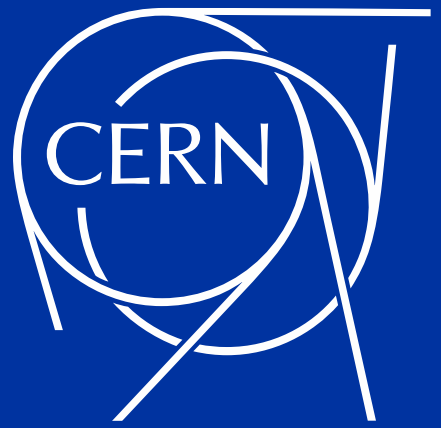


Updates on LHC external dump (TDE)
Evian 2021 workshop

M. Calviani on behalf of SY-STI

23rd November 2021

Outlook

- Introduction to LHC dump
- Challenges and behavior during beam impact
- Dump upgrades during LS2
- Questions on core behavior following beam impact
- Work ahead & Conclusions

Acknowledgments

SY/STI, BE/CEM, EN/MME, TE/VSC, EN/HE, SY/ABT, BE/OP, IPT, EN/ACE, EN/EL, NTNU, external industrial partners

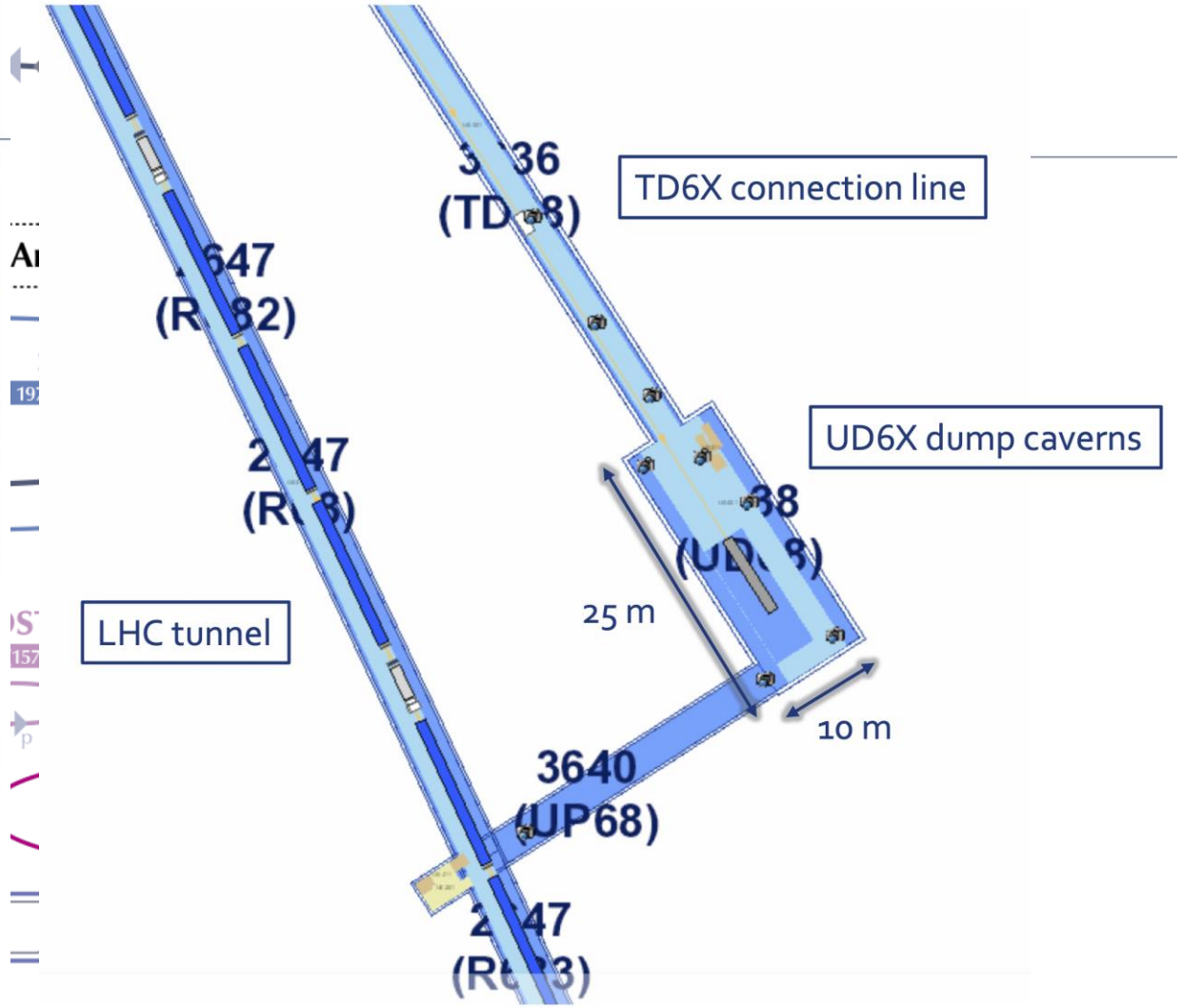
Large Hadron Collider beam dump

- LHC beam kinetic energy reaching **several hundreds of MJ**
  - **This energy is sufficient to melt more than 2.5 tons of Cu**

	Run 1 (2009–2013)	Run 2 (2015–2018)	Run 3 (2022–2024)	HL-LHC (2027–)
E_{prot} (TeV)	4	6.5	6.8	7
Δt_b (ns)	50	25	25	25
N_b	1380	2556	2748	2760
I_b (p)	1.7×10^{11}	1.2×10^{11}	1.8×10^{11}	2.2×10^{11}
E_{beam} (MJ)	150	320	539	680
ε_n (μm rad)	≈ 2.5	≈ 2	1.8–2.5	2.5

Where do we safely dispose of these beams without damaging sensitive equipment?

Large Hadron Collider beam dump

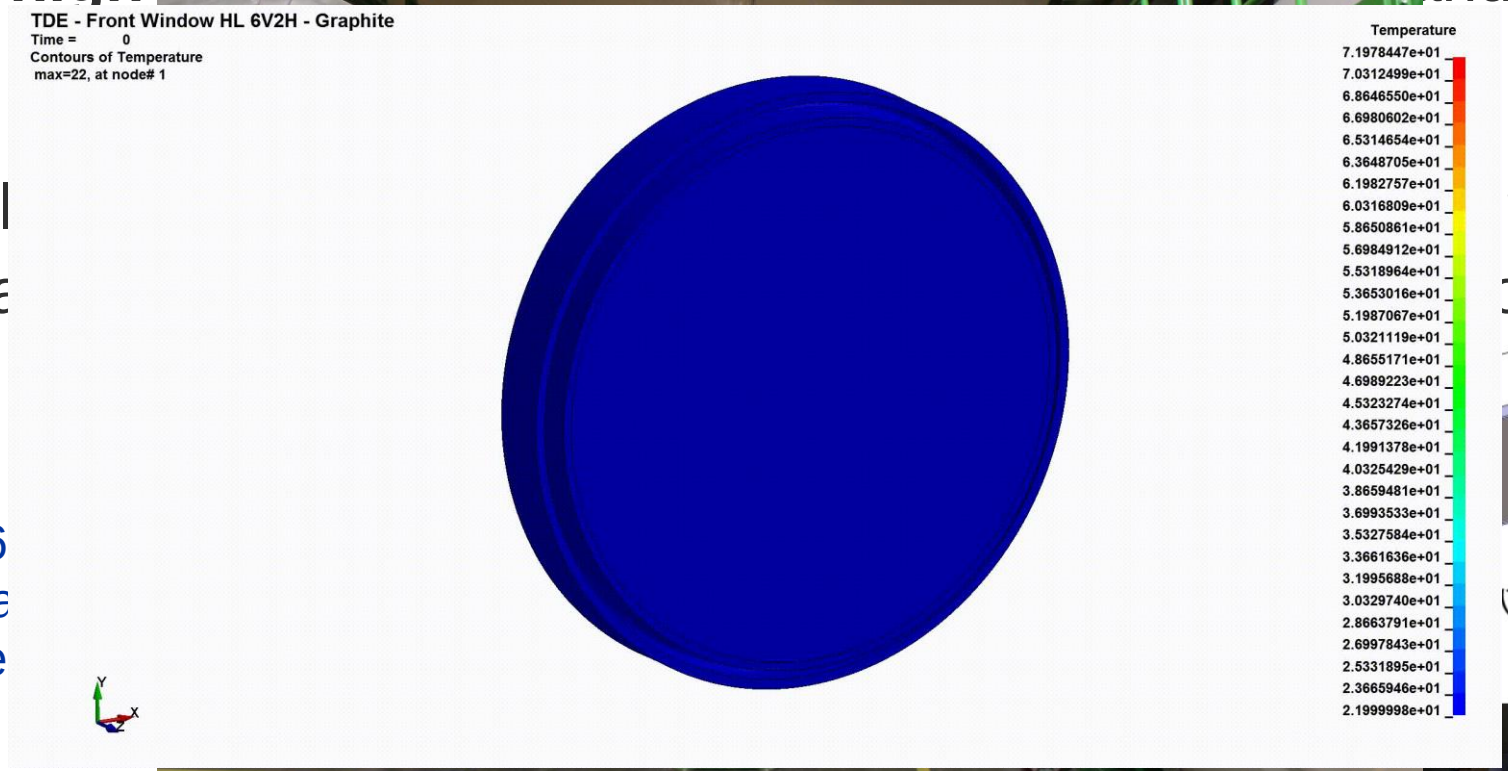


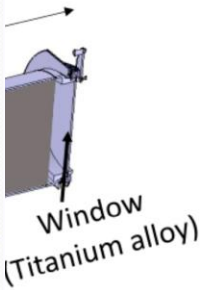
LHC beam

- The LHC TDE stituted by a **graphite (low and high and 700 mm diameter**
- It is install **nless-steel (1.4462)** a ospheric pressure

