# Geant4 general status and prospects

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On behalf of the Geant4 Collaboration

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@ LPCC Detector Simulation Workshop

SLAC NATIONAL ACCELERATOR LABORATORY

U.S. DEPARTMENT OF ENERGY

Office of Science

# Version 10.3

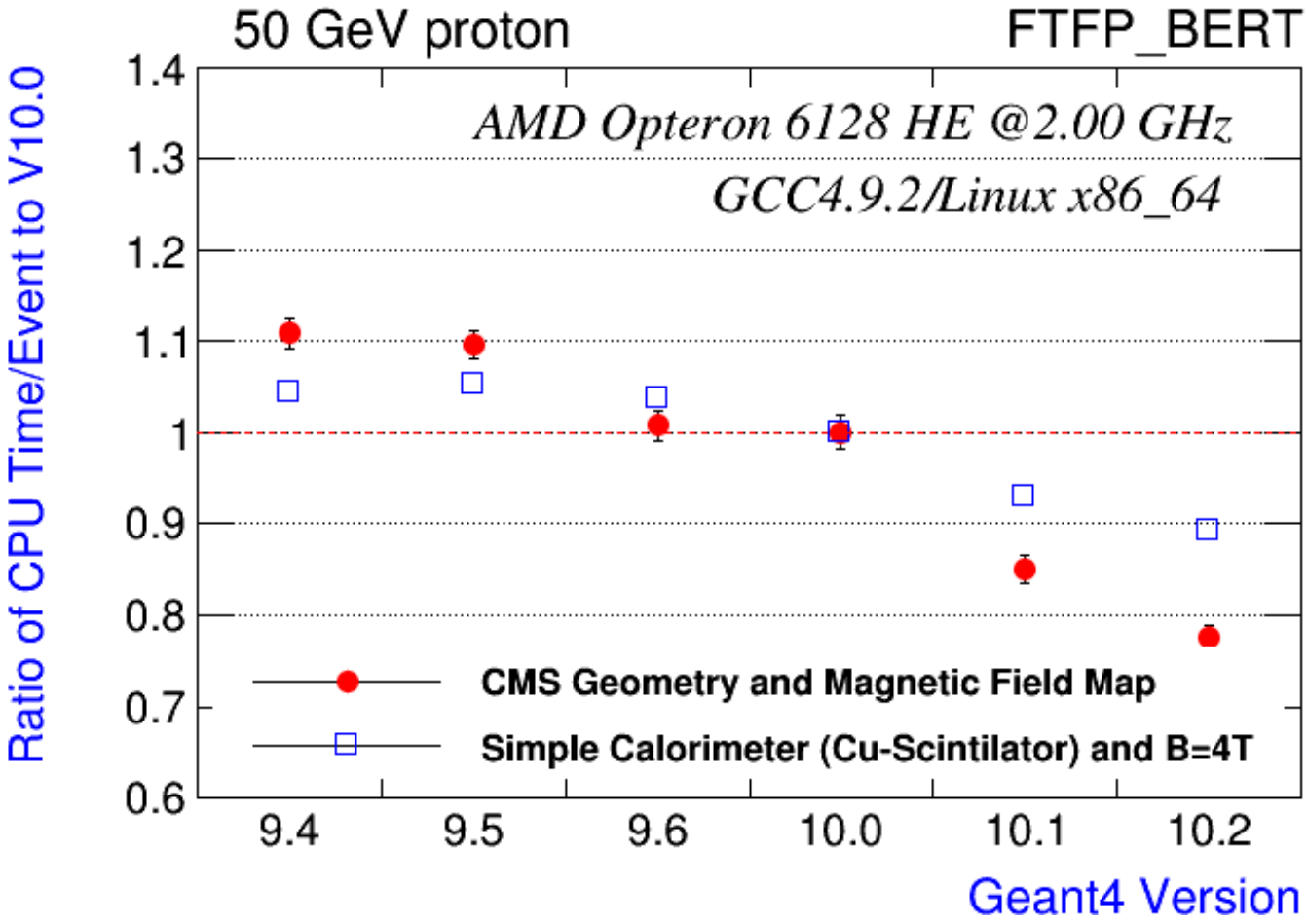
- Released on December 9th, 2016
  - Feb 24th, 2017 – Geant4 10.3-patch01 release
- Compilation using the C++11 Standard is now mandatory.
- CMake 3.3 or higher is required.
- Platforms:
  - Linux, gcc-4.8.5.
    - Tested on 64 bit architectures (Intel or AMD) with CERN CentOS Linux 7 (CC7) (based on CentOS Linux 7).
  - MacOSX 10.12 Sierra with clang-3.8 (Apple LLVM/Clang-8.0.0)
  - Windows-10 with Visual C++ 14.0 (Visual Studio 2015)
- More verified and tested configurations (64 bits):
  - Linux, gcc-4.9.3, gcc-5.3.0, gcc-6.2.0, clang-3.9
  - Linux, Intel-icc 16.0
  - Linux for Intel Xeon Phi with Intel-icc 16.0 (gcc-4.9 compatibility layer)
  - MacOSX 10.10 with clang-3.6, MacOSX 10.11 with clang-3.7
  - Windows-7 with Visual C++ 14.0 (Visual Studio 2015)
    - Note: Windows platforms are supported/verified only for the sequential mode. Multithreading capability is not yet supported on Windows.

