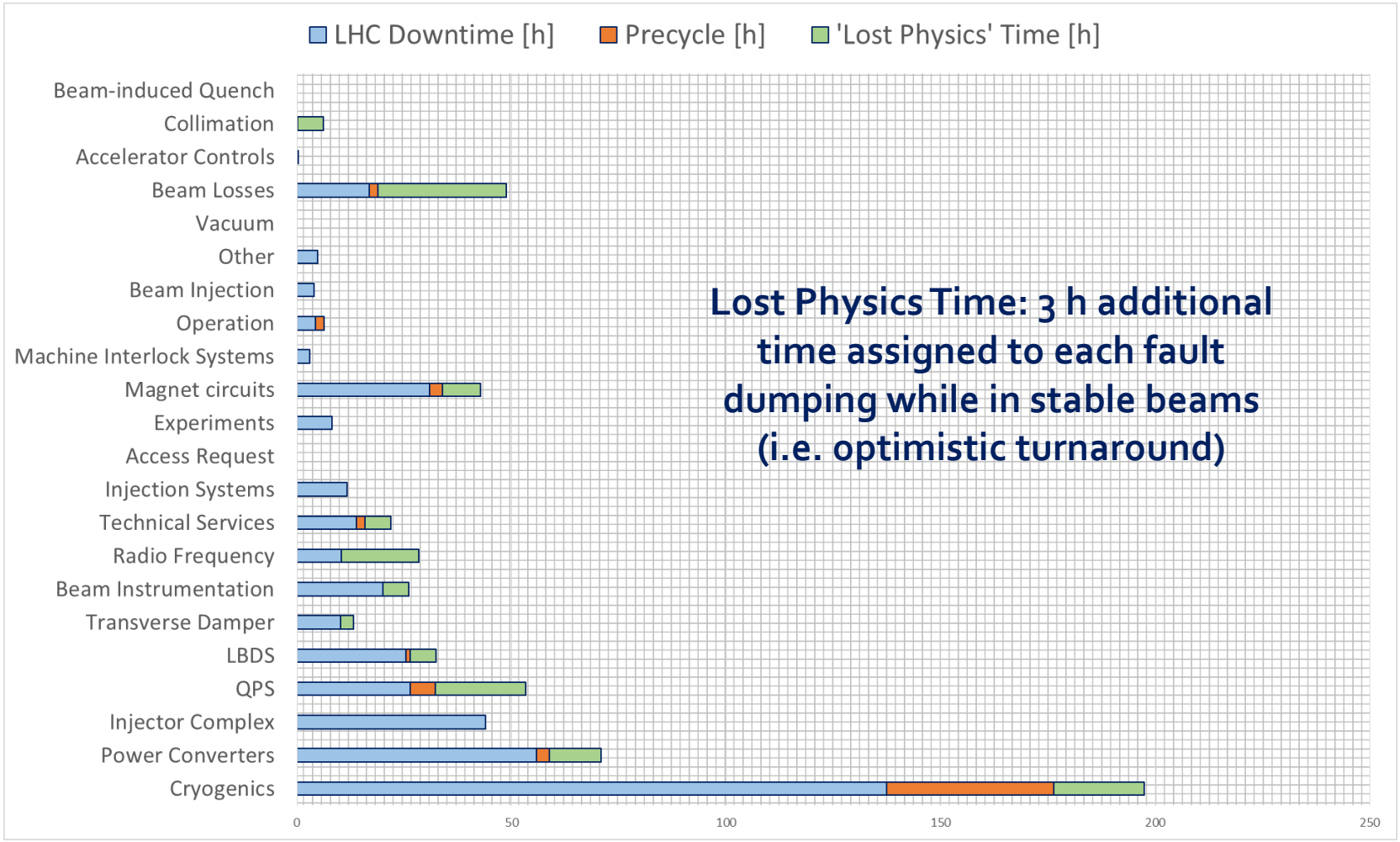
STATISTICAL ANALYSIS OF LHC TURNAROUND AND FAULTS

Milan

Thanks to: Andrea Apollonio, Arto Niemi, Chris Roderick

2015 concept of lost physics (Chamonix Workshop)



Intro to Availability

AFT PM LogBook TIMBER

Fault and performance tracking

AvailSim

Development of tools for performance predictions

Extrapolate to future scenarios based on experience

Availability and reliability metric

Lost Physics

- If a stable beam run is cut short by a fault we say we have “Lost Physics”.
  - Cut short?
  - Why is Lost Physics Important?
  - How does this project help resolve the problem?
    - Improve understanding of factors driving turnaround time (including faults)
  - For High-Lumi turnaround duration will be a critical parameter for integrated luminosity production
    - Shorter fill lengths due to levelled operation – more frequent dumps ergo more frequent turnarounds

