Injection losses vs Operational Availability

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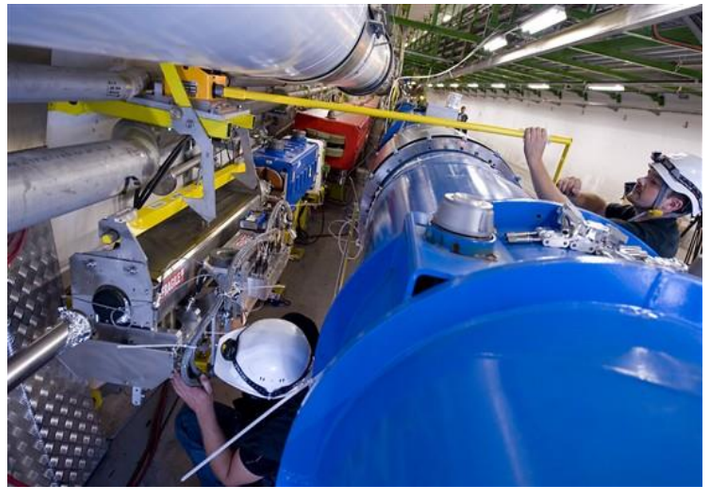
LHC Injection constraints

High beam quality required: transverse and longitudinal

Depending on LHC + whole injector chain

- Minimize satellites from injectors
- Minimize unbunched beam at location of next injection

- Transfer line collimators at the end of line → cross-talk with LHC BLMs
  - Keep bunches short
  - Remove beam tails → scraping
  - Keep trajectory stable at TCDIs



- Keep injection oscillations small
  - Below 2 mm for aperture and maximum damper performance (interlock at 1.5 – 1.75 mm)

- Minimize time spent at injection
- Keep injection safe → inject first intermediate, steer with intermediate

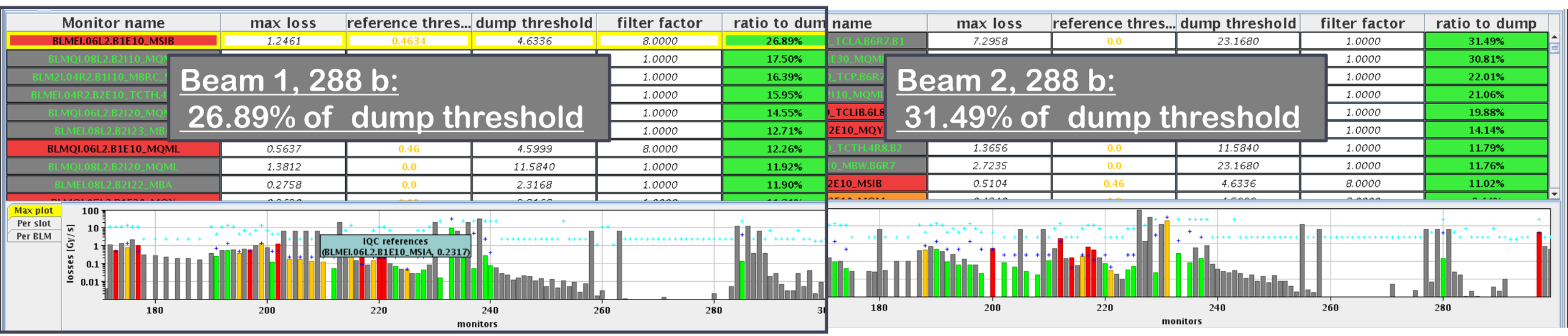
LHC Injection status

- Injecting routinely 144 bunches, 50 ns
  - Small emittances

- Can inject 3.5 μm emittances with 4.5 σ TCDIs
  - Similar loss levels as nominal 50 ns

