recent development and nucleus-nucleus extension of INCL++

Davide Mancusi

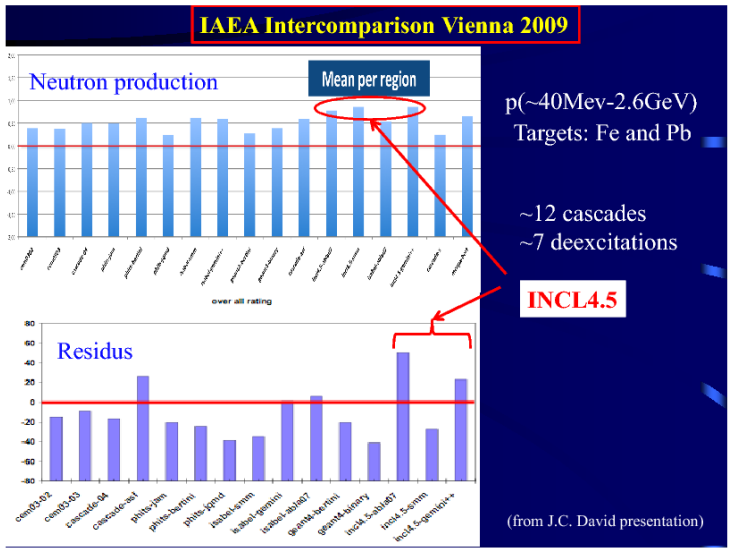
Geant4 collaboration meeting
Chartres, 12th September 2012

from `INCL4.6` to `INCL++`

nucleus-nucleus extension

INCL v4.6

Liège Intranuclear Cascade model



- excellent overall physics performance
- cluster emission
- Fortran77

☞ yesterday's talk by A. Boudard

complete redesign in C++

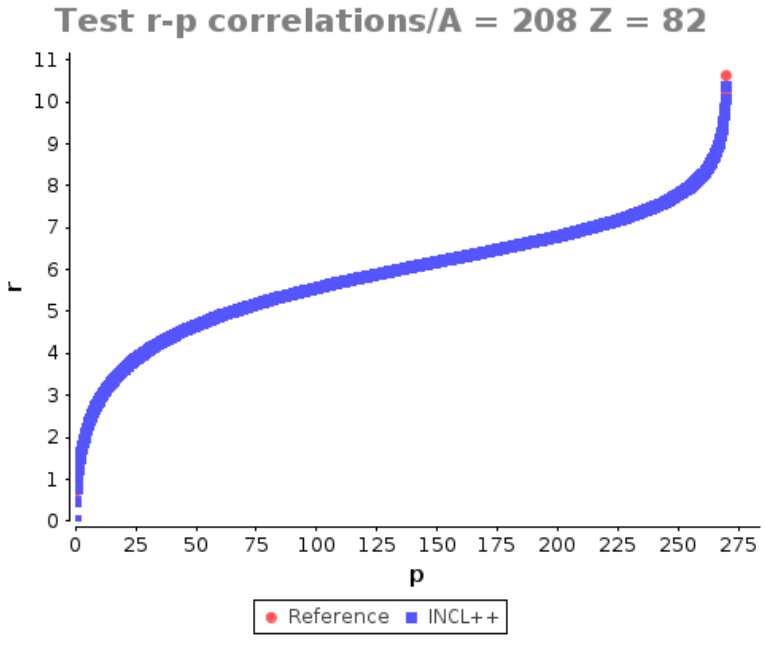
- keep only the best physics from INCL4.6

