



Статус ускорителя ЛНС



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26 декабря 2018 года

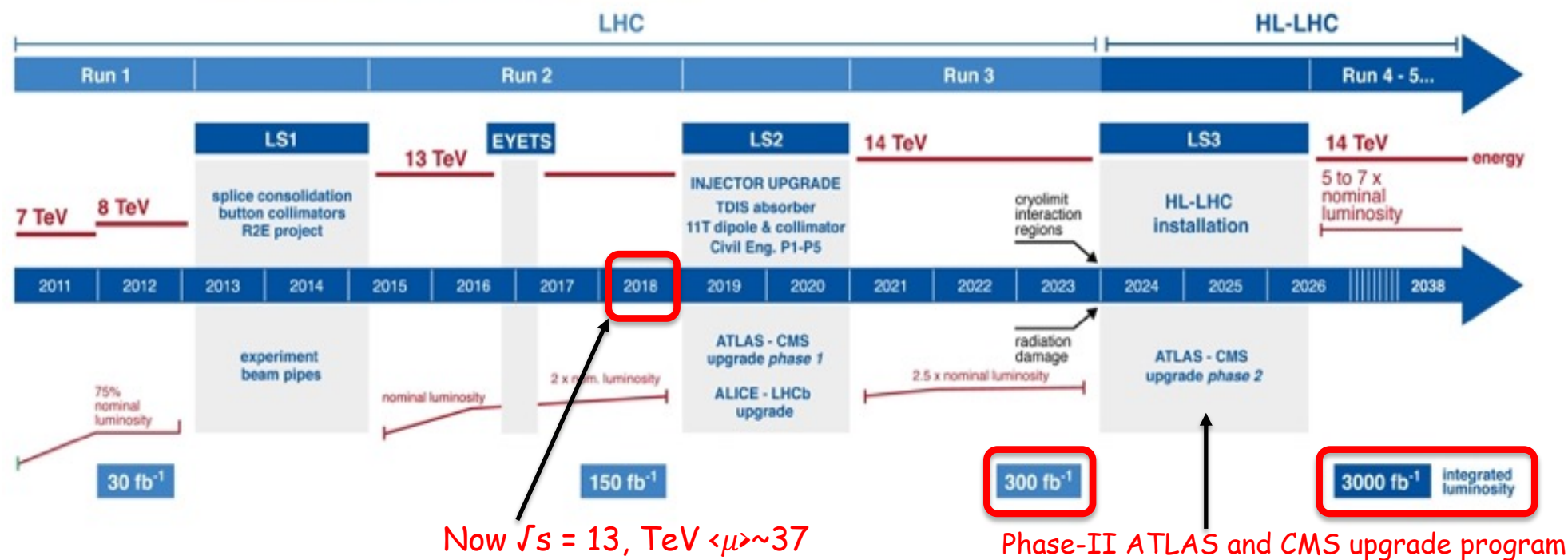


План работы ускорителя LHC



The High-Luminosity LHC program

LHC / HL-LHC Plan



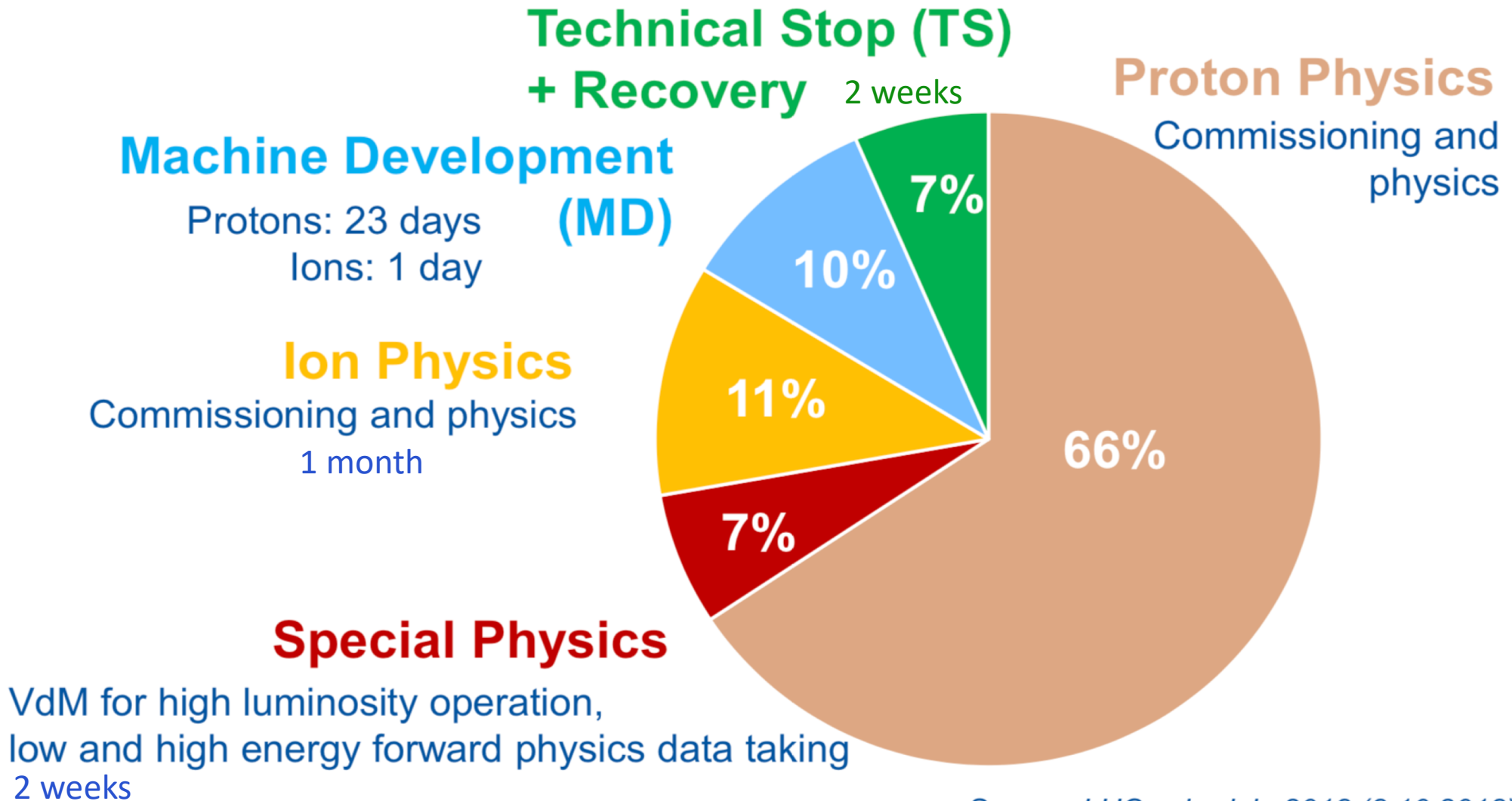
□ fff



LHC Beam operation 2018



Counted from 1st to last beam (~8 month)



Source: LHC schedule 2018 (8.10.2018)

From report of M. Schaumann, 191st CERN Council Open Session



Operation vs Design parameters



Parameters	Design	2018
Bunch population N_b [10^{11} p]	1,15	1,2 (->1,4)
No. of colliding bunches	2808	2556
No. bunches per train	288	144
Emittance ε [mm mrad]	3,75	$\sim 2,2$
Full crossing angle [urad]	285	300->260
Beta* (point 1/5) [cm]	55	30->27,5->25
Peak luminosity [10^{34} cm $^{-2}$ s $^{-1}$]	1.0	~ 2

