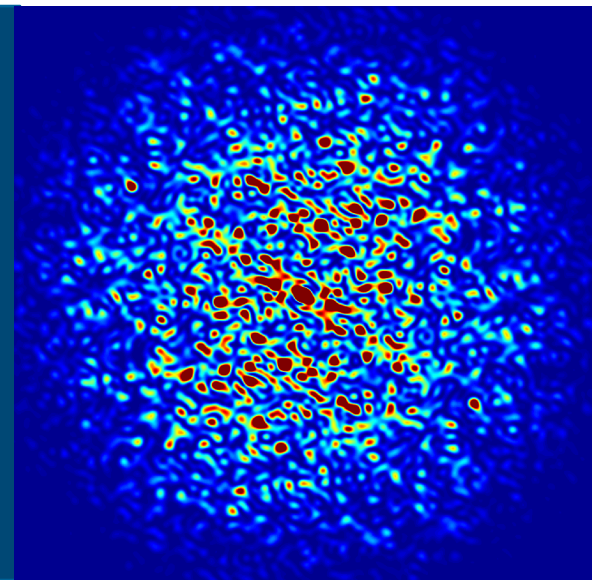


Data Acquisition System for the APS Upgrade

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ICALEPCS 2019

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APS-U Project Scope

Feature beamlines

- Suite of beamlines, including long beamlines, designed for best-in-class performance

New storage ring

- 6 GeV with 200 mA, 42 pm-rad emittance
- Hybrid 7BA lattice with reverse bends
- Improved electron and photon stability

New insertion devices

- Including superconducting undulators

New/upgraded front ends

Injector improvements

- Increase performance beyond present capability

Beamline enhancements

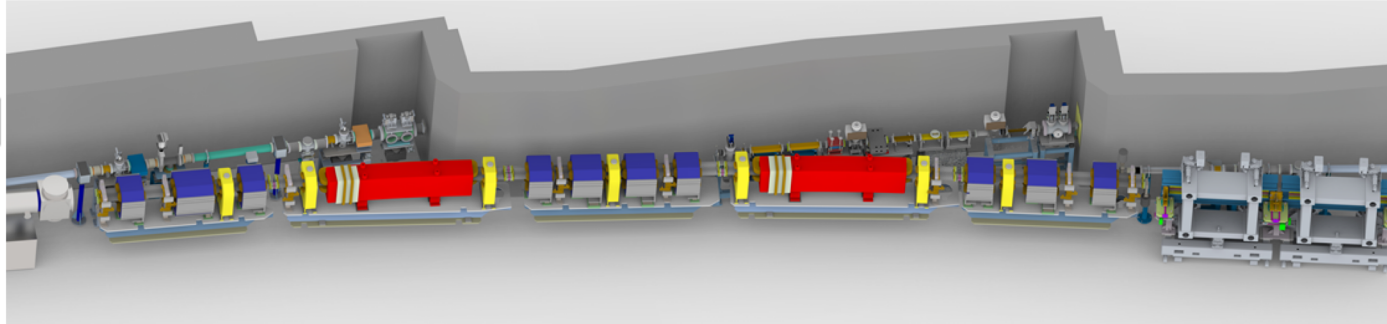
- Improvements to make beamlines "Upgrade Ready"
- Existing beamlines are planned to come back on-line after the upgrade