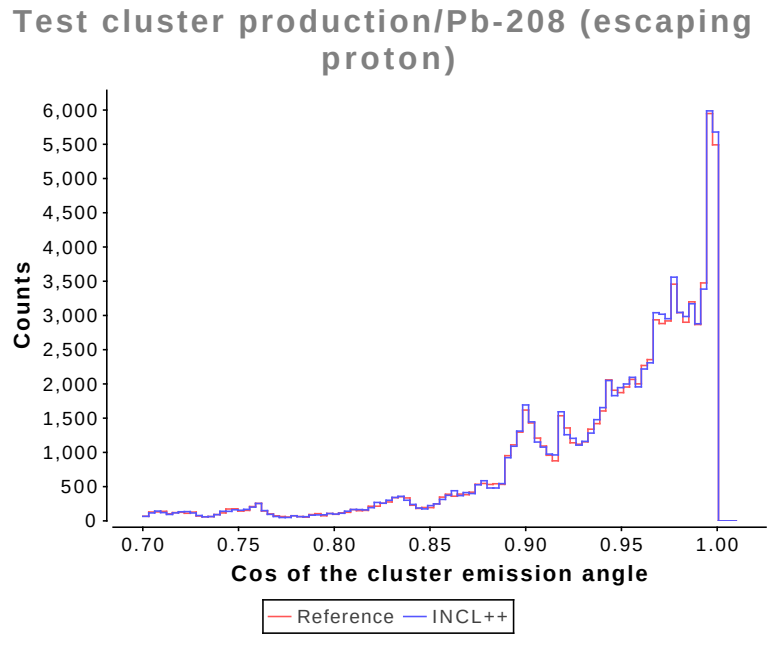
complete redesign in C++

- keep only the best physics from INCL4.6
- flexible and extensible code
  - nucleus-nucleus extension
  - curved trajectories

complete redesign in C++

- keep only the best physics from INCL4.6
- flexible and extensible code
  - nucleus-nucleus extension
  - curved trajectories
- Fortran/C++: 18 unit tests, $\sim$ 350 plots





by P. Kaitaniemi and DM

INCL++ v5.0

- available since G4 v9.5
  - builders
  - QGSP_INCLXX physics list
- physics-wise equivalent to INCL4.6

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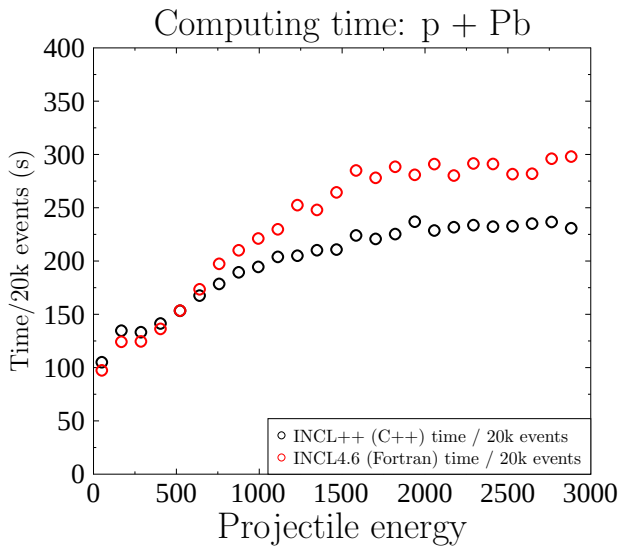
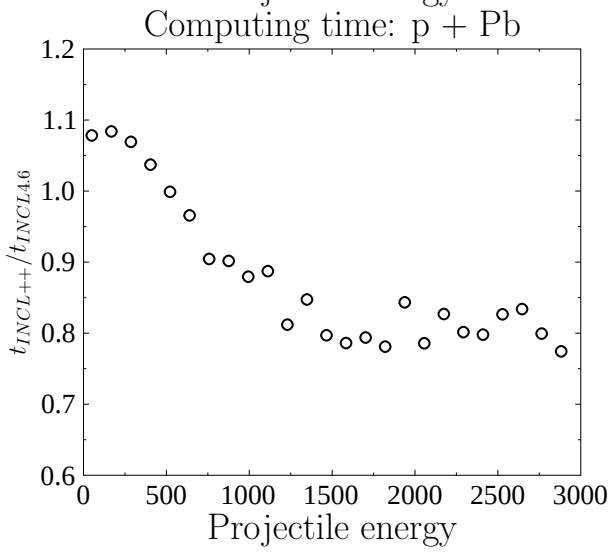




INCL++ v5.0

- available since G4 v9.5
  - builders
  - QGSP_INCLXX physics list
- physics-wise equivalent to INCL4.6
- slightly better CPU time!

