



Operation of cryogenics for LHC detectors: what did we learn?

U. Wagner, CERN

Topics

- Introduction ATLAS and CMS
- Operation history 2011, 2012, 2015
 - Availability data
 - Reasons for down time
 - Impurities and filter clogging
 - Inbuilt impurity handling
 - Filter clogging development 2011, 2012/13, 2015
- Oil contamination 2015
 - Identified reason
 - Realised modifications

Topics

- Introduction ATLAS and CMS
- Operation history 2011, 2012, 2015
 - Availability data
 - Reasons for down time
 - Impurities and filter clogging
 - Inbuilt impurity handling
 - Filter clogging development 2011, 2012/13, 2015
- Oil contamination 2015
 - Identified reason
 - Realised modifications

ATLAS and CMS cryogenics

- ATLAS
 - Two separate cryogenic services
 - LN₂ cooling system for the LAr calorimeter
 - He cooling system for the superconducting magnets
 - One refrigerator for 40 K – 60 K cooling; (Shield Refrigerator)
 - One refrigerator for 4.5 K cooling; (Main Refrigerator)
 - Two magnet systems
 - One solenoid magnet cooled in thermosiphon mode
 - Several toroidal magnets cooled by forced flow
 - In this presentation only the **Main Refrigerator (MR)** is considered

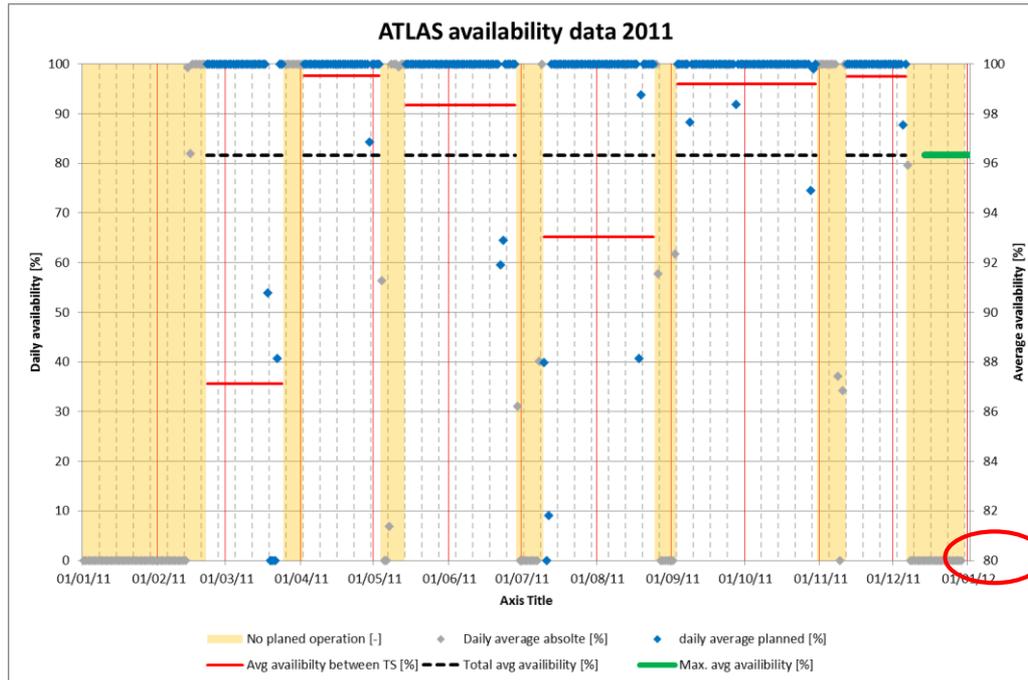
ATLAS and CMS cryogenics

- CMS
 - One single cryogenic service
 - One refrigerator for all loads down to 4.5 K
 - One solenoid magnet cooled in thermosiphon mode

