NERSC HEP Requirements Planning Review
November 27th, 2012

Perspectives from High Energy Physics

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Office of Science, U.S. Department of Energy

High Energy Physics (HEP) Program Mission

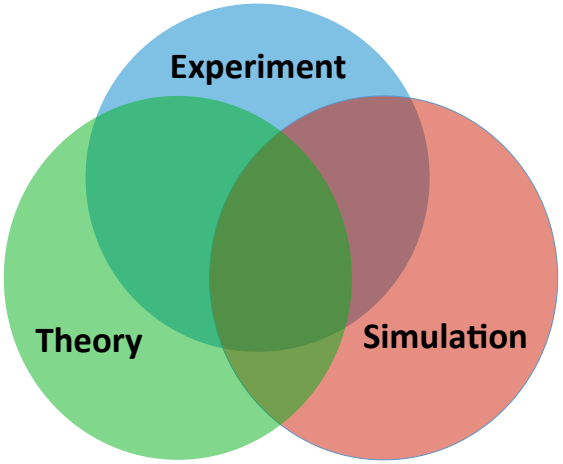
Is to understand

- **How the universe works at its most fundamental level,**
- **By discovering the elementary constituents of matter & energy,**
- **Probing the interactions between them, and**
- **exploring the basic nature of space and time.**

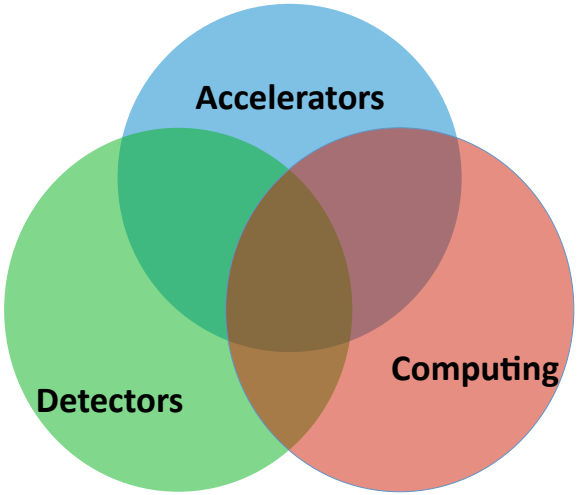
This quest takes us from micro scales deep inside hadrons, to cosmic scales of millions of light years…

Research is characterized by large, multi-institutional, multi–agency–funded, international collaborations and is strongly coupled with Computing .

