

Hadron Verification Suite for the Cascade Energy Region

10 July 2005

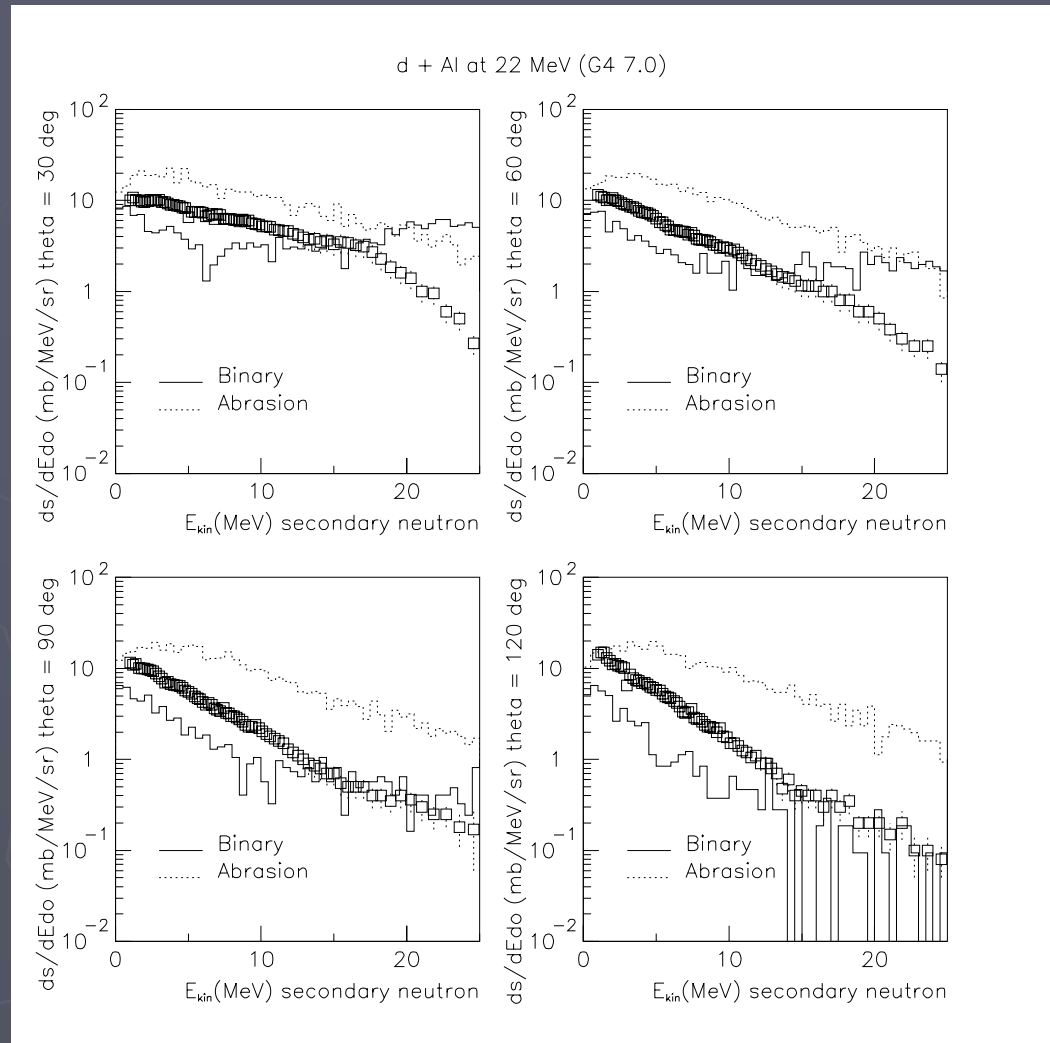
V. N. Ivanchenko

Verification of hadron-nucleus interactions

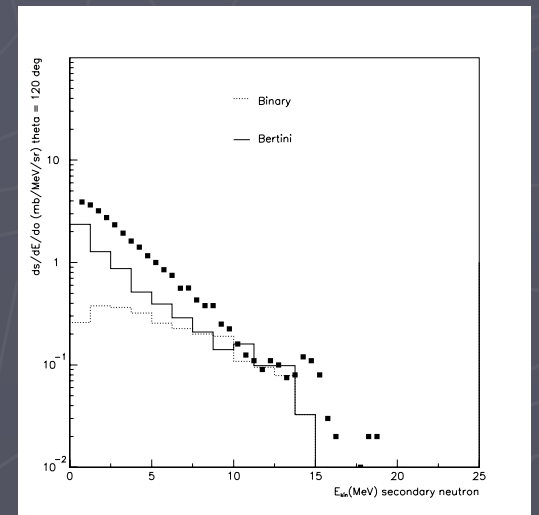
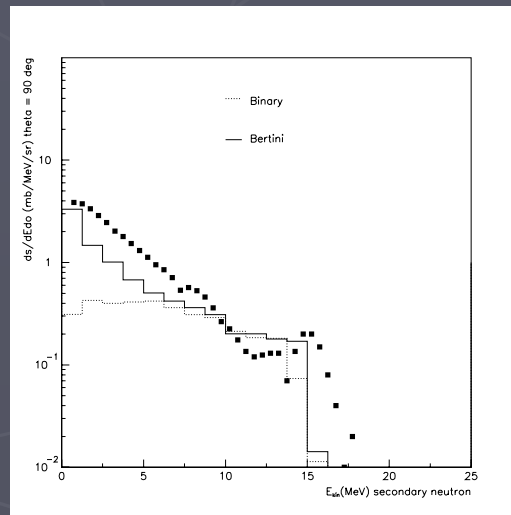
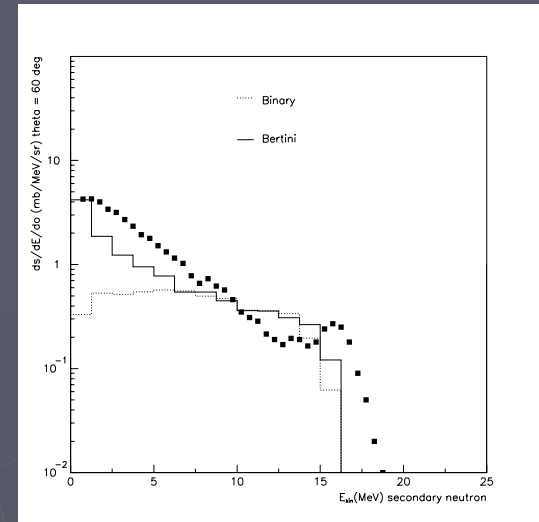
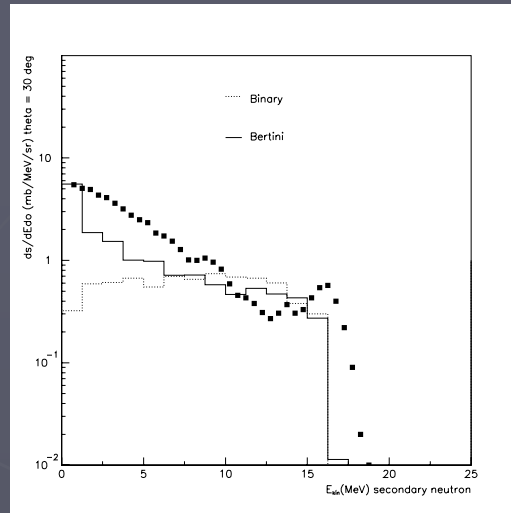
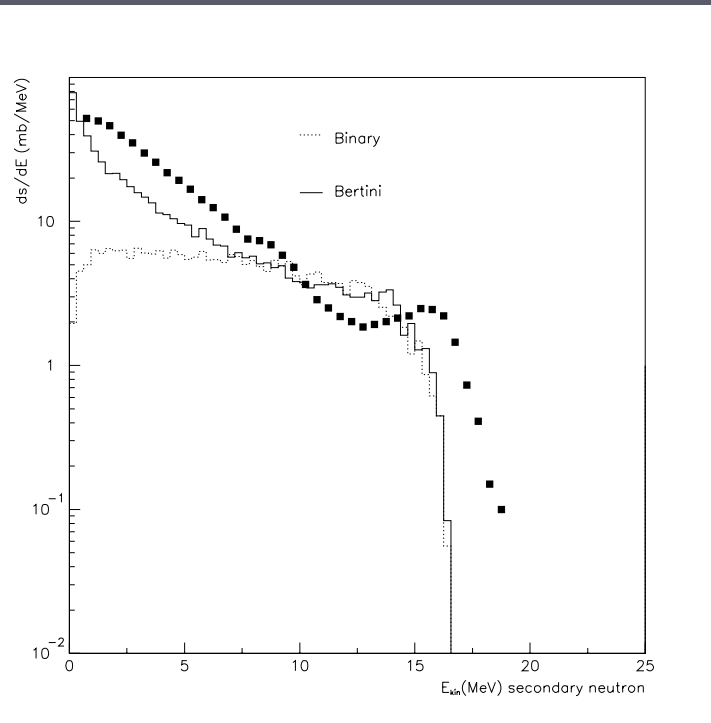
- ▶ Neutron production by p, d, α with $E < 1$ GeV
 - ▶ $P + A \rightarrow n + X$
 - ▶ $d + A \rightarrow n + X$
 - ▶ $\alpha + A \rightarrow n + X$
- ▶ 45 thin target experiments with reasonably small systematic
- ▶ Verification runs before the release
- ▶ Binary Cascade
- ▶ Binary Ion cascade
- ▶ Bertini Cascade
- ▶ Wilson-Abrasion model
- ▶ **Control on differential spectra**
- ▶ The number of problems have been fixed for the Geant4 release 7.0