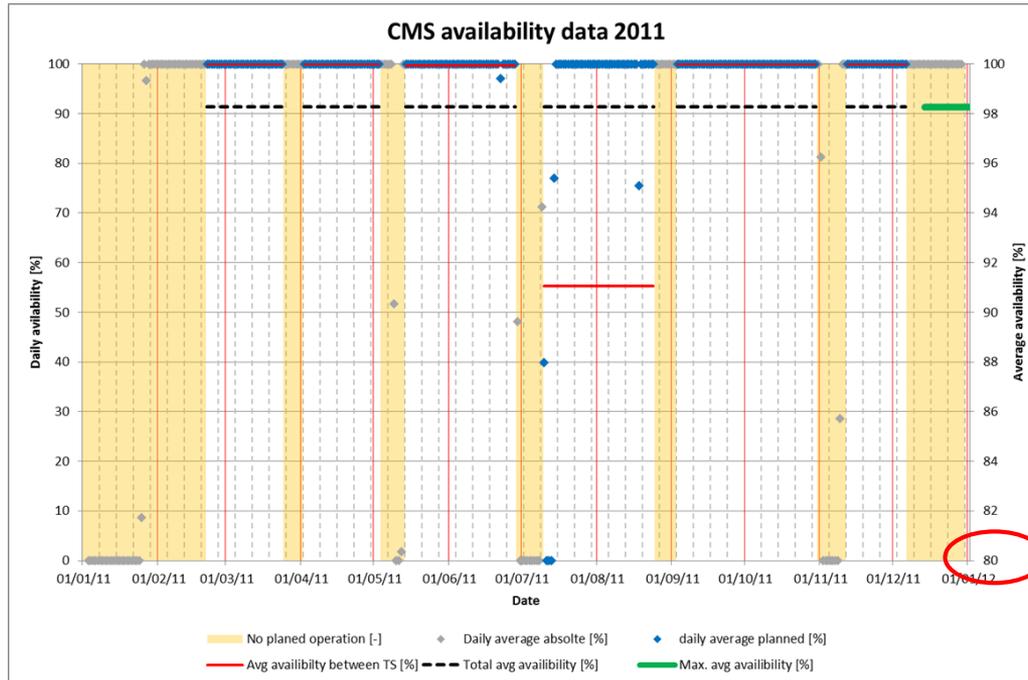
Topics

- Introduction ATLAS and CMS
- Operation history 2011, 2012, 2015
 - Availability data
 - Reasons for down time
 - Impurities and filter clogging
 - Inbuilt impurity handling
 - Filter clogging development 2011, 2012/13, 2015
- Oil contamination 2015
 - Identified reason
 - Realised modifications

