First Results for Collimation Commissioning and Error Scenarios

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The Collimation System of the LHC

must provide:

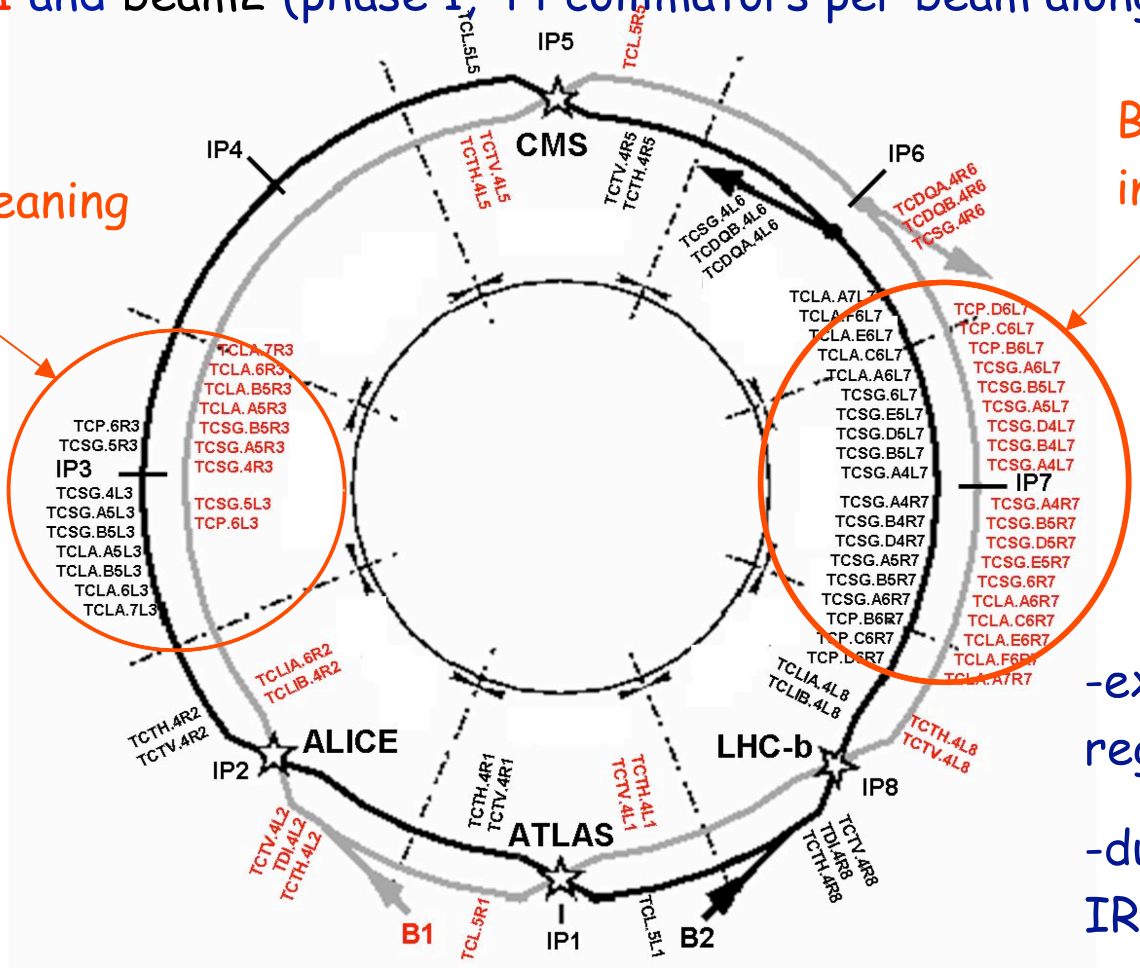
- Beam cleaning: unavoidable beam losses (1% of the beam in 10 s: beam life time 0.2 h) which can cause the quench of the superconducting magnets.
- Machine protection: irregular beam losses (dedicated BLM ⇒ beam dump)
- Minimization of collimation related background at the experiments

It consists of two separated cleaning systems per beam

Collimation system layout

for beam1 and beam2 (phase 1, 44 collimators per beam along the ring)

Momentum Cleaning insertion



Betatron Cleaning insertion

-experimental regions (TCT)

-dump region IR6 (TCDQ)

-injection (TDI,TCLI)

Nominal Intensity:

Ideal Machine

Number of bunches: 2808

Number of particles per bunch: $1.15 \cdot 10^{11}$

Total number of particles: $3 \cdot 10^{14}$

Stability

maximum number of protons: $$N_p^{max} = \frac{\tau \cdot R_q}{\tilde{\eta}_c}$$

where:

τ : beam life time (0.1 h at injection, 0.2 h at collision)

R_q : quench limit ($7 \cdot 10^8$ p/(m*s) injection, $7.8 \cdot 10^6$ p/(m*s) collision)

$\tilde{\eta}_c$: local cleaning inefficiency [1/m]

$$\tilde{\eta}_c = \frac{n_{pl}(s \rightarrow s + \Delta s)}{\Delta s \cdot n_{ap}^{tot}}$$

$\Delta s = 10$ cm $\Rightarrow$ 270000 points

Topics:

1) Early Commissioning Scenarios

2) Error Scenarios

1) Early commissioning scenario

Without any collimator: $\tilde{\eta}_c$= 1 [1/m]

Considering the worst case for beam life time: 0.2 h

Assuming that losses occur over 1 m (pessimistic view)

Maximum intensity : $5{\cdot}10^{11}$ protons (injection)

$5.6{\cdot}10^{9}$ protons (collision)

Increasing the intensity more and more collimators are necessary!

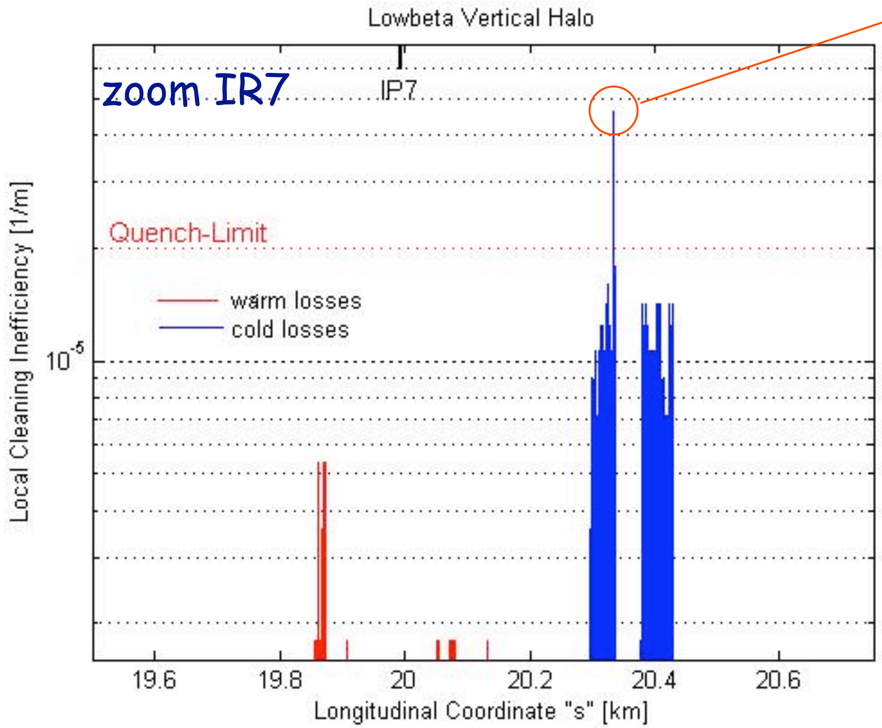
According to the intensity steps previewed for the LHC commissioning:

Stage	k_b	N_b [10^{10} p]	N_{tot} [p]	R_p [p/s]
Pilot	1	0.5	5.0×10^9	6.9×10^6
43 bunch	43	4.0	1.7×10^{12}	2.4×10^9
156 bunch	156	4.0	6.2×10^{12}	8.7×10^9
		9.0	1.4×10^{13}	2.0×10^{10}
75 ns	936	4.0	4.7×10^{13}	5.2×10^{10}
25 ns	2808	4.0	1.1×10^{14}	1.6×10^{11}
		5.0	1.4×10^{14}	2.0×10^{11}
		11.5	3.2×10^{14}	4.5×10^{11}

[R.A. Chamonix 2006]

Looking at the loss maps we can see that even for the "perfect" machine with the complete phase1 layout it's impossible to reach the maximum intensity.

Vertical betatron halo 7 Tev lowbeta nominal case (beam1):



$\tilde{\eta}_c = 4.7 \cdot 10^{-5}$ 1/m

$N_p^{max} = 1.22 \cdot 10^{14}$ protons

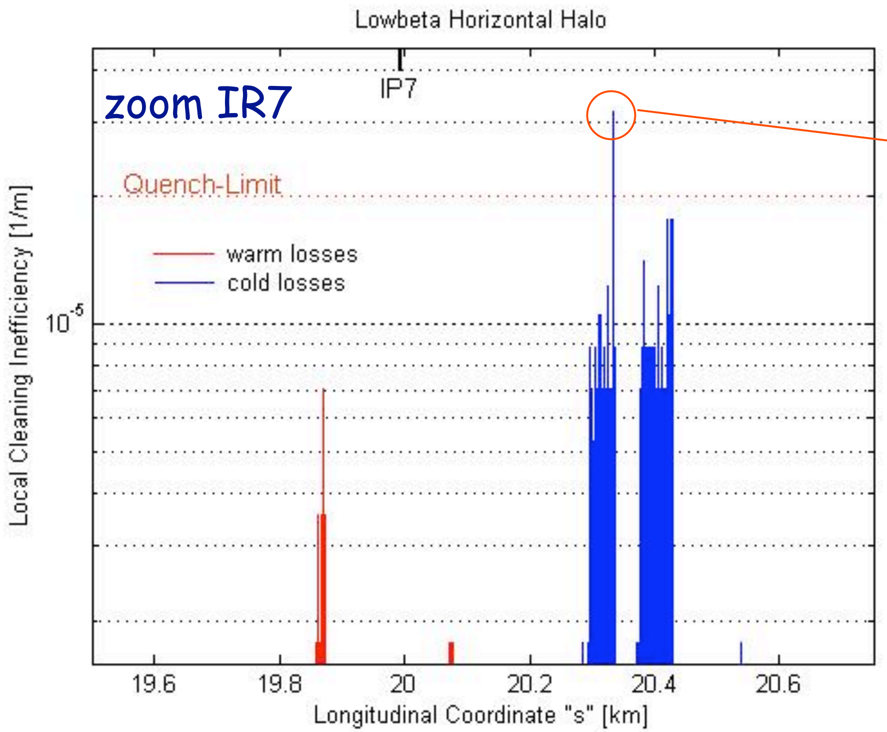
<40% Nominal intensity

In addition to impedance problem!

Additional collimators to increase the intensity (phase2:other 30 collimators, in total with up to 132 collimators it will be possible to reach > 40% nominal intensity)

Horizontal betatron halo 7 Tev lowbeta nominal case (beam1):

Maximum peak lower than for vertical halo but globally we have ~10% more losses for horizontal than for vertical halo.

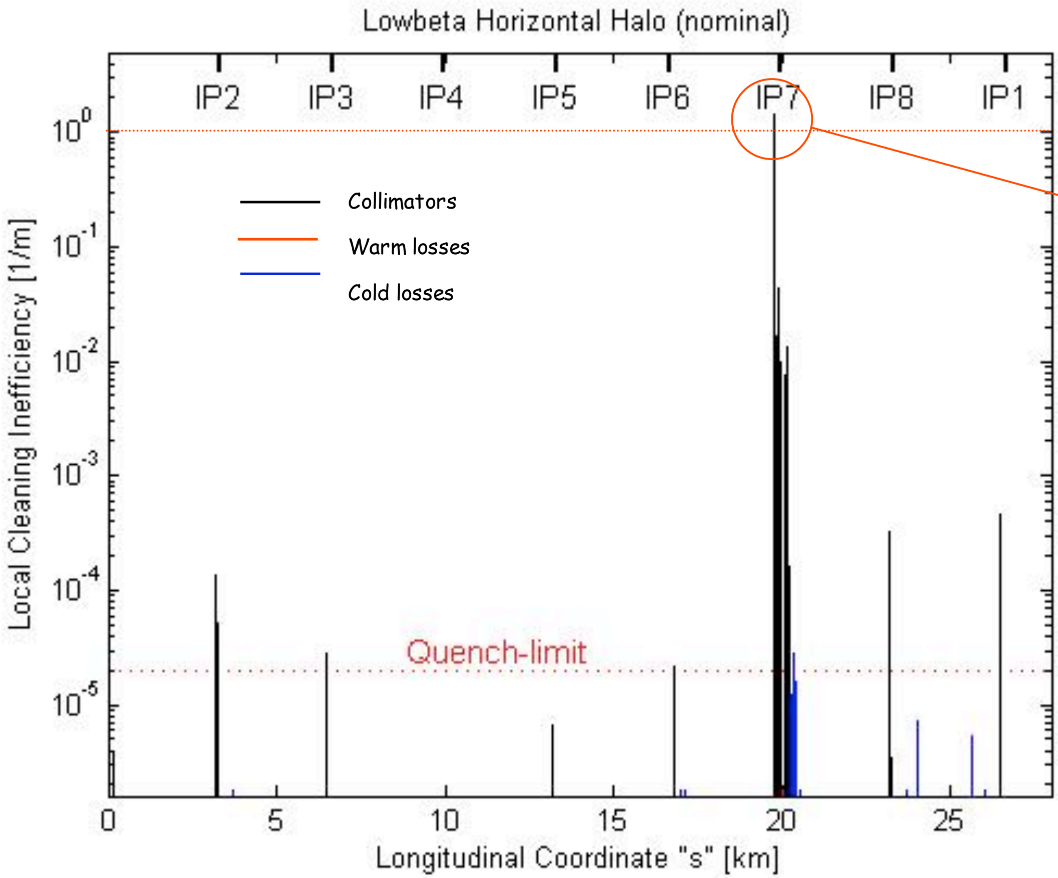


$\tilde{\eta}_c = 3.2 \cdot 10^{-5}$ 1/m

$N_p^{max} = 1.75 \cdot 10^{14}$ protons

Horizontal betatron halo 7 Tev lowbeta nominal case (beam1):

Same as before but with losses on the collimators (black peaks).



