Hadronic generator tests for spallations and low energies

A.V. Ivantchenko, V.N. Ivanchenko

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Status of low-energy CERN tests

- Technical improvements for test30:
  - Fixed target isotope definition
  - Fixed inelastic X-sections for ions
  - Options for Pre-Compound/deexcitation
- Test30 is used routinely
- Test35 extended for forward reactions
  - $\pi^{\pm} + A \rightarrow \pi^{\pm} + X$ for 3 – 12 GeV/c
- The new IAEA test have been developed

IAEA test

- The International Atomic Energy Agency (IAEA) and the Abdus Salam International Centre for Theoretical Physics (ICTP) organized in 2008 an expert meeting on model codes for spallation reactions and propose a common benchmark
- In December 2008 Geant4 decided to participate in the benchmark with following goals:
  - Extension of validation suite, in particular, for light ions;
  - Objective comparison of Geant4 models versus competitive codes;
- IAEA benchmark software have been developed on the base of test30
- Results are obtained with 9.2patch01 and sent to IAEA in April 2009
- J.-M.Quesada presented results on AccApp'09 Conference (Vienna, May 2009)
- Currently results for 9.2ref08 are available

IAEA spallation benchmark

Mandatory set of data with the beam energy 20MeV-3GeV

***Neutron production**

Double-differential Cross Sections

Neutron Multiplicity Distribution

***Light charged ions production (p, d, t, He3, He4)**

Double-differential Cross Sections

***Isotope production cross-sections**

(excitation functions)

***Isotopic distribution** cross-sections with inverse kinematics

***Pion production**

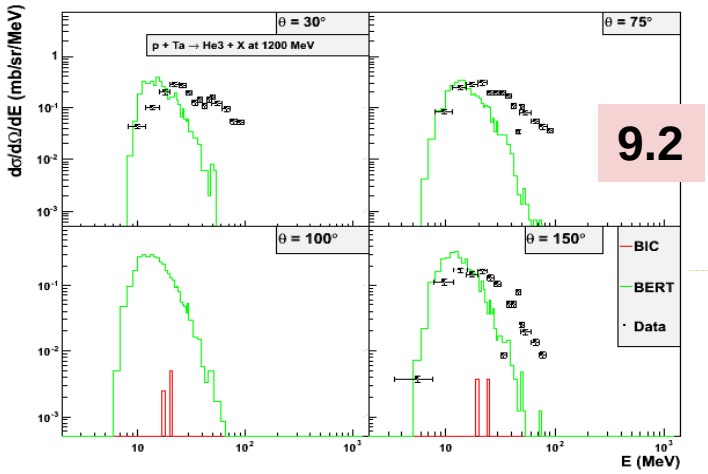
Double-differential Cross Sections

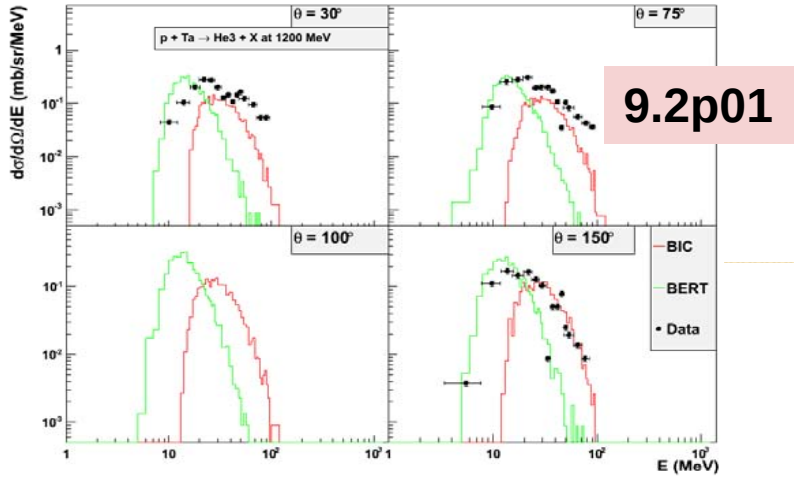
n_Bi_542_ddxs,
n_Fe_65_ddxs,
p_Al_160_ddxs, p_Al_2205_ddxs,
p_Al_730_ddxs,
p_Au_1200_ddxs, p_Au_160_ddxs,
p_Au_2500_ddxs,
p_Bi_62_ddxs,
p C 730 ddxs,
p_Cu_730_ddxs,
p_Fe_100_res_isot, p_Fe_1200_ddxs,
p_Fe_1600_ddxs, p_Fe_3000_ddxs,
p_Fe_300_res_isot, p_Fe56_62_ddxs,
p_Fe_800_ddxs,
p_Ni_175_ddxs,
p_Pb_1000_res_isot, p_Pb_1200_ddxs,
p_Pb_1600_ddxs, p_Pb_256_ddxs,
p_Pb_3000_ddxs, p_Pb_500_res_isot,
p_Pb_63_ddxs, p_Pb_730_ddxs,
p_Pb_800_ddxs,
p_Ta_1200_ddxs,
p_U_1000_res_isot_gsi
Isotope production directories

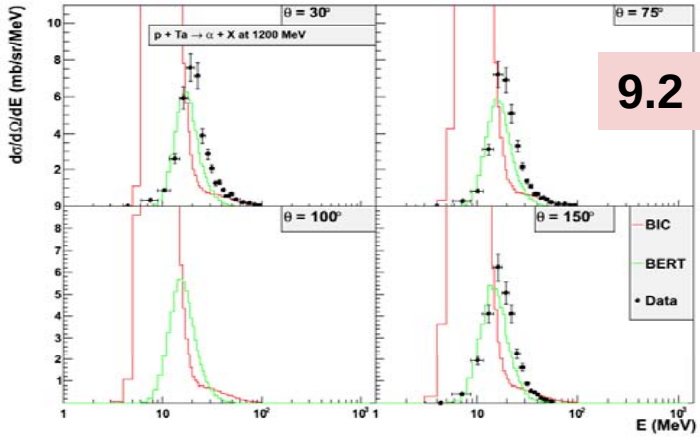
Improvements in Geant4 models using the benchmark results (fixing number of very old problems for 9.2p01)