$\lambda \approx 15$

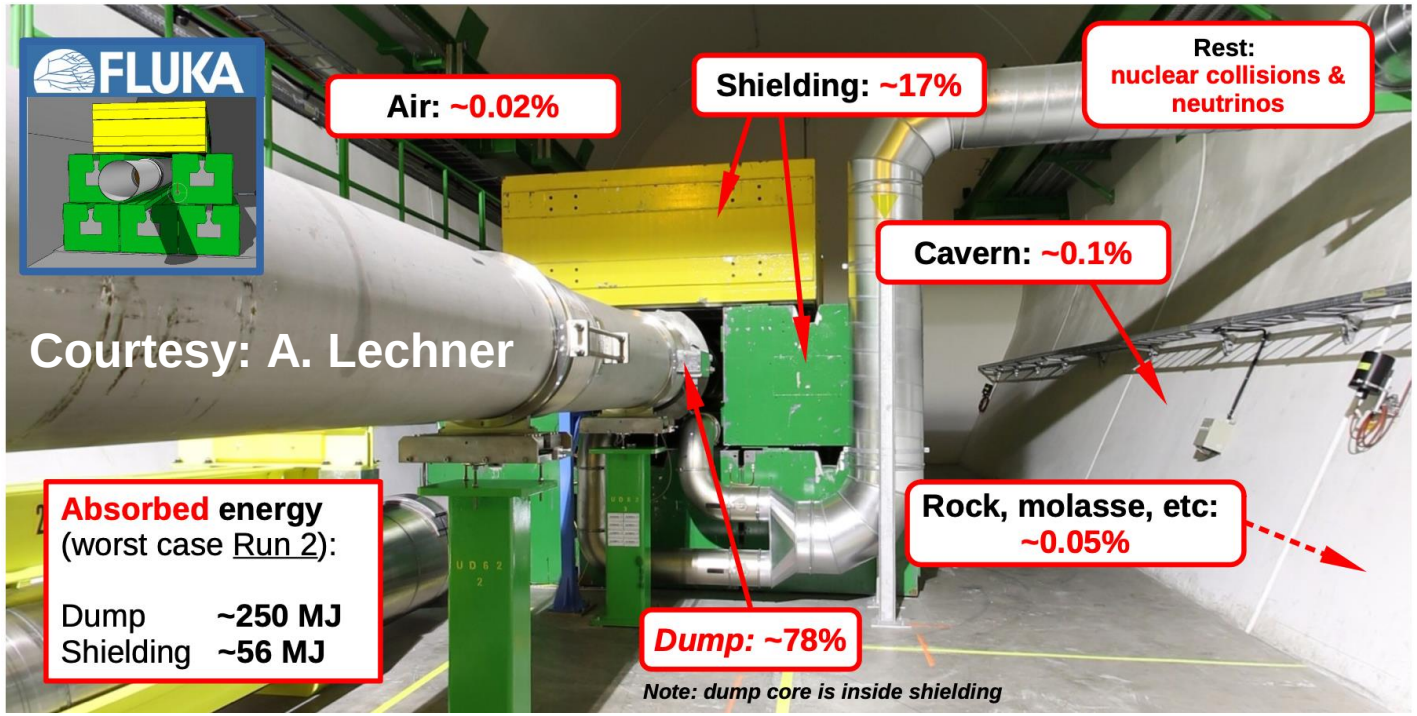
>99.9999% of 6
have an inela
collision in the





What the challenges?

	Fraction of beam energy	Energy deposition (MJ)
Dump:		
Graphite	73.6%	397
Shell	4.2%	23
Windows, flanges etc.	0.04%	0.2
Total	77.9%	420
Environment:		
Shielding	17.4%	94
Air	0.015%	0.08
Cavern	0.12%	0.6
Molasse, rock, etc.	0.04%	0.2
Total	17.6%	95



JINST 16 P11019

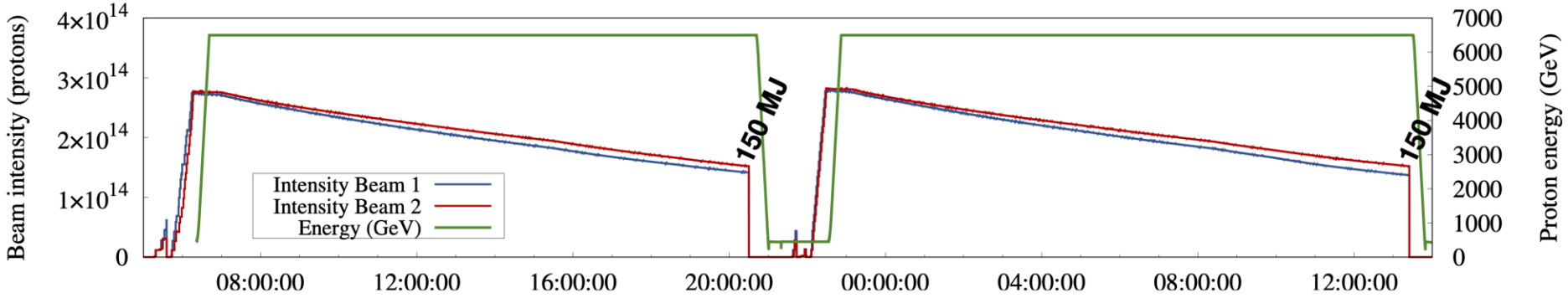
Dumped energy

±200 GJ were dumped so far (60 GJ in Run 1 and 140 GJ in Run 2)

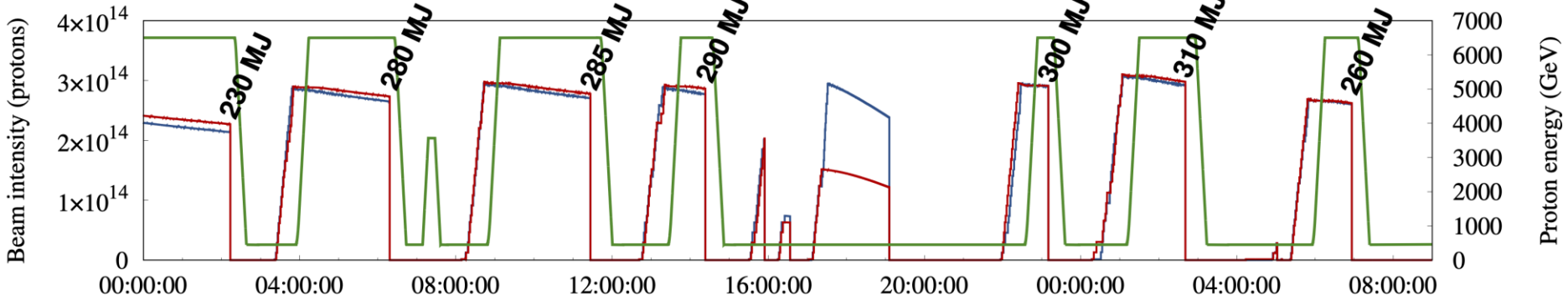
*Dumped energy = **proton energy** × **beam intensity** at the moment of beam extraction*

Good day:

Courtesy A. Lechner, from LHC TDE autopsy review (Nov 2021)



Bad day:



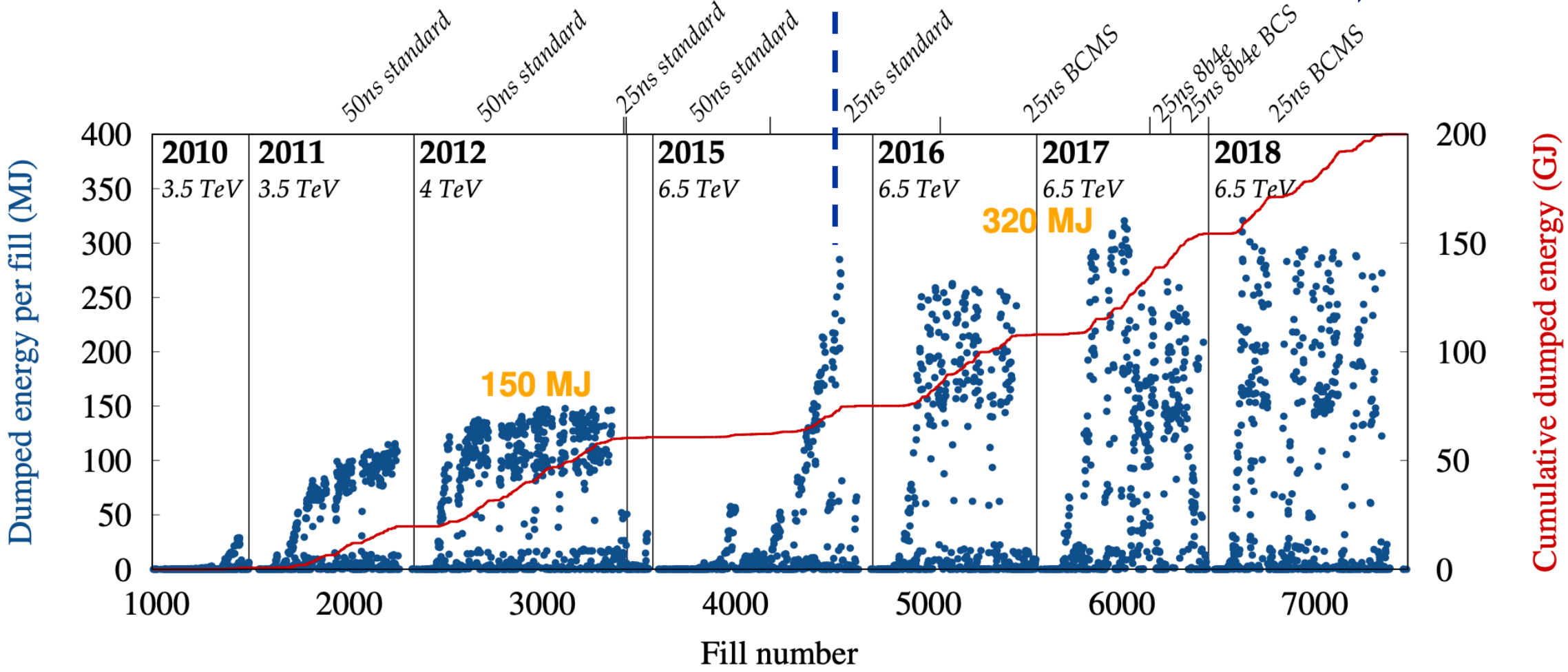
120 MJ

(4.5x smaller than in Run3)

Dumped energy

Operational challenges in the dump started to appear

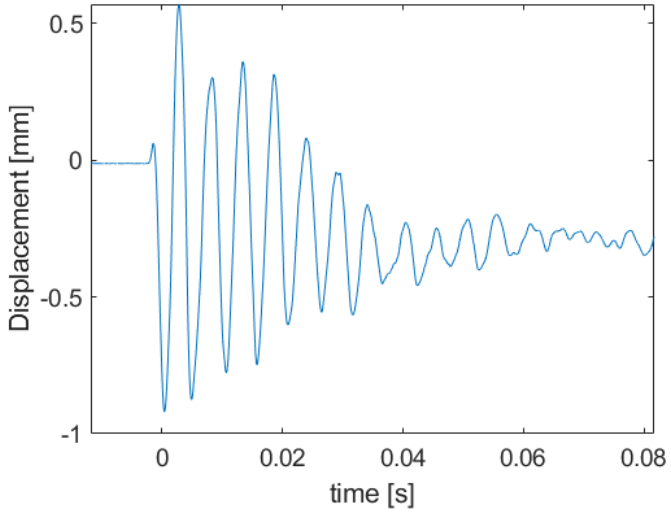
Courtesy A. Lechner, from LHC TDE autopsy review (Nov 2021)

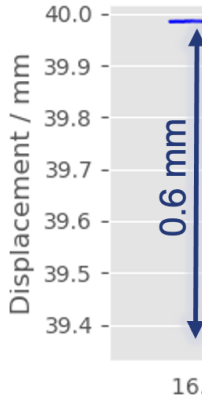


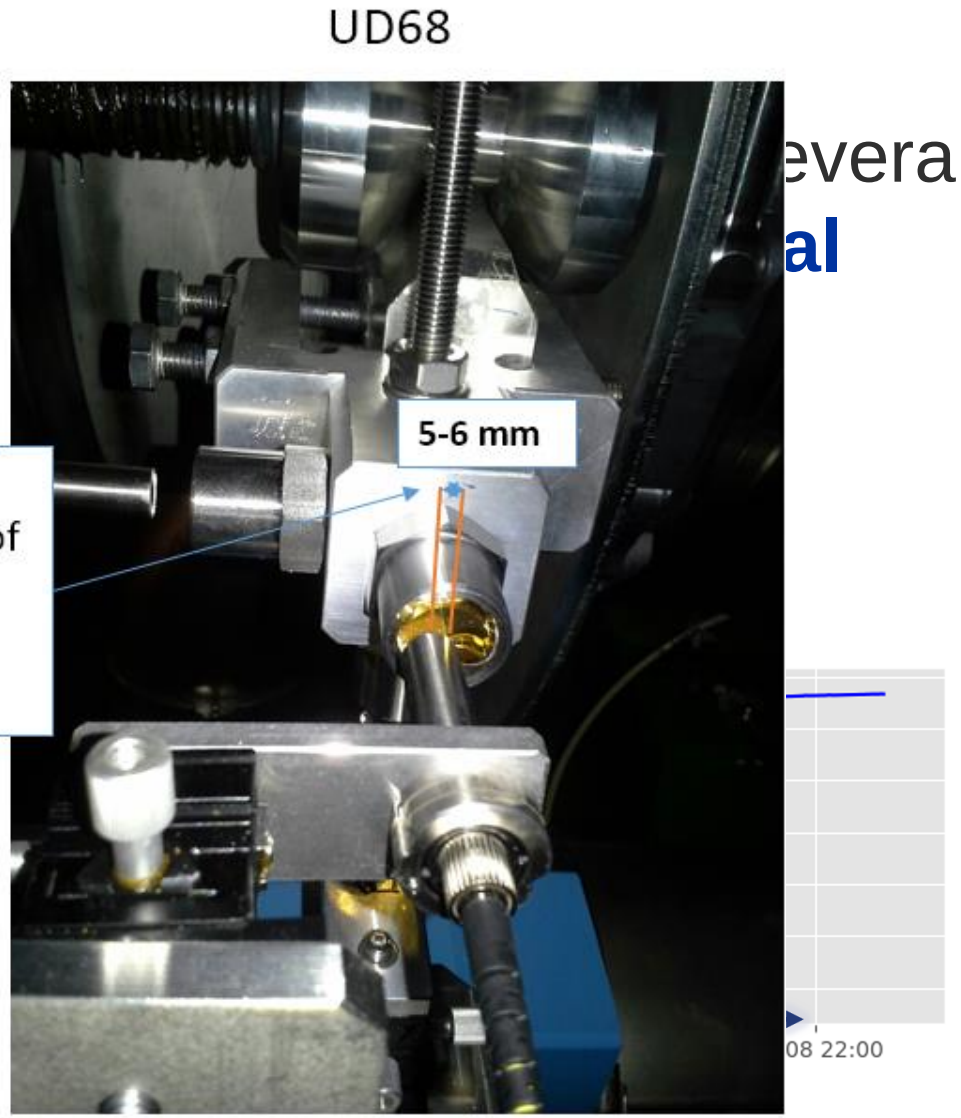
What did we see?

- Starting from end of 2015 (ram … everal problems associated with **N_2 le … al movements**
- What do we saw with instrume …

