BE-ICS openlab activities around Data Analytics and Machine Learning

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CERN-Siemens openlab collaboration

- CERN collaboration with ***Siemens*** since 2011 to work in areas of common interest:
  - Evolution of SCADA systems
  - IoT, machine learning and data analytics
- 2 fellow positions fully funded by Siemens
- Knowledge sharing between Siemens and CERN

Big Data for Industrial Controls

Exploit the Big Data volume produced by our systems to:

- Reduce operational and maintenance costs
  - Anticipate when sensors and actuators have to be replaced
  - Detect anomalous behavior and over-usage of industrial devices
- Make our control systems smarter
  - Detect symptomatic effects in the data which do not trigger alarms
  - Guide engineers and operators to take corrective actions
- Optimise process stablility
- Assist during system engineering

Control System

Data Analytics

The two faces of Data Analytics

In the cloud

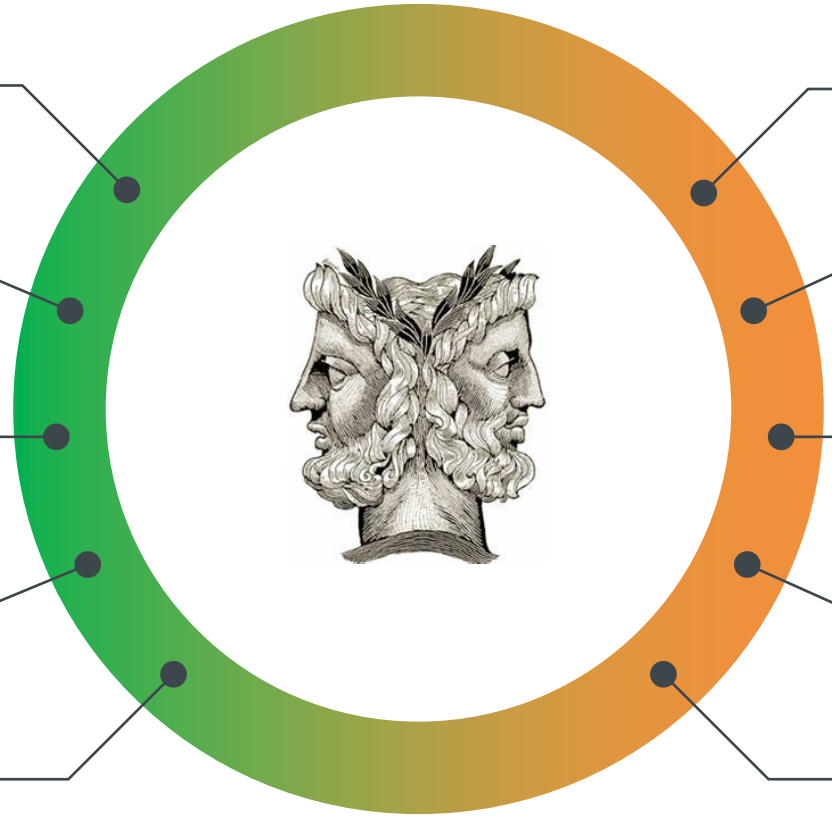
Archived data

Research and development

State-of-the art analytics & AI

☐ Infrastructure available

☐ Well established workflows



At the edge

Live streaming data

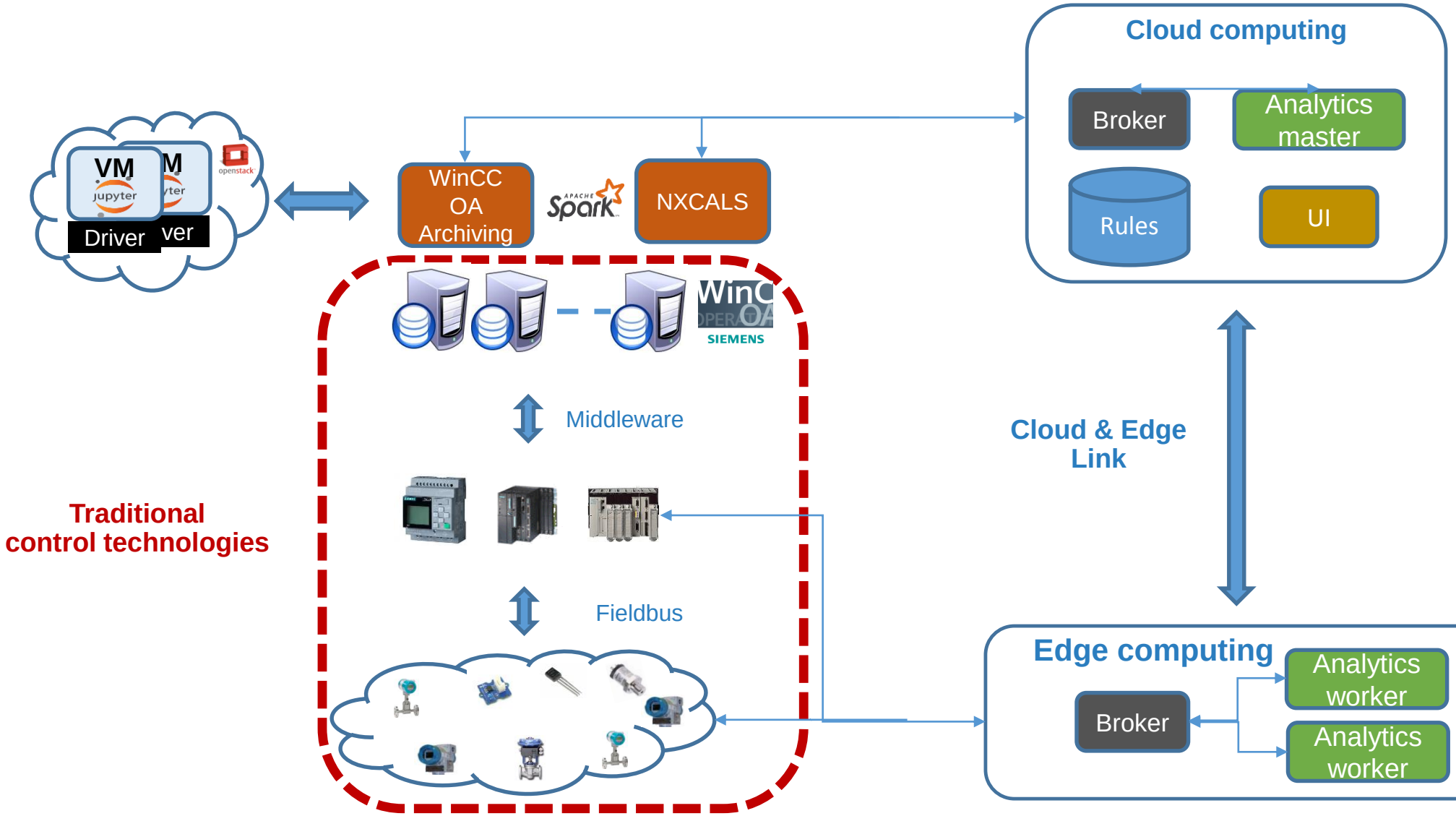
Operations and production

Process control, KPIs

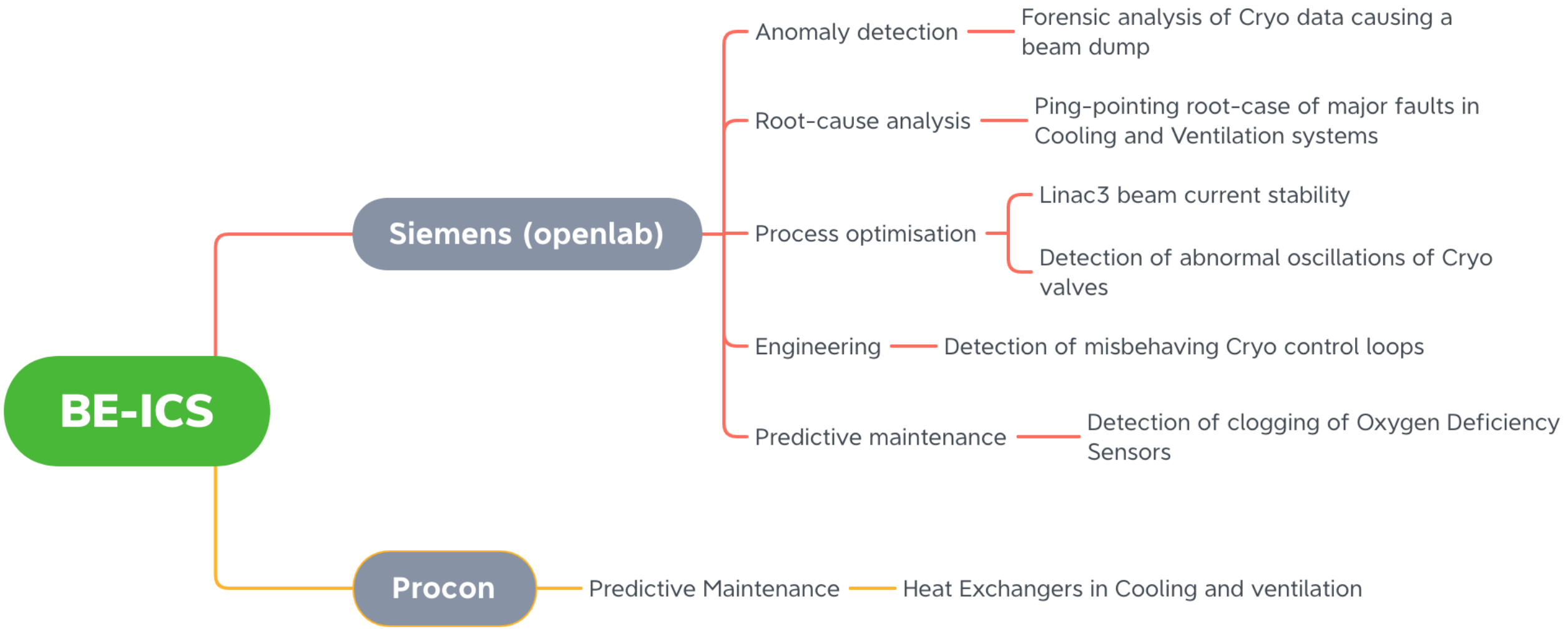
Lacking infrastructure ☒

Only timid efforts so far ☐

Our vision


Cloud computing
Broker
Analytics master
Rules
UI
VM
jupyter
openstack
Driver
WinCC OA Archiving
Spark
NXCALS
SIEMENS
Middleware
Fieldbus
Traditional control technologies
Cloud & Edge Link
Edge computing
Broker
Analytics worker
Analytics worker

BE-ICS Activities



UC1: Oscillation analysis for cryogenics valves

Goal: detect anomalous oscillation of valves

- Lifespan of valves in km!

