LHC Cryogenics

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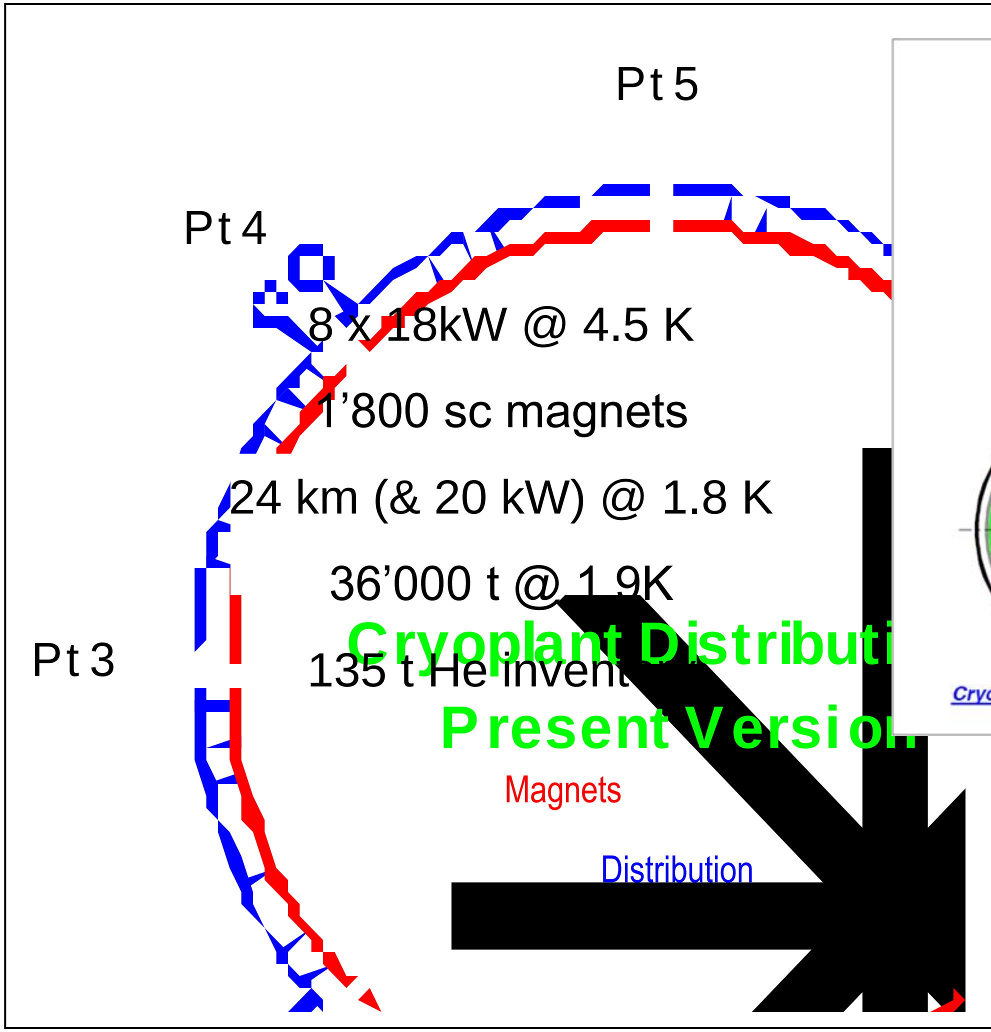
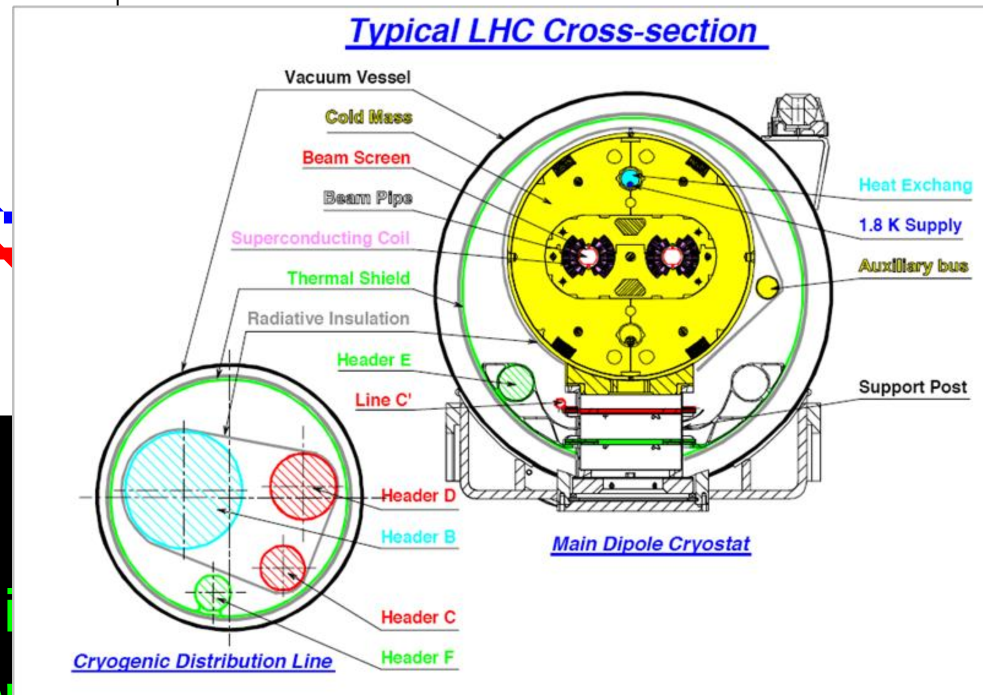
LHC Cryogenic Operations

Content

- Introduction (s)
- Tools and Results pre-LS1
- Specific evaluation for rotating machinery
- Work done during LS1
- Post-LS1 ideas
- Summary

