Validation of Geant4 models and comparison with MCNPX

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11th Geant4 Collaboration Workshop and Users Conference, Lisbon, 9-14 October 2006

Aim

- Define physics settings in G4.8.1.p01 for the simulation of absorbed and organ-equivalent dose to patients undergoing proton therapy
- Estimate Geant4 – MCNPX discrepancy in effective dose calculations used to estimate the risk for radiation induced malignancies

Method

- Comparison with multi-layer Faraday cup measurements: charge distribution of nuclear secondaries in CH_2 for 160 MeV primary protons

- Comparison of neutron energy distributions calculated in a water phantom with Geant4 and MCNPX 2.5 for 100 MeV and 200 MeV primary protons

- Different physics models in Geant4 and MCNPX

Geant4 Models and Processes

- Standard Electromagnetic
- LEP Electromagnetic

- G4LElastic
- G4HadronElastic
- G4NeutronHPElastic
- G4HadronElasticProcess
- G4UHadronElasticProcess

- G4BinaryCascade
- G4CascadeInterface
- LEP Inelastic
- G4NeutronHPInelastic

- LEP ion inelastic
- BinaryLightIon

Geant4 Physics List

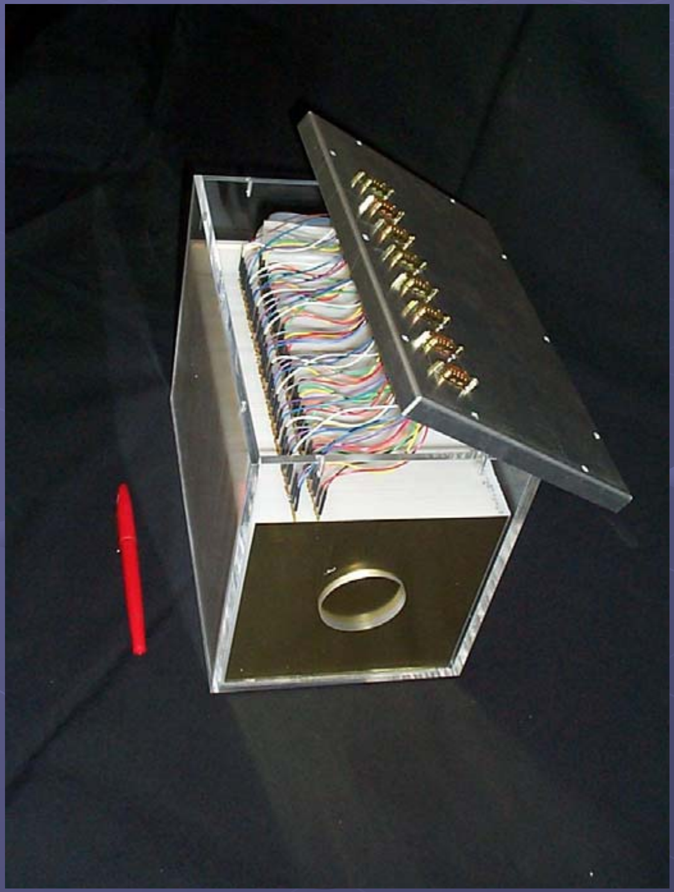
- Reference Physics List:

  Standard EM, G4LElastic (w G4HadronElasticProcess), Binary cascade, (HP), (ions)
- Variant Physics List Modules:
  1. Bertini for p & n inelastic
  2. Low-energy p & n inelastic
  3. Low-energy electromagnetic
  4. G4HadronElastic (w G4HadronElasticProcess)
  5. G4HadronElastic w G4UHadronElasticProcess

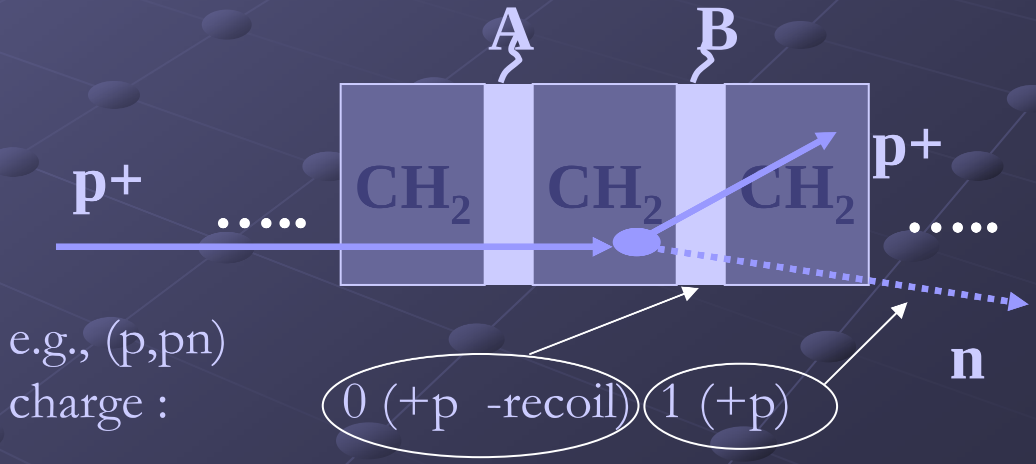
MCNPX Physics Settings

- General Physics
  - Tabulated cross sections used where applicable
  - MCNPX standard elastic scattering model (based on HERMES)
  - Pre-equilibrium model follows intranuclear cascade
  - Normal ion transport
  - Fermi-breakup model for disintegration of light nuclei
- Variant Physics:
  - Intranuclear Cascade
    - Bertini INC for nucleons and pions + Improved Dubna INC (CEM2K)
    - CEM2K + ISABEL INC
  - Pre-equilibrium
    - MPM (LAHET model) for Bertini
    - Improved MEM for CEM2K
  - Equilibrium
    - Dresner model for Bertini
    - CEM97 model for CEM2K

Multi-Layer Faraday Cup (MLFC)



- 160 MeV proton beam
- 66 absorbers (CH_2) interspaced by charge collectors (brass)
- Separates nuclear build-up region from em peak



