Geant4: What's new, improved, or under study in hadronics

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Overview

- Recent improvements in hadronic processes
  - in Release 9.2 (Dec 2008) and its patch 1
- Known issues, challenges
- Validation, improvements underway
- Physics lists
  - Candidates for validation
  - In early development

Improvements in 2008

Improvements in hadronic processes in Release 9.2 (Dec 2008) and its patch 1

Selected from G. Cosmo's talk at March 9th Geant4 Technical Forum meeting

Hadronics: the Improved and New

Improved:

- Corrections & tuning in **pre-compound** and **de-excitation** code
  - affecting results for low-energy secondaries in Binary cascade
- Revised string fragmentation and tuned parameters in **FTF** model
  - For `Pi+P` and `pion-nucleon` interactions
  - Implemented quasi-elastic hadron-nucleus scattering and formation time
- Enabled/added barrier penetration for the Coulomb barrier in **Bertini** cascade

New:

- **INCL** cascade and **ABLA** evaporation model officially released
  - Can be used for incident `p, n, d, t, 3He, alpha` and `pions` from `200 MeV` up to `3 GeV`, on nuclei ranging from carbon to uranium
- *Beta* release of *new* quantum molecular dynamics (**QMD**) model
  - For nucleus-nucleus collisions; valid from `50 MeV` to `5 GeV`

Hadronic processes: major fixes

- Bug fix in the final state multiplicity sampling in **Bertini** cascade
  - Fixes observed problem of quasi-elastic peak in energy spectra
- Corrections to the **multi-fragmentation** model to ensure it conforms with the original SMM model (from its authors)
- Improved energy and angular distributions for both scattered neutron and recoil targets in the **hp_neutron** model
- Code review and performance improvements to **Bertini** code
  - Measured ~25% CPU time boost when using QGSP_BERT for **`50 GeV pi-`**
- Technical
  - Rationalised usage of the nuclear mass tables

Latest Hadronic fixes – 9.2.p01

- Corrected light ion emission in pre-compound/de-excitation
  - Probability of emission in pre-compound
  - Implementation of the emission probability in de_excitation model
  - Added smearing of Coulomb barriers for **`d, t, he3`** and **`alpha`**
- Tuned absorption coefficient in Bertini cascade

- Technical
  - Activate proper deletion of processes, models and cross-sections at job closure

(Personal perspective)

LATEST

Known issues; challenges

- ‘Discontinuity’ in energy deposition in transition between Bertini and LEP QGSP_BERT
  - Reported by CMS
- Deficiencies of LEP model
  - Conservation laws
  - Spectra
- Gap between ‘applicability’ of cascades and string models (general issue for MCs)
  - Bertini validated up to ~5 GeV
  - Binary limited to ~2.5 GeV (protons), ~1.5 GeV (pions)
  - QGS validated from 13/15 GeV
  - FTF potential to fill the gap (under validation 3+ GeV)

