LHC Collimation Project CERN

High Luminosity LHC

Update on failure cases for asynch dump on collimators – worst case vs realistic

L. Lari
IFIC (CSIC-UV) & CERN
R. Bruce, S. Redaelli

Thanks to C. Bracco and B. Goddard

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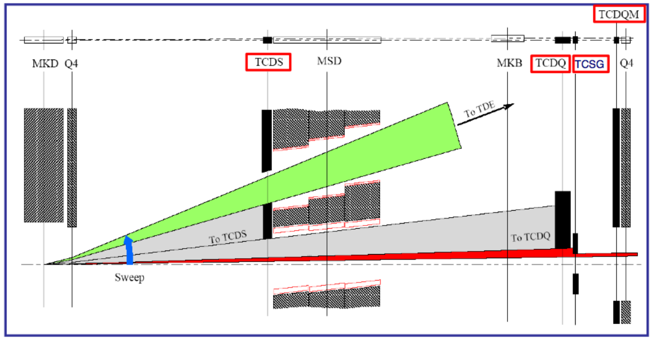
Outline

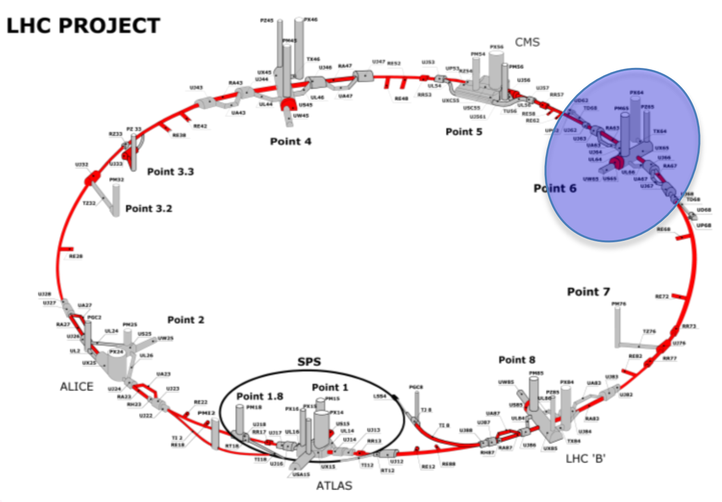
- Introduction/Scope of the work.
- Summary of the of past results.
- Worst case for Post LS1 optics and HLLHCv1.0 optics.
- Towards more realistic cases.
- Conclusions.

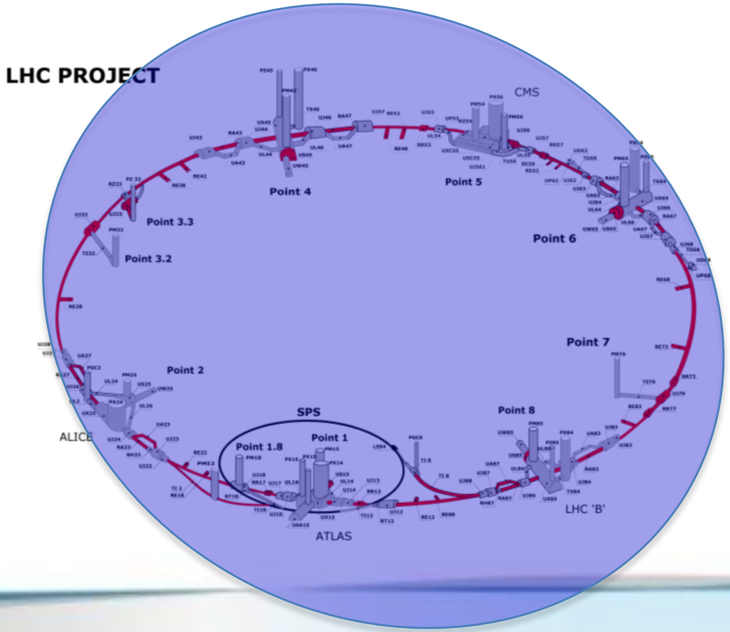
Introduction / Scope of the work

…is to understand the beam loads in different collimators in case of asynchronous beam dump, in order to improve the LHC collimation system design by understanding realistic loss cases.



Not looking at that from the beam dump point of view,
but from the whole LHC collimation system point of view!





