

# Transition to Phoebus at the Karlsruhe Institute of Technology

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# Outline

- KIT accelerators
- Current environment
- Custom systems
- Transition to Phoebus

# Location: Karlsruhe – Germany



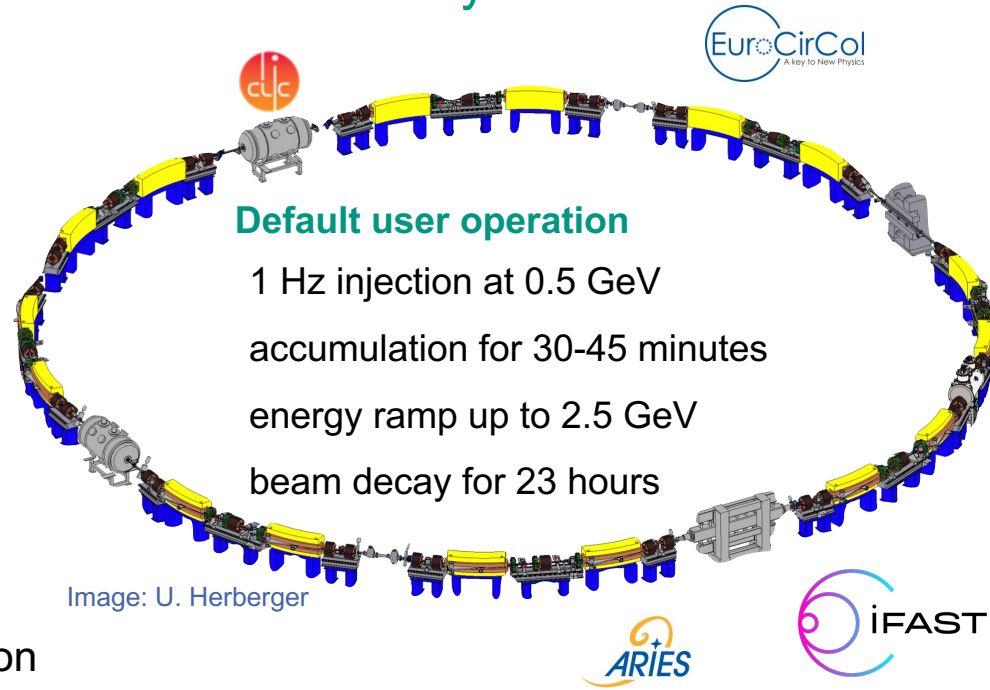
OpenStreetMap.org

# Karlsruhe Research Accelerator (KARA)



## ■ KIT synchrotron light source & accelerator test facility

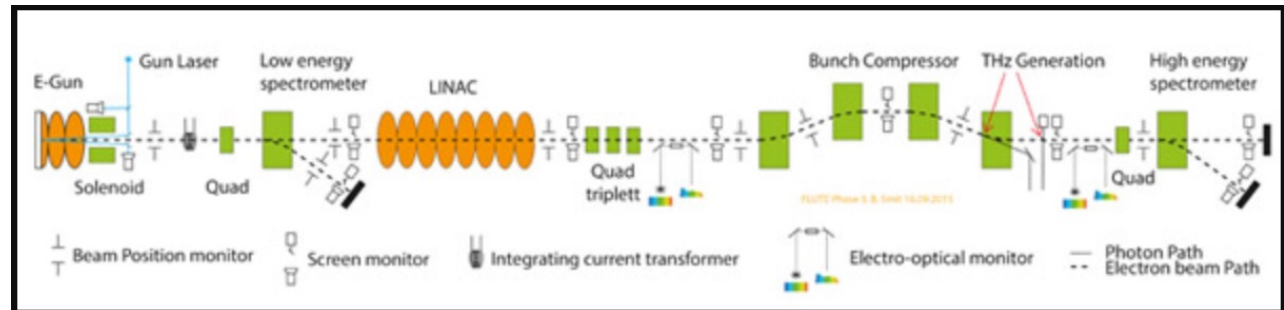
- until 2015 known as “ANKA”
- Circumference: 110.4 m
- Ramped storage ring: 0.5 - 2.5 GeV
- Mostly “stable” IOCs & panels
- One week per month:
  - Beam physics experiments and tests
  - Very variable in energy, filling pattern, bunch current and operational condition



