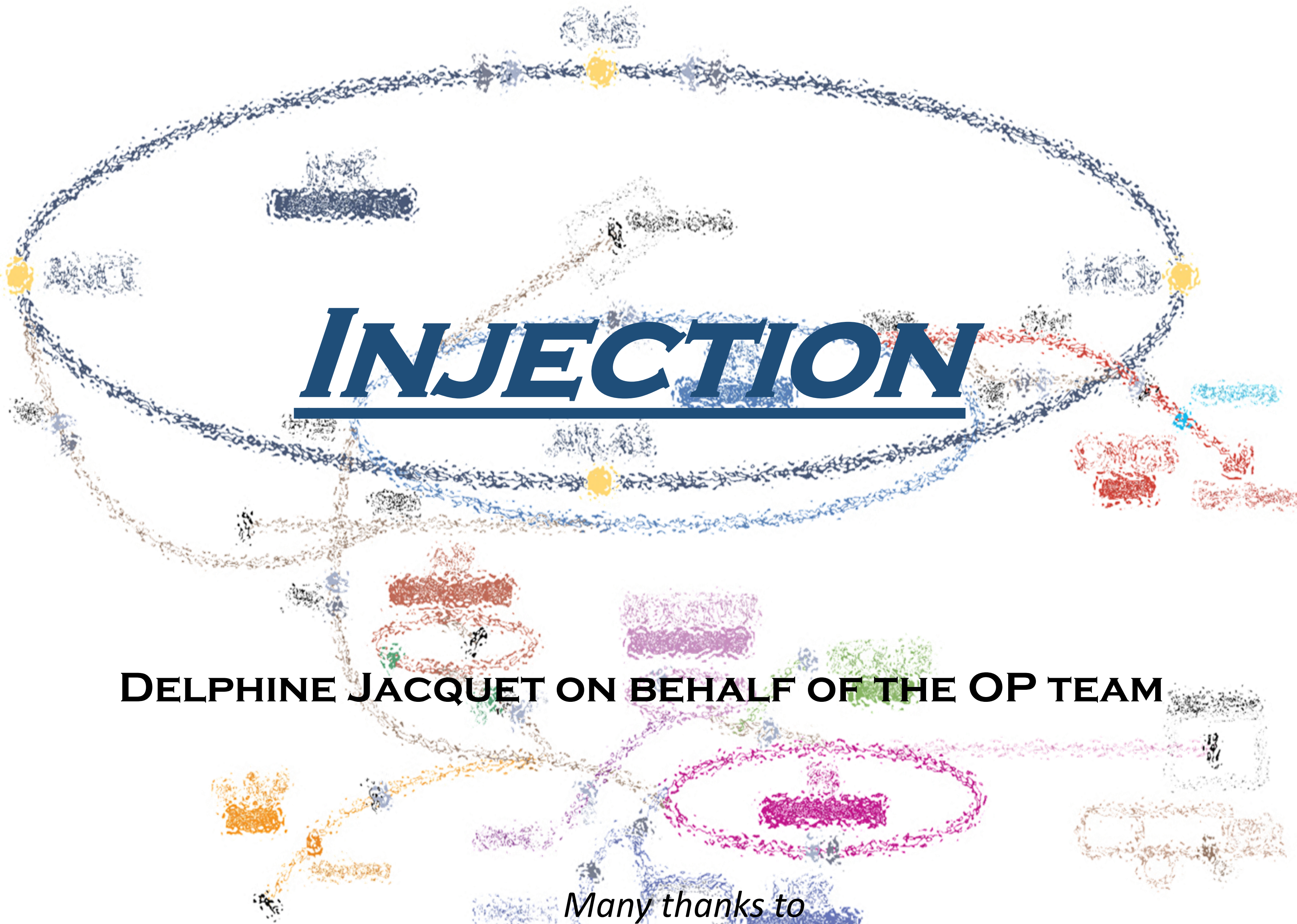
6TH EVIAN WORKSHOP 15-17 DEC 2015 : OPERATIONS