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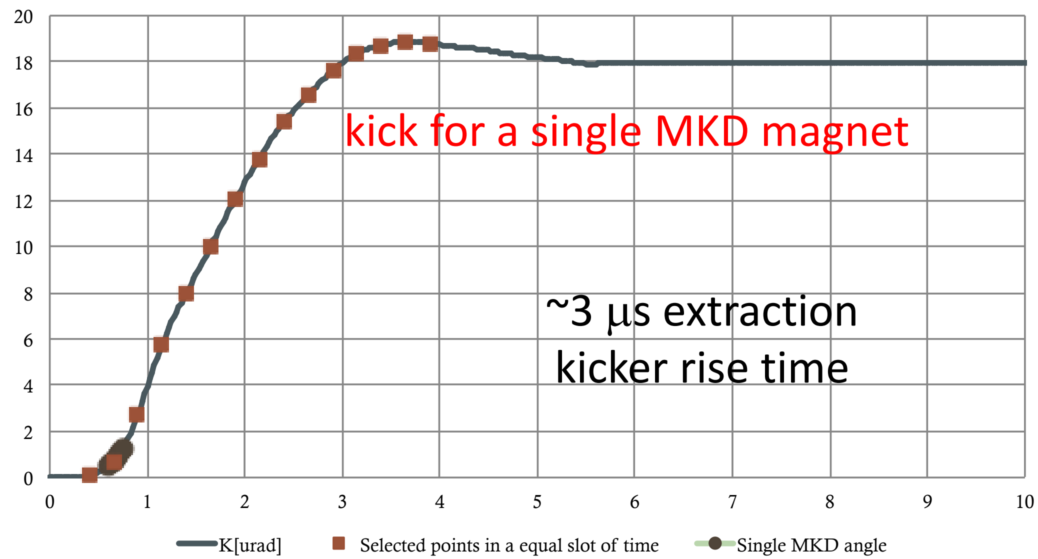
How?

- Using a modified SixTrack collimation routine to allow studies of asynchronous dump with the whole collimation system in place, including the study of different errors.
- Input from the MKD pulse form applied @ each MKD and in case of single module pre-firing → considering the retriggering delay of (650+50-*n) [ns] where n is the number of generators away from the one which pre-triggered.

MKD pulse form - Courtesy B. Goddard



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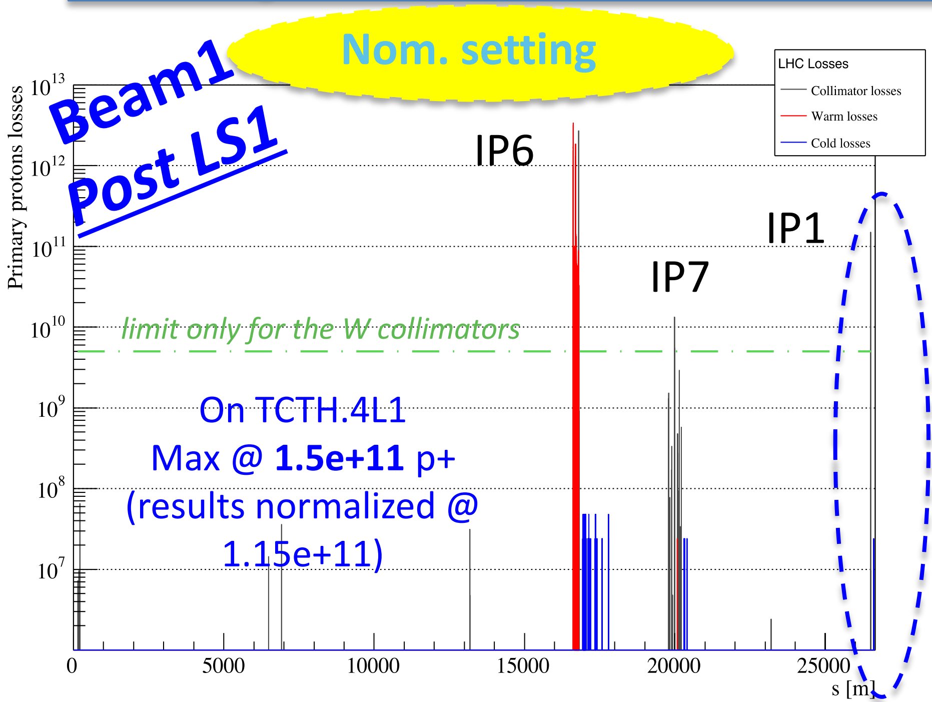
Few reminders: worst cases for the 15 MKDs firing simultaneously

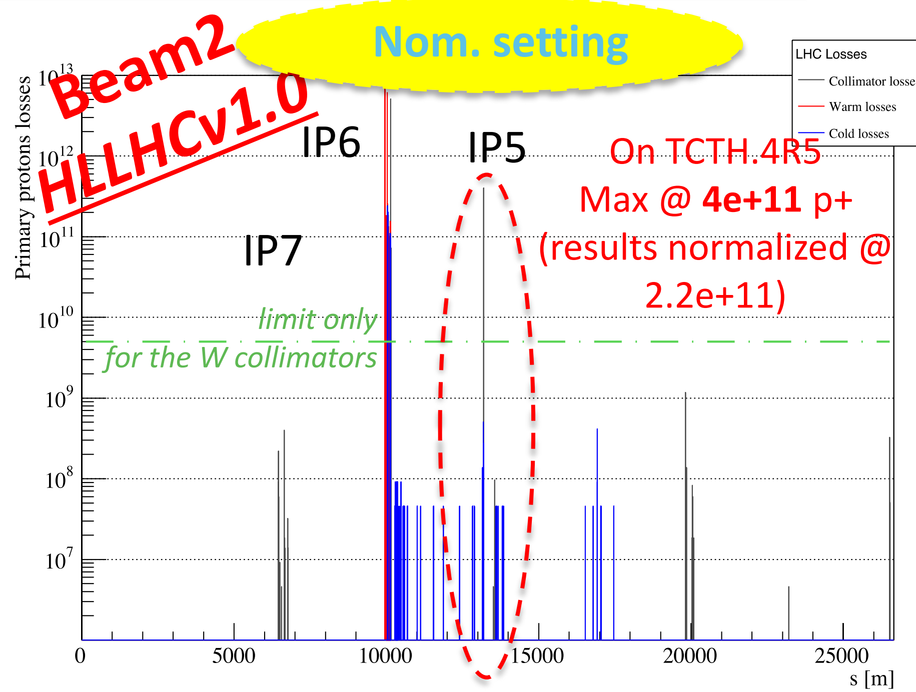
presented @ 83th LHC Machine Protection Panel Meeting

