Injectors

- Unavailability by Machine
- Root Causes
- Strategy and Limitations

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Why this Presentation?

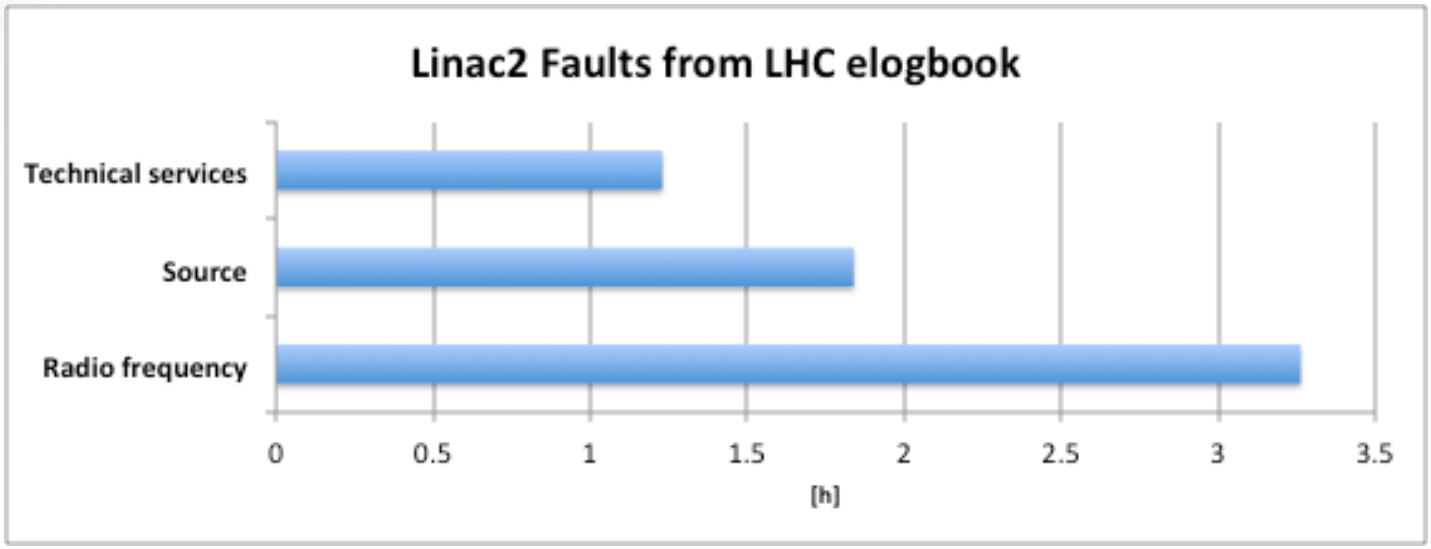
- **Injectors are this year number 1 responsible for LHC downtime**
  - Should take into account that upstream from LHC there are **4 accelerators in series**, all with their own list of potential equipment faults
- **No straight-forward way to analyse from LHC AFT**
  - Which injector is at source of downtime
  - If there are recurrent faults
  - If the situation could be improved
- Can **AFT** or something else be **applied to the injectors** in the future to improve certain limitations?

