UPDATE ON COLLIMATION SYSTEM STUDIES USING SIXTRACK

Ralph Assmann, Stefano Redaelli, Guillaume Robert-Demolaize

Outline

- Status of the tracking code
- Tracking Parameters (injection & collision)
- Comparison of first results obtained with latest release
- Conclusion - Future Work

Status of the tracking code

- For all our studies, we use an extended version of SIXTRACK for Collimation:

  -- based on element-by-element method, we implemented K2 scattering routines to introduce the LHC Cleaning System into the normal tracking procedure,

  -- a database file has been created, in which we have the design parameters of every ring collimator, both mechanical and optical,

  -- we record the trajectories of all halo particles during the tracking, along with saving the locations of particles impact within the collimation system; the corresponding files are then *used as input for the LHC Aperture Model*.

  => complete set of tools for detailed studies: inefficiency curves, loss maps…

Changes since the previous version

- Code is now in its unified form: anyone can have the Collimation Version of SIXTRACK upon request; the webpage along with a user manual are being set up;

- Compared to the original routines, the new changes are:

  -- implementation of all cleaning elements: biggest step forward for our tracking studies: all collimators (primary, secondary, tertiary, absorbers) of both warm insertions (IR3 & IR7) are now present in the lattice and treated as part of the collimation system, as well as all additive collimators (TCLP in IR1/5, TCDQ equipment in IR6…),

  -- correction of the energy treatment: by implementing IR3 collimators, we noticed an error in the initialization of an energy array for updating the particles coordinates after the scattering routines: collimator kicks are now computed in the correct way.

Tracking Parameters

- Only the "Perfect Machine" case has been studied so far with the Full System version of the code, i.e. nominal optics and beam parameters for the LHC Lattice, both for Injection and Collision Optics.

- Collimators setting used are also the nominal one, but for Phase 1 only by now, with:

  -- TCLP.4R1.B1 & TCLP.4R5.B1 (Phase 3) and TCTH.L8.B1 (Phase 2) not included,

  -- TCSMs collimators are not treated (but are included in the code),

  -- TCLAs in IR3 & IR7 included,

  -- Scrapers not included,

  -- TDI included

#name	angle[rad]	Material	Length[m]	Opening [injection]	halfgap[mm]	Opening [collision]	halfgap[mm]
TCL.5R1.B1	0.00	CU	1	900	1242.00	10	2.58
TCTH.L2.B1	0.00	W	1	900	547.69	900	143.94
TDI.4L2	1.57	CU	4	6.8	4.09	900	142.23
TCTV.4L2.B1	1.57	W	1	900	583.69	900	153.34
TCLIA.4R2.B	1.57	C	1	6.8	6.53	900	227.12
TCLIB.6R2	1.57	C	1	6.8	3.23	900	112.14
TCP.6L3.B1	0.00	C	0.2	8	7.85	15	3.86
TCSG.5L3.B1	0.00	C	1	9.3	5.88	18	2.98
TCSG.4R3.B1	0.00	C	1	9.3	4.07	18	2.07
TCSG.A5R3.B1	2.98	C	1	9.3	5.26	18	2.67
TCSG.B5R3.B1	0.19	C	1	9.3	5.90	18	2.99
TCLA.A5R3.B1	1.57	CU	1	10	11.35	20	5.96
TCLA.B5R3.B1	0.00	CU	1	10	10.54	20	5.52
TCLA.6R3.B1	0.00	CU	1	10	9.73	20	5.10
TCLA.7R3.B1	0.00	CU	1	10	6.76	20	3.56
TCTH.L5.B1	0.00	W	1	900	1001.10	8.3	7.55
TCTV.L5.B1	1.57	W	1	900	743.98	8.3	4.77
TCL.5R5.B1	0.00	CU	1	900	1254.30	10	2.54
TCDQ.4R6.B1	0.00	C	8	8	15.06	10	4.94
TCS.TCDQ.B1	0.00	C	1	7	13.39	9	4.52

#name	angle[rad]	Material	Length[m]	Opening [injection]	halfgap[mm]	Opening [collision]	halfgap[mm]
TCP.D6L7.B1	1.57	C	0.2	5.7	4.27	6	1.18
TCP.C6L7.B1	0.00	C	0.2	5.7	6.04	6	1.67
TCP.B6L7.B1	2.22	C	0.2	5.7	5.05	6	1.39
TCSG.A6L7.B1	2.46	C	1	6.7	6.09	7	1.67
TCSG.B5L7.B1	2.50	C	1	6.7	7.23	7	1.98
TCSG.A5L7.B1	0.71	C	1	6.7	7.37	7	2.02
TCSG.D4L7.B1	1.57	C	1	6.7	4.77	7	1.31
TCSG.B4L7.B1	0.00	C	1	6.7	6.70	7	1.83
TCSG.A4L7.B1	2.35	C	1	6.7	6.65	7	1.82
TCSG.A4R7.B1	0.81	C	1	6.7	6.68	7	1.83
TCSG.B5R7.B1	2.47	C	1	6.7	7.68	7	2.11
TCSG.D5R7.B1	0.90	C	1	6.7	7.71	7	2.12
TCSG.E5R7.B1	2.28	C	1	6.7	7.72	7	2.12
TCSG.6R7.B1	0.01	C	1	6.7	10.57	7	2.90
TCLA.A6R7.B1	1.57	CU	1	10	5.88	10	1.55
TCLA.C6R7.B1	0.00	CU	1	10	10.69	10	2.81
TCLA.E6R7.B1	1.57	CU	1	10	10.69	10	2.80
TCLA.F6R7.B1	0.00	CU	1	10	6.61	10	1.74
TCLA.A7R7.B1	0.00	CU	1	10	6.79	10	1.78
TCTV.4L8.B1	1.57	W	1	900	558.51	900	146.70
TCTH.L1.B1	0.00	W	1	900	1001.10	8.3	7.56
TCTV.L1.B1	1.57	W	1	900	744.16	8.3	4.78

Latest Results - Comparison

- Code is now running on CERN LSF-Batch system; the Collimation System is designed to have inefficiency values of the order of 10^{-5}, so one needs to track ~ 5 million particles to have relevant statistics for loss maps.

