# FAIR Control System Overview

CSCO / R. Mueller (*)

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* thanks to R. Baer, J. Fitzek , I. Kraus, S. Matthies for their slides input

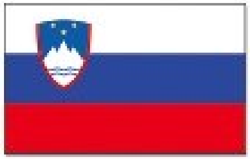
# Agenda

- Scope & Project Plan
- Detailed Control System Overview
- Conclusion

# General Situation

- Control System
  - The WP has a central and integrating character
  - Controls cannot be assigned to a single FAIR machine
  - Instead the full GSI/FAIR accelerator complex is considered
    => there is no specific CR control system...
  - In the FAIR Project: defined as a “Common System“

- Facts: IKRB/Council decisions
  - Control System is an in-kind contribution
    of GSI (Controls Group)
  - With some minor contributions by Slovenia



- Control System for FAIR is already under development
  - GSI Controls group will develop, install, commission
    and optimize the CS

# Scope of the Control System

**Accelerator Control System**

- WP1 Core Controls Software
  WP2 System Software Packages
- WP3 General Machine Timing
- WP4 Bunch Timing System
- WP5 Front-End Hardware
- WP6 Vacuum Controls
- WP7 Cryogenic Controls
- WP8 Controls Infrastructure
- WP9 Controls Networks
- WP10 Main Control Room
- WP11 Machine Prot. & Safety Systems

- The working package "Accelerator Controls" comprises the full electronics, hard- and software infrastructure for all accelerators and beam-lines of FAIR and GSI that is needed to control, commission, and operate the GSI/FAIR accelerator complex.
- Limits of scope: experiments excluded

# Technical Scope Overview (1)

- Equipment Control and Timing
  - FE controllers for all equipment (except BI DAQ systems)
    interfaces to standard equipment already defined (PC, RF, etc.)
  - Equipment interface electronics (standard solutions), e.g. function generators
  - General Machine Timing system (general purpose, ns precision, triggering)
  - Bunch timing system (sub ns precision, clock distribution, covered by RF group at GSI)

- Software
  - Software frameworks (FE system, Setting generation, Applications, etc.)
  - Implementation and coordination of all general equipment control classes
  - Communication middleware software and services
  - Control System services (DB, alarming, logging, trending, many more)
  - All applications programs for standard operation, tools for commissioning
  - Software framework for machine setting/tuning/trimming and data management
  - Software framework and implementation for Industrial Controls

# Technical Scope Overview (2)

- Network & Computing
  - All active and passive technical network components needed for FAIR controls
  - Provide network access for experiments in accelerator environment
  - defines development & runtime environment
  - Cables, racks, crates, infrastructure

- Control Center
  - Central control room installations
  - Consoles, fixed displays, special electronics

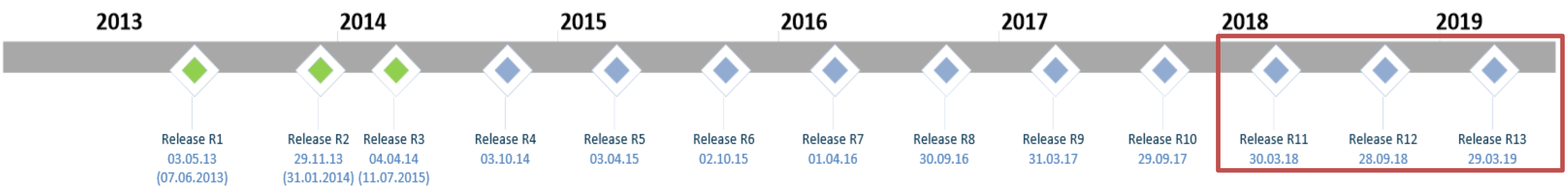
- Machine protection
  - Personnel safety system implementation (access control)
  - Machine protection systems (interlock system, specific MPS)

- Industrial Controls
  - Slow control subsystems

# General Strategy for FAIR Controls

- **Standardization**: define and enforce standards
- Build new system substantially on **proven principles** & solutions of the existing system
- **Modernize** existing system to integrate into new system; obsolete technology needs to be replaced
- Develop and use **uniform frameworks** to simplify development and ease maintenance; provide frameworks to developers
- Implement and **test everything** on existing machines
- Evaluate existing CS solutions/frameworks; **enter collaborations and adapt/extend** to FAIR needs
- Concentrate development on missing things
- Have a team to ensure **system coherency and integrity** all along the development process
- **Replace legacy** components by FAIR solutions once available

# CR Schedule & Major Releases




R11: Control System „Ready for installation“ (hardware commissioning)
R12: Control System „Ready for test operation“ (integration tests)
R13: Control System „Ready for beam operation“ (full system, including MPS)

- Control system development is realized in development cycles with pre-defined milestones.

| Release | Cycle (gross days) | Cycle (eff. days) | Due Day Milestone | CRYRING | HEBT | SIS-100 | p-Linac | p-bar | SFRS | CR | HESR | SIS-Upgr | UNI-Upg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | 220 | | 03.05.2013 (07.06.2013) | | | | | | | | | | |
| R2 | 150 | | 29.11.2013 (31.01.2014) | R2 | | | | | | | | | |
| R3 | 90 | | 04.04.2014 (15.05 - 11.07.2014) | R3 | | | | | | | | | |
| R4 | 130 | 100 | 03.10.2014 | R4.1 R4.2 | | | | | | | | | |
| R5 | 130 | 100 | 03.04.2015 | R5 | | | | | | | | | |
| R6 | 130 | 100 | 02.10.2015 | R6 | | | | | | | | | |
| R7 | 130 | 100 | 01.04.2016 | R7 | | | | | | | | | |
| R8 | 130 | 100 | 30.09.2016 | R8 | R8 | | | | | | | R8.1 R8.2 | R8 |
| R9 | 130 | 100 | 31.03.2017 | R9 | R9 | R9 | | | | | | R9 | R9 |
| R10 | 130 | 100 | 29.09.2017 | R10 | R10 | R10 | R10 | R10 | R10 | | | R10 | R10 |
| R11 | 130 | 100 | 30.03.2018 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 |
| R12 | 130 | 100 | 28.09.2018 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 |
| R13 | 130 | 100 | 29.03.2019 | R13 | R13 | R13 | R13 | R13 | R13 | R13 | R13 | R13 | R13 |

