

MACHINE DETECTOR INTERFACE ALIGNMENT SYSTEM UPDATE

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Many thanks to :

Manuela Boscolo, Michael Koratzinos, Hélène Mainaud Durand, Mika Masuzawa, Luigi Pellegrino, Mateusz Sosin and Vivien Rude

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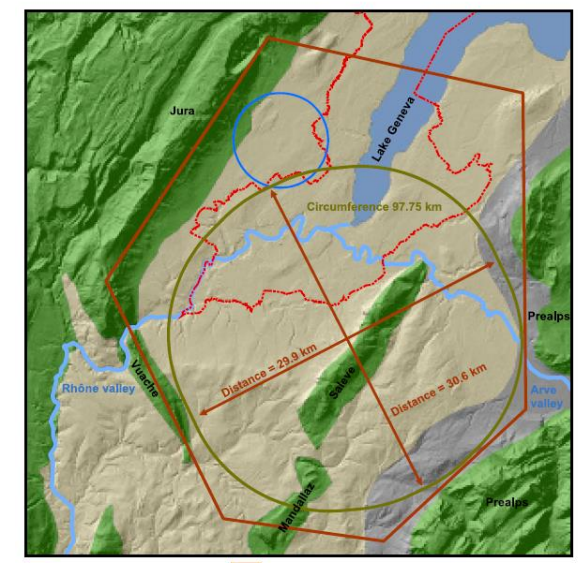
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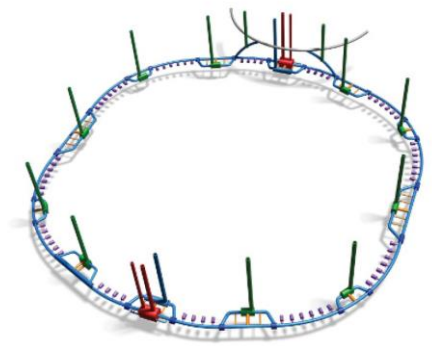
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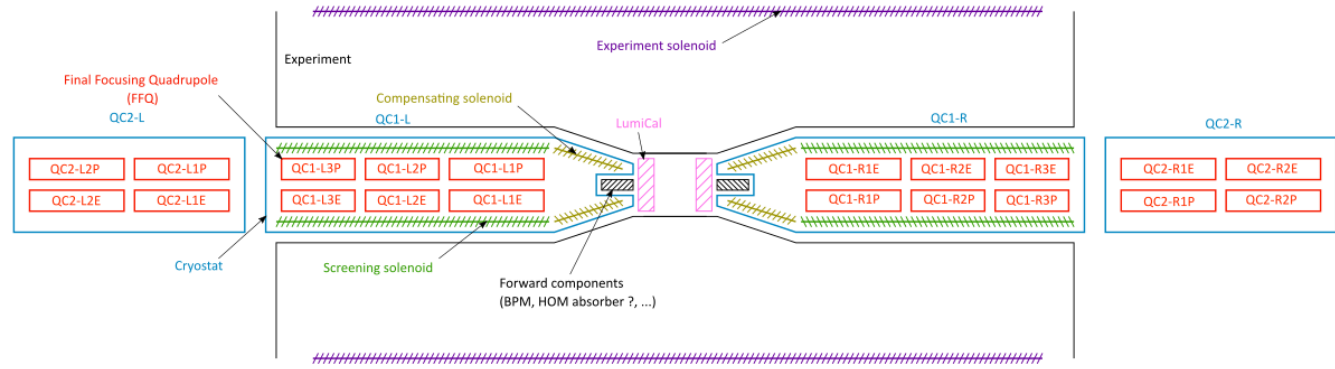
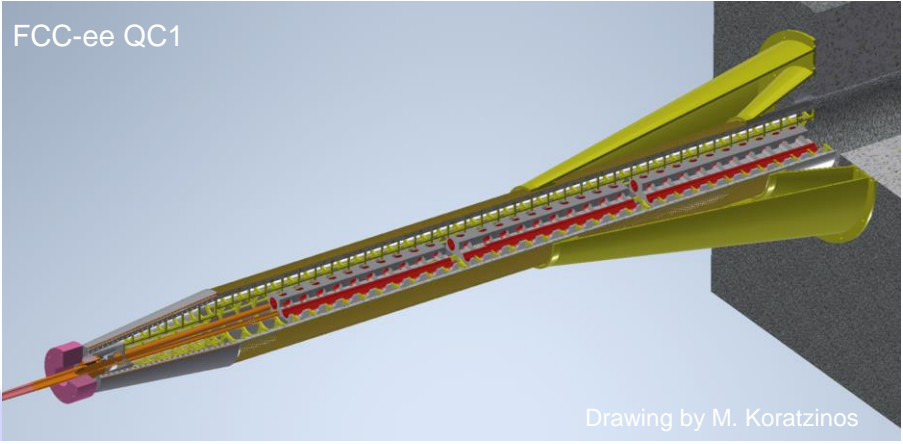
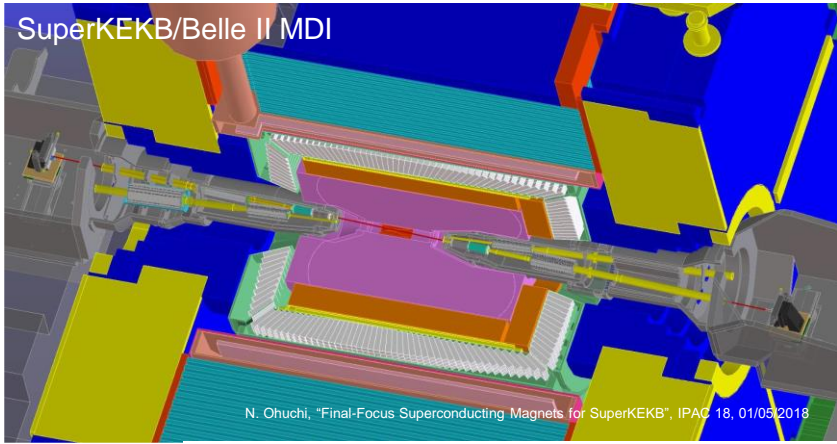
— LHC shape Study boundary Molasse Carried
— FCC shape Limestone molasse





