Early Commissioning Scenarios

Chiara Bracco, Ralph Assmann, Stefano Redaelli,
Guillaume Robert-Demolaize, Thomas Weiler

The Collimation System of the LHC

must provide:

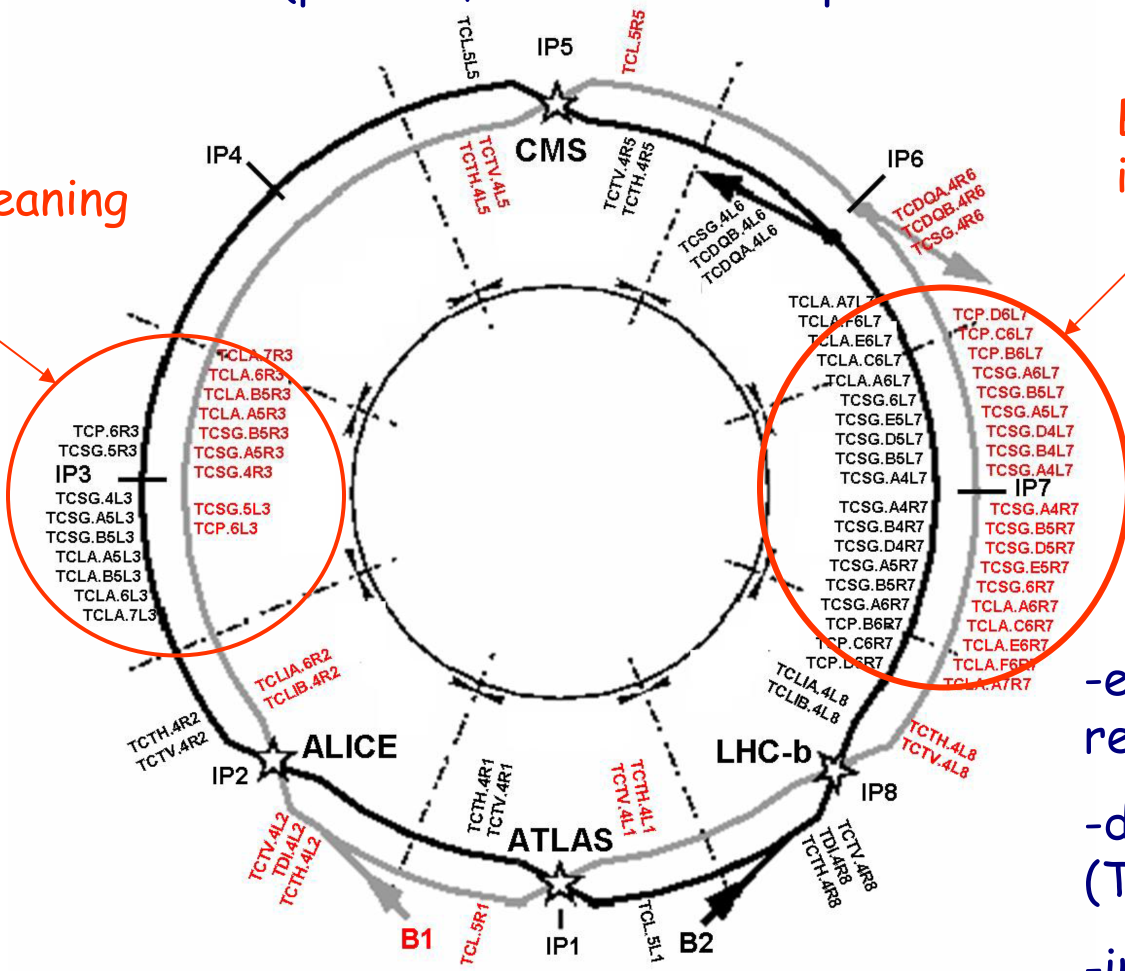
- Beam cleaning: unavoidable beam losses (1% of the beam in 10 s: beam life time 0.2 h) which can cause the quench of the superconducting magnets.
- Machine protection: irregular beam losses (dedicated BLM ⇒ beam dump)
- Minimization of collimation related background at the experiments

It consists of two separated cleaning systems per beam

Nominal 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: 3×10^{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]

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

Δs = 10 cm $\Rightarrow$ 270000 points for loss maps

Tracking simulations:

Tracking simulations for 5×10^6 halo particles for the ideal machine have been performed, for the two beams, considering the nominal optics:

β^*= 0.55 m at IP1 (ATLAS) and IP5 (CMS)

