

# The Geant4 hadronic verification suite for the cascade energy range

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# Outline

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- Introduction
- Motivation
- User interface
- Some results
- Conclusions



# Introduction

- Geant4 toolkit includes a collection of models and packages for hadronic physics
- Abstract interface to physics called a ***process*** is associated with ***particles***
- Allows independent, alternative physics models
- Final state generation is independent of tracking and the access and use of cross sections



# Motivation

- Cascade energy region from reaction threshold to about 5 GeV is problematic for all existing MC packages
- Phenomenology in this region is rich and non-trivial
- This physics affects simulation results at low, medium, and high energies
- Several Geant4 models are available for the cascade energy region
- **Detailed verification of G4 models was required**

# Verification suite for the cascade energy region

- Testing suite created for verification and further development of hadron cascade codes
- Generators of hadronic secondaries are tested against data
  - focussed on  $d^2\sigma/dEd\Omega$ ,  $d\sigma/d\Omega$ ,  $d\sigma/dE$ ,  $Ed^3\sigma/d^3p$
  - for  $p$ ,  $n$ ,  $\pi^+$ ,  $\pi^-$ , and  $A$  secondaries
- Angular asymmetry and energy-momentum balance are also examined
- 50 cases (incident particle, energy, material) tested so far

# Method

- Get nuclear data from EXFOR and SPIRES DB
- Use abstract interface for hadronic generators
- Models currently being verified:
  - Precompound
  - LE parameterized
  - Binary cascade
  - Bertini cascade
- Use scripts + macro input to control test runs
- Generate histograms using AIDA interface and HBOOK
- Paw analysis, eps output, and Latex report



# Program steering

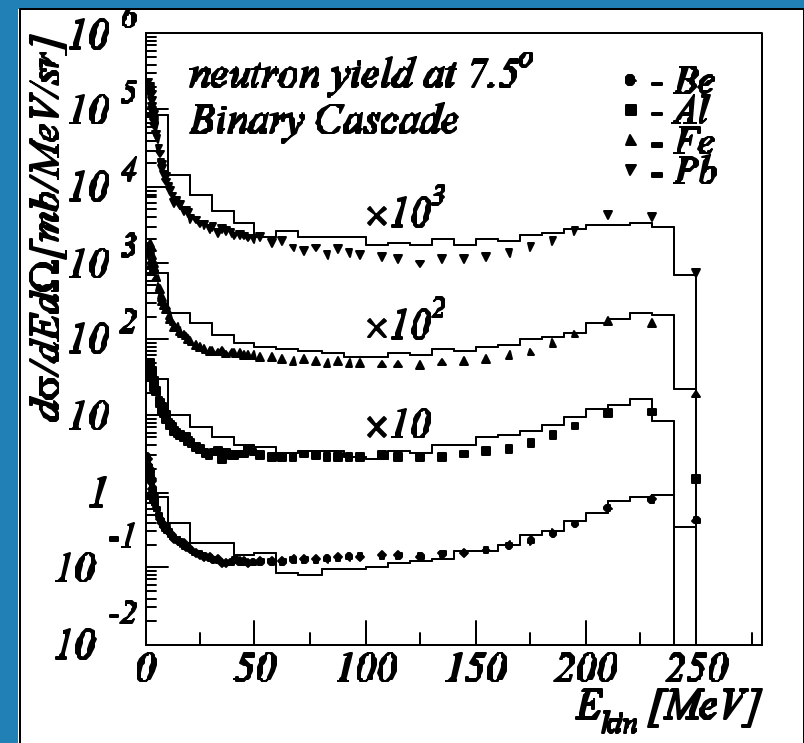
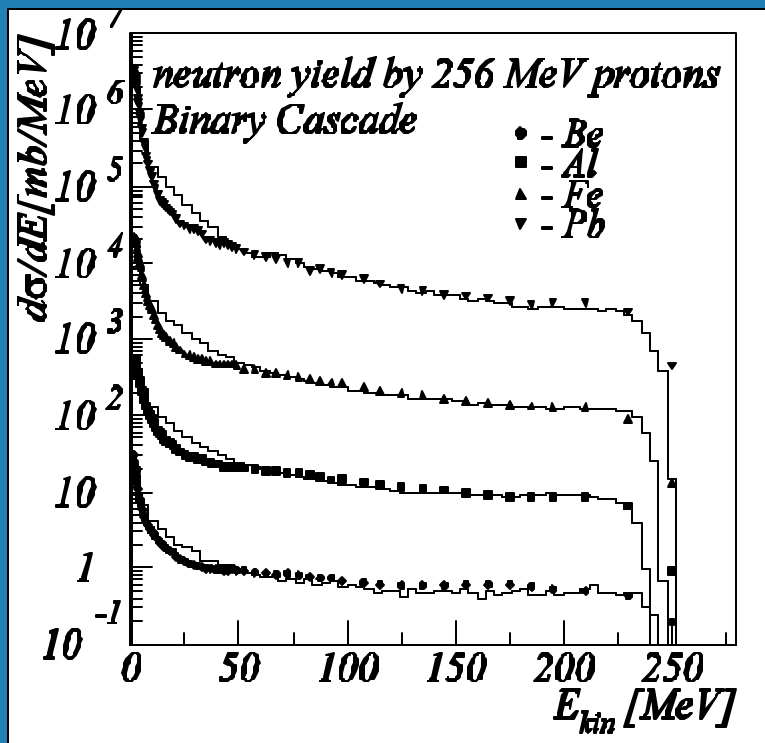
- Steering via macro files and scripts
- Parameters to be specified:
  - Incident particle, its energy
  - Material
  - Hadronic generator
  - Histogram types
  - Bins number , lin, log