Deuteron Fragmentation

- ▶ Data from EXFOR database
- ▶ Simulation – available G4 models

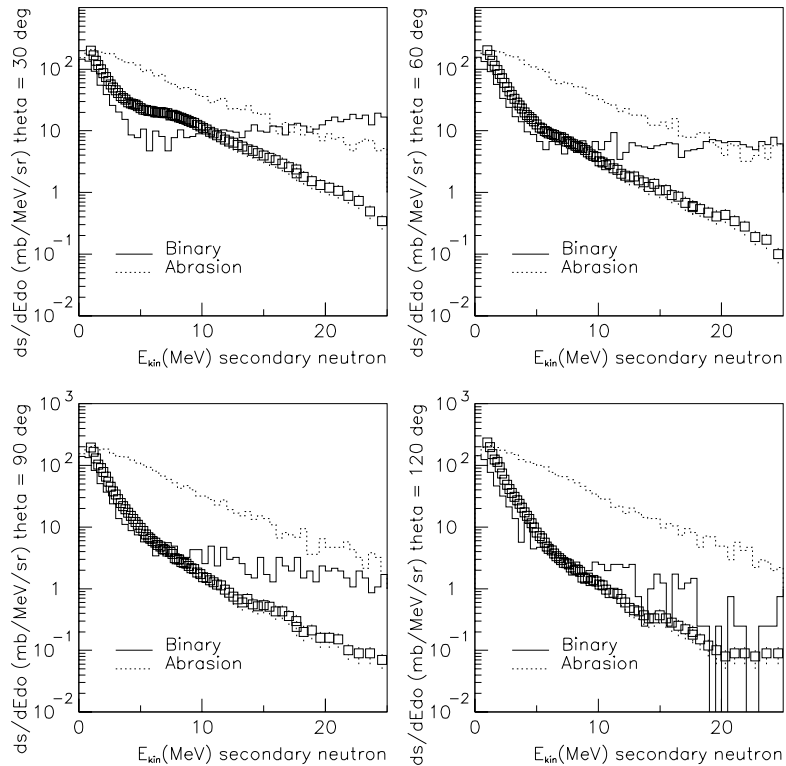


Protons 22 MeV in Aluminum G4 7.0

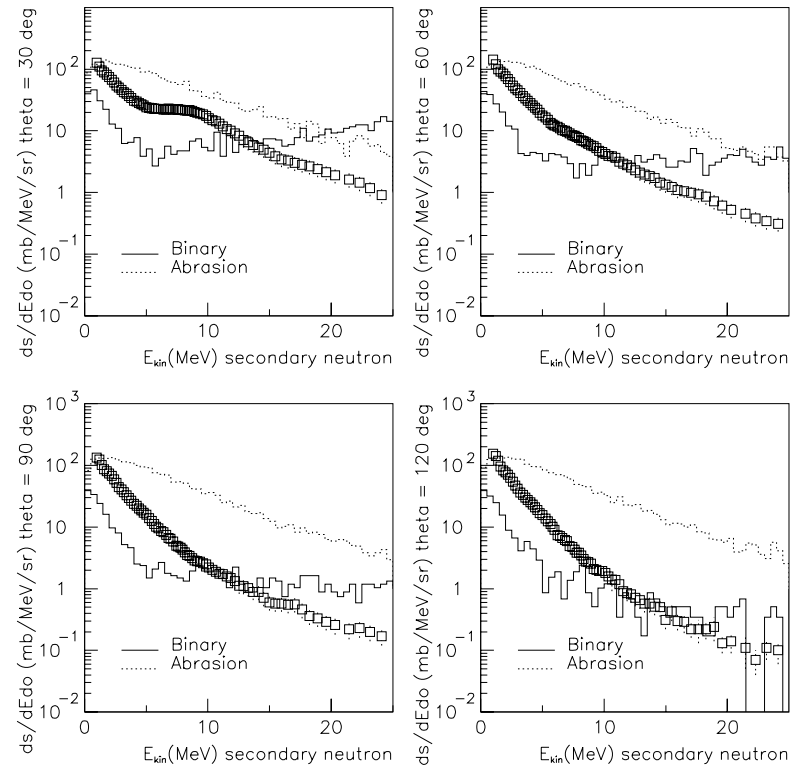


Deuterons 22 MeV: Binary Ion model and Wilson-Abrasion model G4 7.0

d + Ta at 22 MeV (G4 7.0)

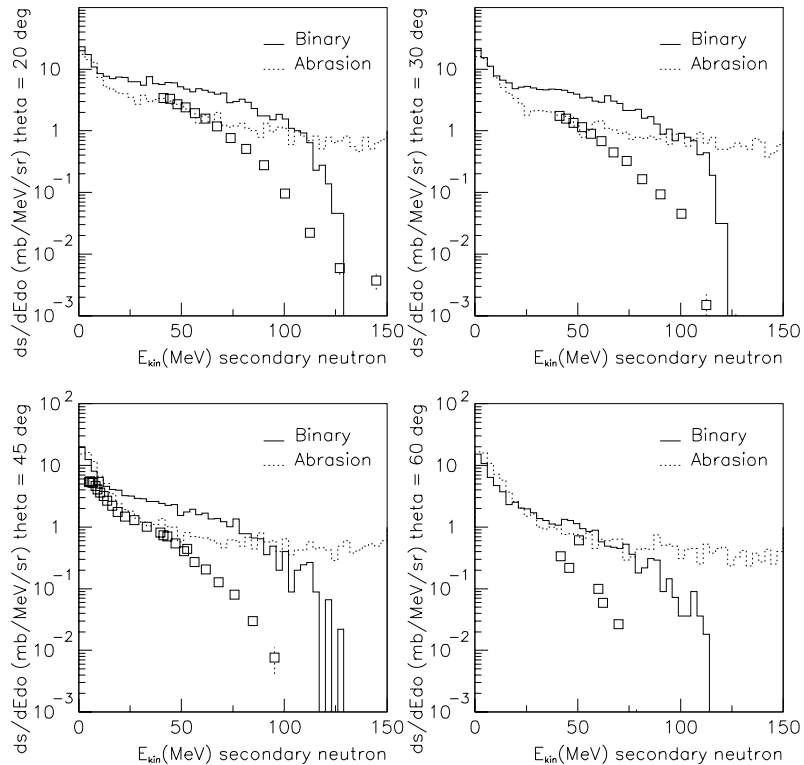


d + Zr at 22 MeV (G4 7.0)