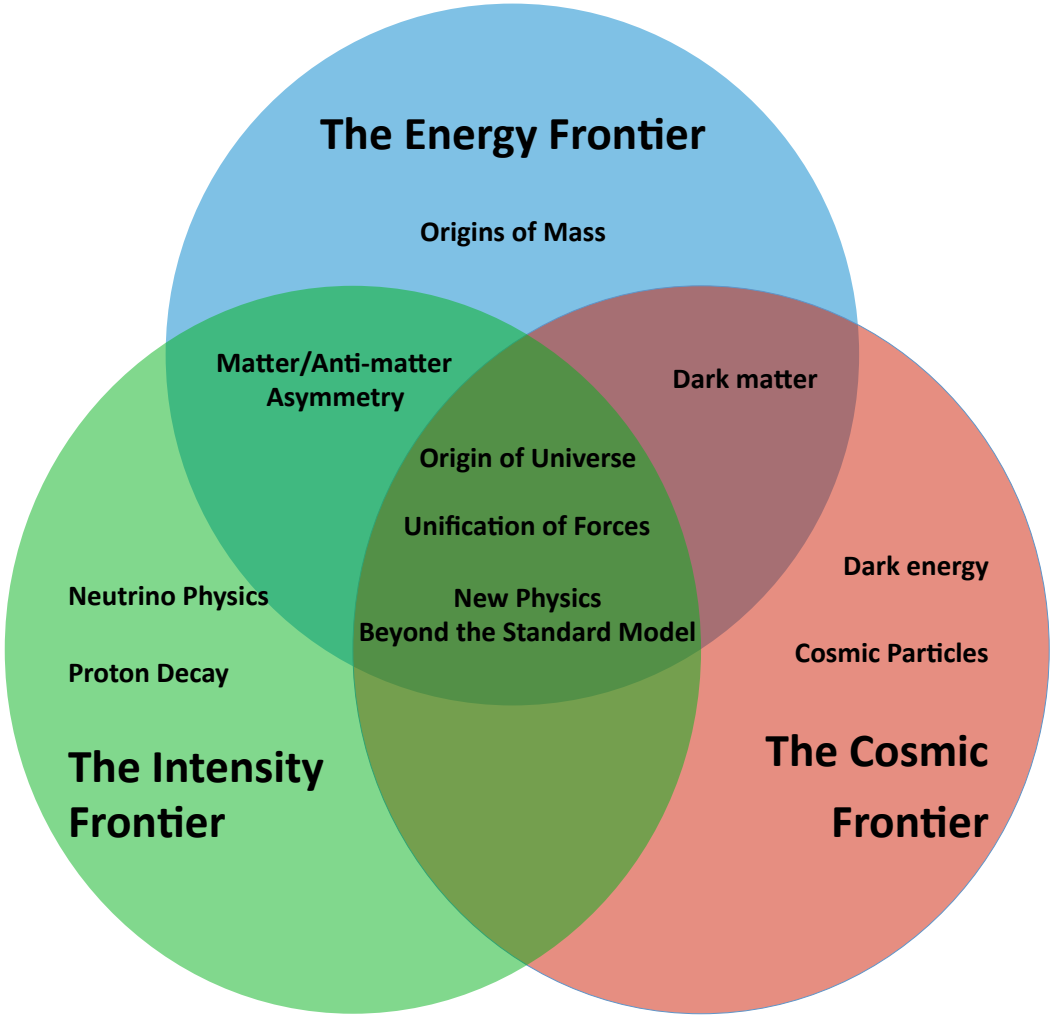
Physics and Technology



Along Three Paths



Enabled by
Advanced Technologies in:



Physics Frontiers

Cosmic Frontier Overview

- **Near-term Science goals :**
- **Discover (or rule out) the particle(s) that make up Dark Matter**
- **Advance understanding of Dark Energy**
- **Recent results :**
- **2011 Nobel Prize awarded for the measurement of the acceleration of the Universe: Permutter, Schmidt, and Riess.**
- **BOSS has measured the characteristic length scale of the universe using baryon acoustic oscillations.**
- **New facilities: Dark Energy Survey (DES) commissioning.**
- **Planned program of major projects:**
- **Large Synoptic Survey Telescope (LSST) is the longer-term centerpiece of this program; aims to make definitive ground-based Dark Energy measurements using "weak lensing".**
- **DOE CD-1 approved, NSF moving ahead also.**

Energy Frontier Overview

- **Science goals: Explore the TeV scale.**
- **Is there anything there but a SM-like Higgs?**
- **Recent results: There is a 'Higgs-like' boson at 125 GeV.**
- **There are many predictions to test to see if it is the "real McCoy".**
- **Near Term Plans include continued LHC running though 2012**
- **Resume running at ~14 TeV in 2014**
- **No new facilities under construction at this time**
- **Planned Program of Major Projects:**

LHC Detector Upgrades: (2017-8) to cope with increased data rates

Participate in the LHC-High Luminosity upgrade with installation around 2022.

Intensity Frontier Overview

- **Near-term Science goals :**
- **Implement comprehensive program to understand neutrino mixing**
- **Deliver much improved limits (measurements?) of charged lepton mixing and hidden sector phenomena**
- **Recent results**
- **Daya Bay reactor neutrino experiment definitively shows that the unmeasured neutrino mixing is large (of order 10%)**
- **New facilities under construction:**
- **NuMI upgrade + NOvA progressing well**
- **Planned program of major projects:**
- **Mu2e to explore charged lepton mixing (CD-1 approved July)**
- **LBNE to make definitive measurements of neutrino properties**

Aiming for CD-1 by the end of the year.