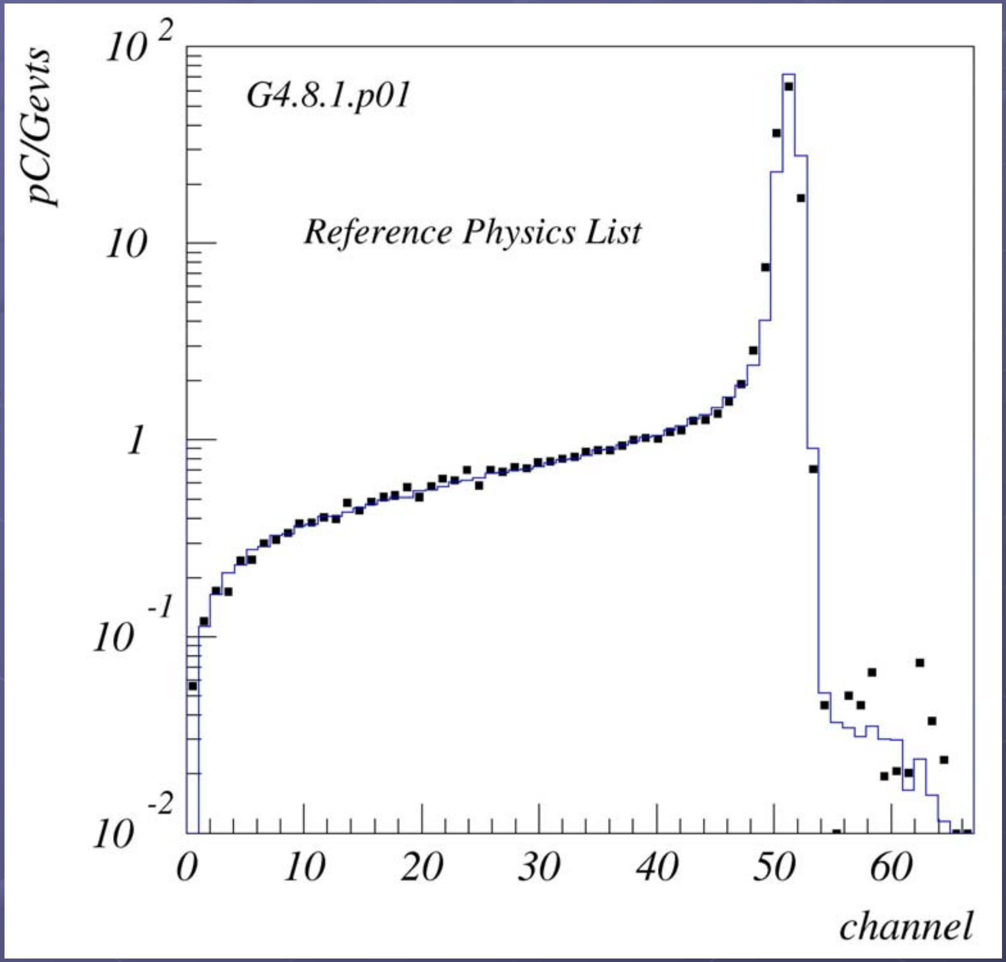
Water Phantom

- Uniform water cube of 1 m side
- Pencil beam at 100 MeV or 200 MeV,
  simulating a 10 cm x 10 cm proton treatment field
- Scoring neutron kinetic energy distributions near the peak and in the plateau region of the depth-dose curves (4 cm, 7 cm, 12 cm, 24 cm depth)

