WP5 Simulation Workshop
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LHC Collimation Project CERN

High Luminosity LHC

SixTrack for failure studies

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

Thanks for inputs to C. Bracco, F. Cerutti, B. Goddard, A. Marsili, B. Salvachua, L. Skordis, G. Valentino, J. Wenninger

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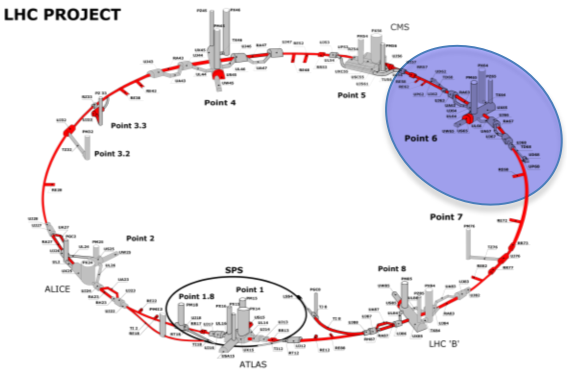
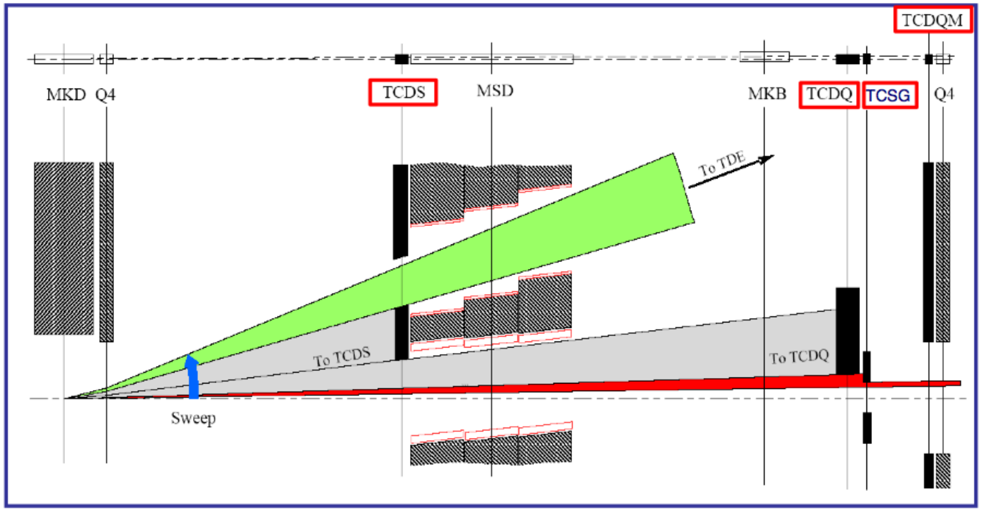
Outline

- Asynchronous dump: what is it?
- A modified SixTrack collimation routine.
- Pre- and Post-processing steps.
- Validation of the simulation set-up.
- Conclusions & possible future works.

Asynchronous dump: what is it?





Fast losses happens when one or all of MKDs not synchronously fired with the abort gap.

A beam dump system fault could lead to severe damage on LHC machine components.

Motivation

During the operation of LHC, a single asynchronous beam dump accident happened on November 19th 2010, without critical consequences.

Afterward, the protection against fast beam failures has been improved.

[REF: C. Bracco et al., *LBDS and abort gap cleaning* , Proc. EVIAN workshop, France (2010).]

However, it has to be pointed out that this kind of accident remains a concern for the future.

The risk of severe damage increases with the beam intensity and energy.

For this reason, efforts are put in developing simulation tools.

A modified SixTrack collimation routine

The advantage is ….

