Fault Tracking at the LHC

Reliability of Accelerators
for Accelerator Driven Systems, 22-06-2015

Chris Roderick *on behalf of AFT team*

(Jakub Janczyk, Isabelle Laugier, Sergio Pasinelli, Laurette Ponce, Pawel Wilk, Bartlomiej Urbaniec, Piotr Sowinski)

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Complete & Consistent Tracking will allow to identify:

- Problems as early as possible

  ☞ allowing for timely mitigation

- Key issues which will limit performance of accelerators or equipment in the future (Run2, Run3, HL-LHC)

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Track faults in two areas:

1. Directly affecting accelerator operation – identify root causes
2. Equipment faults independently of immediate impact on accelerator operation

What has been done in the Past

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Lots of different tools, used by different teams, for logging of faults:

- eLogbook, Post-Mortem, Radiation Working Group pages, tools in equipment groups (JIRA, Excel, Onenote, eLogbook)

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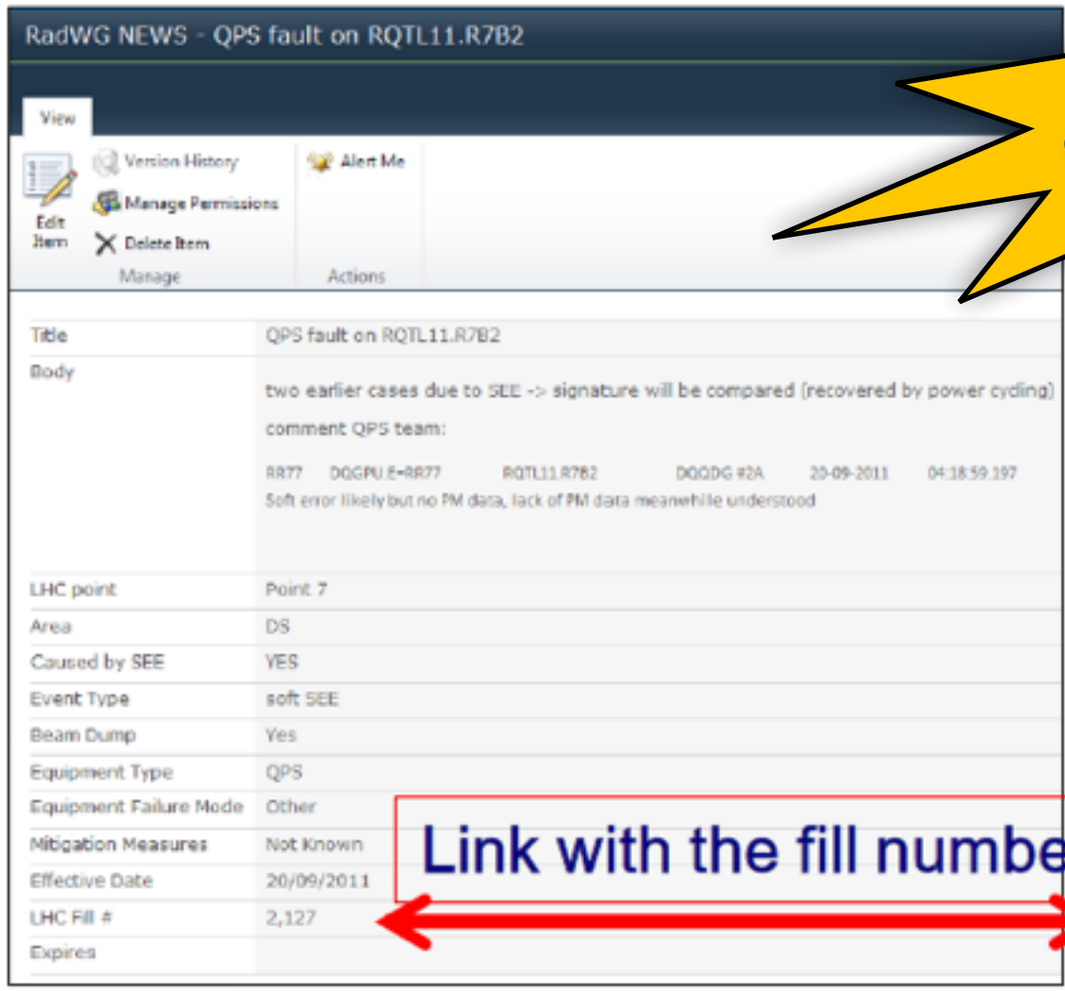
Nevertheless, **difficult to get a consistent picture**

Predictions & Fault-Tracking

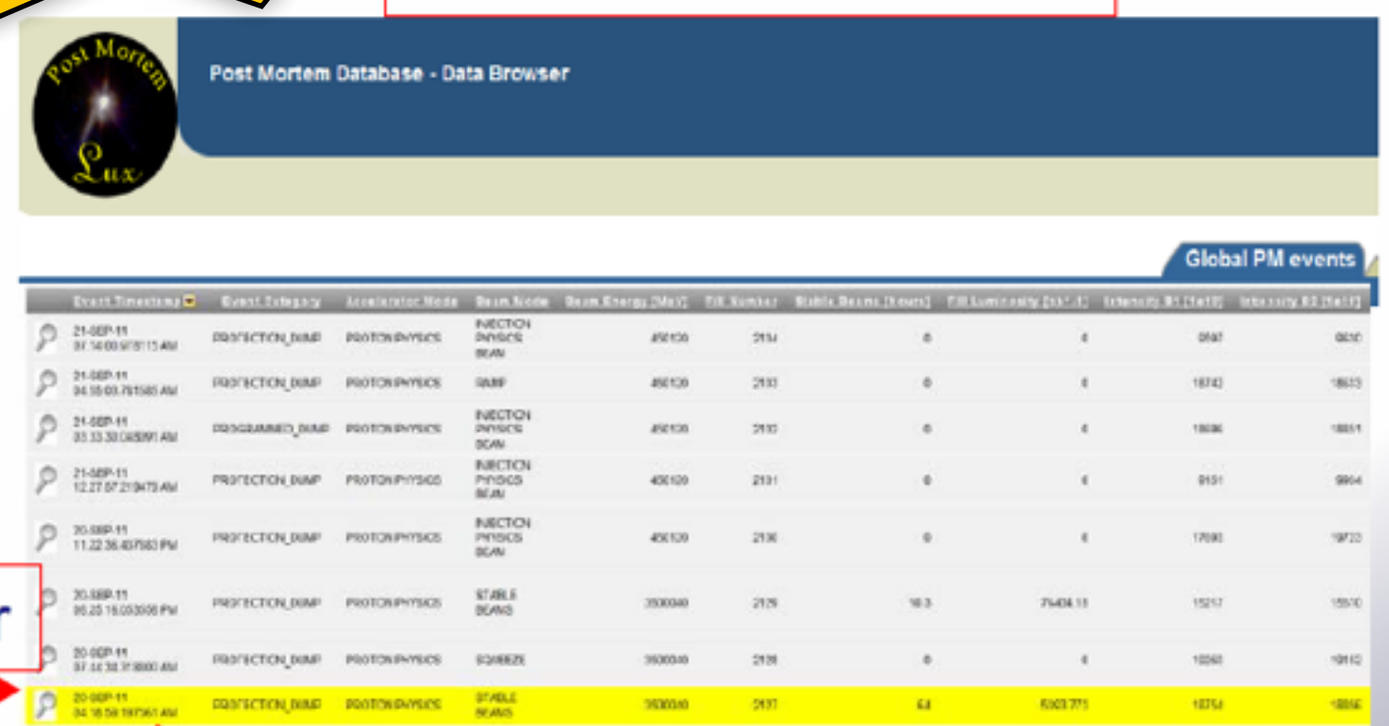
Weekly R2E Shift | eLogBook + 8:30h | Equipment Groups | DBs

Rad WG web site-Detail

Credit Markus Brugger



Post Mortem Database



Link with the fill number

Details on radiation failure

Mps Expert Comment	Mps Dump Cause	Mps First Detection	Seu Dump	Seu Appeared Other Than Dump	Radwg Entry
Suspected SEU on QPS. Dump clean.	QPS	PIC	Possible	YES	RadWG link1 RadWG link2

10-14-2014

LHC Cardiogram

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Graphical analytic tool for combining data from different sources

☞ Operational overview of LHC over time

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Initially created by members of “Availability Working Group”
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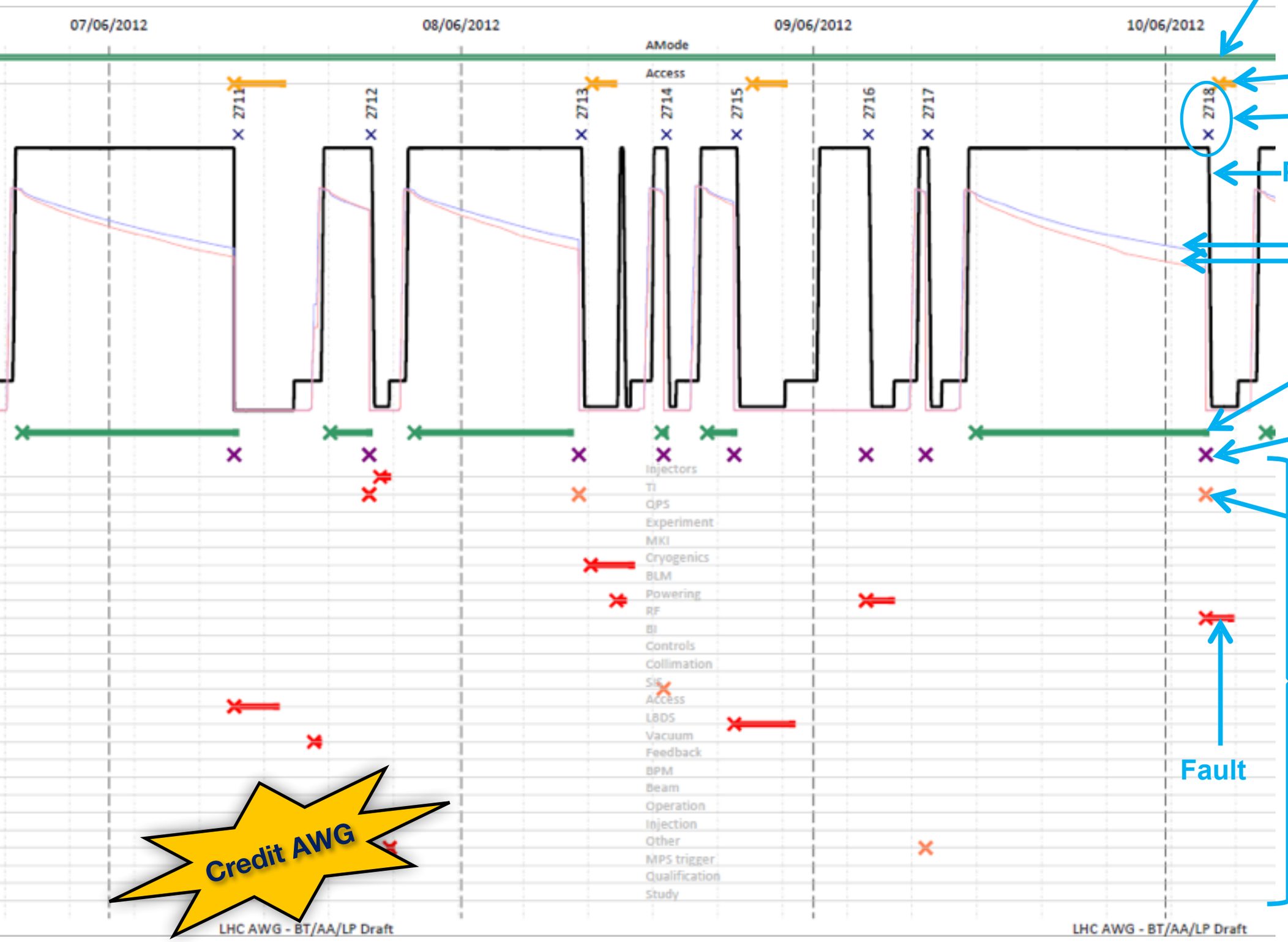
Tedious work to gather and prepare all the necessary data
→several months for 2010-2012 cardiogram

Cardiogram - Example



Accelerator Mode (Proton Physics, Ion Physics, etc.)

Access

Fill Number

Particle Momentum

Beams Intensities

Stable Beams

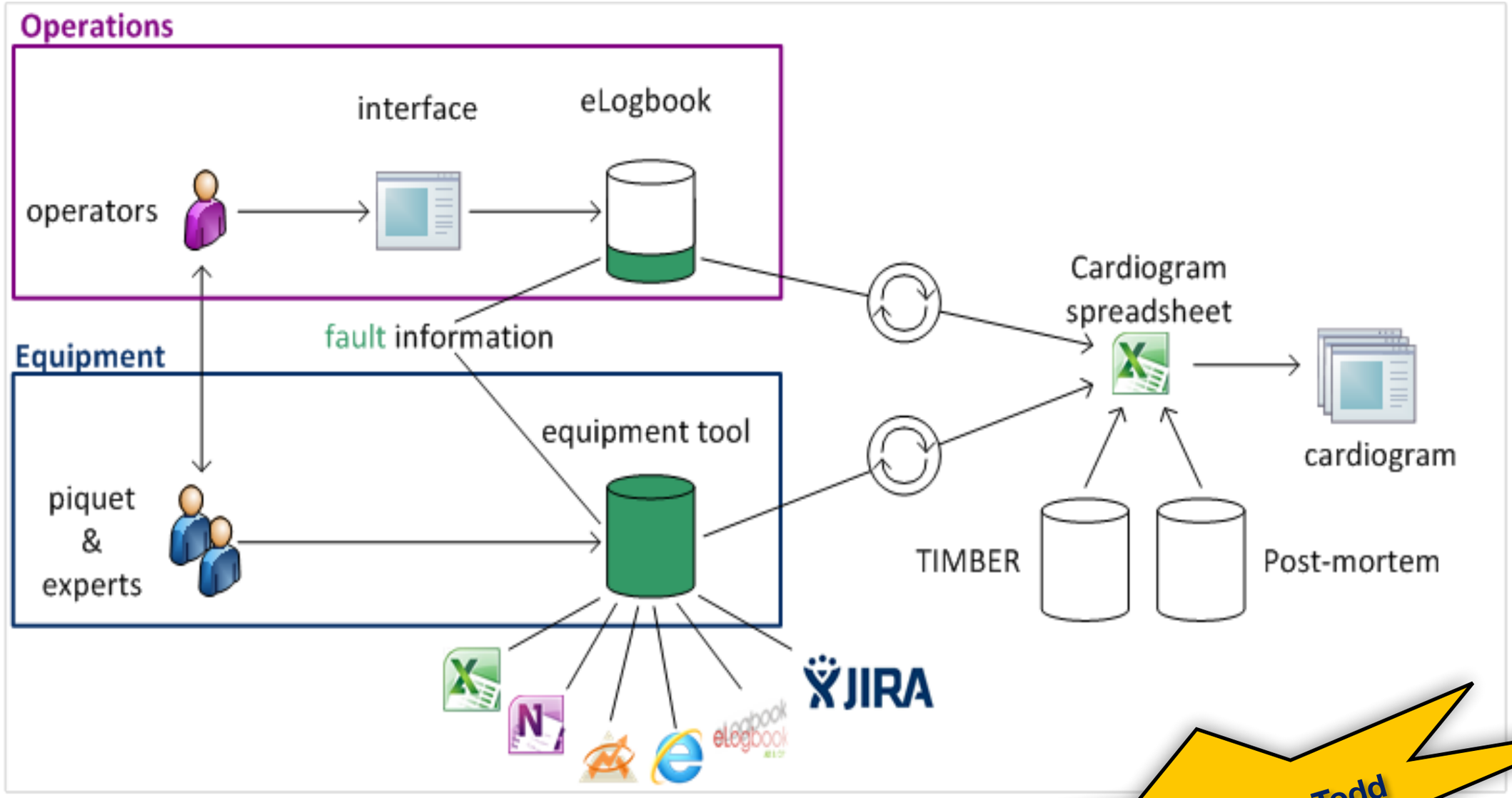
PM Beam Dump

Beam Dump Classification

Fault Lines (Systems- Fault Classifications)

Fault

Cardiogram – Data Preparation



Credit Benjamin Todd

Accelerator Fault Tracking Project

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BE Department Project, launched February 2014

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Based on initial inputs from:

- LHC Beam Operation Workshops
- Availability Working Group
- Workshop on Machine Availability & Dependability for Post-LS1 LHC
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Goals:

- Capture consistent & complete fault data
- Facilitate fault tracking for all interested parties (OP, equipment groups, working groups)
- Single source of data – easier to complete, clean & analyse.
- Provide consistent - standardised statistics, analyses, reports for different uses (daily / weekly reports for meetings and follow-up providing easy summaries)
- Interactive overview of faults (cardiogram on demand)
- Proactively identify incomplete data

AFT Planning

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Provide infrastructure to *consistently & coherently* capture, persist and make available accelerator fault data for further analysis.

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   - Enable data exploitation by others (e.g. AWG and OP) to identify areas to improve accelerator availability for physics
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   - Infrastructure should already support capture of equipment group fault data, but not primary focus

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3. Explore integration with other CERN data management systems (e.g. Infor EAM)
   - potential to perform deeper analyses of system and equipment availability
   - in turn - start predicting and improving dependability

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Initial focus on LHC, but aim to provide a generic infrastructure capable of handling fault data of any CERN accelerator.

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We are here...

