# IR magnets and MDI integration

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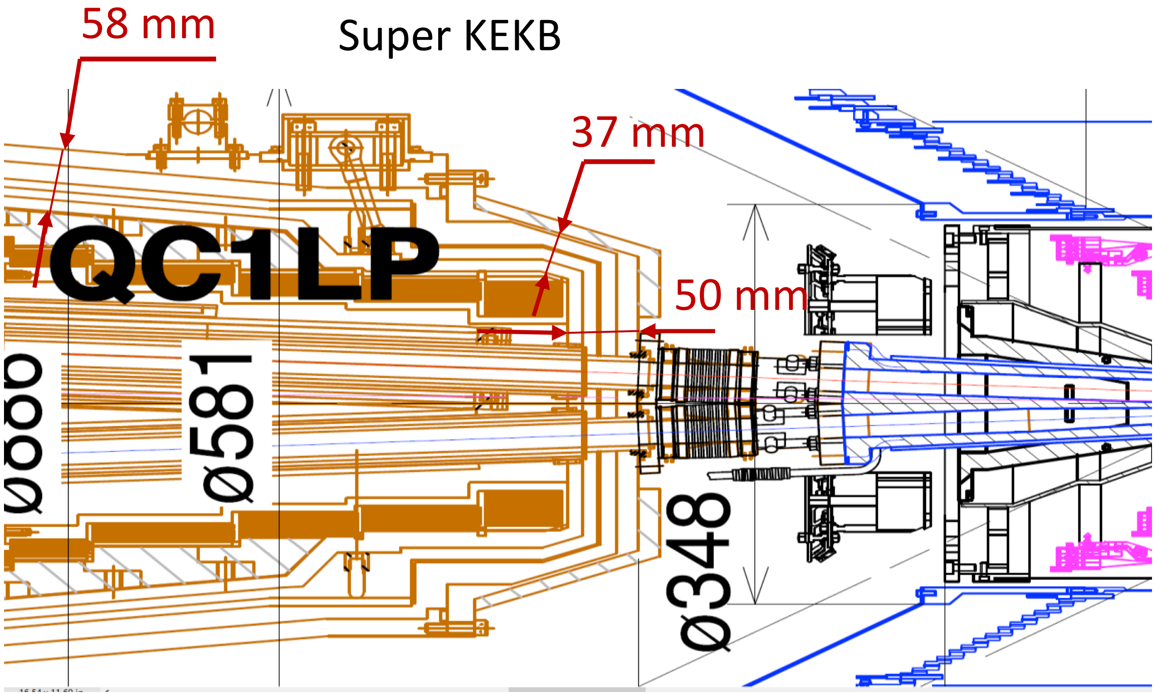
# Initial conditions and constrains

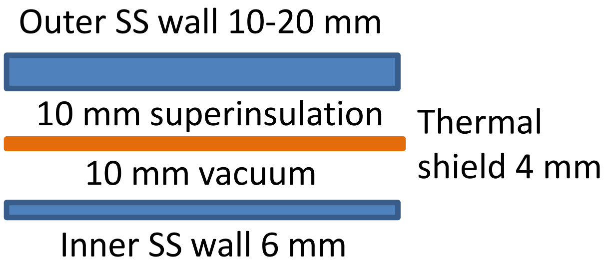
- Full crossing angle 30 mrad.
- First (defocusing) quad QC1 is placed in L*= 2.2 m from the IP.
- Set of magnets (QC1, QC2, A-sol, screening sol, correctors) in a cryostat which has to occupy ≤100 mrad cone.
- Lumical at 1 m to 1.25 m in not symmetrical angle covering +140 mrad … -100 mrad. No material before Lumical.
- IP vacuum chamber with 30 mm inner diameter increasing with distance.
- A BPM (on each tube) before the cryostat, remote vacuum connection (RVC) flanges, bellows for the cryostat adjustment, NEG pumps…

# What is the cryostat “walls” thickness?




Peripheral cryostat steel tank is of 16-17 mm thick because it provides mechanical stability and tolerance for the whole system.

According to BINP experts (~50 SC wigglers), a minimum cryostat “wall” thickness is ~30-50 mm, which corresponds well to the KEK example drawing.



