Hadronic Physics II

Geant4 Users' Tutorial
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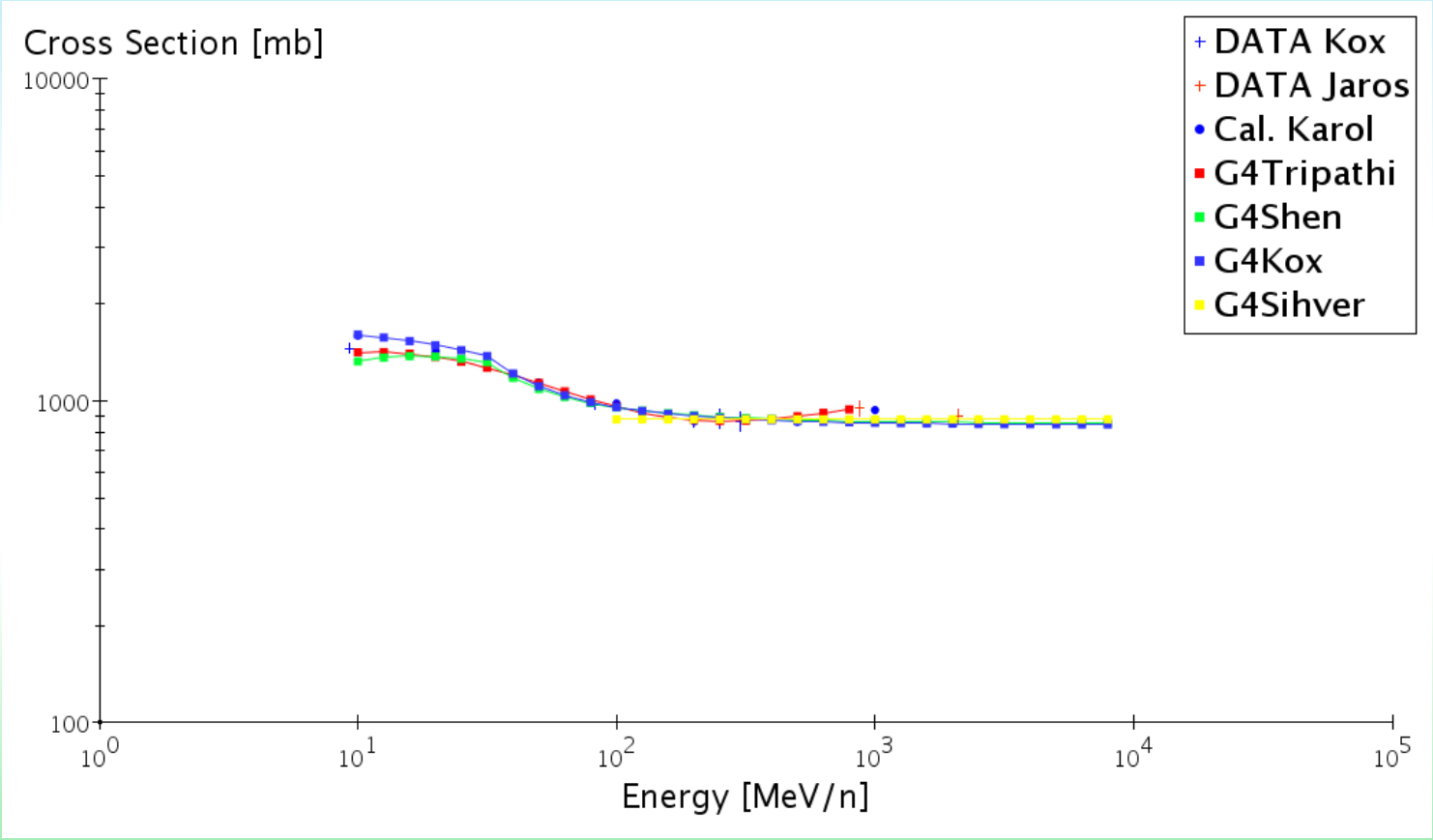
Content

- Ion Hadronic Interactions
  - Low energy: medical research
  - High energy: space applications
- Radioactive decay
- Isotope production

