DESIGN OF THE FUTURE HIGH ENERGY BEAM DUMP FOR THE CERN SPS

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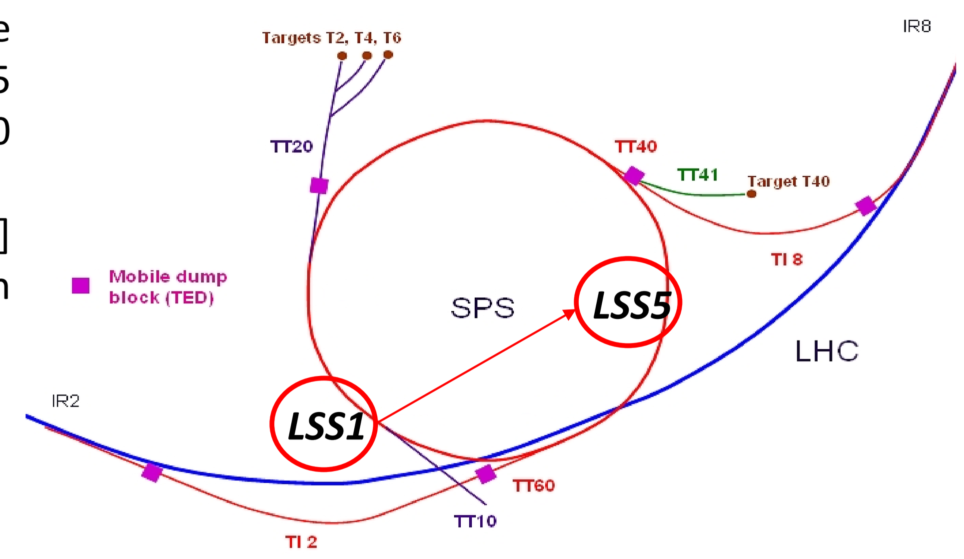
SPS internal dump system upgrading project

A new CERN Super Proton Synchrotron (SPS) internal dump (Target Internal Dump Vertical Graphite, known as TIDVG#5) has been designed within the framework of the LHC injector Upgrade (LIU) project [1] and will be installed during the CERN's Long Shutdown 2 (2019-2020). The future TIDVG#5 will replace both of the present SPS dumps (TIDH and TIDVG#4) and hence it will be required to absorb all the beam energies in the SPS (14 – 450 GeV).

The beam intensity and the repetition rates to be absorbed by the new dump will be significantly higher with respect to the current TIDVG#4 [2] resulting in an increase of average beam power to 236 kW (60 kW is the beam power dumped in the current device). The TIDVG#5 will be relocated in LSS5 [3] in order to overcome the limitations imposed by the current position (LSS1) and meet the goals of the SPS upgrading project, namely:

- Decoupling the dumping and the injection systems;
- Reducing the airborne radioactivity production by shielding;
- Improving ALARA procedures during interventions on the dump system.
- Conceiving a simple and reliable design which guarantees an efficient operation with little or no limitation.



