# NEWS AND PROGRESS OF TURN-AROUND TIME STUDIES

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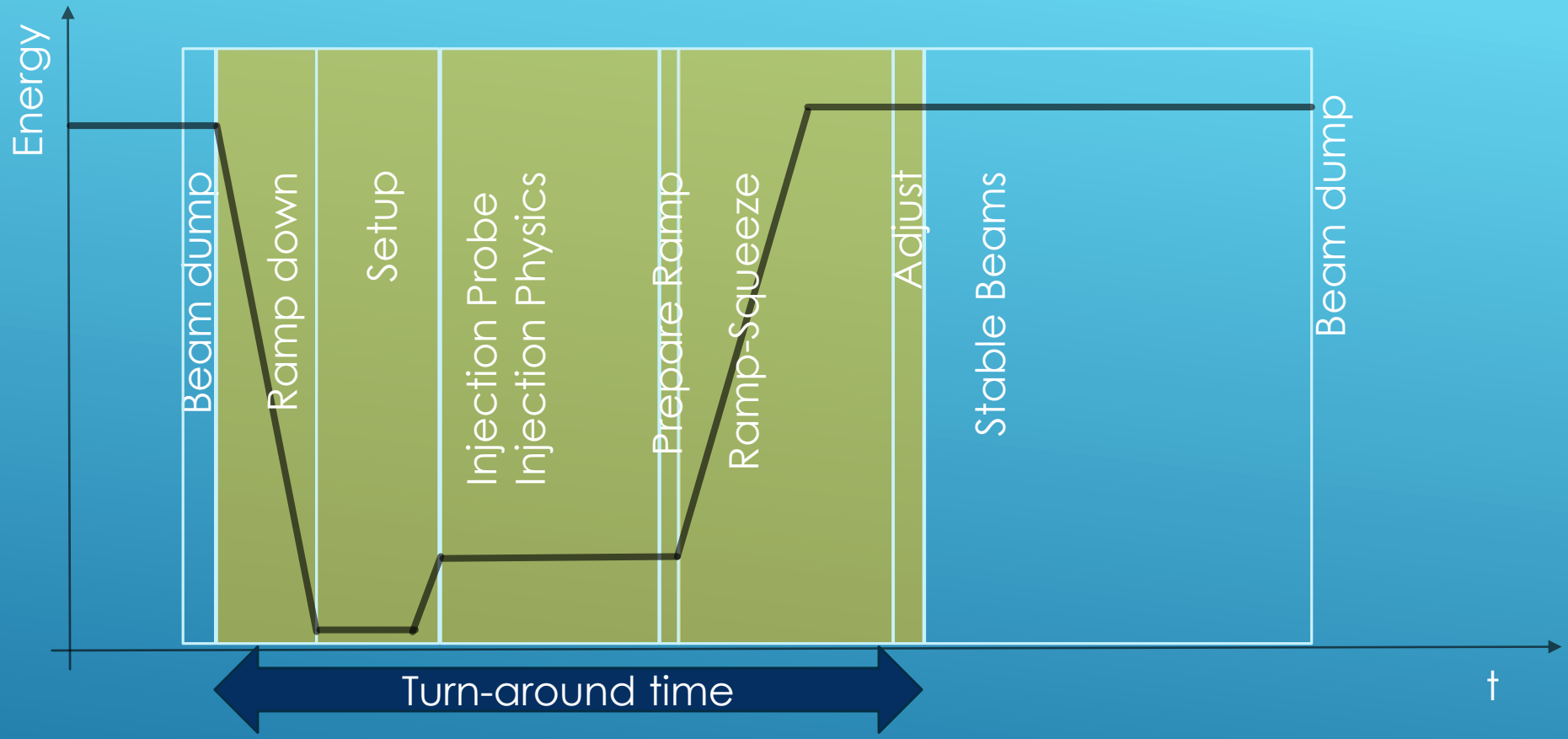
SB: Stable Beams




# FCC-HH OPERATIONAL CYCLE (≈ LHC)

| Opt | LINAC4 | PSB | PS | SPS | 100 km HEB | LHC | FCCinj | Tinj (min) |
|---|---|---|---|---|---|---|---|---|
| | Flattop beam energy (GeV) | | | | | | | |
| OPT1 | 0.160 | 2 | 26 | 450 | | 3300 | 3300 | 36 |
| | | | 72 b | 9 PS->SPS = 648b | | 2x4 SPS->LHC = 2592 b/ring | 4 LHC->FCC = 10368 b/ring | |
| OPT2 | 0.160 | 2 | 26 | 450 | 3300 | | 3300 | 29 |
| | | | | 10 PS->SPS=720b | 15 SPS->HEB =10800 b | | 1 HEB->FCC = 10800 b/ring | |
| OPT3 | 0.160 | 2 | 45 | 1550 | | | 1550 | 34 |
| | | | 80 b | 8 PS->SPS=640 b | | | 2x17 SPS->FCC =10880 b/ring | |

