FCC-EE MDI ALIGNMENT AND MONITORING STRATEGY

Design and simulation stage

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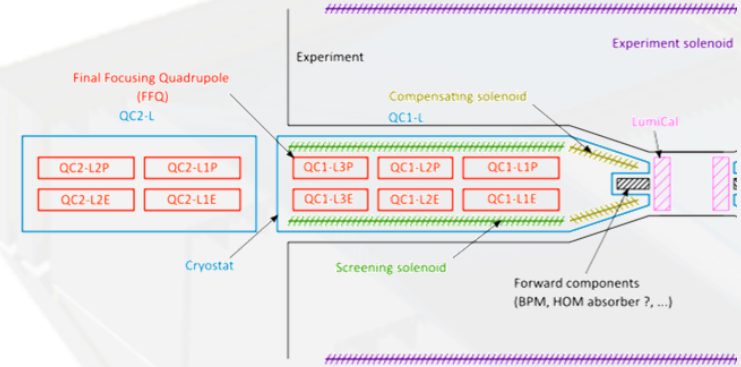
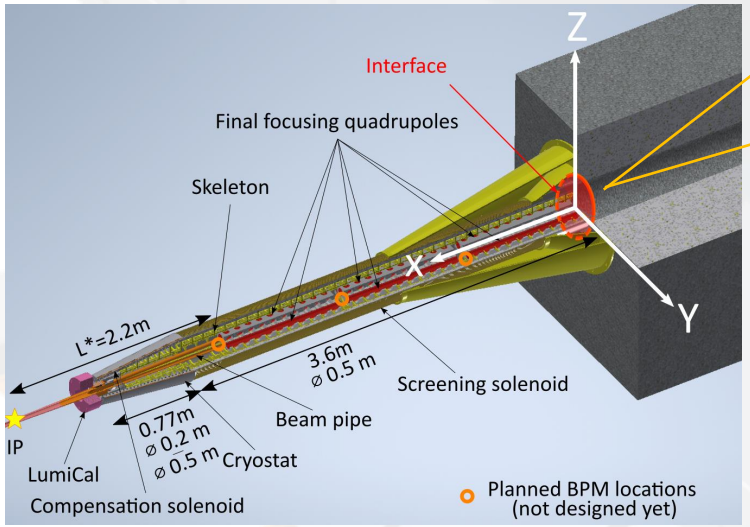
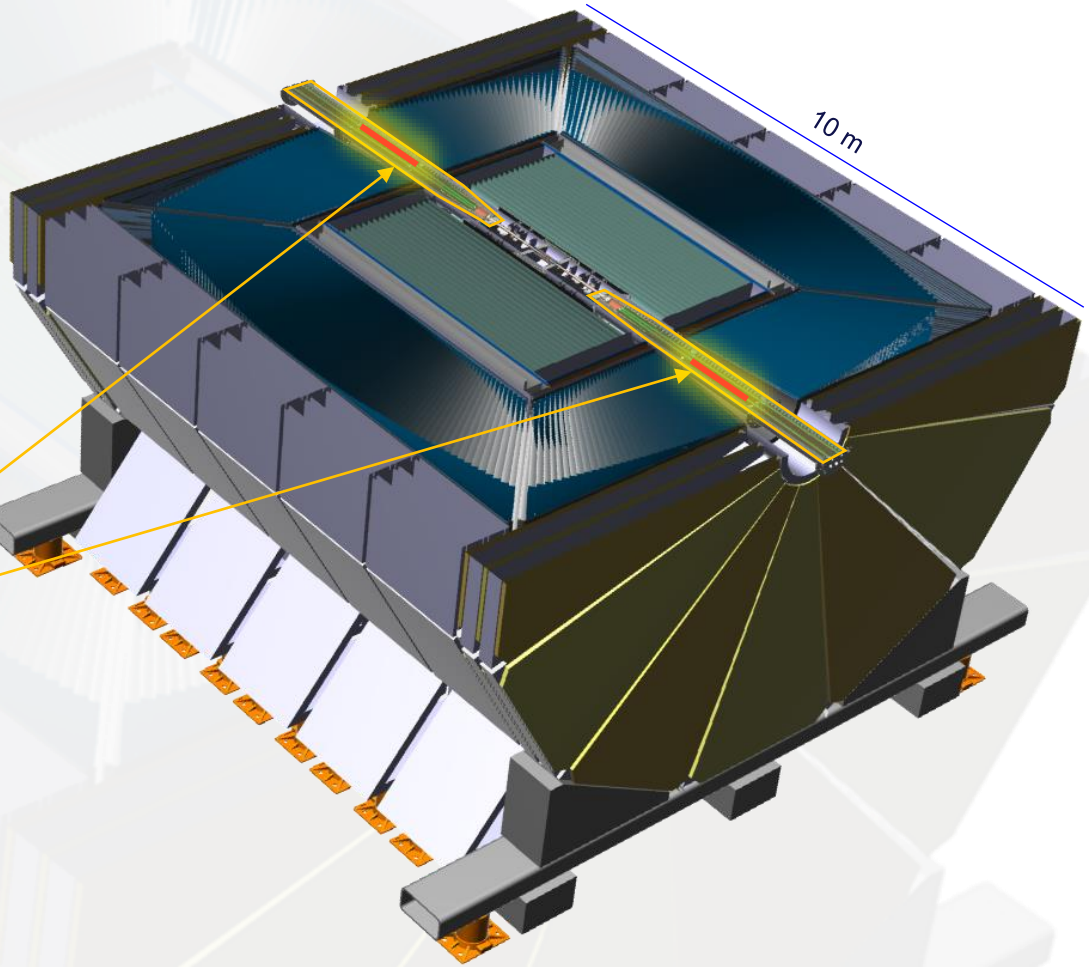
Summary of the FCC-ee MDI design







Focus on the monitoring

Initial alignment can be performed during the assembly, very close to the description by Haijing Wang in yesterday presentation.

Multiple technologies could be used (laser tracker, CMM, photogrammetry …)

CEPC mechanics system

Haijing Wang

中国科学院高能物理研究所 Institute of High Energy Physics Chinese Academy of Sciences

23-27. October, 2023, Nanjing, The 2023 International Workshop on the High Energy Circular Electron Positron Collider

MDI Layouts

- Assuming the detectors are assembled, and the IP chamber is installed and aligned, the assembly sequence for the accelerator devices in the MDI region proceeds as follows:
  - Secure the SC magnets with the supports inside the helium vessel.
  - Assemble the helium vessel to the vacuum vessel of the cryostat and perform pre-alignment in the lab.
  - Assemble the vacuum chambers inside the cryostat and align them with the cryostat in the lab.
  - Assemble the Lumical crystal, Y chamber with IP BPM, and perform alignment in the lab.
  - Assemble the cryostat to the cryostat support system on-site, adjusting the cryostat using the adjusting mechanism with alignment, and then attach the RVC.
  - Move the cryostat into the detector using the moving mechanism of the cryostat support system to its designated location, connecting the Y chamber with the IP chamber using the RVC.
  - Perform the final alignment.

