

# LHC Collimation Quench Test MD

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Acknowledgments to the FLUKA team, ADT team, BLM team

rMPP meeting

2022-10-28



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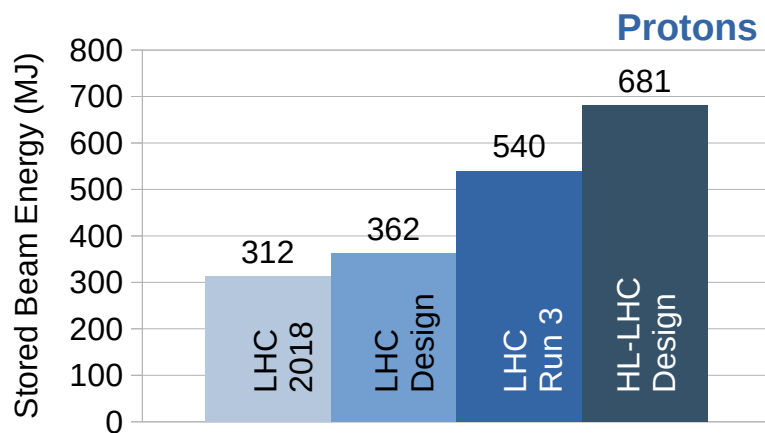
OP Preparation Status

Conclusions

# Introduction

- Tiny fraction of protons on collimators ultimately lost in IR7 DS magnets
- **Quench limit** of IR7 DS magnets **may limit HL-LHC intensity** reach
- Not well understood: previous tests could not reach quench
- **Key hardware upgrades** initially foreseen **might not be available**
  - 11T dipole availability for HL-LHC is uncertain
- **Need to understand quench limit** in operational conditions
- Proposal for **LHC collimation quench test** with protons (ID 7224)

# Collimation quench risk in HL-LHC



Machine	Duration (s)	Min. beam lifetime (s)	Stored beam energy (MJ)	Beam loss power (kW)
LHC	10	720	362	503
HL-LHC	10	720	681	946

↑ Specification Unchanged!

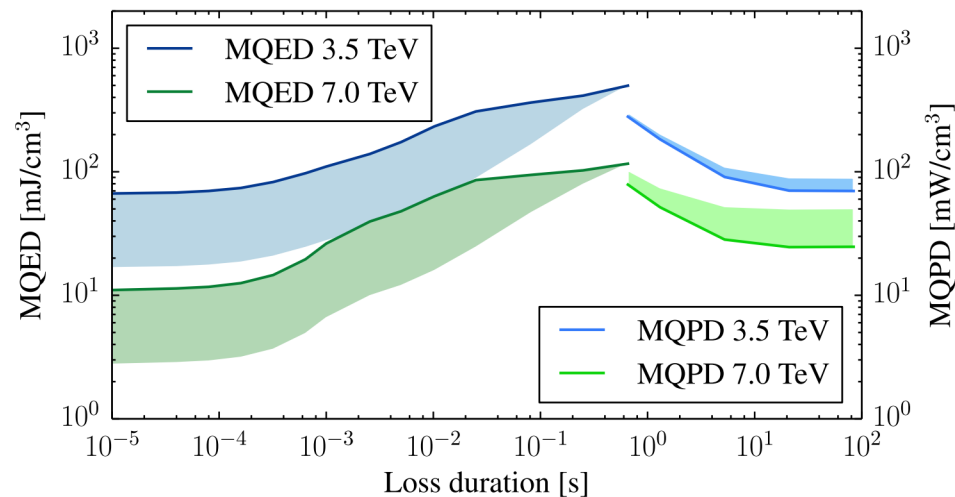
- **HL-LHC: collimation system must sustain ~1MW of power loss over 10s**
- **New DS collimators (TCLD) foreseen in LS2 but deferred** after reliable operation at 7TeV could not be demonstrated in cold testing of 11T dipoles
- Are we risking to quench the DS magnets in HL-LHC if we can't install TCLDs?

# Collimation quench risk in HL-LHC

B. Auchmann et al. PRSTAB 18. 061002

## Quench limit

- Is not straightforward to measure or estimate
- Latest estimate (2019): for 7 TeV with losses of  $\sim 1$ s duration: **20-30 mW/cm<sup>3</sup>**



Year	Machine	Simulated coil power deposition (mW/cm <sup>3</sup> )
2019	HL-LHC	21
2021	HL-LHC	15

2021 simulation with new collimator materials


## Expected DS MB peak power deposition

- Complex simulation chain: particle tracking in SixTrack used as input for detailed power deposition studies in FLUKA