Both loss maps refers to a very pessimistic scenario in which:

1. Retraction of 1.2mm @ IP6
2. + Retraction of 1mm @IP7 for “critical” collimators
3. + TCTHs @IP1 and @IP5 of 1 σ closer to the beam
4. Optics error (*R. Bruce*) → Results refer to the worst case out of 1000 optics configuration with random errors



Physics run with **0.60 m** β^* in IP1/IP5



Physics run with **0.15 m** β^* in IP1/IP5

Few reminders: Collimation setting considered

For **Beam1** and **Beam2**

= Tungsten

	Nom. setting	2σ retraction
TCP.IP7	**6**	**5.7**
TCSG.IP7	**7**	**7.7**
TCLA.IP7	**10**	**10.7**
2*80cm W DS @IP7	**10**	**10.7**
TCP.IP3	15	15
TCSG.IP3	18	18
TCLA.IP3	20	20
TCT.IP1/IP5	**8.3**	**10.5**
TCT.IP2/IP8	30	30
TCL.IP1/IP5 (2 Cu +1 W)	15	15
TCLI/TDI.IP2	Tot opened	Tot opened
TCDQ.IP6	**8**	**9**
TCSG.IP6	**7.5**	**8.5**

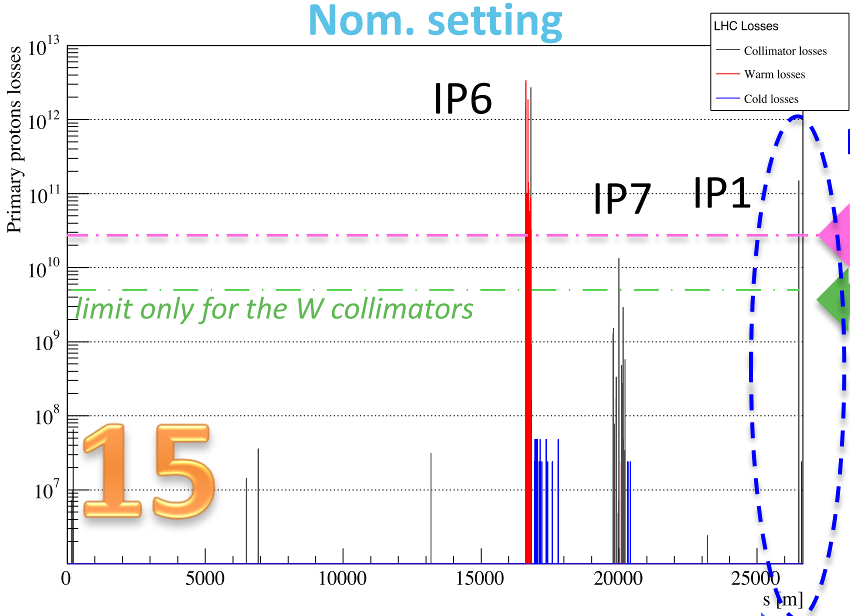
In the next slides….

…will be presented a comparison between worst scenarios in terms of loads on delicate collimators for the cases in which:

- all the 15 MKDs
- 1 MKD fire (single module pre-firing + re-triggering)

Beam 1 – Post LS1 optics

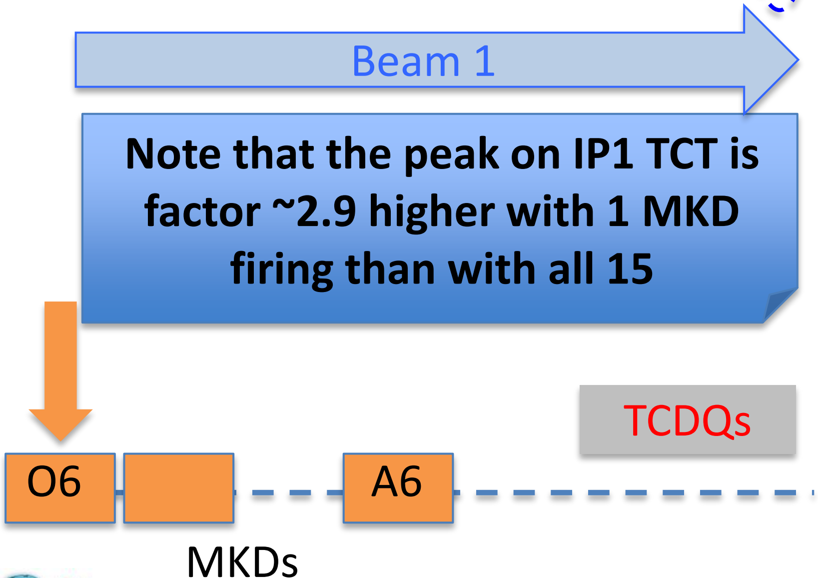
Results are normalized to $1.x15^{11}$ p+ (25 ns)