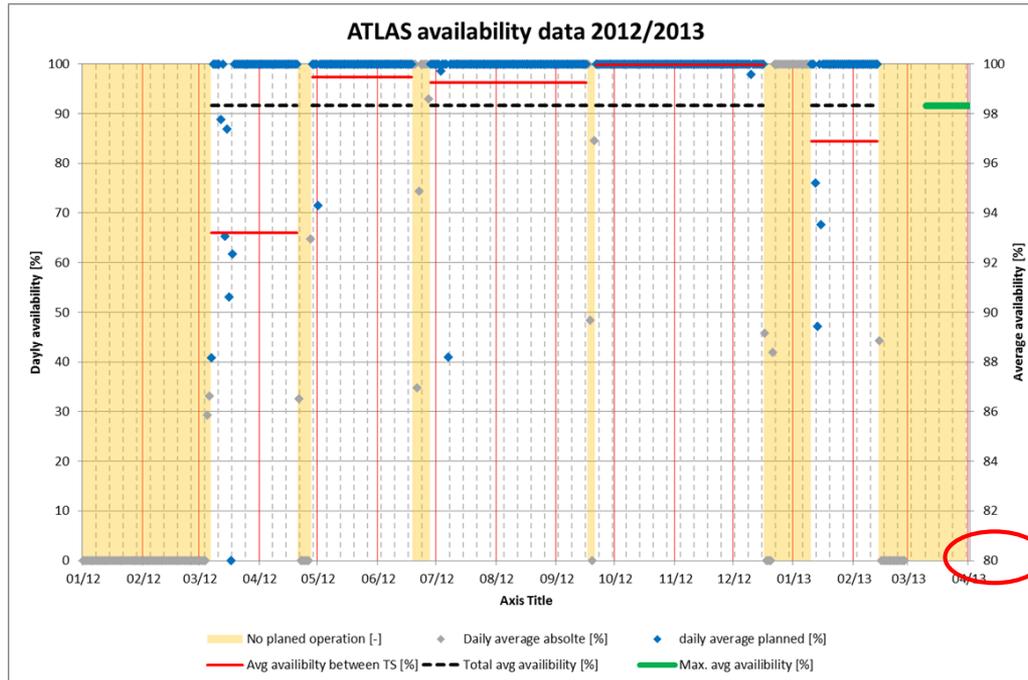
ATLAS availability 2011



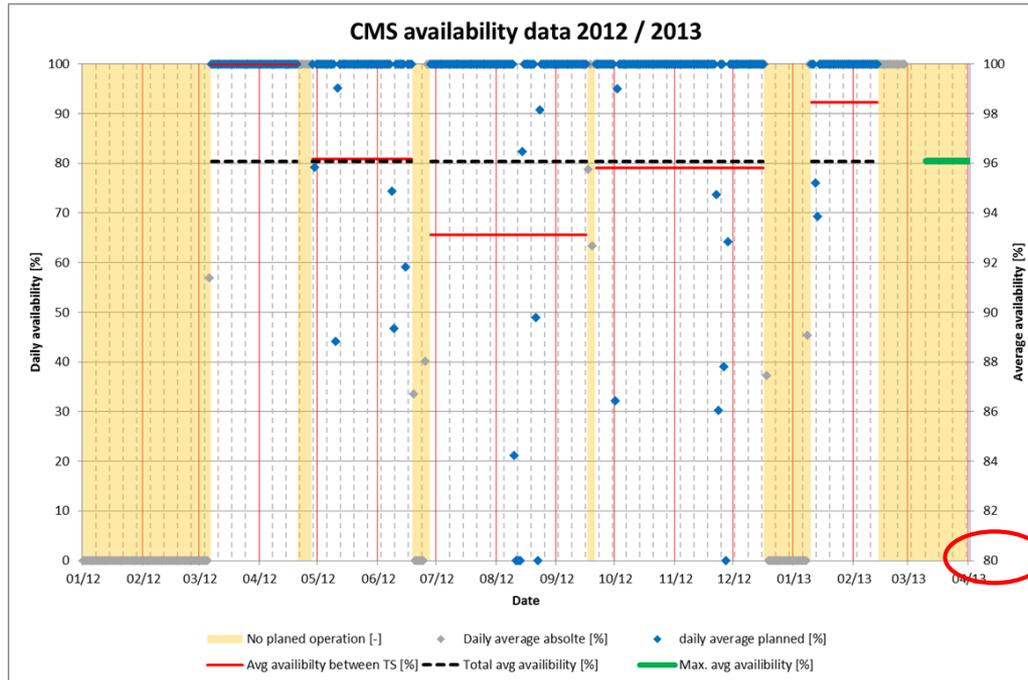
CMS availability 2011



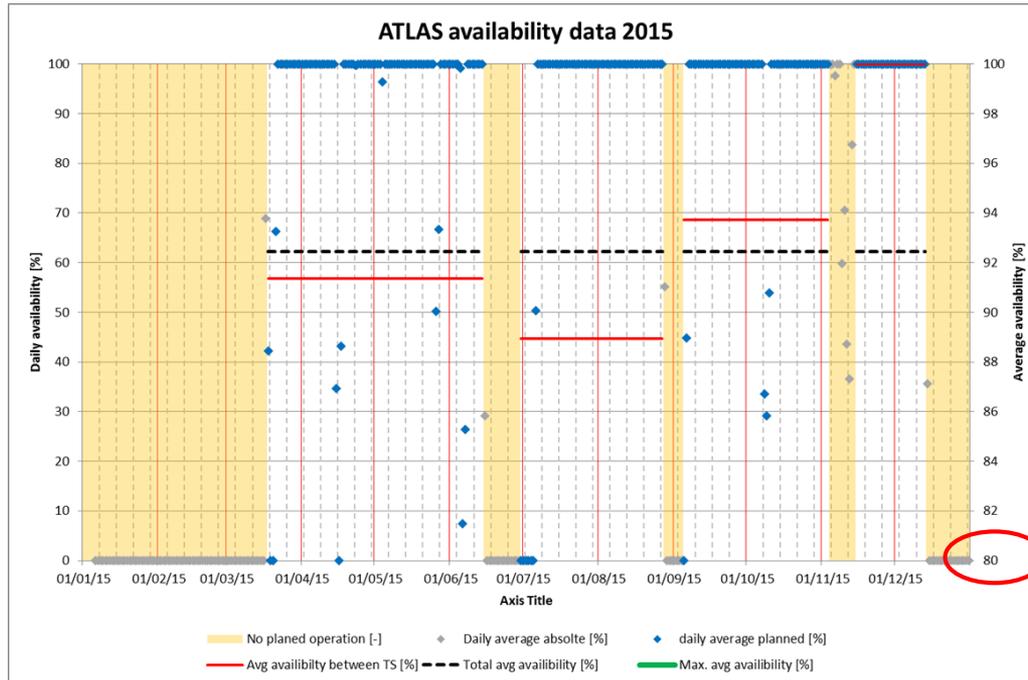
ATLAS availability 2012 / 2013



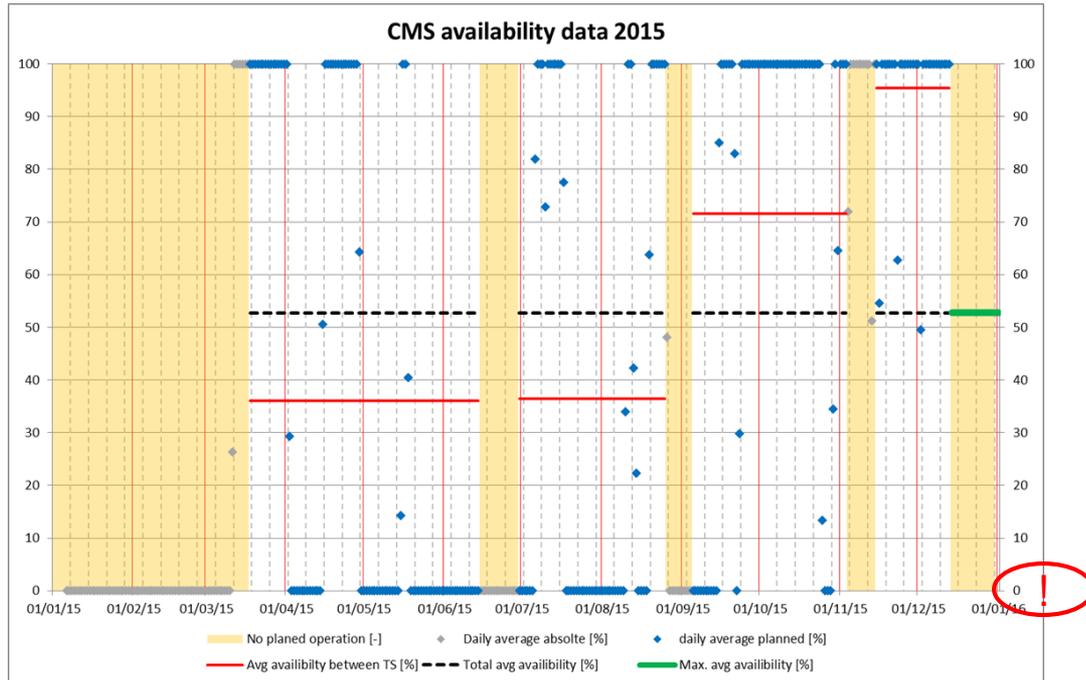
CMS availability 2012 / 2013



ATLAS availability 2015



CMS availability 2015



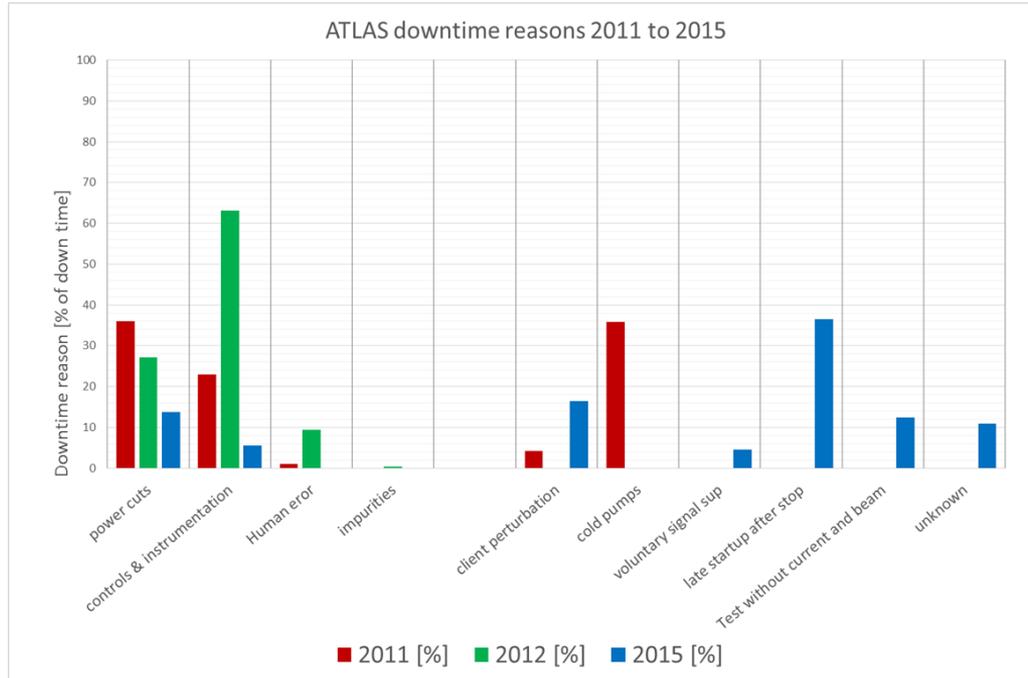
Repetitive common reasons

- Power cuts
 - “Glitches”, typically <120 ms
 - Long term cuts, typically >300 ms to black-out
- Control& instrumentation
 - Electrical contact error, element failure
 - Mistakes or shortfalls in programmed controls
- Human error
 - Operating errors
 - Errors during servicing, working on utilities
 - Once closing by valve by unknown person
- Impurity problems

Isolated reasons

- Only experienced for ATLAS
 - Cold pump problems
 - Client perturbations
 - Test without current and beam (2015)
 - Voluntary signal suppression (2015)
 - Late start-up after technical stop (2015)
- Only experienced for CMS
 - UPS problem

