Specific Validation Tests for Hadron Physics

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Outline

- Introduction
- Specific tests developed for CHIPS validation
  - test19, test29, test39
- Validation suite for the cascade energies (test30)
  - Low energies
  - Recent plots for energies below 1 GeV
  - New plots for energies above 1 GeV
- Verification against HARP data (test35)
  - New plots
- Conclusions

Introduction

- Validation and verifications is performed using different tools:
  - Private developer tests
  - Private verification tests
  - Unit tests
  - User validation
- Special tests available for the collaboration in CVS
  - Published data
  - Infrastructure for comparisons and histograms
  - Difficult to deliver for users

CHIPS validation
test19, test29, test39

Mikhail Kosov, Lisbon, 2006

CHIPS tests (see G4-2005 for details)

- Test19 is used for all on-flight processes except for elastic and nuclear quasi-elastic reactions
  - subdirectories for pictures (photo-, electro-nuclear)
  - projectile/energy/target loop for performance test
- Test29 is used for all at-rest nuclear reactions for negative hadrons, μ^-, τ^-, neutrons, anti-neutrons
  - subdirectories for pictures (annihilation, π^--capture)
  - negative particle/target loop for performance test
- Test39 (new) for elastic scattering (EM/hadronic)
  - no subdirectories yet (CHIPS process is not finished)
  - no projectile/energy/target loop for performance test yet

Goals and applications of CHIPS tests

- Released version defines loops over projectiles, energies, and targets for which CHIPS is applicable (only CHIPS)
  - input data in chipstest.in file must not be changed (automatic call)
  - 0 for projectile PDG code means Loop over predefined projectiles
  - 0 for projectile energy means Loop over predefined energies
  - 0 for target PDG code means Loop over predefined targets
- If projectile/energy/target is specified in chipstest.in, test can be used for debugging/development/comparison
  - if other than CHIPS processes must be tested for comparison with CHIPS, test must be recompiled with proper uncommented lines
- chipstest.in file (containing reaction definition and number of events) can be created for the test executable by kumac-files, which make pictures in subdirectories (the test executable is unique for all CHIPS processes)
  - Number of subdirectories with pictures can increase with time

Verification Suite for the Cascade Energy Region – test30

- Exist since 2002 as test30
- 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
  - P + A -> $\pi^{\pm}$ + X
- 73 thin target experiments with reasonably small systematic
- Control on differential spectra (63 histograms)
- Model level test

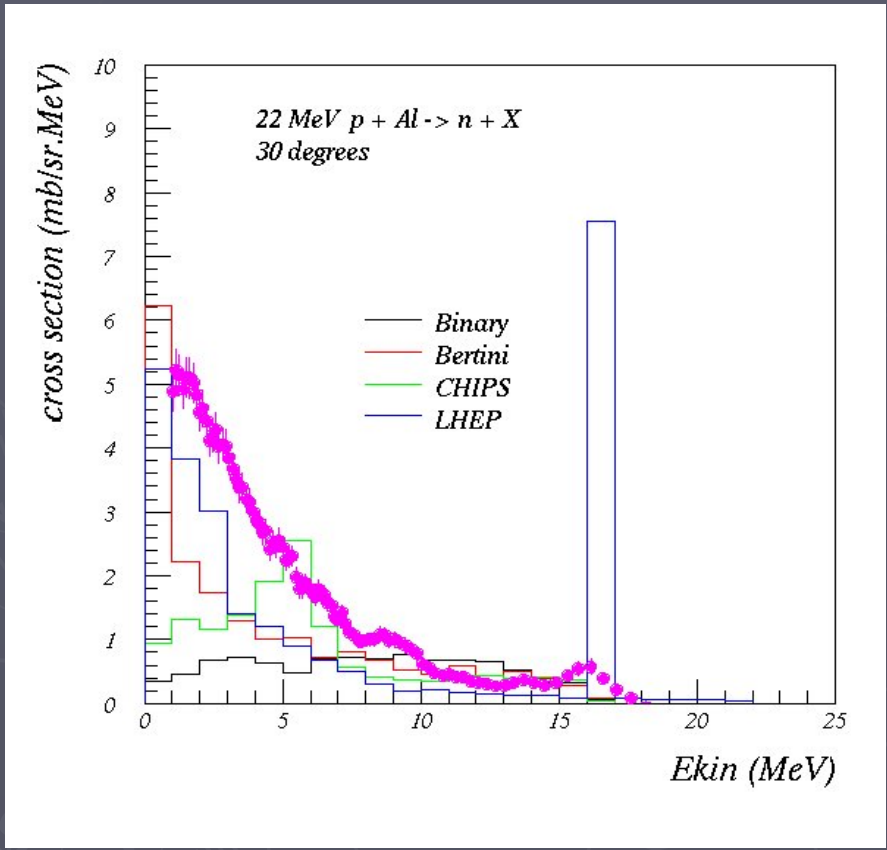
- Models under testing:
  - Binary Cascade
  - Binary Ion cascade
  - Bertini Cascade
  - Wilson-Abrasion model
  - CHIPS
  - LHEP
- Additionally to double differential spectra for comparisons with the data a set of histograms with inclusive spectra is produced

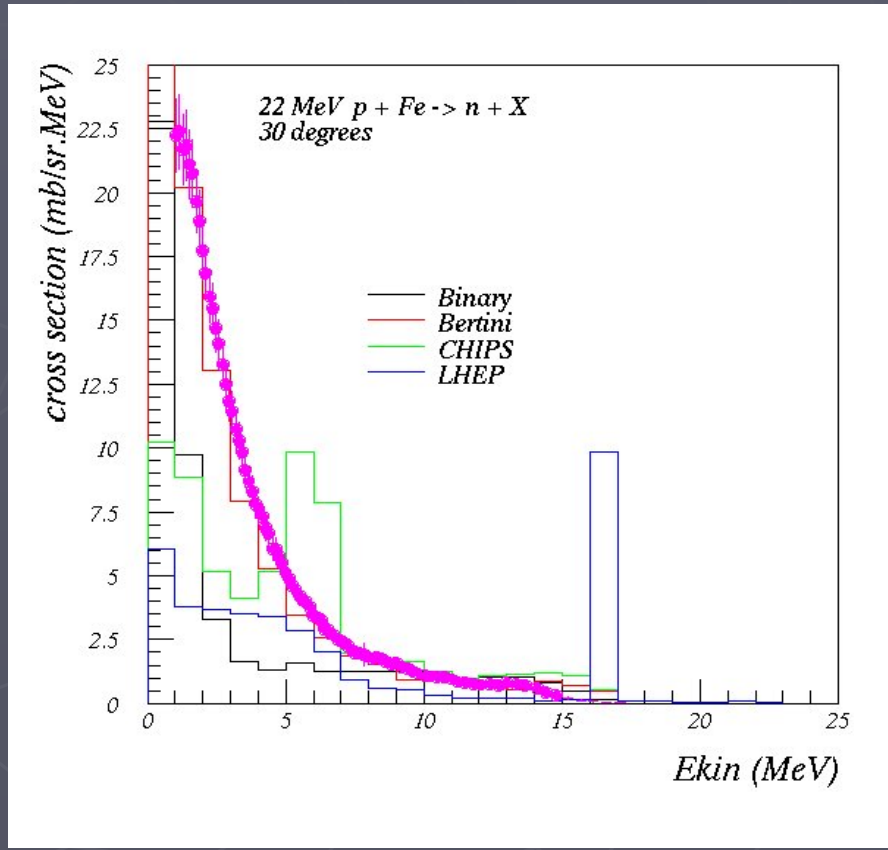
Testing Suite Directory Structure

- AFS public – not CVS
  - Test30 data and results
  - Started from 8.1
  - AFS volume with backup
- Driving by scripts
- From 8.1 running at LXBATCH
- Directories are structured by tag name