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Challenge : definition of the requirements

Conceptual design report citation

> 5.9.6 Interaction regions and collimator areas
>
> The alignment accuracy for the interaction regions is assumed to be the same as for the LHC, i.e. 0.1 mm for the triplets located on the same side of the IP, 0.2 mm from left side of the IP to the right side and 0.5–1.2 mm from the triplets to the detector (all values given at 1σ) [418].

Citation from various presentations

- "**Alignment accuracy of SC magnets = 100µm**"
  M. Boscolo, CEPC workshop MDI design highlight (24th MDI meeting)
- "For a 1mrad tilt of the detector solenoid (wrt the rest of the system – beam, screening and compensation solenoid) the corresponding uncorrected distortion is unacceptably large."
  Mike Koratzinos
- "**IR quadrupoles and sextupoles (75µm in radial and longitudinal, 100µrad roll**), BPM (40µm in radial and 100µrad for the roll relative to quadrupole placement)."
  Summary of emittance tuning results, Tessa Charles, 20/10/2020
- " **The distance between the two calorimeters has to be measured to 110 µm**",
  M. Boscolo, "Summary of the 2nd FCC-ee MDI workshop", Workshop on the mechanical optimization of the FCC-ee MDI, january 30 to february 9 2018, CERN
- "**Internal misalignment should be better than 30µm**",
  M. Koratzinos, "CCTFF quad design status", MDI workshop, 30/01/2018
- "Final Focusing quads misalignment (QC1_1-QC1_3 and QC2_1-QC2_2) (if not respected, beams do not collide):
  - Geodesy : **transverse shift of FF quads with sigma xy= 25µm**
  - vibrations : transverse shift of FF quads with sigma xy= 0.1µm

  IR BPM misalignment (if not respected, beams do not collide) :
  - geodesy : **transverse shift of BPM with sigma xy= 25µm**
  - vibrations : errors of BPM reading with sigma xy= 0.1µm

  The beam parameters are destroyed after correction of 25 µm IR BPM misalignments
  S.Sinyatkin, "Orbit errors at the FCC-ee due to the FF quadrupoles displacements"
- "**Measurement of the component's position inside the detector is needed**",
  A. Bogomyagkov, A. Krasnov , E. Levichev , S. Pivovarov , S. Sinyatkin, BINP, "Summary and comments on Machine Detector Interface", MDI workshop 09-20 september 2019
- "Internal to LumiCal : assembly and metrology/ alignment of Si readout pads to ~1.5µm radial precision External to LumiCal : need very high precision : **distance LumiCal/ nominal IP to be controlled/ measured to ~50µm level**",
  M. Boscolo, "FCC-ee MDI design as outcome of the first week of MDI workshop and goal of this week workshop", Workshop on the mechanical optimization of the FCC-ee MDI, January 30 - February 9 2018, CERN quoting Mogens Dam/ NBI Copenhagen

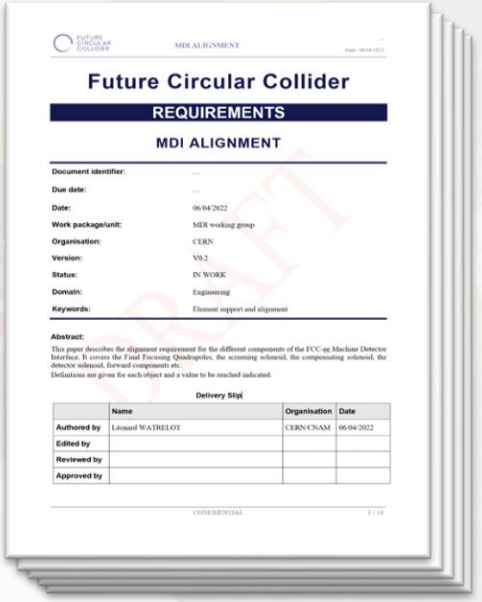
Definition not precise enough yet to be part of a report.

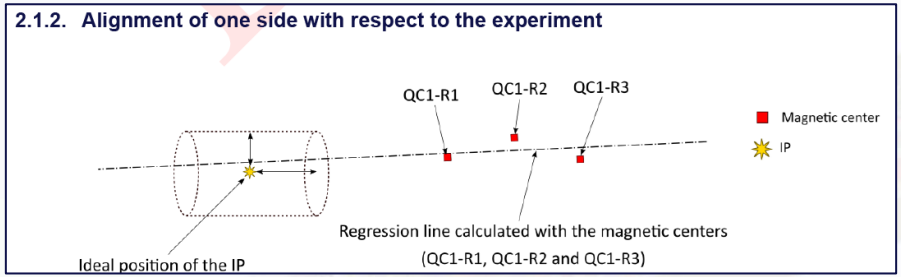
Requirements for the FCC-ee MDI alignment

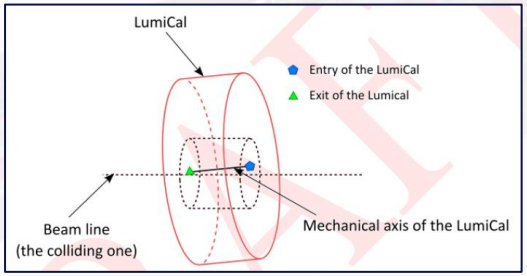
They are giving a first idea, clues and directions towards the final values for these requirements.

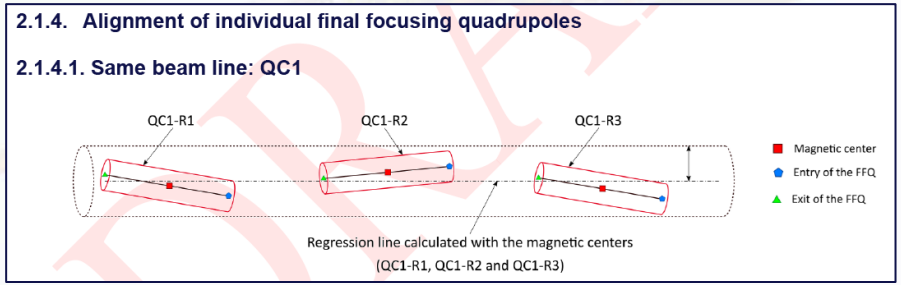
A requirement gathering document have been proposed, to help establish clearly the requirements and converge faster towards final definitions and values.

