



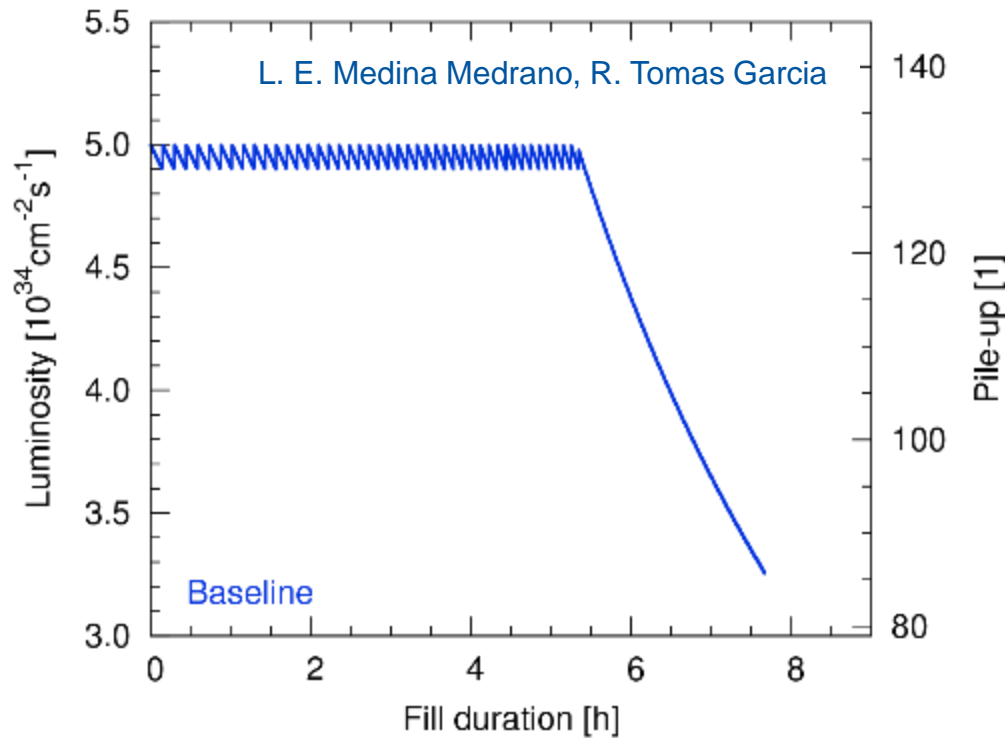
Update on HL-LHC Availability Estimates

A. Apollonio, [J. Uythoven](#), TE-MPE

Many thanks to the AFT team

HL-LHC Annual Meeting, 13 – 16 November 2017, Madrid

Reminder: Integrated Luminosity for HL-LHC



- ❑ Target: 3000 fb^{-1} over HL-LHC lifetime
- ❑ **250 fb^{-1} per year**
- ❑ 160 days of p-p physics
- ❑ 1.56 fb^{-1} per day
- ❑ Levelling: $5 \cdot 10^{34} [\text{cm}^{-2} \text{s}^{-1}]$

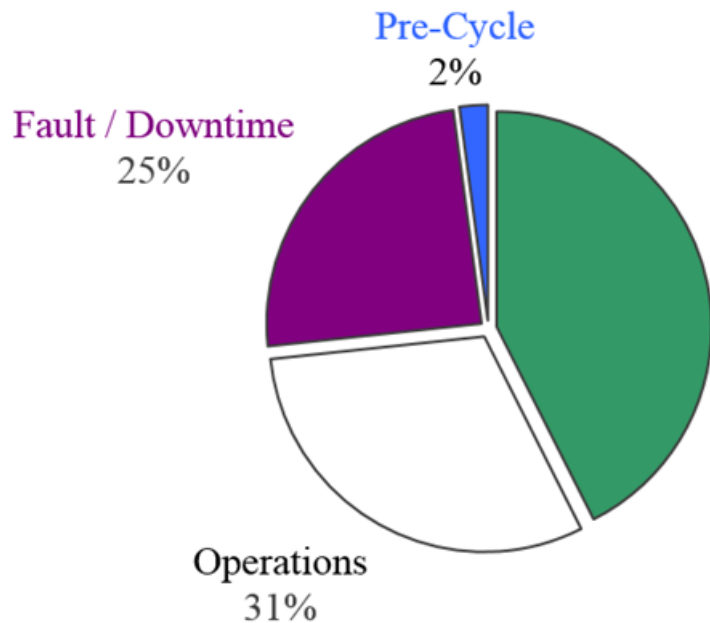
Simple calculation:

- ❑ 12 h HL-LHC fill produces $\sim 1.5 \text{ fb}^{-1}$
- ❑ Requirement for HL-LHC physics efficiency is $\sim 50 \%$
- ❑ The physics efficiency depends on the achieved machine availability

