Recent Geant4 Developments

AARM Meeting
March 2014
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Outline

- Multi-threading

- Electromagnetic Physics
  - multiple scattering
  - phonons
- Radioactive Decay
- Hadronic Physics
  - retired models
  - FTF, Bertini improvements
  - low energy neutrons

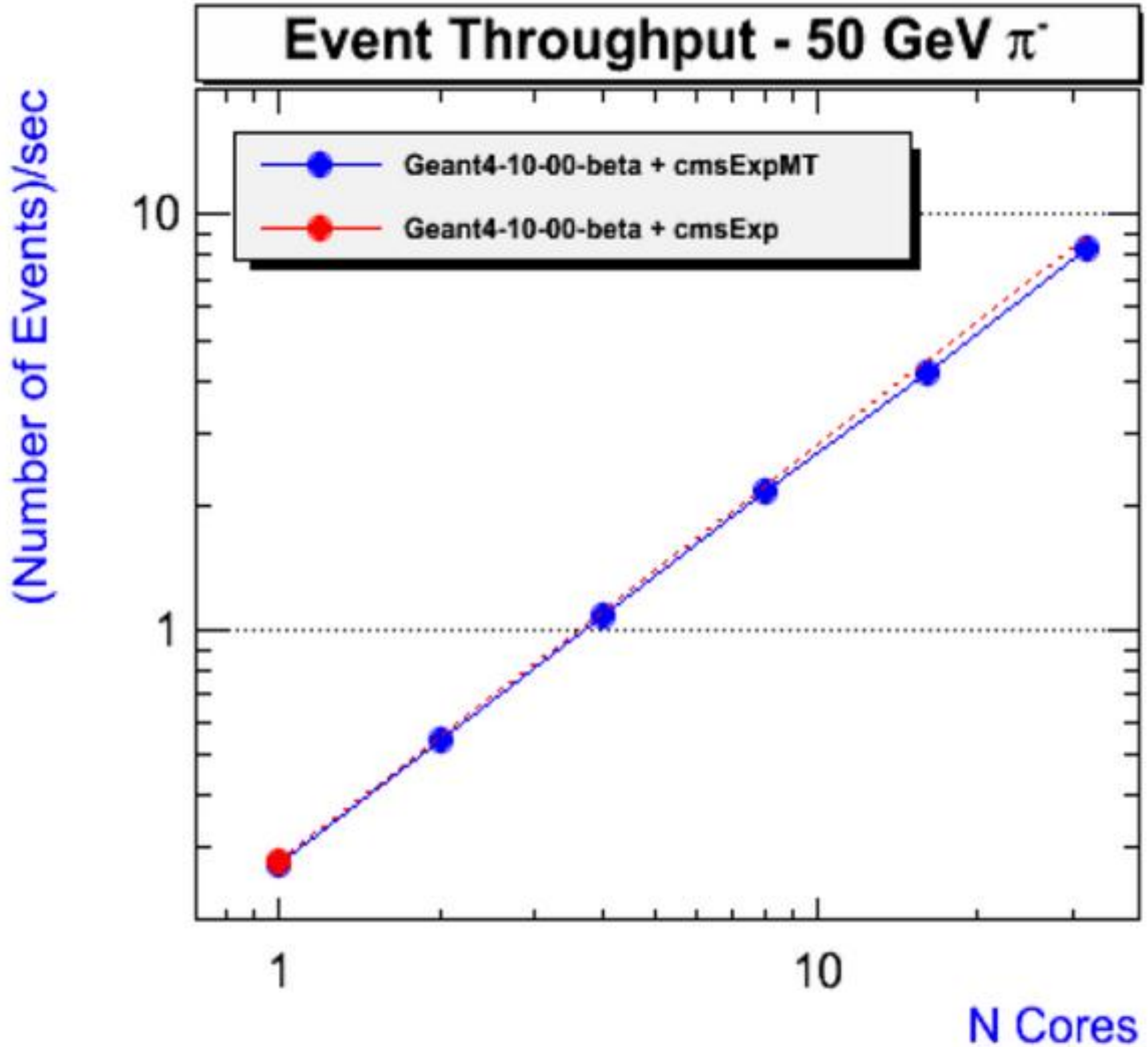
- Coming soon (last half of 2014)

Multi-threading in Geant4

- Version 10 supports (optional) event-level parallelism
  - it is a way to take advantage of the full CPU power of your machine
  - you can configure your application to use N threads
  - it is most efficient when N equals to the number of cores your machine has available (e.g. 8 for a MacBook Pro)
  - you may still opt for a sequential (non-multi-threaded) build

