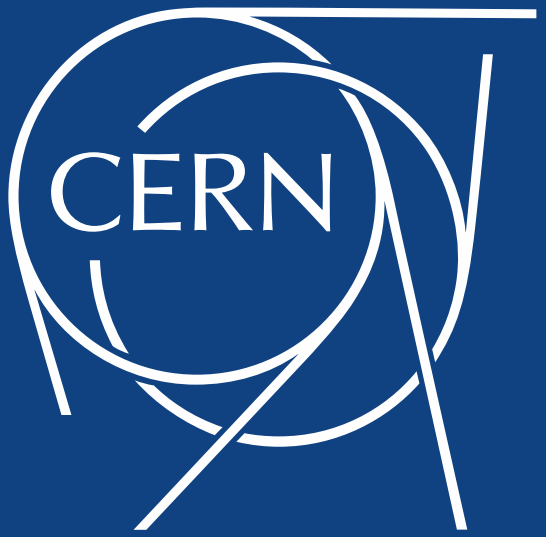

CERN

LHC nominal cycle

M.Solfaroli
BE department
OP group

Thanks to LHC/OP

Outline

- Turnaround
- Cycle phases - analysis
- 2012 comparison
- Changes
- Conclusions

Analysis method

- **Set of fills**
  - Physics fills (with SB)
  - Only proton fills are considered
  - According to the case 50 ns and 25 ns are sometimes separated
- **Beam mode declaration time is used (from logging DB)**
- **Beam dump, Rampdown and Setup are not considered**
  - Beam dump is always very short and the time not really meaningful
  - Separation between Rampdown and Setup is not “reproducible”
  - Rampdown+Setup time is also not considered as
    - It’s mostly representative of faults and/or problems
    - This modes are not always present as the fill number is sometimes changed at injection (very noisy statistic)

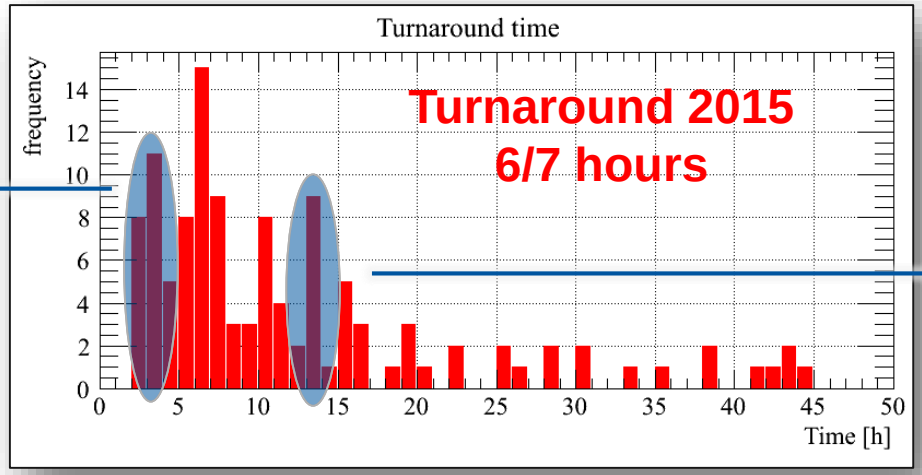
…very very similar to the analysis presented in this workshop in 2012!!

The LHC TURNAROUND

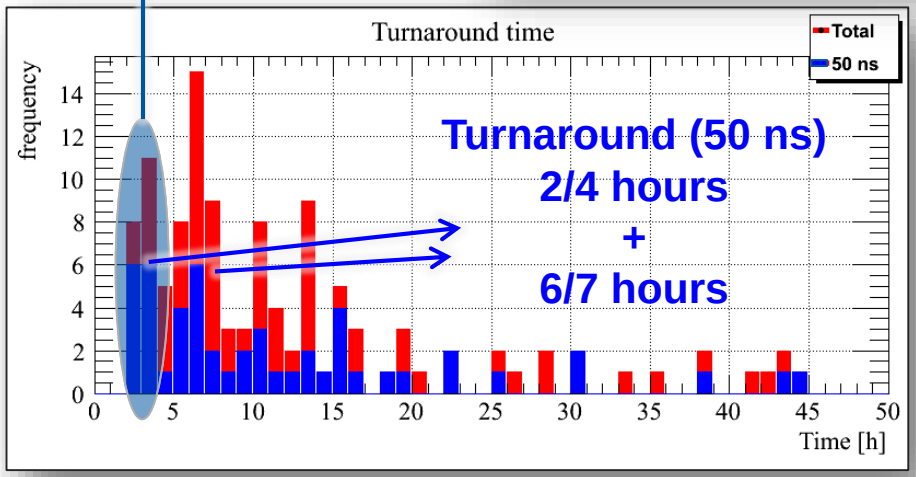
Turnaround = time from SB to SB

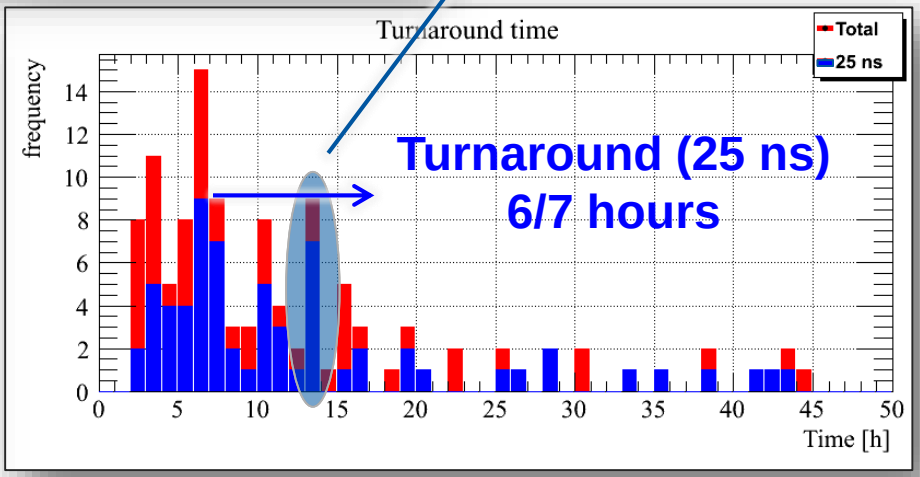
END of SB | time | START of SB

Short time mainly present for 50 ns. Independent on injection time and on chronological distribution