# Neutron production by incident protons

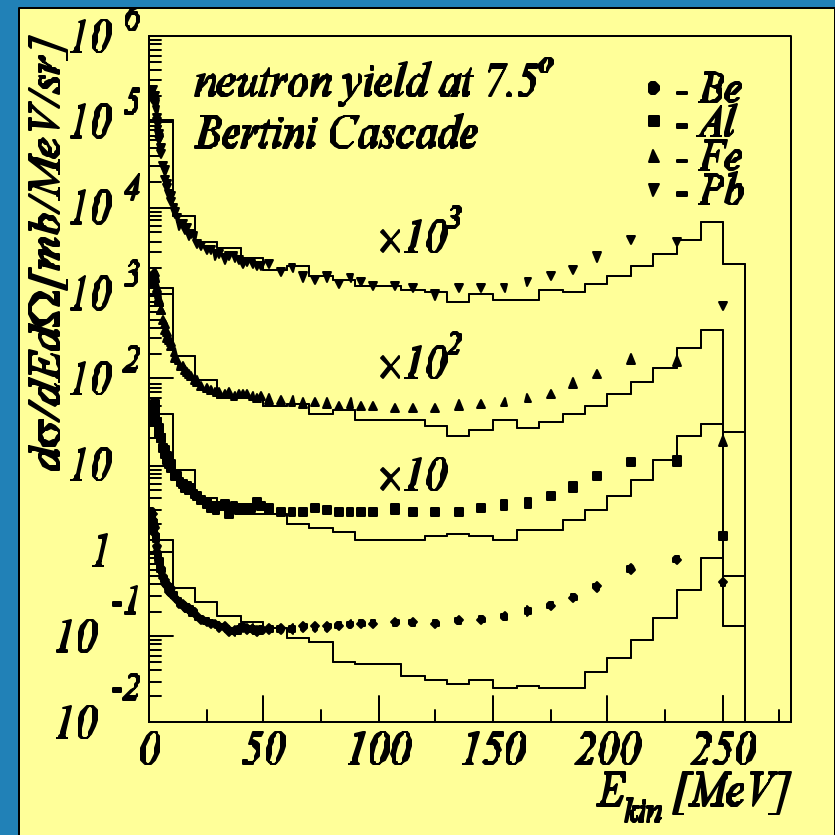
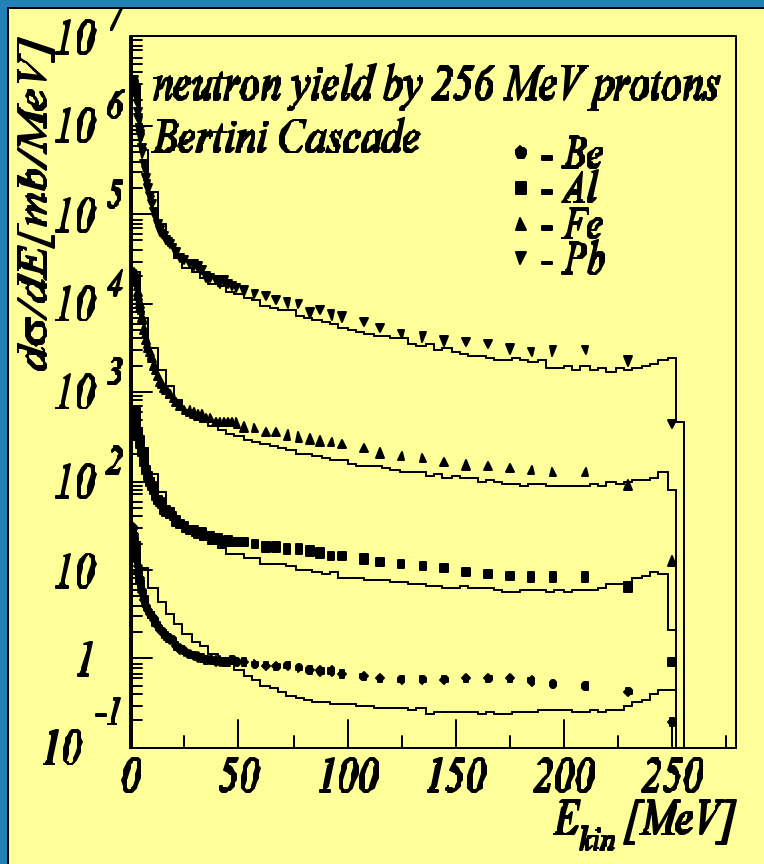
Target nucleus	Beam energy (MeV)
Be	113, 256, 585, 800
C	113, 590, 590
Al	22, 39, 90, 113, 160, 256, 585, 800
Fe	22, 65, 113, 256, 597, 800
Ni	585
Zr	22, 35, 50, 90, 120, 160, 256, 800
Pb	35, 65, 113, 120, 160, 256, 597, 800