2017 Statistics (TS1-TS2)

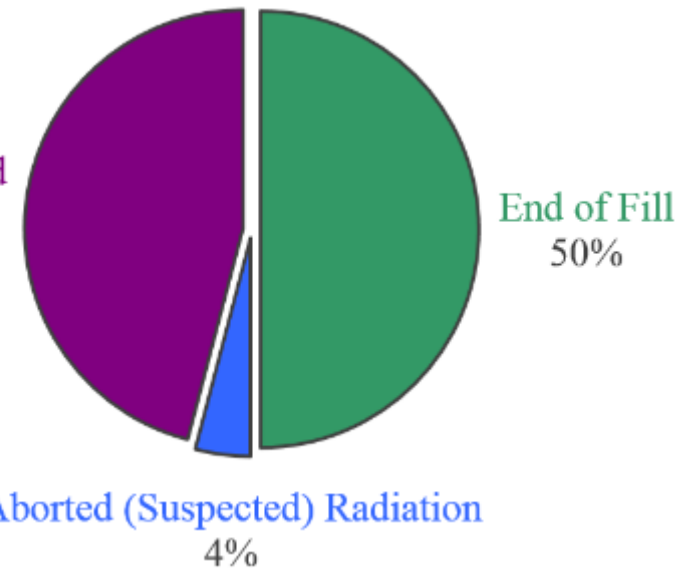
621 h in Stable Beams

98 fills to Stable Beams



Stable Beams
42%

Aborted
46%



End of Fill
50%

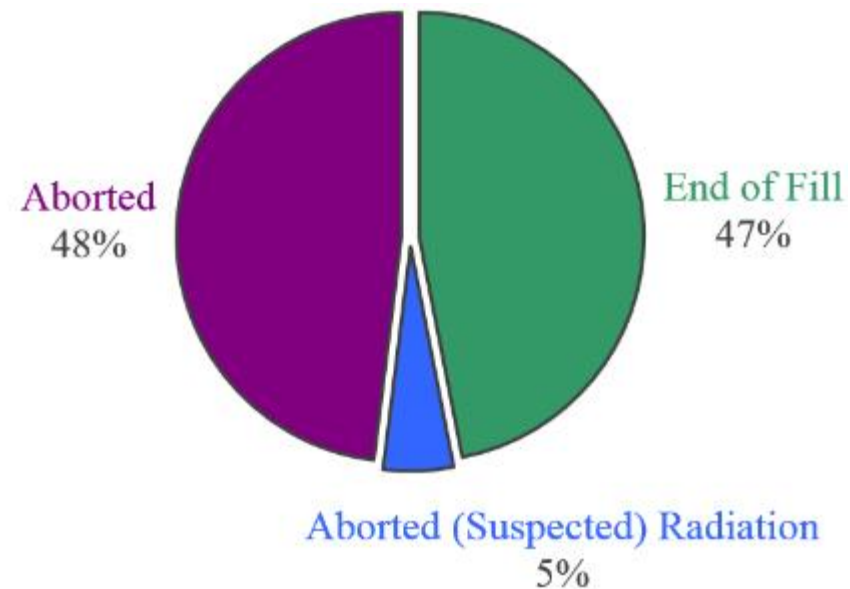
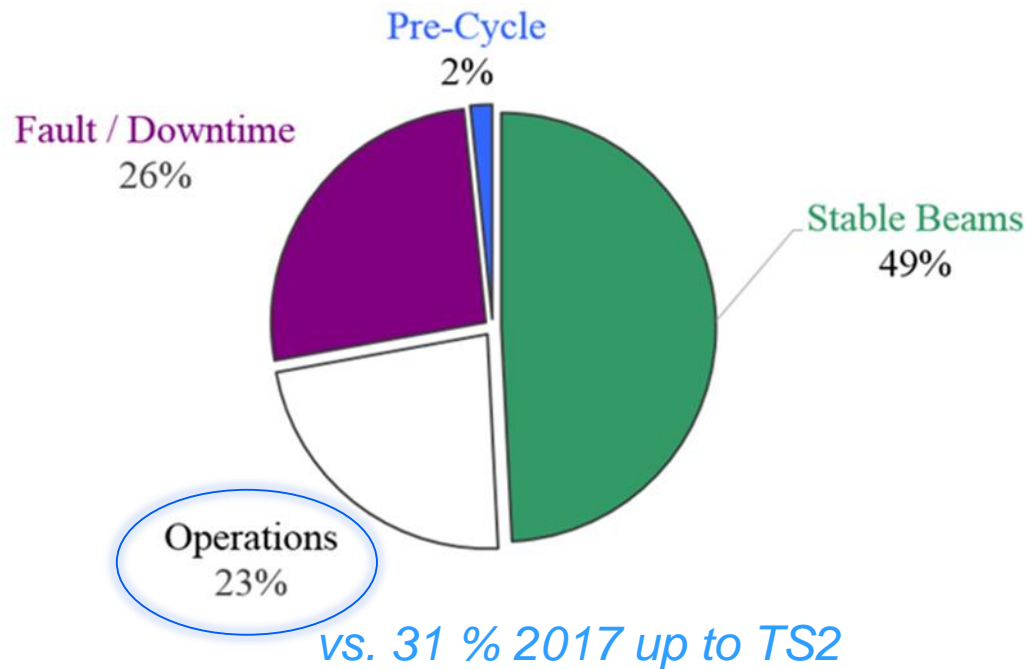
Aborted (Suspected) Radiation
4%

- ❑ 2017 performance limited by recurring dumps due to beam losses in 16L2, otherwise very good machine availability and smooth operation

2016 Statistics (reference year)

1840 h in Stable Beams

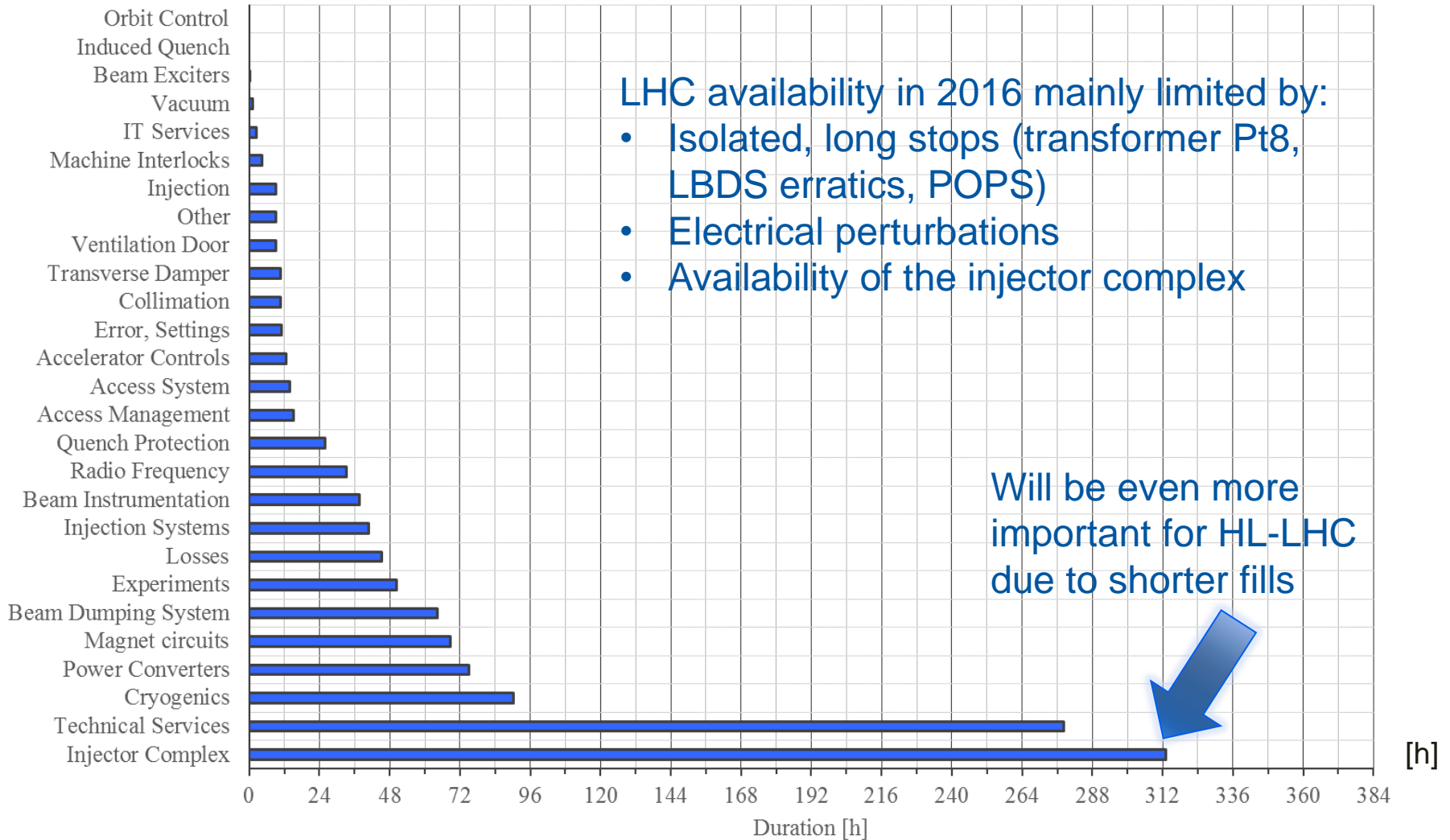
175 fills to Stable Beams



- ❑ 2016 is chosen as a reference for the reproducibility of operating conditions

