~~The LHC Control System~~

CERN Accelerator Control System

Roman Gorbonosov on behalf of the
Beams Department Controls Group

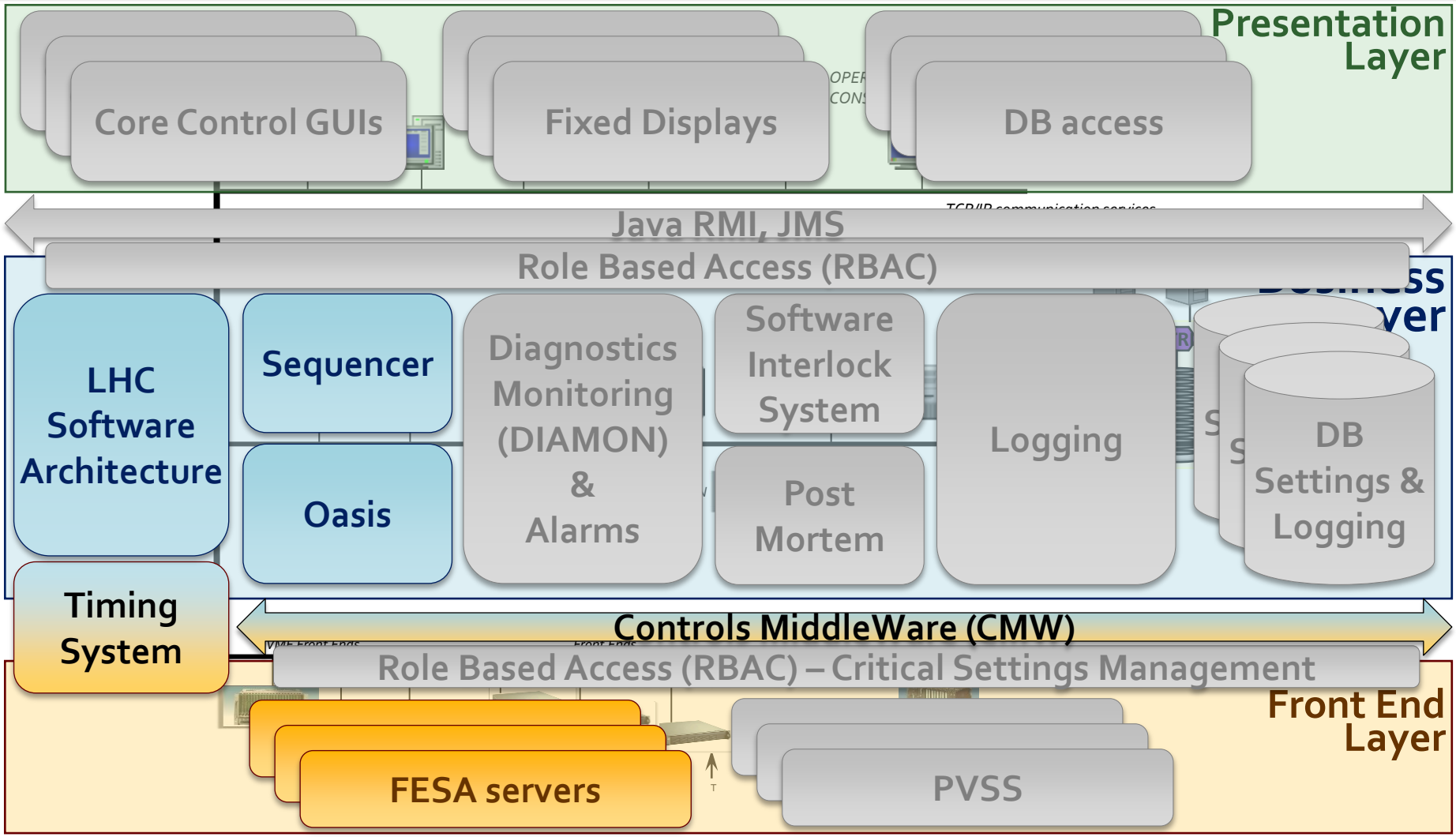
Based on the input from **M.Arruat, V.Baggiolini, JC.Bau, M.Buttner, P.Charrue, S.Deghaye, E.Hatziangeli, G.Kruk, M.Lamont, A.Radeva, U.Raich, C.Roderick, J.Serrano, W.Sliwinski, J.Wozniak**

CERN – Geneva - Switzerland
Accelerators and Technology Sector
Beams Department - Controls Group

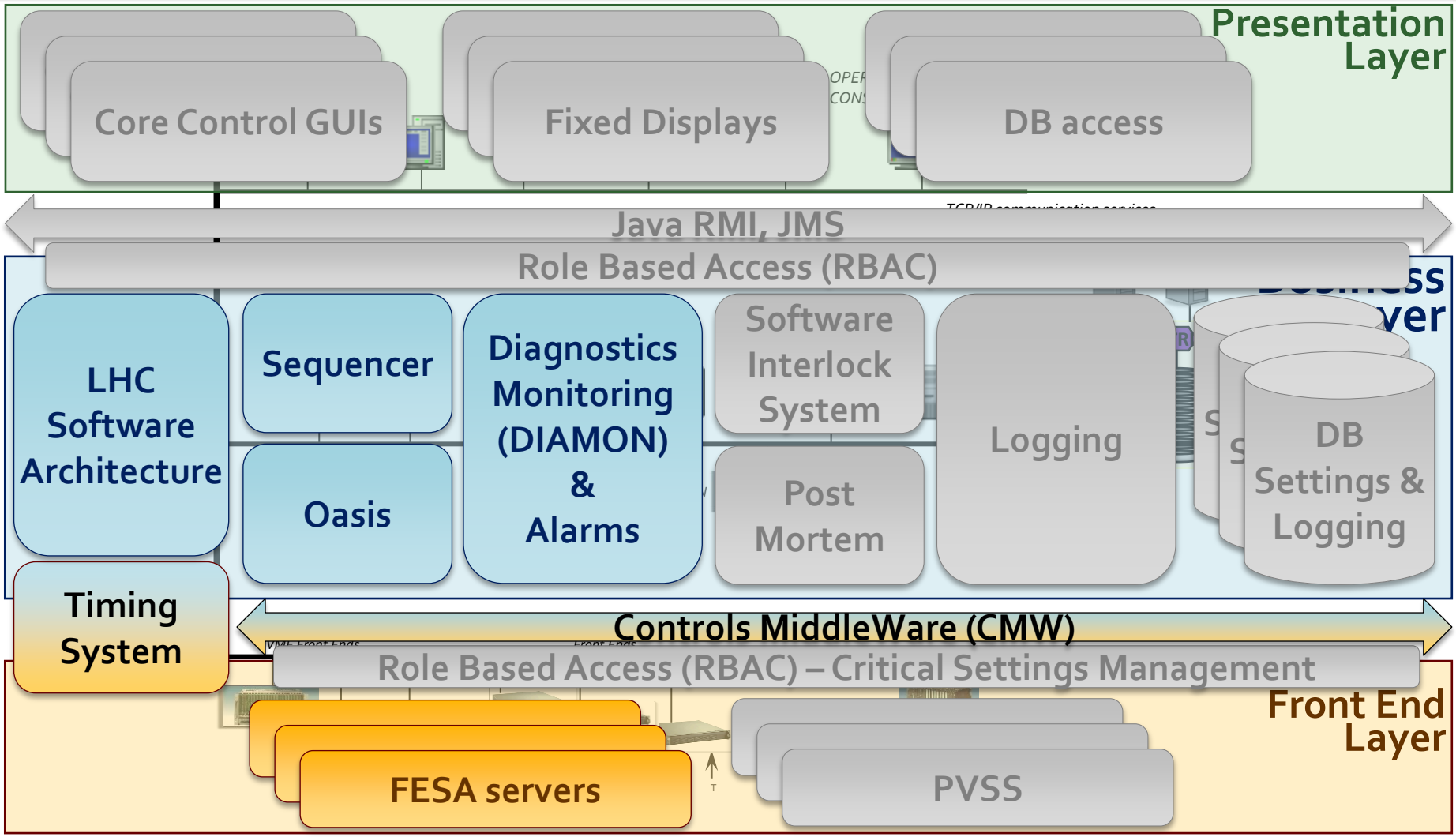
Contents

- LHC control system requirements
- Philosophy of development
- Overview of the architecture
- Key components
- Quality Assurance (QA)
- Outlook towards the Future

Key components



Key components



Diagnostic Monitoring and Alarms

Alarms

Summary of problems in single place

Huge number of SW processes

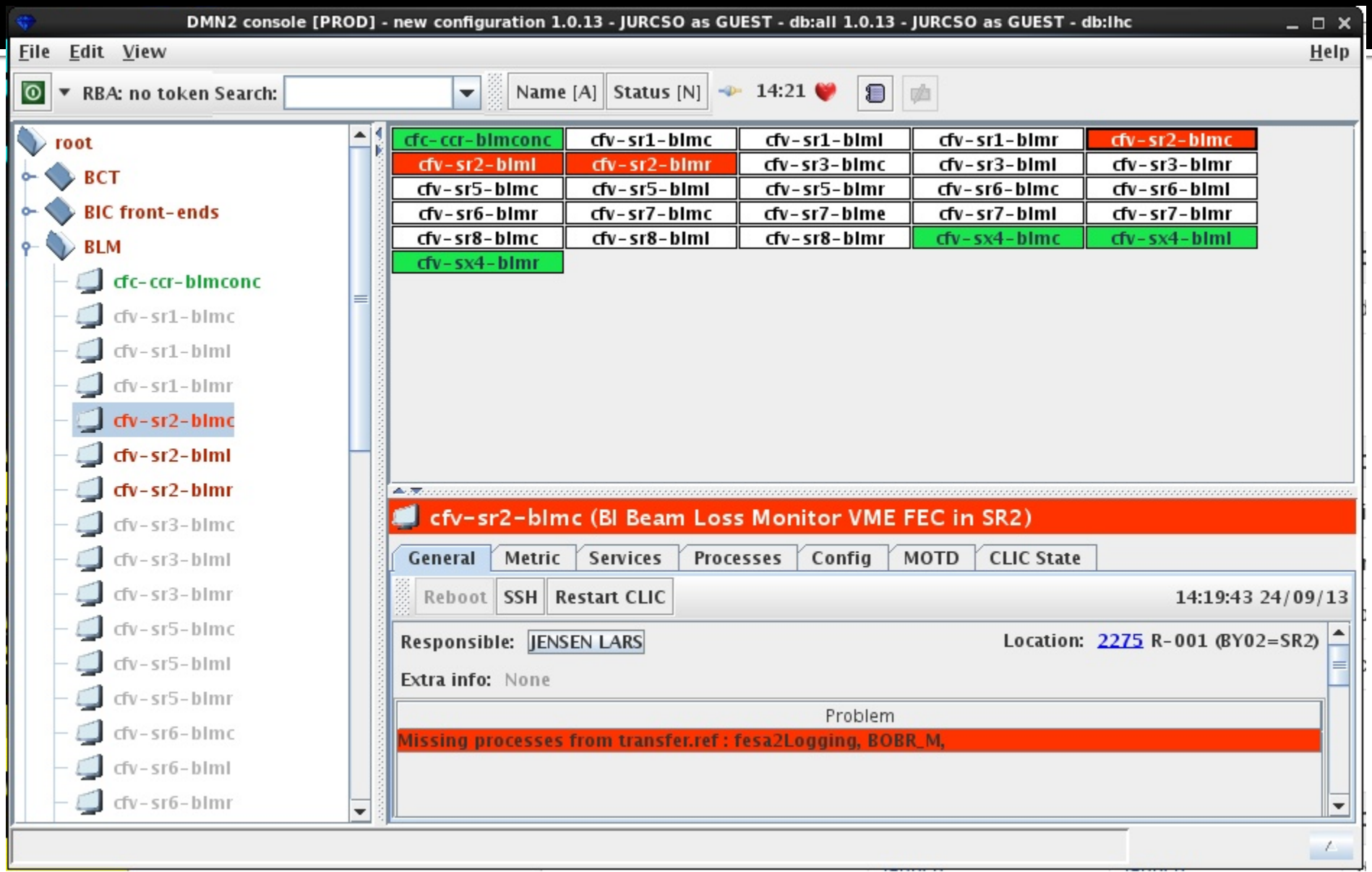
Huge number of devices

Diagnostics Monitoring

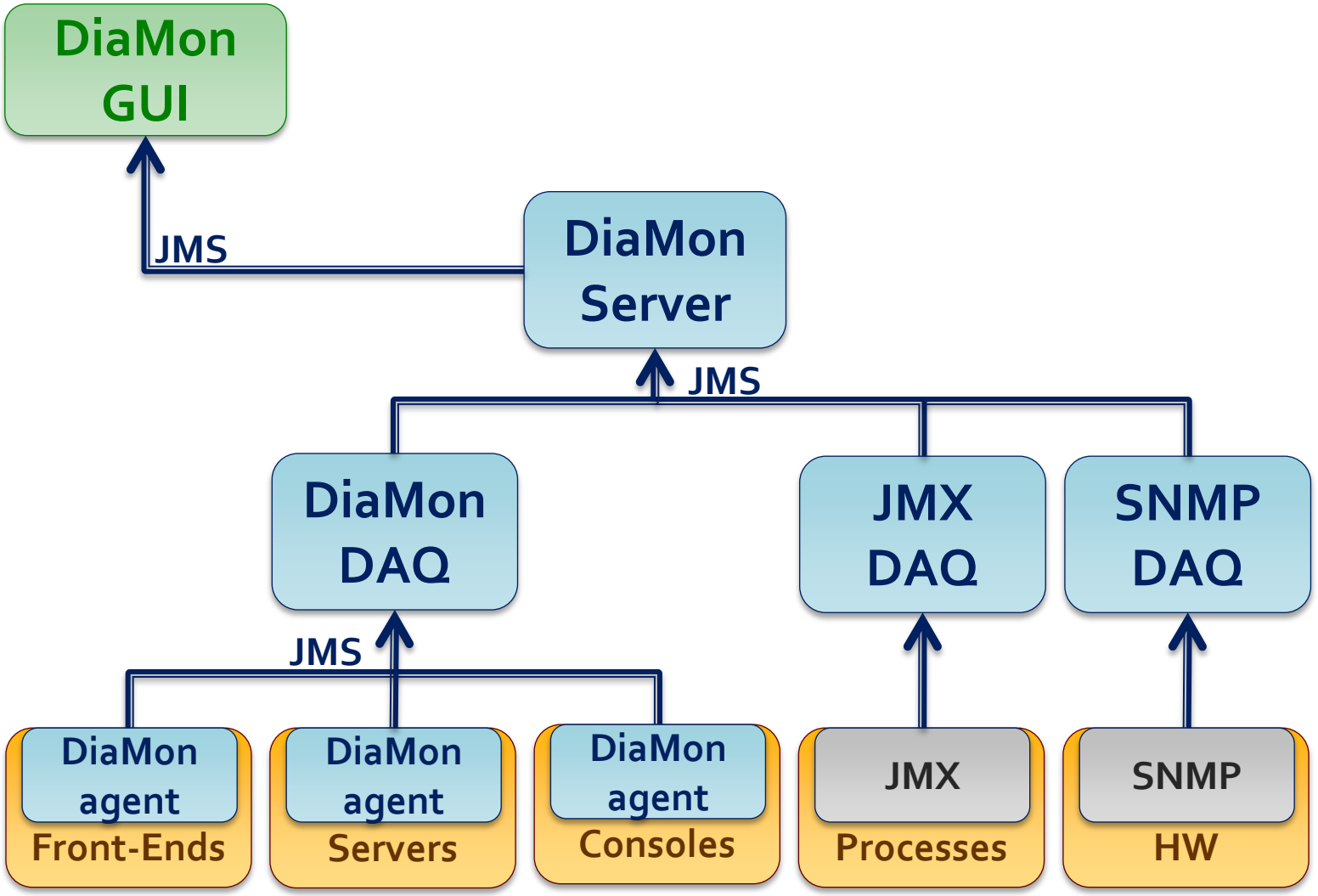
DIAgnostic MONitoring

- **Monitors** controls infrastructure
  - Computers (front-ends, servers, consoles)
  - Network
  - Software applications
- Provides **overview** of infrastructure state

DIAgnostic MONitoring GUI



DiaMon: architecture



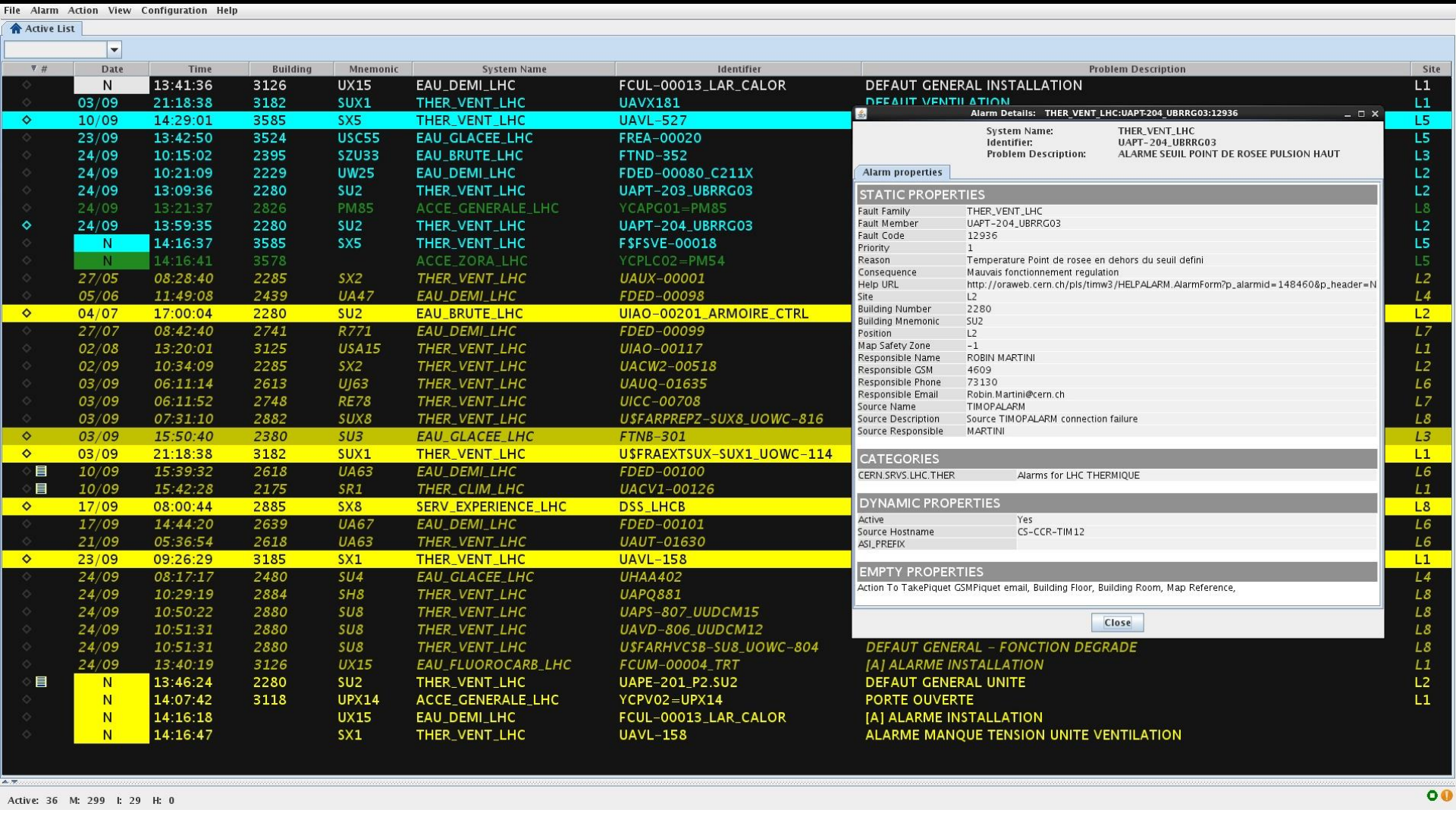
DiaMon: features

- Helps finding the **root cause** of the problem
- Provides **evolution history**
- Allows certain **actions**
  - restart system
  - restart process