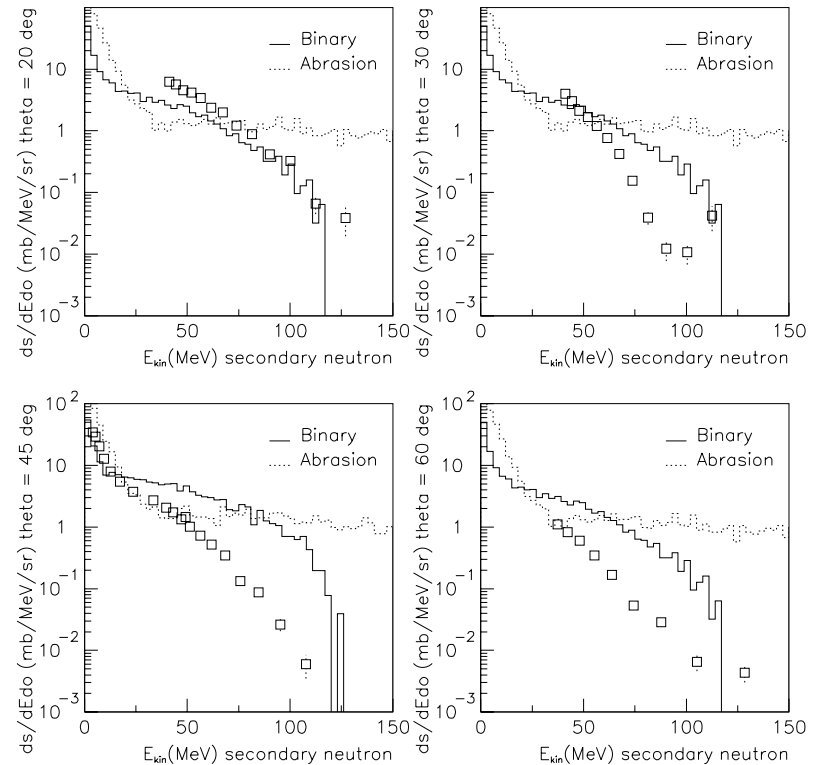


He ions of 140 MeV in Al and Zr G4 7.0

He4 + Al at 140 MeV (G4 7.0)

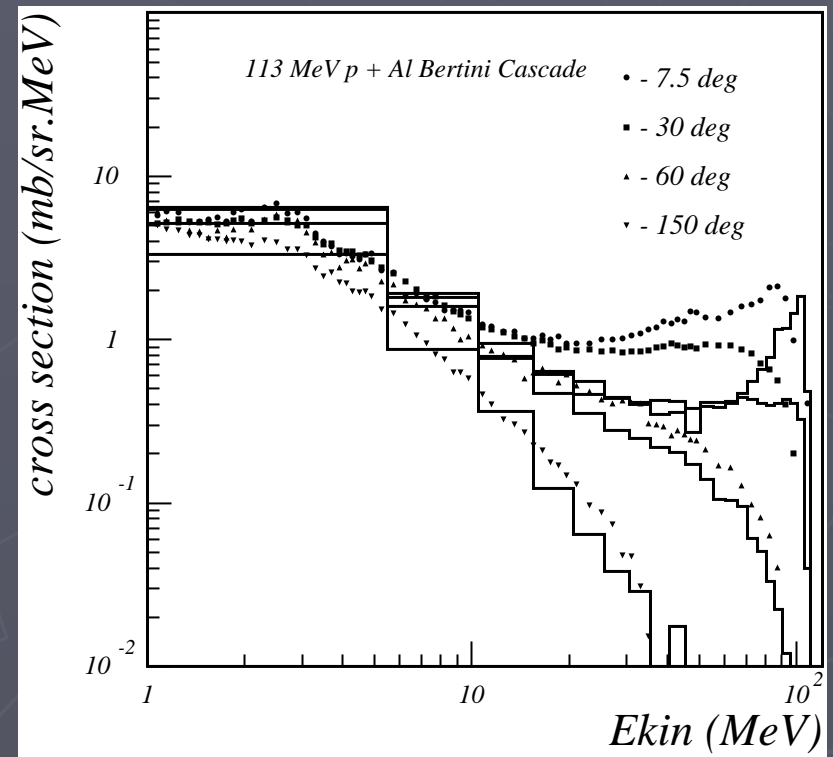
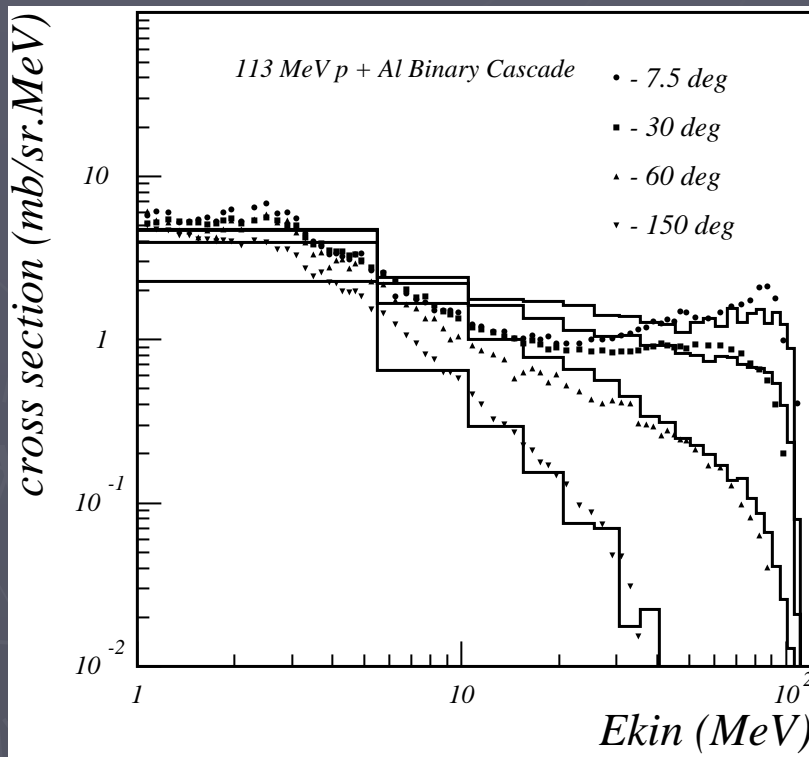


He4 + Zr at 140 MeV (G4 7.0)



