Study of the performance of the CERN Proton Synchrotron internal dump

T. Pugnat*,[1], D. Domange[2], L. S. Esposito[1], M. Giovannozzi[1], E. Gnacadja[2], C. Hernalsteens[1], A. Huschauer[1], S. Niang[1], R. Tesse[2]

[1]CERN, Geneva, Switzerland, [2]Université libre de Bruxelles, Brussels, Belgium

Abstract: In the framework of the LHC Injector Upgrade project, a new internal dump for the CERN Proton Synchrotron (PS) has been designed, installed, and successfully commissioned. This device is meant to move rapidly into the beam and stop charged particles over several turns to provide protection to the PS hardware against beam-induced damage. The performance of the dump should ensure efficient use throughout the PS energy range, i.e. from injection at 2 GeV (kinetic energy) to flat top at 26 GeV (total energy). In this paper, detailed numerical simulations are presented, carried out with a combination of sophisticated beam dynamics and beam-matter interaction codes, assessing the behaviour of stopped or scattered particles. The results of these numerical simulations are compared with the data collected during the routine operation of the PS and its internal dump.

Context

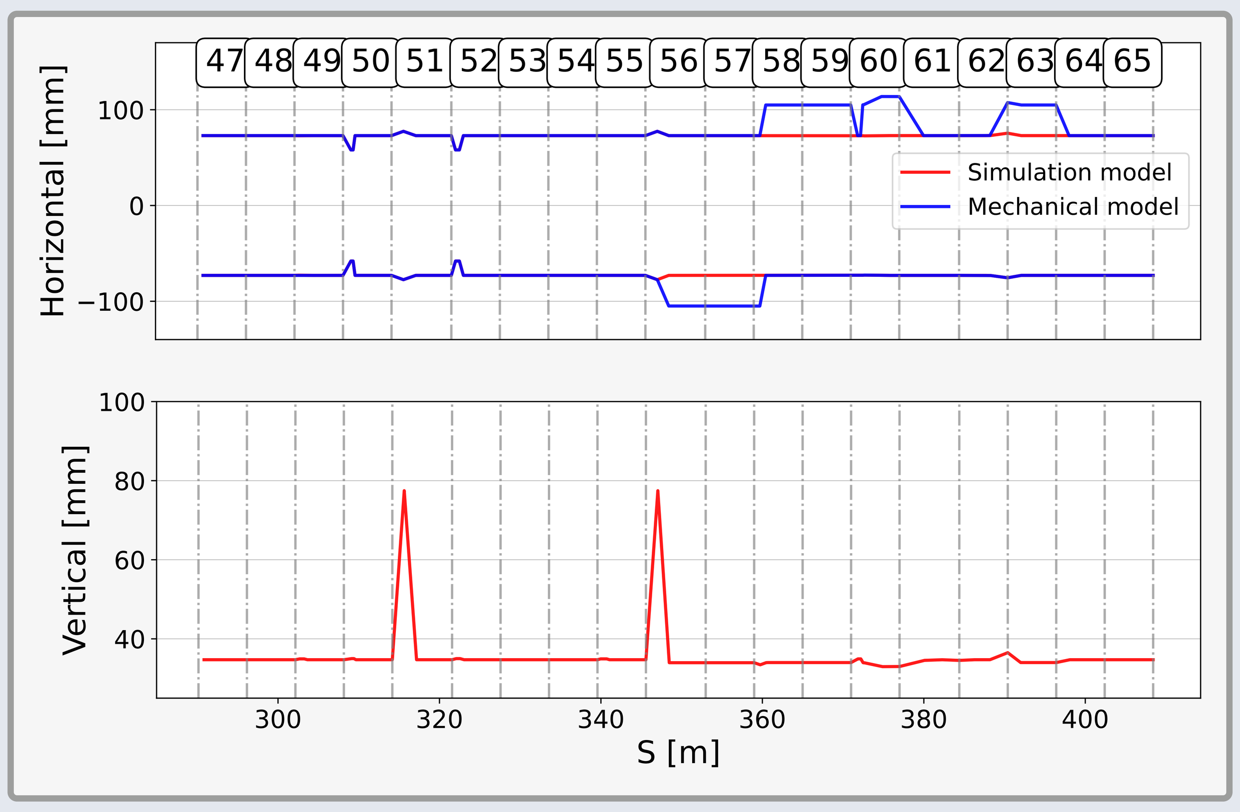
During the LS2 of the CERN accelerator complex, the 2 internal dumps from Straight Section (SS) 47 and 48, have been replaced as part if the LHC Injector Upgrade.