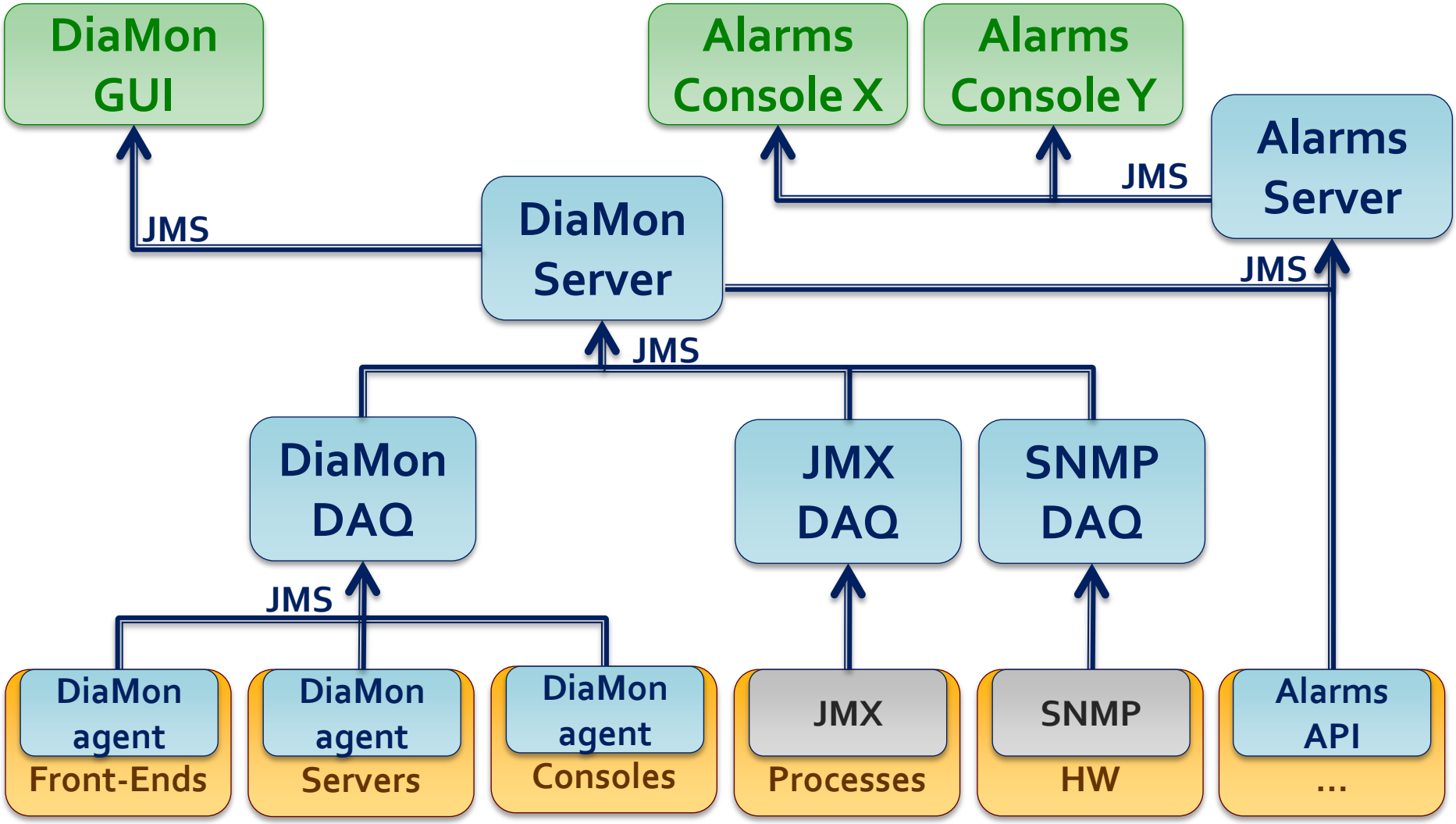
Alarms

- **Software alarms system**
  - Problem => notification
- Does not deal with human/equipment safety
- Notifies about problems requiring **human intervention**

Alarms Console

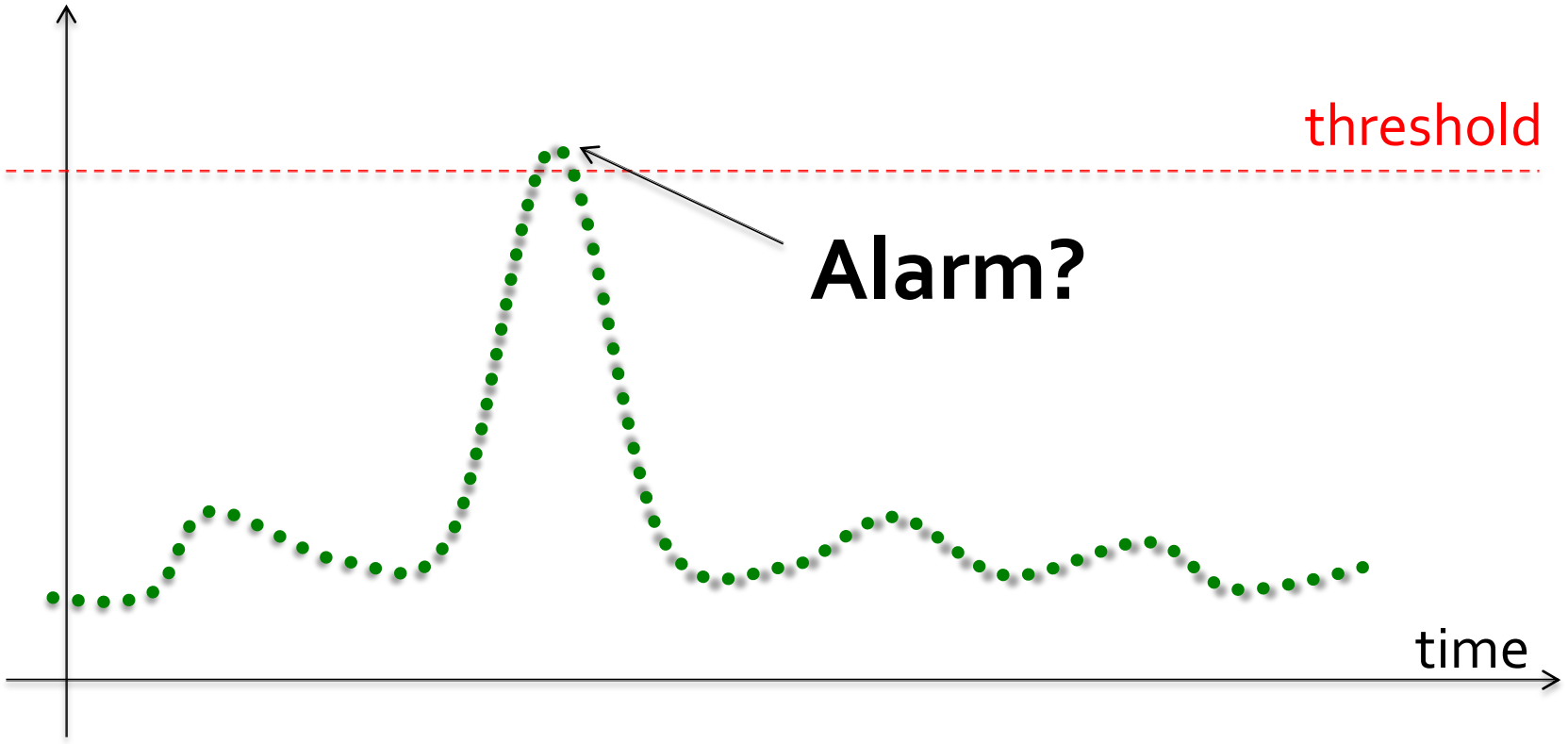


DiaMon & Alarms: architecture



Alarms: features

- **Relevant** alarms only



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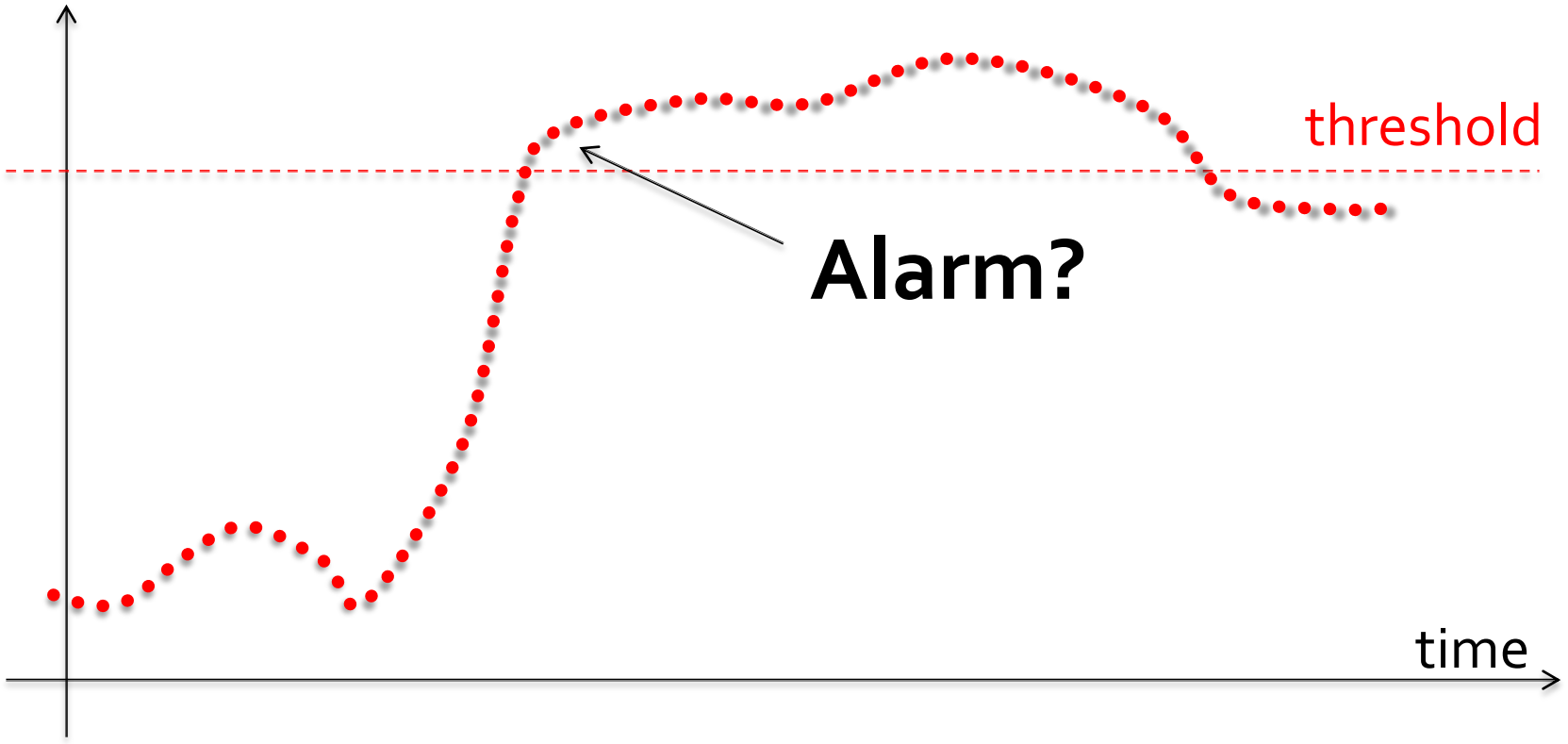

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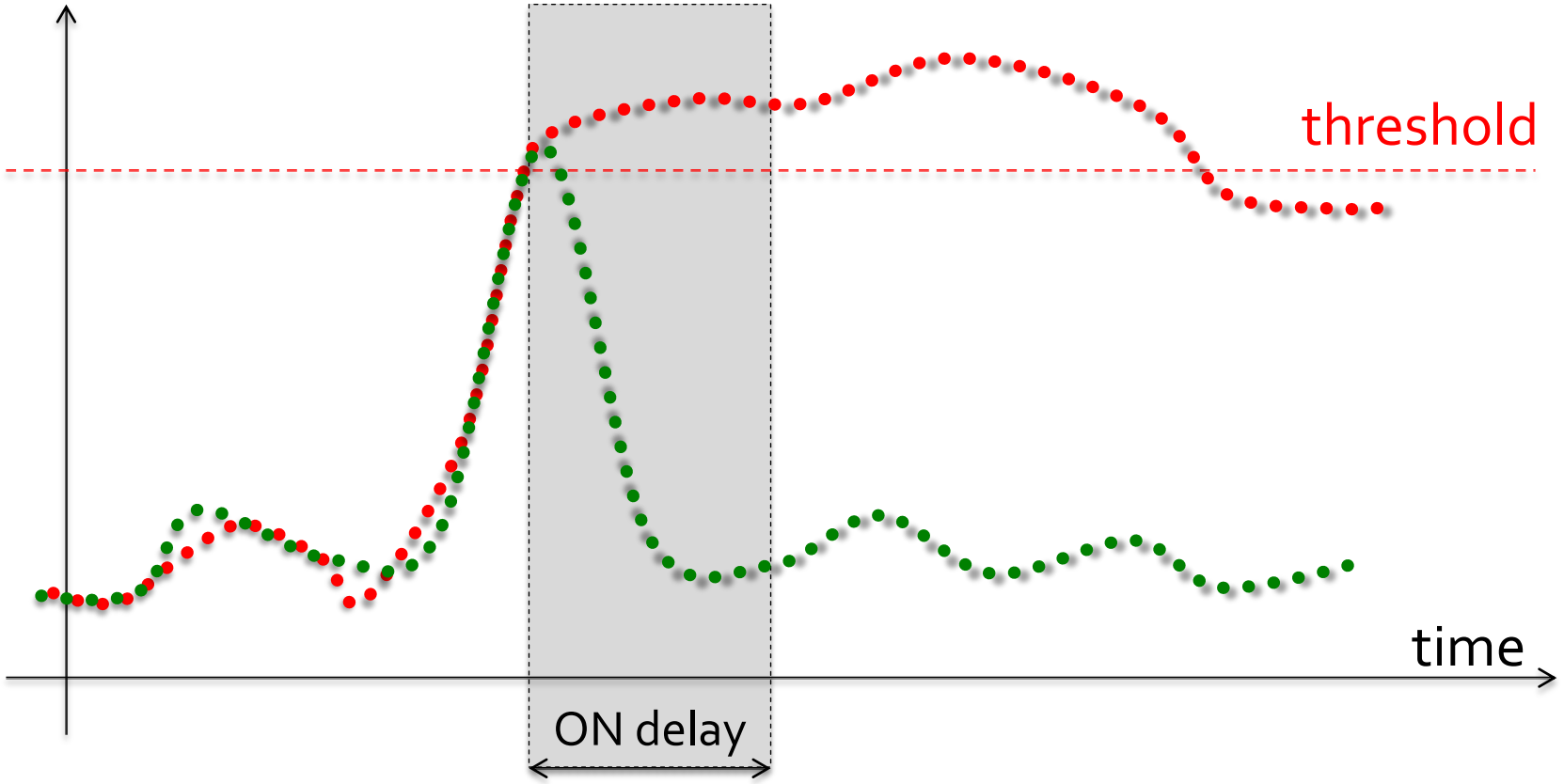
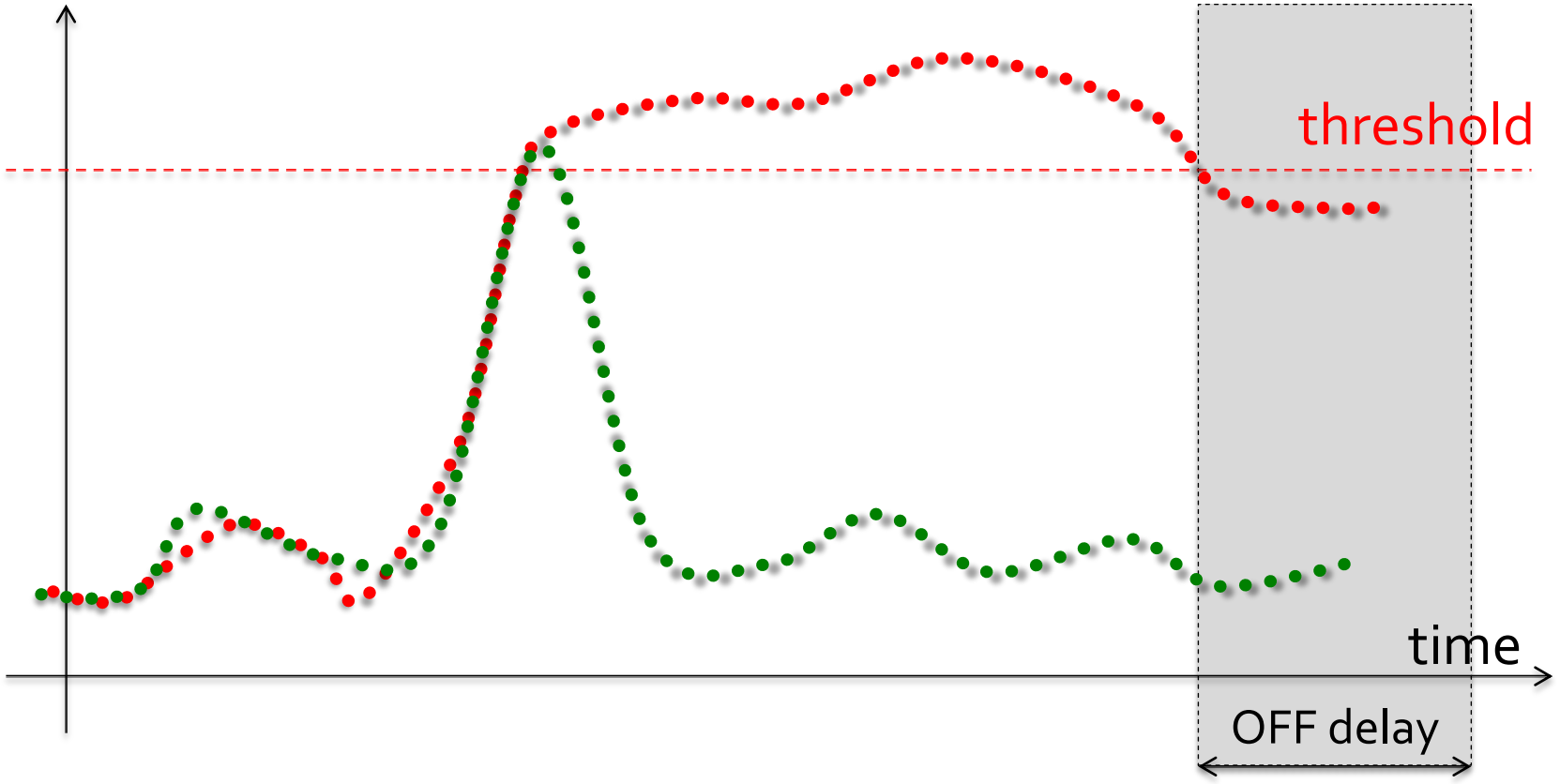


