

Recent Geant4 Hadronic Physics Features

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Geant4 Technical Forum

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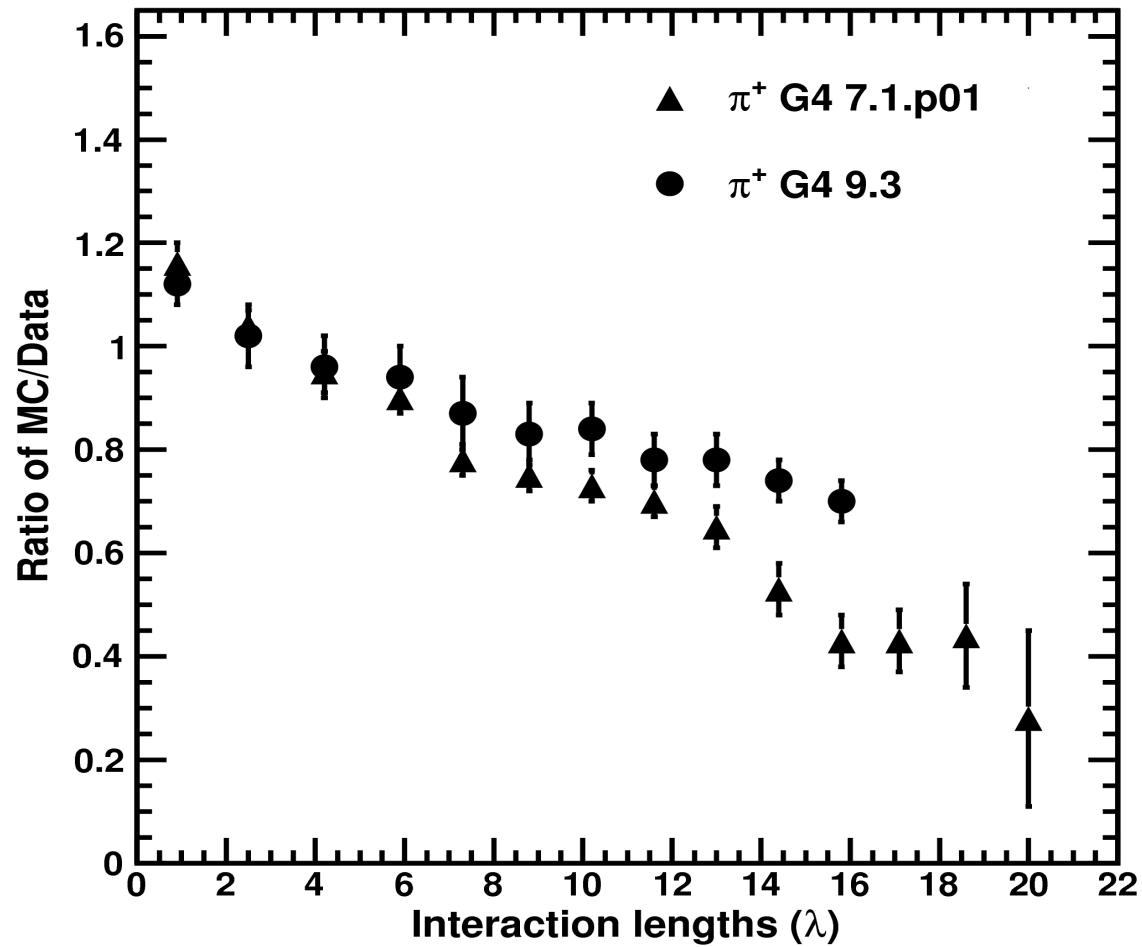
Outline

- Introduction
- A review of major improvements in 9.3 (2009)
- Features in 9.4 beta (June 2010)
- New features in 9.4 (December 2010)
- Plans for 2011

Introduction

- Work of the hadronic group over the past 3-4 years has been driven by requests from LHC detectors
 - better hadronic shower shapes
 - better energy response and resolution
 - good progress, but still work to do
 - improved kaon interactions
 - models extended to handle this
 - ion-ion interactions
 - development ongoing
 - anti-nucleon and anti-ion reactions
 - development program recently begun