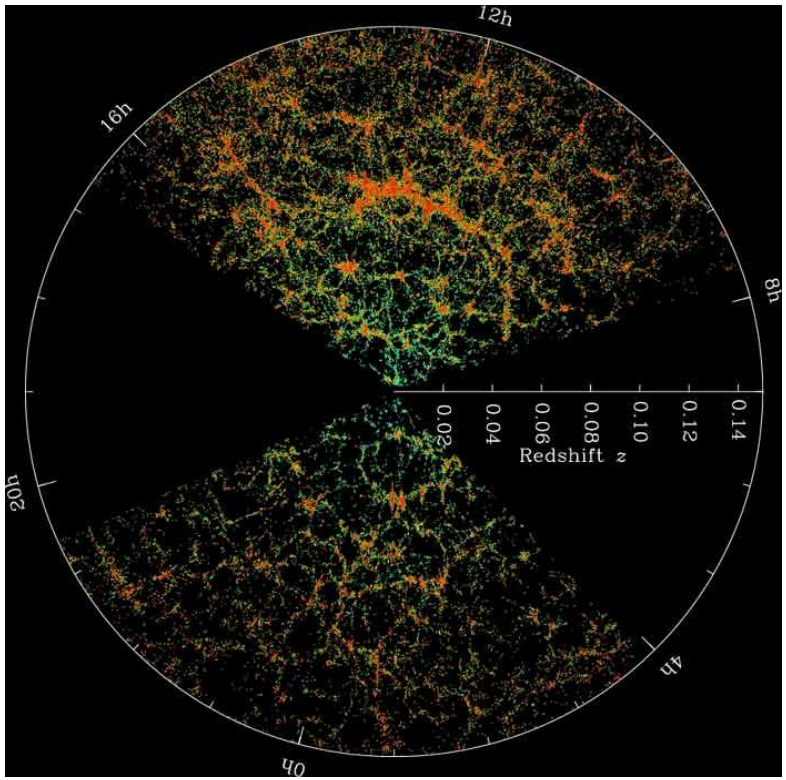
Coupling of HEP with Computing

The 2011 Nobel Prize in Physics to Saul Perlmutter, Adam Riess, Brian Schmidt, " for the discovery of the accelerating expansion of the Universe through observations of distant supernovae" used a robotic telescope equipped with a CCD detector instead of traditional camera and relied heavily on computing

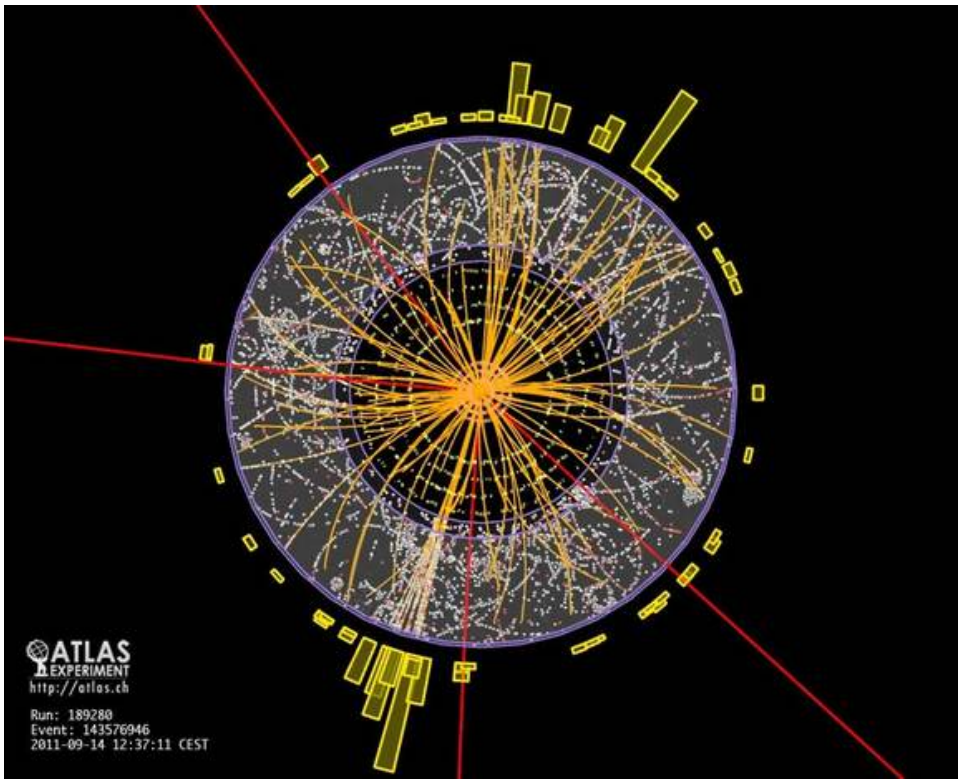
As we move forward along the Cosmic Frontier, we face massive computing and data challenges – both from simulations and from experiments – and likewise for the Energy Frontier - in particular after the planned LHC upgrades…..