Challenges for the alignment of the FCC-ee MDI

FCC-ee MDI overview



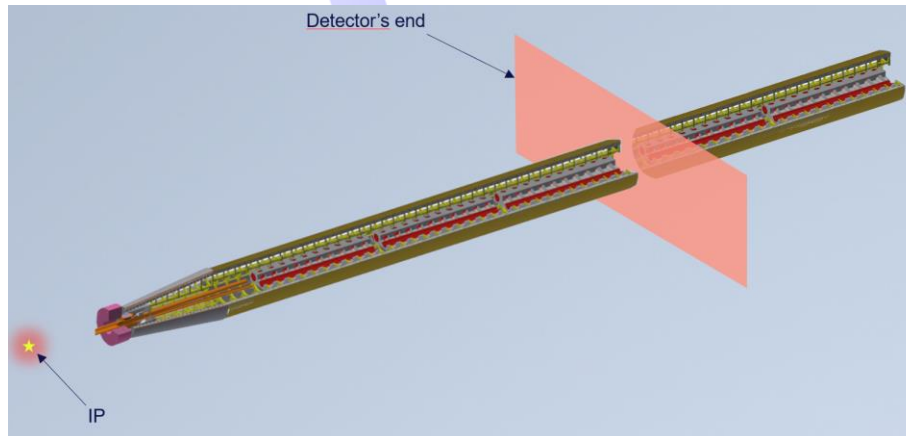
Alignment required for the final focusing quadrupoles, BPMs, Screening and Compensation solenoids and Lumical (for now ...)

Challenges for the FCC-ee MDI alignment

- Misalignment tolerances specified for the MDI are considerably tighter than in the rest of the accelerator (around 1/3 of the $\sim 100 \mu\text{m}$ expected for the misalignment tolerances of elements in the tunnel)
 - have the beam going through the components
 - limit general beam losses caused by any misalignment
 - most importantly, collide the two finely focused beams at the center of the detector
- Very elegant but complex design
- Crab waist configuration with large crossing angle \Rightarrow allows independent final focusing quadrupoles for the two beams and a smaller L^*
 - Double the amount of components to be precisely aligned
- $L^* < \text{detector size}$ \Rightarrow some parts of the accelerator are in the detector
 - Requires a alignment monitoring system inside the detector

Challenges for the FCC-ee MDI alignment

- An alignment monitoring system inside the detector is extremely challenging as it has to be :
 - **Extremely precise** : micrometric precision measurements ($< 10 \mu\text{m}$ goal) in encapsulated objects
 - **Small enough to fit** : has to be placed in an already full location
 - **Resistant to all the harsh conditions inside the detector** : will deal with cold, radiations, magnetic fields ...
 - **Unfailingly reliable** : access will be extremely difficult, maintenance limited as much as possible



Studies of existing MDIs

DAΦNE/KLOE

SuperKEKB/Belle II

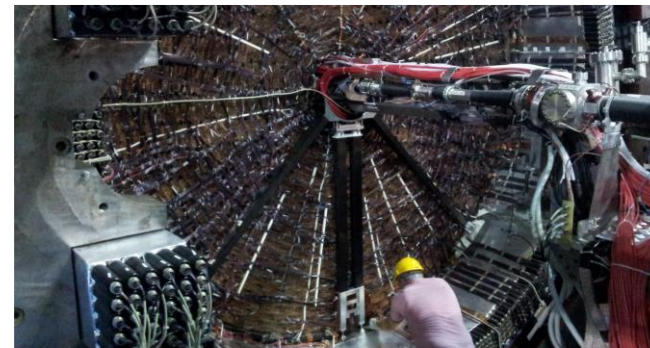
LHC/ATLAS

DAΦNE/KLOE MDI

~ 100 μm misalignment tolerance

- Final focusing components inside the detector supported by a cylindrical structure of the length of the detector
- Alignment procedure (strongly summarized) :
 1. Alignment of the elements on the girder (part of the cylinder) thanks to a laser tracker
 2. Installation of the cylinder in the detector
 3. Re-alignment of the articulated cylinder thanks to laser tracker targets and screws
 4. Occasional partial checks

➤ No alignment monitoring system



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.



Luigi Pellegrino and Giancarlo Sensolini

SuperKEKB/Belle II MDI

~ 100 μm misalignment tolerance

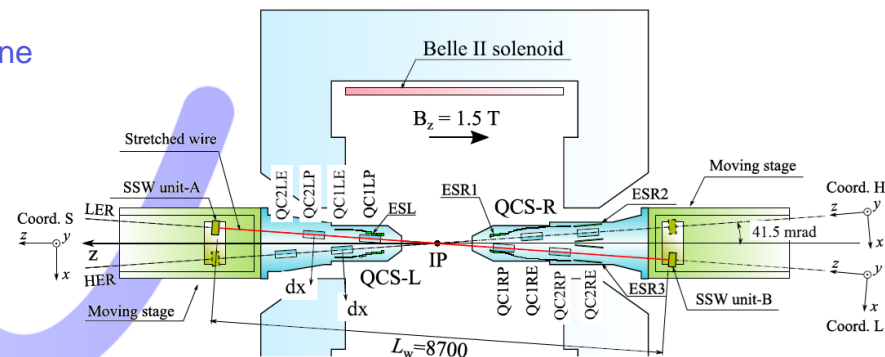
- Final focusing components inside the detector, supported by the cryostat in cantilever configuration
- Alignment procedure (strongly summarized) :
 - Pre-alignment of the components before installing them in the cryostat
 - Fiducialization
 - Alignment of the cryostat (QCS) with respect to the beam line
 - Installation of the cryostat inside the experiment
 - Check of the position of the inner magnets thanks to the Single Stretched Wire (SSW) method, coupled with capacitive measurements between the cryostat and the experiment (before the run of the machine)
 - Final correction on the beam thanks to corrector magnets

➤ No alignment monitoring system

Many thanks to Mika Masuzawa for all the information on SuperKEKB alignment.



