Ion-ion Physics in Geant4

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Outline

- Introduction and Motivation
- Cross sections
- Existing models
- New Models
- Interfaces to external models

Introduction

- Early in Geant4 there were a few models for nucleus-nucleus collisions which covered a limited range of projectile energies and Z and A
- Driven by user requests, Geant4 has developed and continues to develop models to cover this need
- These requests were met in three ways:
  - translation of existing Fortran code into C++
  - creation of C++ interfaces to Fortran code
  - development of new models native to Geant4

Cross Sections for NN Collisions

- Several NN cross section data sets are included in Geant4
  - cover interaction energies from 10 MeV/n – 10 GeV/n
  - these come from empirical and parameterized formula with theoretical insights
  - no single cross section set covers all energies and all A
- G4GeneralSpaceNNCrossSection
  - designed to automatically select correct cross sections set
  - useful for new users

Cross Sections for NN Collisions

- Tripathi general
  - energy range: 10 MeV/n – 1 GeV/n
  - all A
- Tripathi light
  - energy range: 10 MeV/n – 1 GeV/n
  - specialized for d, t, ^{3}He, α projectiles (or targets)
- Shen, Kox
  - energy range: 10 MeV/n – 10 GeV/n
  - all A
- Sihver
  - energy range: > 100 MeV/n
  - all A

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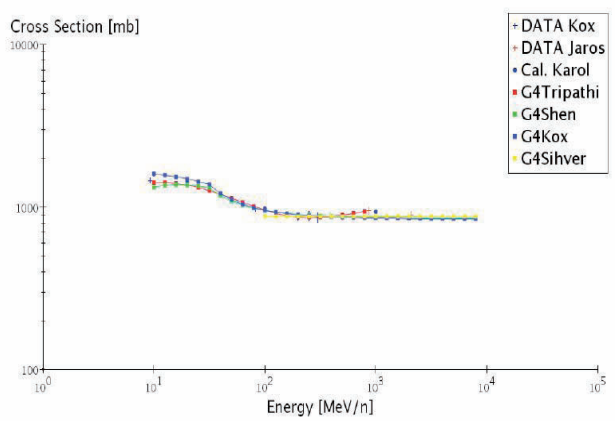
Cross Sections for NN Collisions



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Binary Light Ion Reaction

- G4BinaryLightIonReaction is an extension of the G4 binary cascade model
  - valid from 80 MeV to 10 GeV/n
- Model details
  - Two 3-dimensional nuclei with Fermi momentum sampling
  - nucleus-nucleus interaction simulated by individual nucleon-nucleon collisions and subsequent cascade
- Model limitations
  - interactions between participants ignored => these become important when nuclear mass increases
  - cascade models general not valid above 5 – 10 GeV

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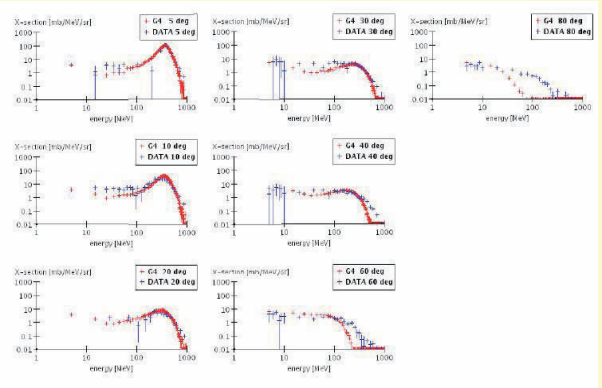
Binary Light Ion Reaction

- Neutrons from 400 MeV/n Ne20 on C
  - data in blue, model prediction in red



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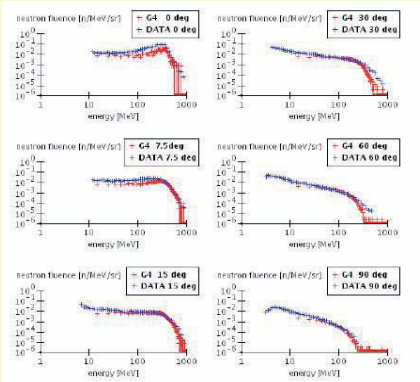
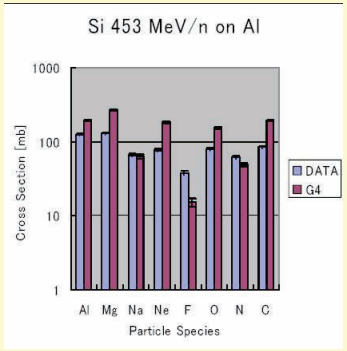
Binary Light Ion Reaction