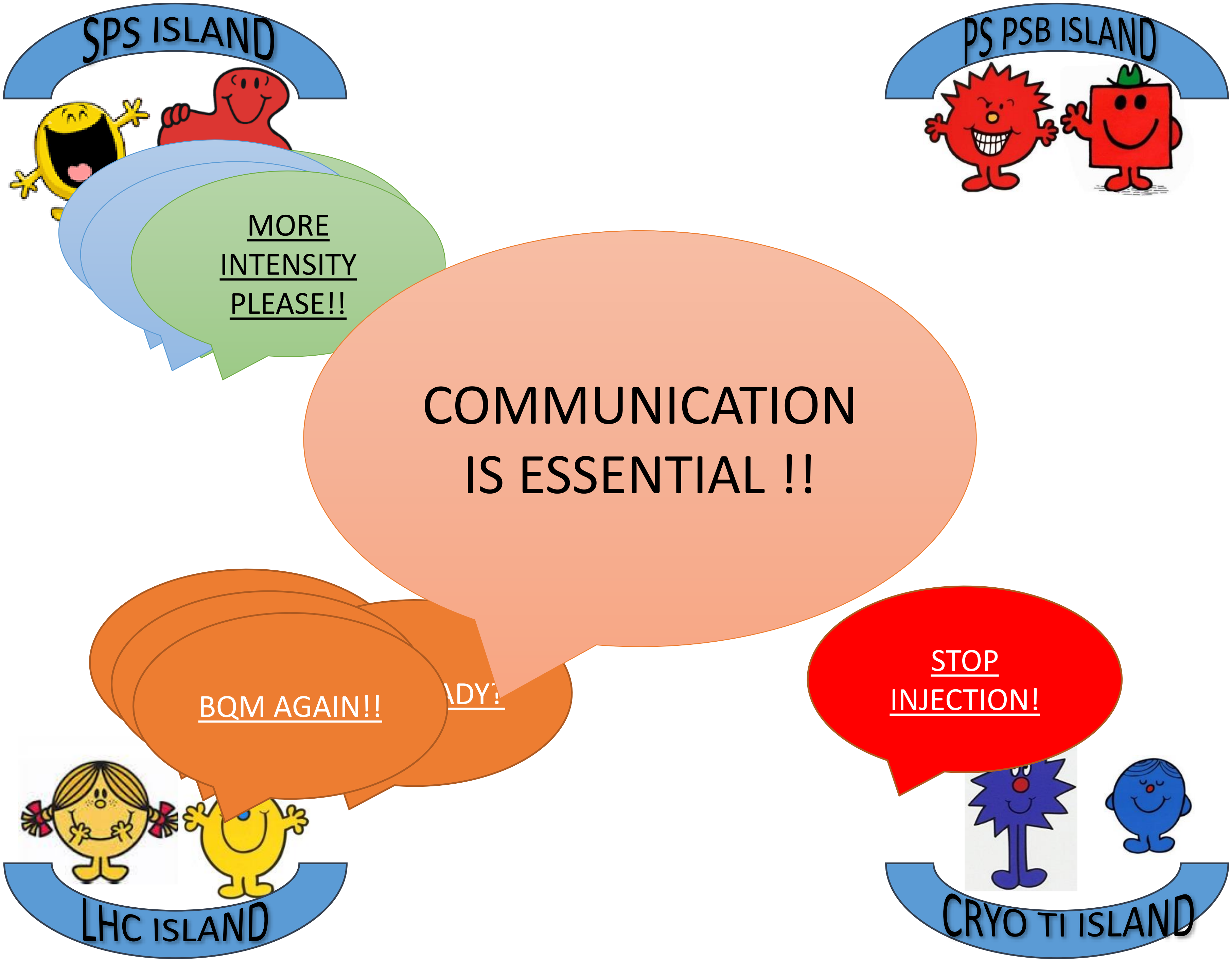


INJECTION

DELPHINE JACQUET ON BEHALF OF THE OP TEAM

Many thanks to

Giulia Papotti, Belen Maria Salvachua Ferrando, Matteo Solfaroli, Mirko Pojer, Chiara Bracco, Jorg Wenninger, Thomas Bohl, Giovanni Iadarola

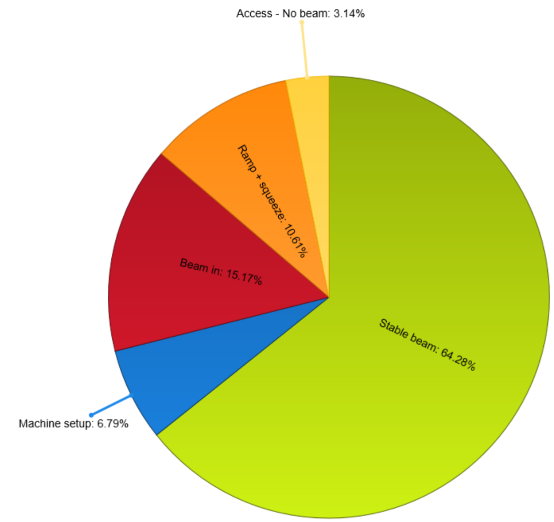

SPS ISLAND
PS PSB ISLAND
MORE INTENSITY PLEASE!!
COMMUNICATION IS ESSENTIAL !!
BQM AGAIN!!
STOP INJECTION!
LHC ISLAND
CRYO TI ISLAND

How long do we stay at injection?

Time at injection for PROTONS PHYSIC stable beam fills

Average nb of inj/fill: 22
SPS supercycle length: 59s
Time at injection in a perfect world: 22 +15 = 37mins

Average time really spent at injection
~1h30

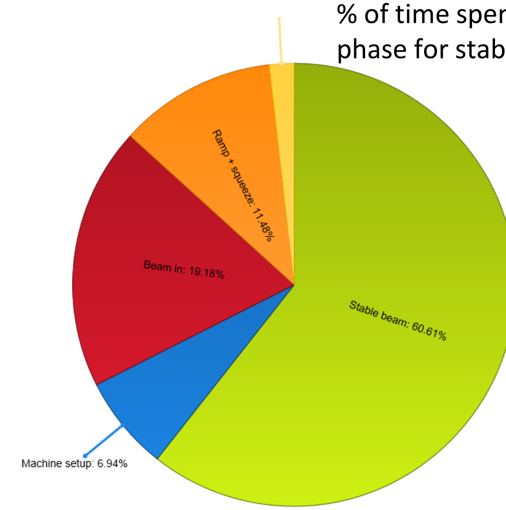


% of time spent for each phase for stable beam fills

Time at injection for IONS PHYSIC stable beam fills

Average nb of inj/fill: 36
SPS supercycle length: 65 s
Time at injection in a perfect world: 39+15 = 54mins

Average time really spent at injection
~1h50



Time spent at injection = beam mode INJECTION PROBE BEAM+ INJECTION PHYSICS BEAM +PREPARE RAMP
We consider only fills that have reached stable beam (discard all the special run and MDs)
Source is Timber and the accelerator performance and statistic page https://acc-stats.web.cern.ch/

Where is the time lost, Can it be improved?

