Investigation of shielding effect from the Beam screen on Quench Heater discharge

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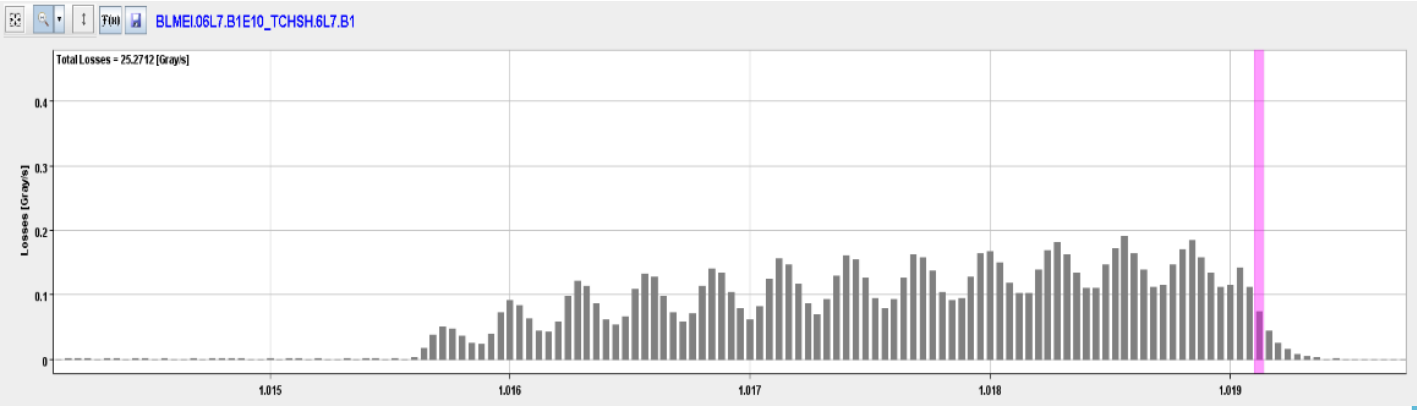
CERN

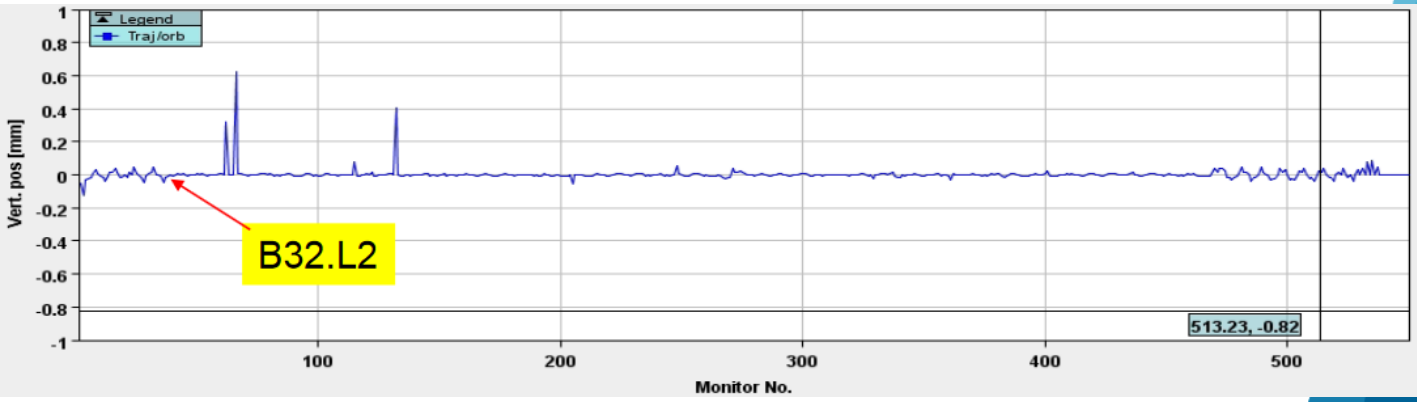
PE section meeting – 5 April 2018

Some history (1)