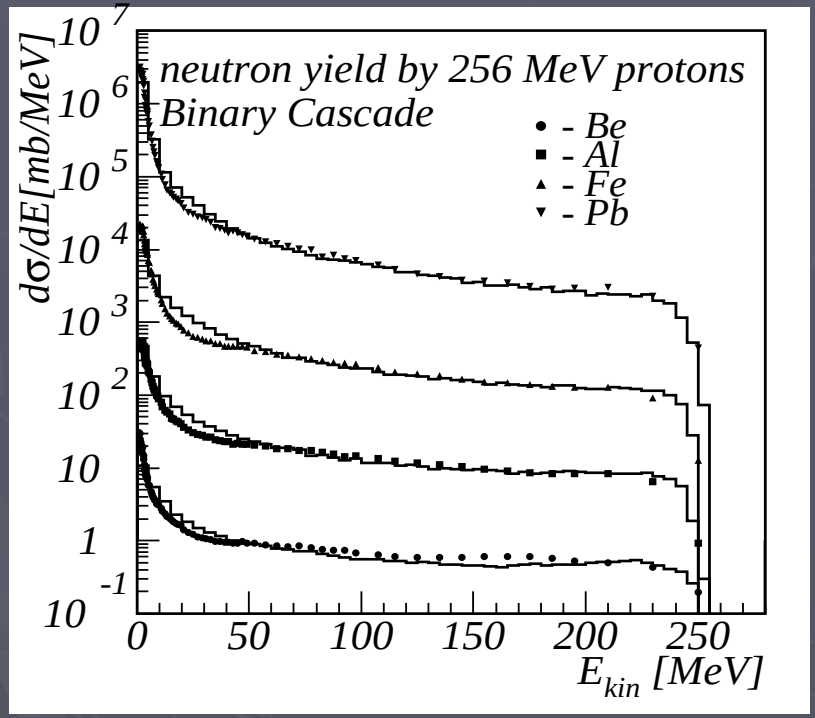
$VFHAD/test30/data/pn_al_256
/pn_al_1500
$VFHAD/test30/geant4-08-01-ref-00/pn_al_256/r.out
/pn_al_256/bic.paw
/pn_al_256/bert.paw

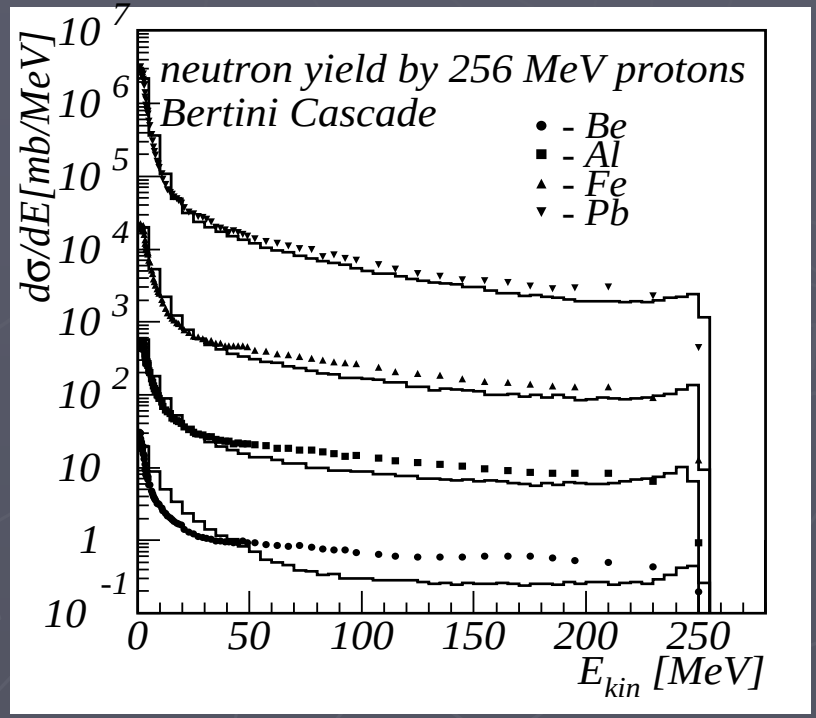
Neutron Production by Protons at Very Low Energy 8.1



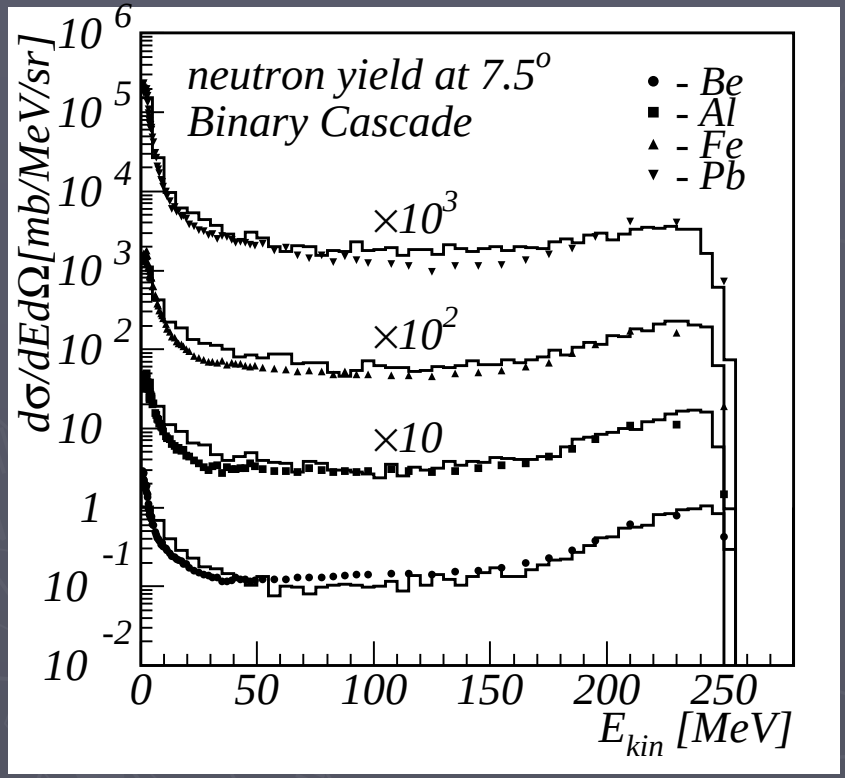


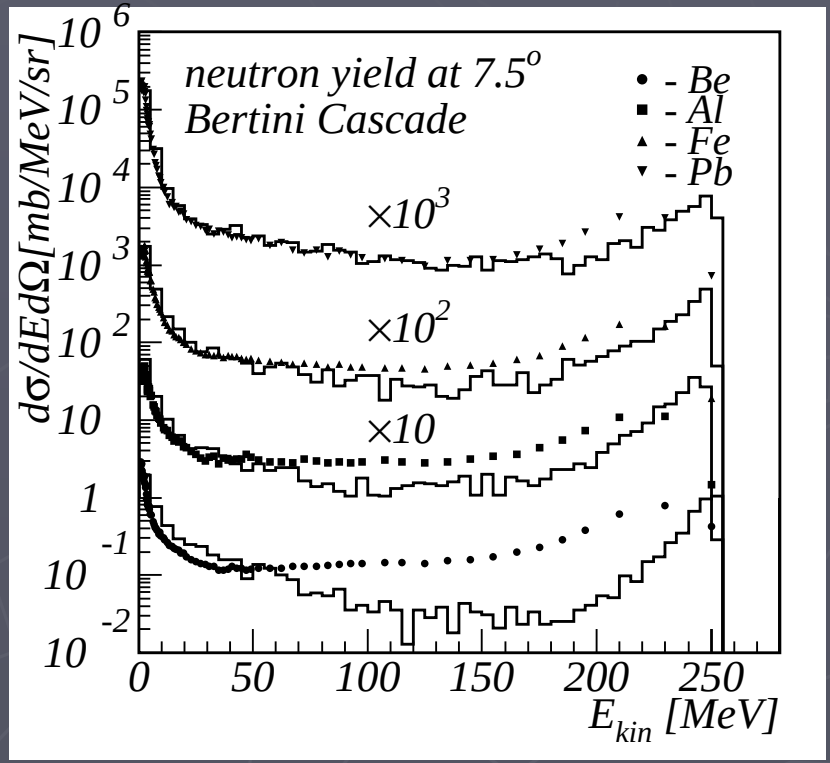
Neutron spectra by 256 MeV protons Binary and Bertini Cascades 8.1