LHC Injector Faults

2016 Injector Fault Analysis

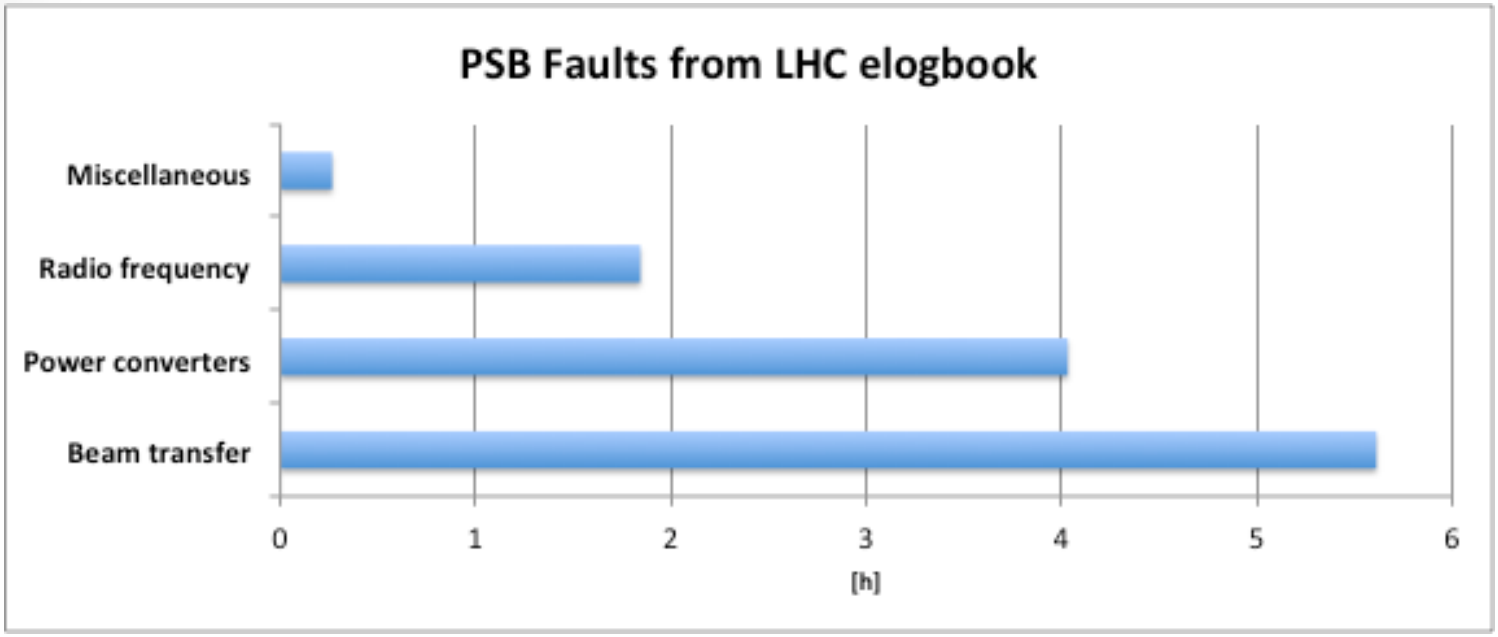
- Data from **2016 LHC proton run: 24/3 – 31/10**
  - **Injector faults as seen by LHC**, extracted from LHC AFT
  - **138 faults; 360.38h = 15d 23m downtime** (9.8% during Beam in Set-up)
  - Only <6 minutes couldn't be attributed to a specific machine
- **Time-consuming manual fault attribution** from individual injector elogbooks for all 138 faults
  - **No automatic link LHC <–> Injector elogbooks** (fault duration for injectors mostly in addition different to LHC fault duration)
  - Often LHC injector faults not marked in injector elogbooks (see remarks later)
  - Root causes have to be understood

Linac2 Faults for LHC



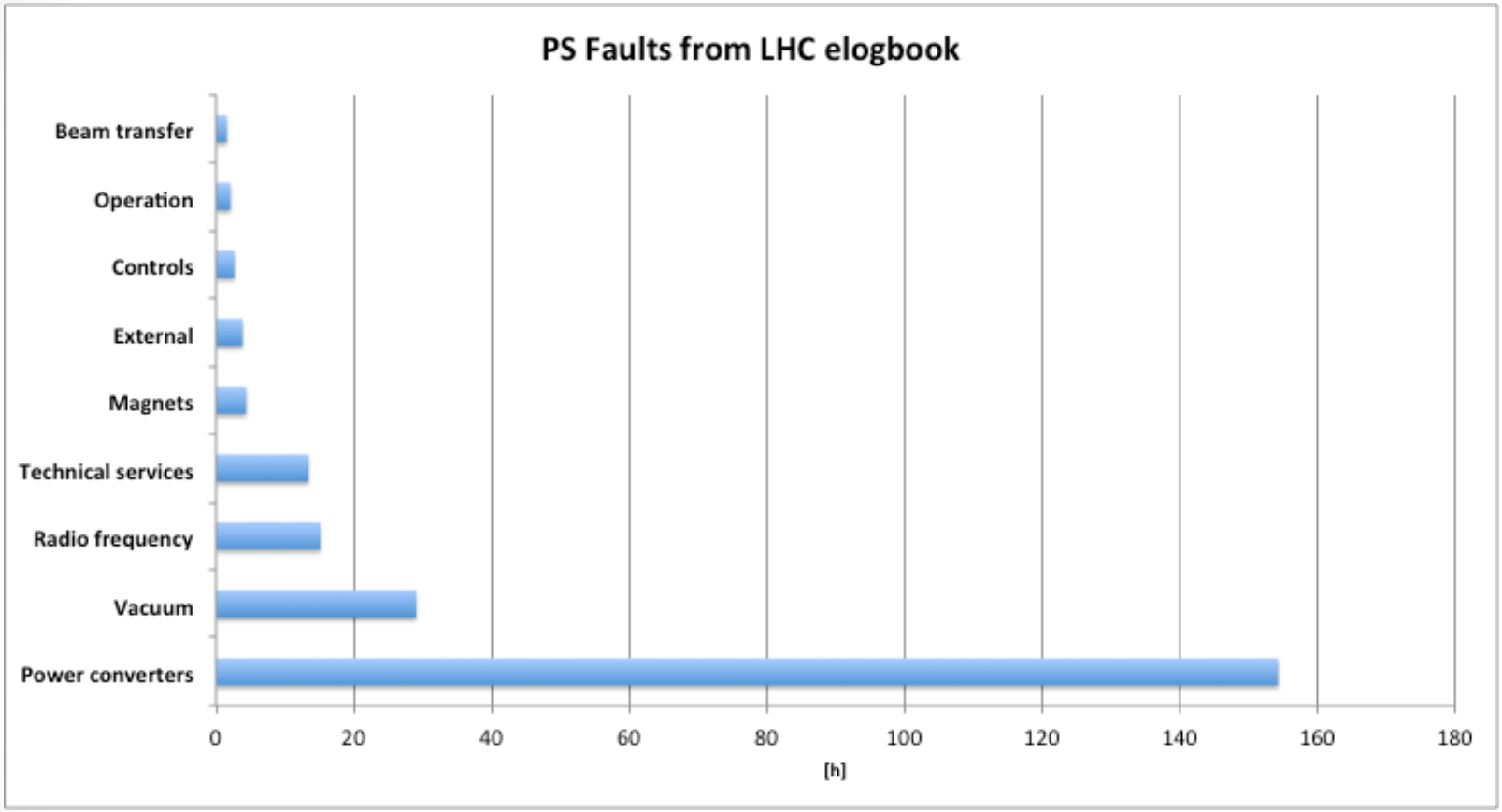
- Total downtime seen by LHC: **6h 20m**
- Only 3 faults; main fault **replacement of ignitron for RFQ and tank 1** on 29/10, followed by source parameter tuning after intensity fluctuations and a problem with a PLC of the cooling station