Crossing angle & β^* levelling in IP1/5

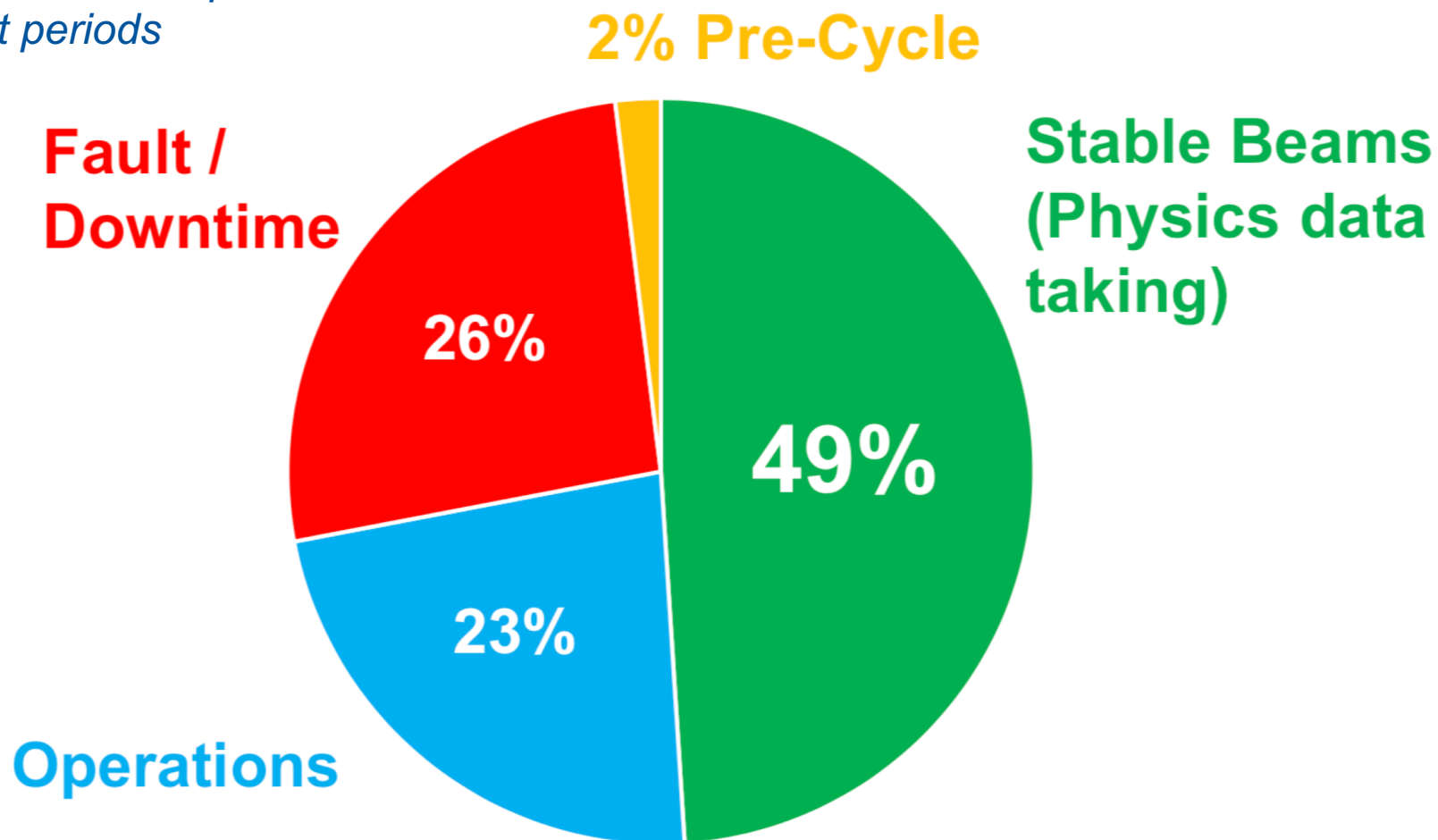
- ❑ *Many upgrades have already been implemented*
- ❑ **Beam quality from the injectors:** bright beams in various schemes
- ❑ **Direct luminosity enhancement:** ATS optics & anti-levelling
- ❑ **Cycle optimization:** e.g. simultaneous ramp and squeeze



LHC Availability: Proton Physics



Excluding Technical Stops and Machine Development periods



Source: Availability Working Group Reports: Restart to TS1, TS1 to TS2, TS2 to TS3

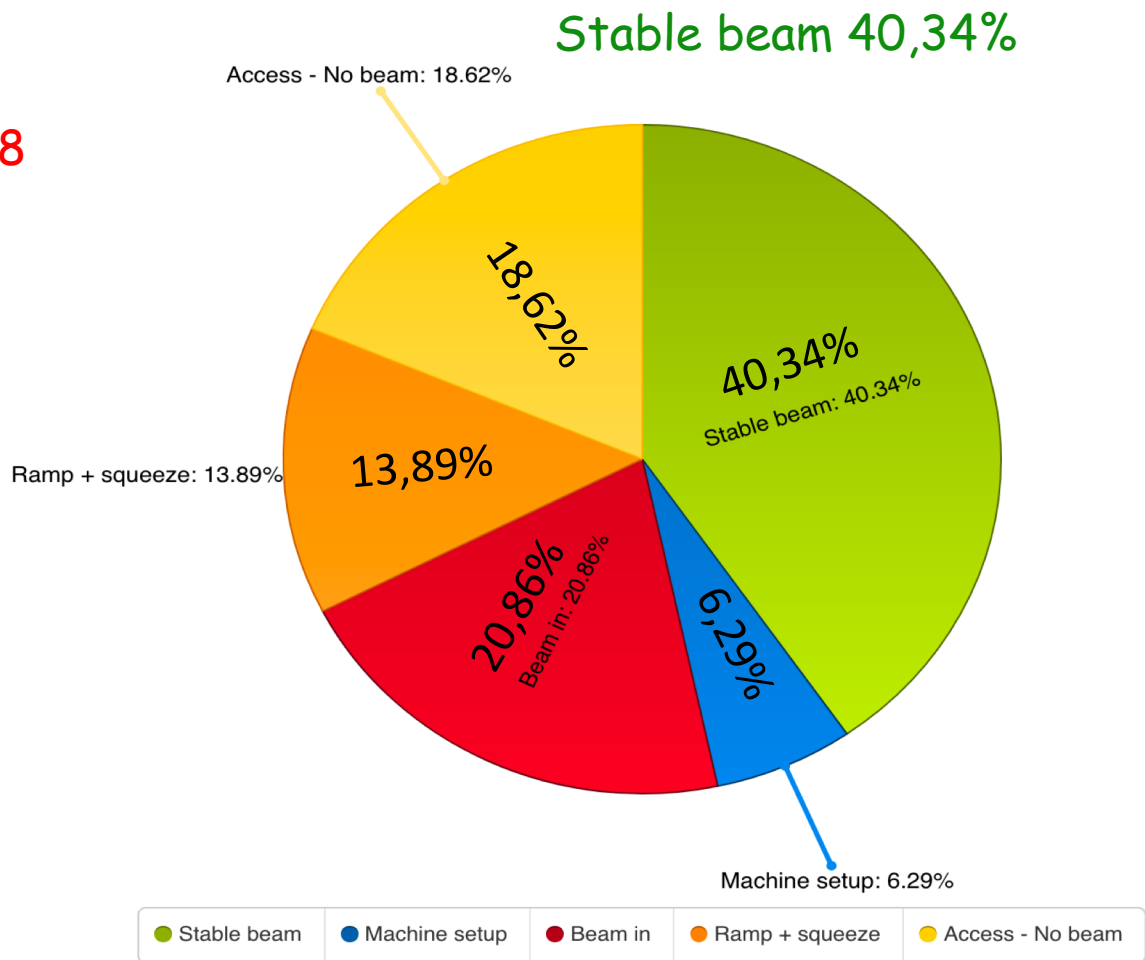
From report of M. Schaumann, 191st CERN Council Open Session



LHC Run efficiency



2018



Stable beam:

2015	35,29%
2017	42,06%
2018	40,34%



Main Limitations



□ *On Intensity:*

➤ Electron cloud

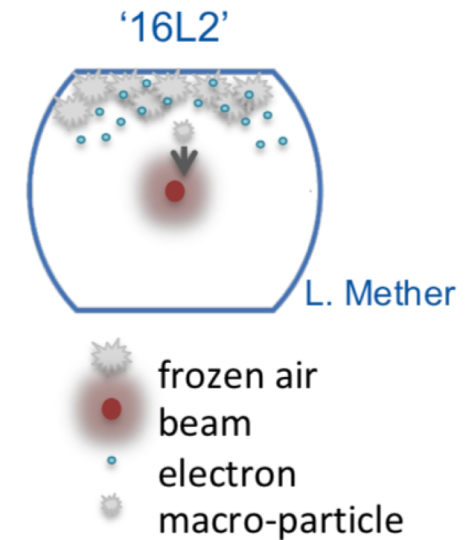
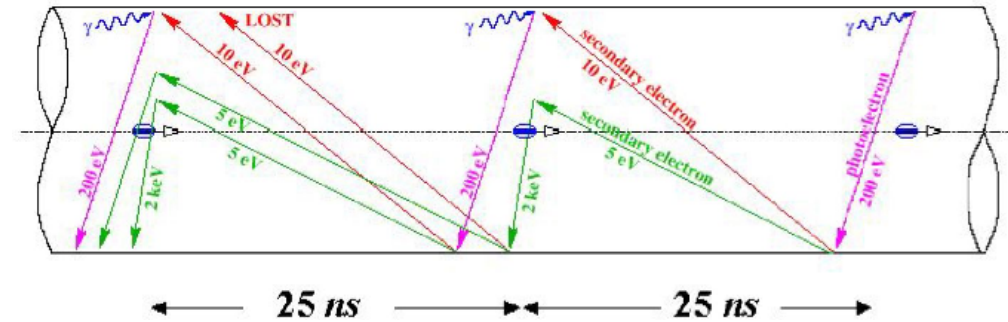
- Excessive energy deposition on vacuum chamber ->Heat load on cryogenic system
- Beam quality degradation

➤ '16L2' premature beam dumps

- Believed to be caused by frozen air particles falling through the beam.
- Bunch intensity limited to $\sim 1.15 \cdot 10^{11}$
- *No 16L2 event since August*

□ *On Peak Luminosity:*

- ### ➤ Limited to $\sim 2 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ by cryogenic cooling capacity in the triplet.

