BINP activity for FCC-ee/SCTF MDI development

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List of activities

- Prototype and test of the 3-layer vacuum chamber
- Test of improved version of the remotely fixed flange
- Design, production and measurement of the double-aperture iron yoke FF quadrupole
- Small aperture magnet field measuring equipment
- 3D simulation of the MDI magnetic field
- Mechanical integration of the MDI area

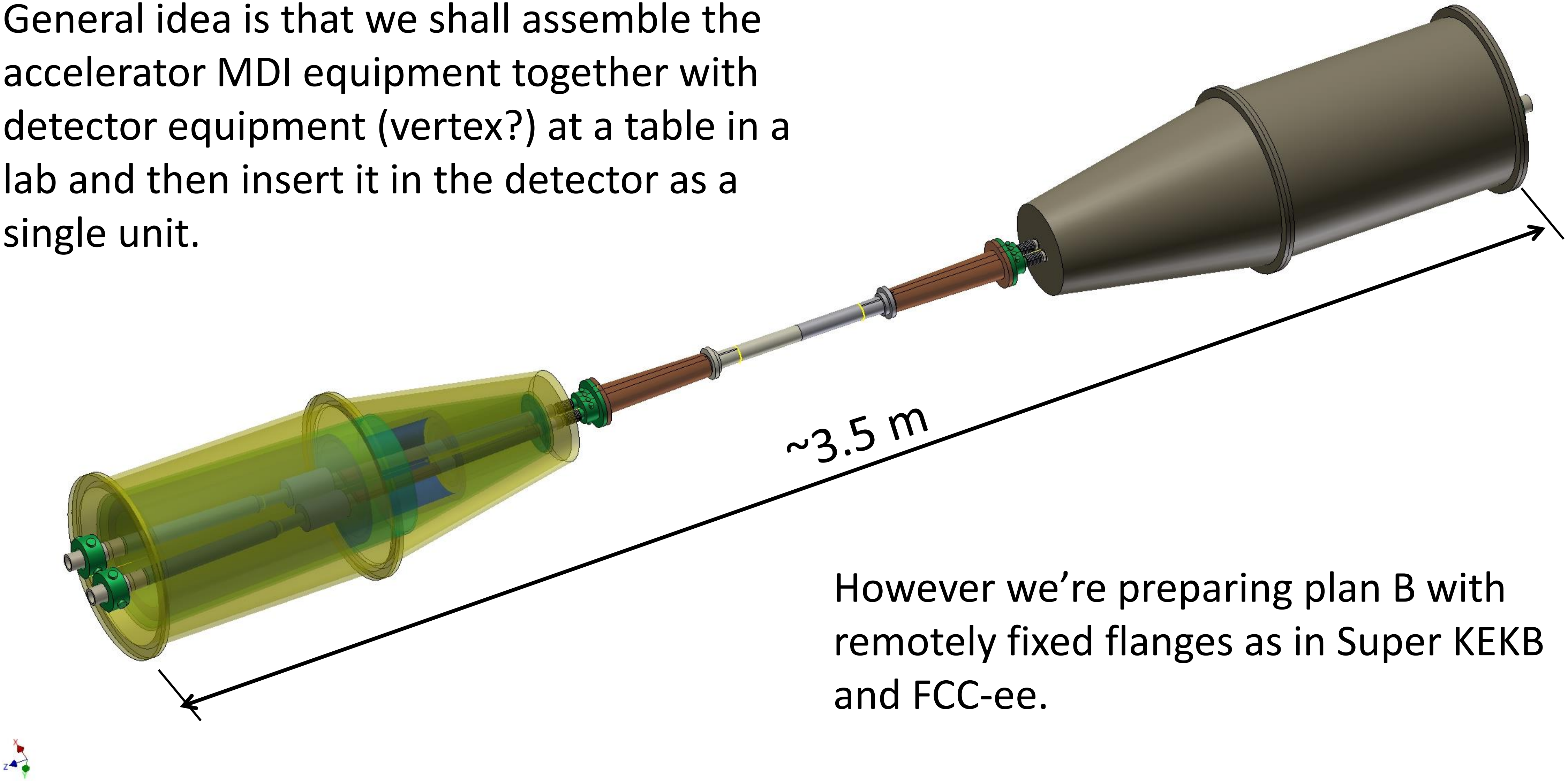
Main goal

Design and development (and may be prototyping and testing) of the MDI that

- satisfies beam optics and dynamics requirements (vertical emittance blow-up, coupling blow up, nonlinear aberrations/corrections, etc.)
- satisfies high current issues (resistive and HOM heating, low impedance, etc.)
- provides required radiation protection for both detector background and SC magnets quenches
- provides low residual gas pressure (high vacuum conditions)
- meets mechanical requirements (integration with detector systems, rigidity, stability, easy access and assembling/reassembling, etc.)

SCTF MDI

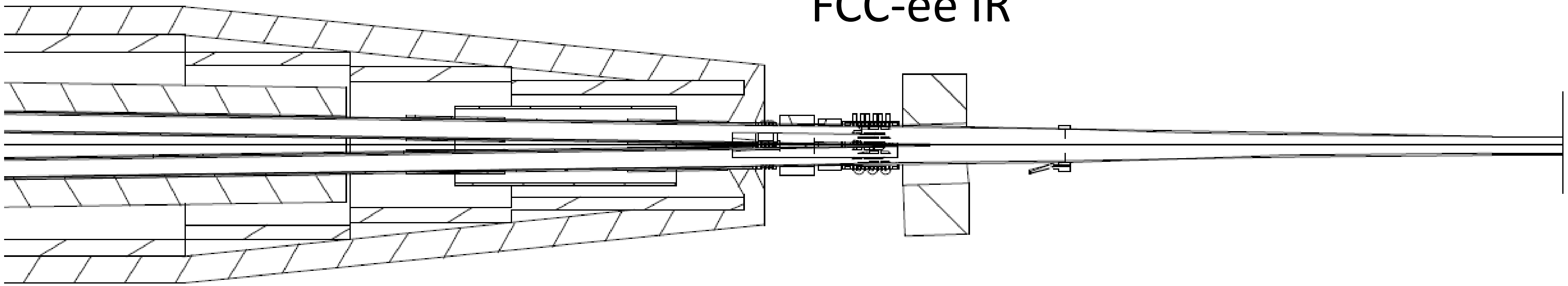
General idea is that we shall assemble the accelerator MDI equipment together with detector equipment (vertex?) at a table in a lab and then insert it in the detector as a single unit.



