



Status of the Accelerator Complex

Rende Steerenberg – BE/OP

LHC Experiments Resources Review Boards, 23 October 2023

Summarising 2023 in a few words...

For the LHC, 2023 was an eventful year with many challenges

We did not manage to reach all our integrated luminosity goals

For both Protons and Lead ions we have been exploring uncharted territory

Taking lessons learned to the benefit of future runs

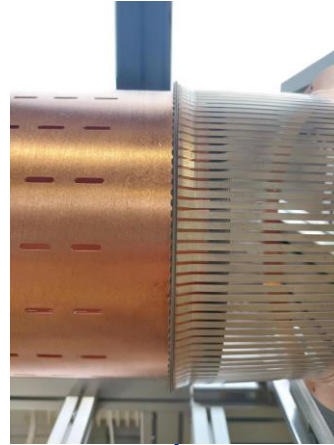
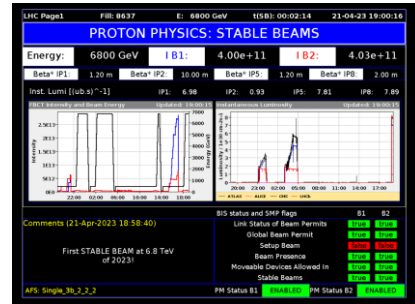
Overall excellent performance and availability from the Injectors chain

2023 LHC Machine Main Events Timeline



20.03.2023
Beam 1
Crystal collimator
mechanics
broke after
testing

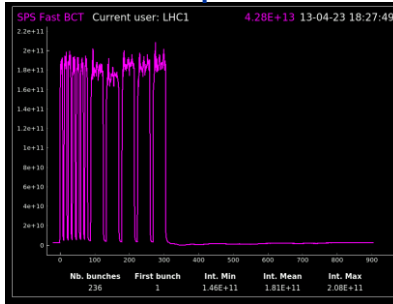
21.04.2023
1st stable beam of 2023



25.05.2023
RF finger module issue.
Vacuum spikes
caused by
beam induced
arcing/heating.
Partially
plasticised
spring.
Intensity limit
 1.6×10^{11} ppb



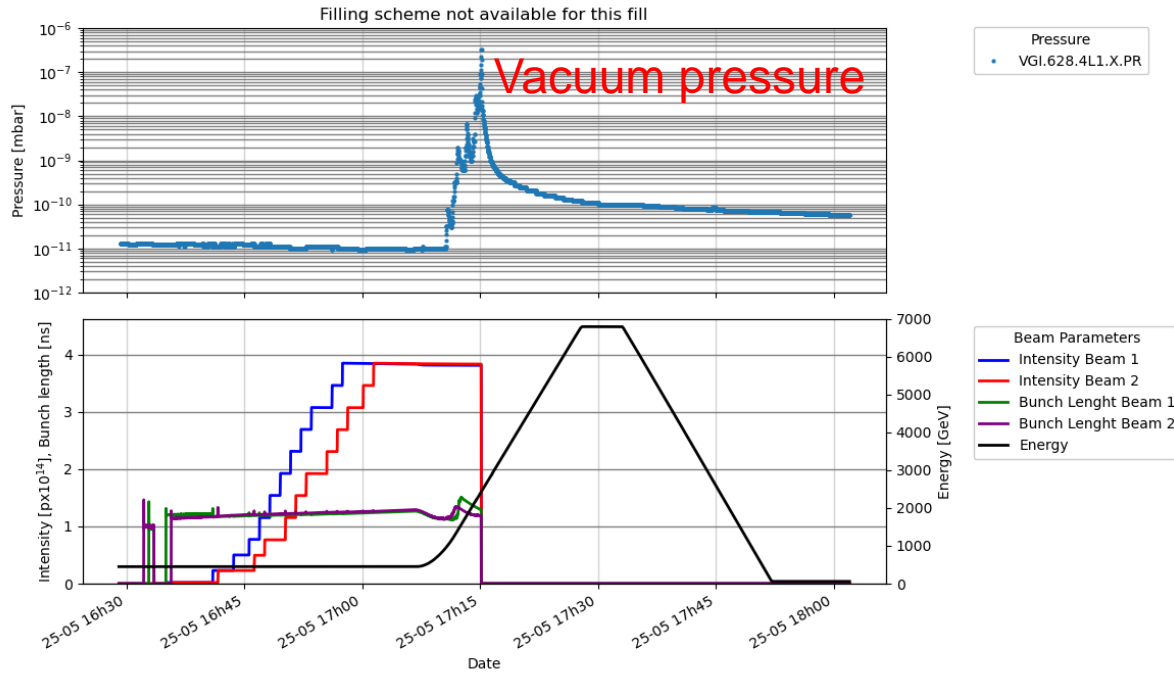
02.04.2023
RF Rupture discs B1 & B2 following trip of the LHC 18kV SVC point 4



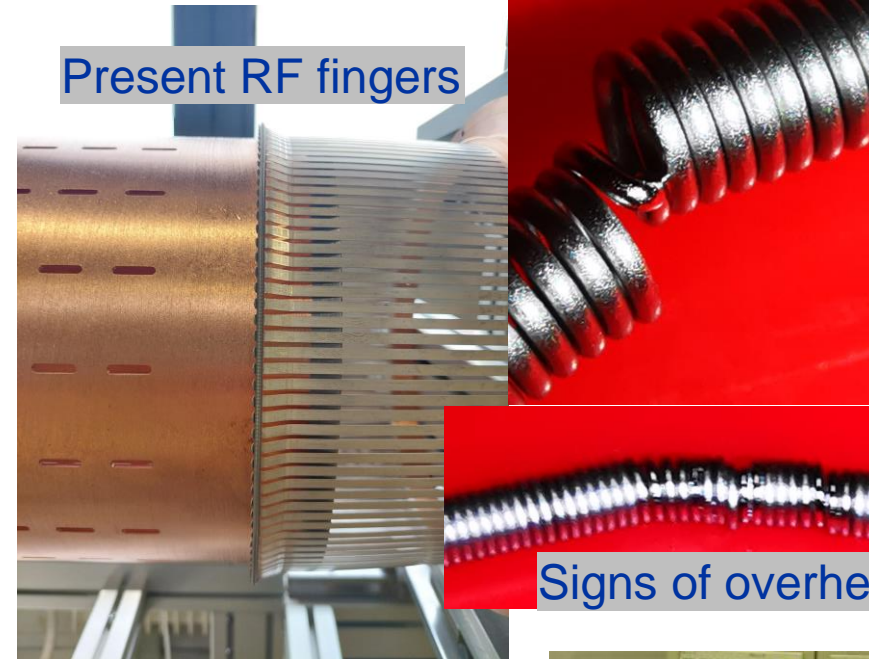
12.05.2023
1st collisions
2374 bunches
mixed scheme
1x8b4e + 3x36b
minimising heat load
maximising lumi