LHC cryogenics distribution scheme



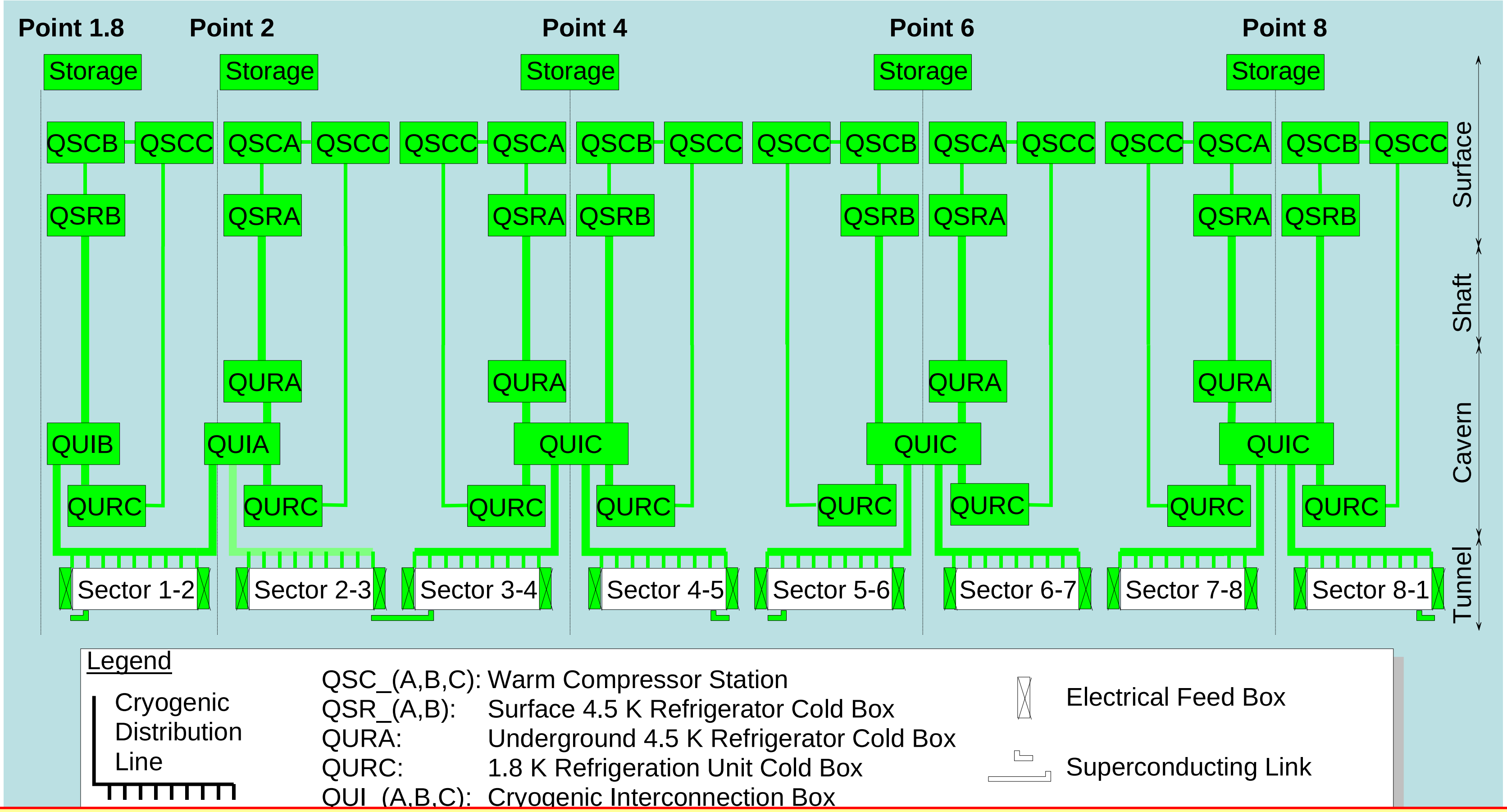


5 sites equiped with refrigerators

Separate cryoline

Standard cooling cell: 107m

LHC Cryogenics architecture

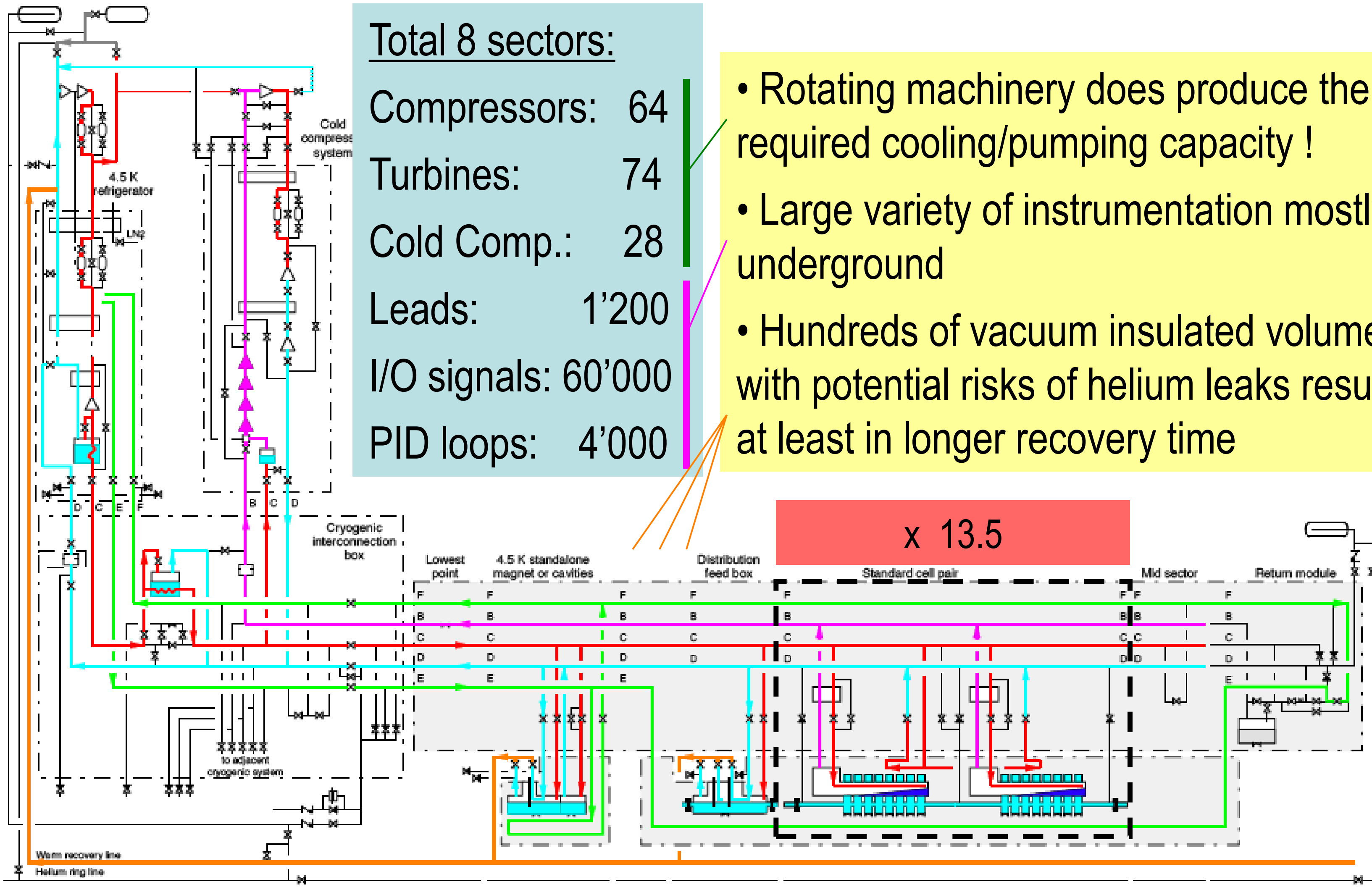


Large variety of configuration, with provision to use 1 cryoplant on 2 sectors for helium management and up to “low intensity” physics

(Flexibility in case of failure of a component, already used before LS1)

LHC Cryo-OP

1/8e of LHC: production-distribution-magnets



Total 8 sectors:

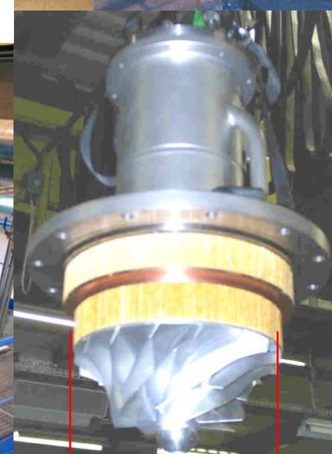
Compressors:	64
Turbines:	74
Cold Comp.:	28
Leads:	1’200
I/O signals:	60’000
PID loops:	4’000

- Rotating machinery does produce the required cooling/pumping capacity !
- Large variety of instrumentation mostly underground
- Hundreds of vacuum insulated volumes, with potential risks of helium leaks resulting at least in longer recovery time

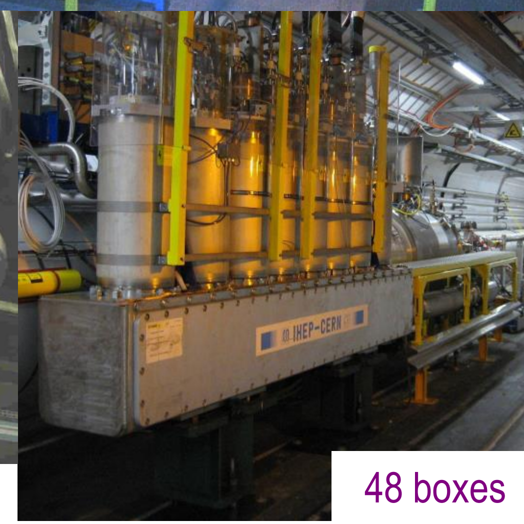
Selection of typical LHC cryogenic hardware

33 kW @ 50 K to 75 K - 23 kW @ 4.6 K to 20 K - 41 g/s liquefaction

4.2 MW



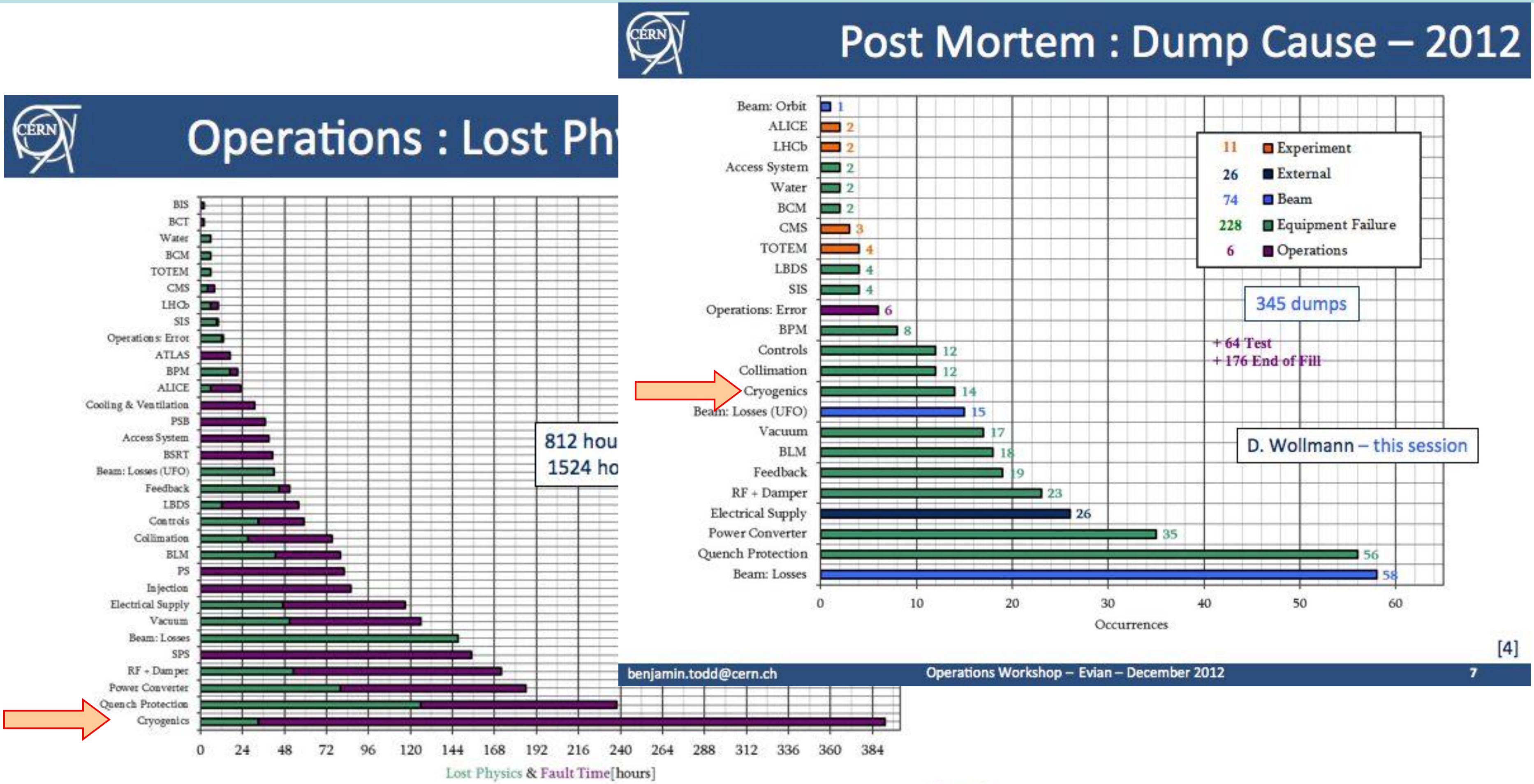
Diam: 250mm



48 boxes

Cryogenics seen by others !