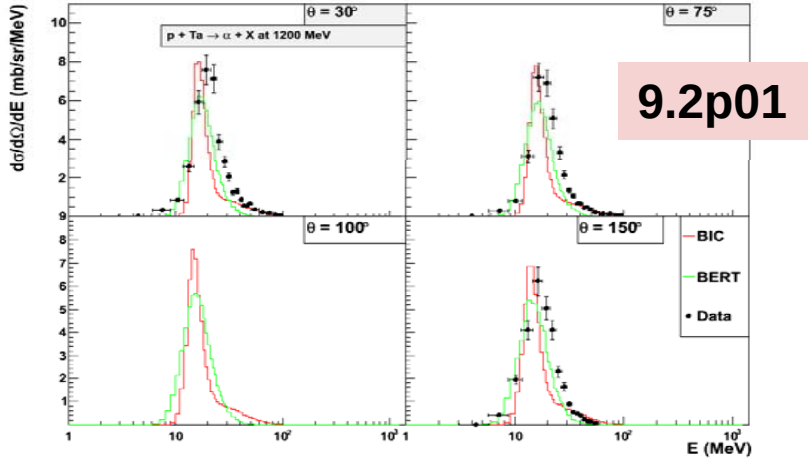
- Bertini model
  - Fixed pion absorption (D.Wright)
- PreCompound and deexcitation models
  - Fixed computation of emission probabilities for light ions (J.M.Quesada)
  - Tried different Coulomb barrier factors (J.M.Quesada)
  - Fixed GEM model for isotopes production (T.Koi and J.M.Quesada)
- Fission model (J.M.Quesada)
  - Fixed computation of fission probability
  - Tried different probability functions for fission
  - Fixed 4-momentum balance in fission
- Checked multi-fragmentation model
  - Not relevant for this data

Examples of improvements for 9.2p01
^{3}He and ^{4}He production in Ta at 1.2 GeV









Comparison of relative CPU time for 1 GeV p beam interaction with Fe and Pb targets (pcgeant04, geant4-09-02-ref-05)

Model	p+Fe	p+Pb
Bertini	1	2.0
Binary	9.5 (10.6*)	35.5 (37.0*)
Binary_ion	11.4 (9.7*)	37.0 (36.2*)
QMD	10756	13880
CHIPS	7.6	8.1
INCL	7.5	38.1

* - GEMEvaporation added

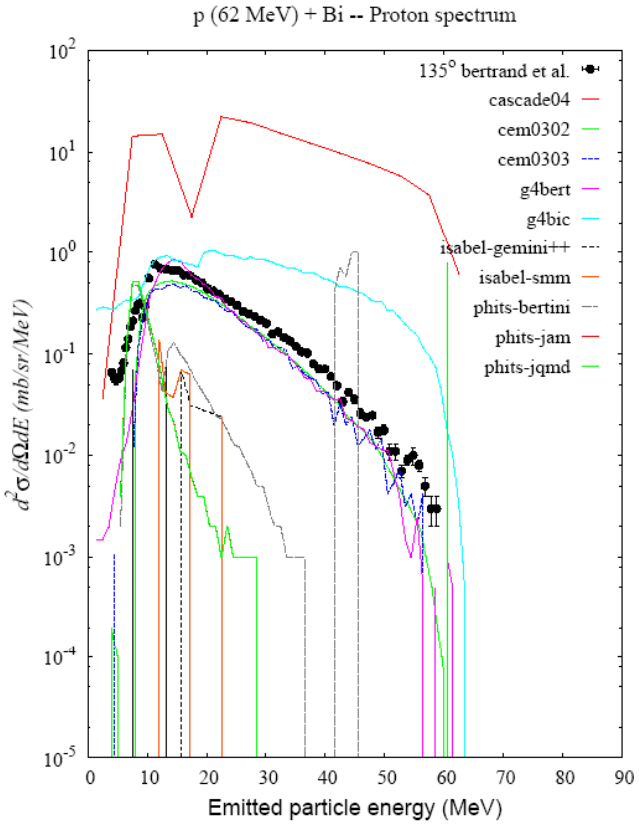
RESULTS sent to the IAEA and presented on the AccApp'09 conference at Vienna (May, 2009) (Geant4 official release 9.2 patch p01)

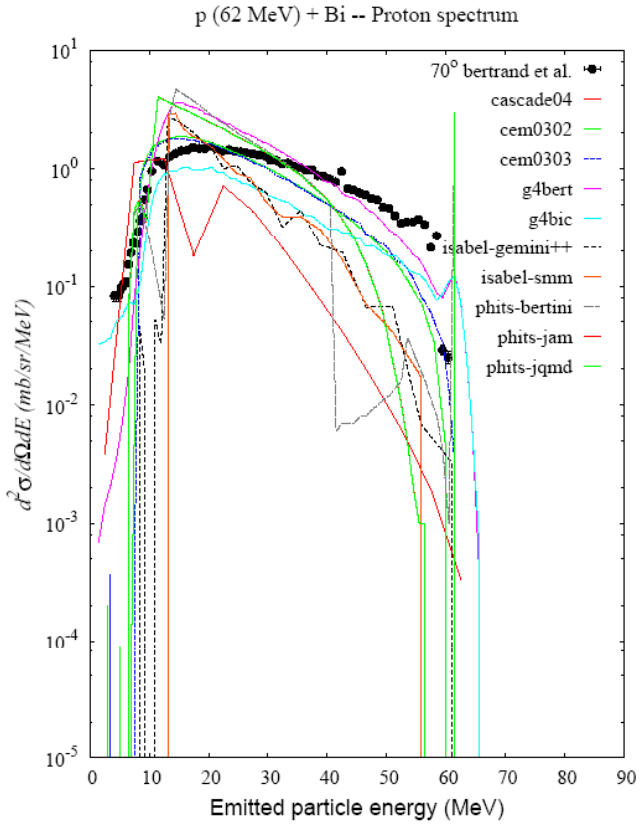
- List of active participants
  - CEM03
  - PHITS
  - Cascade04
  - Isabel
  - Geant4
  - INCL4 ??
  - FLUKA ??