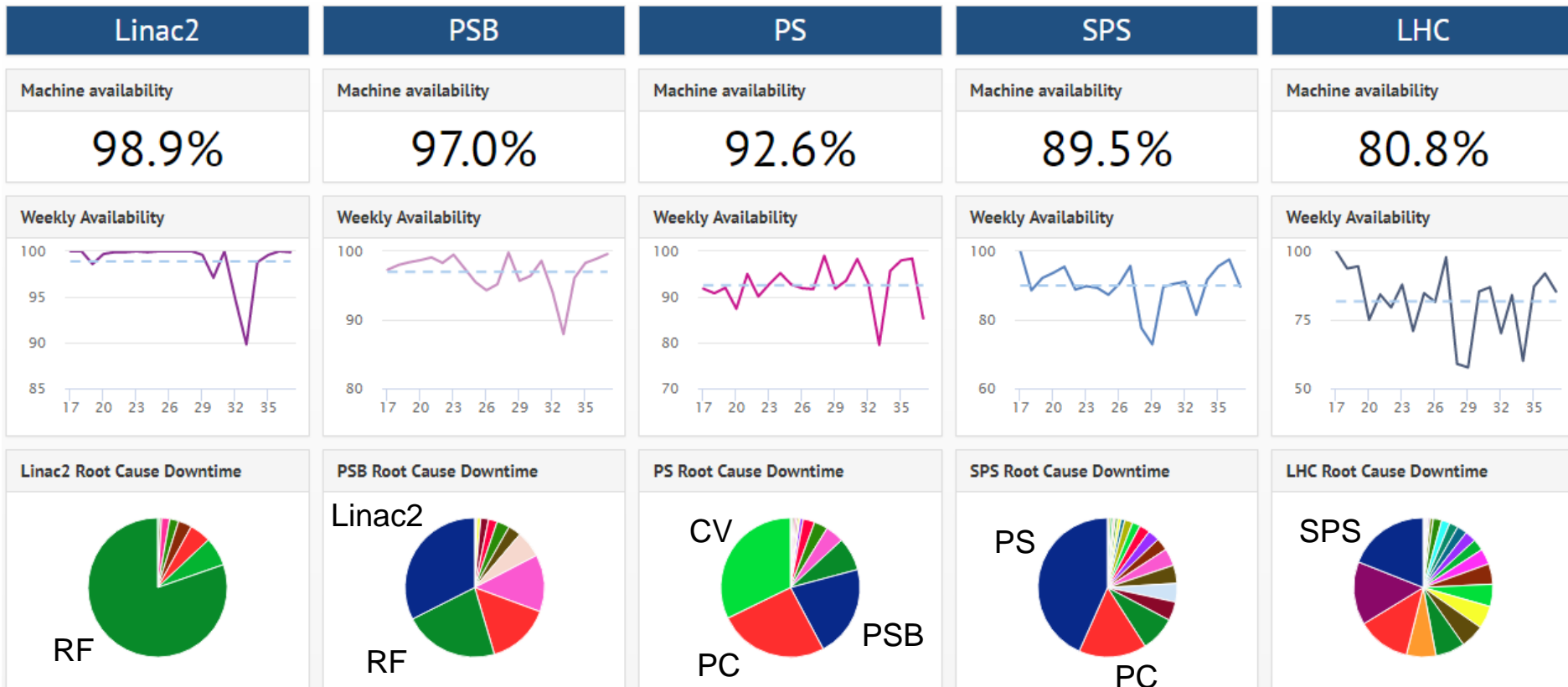
2016 Downtime Distribution

Stacked Pareto - Fault Duration, Machine Downtime and Root Cause Duration vs Root Cause System



2017 Performance of the Injector Complex (May – Sep)

- Accelerator Fault Tracker in use from the beginning of 2017 in all injectors



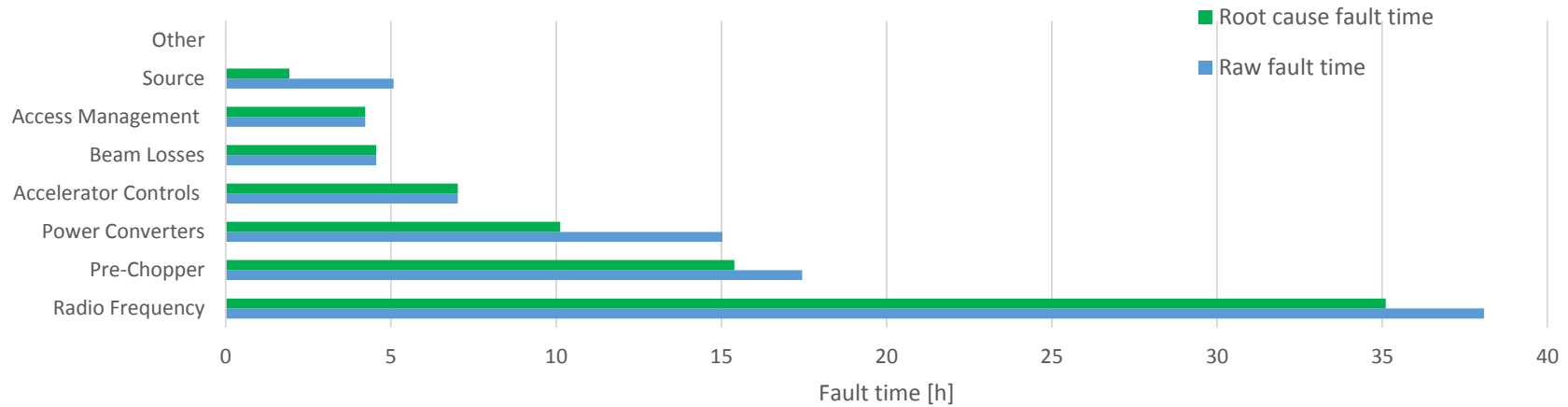
First Results from Linac4 Reliability Run