2. Focus on equipment group fault data capture
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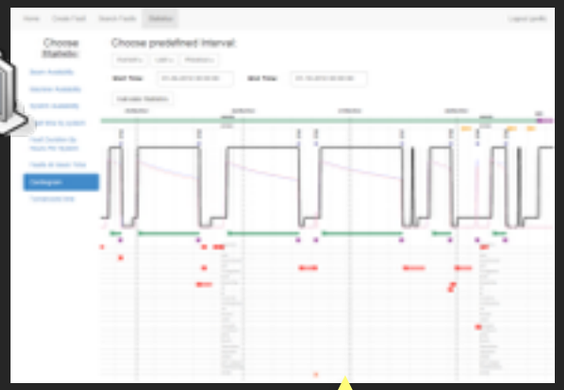
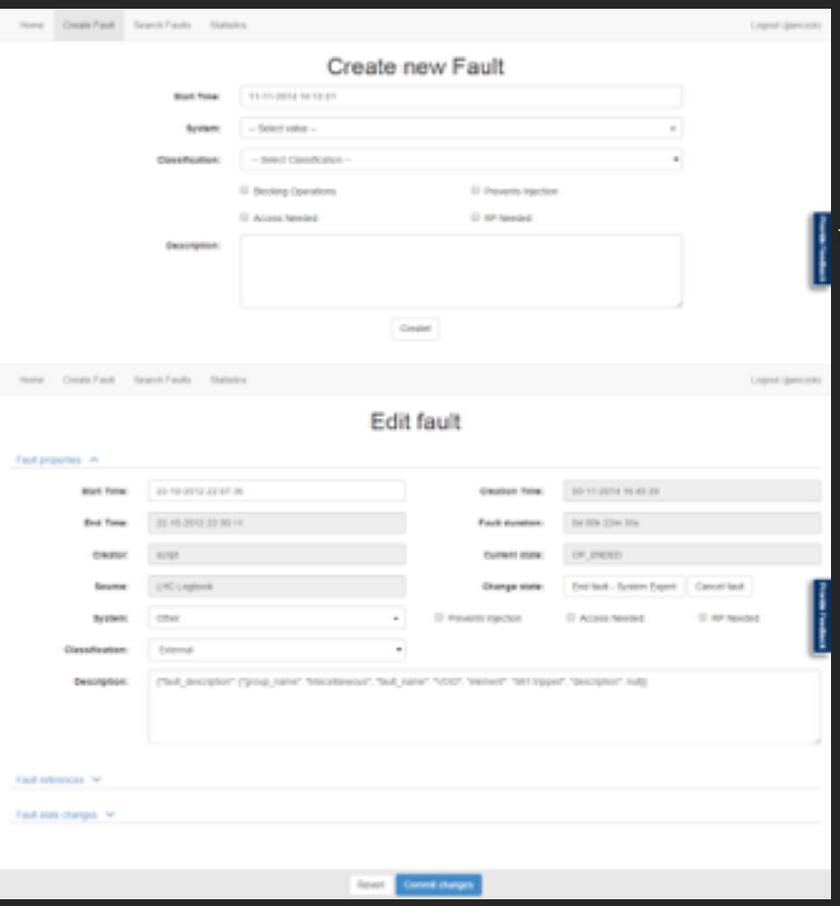
Architecture

< Statistics / Reports / Analysis >



< Fault Creation / Advanced Editing - EQP/OP>



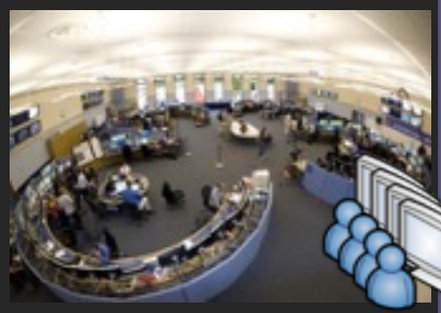
ORACLE
AFT DB

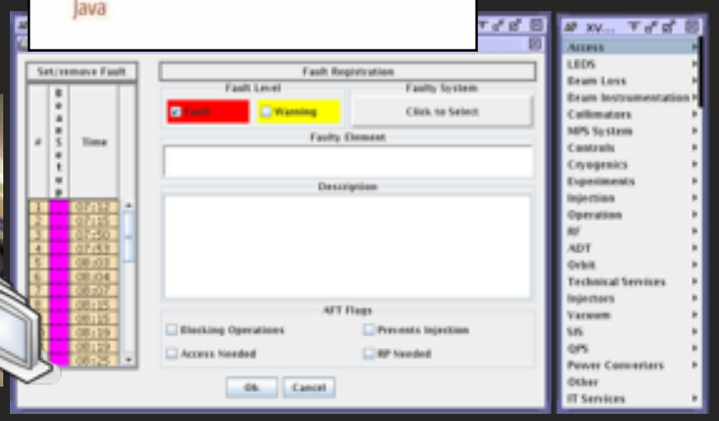
Web API

Java
AFT Server
(stateless)

ORACLE
Logging DB

Java AFT Client API





< Fault Creation & Basic Editing (e-Logbook) OP >

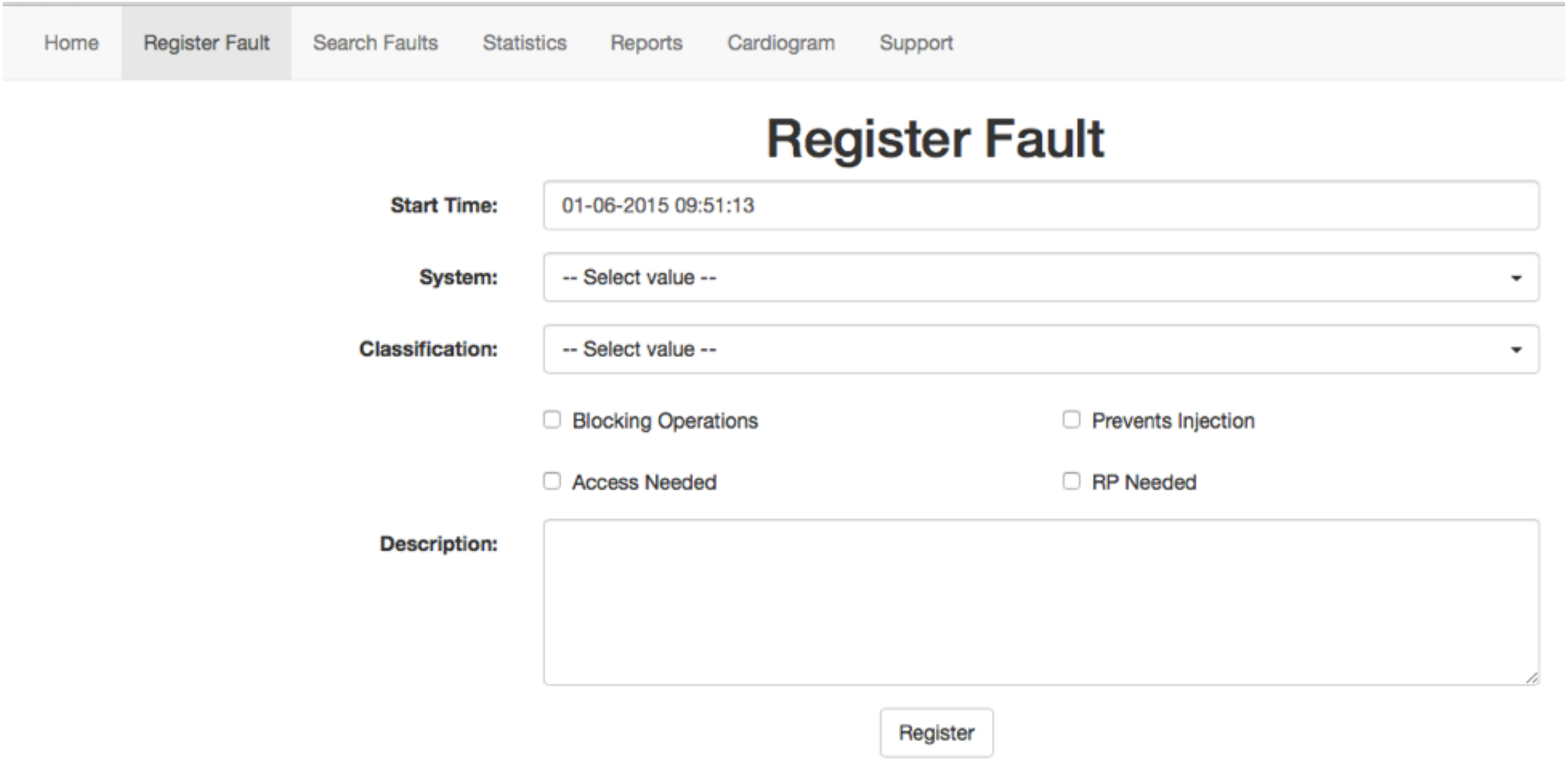
Java AFT Client API

Future Providers

< Fault Creation Equipment Groups >

Fault Capture

Web interface available



but…

Fault Capture by Operators

Important for OP not to use a new / additional tool

☞ fault capture via existing operational Logbook - ensure complete data

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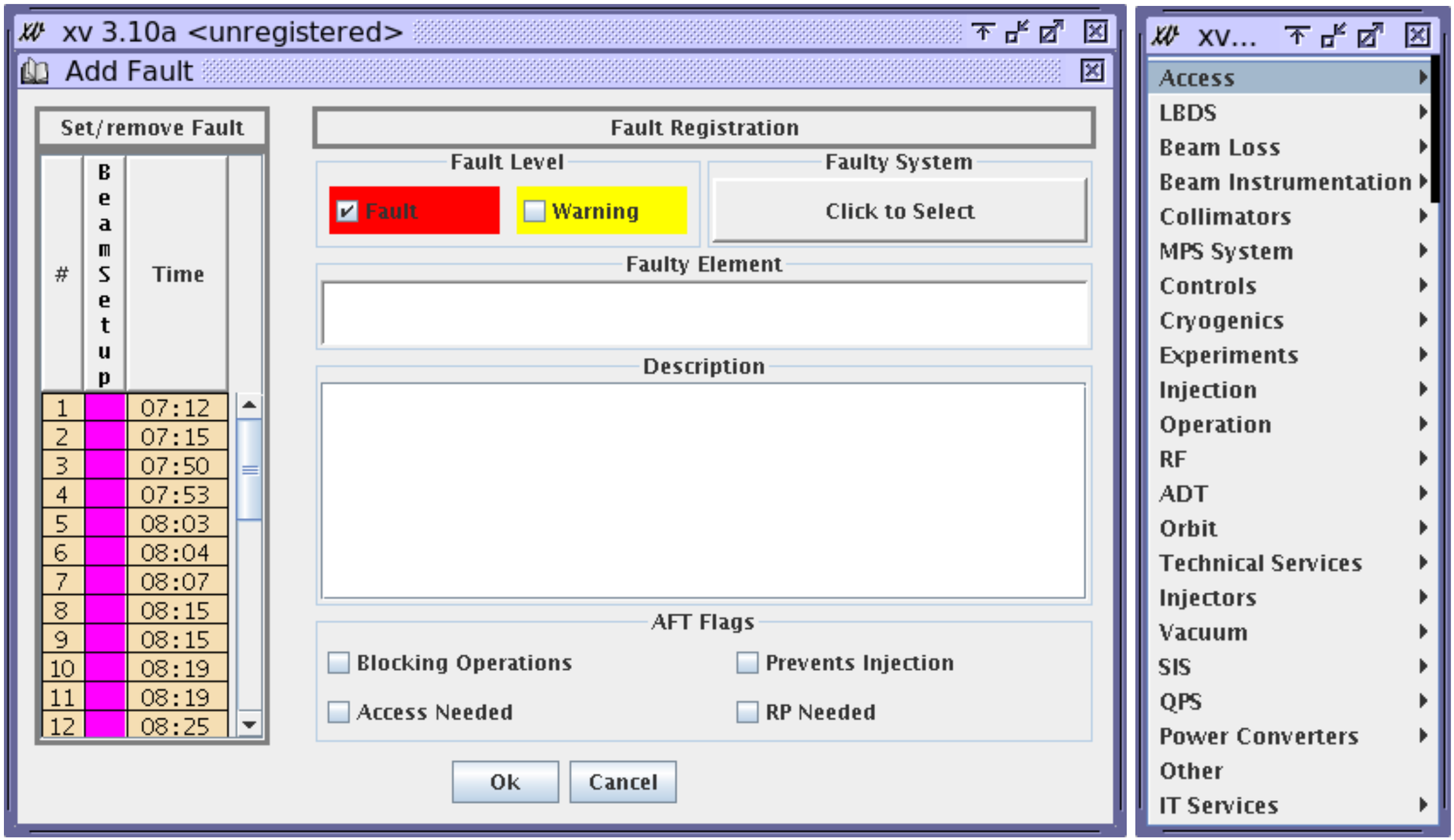

Fault Updates by AWG

In order to ensure coherent data, weekly review by Availability Working Group

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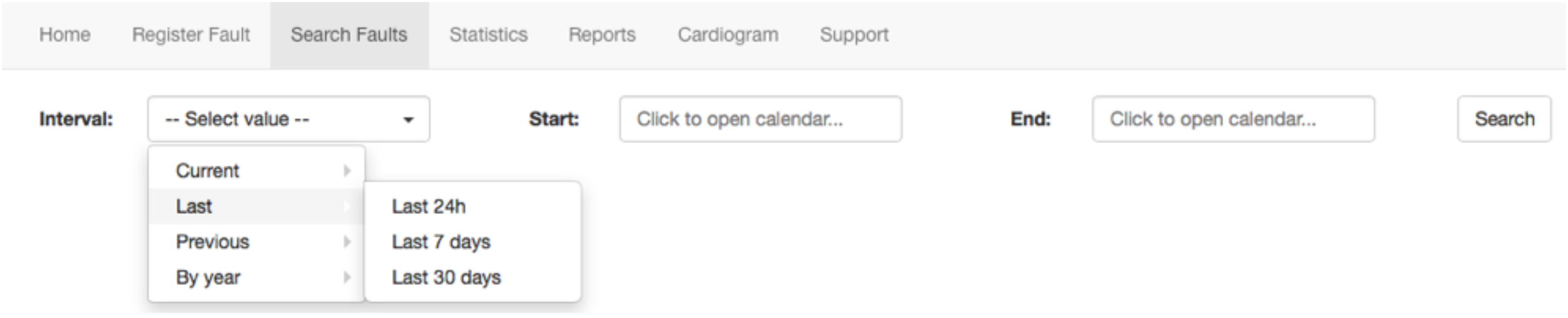

Fault Updates by AWG

In order to ensure coherent data, weekly review by Availability Working Group

Home | Register Fault | Search Faults | Statistics | Reports | Cardiogram | Support

Interval: -- Select value -- **Start:** Click to open calendar... **End:** Click to open calendar... Search

- Current
- Last
  - Last 24h
  - Last 7 days
  - Last 30 days
- Previous
- By year

Home | Register Fault | Search Faults | Statistics | Reports | Cardiogram | Support | Login

Interval: -- Select value -- **Start:** 01-05-2015 00:00:00 **End:** 08-05-2015 00:00:00 Search

Filter

By State: All Values

By System: All Values

Exclude child faults

Clear Filters

Search results

Name	Start time	End time	OP Duration	State
LHC » Injectors » No beam	07-05-2015 17:16:51	07-05-2015 17:18:06	0d 00h 01m 15s	OP Ended
LHC » Injectors » No beam	07-05-2015 16:04:33	07-05-2015 16:45:52	0d 00h 41m 19s	OP Ended
LHC » Injectors » No beam	07-05-2015 15:50:40	07-05-2015 15:55:50	0d 00h 05m 10s	OP Ended
LHC » Operation » Operational error	07-05-2015 14:10:36	07-05-2015 14:10:37	0d 00h 00m 01s	OP Ended
LHC » Injectors » No beam	07-05-2015 10:29:57	07-05-2015 11:19:09	0d 00h 49m 12s	OP Ended
LHC » Injectors » No beam	07-05-2015 08:09:06	07-05-2015 08:16:09	0d 00h 07m 03s	OP Ended

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LHC » Operation » Operational error	07-05-2015 05:49:13	07-05-2015 05:49:14	0d 00h 00m 01s	OP Ended
LHC » QPS » Controller	07-05-2015 03:28:47	07-05-2015 04:26:18	0d 00h 57m 31s	OP Ended
[illegible]	07-05-2015 03:04:21	07-05-2015 03:04:22	0d 00h 00m 01s	OP Ended

View | Edit fault

Fault Updates by AWG

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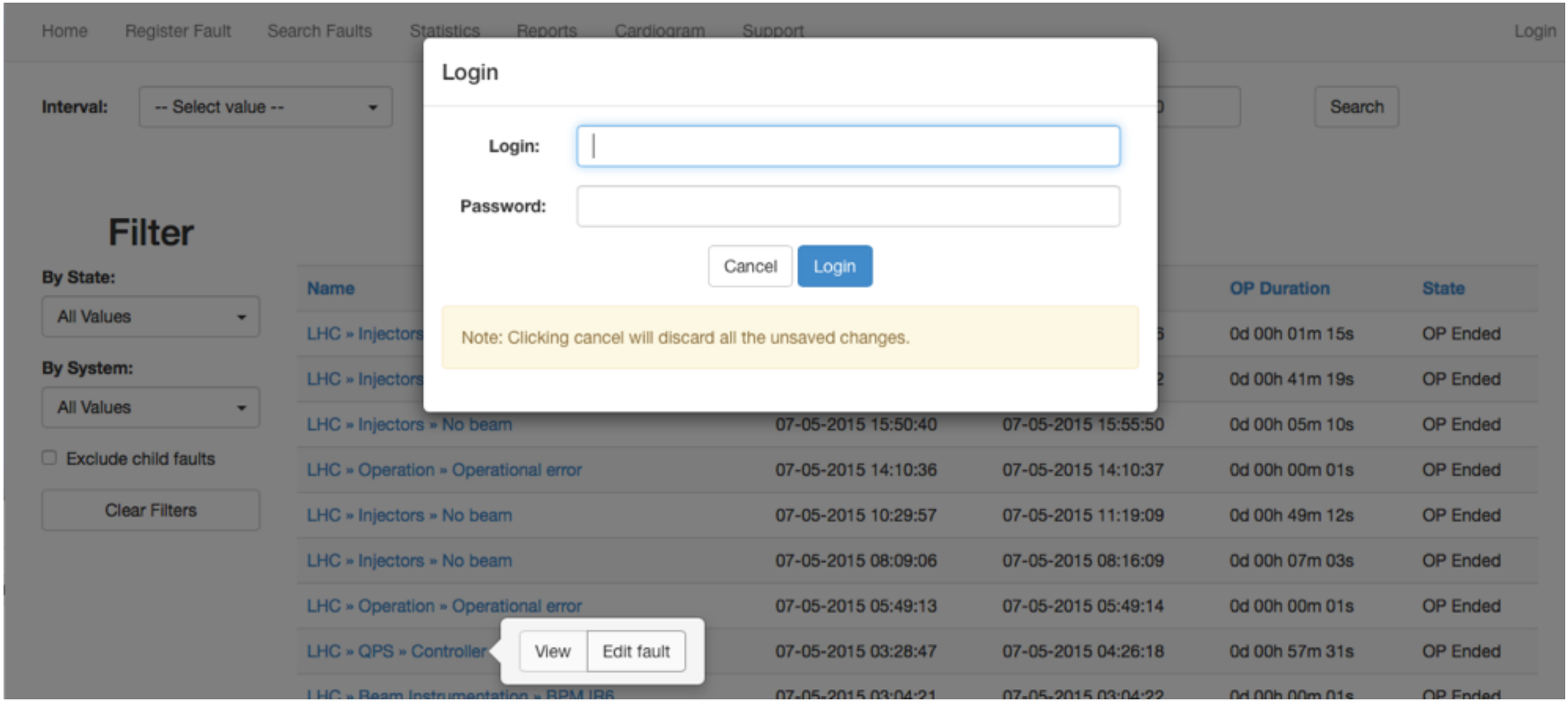