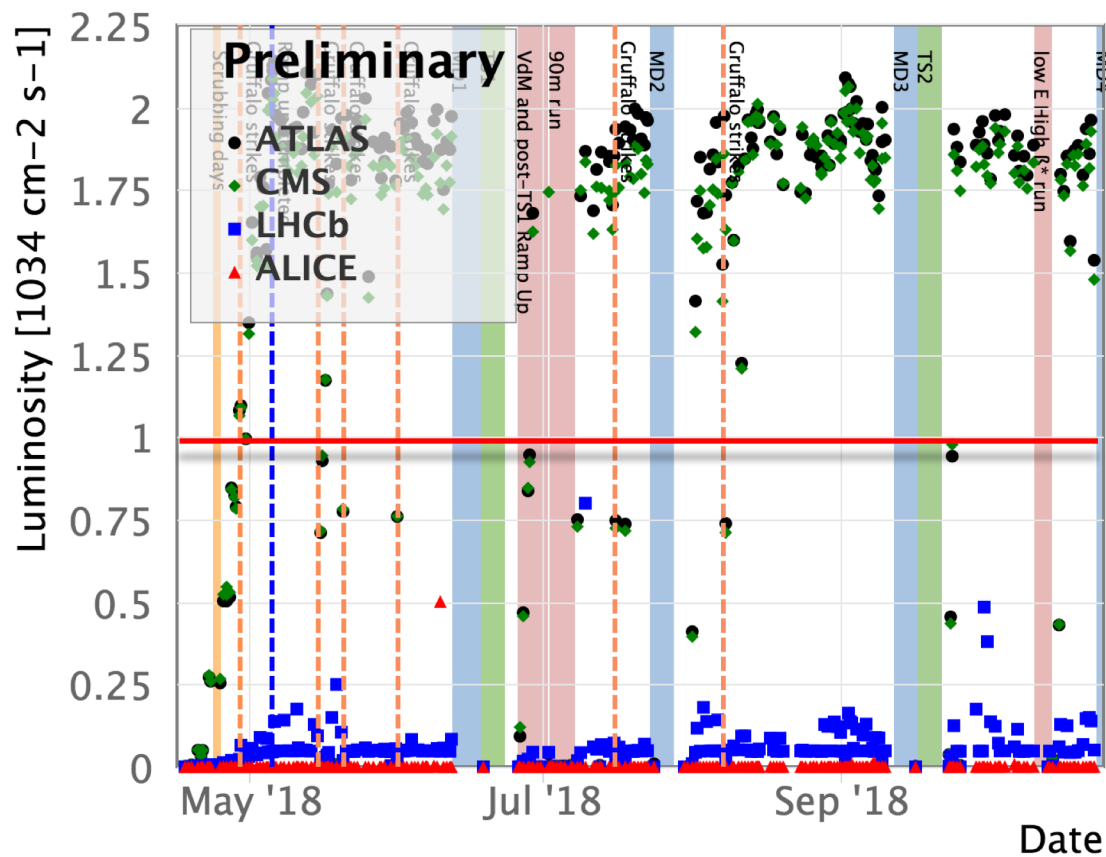




2018 Peak Luminosity per Fill



Peak Luminosity in 'Stable Beams'



New record of
 $L=2.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

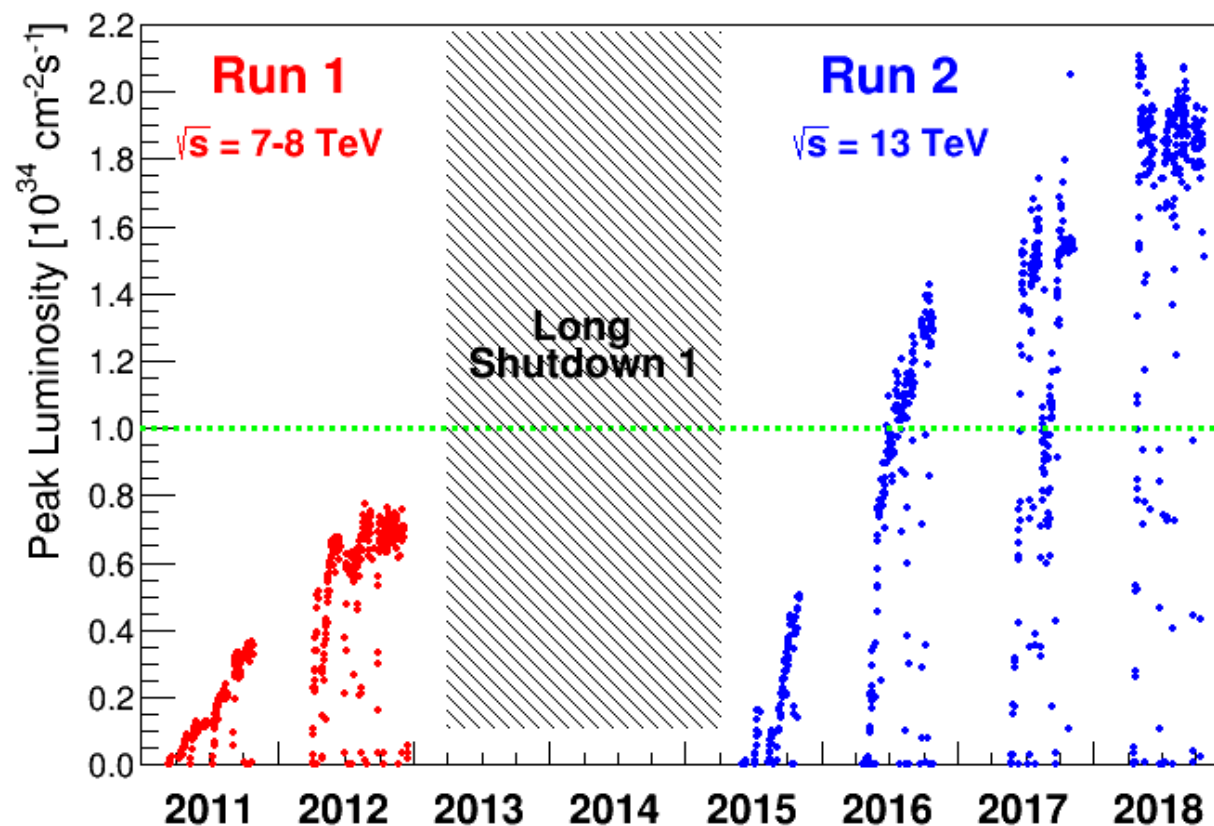
up to **2x design!**



Peak Luminosity- Run1 & Run2



2018 shows fastest increase in peak luminosity of all years with constant performance.



Source: <https://twiki.cern.ch/twiki/bin/viewauth/LhcMachine/LhcCoordinationMain>



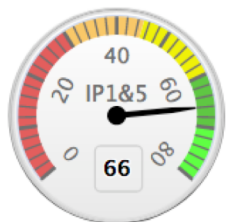
Luminosity Production 2018



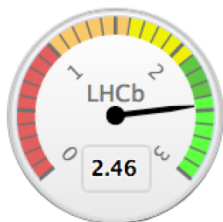
Official luminosity goal 2018:

- 60 fb⁻¹ for ATLAS/CMS,
- 2 fb⁻¹ for LHCb

Delivered luminosity



ATLAS/CMS

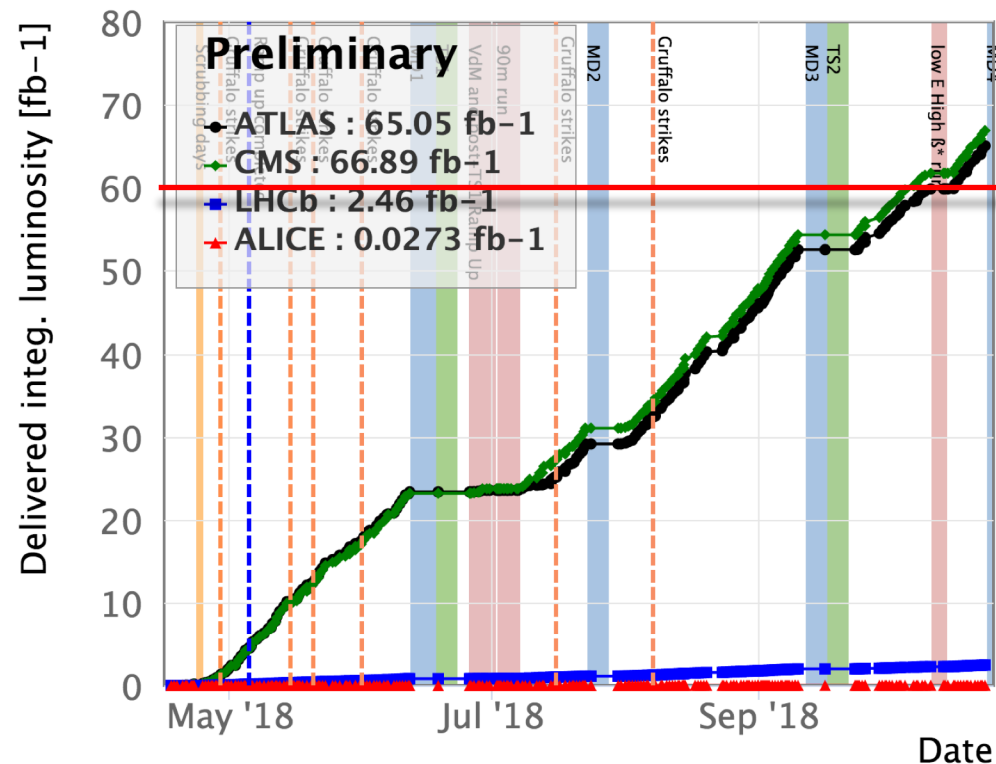


LHCb



ALICE

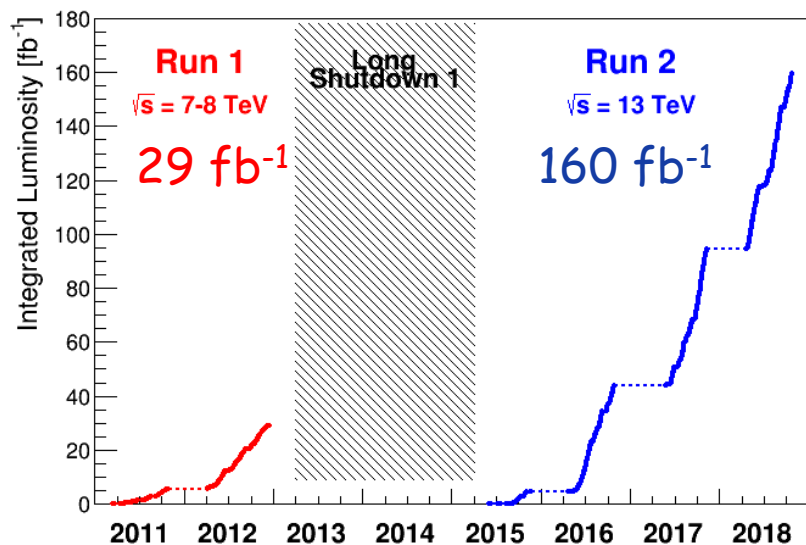
Delivered Luminosity 2018



Source: <http://lpc.web.cern.ch/>

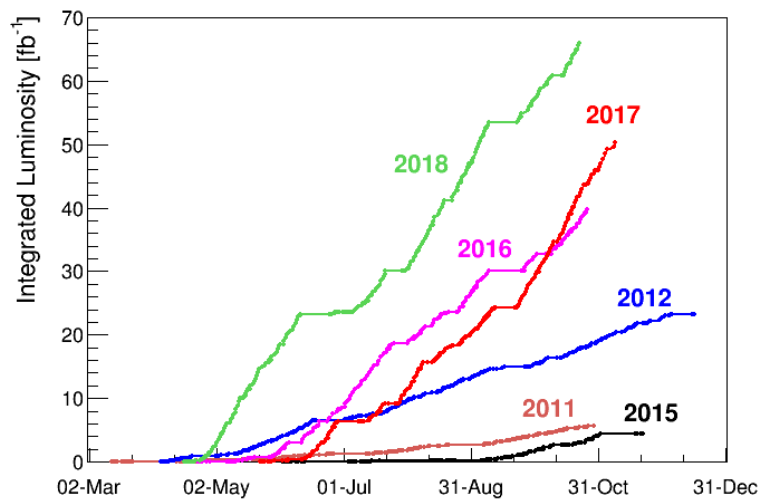


Luminosity Production - Run1+ Run2



- Integrated luminosity Run 2: 160fb^{-1}
- LHC total integrated proton-proton luminosity: **189fb^{-1}**

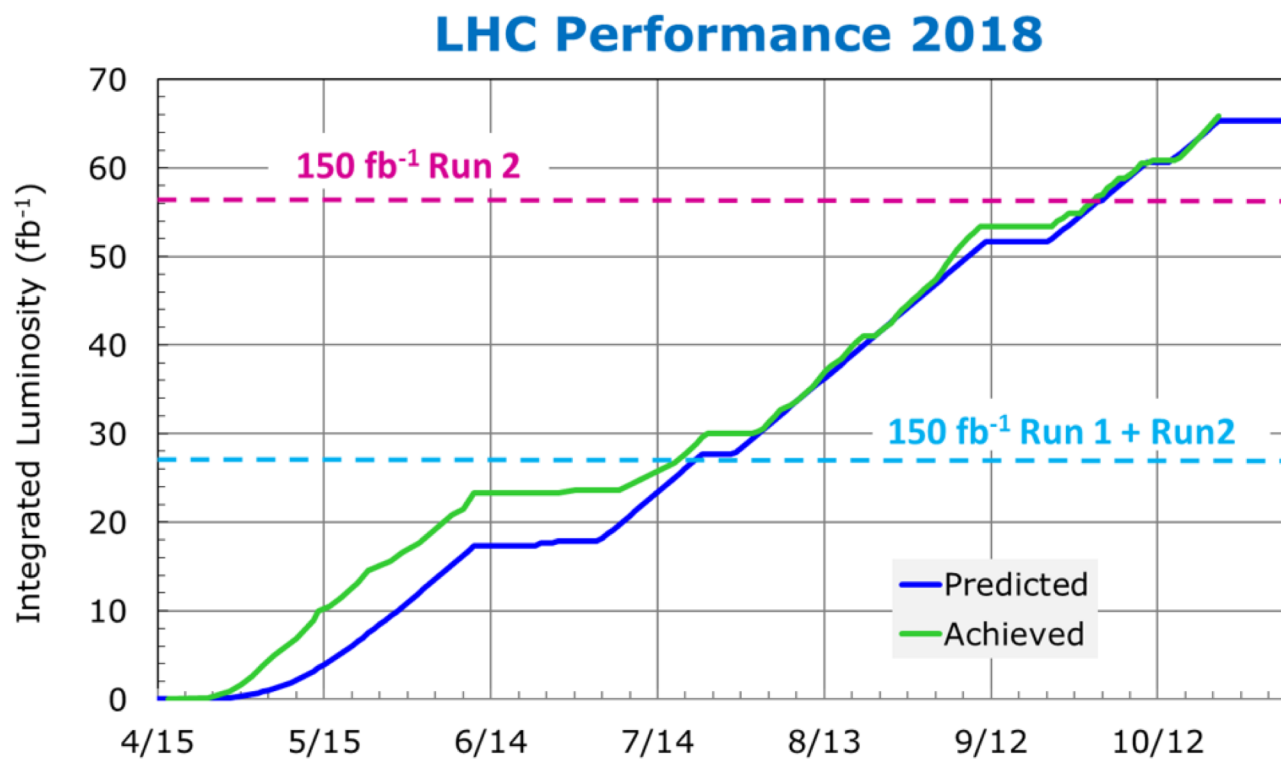
Period	Int. Luminosity [fb^{-1}]
Run 1	29.2
Run 2: 2015	4.2
Run 2: 2016	39.7
Run 2: 2017	50.2
Run 2: 2018	66
Total Run 1+ 2	189



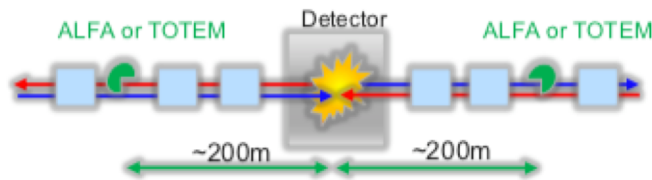
Source: <https://twiki.cern.ch/twiki/bin/viewauth/LhcMachine/LhcCoordinationMain>



LHC Performance 2018



Source: <https://twiki.cern.ch/twiki/bin/viewauth/LhcMachine/LhcCoordinationMain>



- Forward, low angle physics for **ALFA & TOTEM**
 - Measuring particles as close as possible to the beam to have acceptance for scattering processes at low momentum transfer (low t).
- Requirements:
 - **Large β^*** (low divergence) at the collision point & **low background**
 - **5 preparation sessions** in 2017/18 to investigate feasibility and data quality.
- Feasibility of the run relied on the **invention of two collimation schemes** to bring background down to required conditions.
- Total physics operation: 3d 15h
 - Excellent machine availability (95%)
 - Both detectors achieved the goal of **one million events** in good background conditions.