- SIXTRACK was originally limited to 64 particles per run => a loop has been implemented in order to track thousands of particles within the same run. Even with this upgrade, a compromise for computing facilities was to be found

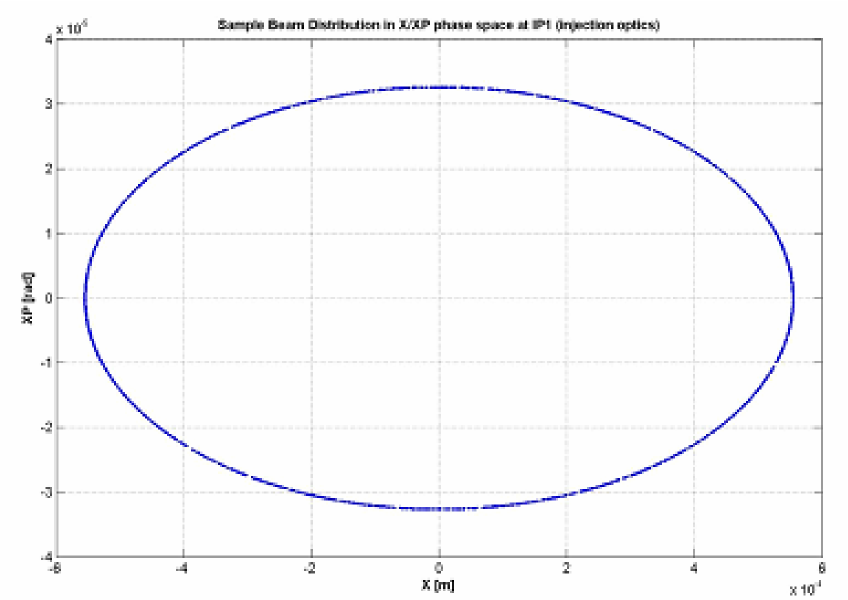
  => currently, jobs are running with 50 packs of 64 particles over 200 turns: need to launch 1600 jobs to achieve 5 million particles (estimated average computing time required: ~ 20 hours for injection case, ~ 30-35 hours for collision case).

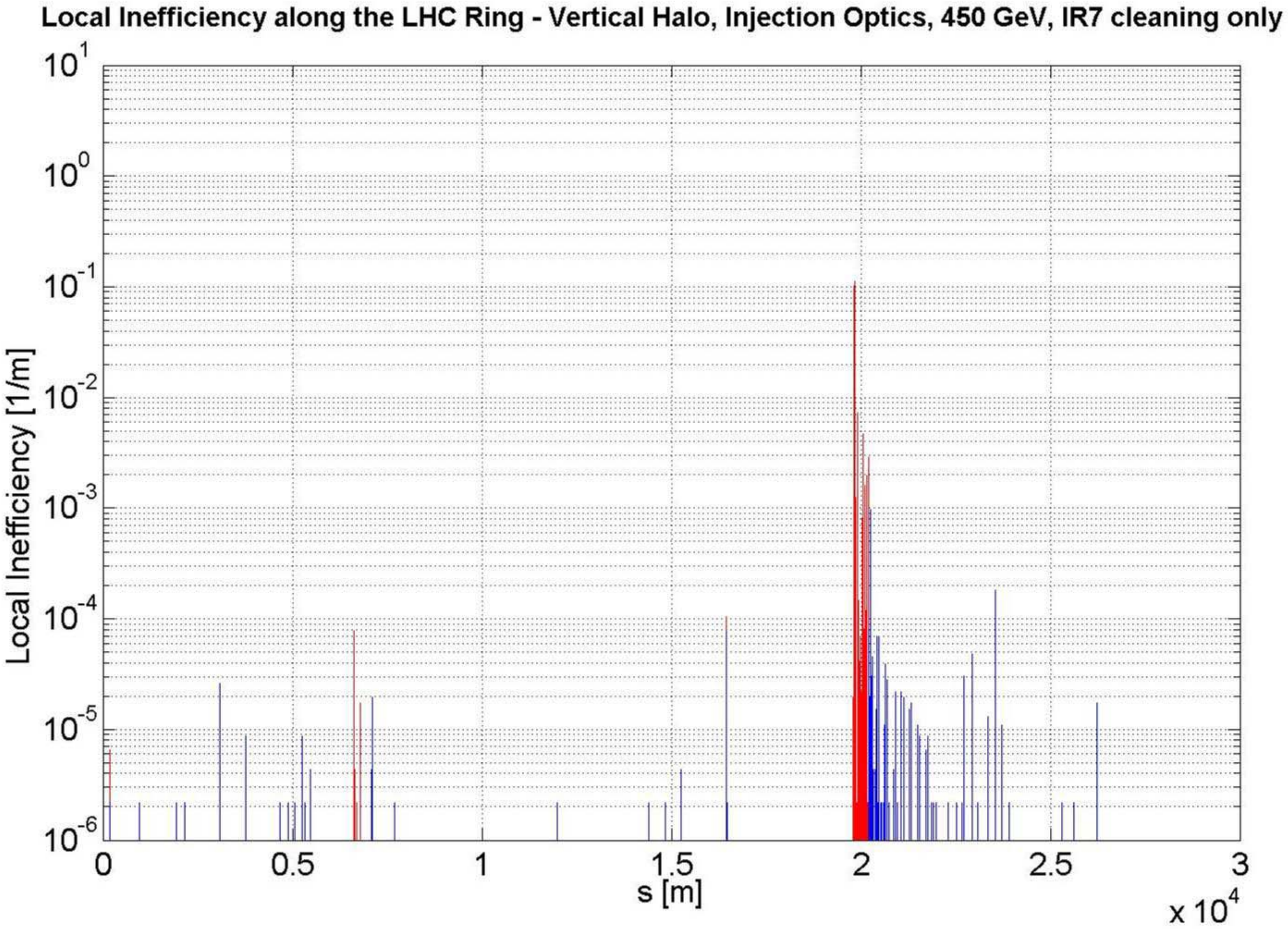
How to simulate ?

