Geant4 Status and Prospects

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AARM Meeting
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Outline

- General
  - release 10.1 highlights
  - geometry
- Update on Phonons
- Radioactive Decay
- Low energy hadrons
  - NeutronHP
  - ParticleHP
- High Energy Nucleus-nucleus Collisions
- Coming attractions

Release 10.1 Performance Highlights

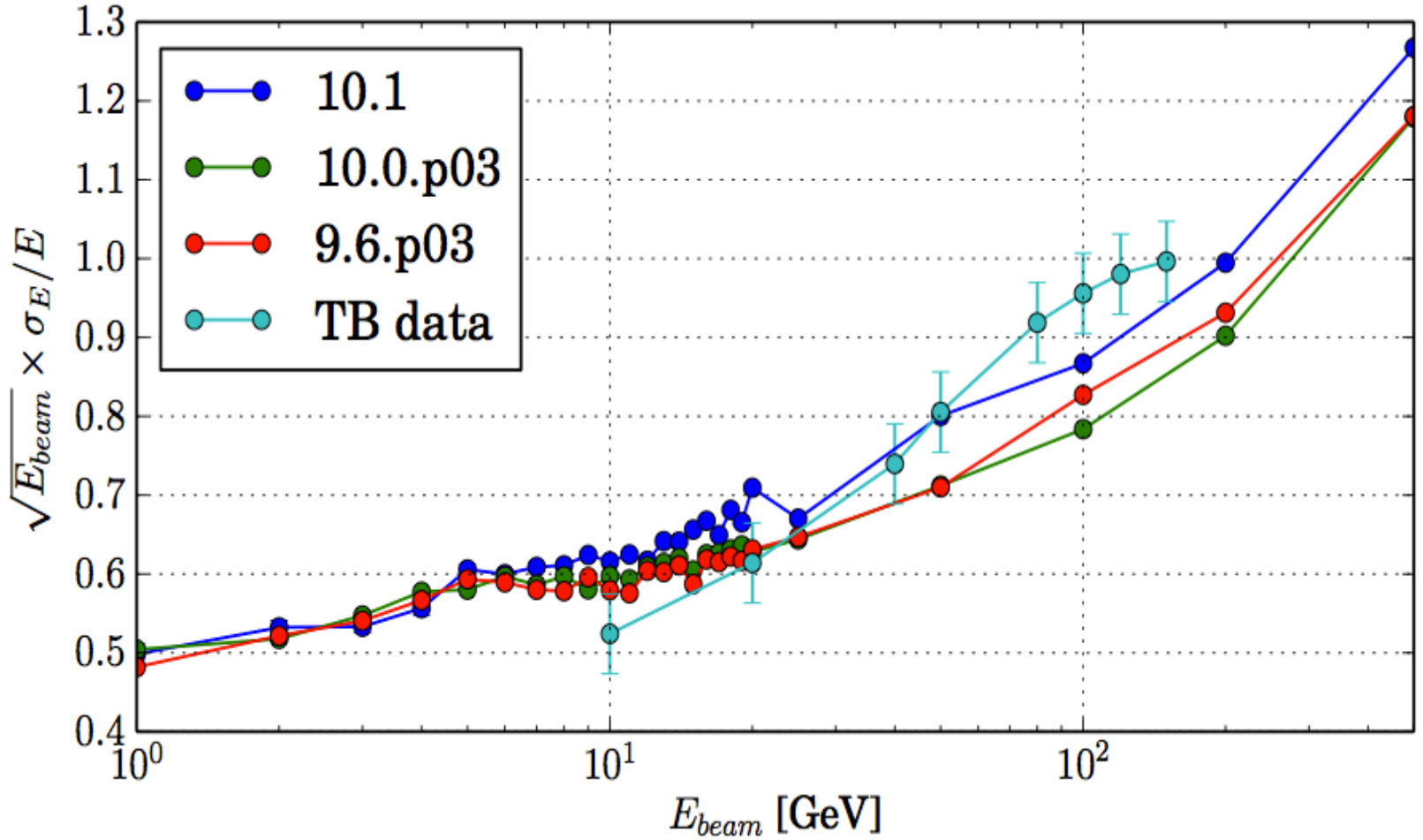
- Speed and memory
  - memory space required per thread reduced to less than half
    - does not effect space defined in user code
  - up to 10% speedup in several use-cases
  - these improvements arise from optimization of multi-threaded code in all parts of Geant4

- Electromagnetic Physics
  - all internal physics tables now shared among threads
  - contribution of EM to memory per thread reduced

- Hadronic Physics
  - improvements in FTF high energy code lead to improved resolution in calorimeters

