Risk of Halo-Induced Magnet Quenches in IR6 with HL-LHC beams

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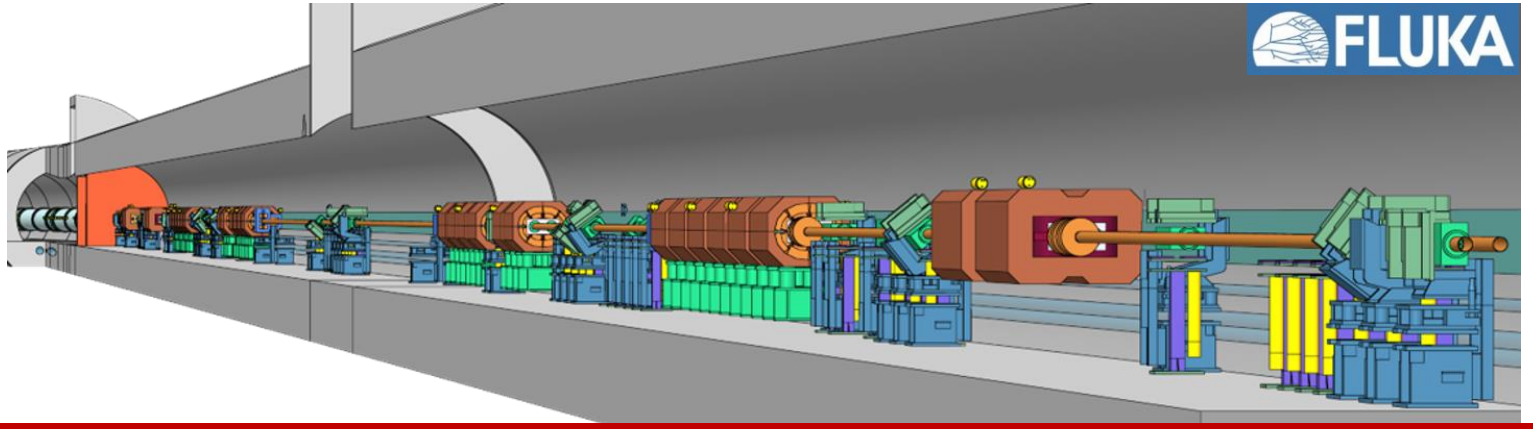
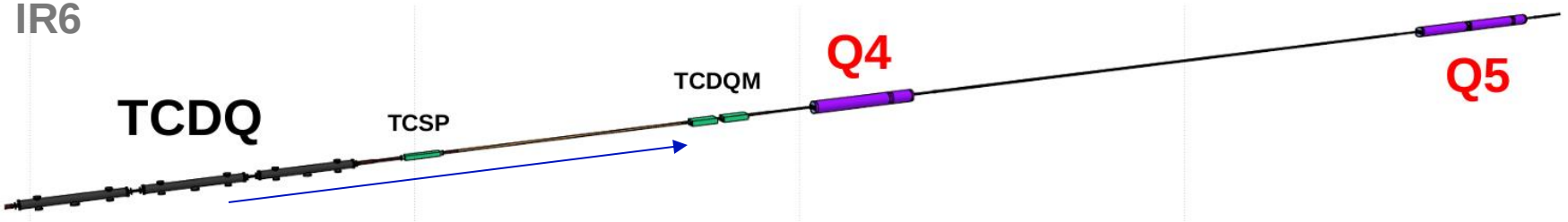
Introduction

IR7



Collimation system in IR7 intercept particles with large betatron oscillation amplitudes

