
CERN

Linac4 Fault Tracking: Tools and Modalities

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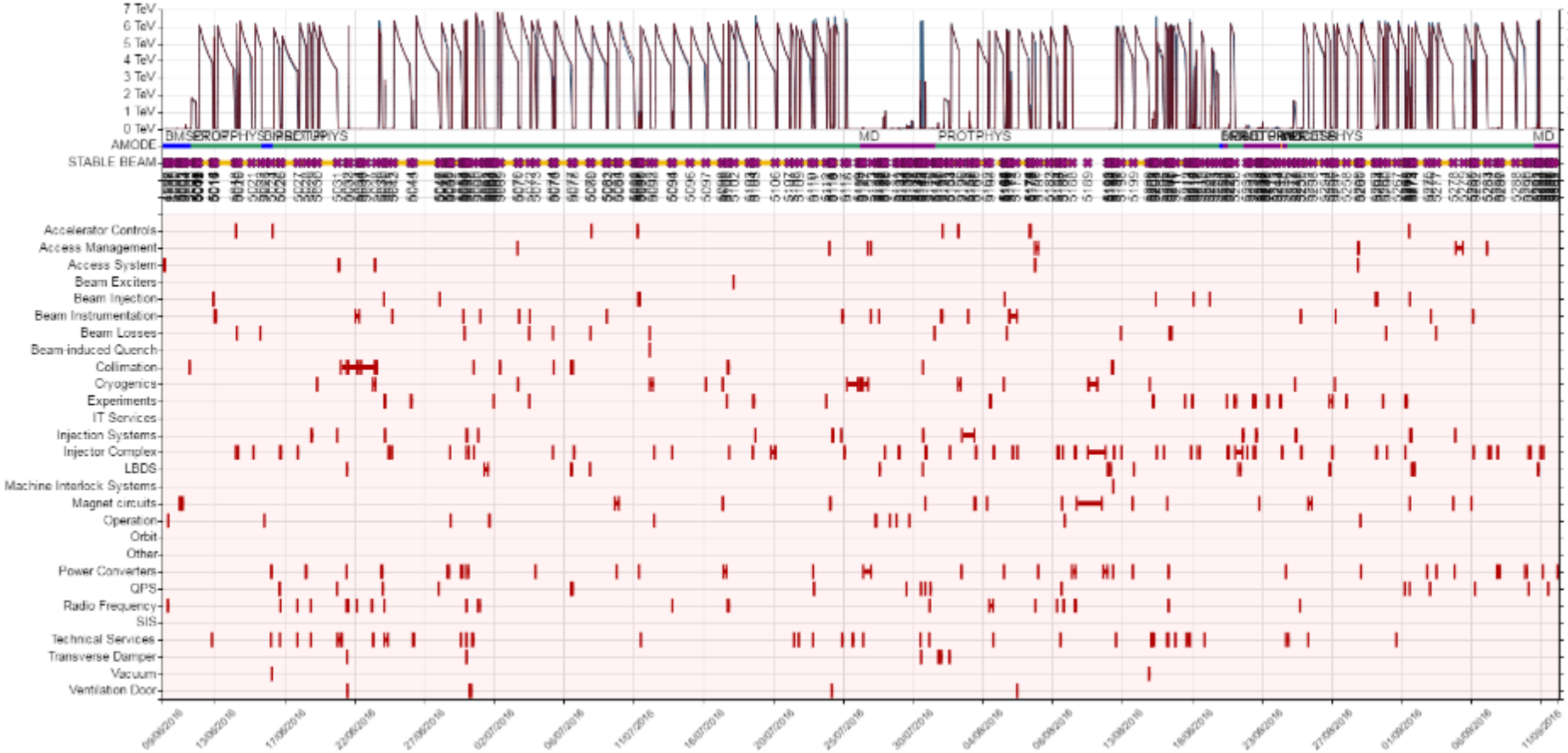

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possible reduction in β* is to increase the overall time in collision for the scheduled time. The availability tool (ATF) developed for the 2015 run is a very powerful way of maximizing the return of investment and prioritizing consolidation tasks.