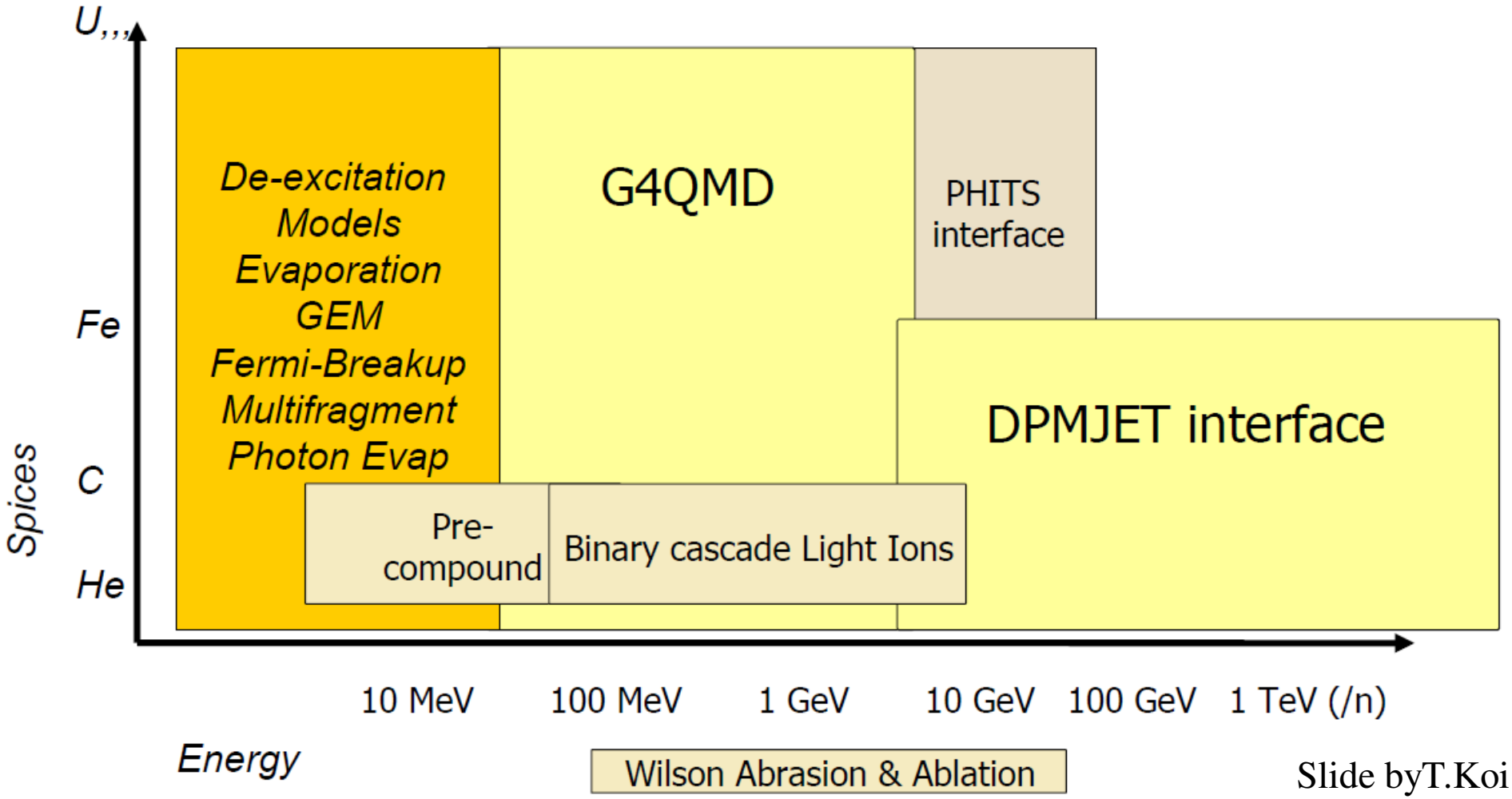
Ion Interactions

- Inelastic Nucleus nucleus
  - Cross sections
    - Parameterisations from Tripathi, Shen, Kox and Sihver
  - Final state
    - Binary light ion cascade
    - QMD (since 9.2)
    - INCL/ABLA (since 9.2)
    - Wilson Abrasion/Ablation
    - Electromagnetic dissociation
    - Interface to DPMJet at high energies
- Radioactive decay