O. Rey Orozco

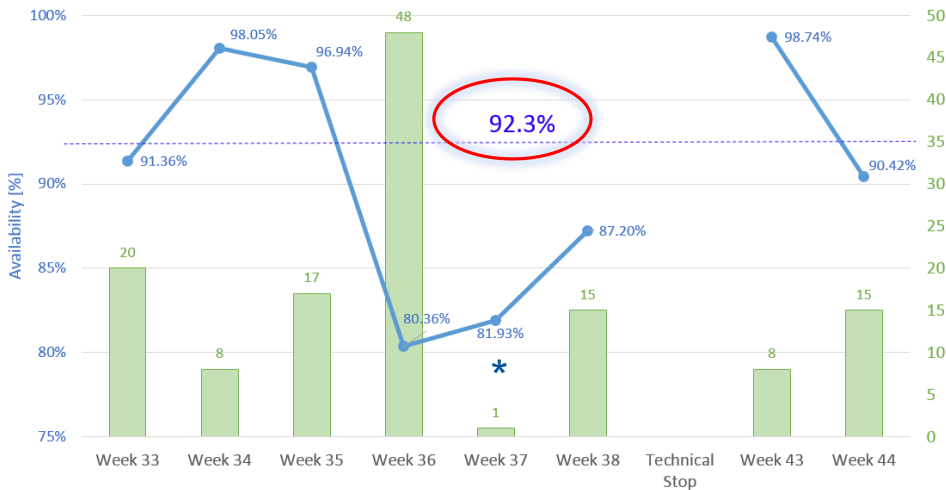
Period: 14/08/2017 – 06/11/2017

Last time updated: 08/11/2017

Root cause / Raw Fault times by system



Weekly Availability / Fault Count



- 11 systems out of 18 (61 %) operated without faults
- Achieving high Linac4 availability will be crucial for HL-LHC goals!
- **Official target availability is 95 %**

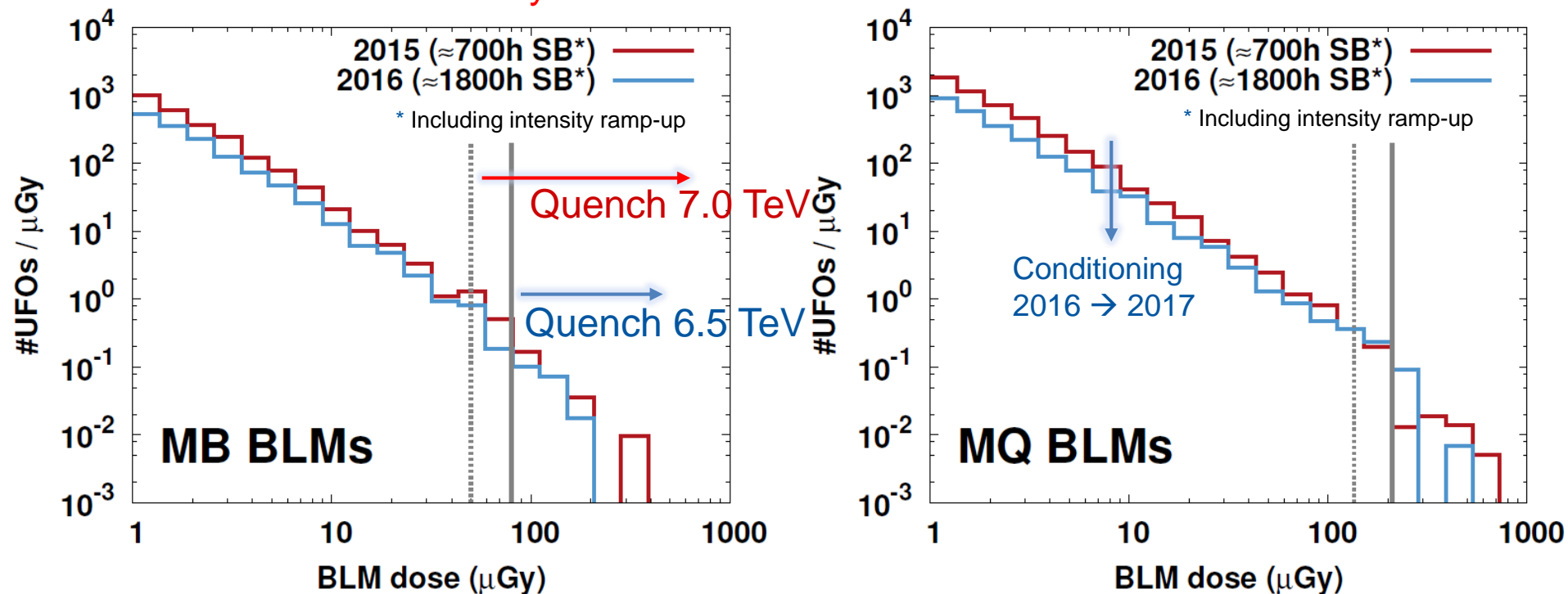
* only 1 day of operation that week, planned intervention



UFOs at 7 TeV

UFO's measured by UFO buster in 2016/2017 and their losses

A. Lechner



For a given UFO rate, # of UFOs which have potential to induce a quench increases by a factor of 2-4 when moving to 7 TeV

The strong dependence of the UFO rate on the machine conditioning status implies that the impact of UFOs on operation at 7 TeV can be critical after a long shutdown

Extrapolation to HL-LHC

- ❑ **Operation at 7 TeV + higher beam brightness:**
 - ❑ UFOs:
 - ❑ UFO rate: release mechanism not understood, scaling with intensity unknown
 - ❑ Lower magnet quench levels (30 %) → Potentially 3x more quenches due to UFOs
 - ❑ Impact of R2E: target 0.1 SEUs dumps / fb-1 (order of 25-30 per year)
 - ❑ Possibly increased failure rate of LBDS due to running at higher voltage (consolidation in LS2 foreseen)