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



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

LHC/ATLAS MDI

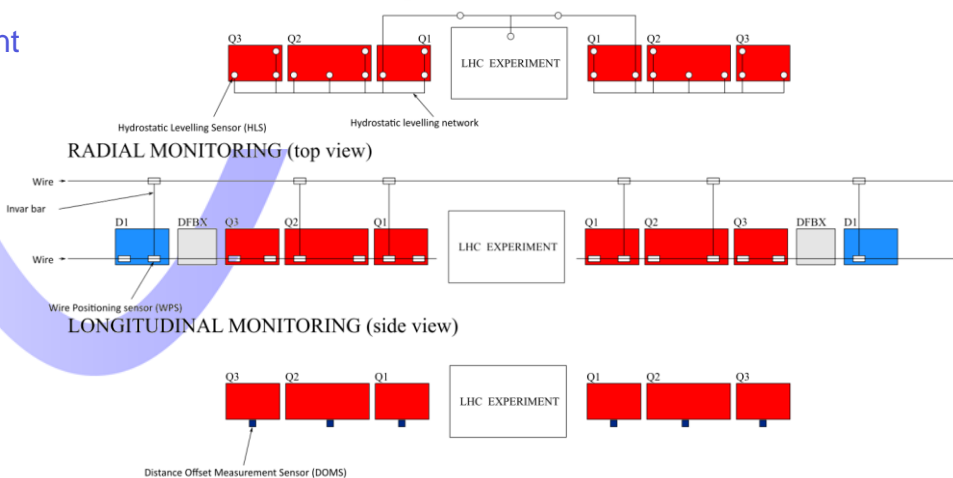
~ 100 μm misalignment tolerance

- Final focusing elements out of the detector
- Heavily monitored MDI
- Alignment (strongly summarized) :
 1. Installation of the magnets inside the cryostats
 2. Fiducialization
 3. Alignment of the cryostats with respect to the alignment targets placed in the tunnels
 4. Installation of the monitoring system

➤ Alignment monitoring system, but MDI very different from the FCC-ee MDI



VERTICAL / ROLL MONITORING (top view)



Studies of project accelerators MDIs

HL-LHC

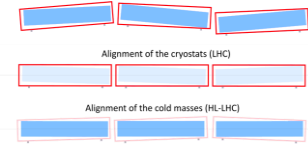
CLIC

ILC

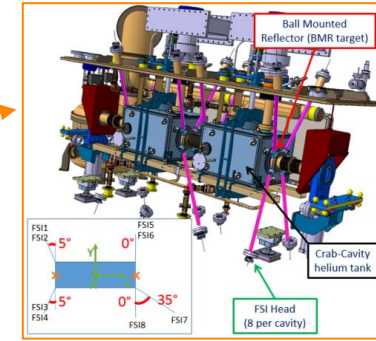
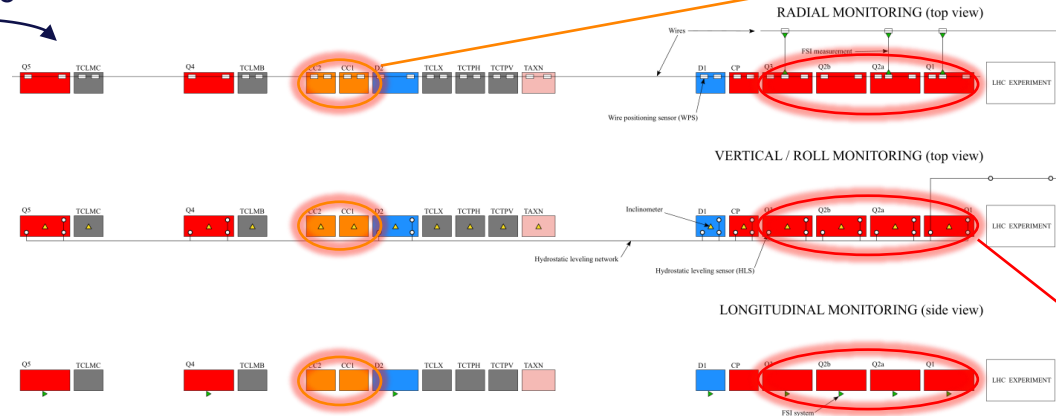
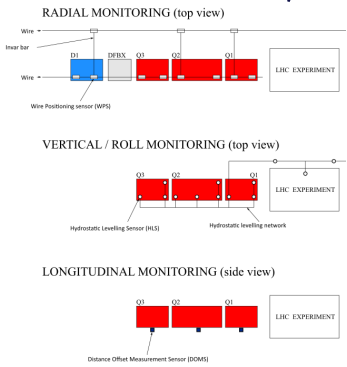
HL-LHC MDI

~ 100 μm misalignment tolerance

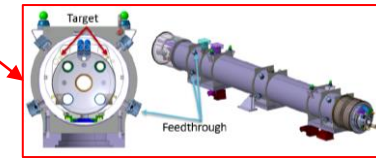
- Upgrade of the LHC MDI alignment system for a better monitoring (same sensors, denser network):
 - More components monitored
 - Better network : correction of major weak points, and add redundancy in case of a sensor failure
 - Components are better monitored (cold mass monitoring rather than cryostat)
- ❖ The better precision is only a result of these modifications, but not the first goal



Upgrade



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



Mainaud Durand, Helene, et al. "Frequency Scanning Interferometry as new solution for on-line monitoring inside a cryostat for the HL-LHC project." (2018): WEPAF068.

