DESIGN AND CONSTRUCTION OF THE CERN SPS EXTRACTION PROTECTION ELEMENTS FOR LIU

B. Balhan ,C. Baud, J. Borburgh, M.A. Fraser, M. Hourican, L.O. Jorat, F-X. Nuiry, S. Pianese, CERN, Geneva, Switzerland

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INTRODUCTION :

At CERN, the SPS synchrotron is equipped with two fast extraction channels towards the LHC. The extraction septa (MST and MSE) are protected from accidental beam impact by extraction protection devices. The existing protection devices (TPSGs) are designed to dilute the beam such that the energy deposition and subsequent temperature rise in the conductors of the downstream septa remain below tolerable thresholds in the unlikely event that the beam is mis-steered. The existing devices were designed to protect the downstream septa from the direct impact of the full LHC ultimate intensity (a single shot) without sustaining irreversible damage. These requirements remain the same for the upgrade.

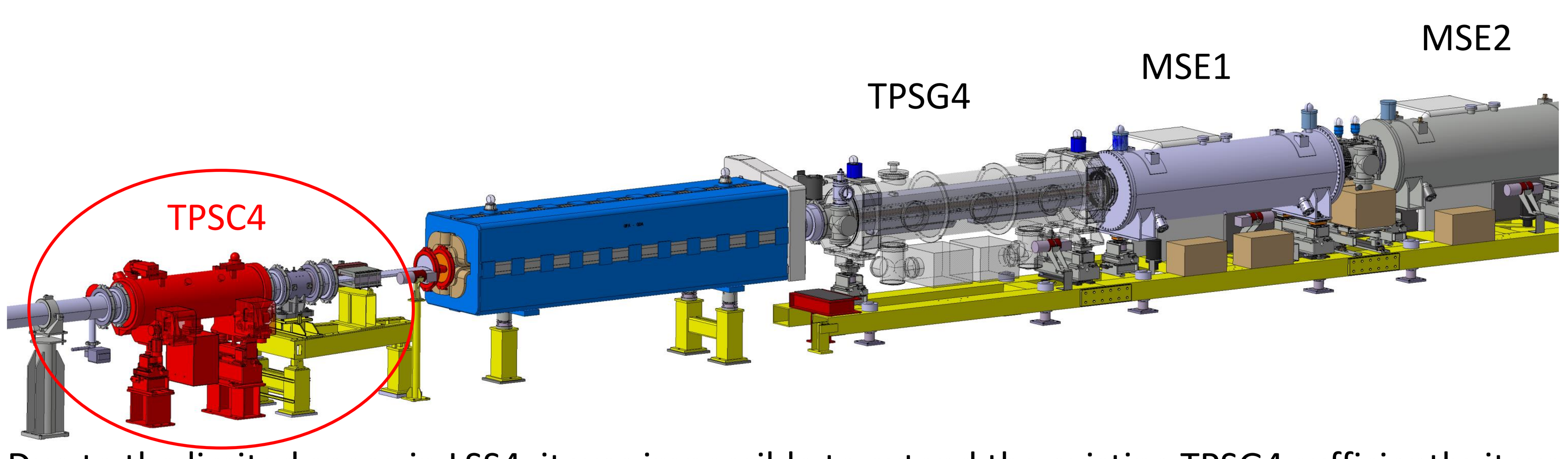
The protection requirements for each TPSG are based upon the assumption that the coil can withstand the same dynamic pressure as the pressure at which the coils are statically tested during construction. The maximum permissible copper temperature rise is determined by the space available in the yoke for the adiabatic thermal expansion after beam impact. Finally the maximum water temperature rise in the cooling channels is determined from the permissible pressure rise using the ELSE code. This yields limits of 20 bar pressure rise in the MST septa cooling channel, 50 bar pressure rise in the MSE cooling water channels, corresponding to a 4 and 6◦C temperature rise in the MST and MSE cooling water respectively. The copper conductor temperature should remain below 100◦C. Up to the Long Shutdown 2 (LS2, 2019 - 2020) both the extraction protection devices in LSS4 and 6 made use of state-of-the-art 2D Carbon Reinforced Carbon (CfC). The absorbing sandwiches have a total length of 3.1 m for the TPSG4 (extraction towards the CCW LHC beam) and 3.5 m for the TPSG6 (extraction towards the CW LHC beam). The new beam conditions require upgrades to both extraction protection systems, i.e. a new complementary unit TPSC4 in LSS4 and an additional unit TPSG6 in LSS6