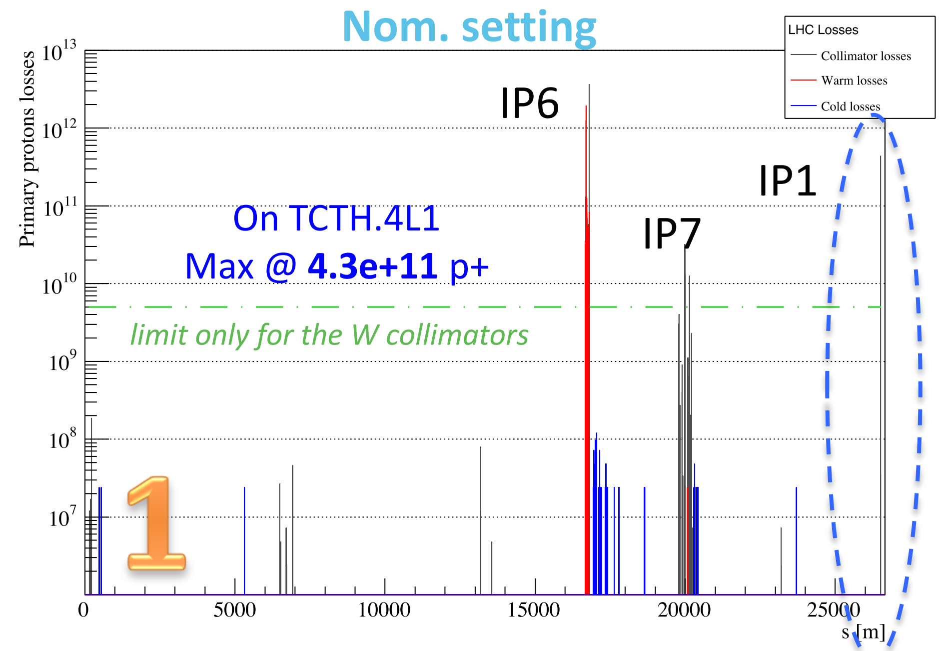
Limit for fragment ejection: $2x10^{10}$ p+

Onset of plastic damage on Tungsten collimators : $5x10^{9}$ p+

[REF: A. Bertarelli et al. *Updated robustness limits for collimator material*, LHC Machine Protection Workshop, Annecy, France]

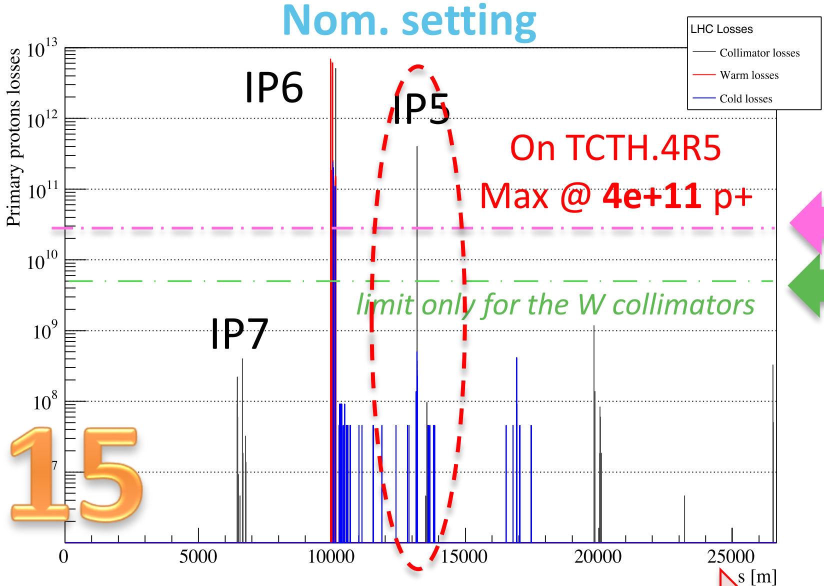


Note that the peak on IP1 TCT is factor ~2.9 higher with 1 MKD firing than with all 15



Beam 2 - HLLHCv1.0 optics

Results are normalized to 2.2×10^{11} p+ (25 ns)



