Status of the LHC

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on behalf of the LHC operation team

September 1st, 2025

163rd LHCC OPEN Session

LHC, TI2. TI8 and experiments closed xall valves open

Start Beam Commissioning

First Stable beams

Collisions with 1200 bunches

Wk	Apr 14	15	16	17	May 18	19	20	21	Jun 22	23	24	25	26
Mo	31	7	14	Easter 21	28	Cryo reconf. 5	12	19	26	2	Whitsun 9	16	23
Tu						Scrubbing							
We	Machine checkout	Re-commissioning with beam											TS1
Th	TI2/TI8 test				1st May				Ascension			MD 1	
Fr			G. Fri.			Interleaved commissioning & intensity ramp up							
Sa													
Su													

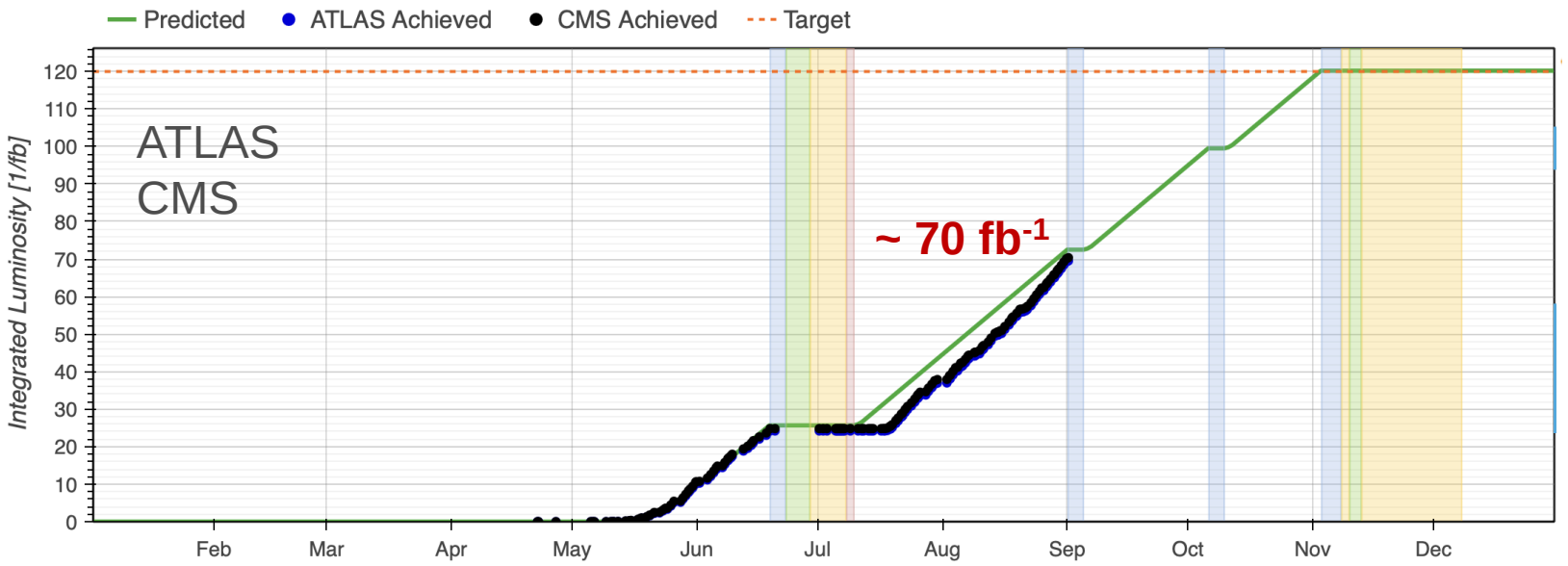
Wk	Jul 27	28	29	30	Aug 31	32	33	34	35	Sep 36	37	38	39
Mo	30	7	14	21	28	4	11	18	25	1	8	15	22
Tu	O ion setting up	Ne-Ne run								MD 2			
We		ZDCs out											
Th	MD 1b	VdM program									Jeune G.		
Fr													
Sa	O-O & p-O Ions run												
Su													

Availability

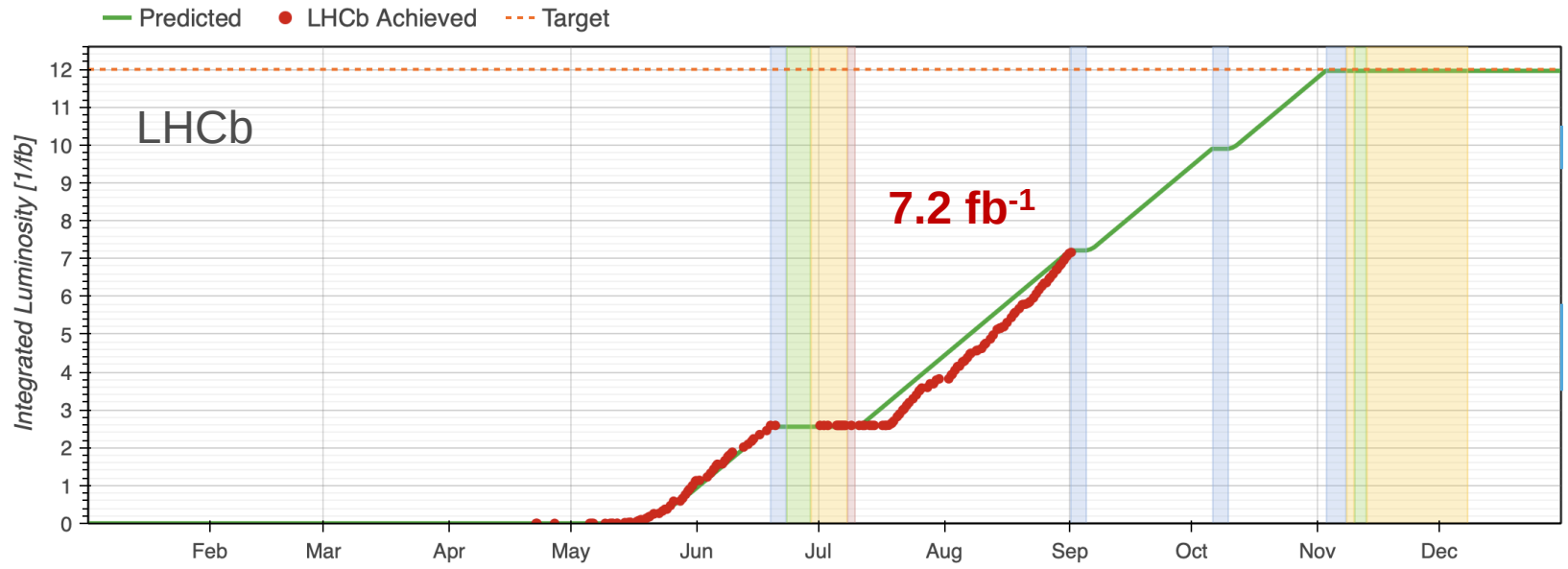
74.0%

Stable beams (SB)