Alarms: features

- **Relevant** alarms only



Alarms: features

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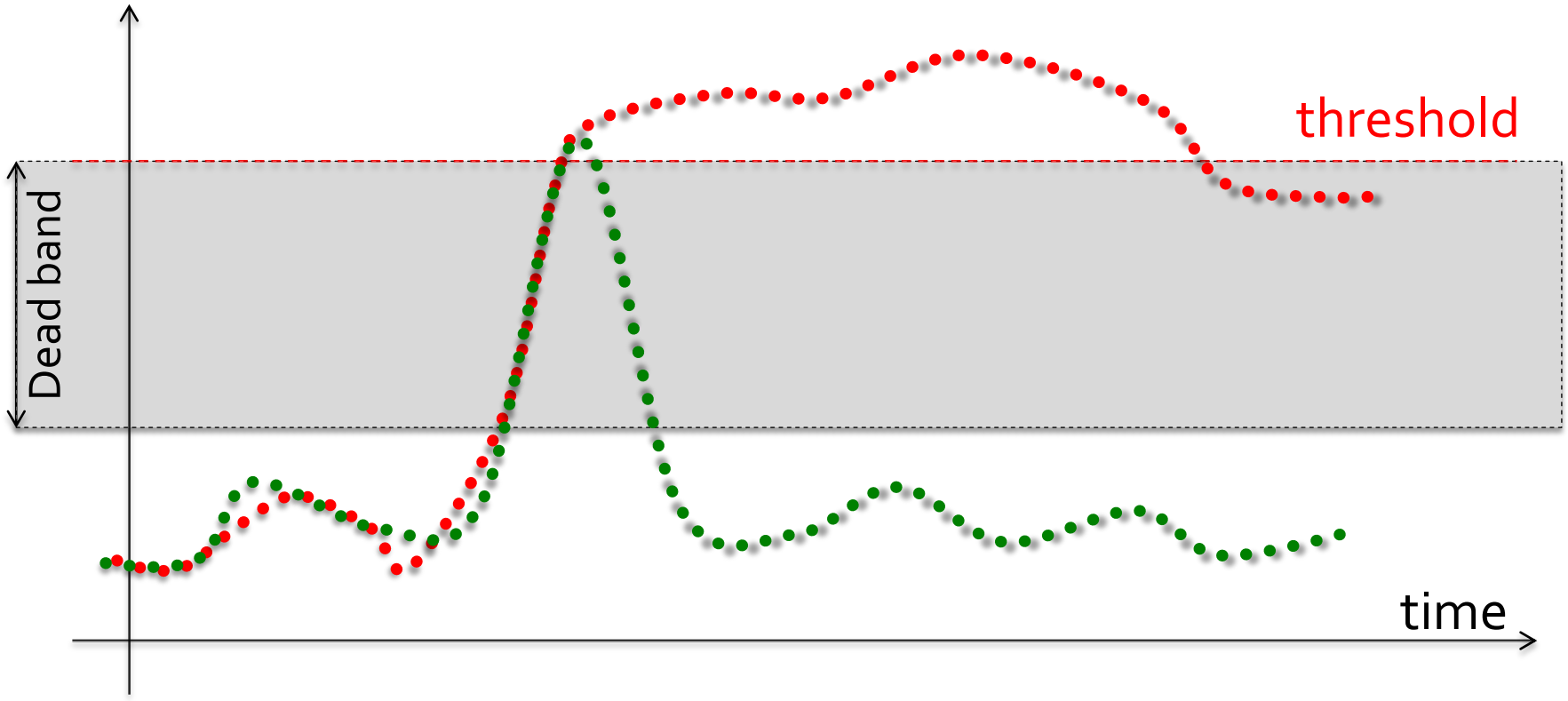

Alarms: features

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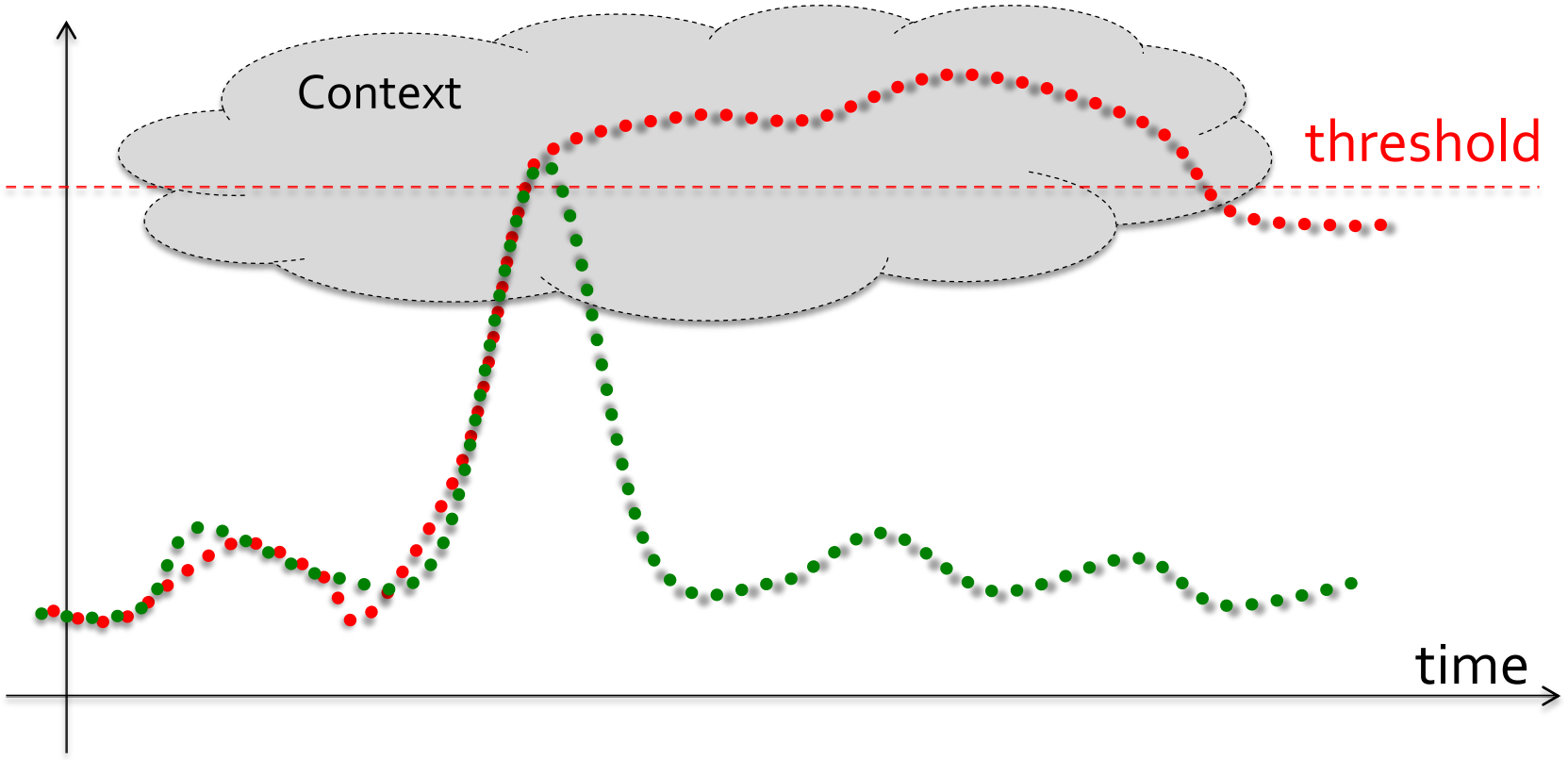


Alarms: features

- **Relevant** alarms only
  - Quality of raised alarms
  - Dependent on clients: ex. different accelerators
- Alarms **history**
- **Maps** alarms **to people** and **possible actions**
- Alarms **priority**

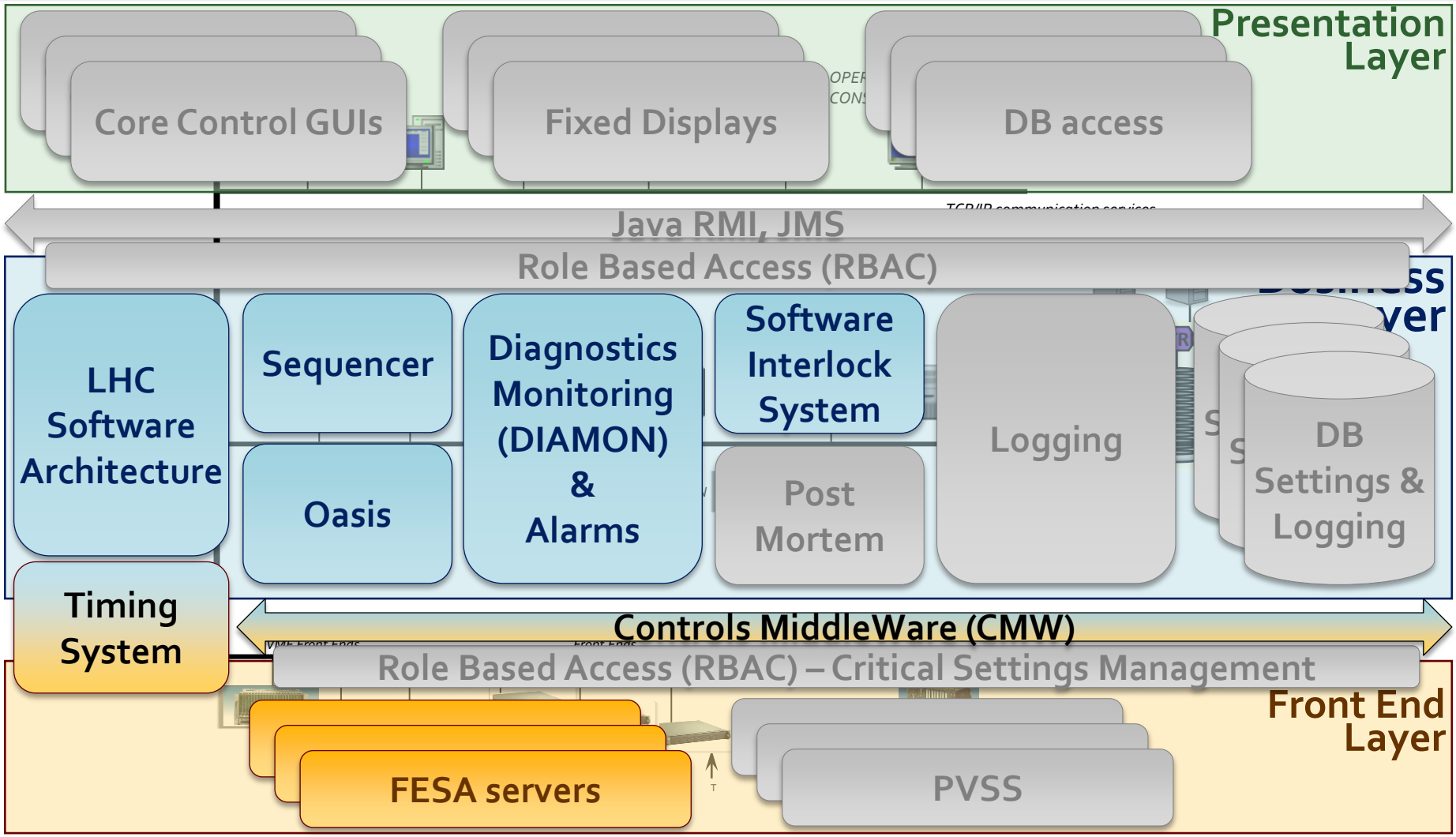
DiaMon & Alarms: today

- Diagnostic Monitoring
  - Metrics from >2000 computers
  - ~10 M updates / day
- Alarms
  - ~200 K alarm definitions (80'000 for LHC)
  - ~150 alarm events / minute

DiaMon & Alarms: future

- Extend monitoring to process internals
  - JMX metrics
  - Periodic sanity checks
- Automatic alarms analysis
  - Frequent, oscillating alarms => contact expert
  - Long-standing alarms => reconsider alarm

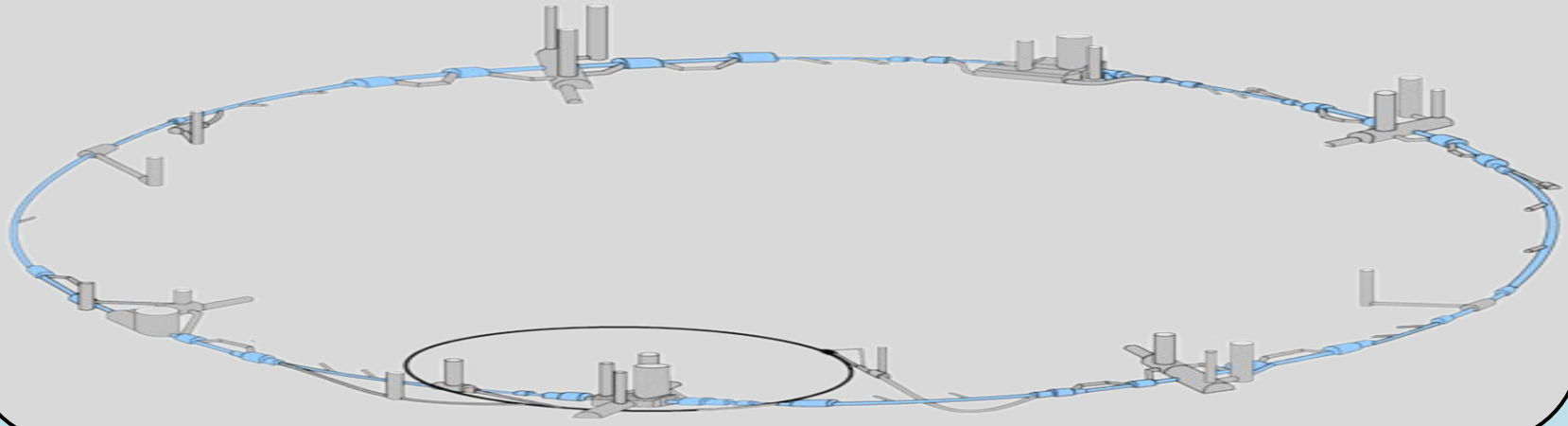
Key components: SIS



Machine Protection: birds-eye view

Software Interlock System

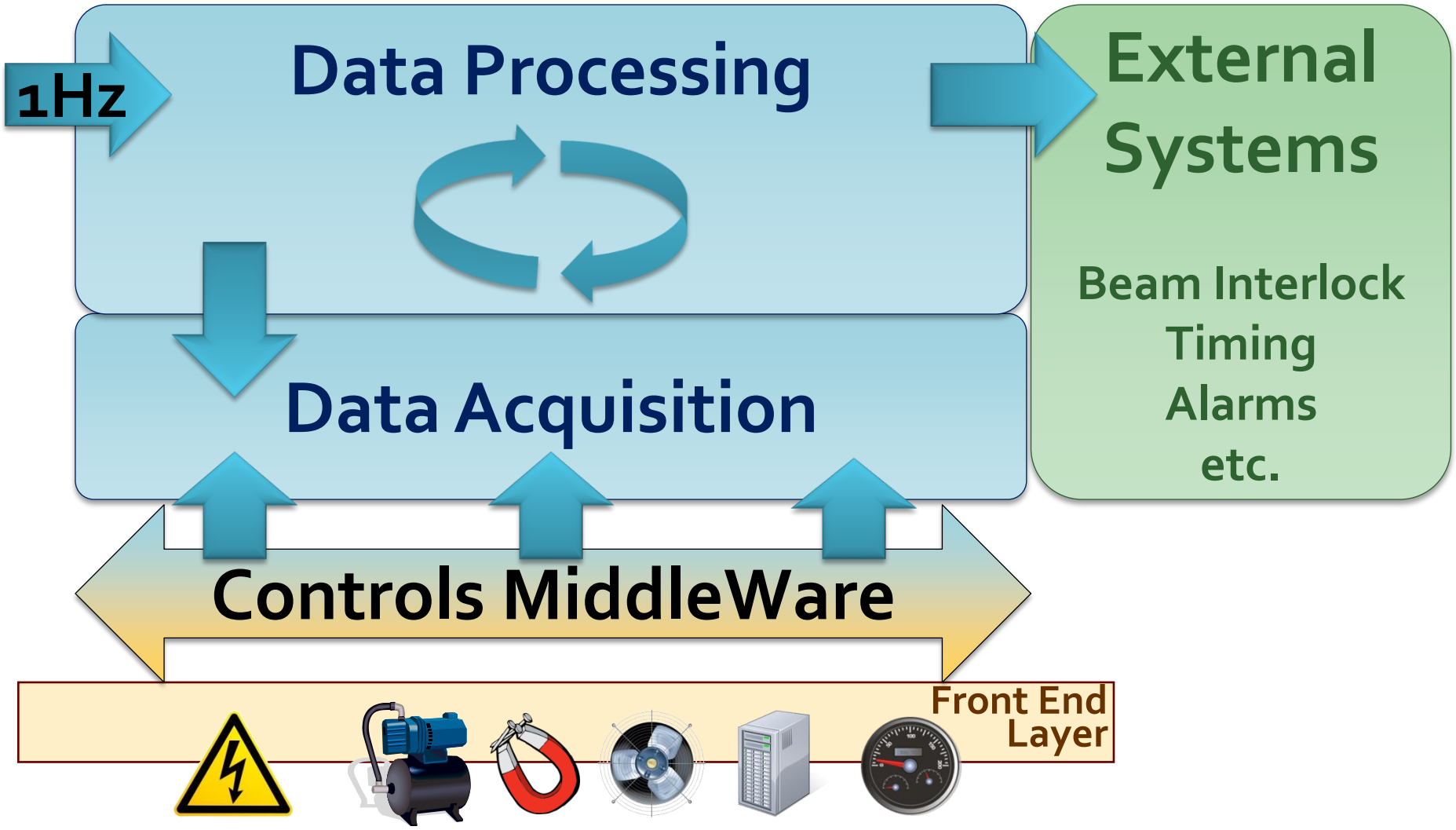
Hardware Machine Protection



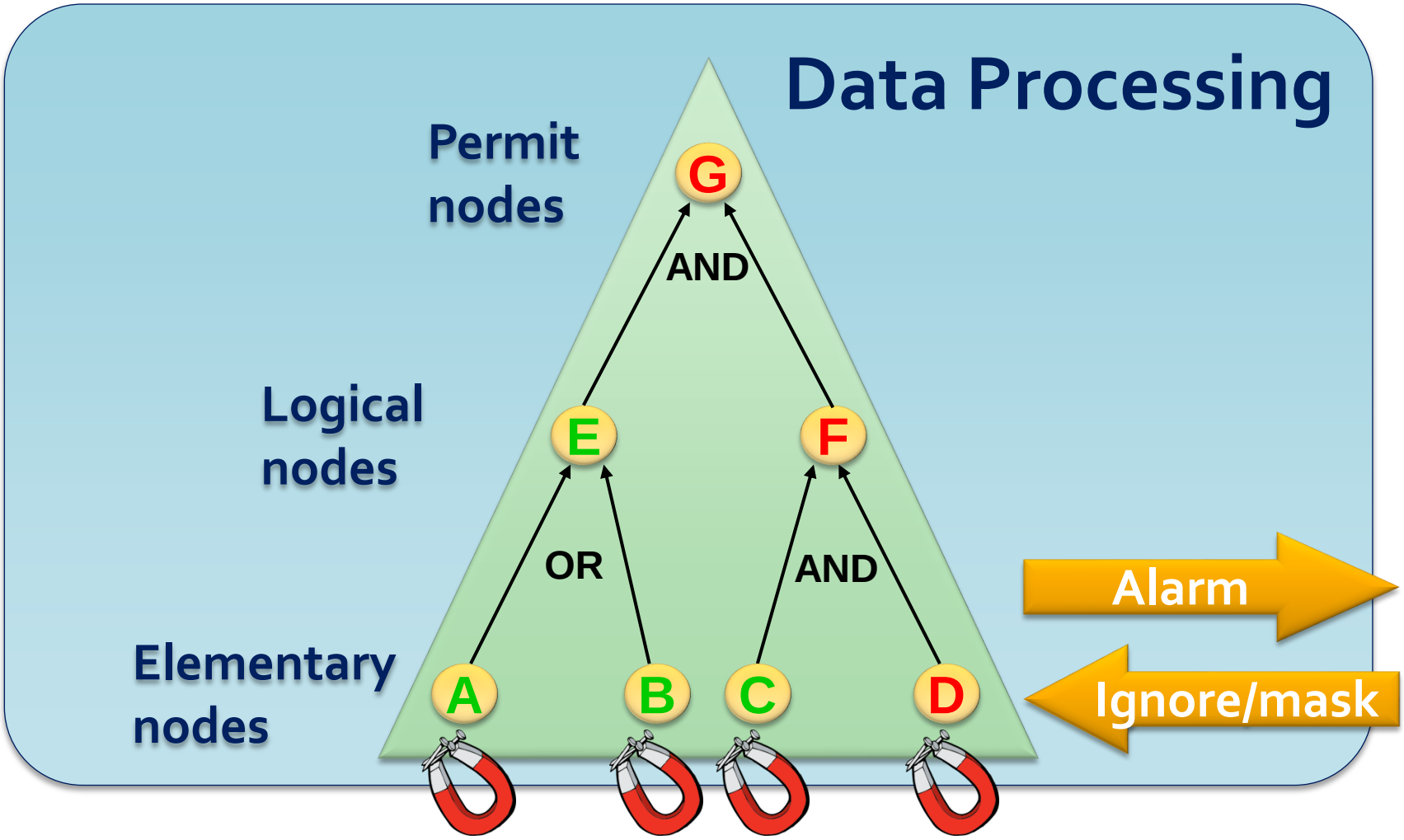
Software Interlock System (SIS)