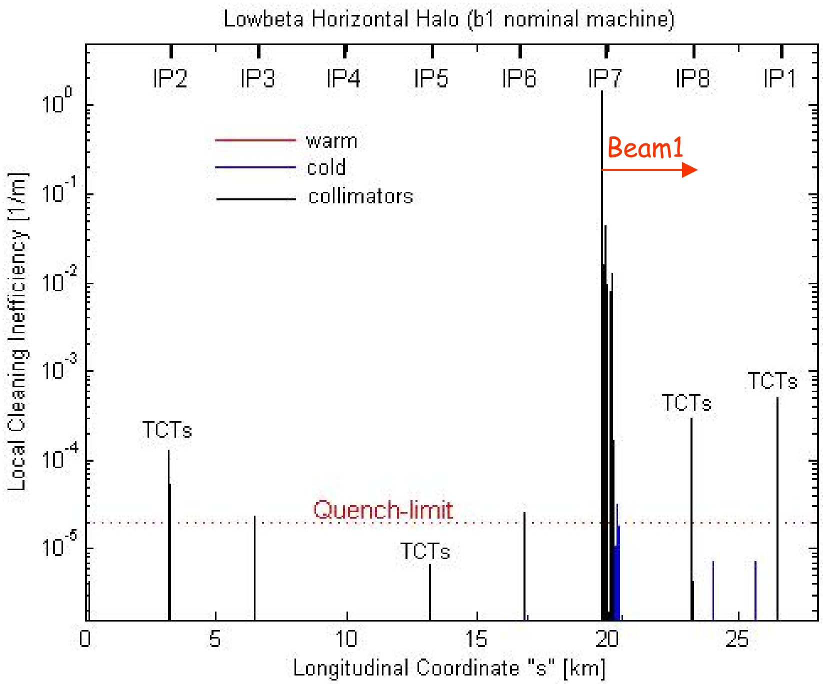
β^*= 10 m at IP2 (ALICE) and IP8 (LHC-b)

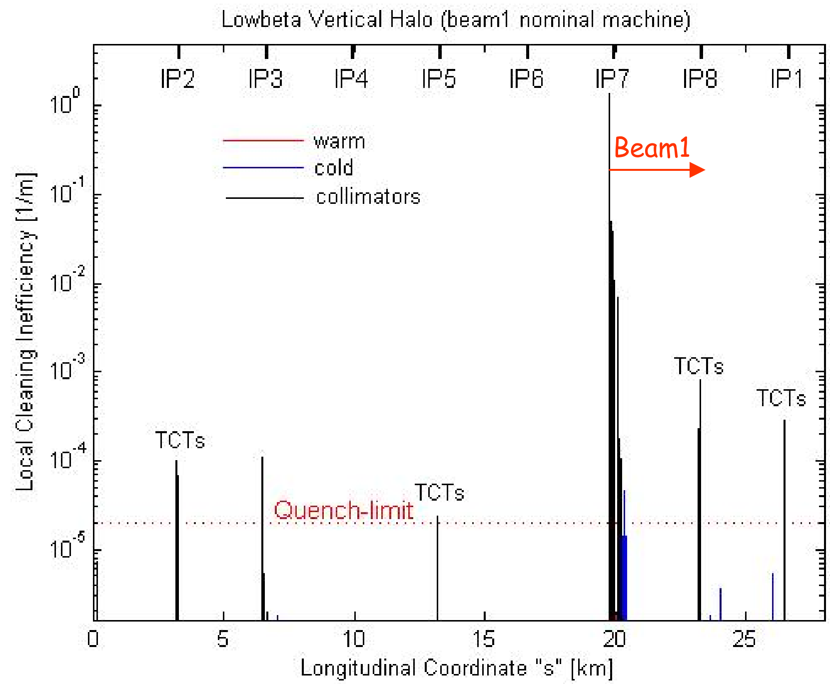
and the nominal setting of collimators.

The half gap, in unit of sigma, for the different collimators are presented in the next table:

TCP	TCSG	TCLA	TCT	TCDQ
6σ	7σ	10σ	8.3σ	7.5σ

Loss maps for nominal machine Beam1 horizontal and vertical halo:

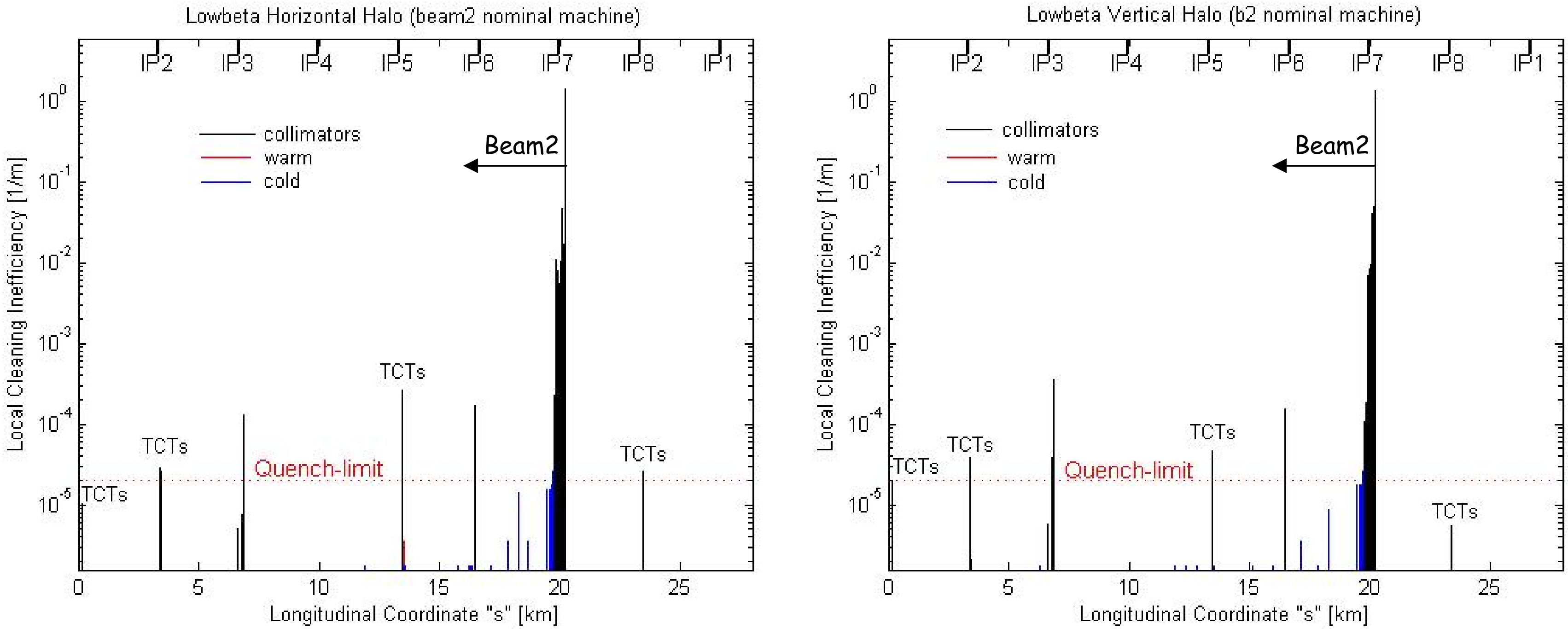




Collimator	**TCTH.4L2**	**TCTV.4L2**	**TCTH.4L5**	**TCTV.4L5**
η_c[1/m] hor.	1.3E-4	5.3E-5	6.5E-6	1.9E-6
η_c[1/m] ver.	1.0E-4	6.7E-5	1.6E-5	2.4E-6
Collimator	**TCTH.4L8**	**TCTV.4L8**	**TCTH.4L1**	**TCTV.4L1**
η_c[1/m] hor.	3.0E-4	4.2E-6	4.9E-4	3.9E-6
η_c[1/m] ver.	2.3E-4	8.3E-4	2.9E-4	2.4E-5

The table showes the values of the local cleaning inefficiency for tertiary horizontal and vertical collimators for the two halos of beam1 .

Loss maps for nominal machine Beam2 horizontal and vertical halo:



Collimator	TCTH.4R2	TCTV.4R2	TCTH.4R5	TCTV.4R5
η_c[1/m] hor.	2.6E-5	2.8E-5	2.6E-4	1.2E-5
η_c[1/m] ver.	2.1E-6	3.9E-5	1.3E-4	4.6E-4
Collimator	**TCTH.4R8**	**TCTV.4R8**	**TCTH.4R1**	**TCTV.4R1**
η_c[1/m] hor.	2.7E-5	1.0E-6	7.3E-6	1.0E-6
η_c[1/m] ver.	1.7E-6	5.6E-6	<1.0E-6	2.0E-5

The table shows the values of the local cleaning inefficiency for tertiary horizontal and vertical collimators for the two halos of beam 2.

Early commissioning scenario

intensity steps

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]

Without any collimator, considering the worst case for beam life time of 0.2 h and assuming that losses occur over 1 m (pessimistic view):
Maximum intensity allowed : $5\text{x}10^{11}$ protons (injection)
$5.6\text{x}10^{9}$ protons (collision) $\Rightarrow$ Pilot

Increasing the intensity more and more collimators will be necessary!

For the early commissioning of the LHC a minimal system of collimators (no TCL,TCLI,TDI and TCTV in IR2 and IR8), with increased gaps and more relaxed tolerances, will be installed.

Different early Scenarios for tracking simulations (1/2):

I simulated more scenarios with different openings and different subset of collimators to investigate the behavior of the losses and to address the minimal reliable collimation system at low intensity.

The optics used for these scenarios is a slightly different "early optics" with β^*= 2 m at IP1, IP5 and IP8.

I analyzed four "main" scenarios either for beam1 and beam2 considering only the horizontal betatron halo.

Different early Scenarios for tracking simulations (2/2):

For beam1:

- vertical halo studies for the two most interesting main scenarios, to check if the lack of a vertical tertiary collimator could be a constraint for the experiment in IP8.