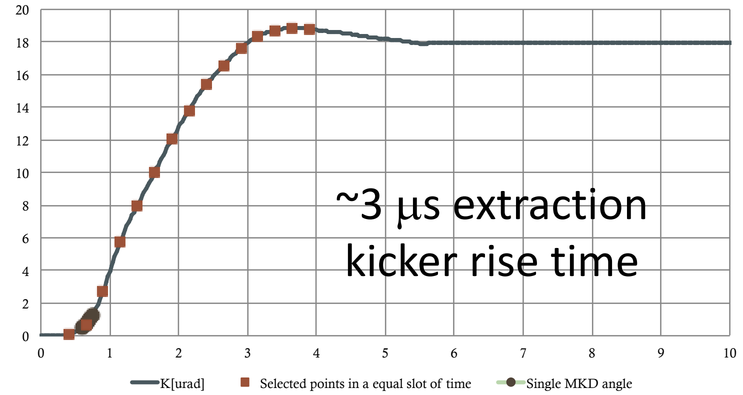
… to allow studies of asynchronous dump with the whole LHC collimation system in place, including studies of **different errors** (i.e. setting, orbit and optics errors) → to understand realistic loss cases, from the whole LHC collimation point of view.

A modified SixTrack collimation routine

1. fort.3 modified to allow different angular values for each MKDs @ IP6 (2 lines added @ the end of the file, with logics 1 – 0 for activation ←→ sixve.f routine modified to read the input data)

```
.TRUE. .FALSE. HoriLowbcoll 101 1 1.
1 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3
0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3 0.935635072e-3
NEXT
```

For each of the 15 MKDs for both Beam lines data are extracted from the MKD pulse form.



A modified SixTrack collimation routine

2. In track.f → collimation subroutine modified → 15 new vacuum TCSGs at the place of each MKDs.

TURN 1 → coll. set in nominal position as in CollDB

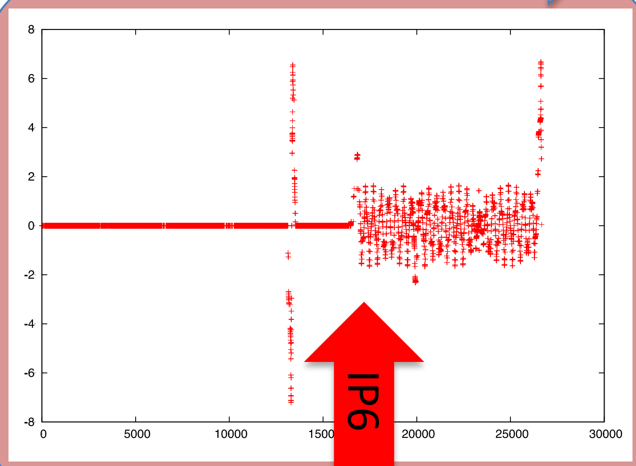
TURN 2 → angular kick in fort.3 applied to each MKD

TURN 3 → dump (i.e. max kick applied to each MKD)

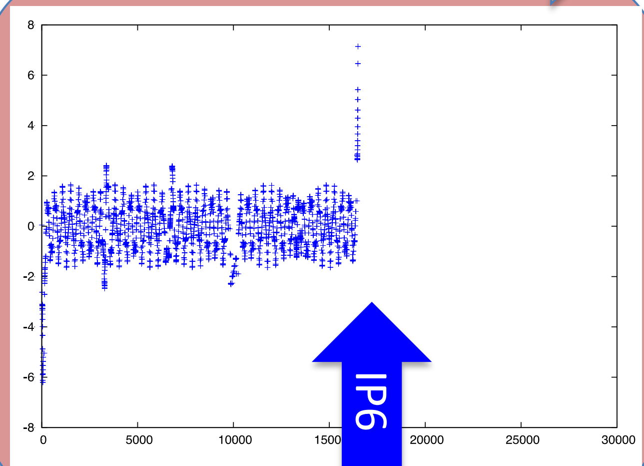
1st turn

The collimator are put in place with respect to the optic scenario under study

IP1 2nd turn IP8



IP1 3rd turn IP8



A modified SixTrack collimation routine

3. In CollDB the TCSGs@MKDs are added, the “first” one met by the beam is closed to allow to recover all data in tracks2.dat output file.