- Installation
  - as usual, see the Geant4 Installation Guide accessible from the Geant4 web page (User Support -> Documentation -> Installation Guide)
  - see also latest developments and performance at twiki.cern.ch/twiki/bin/view/Geant4/MultiThreadingTaskForce

Linearity (MT vs. Sequential Cores)

- 

Physics Performance of Geant4-MT

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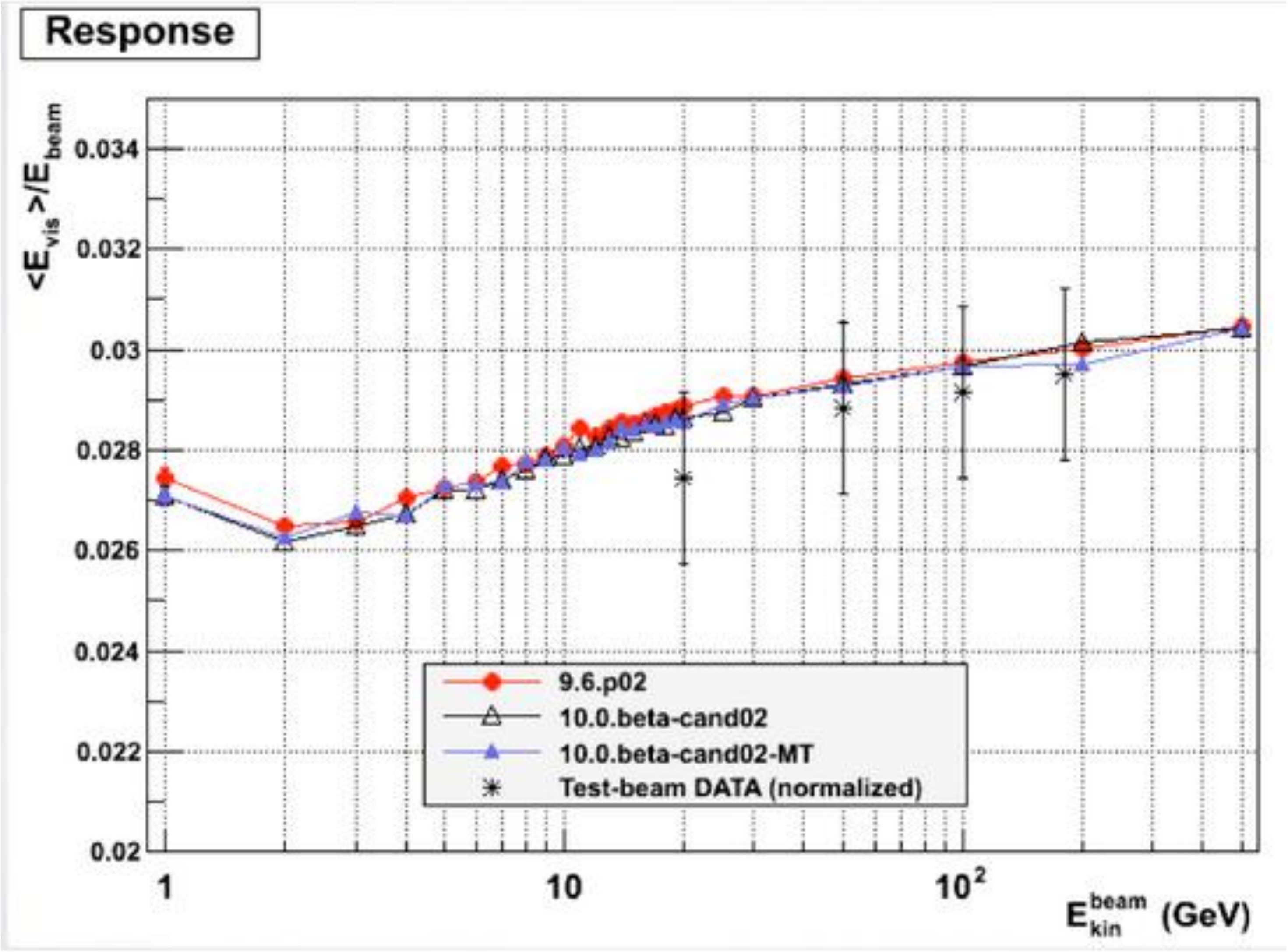


Some Multi-threading Details (1)