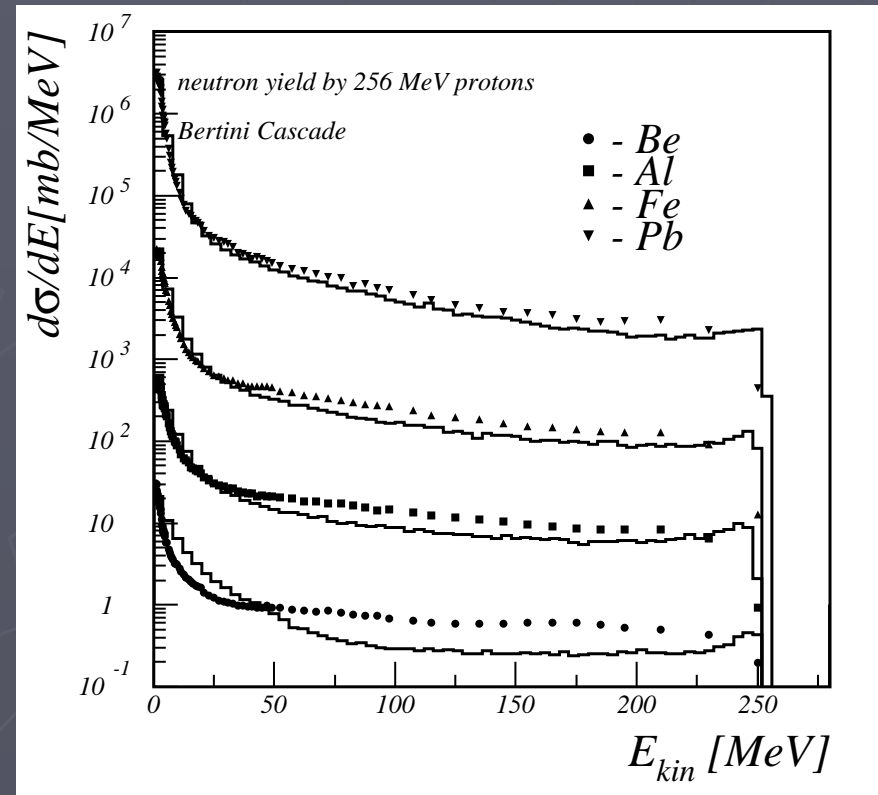
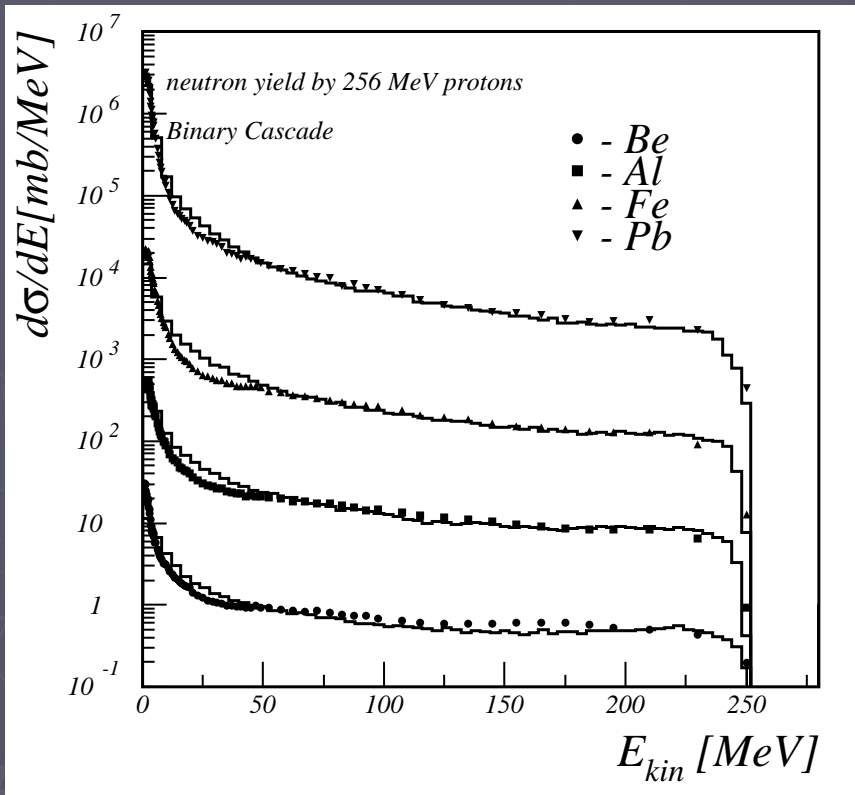
Neutron spectra by 113 MeV protons

Binary and Bertini Cascades G4 7.0



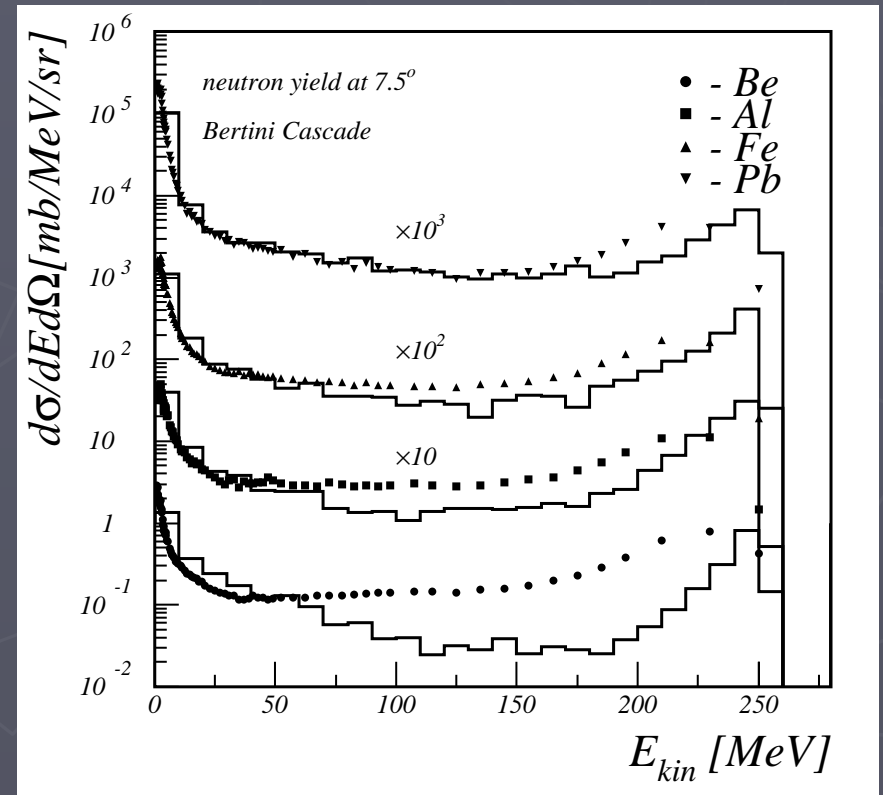
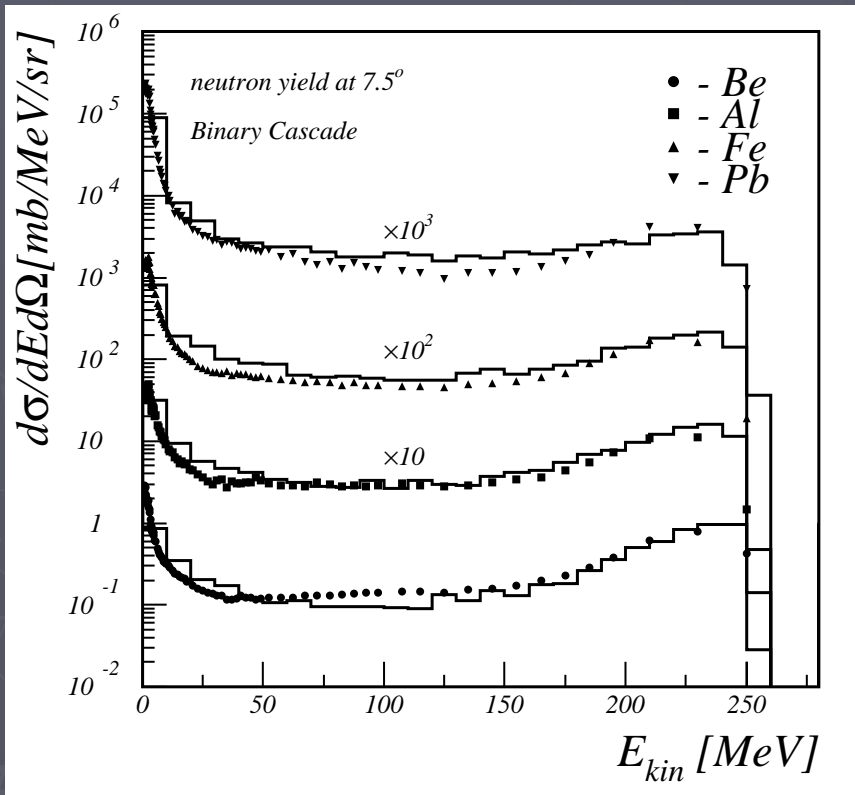
Neutron spectra by 256 MeV protons