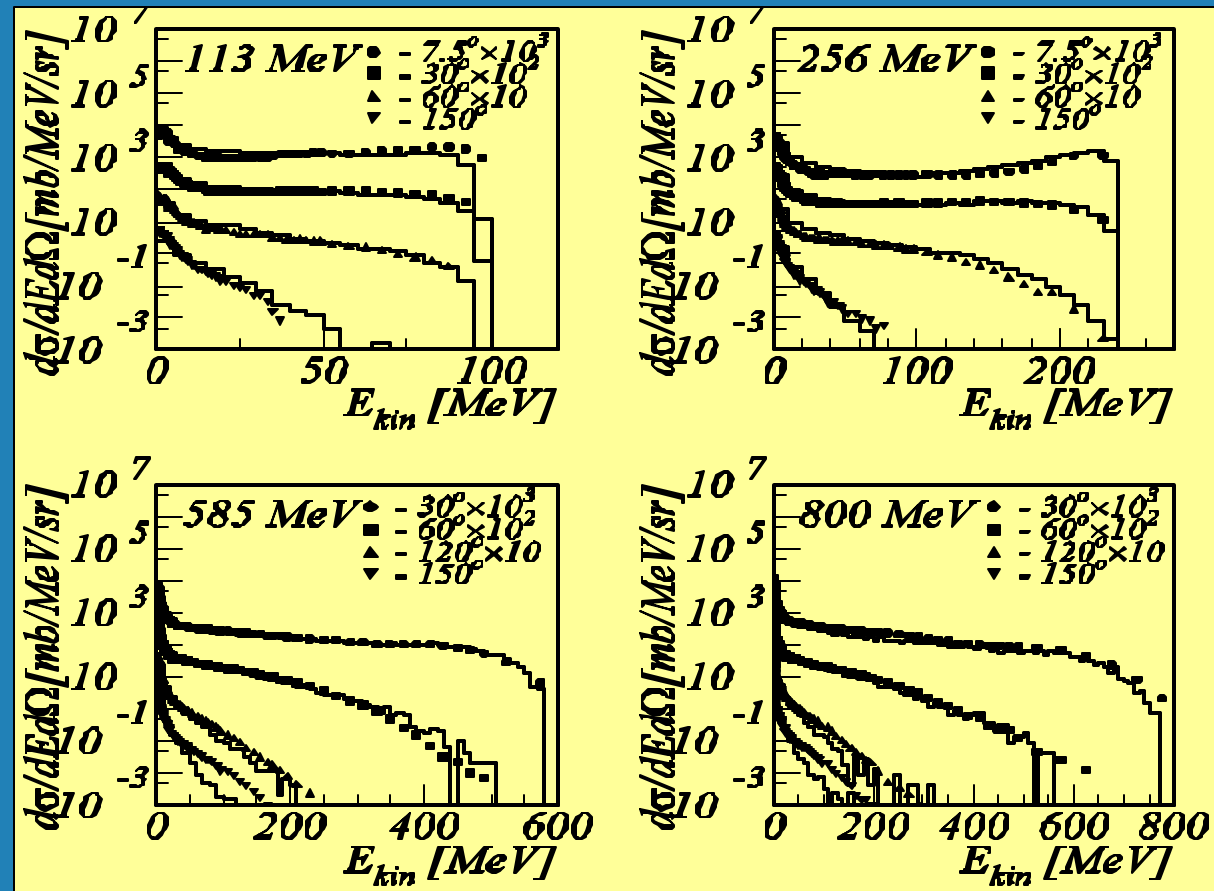
# Binary cascade verification



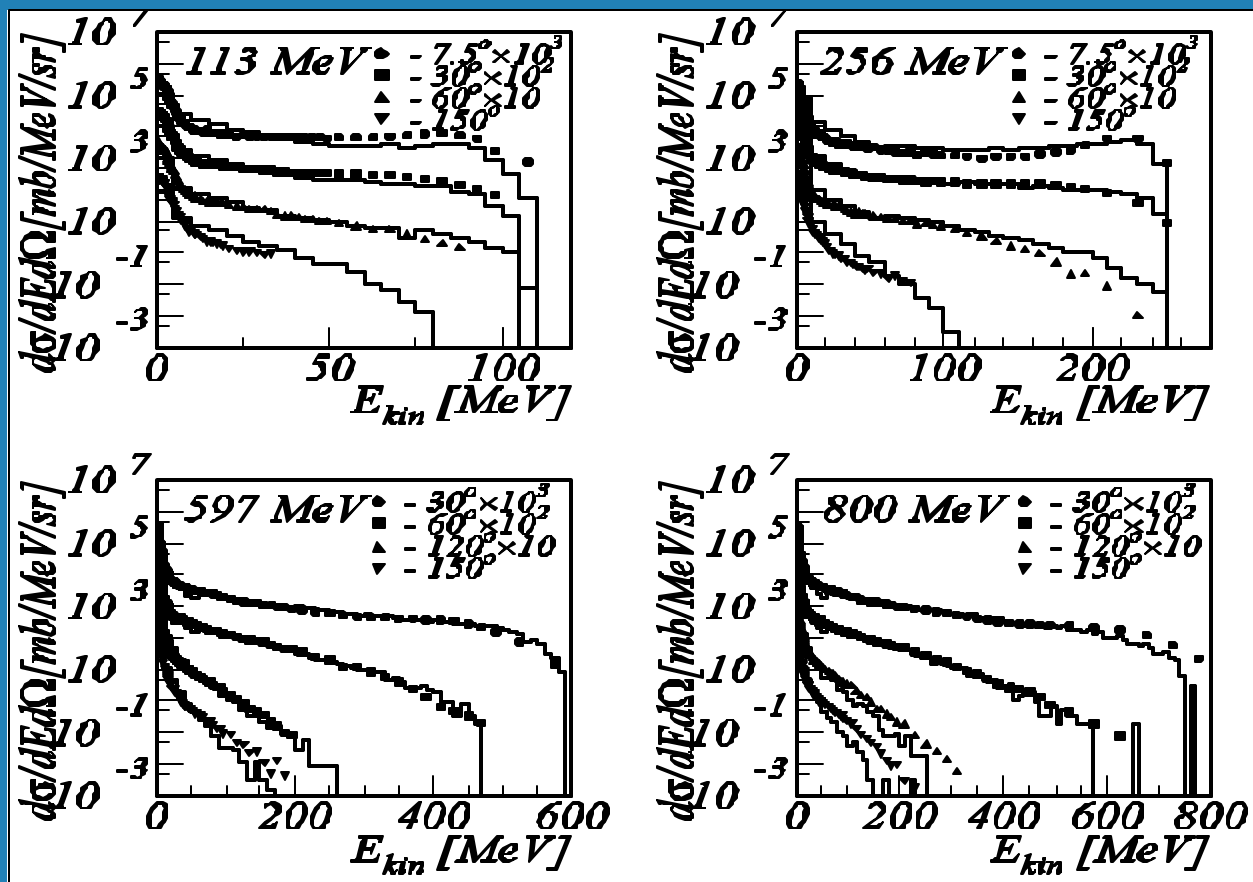
# Bertini Cascade verification



# Binary cascade