Cosmic and Energy Frontiers

Experimental and Observational HEP relies on Advanced Computing



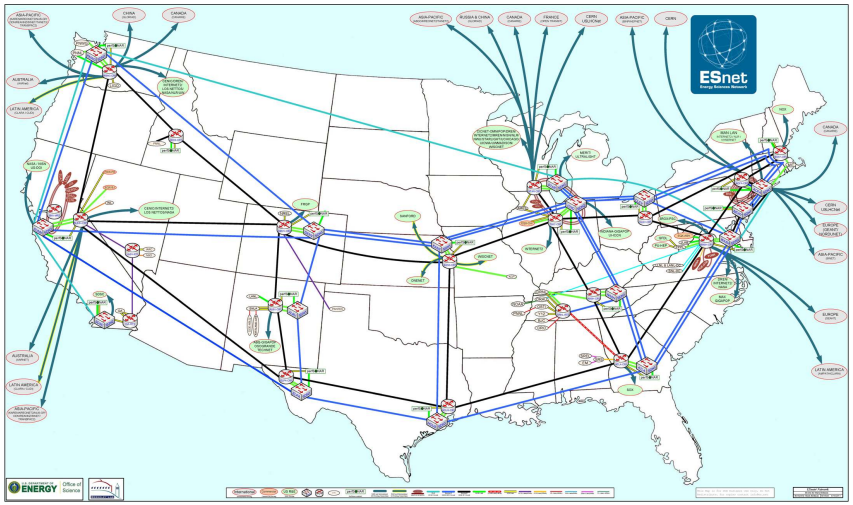
Sloan Digital Sky Survey



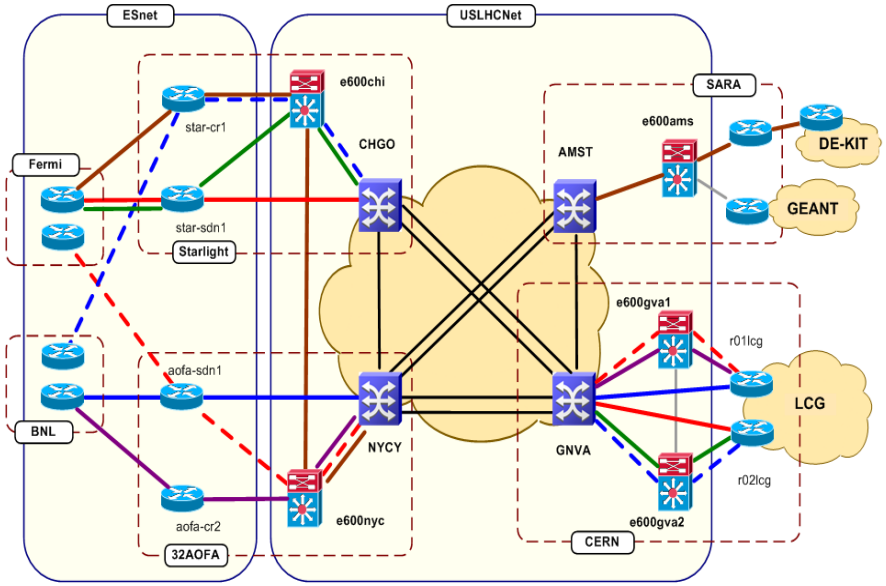
LHC Event

HEP Computing and DOE

- **Department of Energy Office of Science**
  - **Provides important national and international networks critical for HEP**



ESnet Backbone and Science Data Network



US LHCNet

Example -Intensity Frontier

Computational High Energy Physics at HEP

SciDAC (Scientific Discovery through Advanced Computing):

