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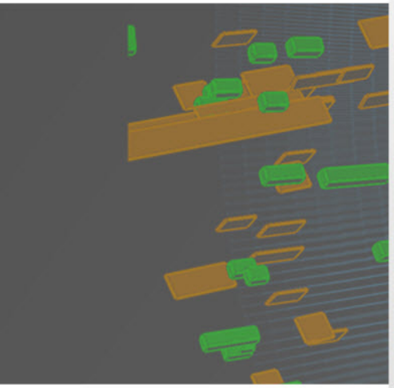

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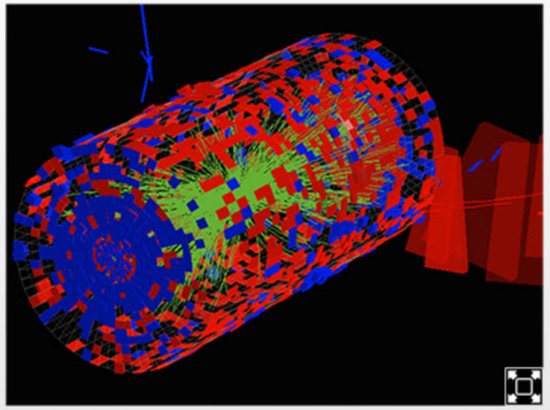
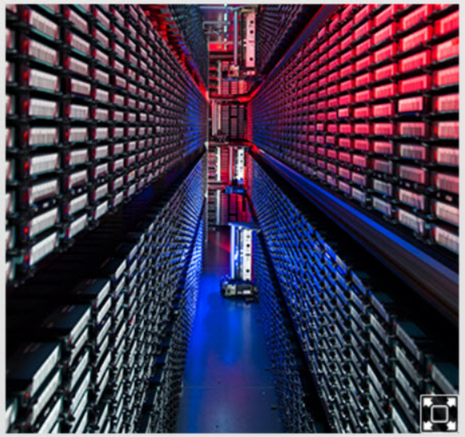
USCMS FNAL Tier 1 Facility

The USCMS Tier 1 Facility at Fermilab offers the largest share of storage and compute resources to the CMS experiment at the CERN LHC outside of CERN itself. As a Tier 1 center it provides over 33 Petabytes custodial tape storage to archive LHC collision data and simulation. The facility is unique among Tier 1 centers in CMS by also providing considerable analysis facilities, the LHC Physics Center, for USCMS physicists. Between the analysis and production Tier 1 facilities, over 20k CPU cores are provided in HTCondor batch farms, and over 20 Petabytes of disk storage are provided in its dCache and EOS distributed disk pools.

This past year the FNAL Tier 1 transitioned to the ESNet EEX Transatlantic network providing redundant 40 Gbit/s links to the CERN and the CMS experiment. This fast connectivity to CERN, the large quantity and high availability of its computing and storage, have made the FNAL Tier 1 an indispensible resource for CMS in the physics discoveries of LHC Run 1, including the discovery of the Higgs Boson, and continue to be for the exciting searches for new physics now beginning in LHC Run 2.





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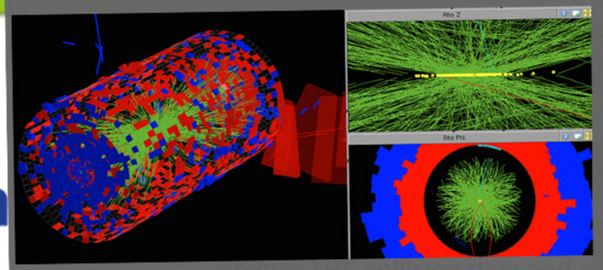
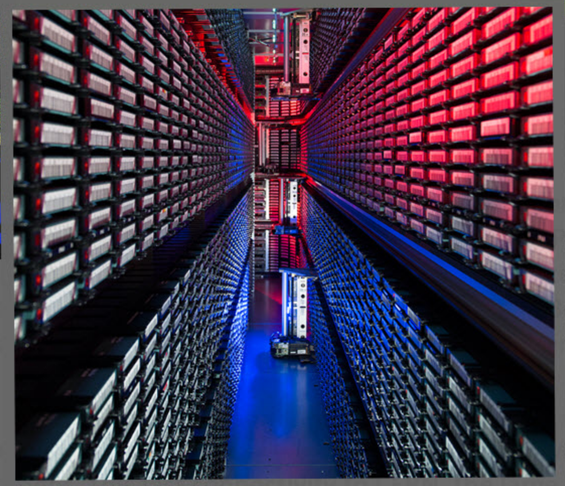
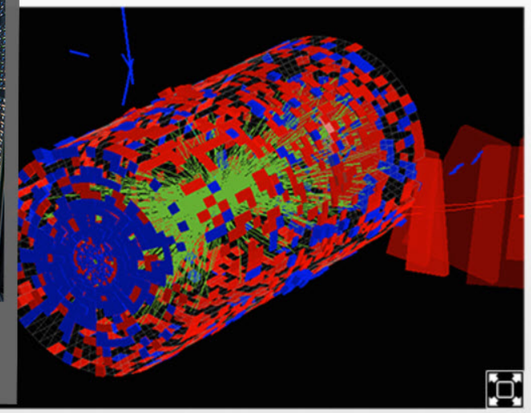


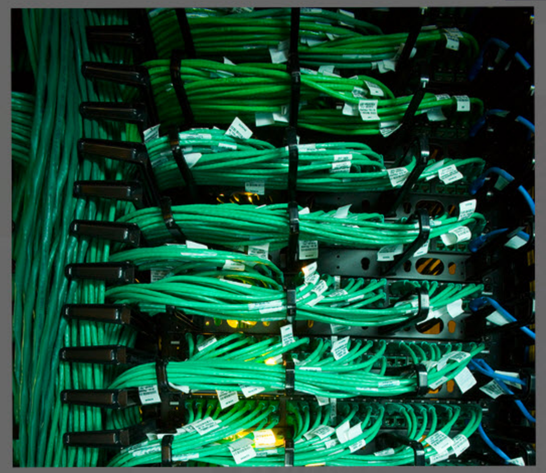
As the luminosity of the LHC increases, more and more simultaneous collisions will occur in the physics events CMS records. The increased complexity of events like the pictured event, here with 78 simultaneous interactions, will require large amounts of CPU and fast and reliable storage and network to reconstruct and analyze. This past year the FNAL Tier 1 Facility was one of the only CMS sites able to generate the CPU and I/O intense simulation of future data like this, facilitating decisions made on the direction of needed CMS detector upgrades.