Assumptions:

- Bunch intensity 1e11 p+
- SPS extraction kicker and HEB injection kicker flattops long enough to inject all SPS trains at once
- HEB single ring; extraction in packets assuming no significant delay
- SPS cycle time = 10.8 + n x PS cycle time for n PS batches (except for OPT3)

**Tinj = filling time + ramp up/ramp down + 10 s.**
**No extra possible overheads.**

# INJECTION PHASE IN FCC

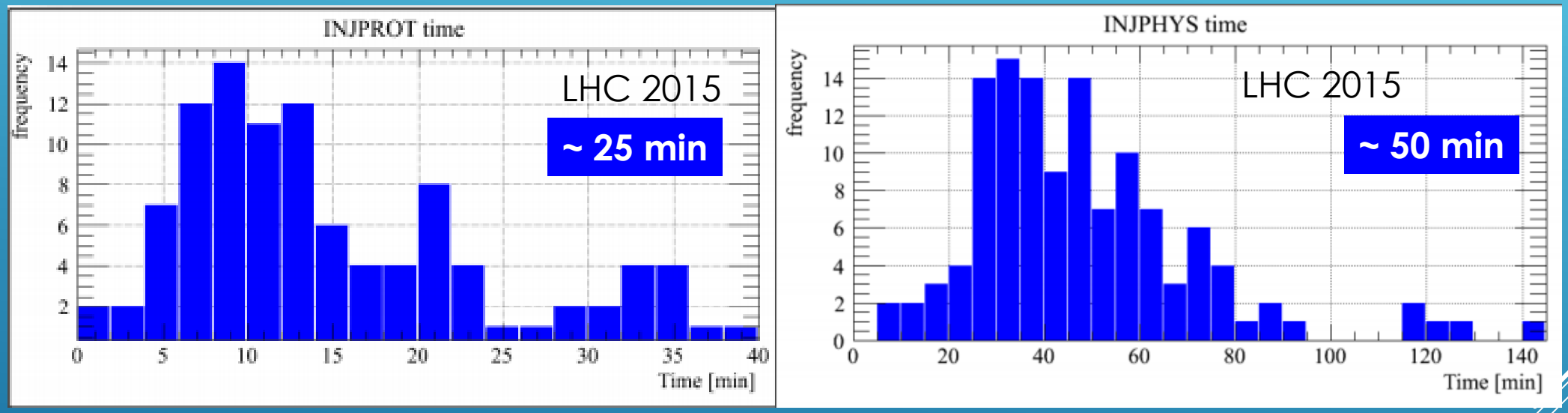
Results by Linda Stoel and Florian Burkart

1. Injection of pilot bunch per beam (~1e10 p+) (could be that reinjection of pilots is required)
2. Measure and correct: Q, Q', C, orbit, phase error
3. Injection of 2x12 bunch train per beam:
    1. check transfer line and injection oscillations
    2. If not good ➔ transfer line steering (needs time in LHC)
    3. If good ➔ measure emittance
4. Injection of the rest of the physics beam
5. Once machine full ➔ PREPARE RAMP

