

Proposed layout for crystal test at the LHC

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Different scenarios have been investigated:

- ✓ crystals in the horizontal and vertical planes separately
- ✓ 7TeV beam with nominal collision optics ($\beta^*=55\text{cm}$)
- ✓ only one secondary collimator inserted to absorb the channeled and extracted beam
- ✓ full collimation chain downstream the crystal in place
- ✓ Statistics of $>10^7$ protons intercepted by the collimation system, to allow estimation of losses $\sim 10^{-6}$.

Simulations have been done for a perfect machine and crystal:

- no optics and orbit errors
- no collimator setup errors
- no miscut angle, amorphous layer

Introduction on Crystal effects

What comes in:

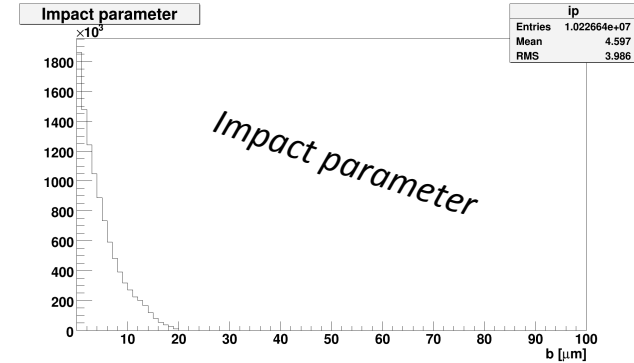
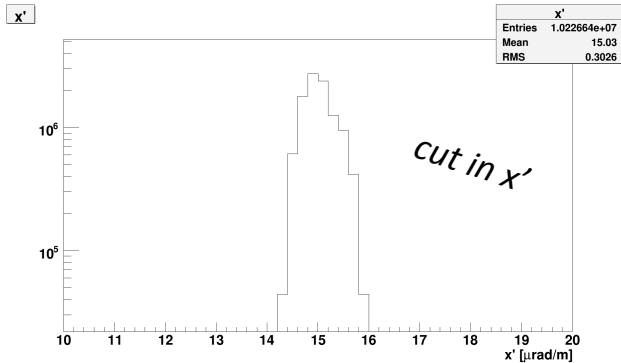
Parametric studies have been performed on the halo generation changing its amplitude and spread.



Taken the one which leads to reasonable computing time needed to run the simulations, and at the same time gives a single-pass channeling efficiency comparable with the H8 experimental data

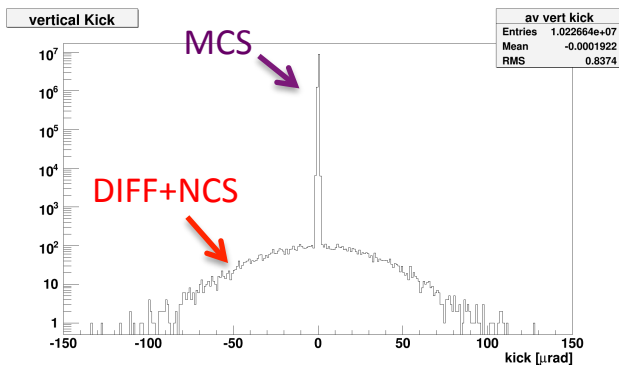


Average impact parameter used $\sim 5\mu\text{m}$



What comes out:

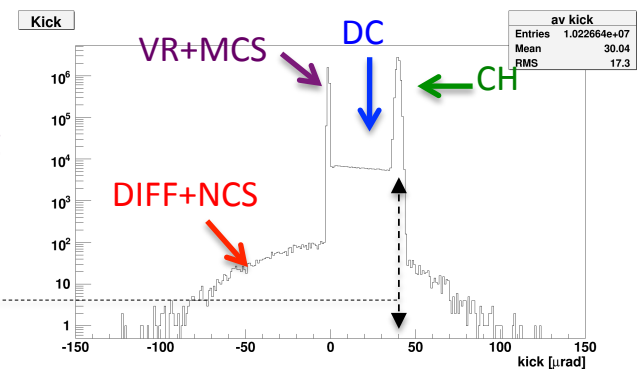
Vertical kick



- CH: Channeling
- DC: Dechanneling
- VR: Volume Reflection
- MCS: Multiple Coulomb Scattering
- NCS: Nuclear Elastic Scattering
- DIFF: Single Diffractive


Crystal bending: $40\ \mu\text{rad}$

Horizontal kick




Main constraints in the layout design:

- Be able to demonstrate an efficient crystal collimation (using ideally only one TCSG) in the various machine configurations (injection, ramp, squeeze, etc)

 *can we beat the present excellent cleaning? Can we address the operational challenges of the LHC?*

- Minimum impact on present layout and infrastructure (control cabling, supports, etc.)
- Absorption of channeled and extracted halo sufficiently upstream from cold magnets
- Changes of optics are in principle possible

 *the overhead for beam tests will become too important*

 *conceive optimum layouts for the nominal IR7 optics*

Study based on Semi-analytical Models and full SixTrack simulations have been performed to find a layout which fullfils all the requirements

Calculated the trajectory of the channeled beam for any available position of the crystals :

$$x_s = \sqrt{\frac{\beta_s}{\beta_{Cr}}} \cos(\Delta\phi) x_{Cr} + \Theta \sqrt{\beta_s \beta_{Cr}} \sin(\Delta\phi)$$

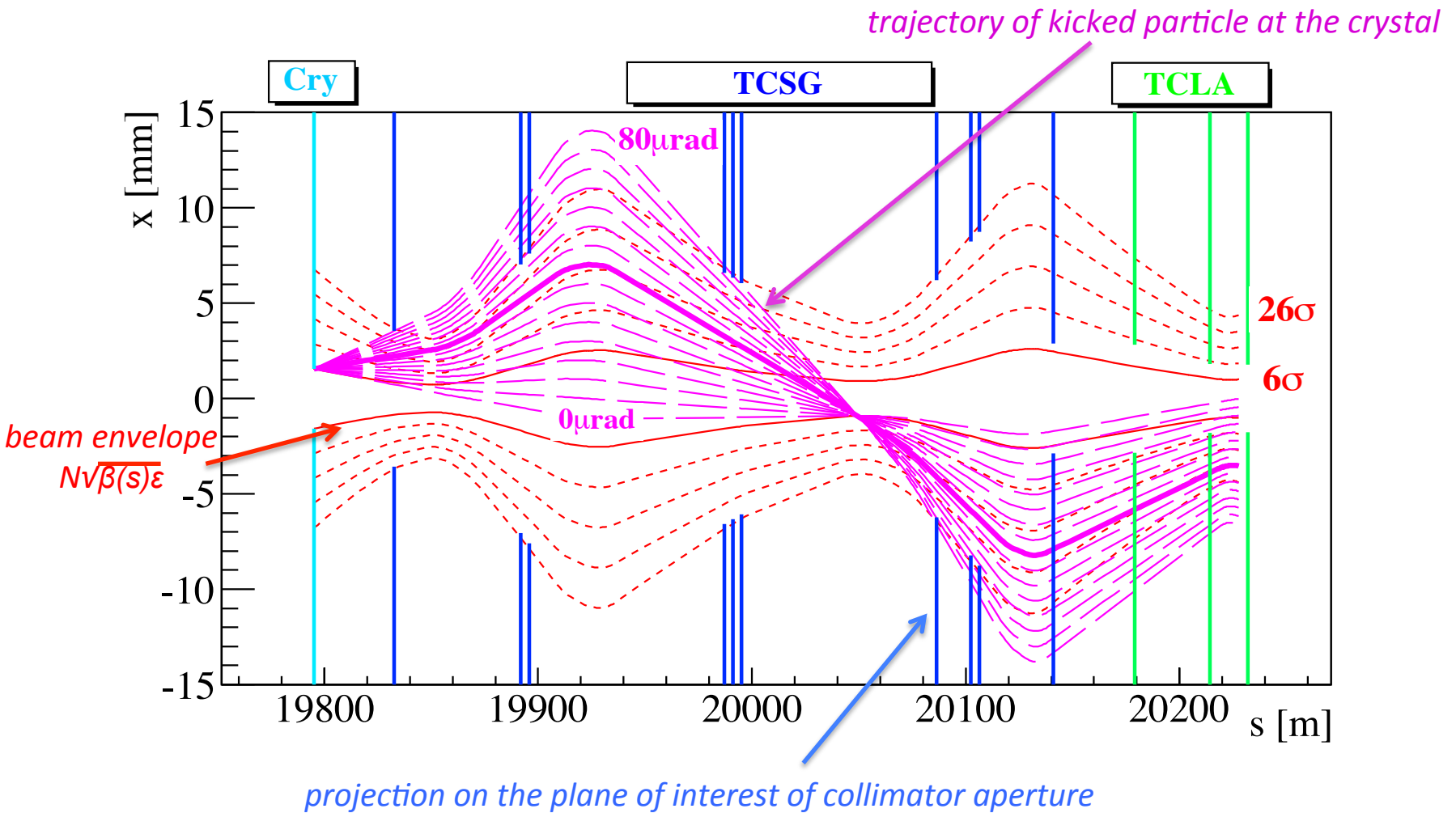


First selection of the layouts that give better impact parameters on the secondary collimator at any energy