A primary task of a Tier 1 center like FNAL is to host custodial copies of the unique LHC data in its tape archive. As collisions occur in the CMS detector and are recorded at CERN, a second copy is immediately transferred to Tier 1 sites. The largest share of which comes FNAL to provide a redundant archival copy of the data.

FNAL provides over 20k CPU cores of compute resources for processing and analysis of the CMS data, or generating simulated events to model that data. These resources join a worldwide HTCondor/GlideinWMS pool transparently giving CMS users access to over 130,000 CPU cores.





Reliable and fast network connectivity across the Atlantic to CERN and internally between our computing and storage resources is essential to enable CMS to quickly produce physics results. Redundant 40Gb/sec transAtlantic links maintain a close connection to the CERN, and 160Gbit/s links between storage and CPU ensure the compute farm is reliably fed with interesting LHC data.

Operated by Fermi Research Alliance, LLC under Contract No. De-AC02-07CH11359 with the United States Department of Energy.

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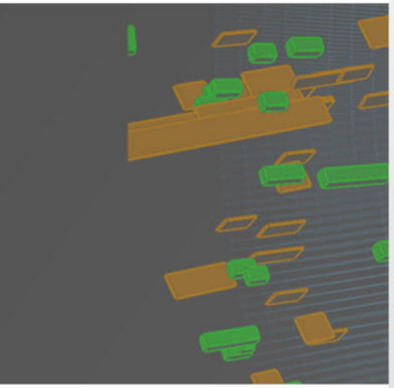

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Why Lattice QCD matters?

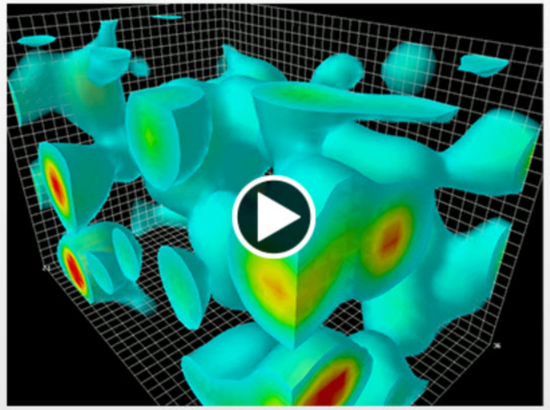
The necessity for Lattice QCD in high energy and nuclear physics.

As a key component of the Standard Model of the Universe, Quantum Chromodynamics (QCD) describes the interactions between quarks and gluons as they compose particles such as the proton or neutron. Experimental evidence affirms that QCD accurately describes the laws of particle physics. Lattice QCD (LQCD) is the well-established approach to solving QCD problems. Lattice QCD calculations are needed for experiments such as Muon g-2, the U.S. neutrino program, LHCb, and B-factories to interpret their results. The visualization on the right shows the evolution of the topological structure of a gluon field using Lattice QCD.

Lattice QCD codes spend most of their time inverting very large and highly sparse matrices. Iterative techniques like "preconditioned conjugate gradient" are used to perform these inversions. Matrix-vector multiplies (3x3 times 3x1 in complex numbers) dominate the computation. The matrices describe gluons, and the vectors describe quarks. The 4-dimensional Lattice QCD simulations are divided across hundreds to many thousands of cores, and each core interchanges data on the faces of its 4D-sub-volume with its nearest neighbor. The codes employ MPI or other message passing libraries for these communications.

USQCD is a collaboration of the majority of U.S. scientists exploiting supercomputers for Lattice QCD. Fermilab builds and operates commodity hardware for Lattice QCD optimized to be the most cost effective and appropriately balanced combinations of processor and network interconnect. Clusters with floating point acceleration (GPU and MIC) play an increasing role in the USQCD program.

The video on bottom right blends scientific visualization with artistic rendering to explain the scale and purpose of LQCD computations. The last sequence features LQCD calculations of the wave function for a Pion (a quark bound to an anti-quark) superimposed upon quantum fluctuations of the QCD vacuum.



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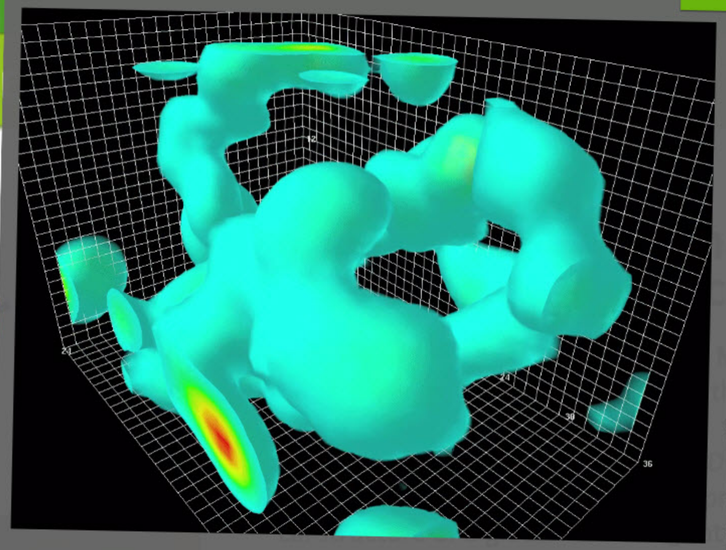