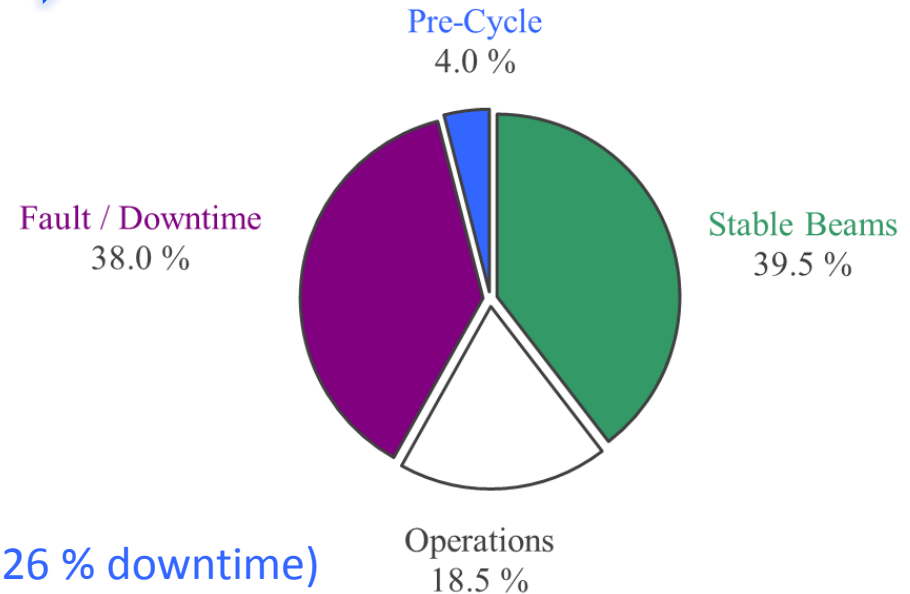
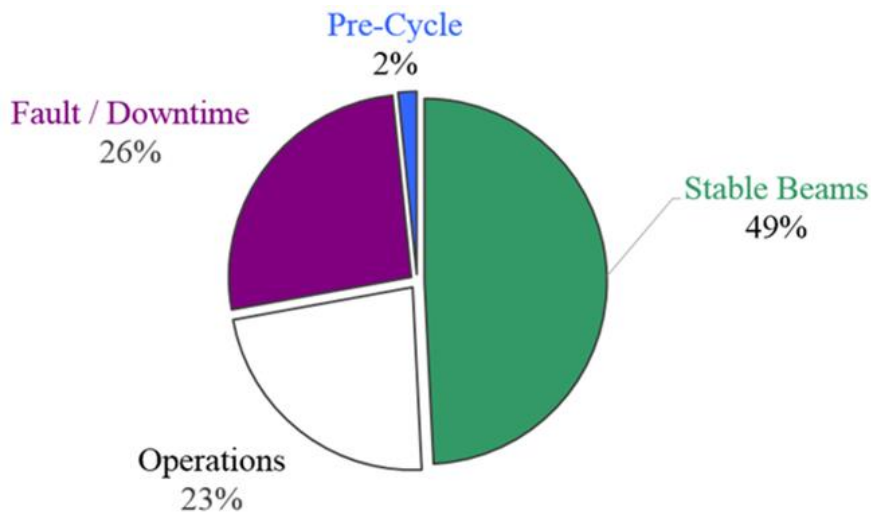
- ❑ **New systems:**
 - ❑ Quench behaviour of Nb₃Sn magnets, reliability of HTS links
 - ❑ Reliability of crab cavities (failure rate, failure modes and effects)
 - ❑ Hollow e-lens, if installed
 - ❑ New cryogenic configuration (Pt. 1-5, 4)

Impact of 7 TeV Operation on Availability

Proton Run 2016



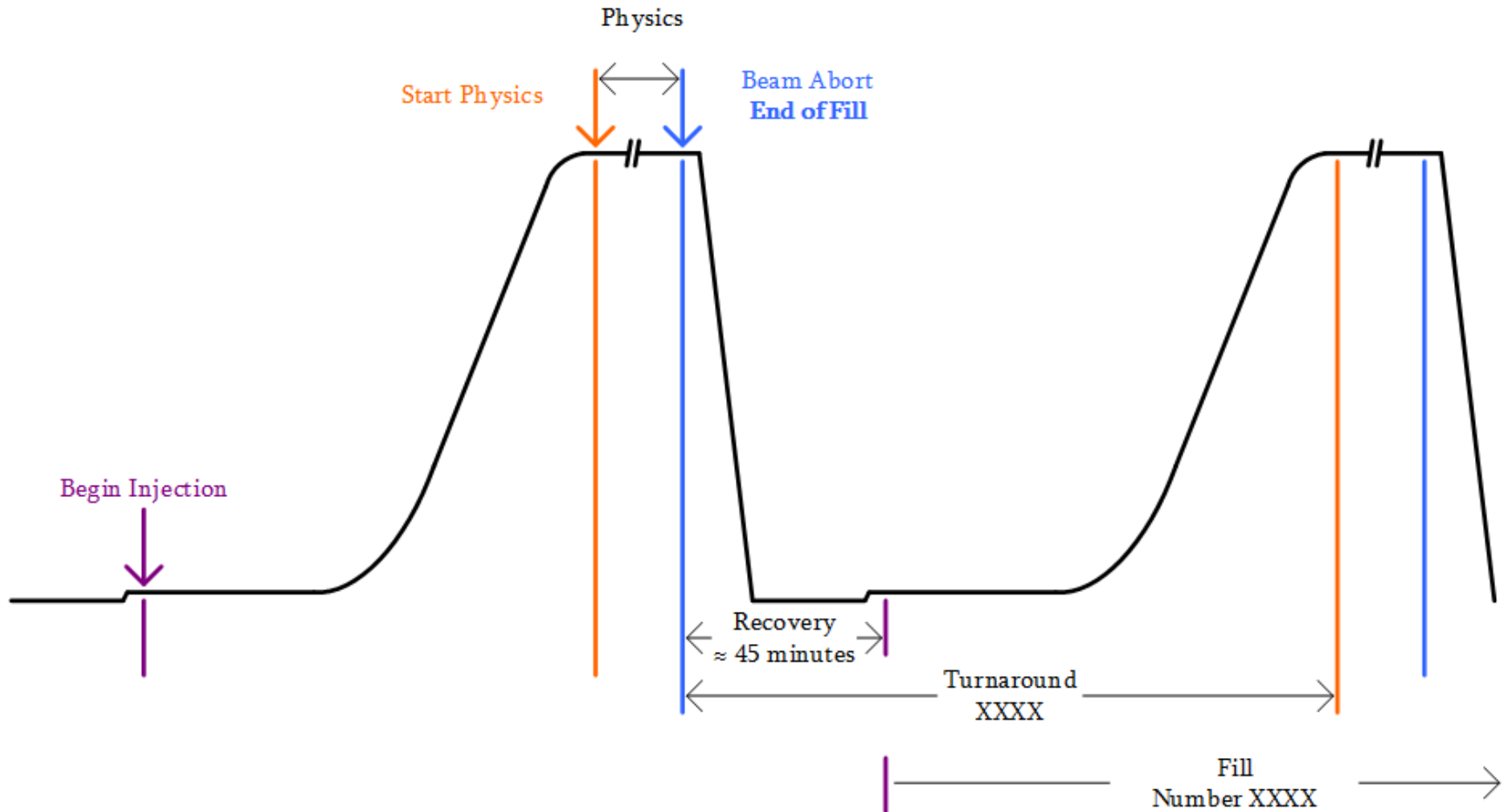
Projection HL (160 days)



- 2016-like fault distributions (26 % downtime)
- 2016-like operation efficiency
- + 4 MKD erratics (2 per beam) ~ 8 days downtime
- + 6 MKB erratics ~ 2 days
- + 10 flat-top quenches ~ 4 days
- + 10 UFO-induced quenches ~ 3 days
- + 4 cold compressor failures ~ 2 days
- + 100 % precycles