- 9th May, Rudiger finds a strange loss pattern following a UFO induced quench

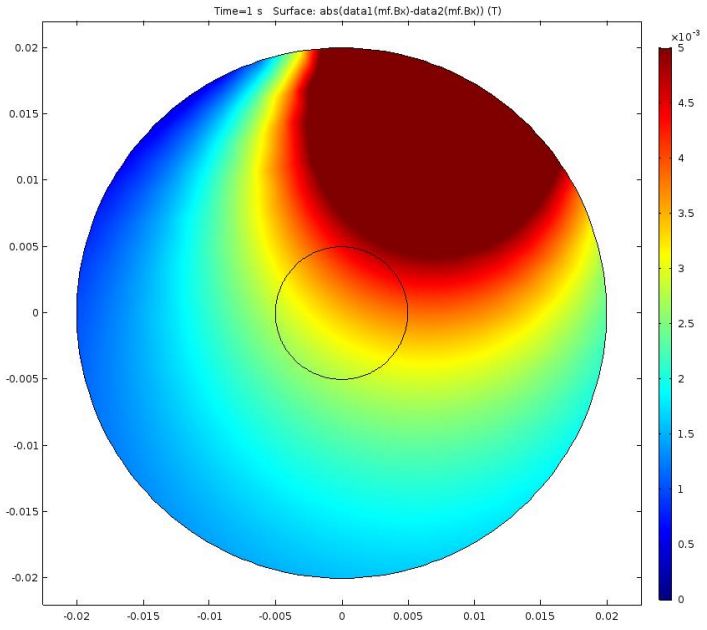


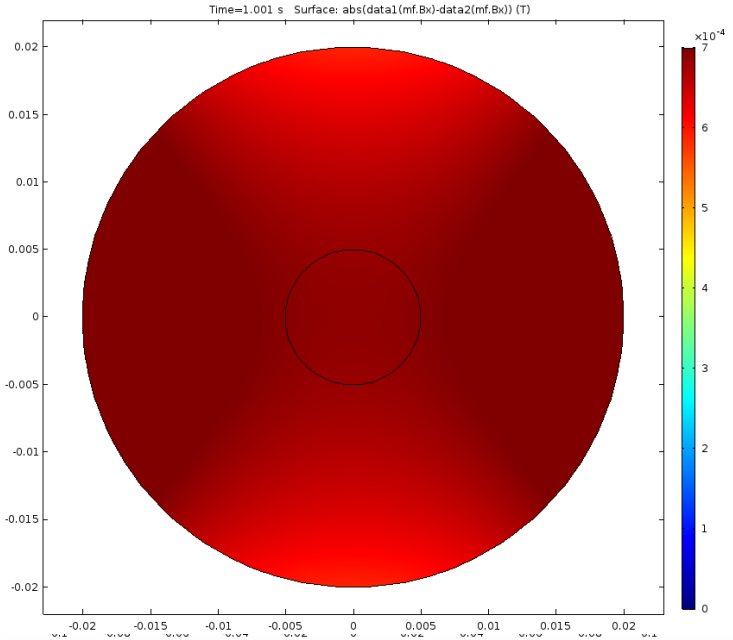
- There is an orbit shift starting from the said magnet, ~0.7 mT



Some history (2)

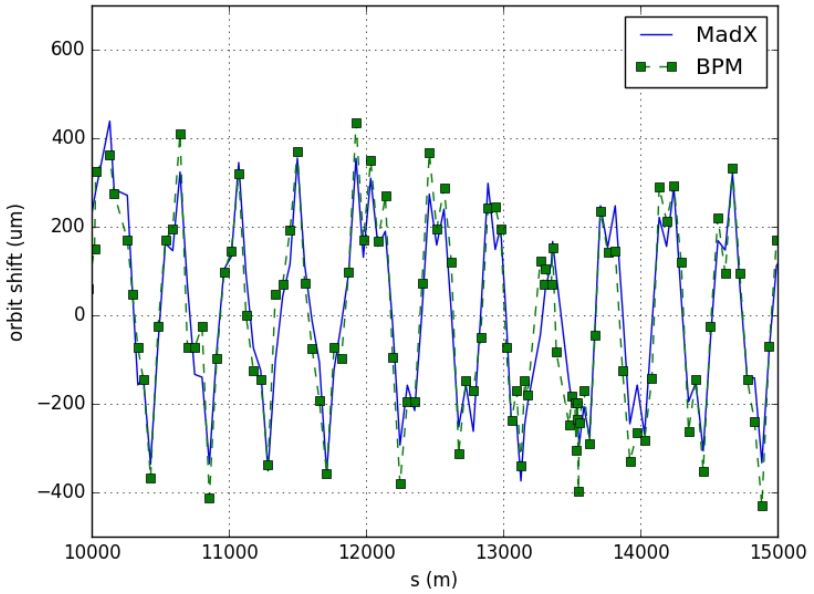
- Lorenzo runs some simulations.
  - Current distribution is too slow and the field change would be too large (5 mT).
  - The Quench Heater discharge is a perfect candidate.



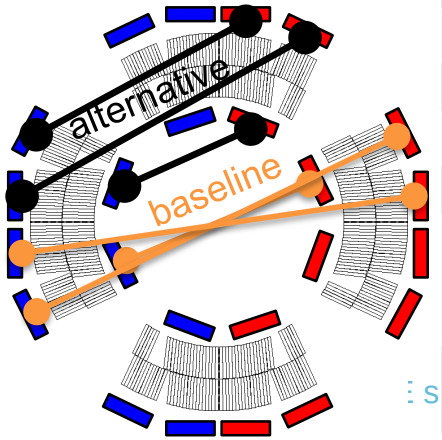


Some history (3)

- A MadX simulation and MD later …
- A perfect fit !