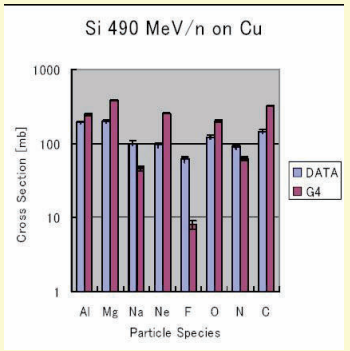
- Neutrons from 400 MeV/n Fe on Pb
  - data in blue, model prediction in red



Binary Light Ion Reaction

- Nuclear fragment production

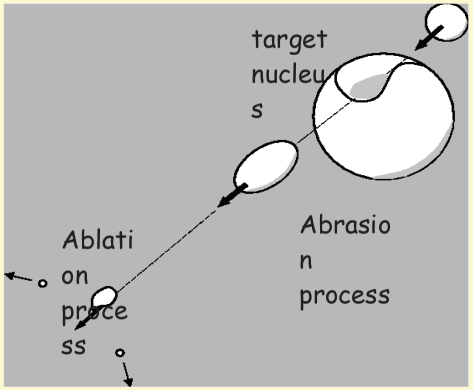




Wilson Abrasion and Ablation Models

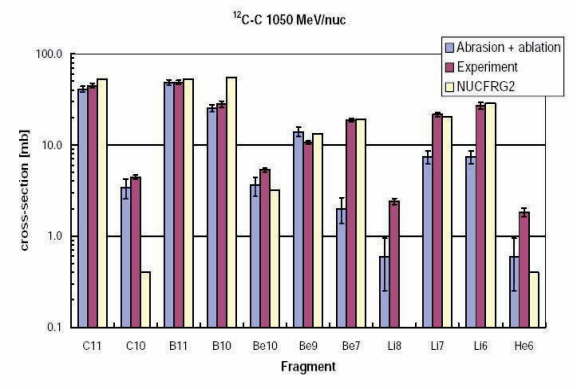
- G4WilsonAbrasion and ablation models are a simplified macroscopic model of nucleus-nucleus interactions
  - based largely on geometrical arguments
  - abrasion part handles initial nucleus-nucleus collision
  - ablation part handles de-excitation of nuclear fragment
  - valid from 70 MeV/n – 10 GeV/n
- Model features
  - fast, due to macroscopic nature of code
  - not much detail: energy distributions of secondary nucleons no well-described

Wilson Abrasion and Ablation



G4WilsonAbrasion and Ablation

- Nuclear fragment production



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Electromagnetic Dissociation Model

- Models the liberation of nucleons or nuclear fragments as a result of virtual photon exchange from electromagnetic field
  - important for relativistic nucleus-nucleus interactions
  - G4 model is an implementation of the NASA NUCFRG2 model
  - valid from 100 MeV/n – 500 GeV/n
  - valid for all nuclei, but especially important for high Z
- Model features
  - uses cross section table to get probability to produce fragment (Z,A)
  - uses detailed G4 de-excitation codes to handle excited fragments and target residual

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Validation of G4EMDissociaton Model

Target Emulsion nuclei: Ag 61.7%, Br 34.2%, CNO 4.0% and H 0.1%

Projectile	Energy [GeV/nuc]	Product from ED	G4EM Dissociation [mbarn]	Experiment [mbarn]
Mg-24	3.7	Na-23 + p	124 ± 2	154 ± 31
Si-28	3.7	Al-27 + p	107 ± 1	186 ± 56
	14.5	Al-27 + p	216 ± 2	165 ± 24† 128 ± 33‡
O-16	200	N-15 + p	331 ± 2	293 ± 39† 342 ± 22*

M A Jilany, *Nucl Phys*, **A705**, 477-493, 2002

Geant4 Tutorial Course 2007

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Native Geant4 QMD Model

- New Geant4 model for nucleus-nucleus collisions
- See talk by T. Koi

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Interfaces to External Codes