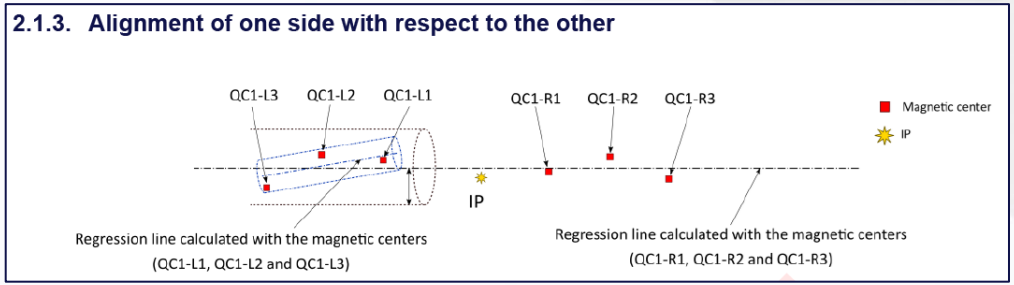
(Heavily inspired by the LHC document, as a first iteration)







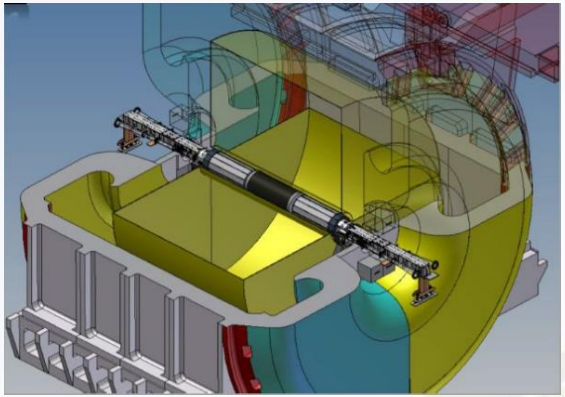




One could question the need of such monitoring, but …

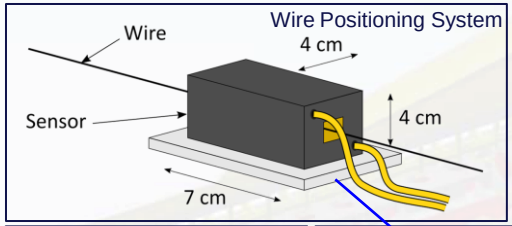
Such MDI alignment monitoring have been asked and reached or partially reached in some existing MDIs

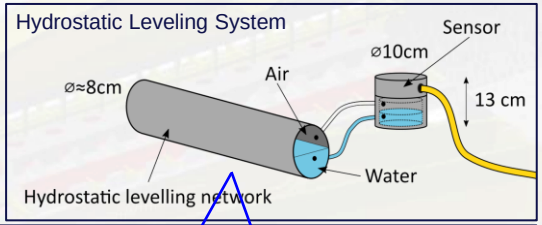
DAFNE

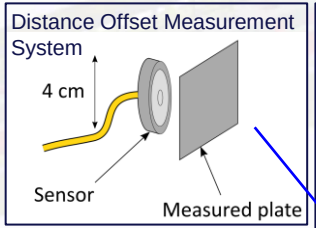


L. PELLEGRINO, MDI mechanical design, integration and assembly at DAFNE/KLOE with the crab-waist configuration, 3rd FCC-ee MDI workshop, 9-20 September 2019, CERN.

LHC







But these designs are very different from the FCC-ee MDI

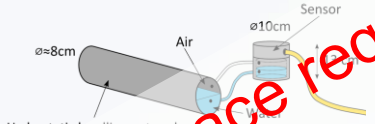
One could question the need of such monitoring, but …

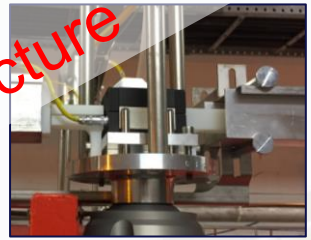
Other similar projects required such system and did important R&D on it.

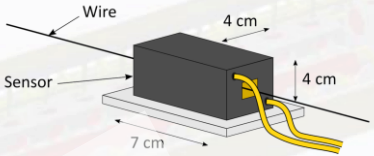
CLIC ILC

Capacitive sensors

Hydrostatic Leveling System (HLS) Wire Positioning System (WPS)





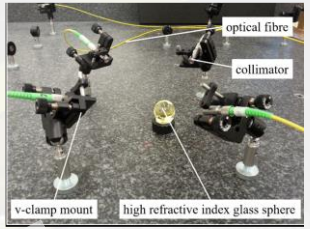


Optical sensors

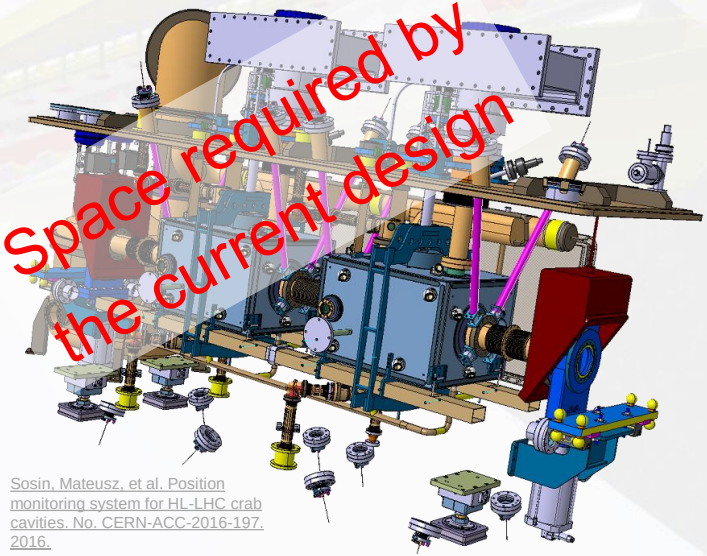
Gayde, J. C., et al. "HIE ISOLDE alignment and monitoring system: design and project status." eConf 1209102.CERN-ATS-2012-269 (2012): 2

BCAM, Open Source Instrument

Interferometric sensors



Gayde, J-Ch, and Kamugasa, S., "Evaluation of Frequency Scanning Interferometer Performances for Surveying, Alignment and Monitoring of Physics Instrumentation." (2018): WEPAF069.



