



Cycle with beam: analysis and improvements

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TE/EPC and BE/OP

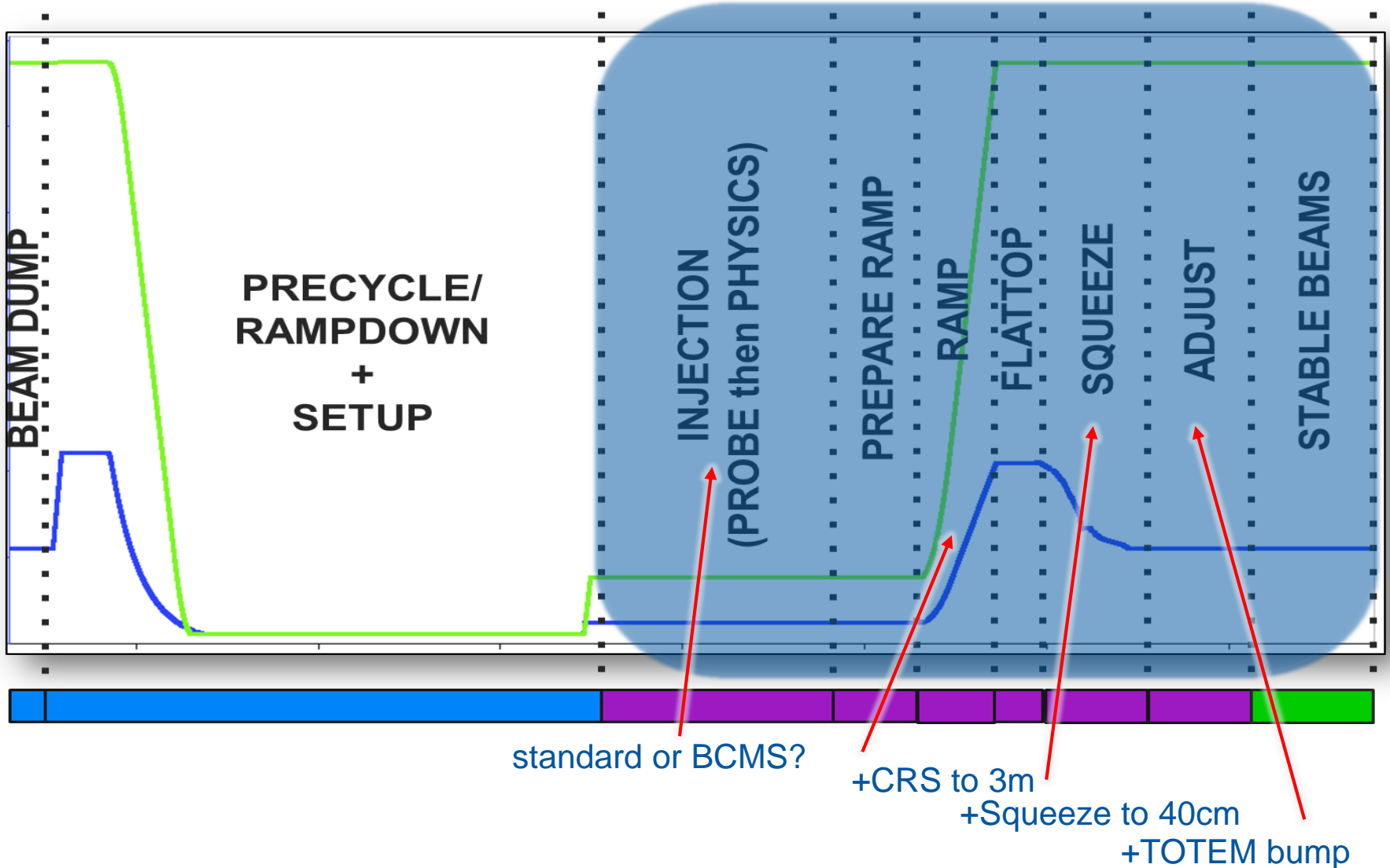
Thanks to
M. Solfaroli, K. Fuchsberger, OP/LHC