Charge distributions –

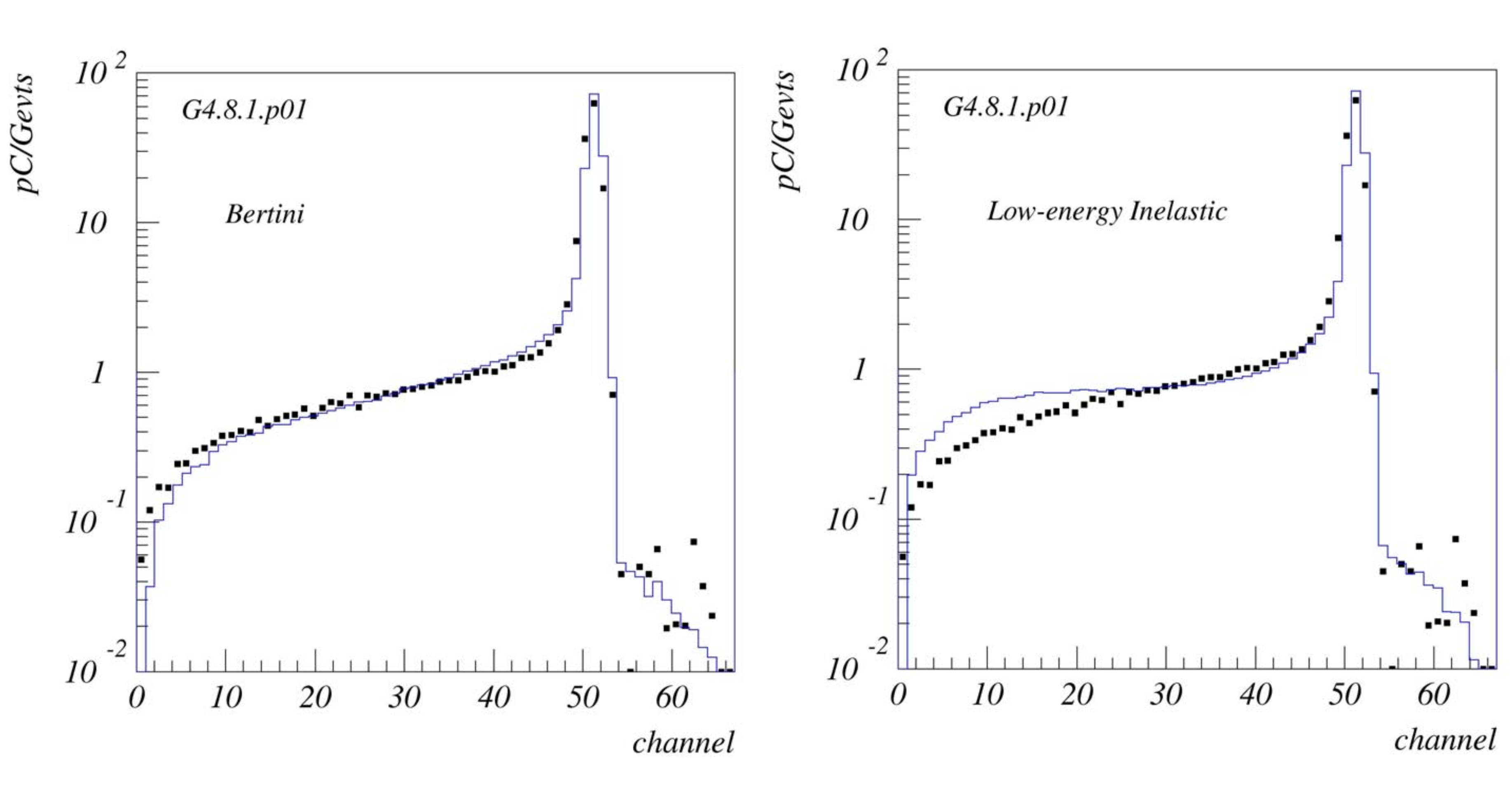
Multi-layer Faraday cup

MLFC - Reference Physics List

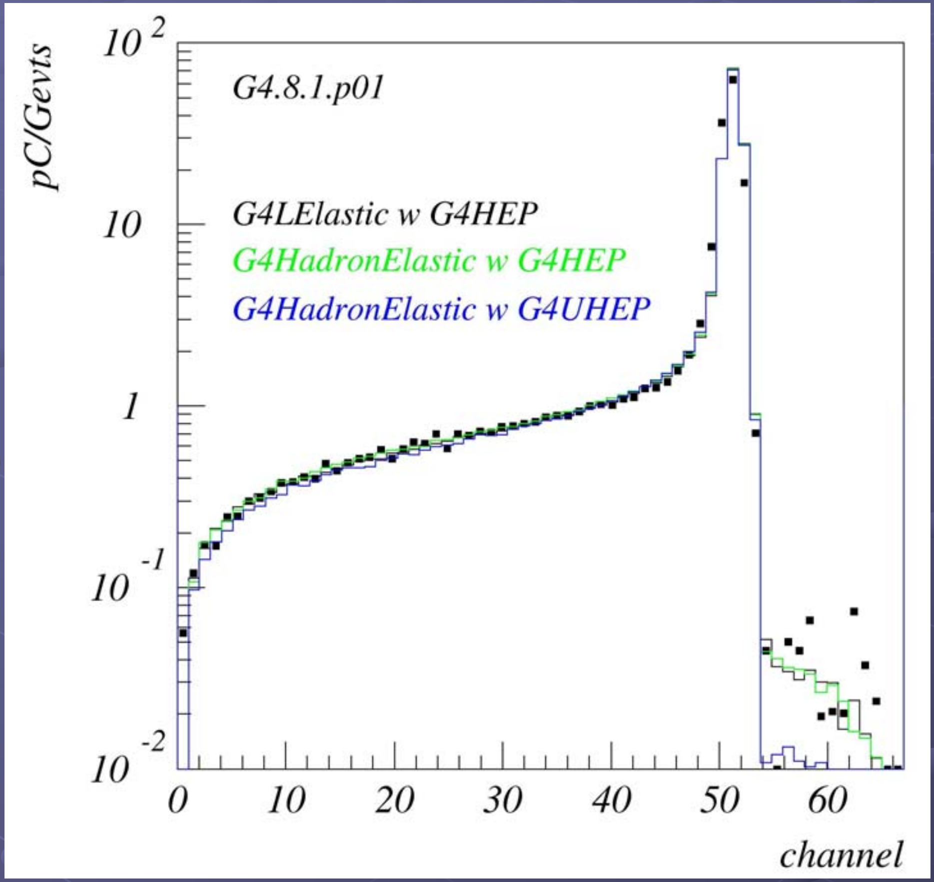


- Standard EM
- Binary cascade
- G4LElastic
- G4HadronElasticProcess
- High-precision neutron

MLFC – Inelastic Scattering



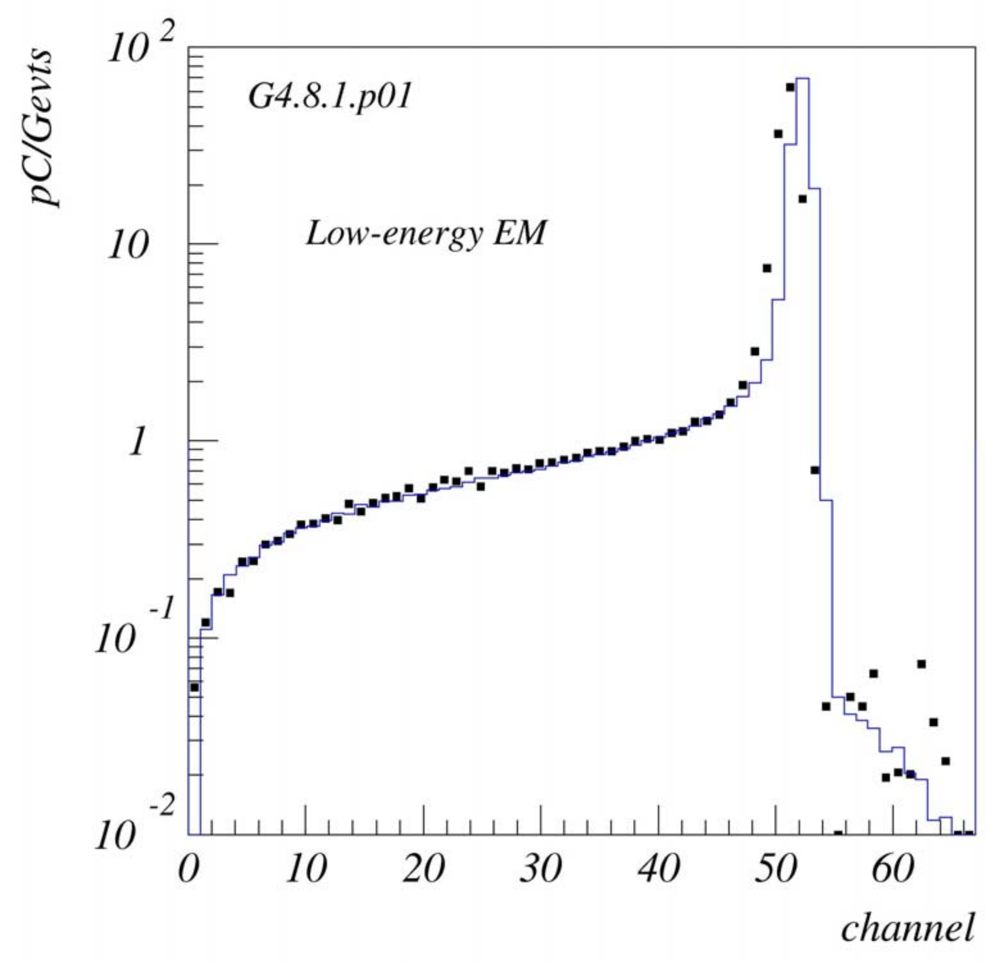
MLFC – Elastic Scattering



Two models and two processes:

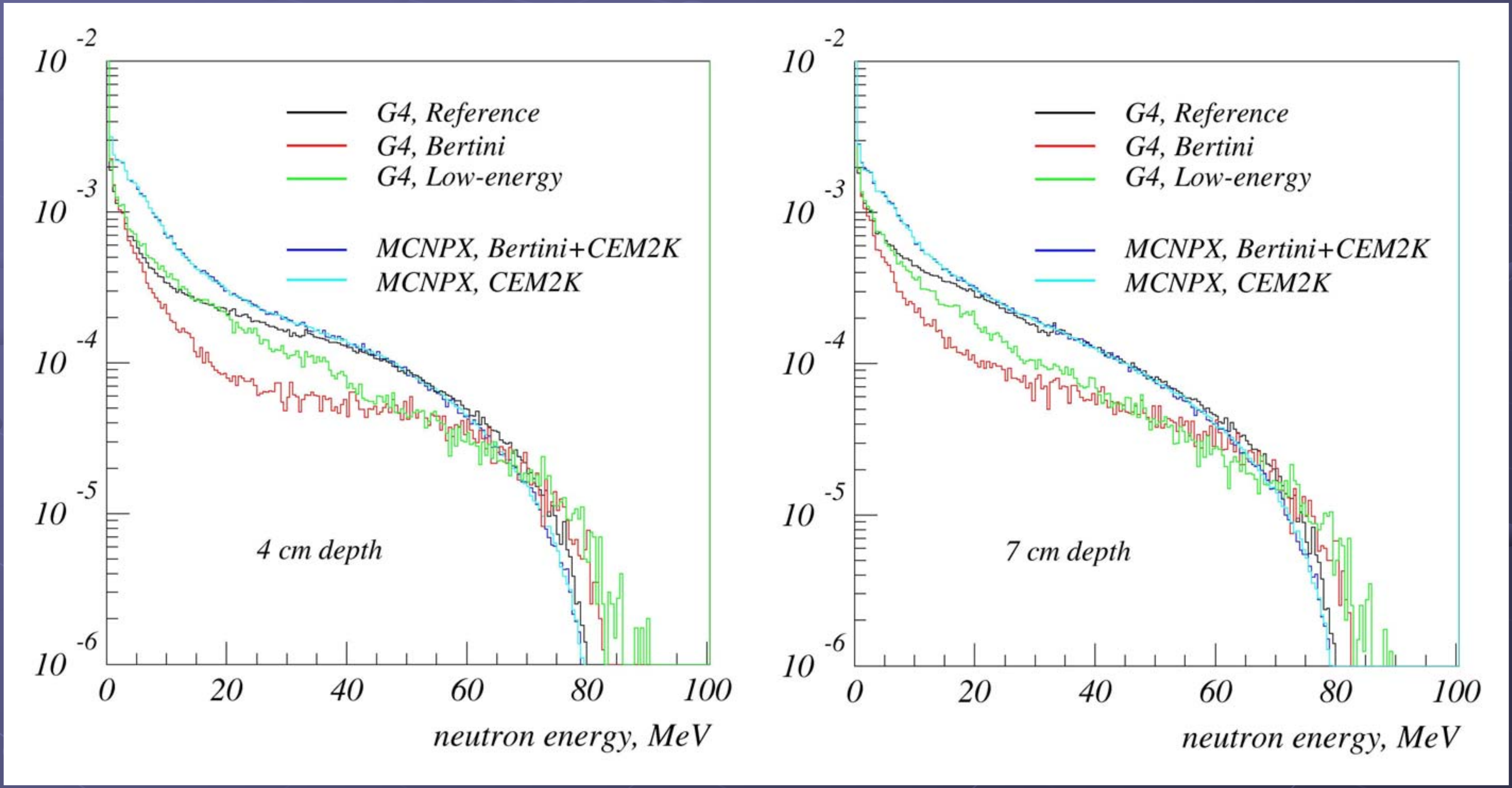
- G4LElastic w G4HadronElasticProcess
- G4HadronElastic w G4HadronElasticProcess
- G4HadronElastic w G4UHadronElasticProcess