Home Create Fault Search Faults Statistics

Fake Data

Edit fault

Fault properties

Start Time: 22-10-2012 22:07:36

End Time: 22-10-2012 22:30:11

Creator: script

Source: LHC Logbook

System: Other

Classification: External

Creation Time: 05-11-2014 16:45:39

Fault duration: 0d 00h 22m 35s

Current state: OP_ENDED

Change state: End fault - System Expert | Cancel fault

Prevents Injection | Access Needed | RP Needed

Description:

{"fault_description": {"group_name": "Miscellaneous", "fault_name": "VOID", "element": "S81 tripped", "description": null}}

Fault references

Fault state changes

Revert | Commit changes

Provide Feedback

Fault references

Parent fault:

LHC » LBDS

Child faults:

LHC » LBDS

Faults blocked by current fault:

LHC » Beam Instrumentation » BPM IR6

Start time: 03-11-2014 10:09:58

End time: 27-11-2014 10:13:04

Faults blocking current fault:

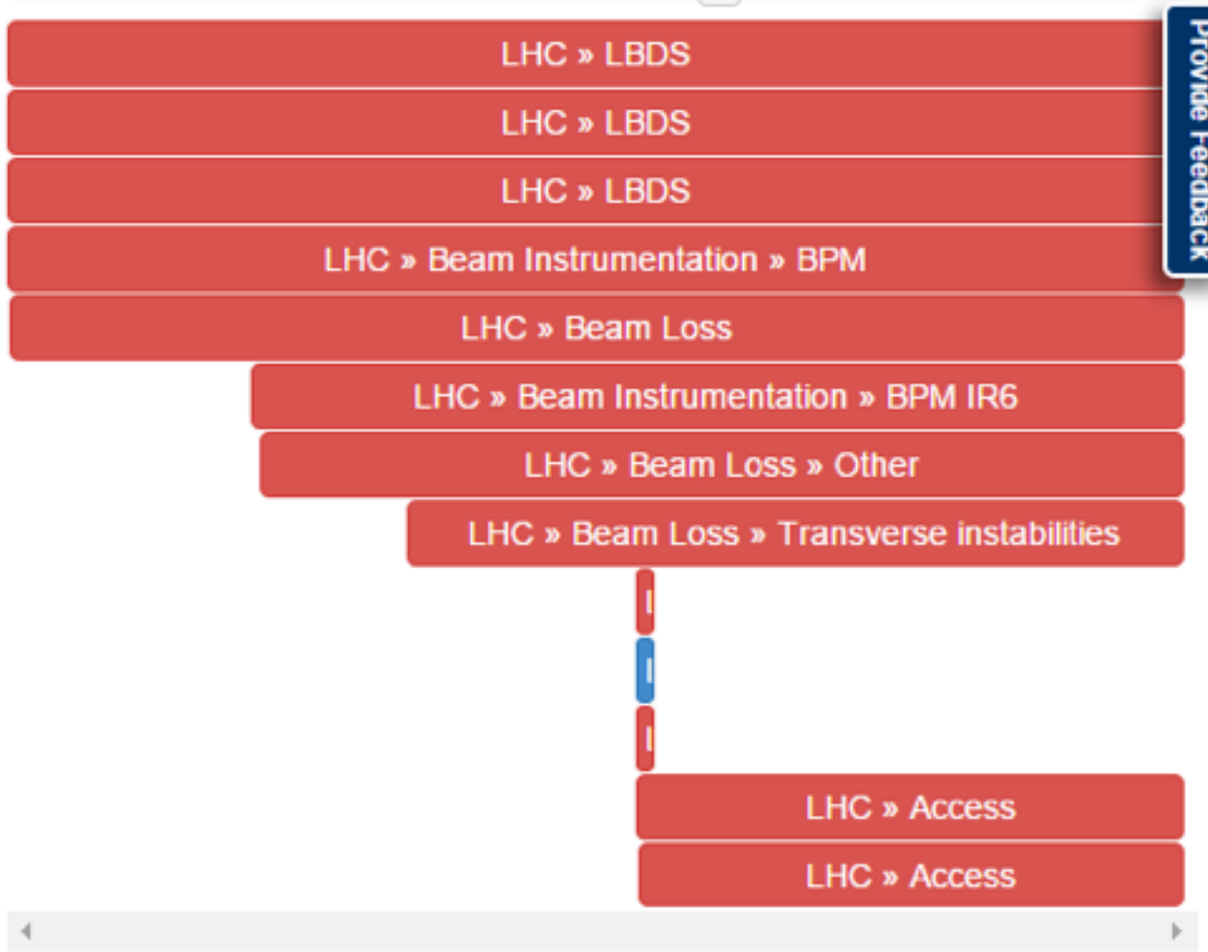
LHC » Beam Loss » Transverse instabilities

Faults from: 31-10-2014 15:20:5

Faults to:

Update

Fake Data



Fault state changes

State change time	State	Creator
26-10-2014 15:21:14	NON_BLOCKING_OP	rbaguest
27-10-2014 15:29:53	BLOCKING_OP	rbaguest
28-10-2014 15:29:54	NON_BLOCKING_OP	rbaguest

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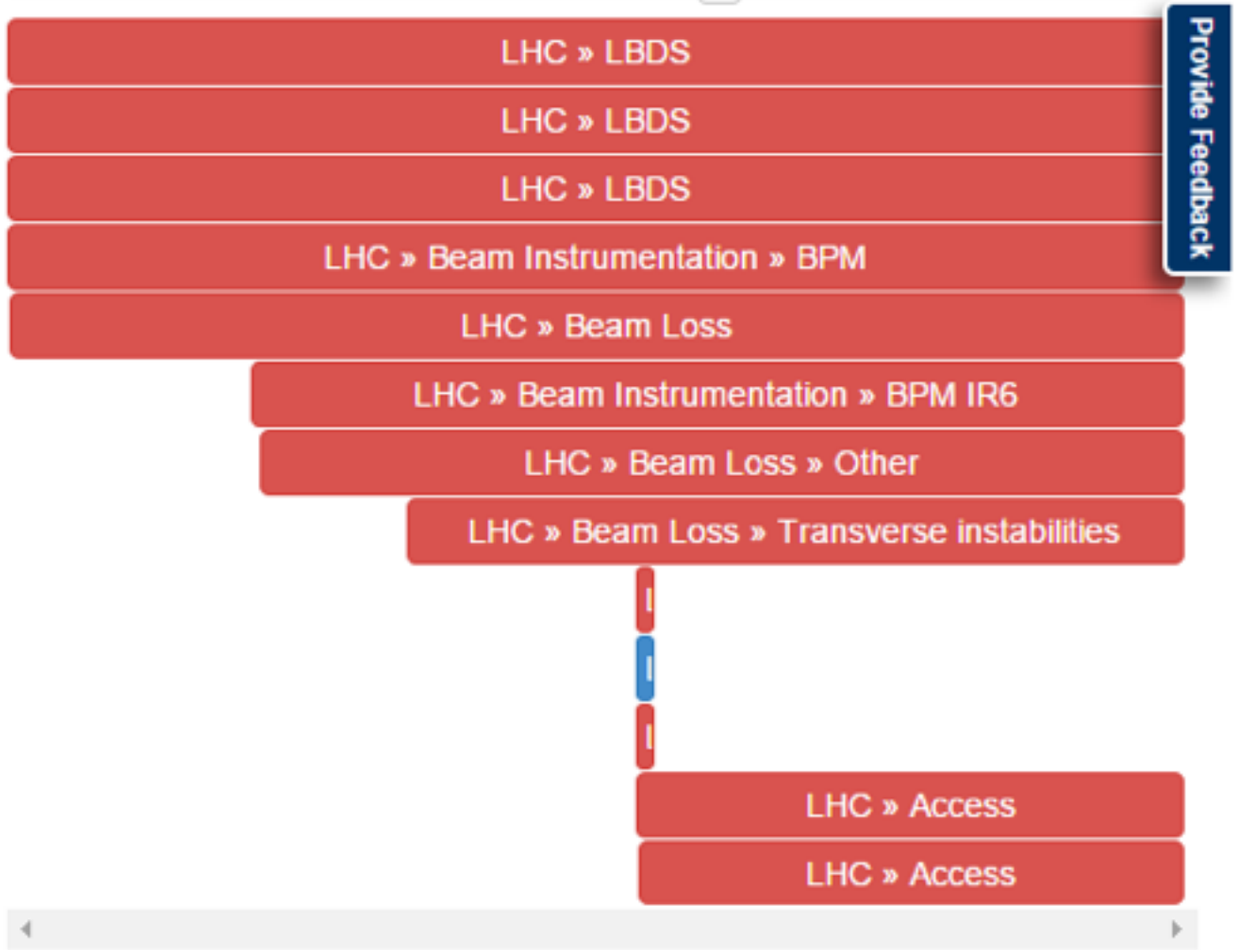

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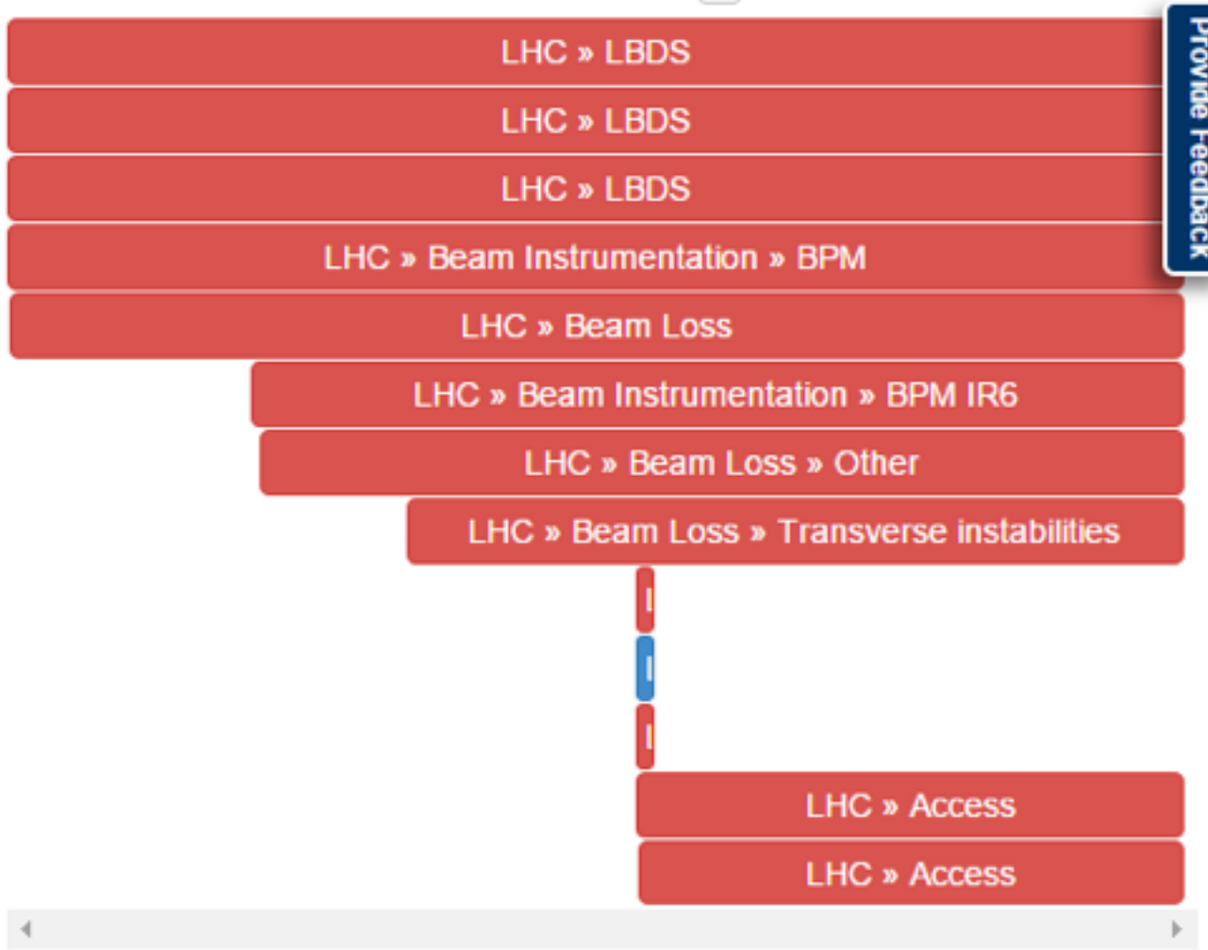

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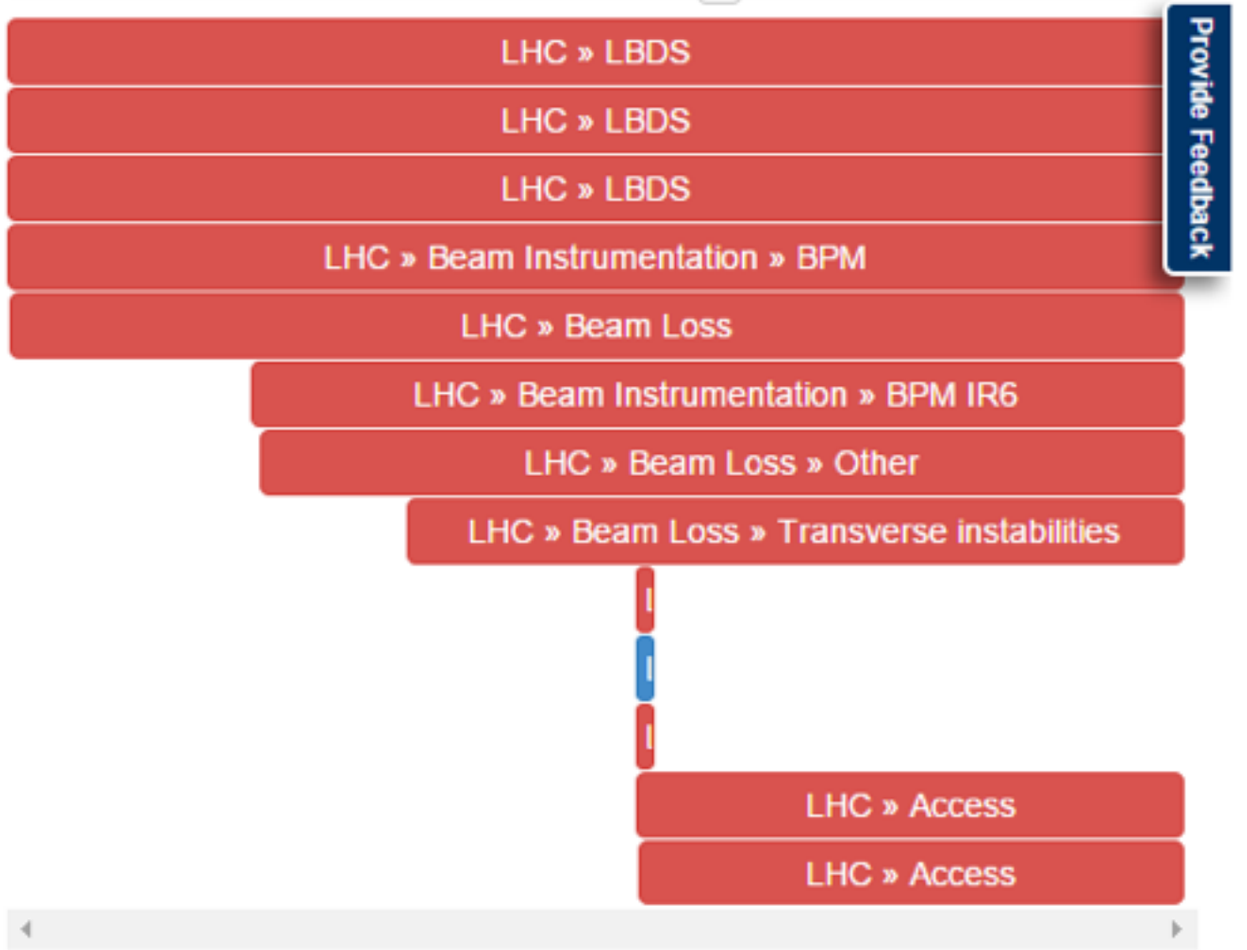

Provide Feedback

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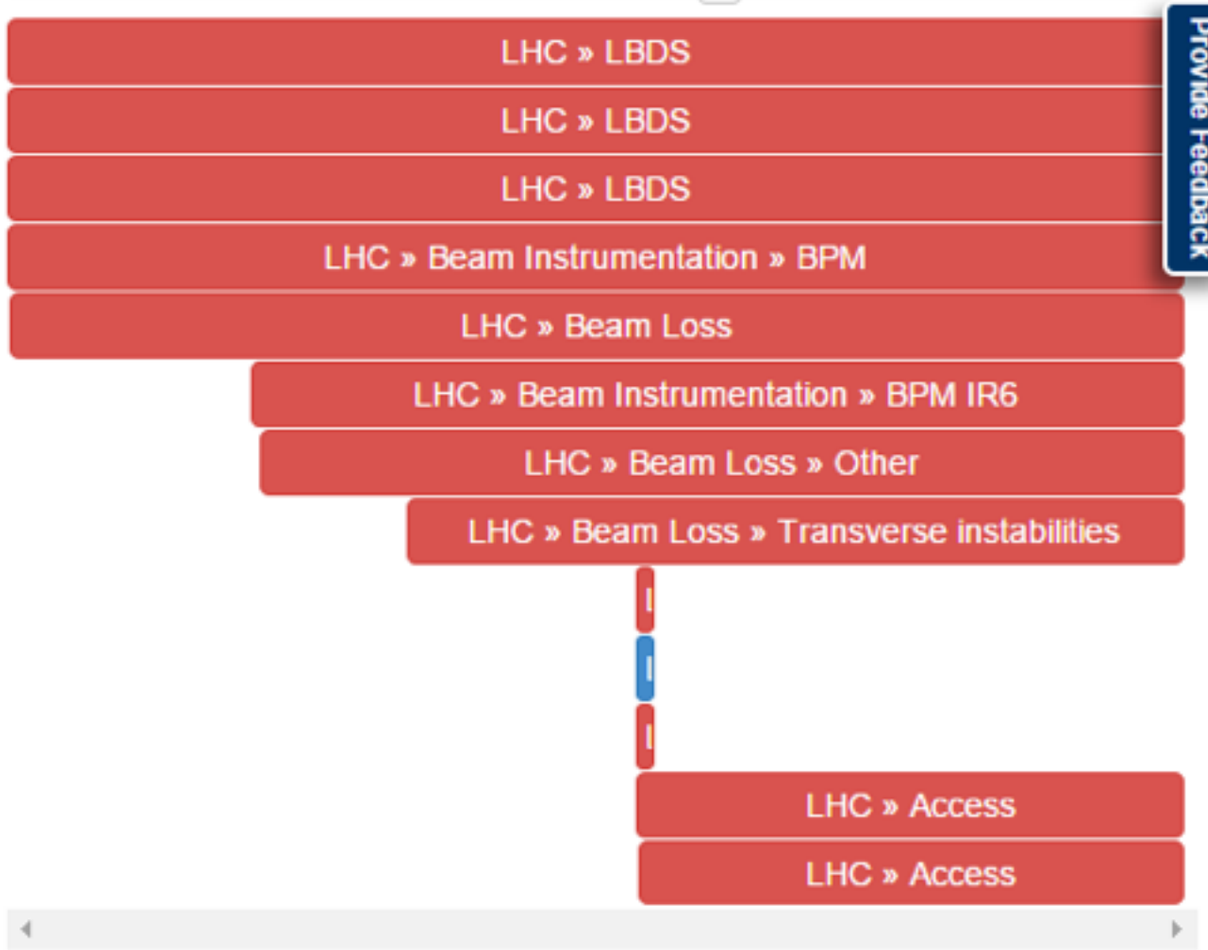

