High energy neutrons in DM detectors

P. Beltrame, J. Dobson, A. Murphy

THE UNIVERSITY *of* EDINBURGH

DM-UK meeting
Durham 09 June 2014

- Neutrons indistinguishable background WIMP direct search experiments.
- Various origins of neutrons in DM search environment

  From **detector components**

  From cosmic radiations: **μ-induced**. Energies O(10 - 100) MeV.

- Neutron propagation mostly GEANT4 based. Inaccurate for neutrons above 20 MeV.

- New treatment for neutrons in hydrogen and carbon (H_nC_m) new treatment

  based on data from A. Spyrou et al., Physics Letters B 683 (2010) 129.

  Z. Kohley et al., Nucl. Instr. Meth A 682 (2012) 59-65 developed MENATE_R.

GEANT4 vs. MENATE_R

- GEANT4, neutron reactions and propagation based on data where available (typically < 20 MeV), and on physics models where data are sparse.

- MENATE_R relies solely on experimental data:

  • Limitations: input cross-sections for the discrete reaction channels and not all materials.

  • However: hydrocarbons are commonly employed in neutron shielding and scintillator veto detectors in low background experiments.

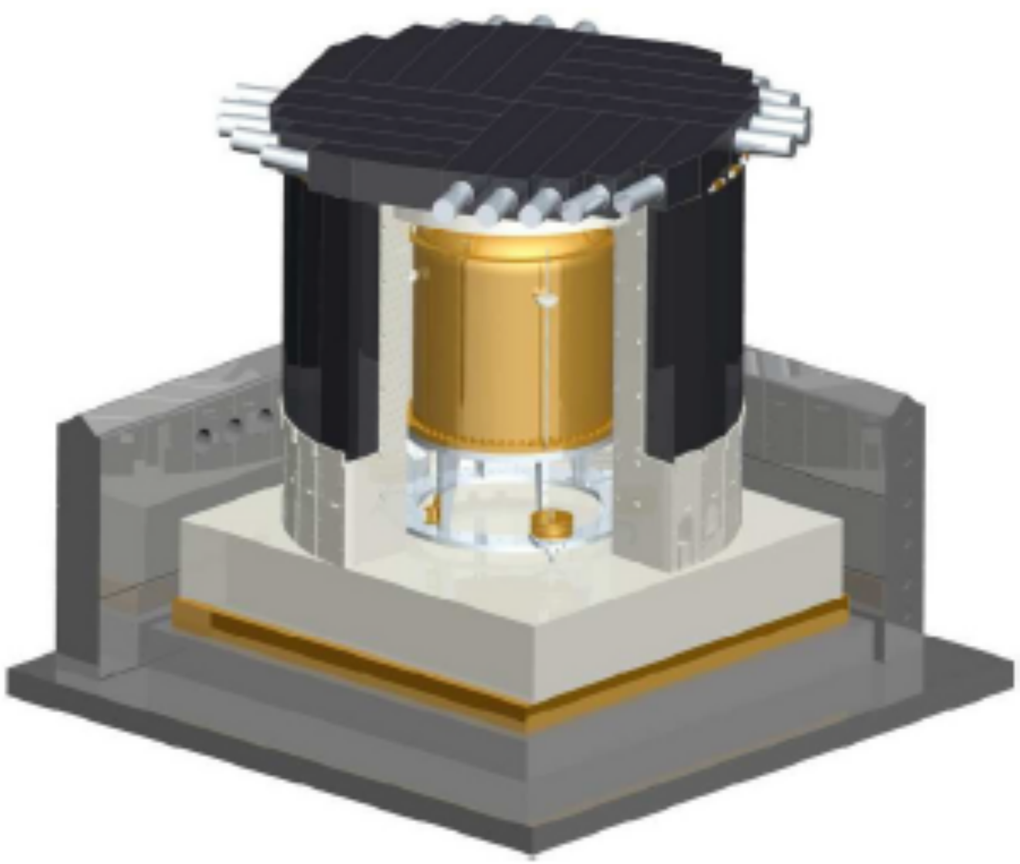
- **Preliminary tests**: ($7{\times}7{\times}7$ m^3 C_6H_{14} box), 20-100-200 MeV n

  standard GEANT4.9.5p02 (Shielding v1.0) vs. MENATE_R (for neutron interactions)