**With uncertainties: very tight margin for HL-LHC upgrade! Quench test needed!**

# Previous quench tests

Year	Species	Energy (TeV)	Test type	Max. power load at TCP (kW)	DS power density* (mW/cm <sup>3</sup> )	Quench achieved?
<a href="#">2011</a>	Protons	3.5	Collimation	510	-	No
<a href="#">2013</a>	Protons	4.0	Collimation	1050	-	No
<a href="#">2015</a>	Protons	6.5	Collimation	585	23	No
<a href="#">2015</a>	Pb ions	6.37Z	Collimation	13.7	25-30	Yes
<a href="#">2015</a>	Pb ions	6.37Z	BFPP	-	20	Yes

 [Click for references](#)

\*) simulated with FLUKA

- No quench achieved so far in proton collimation quench test
- With higher magnet currents at 6.8 TeV better chances of quenching

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# Requirements

**Goal:** Induce high losses at collimation system to quench DS MB magnet

## Loss duration and level

- Target level **1MW for 10s** : ramp losses from 0 to 1MW in ~5s
- Corresponds to HL-LHC specification at 7 TeV, but quench test at 6.8 TeV (quench limit slightly higher)

## Optics & Beam

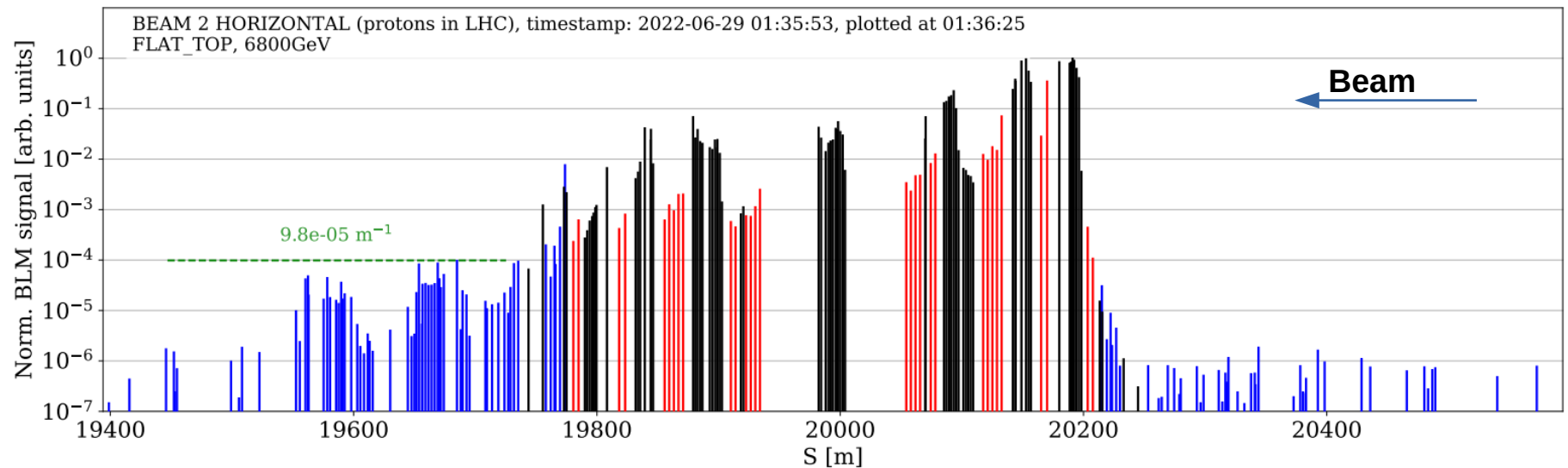
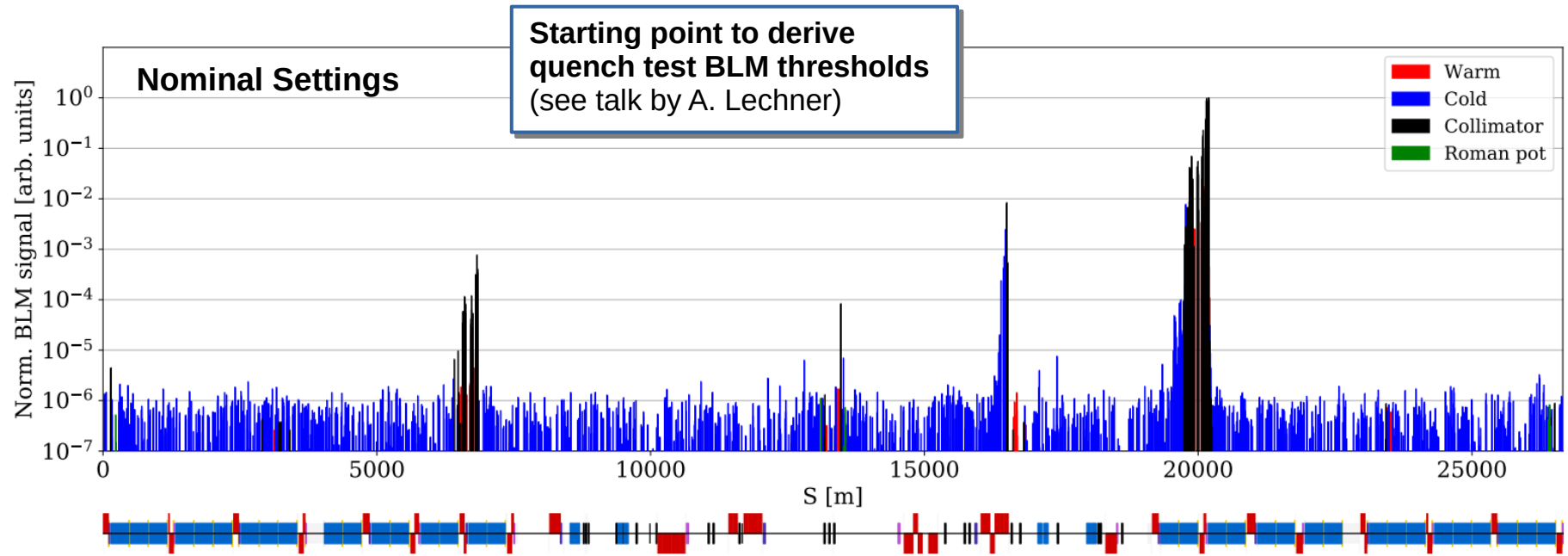
- Top energy (6.8TeV) at flat top (1.33m)
- Beam 2 horizontal plane: also used in past experiments
- Number of bunches: 144 or 192