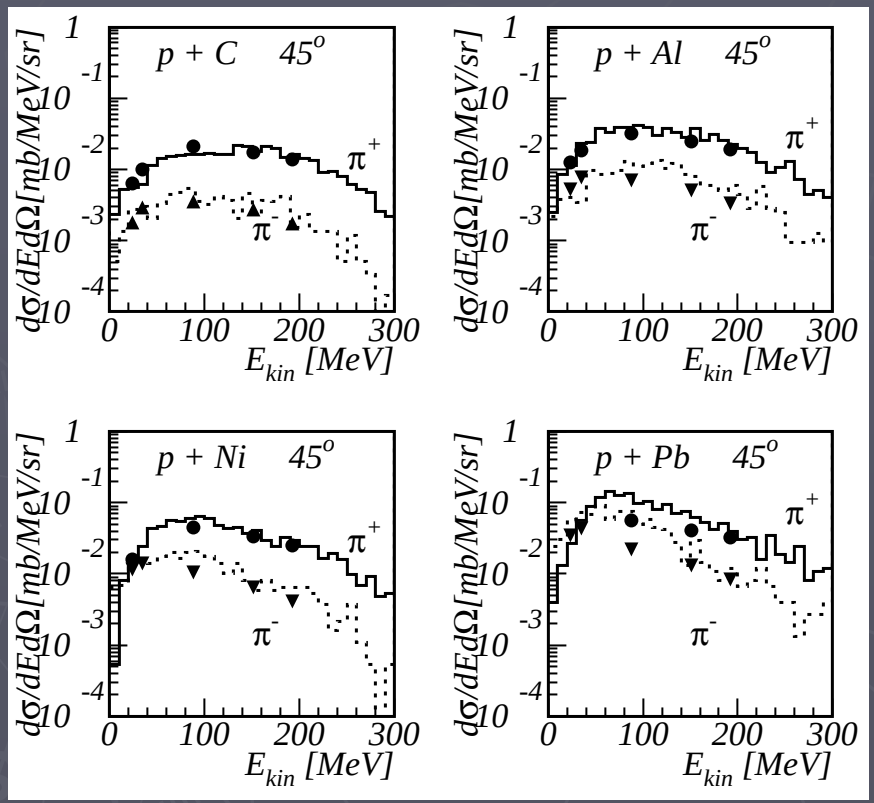
Neutron spectra by 256 MeV protons Binary and Bertini Cascades 8.1