# INJECTION PROBE & INJECTION PHYSICS BEAM IN LHC: WHAT WE DO

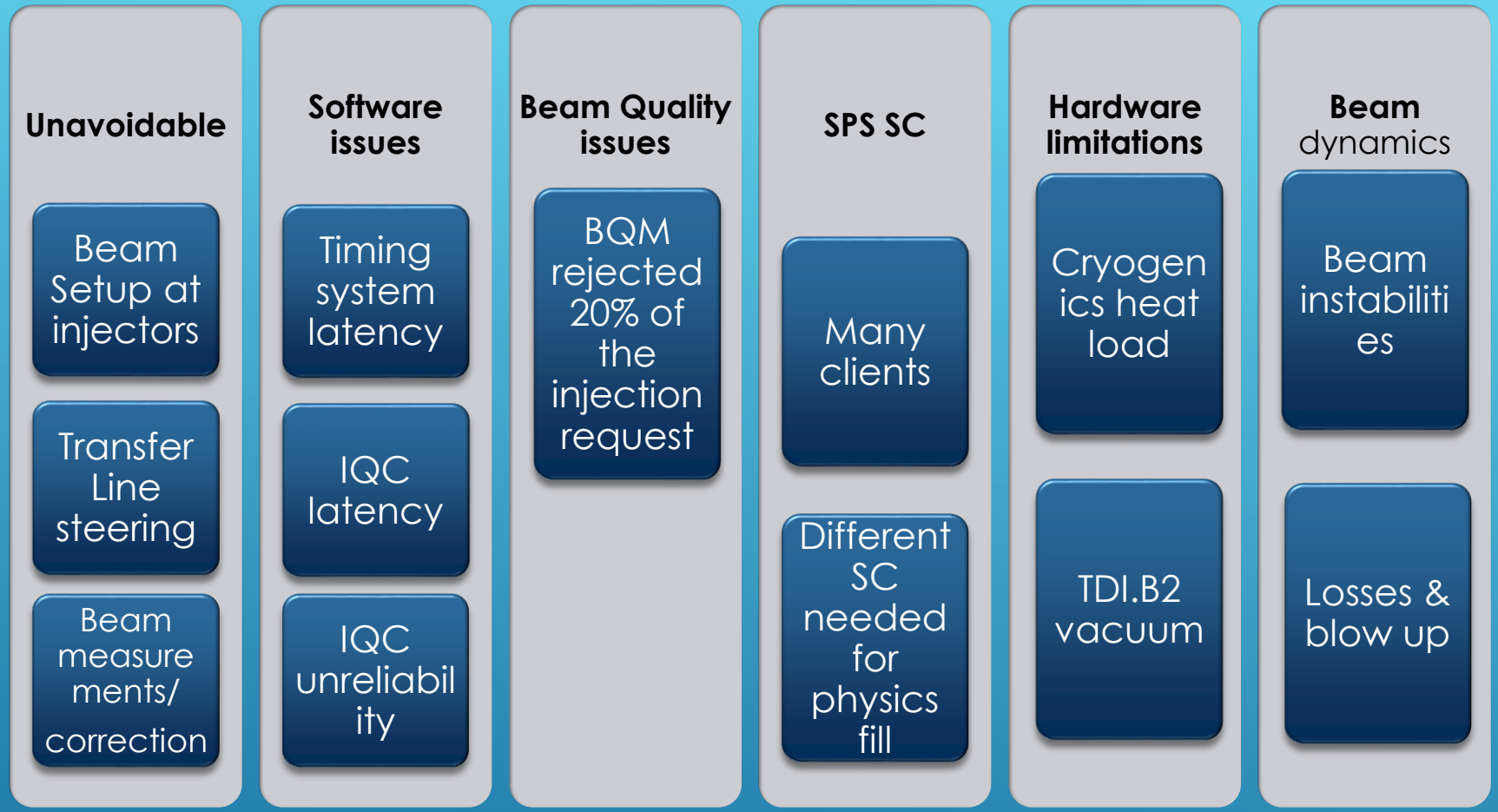
The theoretical minimum injection time in LHC is defined by the number of injections required x SPS super cycle length:

Average number of injections per fill = 22
SPS SC length = 59 s (not optimized for a dedicated LHC filling!)
Minimum injection time in LHC = **22 minutes**