Outline

- Cycle phases - analysis
- Historical comparison
- Changes ahead?
- Conclusions

LHC operational beam modes

RB.A12
RQ5.L1

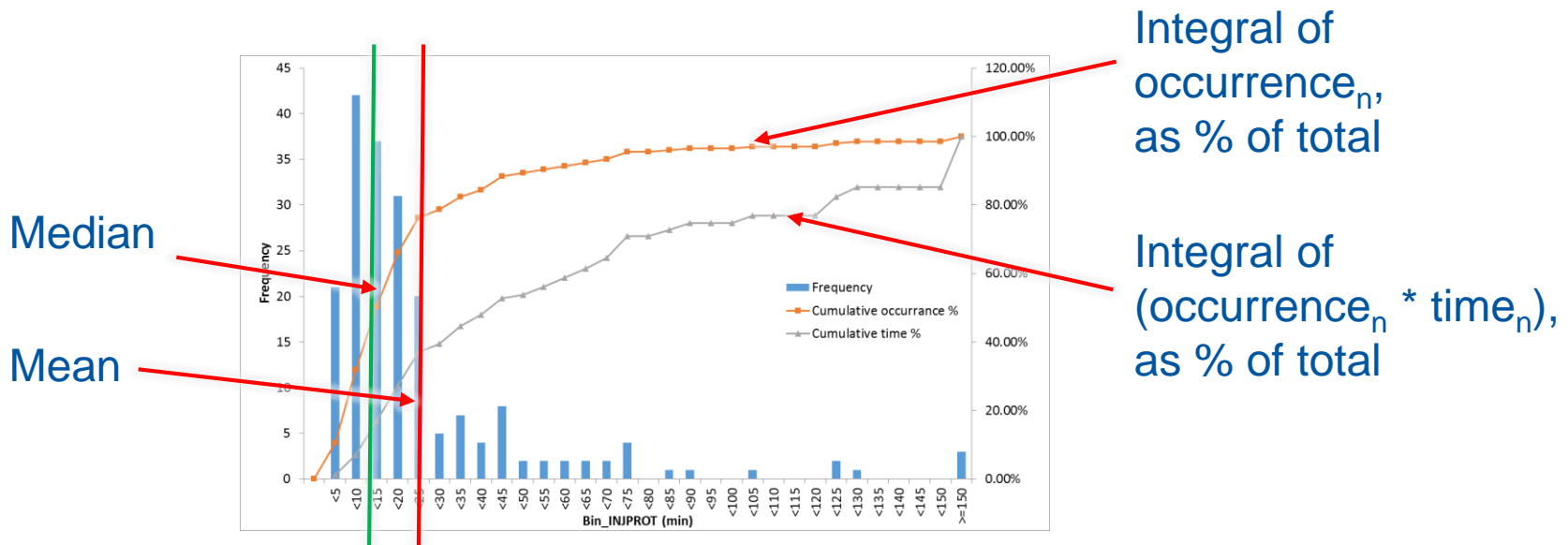


Beam Cycle analysis method

➤ Set of fills

- Only proton fills are considered
- Only physics fills that arrived to Stable Beams
- A total of 178 fills

➤ Beam mode declaration time is used (from logging DB)

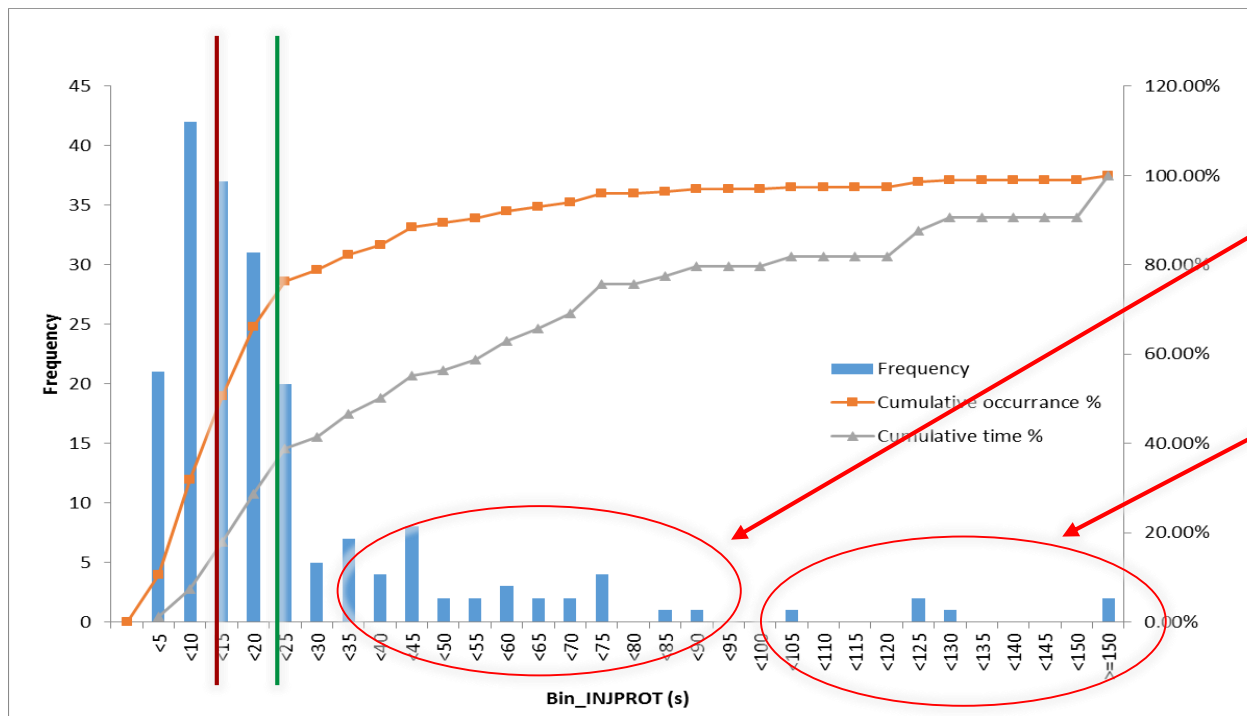


Injection (pilots)

