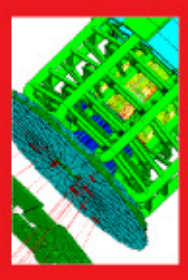
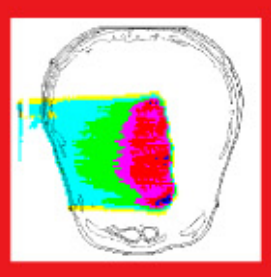
Detector Design & Physics Simulation

Simulation programs play a fundamental role in optimizing the design of detectors used in particle physics experiments. Once detectors have been built, simulation programs validate physics analysis procedures by modeling both already-known physics processes and the effects of detectors.

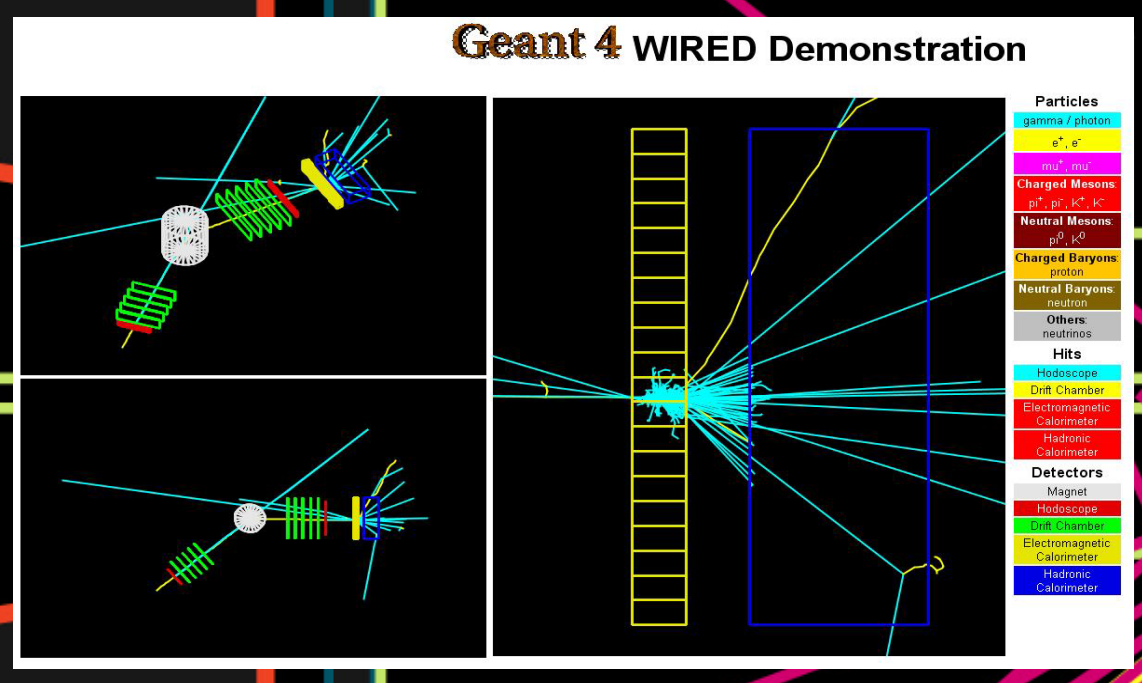




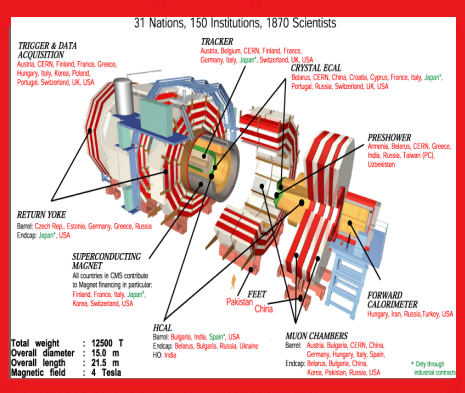
Simulation tools: GEANT4

Taking into account the requirements of new HEP experiments with high complexity, a computer program named GEANT4 was developed by a world wide collaboration of more than 100 physicists and computer scientists associated with particle physics. GEANT4 uses the most modern software engineering technologies. This software toolkit was designed to simulate particle interactions with matter. It allows one to model in detail the geometry and materials of complex particle detectors, and propagate simulated particles in the presence of magnetic and electric fields.

The GEANT4 users community has recently been expanded to incorporate scientists from the space and medical application fields. GEANT4 is used in space research projects at ESA (European Space Agency) and NASA for estimating radiation doses of astronaut and semiconductor devices in ISS (International Space Station) and other spacecraft. In the medical area, GEANT4 is helping to optimize and redesign cancer treatments ranging from conventional photon-beam radiotherapy to brachytherapy, hadron therapy and boron capture therapy. Like the World Wide Web, GEANT4 is a successful examples of technology transfer from particle physics to the rest of society.



CMS (CERN) Detector



Watch the construction of the main structural components of CMS.

Detector Simulation

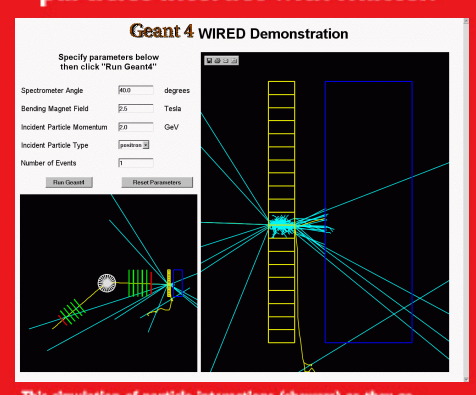
The complexity of the detectors and the size of the data samples pose a challenge to the computer systems and simulation tools needed by modern experiments. For example, the BaBar experiment at SLAC PEP-II has already generated more than 500 million events and this number is continuously growing.

At LHC (Large Hadron Collider) at CERN, the amount of simulated raw data needed by the CMS and ATLAS detectors is estimated to be of the order of tens of Peta (10^{15}) bytes. The large dimensions of the CMS detector, the variety of materials utilized, the complexity of the physics processes involved, and the huge number of electronic channels of its read out system (millions) push the current computing and simulation tools to the limit and encourage new developments.

Data Analysis

A high energy collision like the one shown above, observed by the DZERO detector at the Tevatron-Fermilab, involves the detection of thousands of tracks and energy depositions which need to be simulated from basic physics processes to tune the reconstruction programs and distinguish interesting events from background during data analysis.

Try to see how elementary particles interact with matter.



This simulation of particle interactions (showers) as they go through the detector is implemented in GEANT4. You can specify interactively the type and energy of the particle, as well as the detector material.