

Availability 2017: Injectors

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Many thanks for their contributions to:

A. Apollonio, K. Cornelis, G.P. Di Giovanni, J-C. Dumont, D. Kuechler, V. Kain, K. Hanke, L. Ponce, C. Roderick & AFT team, F. Tecker, B. Todd

Introduction

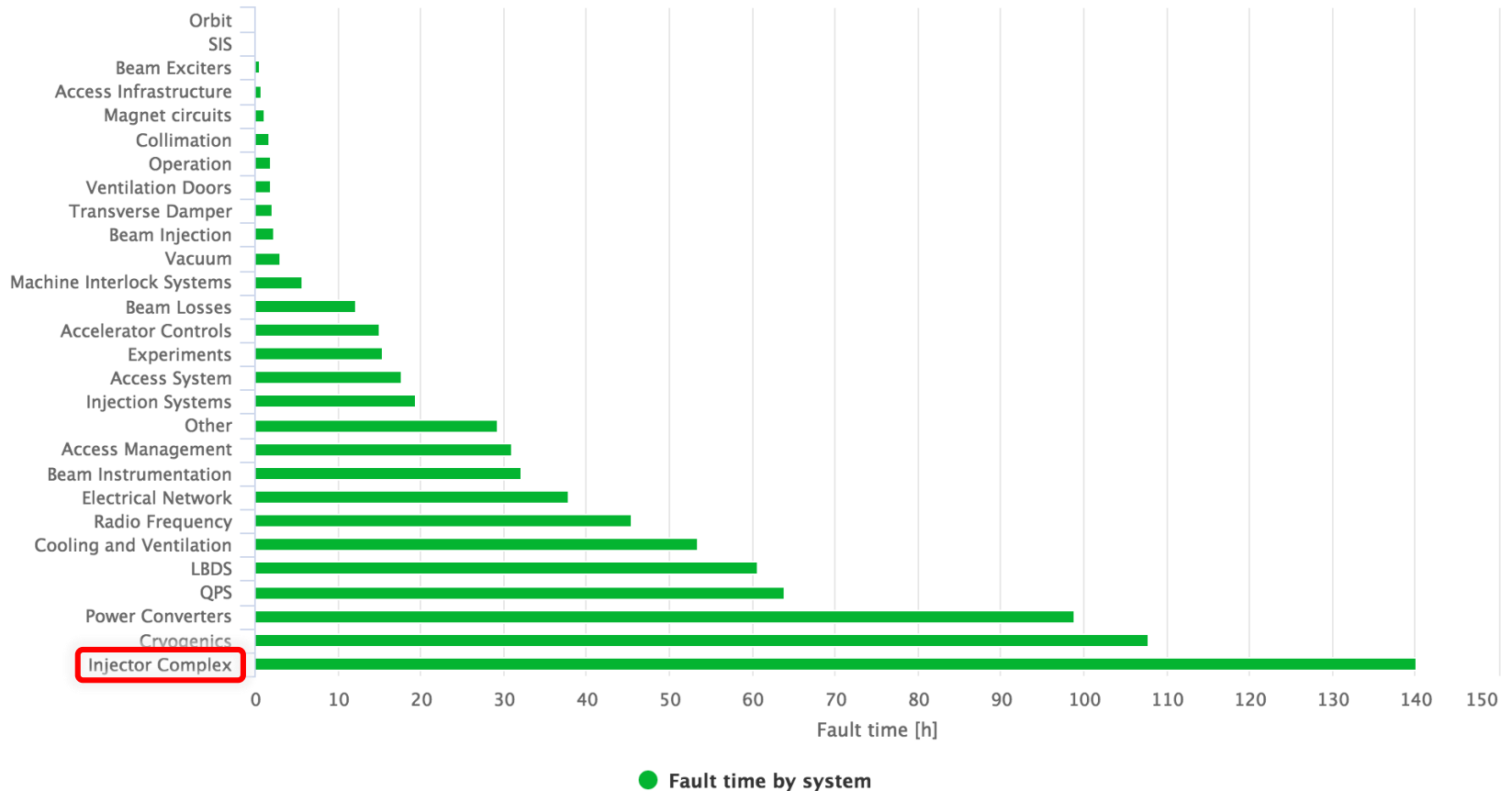
- Chamonix 2016 (Jan. 2017): Request AFT for Injectors
- Several AFT releases during 2017
 - Adapting AFT to specificities of injectors (4 rings, impacted destinations, etc.)
 - Bug corrections
 - Steady improvements of functionality
- 2017 analysis for injectors based on AFT
 - Injector faults affecting LHC p run
 - Injector faults during LHC p run period to understand trends

