Hadronics Developments for 10.0 Release

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GEANT4 Collaboration Meeting
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Introduction

Significant developments in many hadronic areas

- Particles: discrete isomer levels
- FTF string model
- INCL++
- BERT intranuclear cascade
- Particle HP
- PreCompound, De-excitation, Photon Evaporation
- Radioactive Decay
- Leptonuclear

Systematic modifications required for MT compatibility and optimization

Isomer States

Through 9.6, G4Ions may be created with any (double) excitation energy

- Cascade models end up with excited residual nuclei
- Radioactive decay goes to excited final state
- Capture/absorption/quasi-elastic excites target

With MT, cannot create "infinite" states within events, and have them shared across threads

G4Ions with **known** (tabulated) excitation energies will be pre-created at start of job

- Measured isomer states from photo-evaporation tables
- Finite (short, 1 ns) lifetime to limit quantity
- Labelled with integer level number, not double energy
- Accessible to all threads

Temporary/unstable G4Ions may be created within events ~~but won't be shared~~

Fritiof (FTF)

Detailed description added to Physics Reference Manual

Retuning of model parameters in progress

Major development to support nucleus-nucleus collisions

- Interfaces to Binary Cascade and PreCompound
- Energies from 3∼4 GeV/A up to RHIC supported
- Important tool for RHIC Beam Energy Scan program (BES)

Poor validation against LHC (Pb-Pb) data

- Understandable: quark-gluon plasma must be simulated
- Results may still be useful for design of LHC configurations

Also useful for cosmic ray simulations

Vladimir Uzhinskiy, JINR

Liege Cascade (INCL++)

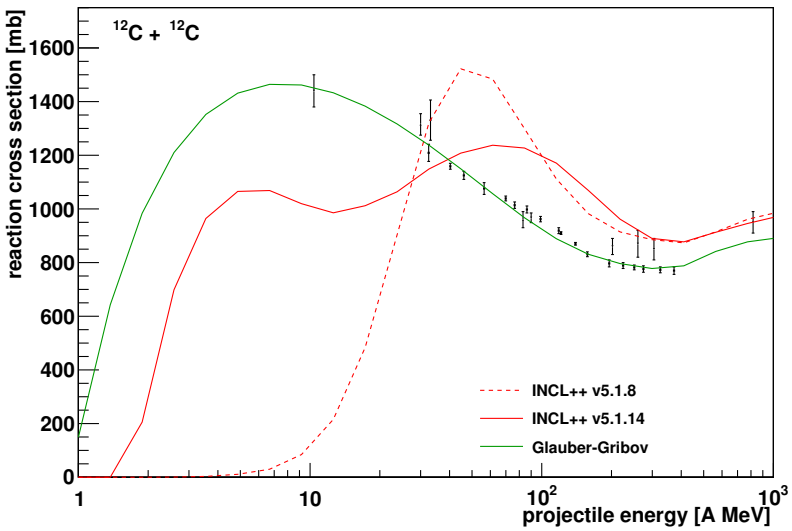
- Low-energy fusion retuned against data
- Extensive validation with nucleus-nucleus data
- Improved cross-sections for small clusters (INCL 4.6 $\rightarrow$ INCL++)
- Extending validity up to 10–15 GeV