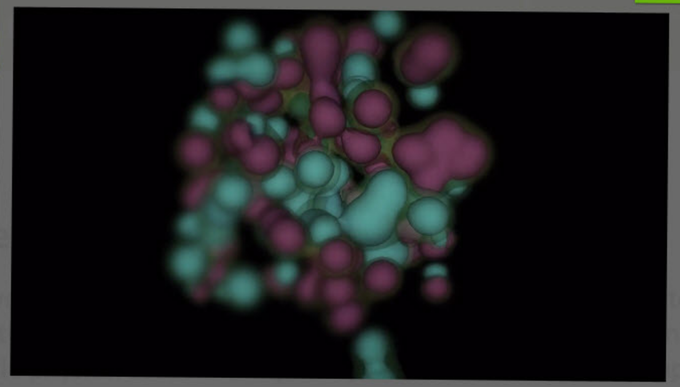

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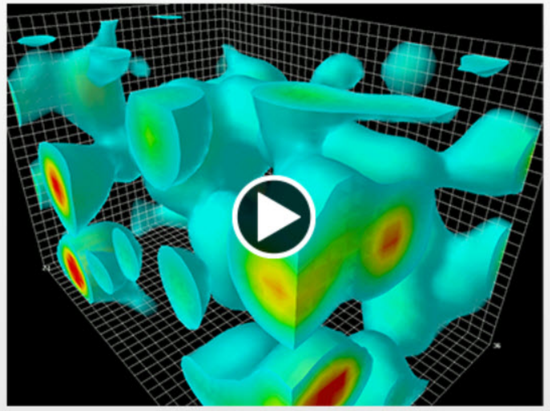

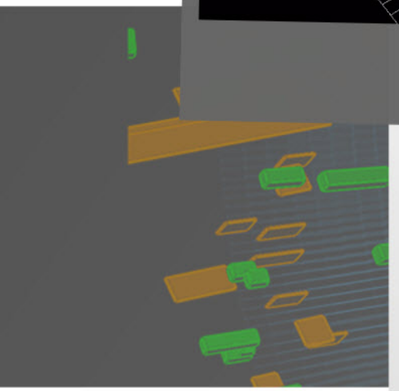

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Funded by the United States Department of Energy, Office of Science, Offices of High Energy and Nuclear Physics under project (investment) identifier: 019-20-01-21-02-1032-00.

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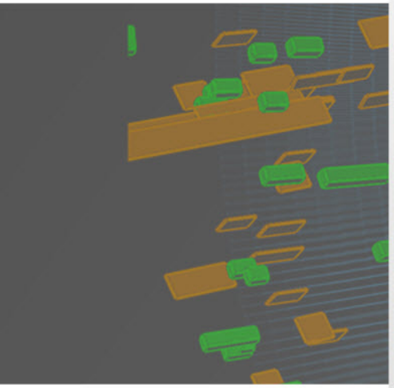

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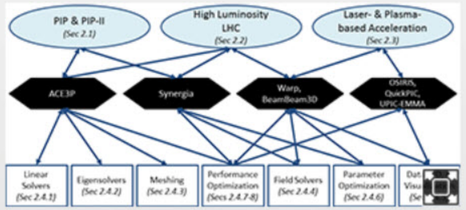
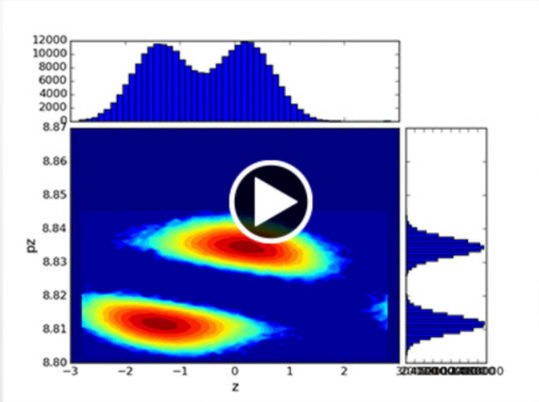
ComPASS

Community Project for Accelerator Science and Simulation

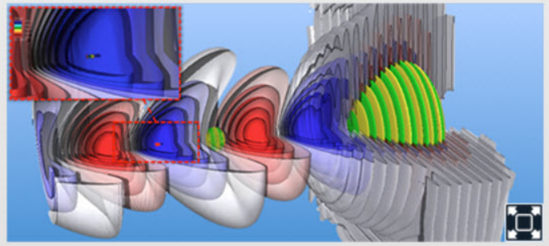
High Performance Computing for Accelerator Design and Optimization
Particle accelerators are critical to scientific discovery, both nationally and worldwide. The mission of the ComPASS collaboration is to develop and deploy the state-of-the-art accelerator modeling tools necessary to advance new designs, concepts and technologies for particle accelerators.

ComPASS is a cross-cutting effort in support of near-term accelerators at Fermilab (PIP and PIP-II) and CERN (High Luminosity LHC), as well as longer-term research into advanced accelerator concepts (laser- and plasma-based accelerators). It brings together accelerator physicists with applied mathematicians and computer scientists.

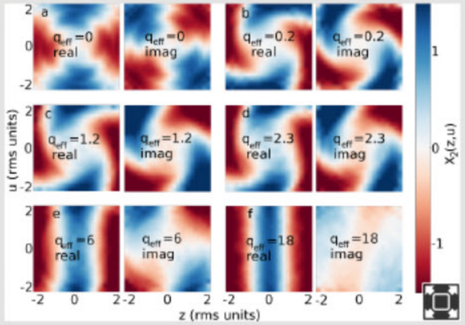




WARP, a ComPASS code for the simulation of plasmas, has been used to validate a new concept for the injection of high-quality beams in plasma acceleration. Plasma-based acceleration holds the promise of creating much more compact future accelerators.



Synergia, a ComPASS code for the simulation of beam dynamics in the presence of collective effects, has been used to test theoretical predictions of modes and mode evolution in beams with space charge.