56.8%



120 fb^{-1}



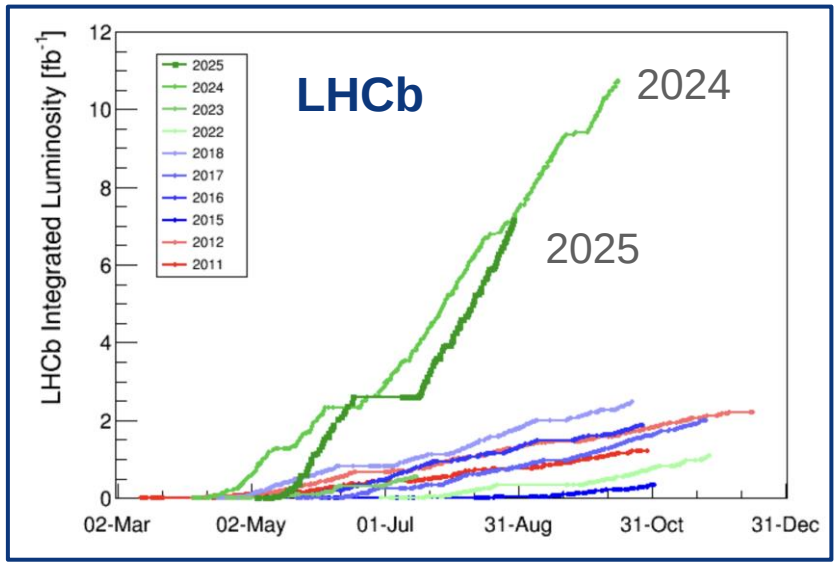
12 fb^{-1}

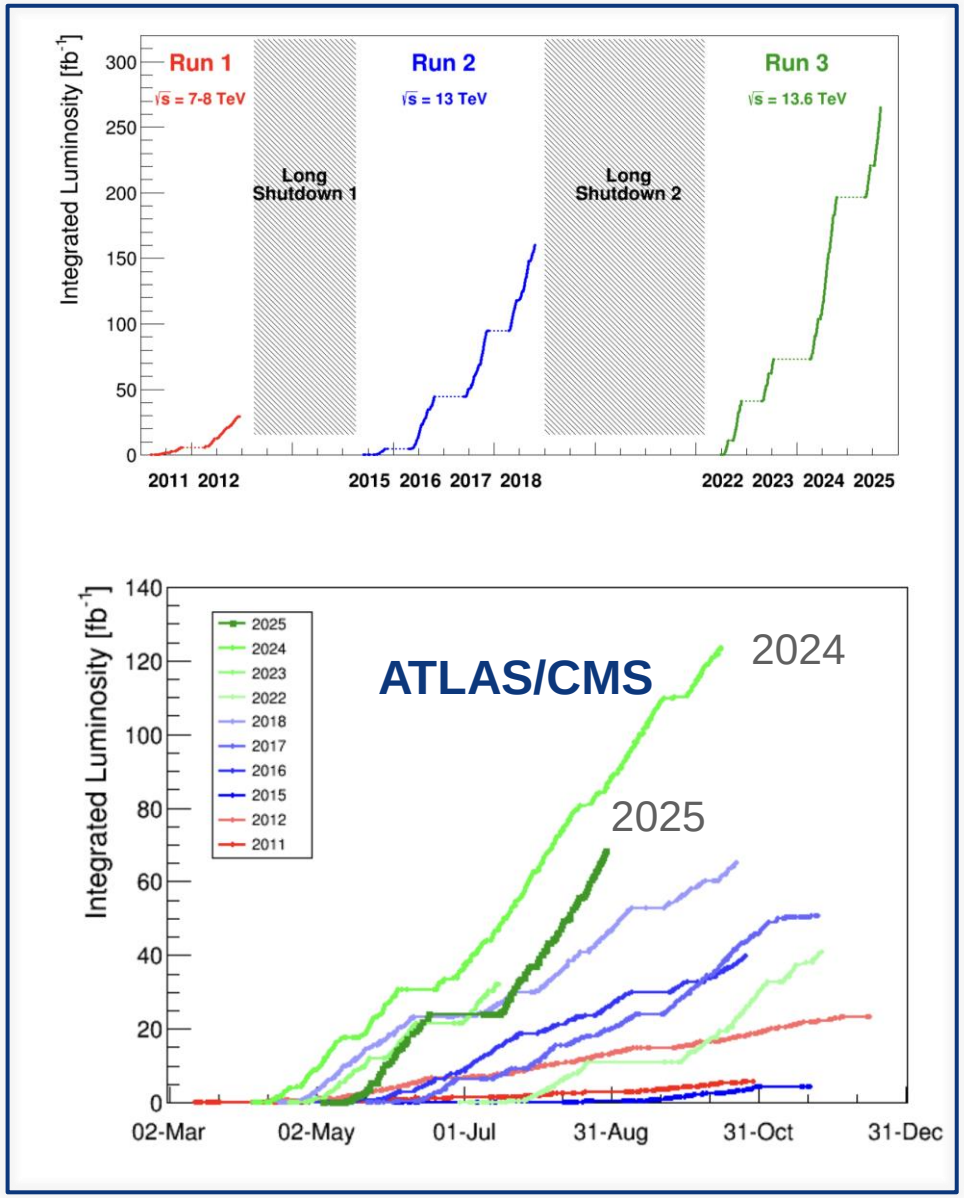
Outline

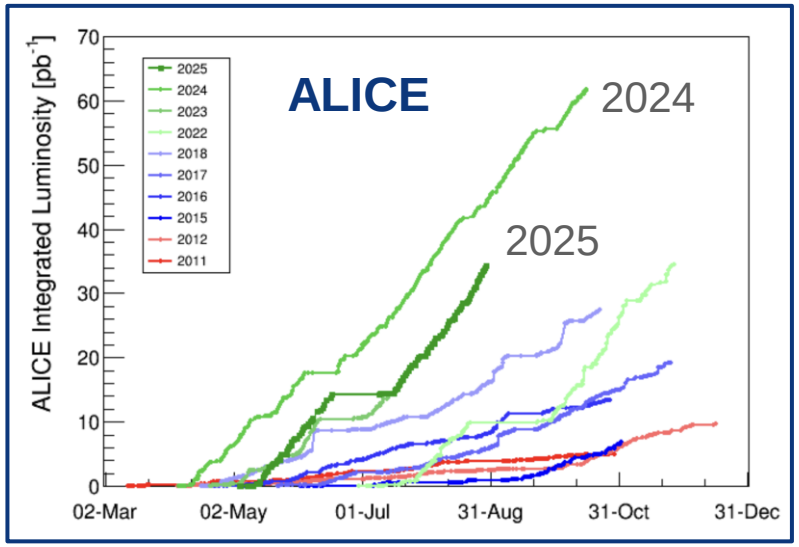
- Proton run
  - Luminosity production
  - Machine performance
  - Challenges and issues
- Light ion run: p-O, O-O and Ne-Ne
- Conclusion and outlook for the rest of the year

2025 so far…

- **~70 fb^{-1}** in ATLAS/CMS
- **7.2 fb^{-1}** in LHCb
- **~35 pb^{-1}** in ALICE
- **Full steam production on-going!**







Record 24h rate = **1.7 fb^{-1}/24h**
(midnight to midnight on August 30)

Record 7-day rate = **9.1 fb^{-1} / 7d**
(August 24 to 30)

Levelling in physics

2025

Inject, ramp, squeeze to 120/120 cm | Flip crossing planes – IR1,5,8 | Collide at 120/120 cm | β* levelling to 60/60 cm | β* levelling to 60/18 cm | Xing anti-levelling to 120 urad

