Jlab12 Scientific Computing: present and future

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Workshop Commissione Calcolo e Reti

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Jefferson Lab

- Located in Newport News (VA)
- In operation since 1997
- Hosts the Continuous Electron Accelerator Facility (CEBAF):
  - superconducting electron accelerator
  - presently being upgraded from 6 to 12 GeV
  - 4 experimental Halls (A,B,C,D) and a Free-Electron-Laser facility

- Physics Mission:
  - nuclear and hadronic structure
  - hadron spectroscopy
  - standard model tests
  - search for dark matter
- User and Staff: about 700 employees and 1300 users from several countries

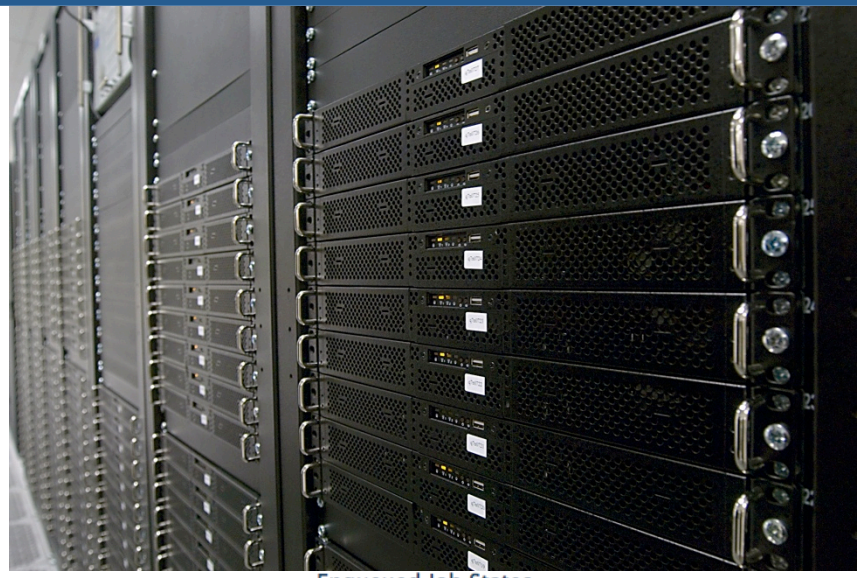
Jlab12: the Italian collaboration at JLab

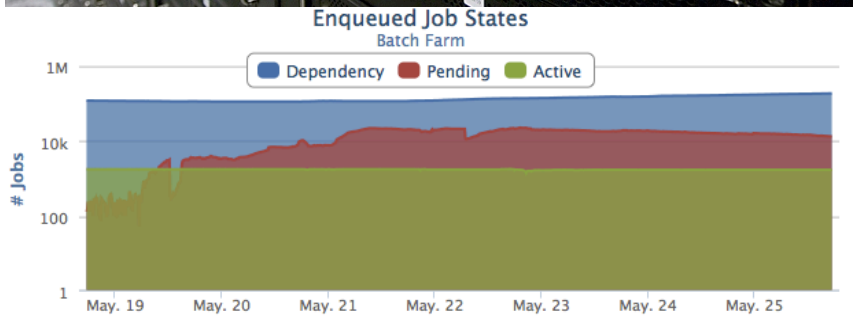
- The Italian Collaboration presently includes 80 scientists, among experimentalists and theorists, from 18 INFN Units and National Laboratories.
- Main physics interests:
  - Structure of the nucleon
  - Hadrons in cold nuclear matter
  - Hadron Spectroscopy
  - Low-energy tests of the standard model and fundamental symmetries
  - Dark matter searches
- Involved in Hall A and B research programs
- Close collaboration of Italian theorists with Jlab Theory Group

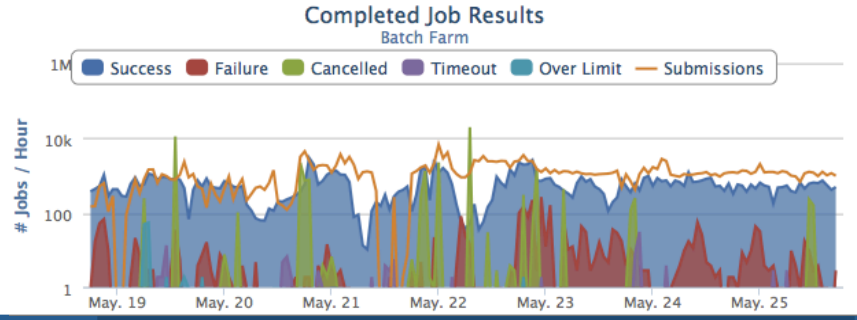
Scientific Computing at JLab

- Support for online and offline computing, providing resources for data storage and processing
- Resources presently available:
  - High Performance Computing (HPC) for LQCD, ~10,750 cores, ~700 GPUs, and 64 Xeon Phi cards
  - Batch Computing for Experimental Physics (the "farm"), ~1400 cores
  - Multiple Disk Systems (online storage), ~1.3 Petabytes
  - The Tape Library for offline storage, 10 Petabytes
  - Interactive nodes, a wide area gateway node, and several system administration support nodes
- Strong increase of storage (+5PB/y) and farm (x10) in the next 4 years to cope with 12 GeV upgrade demand
- Guidelines for experimental collaborations:
  - Common raw data format to all experiments: EVIO
  - Multi-threading encouraged: 1 job/node instead 1 job/core
  - Collaborations free to define software frameworks compatibly with available resources
- Jlab resources accessible by users for physics analysis and simulations with limitations: use of external resources is crucial for completion of physics program

https://scicomp.jlab.org







Jlab12 computing models

Different computing models were/are being developed, depending on the experimental equipment and experiment size (computing needs and number of users)

