Applications of Geant4 Hadronic Physics Models in Simulation for Neutrino Experiments

J. Yarba
Fermilab

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The Aim

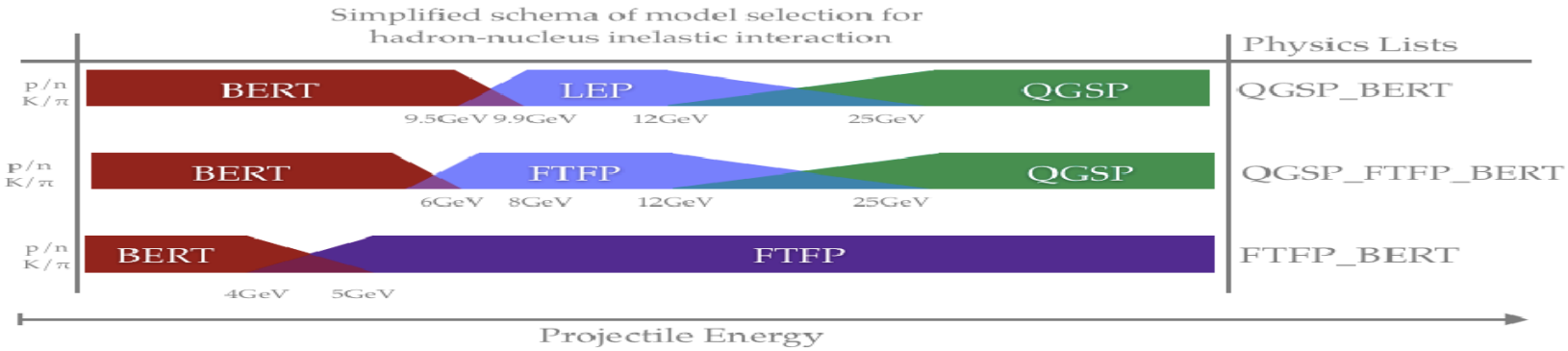
Provide FNAL Neutrino Community with best possible hadronic physics modeling tools within Geant4 by improving hadronic models and Physics Lists

Geant4 Hadronic Physics - General Remarks

- There is NO "unified" hadronic model
- Hadronic models are valid (or better fit) for combinations
  particle type – energy (- target material)
- Need to choose a set of hadronic models to cover all possible interactions – Physics List (what a user typically sees)
- The choice is NOT a "black box" but depends on use-case:
  - The particles in simulation
  - The energy scale
  - The compromise between accuracy and CPU
- Collection of ready-to-use physics lists exists
- Users can also tailor any of those, or write their own

Physics Lists Composition and Transition Between Models

- Hadronic models may overlap in their validity range – this is also reflected in the composition of Physics Lists



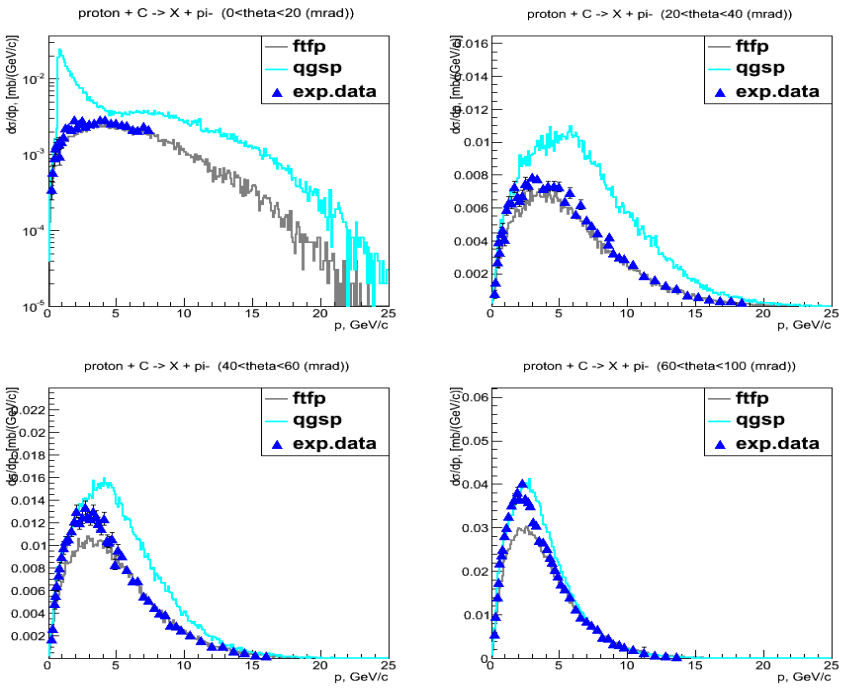
- Choice is based:
  - General Validation (benchmarking vs exp.data)
  - Use-case(s)

Simulation for Neutrino Experiments - Use-Case (the way we see it)