WHAT WE DO

- ✓ Pilot injection
- ✓ Q & Q' & coupling correction
- ✓ Frequency phase adjustment
- ✓ Orbit correction
- ✓ Landau damping off-on for BBQ

MEAN	MEDIAN
23.5 min	14.6 min



Mainly faults

Faults (3)
Special measurements(3)

Injection (physics)

WHAT WE DO

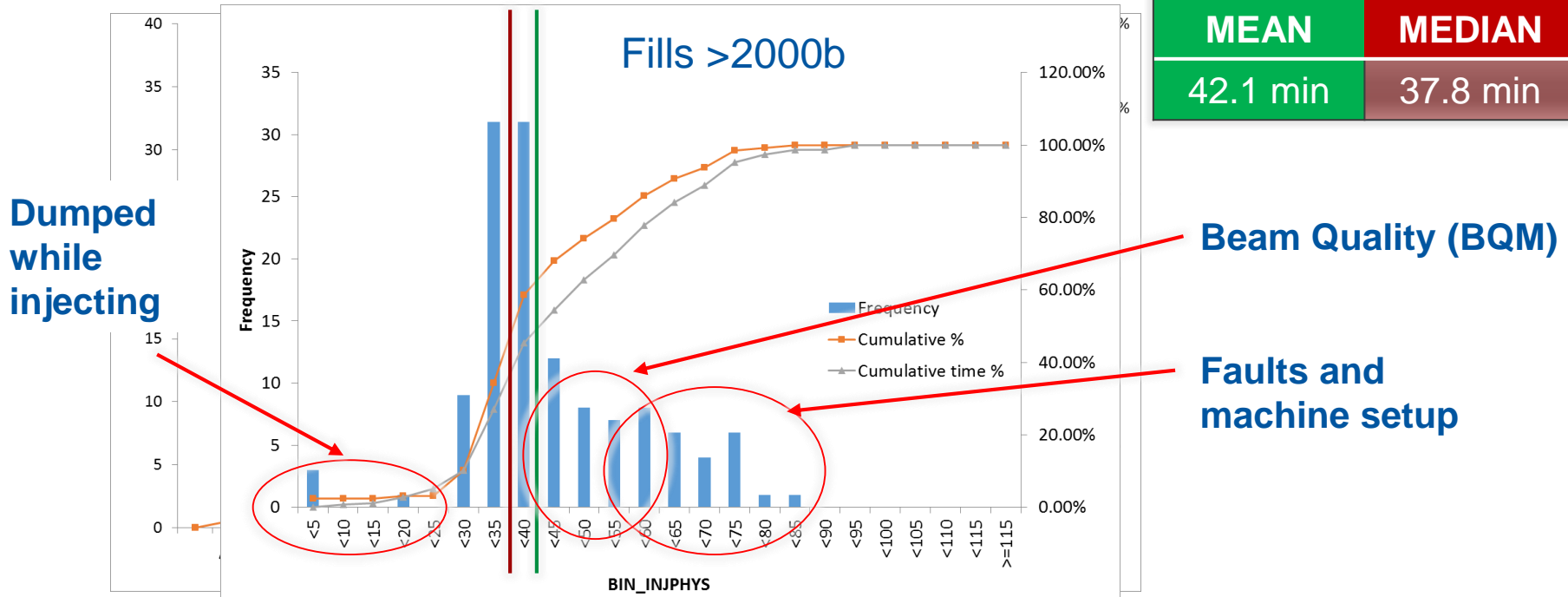
- ✓ Inject 1/12 b (“pilot”), sometimes TL steering
- ✓ Inject up to 96b
- ✓ Wire scanner
- ✓ Fill the machine
- ✓ Close INJ handshake
- ✓ Start moving injection protection out