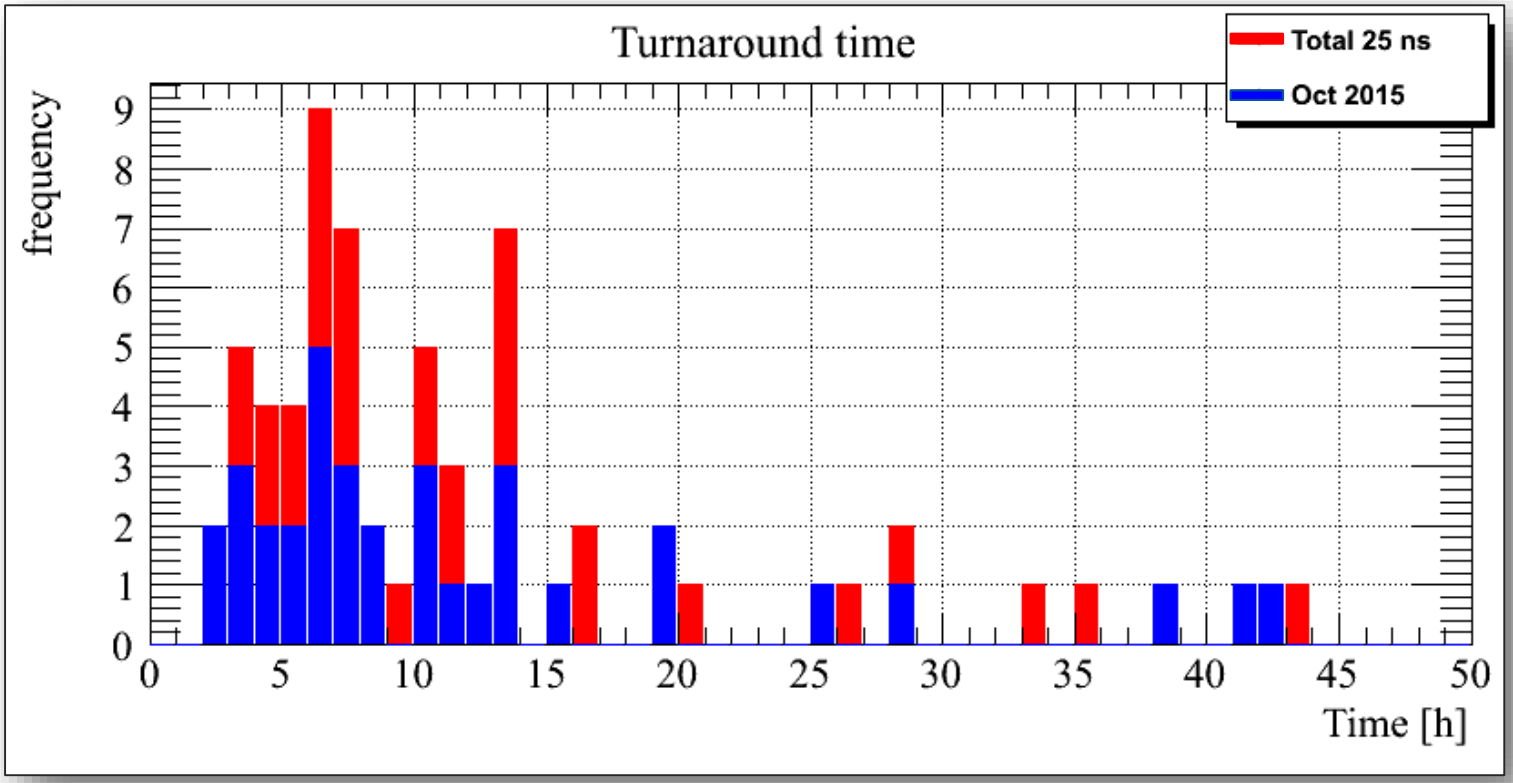
No correlation between the fills:
- Aug-Sept-Oct
- LM, Access, Precycle, TL steering,…
- …





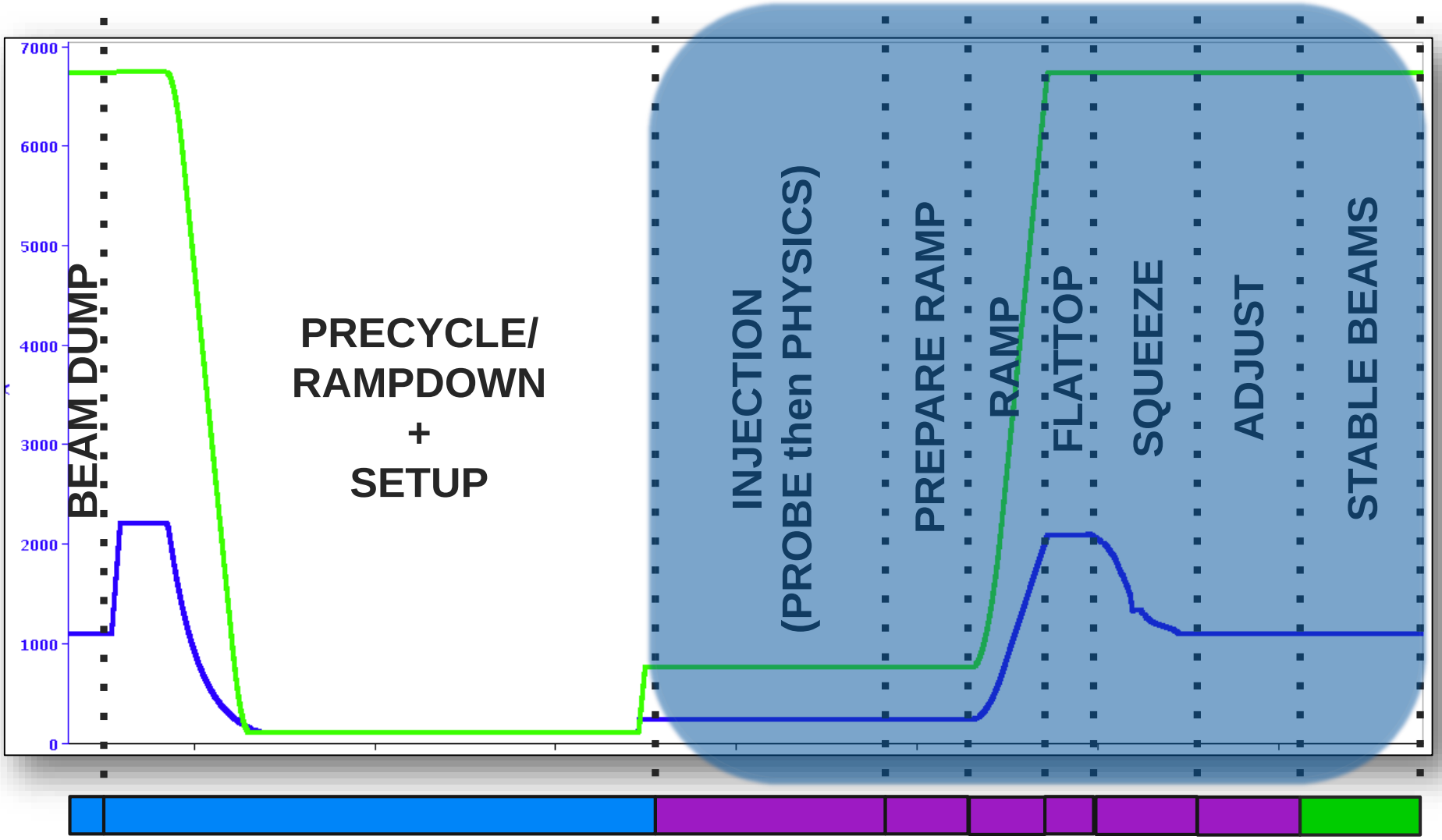
The LHC TURNAROUND (last month)