Inelastic Cross section C12-C12



Ion Models Inventory



Slide byT.Koi

Binary Light Ion cascade

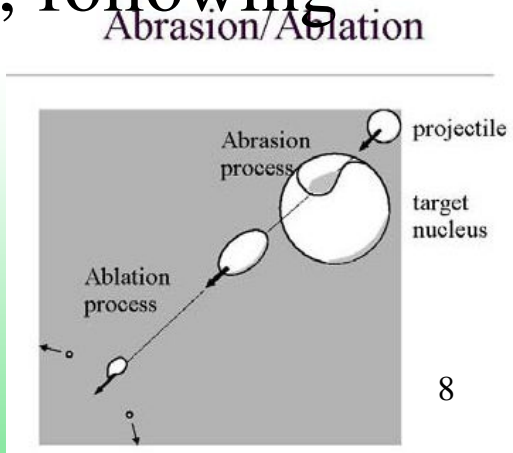
- Binary Light ion cascade is extension to Binary cascade
  - Light nucleus is modeled as a set of independent particles tracked simultanously through the heavy nucleus using Binary cascade
    - May swap projectile and target nucleus
    - De-excitation of heavy nucleus handled by pre-compound model
  - At interaction, Fermi momentum and binding is taken into account
  - Unscattered nucleons of light nucleus form fragment, excitation energy estimated by hit nucleons, fragment undergoes de-excitation
- Validity: 0-10 GeV/nucleon, light nucleus

Quantum Molecular Dynamics

- Quantum Molecular Dynamics is quantum extension of classical molecular-dynamics model.
  - Each nucleon is seen as a Gaussian wave packet
  - Propagation with scattering term taking into account Pauli blocking
  - QMD model is widely used to analyze various aspects of heavy ion reactions.
  - Nuclear fragments de-exciated using GEM evaporation
- Validity: 0-10 GeV/nucleon