# Recent retroactive patch releases

- Dec 5th, 2014 – Geant4 version 10.1 release
  - Feb 5th, 2016 - Geant4 10.1-patch03 release
- Dec 4th, 2015 – Geant4 version 10.2 release
  - Jun 17th, 2016 - Geant4 10.2-patch02 release

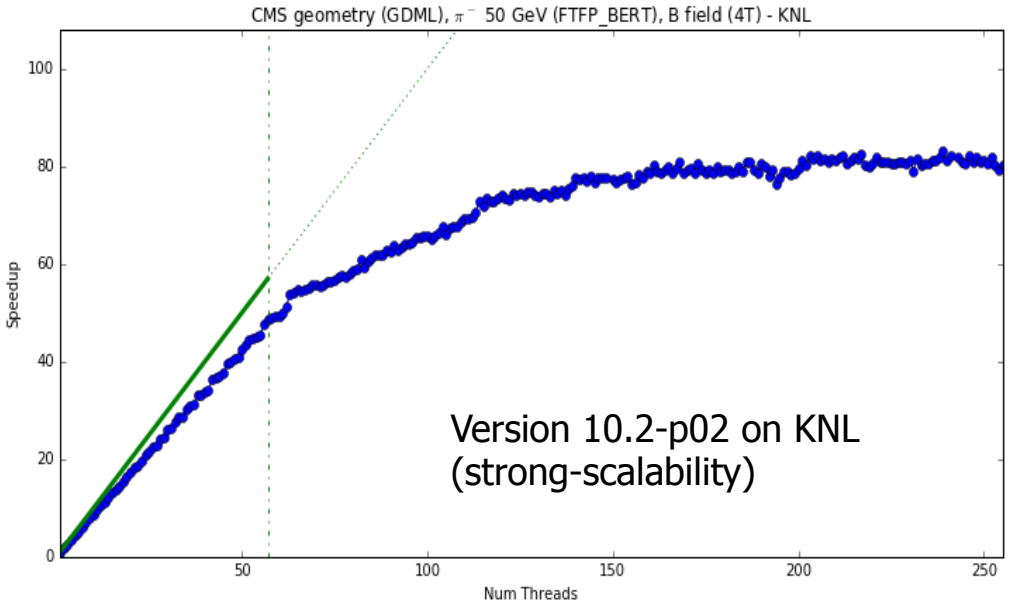
- Versions 10.1 and 10.2 will be supported with necessary patches at least for 2017.
  - Version 10.1 is kept compliant with C++98.

