QMD
and
Low Energy Neutron Development

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QMD

Forward Angle Spallation

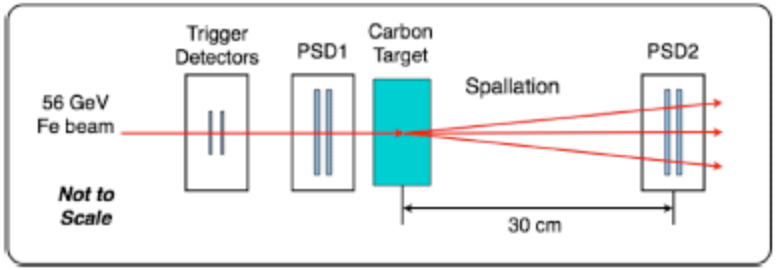


Fig. 1. Experimental setup for Zeitlin et al. [7] experiment. The trigger and PSD1 detectors are for measuring the energy and timing of the Fe ions, and the PSD2 detectors measure the energy deposition from the nuclear fragments.

M.A. Clemens et al.,
IEEE TRANS, VOL. 56, 3158 (2009)

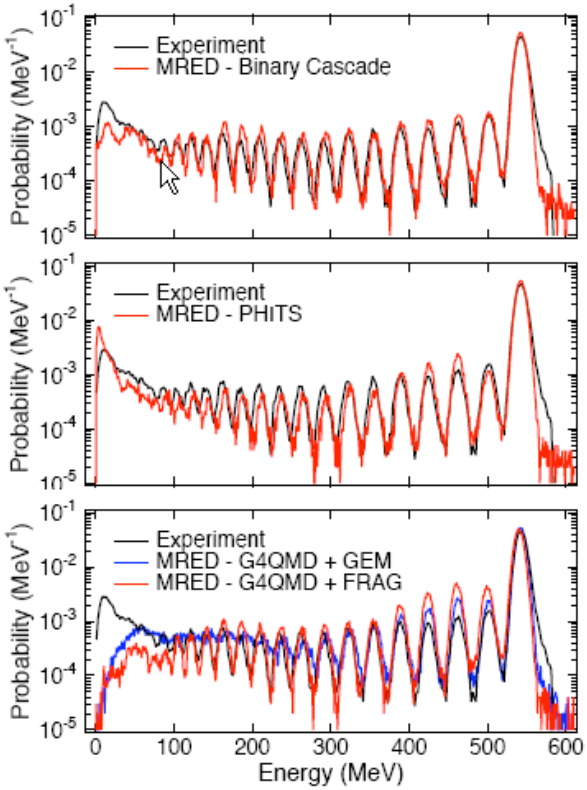
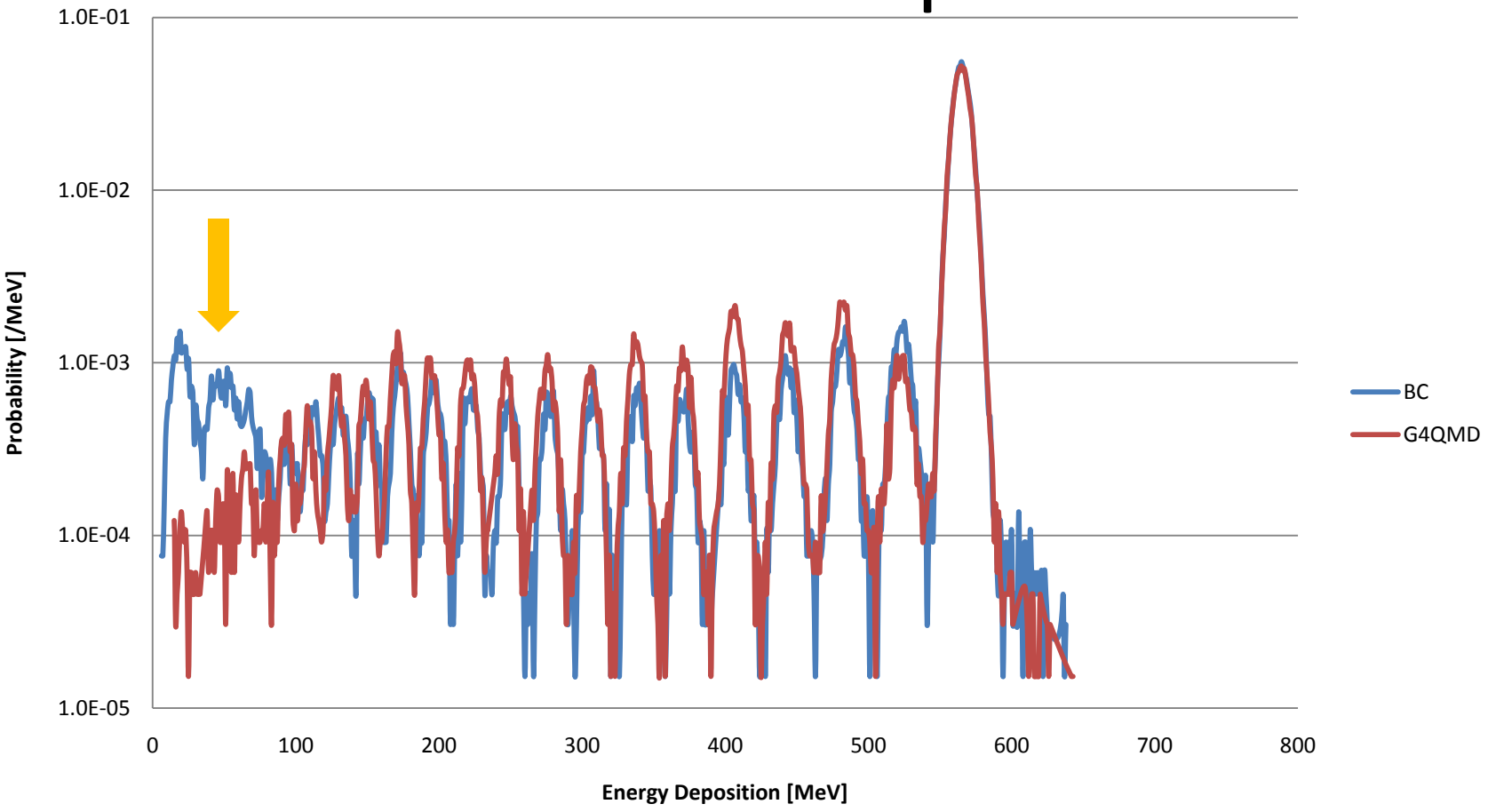
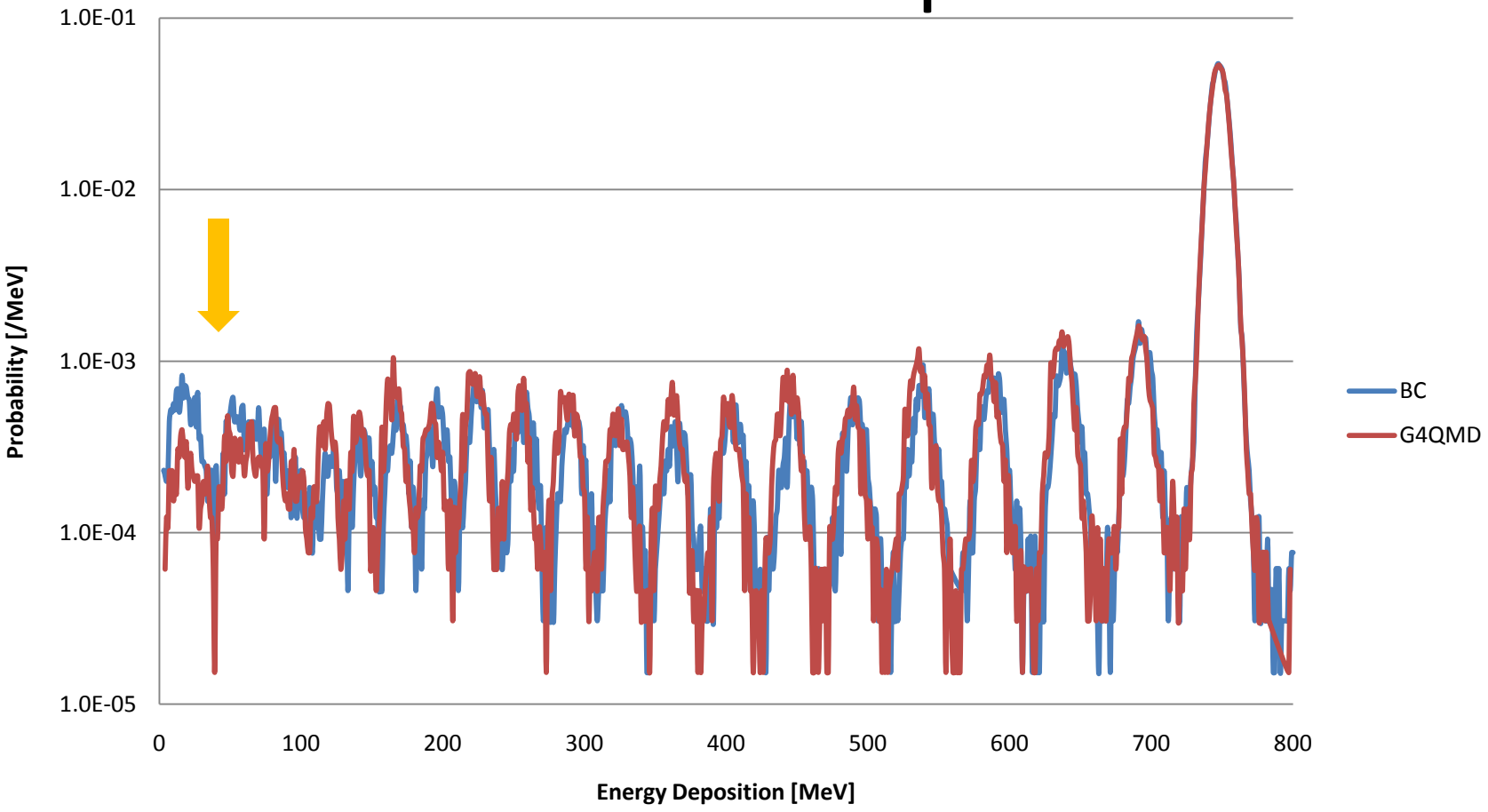