M. Solfaroli, EVIAN 2015

# INJECTION PROBE & INJECTION PHYSICS BEAM IN LHC: THEORY VS REALITY

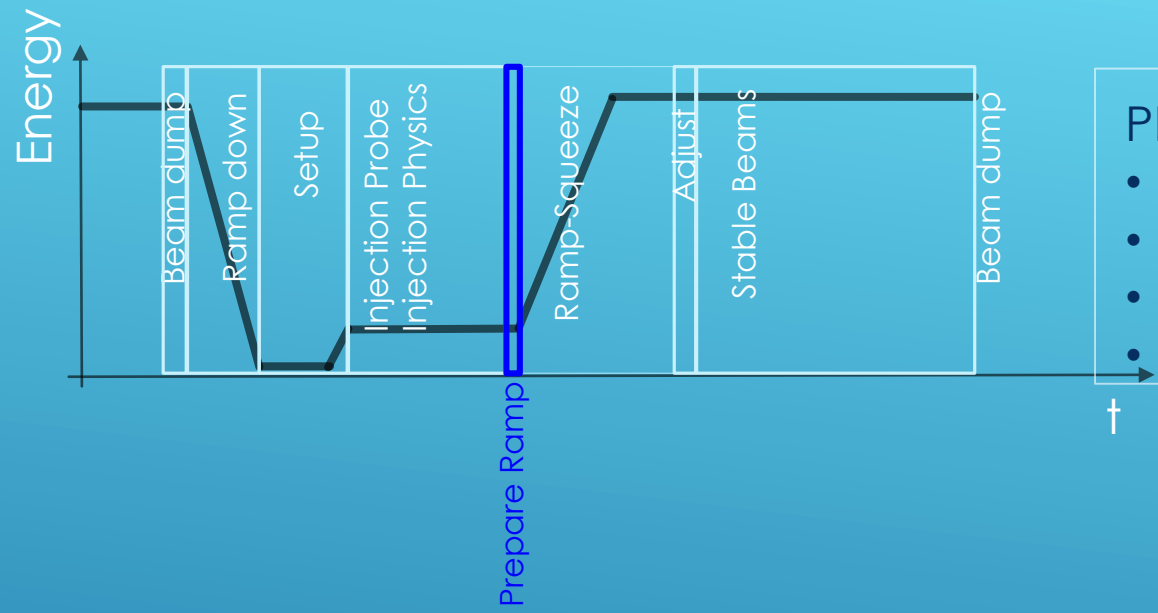



D. Jacquet EVIAN 2015

# INJECTION PROBE & INJECTION PHYSICS BEAM IN LHC: WHAT CAN GO WRONG

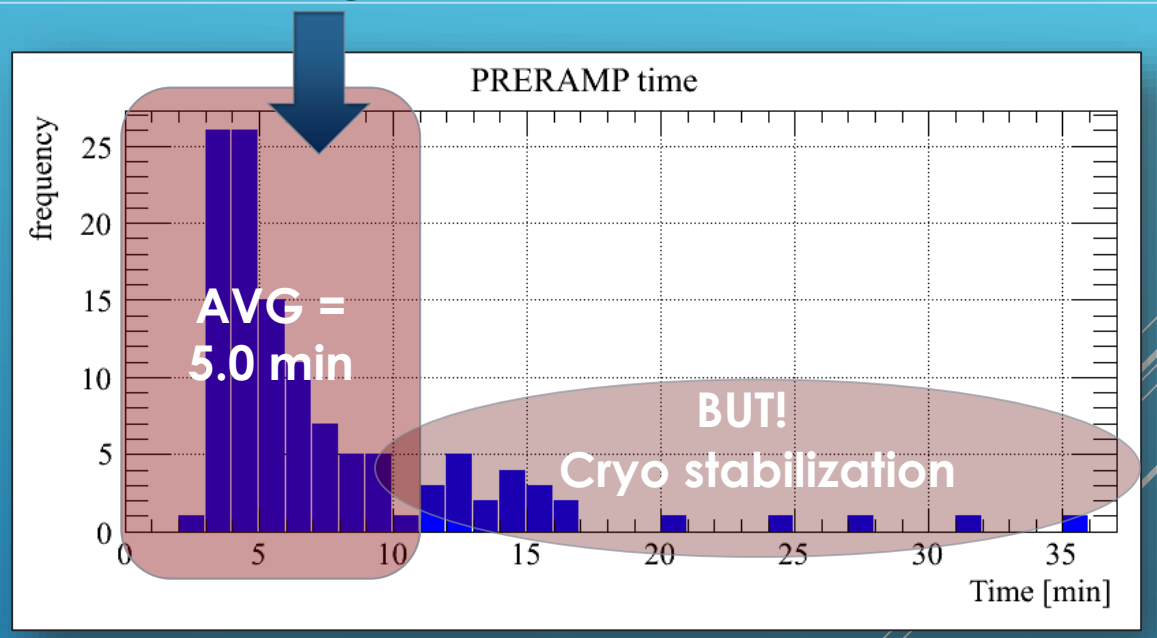


SC: Super Cycle
BQM: Beam Quality Monitor
BS: Beam Screen




PREPARE RAMP IN LHC:

- Injection protection collimators to parking
- Settings incorporation in the ramp function
- Load settings in RF, PC, collimators, transverse dampers
- Feedbacks being prepared to follow the ramp

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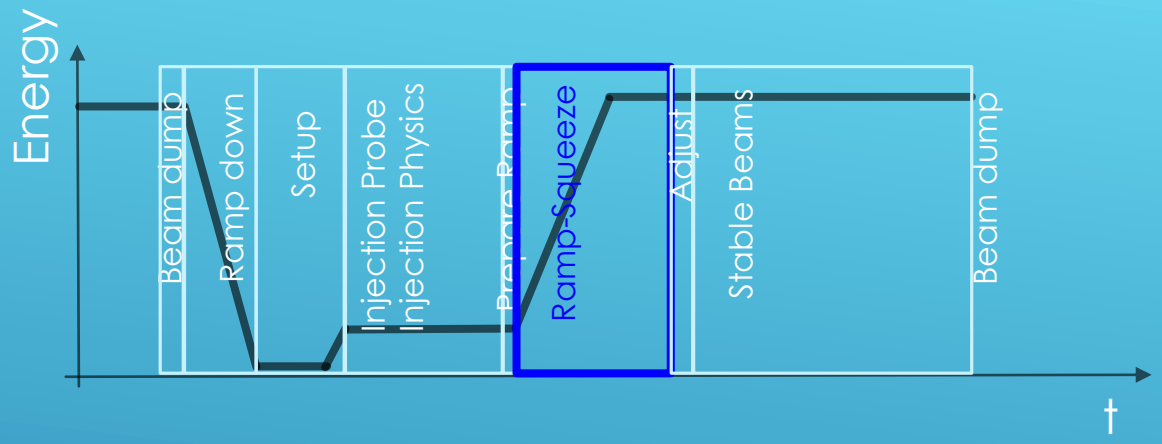
# PREPARE RAMP