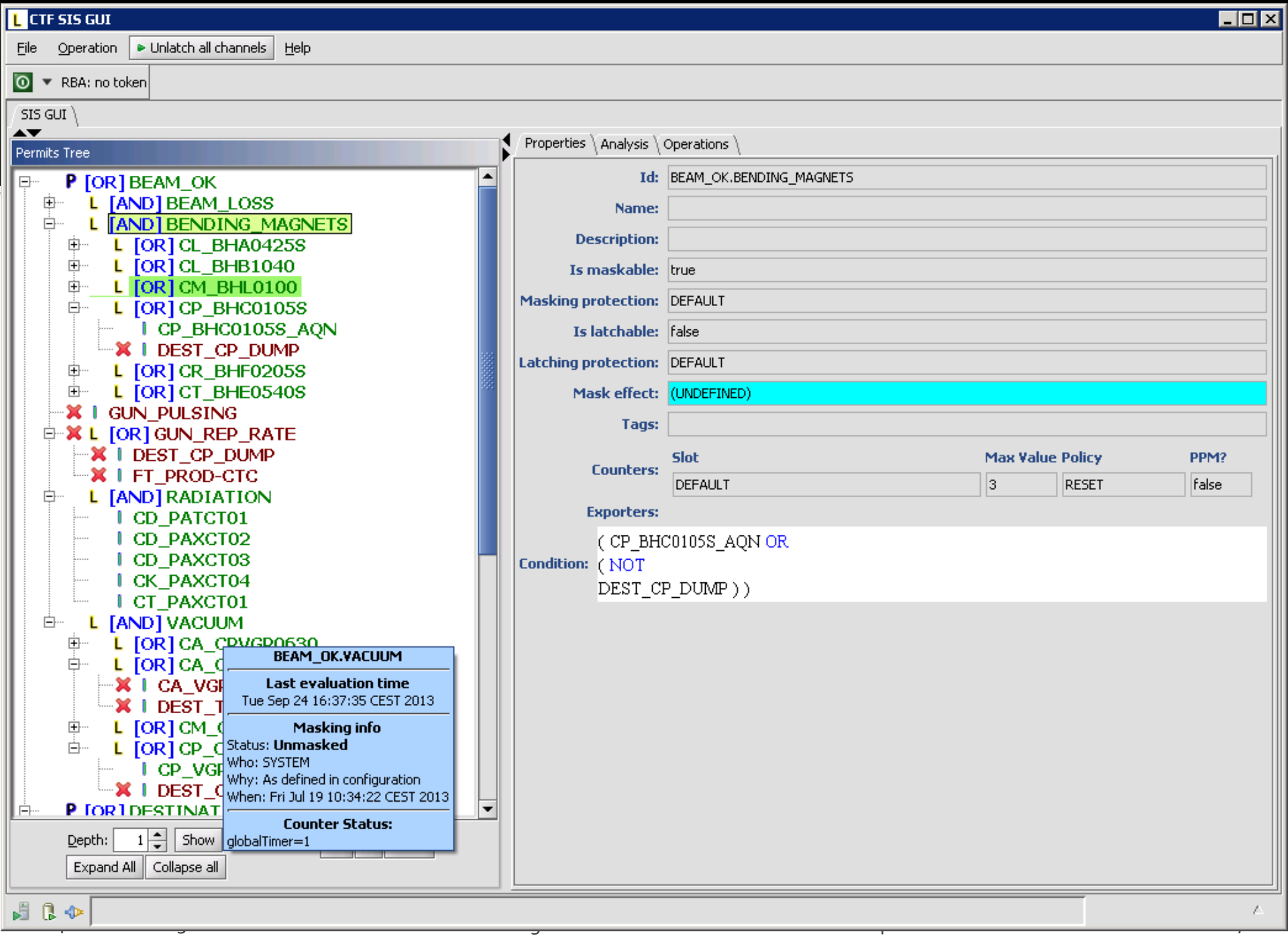
- **Surveys** the state of key LHC components
- **Acts** if necessary
  - abnormal situation $\Rightarrow$ beam dump
- Part of overall **Machine Protection**

SIS: architecture



SIS: implementation




CTF SIS GUI
File
Operation
Unlatch all channels
Help
RBA: no token
SIS GUI
Permits Tree
P [OR] BEAM_OK
L [AND] BEAM_LOSS
L [AND] BENDING_MAGNETS
L [OR] CL_BHA0425S
L [OR] CL_BHB1040
L [OR] CM_BHL0100
L [OR] CP_BHC0105S
CP_BHC0105S_AQN
DEST_CP_DUMP
L [OR] CR_BHF0205S
L [OR] CT_BHE0540S
GUN_PULSING
L [OR] GUN_REP_RATE
DEST_CP_DUMP
FT_PROD-CTC
L [AND] RADIATION
CD_PATCT01
CD_PAXCT02
CD_PAXCT03
CK_PAXCT04
CT_PAXCT01
L [AND] VACUUM
BEAM_OK.VACUUM
Last evaluation time
Tue Sep 24 16:37:35 CEST 2013
Masking info
Status: Unmasked
Who: SYSTEM
Why: As defined in configuration
When: Fri Jul 19 10:34:22 CEST 2013
Counter Status:
globalTimer=1
Depth:
1
Show
Expand All
Collapse all
Properties
Analysis
Operations
Id:
BEAM_OK.BENDING_MAGNETS
Name:
Description:
Is maskable:
true
Masking protection:
DEFAULT
Is latchable:
false
Latching protection:
DEFAULT
Mask effect:
(UNDEFINED)
Tags:
Counters:
Slot
Max Value
Policy
PPM?
DEFAULT
3
RESET
false
Exporters:
Condition:
(CP_BHC0105S_AQN OR
(NOT
DEST_CP_DUMP))

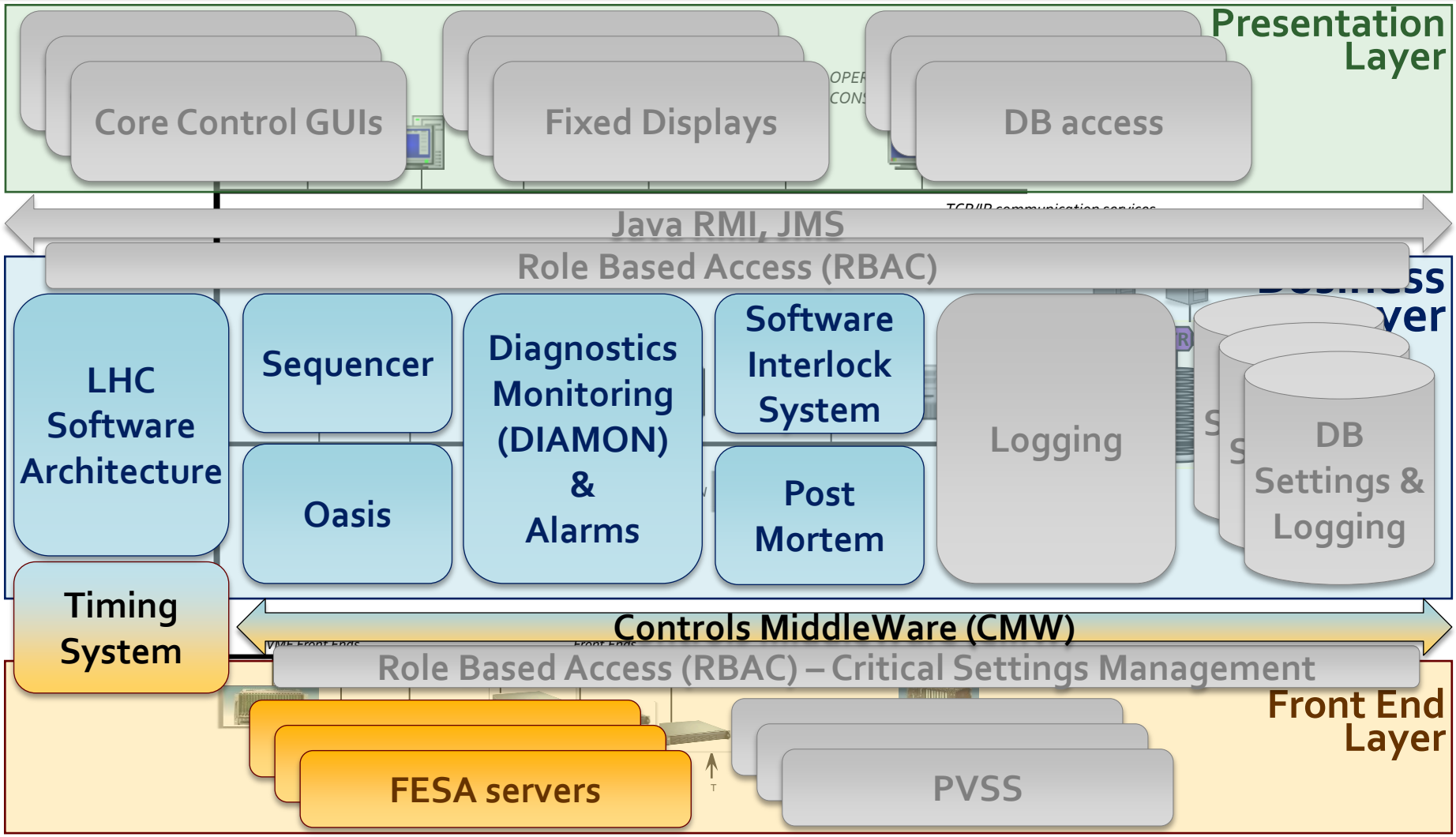
SIS: features

- **Domain conditions** representation
- **Complex** condition **logic**
- Provides the operations with condition calculation **diagnostics**
- **Extensible**
- **Deterministic** and highly **reliable**

SIS: today

- Deployed practically for all accelerators
- SIS for LHC has
  - ~2700 subscriptions
  - ~5200 elementary / ~800 logical / 8 permits
- SIS for SPS is used to save energy
  - Up to 200'000 euro/year

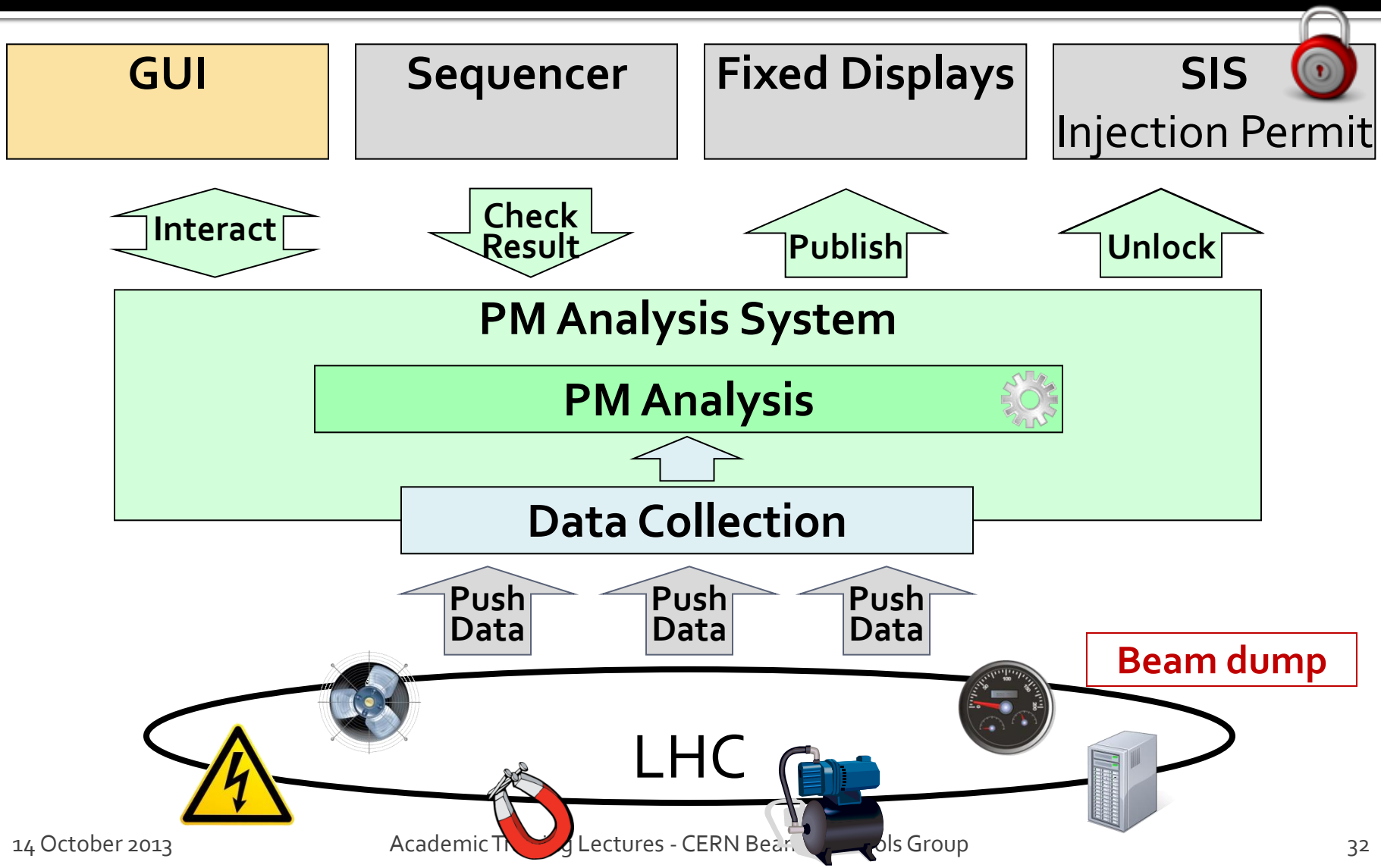
Key components: Post-Mortem



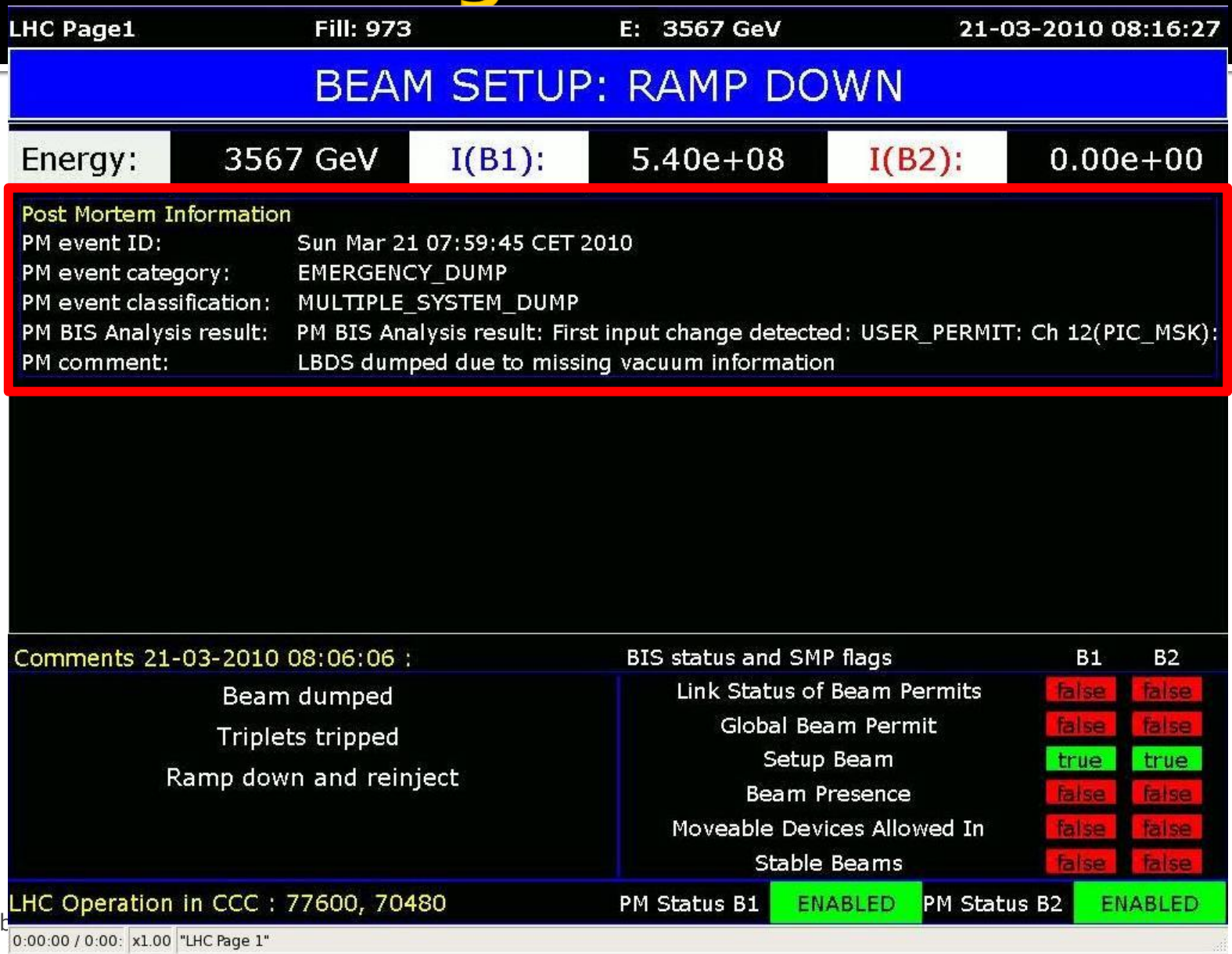
Post-Mortem Analysis (PMA)