Sosin, Mateusz, et al. Position monitoring system for HL-LHC crab cavities. No. CERN-ACC-2016-197. 2016.

Space required by the infrastructure

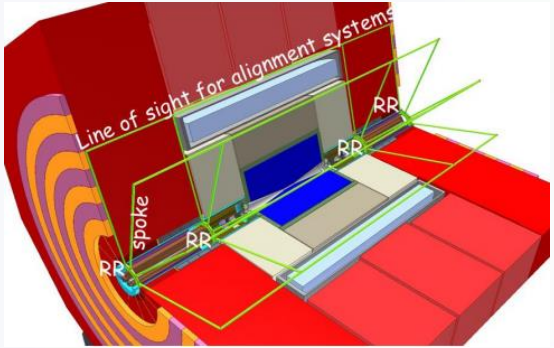
Space required by the current design

Sensitivity to radiation

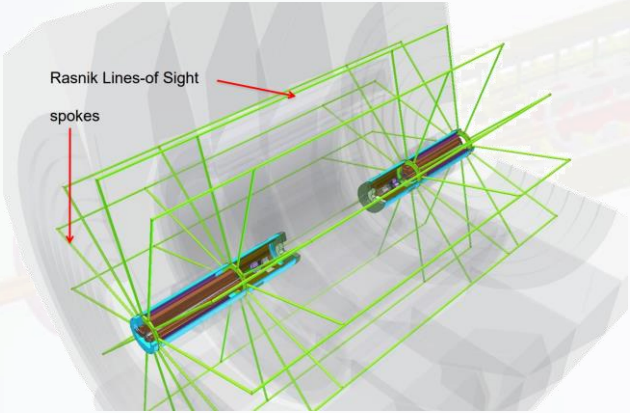
One could question the need of such monitoring, but …

Other similar projects required such system and did important R&D on it.

CLIC

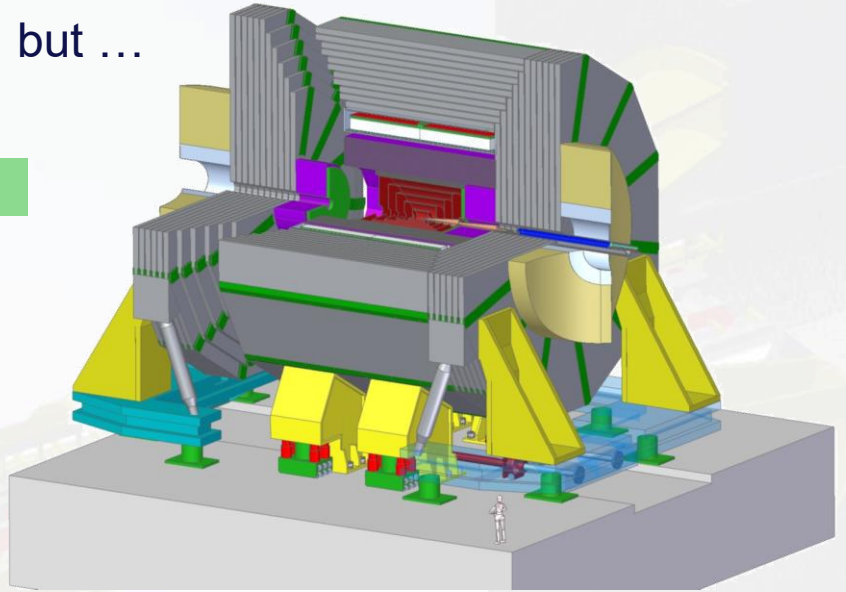


Gatignon, Lau. "Clic mdi overview." arXiv preprint arXiv:1202.6511 (2012).

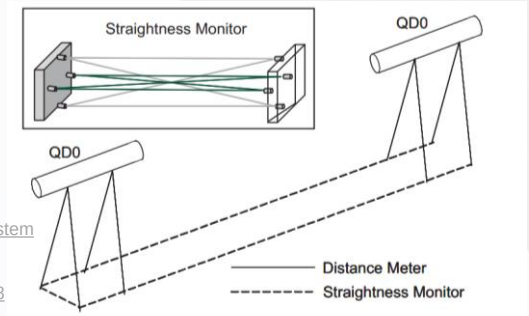


H. Van der Graaf, MDI alignment progress, IWAA 2012, sept. 13, 2012, Fermilab USA

ILC



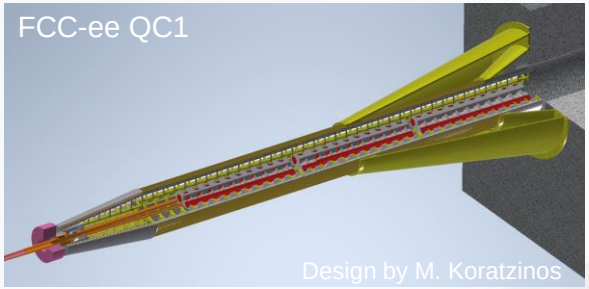
Breidenbach, M., et al. "Updating the SiD Detector concept." arXiv preprint arXiv:2110.09965 (2021).