Fig. 2. Histogram of Zeitlin et al. experiment [12] and MRED simulations using the binary light-ion cascade model (top), The PHITS model (middle), and the G4QMD (bottom) with the GEM and Frag models. The rightmost peak corresponds to Fe ions, and each lower energy peak corresponds to lower Z fragments.

Forward Angle Spallation 1GeV/n 56Fe on Carbon Geant4 v.9.3.p01



Forward Angle Spallation 500MeV/n 56Fe on Carbon Geant4 v.9.3.p01



Indicate non covariant kinematics caused this trouble

Lorentz covariant dynamics approach (1)

- 8N-dimensional phase space

  6N configuration- and momentum-space + 2N Eigen time and energy
- Physical events are described as world lines in the 6n-dimensional phase space
- 8N-dimensional phase space should be constrained 2n-1 degree of freedom and have 6N+1(grobal timeτ) degree of freedom

- N mass-shell constraints

$$H_i = p_i^2 - m_i^2 - V_i = 0$$

- And N-1 constraints which connect the relative times of the particles

$$\chi_i = \sum g_{ij}\, p_{ij}\, q_{ij} = 0$$

$$q_{ij} = q_i - q_j^{j \neq i}, \quad p_{ij} = p_i + p_j, \quad g_{ij} = \exp\left(q_{ij}^2 / L \right) q_{ij}^{-2}$$

Lorentz covariant dynamics approach (2)

- Hamiltonian

$$H = \sum_{i=1}^{N} \lambda_i H_i + \sum_{i=1}^{N-1} \delta\mu_i \chi_i$$

- Equations of motion

$$\frac{dq_j}{d\tau} = \frac{\partial H}{\partial p_j} = 2\lambda_j p_j - \sum_{i=1}^{N} \lambda_i \frac{\partial V_i}{\partial p_j}$$

$$\frac{dp_j}{d\tau} = -\frac{\partial H}{\partial q_j} = \sum_{i=1}^{N} \lambda_i \frac{\partial V_i}{\partial q_j}$$

with the coefficients λ_i

Lorentz covariant dynamics approach (3)

- And λ_i is

$$\lambda_j \approx -\frac{\partial \chi_N}{\partial \tau} S_{Ni}$$

$$\left(S^{-1}\right)_{ij} \equiv \left\{H_i, \chi_j\right\}_{\text{Poisson bracket}}$$

- In order to solve the equations of motion one needs to calculate the coefficients λ_i. For their calculation the matrix S^{-1} must be inverted.