verification: neutron spectra induced by protons on aluminum



# Binary cascade verification: neutron spectra induced by protons on lead



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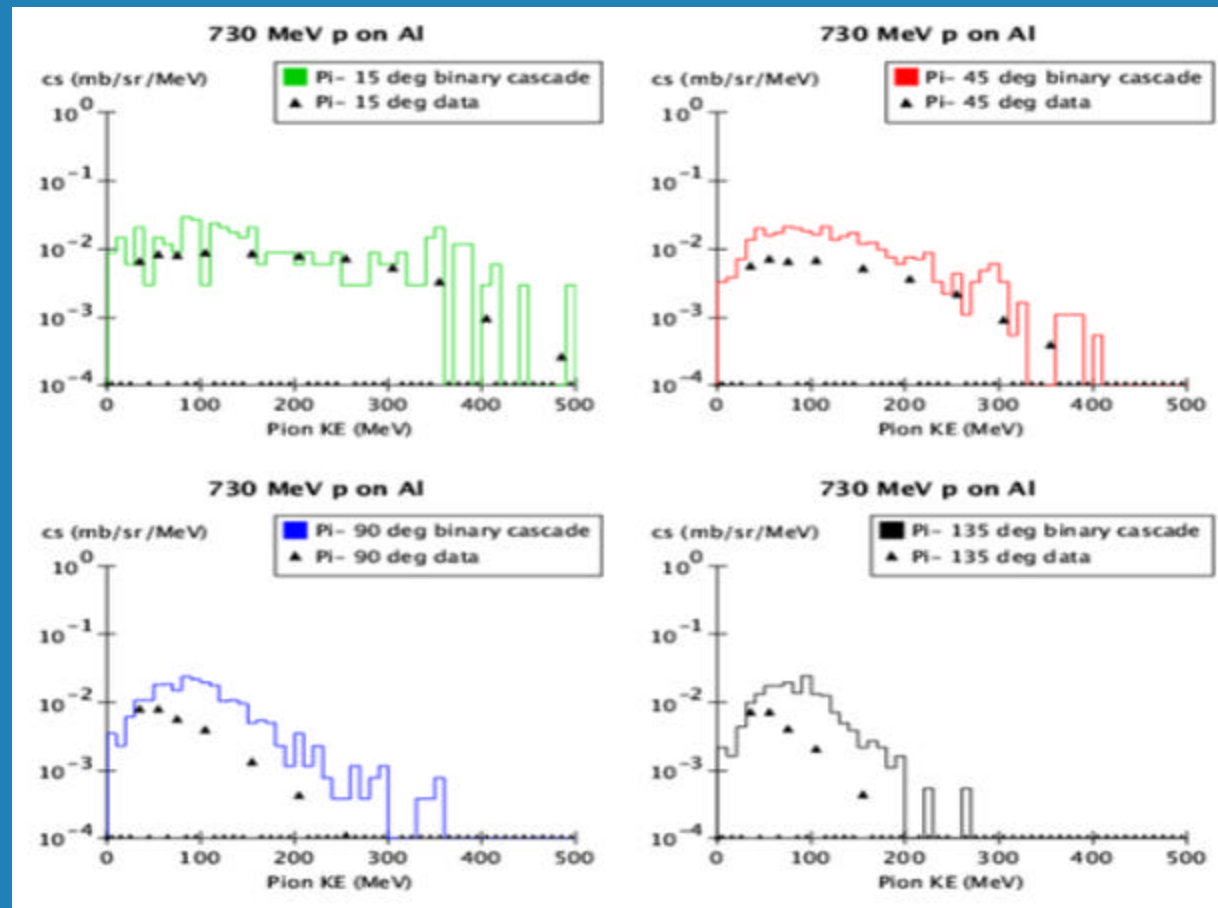
Test suite

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# Pion production by incident protons