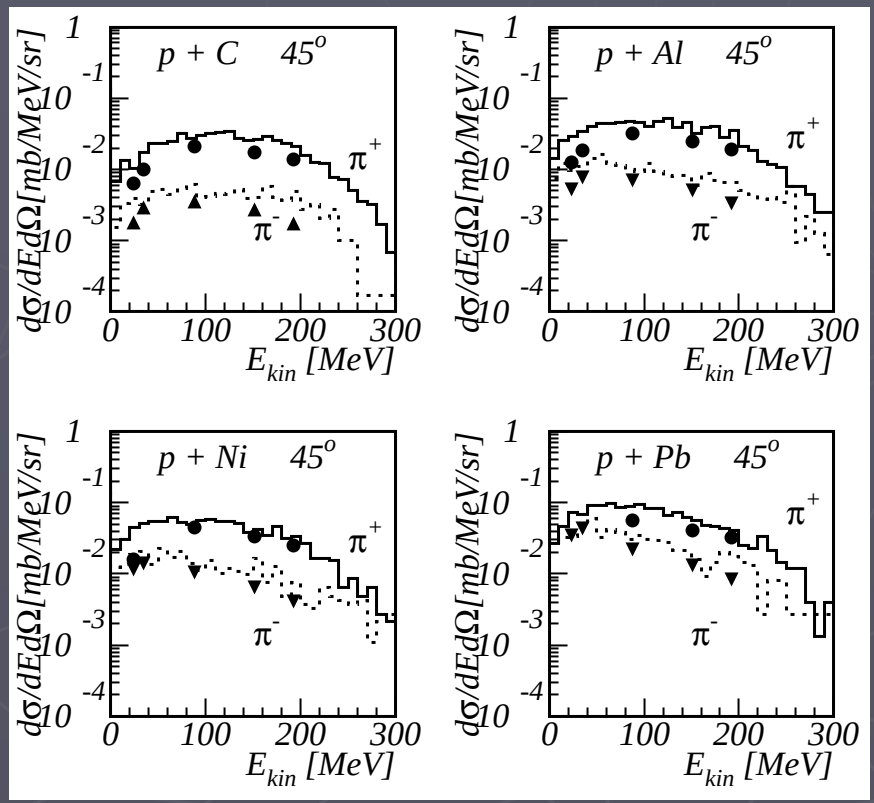


Charged pions spectra produced by 600 MeV protons at 45 degrees 8.1

Binary Cascade

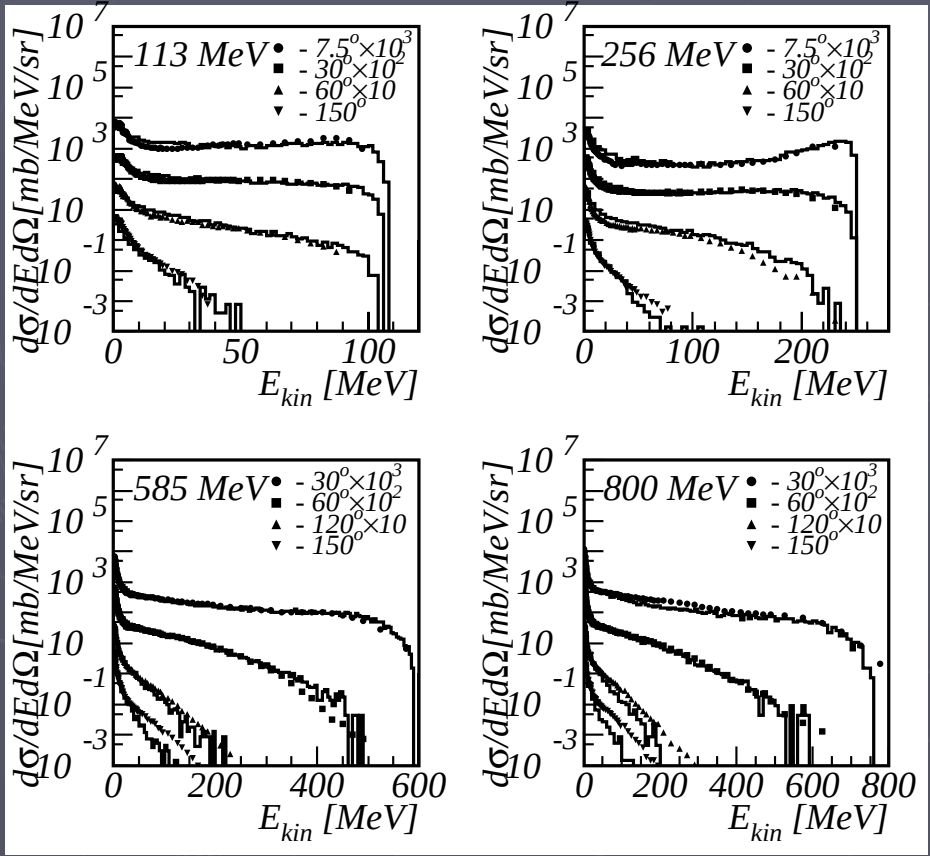


Bertini Cascade

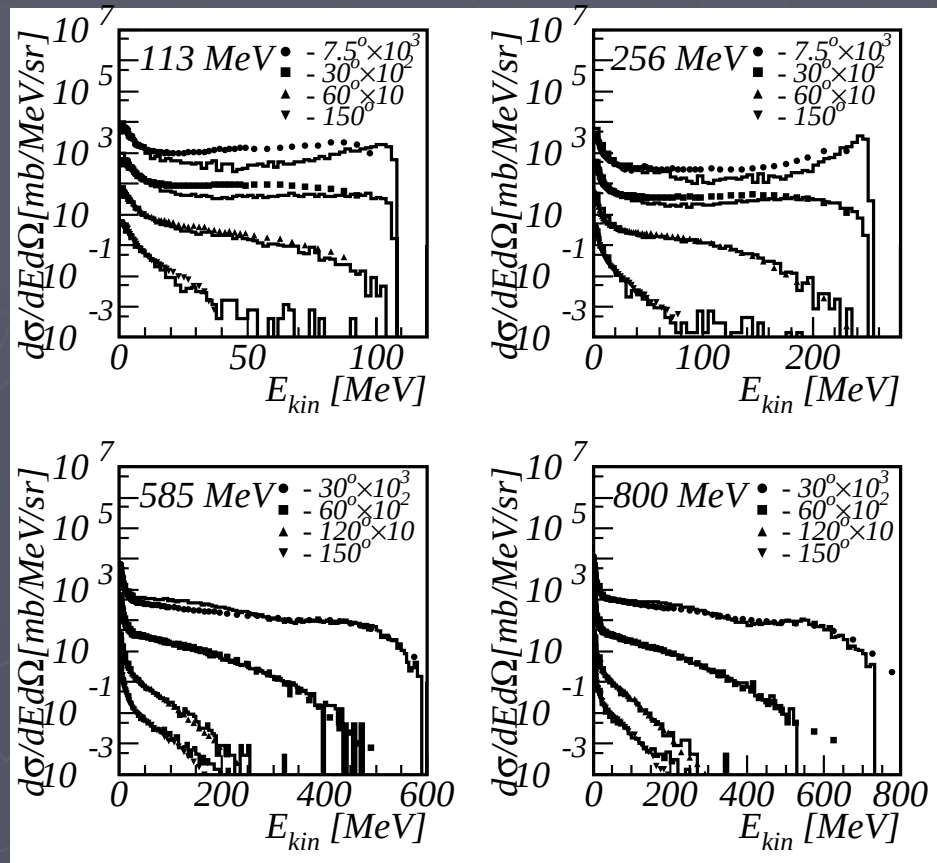


Neutron spectra by protons in Aluminum 8.1

Binary Cascade

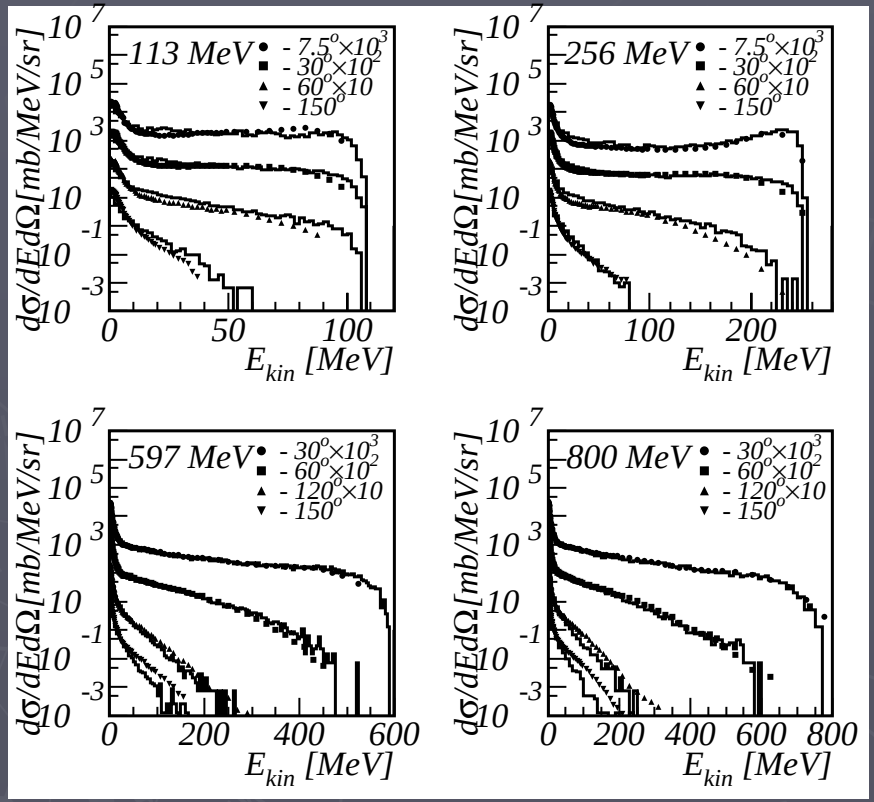


Bertini Cascade

