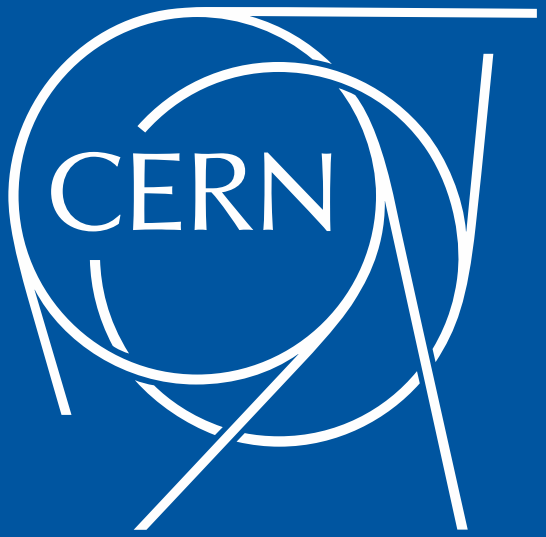
CERN

# MPP#131

# Vertical orbit kicks due to quench heater firing in main dipoles after beam induced and training quenches. Study of worst case magnets

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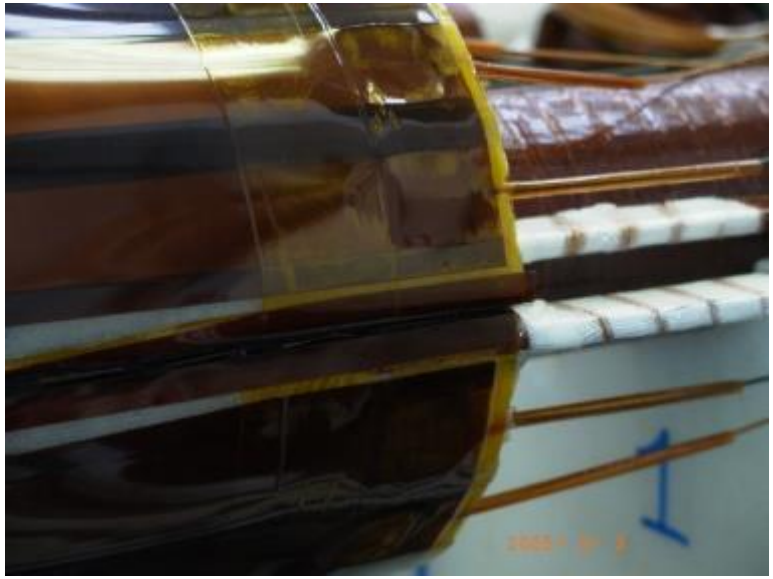
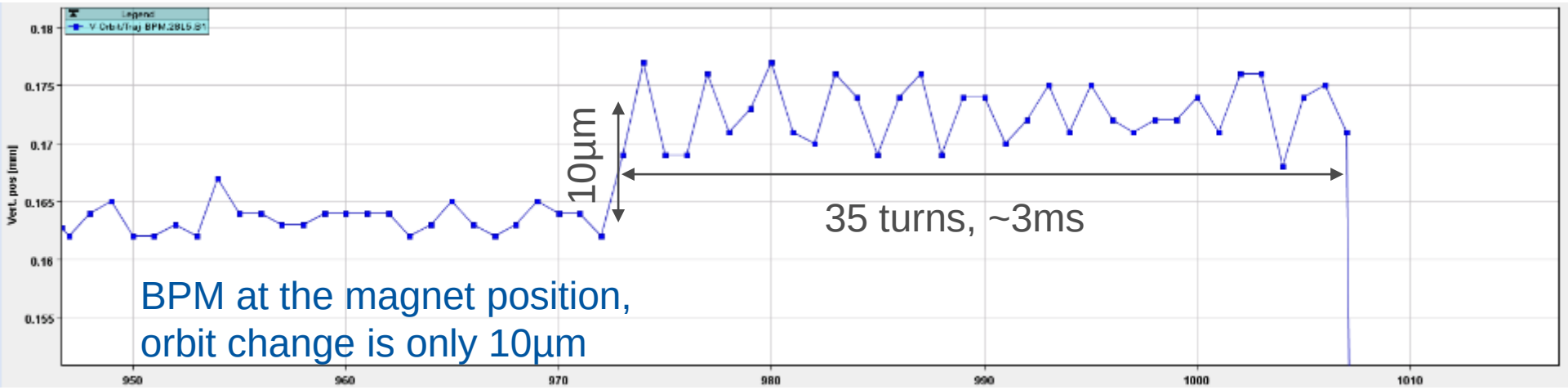
# Description

- The Quench Heaters (QH) are installed in the superconducting magnets cryostat.
- They allow quenching a larger portion of the cold mass to dissipate energy in a large volume and protect the magnet.
- The QPs detects the quench, fires the QH, triggers a FPA and opens the BIS loop.



