Geant4 Hadronic Physics: Validation and Optimization of Physics Lists for the FNAL Intensity Frontier Program

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General Information

- Previous meetings (scope of the task, general info, etc.)
  https://indico.fnal.gov/conferenceDisplay.py?confId=6808
  https://indico.fnal.gov/conferenceDisplay.py?confId=7150
- Topics at the 7/18/2013 meeting:
  - HE, IE models and status of test19, test23:
    - Modeling options
    - Datasets, observables
    - Composition of experimental physics list(s)
    - Collaboration with NuMI-X
  - Local Geant4 Documentation (upgraded G4-at-FNAL website)
  - Software restructuring in (part of) the HAD Validation suite

Status of Work – High Level View

- Based on testing (19, 23) results, an experimental physics list NuBeam has been composed:
  - Similar to FTFP_BERT
  - QGSP+G4LundStringFragmentation for protons at E>100GeV
    - http://geant4.web.cern.ch/geant4/UserDocumentation/UsersGuides/PhysicsReferenceManual/fo/PhysicsReferenceManual.pdf
    - Geant4 LXR code browser at KEK (not always operational)
  - Bertini-FTFP overlay at 7-10GeV
- NuBeam presented to NuMI-X (talk by JY on 10/21/2013), offered for initial testing and feedback
- G4-at-FNAL website ported to SharePoint, contents significantly upgraded (thanks to all who contributed !)
- G4 HAD Validation suite – restructuring started, test23 (incl. shared SW) and test19 committed/accepted; more to come

Status of Work – More Details

- Datasets:
  - HE – NA61 (p+C), NA49 (p+C, also p+p – in progress)
  - HE – MIPP ??? Doubts on neutrons ? K/pi ratio ?
  - IE – HARP (8-8.9GeV/c p+Be, p+Ta; also in progress p+C, p+Al, p+Cu)
  - IE-to-HE – BNL-802 (part of test47, p+Be,Al,Cu,) is an important reference but doesn't run regularly; what do we do ???
- Analysis tools/scripts:
  - Direct G4-model-data overlay
  - MC/Data ratio – being introduced to test19, test23
  - More sophisticated metric(s) ???
  - How to efficiently detect situations when there's an improvement in one corner but a damage in other area(s) ?

    Recent example – FTF modifications in 9.6.ref08-ref10 that improved pion multiplicity but jammed pt spectra and other particles

Improvement of Models and Physics Lists ?

- We have a good suite to attest the quality of Geant4 hadronic models, to detect deviations, etc.
- Results are archived and advertised:

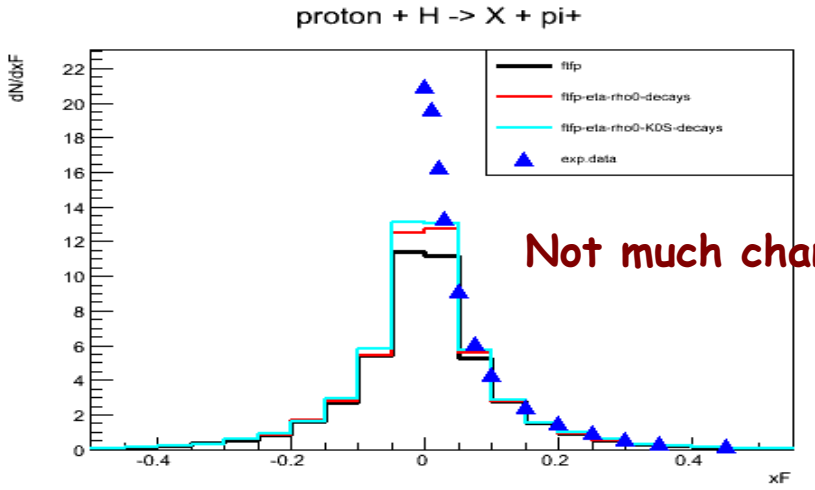
http://g4validation.fnal.gov:8080/G4ValidationWebApp/G4ValHAD.jsp