All physics fills

MEAN	MEDIAN
39.2 min	37.0 min

Fills >2000b

MEAN	MEDIAN
42.1 min	37.8 min



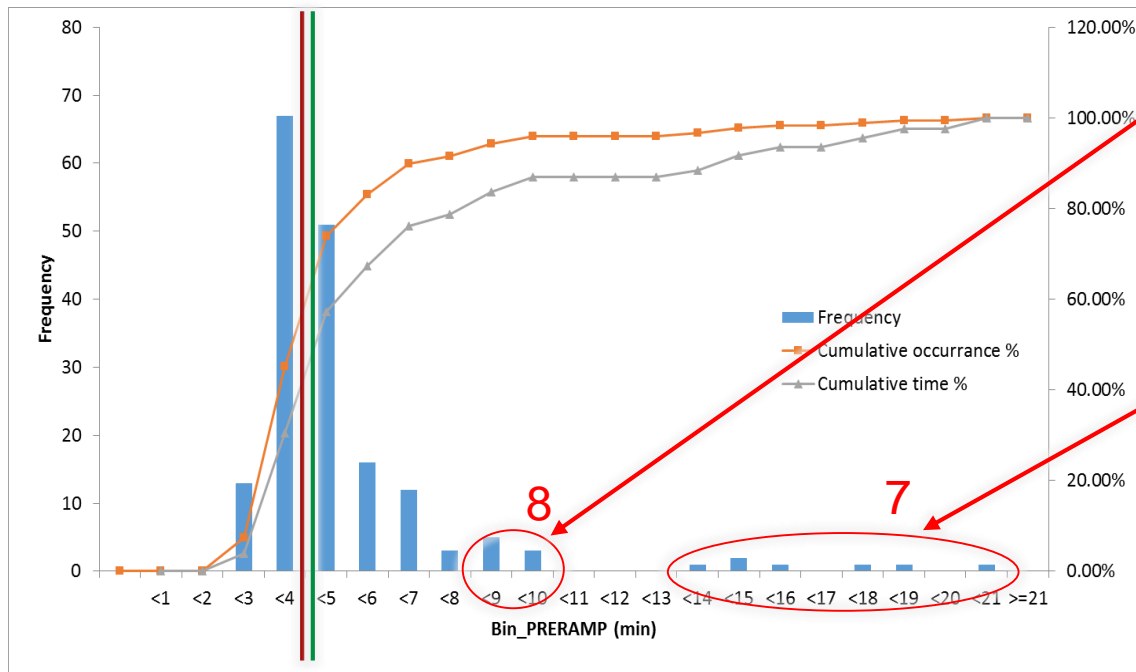
Prepare Ramp

WHAT WE DO

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

MEAN	MEDIAN
4.9 min	4.2 min

Outliers are predominantly problem solving



Cryo (1)
No issue identified (4)
Qtrim ref mismatch (2)
Collimator ref mismatch (1)

MD (1)
Cryo (1)
Qfb noise (2)
Slow incorporation (1)
ADT from sequencer (1)
Qtrim ref mismatch (1)