- Two distinct cases:
  - Modeling interaction of high energy proton beam with primary target and neutrino flux prediction
  - Modeling of neutrino-induced hadronic showers in the detector
    - lower-to-intermediate energy range
- Available Geant4 models:
  - High energy – FTF (from ~3GeV up), QGS (from ~15GeV up)
  - Intermediate energy – Intra-nuclear cascade models (from 0 to 5-30GeV): Bertini, Binary, INCL++ (under development), partially FTF
  - PreCompound model to treat excited nuclei
- Questions:
  - How to compose models together for this specific use-case
  - How to improve models (for this specific use-case or in general)

Elements of Geant4 Validation Suite (I)

- High energy validation:
  - FTF(P) and QGS(P) models
  - Single interaction simulation



Experimental data:

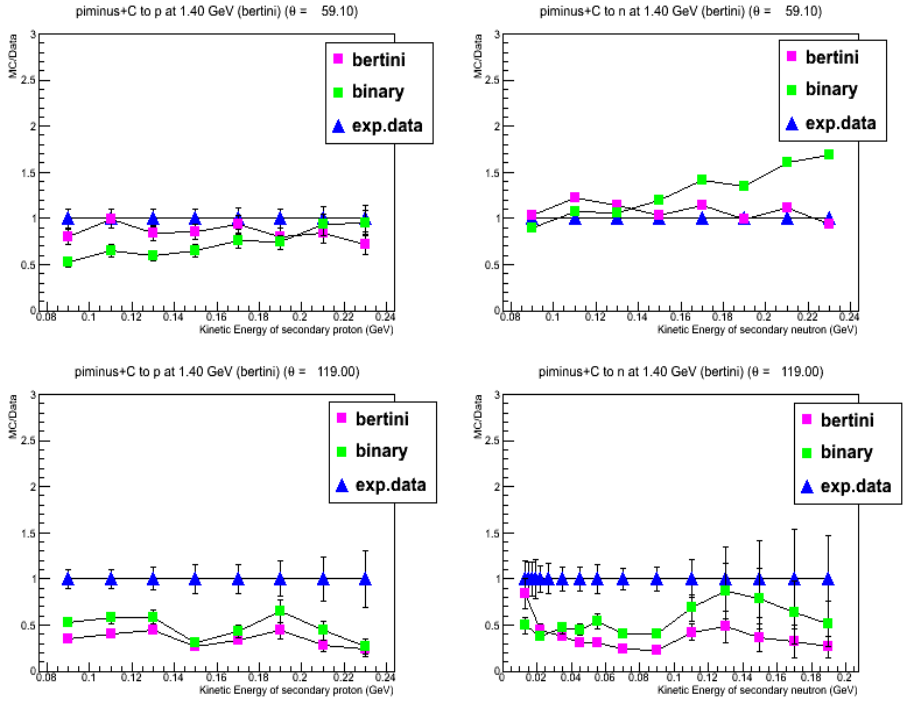
NA61 (31GeV/c p+C, various p+p)
NA49 (158GeV/c p+C, p+p)
MIPP (56-120GeV/c p on various targets)

Sample plots:

Momentum distribution of pi+ produced in 31GeV/c p+C interaction, in different theta-bins

Elements of Geant4 Validation Suite (II)

- Lower-to-Intermediate energy:
  - Bertini, Binary, (part) FTF, INCL++
  - Single interaction simulation



Experimental data:
www-pub.iaea.org (22MeV to 3GeV p on various targets)
HARP & HARP-CDP (3-15GeV/c p, pi+, pi- on various targets)
ITEP (1.4-7.5GeV p, pi+, pi- on various targets)

Sample plots:
Momentum distribution of p and n produced in 1.4GeV/c pi- on C interaction, in different theta-bins

Elements of Geant4 Validation Suite (III)

- A variety of other validation tests:
  - Geometry/navigation/transportation
  - EM processes
  - Cross sections
  - Full Physics Lists
    - these tests are somewhat LHC/Calorimetry biased
    - we would like to introduce other types of testing, also with the focus on the needs of Neutrino Program

Tests Conducted in Experiments vs Geant4 Validation

- More complex/specific geometry
  - Single interaction
  - Particles may re-interact
- Use of complete Physics List vs single model
  - A good chance to land in the area of models overlap
- A variety of observables:
  - Production of individual particles (inclusive/exclusive)
  - More complex observables such as shower shapes, resolutions, etc.
- This is an excellent source for identifying issues
  - In models themselves
  - In how the models are combined together

What Is in the Plans of the Neutrino Community ?

- Specific interests:
  - Particle types ?
  - Energy range ?
- What datasets to use for tuning:
  - Existing/published data ?
  - Ongoing measurements ?
  - Future test beam plans ?
- What are the testing applications in the Neutrino Community:
  - Beam-target configuration ?
  - Physics Lists in current use or of potential interest ?
  - Specific observables ?

Not a Summary but…

- Your feedback is vital for improving Geant4 hadronic models and their composition into Physics Lists !!!
- We can serve as liaison between Fermilab Neutrino Community and the Geant4 collaboration

Just FYI: large collection of Geant4 hadronic validation materials is available:

http://g4validation.fnal.gov:8080/G4ValidationWebApp/G4ValHAD.jsp