LHC Cryo-OP



“ The one at the bottom of the list,
despite significant progress in reducing their number of faults “

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Availability: a signal Yes/No is required

T2 = Achieved up time during required time / Required time x 100 (operational availability)

T2 indicator w.r.t EN 15341

CM
CS
SP — set-point
CS
CM

Cryo Maintain: Few important conditions checking integrity of HW, with slow power abort in case this signal is lost (leading to beam dump!)

SP: set-point

Cryo Start: set of conditions to allow powering of concerned sub-sector, with no action if powering started (illustrates good stability of process)

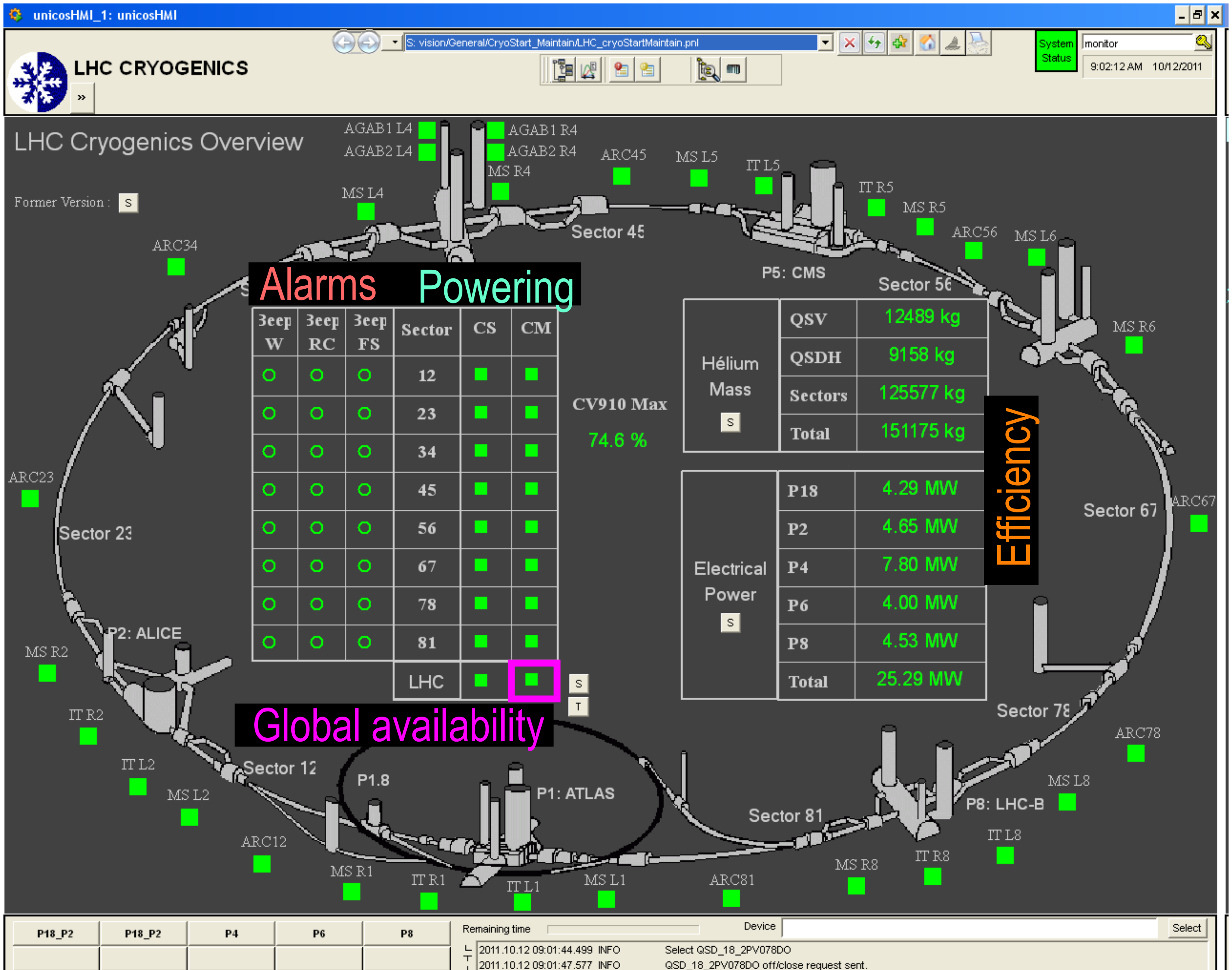
- We were not obliged to do so !

(could wait to be asked for explanation…)

- We decided to be pro-active and take our responsibilities, without much help/tools.
- Performance monitoring is already giving you some incentive to improve !!!

Possibility to treat thousands of channels in a structured way to match at best the LHC powering sub-sectorisation and the cryo sub-sectorisation