Similar to 2015, the last four weeks of operation of the LHC are dedicated to heavy ion beam operation. The committee was a bit surprised to hear that the requirements for the run are not final yet. While the accelerator operations team can apparently accommodate a late request it certainly would be useful to make a longer term plan.

Recommendations:

1) Continue to operate at 6.5 TeV
2) Minimize the number of configuration changes
3) Use the availability tool to optimize consolidation investments

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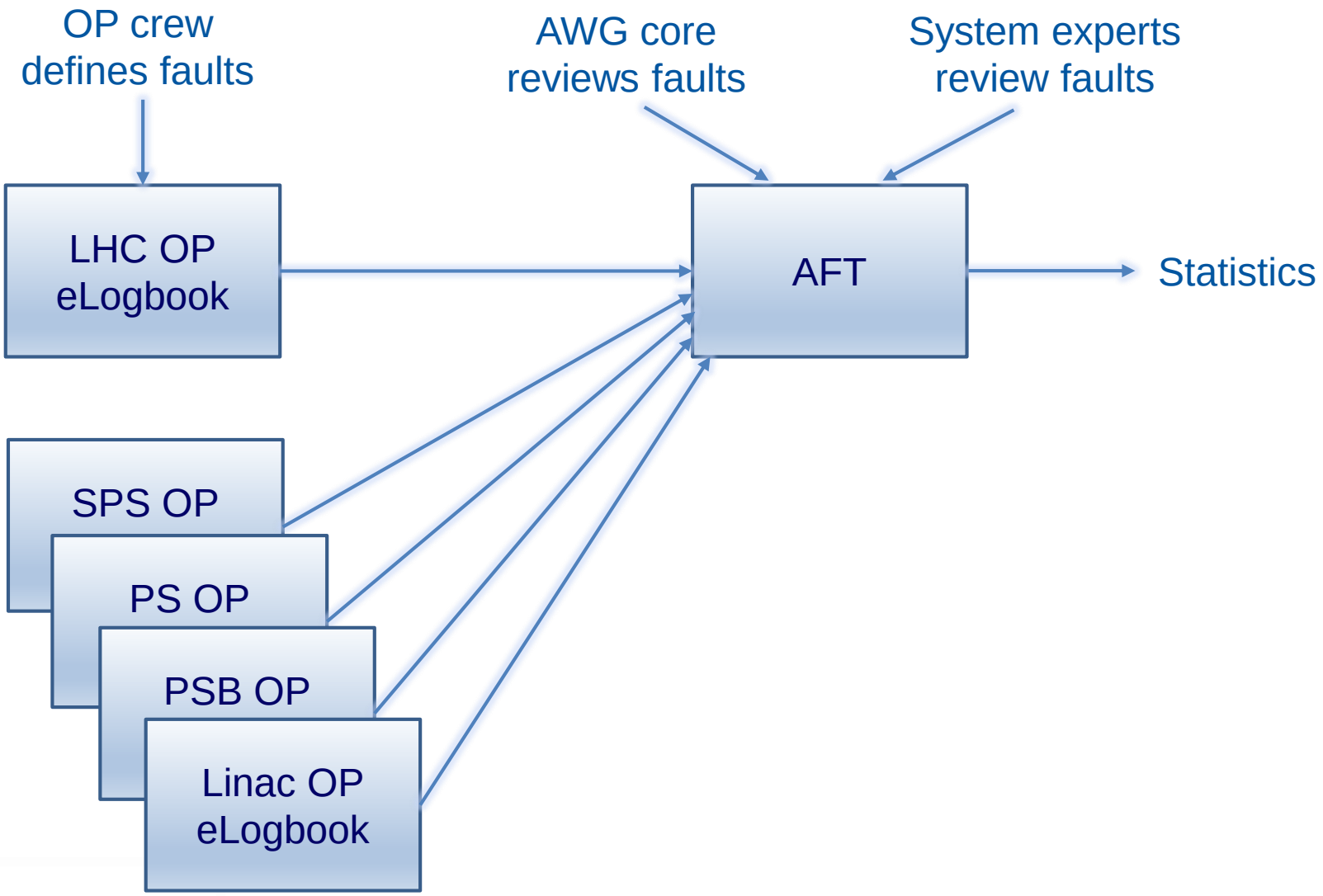
- LHC Availability analysis based on AFT regularly presented at LMC
- Very positive feedback from CMAC in Chamonix 2016 on the use of AFT
- An initiative was launched to explore the interest of extending the AFT also to the injector complex