Proton Spectrum with low energy projectile

Overestimated

Underestimated

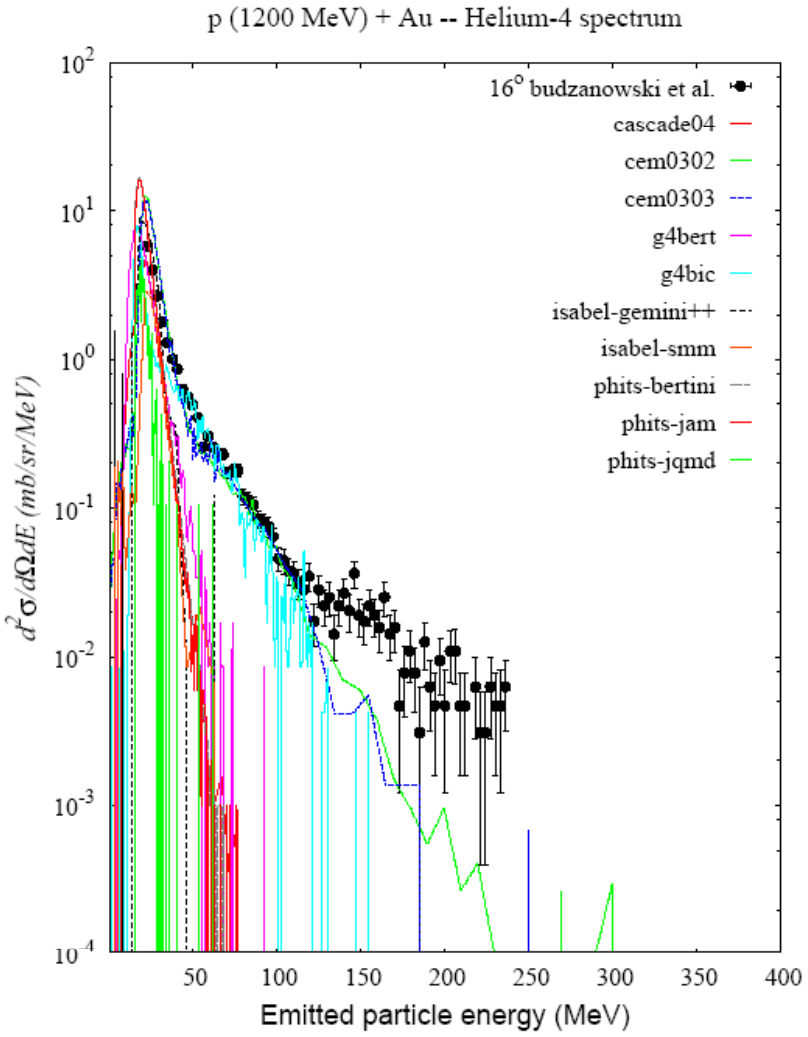




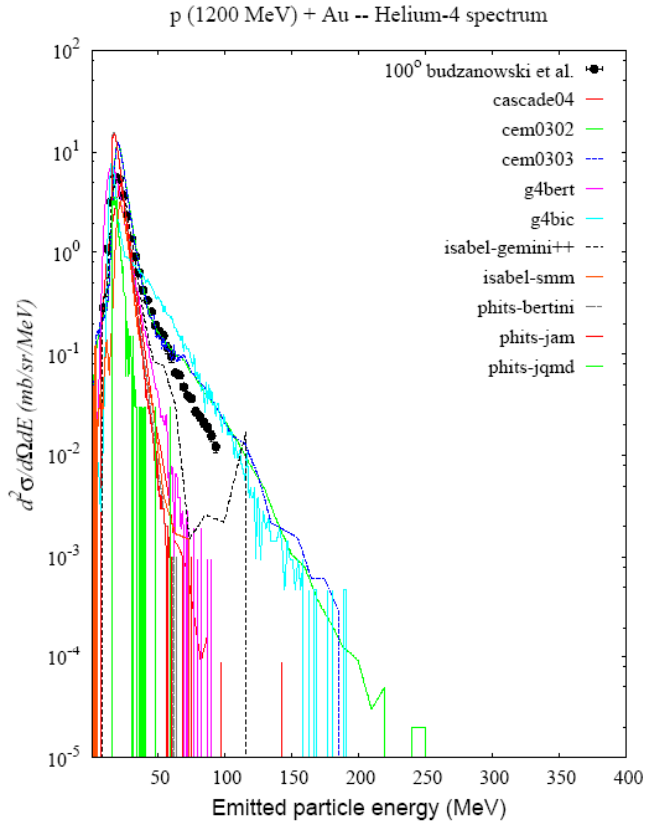
Binary is not good enough
Bertini is one of the best