## Collimator settings

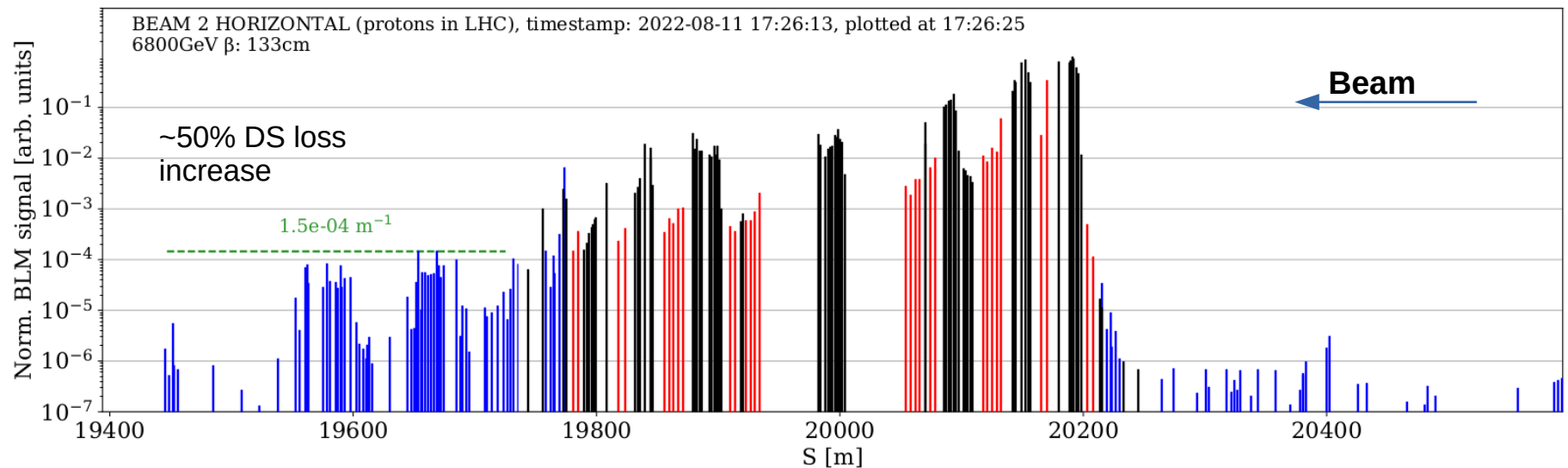
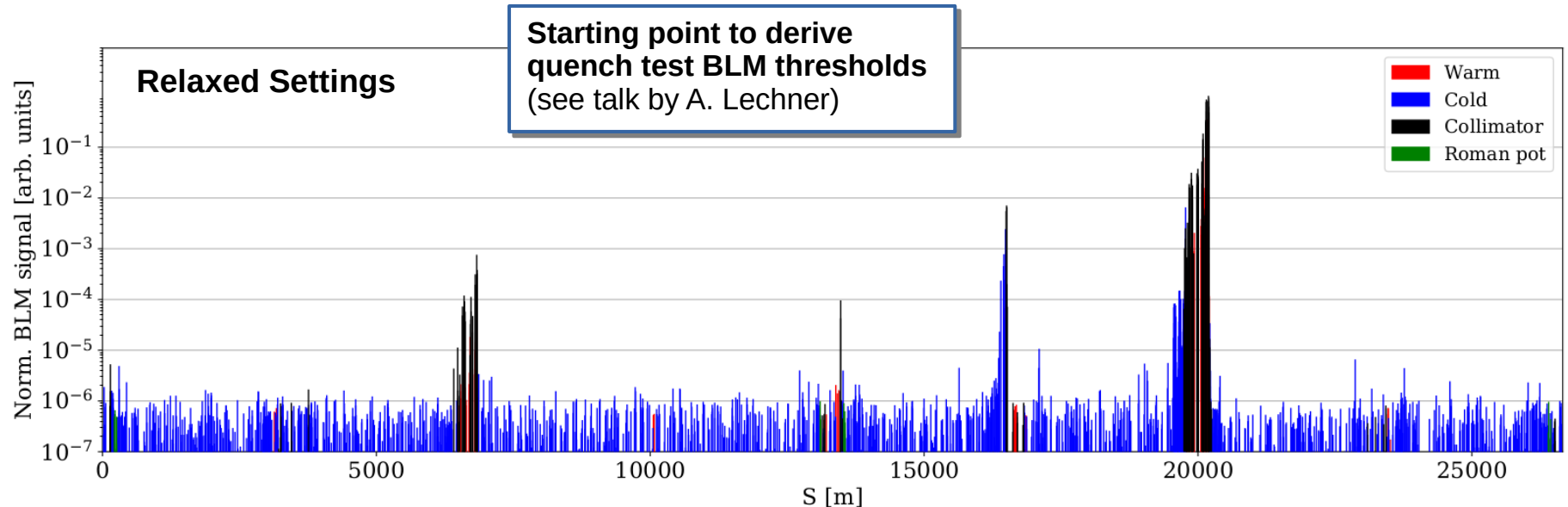
- Start conservatively with nominal settings (IR7 **5 $\sigma$ /6.5 $\sigma$ /10 $\sigma$** )
- If no quench achieved: relaxed settings (IR7 at **5 $\sigma$ /8.5 $\sigma$ /10 $\sigma$** ) to increase DS losses per kW of TCP power loss