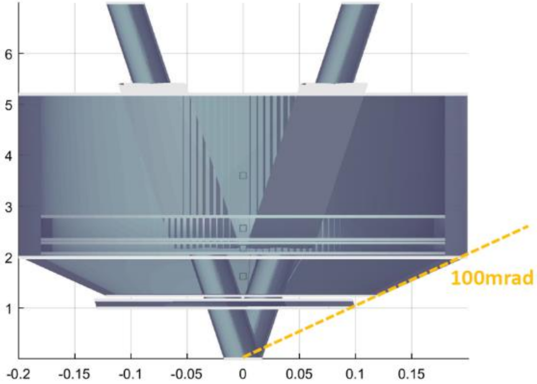

In total: ~40-45 mm

# February MDI meeting at CERN

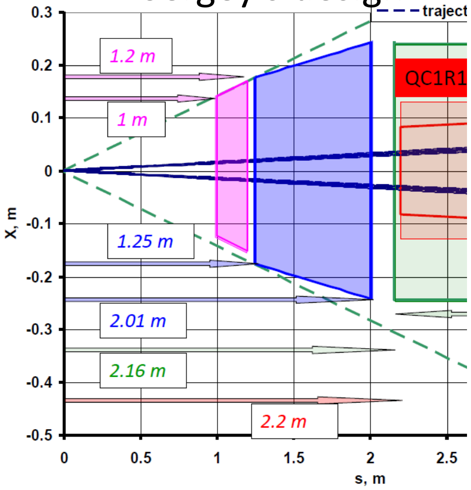
Anti-sol by Mike

Anti-sol by Sergey

Mike's design

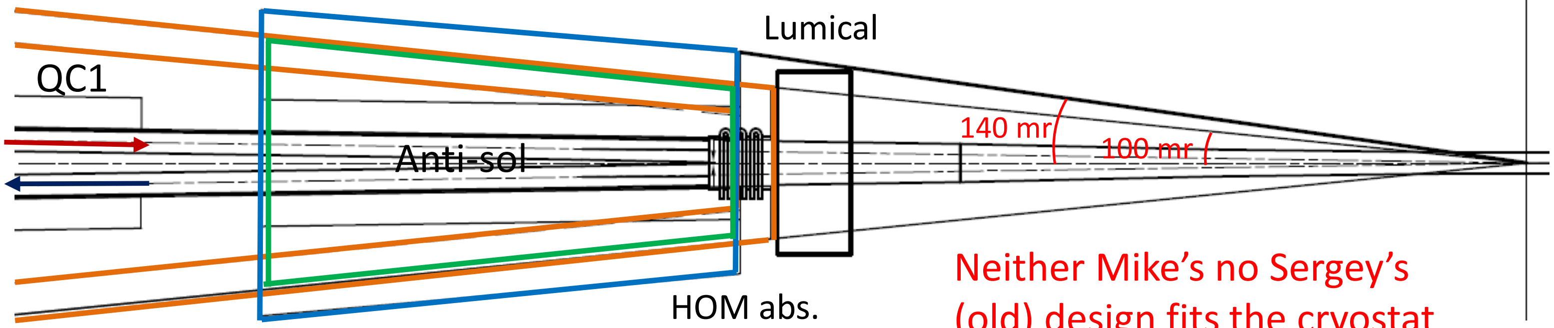



Sergey's design



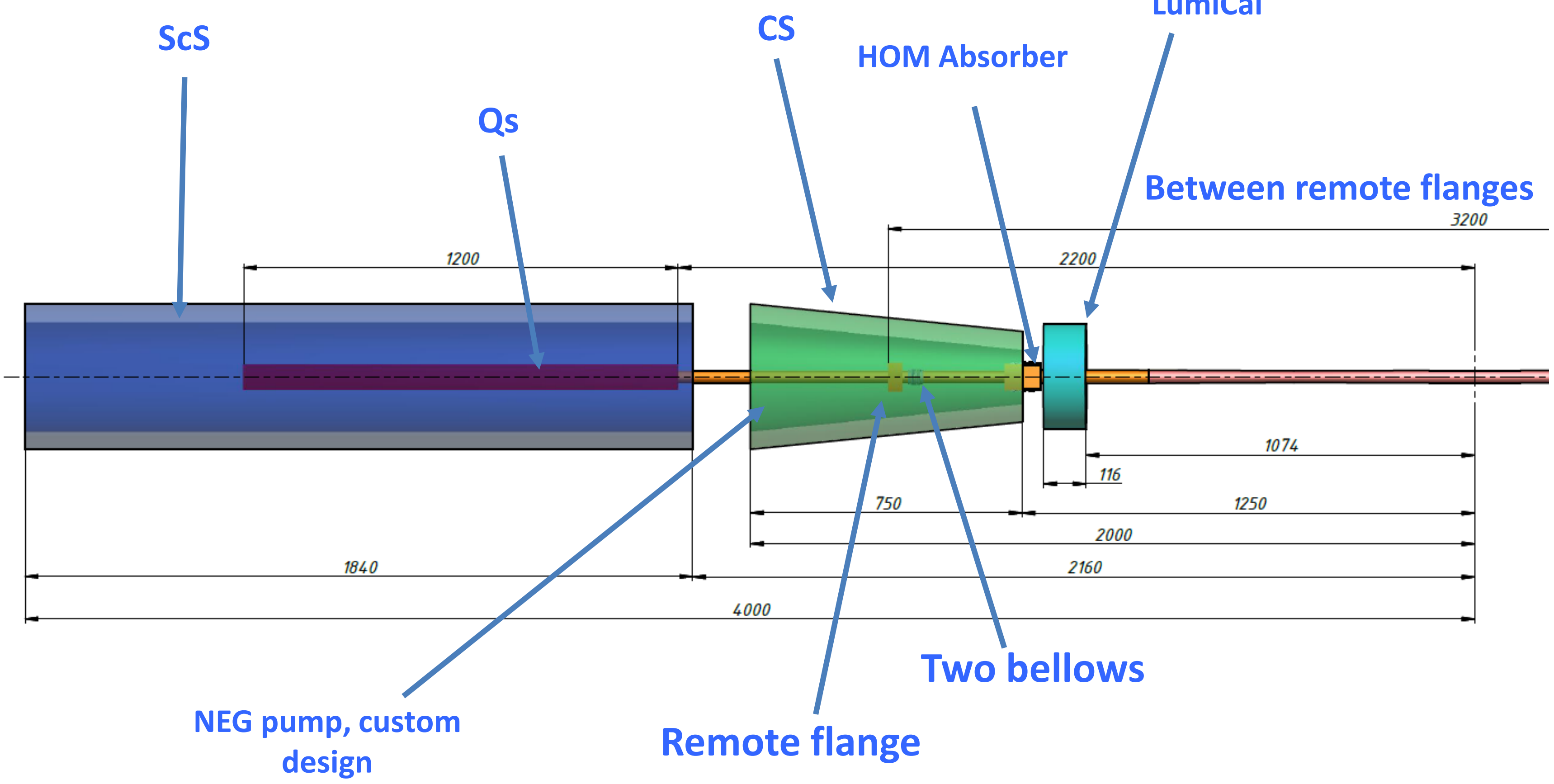

- I was asked to redesign the IR magnets sticking to the original 100mrad cone
- I have done so. Please note that only the coils are within the 100mrad cone. The cryostat will be outside the cone.

Cryostat in 100 mrad cone with 50 mm wall




Neither Mike's no Sergey's (old) design fits the cryostat

# February MDI meeting at CERN



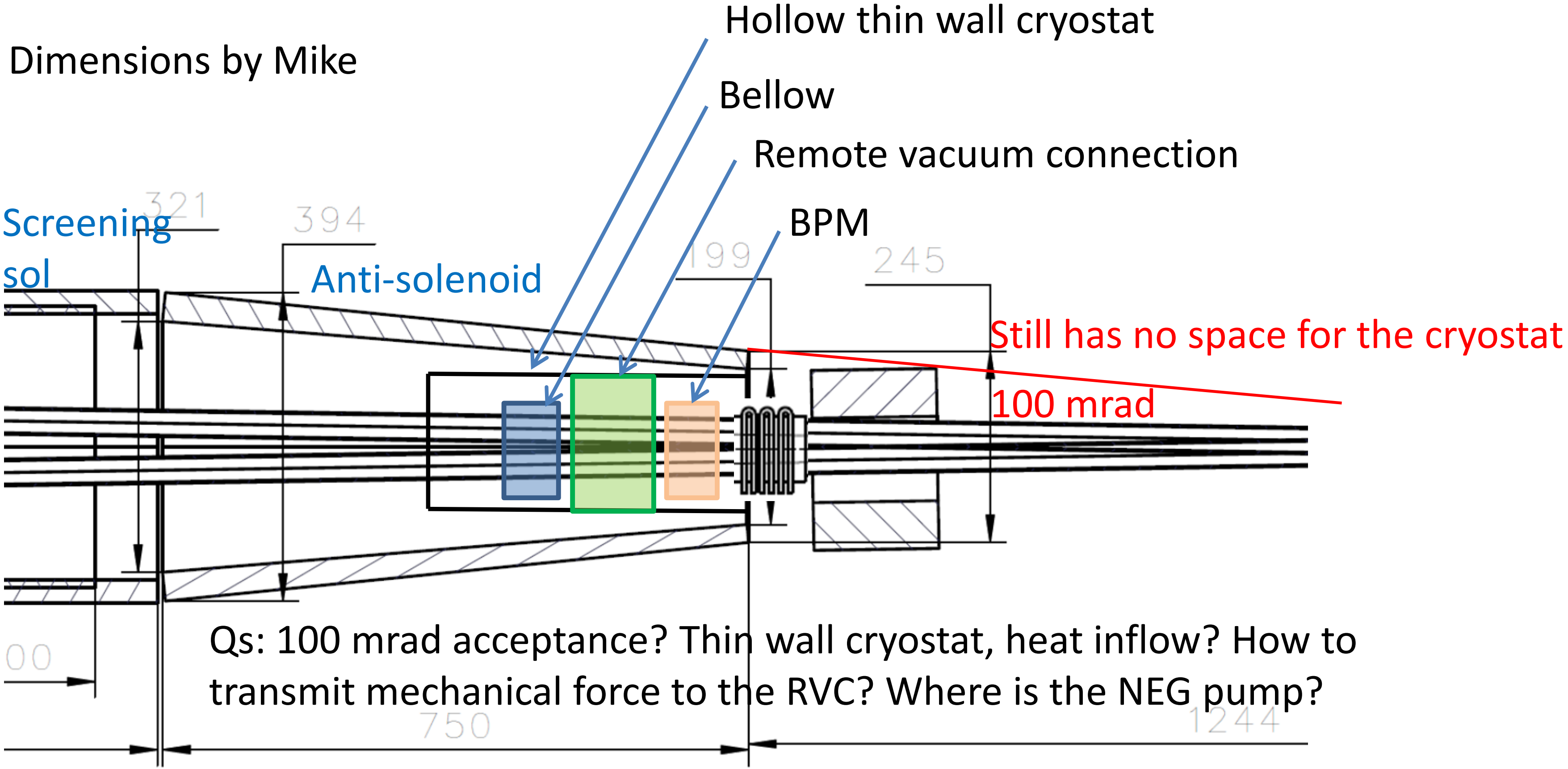
# Current IR design

- The cryostat is out of 100-mrad-cone.
- Difficult to find space for HOM absorber, flanges, bellows, BPMs, NEG pump.
- Assembling/disassembling procedure is unclear.
- Stray field from large diameter anti-solenoid needs 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.