Alpha Spectrum with high energy projectile

Forward angle



Backward angle

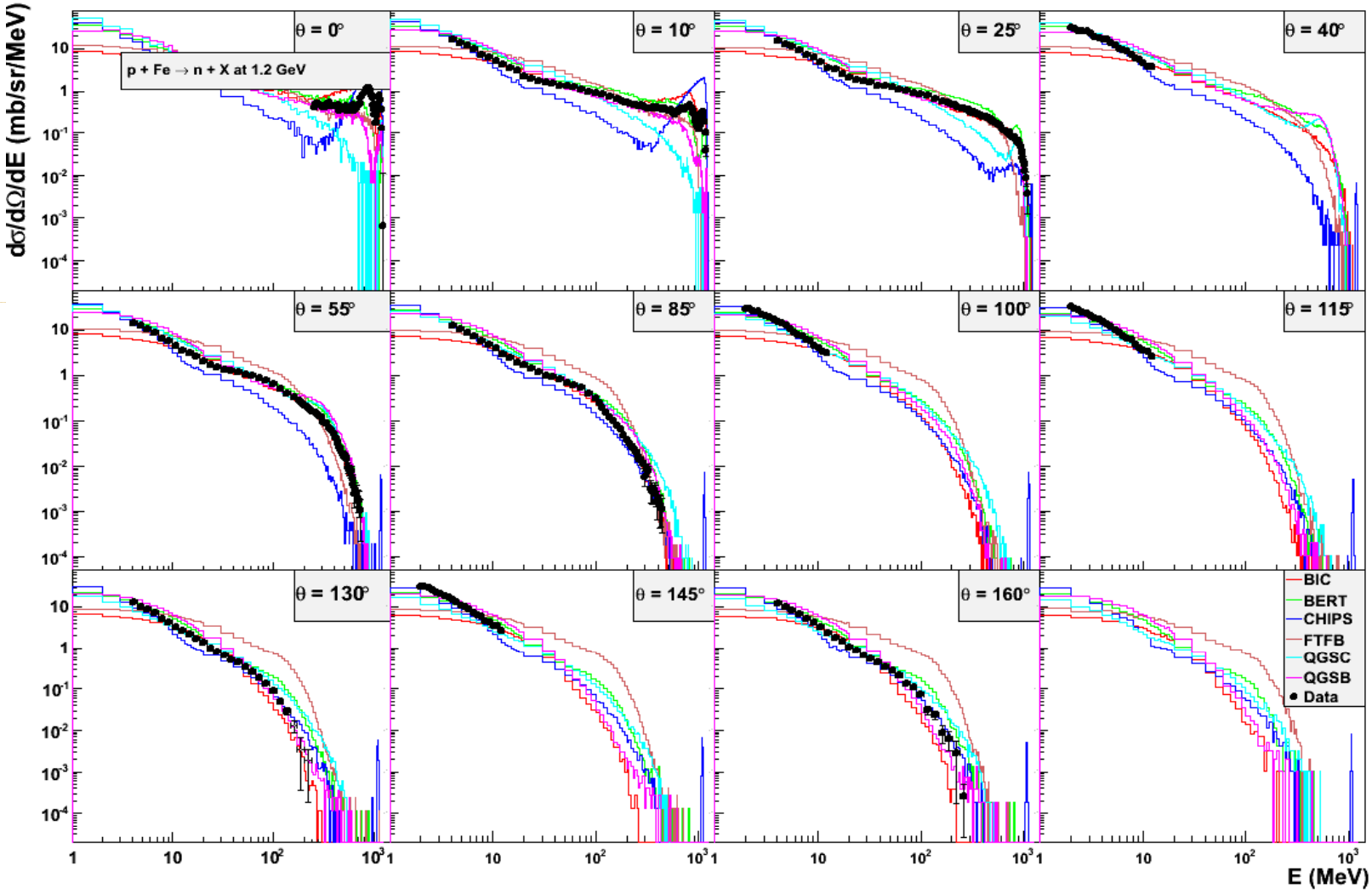


Binary is advanced
Bertini is not good enough

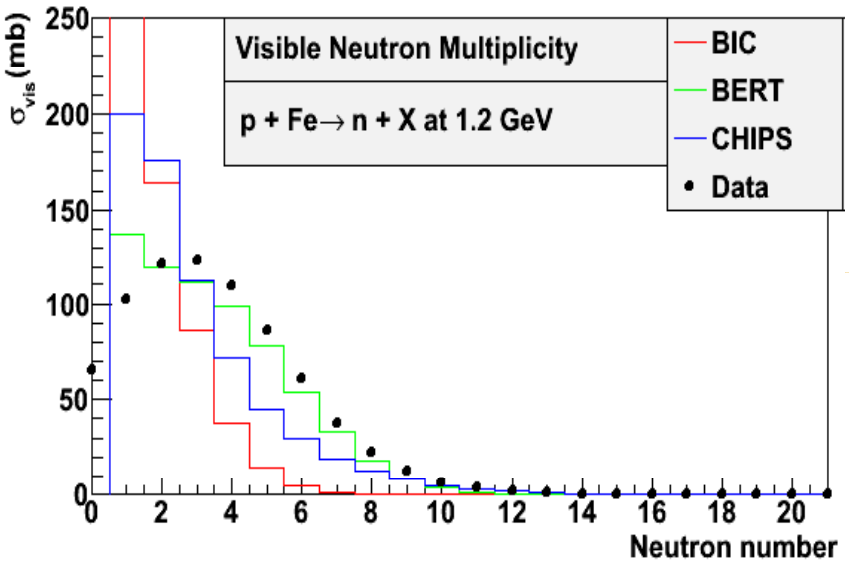
RECENT RESULTS

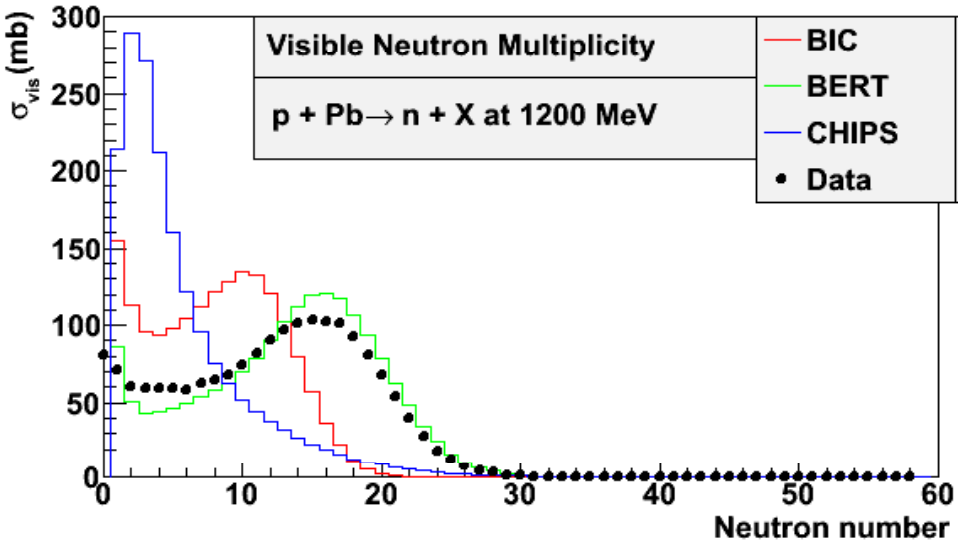
(geant4-09-02-ref-08)