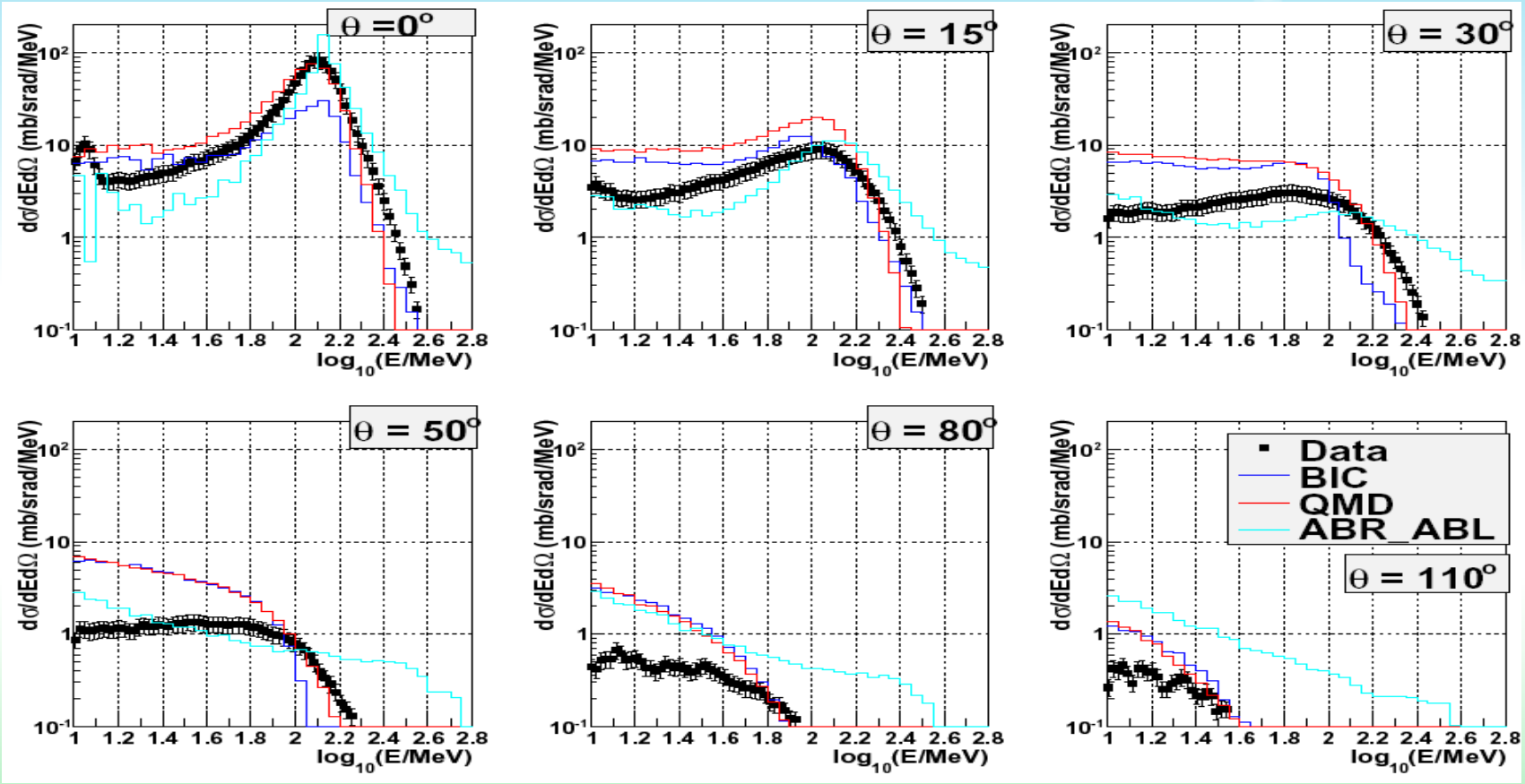
Geant4 Wilson Abrasion/Ablation

- Abrasion is simplified macroscopic model based largely on geometric arguments
  - Faster
- Validity range 70 MeV/nucleon – 10 GeV/nucleon
- Ablation models nuclear de-excitation, following NUCFRG2 (NASA TP 3533)



Ion model results

C + C → n + X at 135 MeV/nucleon



Data: H.Sato et al., Phys. Rev. C, 64, 054607 (2001)
Measurements of double differential neutron production cross sections by 135 AMeV He, C, Ne, and 95 AMeV Ar ions

Plots by Cirrone, Cuttone and the LNS-INFN Geant4 Group

Electromagnetic Dissociation

- Liberation of nucleons or nuclear fragments as a result of electromagnetic field
  - exchange of virtual photons, rather than the strong nuclear force
  - important for relativistic nuclear-nuclear interaction, especially for high Z nuclei
- G4EMDissociation model and cross section are an implementation of the NUCFRG2 (NASA TP 3533) physics
- Validity: $0 < E < 100$ TeV

Interface to DPMJet-II.5

- DPMJet is external code
  - 5 GeV/nucleon to very high energies (1 PeV/nuc)
  - Applicable to all nuclei as projectile and target
  - Models prompt, high energy part of interaction
- Geant4 provides interface to DPMJet-II.2
  - Nuclear de-excitation using G4Precompound
    - User can override this
- DPMJet requires Glauber profile data
  - Integral probability function used to sample impact parameter
  - Current set up to A=58, for both projectile and target
- Work in progress

Radioactive Decay

- Decay of radioactive nuclei by α, e^-, e^+, or electron capture from K and L shell.
  - Followed by gamma de-excitation
- Radioactive daughter products are decayed, ie decay chains are handled
- Data derived from Evaluated Nuclear Structure Data File (ENSDF)
  - Nuclear half-lives, level structure, nuclear decay branching ratio, Q-value of decays
- Biasing techniques available
  - Decay time distributions function can be supplied
  - Splitting prior to decay
  - Biasing of branching ratios

Isotope production model

- Low energy (< 100 MeV) proton/neutron induced isotopeproduction
  - parasitic to the transport models.
  - Data driven model, using data IsotopeProduction data in G4NDL

Exercise 5.b

- Compare hadronic and EM showers