Atlas Tile Cal Longitudinal Shower Shape for Incident Pions



Summary of Major Improvements in 9.3

- **FTF model**
 - added excitation energy calculation and introduced Reggeon cascading
 - resulted in extension of applicability to lower energies
 - smoother transition to cascade possible
 - improved pion absorption
- **Bertini-style cascade**
 - full review of pi-nucleon and nucleon-nucleon partial cross sections
 - many corrections made

Summary of Major Improvements in 9.3

- **Precompound and de-excitation models**
 - GEM model fixed and re-introduced
 - replaced old-style emission probabilities (based on pre-1960's data) with new parameterization
- **BinaryLightIon cascade**
 - improvements to allow de-excitation of smaller fragments
- **QMD model (ion-ion collisions) extended up to 5 GeV/n**
- **CHIPS models extended to all particles, all energies**
 - validation in progress, some problems found

Features in Geant4 9.4 beta

- Extension of FTF model down to 3-5 GeV for hadron-nucleus scattering
 - tuned parameters of Reggeon cascading
 - improved fragmentation of small-mass strings
- As a result, improved behavior below 8 GeV
 - smoother transition from cascade to string model in physics lists (e.g. FTFP_BERT)
 - transition from cascade to string model now possible at lower energies
 - can now consider using Binary cascade as alternate to Bertini