Comparison on μ-induced neutrons in ZEPLIN-III

THE UNIVERSITY of EDINBURGH

- Discrepancies highlighted by Spyrou et al. and Kohley et al., confirmed by our preliminary tests (which I didn't show…)
- Implementation of MENATE_R package into the ZEPLIN-III simulation
- Neutron production from cosmic-ray μ interactions in lead.



- L. Reichhart et al., Astroparticle Physics 47 (2013) 67
  - Agreement within 25% in the absolute number of neutrons produced,
  - Good descriptions of the resulting energy depositions within the veto.

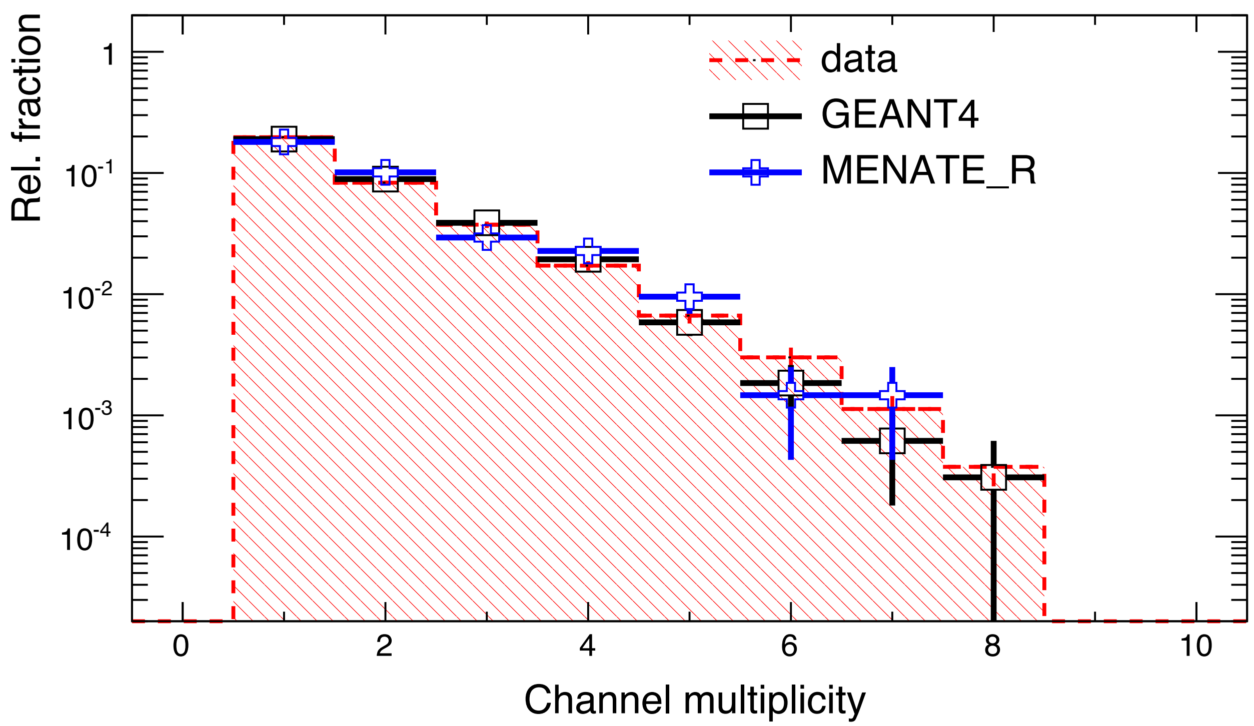
Comparison on μ-induced neutrons in ZEPLIN-III

