Report to Delta Review: Hadronic Physics

19 January 2009

CERN

Outline

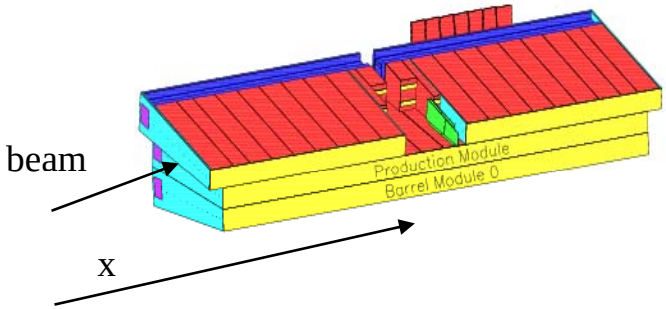
- Hadronics highlights since 2007 review
- Responses to reviewers' recommendations 6,7,8, and 9

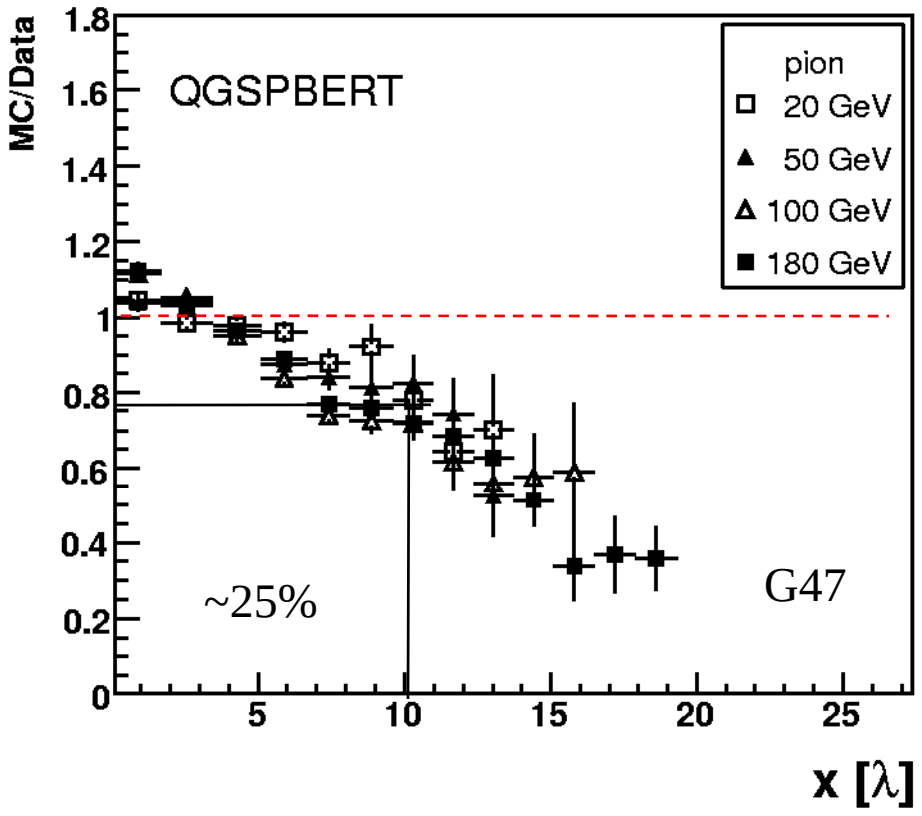
Hadronics Highlights Since 2007 Review

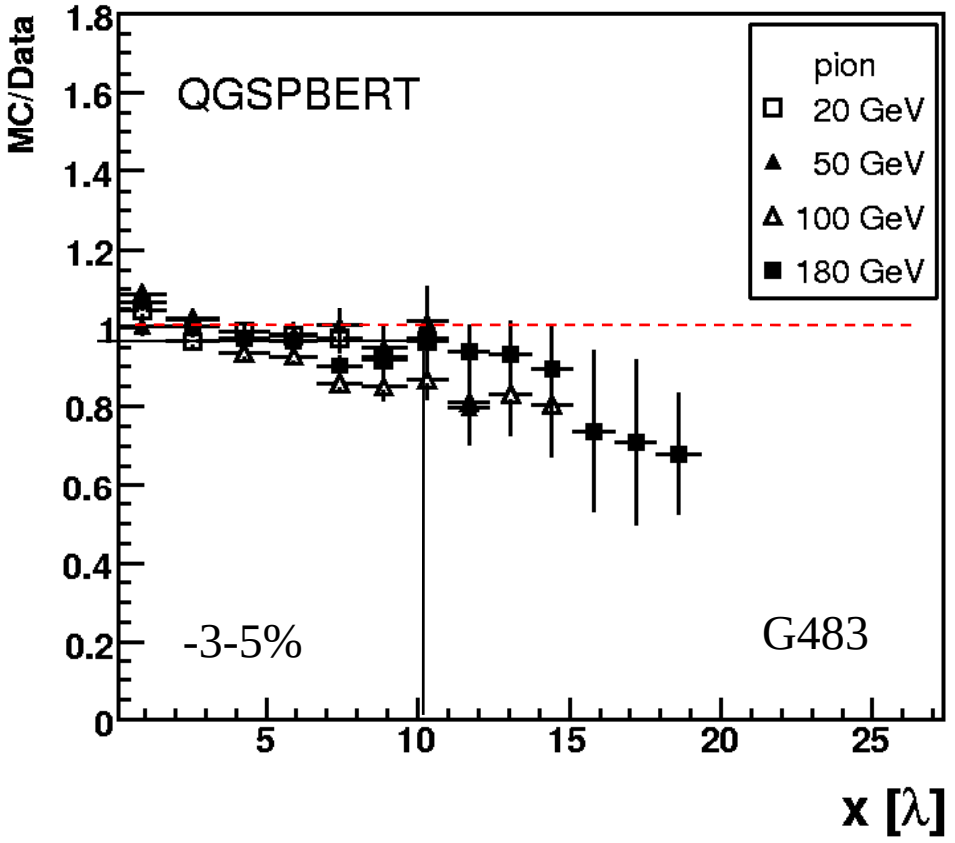
Hadronics Highlights (1)