Shower Energy Resolution in Cu-LAr Calorimeter

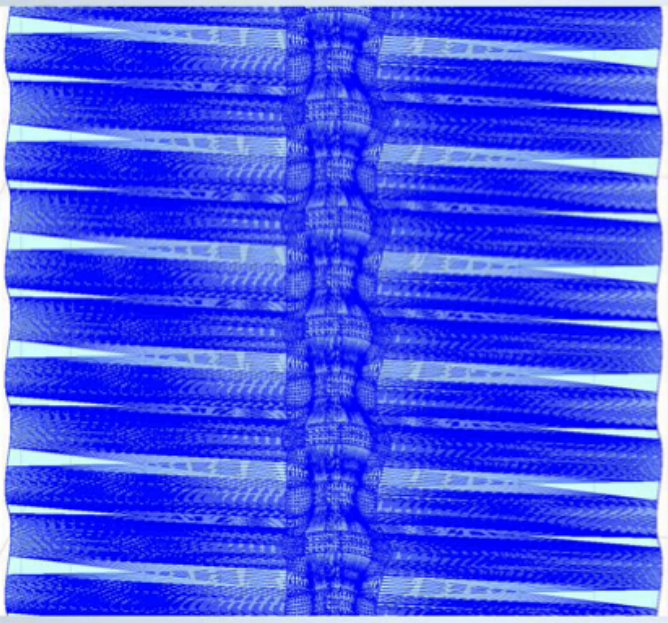
- Comparison to LHC test beam data indicates partition of energy among hadrons has improved with recent tuning of FTF mode



New Unified Solids Library

- Deep review of algorithms completed for most geometrical primitives in Geant4
- In most cases speed was increased:
  - time to calculate intersections with tessellated solids dramatically reduced by decomposing its facets into 3-D grid of voxels