CS ready for installation    CS ready for test operation    CS ready for beam operation

# Standardization & Coordination

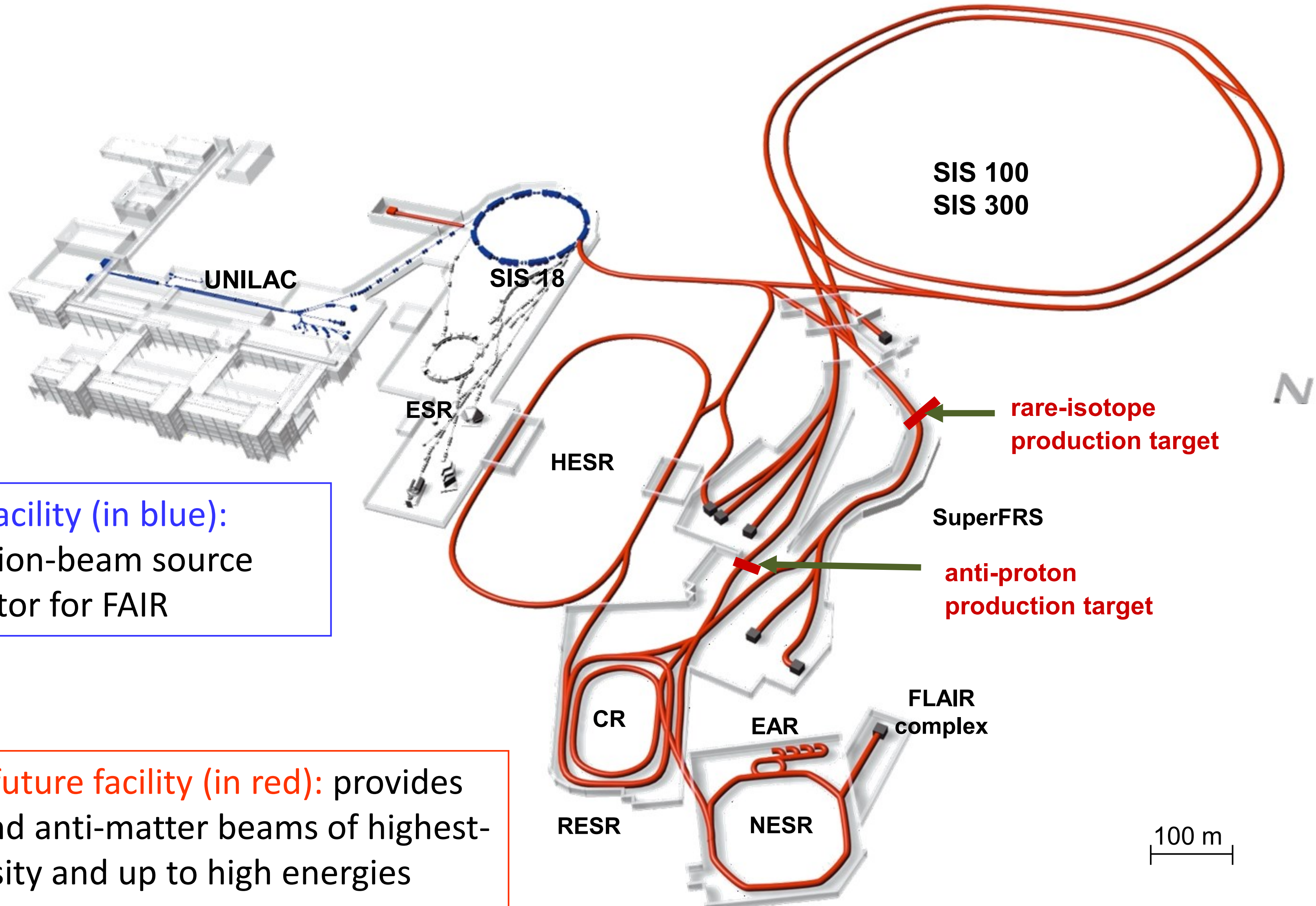
- Standardization
  - Is an absolute MUST: strict standardization of Controls and interfaces,
  - compliance to Technical Guidelines,
  - Common and Detailed Specs!
- Communication & Coordination
  - Machine Controls Coordinator (MCC) defined (R. Müller for CR)
  - There shall be a contact/coordinator at BINP defined.
- Discussions about CR commissioning strategy
  - tools, specific functional requirements, etc.
  - implementation of non-standard equipment?