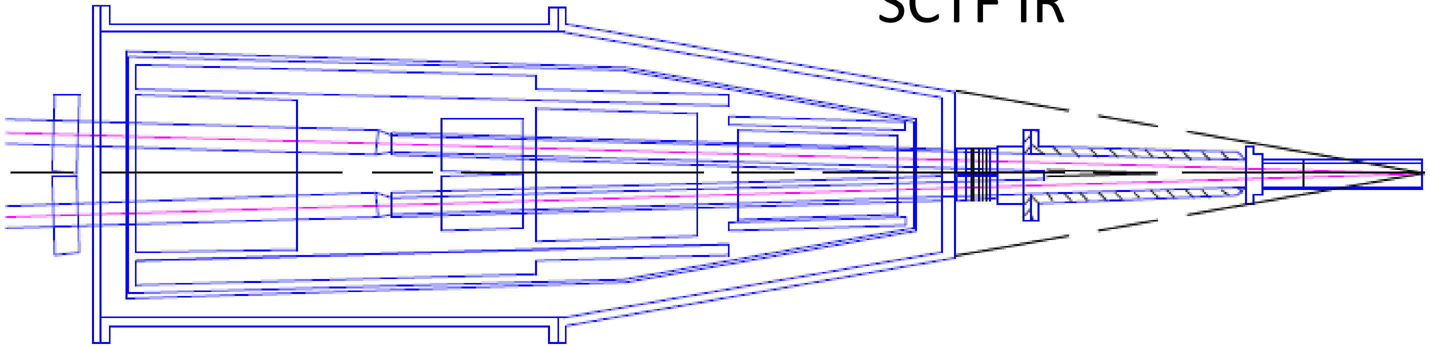
However we're preparing plan B with remotely fixed flanges as in Super KEKB and FCC-ee.

Novosibirsk SCTF and FCC-ee

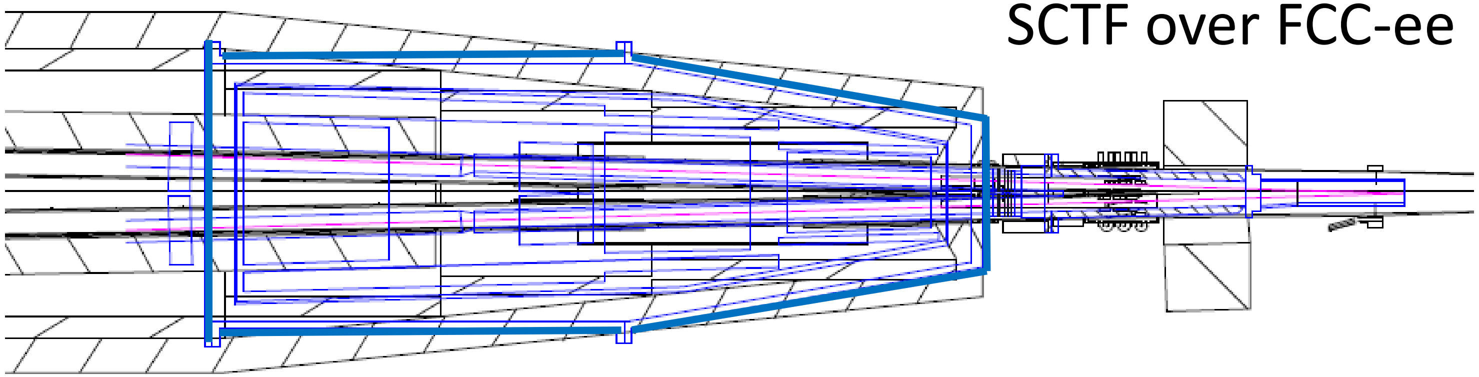
FCC-ee IR



SCTF IR



SCTF over FCC-ee



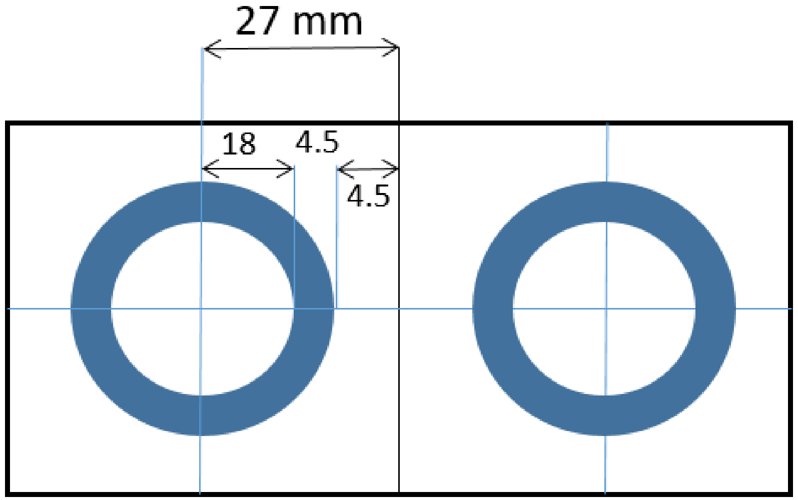
Dimension of the first section (most critical and complex) of the FCC-ee and SCTF IRs are very similar

Design by S. Pivovarov

Novosibirsk SCTF and FCC-ee

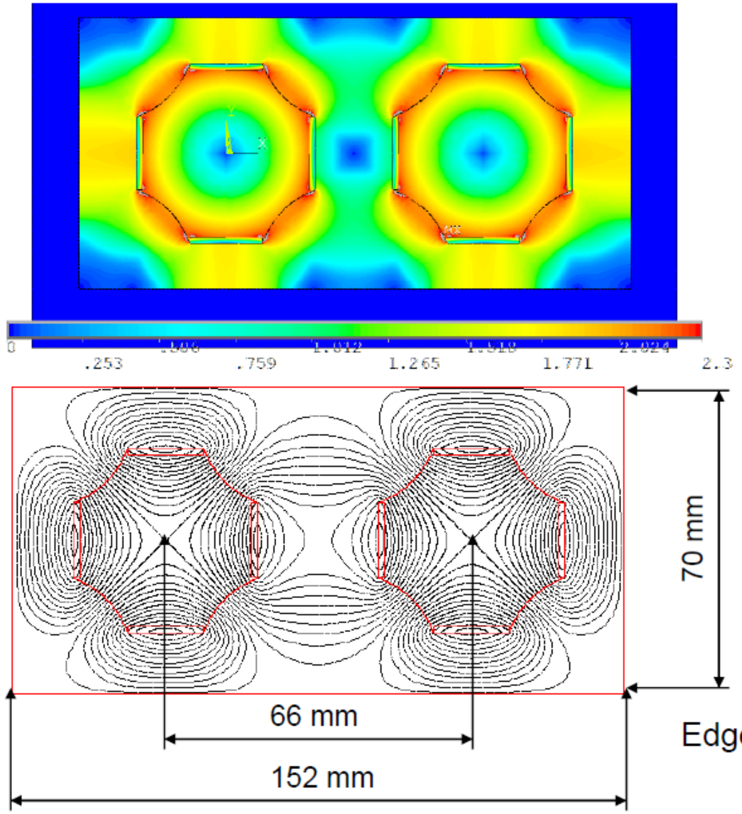
During 2019 we decided to build and test a 2-aperture SC iron yoke quadrupole (Vobly's design) for SCTF. When we moved QD0 from L*=600 mm → 900 mm with the full angle 60 mrad, its transverse dimensions are very similar to FCC-ee (L*=2200 mm, 30 mrad).