Injector Faults Responsible for LHC Proton Run Downtime

2017 LHC Root Cause Fault Time per System (1)

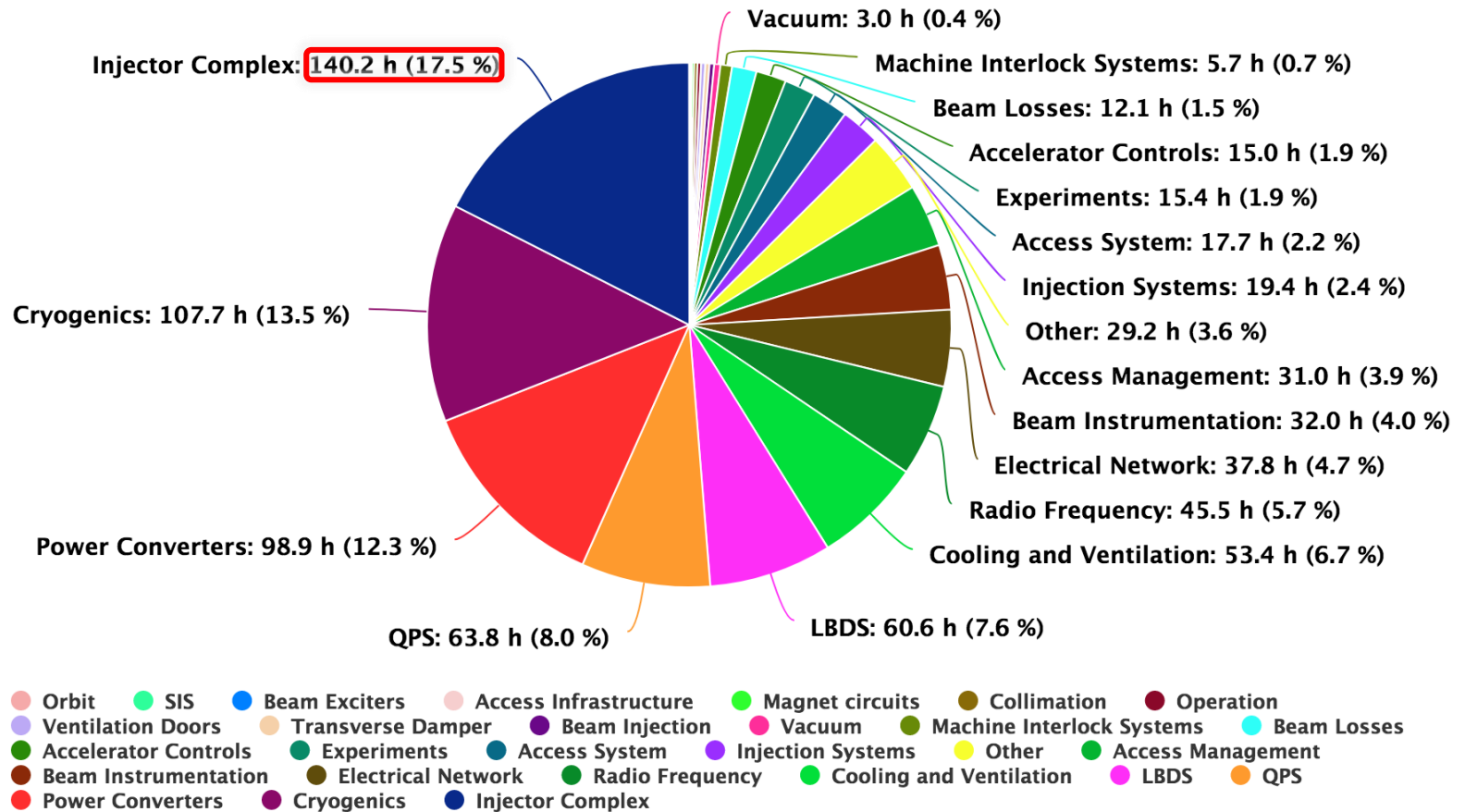
- Injector Complex once more in top position...