- Detects the cause of the beam dump
- Checks if all the protection equipment behaved as expected
- Decides if it safe to continue the operations
- Blocks the next injection otherwise
- Part of overall **Machine Protection**

PMA: workflow

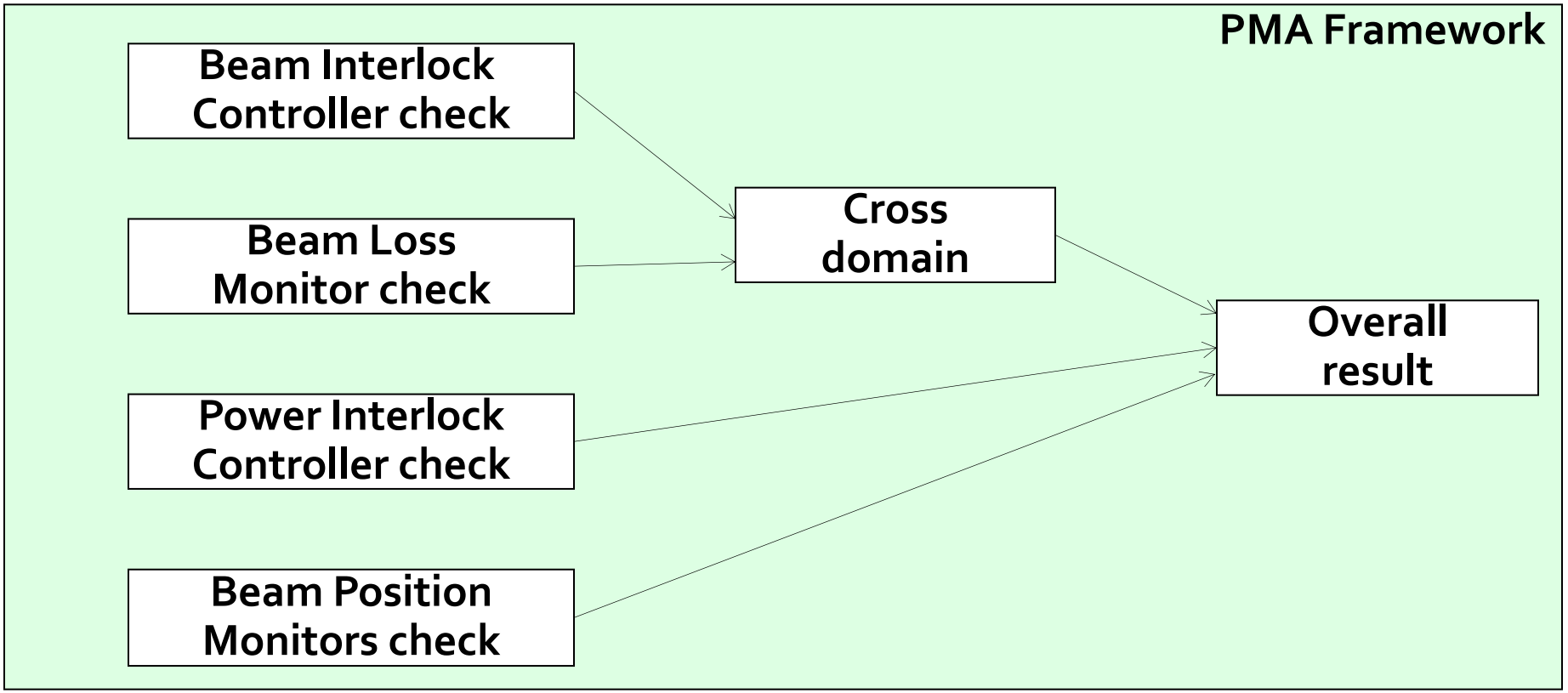


PMA: LHC Page 1



PMA: implementation

- Analysis is based on a graph of analysis modules



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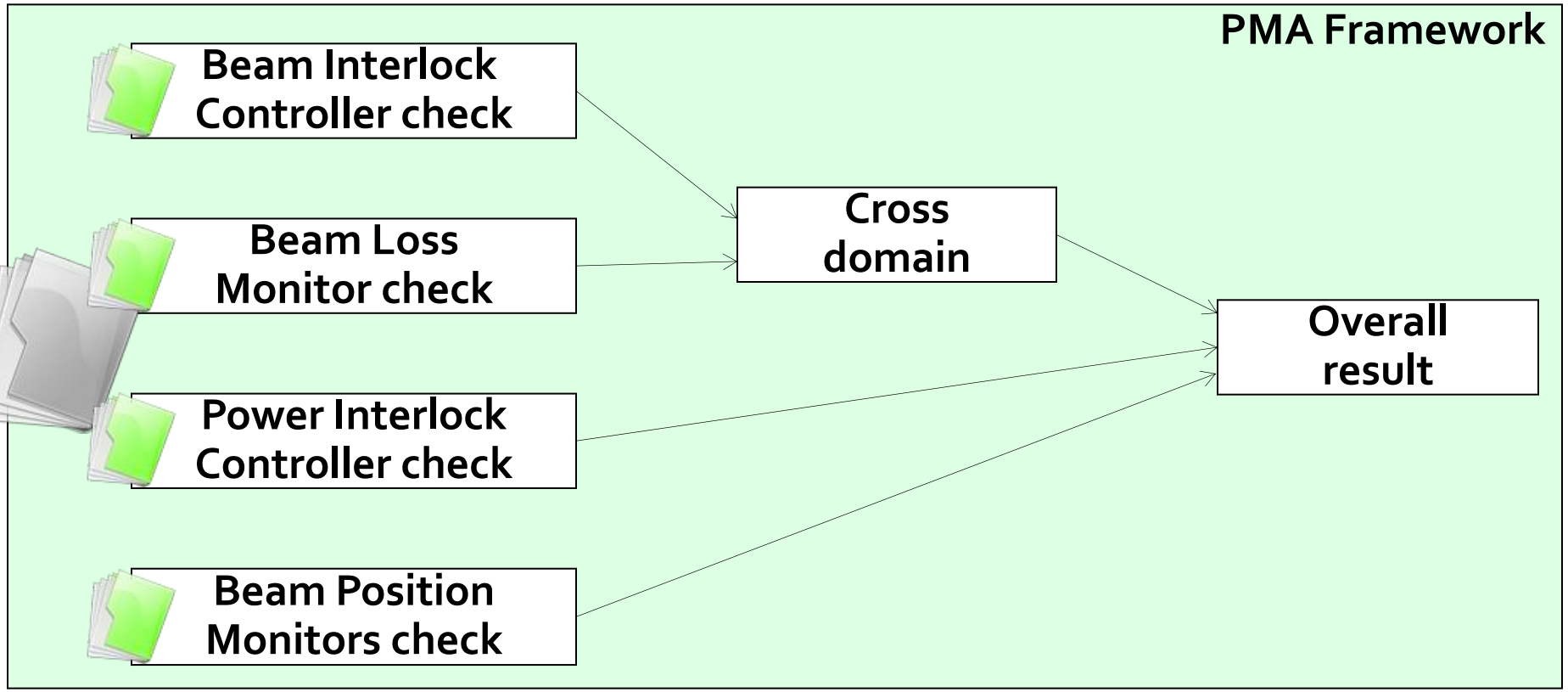

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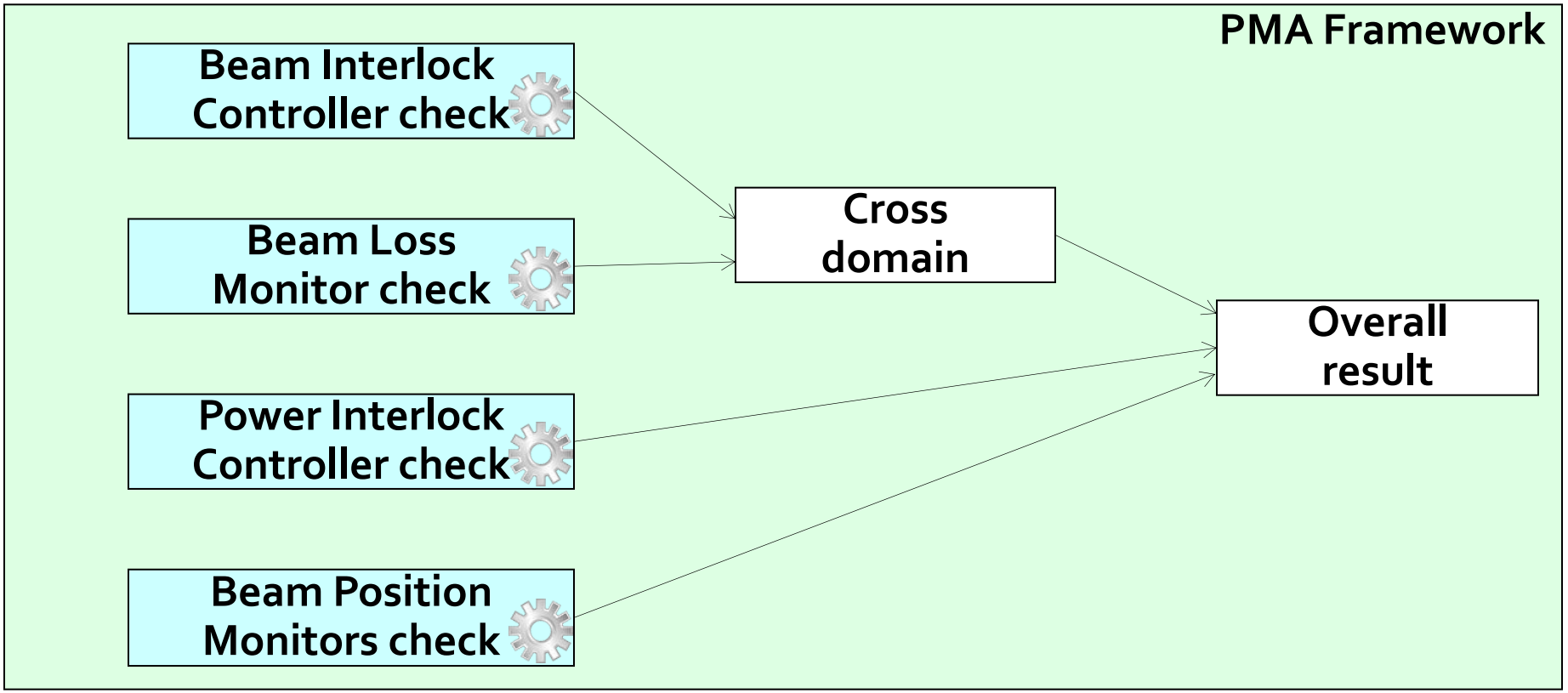

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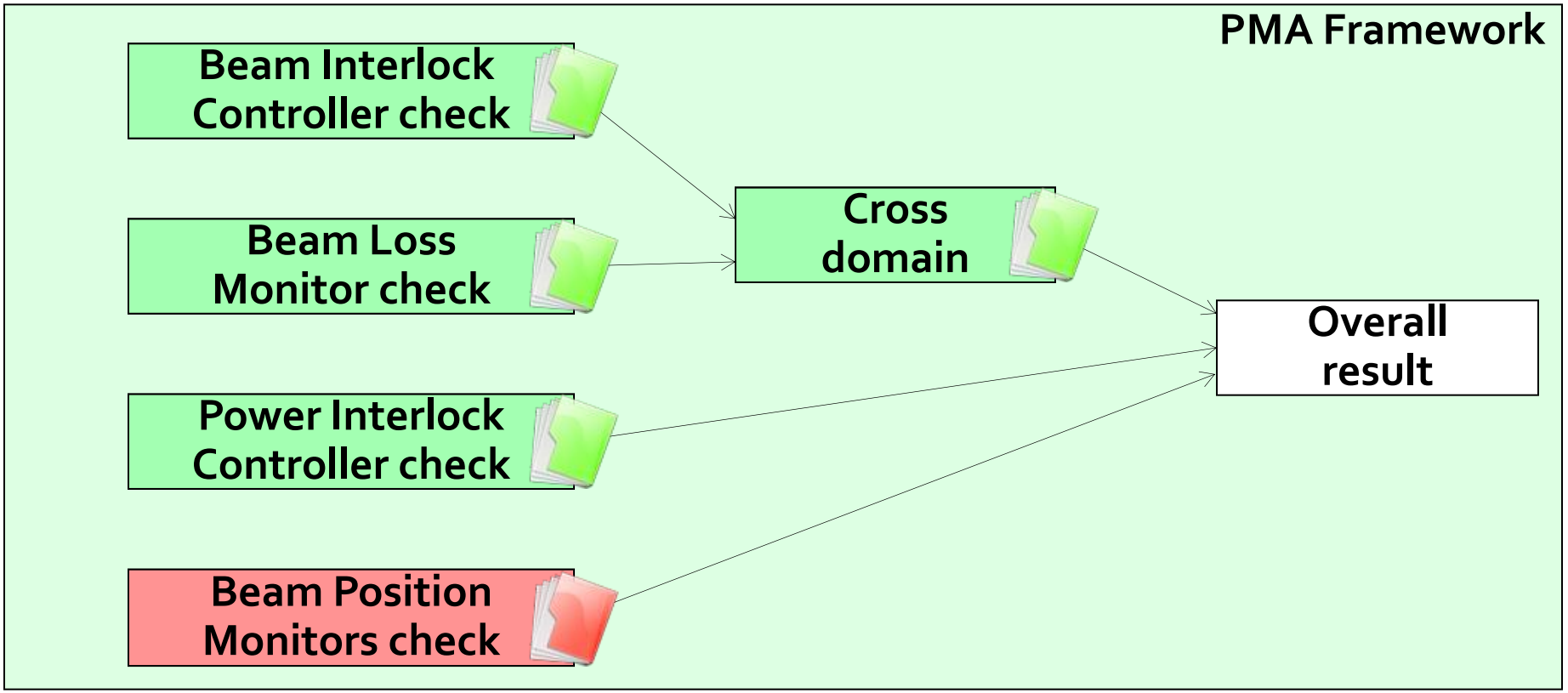

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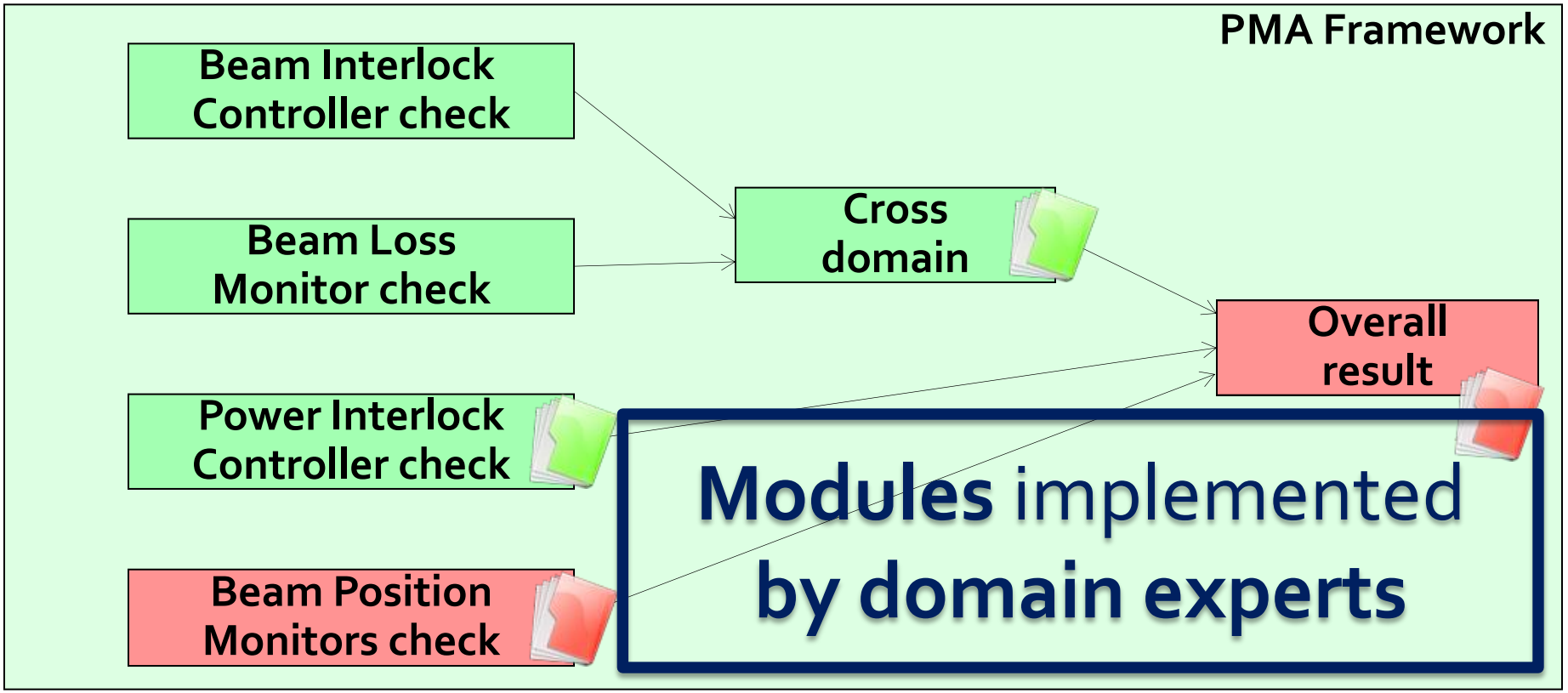
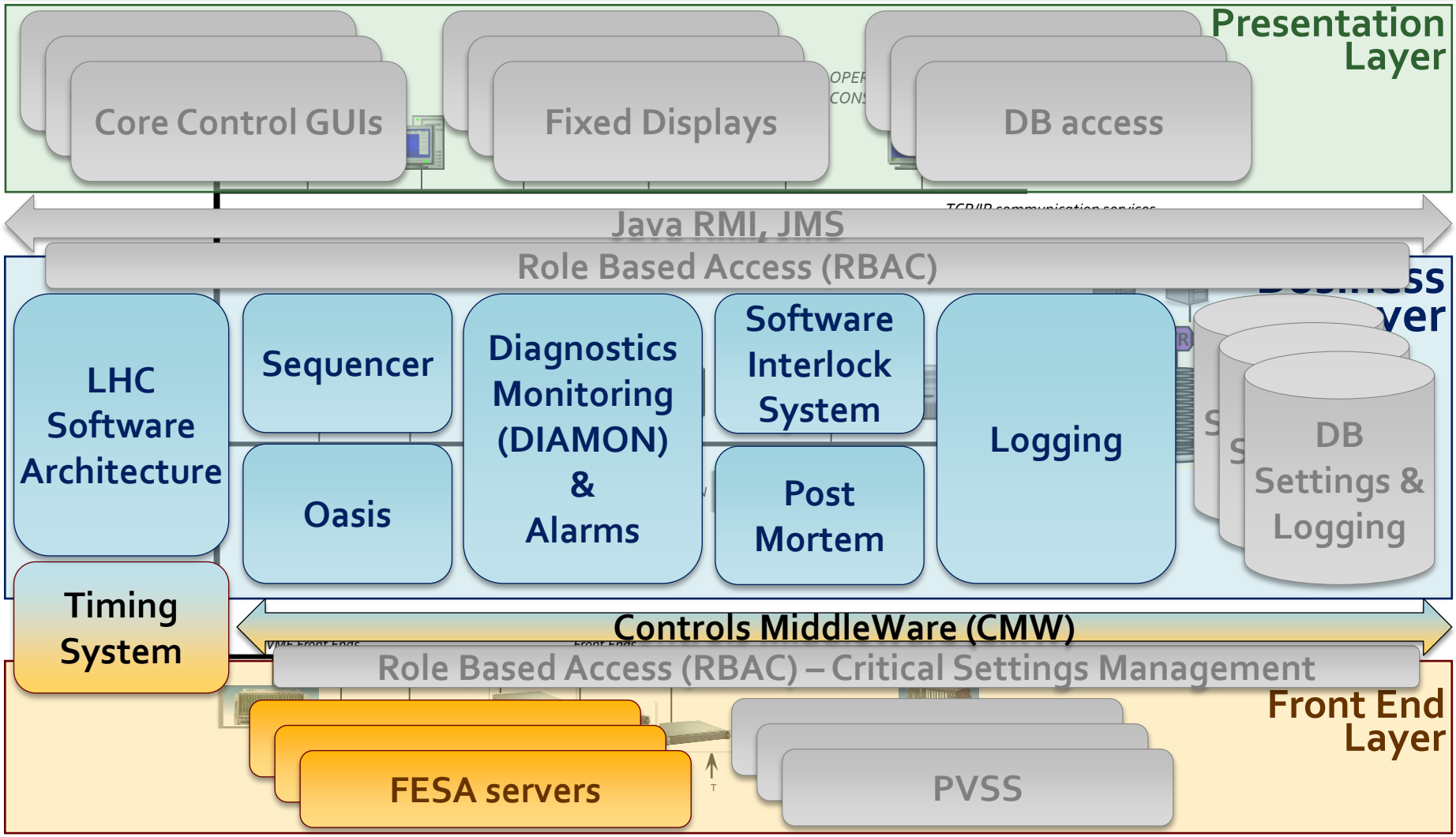