PS Dump characteristics:

- Move vertically at 0.8 m/s;
- Composed of two elements: a 12 cm-long graphite block (upstream) and an L-shaped block in CuCr1Zr with a 10.8 cm thick feet (downstream).

Aperture model:

- The standard cross section is an ellipse of half axis 73/35 mm;
- The presence of extraction regions introduces variations in the cross section. Sometimes, the geometrical centre of the cross section is displaced to optimise the beam aperture.



Evolution of the horizontal (top) and vertical (bottom) dimensions of the beam pipe (blue) and of the approximation used in the simulations (red).

Beam and optics characteristics:

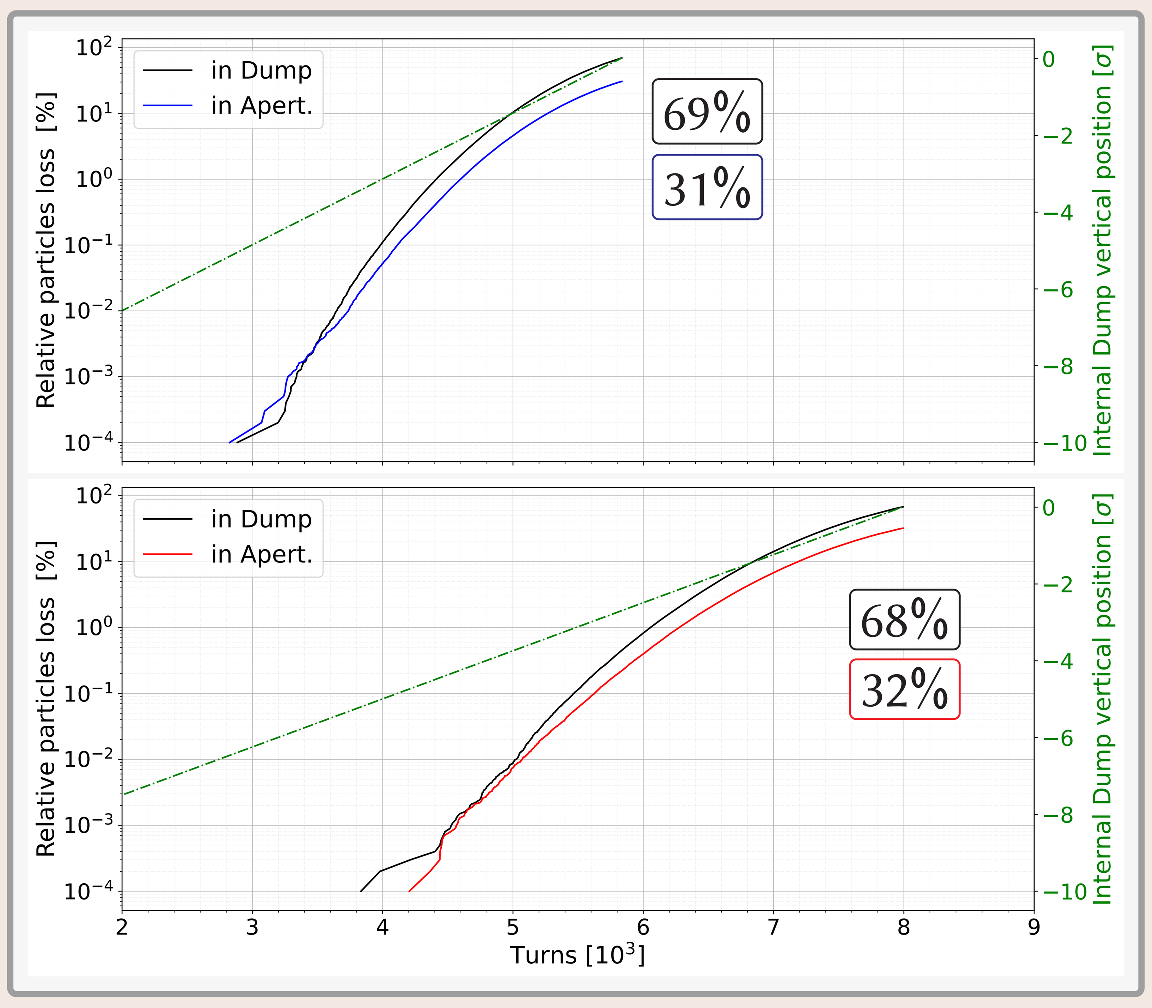
Each simulation consists of computing the evolution of 10^6 particles across the PS ring, and for various beam types and optics throughout the PS energy range.