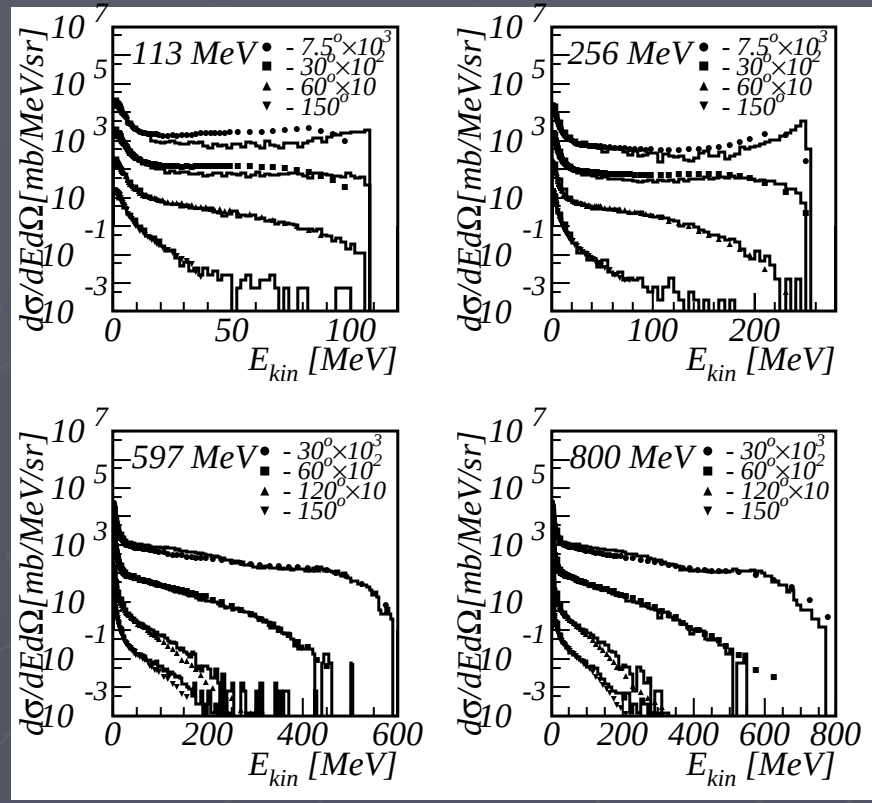


Neutron spectra by protons in Iron 8.1

Binary Cascade



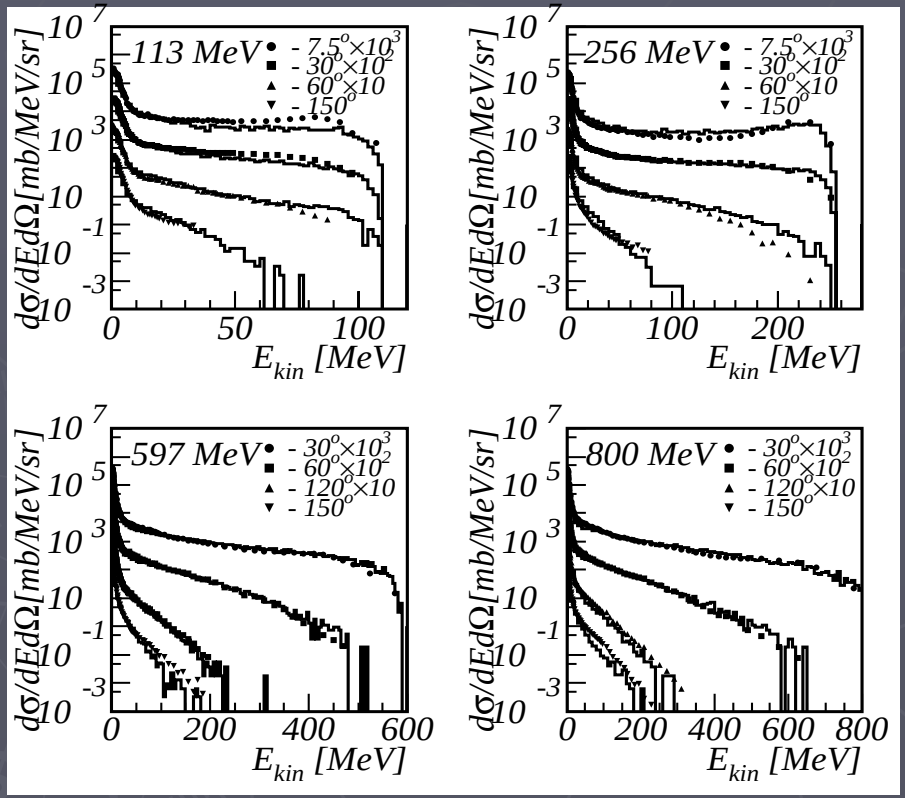
Bertini Cascade

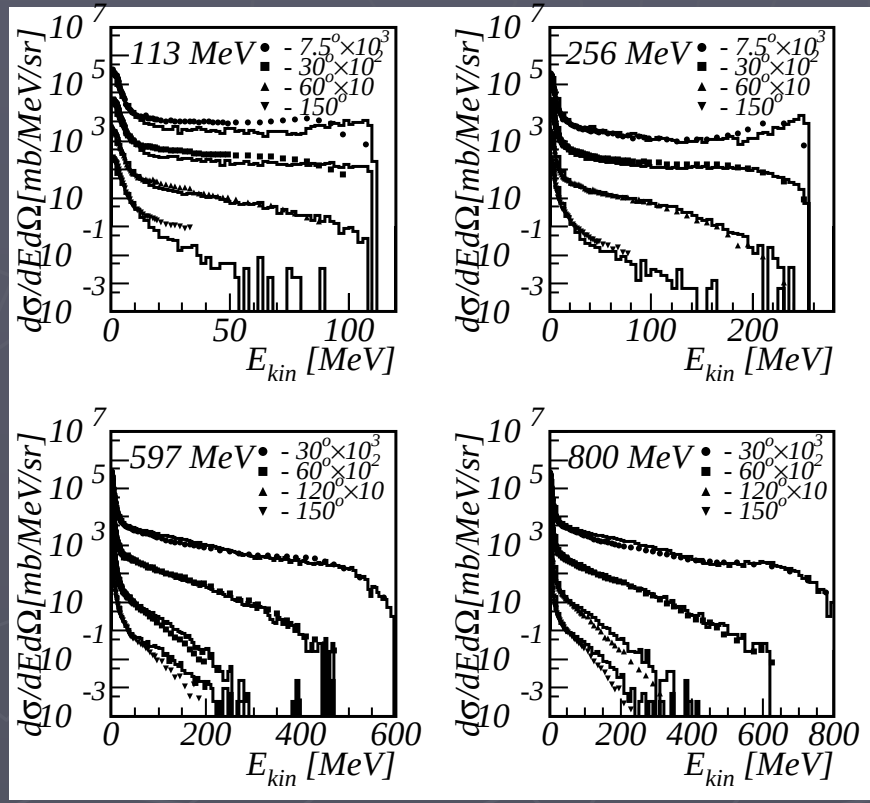


Neutron spectra by protons in Lead 8.1

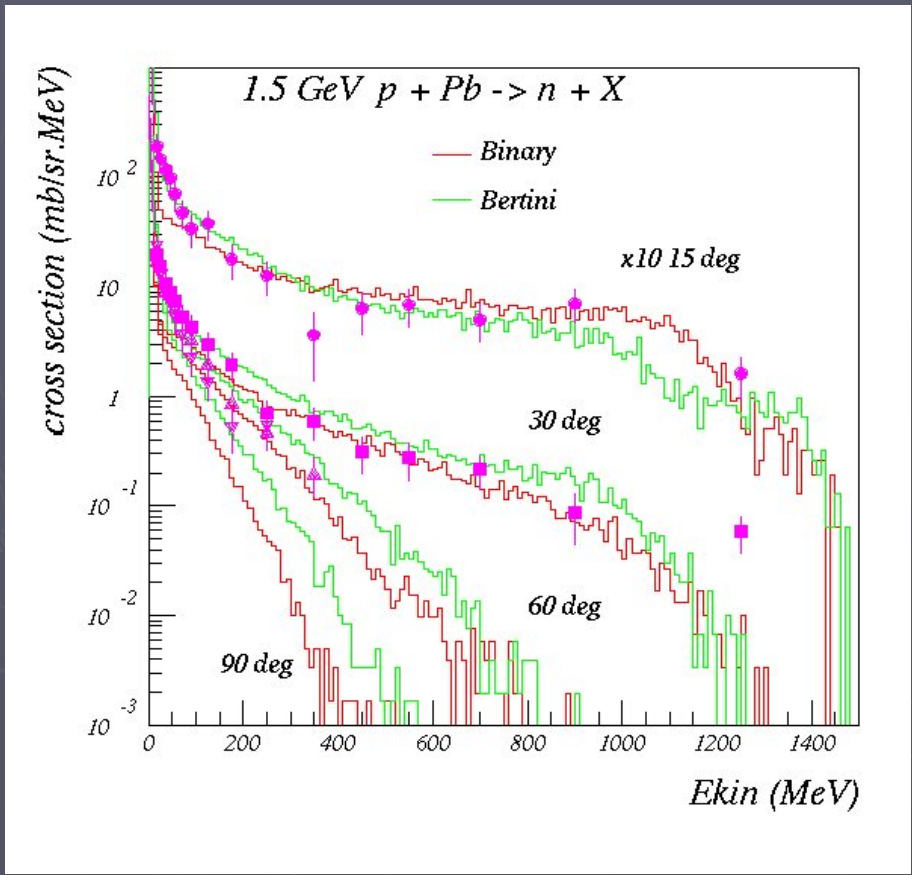
Binary Cascade

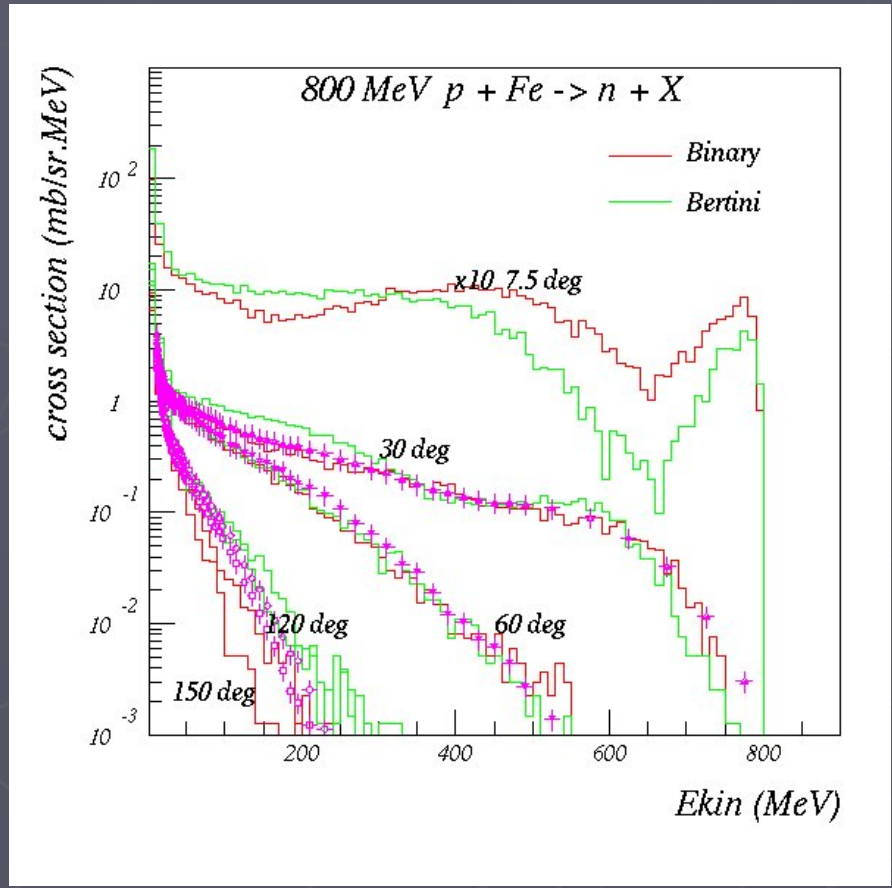
Bertini Cascade