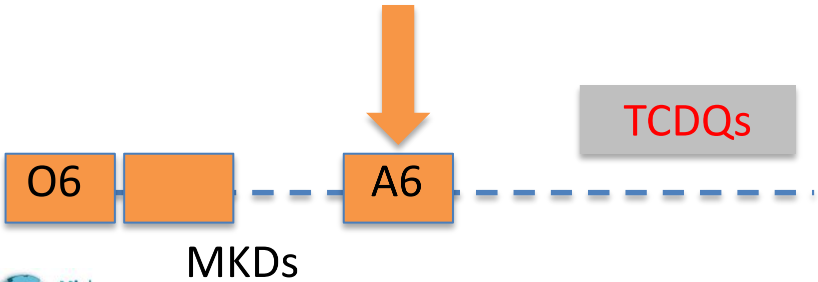
Beam 2

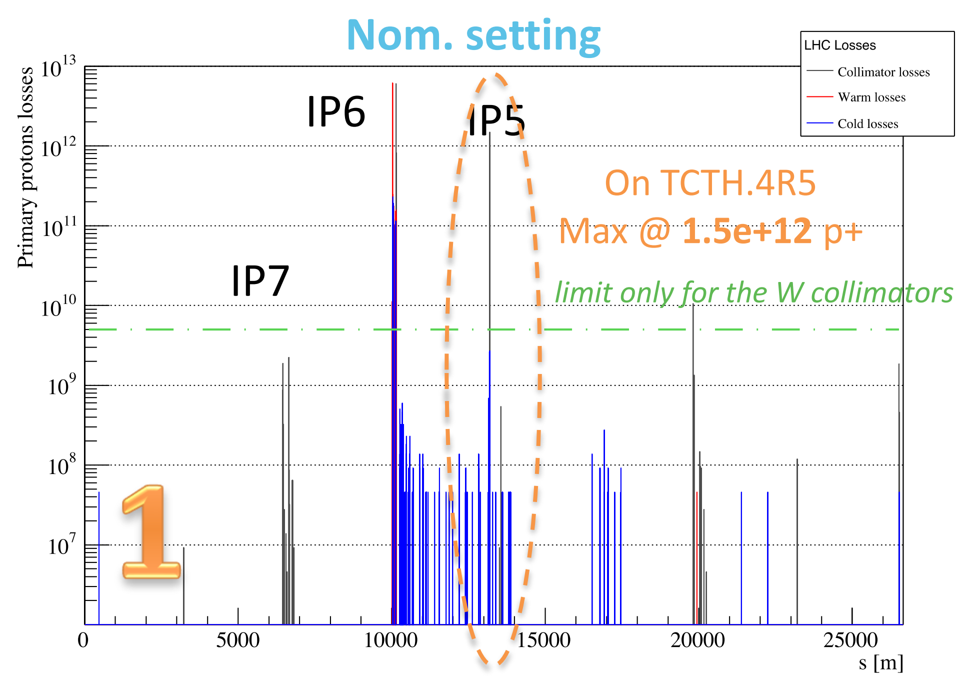
Limit for fragment ejection: 2×10^{10} p+

Onset of <u>plastic</u> damage on Tungsten collimators : 5×10^{9} p+

[REF: A. Bertarelli et al. *Updated robustness limits for collimator material*, LHC Machine Protection Workshop, Annecy, France]

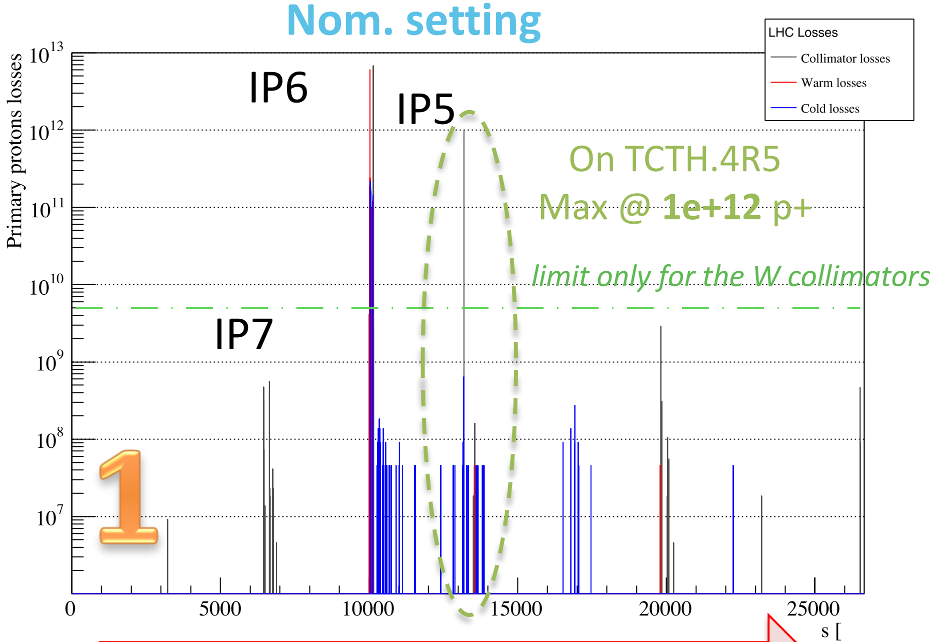
Note that the peak on IP5 TCT is factor ~3.5 higher with 1 MKD firing than with all 15