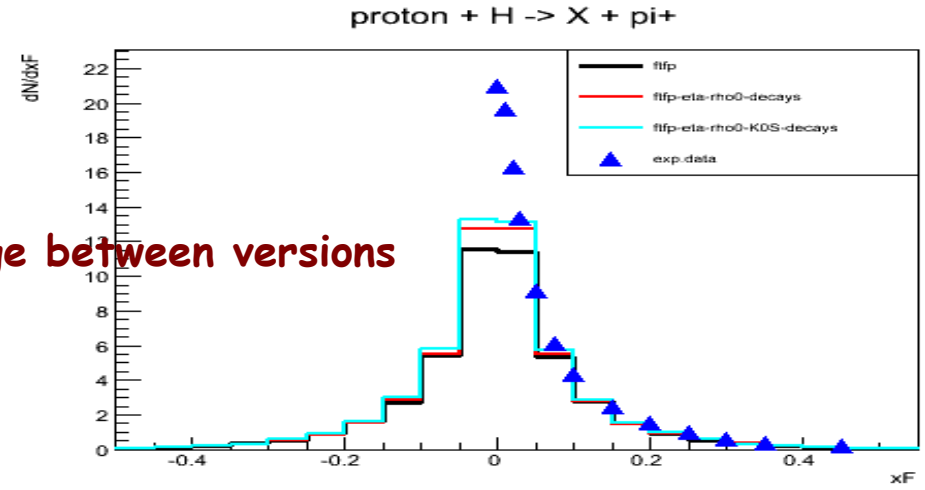
- We plan/work to improve/expand the suite some more
- We have identified custom options for the IF experiments
- We need (non-G4) tools that'd allow more flexibility/ configurability, look at more sophisticated observables, etc.
- BUT !!! We have a limited number of "nobs" (NOT on models)
- IF projects are looking for more precise effects than LHC
- Physics list is only as good as included models
- In a big picture, the question boils down to improving models

What Are We Tuning ? (I)

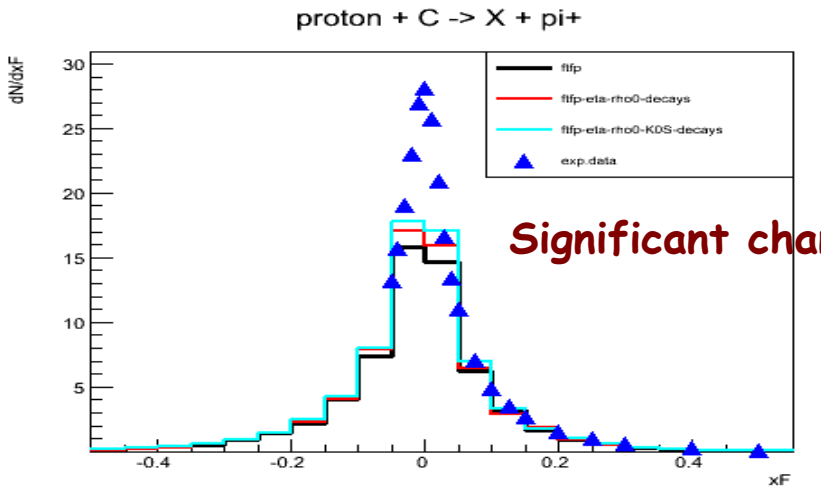
- As an example, let's consider NA49:
  - 158GeV/c p+C or p+p -> pions (since important to IF)
- The concept is also applicable to NA61, HARP, BNL-802,…
- Pion production:
  - Direct
  - From decays of resonances
- Are experimental data "bulk" ?
  - Most likely yes (incl. short-lived resonances, perhaps K0,…)
- G4 hadronic validation tests (seem to) judge G4 model(s) by looking at the outcome of a single interaction and benchmarking specific particles vs exp.data
  - At that point (in G4 event history) resonances are NOT decayed !