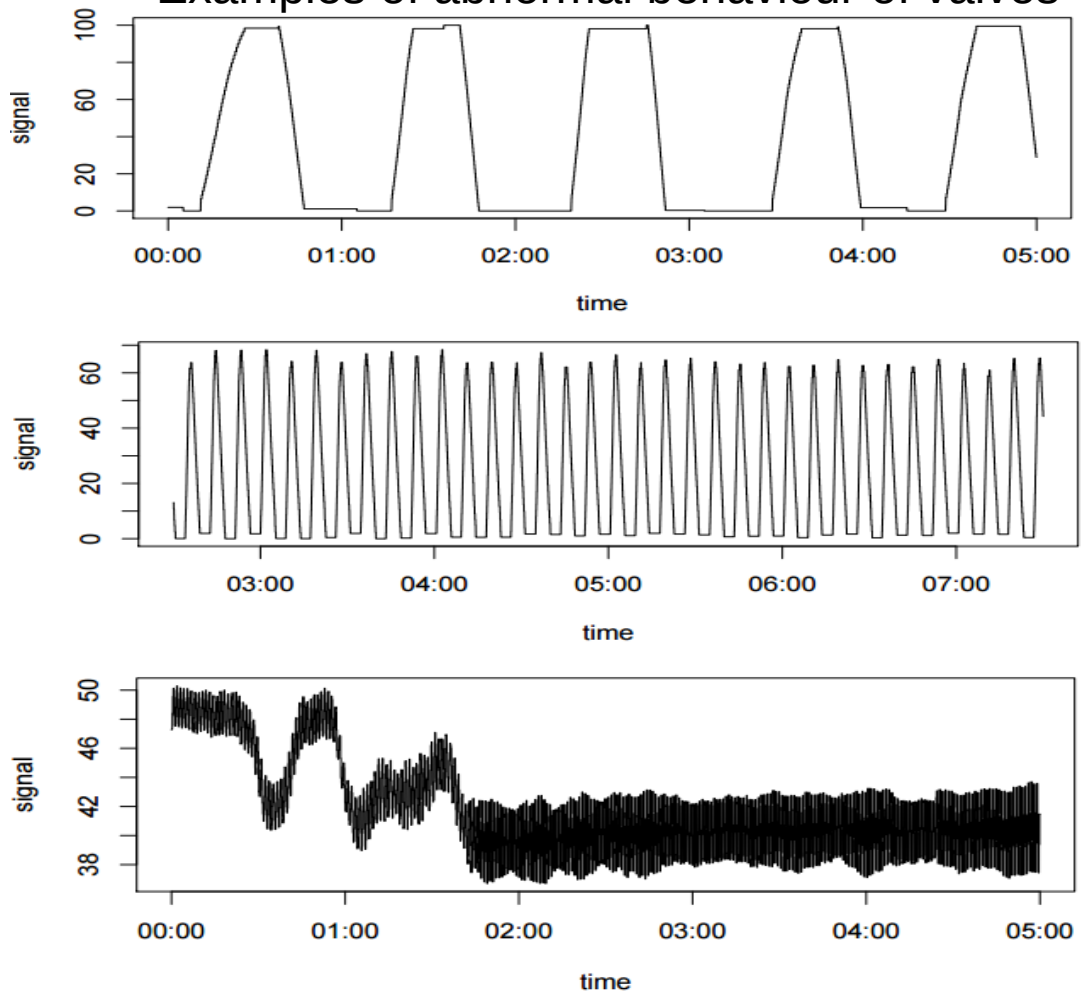
Impact on:

- Process system stability and safety
- Communication load
- Maintenance (overuse of valves)
- Performance (Physic time)

Why data analytics?

- General algorithm to detect different oscillations
- Monitoring several thousands of signals (not manually!)
  - Over 34000 physical instrumentations and channels
    - 12136 AI, 4856 AO,4536 DI,1568 DO,8000 spare and virtual channels, ~4000 analogical control loops
  - More than 120 PLCs
    - Siemens S7-416-2DP,30000 conceptual objects/parameters

Examples of abnormal behaviour of valves



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UC2: Anomaly detection in CRYO signals

Presence of different anomalies not detected by the control systems!

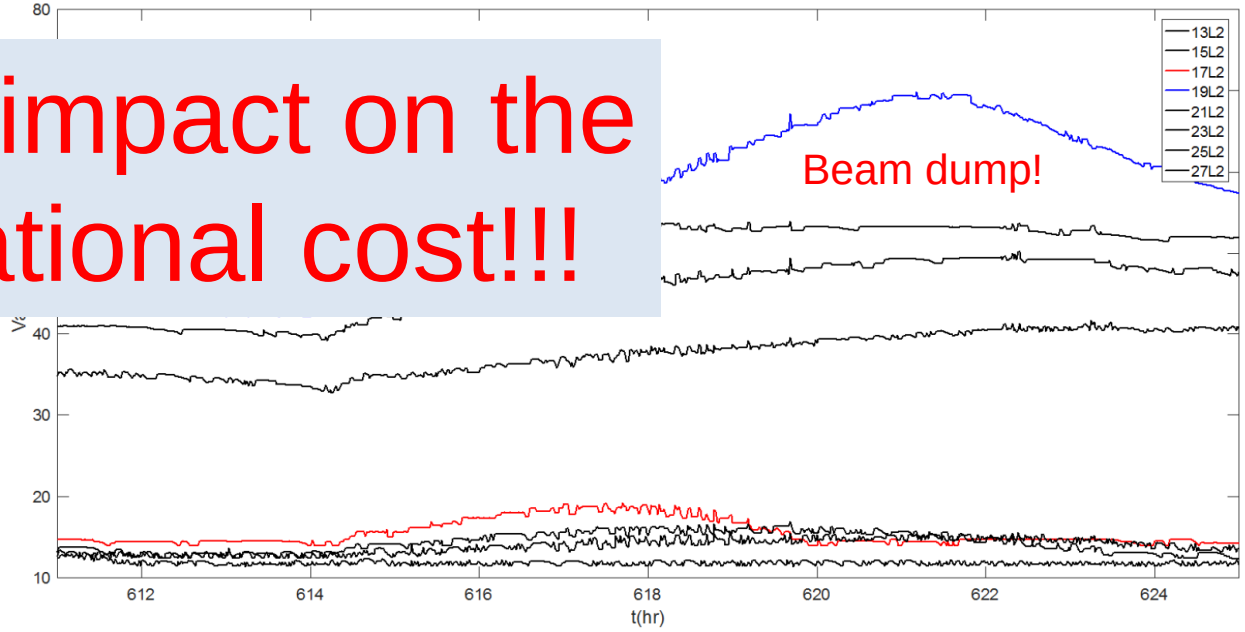
Possible causes:

- hardware failures/degradations
- wrong tuning/structure
- false measurements…

Impact

- Process stability and safety
- Maintenance (overuse of valves)
- Performance and downtime

Valves CV910 positions in L2 (26th June 2017)



Direct impact on the operational cost!!!

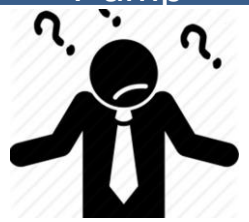
Why data analytics?