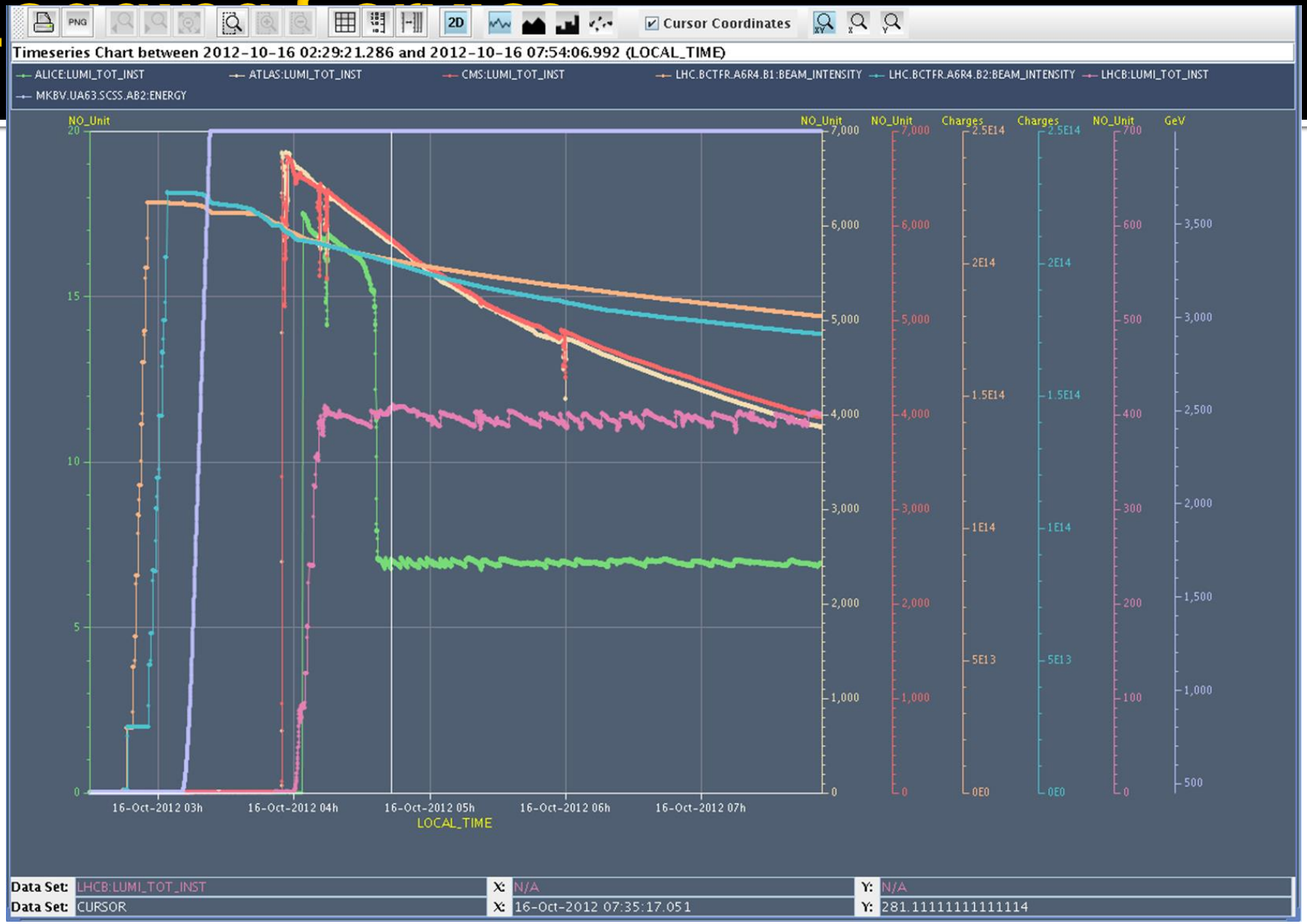
PMA: today

- 4 mission critical LHC applications
  - LHC Beam Dump Analysis
  - eXternal Post-Operational Check (XPOC)
  - Injection Quality Check (IQC)
  - Powering Event Analysis
- 45 analysis modules
- 10 module developers from different teams
- 2 GB per LHC Beam Dump

Key components: Logging



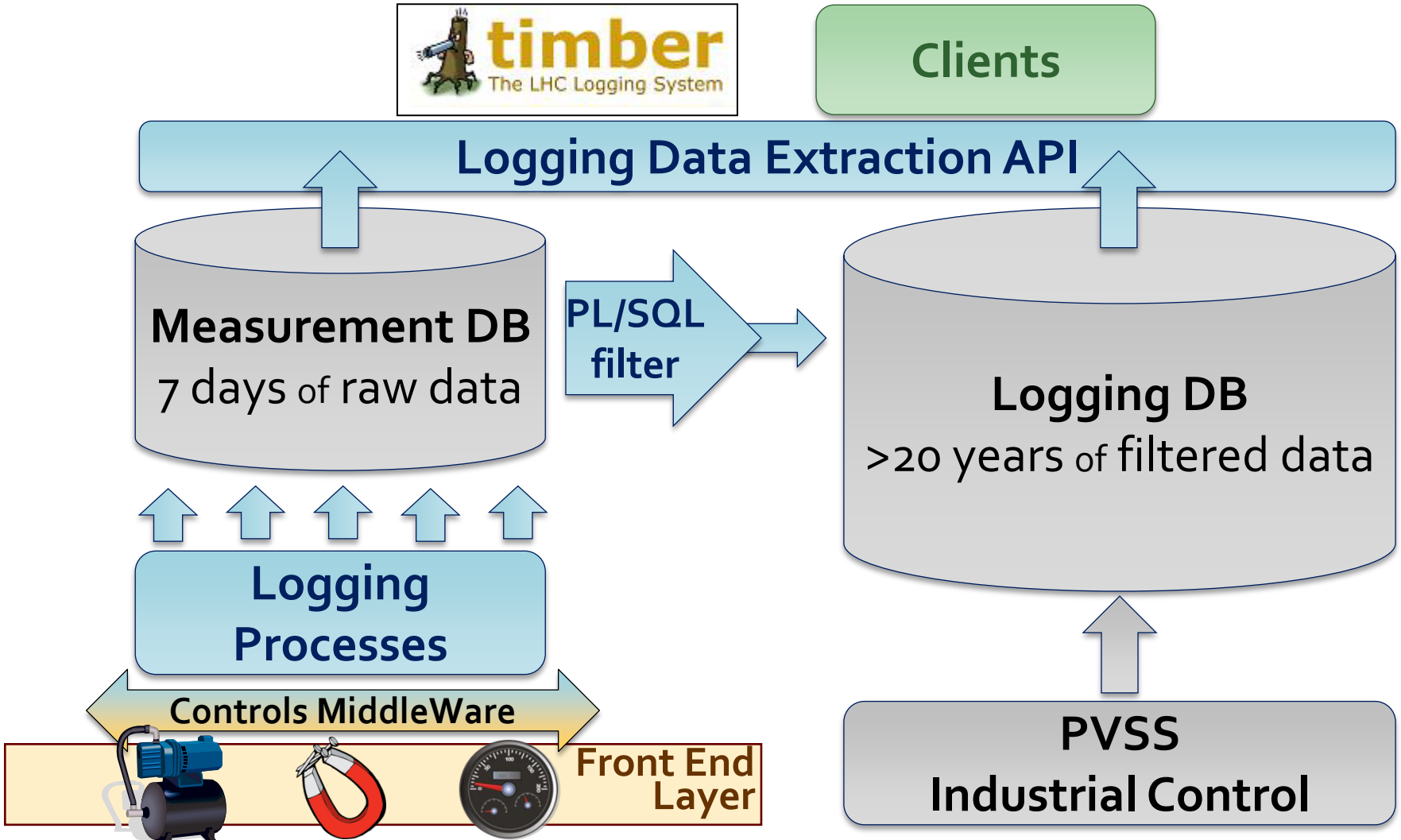
L


Cursor Coordinates
Timeseries Chart between 2012-10-16 02:29:21.286 and 2012-10-16 07:54:06.992 (LOCAL_TIME)
ALICE:LUMI_TOT_INST
ATLAS:LUMI_TOT_INST
CMS:LUMI_TOT_INST
LHC.BCTFR.A6R4.B1:BEAM_INTENSITY
LHC.BCTFR.A6R4.B2:BEAM_INTENSITY
LHCB:LUMI_TOT_INST
MKBV.UA63.SCSS.AB2:ENERGY
NO_Unit
Charges
GeV
16-Oct-2012 03h
16-Oct-2012 04h
16-Oct-2012 05h
16-Oct-2012 06h
16-Oct-2012 07h
LOCAL_TIME
Data Set: LHCB:LUMI_TOT_INST X: N/A Y: N/A
Data Set: CURSOR X: 16-Oct-2012 07:35:17.051 Y: 281.11111111111114

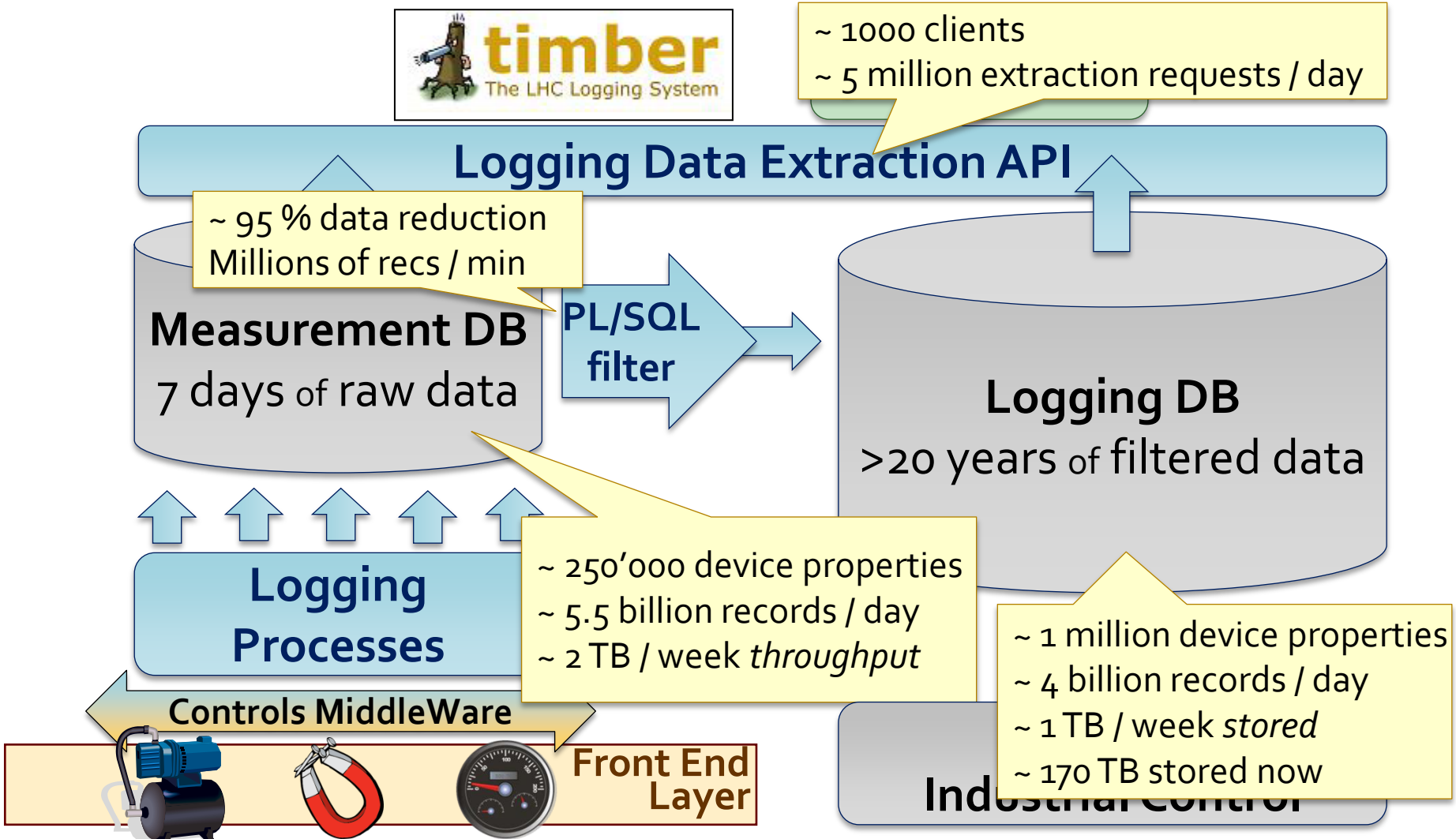
Logging Service

- **Storage** for beam & equipment data beyond LHC lifetime (>20 years)
  - Does not store experiments' data
- **Online** storage (Oracle DB, RAC-based)
- Allows **analysis of accelerator behaviour** over **long periods of time**