SCTF



QD0 G = 100 T/m

Aperture 4.5 cm



Edge of quad close to IP

FCC-ee

Main parameters:

- Max.gradient 100 T/m
  Length 120 cm
- Aperture 4.2 cm
- Clear aperture 3 cm
- NbTi 1.4 x 0.8 mm^2
  Saddle-type coils
- Permendure iron yoke

Iron yoke twin-aperture SC quadrupole (1)

BINP: iron yoke twin-aperture SC FF quadrupole (Pavel Vobly)
FCC-ee: CCT technology (Eugenio Paoloni/Mike Koratzinos)
CEPC: cosine-theta regular technology

Advantages of our design (our vision):

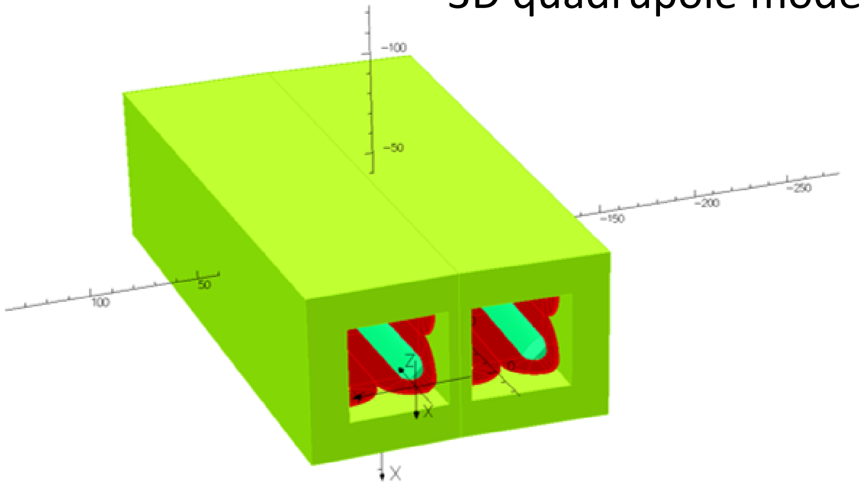
- Iron yoke prevents field cross-talk between apertures
- High field quality (both local and integral) can be achieved
- Relative position of the apertures is of high precision
- Quadrupoles block is rigid and can be easily aligned
- Well proven technology
- Simple and cheap

Disadvantage: no additional coils can be inserted; separate correctors are needed before/after the quad (not a big problem)

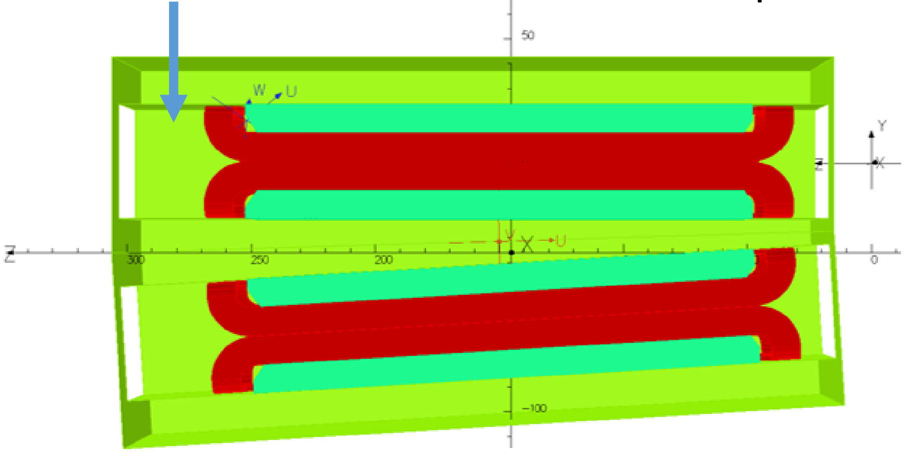
Iron yoke twin-aperture SC quadrupole (2)

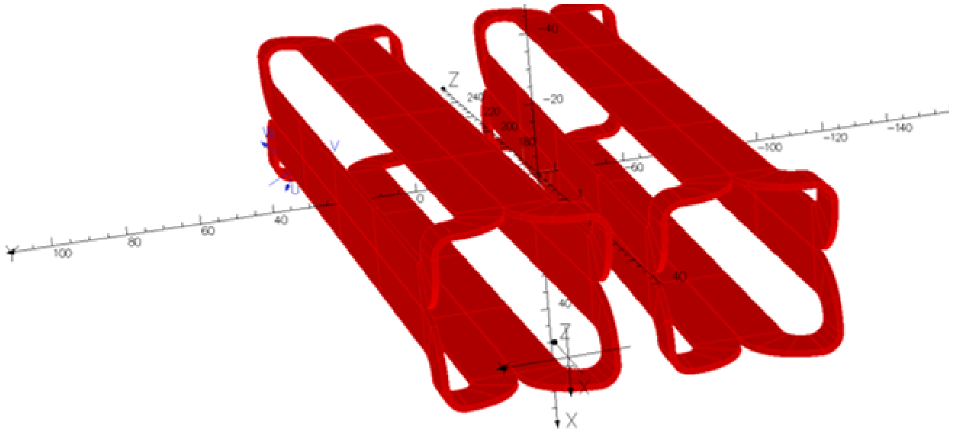
Intensive simulation of the twin-aperture magnetic field is underway (field distribution, field quality, influence of manufacture and assembly tolerance, etc.)

