NEW IR OPTICS DESIGN AND DETECTOR BACKGROUNDS

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Outlook

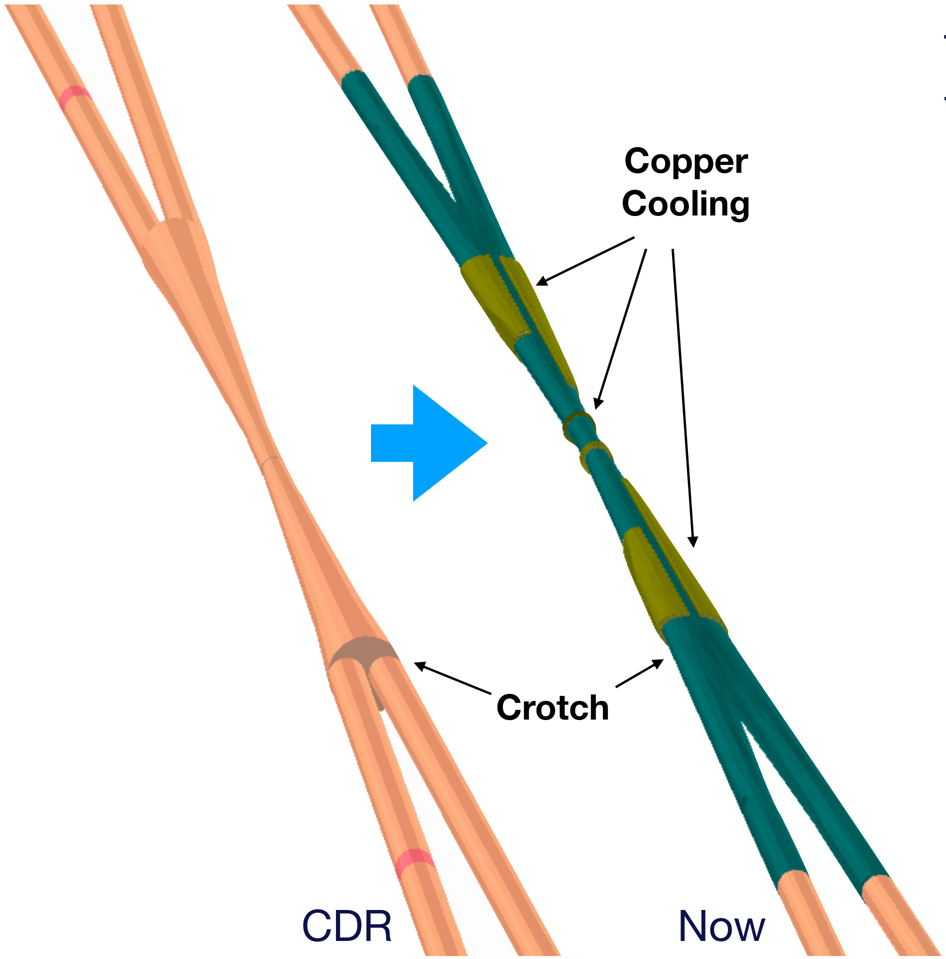
Improving the MDI description in Key4hep

- necessary to have realistic estimates of backgrounds
- CAD-model beam pipe
- Magnetic fields in the IR
- what to improve next

Coupling Correction Scheme

- coupling induced by the experiments' solenoids corrected "á la DAΦNE"
- removed screening solenoids -> more space available in the IR
- first look to chromatic coupling
- next steps

Improving the MDI model: beam pipe



The upgrade of the MDI model present in Key4hep is necessary to have a correct estimate of the **backgrounds**.

Engineered CAD model of AlBeMet162 beam pipe developed by INFN-LNF (many thanks to F. Fransesini) imported in **Key4hep**.

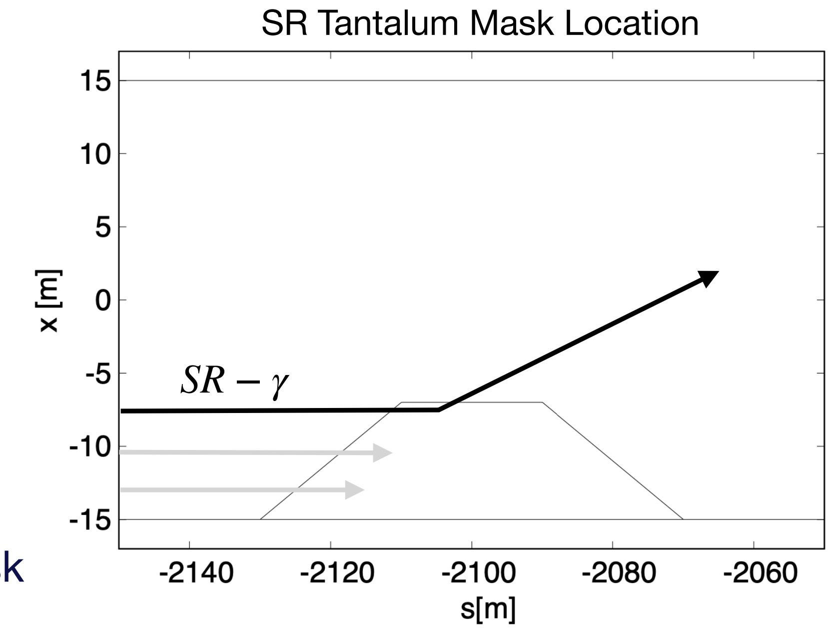
Upgrades respect to old model:

- Double-layered central section for paraffine cooling
- **Copper cooling** sections implemented
- Improved modelling of the beam pipe **separation region** (crotch), congruent to impedance studies

Future upgrades:

- realistic **bellows** to be placed before beam pipe separation, currently under development
- IR+Lumical **support tube** proposal (see F. Fransesini)

SR Mask and Shieldings



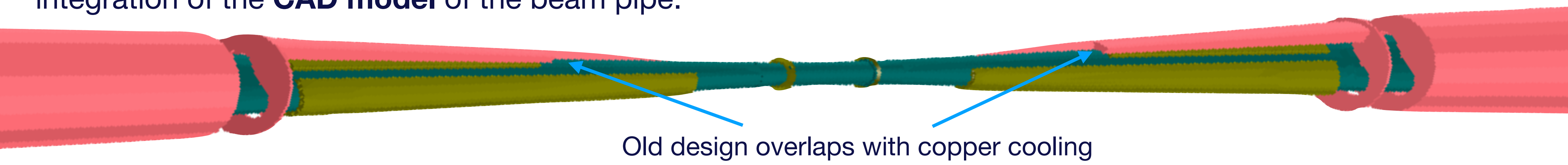
Horizontal masks located 2.1m upstream the IP are used to intercept SR photons coming from the **last bend**.

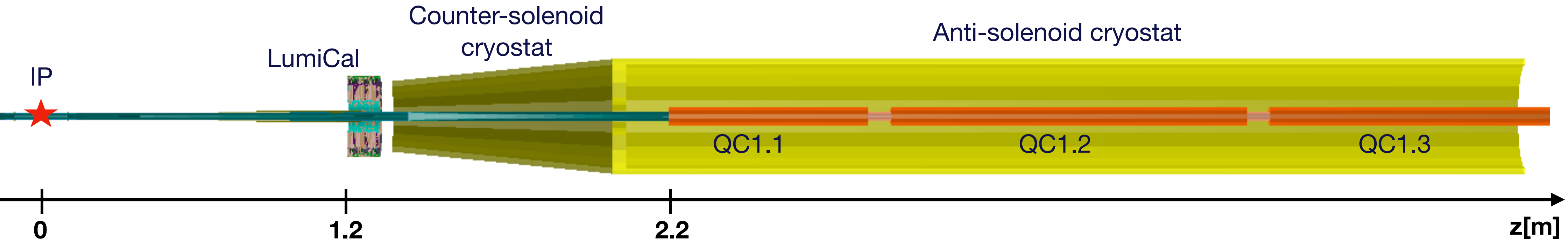
Current description is an **Tantalum mask** reaching **7mm** from the beam pipe center.

SR photons may be **diffused at large angle** from the tip of the mask and be the source of background in the detector.

During CDR, ~200kg **Tungsten shielding** to protect the experiment from these photons has been designed.

The possibility to **eliminate** or **redesign** this shielding is under evaluation, also considering the recent integration of the **CAD model** of the beam pipe.





Other IR Elements

Currently present in the Key4hep description:

- Simple **quadrupole** geometry for power deposition studies
- **LumiCal** detailed description
- Cryostats for antisolenoids: **hollow shell** with 2cm thick walls

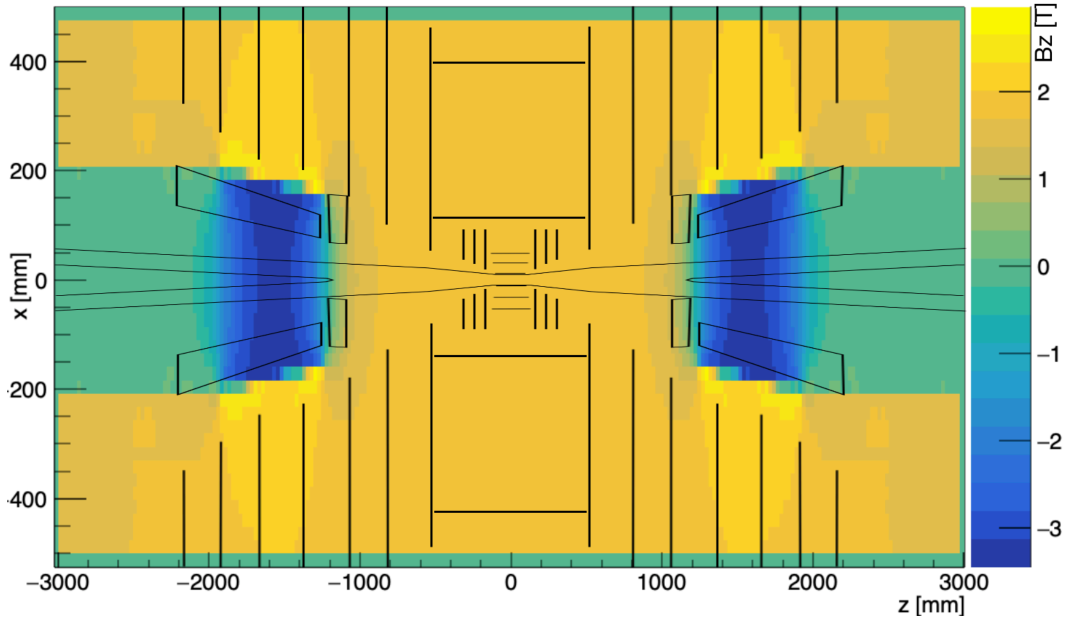
A more detailed description of the anti-solenoid **cryostats** and **support structures** for the various subdetectors is necessary for a better estimate of the **secondary showers** which can be produced by background particles in that region (e.g. from beam losses in the FF quads).