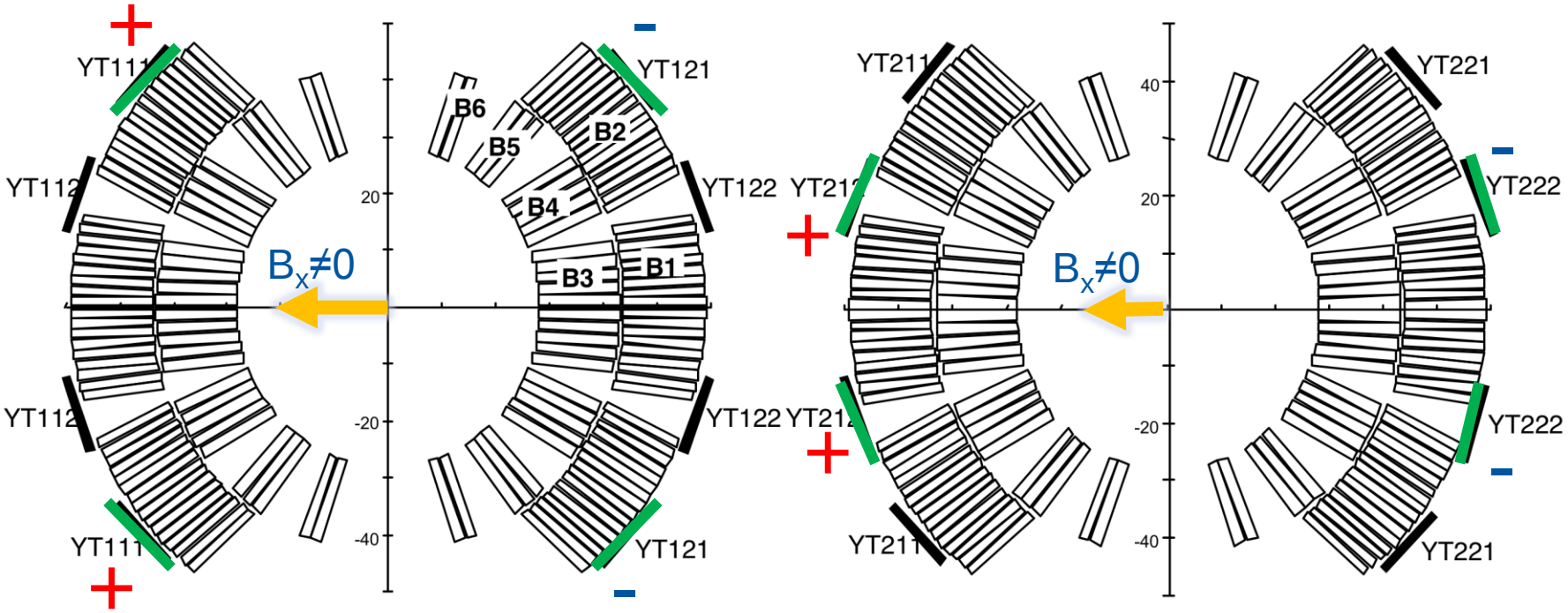
# Data from July the 12th

- During a luminosity fill, a beam induced quench happened on MB.C28L5 after nearly 14h in Stable Beams.
- The beams were dumped correctly, triggered by the QPS via the PIC and the BIC.
- An orbit oscillation of about 40µm (0.1$\sigma$) was observed around the ring, similarly to other QH firing occurrences.
- The beam stayed in the machine for about 3ms, with current in the QH before being dumped:



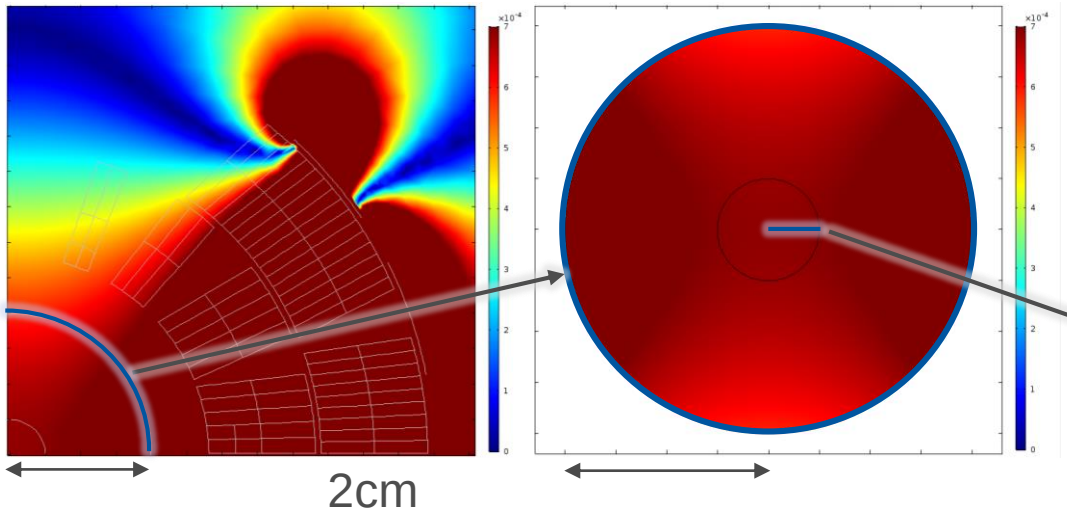
# Connection scheme

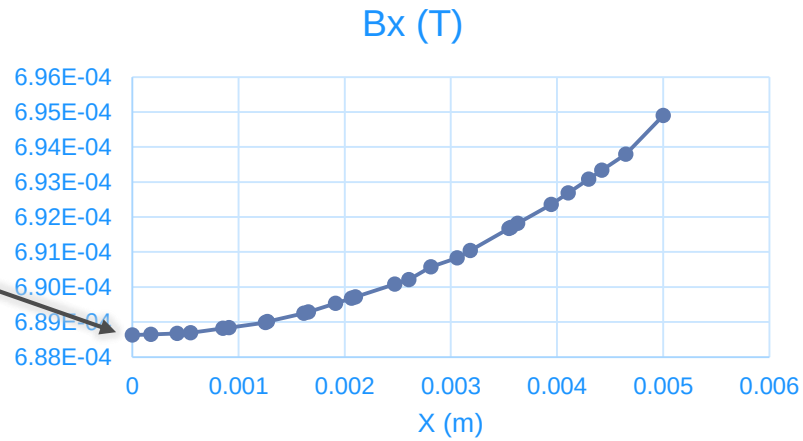
- To avoid coupling with the MB magnetic field the QH are connected in a skew dipole scheme.
- High field QH are more effective at quenching and used until they must be replaced by the Low Field ones.



# Induced Magnetic Field – High Field QH

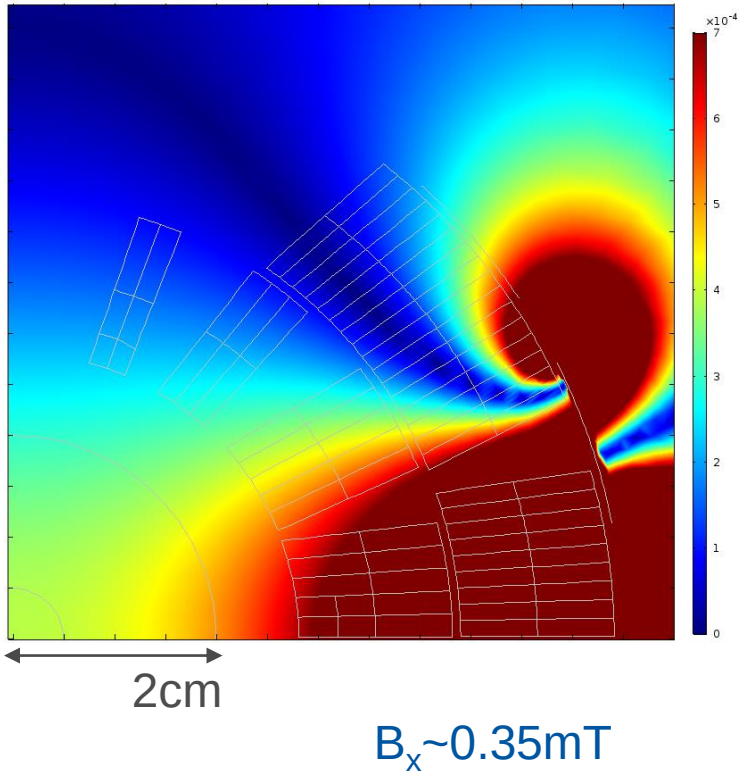
- The horizontal field reaches 0.688mT in the beam area, $B_y$ is negligible.
- There is also a small sextupole component which is neglected.