- Which in leads to a full evaluation of QH kicks and new connection schemes

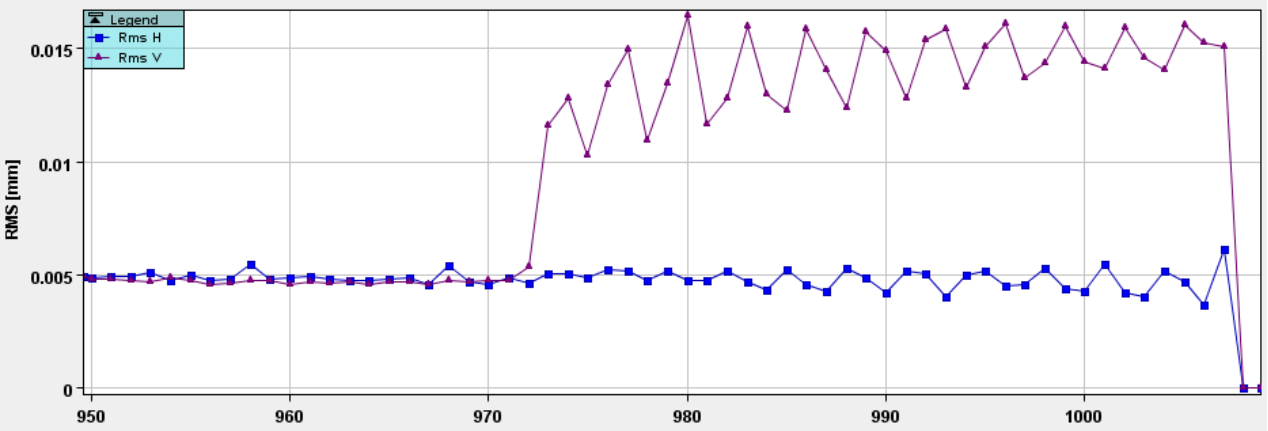


Magnet	BL (T.m)	β (m)	kick (σ)
MB	0.01	420	0.49
MQ	0.002	575	0.15
D1	**0.008**	**18 km**	**1.98**
D2	**0.0125**	**5.8km**	**2.44**
11T	0.02	144	0.42
Triplet w/out IL	**0.11**	**4.5km - 21km**	**28.8**
Triplet with IL	**0.20**		**52.0**

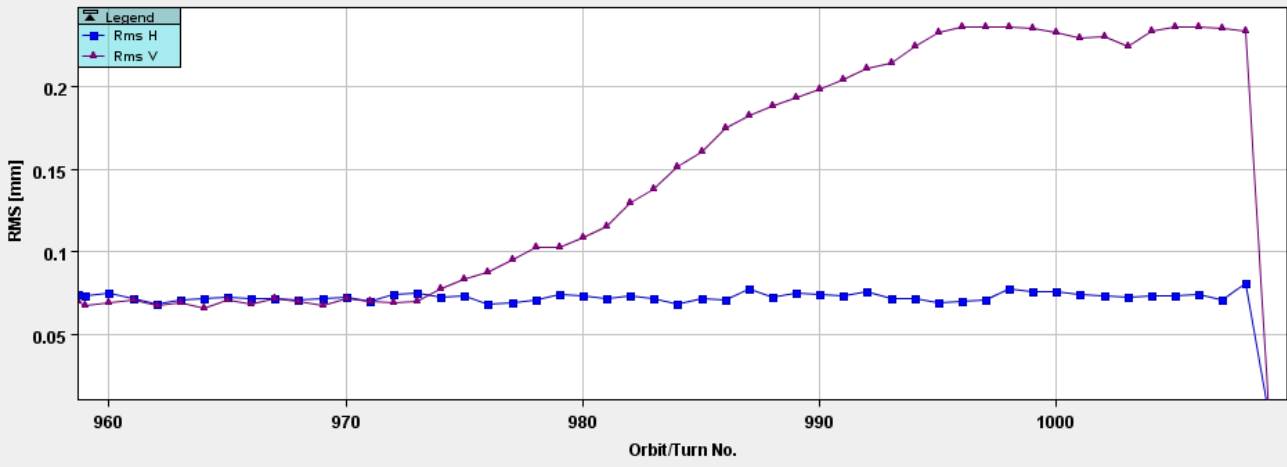
Some history (4)

- Mission accomplished ? Not yet !

- Rudiger's event:

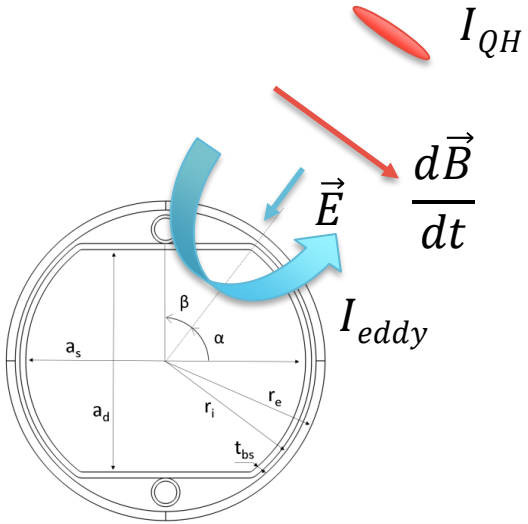


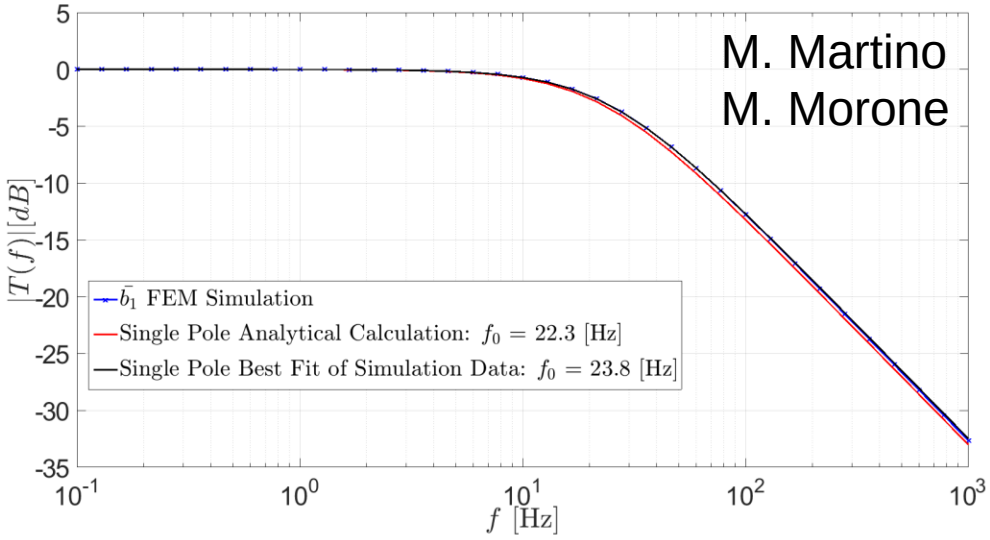
- Matthieu's event:



Beam screen shielding

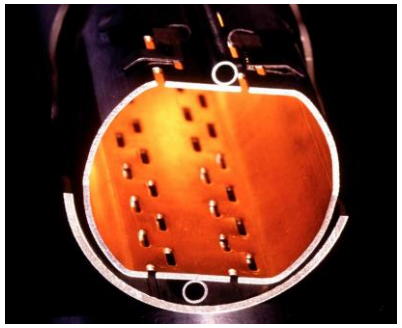
- The copper beam screen should shield the beam from such fast effects.
- 25 µs rise time vs 23 Hz cutoff frequency
  (43 ms response to a step function)





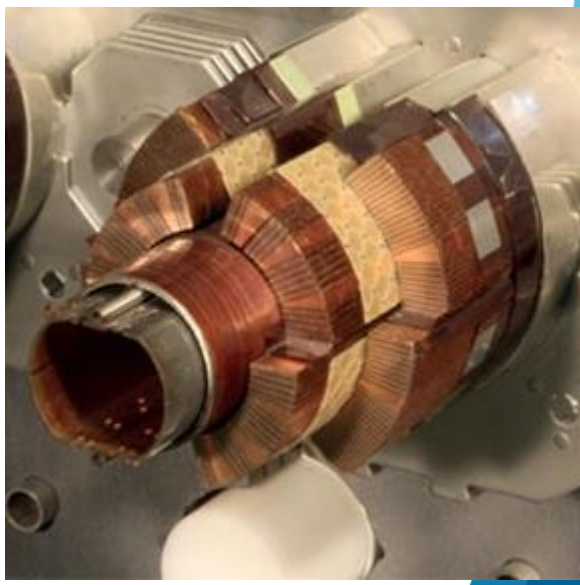
(a) LHC Main Dipoles at 20 K

Investigation



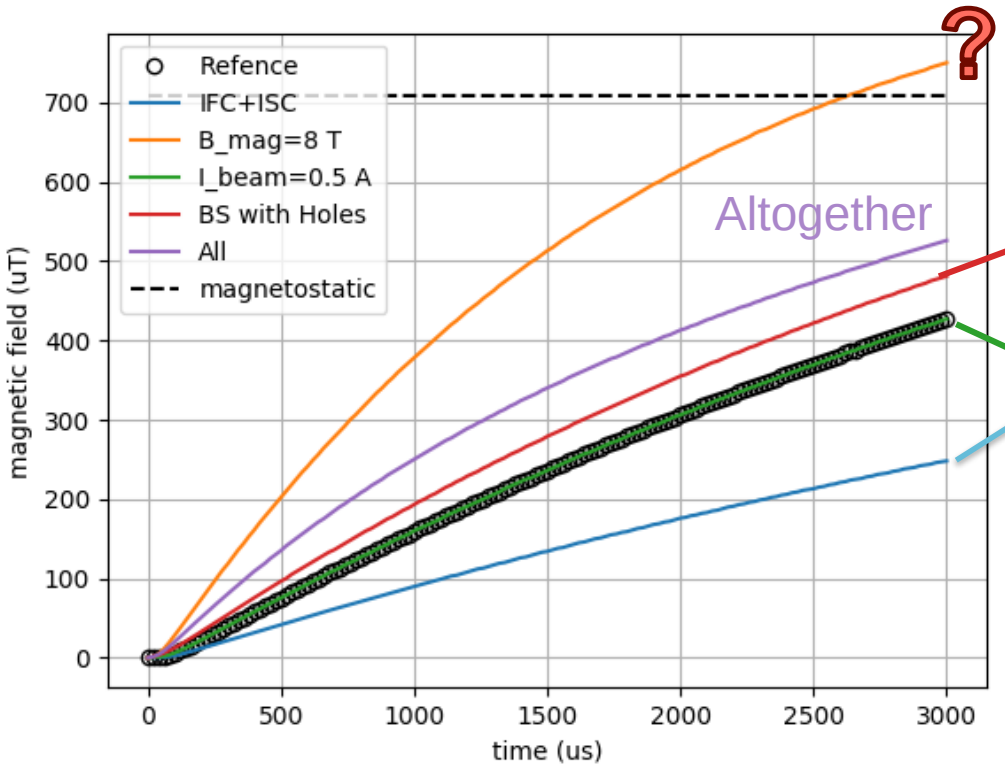
- Potential suspects:
  - Holes in the Beam Screen
  - Copper magneto resistivity $\rho = \rho(T) + \alpha.B$
  - Beam image currents (only 0.5 A)
  - Image currents from the ramp (short timescales)