| Common Specifications (CS) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | Type | Name | Version | Author(s) | inkind | PSP | EDMS link |
| F-CS-C-01e | CS | Common Specifications Accelerator Control System | v3.1 | Bär et al | GSI | 2.14.10 | https://edms.cern.ch/document/1174186/6 |
| Detailed Specifications (DS) | | | | | | | |
| Number | Type | Name | Version | Author(s) | inkind | PSP | EDMS link |
| F-DS-C-01e | DS | FEC software framework (FESA) | v3.0 | Schwinn, Hechler | GSI | 2.14.10.1.2 | https://edms.cern.ch/document/1176025/1 |
| F-DS-C-02e | DS | Equipment Interface and Control | v3.0 | Thieme | GSI | 2.14.10.5.1, 2.14.10.5.2, 2.14.10.5.3, 2.14.10.5.4, 2.14.10.5.5, 2.14.10.5.7, 2.14.10.5.8 | https://edms.cern.ch/document/1176026/1 |
| F-DS-C-03e | DS | Settings Management System | v3.0 | Fitzek, Müller, Ondreka | GSI | 2.14.10.1.1, 2.14.10.2.1 | https://edms.cern.ch/document/1176027/1 |
| F-DS-C-04e | DS | User applications | v3.0 | Fröhlich et al | GSI | 2.14.10.2.2 | https://edms.cern.ch/document/1176028/1 |
| F-DS-C-05e | DS | General machine timing system | v3.0 | Beck | GSI | 2.14.10.1.5, 2.14.10.3 (without 2.14.10.3.3) | https://edms.cern.ch/document/1176029/1 |
| F-DS-C-06e | DS | Timing Receivers | v3.2 | Timing Team | SLO | 2.14.10.3.3 | https://edms.cern.ch/document/1176030/5 |
| F-DS-C-07e | DS | Vacuum control system | v3.1 | Betz | SLO | 2.14.10.6 | https://edms.cern.ch/document/1176035/4 |
| F-DS-C-08e | DS | Interlock system | v3.1 | Fitzek , Fröhlich, Krause | SLO | 2.14.10.11.3 | https://edms.cern.ch/document/1176036/4 |
| F-DS-C-09e | DS | Alarm system | v3.1 | Huhmann | SLO | 2.14.10.2.7 | https://edms.cern.ch/document/1176037/4 |
| F-DS-C-10e | DS | Diagnostic logging system | v3.0 | Handel, Müller | SLO | 2.14.10.2.8 | https://edms.cern.ch/document/1176038/4 |
| F-DS-C-11e | DS | Archiving system | v3.0 | Hechler | SLO | 2.14.10.2.9 | https://edms.cern.ch/document/1176039/3 |
| F-DS-C-12e | DS | Beam transmission monitor system | v3.1 | Fröhlich, Jülicher | SLO | 2.14.10.11.4 | https://edms.cern.ch/document/1176040/4 |
| F-DS-C-13e | DS | Post mortem system | v3.0 | Fitzek | SLO | 2.14.10.11.5 | https://edms.cern.ch/document/1176041/5 |
| F-DS-C-14e | DS | Soft oscilloscope system | v3.0 | Fitzek | SLO | 2.14.10.2.10 | https://edms.cern.ch/document/1176042/3 |
| F-DS-C-15e | DS | FEC device classes (FESA) | v3.0 | Krause | SLO | 2.14.10.2.11 | https://edms.cern.ch/document/1176043/3 |
| F-DS-C-16e | DS | Motion control FECs | v3.0 | Krause | SLO | 2.14.10.5.9 | https://edms.cern.ch/document/1176044/4 |
| F-DS-C-17e | DS | Serial equipment control FECs | v3.0 | Krause | SLO | 2.14.10.5.9 | https://edms.cern.ch/document/1176045/3 |
| F-DS-C-18e | DS | Industrial Control Framework | v3.0 | Betz | GSI | 2.14.10.1.3 | https://edms.cern.ch/document/1238324/1 |
| F-DS-C-19e | DS | Middleware and communication framework | v3.0 | Huhmann | GSI | 2.14.10.1.4 | https://edms.cern.ch/document/1238328/1 |
| F-DS-C-20e | DS | Personnel Safety System | v3.0 | Pfeil, Betz, SiSt | GSI | 2.14.10.11.1 | https://edms.cern.ch/document/1238335/1 |
| F-DS-C-21e | DS | Main control room environment | v3.0 | Vincelli, Schiebel | GSI | 2.14.10.10 | https://edms.cern.ch/document/1240222/1 |
| F-DS-C-22e | DS | Console environment system | v3.0 | Huhmann | GSI | 2.14.10.2.3 | https://edms.cern.ch/document/1240223/1 |
| F-DS-C-23e | DS | Data acquisition (DAQ) framework | v3.0 | CCT | GSI | 2.14.10.1.6 | https://edms.cern.ch/document/1240224/1 |
| F-DS-C-24e | DS | Data management | v3.0 | Jülicher, Steinmetz | GSI | 2.14.10.1.7 | https://edms.cern.ch/document/1240225/1 |
| F-DS-C-25e | DS | Controls IT environment, part 1 (Computing) | v3.0 | Schiebel, Handel, Steinmetz | GSI | 2.14.10.8, 2.14.10.5.6 | https://edms.cern.ch/document/1240226/1 |
| F-DS-C-26e | DS | Controls IT environment, part 2 (Network) | v3.0 | Schiebel, Handel, Steinmetz | GSI | 2.14.10.9 | https://edms.cern.ch/document/1240227/1 |
| F-DS-C-27e | DS | Controls IT environment, part 3 (Software) | v3.0 | Handel, Steinmetz, Schiebel | GSI | 2.14.10.1.8 | https://edms.cern.ch/document/1240228/1 |
| F-DS-C-28e | DS | Equipment Control Software | v3.0 | Krause | GSI | 2.14.10.2.4 | https://edms.cern.ch/document/1240229/1 |
| F-DS-C-29e | DS | Existing machines and CS integration | v3.0 | Krause, CCT | GSI | 2.14.10.2.5 | https://edms.cern.ch/document/1240230/1 |
| F-DS-C-30e | DS | Extended system services | v3.0 | CCT | GSI | 2.14.10.2.6 | https://edms.cern.ch/document/1240231/1 |
| F-DS-C-31e | DS | Machine protection systems | v3.1 | Fitzek, Bär | GSI | 2.14.10.11.2 | https://edms.cern.ch/document/1240232/2 |
| F-DS-C-32e | DS | White Rabbit Switch | v1.0 | Beck | GSI | 2.14.10.3 | https://edms.cern.ch/comment/1385239/1 |
| Technical Guidelines (TG) | | | | | | | |
| Number | Type | Name | Version | Author(s) | inkind | PSP | EDMS link |
| F-TG-C-01e | TG | Ethernet network connectivity | v3.1 | Schiebel et al | GSI | 2.14.10 | https://edms.cern.ch/document/1171993 |
| F-TG-C-02e | TG | Control System Equipment Control Interfaces | v3.0 | diverse | GSI | 2.14.10 | https://edms.cern.ch/document/1171994 |
| F-TG-C-03e | TG | Control System Equipment Interlock and Status Signal Interface | v3.0 | diverse | GSI | 2.14.10 | https://edms.cern.ch/document/1171995 |
| F-TG-C-04e | TG | Control System Equipment Functional Requirements | v3.0 | diverse | GSI | 2.14.10 | https://edms.cern.ch/document/1171997 |
| F-TG-C-05e | TG | System for Nomenclatures | | Schaa | GSI | 2.14.10 | https://edms.cern.ch/document/1172128 |
| Development Guidelines (DG) | | | | | | | |
| Number | Type | Name | Version | Author(s) | inkind | PSP | EDMS link |
| F-DG-C-01e | DG | FESA Development Guideline | v1.1 | Schwinn | GSI | 2.14.10 | https://edms.cern.ch/document/1235310 |
| F-DG-C-02e | DG | GUI Guideline | v1.1 | BEL-AP | GSI | 2.14.10 | https://edms.cern.ch/document/1235719 |
| F-DG-C-03e | DG | Software Architecture Guideline | v1.0 | Huhmann et al | GSI | 2.14.10 | https://edms.cern.ch/document/1235720 |
| F-DG-C-04e | DG | Equipment Integration Guideline | v1.1 | Fitzek, Hechler | GSI | 2.14.10 | https://edms.cern.ch/document/1235721 |
| F-DG-C-05e | DG | Control System Naming Guideline | v1.0 | Huhmann | GSI | 2.14.10 | https://edms.cern.ch/document/1240613 |