- Injectors and beam set-up time
- Filling schemes
- Transfer line steering
- Injection quality check
- Measurements at injection
- Limitations

Injectors supercycle length

- For protons, the SPS supercycle length could be optimized to reduce the injection time.
  - Supercycles: up to 1mins
  - Nominal LHC proton cycle: 21.6s

- Fully dedicated supercycle not possible:
  - Time needed between 2 SPS consecutive cycles for continuous injection
    - Interleaved injection: 3-4 seconds (next request after injection event)
    - One beam at a time: 10s (next request after the IQC analysis)

  - LHC cryo limitation requires to inject slowly and with pauses
  - In this situation, dedicated supercyle would penalize too much the north area physic

- May be reconsidered next run
  - If the cryo is stable and we inject continuously
  - If we manage fast setting up and fast injection
  - If we continue to do most of the steering while filling

  - Advantage for the SPS users:

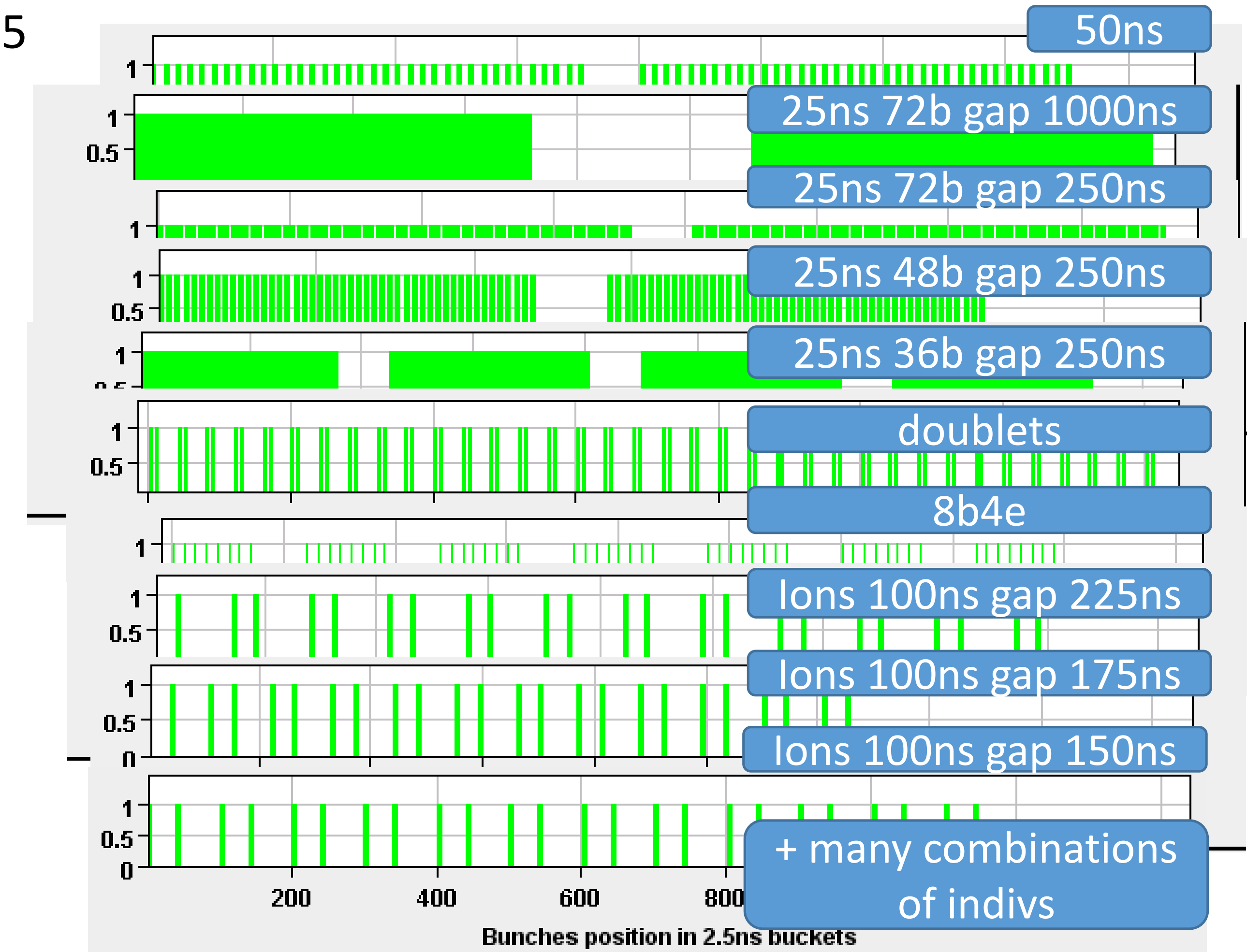
  LHC cycle in the supercycle = bad fixed target beam quality and less duty cycle for them
  With fast dedicated LHC filling they could even gain beam time.