Root Cause Fault Times by System



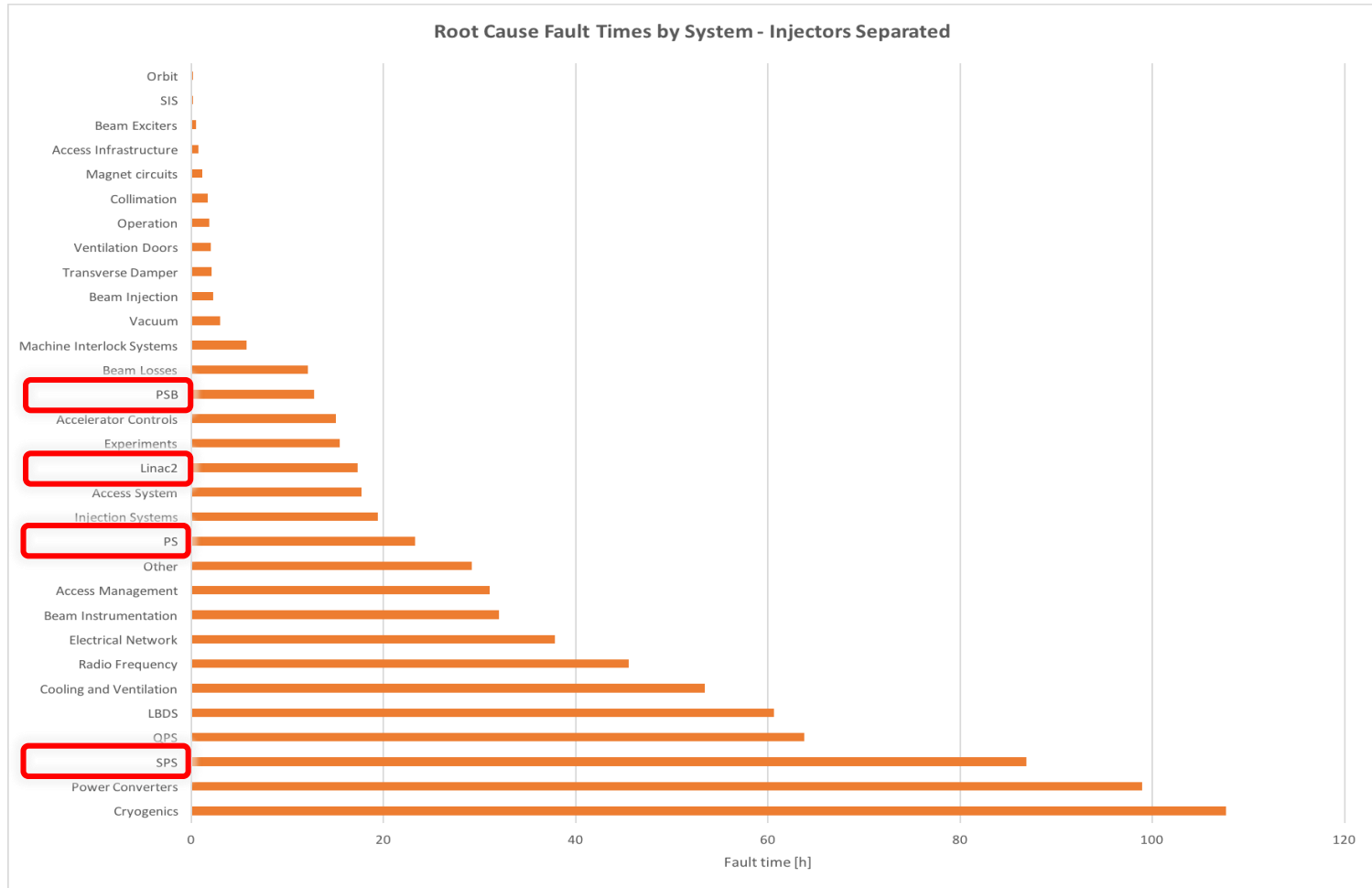
LHC Fault Distribution

Root Cause Fault Time Distribution



2017 LHC Root Cause Fault Time per System (2)

- And how it would be fairer to be represented...