ATLAS downtime reasons



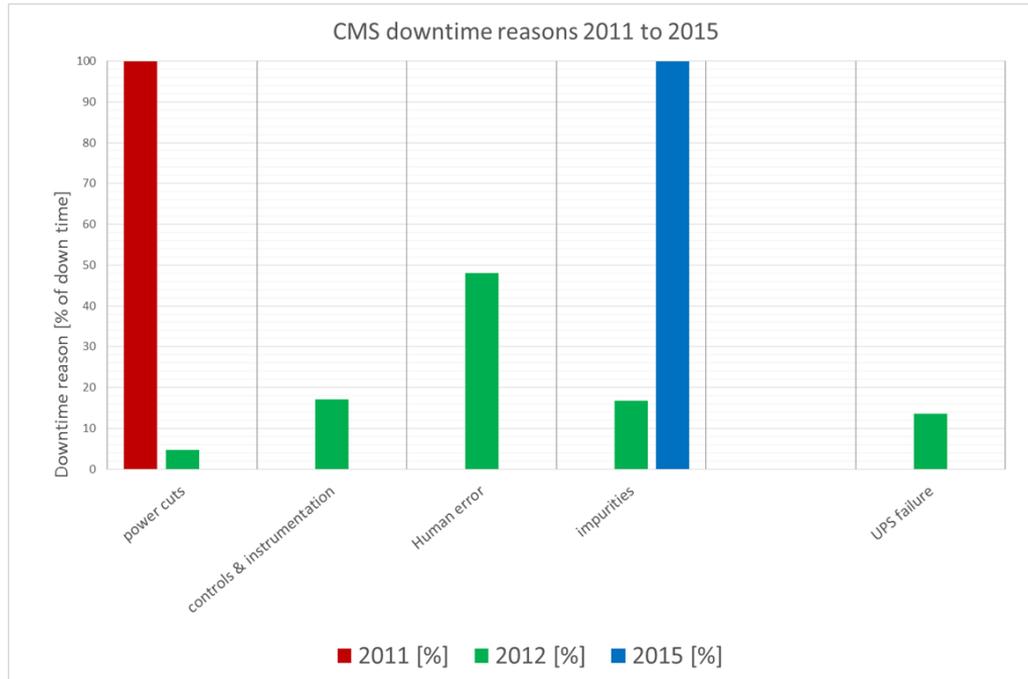
ATLAS modifications 2014

- Power cuts
 - 2011 and 2012 all “glitches” lead to a stop of the installation
 - Detailed fault chain analysis
 - Readjustment of hard and soft safety to be tolerant to power losses of < 120 ms.
- Result 2015
 - No more installation stops due to short power loss.
 - Now most of the glitches are seen by the client system.

ATLAS modifications 2014

- Control and instrumentation
 - Existing electrical cabinets removed and completely replaced
 - Turbine speed measurement changed against more reliable and more precise equipment
 - The original equipment was from 1990 and was “moved / modified” several times by CERN
 - Documentation not up to date

CMS downtime reasons



CMS modifications 2014

- Nearly none
 - Operation 2011 showed no real shortcomings
 - Availability at 98.3%, only power cuts.
 - Failing UPS system exchanged
 - Was part of problematic batch
 - Control and instrumentation problems due to failing temperature switch in hard-wired compressor safety.
 - Hard wired safety chain modified.

Topics

- Introduction ATLAS and CMS
- Operation history 2011, 2012, 2015
 - Availability data
 - Reasons for down time
 - Impurities and filter clogging
 - Inbuilt impurity handling
 - Filter clogging development 2011, 2012/13, 2015
- Oil contamination 2015
 - Identified reason
 - Realised modifications

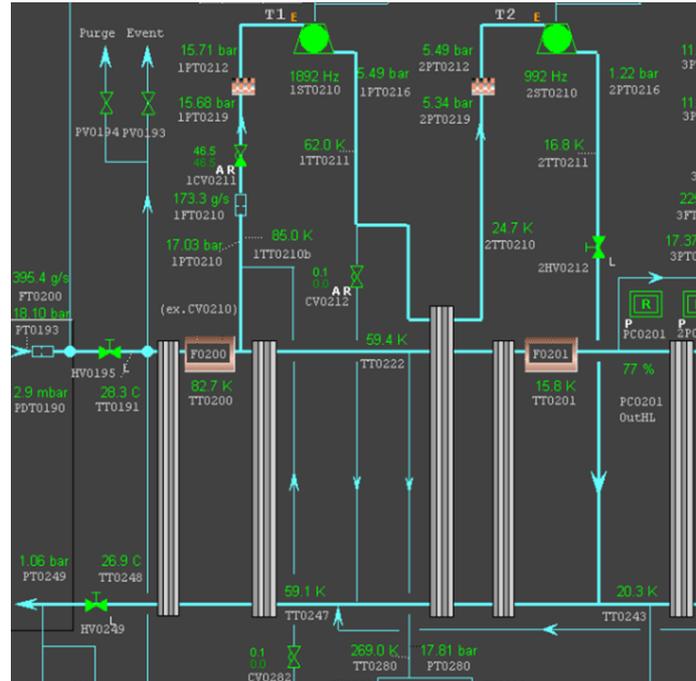
Inbuilt impurity handling

- Solids
 - The installations have filters
 - More to protect delicate equipment than to remove a constant flow of solid impurities.
- Liquids
 - We rely on the final oil removal system for oil.
 - We rely on the heat exchanger design for water.
 - We rely on purges and oil adsorber heating to remove water during a start-up phase.
 - Water from top-up oil.