To allow any checks on orbit and tracked protons when any kick is applied at the location of each MKDs, during each turn.

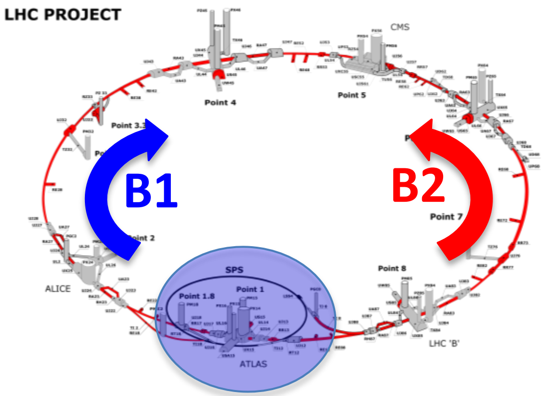
Where in track.f?

At the beginning at the THIN6D routine
After the collimator name check

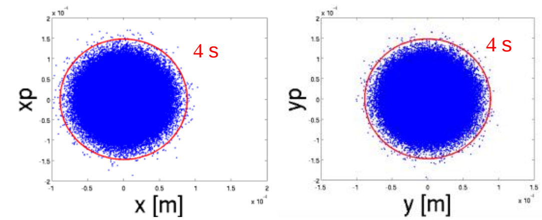
```
     &(bez(myix)(1:3).eq.'TCD'.or.bez(myix)(1:3).eq.'tcd') .or.        &
     &(bez(myix)(1:3).eq.'TDI'.or.bez(myix)(1:3).eq.'tdi') .or.        &
! UPGRADE MAI 2006 -> TOTEM
     &(bez(myix)(1:3).eq.'TCX'.or.bez(myix)(1:3).eq.'tcx') .or.        &
! TW 04/2008 adding TCRYO
     &(bez(myix)(1:3).eq.'TCR'.or.bez(myix)(1:3).eq.'tcr') .or.        &
!RHIC
     &(bez(myix)(1:3).eq.'COL'.or.bez(myix)(1:3).eq.'col') ) then
!GRD      write(*,*) bez(myix),'found!!'
!APRIL2005
          myktrack = 1
           else
             myktrack = ktrack(i)
           endif
!
!           write(*,*) 'ralph>  Element name:  ', bez(myix), ktrack(i),
!      &                    myktrack
!
           goto(10,30,740,650,650,650,650,650,650,650,50,70,90,110,130,   &
     &150,170,190,210,230,440,460,480,500,520,540,560,580,600,620,       &
     &640,410,250,270,290,310,330,350,370,390,680,700,720,730,748,       &
     &650,650,650,650,650,745,746),myktrack
           goto 650
   10      stracki=strack(i)
!========================================
!Ralph drift length is stracki
!bez(ix) is name of drift
!GRD
!GRD
           totals=totals+stracki
!           write(*,*) 'ralph> Drift, total length: ', stracki,totals
!
!++  If we have a collimator then...
!
!Feb2006
!GRD (June 2005) 'CO  option is for RHIC collimators
!
!     SR (17-  -2006): Special assignment to the TCS.TCDQ for B1 an   B4,
!     usin  the new naming as in V6.500.
!     No   that this must be in the loop "if TCSG"!!
!
!     R, 17-01-2006: Review the TCT assignments because the MADX names
!     have changes (TCTH.L -> TCTH.4L)
!
!  ULY 2008 added changes (V6.503) for names in TCTV -> TCTVA and TCTVB
!  both namings before and after V6.503 can be used
!
 OCT2012 modification for asy dump studies - Luisella
!
!        If we have a kick in a 2nd turn....
         if(a_kick.ge.1)then
!
                 if((iturn.eq.2).and.                                  &
     &((bez(myix)(1:4).eq.'TCSG').or.(bez(myix)(1:4).eq.'tcsg')).and.  &
     &((bez(myix)(10:11).eq.'MK').or.(bez(myix)(10:11).eq.'mk'))) then
  output fort.91 in order to check the input data
               write(91,*) iturn, bez(myix), icoll,xv(1,1),yv(1,1)
!  if to change for each MKD the fire angle
!
                   if((bez(myix)(6:8).eq.'406').or.                    &
     &                (bez(myix)(6:8).eq.'4o6')) then
                             do jjjj=1,napx
                             yv(1,jjjj)=yv(1,jjjj)+a_mkd_o516
! output  ort.120 in order to check if the kick is applied to the MKD.05
                             write(120,*) iturn,xv(1,j),yv(1,j)
                             enddo
                   endif
!
!
                   if((bez(my                                          &
```