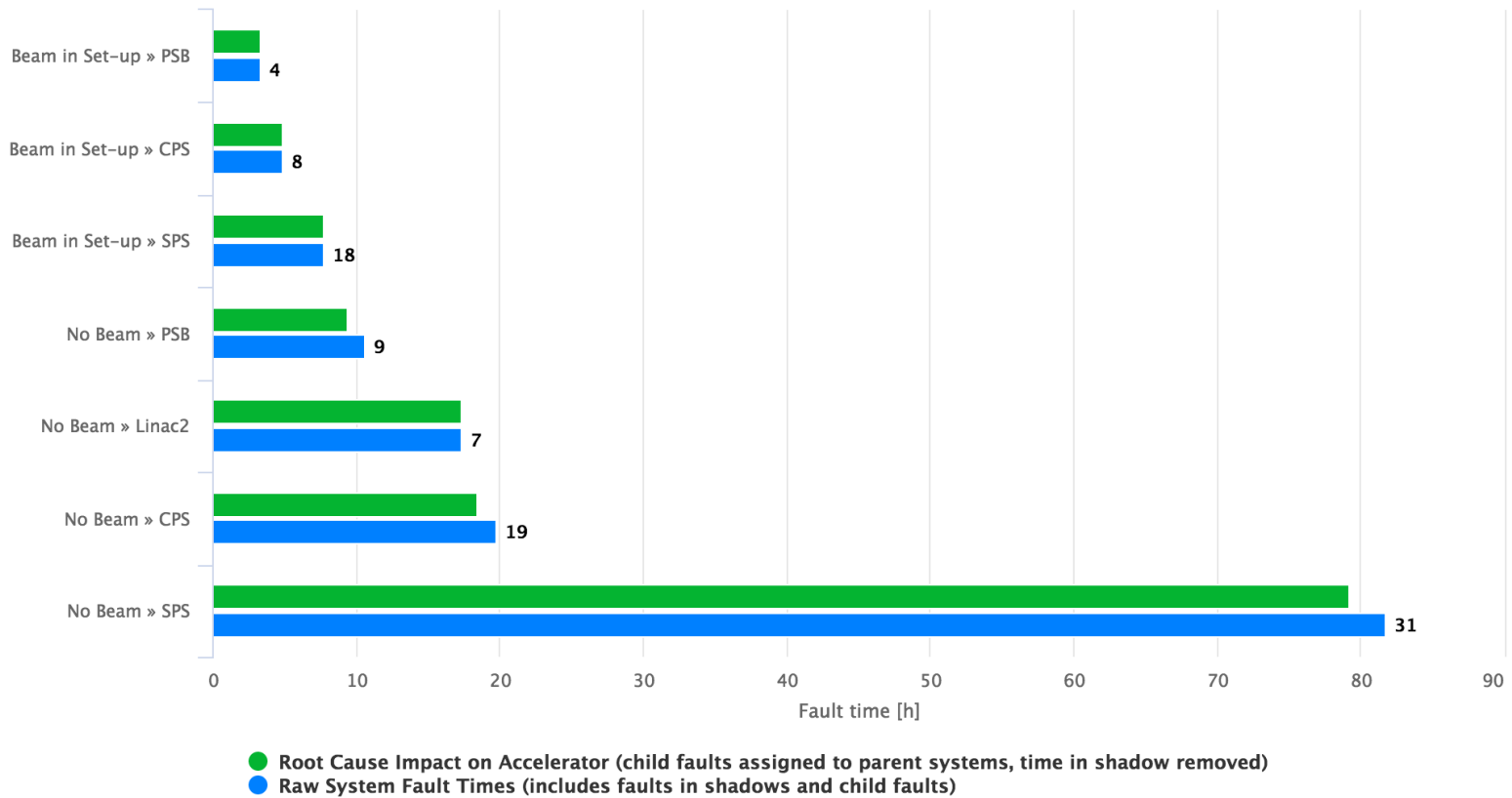


Beam in Setup / No Beam Injector Faults

Beam in Setup: 15.9 h total (11.3%),
30 faults

No Beam: 124.3 h total, 66 faults

System Downtime Vs Accelerator Impact (Injector Complex)



Summary Injector Faults for LHC

- **2017 LHC p run**

- 28/4 – 10/11 (~196 days)
- **96** root faults and **140.2 h** downtime
- **17.5%** of total LHC downtime

2017	Root Fault duration [h]	% of total injector faults
Linac2	17.3	12.3%
PSB	12.8	9.1%
PS	23.3	16.6%
SPS	86.9	70.0%

- **2016 LHC p run**

- 24/3 - 31/10 (~221 days)
- **138** root faults and **360.4 h** downtime
- **>25%** of total LHC downtime

2016	Root Fault duration [h]	% of total injector faults
Linac2	6.3	1.8%
PSB	11.8	3.3%
PS	226.6	62.9%
SPS	115.6	32.1%

Remarks for 2016 data: Long downtime in PS/SPS due to MPS,POPS/TIDVG issues!
Linac2 long-lasting source interventions planned to minimise impact for LHC

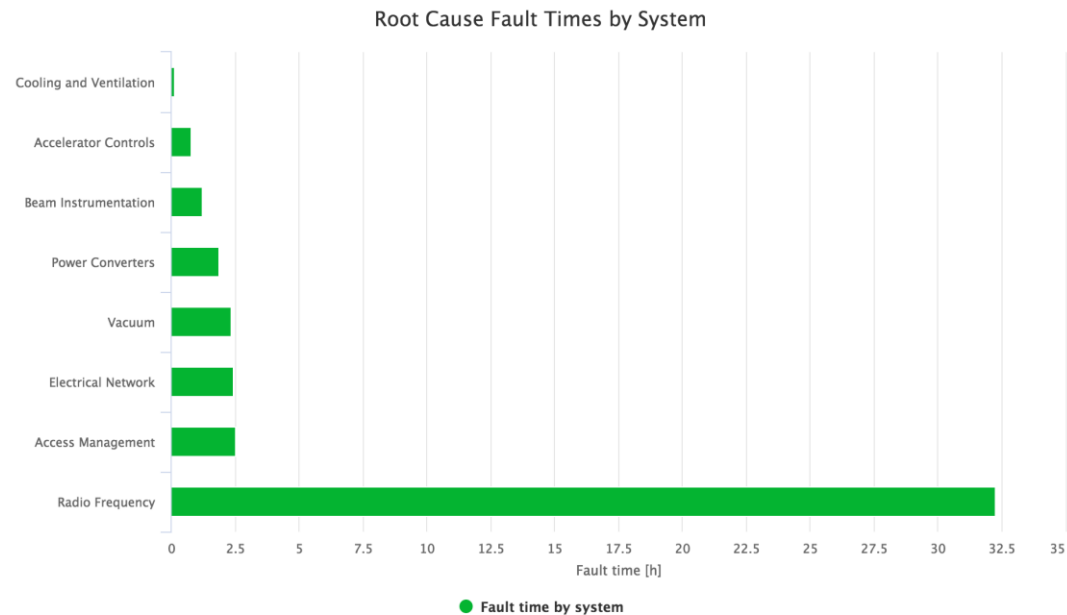
Injector downtime improved in 2017 by a factor of 2.3! (normalised)