42 pm-rad

On-axis "swap-out" injection

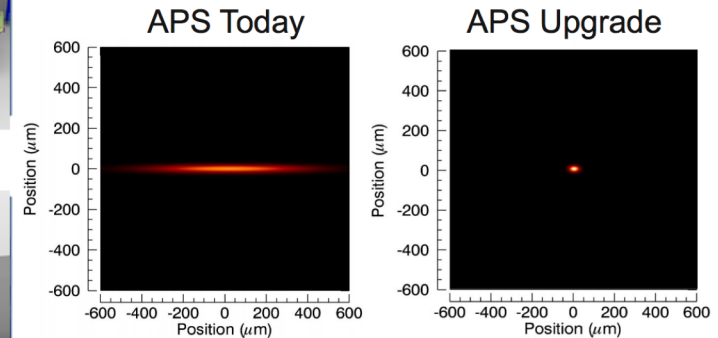
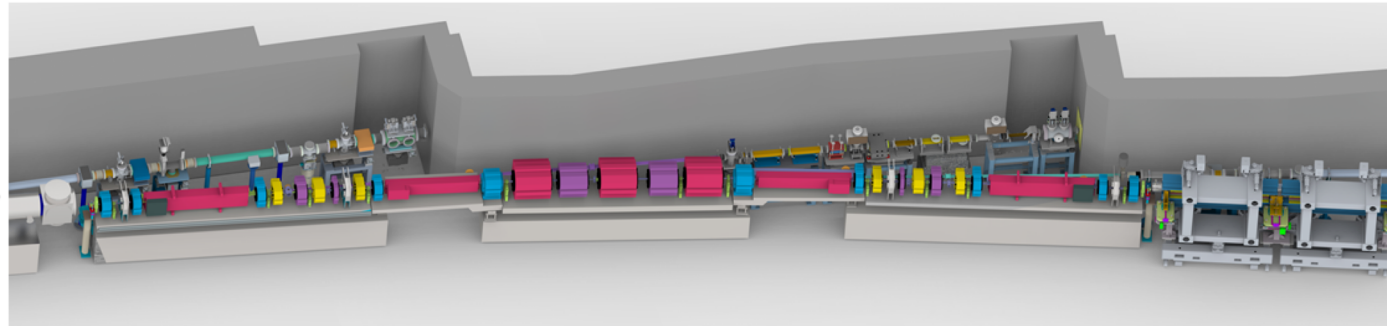
APS-U – High Brightness Storage Ring

APS double bend lattice



3000 pm-rad
emittance

~70-fold
reduction in
horizontal
emittance



42 pm-rad
emittance

APS-U 7-bend achromat lattice

Hybrid 7BA lattice with longitudinal gradient, transverse gradient and reverse bend dipoles