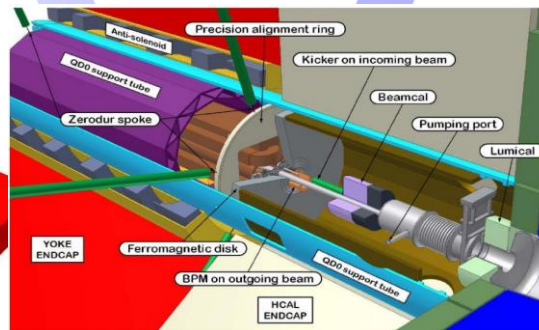
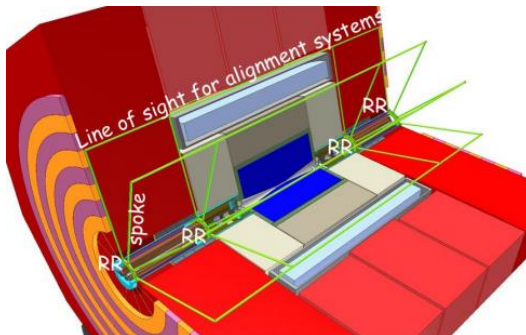
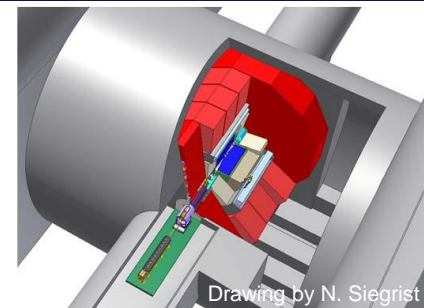
Many thanks to Vivien Rude for all the information on HL-LHC MDI alignment.

CLIC MDI

< 20 μm misalignment tolerance

- Requirements (at the beginning) :
 - two detectors in push-pull configuration → two different L^* , both $L^* < \text{detector size}$
 - Alignment at unprecedented precision → 10 μm as requirement for QD0 prealignment system

- Proposition for an alignment system for the MDI :
 - Monitoring QD0 thank to zerodur rods and optical alignment system inside the detector.
 - But it was not shown to work.



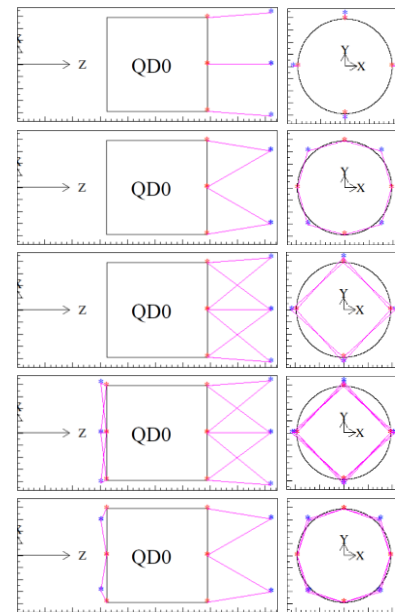
CLIC Machine Detector Interface, MDI mini workshop, HKUST IAS, Philip Burrows on behalf of Lau Gatignon, 2020

ILC MDI

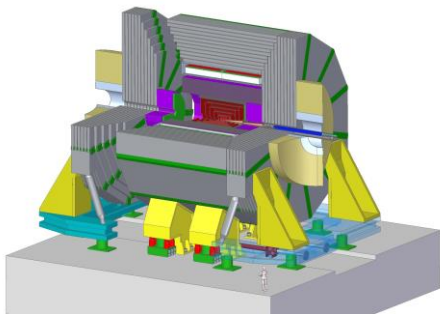
~ 20 μm misalignment tolerance

- Requirements :
 - two detectors in push-pull configuration \rightarrow two different L^* , both $L^* <$ detector size
 - Alignment at unprecedented precision \rightarrow 20 μm as requirement for QD0 prealignment system

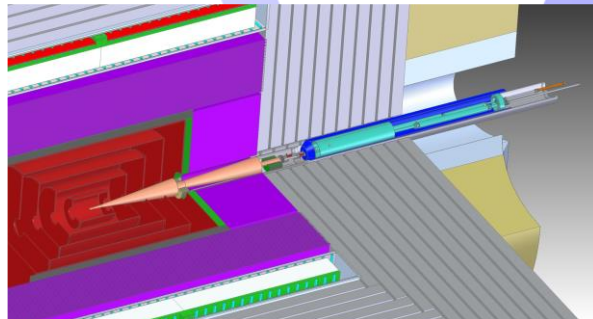
- Proposition for an alignment system for the MDI :
 - Monitoring QD0 thank to frequency scanning interferometry distance measurement
 - Studies stopped in 2011 – Maybe restarted ?