Binary and Bertini Cascades G4 7.0

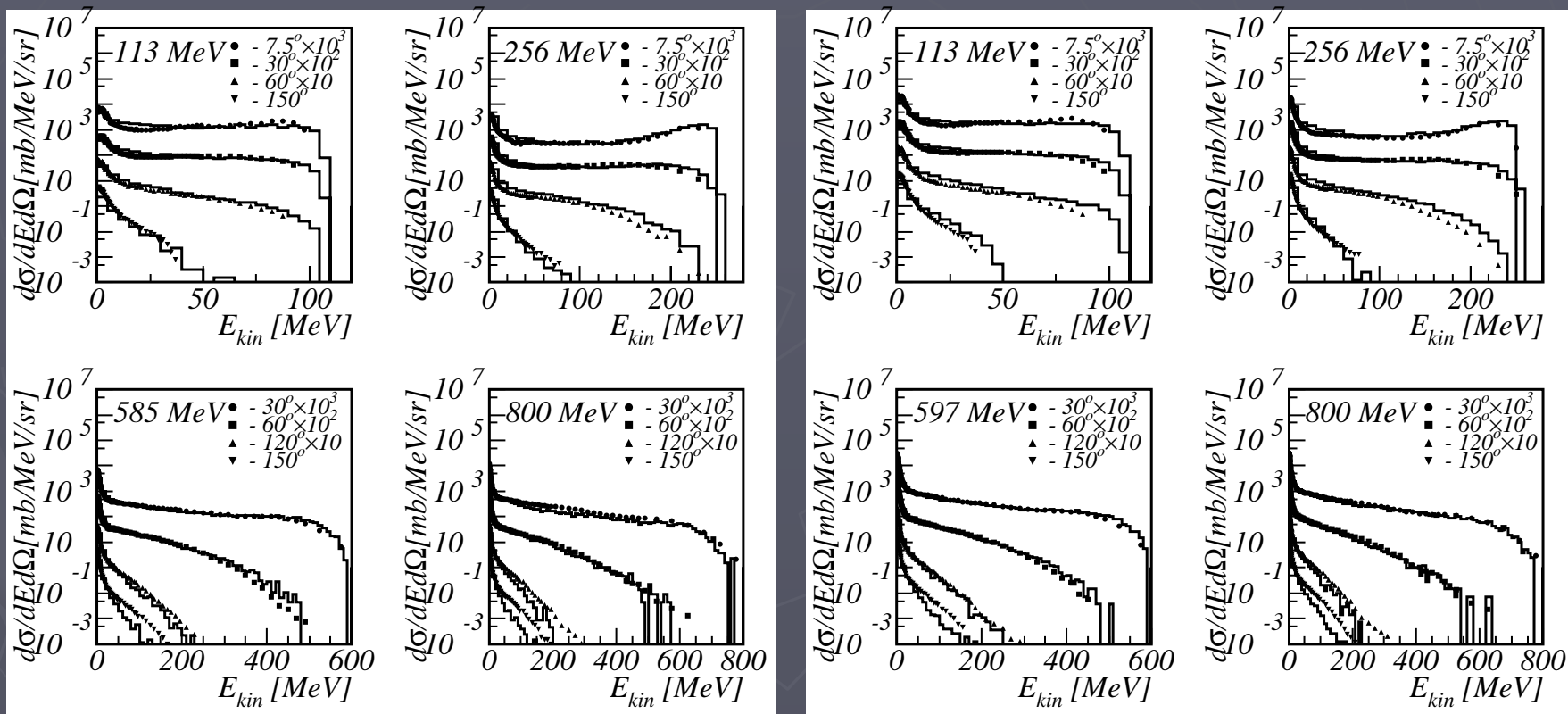


Neutron spectra by 256 MeV protons

Binary and Bertini Cascades G4 7.0



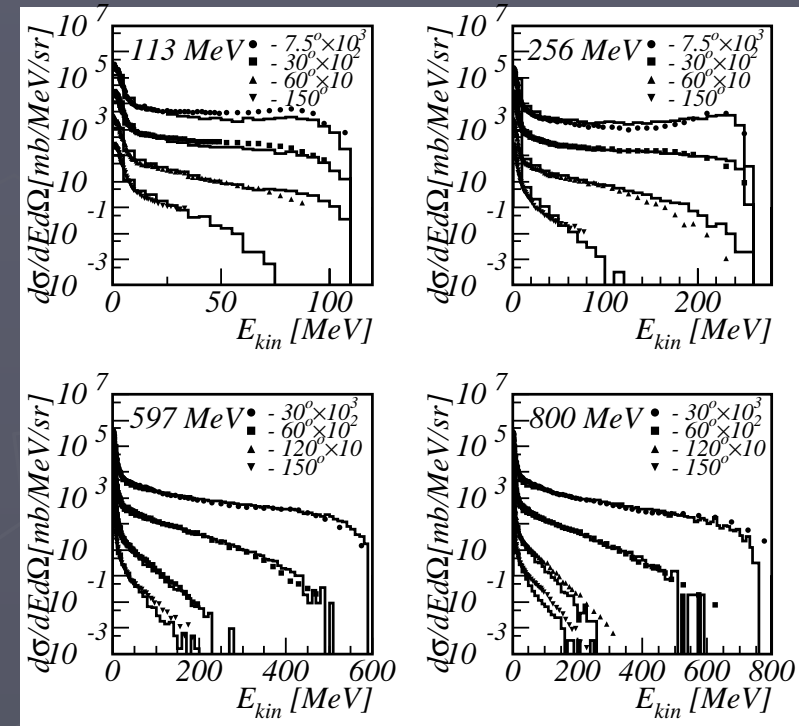
Neutron spectra by protons below 1 GeV in Al and Fe Binary Cascade G4 7.0



The status of G4 7.0 for the cascade energy range

- ▶ Binary Cascade is the most precise model for protons and light ions
- ▶ Bertini Cascade work well except for the light materials
- ▶ Wilson-Abrasion model is not good for light ions

Binary Cascade in Pb

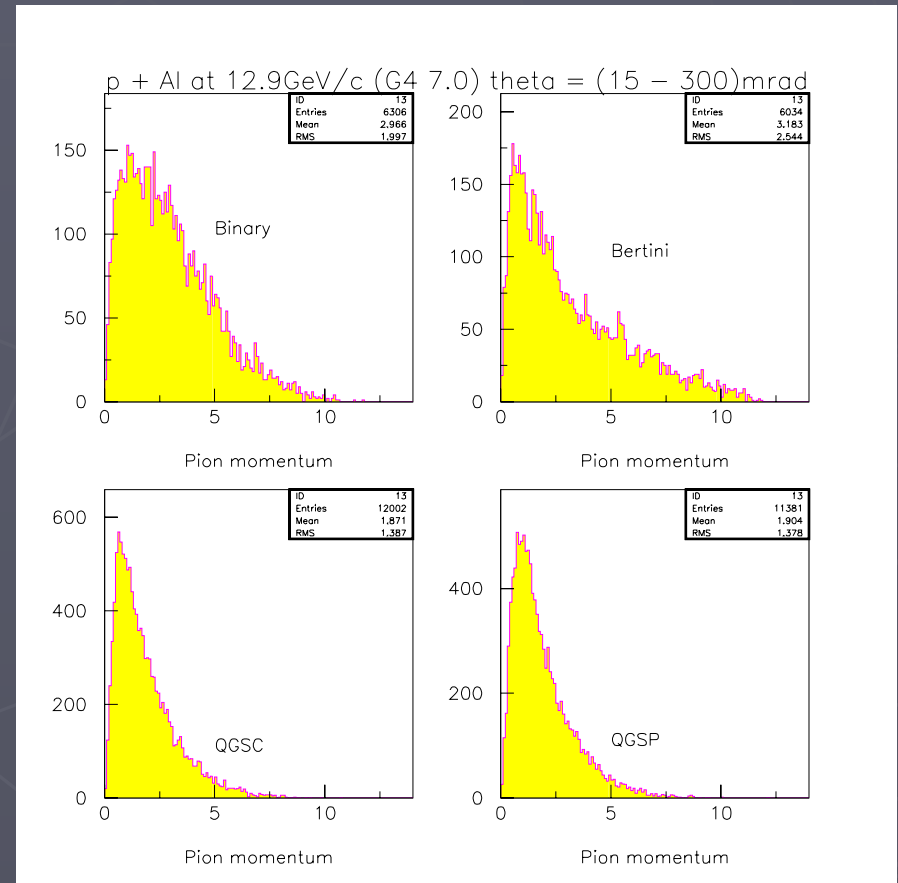
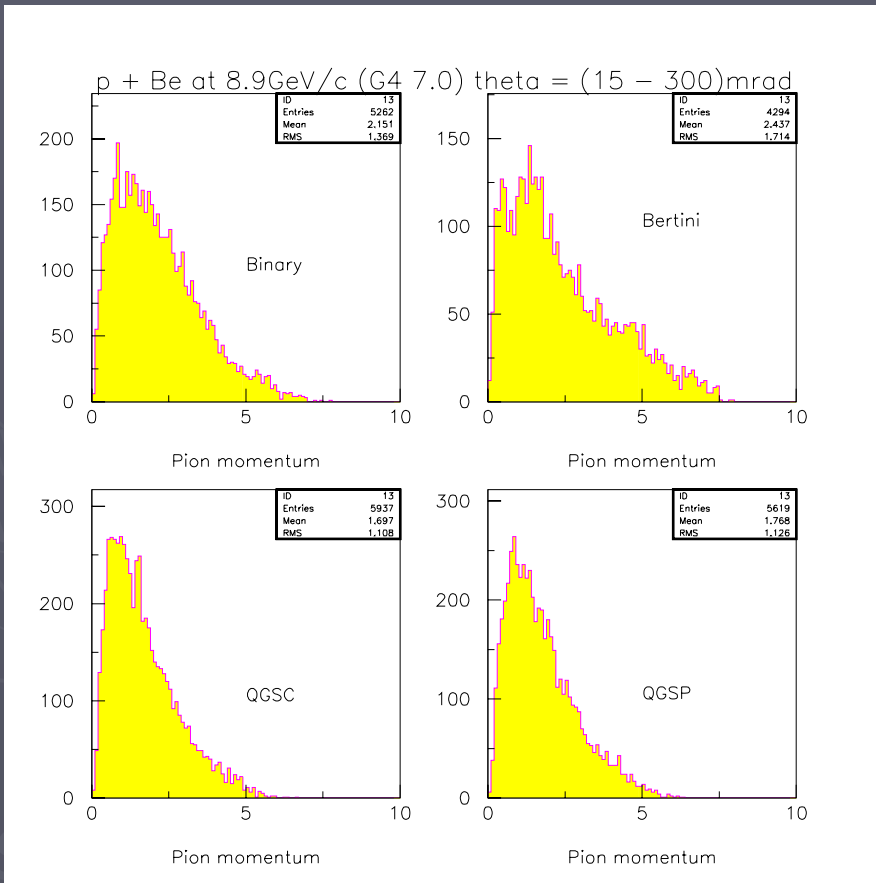


CPU	Be	Al	Fe	Pb
Binary	3.0	5.9	9.7	30.2
Bertini	1.4	1.7	2.4	5.7

HARP test

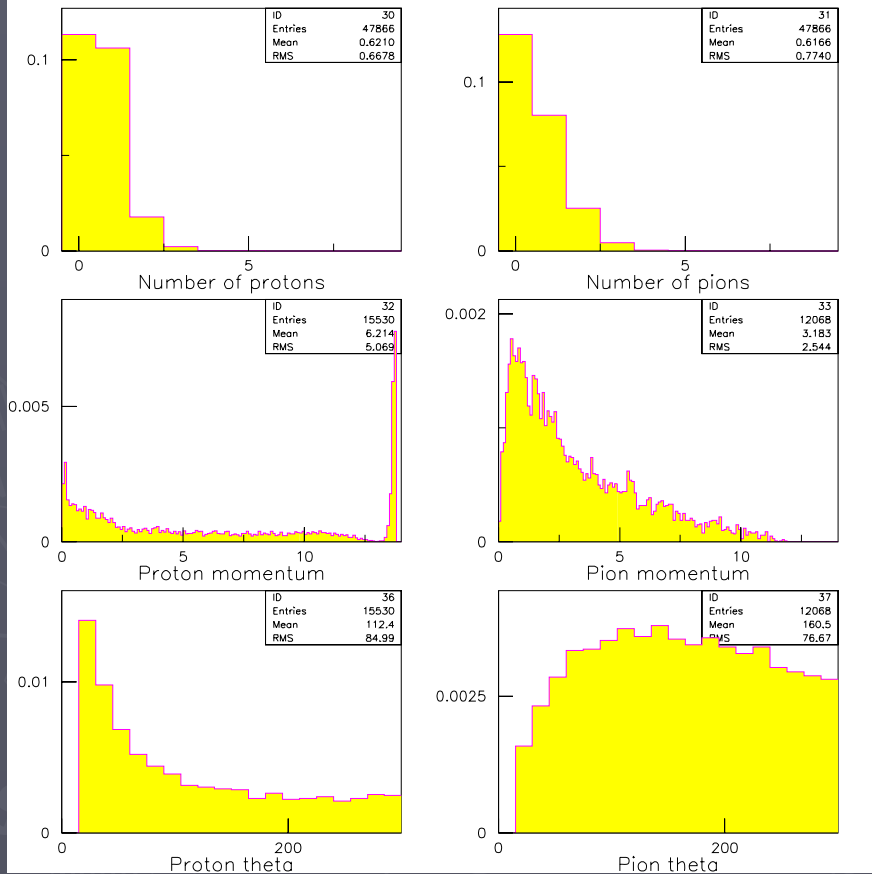
- ▶ Is created for further utilisation of HARP results for verification of G4 models
- ▶ There are no official comparison with the data yet
- ▶ First HARP publication will be submitted in July

Pion production by protons of 8.9 GeV/c and 12.9 GeV/c in Be and Al G4 7.0

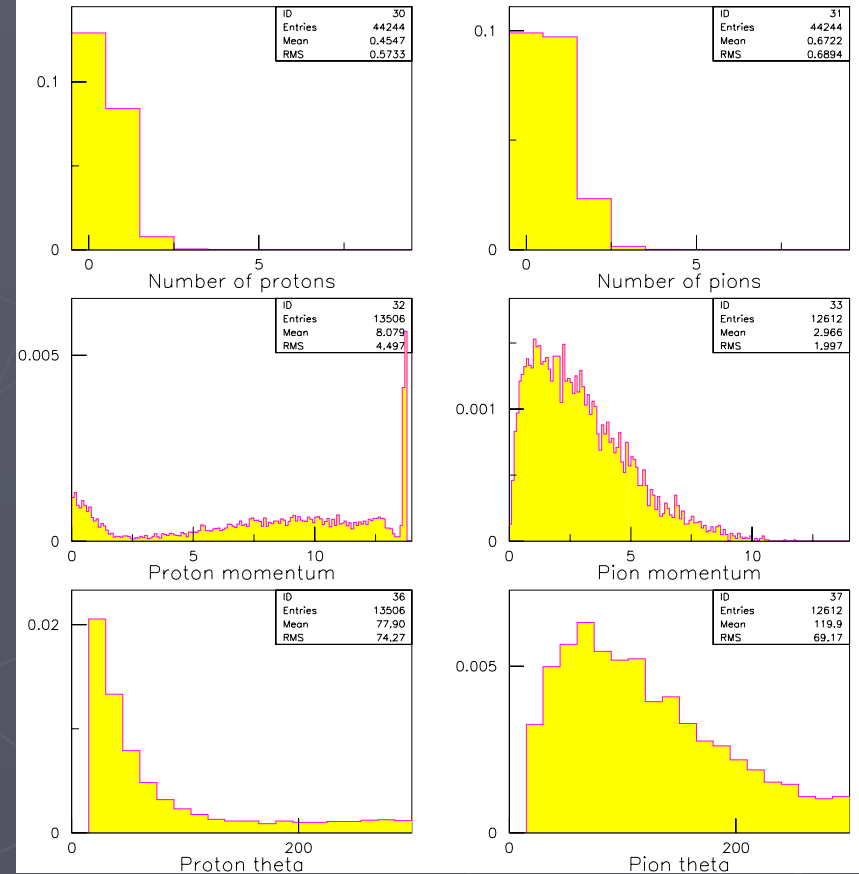


Binary and Bertini Cascades Pion and proton production by protons of 12.9GeV/c in Al G4 7.0