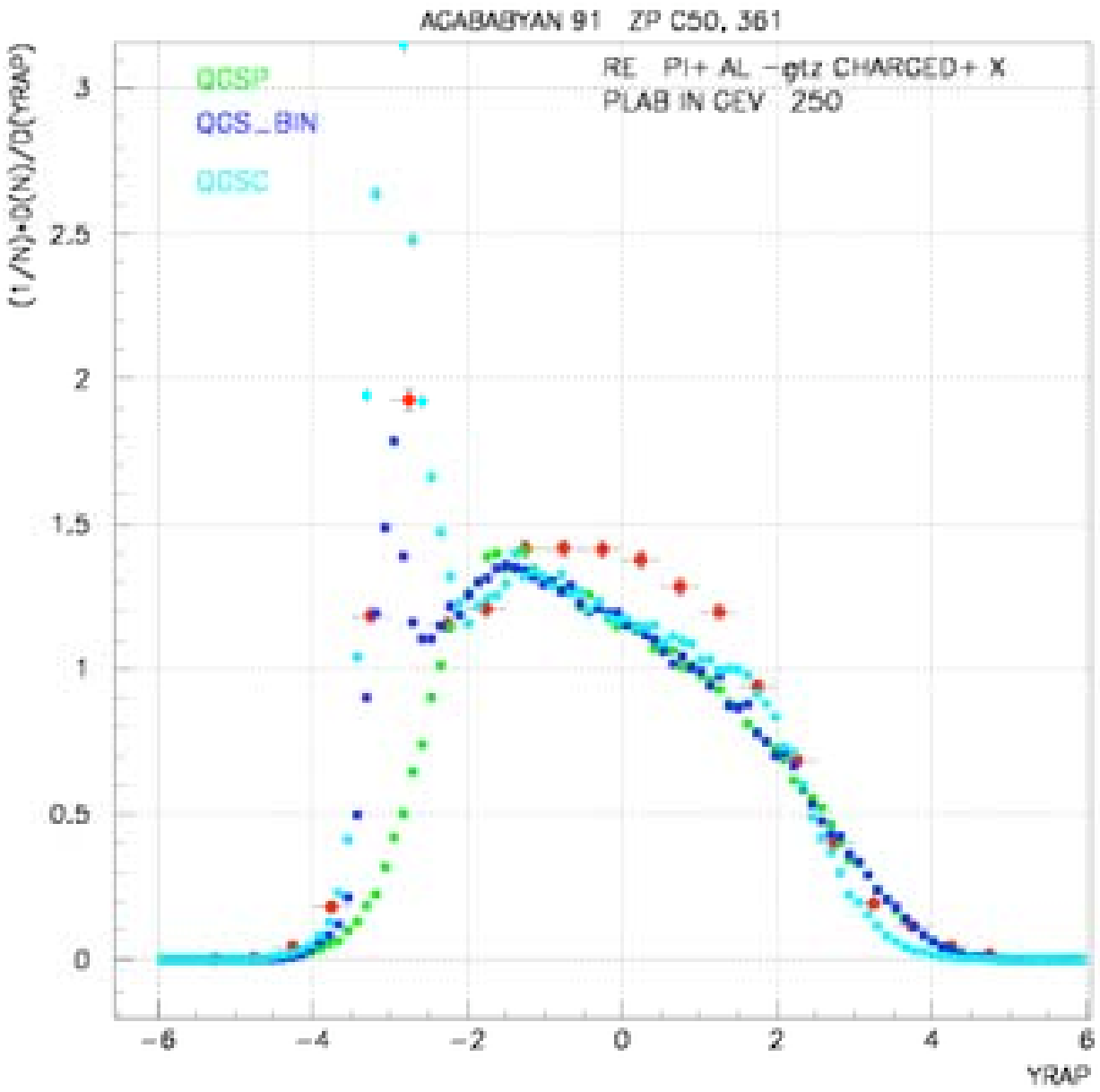
Background: QGSP_BERT

- Elastic n/p from M. Kosov
- Uses BERTini up to about 9.7 GeV for p/n/pi
- Uses LEP for most interactions 9.7<E<18 GeV
  - And for hyperons
- QGS for most interactions E> 18 GeV
  - Links with Precompound for de-Excitation
    - Underestimates target framentation
- Neutron capture from LEP model
  - Significant limitations
    - alternative HP can be used via QGSP_BERT_HP)

Underway

- Expansion of validation
  - Status for 5-20 GeV presented at CHEP 2009
    - Additional comparisons being prepared & sought
  - Future 25-70+ GeV
- Linking of cascade to string model(s)
  - To model re-interaction of low-energy products
- Study of transitions between models
  - Multiplicity, energy moments of products
- Trial physics lists
  - FTF in place of LEP and QGS
  - Others without LEP models

- Effect of re-interaction



Transitions between models

- Transitions in existing physics lists
  - QGSP_BERT: Between Bertini, LEP and QGS/P
    - Bertini E< 9.9; LEP: 9.5<E<25; QGS/Preco: E>12.5
- Studying
  - Energy in π^0, π^+/π^-, p, n, light ions
  - Multiplicities
  - Spectra (to do)
- Future
  - Identifying best criteria for transitioning between models

Potential production physics lists

- Old: LHEP, QGSP
  - QGSP: uses QGS/Preco phased in over interval 12-25 GeV)
  - Alternative: QGSC (CHIPS as de-excitation, QGS 8-25)
- 'Production' at LHC: QGSP_BERT
- Emerging: Featuring FTF in place of LEP and QGS
  - FTF_BERT: transition from BERTinit to FTF at 4-5 GeV
    - QGS not used at all
- New: Linking of cascade to string model(s)
  - To model re-interaction of low-energy products
    - Improve target fragmentation
  - FTF_BIC and QGS_BIC

Development / Trial physics lists

- Others without LEP models
  - QBBC: Binary for p/n, BERTini for pions
- Trial: temporary developments
  - QGSP_NOLEPx
- …

OTHER / BACKUP

New Features – physics - 2

- Standard Electromagnetic processes
  - Enabled by default Cubic Spline interpolation of **`dedx`** and cross section tables
  - New multiple-scattering process and model
    - **`G4eMultipleScattering`**, specialized for simulation of e+ and e-
    - **`G4WentzelVIModel`** for multiple scattering of muons and hadrons
  - New Bremsstrahlung model, **`G4eBremsstrahlungRelModel`**, including advanced description of LPM effect
  - New utility classes
    - **`G4EmSaturation`** for sampling of Birks saturation; **`G4ElectronIonPair`** based on the ICRU'31 report for sampling electron/ion pairs in sensitive detectors; **`G4EmConfigurator`** for configuration of models in physics lists
  - Initialization of **`SubType`** added for all processes

Major fixes – physics - 1

- Electromagnetic processes
  - Improved implementation of the **`G4LogLogInterpolation`** class
    - Providing visible CPU improvement in low-energy physics processes
  - More precise multiple scattering model for e- and e+
    - Providing wider shower (about 0.5% measured for the CMS calorimeter)
    - Increase of visible energy in sampling calorimeters (due also to Spline approx)
  - Fixed cases of string comparison when computing transport cross-sections in MSC models, compare masses instead
  - Speedup run-time computations in e-Coulomb scattering model
    - Using pre-computed nuclear form-factors per element
  - Added scintillation with Birk's law and modified sampling of the Cerenkov photon origins

Improved in 2008: De-excitation

- De-excitation reviewed & corrected
  - Many components improved
    - Pre-compound model (JM Quesada)
    - Evaporation (A Howard, JM Q)
    - Multi-fragmentation (donated by SMM authors)