# Induced Magnetic Field – Low Field QH

- The horizontal field reaches 0.35mT in the beam area, $B_y$ is again negligible.
- This symmetrical case was simulated for convenience, it is not possible since only one of the High Field QH circuits is replaced by the Low Field one in (currently) three of the LHC MBs.
- The asymmetric case has a lower $B_x$ and a smaller $B_y$ component.

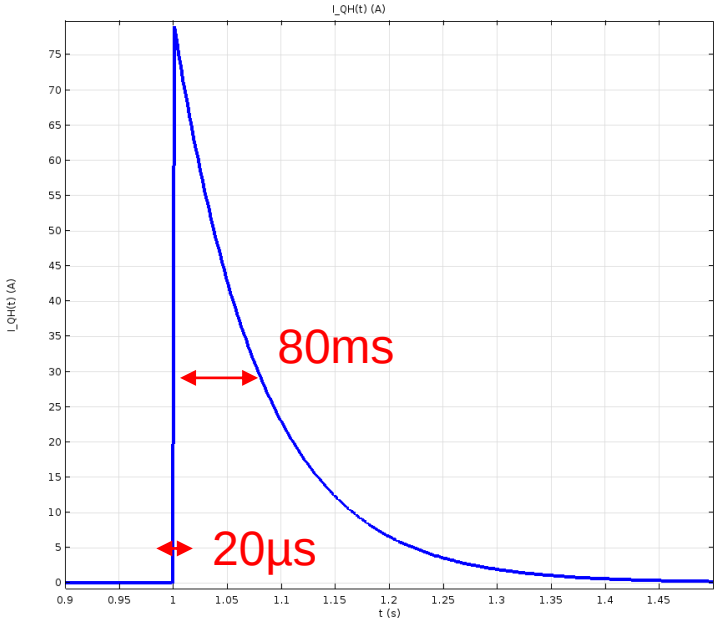



$B_x$~0.35mT

# Effect on optics

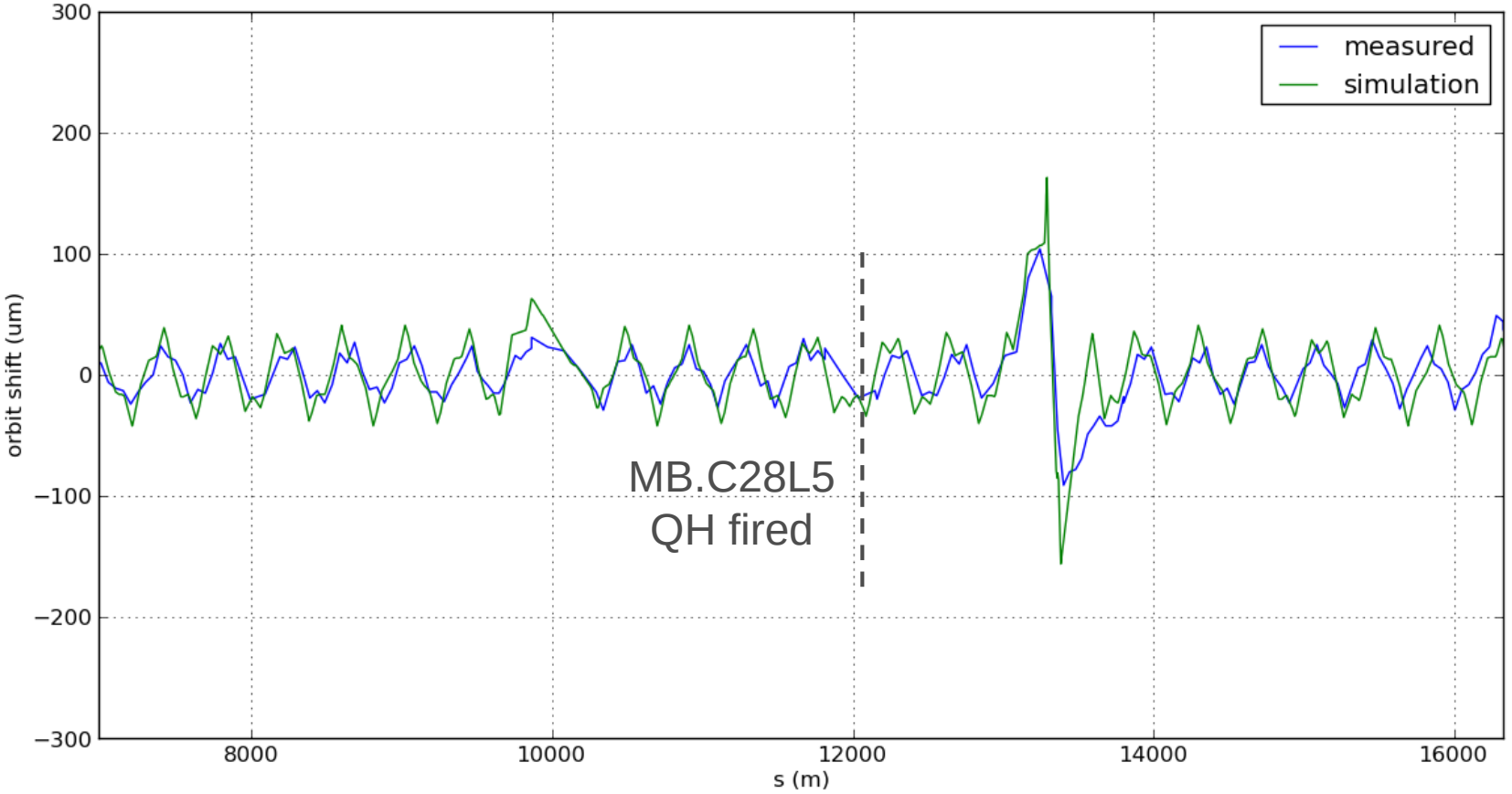
- The current settles in 20-30$\mu$s (<89$\mu$s), and decays in 80ms.