Injectors beam setting-up time

152h downtime assigned to no beam from injector

28 h assigned to injector setting-up in 2015

- Many LHC beams in 2015



Injectors beam setting-up time

152h assigned to no beam from injector

28 h assigned to injector setting-up

- Many LHC beams in 2015

- At least 3 types of beam per filling, 3 beams to check and optimized before each filling period

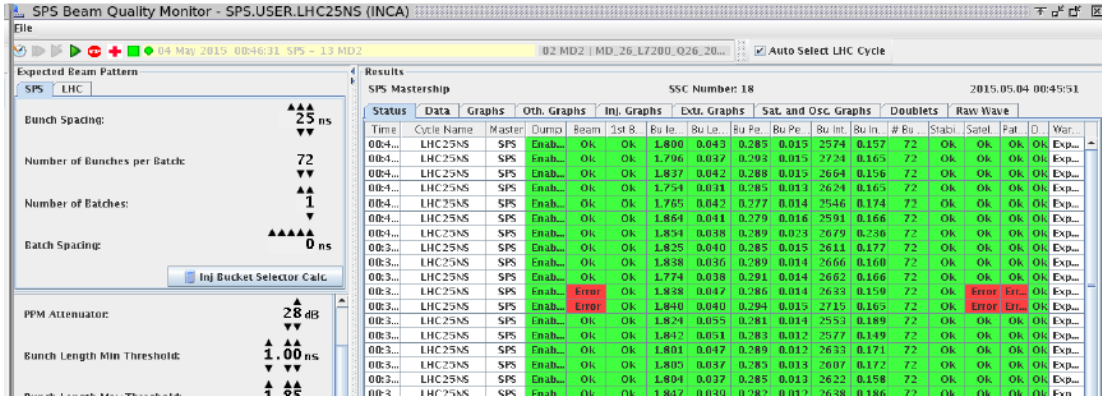
- TIDV dump intensity interlock slow down the setting-up (will get worse with 288 bunches)

- Many clients in SPS for MDs, not always compatible with LHC beam preparation
  ➡ Can be improved by a better synchronisation of LHC and SPS planning

- Sometime too short notice for new requests
  ➡ Can be improved by a better communication and anticipation from the coordinators

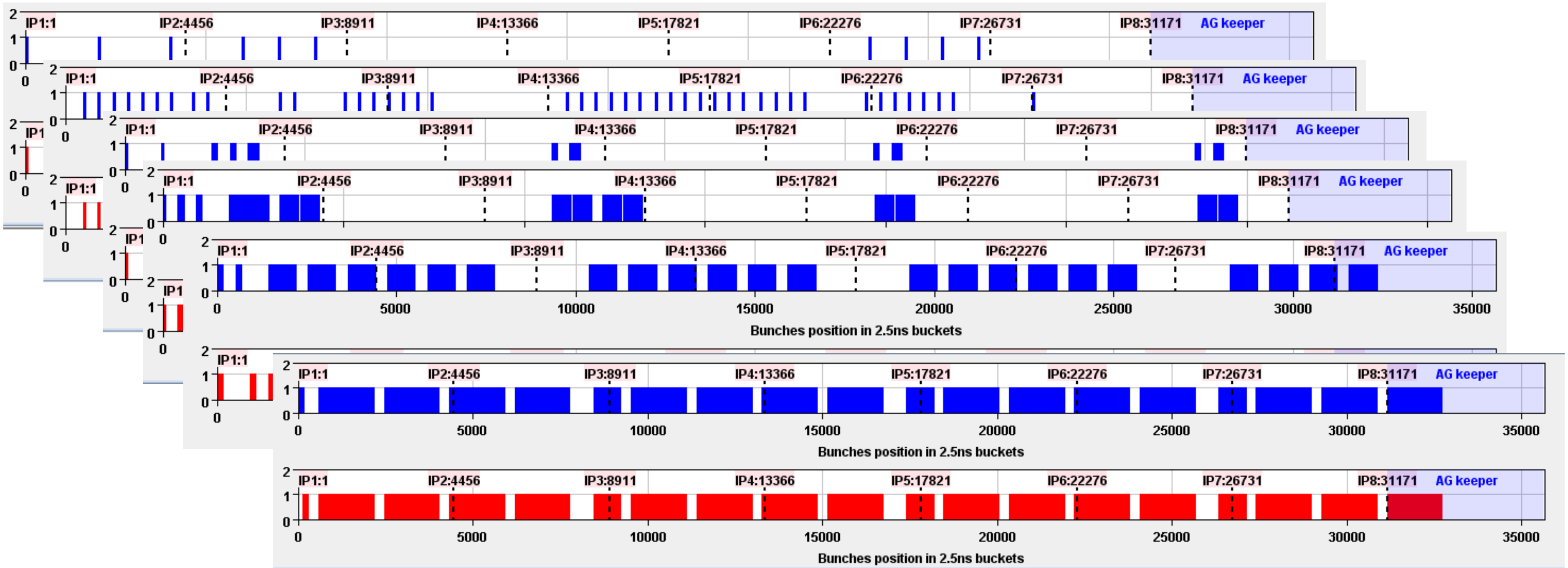
SPS Beam Quality

- Several parameters are checked before extraction to guarantee that the injected beam has the requested parameters and the rephasing is OK
  - Bunch length, bunch pattern, satellites, bunch peak spread etc…



- SPS beam quality monitor dumps (statistics for 25ns protons)
  - 15% for 12 bunches or pilots and Indiv
  - 20% of the nominal beam requests.
  - For a 22 injections scheme, we loose around 4 mins
- The thresholds for each parameter have to be the best compromise between efficiency of the injection and quality of injected beams.