RAMP-SQUEEZE IN LHC:

- Function playing (no human intervention)
- Q, Orbit and Transverse Feedbacks follow

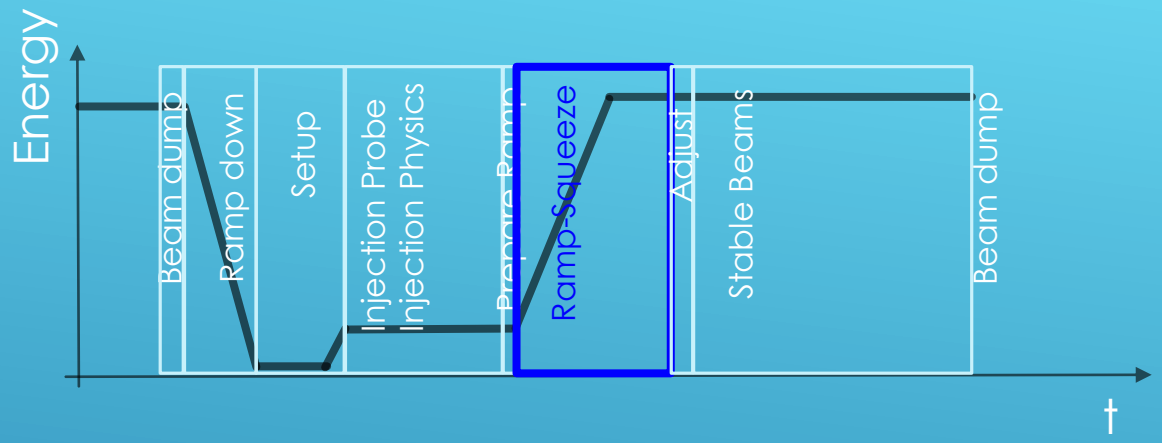
- **RAMP TIME**:
  - LHC energy factor from 450 GeV to 7 TeV is 15.5
  - FCC-hh energy factor from 3.3 TeV to 50 TeV is 14
  - Since both factors are equal ➔ same ramp time for FCC = **20 minutes**
- **SQUEEZE TIME**:
  - LHC squeeze from 11 m to 0.8 m (IP1&5) = 12.5 minutes
  - FCC-hh baseline squeeze from 5 m to 1.1 m ➔ half of the LHC squeeze ➔ **6 minutes**
  - Since combined with the ramp, remains in the shadow

Assuming same equivalent LHC configuration

Ways of improving this number:

- Optimized sectorization
- Optimized inductance distribution

# RAMP-SQUEEZE



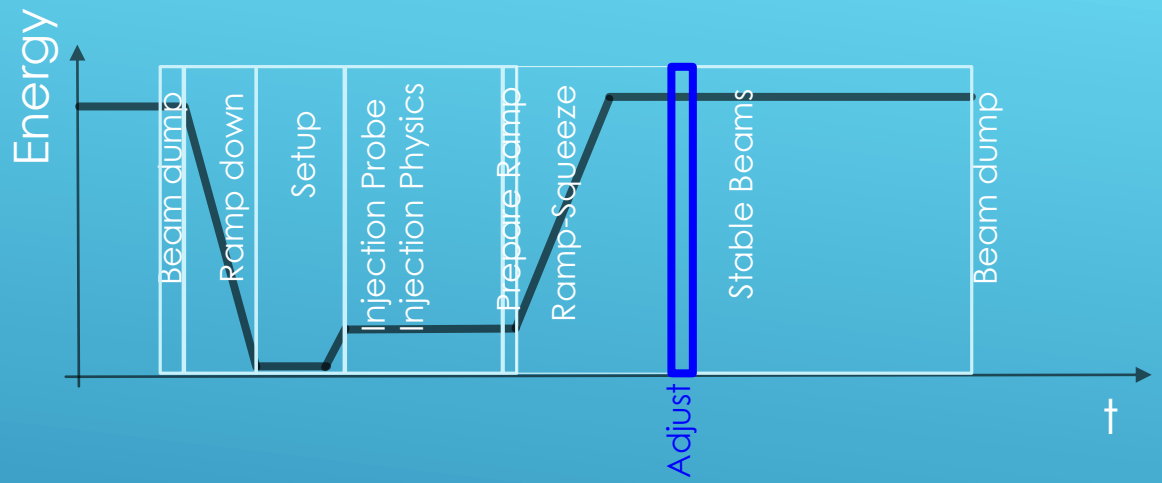

RAMP-SQUEEZE IN LHC:

- Function playing (no human intervention)
- Q, Orbit and Transverse Feedbacks follow

- LHC up to 2015: RAMP, FLAT TOP, SQUEEZE ➔ from 2016: RAMP-SQUEEZE (11 m ➔ 3 m), FLATOP, SQUEEZE (3 m ➔ 0.x m)
- **FLAT TOP**: several actions are performed sequentially by the operator; takes ~ **5 minutes**
- But with appropriate control system everything could be done automatically until the end of the squeeze, therefore RAMP-SQUEEZE mode would be enough

# RAMP-SQUEEZE

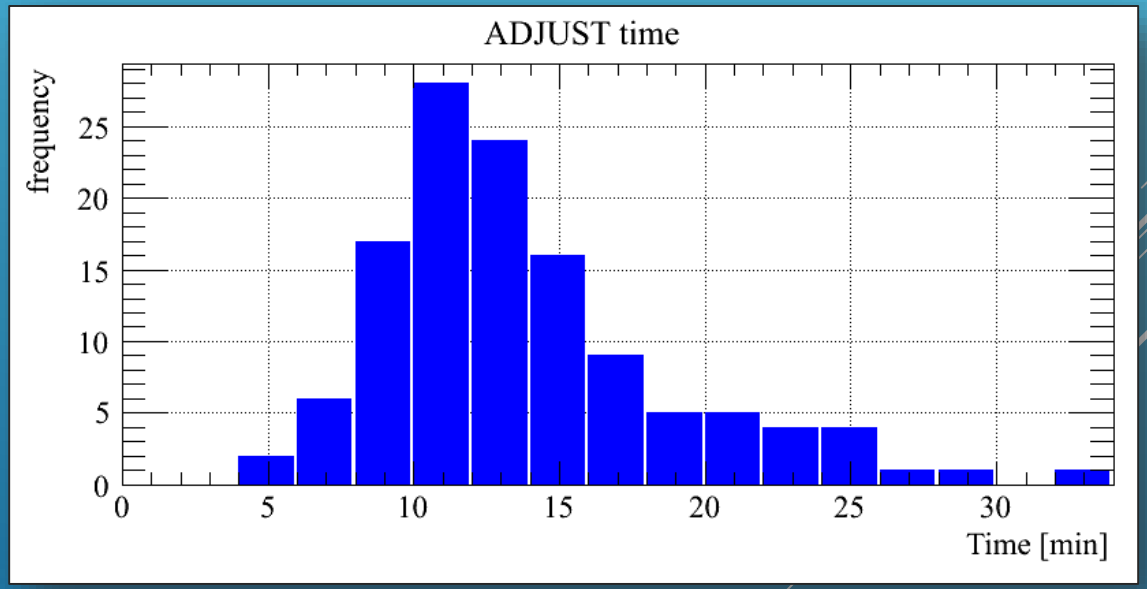
| Mode | Time (min) |
|---|---|
| RAMP | 20 |
| FLAT TOP | 5 |
| SQUEEZE | 6 |
| TOTAL | 20+5 |




ADJUST IN LHC:

- Settings incorporation
- Functions playing (no human intervention)
- Experiments luminosity optimization