RF Finger Module

Fill 8828: 2023-05-25 16:29:00 - 2023-05-25 18:02:00



Present RF fingers

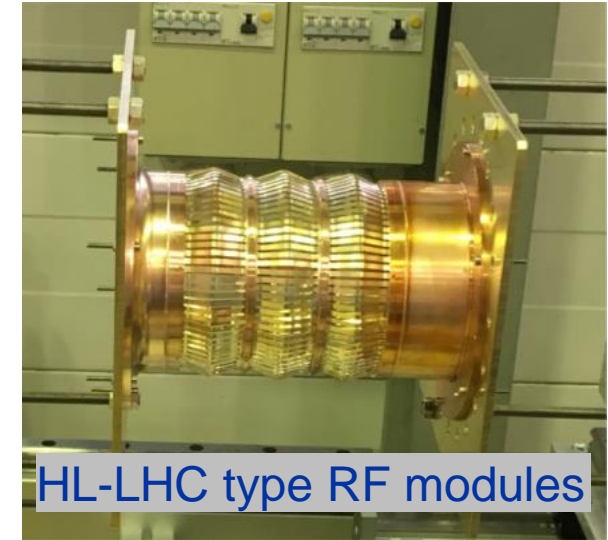


Signs of overheating



Vacuum pressure spikes during the ramp with beam dump due to losses

- Limiting bunch intensity to 1.6×10^{11} p/b
- Will partly be addressed during Year End Technical Stop 23-24



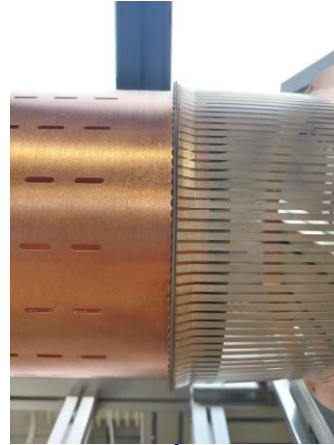
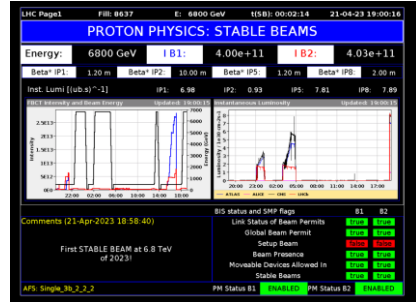
HL-LHC type RF modules

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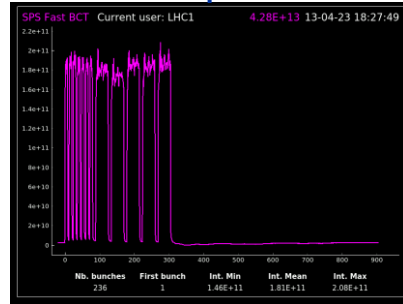
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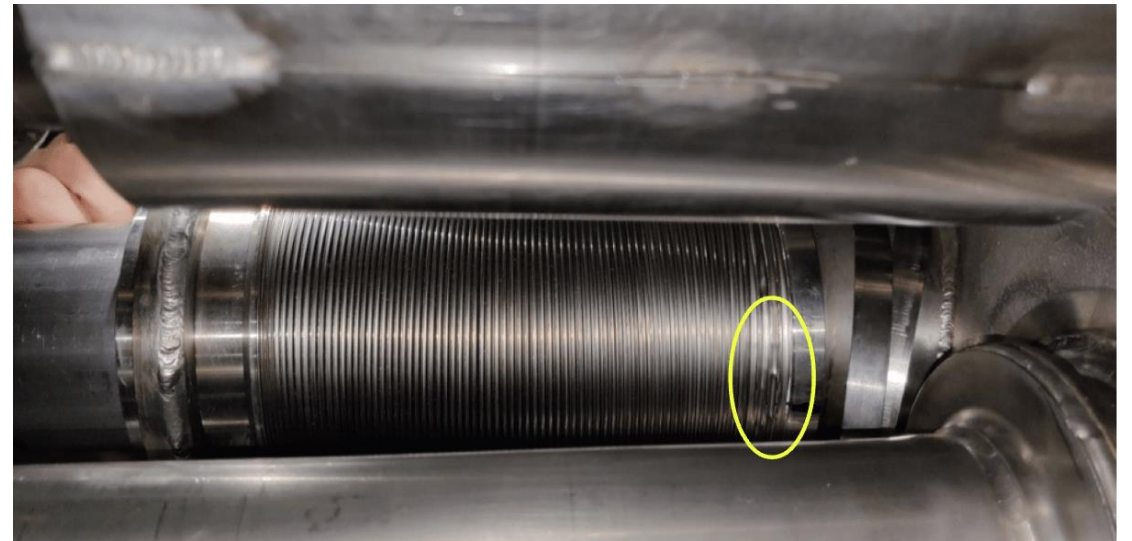


17.07.2023
Fallen tree in VD causing power glitch, magnet quench, and **leaking bellow between cold mass and insulation vacuum**

Inner triplet bellow leak



- A small hole (1 mm²) in an edge welded bellow with major consequences
- Thinking out of the box by expert teams allowed for a restart in 2023
- [Photo story](#) in CERN Bulletin

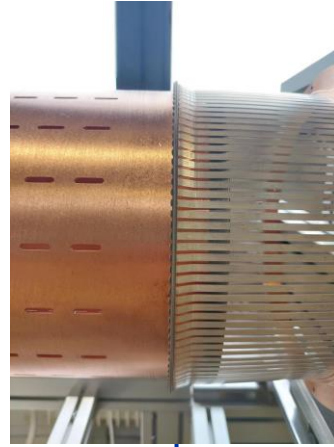
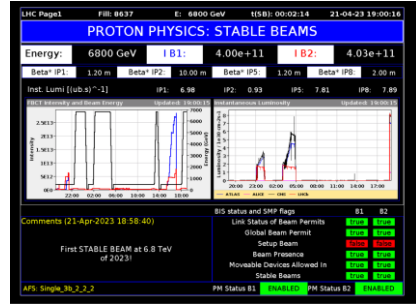


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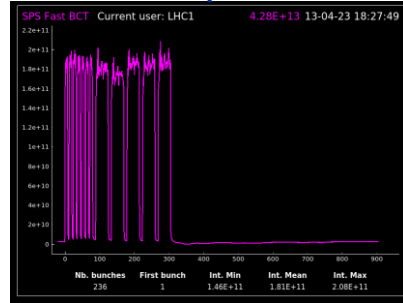
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31.08.2023 (B)
08.09.2023 (A)
2 x injection protection device (TDIS)
Point 8 vacuum leak.
Preventing p+ operation, but Pb ion possible