ATLAS: V → H
CMS : H → V
LHCb : H → V

ATLAS: 18 cm in V
CMS : 18 cm in H

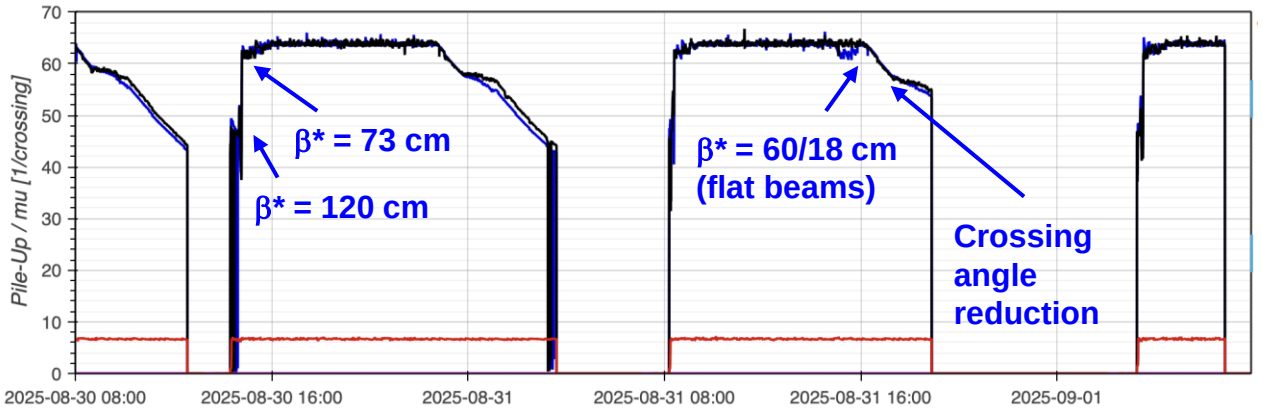
Stable beams

Combined (β* + separation) **levelling** allows for

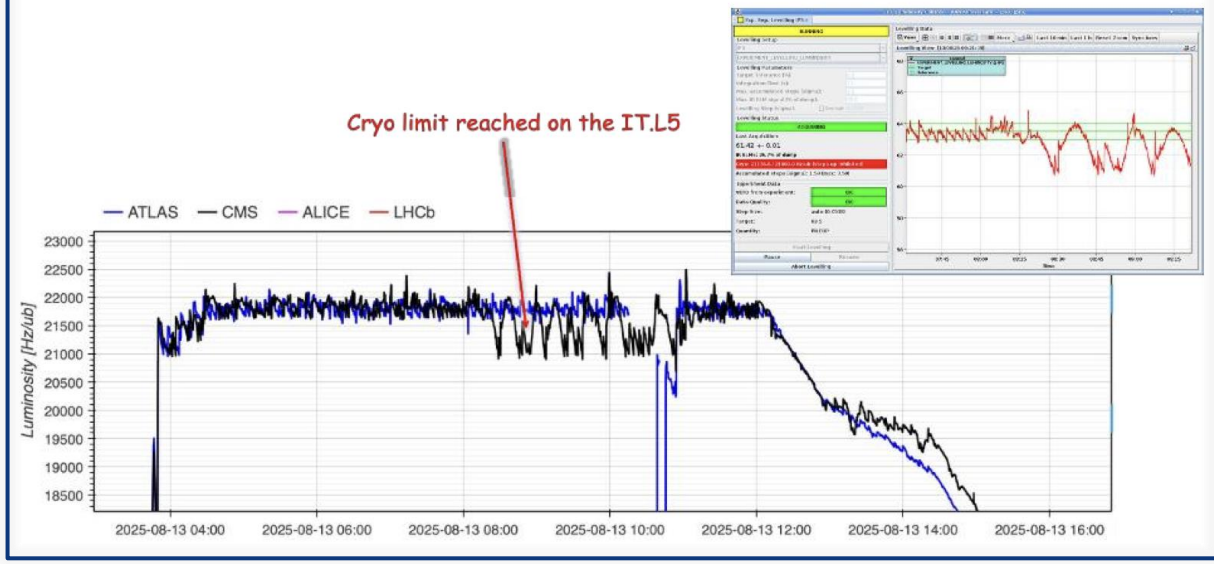
- **7 to 8 hours in levelling** with high-brightness beams
- Additional crossing-angle levelling to slow-down the luminosity decay when reaching end of separation levelling (from 160 to 120 µrad)

Separation levelling tolerance reduced to 0.8 % for ATLAS/CMS and to 2.5 % for LHCb

LHCb levelled **through the entire fill (up to ~ 14h)**

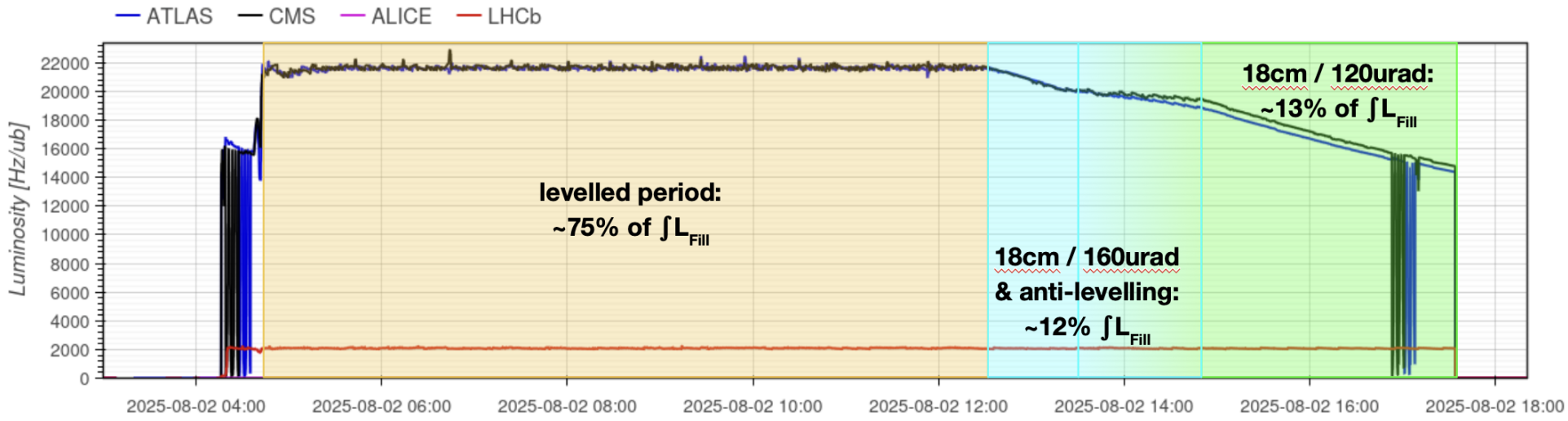


Target pile-up increased to **64** mid-August, allowed by good cryogenics performance and margin after fine tuning in ITL5



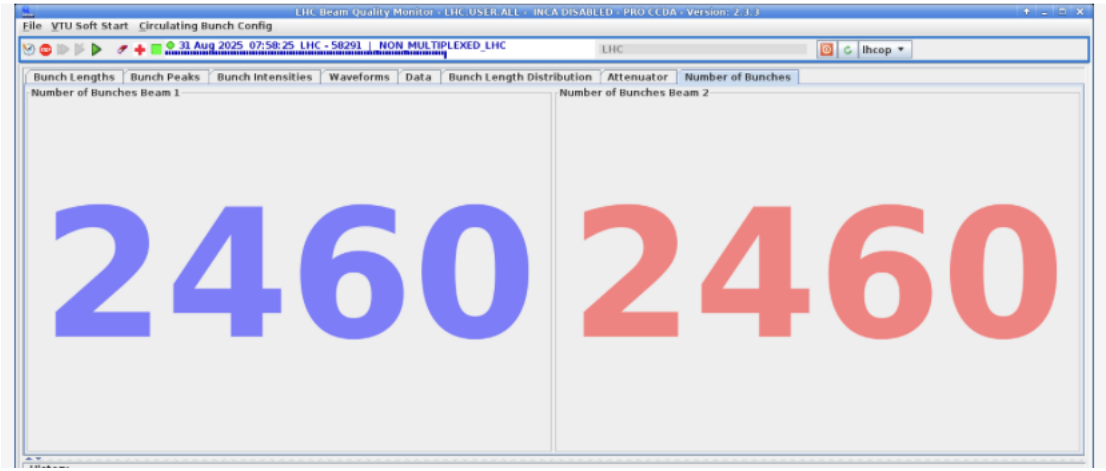
Luminosity imbalance between ATLAS and CMS

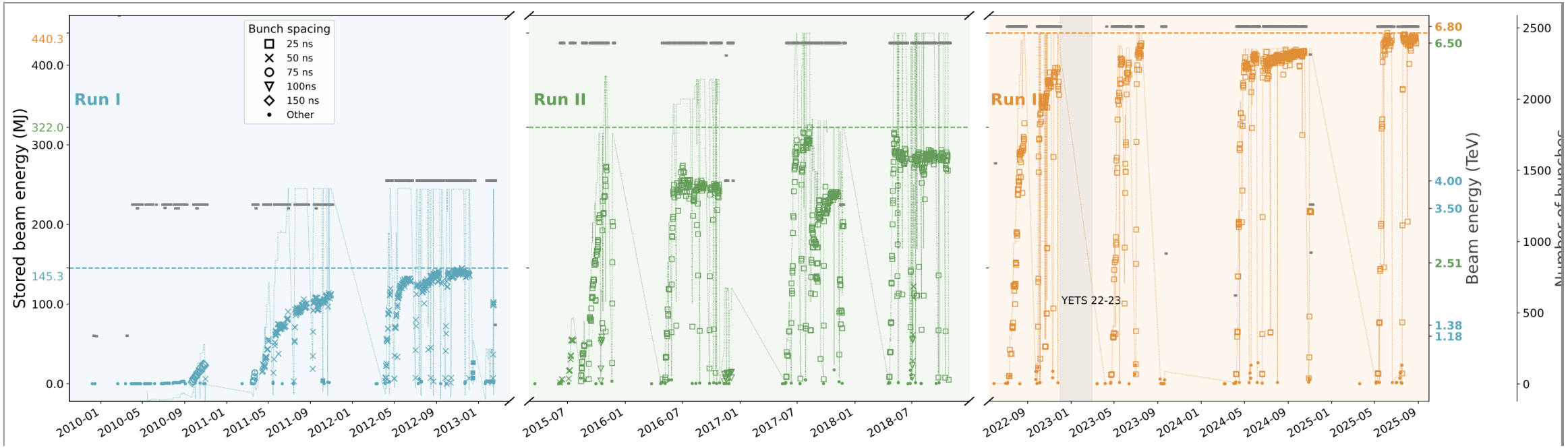
- Systematic ATLAS/CMS luminosity imbalance observed during luminosity decay: a consistent 3% imbalance starts during crossing-angle levelling
- Impact on integrated luminosity is small as it only affects the out-of-levelling period (estimated impact of lower than 1 % on the integrated luminosity)
- **Multi-ingredient effect**, on-going investigations:
  - Emittances asymetry too small to explain the 3% effect
  - Beam-beam effect has a small contribution but can only explain 50% of the observed effect
  - Luminometer non-linearity dependence on crossing angle has been excluded
  - Latest tests of longitudinal beam spot displacement at 160 µrad revealed that waist shift is not main culprit to explain the imbalance evolution with crossing angle