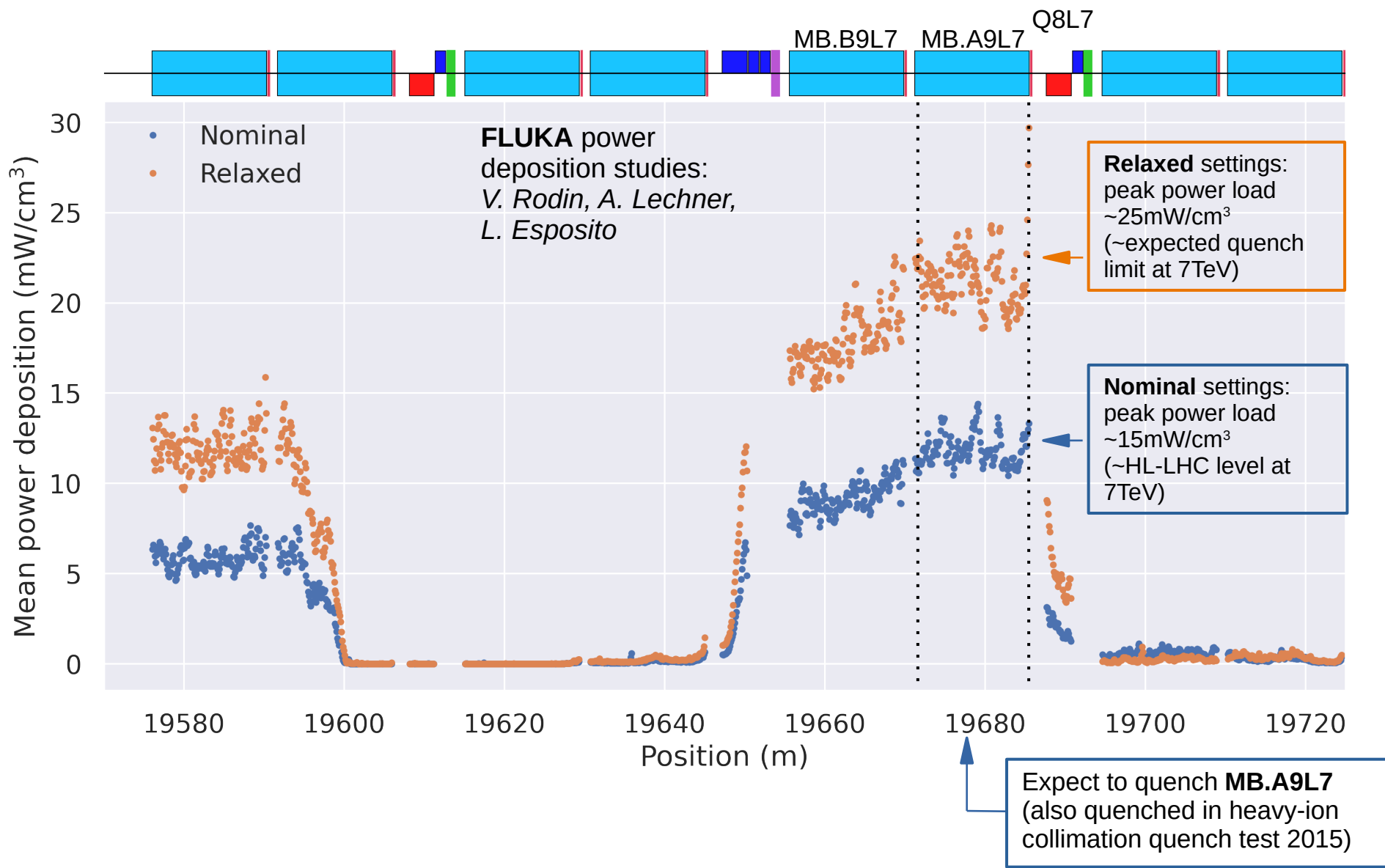
# Qualification loss map B2H



# Qualification loss map B2H

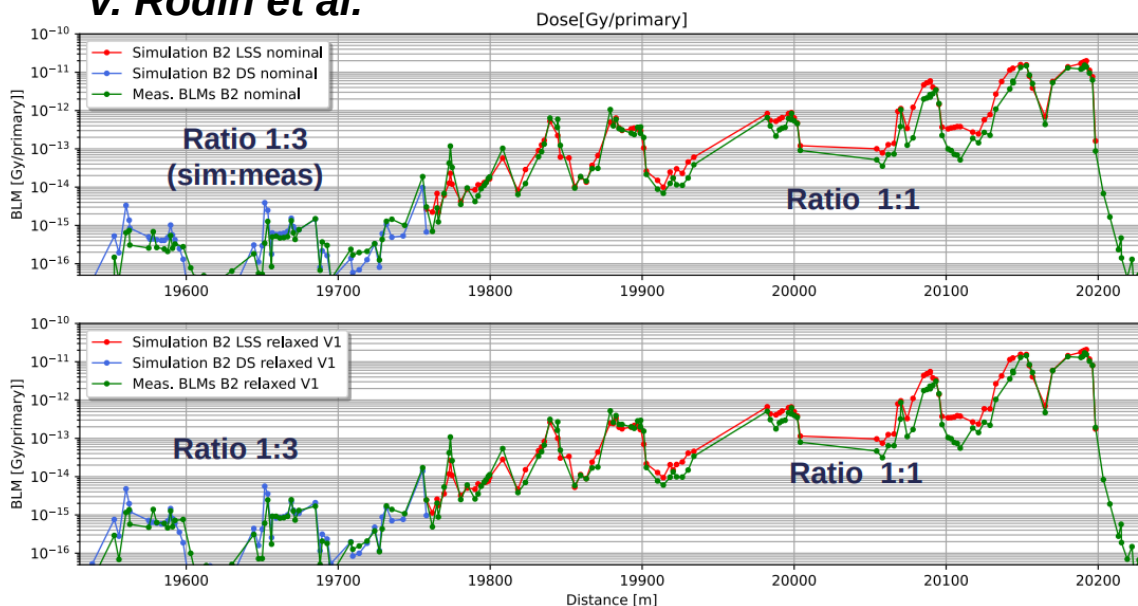


# Expected peak power load



# FLUKA Simulations

V. Rodin et al.



- Both nominal and relaxed settings well understood in simulations and measurements
- Excellent agreement between SixTrack/FLUKA simulations and measured qualification loss maps

- Collimator power deposition not critical (nominal settings studied as worst case)
- TCSPM coating exposure less than HL-LHC design scenario

V. Rodin et al.

Simulation study	TCPPM.C6, J1/J2 (full), kW	TCP.B6 J1/J2 (full), kW	TCSG.A6 J1/J2 (full), kW	TCSPM J1/J2 (full), kW	TCSPM Mo coating PPDD, W/cm <sup>3</sup>
A. Waets 2020, B1, (HL-LHC baseline)	4.25/4.13 (23.5) MoGr	10.12/10.08 (42.5) CFC	5.8/5.27 (28.1) CFC	5.03/3.75 (19) MoGr B5	175 B5
V. Rodin 2022, B2, (LHC today, depicted)	4.5/4.07 (23.6) MoGr	10.33/10.03 (42.52) CFC	5.53/5.09 (26.65) CFC	1.95/1.92 (8.03) MoGr D4	72 D4