02.04.2023
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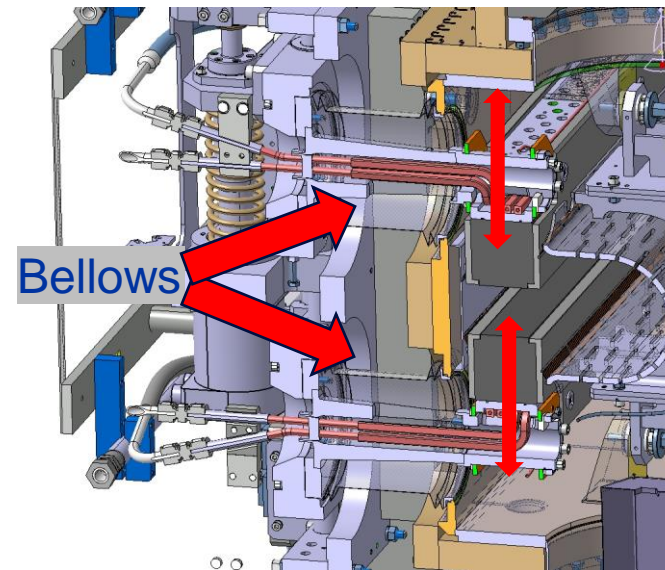
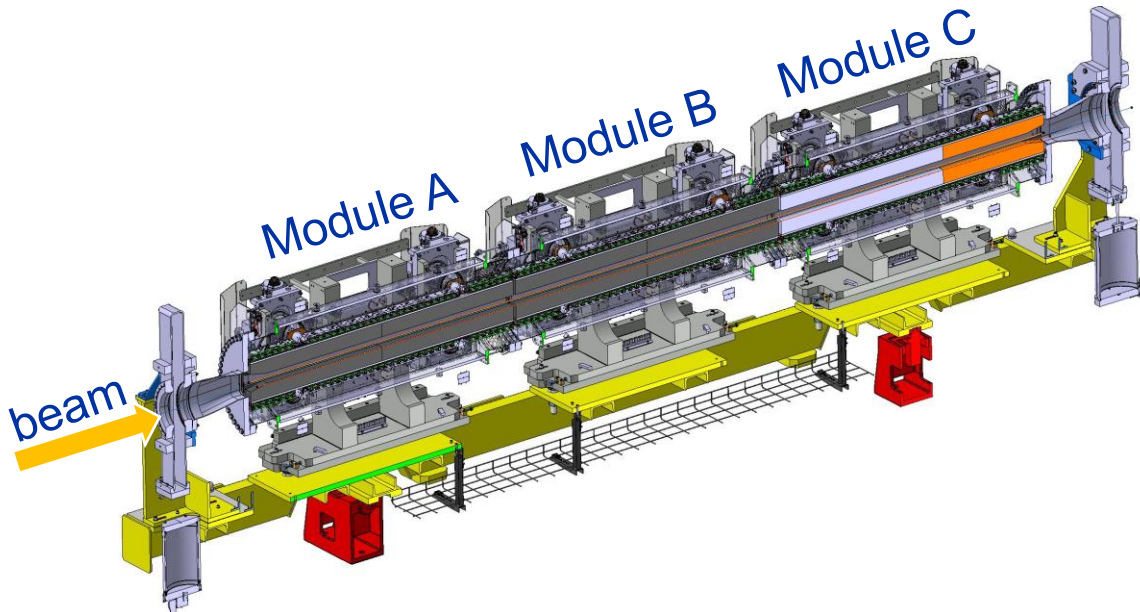
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TDIS (Target Dump Injection Segment)

- Machine protection devices used during injection process – moving in and out
- Located in front of IP2 (ALICE) for beam 1 and IP8 (LHCb) for beam 2
- Each TDIS contains 3 modules with 12 edge welded bellows per TDIS
- Two leaking bellows started on separate modules of the same TDIS (IP8) within 1 week
 - Both varnished and blocked out - limiting severely proton beam intensity, but allowing Pb ion operation



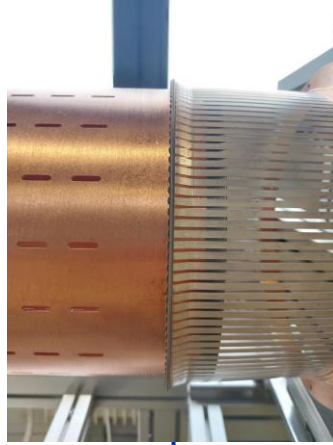
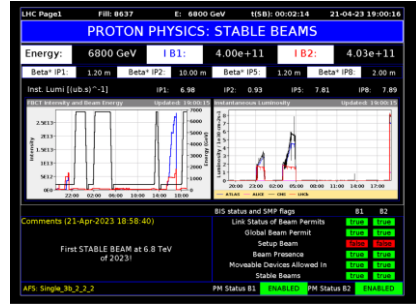
**Both TDIS
will be replaced
by spares
during
YETS 23-24**

2023 LHC Machine Main Events Timeline

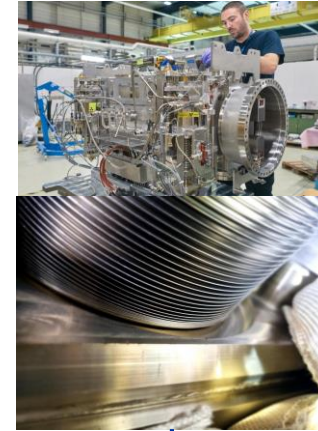


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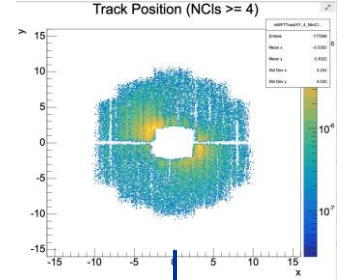


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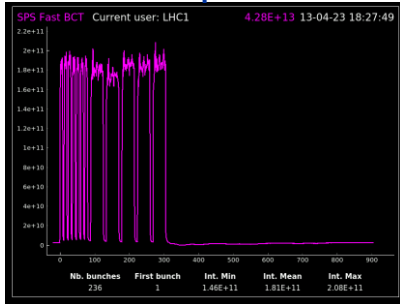


31.08.2023 (B)
08.09.2023 (A)
2 x injection protection device (TDIS) Point 8 vacuum leak.
Preventing p+ operation, but Pb ion possible

