Evolution of the FLASH DAQ System

Motivation, Concepts, Evolution and Experiences

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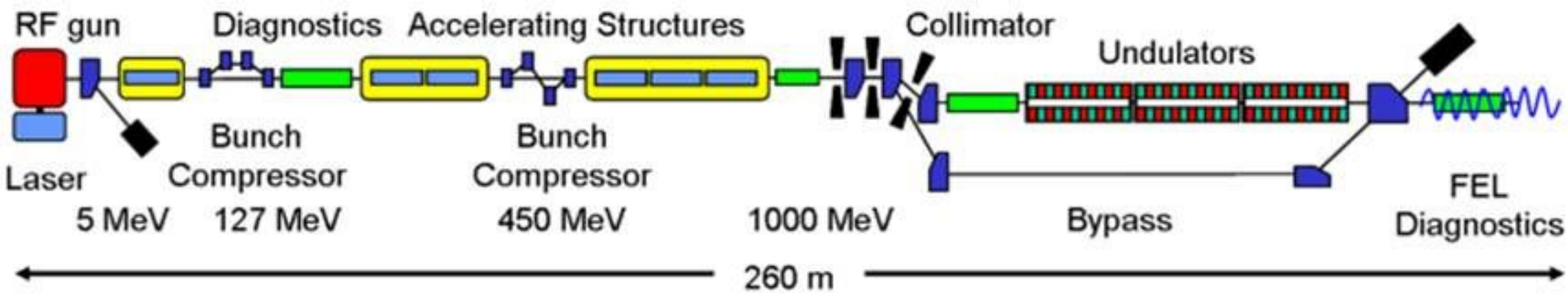
HELMHOLTZ ASSOCIATION

DESY

Free-Electron Laser at Hamburg (FLASH)

- Successor to TESLA Test Facility (TTF).
- User facility for photon science community providing a pulsed light source in the extreme ultraviolet and soft X-ray regime since 2005.
- Test bed for exploring and testing new superconducting accelerator technologies for the European XFEL and ILC.
- Currently being upgraded to sFLASH – restart mid next year.



Electron Energy: 0.4 … 1 GeV
Photon wavelength: 6 … 32 nm
Bunch charge: 1 … 3 nC

Bunch repetition rate: 5 ... 10 Hz
Bunch frequency: 1 … 3 MHz
Bunch train length: 800 µs