Many filling schemes

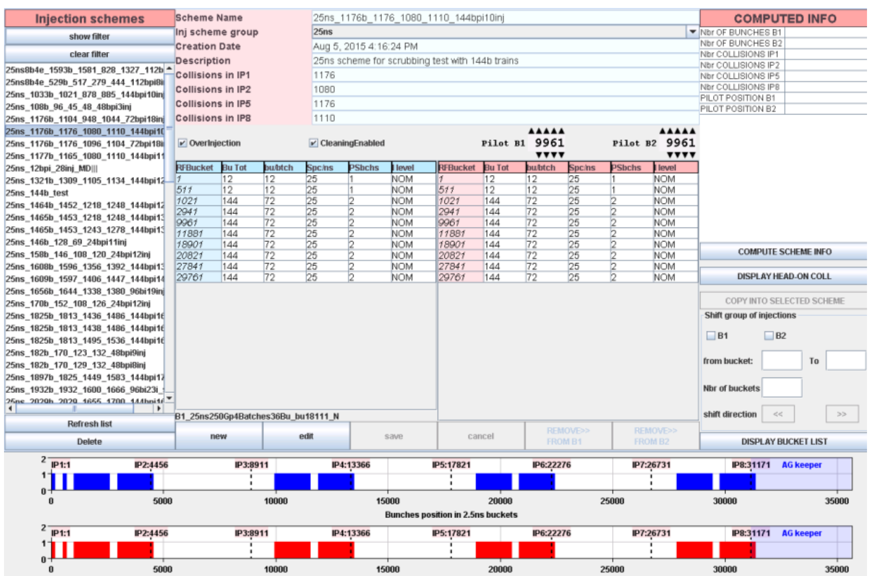


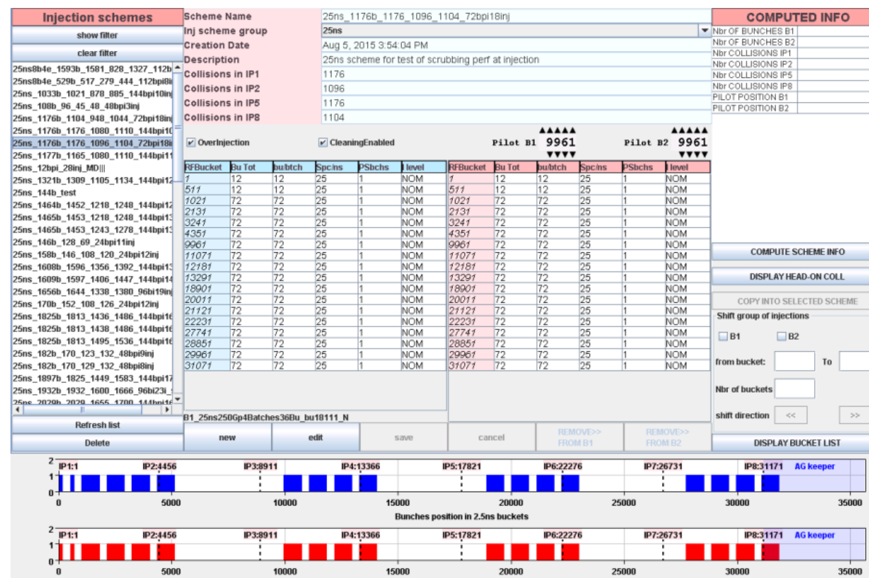
~200 filling schemes have been used in 2015

- 48 for protons physics. (but almost as many created as spare or alternative and not used)
- 7 for ions physics
- 44 used for scrubbing
- The rest for setting-up and MDs

Filling scheme's impact on injection duration

- ➢Number of injections not optimal
  - ➢Limitation to 144 bunches/ injection from the TDI instead of 288 nominal.
  - ➢For some fills : reduction of the number bunches/injection to reduce the e-cloud





Same number of bunches and collisions but the second one takes 16 mins more to inject

Filling scheme's impact on injection duration

- ➢ Filling schemes have to be optimize to reduce the number of SPS cycle change.

Scheme Name	25ns_86b_74_53_54_24bpi7inj
Inj scheme group	25ns
Creation Date	Aug 13, 2015 5:07:01 PM
Description	25ns scheme for intensity rampup step 3
Collisions in IP1	74
Collisions in IP2	53
Collisions in IP5	74
Collisions in IP8	54

☑ OverInjection ☑ CleaningEnabled Pilot B1 8991 Pilot B2 8991

RFBucket	Bu Tot	bu/btch	Spc/ns	PSbchs	I level	RFBucket	Bu Tot	bu/btch	Spc/ns	PSbchs	I level
51	12	12	25	1	INTR	51	12	12	25	1	INTR
2001	12	12	25	1	INTR	3001	12	12	25	1	INTR
8991	12	12	25	1	INTR	8991	12	12	25	1	INTR
13451	1	1	0	1	NOM	13451	1	1	0	1	NOM
17881	24	24	25	1	NOM	17881	24	24	25	1	NOM
22391	1	1	0	1	NOM	22391	1	1	0	1	NOM
26751	24	24	25	1	NOM	26751	24	24	25	1	NOM

Worse case: SPS supercycle changed 6 times

Scheme Name	25ns_86b_74_53_53_24bpi7inj
Inj scheme group	25ns
Creation Date	Aug 14, 2015 7:26:06 AM
Description	25ns scheme for intensity rampup step 3 - INDIVs last
Collisions in IP1	74
Collisions in IP2	53
Collisions in IP5	74
Collisions in IP8	53

☑ OverInjection ☑ CleaningEnabled Pilot B1 8991 Pilot B2 5181

RFBucket	Bu Tot	bu/btch	Spc/ns	PSbchs	I level	RFBucket	Bu Tot	bu/btch	Spc/ns	PSbchs	I level
51	12	12	25	1	INTR	51	12	12	25	1	INTR
2001	12	12	25	1	INTR	3001	12	12	25	1	INTR
8991	12	12	25	1	INTR	8991	12	12	25	1	INTR
17881	24	24	25	1	NOM	17881	24	24	25	1	NOM
26751	24	24	25	1	NOM	26751	24	24	25	1	NOM
28981	1	1	0	1	INTR	28981	1	1	0	1	INTR
30981	1	1	0	1	INTR	30981	1	1	0	1	INTR

