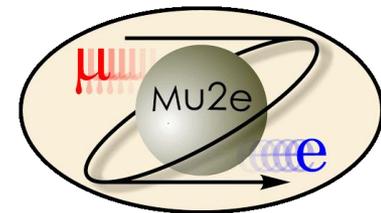# *Online DAQ and slow control interface for the Mu2e experiment*

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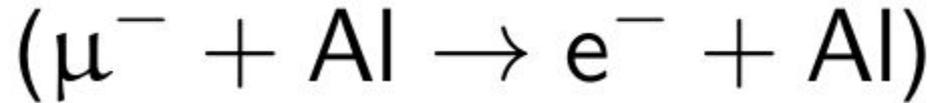
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July 28, 2021
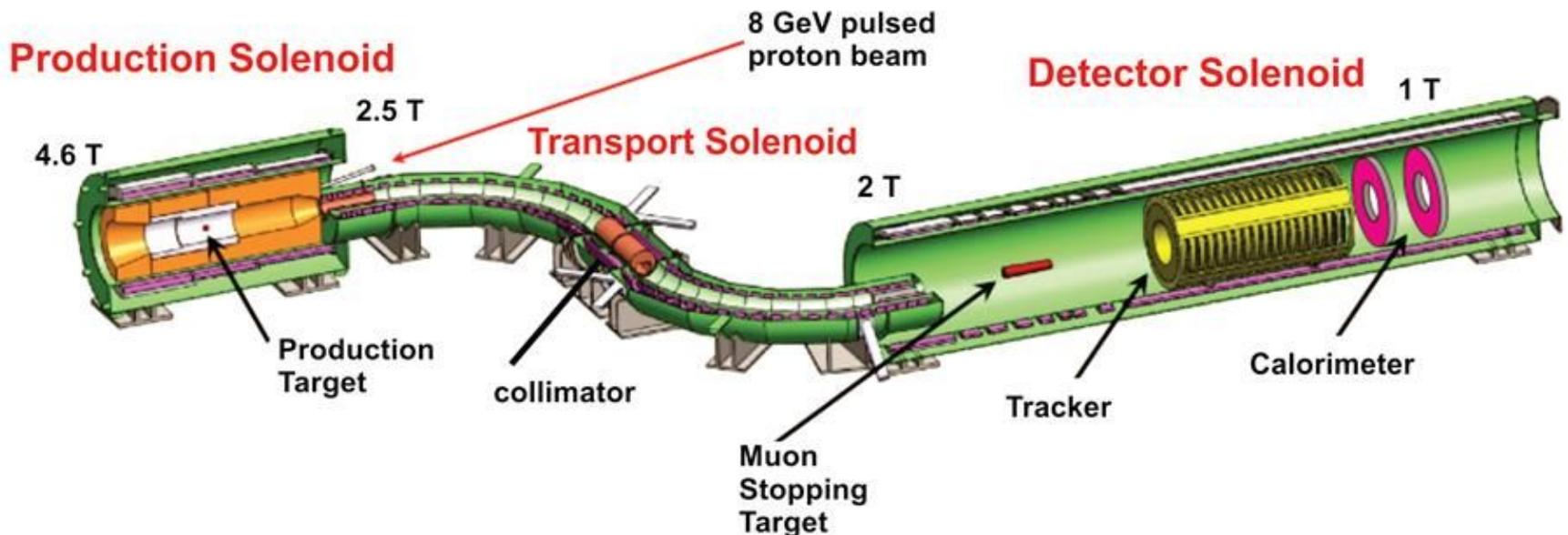
# *The Mu2e Experiment at Fermilab*

$$(\mu^- + Al \rightarrow e^- + Al)$$

With the expected experimental sensitivity, Mu2e will **improve** the SINDRUM II limit ($7.0 \cdot 10^{-13}$) of **four orders of magnitude**

(Mu2e intends to reach a single event sensitivity of $3.0 \cdot 10^{-17}$, assuming we will run for three years, with $3.6 \cdot 10^{20}$ protons, with a run time of $6.0 \cdot 10^7$ s, requiring a background level below 1 event)

The Mu2e Experiment at Fermilab

The signal we are looking for is a delayed monoenergetic electron with an energy of just under 105 MeV (muon mass)


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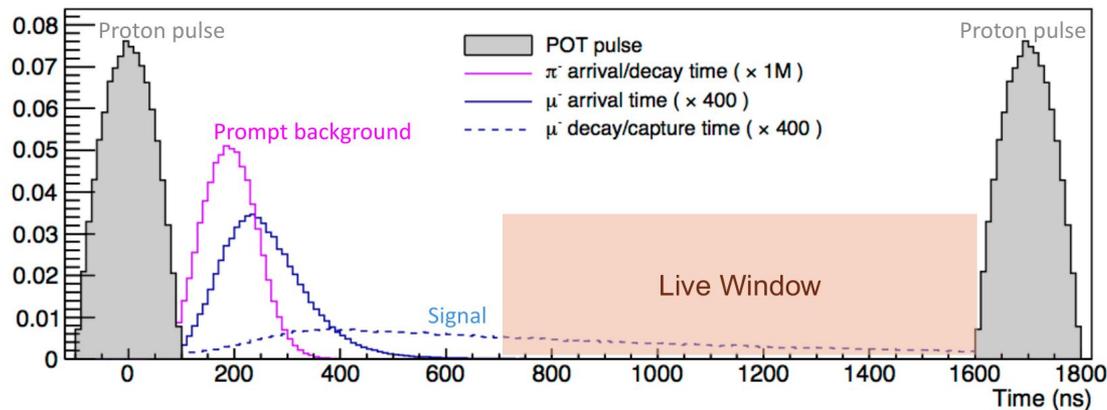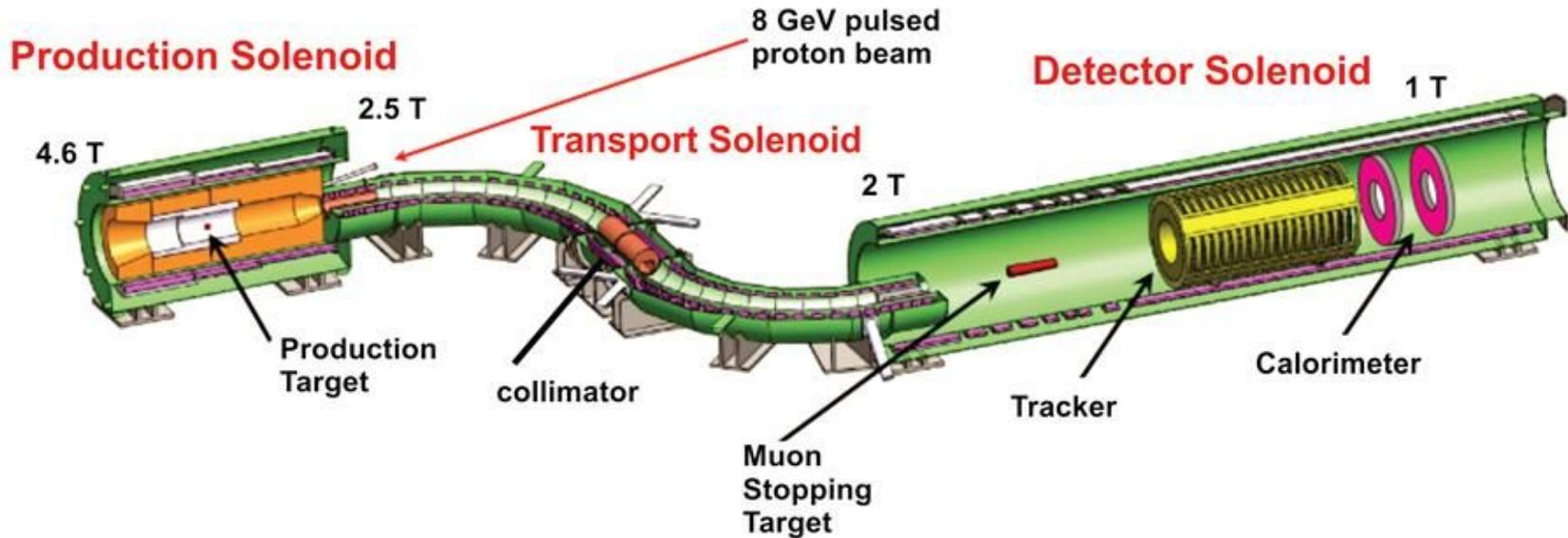
Mu2e TDAQ and Slow Control integration

Summary:

- Mu2e TDAQ components Diagram

- Mu2e Timing Distribution

- Mu2e TDAQ Readout scheme

- Online DAQ (***otsdaq***) overview

- Slow control and its integration in ***otsdaq***

  – Monitoring and Slow Controls GUI

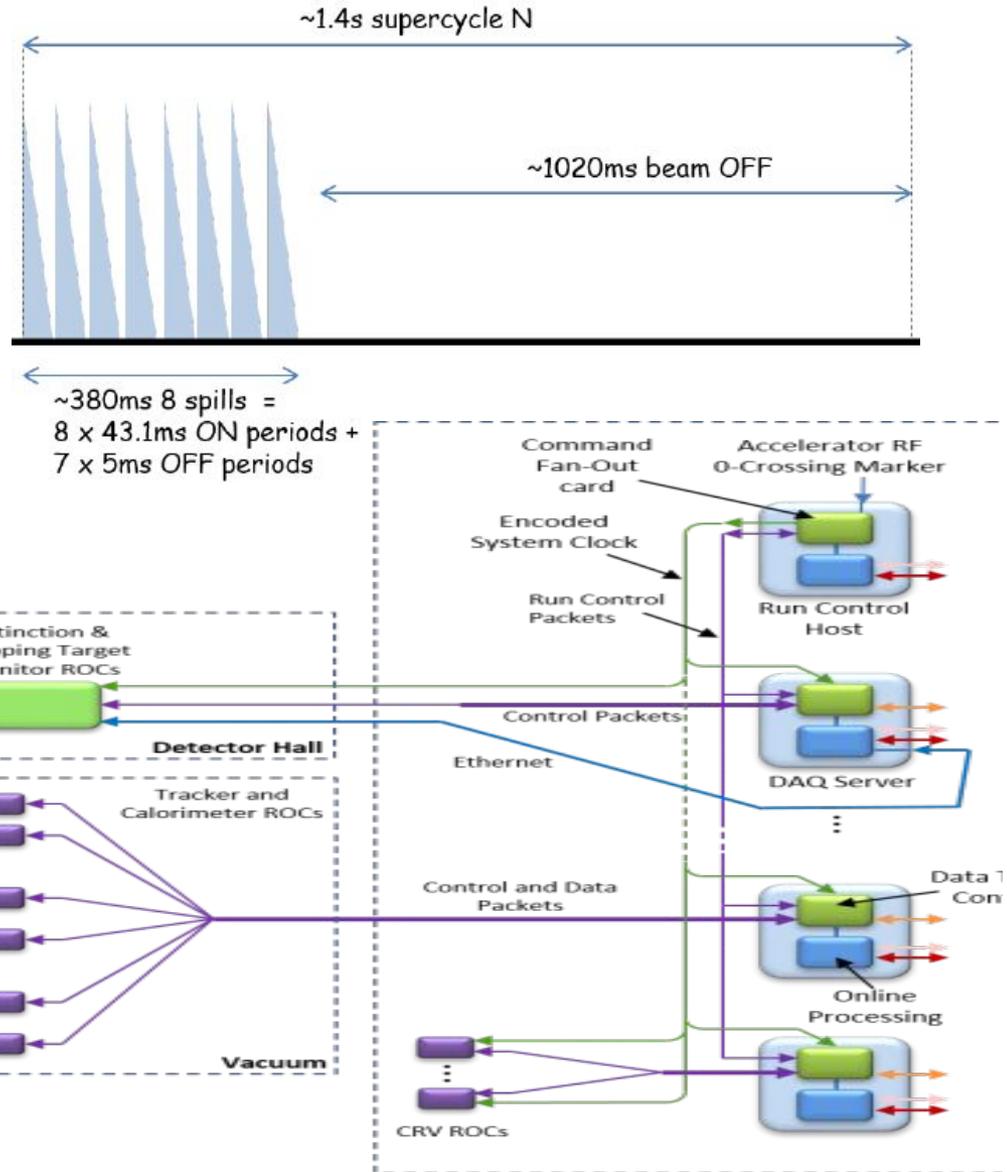 – Slow Controls Integration with ***otsdaq*** State Machine and Alarm handling

- Conclusions

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Mu2e TDAQ components Diagram

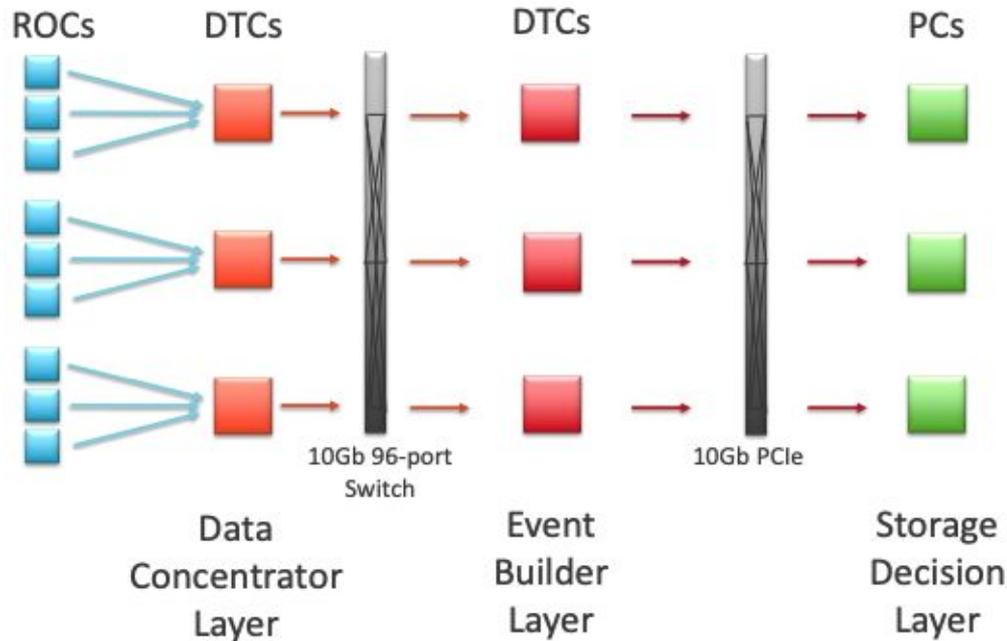Antonio Gioiosa | EPS-HEP 2021
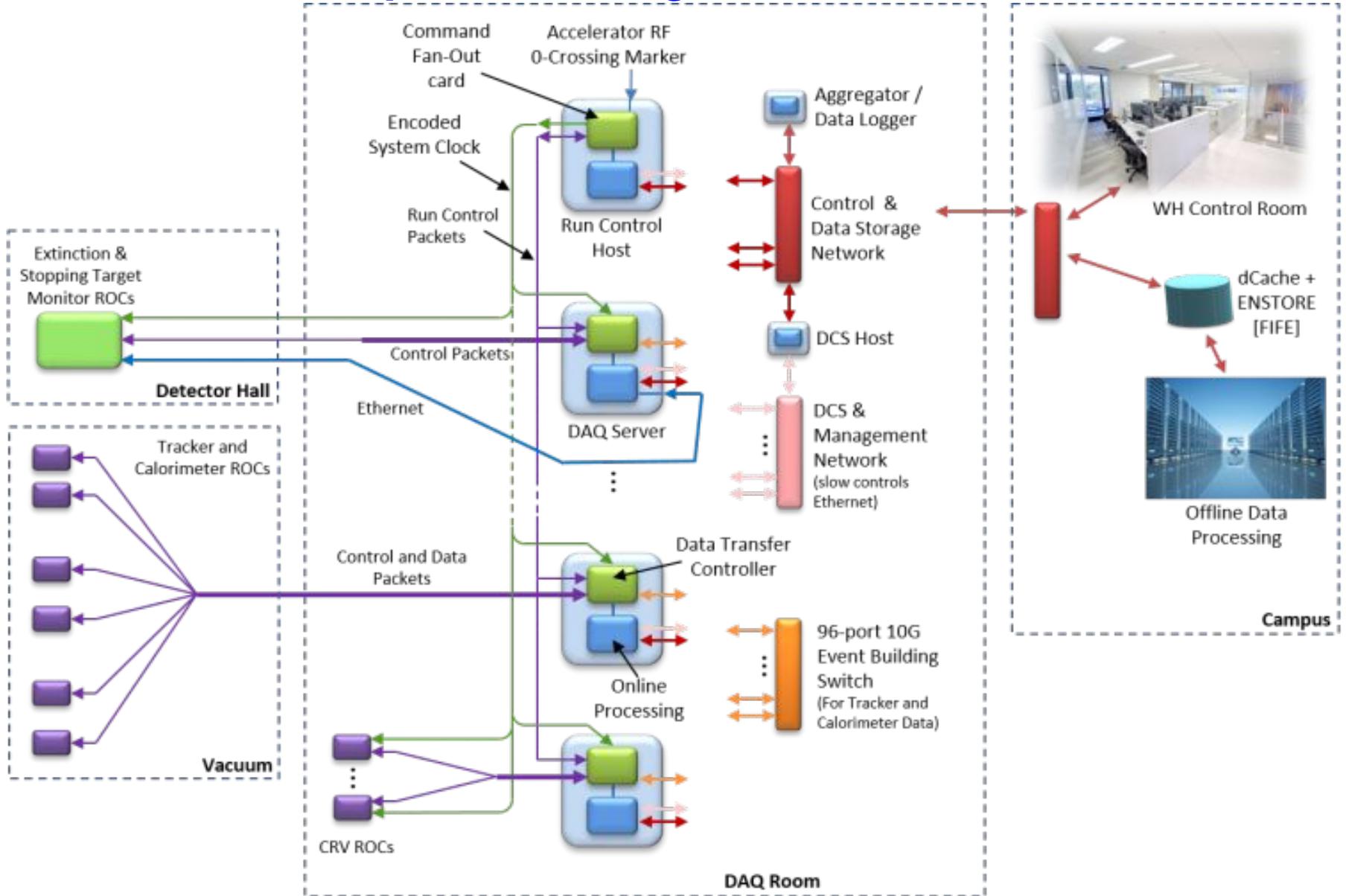
Mu2e Timing Distribution

Requirement is to process 200K events/s

- Mu2e Runs are broken up into contiguous Event Windows

- Experiment defined Run Plan is coordinated by the Command Fan-Out Card (CFO)

- The System Clock (40MHz) and Event Window markers originate at the CFO ...and are distributed to ROCs:

  1. CFO distributes System Clock and Event Windows to DTCs with fixed latency

  2. DTCs distribute System Clock and Event Windows to ROCs with fixed latency

  3. ROCs respond to Data Requests

DTC⇆ROC Heartbeat packet (16 bytes) to specify the detail of each Event Window

~1.4s supercycle N

~1020ms beam OFF

~380ms 8 spills =
8 x 43.1ms ON periods +
7 x 5ms OFF periods

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TDAQ Readout scheme

- 396 ROCs 69 DTCs (Kintex-7) for data readout and event building

- Large front end buffers to average over long off-spill time

- 800 threads on 40 nodes for HLT → ~5 ms per event

- ~40 GB/s data read out to storage decision layer, ~280 MB/s written to disk

High Level Trigger Software

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The Test Stand

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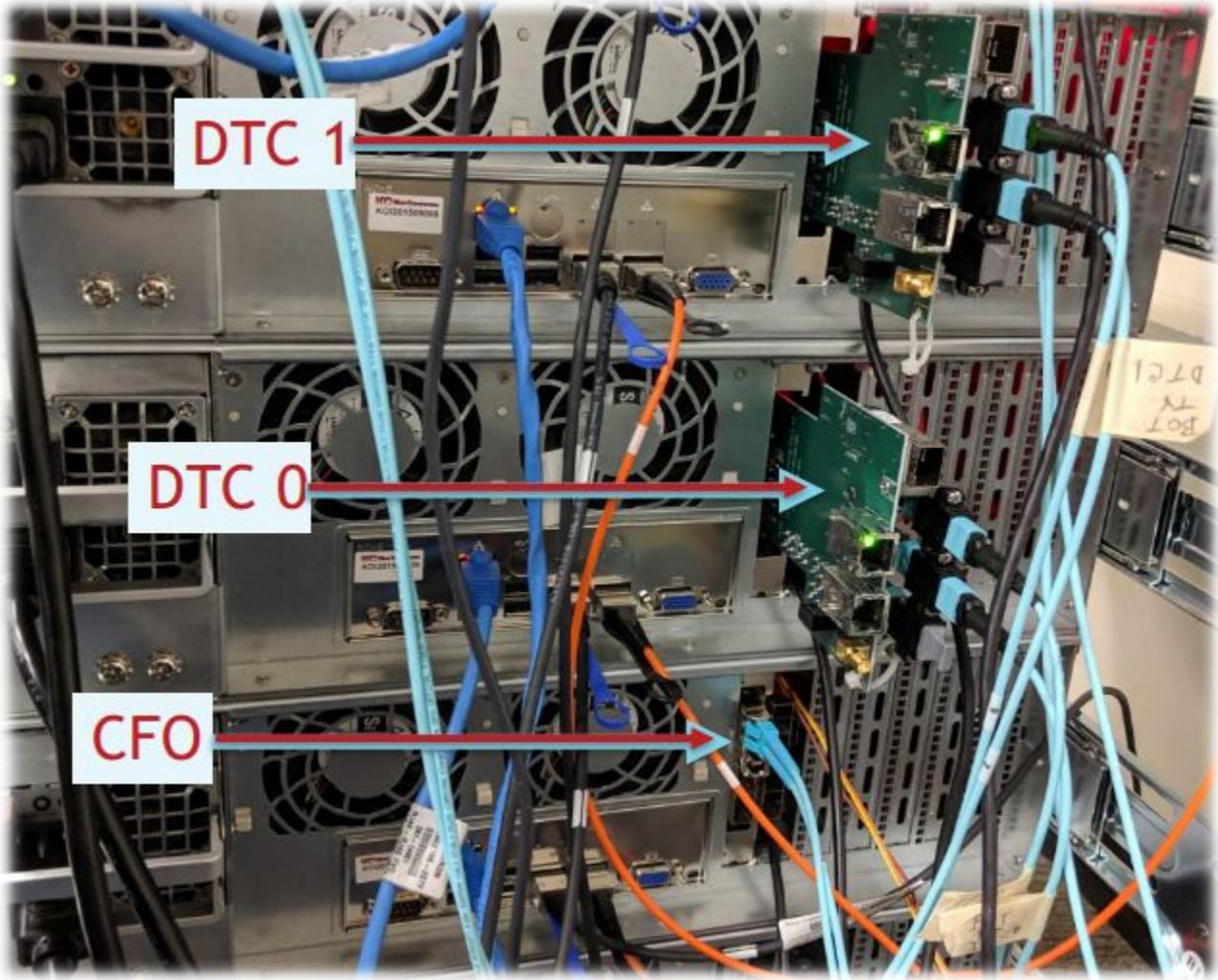
Mu2e Online DAQ solution: *otsdaq*

otsdaq overview
Acronym for "off-the-shelf data acquisition."

- ***otsdaq*** is a Ready-to-Use data-acquisition (DAQ) solution aimed at test-beam, detector development, and other rapid-deployment scenarios

- it uses the ***artdaq*** DAQ framework under-the-hood, providing flexibility and scalability to meet evolving DAQ needs

- ***otsdaq*** provides a library of supported front-end boards and firmware modules which implement a custom UDP protocol

- Developments are in two directions: **server** side and **web** side.

- An integrated Run Control GUI and readout software are provided, preconfigured to communicate with ***otsdaq*** firmware

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otsdaq overview

More info at ***otsdaq*** web page https://otsdaq.fnal.gov/

otsdaq overview

Data Flow Block Diagram

Server side is C++. User code is added through plugins (C++ classes inheriting from the appropriate class)

Web side is HTML and JavaScript. User code is added in the form of web-apps through .html files (including the appropriate .js and .css files)

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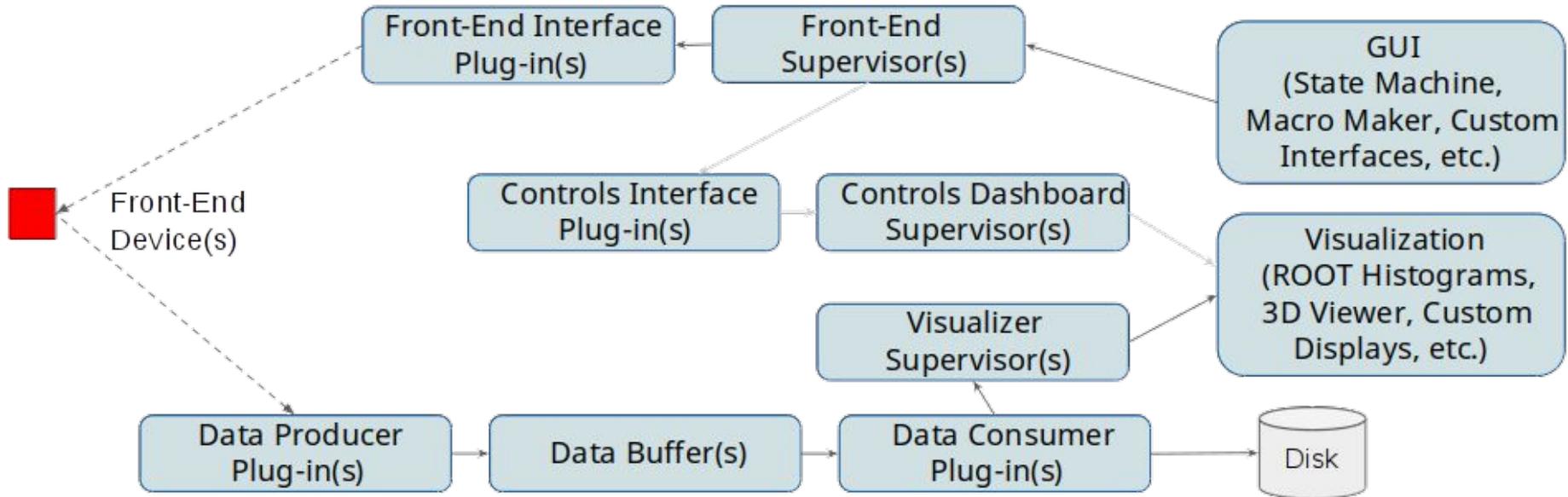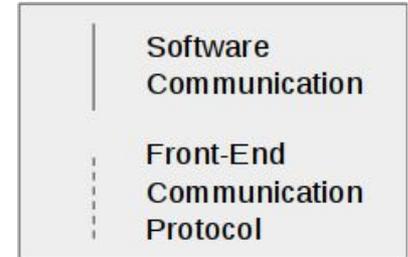
otsdaq overview

Data processing: Data Quality monitor GUI example

- Mu2e's event window data will be processed through artdaq modules

- Data processor and Data Quality Monitor DQM plugins are provided by otsdaq core

- DQM generates data products that are sent to an artdaq Dispatcher, which aggregates DQM metrics and presents them to a visualizer application

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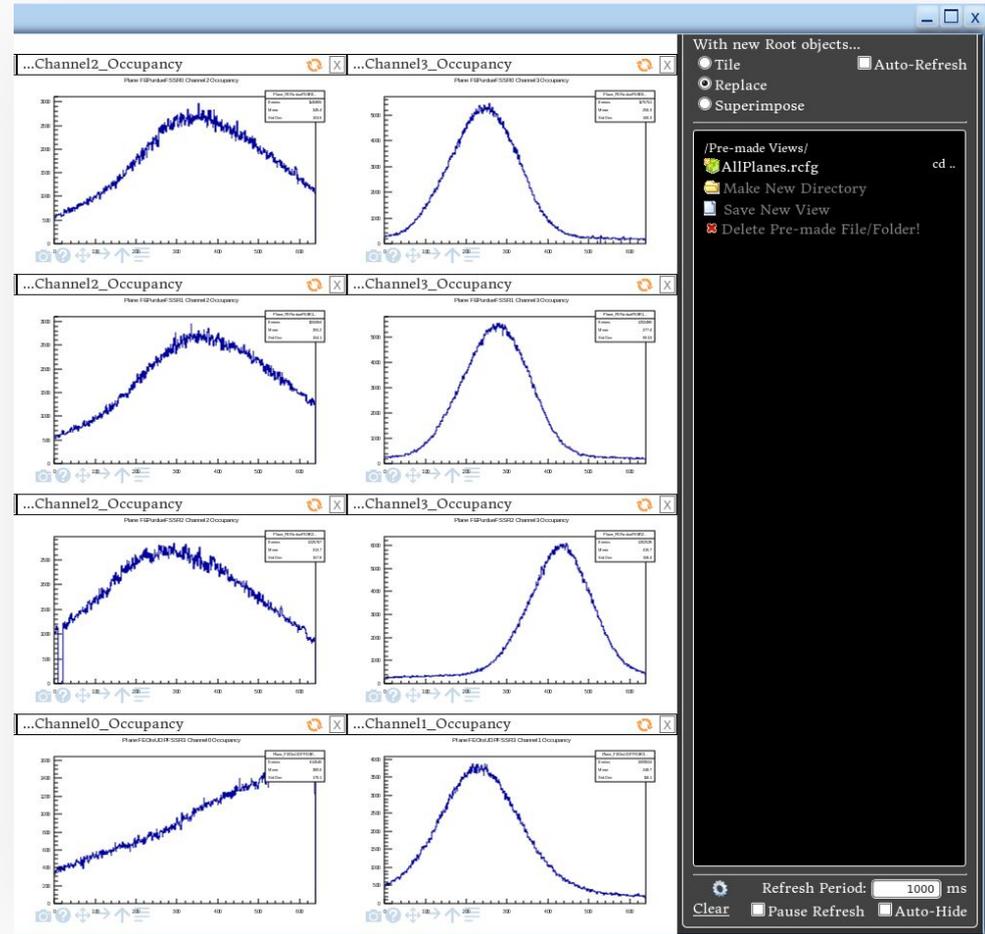
Slow Controls connection and EPICS plugin development in otsdaq

Experimental Physics and Industrial Control System
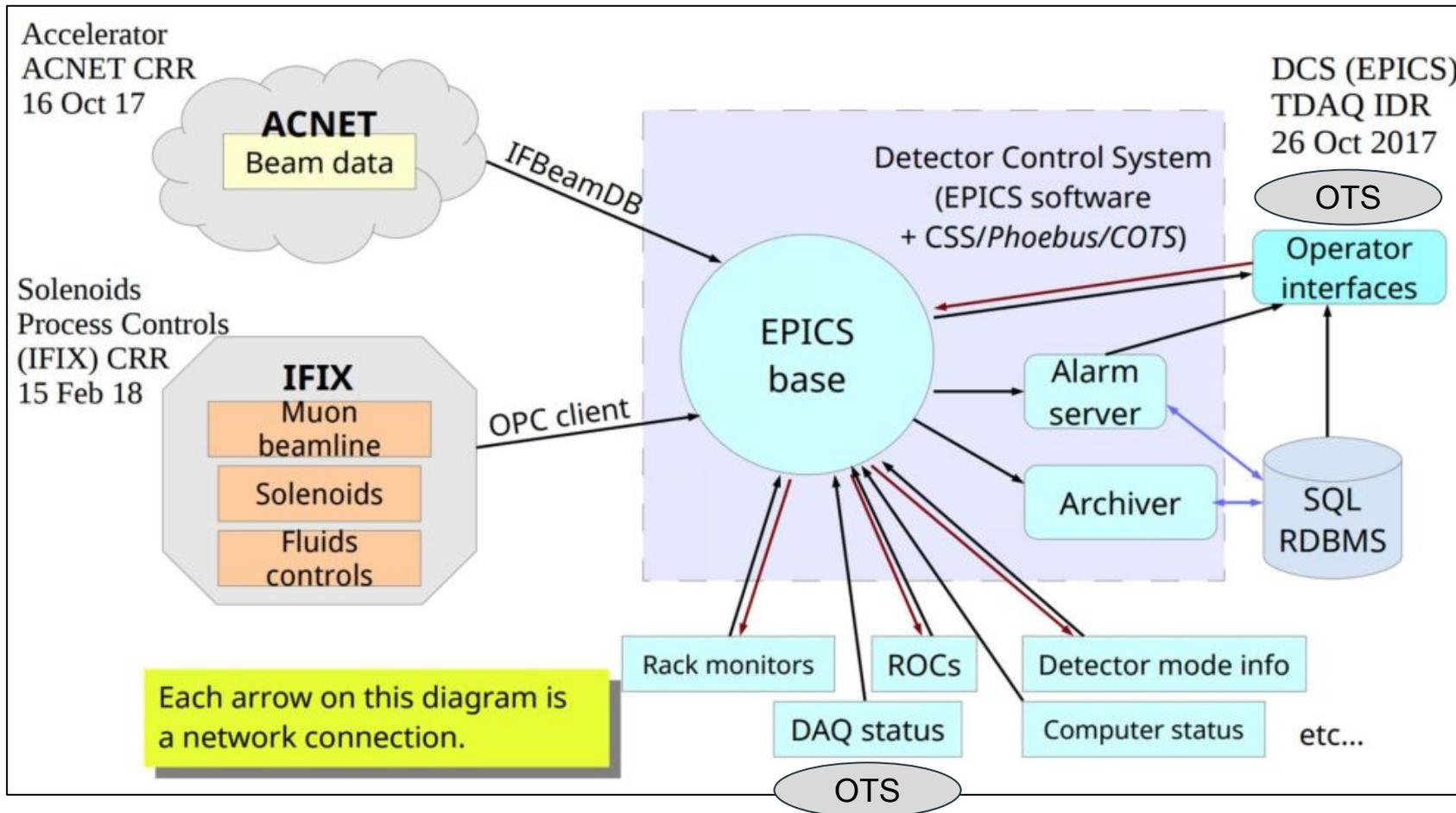
Slow Controls connection and *EPICS* plugin development in *otsdaq*
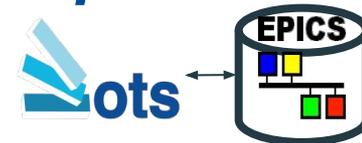
Channel subscription to EPICS uses Input Output Controller (IOC)

- integration of slow control in the online daq uses the same Interface plugin for:

  a. Monitoring of all mu2e slow control channels

  b. Sending Process Variables (PVs) of DAQ hardware info as EPICS channels and PVs settings into EPICS databases

- The Interface plugin:

  a. Performs channel subscription to EPICS using Channel Access EPICS C++ libraries to send and retrieve slow control data information like: Value, Alarm (Status, Severity), Settings

  b. Uses Postgres database C++ libraries to set channels and retrieve channels and alarms histories from EPICS databases

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Slow Controls Monitoring in otsdaq
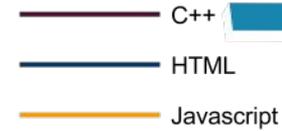
Slow Controls GUI Hierarchy

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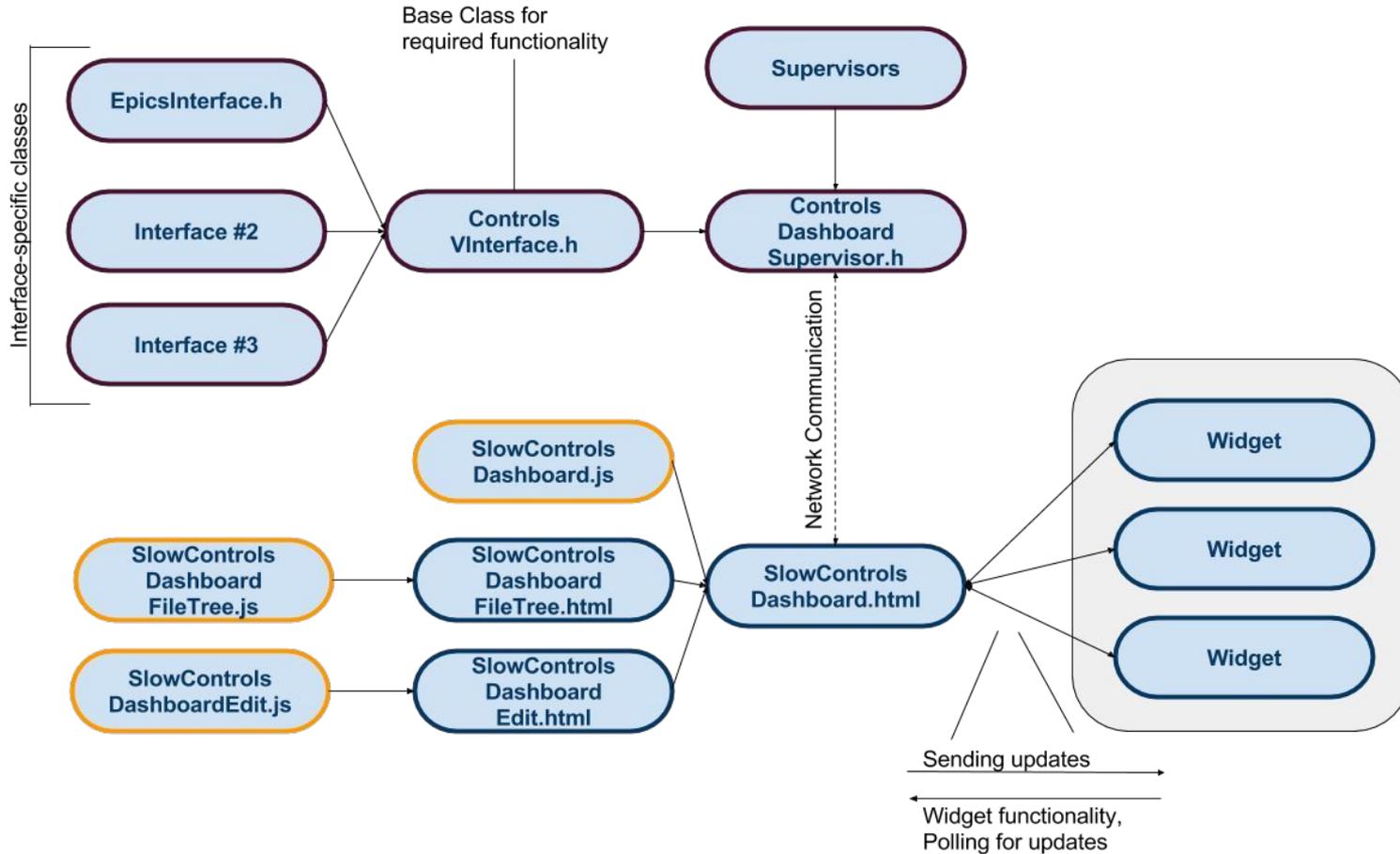
Slow Controls Monitoring GUI in otsdaq

Examples

Example of page loading

Example of loaded page

Calorimeter monitor in the slow control GUI

Integration with State Machine

- State Machine Configuration and data subscription to EPICS

- Alarm propagation (from EPICS) and *otsdaq* State Machine handling

DAQ HW, artdaq and DQM metrics configuration

Alarm Configuration

artdaq EPICS metrics Plugin

otsdaq EPICS Plugin

EPICS

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Conclusions

- Mu2e Experiment is under construction at Fermilab and will be ready for data taking in two/three years

- Mu2e TDAQ and slow control are in large part developed according to the requirements (200K events/s for data taking) and hardware tests are going on

- Slow control integration in the online DAQ system, *otsdaq*, provides an advanced slow controls monitoring, an interface to send *otsdaq* front-end DAQ hardware, data processing, and DQM slow controls information to EPICS, and a real configuration and Integration with the *otsdaq* State Machine
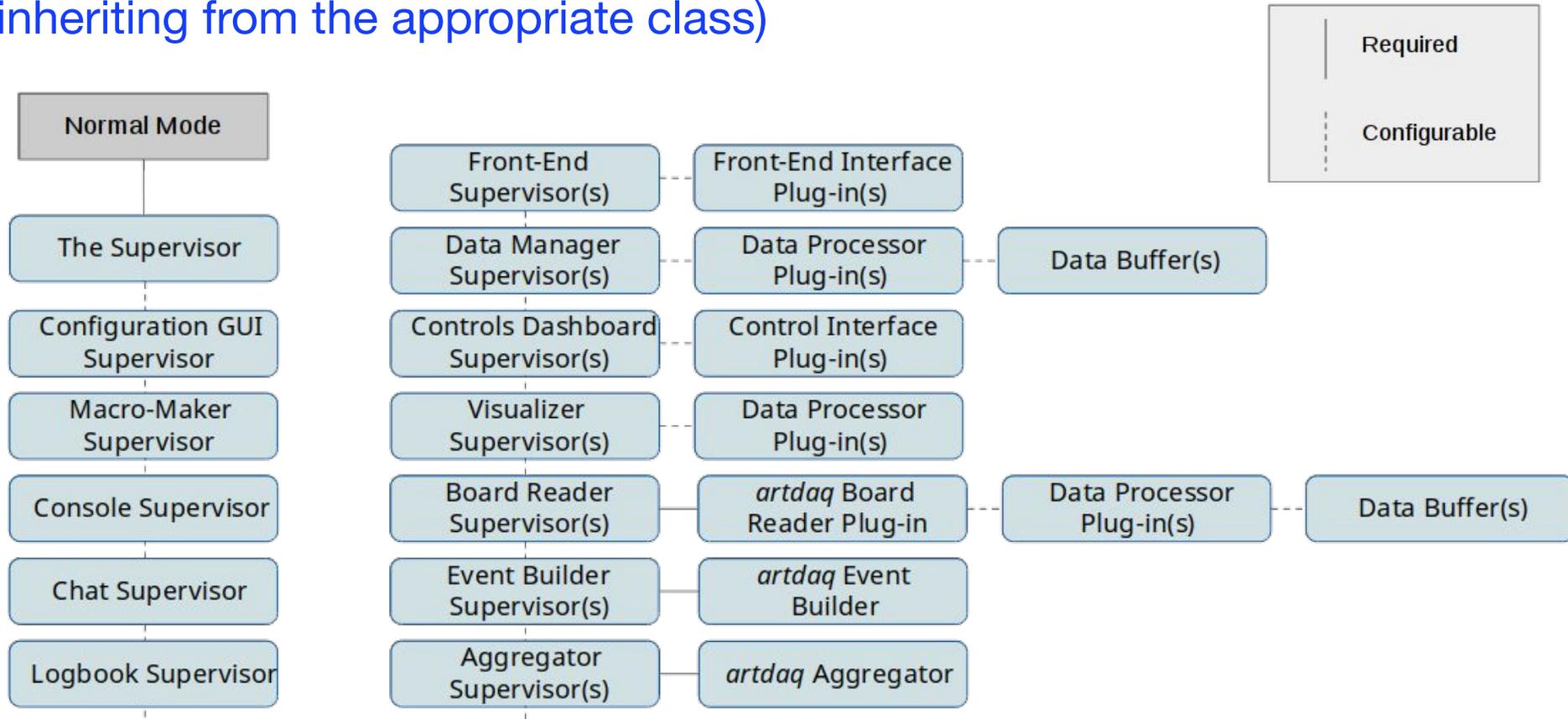
Backup Slides

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otsdaq overview

Server side is C++. User code is added through plugins (C++ classes inheriting from the appropriate class)

|	Required
	Configurable

Normal Mode		Front-End Supervisor(s)	Front-End Interface Plug-in(s)	
The Supervisor		Data Manager Supervisor(s)	Data Processor Plug-in(s)	Data Buffer(s)
Configuration GUI Supervisor		Controls Dashboard Supervisor(s)	Control Interface Plug-in(s)	
Macro-Maker Supervisor		Visualizer Supervisor(s)	Data Processor Plug-in(s)	
Console Supervisor		Board Reader Supervisor(s)	*artdaq* Board Reader Plug-in	Data Processor Plug-in(s) — Data Buffer(s)
Chat Supervisor		Event Builder Supervisor(s)	*artdaq* Event Builder	
Logbook Supervisor		Aggregator Supervisor(s)	*artdaq* Aggregator	

Web side is HTML and JavaScript. User code is added in the form of web-apps through .html files (including the appropriate .js and .css files)

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Slow Controls Monitoring in otsdaq

Slow Controls C++ Hierarchy

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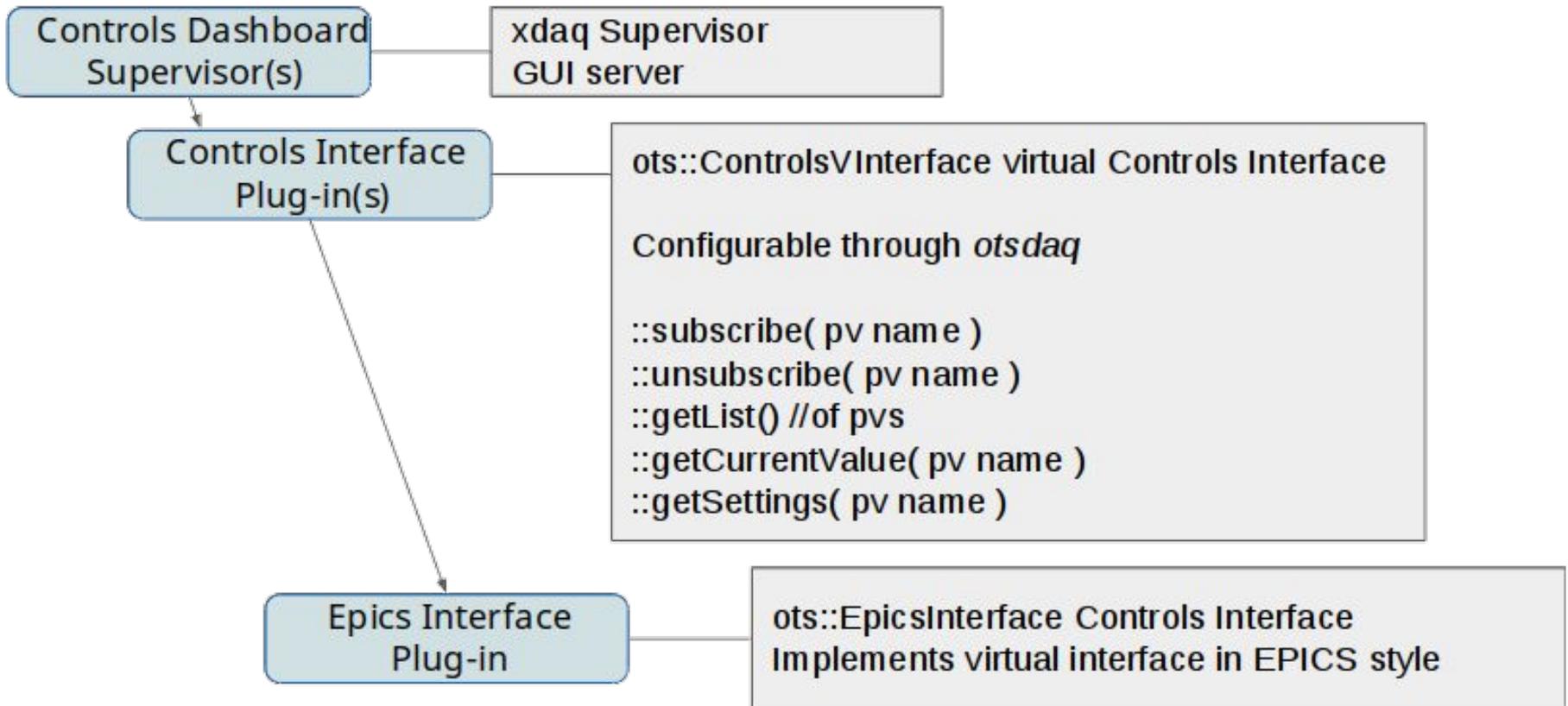
Slow Controls Monitoring in otsdaq

Configuring by specific tables in otsdaq

DesktopIconTable, XDAQApplicationPropertyTable, XDAQApplicationTable, XDAQContextTable

Configuration GUI in otsdaq desktop environment

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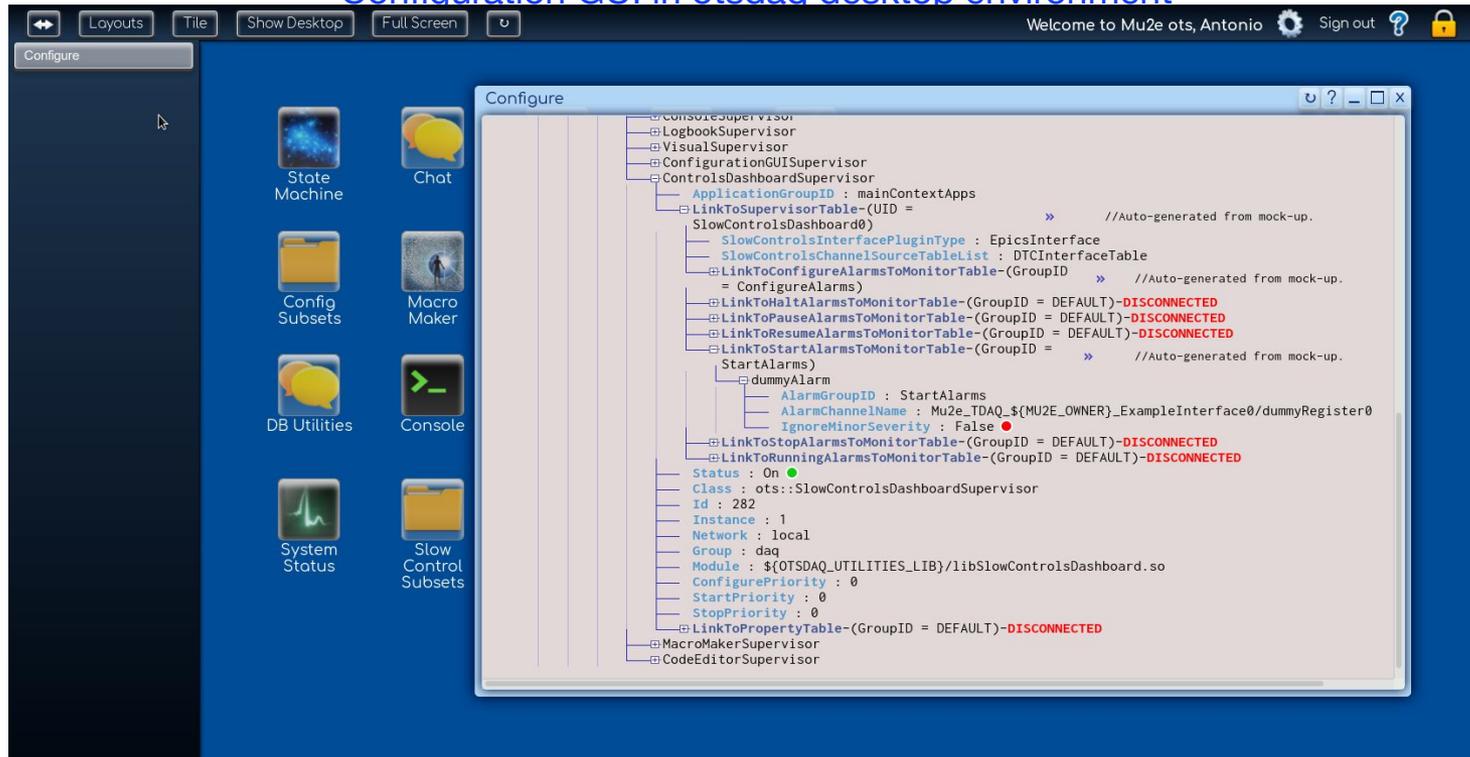
EPICS Database

- Postgres DBMS
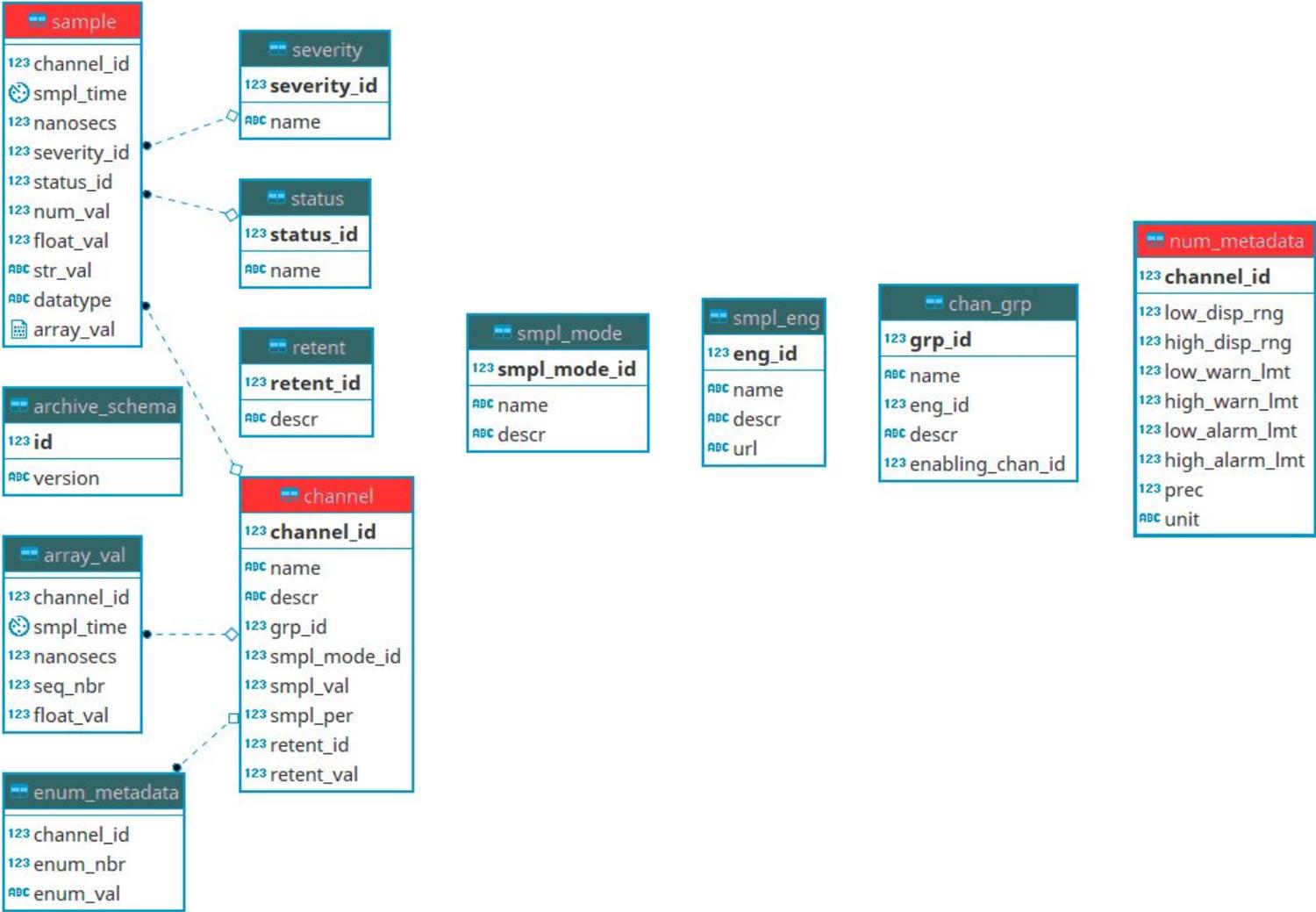
Integration with State Machine

- *otsdaq FE (DTC/ROC/CFO) / artdaq metric new channel or new slow control setting → configuring State Machine → EPICS DBs and IOC configuration*

- *otsdaq Interface→ otsdaq CA subscription and DBs select → Monitoring*

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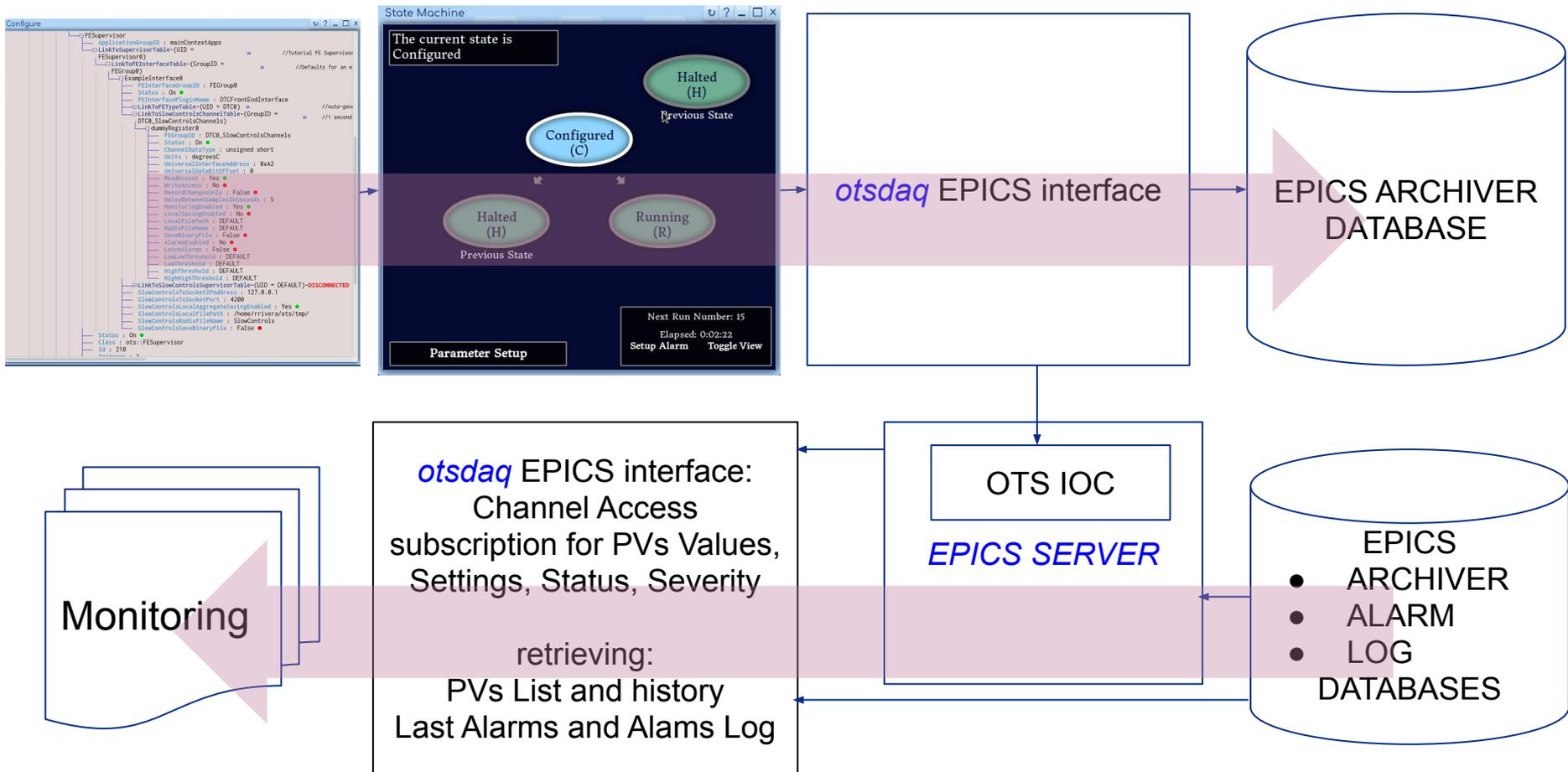
Integration of otsdaq front-end DAQ hardware and artdaq metrics with EPICS

Actions designed and developed in *otsdaq*

1. *otsdaq* DCS channels Front End and tables configuration

2. *otsdaq* State Machine configuration implementation

3. add/update channels info for IOC and Archiver DB

4. software IOC restarting

5. EPICS Archiver restarting

6. new *otsdaq* epics_plugin channels subscriptions to EPICS

7. Sending configured channels values to EPICS:

   otsdaq DCS channels new values → artdaq Metric Manager → software IOC → EPICS → otsdaq DCS GUI

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Integration with State Machine

- **Alarm** propagation (from **EPICS**) and *otsdaq* state machine handling is available: needs just to identify which **PV alarms**, *status* and *severity* will be propagated

- *Tables and parameters designed for configuration*
  - SupervisorTable parameters:
    - *Slow Controls Interface Plugin Type*
    - *Slow Controls Channel Source Table List* (HW list i.e. DTC Interface, CFO Interface)
  - Alarms To Monitor Tables for transition to states:
    - *Configure*
    - *Halt*
    - *Pause*
    - *Resume*
    - *Start*
    - *Running*

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Integration with State Machine

- Alarm propagation (from EPICS) and *otsdaq* state machine handling: Example on "Start" transition

Slow Controls WEB Monitoring GUI in otsdaq

developed in JavaScript and HTML (client side) and C++ (server side)

Basic Widget Mechanism
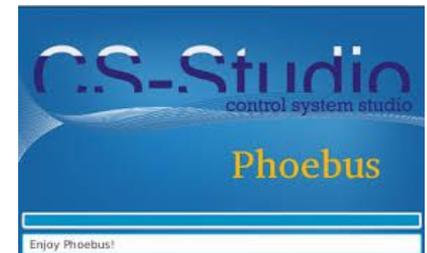
- All widgets have six required methods:

  init(), getParameters(), setParameters(), setupPVs(), newWidget(), and newValue()

Widget properties

- Dynamic sizing
- Proper handling of setups
- Value error, warning and alarm handling
- Disconnection handling

Load and save dashboard page in XML

Cs-Studio Phoebus (EPICS GUI) compatible format

Slow Controls Monitoring in otsdaq

Examples

Example of widget settings window

Editor

widget attributes editor

Calorimeter monitoring and the Slow Controls GUI

Examples: Import an xls file in a 2D-stop light widget

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Slow Controls alarm notification by System Message

System message alarm notification example