End Sep – Early Oct
ALICE background issue followed by studies and solution



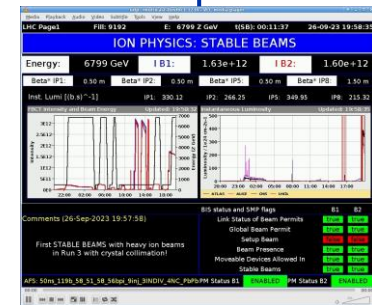
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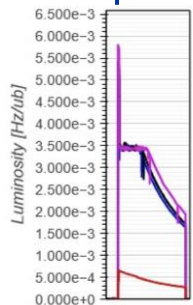
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26.09.2023: 1st stable Pb ion beam of 2023



October
Beam loss induced SEU causing trips, quenches, etc.
Studies, Lumi levelling

2023 LHC Schedule Q3

	Aug							Sep			Oct		
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	3	10	17	24	31	7	14	21	28	VdM 2 4	11	18	25
Tu												TS2	p-p ref run
We			High β run										
Th							MD 2			Jeune G.		p-p ref setup	ion setting up
Fr											MD 3		
Sa												p-p ref run	
Su													

End 25 ns run [08:00]

RRB April

	Aug							Sep			Oct		
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	3	10	17	24	31	7	14	21	28	collisions injection 4	High β run 1	High β run 18	25
Tu										High β run		p-p ref cryo reconfig	LHC Pb- Pb ion run
We										VdM 2			
Th										Jeune G.			
Fr													
Sa										High β setup p-p ref setup	High β run	High β run	
Su												ion setting up	VIP

As executed

Unscheduled stop Cold mass - insulation vacuum leak repair

- Proton run was cut short
- Machine Development sessions were cancelled
- The re-start in end of August was efficient
- All activities squeezed in September period – very challenging
- p-p reference run to be scheduled in 2024
- Pb ion period extended, but with a challenging start

2023 LHC Schedule Q4

End of run [06:00]

Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	2	9	16	23	30	6	13	20	27	4	11	18	Xmas 25
Tu			MD 4										
We													
Th			LHC Pb- Pb Ion run					YETS					Annual Closure
Fr													
Sa													
Su													

End of run [06:00]

Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	2	9	16	23	30	6	13	20	27	4	11	18	Xmas 25
Tu					MD2b								
We			MD2a										
Th								YETS					Annual Closure
Fr			LHC Pb- Pb Ion run										
Sa	VIP												
Su													

Only little changes

2023 physic run will end on Monday morning 30 October at 06:00

LHC Beam time accounting

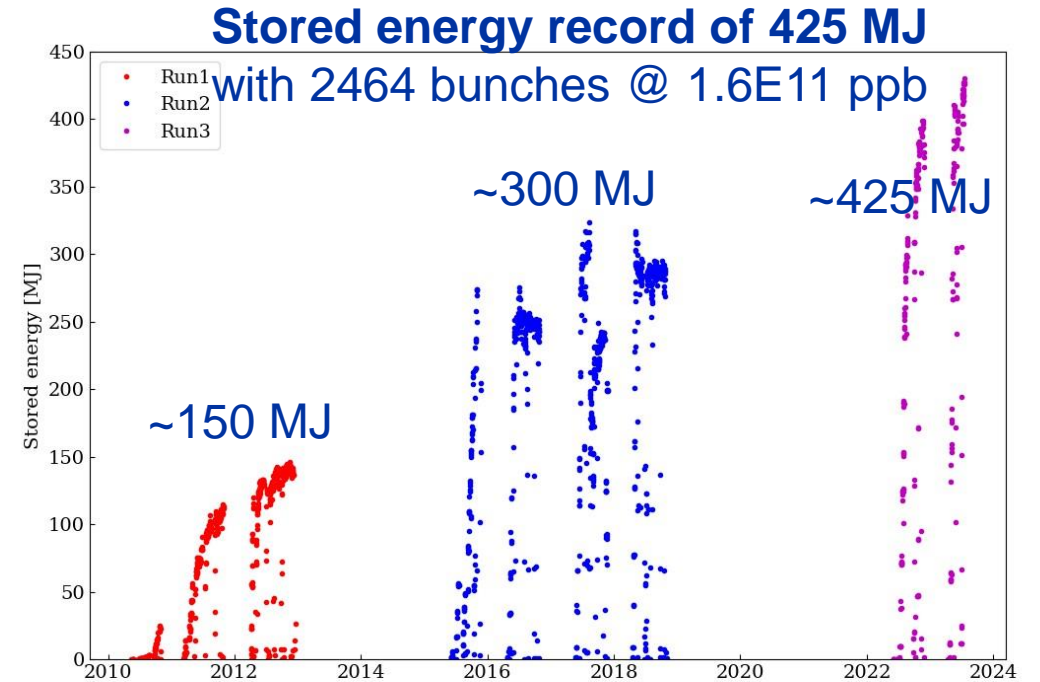
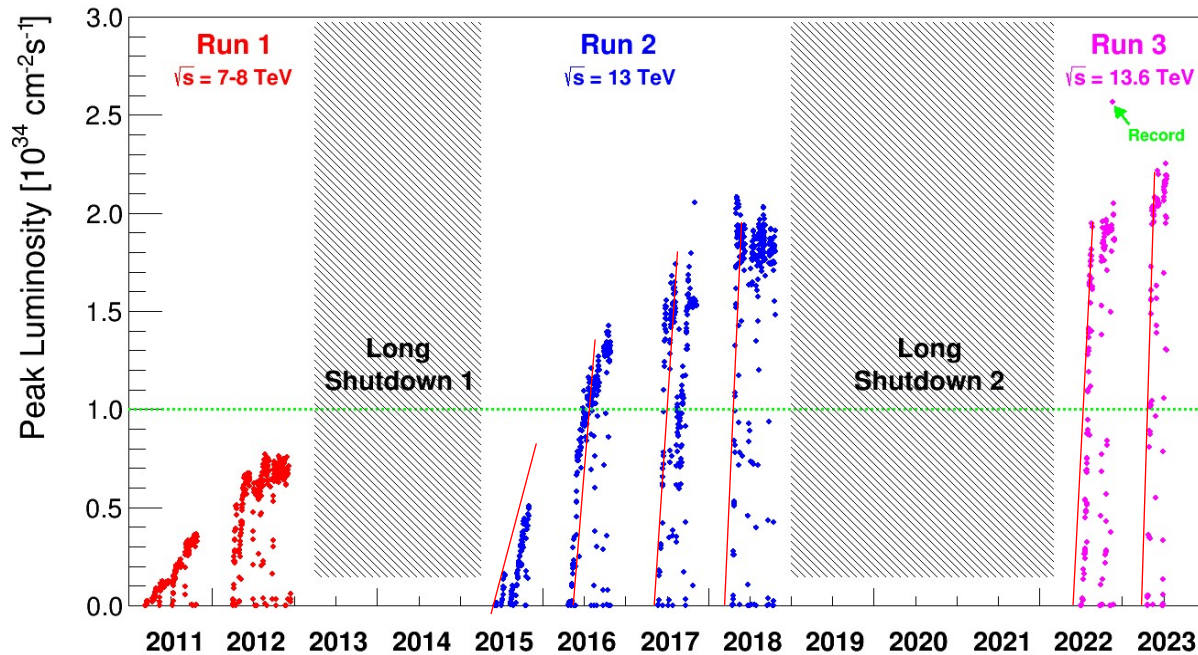
Activity	Version 1.2. (April)		Version 1.5. (October)	
	Duration [days]	Ratio [%]	Duration [days]	Ratio [%]
Beam Commissioning & Intensity ramp-up	46	21.2	46	21.2
Scrubbing	2	0.9	2	0.9
25 ns physics (>1200 bunches)	96	44.2	47.5	21.9
Special physics runs (incl. setting-up)	7	3.2	12.5	5.8
Pb-Pb ions & p-p ref. setting-up	6	2.8	7.5	3.5
Pb-Pb ions physics & p-p ref. run	32	14.7	32	14.7
Technical stop	8	3.7	7	3.2
Technical stop recovery	2	0.9	13.5	6.2
Other stops	2	0.9	42	19.4
Machine Development blocks (incl. floating MDs)	16	7.4	7	3.2
Total:	217	100	217	100

