Controls at the Fermilab PIP-II Superconducting Linac

ICALEPCS 2023

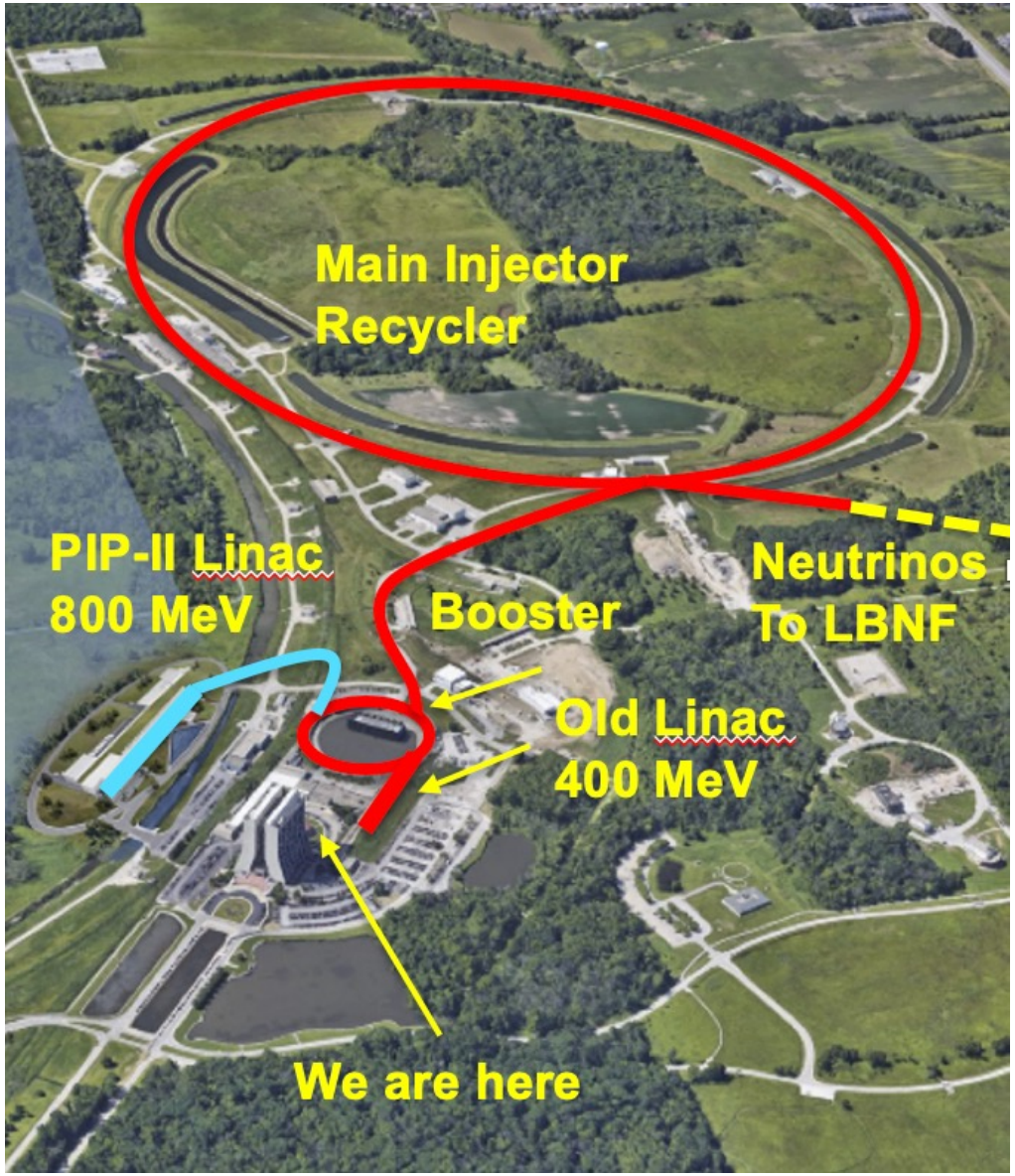
Dennis J. Nicklaus, Fermilab

FERMILAB-SLIDES-23-313-AD

Outline

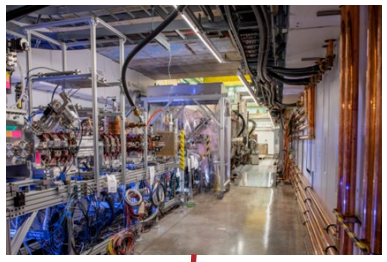
- Introduction to PIP-II at Fermilab
- EPICS at PIP-II
- EPICS Extensions/Customizations for Fermilab

PIP-II Overview



- An 800-MeV superconducting H^-, CW-compatible Linac
- Beam transport of 800-MeV H^- from the SRF Linac to the Booster.
- A new injection area in the Booster.
- **PIP-II is the first US/DOE accelerator to be built with significant international contributions/partnerships.**
  - **US, India, Italy, UK, France, Poland**

PIP-II Layout



PIP2IT successfully demonstrated 17 MeV beam with parameters required for LBNF/DUNE operations

Cryoplant
2.5kW @ 2K

HWR
162.5 MHz

Single Spoke 1
SSR1 x (1 + 2)
325 MHz

Single Spoke 2
SSR2 x (1 + 7)
325 MHz

Elliptical
LB650 x (1 + 9)
650 MHz

Elliptical
HB650 x (1 + 4)
650 MHz

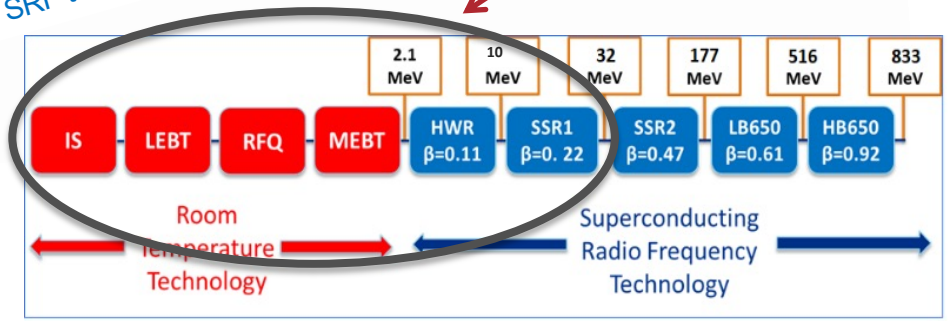
CD S

SRF technology

Room temperature technology

4

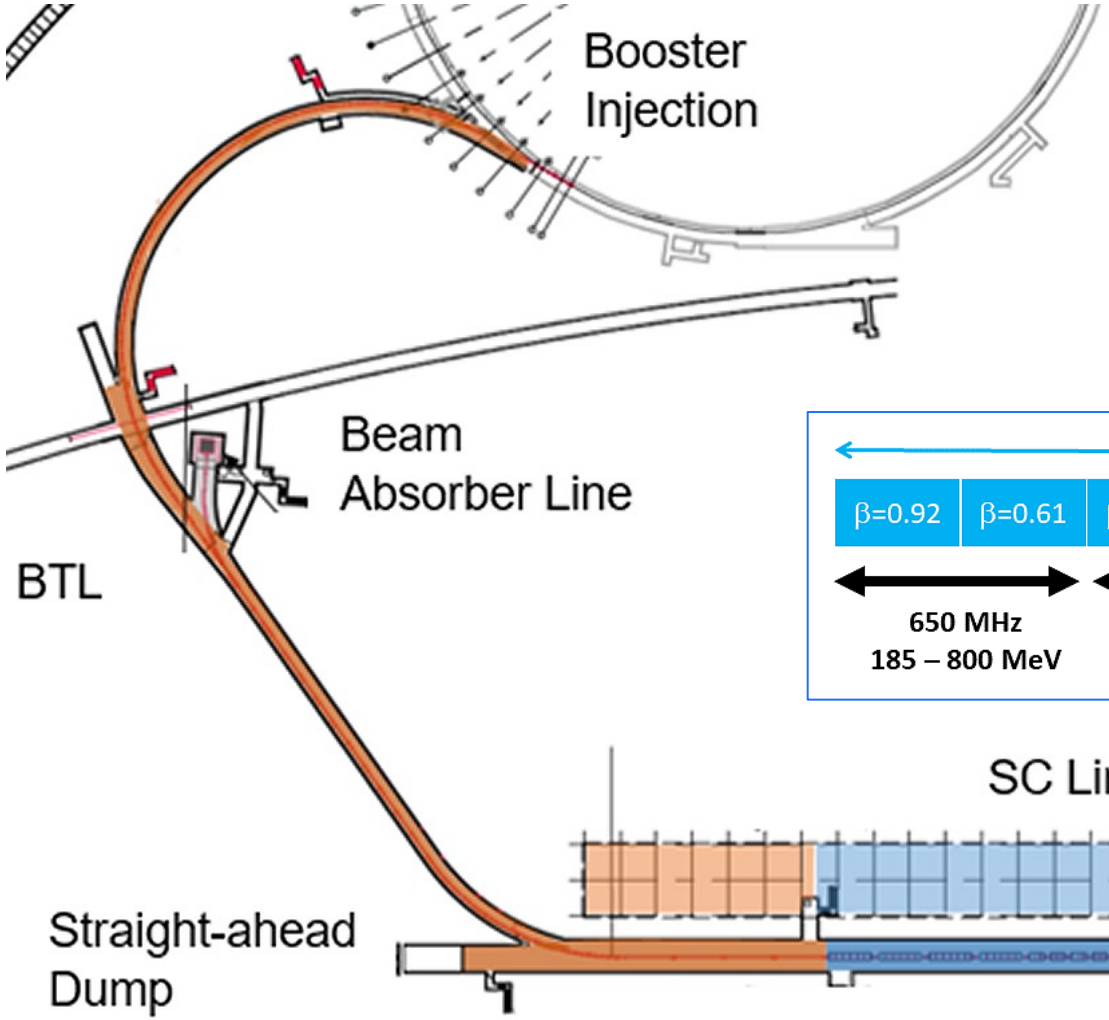
Tested at PIP2IT

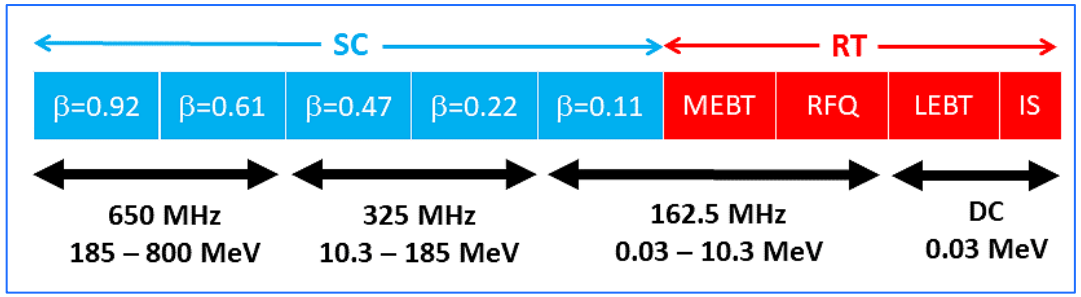


PIP-II technology map

PIP-II Layout

Linac consists of:
- Room temperature front end (up to 2.1 MeV)
- Superconducting (cold) linac
  - 5 types of Superconducting cavities: HWR, SSR1, SSR2, LB650, HB650
  - 3 RF frequencies are used for acceleration: 162.5, 325, 650 MHz






EPICS

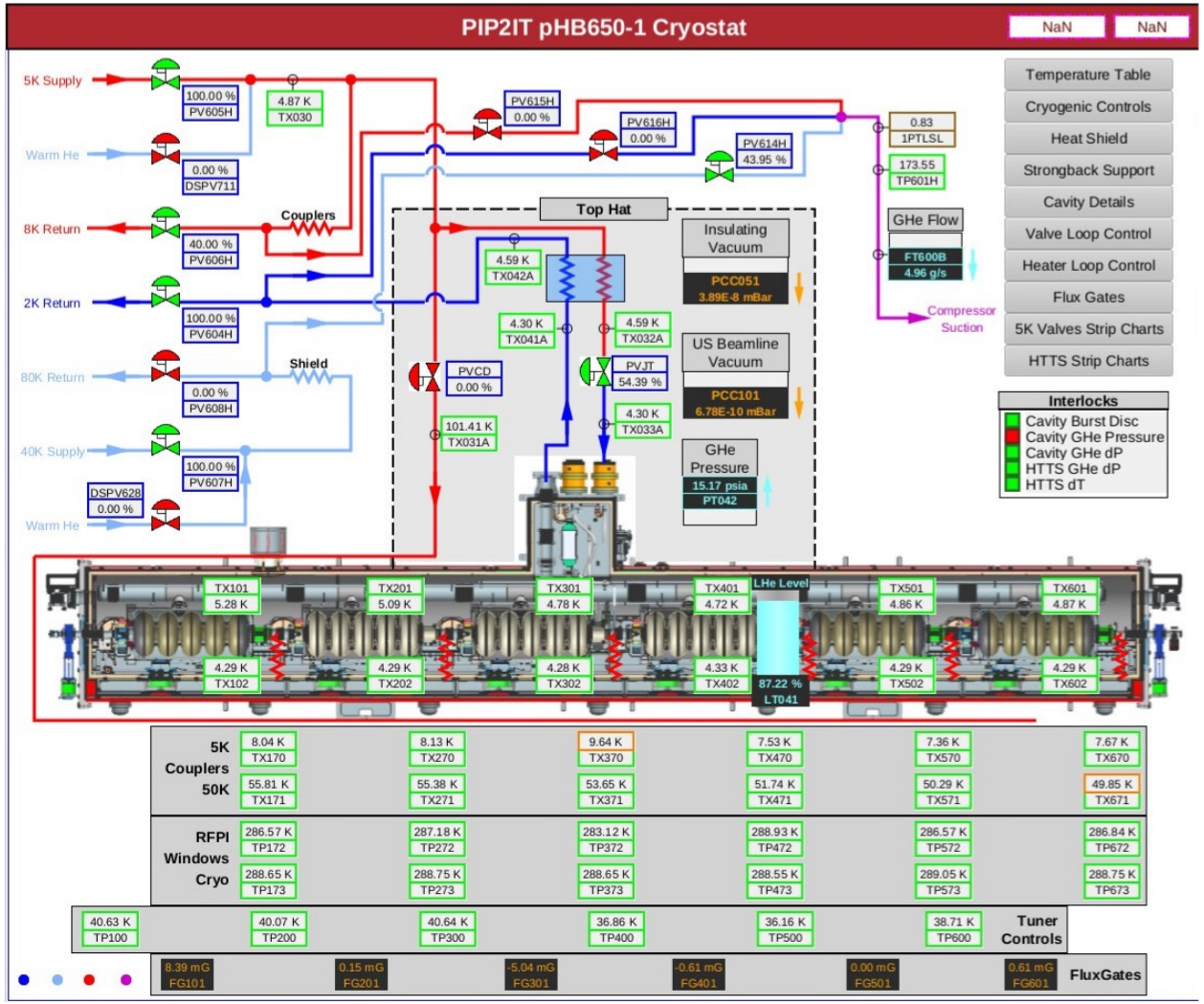
But!

- Beyond Base, EPICS is just a toolkit, configured a little differently at each lab
  - What pieces/applications to we choose?
- Special integration requirements at Fermilab

- Base Version 7 – PV Access
  - We can specify requirement of v. 7 for collaborators
  - But longstanding LLRF collaboration isn’t at v. 7 yet.
- Phoebus version of CSS
- Archiver Appliance
- Alarms Server
- Channel Finder
- …

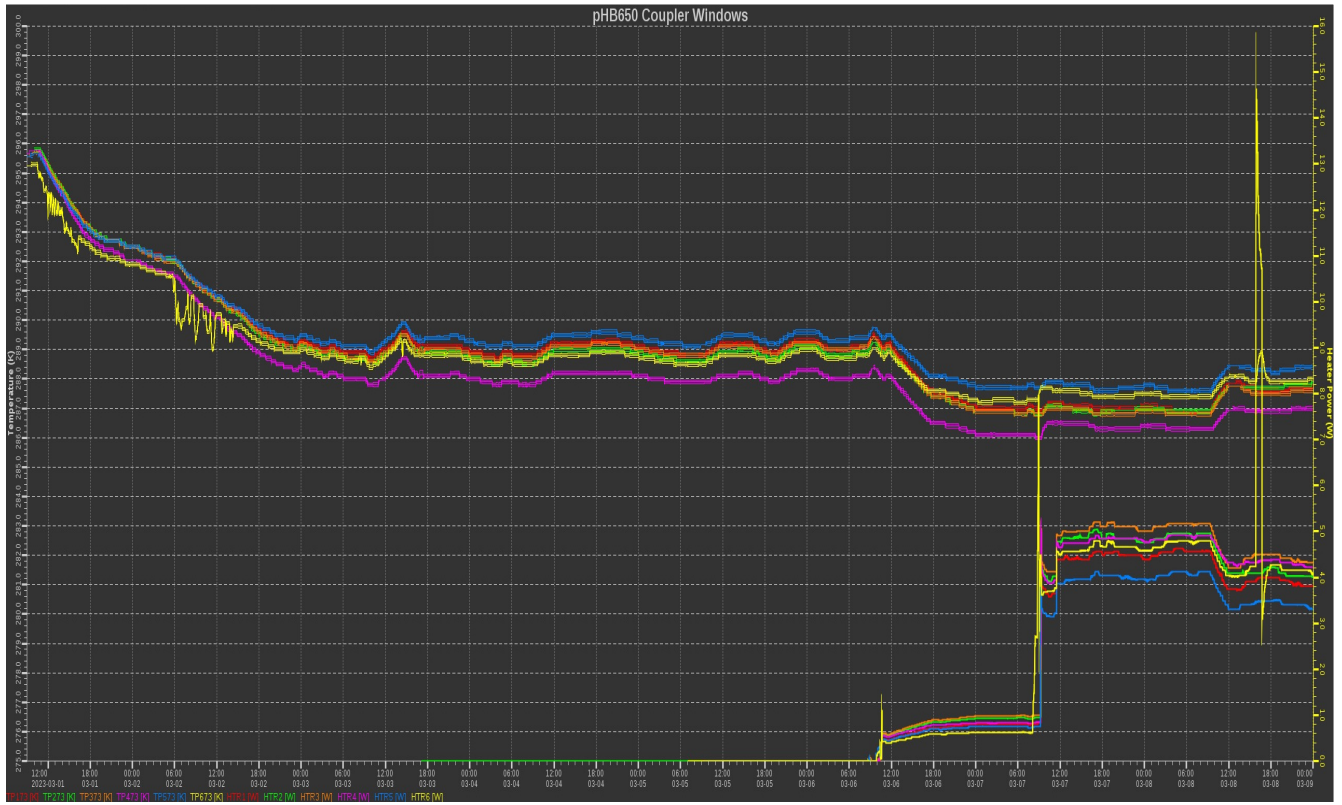
Phoebus

- **Good experience with Phoebus at our cryomodule test stand (PIP2IT)**
- **Even though it works well, we encounter further work to do:**
  - Develop scheme for repo & distribution of user-created .bob files
  - ACNET plug-in
  - …
- **Phoebus consumes a lot of resources**
  - Large memory footprint
  - Slow displays over network:
    - Ssh compression
    - XPRA
    - Remote Desktop/VNC?



Archiver Appliance

- **Again, very good experience at PIP2IT**
- **Benchmarks suggest it will meet PIP-II's volume requirements.**

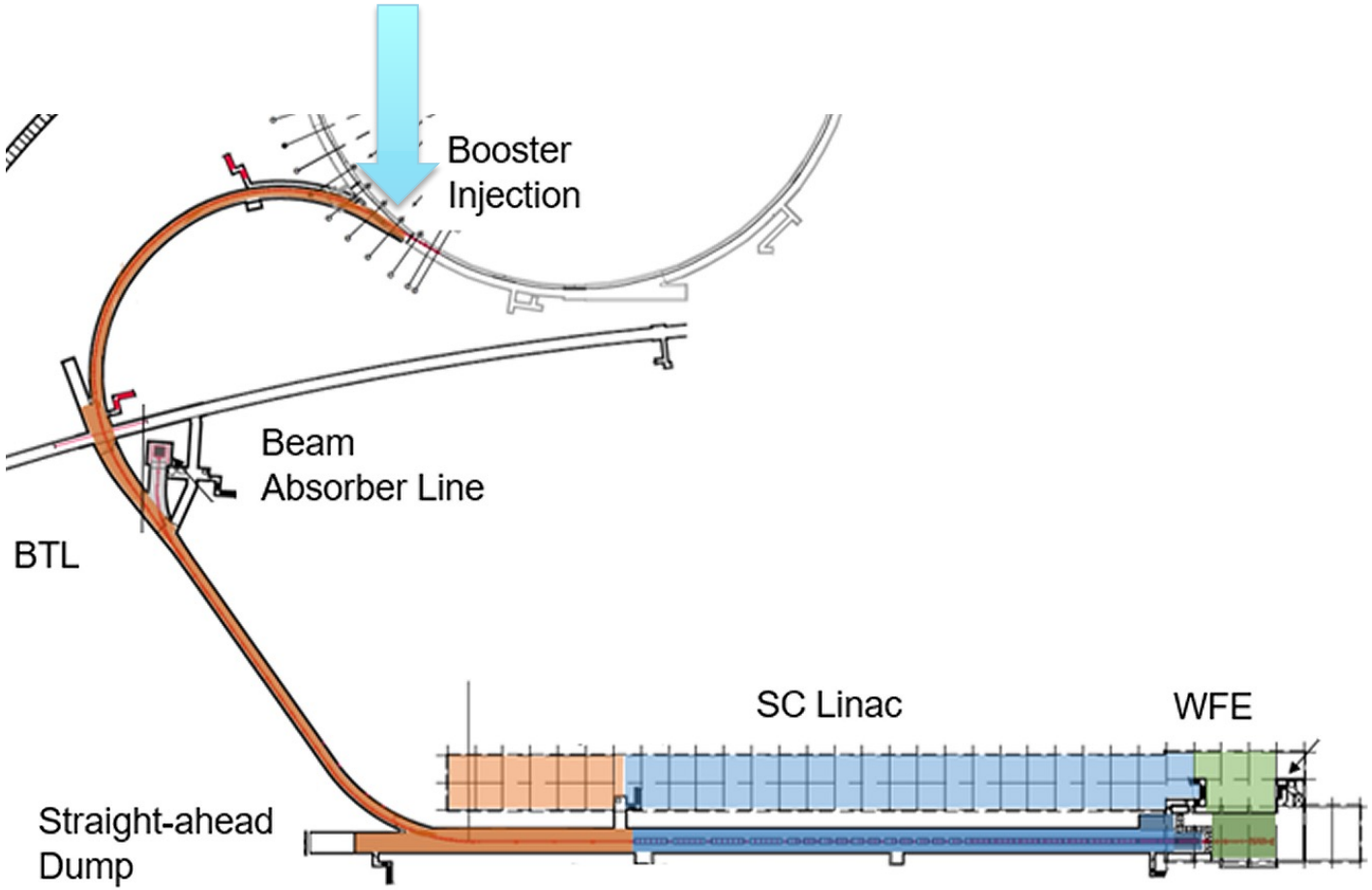


Channel Finder, Alarms Server, etc.

- Some products are a bit complicated to configure & install
  - But we've figured it out.
- We've thought of several ways that Channel Finder and its data could be used in the control system
  - Hooks via API to the Channel Finder data for integration with our ACNET databases and general control system information or as an aid to data acquisition.

EPICS and ACNET Cooperation

- **The PIP-II beam will feed into our existing Booster accelerator.**
- **This implies some level of cooperation between EPICS at PIP-II and ACNET at the rest of the accelerator complex.**
- **Could simply run side-by-side, but:**
  - Operators want unified interface
    - E.g., one alarm screen
  - Correlation of data from two systems is difficult.



EPICS and ACNET Cooperation – the DPM Center

- Existing Fermilab control system has a central layer called the Data Pool Manager (DPM)
- Manages data acq. and setting requests
- Consolidates requests to front-ends (IOCS)

- We've made extensions to DPM that enable it to communicate with EPICS via PV Access.

EPICS, ACNET, DPM – Authentication and The Big Plan

- **Funnel access from both ACNET and EPICS clients through DPM**
- **Use Keycloak with the Fermilab Single-Sign-On system to present authentication credentials to DPM**
  - Simple SSO system that users are familiar with
  - Leverages existing technologies to help with authentication
- **DPM authorizes authenticated users to access different devices or features of the control system**
- **By design, DPM is scalable to avoid restrictive bottlenecks**

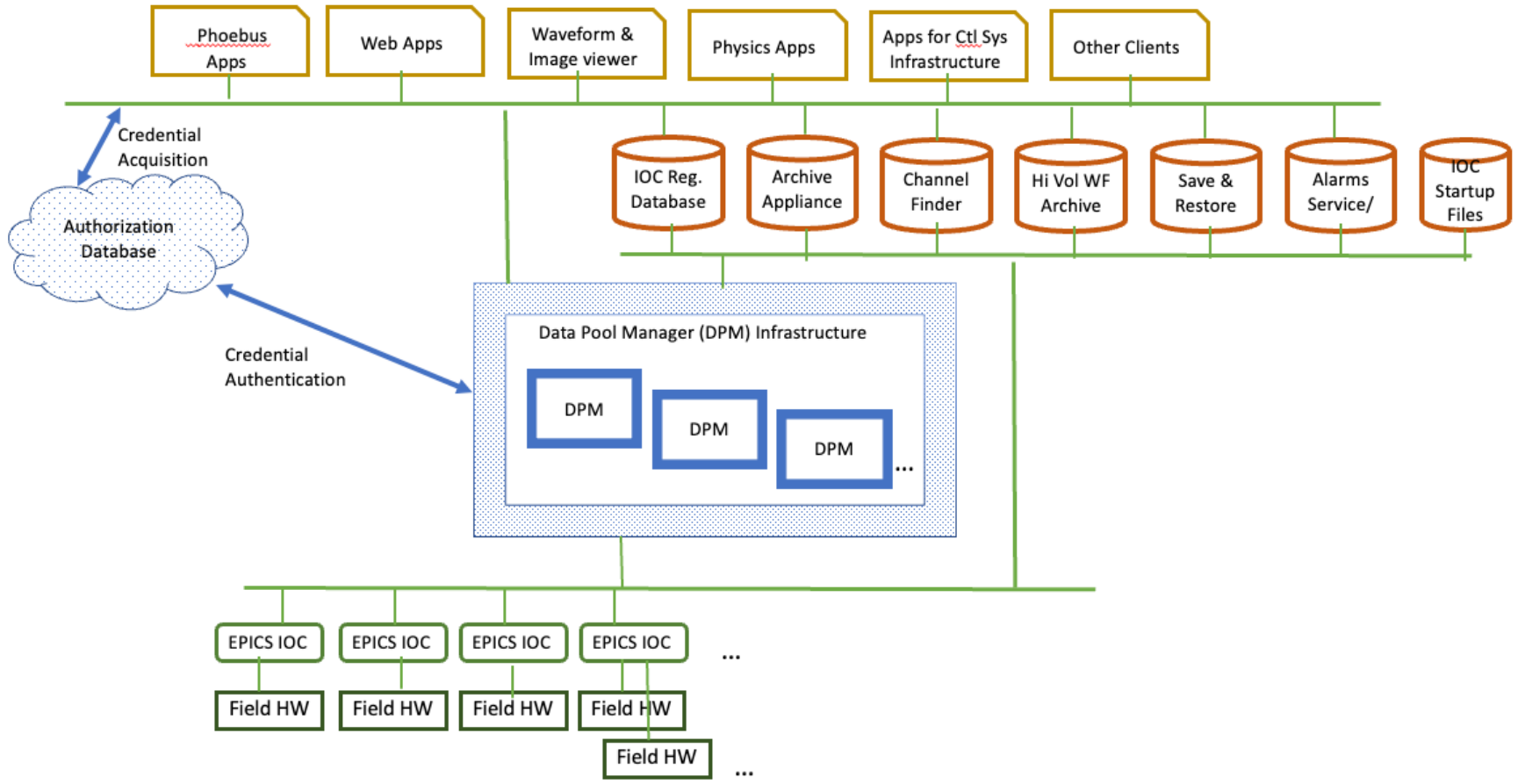
PIP-II Controls

- **3-tier Controls architecture**

User/Operator interface

Core services

Field Level



EPICS & ACNET – Other works

- **Alarm Server**
  - Working to integrate ACNET alarms
- **Phoebus**
  - ACNET plug-in for readings/settings
  - Add Authentication module
- **Channel Finder**
  - There is a lot of useful information
  - Possibly useful to the DPM
  - Other integration with the ACNET device database
- **Database to Track IOCs**
  - Integrate with similar ACNET database of ACNET nodes
  - Contains purpose, host, programmer, …
- **Save/Restore and Settings History**
  - Under Development
- **Prototype Web-based application – Dart/Flutter based**
  - Integrates access to both with authentication method

PIP-II Timing System

- **An integral component of the control system**
- **Coordinates the operation of both the Linac and the rest of the accelerator complex by the distribution of the required clocks, machine resets, triggers and system state information**
- **Two part system:**
  - ACLK
    - Event based timing for the whole Fermilab accelerator complex
  - LCLK
    - RF synchronized clock system unique to the PIP-II linac*
      - *Source, Linac, Booster Transfer Line & Injection System

PIP-II Timing System – Commonalities and Differences

- **ACLK and LCLK will share common hardware, e.g.:**
  - Fanouts
  - Decoding
  - Multi Function Timing Unit
- **Both systems will have a clock output with a data frame of 16 event bits + 32 data bits with frames broadcast at 650 MHz**
- **ACLK System will make use of an external 10 MHz signal source as a reference for its 650 MHz phase lock as it is the reference frequency for the legacy TCLK**
- **LCLK will use a PIP-II Linac RF reference (162.5 MHz) from the Linac LLRF system to allow beam synchronized event placement ACLK**
- **Appropriate TCLK/ACLK events will be decoded and reflected onto LCLK**
- **Expected number of events:**
  - ACLK -- ~200
  - LCLK -- ~30

PIP-II Controls – “Hidden” Layers

- **Much of the discussion centers around software frameworks or data acquisition hardware architectures**
- **A very significant effort goes into infrastructure including:**
  - Network
  - Back-end Server Computers
  - Control Room Consoles & Monitors
  - System Administration for the above
  - Code Repositories
  - CI/CD Pipeline

Acknowledgements

- **Many thanks to controls collaborators at Fermilab:**
  - Pierrick Hanlet
  - Charlie King
  - Richard Neswold
  - Larry Mills
  - John Diamond
  - Jim Huang
  - Jianming You
  - Mark Austin
  - Dan MacArthur
  - Mariana Gonzales Velarde
  - William Badgett
  - And many more!
- **Thank you to the EPICS community!**
- ***Work supported, in part, by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, under U.S. DOE Contract No. DE-AC02-07CH11359. Fermilab Document*** FERMILAB-SLIDES-23-313-AD


Thank you!
Questions?