Target nucleus	Beam energy (MeV)
H	585
D	585
Be	585
C	590
Al	585, 730, 1000
Cu	730
Ni	200, 585
Pb	585, 730

# Binary cascade verification: pi-production by 730 MeV protons on Aluminum

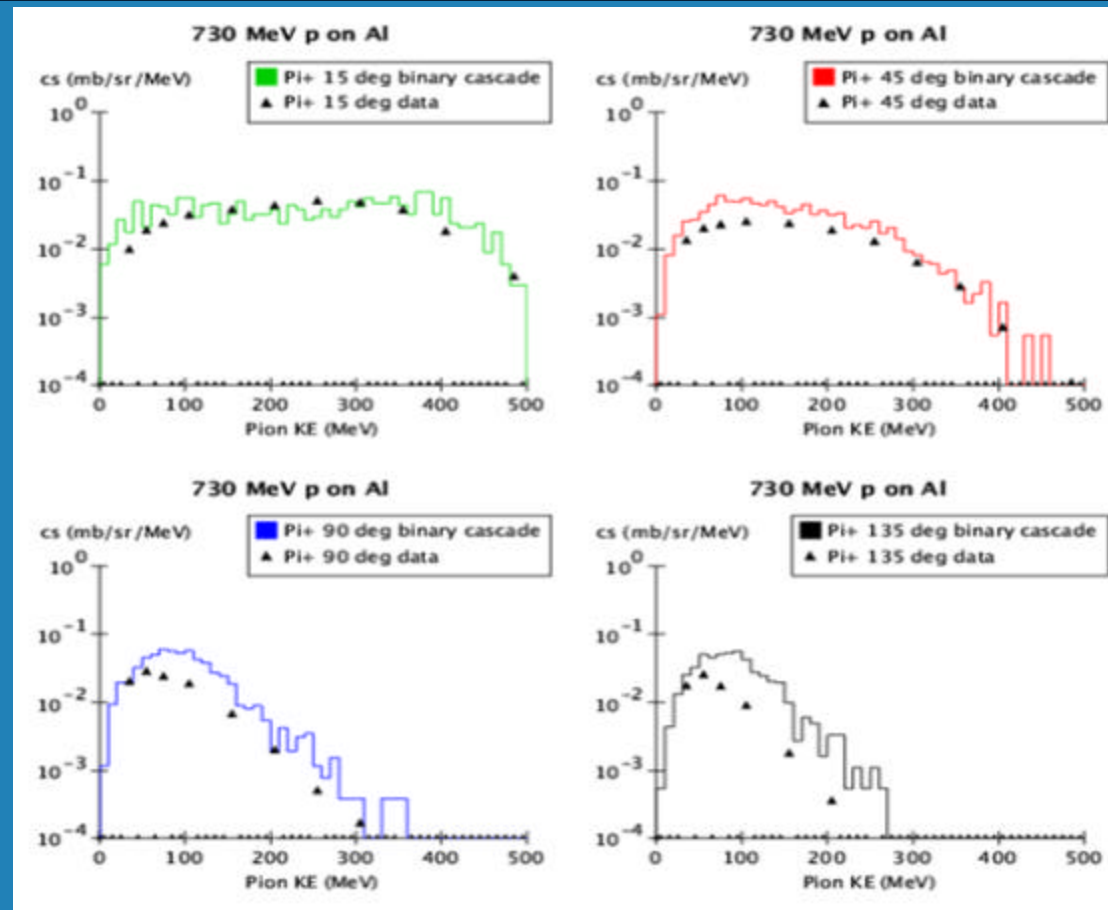


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Test suite

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# Binary cascade verification: pi+ production by 730 MeV protons on aluminum