# Far-Infrared Linac and Test Experiment



- 50 MeV linear electron accelerator
- Goal: Ultra short electron pulses (1-300 fs)
- **Panels and IOCs much more fluid**
- Overlap in panels, IOC support and general controls infrastructure
- But separate network, building, operators and users



# Current Setup

# Controls Environment



## ■ EPICS 7

- IOCs mostly on virtual machines

## ■ (Historically) quite a few complex EPICS applications run in Java

- Example: Orbit correction

## ■ Recently more and more Python

- Including Python **SoftIOC**

## ■ Ubuntu LTS for all servers and terminals

## ■ Code repository: historically Subversion

- Migration to **GitLab** ongoing, using **CI** for automation

## ■ IT orchestration: **Salt Project**

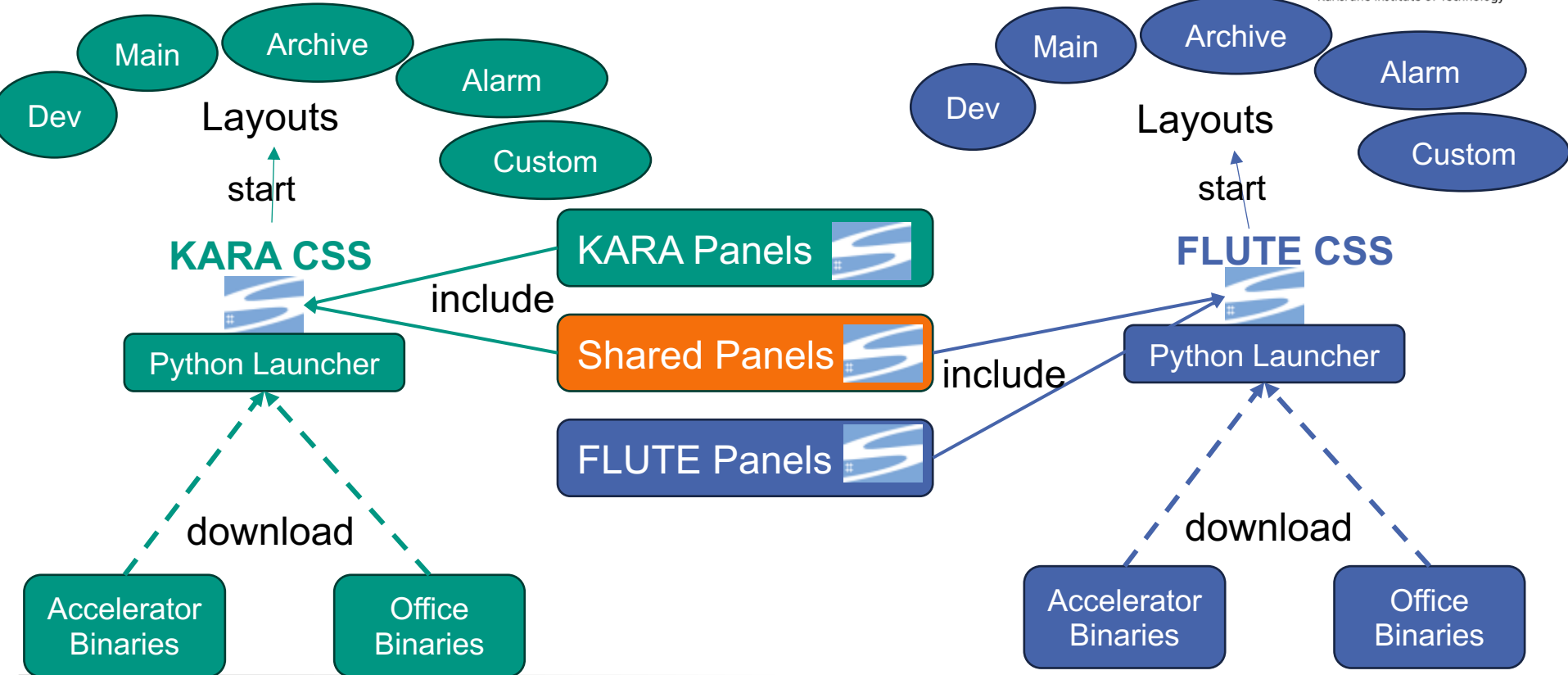


# Control System Studio

- Transition to EPICS started around **2012**
  - Control System Studio was chosen as the main GUI
- Required to build our own CSS flavour
  - Site specific settings
  - Custom plugins
    - Archiving system
    - Save and restore system
    - Alternative EPICS Java library (Jackie)
- Building was quite complex, so did not update base version of CSS regularly
  - Current CSS base version 4.1



# Software and Panel Distribution



# Panels

**Operation Status**

Beam Energy: **0.000 GeV**

Beam Current: **-0.008 mA**

Injection Rate: **0.001 mA/5s**

Lifetime: **00:00:00**

Fill Number: +1 **8359**

Operation Mode: <-> **User Operation**

Operator: -- **Andreas Grau**

Operator Phone: **26170**

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**Global**

TOP	Timing	Vacuum
Operation Status	IOC	ELog
Power Consum.	Auxiliary	Plots / Screens

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**Microtron**

Magnets	RF	Vacuum
E-Gun	Modulator	Signals

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**Injection Line**

Magnets	Signals	Vacuum