Performance - Beams brightness

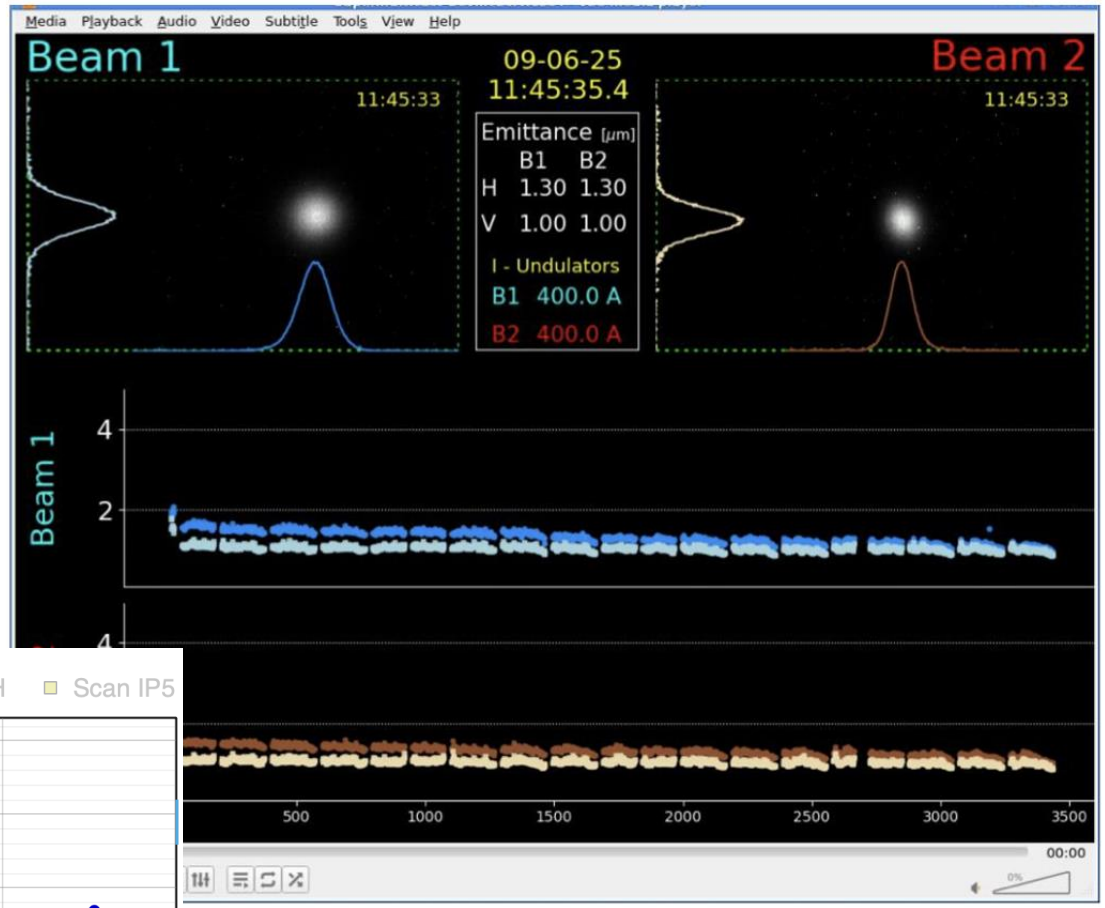
- Record stored beam energy reached this year, at **440 MJ per beam** (average) at start of stable beams, corresponding to ~4 x 10^{14} protons
- 2025 filling scheme features 2460 bunches over 20 injections

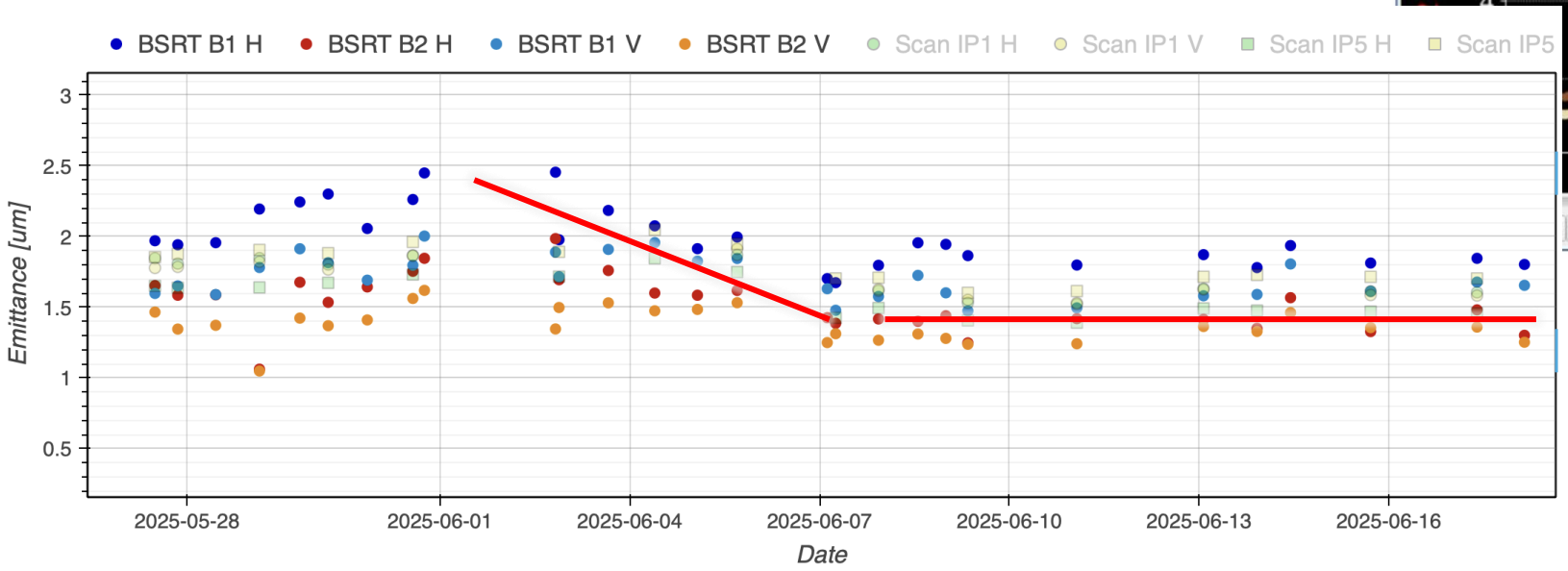




Performance - Beams brightness

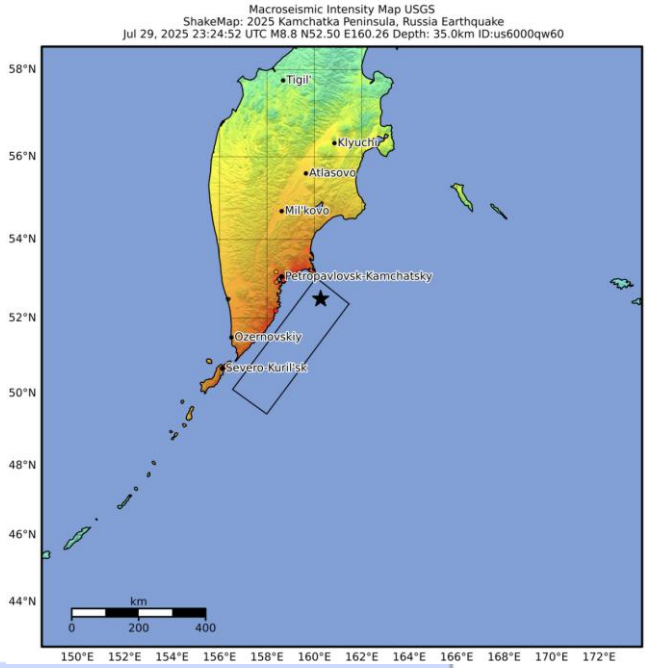
- Lower emittances, hence smaller beam sizes and longer levelling time, delivered by the injectors chain following an adjustment of the SPS tunes
- Emittances at injection at 1.3 µm (H) / 1.0 µm (V) with the gains preserved up to flat-top and start of stable beams