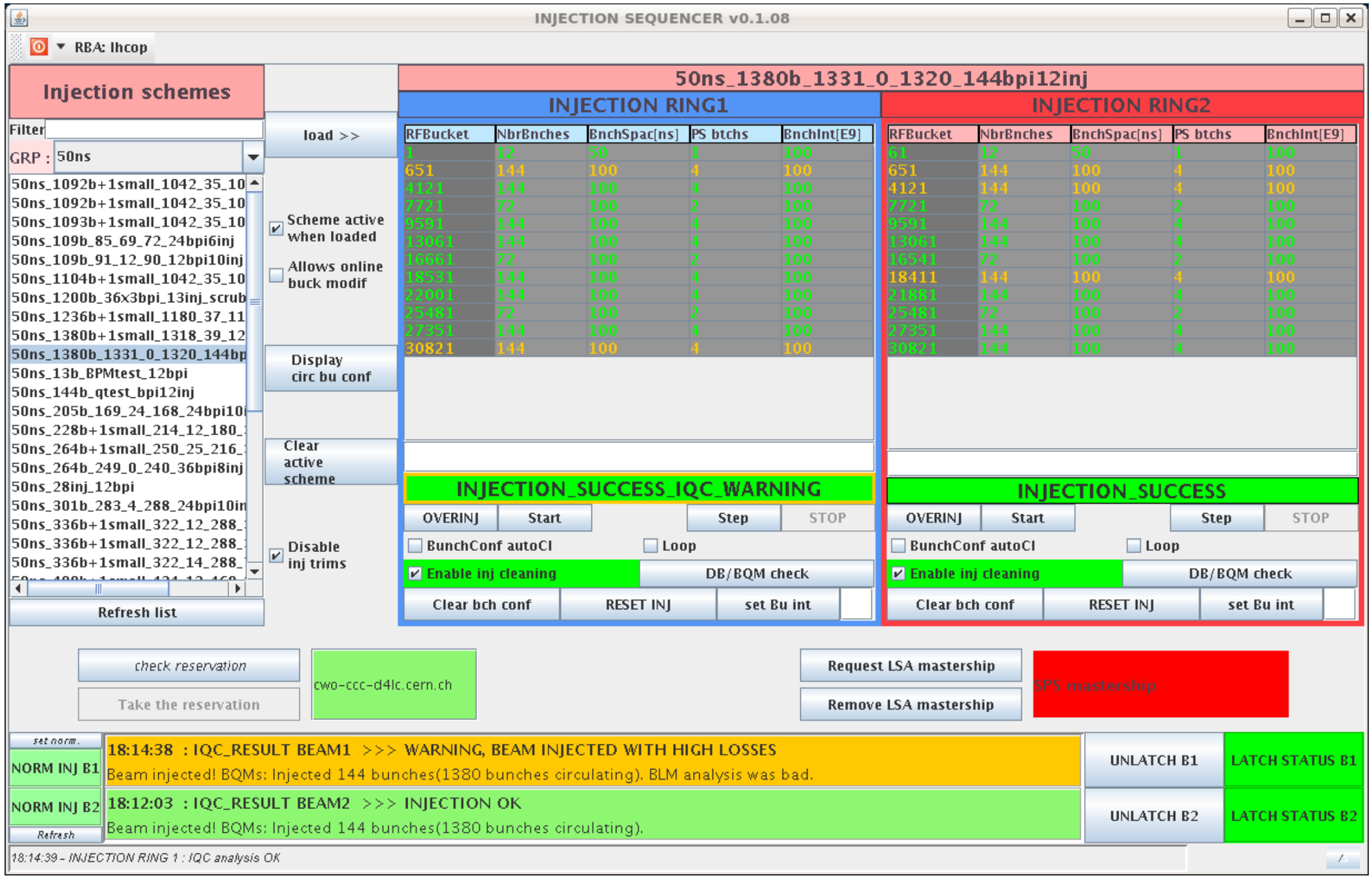
Result:
MD 1 – Injection Quality

- Can inject 288 bunches, 25 ns, without problem!
  - Slightly smaller bunch intensity than nominal, slightly smaller emittance



- Set up transfer line collimators once during the run 2011
  - End of February/ beginning of March
  - One trajectory reference for the whole year

- Average bunch intensity 1.45e+11. Record bunch intensity 2011. Fill 2222.