Magnetic Fields in the IR

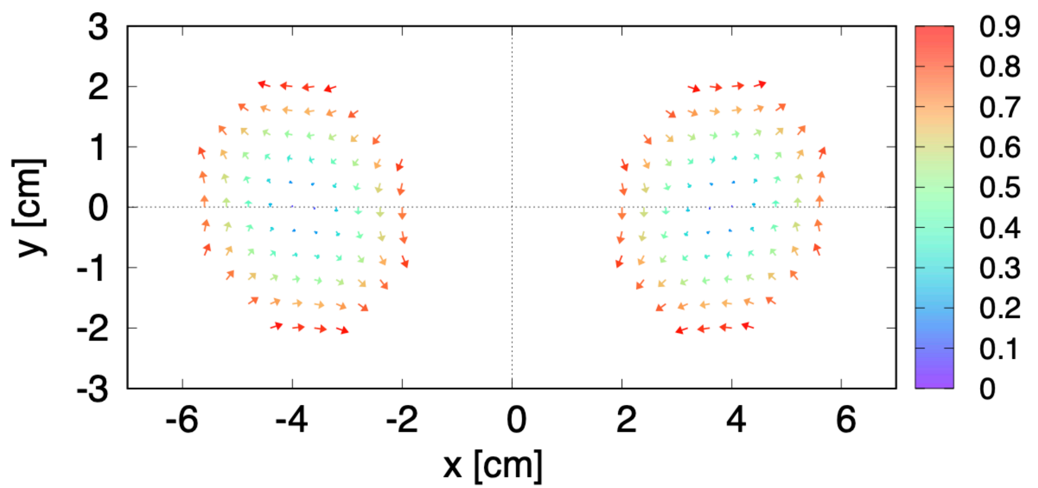
In addition to the 2T solenoidal field of the experiment, allow for correct tracking of charged background particles, in particular those generated in the separated beam pipe region of the MDI area.

- Field coming from the **anti-solenoids** (counter-S, compensating-S) imported via **field map** to account for fringe effects

- Implementation of **FF quadrupole fields** in the Key4hep geometry under progress



B_T[T], at QC1L1 entrance



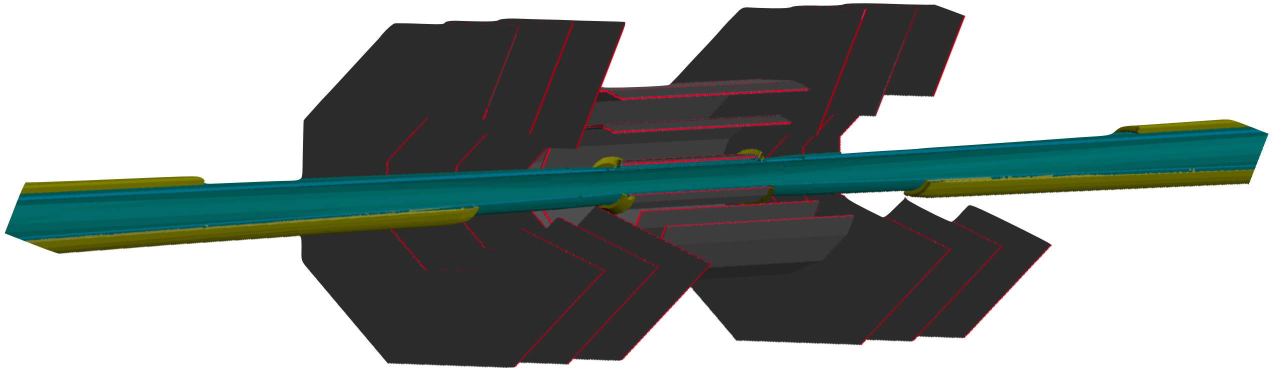
CLD Detector: Vertex Detector

Difference since CDR: smaller beam pipe central chamber.