THE UNIVERSITY of EDINBURGH

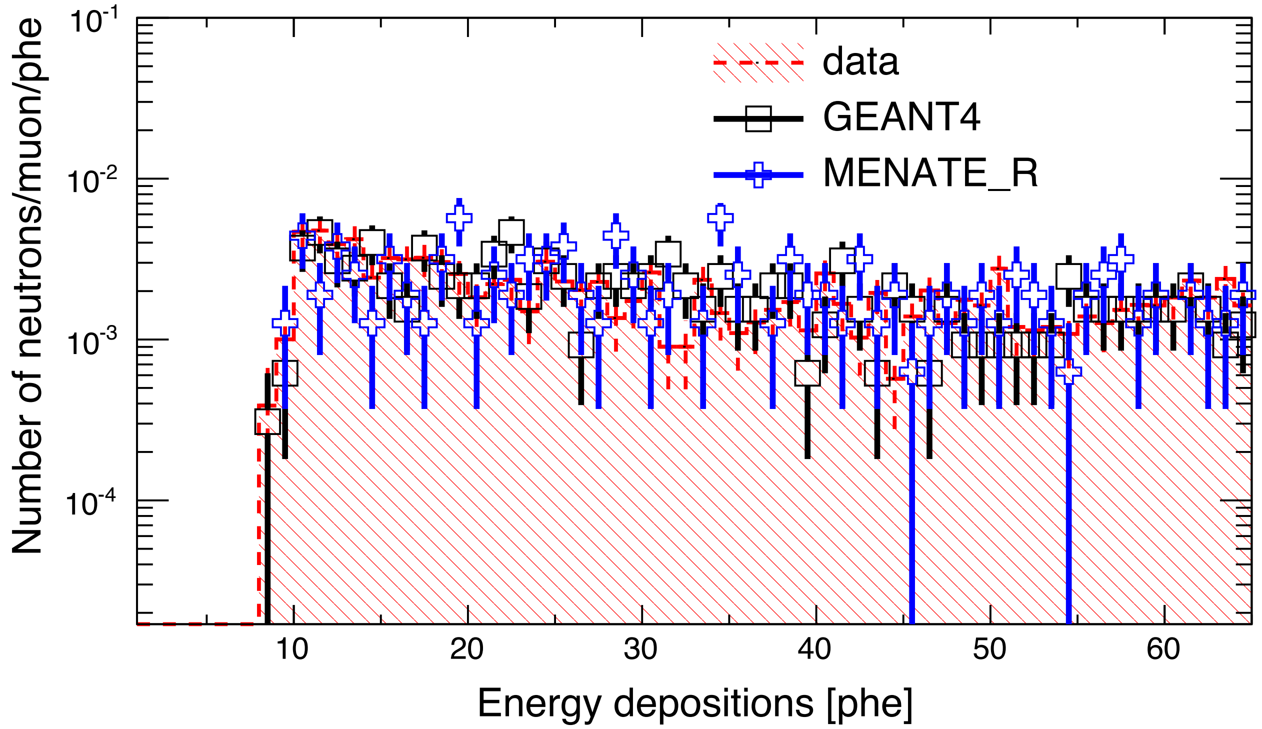
- High energy neutrons induced by cosmic-ray μ: sufficient large energy depositions in the plastic scintillators sufficiently large.
    1. Threshold of 10 photoelectron (phe) in any single scintillator block, or at least 8 phe total in two or more scintillator blocks
    2. Signals required to occur between 40 and 320 μs after the muon.
    3. A detailed description of the experimental apparatus.
    4. Cosmic-rays muons with mean energy of 260 GeV generated high-energy neutrons. Primary muon spectra and angular distributions using the MUSIC code sampled with the MUSUN. 1.5 million μ.
- ZEPLIN- III experiment - polypropylene (C_3H_6) plastic scintillator active veto - comparing a standard GEANT4.9.5p02 with a simulation incorporating MENATE_R.