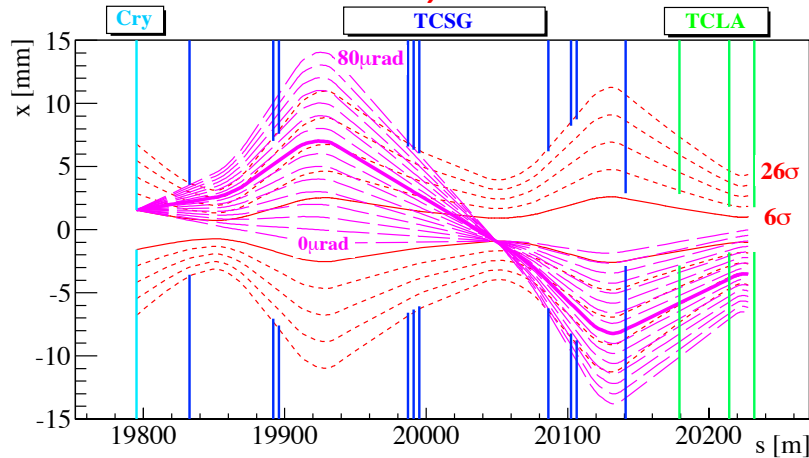
Full SixTrack simulations with complete layout and geometry implemented for the choose subset

Example of Optics Studies

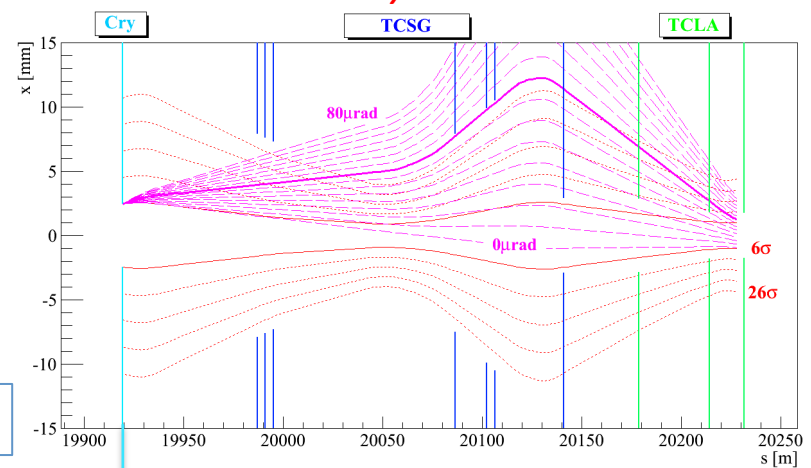


Found a subset of suitable positions for crystals installation

Horizontal crystal at the TCP

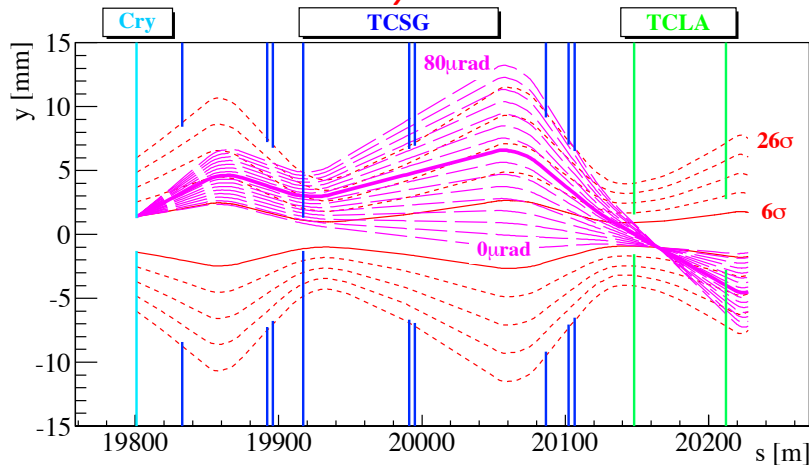


Horizontal crystal at the TCSG

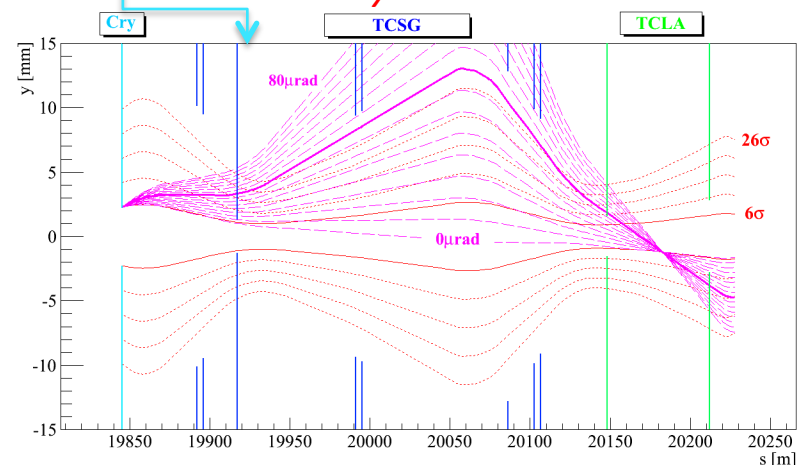


@7TeV

Vertical crystal at the TCP



Vertical crystal at the TCSG



Summary table of the collimation chain settings used in the SixTrack simulations shown in the next slides

IR7 for Std. Collimation:

Coll. Name	Setting [σ]
TCP.*	6
TCSG.*	7
TCLA.*	10

IR3 in both cases:

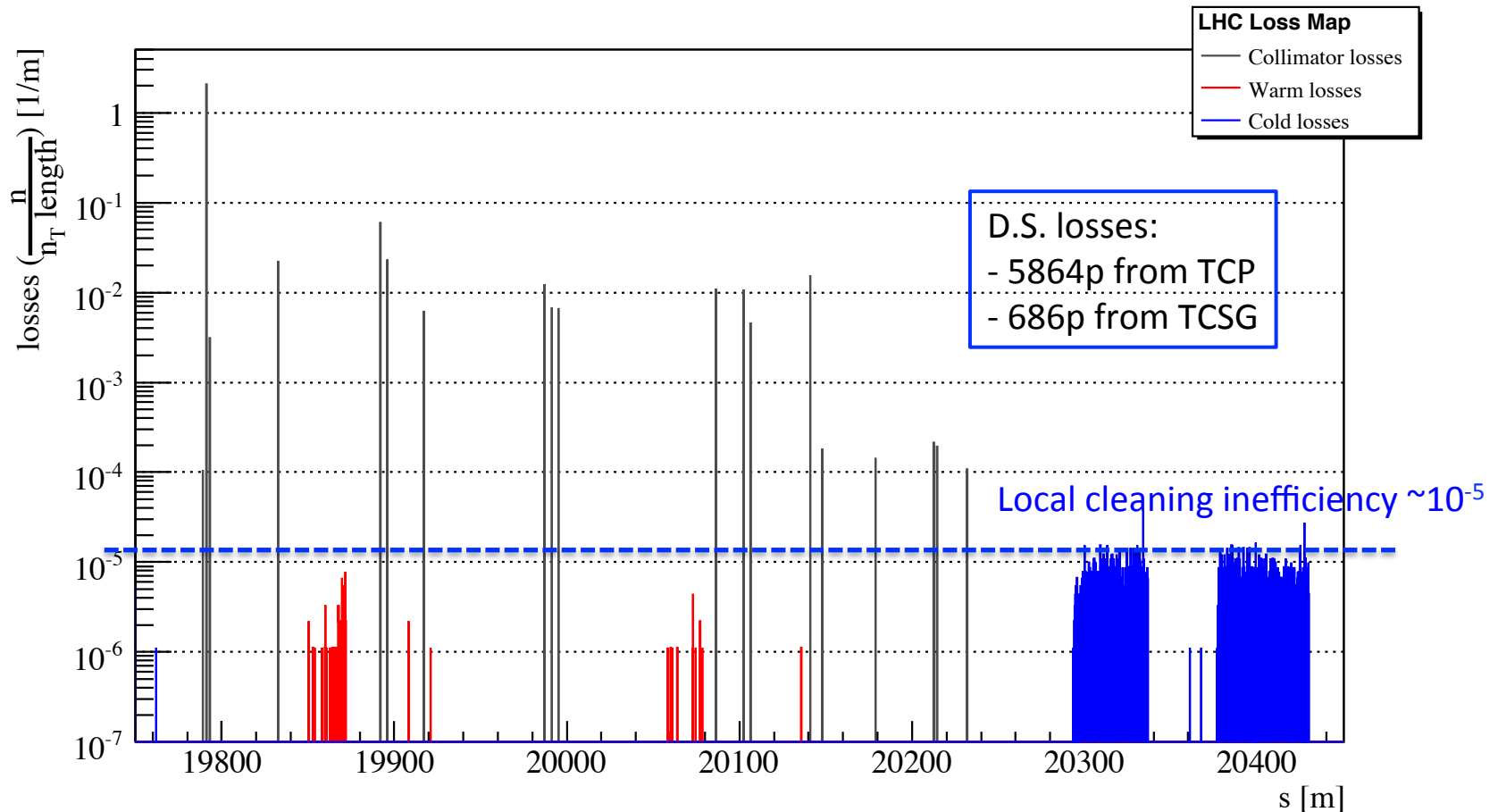
Coll. Name	Setting [σ]
TCP.*	15
TCSG.*	18
TCLA.*	20

IR7 for Crystal assisted Collimation:

Coll. Name	s [m]	Orient.	Setting [σ] Hor. plane (Cr @ TCP)	Setting [σ] Ver. plane (Cr @ TCP)	Setting [σ] Hor. plane (Cr @ TCSG)	Setting [σ] Ver. plane (Cr @ TCSG)
CRY.TCP.H	19795.18	Hor.	6	99	-	-
CRY.TCP.V	19800.78	Ver.	99	6	-	-
CRY.TCSG.H	19919.24	Hor.	-	-	6	99
CRY.TCSG.V	19845.30	Ver.	-	-	99	6
TCP.*	-	H/V/S	99	99	99	99
TCSG.*	-	Skew	25	25	30	30
TCSG.D4L7	-	Ver.	25	7	30	7
TCSG.6R7	-	Hor.	7	25	7	30
TCLA.*	-	H/V	10	10	10	10

Loss Maps (Std. Coll.)