Vertex Detector adaptation:

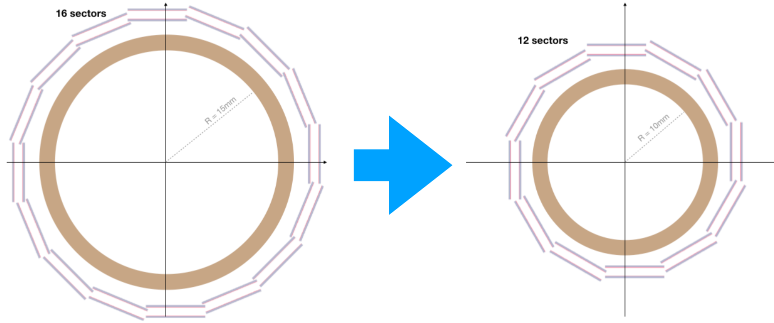
- Reduced number of sectors in innermost barrel layer
- Modified barrel layers to keep same angular acceptance

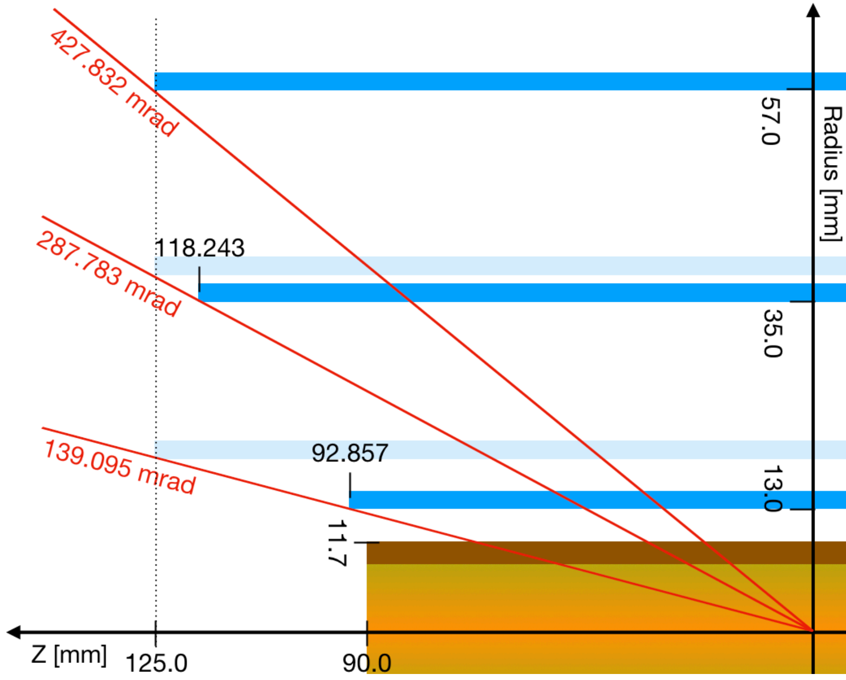
Only **support layers** for Si-pixels inbetween double layers



R=15mm
16 sectors

R=10mm
12 sectors





Coupling Correction Scheme at FCC-ee

- Effect of 2T solenoids + antisolenoids to coupling
- Coupling correction only by:
  - rotation of FF quads
  - skew quads at sextupoles location
  - alternated solenoid sign
- chromatic coupling: first look

The great advantage of this approach is that removes the need for screening solenoids, making a lot of space in the (very crowded) IR

HFD Lattice v51a1 - Z
thin lattice treatment, TEAPOT slicing

	dipoles	quadrupoles	sextupoles	FF-quads
slices	4	12	4	20

This approach can - in principle - be applied also to the current lattice baseline.

On-axis solenoids introduced in the MAD-X thin lattice as 100 equally spaced slices.
EMIT function has been used to get emittance values.

Coupling induced by on-axis solenoids

2T solenoids introduced at the 4 IPs, collinear to the beam (no angle).

Vertical emittance grows due to coupling of a **factor x50**.

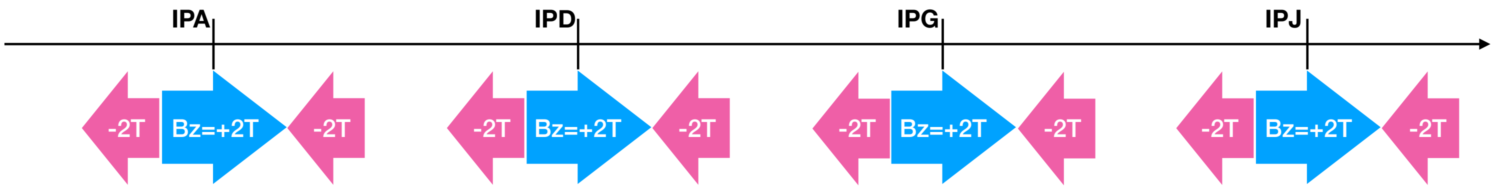
$$\left(\frac{\epsilon_y}{\epsilon_x}\right)_{original} = \frac{0.001[\pi\, nm\, rad]}{0.508[\pi\, nm\, rad]} = 0\,\%$$

$$\left(\frac{\epsilon_y}{\epsilon_x}\right)_{sol} = \frac{0.048[\pi\, nm\, rad]}{0.481[\pi\, nm\, rad]} = 10\,\%$$

Two anti-solenoids must be introduced for **polarization** $\int B_Z^{AS} dl = -\frac{1}{2}\int B_Z^{S} dl$

First approach: $B_Z^{AS} = -B_Z^{S}$ $L^{AS} = 0.5 L^{S}$, 100 thin element slices.
Located at **±25.2m from IP**, midway in the ~30m drift after QF1B.

