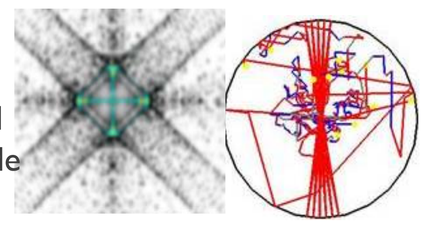
Geant4 Software

Introduction

Geant4 is being used in many different fields where simulation of radiation passing through and interacting with matter is critical. User domains include: high energy and nuclear physics, medical physics and space engineering, shielding protection and more. Its abstract layers based on robust OO design enables flexibility and extendibility of the code, and its open-source code and open collaboration have allowed substantial extensions of the code. New features are constantly added to the code, while increasing attention is paid to improving software performance and robustness by employing cutting-edge software engineering technologies.

New physics

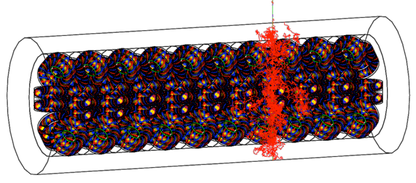
The flexibility and extendibility of Geant4 design allows it to be applied to new physics domains. These include the physics of condensed matter (phonon transportation in crystals, drift of electrons and holes in semiconductors) and processes for bio-chemical substances and DNA.



SuperCDMS Cryogenic Dark Matter Search seeks to directly detect dark matter. Geant4 models the caustic pattern in a Ge crystal (left) by tracking individual phonons (right)

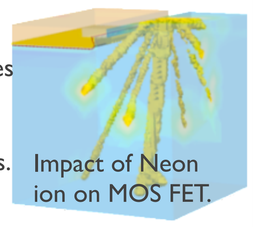
Reaction	Reaction rate (10^{10} M^{-1} s^{-1})
$H^{\bullet} + e^-_{aq} + H_2O \rightarrow OH^- + H_2$	2.65
$H^{\bullet} + {}^{\bullet}OH \rightarrow H_2O$	1.44
$H^{\bullet} + H^{\bullet} \rightarrow H_2$	1.20
$H_2 + {}^{\bullet}OH \rightarrow H^{\bullet} + H_2O$	4.17×10^{-3}
$H_2O_2 + e^-_{aq} \rightarrow OH^- + {}^{\bullet}OH$	1.41
$H_3O^+ + e^-_{aq} \rightarrow H^{\bullet} + H_2O$	2.11
$H_3O^+ + OH^- \rightarrow 2\,H_2O$	14.3
${}^{\bullet}OH + e^-_{aq} \rightarrow OH^-$	2.95
${}^{\bullet}OH + {}^{\bullet}OH \rightarrow H_2O_2$	0.44
$e^-_{aq} + e^-_{aq} + 2\,H_2O \rightarrow 2\,OH^- + H_2$	0.50

Reactions of radicals available in Geant4.

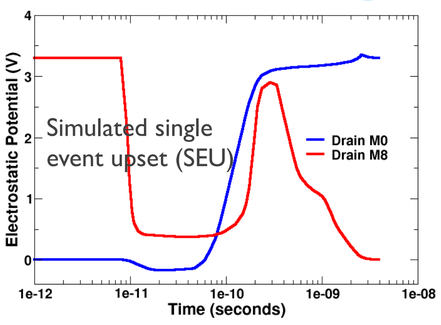


Energy depositions in DNA structure.

Geant4 performs mission critical studies of radiation and charging effects on spacecraft electronics.

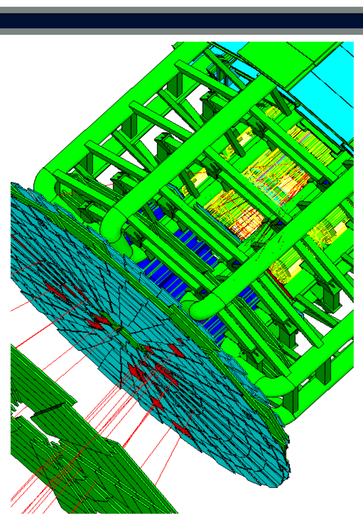


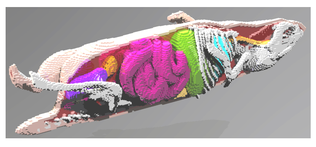
Impact of Neon ion on MOS FET.