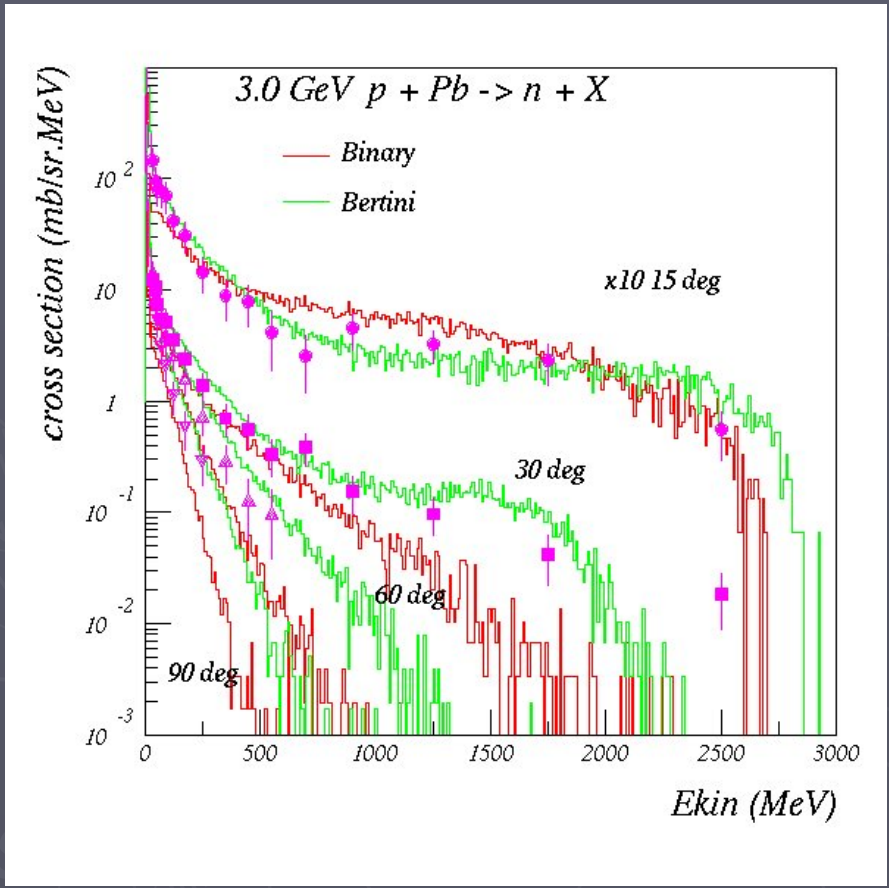


Neutron spectra by 0.8 and 1.5 GeV protons 8.1





Neutron spectra by 3 GeV protons 8.1



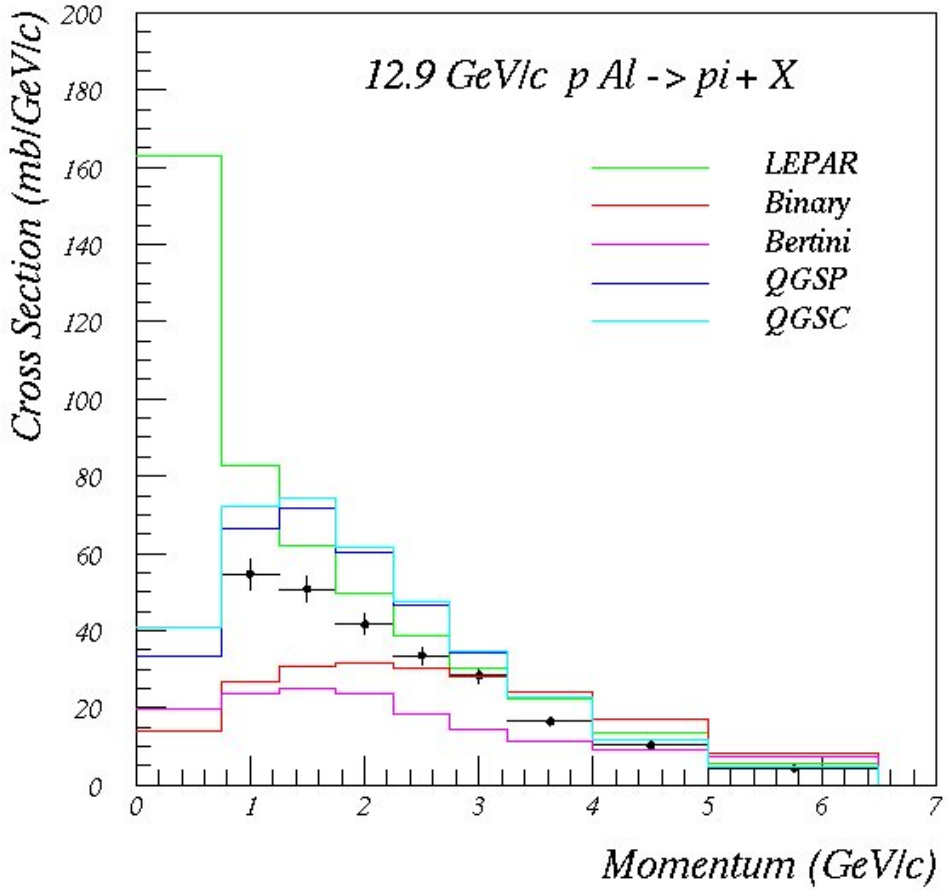
- There are more forward neutrons produced by Binary Cascade
- There are more low-energy neutrons produced by Bertini Cascade
- There are more backward neutrons produced by Bertini Cascade

