Anticpated Needs of LHC experiments and CALICE

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Geant4 Collaboration Meeting, Seville, 26 September 2013

ATLAS, CMS, CALICE (1/4)

- By far, the most important and stringent requirement of these experiments on Geant4 hadronic physics is coming from the **simulation of** (QCD or electroweak) **jets**
- The simulation of jets depend by three main ingredients
  1. Monte Carlo Event Generator
  2. Geant4 : simulation of hadronic showers
  3. Experiment specific : dead materials, digitization, pile-up
- Up to now, the simulation of jets is in good agreement with LHC data, but the foreseen increase in statistics will possibly reveal some shortcomings...
- Therefore, for the Geant4 side, we need:

1. To improve the simulation of hadronic showers as much as possible, based on calorimeter test-beam data
2. Prepare alternative models to help in disentangling the source(s)^2 of the problem and/or evaluate the systematic uncertainties

ATLAS, CMS, CALICE (2/4)

- Calorimeter observables of hadronic showers

  - **Energy response**
    - **Very important for the jet energy scale** for traditional calorimeter jets
    - Currently described with an accuracy of ~ few %
    - Sensitive to nearly all (string model, cascade, precompound/evaporation)

  - **Lateral shower shape**
    - **Essential for the particle flow approach**
    - Relevant also in general for cluster identification, jet structure, isolation requirements, and jet overlaps
    - Currently described with an accuracy of ~ 10 – 20 %
    - Sensitive mostly to the intra-nuclear cascade, a bit less on the string model

  - Energy resolution
    - Important for the di-jet mass resolution, e.g. hadronic decays of W, Z, H for traditional calorimeter jets
    - Currently described with an accuracy of ~ 10 – 20 %
    - Sensitive to nearly all (string model, cascade, precompound/evaporation)

  - Longitudinal shower shape
    - Important for particle identification, jet-calibration, punch-through
    - Currently described with an accuracy of ~ 10 – 20 %
    - Sensitive mostly to forward physics (elastic, quasi-elastic, diffraction)

ATLAS, CMS, CALICE (3/4)

- Alternative models for hadronic showers
  - High-energy string model: **FTF** , **QGS**
  - Intra-nuclear cascade model : **BERT**, **BIC**, **INCL**
  - Nuclear de-excitation : **Precompound/evaporation**, **INCL+ABLA**

- Some work would be required to consolidate **BIC** and **ABLA**, but most of the effort would be required to improve **QGS** and to extend it to lower energies:
  - Use ReggeonCascade as for FTF
  - Improve sampling of QGS
  - Debug, tune, validate with thin-target data (test22 can be used)

  QGS model is more theory-based than the phenomenological FTF model, and can be applied to higher energies

ATLAS, CMS, CALICE (4/4)

- Tau, c-hadrons, b-hadrons nuclear inelastic interactions
  - τ : lifetime = 87 μm , mass = 1.777 GeV
    D+/- : lifetime = 312 μm , mass = 1.870 GeV (longest lived c-hadron)
    B+/- : lifetime = 492 μm , mass = 5.279 GeV (longest lived b-hadron)
  - These particles, if highly boosted, could cross the first layers of the tracker detectors, hence could interact hadronically
    - Interest expressed by ATLAS at the end of 2012
      - *> 30 cm important*
      - *> 5 cm would like to have*
      - *> 1 cm would be nice*
      - *< 1 cm not needed*
    - We asked for numbers (from MC generator + G4 simulation) in support
  - Tau-nuclear interactions would required a medium-level effort to be implemented in Geant4
  - Charm and bottom hadron – nuclear interactions would required a major effort to be implemented in Geant4
    - For the final state, models exist in MC Event Generator (Pythia6&8, Herwig(++))
    - For cross sections, an approximated approach exist in literature

LHCb and ALICE

- These are mainly tracker-based experiments
- For hadronics, the main interest is on single hadron-nucleus inelastic interactions in the tracker (i.e. gas, Be, Si, Al, etc.)
  - Frequency of interactions (i.e. **cross sections**)
  - **Final state** produced
    - **Multiplicities** of secondaries produced
    - **Spectra** of secondaries
- Need a reasonable description not only for **pion**s, **proton**s and **neutron**s, but also for kaons, hyperons, and antiprotons
  - Also light anti-ions for ALICE
- It is important for them to see our validation plots:
  - Thin-target benchmarks of Geant4 hadronic models
  - Comparisons of hadronic cross sections
    - between versions and with experimental data whenever possible

AEgIS , ASACUSA antiproton annihilation (nearly) at rest

- They are using Geant4 **FTF + Preco** or **CHIPS** for the simulations of antiproton annihilations (nearly) at rest
- The description of test-beam data
  - AEgIS annihilation of antiproton at rest in Silicon

  looks reasonable but not excellent
- It is likely that at some point they will require better models of antiproton annihilation (nearly) at rest
- What can we do?
  - Try and improve FTF_BIC ?
  - Provide a special tuning of FTF aimed only for antiproton annihilations (nearly) at rest ?
  - Other ideas ?

Exotica

- R-hadrons
- Q-balls
- ...

Ad-hoc models for these exotic particles have been developed over the years independently by some Geant4 users.

At some point in the future, we could review them, and eventually distribute “official” versions:

- to avoid duplication of efforts
- to avoid mistakes in the use of Geant4 hadronic framework
- to maintain the code in sync with the evolution of Geant4