Turnaround = time from SB to SB



No visible improvement in the last month (Oct 2015)
the statistics reflects the 25 ns one

LHC operational beam modes

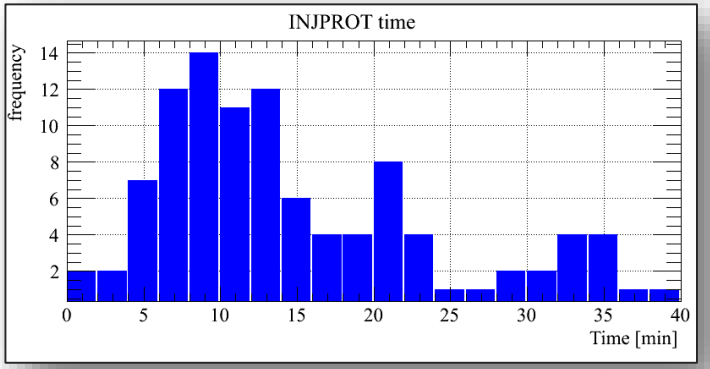


Injection

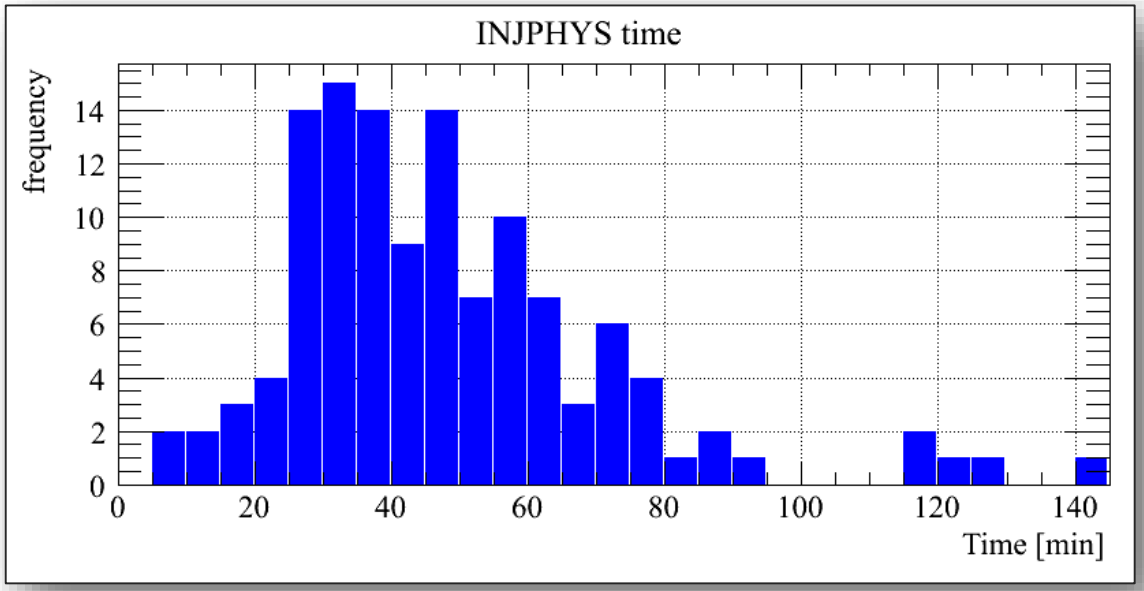
WHAT WE DO

- ✓ Inject 1/12 b (“pilot”)
- ✓ Sometimes TL steering
- ✓ Inject 144 b
- ✓ Wire scanner
- ✓ Fill the machine
- ✓ Close INJ handshake
- ✓ Start moving injection protection out