- May 2007
  - improved treatment of FTF model for baryon-nucleus interactions
- June 2007
  - quasi-elastic channel added to QGS
  - improved cross sections, Barashenkov cross sections added
  - Doppler broadening in HP neutron models can be switched off to improve speed
- September 2007
  - longer shower shapes achieved, much better agreement with CMS, ATLAS test beam data
  - medium energy validation suite released

Longitudinal Shower in TileCal
Pion G47 vs G483





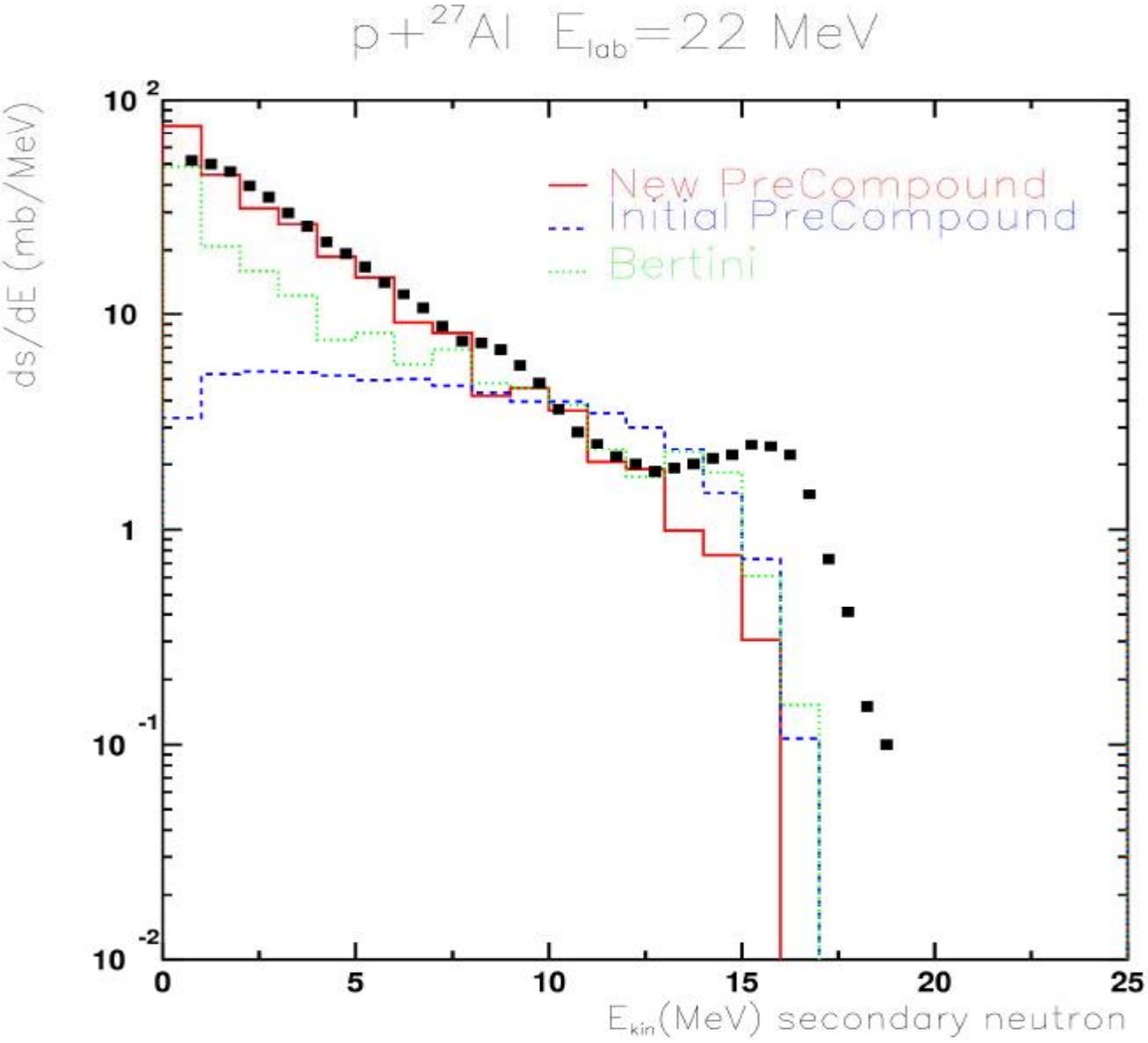


New Geant4 version has longer showers due to quasi-elastic scattering
Good agreement with data for pions

Hadronics Highlights (2)

- December 2007
  - Propagate() method added to Binary cascade, allowing re-interaction of particles from HE collisions
  - alpha release of INCL (cascade) and QMD (nucleus-nucleus) models
  - bug fixes and completed implementation of theory in G4Precompound and G4Evaporation models
  - improved treatment of FTF model for meson-nucleus interactions
- May 2008
  - missing Fermi momentum added to quasi-elastic scattering
  - tuning of FTF model parameters
  - coupling of FTF and BIC models, tuning of formation time