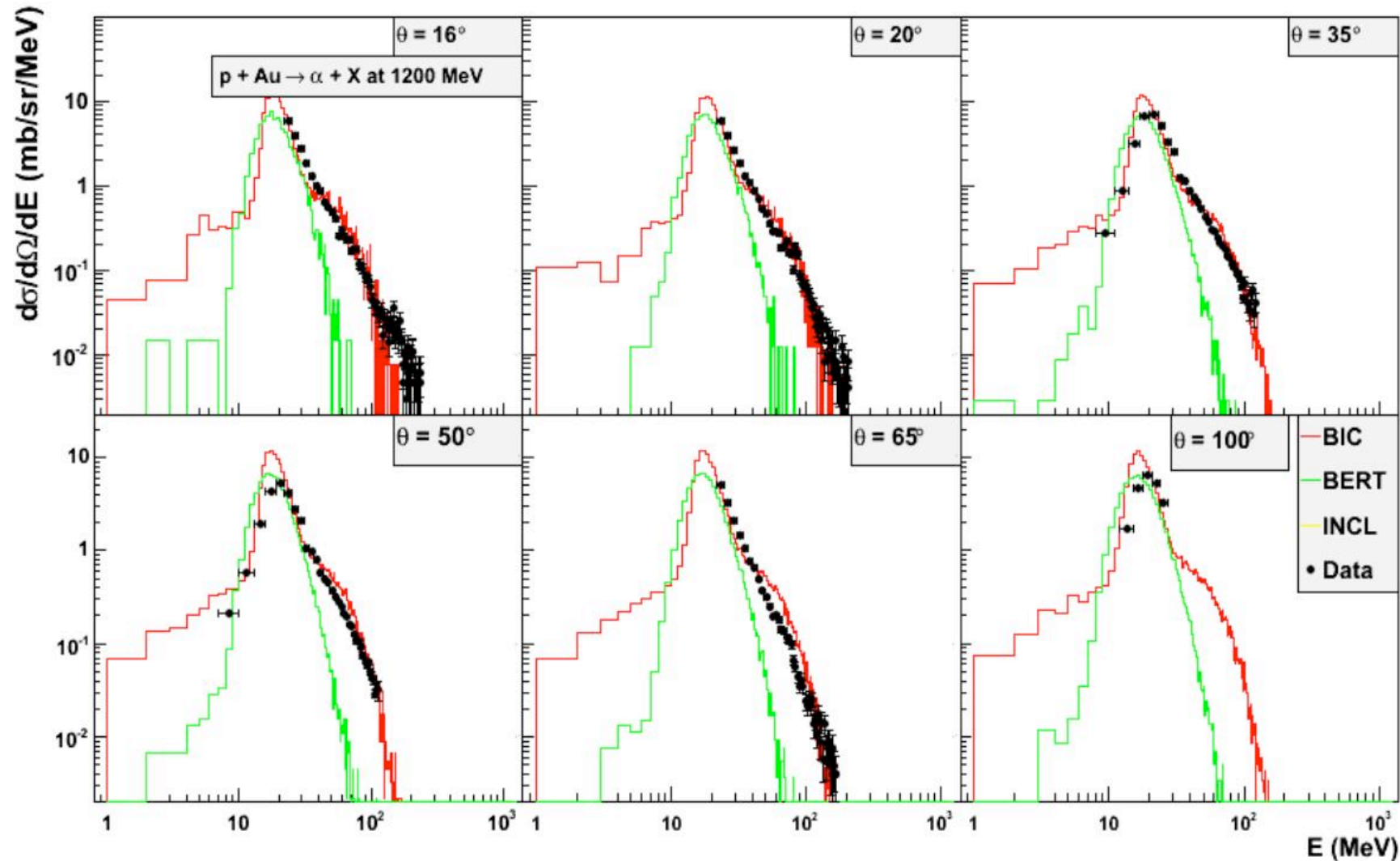
Features in Geant4 9.4 beta

- Bertini-style cascade
 - almost all energy-momentum non-conservation removed
 - old pion-nucleon and nucleon-nucleon angular distributions replaced (for two-body final states)
 - reduction of memory churn by factor ~ 10
- Partially completed transition to using integer A and Z exclusively in hadronic code
 - now require use of specific isotopes – no effective Z or average A allowed
 - can no longer use materials with average Z and A

Features in Geant4 9.4 beta

- Extensive improvements in G4Precompound model and de-excitation code
 - hybrid use of Weisskopf-Ewing and GEM models to improve nuclear fragment spectra from decay
 - improved inverse capture cross sections
 - numerous bug fixes and improvements in logic
 - enable use of multi-fragmentation model

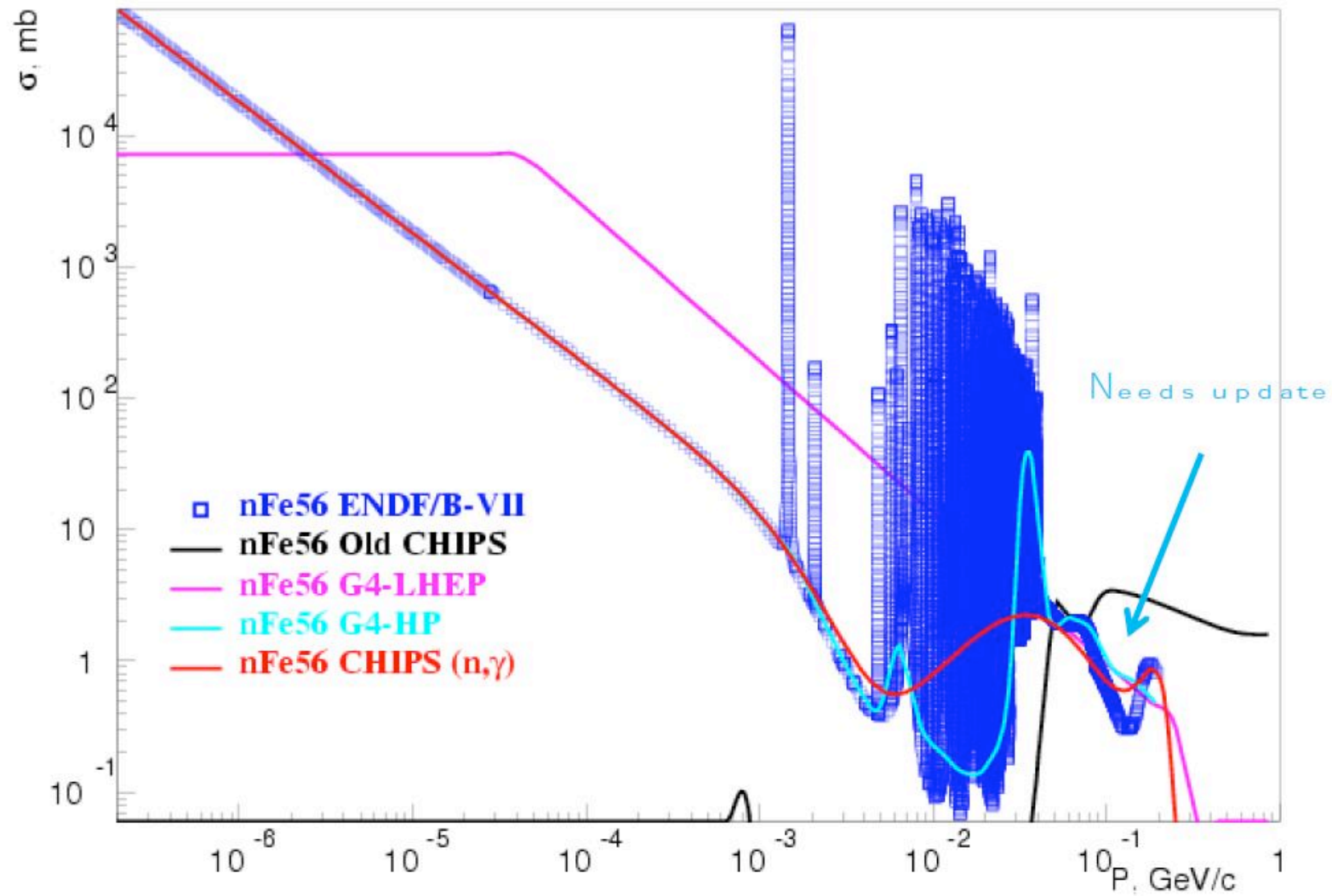
Precompound and De-excitation Models vs. IAEA Data for $p+Au \rightarrow \alpha + X$