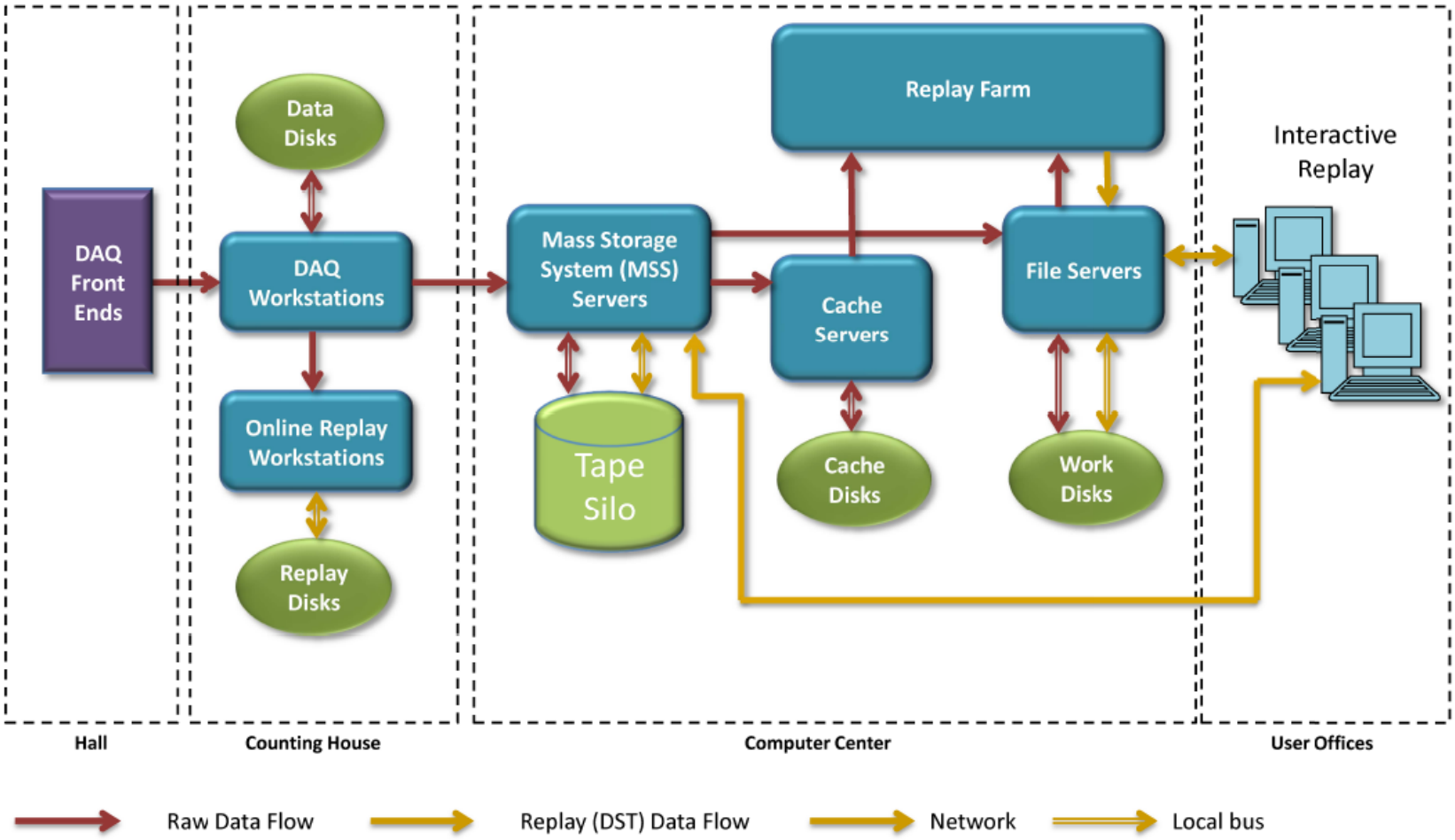
Hall A:

- Experiment configuration undergoes major changes depending on the specific physics goal with run periods of the order of weeks/months managed by independent collaborations
- Experiment typically employs base equipment (e.g. HRSs, targets) in varying configurations and add-on equipment
- Highly modular software to handle the varying configuration
- Software for add-on equipment usually provided by users (members of the experiment's collaboration)

Hall B:

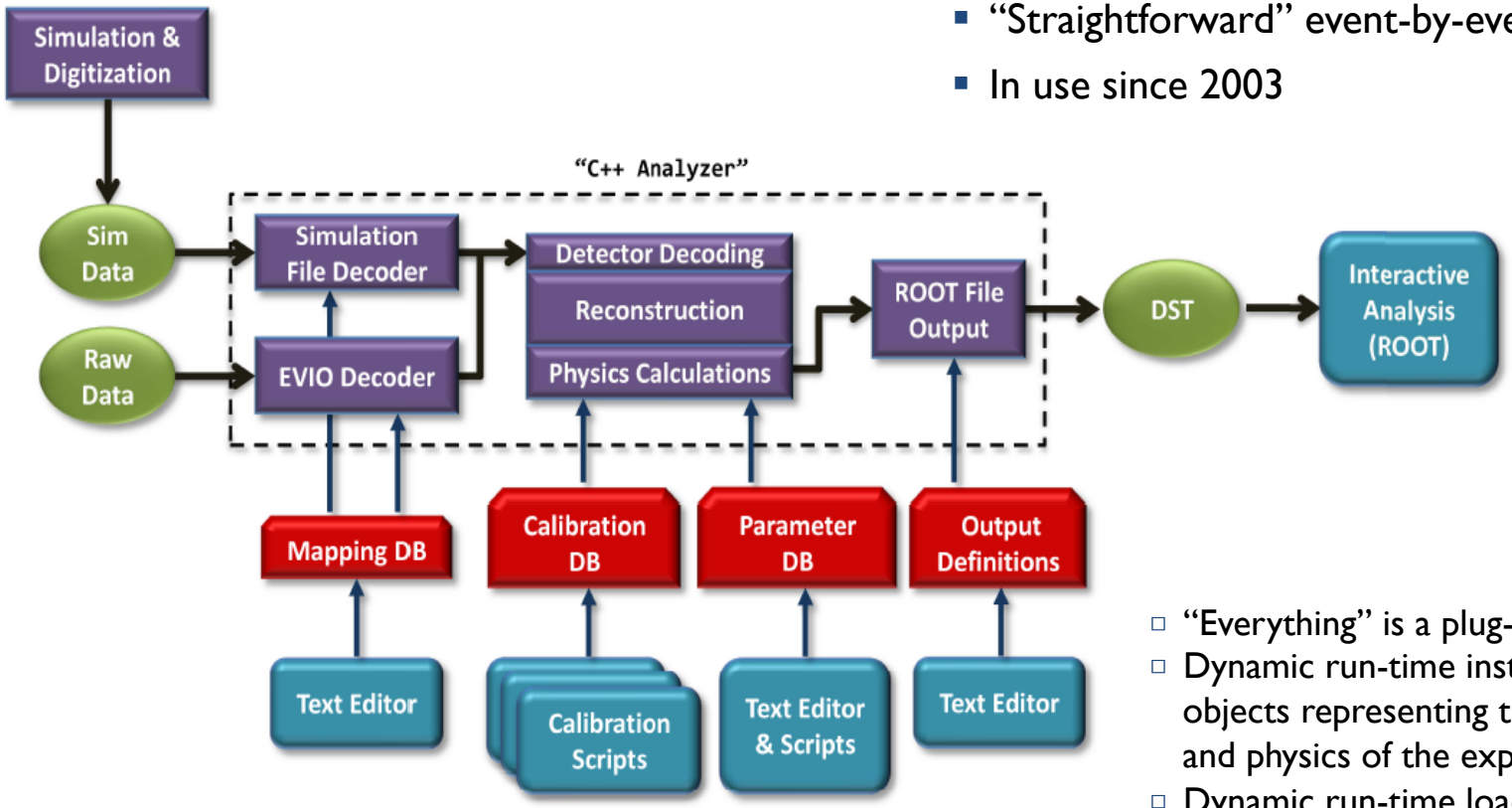
- Permanently hosting the CLAS12 spectrometer managed by the CLAS Collaboration
  - Spectrometer based on toroid and solenoid superconducting magnets
  - 100 MB/s of raw data to tape
  - 200 collaborators
  - Will use 50% of the JLAB computing resources starting from 2016
- Hosts also medium-short experiments that use different equipment: Heavy Photo Search Experiment (HPS)
- Shared electronics and online but independent software frameworks

Hall A: data flow



Hall A: reconstruction software

- Highly modular C++/ROOT-based framework
- "Straightforward" event-by-event replay
- In use since 2003



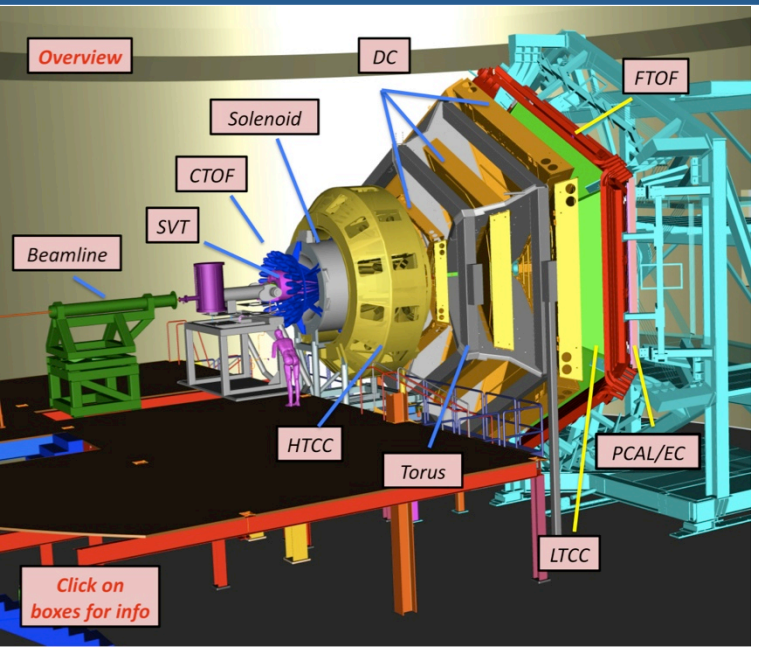
- "Everything" is a plug-in
- Dynamic run-time instantiation of objects representing the configuration and physics of the experiment
- Dynamic run-time loading of external module libraries
- Software Development Kit (SDK) available
- Supported on Linux, Mac OS X, Solaris, 32 and 64 bit

The Heavy Photon Search Experiment

- Search for a vector boson, or dark photon, coupled to the dark matter sector
- Dedicated experimental setup involving a E.M. calorimeter and silicon vertex tracker

- Simulation and reconstruction developed over several years at SLAC for ILC design and benchmarking
- Suite of software tools is fully supported by SLAC and compatible with Windows, Linux and OS X environments
- Consists of five main components:
  - **hps-detectors**: XML geometry and detector description files
  - **GeomConverter**: Java-based package which converts xml detector descriptions into suitable input for SLIC, the simulation package
  - **SLIC**: GEANT4-based event generation and simulation package, written in C++
  - **org.lcsim**: collective name for utilities and code supporting analysis and reconstruction. Several elements in common with ILC software, including freehep and LCIO, with HPS-specific code referred to as **hps-java**
  - **JAS3** analysis tool
- Estimated computing needs: 2.5 M CPU-hours on 2.4 GHz cores (80% for simulations)