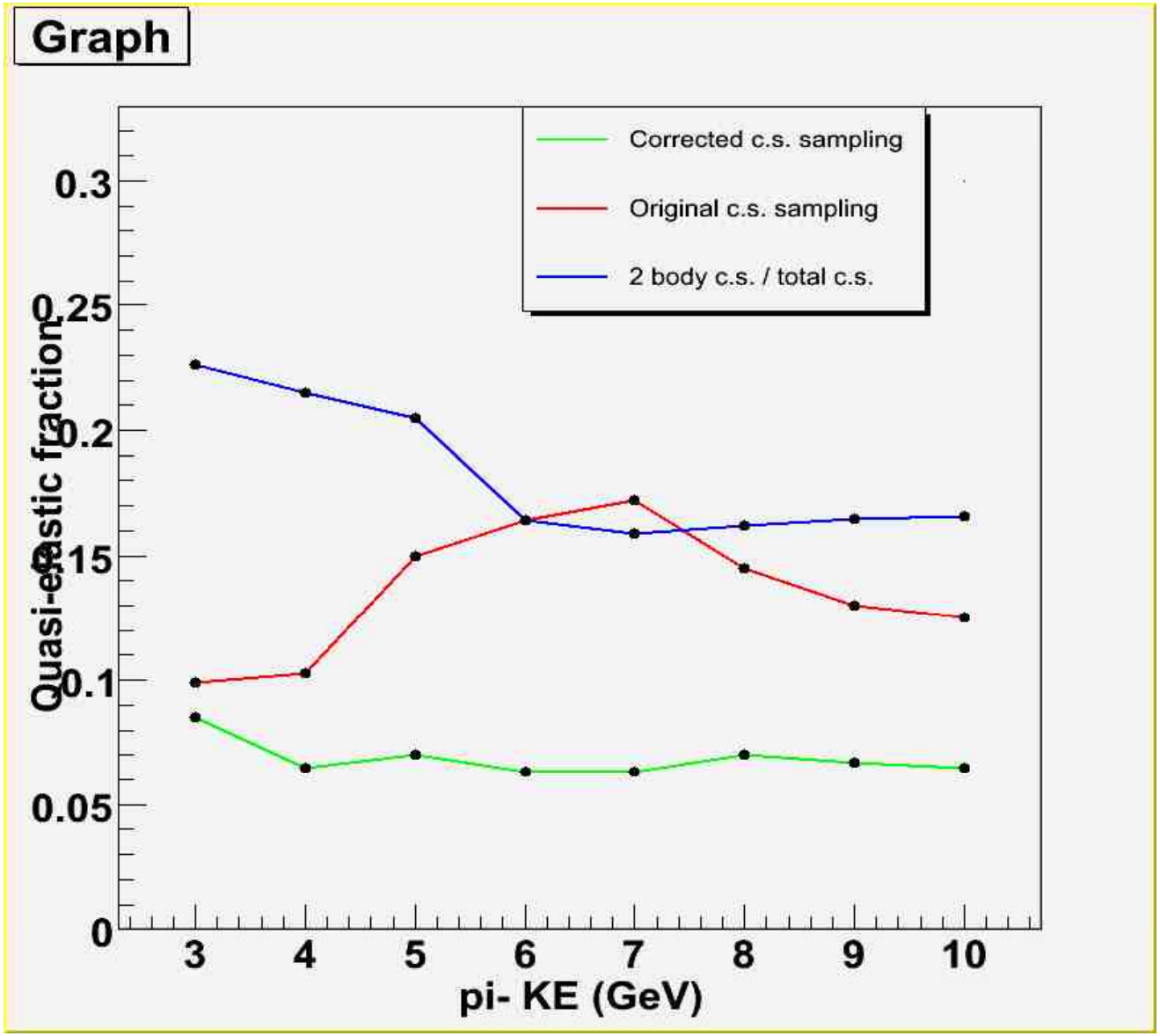
Improved Precompound model (p + 27Al -> n X) 22 MeV



Hadronics Highlights (3)

- September 2008
  - bug fixes in LHEP models to remove oscillatory behavior seen by HARP
- October 2008
  - Coulomb barrier added to Bertini cascade
- November 2008
  - found cause of large quasi-elastic scattering in Bertini cascade (fix expected to reduce discontinuities observed in calorimeter energy response)
- December 2008
  - full release of INCL/ABLA models (alternative to Bertini, Binary cascades)
  - first improvements to unify nuclear mass tables

Bertini Quasi-elastic Fix (6 GeV π^- on Pb)



Responses to Reviewers' Recommendations

Recommendation 6: Dialog with FLUKA, Provide Users Best of Geant4 and FLUKA

- Informal discussion held
  - sufficient common ground not yet found
- Spoken with key users who requested this:
  - they are currently not actively seeking to invest in this convergence
- Effort to create interface, if possible, is significant
  - manpower for development and validation
  - problems with support
- Effort planned in CERN Simulation Project to improve existing FLUGG package
- Root Virtual Monte Carlo is already known to users and provides for portability of applications between Geant4 and FLUKA

Recommendation 7: Develop detailed plans to improve the hadronic package

- Treated later in sections:
  - Hadronic Plans for 2009, 2010-2012
  - Addendum (milestones 2009, 2010-2012)

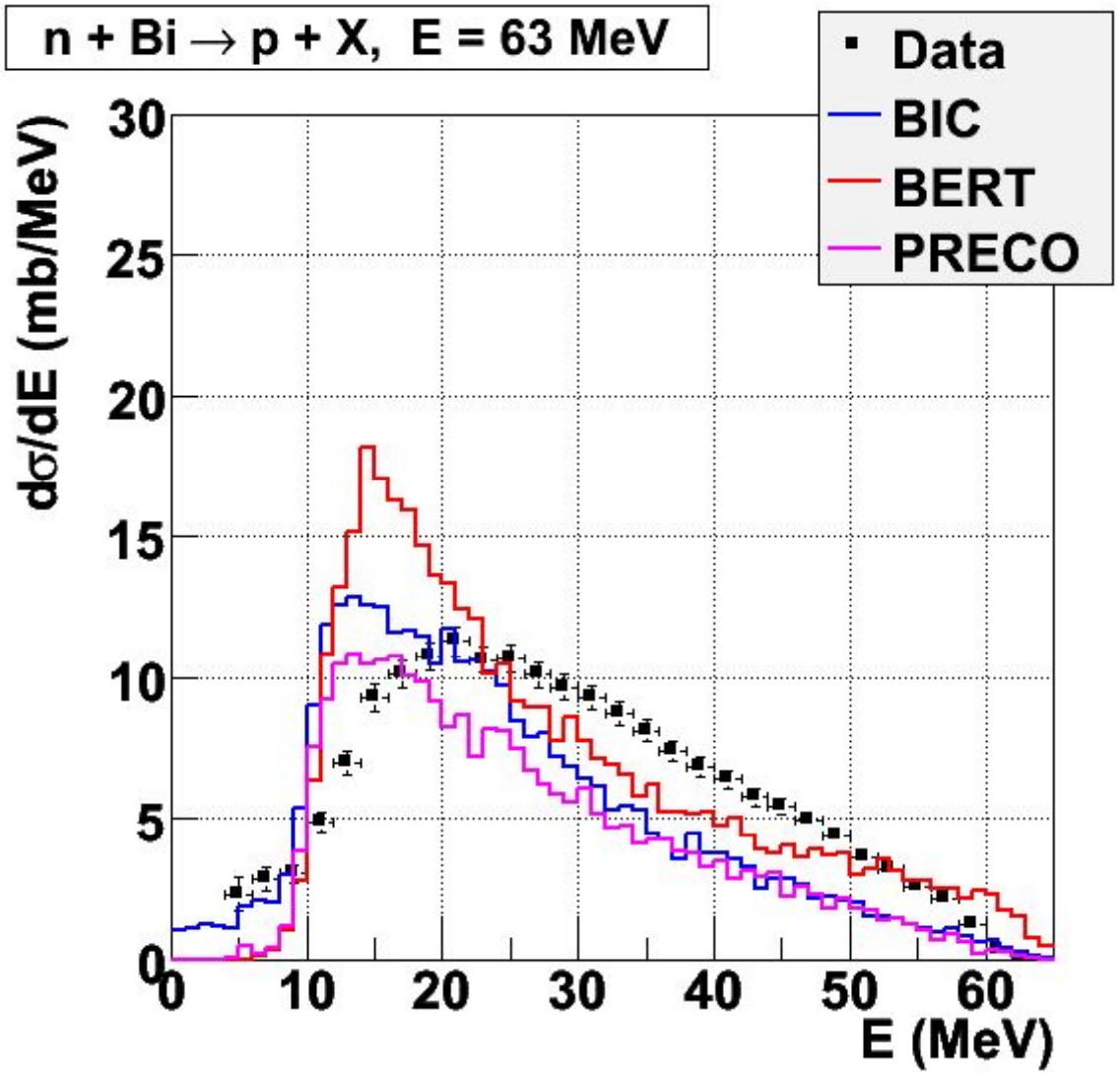
Recommendation 8: put in place a set of simple benchmarks