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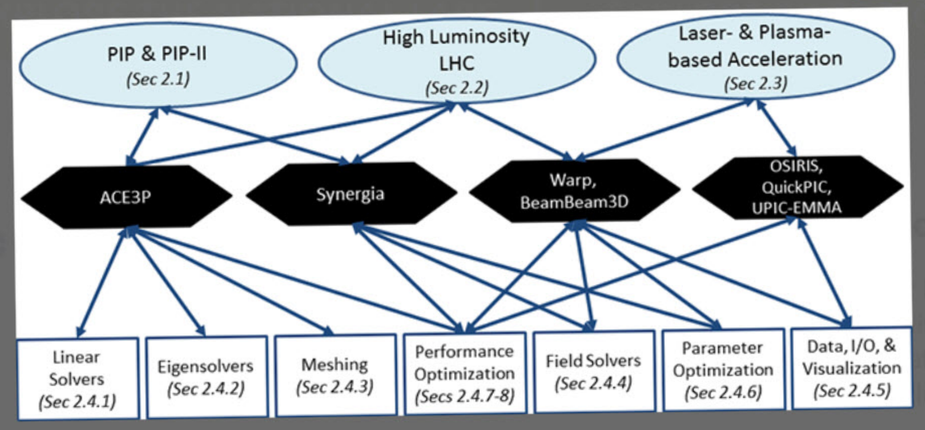

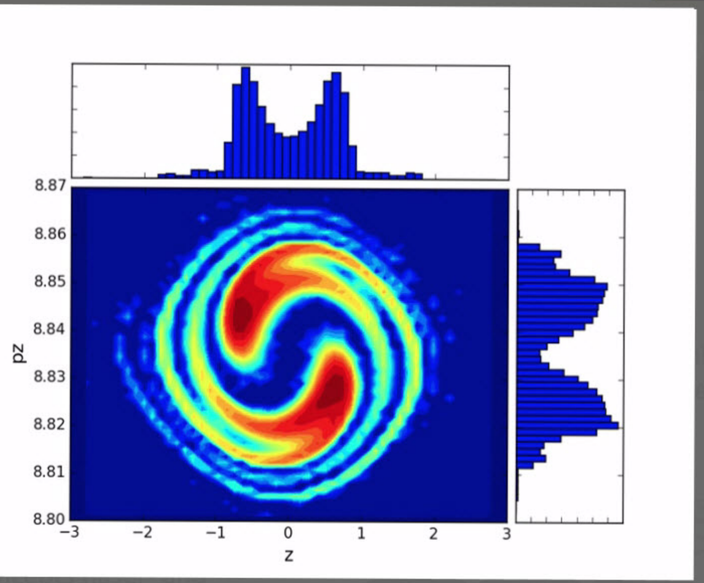

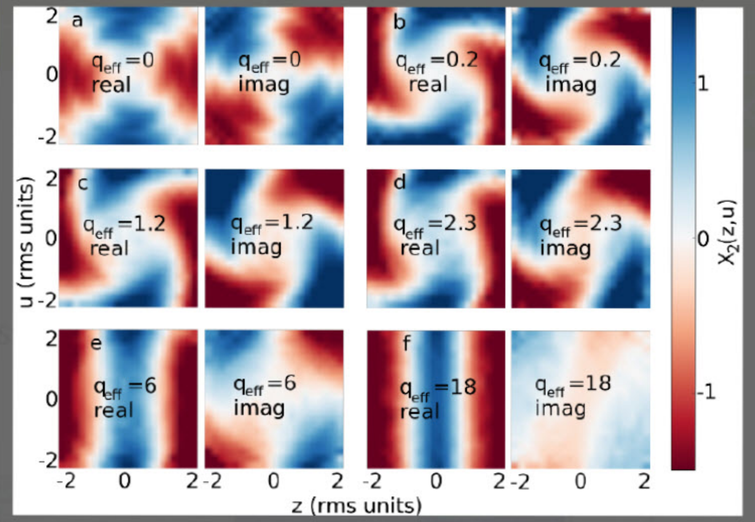

ComPASS is a cross-cutting effort in support of [illegible] Fermilab (PIP and PIP-II) and CERN (High Lumino[illegible]

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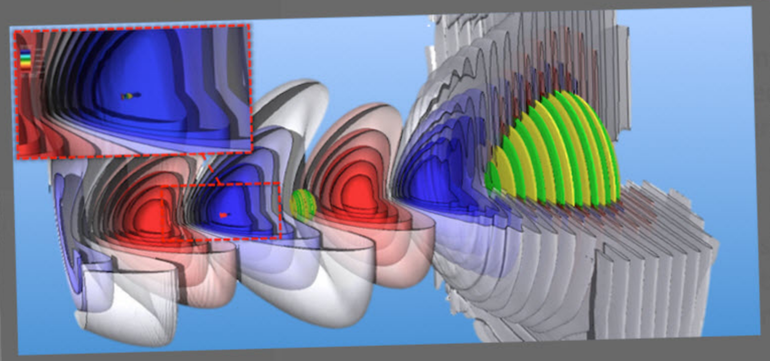

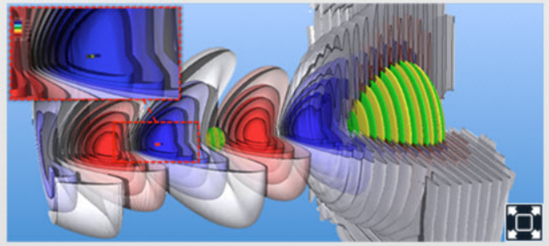

ComPASS is funded by the DOE Scientific Discovery through Advanced Computing (SciDAC) program.

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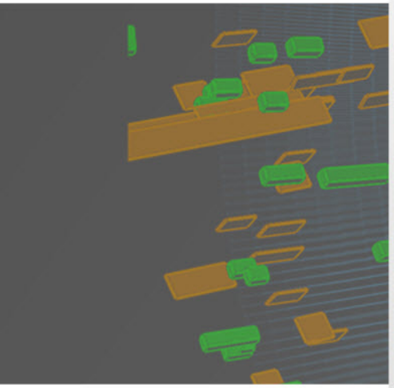

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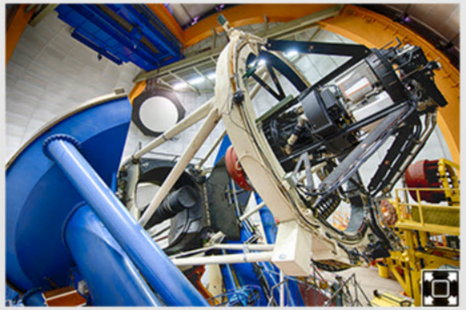
Finding the Astrophysical Objects that Produce Gravity Waves

The DESGW collaboration

Gravitational waves are directional ripples in space time. They have been seen in decay of the orbits of binary pulsars, and in the now running science scan the Advanced LIGO gravitational wave detectors seek them from other sources. The problem is that LIGO's ability to locate the source of its detected gravity wave is limited--- their error ellipses on the sky are roughly the size of the galactic plane seen behind the Blanco Telescope dome below.