- At the end of the first kernel initialization, N worker threads are created and initialized
  - each of these threads is responsible for simulating events
- Each thread is tasked with an event on first come, first serve basis
  - event numbers per thread are not sequential
- Objects that consume the largest fraction of memory are shared among threads
  - geometry
  - physics tables
- Built-in command-based scorers or g4tools histogramming perform collection and reduction of all events automatically at end of each run
  - user is responsible for collecting user-developed quantities

Some Multi-threading Details (2)

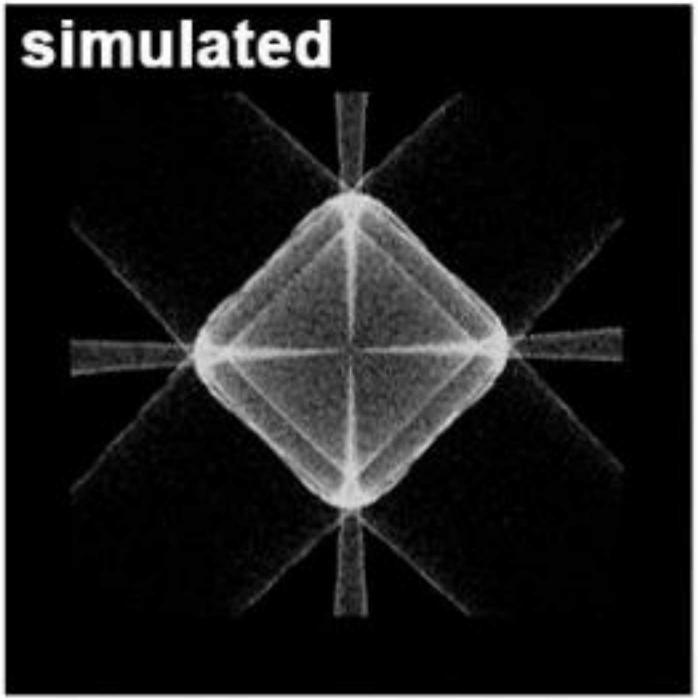
- Based on POSIX standards (pthreads) and on an extension of thread local storage (TLS)
  - smaller chunks of memory need not be shared
- Caveats:
  - although heavily tested, note that this a major architecture modification
    - can expect some bugs
  - integral numbered build
    - developers allowed to break user code if absolutely necessary => not necessarily related to multi-threading
- Version 10.0 patch1 already released
  - subsequent patches expected

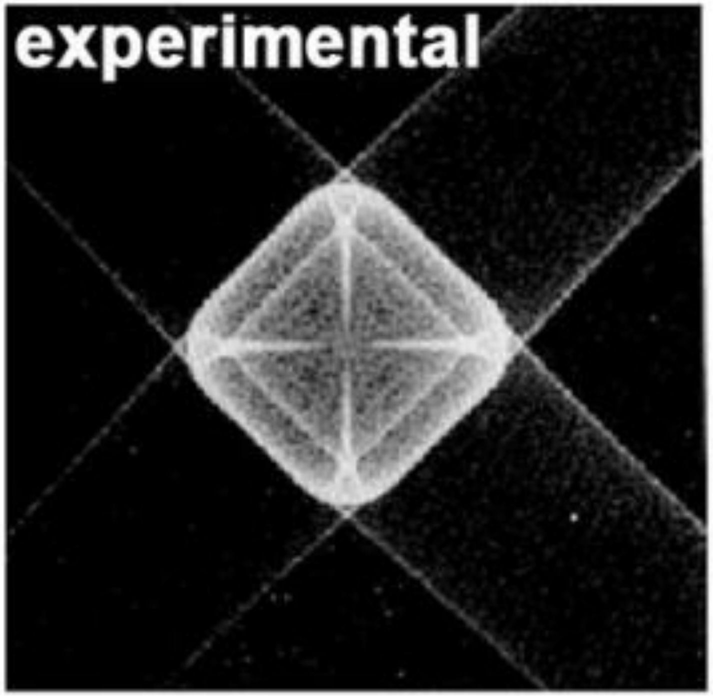
Electromagnetic Physics Improvements

- New multiple scattering model
  - G4UrbanMscModel
    - improved tuning of the Urban multiple scattering model
    - replaces all previous versions: Urban 90, 93,95, 96
- Improved e^+/e^- pair production by HE muons and hadrons
  - more detailed tabulation grid of differential cross sections
- New, minimal framework for low temperature phonon propagation introduced
  - G4 materials can now support crystal structure
  - new particle types: G4Phonon
  - new phonon processes: scattering, down-conversion
  - see examples/extended/exoticphysics/phonons
  - details and work-in-progress (slide 13 ff):

http://www.slac.stanford.edu/~kelsey/geant4/Tutorial_SLAC14/PhysicsIII.pptx

Propagated Phonon Pattern at Face of Ge Crystal (caustic)