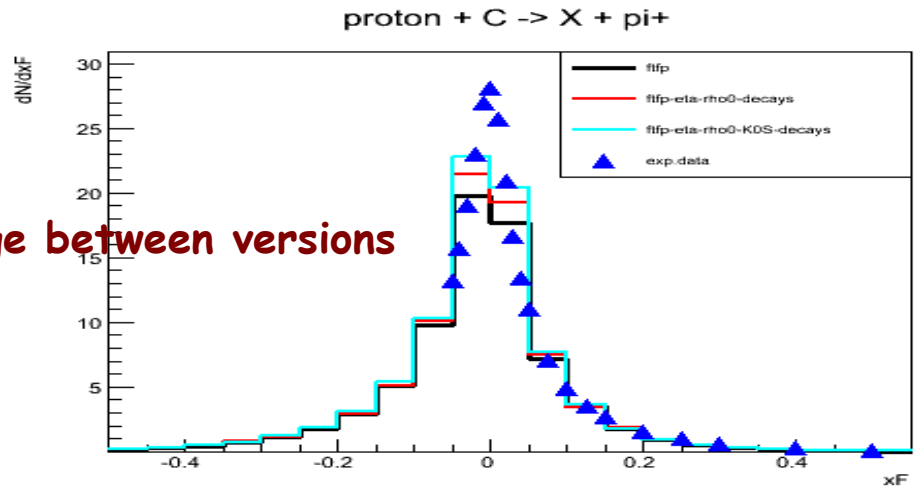
What Are We Tuning ? (II)
Case FTF: 9.6.p02 (l) vs 9.6.ref10 (r)
158GeV/c p on p/C -> pi+ X





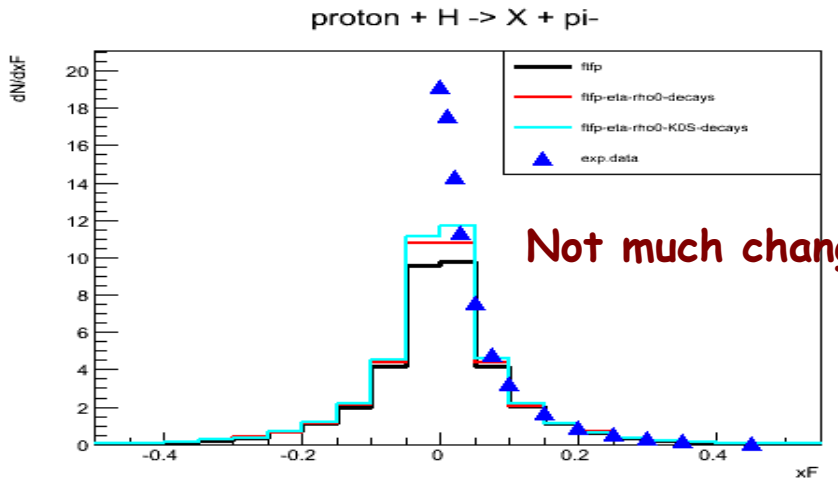
Not much change between versions

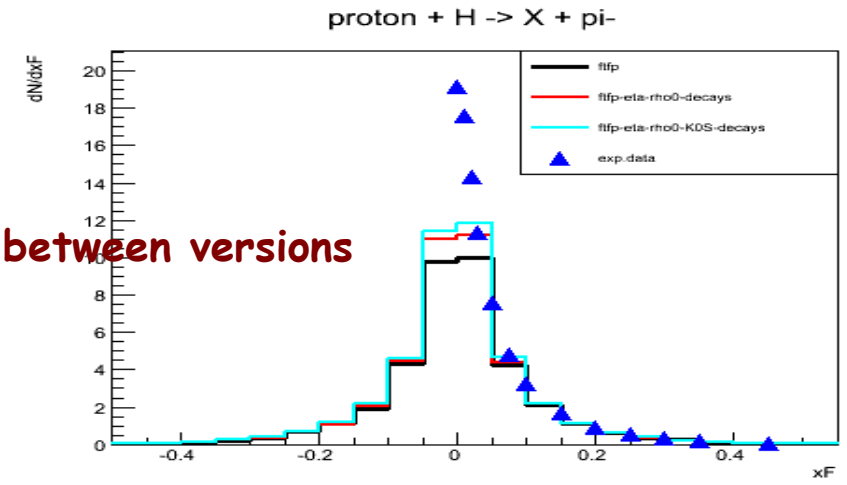




Significant change between versions

What Are We Tuning ? (III)
Case FTF: 9.6.p02 (l) vs 9.6.ref10 (r)
158GeV/c p on p/C -> pi- X