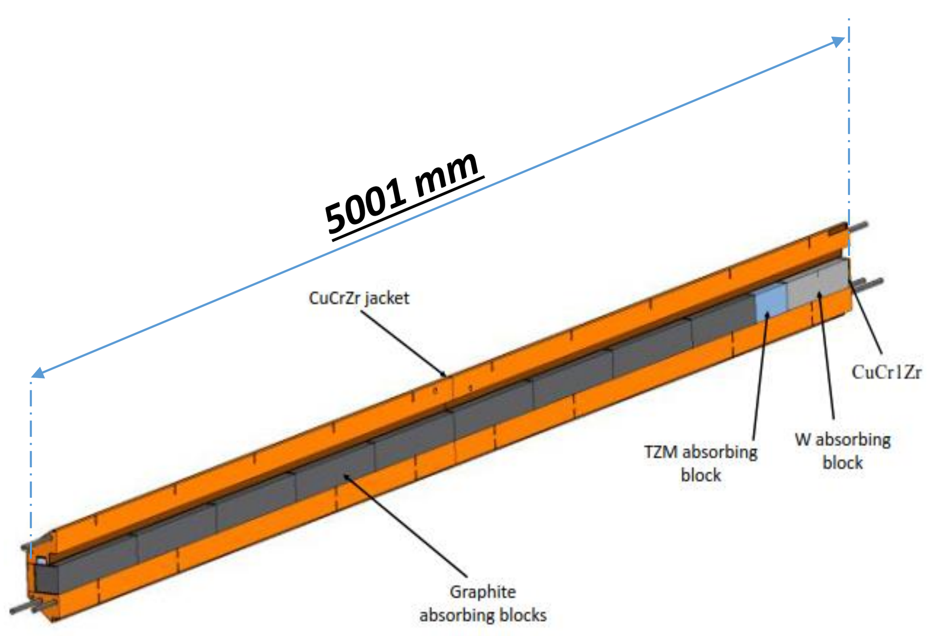
TIDVG #5 Design Innovations

In order to cope with an average beam power four times higher than the current device, several innovations have been implemented in the design of the TIDVG#5.

➢ ***Core***

- Total length increased by 70 cm leading to a 5.0 m long dump;
- New material sequence such as to minimise the energy density deposited by the beam;
- Attenuation factor higher than that of the TIDVG#4;
- Smaller beam aperture, hence beam dumped more centred with respect to the mechanical assembly.

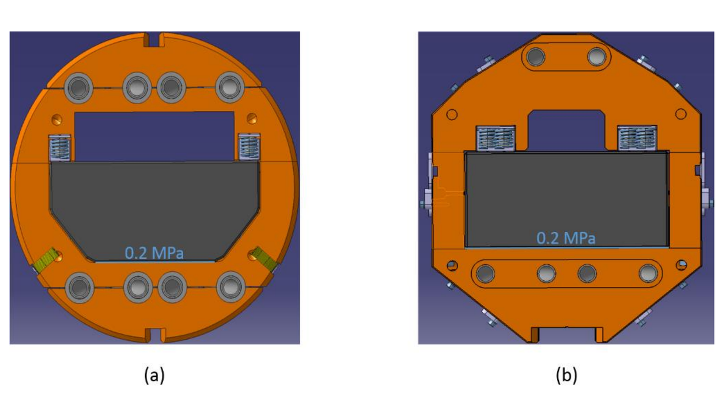
N.	Material	Total length
#1	Graphite R7550	440 cm
#2	TZM	20 cm
#3	Pure Tungsten	39 cm
#4	CuCr1Zr	1 cm



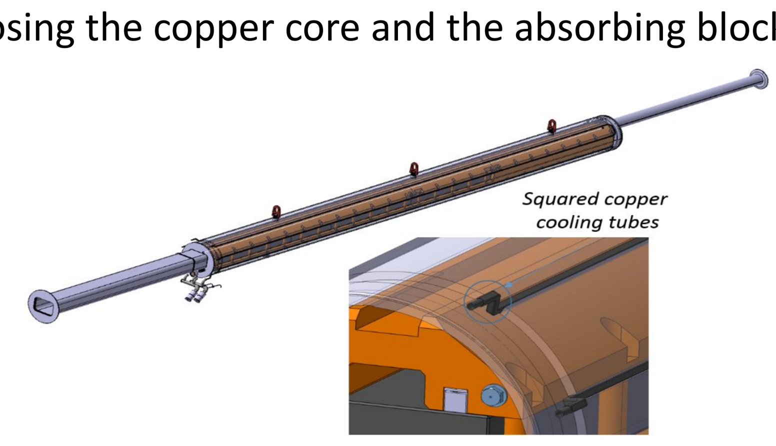
TIDVG#5 internal absorbing blocks surrounded by the water cooled CuCr1Zr jackets.