- What we simulate: taking into account the normal losses mechanisms, we assume a drift speed of 5.3 nm/turn.

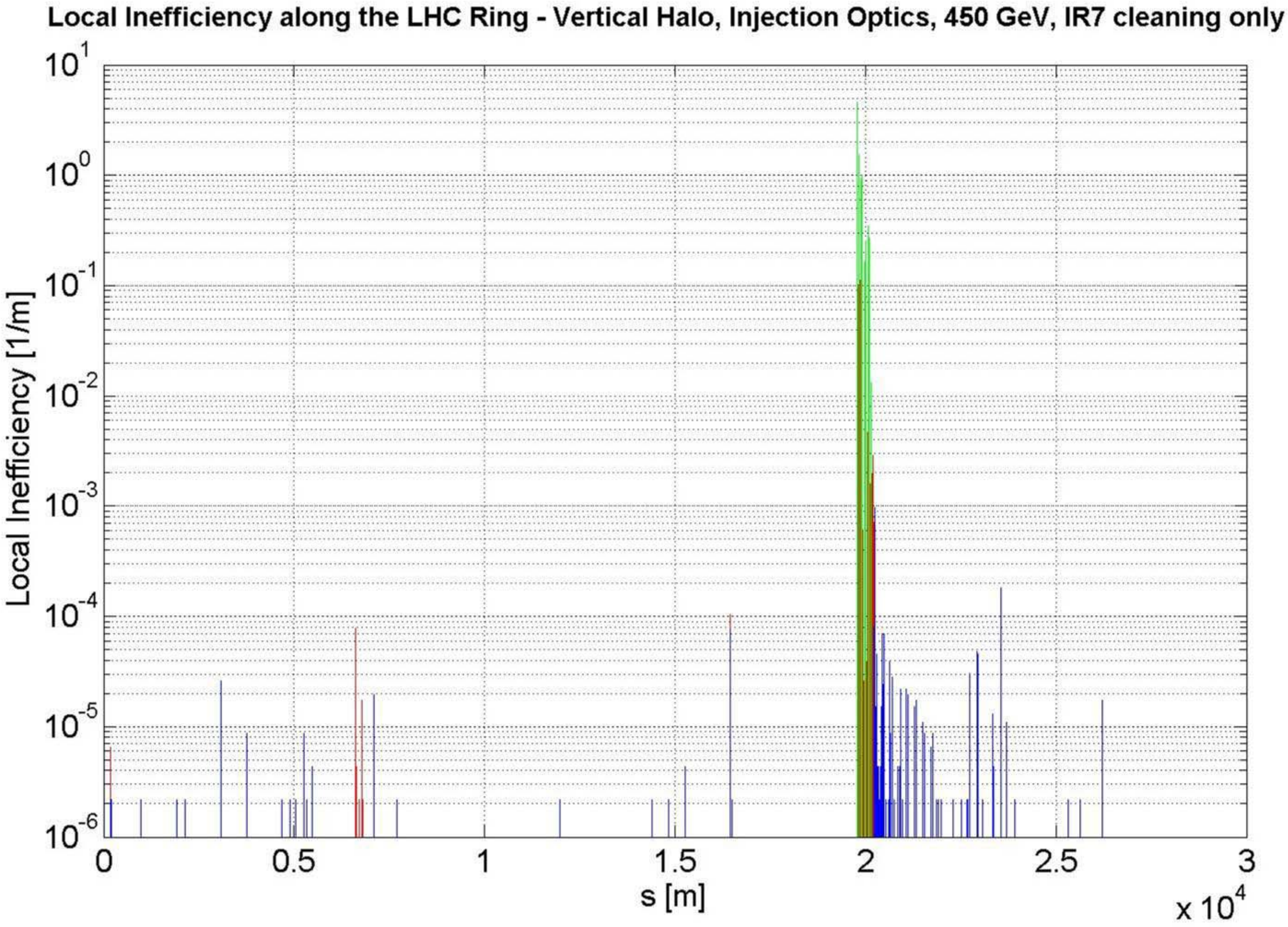
  One way to do our simulations is to generate a distribution of the particles that will hit the collimator jaws, i.e. the external part of the beam which has already drifted above 6 σ.