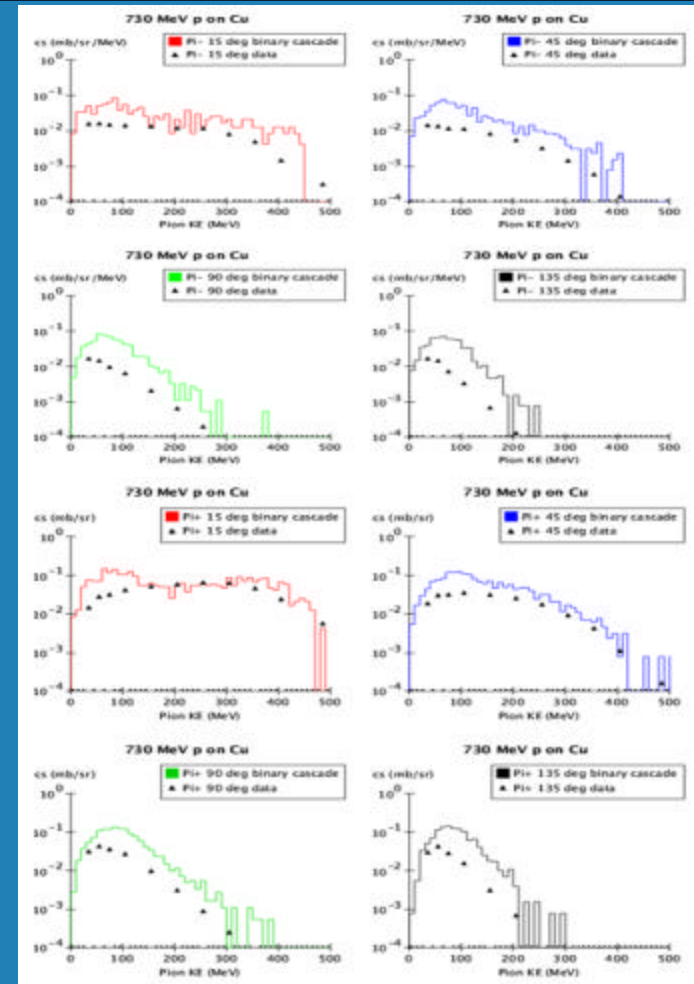
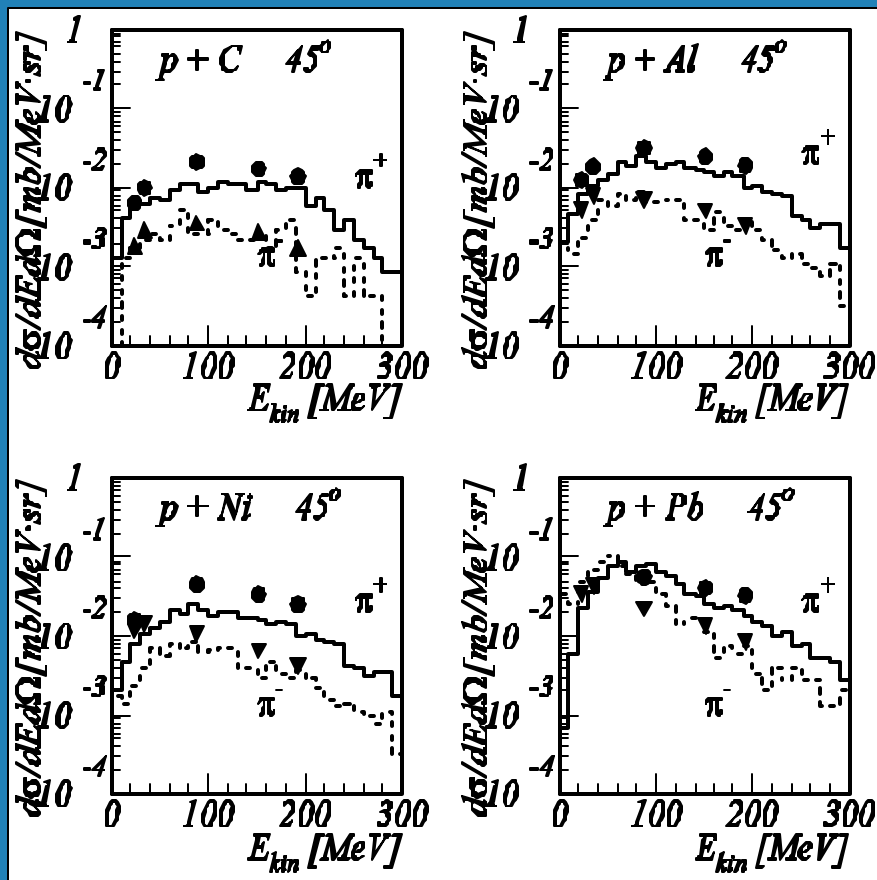


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Test suite

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# Binary cascade verification: pion production by protons