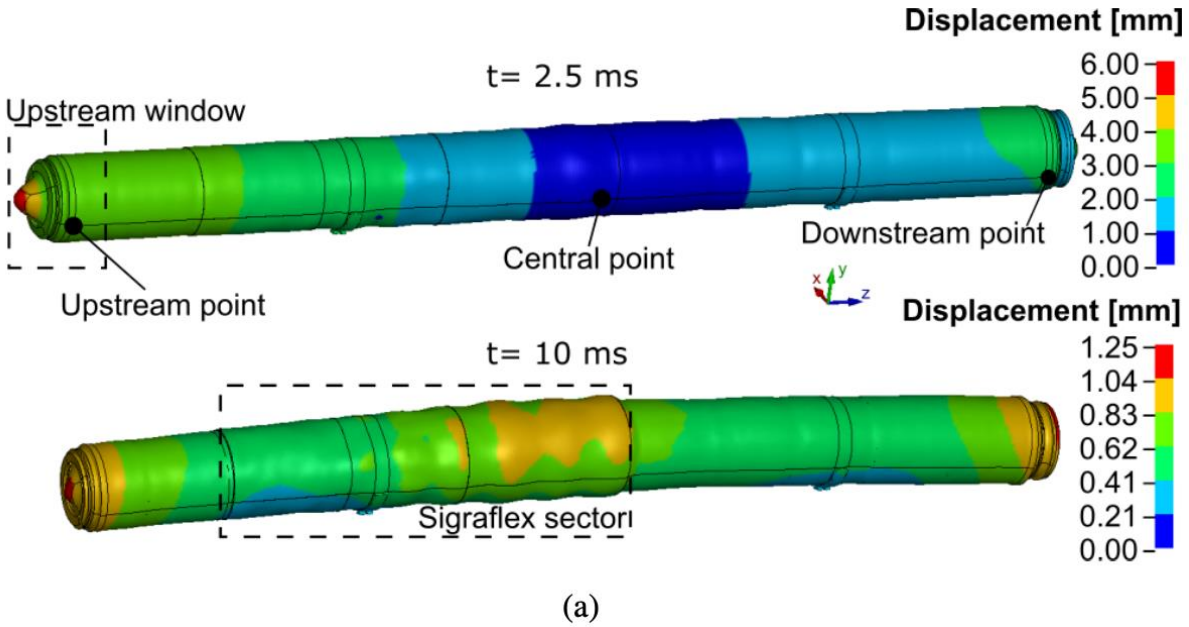
Time scale of 100 ms



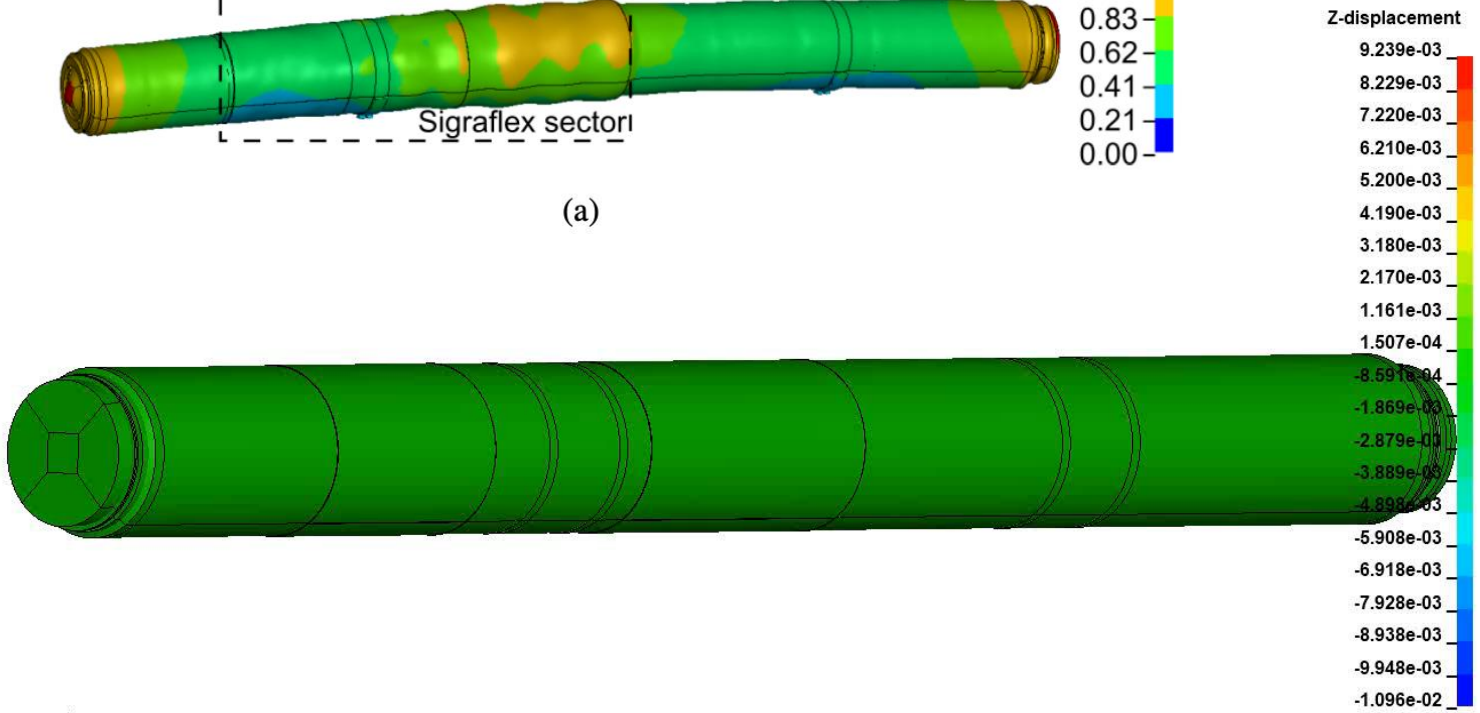


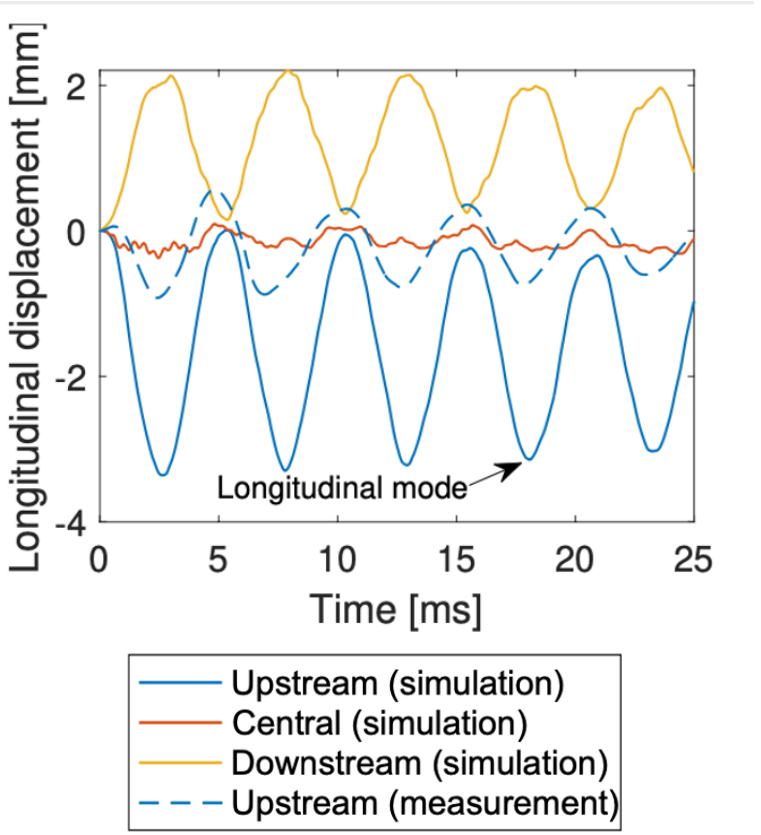


Dump fast response



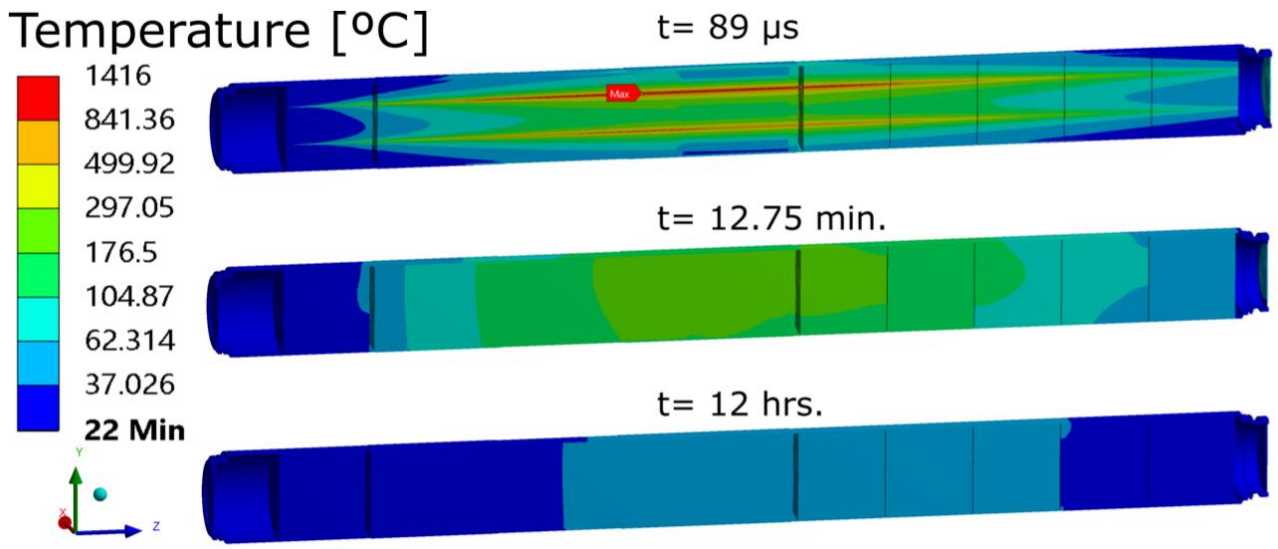
(a)