NOT screening solenoids!
Far from the IP, more space available in the IR.
Also, they are not tilted



$$\left(\frac{\epsilon_y}{\epsilon_x}\right)_{S+AS} = \frac{0.038[\pi\, nm\, rad]}{0.500[\pi\, nm\, rad]} = 7.6\,\%$$

Coupling does not completely disappear because most of it is **induced by FF quads.**

Coupling correction: rotation of FF quads

Coupling correction is achieved (at first) via a tilt* of the active Final Focus quadrupoles **QD0A** and **QF0**.

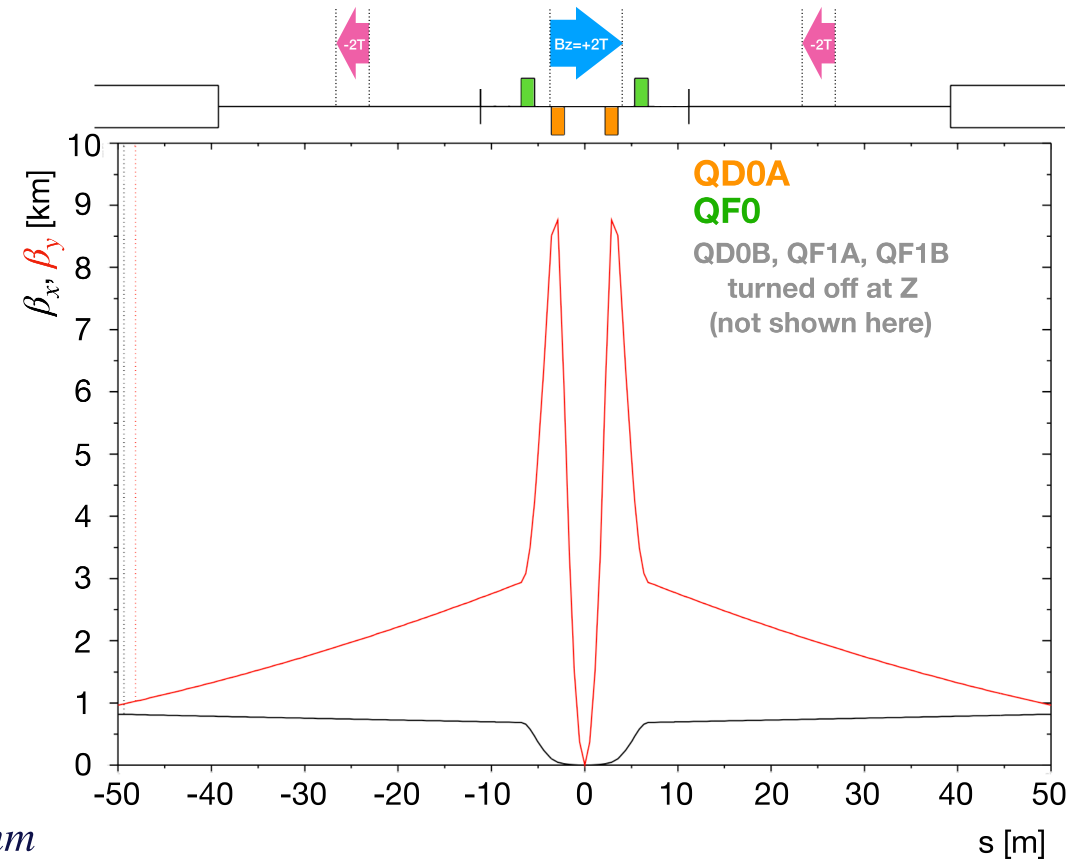
Best solution obtained when the rotation is asymmetrical w.r.t. IP: $\theta_{QD0A,L} = -\theta_{QD0A,R}$

Fine tuning by minimizing the coupling contribution to the vertical emittance $\epsilon_{y,c}$ is obtained for:

$$\theta_{QD0A,L} = +2.07\ mrad \qquad \theta_{QF0,L} = -2.90\ mrad$$

$\Rightarrow$

$$\epsilon_{y,c} = 0.073\ [\pi\ pm\ rad] \qquad \beta_x = 0.23\ m \quad \beta_y = 1.76\ mm \qquad Q_x = 0.347 \quad Q_y = 0.992$$