Fermilab's DECam mounted on the NOAO Blanco 4m telescope n Chile is uniquely able to cover large areas of the sky to the depths necessary to find the faint optical glows expected from the merging neutron stars that produce the strongest gravitational wave signals. One nights follow up produces 100 GB of images which must be turned into candidates for spectroscopy in a day. Fermilab's FermiGrid provides the throughput necessary to reduce, mosaic the images, and then subtract a template image to locate candidates in a few hours per image, for all images simultaneously.



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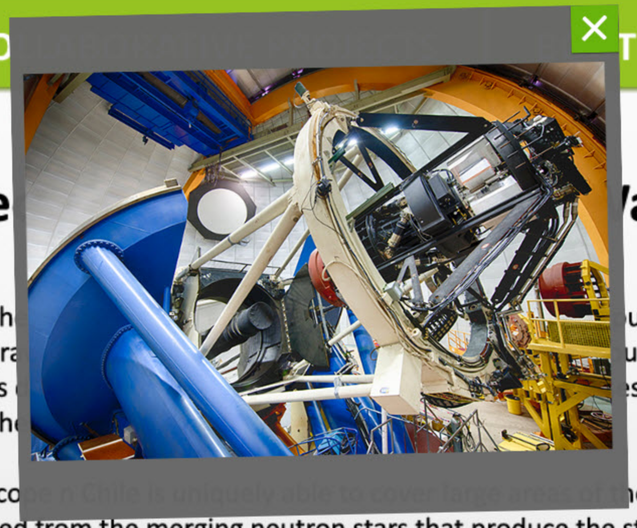

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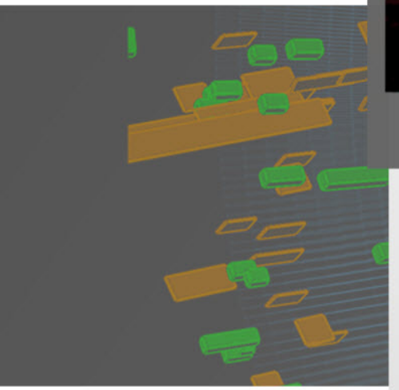

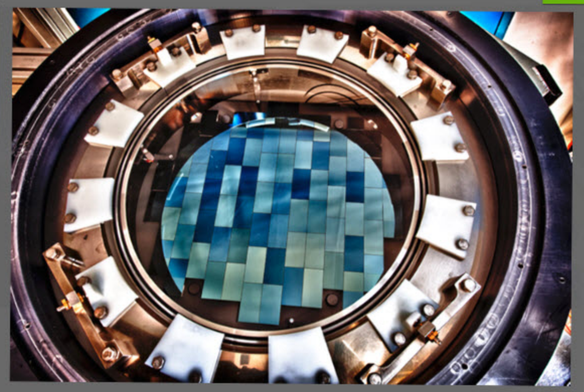

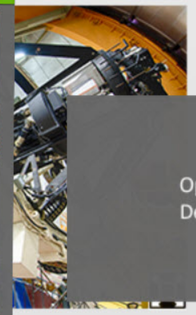

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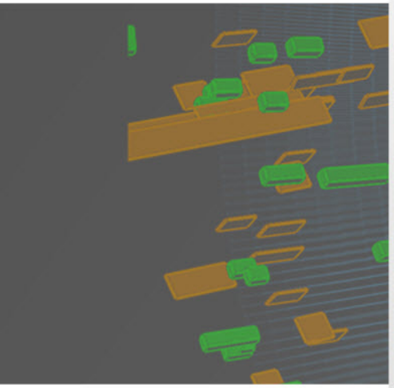

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Fermilab HEPCloud Facility

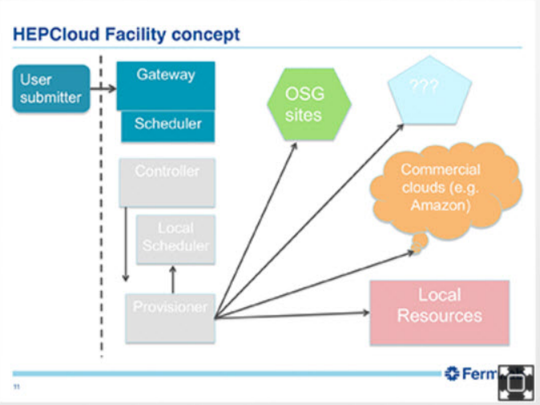
Evolution of the HEP Computing Paradigm

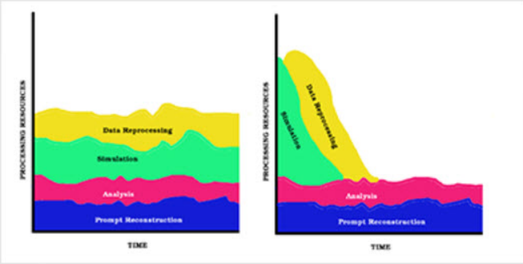
Currently, US HEP facilities support dedicated and shared sources, for data and compute intensive workflows.

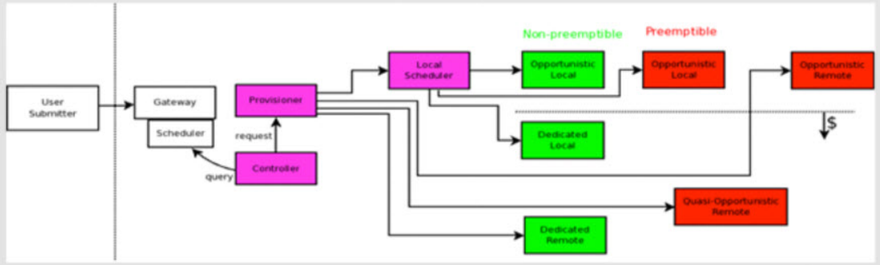
US-HEP facilities could ***incorporate and manage*** "rental" resources, achieving "elasticity" that satisfies demand peaks without overprovisioning local resources. The goal is to integrate "rental" resources into the current Fermilab computing facility in a manner transparent to the user.