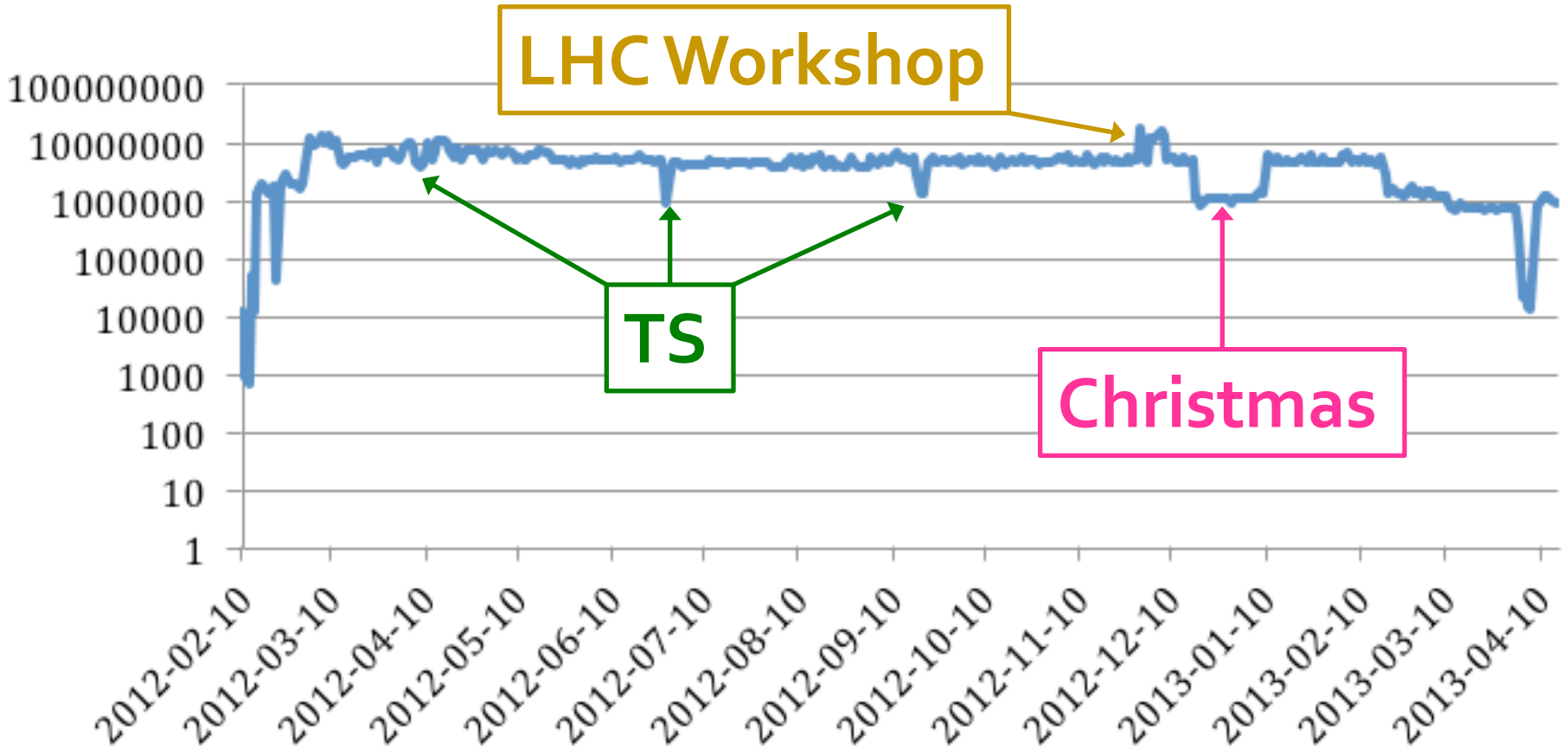
Logging: architecture



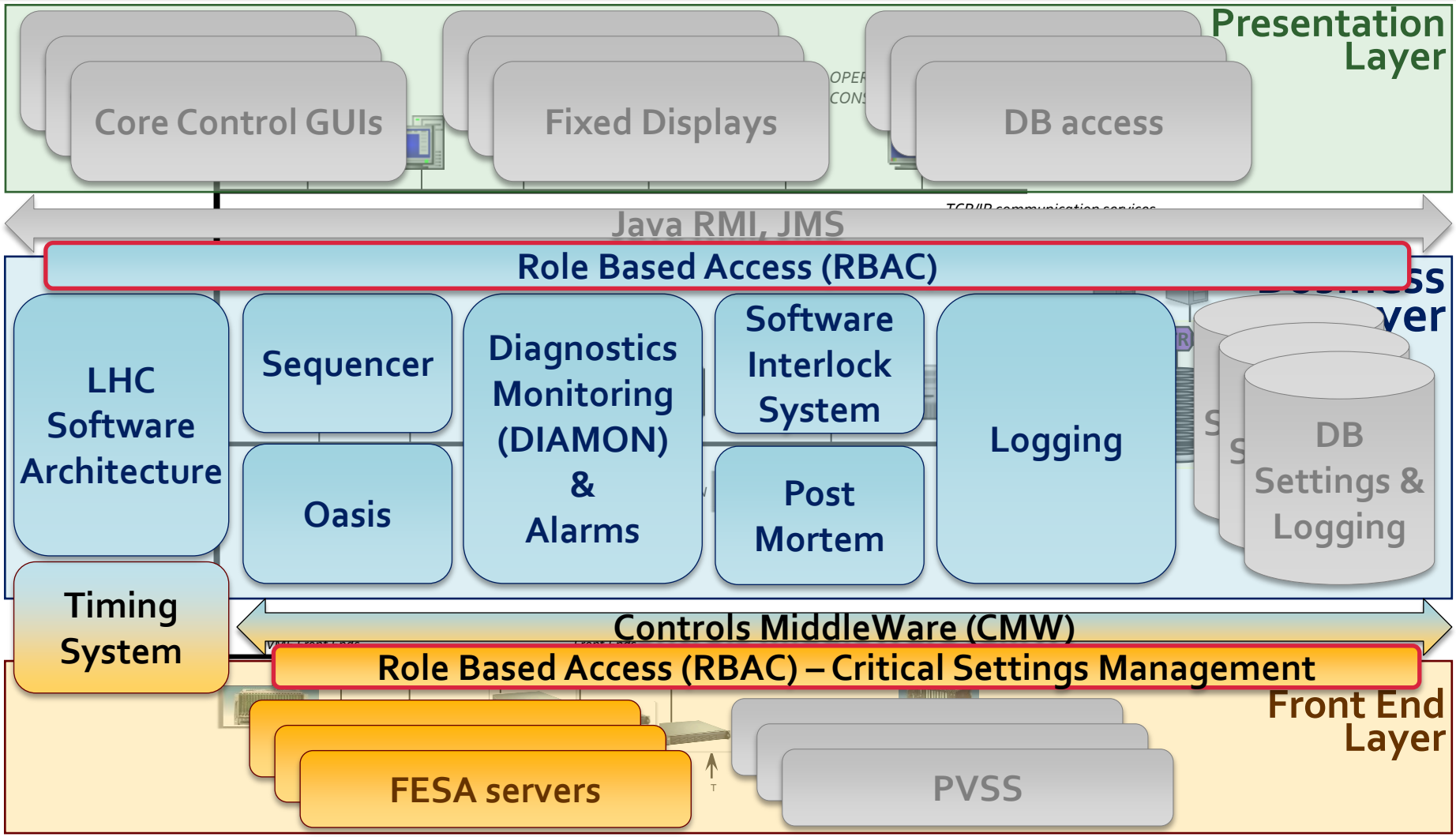
Logging: today



Logging: daily extraction requests



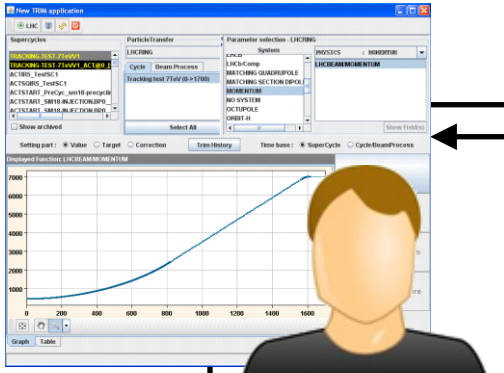
Key components: RBAC - MCS



Role Based Access Control (RBAC)

- **Protect** against unauthorized access
- Access audit
- Integrated with all 3 layers
  - front-end, business, presentation

RBAC: HW and SW protection



1. credentials: name, password, location

2. token with roles

3. token

CMW

RBAC

FESA server

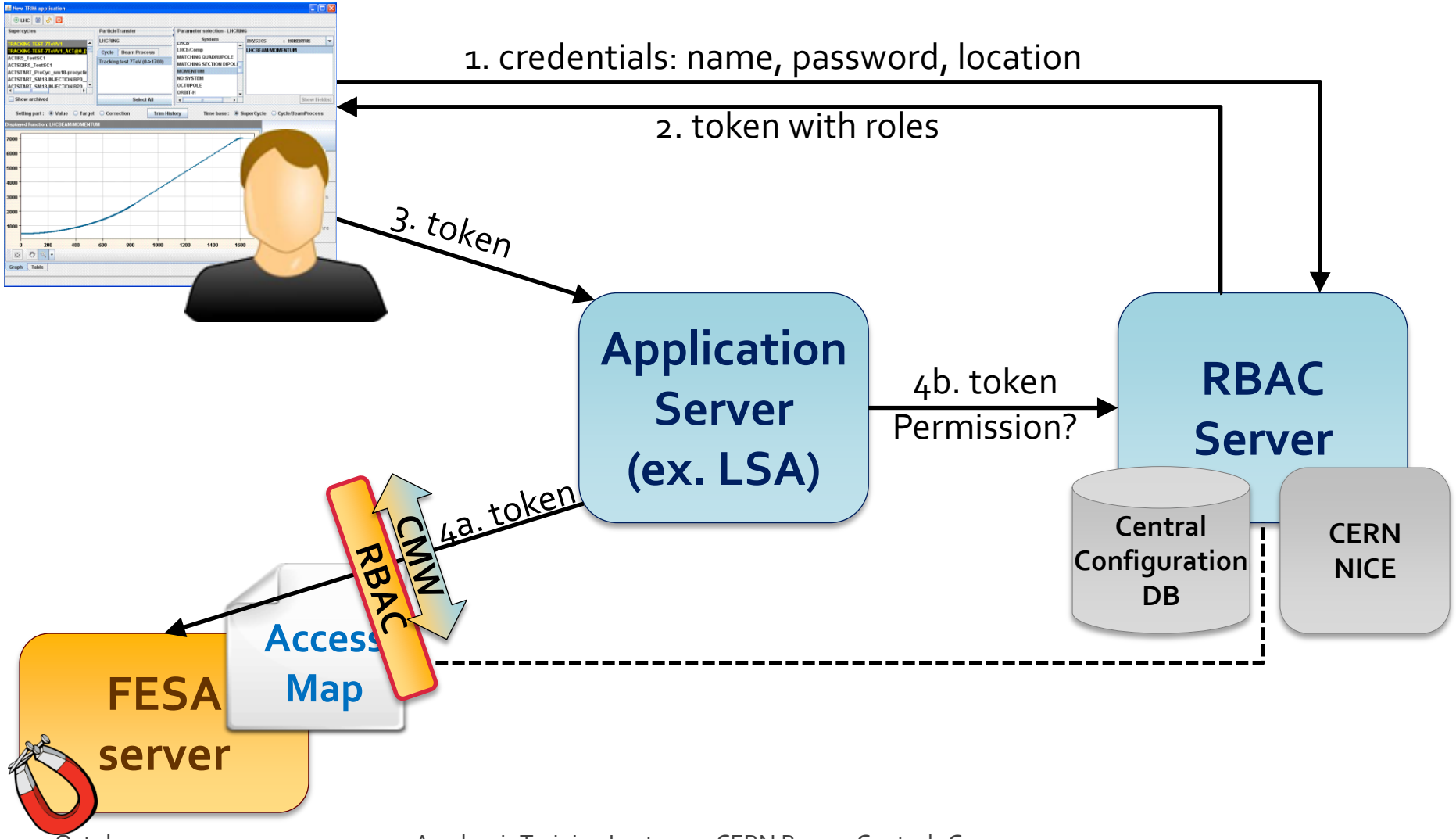
Access Map

RBAC Server

Central Configuration DB

CERN NICE

RBAC: HW and SW protection



RBAC: features

- Authentication
- Authorization
  - Business layer
  - Front-End layer
- Permission definitions
  - Who, what, when, from where
- Flexibility
  - Login-by-location
  - Temporary permissions
  - Operational-mode dependent

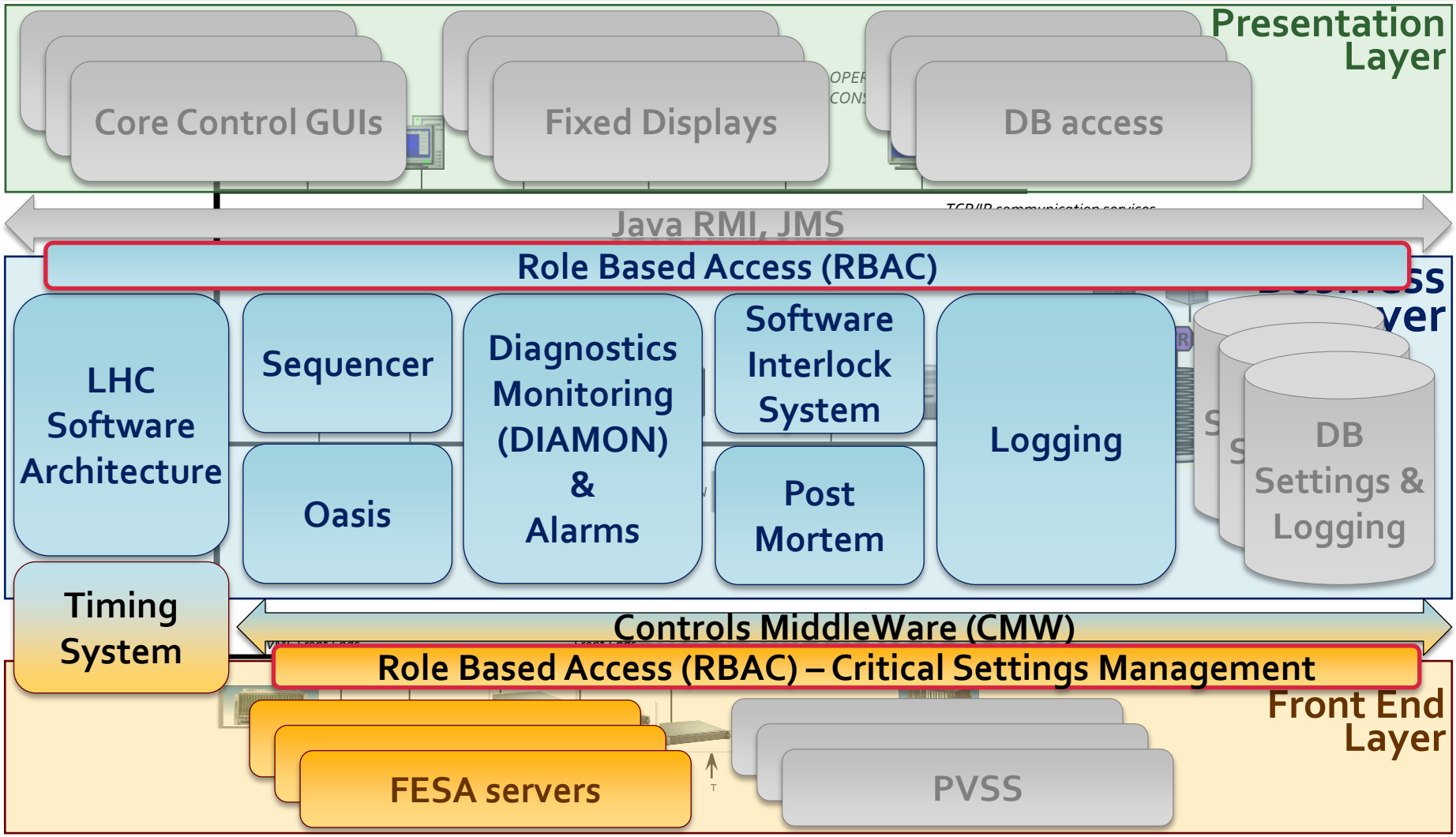
RBAC: today

- RBAC protects all the LHC equipment
- ~500'000 permission definitions
- ~500 users

Management of Critical Settings

- **Protects the value**, not the action
  - BLM, BPM thresholds
  - Collimator thresholds
  - SIS configuration
- Only experts can modify the value
- All the operators can use this value
- Digitally signed values
- 100 critical value types => 1500 properties

Key components



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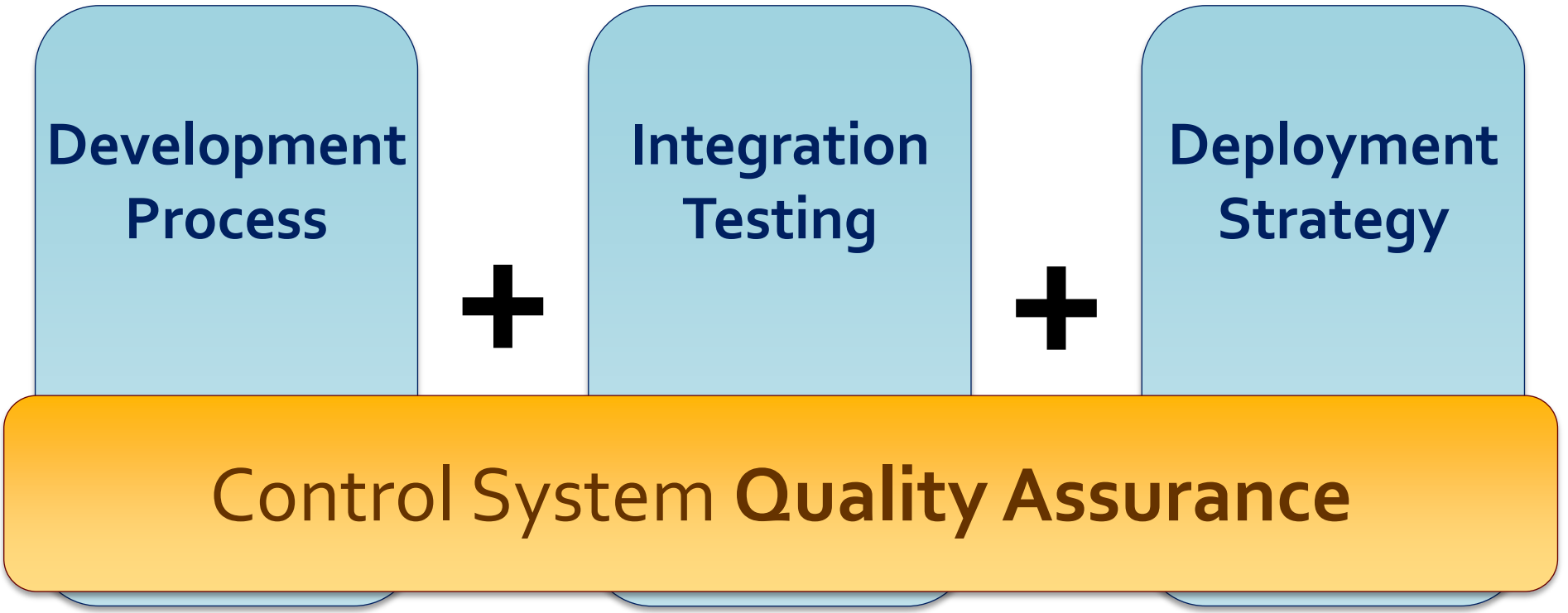
- Quality Assurance (QA)
- Outlook towards the Future

Highly modular distributed system
Big developer community

- **Front-End Layer (C/C++)**
  - 85'000 devices controlled by 2000 different machines
  - 600 different device types (FESA, PVSS, FGC)
  - Developed by 100 people from 16 different groups
- **Business and Presentation Layer (Java)**
  - 400 different GUIs and ~50 server applications
  - Up to 600 processes on 400 machines
  - Developed by ~100 people from 10 different groups
- Control system performs **mission-critical tasks**
- Control system must **evolve**

Quality Assurance

Quality Assurance is essential



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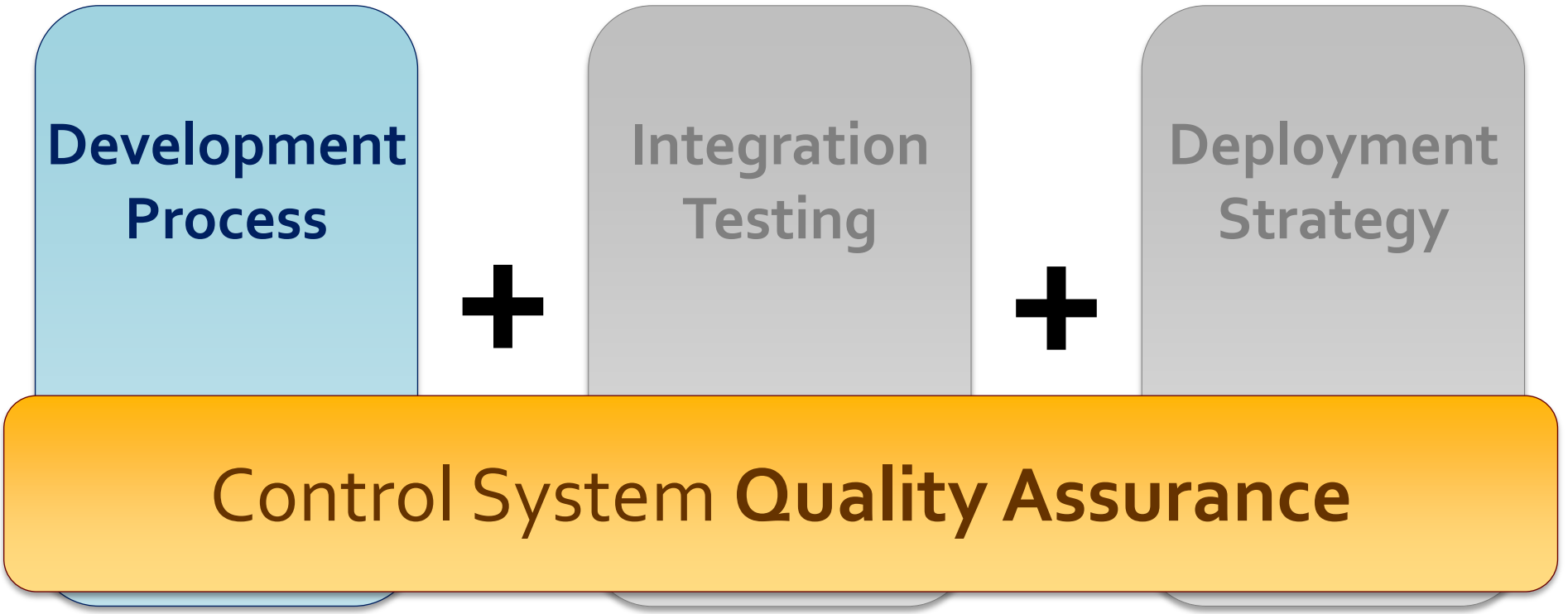
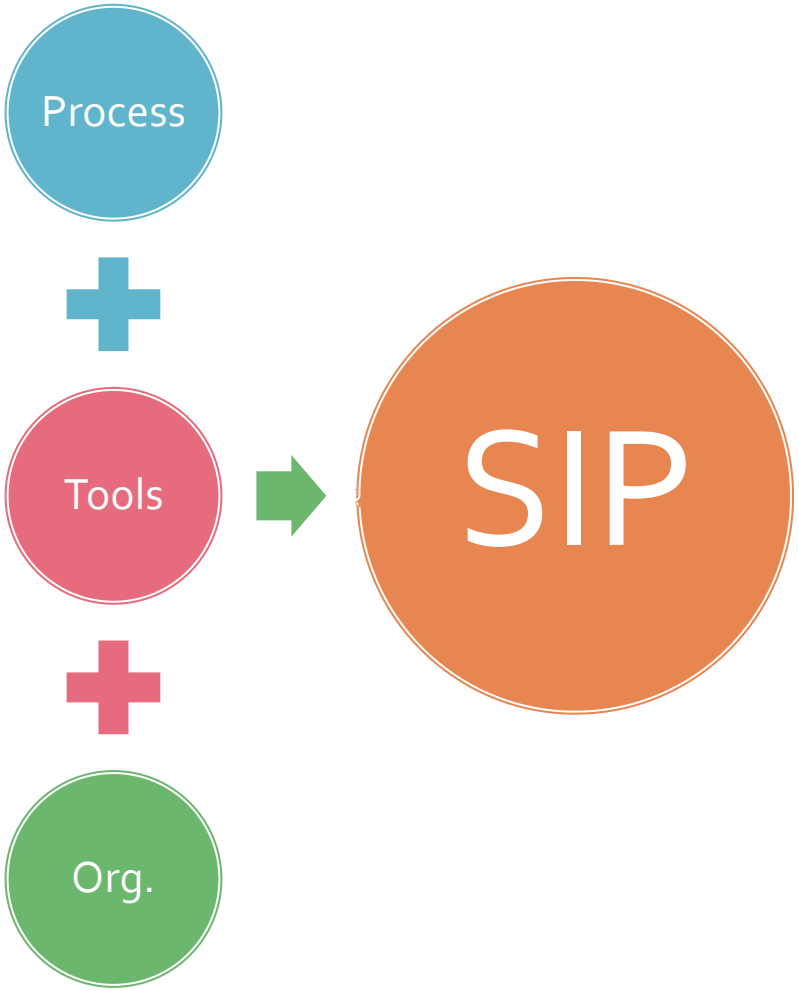