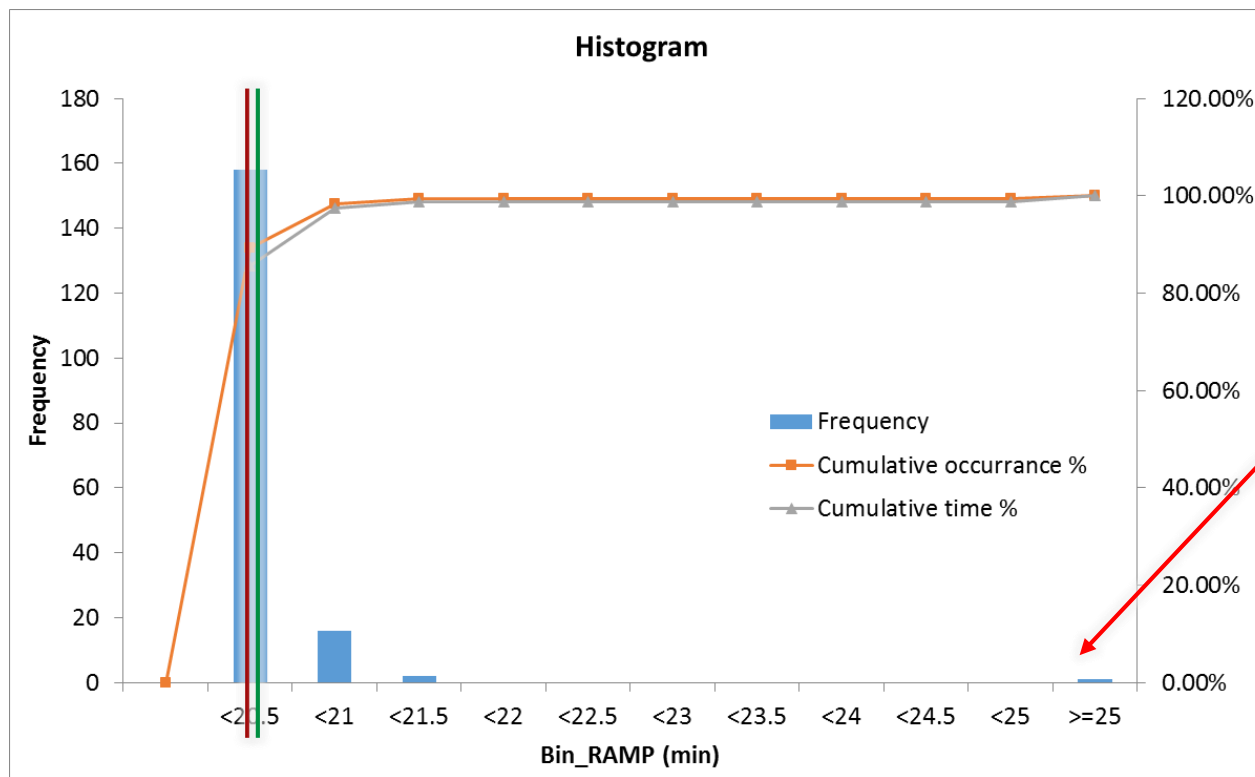
Ramp

WHAT WE DO

- ✓ Ramp settings play
 - ✓ settings length today = 1210 s
 - ✓ is it possible to reduce to 1100 s?

See Matteo
EYETS recovery (Thurs)

MEAN	MEDIAN
20.5 min	20.4 min



Very good reproducibility

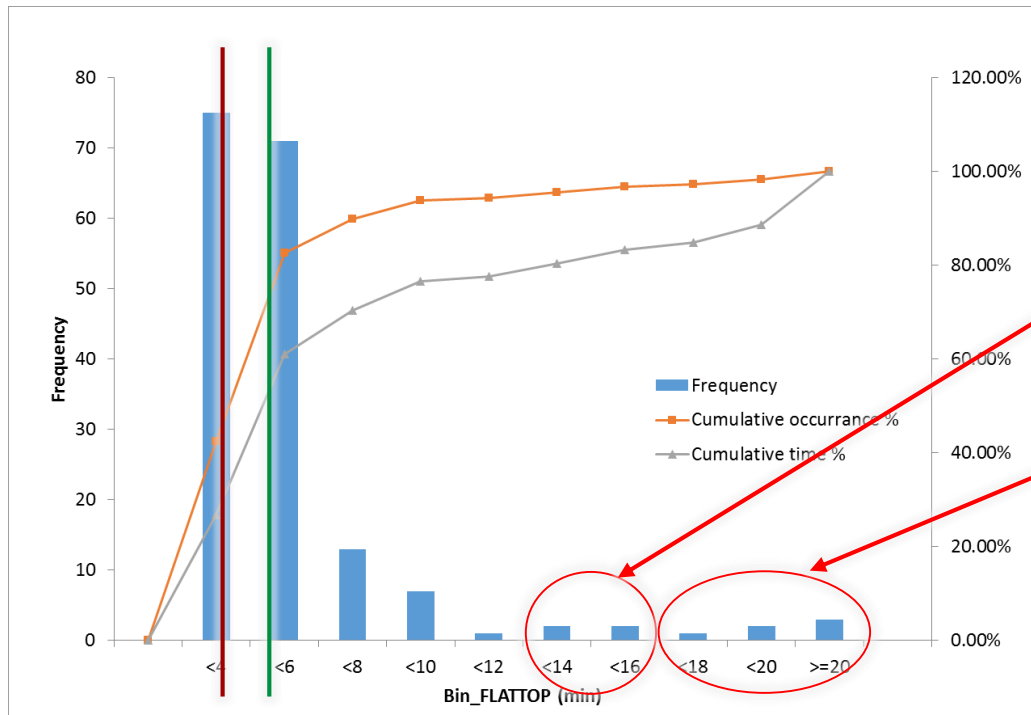
Outlier is 48min long
(LBDS check following
intervention, fill 5274)

Flattop

WHAT WE DO

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

MEAN	MEDIAN
5.6 min	4.2 min



Unexplained (2)
Long regeneration (1)
FBCT checks for VdM (1)