$$\varepsilon \propto \frac{E^2}{(N_D N_S)^3}$$

N_D = # dipoles/sector
 N_S = # sectors

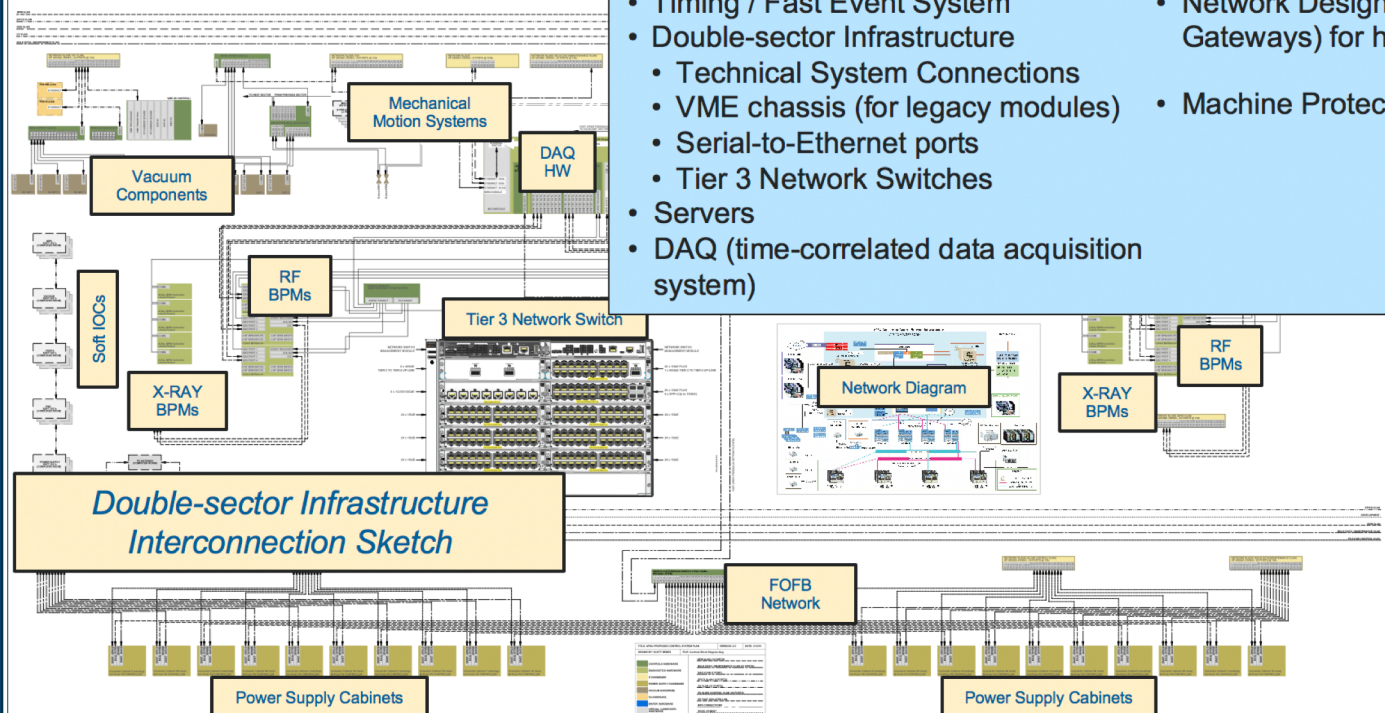
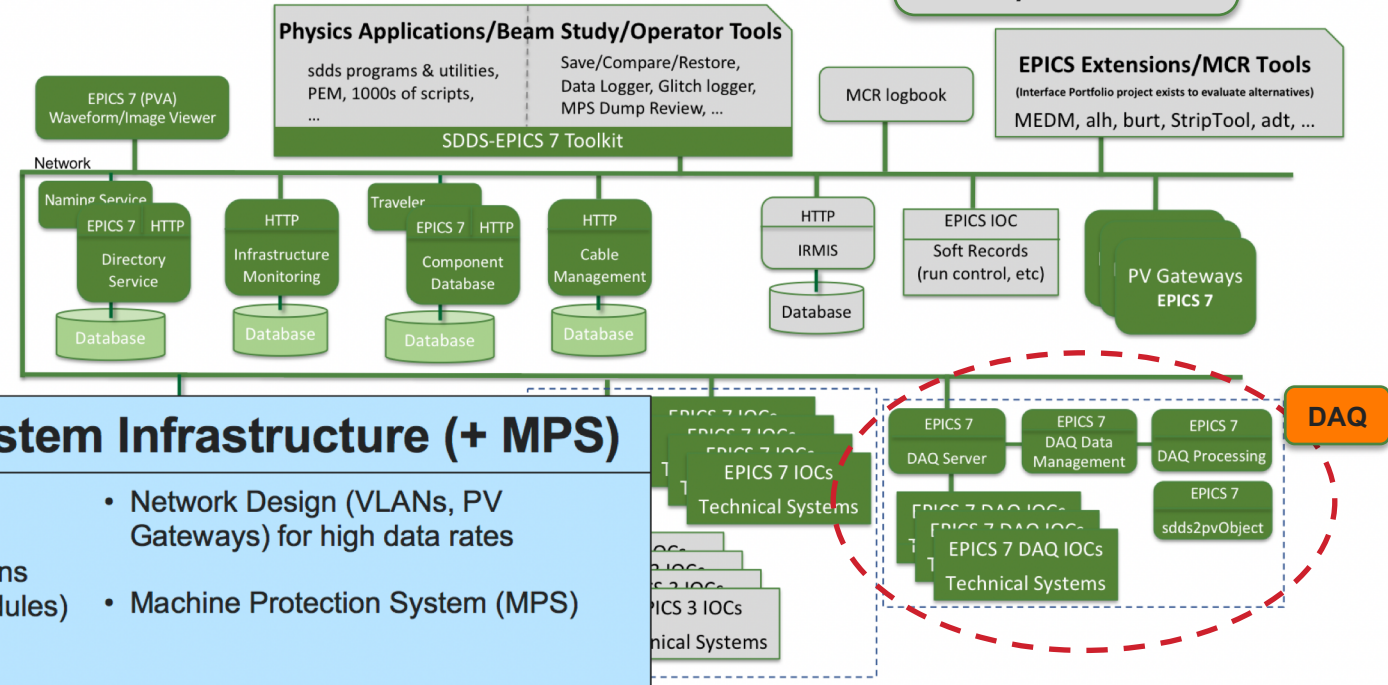
Gray items are supported/enhanced by “Operations”

<h1>APS-U Controls High Level Applications</h1>	
<ul style="list-style-type: none"> • EPICS 7 Waveform/Image Viewer • EPICS 7 <u>sdds</u>-epics toolkit enhancements • Process Variable Directory & Name Service • Infrastructure Monitoring • High Level Applications for Specific Systems (e.g. orbit, synchronous PS setpoint, post-mortem, ...) 	<p>< Project-wide Tools ></p> <ul style="list-style-type: none"> • Component Database • eTraveler • Cable Management Application
<div> <h2>APS-U Control Sy</h2> <p>Tuning / Fast Event Systems</p> </div>	