3D quadrupole model



Yoke extension to reduce the apertures cross-talk

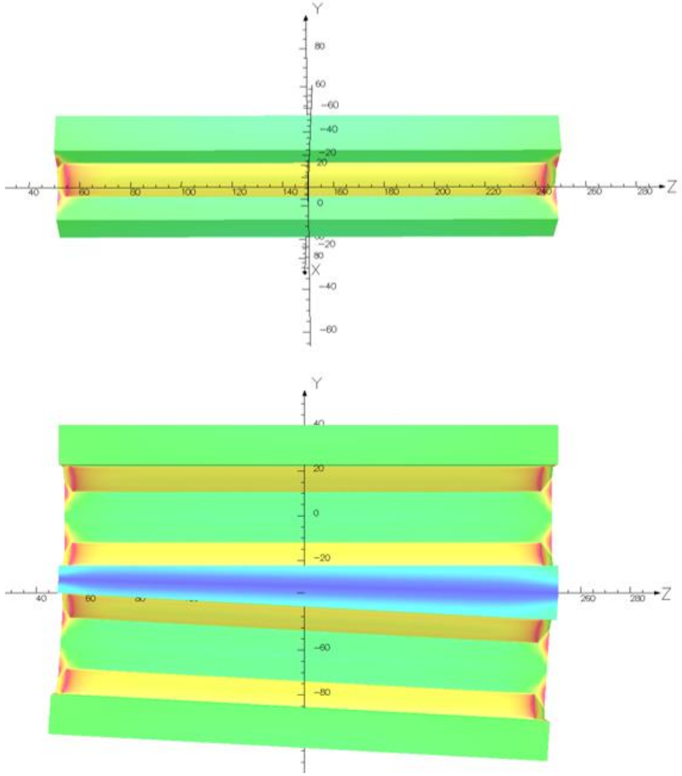


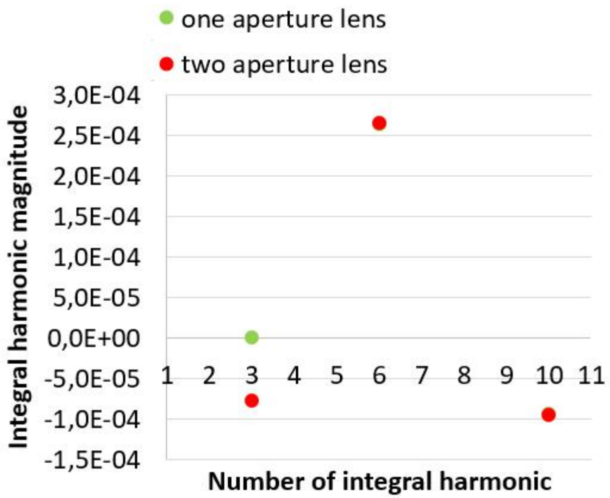


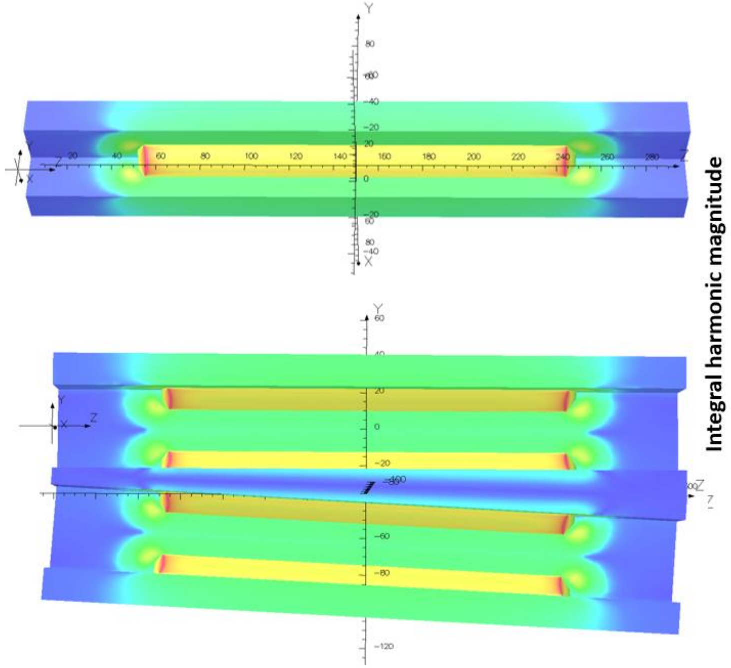
Aperture radius, mm	23
Gradient, T/m	100
Gradient integral, T	22
Current, kAmper turn	21.5

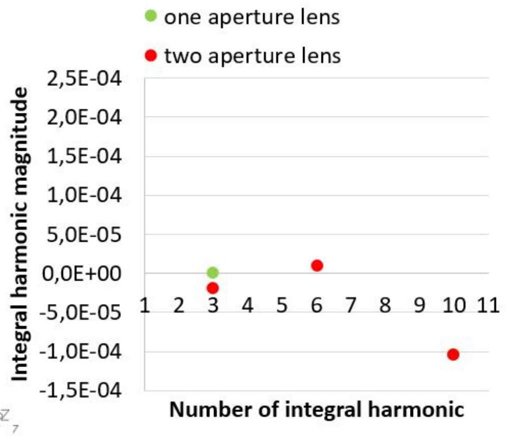
Iron yoke twin-aperture SC quadrupole (3)

Yoke extension reduces the third integral (skew sextupole) harmonic from -8×10^{-5} to -2×10^{-5}. End pole chamfers reduce the sixth harmonic from 2.7×10^{-4} to 1.8×10^{-5}.