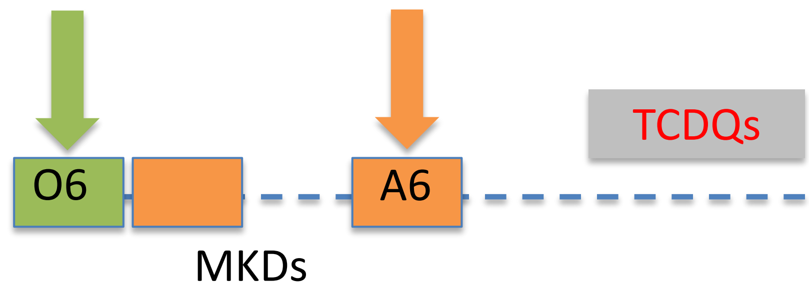


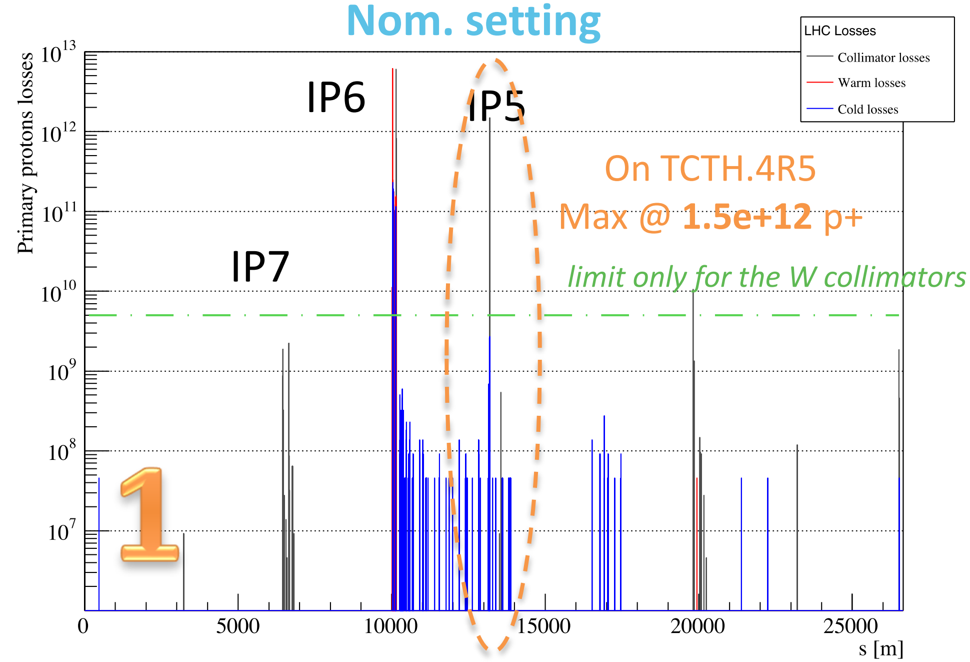
Beam 2 - HLLHCv1.0 optics

Results are normalized to 2.2×10^{11} p+ (25 ns)



Beam 2





Note that the peak on IP5 TCT is factor ~1.5 higher with the 1 MKD firing closer to the TCDQs than with the 1 MKD firing at the O6 position.

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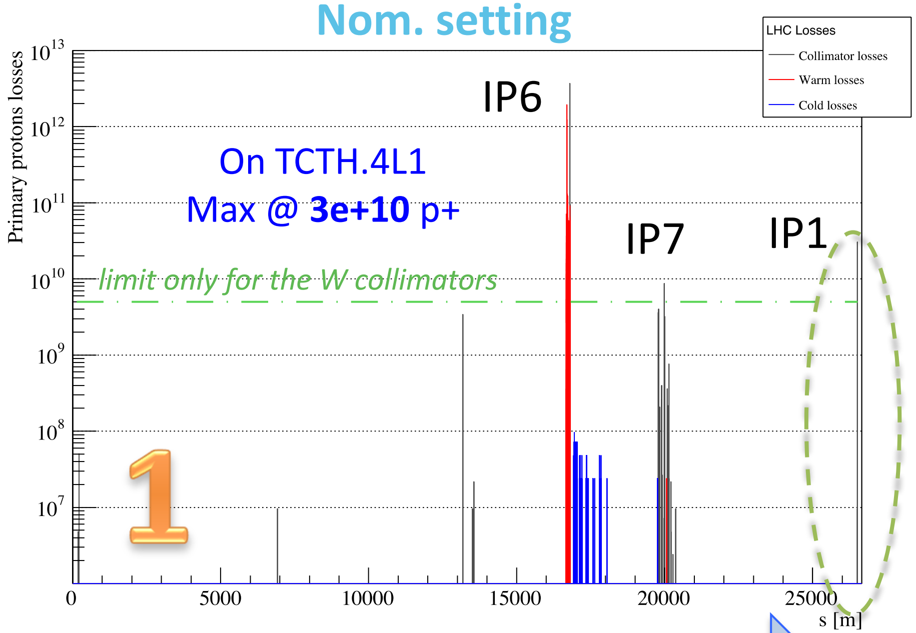
More realistic imperfections

