Validation of Hadronic Physics in Geant4

Outline

- Why Validation?
- Hadronic Physics in Geant4
- Possible Strategy

GDS-FNAL G4 Activities
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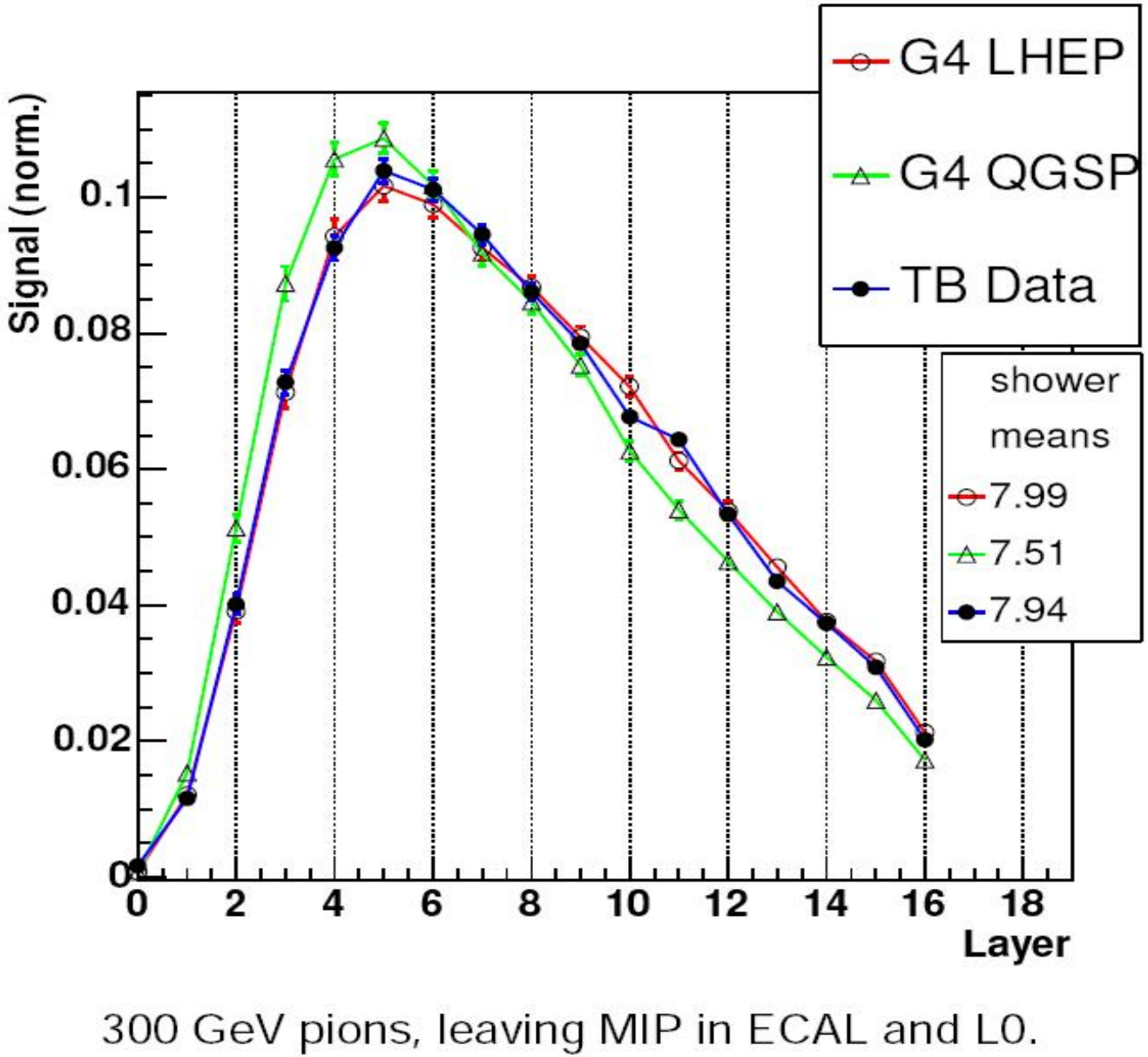
Why Validation?

- Geant4 will be used in understanding detector effects in LHC, .. Experiments.
- To have confidence in the description of detector simulation to match against real data, the physics processes inside Geant4 better be validated
- In some of the earlier comparisons of Geant4 simulation results with experimental data, some discrepancies were observed
  - shower shapes for hadrons (longitudinal shower profiles)
  - neutron fluxes
  - some spurious behaviour in some spectra (e/h, ...)