Typical beam and optics parameters used in the simulations from the PS specifications.

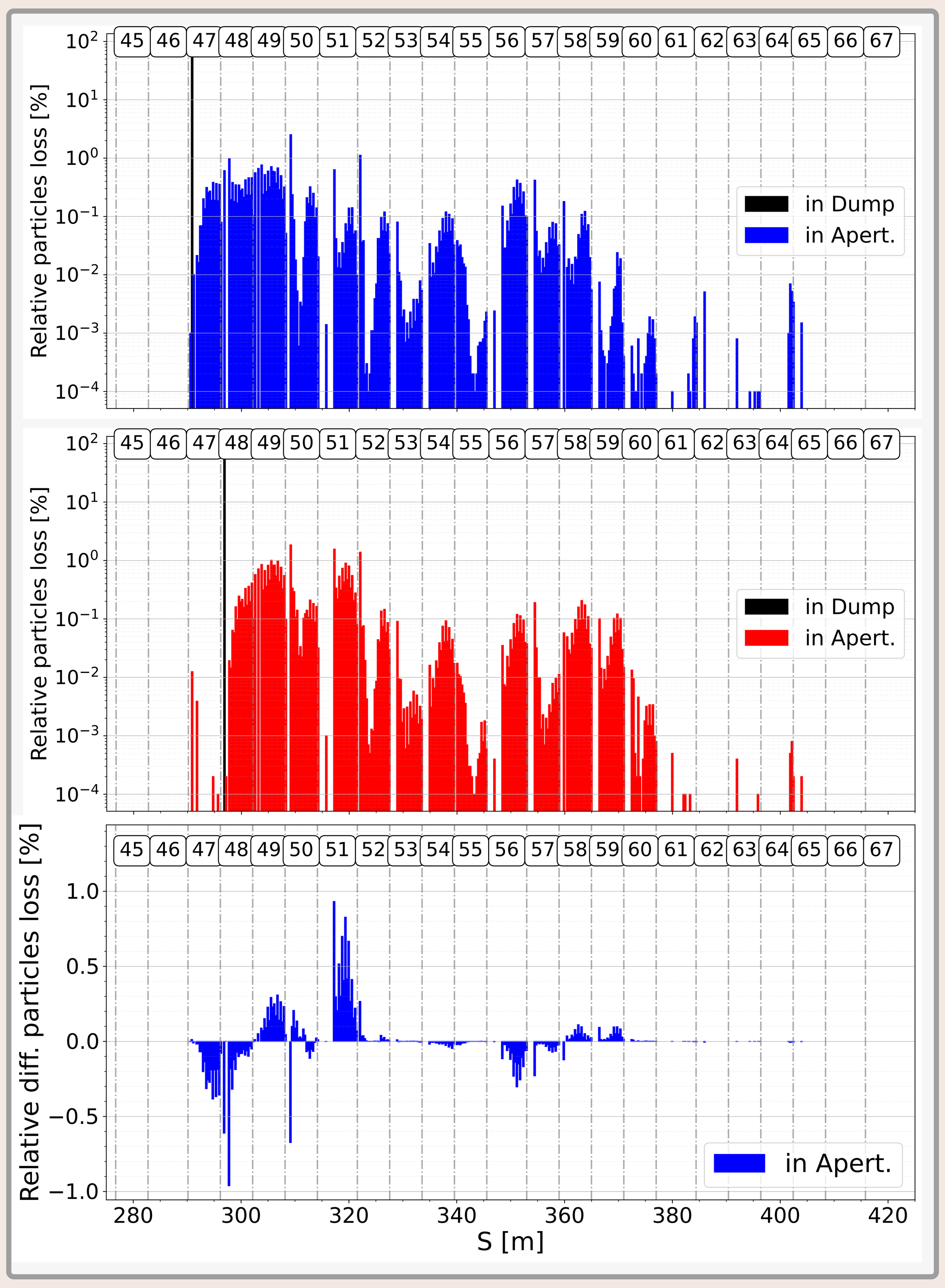
		LHC	SFTPRO
E_t	[GeV]	26.4	14
$\epsilon^*_x/\epsilon^*_y$	[mm mrad]	2.3	9/5
Q_x		6.217	6.247
Q_y		6.280	6.298
Q'_x		1.67	3.93
Q'_y		0.44	1.91
σ_δ	$[10^{-3}]$	0.4	0.1