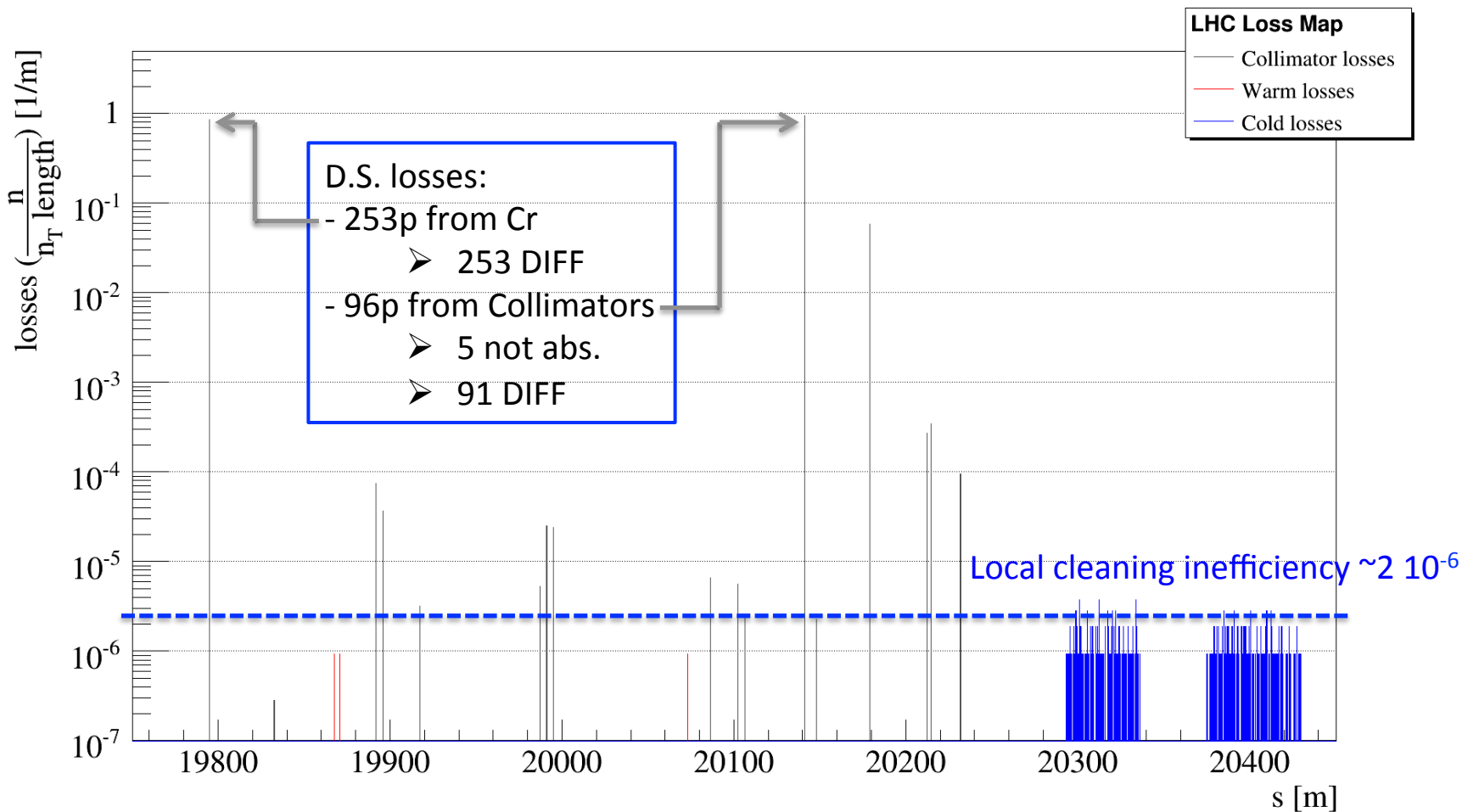
IR7 zoom for reference Loss Map of cleaning performance of the present collimation system



Loss Maps (H. Cr. @ TCP)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

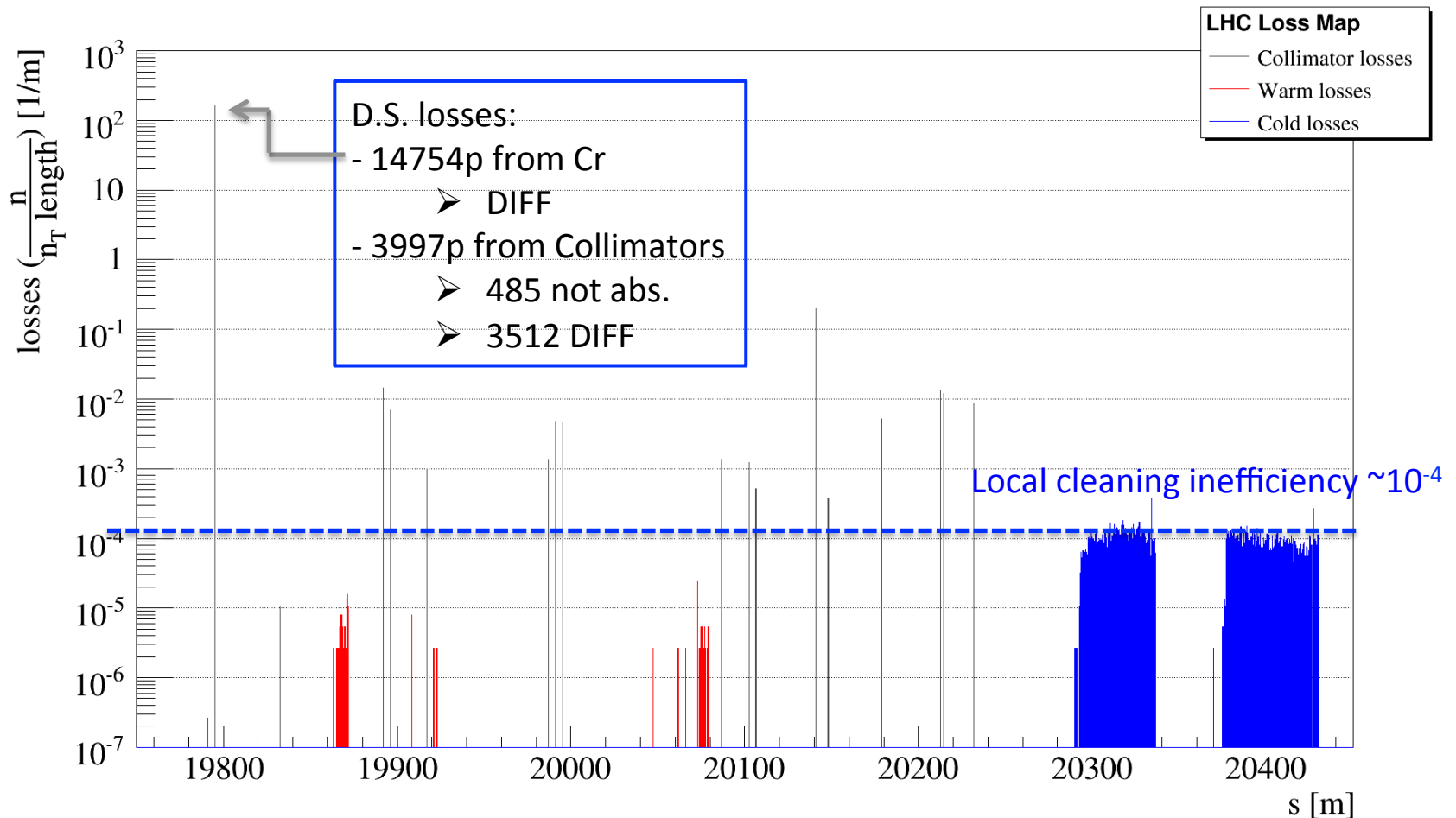
Only one TCSG (6R7) in place



Loss Maps (H. Cr. @ TCP)