Even if we increase 100 mrad to 140 mrad, there are still problems with accommodation of HOM absorber, flanges, bellows, BPMs, vacuum pump…

# How to fit the current IR design?

Dimensions by Mike

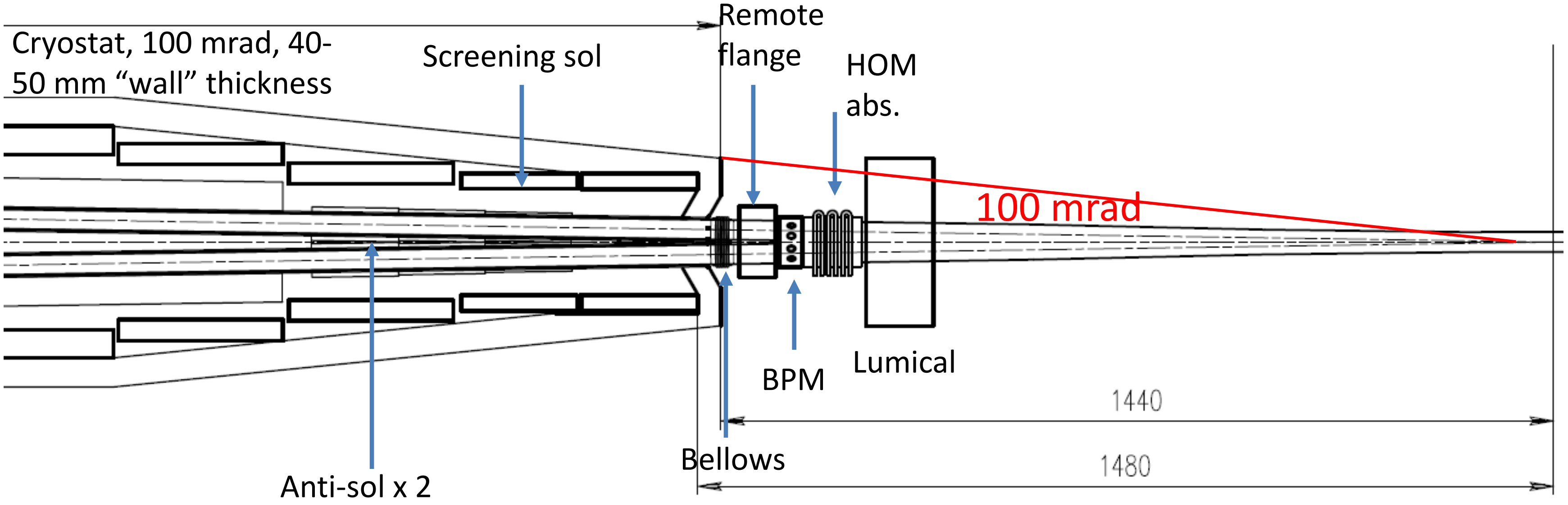



Qs: 100 mrad acceptance? Thin wall cryostat, heat inflow? How to transmit mechanical force to the RVC? Where is the NEG pump?

# New design of the cryostat tip

We have tried to imagine how to meet all above severe requirements on the basis of…

… Individual anti-solenoid for each beam covered by common screen-solenoid ( –2 T) shifted closer to QC1.



# Compact single beam solenoid

Design of the individual anti-solenoids for each beam covered by common screen-solenoid ( –2 T) is a critical issue. Pro and contra:

Pros:

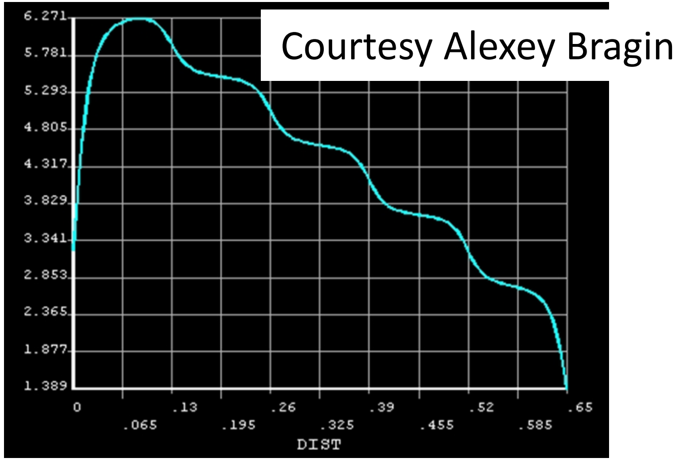
- 100 mrad cone is satisfied with cryostat.
- Individual field tuning for e+ and e-.
- Small aperture, easier to reach the field amplitude.
- Small aperture, short area of stray field, the solenoids could be placed closer to QC1 (space saving).
- Common screen solenoid subtracts 2 T from anti-solenoid.
- Vertical emittance and coupling tuning by correction coils.

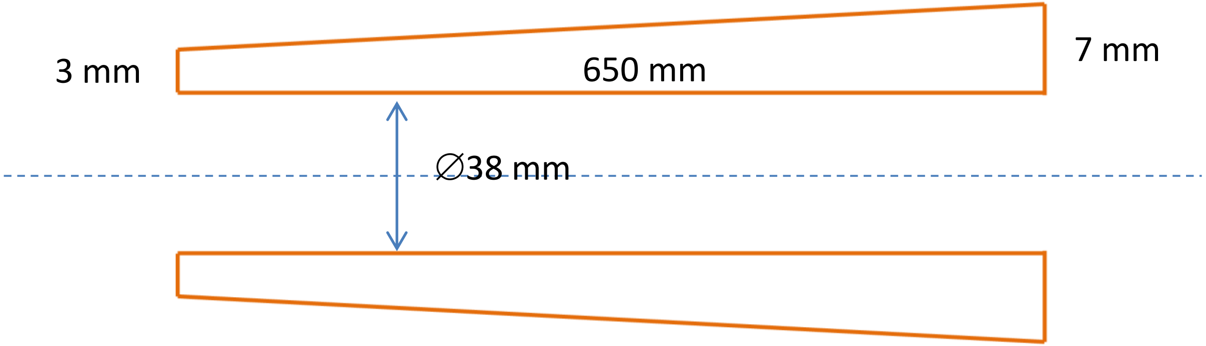
Cons:

- Very narrow gap between vacuum tubes to place the solenoids.
- There is a field cross-talk between solenoids in the fringe field area (off-axis orbit reduces the effect), so correction coils are needed here for compensation. (However, if we shall manage to introduce the coils, we can use them to stir the beams at the IP.)

# First attempt

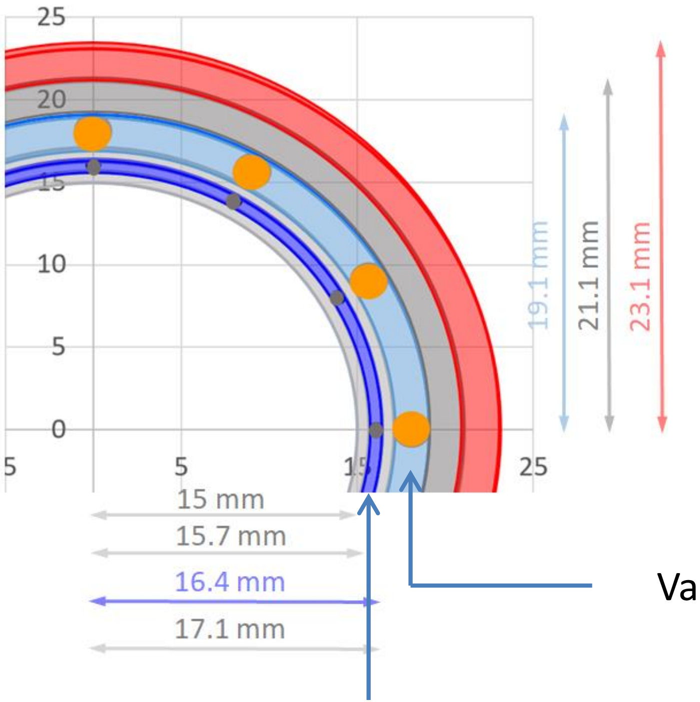
| | |
|---|---|
| Solenoid length, m | 0.65 |
| Layers number, (3+1+1+1+1) | 7 |
| Inner radius, mm | 19 |
| Current, A | 660 |
| Max. field at the coil, T | 6.3 |
| Max. field at the axis, T | 6.27 |
| Field integral, Tм | 2.9 |
| Wire diam (NbTi), mm | 0,9 |
| Critical current at 7 T, A | 650 |
| Stored energy, kJ | 7.8 |




With $Nb_3Sn$ wire the field can be increased by factor ~1.3-1.5.