PSB Faults for LHC



- Total downtime seen by LHC: **11h 45m**
- **Beam Transfer**: Several faults throughout year mainly with electrovalves for septa cooling (access needed)
- Longest individual PSB fault for LHC of 4h due to a problem with the controller of a power supply in recombination line

PS Faults for LHC

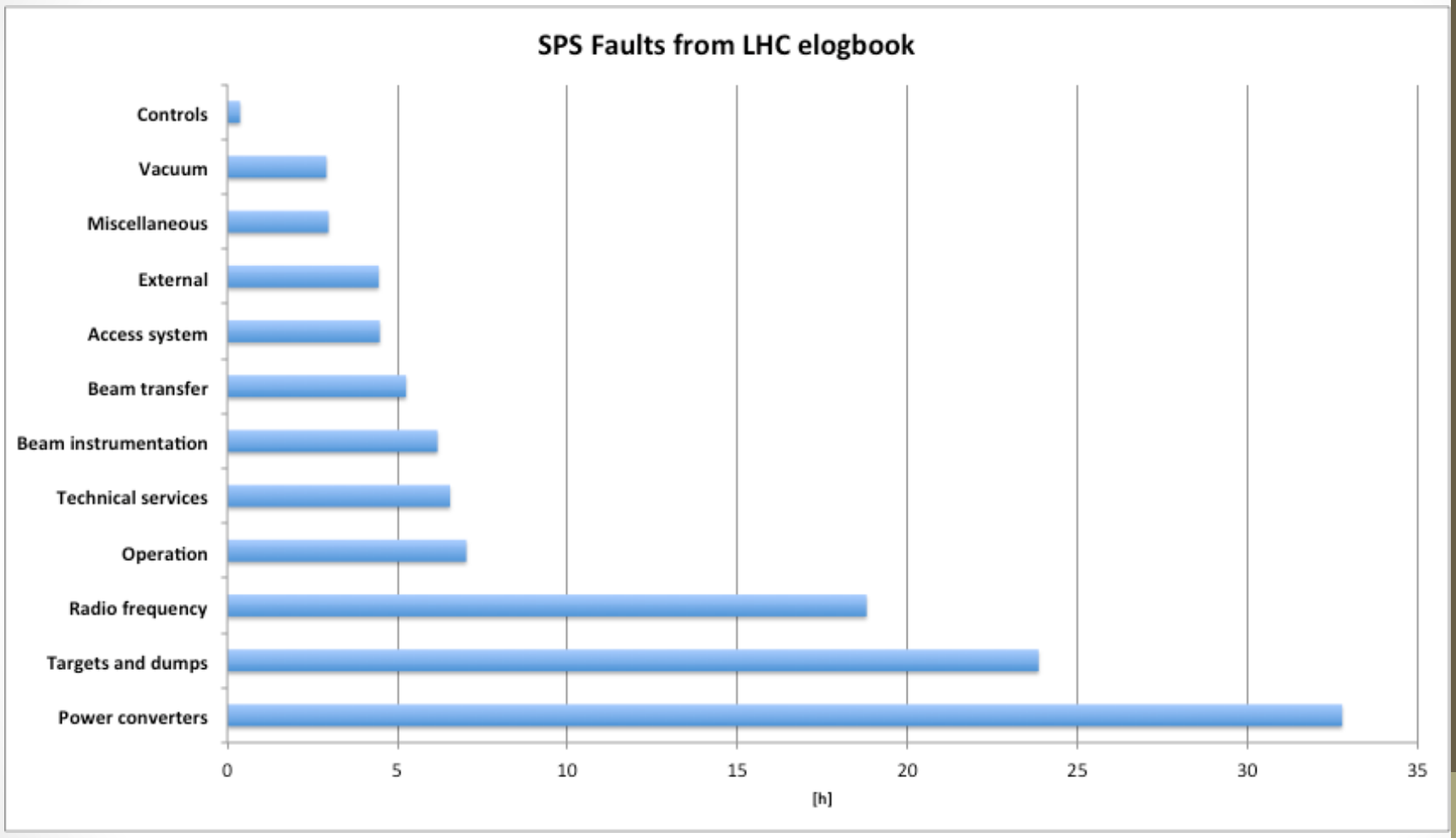


- Total downtime seen by LHC: **9d 10h 34m**

PS Faults for LHC – Main Faults

- **Power converters** (6d 10h 17m):
  - MPS fault (21/5; start of fire of 6 kV high power switch): 5d 19m
  - POPS (27/4; short circuit of DC1 capacitor bank): 21h 26m
  - POPS (5/10; replacement of motor of cooling pump): 5h 14m