- Potential counter-effects also not taken into account previously:
  - Shielding from the superconductor and the coil

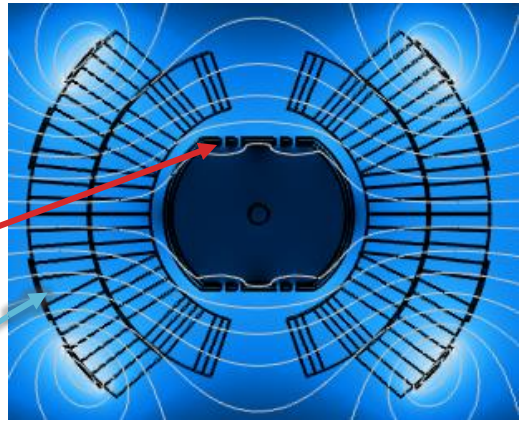


Simulations (2)

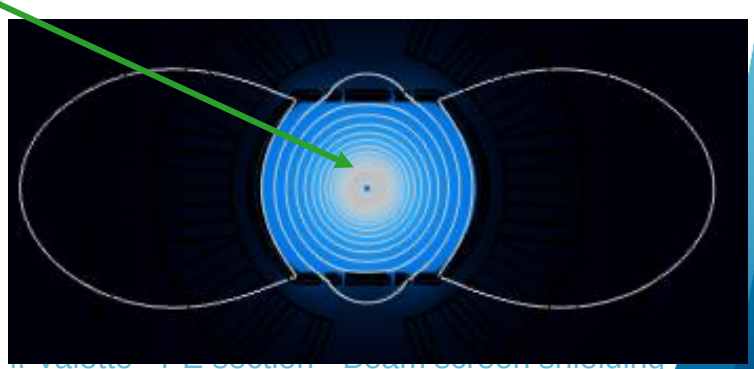
- CONSOL™ simulations redone by adding parameters one by one to the reference case then all together in time domain:



T=1 ms



T=0 ms



Reconstruction of the kick

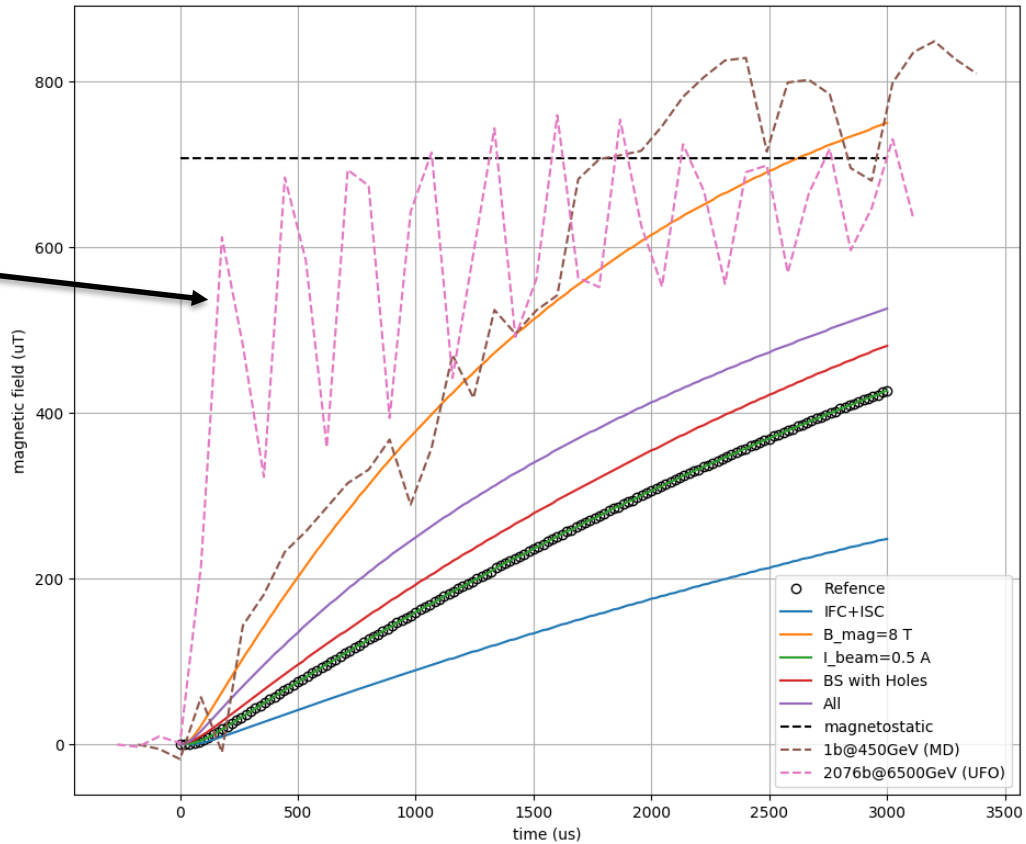
- The magnetic field is reconstructed using the following formula:

$$\Delta y(s) = \frac{\sqrt{\beta(s)\beta(s_0)}}{2 * \sin(\pi Q_y)} \frac{B_x L_{MB}}{B\rho} \cos(\pi Q_y - 2\pi|\mu(s) - \mu(s_0)|)$$