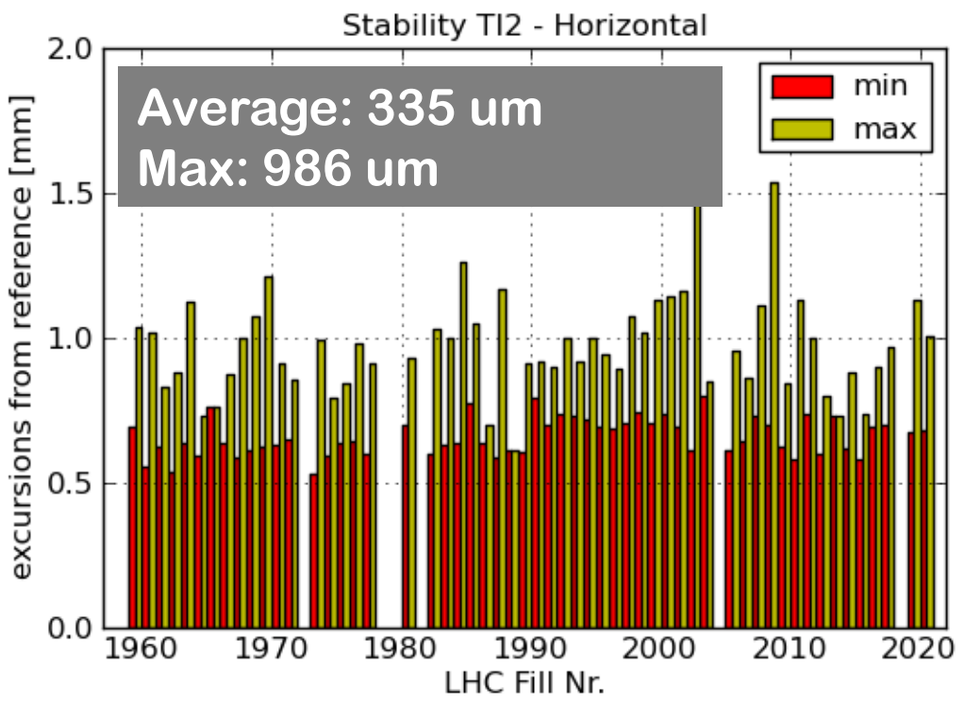


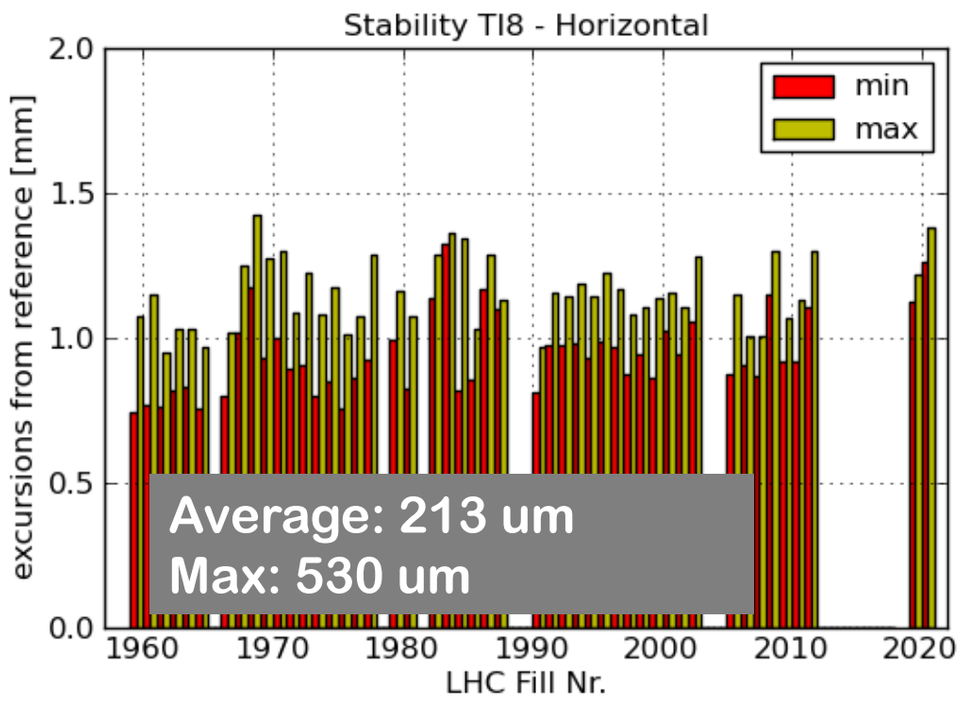
- Very good injection quality

But…

- Beam quality not stable
  - Emittances and tail population especially (different booster rings,…)
  - We know we can take these variations if we are well-centered in the TCDIs