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Fault Statistics & Reports *work-in-progress…*

Home | Register Fault | Search Faults | Statistics | Reports | Cardiogram | Support | Login

Choose Statistic:

System Availability

Turnaround time

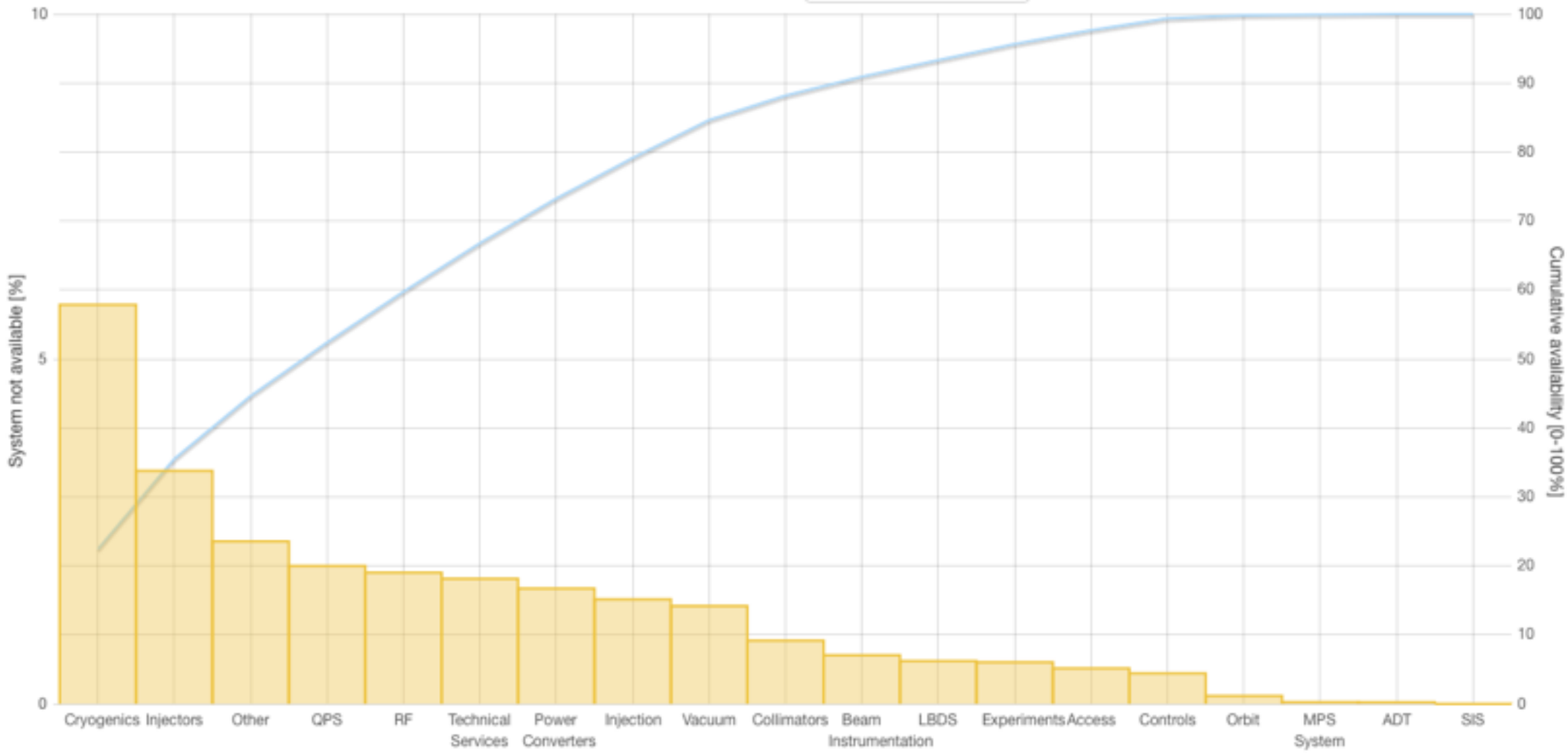
Interval: -- Select value --

Start Time: 01-04-2012 00:00:00

End Time: 01-11-2012 00:00:00

Calculate Statistics ?

Export Data



Fault Statistics & Reports *work-in-progress…*

Home | Register Fault | Search Faults | Statistics | Reports | Cardiogram | Support

2015 Week 22

Monday (25.05)

00:56 - 00:58 Duration: 0d 00h 02m 01s	LHC » LBDS » XPOC
07:57 - 08:30 Duration: 0d 00h 33m 11s	LHC » Cryogenics » Controls MR8 cryo start and maintain lost
16:55 - 18:03 Duration: 0d 01h 08m 34s	LHC » Vacuum » Pressure Closing of VPIZ.683382.B caused a trigger of the LBDS (B1)
18:14 - 22:28 Duration: 0d 04h 13m 55s	LHC » QPS » Hardware precycle needed
23:22 - 23:58 Duration: 0d 00h 35m 57s	LHC » Operation » Operational error TI2/TI8 HS opened when trying to open Injection HS

Tuesday (26.05)

01:10 - 01:11 Duration: 0d 00h 01m 45s	LHC » Beam Loss » UFO
02:14 - 02:14 Duration: 0d 00h 00m 01s	LHC » Operation » Operational error
03:52 - 03:52	LHC » Beam Loss » UFO

Cardiogram

Home
Register Fault
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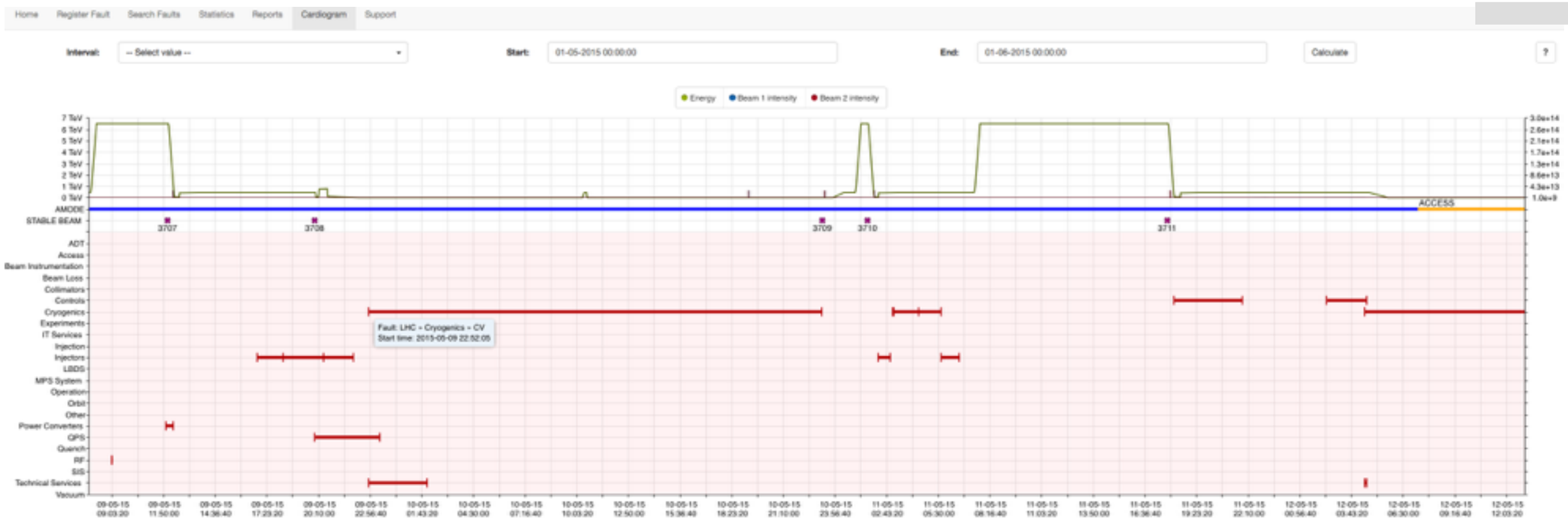
Support
Interval:
-- Select value --
Start:
01-05-2015 00:00:00
End:
01-05-2015 00:00:00
Calculate
?
Energy
Beam 1 intensity
Beam 2 intensity
7 TeV
6 TeV
5 TeV
4 TeV
3 TeV
2 TeV
1 TeV
0 TeV
3.0e+14
2.6e+14
2.1e+14
1.7e+14
1.3e+14
8.6e+13
4.3e+13
1.0e+9
BMSETUP
ACCESS
BMSETUP
AMODE
STABLE BEAM
ADT
Access
Beam Instrumentation
Beam Loss
Collimators
Controls
Cryogenics
Experiments
IT Services
Injection
Injectors
LBDS
MPS System
Operation
Orbit
Other
Power Converters
QPS
Quench
RF
SIS
Technical Services
Vacuum
01-05-15 00:00:00
01-05-15 19:06:40
02-05-15 22:53:20
04-05-15 02:40:00
05-05-15 06:26:40
06-05-15 10:13:20
07-05-15 14:00:00
08-05-15 17:46:40
09-05-15 21:33:20
11-05-15 01:20:00
12-05-15 05:06:40
13-05-15 08:53:20
14-05-15 12:40:00
15-05-15 16:26:40
16-05-15 20:13:20
18-05-15 00:00:00
19-05-15 03:46:40
20-05-15 07:33:20
21-05-15 11:20:00
22-05-15 15:06:40
23-05-15 18:53:20
24-05-15 22:40:00
26-05-15 02:26:40
27-05-15 06:13:20
28-05-15 10:00:00
29-05-15 13:46:40
30-05-15 17:33:20
31-05-15 21:20:00

Cardiogram


Home
Register Fault
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Reports
Cardiogram
Support
Interval:
-- Select value --
Start:
01-05-2015 00:00:00
End:
01-06-2015 00:00:00
Calculate
?
Energy
Beam 1 intensity
Beam 2 intensity
7 TeV
6 TeV
5 TeV
4 TeV
3 TeV
2 TeV
1 TeV
0 TeV
3.0e+14
2.6e+14
2.1e+14
1.7e+14
1.3e+14
8.6e+13
4.3e+13
1.0e+9
AMODE
ACCESS
STABLE BEAM
3707
3708
3709
3710
3711
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Access
Beam Instrumentation
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Other
Power Converters
QPS
Quench
RF
SIS
Technical Services
Vacuum
Fault: LHC - Cryogenics - CV
Start time: 2015-05-09 22:52:05
09-05-15 09:03:20
09-05-15 11:50:00
09-05-15 14:36:40
09-05-15 17:23:20
09-05-15 20:10:00
09-05-15 22:56:40
10-05-15 01:43:20
10-05-15 04:30:00
10-05-15 07:16:40
10-05-15 10:03:20
10-05-15 12:50:00
10-05-15 15:36:40
10-05-15 18:23:20
10-05-15 21:10:00
10-05-15 23:56:40
11-05-15 02:43:20
11-05-15 05:30:00
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11-05-15 13:50:00
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12-05-15 00:56:40
12-05-15 03:43:20
12-05-15 06:30:00
12-05-15 09:16:40
12-05-15 12:03:20

Cardiogram

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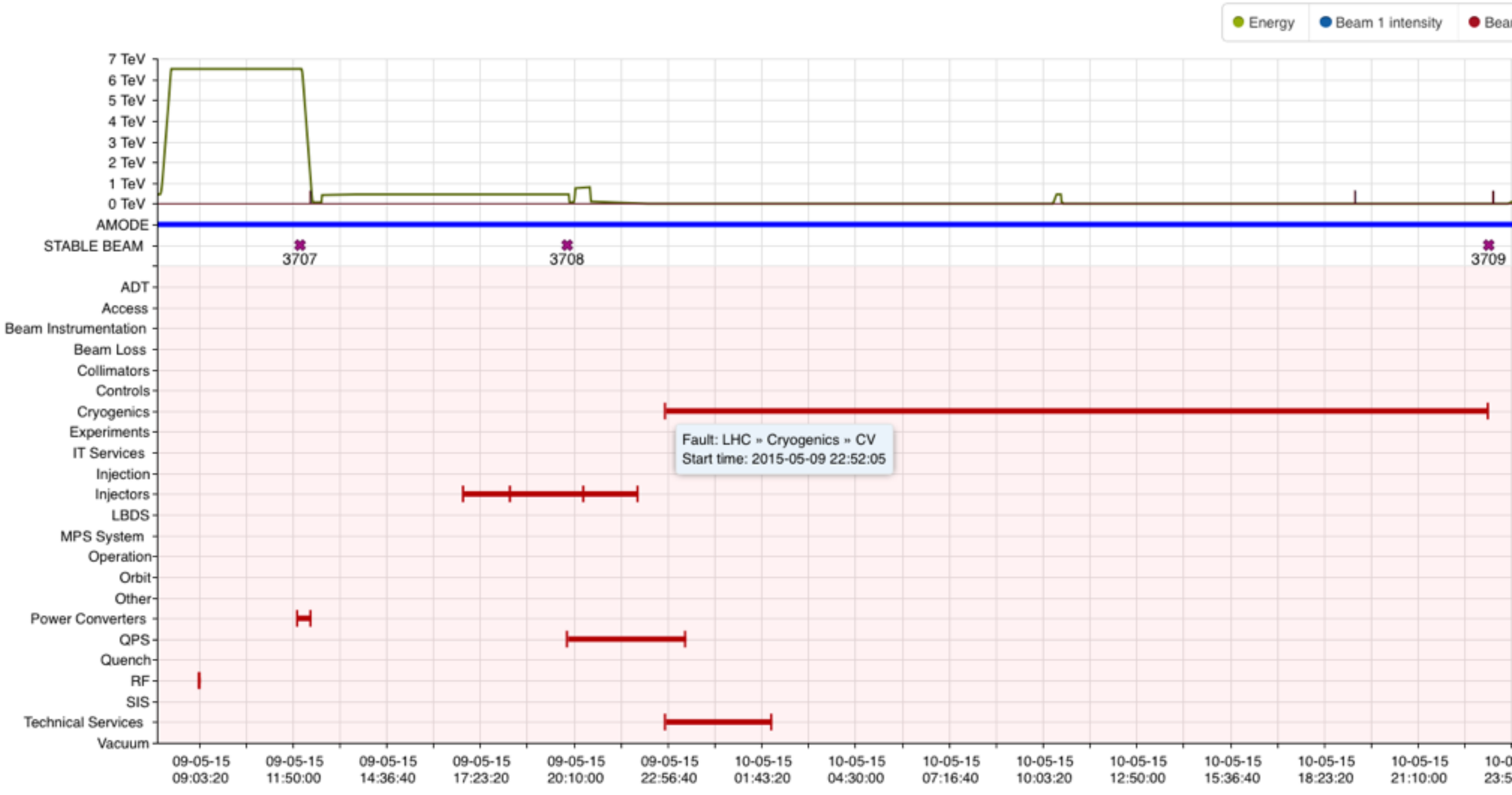
Interval: -- Select value --

Start: 01-05-2015 00:00:00



Cardiogram link to Fault

Home | Register Fault | Search Faults | Statistics | Reports | Cardiogram | Support

View fault

Start Time:	09-05-2015 22:52:05
OP End Time:	10-05-2015 23:14:35
Expert End Time:	
Creation Time:	09-05-2015 22:53:43
OP duration:	1d 00h 22m 30s
Expert duration:	43d 14h 06m 55s
Description:	

Creator:	
Source:	LHC Logbook
System:	LHC » Cryogenics » CV
Classification:	
Fault state:	OP Ended
eLogbook:	link

Prevents Injection	Access Needed	RP Needed
×	×	×

Parent fault:

LHC » Technical Services » Cooling/Ventilation

Child faults:

Faults blocking current fault:

Faults blocked by current fault:

Faults state changes:

State change time	State	Creator
09-05-2015 22:52:05	Blocking OP	
10-05-2015 23:14:35	OP Ended	

Next Steps

Current focus is on usability / time saving features

Followed by additional statistics & improved reports

Then Phase 2 - inclusion of data from equipment groups

and Phase 3 - integration with other systems e.g. Asset & Intervention Management

Summary

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Summary

Consistent & Complete Fault Tracking is key to identify and efficiently mitigate issues

AFT already eases the recording of LHC faults and identification of root causes in a complete and consistent way. There is huge potential to bring further added value.