DILUTER UPGRADE :

Beam Parameters	Present TPSG4	LIU upgrade	Present TPSG6	LIU upgrade
Beam momentum [GeV/c]	450	450	450	450
Protons per spill [10^{11}]	288 x 1.7	288 x 2.3	288 x 1.7	288 x 2.3
Transverse emittance [µm]	3.5	2.1	3.5	2.1
Emittance [nm rad]	7.3	4.4	7.3	4.4
Beam size at diluter H [mm]	0.86	0.66	0.67	0.52
Beam size at diluter V [mm]	0.50	0.38	0.65	0.50
Bunch train length [µs]	7.8	7.8	7.8	7.8

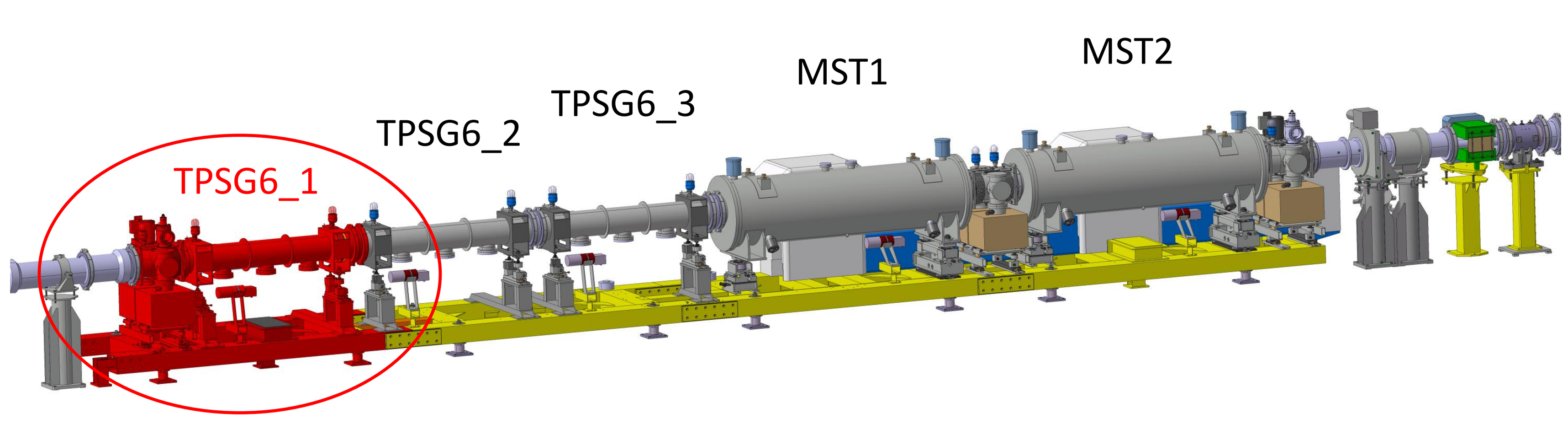
Diluters Parameters	Present TPSG4	LIU upgrade	Present TPSG6	LIU upgrade
3D Carbon [m]		1.35		1.75
Graphite (CZ5) [m]	0.5	0.5		
Carbon C/C [m]	0.5	0.5	1.75	1.75
Graphite (CZ5) [m]	0.3	0.3	0.85	0.85
Titanium (TiAl6V4) [m]	0.3	0.3	0.3	0.3
Inconel (Inco 718) [m]	0.3	0.3	0.6	0.6
Total dilution length [m]	3.1	4.45	3.5	5.25
Diluter width (mm)	21	19.3 – 21	6	6

LSS4 UPGRADED LAYOUT :