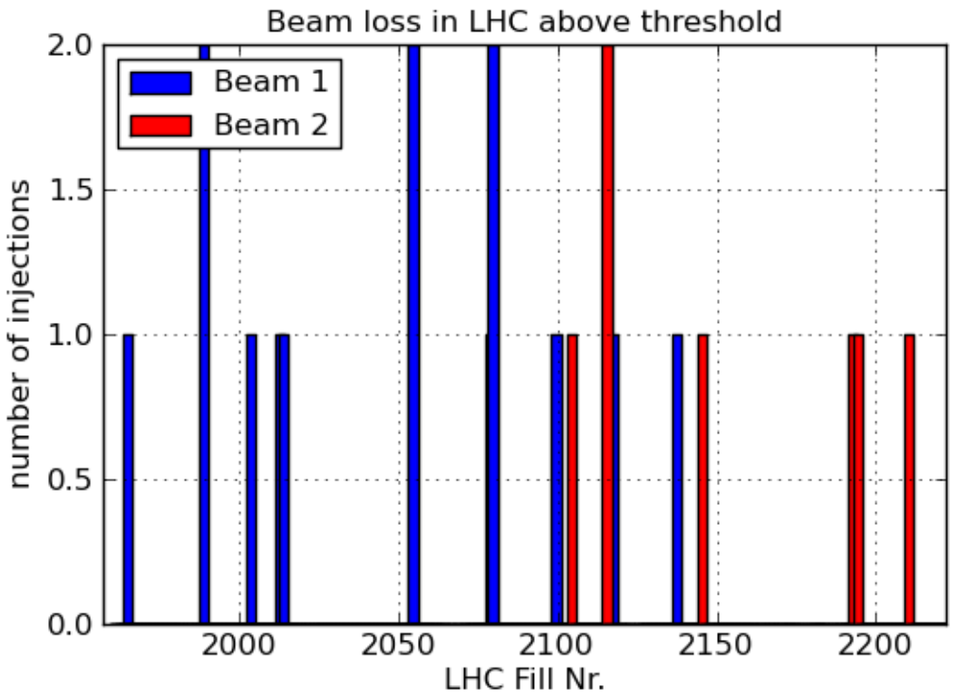
- Transfer line trajectories too unstable in the horizontal plane
  - Drifts
  - Supercycle dependence
  - Large shot-by-shot variations





Dumps due to injection losses

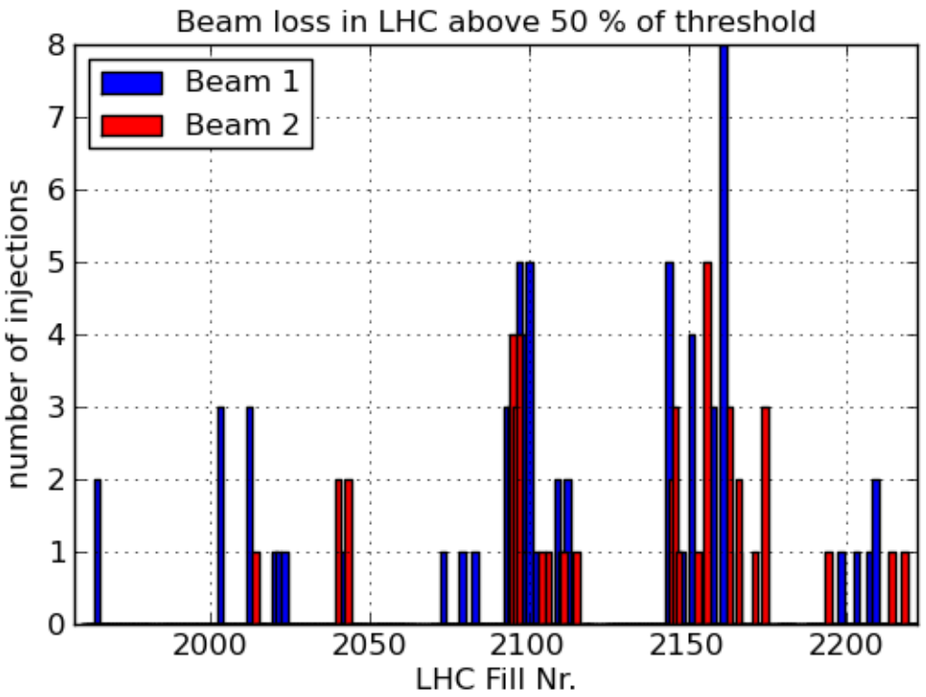
- Number of dumps due to injection losses since middle of July