- **Vacuum** (single fault of 1d 5h 5m): Leak on vacuum flange downstream of dump at injection septum
- **Radio Frequency** (15h 9m): No systematic faults; integration of several RF faults (mostly cavity trips)

SPS Faults for LHC



- Total downtime seen by LHC: **4d 19h 38m**

SPS Faults for LHC – Main Faults

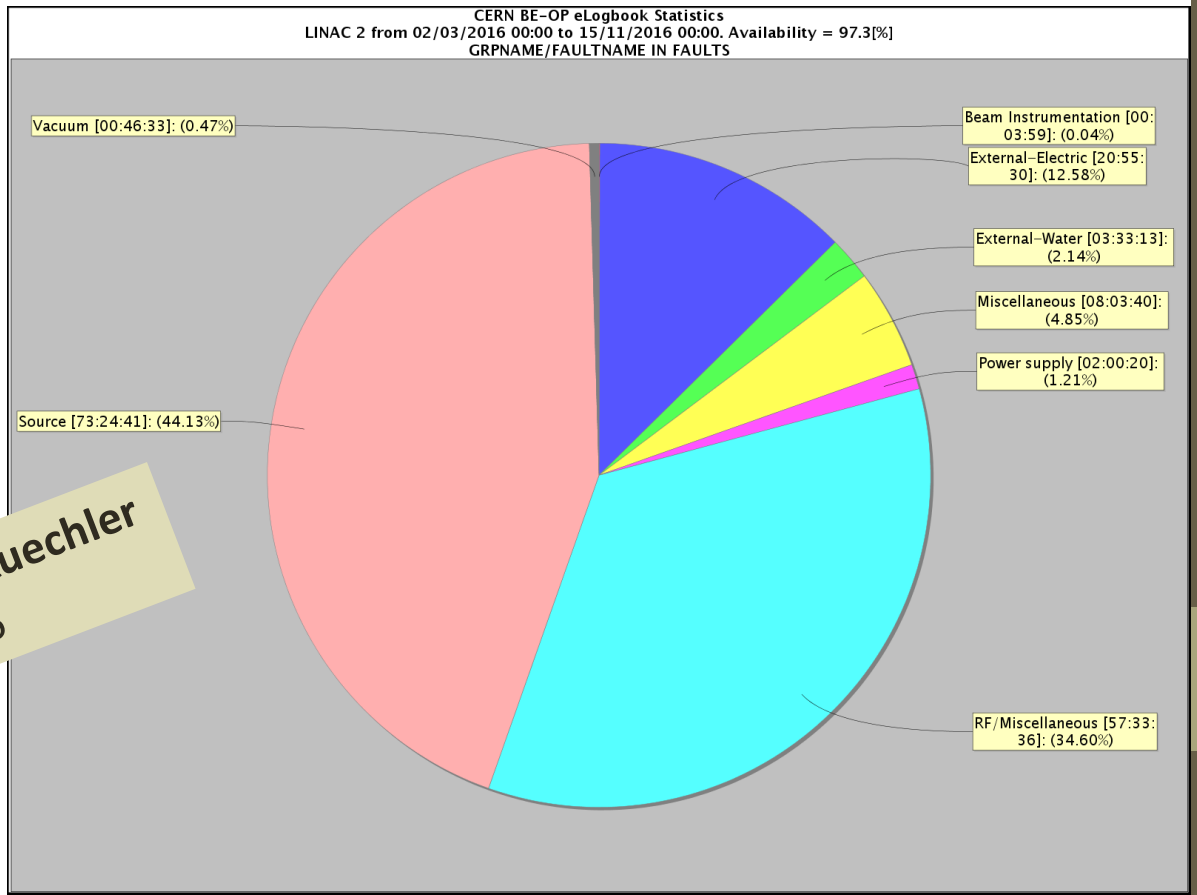
- **Power converters** (1d 8h 47m): No systematic faults
  - 18 kV cable head fault (12/10; MBE2103): 8h 33m
  - BETS (5/4; DCCT on MBI): 7h 36m
  - Removal of busbar after water leak on MSE2183 (29/9): 6h 5m
- **Targets and Dumps** (23h 51m):
  - TIDVG problems; longest downtime 16h 52m (26/4)
- **Radio Frequency** (18h 48m): No systematic faults; both LL/controls and HL