- simplified calorimeters
  - 3 benchmarks (ATLAS HEC, ATLAS tilecal, CMS HCAL)
  - http: //lcgapp.cern.ch/project/mgmt/doc.html
- low energy and cascade region (test30)
  - 44 benchmarks from 22 MeV to 3.0 GeV
  - http: //cern.ch/vnivanch/verification/verification/hadronic/test30
- inclusive pion production (test35 -HARP data)
  - 36 benchmarks from 3 to 13 GeV
  - http: //cern.ch/vnivanch/verification/verification/hadronic/test35
- neutron yield (test45)
  - 3 benchmarks at 50 MeV
  - http: //cern.ch/vnivanch/verification/verification/hadronic/test45

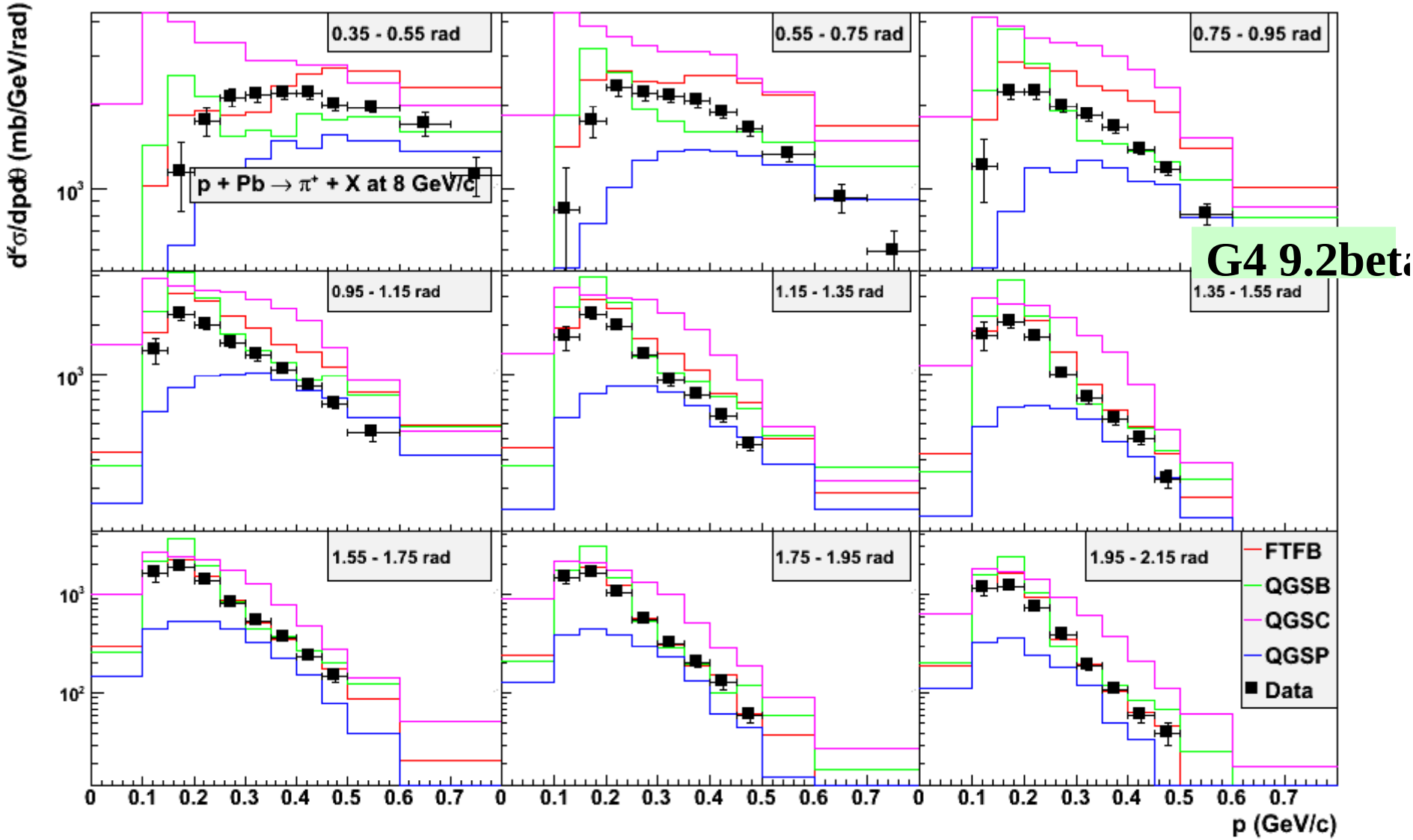
Recommendation 8: put in place a set of simple benchmarks

- medium energy and cascade region (proton incident)
  - 4 benchmarks (more to be added) from 1.4 – 14.6 GeV
  - http://geant4.fnal.gov/hadronic_validation/validation_plots/thin_target/hadronic/medium_energy/index.shtml
- high energy (test43) (pion and proton incident)
  - 5 benchmarks from 100 to 400 GeV
  - http://geant4.fnal.gov/hadronic_validation/validation_plots/thin_target/hadronic/high_energy/index.shtml