Neutron production at 1200 MeV in Fe



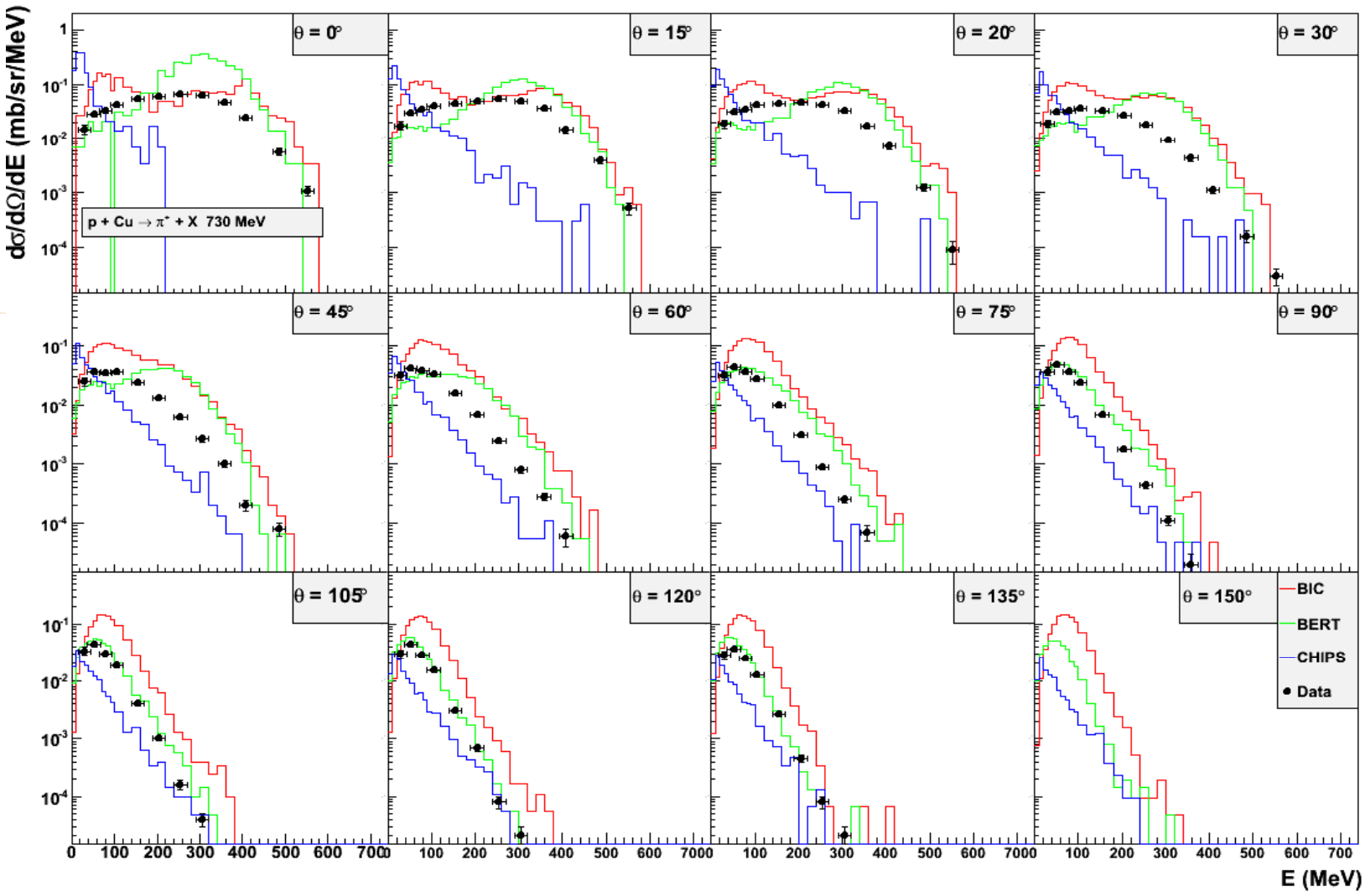
Neutron multiplicity



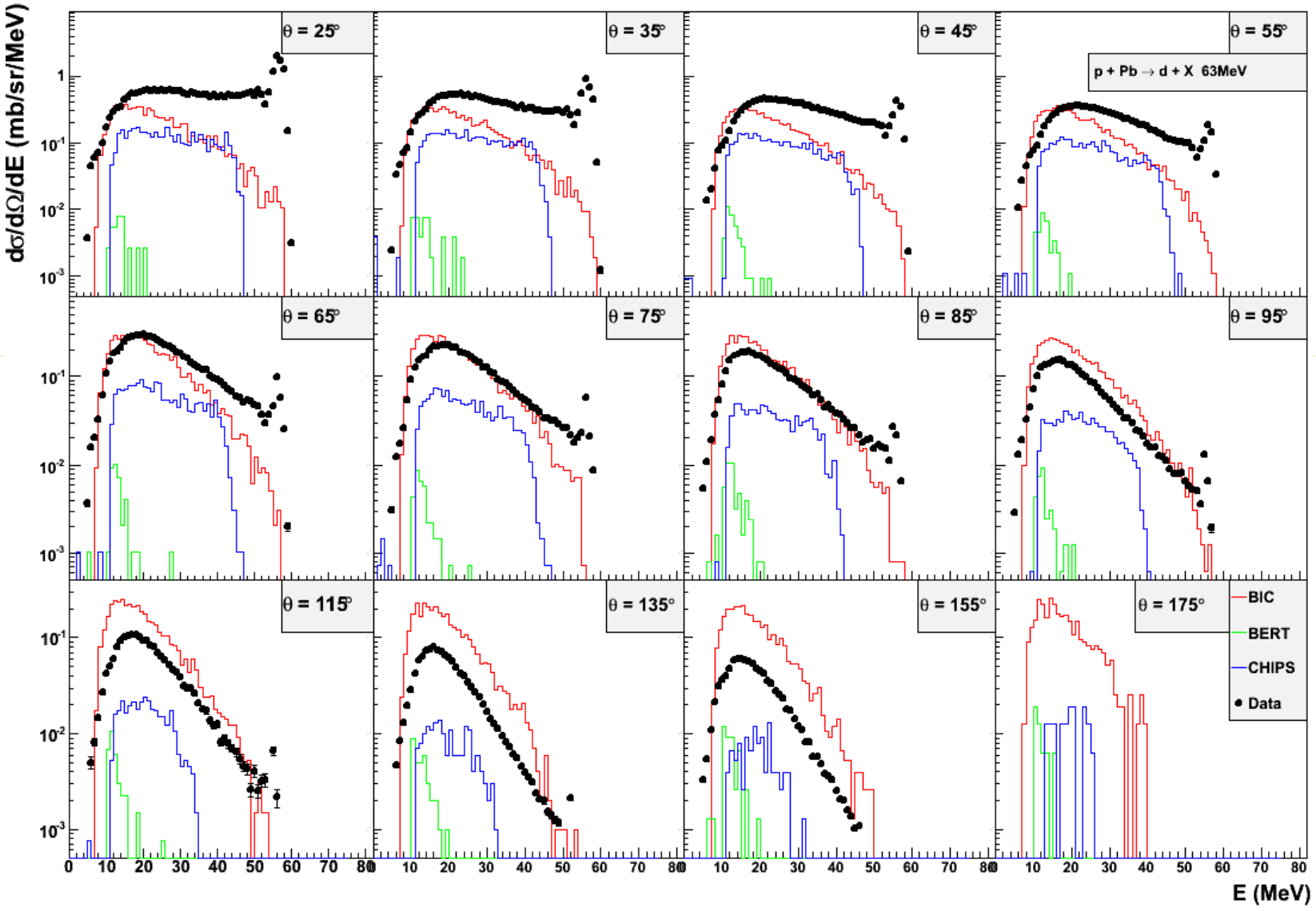


- This results demonstrates that at 1.2 GeV the Bertini cascade provides a correct multiplicity of secondary neutrons