Major change in beam time:

- 25ns p+ physics time only 49% of initially scheduled
- Integrated lumi: 32 fb⁻¹ instead of 75 fb⁻¹
- Stop for cryo bellow repair 37 days
- Restart after repair 11.5 days
- Increased time to complete the high beta run – goal achieved

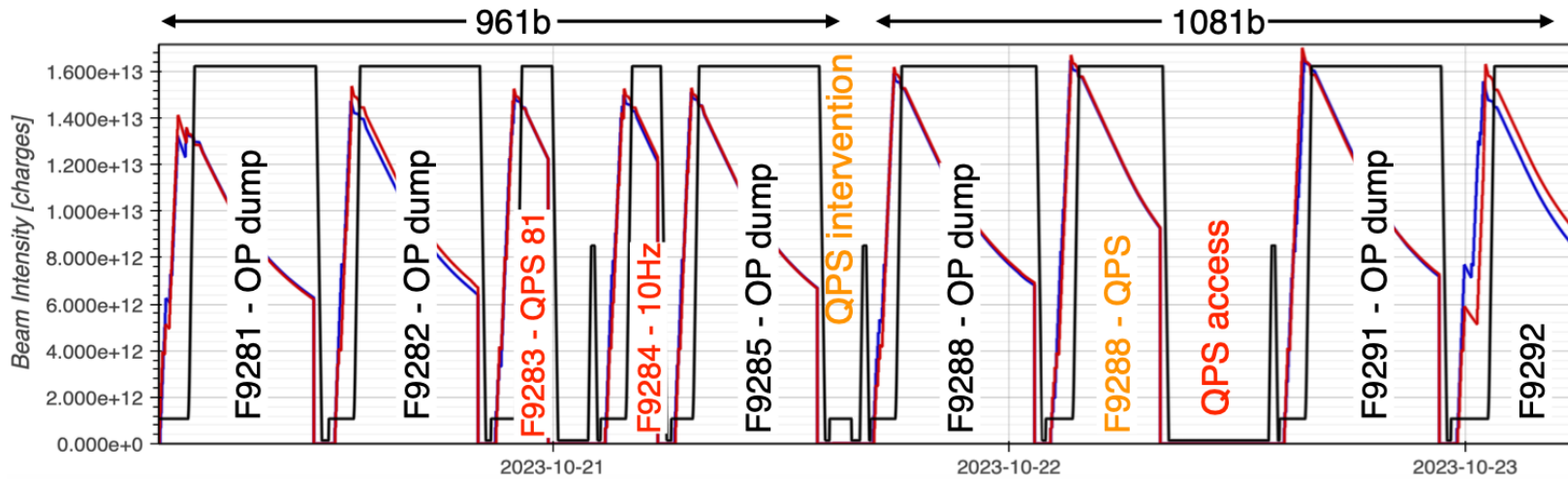
Proton Performance when running

- Proton period 01/07 – 17/07: availability 76%, stable beams 52% - just before cryo leak

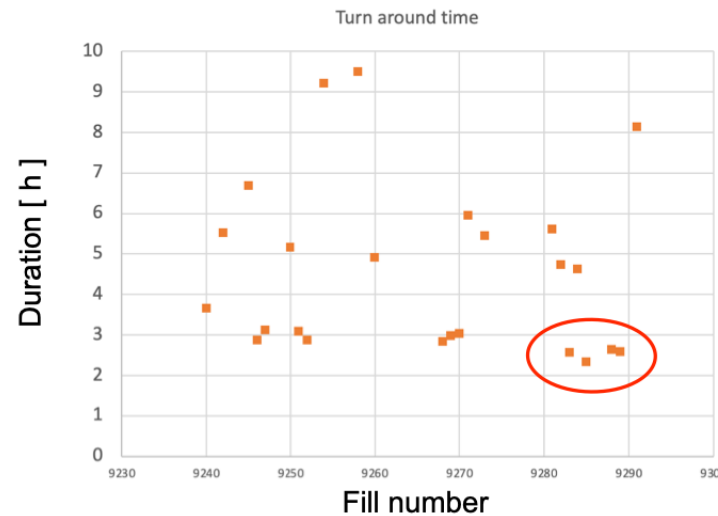
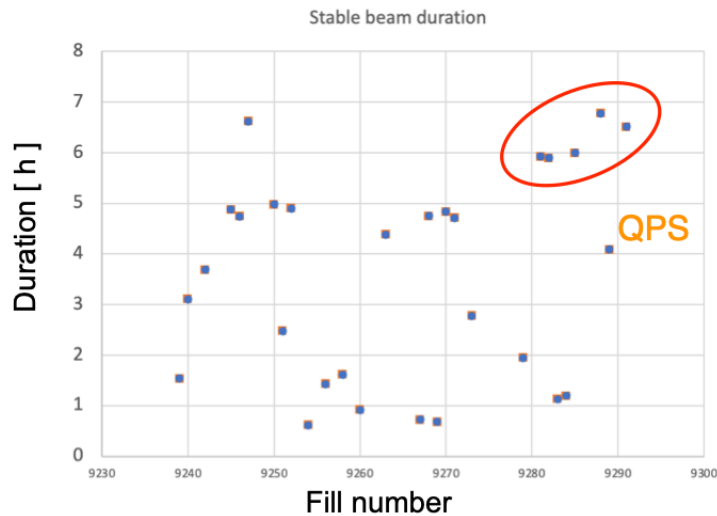
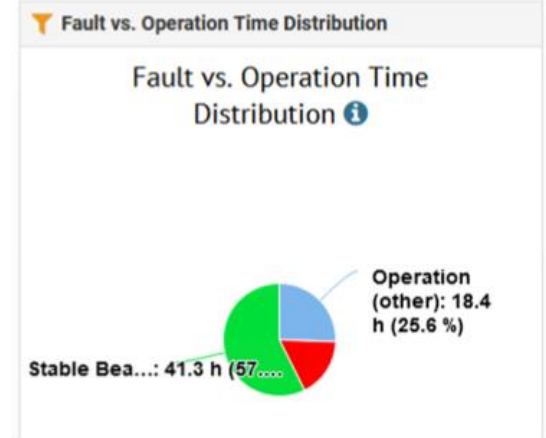