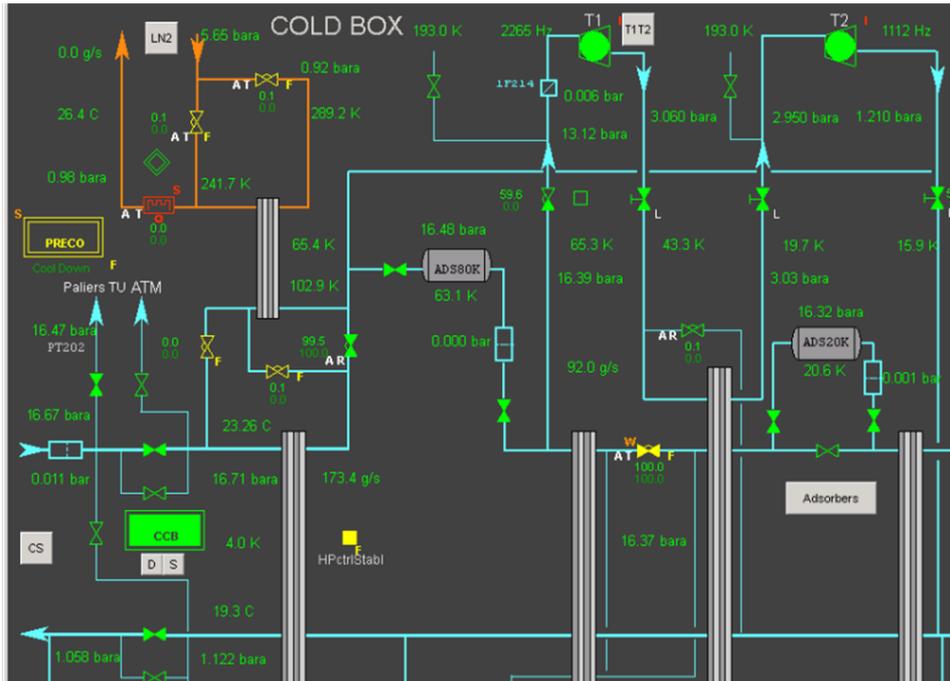
Inbuilt impurity handling

- Gasses
 - Both refrigerators have one guard adsorber at 80 K.
 - Neither has a by-pass
 - Only the CMS adsorber can be isolated, requiring a cold box stop.
- In short, this means there is virtually no impurity handling.
 - CERN responsibility as specified accordingly.

ATLAS MR 80 K adsorber



CMS 80 K adsorber



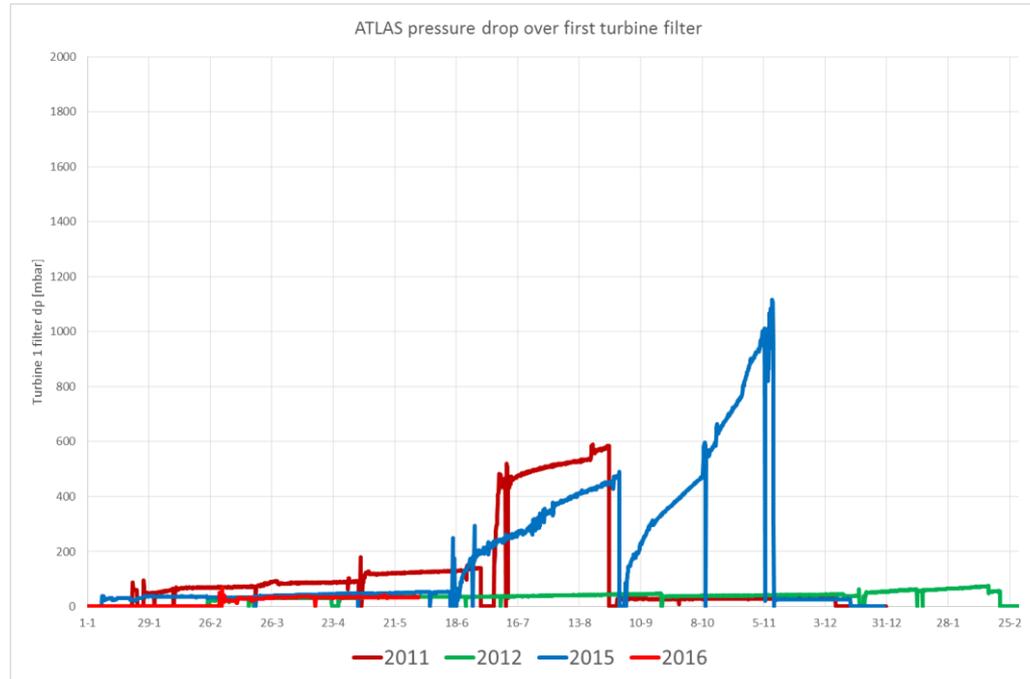
Inbuilt impurity handling

- The 80 K adsorber will charge with N₂/O₂ impurities principally during the first cool down phase.
 - At high partial impurity pressure
- This adsorber will always be subject to temperature fluctuations.
 - Due to operation interruptions, load changes
 - At low partial impurity pressure
 - Impurities will migrate to the adsorber outlet and finally desorb into the helium stream.