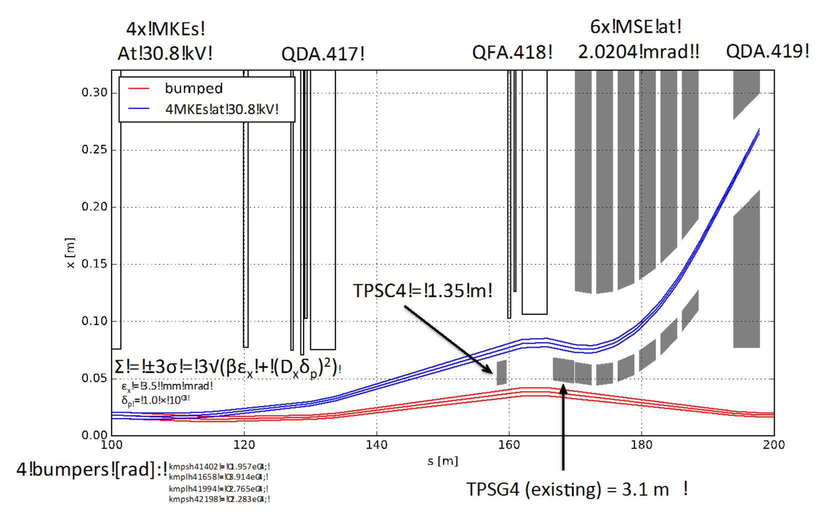
Due to the limited space in LSS4, it was impossible to extend the existing TPSG4 sufficiently, it was decided to split the protection device either side of quadrupole 418.

LSS6 UPGRADED LAYOUT :

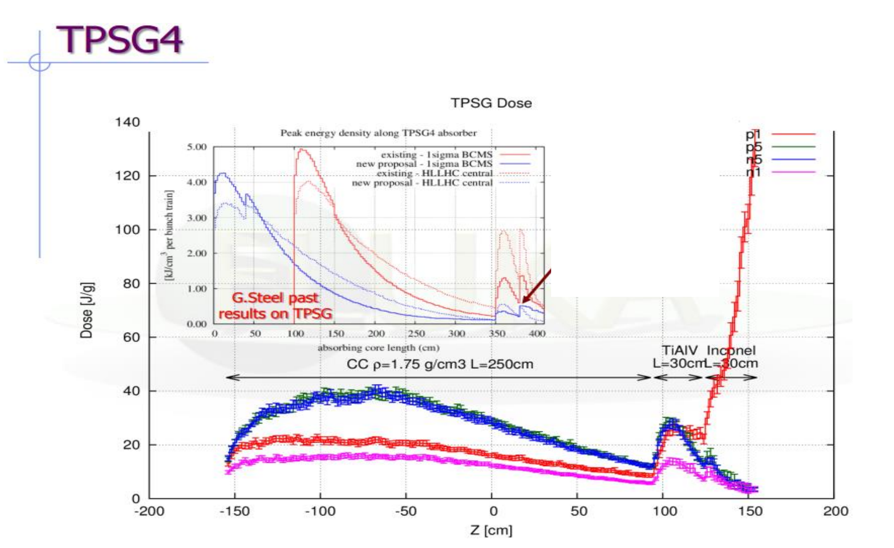


In LSS6 sufficient space could be freed up to accommodate an extended diluter directly upstream of the septa, installed on a common girder.