# We are making it faster!




*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




- 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

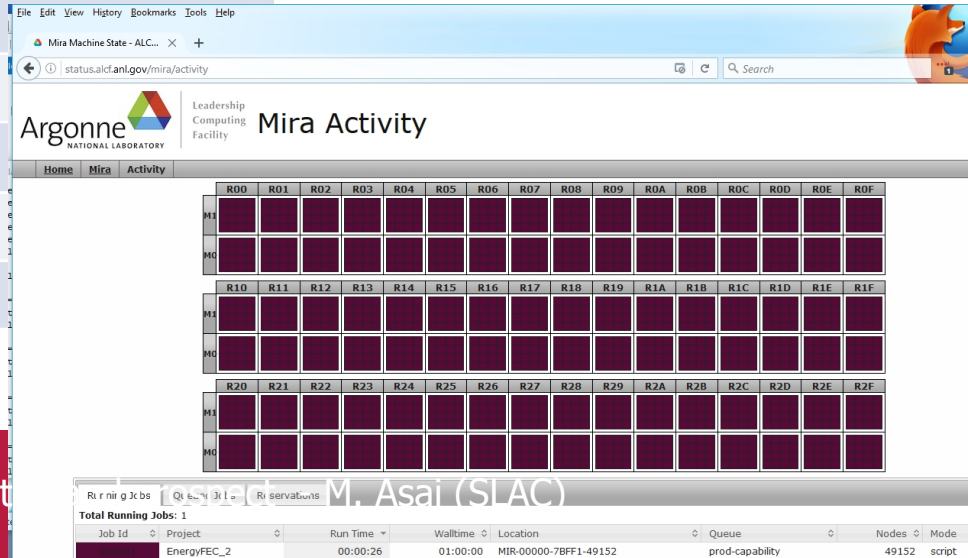
| Version | Intercept | Memory/thread |
|---|---|---|
| 9.6 (seq.) | 113 MB | (113 MB) |
| 10.0.p02-seq | 170 MB | (170 MB) |
| 10.0.p02-MT | 151 MB | 28 MB |
| 10.3.beta-MT | 148 MB | 9 MB |

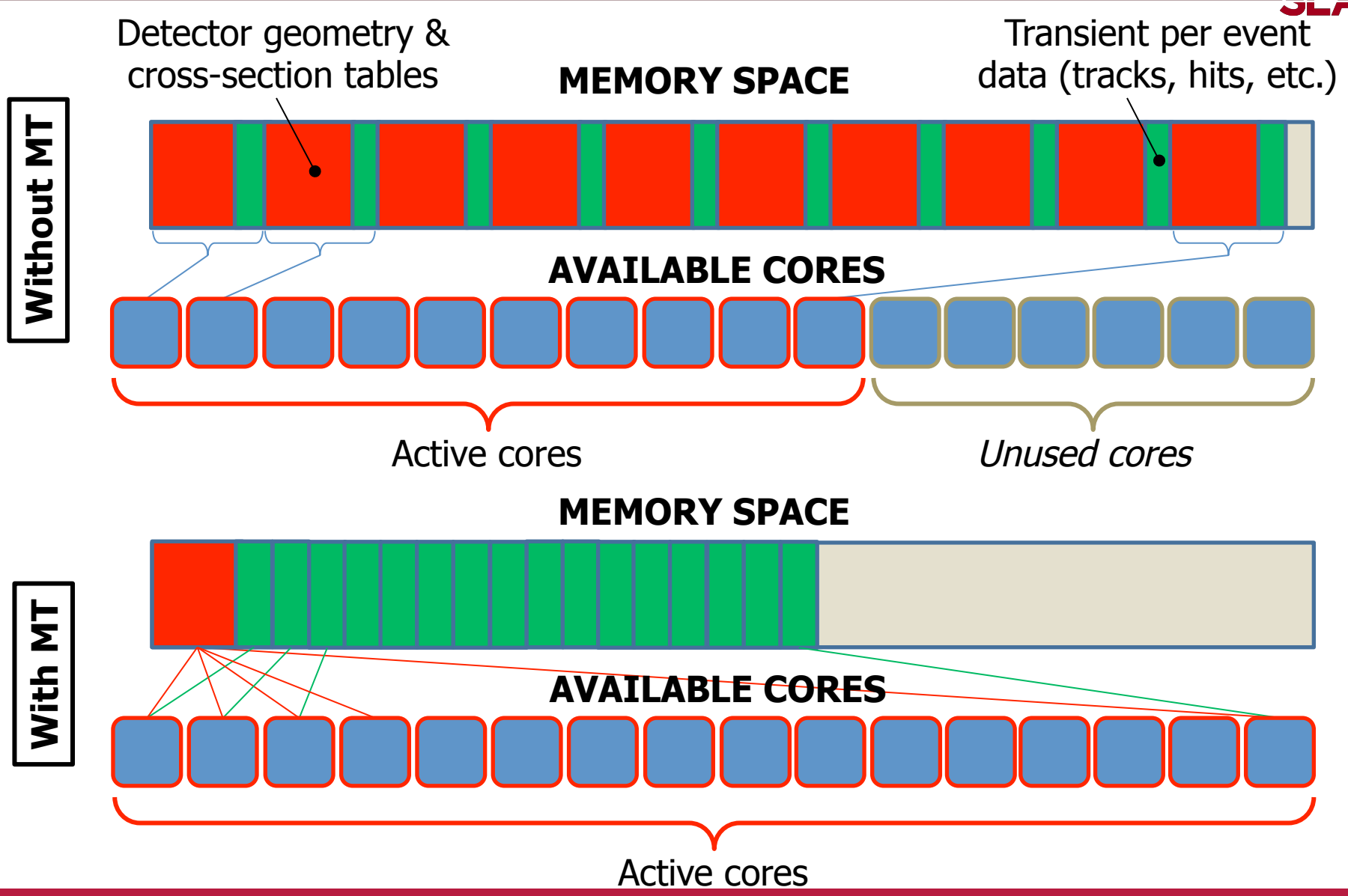
Memory space required for Intel Xeon Phi 3120A
Full-CMS geometry (GDML), 4 Tesla field, 50 GeV pi- (FTFP_BERT)