R. Bruce

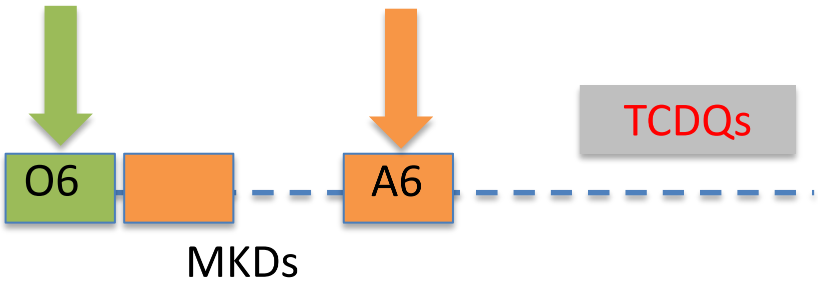
- Preliminary analysis of probabilities for orbit drifts
- Considering 2012 BPM data at TCTs and in IR6, joint with the 5% RMS beta-beat converted to mm, to estimate cumulative distribution function of total drifts.
- Results :
  - Probability of 1 sigma drift at TCT combined with 1.2mm in IR6 is below numerical error of model (~1e-3)
  - Probability of 0.2mm drift at TCT and 0.9mm in IR6 has approximately 1% probability. Study this case for more realistic errors.

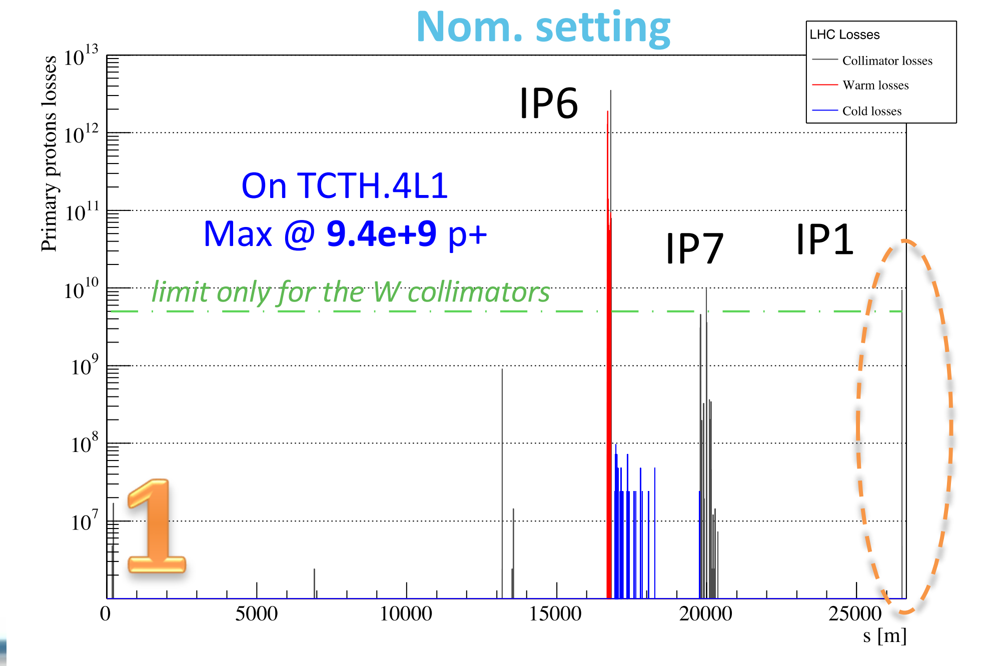
Beam 1 – Post LS1 optics

Results are normalized to 1.15×10^{11} p+ (25 ns)



Beam 1





Note that the peak on IP1 TCT is factor ~1.5 higher with the 1 MKD firing closer to the TCDQs than with the 1 MKD firing at the O6 position.