2017 preparation (3 session)	33 h
2018 preparation (May)	15 h
2018 preparation (September)	16 h
2018 data taking inc. setup	3d 15 h
Grand total	6 d 7 h



Heavy Ions in the LHC



- LHC has operated in 5 different modes, but was designed only for 2:
 - Design: **p-p, Pb-Pb**
 - Upgrade: **p-Pb, Xe-Xe (pilot run), Pb81+ (MD in July)**
- Since 2012 all 4 experiments have participated in heavy-ion data taking.
- Pb-Pb run was the last physics before LS2
- LHC Phase 1 luminosity goals for Pb-Pb have been exceeded in 2015+2018:
>1 nb⁻¹ for ALICE, ATLAS, CMS



Run Parameters



	Pb-Pb (Design)	Pb-Pb (2018 achieved)
Energy [TeV]	7Z	7Z
β^* at IP (1/2/5,8) [m]	(0.5, -)	(0.5, 1.5)
Emittance [μm]	1.5	~2
Bunch Intensity [10^8 ions]	0.7	2.3
No. Bunches	592	733
Bunch Spacing	100ns	100ns ->50 ns
Peak Luminosity at IP1/2/5/8 [$10^{27}\text{cm}^{-2}\text{s}^{-1}$]	- / 1 / 1 / -	6.4 / 1 / 6.4 / 1

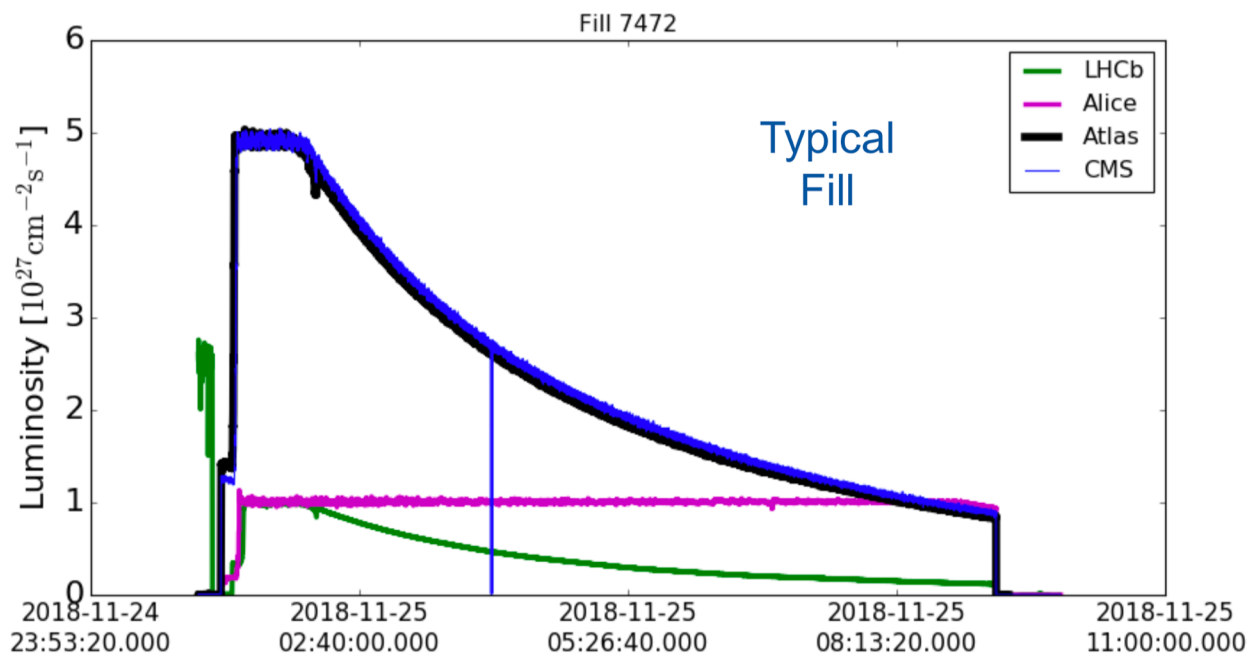
Green values reached & exceeded LHC design



Luminosity Evolution



- **Design peak luminosity was exceeded** by more than a **factor 6** in ATLAS/CMS.
 - **Almost reaching nominal HL-LHC target luminosity**
 - Demonstrated feasibility in ATLAS/CMS
- **ALICE levelled** to design saturation value **most of the time** in **Stable Beams** over an equivalent of 10.5 days.