Riles K., Yang H-J., Chen T., "Update on FSI R&D for SiD Tracking and Final Focus Magnet Alignment", SiD Workshop, SLAC, 14/12/2011



Marcel Stanitzki, The SiD Detector – Machine Backgrounds, 01/2020, Hong Kong



Marcel Stanitzki, The SiD Detector – Machine Backgrounds, 01/2020, Hong Kong

Toward a new alignment system

Limits of the existing monitoring systems

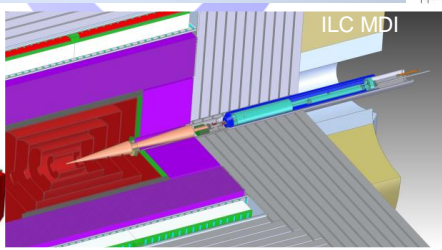
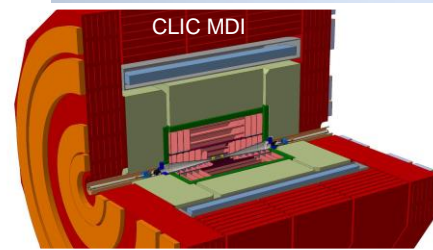
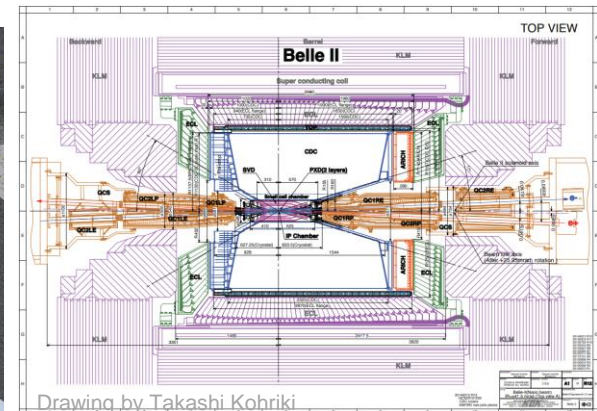
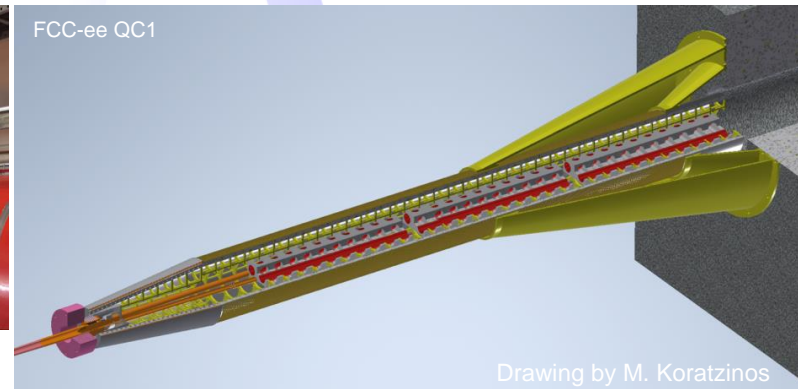
Ongoing studies

Realignment studies

The challenge of the FCC-ee MDI

Use a complete alignment monitoring system as in the LHC/ATLAS MDI on a MDI as complex as the SuperKEKB/Belle II MDI with alignment precisions similar to the CLIC-ILC MDI.

~ 30 μm alignment requirement for Final Focusing Quadrupoles

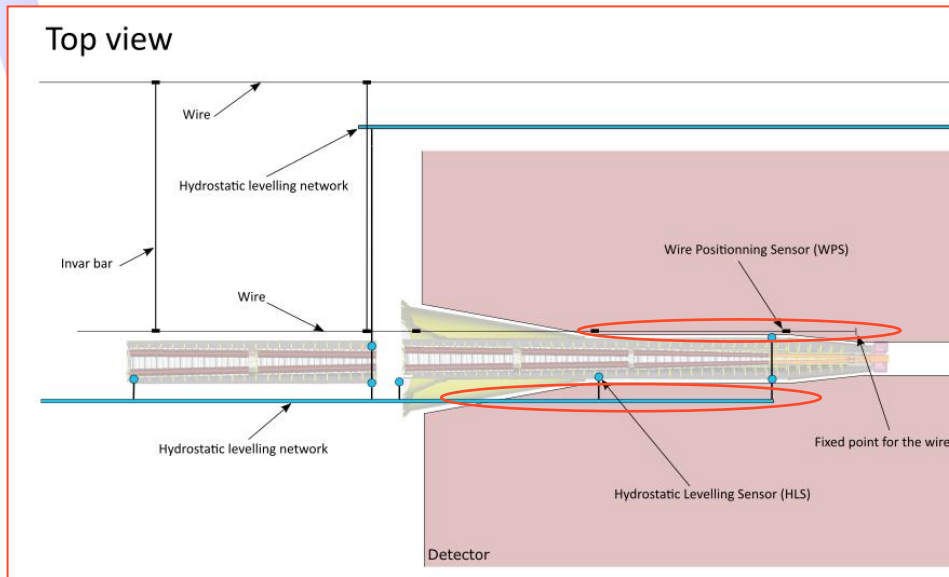
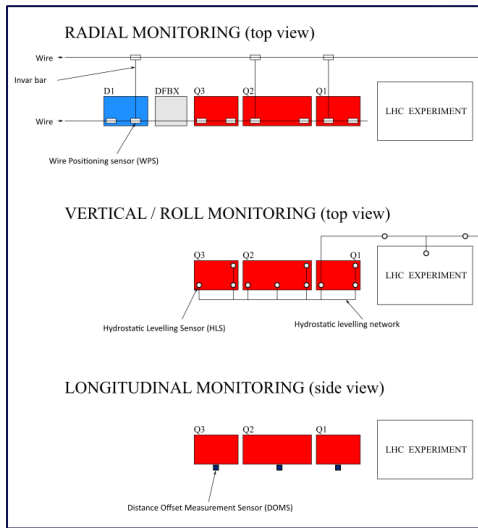


CLIC Machine Detector Interface, MDI mini workshop, HKUST IAS, Philip Burrows on behalf of Lau Gatignon, 2020

Marcel Stanitzki, The SiD Detector – Machine Backgrounds, 01/2020, Hong Kong

Limits of the existing monitoring system

- The first step was to try to apply the existing monitoring system
 - The LHC/ATLAS MDI alignment monitoring system is inadequate for the FCC-ee MDI : cannot fit and would not be precise enough