- can only treat p, n and $\pi^{\pm}$ projectiles

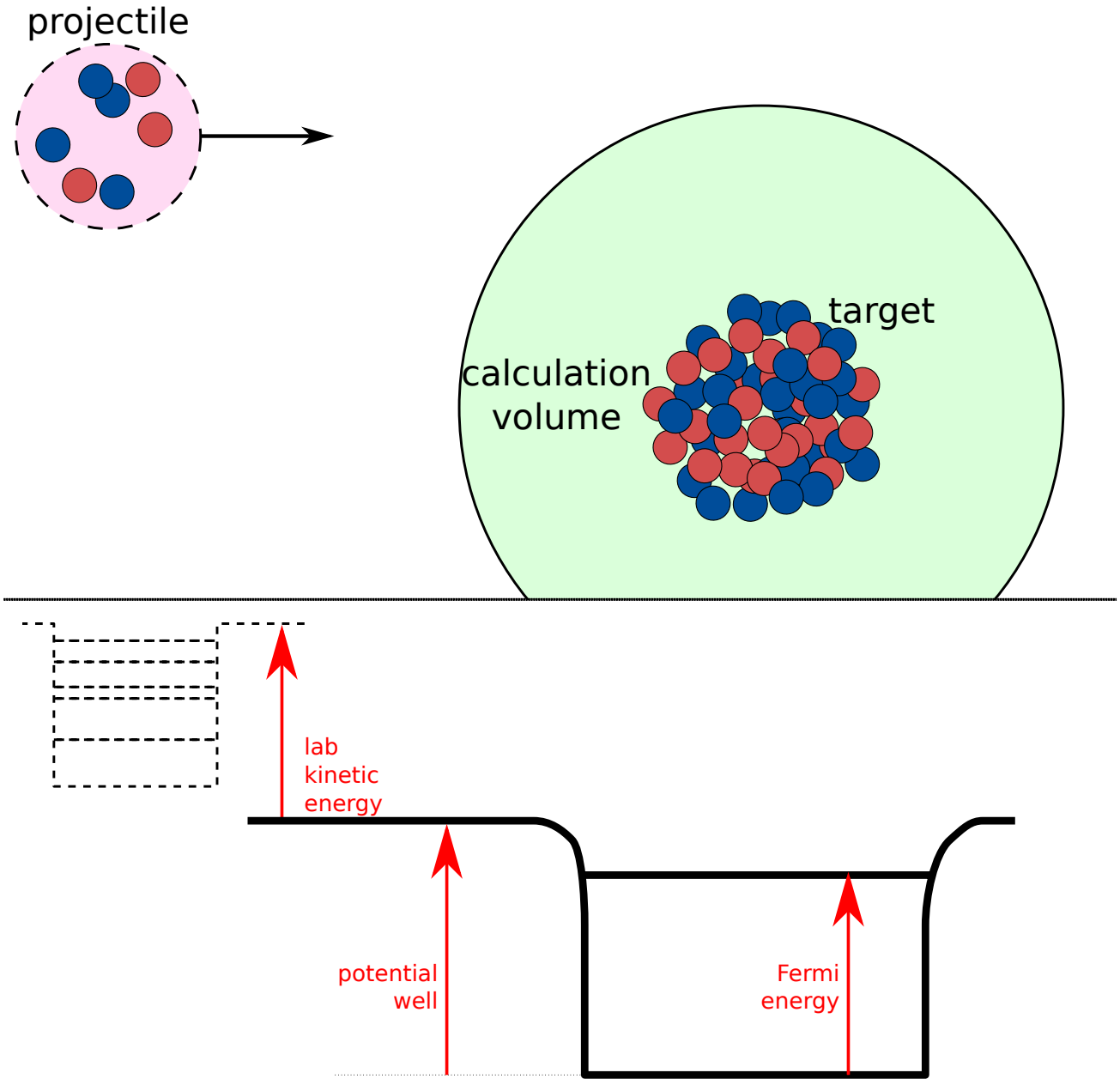
from `INCL4.6` to `INCL++`

nucleus-nucleus extension

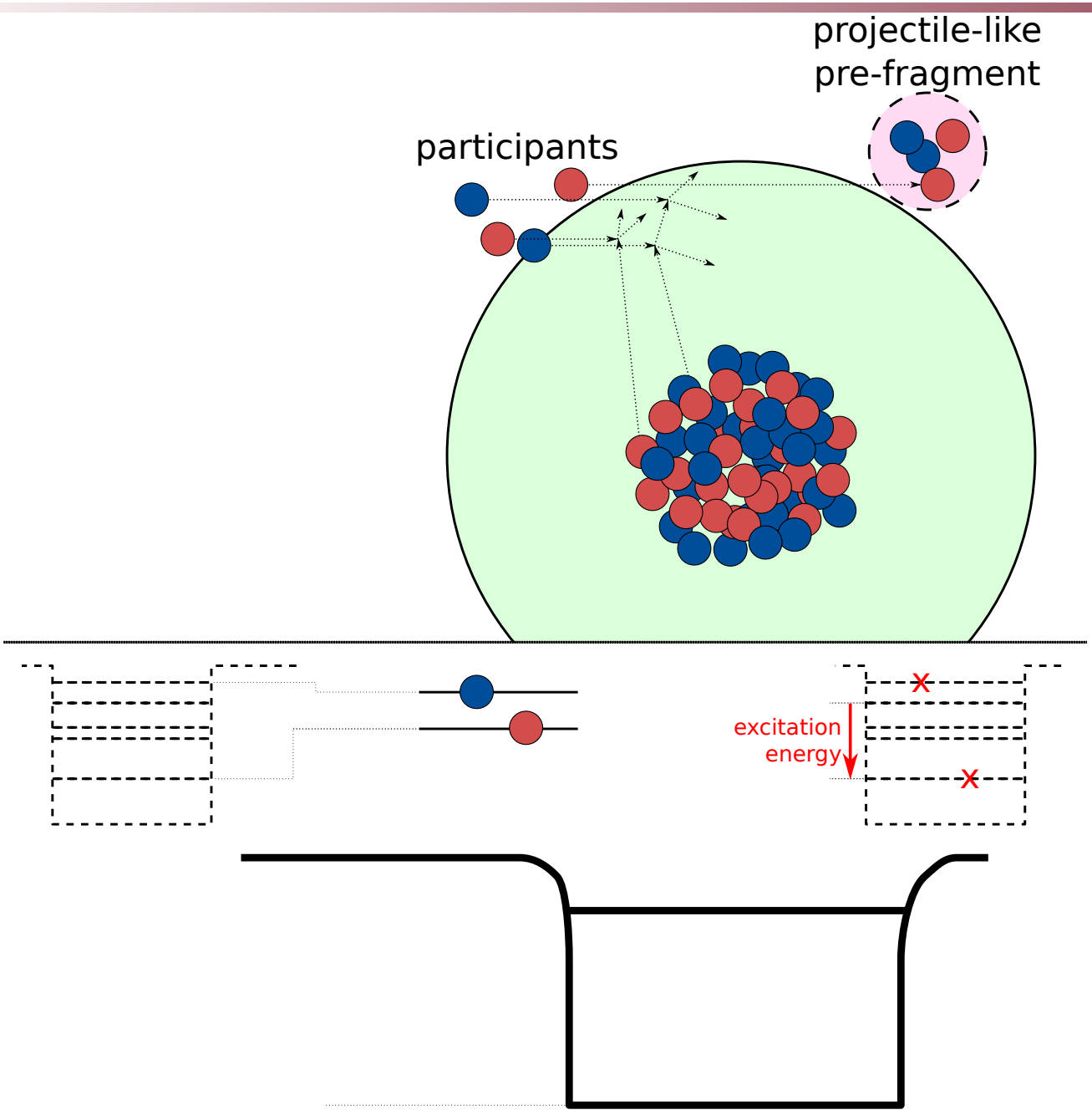
nucleus-nucleus extension: ingredients

- realistic $r-$ and $p-$densities for the projectile
- Coulomb distortion
- frozen Fermi motion
- complete fusion model at low energy