- ✓ Pilot injection
- ✓ Q & Q’ & coupling correction

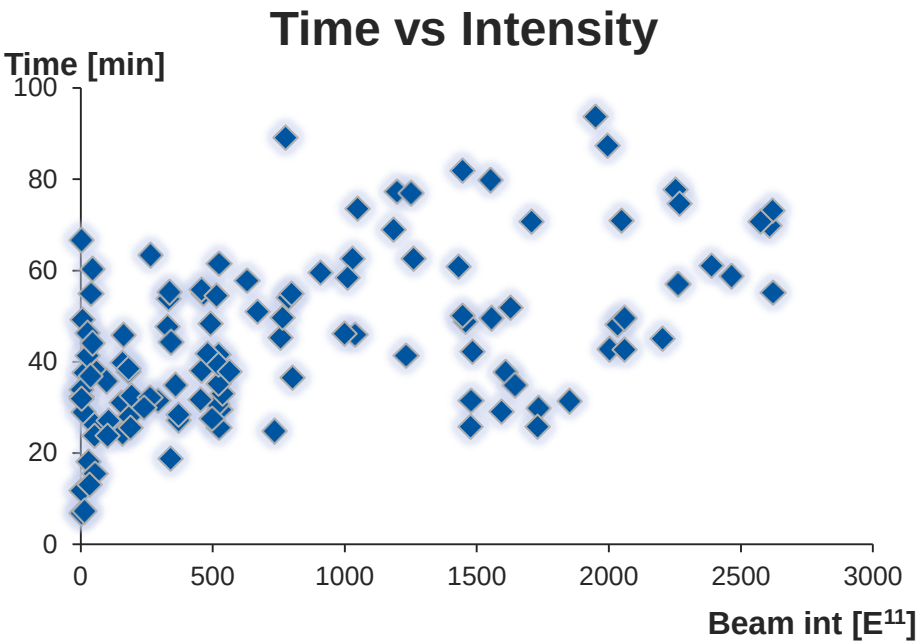


MEAN	MEDIAN
23.9 min	14.0 min



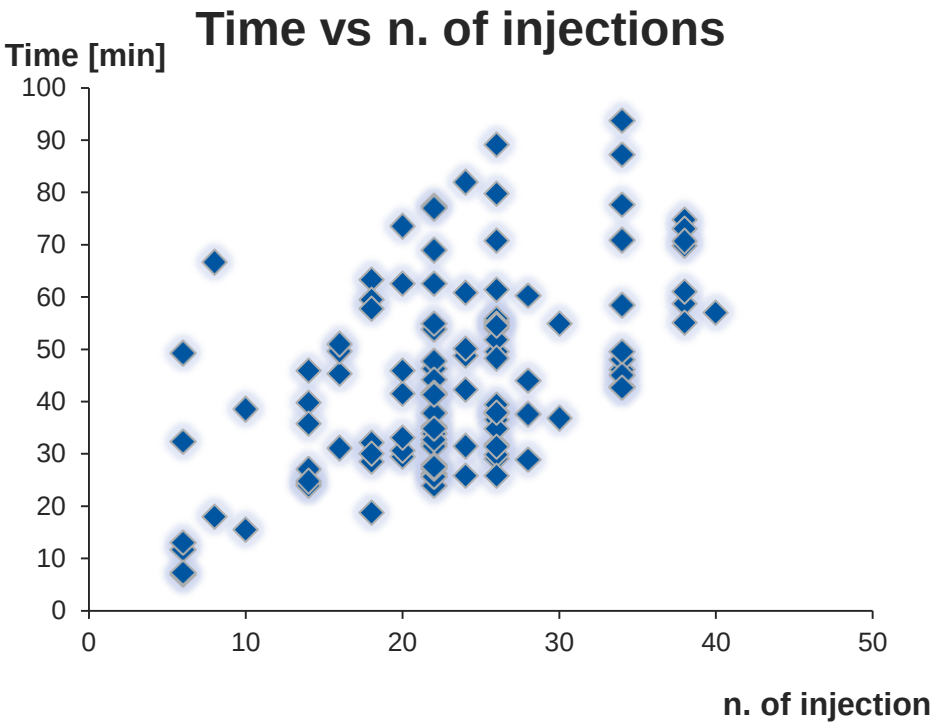
MEAN	MEDIAN
48.2 min	44.1 min

Some analysis attempts

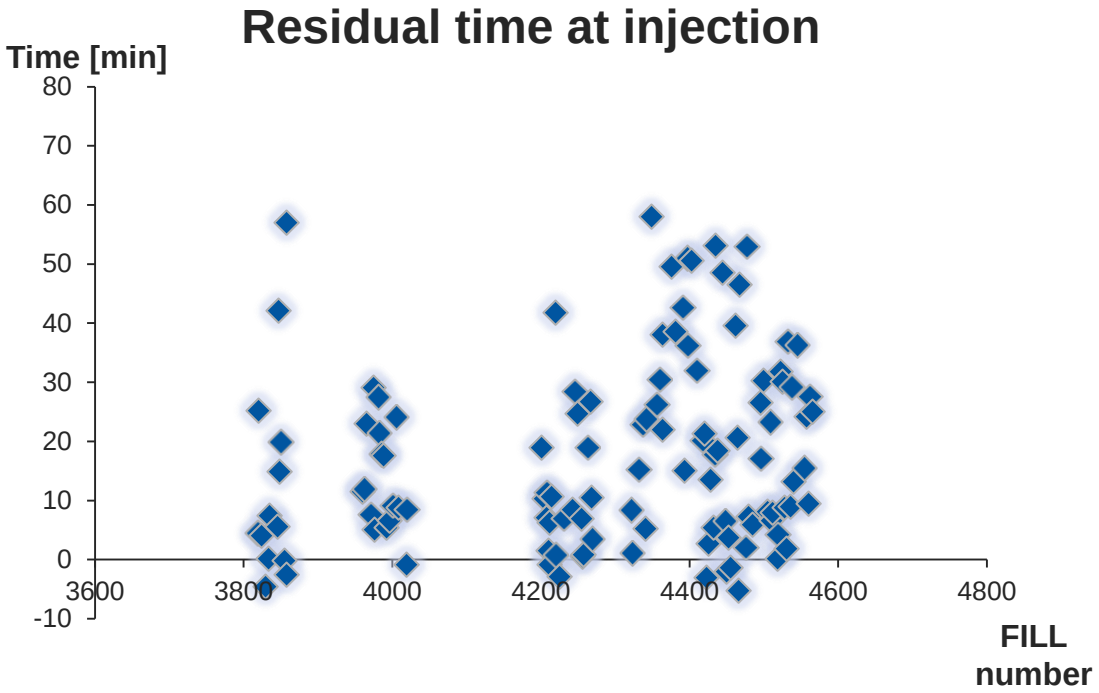


Theoretical injection (physics) time
=
N#injections * SPS supercyle length
(~1 minute)

…up to ~45 minutes in 2015



Some (more) analysis attempts



$T_{INJ} - T_{eff} - T_{miss\_inj}$

EFFECTIVE injection time
T_{eff} = SPS supercycle length * n. of injections

Compensation for missed injection
T_{miss} = SPS supercycle *20% of injections

…it's just pure luck!!

Several factors impact the injection process:

- Intensity (vac, cryo,etc)
- Number of injections
- TL steering
- Quality & availability of the beam from injector chain
- Not standard increase of fill numbers

