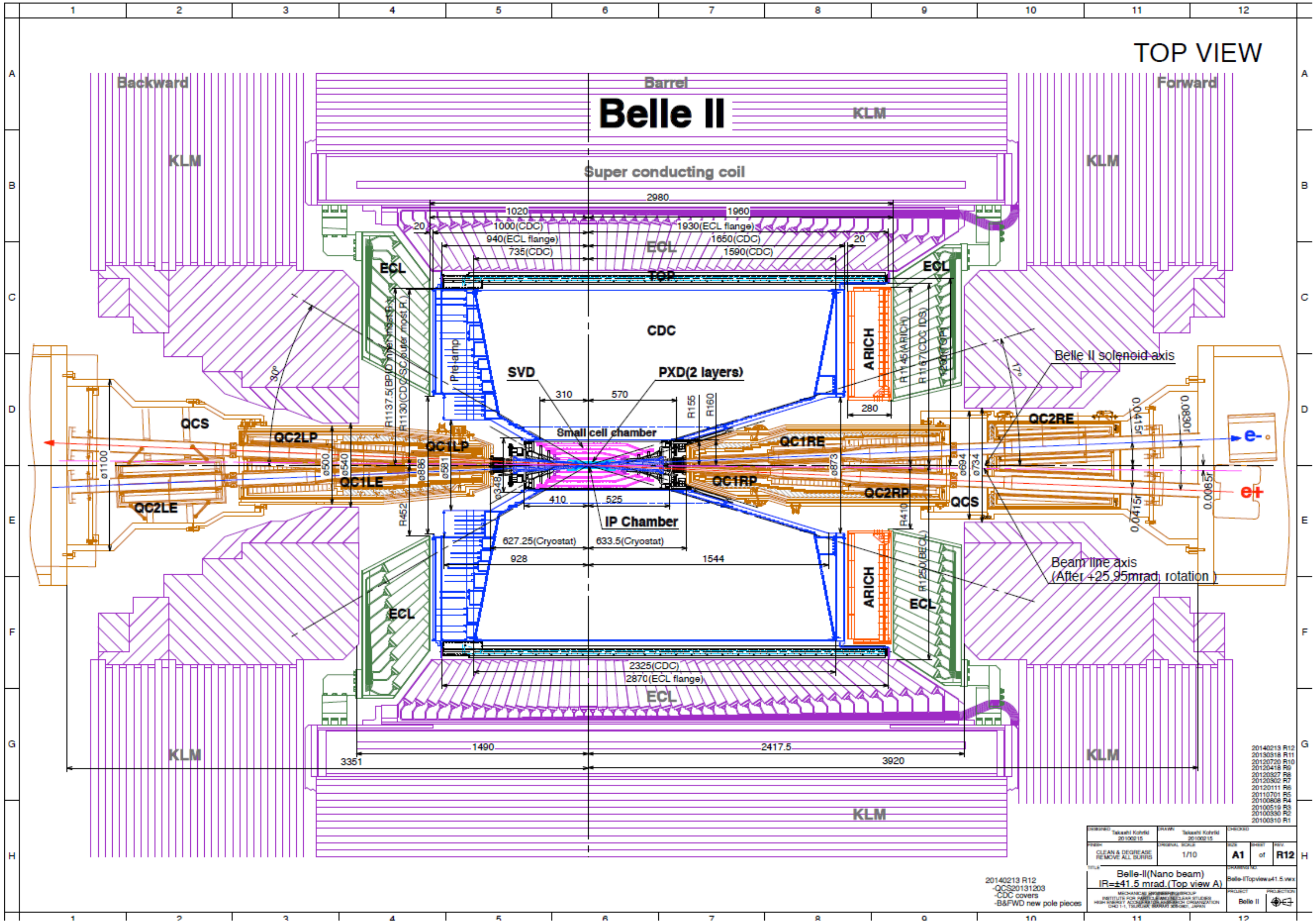


SuperKEKB

RVC backward mounted on to the QCSL



SuperKEKB


TOP VIEW
Backward
Barrel
Forward
Belle II
KLM
Super conducting coil
ECL
TOP
CDC
SVD
PXD(2 layers)
ARICH
Small cell chamber
IP Chamber
QCS
QC2LP
QC1LP
QC1LE
QC2LE
QC1RE
QC2RE
QC1RP
QC2RP
Belle II solenoid axis
Beam line axis
(After +25.95mrad rotation)
e-
e+
Belle-II(Nano beam)
IR=±41.5 mrad.(Top view A)
A1
R12
1/10