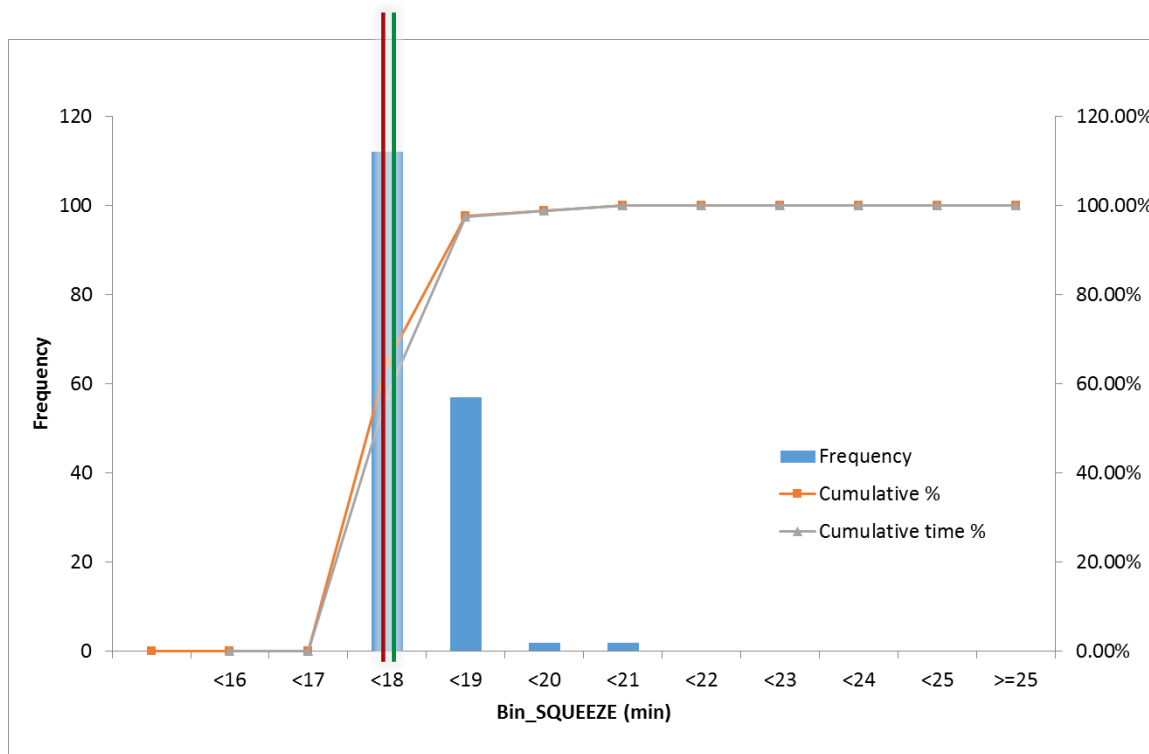
VdM scans @ 40cm (2)
Study (3)
VdM scans @ 24m (1)

Squeeze

WHAT WE DO

- ✓ Squeeze setting play

MEAN	MEDIAN
18.1 min	18.0 min



Very good reproducibility

Note: does not include data from 4 VdM scans (CRS to 24m)

Reminder: squeeze to 40cm (80cm in 2015)

Adjust

WHAT WE DO

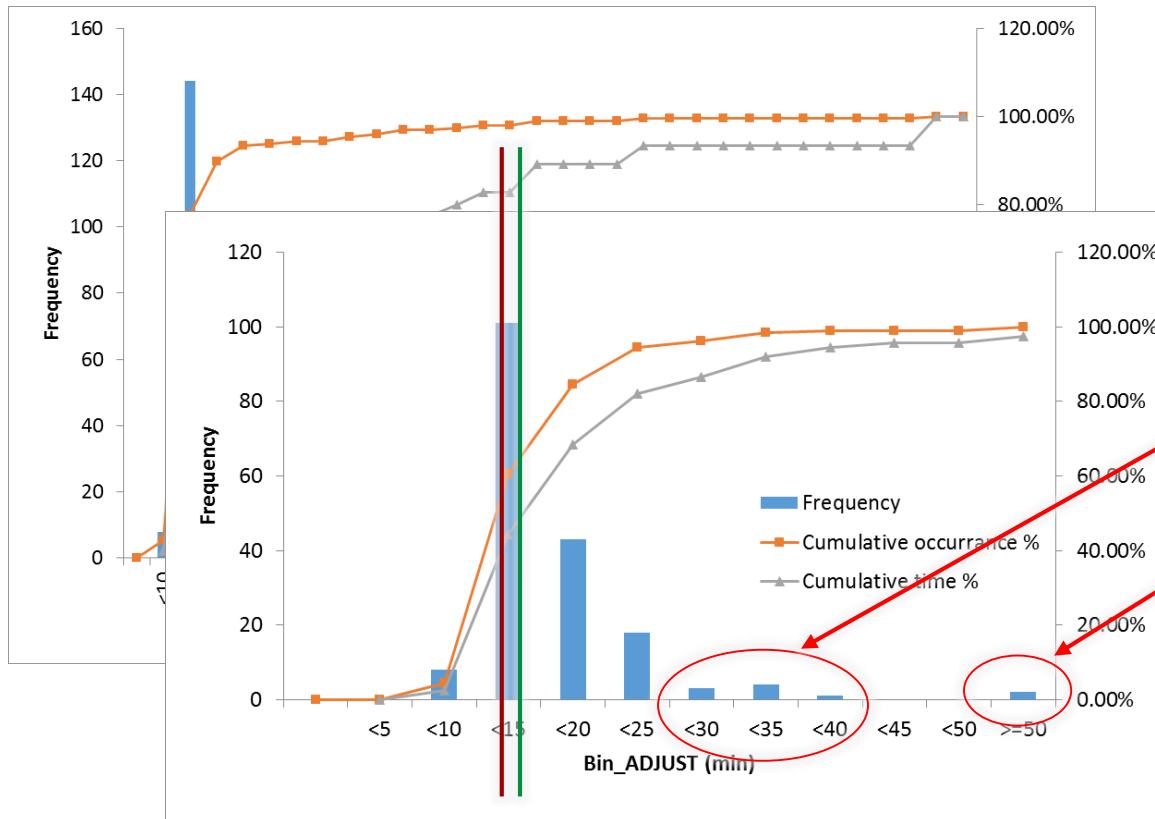
- ✓ 'TOTEM' Bump
- ✓ Setting incorporation and play
- ✓ Optimization of IP1/5