| # 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.
  - 2017 work item
  - Targeting also Cori @ NERSC




Without MT
Detector geometry & cross-section tables
MEMORY SPACE
Transient per event data (tracks, hits, etc.)
AVAILABLE CORES
Active cores
Unused cores
With MT
MEMORY SPACE
AVAILABLE CORES
Active cores

# Other new features in kernel, Vis/GUI

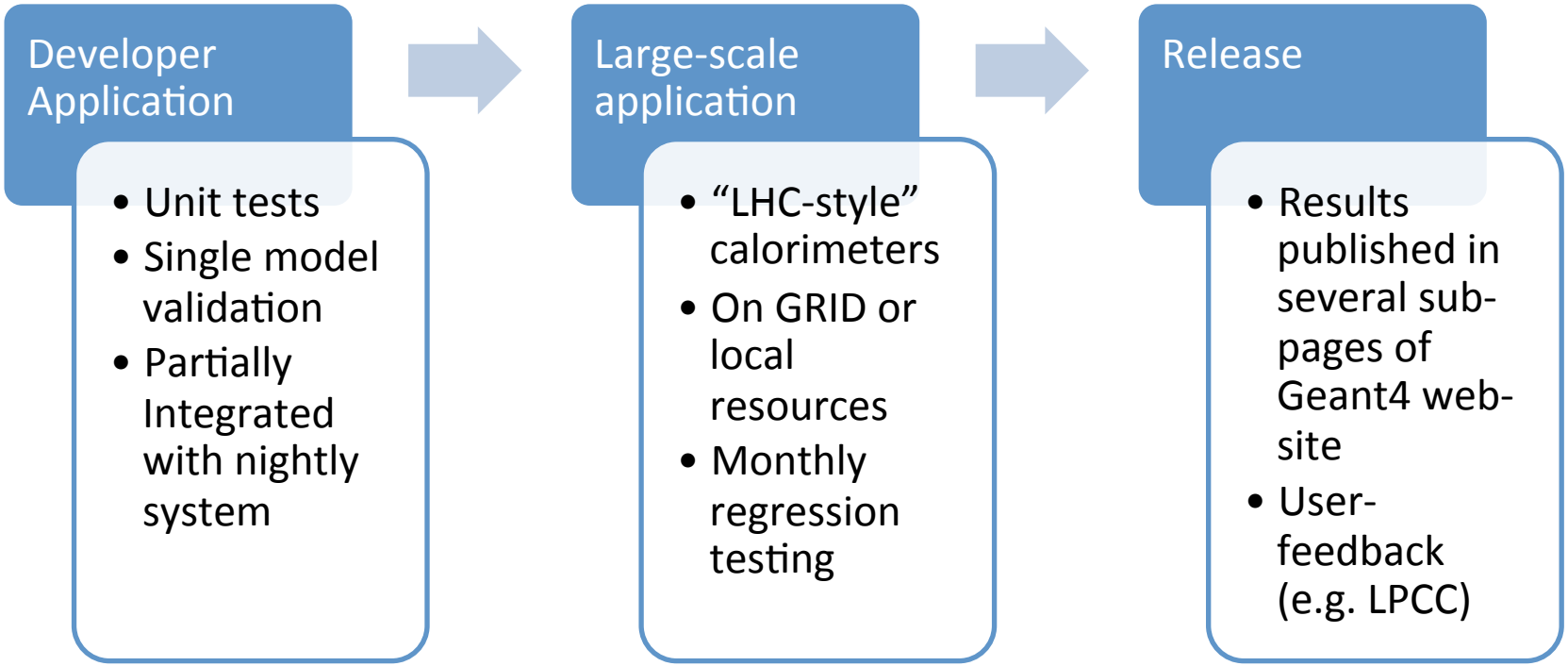
- Introduced new utility class G4MTBarrier implementing a synchronization point between threads
- Multiple user actions, multiple sensitive detectors
  - Allows experiments to add temporal user hooks without dropping existing ones
- Introduced G4ExtendedMaterial and G4VMaterialExtension for specific extensions to G4Material.
  - First concrete extension G4CrystalExtension is also introduced
    - E.g. for simulation of channeling effect in crystal
- Introduced new floating level base to ions and related classes
  - Adapted nuclide table to conform to the new scheme
- Biasing scheme has been unified for all biasing options
  - New biasing options: e.g. forced interaction, forced passage, etc.
  - Ability of defining geometry-based biasing in a parallel world
- Built-in analysis tools (G4tools) for thread- and MPI-transparent histogramming
- Significant improvements in the Qt interface and graphics