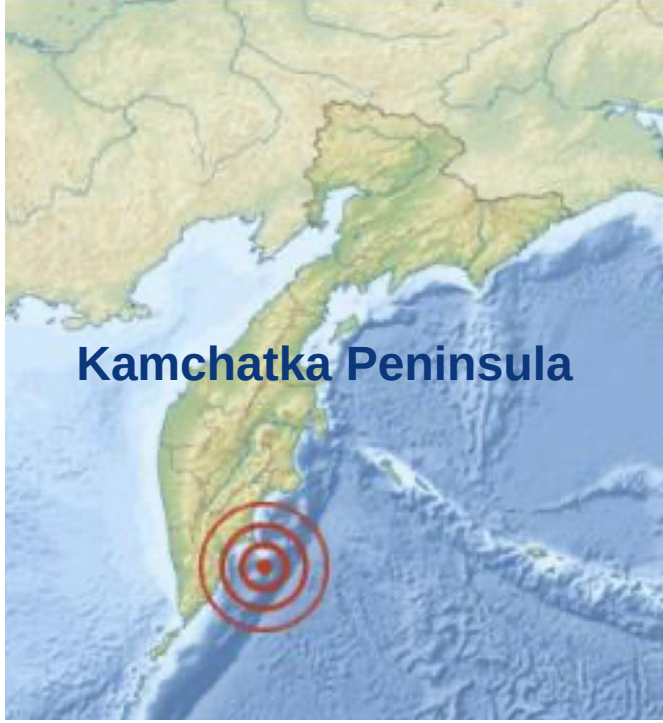


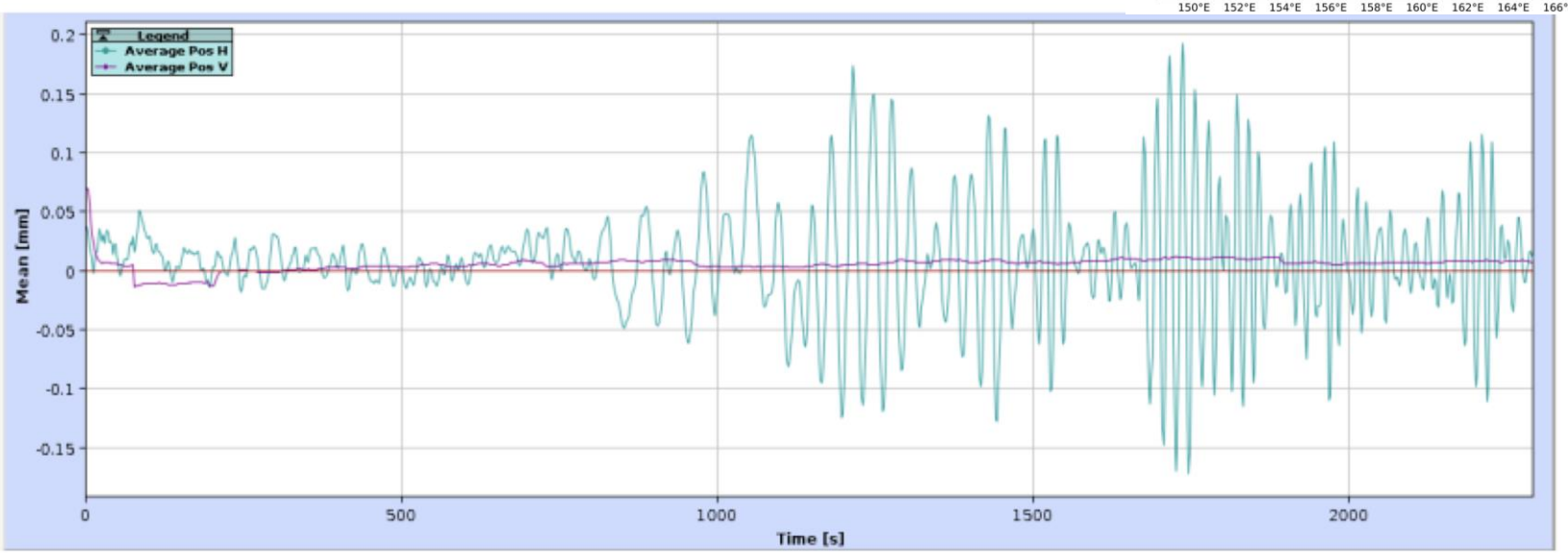


Interesting observation - Earthquake in fill #10888

- On July 29, a magnitude 8.8 earthquake, the largest one worlwide since 2011, occurred in the Kamchatka Peninsula
- Earthquake-related effects commonly observed in the LHC



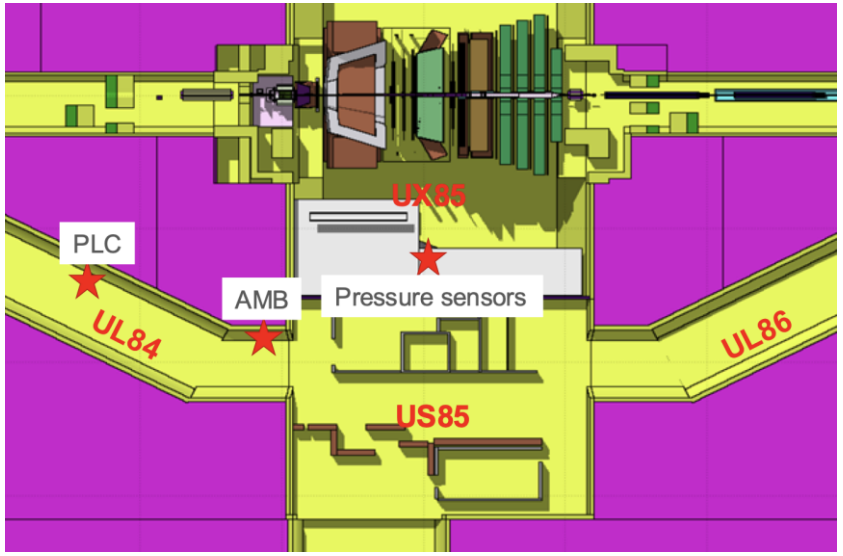


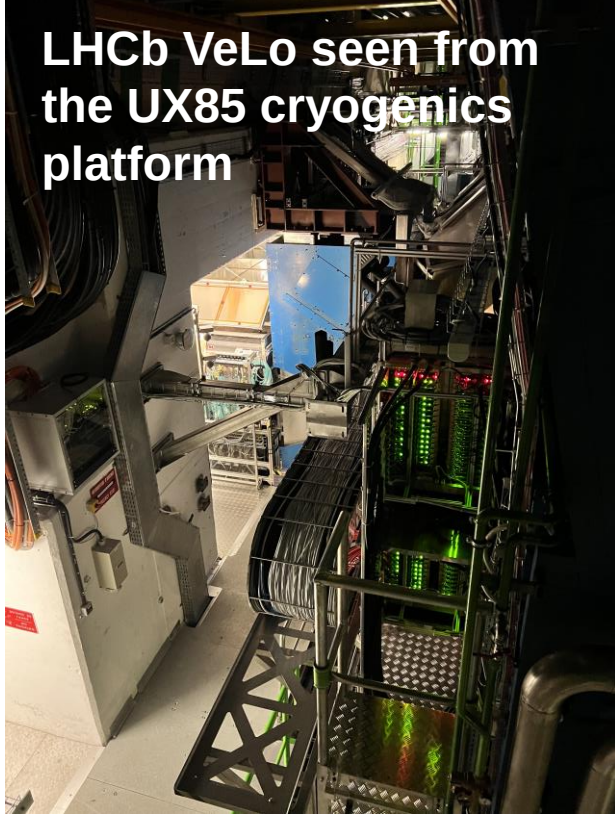


- Large orbit oscillations up to 250 um (rms) were observed in the LHC for approximately 25 minutes, and milder effects continued during ~4 hours