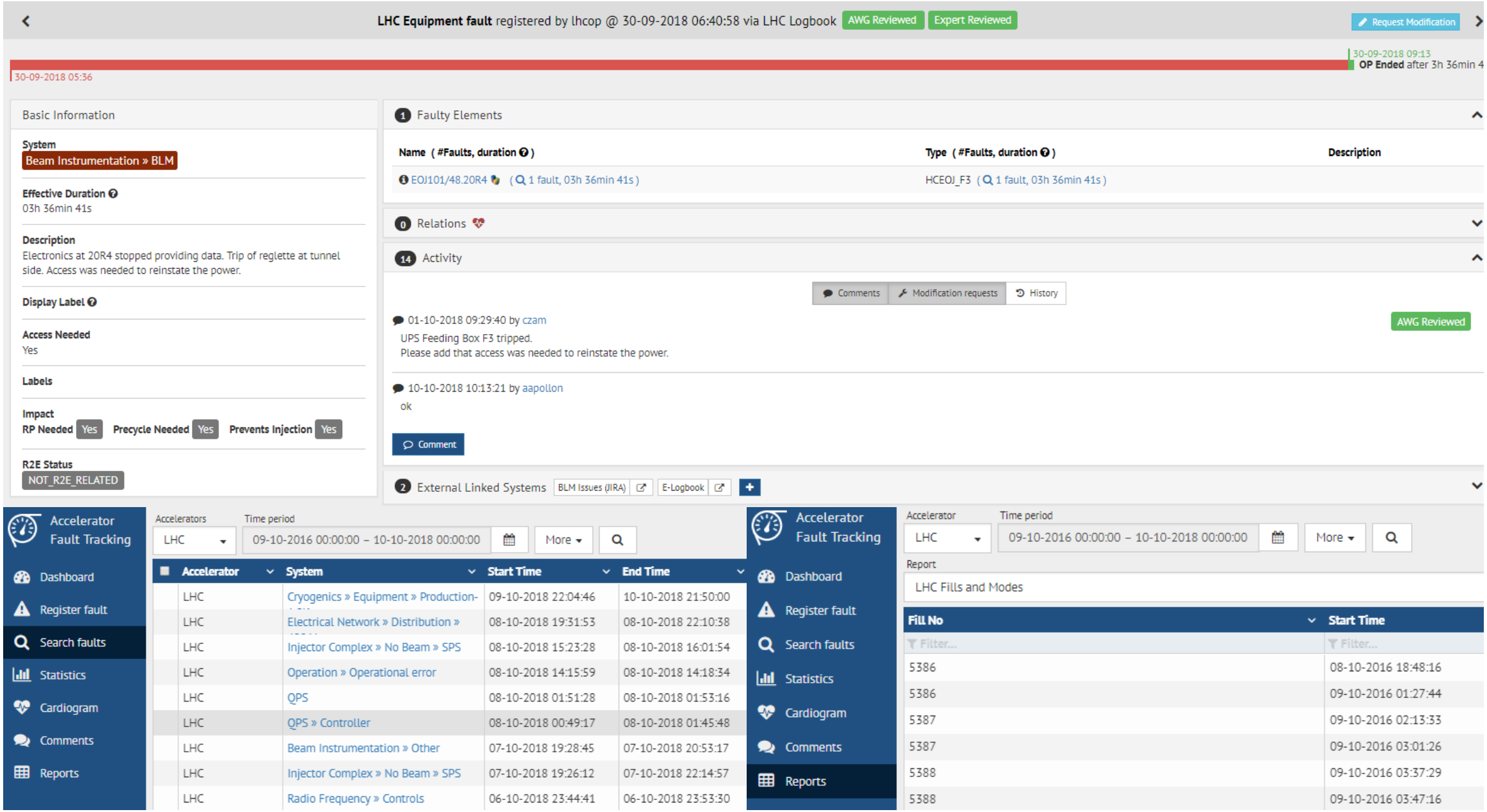
Contents

- Intro
  - Activity Tracking
  - Tools utilised
- Turnaround
  - Intro
  - Analysis & Progress
- AvailSim
  - Progress
- Outlook

Feel free to stop me at any time!

AFT (Accelerator fault tracker)

- Main Centre for obtaining data (OP modes and Faults)
- Built in filter to attain objective data faster
  - Blocking/Non-Blocking
  - Accelerator
  - Date Range


LHC Equipment fault registered by lhcop @ 30-09-2018 06:40:58 via LHC Logbook
AWG Reviewed
Expert Reviewed
Request Modification
30-09-2018 09:13
OP Ended after 3h 36min 4
30-09-2018 05:36
Basic Information
System
Beam Instrumentation » BLM
Effective Duration
03h 36min 41s
Description
Electronics at 20R4 stopped providing data. Trip of reglette at tunnel side. Access was needed to reinstate the power.
Display Label
Access Needed
Yes
Labels
Impact
RP Needed Yes
Precycle Needed Yes
Prevents Injection Yes
R2E Status
NOT_R2E_RELATED
1 Faulty Elements
Name (#Faults, duration)
Type (#Faults, duration)
Description
EOJ101/48.20R4 (1 fault, 03h 36min 41s)
HCEOJ_F3 (1 fault, 03h 36min 41s)
0 Relations
14 Activity
Comments
Modification requests
History
01-10-2018 09:29:40 by czam
AWG Reviewed
UPS Feeding Box F3 tripped.
Please add that access was needed to reinstate the power.
10-10-2018 10:13:21 by aapollon
ok
Comment
2 External Linked Systems
BLM Issues (JIRA)
E-Logbook
Accelerator Fault Tracking
Dashboard
Register fault
Search faults
Statistics
Cardiogram
Comments
Reports
Accelerators
LHC
Time period
09-10-2016 00:00:00 – 10-10-2018 00:00:00
More
Accelerator
System
Start Time
End Time
LHC Cryogenics » Equipment » Production- 09-10-2018 22:04:46 10-10-2018 21:50:00
LHC Electrical Network » Distribution » 08-10-2018 19:31:53 08-10-2018 22:10:38
LHC Injector Complex » No Beam » SPS 08-10-2018 15:23:28 08-10-2018 16:01:54
LHC Operation » Operational error 08-10-2018 14:15:59 08-10-2018 14:18:34
LHC QPS 08-10-2018 01:51:28 08-10-2018 01:53:16
LHC QPS » Controller 08-10-2018 00:49:17 08-10-2018 01:45:48
LHC Beam Instrumentation » Other 07-10-2018 19:28:45 07-10-2018 20:53:17
LHC Injector Complex » No Beam » SPS 07-10-2018 19:26:12 07-10-2018 22:14:57
LHC Radio Frequency » Controls 06-10-2018 23:44:41 06-10-2018 23:53:30
Accelerator Fault Tracking
Dashboard
Register fault
Search faults
Statistics
Cardiogram
Comments
Reports
Accelerator
LHC
Time period
09-10-2016 00:00:00 – 10-10-2018 00:00:00
More
Report
LHC Fills and Modes
Fill No
Start Time
5386 08-10-2016 18:48:16
5386 09-10-2016 01:27:44
5387 09-10-2016 02:13:33
5387 09-10-2016 03:01:26
5388 09-10-2016 03:37:29
5388 09-10-2016 03:47:16

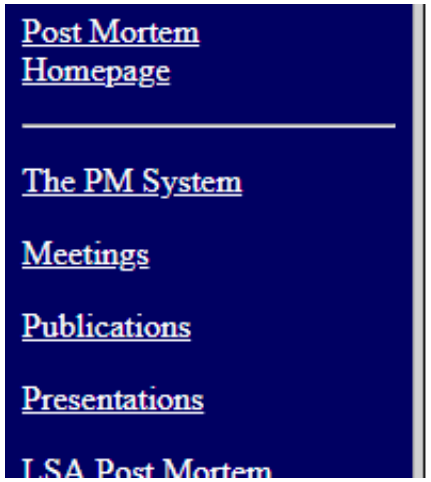
E-Logbook

- Basis of comparison with accuracy of data from AFT
  - Analysis revealed problems with AFT data extraction for OP Modes. Solved!
- Provides foundation of understanding for the operational processes and cycles of LHC
- Shows all events registered from CCC operators