All data:

MEAN	MEDIAN
22.7 min	14.6 min

Removing 15x EoF MDs:

MEAN	MEDIAN
16.1 min	14.1 min

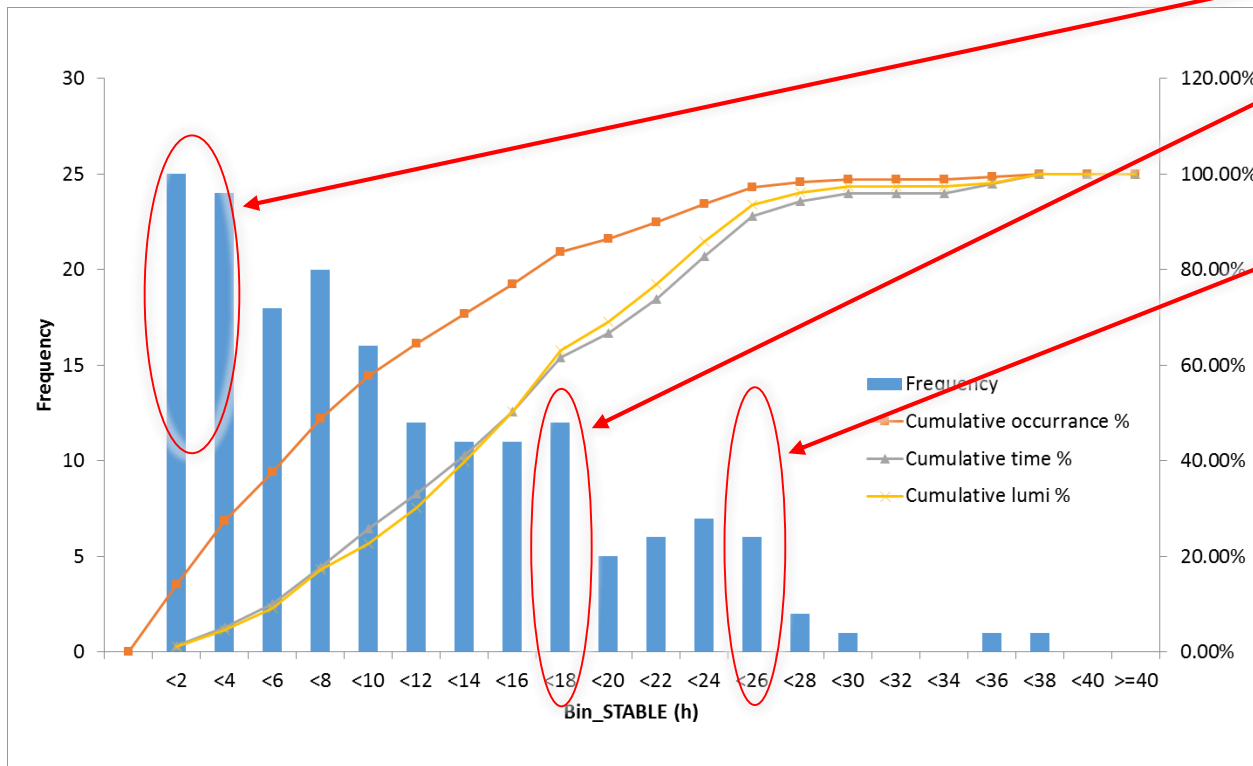


Slow regeneration,
problematic lumi publication,
'quick checks'

78min: BPMs interlocking
prevent declaration of SB
53min: Where are the
collisions? (CMS bump in 5R)