Challenges with cryogenics

- Cryogenics faults in point 8 impacted availability in June, one event re-occurred in August
  - Radiation-induced effects, **faults are stochastic and proportional to integrated luminosity**
  - Some (but not all) pressure sensor faults are now mitigated by software fixes (which saved the day a couple of times already!)
  - P8 is the only point where cryogenics equipment are located in the experimental cavern



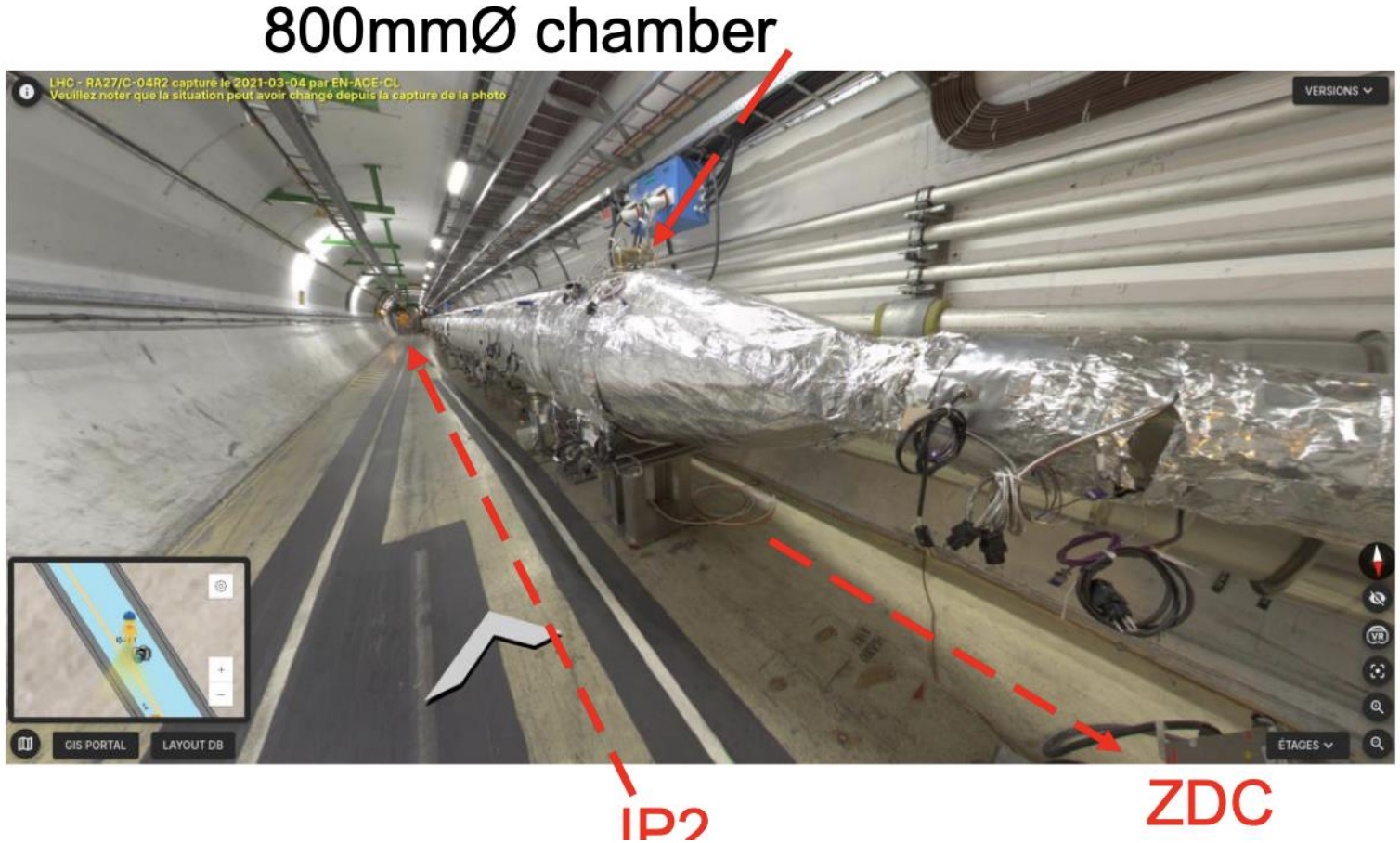


Concrete shielding now replaced by steel shielding

Vacuum spikes near IP2 and background to ALICE

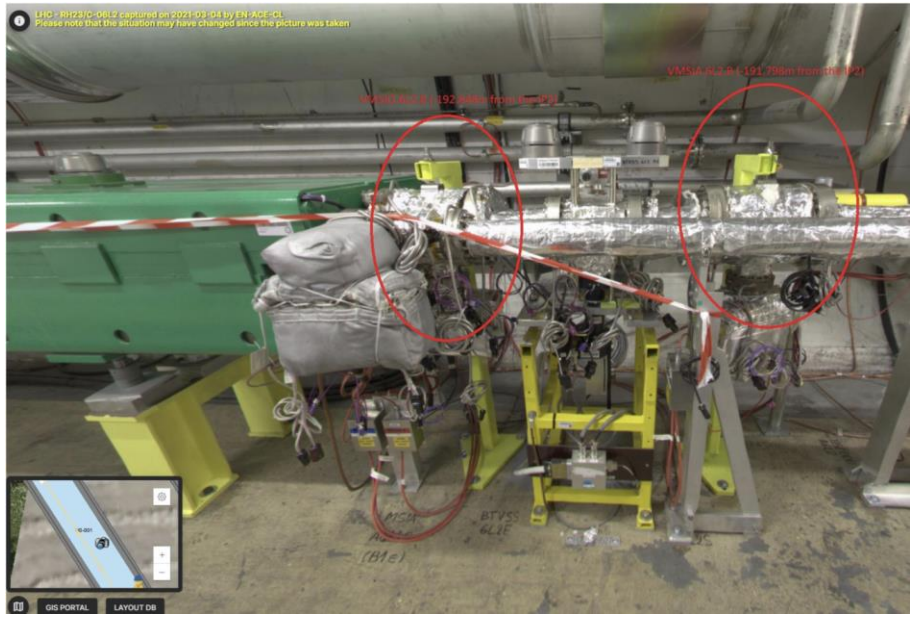
- Vacuum spikes were observed in some fills (4-8 August) in the wide common chamber around ALICE, shortly after start of stable beams

- Increase of background and trip of ALICE detectors
- **Mitigation**: reduced voltage on the ion pumps in 4L2 and 4R2, which is expected to help in case of pump degradation
- No large spikes were observed since

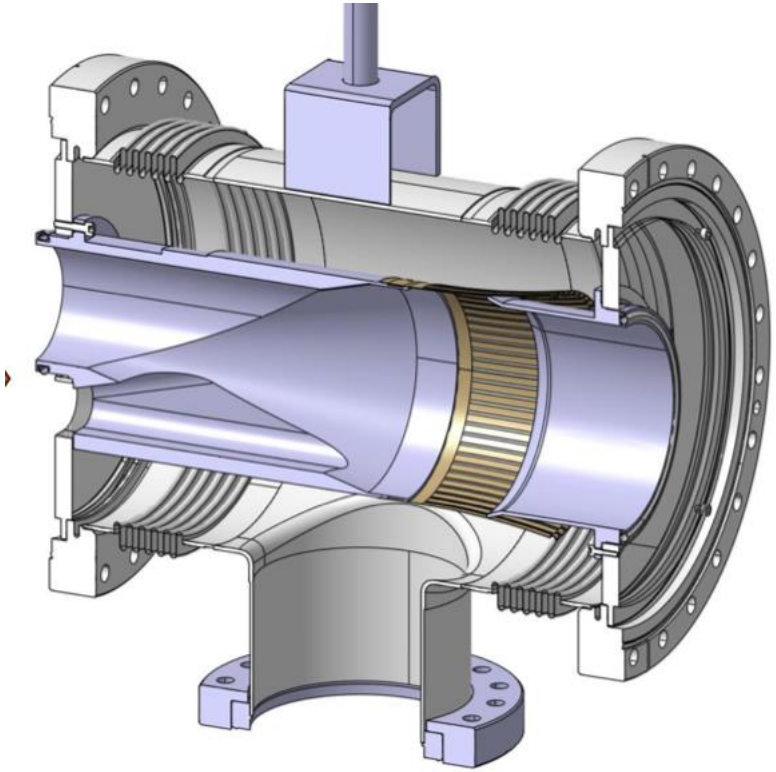


Vacuum issues with warm transition modules

- Slow losses in LSS2 initially observed end of July and correlated with pressure spikes in sector A6L2
- Two warm transition modules identified as potential sources, due to rf “fingers” issue

