Options for adding a warm skew quadrupole next to D2

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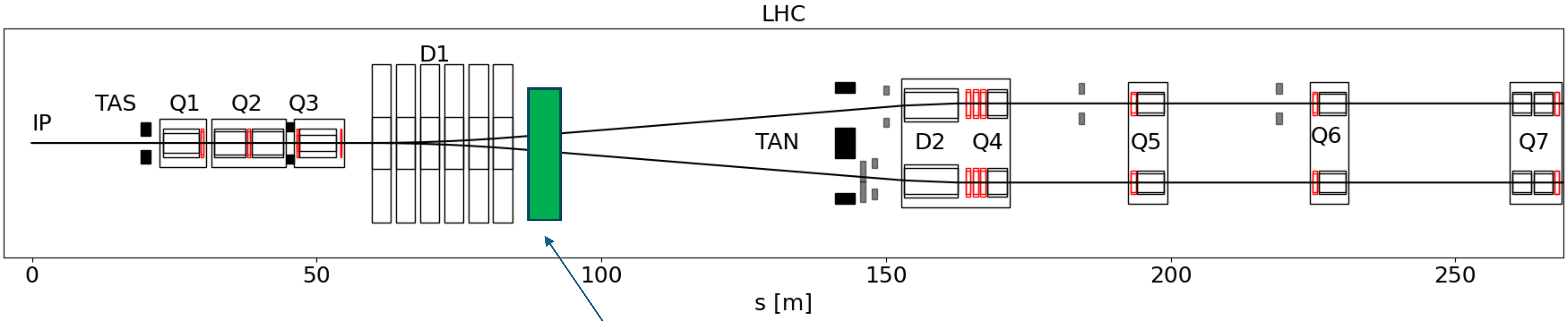
Background/Introduction

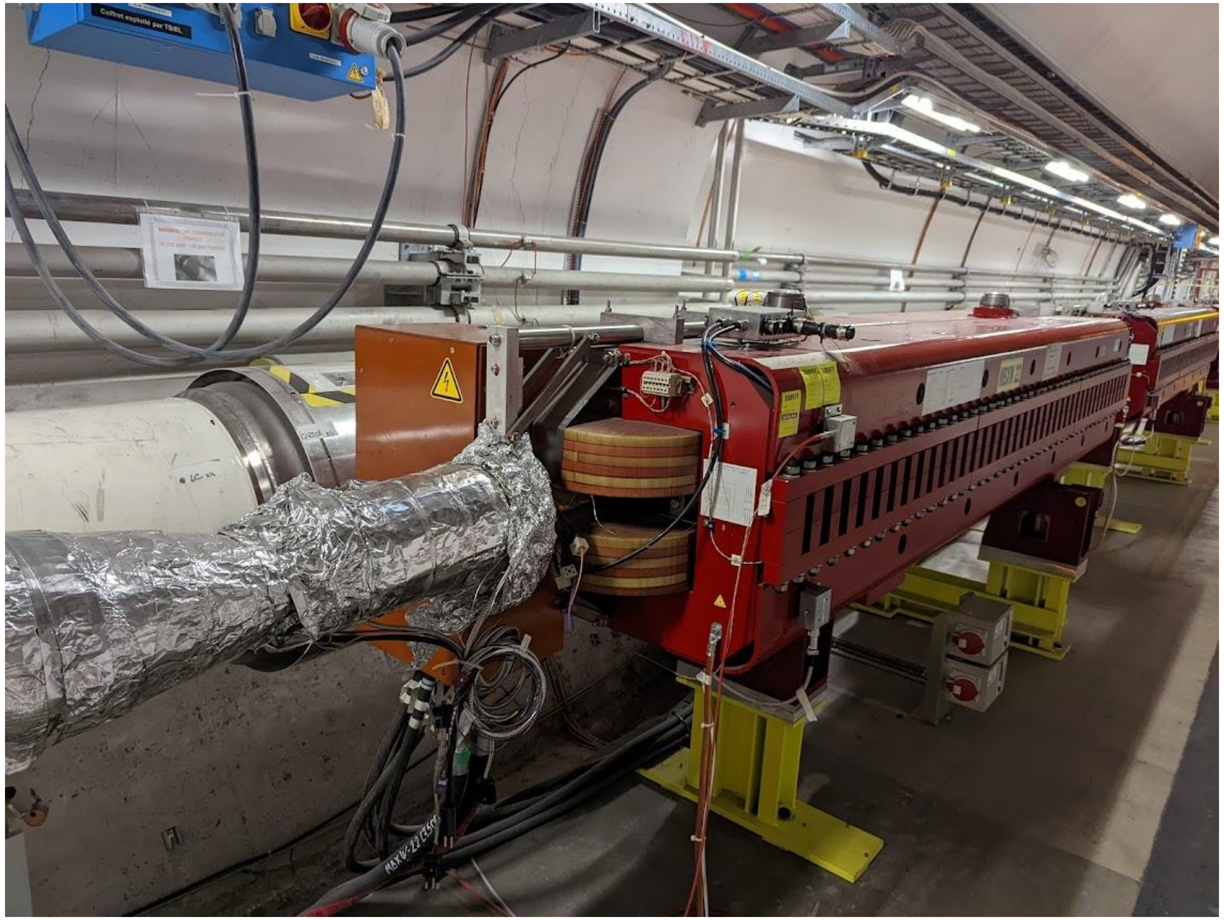
- In the LHC there is a risk that the MQSX will start failing due to radiation
  - We have studied several options to replace it with a warm skew quadrupole in case of failure
  - Are there any lessons we can learn from this and in general from our experience with local coupling measurements and corrections in the LHC?
- Caveat: Study not updated to HL-LHC but as you will see the main points will remain valid