Pre-Processing steps

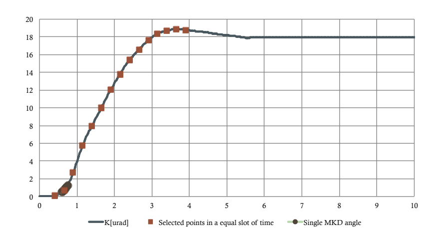
1. The SixTrack collimation routine has been modified to start the tracking @ IP1 as usual.



2. Input used: random Gaussian distributions of p+, created at the IP1 (created by a MATLAB scripts).



1. Each kick data in fort.3 is extracted from the MKD pulse form in such a way to allow ***any combination of kick angle*** (using auxiliary bash scripts).



Combination of kick angles

1. CASE 1: Studies of asynchronous dump tests (abort gap population) → mapping on all the MKD pulse form for any angle → step of 50 or 25ns.
   [REF: L.Lari et al. *Simulations and Measurements of Beam Losses on LHC Collimators during Beam Abort Failures*, IPAC13, Shanghai, China]
2. CASE 2: Studies of asynchronous dump for the most critical bunches angles. [REF: L.Lari et al. *Studies of thermal loads on collimators for HL-LHC Optics in case of fast losses*, IPAC13, Shanghai, China]
3. CASE 3: Studies of optics errors [REF: R.Bruce, Collimator hierarchy limits: assumptions and impact on machine protection and performance, MPP workshop, Mar 2013]

```
1 3.9280474209999995e-3 3.8549066999999975e-5 2.2529674e-5 9.714159999999987e-6 -5.392442048446328e-21 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
NEXT
MULT
mbas2.1r1          1.7000000000e+01     1.0000000000e+03
NEXT
MULT
mbxw.a4r1          1.7000000000e+01     1.8817477910e-01
   0.    0.    0.    0.
   0.    1.    0.    0.
NEXT
MULT
mbrc.4r1.b1..1     1.7000000000e+01     2.8226216866e-01
   0.    0.    0.    0.
   0.    1.    0.    0.
NEXT
```