Crystal in amorphous orientation, no relevant spikes around the whole LHC ring, shown only the IR7

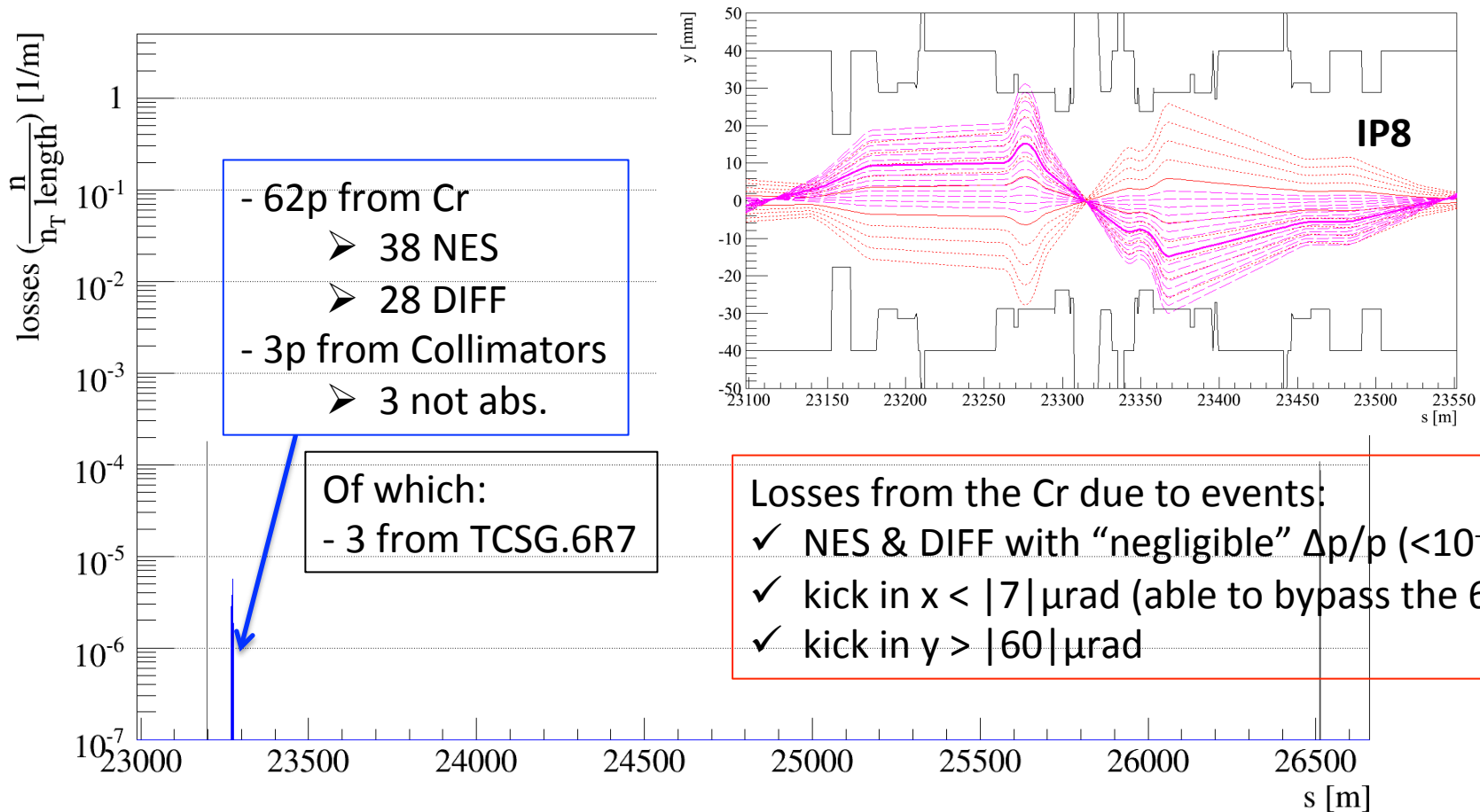
Only one TCSG (6R7) in place



Loss Maps (H. Cr. @ TCP)

Example of far losses generation “playing” with the collimators setting and coverage given by the Coll. chain

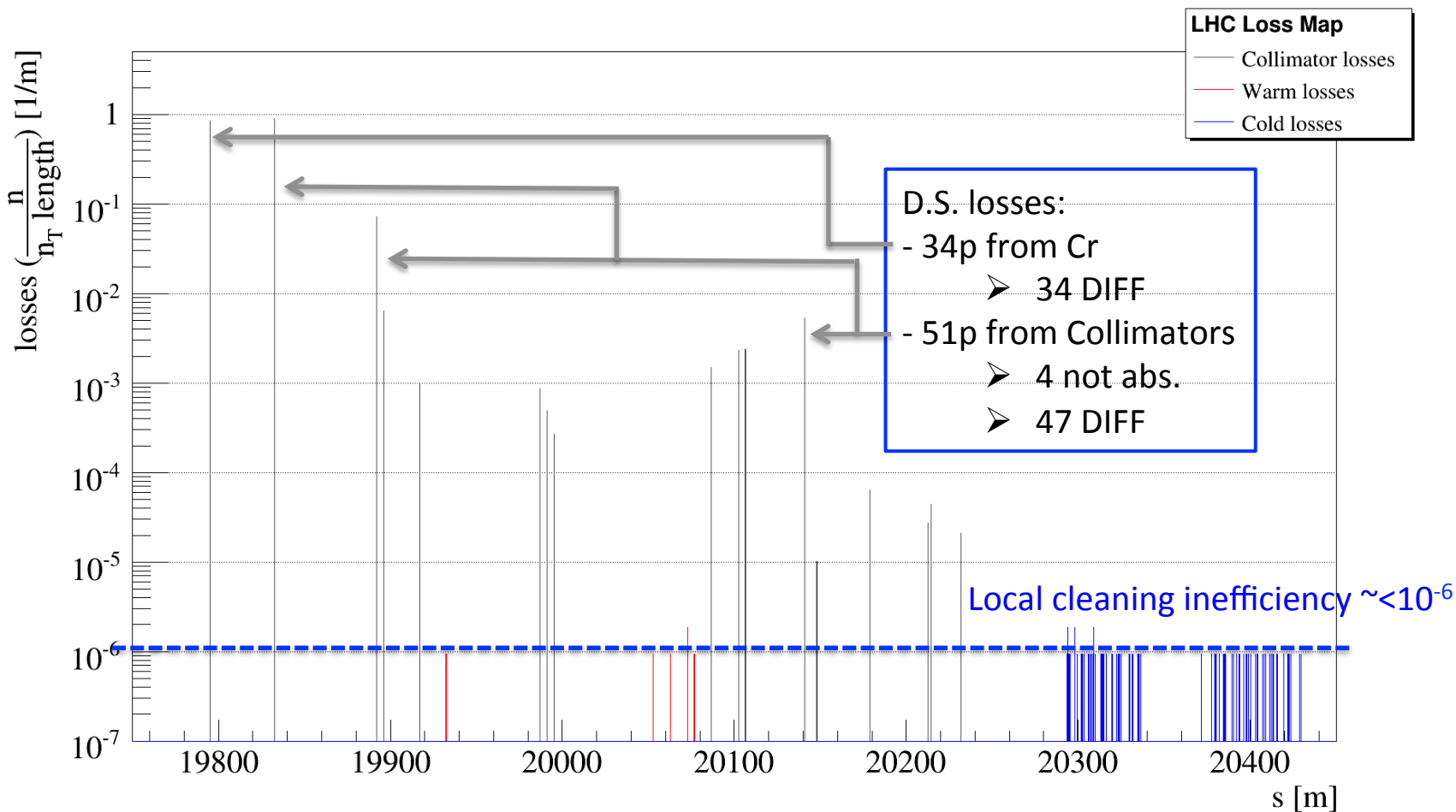
Crystal in channeling, IR7 TCSG @ 30σ and Vertical TCLA @ 20σ (look slide 6 and 3)