Results

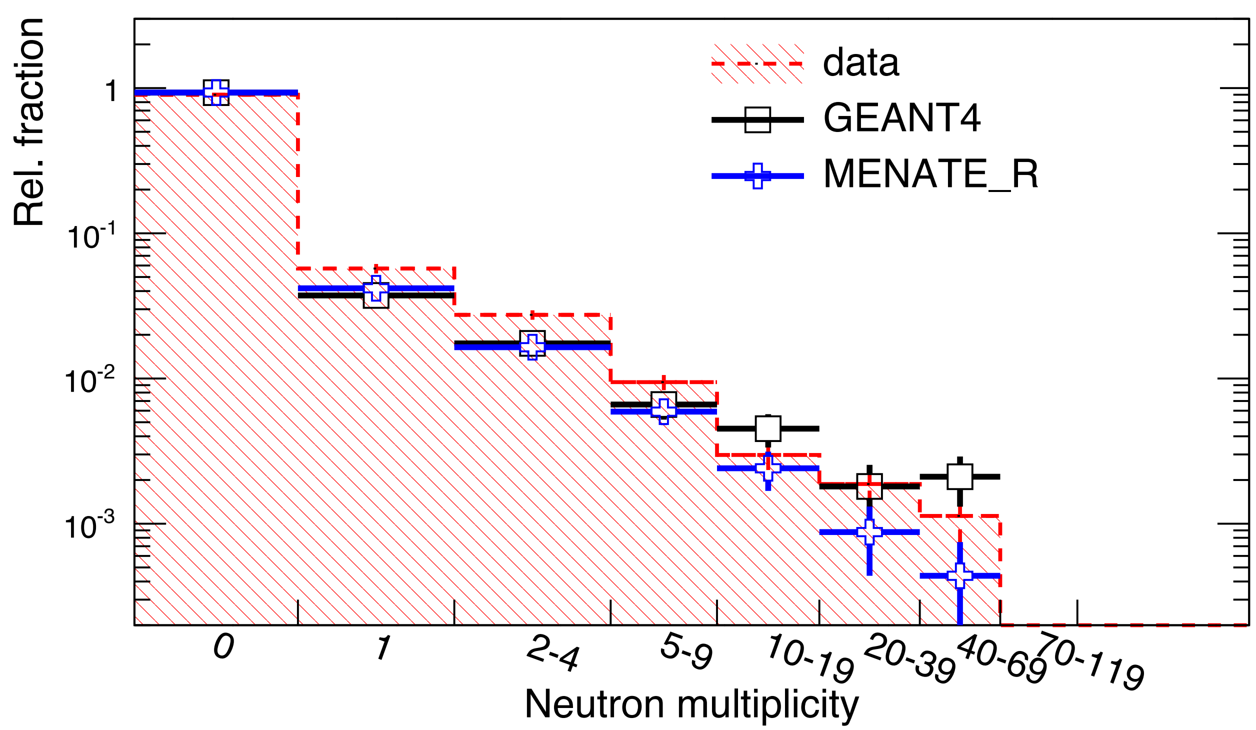
Scintillator module multiplicities



Neutron energy depositions



Neutron multiplicity per muon



Summary

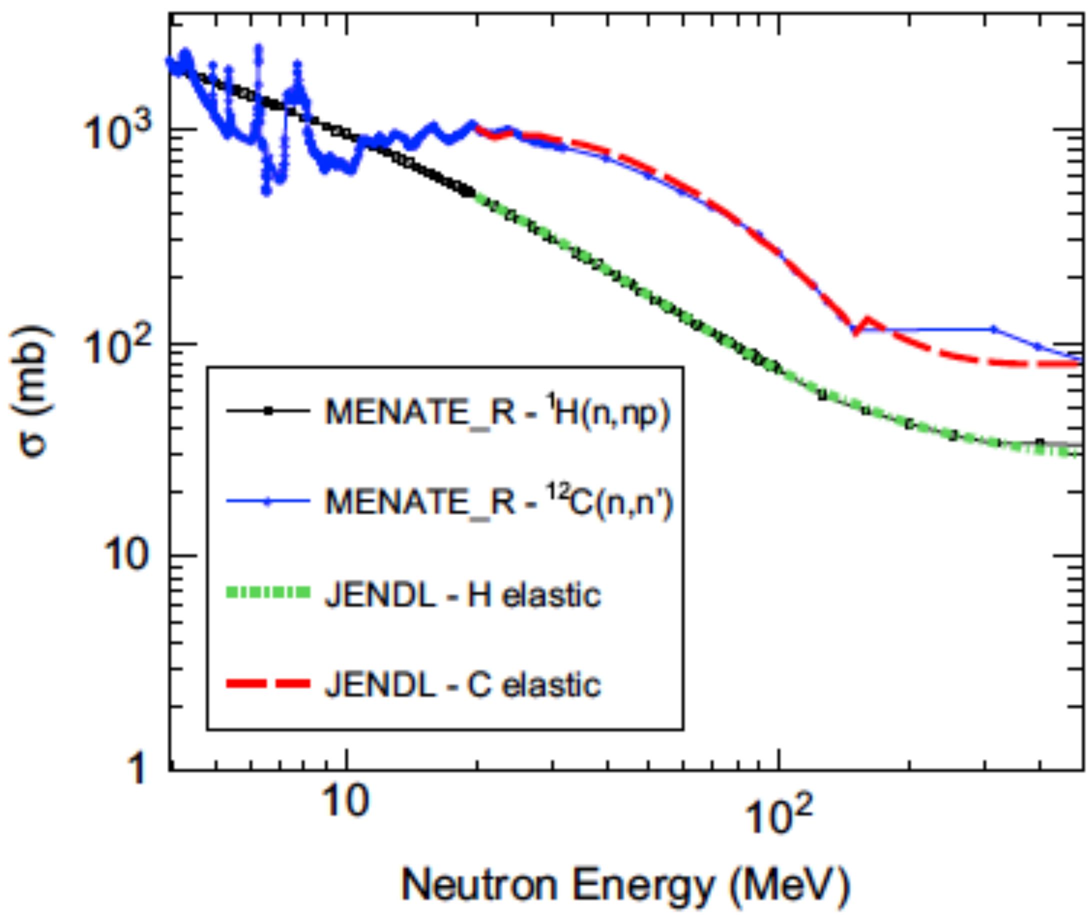
THE UNIVERSITY of EDINBURGH

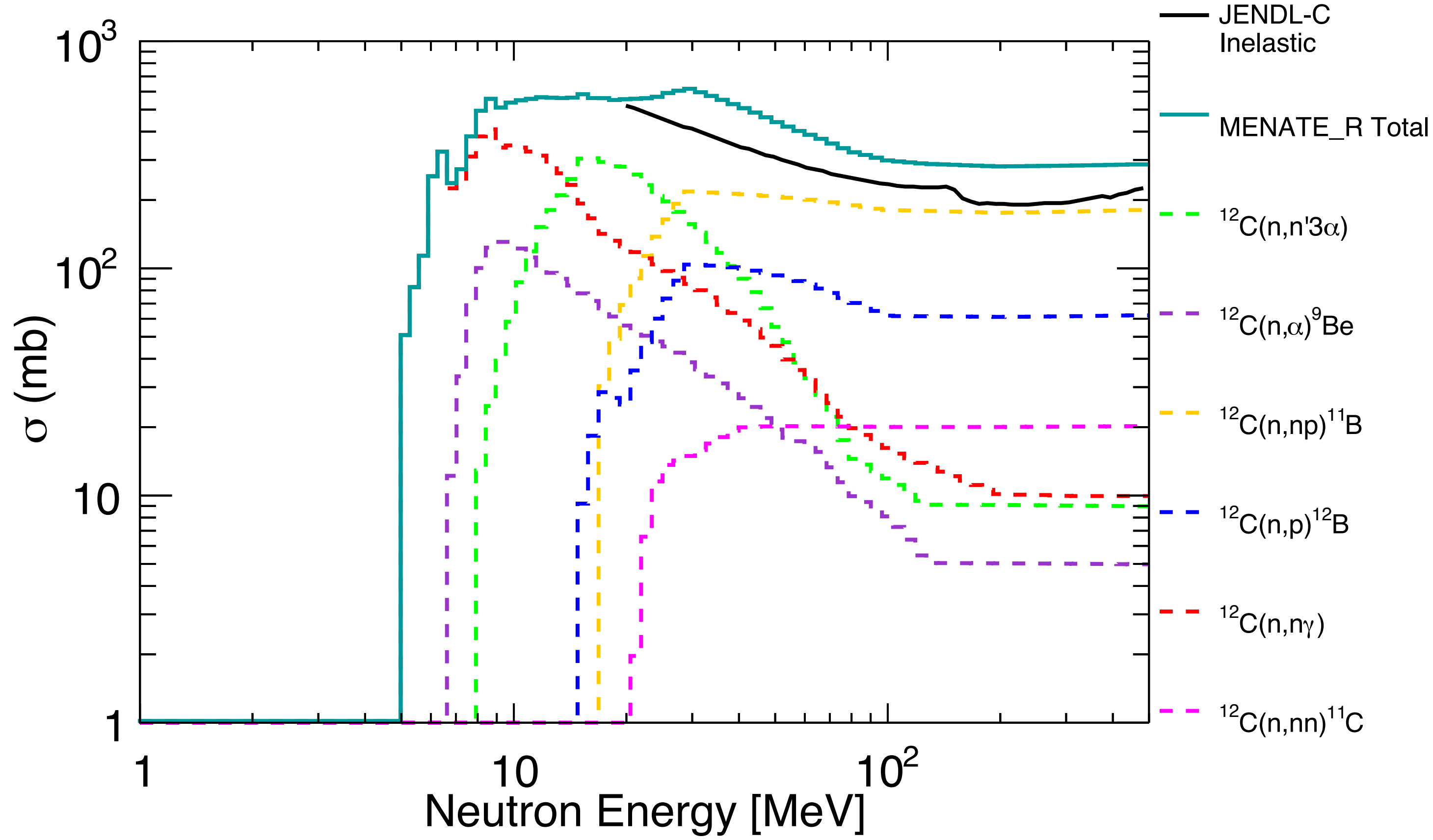
- Neutrons from cosmic-ray interactions a potential concern for rare event searches. Neutron propagation above 20 MeV uncertain.
- New MENATE_R package implemented for neutron propagation to check the impact of these uncertainties.

- MENATE_R implemented into ZEPLIN-III complete simulation - Xe target with a surrounding segmented hydrocarbon veto and outer lead shielding - exposed to μ-induced neutrons.
- We do not observe any significant differences (for the experimental observable parameters) with respect to the previous developed simulation packages.

Backup slides

GEANT4 vs. MENATE_R





Left: Cross sections for elastic scattering of neutrons with hydrogen and carbon, as implemented in MENATE_R and reproduced from the JENDL-HE library,
Right: Neutron - carbon reaction cross-sections, as a function of the incident neutron energy. MENATE_R uses the six different discrete reaction channel cross-sections while the G4-Physics package uses the total inelastic reaction cross-sections taken from the JENDL-HE library.