# IP vacuum chamber design (A.Krasnov)

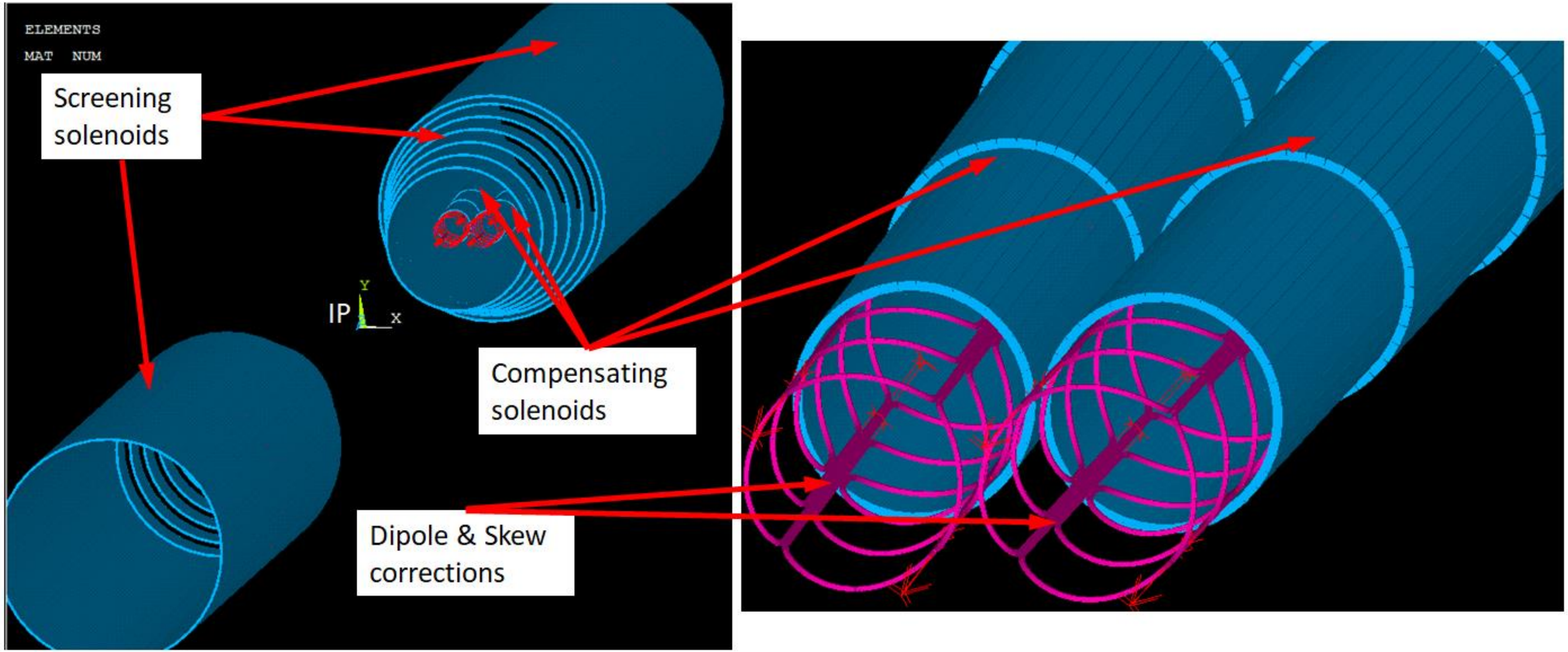



1 – Coil of solenoid
2 – Chamber (2 mm, )
3 – Vacuum space (2mm, 1mm?)
4 – Nylon (2 mm, 1mm?)
5 - Chamber (0.7 mm)
6 – Water (0.7 mm)
7 – Stainless wireless (0.7 mm)
8 – Chamber (0.7 mm)

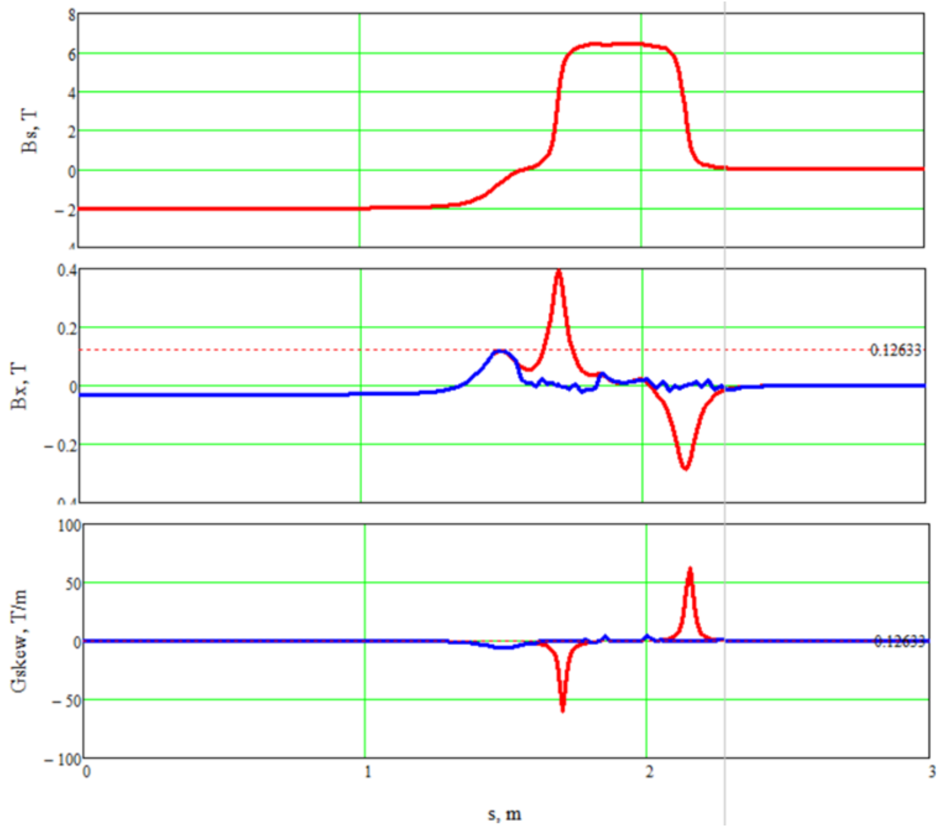
Vacuum insulation with nylon wire.

Two layers (0.7 mm each) of SS vacuum chamber with the SS spiral wire providing mechanical stability and turbulent flow of cooling water.

# Solenoids with correctors (S.Syniatkin)



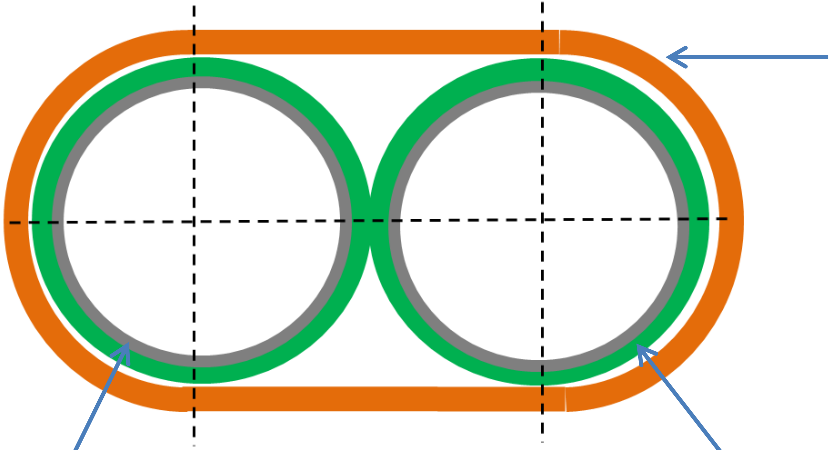
# Solenoids with correctors - results (S.Syniatkin)




Fringe field of two adjacent solenoids produce horizontal and skew components. But four (at each end of solenoid) weak correction coils compensate the components and reduce the vertical emittance contribution down to 0.023 pm (conventional result is ~0.3 pm)

Red/blue – without/with correction correspondingly

# Further possible development



Elliptical/oval compensating solenoid.