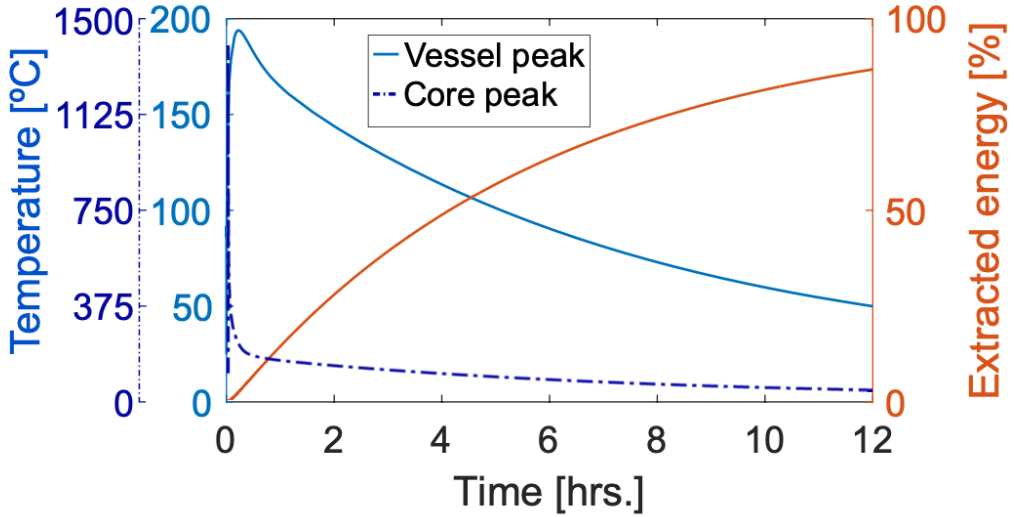


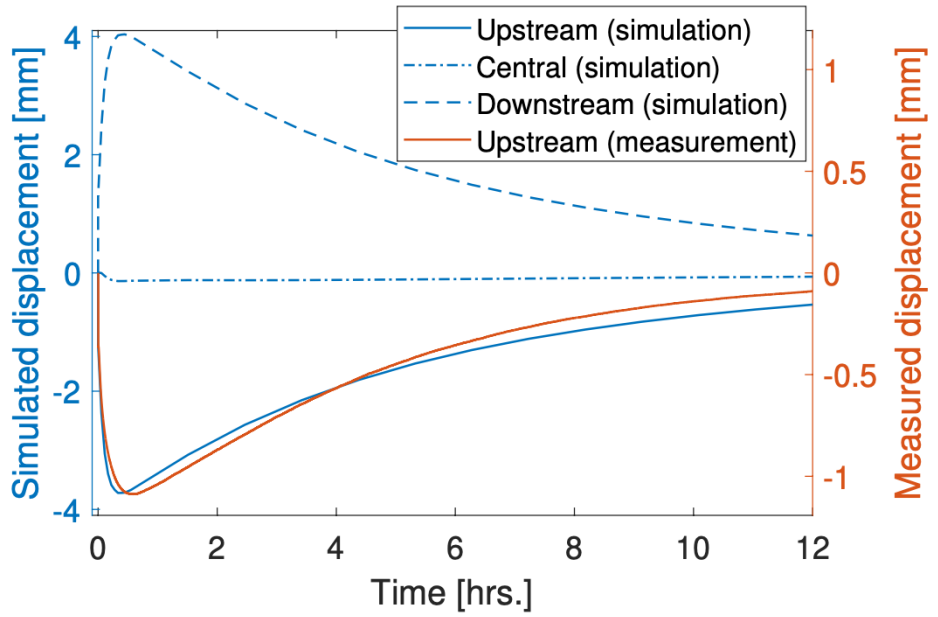


Simulation package appears to be in good agreement with data

Dump slow response







Simulation package appears to be in good agreement with data

Modifications for Run 3

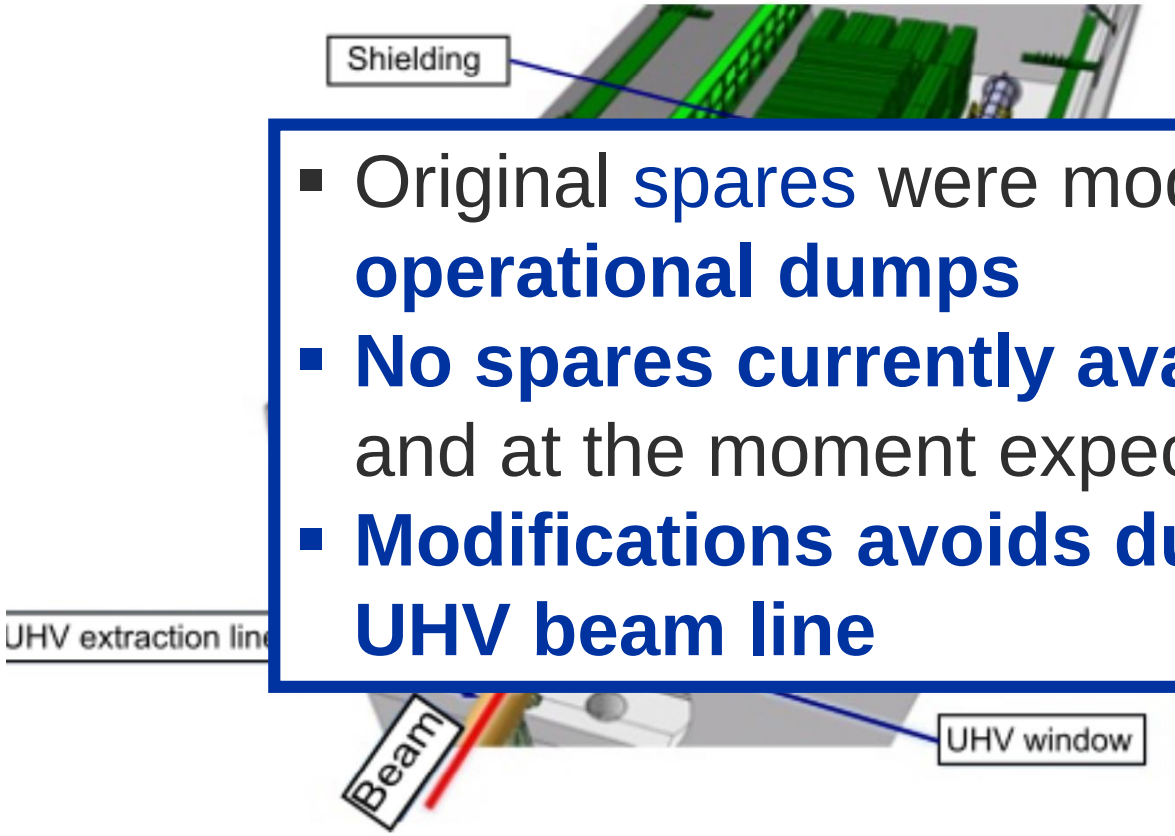
- During Long Shutdown 2, a large effort has been devoted to provide a Run 3 compatible beam dump system
  - NB: Cannot remove the physical origin of the vibration – must work on mitigating the effects of vibration

- Endorsement at January 2020 TDE review and ensuing LMCs (LMC 417, 402, 399, 394, 390)

  - LS2 upgrades focused on
    - **Vibration effects mitigation** (N_2 leaks)
    - **Dump Windows upgrade**

Short summary of LS2 modifications

Run1-2

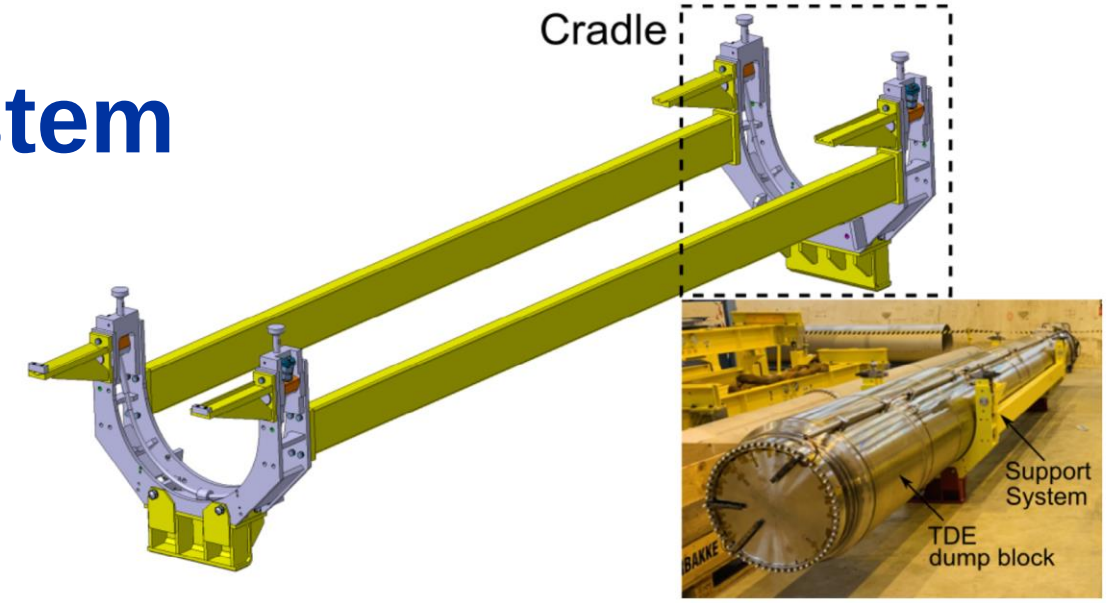


- Original spares were modified and employed as **new operational dumps**
- **No spares currently available** – under production and at the moment expected for mid 2023
- **Modifications avoids dump-induced leaks in the UHV beam line**