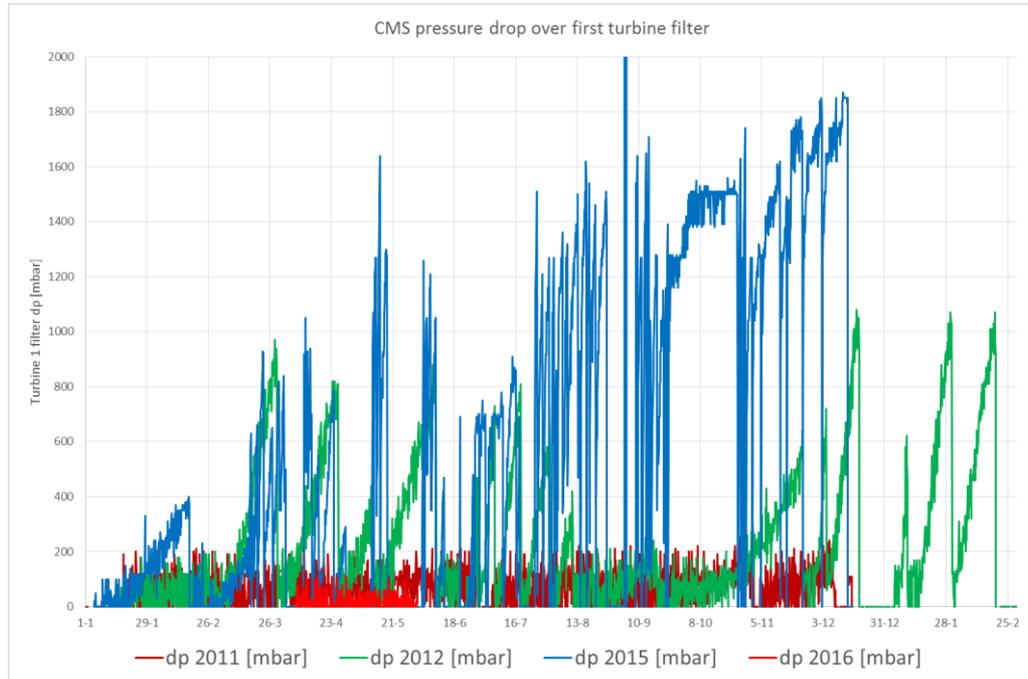
Filter clogging

- Impurities passing the 80 K adsorbers will clog the turbine inlet filters.
 - This happens regularly
 - Small quantities of impurities are sufficient.
 - In case of gaseous impurities, filter warm-up removes the clogging agent.
 - In case of liquid impurities a persistent Δp off-set usually remains

ATLAS filter clogging 2011 to 2015



CMS filter clogging 2011 to 2015



Impurities conclusion

- We live with impurities
 - Valid for all our installations
 - The absence of an adapted handling system for gaseous impurities is a nuisance.
- Oil impurities in 2015 were **NOT** limited to CMS.
 - We have seen the same effect in much smaller scale at ATLAS.

Topics

- Introduction ATLAS and CMS
- Operation history 2011, 2012, 2015
 - Availability data
 - Reasons for down time
 - Impurities and filter clogging
 - Inbuilt impurity handling
 - Filter clogging development 2011, 2012/13, 2015
- Oil contamination 2015
 - Identified reason
 - Realised modifications

Oil contamination 2015

- The identified reason for the peak of oil contamination is a bad choice of the adsorbent material of the final oil adsorber.
 - During the long shut-down in 2013 / 2014 all oil adsorbers were equipped with this adsorbent in the frame of preventive maintenance.
 - The adsorbent material was changed from activated charcoal (coconut shell based) to activated coal (anthracite based)
 - Reasons were cost driven combined with a total lack of understanding.
 - We only noticed this change in late summer 2015.

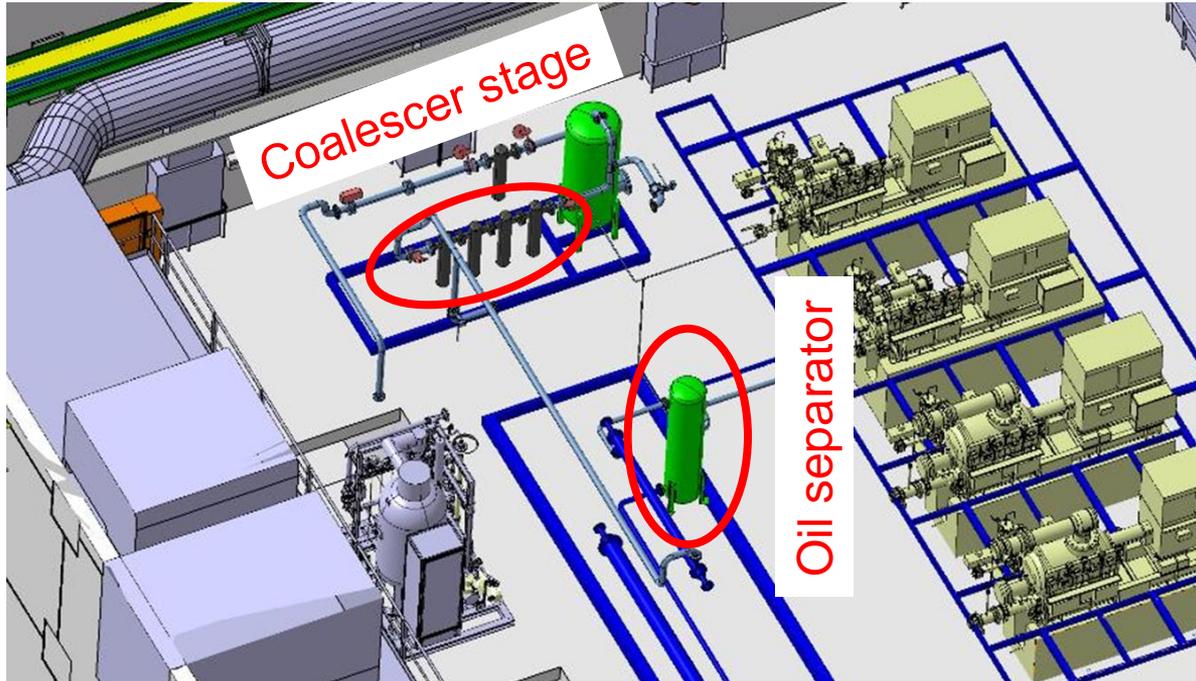
Oil contamination 2015

- The reason why the ATLAS system suffered much less lies in the difference of the respective oil treatment systems up stream of the adsorber.
 - No unplanned down time due to oil contamination
- Installations with well performing oil separators and coalescers suffered little.
- Unfortunately the separator coalescer units for CMS were the worst ever receptioned at CERN.