LHC Triplet Task Force Report - CERN Document Server



Main proposal for the installation in the LHC in case of failure

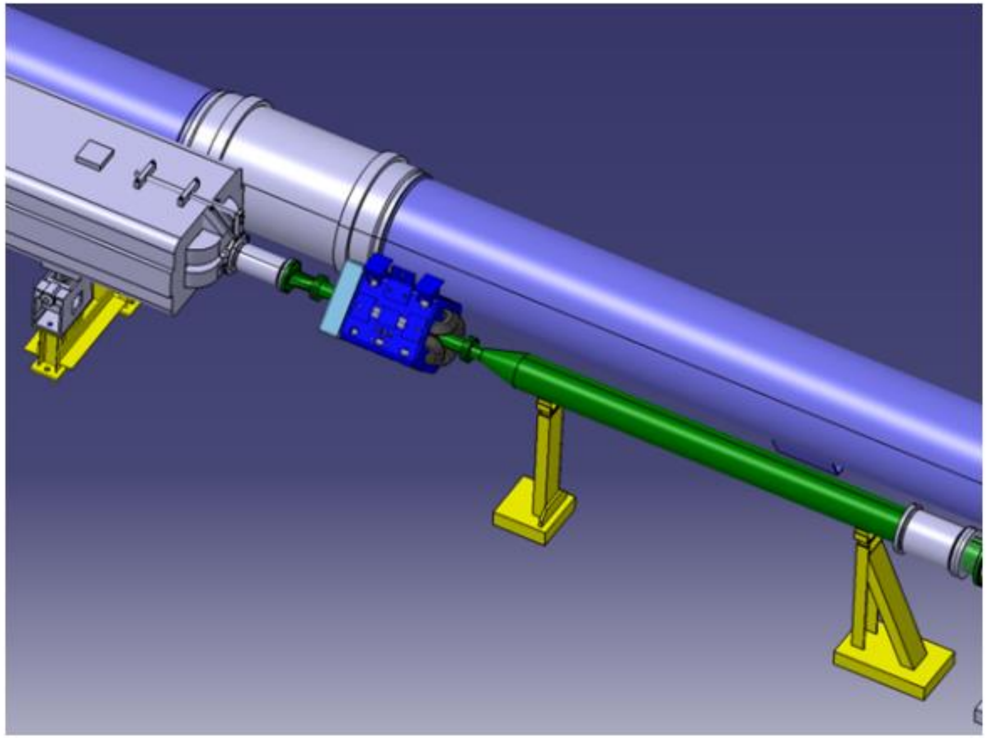
How it looks like in the tunnel



Direction of the triplet

Direction away from the triplet
The magnet could be placed close to here

Layout view



What is available? (SPLQS__NWP (LQS))

Figure 36: LQS skew-quadrupole.

Six of these magnets are currently used in the SPS **and nine spares are available**

Parameter	Value
Name	SPLQS__NWP
Family	Quadrupole
Cooling system	Water
Aperture diameter [mm]	90
Iron Length [mm]	500
Total Length [mm]	750
Total Width [mm]	550
Total Height [mm]	750
Weight [kg]	575
Peak current [A]	180
RMS current [A]	180
Resistance at 20 °C [mΩ]	198
Inductance at 20 Hz [mH]	75
Power [kW]	6.4
Nominal ΔP [bar]	10
Nominal ΔT [°C]	28
Integrated gradient at Peak Current [T]	7.07

Table 16: LQS main characteristics.