AFT and eLogbook



LHC Fault Review Process

- Meeting of AWG core on a weekly basis for data correction
- System experts are notified when faults occur and can confirm/propose changes
- The dataset is frozen before each TS → statistics produced and presented

Name	Start time	End time	OP Duration	State	Faulty element	Description	AWG reviewed	Expert reviewed
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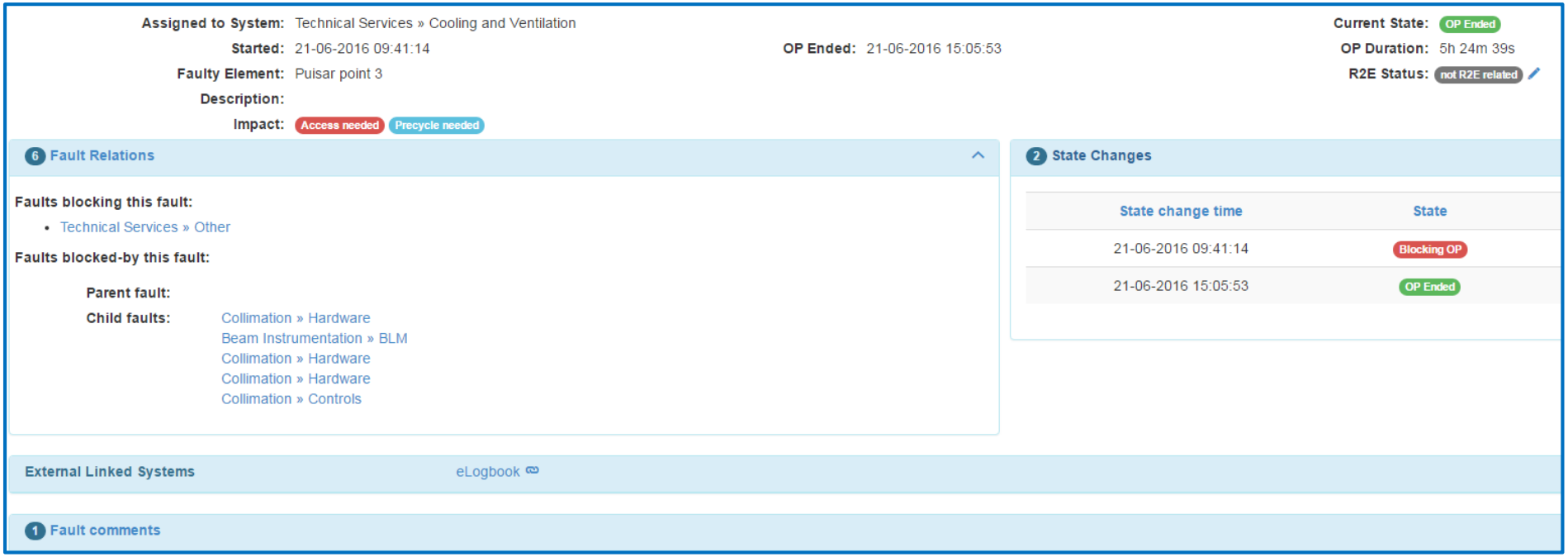
Injector Complex » Beam in Set-up » SPS	28-11-2016 20:40:07	28-11-2016 21:07:29	27m 22s	OP Ended

SPS	RF 800MHz	Un-reviewed	Un-reviewed	not R2E related

Fault Attributes and Dependencies

- Addressing potential fault overheads: precycles, RP needed
- Link faults to their root cause (‘parent’), …