Geometry

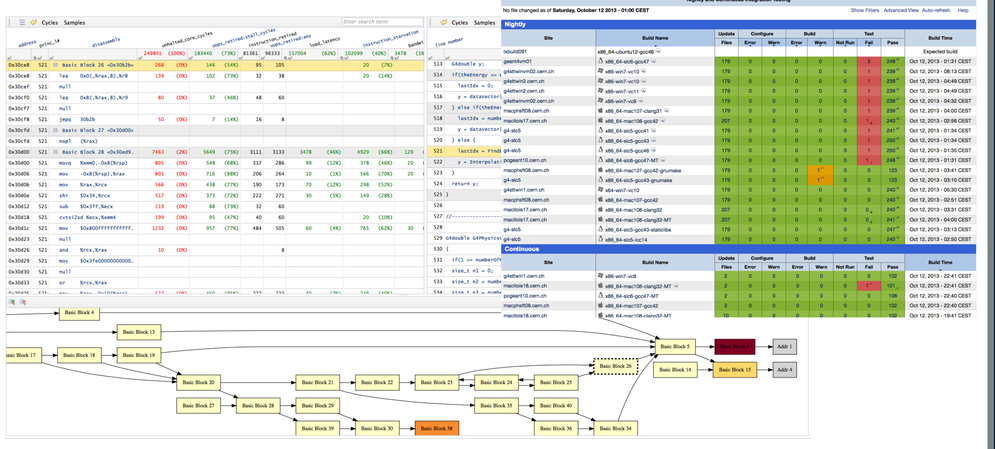
The flexibility and extendibility of Geant4 design also enables handling rich collection of shapes including CSG (Constructed Solid Geometry), Boolean operation, Tessellated solid, etc. and the user can easily add new shapes. Geant4 geometry navigation can deal with setups up to billions of volumes with automatic optimization. In addition, geometry models can be 'dynamic', i.e. changing the setup at run-time, e.g. "moving objects".





Software quality assurance

Geant4 uses modern tools to manage the code and improve code quality: from handling issues with JIRA to continuous testing integration with CTest/CDash, profiler based optimizations, Quality/Assurance (Coverity, Valgrind, etc.), and IDE integration (Xcode, Eclipse, VisualStudio).



New era - Geant4 version 10 series

The new release of Geant4 – Version 10.0 (December 2013) include event-level parallelism via multi-threading. To efficiently use new computing architectures the workload of a single job is sub-divided to many worker threads each responsible for the simulation of one or more events. Version 10.0 has already shown good scalability on a number of different architectures: Intel Xeon servers, Intel Xeon Phi co-processors and low-power ARM processors

- Proof of principle
- Identify objects to be shared
- First testing

- API re-design
- Example migration
- Further testing
- First optimizations

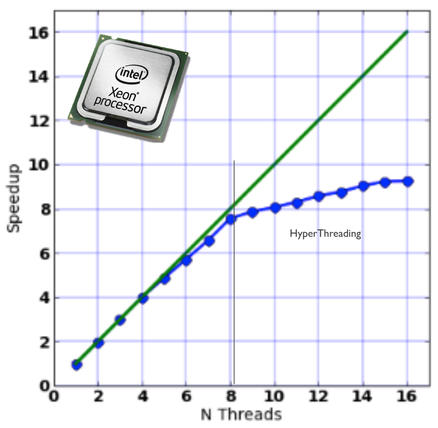
- Further refinements

G4MT prototype-9.4 (2011) → G4MT prototype-9.5 (2012) → G4 10.0.beta (June 2013) → G4 10.0 (Dec. 2013) → G4 10 series (2014~)