➢ ***Cooling of the absorbing blocks***

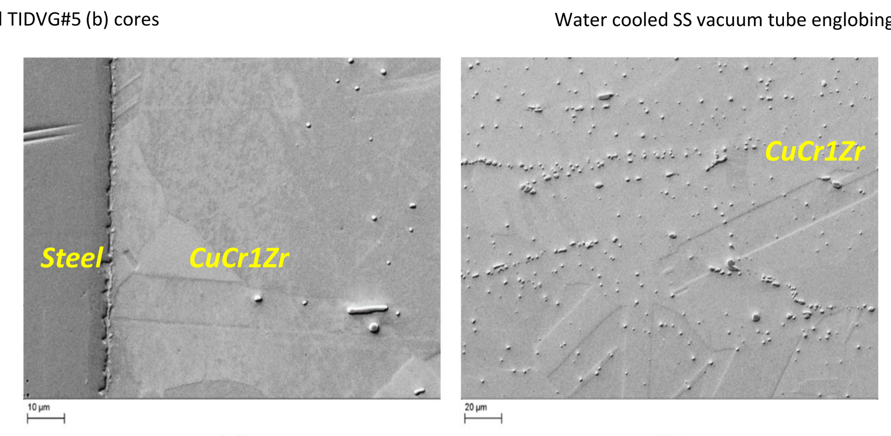
- Larger contact surface between the absorbing blocks and the CuCr1Zr jackets;
- A total water flow of 15 m^3/h , distributed between 6 parallel circuits;
- Stainless steel 316L cooling tubes, diffusion bonded to the CuCr1Zr plates by means of Hot Isostatic Pressing (HIP) [4] in order to maximise the thermal conductivity;
- Water-cooled, seamless vacuum chamber enclosing the copper core and the absorbing blocks.



Cross section of TIDVG#4 (a) and TIDVG#5 (b) cores



Water cooled SS vacuum tube englobing the core



SEM pictures of the interfaces after HIP: (a)-Steel/CuCr1Zr and (b)-CuCr1Zr/CuCr1-Zr

After the HIP process the contact is achieved fully, no discontinuity is visible at the CuCr1Zr/CuCr1Zr interface.

In the worst-case scenario, a total power of 166 kW is deposited in the core and must be evacuated by the CuCr1Zr jackets.

➢ ***Radiation shielding***

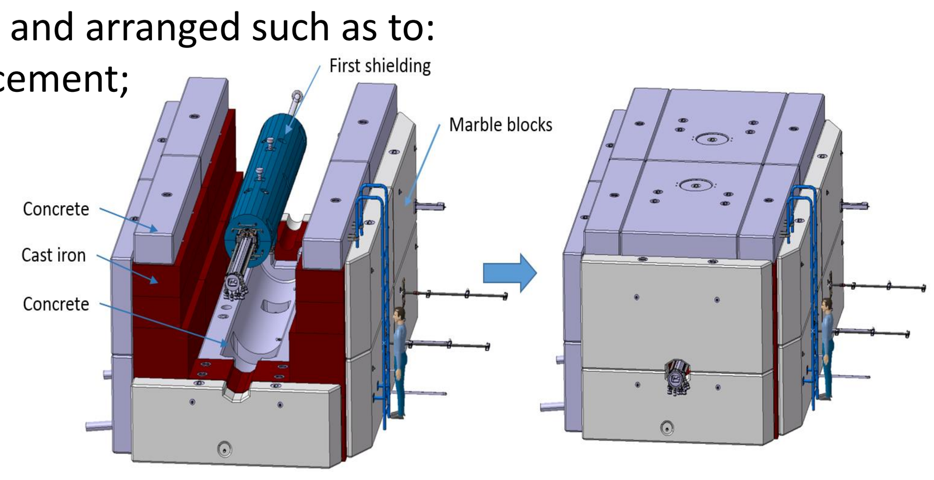
Beyond the first shielding made of cast iron, the TIDVG#5 is equipped with a multi-layered external shielding which consists of:

- Inner layer of 50 cm of concrete;
- 1 m of cast iron;
- External layer 40-50 cm of concrete/marble.