Run2 data will be essential to identify future performance-availability limitations towards HL-LHC

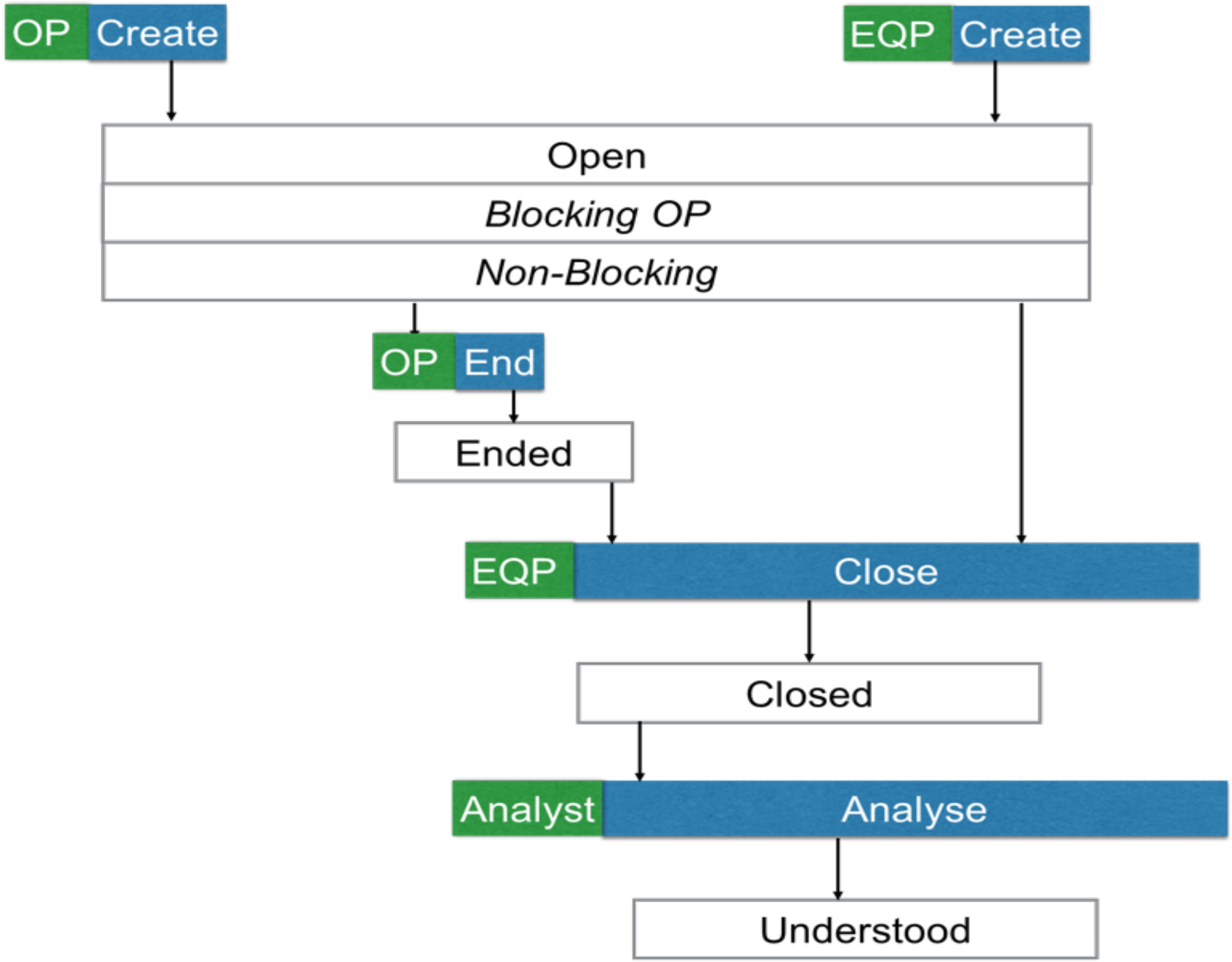
Quality and completeness of the data requires effort from all involved parties

Questions ?