Inefficiency > 1 because the unit is [1/m] and the length of the primary is 0.6 m.

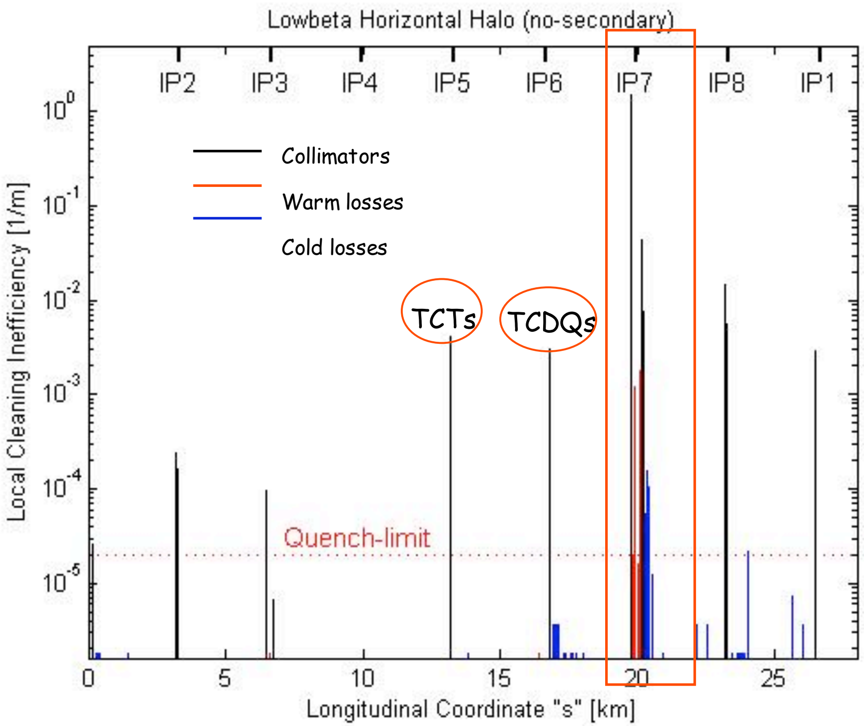
In this case $\tilde{\eta}_c = 1.44\ m^{-1}$

then $\eta_c = 0.87 \Rightarrow$ 87% of the inelastic scattering happens in primary collimator.

Early collimation setup (see R.A. talk at Chamonix 2006)

Idea: can we rely on a "poor man's" two stage cleaning system with primary (CFC) and absorbers (W) as secondary collimators at wrong phase position in IR7??

To prove this I performed simulations with the nominal collimation setting but with no secondary collimators



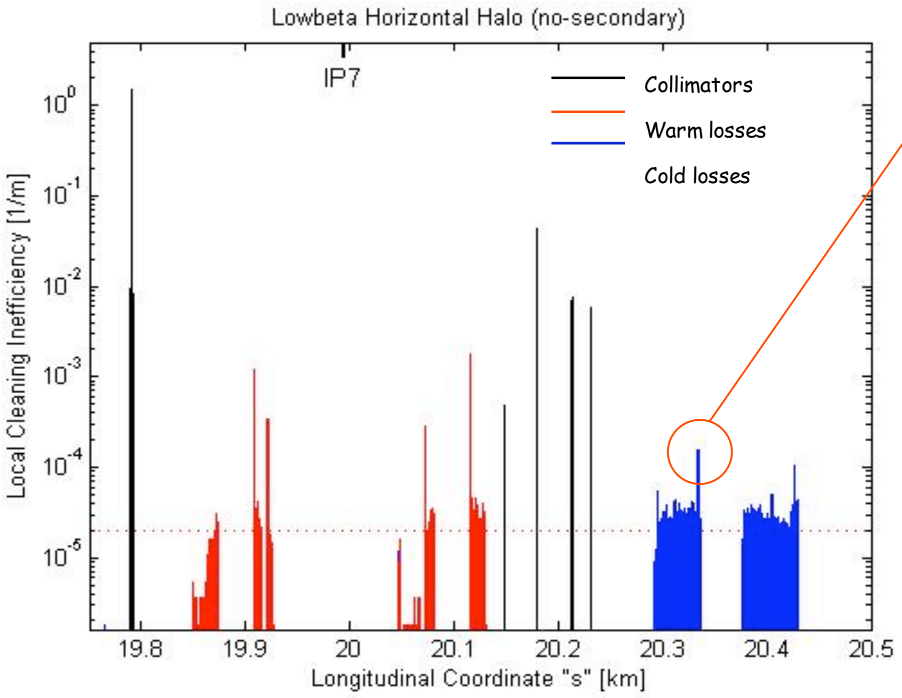
Horizontal halo 7 Tev (beam1):

Now tertiary collimators (TCTs) and TCDQs start acting as secondary collimators.
Two possibilities:

-Acceptable for low intensity and nominal settings

- Open settings by using early nominal optics (β* of 2m instead of the nominal 0.55m)

Zoom on IR7 for horizontal halo 7Tev (beam1):



Limited to 10% of the nominal intensity

Stage	k_b	N_b [10^{10} p]	N_{tot} [p]	R_p [p/s]
Pilot	1	0.5	5.0×10^9	6.9×10^6
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Deposition energy(FLUKA): about a factor 7 worse for the minimal system respect to the nominal one

Magnet	Full system P_{dep}^{peak} [mW/cm^3]	Minimal system P_{dep}^{peak} [mW/cm^3]
Q6 (MQTL)	0.22	1.34
Q11	1.55	9.94
MB9	0.55	4.05

Before drawing the final conclusions we need to perform simulations for the 2m early optics with relaxed TCTs' and TCDQs' apertures