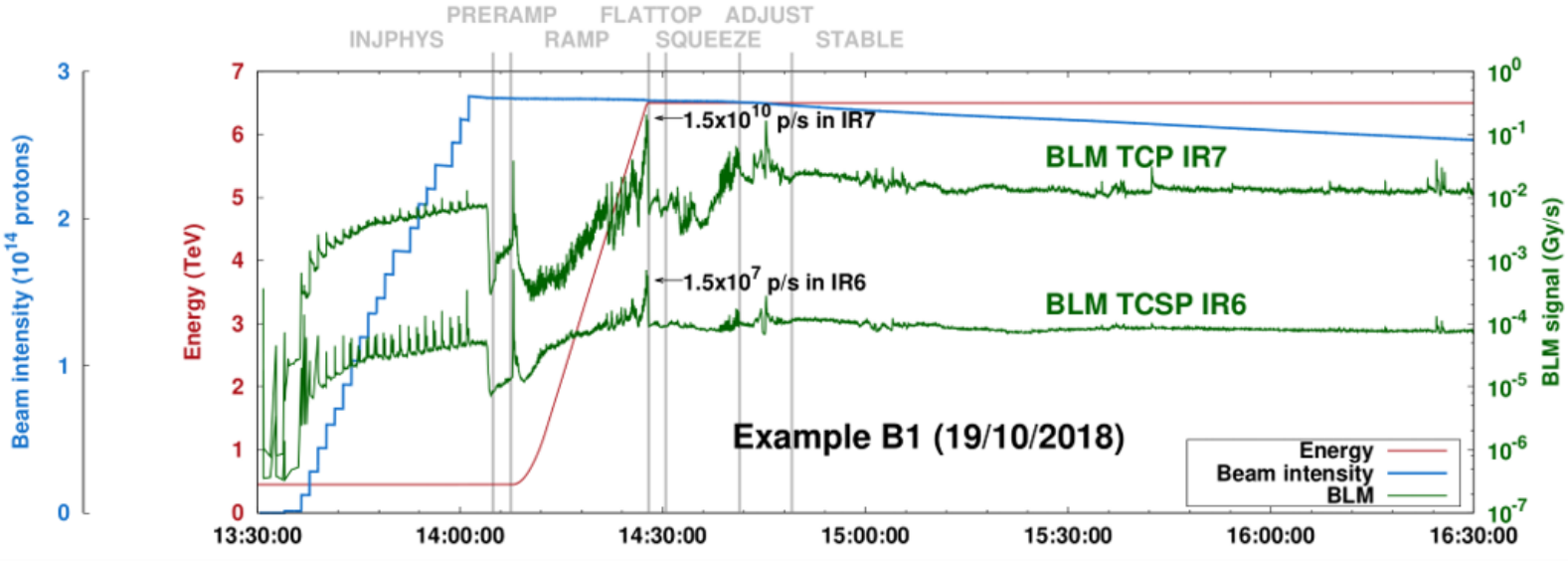
IR6



TCDQ/TCSP protect magnets in case of asynchronous beam dump, but they also intercept a fraction of halo particles scattered out of IR7

Introduction

Beam loss monitors measurements



$$\dot{N}_{IR6} = f_{IR6} \times \dot{N}^{*}$$

In this presentation, we investigate if IR7 halo leakage to IR6 might cause quenches in case of the HL-LHC worst case scenario:
8.8E11 lost protons/s

* $\dot{N}$ is the betatron loss rate, most protons are lost in IR7

Collimator settings in Run 2

Year	TCP	TCSG	TCLA	TCDQ
2015	5.5	8	14	9
2016	5.5	7.5	11	8-8.5
2017	5-5.5	6.5-7	10-10.5	7.5-7
2018	5	6.5	10	7.4

Collimator halfgap in unit of sigma (emittance of 3.75um)