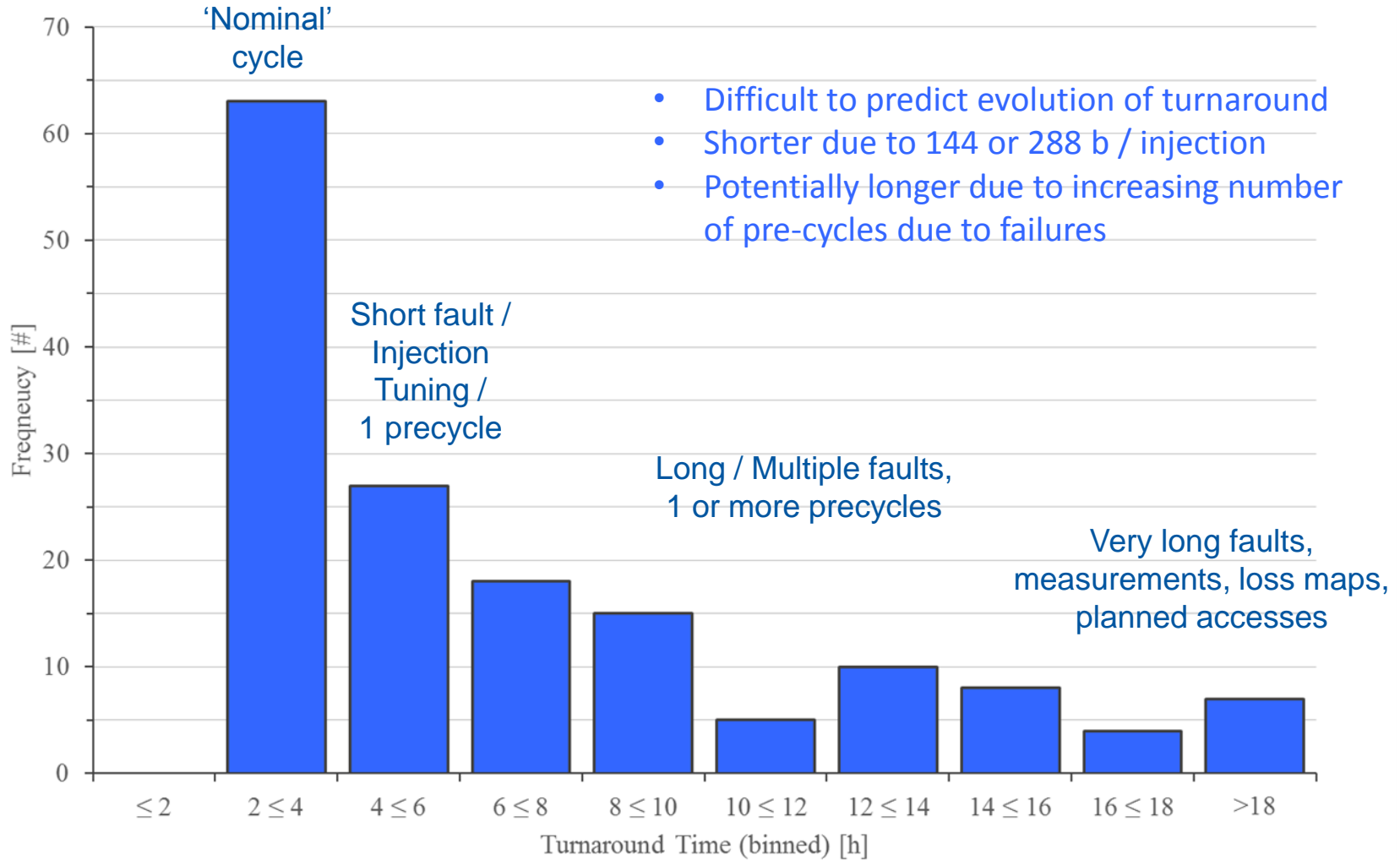
- 14 % Availability
- 9.5 % Stable Beams

