A Summary of Physics Validations and Developments: Hadronic

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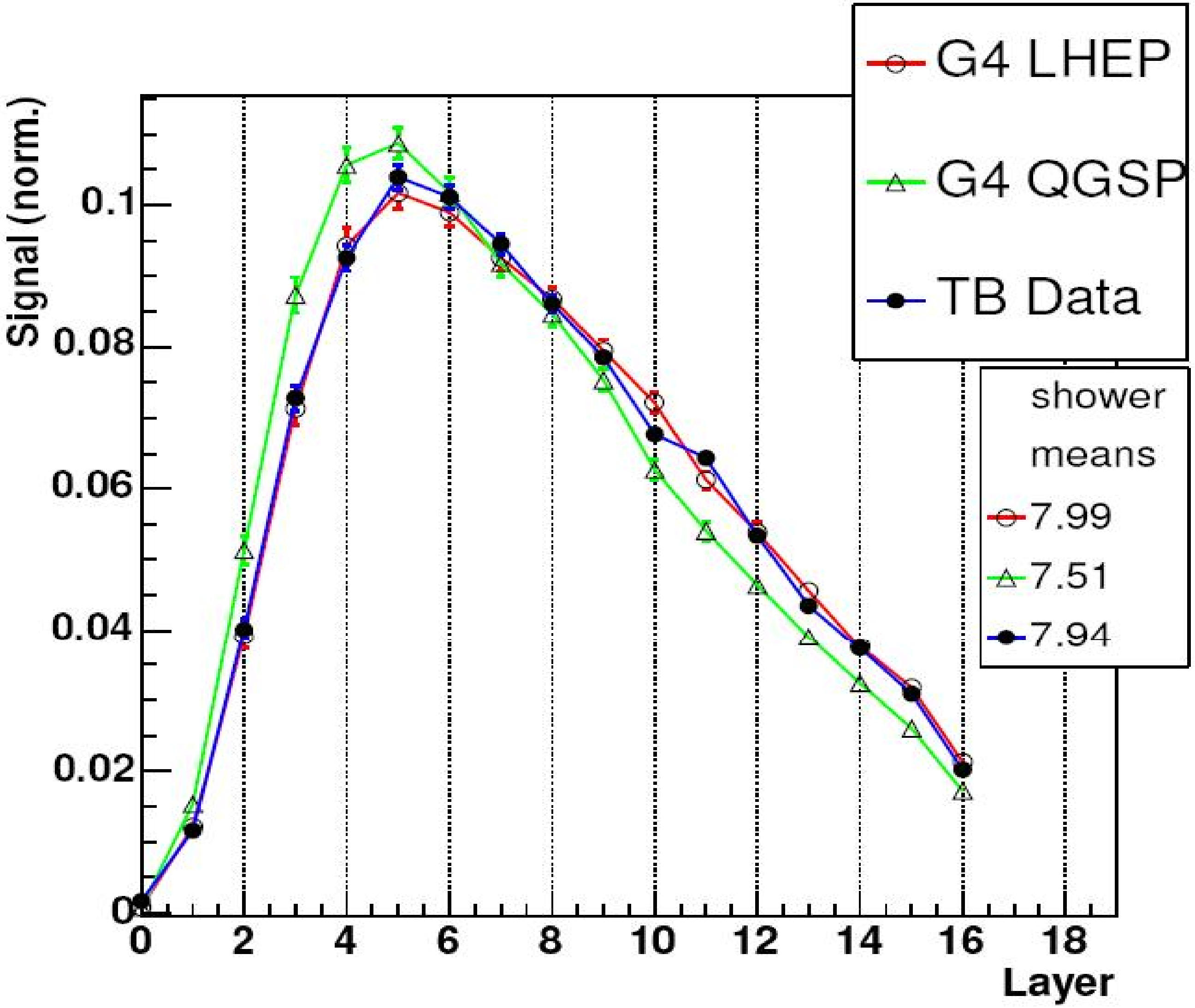
Outline

- Recent Hadronic Model Improvements and Their Effects on Shower Shapes
- Validation web sites and Recent Results
- Neutron Notes
- Two Important Bug Fixes
- New Hadronic Models
- Precompound Workshop Summary

CMS Test Beam Shower Shapes



300 GeV pions, leaving MIP in ECAL and L0.

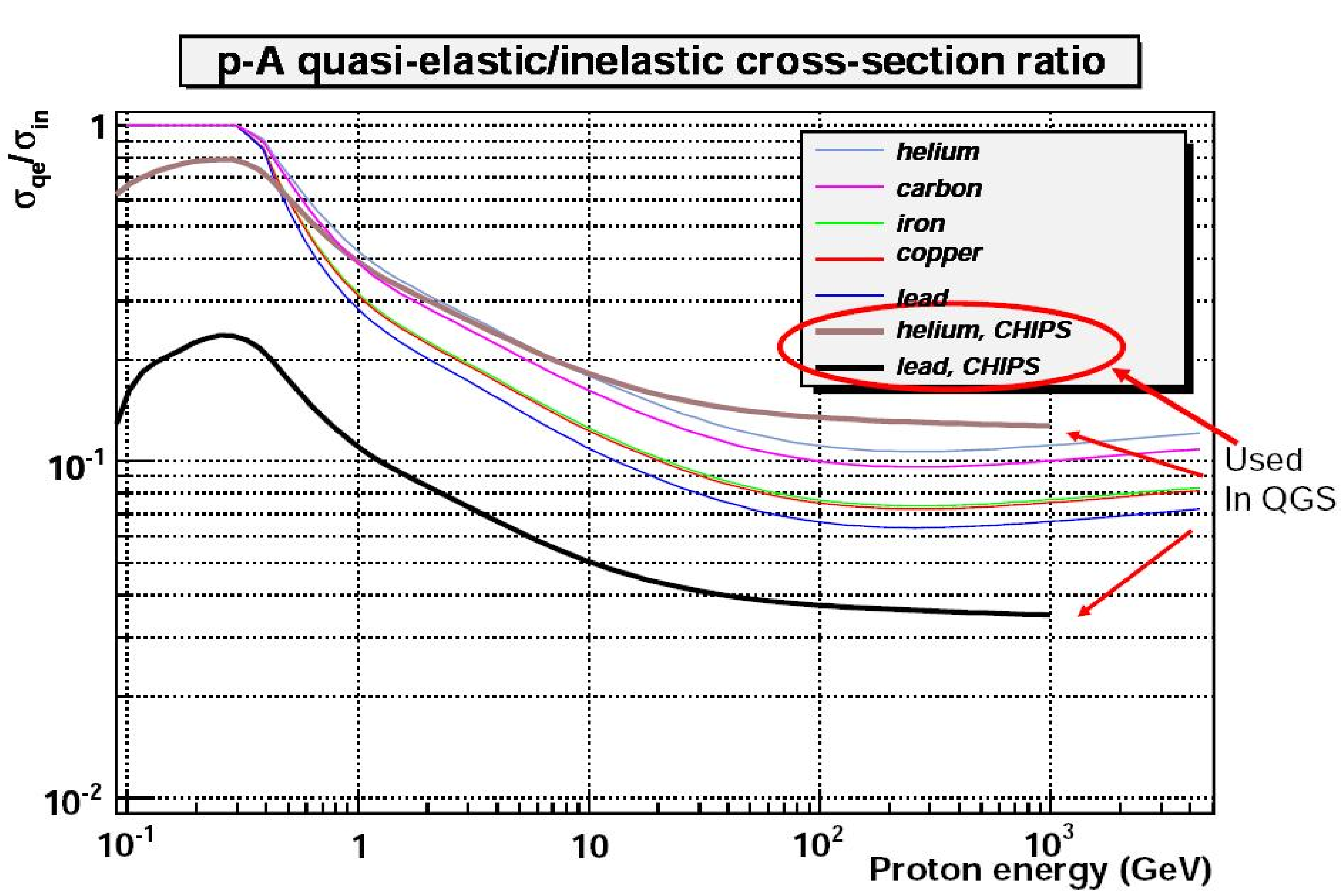
What Was the Cause of the "Short Showers" ?

- For 1.5 years, hadronics group looked at:
  - cross sections
  - pion fraction in hadronic shower
  - longitudinal fragmentation in quark-string models
  - quasi-elastic scattering
  - Birk's law in scintillators
- Work is still going on, but major progress was made
  - most important effect: treatment of quasi-elastic scattering
  - other effects:
    - pion-Cu cross section was corrected (no longer 4% low)
    - treatment of diffraction in quark-string models

New Quasi-elastic Channel

- The Quark-Gluon String (QGS) model handles the high energy part of the physics list interactions (E > 12 GeV)
- QGS models only the deep inelastic interactions
  - but the model cross sections include both quasi-elastic and deep inelastic
  - quasi-elastic is typically 4-8% of cross-section
- Treat quasi-elastic scattering by making it a separate channel which competes with deep inelastic
  - fewer deep inelastic scatterings cause longer hadronic showers
- G4QuasiElasticChannel used starting from G4 8.3 in QGSP & variant Physics Lists (QGSP_EMV, QGSP_BERT, ..)
- Use of this channel is optional
  - new lists QGSP_NQE, QGSP_EMV_NQE, and QGSP_BERT_NQE ignore new quasi-elastic

G4QuasiElasticChannel uses G4QuasiFreeRatios (M. Kossov)



Quark-String Models (QGS and FTF)

- Improvements to QGS model, but small effect on shower shapes
  - energy-momentum conservation bug fixed
  - improved fragmentation code
- Alternate model to QGS: FTF (Fritiof Fragmentation)
  - significant revisions by V. Uzhinski in 8.3 and 9.0
    - single diffraction added (double diffraction already there)
    - improvements made to longitudinal fragmentation code
    - tuning for proton- and pion-incident
    - can start as low as 4 GeV
  - result: showers are now longer than with QGS
  - FTF-based physics lists also use new quasi-elastic channel

Hadronic Shower Shapes

Considering a 100 GeV π^- beam on a Iron-Scintillator sampling calorimeters (a kind of simplified version of the ATLAS TileCal calorimeter), we can look how the visible energy is distributed in four longitudinal quarters:

	G4 8.2.p01		G4 9.0	
	QGSP	FTFP	QGSP	FTFP
f_{L1}	55.7%	56.5%	54.5%	52.2%
f_{L2}	33.6%	33.6%	34.0%	34.6%
f_{L3}	8.9%	8.2%	9.5%	10.6%
f_{L4}	1.8%	1.6%	2.0%	2.6%

The longitudinal shower shapes are longer in G4 9.0 because of the quasi-elastic scattering. Furthermore, Fritiof model has been improved.

Validation Web Sites

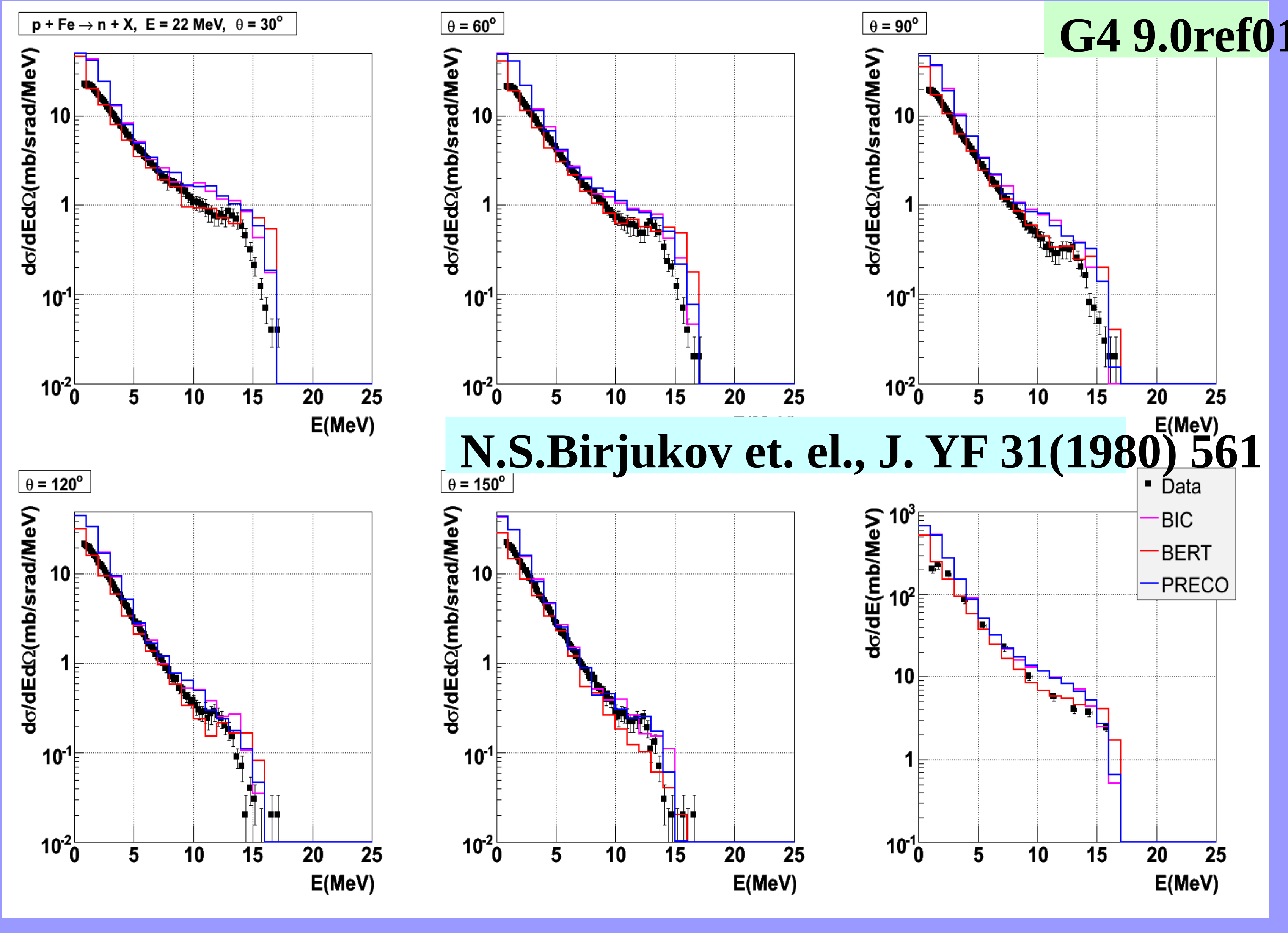
- geant4.web.cern.ch/geant4/results/validation_plots
  - prototype validation web page for Geant4 hadronics
  - covers all energies, most models
  - thin target, thick target, test beam and benchmarks
  - link to data sets used or planned to be used in validation
  - still incomplete, but growing
  - larger, better website now being designed at FNAL
- vnivanch.web.cern.ch/vnivanch/tests.shtml
  - both EM and hadronic validations
  - hadronic part covers test30, test35
  - covers precompound and cascade models

Validation suite for thin target data on hadron inelastic interaction

- Exist since 2002
- Neutron production by p, d, α, ^{12}C with E <= 3 GeV
  - p + A -> n + X
  - d + A -> n + X
  - α + A -> n + X
  - ^{12}C + A -> n + X
- Pion production by protons and pions P<13 GeV/c
  - P + A -> $\pi^{\pm}$ + X
- More 100 thin target setups
- Data versus Geant4 models
- Control on differential spectra
- Model level test

- Models under testing:
  - PreCompound
  - Binary Cascade
  - Binary Ion cascade
  - Bertini Cascade
  - Wilson-Abrasion model
  - LHEP
  - QGSP
  - QGSC
  - FTFP
- A new model can be easily included
- About 1000 comparison plots produced

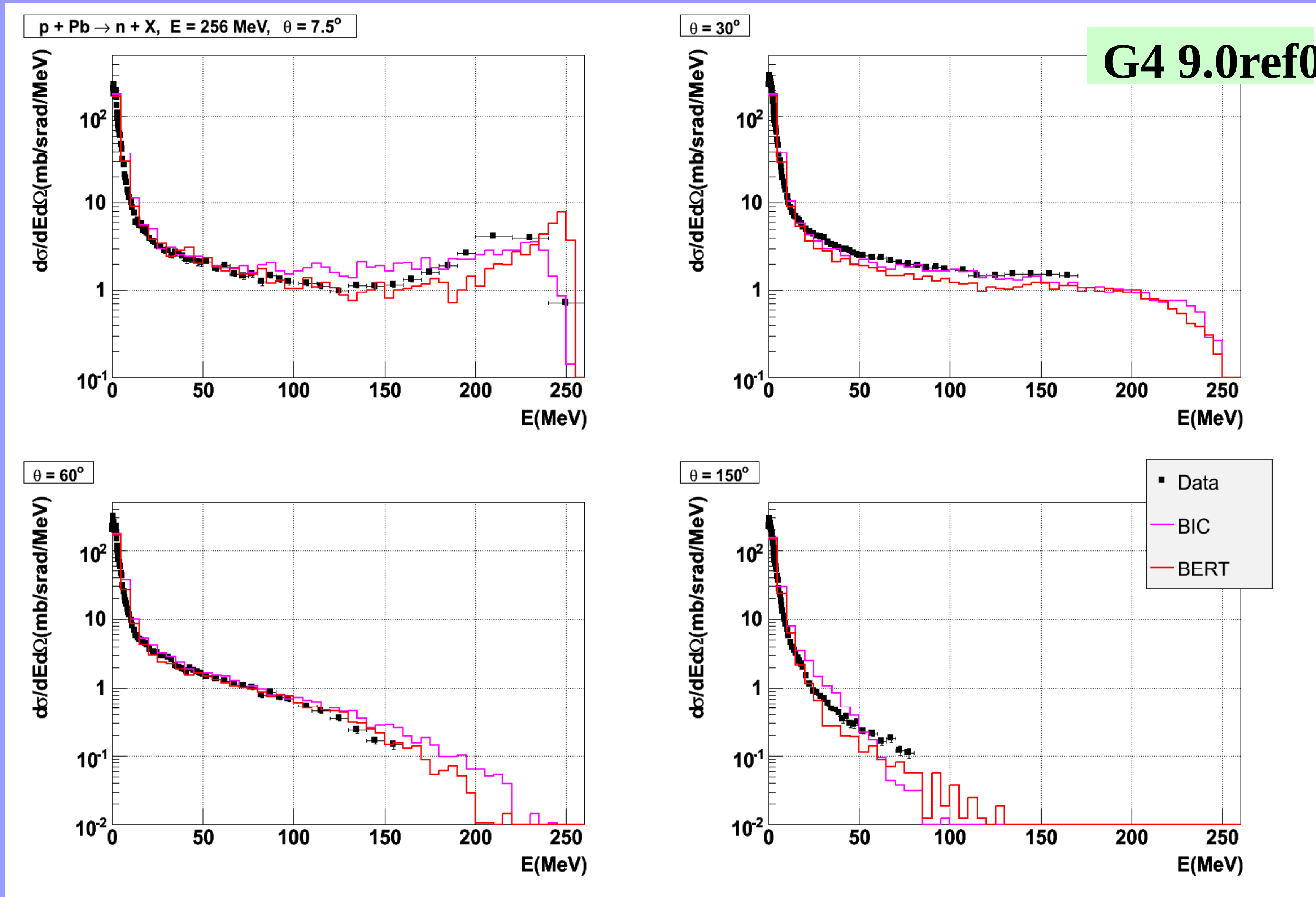
p + Fe -> n + X at 22 MeV



G4 9.0ref01

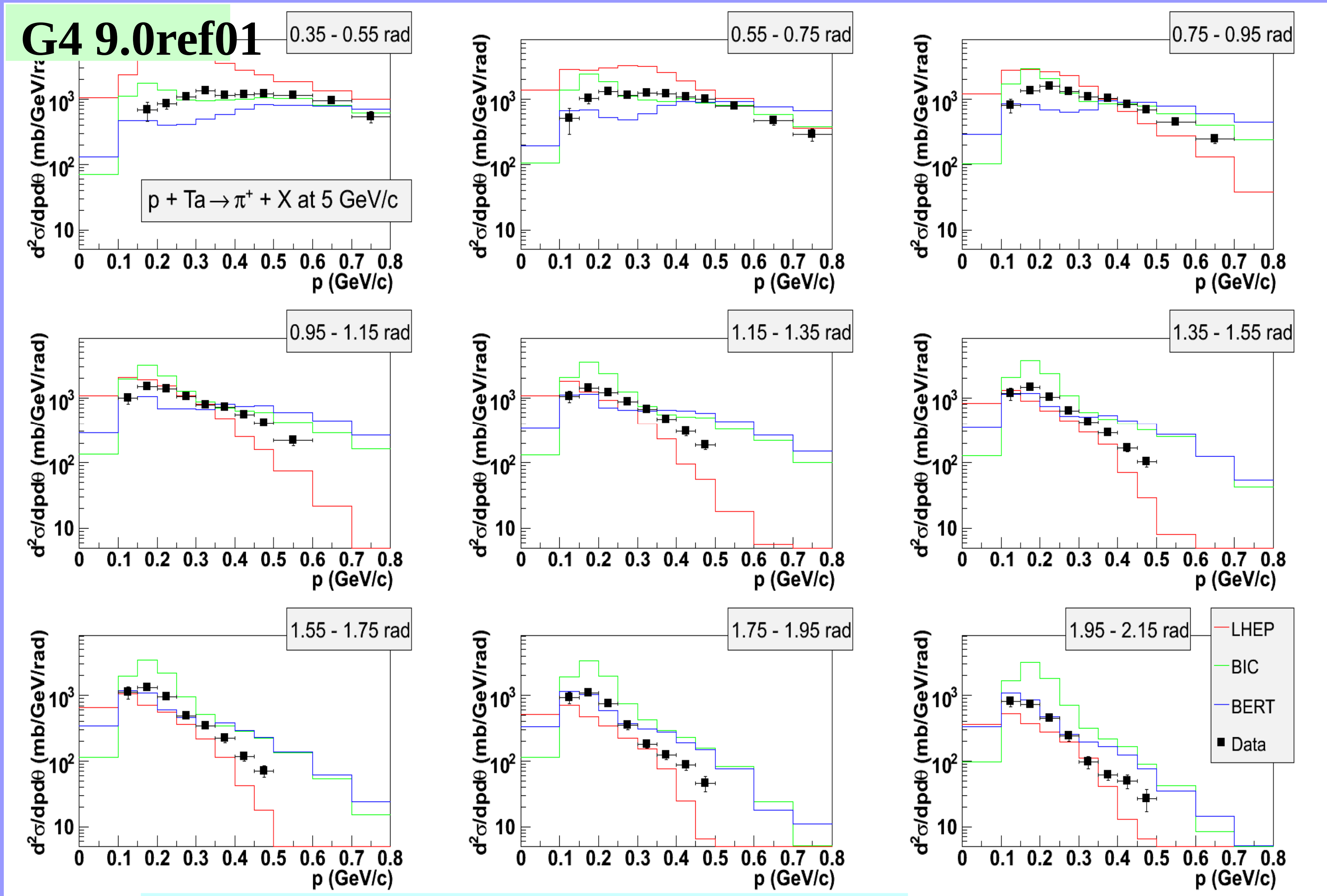
N.S.Birjukov et. el., J. YF 31(1980) 561

p + Pb -> n + X at 256 MeV



M.M. Meier et. el., J. Nucl. Sci. Eng. 110 (1992) 289

p + Ta -> π^+ + X at 5 GeV/c



G. Catanesi et. el., Eur. Phys. Jour. (2007)

Precision Neutrons (1)

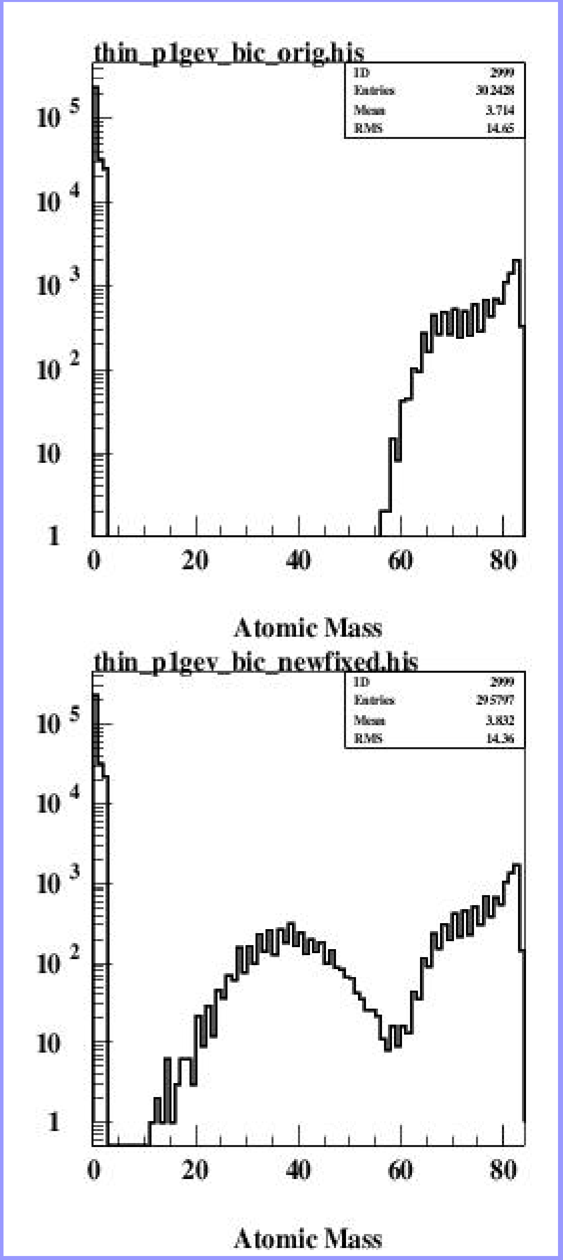
- When using high precision neutron code, user may now change the behavior of the high precison neutron module
  - force use of Photon Evaporation model for neutron capture instead of final state data:
    - set G4NEUTRONHP_USE_ONLY_PHOTONEVAPORATION
  - use only exact isotope data files
    - instead of allowing nearby isotope files to be used (the default)
    - if the exact file is not available, the cross section will be set to zero and a warning message will be printed.
    - set the environment variable G4NEUTRONHP_SKIP_MISSING_ISOTOPES.
- Note: renamed NeutronHPCrossSections to G4NEUTRONHPDATA
  - sets the path for the G4NDL data set
  - must change this user environment variable

Precision Neutrons (2)

- New data for neutron cross-sections, G4NDL.3.11
  - added Germanium data and Silver data
  - added special file 0_0_Zero which gives 0 cross section at all energies

Fixes (1)

- LEP model: correction in units
  - removes unphysical peak at 180 degrees and reduces the number of very low energy nucleons produced.
  - Typical effects for 2 - 10 GeV incident particles:
    - shift angular distributions forward by ~ 5-10 degrees
    - increases mean secondary KE by 20 - 30 MeV
    - at higher energies the effect is small
    - little change in shower shape benchmarks



Fixes (2)

- Evaporation and fission models:
  - compete for A > 65
  - probability for fission was negative
  - now in agreement with formula in Physics Reference Manual
- Above models invoked by G4PreCompound model, so that model is affected also
- Additional protections against negative channel probabilities implemented

New Models

- Just released
  - LLNL Fission model
  - improved CHIPS-based muon capture process
  - G4UHadronElasticProcess and G4HadronElastic
- Soon to be released (December)
  - Liege cascade (for p, n up to ~3 GeV)
  - ABLA
- Further down the road (June or December 08)
  - QMD-based ion-ion model
  - alternate precision neutron code (based on LLNL database)
  - medium energy parameterized interaction model

Precompound/Evaporation Workshop

- Workshop held in July to evaluate the many precompound, de-excitation and evaporation models in Geant4
- Motivation:
  - these models ($0 < E < 170$ MeV) are important for many user communities
- Outcomes
  - common interface for precompound models to be designed
  - theoretical basis and implementation of G4PreCompound was re-examined – several problems fixed and improvements made
  - standard framework for de-excitation sub-models to be designed

More Hadronic Physics to Come

- Saturday morning plenary session:
  - using CHIPS models (M. Kosov)
  - new developments in cross sections (V. Grichine)
- Saturday afternoon tutorial:
  - introduction to Geant4 hadronics
  - low background physics lists