For beam2:

- efforts concentrated on the influence of TCDQ on beam intensity limitation

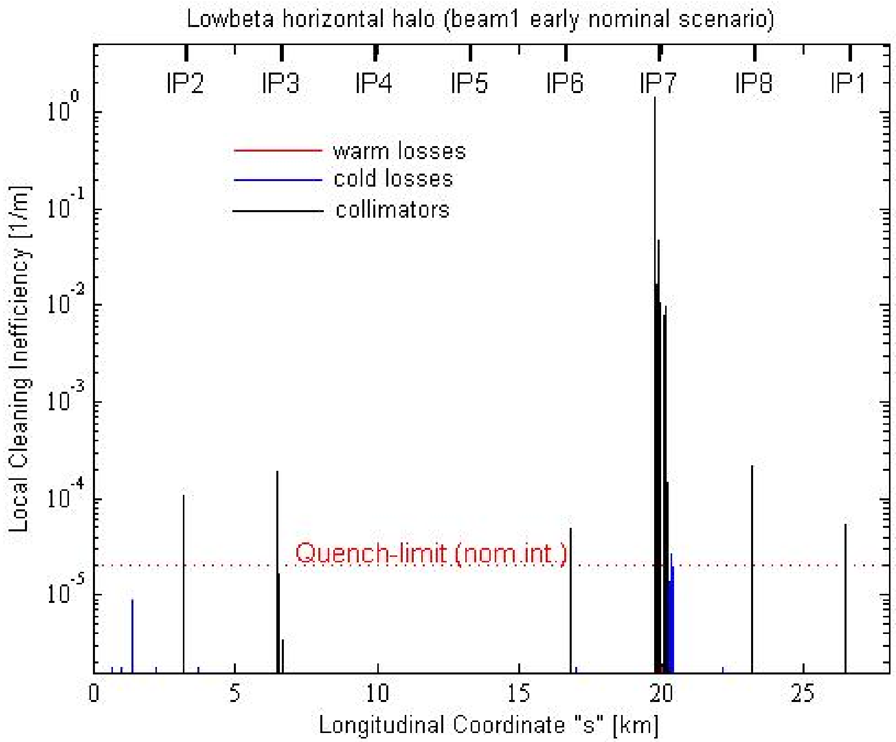
- different opening settings for TCDQ with secondary collimators fully retracted.

$\Rightarrow$ Results for beam1 only follow.

Early nominal scenario horizontal halo beam1:

TCP	TCSG	TCLA	TCT	TCDQ
6σ	7σ	10σ	17σ	8σ

Collimators half gaps

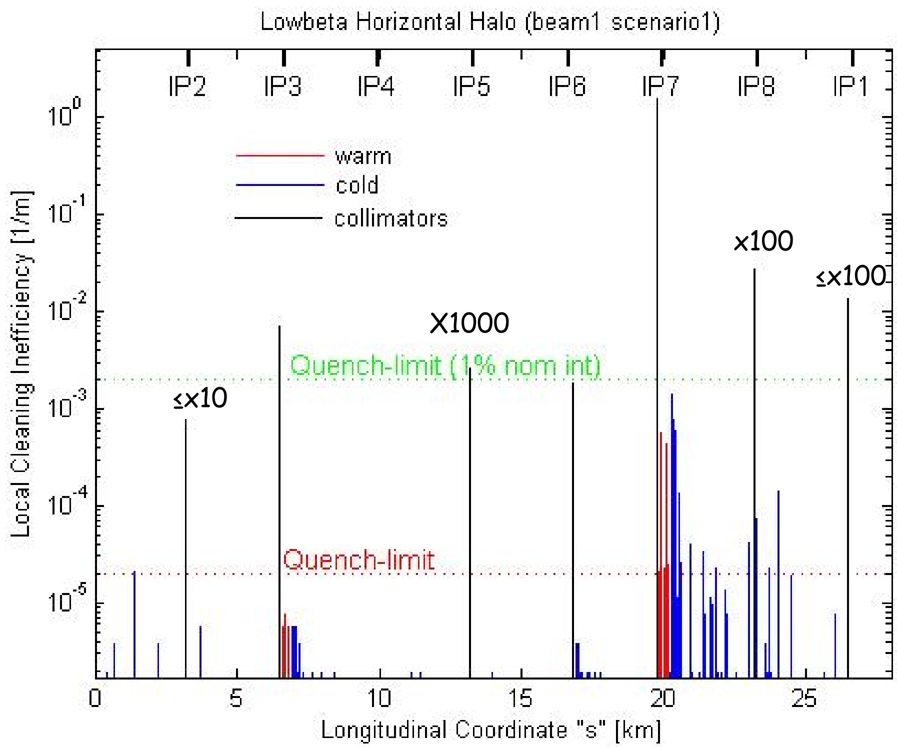


For this case only the aperture of TCTs and TCDQs is increased respectively from 8.3σ to 17σ and from 7.5σ to 8σ.
The losses on the cold aperture and on the collimators don't change significantly with respect to the nominal machine.
Fort TCTs losses are even smaller and at IP5 there are no losses at all.
The same behavior is found also for the vertical halo.