# Agenda

- Scope & Project Plan
- Detailed Control System Overview
- Conclusion

# The FAIR Accelerators

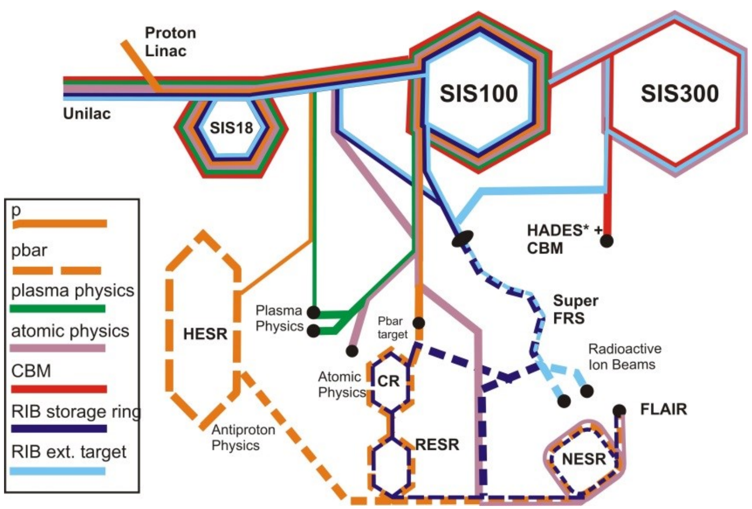


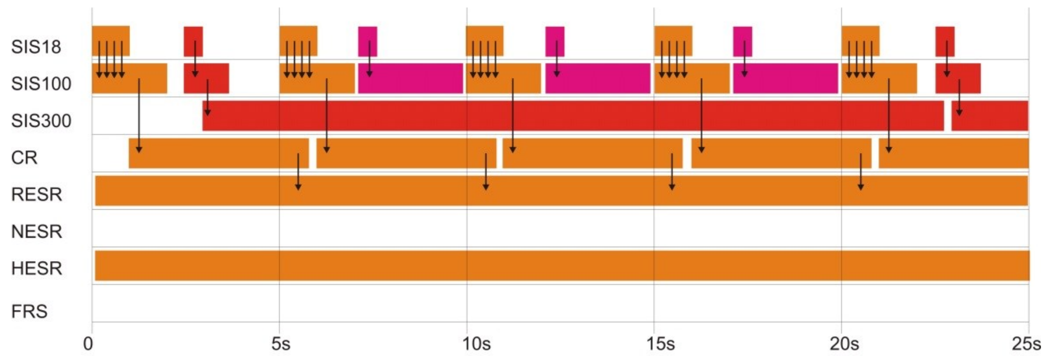

Existing facility (in blue): provides ion-beam source and injector for FAIR

New future facility (in red): provides ion and anti-matter beams of highest-intensity and up to high energies

# Major Controls Challenges

- Parallel Operation
  - Important consideration of FAIR is a high degree of parallel operation of different research programs
  - Provide maximum integrated beam time or luminosity
  - Up to 5 different research programs may be served in parallel
  - Sophisticated coordination and synchronization of accelerator production chains needed (timing, sequencing)




Operation Mode #5: pbar in HESR, CBM in SIS300 and high energy Atomic Physics.

