U.S. DEPARTMENT OF ENERGY | Office of Science

Transforming Geant4 for the Future

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Outline

Geant4 and its importance to High Energy Physics

The “Transforming Geant4 for the Future” workshop

Findings and Path Forward

The Energy Frontier

The Large Hadron Collider is the world's largest particle accelerator.

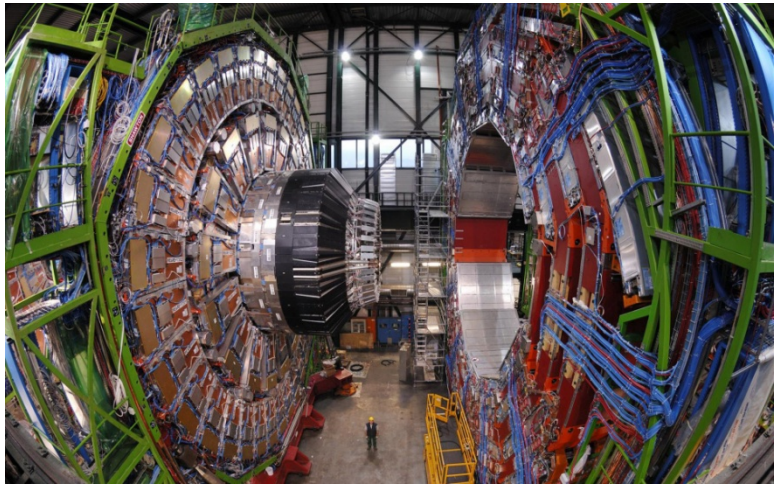
- **It collides beams of protons at 8 TeV.**
- **Possibly the largest machine of any kind.**

There are four large experiments there:

- **ATLAS & CMS (general purpose)**
- **ALICE & LHCb (specialized)**

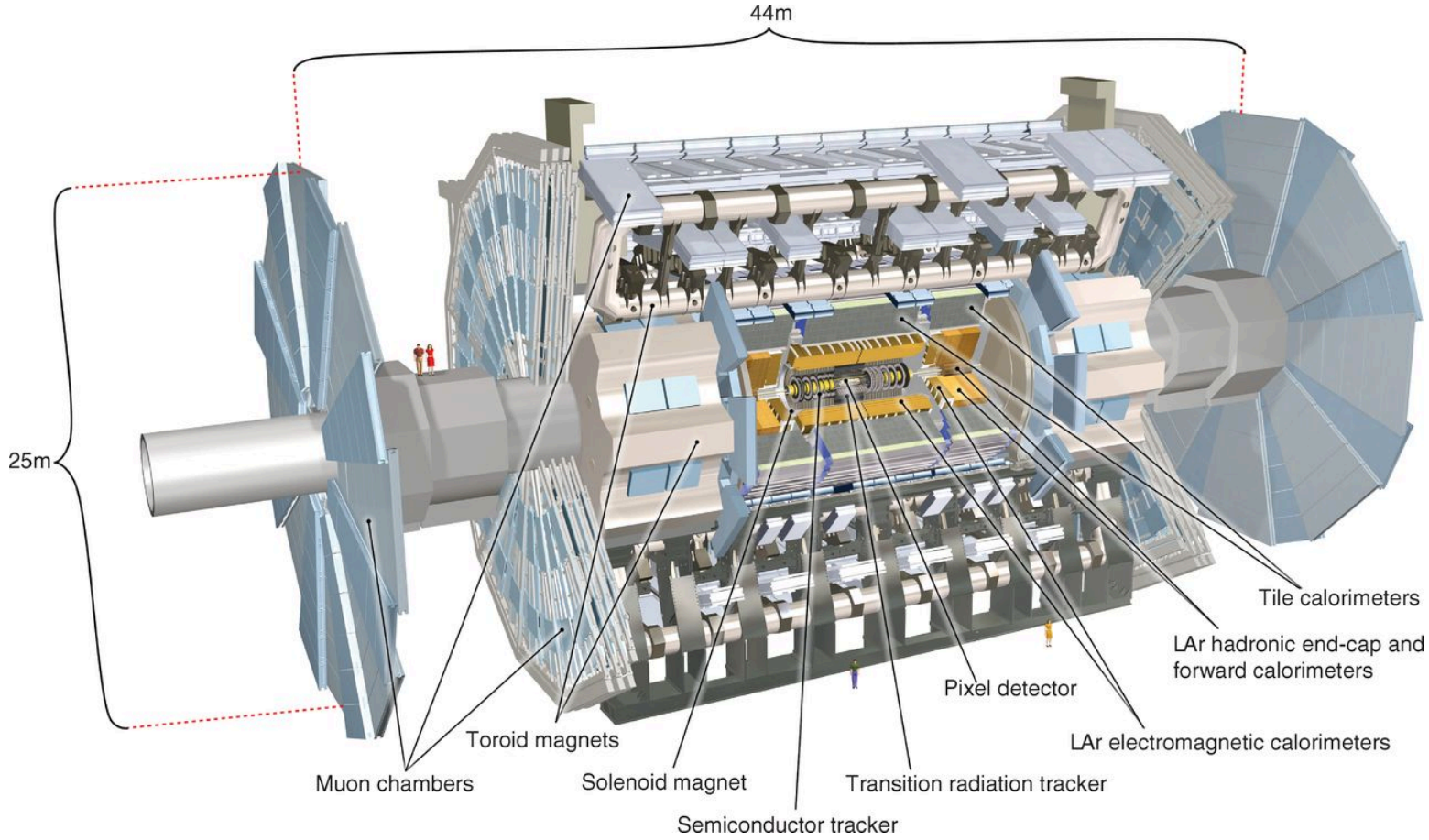
The experiments intend to shed light on several fundamental questions:

- **Why is the weak nuclear force so weak? The "Higgs mechanism" is one answer to this.**
- **What is the Dark Matter (80% of the universe?)**
- **Why is the universe made out of matter, not antimatter?**
- **Why is gravity so much weaker than the other forces?**



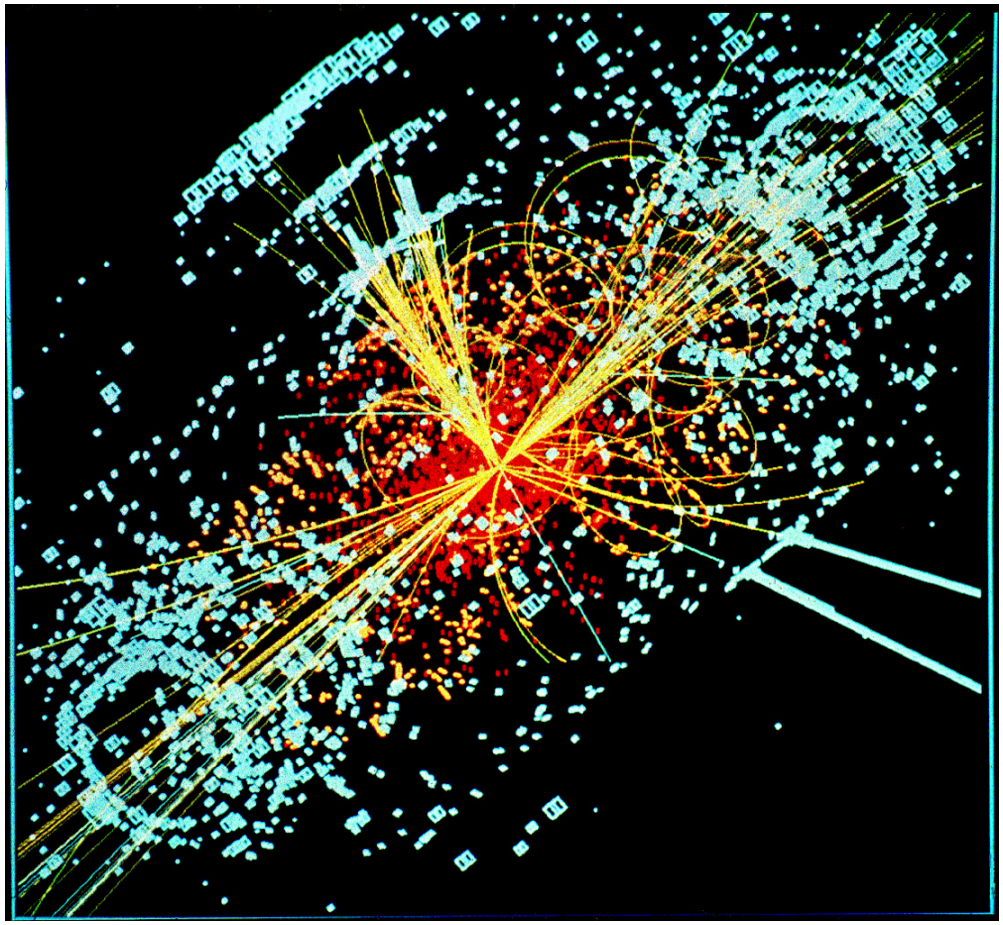
The ATLAS Detector

It takes a lot of "stuff" to detect particles!