Scenario1 horizontal halo beam1:

TCP	TCSG	TCLA	TCT	TCDQ
10σ	-	-	17σ	13.5σ

Collimators half gaps

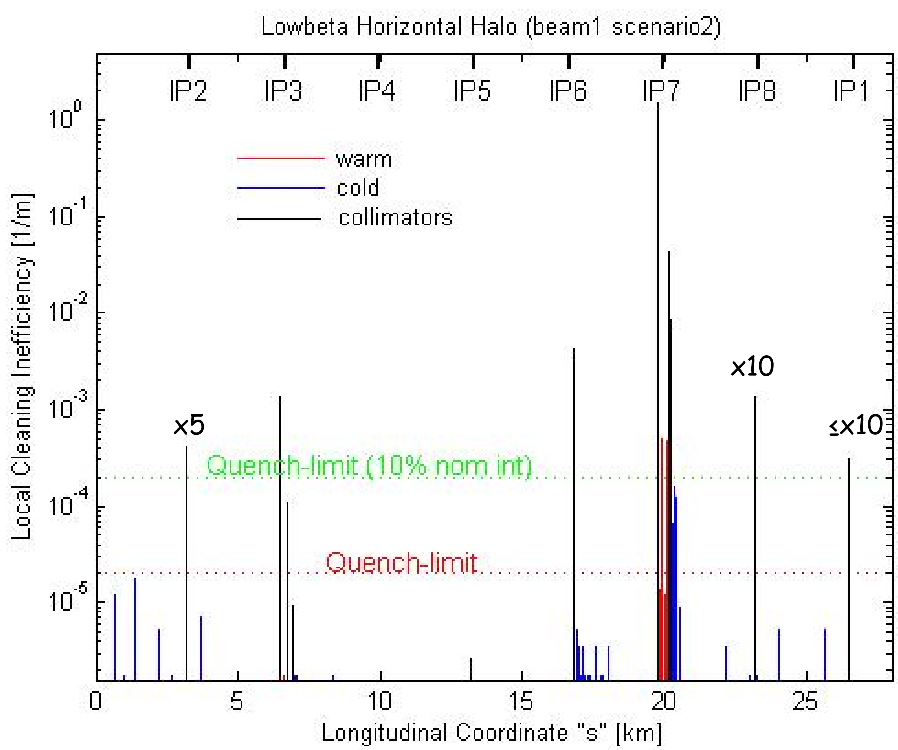


Secondary collimators and absorbers are fully retracted and the system is reduced to a one stage cleaning system. Many cold losses appear in IR7 and IR8 and losses on the collimators are extremely high.
The worst situation is met at IP5 where losses are at $3x10^{-3}$.
In IR8 and IR1 losses on the tertiaries are increased of a factor 100.
It's important to remember that for this scenario the intensity is reduced to less than 1% of the nominal one and this scaling factor must be taken into account.

Scenario2 horizontal halo beam1:

TCP	TCSG	TCLA	TCT	TCDQ
6σ	-	10σ	17σ	8σ

Collimators half gaps

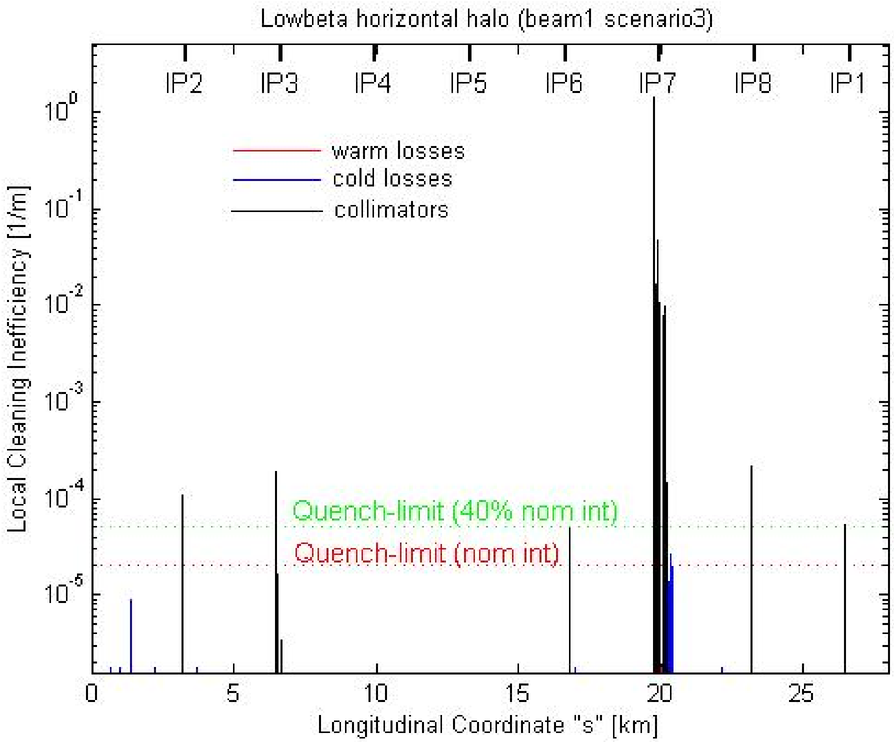


The absorbers now are at 10σ and they act as secondary collimators at the wrong phase position.
We have again a two stage collimation system and cold losses are lower compared to scenario1.
Also losses on collimators are reduced and in the worst cases they are increased at most by a factor 10 respect to the nominal machine.
Again the intensity is limited to 10% of nominal ($3x10^{14}$ protons).
All these considerations are valid also For the vertical halo.