Operation, indicators

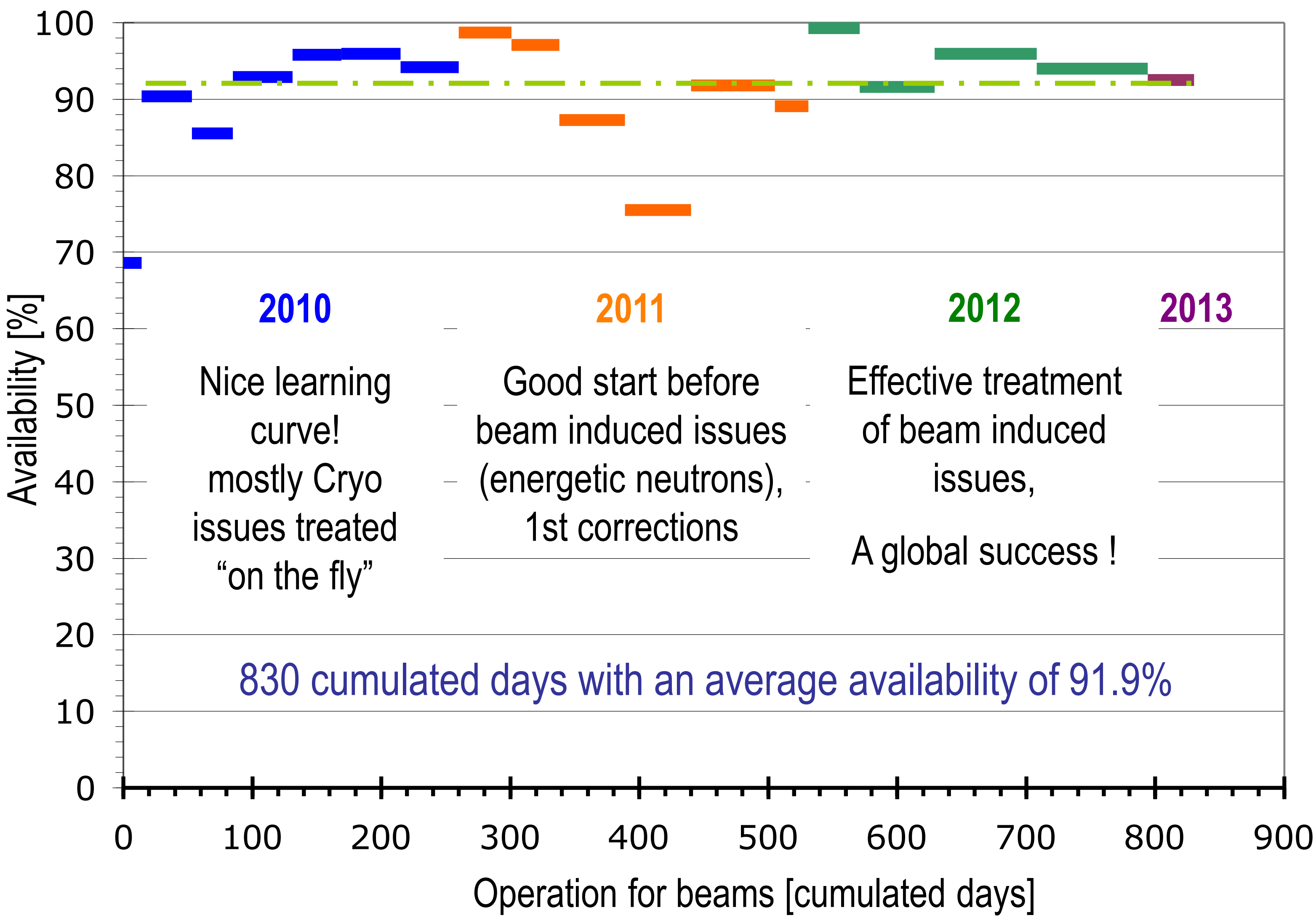


Tools so far

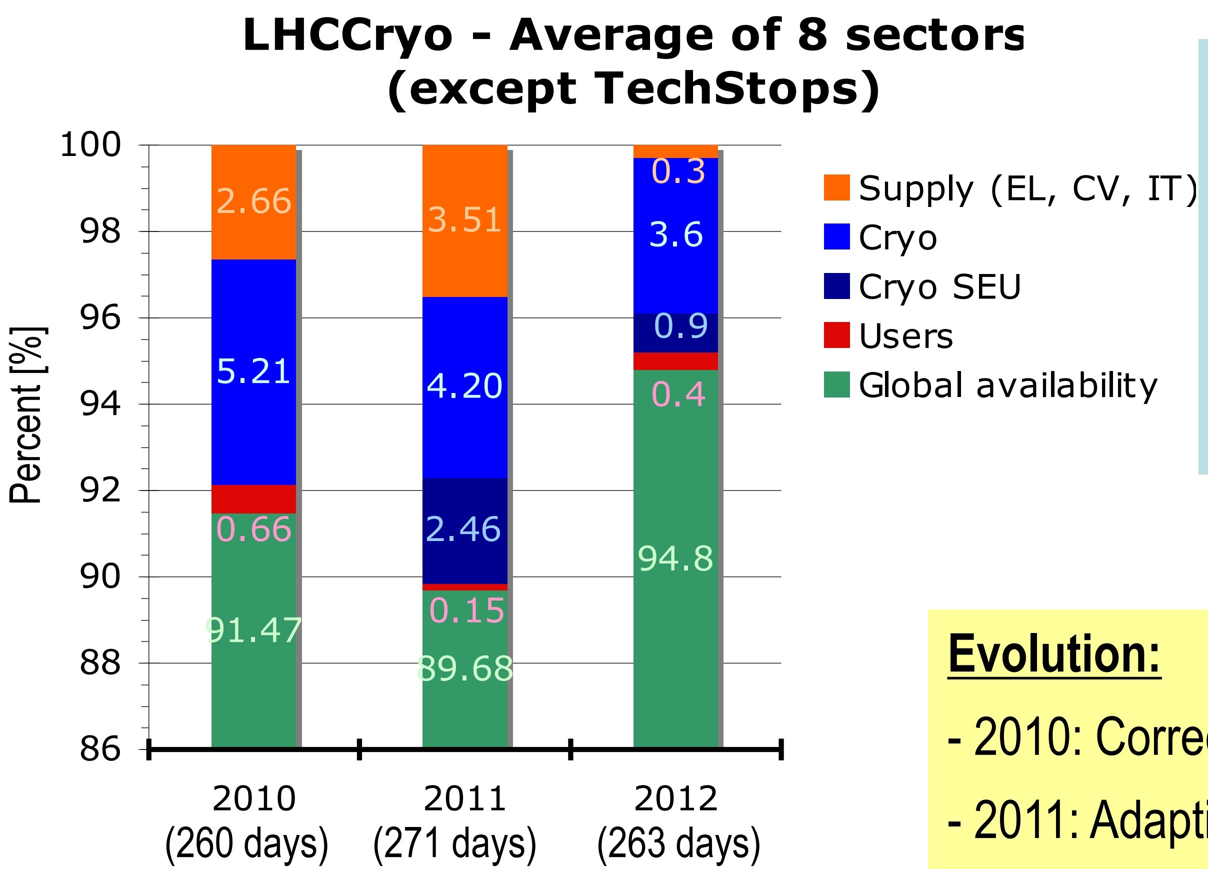
- Criterion OK-NotOK in real time (Cryo_Maintain)
- E-Logbook (manual entries so far) to keep track of facts and trigger a follow-up
- Losses of CM logged globally and for each sector (XL), with systematic evaluation of root-cause [1] and validation by cryo_OP leaders [2]
- Bi-weekly TE-CRG review with support teams and management to address issues a.s.a.p
- Stops of cryoplants (long stops) logged separately (XL) and treated with high priority

The best we could do "on-the-fly" without programmers nor DB specialist in our team, but already valuable for results and illustration of what should be done!

LHC Cryo global availability



Performance and origin of downtine



(Full days, Mondays & Fridays of Technical Stops not counted here)

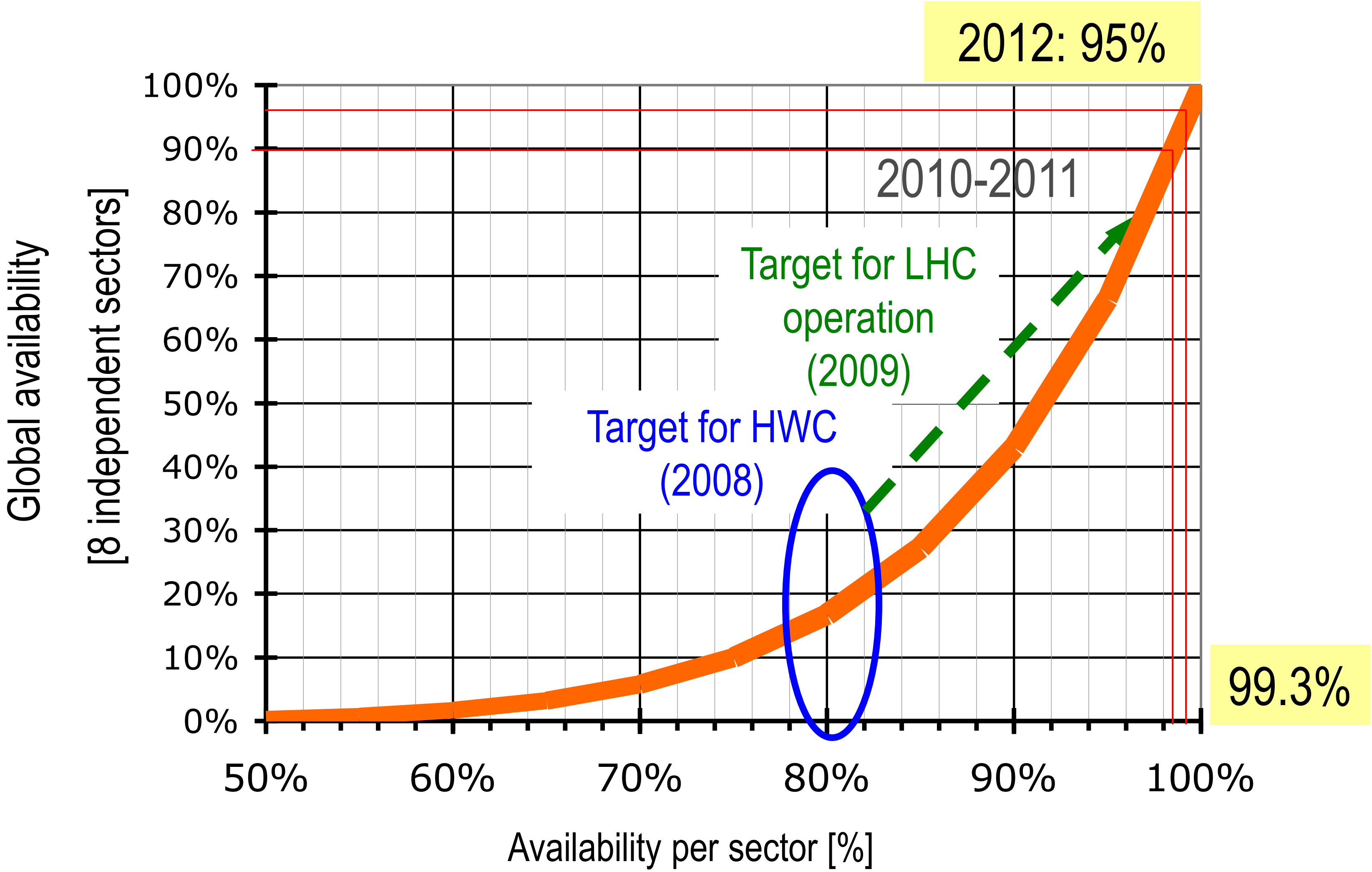
Global availability
as seen by LHC during beam operation periods

Others
according to relative ratio of their average for the 8 sectors

Evolution:

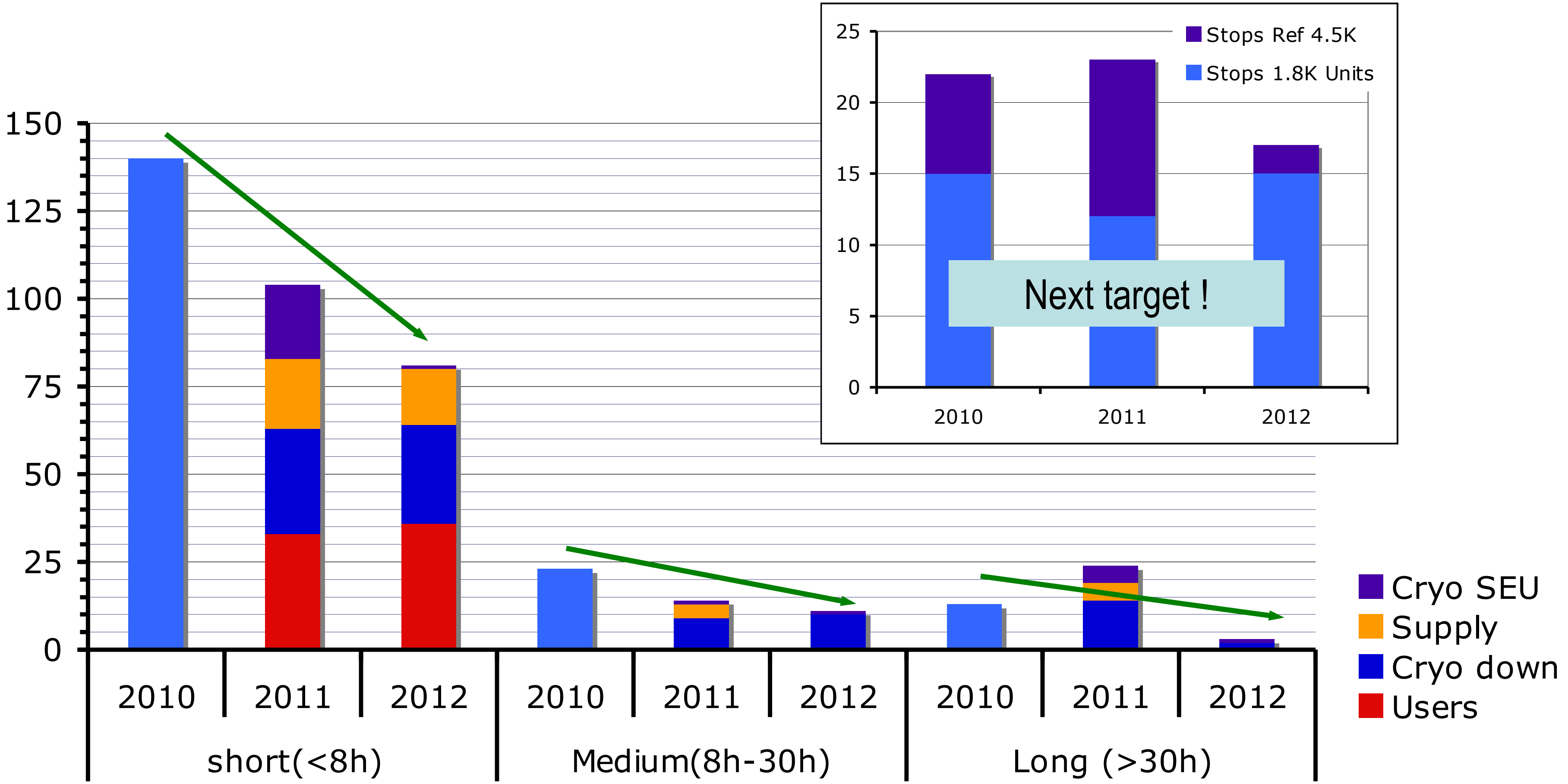
- 2010: Correcting early Cryo bugs
- 2011: Adapting to SEU (corrected @Xmas)
- 2012: Outstanding performance !

Availability



Much better than expected, but big incentive to keep going !

Systematic analysis of downtime



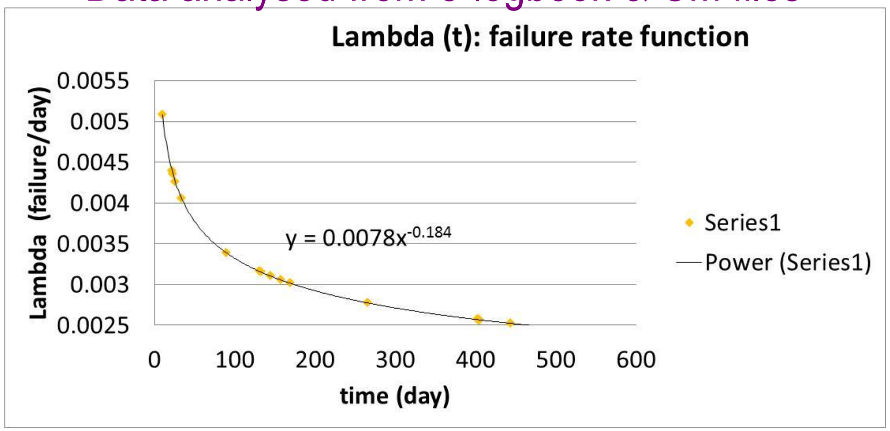
From the books:

Immediate effect of (good!) practice	Annoying if frequent, to be kept low with moderate efforts	Serious cases requiring specific monitoring and significant efforts

Criticality Analysis

- Summer student: Jimmy MARTIN
  - Functional analysis
  - Critical analysis

Data analysed from e-logbook & CM files



- Presentation by Jimmy 1stNov'12

  Available via web OA-CryoLHC-Doc

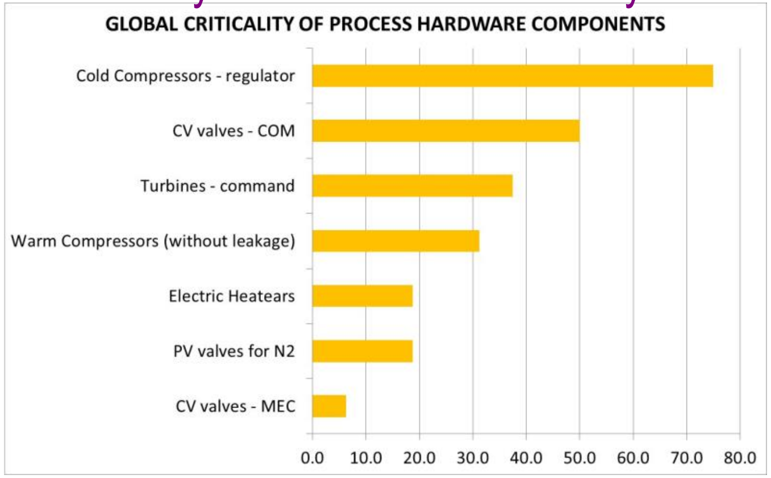
Occurence

Failure rate	N < 10	10 ? N < 20	20 ? N < 30	30 ? N
Decrease				
Stable				
Moderate increase				
Serious increase				

Severity

	T < 8h or CM=1	8h ? T < 18h	18h ? T
CM=0' <2			
2 ? 'CM=0' < 4			
4 ? 'CM=0'			

Criticality = Occurrence x Severity



- Being continued:
  - Analysis by individual failure mode for few significant components
  - Cryo-Maintain loss table to be detailed down to component failure (mode)

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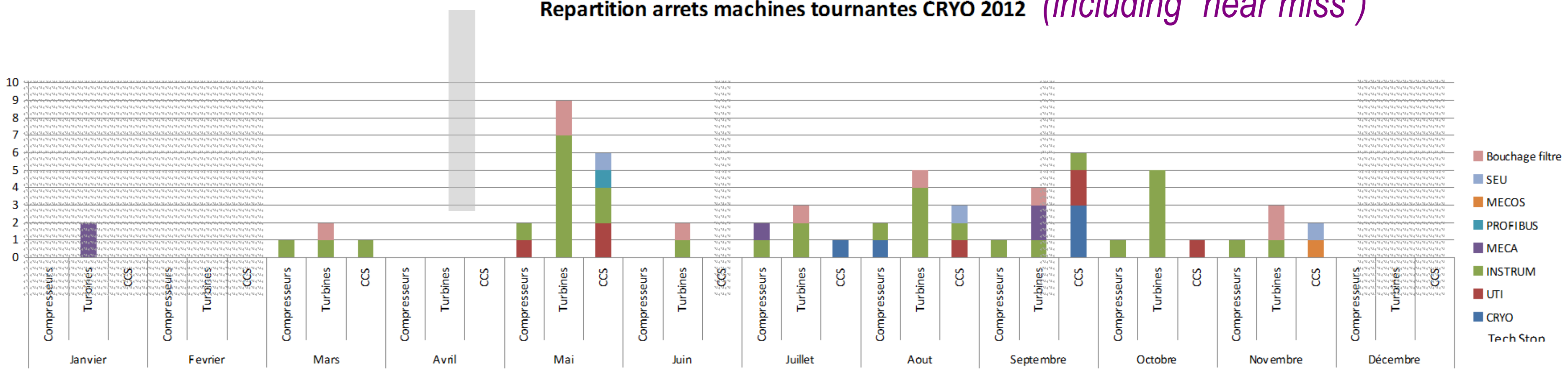
Rotating machinery

Operating LHC at 6+ TeV will induce more resistive heat loads (x4), and beam parameters for increased luminosity will as well induce more dynamic heat loads, resulting in less capacity margin (still below installed capacity!).