- ## APS-U Control System Infrastructure (+ MPS)

- ## 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
- 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

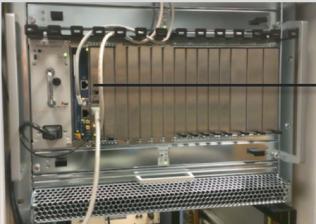


MBA Technical Subsystems – Data Rates

- Embedded IOC



- Local IOC



- Ethernet-based instrumentation / controllers



- "Soft" IOCs (no hardware coupling with technical system)



Network

Subsystem	Sample Rate [kHz]	Data Rate [MB/s]	Number of Nodes
SRRF BPM	271	99.7	20
SRXR BPM	10	0.5	20
FBC	22.6	25.8	20
BiPS	22.6	13.2	20
UniPS	22.6	32.7	20
SRRF	271	67.2	1
InjPS	0.2	1.3	1
BunCM	10	26.0	1
BunLS	2440	458.7	1

BPM TBT Data include timestamp, x/y position and sum

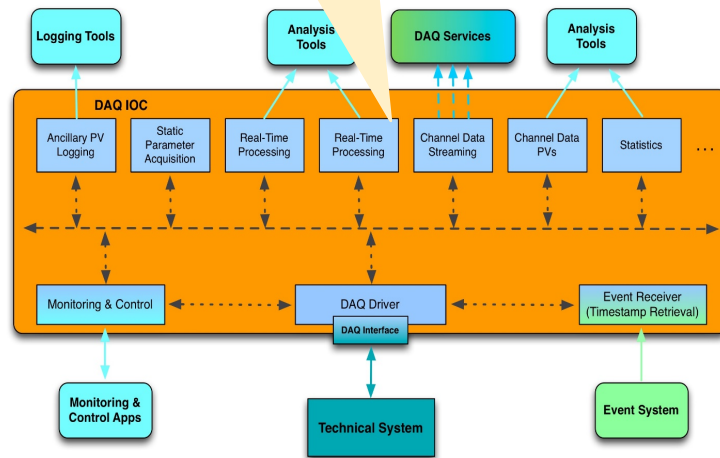
- Total double sector data output (with essential TBT signals only): **172 MB/s**
- Cumulative data rate for the entire DAQ system: **4 GB/s**
- Generated TBT data may include up to 8 additional signals per BPM (240 per double sector) => this would result in up to **260 MB/s of additional data** per double sector, or up to **5.2 GB/s of additional data** for the entire system

DAQ: Time-correlated Data Acquisition System

DAQ software represents framework and tools that enable fast data collection for controls, statistics and diagnostics of the embedded controllers utilized by the APSU MBA.