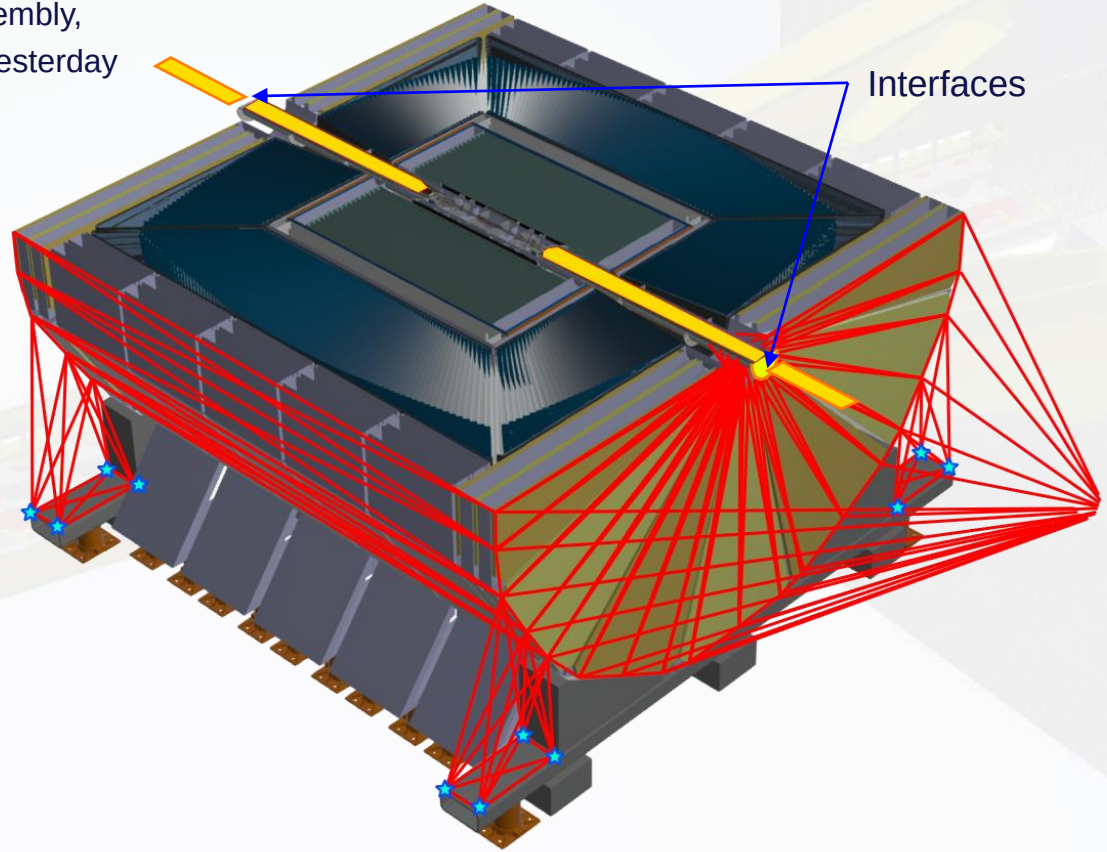


Warden, M., et al. "MONALISA: A precise system for accelerator component position monitoring." EUROTeV-Report-2008-08 (2008).

Proposition of a strategy for the alignment and monitoring of the MDI

Initial alignment can be performed during the assembly, very close to the description by Haijing Wang in yesterday presentation.





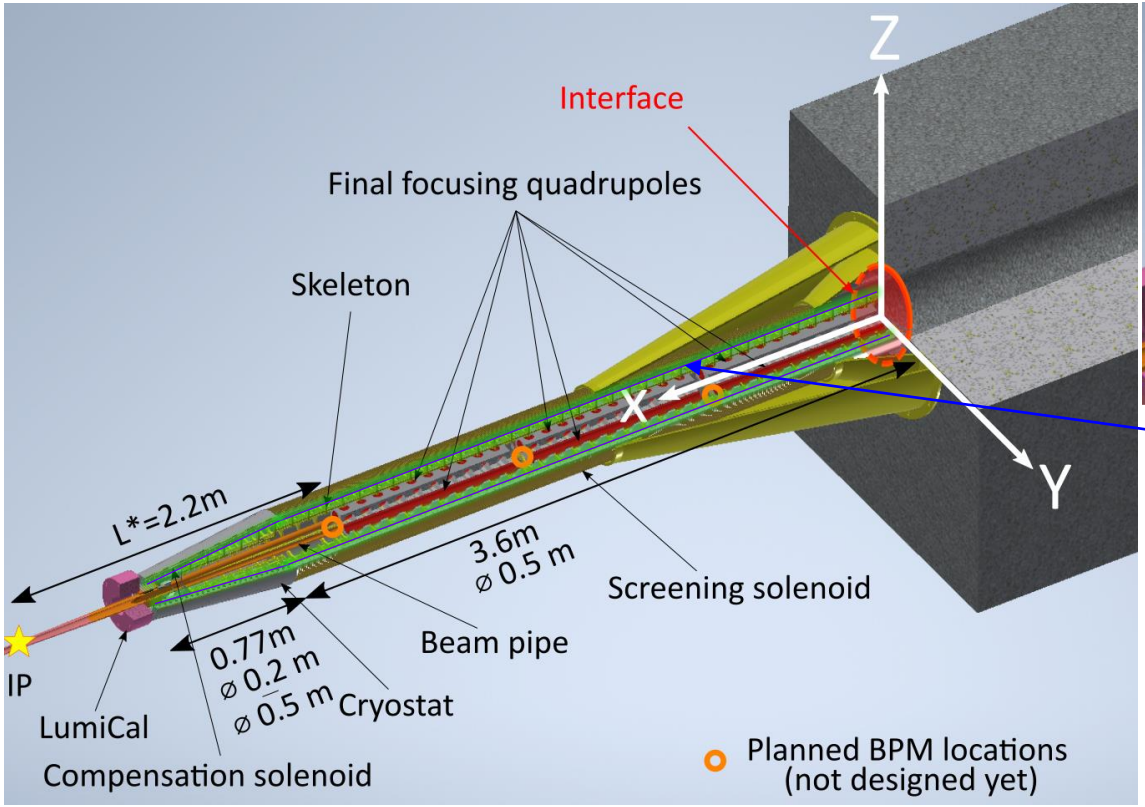
Alignment and monitoring system composed of :

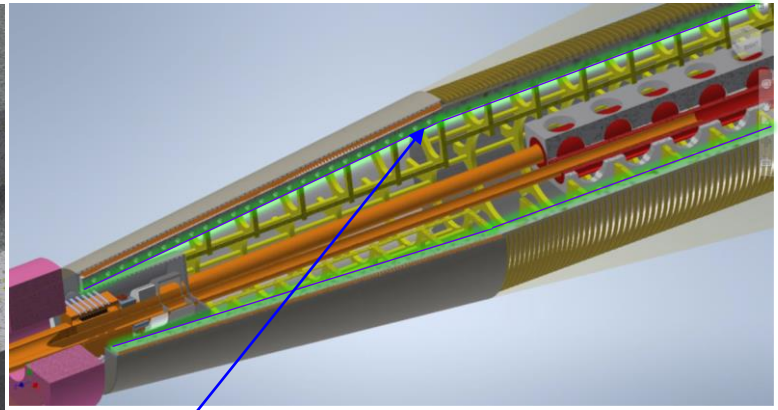
- External alignment system
- Internal alignment system

Attempt to propose a solution

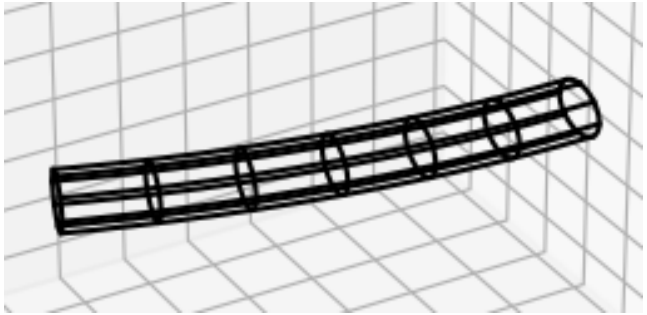
Direct measurement of the components is not possible.