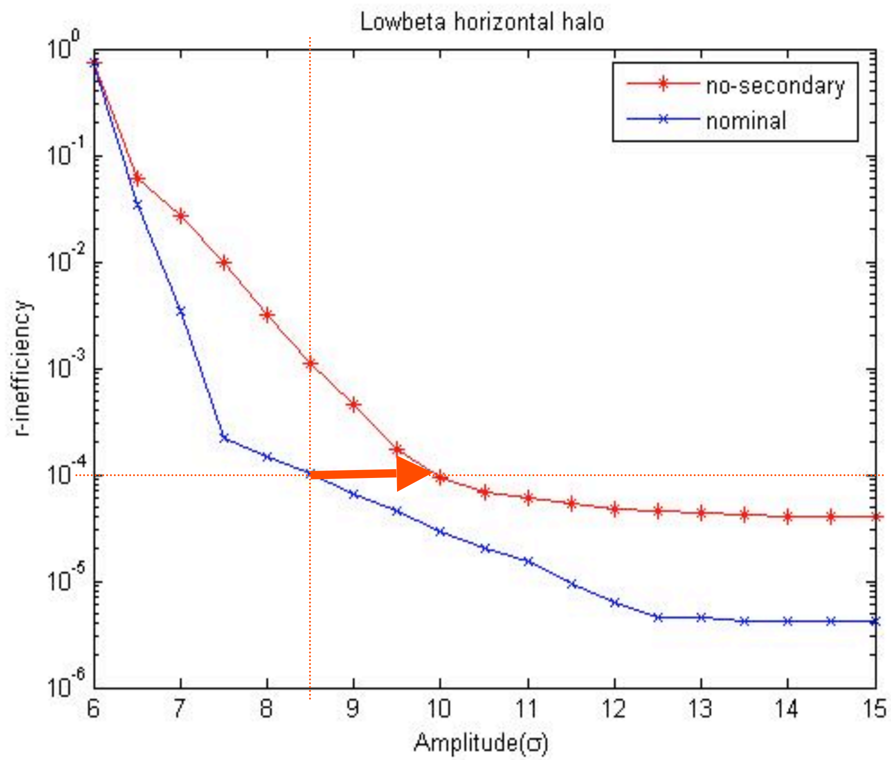
[R.A. Chamonix 2006]

Comparison of inefficiency curves between nominal and minimal scenarios

Cleaning inefficiency:

$$\eta_c(A_0) = \frac{N_p(A > A_0)}{N_{abs}}$$

At 8.5σ we loose one order of magnitude respect to 10^{-4}



Possible solution: relax setting by ~ 1.5σ for TCTs and TCDQs to get an acceptable level of inefficiency.

Conclusions:

-This minimal workable system allows to reach the 10% of nominal intensity (β^*=0.55m) or to use more relaxed settings for tertiary collimators and TCDQs (β^*=2m)

- The system has much more relaxed tolerances and is less affected by imperfections

Future works:

- Investigate new minimal systems for different optics for beam1 and beam2 :

β^* [m]	n_1 [σ]	n_2 [σ]	n_a [σ]	n_3 [σ]	n_{tcdq} [σ]
2.00	10.0	-	-	17.0	13.5
2.00	6.0	-	10.0	17.0	8.0
2.00	6.0	9.5	10.0	17.0	8.0
2.00	6.0	8.0	10.0	17.0	8.0
2.00	6.0	7.0	10.0	17.0	8.0
2.00	6.0	7.0	10.0	17.0	8.0
0.55	6.0	-	-	8.3	7.5
0.55	6.0	-	10.0	8.3	7.5
0.55	6.0	8.0	10.0	8.3	7.5
0.55	6.0	7.0	10.0	8.3	7.5
0.55	6.0	7.0	10.0	8.3	7.5
0.55	6.0	7.0	10.0	8.3	7.5

[R.A. Chamonix 2006]

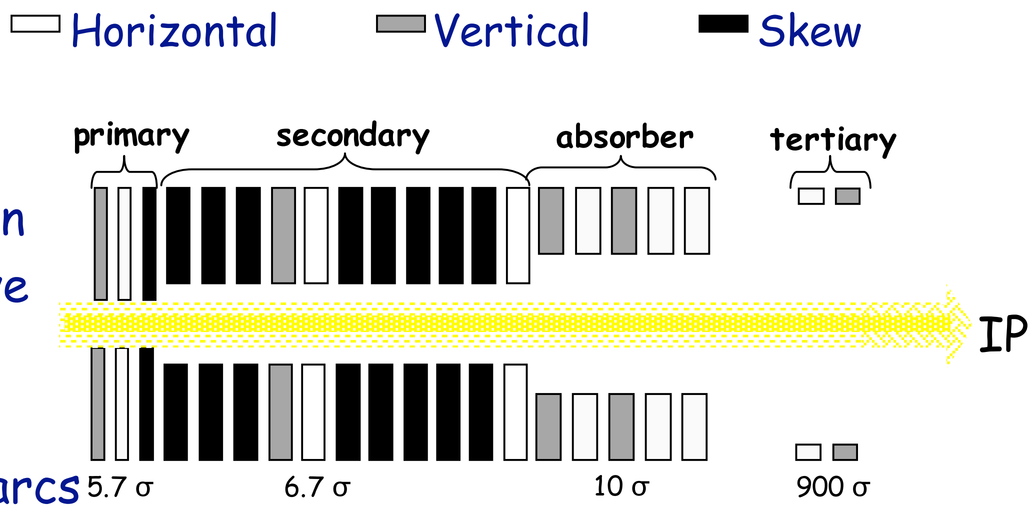
Topics:

1) Early Commissioning Scenarios

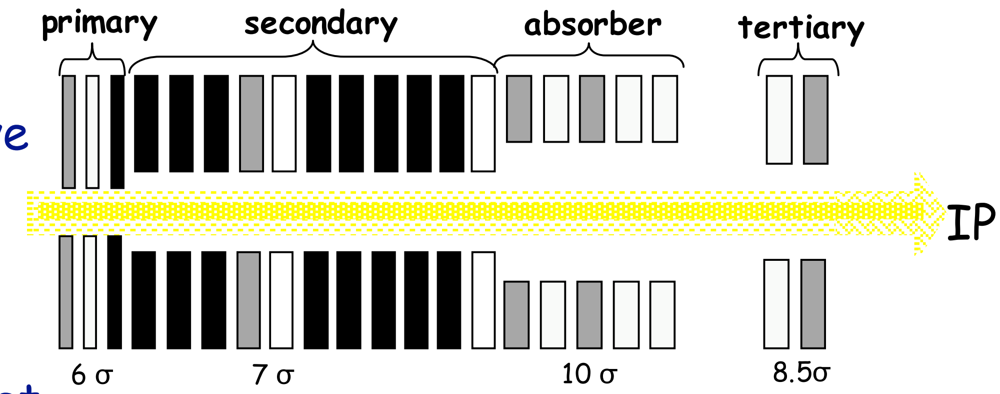
2) Error Scenarios

Betatron cleaning insertion (IR7)

Injection effective 3 stage cleaning before arcs



Collision effective 4 stage cleaning before SC triplet



Physical aperture in the arcs: ~ 40mm

Minimum physical aperture collimator in IR7:

Injection ~ 8 mm

Collision ~ 1 mm

Why simulate an error scenario?