nucleus-nucleus extension: scheme



nucleus-nucleus extension: scheme



definition of the pre-fragments

target-like pre-fragment

- cascade takes place in the target volume
- end of cascade
- target-like pre-fragment given by the normal `INCL` procedure

projectile-like pre-fragment

- almost no dynamics
- E^* assigned by semi-empirical particle-hole model

projectile/target asymmetry

participant region
target-like pre-fragment

projectile-like pre-fragment

✔ solid description

✗ semi-empirical description

projectile/target asymmetry

accurate target/projectile description

accurate target description mode

- normal `INCL++` cascade (projectile on target)

accurate projectile description mode

- boost to inverse-kinematics frame
- run `INCL++` cascade (target on projectile)
- boost back to lab frame

the choice depends on the relevant observables! e.g.

projectile fragmentation: **accurate projectile**
particle spectra: **accurate projectile**
material damage: **accurate target**

remarks

- INCL++ internally calls another model if $A_1, A_2 > 18$
  - Binary
  - QMD?
  - Fritiof?

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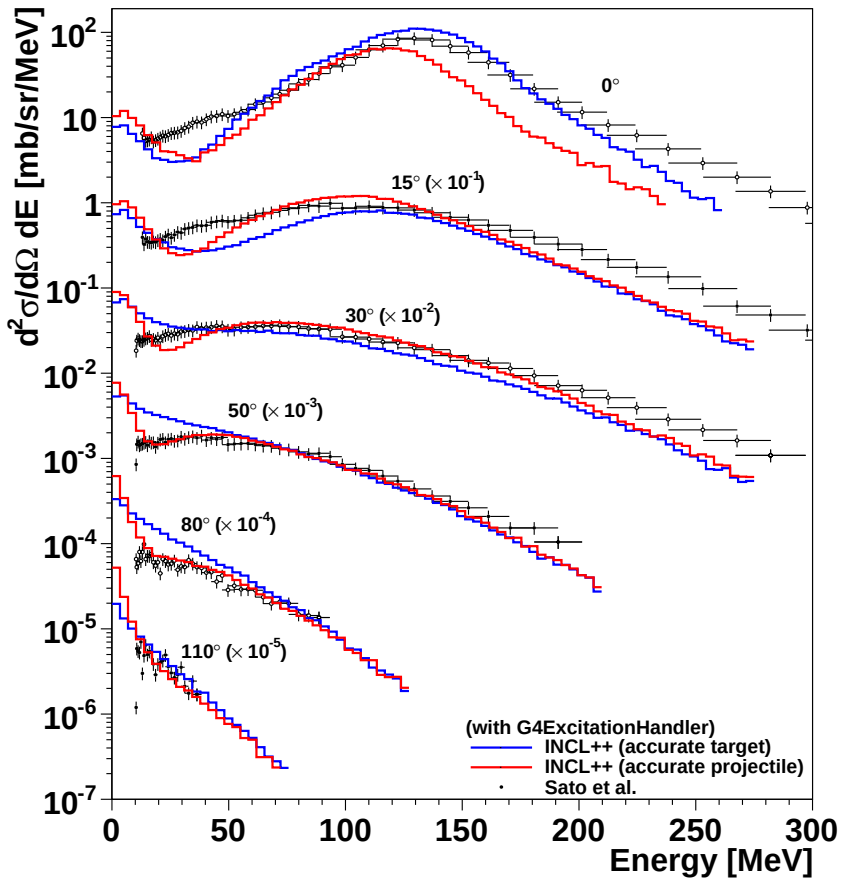
- INCL++ internally calls another model if $A_1, A_2 > 18$
  - Binary
  - QMD?
  - Fritiof?
- similar nucleus-nucleus extension in INCL4.2
  - INCL++ guarantees energy and momentum conservation **at the keV level**