- Too complex to embed calculations into the control systems
- Learn from historical data the group of signals with similar behaviour

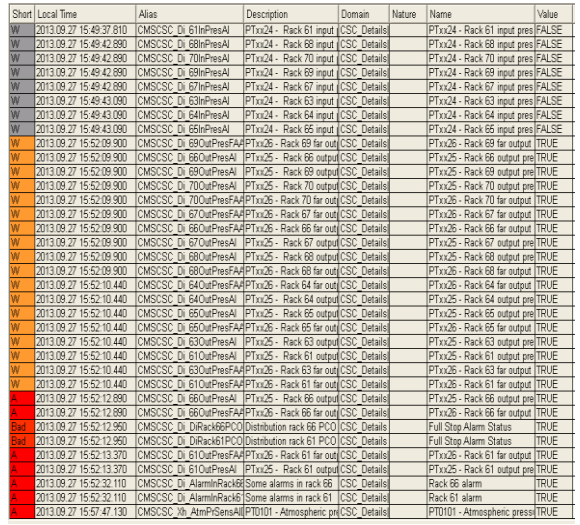
UC4: Root-cause analysis in Experiments Gas Control Systems

Diagnose Alarm flood

Misleading feedback! Actual problem in the distribution and not in the Pump



Domino effect



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W	2013.09.27 15:49:42.890	CMSCSC_Di_68InPresAl	PTxx24 - Rack 68 input	CSC_Details		PTxx24 - Rack 68 input pres	FALSE
W	2013.09.27 15:49:42.890	CMSCSC_Di_70InPresAl	PTxx24 - Rack 70 input	CSC_Details		PTxx24 - Rack 70 input pres	FALSE
W	2013.09.27 15:49:42.890	CMSCSC_Di_69InPresAl	PTxx24 - Rack 69 input	CSC_Details		PTxx24 - Rack 69 input pres	FALSE
W	2013.09.27 15:49:42.890	CMSCSC_Di_67InPresAl	PTxx24 - Rack 67 input	CSC_Details		PTxx24 - Rack 67 input pres	FALSE
W	2013.09.27 15:49:43.090	CMSCSC_Di_63InPresAl	PTxx24 - Rack 63 input	CSC_Details		PTxx24 - Rack 63 input pres	FALSE
W	2013.09.27 15:49:43.090	CMSCSC_Di_64InPresAl	PTxx24 - Rack 64 input	CSC_Details		PTxx24 - Rack 64 input pres	FALSE
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W	2013.09.27 15:52:09.900	CMSCSC_Di_66OutPresAl	PTxx25 - Rack 66 output	CSC_Details		PTxx25 - Rack 66 output pre	TRUE
W	2013.09.27 15:52:09.900	CMSCSC_Di_69OutPresAl	PTxx25 - Rack 69 output	CSC_Details		PTxx25 - Rack 69 output pre	TRUE
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A	2013.09.27 15:52:13.370	CMSCSC_Di_61OutPresAl	PTxx25 - Rack 61 output	CSC_Details		PTxx25 - Rack 61 output pre	TRUE
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⊗ **Fault in the distribution system**

Alarms flooding

- **Diagnosing a fault is complex:** it may take weeks!
  - Alarms flood: a single fault can generate up to thousands of events
  - The 1st alarm is not necessarily the most relevant for the diagnosis
  - The same fault generates different events sequence depending on the system status
  - A single fault can stop the whole control process