Loss Maps (H. Cr. @ TCP)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

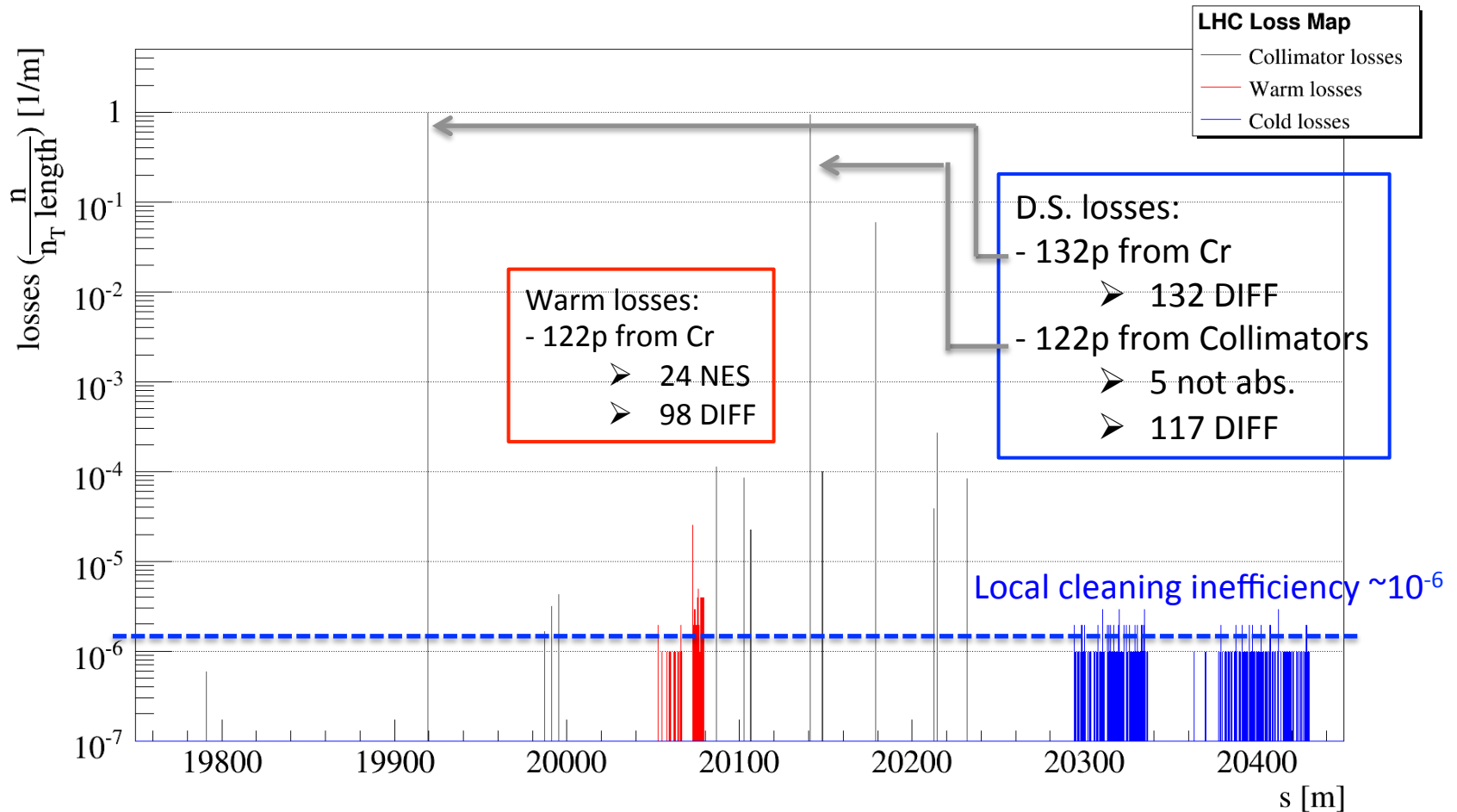
Full chain of TCSG downstream the crystal in place



Loss Maps (H. Cr. @ TCSG)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

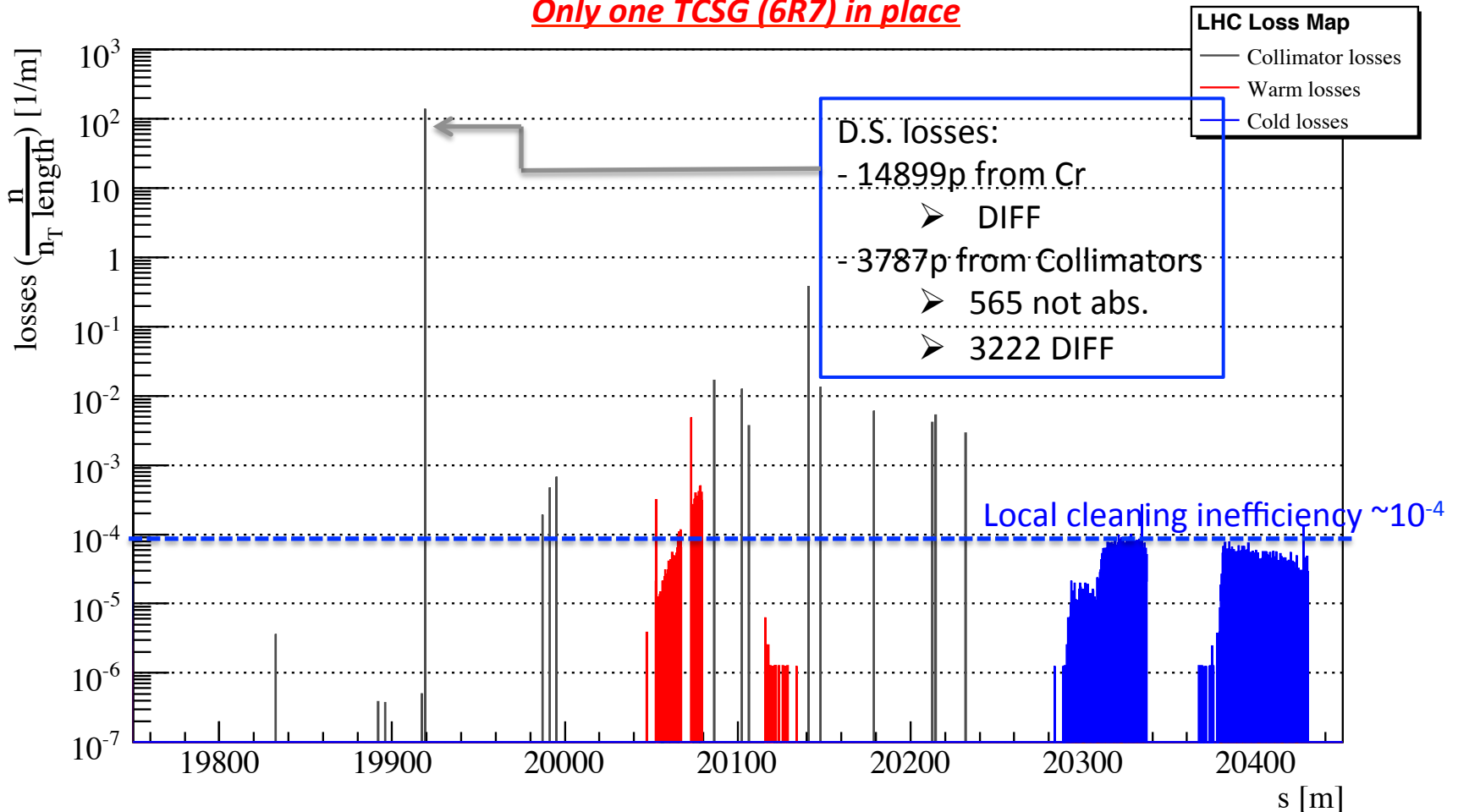
Only one TCSG (6R7) in place



Loss Maps (H. Cr. @ TCP)

Crystal in amorphous orientation, no relevant spikes around the whole LHC ring, shown only the IR7