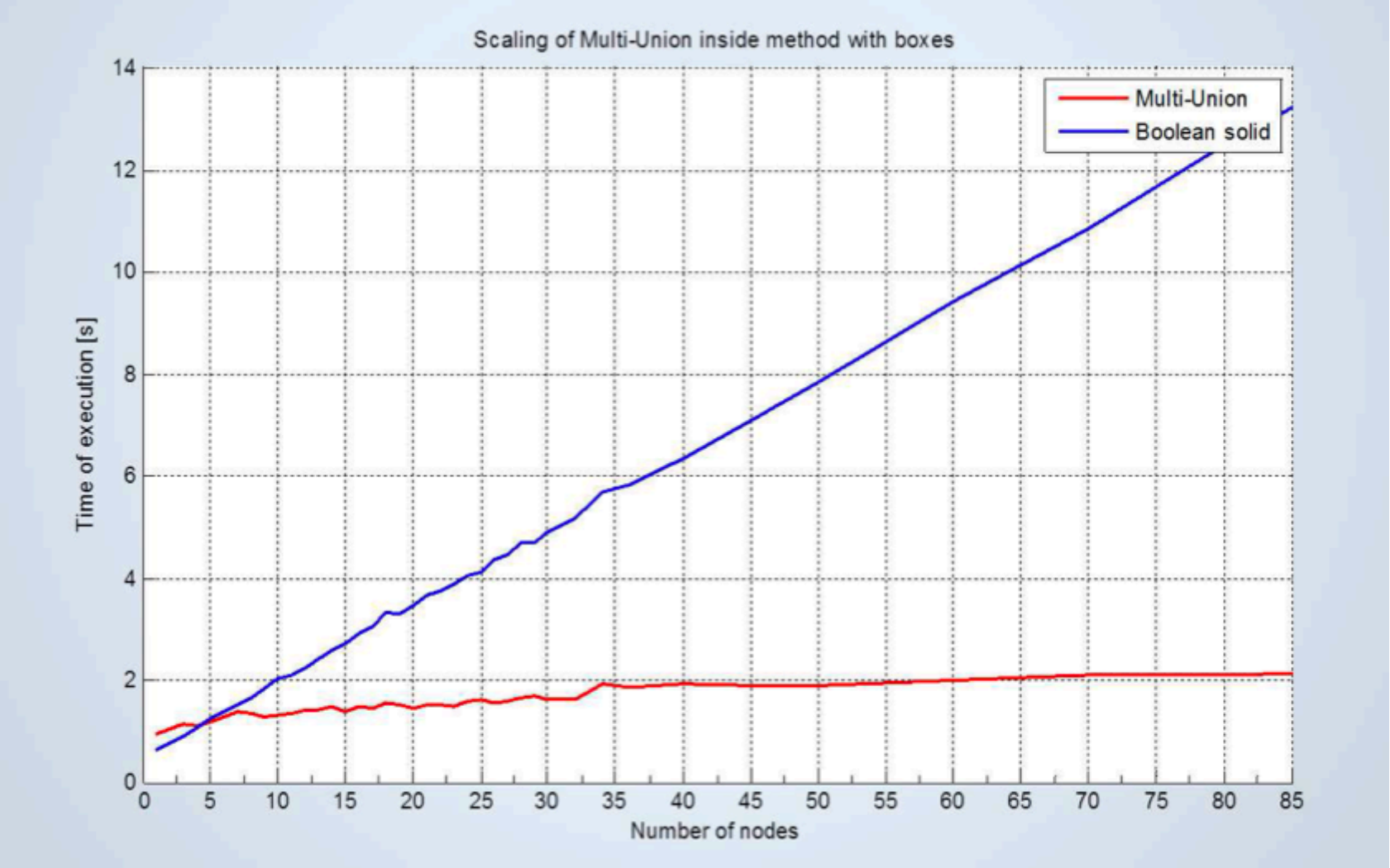
VELO detector LHCb



Method	Speedup
Inside	2423x
DistanceToIn	1334x
DistanceToOut	1976x

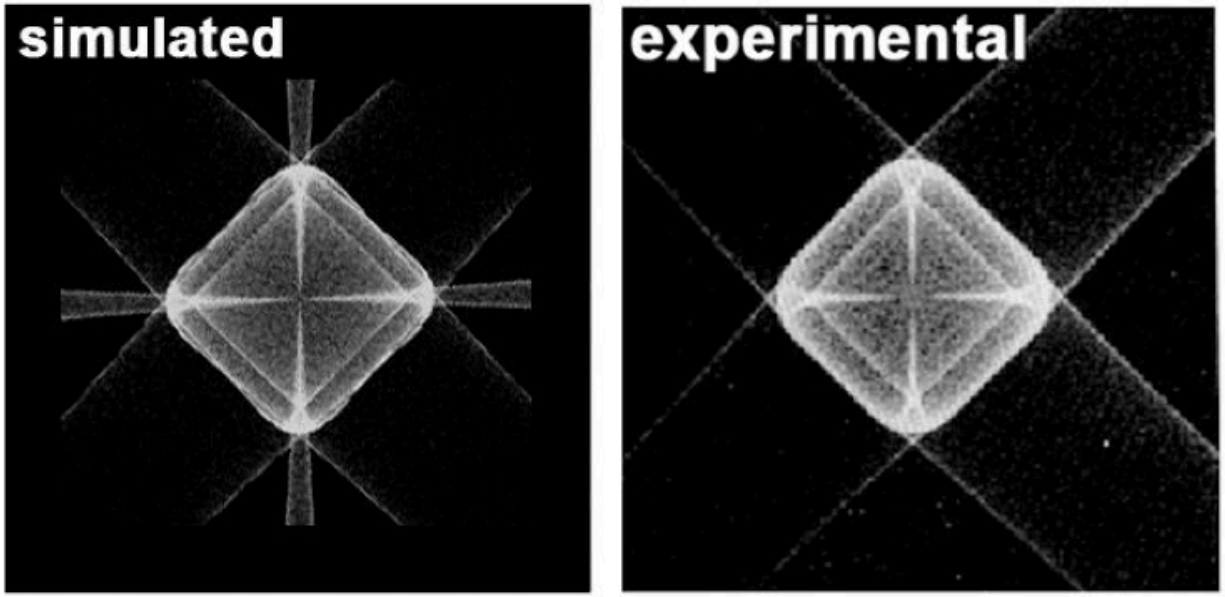
Information	Value
Number of facets	164.149
Number of voxels	100.000
Memory saved compared with original Geant4	22% (51MB)

Speed: Multi-union vs. Boolean Solid



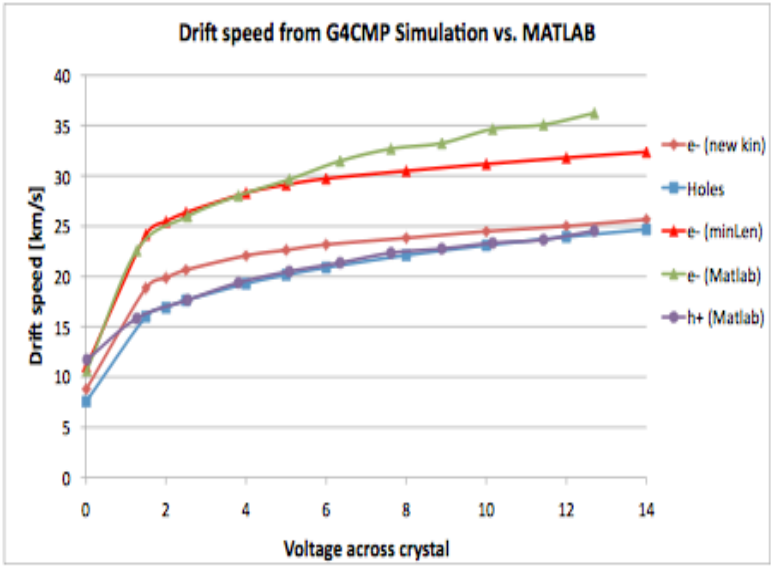
Update on Phonons (1)