Without the issues and the major downtime, the challenging goal of 75 fb^{-1} for 2023 would have been in reach

Pb ion Performance last weekend



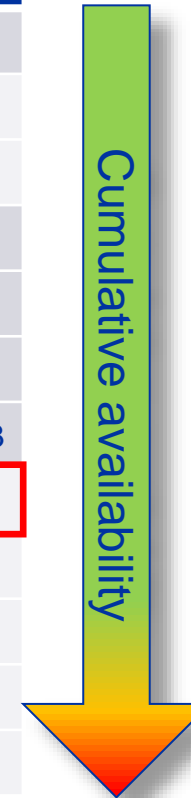
Availability	Stable beams (SB)
82.9%	57.4%



- Typical optimum fill length: ~ 6 hours
- Turn-around time: ~ 3 hours
- Goals vs Achieved today:
 - ALICE: 3.25 nb⁻¹ → 1.5 nb⁻¹
 - ATLAS: 3 nb⁻¹ → 1.2 nb⁻¹
 - CMS : 3 nb⁻¹ → 1.4 nb⁻¹
 - LHCb: 0.4 nb⁻¹ → 0.16 nb⁻¹
- 1 more week to go...

Availability Overview LHC Injector Chain + LHC

Facility	Destination	'21/'22 Overall [%]	Achieved 2023		Period
			Overall [%]	Per destination [%]	
LINAC4	PSB	97.3/96.8	98	98	03.03.2023 – 02.10.2023
PSB	PS	94.5/94.8	96.1	96.4	10.03.2023 – 02.10.2023
	ISOLDE			96.6	17.03.2023 – 02.10.2023
PS	SPS	88.1/89.6	92	92.8	17.03.2023 – 02.10.2023
	East Area			93.5	27.03.2023 – 02.10.2023
	nTOF			92.8	03.04.2023 – 02.10.2023
	AD			92.6	12.06.2023* – 02.10.2023
SPS	LHC			94.3	27.03.2023 – 02.10.2023
	North Area	73.4/74.1	86	86.6	24.04.2023 – 02.10.2023
	AWAKE			98.4	01.05.2023 – 02.10.2023
	HiRadMat			99.1	22.05.2023 – 27.08.2023
LHC	-	- /76.3	43.7	43.7**	15.05.2023 – 13.06.2023



In the injectors overall very good availability

Overall includes all other beams such as MD etc.