All Injector Faults During LHC Proton Run Period

Linac2 Root Cause Faults during LHC p Run

- Faults dominated by **RF**
 - Took some time to diagnose and fix (e.g. buncher1 amplitude problem – sparking in directional coupler)
- **No faults of the source!**
 - Source faults dominated in 2016
 - **Careful and continuous maintenance pays off**
- No recurrent faults
- Vacuum situation remains worrisome (e.g. corrosion on intersection tank1 etc.)

Average availability: **99.1%**
(2016: data not consistent in AFT*)



* Linac2 faults during 2016 still registered mainly in PSB elogbook

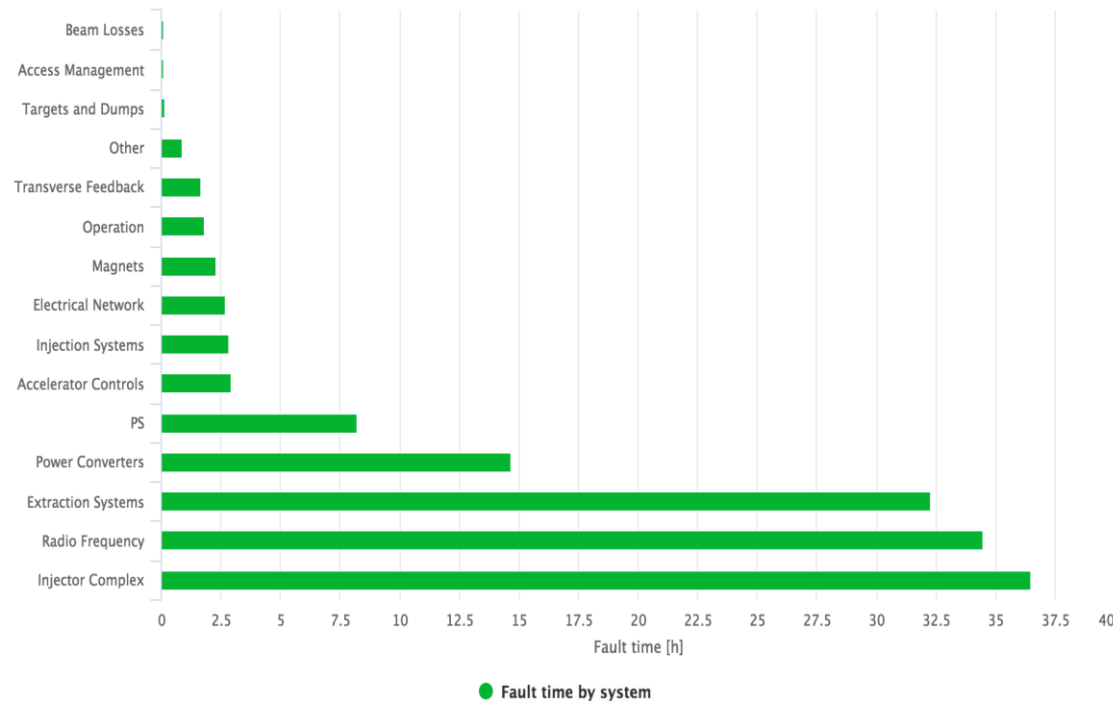
PSB Root Cause Faults during LHC p Run

- Faults dominated by **RF** (C02, C16 and TFB) and **Extraction systems**
 - Longest downtime (~13h) due to replacement of burnt stripline of BT1.SMV10, followed by BR3.C16 cavity problems
 - RF: Need sufficient maintenance time; from LS2 availability should increase with Finemet
 - Septa striplines will be thoroughly checked during YETS (difficult to access)
- No recurrent faults

Average availability: **96.9%**
(2016: 95.6%)