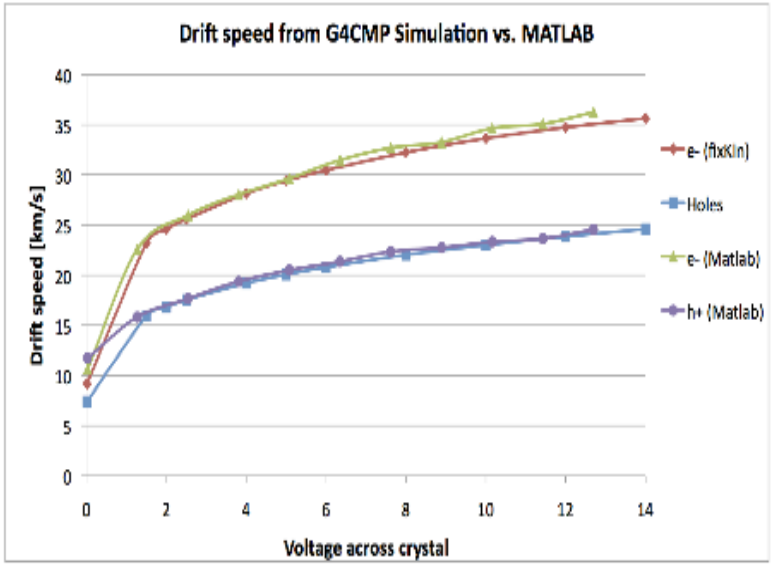
- Phonon propagation now officially supported in Geant4
  - moved up from example
  - not all features publicly available yet
- Development of G4CMP (phonon and charge carrier simulation for solid state materials) continues
  - currently a single event takes from seconds to minutes -> need to speed up code



Update on Phonons (2)

- Electron drift speed discrepancy vs. MATLAB now resolved
  - reverted to original kinematics calculation for computing Luke scattering
  - results now nearly identical to MATLAB





Update on Phonons (3)

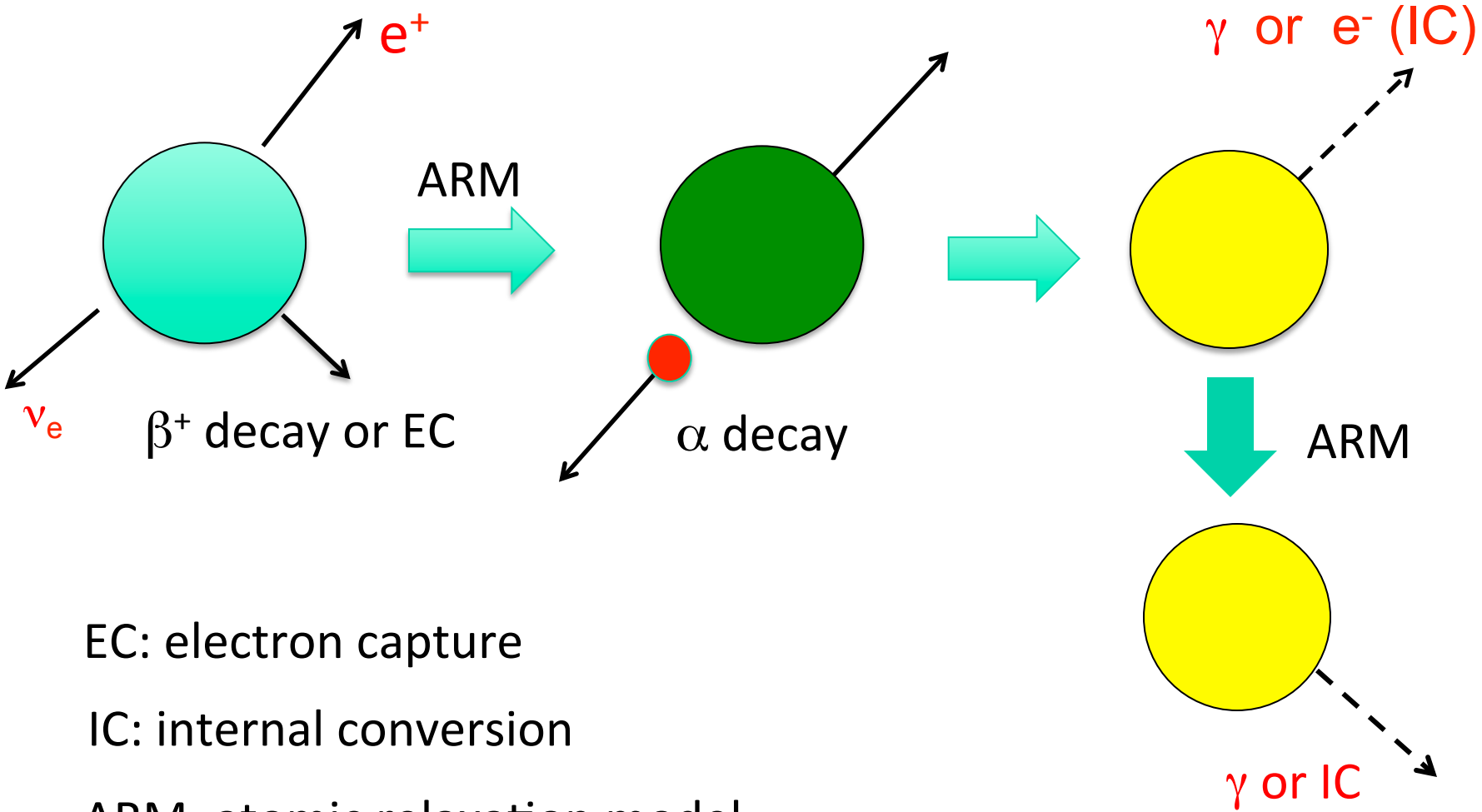
- Dynamic mass bug in Geant4
  - resolution of drift velocity discrepancy uncovered bug in G4Transportation -> field swimmer incorrectly maps velocity to kinetic energy
  - not seen in Geant4 testing because particle masses rarely differ during transport, and if so, mass difference is small