Reference

Poincaré invariant Hamiltonian dynamics: Modelling multi-hadronic interactions in a phase space approach, H. Sorge, H. Stocker and W. Greiner *Ann. Phys*. **192**, 266 1989

Microscopic Models for Ultrarelativistic Heavy Ion Collisions S. A. Bass et al., *Prog. Part. Nucl. Phys*. **41**, 225 1998

However, recently developer of JQMD group published a new paper

- “In high-energy reactions, two-body collisions are dominant; the purpose of the Lorentz-covariant formalism is only to describe relatively low-energy phenomena between particles in a fast-moving medium. Therefore, we assume a simpler form for the time fixations, namely we set the time coordinates of all the particles to be the same. “

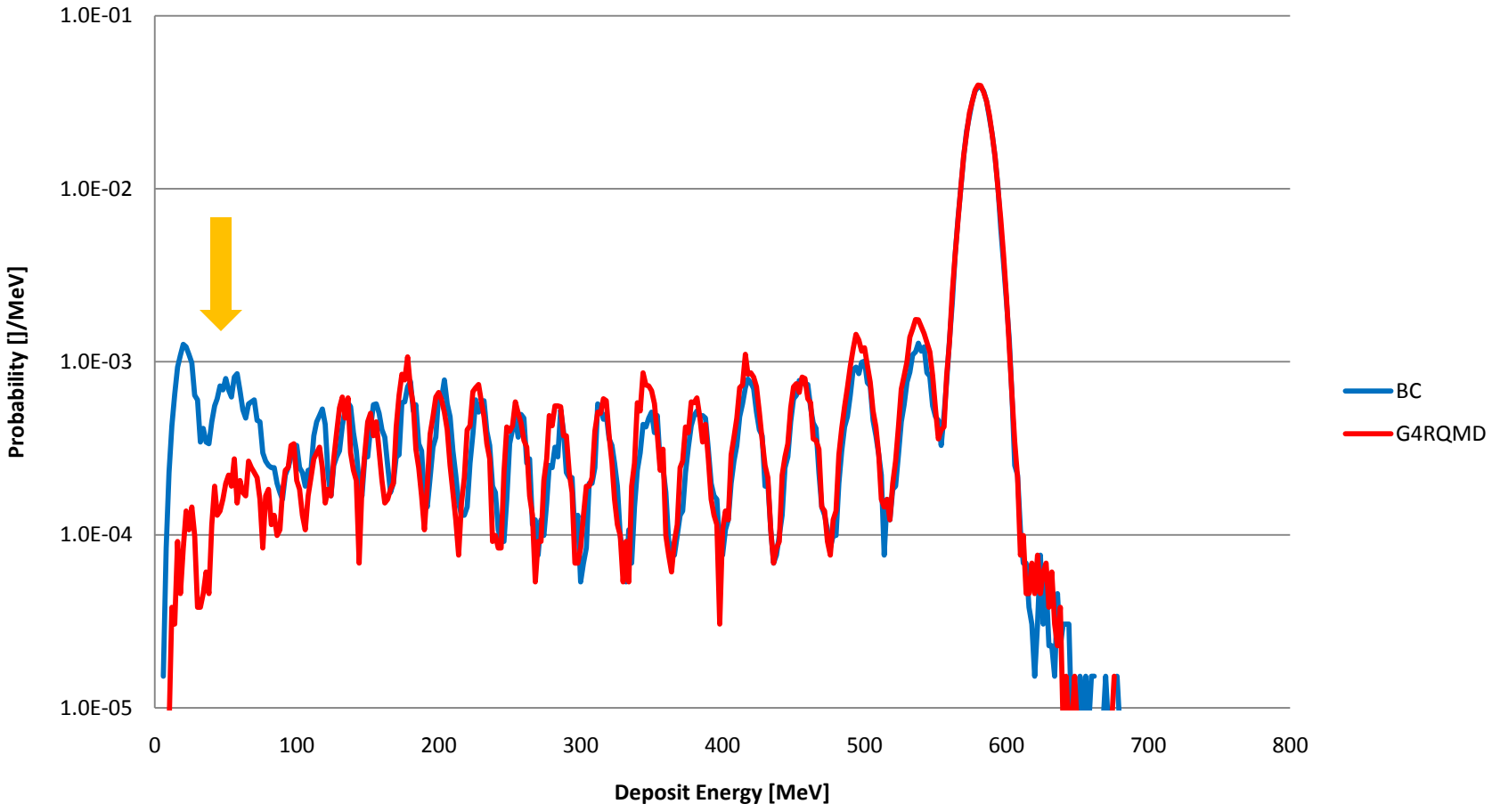
$$\phi_{i+N} \equiv a \cdot (q_i - q_N) \quad (i = 1,2,,,,N-1)$$