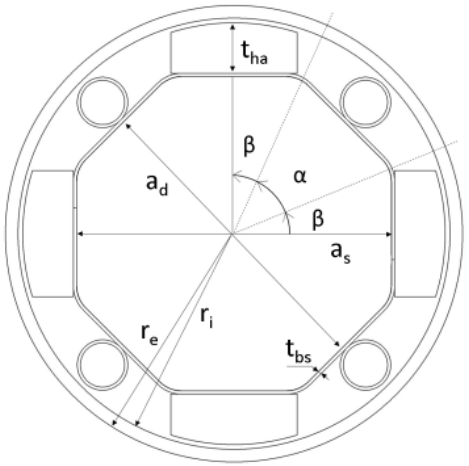
Adiabatic kick assumption so the fast-ramping kick is affected by the 3-turn vertical tune of the LHC

Что делать?

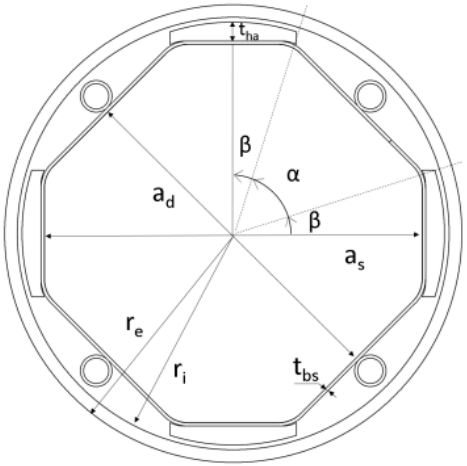
What can explain such fast ramps ?
Any magnet experts in the room ?



HL-LHC magnets



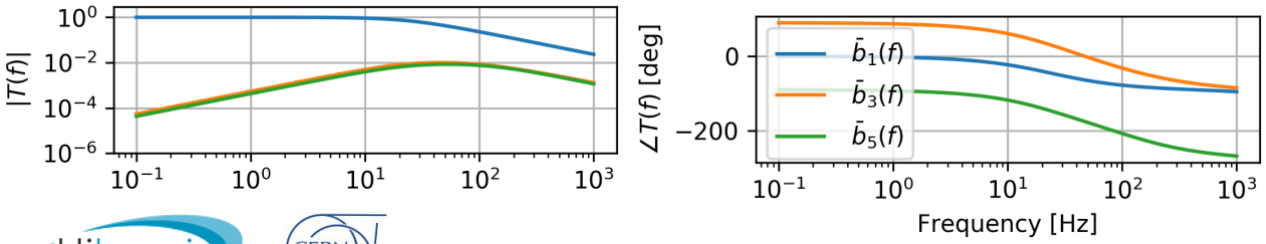
(a) Q1 beam screen cross section.



(b) Q2-Q3-D1 beam screen cross section.

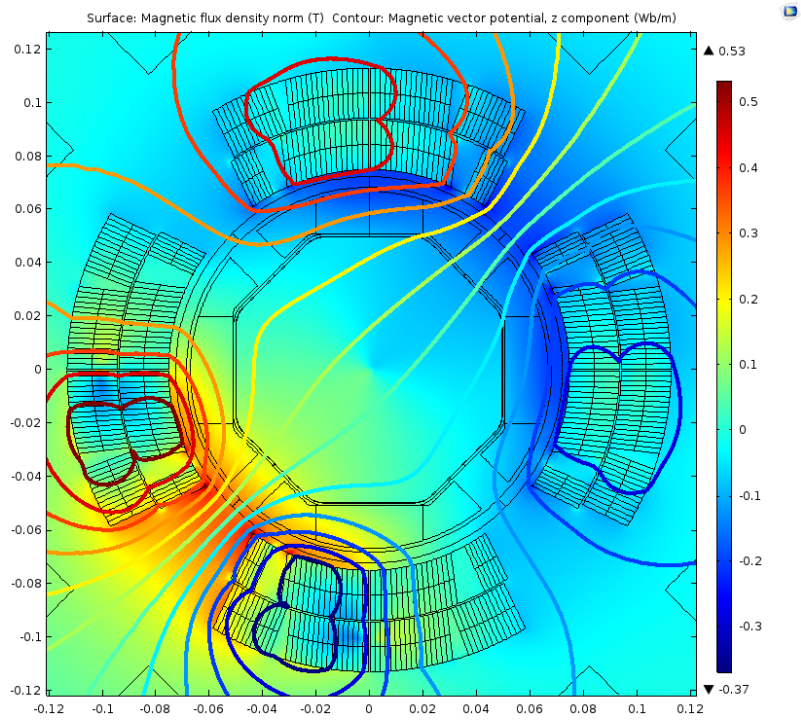
- Back to the initial problematic, some HL-LHC magnets will be protected by 24 QH strips powered with 200 A and have a beam screen with similar designs.
- Can we rely on them ?