HEP funds SciDAC -3 projects in the areas:

- ***Lattice Gauge Theory Research*: sharpens our understanding of the universe through precision tests of the standard model and probes of new physics Beyond the Standard Model interfacing the Energy and Intensity frontiers;**
- ***Cosmic Frontier Scientific Simulations:* critical for understanding the nature of dark energy & dark matter, interfacing the Cosmic Frontier;**
- ***Accelerator Science Modeling & Simulation:* to strengthen our accelerator design and technology for more powerful ways to explore the Energy and Intensity frontiers**

Scientific Computing –

Addresses community needs for Event Generators, Data Tools, Frameworks, Distributed Computing, Networks, Software …..

HEP and NERSC

HEP values the SC High Performance Resources available through NERSC and the various current and potential partnerships.
Allocation requests this year exceed double what is available.
Largest users are from the topical areas covered in SciDAC-3
New efforts for Energy and Cosmic Frontier experiments and other new users to utilize NERSC & HPC underway

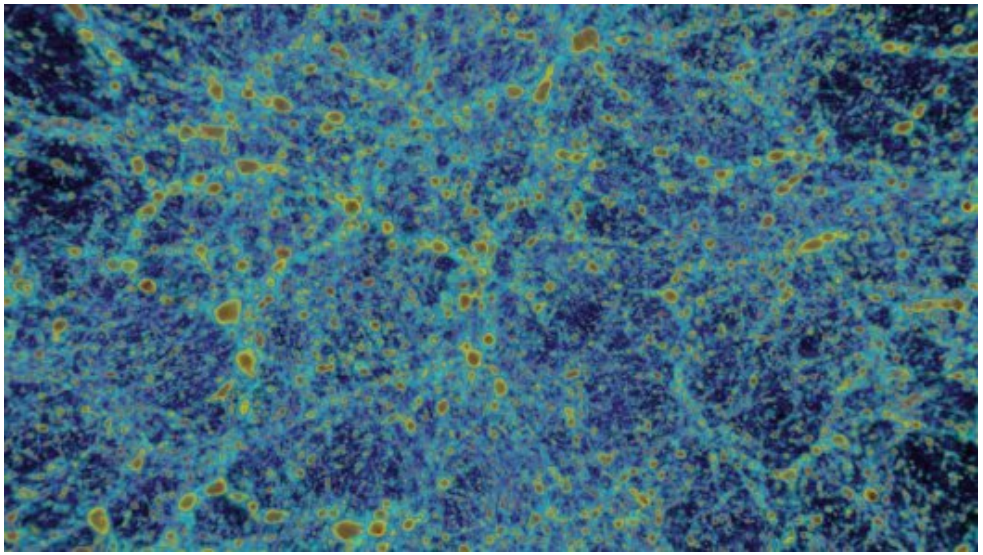
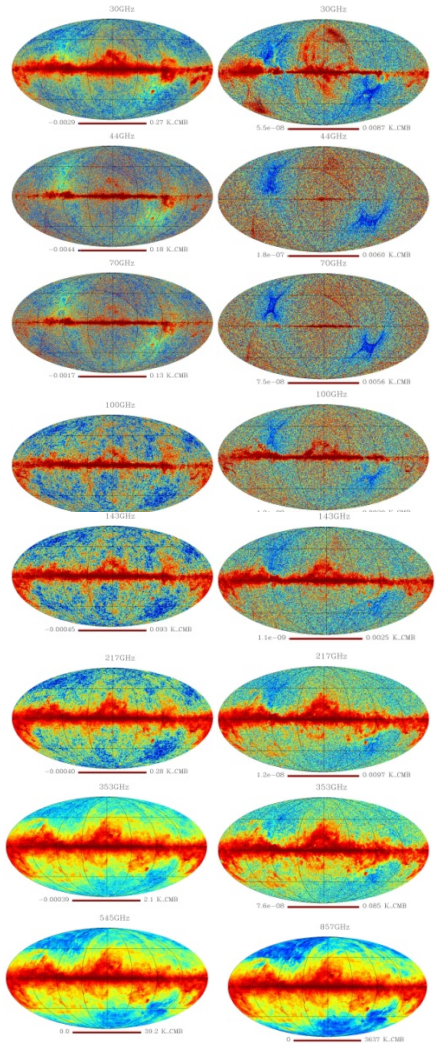


Image for Simulation of the universe taken from article in popular science e-zine: http://www.popsci.com/technology/article/2012-11/video-largest-most-hi-res-cosmological-simulations-known-universe

These codes are also on a NERSC PILOT project and a partnership for a Data Workflow Portal (PDACS)

Simulations for Science



One simulated realization of the temperature and polarization of the sky as observed by Planck at each of its 9 observing frequencies (2 unpolarized).