$^{12}C(^{12}C,x)n$

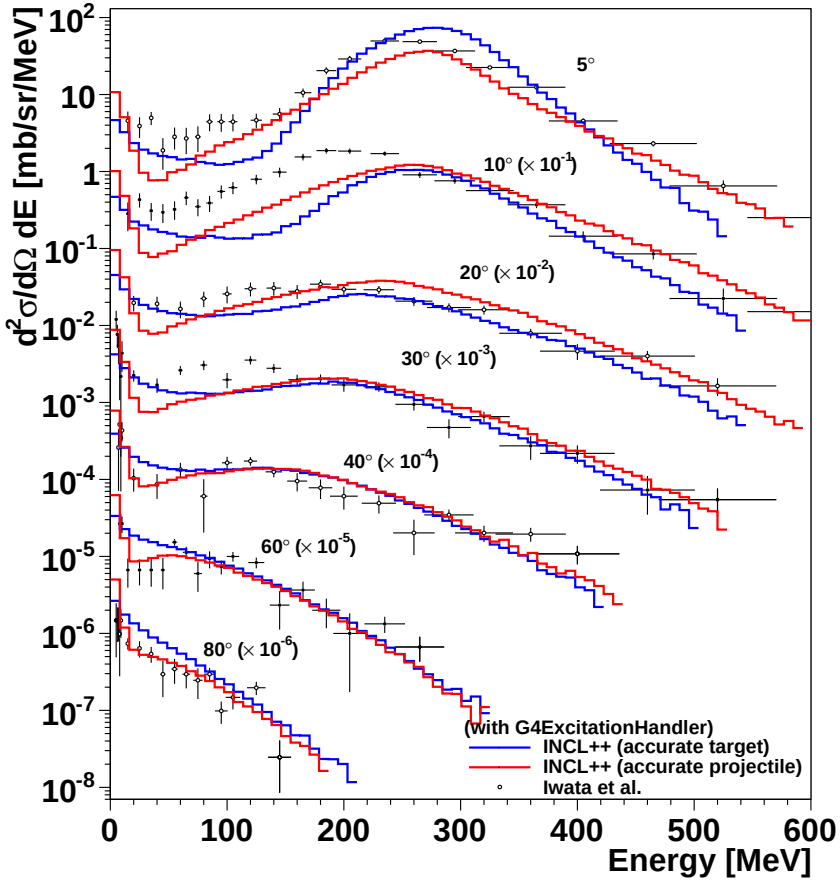
135 *A*MeV



H. Sato *et al.*

Phys. Rev. C64 (2001) 034607

290 *A*MeV



Y. Iwata *et al.*

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