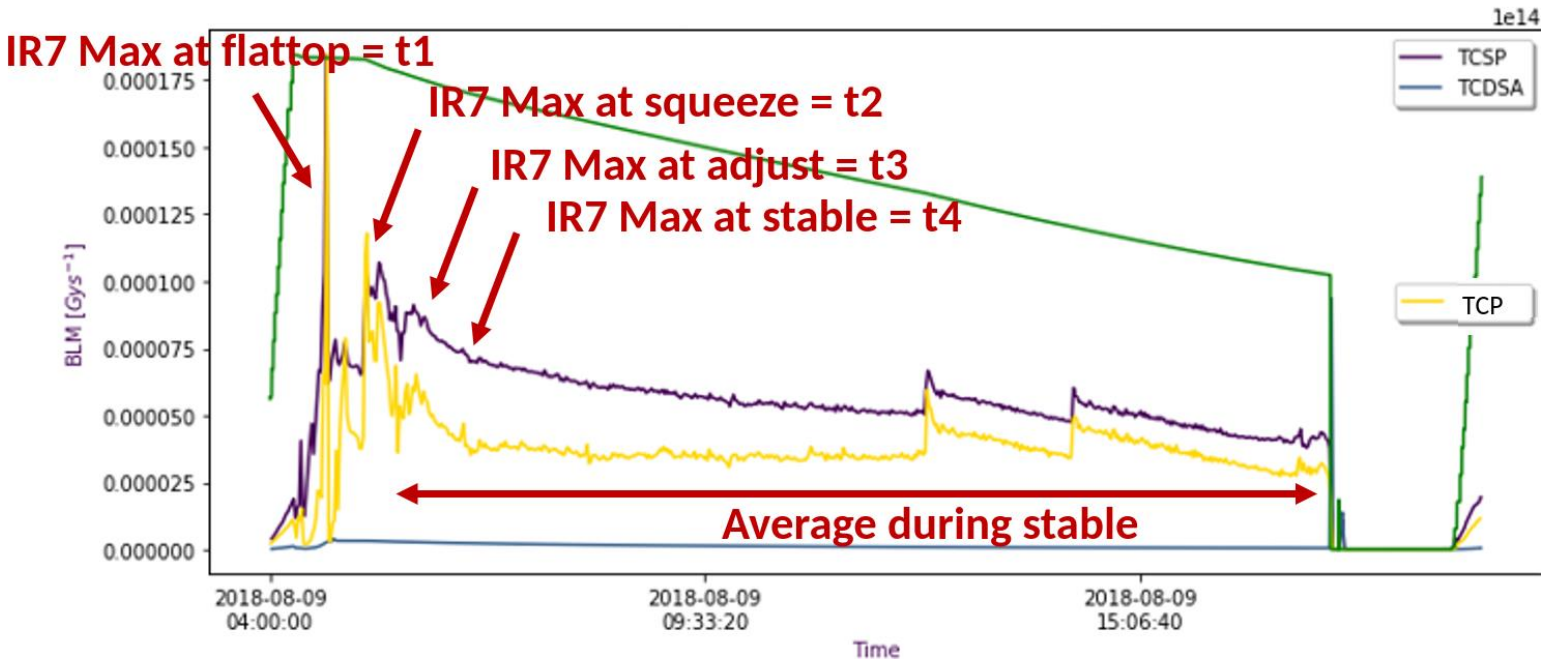
Different collimator settings every year possibly lead to different leakage ratio