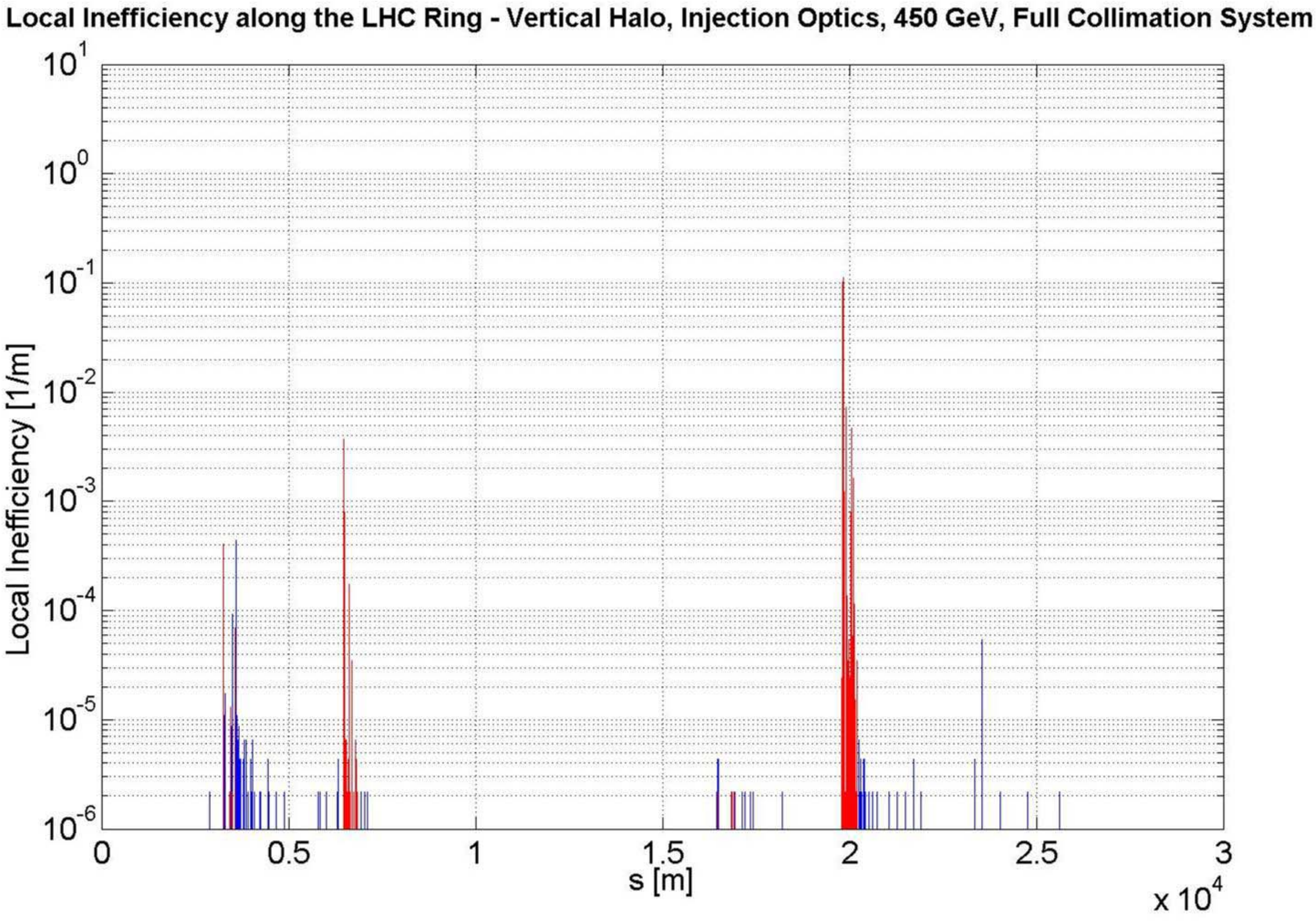
- we first track taking normal losses into account, then we implement the various imperfections (beta-beating, alignment error, coupling…) and accident scenarios.