Year 1 demonstrators: LHC Compact Muon Solenoid, NOvA neutrino experiment, Dark Energy Survey Gravitaitonal Wave experiment

This model can be extended beyond traditional "loosely-coupled" architectures. Working with DOE ASCR facilities to fully understand constraints and requirements will enable us to identify such use cases and develop the HEPCloud process, policies and tools necessary for HPC access. Could build on current successful efforts: Event Generation (Alpgen, pythia, …) in production mode – minimum data ingress, simpler workflows.







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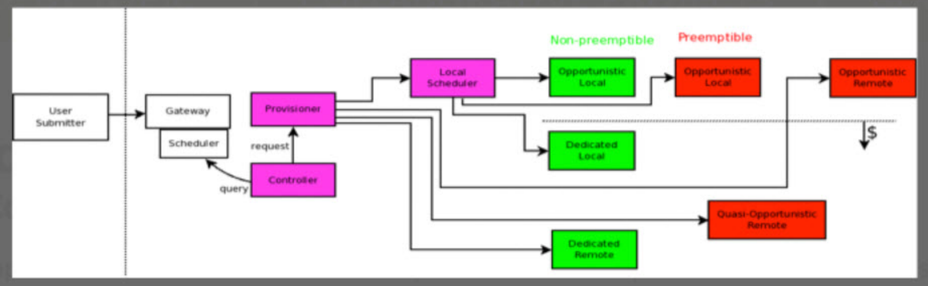
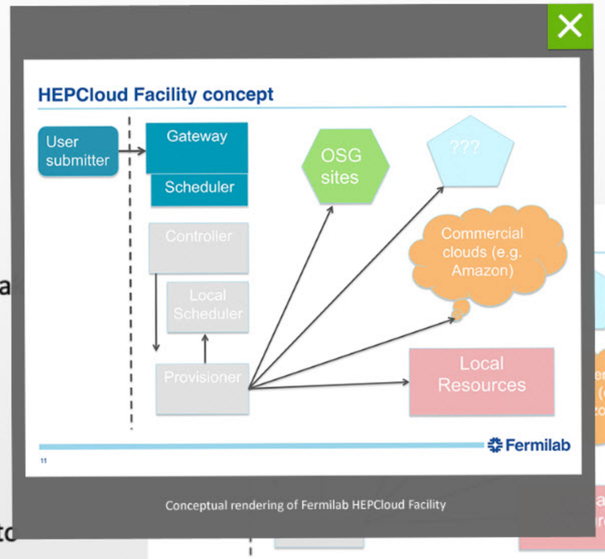
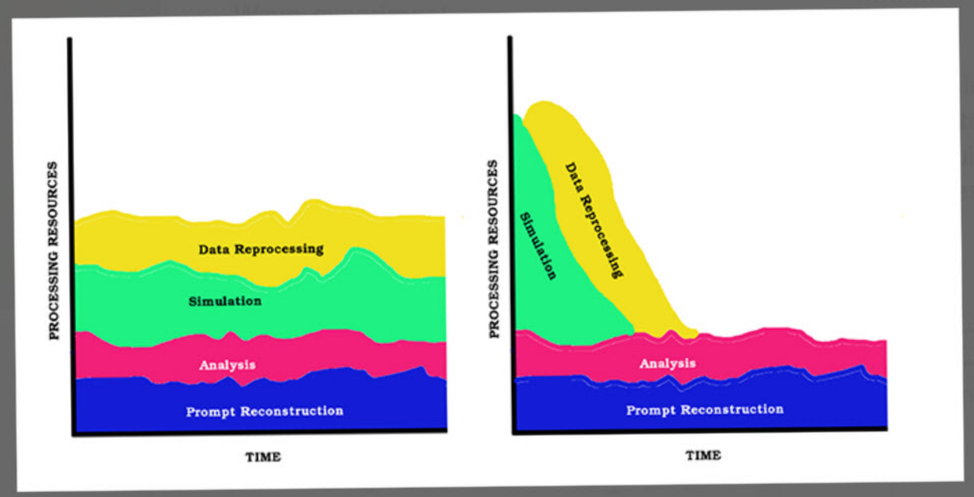


Architectural overview for Fermilab HEPCloud Facility



Conceptual rendering of Fermilab HEPCloud Facility



Provisioning for the peak — ideal case (left) vs. reality (right)

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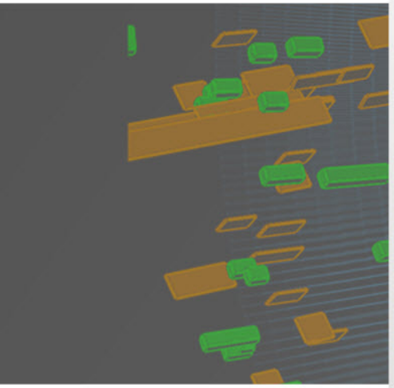

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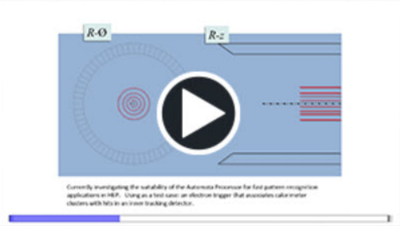
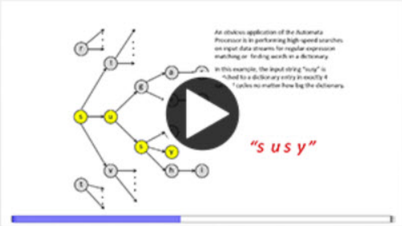
HEP Pattern Recognition with an Automata Processor

Christopher Green (Fermilab), Ke Wang (University of Virginia), and Michael Wang (Fermilab)

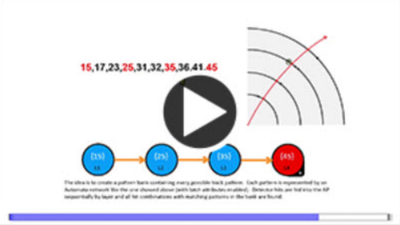
At Fermilab, we are exploring the application of novel architectures like the Micron Automata Processor to address the growing computational demands of pattern recognition due to the trend towards more complex event topologies and higher densities in today's new generations of High Energy Physics (HEP) experiments.