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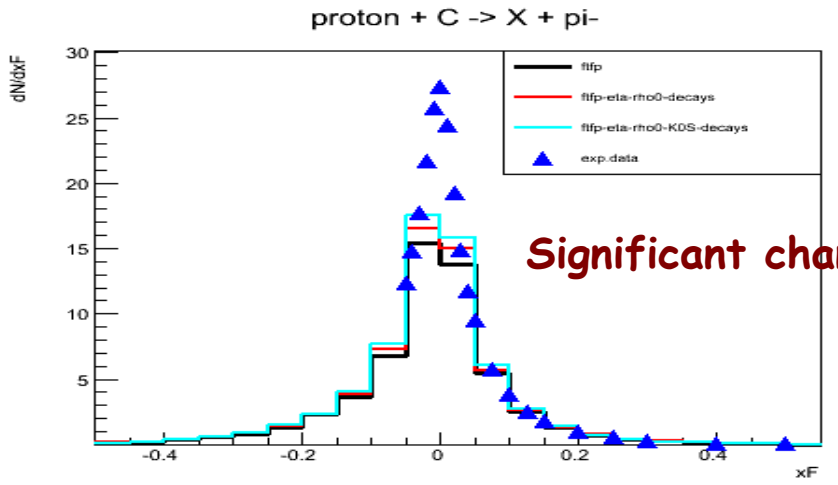
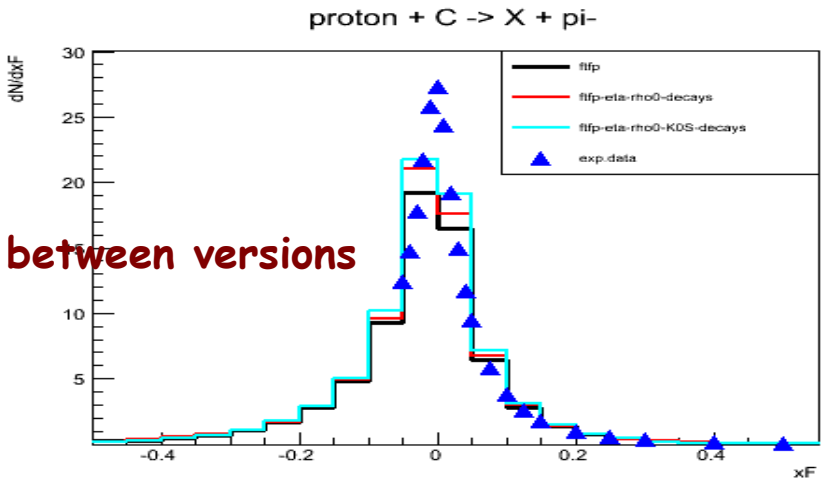