The secondary collimators must intercept the particles scattered by the primary collimators without influencing the unscattered beam.

For this reason secondary collimators have to be placed in the shadow of the primary and mustn't be closer to the beam than the corresponding primary.

I simulated an error scenario where a secondary collimator becomes a primary either for Beam 1 and Beam 2 injection and collision case for the horizontal halo.

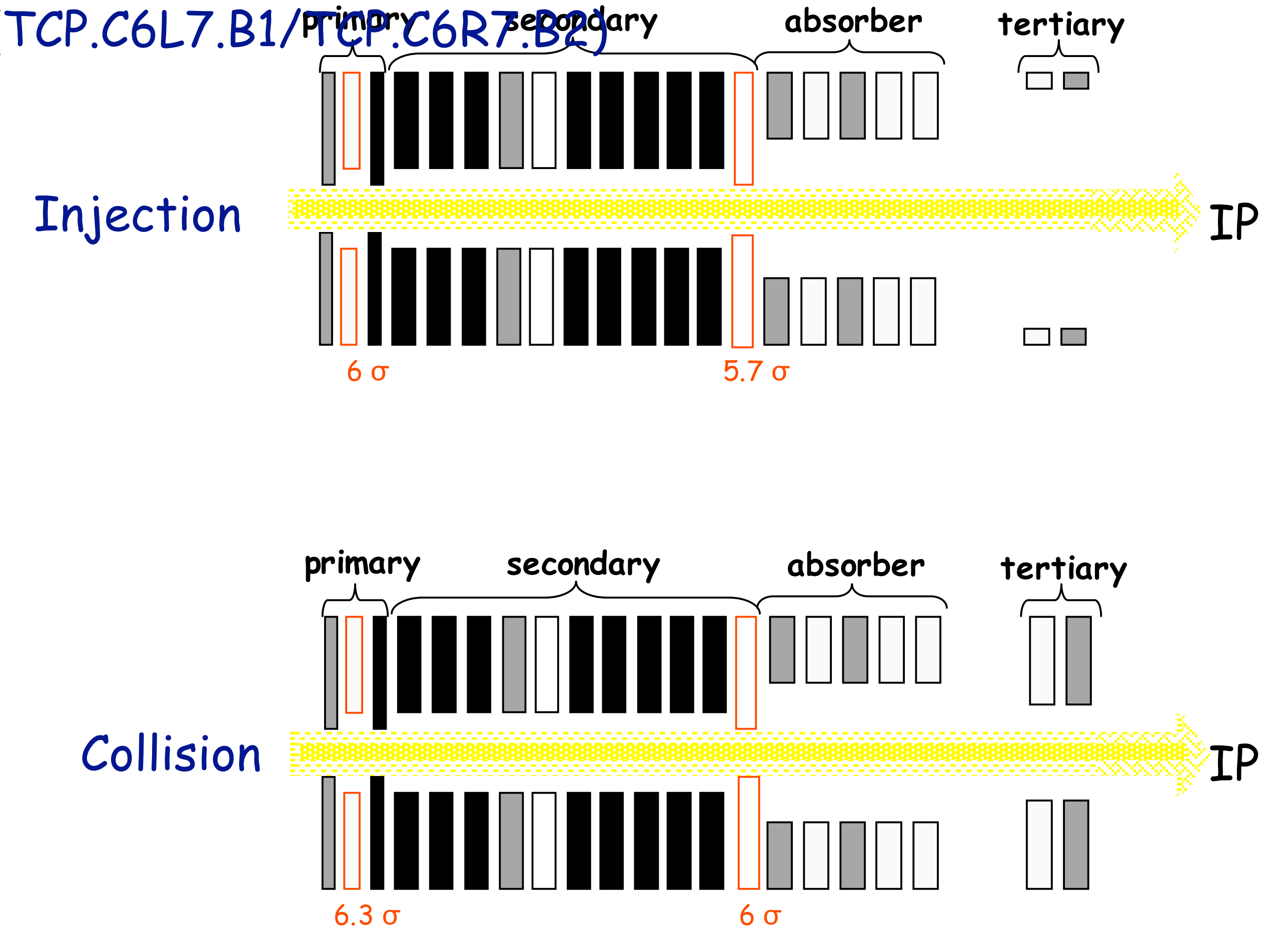
Why is this interesting?

-To understand beam loss signature and associated BLM readings

-To provide inputs to BI group for studies on BLM (data already sent)

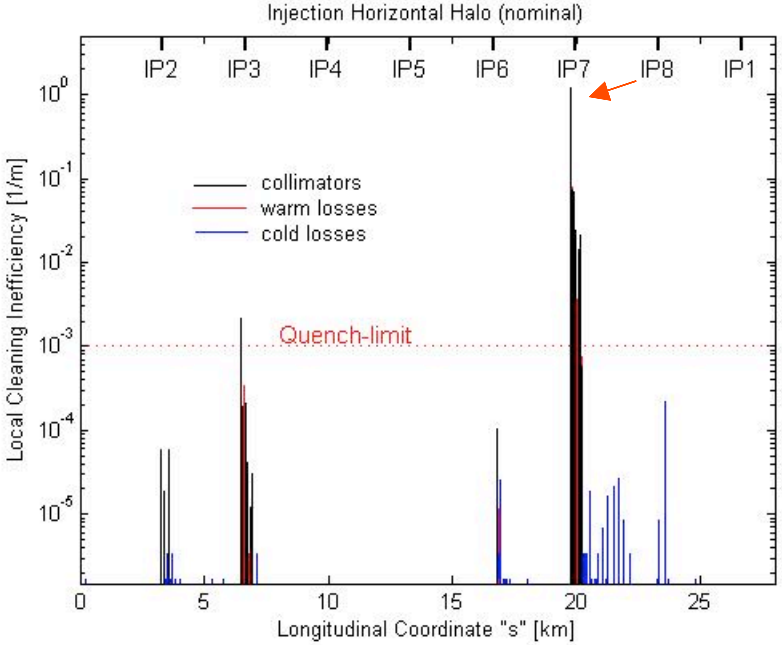
Error Scenario scheme

The last secondary horizontal collimator (TCSG.6R7.B1/TCSG.6L/.B2) is closer to the beam than the only horizontal primary (TCP.C6L7.B1/TCP.C6R7.B2)