Turnaround Time



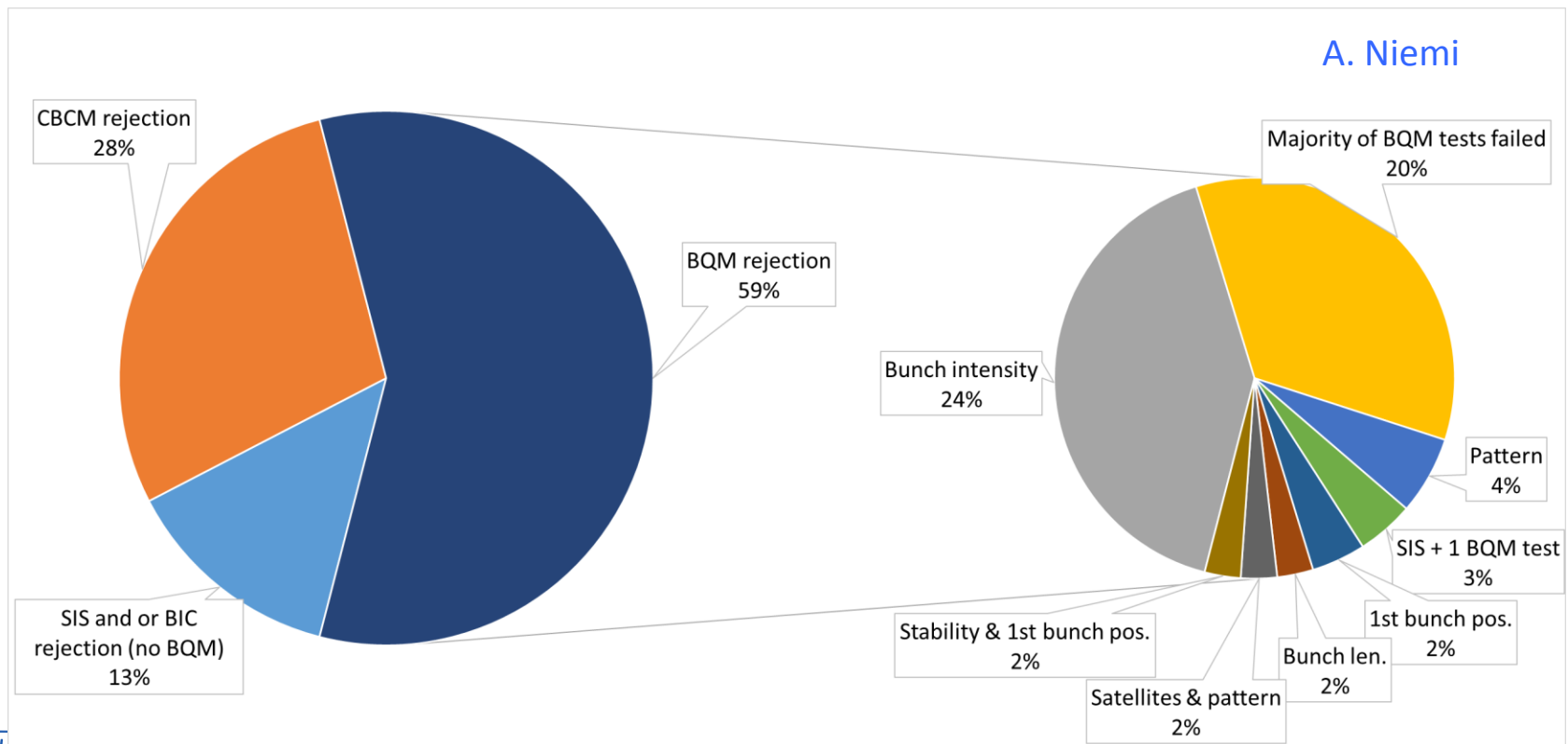
Turnaround Distribution 2016

Turnaround Time Histogram



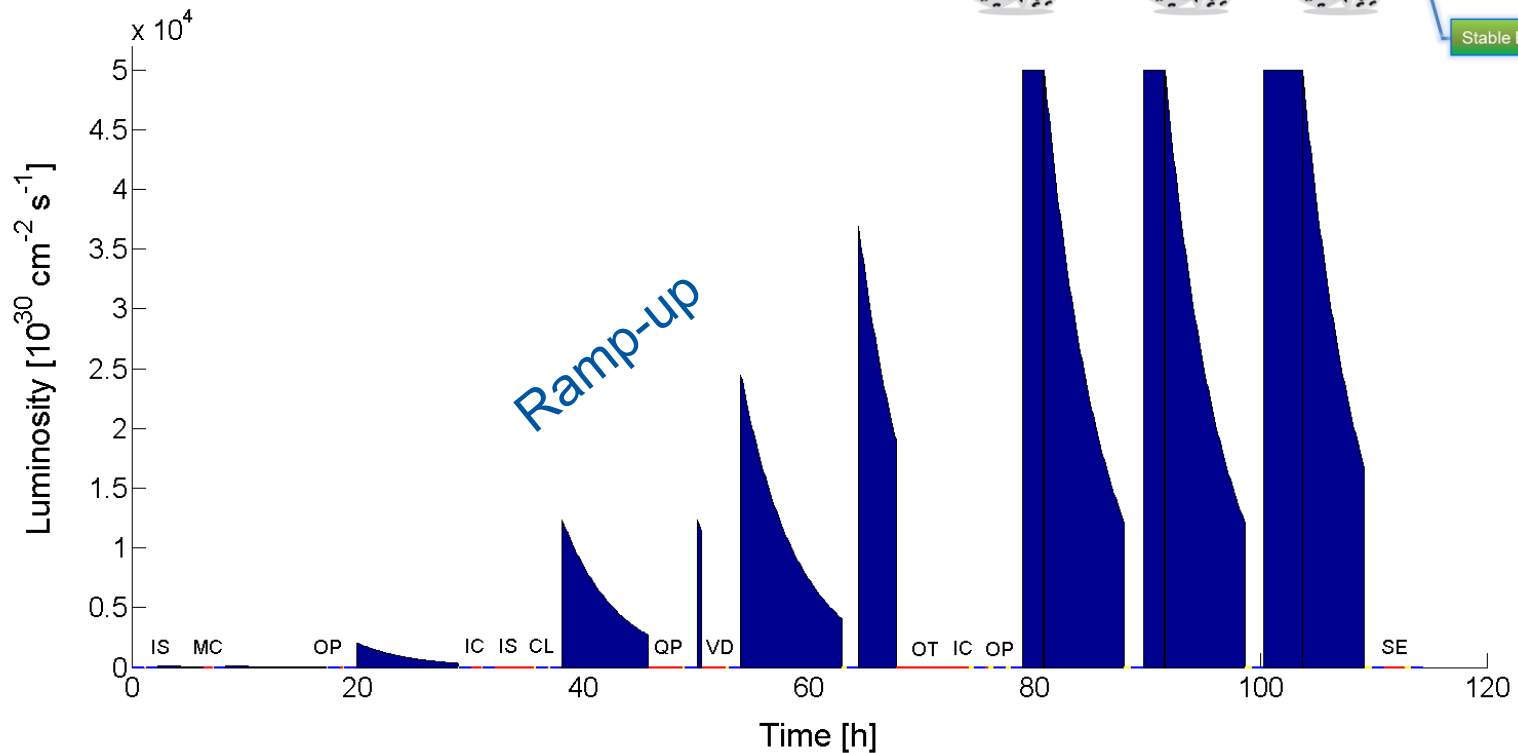
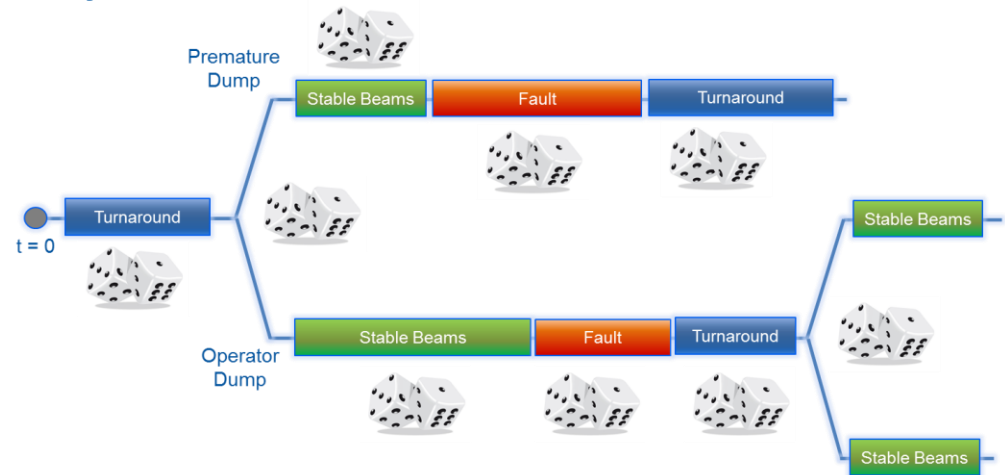
Analysis of Injection Performance

- Variability in cycle duration is driven by the injection phase → injectors' performance + injection process
 - Efficiency of the injection process → tool under development in OP to promptly identify and register the reason of rejected injections (20 % in 2017)
 - Extrapolation for HL-LHC beams to be carried out