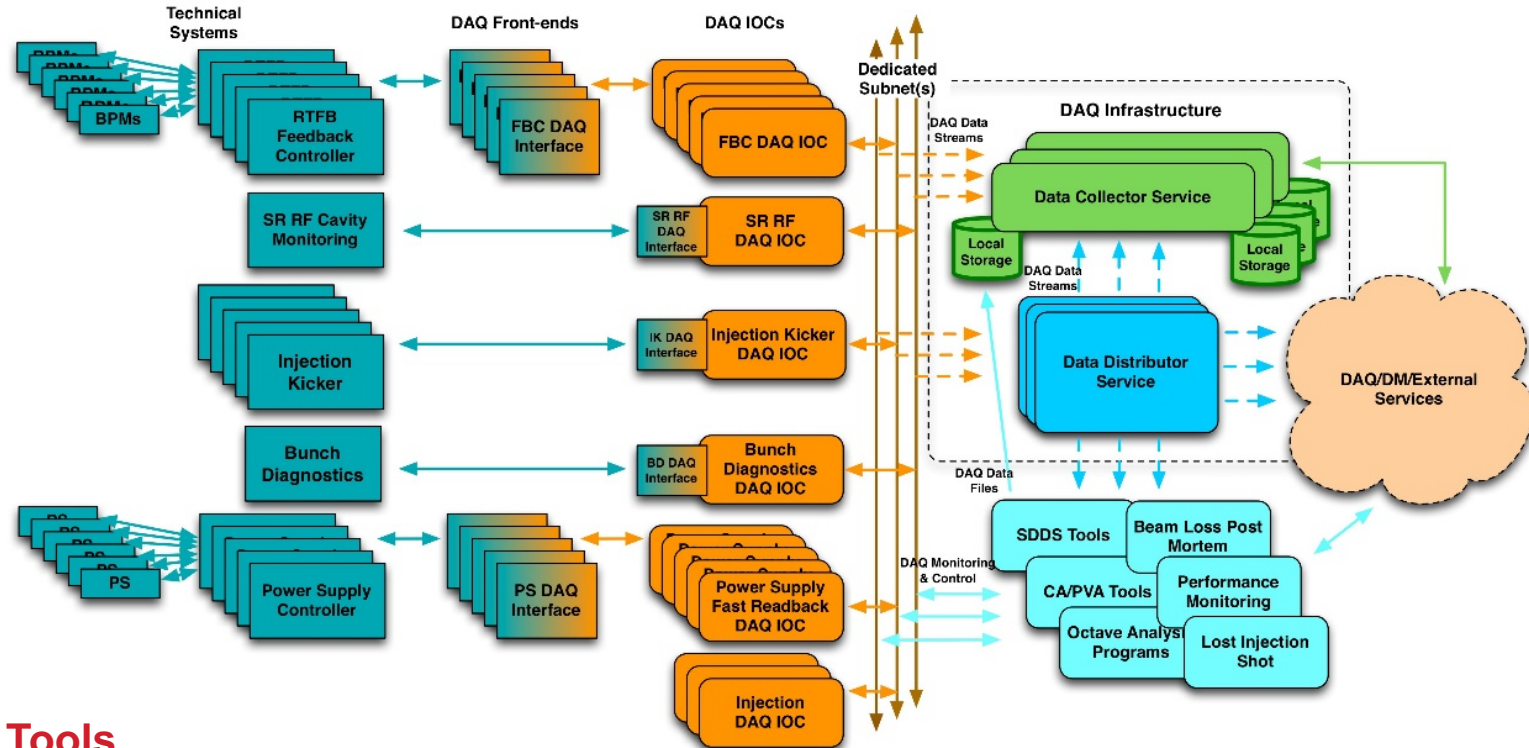
DAQ IOCs use Area Detector framework

DAQ IOC

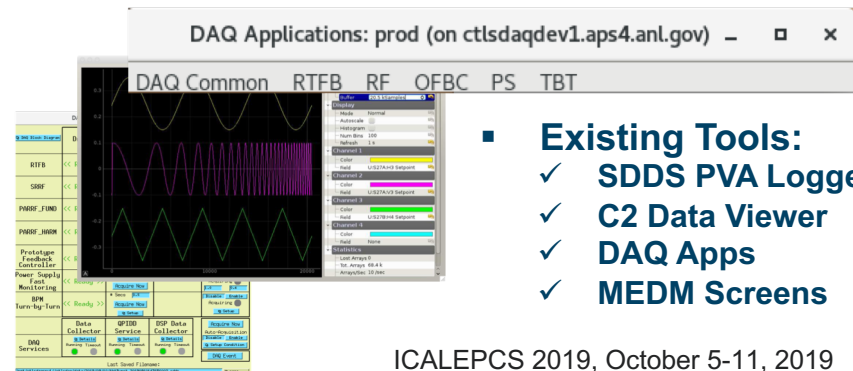


- Existing IOCs:
 - ✓ RTFB
 - ✓ PS
 - ✓ TBT
 - ✓ FBC
 - ✓ SRRF
 - ✓ PAR (Fund/Harm)

DAQ System Architecture



DAQ Tools



- Existing Tools:
 - ✓ SDDS PVA Logger
 - ✓ C2 Data Viewer
 - ✓ DAQ Apps
 - ✓ MEDM Screens

- Existing DAQ/DM Services:
 - ✓ Data Collector
 - ✓ Data Distributor (P2P GW)
 - ✓ SDDS To Data Object Service
 - ✓ AD Image Service
 - ✓ DM Services (Processing Service, Metadata Catalog,...)