2	15:11	SB	Global Post Mortem Event Confirmation Dump Classification: QPS trigger Operator / Comment: dawalsh / QPS fault/slow abort on RD4.L4, due to loss of voltage readings from a faulty connection
3	15:11	SB	Global Post Mortem Event Event Timestamp: 07/05/18 15:11:02.205 Fill Number: 6650 Accelerator / beam mode: PROTON PHYSICS / STABLE BEAMS Energy: 6499320 [MeV] Intensity B1/B2: 21084 / 22278 [e^10 charges] Event Category / Classification: PROTECTION_DUMP / MULTIPLE_SYSTEM_DUMP First BIC input Triggered: First USR_PERMIT change: Ch 12-PIC_MSK: A T -> F on CIB.UA43.L4.B1
4	15:12	1	Lost voltage reading on the quenche heater of RD4.L4. This caused a slow abort, thus dumping the beam
5	15:13	1	**BEAM MODE > BEAM DUMP** LHC RUN CTRL: BEAM MODE changed to BEAM_DUMP
6	15:14	1	**BEAM MODE > RAMP DOWN** LHC RUN CTRL: BEAM MODE changed to RAMP_DOWN
7	15:20	1	QPS expert called to inform us that there was a slow heater discharge on the RD4.L4, which was detected by SiS which as a consequence r An intervention is required by the QPS team in the UA. We ramp down and prepare for access.
8	15:22	1	LHC RUN CTRL: New FILL NUMBER set to 6651
9	15:52	1	**ACCESS > Access** LHC SEQ: preparing the LHC for access in service areas

Post Mortem

- Snapshot of machine state at failure
- Injection scheme 2556 bunches at spacing 25ns
- Use columns to filter information from AFT and E-Logbook
  - 2556

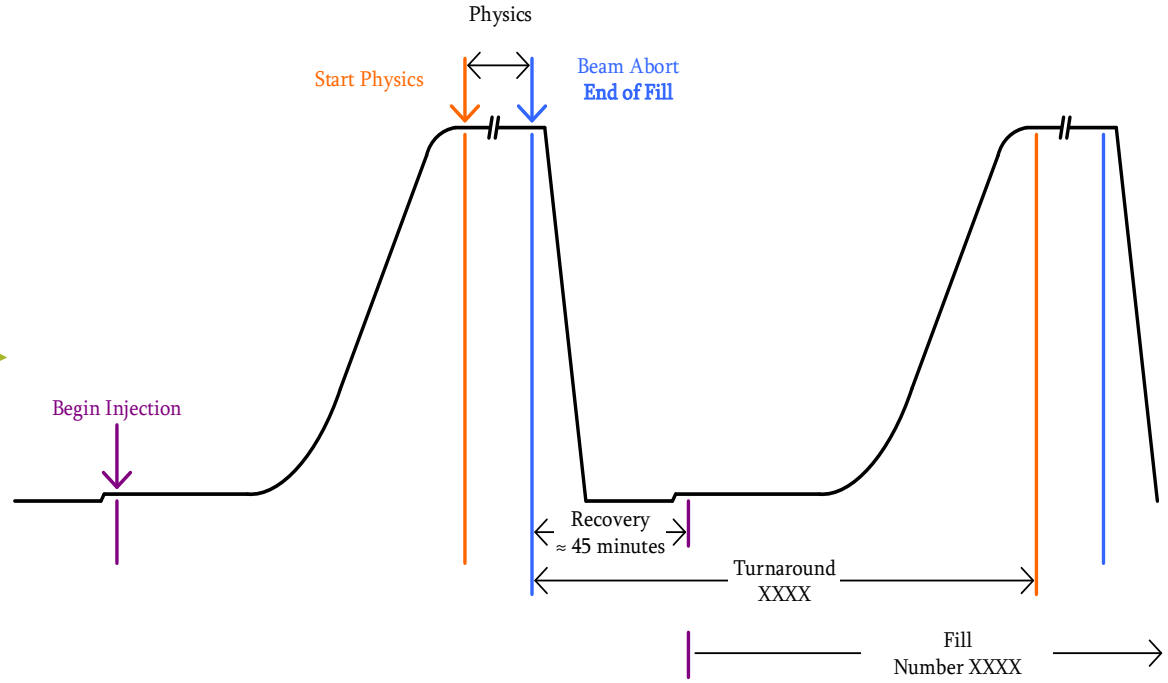


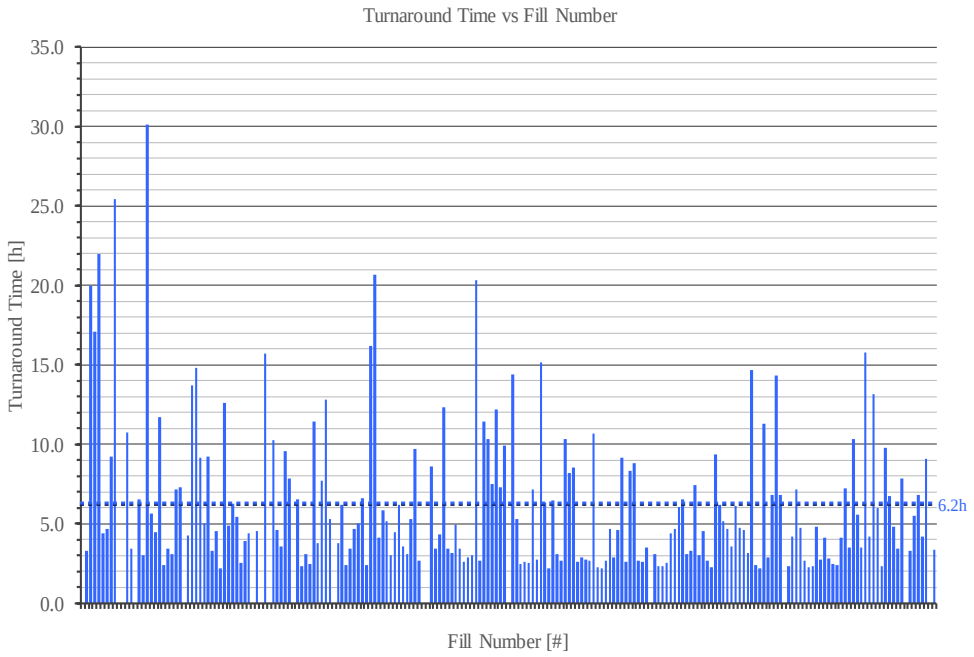
Injection Scheme = '25ns_2556b_2544_2215_2332_144bpi_20injV2'