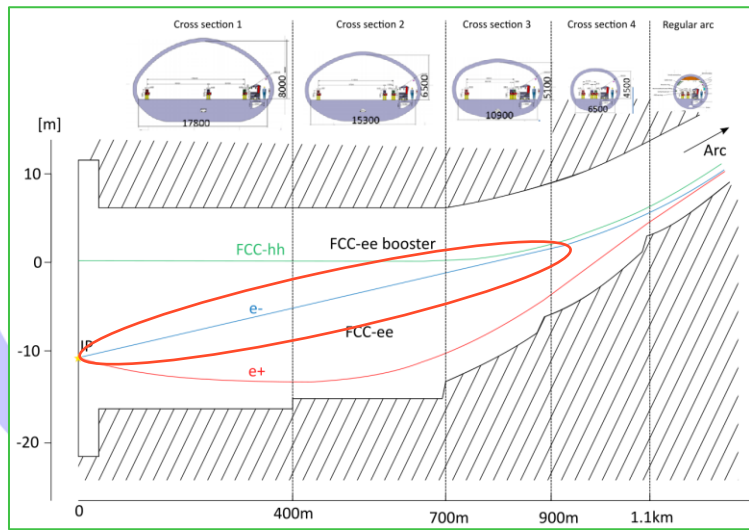
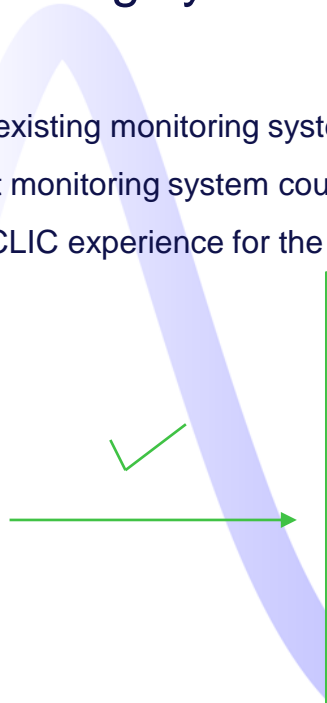
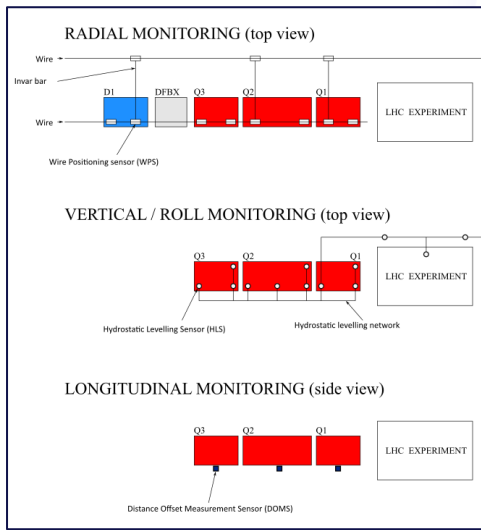


~ 100 m long alignment (per side)
> 100 μm alignment precision

~ 4 m long alignment (per side)
~ 30 μm alignment requirement

Limits of the existing monitoring system

- The first step was to try to apply the existing monitoring system
 - The LHC/ATLAS MDI alignment monitoring system could work for the straight portion before the IP. The requirements are tight, but the CLIC experience for the alignment of the BDS could be applied here.



~100m long alignment (per side) LHC / ~500m for HL-LHC

> 100 μm alignment precision

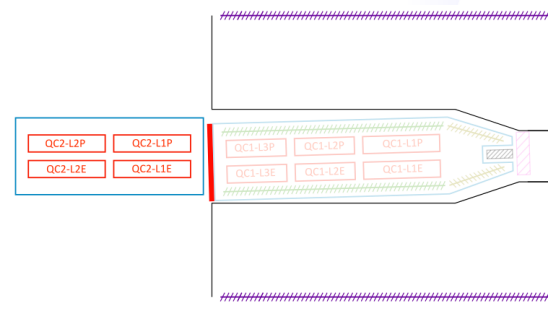
~ 900 m long alignment (per side)

100 μm misalignment tolerance (quadrupoles) => ~ 30 μm alignment precision required