- Geant4 nucleus-nucleus codes do not currently provide detailed spectra for projectile energy above ~5 GeV/n
- Several Fortran codes outside of Geant4 do
- Use C++ interface to Fortran codes to make these available to Geant4 users
  - current Geant4 policy is that these interfaces are not distributed with Geant4 release
  - users can get them by permission of author

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DPMJET Interface

- DPMJET treats hadron-nuclear and nuclear-nuclear interactions from 5 GeV/n up to about 1000 TeV
  - capability requested of Geant4 by simulators of cosmic rays and cosmic ray backgrounds
  - Fortran code for v2.5 (J. Ranft) is publicly available
  - no native Geant4 code covers such high energies -> develop interface to existing Fortran code
- Interface to Geant4 being developed by Qinetiq under the ESA MarsREM contract
  - will be specifically developed for nucleus-nucleus collisions
  - ready sometime in 2008

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WP1 DPMJET-2.5 & DPMJET-3

- Two versions currently available, both of which treat nuclear-nuclear interactions:
  - DPMJET-2.5 (Johannes Ranft) - source code publicly released
  - DPMJET-3 (Stefan Roesler) - access to source controlled by Roesler
- Both versions of DPMJET available in FLUKA-2006, but distributed as compiled libraries
- A version of DPMJET-II.5 has been implemented as the model G4DPMJET2_5Model and is being tested. There have been challenges:
  - Very limited documentation on the code, none covering explanation of design / organisation
  - How to handling Glauber data generated as a part of the DPMJET-II.5 initialisation process

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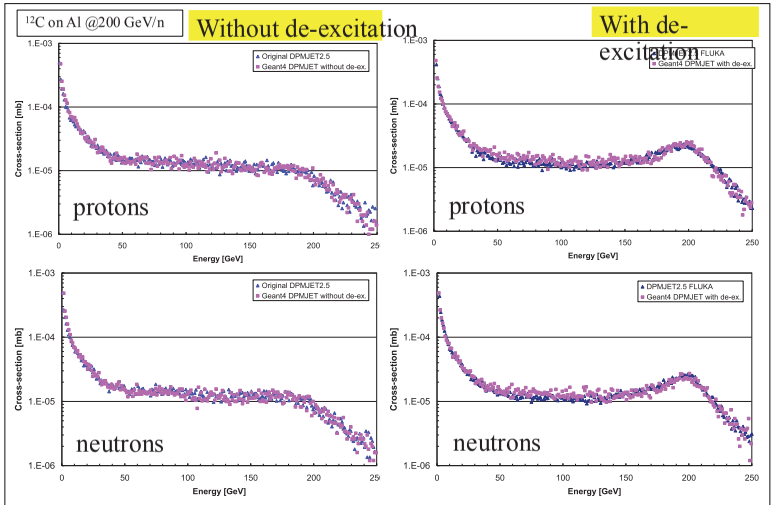

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JQMD-Phits Interface

- See talk by T. Koi

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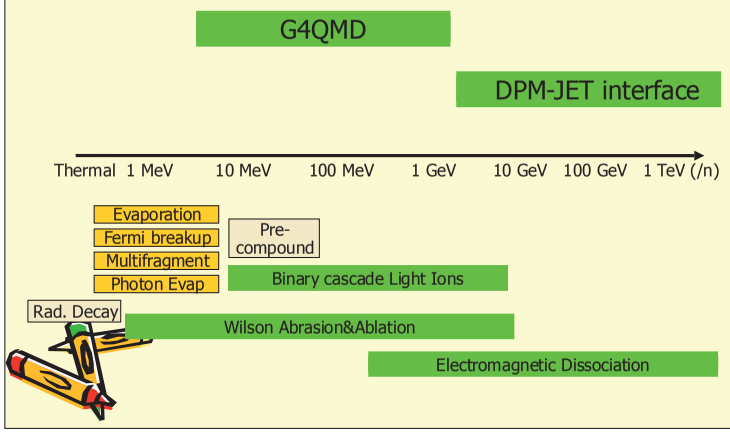
Ion Models Inventory



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Summary

- We are making an attempt to cover all energies in ion-ion collisions
  - using existing Geant4 models
  - using interfaces to external models
  - developing new models
- A number of cross section data sets are already provided to cover these energies
- Special attention is being paid to validation of nuclear fragment production

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