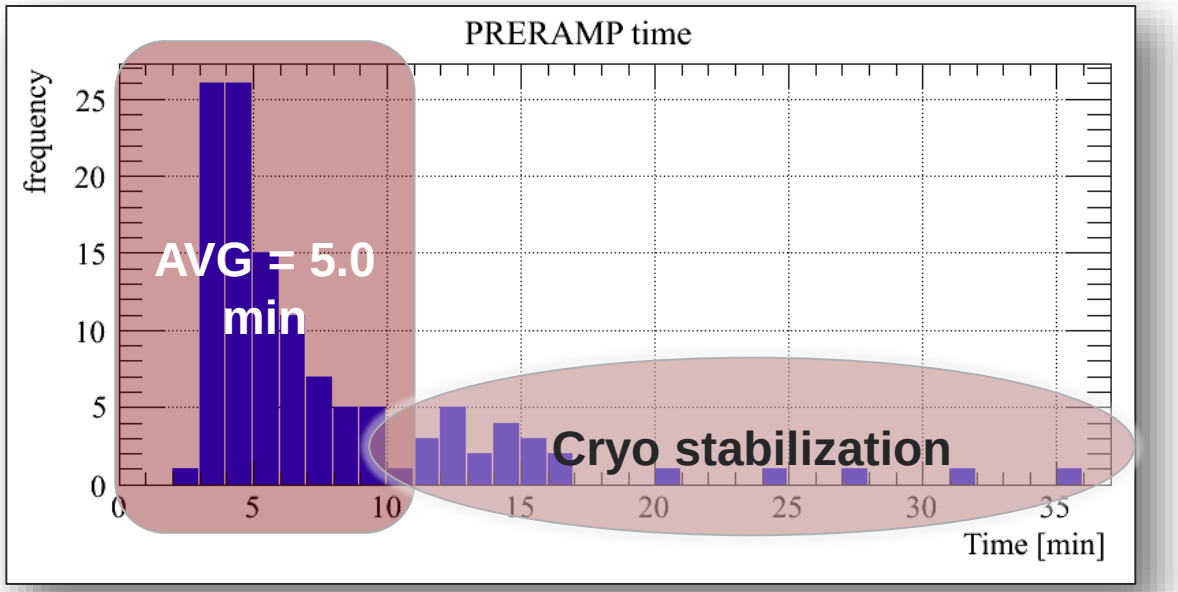
Prepare Ramp

WHAT WE DO

- ✓ **Change feedback references**
- ✓ **Settings incorporation**
- ✓ **Settings loading (RF, PC, COLL)**

Theoretical time ~ 4 min

- ✓ **Waiting for cryo stabilization (sometimes)**



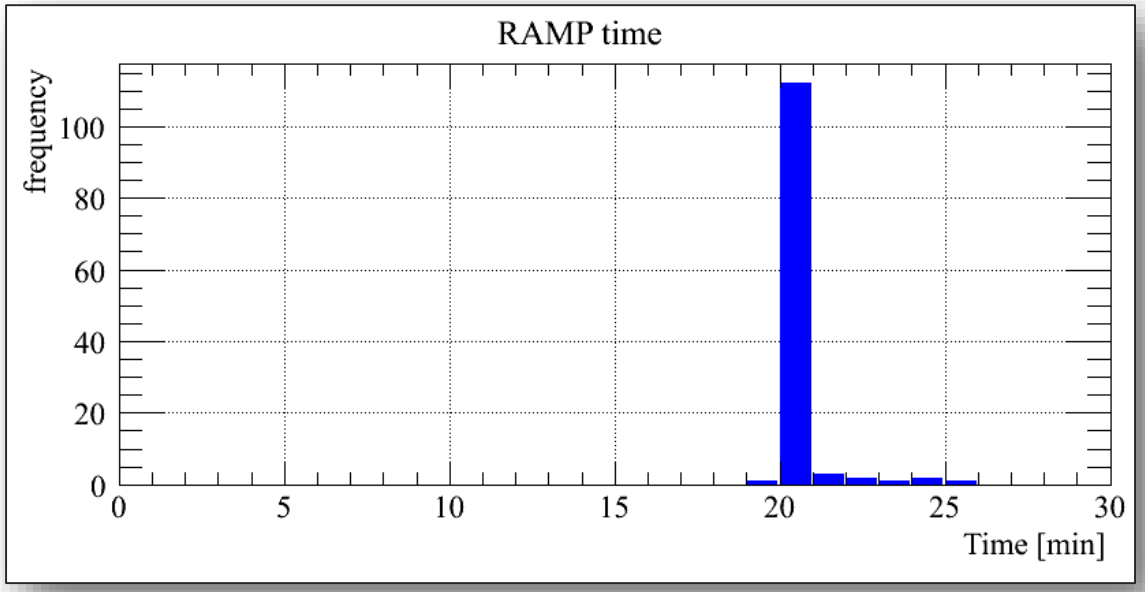
MEAN	MEDIAN
10.0 min	5.4 min

- Cryo stabilization (with high intensity)
- K-level incorporation of settings (randomly happening)
- Fidel-like manual incorporation of Q (beginning of the year)

Ramp

WHAT WE DO

✓ **Ramp settings play** ➔ **settings length = 1210 sec**



MEAN	MEDIAN
20.7 min	20.4 min

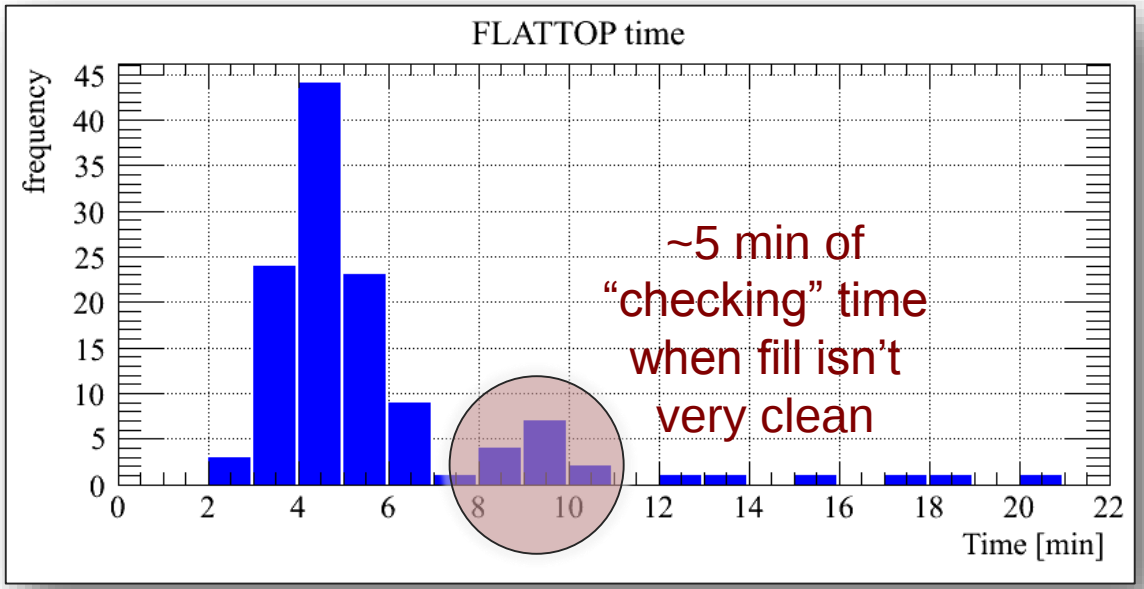
Very good reproducibility as in the majority of cases a “run” command is sent to the sequencer (next BM is declared as soon as the settings table is completed)