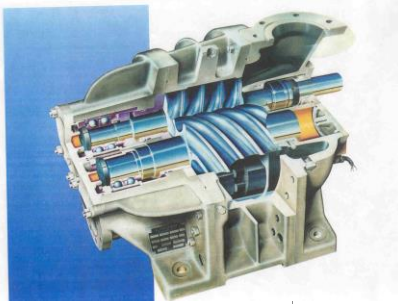
Cooling capacity is directly associated with rotating machinery

(including "near miss")

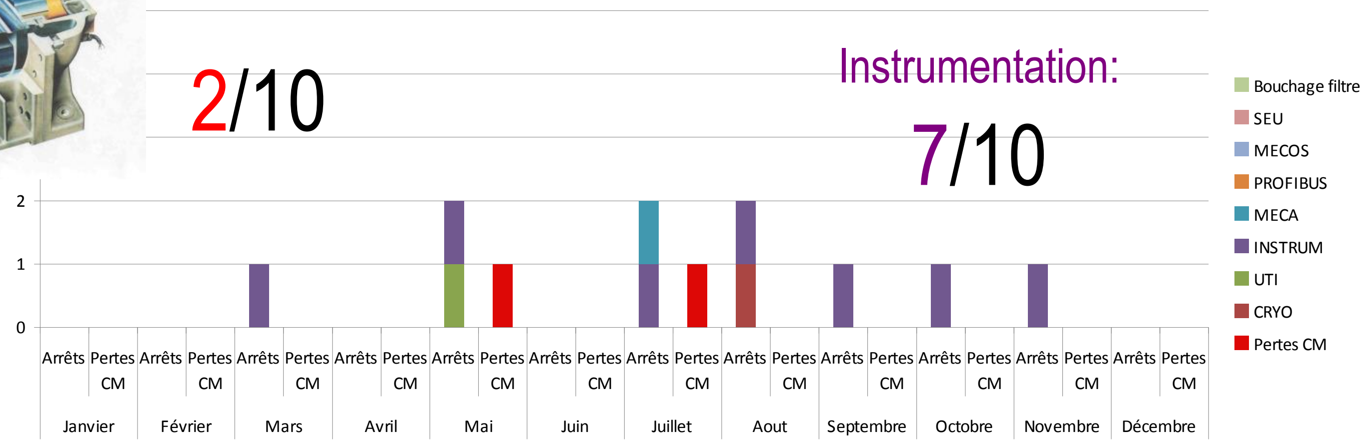


Analysis performed by Eric Duret-Bourgoz

Screw Compressors + motors



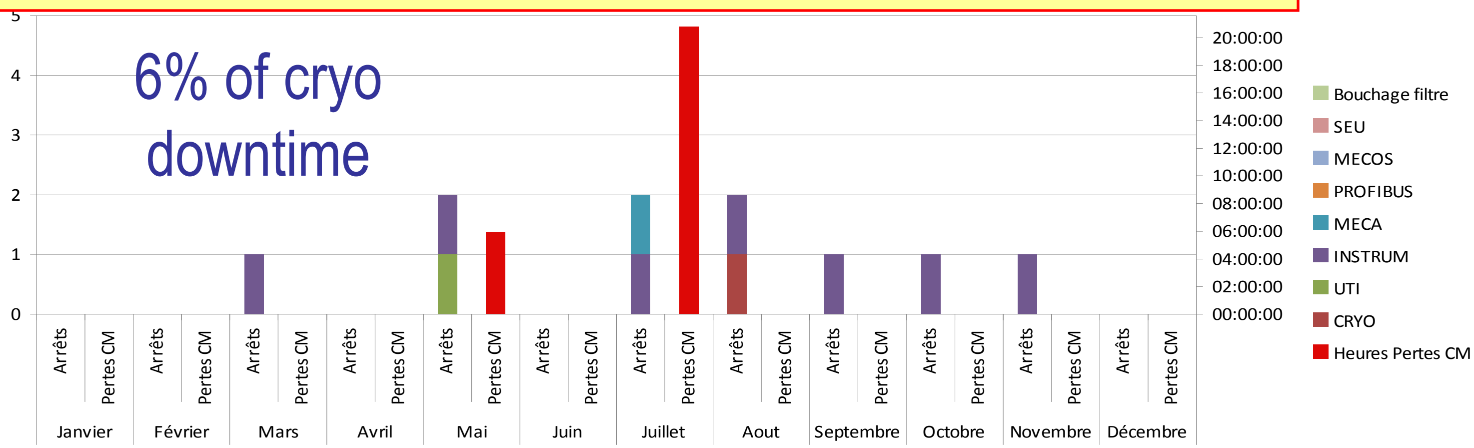
Nb Arrêts compresseurs vs Nb Pertes CM 2012



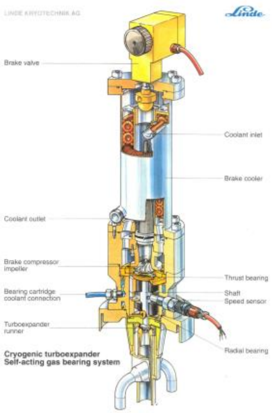
How far were the "near" miss cases ?!?

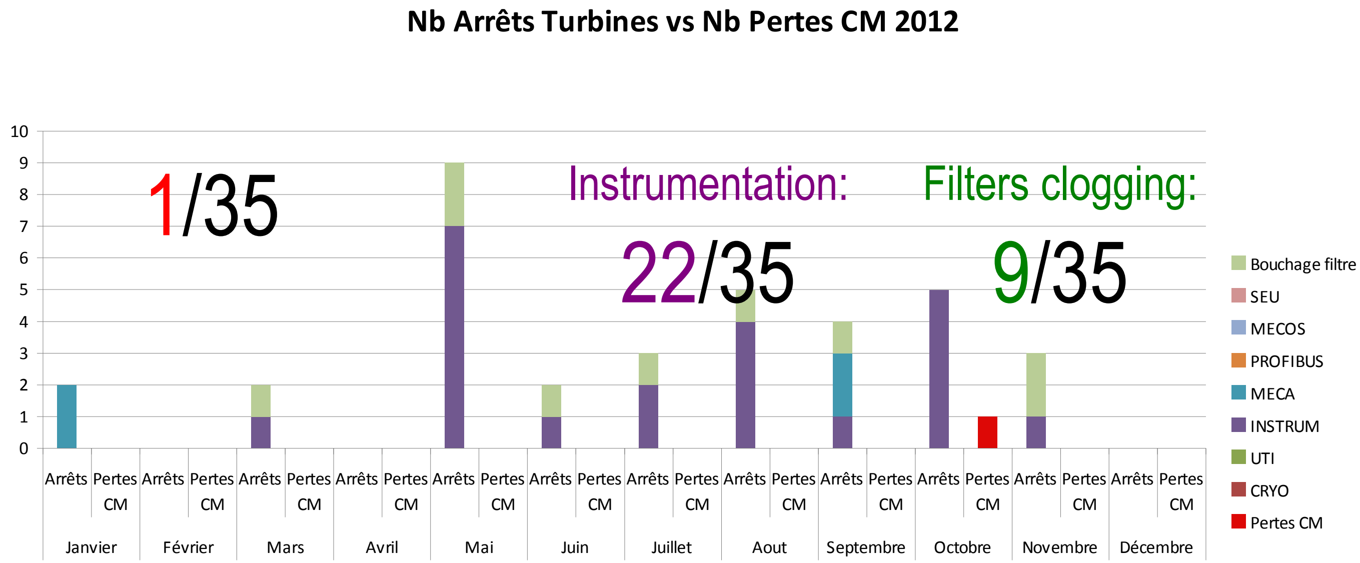
Nb Arrêts compresseurs vs Heures Pertes CM 2012