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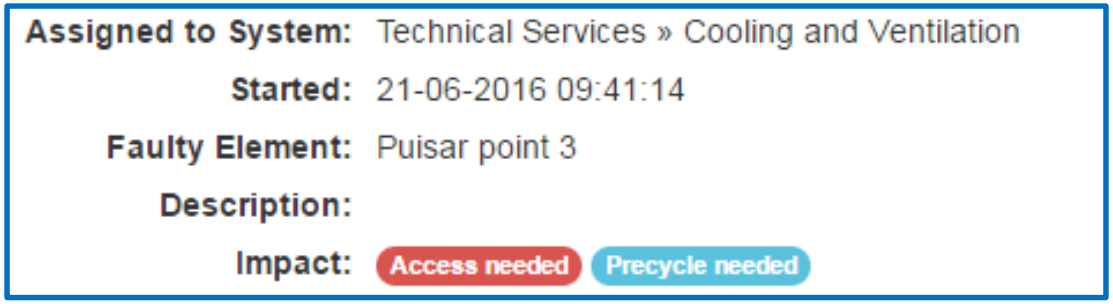
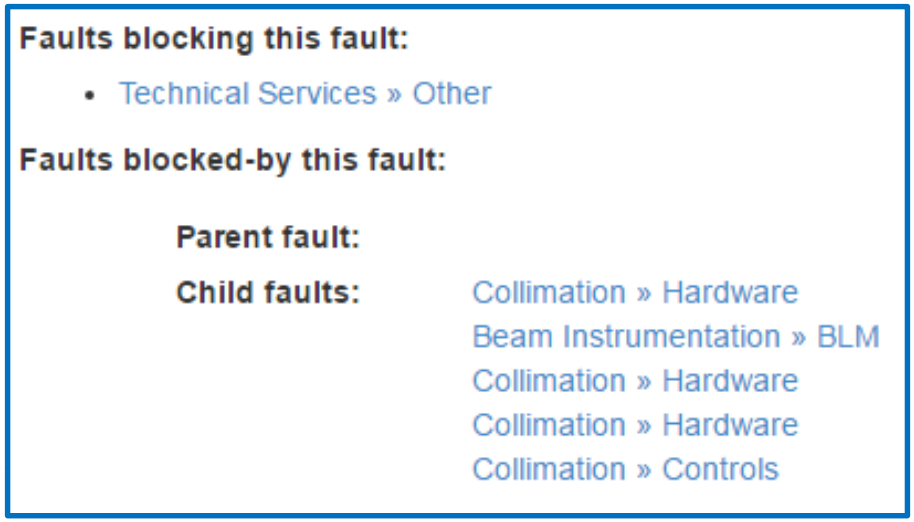
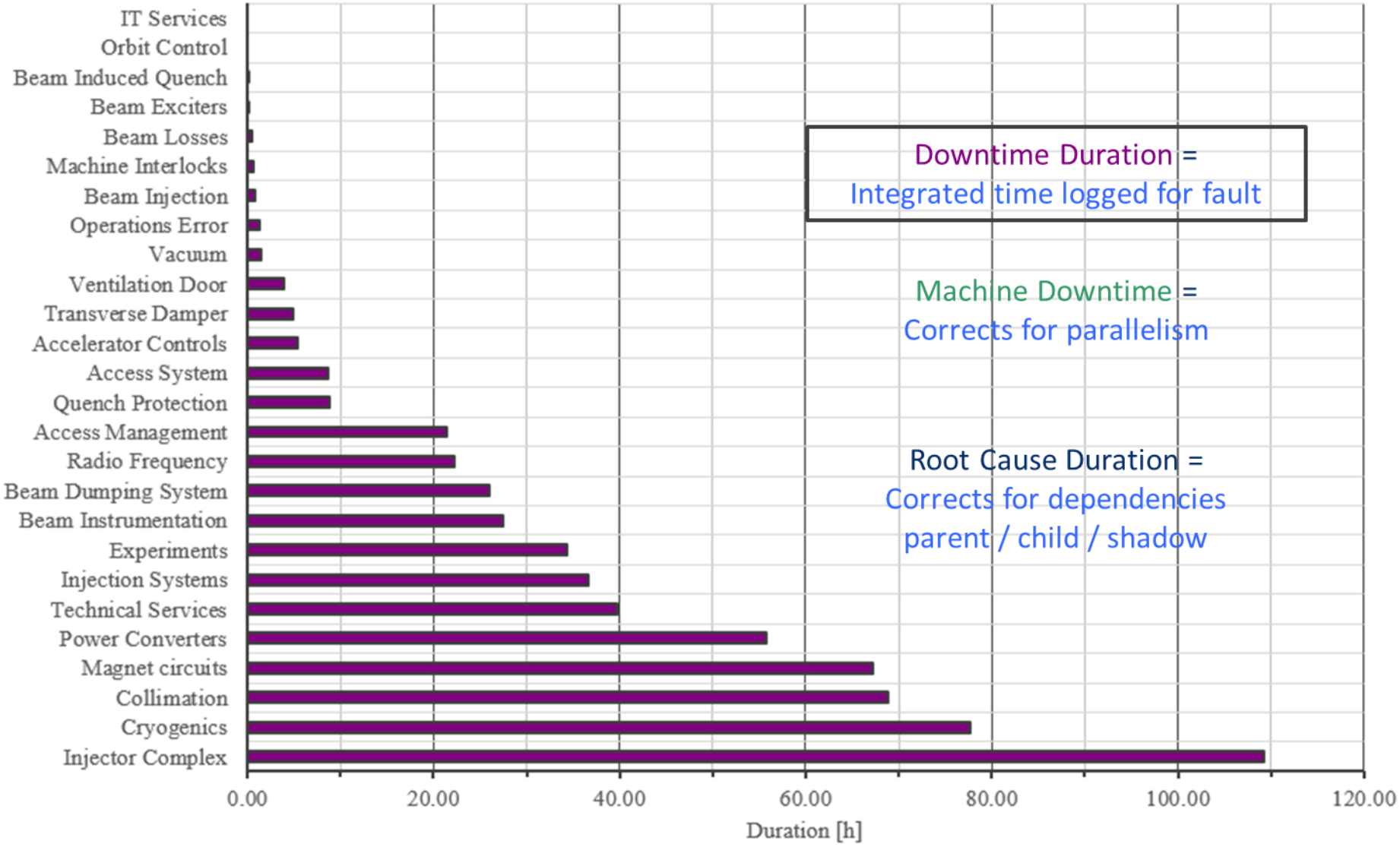