- Significant speed up for OpenGL viewers (including Qt) on some platforms due to better use of the graphics pipeline
- New fly through feature for saved views with associated UI command /vis/viewer/interpolate

# New geometry features

- Updated VecGeom library (USolids)
  - Optional replacement of original Geant4 solids
  - Selection made at configuration
  - External library VecGeom v00.03.00
    - https://gitlab.cern.ch/VecGeom/VecGeom/tree/v00.03.00
  - Possibility to choose replacement of all available shapes or only selected primitives
  - Selection specified at configuration by shape name
    - Available shapes for replacement:

      Most of CSG solids and some special solids (e.g. polycone, polygon)
- G4ScaledSolid
  - Ability to scale dimensions of a shape along Cartesian axes
- New minor release of GDML schema: GDML-3.1.4
  - fully compatible with old schema versions with supports for scaled solids
- New 3rd and 5th order Runge Kutta steppers
- Fully revised algorism for navigating tessellated solid, boolean solid, general trapezoid, etc.

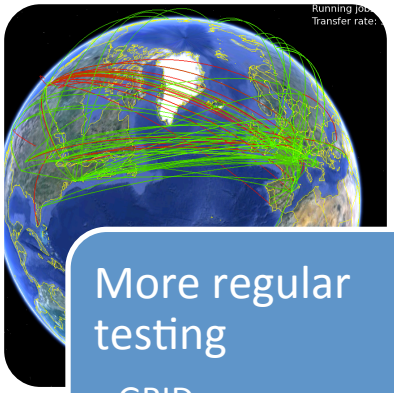
# Geant4 Validation: Current Strategy



# Geant4 Validation: Under development

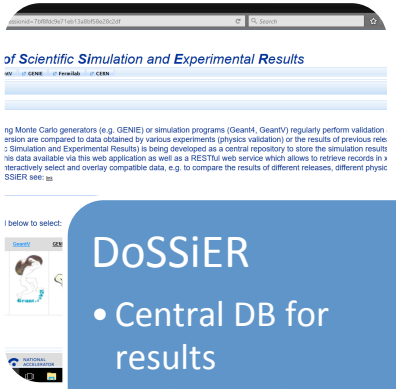
## Extend existing test suite

- Process-level regression testing
- Medical Benchmarks
- Geant4 docker application