More details in LHC Collimation Working Group #269

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# MD Time Plan

- **Preparation:** BLM thresholds adjustment, activate 100Hz BLM and FBCT logging
- **First Ramp: ADT setup, calibration and testing**
  - 4 - 6 INDIV + 4 × 48 bunches\*
  - First quench attempt with nominal collimator settings  
→ allows check + fine-tuning BLM thresholds + ADT profile
- **Second Ramp: Quench attempt(s) with nominal collimator settings**
  - 4 - 6 INDIV + 2 × (4 × 48) bunches\*
  - FLUKA simulations: expect ~15mW/cm<sup>3</sup> (~ expected HL-LHC level at 7TeV)
- **Third Ramp: Quench attempt(s) with relaxed collimator settings**
  - 4 - 6 INDIV + 2 × (4 × 48) bunches\*
  - FLUKA simulations: expect ~25mW/cm<sup>3</sup> (~ expected quench limit at 7TeV)

\*) 4x48 bunches if < 1.4e11 p/b

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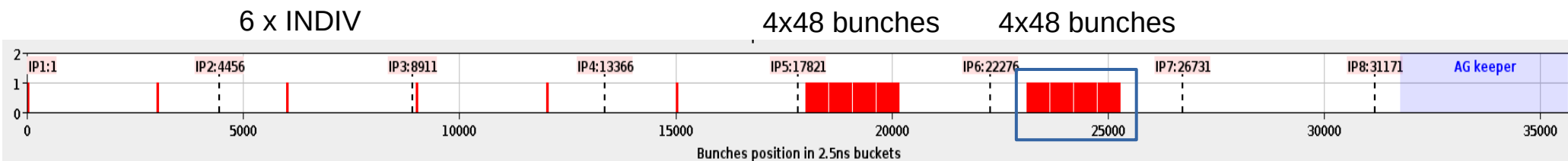
Time Plan

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# Filling pattern

- Require 1MW: blow up several bunch trains simultaneously
- Proposal: **4x48 bunches\* per quench attempt** + some nominal bunches to test ADT with increased window before excitation of bunch trains
- Stored energy in 4x48 bunches with  $1.2 \times 10^{11}$  intensity:  $\sim 22$  MJ
- Filling pattern *Quench\_test\_2022* prepared by D. Mirarchi :



Optional (if no concerns from MP side) inject twice the bunch trains needed for one quench attempt

\*) 3x48 bunches for  $1.4 \times 10^{11}$  p/b or 4x48 bunches for  $1.2 \times 10^{11}$  p/b



# Collimator sequence ready

LSA Applications Suite (v 15.16.52)

File Applications Search Help

Settings Management x Compare Settings x Settings Compare Result 1 x

Source

Beam Process	Parameter Group	Parameter Type	Parameter
EZE-6.8TeV-ATS-1.3m_V1@1275 [END] QuenchTest	BETA-STAR	COLL_BBCentre	TCSG.6L7.B2/NSIGMA
	CHROMATICITY	COLL_BBOptics	TCSG.A4L7.B2/NSIGMA
	CHROMATICITY_NLIN	COLL_BBParam	TCSG.A4R7.B2/NSIGMA
	CHROMATICITY_REF	COLL_HalfGap	TCSG.A5R7.B2/NSIGMA
	COLLIMATORS	COLL_HalfGap_TOL	TCSG.A6R7.B2/NSIGMA
	COUPLING	COLL_JAW	TCSG.B4R7.B2/NSIGMA
	CRYSTAL_COLLIMATORS	COLL_JAW_TOLERANCE	TCSG.B5L7.B2/NSIGMA
	IP_ANGLE	COLL_NSIGMA	TCSG.B5R7.B2/NSIGMA
	IP_CROSSING	COLL_NSIGMA_TOL	TCSG.D4R7.B2/NSIGMA
	IP_OFFSET	CollimatorLvdOffset	TCSG.D5L7.B2/NSIGMA
	IP_SEPARATION	LHCCollimator/BetastarActiveIP	TCSG.E5L7.B2/NSIGMA
	IP_SPECTROMETER	LHCCollimator/BetastarThreshold	TCSPM.6L7.B2/NSIGMA
	LANDAU DAMPING	LHCCollimator/EnergyThreshold	TCSPM.B4R7.B2/NSIGMA
	LHC LOSS-MAPS	LHCCollimator/InterlockThresholdFunc	

Setting Part:  Value  Target  Correction Time Base: Trim period 0 Trim History

Transpose table 2.0 Add delta Table/Function

PARAMETER	Value	Table/Function
TCSG.6L7.B2/NSIGMA	60.031695747093586	RAMP-SQUEEZE-6.8TeV-ATS-1.3m_V1@1275_[END]_QuenchTest
TCSG.A4L7.B2/NSIGMA	8.5	
TCSG.A4R7.B2/NSIGMA	8.5	
TCSG.A5R7.B2/NSIGMA	8.5	
TCSG.A6R7.B2/NSIGMA	8.5	
TCSG.B4R7.B2/NSIGMA	85.01940365455226	
TCSG.B5L7.B2/NSIGMA	8.5	
TCSG.B5R7.B2/NSIGMA	8.5	
TCSG.D4R7.B2/NSIGMA	8.5	
TCSG.D5L7.B2/NSIGMA	8.5	
TCSG.E5L7.B2/NSIGMA	77.8935791760756	
TCSPM.6L7.B2/NSIGMA	8.5	
TCSPM.B4R7.B2/NSIGMA	8.5	
TCSPM.D4R7.B2/NSIGMA		
TCSPM.E5L7.B2/NSIGMA	8.5	