Event Timestamp	Event Category	Accelerator Mode	Beam Mode	Beam Energy [MeV]	Fill Number
05-MAY-2018 14.21.00.810000	PROTECTION_DUMP	PROTON PHYSICS	STABLE BEAMS	6499320	6643
05-MAY-2018 19.34.38.136006	PROTECTION_DUMP	PROTON PHYSICS	STABLE BEAMS	6499200	6645
06-MAY-2018 06.14.40.536010	PROTECTION_DUMP	PROTON PHYSICS	STABLE BEAMS	6499200	6646

Turnaround analysis

- Define turnaround(The interval from the beam abort in one fill, to the start of stable beams in the next is referred to as the *turnaround* time. Note that turnaround time is labelled with the fill number where stable beams starts)



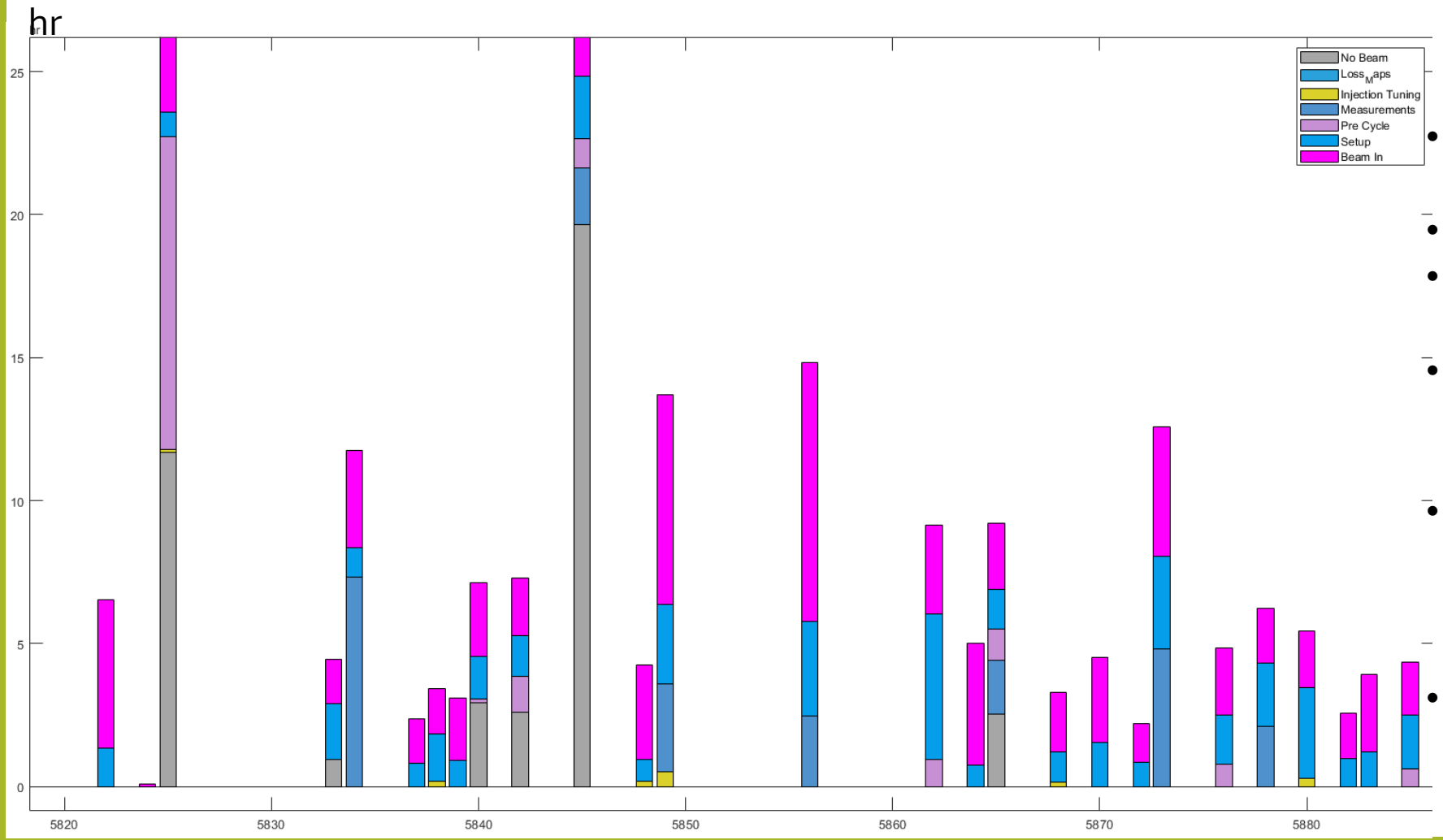


Not broken down into OP modes, very general and not much can be interpreted. Theoretical min is 2 hours average (mean) is 5 hours

OP Modes

- No Beam – Long faults and/or planned access
- Loss Maps – Mapping loss locations in LHC in order for comparison later on
- Injection tuning – Adjust transfer line settings to minimise losses at injection
- Measurements
- Pre-Cycle – cycle magnets up to 3.5TeV to prepare for next injection following fault
- Setup – no beam but setting up for next cycle
- Beam In – cycle with beam
- Stable Beams - collisions