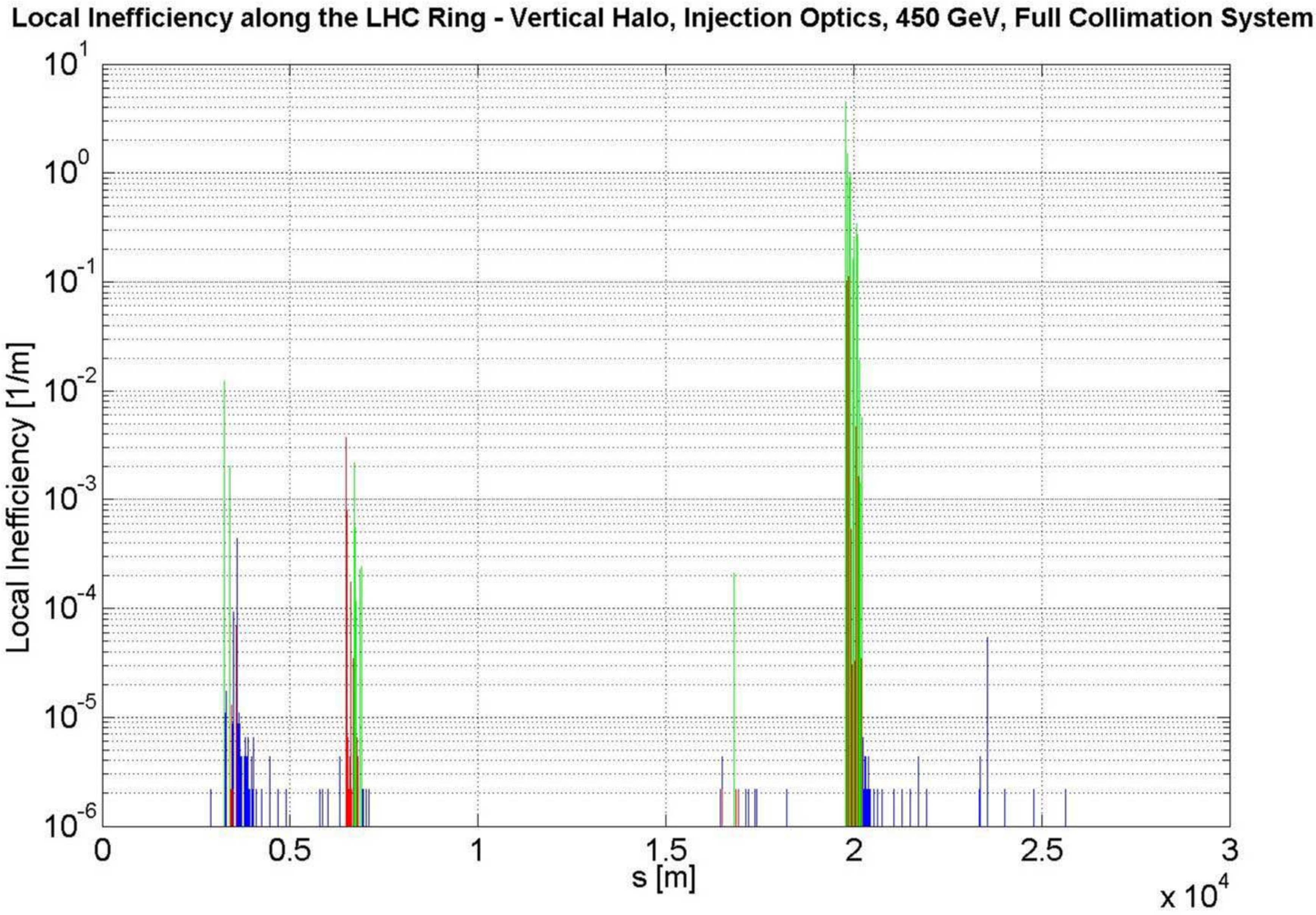




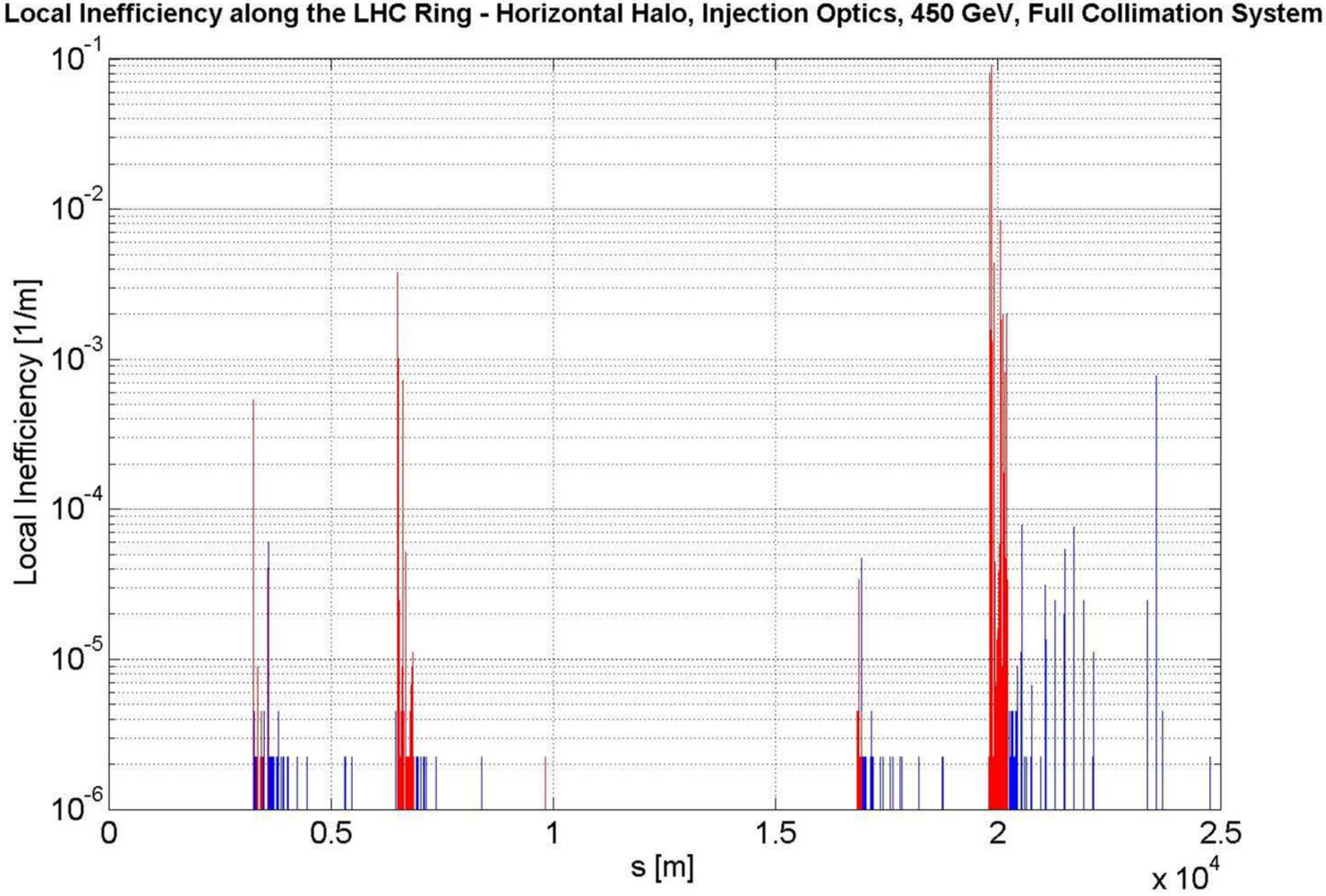
Local Inefficiency along the LHC Ring - Vertical Halo, Injection Optics, 450 GeV, IR7 cleaning only
Local Inefficiency [1/m]
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
0
0.5
1
1.5
2
2.5
3
s [m]
x 10^4


Local Inefficiency along the LHC Ring - Vertical Halo, Injection Optics, 450 GeV, IR7 cleaning only
Local Inefficiency [1/m]
s [m]
x 10^4
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
0
0.5
1
1.5
2
2.5
3