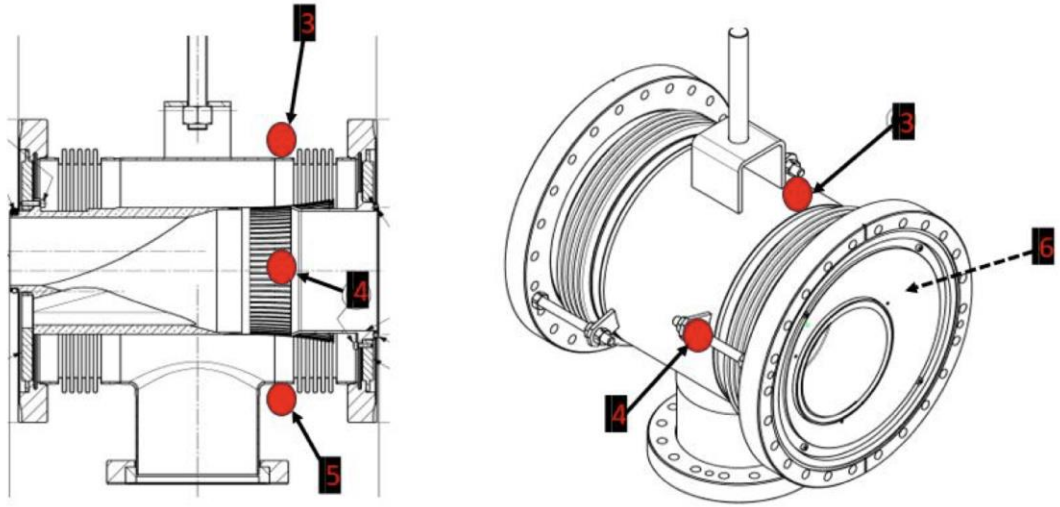


VMSIO module : design change took place during LS2, new design installed



Vacuum issues with warm transition modules

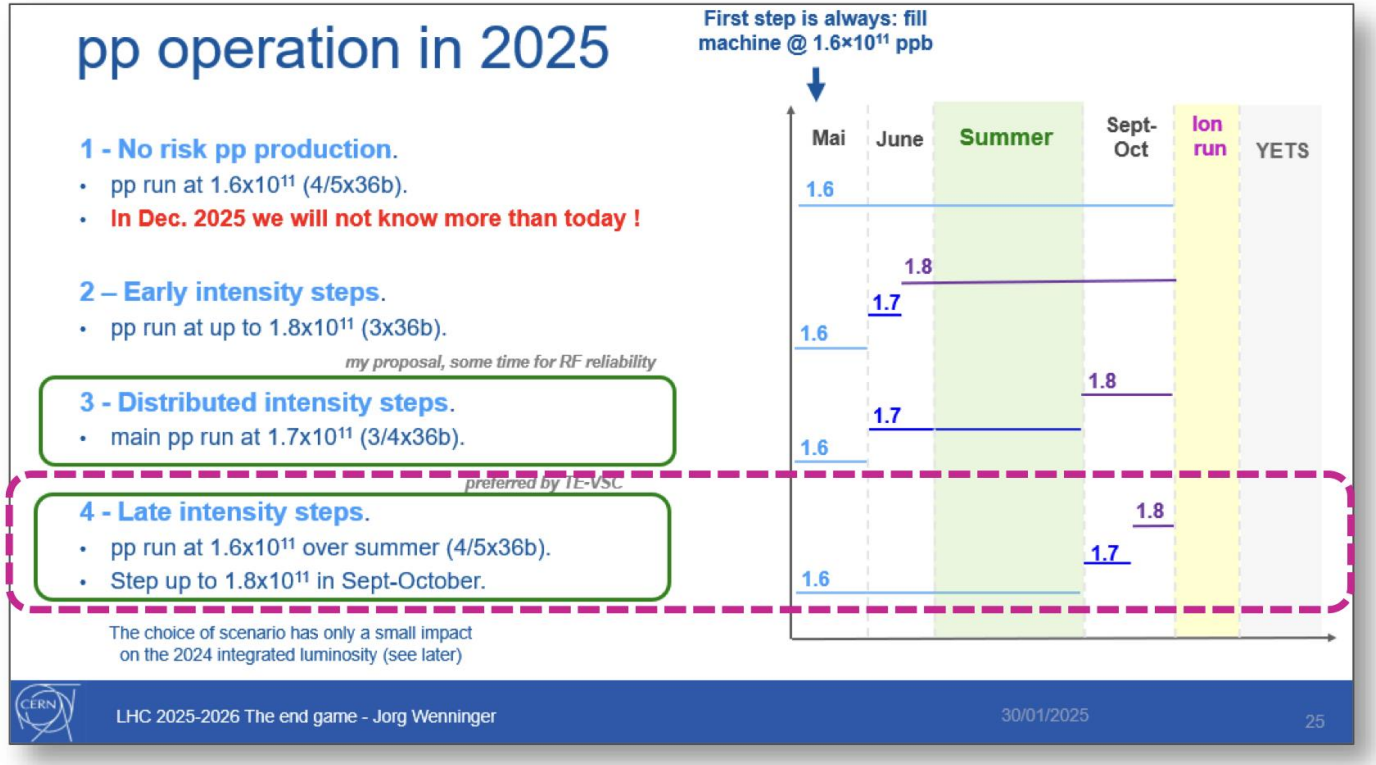
- High intensity operation was stopped and X-ray inspection was organized, a defect of the tension spring (holding the rf fingers in place) was found
- Thermocouples have been put in place on the vacuum module body
- Situation actively monitored since, no further deterioration of the rf contact observed since



TCs are installed on the external surface of the warm module body (under the bake-out layer)

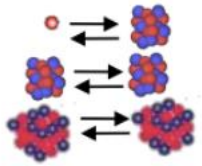
Plans for intensity increase

- Initial plan foresees an step-by-step intensity increase, from 1.6 x 10^{11} ppb to 1.8 x 10^{11} ppb starting in September
- The rf contacts of the warm elliptical transition modules near the D1 (IR 1-5, 24 modules in total) are known to be prone to fault and will be inspected prior to any intensity increase
- X-rays are planned for this week and plans will be finalised based on these results and possible developments from further obversation of vacuum spikes in 6L2