- The analysis of Cosmic Microwave Background data depends on computationally challenging simulations with up to 10,000 realizations of the entire experiment for Monte Carlo studies.
- Researchers generated the first comprehensive simulation of the ongoing ESA/NASA Planck mission, including 100 MC realizations.
- This ran on up to 100,000 cores of NERSC's *Hopper* supercomputer, taking 500,000 CPU-hrs and generating 35TB of data.
- This simulation is now being used to validate the ongoing analysis of the real Planck data in preparation for their release in January 2013.

Julian Borrill – Computational Cosmology Center, Berkeley Lab (for the US Planck team)

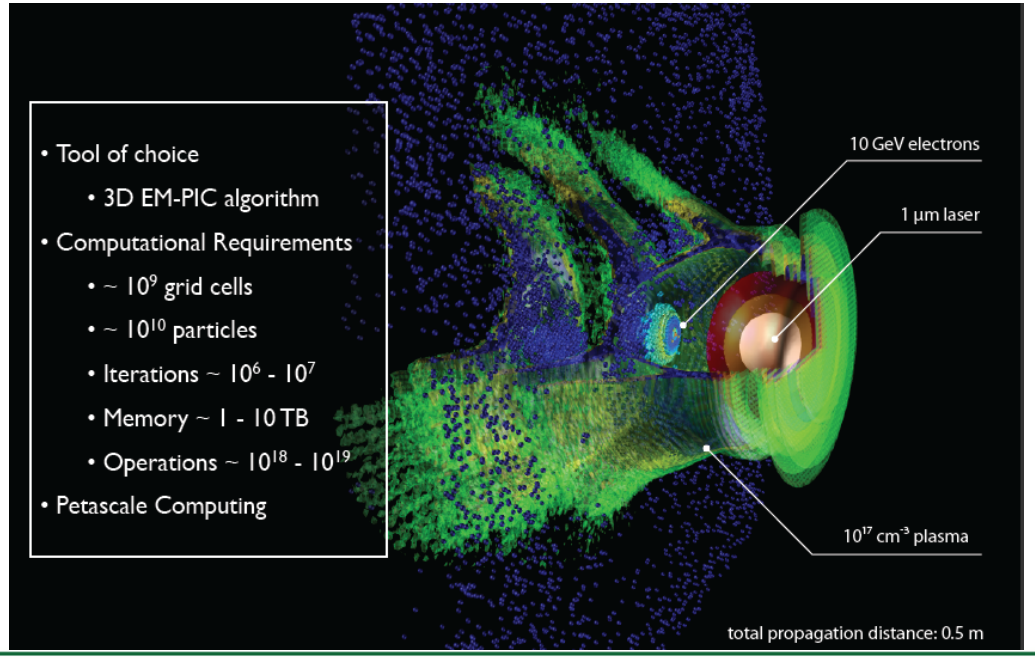
HEP and Accelerator Stewardship

HEP has invested in particle Accelerator R& D for decades to access physics at the Highest energies and this effort continues.

HEP has responsibility to work on a national stewardship program for accelerators. Plan and related activities in process.

Modeling and Simulation enabled by HPC and NERSC are important for HEP research and also stewardship activities

Image : SciDAC Project (ComPASS)



Community Participation in Program Development

- As we continue with Science on all 3 frontiers - we need active participation of our community in the development of the science case, with lab leadership in the background
- A DPF Planning Process is currently in progress in partnership with DOE/NSF, supported by all the Labs
- Our goal includes increasing connections to other SC programs such as material science and computing and developing new technologies for use by HEP and for transferring HEP expertise to other fields
- The Computing Frontier (CF) of the DPF effort is working with the three science frontiers to understand and address the science, computing and infrastructure challenges for HEP
- They (CF) are meeting here for information exchange with ASCR, NERSC & Leadership Computing Facilities from ANL and ORNL

Energy Frontier Computing

- **What have we learned from 2 years of real LHC data?**

About the hierarchical distributed computing model? About access to data? About frameworks and event storage? About the need to respond to change?