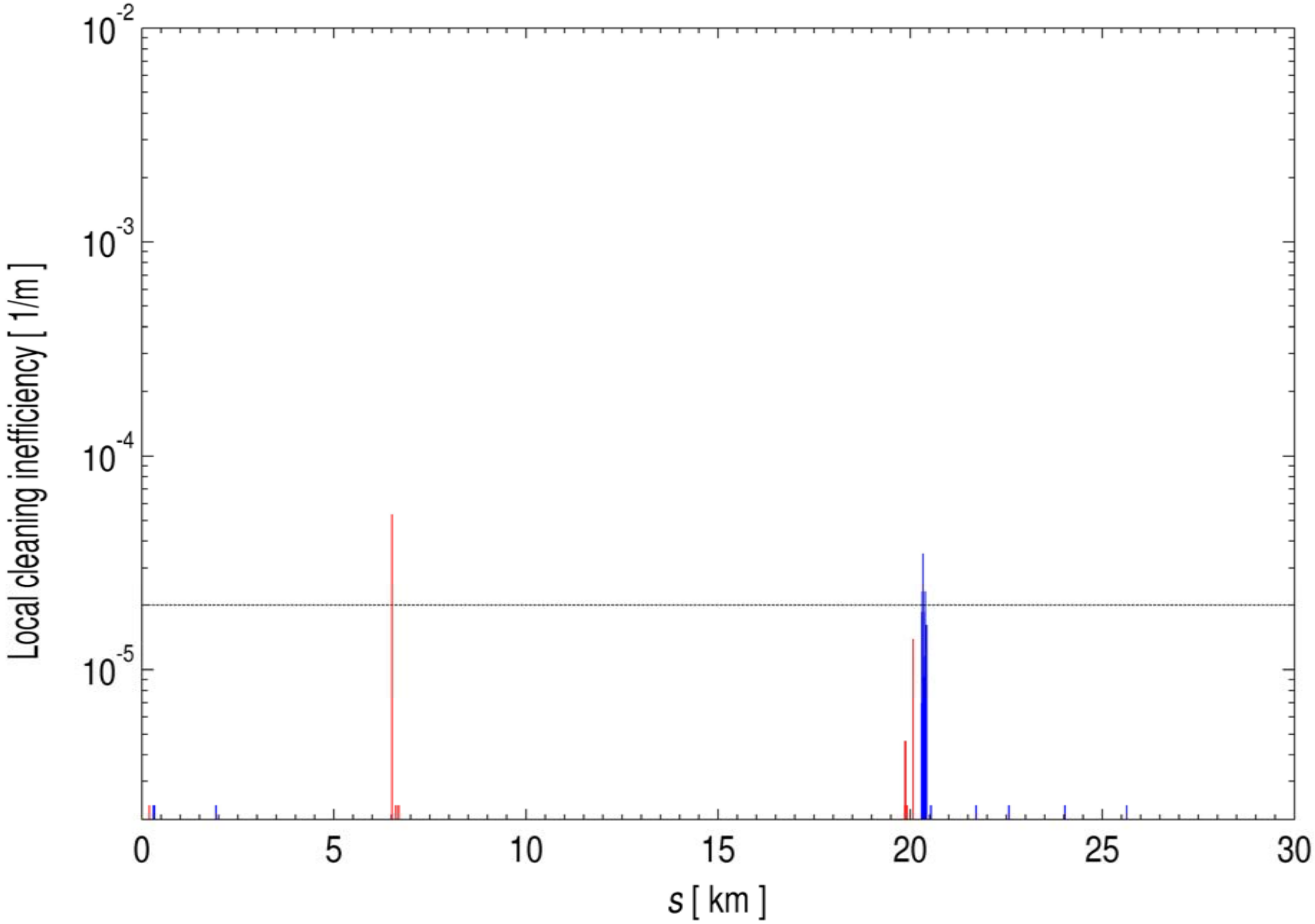

Local Inefficiency along the LHC Ring - Vertical Halo, Injection Optics, 450 GeV, Full Collimation System
Local Inefficiency [1/m]
s [m]
x 10^4
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
0
0.5
1
1.5
2
2.5
3


Local Inefficiency along the LHC Ring - Vertical Halo, Injection Optics, 450 GeV, Full Collimation System
Local Inefficiency [1/m]
s [m]
x 10^4
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
0
0.5
1
1.5
2
2.5
3