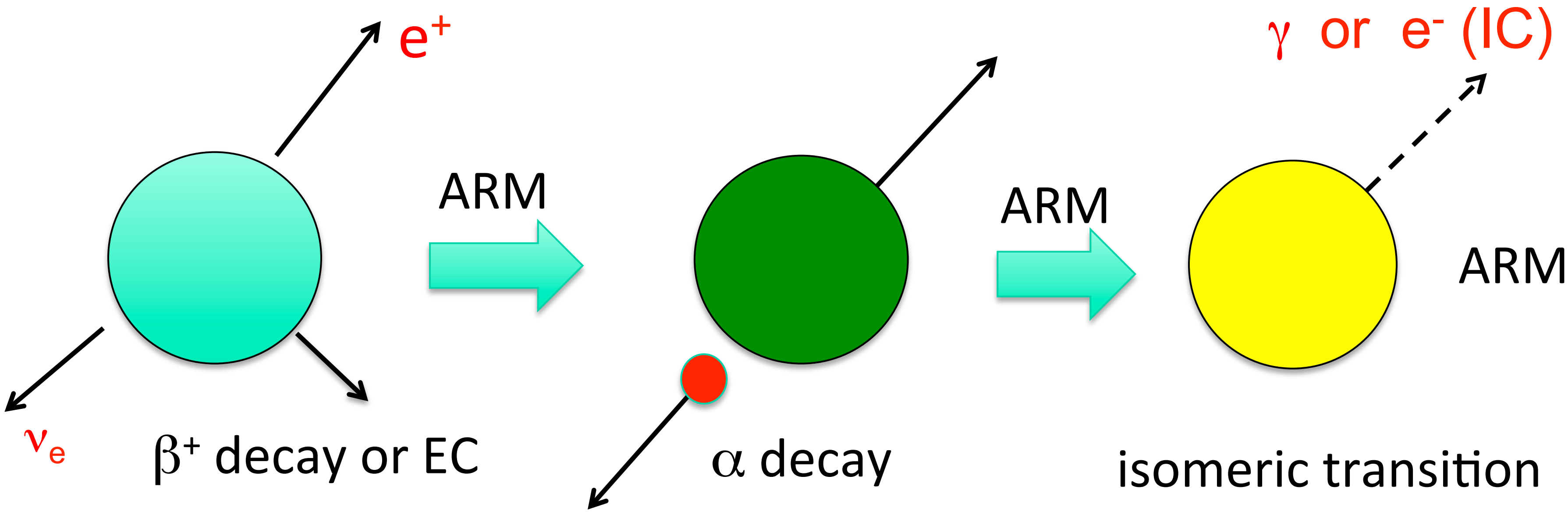
Caustics in Ge collected by phonons example

Caustics in Ge observed by Northrop and Wolfe PRL 19, 1424 (1979)

Radioactive Decay

- Process to simulate radioactive decay of nuclei
  - α, β^{+}, β^{-}, γ decay, electron capture (EC), internal conversion (IC), Auger and fluorescence processes implemented
- Many improvements for version 10.0:
  - now 2792 data files taken from Evaluated Nuclear Structure Data Files (ENSDF)
    - download-able as RadioactiveDecay4.0
    - includes all meta-stable states with lifetimes longer than 1 ns
  - all known gamma transitions (regardless of lifetime) for 2071 nuclides
    - download-able as PhotonEvaporation3.0
  - more consistent treatment of decay chains