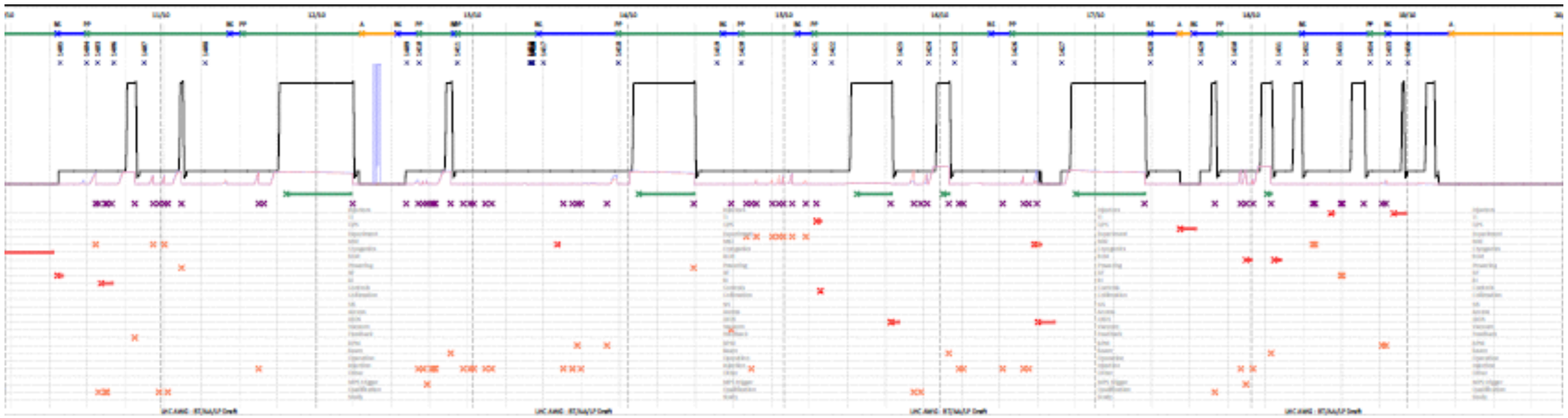
Chris.Roderick@cern.ch

Extra Slides

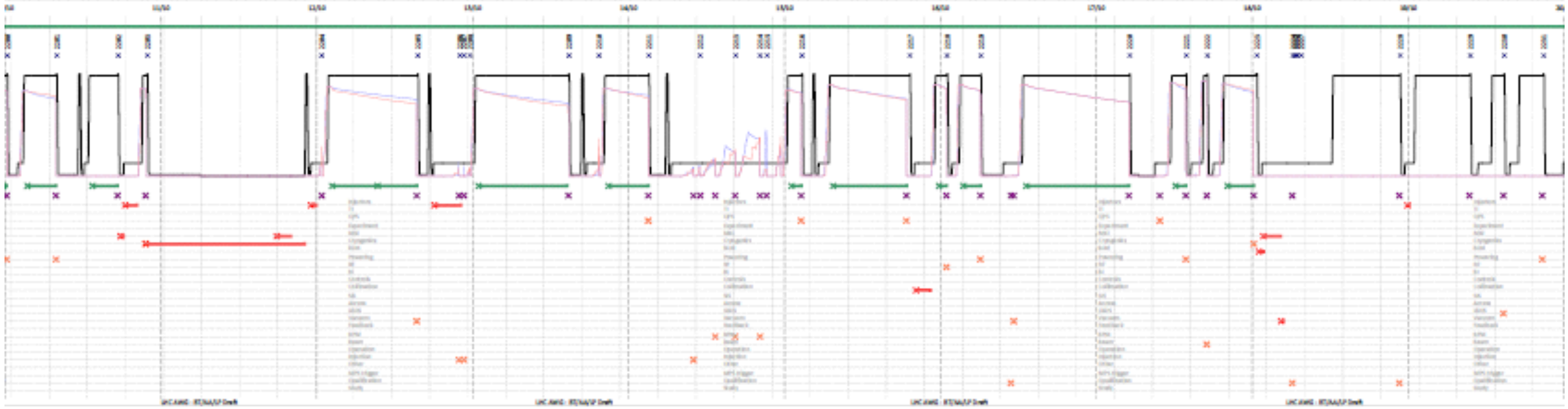
Roles and simplified workflow



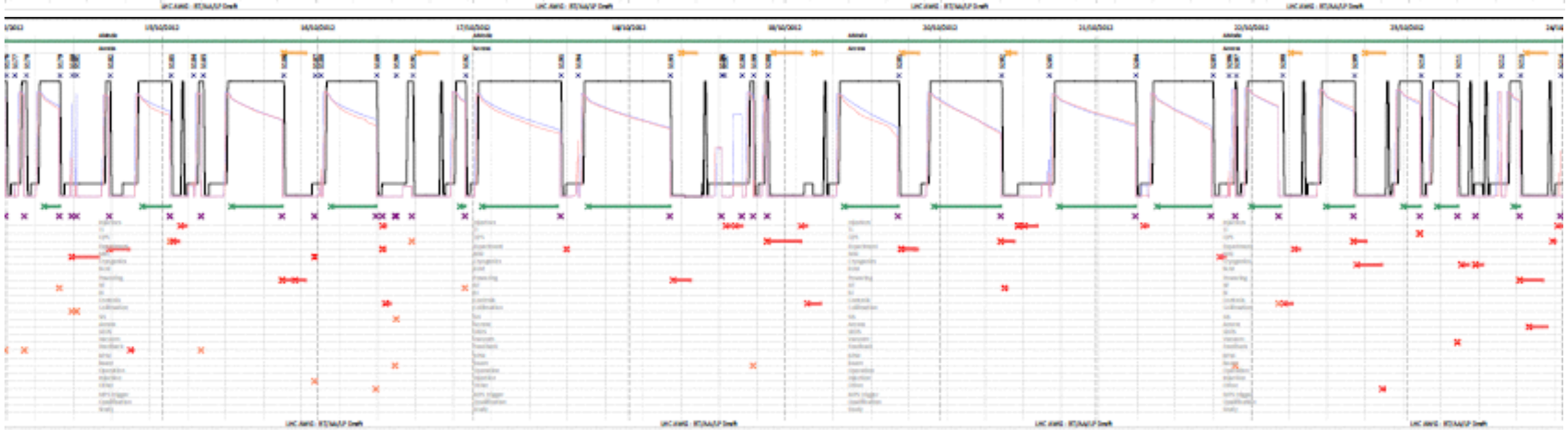
2010



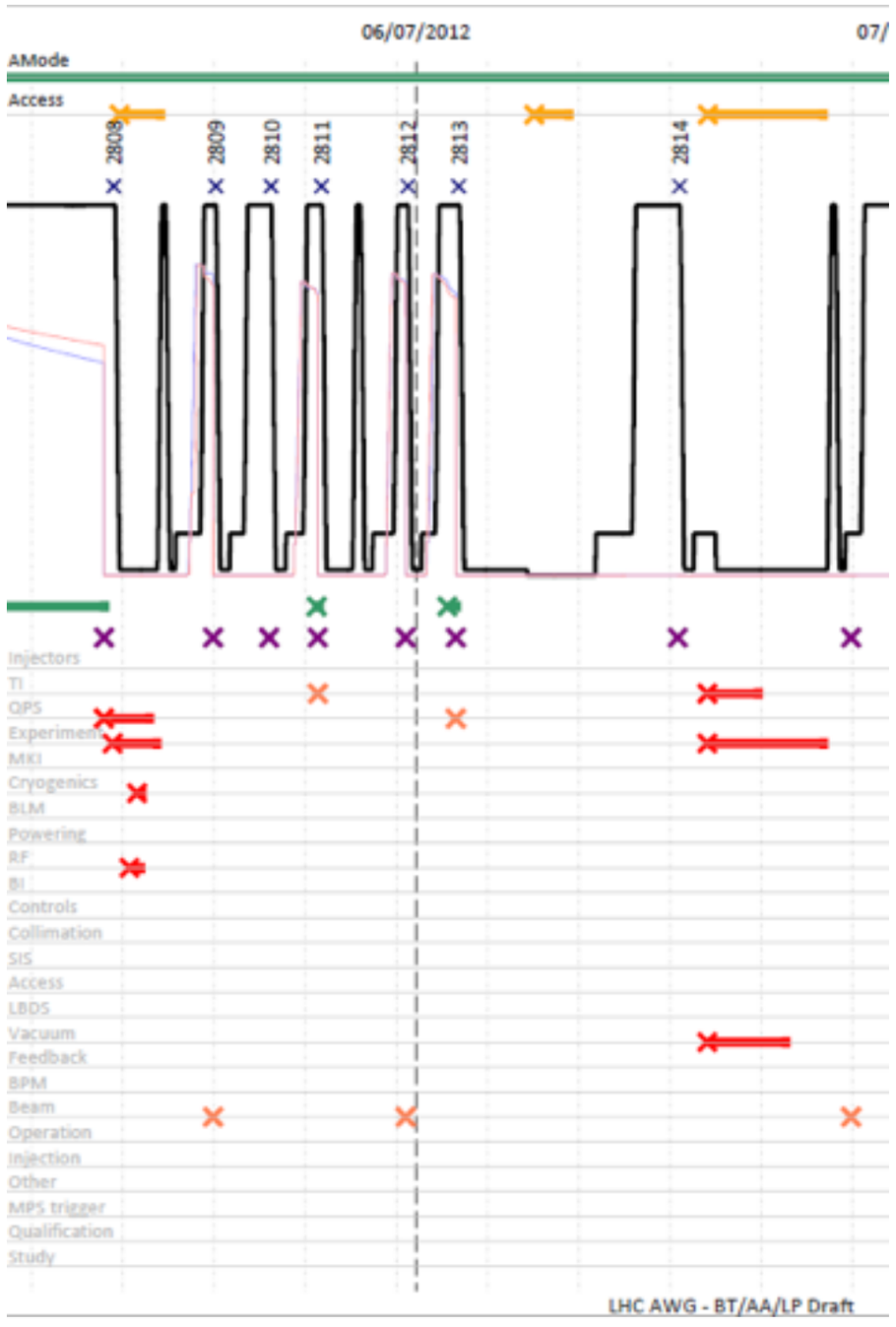
2011



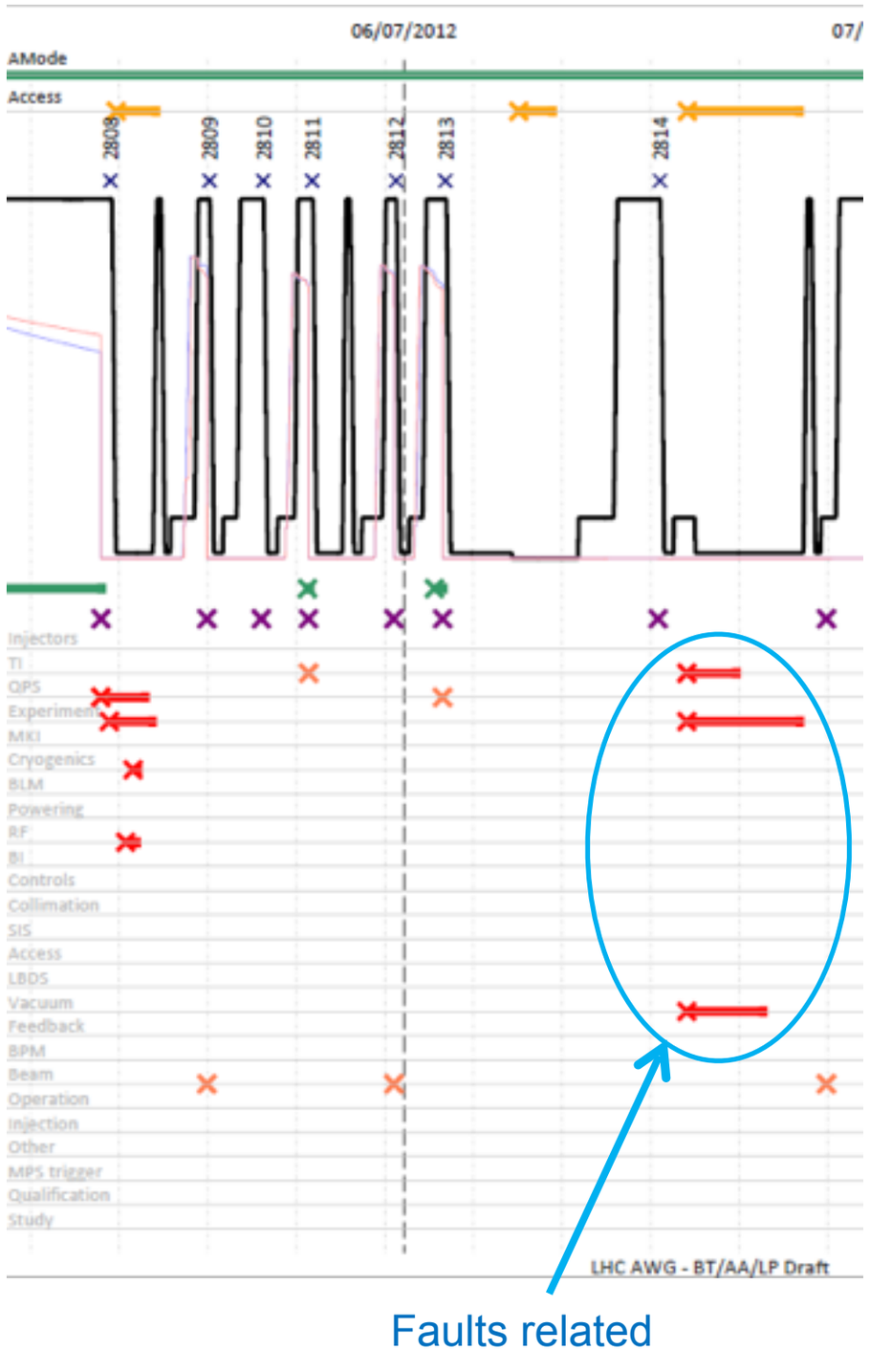
2012



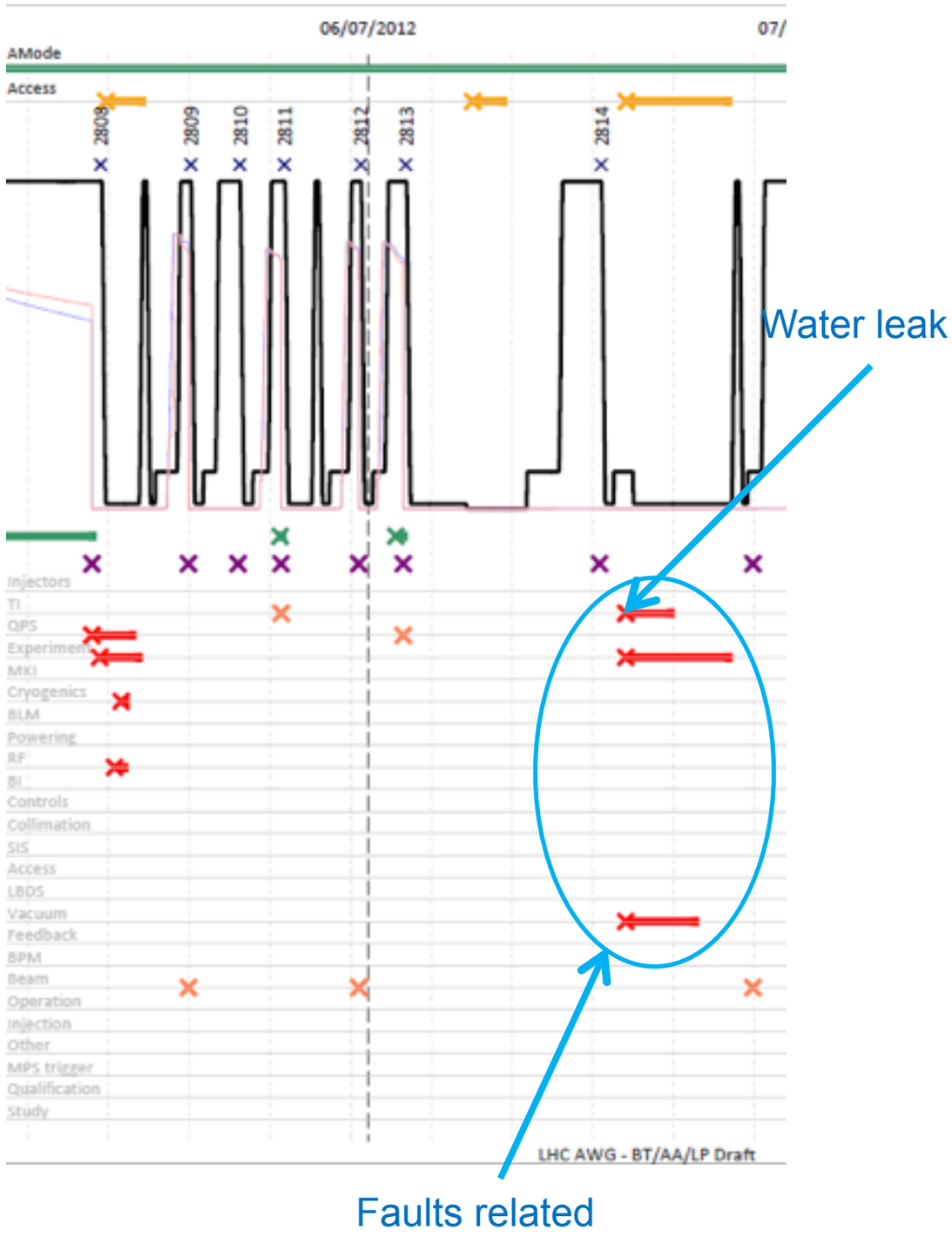
Multiple failures



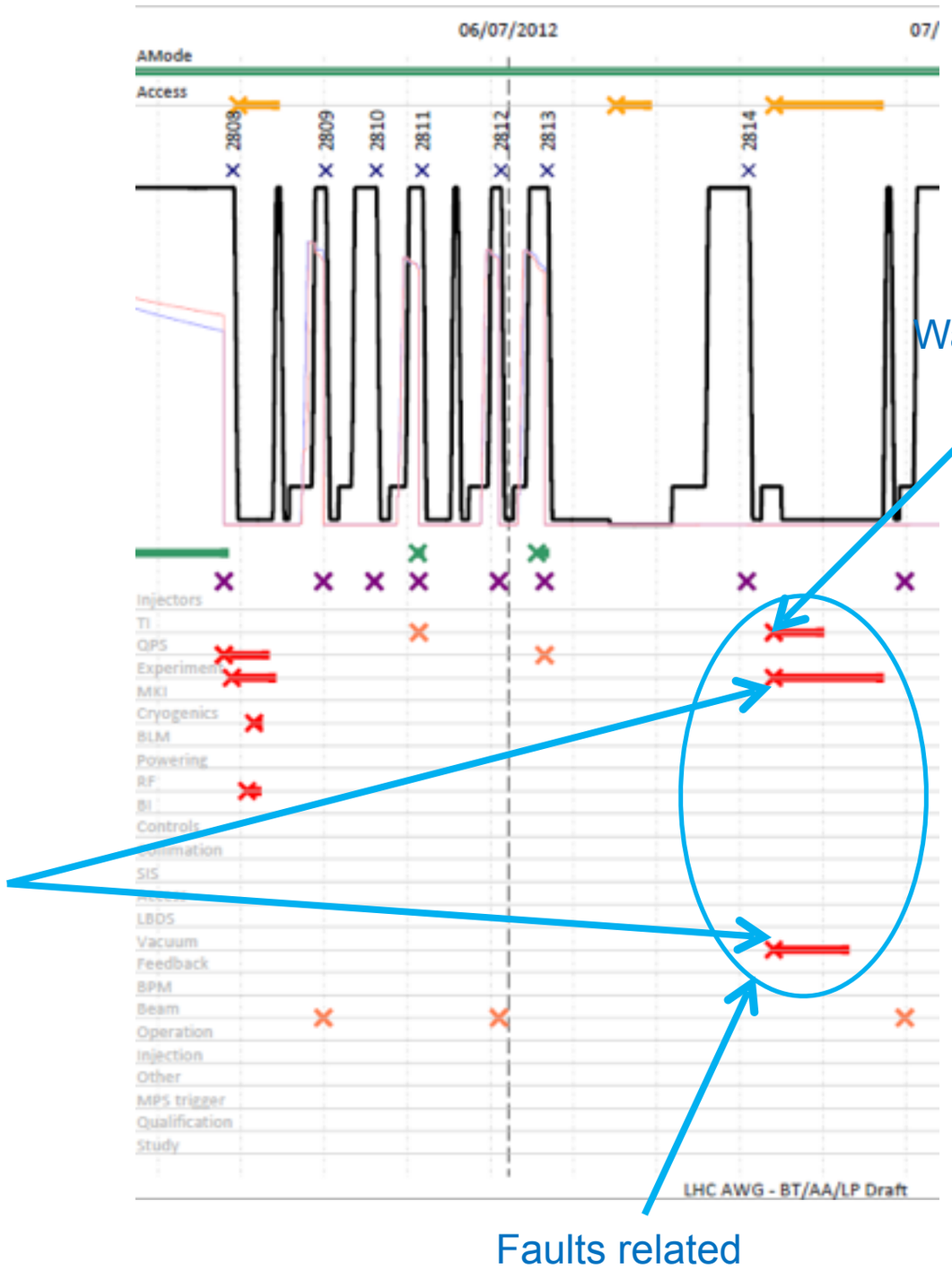
Multiple failures



Multiple failures



Multiple failures

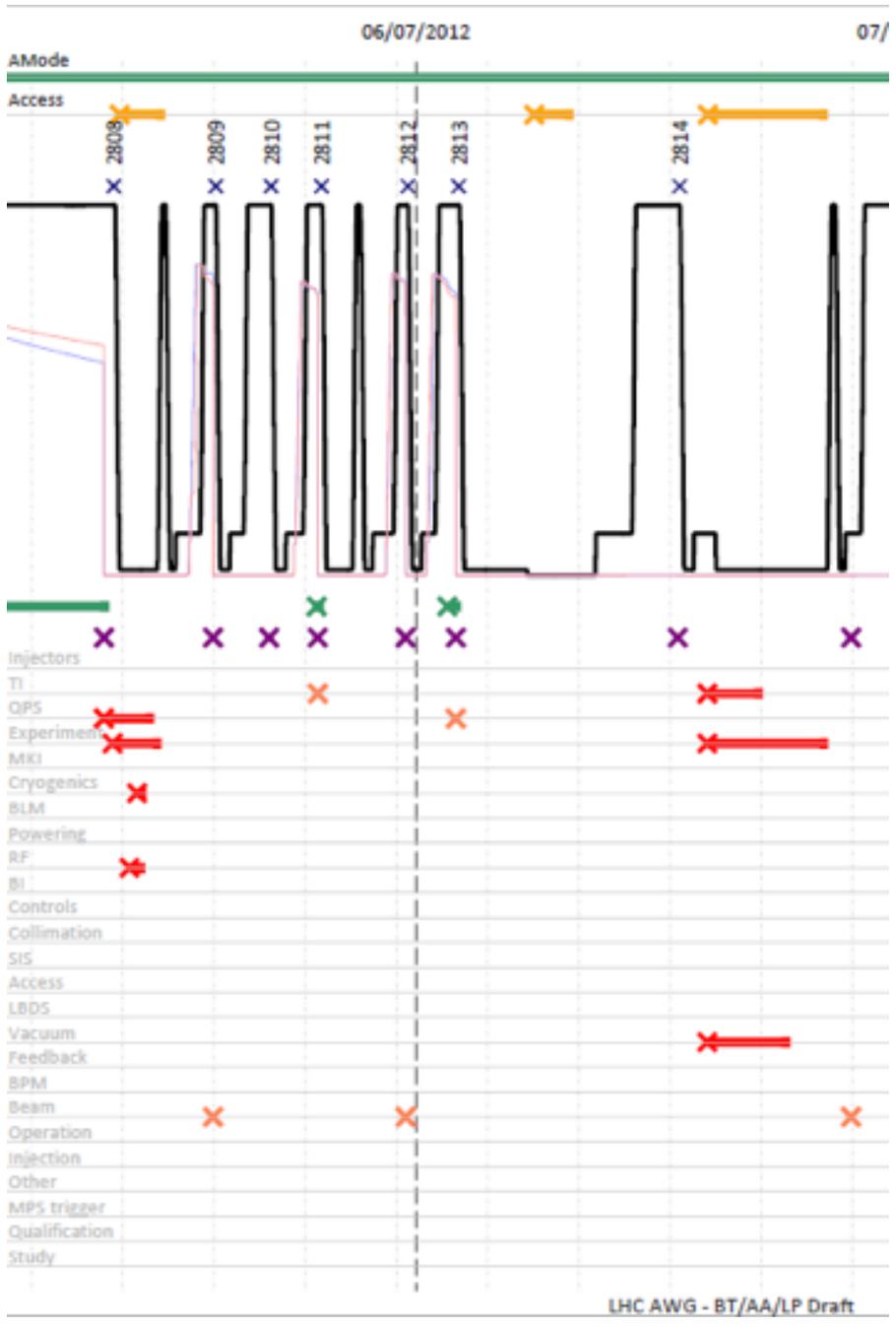


Water leak

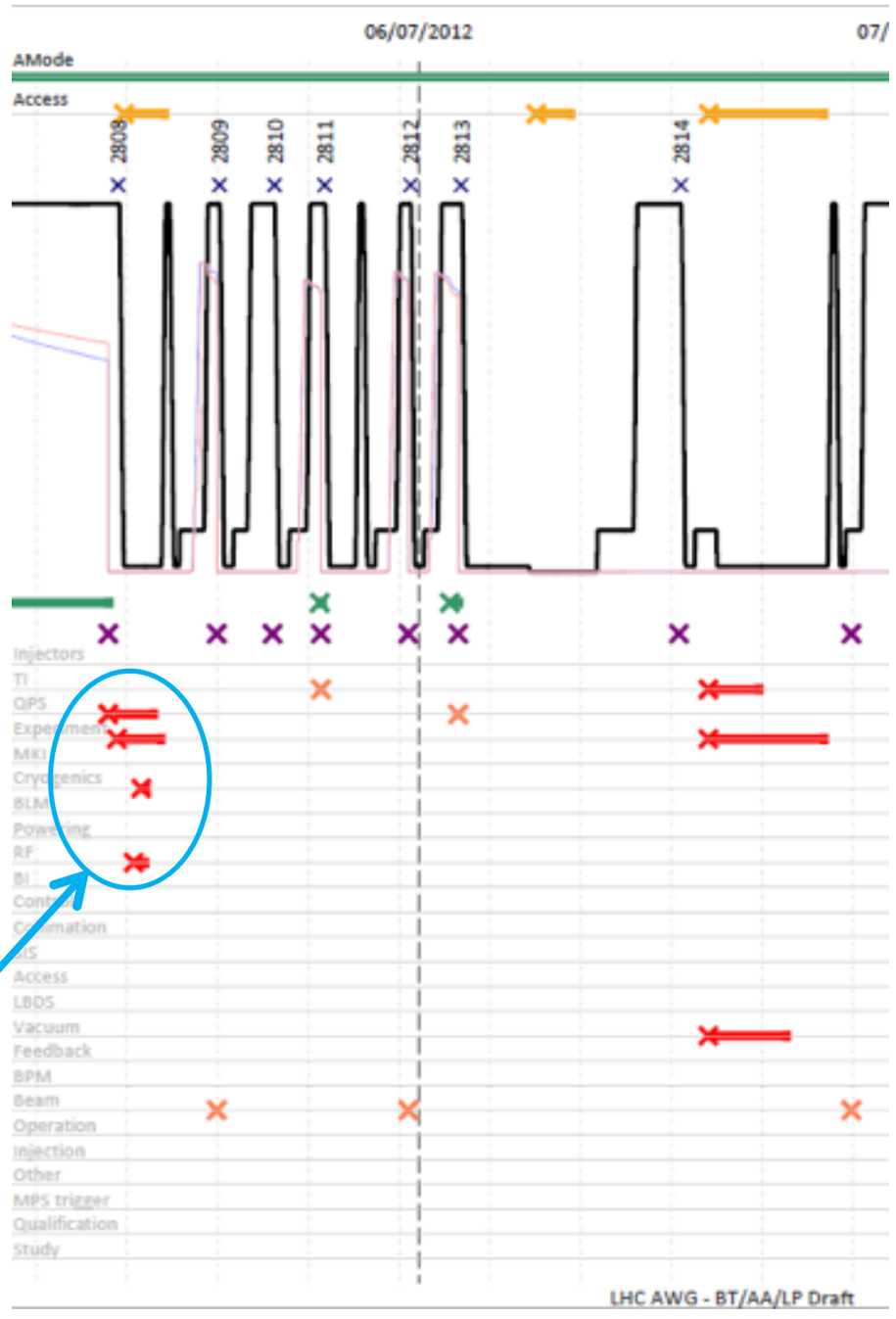
Problems caused by water leak

Faults related

Multiple failures

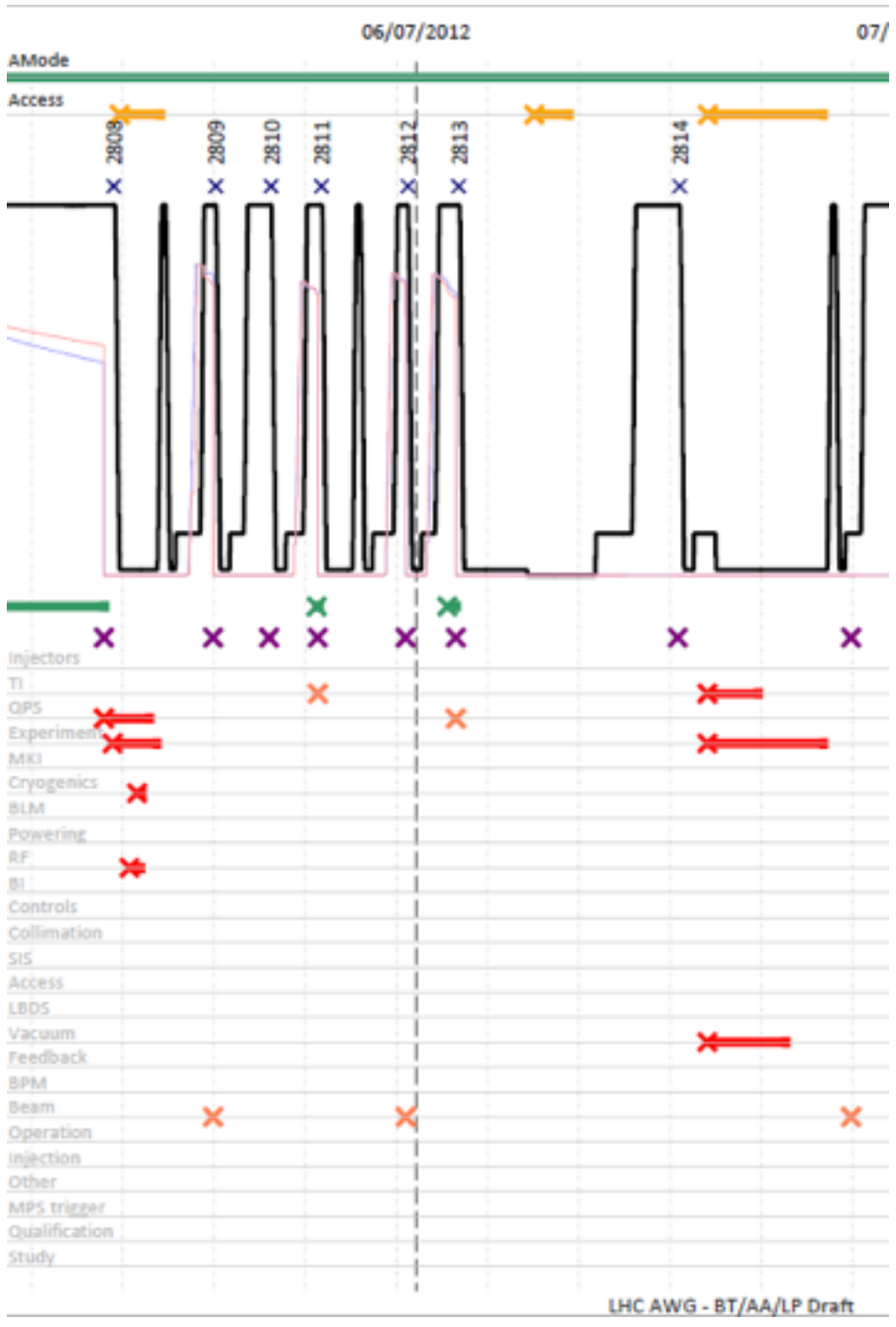


Multiple failures



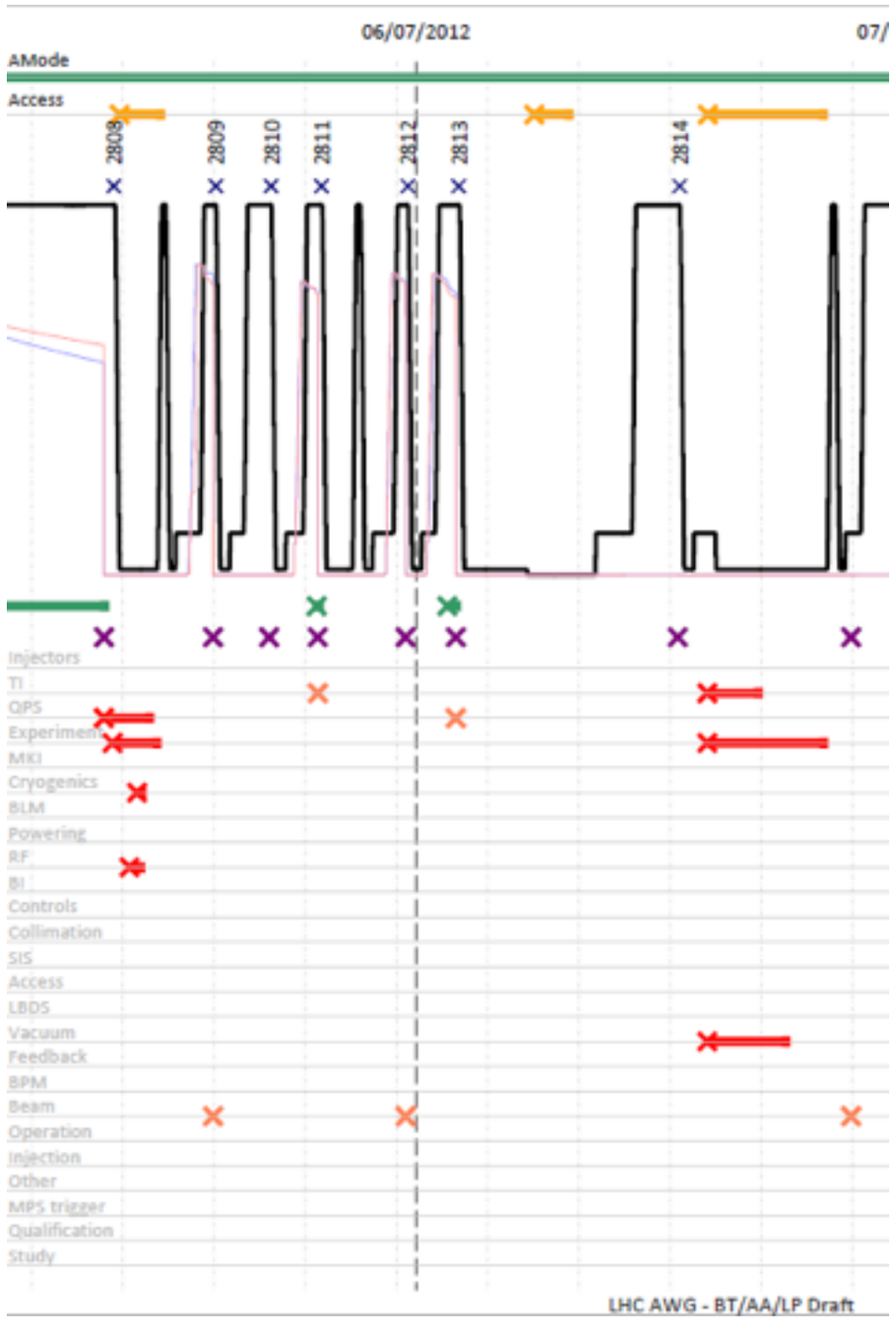
Faults not related –
QPS failed and rest of
them are accesses
in shadow