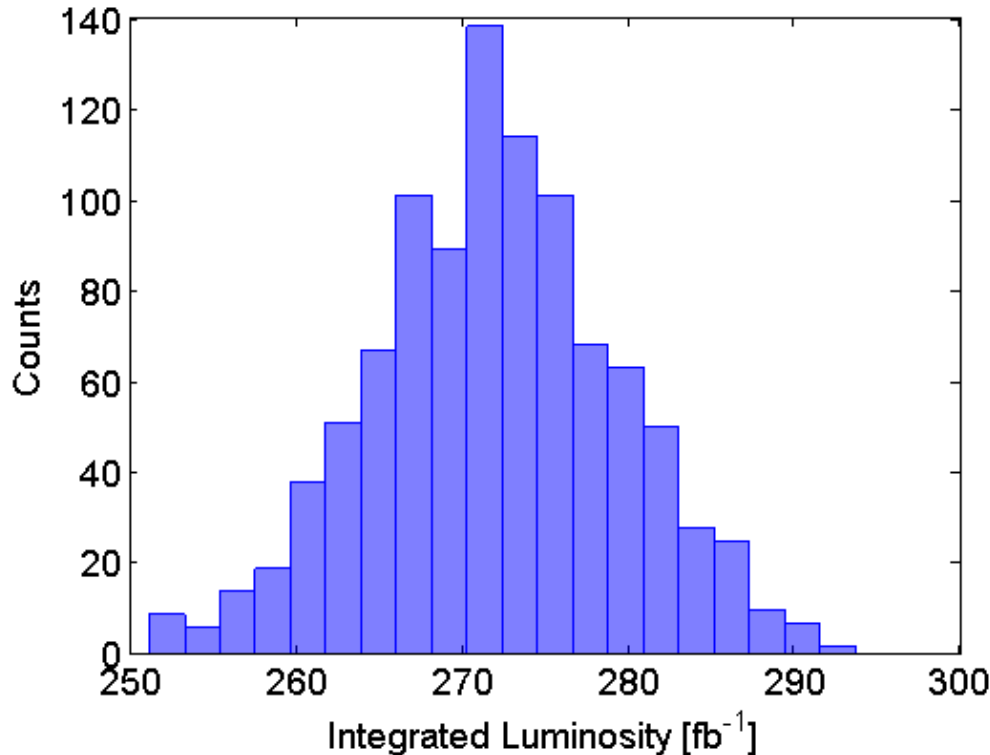


HL-LHC Luminosity Predictions

- Using the Monte Carlo model to describe integrated luminosity production as a function of LHC availability



HL-LHC Availability and Luminosity Predictions – based on 2016 figures



Assumptions (from WP2):

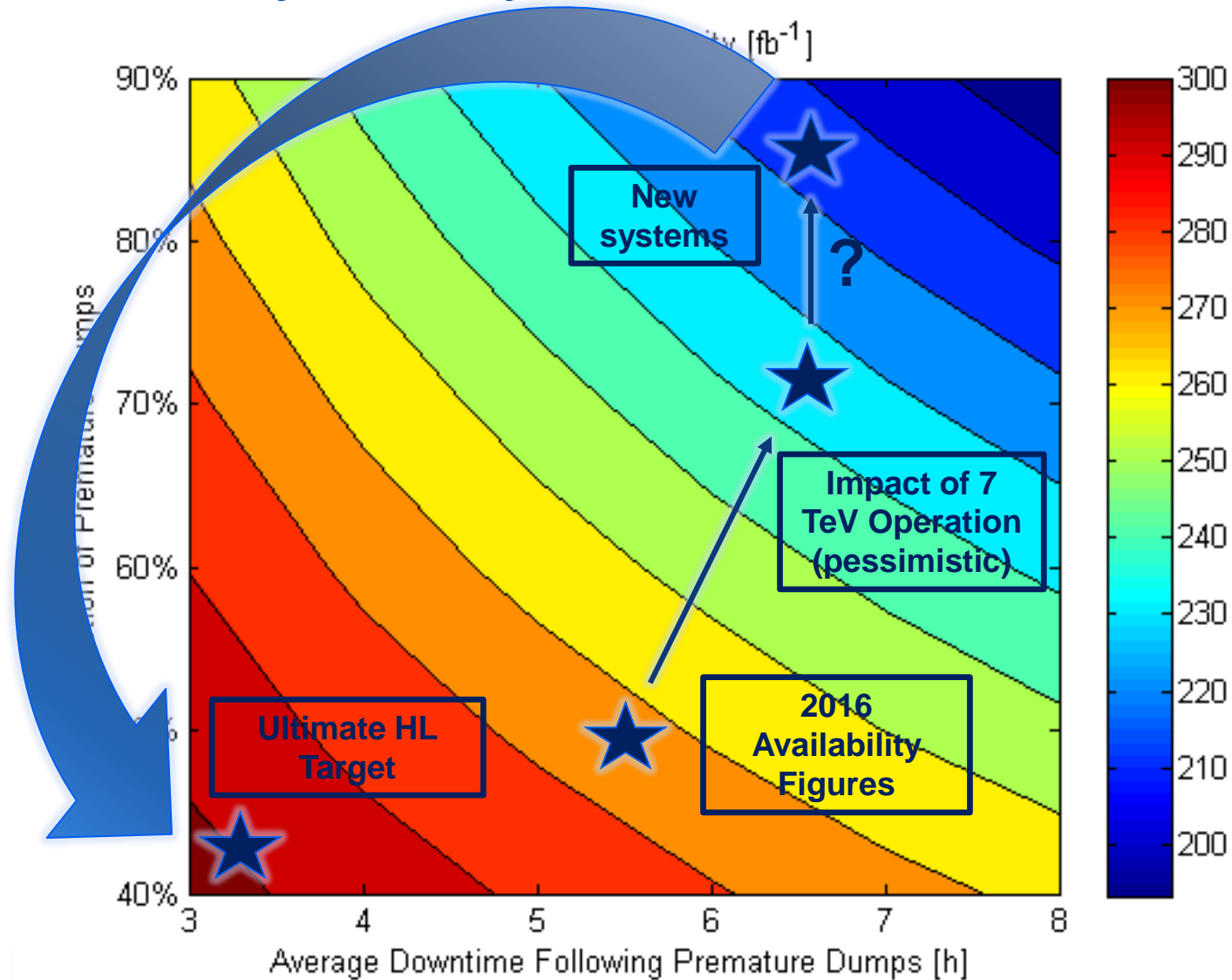
- ❑ Lumi Levelling Time: ~5 h
- ❑ Lumi Lifetime (exp) after levelling: ~5 h
- ❑ 2016 fault and turnaround distributions

Model Output (160 days operation):

- ❑ Availability: 74.6 %
- ❑ Stable Beams Efficiency: 44.6 %
- ❑ Integrated Luminosity: 272 fb⁻¹

For the same equipment availability, the stable beams efficiency is lower for HL-LHC → higher sensitivity to turnaround time and injectors' performance

Sensitivity Analysis



Conclusions

- The HL-LHC target luminosity can be reached with the good machine availability as seen in the last years (2016, 2017)
 - Detailed model predicts $272 \text{ fb}^{-1} / \text{year}$
- Significant lumi reduction can occur because of
 - Operation at higher energy and higher beam intensities
 - Specifically UFO's can become an issue
 - New equipment without known availability numbers
 - End-of-life of not consolidated equipment
 - Modelled numbers down to $210 \text{ fb}^{-1} / \text{year}$
- How to obtain HL target or even Ultimate HL-target of 300 fb^{-1} ?
 - Reliable design, testing and reliability runs of critical equipment, as being done for LINAC4
 - Optimise where you can gain:
 - Measure to improve: AFT → start to use Expert Data
 - Turnaround time and injection performance
 - Experience & time

Thanks a lot for your attention!



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