Some reference is required to keep a reasonable alignment uncertainty along the entire cylinder.

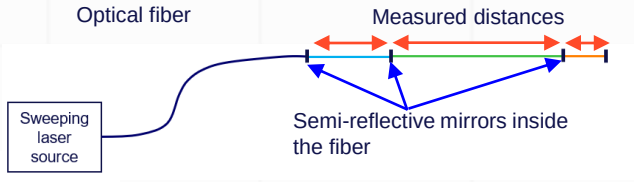


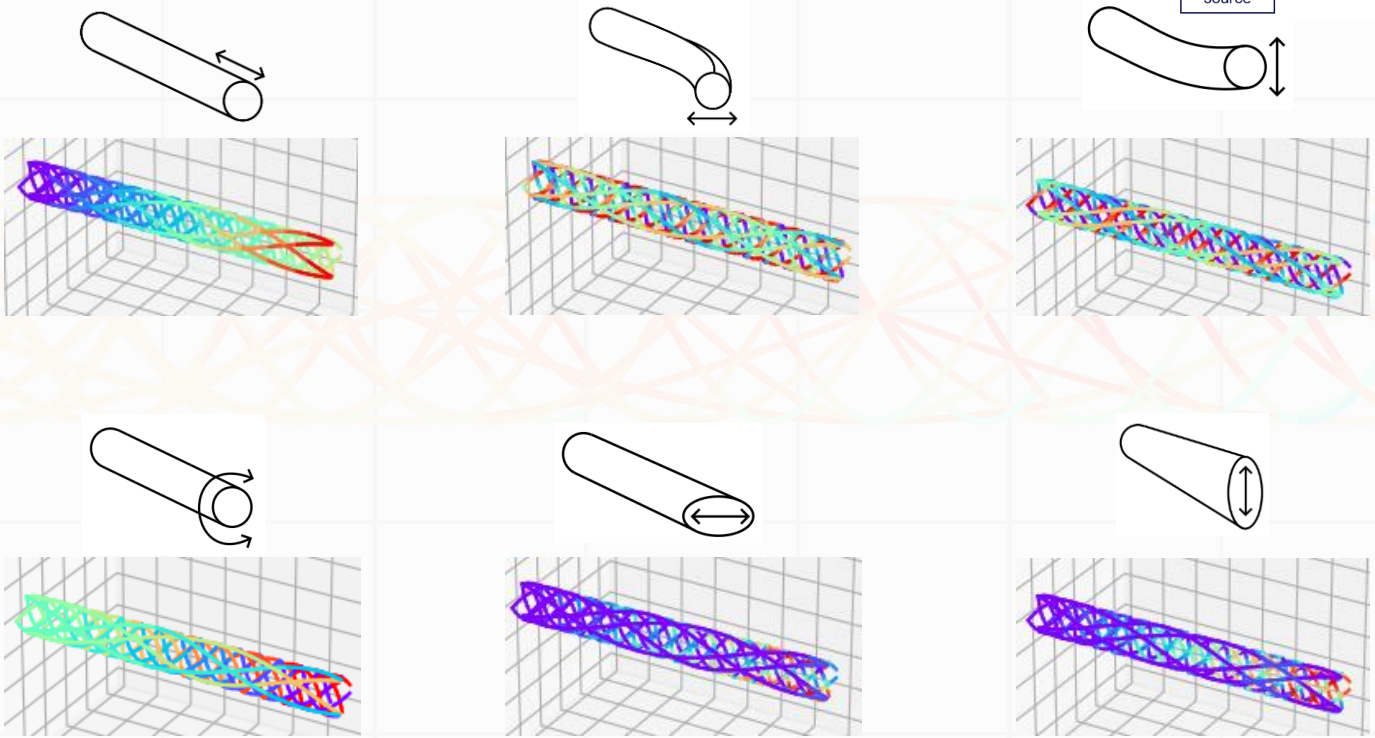


Idea : deformation monitoring



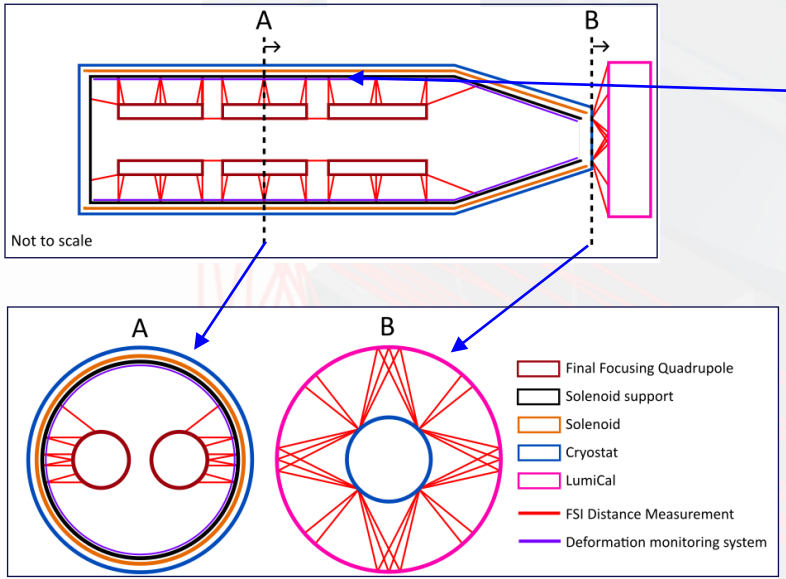
Deformation monitoring: “in-fiber” helix measurement