Flattop

WHAT WE DO

- ✓ **FB reference change**
- ✓ **Q change settings load and play**
- ✓ **FB reference change for squeeze**
- ✓ **Settings incorporation**
- ✓ **Squeeze settings load**

Theoretical time
~ 5 min
(20 sec of settings for Q change)



MEAN	MEDIAN
5.9 min	4.8 min

~4min spread is due to manual operations (no systematic problem appeared)

Squeeze

WHAT WE DO

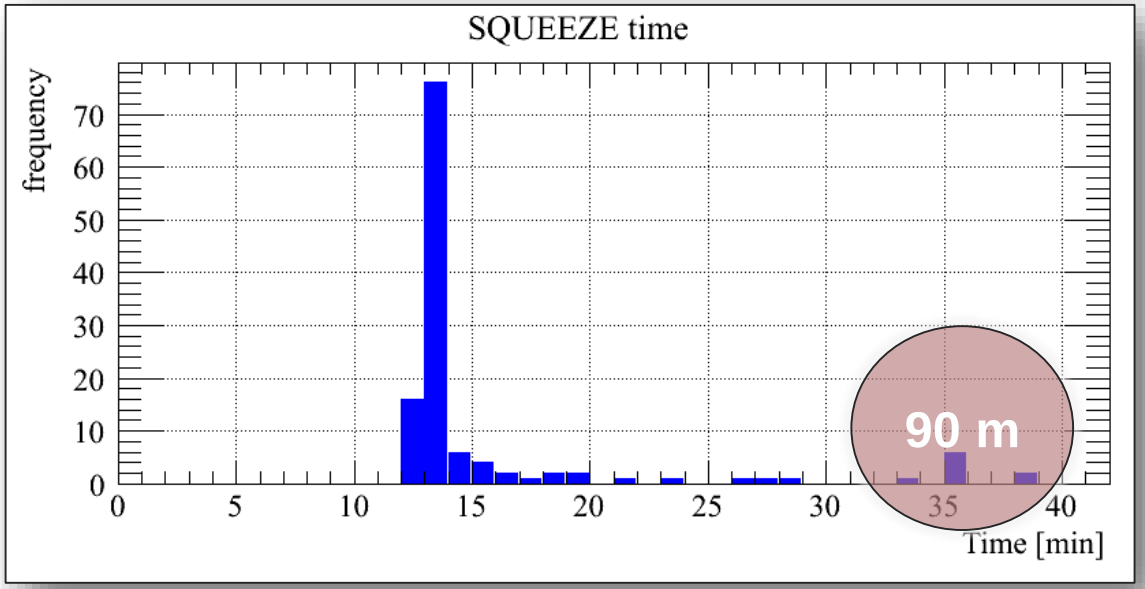
- ✓ **Squeeze setting play ➔ settings length = 749 sec (12.5 min)**

All data

MEAN	MEDIAN
15.7 min	13.2 min

90 m excluded

MEAN	MEDIAN
14.1 min	13.1 min



Very good reproducibility as in the majority of cases a “run” command is sent to the sequencer (next BM is declared as soon as the settings table is completed)

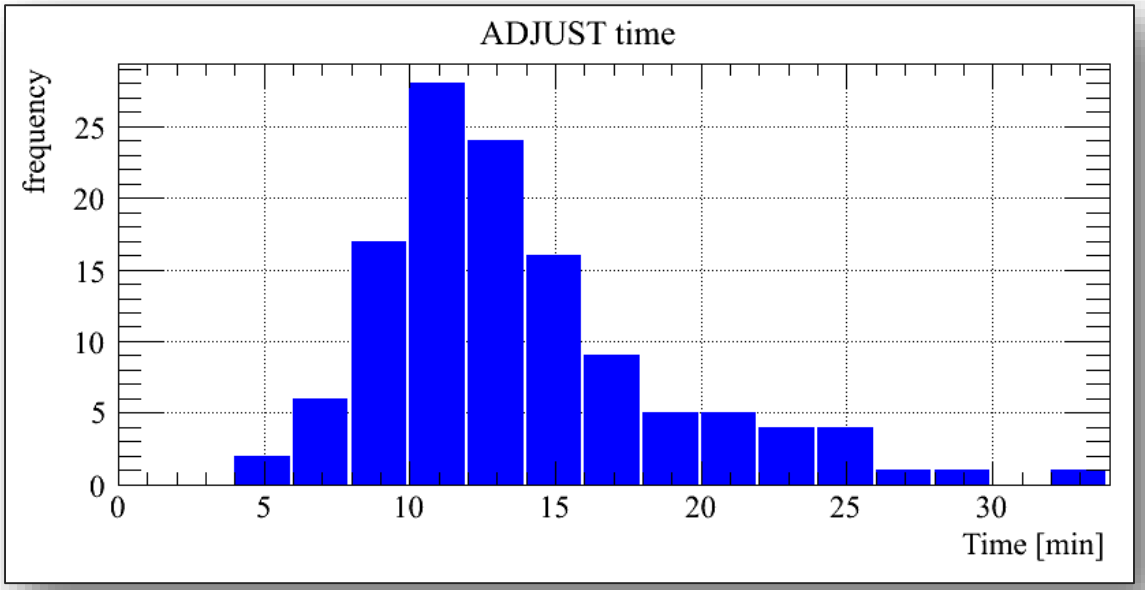
Adjust

WHAT WE DO

- ✓ **Setting incorporation and play**
- ✓ **Optimization of IP1/5 (if needed)**
- ✓ **Settings incorporation and play**
- ✓ **Optimization of IP1/5**

(between ADJUST and STABLE BEAMS)

Theoretical time
~ 10 min
(150 sec of settings)