LSS4 BEAM OPTICS AND ENERGY DEPOSITION

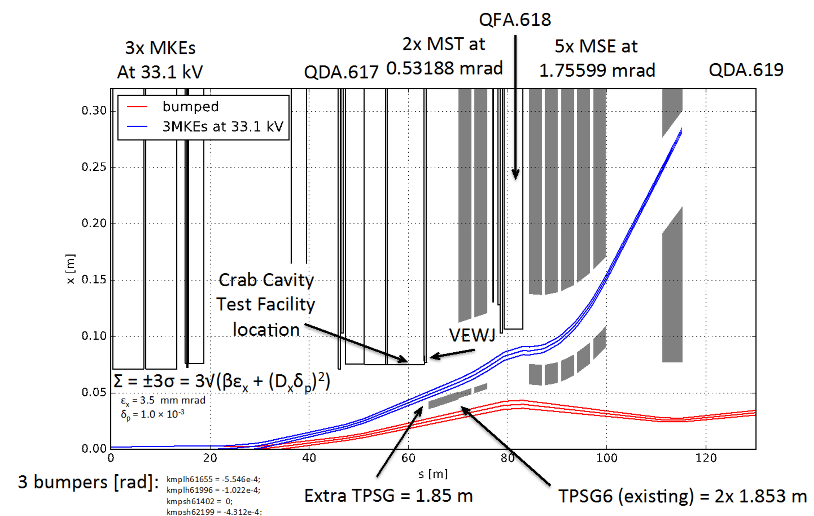


Final design choice for the LIU TPSG4 upgrade with the TPSC4 installed upstream up QFA.418

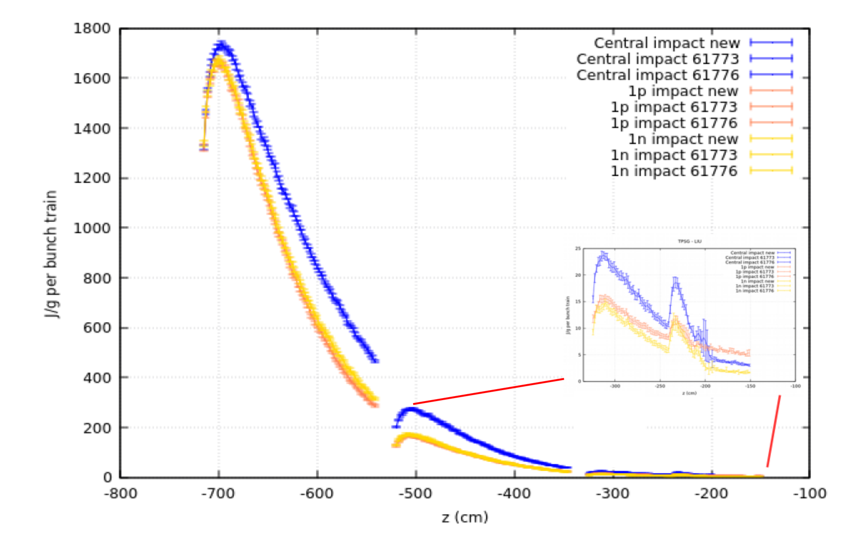


Energy deposited peak, 1070 J/cm3, on the last high density Inconel block has been found in the case of 1 σx impact on the outer edge.

LSS6 BEAM OPTICS AND ENERGY DEPOSITION

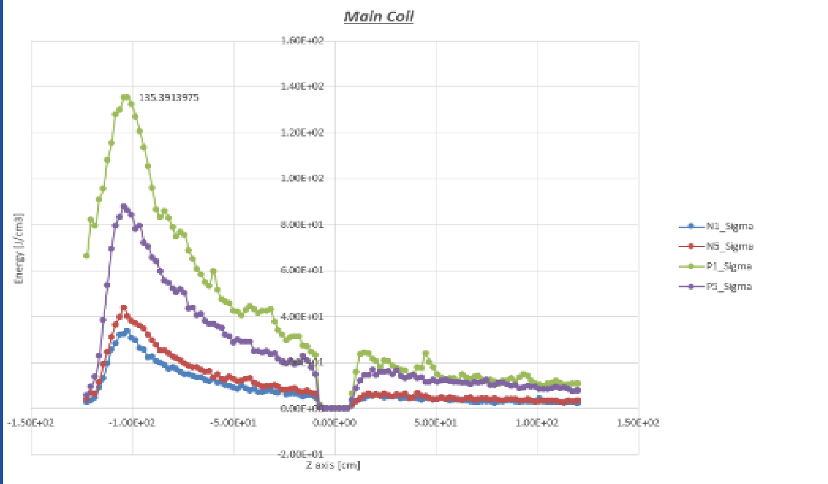


Final design choice for the LIU TPSG6 upgrade with a third tank installed upstream