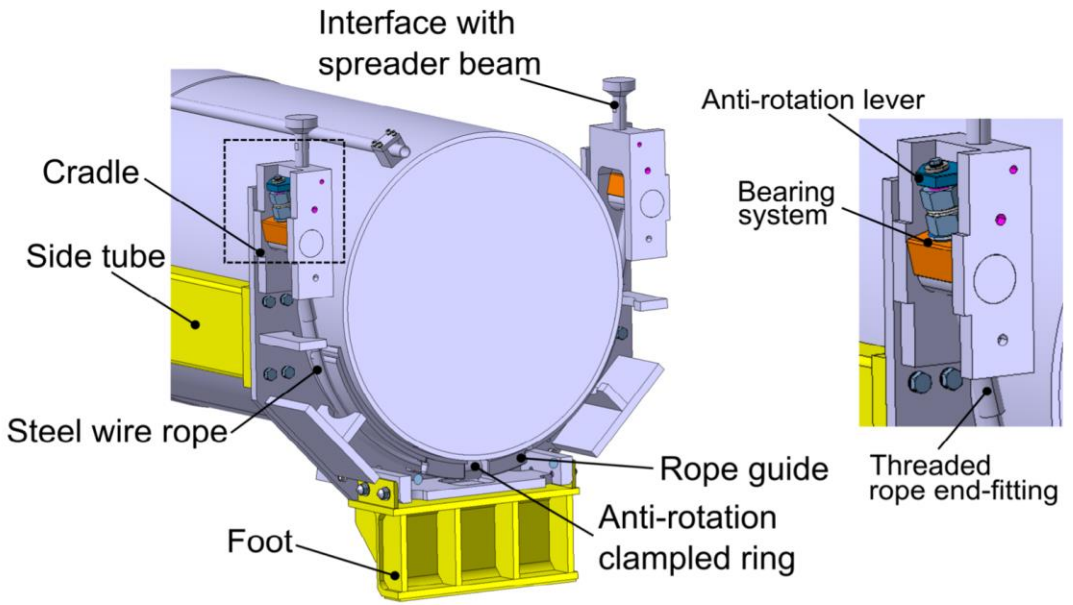
Dump configuration

Upgraded dump support system

- Based on **two steel wire rope loops** that suspend the dump block inside a frame
- Freedom to **accommodate vibrations**
- **Avoids any accumulative movement of the dump** over repeated expansion and retraction cycles



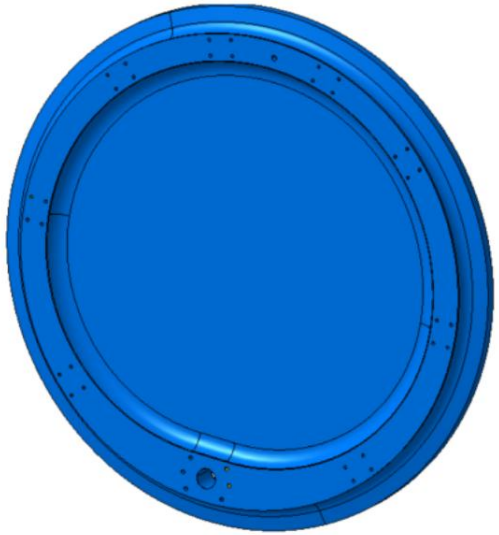
(a)

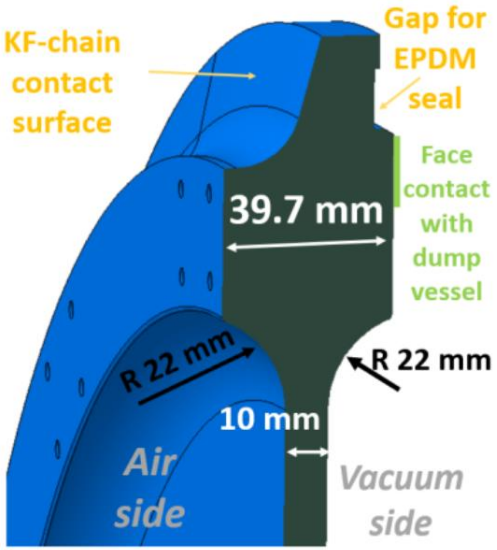


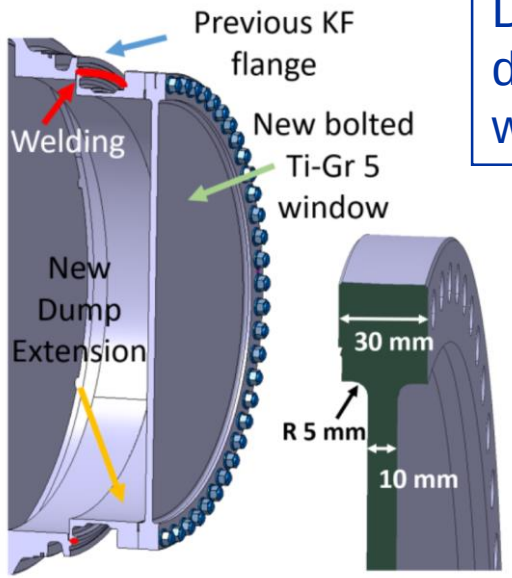
Dump windows

- Provide **robust enclosures** at the extremities of the stainless-steel dump block vessel (TiGr2 → TiGr5)
- **Contain the internal N_2 atmosphere** while withstanding the beam-induced thermo-mechanical and dynamic loads