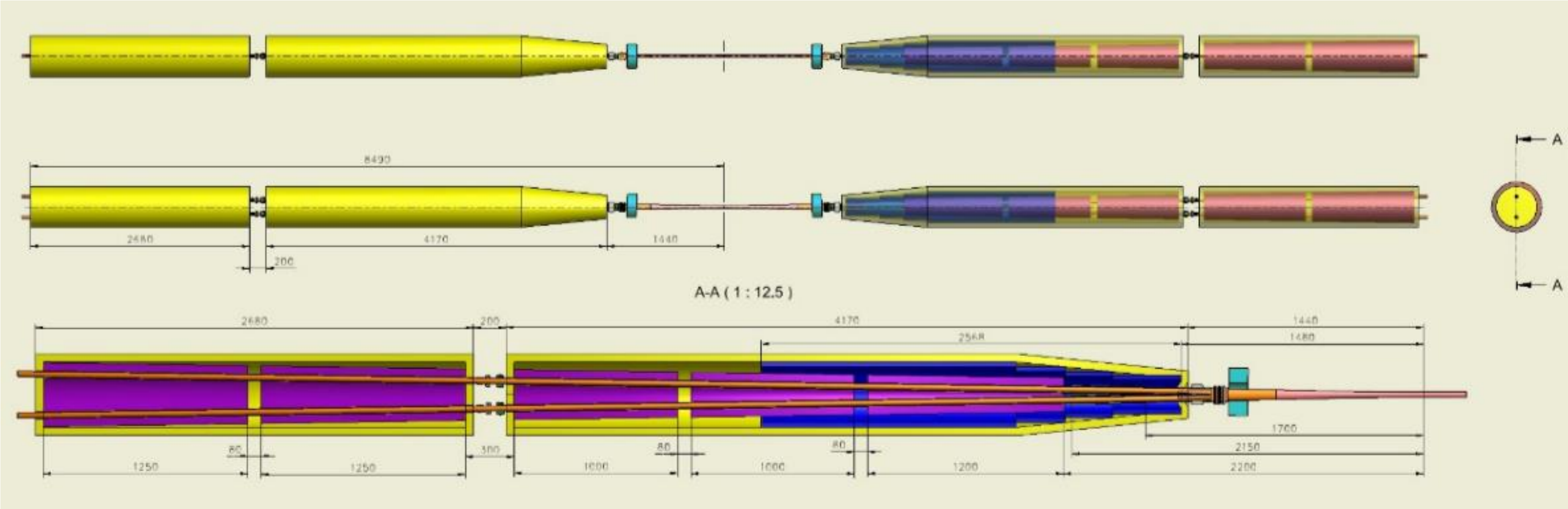
Pro – low vertical gap, the solenoid can be placed close to QC1.
Con – it produces horizontal and skew components at the beams axis

Vacuum chamber

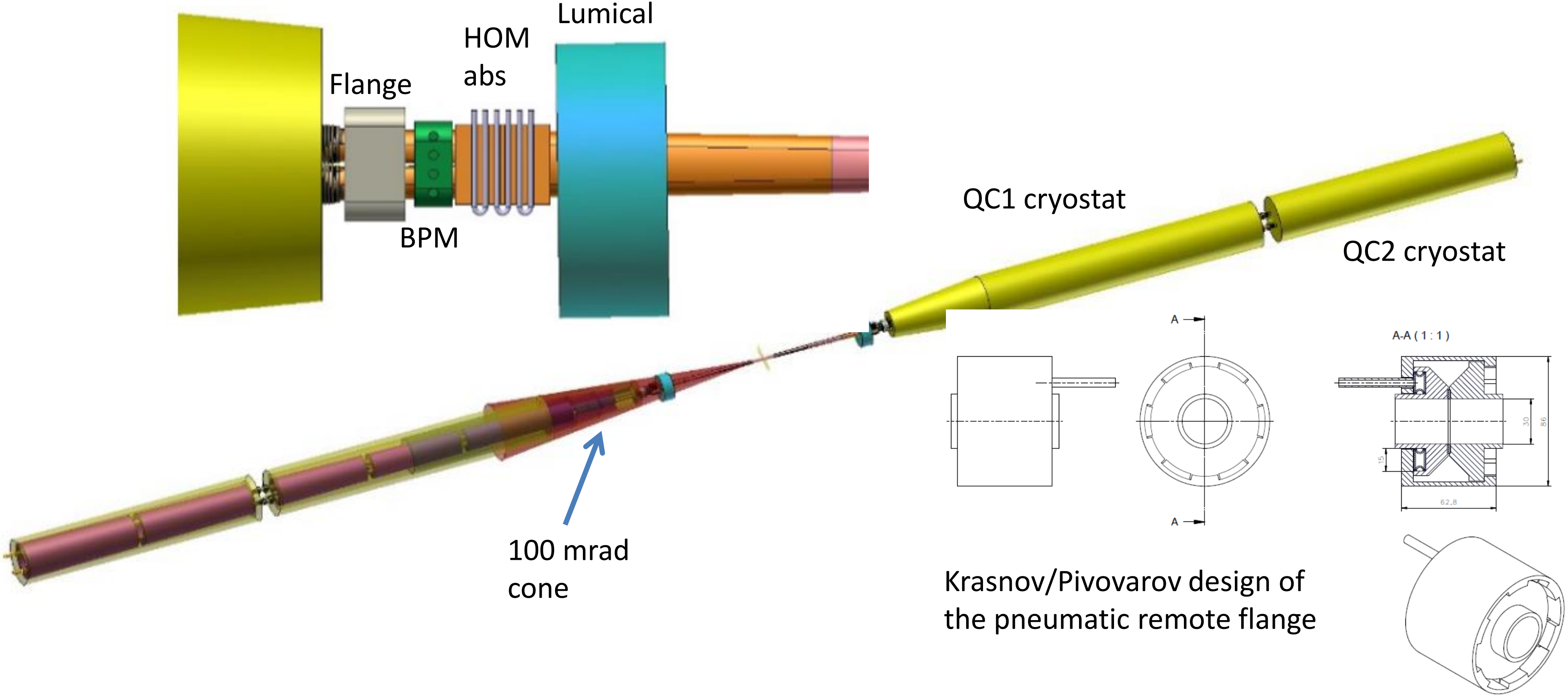
Individual weak (hor/ver/skew) correctors (1) to correct unwanted field components and (2) to control individual beam parameters (coupling, COD at the IP) in general.

No severe space limitation for the compensating solenoid compare to the previous slides.