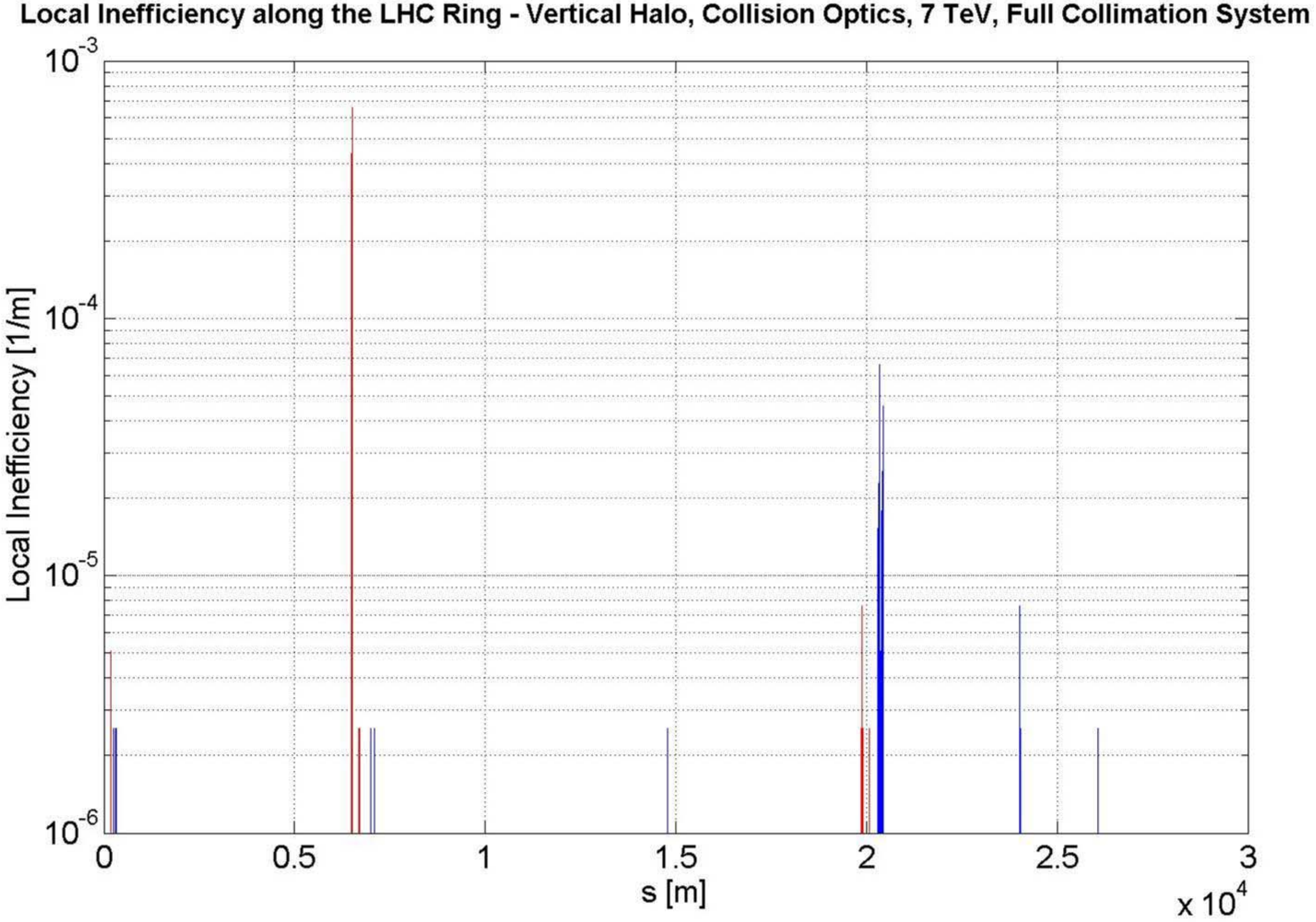
Quick glance at the horizontal plane…



Top Energy Case (horizontal halo)



Top Energy Case (vertical halo)



Comparison of Peak Losses

If we compare the location and value of the 5 highest peaks from the previous loss maps, we can see that we have at least a factor 2 reduction in the losses:

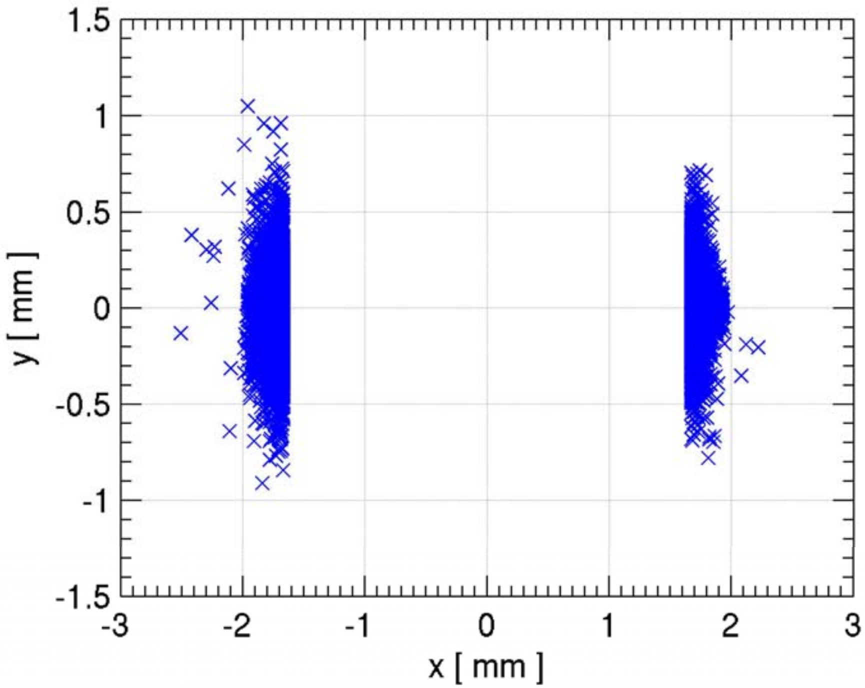
Full System	s [m]	η [1/m]
DFBA	3589.4	4.40E-04
MCBYV	3494.1	9.36E-05
MQML	23553.2	5.44E-05
MQM	3592.4	2.18E-05
MQX	3301.2	1.74E-05

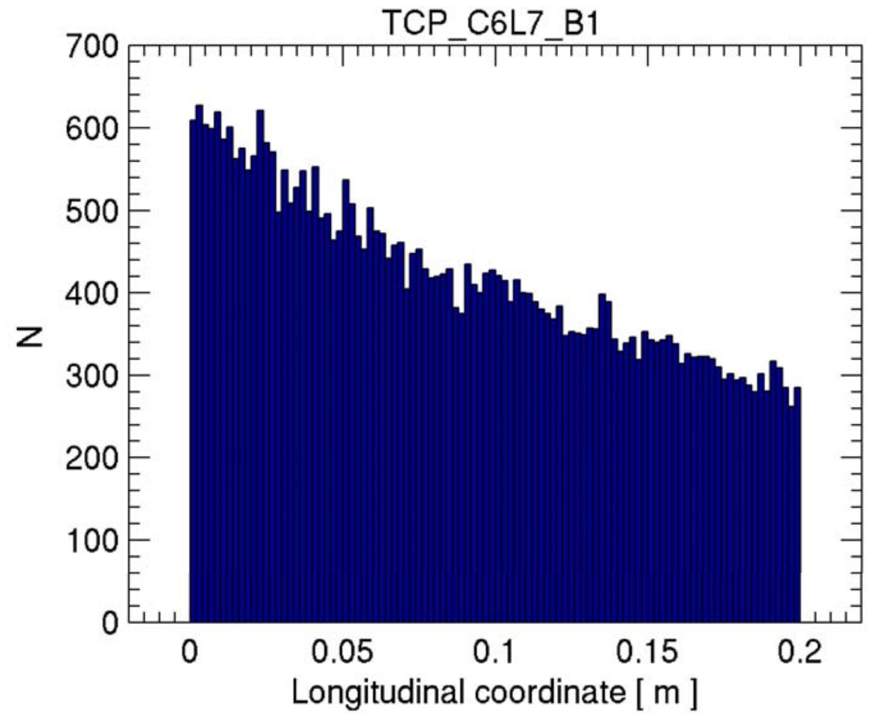
IR7 elements only	s [m]	η [1/m]
DFBA	20253	9.70E-04
MQML	23553.2	1.81E-04
MQTLH	20218	8.07E-05
MQY	16450.9	7.63E-05
MQ.7R3	20427.4	6.98E-05

=> Values of peaks for full system case are about 2 orders of magnitude below the quench limit (10-3 at injection optics); still, this is for a perfect machine case, so values will have to be compared once error models are applied in simulation runs.