Motivation

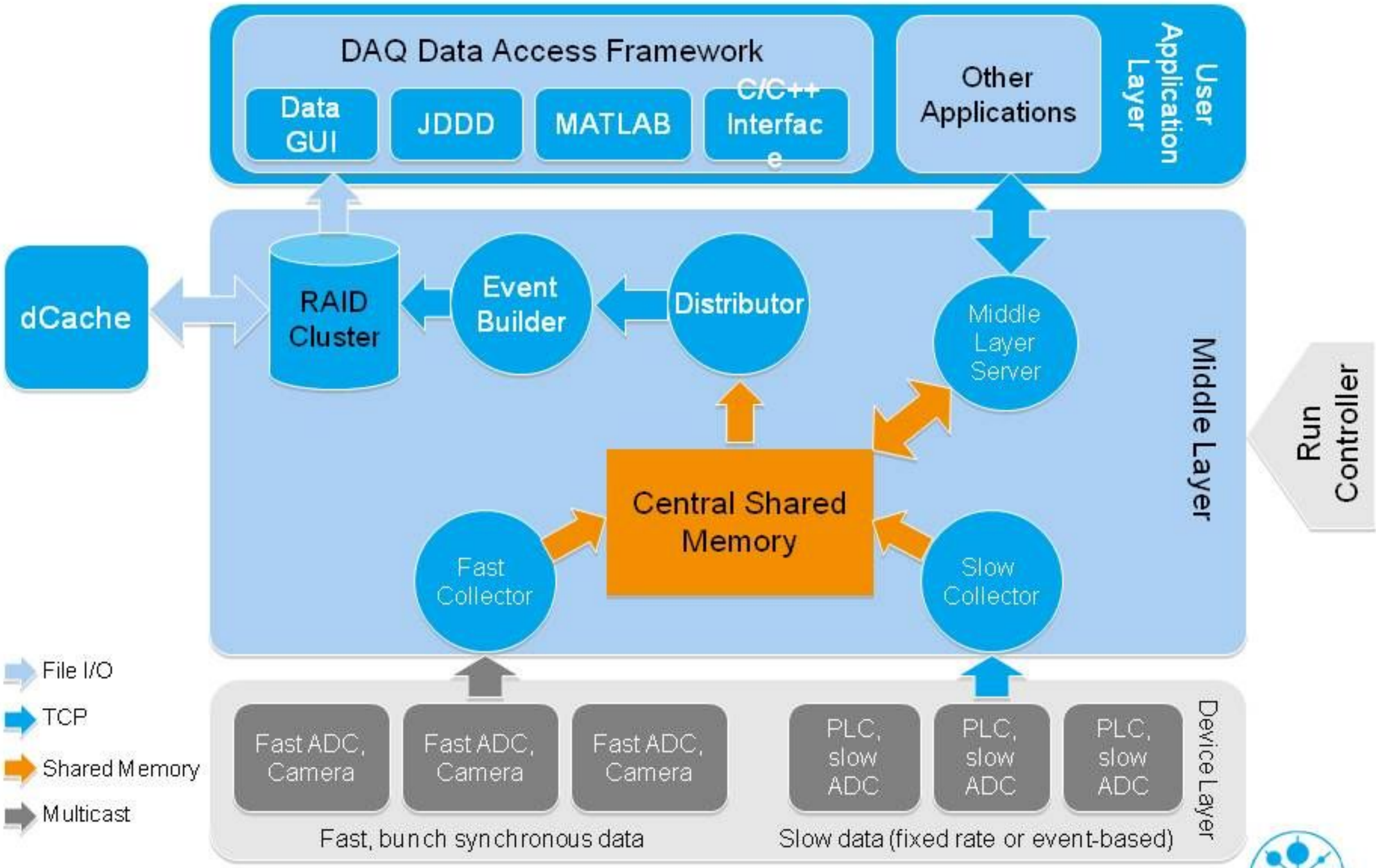
Two-fold operation and usage requires a versatile control system.

- Integrate a DAQ into DOOCS-based control system to support both operation modes.
- Store all relevant information needed for operations, R&D work and photon beam experiments.
- Combine accelerator and experiment information to enable data analysis across machine and experiment.
- Handle large number of accelerator control and diagnostic devices.
- Allow for frequent modifications of controls, diagnostics and user experiments.
- Provide tools for online and offline data access and processing.

Basic Concepts

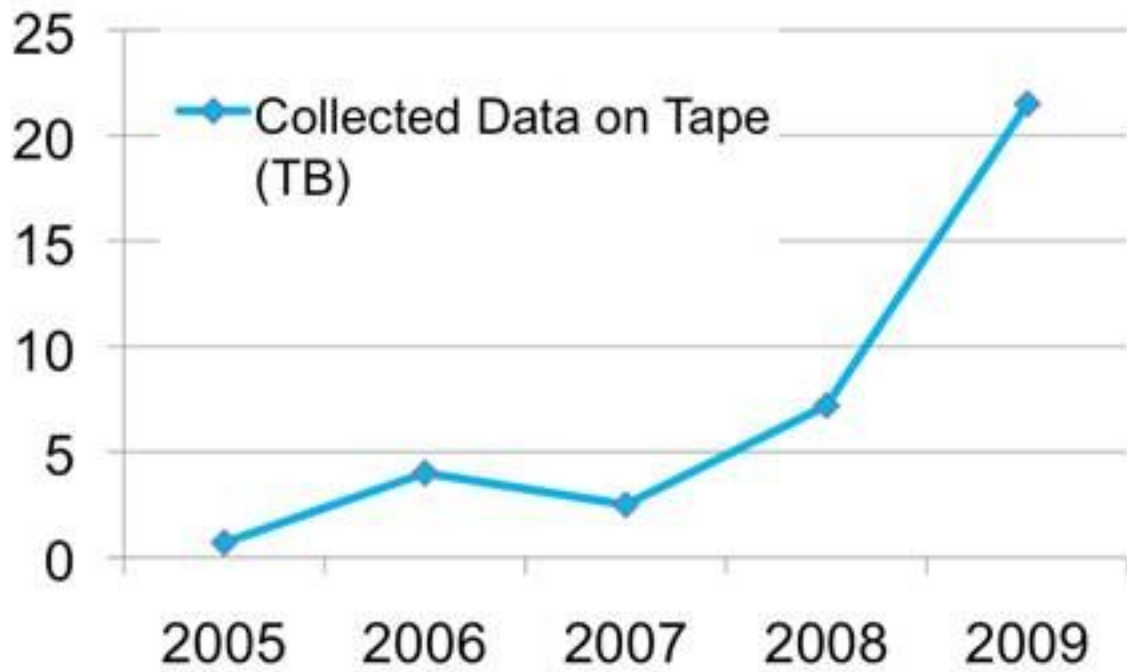
- **Fast, bunch-synchronous data collected from ADCs via multicast.**
  - *Slow data* is retrieved separately from slowly varying sources with fixed update rates.
- **Bunch-synchronized event identification for all data.**
  - Timing system distributes bunch-synchronous event number matching macro pulse or shot.
- **Centralized shared memory stores all synchronized data.**
  - A buffer manager using up to 32 Gbyte of shared memory keeps short history of synchronized data for assembling the full event record.
  - *Middle layer servers* have full read and write access to the shared memory.
- **Scalable and extensible architecture.**
  - Distributed, concurrently running DAQ instances.
  - *Streams* for separating raw data by device group or experiment.
  - HEP-style *run control* and *configuration database* for tagging specific machine or experiment setups.