CLAS12



CEBAF Large Acceptance Spectrometer at 12 GeV:

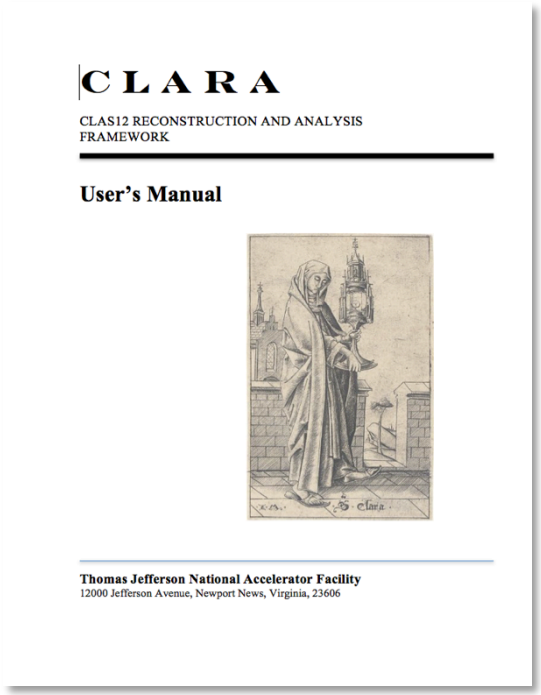
- Based on toroid and solenoid magnets
- Start of production running in 2016
- 110000 readout channels
- 10 kHz event/rate, 10 kByte/event
- 2-3 PB/year of data
- ~12000 cores for raw data processing and simulations
- The major "consumer" of computing resources at Jlab

CLAS12 Software Framework:

- CLAS12 Reconstruction & Analysis framework (CLARA), cloud computing framework based on a service oriented architecture
- GEANT Monte Carlo (GEMC): object oriented design, parameters (geometry, fields, material, ...) defined in databases (MYSQL, TXT, GDML, C++ plugins)
- Cloud Offline Analysis Tool (COAT): data management and file tagging system
- Common tools: evio I/O, histogramming, geometry DB, calibration DB

CLARA

- Cloud computing framework based SOA architecture
- Major software components for data processing as services (SaaS), components can be rearranged to create new application
- Multilingual support, services can be written in C++, Java and Python
- Data (storage and persistency) as a services (IaaS)
  - On-demand data processing
  - Location independent resource pooling
- Supports both traditional and cloud computing models
  - Single process as well as distributed application design modes
  - Centralized batch processing
  - Distributed cloud processing
- Utilization of multicore processor systems: built in Multi-threading of a user service, requires thread safety of a service code
- Ability to expand computing power with minimal capital expenditure
  - Highly dynamic system
  - Utilization of IT resources of collaborating Universities
  - Take advantage of available commercial computing resources


CLARA

CLAS12 RECONSTRUCTION AND ANALYSIS FRAMEWORK

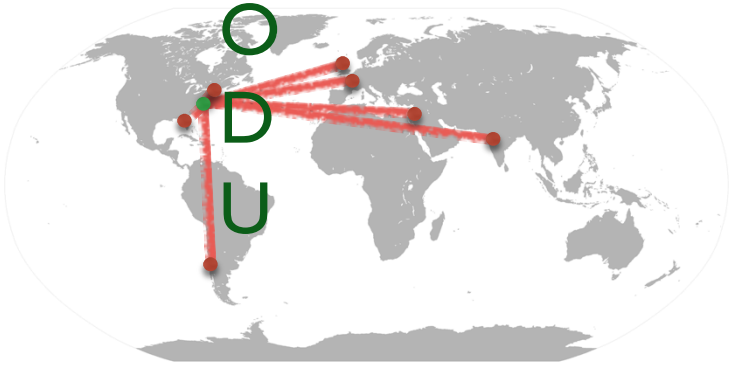
User's Manual

Thomas Jefferson National Accelerator Facility
12000 Jefferson Avenue, Newport News, Virginia, 23606

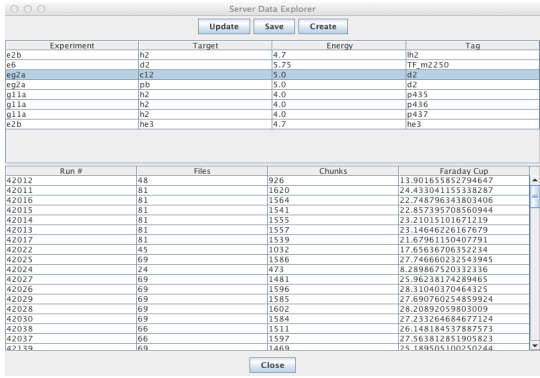
- ✧ Presently utilized as framework for CLAS12 reconstruction
- ✧ Foreseen as framework for the JLAB Electron-Ion Collider Project