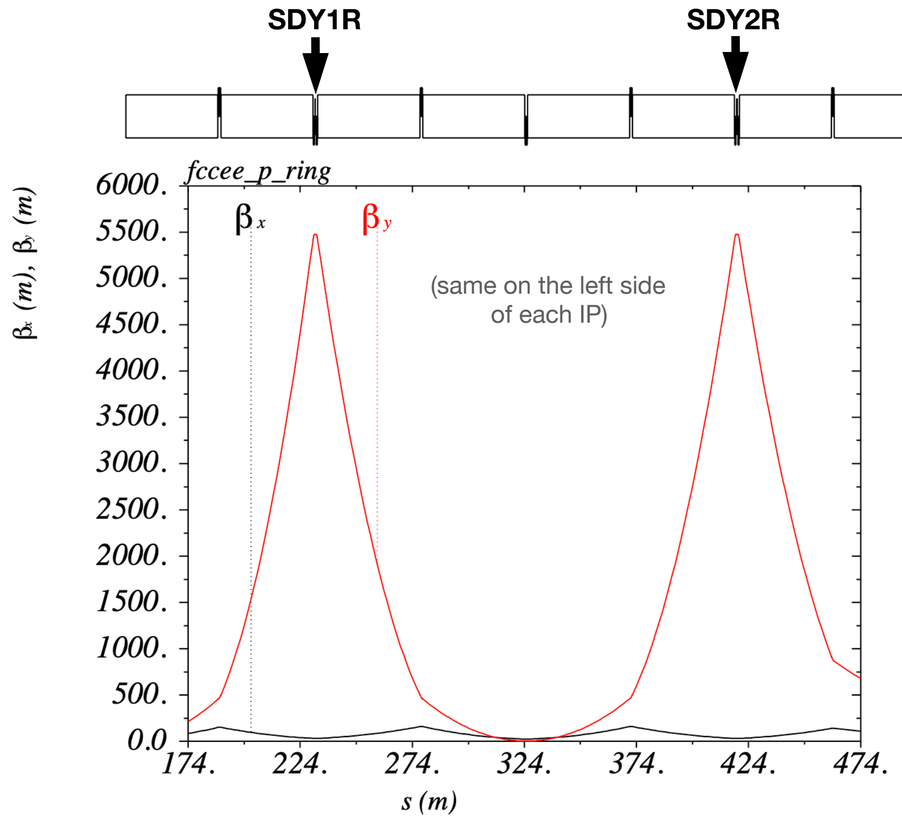


Rematching the straight section to correct tunes and betas:

$$\epsilon_{y,c} = 0.45\ [\pi\ pm\ rad] \qquad \beta_x = 0.17\ m \quad \beta_y = 0.66\ mm \qquad Q_x = 0.324 \quad Q_y = 0.316$$

* this rotation will be translated to a skew quadrupole winded around the main ones

Coupling correction: skew quads at sextupoles location



To better control coupling and also ease the matching, skew quadrupoles have been placed in correspondence of the SDY1 and SDY2 sextupoles.

The absolute value of the gradient is the same, but the sign is asymmetric w.r.t. IP: $K_{SQY} = K_{SQY1/2,L} = -K_{SQY1/2,R}$

Tuning this value to minimize $\epsilon_{y,c}$ and rematching one obtains:

$$K_{SQY} = -0.004 \cdot 10^{-3}\ [m^{-2}]$$
$$\epsilon_{y,c} = 0.14\ [\pi\ pm\ rad]$$
$$\beta_x = 0.196\ m \qquad \beta_y = 0.773\ mm$$
$$Q_x = 0.324 \qquad Q_y = 0.317$$

… gaining a factor 3 w.r.t. previous slide.

Skew quadrupoles have been placed also at SDY3/4 location, but their effect is negligible.

Reduced Coupling by Alternating Solenoid Signs

Regardless of the correctors, the coupling can be reduced of a factor 4 simply by alternating the sign of the detector's magnetic field.

Experiments should be symmetrical w.r.t. the x-y plane, so changing the sign of the 2T solenoidal field should not be a problem.

Also the antisolenoids should have alternated sign.

$$\left(\frac{\epsilon_y}{\epsilon_x}\right)_{sol} = \frac{0.048[\pi\, nm\, rad]}{0.481[\pi\, nm\, rad]} = 10\,\%$$

$$\left(\frac{\epsilon_y}{\epsilon_x}\right)_{alt.\,sol} = \frac{0.012[\pi\, nm\, rad]}{0.512[\pi\, nm\, rad]} = 2.3\,\%$$

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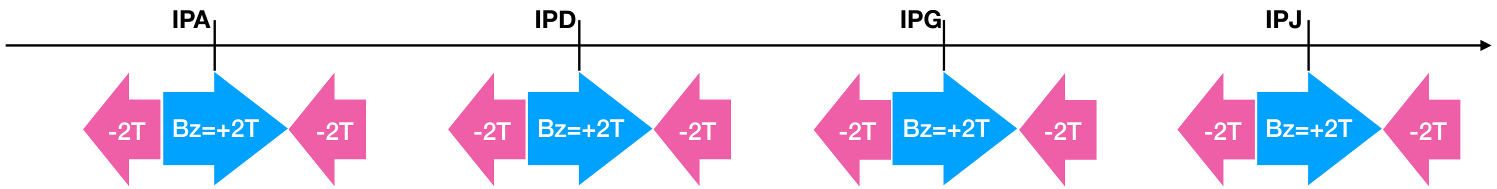