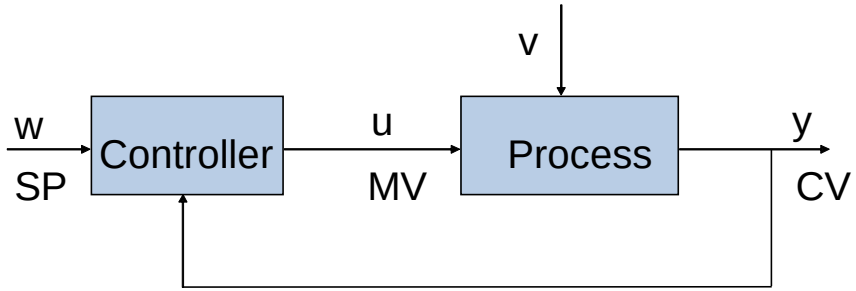
UC5: Evaluation of PID performance

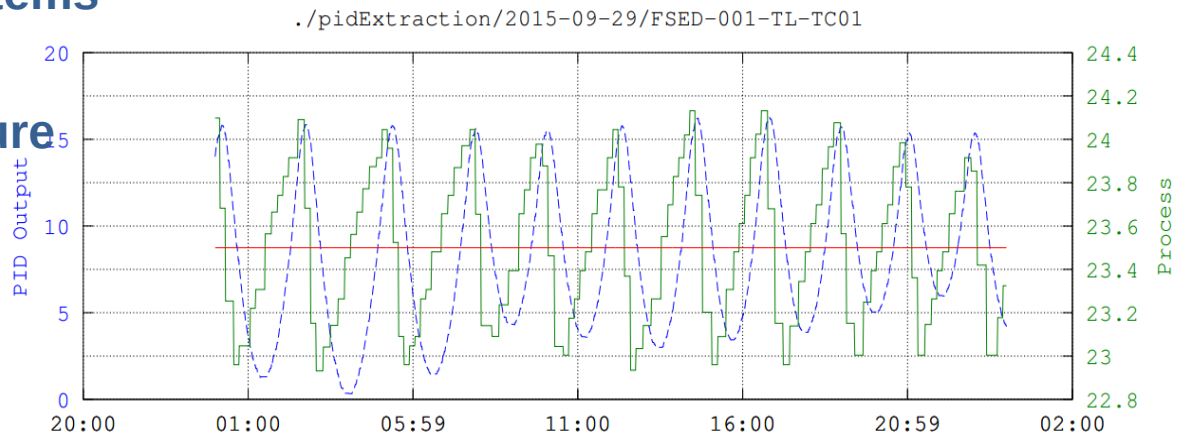
Assist system engineering

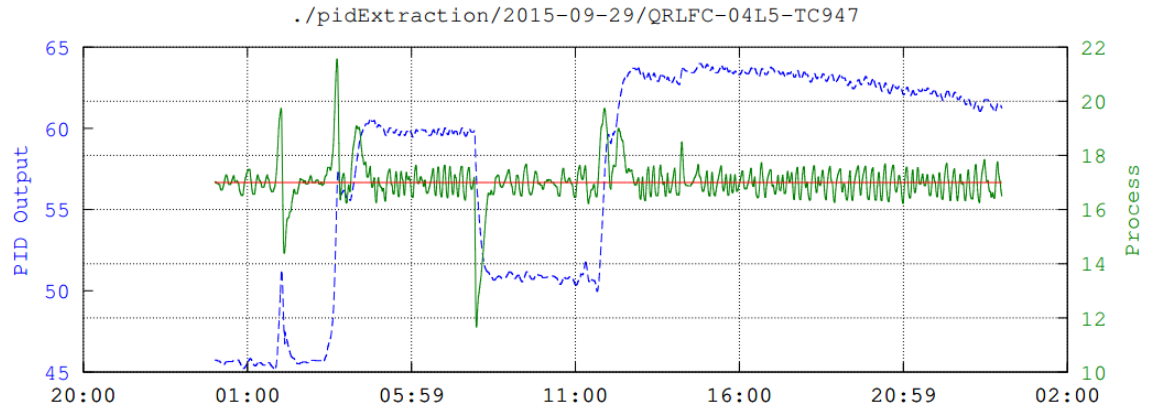
BE-ICS in collaboration with the University of Valladolid (*not an openlab activity with Siemens*)

Based on: "Performance monitoring of industrial controllers based on the predictability of controller behaviour", R. Ghraizi, E. Martinez, C. de Prada

- **Impact on the regulation of the entire control systems**
- **Too many PIDs to check manually!**
- **A general method to assess different PIDs structure**
- **Many sources of faults/malfunctions**
  - System status dependency
  - External disturbances/factors
  - Bad tuning/Wrong controller type/structure
  - Slow degradation







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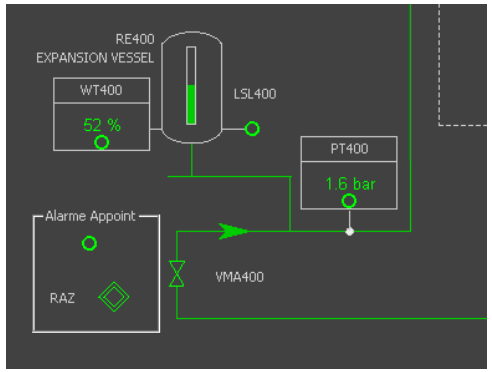
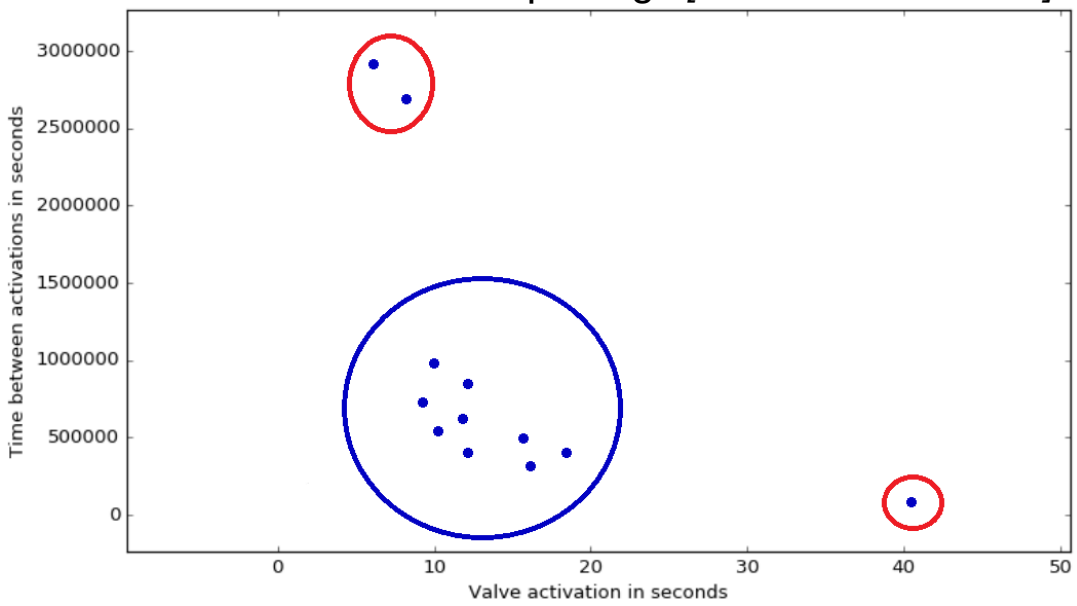
UC6: Leak detection in Cooling and ventilation systems

- Problem:
  - Manually set alarms thresholds
  - Changing filling conditions
- Anomaly detection based on historical data
  - Detection of “large” leaks:
    Anomalous valve opening time
  - Detection of “small” leaks:
    Anomalous frequency of valve openings
- Achievements:
  - Identification of anomalous behaviours
  - Improving thresholds setting