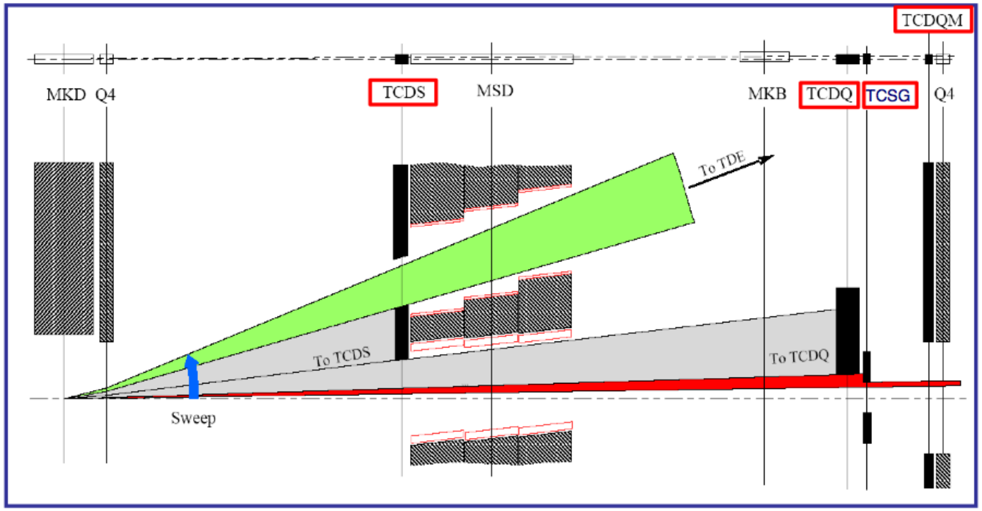
1. Link MADX output file fc.16 → fort.16
2. Include in fort.3 data from MADX output file fc.3 → between 2 **NEXT**

High Luminosity LHC

Post–Processing steps

To allow qualitative comparison with BLM data, primary protons losses saved in the LPI files are cleaned by the losses supposed to go in the dump line (i.e. at the 2nd turn for big kick and at the 3rd turn when it is supposed to dump).

← →not consider all the p+ after the last MKD and the TCDS.



Some numbers

As reference CASE 1:

INPUT

- 4800 p+ (=64x75) for each of the 10 job per angle
- Total per angle = 48000 p+
- Total per all the 142 angles = 6’816’000 p+

OUTPUT (all the case in average)

- Tot primary p+ absorbed LPI 1’850’000 (~27% input p+)
- Tot primary p+ absorbed coll 1’600’000 (~23% input p+)