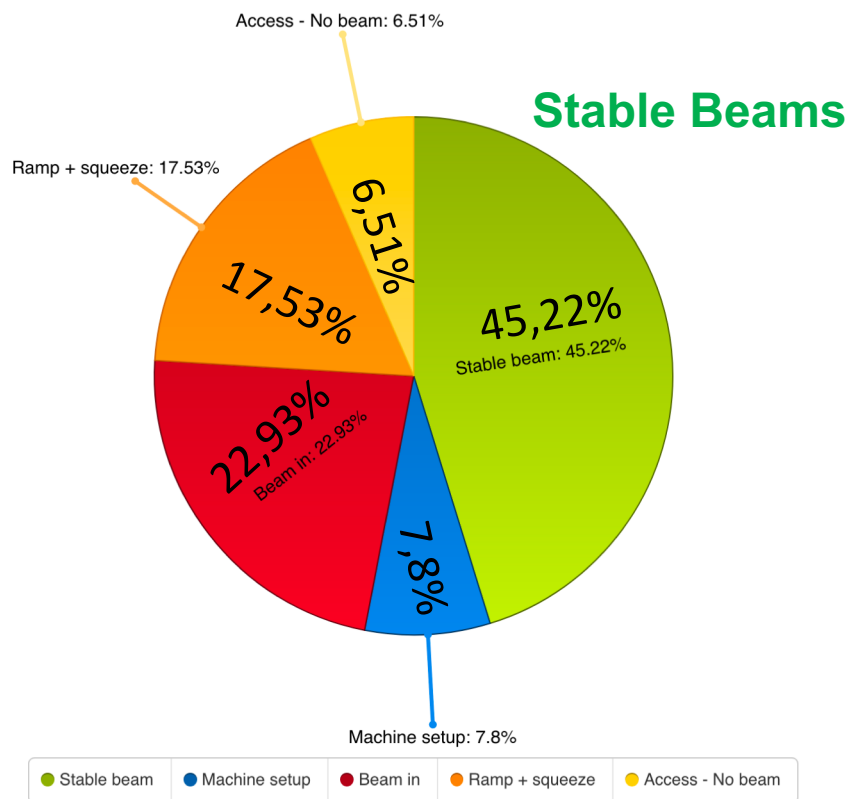




Accelerator Performance and Statistics



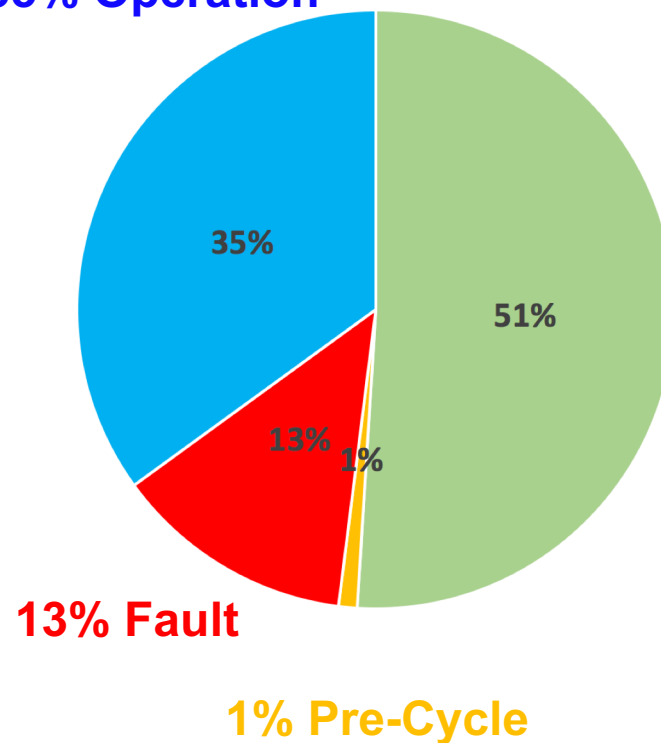
Efficiency



Availability 87%

35% Operation

51% Stable Beams



13% Fault

1% Pre-Cycle



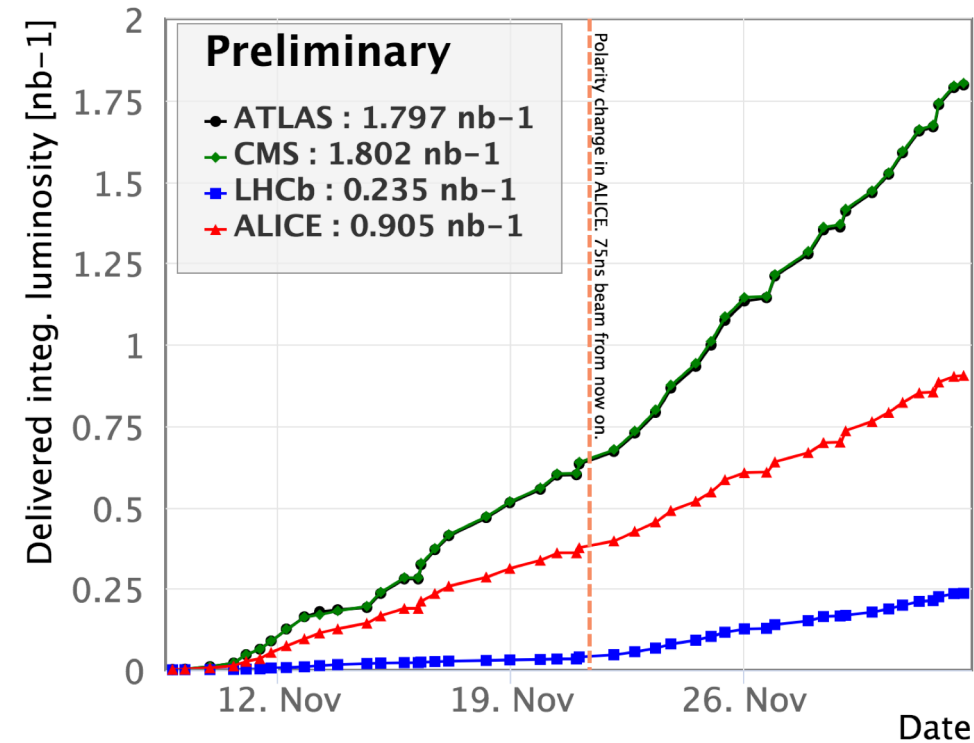
Delivered Luminosity



Performance of 2015 was well exceeded!

Initial 10 year Pb-Pb luminosity goal of 1nb^{-1} reached in 2 runs.

Delivered Luminosity 2018



	Delivered (by 03.12.2018)	2015 Pb-Pb	
ATLAS/CMS [μb^{-1}]	1800	584	x3
ALICE [μb^{-1}]	905	433	x2
LHCb [μb^{-1}]	235	6	x 39

LHCb int. luminosity ~two orders of magnitude above 2015 performance

Source: <http://lpc.web.cern.ch/>



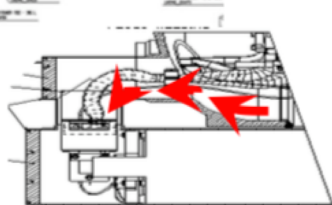
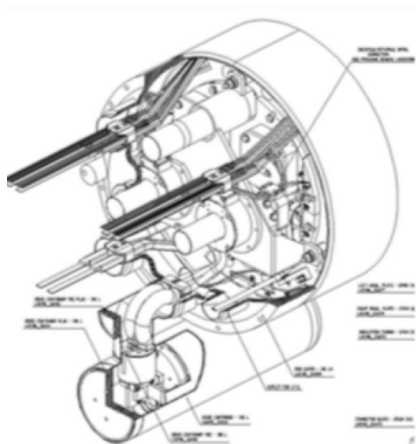
The Long Shutdown 2 (LS2)



The Long Shutdown 2 (2019-2020) is driven by a **major upgrade of the LHC injectors** to reach the HL-LHC beam parameter targets!

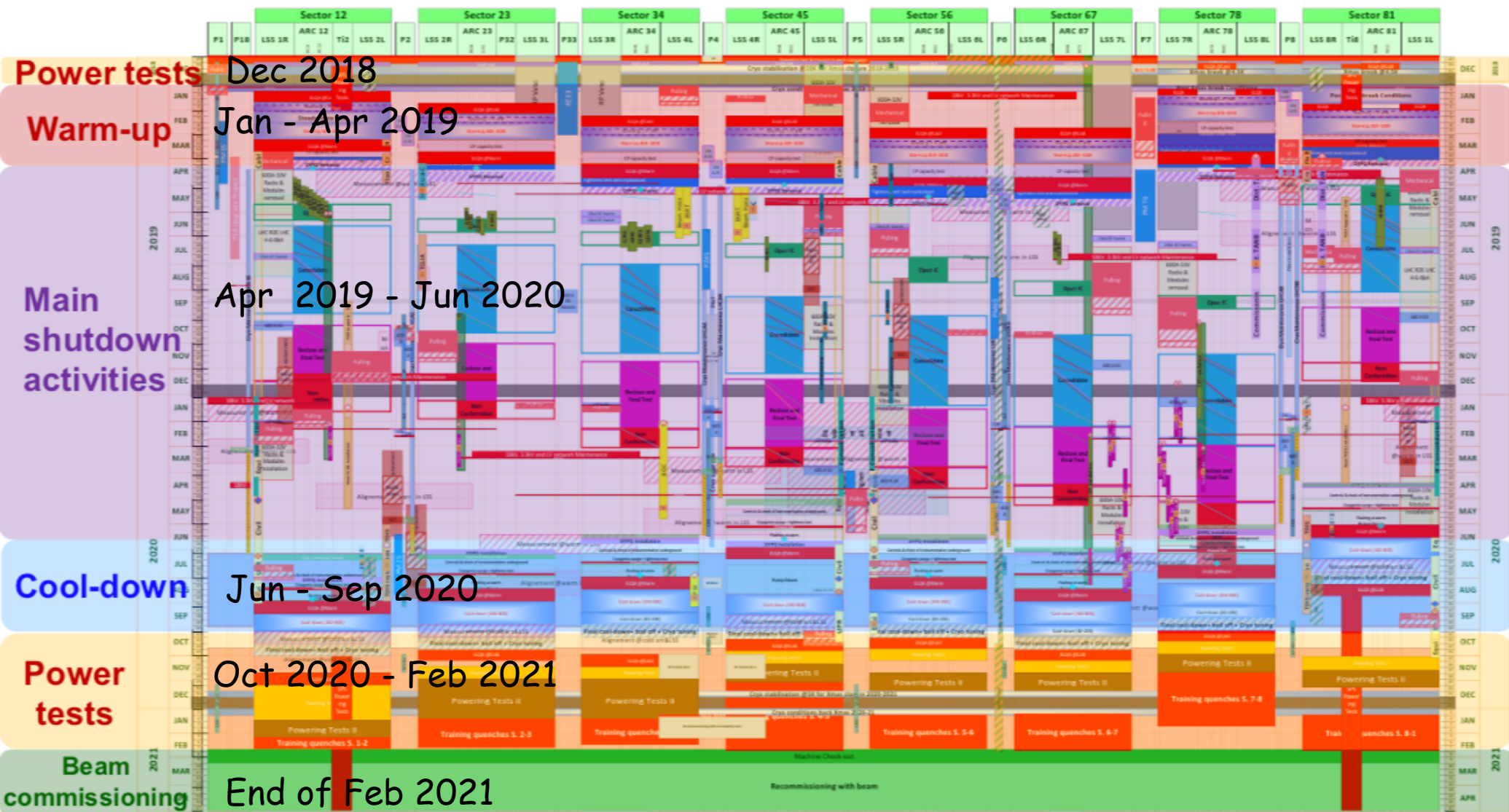
Major activities for LHC are:

- ❑ Consolidation of **diode insulation**
- ❑ Installation of **4 x 11 T magnets**
- ❑ Replacement of **~20 magnets** with non-conformities
- ❑ **Maintenance and consolidation** of several machine elements (cryogenics, collimators, beam instrumentation, RF, ...)