Scenario3 horizontal halo beam1:

TCP	TCSG	TCLA	TCT	TCDQ
6σ	9.5 σ	10σ	17σ	8σ

Collimators half gaps



With secondary collimators not fully retracted but with a wider aperture, losses on the cold elements are only slightly higher in IR3 and IR7 but are confined at their original location.
Losses on tertiary collimators are of the same order of magnitude as the nominal case.
For this scenario the system could reach 40% of the nominal intensity which is the limit foreseen for the Nominal phase1 setting

Conclusions:

Simulations have been performed for beam1 and beam2 for different early commissioning scenarios with minimal settings of collimators (no TCTV in IR2 and IR8), with wider aperture and more relaxed tolerances.

The worst situation is met when secondary collimators and absorbers are fully retracted (in average a factor 100 more losses on tertiary collimators).

If the system keeps its characteristic of being a two stage cleaning system (absorbers in) losses are increased only by a factor of 10.

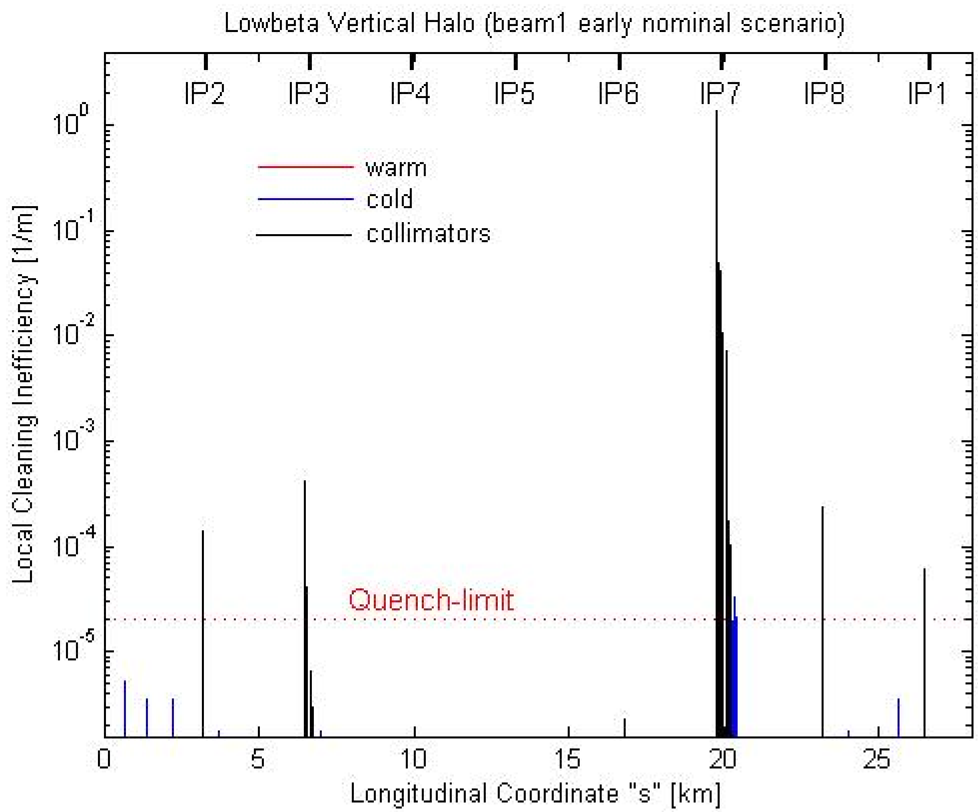
The increase in losses is due to the setting of the collimators installed but doesn't depend on the absence of two vertical tertiary collimators close to the experimental insertions.

The intensity for the various scenarios is lower than the nominal one and this compensates the higher losses.

Results have been presented only for beam1 but for beam2 the situation is nearly identical (data are available).