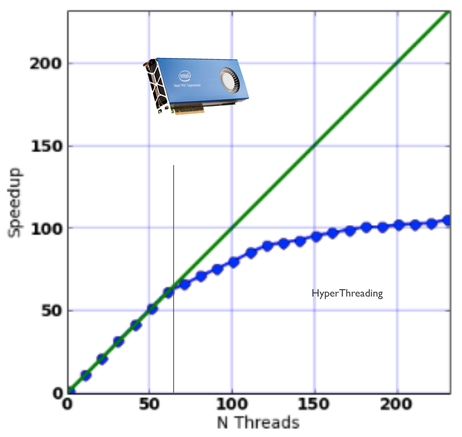
- MT code integrated into G4

- Production ready
- Public release

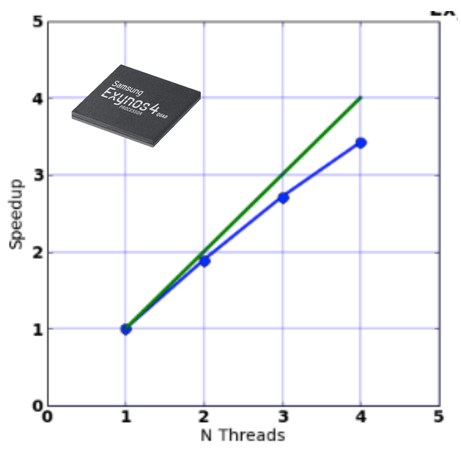
Intel Xeon L5520 @ 2.27GHz



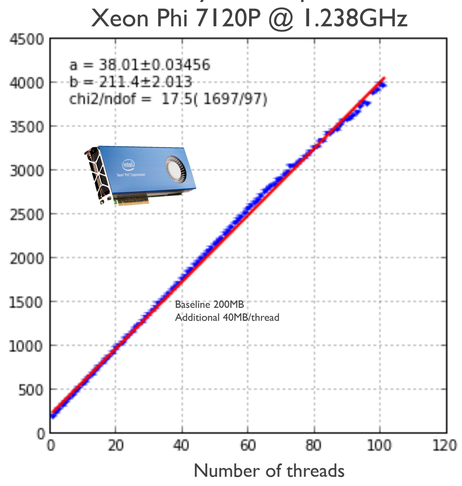
Intel Xeon Phi 7120P @ 1.238GHz

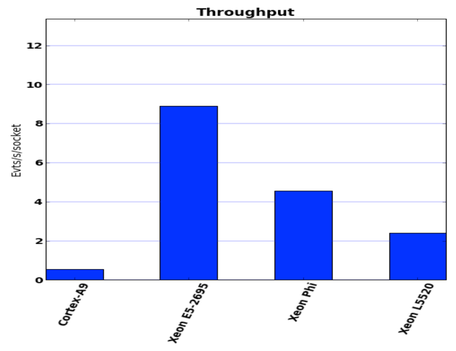


Exynos 4412 Quad-Core @ 1.7 GHz



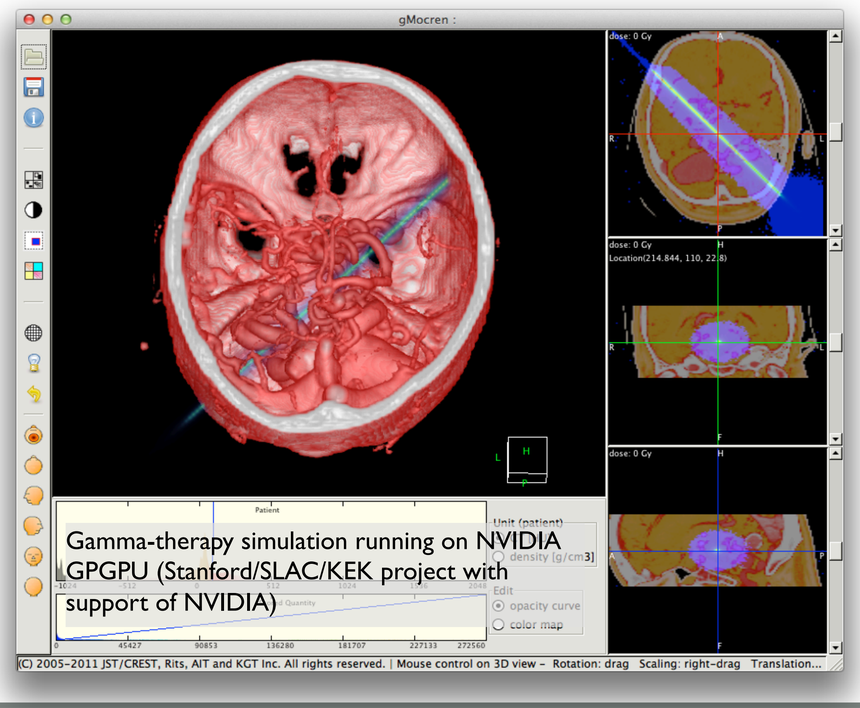
Total memory consumption of Intel Xeon Phi 7120P @ 1.238GHz





Investments for the future

Geant4 collaboration members are participating in various explorations of emerging technologies. These technologies include GPU/CUDA, OpenCL, OpenACC, vectorization, DSL, etc.



Gamma-therapy simulation running on NVIDIA GPGPU (Stanford/SLAC/KEK project with support of NVIDIA)