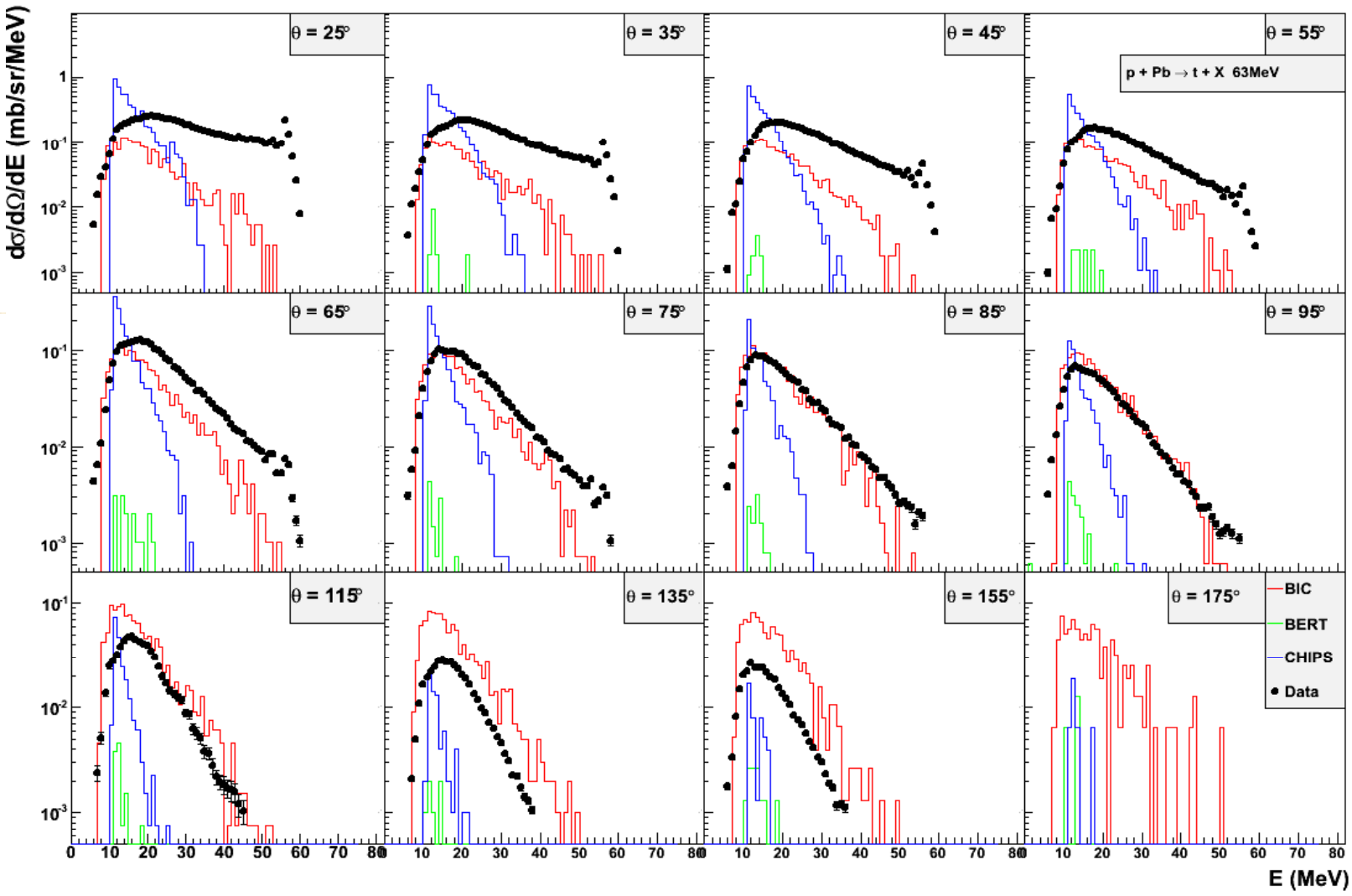
Pion production at 730 MeV in Cu



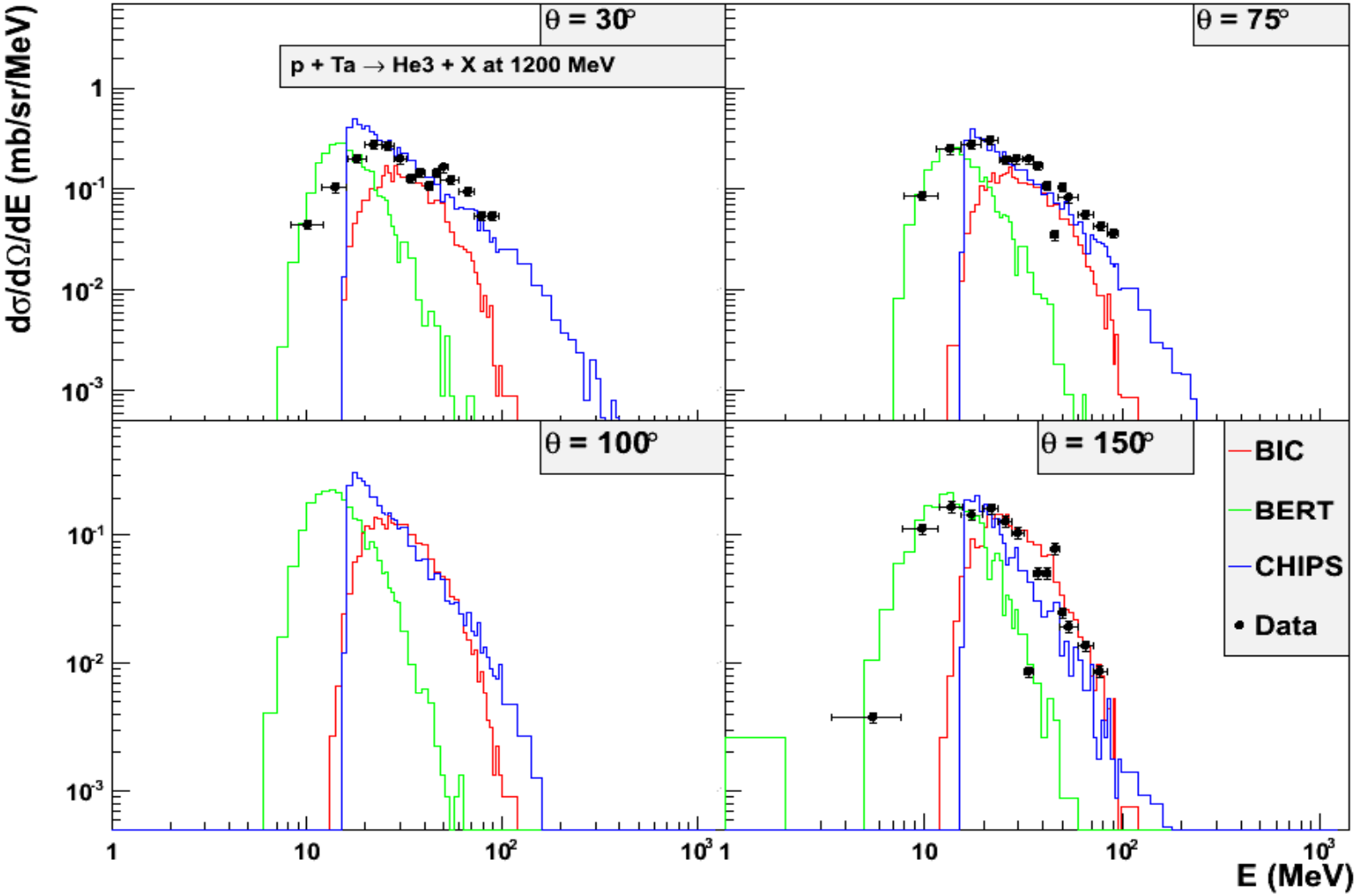
Deuteron production at 63 MeV in Pb



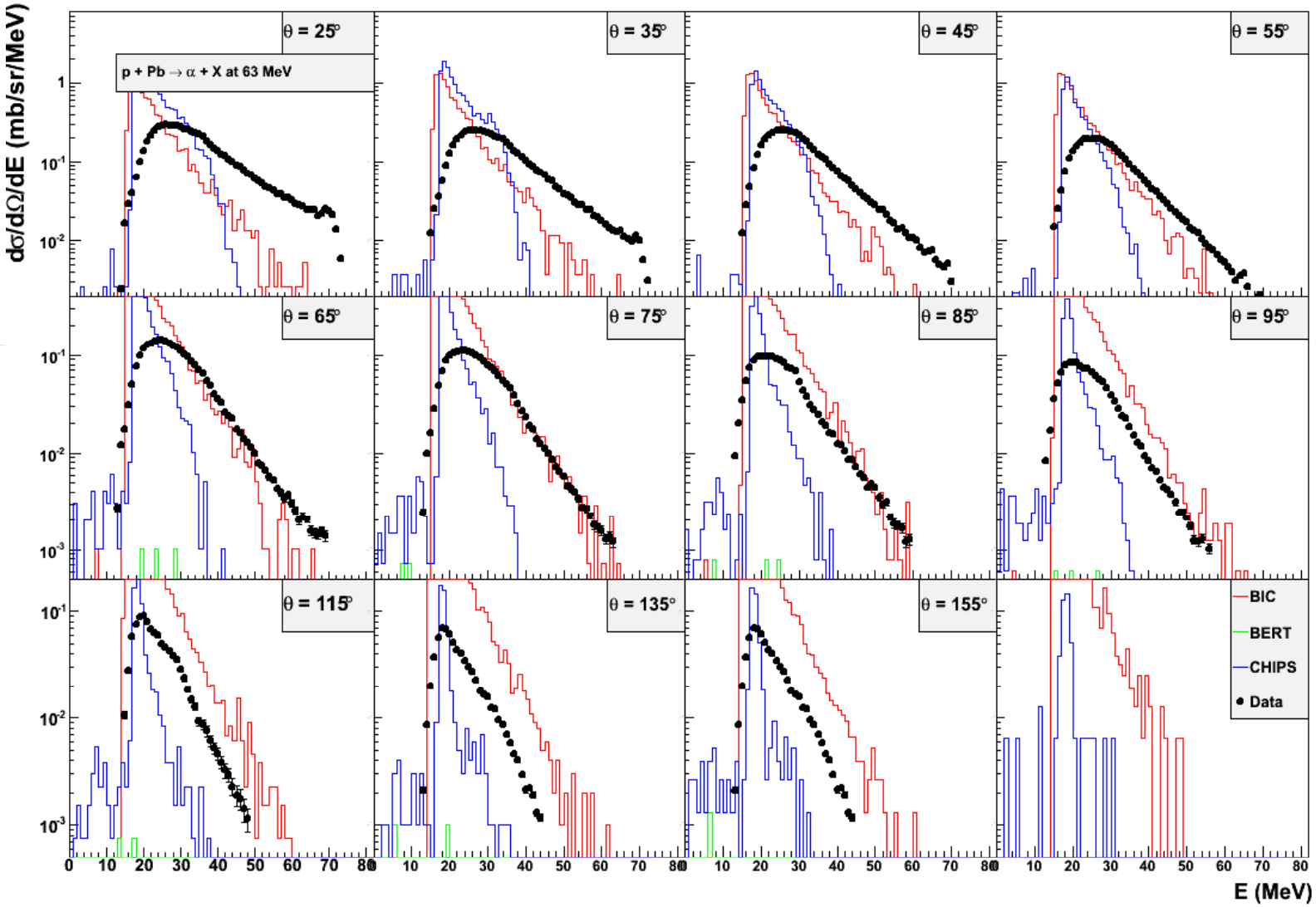
Tritium production at 63 MeV in Pb



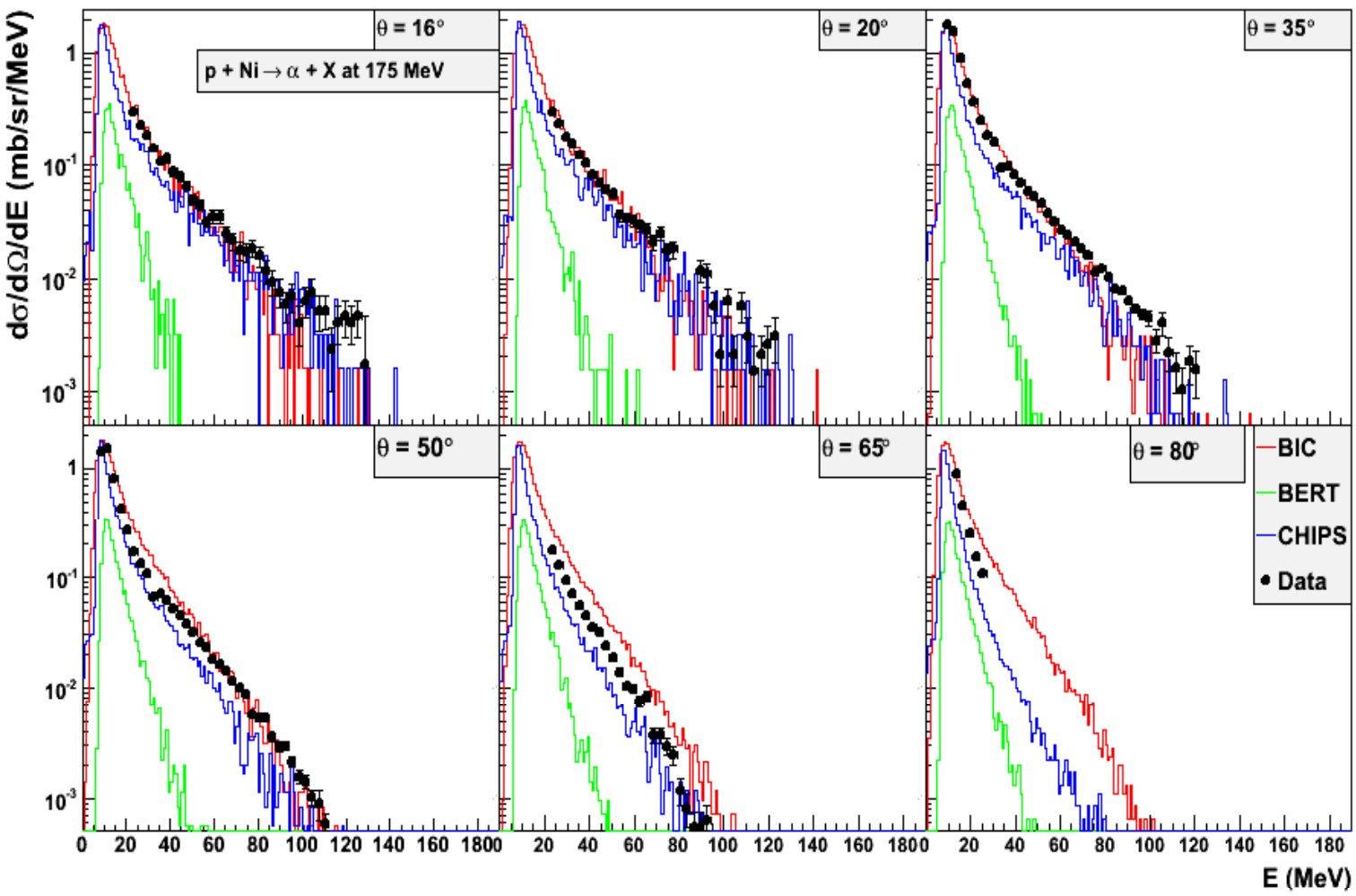
^{3}He production at 1200 MeV in Ta