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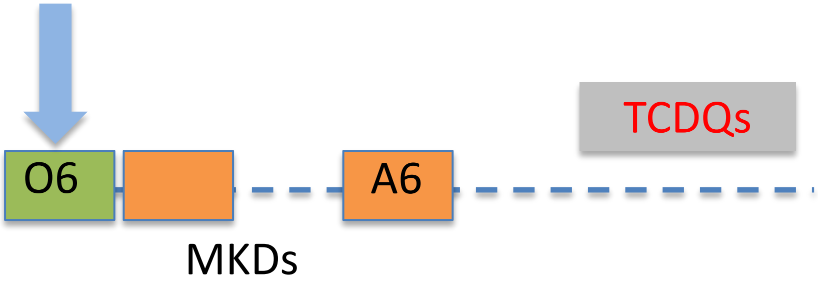
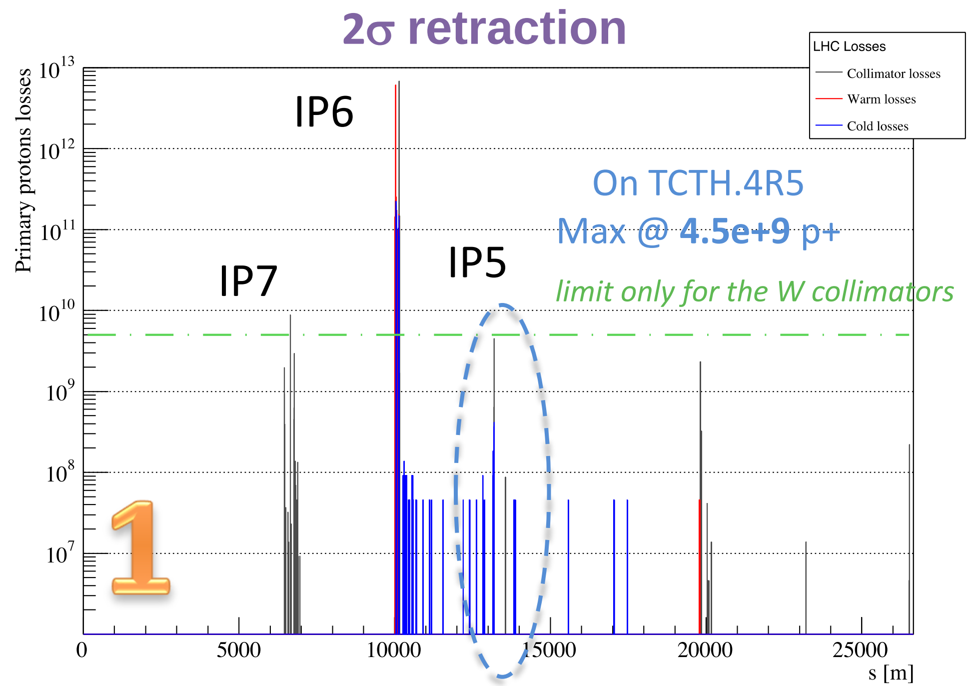
Beam 2 - HLLHCv1.0 optics



Results are normalized to 2.2×10^{11} p+ (25 ns)



Preliminary results using a 2σ retraction collimation setting show that we are closer to the limit for W collimators (5e+9 p+) .

Conclusions

- A preliminary comparison between worst scenarios in terms of loads on delicate collimators for the cases in which all the 15 MKDs or 1 MKD fire (single module pre-firing + re-triggering) not synchronously with the abort gap, were presented.
- A factor ~3 higher with the with 1 MKD firing than with all 15 MKDs was found.
- In terms of protection from an asynchronous dump accident, the 2 σ retraction collimation settings (baseline for the startup, if no impedance problem) is more tolerant for the Post LS1 and HLLHCv1.0 optics.
- The tools developed for this studies are applied to the recent HL-LHC optics, working in collaboration with the HSS optics team with the scope of supporting and improving the development of HL-LHC optics.
- Realistic error scenarios chosen are based on BPM 2012 data analysis made by R. Bruce, that will be presented in the detail in a future collimation related meeting.
- For the realistic errors scenarios studies for both optics (i.e. HLLHCv1.0 and Post LS1), the SixTrack outputs are available for future FLUKA and structural analysis study on actual W TCTs @IP5 (Beam2) and @ IP1 (Beam1).

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Phase advance

Calculated from the MKD.4O6
(the furthest away form TCDQs)

Post LS1 optics

	~~7TeV nominal~~ → 55 cm	**SLHC_3.1b → 15 cm**	**HL-LHC v1.0 → 15 cm**
Beam1			
TCTH.4L1.B1	55.8	97.2	208.8
TCTH.4L2.B1	257.3	182.8	265.7
TCTH.4L5.B1	47.3	145.6	244.6
TCTH.4L8.B1	335.7	166.5	213.1
Beam2			
TCTH.4R1.B2	198.1	303.2	139.6
TCTH.4R2.B2	170.4	184.7	230.9
TCTH.4R5.B2	175.8	220.4	103.5
TCTH.4R8.B2	18.7	225.2	215.2

[See also R.Bruce et al. *Collimation requirements for the IR1/5 layout and on-going WP5 studies*, 8th HL-LHC Extended Steering Committee meeting, 13/08/2013, CERN]

Possible mitigation actions to be evaluated & some future possible steps

- New collimation materials for TCT jaws with higher limit damage.
- MDs for Beam2 to benchmark simulation results in IP5.
- BPM buttons used to improve control on orbit.
- Tighter collimation position limit.
- Improve the phase advance @TCTH in IP5 for the HLLHCv1.0 optics.
- Include as first the BPM buttons in the critical collimation locations.