LHC Availability Statistics (TS1-TS2)



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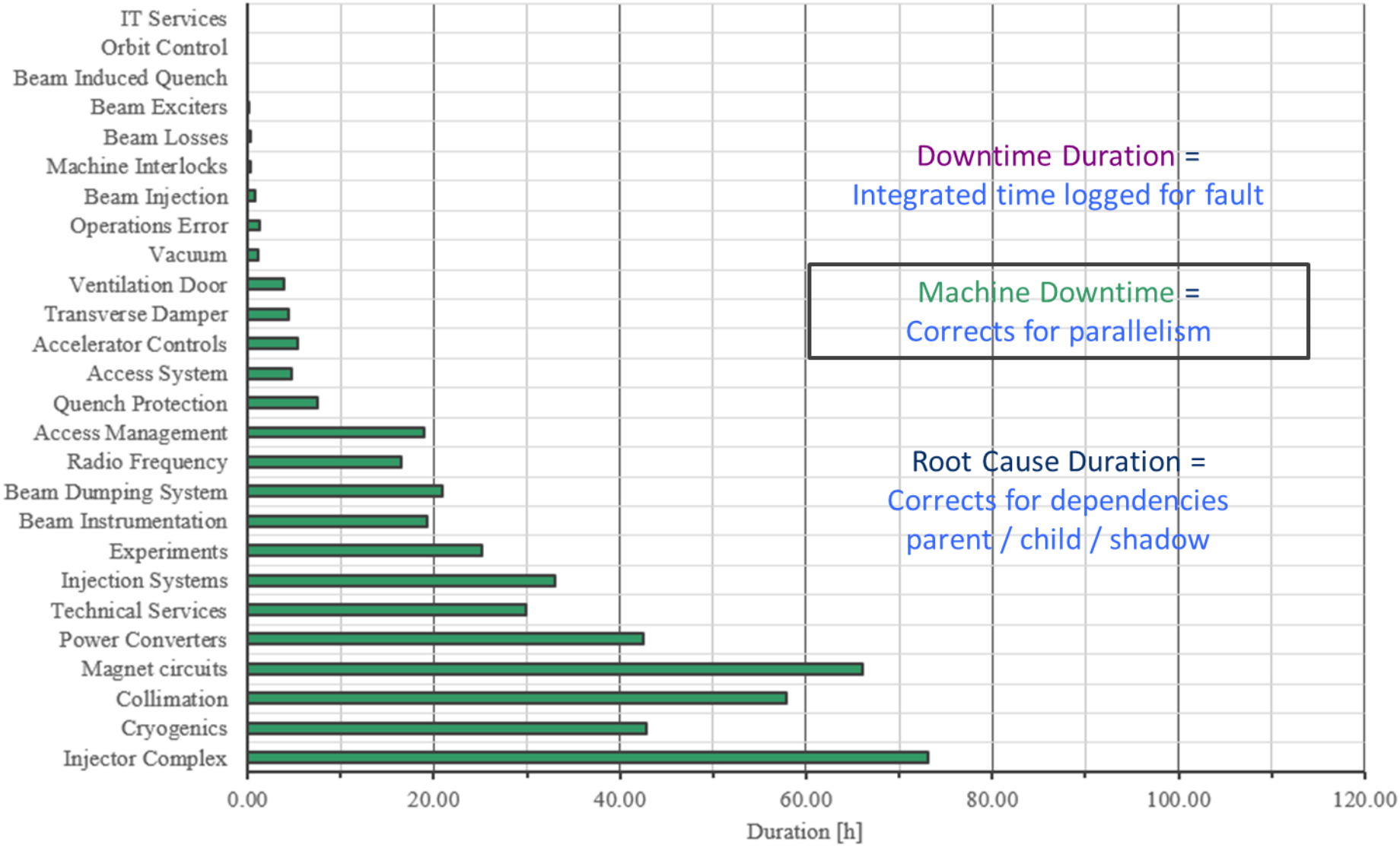