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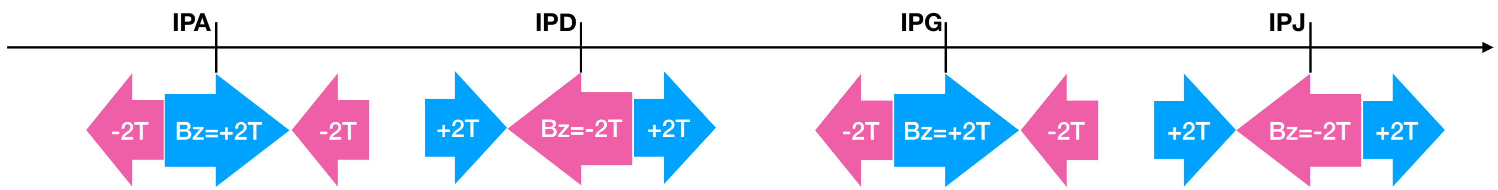


$$\left(\frac{\epsilon_y}{\epsilon_x}\right)_{alt.\,sol} = \frac{0.011[\pi\, nm\, rad]}{0.519[\pi\, nm\, rad]} = 2.1\,\%$$

Correcting Coupling w/ Alternating Solenoid Signs

In the scenario where the experiments' fields have alternated sign, the coupling correction has been performed with the same handles used before.

The sign of angles/gradients has been changed accordingly to the solenoid fields.

Fine tuning and rematching one obtains:

$$\theta_{QD0A,L} = +2.075\ [mrad]$$
$$\theta_{QF0,L} = -3.145\ [mrad]$$
$$K_{SQY} = -0.003 \cdot 10^{-3}\ [m^{-2}]$$

$\Rightarrow$

$$\epsilon_{y,c} = 0.0187\ [\pi\ pm\ rad]$$
$$\beta_x = 0.214\ m \qquad \beta_y = 0.796\ mm$$
$$Q_x = 0.325 \qquad Q_y = 0.294$$

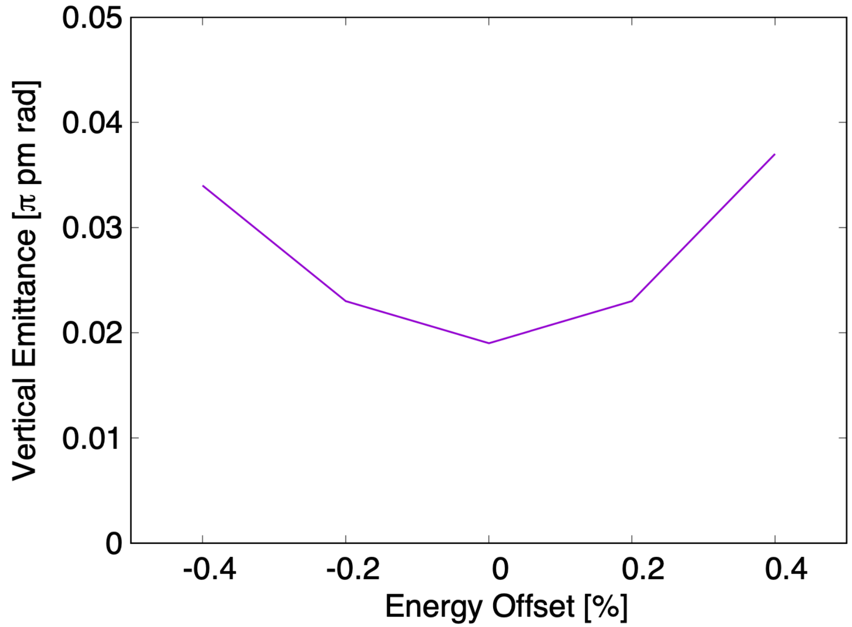
The final contribution to vertical emittance value is **only few percents of the nominal one** $\epsilon_y = 1\ [\pi\ pm\ rad]$.

Chromatic Coupling

The effect of chromatic coupling has been estimated by performing a scan on the relative energy offset of the beam.

Without corrections this effect is small, still contributing with few percents to the nominal vertical emittance value.