## More regular testing

- GRID
- Local Farms
- Public Clouds




## DoSSiER

- Central DB for results
- Web portal
- Web application: query, download data, compare with experiments

DoSSiER

- Hosted and developed at FNAL in collaboration with SLAC and CERN
- Status: Geant4 results and experimental data being added
- Extended to other toolkits in addition to Geant4:
  - Adopted by GENIE (neutrino-interaction simulation system)
  - Being evaluated by Geant-V R&D

# Dossier

DOSSIER

**Database of Scientific Simulation and Experimental Results**

Home | Geant4 | Geant4 Collaborators | GeantV | GENIE | Fermilab | CERN

Mon Jun 26 03:28:34 CDT 2017

Left

Main

- Display exp. data
- Display Geant4 data
- Display GeantV data
- Display GENIE data
- Display Statistics
- Display Dictionaries
- RESTful web service

Select Geant 4 test

**Meta data**

| ID | Name | Description | Responsible | Working group | Keywords |
|---|---|---|---|---|---|
| 2001 | simplifiedCalo | Test of Shower shapes using selected simplified calorimeter setups. | Andrea Dotti (SLAC)<br>Alberto Ribon (CERN) | Geant4 hadronic working grou | shower profiles<br>energy response<br>energy resolution<br>calorimeter<br>Atlas<br>CMS |

**References to experimental data used to validate this test**

| Reference | Title | Journal/URL | Authors | Link |
|---|---|---|---|---|
| 60 | GEANT4: A Simulation toolkit | Nucl.Instrum.Meth.**A506** (2003) , p: 250-303 | Agostinelli, S. et al. | link |
| 61 | Validation of Geant4 Releases with distributed resources | J.Phys.Conf.Ser.**396** (2012) , p: 032033 | Dotti, Andrea et al. | link |
| 62 | Simulation of Showers with Geant4 | (2013) , p: 247-253 | Dotti, Andrea et al. | link |
| 63 | Description of hadron-induced showers in calorimeters using the GEANT4 simulation too | (2011) , p: 2128-2134 | Dotti, Andrea et al. | link |