MLFC – Electromagnetic Physics

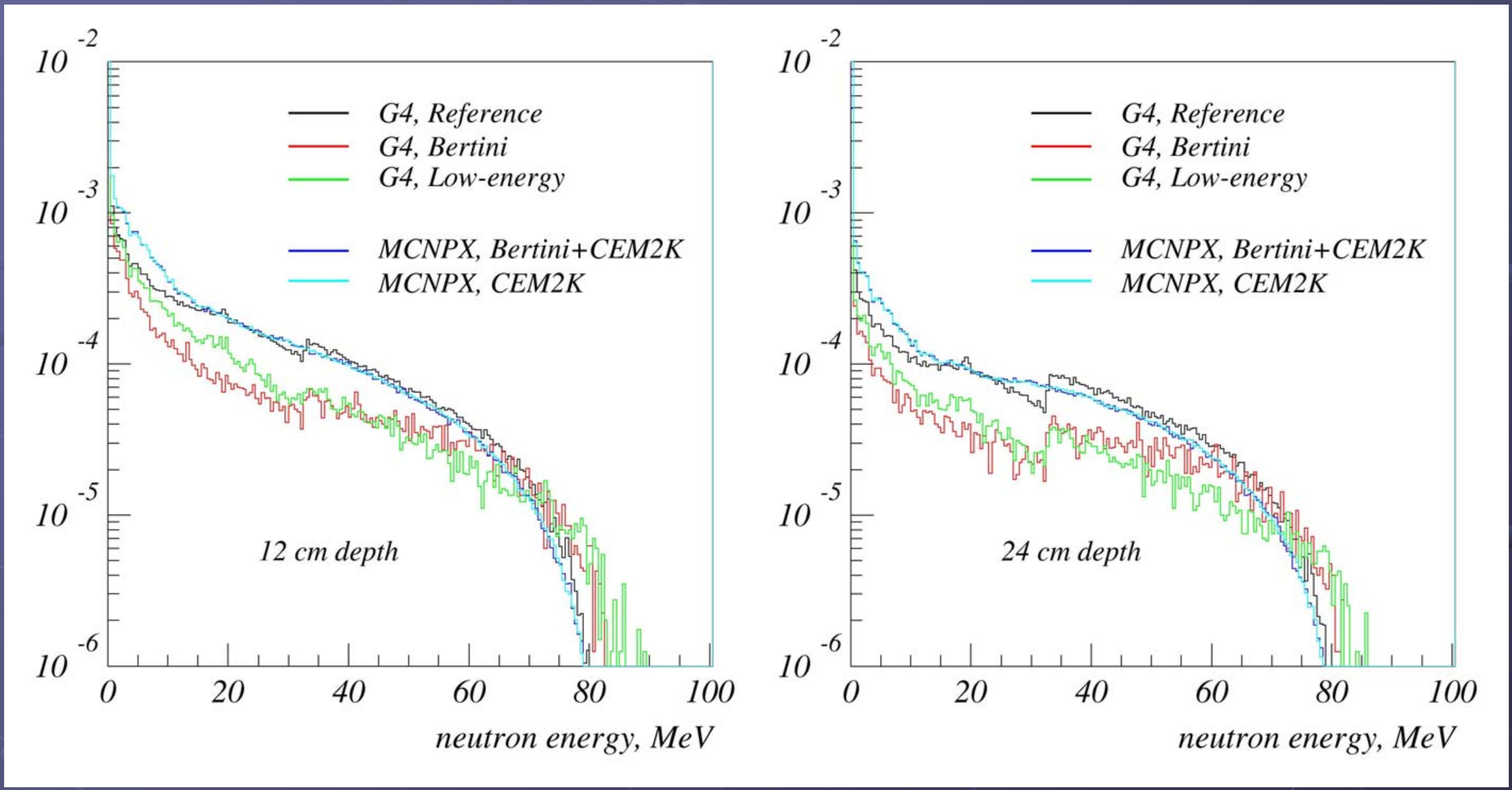


Neutron Fluence – Water Phantom

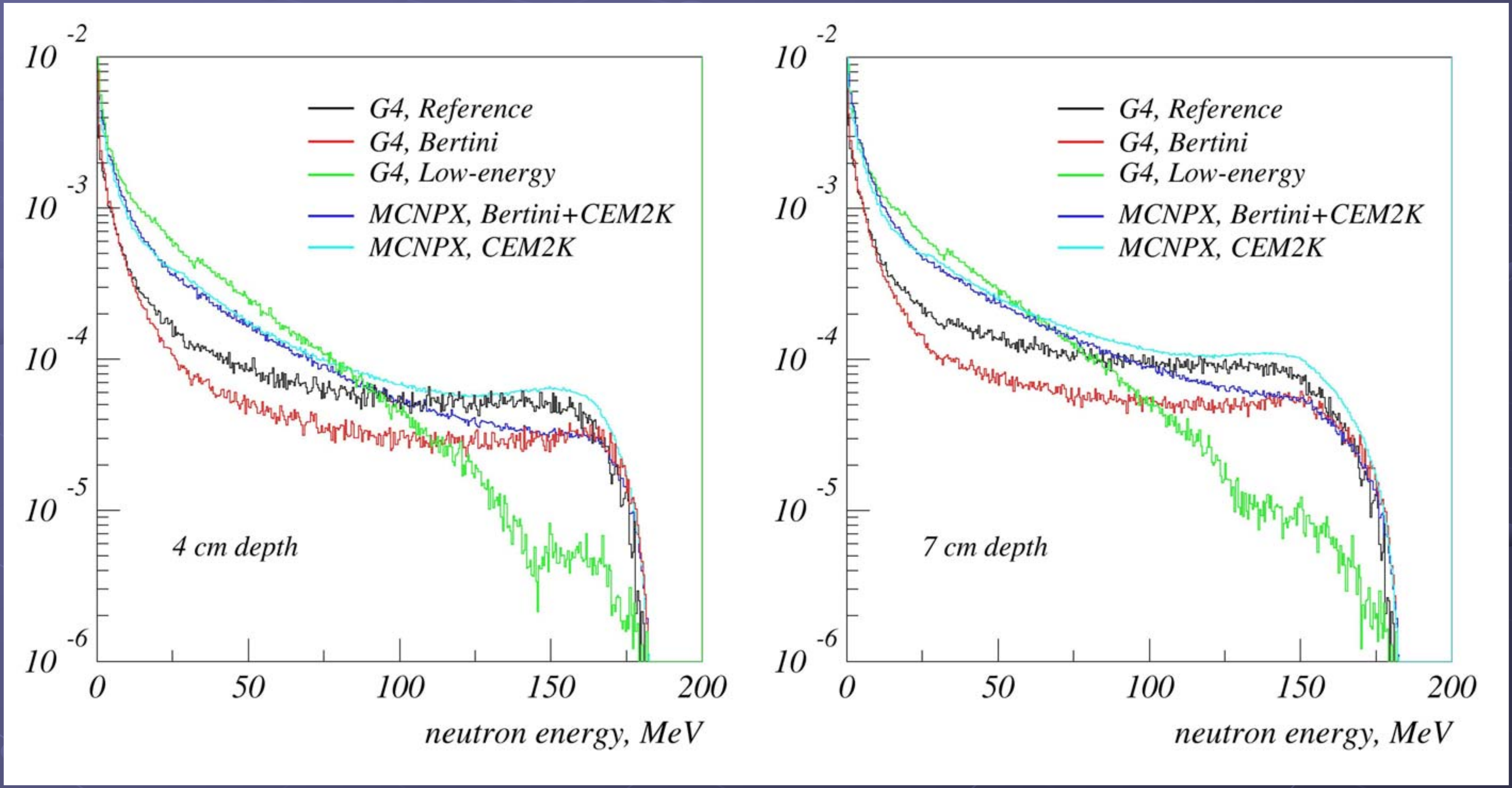
Phantom – Inelastic at 100 MeV



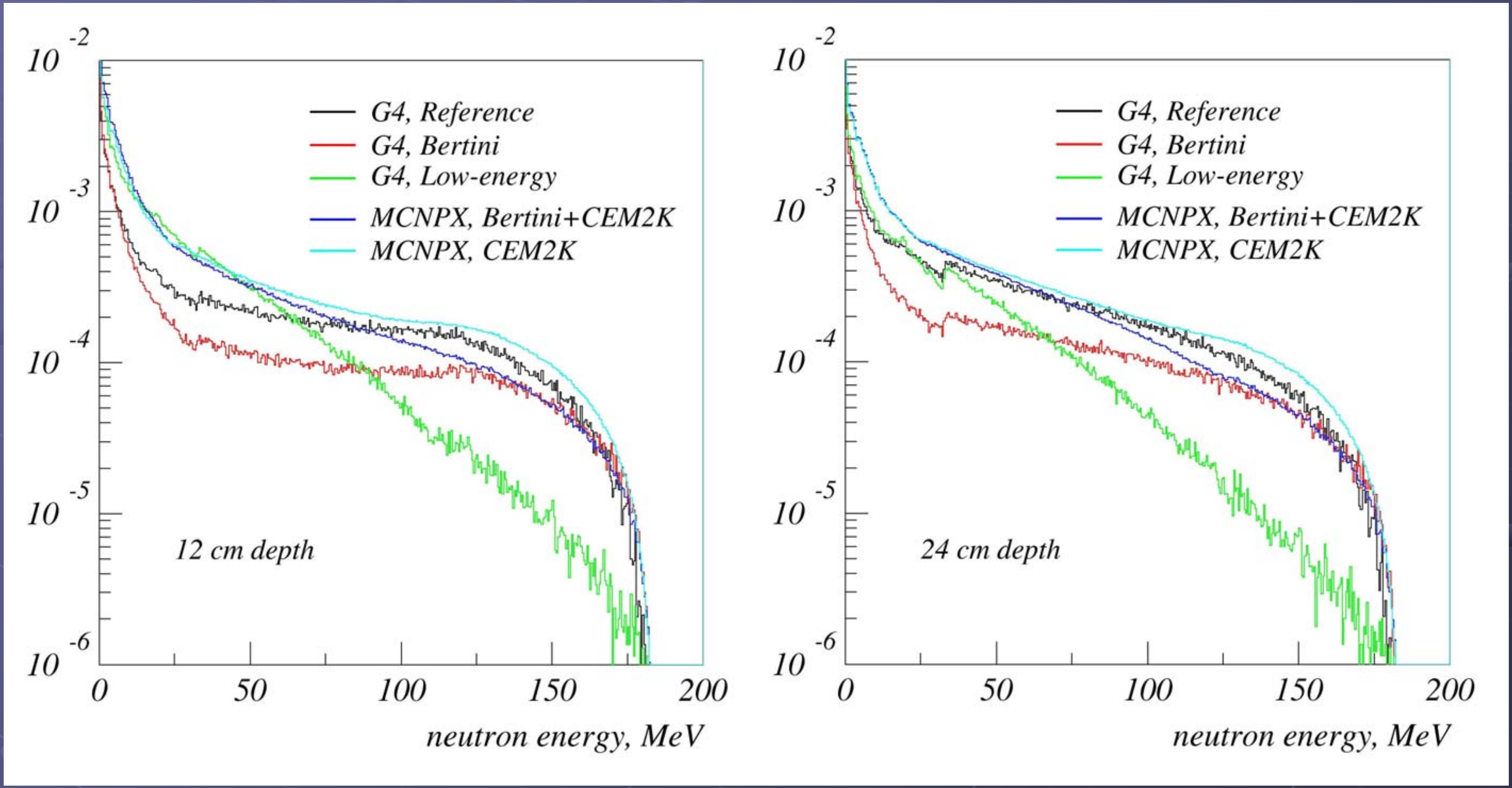
Phantom – Inelastic at 100 MeV



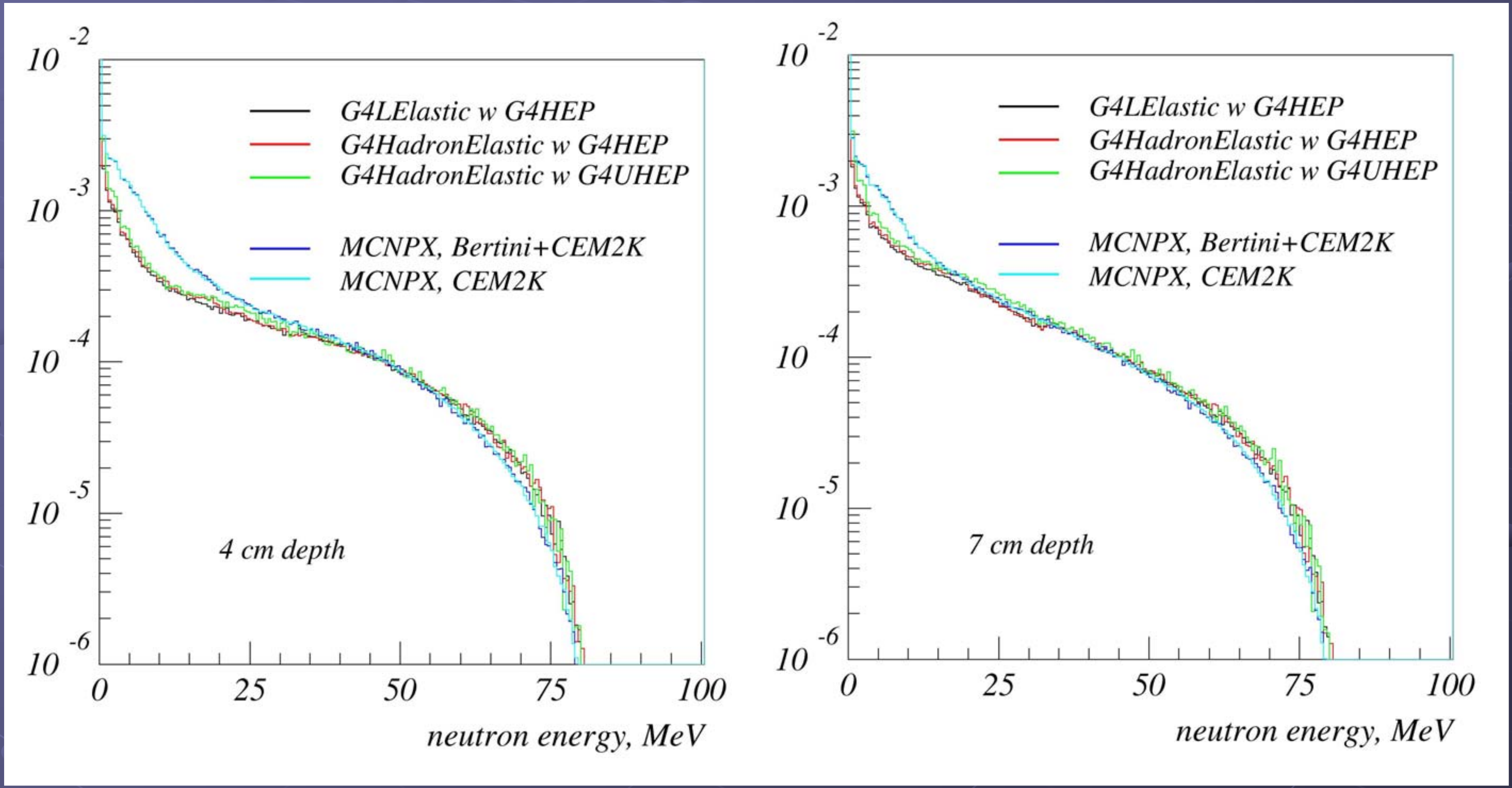