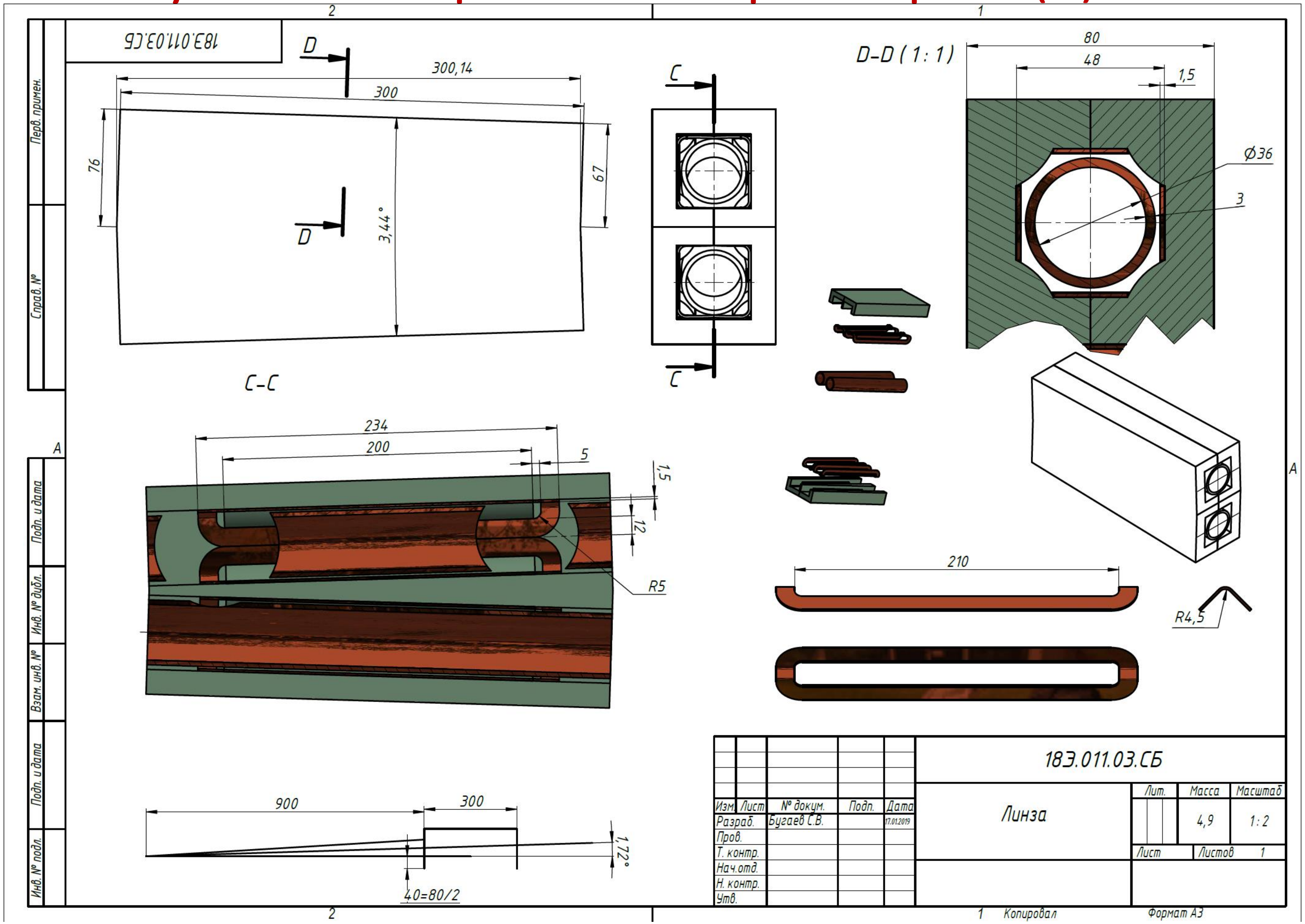






We started detailed manufacturing design of the twin-aperture quadrupole and the Hall probe magnetic measurement equipment for a full scale magnetic measurement.

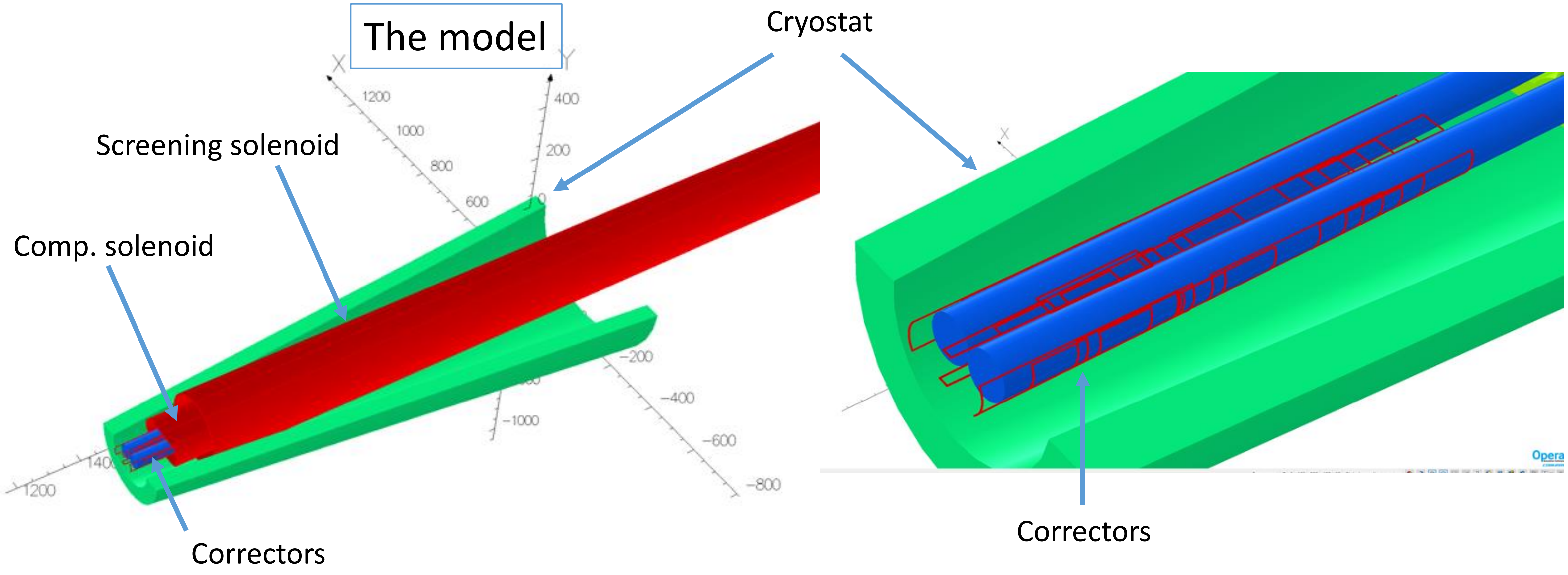
Iron yoke twin-aperture SC quadrupole (4)



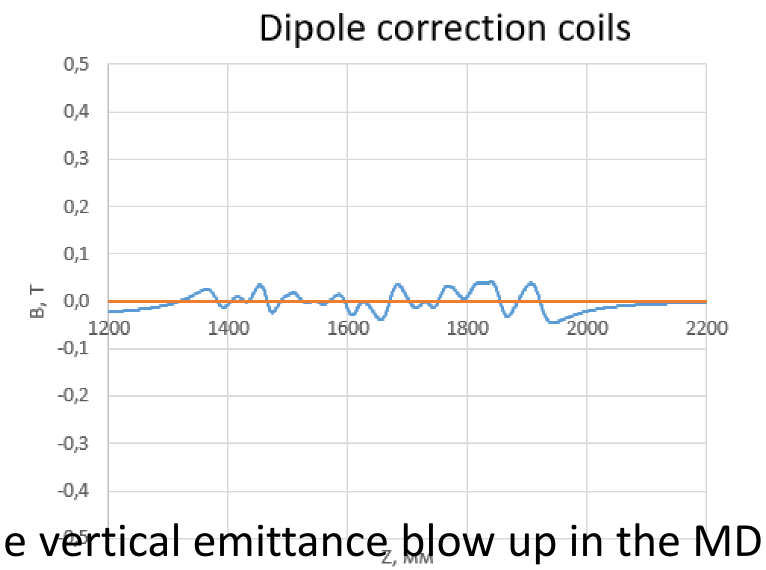
General view drawing of the iron yoke quadrupole. Technical design is in progress.