Output files for FLUKA studies

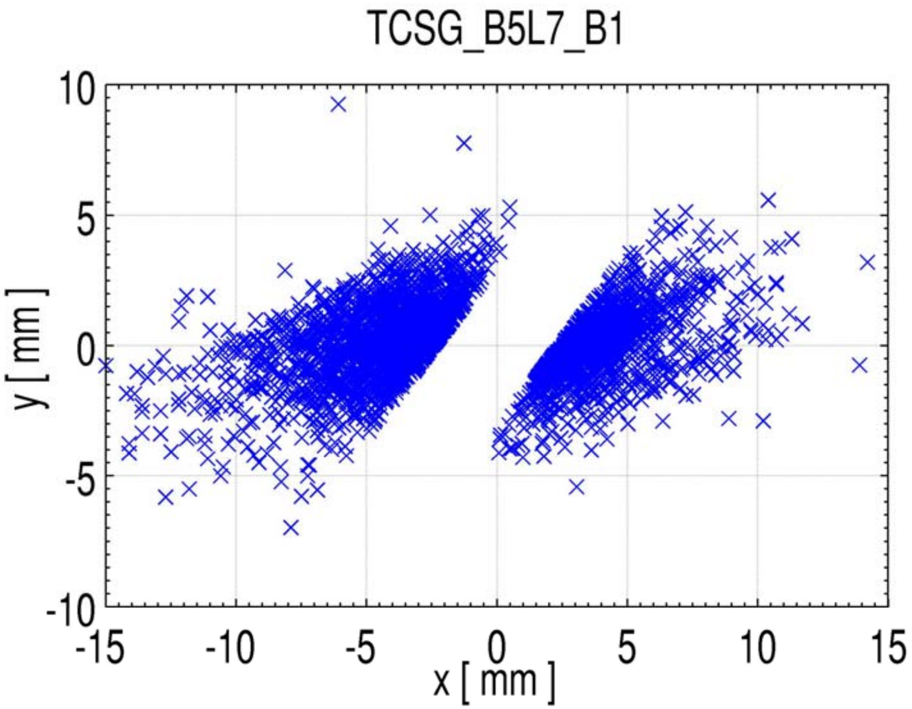
- Possibility of saving a file which includes the location *s* along any collimator jaw of all inelastic interactions; for example, if we track a horizontal halo at collision optics and look at the impacts on the TCP.C6L7.B1 (horizontal primary collimator):

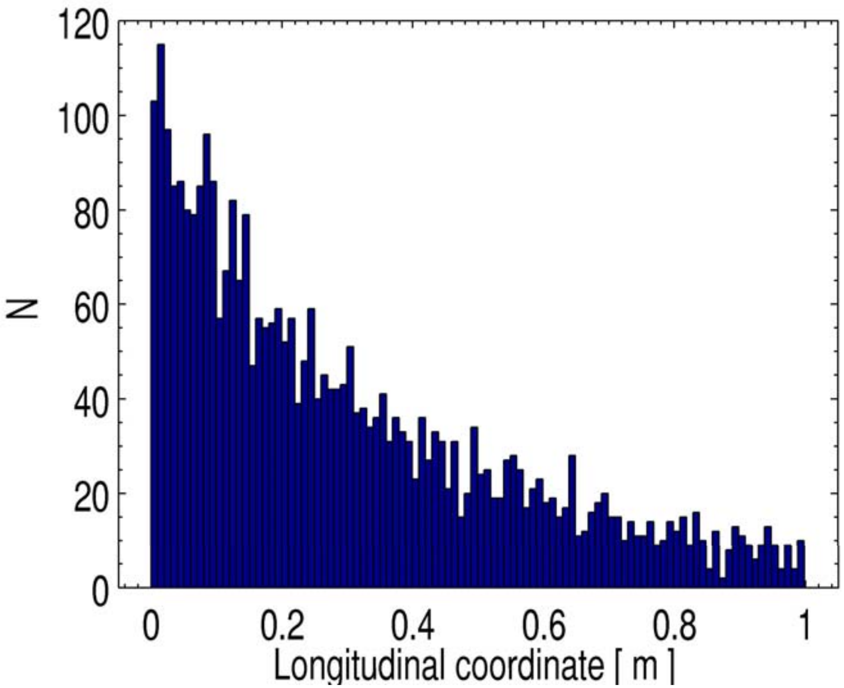




Output files for FLUKA studies (ctd)

- If we now look at the impacts on the TCSG.B5L7.B1 (skew secondary collimator):





Conclusion - Future Work

- We can now work with a complete set of really detailed tools for the complete LHC Collimation System:

  -- a tracking tool which treats every single collimator with correct energy change and kick calculation,

  -- this program can produce input files for both a detailed aperture program (with a 10 cm resolution) and FLUKA studies (distribution of absorptions along any given jaw).

- Future studies include the description of various halo shapes, the integration of complete error models (orbit, coupling, magnet non-linearities) and scenarios of accident cases; a benchmark of the code is also foreseen with RHIC loss maps for proton runs.