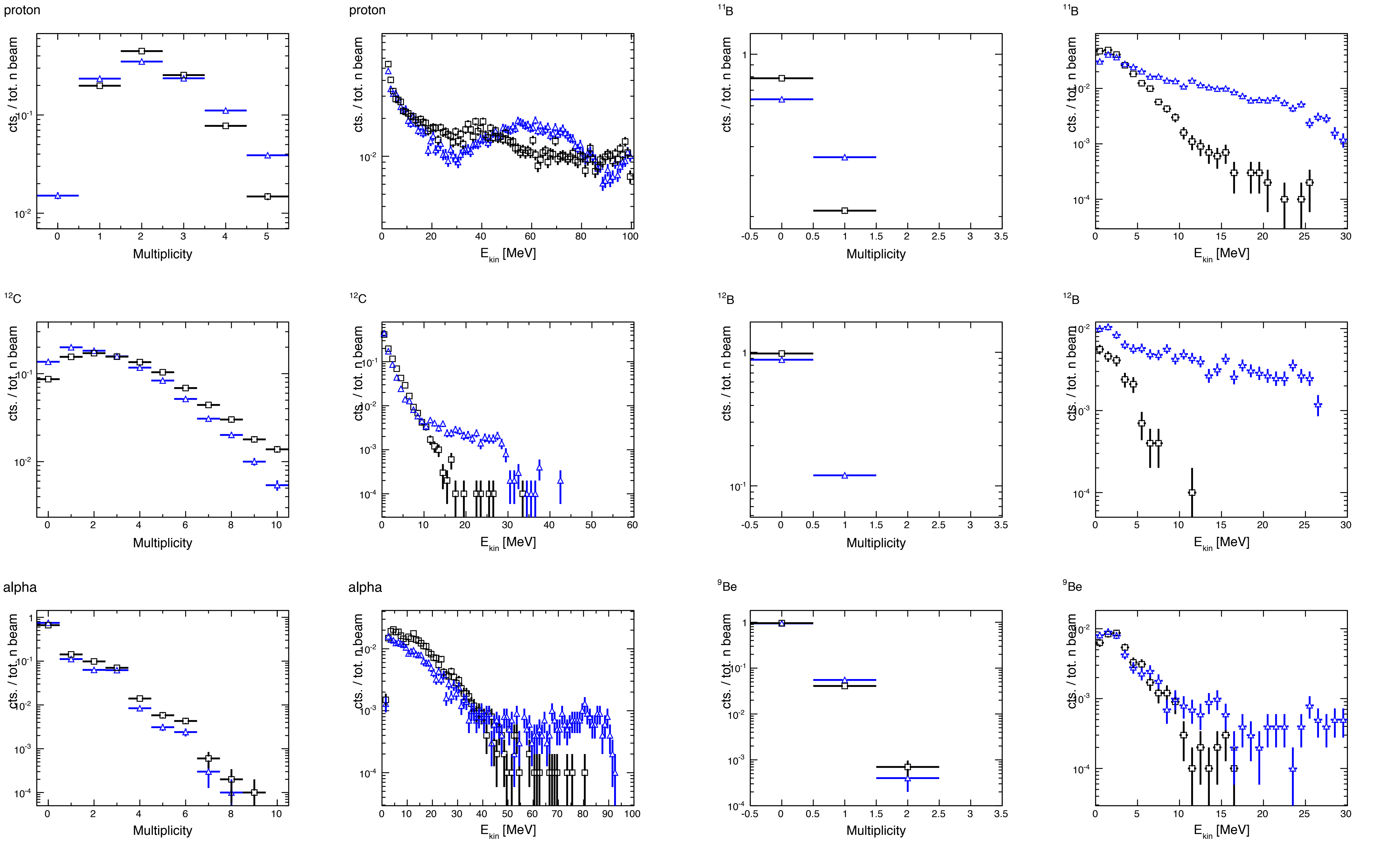
GEANT4 Physics lists

THE UNIVERSITY of EDINBURGH

- GEANT4.9.5p02 alone code the Shielding v1.0 - FTFP_BERT classes.
  - Neutron Elastic processes:
    NeutronHPElastic (0 - 20 MeV) and hElasticCHIPS (20 MeV - 10 TeV)
  - Thermal process:
    NeutronHPThermalScattering (< 4 eV).
  - Neutron inelastic processes:
    NeutronHPInelastic (< 20 MeV), BertiniCascade (20 - 5 GeV), FTFP (5 GeV - 10 TeV).
  - Neutron capture
    NeutronHPCapture (0 - 20 MeV) and by G4LCapture above.