Corrected for only 3 supercycles changes

- ➢ Filling scheme that includes at least 3 intermediate beam injections allows steering while filling

RFBucket	Bu Tot	bu/btch	Spc/ns	PSbchs	I level
191	1	1	0	1	NOM
551	12	12	25	1	INTR
1051	12	12	25	1	INTR
1561	144	72	25	2	NOM
3781	144	72	25	2	NOM
6001	144	72	25	2	NOM
8221	144	72	25	2	NOM

RFBu				PSbchs	I level
81	[illegible]	[illegible]	[illegible]	[illegible]	INTR
1051	[illegible]	[illegible]	[illegible]	[illegible]	INTR
1561	[illegible]	[illegible]	[illegible]	[illegible]	NOM
3781	[illegible]	[illegible]	[illegible]	[illegible]	NOM
6001	144	72	25	2	NOM
8221	144	72	25	2	NOM
10501	144	72	25	2	NOM

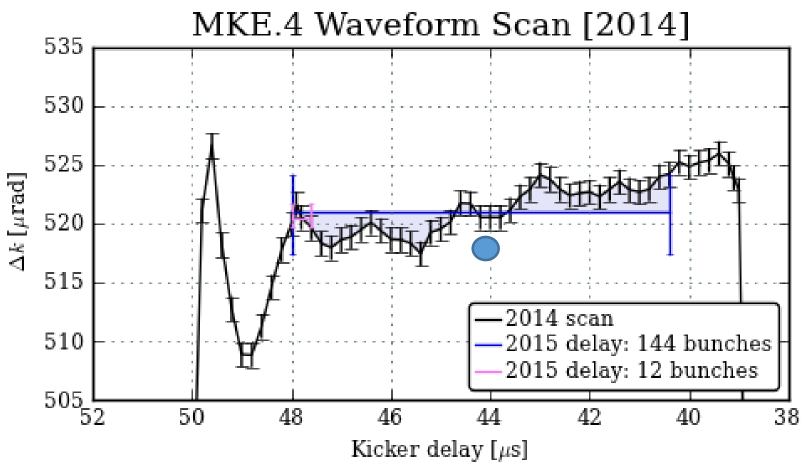
Orbit correction

Transfer line correction

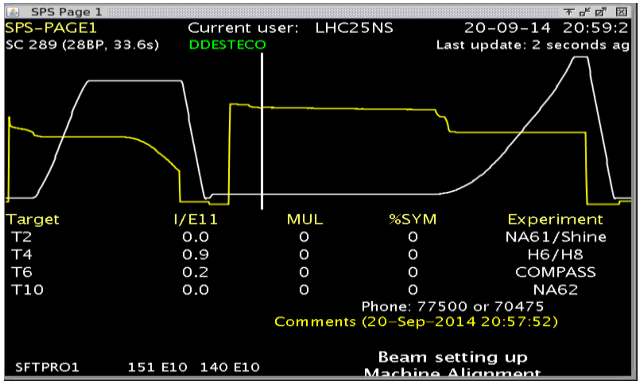
Correction check

Transfer line commissioning

- Establish the transfer line references with pilot
- Procedure improved for the pilot trajectory to be more representative of the nominal :



Kickers delays changed for the MKEs and the MKIs so that the pilot is positioned at the middle of the waveform



In the SPS pilot on the nominal cycle for comparable magnetic history

Chiara Bracco

Transfer lines steering

- The trajectory references were better than in 2012

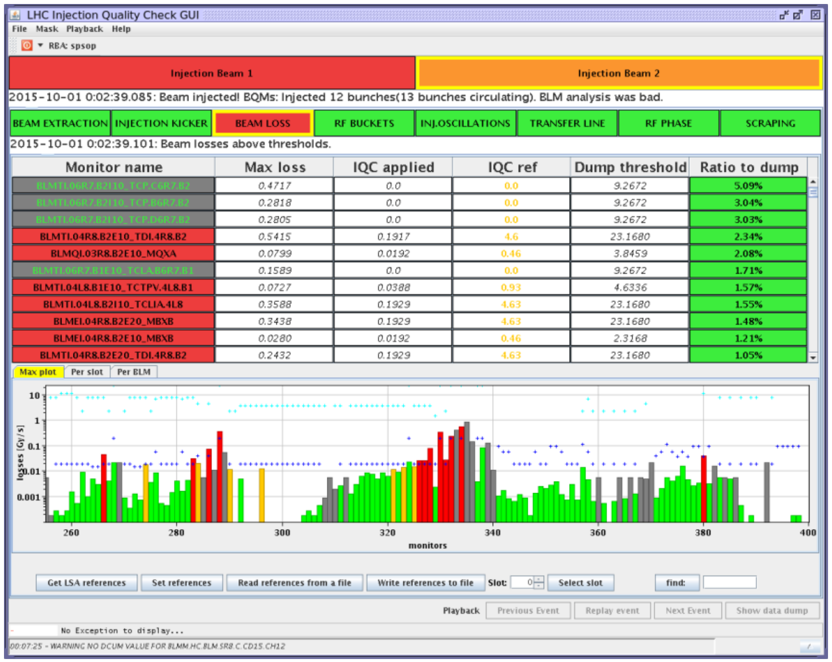
- Only 14 hours spent for dedicated steering during protons run.

- 50% of the steering were done while filling, thanks to appropriate filling schemes: several hours gained!

- Shot by shot instabilities cured after LS1 hardware change at the SPS extraction septa to supress the current ripple.(Florian Burkart's talk)

- Almost no dump due to injection losses
  - Optimization of the BLM thresholds
  - Replacement of some BLMs by LICs (ionization chambers) , less sensitive, more margin
  - but keep in mind that we were limited to 144b.