With less margin, some compressors could become more visible

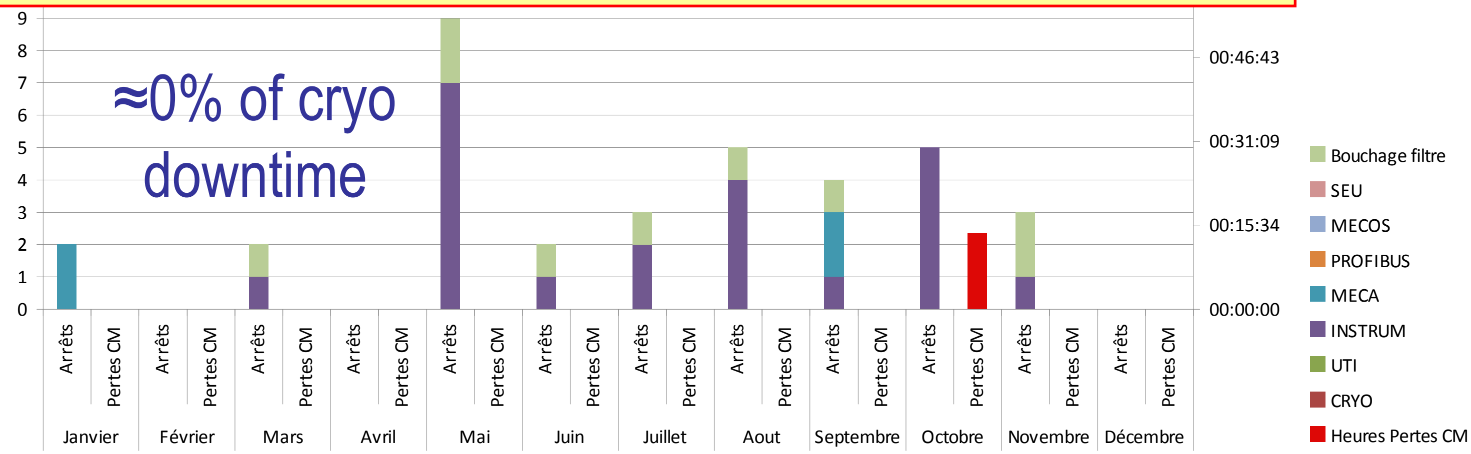


Turbines

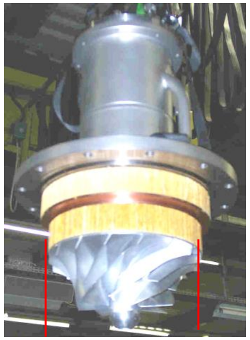




Low temperature turbines issues might become more visible



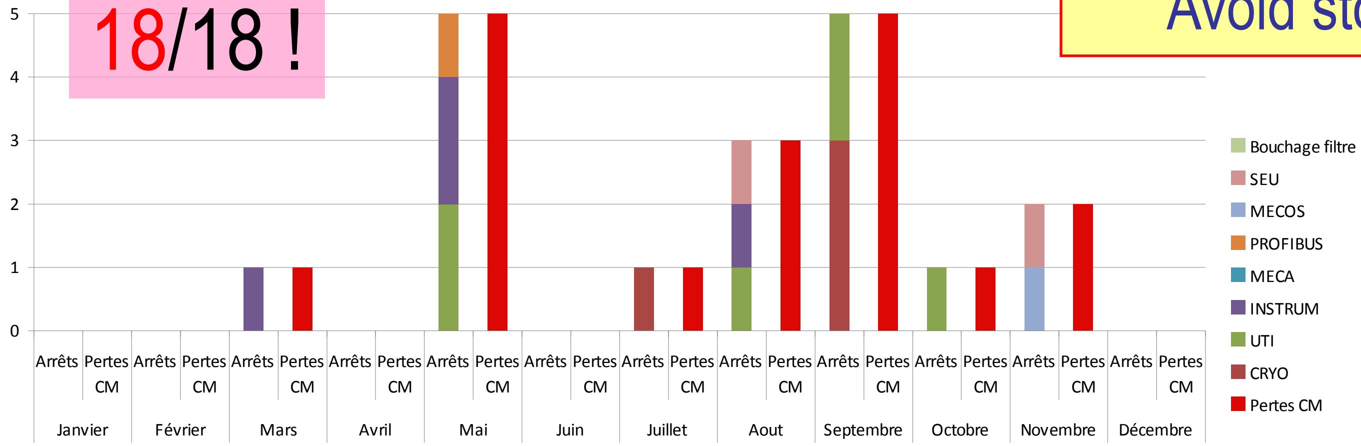
Cold Compressors



Diam: 250mm

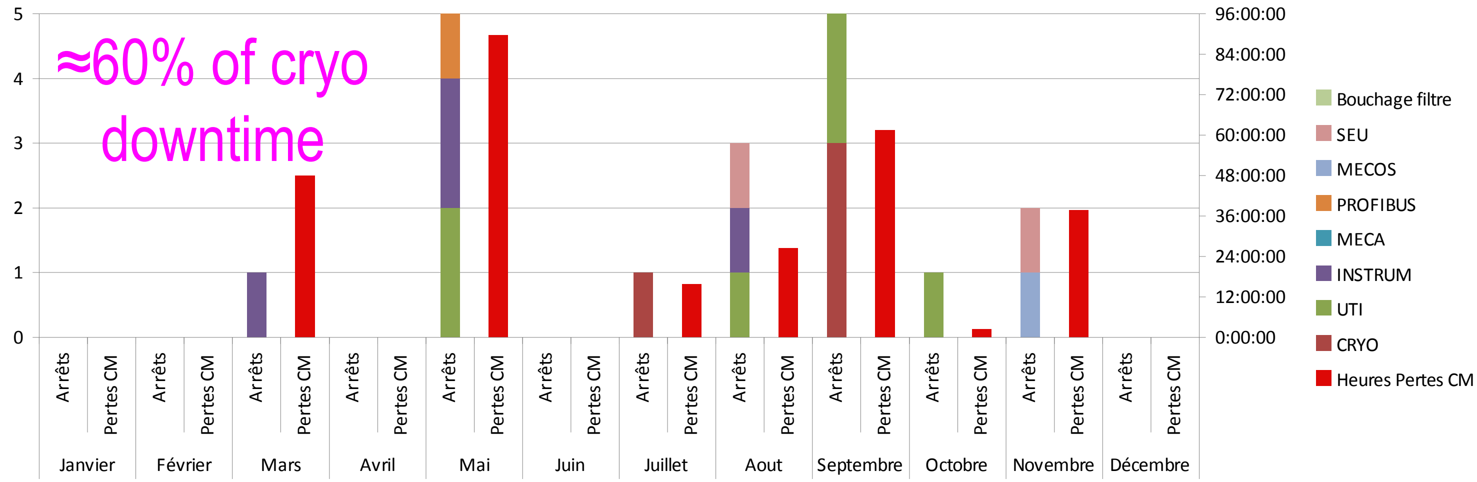
Nb Arrêts CCS vs Nb Pertes CM 2012

18/18 !



Only one way out:
Avoid stops !

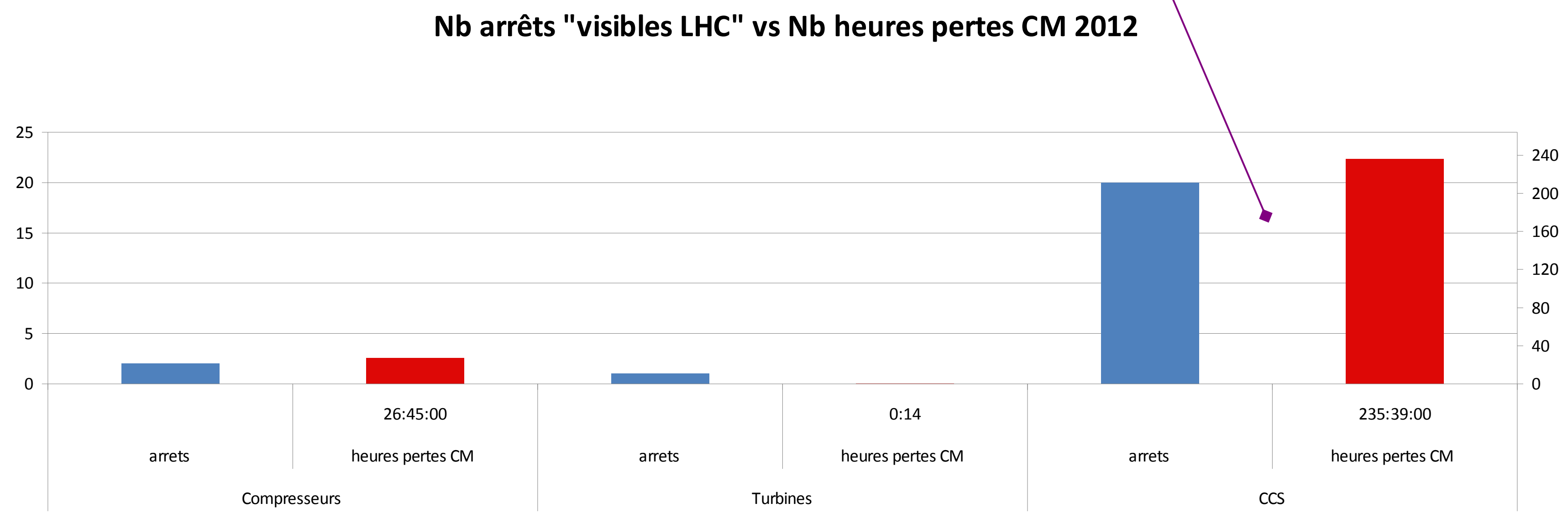
≈60% of cryo downtime



Downtime related to rotating machinery

Multiple efforts to help reducing cold-compressors related failures:

- Machinery (bearings maintenance + periodic checks)
- Process controls algorythms
- Magnetic bearings HW and cabling
- R2E (P4, P8) on crucial elements



Failures of rotating machinery will be more visible, with impact on availability (short term) or physics capacity (medium term).

For long term: on the shelve spares exists now for all type at cern: screw compressors, turbines, cold compressors (10 to 100hrs to restore original capacity)