Longitudinal Shower Profile



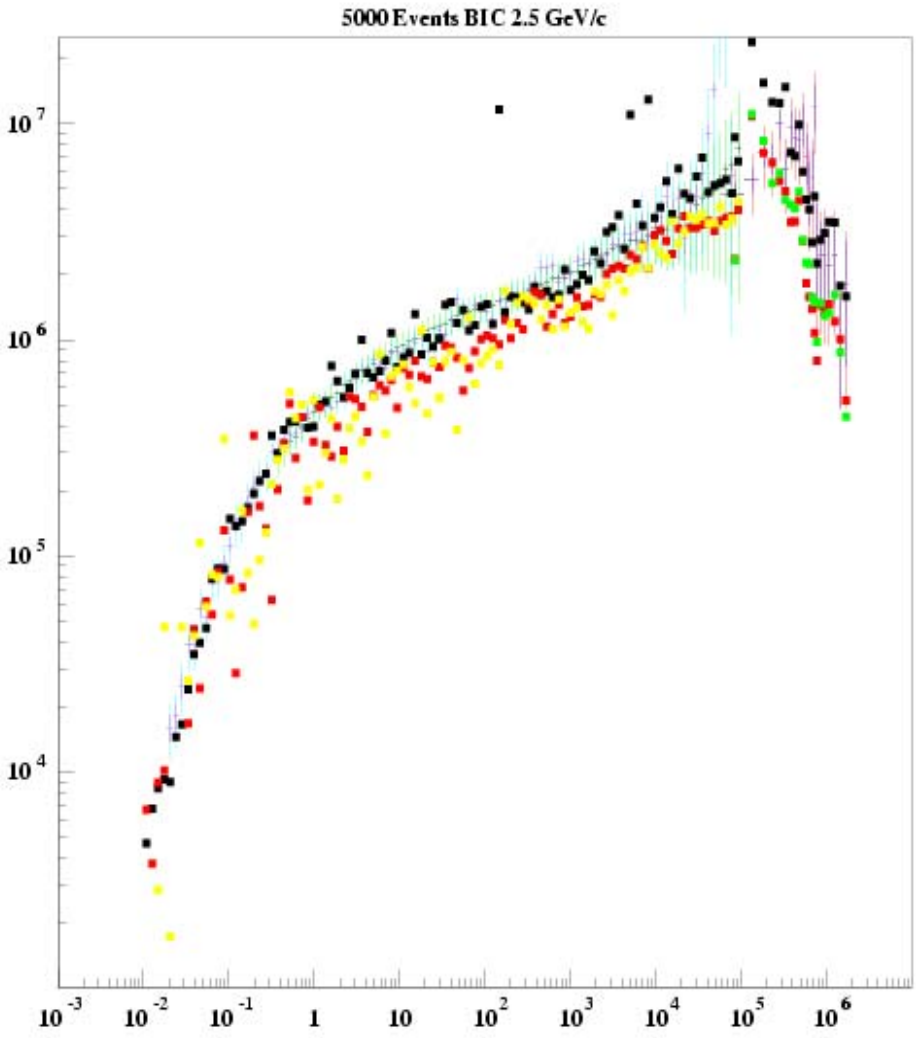
300 GeV pions, leaving MIP in ECAL and L0.