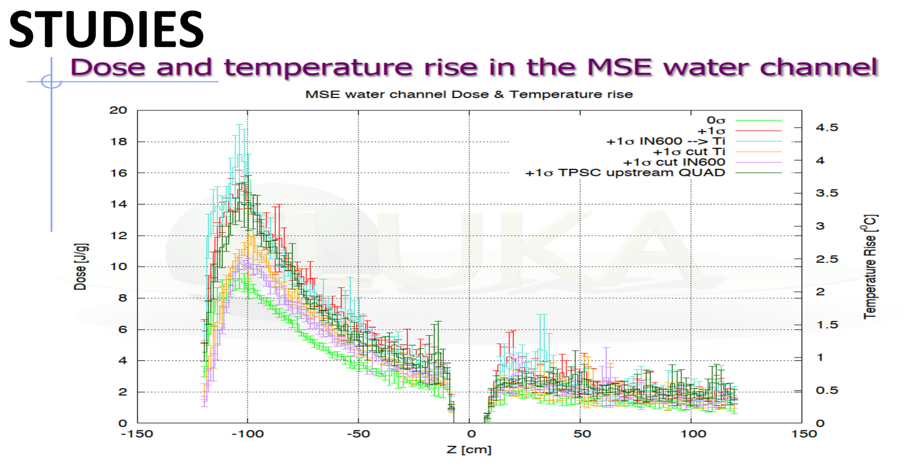


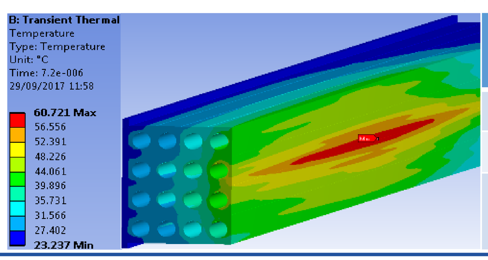
The central impact and $1\sigma_x$ from both sides of the TPSG6.61770 have been simulated, but the highest energy as well as temperature peaks on each block were reached with the central one

MSE COILS THERMO-MECHANICAL STUDIES



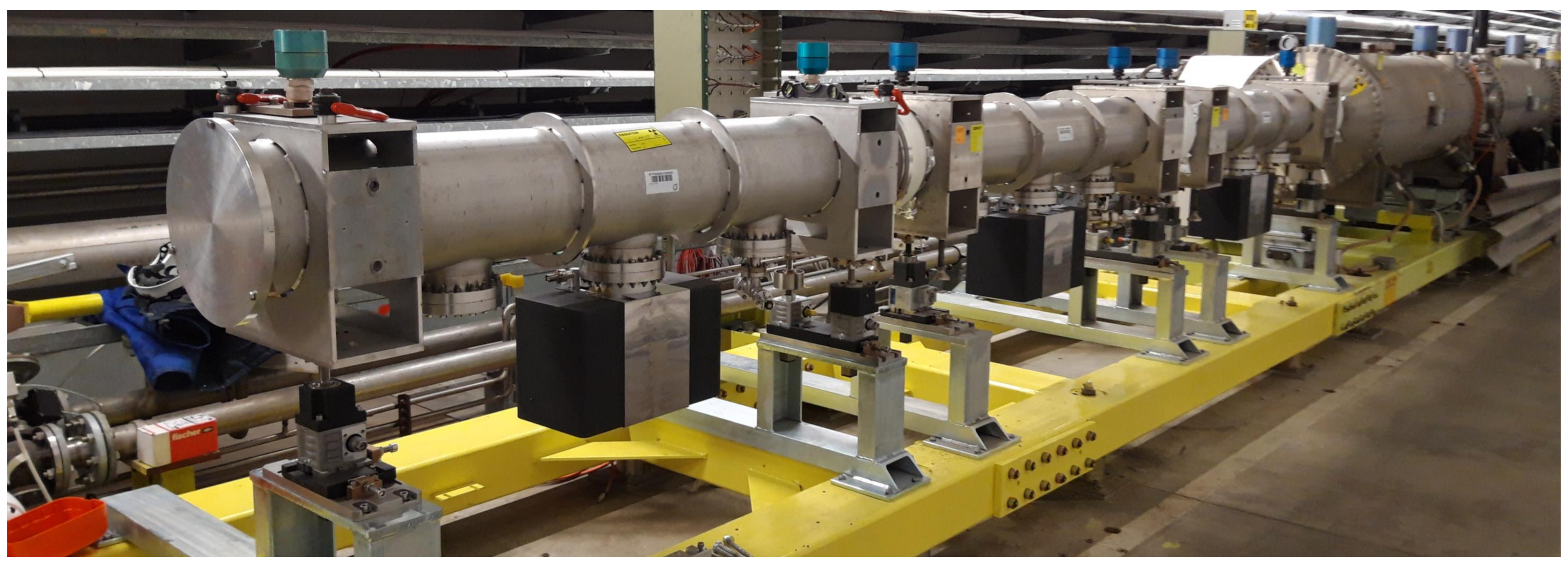
Energy deposition in MSE main coil using different losses scenarios