Very difficult year for the LHC

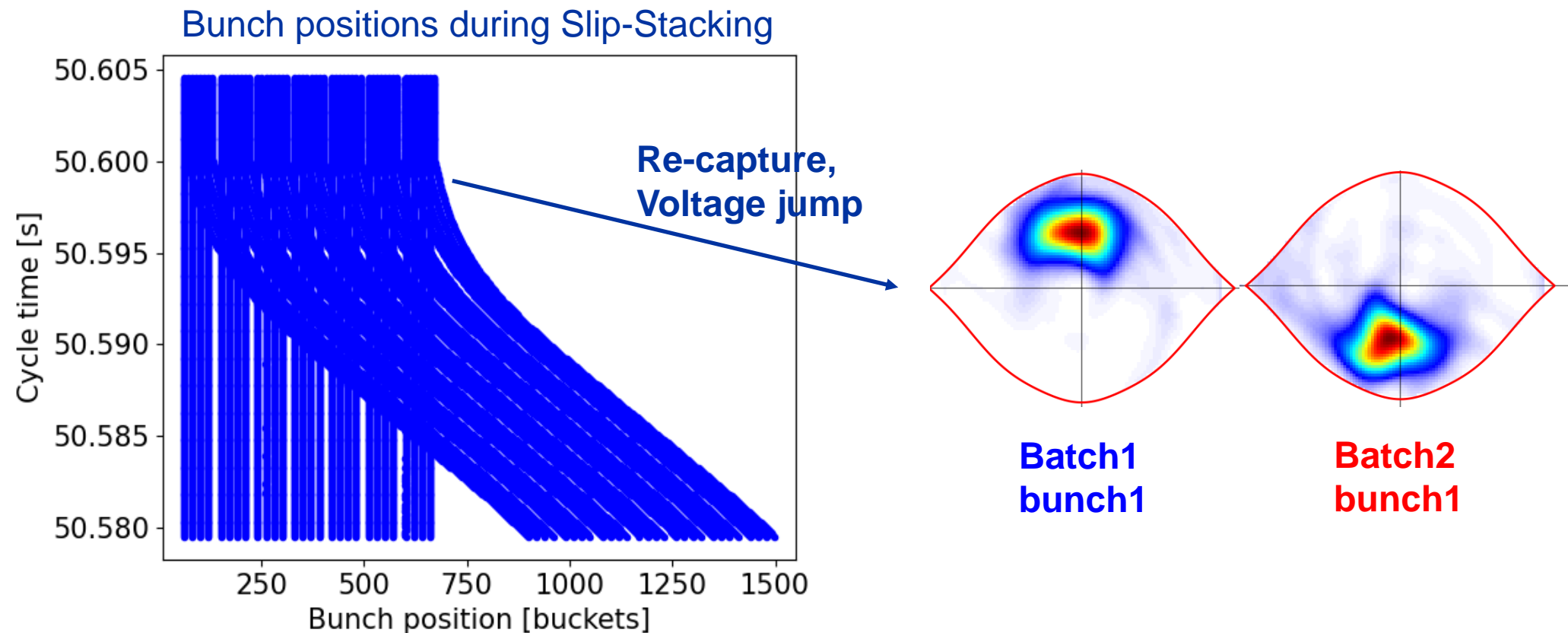
- 43.7% machine availability overall

*Revised AD start date following quadrupole water leak

**Includes RF finger module exchange & Cold mass to insulation vacuum repair

SPS: Pb ion Slip-Stacking Successfully Commissioned

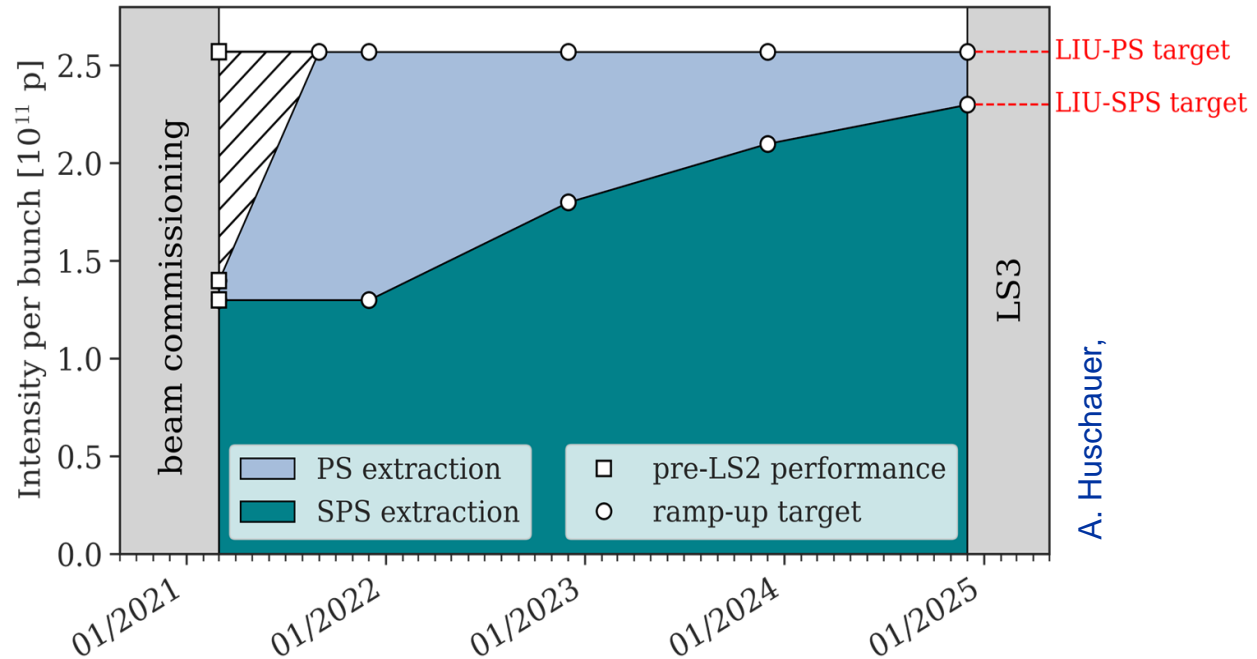
- From 100 ns bunch spacing to 50 ns – doubling the number of bunches in the LHC



Injectors: Run 3 LHC Beam Intensity Ramp-up Plan

Year-by-year intensity goals of the ramp-up at SPS extraction

- 2021: $1.3 \cdot 10^{11}$ p/b – Pre-LS2 beam parameters
- 2022: $1.8 \cdot 10^{11}$ p/b – For LHC 2023 operation
- 2023: $2.1 \cdot 10^{11}$ p/b
- 2024: $2.3 \cdot 10^{11}$ p/b – For HL-LHC post-LS3



The intensity reach was demonstrated on 13.06.23 and 18.08.23:

4 x 72 bunches with 2.2×10^{11} p/b at flat top

Concluding Remarks

- **The Injectors complex is running well with good beam performance and availability**
 - HL-LHC beam parameters demonstrated
 - Slip-stacking for Pb ion commissioned successfully
- **LHC had a challenging year working in uncharted territory for Protons and Pb ions**
 - Unprecedented stored proton beam energy and very efficient performance ramp-up
 - Serious issues caused substantial down time – Proton run was cut short to 49% of initial time schedule
 - Pb ion run with double the number of bunches came with more challenges than anticipated – lately very good running
- **Year End Technical Stop starts Monday 30 October at 06:00**
 - One more week to go....
 - Mitigating issues and applying lessons learned during YETS
- **First 2024 beam expected in the LHC on 11 March**
 - 2024 baseline schedule available, to be revised in the light of the 2nd half of the 2023 run

Thank you for your attention

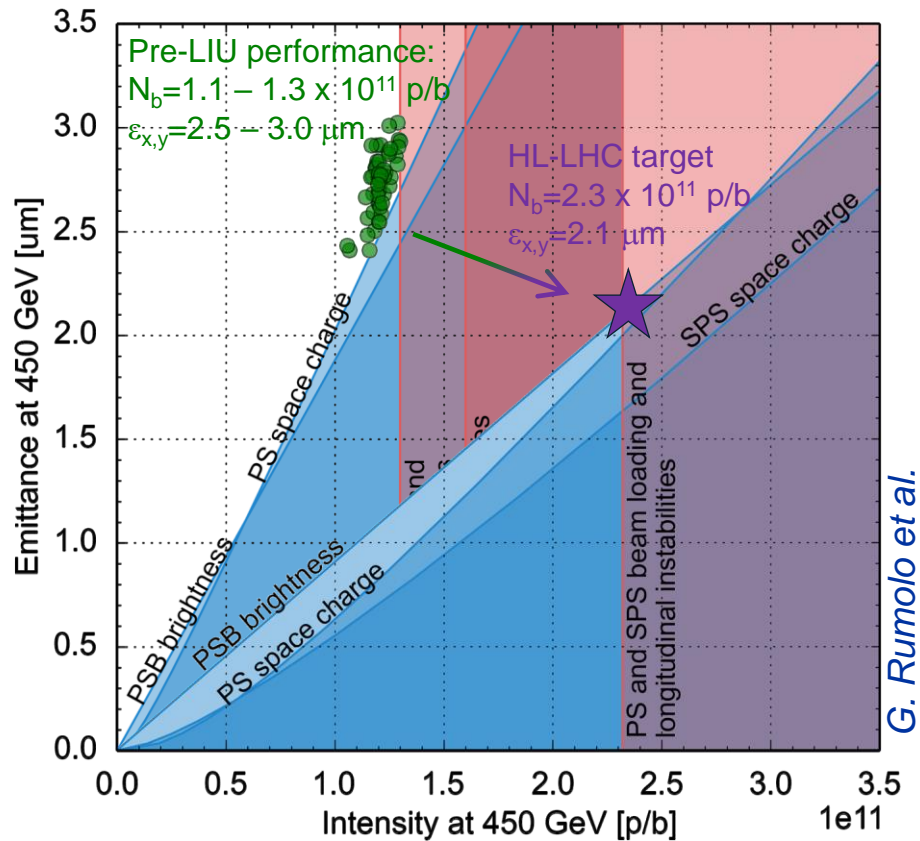


Any questions...?