- **Remark**: Although not counted as downtime, but a few systematic issues affecting # bunches, total intensity, beam quality and setting up efficiency (limit in intensity due to TIDVG, QF glitches, cavity 3 vacuum issues, MKP4 weakness) → **degraded mode**

2016 Injector Faults

Linac2 Faults during 2016 p Run

- Period considered**: 2/3 – 14/11/2016**; 6055 h (252d 7h)
- 97.3% uptime (a bit less than last 15-year average of 98.3%)
- **166h downtime** (6d 22h; of which only **6h 20m** 'seen' by LHC)



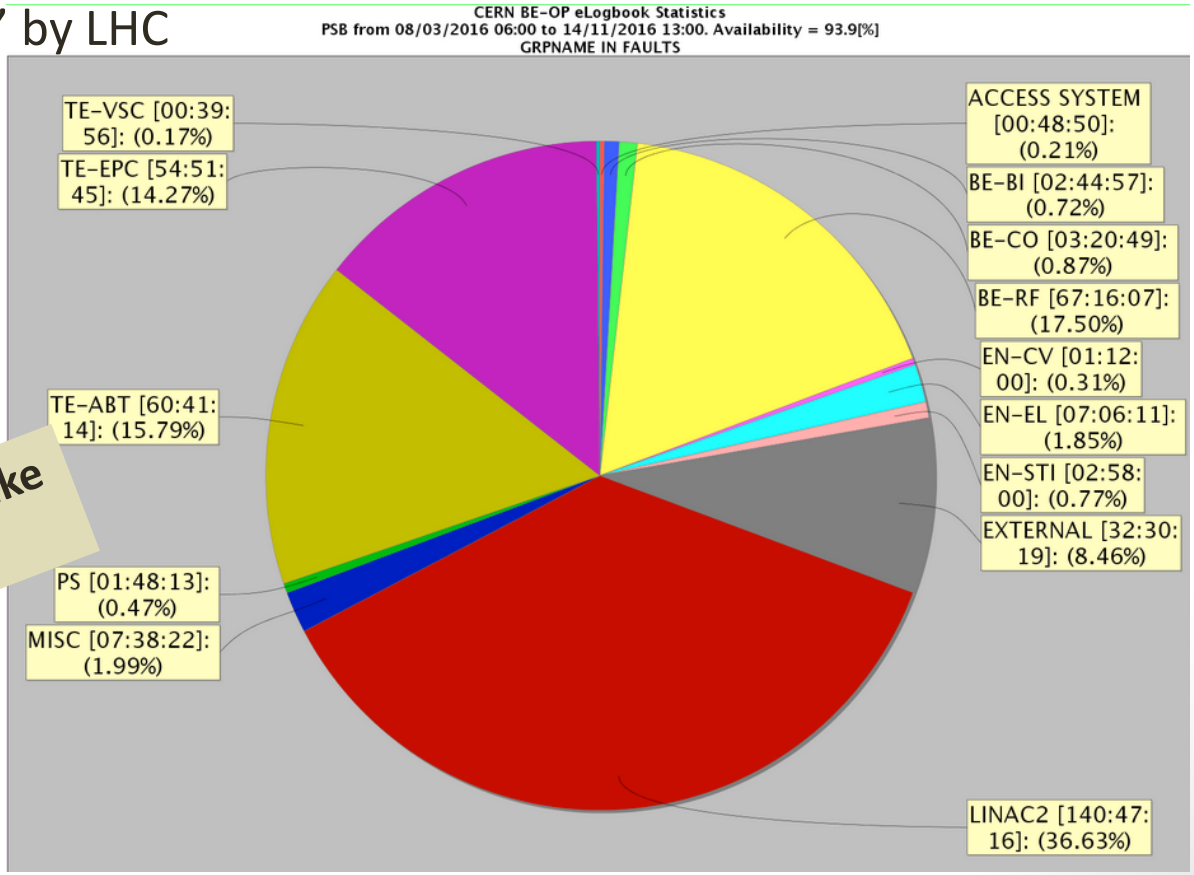
Analysis from **D. Kuechler** FOM 22/11/2016

Linac2 Faults during 2016 p Run (2)

- 3 main faults accounting for >91% of total faults:
  - **Source**: 44.1%: source performance degraded over long periods of the year, but LHC beams didn't suffer too much
    - 2 vacuum leaks (very difficult to detect), 2 cathode exchanges, time for performance diagnostics
    - ➢ **New source** will be tested during EYETS
  - **RF System**: 34.6%
    - HV system (ignitron, RF amplitude jitter due to broken HT cable), broken tuner in RFQ, reference amplifier
    - ➢ **RF team is analysing situation** to see if preventive maintenance could help to reduce downtime during 2017
  - **External** (electric + CV): 14.7%
    - Power glitches, availability of cooling water

PSB Faults during 2016 p Run

- Period considered**: 8/3 – 14/11/2016**
- 93.9% uptime (compared to 92.5% in 2015)
- **384h downtime** (16d, including 6d 22h Linac2 downtime)
  - **11h 45m** 'seen' by LHC