Radioactive Decay Chain in Version 10.0

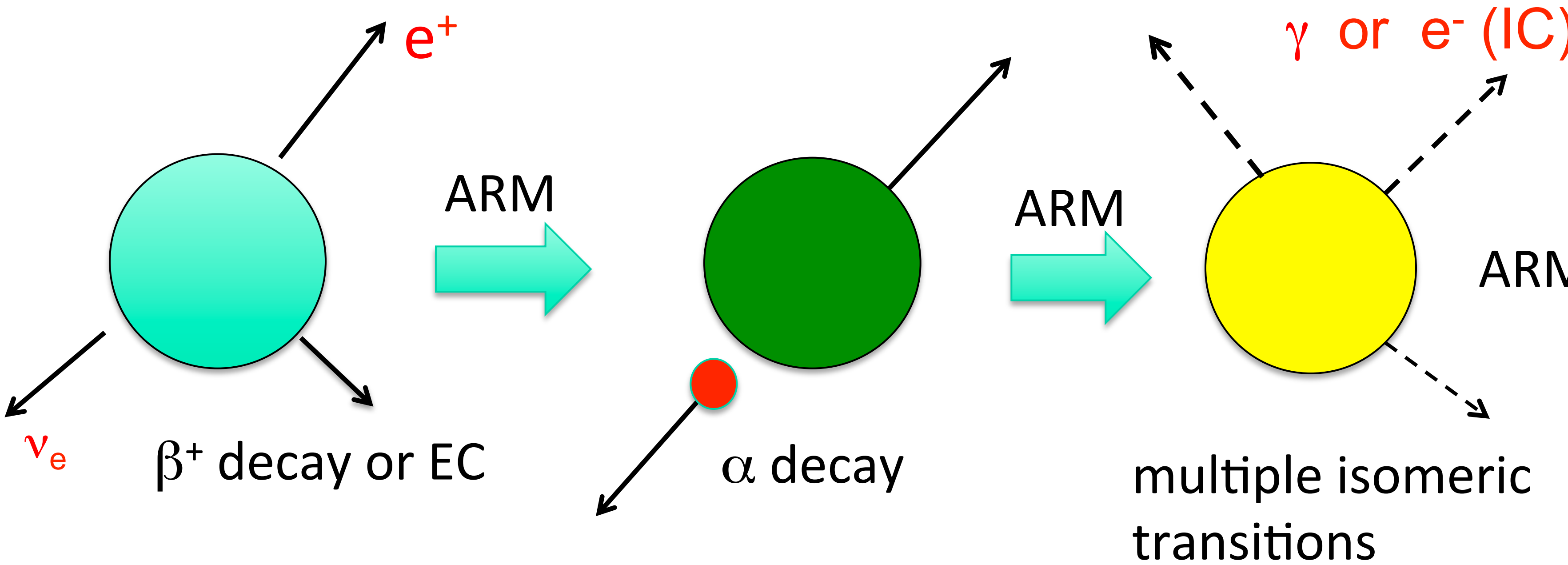


EC: electron capture

IC: internal conversion

ARM: atomic relaxation model

Radioactive Decay Chain before 10.0



States with γ decay lifetimes < 1 ns would decay immediately in the same step all the way to the ground state

Gammas from ^{60}Co decay, e.g., would not have correct timing

Radioactive Decay Errata

- Events using radioactive decay are not reproducible in multi-threaded mode
  - random seed at end of series of events not always the same given identical seeds at beginning
  - completely reproducible in sequential mode
  - working on this
- Small energy non-conservations (~ keV) still exist for some reactions (α , γ)
  - working on this, too
- Minor inconsistencies between ground state gamma transitions in RadioactiveDecay4.0 and PhotonEvaporation3.0
  - fixed in RadioacticeDecay4.1 and PhotonEvaporation3.1

Retired Hadronic Models

- LEP, HEP (Low and High Energy Parameterized) models
  - based on the old GHEISHA Fortran models of Geant3
  - replaced by extended versions of the Bertini cascade and FTF qcd string models
- CHIPS (Chiral Invariant Phase Space) models
  - thermodynamic clustering model of hadron nucleus interactions
  - formerly used for stopping, electro-, gamma-nuclear reactions
  - now replaced by Bertini, FTF
  - some CHIPS elastic and inelastic cross sections retained and made into separate classes
- Isotope production model
  - based on LEP models
  - now redundant, since all recoil nuclei are kept for tracking

Hadronic Physics Improvements

- Bertini cascade (0 – 10 GeV) improvements
  - better two-body nucleon final state angular distributions (from SAID)
  - improved multi-body phase space calculations
  - can now do muon capture by using quasi-deuteron absorption model

- FTF model improvements (> 3 GeV)
  - re-tuned, based on enlarged body of thin-target data
  - improved nucleon-nucleon diffraction
  - can now do nucleus-nucleus collisions

Bertini Muon Capture (red), old model (black)