Stable Beams

MEAN	MEDIAN
10.0 h	8.2 h



Includes intensity ramp-up

Dump standard beam after ~14-16hrs

Dump BCMS beam after ~22-24hrs

2016 vs 2015

	AVG 2015	AVG 2016	Diff	Comment
INJECTION	72 min	65.6 min	-6.4 min	(for >2000b). A little better...
PREPARE RAMP	10 min	4.9 min	-5.1 min	Getting better...
RAMP	20 min	20.5 min	+0.5 min	
FLATTOP	5.9 min	5.6 min	-0.3 min	
SQUEEZE	15.7 min	18.1 min	+2.4 min	Added Beta* from 80cm to 40cm
ADJUST	13.7 min	16.1 min	+2.4 min	We added the 'Totem Bump'
STABLE	5.7 hours	10.0 hours	+4.3 hrs	
Total	137.3 min + 5.7 hours	129.0 min + 10.0 hours	-6.5 min +4.3 hours	Not bad...

Measured v Theory

- The machine is 'fully loaded' during the following beam processes.
 - The faster the better!

Beam Mode	Median (A)	Beam process (B)	Setup (A-B)	Comment	Target 2017?
PRERAMP	4.2 min	0 min	4.2 min	Can we optimize sequencer?	
RAMP	20.4 min	20.1 min	0.3 min	Can we save 100s in ramp?	
FLATTOP	4.2 min	0.3 min	3.9 min	Setup for Qchange and Squeeze included in flattop	
SQUEEZE	18.0 min	17.5 min	0.5 min	Options available to reduce this.	
ADJUST	14.1 min	5.1 min (150s + 45s + 110s)	9.0 min	Includes Totem bump and IP optimization	
Total	60.9 min	43 min	17.9 min		

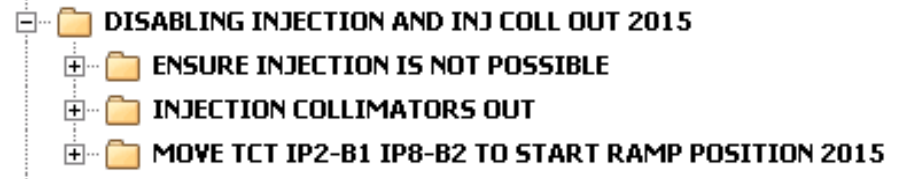
CRS

- In 2016 we ran with a Combined Ramp and Squeeze that delivered proton beams to flattop with 3m Beta*
 - Chosen because first point when optics corrections may be required.
 - Conservative approach for first year
 - Requires a subsequent squeeze of 1050s to reach 40cm
- For 2017 should we go lower in the ramp?
 - **1.0 m Beta*** will gain ~150s
- Actual squeeze is in particular limited by Q6 either side of IP1 and IP5
 - Can we learn from the ATS optics experience?
 - Updating the standard optics could gain a further ~500s
 - What about moving the Qchange to the end of squeeze?
- So we could go for a more aggressive standard CRS+squeeze!
- Or we could just go for ATS

*See Rogelio+Stephane
ATS optics (Tues)*

Sequencer

- Big role in the reproducibility and integrity of the machine
- At injection the faster we can start the ramp, the better the beam quality
 - Can loading of PC and RF be made in parallel?
 - Can loading and driving of injection collimators be made in parallel?



- Another area where we could gain time is finding collisions
 - Do we keep the TOTEM bump?
 - Should we collide all IPs together in 2017?
- Some other observations from 2016
 - Slow incorporation → solved by improving LSA cache
 - Should these be pre-calculated for the entire BP during the ramp?
 - Can calculation of OFB optics by the BFSU be quicker?

Putting it all together

Beam Mode	Median (A)	Beam process (B)	Setup (A-B)	Comment	(Median) Target 2017?
PRERAMP	4.2 min	0 min	4.2 min	Can we optimize sequencer?	3 min
RAMP	20.4 min	20.1 min	0.3 min	Can we save 100s in ramp?	19 min
FLATTOP	4.2 min	0.3 min	3.9 min	Setup for Qchange and Squeeze included in flattop	4 min
SQUEEZE	18.0 min	17.5 min	0.5 min	Options available to reduce this.	7 min
ADJUST	14.1 min	5.1 min (150s + 45s + 110s)	9.0 min	Includes Totem bump and IP optimization	7 min
Total	60.9 min	43 min	17.9 min		40 min

Conclusions

- 2016 was an excellent year
 - Data shows improvements for all beam cycles
- There is still room for efficiency improvement, but the gains are diminishing:
 - ✓ Injection is the biggest overhead
 - ✓ Changing the CRS and squeeze offers the biggest gain
 - ✓ More parallelization/optimisation for some sequencer tasks?
- We know how to find up to 30% efficiencies once the machine is filled
 - ✓ 'Just' leaves the beam injection process still to be optimised