14 dumps for beam 1

6 dumps for beam 2

- Try to avoid dumps, start steering before we reach dump level



Steering frequency:

Beginning of year: ~ once a week
September: every 2 – 3 fills
Now: every couple of days

Steering mainly triggered by losses

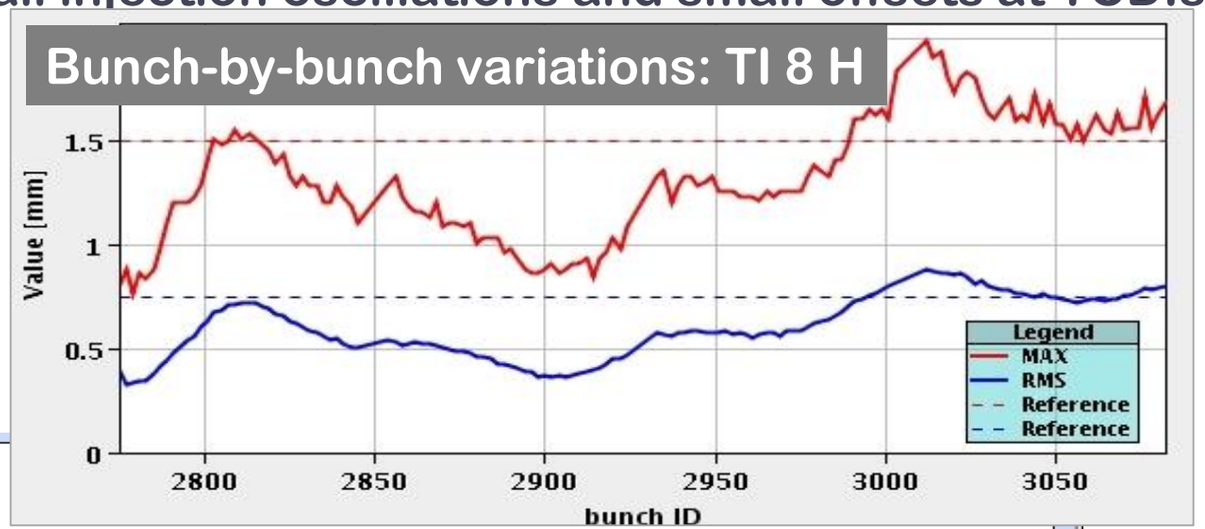
How much time is lost?