The Automata processor is a unique pattern search engine designed to find patterns like strings in data streams at a constant rate of 1Gbps. However, the symbols comprising these patterns need not be confined to characters and could just as well represent other quantities like the coordinates of charged particle trajectories in the tracking detectors of a HEP experiment.



The basic operating principle of an automata-based particle track finder is illustrated in this simplified example. State transition elements are strung together and programmed to recognize a particular sequence of symbols representing the coordinates of a possible charged particle trajectory in the detector.



A workbench simulation of an automaton designed to recognize a pattern of four 16-bit hit coordinates from a 4-layer particle detector, allowing up to one missing hit due to detector inefficiencies. State transition elements change color (representing a state change) in response to the incoming data stream in the upper right corner.

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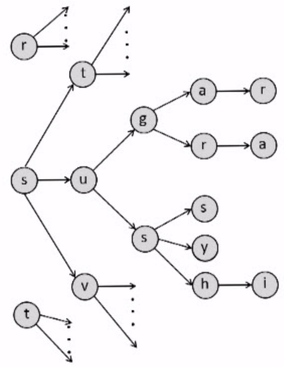
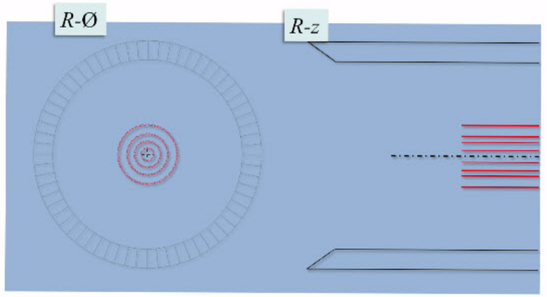
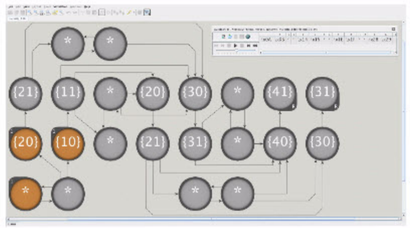
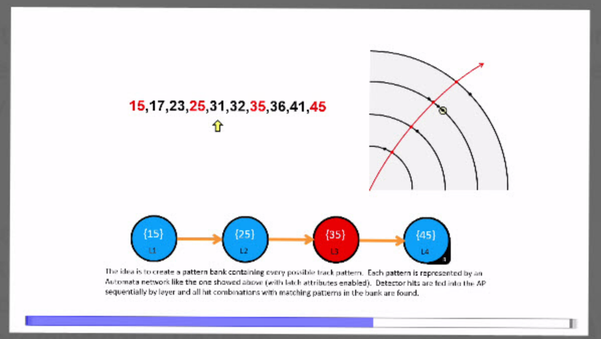


An obvious application of the Automata Processor is in performing high-speed searches on input data streams for regular expression matching or finding words in a dictionary.



Currently investigating the suitability of the Automata Processor for fast pattern recognition applications in HEP. Using as a test case: an electron trigger that associates calorimeter clusters with hits in an inner tracking detector.





The idea is to create a pattern bank containing every possible track pattern. Each pattern is represented by an Automata network like the one showed above (with latch attributes enabled). Detector hits are fed into the AP sequentially by layer and all hit combinations with matching patterns in the bank are found.

Operated by Fermi Research Alliance, LLC under Contract No. De-AC02-07CH11359 with the United States Department of Energy.

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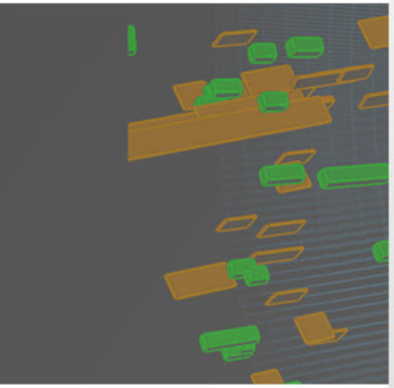
Fermilab



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Off-the-Shelf Data Acquisition

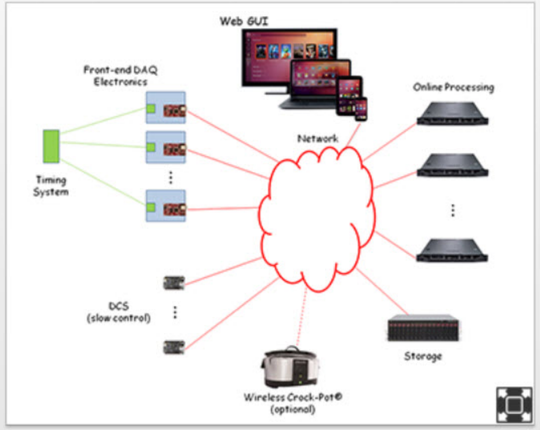
User-friendly and web-based DAQ solutions are within the reach of Physics applications at every scale.

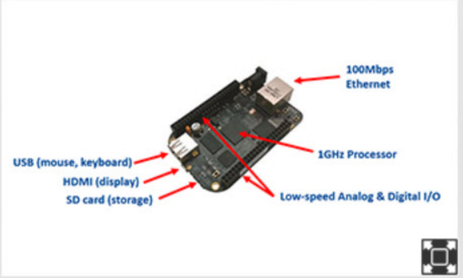
Motivation for OtS DAQ:

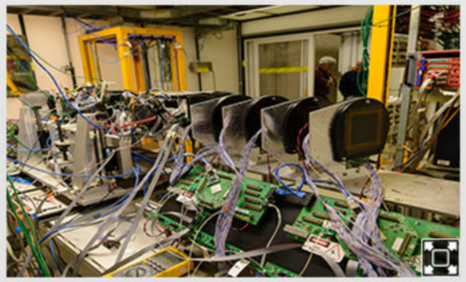
- If we are more efficient and cost-effective with our budgets, then experiments can do more with less. So a ready-made Data Acquisition (DAQ) solution is a valuable commodity to experiments on the horizon.
- Industry is moving from centralized crates and backplane systems to distributed systems connected by high speed links.
- Ethernet and Internet Protocol has been the one communication technology standard that has far outlived any other. The "Internet-of-Things" market value was $1.9 trillion in 2013 and is estimated up to $19 trillion by 2020.