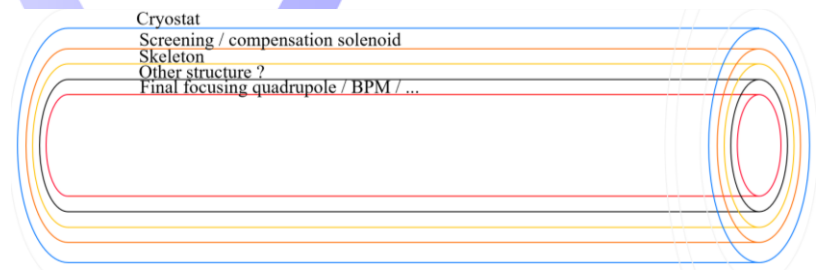
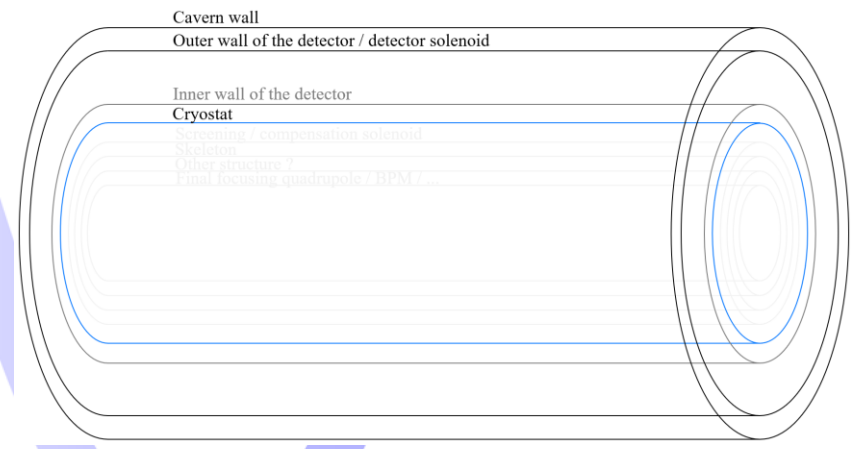
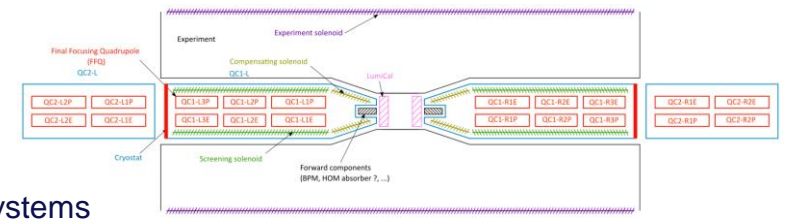
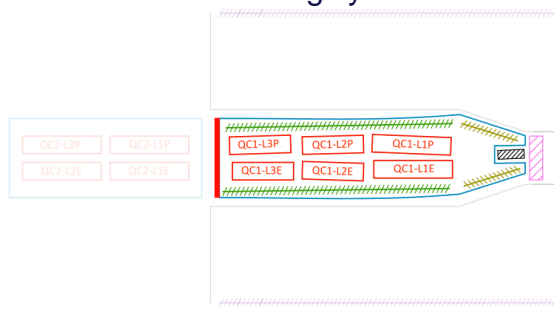
(for more info, cf. Tessa Charles presentation done on Tuesday)

Ongoing studies

- One idea would be to separate the alignment of the MDI in two sub-systems
 - An external monitoring system



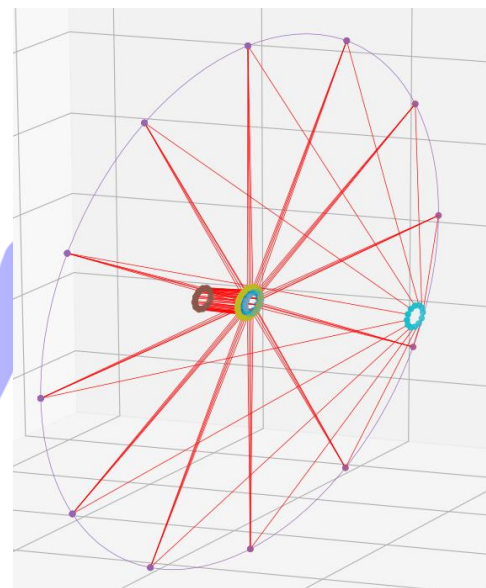
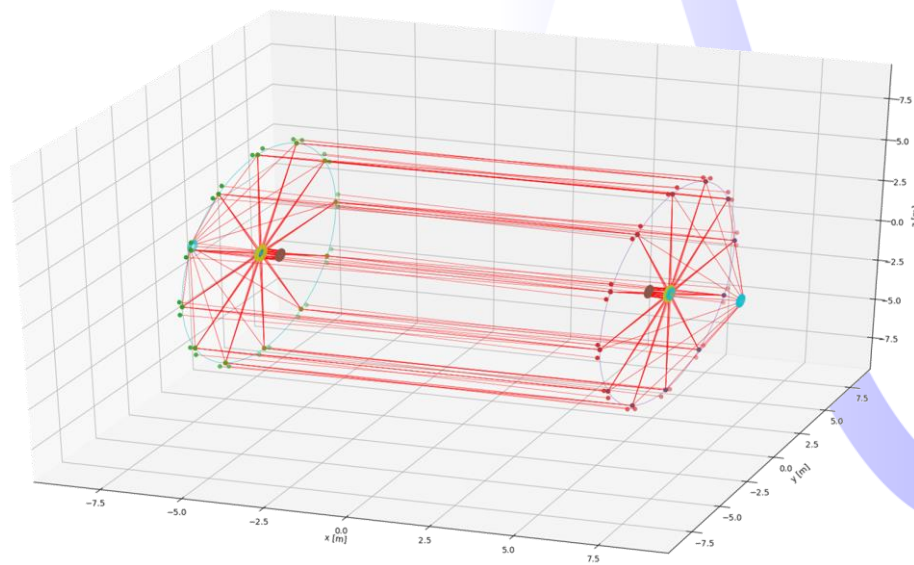
- An internal monitoring system





External monitoring system

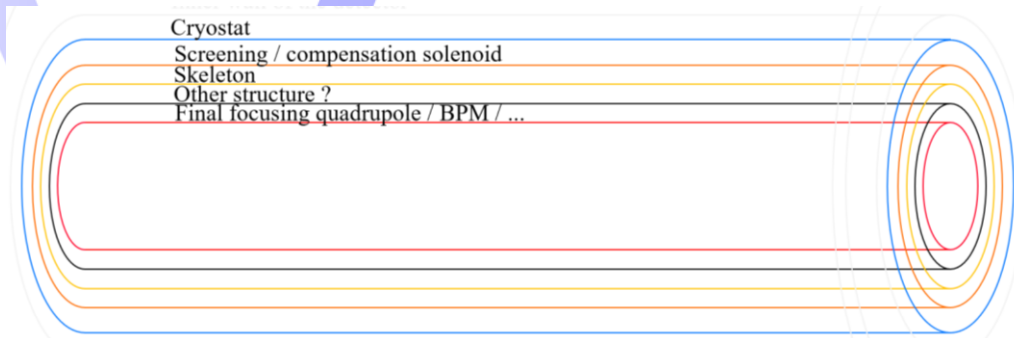
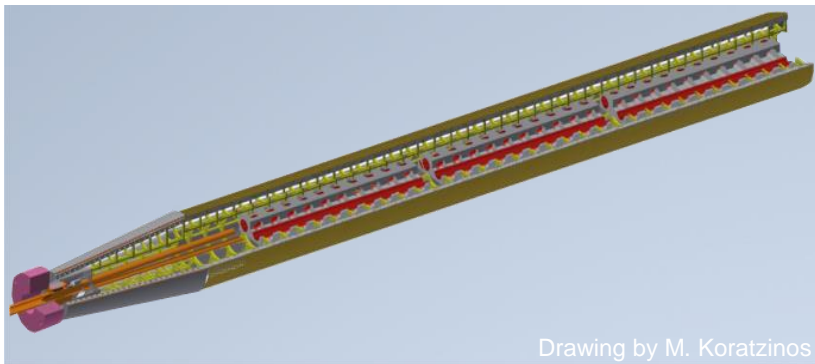
- Distance measurement network with micrometric precision aim
- Lot of R&D and simulations to do (simulations done with LGC++, software used by the GM group, developed at CERN)