Validation of the simulation set-up

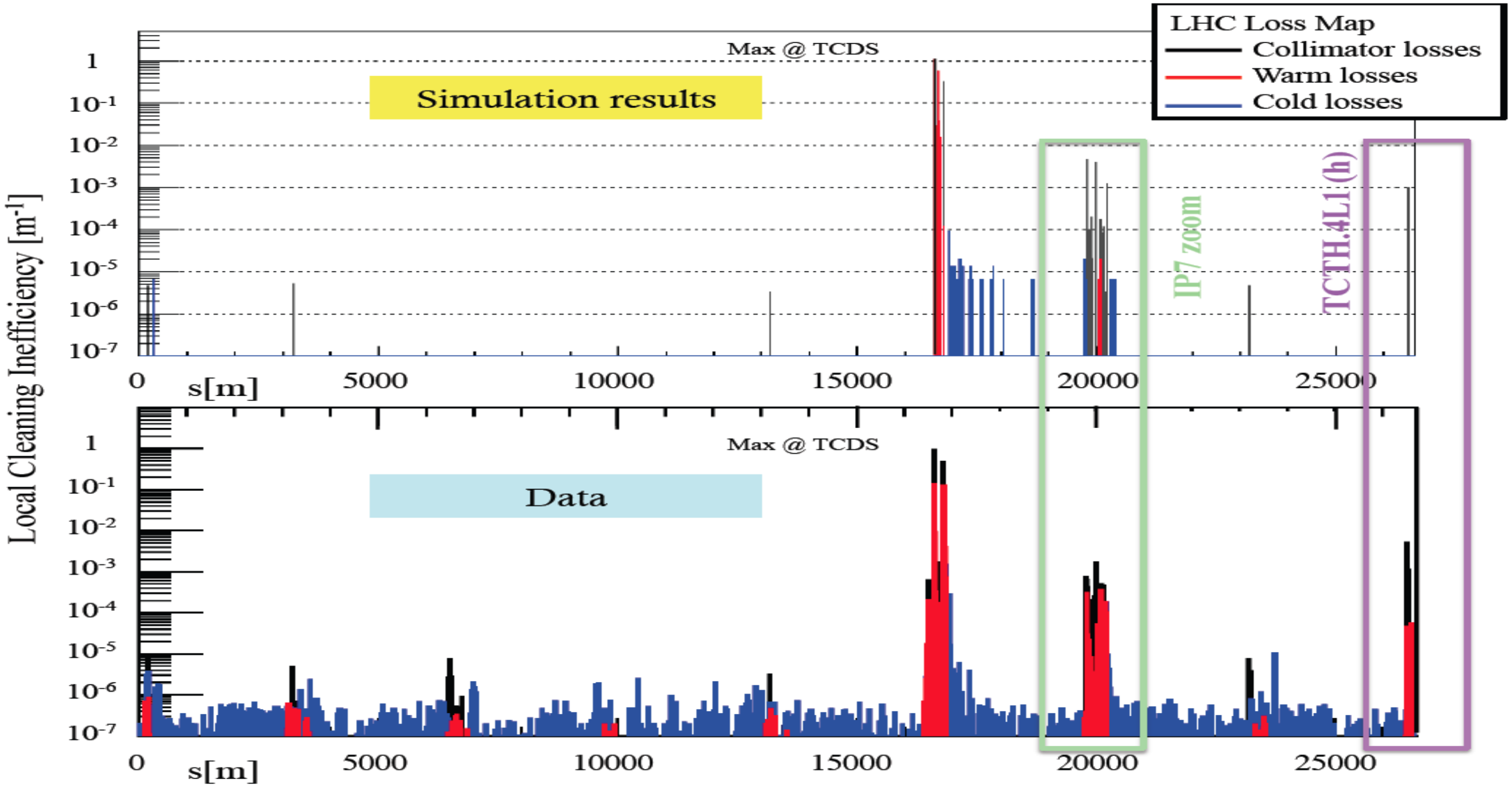
June 2012

4TeV nom. Optics + out 1.5 mm @IP6

+ 1 mm out 3 TCSG +1 TCLA @IP7

+1σ in the most exposed TCT @IP1

Factor 7 in the BLM signal TCT/TCP for p+ lost



Thin lens → optic 'as-built' V6.503 : /afs/cern.ch/eng/lhc/optics/V6.503/V6.5.thin.seq
/afs/cern.ch/eng/lhc/optics/V6.503/V6.5.thin.coll_special.4.0TeV_0.6m3m0.6m3m.str

Configuration 1 : /afs/cern.ch/eng/lhc/optics/V6.503/job.sample.4.0TeV.madx

[REF: L.Lari et al. *Simulations and Measurements of Beam Losses on LHC Collimators during Beam Abort Failures*, IPAC13, Shanghai, China]