LHC RUN1 28/04/17-03/07/17

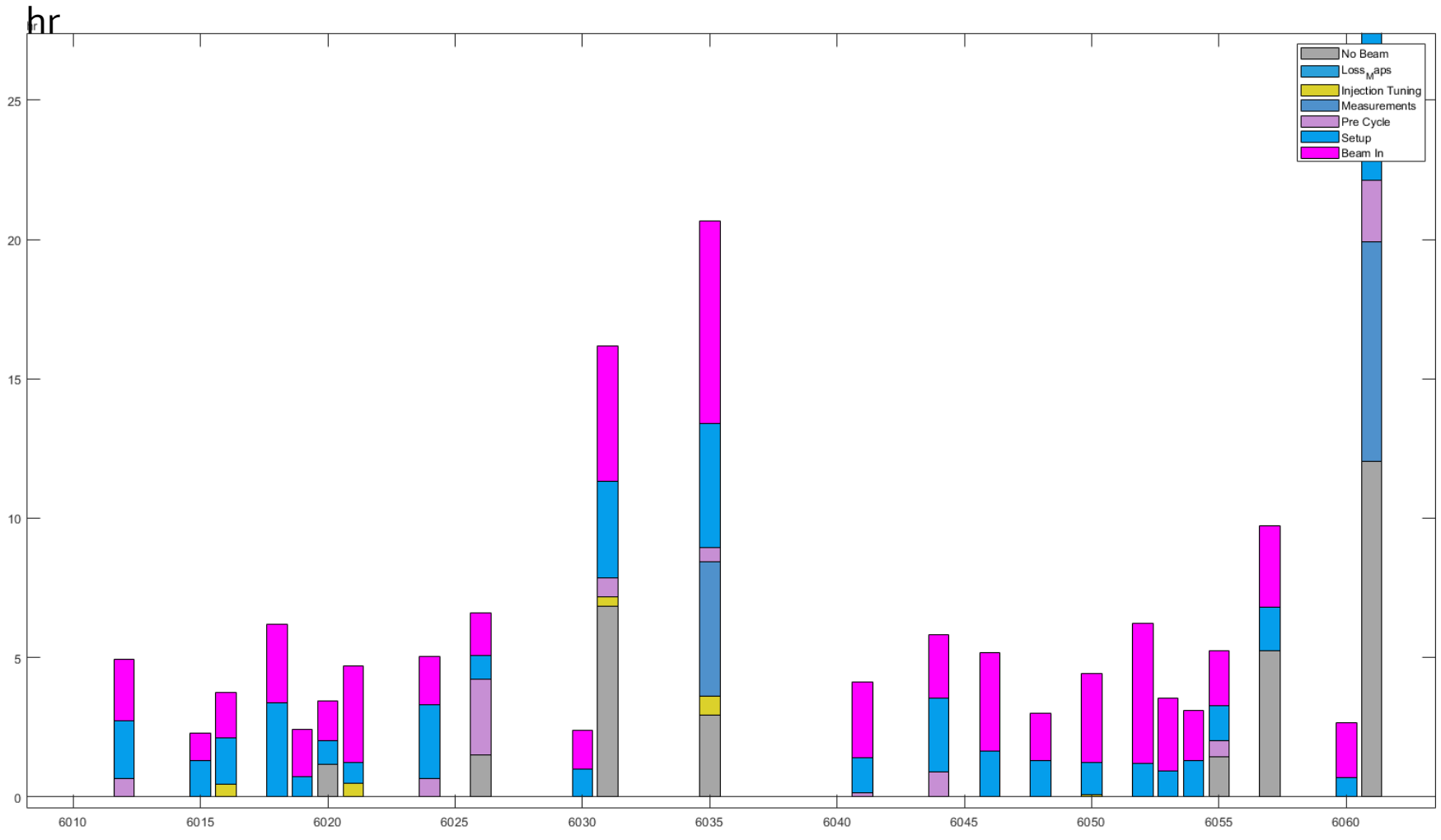


Mean

1.4891 hr	No beam
0.21104 hr	Loss Maps
0.05159 hr	Injection Tuning
5.0838 hr	Measurements
0.55737 hr	Pre Cycle
2.0218 hr	Setup
3.0862 hr	Beam in

- Breakdown into different OP modes
- For each fill
- Colour coded according to E-Logbook
- Working on implementing "Net OP mode times and time in fault"
- Can break down into mean OP mode duration and count per fill – can narrow down elements which may contribute to faults
- Knock on effects with improving availability for High-Lumi

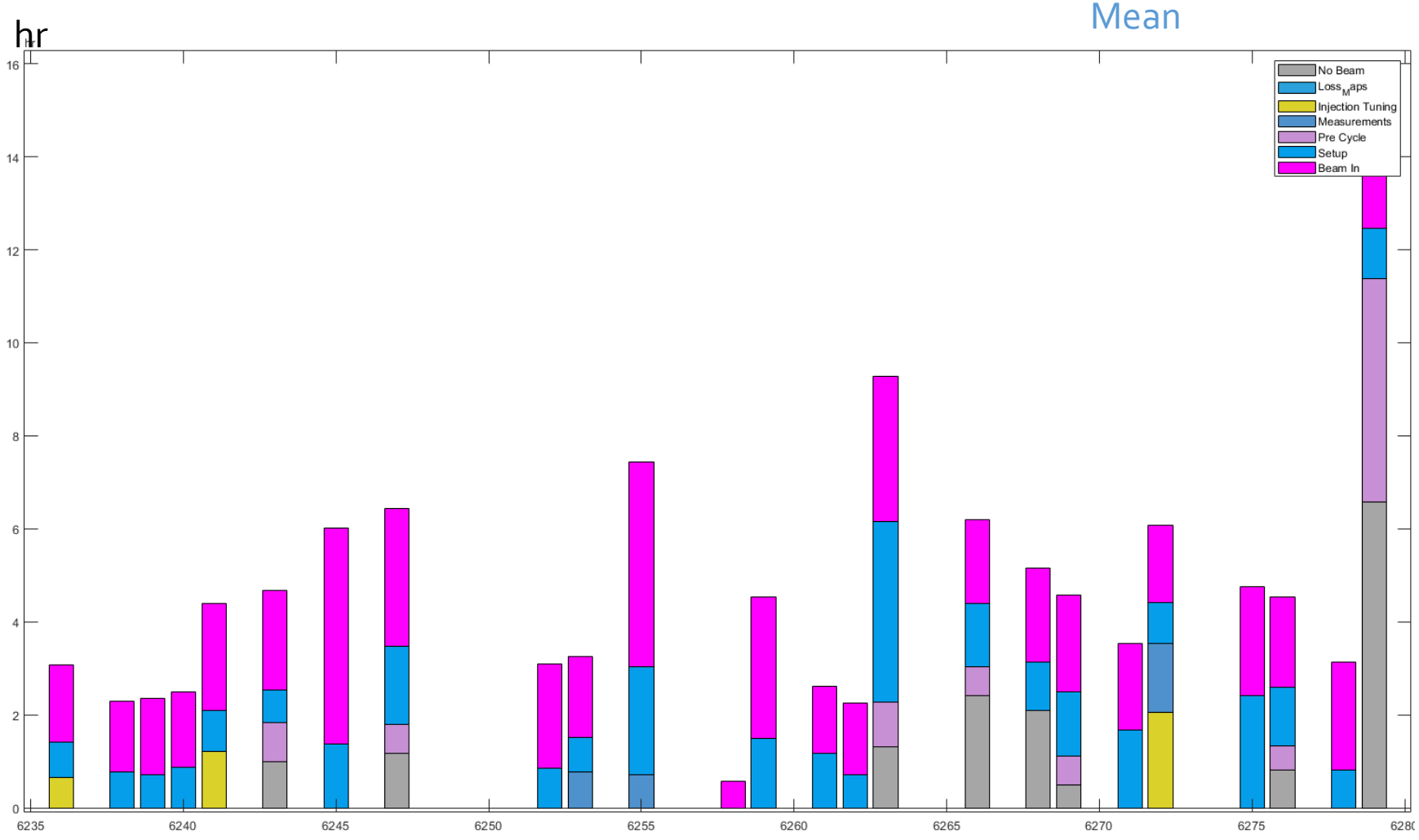
LHC RUN2 07/07/17-18/09/17



Mean

2.4783 hr	No beam
0.06612 hr	Loss Maps
0.06052 hr	Injection Tuning
0.45479 hr	Measurements
0.30889 hr	Pre Cycle
2.7411 hr	Setup
3.1583 hr	Beam in