- In case of the self-triggering of a QH the delay for opening the Bis loop can be as long as 5.5ms (20 times longer than the dump delay)
- Field will be assumed to set instantly and remain constant afterwards.
- Multiple firing will not be studied here, quench propagation is much slower (100s of ms), multiple self-triggering is discarded because of reliability.

QH current decay



# Simulation of July's event

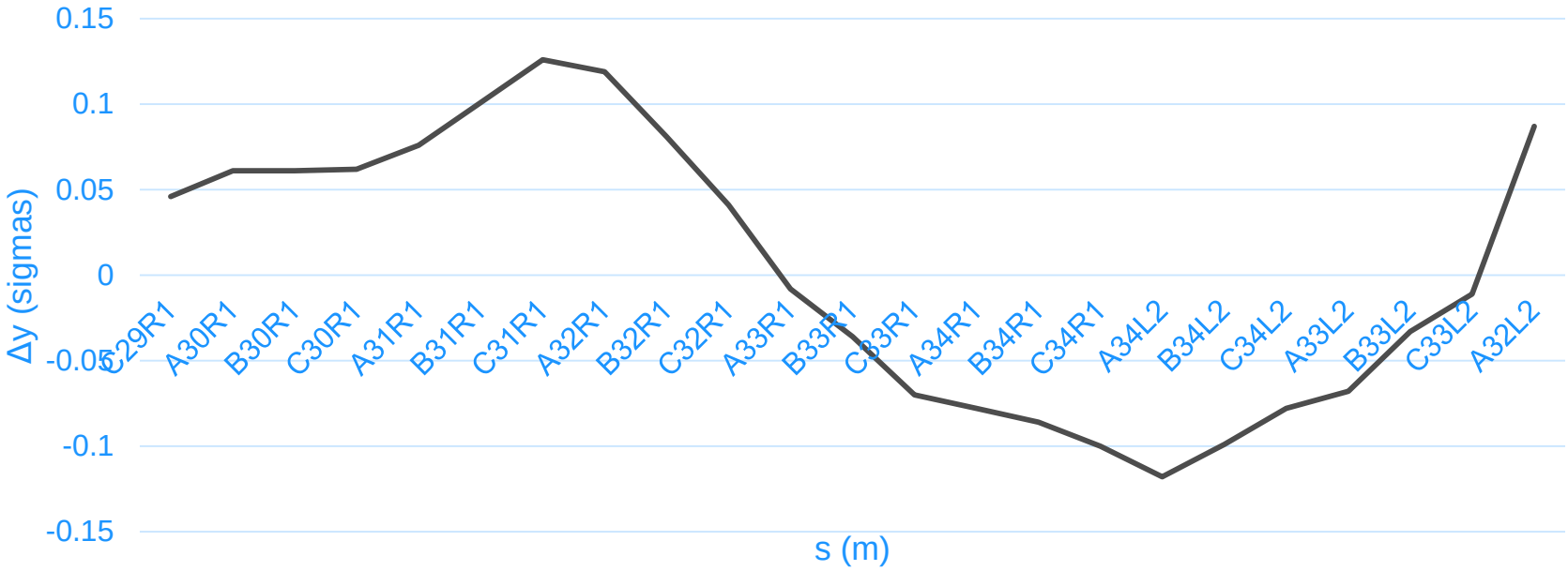
- The kick on the beam was simulated using MADX with up to date optics[1], for the 30th turn after QH firing.