Science, Vol. 338, No. 6114, December 2012.

Simulated Higgs Event in CMS



Geant4 (GEometry ANd Tracking)

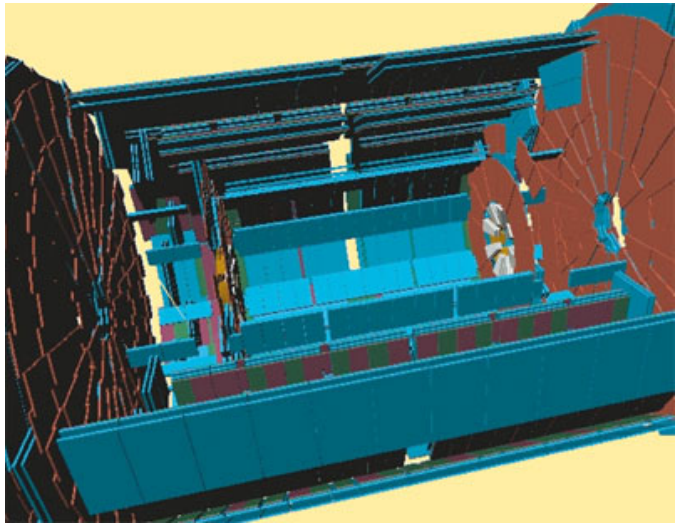
Geant4 is a C++ tool kit that tracks particles through matter, breaking the particle motion into small segments, applying appropriate physical processes and probabilities at each segment.

- These processes can destroy old particles, modify state or create new ones.
- Processes include atomic processes like ionization and excitation, decay processes, photonic transitions, secondary emission, etc.
- The wide coverage of physical processes comes from mixture of theory-driven, parameterization, and empirical formulae.
- Successor to Geant3, the Geant4 Project began in 1994 with the first public release in 1998.

Geant4 is Unique

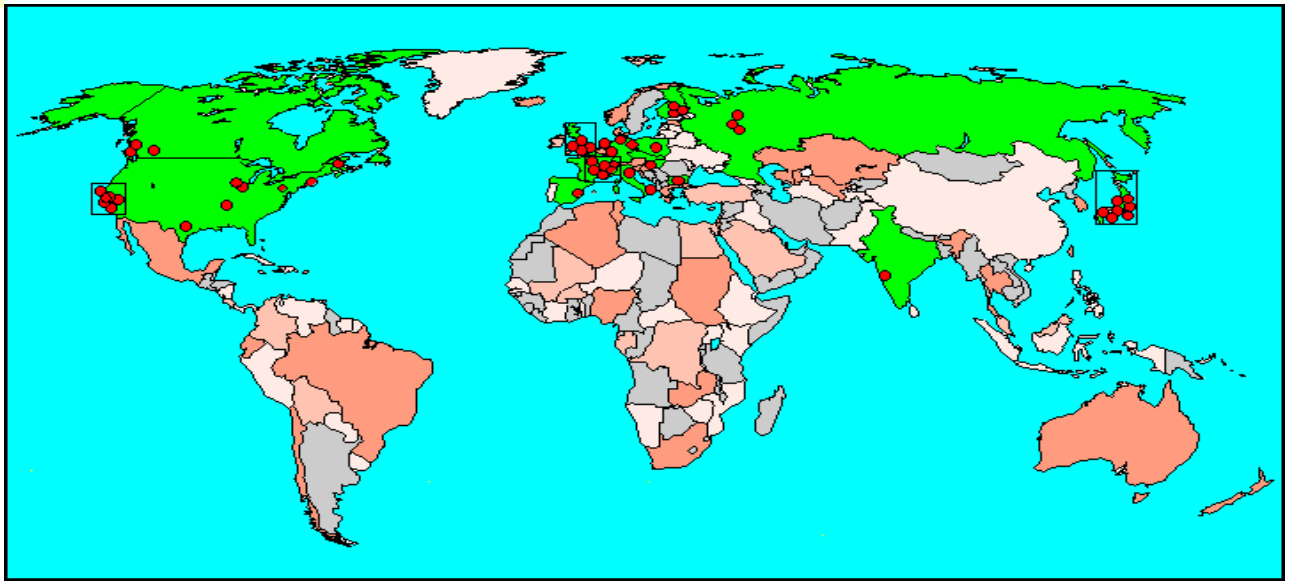
Geant4 is distinguished from other Monte Carlo Particle Transport codes by

- The comprehensive suite of physics processes and particle types.
- The complexity of geometrical descriptions leads to realistic representations.
- A collaborative open source model leveraging international expertise.