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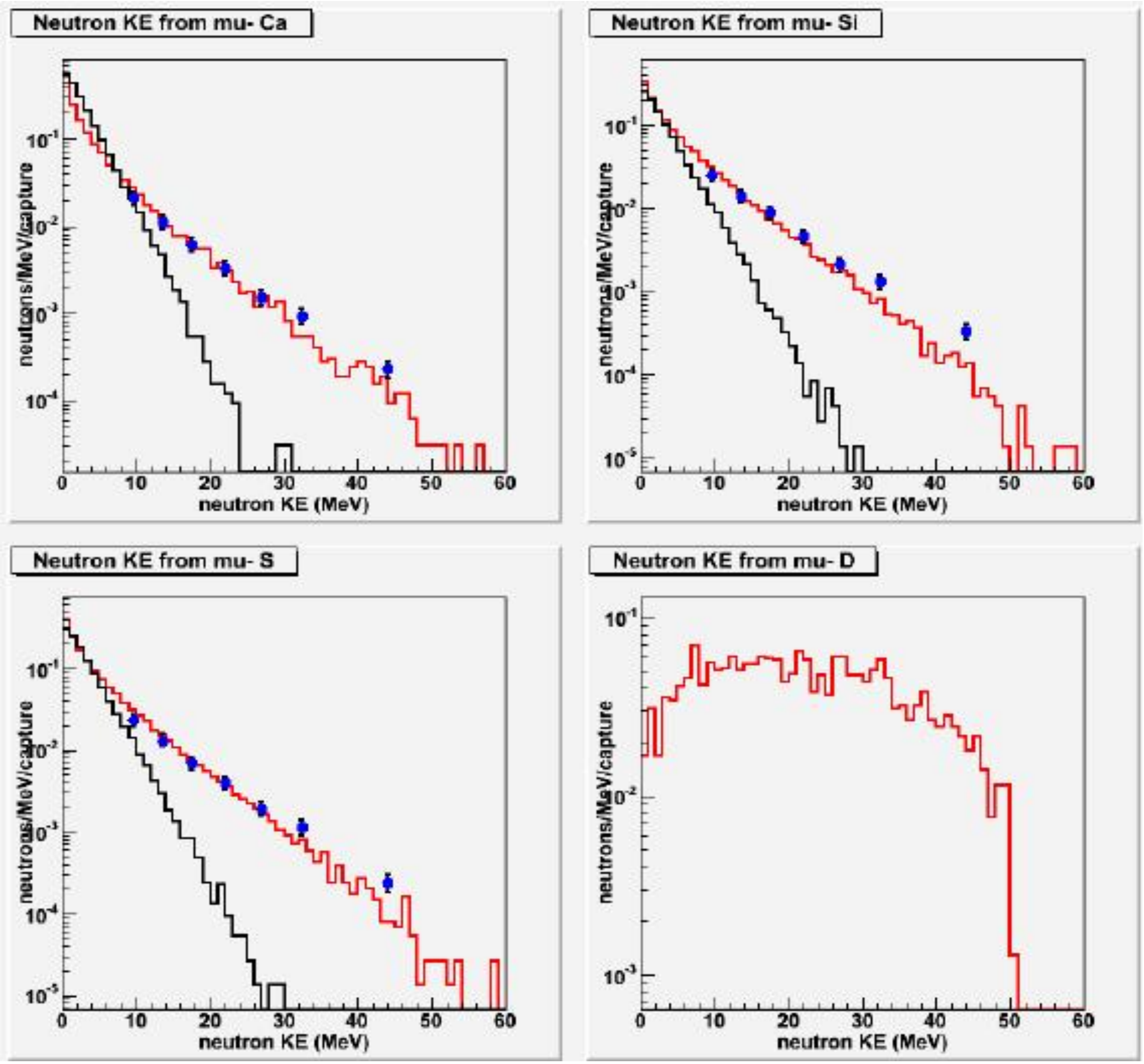

Hadronic Physics Improvements

- Neutrons
  - High Precision neutron models can now read compressed data files -> significantly reduced size of G4NDL database
  - alternate low energy neutron models: G4NeutronInelasticXS and G4NeutronCaptureXS
    - use high precision data but faster than traditional HP models
    - automatically included in all non-HP physics lists

- Meta-stable isotopes now produced in hadronic interactions
  - default minimum lifetime is 1 μs
  - user my set smaller value by setting G4ENSDFSTATDATA to point to new (optional) data set
  - uses new G4ENSDFSTAT-1.0 database (download-able)

Coming in 2014

- High precision charged particle induced reactions
  - like NeutronHP but for incident p, α
  - we've been promising this for the last two years
    - sorry about that
    - manpower allocation seems to be worked out

- Further radioactive decay improvements
  - more validation
  - better examples
  - rare reactions (double beta decay)

- Improved Quark-Gluon string model to compete with FTF model at high energies