Hadronic Validation: Status and Plans

Geant4 Collaboration Meeting
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Outline

- Overview of hadronic validation
- Highlighted results from 2017/2018
  - trends in models (FTF, QGS, Bertini)
- Under-validated areas
  - RDM, HP, thick target (not calorimeters)
- Infrastructure
  - problems, metrics, repository
- Plans

Overview of Hadronic Validation (1)

- Purpose:
  - monitor evolution of hadronic models
  - provide feedback to developers
  - inform user community
  - quality assurance (and credibility)

- Hadronic validation taking place mainly at FNAL and CERN
  - other efforts in special areas (hadron therapy, radioactive decay)

- Wide range of energies, target elements, reactions tested
  - some gaps still exist
  - shower shapes not usually included here → calorimeter studies

Overview of Hadronic Validation (2)

- Longitudinal validation is done regularly
  - all public releases
  - most reference tags
- Several different infrastructures currently used for validation
  - automated comparisons with online displays
  - hundreds of Geant4 tests (also used for system testing)
  - developer tests run by individuals
- Large, important effort
  - perennially under-staffed

Validation Effort at FNAL

- Compare to data from 0 to 158 GeV
  - Beams: p, p-bar, π, K, μ, γ
  - Targets: H through U
  - Includes data from HARP, NA61, BNL, MIPP, CMS
  - Tests 19, 23, 47, 48, 75

- Processes and models tested
  - Capture/annihilation
  - γ–nuclear
  - Intranuclear cascades
  - QCD string models
  - Selected physics lists: FTFP_BERT, QGSP_BERT, NuBeam, Shielding,

- Validations performed at each release, most reference tags and when significant developments occur

Validation Effort at CERN

- Hadronic tests
  - NeutronXS2.0
  - Test30 (low to intermediate energy)
  - Test35 (intermediate energy)

- Shower shapes (not strictly hadronic, but strongly related)
  - Compared to ATLAS, CMS test beam data
  - Length, width, visible energy, resolution
  - Analysis performed regularly and monitored for change

- Validations performed at each release, most reference tags and when significant developments occur

Others

- Neutrons
  - Livermore : GND
  - CIEMAT: HP database
- Low energy models
  - INFN
  - Sevilla : cascades with n_TOF neutrons
- Validation for hadron therapy
  - INFN Catania
  - Wollongong
- Radioactive decay (Laurent Desorgher, Dennis Wright)