Bertini G4 7.0 theta = (15 - 300)mrad, p = (0.2-13.0)GeV

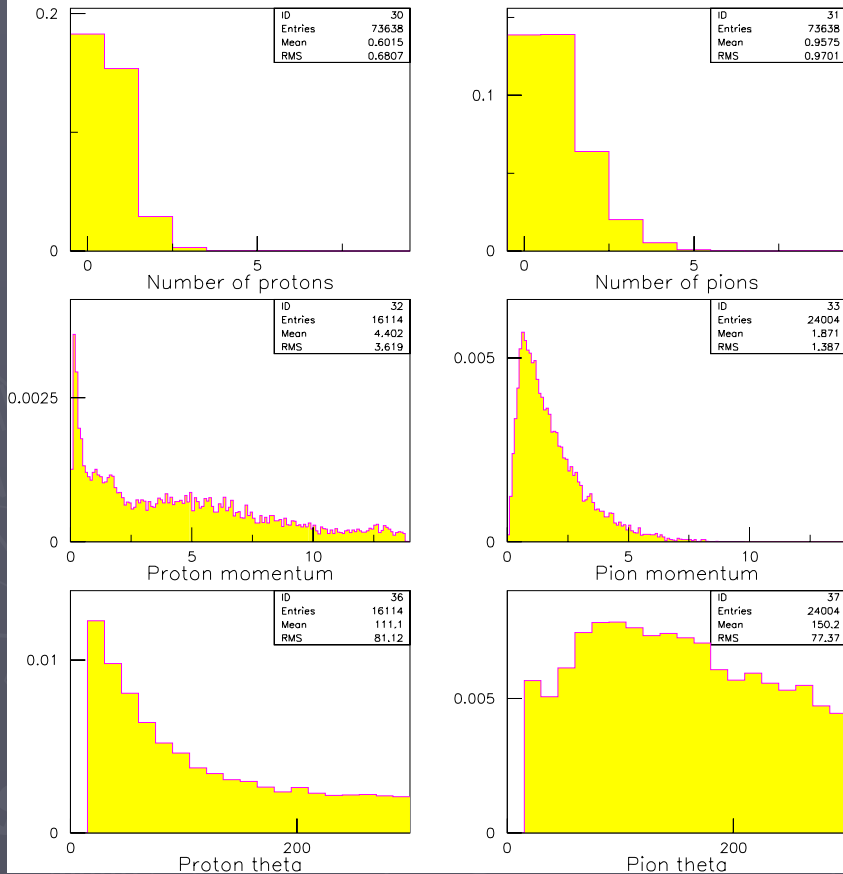


Binary G4 7.0 theta = (15 - 300)mrad, p = (0.2-13.0)GeV

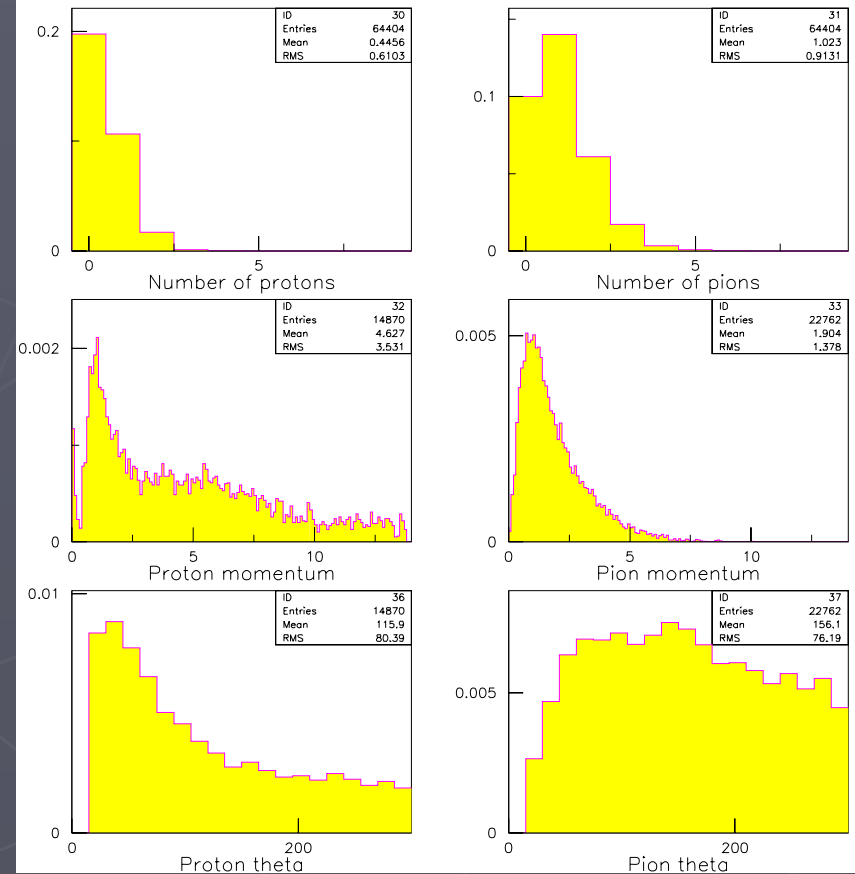


QGSP and QGSC Pion and proton production by protons of 12.9 GeV/c in AI G4 7.0

QGSC G4 7.0 theta = (15 - 300)mrad, p = (0.2 - 13.0)GeV

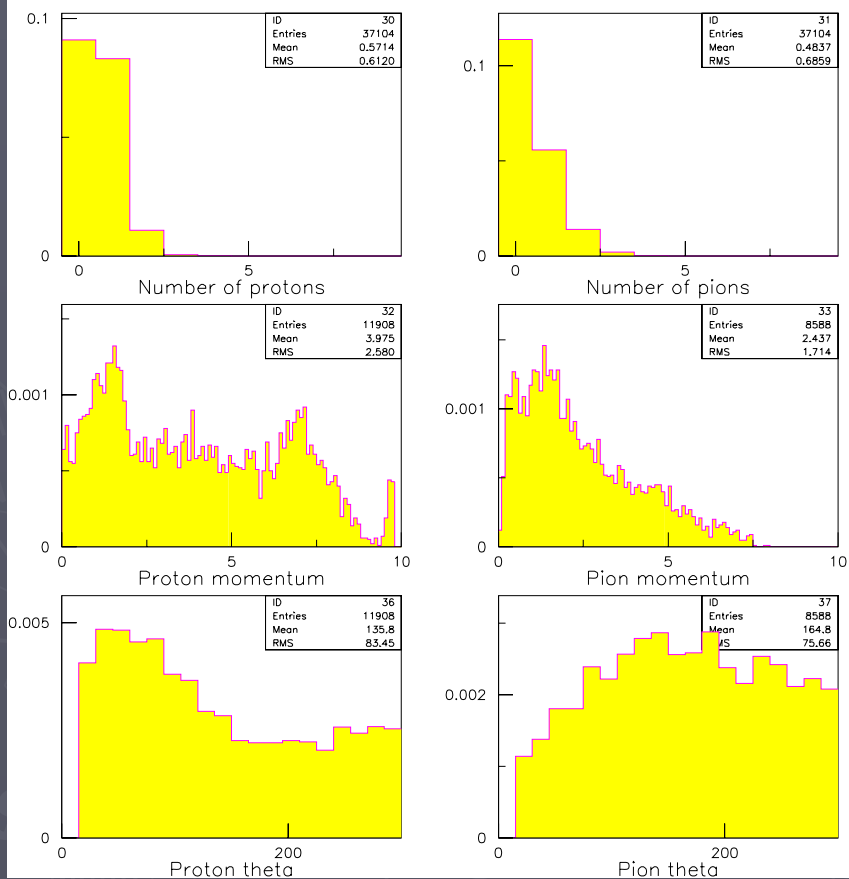


QGSP G4 7.0 theta = (15 - 300)mrad, p = (0.2 - 13.0)GeV

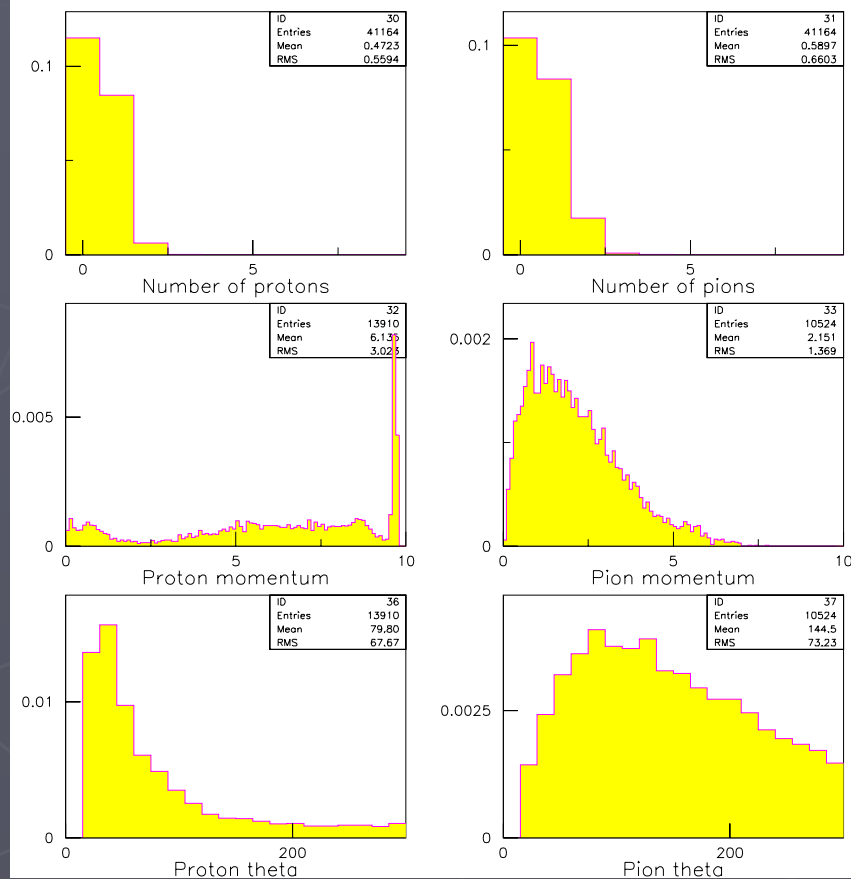


Binary and Bertini Cascades Pion and proton production by protons of 8.9GeV/c in Be G4 7.0

Bertini G4 7.0 theta = (15 - 300)mrad, p = (0.2-10.0)GeV



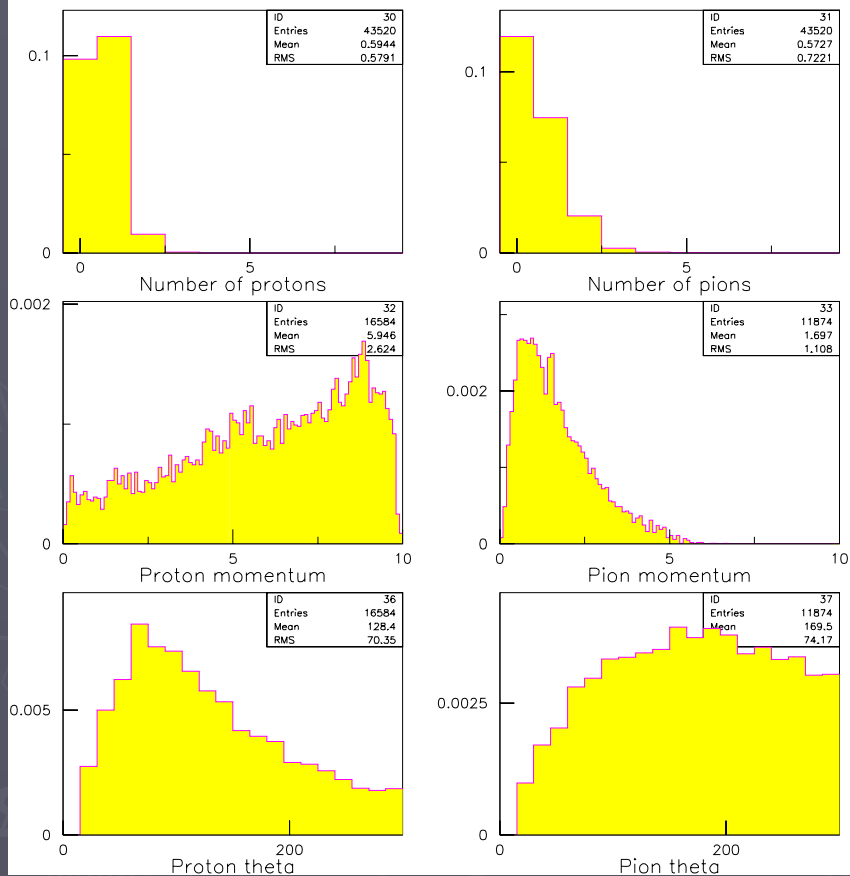
Binary G4 7.0 theta = (15 - 300)mrad, p = (0.2-10.0)GeV



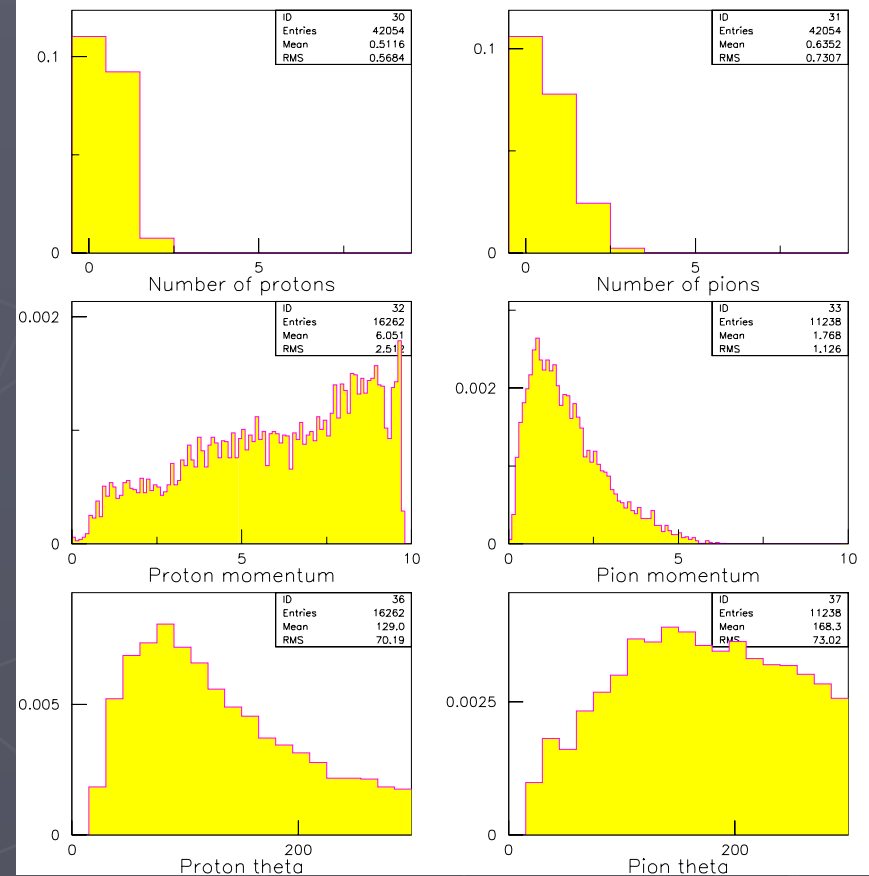
QGSP and QGSC Pion and proton production by protons of 8.9 GeV/c in Be

G4 7.0

QGSC G4 7.0 theta = (15 - 300)mrad, p = (0.2-10.0)GeV



QGSP G4 7.0 theta = (15 - 300)mrad, p = (0.2-10.0)GeV



Conclusion remarks

- ▶ Routine procedure for verification of hadron generators were extended to HARP energy region and to **deuteron and alpha** as a primary
- ▶ **Binary Ion Cascade and Wilson-Abrasion** generators are included in the procedure
- ▶ The complete run have been performed before the Geant4 release 7.0 and number of problems were identified and fixed
- ▶ For the energy below 1 GeV the **Binary Cascade is the most precise generator, however some problems in evaporation persist**
- ▶ The Bertini Cascade is reasonably good in the cascade energy region and is significantly faster than the Binary Cascade
- ▶ The Wilson-Abrasion model needs some improvements
- ▶ For 10 GeV proton beam the verification performed for the Binary, Bertini, QGSC, QGSP generators
- ▶ Some problems are observed in differential spectra of all generators
- ▶ **Complete test have been performed before 7.1 - results are the same, in general**