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**Booster**

Magnets	RF	Vacuum
Ramping	Bunch By Bunch	Signals

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**Extraction Line**

Magnets	Signals	Vacuum
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**Storage Ring**

Main Magnets	RF	Vacuum
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**Orbit**



Start Orbit Correction   Stop Orbit Correction   Horizontal Active   Vertical Active

Restart OC on Both Planes   Restart OC Only Horizontal   Restart OC Only Vertical   Expert OC...

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Manual Operation   State Machine

**Beam Dump**

- Mode "Injection"
- BL FE Shutter closed
- Open All IDs
- Dump Beam
- Cycle Main Magnets
- Cycle Corr. Magnets

**Start Up**

- Increment Fill Number
- Check Operator...
- Injection Magnets On
- Open Daily Valves
- E-Gun "HVPS"
- Modulator "HV Pulse"

Set Main Magnets

Set RF Frequency

Group: SR\_PS\_CC (Inject)

44/44 different from

Reset

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**Injection**

Injection Trigger: Start Trigger   Stop

Injection stopped.

Microtron Power Control: -8.47 dBm

Injection Septum: 0.5 A

0.00 V

RF Frequency: 499.7430 MHz

SR Horizontal Corrector 01: -0.000 A

Extraction Septum: 0.00 V

**Energy Ramp**

- Stop Injection Trigger
- Start OC Vertical
- Ramp Energy
- Injection Magnets Off
- E-Gun to HV Enabled
- Modulator to Red
- Start Full OC

**Web Message**

Injection finished. Next injection

Set web message

Injection finished. Next injection Bam

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**Insertion Devices**

ID Control

Close Selected   Abort All   Open All

**Clean Up**

- Close Daily Valves
- E-Gun to Black

**Internal Message**

BPM Electronics issue massive o

# Panels

## Extraction Line Magnets

iTest PS Overview...

Cycling...

### Commands

On Off Reset

### Temperature Status

EL Sum   Reset ...

### Horizontal Correctors

Group Control    On Off Reset

Corrector	Group Control	Current	Delta	Target	Bar
MCH-01	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	-0.000 A	
MCH-02	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	-0.000 A	
MCH-05	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	-0.000 A	
MCH-06	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	0.000 A	

### Vertical Correctors

Group Control    On Off Reset

Corrector	Group Control	Current	Delta	Target	Bar
MCV-01	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	-1.620 A	▲▼	0.000 A	
MCV-02	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	0.000 A	
MCV-03	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	0.000 A	
MCV-04	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	0.000 A	
MCV-05	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	0.000 A	▲▼	0.000 A	
MCV-06	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	-1.600 A	▲▼	-0.000 A	

### Quadrupole Magnets

Group Control    On Off Reset

Quadrupole	Group Control	Current	Delta	Target	Bar
MQ-01	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	24.50 A	▲▼	0.01 A	
MQ-02	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	3.00 A	▲▼	0.01 A	
MQ-03	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	37.30 A	▲▼	0.00 A	
MQ-04	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	29.00 A	▲▼	0.02 A	
MQ-05	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	31.00 A	▲▼	0.01 A	
MQ-06	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	33.00 A	▲▼	0.00 A	
MQ-07	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	57.00 A	▲▼	-0.02 A	
MQ-08	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	52.00 A	▲▼	-0.00 A	
MQ-09	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	51.90 A	▲▼	-0.01 A	

### Bending Magnets

Group Control    On Off Reset

Bending Magnet	Group Control	Current	Delta	Target	Bar
MB-01	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	181.15 A	▲▼	0.01 A	
MB-02	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>	182.03 A	▲▼	-0.01 A	

### Save and Restore

Group: EL\_PS (Injection)

11/21 different from Default

Revert to Default

Revert...

### iTest Chassis

iTestPSRack:02	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>
iTestPSRack:03	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>
iTestPSRack:04	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>
iTestPSRack:06	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>
iTestPSRack:07	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>
iTestPSRack:08	<input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>

Reset Interlock

# Custom Tools

# Archiver

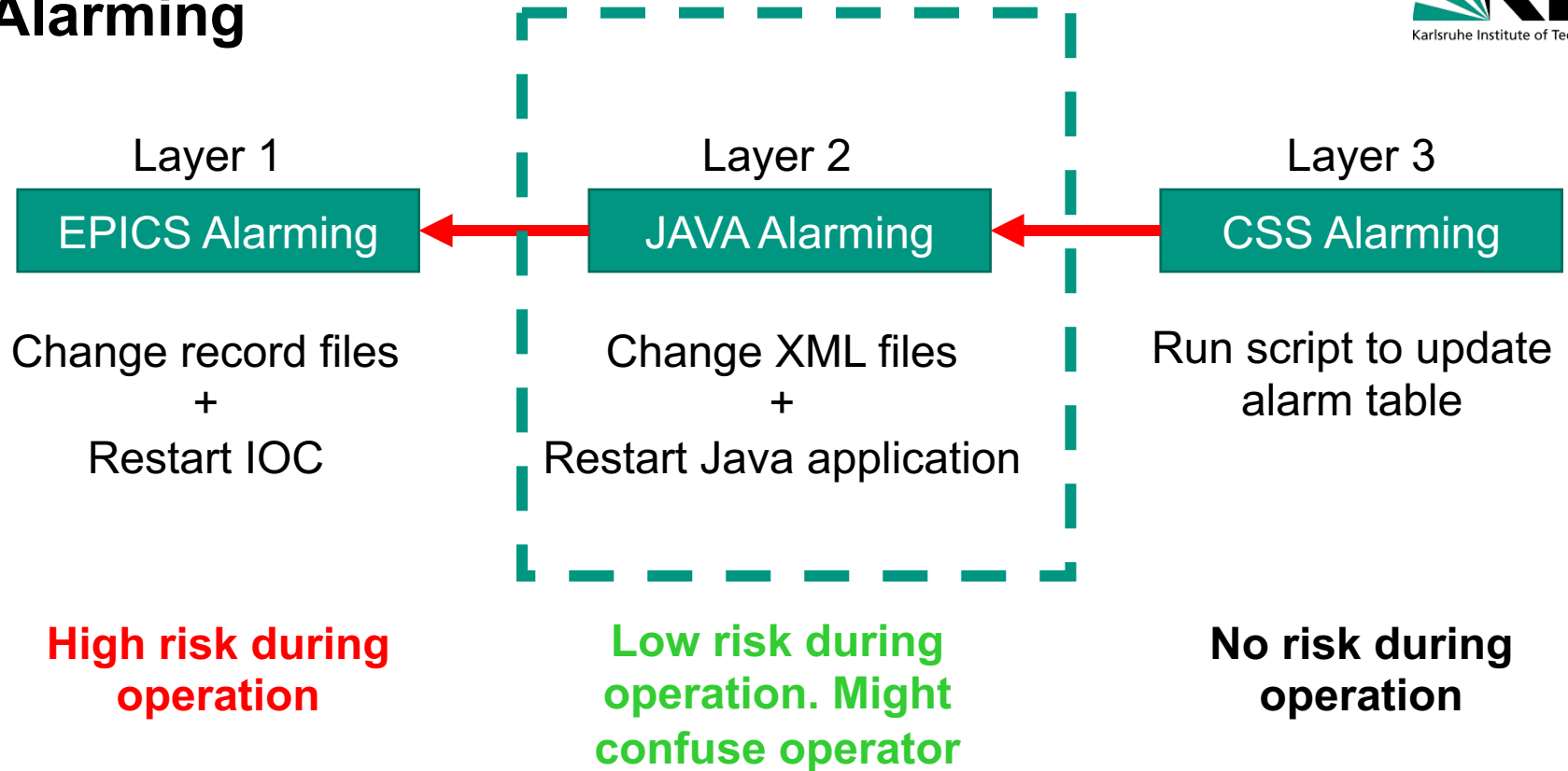


- NoSQL Cassandra cluster
- High data throughput for writing
- CSS integration via custom JSON protocol
  - Also Python module
- Central archive configuration
  - Monitor or scan
  - Compression or no compression
  - ...
- Making data available of 12+ years of operation

# Alarming

- Due to very variable operational conditions for KARA we require a “dynamic” alarm system
- Certain states should only be an alarm depending on the operation state
  - Example – injection kicker:
    - If not **on** during injection -> **ALARM**
    - If not **off** during ramping/operation -> **ALARM**
- IOC **independent** alarm configuration
  - Multiple configurations for one record, based on “status PV” (operation state)
  - Without additional effort also possible for embedded devices

# Alarming



# Alarming

## Pros

- Centralised alarm configuration
- Dynamic alarm state switching
- Embedded and native IOCs managed in the same format
- More flexible
  - Complex summaries
- Integrate non-EPICS alarms
  - Ping alarm

## Cons

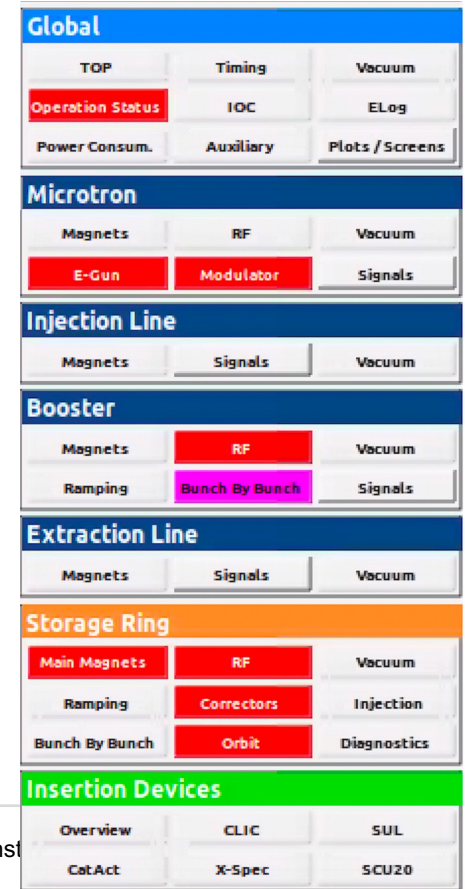
- Centralised alarm configuration
  - Keeping alarms synchronised to IOC development
  - Philosophy shift over time
- Each alarm creates additional PV
  - Panel integration?
- Custom software layer
  - Bugs
  - Adds Java to the mix
  - Scaling
  - Maintenance



# Alarm Status Panel

- Summary alarms
- Also used for the launcher

Global	Microtron	Injection	Booster	Extraction	SR	IDs	IT
PSS SR	Magnets	Magnets	Magnets	Magnets	Magnets	Clic	Hosts
Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	SUL	
Timing	RF		RF		RF	CatAct	
PSS BL	E-Gun		Ramping		Ramping	X-Spec	
IOC	Modulator		BBB		BBB	SCU20	
					Orbit		
					Diagnostic		



The screenshot shows a hierarchical view of the alarm status panel. It is organized into several sections, each with a blue header and a grid of buttons. The buttons are color-coded: red for active or critical status, green for normal status, and pink for specific components like BBB and Bunch By Bunch.

- Global:** TOP, Timing, Vacuum, Operation Status (red), IOC, ELog, Power Consum., Auxiliary, Plots / Screens.
- Microtron:** Magnets, RF, Vacuum, E-Gun (red), Modulator (red), Signals.
- Injection Line:** Magnets, Signals, Vacuum.
- Booster:** Magnets, RF (red), Vacuum, Ramping, Bunch By Bunch (pink), Signals.
- Extraction Line:** Magnets, Signals, Vacuum.
- Storage Ring:** Main Magnets (red), RF (red), Vacuum, Ramping, Correctors (red), Injection, Bunch By Bunch, Orbit (red), Diagnostics.
- Insertion Devices:** Overview, CLIC, SUL, CatAct, X-Spec, SCU20.

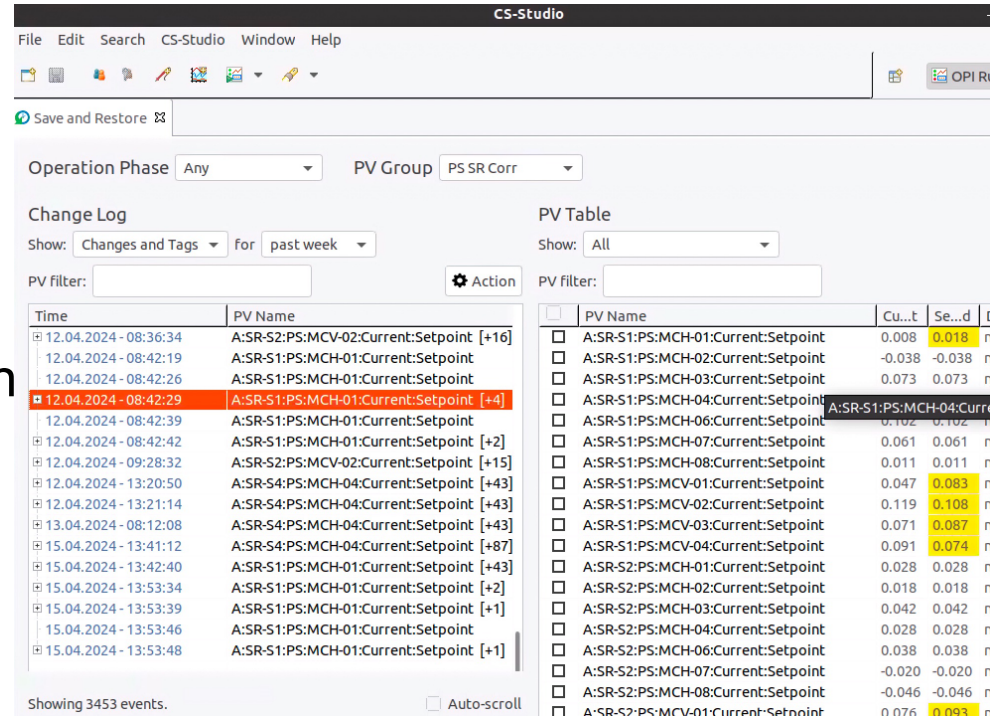
# Save and Restore

- Around 2013-2014 looking for a save and restore system
  - Also “track“ any **operator** change to machine parameters
    - *“So, what were all the changes made during last shift?”*
  - View, compare and restore operator changes over any period of time
  - Set labels and defaults for groups of PVs
- Yet another custom solution with another (sql) database and external configuration