Could this solution be used for HL?

- The phase advance between the MQSX and the MQWSX is very small
  - Makes it ideal to replace the MQSX but not to find a combination with a MQSX like magnet to compensate both beam1 and beam2
- Also, I haven't checked layout here nor aperture, but I think it can anyway be excluded on the main fact that it has the same issue as the MQSX

How strong is the error in D2?

MBRD length: 7.78 m
a2: +-6 units - K1SL (K1SL / L):
+**-2.3e-05 m^-1** (-3.0e-06 m^-2) (from Josch)

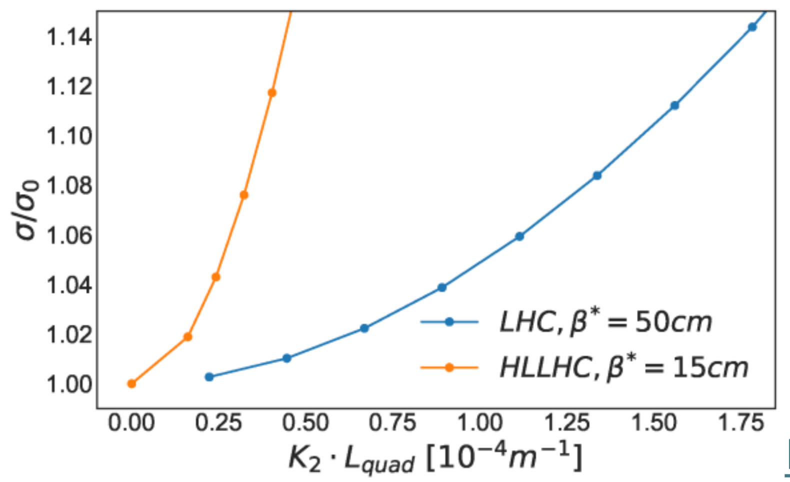
l.MQSX := 0.223;

K1SL m-1	Ratio-to-D2 error
2.5e-4	11

This corresponds for 7TeV to an integrated gradient of **0.54T**

IR	Circuit	K_{1S} $[10^{-4}\,\mathrm{m}^{-2}]$		
		2016-2018 [184]	2022 SbS	2022 RWS
IR1	RQXS.3L1	11	8	11.5
	RQXS.3R1	7	7	3.5
IR5	RQXS.3L5	7	6	4
	RQXS.3R5	7	6	8

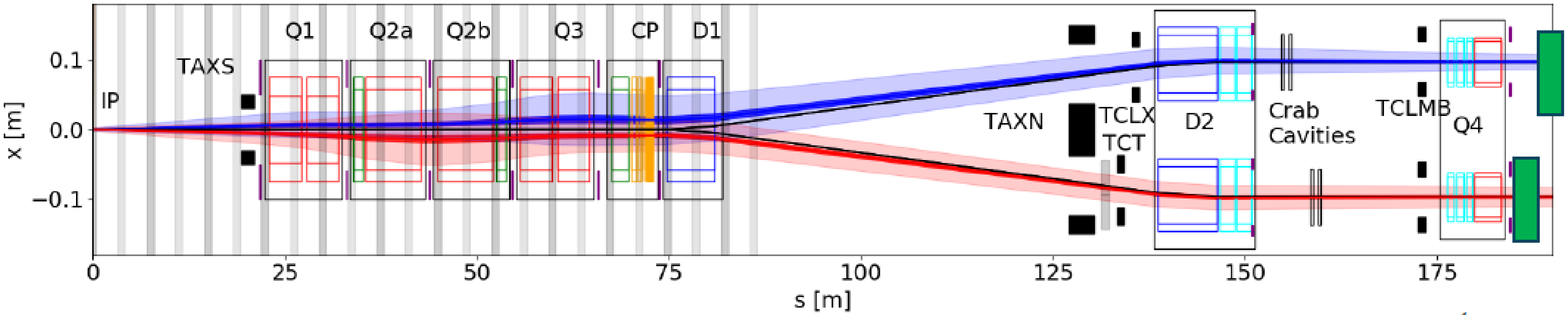
TABLE 4.7: Final values of local IR skew quadrupole correctors powering at the two main LHC experiments, as determined with segment-by-segment (middle), compared to the values used in the LHC Run 2 (left) and the values after RWS adjustments (right).



F. Soubelet

The effect corresponds to roughly 1e-4 in the MQSX but of course the sqrt(betx*bety) is also significant smaller at this location
It will have a significant impact on the global coupling but more limited on the local beam size

If one were to install the warm skew quadrupole?