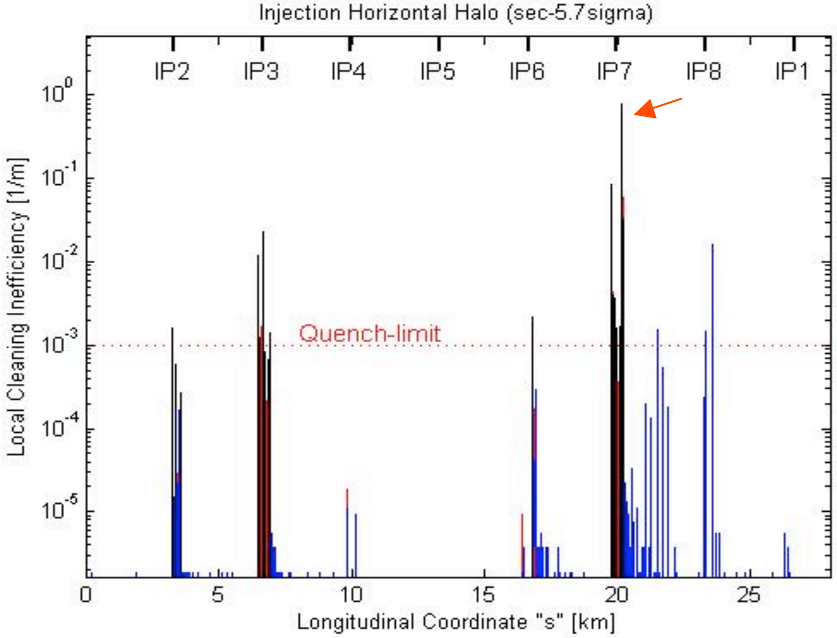


Loss maps injection beam1

Nominal setting



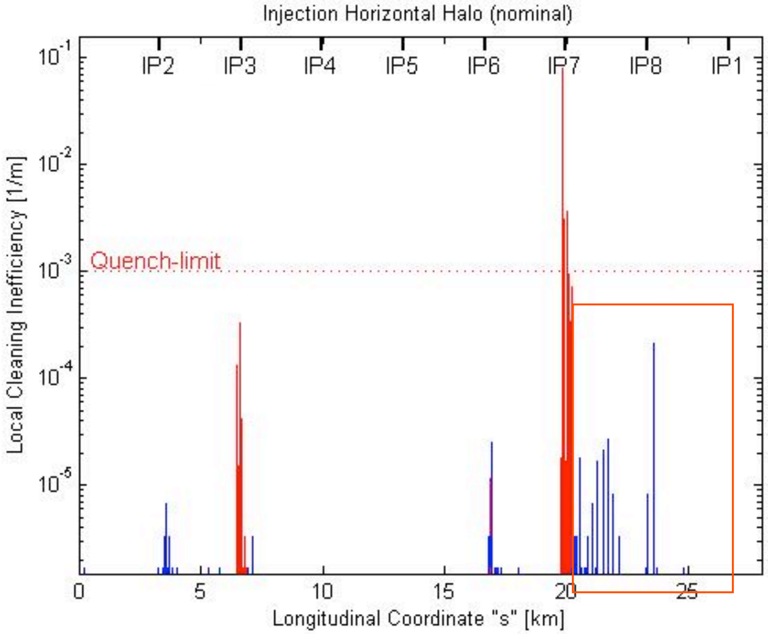
Error scenario



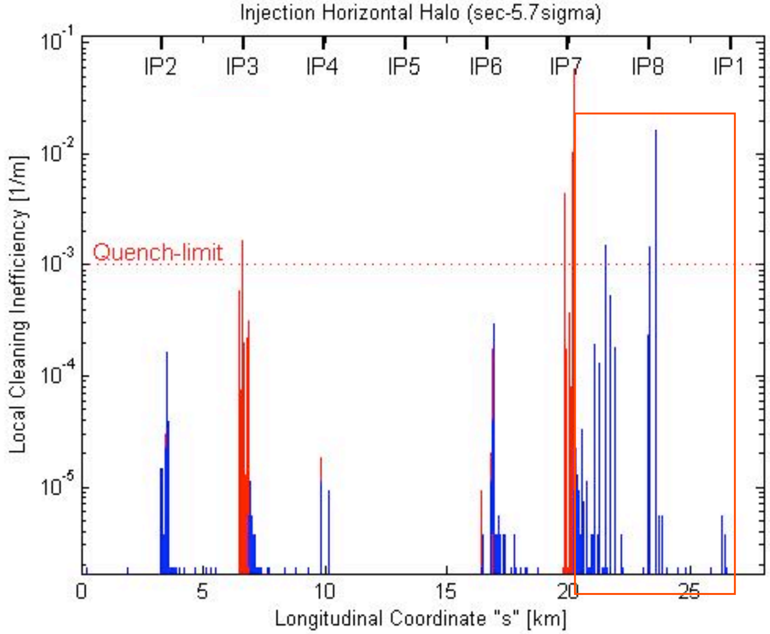
Red arrows show how for the error scenario the highest loss peak is shifted from the primary to the secondary horizontal collimator. In IR2 and IR3 losses on collimators are increased of 1 order of magnitude for the error case.