Injection Quality Check unreliable analysis



Example of IQC giving a warning because losses on the TDI at 2.34% of dump threshold!

?

- IQC analysis scales the losses to 288 bunches.
- At the TDI : mostly unbunched beam losses
- Scaling doesn't apply here, we get warning at almost every injection

Too many unjustified warnings or errors

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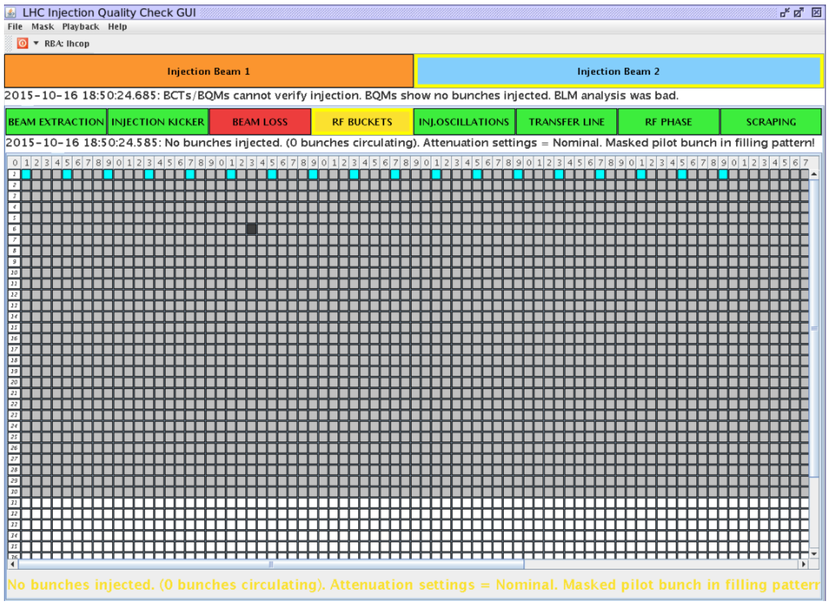
Big risk to disregard real problems

Injection Quality Check unreliable analysis



Example of IQC not able to determine if beam was injected or not.

?

- Analysis relies on 2 BCTs and the BQM
- Since modification during LS1, BQM post mortem less reliable.
- IQC gets "No beam injected" from BQM and "Beam injected" from BCTs and get confused

Several time per fill, IQC unable to know if beam is injected

- Injection process stopped
- LHC operator has to check if beam is injected, unlatch the IQC and resume the injection requests
- The analysis result is not published

Injection Quality Check unreliable analysis

- In 2015, IQC has lost its credit, and didn't fulfil its role

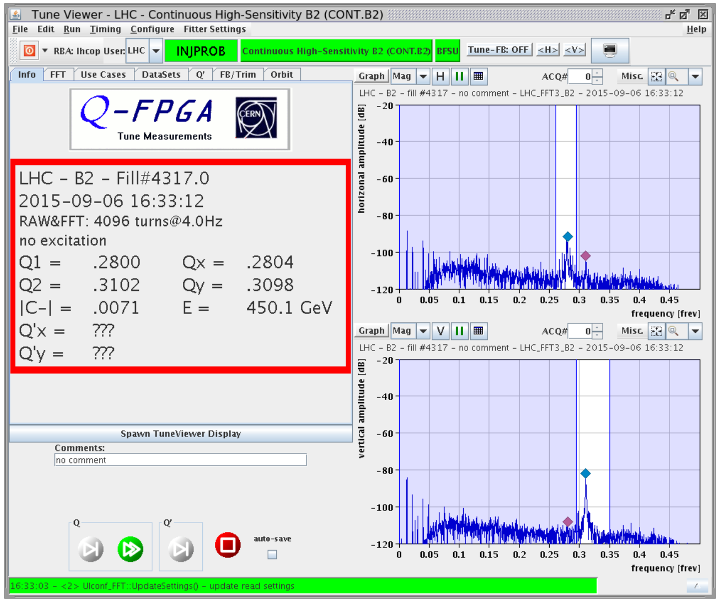
- This could be improved for next run
  - Review the BLM warning limits and apply an appropriate scaling.
  - Give OP the possibility to control the warnings and error thresholds easily and anytime (like for SPS BQM)
  - The LHC BQM have to be modified to give reliable PM data

- The IQC analysis can be pushed farther to help understanding when steering is needed : correlate the beam position at the collimators with the beam losses and spot the critical beam positions.

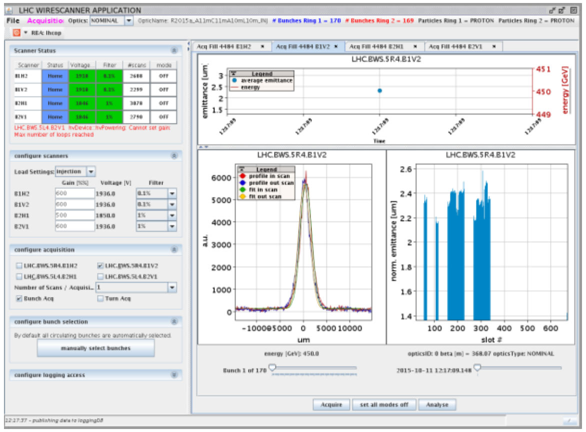
Measurements at injection

- Tune and chromaticity measurement:
  - Transverse dampers new gain management : lower damper gain applied to the first 400 Buckets
  - Gives a constraint on the filling scheme to have beam in the first 400 buckets.