Selection of lifetime dips

Methodology

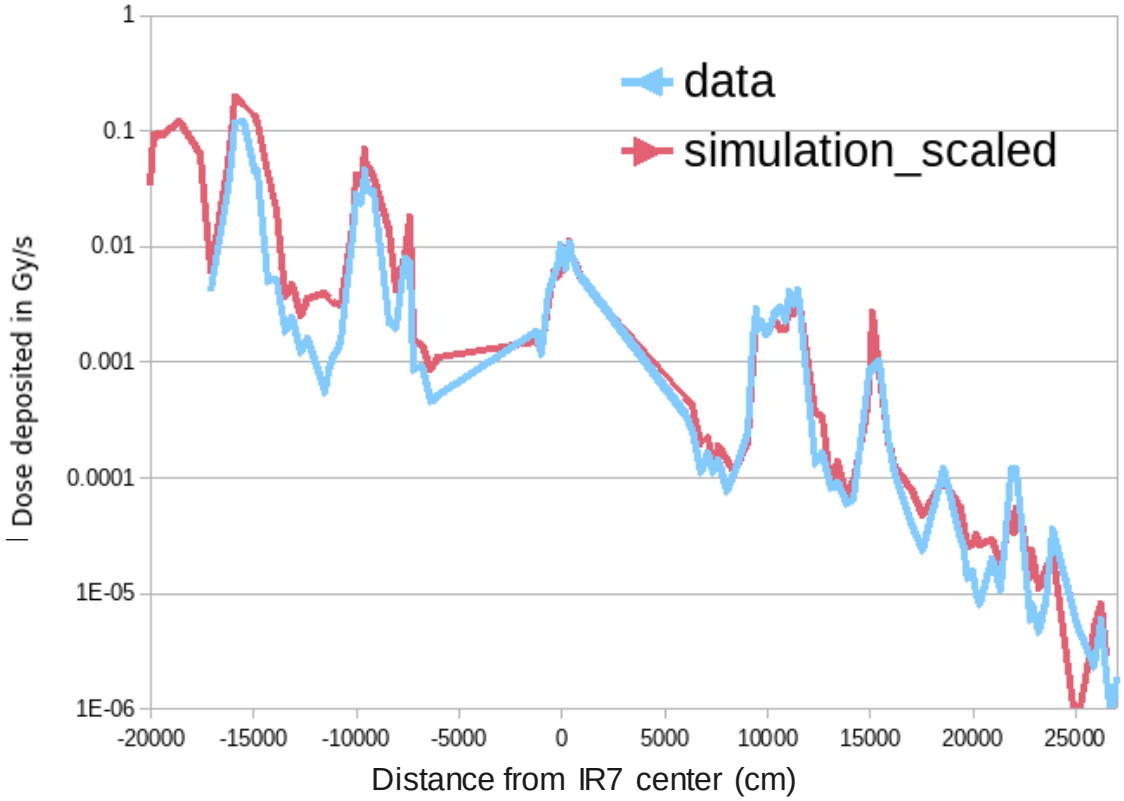
Peak Losses: RS09 (1.3sec) was used for the analysis

- Fills with high number of bunches selected for each year
- Maximum proton lost rate in IR7 for each beam mode



Determination of loss rate in IR7

Simulated BLM pattern scaled to measured ones



IR7 simulations are compared to their associated measurements to reconstruct the proton leakage

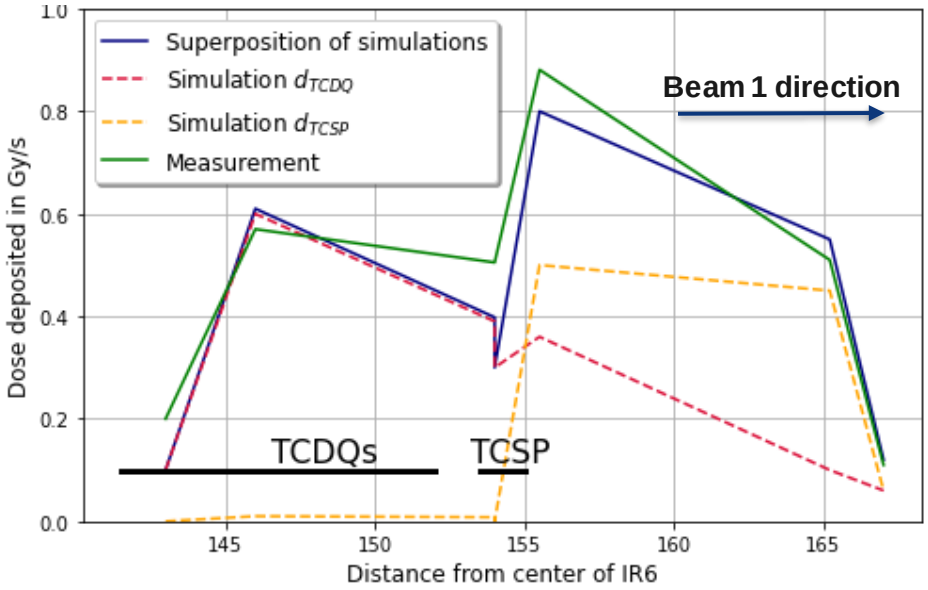
Determination of loss rate in IR6

Simulated BLM pattern scaled to measured ones

$$\dot{D}_{IR6} = \dot{N}_{IR6}[f.d_{TCDQ} + (1-f).d_{TCSP}]$$

- d in $Gy/primary$
- $\dot{D}$ in Gy/s
- $\dot{N}$ in $primary/s$
- f the fraction of TCDQ losses