Enables the user to select physics processes/models and choice of GUI, visualization, persistency, and histogramming technologies.

Geant4 is an International Collaboration



TRIUMF

Lebedev

J.W.Goethe Universität

Collaborators also from non-member institutions, including
Budker Inst. of Physics
IHEP Protvino
MEPHI Moscow
Pittsburg University

Geant4 is Big

Computation

- Large ensembles of sequential jobs
- Runs on a worldwide Grid of processors
- Significant Computing Hardware investment worldwide in order to satisfy demand

Data

- HEP has more simulated than collected data
- LHC data is currently ~100 PB and rapidly increasing

Challenges for Geant4's Future

Geant4 is a sequential C++ toolkit

- MC runs are ensembles dispatched to the Grid
- It can take months to simulate a billion particles
- Code as it stands now is extremely "serial"

CPU capability has plateaued

- Dennard scaling has ended

Potential to constrain progress in HEP if we don't react

Joint ASCR/HEP Workshop

"Transforming Geant4 for the Future" workshop was held in Rockville, MD on May 8th-9th 2012.

Website: http://www.orau.gov/transformwkshop2012/

Goals:

- Review status, successes and limits of Geant4
- Determine challenges posed by emerging architectures
- Consider opportunities in algorithms and optimization
- Ascertain research for robust, sustainable code
- Create foundation among ASCR and HEP investigators
- Understand and not duplicate international efforts
- Explore transformative advances via HEP-ASCR collaboration.

Participants

- Co-chaired by Bob Lucas (USC) and Rob Roser (Fermilab)
- 50 participants from HEP and ASCR communities
- Ceren Susut (ASCR) and Lali Chatterjee (HEP)

David	Asner	Pacific Northwest National Laboratory
Amber	Boehnlein	SLAC National Accelerator Laboratory
Richard	Brower	Boston University
Paolo	Calafiura	Lawrence Berkeley National Laboratory
Philippe	Canal	Fermi National Accelerator Laboratory
Lali	Chatterjee	DOE Office of High Energy Physics
Gene	Cooperman	Northeastern University
Terence	Critchlow	Pacific Northwest National Laboratory
Pedro	Diniz	University of Southern California
V. Daniel	Elvira	Fermi National Accelerator Laboratory
Michael	Ernst	Brookhaven National Laboratory
Robert	Fowler	University of North Carolina
Salman	Habib	Argonne National Laboratory
Andrew	Hanushevsky	SLAC National Accelerator Laboratory
Jim	Kowalkowski	Fermi National Accelerator Laboratory
David	Lange	Lawrence Livermore National Laboratory
Randall	Laviolette	DOE Office of Advanced Scientific Computing Research
Thomas	LeCompte	Argonne National Laboratory
Steven	Lee	DOE Office of Advanced Scientific Computing Research
Qing	Liu	Oak Ridge National Laboratory
Bob	Lucas	University of Southern California
David	Malon	Argonne National Laboratory
Gabriel	Marin	Oak Ridge National Laboratory
John	Mellor-Crummey	Rice University
Richard	Mount	SLAC National Accelerator Laboratory
Esmond	Ng	Lawrence Berkeley National Laboratory
Boyana	Norris	Argonne National Laboratory
Lucy	Nowell	DOE Office of Advanced Scientific Computing Research
Bruce	Palmer	Pacific Northwest National Laboratory
Karen	Pao	DOE Office of Advanced Scientific Computing Research
Marc	Paterno	Fermi National Accelerator Laboratory
Joseph	Perl	SLAC National Accelerator Laboratory
Allan	Porterfield	University of North Carolina
Lawrence	Price	DOE Office of High Energy Physics
Michael	Procario	DOE Office of High Energy Physics
Kenneth	Roche	Pacific Northwest National Laboratory
Rob	Roser	Fermi National Accelerator Laboratory
Paul	Ruth	University of North Carolina
Allen	Sanderson	University of Utah
Elizabeth	Sexton-Kennedy	Fermi National Accelerator Laboratory
Panagiotis	Spentzouris	Fermi National Accelerator Laboratory
Ceren	Susut	DOE Office of Advanced Scientific Computing Research
Timothy	Tautges	Argonne National Lab
Craig	Tull	Lawrence Berkeley National Laboratory
Brian	Van Straalen	Lawrence Berkeley National Laboratory
Torre	Wenaus	Brookhaven National Laboratory
Dennis	Wright	SLAC National Accelerator Laboratory
John	Wu	Lawrence Berkeley National Laboratory