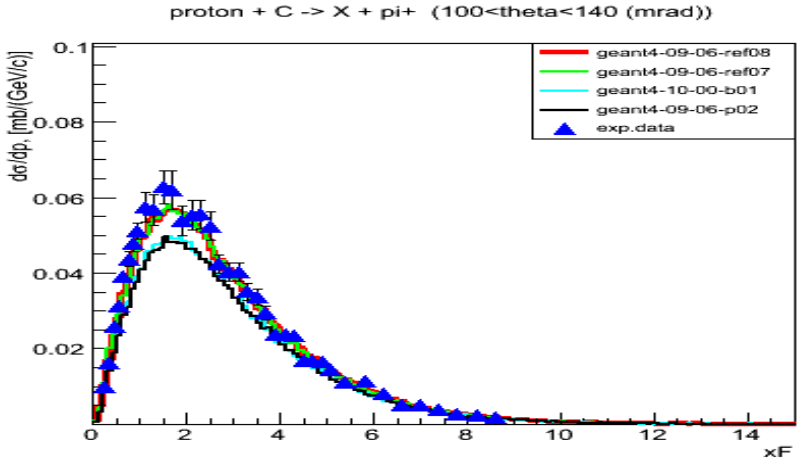
Significant change between versions

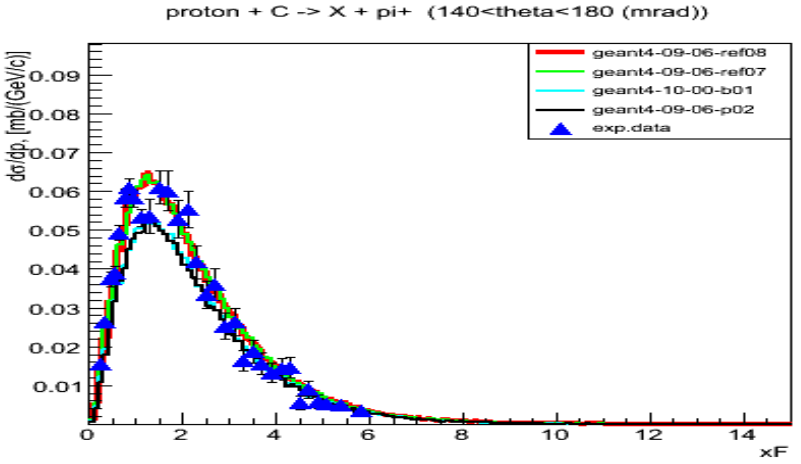
What Are We Tuning ? (IV)

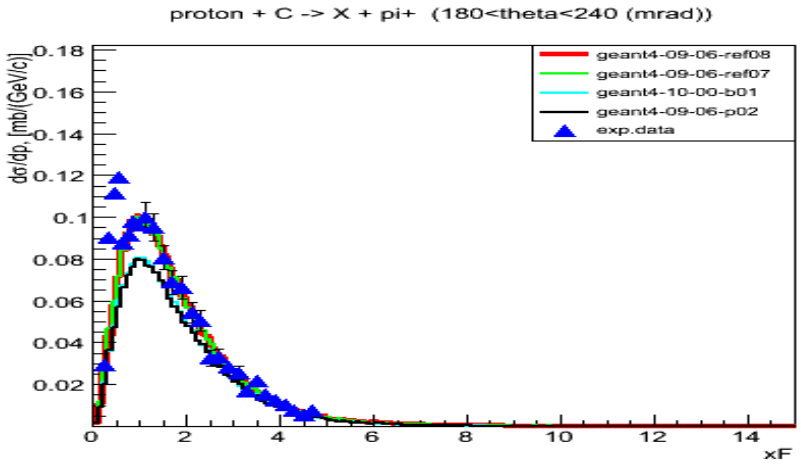
FTF evolution 9.6.p02 -> 9.6.ref07-08(-10)

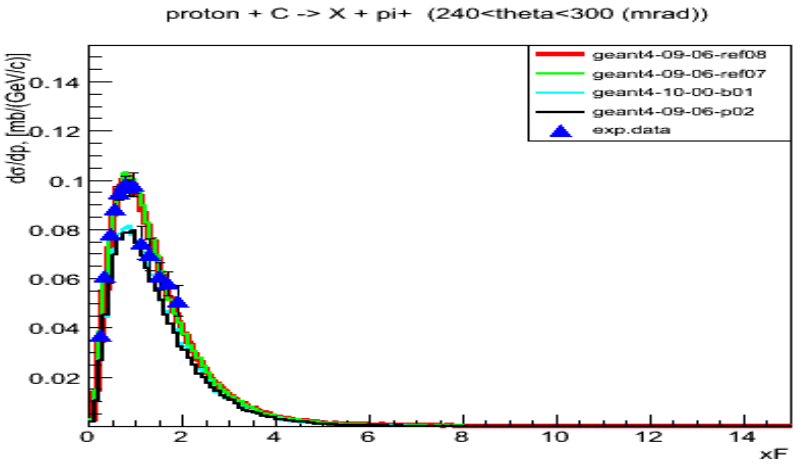
NA61 31GeV/c p on C -> pi+ X

Direct pion production ! What if we add decays ???