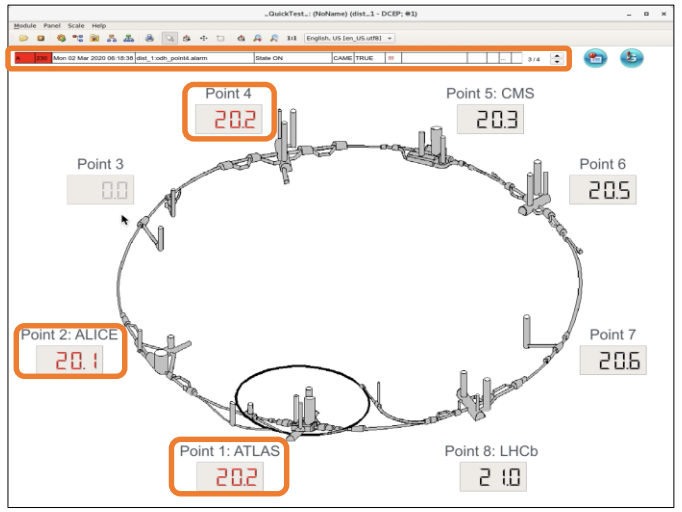


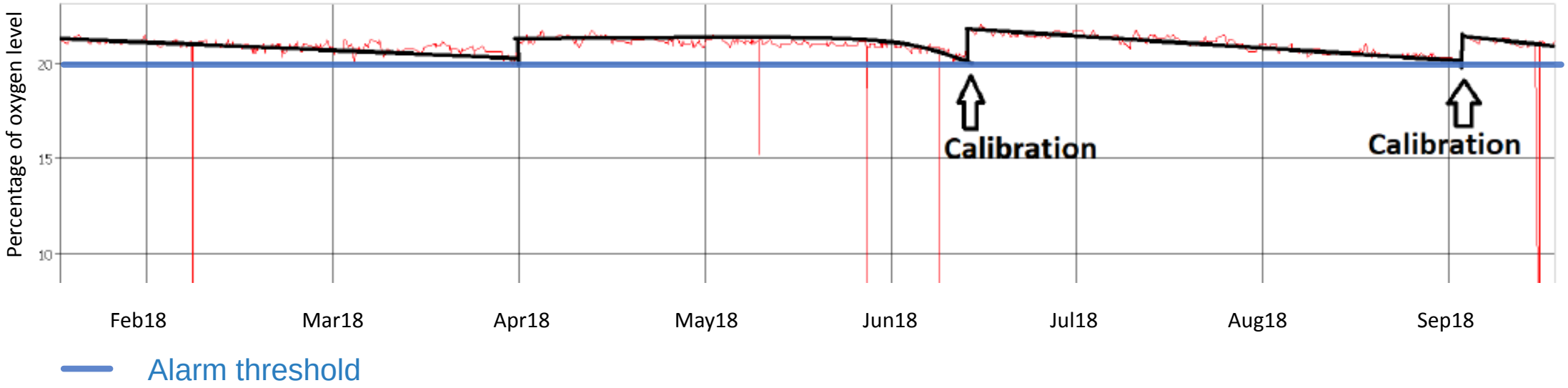
Distribution of valve openings *[FSED_001_VMA400]*



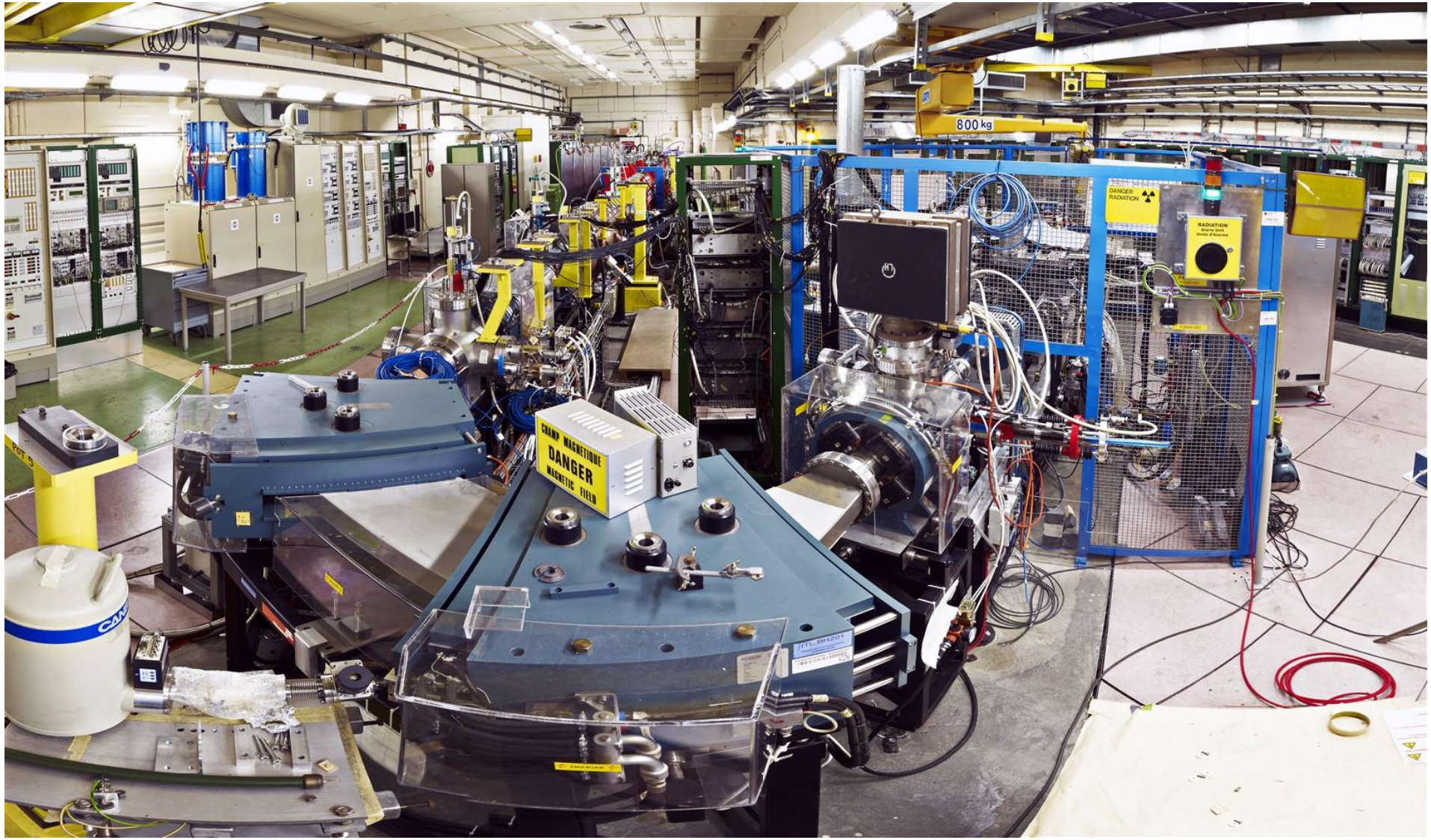
O_2 level monitoring in the LHC tunnel

- 378 oxygen sensors are spread across LHC tunnel
- Periodically sensors get clogged
- We want to avoid false alarms
- Anticipate when recalibration is required