New Features in Geant4 9.4

- **Faster neutron capture model**
 - includes some of the detail found in HP neutron models
 - old GHEISHA-based model too simple
 - high precision neutron model too slow
- **ENDL-based (Livermore) precision neutron models**
 - alternative to HP models
 - more isotopes than HP models
 - based on Livermore neutron DB
 - not expected to be any faster

n + Fe Cross Section Data vs CHIPS, LHEP, and FastHP Parameterizations



New Features in Geant4 9.4

- **p, n, d, t, 3He, α - nucleus cross sections**
 - first step in expanding hadronic models to handle incident anti-nucleons and anti-light ions
 - Glauber-Gribov parameterization
 - CHIPS cross sections
- **Interfaces of cascade models to G4Precompound model**
 - allows our best de-excitation model to be used in a uniform way with existing cascade codes
 - Bertini-style cascade
 - already used by Binary cascade

New Features in Geant4 9.4

- Nucleus-nucleus collisions
 - nucleus-nucleus cross sections
 - Glauber-Gribov-parameterized cross sections cover targets and projectiles of all A
 - projectile energy down to ~ 1 MeV and up to \sim TeV

Plans for 2011

- Shower shape and calorimeter response improvements
 - develop and validate new physics lists to exploit recent model extensions
 - try new implementation of nuclear trailing effect in Bertini cascade
- Completed implementation of hadronic cross section de-design
 - developed plan last year to treat large number of cross section data sets uniformly
 - will allow smoother joining of one set to another

Plans for 2011

- Anti-nucleon, anti-nucleus extensions
 - Bertini-style cascade
 - FTF model
- Kaon oscillation, cross section improvement for kaons, hyperons
- Installation of CIEMAT alternative to G4NDL (high precision neutron libraries)
 - use of ENDF-VII database, but processed differently than G4NDL

Plans for 2011

- Add initial and final state clustering models to Bertini
 - to improve light ion production at cascade energies
- Interface of G4Precompound and de-excitation to INCL cascade

Plans for 2011

- Nucleus-nucleus scattering
 - currently our models do not perform well above ~ 5 GeV/c
 - extend them: FTF, RQMD
 - low energy scattering
 - current models do not go below ~ 100 MeV
 - will then have complete coverage of nucleus-nucleus A and incident energy
 - develop and validate new physics lists to use new ion-ion models and cross sections