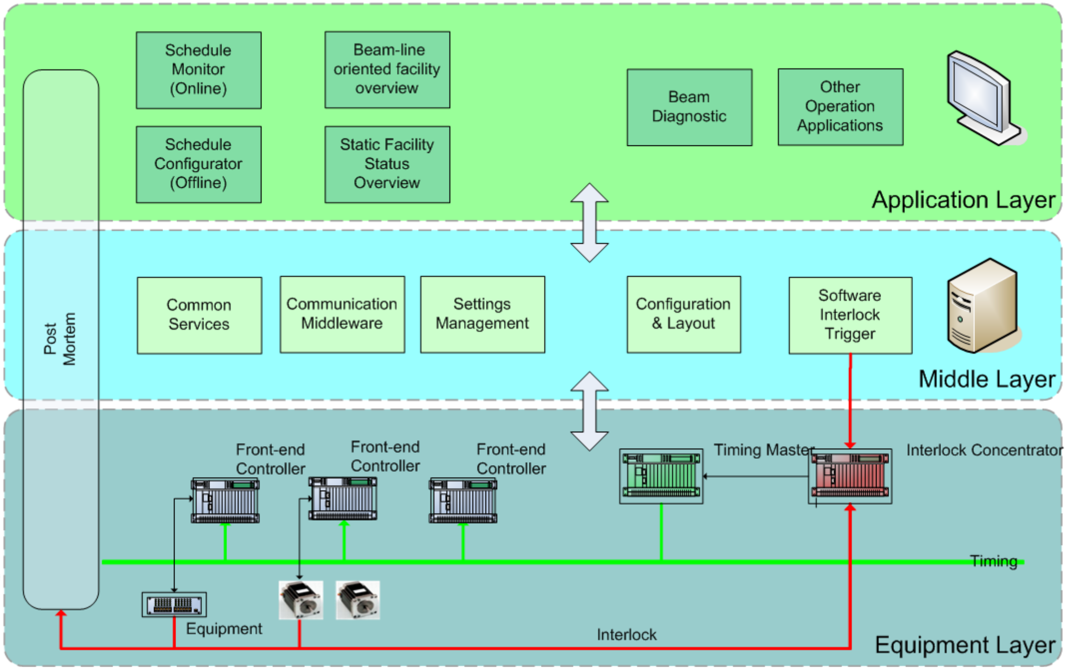
# Layer Overview

- Standard model (or: every system is the same…)
- Decentralized, distributed, OO system, …
- Modular design with well defined interfaces

**Presentation Tier**

**Middle Tier**
powerful servers,
LSA

**Resource Tier**
FESA



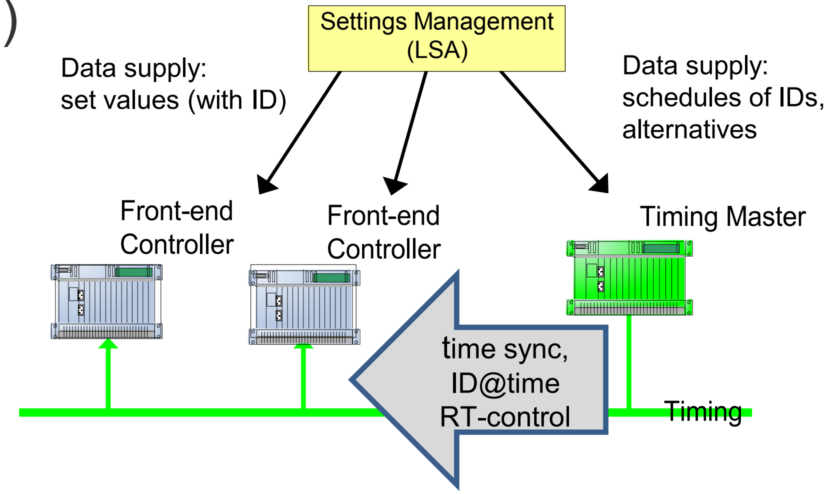

**Network**

**Middleware**

**TimingSystem**

# Timing System

- GMT (General Machine Timing System)
  - Parallel execution of beam production chains
  - Cycles: 20ms to hours
  - Trigger and synchronize equipment actions
  - 1 µs precision in 99% of all cases
  - One ns accuracy for special cases
  - (Few ps for rf-systems: BuTiS)
- Many rings
  - >2000 devices connected to timing system
  - Large distances
  - Robustness: loose at most one message per year

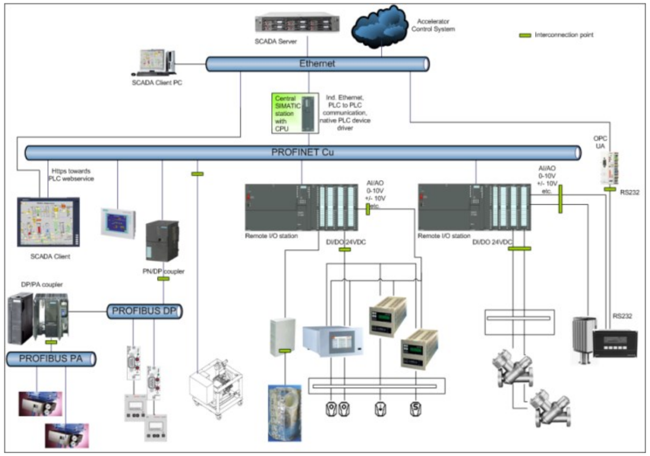


# Equipment Controller: SCU
(Scalable Control Unit)

- Custom and cost-effective solution for equipment control
  - Base board with powerful FPGA for time-critical functions
    (e.g. timing receiver, function generators)
  - COM express module with Intel Atom CPU
  - Primary interface: SCU Bus (16-bit wide parallel bus)
  - Option: high-speed serial connectors (>500 MBit)
  - 2 SFP slots on base board (timing), 1 GbE for communication
- Used as central Front-end controller for FAIR
  - About 1500 units for PCs, RF,...
  - Integrated in equipment
    (e.g. power converter cabinet)
  - Form factor / bus system
    evolution for compatibility / upgrade

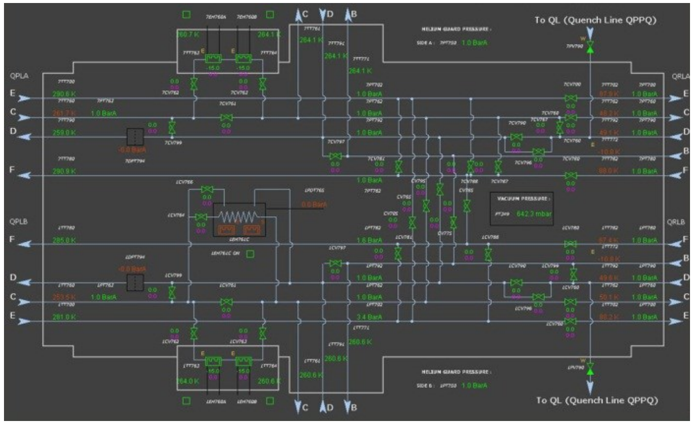
# Industrial Controls

- Industrial Controls will be used for slow control subsystems such as
  - Vacuum Control (SLC in-kind)
  - Cryo Control
  - Personnel Safety System
  - Interlock System