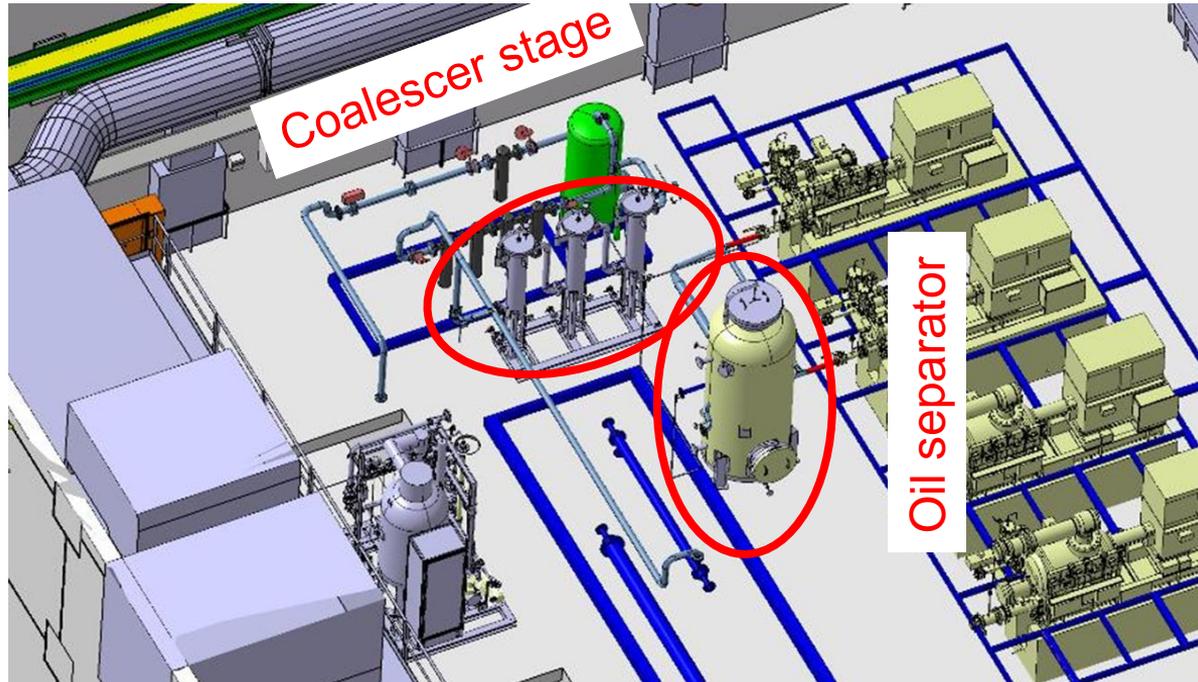
Realised modifications at CMS

- Exchange of the adsorbent material
 - As well for ATLAS
- Exchange of the final oil separator and coalescer stages.
 - We really wanted to be on the safe side:
 - We consciously over specified the amount of circulating oil.
 - We asked for a generous design leading to low oil carry over from the separator.

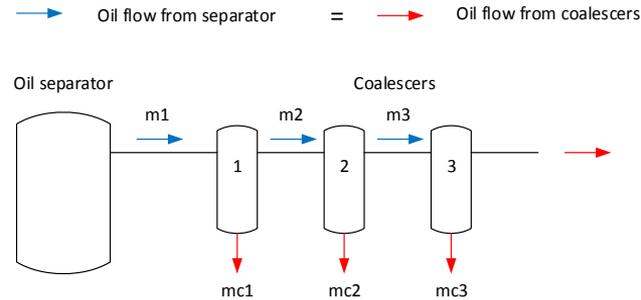
Original CMS oil removal system



New CMS oil removal system



Measurement of oil carry over



- Oil carry over from the separator.
 - $m1 = mc1 + mc2 + mc3$
 - CERN specification < 100 ppm mass
 - Original system ~ 750 ppm mass
 - New system ~ 20 ppm mass

Conclusions

- What did we learn?
 - For cryogenic systems that are supposed to accumulate long periods of uninterrupted operation, 80 K adsorbers need a means to be regenerated during the run.
 - Be weary in case different / cheaper alternatives for spares or replacement material is proposed.
 - The final oil separator is an important element in the final oil removal system.
 - The bad performance of a separator cannot be recovered by adding coalescers.
 - We seriously consider to tighten the specified limit of 100 ppm mentioned above.