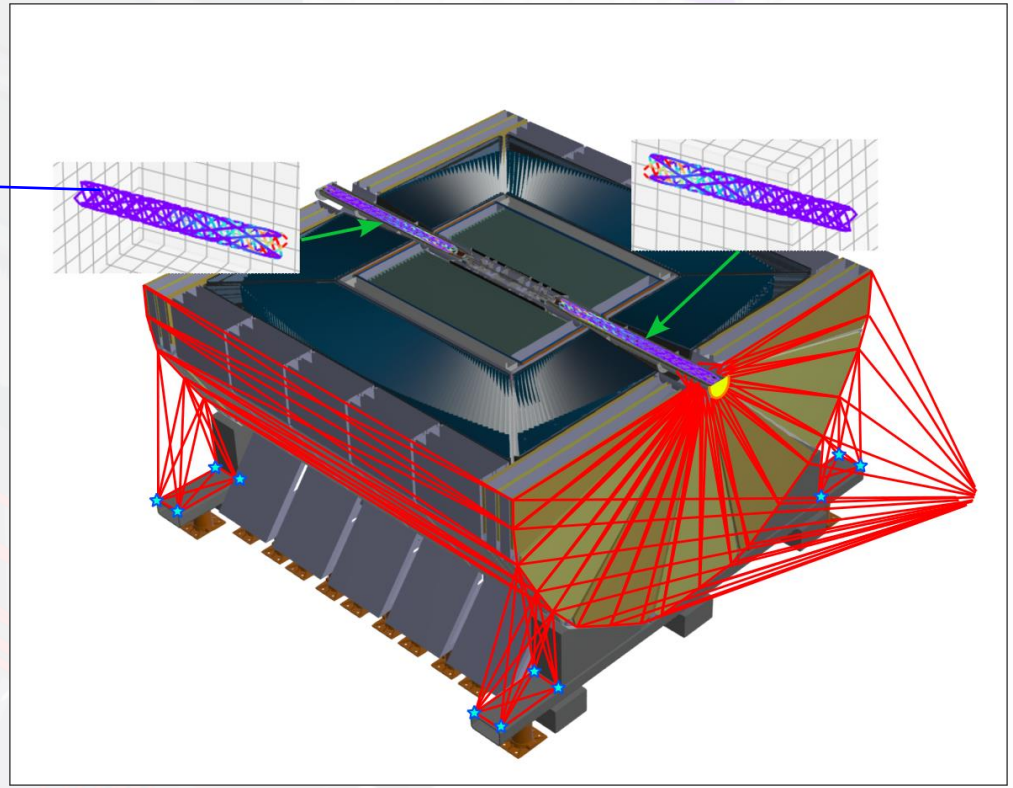




Watrelot, Léonard, Mateusz Sosin, and Stéphane Durand. "Frequency scanning interferometry based deformation monitoring system for the alignment of the FCC-ee machine detector interface." Measurement Science and Technology 34.7 (2023): 075006.

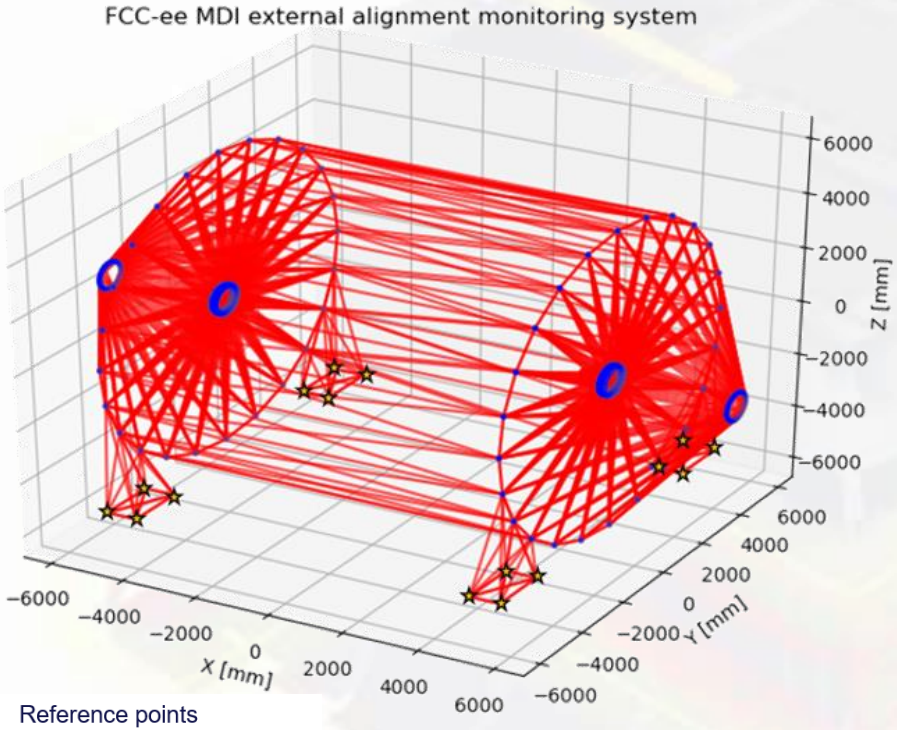
Internal alignment monitoring system



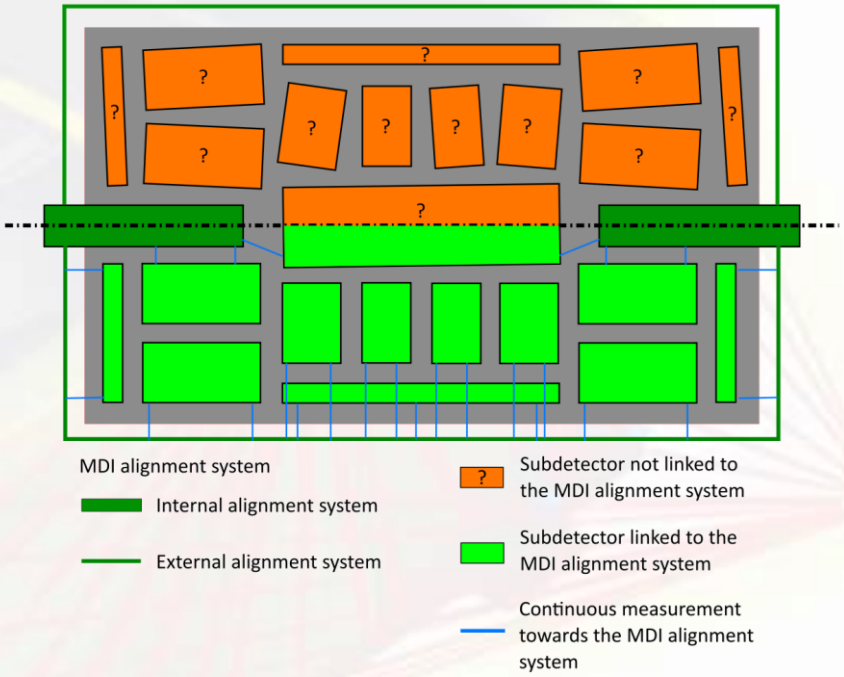


External alignment monitoring system

Computation performed by combining Python and LGC++



- Reference points
- Points part of the external monitoring system network



Optimal network : too much measurements, some (plenty) wont be possible.
Any update on the design would be much welcomed.