Without Linac2 and PS
access: **97.9%**

Root Cause Fault Times by System



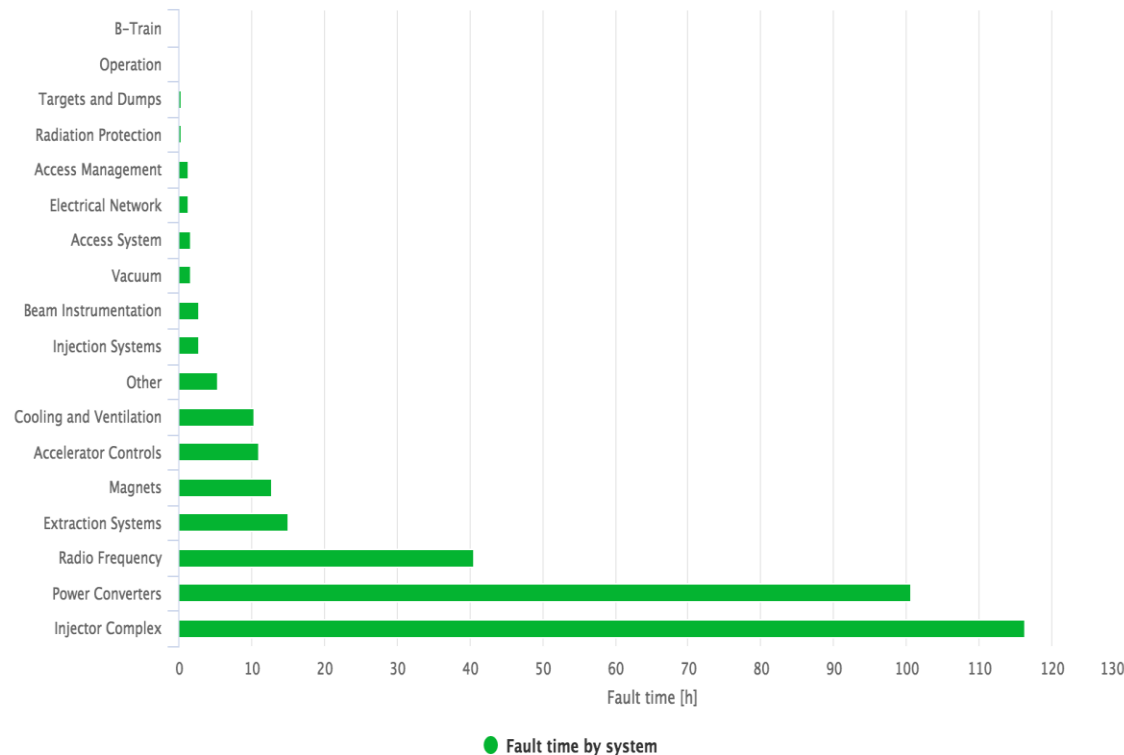
PS Root Cause Faults during LHC p Run

- Top fault category **Power converters**, followed by **RF**
 - Many issues towards beginning of the run with Pole Face Winding power supplies
 - From October frequent POPS trips (solved now)
 - Remark: **Longest power converter faults did not affect the LHC (destination AD or EAST!) → need statistics by destination!**
 - Very complex PS RF system → need to continue allowing for **adequate maintenance time**

Average availability: **93.1%**
(2016: 88.9%)