Dump upstream window





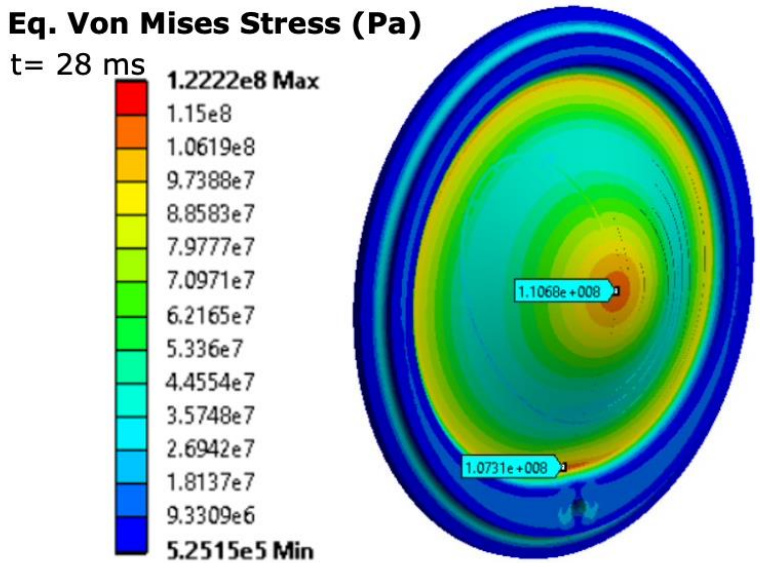


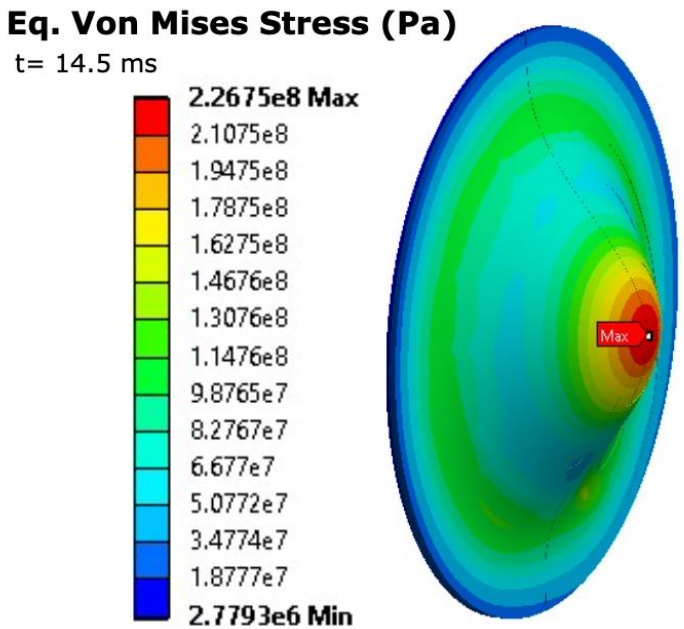
Dump downstream window

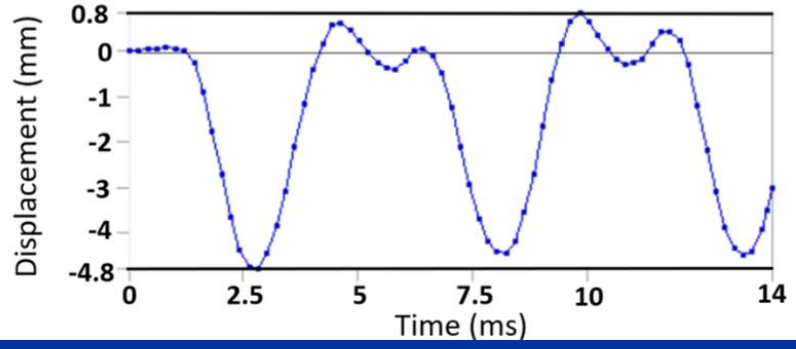
Dump windows

Beam e

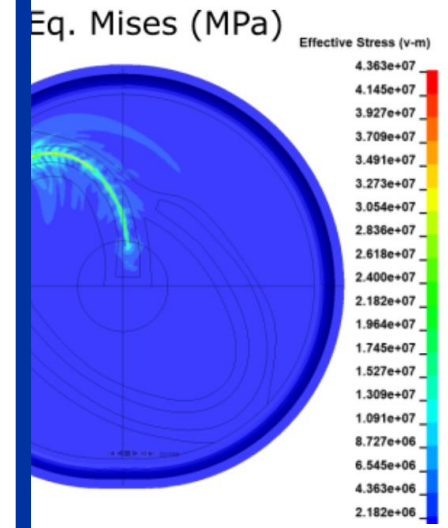
- Dump
  - T_{max}
  - Tails
    the b
    patte
- Dump
  - T_{max}
  - Due
    gene
    dump core

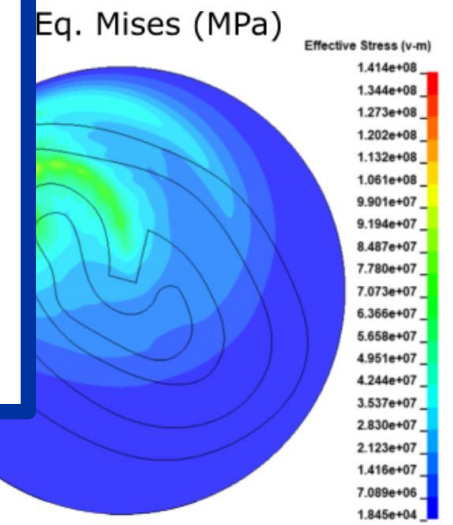






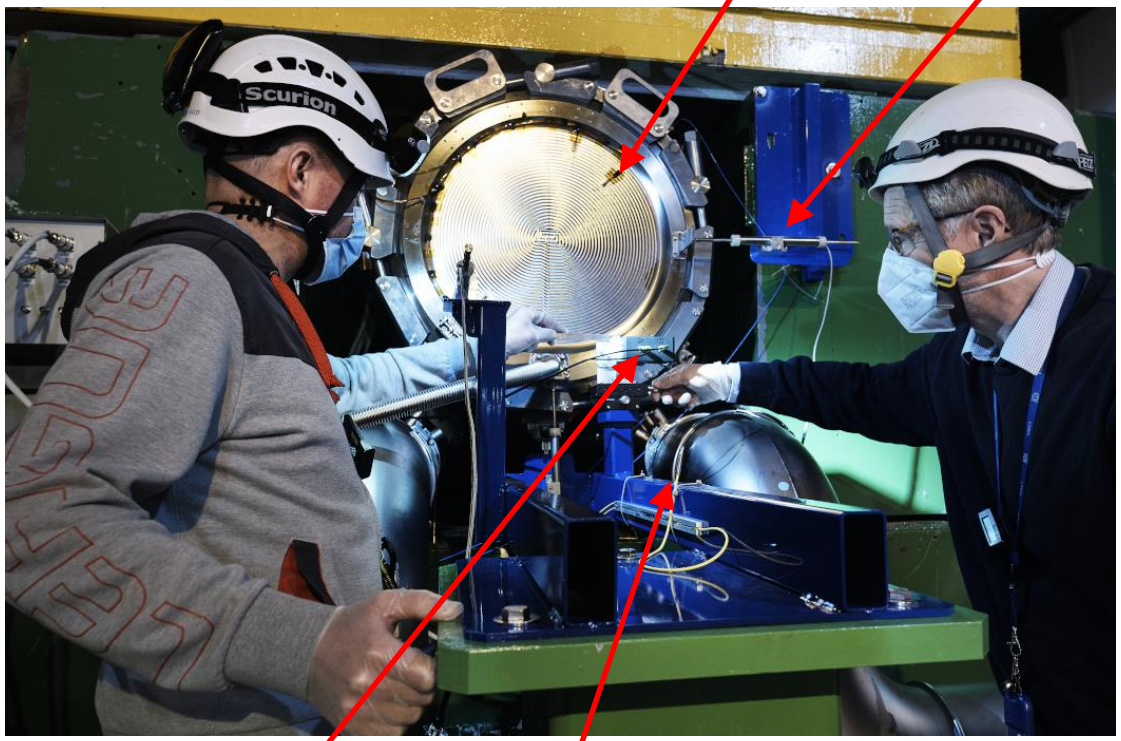
230 MPa induced by **vibration (!)** **>> beam loading**