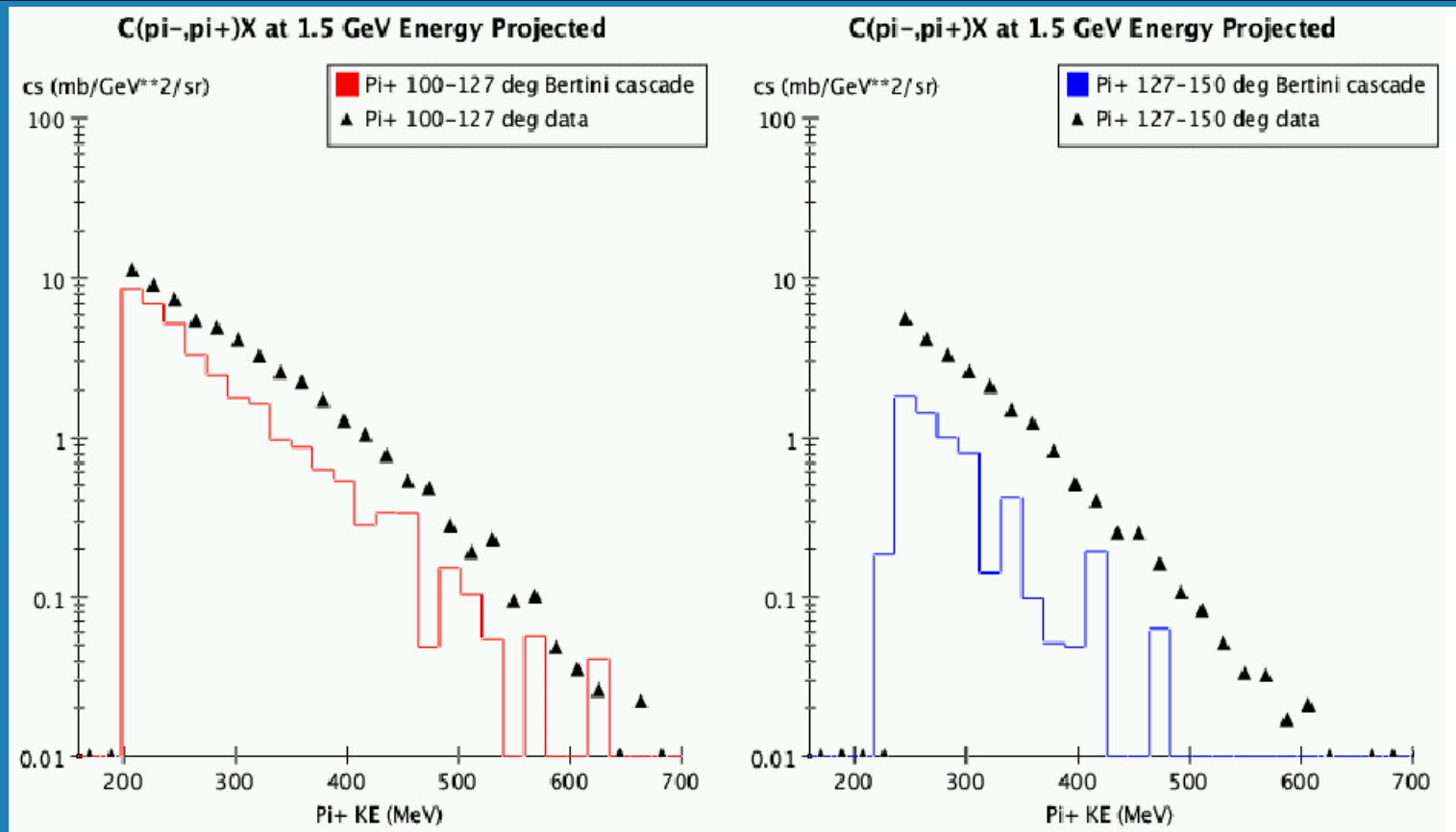


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Test suite



# Pion production by 1.5 GeV pi- on carbon with Bertini Cascade





# Plans

- provide a complete set of tests for incident protons in the energy range 0-15 GeV
- provide a set of tests for incident pions
- provide a set of tests for incident neutrons



# Conclusions

- A verification suite for the cascade energy region has been created
- Verification is done by comparing against experimental thin target data
- Verification suite was used extensively in developing the release of the Binary and Bertini Cascade packages in Geant4
- Work on extending and improving the suite is in progress

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Test suite

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