Analysis from **K. Hanke** FOM 22/11/2016

PSB Faults during 2016 p Run (2)

- 4 main faults accounting for >84% of total faults (384h):
  - **Linac2**: 36.6%
  - **RF System**: 17.5%
    - **Degraded mode has still to be deduced** (running without C16 cavity after Finemet water leak) → will result in much reduced downtime due to RF
  - **Beam Transfer**: 15.8%
    - Many issues with new type of septa electro-valves (assumed to originate from radiation damage) → **valves will be exchanged during EYETS with new type**
  - **Power converters**: 14.3%
    - Uncorrelated and random faults

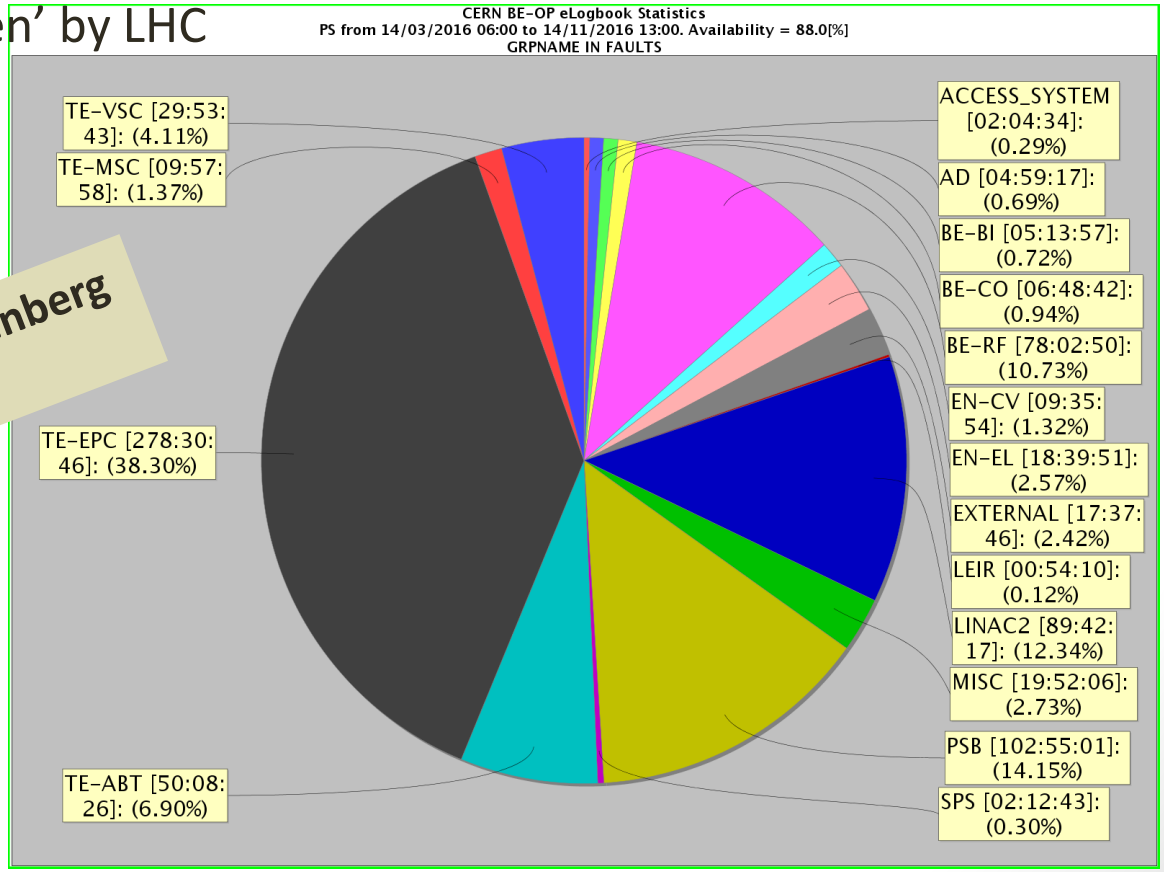
- 4 main faults accounting for ~83% of total faults (353h):
  - **Linac2**: 39.8%
  - **Beam Transfer**: 17.2%
  - **Power converters**: 15.5%
    - Sometimes difficult restart after power glitches → to be looked into
    - Renovation during LS2
  - **RF System**: 10.3%
    - **Corrected for 2 phases of degraded mode end October (C16 not available)**

➢ **Degraded mode to be removed from faults in 2017 statistics**

PS Faults during 2016 p Run

- Period considered**: 14/3 – 14/11/2016**;
- 88% uptime (compared to 91.3% in 2015)
- **727h downtime** (30d 07h, including 08d 01h from injectors)
  - **9d 10h 34m** 'seen' by LHC

Analysis from **R. Steerenberg**
FOM 22/11/2016



PS Faults during 2016 p Run (2)