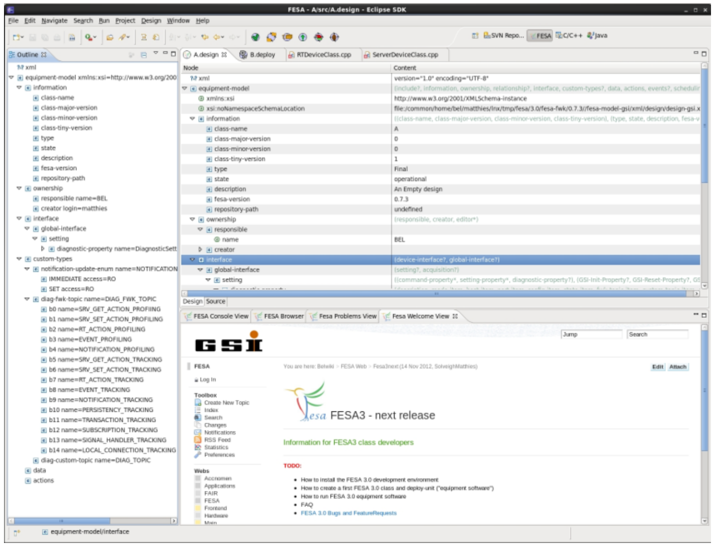

- UNICOS framework from CERN is based on PLC (Siemens) and SCADA (WinCC OA) and will be used as basis for development

- System consists of three layers:
  1. Field layer:
     Sensors, actors as PLC Remote I/Os
  2. Control layer:
     PLC logic
  3. Supervision layer:
     SCADA logic and visualization



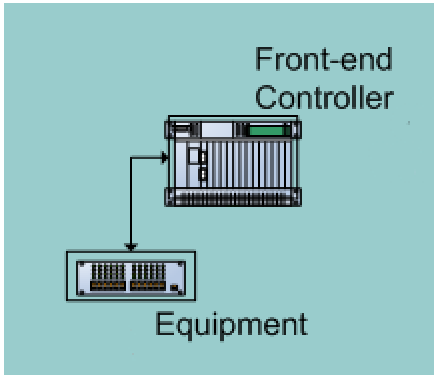
# Equipment Control Software: FESA (1)

- FESA (Front-end Software Architecture) will be the core component of the "FEC Software Framework" for the FAIR accelerator complex
  - Developed and maintained in collaboration between CERN and GSI since 2009
  - Allows to develop standardized and coherent equipment software for accelerator operation
  - Development tool is integrated into the Eclipse IDE:
    code generation, building+linking, debugging, documentation, SVN integration, deployment
  - XML description of the device interface
  - Object-oriented C++ sources are generated
  - Target system is a Front-end operating with Linux (currently Scientific Linux), e.g. the SCU



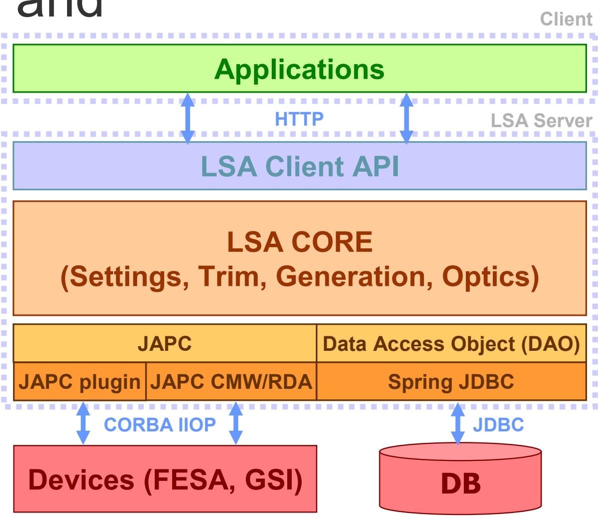
# Equipment Control Software: FESA (2)

- FESA Features:
  - Multiplexing
  - Real-time actions: threads with configurable priorities
  - Mapping of hardware registers
  - Timing system usage (real and simulated)
  - Scheduling
  - Standardized data types
  - Management of persistent data
  - Set of standardized properties for FAIR equipment software
  - ... and more



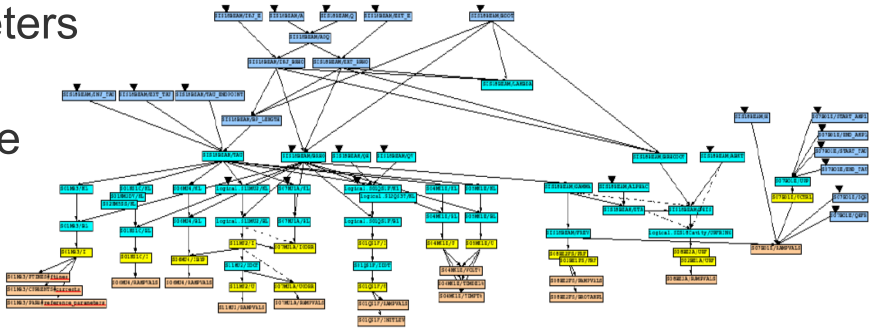
# Settings Management: LSA (1)

- LSA (LHC Software Architecture) will be the core component for  the accelerator settings management system
  - Was developed at CERN, now maintained and enhanced in collaboration since 2009
  - Operates LHC, SPS and other CERN accelerators
  - Highly data driven
  - DB is the master, contains optics, devices, cycles, etc. for all accelerators
  - Devices are accessed using an abstraction layer that hides different middleware
  - Flexibility to change operation modes on a daily basis
  - Tested successfully at GSI SIS18