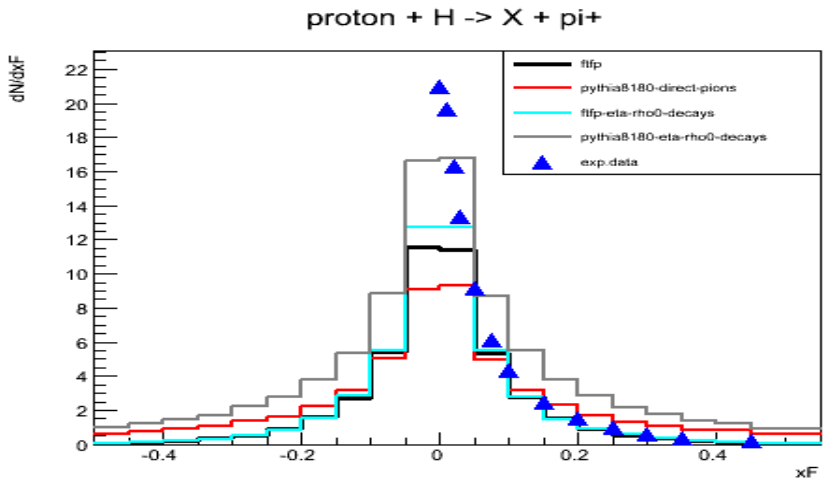


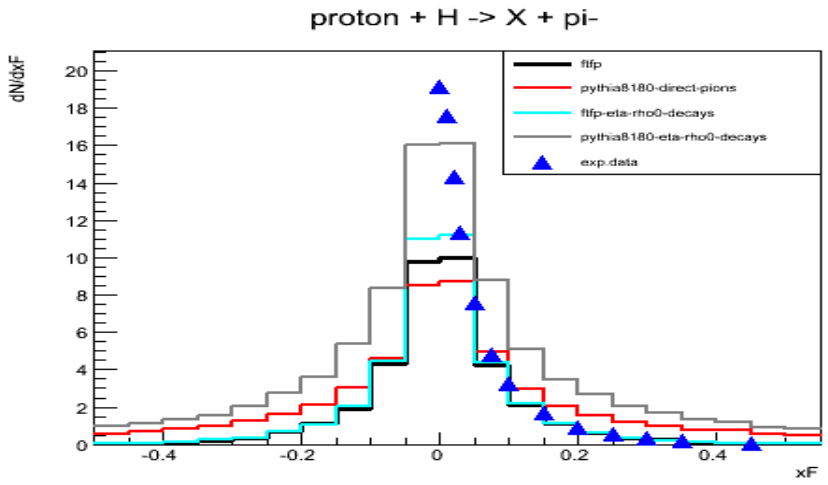






What Are We Tuning ? (V)
FTF (9.6.ref10) vs Pythia8.180 (default tune, MB)
(158GeV/c p+p -> pions X





(If we want to) We can open up a discussion:

- Who does direct pi production better ?
- Who does resonance production better ?
- Etc…

Note: Pythia8 does pions <pT> vs xF nicely

The questions (to G4) remain:

- What are we tuning ?
- How consistently are we tuning ?
- Where/how to improve further ?

Summary

- More work has been done on improving physics lists and in the validation domain:
  - An experimental physics list for NuMI-X
  - Upgrade of G4-at-FNAL website with new materials on phys.lists
  - Restructuring of test23, 19; several other tests in progress
  - Ongoing expansion of dataset collection for phys.lists tuning
  - Regular validation efforts/round
  - Archiving of results
- But we can compose physics lists from a limited number of options
- The big question is how to further improve models (HE,…)