The Long Shutdown 2 (LS2)



First Run 3 physics expected in May-June 2021



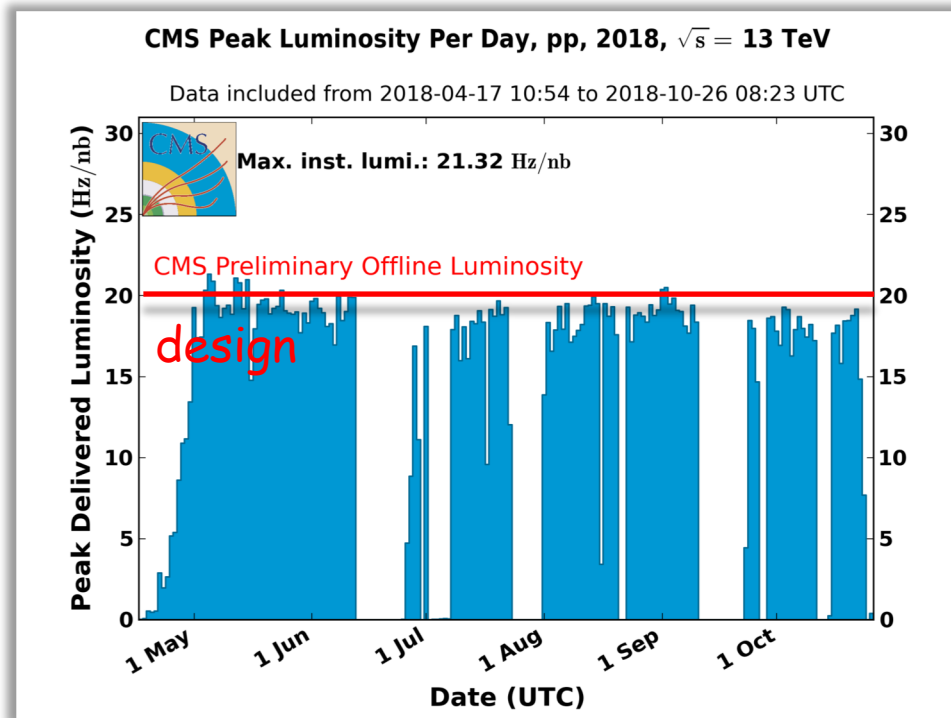
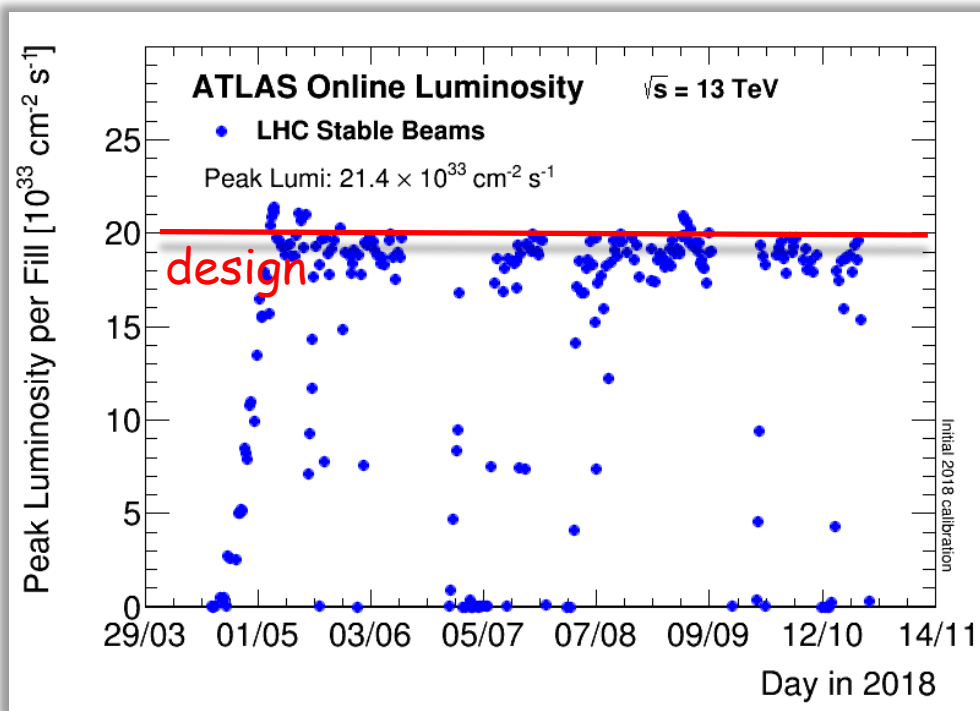
SHUTDOWN: NO BEAM

СПАСИБО ЗА ВНИМАНИЕ

		BIS status and SMP flags		B1	B2
Comments (10-Dec-2018 09:18:01)		Link Status of Beam Permits	false	false	false
		Global Beam Permit	false	false	false
LS2		Setup Beam	true	true	true
		Beam Presence	false	false	false
		Moveable Devices Allowed In	false	false	false
		Stable Beams	false	false	false



Peak luminosity ATLAS & CMS

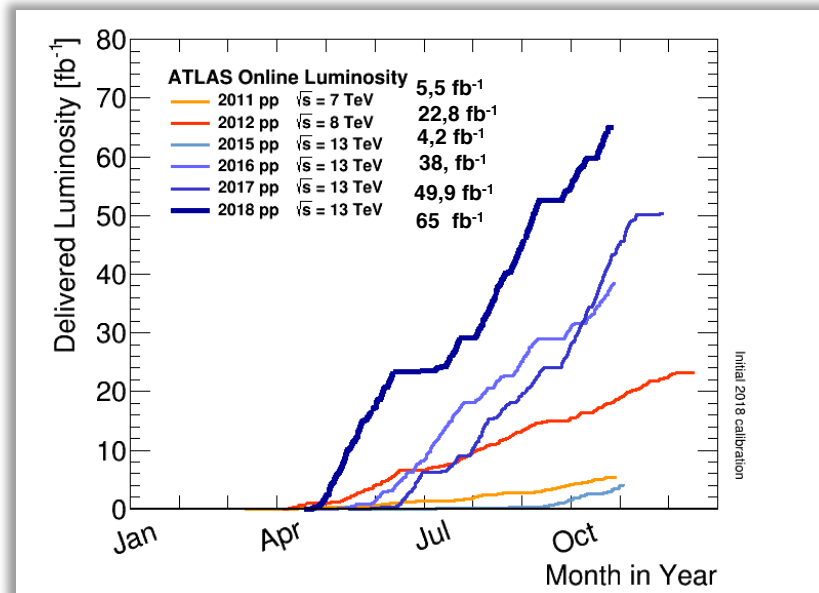
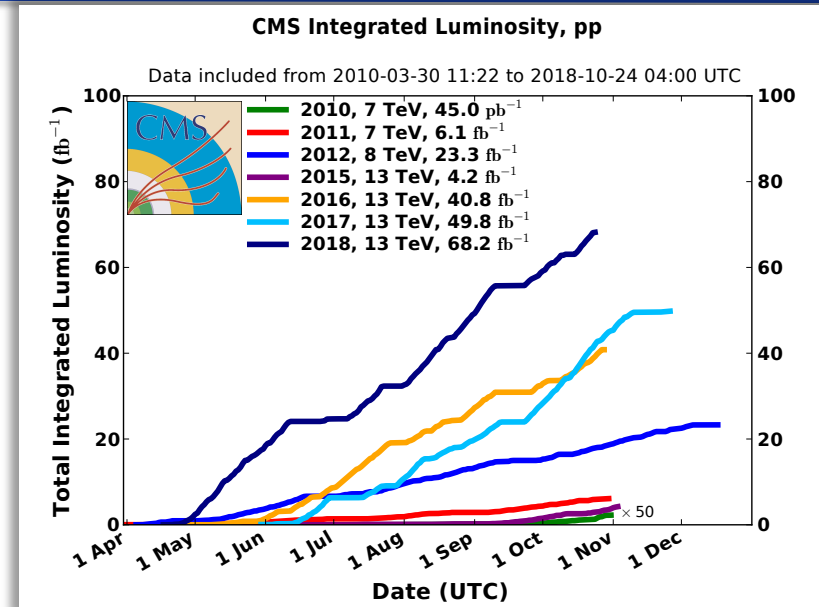
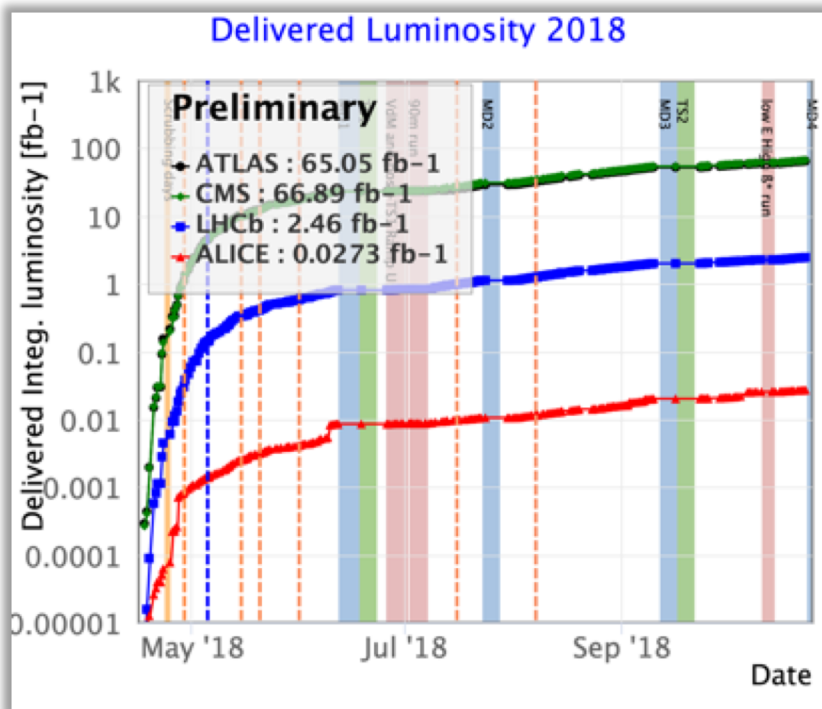