Verification against HARP data: test35

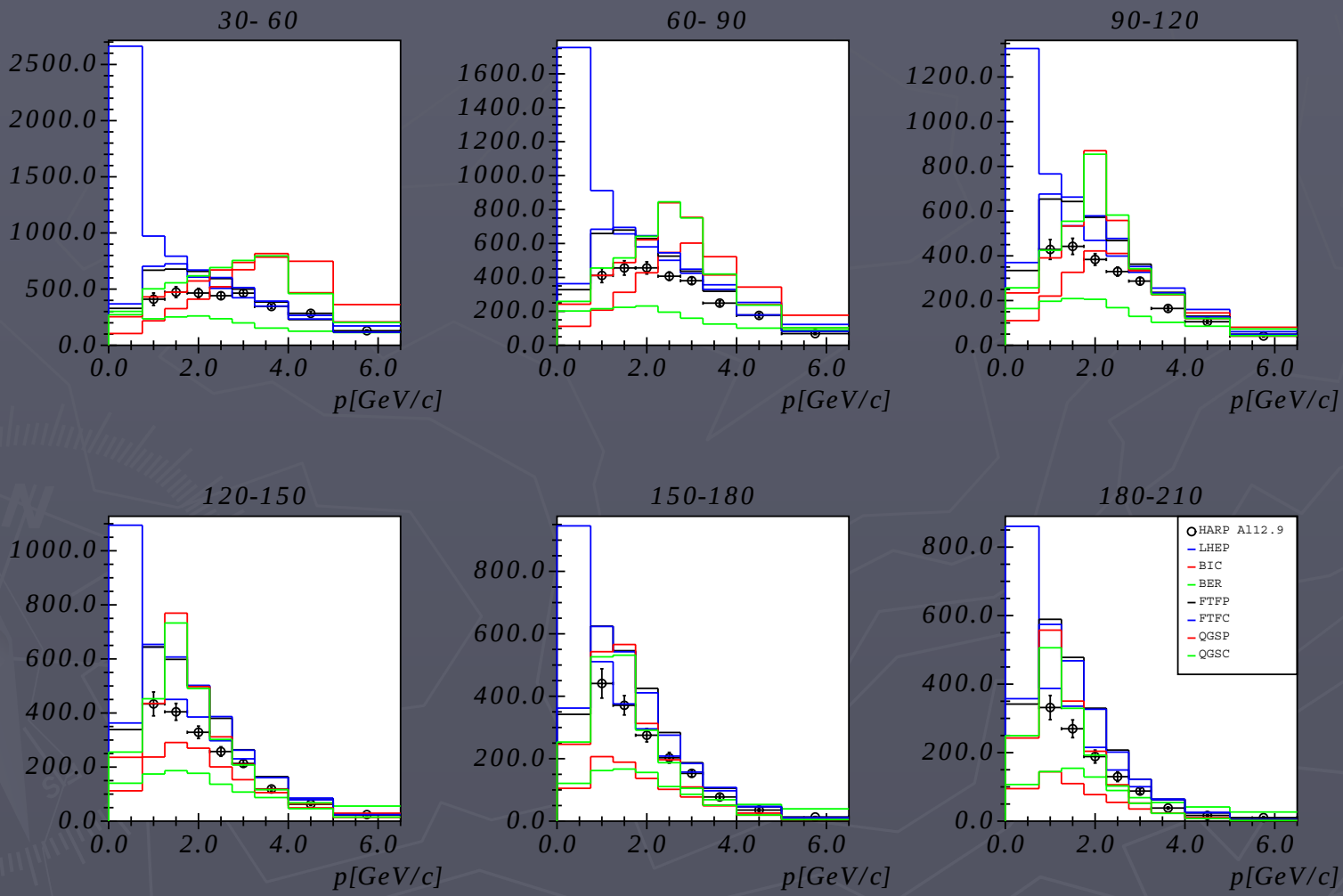
- Was reorganized for G4 8.1
  - Data and test results at afs
  - Directory structure as for test30
  - Scripts for running at LXBATCH
- Focus on charged pion production in proton and pion beams with momentum (1.5 – 15) GeV/c
- 2 setting have been used for recent releases
  - 8.9 GeV/c p + Be forward (MiniBooNE setup)
  - 12.9 GeV/c p + Al forward (K2K setup)
- Other settings are running without comparison with the data
  - 3, 5, 8, 12 GeV/c p + Ta large angles (neutrino factory)
  - 3, 5, 8 GeV/c p + C forward (background study)
- Models under study:
  - Binary, Bertini, LHEP, QGSP, QGSC, FTFP, FTFC
  - Model applicability range extended to cover HARP energy range

Forward π^+ Production in Al by 12.9 GeV/c Proton Beam

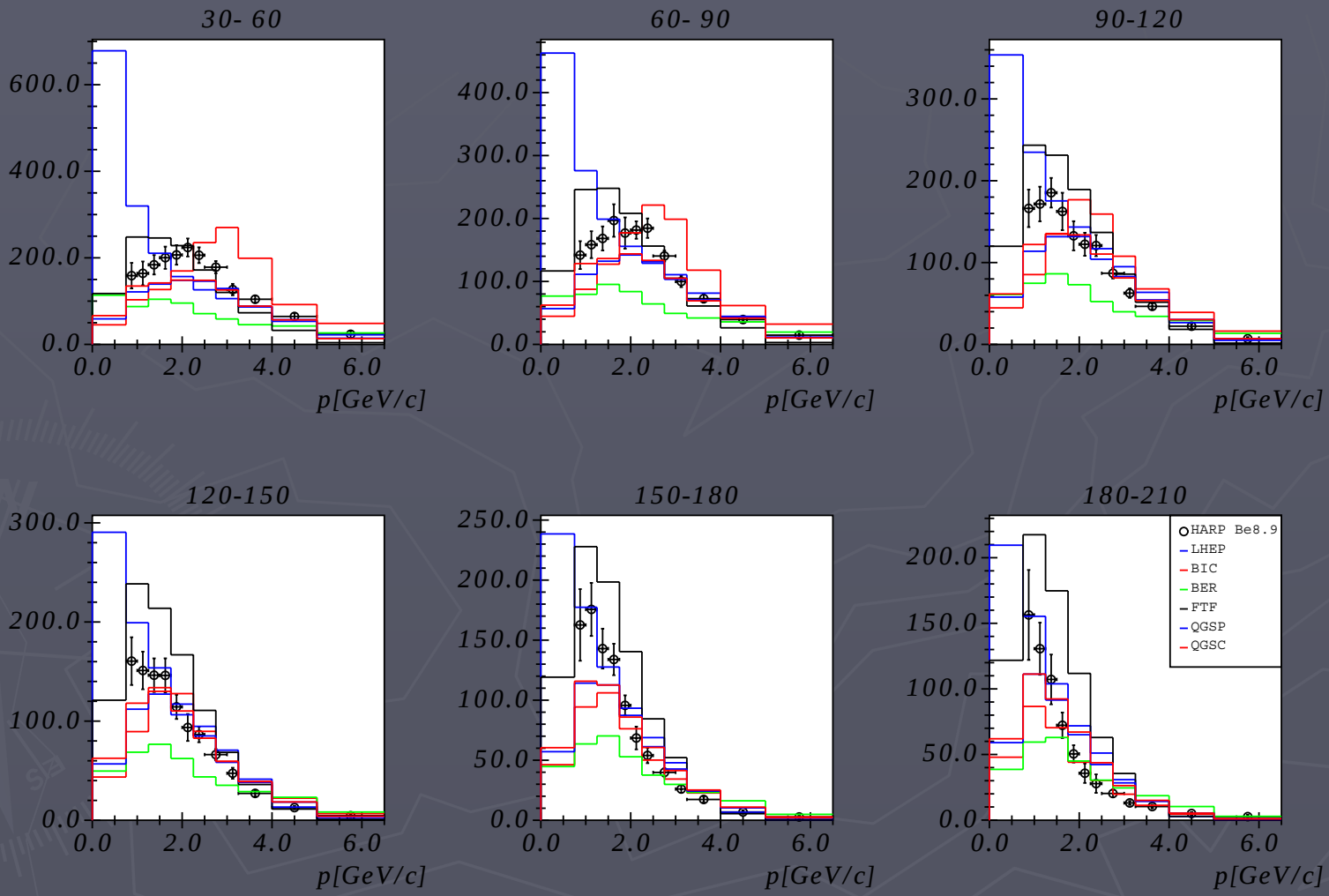
- $0.03 < \theta < 0.21$ rad
- LHEP has obvious problem producing too many low energy pions
- QGS model seems to predict pion yield the most closed to the data
- QGS model has wrong angular distribution
- Both cascade models underestimate low energy pion production



Double Differential Cross Section of π^+ Production by 12.9 GeV/c Protons in Al



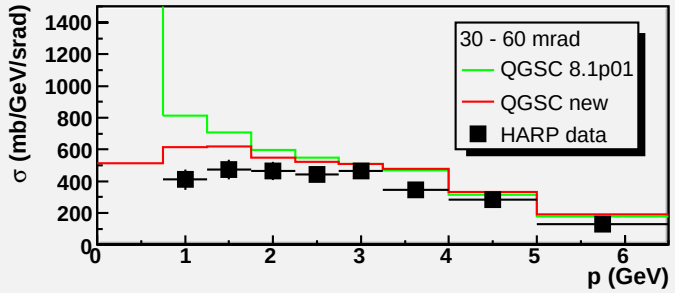
Double Differential Cross Section of π^+ Production by 8.9 GeV/c Protons in Be