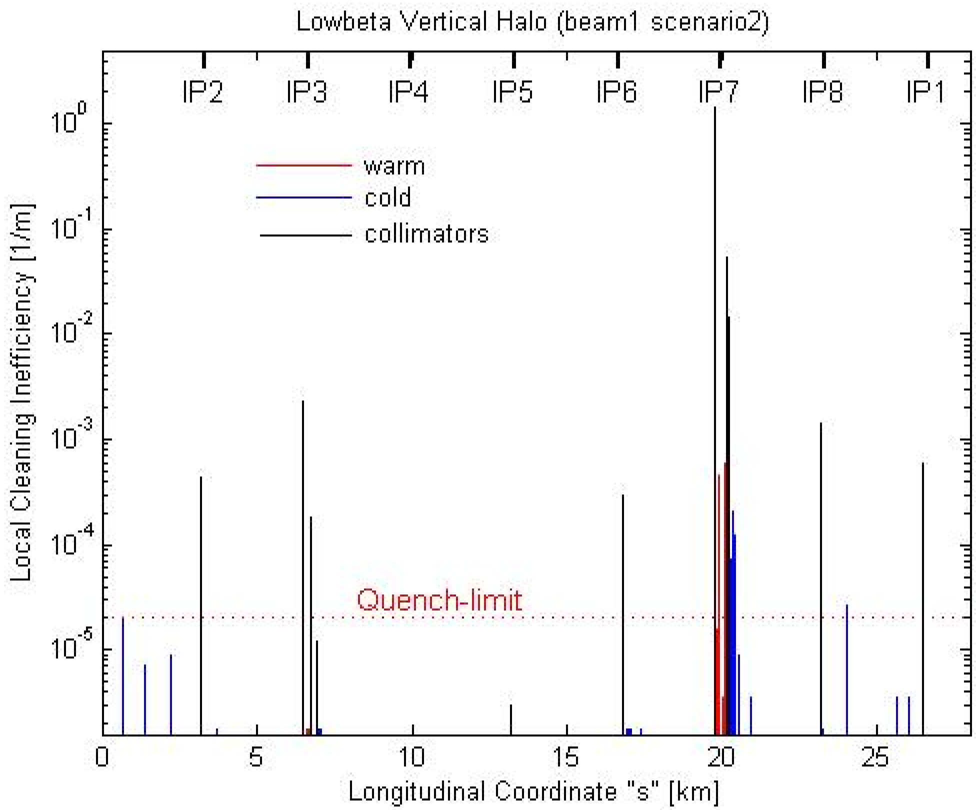
Appendix:

Early nominal scenario vertical halo beam1:



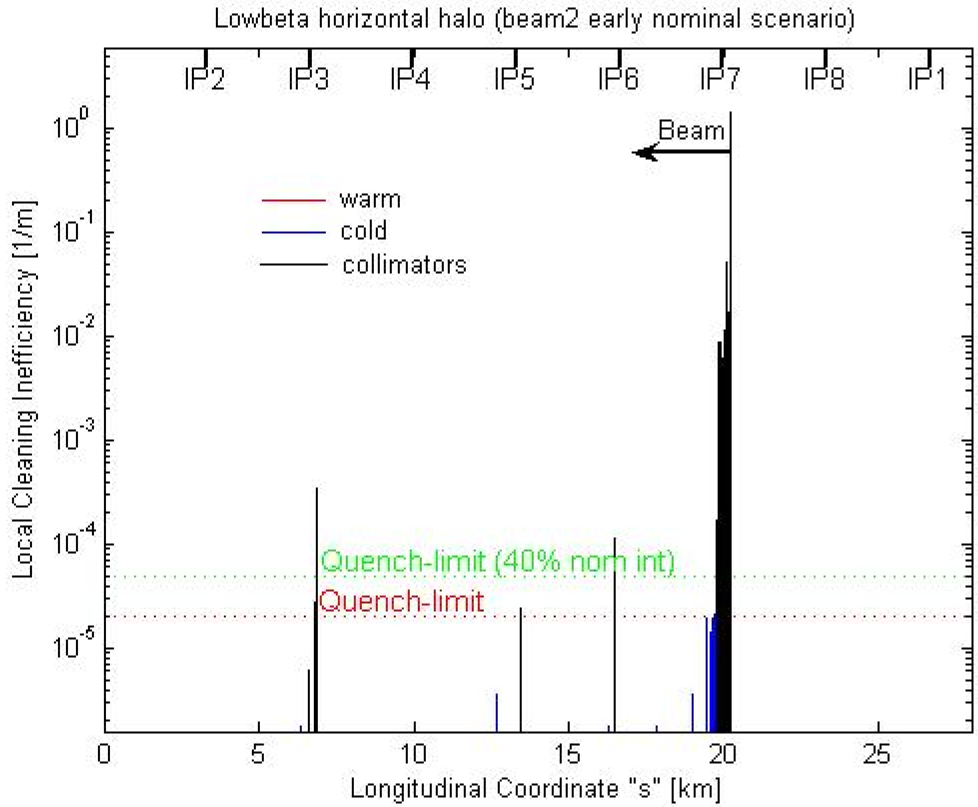
Appendix:

Scenario2 vertical halo beam1:



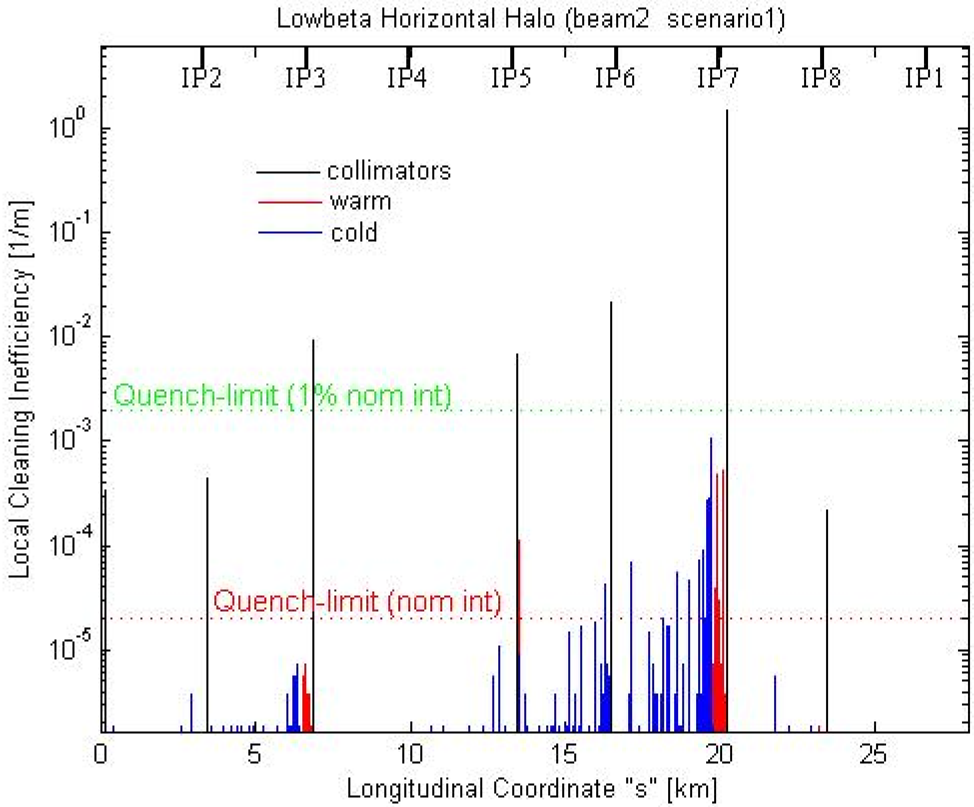
Appendix:

Early nominal scenario horizontal halo beam2:



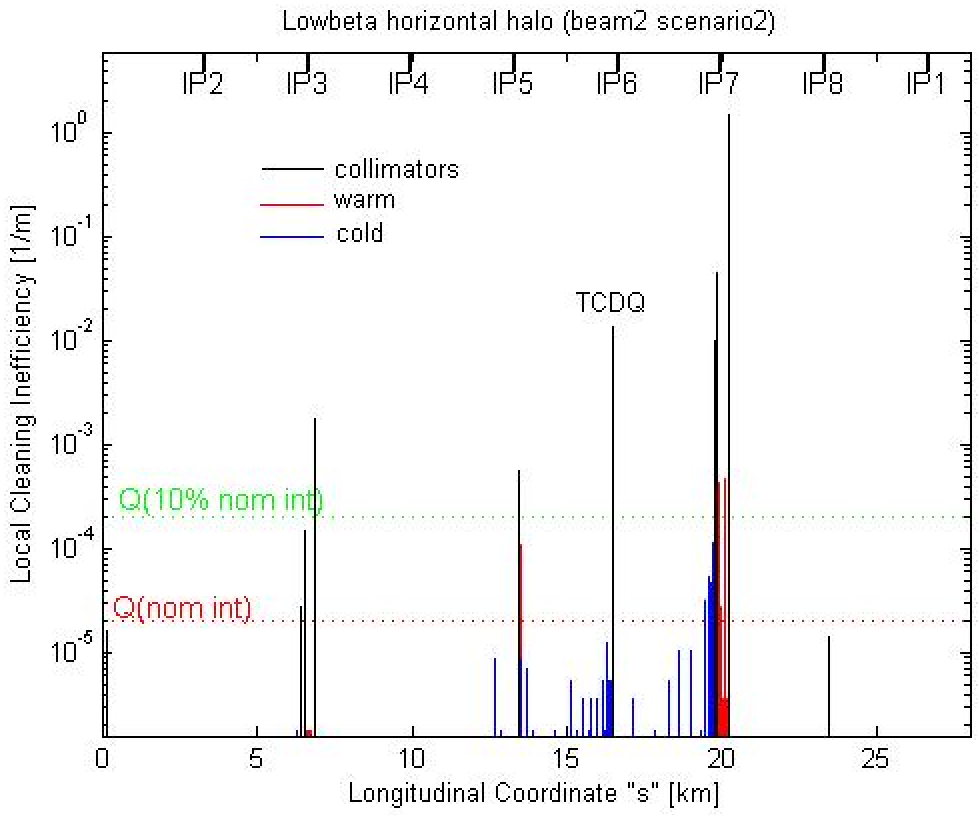
Appendix:

Scenario1 horizontal halo beam2:



Appendix:

Scenario2 horizontal halo beam2:



Appendix:

Scenario3 horizontal halo beam2: