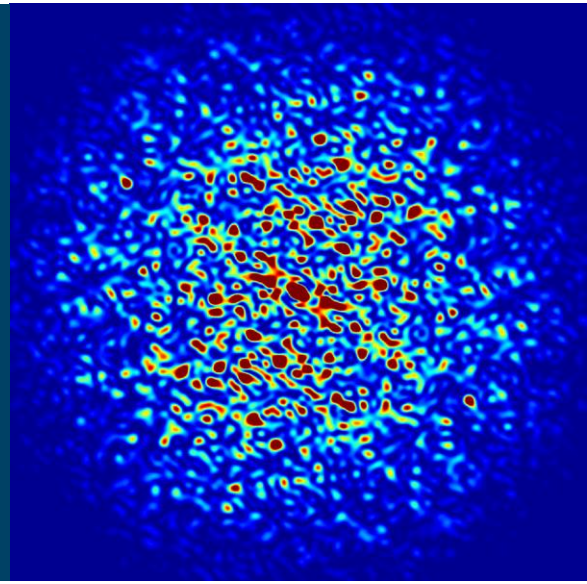
APS-U Accelerator Controls System Update



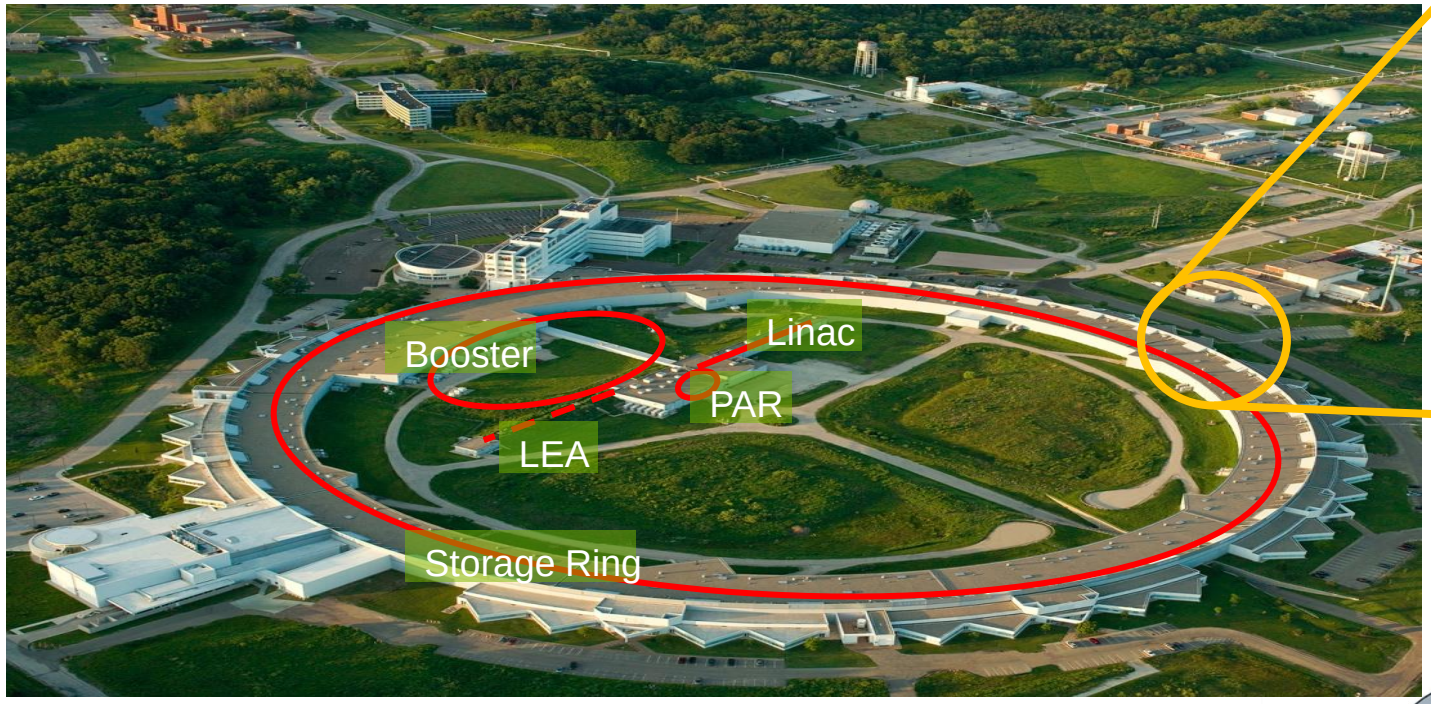
PRESENTED BY KAREN WHITE FOR APS-U CONTROLS

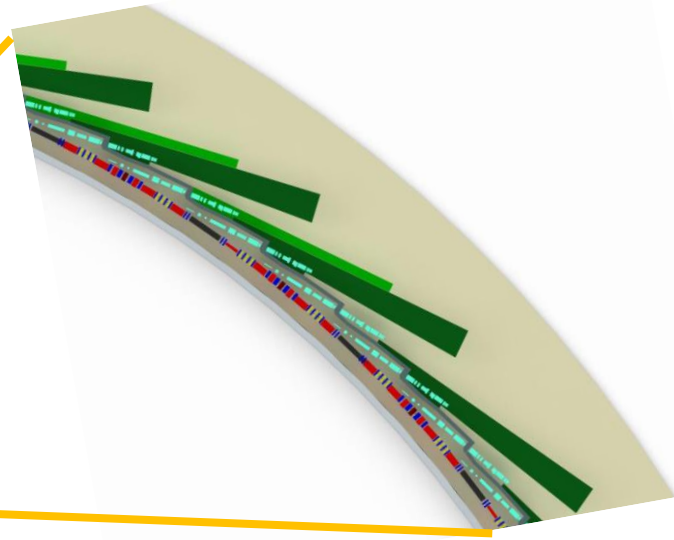
Advanced Photon Source
Argonne National Laboratory

09-14-2022

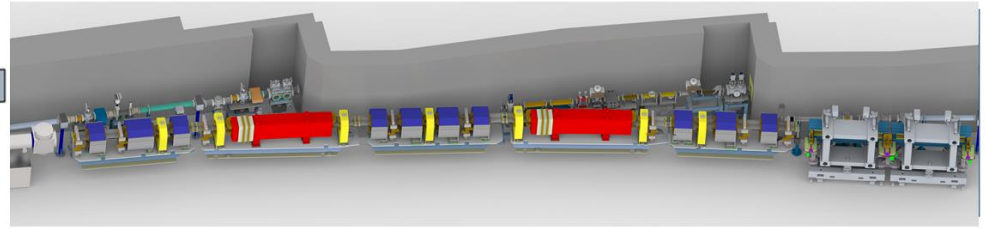
APS & APS-U Overview

- APS Accelerator Complex & its Upgrade

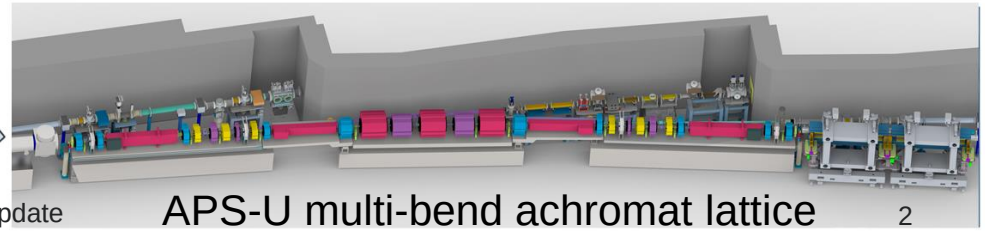




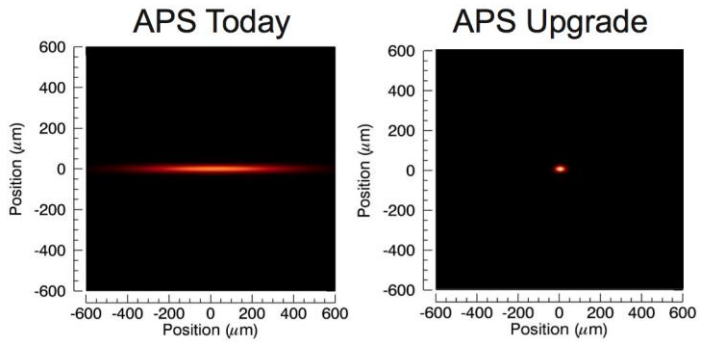
APS double bend lattice



~70-fold reduction in horizontal emittance

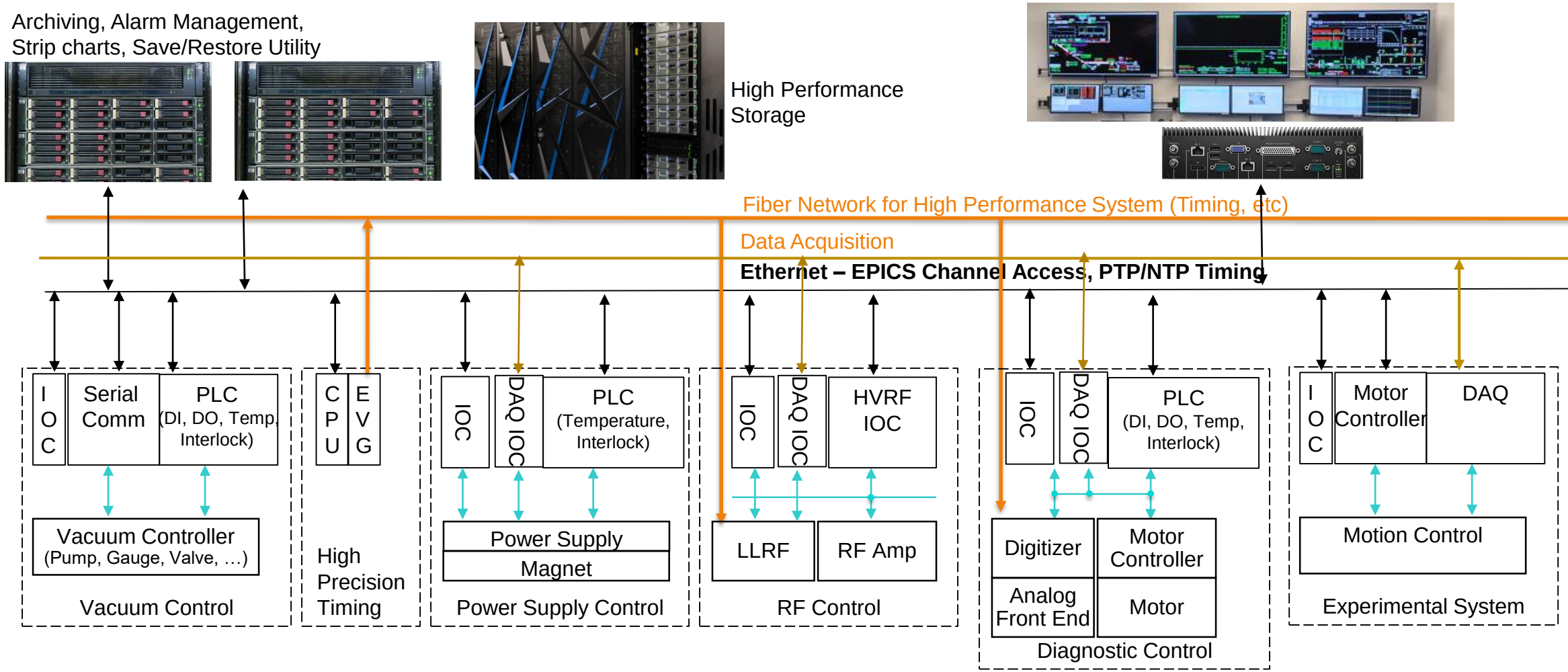


APS-U multi-bend achromat lattice



APS-U Controls System Architecture

- Standard 3-tier distributed structure with EPICS7 as software framework



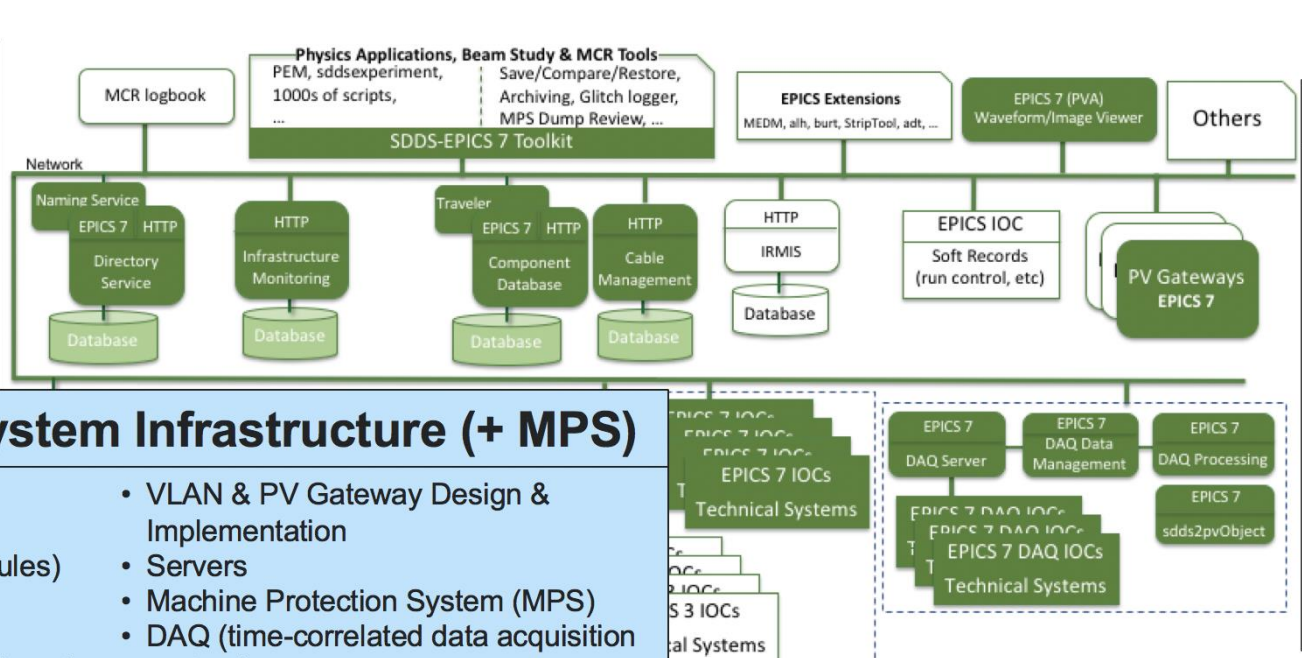
Overview of APS-U Controls System

APS-U Controls High Level Applications

- EPICS 7 Waveform/Image Viewer
- EPICS 7 sdds-epics toolkit enhancements
- Process Variable Directory & Name Service
- Infrastructure Monitoring
- High Level Applications for Specific Systems (e.g. orbit, synchronous PS setpoint, post-mortem, …)

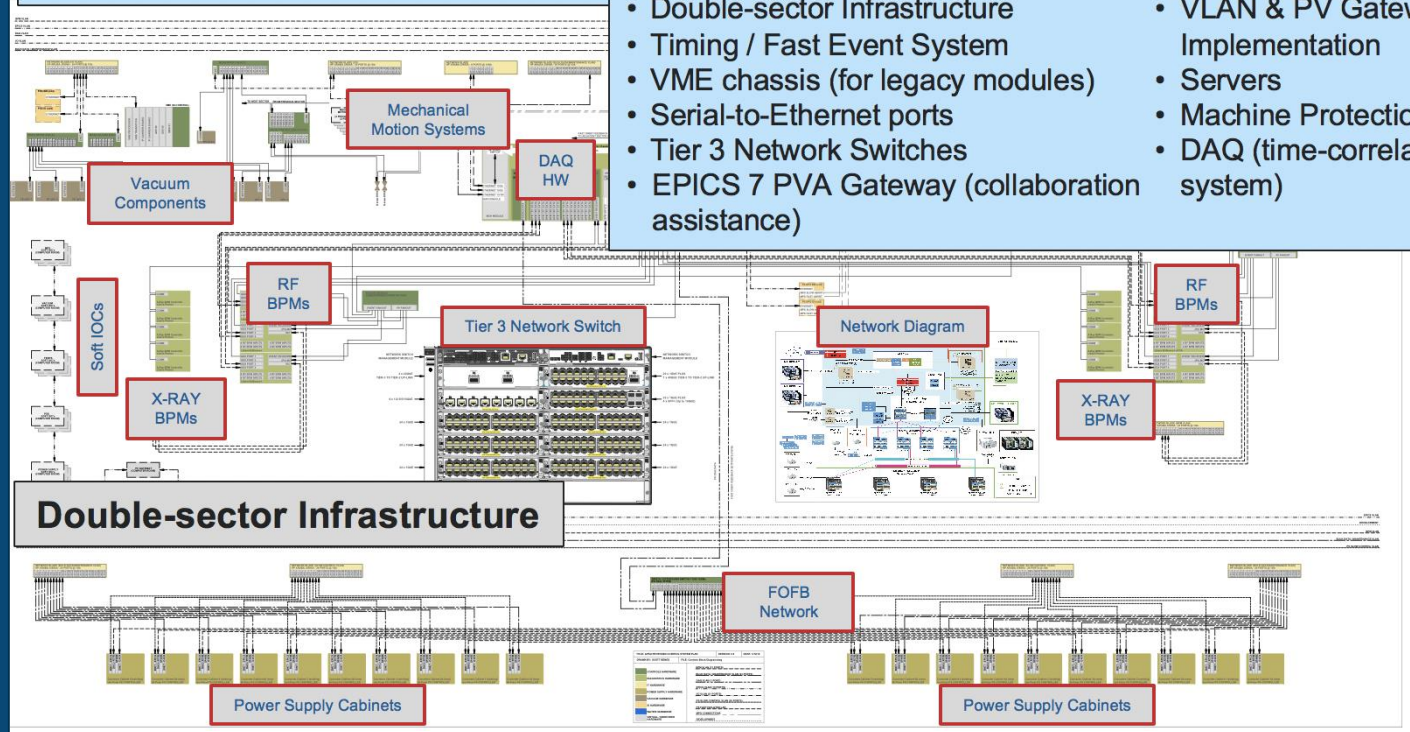
< Project-wide Tools >

- Component Database
- eTraveler
- Cable Management Application



APS-U Control System Infrastructure (+ MPS)

- Double-sector Infrastructure
- Timing / Fast Event System
- VME chassis (for legacy modules)
- Serial-to-Ethernet ports
- Tier 3 Network Switches
- EPICS 7 PVA Gateway (collaboration assistance)
- VLAN & PV Gateway Design & Implementation
- Servers
- Machine Protection System (MPS)
- DAQ (time-correlated data acquisition system)



Double-sector Infrastructure

APS-U Technical System Interfaces

- Unipolar Power Supplies + DAQ
- Bipolar Power Supplies + DAQ
- Vacuum Systems + Beam Dumps
- Bunch Lengthening System Interlocks/LLRF + DAQ
- BLS Cryo-system + Distribution
- Injection/Extraction + DAQ
- RF BPM (Libera) + DAQ
- X-Ray BPM + DAQ
- X-Ray Intensity Monitor
- BPLD
- Beam Size Monitor (absolute)
- Beam Size Monitor (relative)
- Mechanical Motion System
- DCCT
- Bunch Current Monitor
- Fast Orbit Feedback + DAQ
- Longitudinal Feedback + DAQ
- Transverse Feedback + DAQ
- Booster/SR 352MHz Timing
- Slow Abort Sequencer

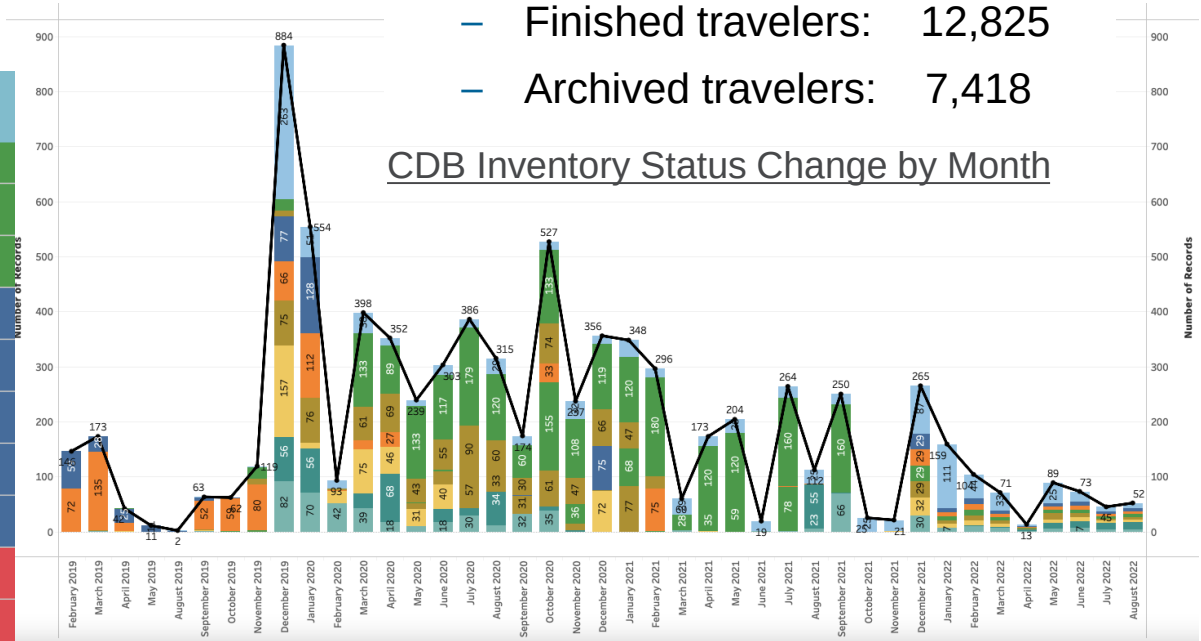
Database Applications

- CDB, CDB/Cable, eTraveler are actively supporting project construction
  - CDB Mobile application provides sufficient flexibility to support in field work
  - Some statistics of data entry
    - ❖ CDB:
      - Registered Users 341
      - Catalog Items 2,706
      - Inventory Items 33,841
      - Machine Elements 30,391
      - MAARC Items 163,063
    - ❖ Cable:
      - Cable Catalog Items 176
      - Cable Inventory Items 2,365
      - Cable Design Items 11,875
    - ❖ eTraveler
      - Registered Users: 287
      - Draft Forms: 703
      - Released Forms: 960
      - Active travelers: 18,564
      - Finished travelers: 12,825
      - Archived travelers: 7,418

Inventory Item Tracking in CDB

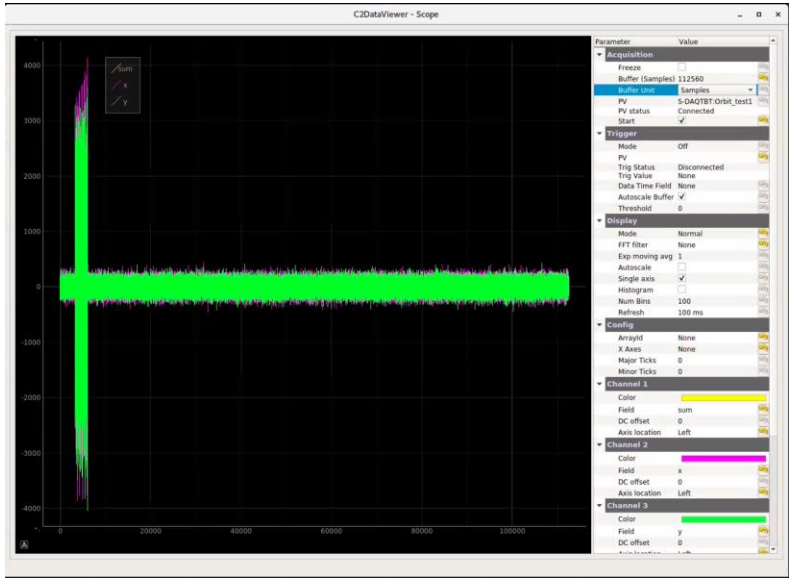
Function Name	Project Name	Catalog Name	Tag	QR ID	Inventory Id	Location1	Inventory Hyperlink	Status
			Unit: 4	2852	3718	400	View Item	Installed
			Unit: 2	2850	3716	400	View Item	Installed
			Unit: 1	2213	2922	400	View Item	Installed
Controller - Motor	APS-U Production	Horizontal Collimator Controller Chassis	Unit: 0001	Null	196716	No Data	View Item	Planned
		MAXv	Unit: 0005	24691	250519	No Data	View Item	Planned
			Unit: 0004	24690	250518	No Data	View Item	Planned
			Unit: 0003	24689	250517	No Data	View Item	Planned
			Unit: 0002	24688	243383	No Data	View Item	Planned
CPU	APS-U Production	MVME2500 CPU	Unit: 0027	33261	107989	L2109	View Item	Ready For Use
			Unit: 0028	33262	107990	L2109	View Item	Ready For Use

CDB Inventory Status Change by Month



EPICS 7 Waveform/Image Data Viewer (C2DV)

- C2DV: A Python based data visualization tool for EPICS 7 high speed DAQ system
  - A scope viewer for plotting PVA waveforms
  - An image viewer for displaying streaming Area Detector image data over PVA
  - A striptool for monitoring CA and PVA scalar PVs



Scope viewer

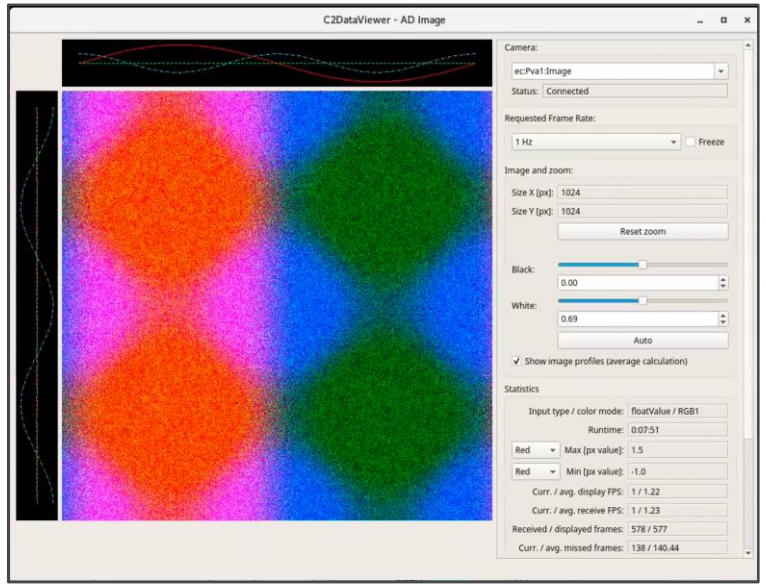
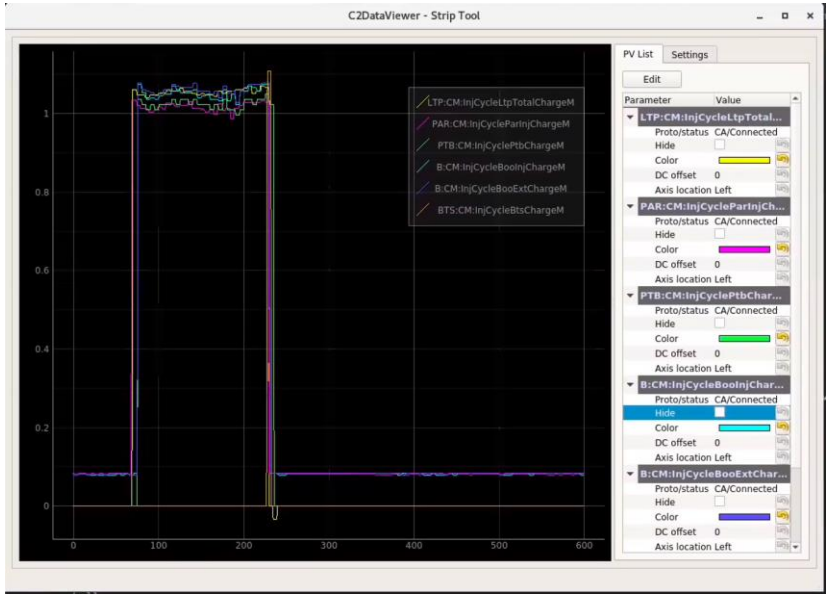


Image viewer



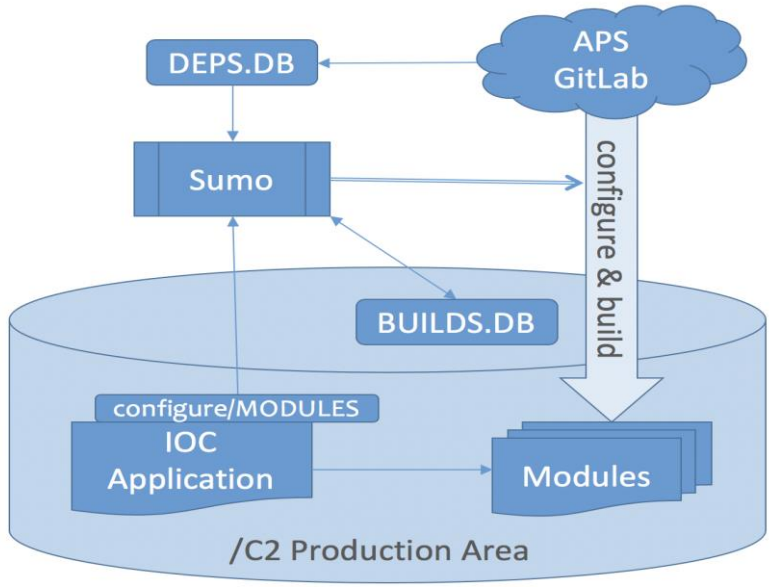
Striptool

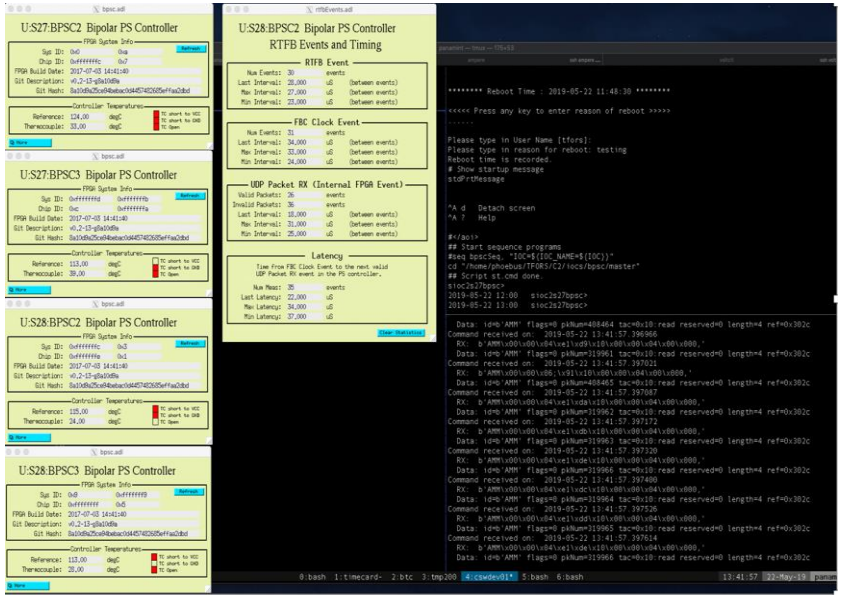
Other High-Level Applications

- A web-based naming system, which was developed originally at FRIB, has been introduced to manage the APS-U naming convention
  - 600+ name entries captured in the naming system
- OpenNMS was selected to monitor controls system infrastructure
- Olog is deployed as next logbook management system
  - Existing Controls logbook data has been migrated into this system now
- Logging as well as IOC console message to be logged into ElasticSearch using logstash, and browse it on Kibana

EPICS Module Configuration, Build, and Management

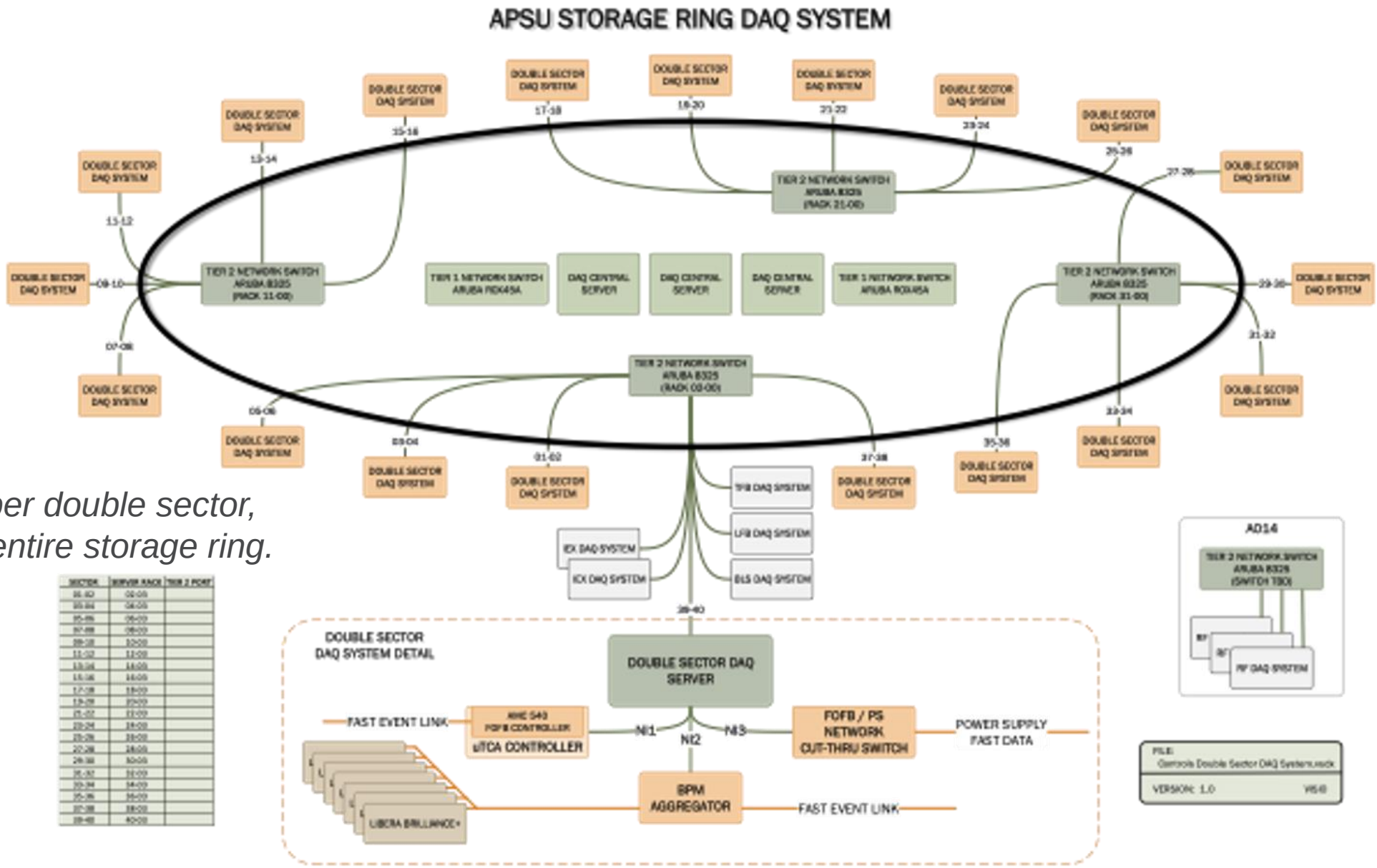
- Using Conda for software environment management including EPICS
- Adopted ‘Sumo’ package to automate IOC modules configure/build
  - Sumo (HZB/BESSY) to build IOC support modules from source on demand
  - All source comes from APS’ GitLab server
  - IOC applications will specify needed support modules and versions
  - Sumo is used similarly to create private module build areas to assist development
  - Where appropriate we hope to include PLC, FPGA, and DSP code in the same environment
  - We are developing against an EPICS 7 release





APS-U Time-Corelated DAQ System

- Architecture



data rate of ~ 150MB/s per double sector,
& 3+ GB/s data rate for entire storage ring.

SECTOR	SERVER RACK	TIER 2 PORT
01-02	02-05	
03-04	04-05	
05-06	06-07	
07-08	08-09	
09-10	10-09	
11-12	12-09	
13-14	14-09	
15-16	16-09	
17-18	18-09	
19-20	20-09	
21-22	22-09	
23-24	24-09	
25-26	26-09	
27-28	28-09	
29-30	30-09	
31-32	32-09	
33-34	34-09	
35-36	36-09	
37-38	38-09	
39-40	40-09	

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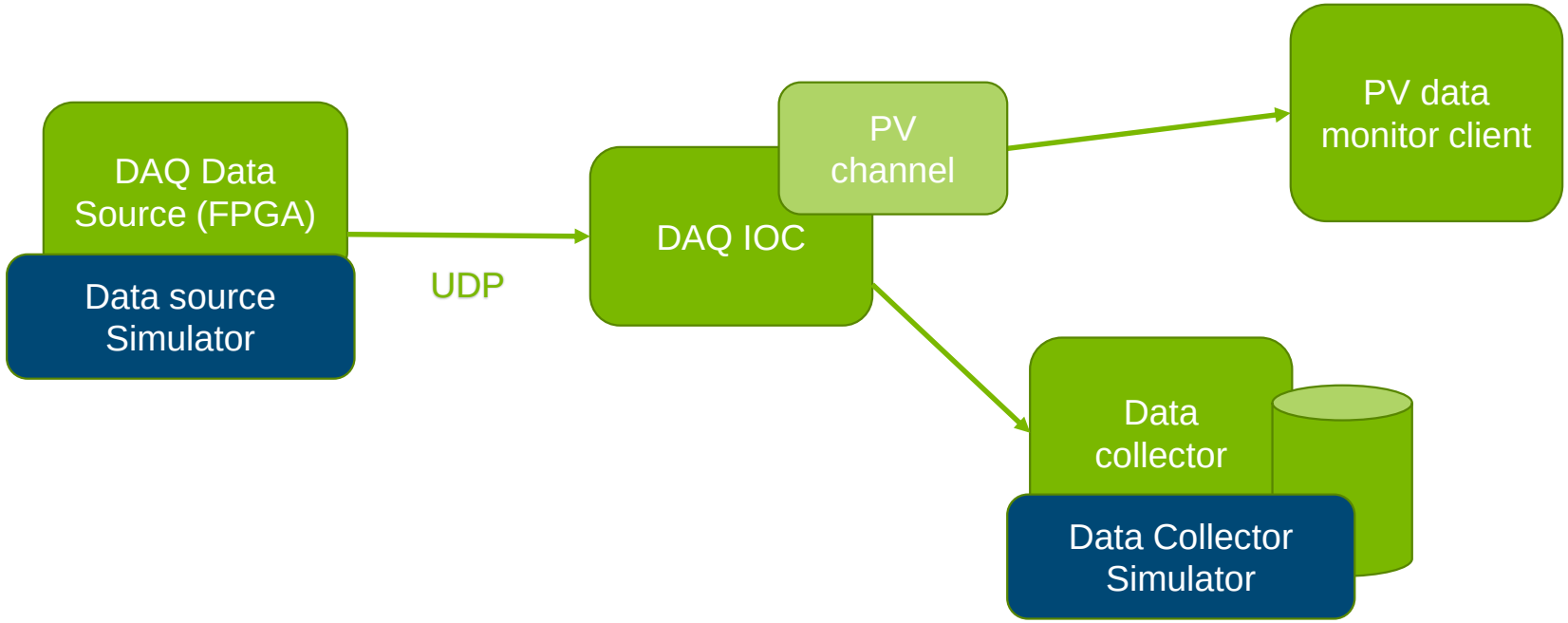
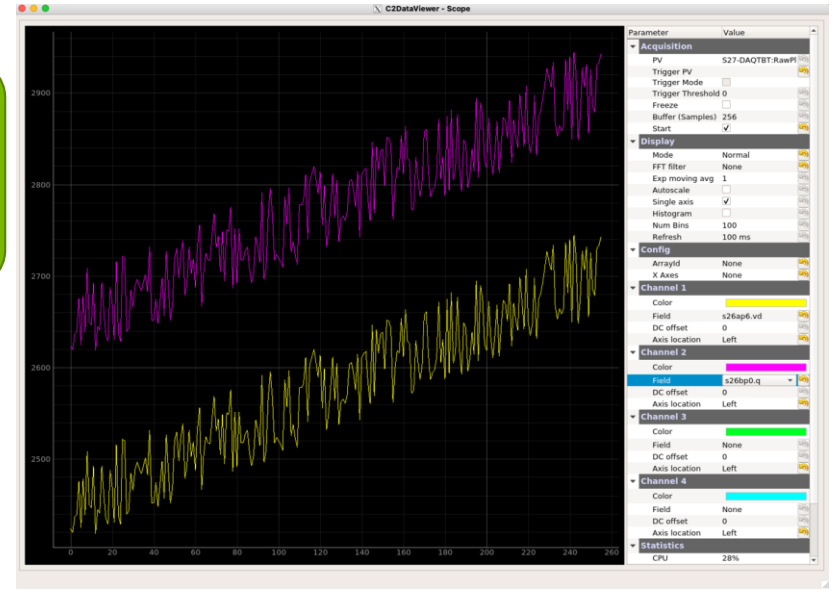
DAQ System Simulation Environment

- In order to run the DAQ system in different test environments, several simulation tools were developed including data source simulator and data collector simulator
  - Data source simulator: simulate the hardware that generates and sends data to a specific DAQ IOC. The simulation generates simple linear data with noise to easily verify that the data was processed correctly
  - Data collector simulator: captures PV objects published by the DAQ IOC, and save the data into a local file in desired format like HDF5, or other site-specific data format (e.g. Self-Describing Data Sets [SDDS] at APS)





C2DV Client

APS-U Time-Corelated DAQ System

- DAQ Hardware

Fully assembled DAQ aggregator FPGA chassis

DAQ Linux Servers

PS DAQ aggregator FPGA chassis

TBT DAQ aggregator FPGA chassis

Example of DAQ Linux Servers installed

APS-U MRF Fast Event/Timing System

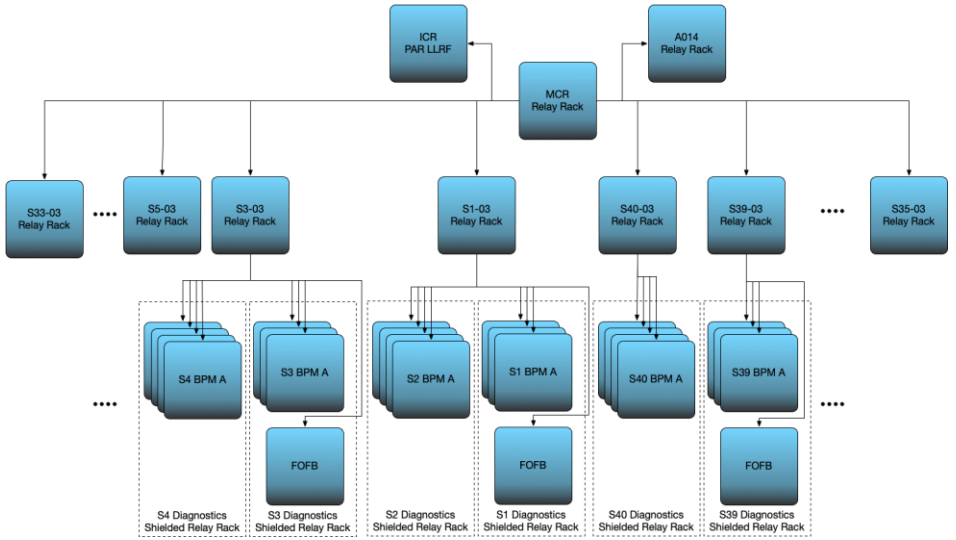
- New timing system with MRF 300-series hardware
  - Event Link distributed to 232 technical systems
  - 113 + Individual Triggers (TTL) to technical systems

Generator	Receiver	Fanout	Rear Transition	TTL Input	TTL Output
33	41	45	9	31	162

- Jitter measured relative to event clock reference at APS

	UNIV Output		CML Output	
PLL Bandwidth	RMS	Pk-Pk	RMS	Pk-Pk
MH (375 Hz)	16.15 ps	101.56 ps	8.70 ps	78.13 ps

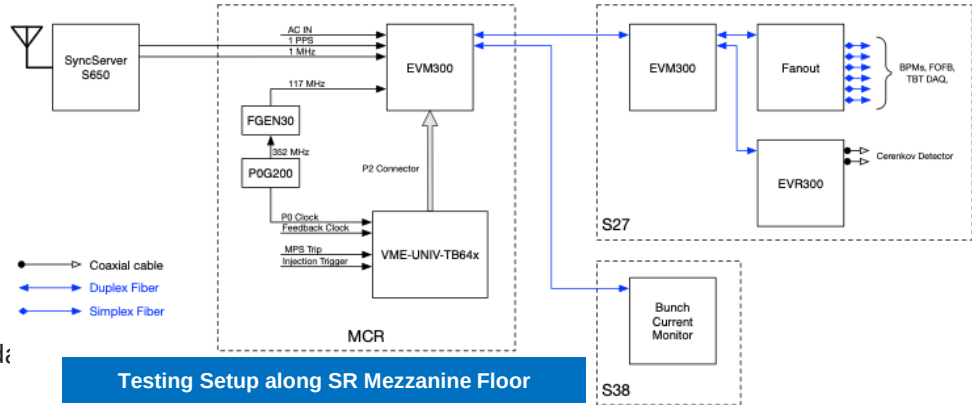
- Fully use delay compensation function to compensate the time delay in the fibers
- A few testing stands setting up
  - In Diagnostics lab, supporting RF BPM acceptance test
  - Along SR mezzanine floor
  - In installation preparation warehouse



VME-EVM-300

VME-EVR-300

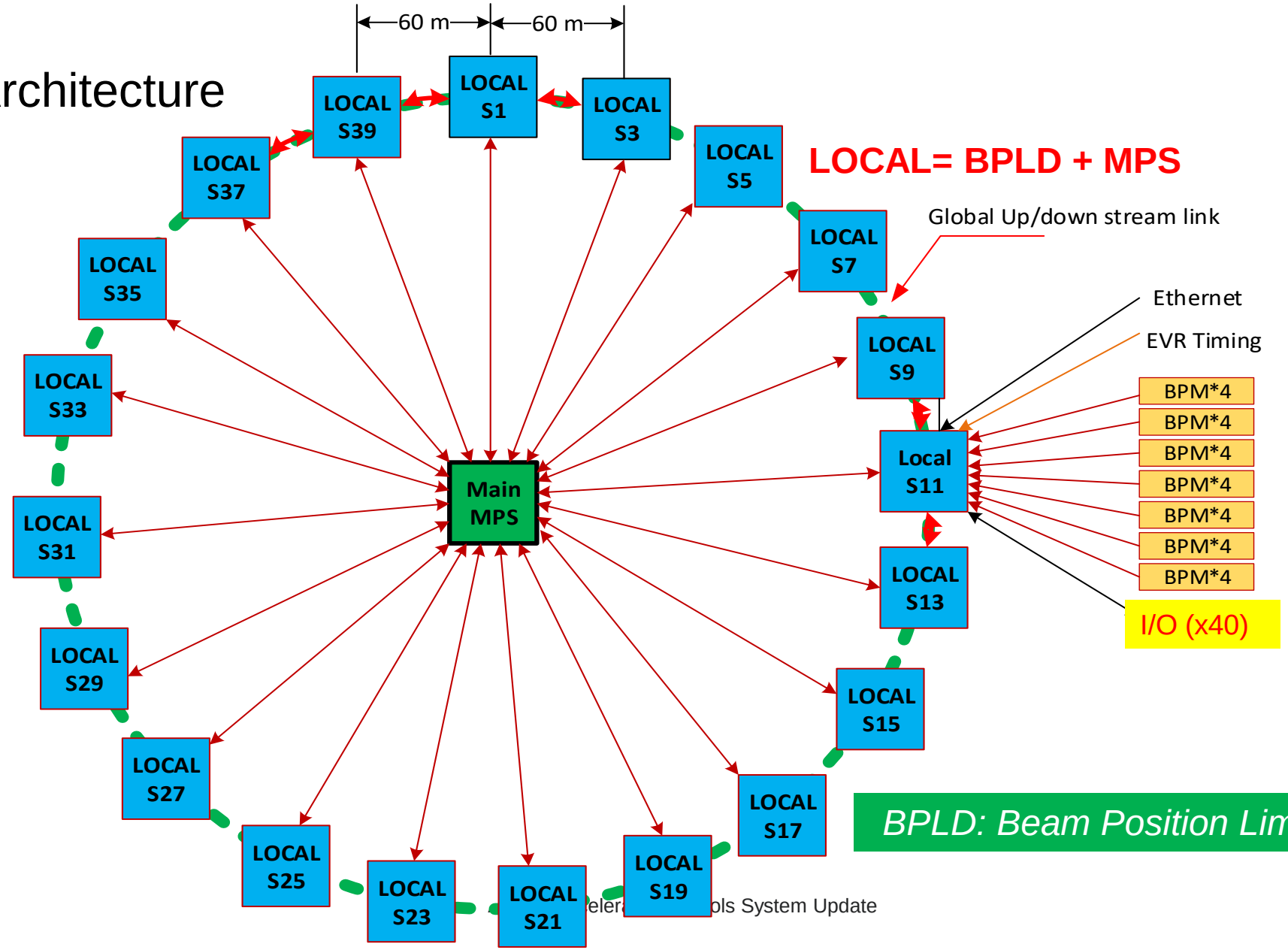
VME-FOUT-12



Testing Setup along SR Mezzanine Floor

APS-U MPS and BPLD System

- System Architecture



BPLD: Beam Position Limit Detector

APS-U MPS and BPLD System

- System Hardware

Main MPS Chassis

Local MPS/BPLD Chassis

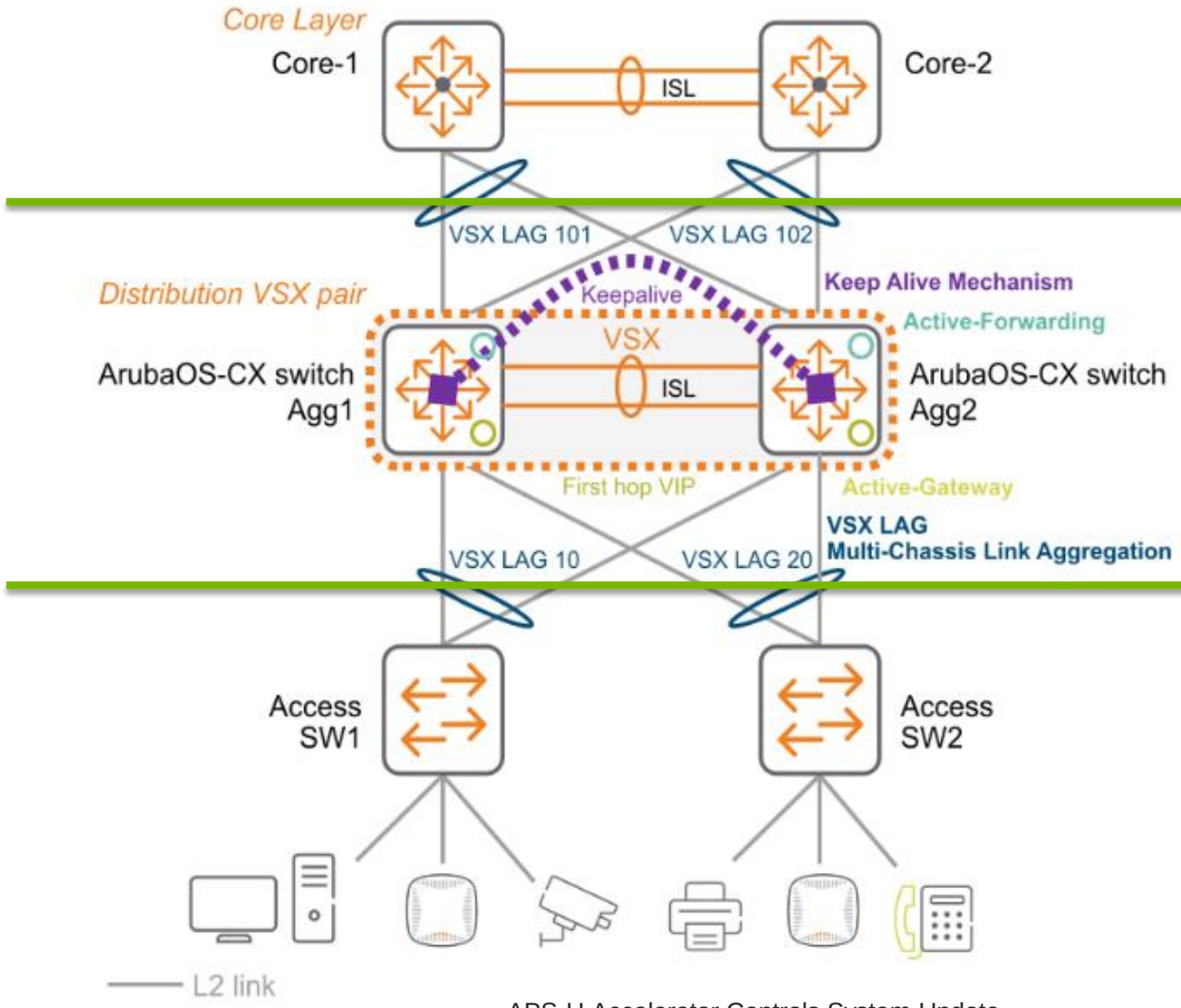
MPS Chassis Power Supply

Fully populated MPS stand under integration testing
Left to right:

- *MPS chassis rack #1,*
- *MPS chassis power supply rack,*
- *electronics rack (BPM, MRF timing, network, etc),*
- *MPS chassis rack #2*
- *MPS chassis rack #3*

APS-U Accelerator Network

- Architecture



Tier-1 to Tier-2
- 200Gbps

Tier-2 to Tier-3
- 50Gbps (2x25Gbps)

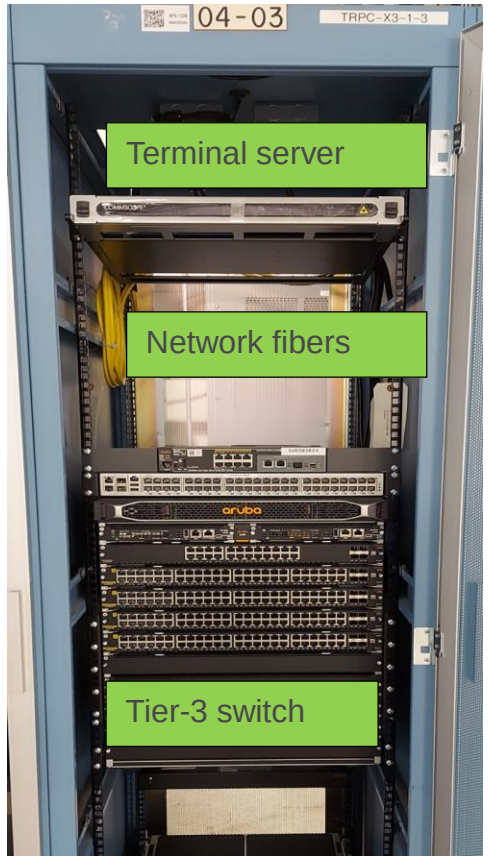
Tier-3 to electronics
- Gbps
- 10Gbps

APS-U Accelerator Network

- Network Infrastructure Status
  - APS-U network installation finished, including its fibers
  - Network subnet/VLAN (total 31 VLAN) design finished, implemented, and ready to use

Vlan Name (32 max)	Max Hosts	DHCP
MCR-Workstations	250	yes
DAQ-Servers	64	yes
MPS	250	no
Accelerator-Timing	250	no
Injection-Extraction-System	125	no
Spark-BPM-DAQ-System	250	yes
RF-BPM-Libera-Brilliance	250	yes
RF-BPM-Spark	250	yes
BSM-Motion-XBPM	250	no

Example APS-U accelerator VLAN implemented and ready



Tier-3 Network installed

Summary

- APS-U is under active construction and preparation for its dark time starting from April 2023
- Database application like CDB, Cable, as well as eTraveler system plays critical role to support the project
- EPICS7 based time-corelated DAQ system capable to stream data over pvAccess with data rate higher than 3GB/s, which is gaining more and more interesting in supporting beam commissioning and future operation
- MRF 300-series based timing system, with lots of new functions enhanced to meet APS-U needs including full functional delay compensation capability
- The MPS/BPLD system starts with a star connection topology with future extendibility to a ring structure
- A high-performance network with 31 VLAN in place to meet various needs
- Installation started in the place where suitable including network as well as rack mounted DAQ computer server