[1] *opt_400_10000_400_3000_totem5.madx*

# Dependency on dipole

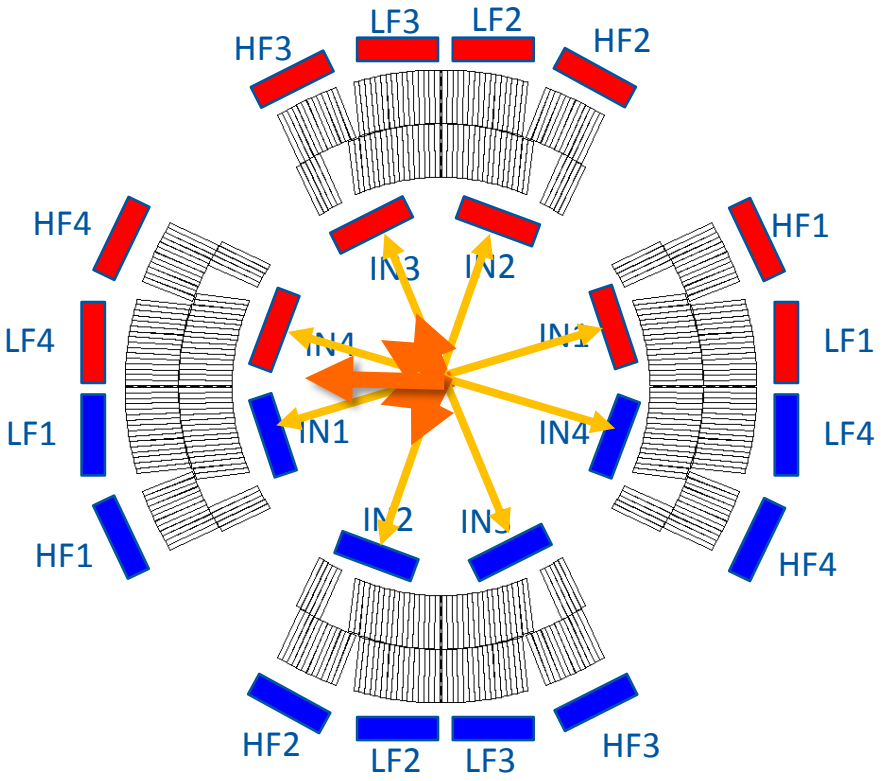
- The kick and beam displacement depends on phase advance and beta function, QH misfire for each magnet of a betatron period were simulated.
- Losses will be first seen at the aperture bottleneck in the vertical plane, resulting beam displacements are shown for the vertical collimator in IP7 position: TCP.D6L7.B1



# Conclusion & Outlook

- The Quench Heaters are confirmed to be the source of the orbit oscillation observed.
- The kick observed and simulated is not worrying, independently of the magnet.
- The connection scheme on Quench Heaters in the MQ, IPQ and triplet is different.
  - MQs and IPQs have small magnetic length.
  - All QH in the triplet are fired at the same time.
- For the Hi-Lumi large-aperture triplet, SC D1 and D2, the QH are numerous and the baseline connection scheme is unfavourable:
- Other protection methods such as CLIQ will have an effect on the beam, to be followed up …

Resulting field is only shown for inner circuits.

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