- 4 main faults accounting for >82% of total faults:
  - **Power converters**: 38.3%
    - **Serious problems with POPS and MPS this run** (longest fault of **>150h** after start of fire of high power switch of rotating machine 20/5); **corrective measures taken** → reduced probability of re-occurrence for 2017 run
  - **Injectors**: 26.6%
  - **Radio Frequency**: 10.7%
    - Multiple reasons
  - **Beam Transfer**: 6.9%

  - Remark: **Availability varies per user** (~79-94% for p users)
    - Different start dates per user
    - Users not always requested / in supercycle
    - Different availabilities due to the use of some user-dedicated equipment

PS: POPS/MPS Changes during EYETS

- POPS:
  - **Construction of two new containers with new capacitor technology**
    1. 1 container to replace DSP1 (explosion) plus a spare
    2. Total capacitance divided into four groups, each one protected by an individual fusing element → reduce amount of energy and peak current discharged in case of internal fault
    3. New design of capacitors to mitigate weakness of older version
  - **Cooling water pumps**
    - Replacement of all water pump motors with new pump motor model
- MPS:
  - Repair done; **tests at end of run** to guarantee it can serve as backup

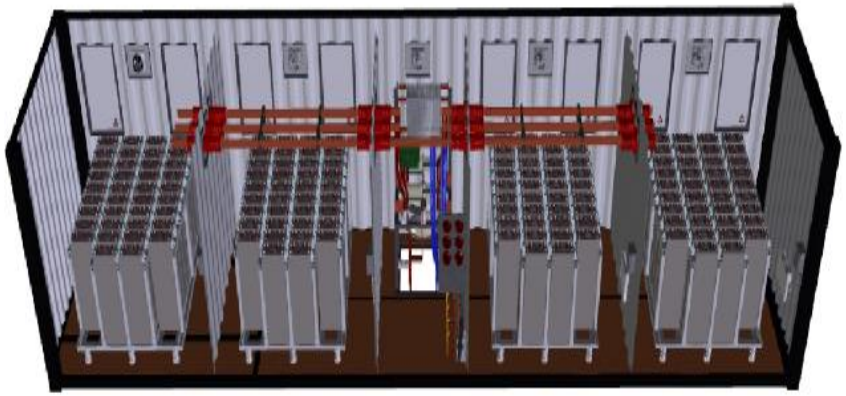
POPS Modifications

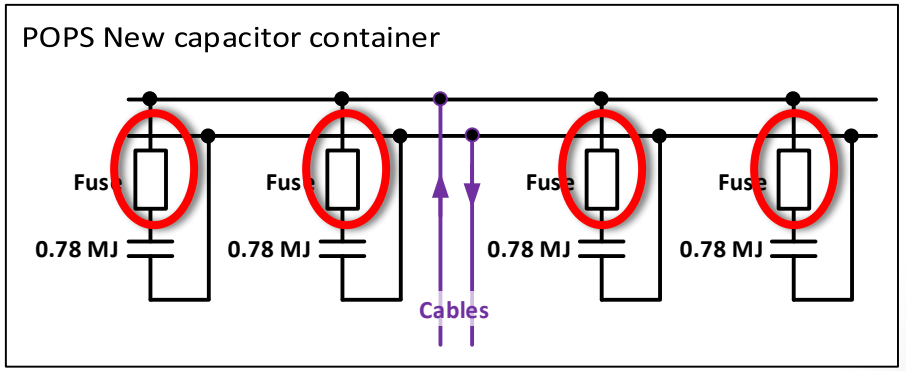
New Spare container

New container to replace exploded DSP1

1.

2.