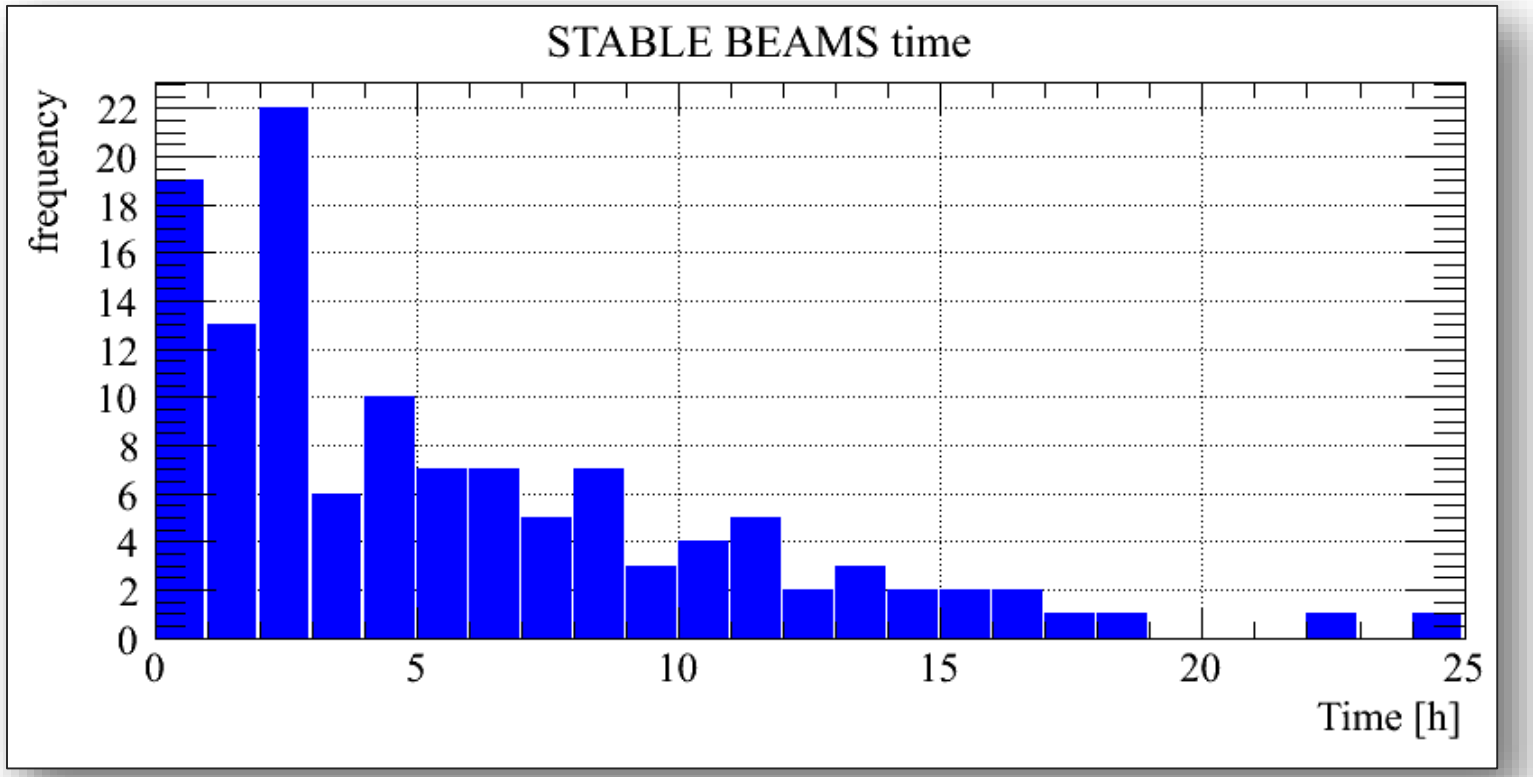


MEAN	MEDIAN
13.7 min	12.5 min

The large spread is mostly due to difference in applied strategies about the order of actions performed once beams colliding (SB declaration)

Stable Beams

MEAN	MEDIAN
5.7 h	4.2 h



2012 vs 2015

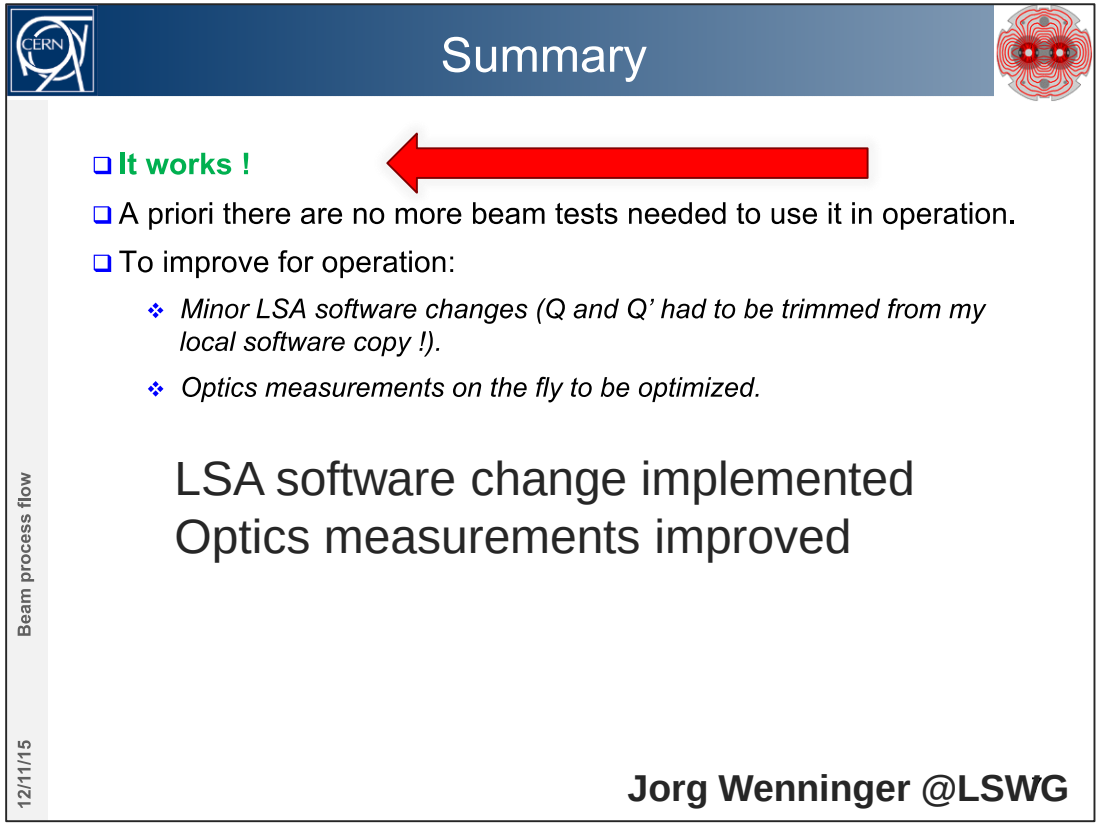
	AVG 2012	AVG 2015	Diff	Comment
INJECTION	67 min	72 min	**+5 min**	25 ns (TDI, vac), often TL steering during filling
PREPARE RAMP	4.8 min	10 min	**+5.2 min**	Heat load (cryo stabilization)
RAMP	13.5 min	20 min	**+6.5 min**	Higher E = longer ramp (7.4 min)
FLATTOP	6.8 min	5.9 min	**-0.9 min**	Tune change in 2012 was included in the squeeze, but we did a systematic check of Q with current of correctors
SQUEEZE	17 min	15.7 (14.1) min	**-1.3 (2.9) min**	Higher E (+ no Q change) = shorter squeeze (2.9 min)
ADJUST	9 min	13.7 min	**+4.7 min**	Settings slightly shorter (70 sec)
STABLE	6.5 hours	5.7 hours	**-0.8 hours**	;-((

Any changes?