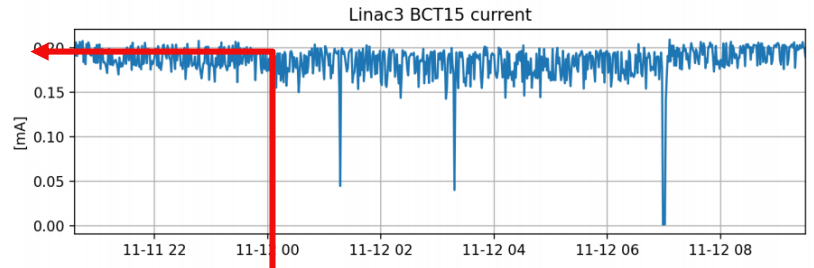


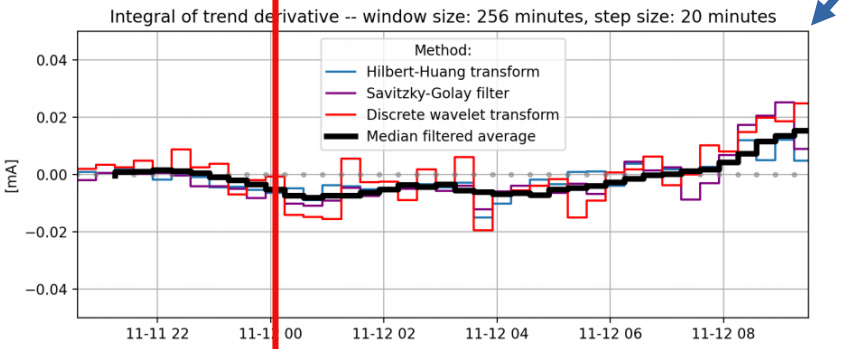


LINAC3 heavy ion beam



Predicting LINAC3 beam current



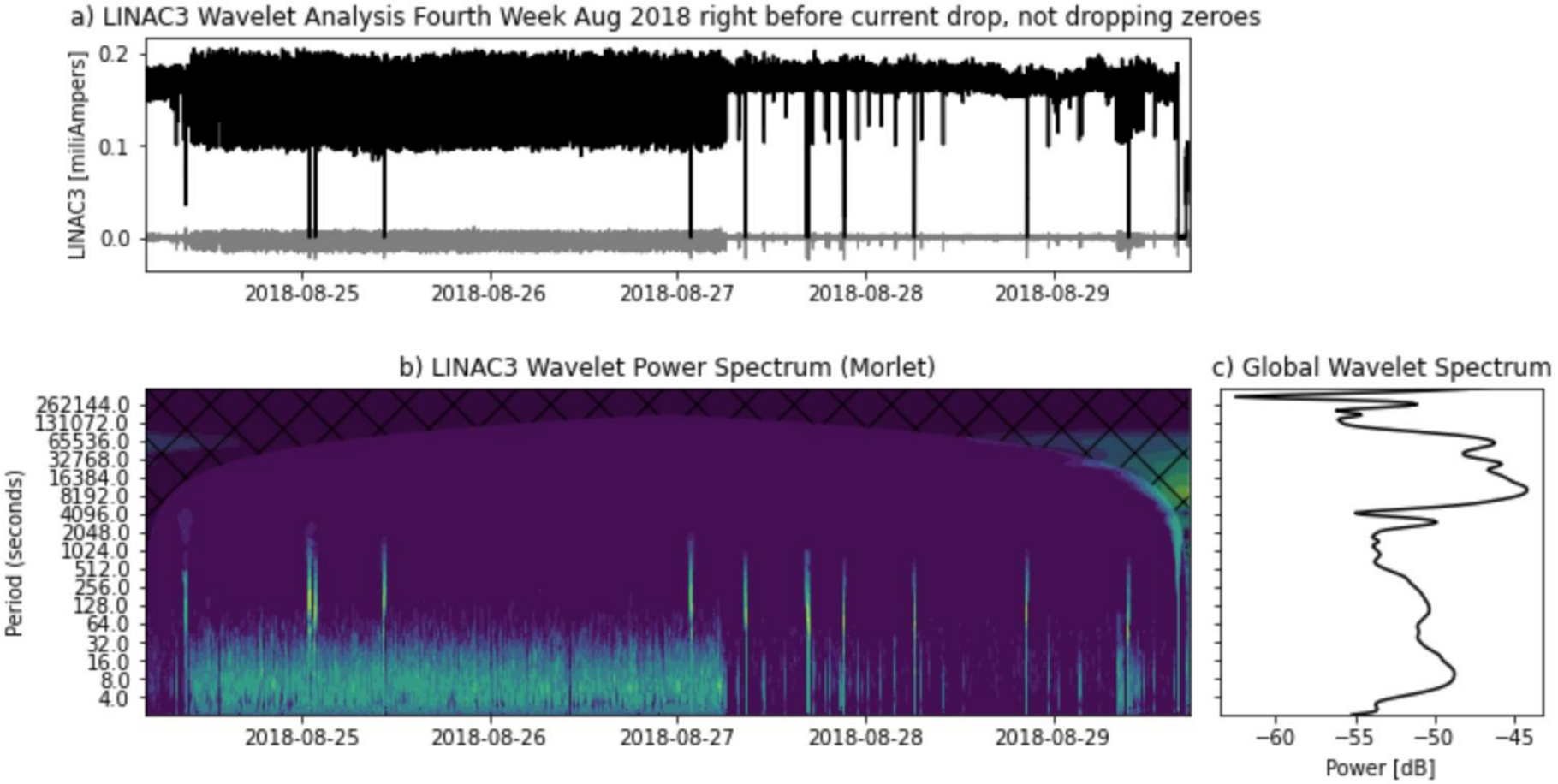


Pb^{54+} ion beam @ 4.2 MeV/u

- Predict adiabatic beam decay
- Beam current forecasting (ongoing)
- Collaboration with BE-ABP-HSL

