Comments on simulation challenges

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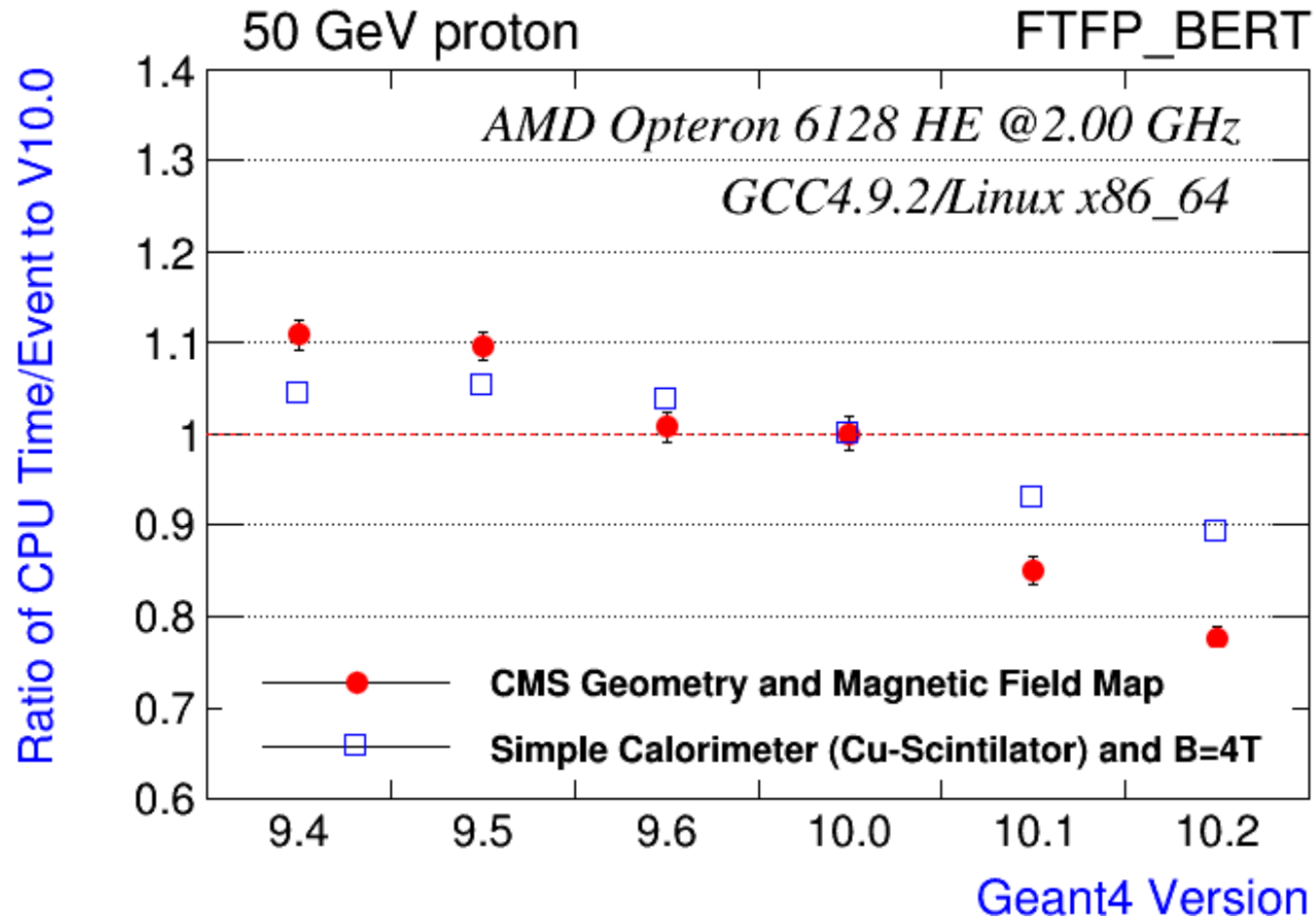U.S. DEPARTMENT OF ENERGY