# Overall size

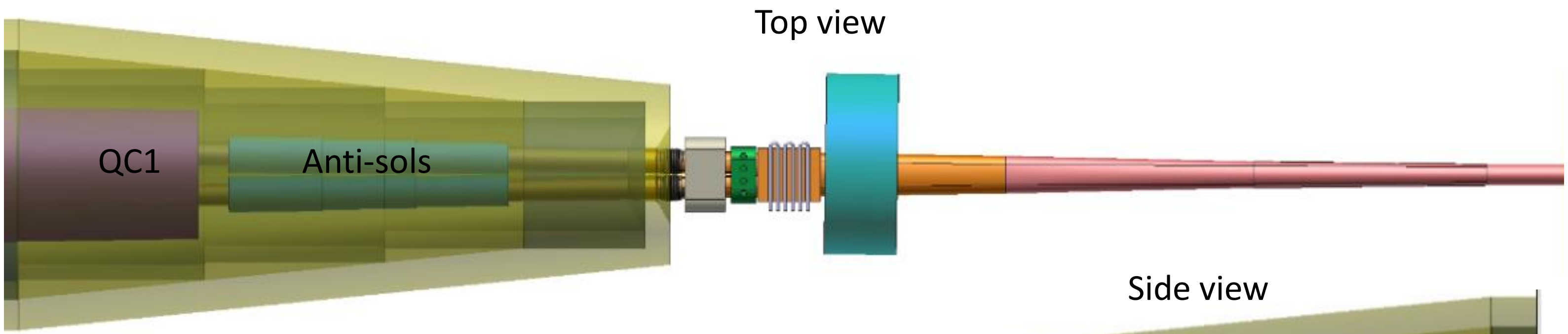


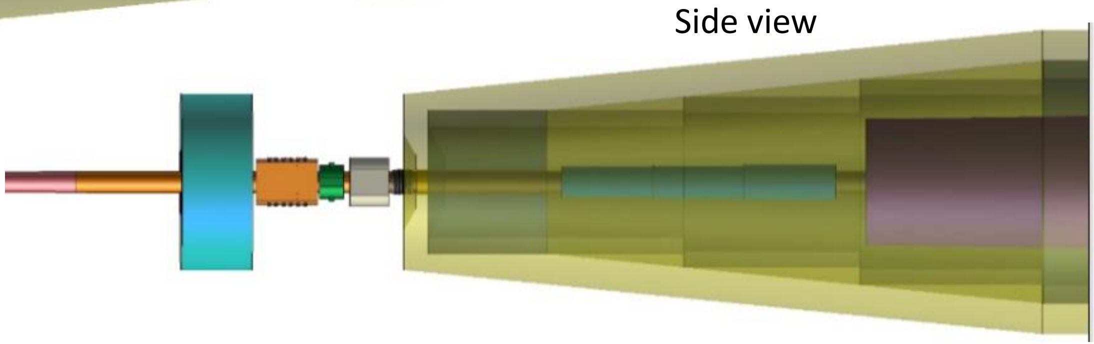
# 3D views I

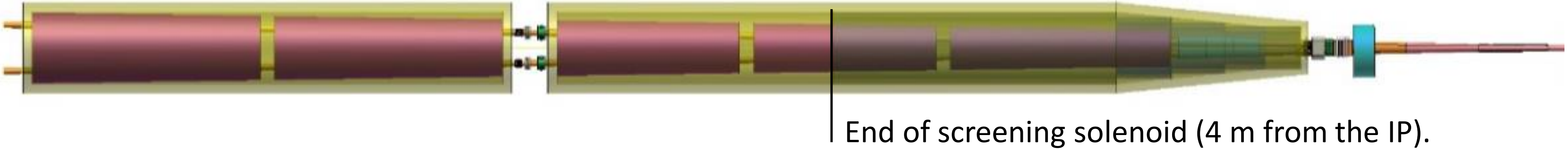



Krasnov/Pivovarov design of
the pneumatic remote flange

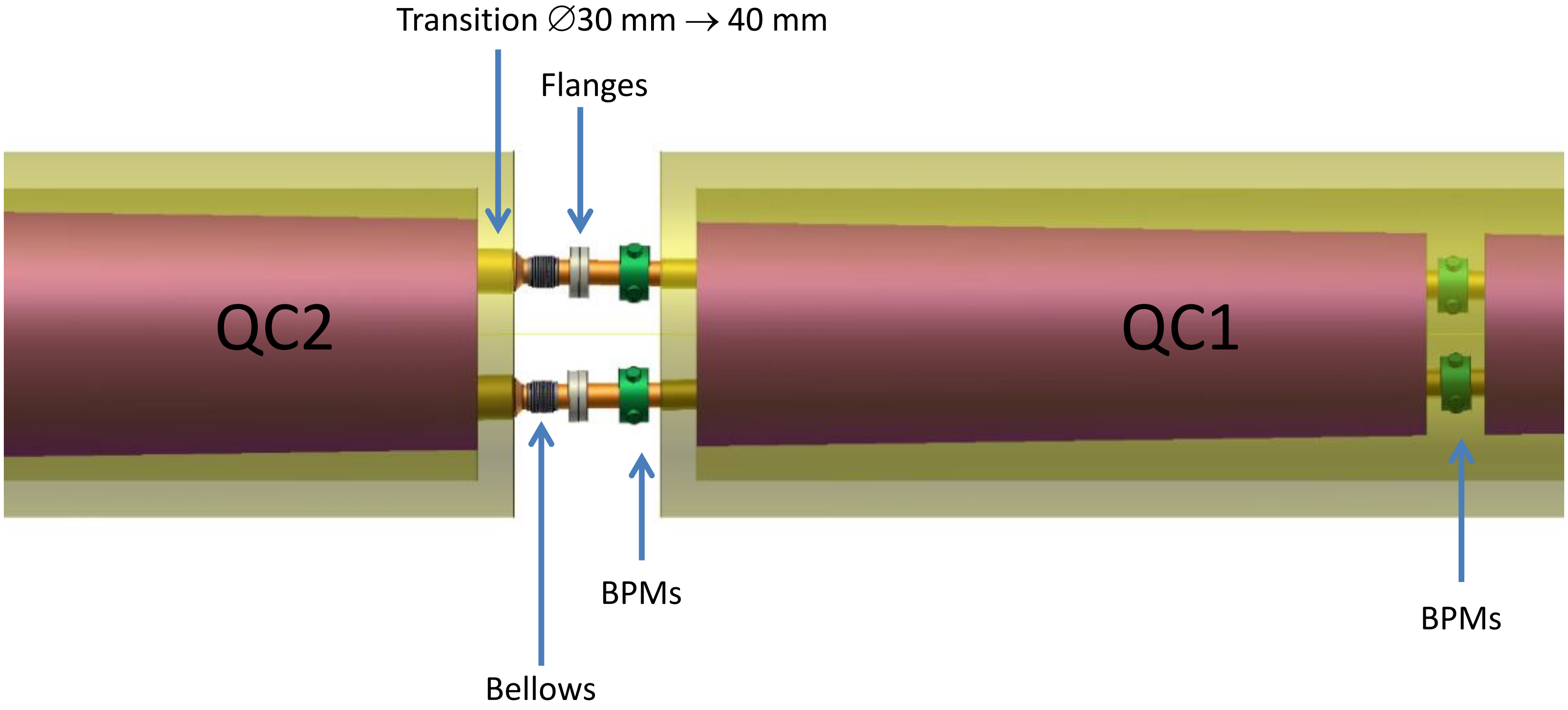
# 3D views II


Top view
QC1
Anti-sols

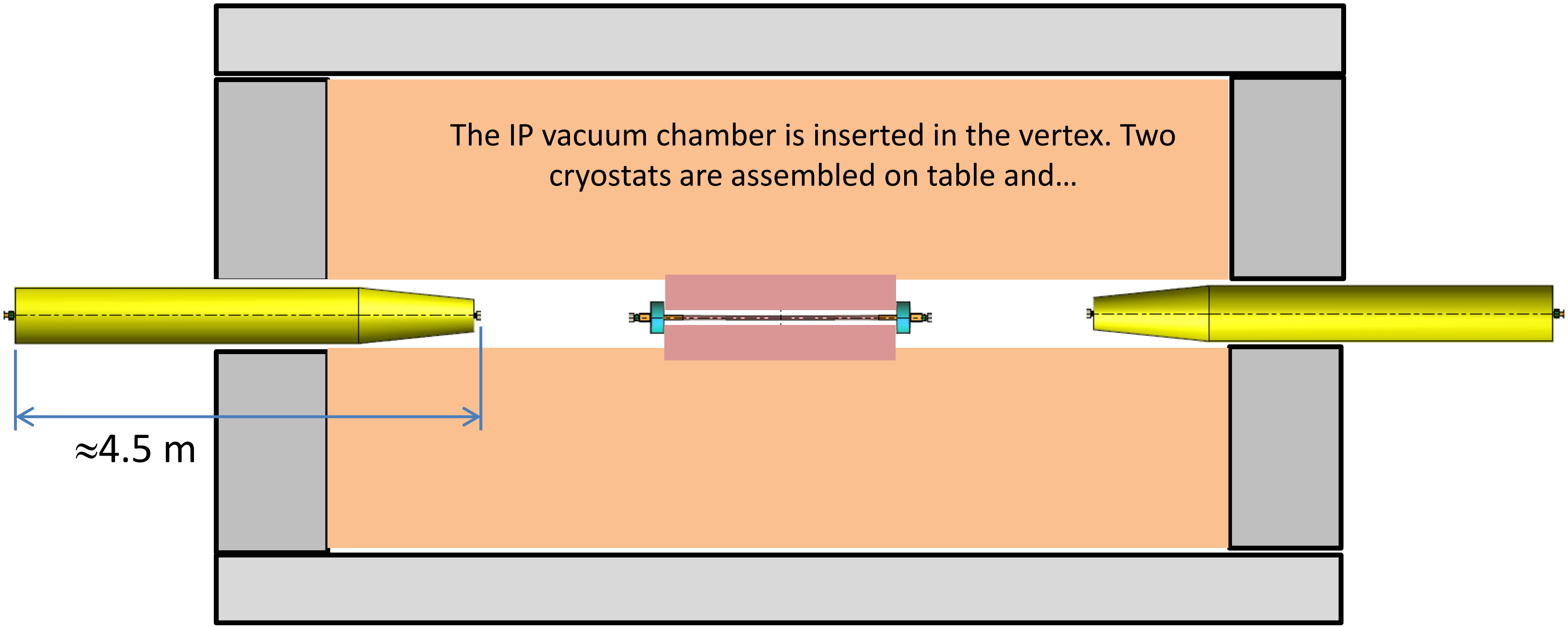

Side view


End of screening solenoid (4 m from the IP).