DAQ Features

- Capability to acquire time-correlated data from *multiple subsystems at different sample rates*
- Support for *continuous* data acquisition
- Ability to route data to any number of applications
- Multiple signals (waveforms) can be acquired within a single DAQ IOC
- Assigns timestamp *to each acquired sample* as close as possible to the acquisition point (usually within an FPGA)
 - Turn-by-turn is the fastest requirement so far, bunch-to-bunch data would need to be handled differently
- Initial real-time processing may occur within the IOC using area-detector plugins
- Signal and timestamp arrays from a DAQ IOC are passed over the network within a single object to ensure data correlation integrity
- DAQ Objects may include:
 - “Fast Data”: signals sampled at the common rate for this IOC
 - “Slow Data”: data that does not need to be sampled at the acquisition rate but may change and is helpful to include
 - “Parameters”: static values one wants to record
- Continuously running DAQ services receive/process/save acquisition sets and also provide throttled and condensed data to users/experimenters
 - Saved acquisitions from different technical systems can be immediately plotted on the same graph using the Timestamp arrays

RTFB DAQ has ~2050 channels @ 1.6kHz

The screenshot displays the RTFB DAQ configuration interface, titled "Driver: DAQ.RTFB.DRV:". It is divided into several sections:

- Arrays to Include in Stream:** A table with columns for "Default", "X-PLANE", "Y-PLANE", and "Both". It lists various data arrays such as "BPM Pos", "P0 Pos", "CP0 Pos", "xBPM ID", "xBPM BM", "BPM StPts", "BPM Err", "Corrector SetPt", "Corrector Error", "Datapool", and "Correctors". Each array has a "No Include" button and a numerical value in parentheses.
- DAQ Acquisition:** A section with a "Keep < 64000" label and a "Driver Comment" field.
- Stream Plugin (multiple files):** A section with a "# of Seconds to Capture per File" set to 0.5, "NDarrays" set to 6, and "Files" set to 0. It also shows "Size: 2e+06 Bytes" and "to Store in File".
- TBT BPM 1 Data:** A section with a table of parameters including "Packet Id", "Va", "Vb", "Vc", "Vd", "Sum", "Q", "X", "Lmt High", "Lmt Low", "Mt High", "Mt Low", "Crc", "Status", "Res", and "Y". Each parameter has a "No Include" button and a numerical value.

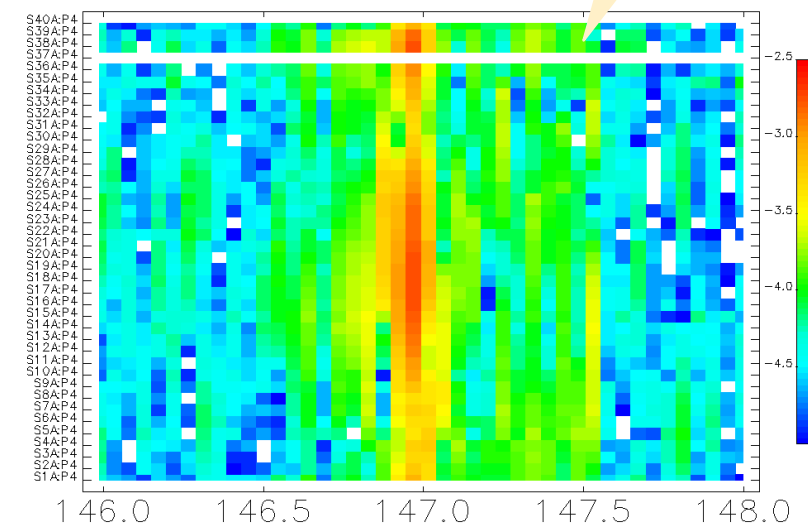
Available BPM signals for TBT DAQ

Diagnostics with DAQ (L. Emery)