Validation of the simulation set-up

November 2012
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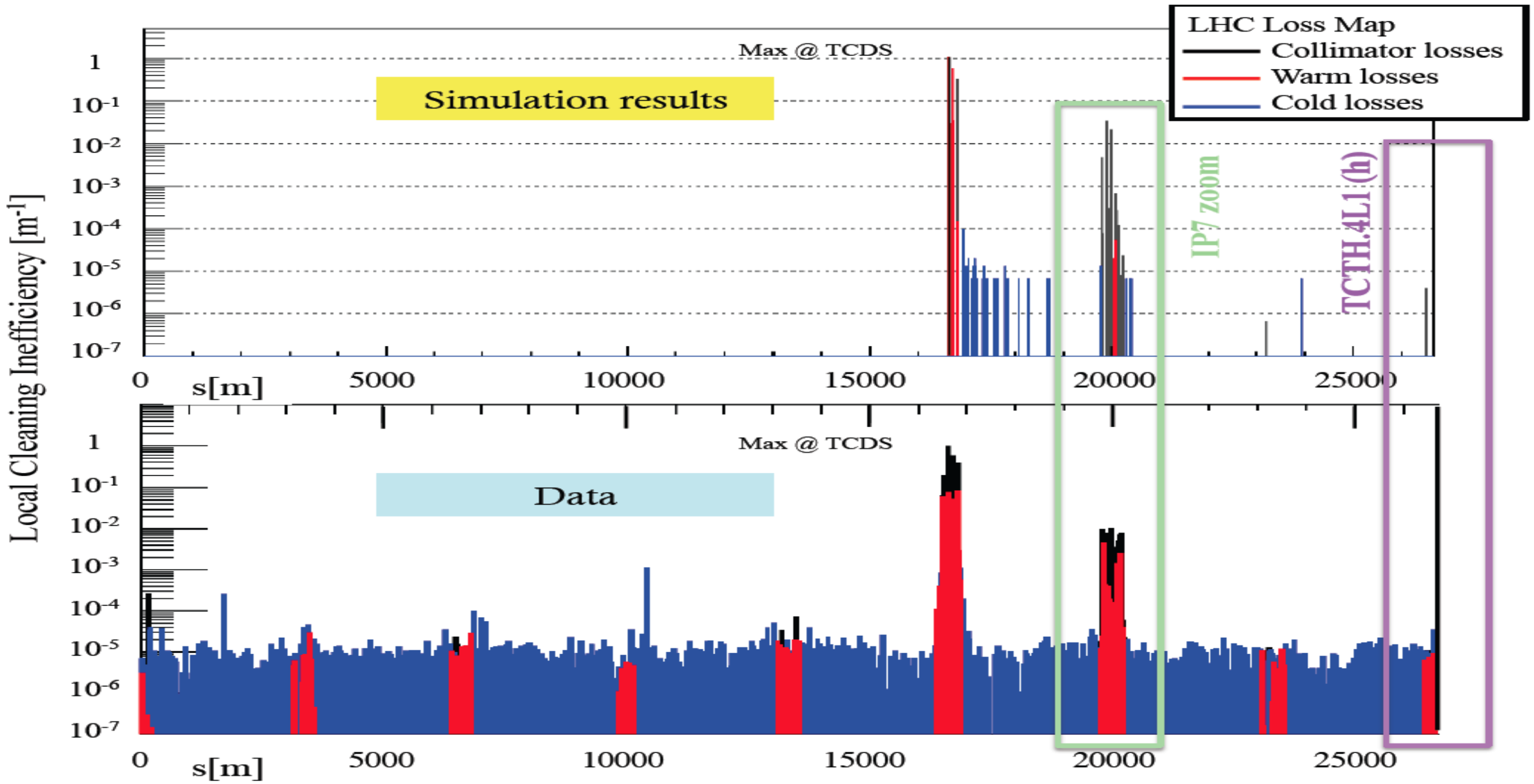