Without injector faults: **95.6%**

Root Cause Fault Times by System



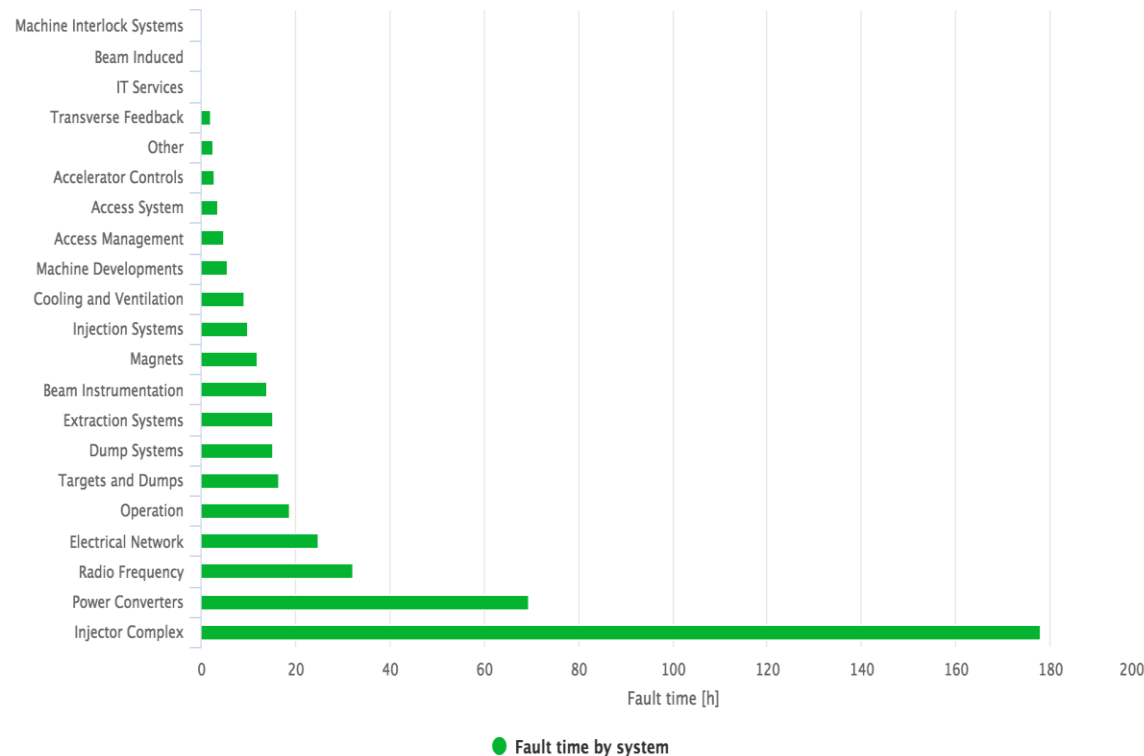
SPS Root Cause Faults during LHC p Run

- Top fault category **Power converters**, followed by **RF**
 - Power converter longest fault (1d4h30m; MBI/QF glitches due to Profibus communication error)
 - Power converter issues solved or being followed up
 - RF mainly short trips
- Second and third longest faults for **Electrical Network** (18kV fault of 23h5m and BEQ3 static var compensator 14h15m)

Average availability: **90.7%**
(2016: 79%)

Without injector faults: **94.5%**

Root Cause Fault Times by System



Observations

- Availability for beam can be well quantified thanks to AFT. Even more precise numbers possible through 'automatic fault entries' (to be carefully done for rapidly cycling machines with many users)
- Availability for LHC not fully quantifiable yet: Setting up is not a fault and depends on the complexity of the beam requests as well as other programs going on in the injectors (HiRadMat, unmapping of operational beams due to MDs,...)

Side remark:

- Availability does not give information about beam quality. Quality tracking not (fully) operational yet. Other tools are used, but these tools are less developed and not optimised to all needs.

Results through AFT

How is AFT used and could it be used more efficiently?

- Report at LMC (LHC) and at FOM (Injectors); next year also at IEFC (Injectors); allows to realise trends/recurrent faults
- Evian, Chamonix → analyse what could be improved next year
- **Should perform more in-depth data analysis** to target improvements or prioritise consolidation, also for **equipment groups**; will be eased with 2018 new AFT features

Planned AFT Improvements for 2018

- Link faults across accelerators (parent/child)
- More detailed availability statistics
 - Availability per impacted destination
 - Affected beam type inferred from LSA cycle
- Report for potentially missing faults from upstream machines → will increase completeness and quality of data
- Faulty element: Select from layout DB → potentially very useful for equipment experts (and OP)
- Introduce notion of ‘suspended faults’: exclude fault duration from statistics during periods without support (Linac4 reliability run, ISOLDE...)

Fault Details AFT

Fault details

PSB



Equipment fault registered by psbop @ 18-08-2017 17:22:12 via PSB Logbook AWG Reviewed Requires Expert review

Assigned to System **Radio Frequency » Hardware**

Started 18-08-2017 17:10:48

OP Ended 18-08-2017 17:19:04

Current State **OP Ended**

OP Duration 08min 16s

Faulty Element **BR3.C02**

Display Label

R2E Status **Not R2E related**

Description

Impact

Labels

Impacted Destinations **ISOGPS ISOHRS PS**

Affected Rings **Ring 1 Ring 2 Ring 3 Ring 4**

Timing User **NORMHRS** Destination **ISOHRS** Mapped Cycle **1**

1 Relations

Blocking faults:

Blocked faults:

Parent fault: **Electrical Network**

Child faults:

2 State Changes

State change time

State

Username

18-08-2017 17:10:48

Blocking OP

copera

18-08-2017 17:19:04

OP Ended

copera

1 External Linked Systems **E-Logbook**


0 Comments

Configurable Dashboards

Blocking faults during 2017 LHC proton run

Availability

96.9%

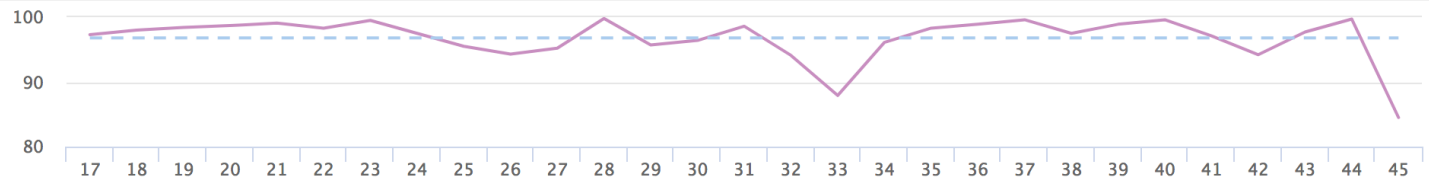
 Fault duration

145.5h

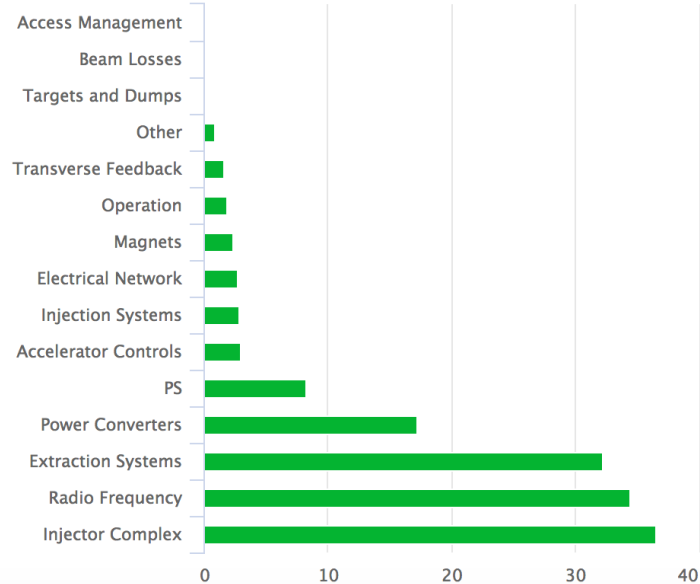
Fault Count

250

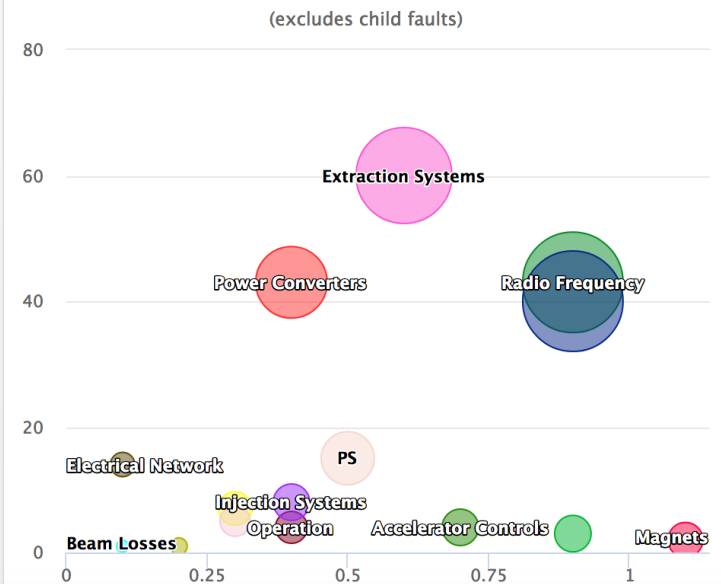
Weekly Availability



Root Cause Fault Times by System - Blocking Faults



Fault Duration Vs. Frequency



Conclusions AFT for Injectors

- **AFT for Injectors implemented during 2017**
 - Evaluation of specific needs done by WG; **first AFT version for injectors available at 2017 injector complex restart (!)**; faults attributed to impacted destination instead of timing user; fault duration per destination; degraded mode added; for PSB fault per impacted ring
 - Several modifications to elogbook implemented (more still required)
 - Harmonisation of injector fault categories similar to LHC
 - Used by now by all machines (except AD)
 - Linac3 elogbook fault entries incomplete (not done systematically)
 - Offline review by equipment specialists often not done (update list)
 - **Constant improvements and increase of functionalities will continue in 2018**
- **Weekly review of Injector faults by machine supervisors and AWG**
 - Proven essential to clarify difficult cases and to feed back open issues, although some non-negligible additional work...
 - **Missing weekly cross-check of LHC injector faults** – could LHC machine coordinator of the week join these meetings?

Summary Injectors Availability

- 2017 was an excellent year for the injectors
 - **Availability of 97% during LHC p run for Linac2, PSB, PS and SPS combined** (93.2% in 2016); **each machine increased its availability**
 - In general the Injector availability is critically dependent on a few long-lasting faults; no long-lasting recurrent faults during 2017
 - Certain equipment improvements implemented during EYETS/TS showed their benefits (PSB/PS septa electro-valve exchange, Linac2 source maintenance,...)
 - Controls and monitoring steadily improving like economy mode in SPS or the optimisation of equipment functions
 - New HW solutions help increase availability like installation of solid state amplifiers
 - More efficient and complete hardware + beam commissioning phase at startup helps detecting and solving issues at that stage

Will be difficult to beat in 2018, but we take on the challenge!