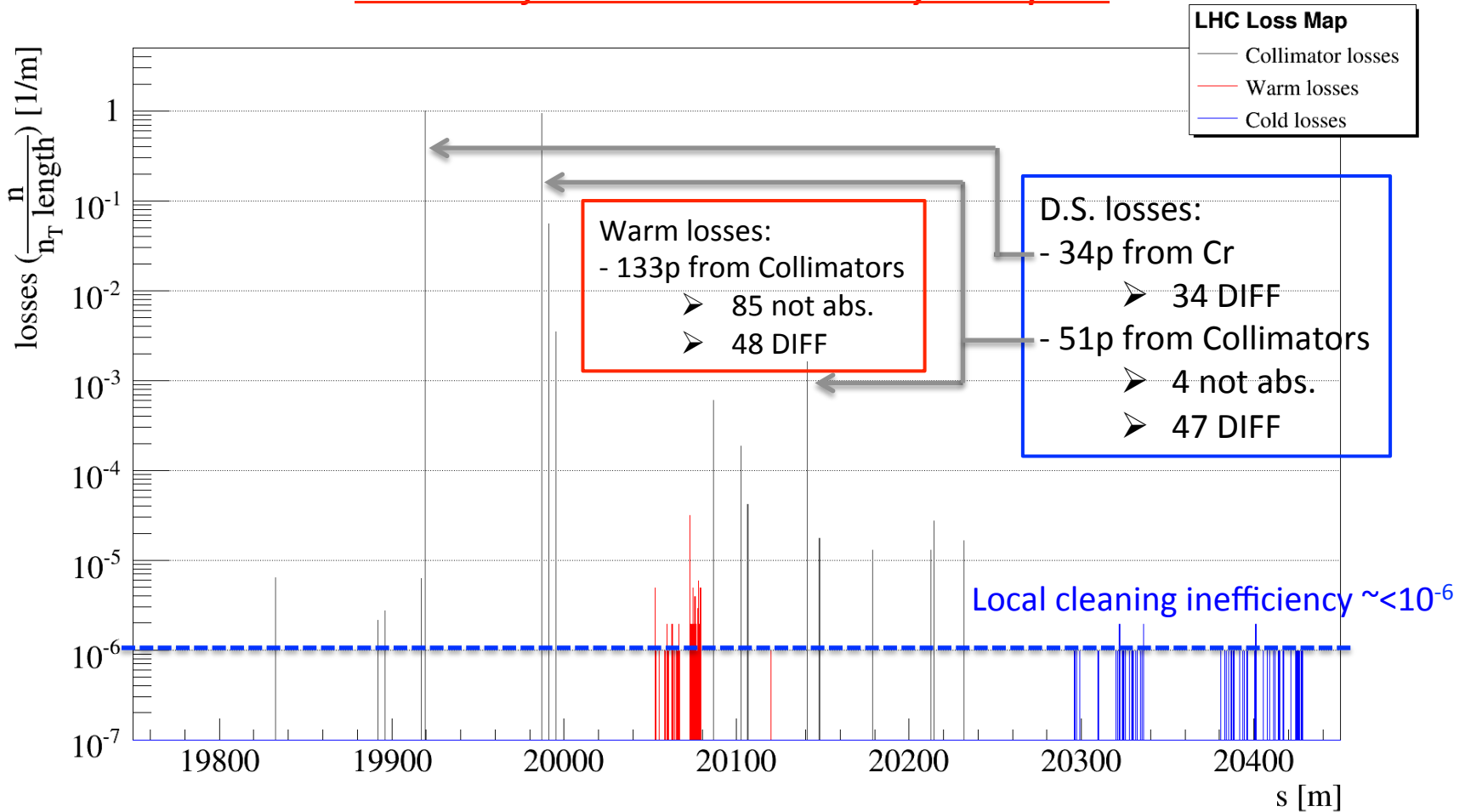
Only one TCSG (6R7) in place



Loss Maps (H. Cr. @ TCSG)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

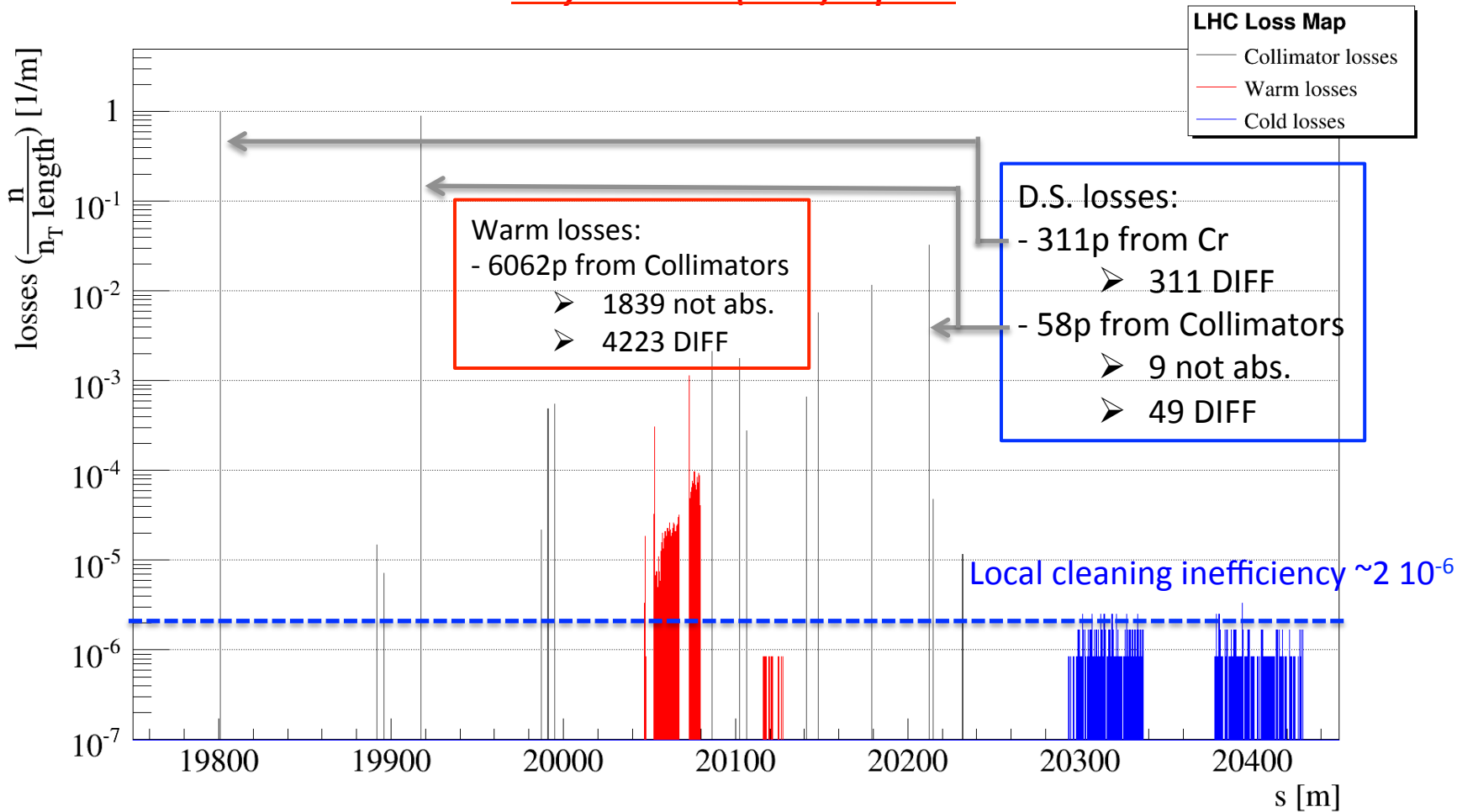
Full chain of TCSG downstream the crystal in place