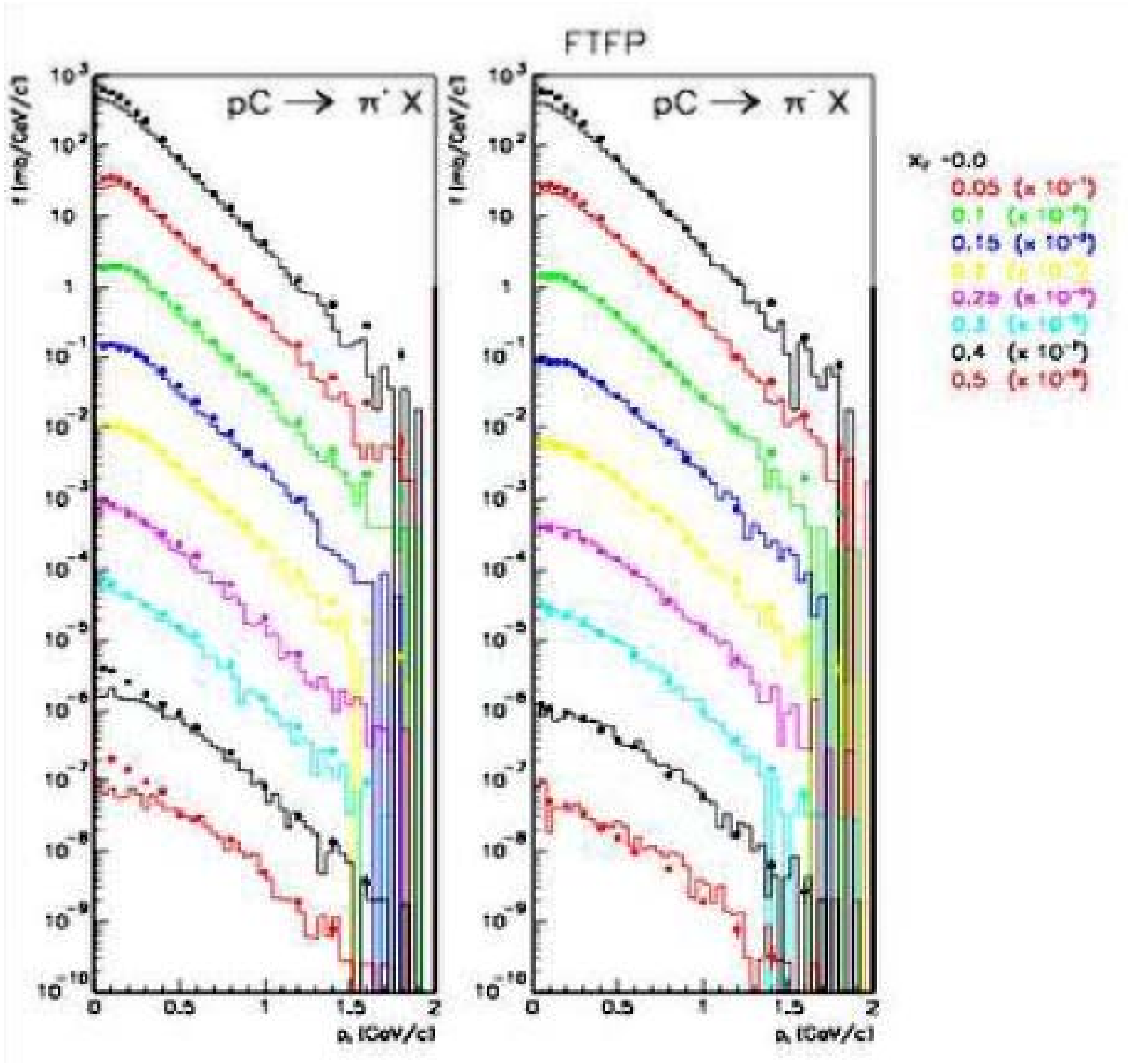
Low Energy Benchmarks



Large-angle HARP Data



NA49 Data 158 GeV/c



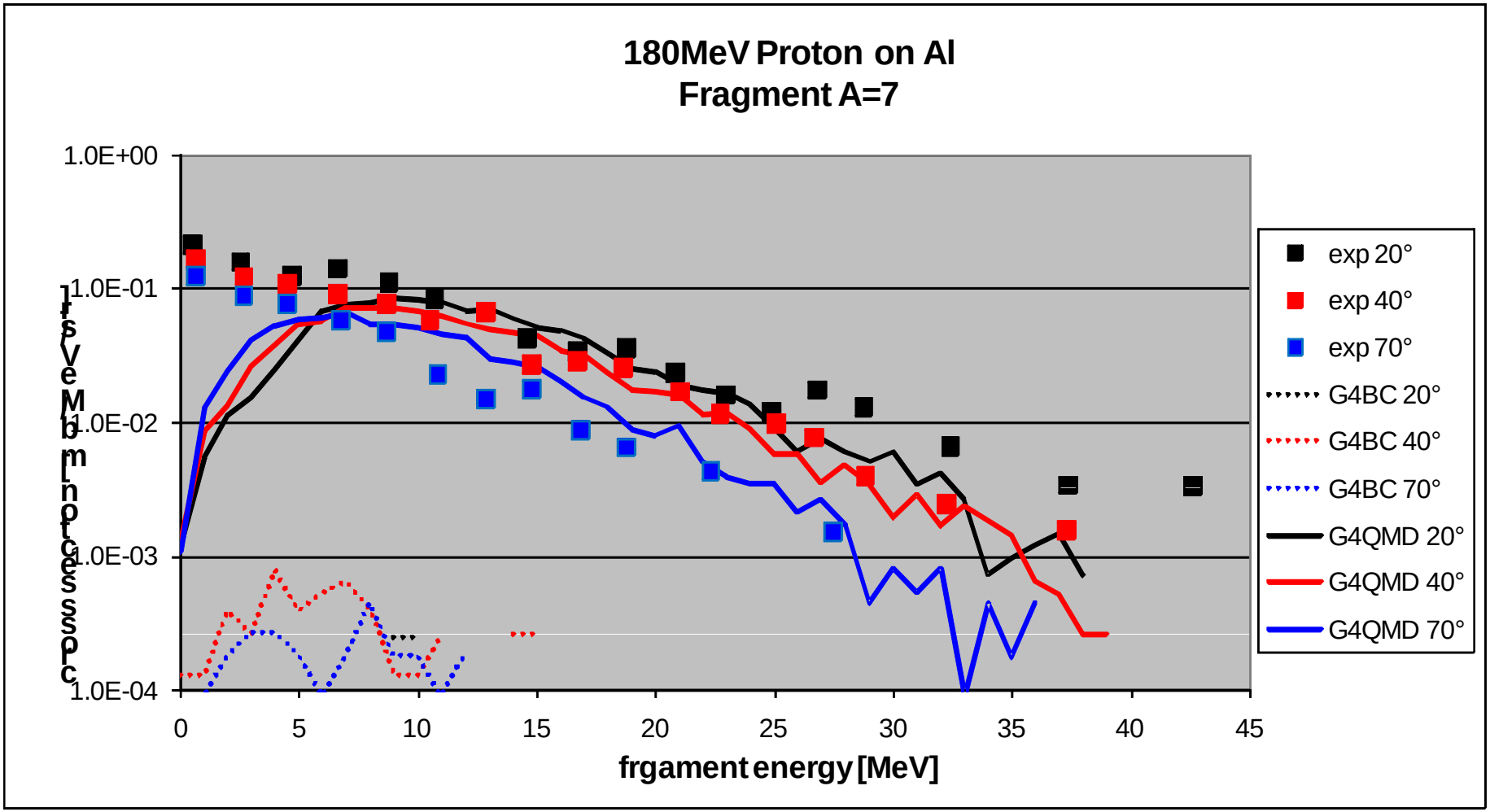
Recommendation 9: physics models that serve needs of space community

- QMD model for nucleus-nucleus collisions essentially complete
  - beta release with Geant4 9.2
  - valid from 50 MeV/n to 5 GeV/n, protons to Uranium
  - first validations against triple differential cross sections (energy, angle, fragment mass) complete, more underway
- String models
  - nucleus-nucleus variant of FTF model (E > 3 GeV/n, target and projectile masses 1 < A < 240) under development
  - nucleus-nucleus variant of QGS model (E > 10 GeV/n, target and projectile masses 1 < A < 240) beginning in 2010

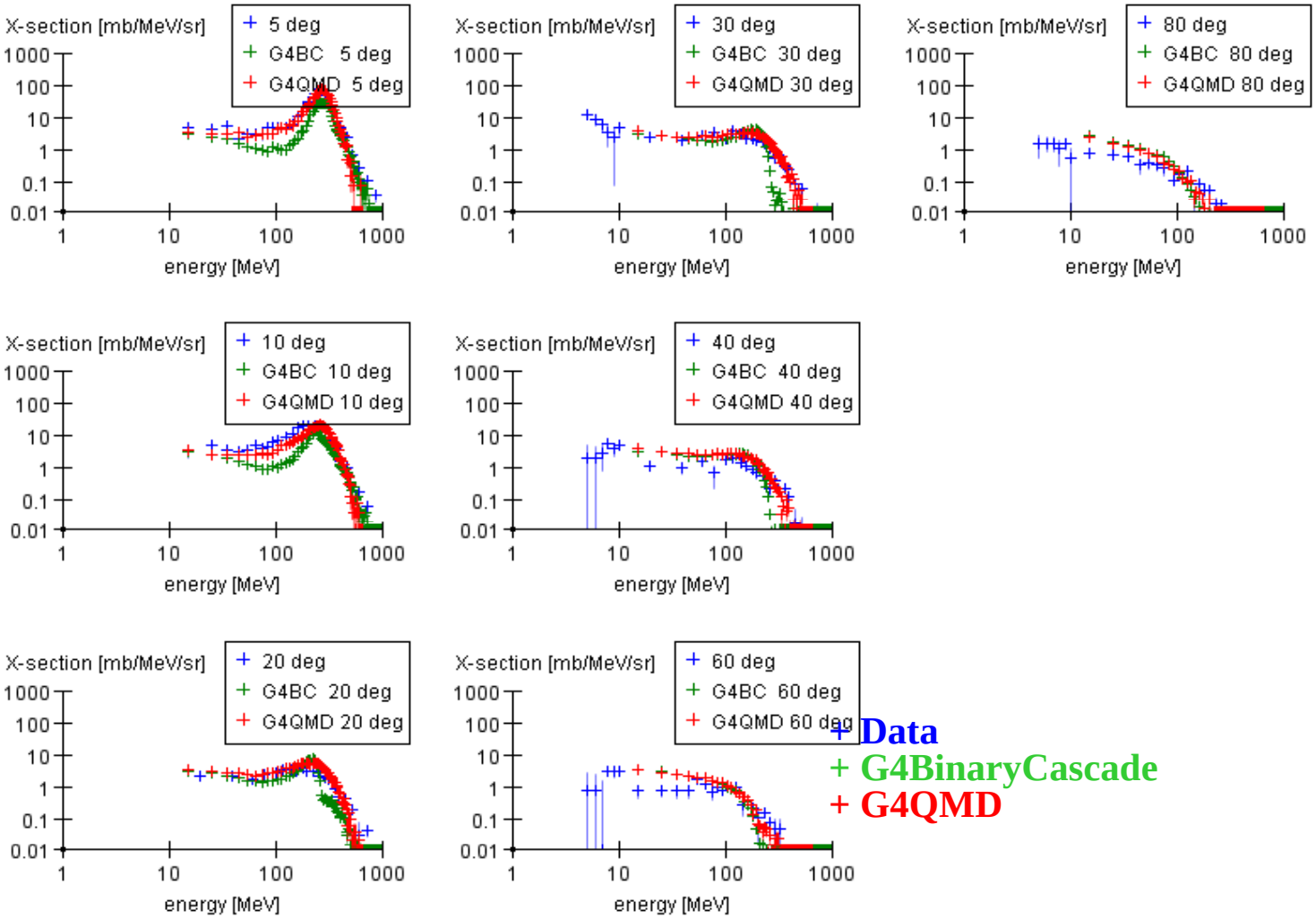
Recommendation 9: physics models that serve needs of space community

- Interfaces
  - JQMD 50 MeV/n < E < 5 GeV/n, pions and protons to U
    - http:// hadron31.tokai-sc.jaea.go.jp/jqmd
  - DPMJET 5 GeV/n < E < 1000 TeV/n, 2 <= A <= 58
    - http:// geant4Hadronics.wikispaces.com/space/showimage/DPMJET-II.5 20080703.ppt
  - PHITS 50 MeV/n < E < 100 GeV/n, neutrons and protons up to U
    - http:// phits.jaea.go.jp

QMD and Binary Light Ion Cascade compared to Triple Differential Cross Sections

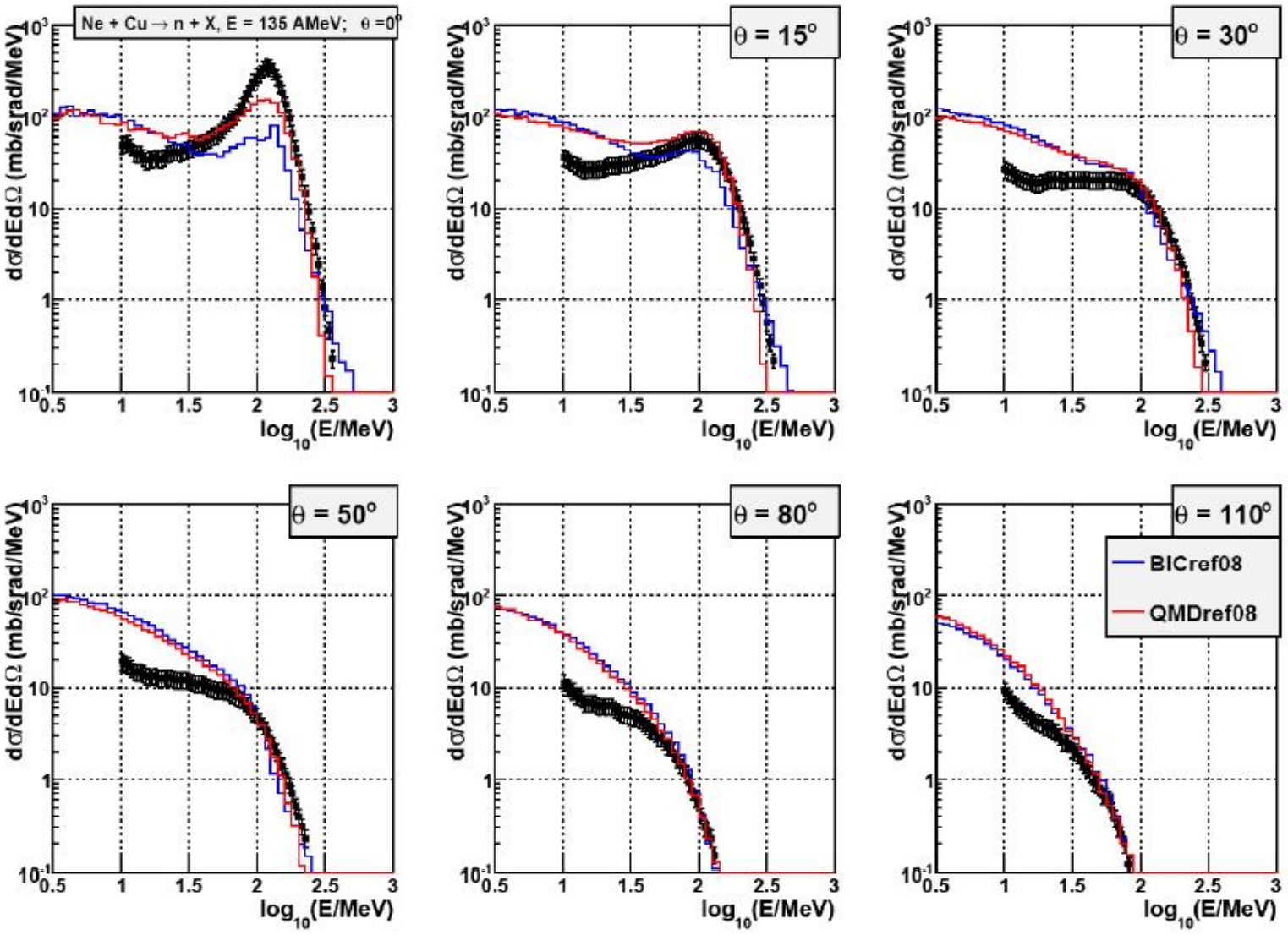


C12 290MeV/n on Carbon
Secondary neutron spectra



+ Data
+ G4BinaryCascade
+ G4QMD

136 AMeV Ne + Cu -> n + X



Hadronic Plans for 2009 and 2010-2012

Hadronics Working Group Major Tasks

- Shower shapes and energy response for HEP
  - discontinuities in energy response, particle multiplicities
  - coupling string models to cascade models in 5 – 15 GeV region
  - improvement of QGS model, including implementation of new diffraction cross section calculations
  - model matching
  - improvement of quasi-elastic scattering in models
    - QGS, Bertini (delayed due to lack of manpower)
- Low energy behavior
  - improve approximate neutron transport (elastic and capture)
  - improve negative particle stopping
  - pion absorption in nuclei (important below 4 GeV)
  - protons below 200 MeV

Hadronic Major Tasks (2)

- Cross section review
  - review of high energy external cross sections complete
  - review of low energy cross sections needed
  - review of internal cross sections (used by models) is underway
  - set up easy printout and plotting of cross sections
  - examine for discontinuities
- Validation
  - continue existing effort, expand existing validations, add new validation suites for stopping particles and ion-ion
  - compare results with other MC codes (deferred due to lack of manpower and expertise in other codes)
  - prepare validation benchmarks for Hadronic Shower Shape Workshop (time to be determined)

Hadronic Major Tasks (3)

- Testing
  - completion of system tests
  - select set of unit tests which can be run as regression tests (deferred until 2010)
  - complete energy/momentum tests
  - devise tests for quantities not usually examined (sanity check) (deferred until 2010)
- Documentation
  - document model implementations (deferred)
  - completion of model descriptions and validity ranges

Hadronic Major Tasks (4)