Basic Concepts - Data Flow



Evolution – Hardware and Data

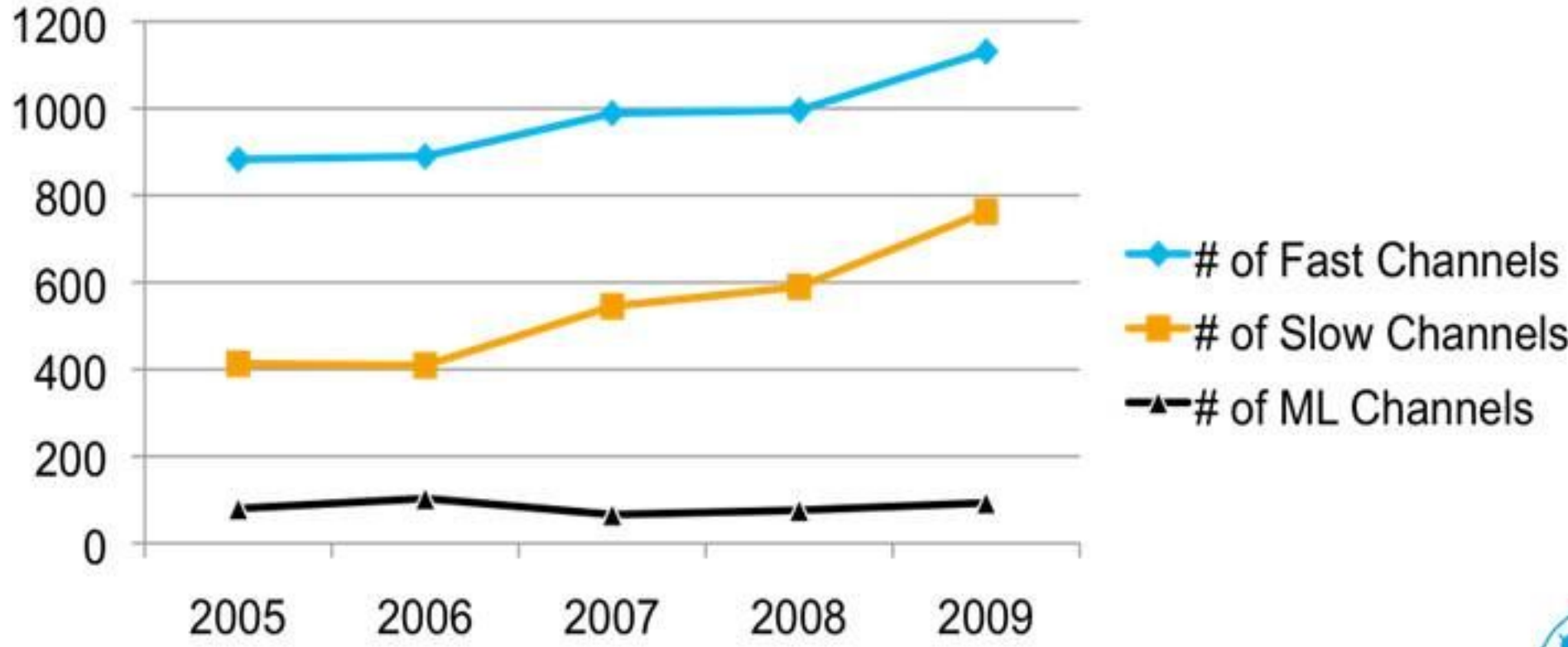
- FLASH is operating since August 2005.
  - Basic DAQ implementation was present and running on day 1.
  - Upgraded DAQ server cluster – now two work horses (Sun E 2900 and M 4000 – each 32 Gbyte shared memory) and two Sun storage nodes (RAID 20 TB + 40 TB).
- DAQ produces on average 1 Tbyte/day
  - Most accelerator data not taped but kept for 2 – 4 weeks on disk (migration).
  - Photon diagnostics, experiment and R&D data kept on disk and taped (dCache).
  - Rate OK right now – might require filtering and dedicated run configuration in future.