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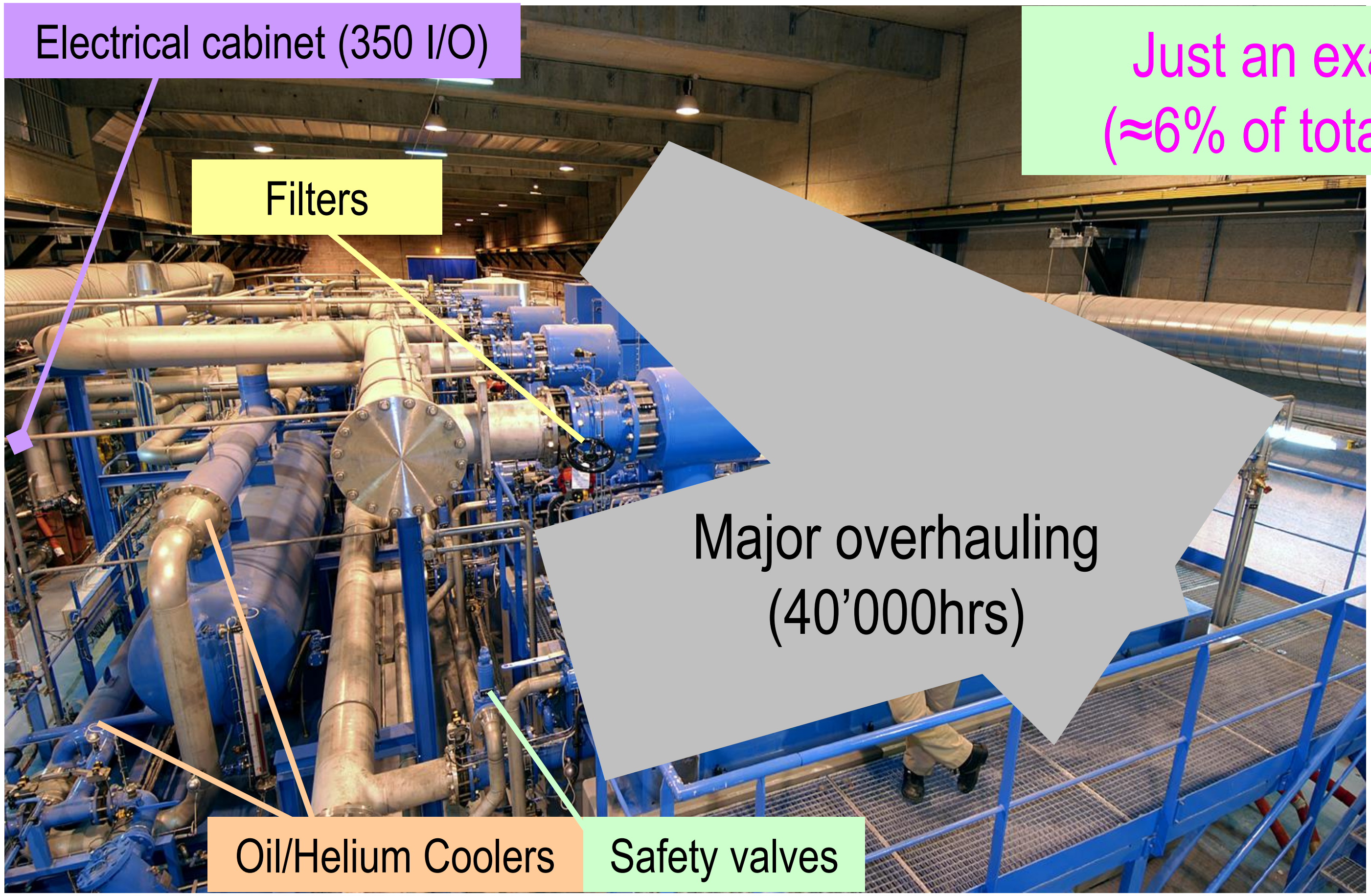
Maintenance



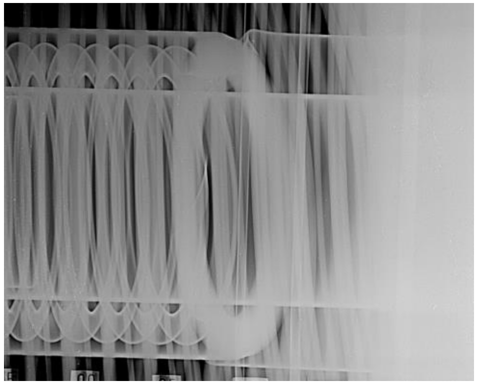
Just an example
(≈6% of total work)

This should help global availability post-LS1
(after possible adjustments in 2014)

Leaks

- Refrigerators (QSR's)

- Main cryogenic distribution line (QRL)



- Electrical feedboxes (DFB's)

As before LS1, should not have impact on recurrent availability
(or a big one !)

Consolidations

- Helium ring line:
  - Remote handling of sectorisation valves (safety improvement)
- Access to cryo valves (tunnel):
  - Platforms for hundreds of service modules, with improved access to air valves involved in “cryo lock-out”
- Cold compressors (bearings + electronics):
  - \+ + New version of magnetic bearings controler, powering/connectors re-inforced against EMC
- EL/CV works:
  - \- 3.3kV monitoring and tolerance to glitches: more rational approach (HW safety) but possible impact on availability
  - Back-up towers to allow at least 1 cryoplant/site all the time
- Remote resets & R2E works:
  - \+ + + New steps (P4) and provisions (P6, P2)

The net result should be positive

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Sensitivity to post-LS1 beams

- Higher energy:
  - x4 heat load (Ri2 with ix2), towards nominal
- Higher luminosity:
  - Local impact expected (inner triplets)
- Lower bunch spacing (25ns):
  - Identified valves changed not to limit performance
  - Significant effect expected during scrubbing runs
  - No effect expected during "physics" operation
- Expected effect: periodic capacity change
  - Cabled signal "ramp" expected to help tuning cryo-controls

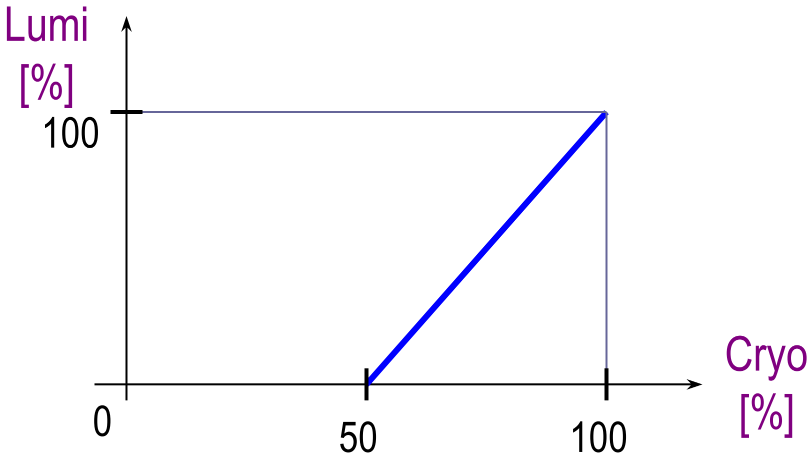
=> We should be able to handle the corresponding transients

Less capacity margin = installed-required, sensitivity to previous "near-miss"

Possible future availability follow-up

- Cryo_Maintain based availability monitoring [as for pre-LS1]
  - Integration into "LHC_wide" availability monitoring possible

- To be completed by a 0-100% coefficient for available capacity:
  - 100% cryo capacity [by default]
  - Various % decrease depending on faulty sub-system
  - Transfer function to max. luminosity

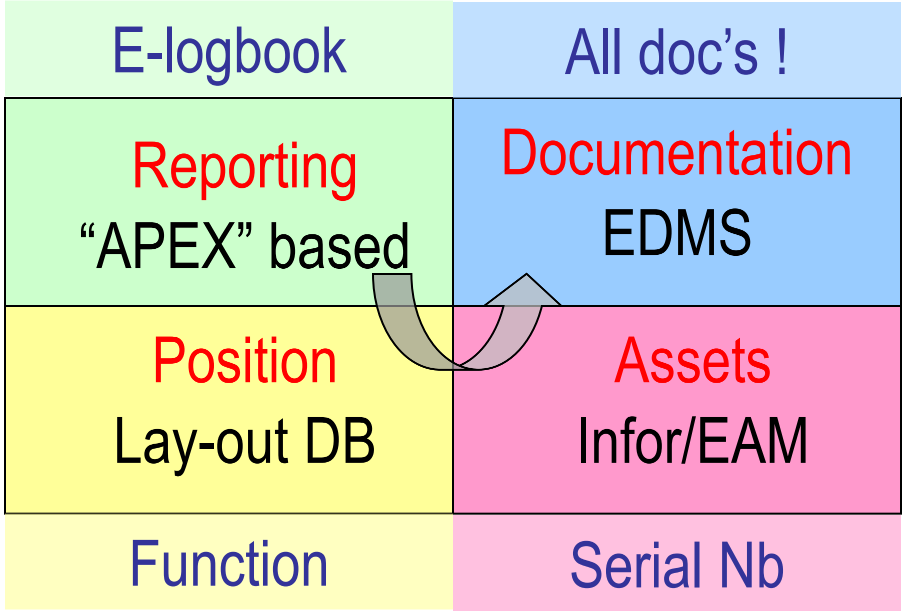


In case of limitation in capacity/luminosity, there could be some interest for beam related activities (MD's?) while preparing for intervention …

Tracking tools *(preliminary)*

Imagination of a non-specialist convinced that appropriate use of modern tools could help!

It helped to link issues in e-logbook [operations] to functions pre-defined as "positions" for diagnostics [expert support teams] , this could be extended for failure modes [av%], or interventions [wo]



LHCCryo, Dec2013

	Cryoplants	Cryo-tunnel
Meca	t.b.d	-
Elec	Basics	Moderate
Instrum	t.b.d	Detailed

Once "positions" will be populated with "assets", all required data will exist to link operation failures down to components failures, allowing efficient statistics (and improvements) !

We will soon investigate further !

Summary

- Pre-LS1 results:
  - We are satisfied with achieved availability, with home-made methodology and tools that have allowed us to progress
- LS1 activities:
  - Various Maintenance & Consolidations to help
- Post-LS1 expected consolidations:
  - "ramp" signal for improved cryo-controls for variable capacity
  - Modernised e-logbook including specific fields for Cryo-Maintain losses and associated component failure modes
  - Possible integration in LHC global availability matrix, methods and tools

+ Estimated future availablity: 2015: 90% - 2016: 92% - 2017: 95%