# Save and Restore

- Custom CSS integration
- Lots of custom code
- Maintenance overhead, yet another external configuration

## CSS View

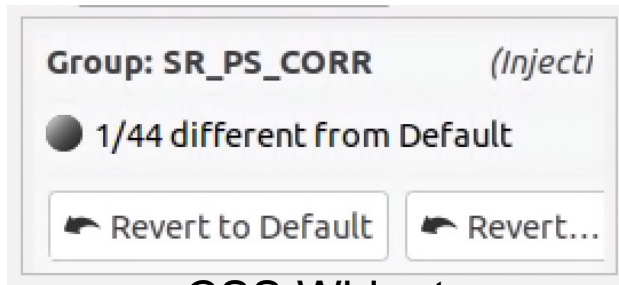


The screenshot shows the CS-Studio interface with the 'Save and Restore' window open. The 'Change Log' section displays a list of events with columns for Time, PV Name, and Action. The 'PV Table' section displays a table of PVs with columns for PV Name, Current, and Setpoint.

Time	PV Name	Action
12.04.2024 - 08:36:34	A:SR-S2:PS:MCV-02:Current:Setpoint	[+16]
12.04.2024 - 08:42:19	A:SR-S1:PS:MCH-01:Current:Setpoint	
12.04.2024 - 08:42:26	A:SR-S1:PS:MCH-01:Current:Setpoint	
12.04.2024 - 08:42:29	A:SR-S1:PS:MCH-01:Current:Setpoint	[+4]
12.04.2024 - 08:42:39	A:SR-S1:PS:MCH-01:Current:Setpoint	
12.04.2024 - 08:42:42	A:SR-S1:PS:MCH-01:Current:Setpoint	[+2]
12.04.2024 - 09:28:32	A:SR-S2:PS:MCV-02:Current:Setpoint	[+15]
12.04.2024 - 13:20:50	A:SR-S4:PS:MCH-04:Current:Setpoint	[+43]
12.04.2024 - 13:21:14	A:SR-S4:PS:MCH-04:Current:Setpoint	[+43]
13.04.2024 - 08:12:08	A:SR-S4:PS:MCH-04:Current:Setpoint	[+43]
15.04.2024 - 13:41:12	A:SR-S4:PS:MCH-04:Current:Setpoint	[+87]
15.04.2024 - 13:42:40	A:SR-S1:PS:MCH-01:Current:Setpoint	[+43]
15.04.2024 - 13:53:34	A:SR-S1:PS:MCH-01:Current:Setpoint	[+2]
15.04.2024 - 13:53:39	A:SR-S1:PS:MCH-01:Current:Setpoint	[+1]
15.04.2024 - 13:53:46	A:SR-S1:PS:MCH-01:Current:Setpoint	
15.04.2024 - 13:53:48	A:SR-S1:PS:MCH-01:Current:Setpoint	[+1]