The sharing factor f was determined empirically

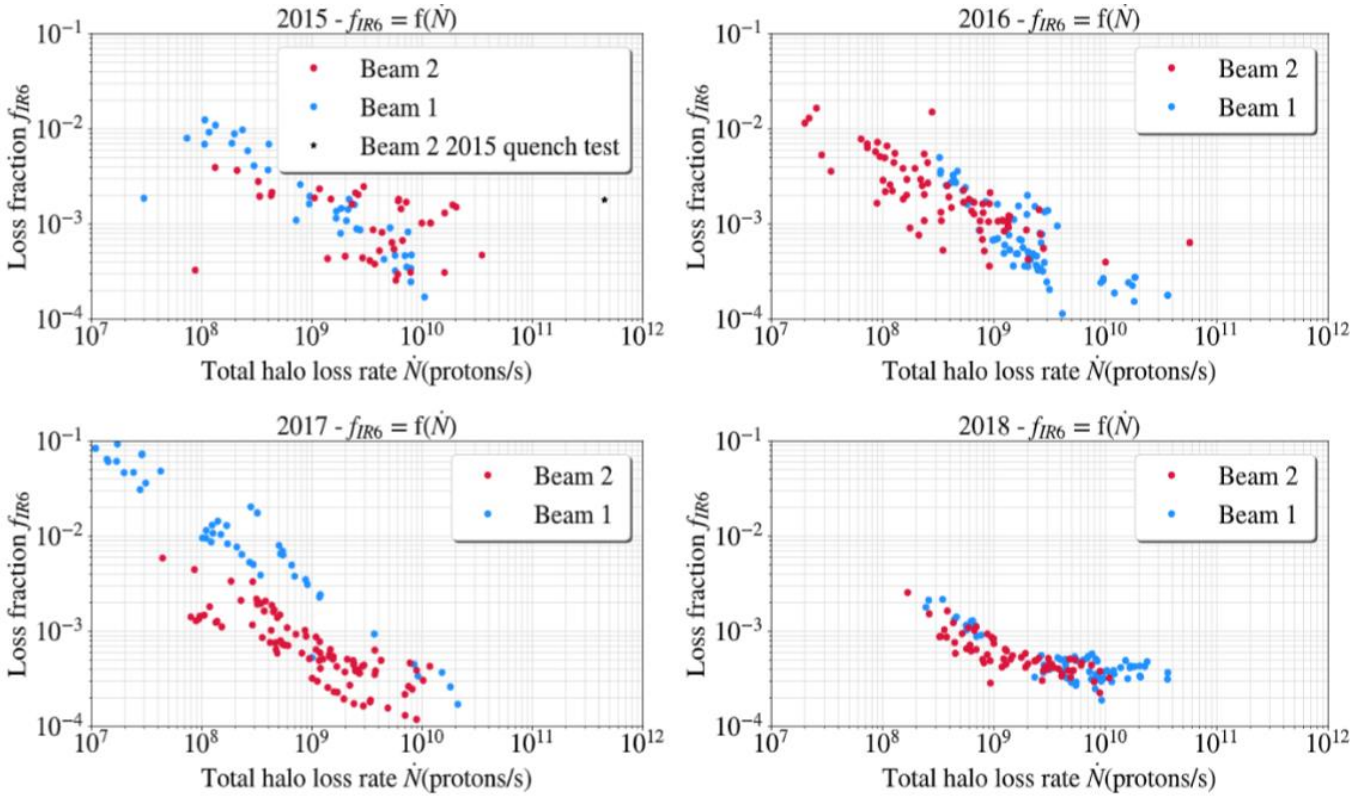


Superposition of FLUKA simulations to match the measurement: [f=0.5, $\dot{N}_{IR6}$=2]