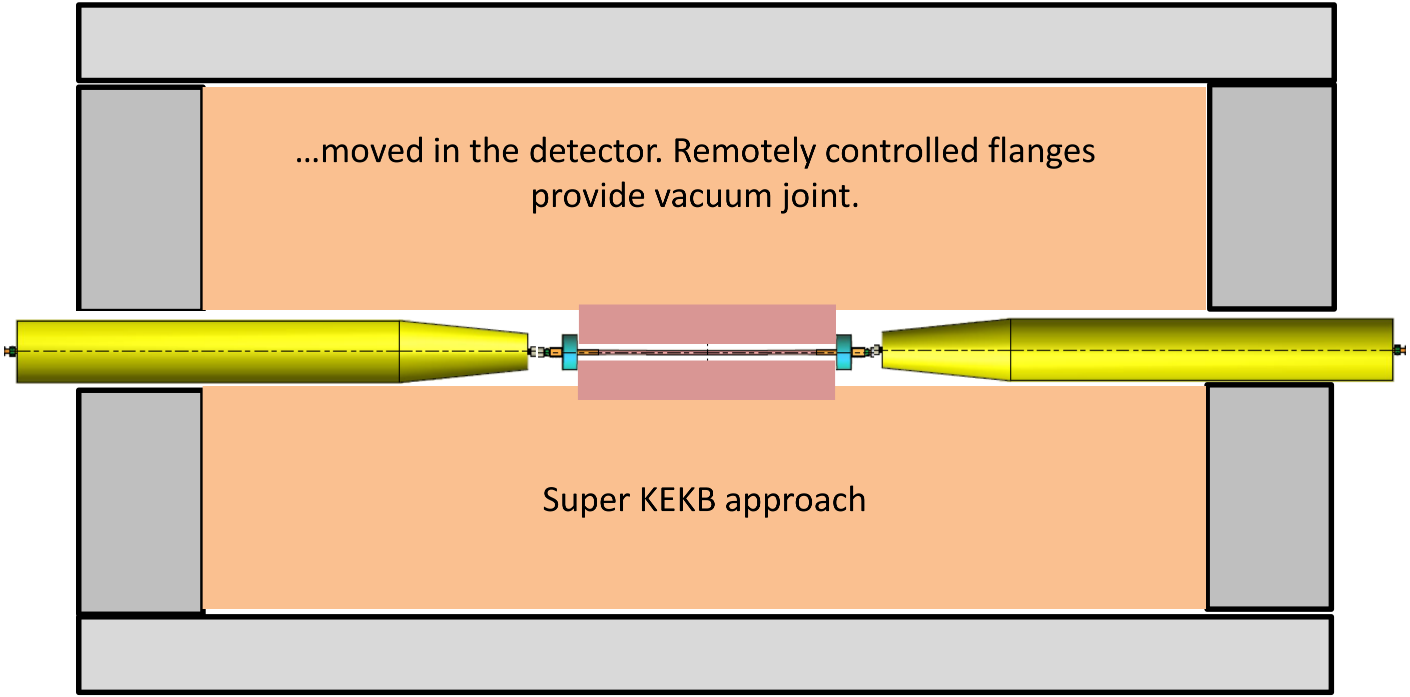
# 3D views III



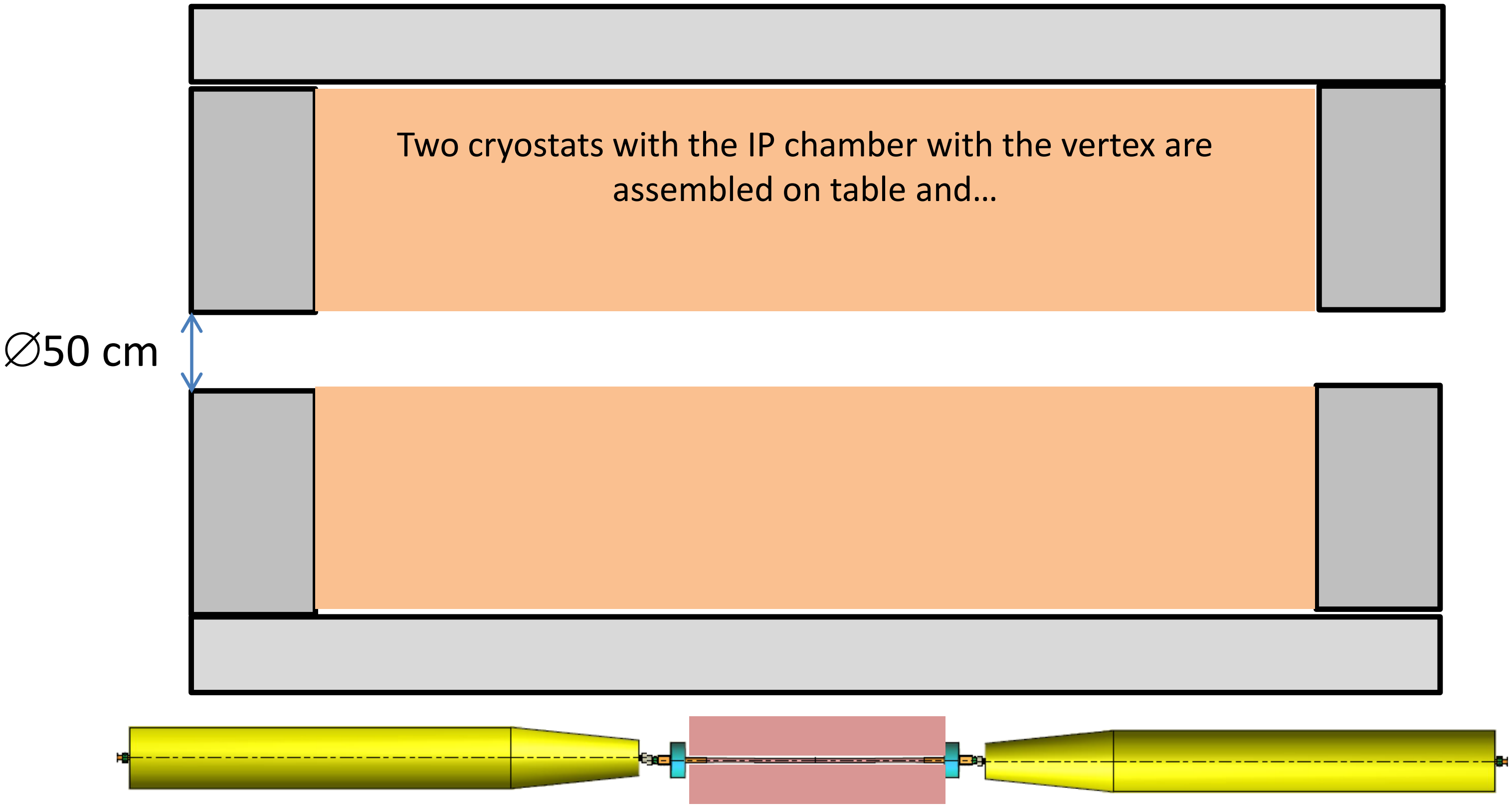
# Assembling with remote control flanges I