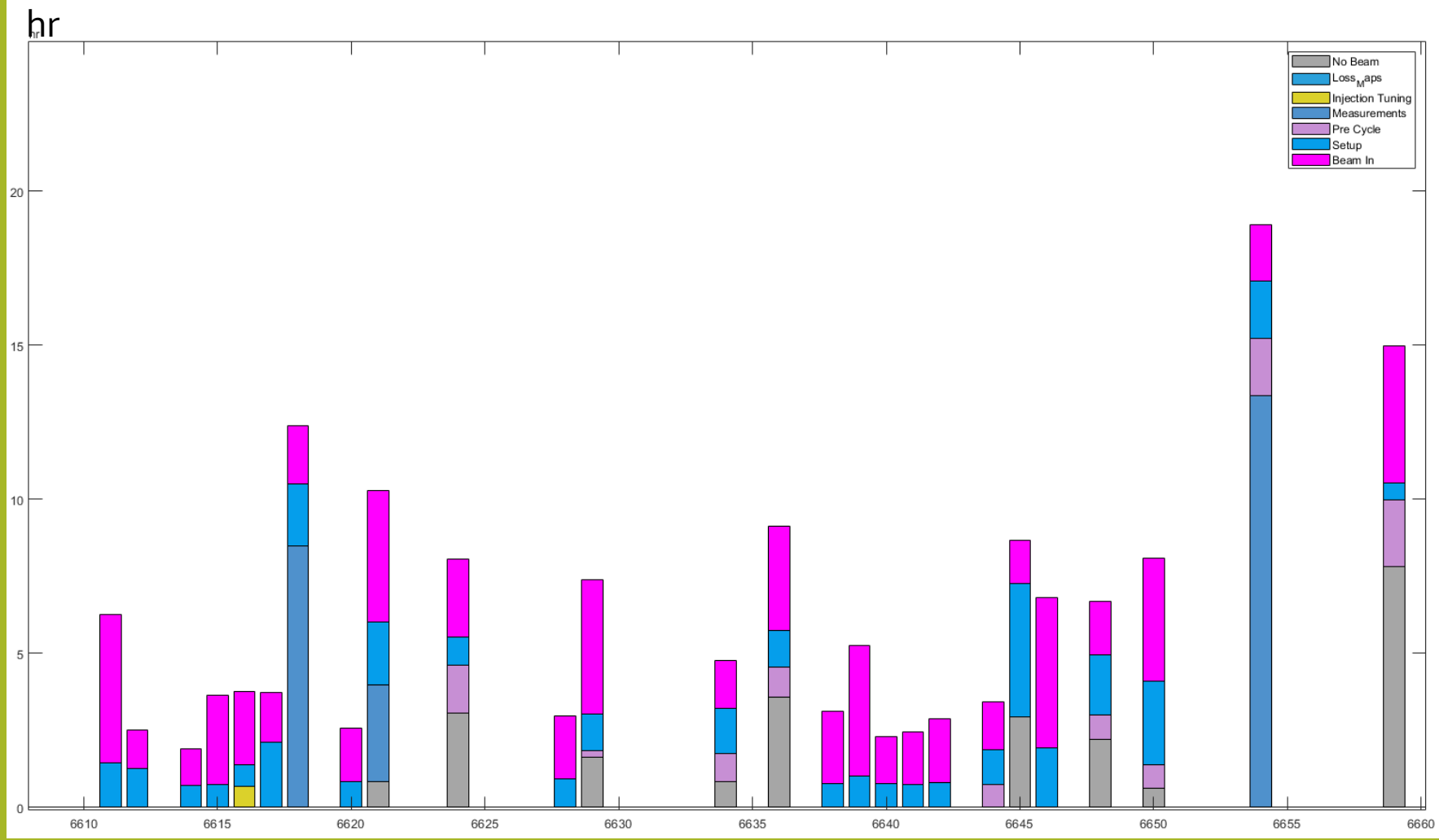
LHC RUN3 21/09/17-10/12/17



Mean

1.1802 hr	No beam
0.03798 hr	Loss Maps
0.06187 hr	Injection Tuning
0.4666 hr	Measurements
0.35846 hr	Pre Cycle
1.8058 hr	Setup
2.1679 hr	Beam in