3D simulation of the MDI field (1)

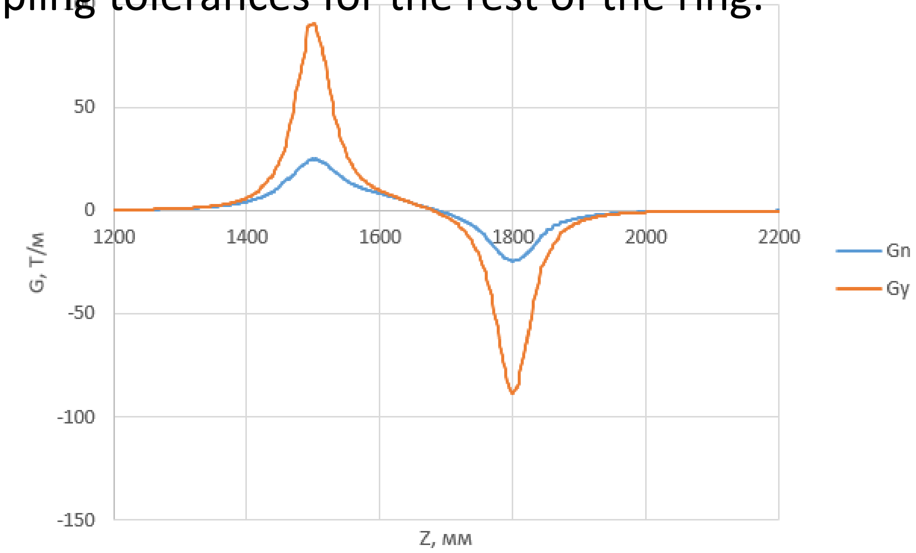
Final goal is a complete 3D pattern of the MDI field (including solenoids, quadrupoles, correctors, etc.) for the beam tracking. We still plan to use individual correctors around the beam tubes to control undesirable horizontal and skew fields, which excite the vertical emittance. Detailed study of the correctors is under way.

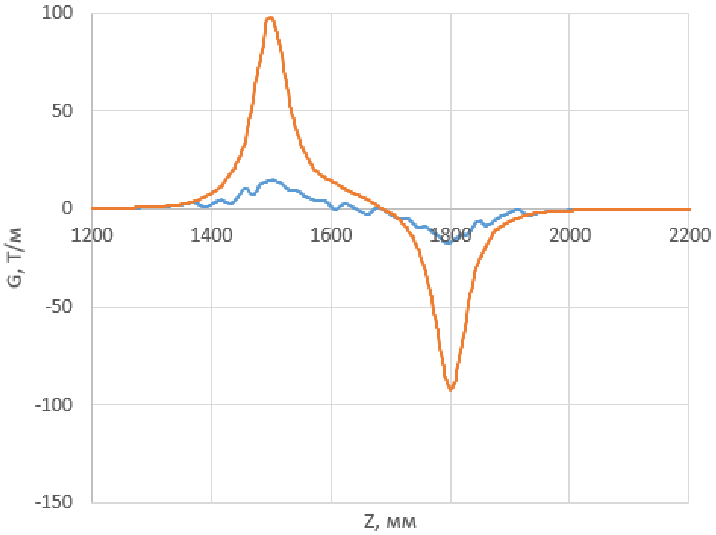


3D simulation of the MDI field (2)



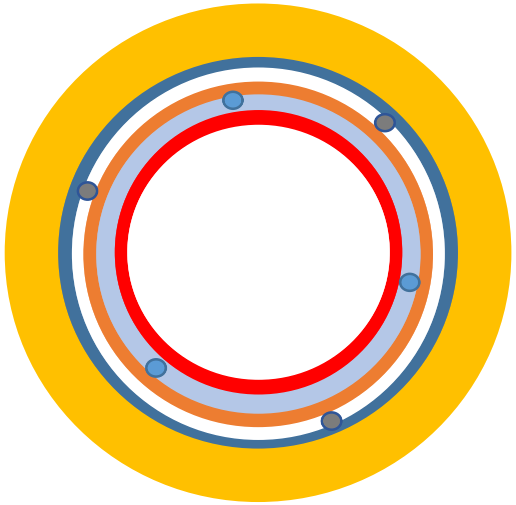
Individual dipole/skew correctors can totally solve the problem of the vertical emittance blow up in the MDI area, relaxing coupling tolerances for the rest of the ring.





Vacuum chamber inside the cryostate

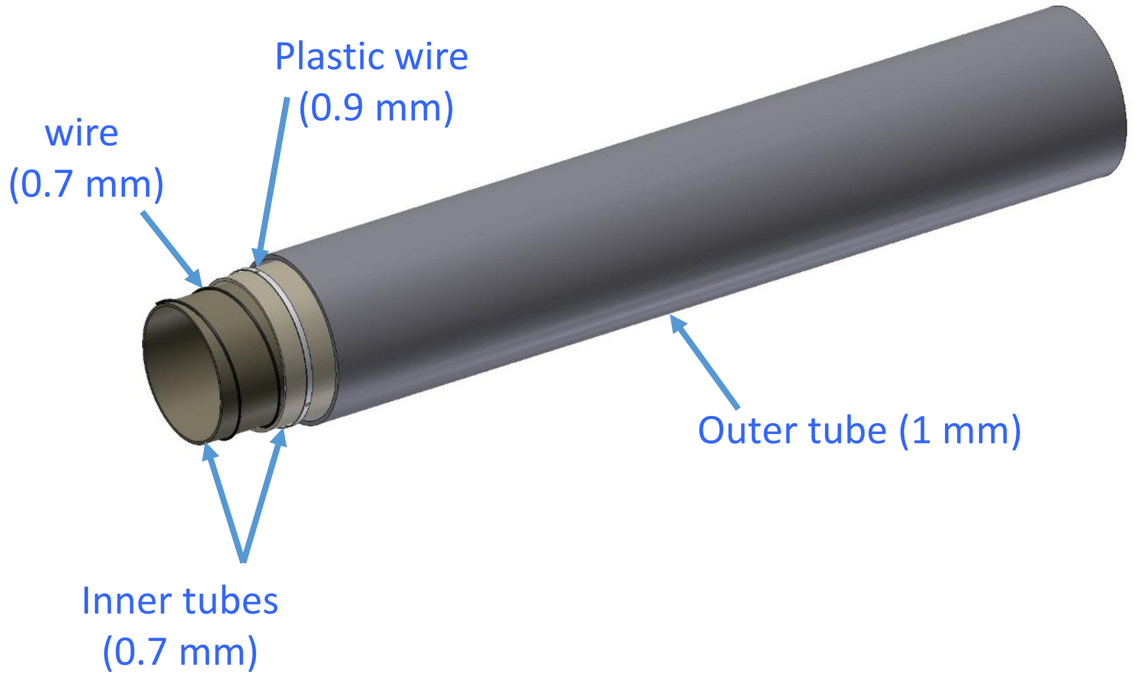
Rough estimation shows for the SCTF MDI vacuum chamber ~100 W/m thermal load due to HOMs and image currents. The task is to develop, produce and test a prototype for the multilayer vacuum chamber inside the cryostat providing tolerable heating of FF magnets.