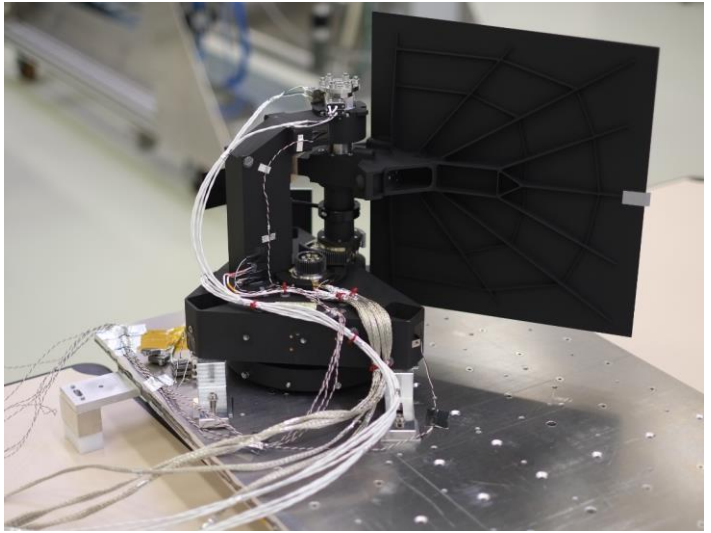
Work ongoing

- Still need to be refined and optimized
- Needs to be adapted to any updates of the design

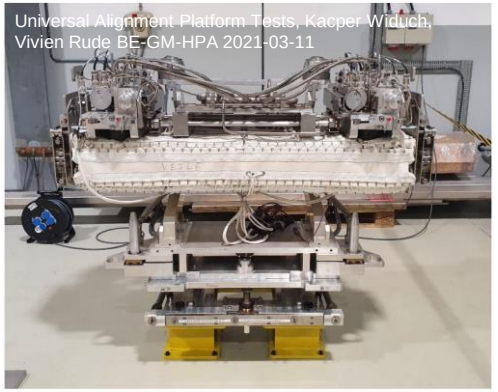
Paths to explore:

- Readjustment system for the MDI
- Alignment of the rest of the FCC-ee machine

The EUCLID VIS Read-out Shutter Unit, which will operate in space



Larchevêque, C., et al. "The Euclid VIS read-out shutter unit: a low disturbance mechanism at cryogenic temperature." *arXiv preprint arXiv:1801.07496* (2018).



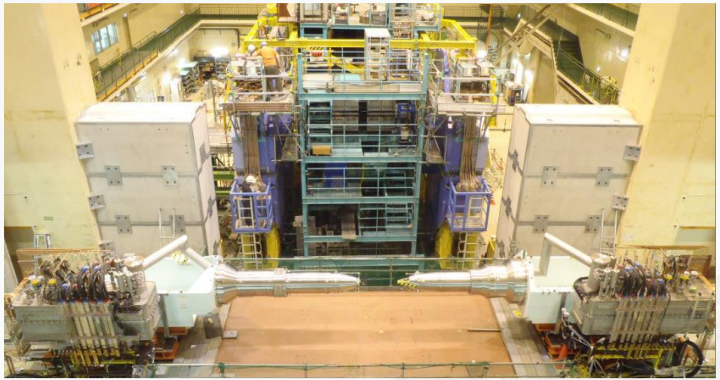
Thank you for your attention

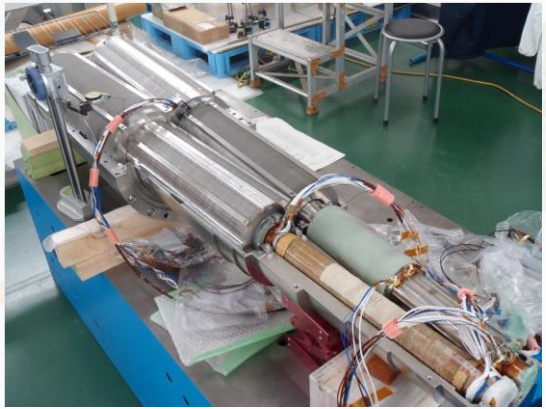
SuperKEKB MDI

Surprises can appear in case of absence of such alignment monitoring system

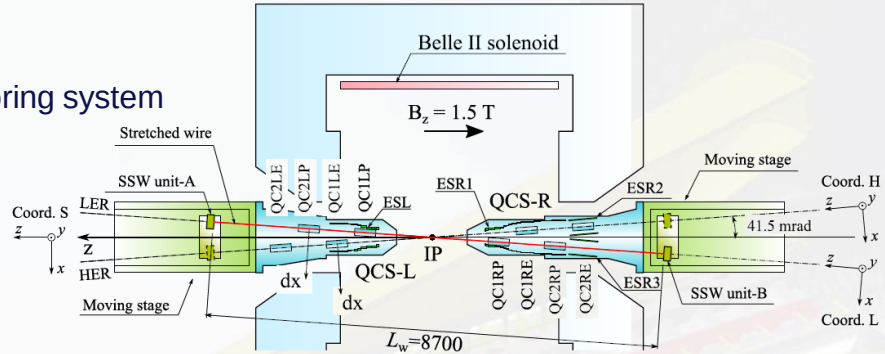
SuperKEKB

N. Ohuchi, "Final-Focus Superconducting Magnets for SuperKEKB", IPAC 18, 01/05/2018





Z. Zong, "SuperKEKB Interaction Region", 2018 international workshop on the high energy Circular Electron Positron Collider (CEPC), November 12-14, 2018, IHEP, Beijing, China



Arimoto, Yasushi, et al. "Magnetic measurement with single stretched wire method on SuperKEKB final focus quadrupoles." IPAC'19, Melbourne, Australia, 19-24 May 2019

Table 2: Measured x-Offset, y-Offset and Roll Angle Relative to Design Parameters. Units of length and angle are mm and mrad, respectively.

Quads.	X-offset		Y-offset		$\Delta\theta$
	Solenoid		Solenoid		Solenoid
	on	off	on	off	on
QC1LE	−0.21	−0.16	−0.29	−0.56	−1.6
QC2LE	0.13	0.11	−0.54	−0.68	−1.5
QC1RE	0.25	0.14	−0.37	−0.54	0.0
QC2RE	0.08	0.07	−0.58	−0.63	−0.7
QC1LP	−0.03	−0.14	−0.21	−0.38	−1.7
QC2LP	−0.31	−0.41	−0.68	−0.83	−4.0
QC1RP	0.64	0.69	−0.30	−0.43	2.0
QC2RP	0.43	0.45	0.04	−0.19	−1.7

Arimoto, Yasushi, et al. "Magnetic measurement with single stretched wire method on SuperKEKB final focus quadrupoles." IPAC'19, Melbourne, Australia, 19-24 May 2019