Office of Science

Evolution of Geant4

- Dec '94 - Project start ; Apr '97 - First alpha release ; Jul '98 - First beta release
- Dec '98 - First Geant4 public release - version 1.0
- Dec '00 : Geant4 version 3.0 release
  - Migration from RogueWave to STL
- Apr '03 – Geant4 version 5.1 release
  - Introducing Cuts-per-region
- Dec '04 – Geant4 version 7.0 release
  - Migration from *math.h* to *cmath.h*
- Dec '05 – Geant4 version 8.0 release
  - Revising General fast simulation (shower parameterization) framework
- Jun '07 – Geant4 version 9.0 release
  - Start offering pre-packaged physics lists
  - Introducing Parallel world navigation
- Dec '08 – Geant4 version 9.2 release
  - Introducing Command-based scorer
- Dec '10 – Geant4 version 9.4 release
  - Introducing Layered mass geometry
- Dec '13 – Geant4 version 10.0 release
  - Introducing Multithread
- We currently provide one public release every year.
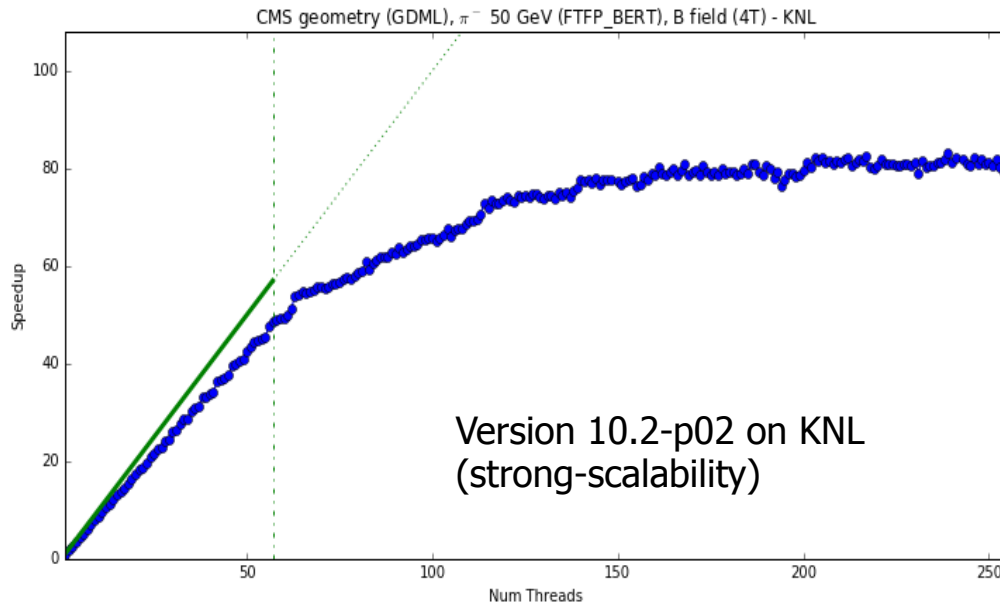
Geant4 Version 10 Series

- Major release Geant4 version 10.0 was released on December 6th, 2013.
  - The first major release since June 2007.
- There are several highlighted features including
  - Multithreading capability with event parallelism
  - Isomer production
  - Enhancements in biasing options
  - Introduction of phonon transport with a new concept of crystal
  - Support for GNUmake and LHEP and CHIPS physics models are ceased
- Following version 10 series were released with lots of improvements in both physics and computing aspects.
- Version 10.3 on December 9th, 2016 is the current version

G4MT prototype-9.4 (2011)	G4MT prototype-9.5 (2012)	G4 10.0 (2013)	G4 10.1 (2014)	G4 10 series (2015~)
• Proof of principle • Identify objects to be shared • First testing	• MT code integrated into G4	• Production ready • Public release	• Memory reduction • First optimizations	• Further refinements

First of all, we are making it faster!

50 GeV proton — FTFP_BERT
AMD Opteron 6128 HE @2.00 GHz
GCC4.9.2/Linux x86_64

Ratio of CPU Time/Event to V10.0 vs Geant4 Version

- ● CMS Geometry and Magnetic Field Map
- □ Simple Calorimeter (Cu-Scintilator) and B=4T

ATLAS : "The 10% CPU improvement we gain from the move from G4 9.6 to 10.1 is invaluable to the collaboration."