Before Shimming

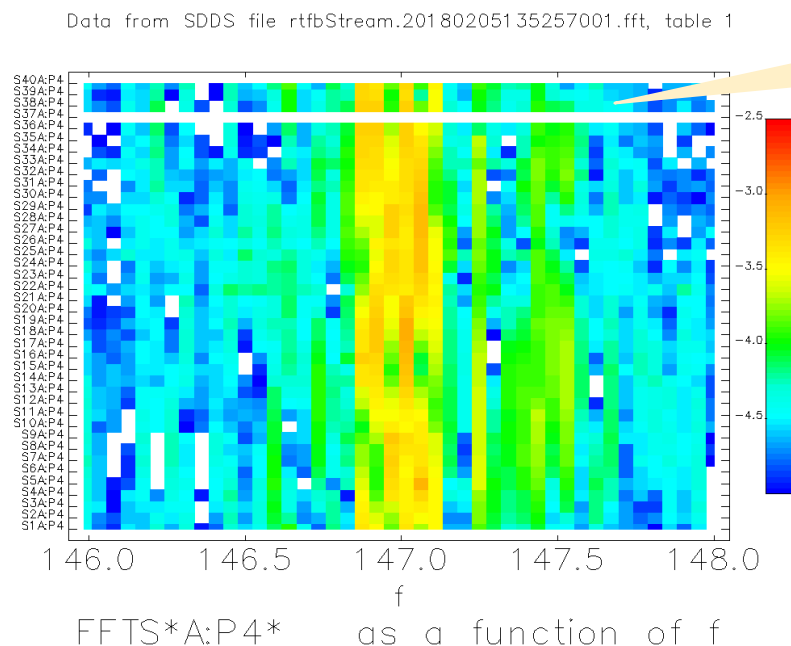
- Suppression of 147Hz vibration source in the ring using the DAQ system + post-processing with FFT
- Vacuum chamber was vibrating and introduced a Bx field
- Identification of the nearest quadrupoles required 400 channels, 20 seconds of continuous DAQ data to get 0.5Hz precision