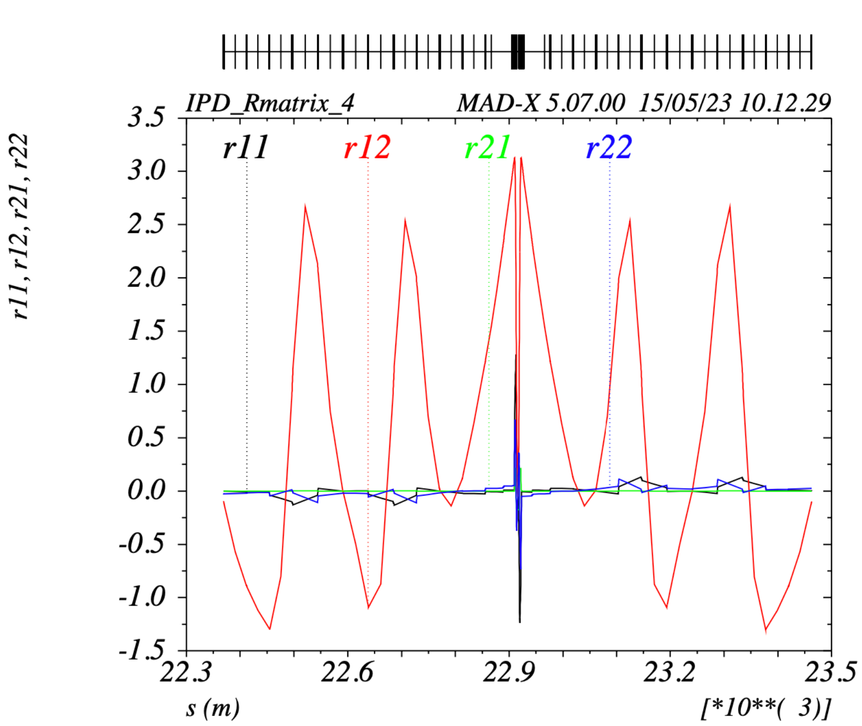
Correction has been attempted by using skew sextupoles in the SDY1/2 location, but no margin for improvement.



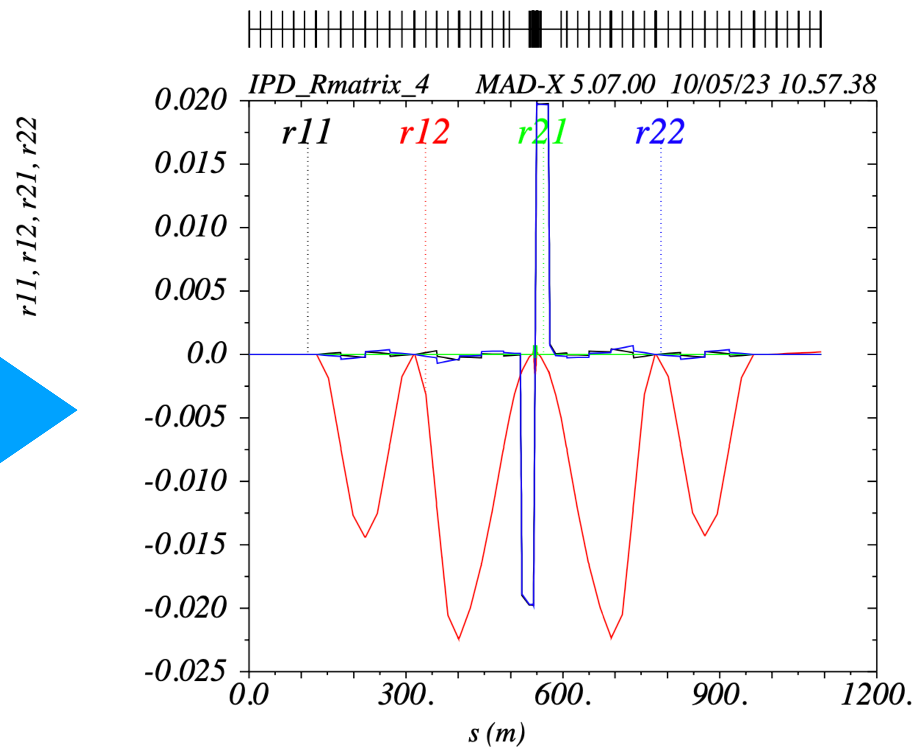
Fit with a 2nd order polynomial:
y = 0.01891429 + 0.003*x + 0.1035714*x^2

Correcting the coupling matrix

Even after the correction, the coupling matrix elements are not zero outside the straight sections. Starting from the initial condition shown in previous slides, matching of these values produced good results on the single straight section (shown IPD), work to extend this to the whole ring is ongoing.



Before coupling matrix matching



After coupling matrix matching

Summary

- Several improvements on the **MDI region key4hep description** applied, several still required.
- "Á la DAΦNE" coupling correction scheme would remove the need for screening solenoids, making lots of space available in the IR
- First attempt with this coupling correction scheme proved **very effective**, reducing contribution to the vertical emittance from $\epsilon_{y,c} = 38\ [\pi\ pm\ rad]$ to $\epsilon_{y,c} = 0.019\ [\pi\ pm\ rad]$ (about only **2%** of the nominal value)
- Chromatic coupling has a slow quadratic increase, with the contribution to ϵ_y remaining to few % of the nominal value within the beam nominal energy spread.
- Further optimization by matching the coupling matrix to zero is ongoing, DA studies needs to be performed.