=> experiments ongoing in SM18



What about CLIQ ?

- The CLIQ discharge Simulations already account for CLIQ.

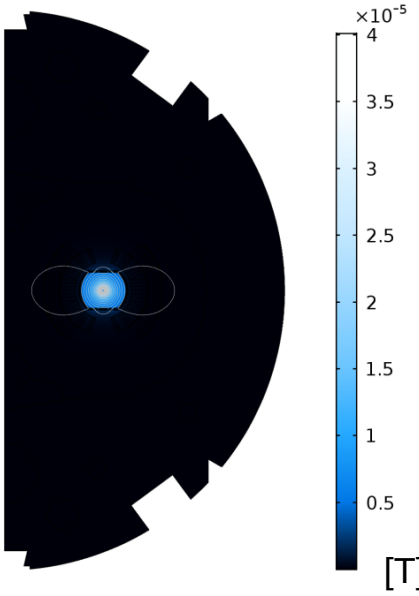


- Frequencies are much lower and should not be damped by the beam screen anyway.
  - Q1: f_{CLIQ}= 13 Hz , f^0_{BS}=36 Hz
  - Q2: f_{CLIQ}= 21 Hz , f^0_{BS}=67 Hz
  - Q3: f_{CLIQ}= 13 Hz , f^0_{BS}=67 Hz

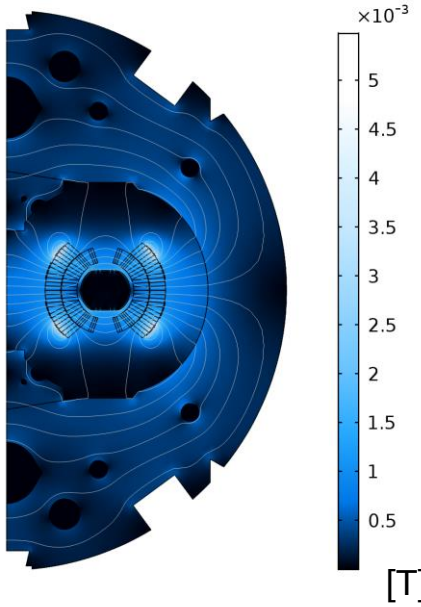
Conclusion and outlook

- Effects allowing the QH discharge to affect the beam in sub-ms timescales are not yet identified.
- They should be reproduced in simulation and in measurements on MB magnets before MQXF magnets.
- CLIQ was not a concern before and is not worse taking this effect into account.

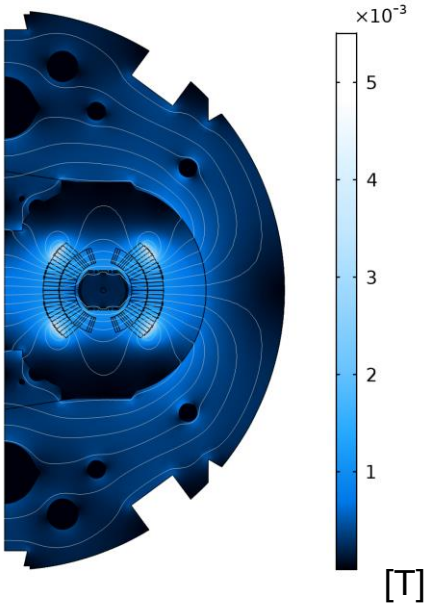
0 us



100 us

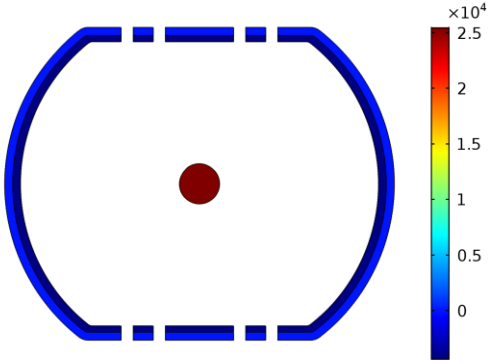


1000 us



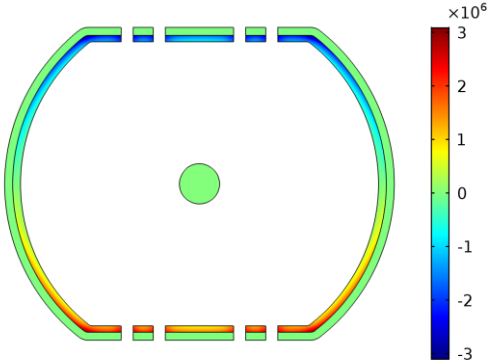
At t=0 us, the beam and the image current are balanced.
Then, the beam screen is repelling the flux lines generate by the quench heater discharge.
The holes on the BS do not affect the discharge, since the QHs create a skew dipole field.