The external shielding blocks have been designed and arranged such as to:

- Minimize handling operations in case of replacement;
- Allow remote handling.

Through holes are foreseen in order to allow for survey and alignment operations of the dump whilst inside the shielding.



Conclusions

- An innovative and reliable design for the future SPS internal dump system has been realized;
- The change of location allows to overcome several previous limitations and enables a comprehensive upgrade of the device;
- The proposed design makes the TIDVG#5 capable of withstanding the highly demanding LIU beams.

Beam parameters and super-cycle composition

The TIDVG#5 will have to absorb various beams types in predefined sequences (super-cycle compositions) [5].

Beam Type	E_{max} [GeV]	Bunch Intensity $[p^+/bunch]$	# of bunches
LIU-SPS 80b	450	$2.43 * 10^{11}$	320
HL-LHC Standard	450	$2.43 * 10^{11}$	288
HL-LHC BCMS	450	$2.13 * 10^{11}$	288
SPS-FT North	400	$1.40 * 10^{10}$	4200
SPS-FT SHiP	400	$1.07 * 10^{10}$	4200

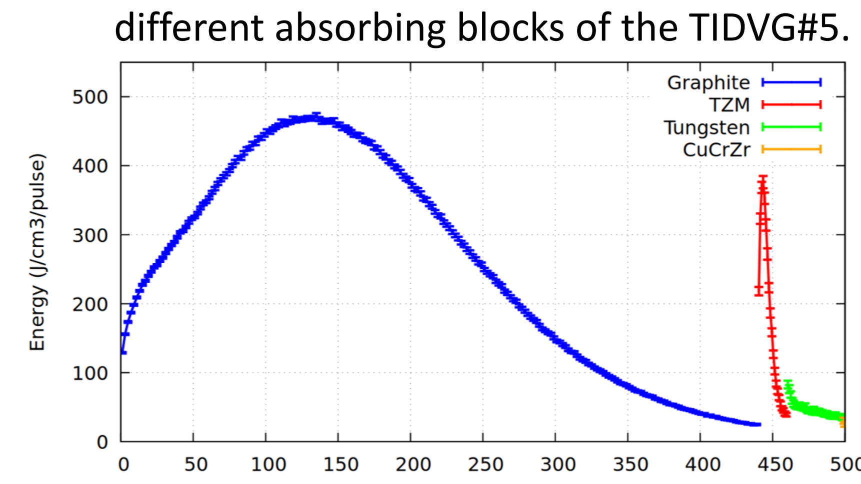
Most demanding super-cycle with 236kW of average beam power (total duration = 36 s)

1. 7.2 s, SPS-FT SHiP pulse period;
2. 22.1 μs, SPS-FT SHiP beam dumping;
3. 7.2 s, SPS-MD period (no beam dumped);
4. 21.6 s, LIU-SPS 80b pulse period;
5. 8.6 μs, LIU-SPS 80b beam dumping.

Actually, this super-cycle is highly unlikely to happen more than a few times consecutively.

Thermo-mechanical simulations

The picture below shows the variation of peak energy density along the beam axis inside the different absorbing blocks of the TIDVG#5.



Energy distribution on the absorbing blocks obtained by means of Monte-Carlo simulations after dumping one LIU-SPS 80b beam [6].

Conservative approach→ The super-cycle above is continuously dumped during long periods of time (hours).

The thermal contact conductance (TCC) at the TZM/CuCr1Zr interface is the lowest one.