| Mode | Time (min) |
|---|---|
| ADJUST | 10 |

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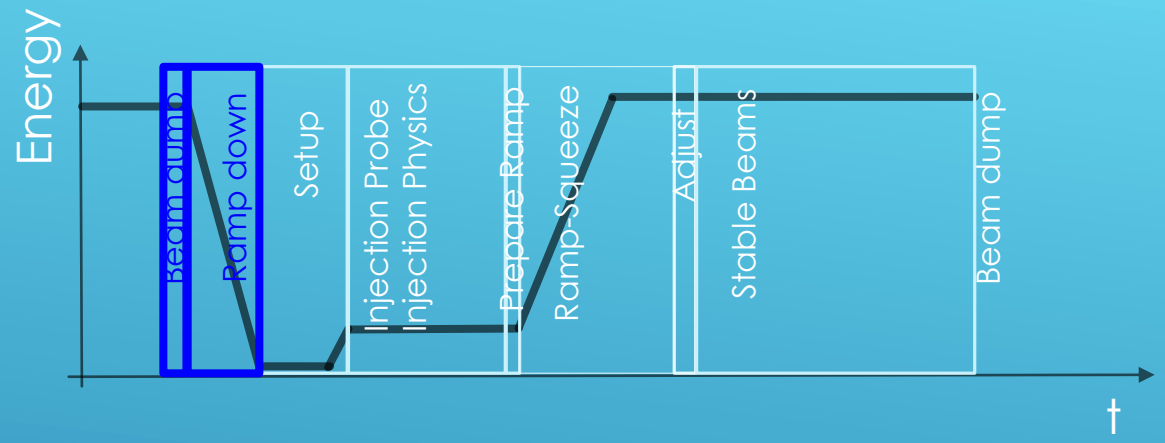
# ADJUST




BEAM DUMP – RAMP DOWN IN LHC:

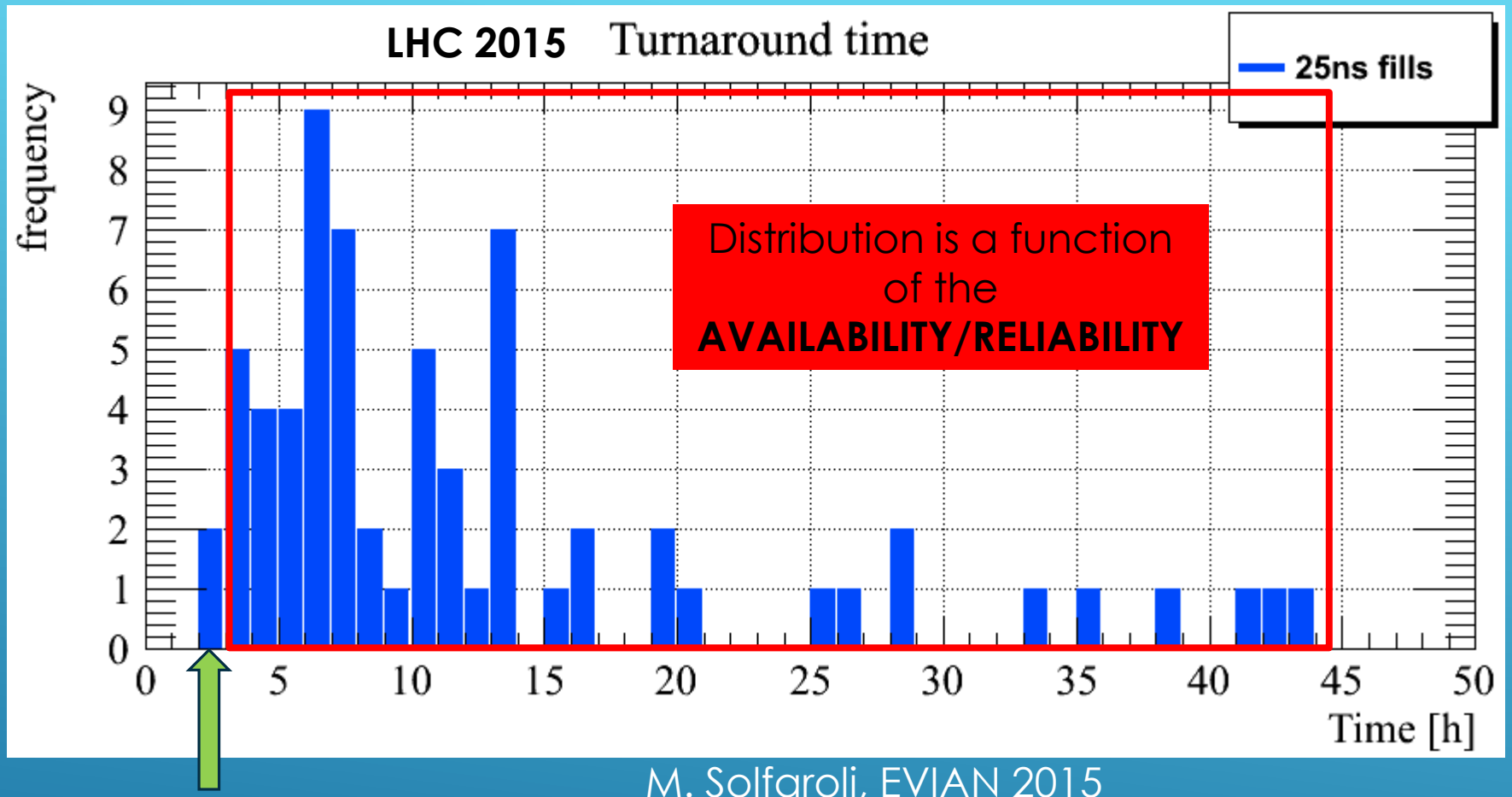
- Handshake for beam dump ~ 5 min (done in SB)
- Beams are dumped and the ramp down starts in parallel to many other tasks to prepare the rest of the machine for the next injection
- But the time is driven by the magnet circuits ramp down