MCdetail | Target | energy response | Submit

Table | Default

Print

energy response

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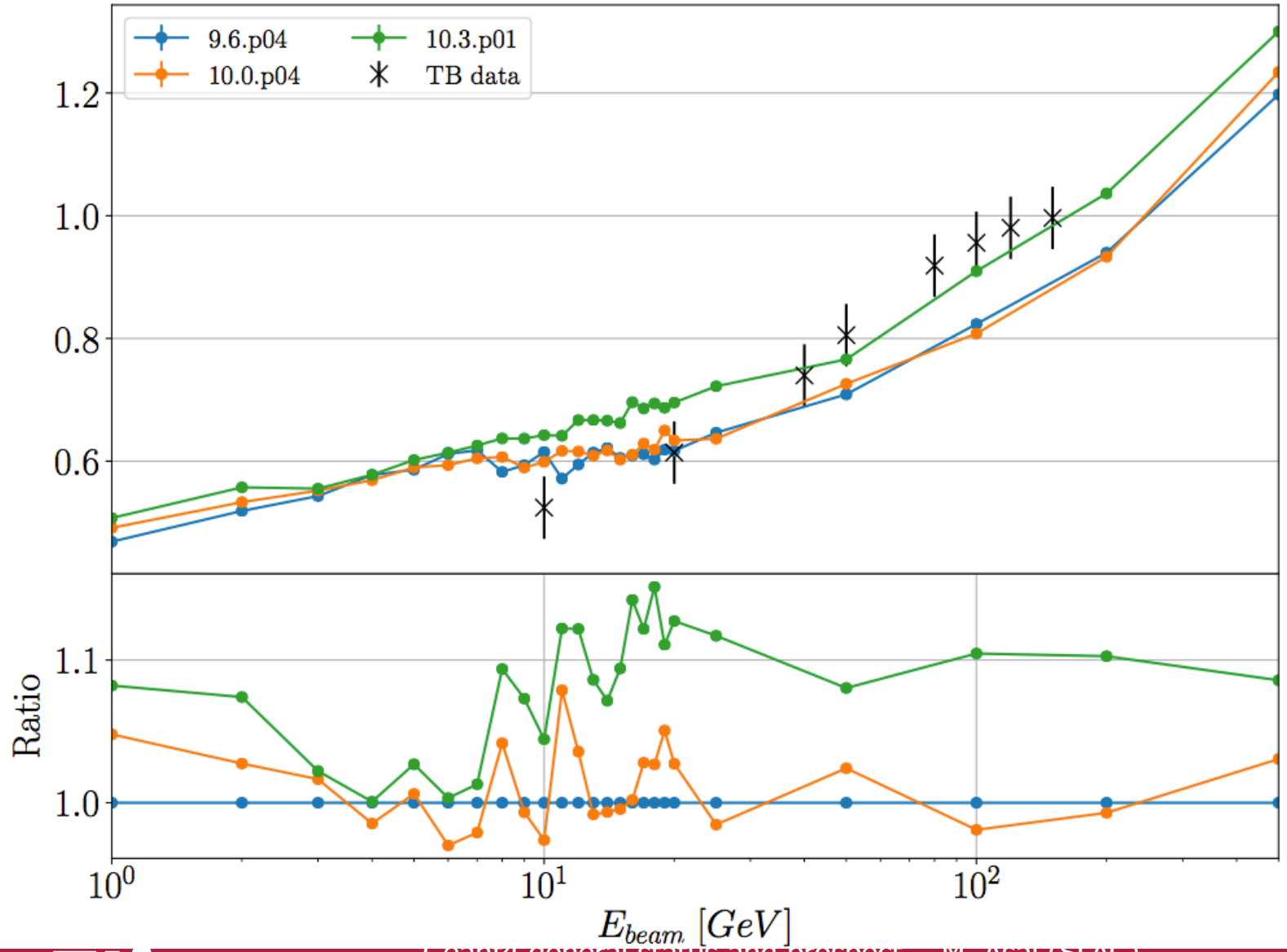
# LAr/Pb Cal. Results: resolution



# Next release – version 10.4

- Releases
  - Next public release : version 10.4 on December 8th, 2017
    - Next beta release : June 30th, 2017
  - Patch releases for versions 10.1, 10.2 and 10.3 will be made as needed
- As announced, 2017 work plan is listed here.
  - http://geant4.cern.ch/collaboration/working_groups.shtml
- Some highlights (physics highlights in next presentations)
  - New design of threading to allow threads to join/leave workers pool with migration from posix threads to std::thread
  - Workspace and memory cleanup in MT
  - Progressive adoption of shapes from VecGeom
  - Muonic atom and its decay
  - Enrich event biasing options: leading particle biasing, DXTRAN-like biasing, implicit
    - Prototype: biasing of charged particles (with cross-section changing over the step); occurrence biasing (continuous density change inside a same volume); material/isotope biasing; Woodcock tracking
  - New driver for export to format readable by Paraview

# Prospects and summary

- Given Geant4 is nowadays mission-critical for many users including all HEP experiments, space missions, medical applications, etc., Geant4 is to be kept maintained and still evolving for at least next decade.
- New physics models for coming experiments
  - e.g. EM physics coverage in multi-tens of TeV, hadronic model for multi-TeV regime, specialized EM model for noble liquid (e.g. liq.Xe), neutrino physics model
- More HPC-friendly
  - e.g. MPI-friendly input data files, sophisticated output reduction mechanisms transparent to user code
  - Allowing HPC's as the main MC production platforms
- We re-invite you to contribute to
  - Technical Forum meetings
  - Requirement tracking system
  - Physics validation database