Software Improvement Process (SIP)

- Development process
  - Recommended / mandatory activities and deliverables
- Tools
  - Support the process by automating as much as possible
- Organization
  - Officially allocate time
  - Dedicated QA days
  - Follow up progress



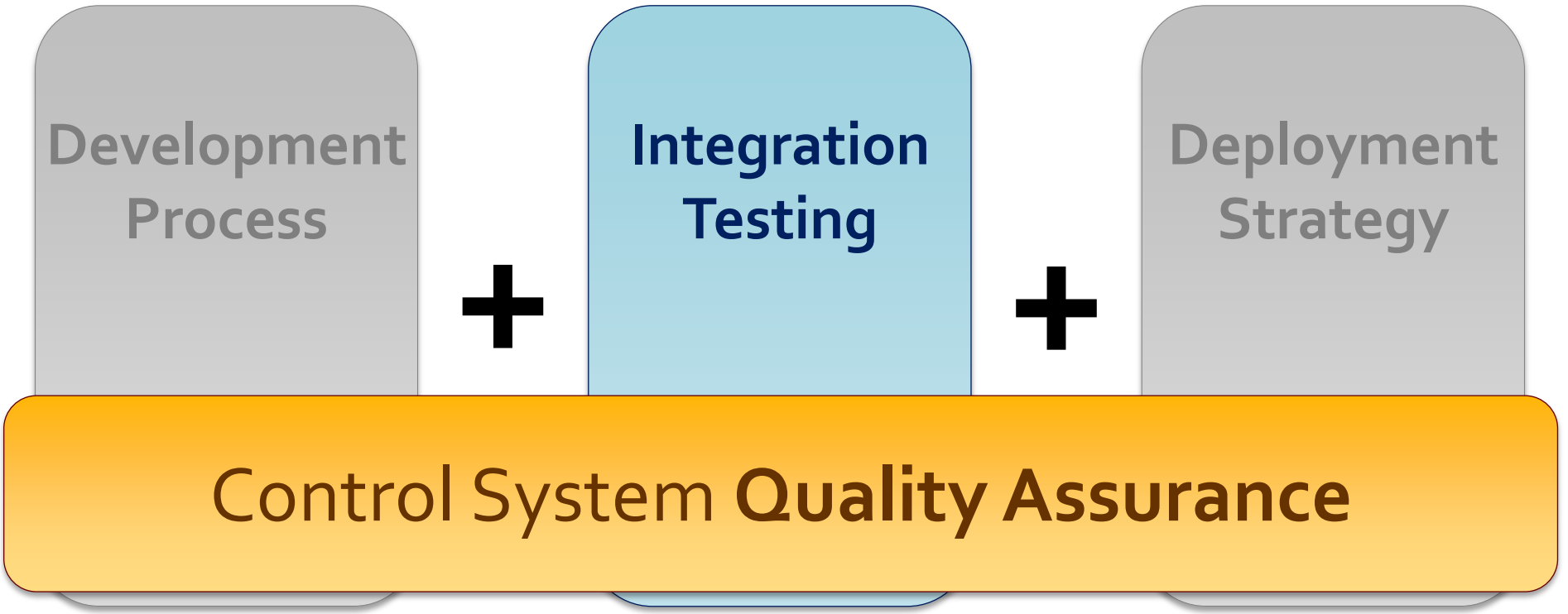
SIP: activities and tools

- Common code style (Eclipse IDE)
- Dependency analysis (Eclipse plugin)
- Unit testing (JUnit, Mockito, Clover)
- Static code analysis (FindBugs, PMD, Sonar)
- Code reviews (FishEye + Crucible)
- Continuous Integration (Bamboo)
- Issues tracking & planning (JIRA + Greenhopper)
- Documentation (Confluence Wikis)
- Agile development methodologies

Links to project pages

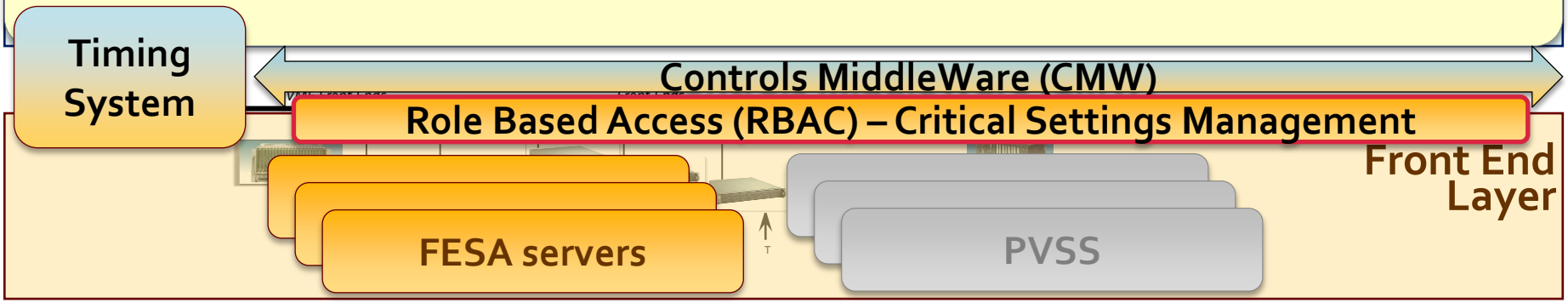
Beams Department Controls Group	espace.cern.ch/be-dep/CO
Timing System	wikis.cern.ch/display/HT(/Timing+Software) www.ohwr.org(/projects/white-rabbit/wiki)
Front-**E**nd **S**oftware **A**rchitecture	wikis.cern.ch/display/FESA3
Controls **M**iddle**W**are	wikis.cern.ch/display/MW
LHC **S**oftware **A**rchitecture	wikis.cern.ch/display/LSA
Sequencer	wikis.cern.ch/display/SEQ
Open **A**nalog **S**ignal **I**nformation **S**ystem	wikis.cern.ch/display/OASIS
Diagnostics **Mon**itoring & Alarms	wikis.cern.ch/display/ADM laser-alarms.web.cern.ch/laser-alarms/
Software **I**nterlock **S**ystem	wikis.cern.ch/display/SIS
Post-**M**ortem (**A**nalysis)	wikis.cern.ch/display/PMS(/Documentation)
Logging Service	wikis.cern.ch/display/CALS
Testbed	wikis.cern.ch/display/CSTBF

Quality Assurance is essential

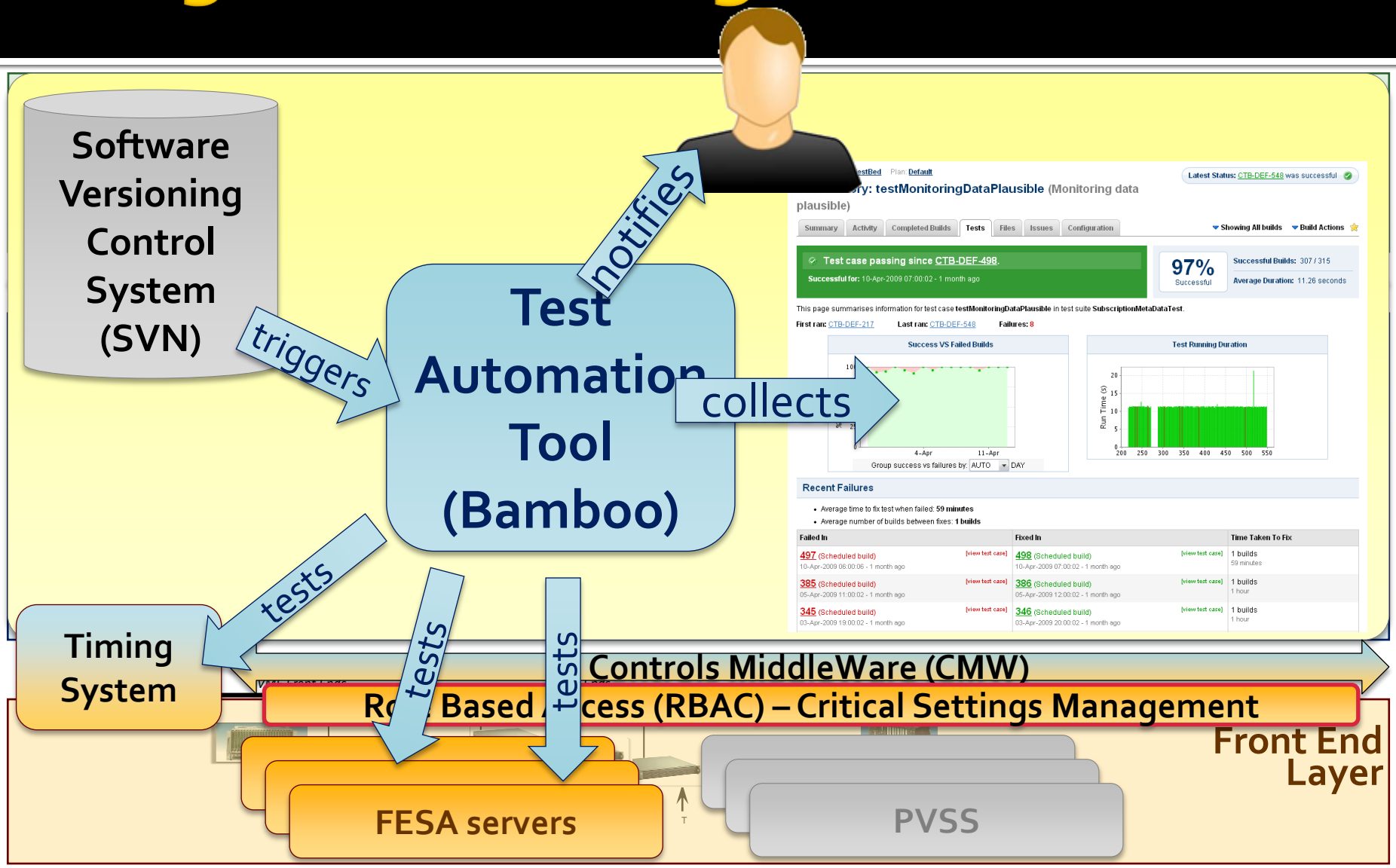


Integration testing: Testbed

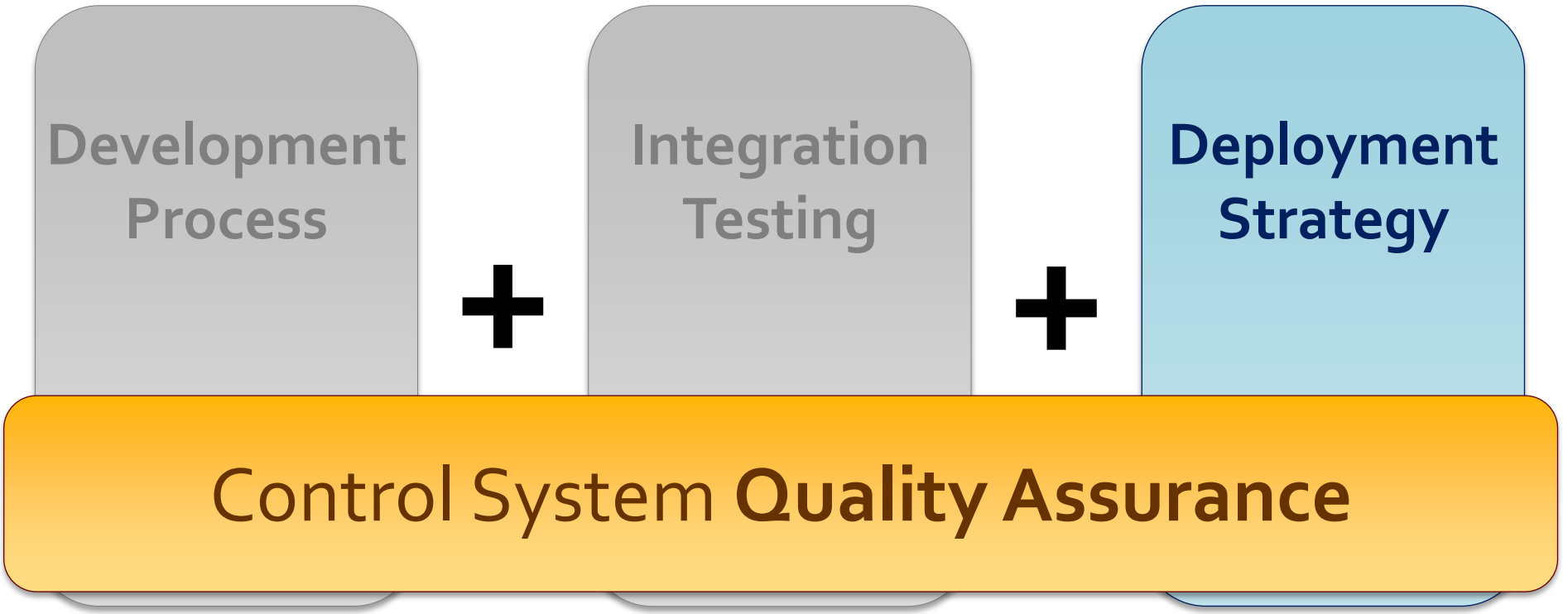
- Test the core components of the control system together
- Validate new versions of the control system before deployment
- Automation



Integration testing: Testbed



Quality Assurance is essential



Deployment: Smooth Upgrades

- **Official approach**
  - **Analyze** the **impact** of a change upfront
  - **Backward compatible** upgrades if possible
  - Non-backward compatible upgrades only with **careful coordination** and follow-up
  - Big changes on central systems only during shutdown
- Other ingredients to **smooth upgrades**:
  - **Planning** before starting development work
  - **Quality Assurance** (development + integration testing)
  - Deploy upgrades first for accelerators that need them
  - **Means** to quickly **roll-back** in case of problems

Contents

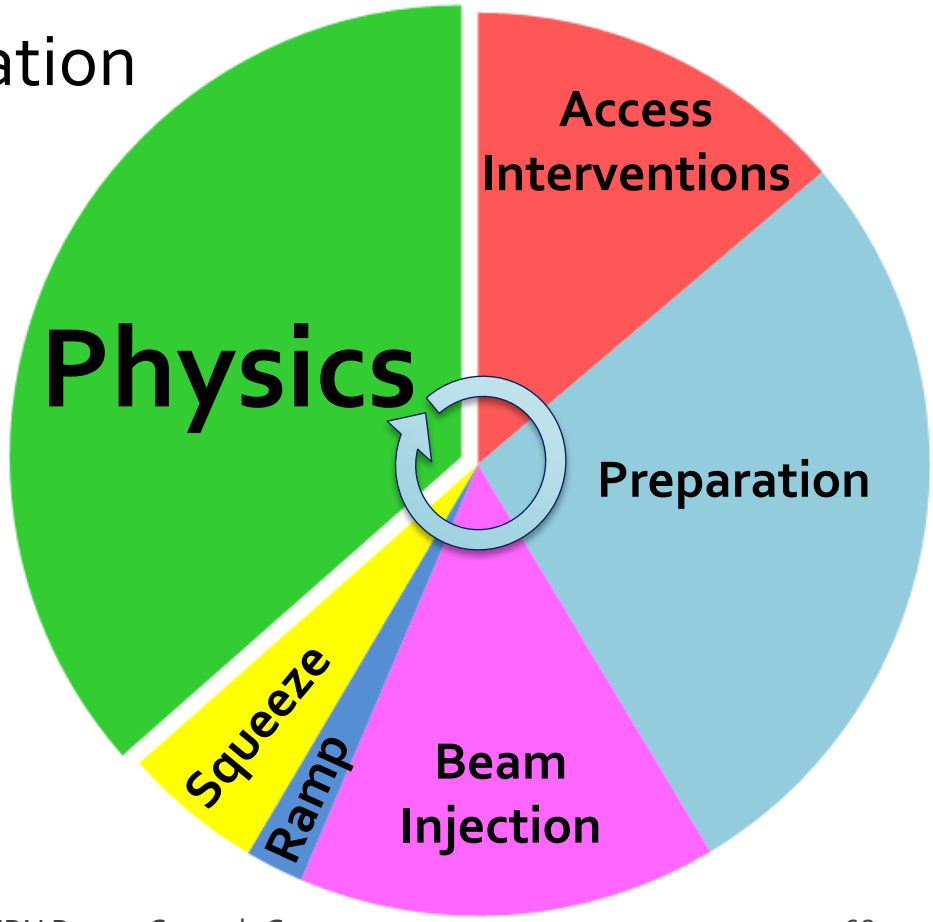
- LHC control system requirements
- Philosophy of development
- Overview of the architecture
- Key components
- Quality Assurance (QA)
- Outlook towards the Future

Consolidation and new functionality

- Control System **consolidation**
- **Common analysis framework** for logged data
- LHC Hardware Commissioning analysis **automation**
- **Technology** replacement
  - Future Front End hardware platform technology
  - Investigations regarding future software technologies
  - Timing => WhiteRabbit, Middleware => ZeroMQ

LHC performance improvement

- "Physics" time maximization
  - LHC procedures optimization
    => provide tools
- Control System fault minimization



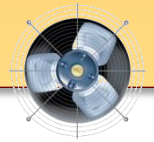
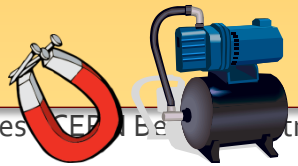
Accelerator downtime minimization

- Early warning system, **problem anticipations**
  - Monitoring
  - Sanity checks
- Improve **first-line problem analysis**
  - Runtime dependency analysis
  - Which expert to call
- Improve **smooth upgrades**
  - Better tools to show what has changed
  - Tools to help **backward-compatibility assurance**

CERN Accelerator Control System

- 150 server applications
- 400 different GUIs
- Up to 600 processes on 400 machines
- Developed by ~100 people from 10 different groups

- 85'000 devices controlled by 2000 different machines
- 600 different device types (FESA, PVSS, FGC)
- Developed by 100 people from 16 different groups


CERN

CERN Accelerator Control System

- **Strategy** behind development:
  - We provide extensible frameworks/tools
  - Clients fill in the domain-specific knowledge
- Clear **guidelines**
  - Coherent model: device-property
  - Architecture and technology choices
- Thorough **Quality Assurance**
- Successful and efficient **collaboration**
  - with equipment groups and operators
  - with other laboratories (FermiLab, GSI, ESRF, etc.)