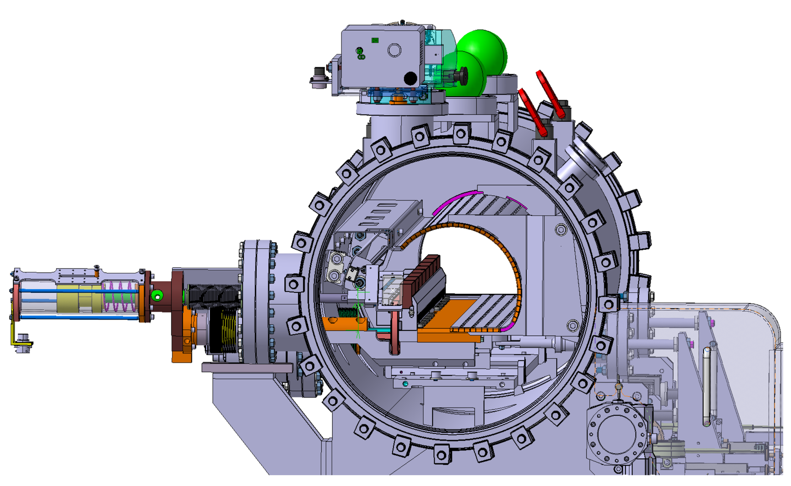


Temperature peaks	Temperature peaks
Main coil (copper)	61.6 °C
Return coil (copper)	44.87 °C
Main coil (water channel)	4°C

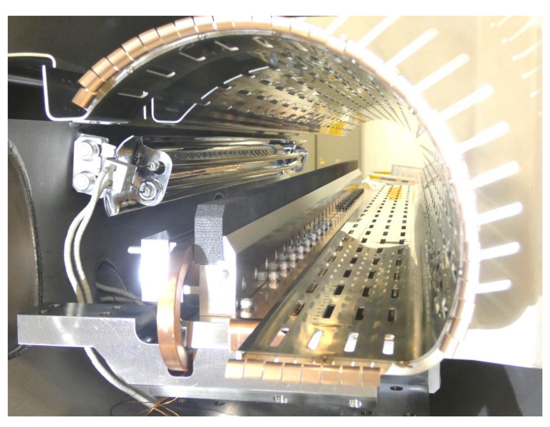
TPSG6 INSTALLATION IN LSS6



TPSC4 MECHANICAL DESIGN



Diluter elements and internal supports.



Clamping arrangement for the diluter blocks and cooling tube.

CONCLUSIONS

- The simulations show that the split-diluter configuration in LSS4 withstands full beam impact of the HL-LHC beam. No failure should occur of the diluter itself, and the downstream septa magnets will be properly protected.
- In LSS6 the integration of an additional diluter is feasible without major changes to the machine layout. The upgrade consists of the installation of 1 additional diluter containing 3D Carbon blocks immediately upstream of the two existing TPSG6 tanks.
- The temperature peaks found on the high Z materials of the existing diluters remain below the acceptable limits.