CMS H2 Test Beam

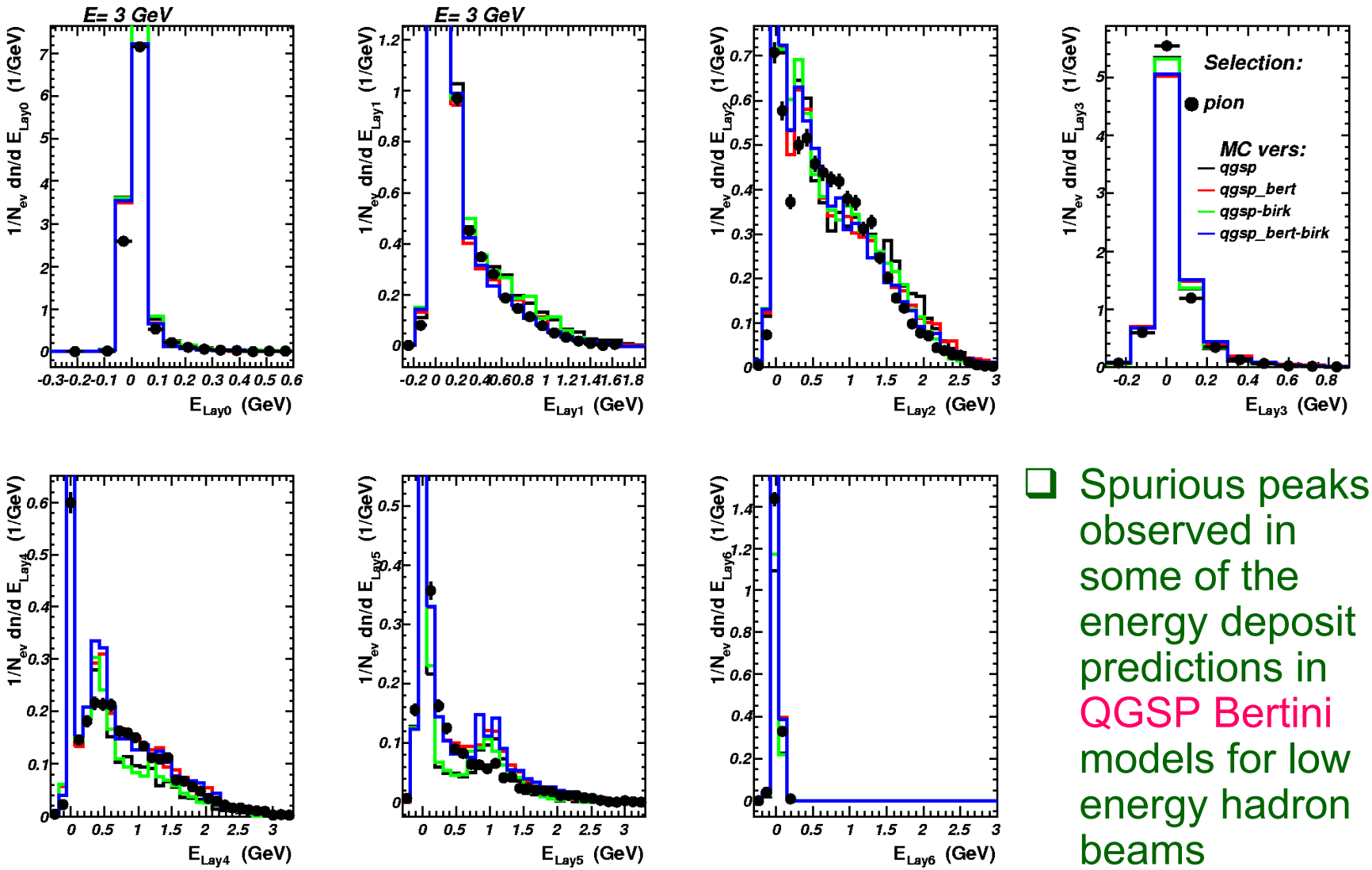
Microscopic models of Geant4 predicts shorter shower profiles than what is seen in the data

Neutron Fluence Comparison

- 2.5 and 3.5 GeV/c protons on 334 tons of Pb – measure neutron capture cross sections
- TARC data match in shape but not in magnitude with predictions from Cascade models (model predictions multiplied by factors 4-6)



Spurious Peaks?



- Spurious peaks observed in some of the energy deposit predictions in QGSP Bertini models for low energy hadron beams

Tasks

Validation of Geant4 physics will try to address these and in the process will do the following tasks:

- Check the codes
- Test physics assumptions in the models
- Tune the model parameters
- Compare with other simulation codes (Fluka, ...)

Collect and maintain a repository of all validation material and identify gaps in the validation process → Fill these gaps

Hadronic Process in Geant4

- Hadronic process inside Geant4 is described over a wide energy region, from thermal energies to few hundred TeV. This is done by a variety of models, each applicable in its own energy domain. The models are usually categorized as data driven, parametrized or theory driven.
- To describe physics interactions for a high energy experiment (like a LHC experiment), one needs to take input from various models and make them into a physics list comprising physics description of electromagnetic as well as hadronic processes. Typical examples are
  - LHEP which uses parametrized hadron models,
  - QGSP which uses a combination of theory driven and parametrized models
  - ……

Strategy (I)

Variety of data is used in validating physics in Geant4

- Thin target experiments
- Thick target experiments
- Various test beam studies of LHC experiments
- Other experiments

- The electromagnetic to hadronic ratio increases with energy due to π^o yield in hA collisions.
  - Low energy data are sensitive to nuclear physics effects
  - High energy data get significant contribution from the description of electromagnetic physics (like multiple scattering)

- So in the validation process, one should try to include observables which can tune electromagnetic shower shapes as well.

Strategy (II)

Measurements exist for

- Electromagnetic shower shapes
  - lateral profiles in crystals
  - longitudinal profiles in sampling calorimeters
- Hadron energy resolution, linearity, e/h
- Shower shapes in hadronic collision
  - lateral profile
  - longitudinal profile

Validation plan could be

- tune electromagnetic profiles first
- tune linearity, e/h for hadronic processes
- tune hadron shower profiles

Since high energy shower eventually ends up with low energy hadrons, it may be worthwhile to start with low energy data to fix low energy model and then to intermediate and finally to high energy models.