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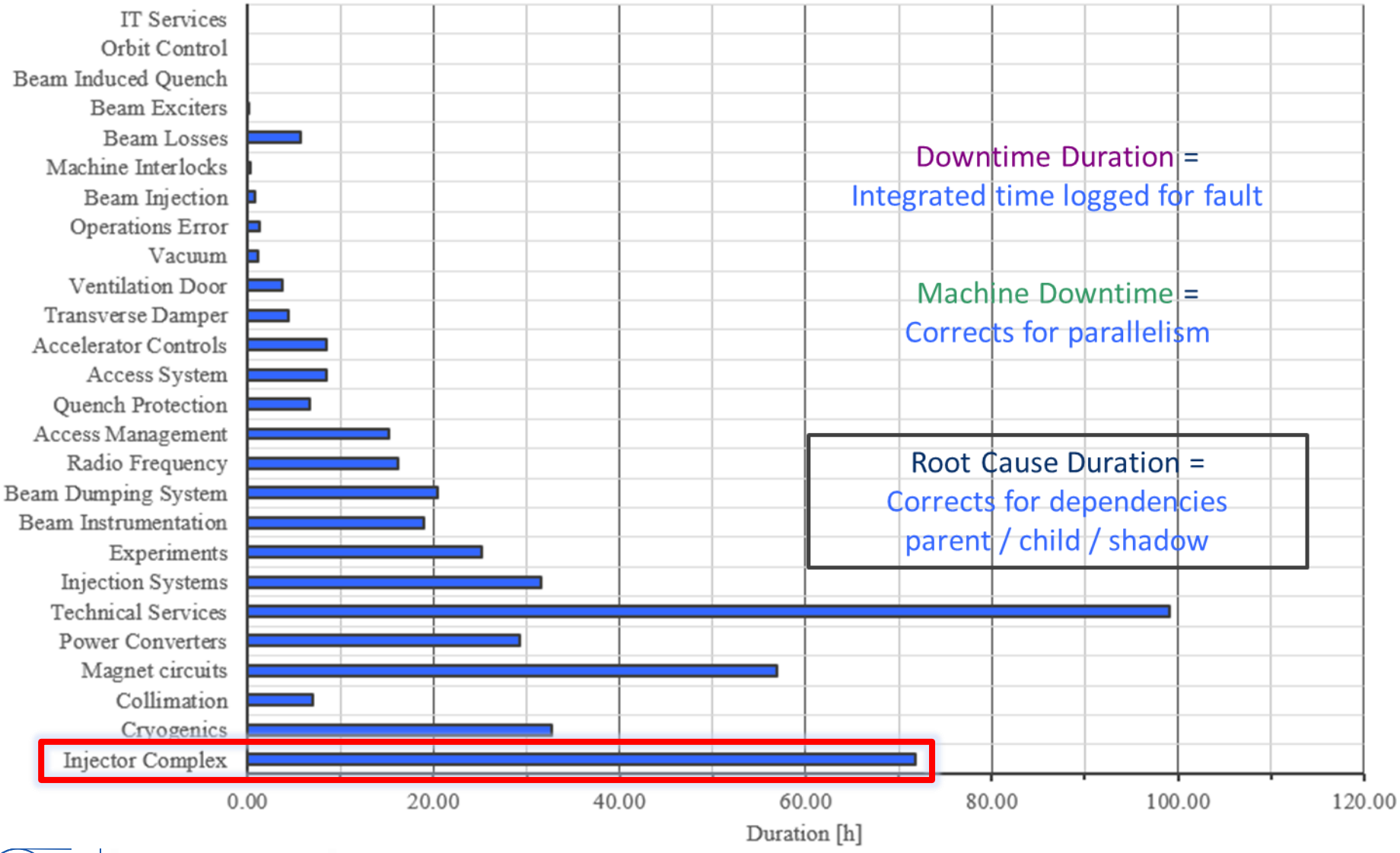