CLAS12: data management and file tagging

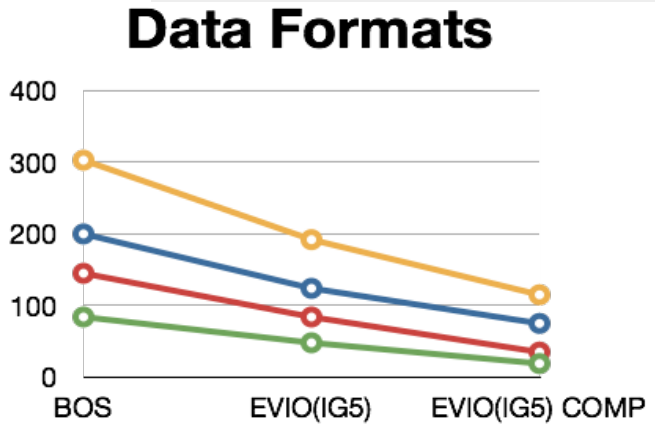
- CLARA based data management, distribution and analysis system:
  - World wide access to the data
  - Analysis Services for specific data sets
  - On-Demand data processing and skimming
  - Ability to download predefined 4-vectors and run full analysis on cloud servers



- Tagged File System:
  - File description services for searching data over many clusters
  - Tagging interface for categorizing files by experiment type (beam, target)
  - Run condition database for tags describing experiment run conditions.
  - GUI for file search and download



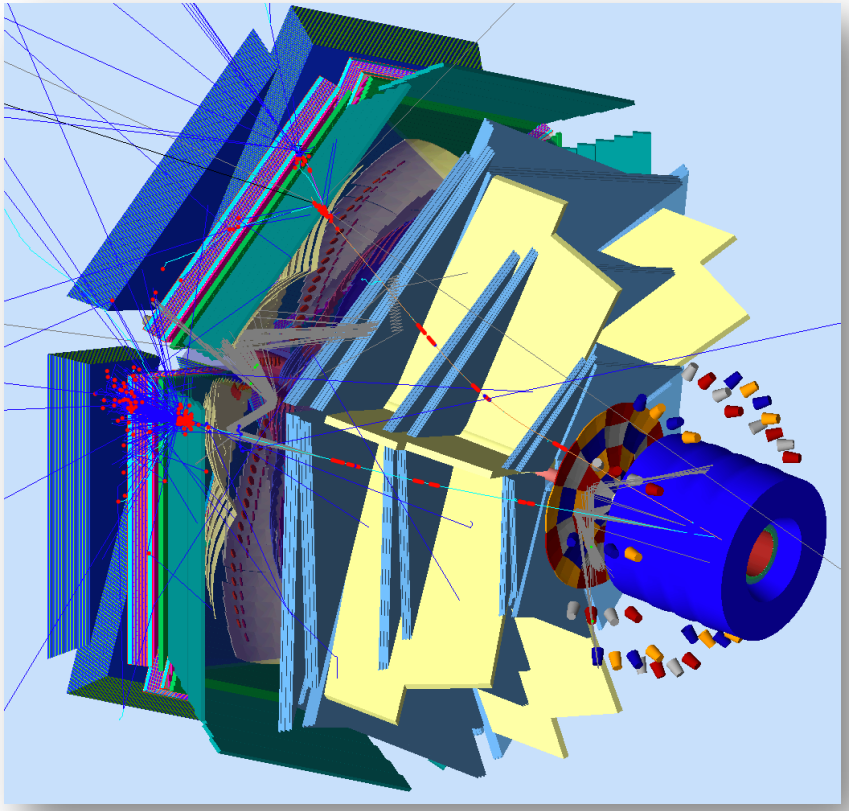
- Efficient Data formats:
  - Custom developed data formats for CLAS data
  - Buffered data stream for efficient transfer between services.
  - Lossless compression for storage efficiency



- Used for ODU Data Mining project:
  - data on ODU servers analyzed by users from Scotland, Germany, Chile, India, Israel, MIT and other US universities

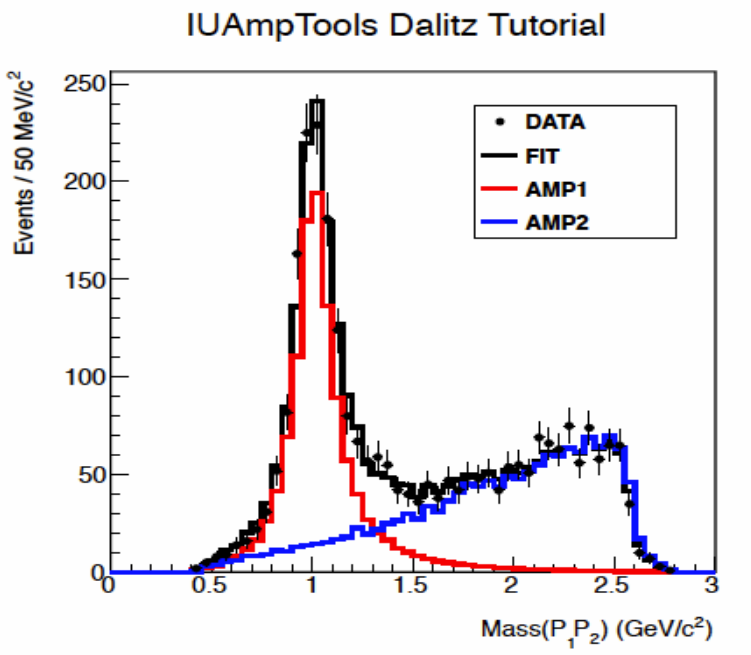
GEMC

- Object Oriented Design
  - C++ classes, standard template library, factory mechanism
- Detector parameters (geometry, fields, material, ...) defined in databases (MYSQL, TXT, GDML, CLARA service, C++ plugins): the same gemc executable can be used for different detectors and experiments
- Possibility of simulating the time response of detectors:
  - front-end electronics and trigger simulations
- In use since 2007 for:
  - input for detector design and optimization
  - event reconstruction
  - high level physics analysis
  - beam background
- Support Linux, Mac OS X (installation as App), Windows 7,8(soon)
- Official gemc website: gemc.jlab.org