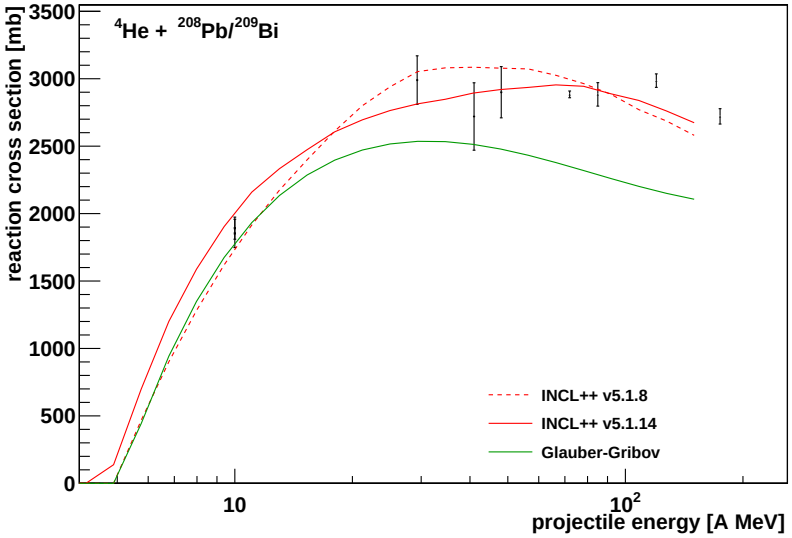
Upcoming development plans

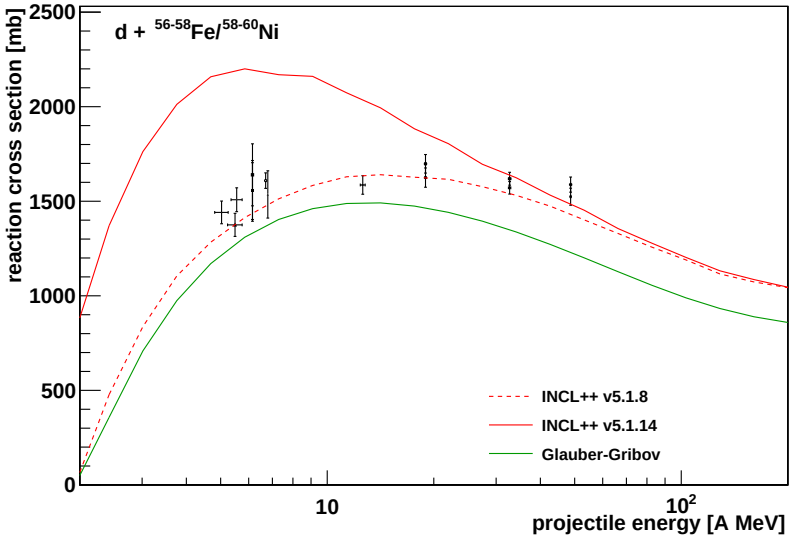
- Automate physics testing (by end of 2013)
- Re-introduce ABLA++ (by end of 2013?)
- Port high energy extension from INCL 4.6 to INCL++
- Include strangeness production

Davide Mancusi, CEA

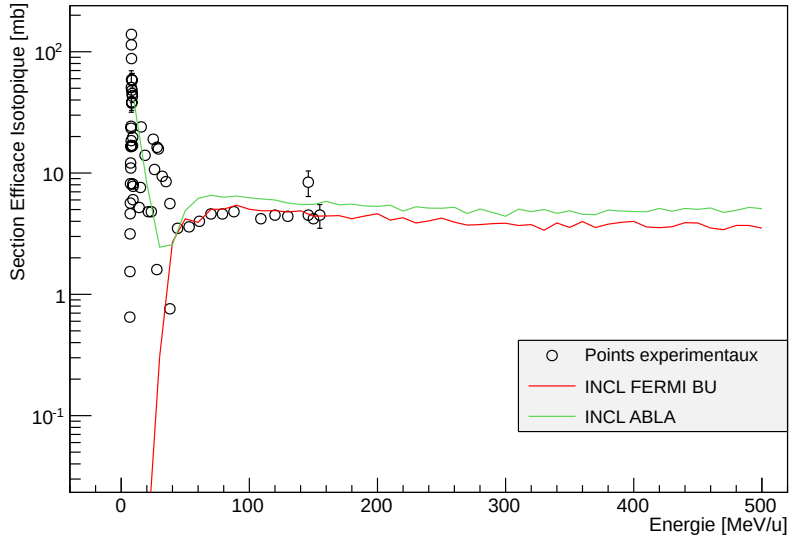
Liege Cascade (INCL++)