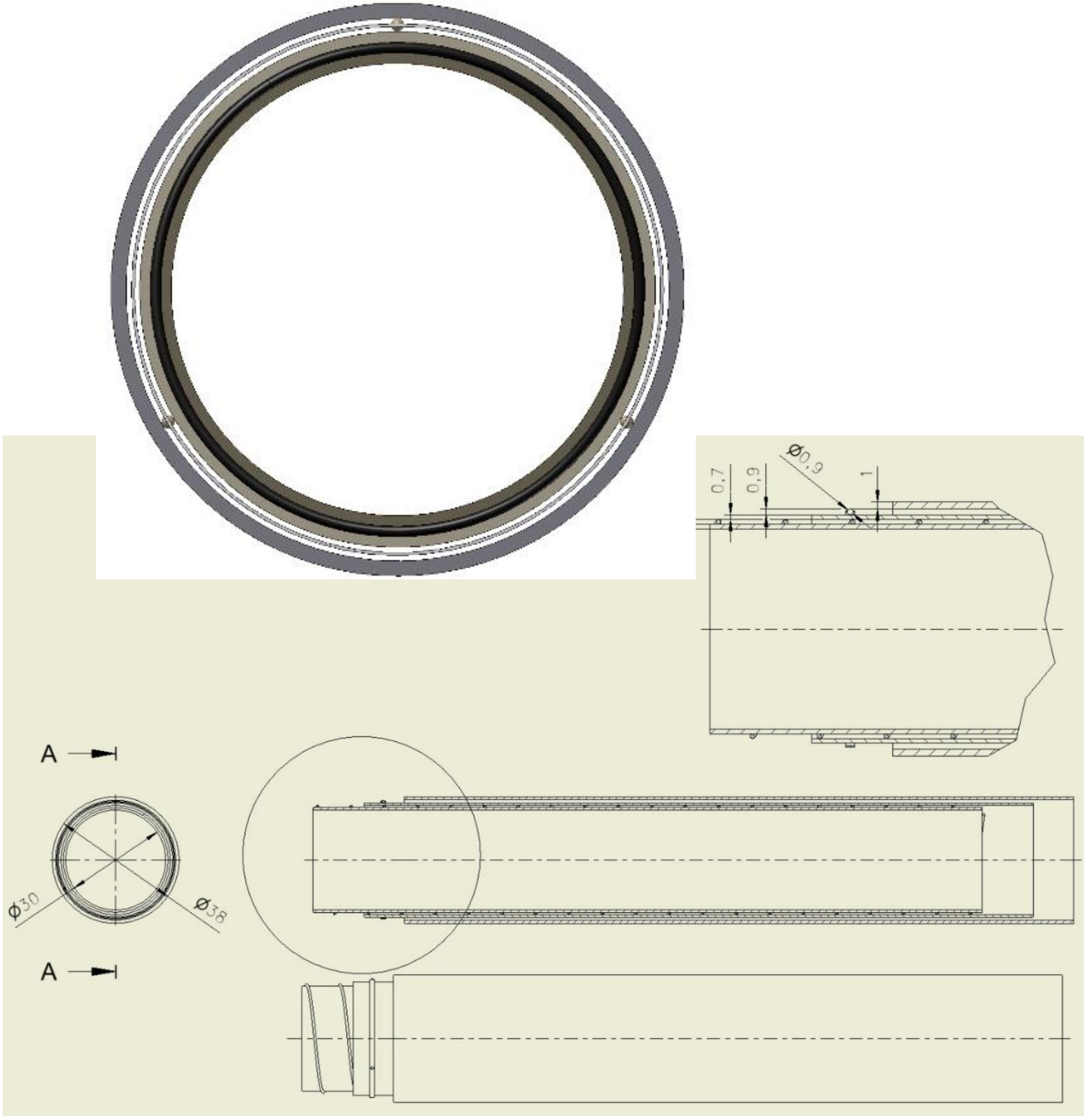


- Inner vessel 0.7 mm thick with copper coating, T=300K
- 0.7 mm cooling water gap against HOM & IC
- Vacuum tube 0.7 mm with mirror-like coating (Cu or Au), T=300K
- 0.9 mm vacuum gap
- Outer 1 mm vessel coated by Cu, T=4.2K
- Superconducting coil on a mandrel