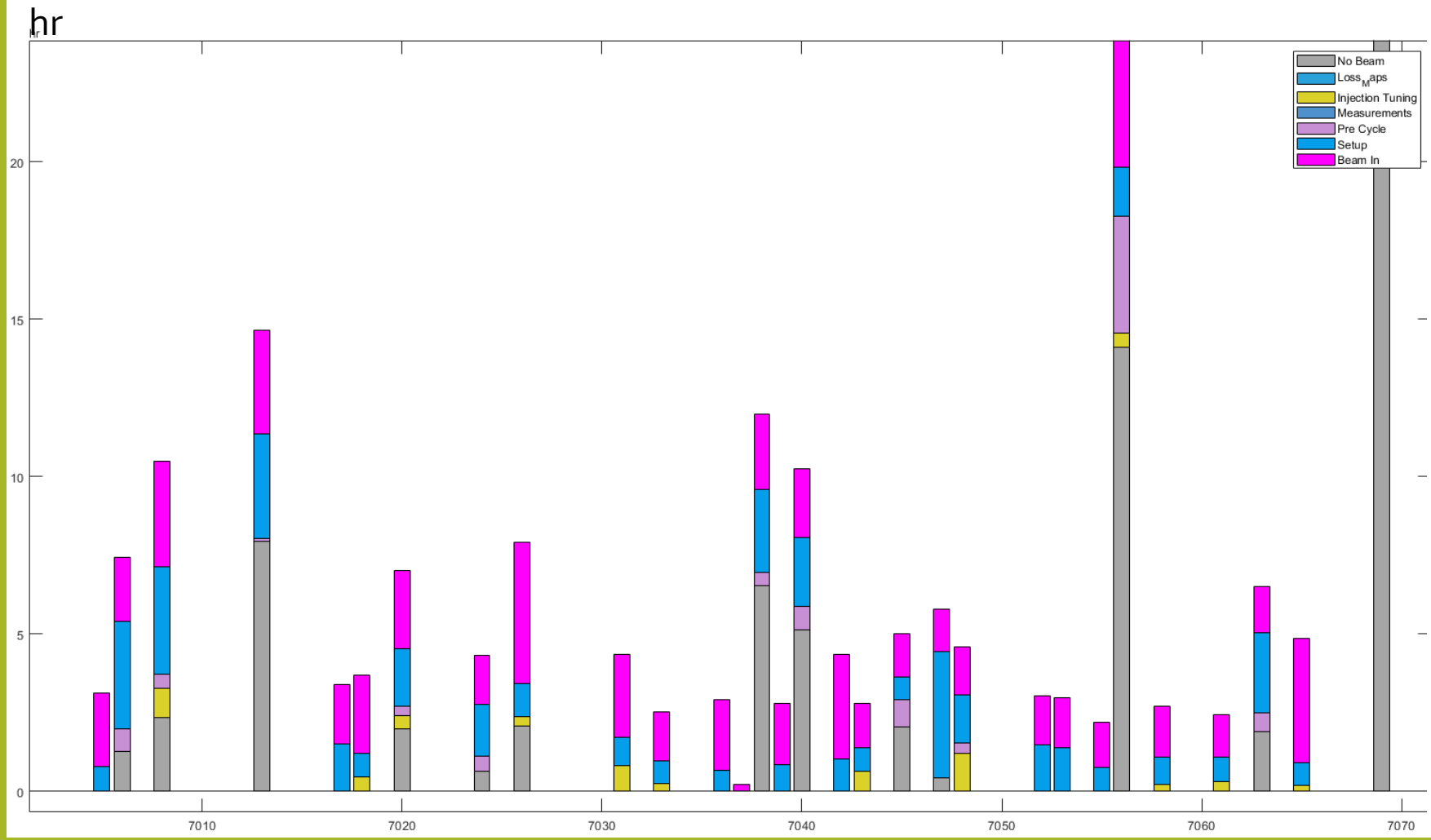
LHC RUN1 30/03/18-18/06/18



Mean

1.7959 hr	No beam
0.03730 hr	Loss Maps
0.10255 hr	Injection Tuning
0.60396 hr	Measurements
0.45992 hr	Pre Cycle
1.8338 hr	Setup
2.7128 hr	Beam in

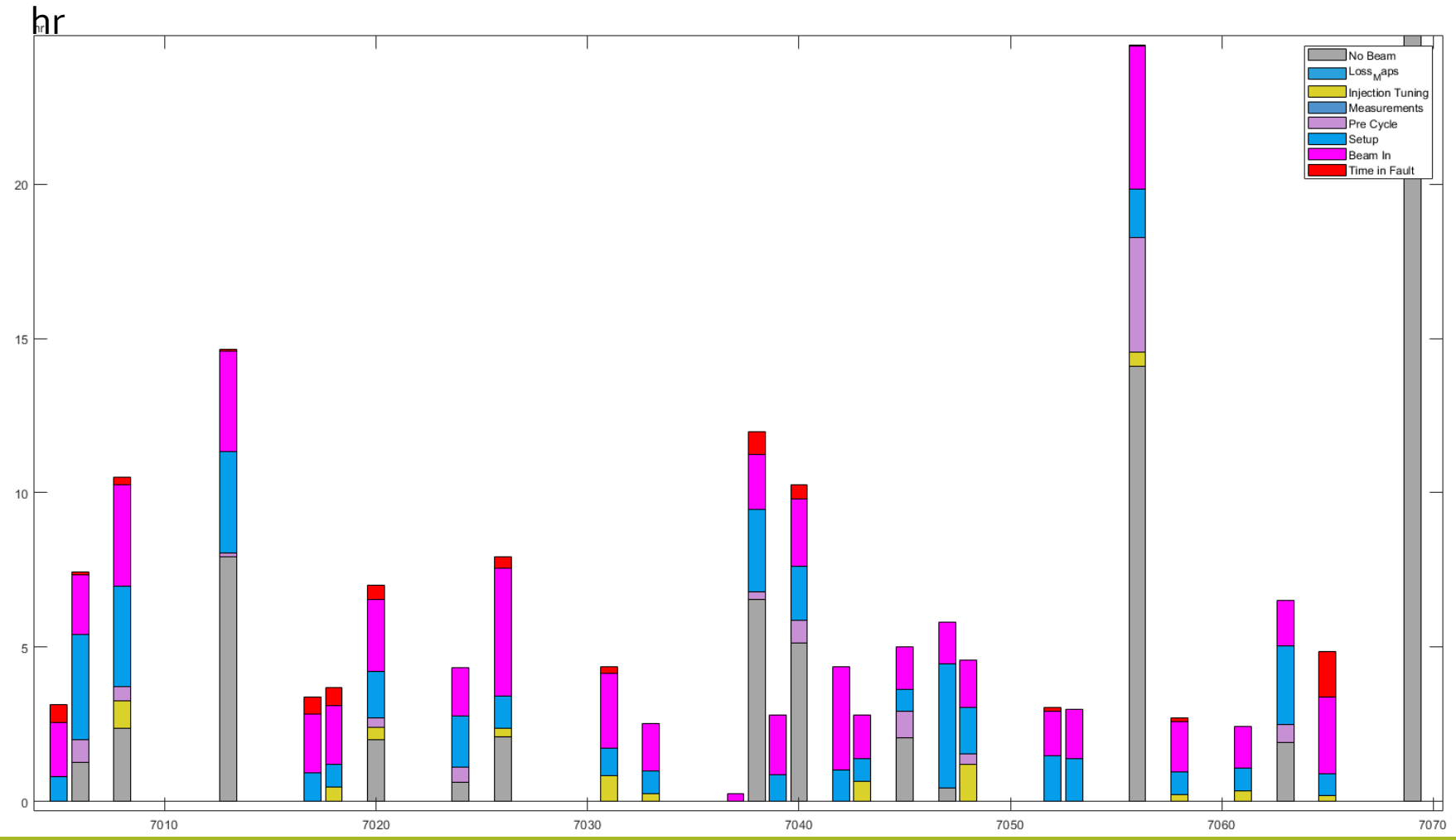
LHC RUN2 21/06/18-19/09/18



Mean

2.381 hr	No beam
0.14425 hr	Loss Maps
0.18865 hr	Injection Tuning
0.34605 hr	Measurements
0.29706 hr	Pre Cycle
2.7105 hr	Setup
2.4766 hr	Beam in