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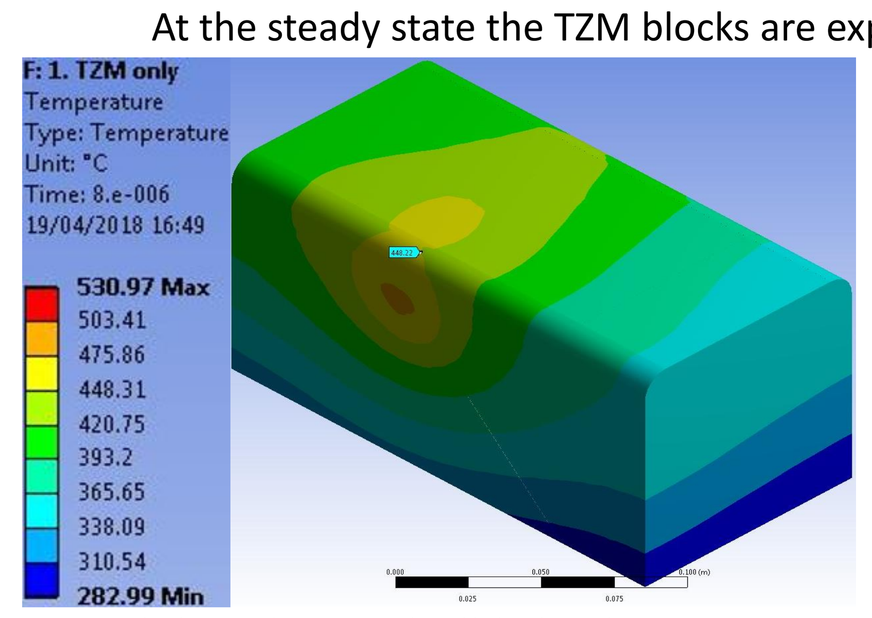
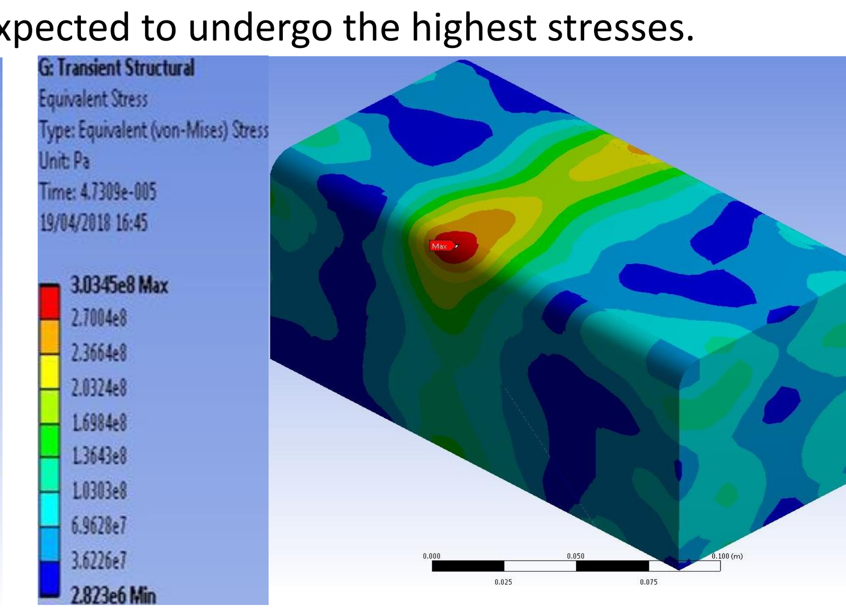
At the steady state the TZM blocks are expected to undergo the highest stresses.



Temperature distribution on the most stressed TZM block at the steady state



von Mises distribution on the most stressed TZM block at the steady state

Peak Temperature	Peak von Mises stress	Yield strength	Safety factor
448 [°C]	303 [MPa]	500 [MPa] @ 600°C [7]	1.65

References

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[4] G. Le Marois et al., "HIP'ing of copper alloys to stainless steel", Journal of Nuclear Material, 233-237, 1996, pp.927-931.

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