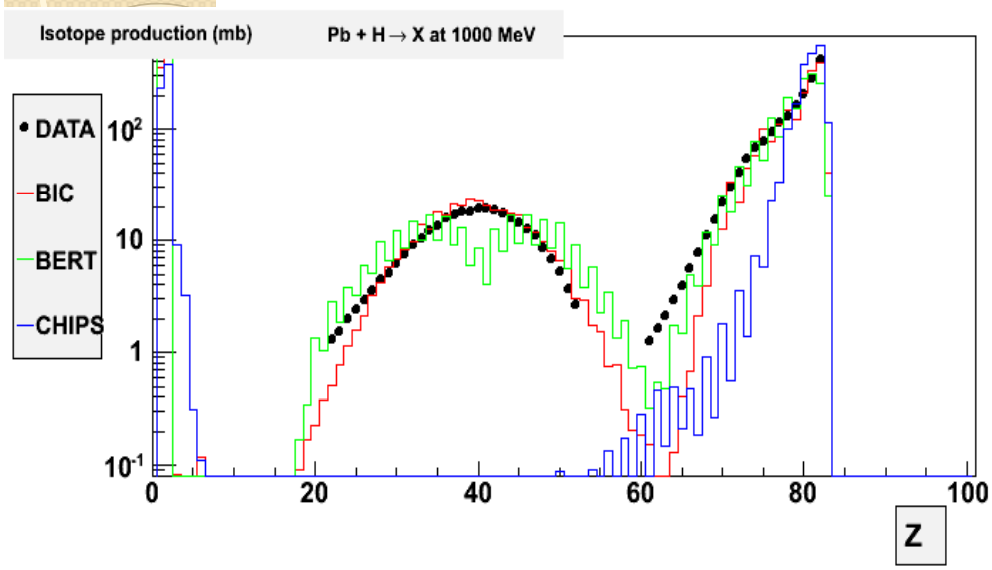
Alpha production at 63 MeV in Pb

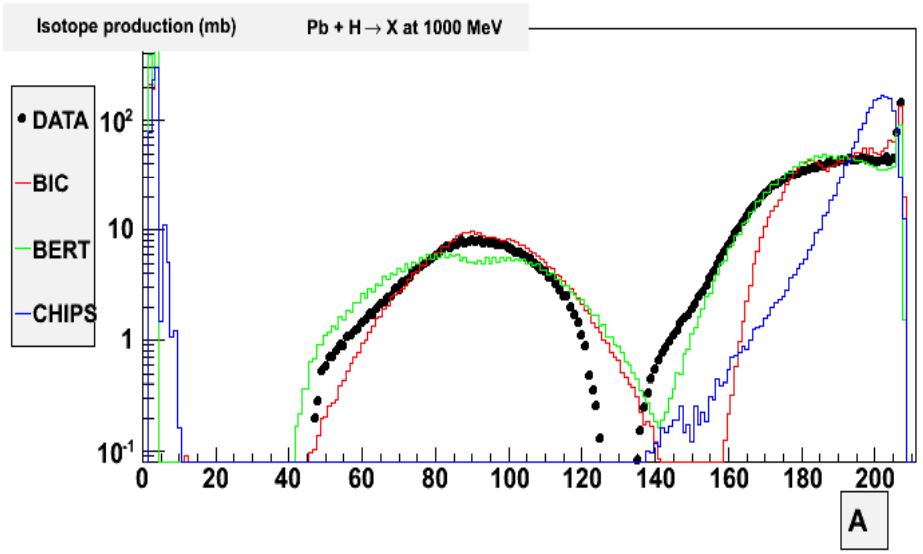


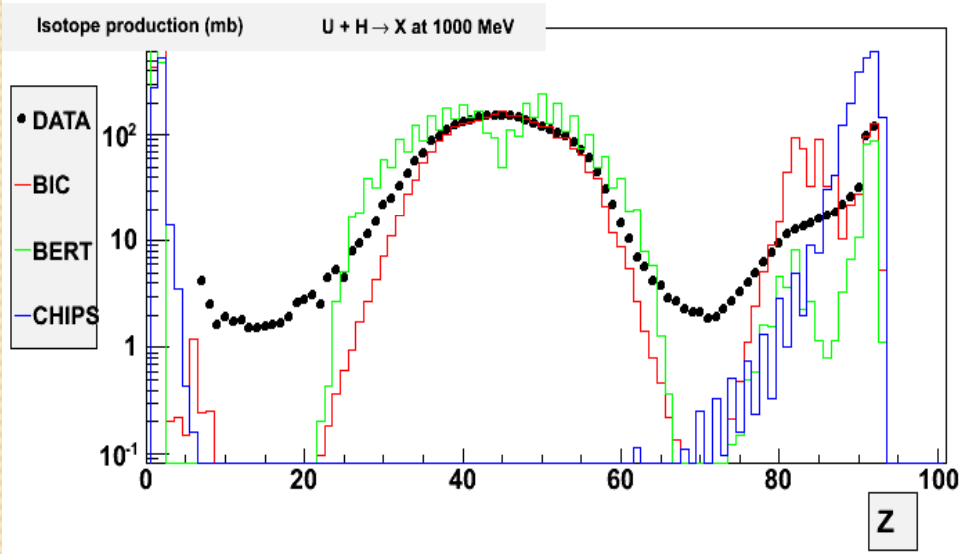
Alpha production at 175 MeV in Ni

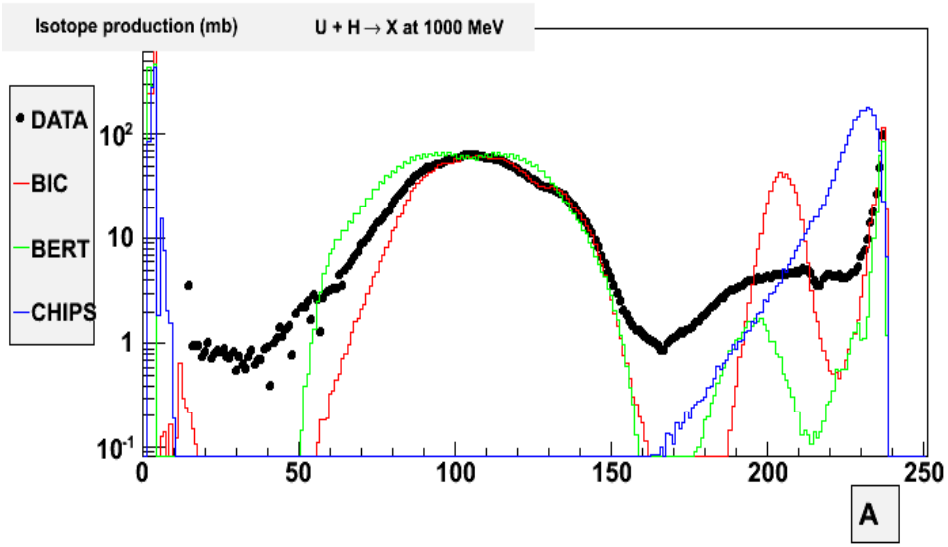


Fission at 1 GeV
(New CombinedGEM is used in Binary cascade)









Summary

- New IAEA benchmark have been created which includes new tests for light ion production, fission, neutron multiplicity
- Test30, test35, and IAEA are now used routinely
- Geant4 provides not ideal but competitive results with other codes used in IAEA benchmark
- There are still problems in Geant4 generators