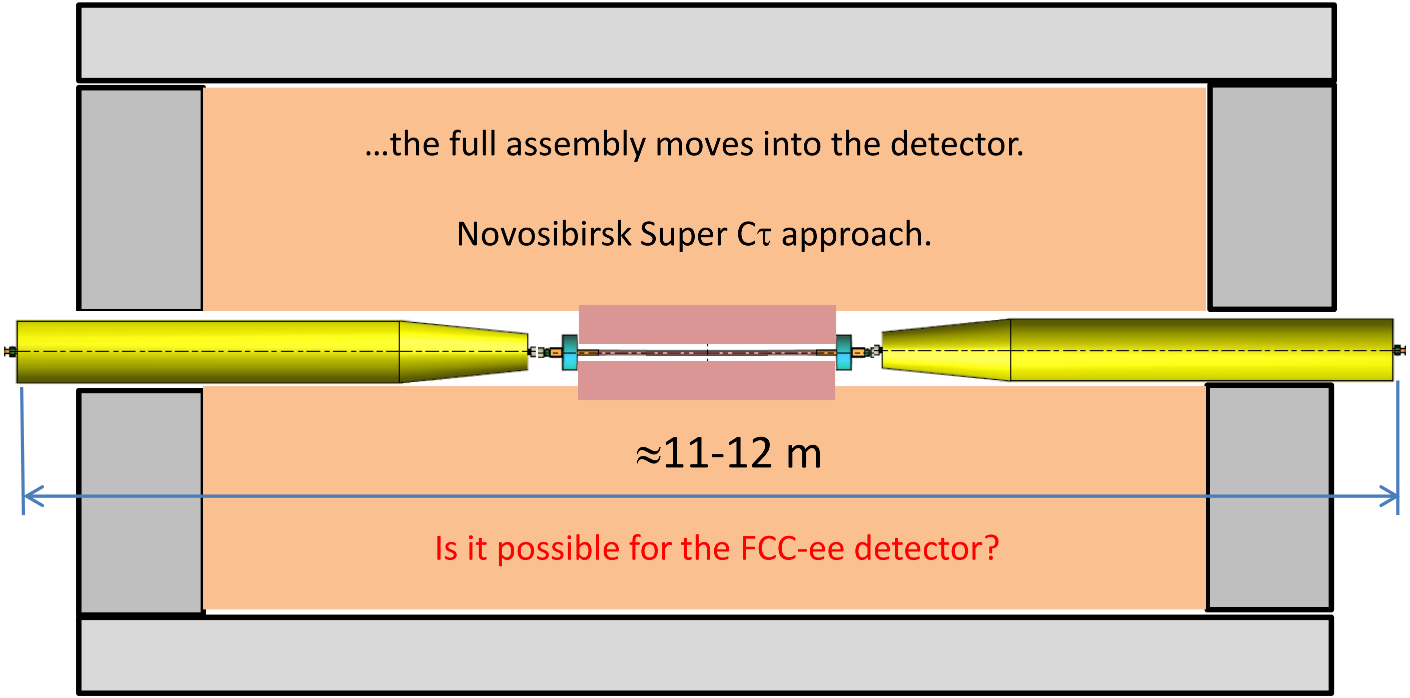
# Assembling with remote control flanges II



# Assembling “on a table” I

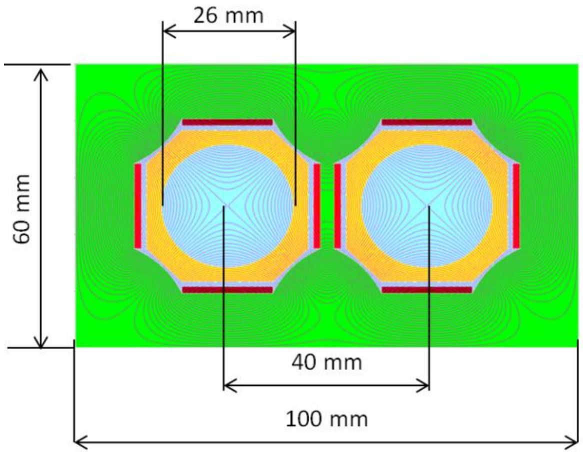


# Assembling “on a table” II

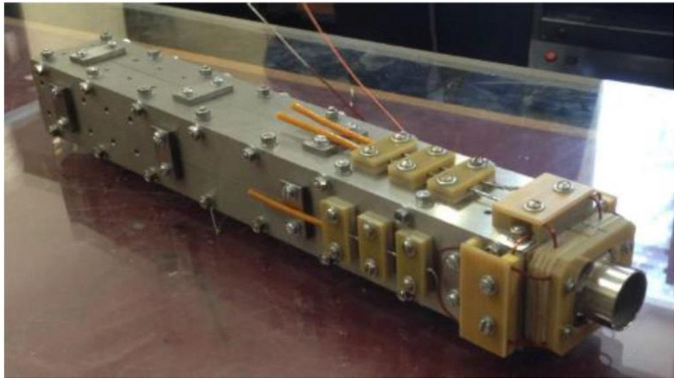


# First SC quadrupole (BINP)

Not much progress since the last FCC Week.




Main parameters:
Max.gradient 100 T/m
Max.current 1100 A
Length 40 cm
Aperture 2 cm
NbTi 1.8 x 1.4 $mm^2$
Saddle-type coils



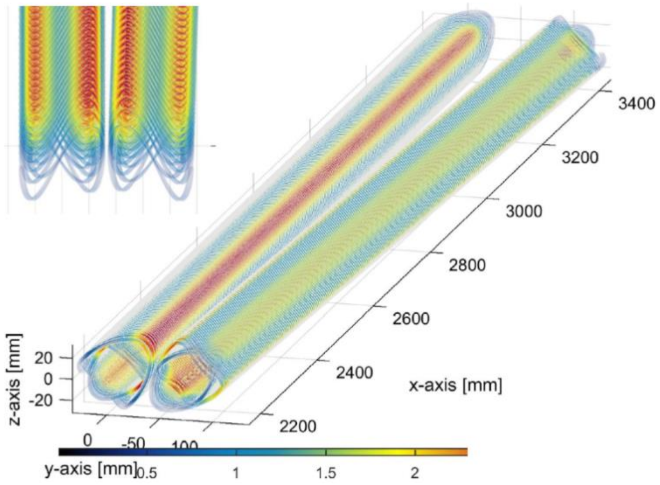
During the first cryo-test (01.02.16) the current of 1060 A was achieved after 3 quenches.

Pros
Conventional well-known design
No cross-talk between two apertures
The prototype was developed

Cons
Correctors inside are difficult

# First CCT SC quadrupole

Proposed by Eugenio Paoloni for Italian Super B project, promoted by Mike Koratzinos for FCC-ee.



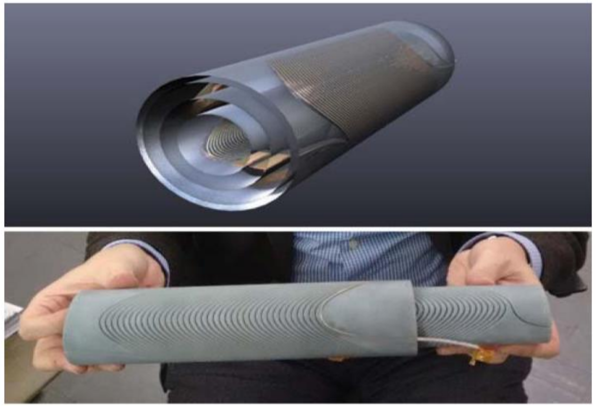



Figure 3: Prototype CCT final focus quadrupole. CAD drawing (top) and 3D printed item (bot).

Mike Koratzinos shows 3D printed tubes for the CCT quad coils

Pros

Easy to incorporate correctors by introducing of additional coil layers

Cons

There is no example, real technological difficulties are unclear

# Concerns

- **Assembly**
  - Remote vacuum connection (ala Belle II)?
  - Bellows between Central chamber and cryostat chambers (at least 1-2 convolutions)
  - Central chamber support
  - Cable and cooling pipe space for central detectors
- **Vibration control**
- **Cryostat support**
- **Magnetic forces**
  - Anti-solenoids have strong expulsion forces?
  - Compensating solenoids have strong expulsion force near detector field edge
- **Overlapping Z space**
  - LumiCal
  - Cryostat
  - Remote vacuum assembly
  - NEG pump
  - HOM absorbers
  - Shielding

M. Boscolo,
February MDI meeting, CERN

# Summary

- The IR design based on the individual compensating solenoids around each beam pipe is proposed. It allows to place the cryostat into the 100 mrad cone and have a space for RVC, bellows, BPMs, etc.
- The individual correctors allow to control the vertical emittance blow up ~10 time less than the previous solution.
- First estimation shows that the solenoid can be developed with required parameters. However further development is necessary.
- For the first and most critical section of the QC1 quadrupole there are still two options (CCT and modified Panofsky).
- Other FF quadrupoles can be either CCT or regular cosine-theta magnets with iron shielding. No difficulties are expected with them.
- Prototype of the vacuum chamber and first magnets in cryostat is highly desirable. (Too many uncertainties with this complex and rather critical section.)