Many core, many thread

CMS geometry (GDML), π^- 50 GeV (FTFP_BERT), B field (4T) - KNL

Version 10.2-p02 on KNL
(strong-scalability)

- For three years we have provided support for running Geant4 on KNC.
  - ATLAS, CMS successfully multithreaded
- We will soon extend our support to KNL.
  - With KNL, thanks to x86 binary compatibility including the use of gcc, work-flow is tremendously simplified.

| System	Time to completion (5k events)
Xeon E5-2620 @ 2.1 GHz (12 cores, 24 threads)	570 s
KNC (31s1P) @ 1.0 GHz (228 threads)	1000 s
KNL (7210, quadrant mode, MCDRAM only) @ 1.3 GHz (255 threads)	378 s (x3 improvement w.r.t. KNC)
KNL (shared library)	480 s (25% slower than static library)

More memory-efficient, more HPC friendly

Version	Intercept	Memory/thread
9.6 (seq.)	113 MB	(113 MB)
10.0.p02-seq	170 MB	(170 MB)
10.0.p02-MT	151 MB	28 MB
10.3.beta-MT	148 MB	9 MB

Memory space required for Intel Xeon Phi 3120A
Full-CMS geometry (GDML), 4 Tesla field, 50 GeV pi- (FTFP_BERT)

# of CPU	# of threads	Speed-up factor	efficiency
10	80	79	98. 8%
20	160	158	98. 8%
40	320	317	99. 0%
80	640	626	97. 8%
160	1280	1251	97. 7%
320	2560	2297	89. 7%
640	5120	3555	69. 4%

Tachyon-2 supercomputer @ KISTI (South Korea)
FTFP_BERT physics validation benchmark

- Geant4 has successfully run with a combination of MT and MPI on Mira Bluegene/Q Supercomputer (@ANL) with all of its 3 million threads
  - Full-CMS geometry & field
- I/O is the limiting factor to scale large concurrent threads:
  - Granular input data files, output data/histograms, etc.
  - Targeting also Cori @ NERSC

Next steps
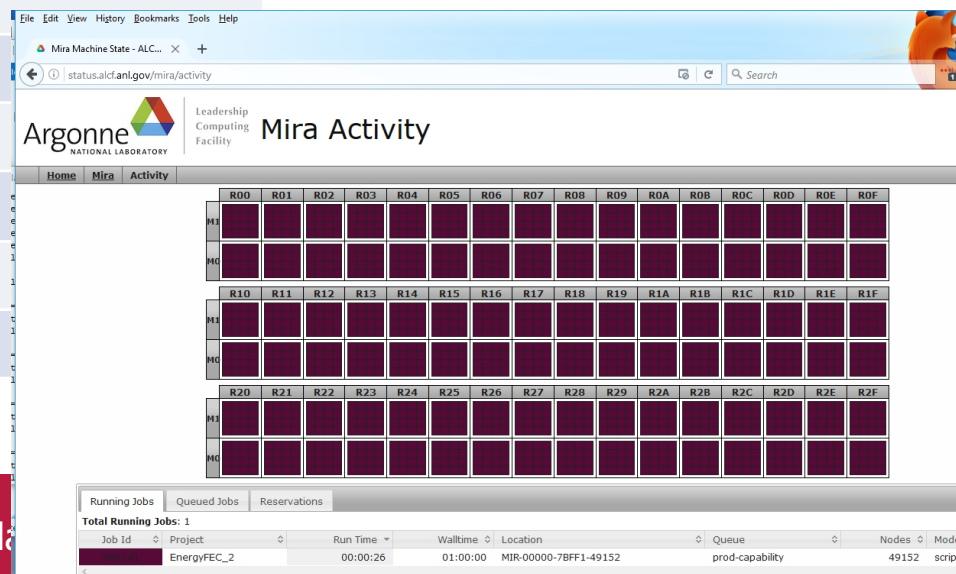
- 2014 was the 20th anniversary of Geant4. After 20 years with several architectural evolutions, Geant4 is still steadily evolving.

  – Latest major evolution was Geant4 version 10.0 released in December 2013 that is the first fully multithreaded large-scale physics software in the world.

  – Next evolution is underway to migrate to the recent C++ standards, C++11/14, that enables us to better manage threads and memories used by threads.

  – New physics models for coming experiments, e.g. hadronic model for multi-TeV regime (for LHC run-II/III/IV), specialized EM model for noble liquid (e.g. liq.Xe) and neutrino physics model (for intensity frontier)

- Many Geant4 collaborators are engaging to several R&D activities to explore the opportunities in MIC, GPU, etc.

- Geant4 is nowadays mission-critical for many users including all the current and near-future HEP experiments. Geant4 will be maintained and continue to evolve for at least next decade.

  – We do appreciate your suggestions/requests.