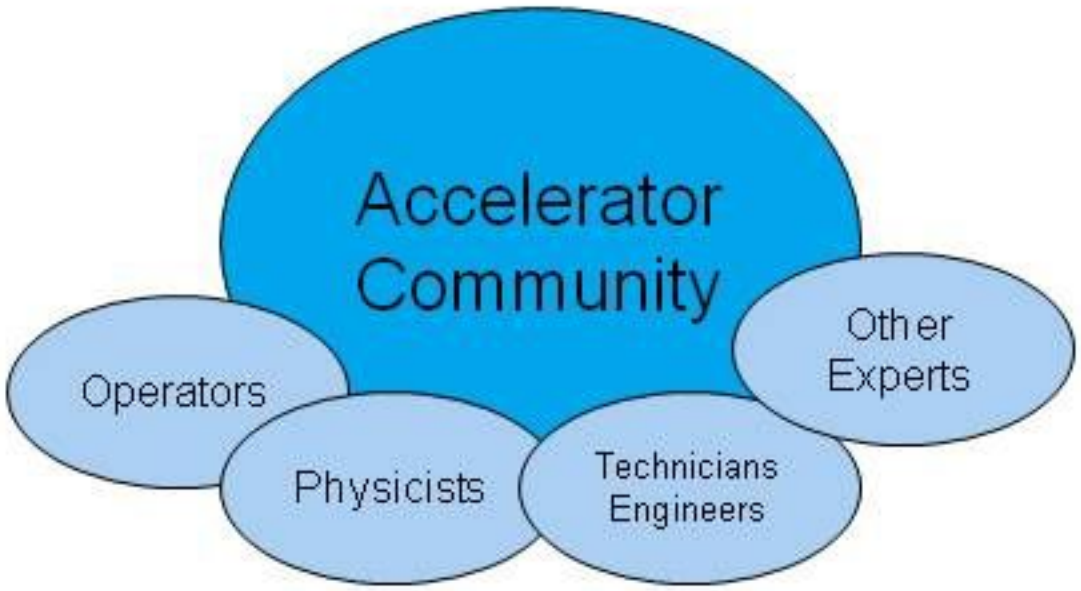
Evolution - Scalability

> Scalability and Extensibility

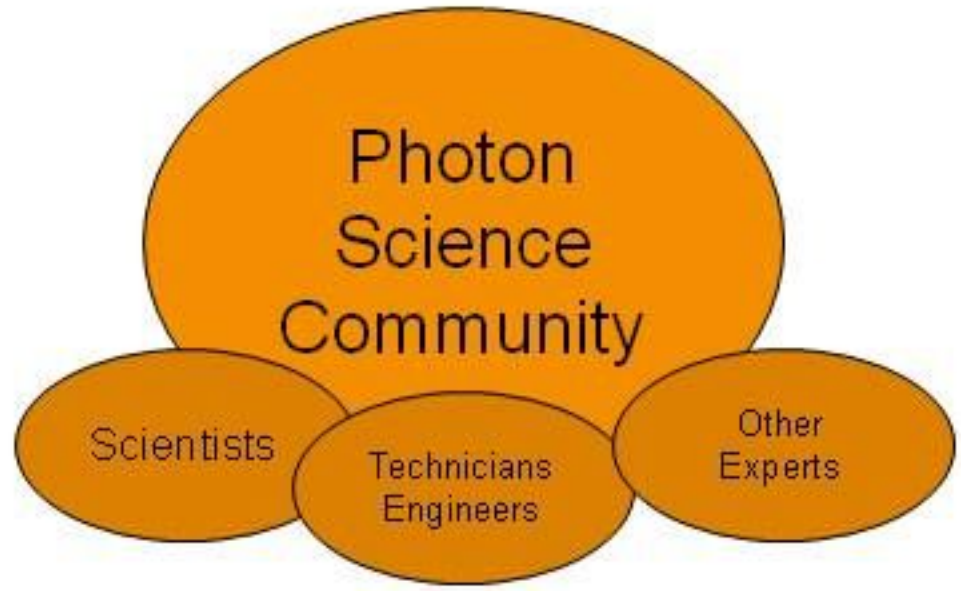
- Relatively simple to add another complete DAQ instance: script for cloning DAQ instance, then add run control configuration with Java-based GUI and adjust.
- Instances share memory, I/O and CPU resources otherwise completely separated.
- Four concurrently DAQ instances are running, seven are ready to run.