Vision for OtS DAQ:

- We want to bring value to the table by surveying and narrowing the "Internet-of-Things" market and providing a coherent package connecting hardware with software, geared toward High Energy Physics (HEP).
- We want to maintain an emphasis on scaling down so that our solutions work for one device or a full experiment.
- We want to let the physicists do physics instead of having to reinvent the DAQ wheel.







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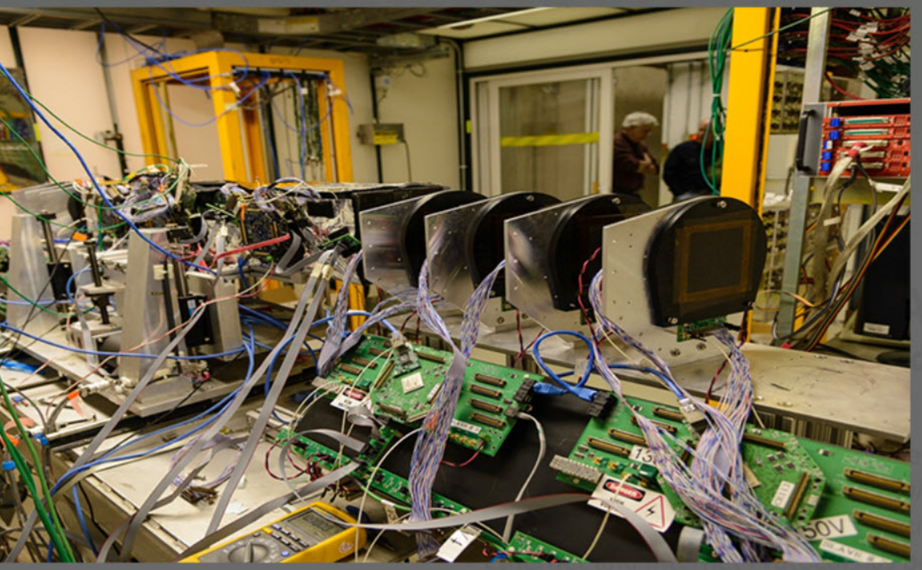
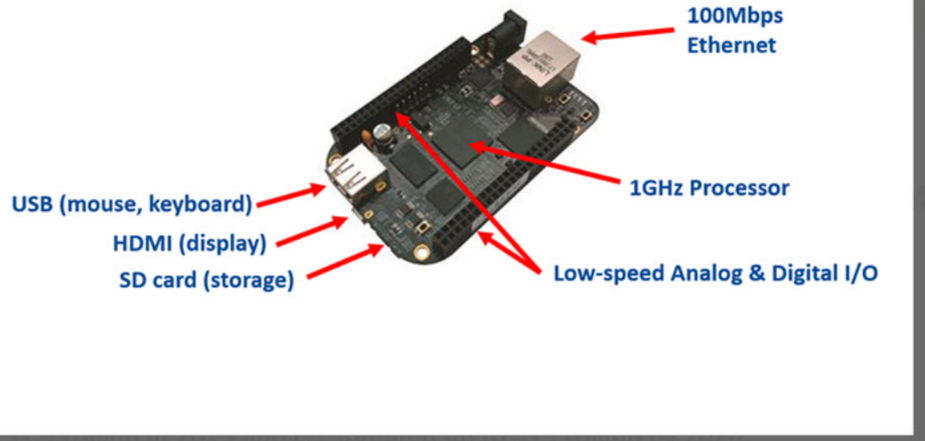
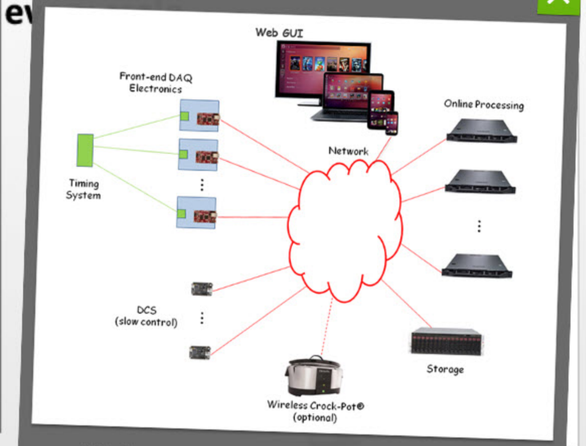


The Fermilab Test Beam Facility is the ideal locale for developing the OtS DAQ approach and getting users to try it out! At the test beam users generally come for 1 or 2 weeks at a time, so a readily available, turnkey, DAQ solution would be a game changer.

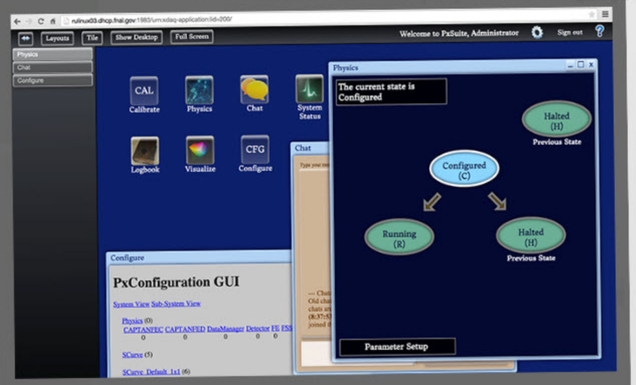


The Beaglebone Black is an Internet-of-Things poster child having sold in the millions. For $50 you get a handheld web-enabled device running Linux. OtS DAQ wants to initially focus on three devices to support - Beaglebone Black is our low-end candidate.

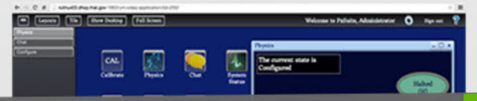


Sketch of an example network topology with web-based user interface, slow controls, front-end detector electronics, online processing, and storage. OtS DAQ targets providing access to a complete DAQ solution so that physicists can spend their time doing physics.

sics instead of having to reinvent the DAQ wheel.



OtS DAQ is focusing on web-based graphical user interfaces as the primary method for user interaction with the DAQ system. The web browser is the best vehicle for rich, informative data displays and intuitive controls.



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