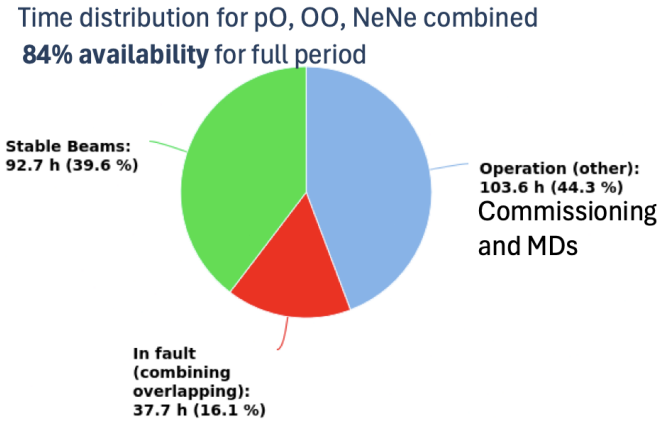


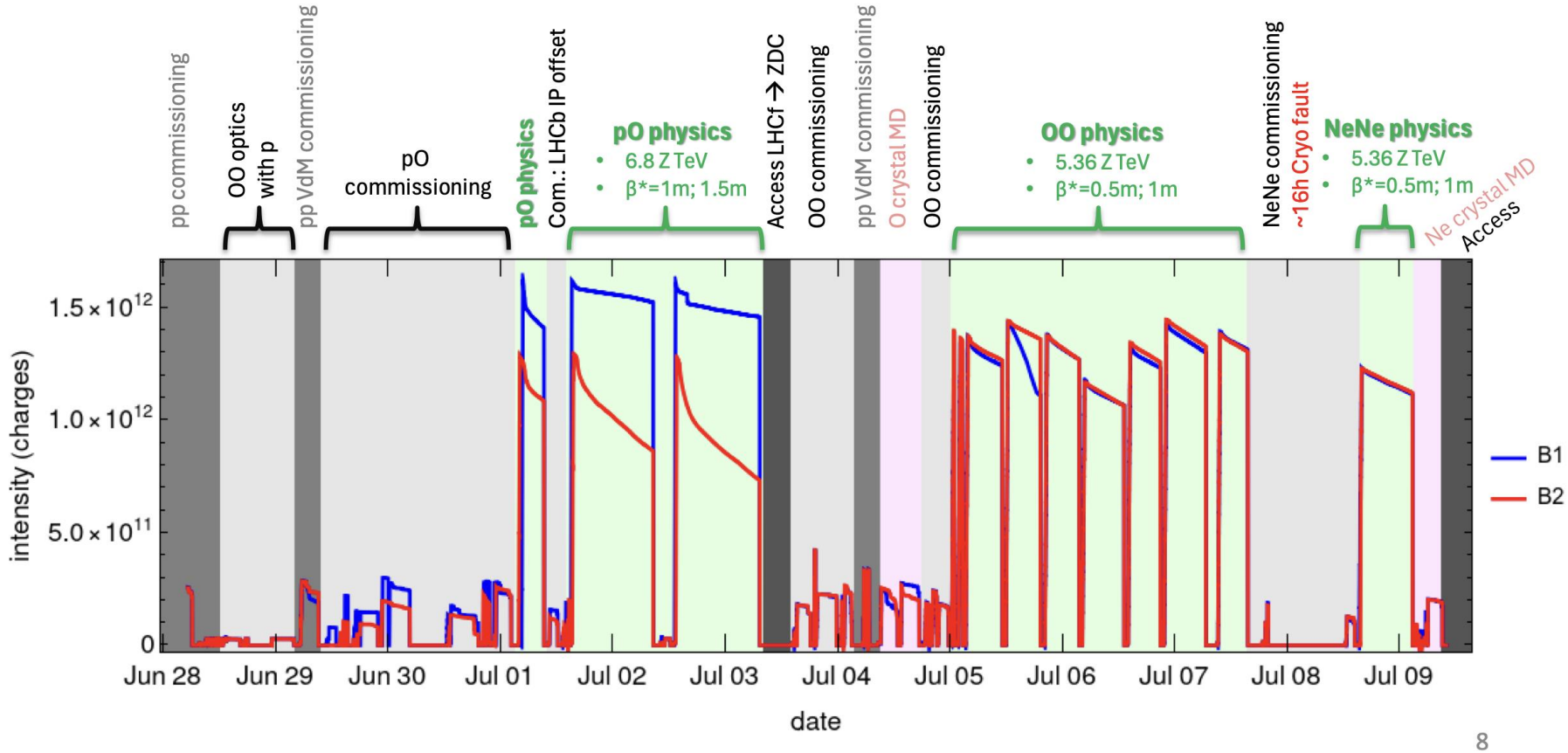
Light ion run

Proton-oxygen (pO)
Oxygen-oxygen (OO)
Neon-neon (NeNe)



- Excellent machine and beam availability, with ~40 % stable beam time





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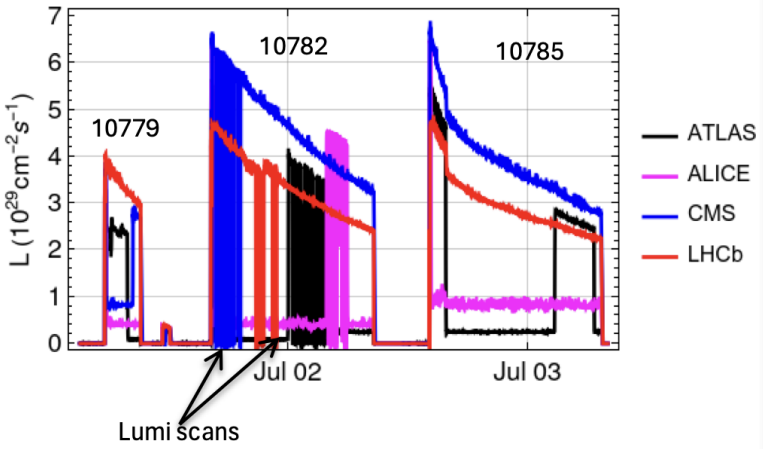
- Rich and intense programme conducted over 12 days involving three non-standard LHC configuration and particle types

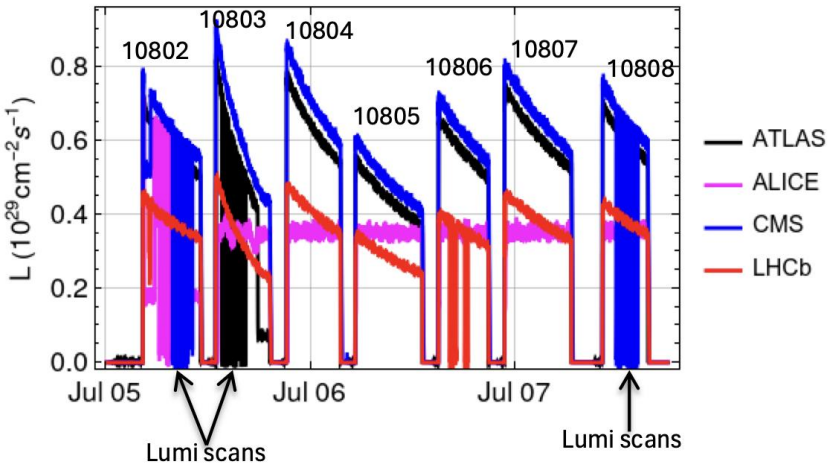
Luminosity targets reached and exceeded by large factors



Proton - Oxygen

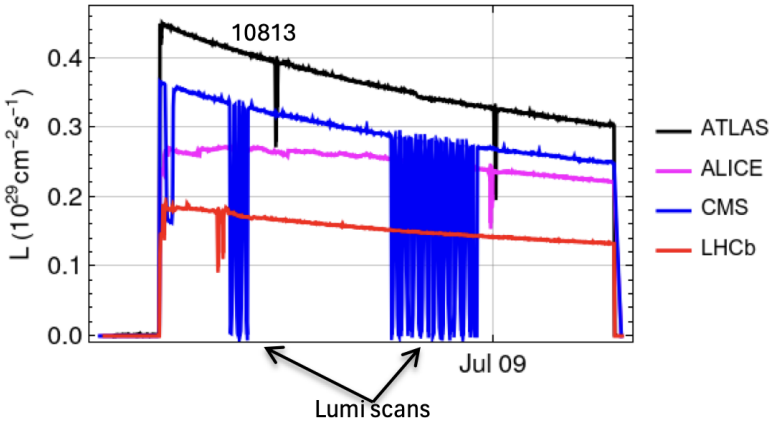
(nb^{-1})	target	delivered	Ratio
ATLAS/LHCf	**1.5**	1.8	1.2
ATLAS	--	6.9	--
ALICE	5	7.85	1.6
CMS	3	48.4	16
LHCb	**2**	33.1	16.6

Preliminary numbers – pending detailed luminosity calibration



Oxygen - Oxygen

(nb^{-1})	target	delivered	ratio
ATLAS	**0.8**	8.2	10.3
ALICE	**0.5**	5.15	10.3
CMS	**0.8**	9.4	11.8
LHCb	**0.5**	5.75	11.5



Neon - Neon

(nb^{-1})	target	delivered	F
ATLAS	0.1	1.0	10
ALICE	0.1	0.91	9.1
CMS	0.1	0.91	9.1
LHCb	0.1	0.61	6.1

Light ion run

- Keys to machine performance and overall success
  - Going to maximum number of single bunches, while keeping commissioning and validation short
  - Commissioning of the special cycles performed ahead of time
  - Very good beam quality from injectors, higher intensities than expected
  - Almost perfect availability (contingency became physics time)
  - And …

... dedication and flexibility of all experts involved!

Conclusion

- LHC is running well, no major issue affecting luminosity production
  - Record-level luminosity production achieved through increased availability and efficiency, high beam brightness from the injectors and cryogenics margins
- Under constant monitoring
  - Vacuum in 6L2
  - Elliptical modules in IR1-5
  - SEU issues on P8 cryogenics
- Looking forward to
  - Continued luminosity production interleaved with MD blocks (MD2 on-going this week)
  - Heavy ion run