- At the moment we don't fully know how much is coming from the triplet
  - Some indications from Rigid Waist Shift tests that the MQSXs might not compensate perfectly for both beams

At the q4 looking away from the IR

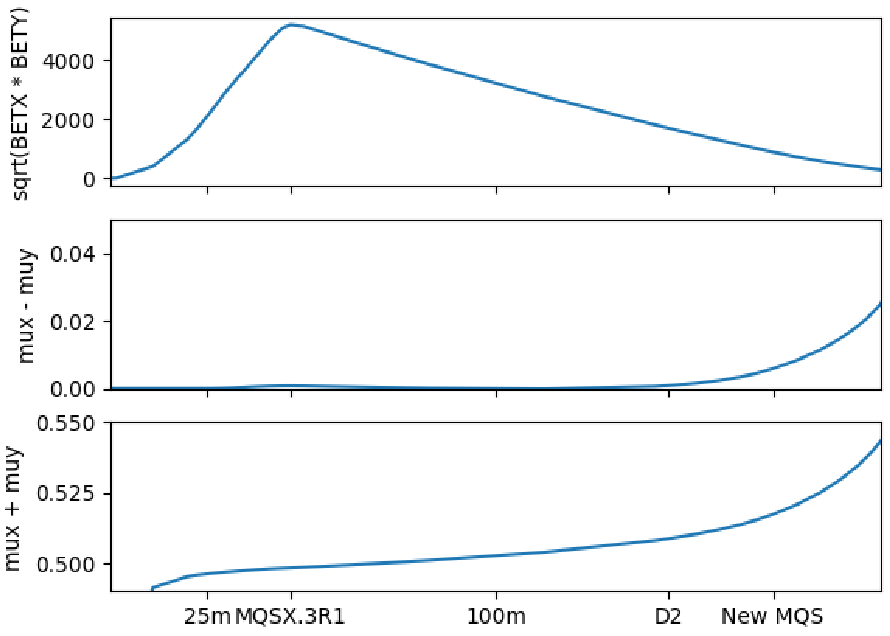
194 mm from centre to centre

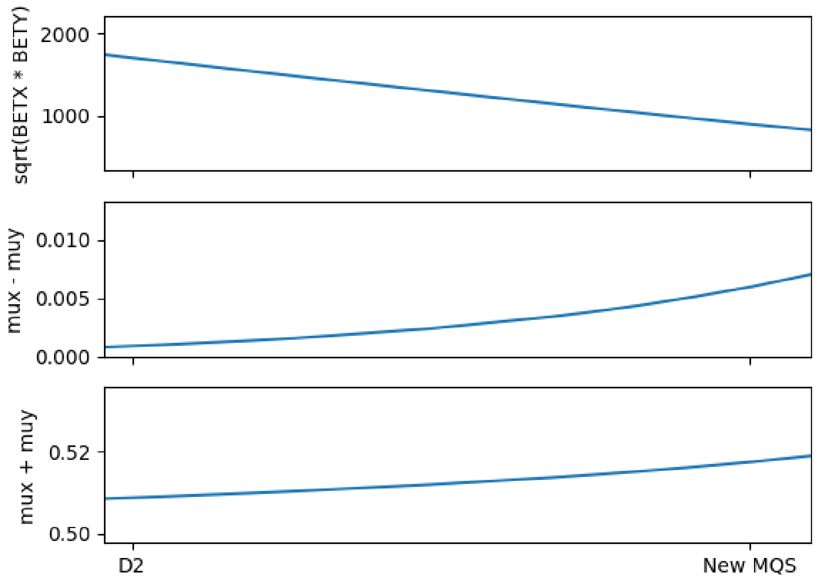
84 mm 84 mm

It is rather tight between the two beams not sure the skew quadrupole could fit easily. -> Would need to be studied in case we choose to continue with this approach.

Beta and phase advance

OBS! LHC optics for 30 cm!! Not HL!!





The sum and difference phase advance is small between the locations.

The beta-functions changes but we have a factor ~12 more in strength than needed -> the beta functions can be a factor 12 lower

Summary and outlook

- The strategy to replace the MQSX foreseen for the LHC is not suitable for the correction of the D2
- The spare skew magnets could be used
  - Would provide additional flexibility for local coupling corrections in general
  - We would use 8/9 spares.
  - The option of installing it in a single beam could also be explored considering that one could then correct everything for the other beam using the MQSX and the rest with the new warm MQS
    - Would only require 4 in that case
- The error is significant but still small if compared to what we correct in the LHC using the MQSXs