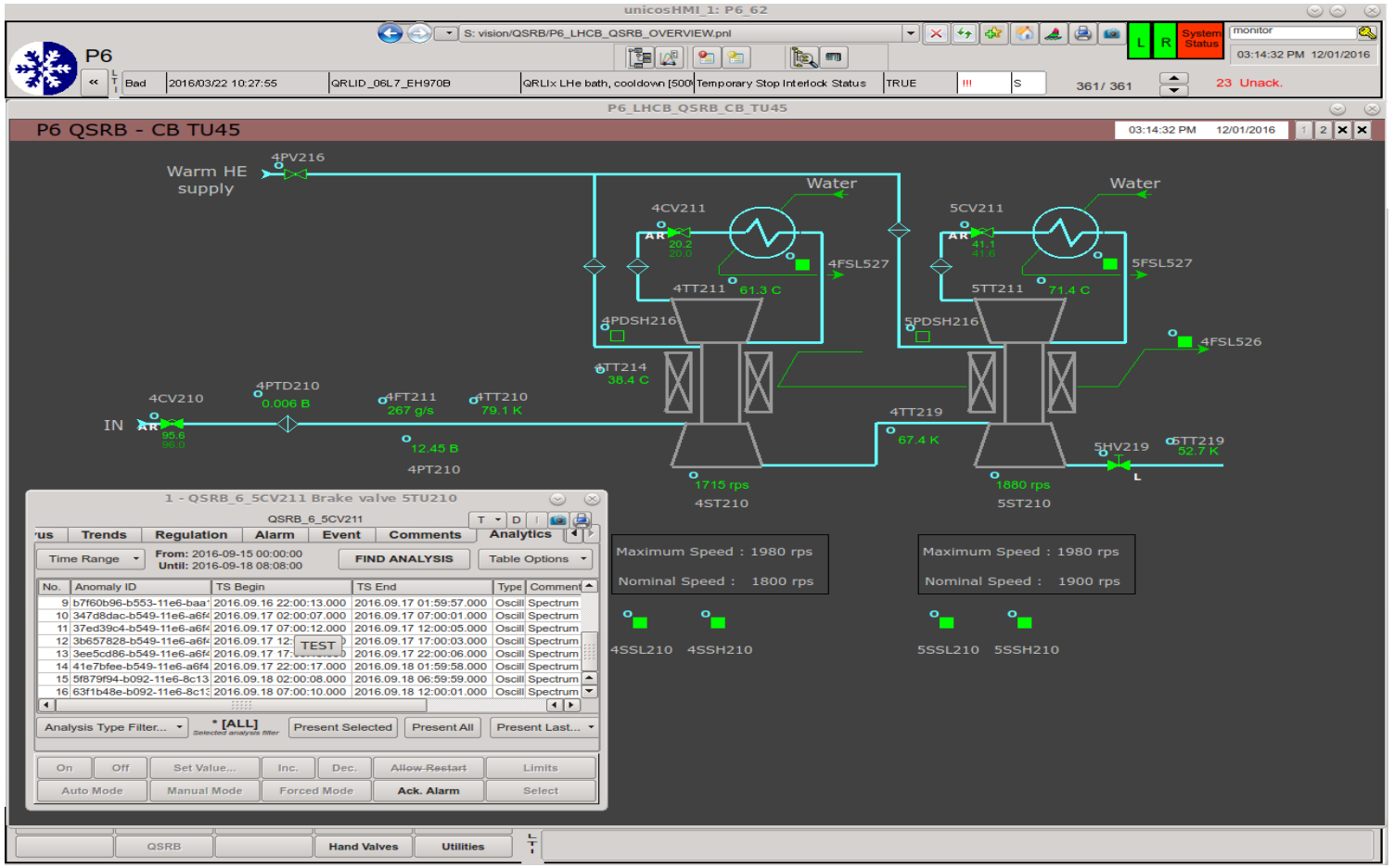
LINAC3 schematic layout

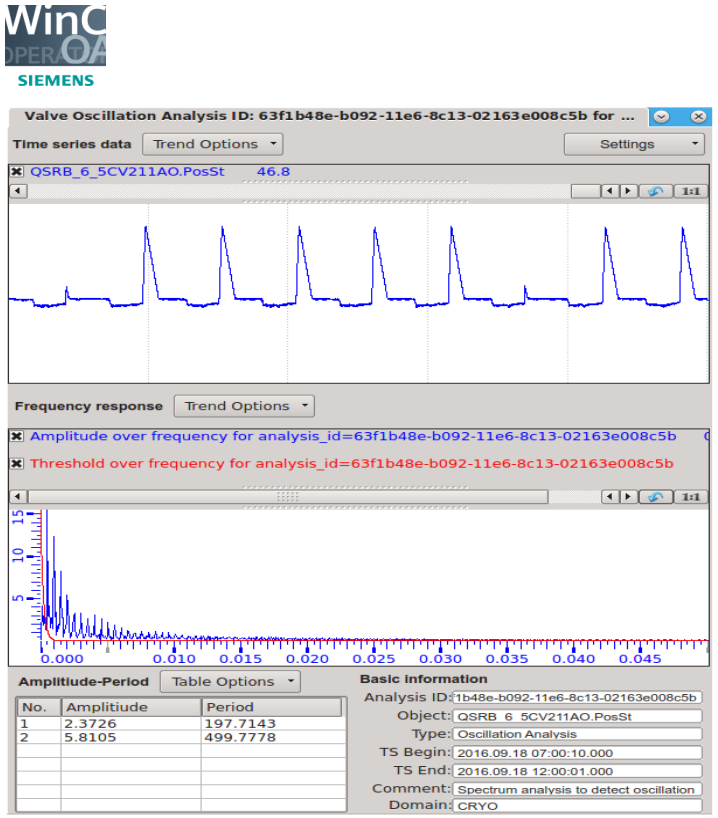
Predicting LINAC3 beam current



UC3: Feed analytical results into the control system

Visualize the results of the analysis to the operators in order to take the proper actions!





Status: Working prototype

Thank you!