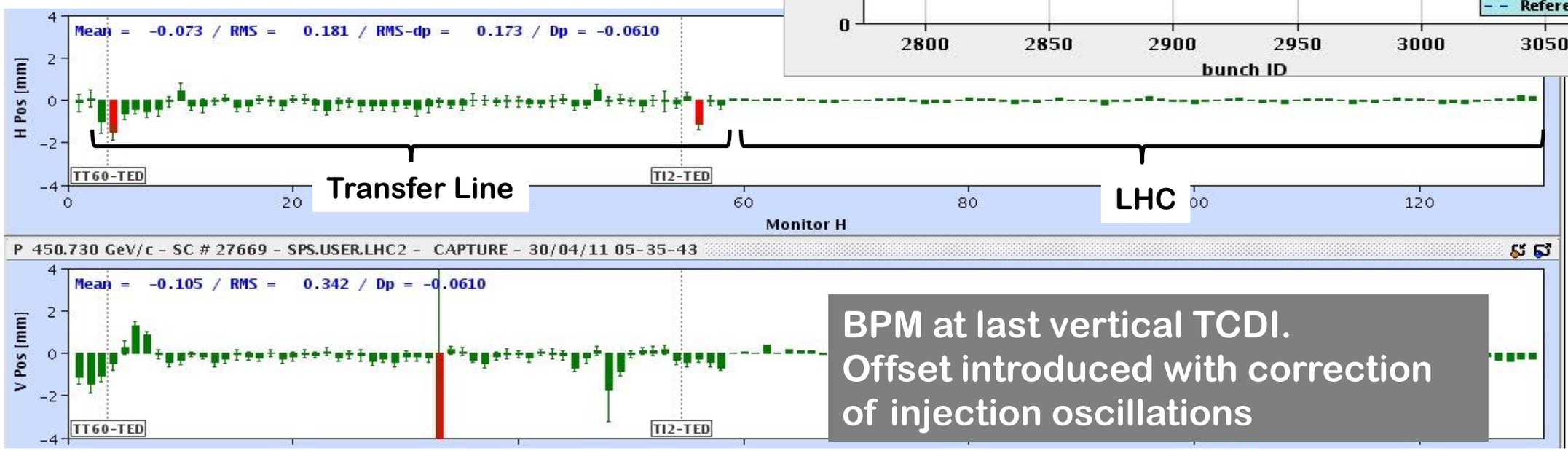
- Filling (excluding switch between intermediate and nominal): **30 minutes**

- Time lost with steering: **~ 30 min to 2 h**
  - Need to take average over several shots

Not easy to steer – compromise between small injection oscillations and small offsets at TCDIs

- LHC orbit and TL have drifted apart
- MKE 4 ripple





BPM at last vertical TCDI.
Offset introduced with correction of injection oscillations

Summary

- We are injecting 144 bunches routinely and mostly very cleanly!!
- The reproducibility of the LHC beams and transfer line stability is however still **NOT good enough**
- Together with the tight constraints from losses, machine protection and injection oscillations, injection is still the **least predictable** part of the LHC nominal cycle.
- Injection tuning is required **several times a week** → time lost probably still acceptable with current turn-around time but not in the long run.

From the 8:30 meeting

- TI2 may benefit from a bit of re-steering next time around
  - Generally injection OK, but transfer lines do need re-steering about every second fill

- **Problems encountered with tin**
  - Cryo PLC problem →
  - Vacuum pump in IR4 →
  - Injection tuning → 10.5 h
  - Controls network → 8.5 h
  - Collimator controls → 5 h
  - Access system → 4 h
  - BPM interlock limits → 1.5 h
  - Total: 66.5 h

Transfer Line Issue: Oscillations

- 16:15 Injecting for physics – SPS some problems setting some injection losses in the LHC

15:52h ***injection beam 1***
optimising beam parameters
strong losses at SPS / Transferline

50ns_1380b+1small_1318_39_1296_144bpi

INJECTION RING1

RFBucket	NbrBnches	BnchSpac[ns]	PS btchs	BnchInt[E9]
1	1	0	1	100
381	12	50	1	100
1041	144	50	4	100
4481	144	50	4	100
8121	72	50	2	100
9981	144	50	4	100
13421	144	50	4	100
17061	72	50	2	100
18921	144	50	4	100
22361	144	50	4	100
25881	72	50	2	100
27741	144	50	4	100
31181	144	50	4	100

INJECTION_SUCCESS

OVERINJ | Start | Step | STOP

BunchConf autoCI | Loop

Enable inj cleaning | DB/BQM check

Clear bch conf | RESET INJ | set Bu int

INJECTION RING2

RFBucket	NbrBnches	BnchSpac[ns]	PS btchs	BnchInt[E9]
1	1	0	1	100
441	12	50	1	100
1041	144	50	4	100
4481	144	50	4	100
8121	72	50	2	100
9981	144	50	4	100
13421	144	50	4	100
16941	72	50	2	100
18801	144	50	4	100
22241	144	50	4	100
25881	72	50	2	100
27741	144	50	4	100
31181	144	50	4	100

INJECTION_SUCCESS_IQC_ERROR

OVERINJ | Start | Step | STOP

BunchConf autoCI | Loop

Enable inj cleaning | DB/BQM check

Clear bch conf | RESET INJ | set Bu int

Fill 2208
Issue with steering TI 8 H