- Bug fixed in patches of 10.1 and 10.0
  - will go into 10.2 minor release December 2015

Radioactive Decay Improvements

- Radioactive decay now reproducible in multi-threaded mode
  - random seed at end of series of events always the same given identical seeds at beginning
  - in 10.0 this was not the case due to complex system of reading in data files
- Complete re-design of RDM package
  - more OO, more easily debugged, old code removed
  - => developers now able to concentrate on single decay channels
  - => significant improvement in energy conservation
    - from ~ keV in some cases to ~ eV for α decay, β decay)
- Atomic relaxation model now applied only to EC, IC

Sample Radioactive Decay Chain



EC: electron capture

IC: internal conversion

ARM: atomic relaxation model

Radioactive Decay Improvements

- Consistent treatment of RDM, photon evaporation databases
  - use G4RadioactiveDecay4.2 and G4PhotonEvaporation3.1
- "Observationally stable" isotopes (^{209}Bi: 1.9 x 10^{19} y) now decay
  - to accommodate double beta decay and rare alpha decays
  - users should always put a time cut on their hit collection
- Code for decay by proton emission now included
  - database entries still required yet
- Ions created as needed, rather than all at once at initialization time

NeutronHP

- Reproducibility (or random seeds) now restored
  - fixed bug first seen in release 10.0
- Problem with multi-threaded running
  - large memory consumption – problem being worked on
- New data set G4NDL-4.5 required
  - available on Geant4 download page

ParticleHP

- The charged particle analogue of the high precision neutron model
  - for p, d, t, α : (α, n) reactions included
  - mostly for E < 20 MeV, but some higher energy data

- Finally in toolkit
  - was promised for more than two years
  - currently database (~Gbytes) is maintained at CIEMAT (Spain), but eventually to be linked to Geant4 web page

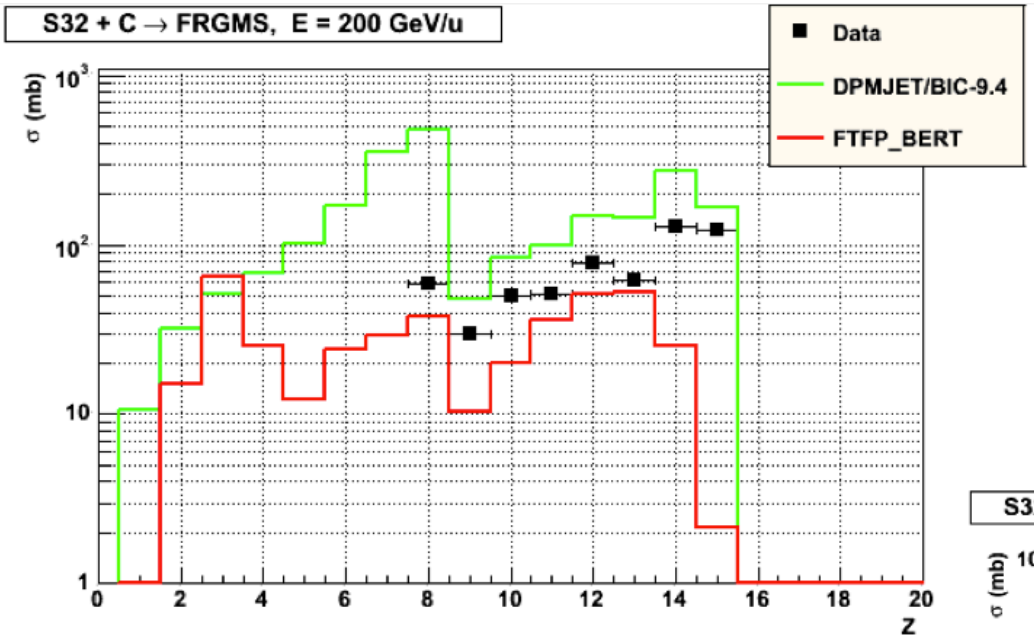
- Plan is to merge ParticleHP and NeutronHP into one package
  => ParticleHP
  - code to be released at completion of testing and validation (end of June)