Phantom – Inelastic at 200 MeV



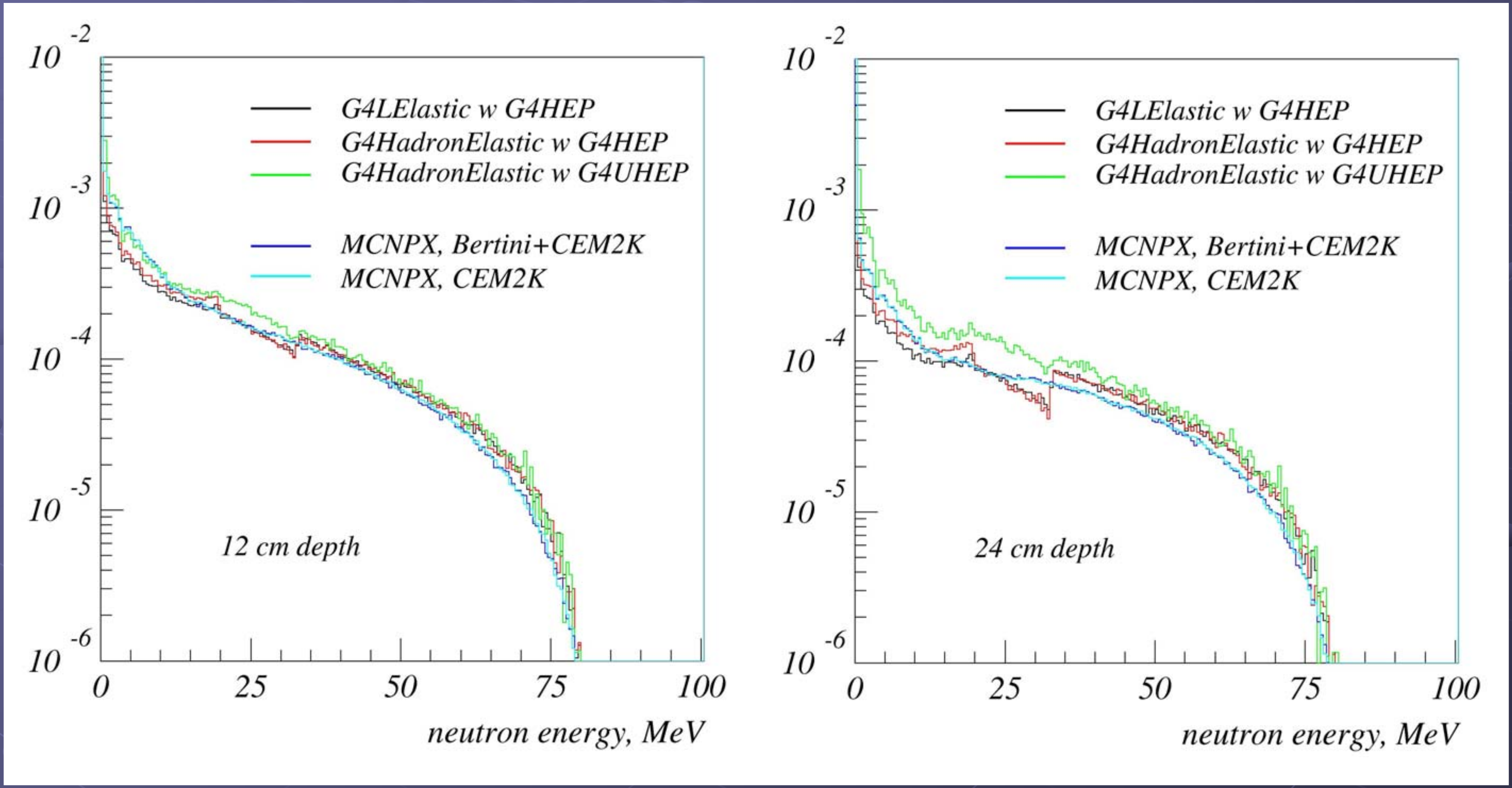
Phantom – Inelastic at 200 MeV



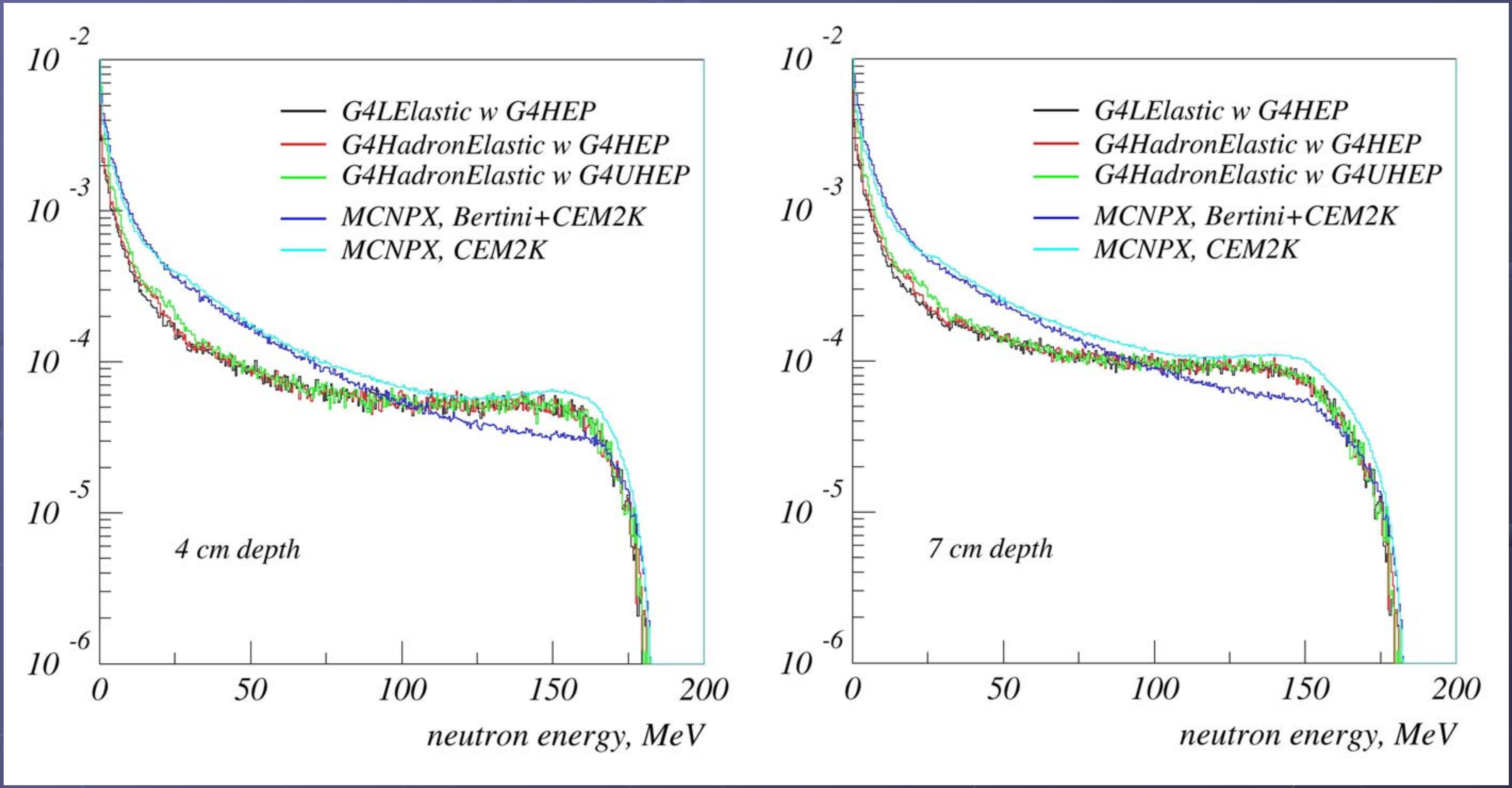
Phantom – Elastic at 100 MeV



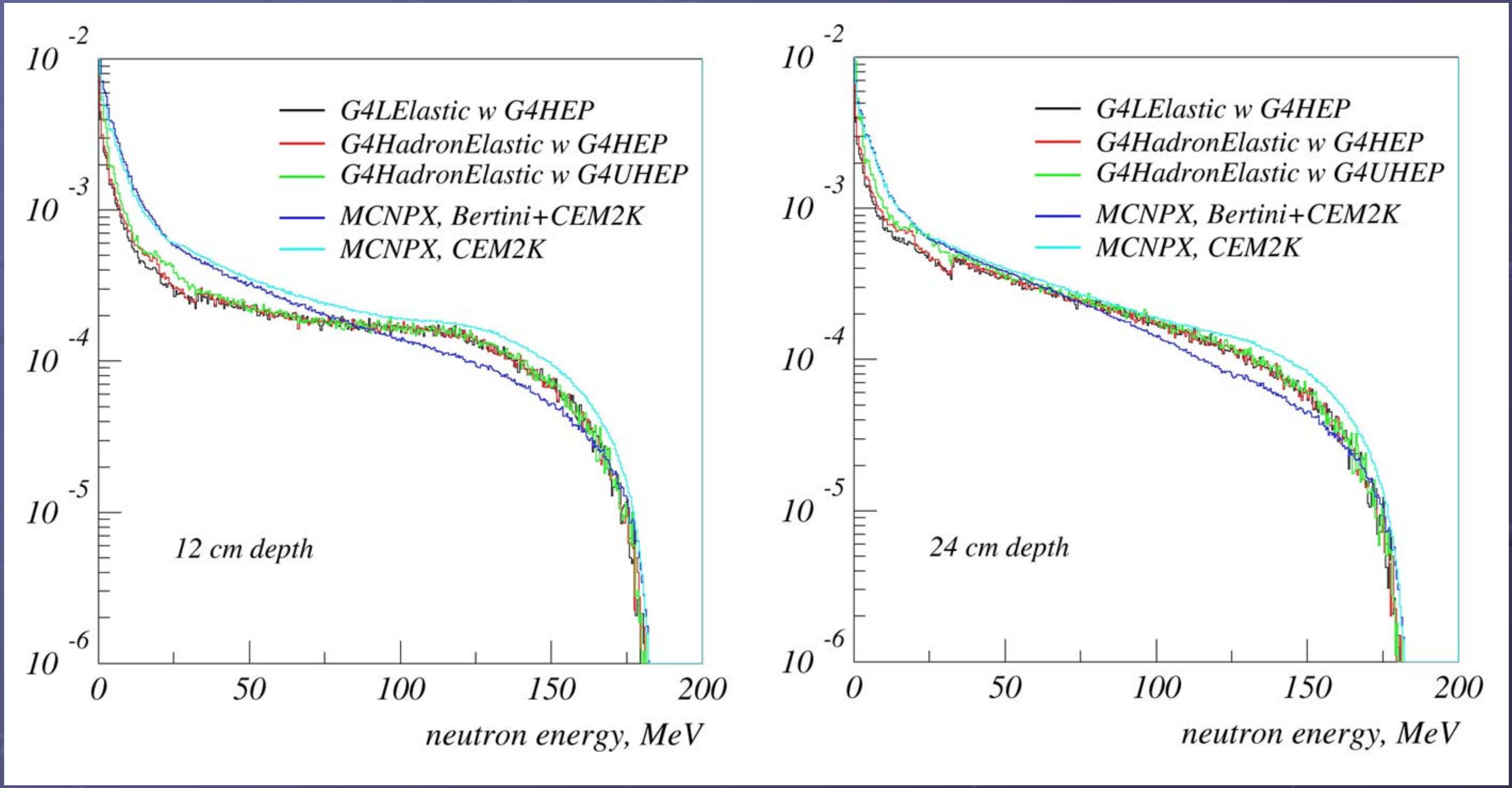
Phantom – Elastic at 100 MeV



Phantom – Elastic at 200 MeV



Phantom – Elastic at 200 MeV



Conclusions

- *Comparison with MLFC measurements:*

  - good agreement for Standard EM and Binary cascade

- *Geant4 neutron fluence in water phantom:*

  - the distributions show a discontinuity at about 30 MeV (table cross-over?) except in the case of G4UHadronElasticProcess

- *Comparison Geant4 – MCNPX:*

  - the differences in neutron fluence are not expected to be significant in terms of secondary dose calculation and risk assessment for radiation induced tumours

  - ongoing calculations of equivalent dose to tissues

Acknowledgements

Vladimir Ivanchenko

Gunter Folger

Tatsumi Koi

Dennis Wright