Example: inner ∅=30 mm, outer ∅=38 mm

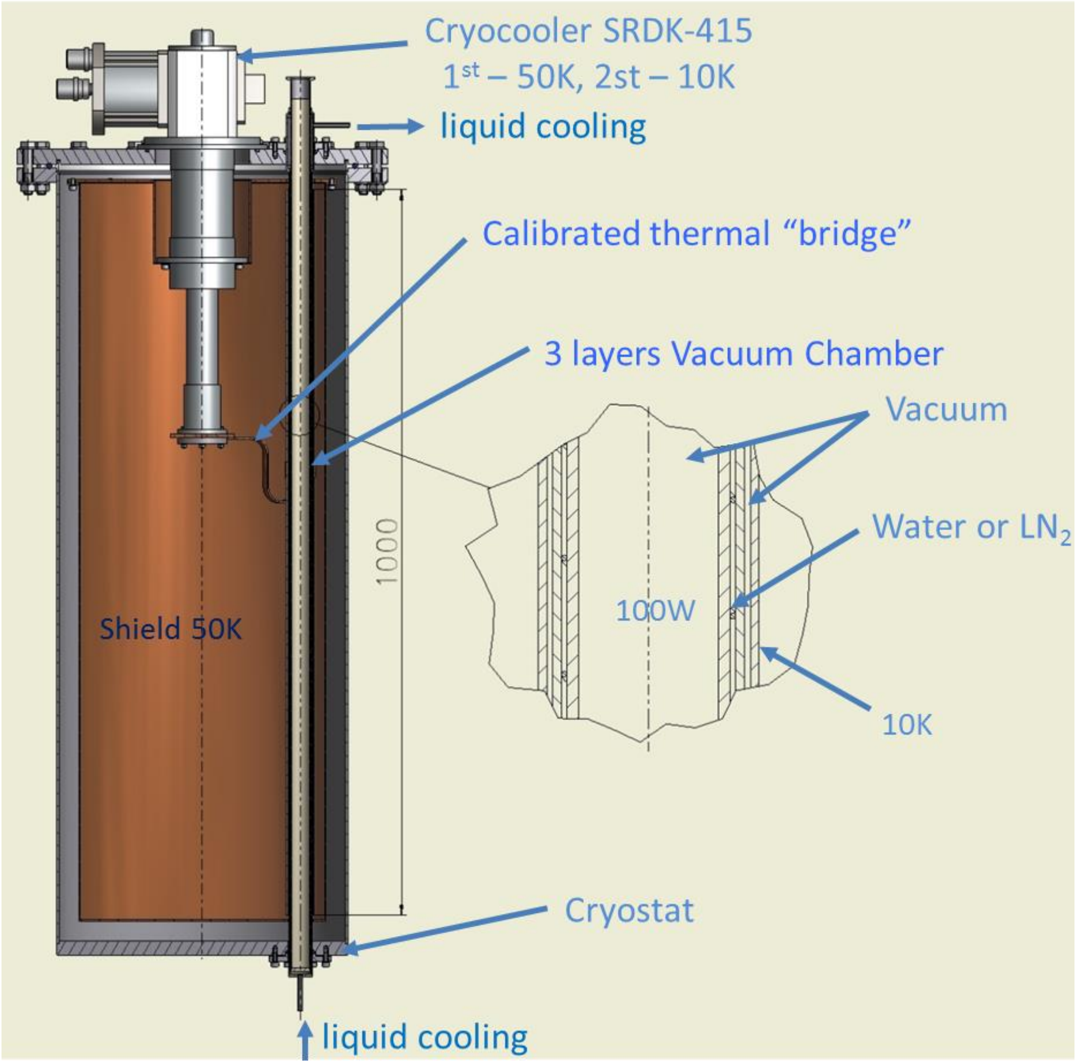
3 layer vacuum chamber prototype





The tube and testing cryostat is under manufacture in BINP workshop.

Testing cryostat and measurement equipment



It is planned to heat the tested tube in the cryostat imitating the beam thermal load. A capacity of cryogenic system will be studied.

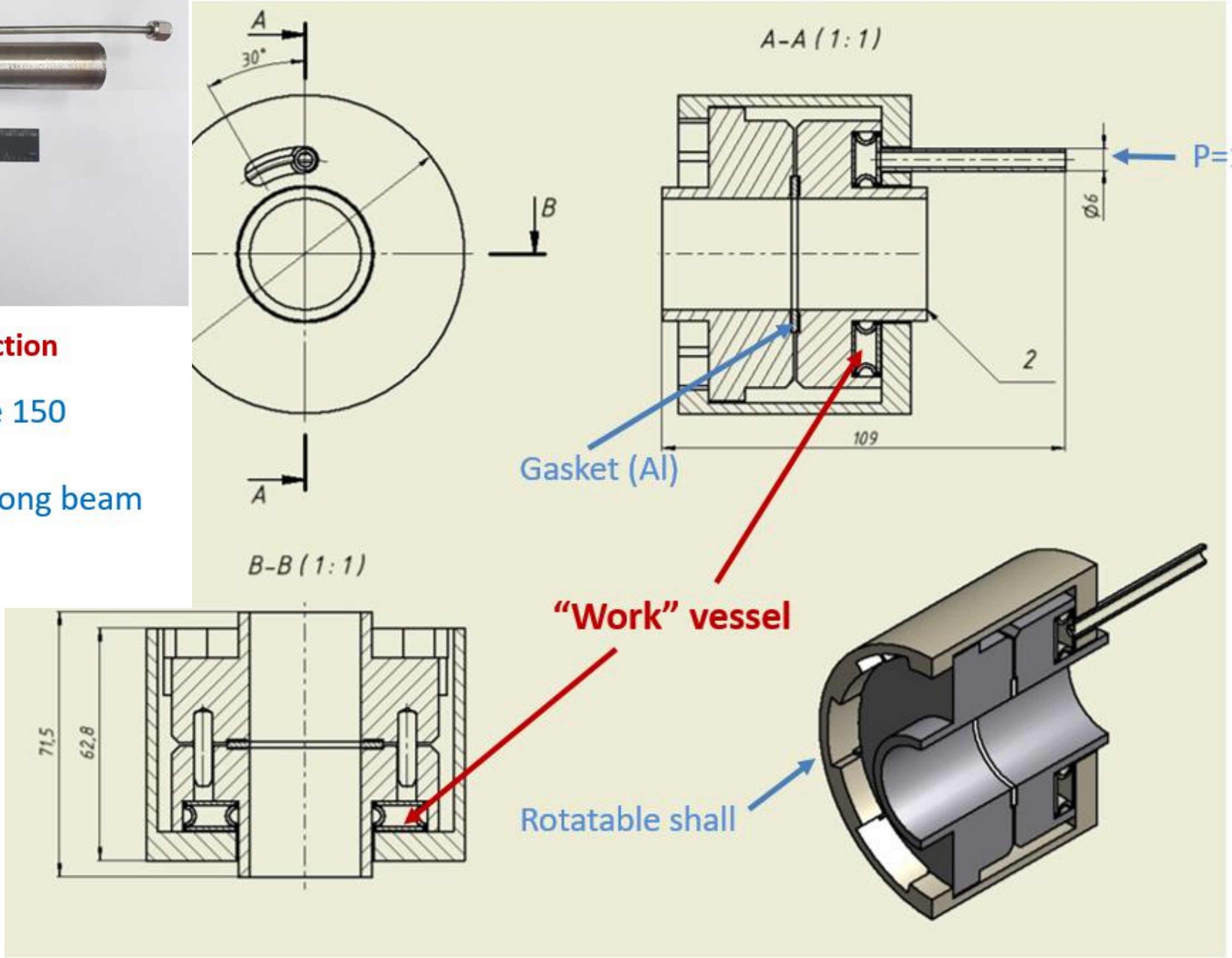
Assembling of the equipment is in a week.

Remotely controlled flange

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 well. Double aperture is under construction.

Conclusion

- BINP continues to develop the MDI area for SCTF/FCC-ee, which seem quite synergetic.
- We plan to produce the twin aperture iron yoke quadrupole in 2019. Magnetic measurement equipment is under development.
- We plan to finish 3D magnetic field simulation and track the beams in resulting fields.
- We plan to finish and test in a cryostat the 3-layer vacuum chamber.
- We are ready to continue the mechanical design of the FCC-ee MDI area.
- There is an agreement with our colleagues from KEK to simulate together the detector background for SCTF. May be this work would be interesting for FCC-ee also.

Present team

A.Bogomyagkov E.Levichev S.Sinyatkin	beam optics and dynamics
P.Vobly K.Ryabchenko A.Starostenko T.Rybitskaya	magnets inside the cryostat
A.Krasnov	vacuum system
S.Buguev S.Pivovarov	SC magnet design MDI design
S.Khruschev V.Shkaruba	cryostat and cryogenic equipment