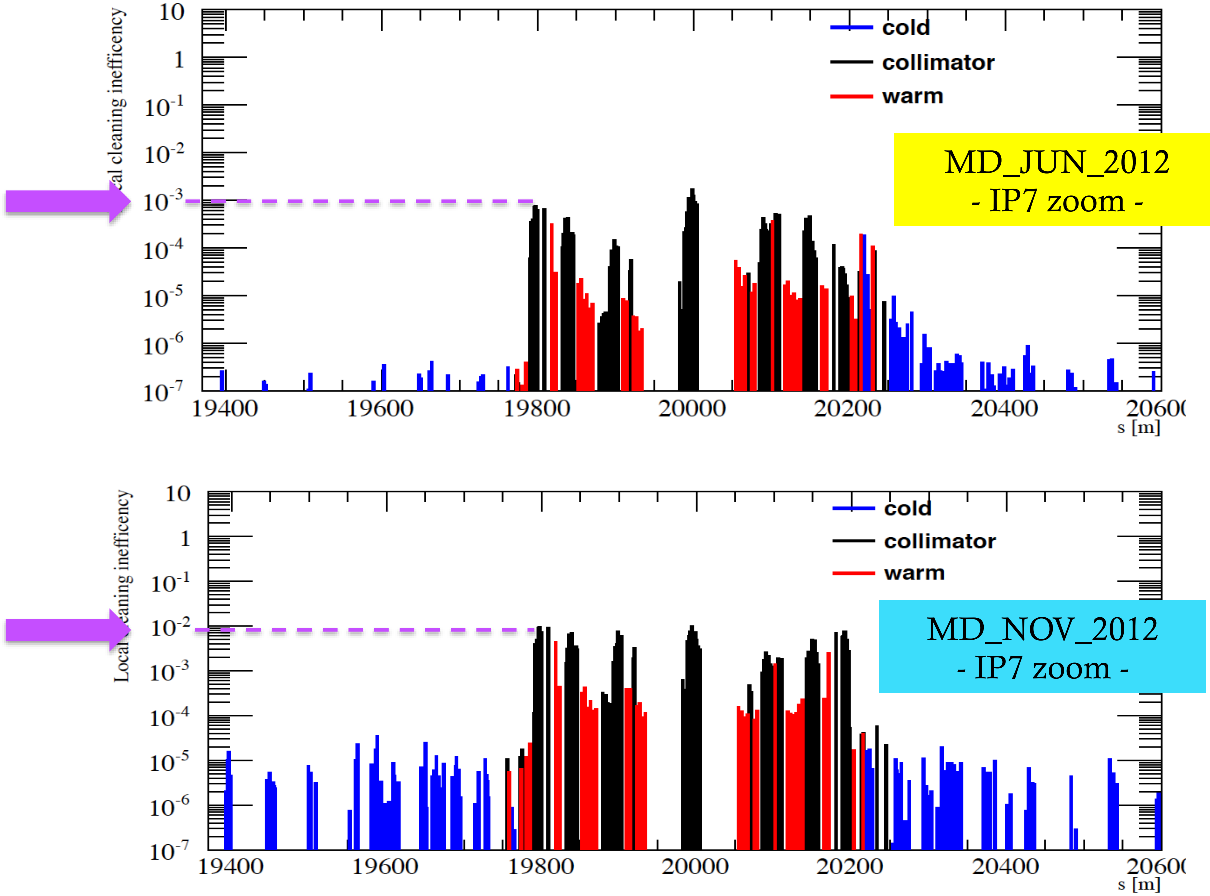
Thin lens → optic 'as-built' V6.503 : /afs/cern.ch/eng/lhc/optics/V6.503/V6.5.thin.seq
/afs/cern.ch/eng/lhc/optics/V6.503/V6.5.thin.coll_special.4.0TeV_0.6m3m0.6m3m.str
Configuration 1 : /afs/cern.ch/eng/lhc/optics/V6.503/job.sample.4.0TeV.madx

[REF: L.Lari et al. *Simulations and Measurements of Beam Losses on LHC Collimators during Beam Abort Failures*, IPAC13, Shanghai, China]

Validation of the simulation set-up

BLMs data

From the 2 MDs the losses on TCP are different → SixTrack study spanning over a range of normalized emittance from 2 to 4 [μm rad] show a variation of the local cleaning inefficiency peak at the primary TCP location of approximately two orders of magnitude.



Conclusions

- The modified SixTrack collimation routine was presented for LHC asynchronous dump studies, including qualitative comparison with data.
- The advantage of this modification is to allow accidental studies with the whole collimation system in place for actual and future optics scenarios including different realistic/pessimistic errors.
- SixTrack output data have been used for following FLUKA and structural analysis studies, in particular on most delicate collimators (such as W jaws TCTS) to evaluate limits of plastic deformation and to investigate different mitigation actions.
- In such a context, the evaluation of mechanical response for different impacts in time sequence (e.g. each 25ns) could be the subject of future work.

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