Updates on instrumentation – what's installed

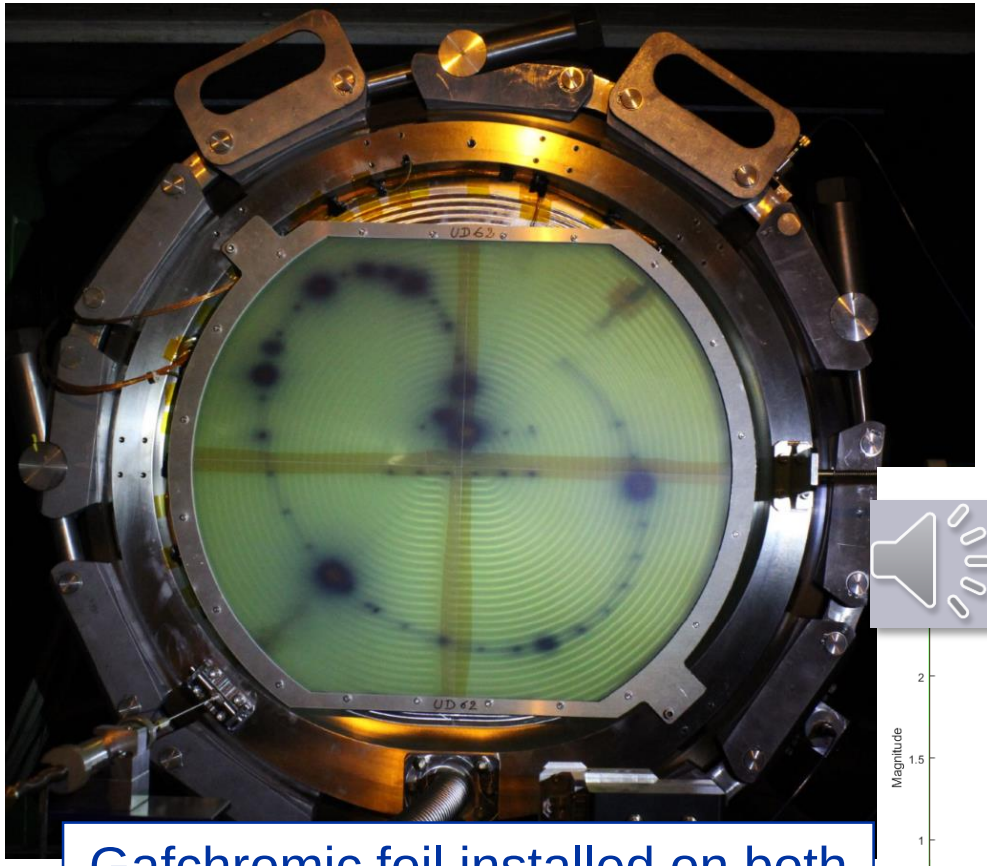
HD camera picture



Data acquisition rack

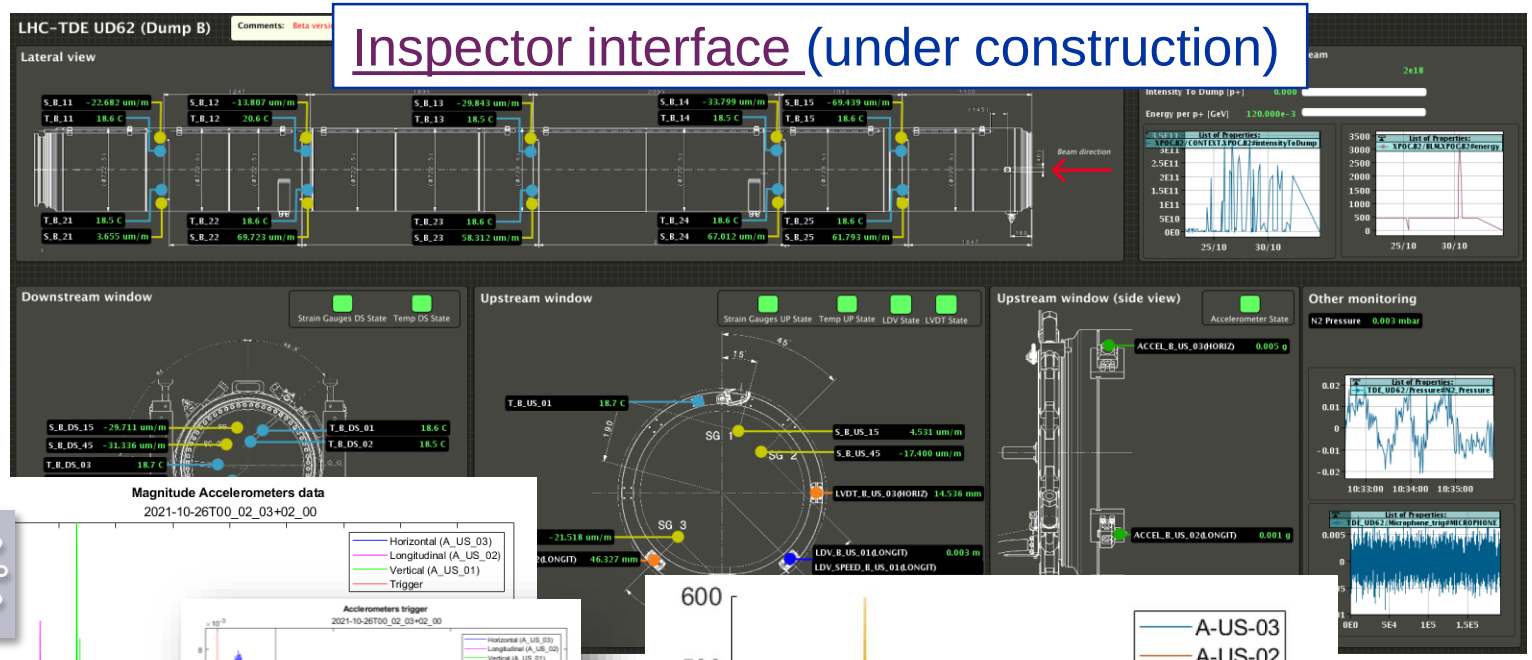
Thanks to BE/CEM and EN/MME

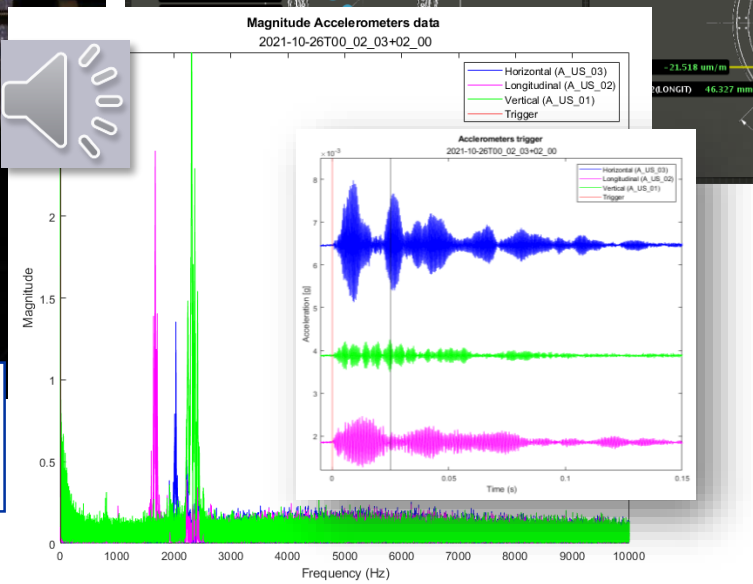
Some early results from 2021 test run

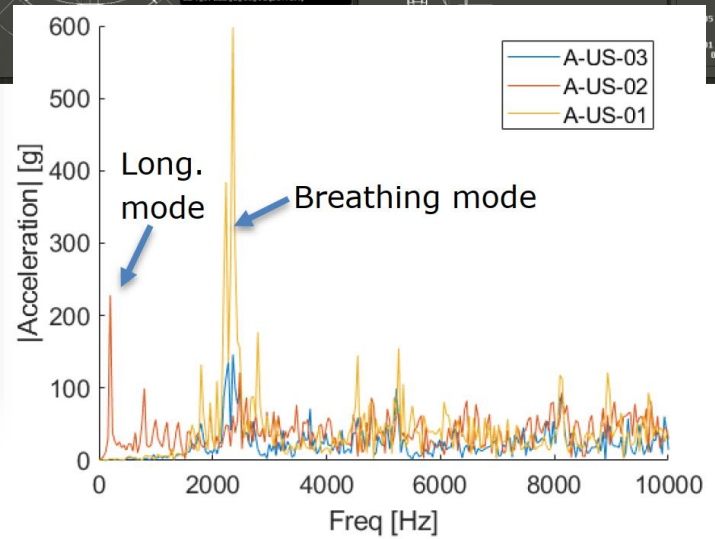


Gafchromic foil installed on both dumps

Inspector interface (under construction)





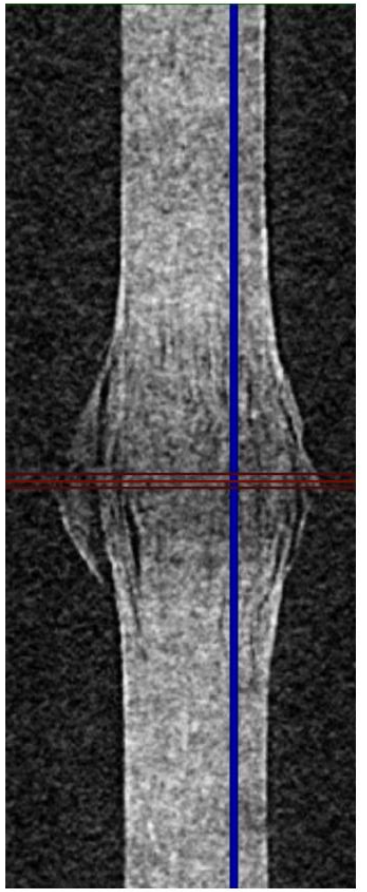


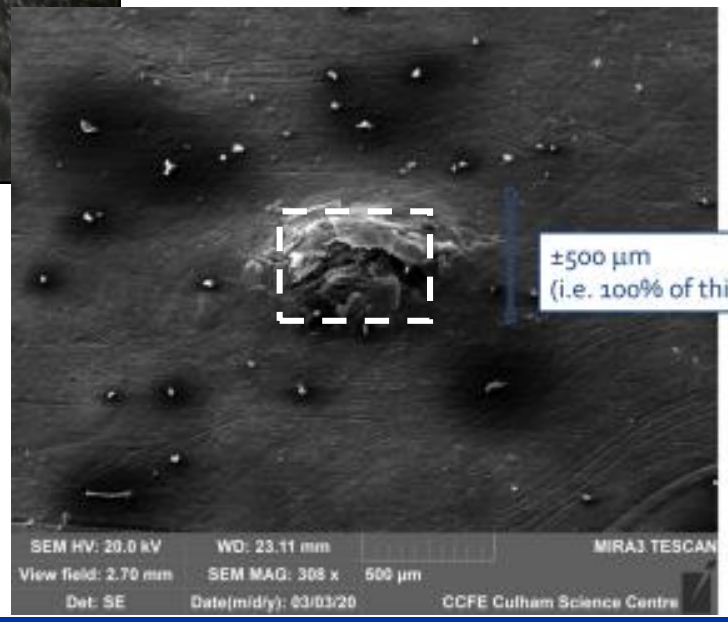
UD62 Dump on 26/10/2021 at 00:02:03, $3.4*10^{11}$ dumped intensity (few bunches)

Are there any open points in view of Run3?

Broken extruded graphite from UD68 dump (summer 2020)

Sigraflex® sample (March 2020)



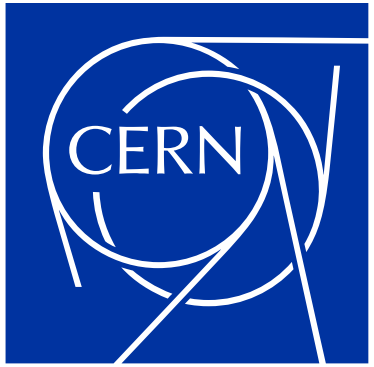


What are we doing to understand whether Run 3 operational conditions?

- Autopsy of the highly radioactive UD68 dump to assess core status (Run 2 parameters)
  - Technical Review November 2021 https://indico.cern.ch/event/1072664/
  - Execution in Jan/Feb 2022, results to follow in the weeks/months
- Execution of HRMT56 and subsequent PIE
  - Experiment completed and results to be available starting from January 2022
- Ongoing CERN-NTNU collaboration (Sigraflex®)

Conclusions

- Despite challenging timeline and scope, LS2 upgrades of LHC dumps have been **successfully implemented**
- **Vessel and windows ready to accept Run3** beam parameters
- Open questions related to **core behaviour** will be hopefully be clarified during 2022 in view of Run3 (as well as spares & HL-LHC dump)



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