O16(p,X)N13



BERT Cascade

Most of 2013 Work Plan implemented

- New angular distributions for two-body final states
- Stopping/capture of muons with generated cascade
- Projectile emplacement, forced interaction validated

Addressed thread safety and re-optimizing for MT

Remaining items from 2013 Work Plan

- Enable post-cascade clustering for light-ion production?
- Use PreCompound as default for all de-excitation?
- Continuing struggle with "better" nuclear model parameters

Michael Kelsey & Dennis Wright, SLAC

Particle HP

Replicates NeutronHP for inelastic scattering of "low" (E<200 MeV) energy particles (γ, n, p, d, t, ^{3}He, α)

Extensive validations against existing databases, other codes

- Cross-sections, secondaries, energy spectra
- TENDL Web data
- *G4PARTICLEHPDATA* vs. Job output
- G4 vs. MCNP (*Note: G4 does not interpolate tables*)

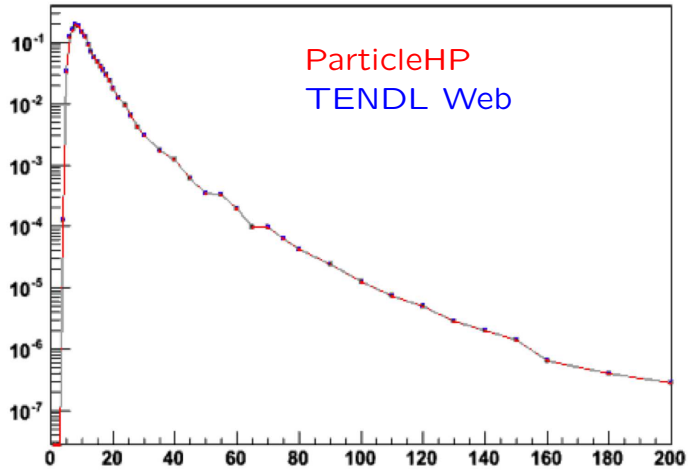
Reproduces existing NeutronHP exactly with neutron projectiles