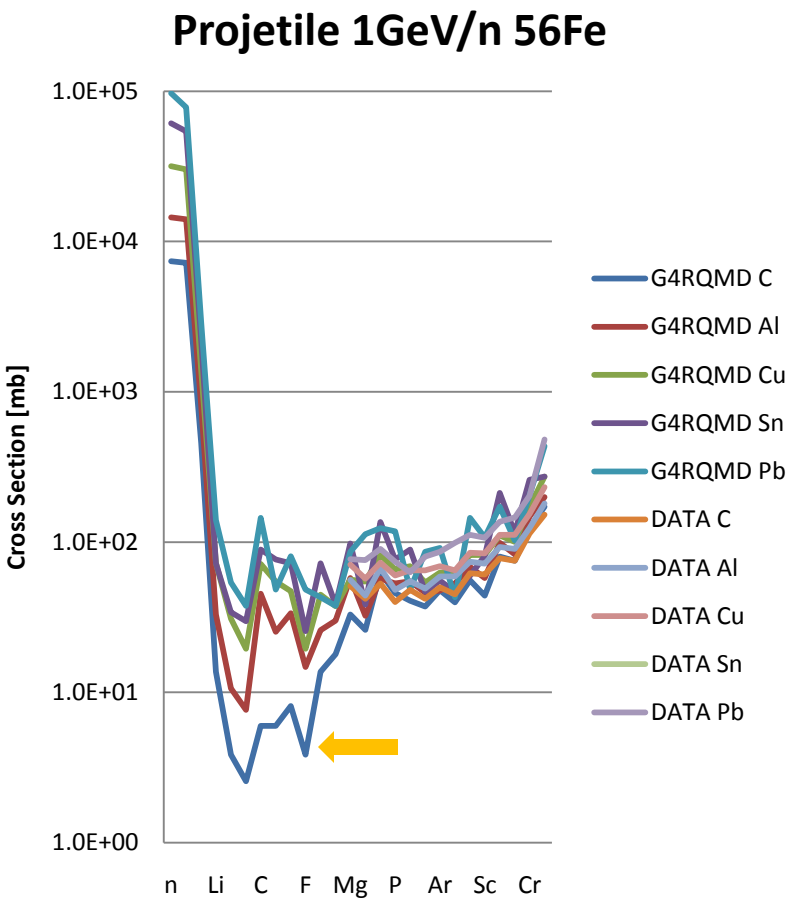
$$\phi_{2N} \equiv a \cdot q_N - t$$

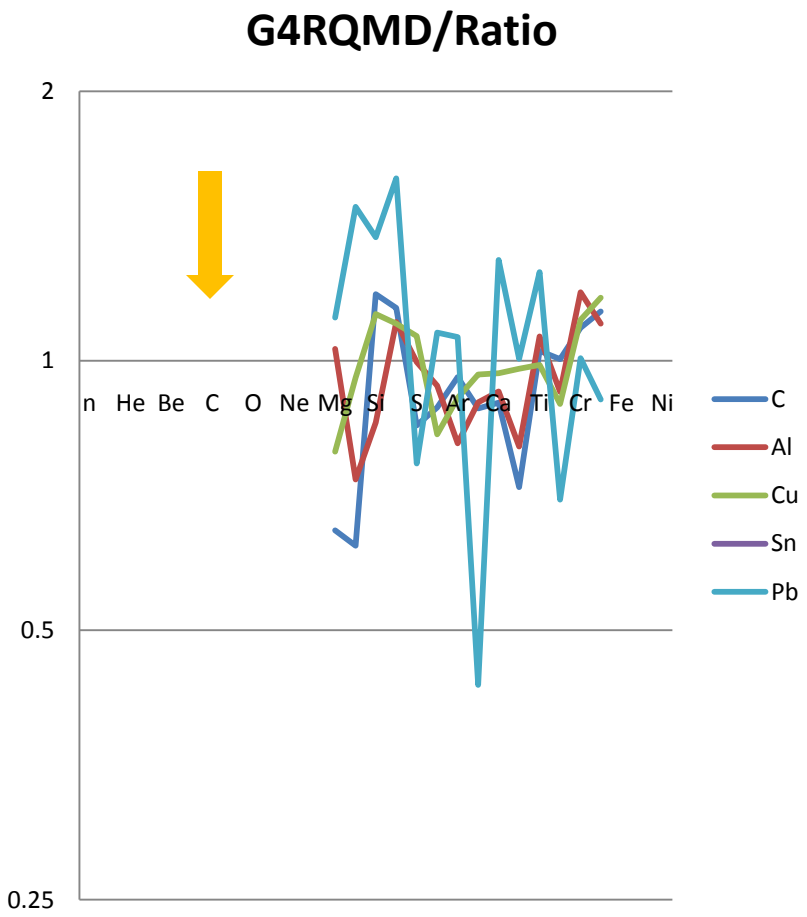
- the invert matrix S is not required

D. M ancusiet al., “Stability of nuclei in peripheral collisions in the JAERI quantum molecular dynamics model”
PHYSICAL REVIEW C 79, 014614 (2009)