Trims History

Time	Description
20-08-2022 04:28:53	Baseline for active settings copied from RAMP-SQUEEZE-6.8TeV
20-08-2022 04:32:04	

Filters: Description All

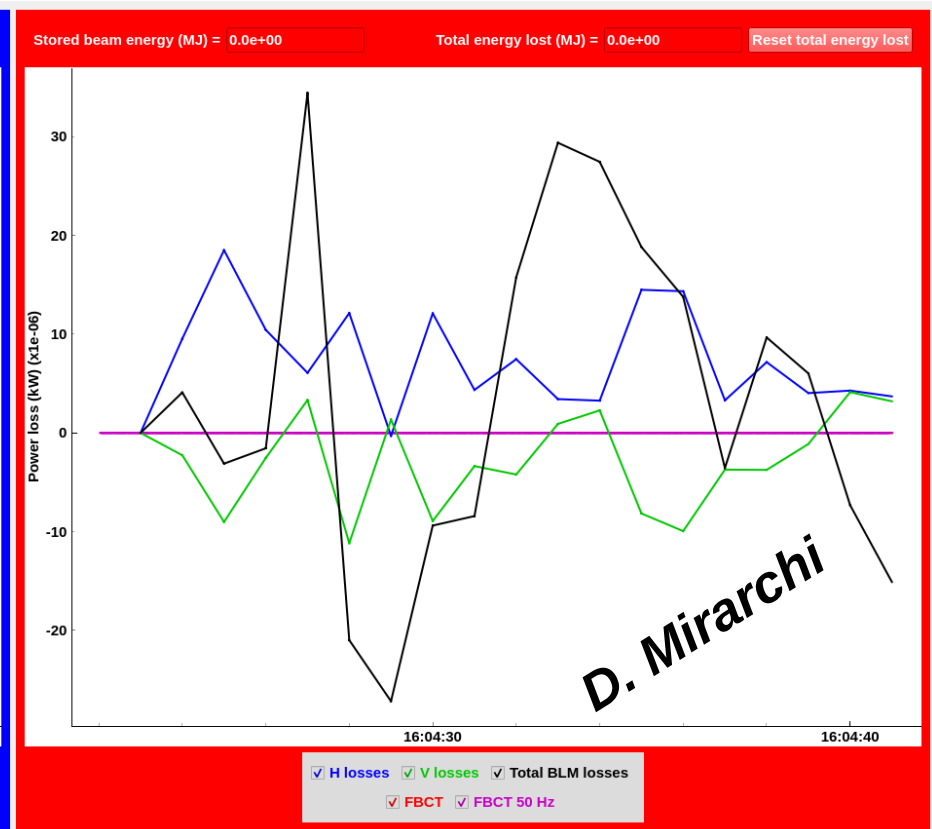
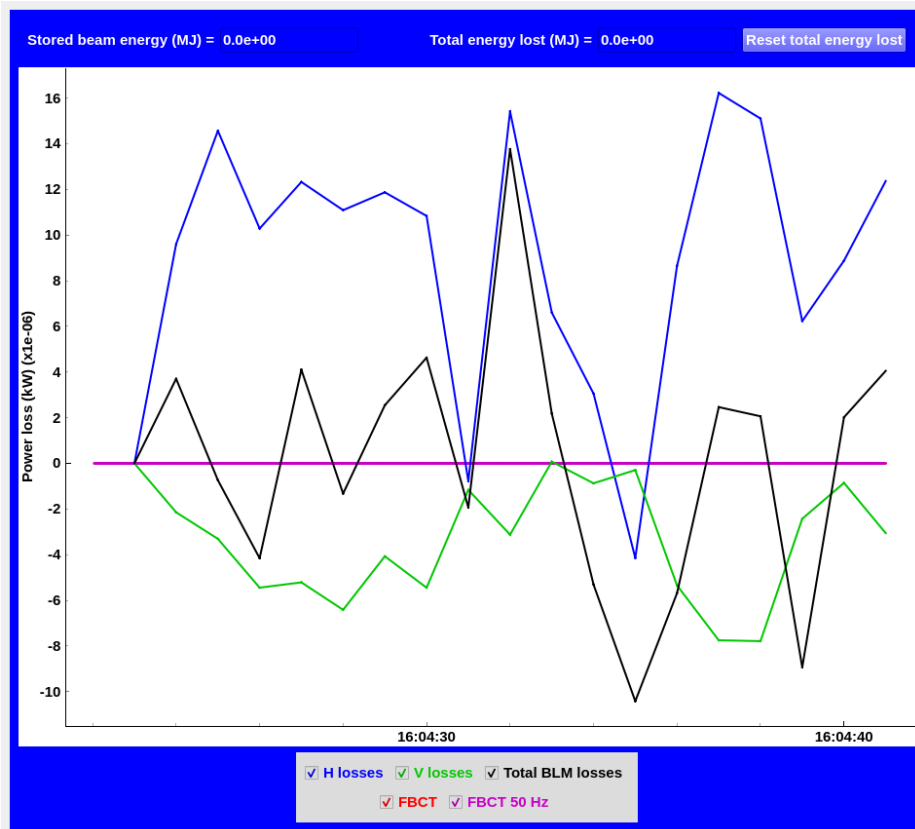
Info Comment Delete Load all tag parameters