IR6 losses are shared between TCDQ/TCSP

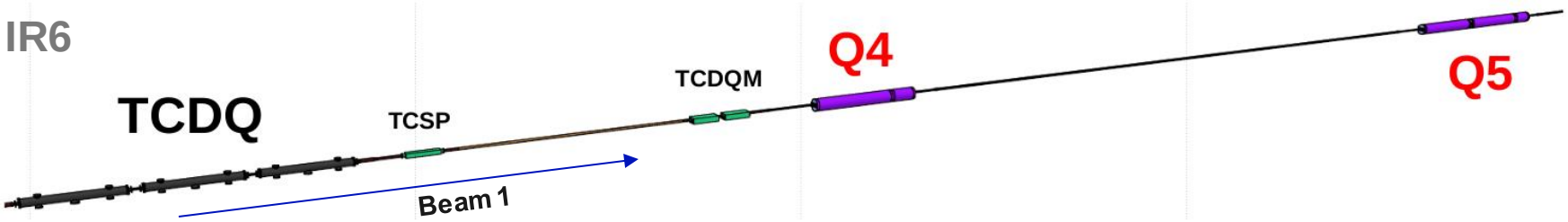
IR7 halo leakage to IR6

Loss fraction function of the total halo loss rate - $\dot{N}_{IR6} = f_{IR6} \times \dot{N}$

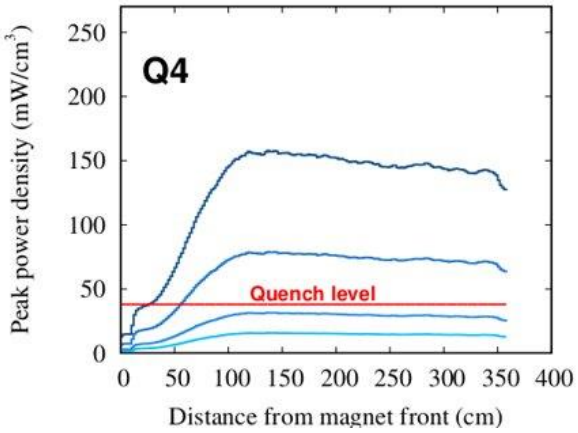


Loss fraction decreases with the total halo loss rate: this trend suggest that for high loss rates (>1E11 p/s) the leakage fraction remains below 1E-3

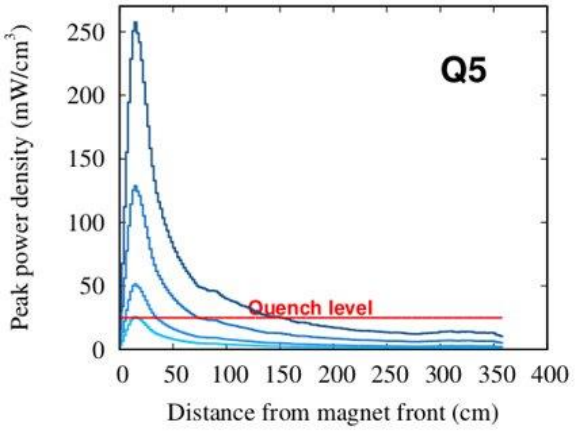
IR6 quench risk



Energy deposition inside Q4 and Q5



Halo fraction f_{IR6}
0.001
0.002
0.005
0.010



The simulation indicate that there should be no risk of quench if f_{IR6} is smaller than 1E-3

Conclusion

- Leakage from betatron collimation system seems to depend on the absolute loss rate
- This unexpected phenomenon might be due to larger impact parameter of protons on the primary collimators in case of high loss rates
- Only a few measurements at high proton lost rate are available. Extrapolating to HL beam intensities indicate an acceptable quench risk for IR6 magnets if the observed trend continue for higher loss rates
- Machine development request submitted for Run 3 to investigate further the leakage from IR7 to IR6
- The 2015 quench test yielded a somewhat higher leakage fraction compared to the lifetime dips in operation -> collimation quench test with protons in 2022 can provide further insight

Thank you for your attention!

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