Dump from SS47 vs SS48

- A large fraction of the beam impacts the vacuum chamber instead of interacting with the dump;
- The difference in time required to dump the beam is due to the difference in beam size ($\beta_{v,SS47} \approx 11$ m, $\beta_{v,SS48} \approx 22$ m);
- Losses are restricted to a region of about 120 m downstream of the dump ($\sim 1/5$ of the ring);
- Discrepancies between dump SS47 and SS48 activation are of the order of the percent.



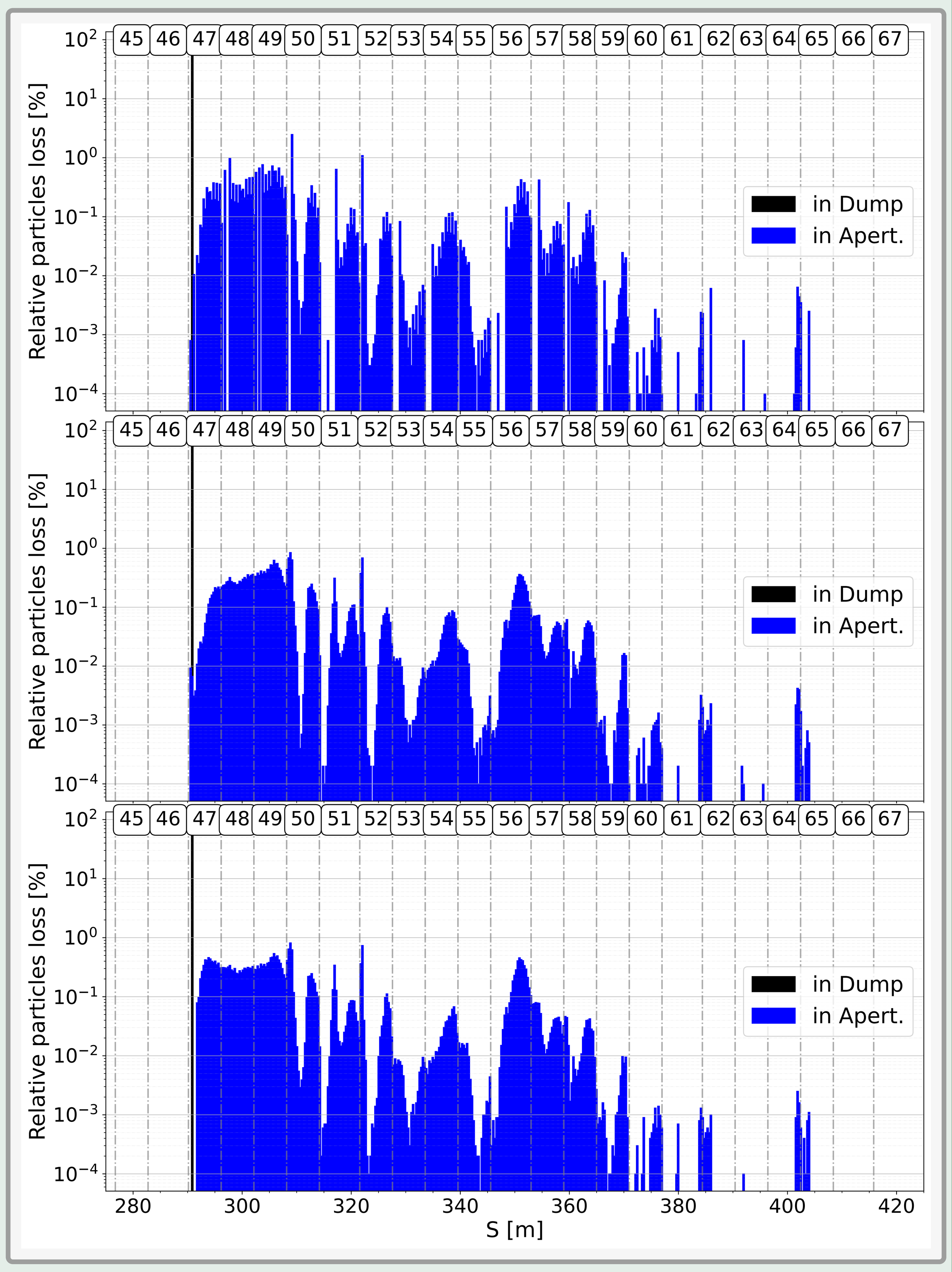
Evolution of the cumulative beam losses as a function of turn for an LHC beam using FLUKA when the dump in SS47 (top) and in SS48 (bottom) are activated.