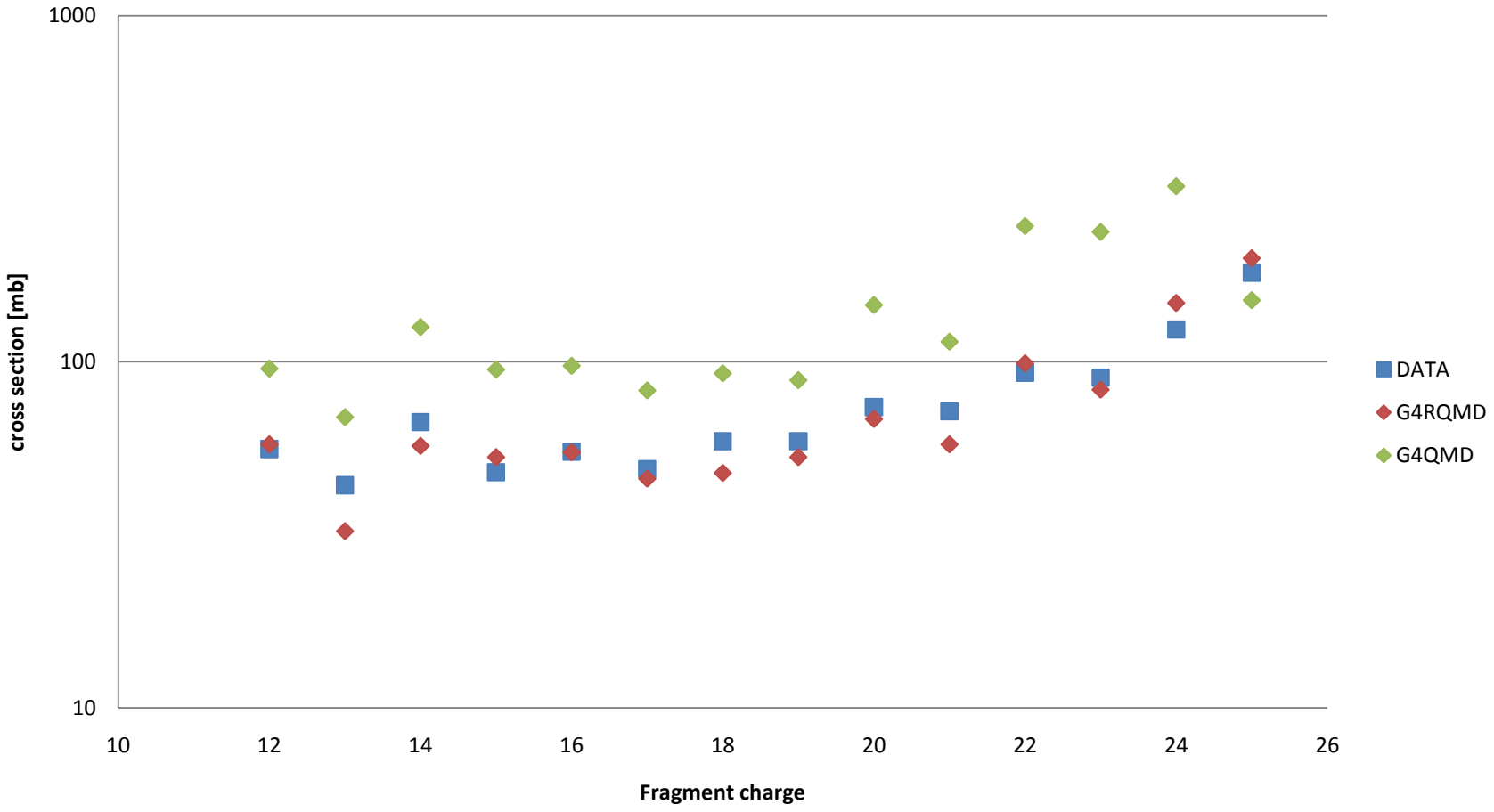
Forward Angle Spallation 1GeV/n 56Fe on Carbon