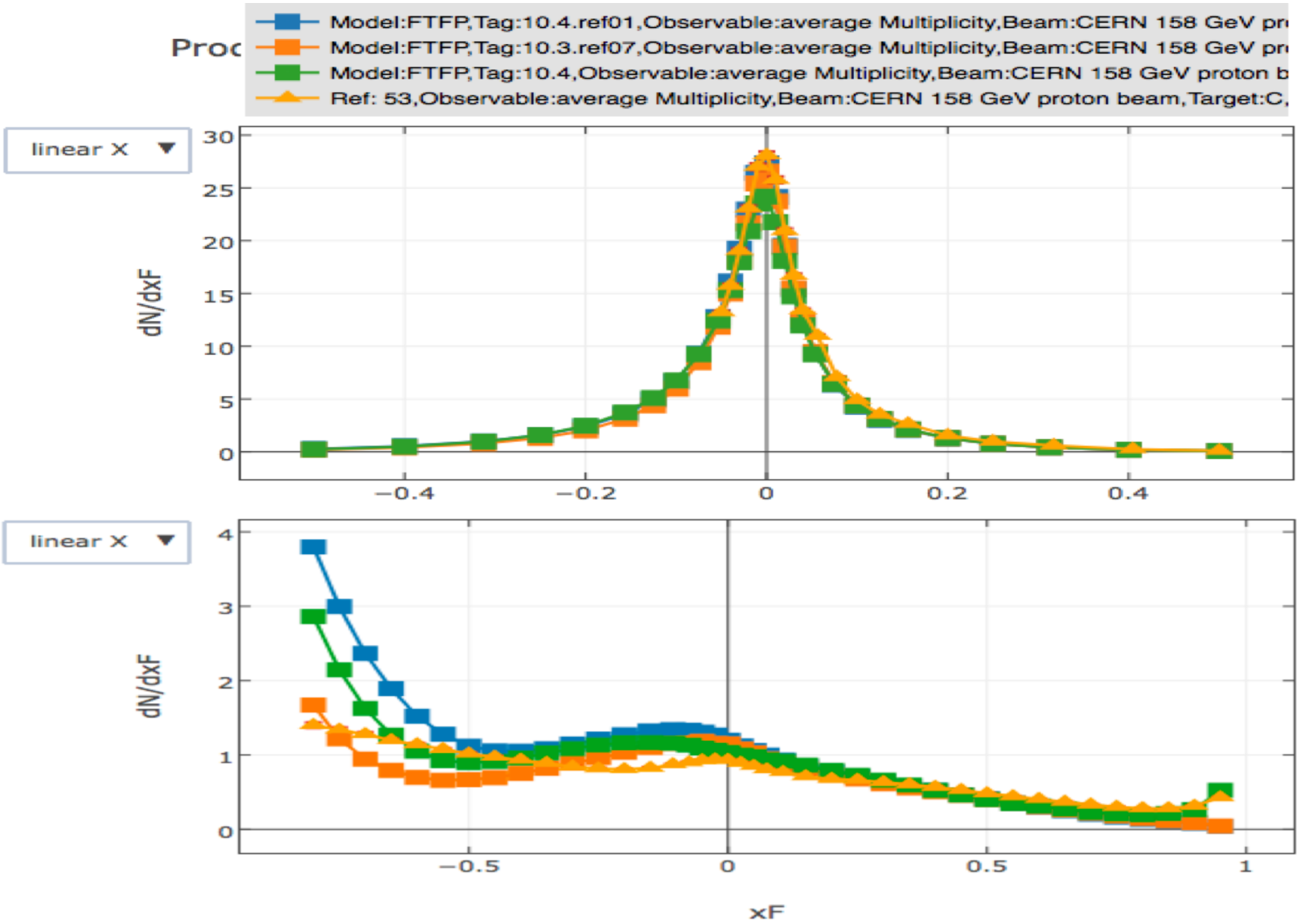
Highlighted Results from 2017/2018

Trends in FTF

- FTF has been in active development for several release cycles
  - largely focused on improving MC agreement with the thin target data at intermediate or high energies
  - however, for the past 2 releases most of the developments were withheld due to negative impact on hadronic showers

- Several additional updates from late 2017 were included in early reference tags of 10.4, with a controversial validation outcome
  - In a number of areas, degradation is observed wrt 10.3 and/or public 10.4, both at intermediate or high energies
  - Details: https://indico.cern.ch/event/702280/contributions/2895765/attachments/1600608/2539512/G4HAD-Feb14-2018-v2.pdf
  - modeling of antiproton production in hadron-nucleus interactions at intermediate energies has “disappeared”

FTF: 158 GeV/c p C → π^+ X (top), p X (bottom)



Trends in QGS

- QGS has been in re-factoring for several development cycles
  - To make the algorithms/implementation better comply with the model as originally published
  - changes in the algorithms require re-tuning
  - work on QGSP somewhat tends to be pushed back due to ongoing attempts to improve FTF
- Updates partially included in public releases but certain things remain in development releases only
  - as validation shows, development revision of QGS already gives somewhat better agreement with the data at the high energy end than the official version
  - Still working on it, so not all updates released

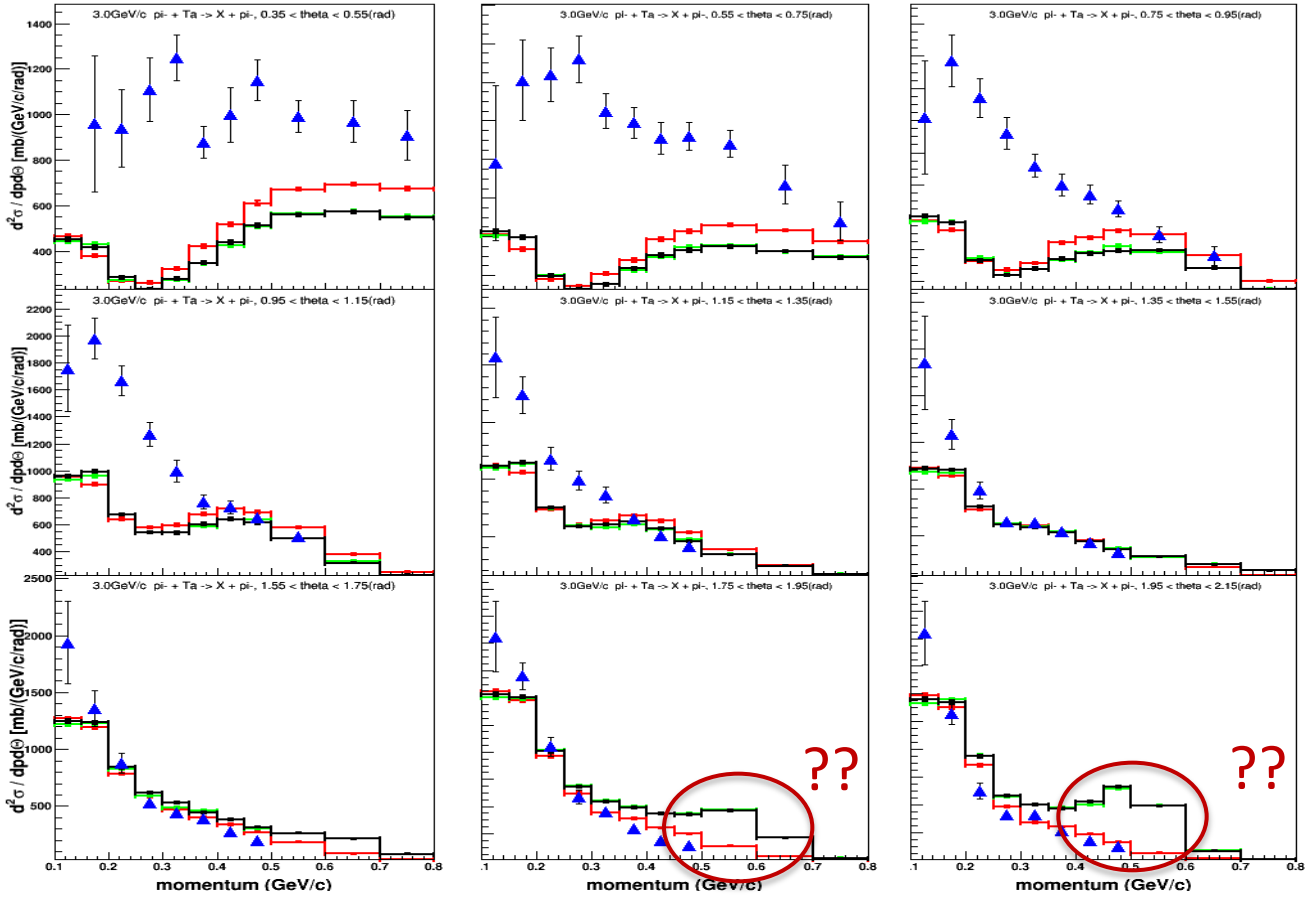
Details:
https://indico.cern.ch/event/702280/contributions/2895765/attachments/1600608/2539512/G4HAD-Feb14-2018-v2.pdf

Trends in Bertini

- Relatively stable for several releases
  - except for bug fix leading into 10.3, that refined production of low energy neutrons in hadron-nucleus interactions
- Recent developments
  - extended strange pair production
  - correct nucleon pair production in pion or muon nuclear absorption
  - collectively (and perhaps combined with other updates in G4/HAD), this resulted in
    - some discrepancies in modeling hadron+nucleus -> hadrons
    - improvement in modeling of pi- capture
  - Details: https://indico.cern.ch/event/735608/contributions/3045899/attachments/1671702/2682288/G4HAD-June20-2018.pdf
- Re-tuning of Bertini is a possibility

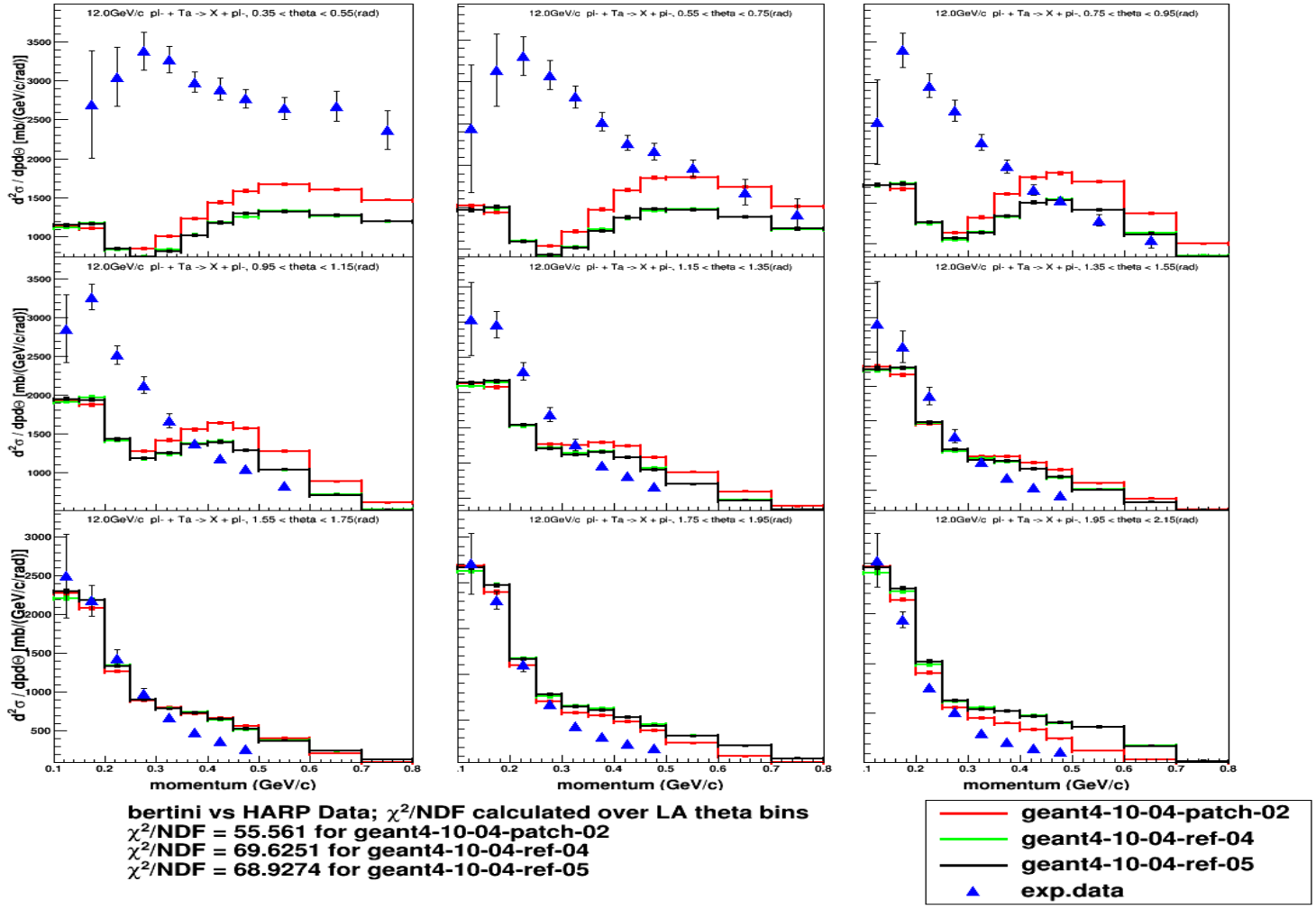
Example Bertini Validation Results (I)

π^- production by 3GeV/c π^- on Ta



Example Bertini Validation Results (II)

π^- production by 12GeV/c π^- on Ta



Under-validated Areas

- Thick target (multiple interaction lengths)
  - we have very few such tests (although some data exist)
  - data from many such experiments are problematic (systematics)
- Radioactive decay
  - database now well maintained, but few tests are done and none are online
- More ion-ion validations would be nice
- Neutrons
  - both HP and GND libraries maintained
  - many tests exist, very few online

Infrastructure

Problems/Challenges

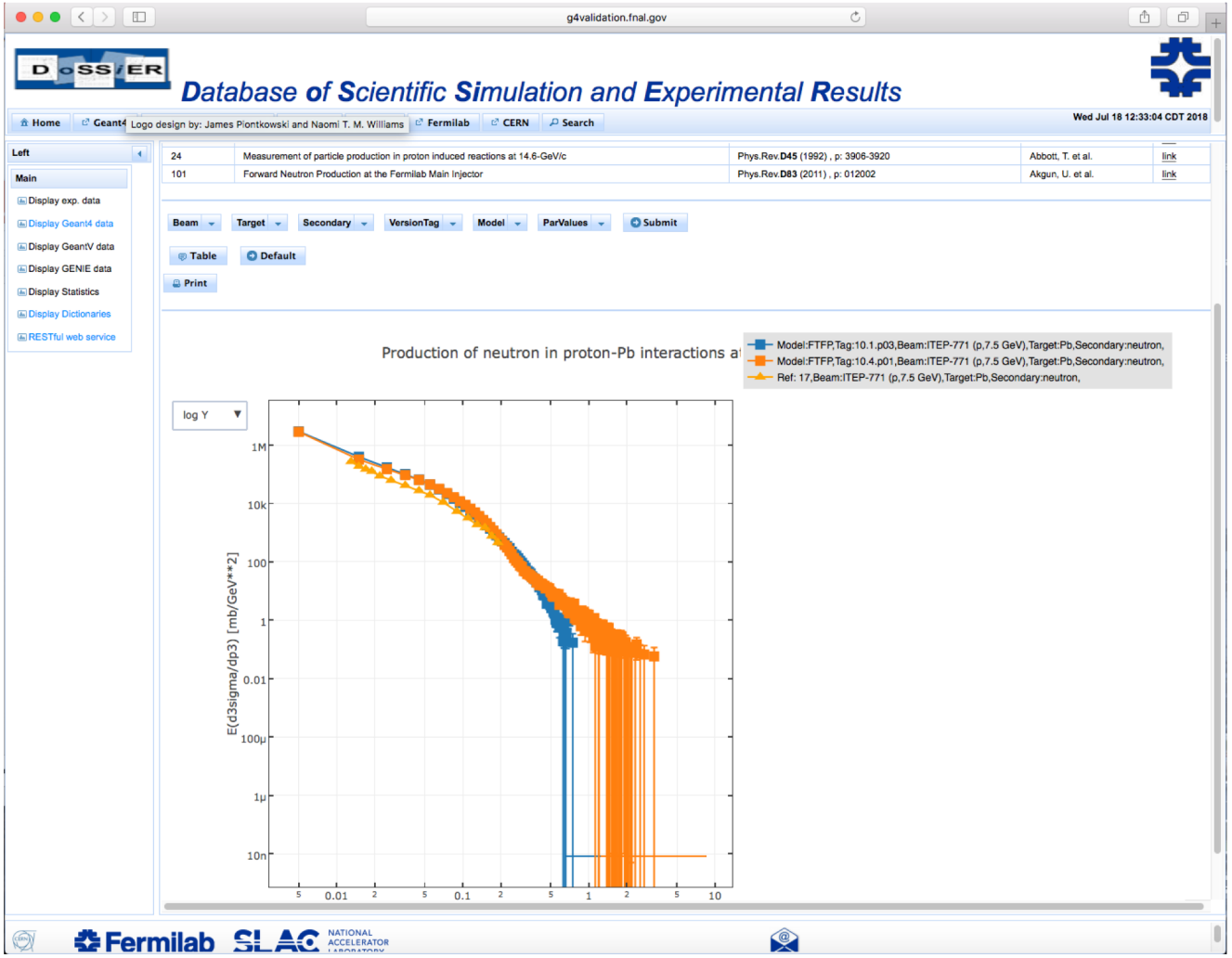
- What metric to use to assess developments/improvements
  - improvements in one area may result in degradation in other areas
  - χ^2/NDF not always a good measure; values often quite large in hadronics
  - still no solution to this problem

- How to compare consistently across many tests/data sets
  - different energy regimes, different targets
  - big challenge in the G4 HAD group: optimize agreement with thin target data vs thick target and bulk effects (e.g. shower shapes)
  - FTF story of the past several years: improved agreement with thin target data gets worse for simulated shower

Metrics

- MC and Data overlay (visual inspection)
  - very useful, but not quantitative
- χ^2/NDF (for individual distributions or groups of distributions)
  - traditional test
  - in hadronics values are typically large and outside meaningful range
  - also, because of strongly peaked distributions, too much weight given to small angles, small energies
- MC/Data ratio
  - sometimes better than χ^2
- Perennial discussion in hadronics group about how to improve the metric
  - G test, γ test

Example DoSSiER Display (II)
7.5GeV/c p+C -> n + X at θ=119deg



Validation Repository

- DoSSiER is available
  - https://g4validation.fnal.gov:8080/DoSSiER
  - web application, using RESTful web service
  - contains comparisons, data references, plots

- Currently under development
  - will replace old interface (no longer maintained)
  - link to old interface is still on Geant4 web page and broken
  - many tests not yet moved over to DoSSiER
  - insufficient manpower?

Plans

Validation Plans for 2018/2019 (1)

- Continued operation and maintenance of existing tests and validations (FNAL, CERN, CIEMAT, INFN, Wollongong, ….)
- Transform test-beam simulations from LHC experiments into stand-alone validation applications (K. Nikolics, W. Pokorski)
- Validation with BNL, MIPPS, new high granularity CMS test beam data (FNAL)
- Low energy model validation (P. Cirrone, C. Mancini)
- Cascade model validation using n_TOF evaluated neutron flux (M. Cortes-Giraldo

Validation Plans for 2018/2019 (2)

- Physics highlights release page
- Evaluate new metrics for validation comparisons
- Restore online validation plots