Cumulative distribution of beam losses along the PS ring for an LHC beam using FLUKA when the dump in SS47 (top) and in SS48 (middle) are activated.

Collimation Codes

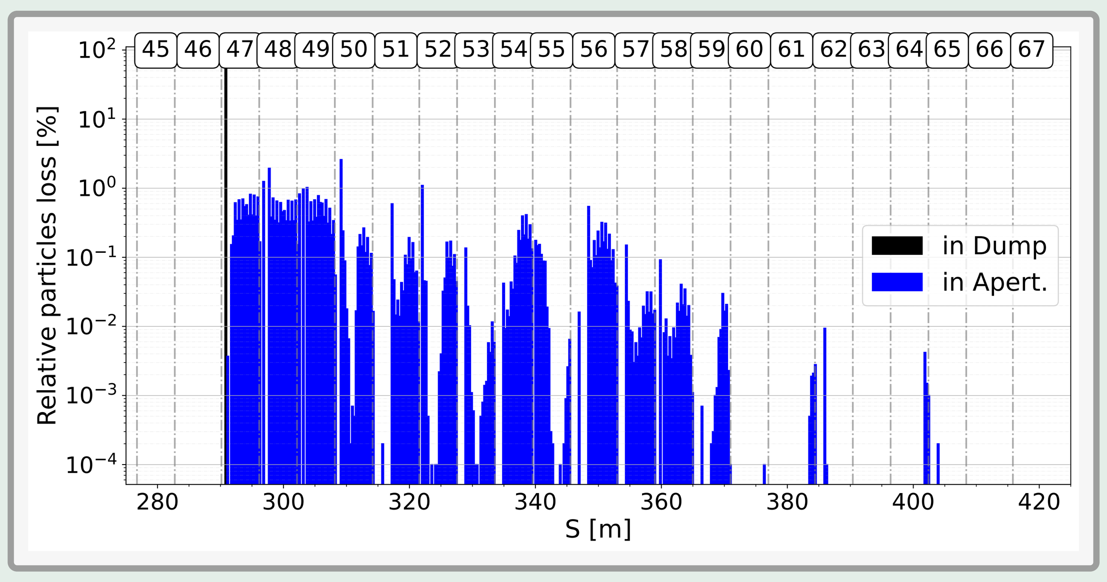
- BDSIM and Xsuite not tested at those energies;
- For the comparison: graphite ($\rho = 1.83\,g/cm^3$) $\rightarrow$ carbon ($1.67\,g/cm^3$) and CuCr1Zr ($8.9\,g/cm^3$) $\rightarrow$ Cu ($8.96\,g/cm^3$).



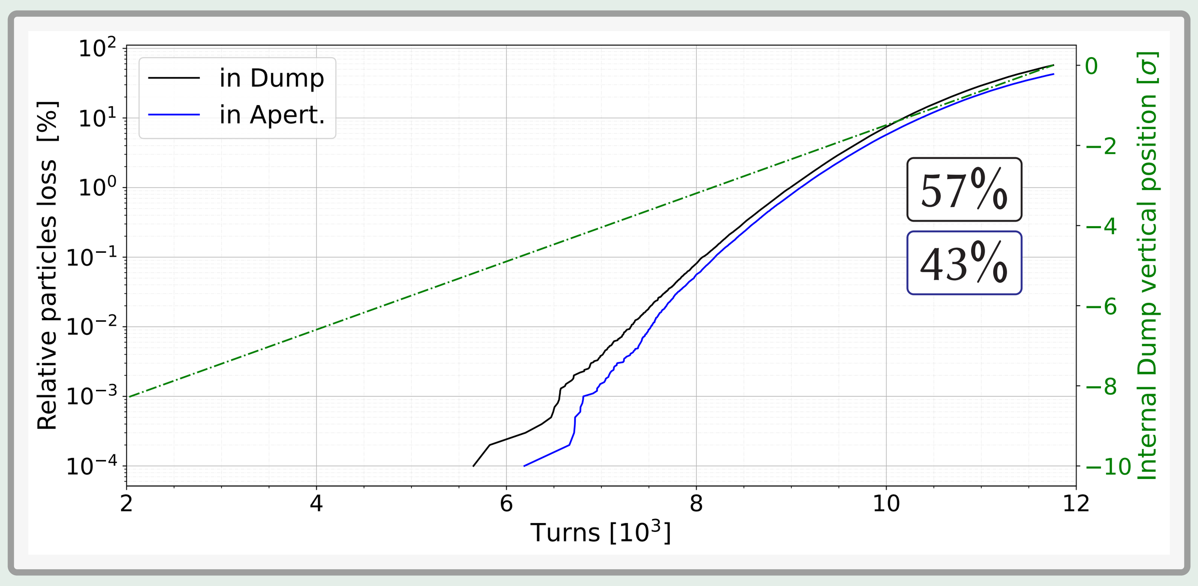
Loss maps in the a LHC beam and dump in SS47 using FLUKA (top), BDSIM (middle) and Xsuite (bottom).