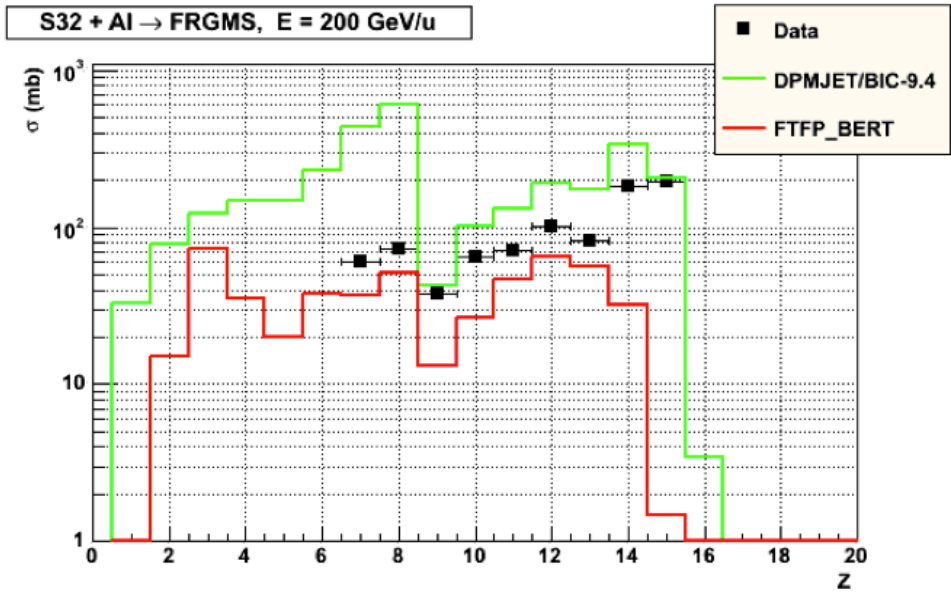
Fritiof Nucleus-nucleus

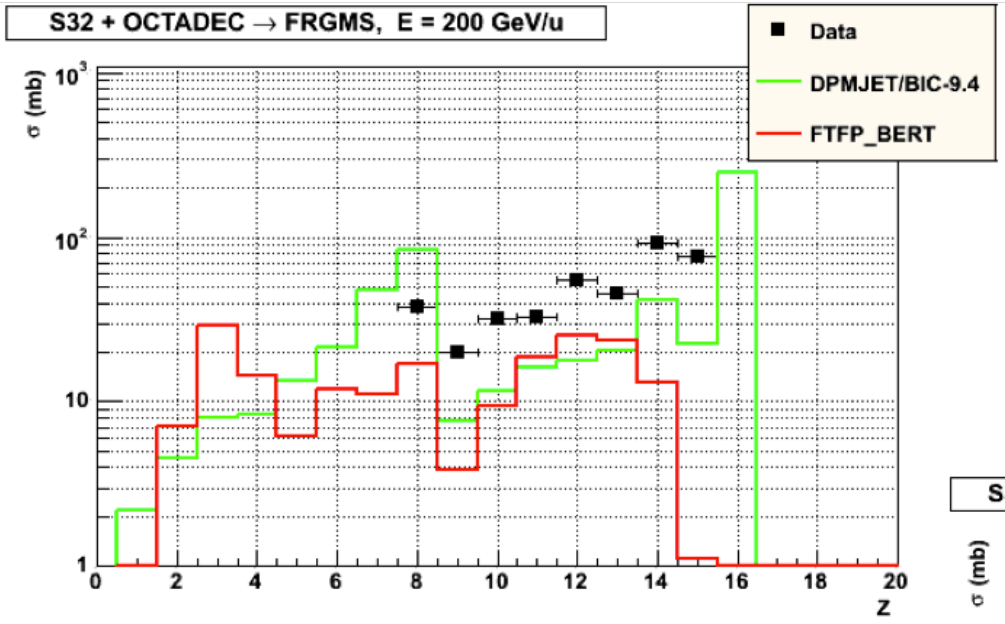
- Interface to DPMJET II.5 no longer works
  - serious energy non-conservation problems and maybe more
  - also limited to Z < 26
  - compiles and runs, but difficult to maintain Fortran code and interface