Multiple failures



Multiple failures

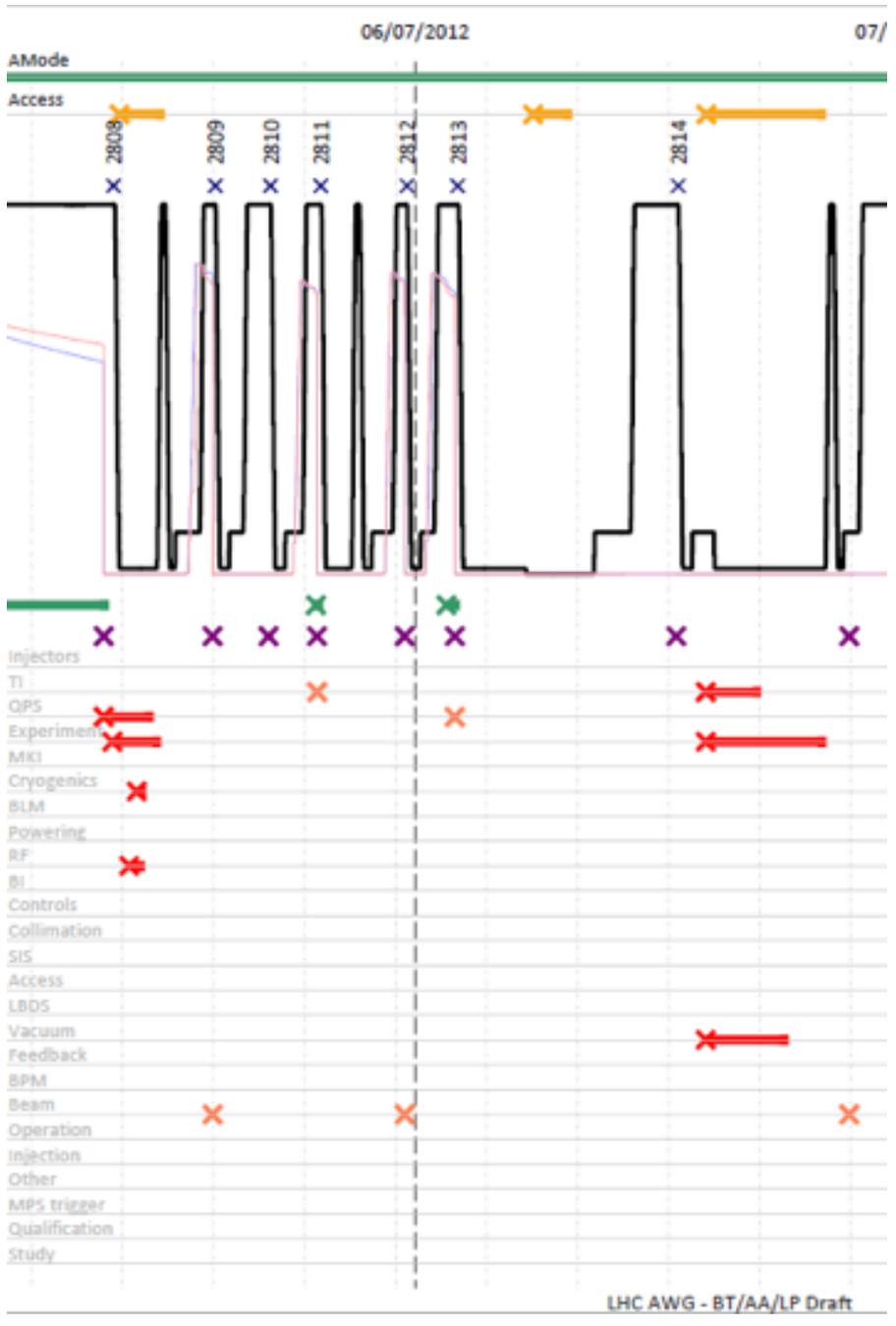
- It is easy to see if there are multiple failures at the same time, but it’s not obvious if they are related.
- One of the goal of AFT project is to capture data that will allow to show the relations between faults.



Access without faults

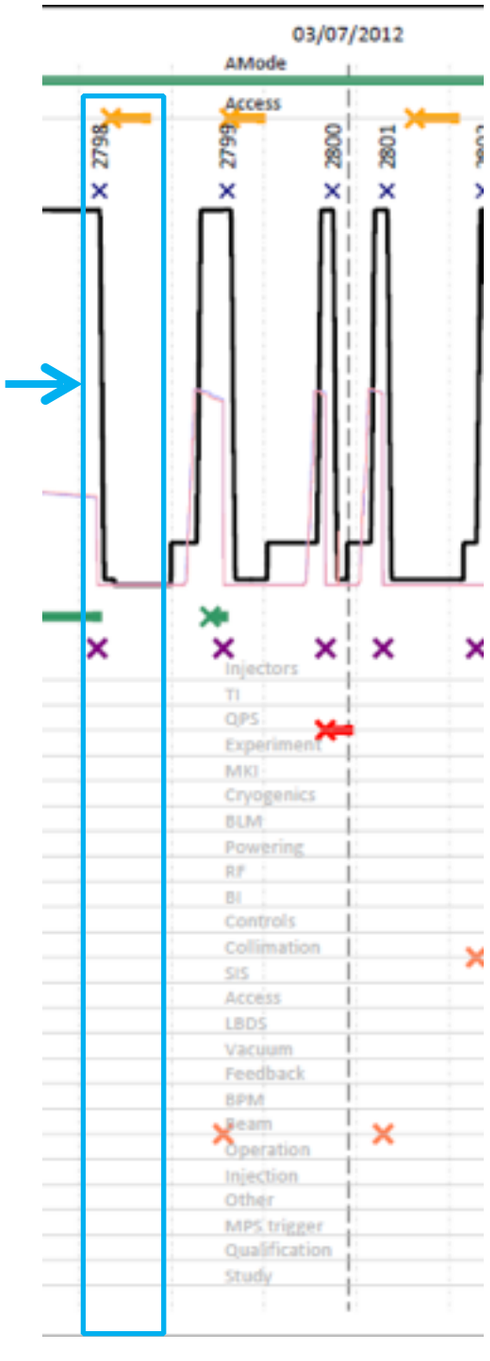
- In 2012, around 40 times there was access without any fault
- The reasons for these accesses are not classified, but often something is repaired
- Inconsistent data – cardiogram allows to spot this

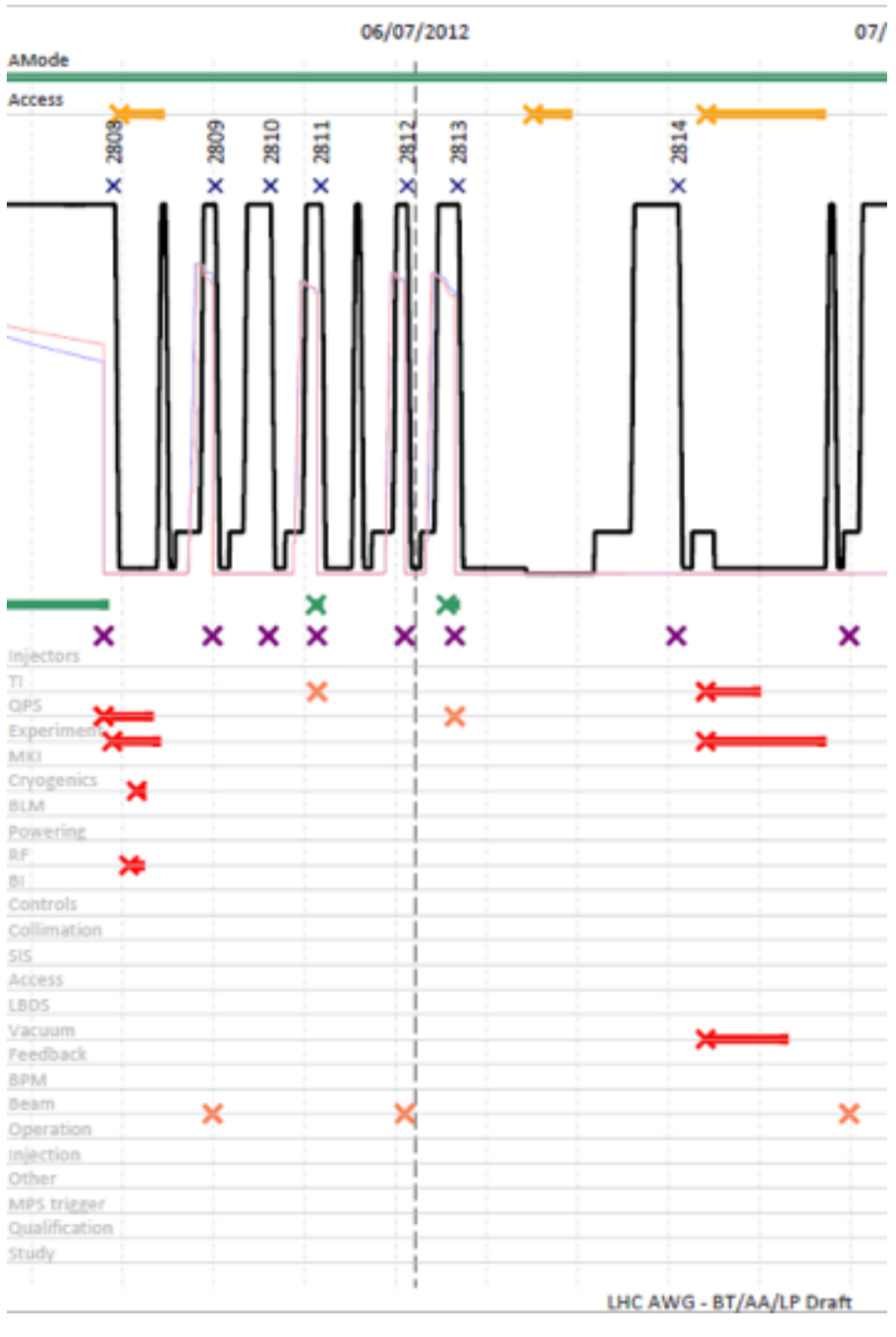
Access without faults - examples



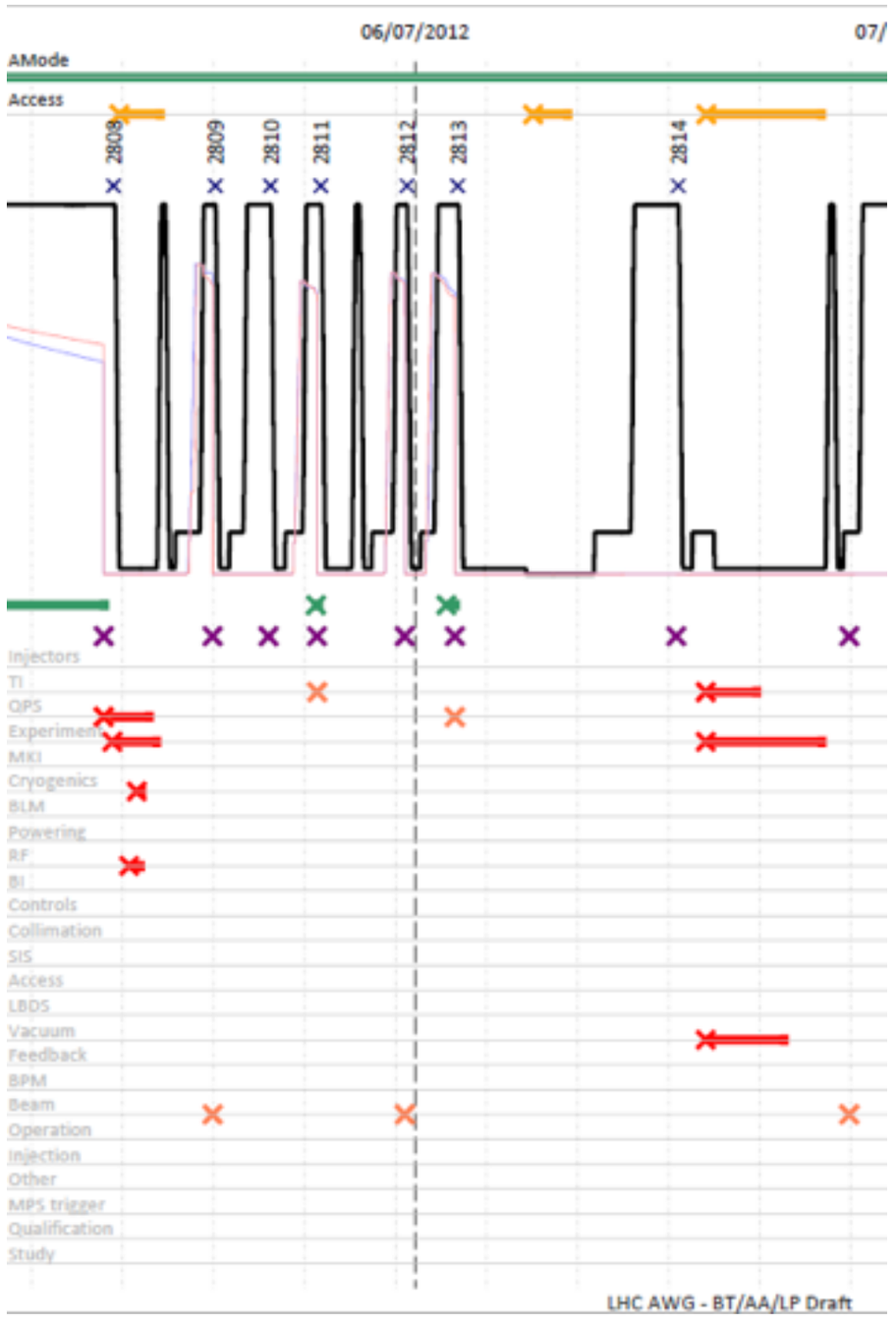
Access without faults - examples

Few accesses:
ATLAS,
Change of PC,
repair of QPS,
intervention on the
crates of the BPMD