0 us



[A/m^2]

100 us



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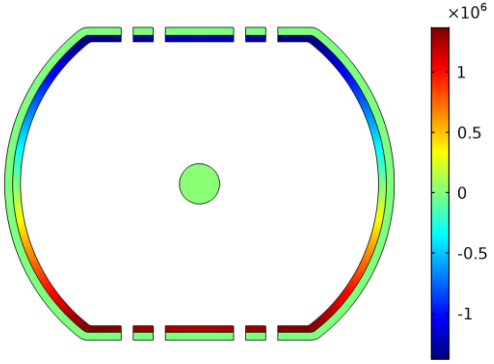
1000 us



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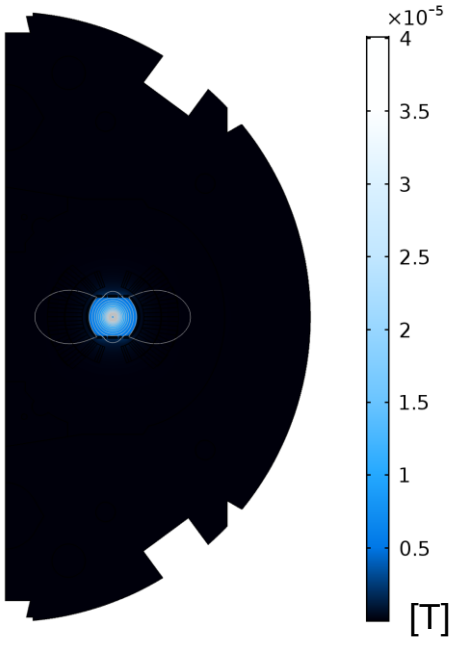
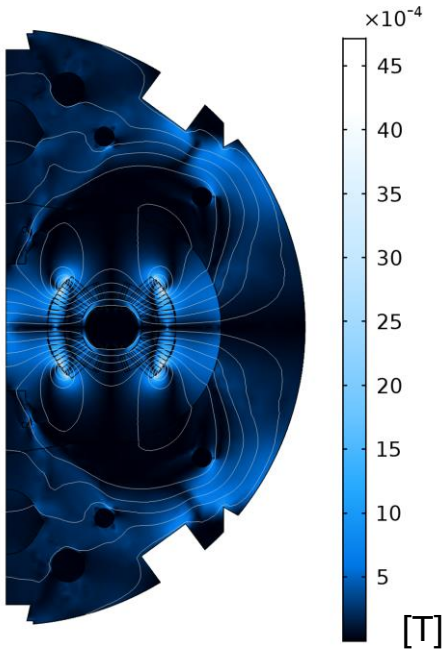
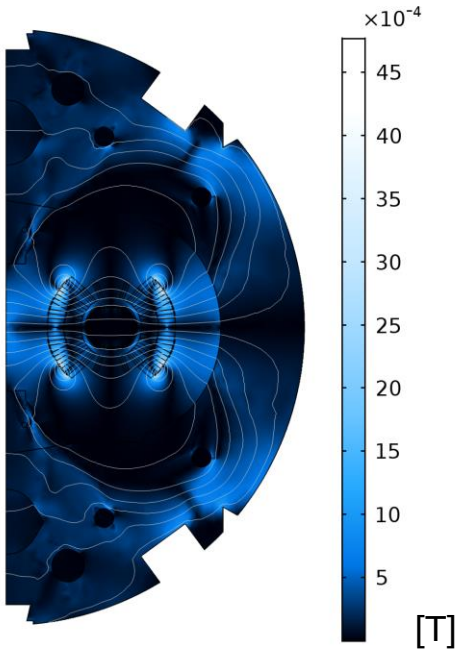


100 us



1000 us



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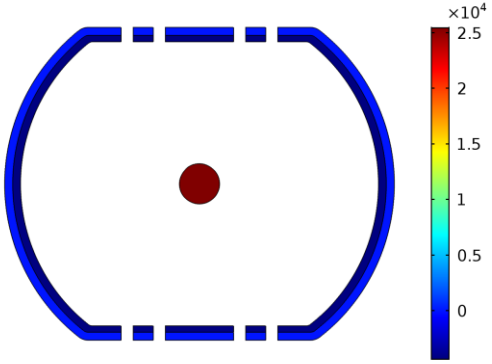
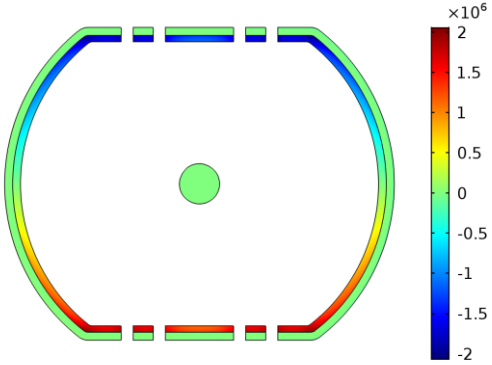


[A/m^2]

100 us



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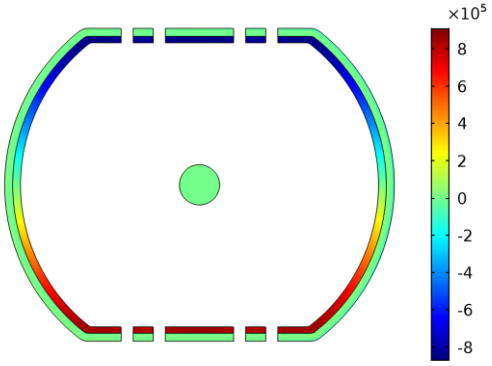

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