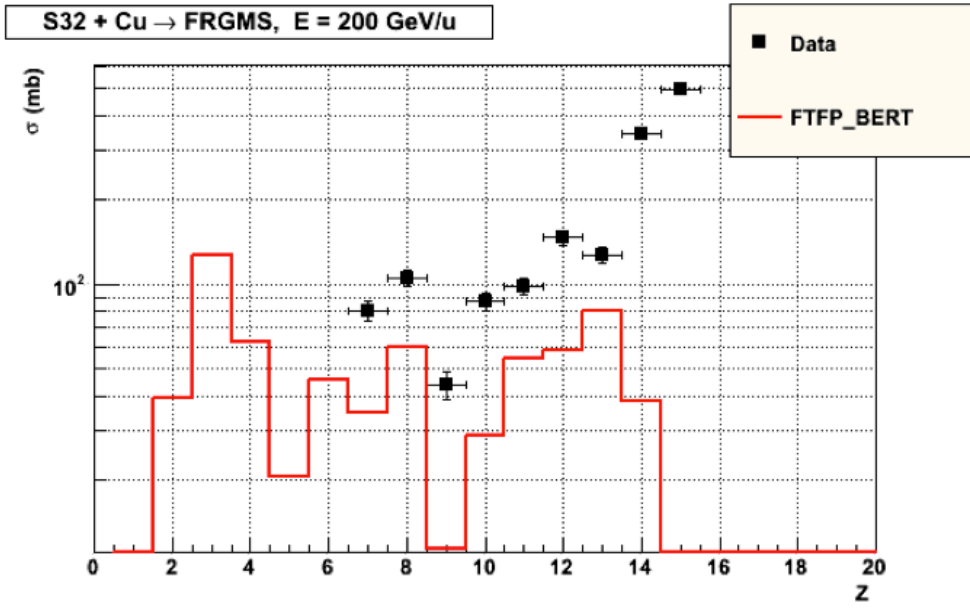
- Would like to have native G4 code for high energy nucleus-nucleus collisions
  - FTF can now do nucleus-nucleus; try it
  - validate against 1987 data from CERN SPS:
    - 200 GeV/u ^{32}S on C, Al, S, Cu, Ag, Pb
  - CPU for DPMJET and FTF similar

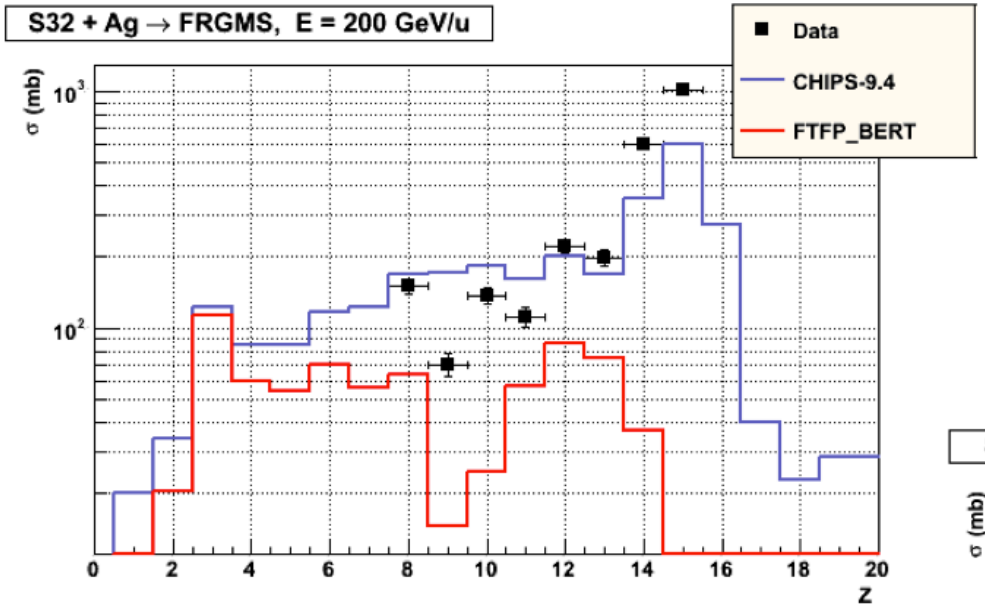
- FTF looks promising
  - better than DPMJET for light targets