PV Name	Current	Setpoint
A:SR-S1:PS:MCH-01:Current:Setpoint	0.008	0.018
A:SR-S1:PS:MCH-02:Current:Setpoint	-0.038	-0.038
A:SR-S1:PS:MCH-03:Current:Setpoint	0.073	0.073
A:SR-S1:PS:MCH-04:Current:Setpoint	0.073	0.073
A:SR-S1:PS:MCH-06:Current:Setpoint	0.061	0.061
A:SR-S1:PS:MCH-07:Current:Setpoint	0.011	0.011
A:SR-S1:PS:MCV-01:Current:Setpoint	0.047	0.083
A:SR-S1:PS:MCV-02:Current:Setpoint	0.119	0.108
A:SR-S1:PS:MCV-03:Current:Setpoint	0.071	0.087
A:SR-S1:PS:MCV-04:Current:Setpoint	0.091	0.074
A:SR-S2:PS:MCH-01:Current:Setpoint	0.028	0.028
A:SR-S2:PS:MCH-02:Current:Setpoint	0.018	0.018
A:SR-S2:PS:MCH-03:Current:Setpoint	0.042	0.042
A:SR-S2:PS:MCH-04:Current:Setpoint	0.028	0.028
A:SR-S2:PS:MCH-06:Current:Setpoint	0.038	0.038
A:SR-S2:PS:MCH-07:Current:Setpoint	-0.020	-0.020
A:SR-S2:PS:MCH-08:Current:Setpoint	-0.046	-0.046
A:SR-S2:PS:MCV-01:Current:Setpoint	0.076	0.093



The screenshot shows the CSS Widget interface. It displays the group name 'SR\_PS\_CORR' and a status indicator '1/44 different from Default'. There are two buttons: 'Revert to Default' and 'Revert...'.

## CSS Widget

# Transition to Phoebus

# Transition to Phoebus

- Use opportunity to re-evaluate current features
- Try to rely on less custom code
- Try to get necessary adjustments to Phoebus upstream from the beginning
- Dockerize as much as possible
- Use opportunity to add long-wanted features
  - Channel Finder
  - Highly available network storage for panels (but also autosave, layouts, etc.)

# Contributions to Phoebus Upstream

- Support for alternative Java channel access library (merged)
  - EPICS Jackie, can be used via `jackie://` instead of `ca://`
  - (Based on experience with lots of Java applications)
- Support for JSON-Archive-Access-Protocol (merged)
  - for Cassandra PV Archiver
- Improvements to the menu bar in macOS (yet to be submitted)
- Support for loading Mementos/layouts via URLs (planned)

# ChannelFinder and Alarm Server

- Run in high availability Docker setup
- Use more features of the Phoebus alarm server instead of custom Java server
  - Summary alarms
- ChannelFinder makes use of already existing infrastructure
  - Each IOC already exports PV lists, filtered by some keywords
  - Does not require additional IOC integration (no RecCaster)
  - Meta data from IOC deployment
- Add authentication
  - Resources will be available in the office versions
  - Added for ChannelFinder -> ElasticSearch
  - tbd for alarm logger -> ElasticSearch

# Cross-Platform-Builds for Native Launcher

- jpackage allows to build native launcher
  - but can only built for platform it is being used with
- Core features of jpackage re-implemented in Python
- Use GitLab CI to build for all platforms
  - Using Linux Docker images
- Limitations compared to jpackage:
  - Slightly larger builds
  - Currently not possible to create installer (but might be possible with external tools)
- At the moment available only internally on our GitLab
  - but can be shared if interest exists

latest 10 Jobs 2 minutes 35 seconds, queued for 2 seconds

Pipeline Needs Jobs 10 Tests 0

Group jobs by Stage Job dependencies

## Build

- ✓ Build for Linux AArch64
- ✓ Build for Linux x86\_64
- ✓ Build for Windows x86\_64
- ✓ Build for macOS AArch64
- ✓ Build for macOS x86\_64

## Packaging

- ✓ Package for Linux AArch64
- ✓ Package for Linux x86\_64
- ✓ Package for Windows x86\_64
- ✓ Package for macOS AArch64
- ✓ Package for macOS x86\_64



# Next Steps

- Panel transition
  - Tests so far look promising, as only visual effects (and file handling) was done with JavaScript/Rules
- Considerations for replacement of SNR system by using archiving data
  - Current system cannot be used with Phoebus
  - Use archiving interface and labeled timestamps instead
  - Integrate into Phoebus upstream
- Evaluation for alarming system
  - Current system can still be used
  - Remove additional alarm PVs, instead adjusting EPICS **record alarm fields** dynamically (using Python SoftIOC instead of Java)