Loss Maps (V. Cr. @ TCP)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

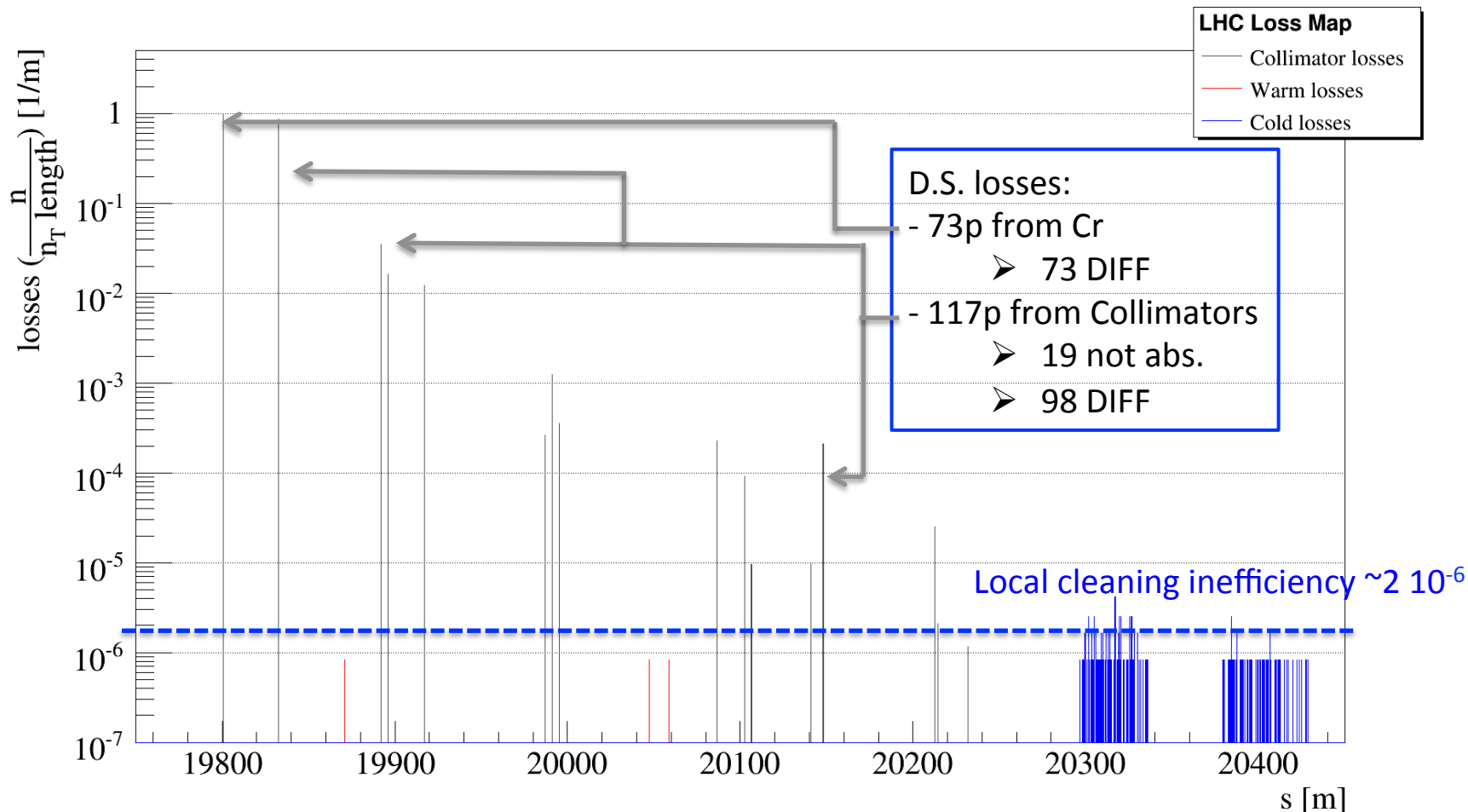
Only one TCSG (D4L7) in place



Loss Maps (V. Cr. @ TCP)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

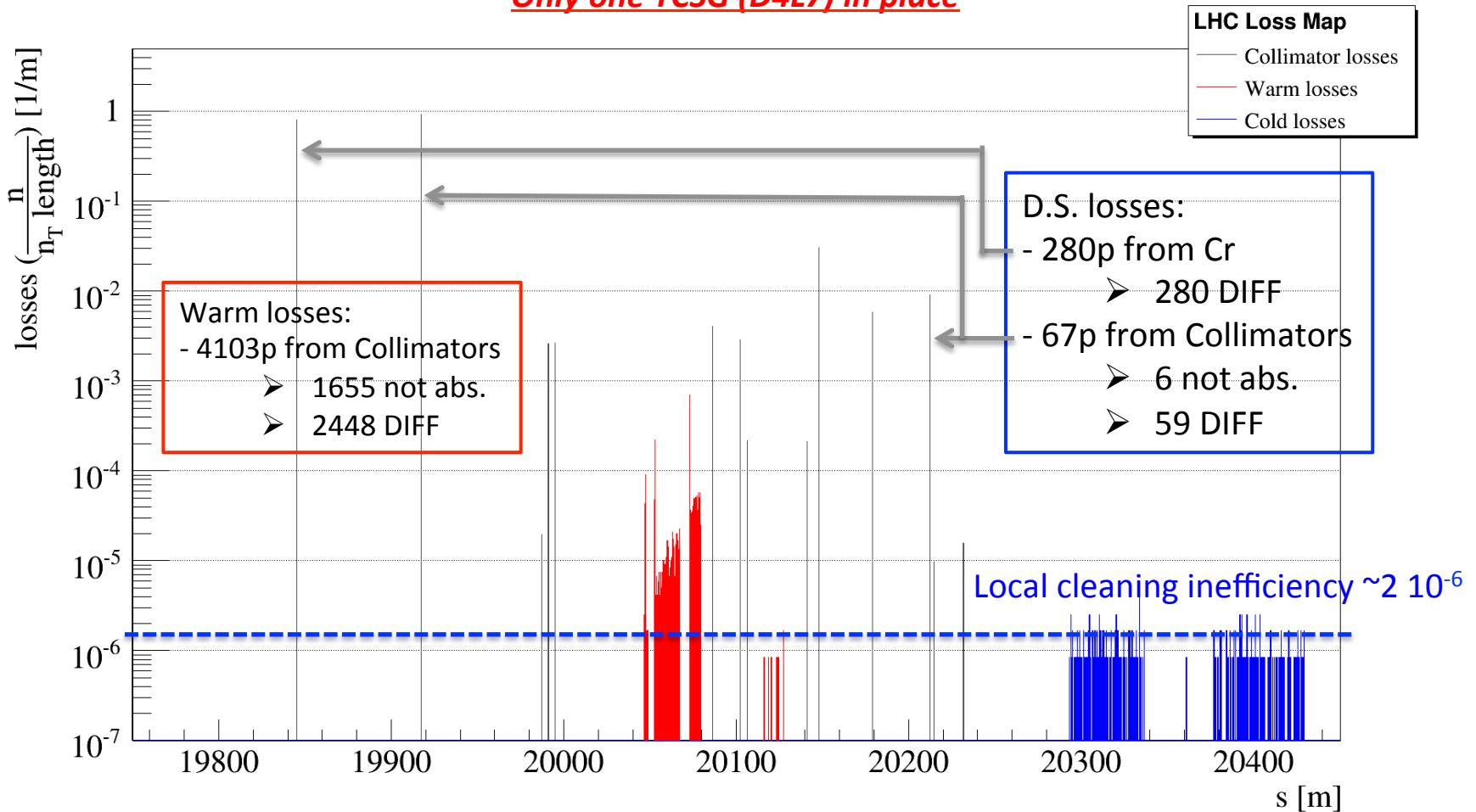
Full chain of TCSG downstream the crystal in place



Loss Maps (V. Cr. @ TCSG)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

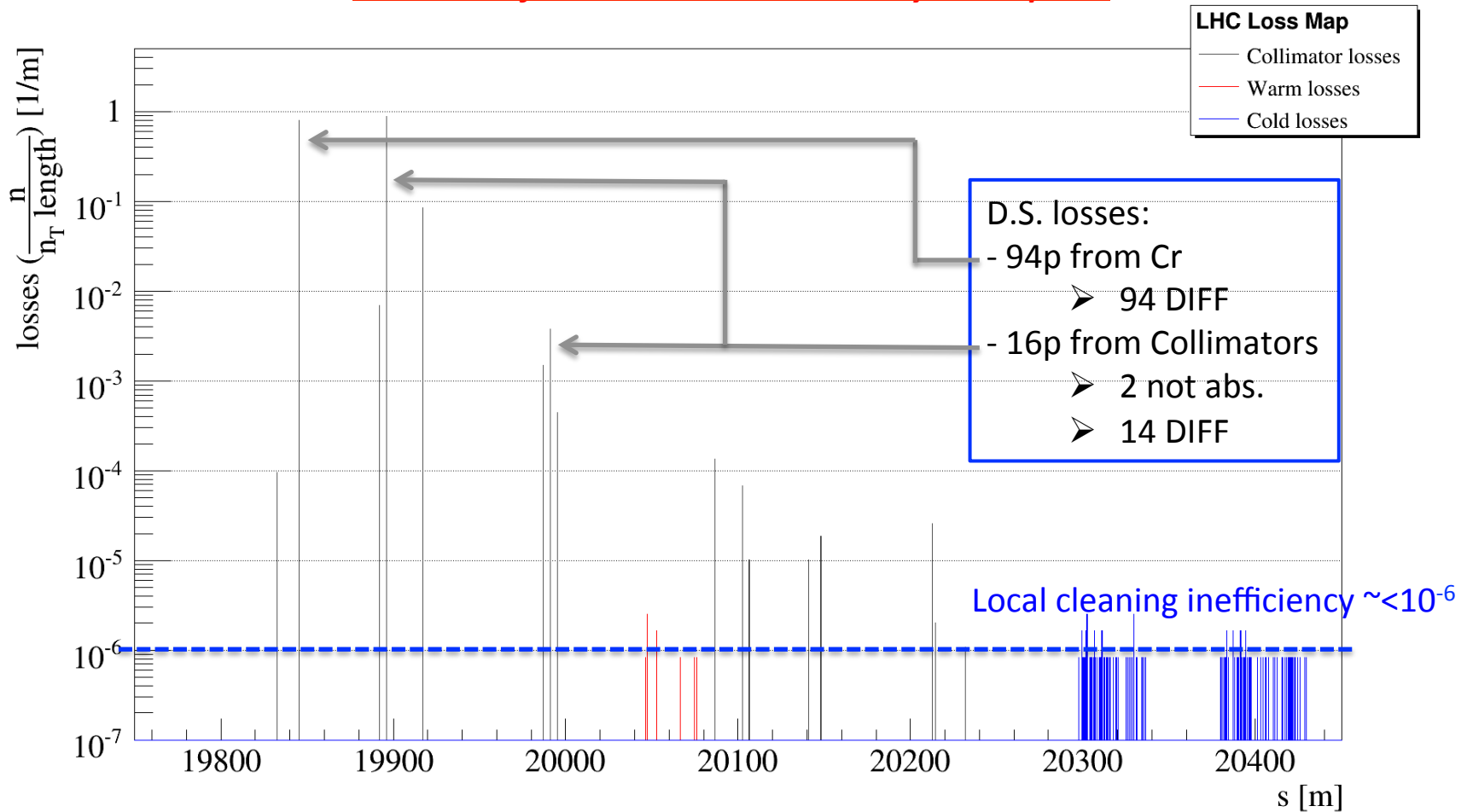
Only one TCSG (D4L7) in place



Loss Maps (V. Cr. @ TCSG)

Crystal in channeling orientation, no relevant spikes around the whole LHC ring, shown only the IR7

Full chain of TCSG downstream the crystal in place



Summary of 7 TeV results

Four suited positions for crystals installations have been found, suitable for beam tests at 7TeV with low intensity:

- two crystals H & V close to the present TCP collimators
- two crystals H & V between the TCSG collimators chain

For both layouts, one can achieve a cleaning better than the present system using one single TCSG as “absorber” (according to simulations).

For both, we should be able to demonstrated the principle feasibility of crystal-assisted collimation without too many problems.