- Easy to include new (supported) devices or individual channels via run control configuration database.



Experiences – Tools = Acceptance?



- Interested, not yet explored full DAQ potential.
- ILC R&D utilized complete DAQ in '09.
- Want ready-to-go applications or known framework for writing some (MATLAB).



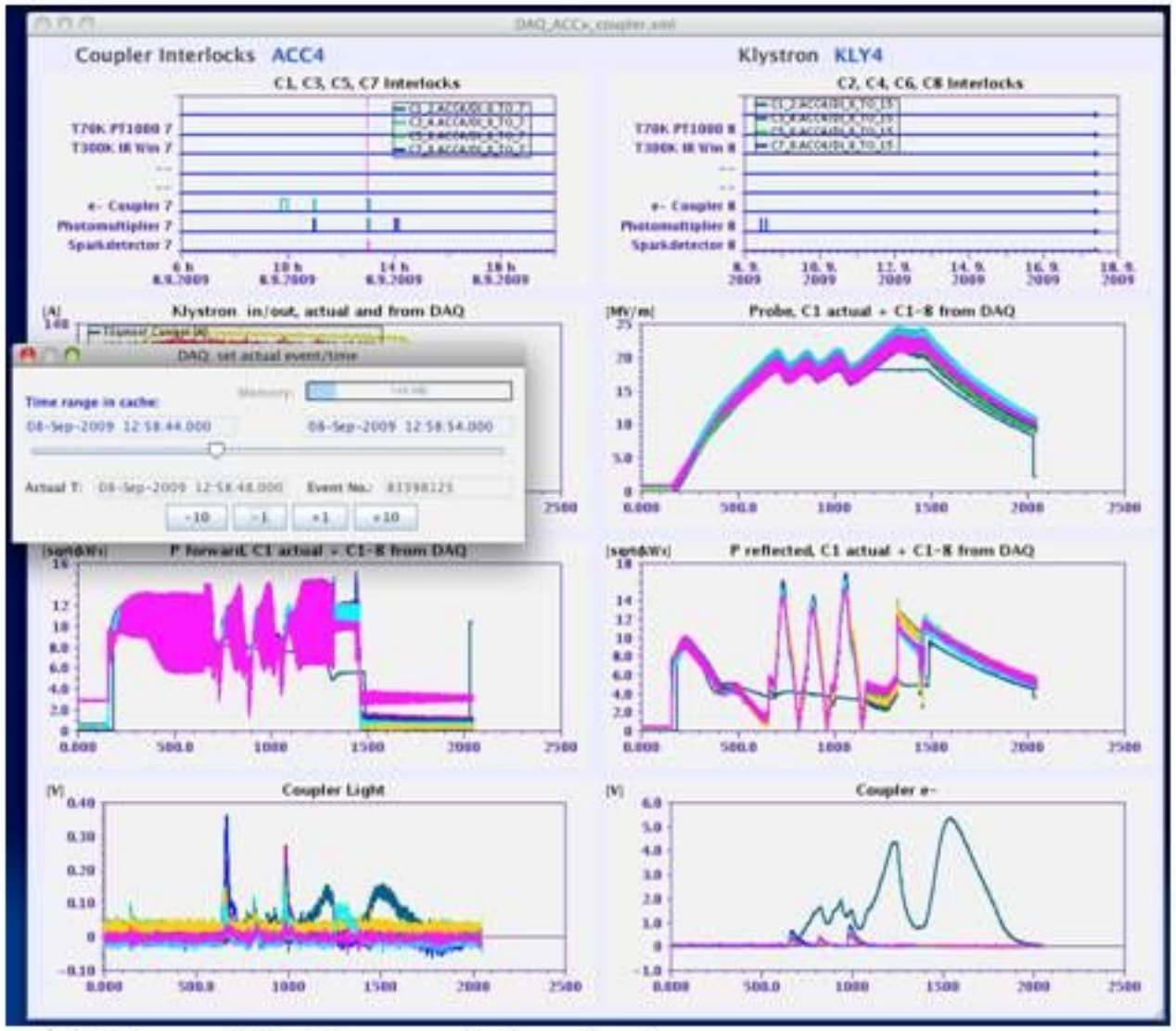
- Interested from the beginning using it.
- Work habits and culture matches more HEP-style design of DAQ.
- Could make use of initial ROOT-based tools.