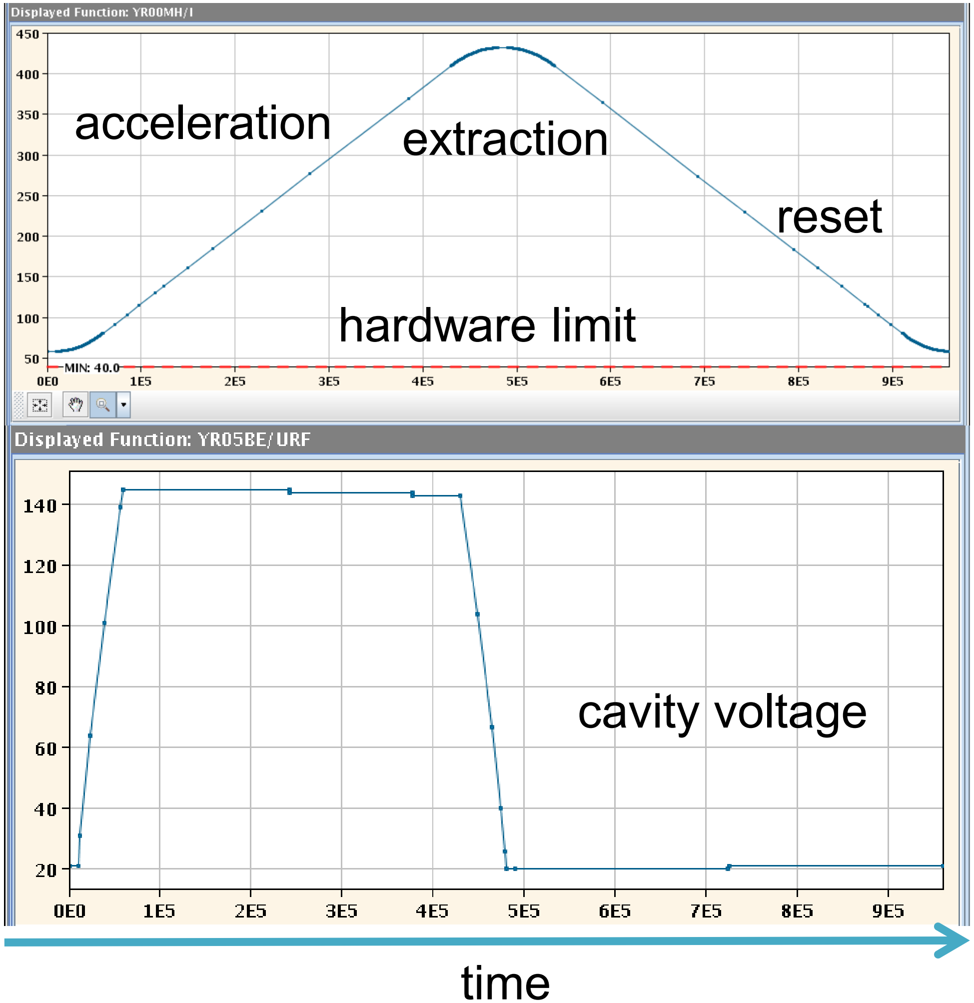
# Settings Management: LSA (2)

- Accelerator modeling in a modular structure:
  - Geometry, optics of accelerator
  - Hardware limits, calibration data, properties of devices
  - Generation, modification and access to set values
    - Data base holds full history of settings
- Parameter hierarchy
  - Complete dependencies
    - From top level parameters (e.g. energy) ...
    - ... to hardware parameter (e.g. current for sextupole magnet)
  - Generic rules
    - For calculating dependent parameters
  - Consistent change of set values
    - For many devices at the same time
- PBSP provides generic models
  - Hierarchies & rules
  - Needs to be enhanced by accelerator specialists / physicists



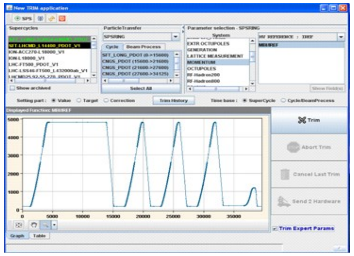
# LSA CRYRING Example
# Bending magnets current

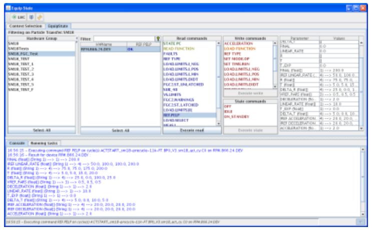
- CRYRING proton cycle with acceleration to 16 MeV



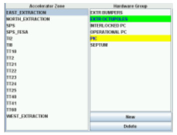
# Applications

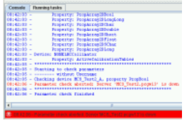
- Applications provided by CO will cover all standard operation software used in the central and local control rooms of FAIR
  - Modular and distributed SW architecture
  - All processes are data driven
  - Separation of concerns, MVC, logic in central or distributed services
  - Usage of frameworks, libraries, widgets, prefilled components
  - Java with Swing / JavaFX as GUI technology

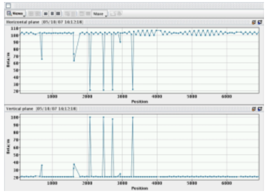




- Console environment:
  - Coherent work environment for operators
  - Central mechanisms for context switching
  - Supports different views on the facility: e.g. focus on beams or accelerators