- **What is the Future of Distributed Computing?**

Has the Distributed Computing Model Worked Fully for LHC? Where else Should it be used? Will it be enhanced or replaced by the Cloud or by HPC?

Open Science Grid (OSG) Enables Distributed Computing For Energy Frontier and Beyond

New Technology

- **How do we best make use of "new" technology (and what happens if we don't)?**
- Highly parallel supercomputers, Highly parallel processor chips (multicore), GPUs, Cloud computing
- **Is there a software strategy to handle any (likely) computing architecture of the next several years.**
  - Cannot rewrite software for each hardware change.

Lattice Gauge Theory teams have been at the forefront of evolving computing architectures for years and continue to work with industry and advanced prototypes

Cosmic Frontier and Accelerator Modeling teams are also engaged in availing of GPUs and other evolving technology

Connections Across Frontiers

- **Experiments usually develop their own computing systems (software and hardware)**
  - Often seems the shortest path for their special needs
  - But does this lead to duplication or "reinventing the wheel"?
  - Is there an argument for more common development of software in HEP? And/Or use of shared processing and storage systems?
  - If so, what is the best path toward this goal?
  - A common software base is an important goal for the field
  - **Recent efforts to restructure GEANT4 for mutli-core machines underway in partnership with ASCR, will support all frontiers**

Other Outstanding Questions

Are there overlaps in the computing & data needs for the three Frontiers and that may allow exchange and even consolidation of some expertise and resources across them?

How long must data be preserved and what are the technical and intellectual challenges involved?

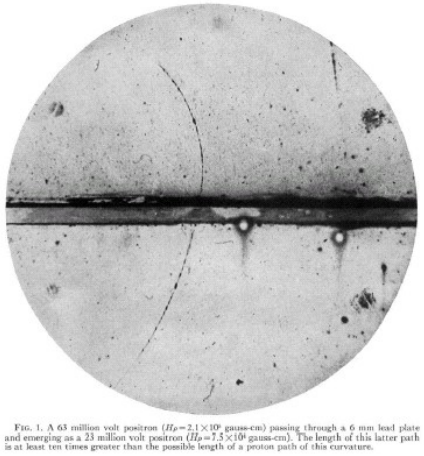
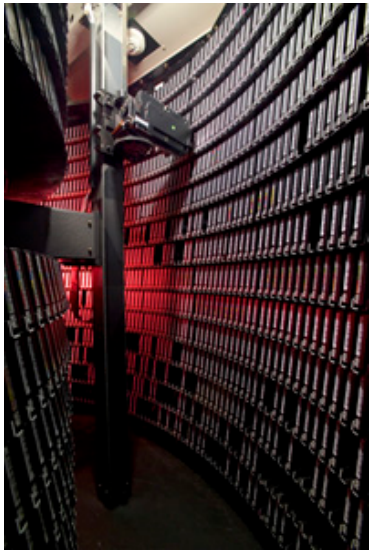