- The NeutronHP are data driven, based on the ENDF/B-VI formats.
- Cross section databases:
  - Elastic processes: GheishaElastic, CHIPSElasticXS, NeutronHPElasticXS.
  - Thermal processes: NeutronHPThermalScatteringData.
  - Inelastic processes: GheishaInelastic, G4CrossSectionPairGG, Barashenkov-Glauber and NeutronHPInelasticXS below 20 MeV.

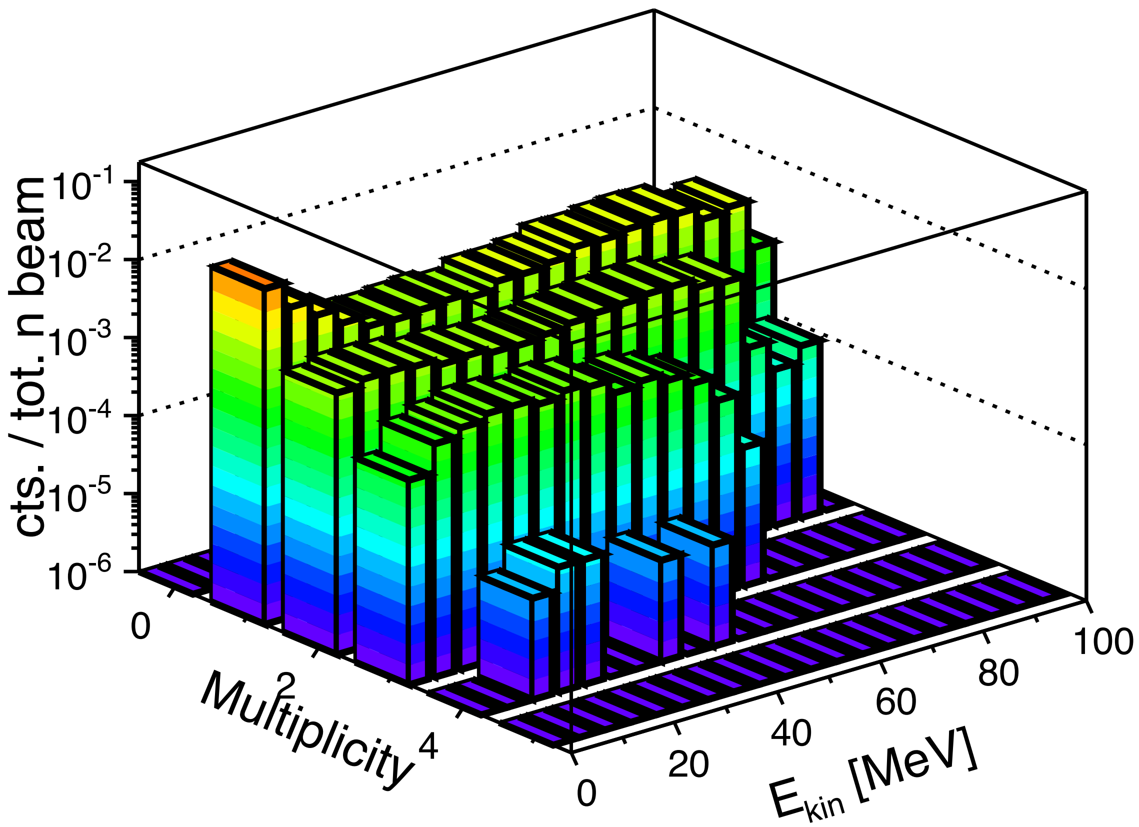
100 MeV

THE UNIVERSITY of EDINBURGH



100 MeV - neutrons

GEANT4



MENATE_R