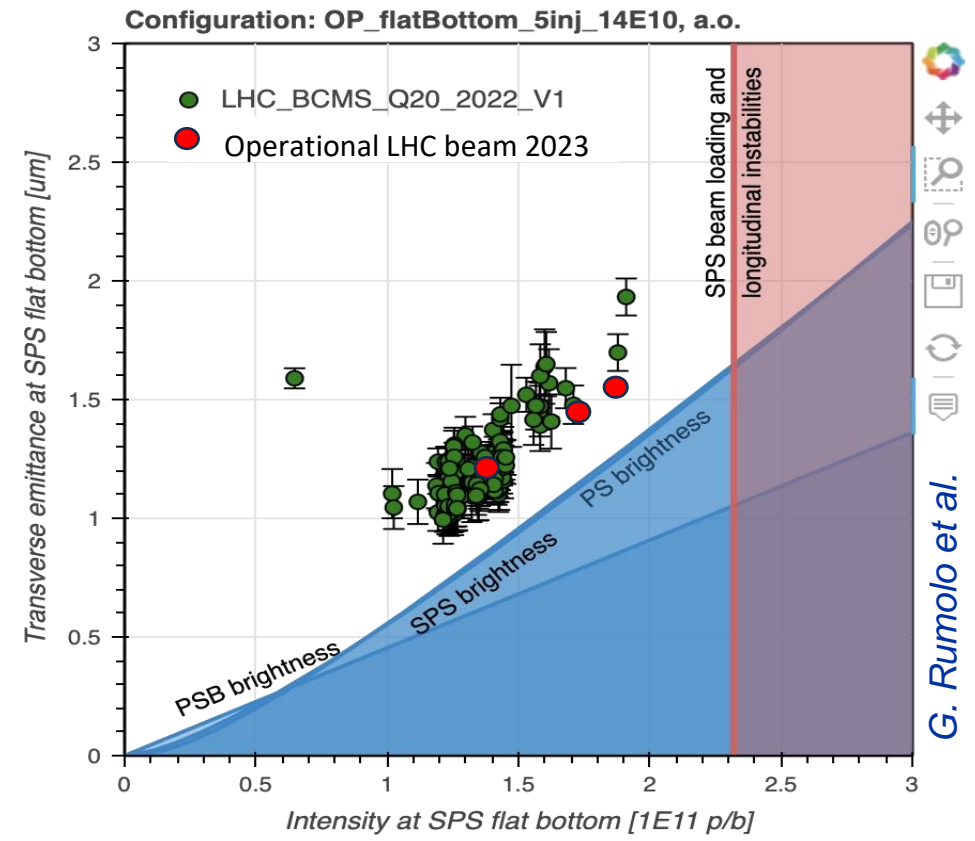
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Exploiting the Performance Potential

Pre-LS2

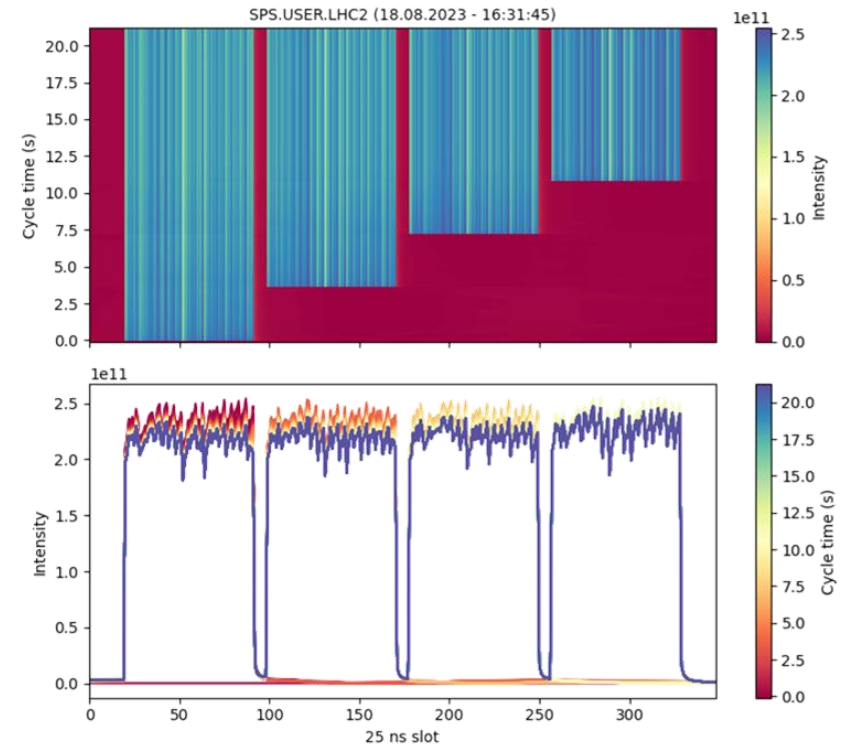
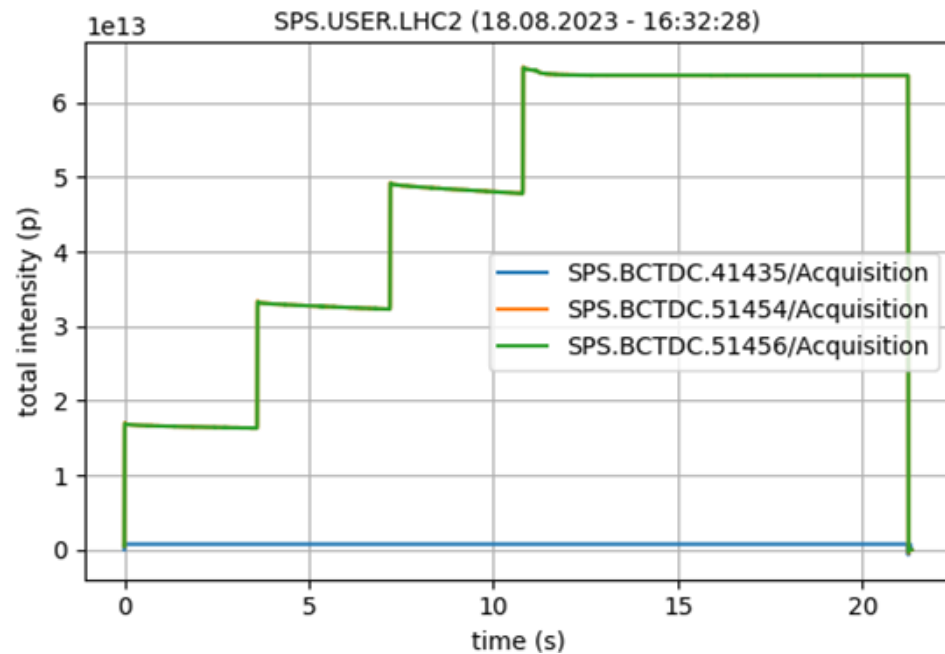


2023



Achieved SPS performance – intensity

Intensity reach demonstrated on 13.06.23, 18.08.23:
4 x 72 bunches with 2.2×10^{11} p/b at flat top



G. Rumolo