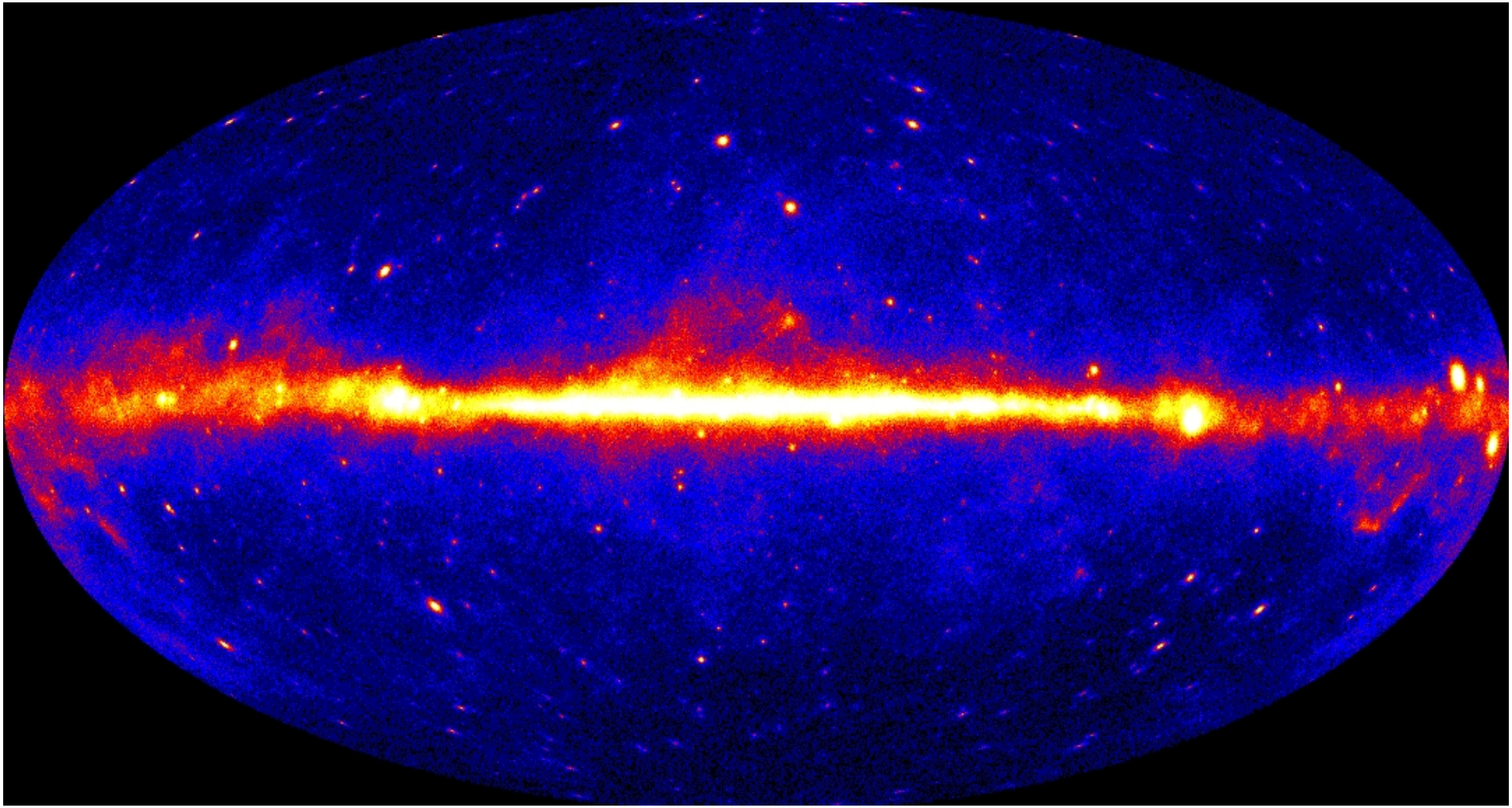
FIG. 1. A 63 million volt positron ($H\rho = 2.1 \times 10^5$ gauss-cm) passing through a 6 mm lead plate and emerging as a 23 million volt positron ($H\rho = 7.5 \times 10^4$ gauss-cm). The length of this latter path is at least ten times greater than the possible length of a proton path of this curvature.



Looking Forward

- HEP is an exciting program pushing ahead all three scientific frontiers.
- After decades of 'We have to find the Higgs Boson' -
- *We have now found* 'A Higgs Like Boson'……
- *We have also found* a long sought neutrino mixing angle θ_{13}
- Our success has always been tied to advances in computing and other technology
- The external world of computing is changing now as fast as it ever has and should open paths to knowledge in physics
- HEP needs to continue to respond to computational challenges posed both by our research demands and by external developments
- More commonality, consolidation, and community planning may be a path for future computing systems in HEP
  - Risk-taking and results are not mutually exclusive
  - The next chapter is yours to write…..

The Universe Awaits



The Universe viewed in Gamma Ray Photons