Q and Q' measurement much improved. (and time gained for the beam tuning)



Measurements at injection



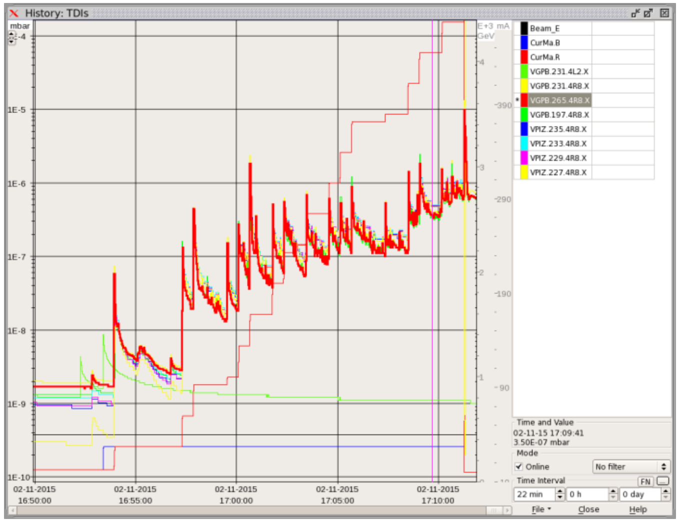
- Wire scanner:
  - Measurement is too slow
    - Waiting for the high voltage ready
    - Takes ages to retrieved the filled buckets
    - No parallel measurement for B1 and B2
    - Good settings difficult to find and not stored
    - Intensity limitation forces the injection process to stop while we measure

- New application for wire scan is much better but still can be improved to get faster measurement.

- With a reliable BSRT, the necessity to measure each fill can be questioned.

Limitations

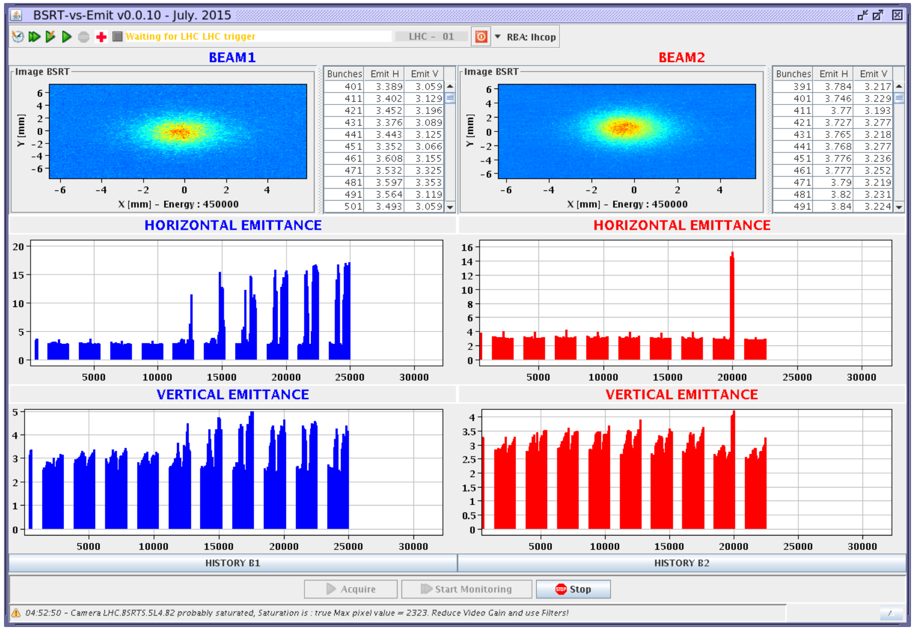
- Cryogenics beam screen: necessary to stop injection process for a while to stabilize the temperature
  - Almost 24h of downtime assigned
  - Fine tuning of the parameters and reduction of the e-cloud by scrubbing improved a lot the situation at the end of the run
  - More details on Cryogenics talk from Krzysztof BRODZINSKI



- TDI.B2 vacuum
  - 3h of downtime, 5 beam dumps at inj
  - We had to inject B2 first and retract the TDI as soon as possible
  - Both TDI will be replaced during the technical stop. (more details on Anton Lechner ‘s presentation on TDI)
- MKI.B2 vacuum
  - limiting the number of bunches per trains
  - 2244 bunches per beam possible only with trains of 36 bunches.
  - How far can the vacuum threshold be relaxed?

Instability and blow-up at injection

- Instabilities and blow-up of the beam started to appear when bunch nbr > 1100
- No every fill, sometime on B1, sometime on B2.
- Beam had to be dumped several times (16 recorded in PM DB, sometime with the need to wait for cryo to stabilize)



- One problem identified and solved on the ADT, the gains optimized.

  We need a better ADT diagnostic at each injection to easily spot this kind of problems
- Higher octupoles an chromaticity necessary (15 both planes)
- The cause of the instabilities is complex and not fully understood
- More details on Lee Robert CARVER's presentation on instabilities

Conclusion

- Ramp, squeeze and rampdown time is driven by the functions settings (only small optimization can be done)
- Injection is the part of the turnover where we can really gain time
  - Optimize the SPS supercycle length
  - Improve the compatibility between LHC needs and SPS daily operation to allow more setting-up time before beam is requested
  - Optimize the filling schemes to reduce the number of SPS supercyle change, reduce the number of injections and allow for steering while filling.
  - Optimize the time spent for beam measurement
- Limitations appear when the number of bunches increases
  - Beam instabilities: still needs to be understood better
  - Cryogenics stability : where is the limit?
  - Heat load

- Next run : injection of 288 bunches, more challenging.