CLAS12 Partial Wave Analysis

- Key technique for hadron spectroscopy
- The angular distribution of final state particles is analyzed to extract the contribution of individual waves
- Analysis involves computational intensive unbinned log-likelihood fits:
  - Needs both data and MC (data x 10)
  - Multiparametric fits (~100 parameters)
  - Complex calculations
  - Ideally suited for massive parallelization



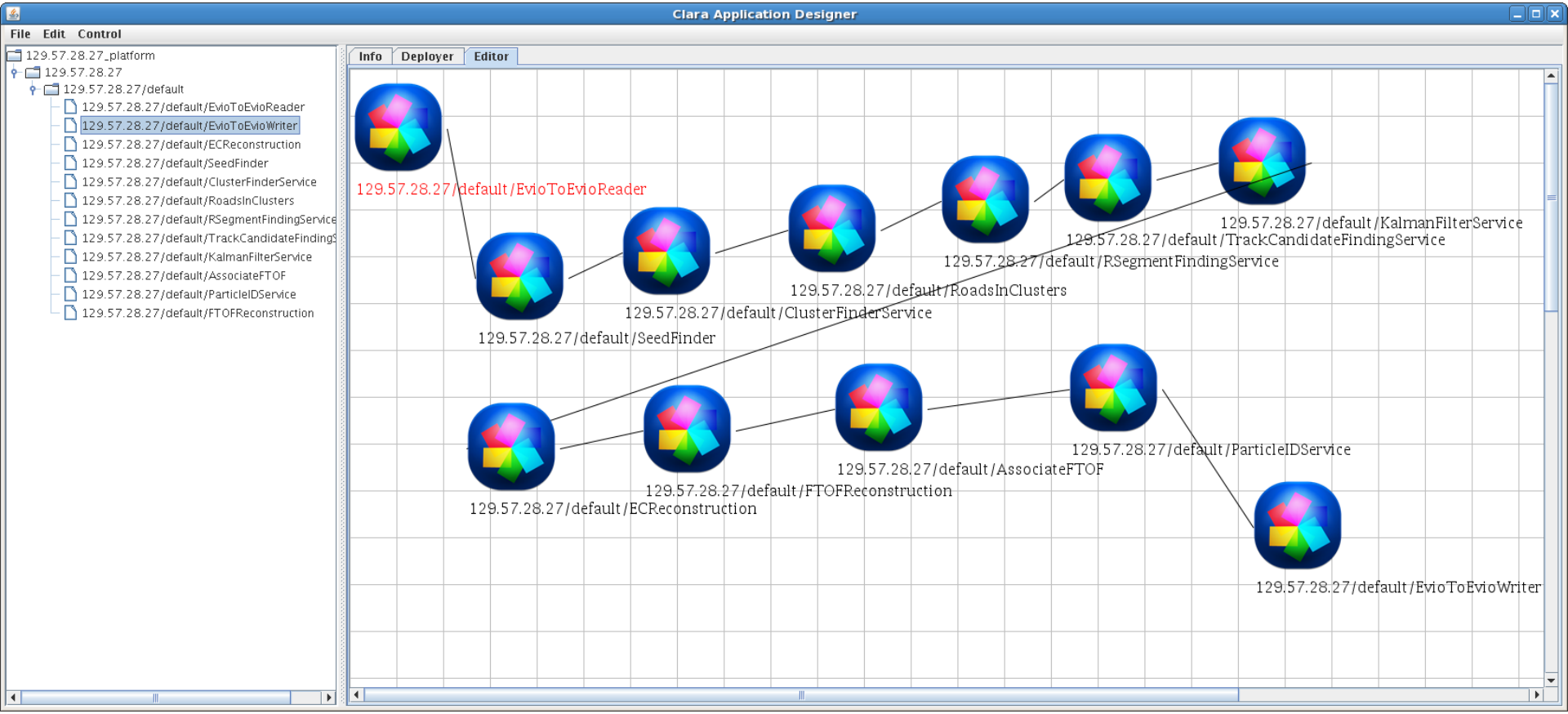
- CLAS12 PWA will use IU AmpTools:
  - Open source
  - User-Oriented
  - User supplies data and defines amplitudes from 4-vectors
  - The Framework drives the fit, uses fitted parameters to plot data and Intensity-weighted Monte-Carlo
  - Support computation on CPU and GPU