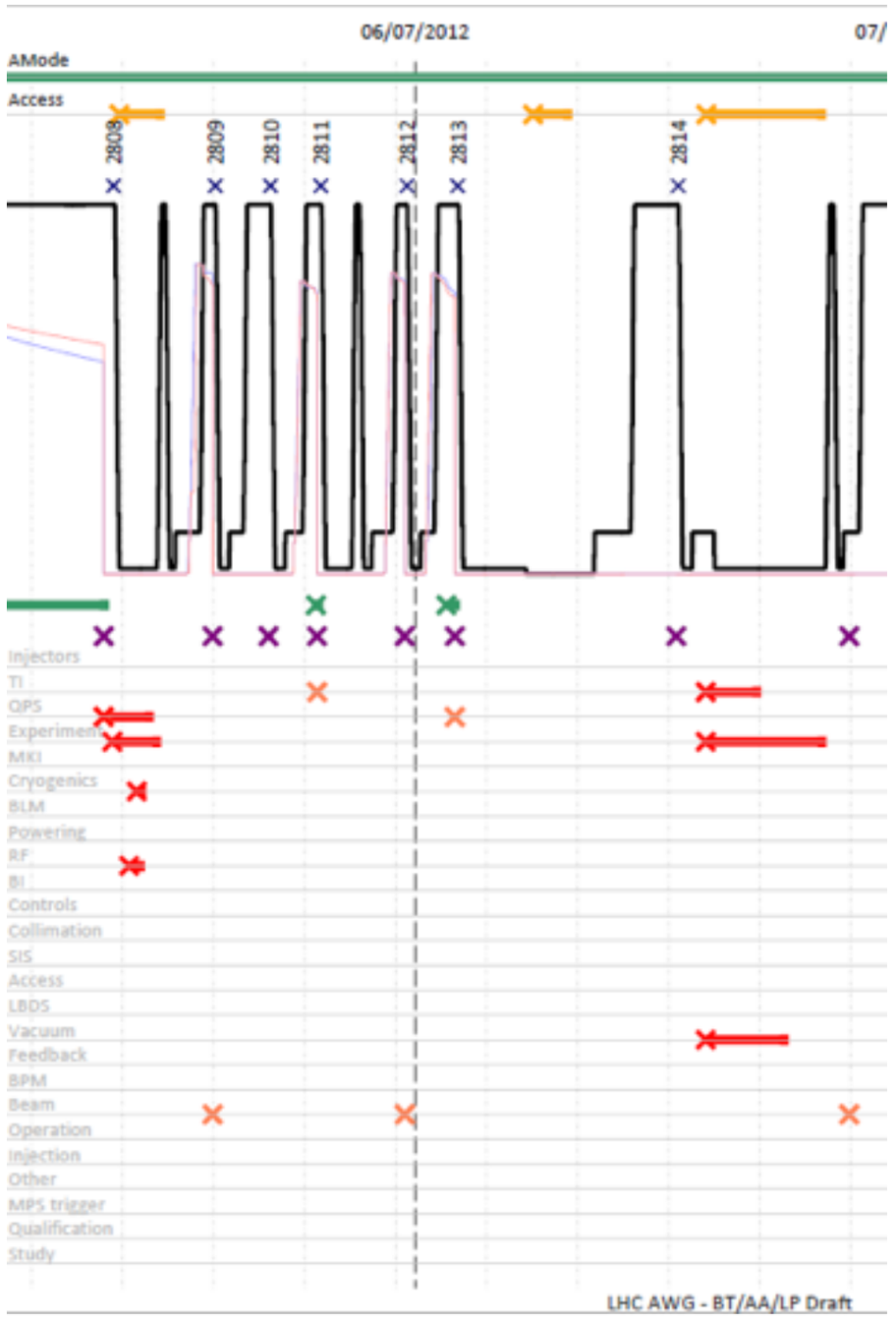


Access without faults - examples

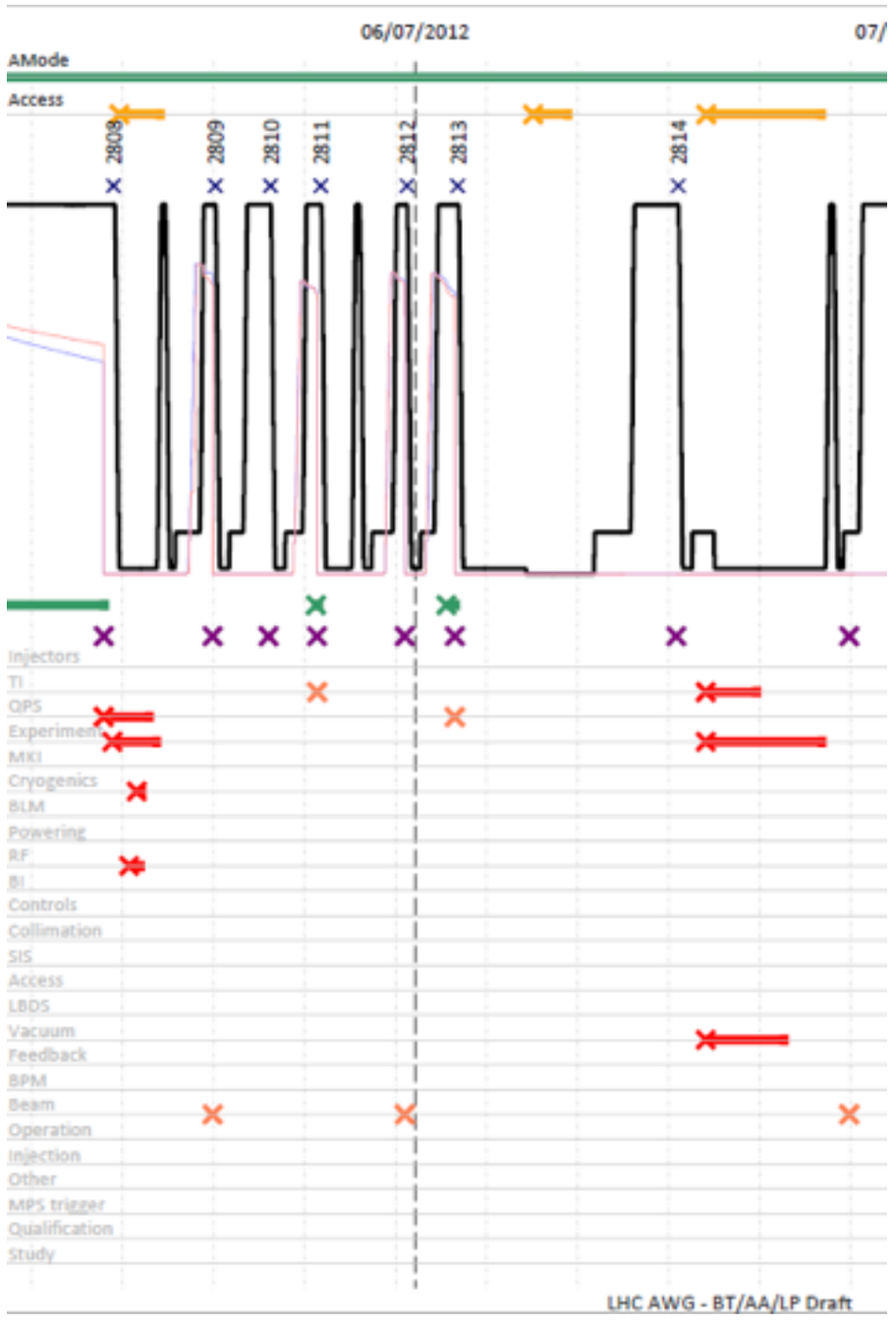


Access without faults - examples

LHCb – fixing muon detectors

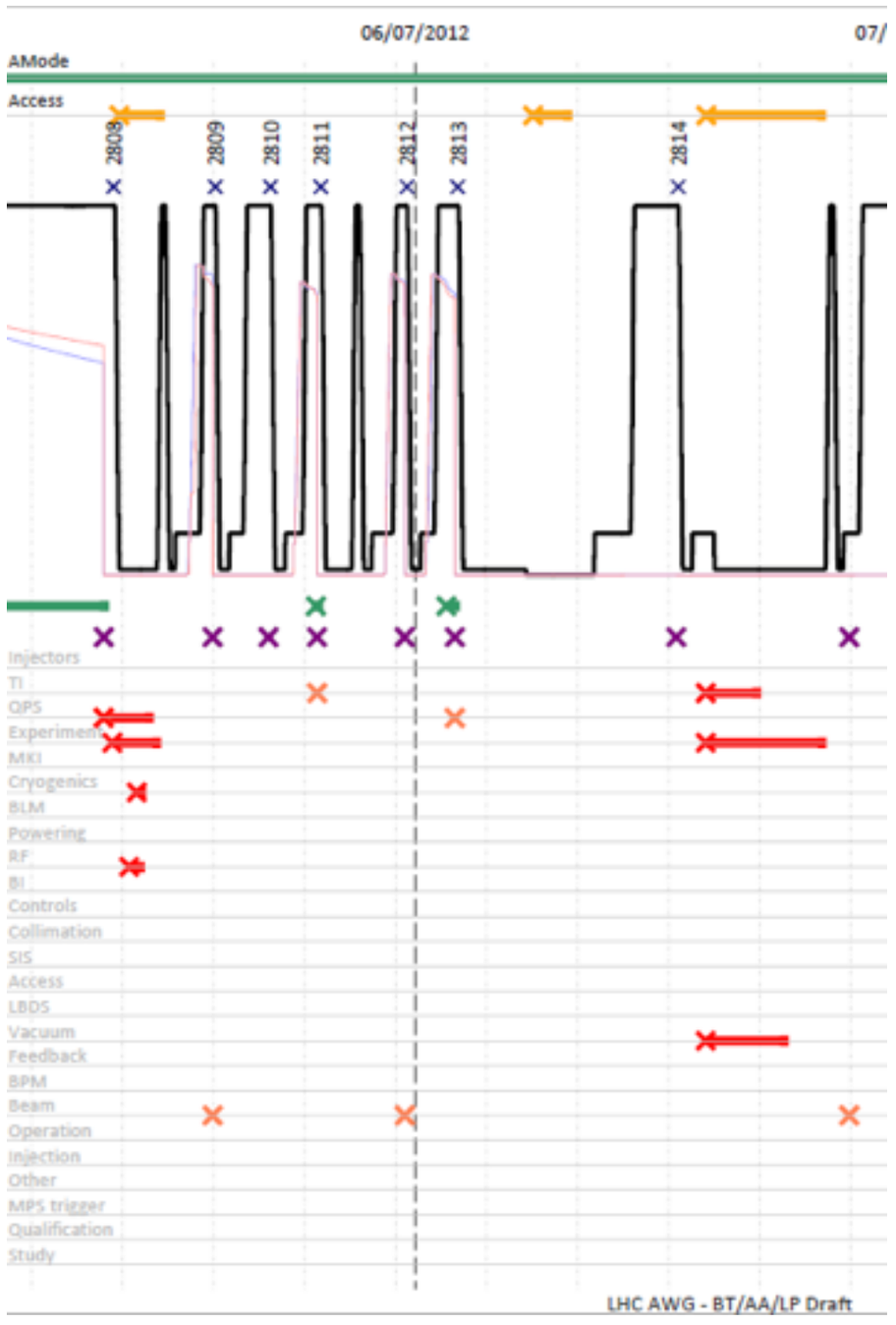


Access without faults - examples

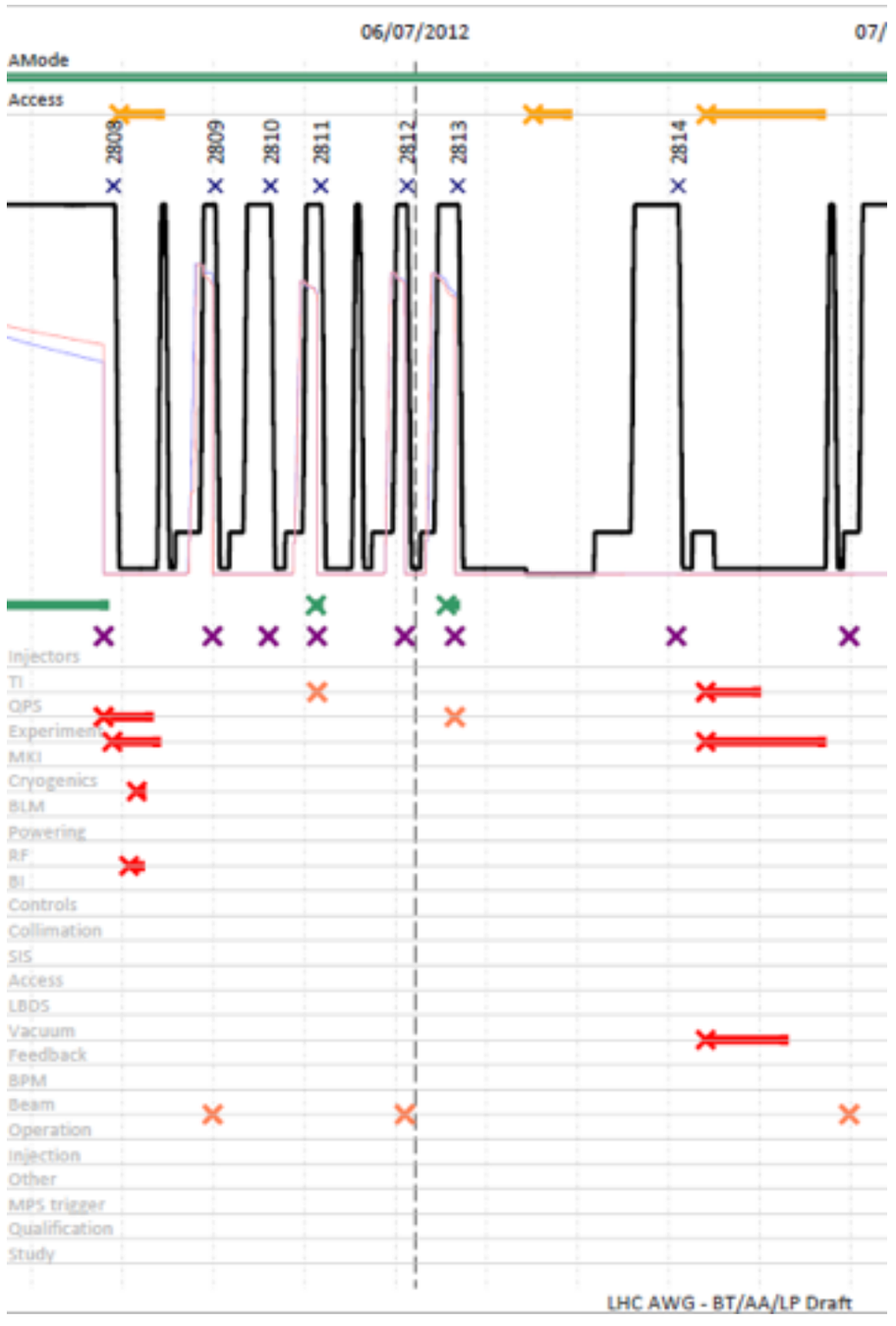


Access without faults - examples

ATLAS access

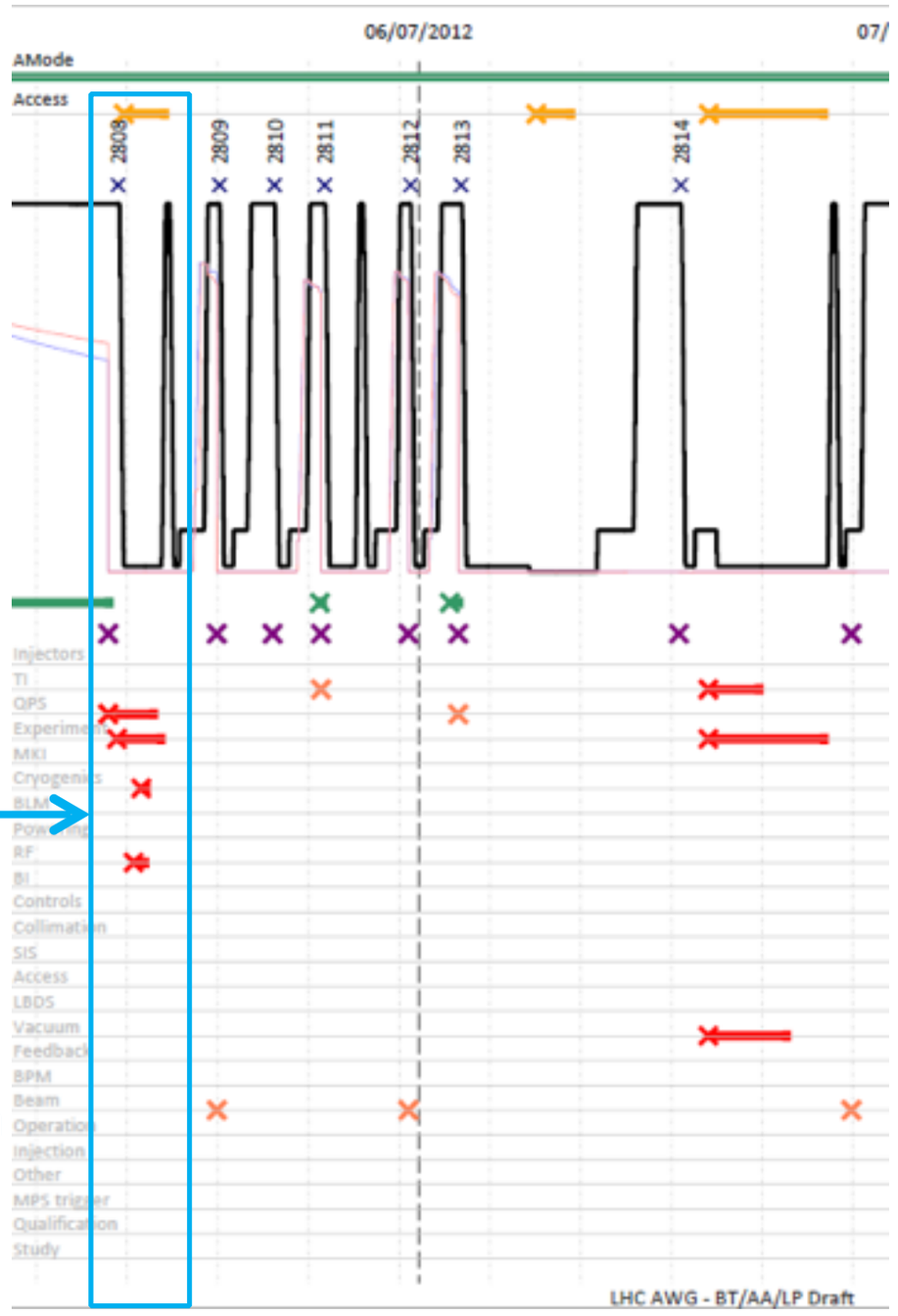
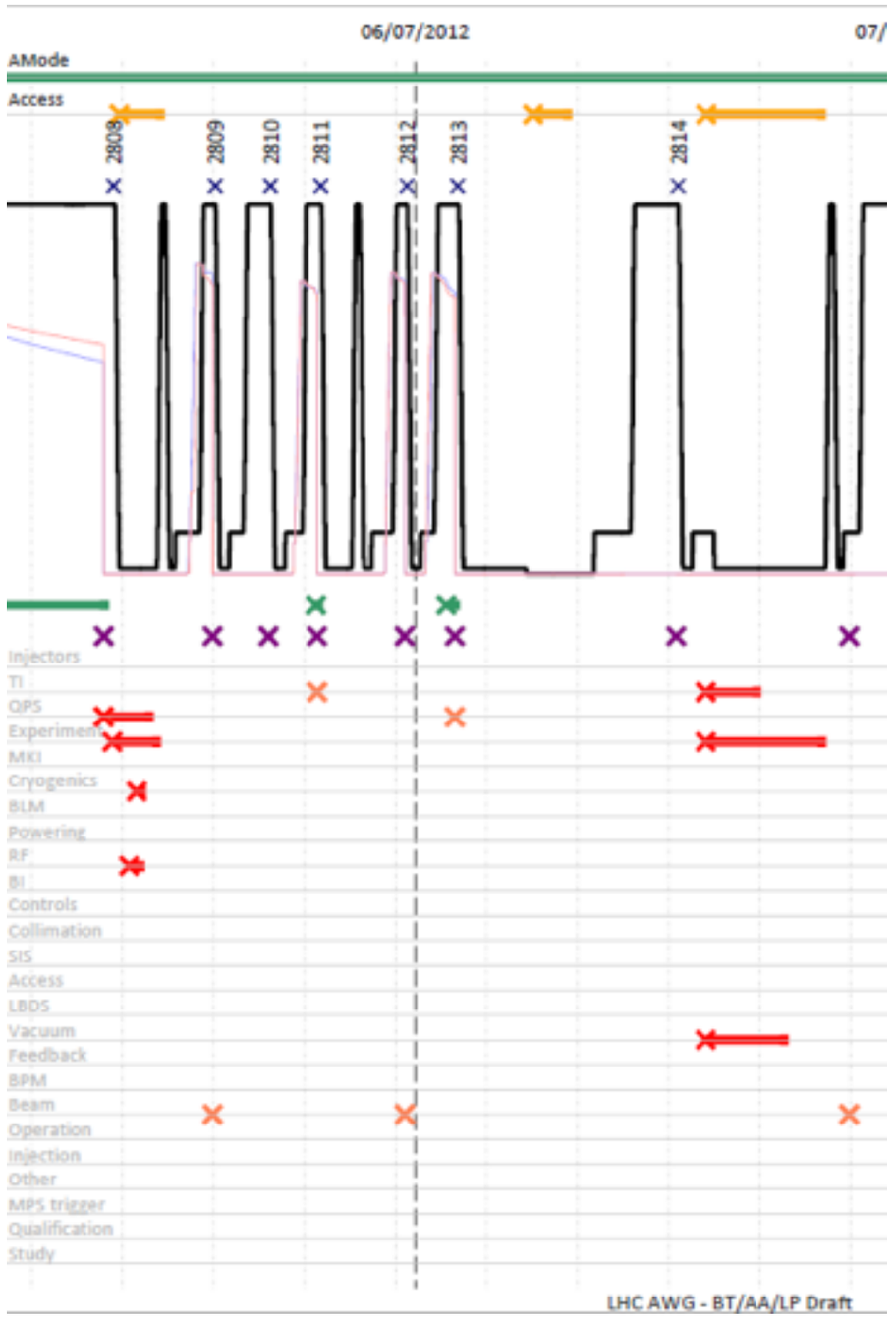


Access without faults - examples



Access without faults - examples

Accesses in shadow of QPS fail:
QPS – reset cards, ALICE and CMS,
Cryogenics – valve regulation,
RF – replacing broken attenuator



Access without faults - examples