Projetile 1GeV/n 56Fe
Cross Section [mb]
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
n Li C F Mg P Ar Sc Cr
G4RQMD C
G4RQMD Al
G4RQMD Cu
G4RQMD Sn
G4RQMD Pb
DATA C
DATA Al
DATA Cu
DATA Sn
DATA Pb


G4RQMD/Ratio
2
1
0.5
0.25
n He Be C O Ne Mg Si S Ar Ca Ti Cr Fe Ni
C
Al
Cu
Sn
Pb

Fe 1GeV/n on Al



Fe 1GeV/n on Al

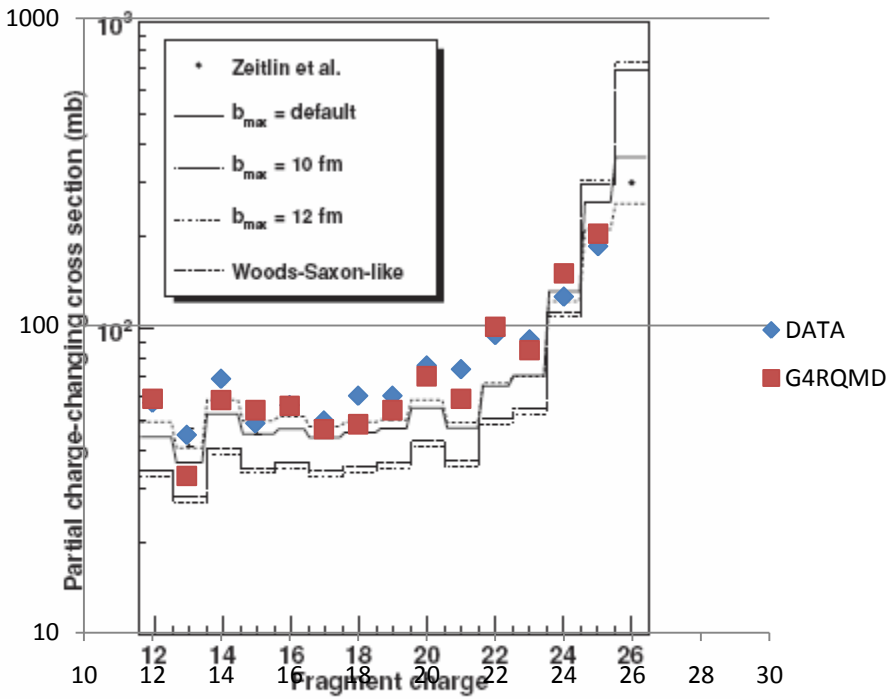
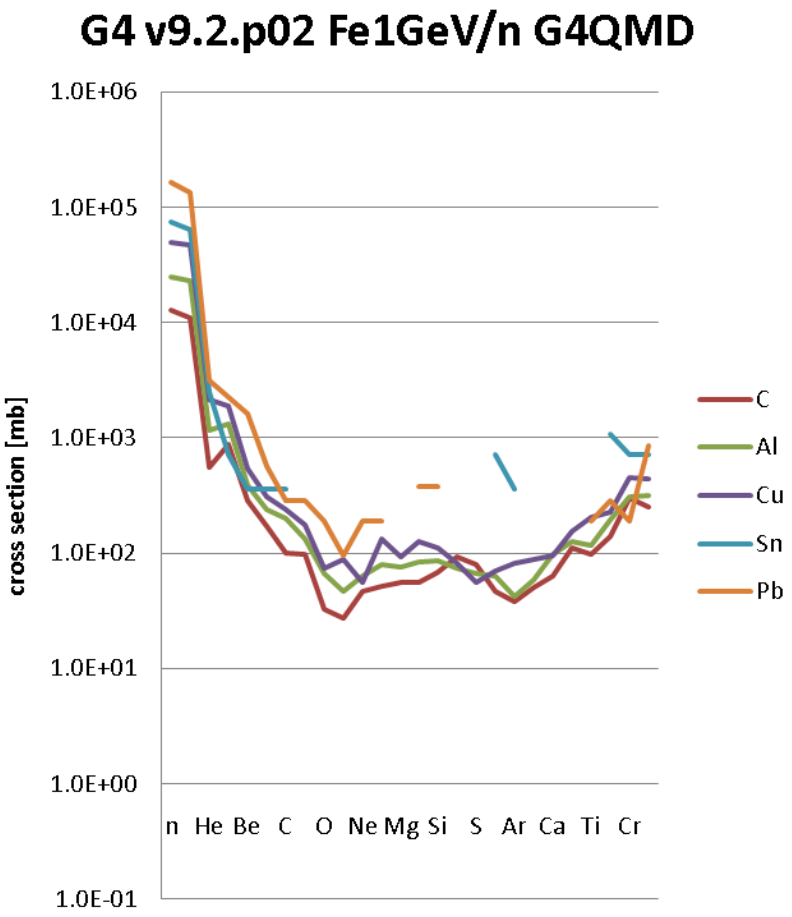
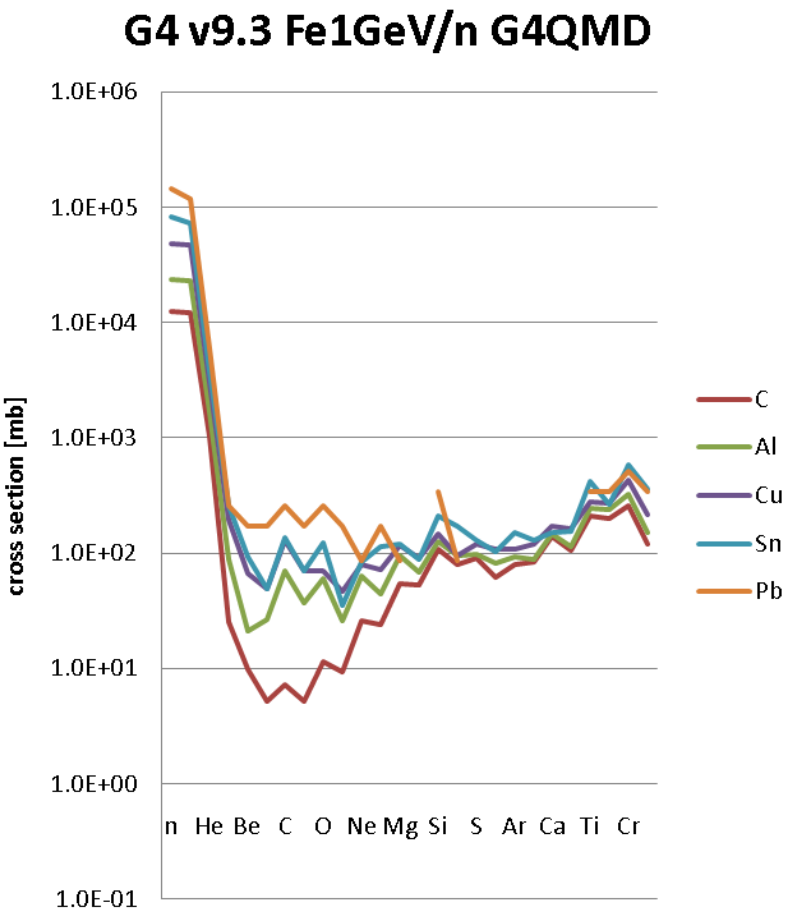