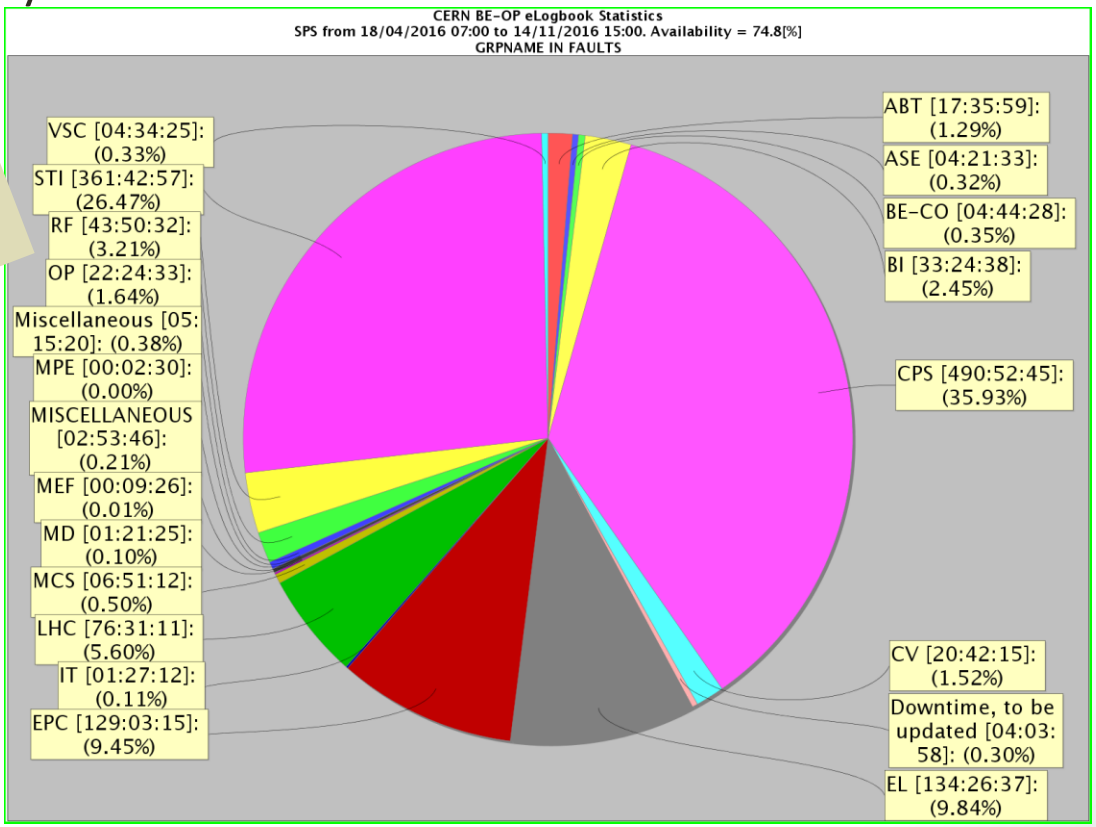




SPS Faults during 2016 p Run

- Period considered**: 18/4 – 14/11/2016**
- 74.8% uptime for FT (compared to 85.5% in 2015)
- **1366h downtime** (56d 22h, including 20d 11h from injectors)
  - **4d 19h 38m** 'seen' by LHC

Analysis from **K. Cornelis, V. Kain, J. Dalla-Costa,** FOM 29/11/2016



SPS Faults during 2016 p Run

- 4 main faults accounting for >81% of total faults:
  - **Injectors**: 35.9%
  - **Targets and Dumps**: 26.5%
    - SPS TIDVG issues → **new internal dump with revised design after EYETS**
  - **Technical Services**: 9.8%
    - Overheating of BA3 transformer
  - **Power Converters**: 9.5%
    - Insulation fault on 18 kV cable head in auto-transformer of MBE2103 (49h 14m)

- Remark: **No systematic faults**;
  several isolated serious issues during 2016

Availability/Fault Statistics

Issues with Injector Availability Statistics (1)

1. **Manual insertion of faults in injector elogbooks**
   - Not everything is captured
   - Could be solved 'à la SPS' with 'Big Sister'
2. **Availability for given destination** (e.g. LHC)
   - Statistics reliable if user always played; current injector approach breaks down for beams on request (LHC, AWAKE, ISOLDE…)
     - If beam not possible, often removed from supercycle (fault for this beam not counted anymore) → high injector flexibility to adapt schedule
   - SPS does not note ANY faults if LHC in supercycle, but under LHC mastership (cannot distinguish between 'no request' and 'request, but fault')
   - Currently faults attributed to timing user (which can be reused for several beams) → will be modified for 2017 (LSA context)
   - No automatic linking of LHC faults with injector entries if declared as injector faults
   - Beam setup: If injectors take longer for LHC, no fault declared in injectors, only in LHC – is that sufficient?

Issues with Injector Availability Statistics (2)

3. **Root fault cause sometimes not correctly identified**
   - Proposal of weekly review by individual machine supervisors
4. **How to account for degraded mode in statistics?**
   - Have to separate degraded mode from faults → will be done for 2017
   - What about long-term degraded mode (examples from 2016: Linac2 reduced source current, TIDVG limitations…)

Plans for Injector Statistics in 2017

- **Implement first version of Injector AFT for p run restart (data capture) → will address some of the issues mentioned before**
  - Harmonise injector fault categories (done; to be implemented in elogbooks)
  - Use LSA contexts (modification of elogbooks)
    - Statistics to be produced by LSA context or group of contexts (e.g. all LHC cycles)
  - Implement interface elogbook/AFT similar to LHC, but context-dependent
  - Separate 'warnings' from 'faults' in statistics
  - Weekly review of root causes per machine
- **Follow-up discussion on outstanding points needed**

Conclusions

- **Excellent year for LHC despite sub-ideal year for injectors** → flexibility and use of BCMS beam
  - **138 injector faults noted by LHC; total of 360.38h**
- Injector fault analysis for LHC p run had to be done manually
  - **6h 20m (Linac2) / 11h 45m (PSB) / 9d 10h 34m (PS) / 4d 19h 38m (SPS)**
- **Injector downtime characterised by a few longer uncorrelated breakdowns** → no systematic faults
  - **Some of the 2016 top injector fault sources should be removed/mitigated to increase availability in 2017**
  - **LHC 'sees' only a subset of these faults**
- **First version of Injector AFT** to be put into place for 2017 run
- Next step: **Improvements for availability statistics**