LHC RUN2 21/06/18-19/09/18 with fault



- Work in progress

Example: data Prep For AvailSim

Time

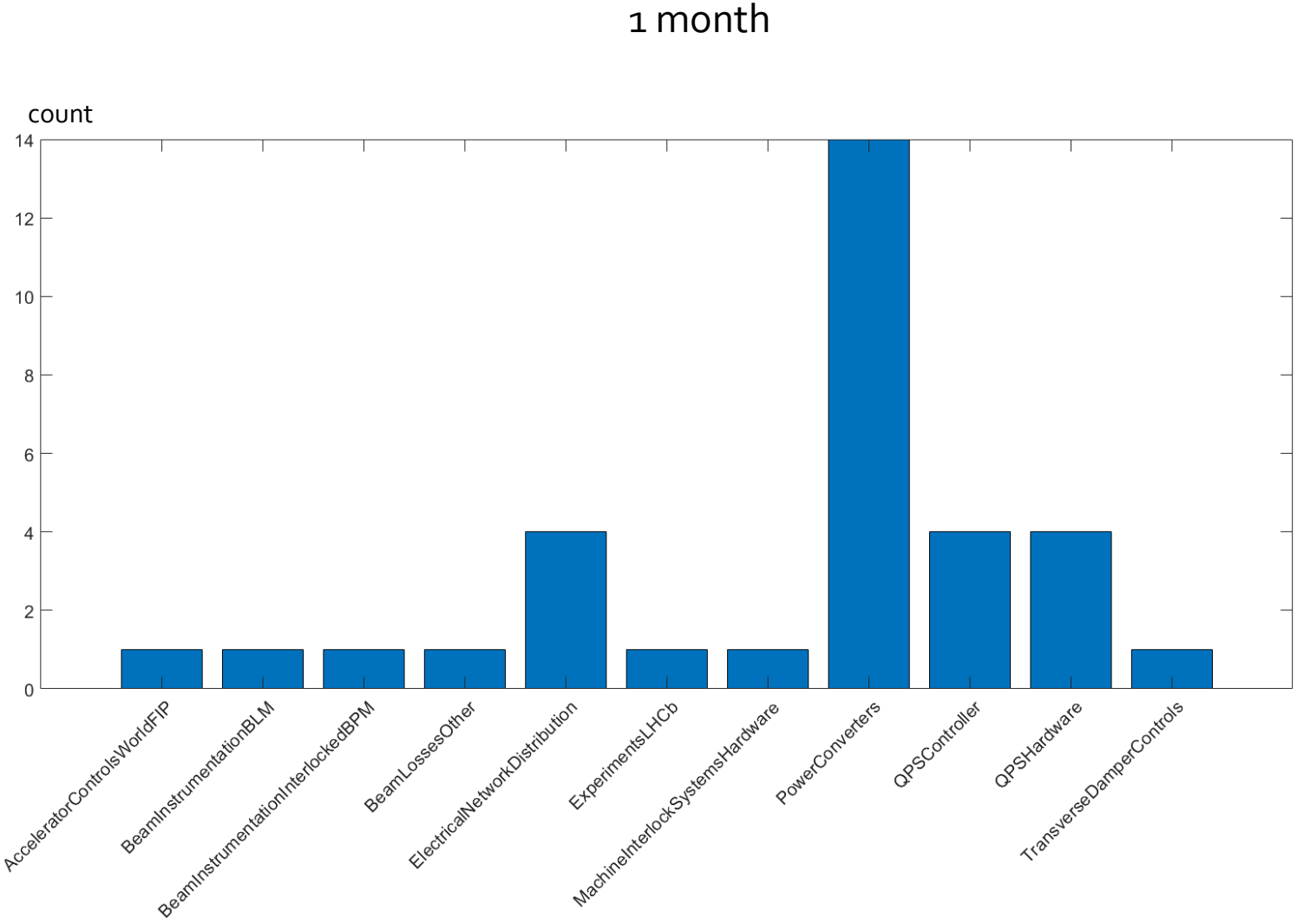
Phase	Duration_Without_DT [h]	Downtime [h]	Phase_Changed_By
Cycle	1.06	[1.67]	Injector Complex Failure
Cycle	1.83	[]	Default
Stable Beams	0.97	[0.10]	Error, Settings Operation Stable Beams
Ramp-down	0.83	[]	Default
Cycle	0.90	[1.67]	Injector Complex Failure
Cycle	1.83	[]	Default
Stable Beams	3.91	[0.10]	Radio Frequency Failure
Ramp-down	0.83	[]	Default
Cycle	1.27	[1.20]	Injection Systems Failure
Cycle	1.83	[]	Default
Stable Beams	0.62	[0.10]	Crab Cavities Failure
Ramp-down	0.83	[]	Default
Cycle	0.19	[1.67]	Injector Complex Failure
Cycle	0.58	[1.67]	Injector Complex Failure
Cycle	0.47	[1.20]	Injection Systems Failure
Cycle	0.05	[1.20]	Injection Systems Failure
Cycle	1.83	[]	Default
Stable Beams	3.19	[0.10]	Losses Occurrence
Ramp-down	0.83	[]	Default
Cycle	0.38	[1.67]	Injector Complex Failure
Cycle	1.83	[]	Default
Stable Beams	8.00	[]	Default
Ramp-down	0.83	[]	Default
Cycle	1.83	[]	Default
Stable Beams	6.74	[0.10]	Losses Occurrence

[…until 160 days of operation are reached…]

X 100 times

- What is AvailSim?
  - Developed by M. Motyka
  - Program predicting accelerator performance based on existing availability and reliability data input.
  - Quantifies lost physics in different scenarios.

Example: fault data Prep For AvailSim



- Shows System and relevant sub(sub)-systems that are applicable to each post mortem entry
- How does it differ from what we already have?
  - Initialised count
  - Solely for 2556 bunch beams

Outlook

- Turnaround graph accuracy
  - Hence "Net OP mode" accuracy
  - Turnaround breakdown including time in fault
- Breakdown of system failures into modes
  - Trickle down count for parent systems eg.
- Development of Lost Physics Metric
  - Analysing and interpreting the existing dataset to find identify areas for Improvement