Summary

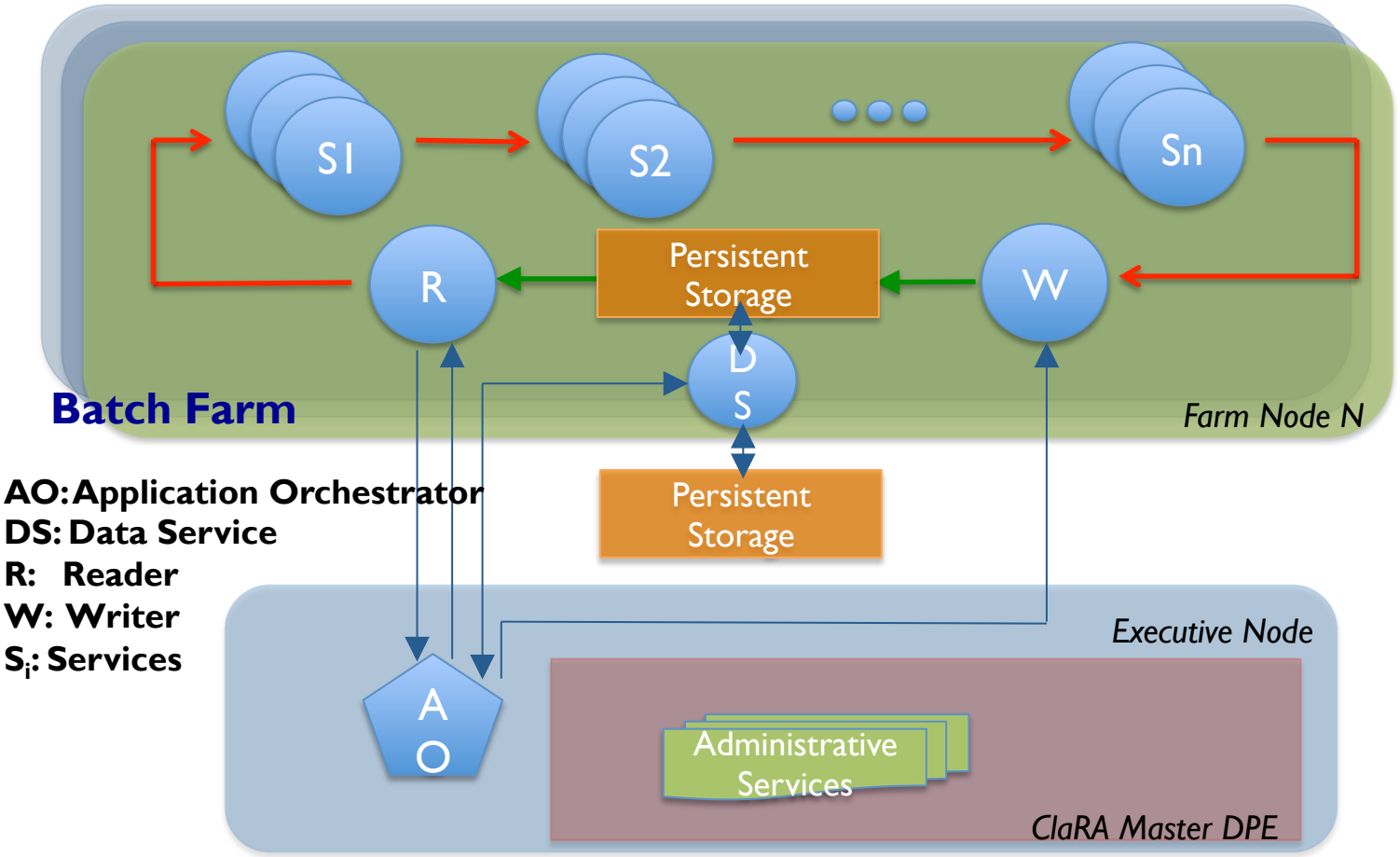
- JLab12 activity at Jefferson Lab involves a broad physics program in the experimental Hall A and B
- Different computational models are developed depending on the size and needs of the experiments
  - C++ object oriented, modular architecture for Hall A analysis
  - ILC java framework for HPS in Hall B
  - Cloud computing framework based on SOA for CLA12 in Hall B
- Evolution of proposed approaches toward more complex and flexible frameworks to allow a more efficient exploitation of resources with distributed data processing and data management