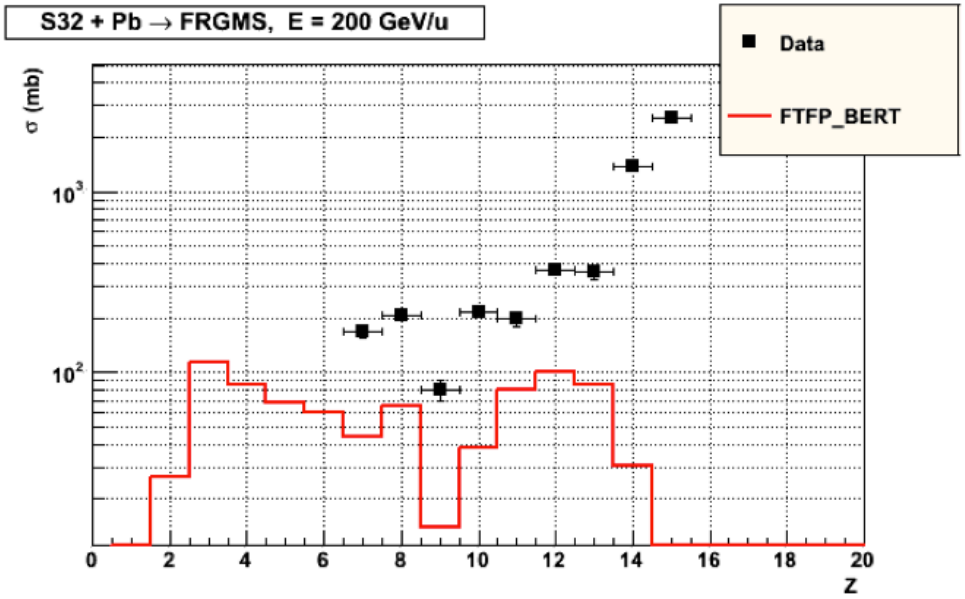

S32 + C → FRGMS, E = 200 GeV/u
Data
DPMJET/BIC-9.4
FTFP_BERT
σ (mb)
Z


S32 + Al → FRGMS, E = 200 GeV/u
Data
DPMJET/BIC-9.4
FTFP_BERT
σ (mb)
Z


S32 + OCTADEC → FRGMS, E = 200 GeV/u
Data
DPMJET/BIC-9.4
FTFP_BERT
σ (mb)
Z


S32 + Cu → FRGMS, E = 200 GeV/u
Data
FTFP_BERT
σ (mb)
Z


S32 + Ag → FRGMS, E = 200 GeV/u
Data
CHIPS-9.4
FTFP_BERT
σ (mb)
10^3
10^2
0
2
4
6
8
10
12
14
16
18
20
Z


S32 + Pb → FRGMS, E = 200 GeV/u
Data
FTFP_BERT
σ (mb)
10^3
10^2
0
2
4
6
8
10
12
14
16
18
20
Z

Coming in 2015/2016

User Variation of Model Parameters

- Requested by several user communities
  - most notably for studies of neutrino production targets
- A means of establishing systematic errors for some models
  - Bertini cascade now under study
    - looking at varying nuclear radius, repulsive core radius, etc.
- To be offered on a restricted basis
  - only users working with model developers

Fast Cross Sections

- One of the largest time sinks in Geant4 hadronic models is cross section calculation and look-up
- Hadronic cross section optimization (work of Renci/UNC Chapel Hill)
  - caching cross sections
    - list of particle/material/process "triplets" built for a given application
    - caching ~10 of these is enough to speed things up considerably
    - being tested in Geant4 now
  - surrogate model
    - automatic construction of empirical model (polynomial) of cross section in a given energy range
    - store polynomials for fast access
    - still in development

Radioactive Decay and Photon Evaporation

- Correlated Gamma Emission
  - Currently photon evaporation code may emit multiple gammas during de-excitation, but they are isotropic and not correlated in angle
  - New code (Jason Detwiler) will make use of J^{π} data in photon evaporation database
    - gamma angular distributions will now be correct

- Spontaneous fission is still in the job queue

Neutrino Interactions

- First step: interface of Geant4 to GENIE
  - goal: allow GENIE neutrino generator to use Geant4 hadronic models for fragmentation and final state interactions within nucleus following initial interaction
    - will allow greater variety of models than now available in GENIE
    - planned for end of 2015

- Second step: interface of GENIE to Geant4
  - goal: allow Geant4 to use GENIE's neutrino-nucleus interactions in a Geant4 neutrino process
    - planned for early 2016

- Third step: once neutrino scattering processes are in place, use new Geant4 biasing techniques to do neutrino propagation