Fault Capture Today in the Injectors

Linac2:

- Managed by PSB OP

PSB/CPS:

- Equipment in fault identified via LASER
- Manual fault insertion by OP crew
  - Start/end times approximate
  - Short stops (< 5 min) sometimes not recorded
  - Root cause not always identified
- Fault tree: System – Element – Fault description + PSB rings affected + timing user
- Fault analysis by Timing User

SPS:

- BIG SISTER used for automatic creation of faults in the logbook after a fixed number of missed cycles → requires follow-up
- Manual fault insertion by OP crew for long faults

Working Team for Injectors AFT

- 6 meetings (April – September 2016)
- Composition:
  - (At least) one representative per machine
  - (At least) one AWG core member
  - People interested in availability studies
  - AFT expert
- Discuss additional requirements for AFT, considering specific needs of the injectors
- Aim: define a plan and timeline for the implementation of the AFT in the injectors
- Quantify required resources

Proposal and Timeline

- Goal: first implementation of AFT for the injectors ready before restart of operation in March 2017

- Two-staged approach:

1. **Data Capture** → Ready by March 2017: full AFT functionality implemented, including change of eLogbook (timing user → LSA context), but no context-dependent statistics available

2. **Data exploitation** → Ready by Q3 2017: availability statistics by LSA context / group of contexts + visualization

Approved by IEFC on 4th November

Definition of AFT Categories for Linac4

- Based on LHC-type categories
- Inspired by the Linac4 failure catalogue developed in collaboration with system experts

1) SOURCE
1.1) HYDROGEN
1.2) RF-SOURCE
1.3) PLASMA GENERATOR
1.4) SOURCE HIGH VOLTAGE
1.5) CESIATION SOURCE
1.6) SOURCE VESSELS
1.7) SOURCE VACUUM
1.8) SOURCE CONTROLS
1.9.) FC ACCESS SYSTEM

2) MAGNET POWERING
2.1) SOLENOIDS
2.2) QUADRUPOLES
2.3) CORRECTORS
2.4) DIPOLES
2.X.1) Power Coverter
2.X.2) Controls
2.X.3) Measurement system
2.X.3) Water Cooling