Similar results in cleaning inefficiency have been found for each proposed layout:

- improvement of a factor between 5 and 10 in cleaning efficiency w.r.t. Std. Coll., if used only one TCSG to intercept the channeled beam
- improvement by factor 10 if the complete TCSG chain is closed (but it would mean to lose the gain in impedance achieved otherwise and the “simplicity of the system” with what it concerns)
- Clearly, intermediate conditions on TCSG’s settings are under investigation

*Main difference between layouts with only one TCSG and the full chain in place:
presence and level of warm losses, almost no losses except that in the DS*

Not dangerous spikes in the losses have been found when crystal in amorphous orientation

The less radioactive environment for crystals installation would be preferred, i.e. the one at the TCSG

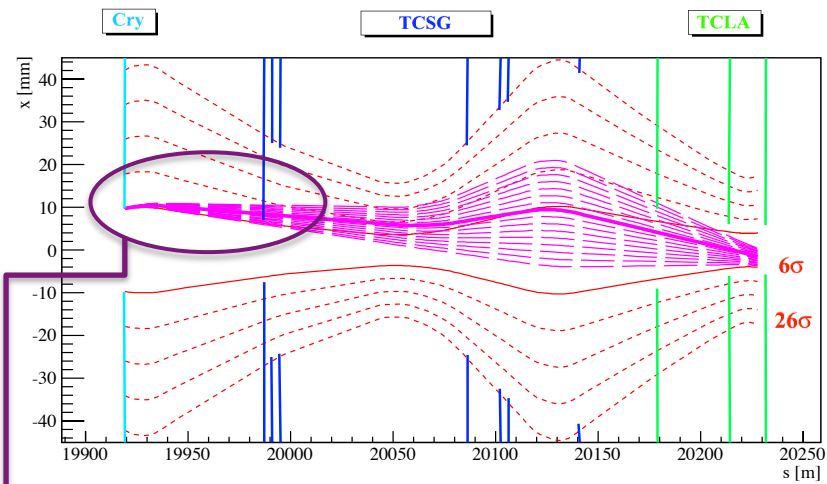
In any case the first tests in the LHC will be made at low intensity ($\sim 5 \cdot 10^9$) to avoid any safety risk for the machine and damages to the collimator jaw used to absorb the extracted halo

Studies are ongoing to determine the best crystal parameters, which are strictly correlated to the final settings of the chain of TCSG will be used in the tests (soon a talk on it)

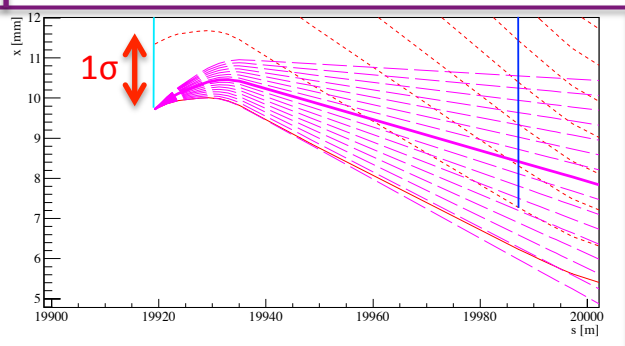
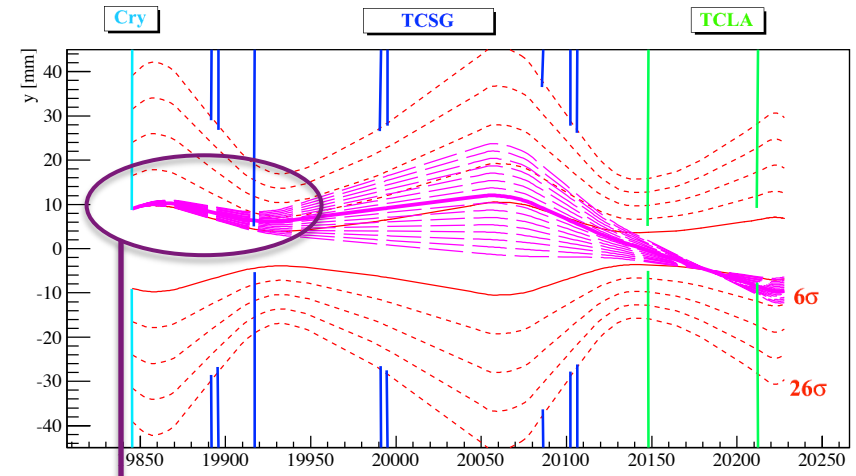
Optics @ injection

Optics studies at 450 GeV for proposed layout (@TCSG, see next slides)

Horizontal

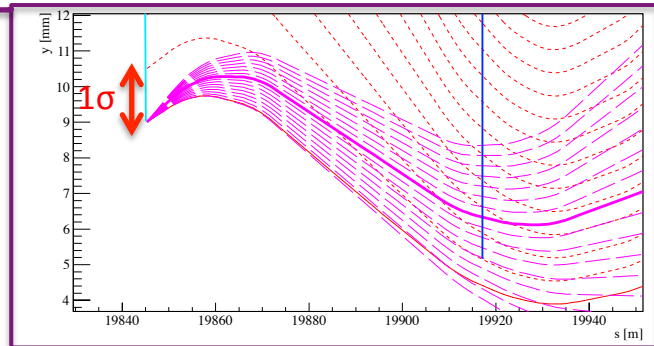


Vertical



Reasonable impact parameter (>1mm) on the selected TCSG also at 450 GeV with bending of 40 μ rad

Under investigation either the possibility to increase the crystal bending, and "smart" settings of the TCSG's chain



Vertical case: no problems, since TCLA are at the same phase of the TCSG.D4L7

Horizontal case: to use the TCSG.B4L7 could be problematic due to the fraction of particles not absorbed and diffractive events in the jaw

Proposed layout - V

*Proposed position for installation of vertical crystal
(shown half cell C6L7)*

Final position moved @ 19843.82
to leave the present support (in the B2 line)
ready for a possible use

Simulations made for
CRY.V.B1 @ $s=19845.30\text{m}$

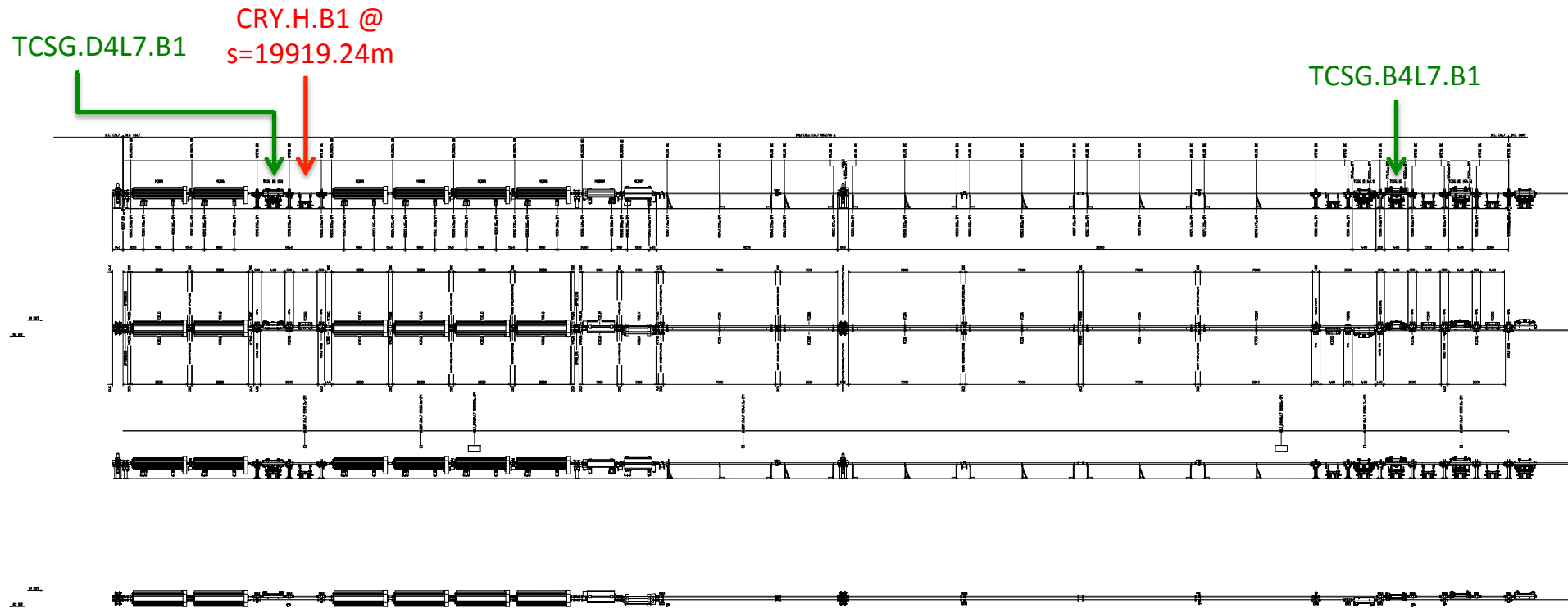
TCP.B1



Tamas.Lker@cern.ch
DEMI-CELLULE: C6L7
PLAN: L0782029PL
Not Valid for Installation
DATE: 23-Oct-2007 10:28:16

Proposed layout - H

*Proposed position for installation of horizontal crystal
(shown half cell C4L7)*



Tamas.Llkei@cern.ch
DEMI-CELLULE: C4L7
PLAN: L0782031PL
Not Valid for Installation
DATE: 23-Oct-2007 10:28:16