Ready for release – should go into toolkit

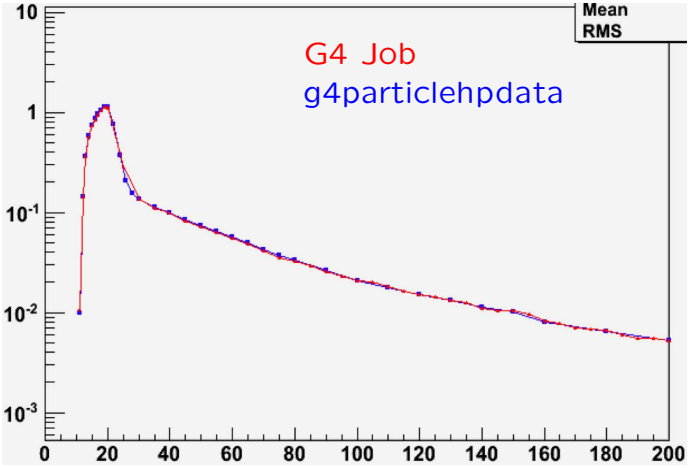
Pedro Arce Dubois, CIEMAT

Particle HP Validation

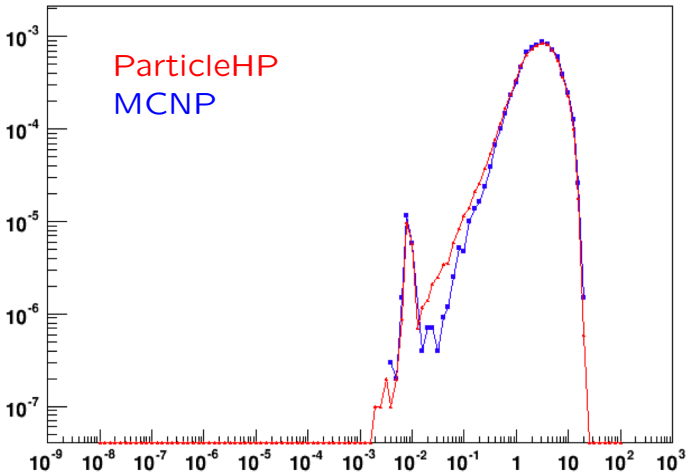
^{14}N (p,α) ^{11}C



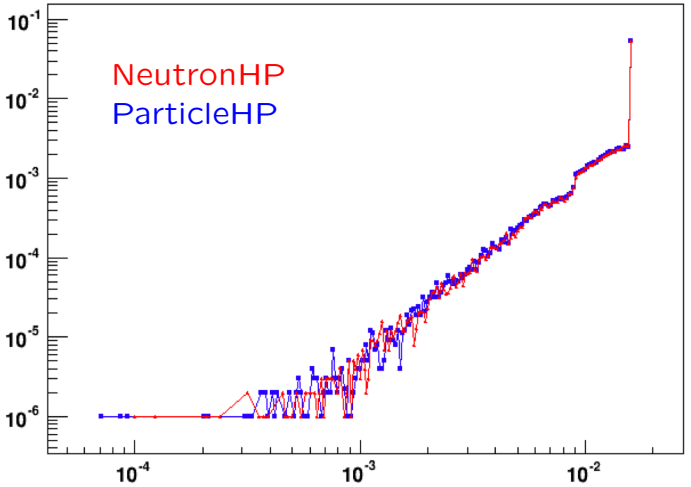
^{208} Pb(p,2n) ^{207}Bi



^{18} O(p,n) X



^{27}Al (n,n) X



Pedro Arce Dubois, CIEMAT

PreCompound

Improvements for multithreaded compatibility

- Fixed logic in soft-cutoff, disabled by default (JMQ)
- Removed all static members
- Finalized migration to integer Z and A
- Added usage of **G4Pow** in several places

José Manuel Quesada Molina, U Sevilla

Vladimir Ivantchenko, CERN/G4AI

De-excitation

Improvements for multithreaded compatibility

- 7 singletons become simple classes w/o statics
- 4 *true* singletons (master thread init, const methods)
- Most memory used by G4FermiFragmentsPool
- Usage of G4Pow in several new places

General improvements in physics, logic

- G4ExcitationHandler avoids unphysical fragments (4n, 5n,...)
- Stop evaporation if Fermi Break-up can decay fragment
- Removed old G4RandGeneralTmp providing ref-08 memory increase

José Manuel Quesada Molina, U Sevilla

Vladimir Ivantchenko, CERN/G4AI

Photon Evaporation

Isomer production has been introduced

- Needed to generate correct de-excitation gamma spectra
- Addresses many questions in HyperNews
- Imporatant for nuclear physics and medical applications

Fragments with $\tau > 1$ μs moved to output secondaries

- Only applies to fragments from isomer table
- Enabled only if isomer table is initialized

Future development of package required

- Old code, revised/cleaned up several times
- Reads data from `G4LEVELGAMMADATA` files (L. Desorgher)
- Data managed by thread-local singleton
- Data is uploaded dynamically
- Memory and CPU overhead, possible I/O contention

José Manuel Quesada Molina, U Sevilla

Vladimir Ivantchenko, CERN/G4AI

Radioactive Decay

`G4RadioactiveDecay` (RDM) fully MT compatible

Nuclide decay tables now stored in map local to RDM

- No longer coupled to particle definition
- Master (static) map and local (per-thread) maps created

On-demand creation of ions (isotopes) still supported

RadioactiveDecay and PhotonEvaporation databases

- updated to ENSDF August 2012
- Versions 4.0 and 3.0, respectively

Re-design of RDM is required (>10.0 development)