Trim Cancel last trim Apply Trim

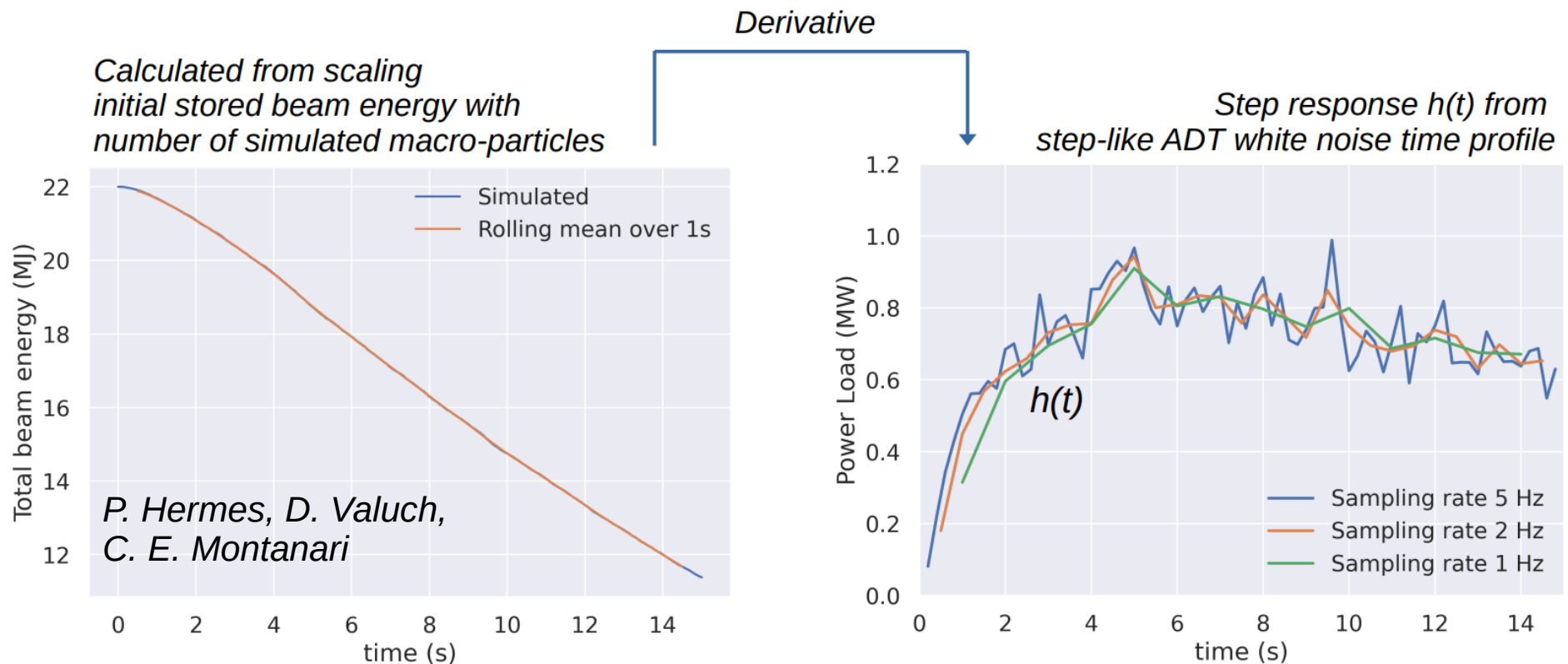
04:32:04 Trim operation successfully completed.

D. Mirarchi

# Power load monitoring



# Preparatory ADT profile simulations



New tracking simulation approach with ADT excitation – maybe can save time in quench test (Quench test not relying on it)

# Summary

Collimation quench test: crucial input for HL-LHC

## Preparation completed for

- ✓ Choice of settings
  - ✓ Energy deposition simulations: no showstoppers
  - ✓ OP filling scheme
  - ✓ OP functions for collimator movement (incl. Limits)
  - ✓ OP power load monitoring tool
- BLM Threshold preparation status report by A. Lechner
- IR6 QPS symmetric thresholds: no change needed (MP3 feedback)

# Round table