Пиковая светимость в 2018 году составила:

- ATLAS $21,4 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- CMS $21,3 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$



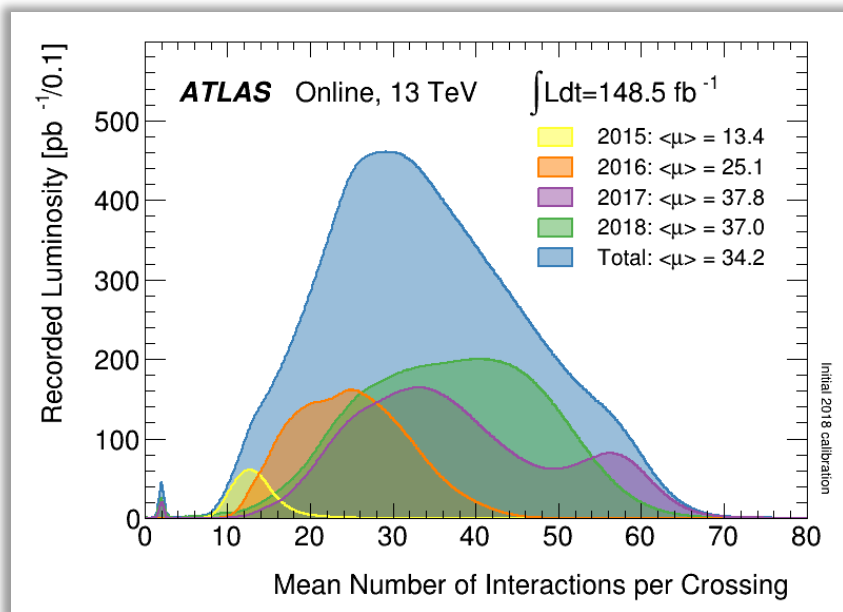
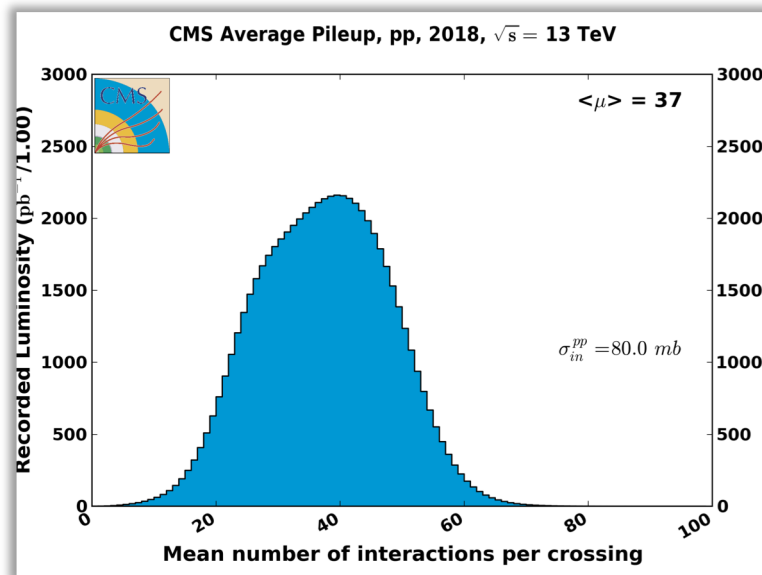
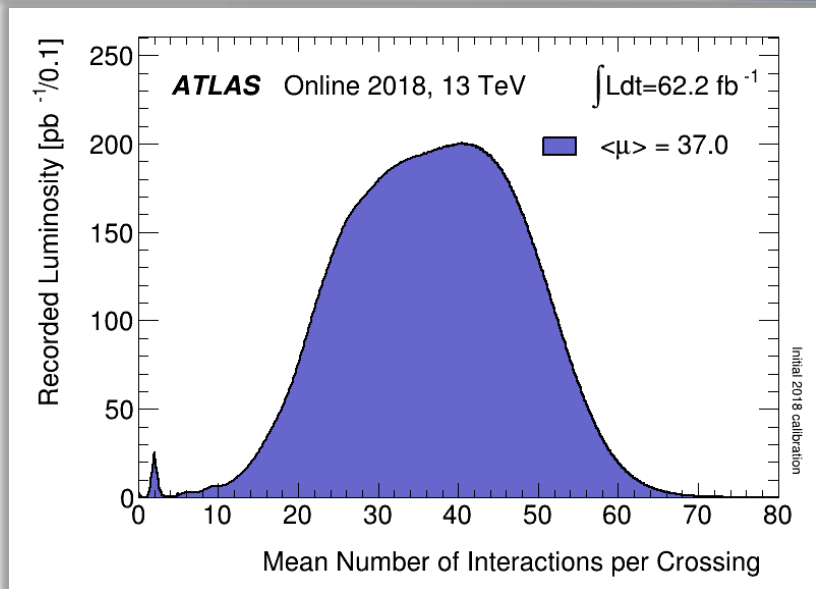
Integrated luminosity ATLAS vs CMS



- Энергия пучков - 6,5+6,5 ТэВ
- Максимальное количество bunches - 2544
- Пиковая светимость в ATLAS в 2018 (2017) году составила $2,1 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$!!! (20,6)
- Среднее кол-во столкновений на одно пересечение пучков - 37 (25)



Pileup



$$\mu = L_{\text{bunch}} \times \sigma_{\text{inel}} / f_r, \sigma_{\text{inel}} = 80 \text{ mb}$$

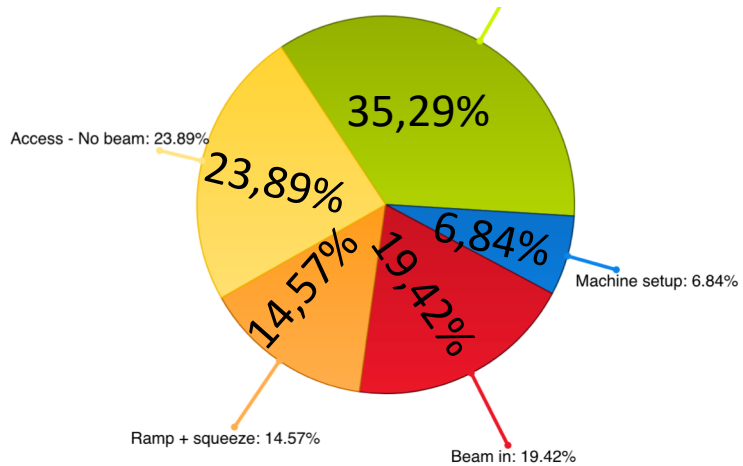


LHC Run efficiency



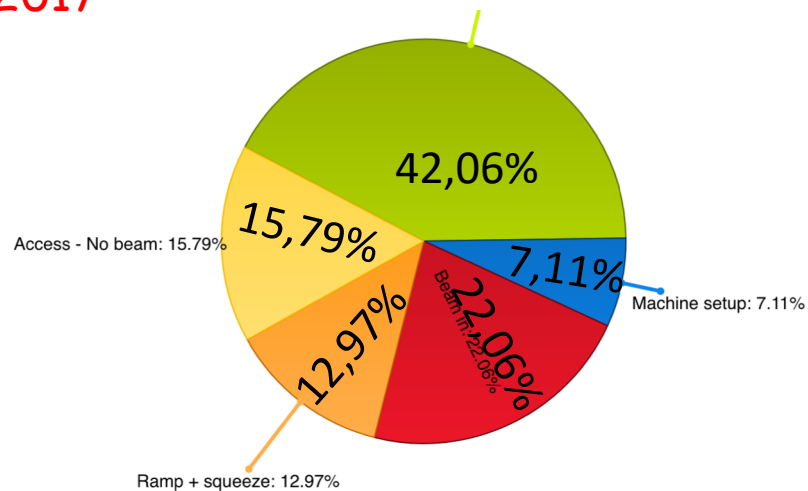
2016

Stable beam 35,29%



2017

Stable beam 42,06%



2018

Stable beam 40,34%