This is a first idea, needs to be adapted to the detector and other elements in the cavern

Internal monitoring system

- The alignment of internal components : the most difficult part of the alignment in the MDI
 - Complex design with multiple layers
 - Very little space
 - Harsh conditions (cold, radiations, magnetic fields ...)
 - Stringent alignment requirements ($\sim 30 \mu\text{m}$) \Rightarrow precise measuring system ($\sim 10 \mu\text{m}$)
- Currently no existing system capable of such precise measurements
- Simulations on new systems are ongoing

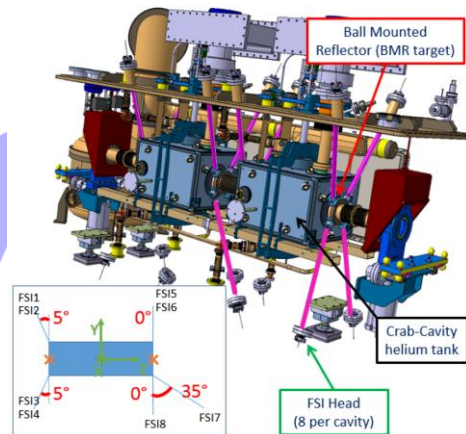
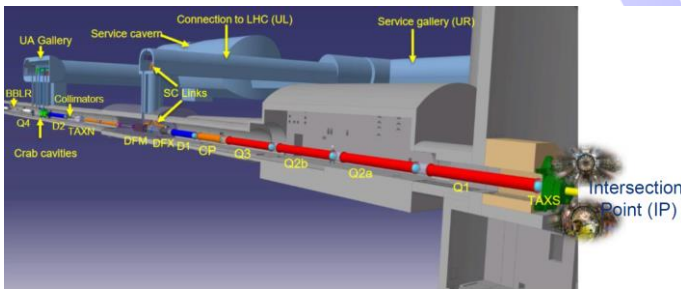


Studies : Reajustment

- Complex MDI with extremely limited access during the entire lifetime
 - Study a realignment system able to do some remote alignment of all/some specific components inside the MDI
 - Would work in tandem with the alignment monitoring system and BPM measurements, similarly to the current LHC MDI or the future HL-LHC MDI



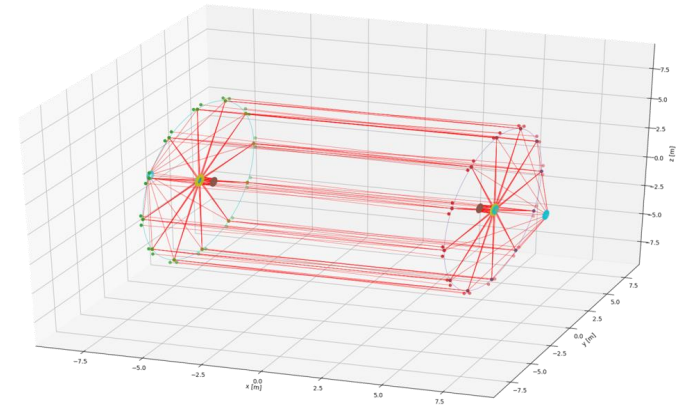
LHC / HL-LHC full remote alignment system for the Low- β quadrupoles



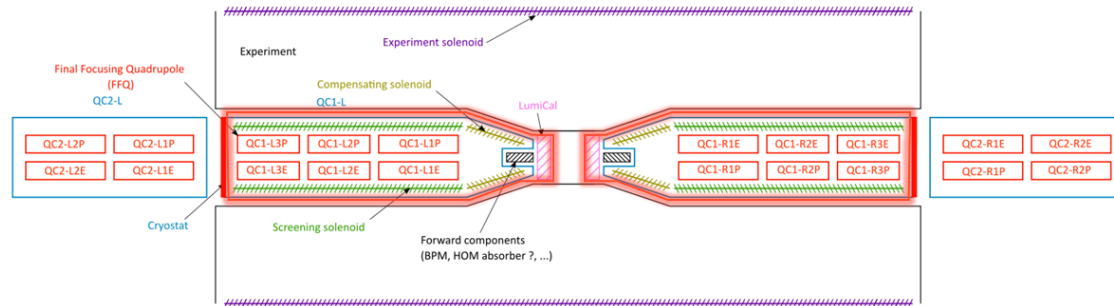
Sosin, Mateusz, et al. Position monitoring system for HL-LHC crab cavities. No. CERN-ACC-2016-197. 2016.

Conclusion

- Main challenges :
 - Still an early design but rapidly evolving
 - Very elegant but complex design
 - No existing alignment system can be used -> requires an new one



- Proposition of a new system
(internal and external monitoring system)
- Simulations are ongoing





Thank you
for your attention