- New models
  - FTF and QGS nucleus-nucleus collision models
  - full release of QMD and improvements
  - alternative to high precision neutron model, based on ENDL (delayed from end of 2008)
  - improve and validate charge exchange process (deferred)
  - RPG (GHEISHA replacement) (deferred – was originally to be completed by end of 2008)

Manpower

- items listed as delayed are late due to lack of manpower
- items listed as deferred will not be completed by 2009 or will not be started in the near future
  - loss of FTEs
  - loss of expertise
- currently looking for funding
- also looking for new collaborators to increase expertise in physics modeling and validation

FTE Gains and Losses 2007 through 2009

- Losses
  - Binary cascade -0.5
  - string models -0.5
  - Bertini cascade, LHEP -0.8
  - CHIPS low energy, quasi-elastic -1.0
  - precompound/evaporation -0.4
  - validation/model testing -0.7
  - nucleus-nucleus/low energy -0.5
  - Total losses -4.4 FTE

FTE Gains and Losses 2007 through 2009

- Gains
  - validation (medium energy) 1.4
  - validation (high energy and shower shapes) 0.5
  - precompound/evaporation 0.5
  - validation (low energy/medical) 0.3
  - Total gains 2.7 FTE
- Net:
  - loss of 1.7 FTE

Major Deliverables and Resources

- High-priority deliverables
  - study and repair of problems which destroy smooth simulated calorimeter energy response
  - identify reasons for differences in shower shape lengths and widths between Geant4 simulation and test beam data from ATLAS, CMS
  - complete validation suite for all energy regions
  - regular validation of hadronic models against thin target and full-setup data
- Resources
  - from 2007 review through 2009, hadronics group will lose 1.7 FTE
  - loss in the area of the above-listed deliverables 2007 through 2009 is 1.6 FTE

Smooth Energy Response (1)

- remove discontinuities in visible energy, multiplicity
  - validation reveals factors of two or more differences in multiplicity within the space of 1 GeV or less in the region where cascade models blend into string models (degree depends on models)
  - visible energy also appears to have dips and wiggles in same region (where none are expected)
- main tasks:
  - study of distribution-matching between cascade and string models
  - review of internal cross sections in string and cascade models
- additional tasks:
  - develop/test re-interaction of particles from string models (Binary cascade)
  - theoretical or parameterized method for smoothly turning off the Bertini cascade in the range 5 – 15 GeV

Smooth Energy Response (2)

- required resources:
  - expertise in QGS, FTF, Bertini, Binary models
  - 2.5 FTE-years:
    - 1.0 distribution matching
    - 0.5 cross section review
    - 0.5 re-interaction of particles
    - 0.5 Bertini turn-off

Shower Composition and Shape (1)

- lengthen and broaden simulated showers
- main tasks:
  - improve energy response characteristics (see previous slide)
  - study and improve pion production, especially pi0
  - improve diffraction for protons
- additional tasks:
  - study neutron and charged particle capture (affects lateral shape)
  - improve approximate neutron transport model
  - study and improve precompound and nuclear physics, especially for protons below 200 MeV

Shower Composition and Shape (2)

- required resources:
  - expertise in low energy neutron propagation, precompound/evaporation models and nuclear physics
  - 2.25 FTE-years:
    - 0.50 pion production study
    - 0.50 proton diffraction
    - 0.25 neutron/charged particle capture study
    - 0.75 development of improved neutron capture and transport model
    - 0.25 precompound/evaporation, nuclear physics study

Completion of Hadronic Validation Suites

- main tasks:
  - complete medium energy suite with metrics and automation
  - develop similar suites for high energy, stopping particle and heavy ion validation
- required resources:
  - 2.00 FTE-years:
    - 0.50 medium energy suite completion (automation)
    - 0.50 development of high energy suite
    - 0.50 development of stopping particle suite
    - 0.50 development of heavy ion validation suite

Regular Hadronic Validation

- main tasks:
  - run all validation suites for each release
  - post results
  - maintain scripts, directories, documentation, etc.
- required resources (continuing):
  - 0.75 FTE:
    - 0.15 test30, test35, test45 validations
    - 0.15 medium energy validation
    - 0.15 high energy validation
    - 0.15 stopping particle validation
    - 0.15 heavy ion validation

Resources

- Effort required:
  - smooth energy response 2.50
  - longer, broader showers 2.25
  - completed validation suites 2.00
  - Total 6.75 FTE-years
  - running validation 0.75 FTE continuing
- Personnel required:
  - QGS expert 0.5 FTE
  - replace Binary cascade lost effort 0.3 FTE
  - replace Bertini cascade lost effort 0.6 FTE
  - replace low energy expertise 0.4 FTE
  - Model integration/testing (replacement + new) 0.6 FTE
  - Total 2.4 FTE

Addendum

Hadronic Milestones for 2009
and
2010-2012

Hadronics Milestones 2009 (1)

- Feb
  - complete IAEA spallation benchmarks
- Mar
  - complete latest validation against changes in Bertini cascade
- May
  - complete study of cascade turn-off in Bertini
- Jun
  - medium energy validation suite completed
- Aug
  - ion-ion validation suite completed
- Sep
  - implementation of developer tests for energy/momentum conservation in all hadronic models

Hadronics Milestones 2009 (2)

- Oct
  - completion of QGS model revision
- Nov
  - Hadronic Shower Simiulation Workshop benchmarks completed (?)
  - ENDL-based model for high precision neutrons implemented
- Dec
  - high energy validation suite completed
  - precompound model improvements completed
  - cross section review completed

Hadronics Milestones 2010-2012 (1)

- Jun 2010
  - SATIF benchmarks completed
  - testing and validation of Propagate interface in Binary cascade
  - Bertini cascade turn-off implemented
  - regular benchmarking against MCNPX
- Dec 2010
  - distribution matching study complete
  - pion production study complete
  - neutron/charged particle stopping study complete
- Jun 2011
  - proton diffraction implemented
  - stopping particle validation suite complete
  - RPG model complete

Hadronics Milestones 2010-2012 (2)

- Dec 2011
  - implementation of distribution matching algorithms
  - improved approximate neutron propagation and capture process
  - Hadron Shower Simulation Workshop benchmarks
- Jun 2012
  - IAEA benchmarks
  - development freeze for documentation month
- Dec 2012
  - very high energy (> TeV) string model additions
  - low energy (< 50 MeV/n) nucleus-nucleus models
  - SATIF benchmarks