- Started with ROOT-based applications. Lacked I/O performance.
- Now more Java-based tools using own I/O-interface. Better performance.
- Added and enhanced MATLAB support.

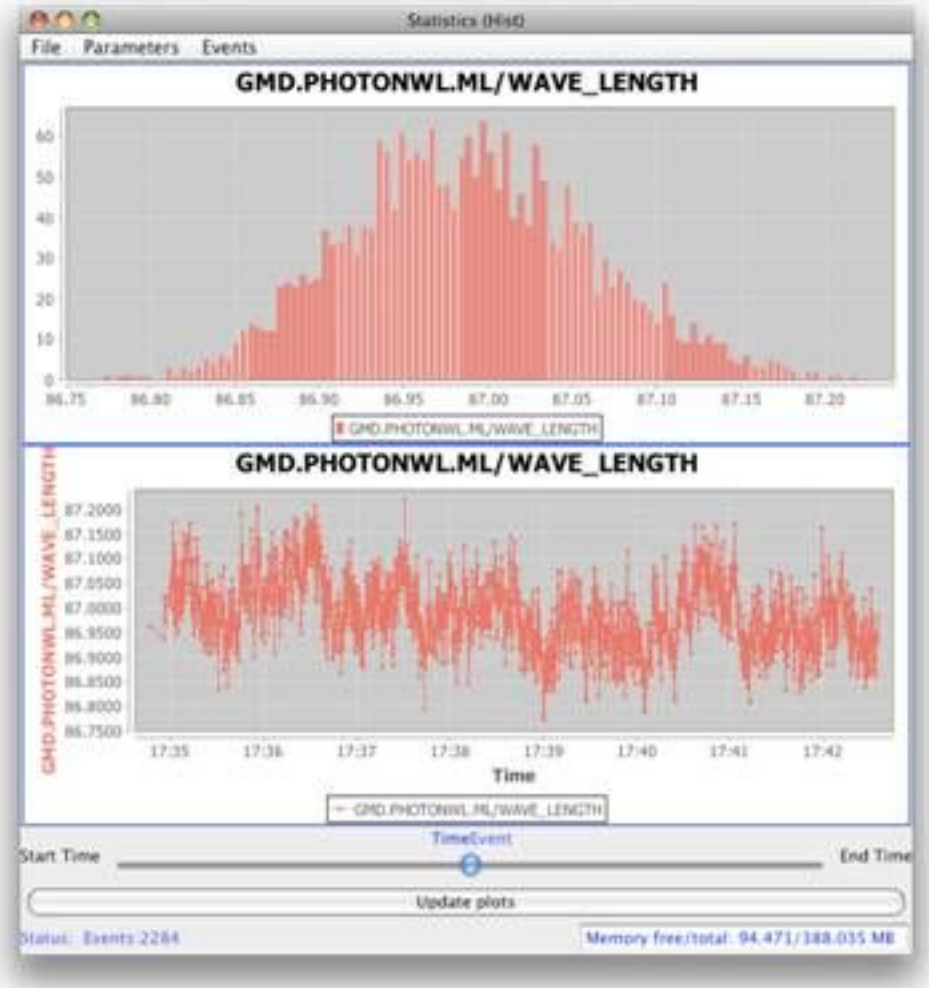
Experience - Tools

> Data Retrieval – Browsing large amounts of data

- Streams and run configuration helped dealing with Tbytes of data.
- Data server cluster provides access to all data on disk via TCP. Interfaces to MATLAB, JDDD, Java-based browser and C/C++ library. Used a lot by users.



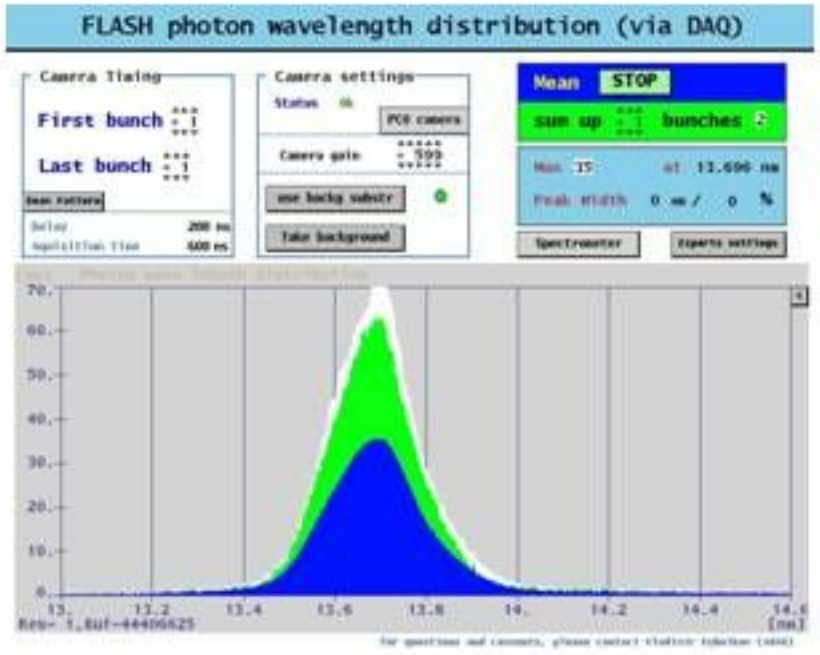
JDDD panel for RF coupler interlocks



FLASH Java-based DAQ GUI

Experiences – File Format

- File Format
  - Initially based on ROOT: good compression (GZIP), highly flexible C++ analysis framework in HEP-style. But poor performance with tree-based layout. No threading for event writer processes running at 8 Mbytes/s maximum.
  - Looked at other solutions, ended up with own, ZLIB-based implementation. Performance much better, multithreaded, writing at ~58 Mbytes/s via NFS, reading an event takes 200 – 700 µs, files are available after 1 – 2 min.
- Middle layer servers became essential for operation over time.
  - Uses MATLAB or C/C++ for computations with access to full data in shared memory.
  - Sufficient response time for many operational tasks and some automation purposes.



Examples: Energy measurement, photon wavelength and energy measurement, gas monitor detector server, LLRF server, orbit server, quench detection server, …

Added new DOOCS data classes for direct shared memory access, currently being tested for faster performance.

Conclusions

- Powerful concept and proven architecture in general.
- Reliably running since 2005 for accelerator and photon science community and its experiments.
- Recording accelerator data continuously and providing middle layer server for operations. DAQ is crucial now for FLASH operations.
- Basic concepts seem to be right, though data storage and applications need more evaluation and experience. Essential for future projects (European XFEL).
- Used with great success for ILC R&D work in 2008 and 2009 (high beam current run at up to 3 MHz bunch frequency) – about 18 Tbyte of recorded data.