3) RADIO FREQUENCY
3.1) RFQ
3.2) BUNCHER
3.3) DTL
3.4) CCDTL
3.5) PIMS

3.6) PRE-CHOPPER
3.7) CHOPPER
3.X.1) Powering
3.X.2) Cooling

3.X.1) Cavities
Movable tunners
Cooling system
3.X.2) RF POWER SYSTEM
Solid State Amplifier
Modulator
Circulators
Loads
Wave-guides
3.X.3) LLRF SYSTEM
Clock card
Cavity Loop
Tuner Loop
Switch and Limit
Crate control
Pre-amplifier
3.X.4) INTERLOCK SYSTEM
PLC
Fast Interlock
RF Swich - Veto RF
Tunner Control
Arc detectors
3.X.5) Breakdown

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4) VACUUM
4.1) ION PUMPS
4.2) GAUGES
4.2) CONTROLS
4.2) LEAK

5) TECHNICAL INFRASTRUCTURES
5.1) ELECTRICAL NETWORK
5.2) COOLING AND VENTILATION

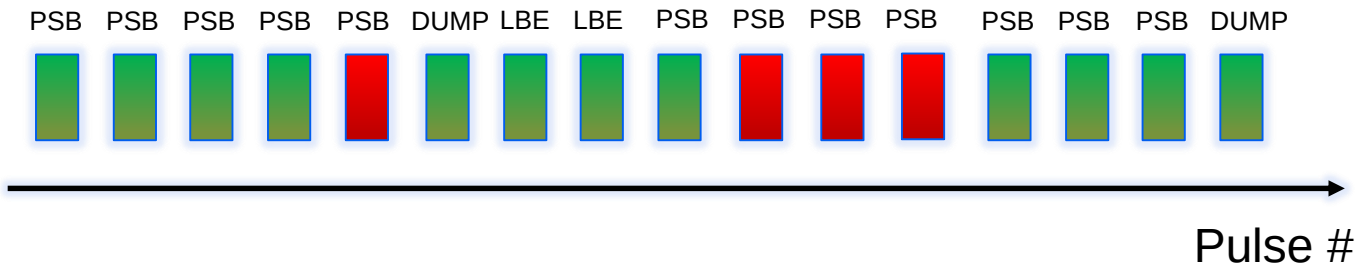
6) BEAM INSTRUMENTATION
6.1) BCTs
6.2) BLM
6.3) BMLEM
6.4) …

7) MACHINE INTERLOCKS
7.1) BIS
7.2) WIC
7.X.1) Hardware
7.X.2) Controls
7.3) SIS

8) ACCELERATOR CONTROLS

9) DUMPS AND ABSORBERS
8.1) BEAM STOPPER
8.X.1) Hardware
8.X.2) Controls
8.2) DUMP

Ideas: Linac4 Availability Monitoring and Statistics



- Availability = # good pulses / total pulses

- Question: how is a ‘good pulse’ defined? (threshold on current/pulse length)
- Question: should we foresee an automatic fault creation after a missed pulse? (as done in the SPS today)
- The BIS can always provide information about the system that triggered a beam stop
- Is the information related to the destination of the pulse relevant?

- Availability (dest. X) = # good pulses (dest. X) / total pulses (dest. X)

Additional Considerations: AFT

- **AFT does not ensure automatically good data quality**
- It requires:
  - Consistent follow-up from OP team
  - Review from responsible for fault follow-up (e.g. 1 person from MPE + 1 person from Linac4 commissioning team?)
  - Support from system experts to identify failure root causes
- To be discussed: organization of AFT training for operators

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Additional Considerations: Parameters and Schedule

- Ideally, for a reliability/availability assessment: machine should run steadily without any change at nominal parameters
- In practice, if not possible:
  - Check with HW experts needs for maintenance (mini-TSs)
    - Think about strategy of replacement vs improvement for faults occurring during the run + track spare parts
  - Consider different stages of the reliability run with increasing duration
  - At the beginning of each stage, agree with Linac4 team on a reference parameter set to be maintained throughout the run

Summary

- AFT framework will be available for the Linac4 reliability run
  - Fault categories have been identified based on the Linac4 failure catalogue
  - Visualization + statistics to be defined
  - Automatic fault capture to be envisaged?
  - Is information about pulse destination relevant?
  - AFT training for operators?

- Good data quality can only be ensured with consistent fault follow-up → this involves OP, system experts and AFT responsible people

- Data should be captured and compared over stable periods of run – duration and parameters to be defined

Thanks a lot for your attention!

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