# Agenda

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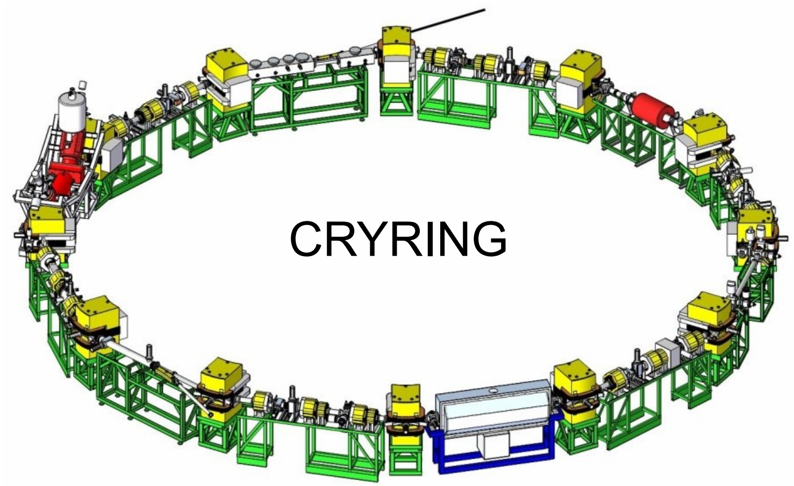
- Detailed Control System Overview
- Conclusion

# Testing the Control System

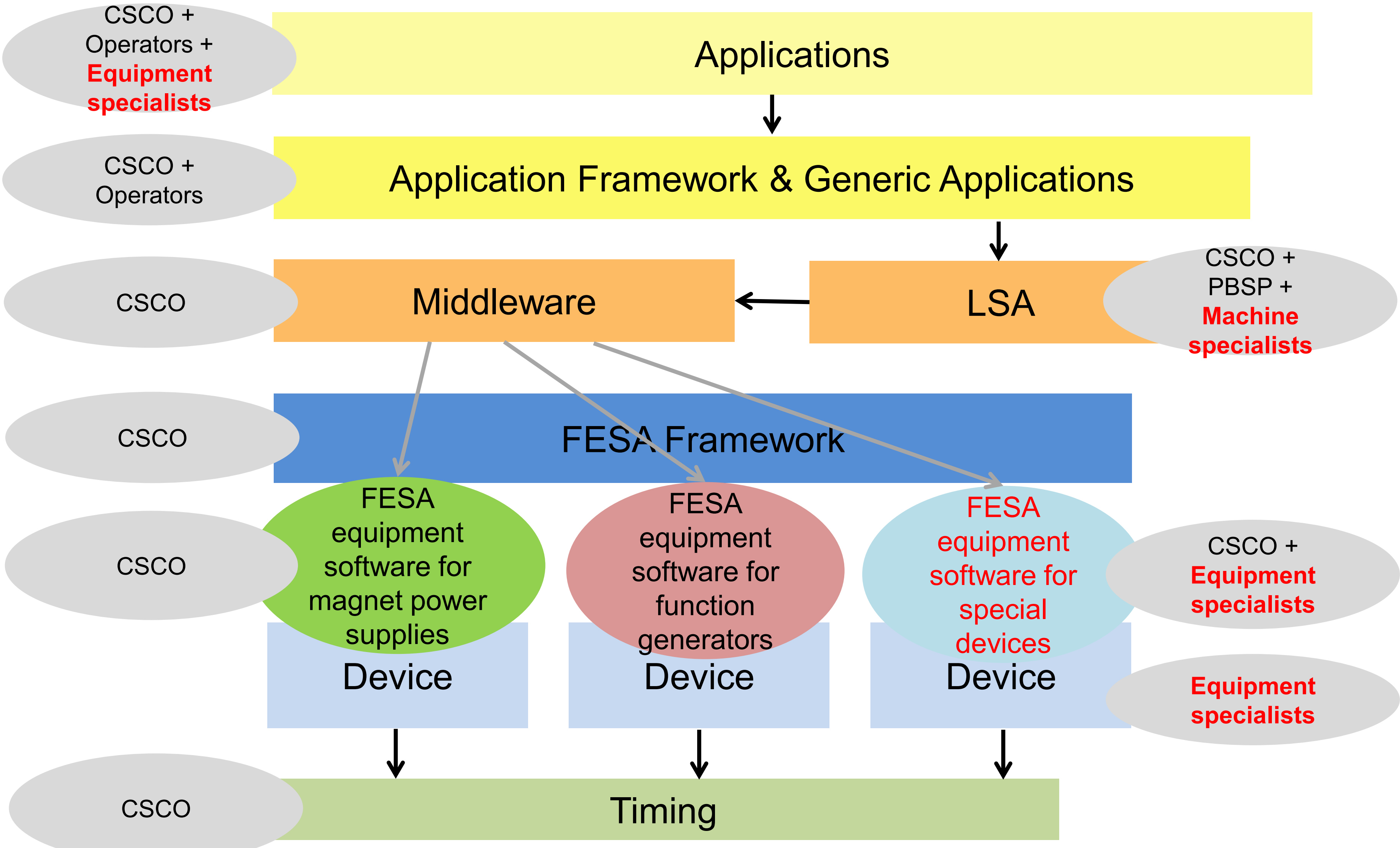
- CRYRING
  - Swedish in-kind contribution, heavy ion storage ring presently under installation at GSI

- Test ground for the new control system
  - Test and validate technical concepts
  - Gaining experience under real conditions
  - Identify design imitations




- and also
  - Validate our project management structures and tools (planning)

# Simplified Control System Stack & Responsibilities



# Where we expect contribution ...

- Experience the new system
  - e.g. during CRYRING or SIS18 commissioning
  - Early stage feedback and requirements
- Equipment
  - Lists to identify special equipment
  - Clarify responsibilities, orders etc.
  - Respect Specs and Guidelines
  - Development of FESA classes (or support during their development)
- LSA Model / Modeling of the CR
  - Physicist point of view
  - Accelerator modes
  - Modeling of special equipment
- Applications
  - Day 1 commissioning applications
    - Special requirements
    - Contact person involved in the development

# Questions