Some "possible" changes
(for next year and beyond)…

- **Combined Ramp&Squeeze** **(see next slides)**
- **ATS**
  - minor modification needed on the settings redistribution for RCS.A78B2
  - optics will be available early January to start planning the MDs
  - no major showstopper for testing
- **Lower beta***
  - 40/50 cm seem to be reasonable values
  - +500 sec of squeeze (80 cm to 40 cm)
  - more details in R.Bruce's presentation
- **IP2 Xing angle flipping**
  - more details in T.Pieloni's presentation
- **2 km high beta**
  - Optics under development, no 'a priori' showstopper

CRS



Reasonable β* value between

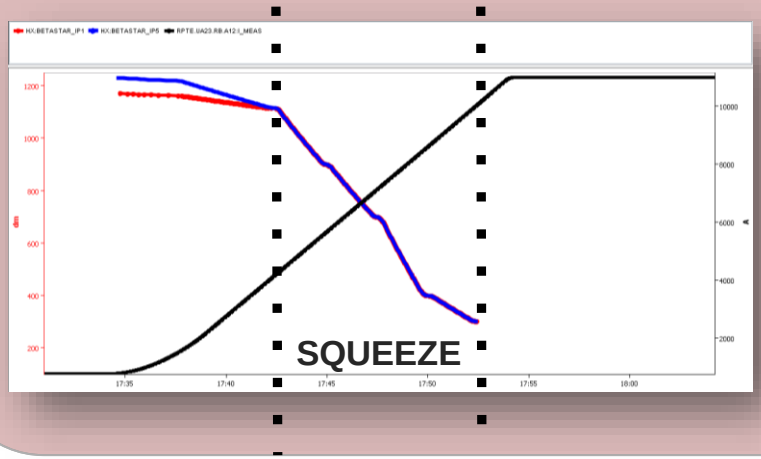
- 3 m (352 sec): historical value where corrections started to be needed. It could be a conservative approach
- 1.2 m (609 sec): more aggressive scenario, aperture and optics OK (see A.Langner's presentation)

Optic distribution strategy has to be defined by a compromised between:

- ✓ Aperture margin
- ✓ Settings flexibility
- ✓ PC performance limitations

CRS experience

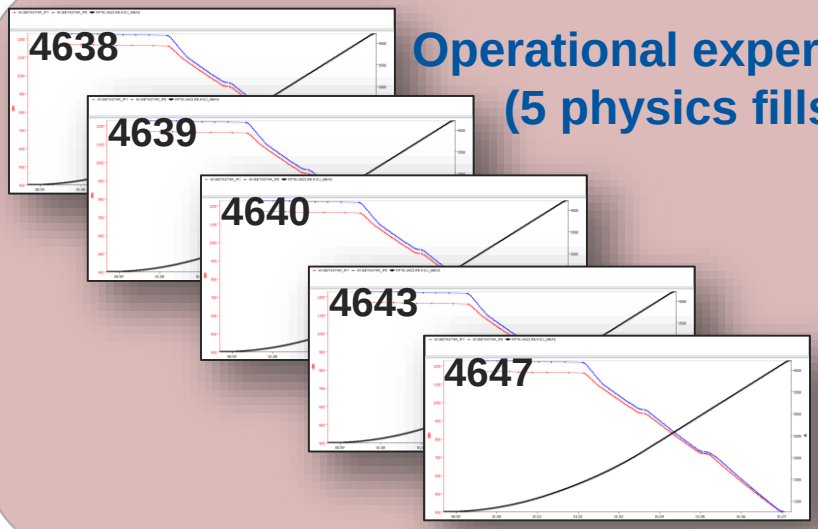
Optics change (11 m to 3 m) in the linear part of the ramp



Experience @6.5 TeV

MD1

Optics	Energy (GeV)	Time (s)	Parabolic fraction
R2015a_A11mC11mA10mL10m_INJ	450	0	0.0
R2015a_A11mC11mA10mL10m_INJ	486	60	0.05
R2015a_A11mC11mA10mL10m_INJ	594	120	0.05
R2015a_A11mC11mA10mL10m_INJ	842	200	0.08
R2015a_A11mC11mA10mL10m_INJ	2481	500	0.1
R2015a_A900C900A10m_0.00950L900_0.00934	3340	650	0.1
R2015a_A700C700A10m_0.00950L800_0.00919	4218	800	0.1
R2015a_A400C400A10m_0.00950L700_0.00906	5075	950	0.15
R2015a_A300C300A10m_0.00950L600_0.00895	5956	1100	0.15
R2015a_A300C300A10m_0.00950L600_0.00895	6500	1210	0.01



Operational experience (5 physics fills)

2.51 TeV run

Optics	Energy (GeV)	Time (s)	Parabolic fraction
R2015a_A11mC11mA10mL10m_INJ	450	0	0.0
R2015a_A11mC11mA10mL10m_INJ	500	60	0.05
R2015a_A11mC11mA10mL10m_INJ	600	120	0.05
R2015a_A11mC11mA10mL10m_INJ	1000	200	0.08
R2015a_A900C900A10m_0.00950L900_0.00934	1200	290	0.1
R2015a_A700C700A10m_0.00950L800_0.00919	1300	380	0.1
R2015a_A400C400A10m_0.00950L700_0.00906	2450	500	0.1
R2015a_A400C400A10m_0.00950L700_0.00906	2510	530	0.1

Conclusions

- It seems that the LS1 break did not affect our operational performance
- There is room for efficiency improvement, mainly:
  - ✓ CRS would result in a >= 352 sec gain
  - ✓ As the most "manual" operation, the injection process has lots of margin for improvement (see D.Jacquet's presentation)
  - ✓ Clear strategy for actions around SB declaration should be defined
- We propose to use CRS (β* value to be defined) as baseline for 2016 operation
- We aim to a wonderful 2016…