Data from SDDS file rtfbStream.20180205093805...fft, table 1



FFTS*A:P4* as a function of f

After Shimming



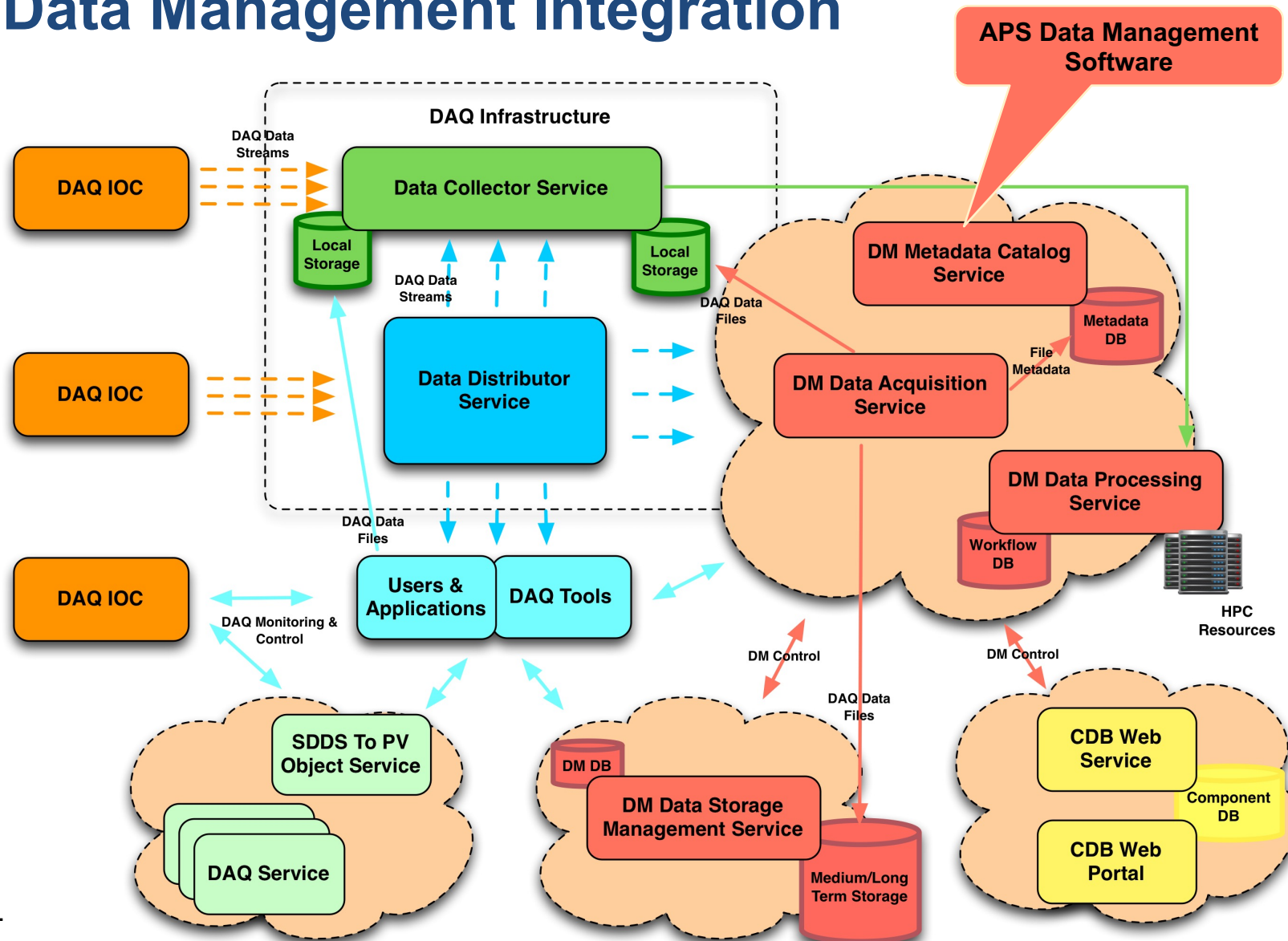
FFTS*A:P4* as a function of f

- This allowed separating line frequencies of 20 pumps
- Shims were inserted between poles and vacuum chamber (S37AQ3, S37AQ2)

DAQ/Data Management Integration

Goals

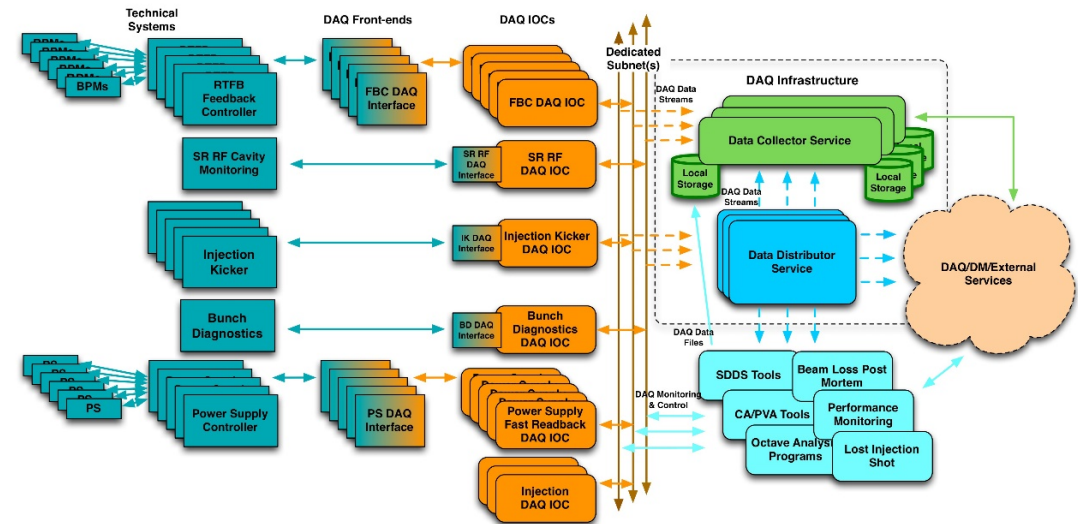
- Manage storage areas:
 - Handle data movement from local (short-term) storage to a more permanent location (medium/long-term storage)
- Enable users and applications to easily find and access data:
 - Metadata Catalog
 - Integration with CDB
- Facilitate data processing and analysis:
 - Real-time (or near real-time) processing of DAQ data using automated workflows
 - User-initiated processing and analysis of data: e.g., request a dataset that satisfies certain criteria, and submit processing job for a user-specified workflow or analysis script



Summary

DAQ: Time-correlated Data Acquisition System

- Acquires data from multiple systems at different sample rates
- Supports continuous data acquisition
- Multiple signals (waveforms) can be acquired within a single DAQ IOC
- Deployed services and IOCs for several technical subsystems during R&D phase
- System has been used extensively for machine studies, diagnostics and troubleshooting



Plans

- Adding missing features
 - Support for event-driven acquisition
- New IOC Development
 - Injection Kicker IOC
 - Bunch Lengthening System IOCs
- Existing IOC Enhancements
 - FBC DSP Apps
 - TBT IOC
- New services
 - Data Correlation and Alignment Service
 - Orbit Service
- New tools, applications
- Production deployment (Conda/Sumo)