- **RAMP DOWN TIME**:
  - If all main power converters are four-quadrant ➔ ramp down = ramp = **20 min**
  - In LHC is not the case and the ramp down is ~ 40 min (2xramp)

# BEAM DUMP - RAMP DOWN

| Mode | Time (min) |
|---|---|
| PRE-INJECTION TO INJECTION | 10 |
| INJECTION | 36 |
| PREPARE RAMP | 5 |
| RAMP-SQUEEZE-FLAT TOP | 20+5 |
| ADJUST | 10 |
| RAMP DOWN | 20 |
| TOTAL | 106 (1.8 hours) |

# FCC-HH THEORETICAL TURN-AROUND TIME

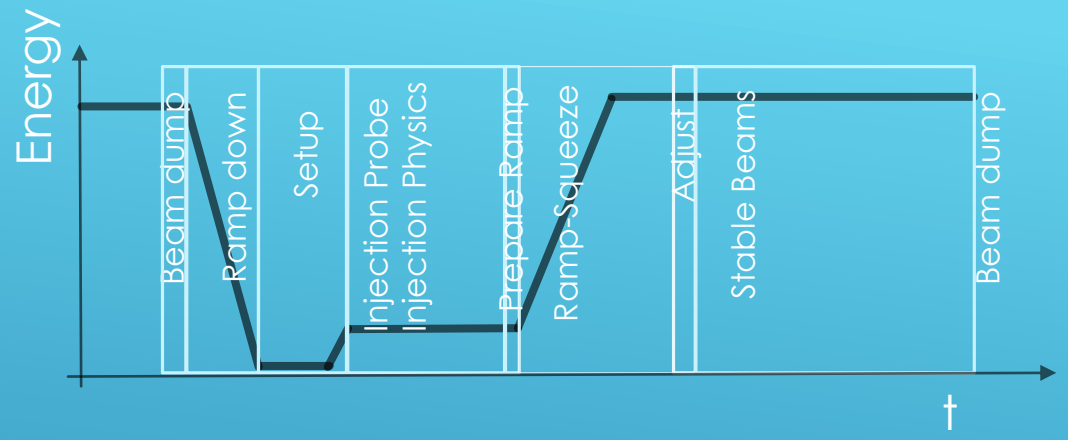



M. Solfaroli, EVIAN 2015

Only two fills made the theoretical minimum!

# LHC TURN AROUND TIME IN 2015

- We propose a FCC-hh nominal cycle a la LHC
- Theoretical times have been calculated to estimate the theoretical TURN-AROUND TIME: **1.8 hours**
- Real machines behave different, e.g. injection phase is more than beam production at the injectors and transfer into FCC
- Next: **The turn-around time NEEDS TO BE CORRECTED BY THE AVAILABILITY-RELIABILITY ESTIMATED FOR FCC-hh**




# CONCLUSIONS

# BACK UP

A very detailed break down of the reason for such a LONG INJECTION TIME IN LHC in 2015 was made by **D. Jacquet at EVIAN 2015**. Below a brief summary from her presentation:

- SPS SC has many clients
- Timing system latency ➔ 3-4 seconds before a new injection request can be processed
- If filling one beam at the time, Injection Quality Check analysis latency up to 10 s
- Many different LHC beams requested in 2015 ➔ 28 hours assigned to injector setting up
- Pilot, indiv, 12 b and nominal trains requires use of two to three different SC within the same fill ➔ switching from one to the other needs few minutes
- 20 % of the nominal beam requests rejected by SPS BQM
- Transfer line steering (though much efficiently done in 2015 than previous years) requires time
- Unreliability of the IQC in 2015 slows down the injection, it can even screw it up
- Some beam measurements in LHC are still manual ➔ slow
- Cryogenics: injection of high intensity beams upsets cryogenics temperature stabilization in the BS; 24 hours down time assigned to this.
- TDI.B2 vacuum issues; 3 hours down time, 5 dumps at injection, forced us to inject one beam at the time and limited the number of bunches per train
- Beam instabilities and blow up at injection (e-cloud, others)

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