Loss maps injection beam1 without losses on collimators

Nominal setting



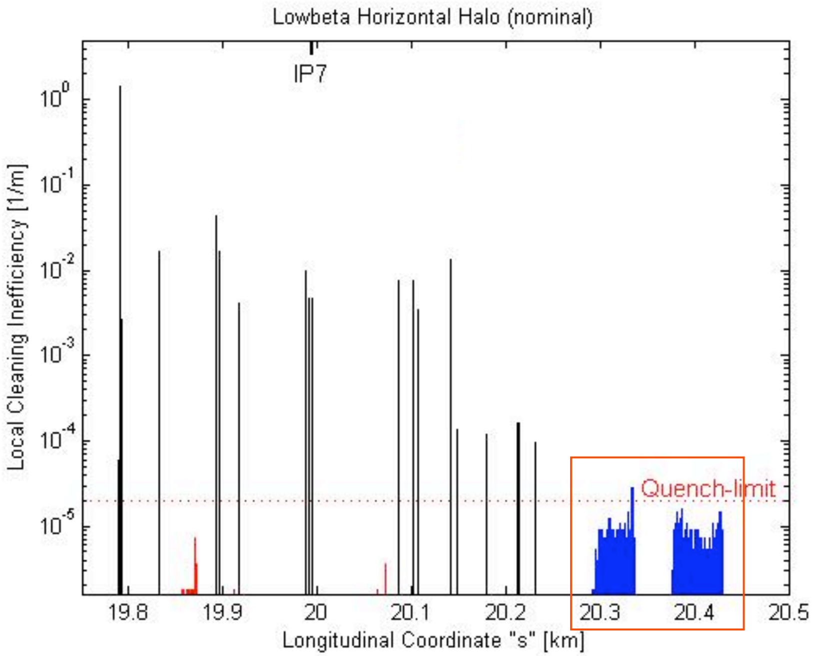
Error scenario



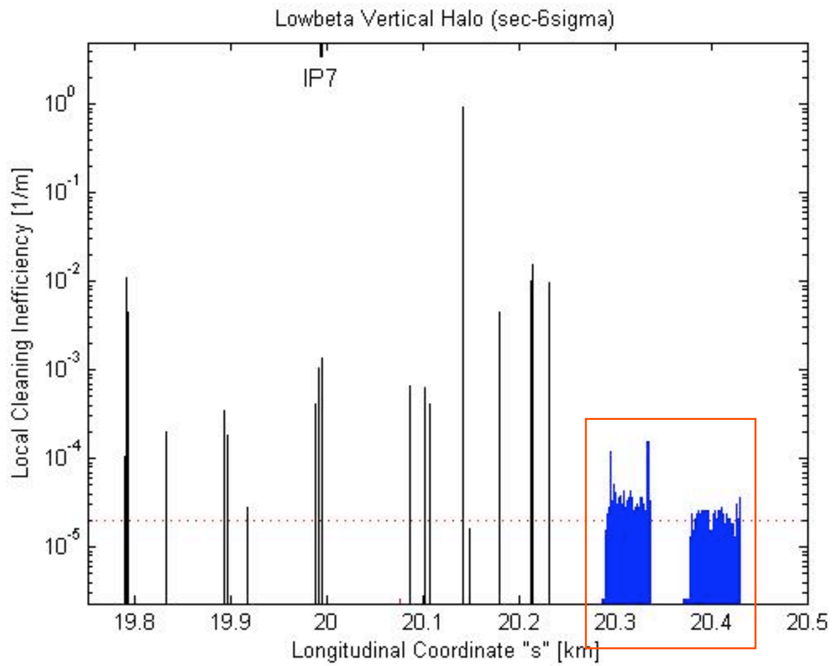
The error scenario presents more and much higher peaks than the nominal case. In highlighted region for error case there are 100 times higher losses 10 times above the quench limit.

Loss maps lowbeta beam1 zoom on IR7

Nominal setting



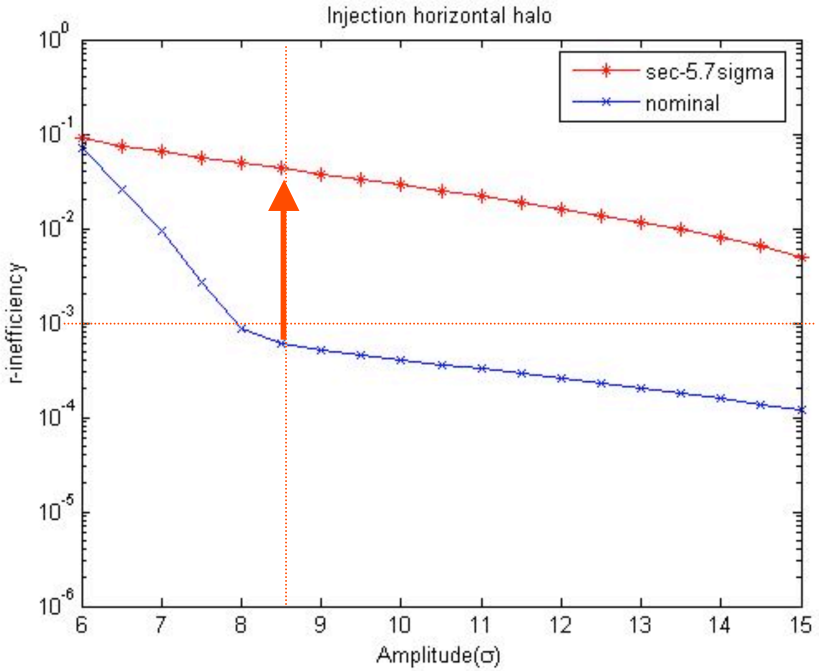
Error scenario



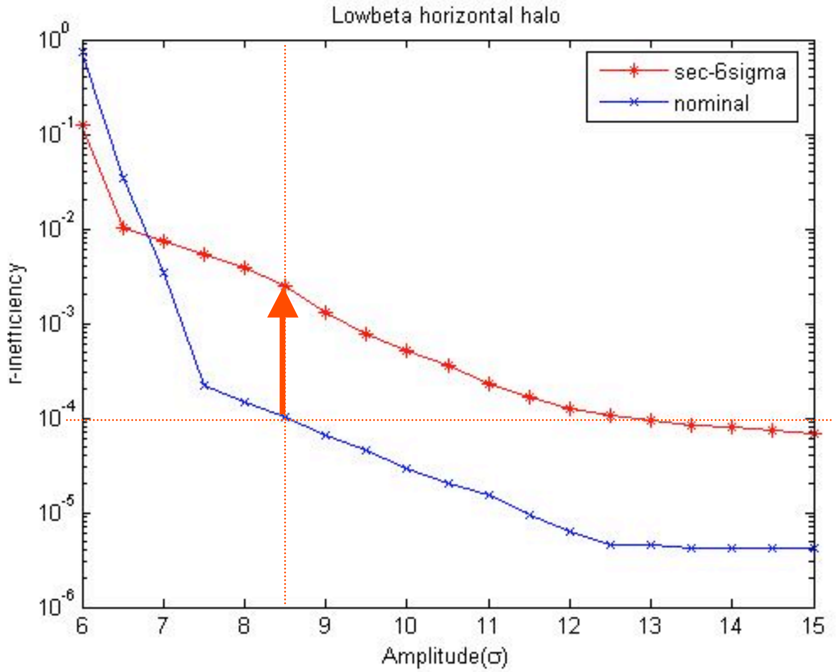
Even in this case for the error scenario losses are 10 times above the quench limit but the increas respect the nominal setting is of a factor 10. This is due to the tertiary collimators which act as secondary.