backup

Application Graphic Designer



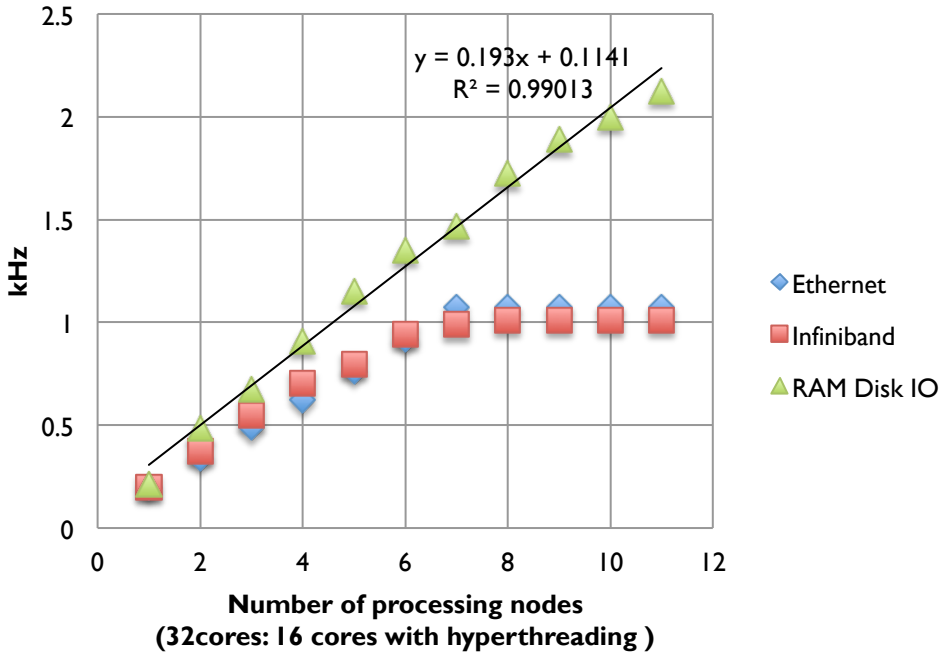
CLARA Batch Processing Workflow



Stress Tests

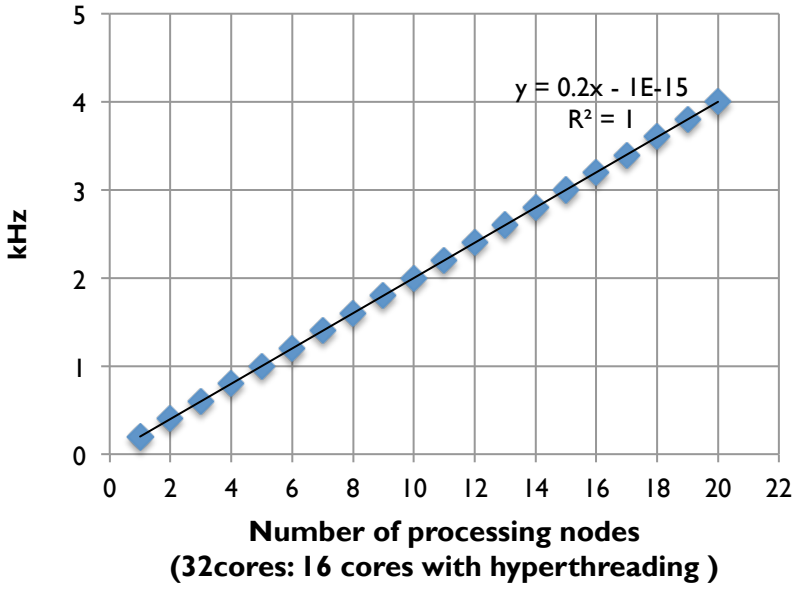
Clas12 Reconstruction: JLAB Batch Farm

Data Processing Rate
Single datastream



2 kHz/10 nodes
Single Data stream

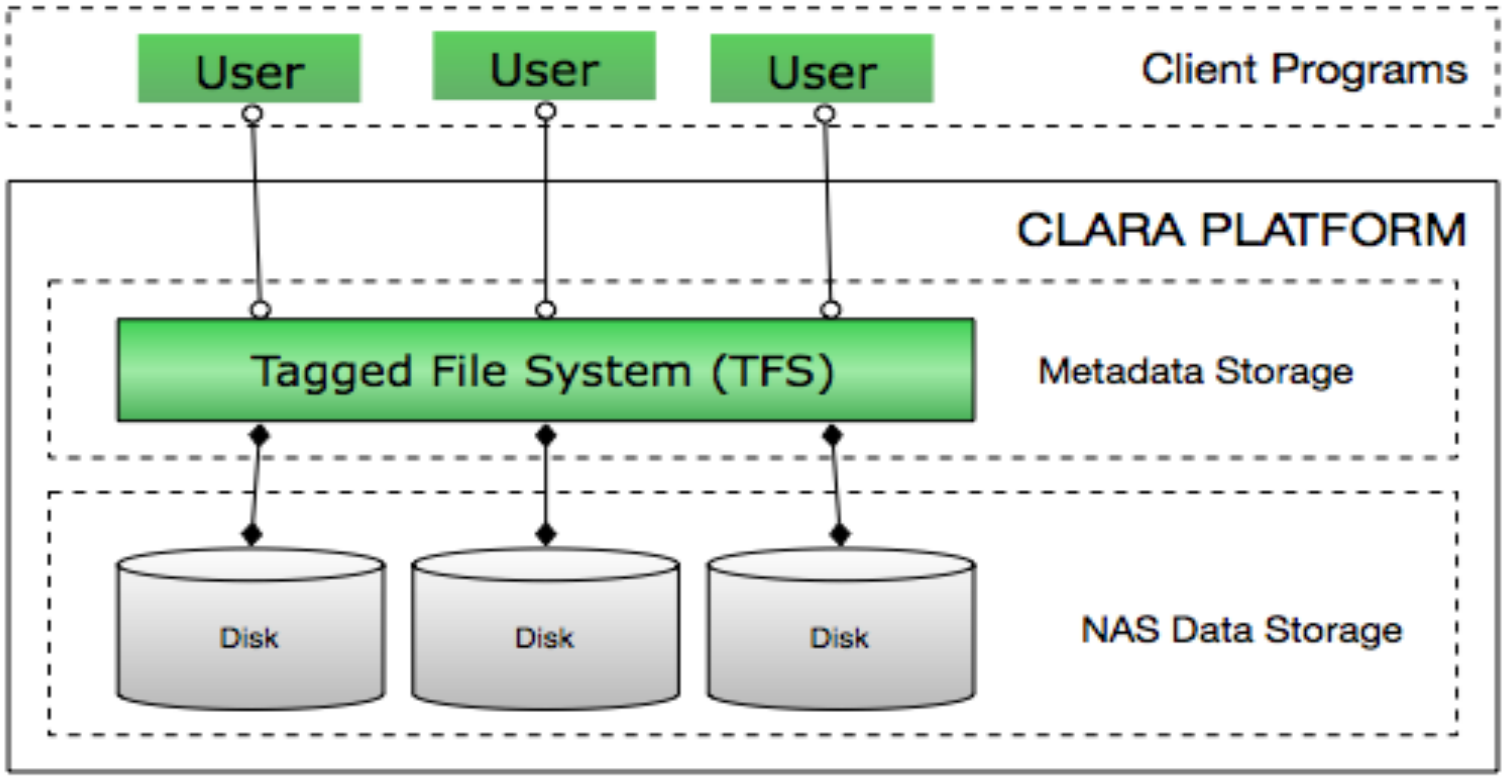
Data Processing Rate
Multiple datastreams
One data-file per processing node
Data-file contains 10K events



4 kHz/20 nodes
Multiple Data streams

Tagged File System

- A tagged file system is developed to sort, arrange experimental data files on NAS storage disks.
- Meta-Data for each file is stored, including run conditions, target, beam type and energy.
- Search algorithms are developed to search through data.
- The tagged file system will be used for CLAS12 data.



TagFS example

- Meta-data for each file on the tagFS file system has attributes:
  - IP address for DPE containing the physical file and IP address of Proxy platform that provides access to the DPE.
  - Tag set associated with run conditions of the run, including beam type, target type beam energy and so on..
  - Property set describing attributes of each individual run file.