FIG. 6. Fragmentation cross sections for 1 *A* GeV ^{56}Fe on Al, calculated with different impact-parameter distributions. Experimental data are taken from Ref. [30].

D. M ancusi et al.,
"Stability of nuclei in peripheral collisions in the JAERI quantum molecular dynamics model"
PHYSICAL REVIEW C 79, 014614 (2009)


G4 v9.2.p02 Fe1GeV/n G4QMD
cross section [mb]
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
n He Be C O Ne Mg Si S Ar Ca Ti Cr
C
Al
Cu
Sn
Pb


G4 v9.3 Fe1GeV/n G4QMD
cross section [mb]
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
n He Be C O Ne Mg Si S Ar Ca Ti Cr
C
Al
Cu
Sn
Pb

Low Energy Neutron

- Neutron HP
- G4NDL
- CIEMAT related
- G4ENDL related

Neutron HP

- Uncorrelated binary scattering in several channels was corrected
- NeutronHP of v9.3 had a trouble
  - No update is included
  - Please use v9.3.p02 or v9.4 beta
- A lot of complain about emission of ultra low energy photons for better conservations.
  - Limit photon energy at the energy limit of Standard EM (~1keV)
- Li data of G4NDL will update to ENDF-VII
  - It has better description than before.

G4ENDL

- The first version will be released Dec 2010.
- The second version will continue with much better performance.

CIEMAT related

- Dennis and John are trying to establish collaboration with them.
- I hope to have a workshop about this early next year.