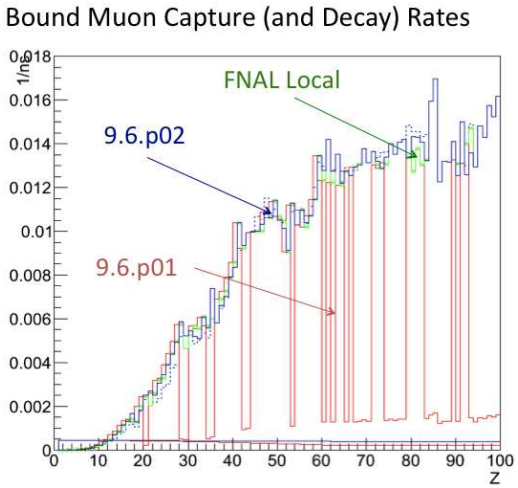
- Internal conversion
- Correct gamma multiplicity

Dennis Wright, SLAC

Muon Stopping and Capture

Muon capture and decay-in-orbit substantially rewritten

- Off-by-one errors in capture rate vs. Z
- New capture rate tables vs. Z,A
- Improved data values in rate tables
- New decay rate calculation vs. Z_{eff}
- New **AlCap** data included after 10.0



Krzysztof Genser, FNAL

Captured muons now processed through BERT

- Muon projectile includes binding energy
- μ^- p, μ^- [pp], μ^- [pn]
- Neutrons, occasionally other secondaries

Dennis Wright, SLAC

Multithreaded Compatibility

Hadronics framework operational for MT applications

- All processes and models converted, validated
- Profiling indicates marginal ($\lesssim 1\%$) effect on CPU
- Larger than desirable use of per-thread memory

Further improvements discussed in Parallel 7B

- Reduce thread-local variables, using class data buffers
- Move large fixed objects to shared memory (static const)
- Provide master and per-thread `Initialize()` for models

Some will be finished for 10.0, some will continue into 2014

Andrea Dotti, SLAC

Summary

Several new physics processes introduced or improved

- Nucleus-nucleus interactions in FTF and INCL++
- Muon capture, decay-in-orbit, and cascades
- Isomers: radioactive decay, photon evaporation
- NeutronHP, ParticleHP

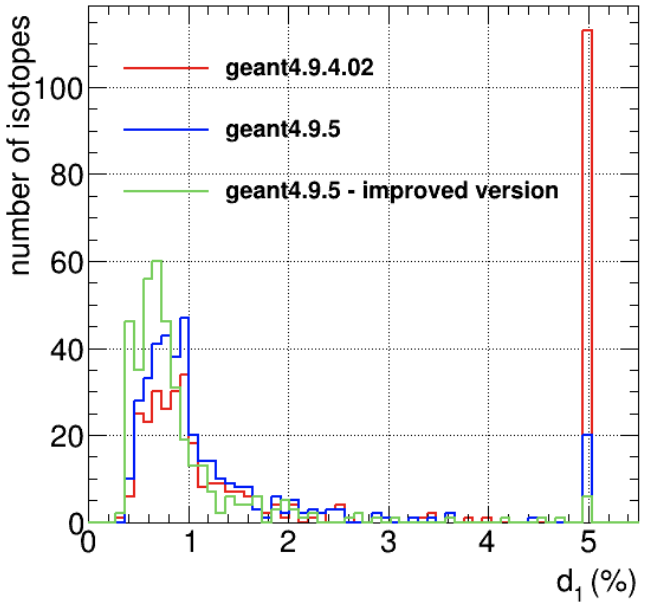
More uniform handling of excited nuclear fragments

Hadronic framework is MT-compatible, optimization work needed

Followup from Parallel 4A Appears to be no problem with NeutronHP code in 9.6: discrepancy due to plot generation

Neutron HP backup

- Major improvements in G4NDL from 3.14 to 4.0
- Significant MCNPX agreement
- Some further refinement 4.0→4.1→4.2



Emilio Mendoza Cembranos, CIEMAT