Agenda

May 8

8:00-8:30 am	Registration Open Continental Breakfast	
8:30-9:00 am	Welcome and Goals ASCR and HEP	Dan Hitchcock, ASCR Jim Siegrist, HEP
	Conference Chairs	Bob Lucas, USC Rob Roser, FNAL
9:00-9:30 am	Geant4 overview	Amber Boehnlein, SLAC
9:30-9:45 am	Geant4 Collaboration and History	Makoto Asai, SLAC
9:45-10:15 am	Physics uses of Geant4	Tom LeCompte, ANL
10:15-10:45 am	Break	
10:45-11:15 am	Trends in multi-core architecture and optimization opportunities	Rob Fowler, UNC
11:15-11:45 am	Exploiting concurrency in Geant4	Jim Kowalkowski, FNAL
11:45 – 12:15 pm	Scientific data management and analysis challenges	Rob Ross, ANL
12:15-12:30 pm	Charge to Workshop Participants	Bob Lucas, USC Rob Roser, FNAL
12:30-1:45 pm	Lunch on your own	
1:45-3:15 pm	Parallel Sessions Multi-core Optimization Scientific Data Handling and Analysis	
3:15-3:30 pm	Break	
3:30-5:00 pm	Resume sessions	
5:00 – 5:30 pm	Report of Parallel Session progress	
5:30 pm	Adjourn for the day	

May 9

8:00-8:30 am	Continental Breakfast
8:30-10:30 am	Resume breakout discussions
10:30-11:00 am	Break
11:00-12:00 pm	Plenary reports from discussions
12:00-12:15 pm	Closing remarks and path forward
12:15-1:30 pm	Workshop adjourn Working lunch for organizers and chairs
1:30 pm	Report preparation

Multi-core Optimization

Daniel Elvira, (FNAL)
Robert Fowler, (UNC)

Scientific Data Handling and Analysis

Gene Cooperman, (Northeastern University)
Rob Ross (ANL)

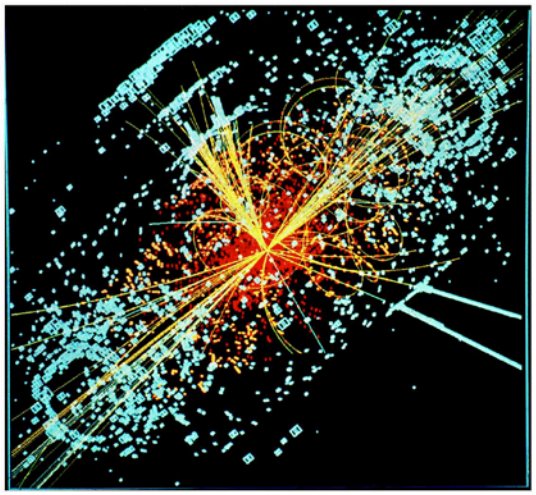
Report

An ASCR/HEP joint program in SciDAC model to:

- Explore existing tools
- Strengthen US efforts to refactor/rearchitect
- Plan and implement necessary validation and testing processes
- Develop efficient I/O strategies
- Explore the possibility of using higher-level abstraction
- Explore how to handle petabyte-to-exabyte scale data with much lower human effort

Transforming Geant4 for the Future

Report from the Workshop on Transforming Geant4 for the Future
September 2012



http://science.energy.gov/~/media/ascr/pdf/research/scidac/GEANT4-final.pdf

Path Forward

- **Optimizations Within the Geant4's Current Framework**
- **Refactoring Demonstrations and Prototypes**

2-year joint ASCR/HEP pilot study is underway.
HEP effort is led by Rob Roser (Fermilab and SLAC).
ASCR effort is led by Bob Lucas (USC, ANL and UNC from SUPER SciDAC Institute).

THANK YOU!

Special thanks to Rob Roser and Bob Lucas for help with these slides and Lali Chatterjee for helpful discussions.