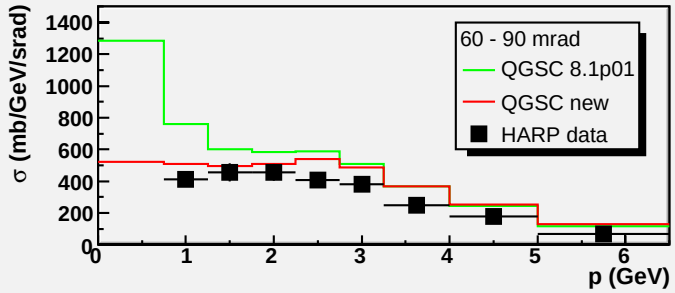


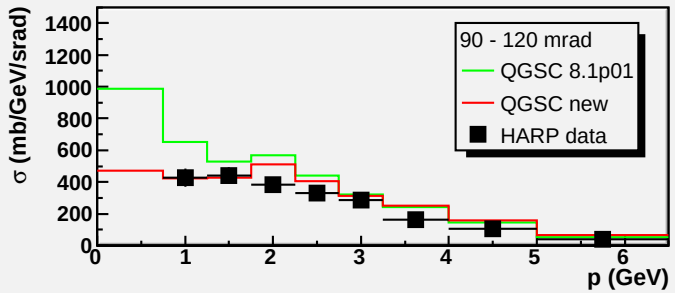
Prototype of Updated LHEP parameterization

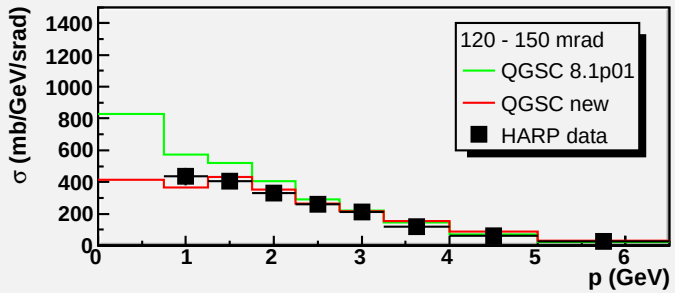
- Other packages (MARS, FLUKA, MCNPX) report about successful comparisons against HARP data
- Optimization of LHEP pion spectra was done on base HARP data for p + Al at 12.9 GeV/c
- The saturation function have been introduced
- Very local change of the model – few lines of code
- QGSC Physics List was chosen for comparisons

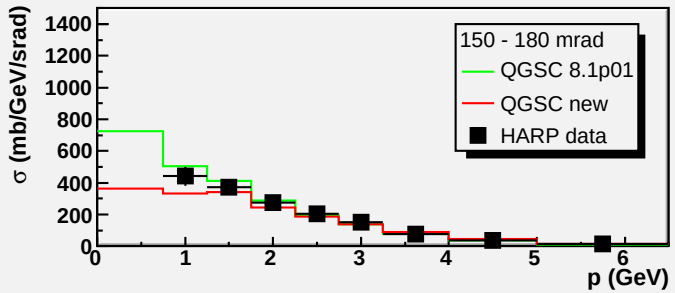
Double Differential Cross Section of π^+ Production by 12.9 GeV/c Protons in Al

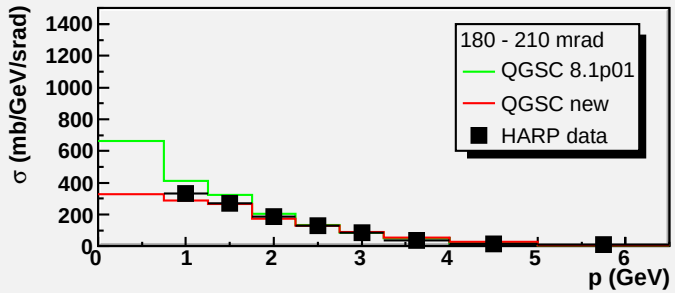




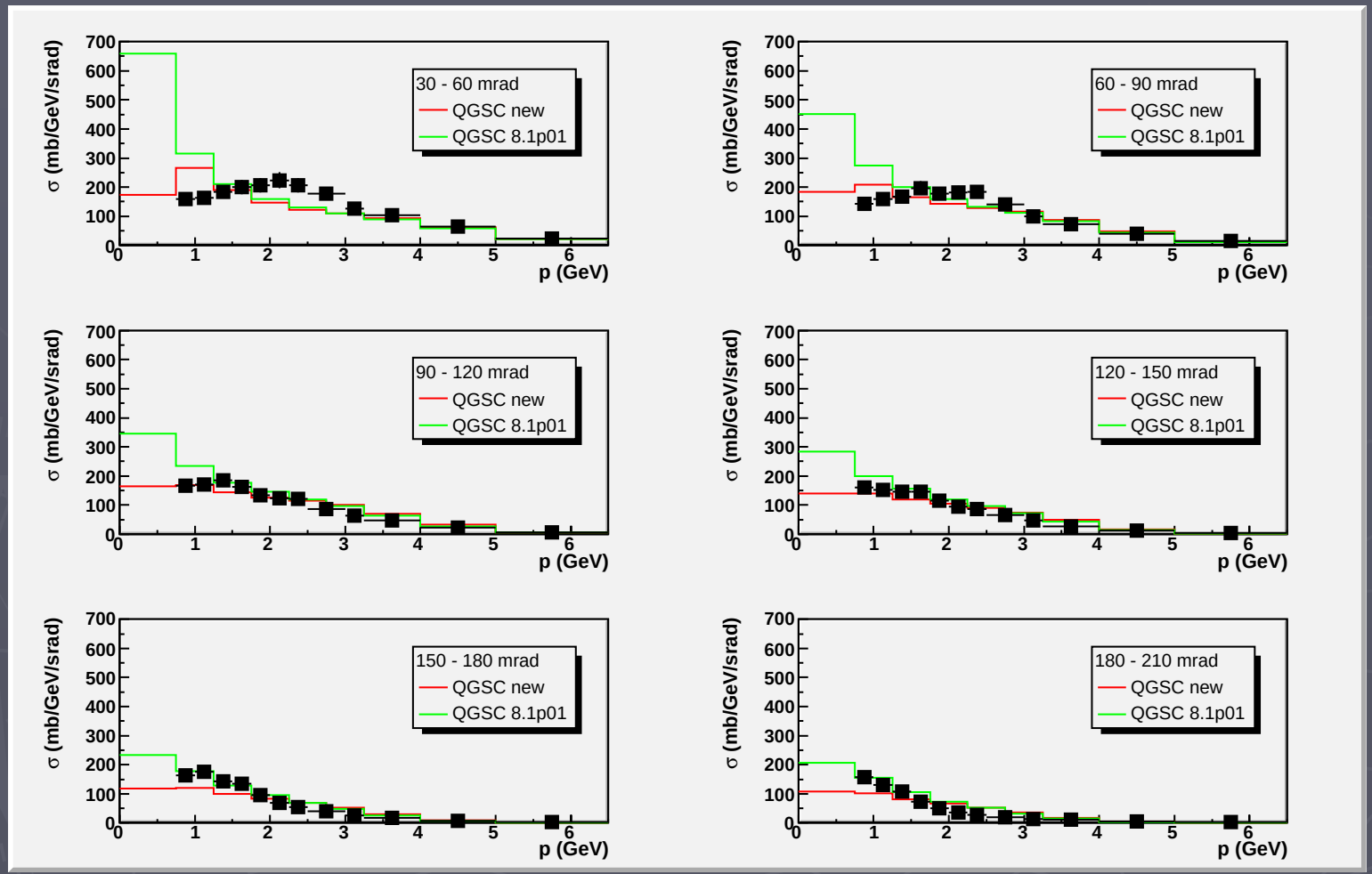








Double Differential Cross Section of π^+ Production by 8.9 GeV/c Protons in Be



Conclusions

- Five special tests for hadronic physics are available
- New test39 have been developed recently by M.Kosov
  - Continuation of test19, test29 series
- test30 and test35
  - Reorganization was done
  - Data sets are extended
  - Running easily at LXBATCH
  - Results are stored at afs
- Tests should be executed before the release
- There are number of concerns to all Geant4 models needs to be addressed
- Testing suite far not cover all aspects of hadronic physics