SFTPRO at 14 GeV

- A lower fraction of the beam has a nuclear interaction with the dump compare to the LHC case;
- Complete beam disposal takes longer, caused by the larger normalized emittance and lower beam energy;
- The extent of the region where beam losses occur is slightly smaller.

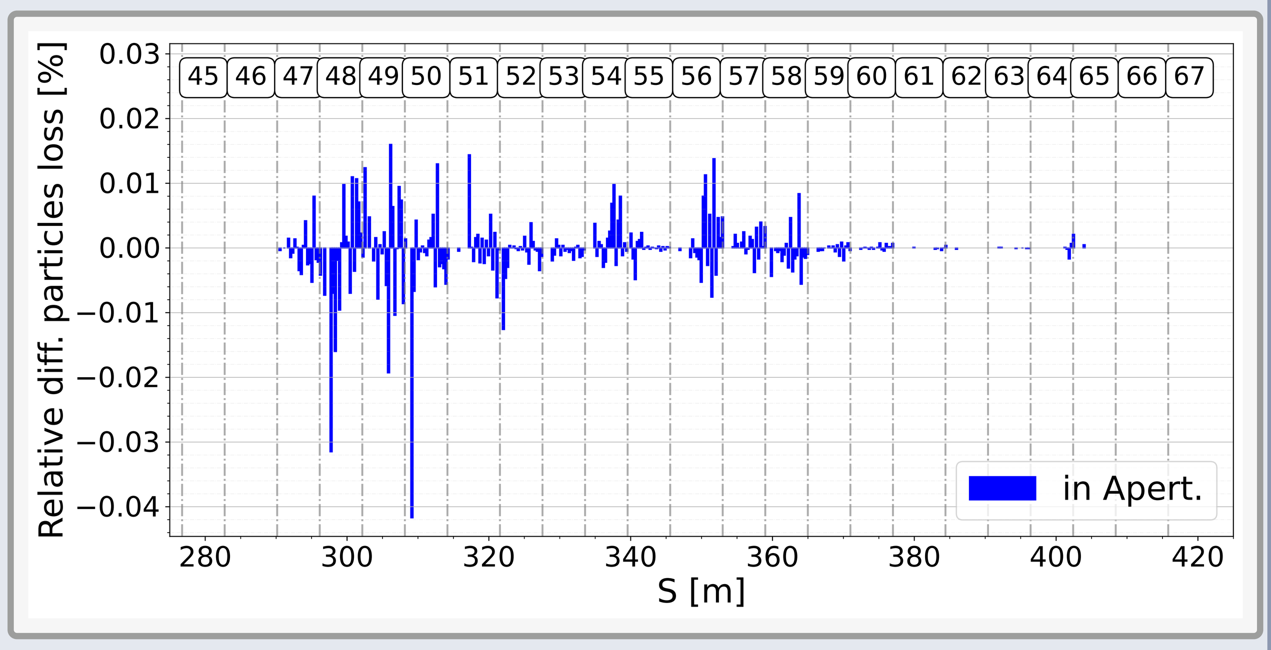


Cumulative distribution of beam losses along the PS ring for an SFTPRO beam using FLUKA when the dump in SS47 is activated.



Evolution of the cumulative beam losses vs turn for an SFTPRO beam using FLUKA when the dump in SS47 is activated.

4D vs 6D simulations



Difference of the beam losses along the PS ring for 6D and 4D tracking simulations for a LHC beam using FLUKA.

*thomas.pugnat@cern.ch