Inefficiency curves

Injection 450 GeV



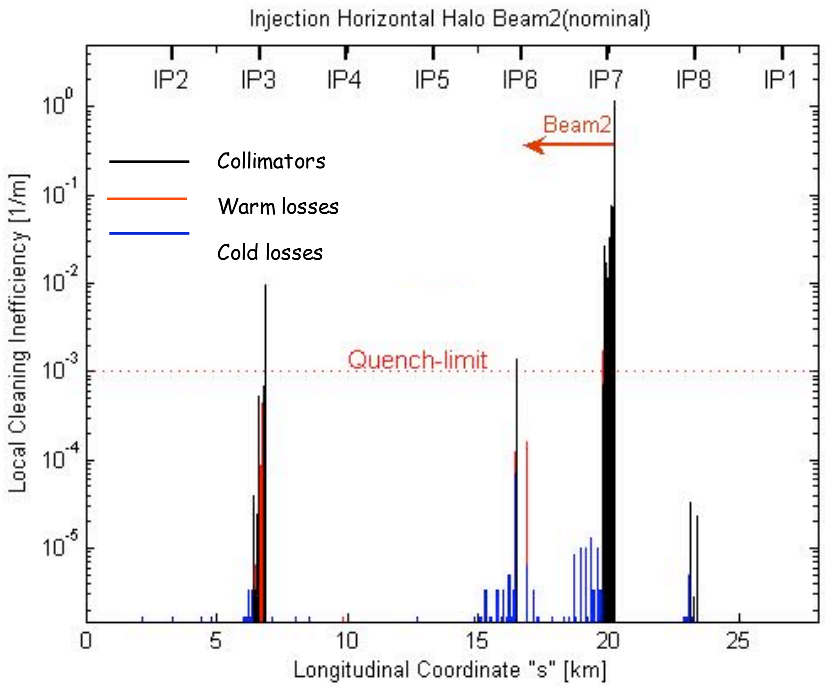
Lowbeta 7 TeV



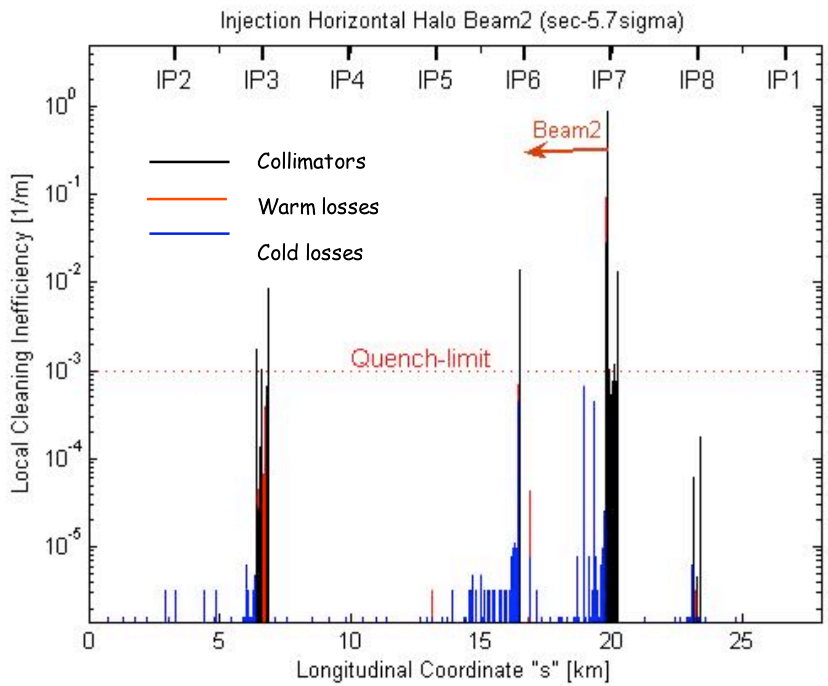
Inefficiency extremly high in both cases,worse for injection

Loss maps injection beam2

Nominal setting



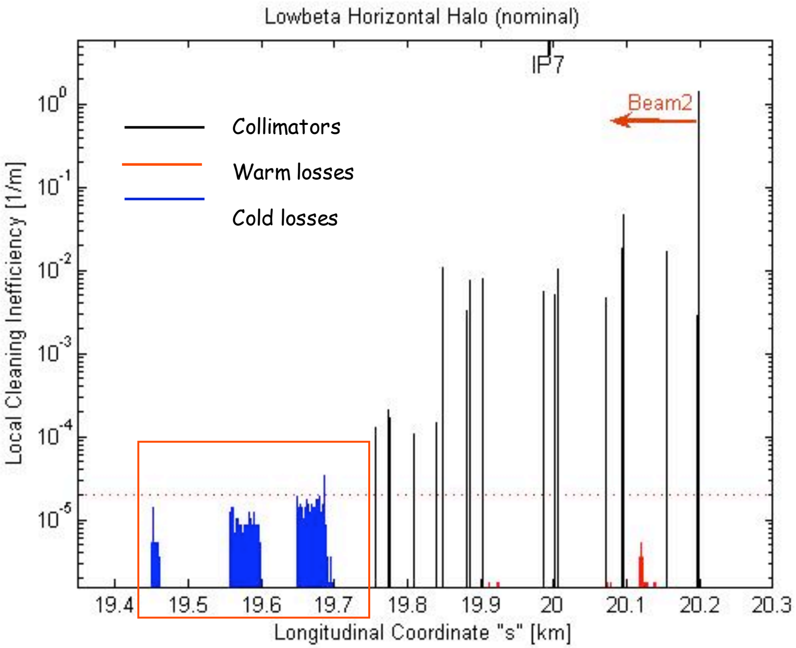
Error scenario



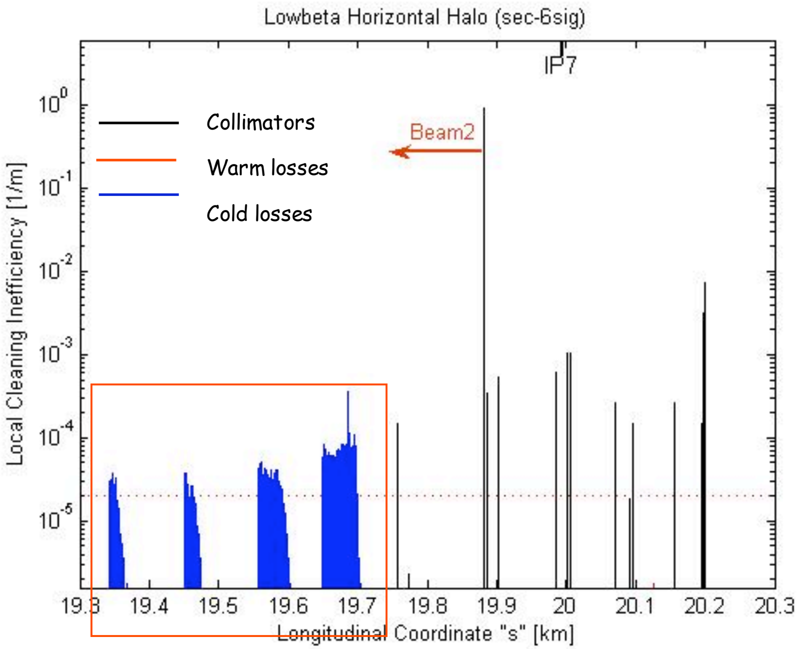
Different from beam1 case since losses are always below the quench limit!!

Loss maps lowbeta beam2

Nominal setting



Error scenario



More or less equivalent to beam1!

Conclusions

-Simulating error scenarios I showed how losses along the machine change with wrong opening settings underlining the importance of having a two stage collimation system.

- Provide more statistic to BI group for studies on BLM.

Future topics

- Studies on momentum cleaning (IR3)

- Phase2 (collaboration with SLAC,BNL and FERMILAB)