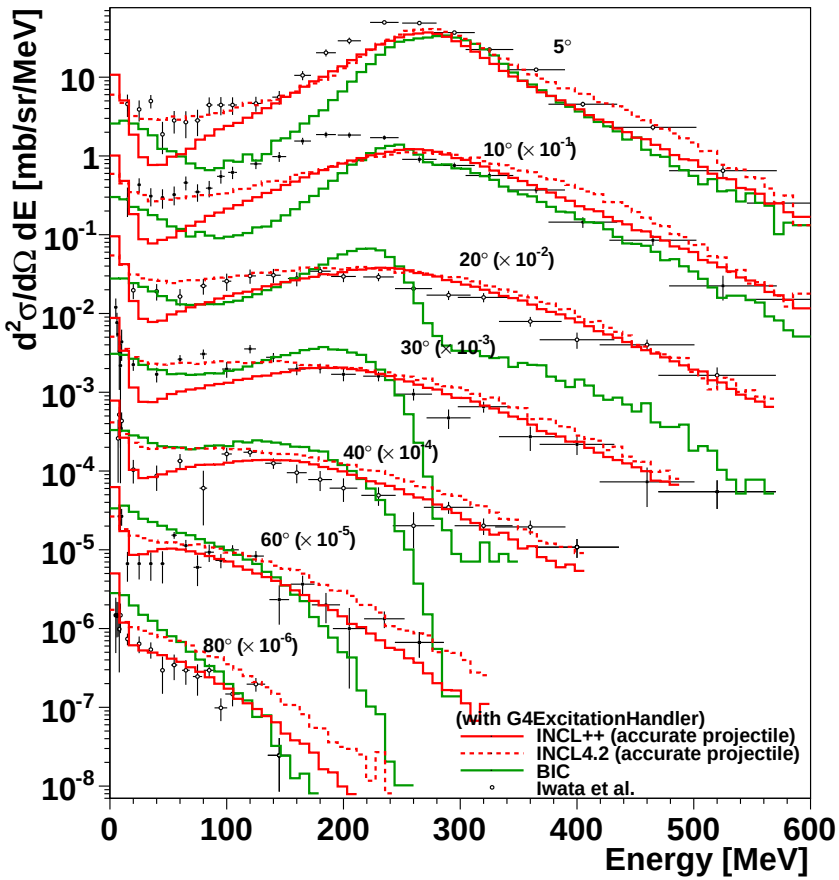

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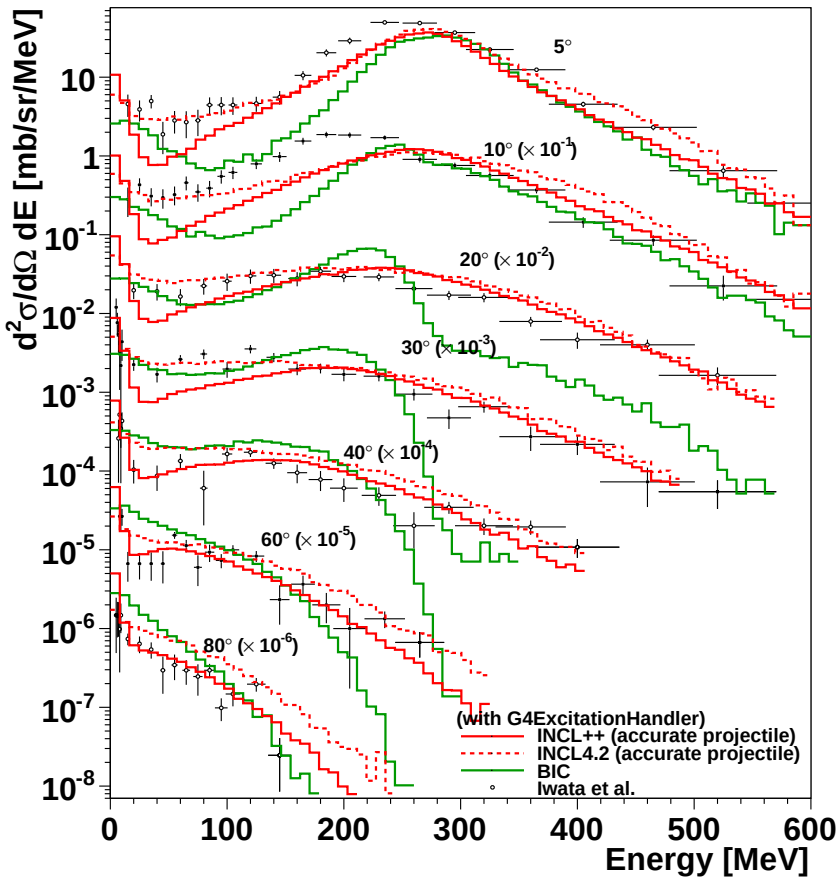

Y. Iwata *et al.*

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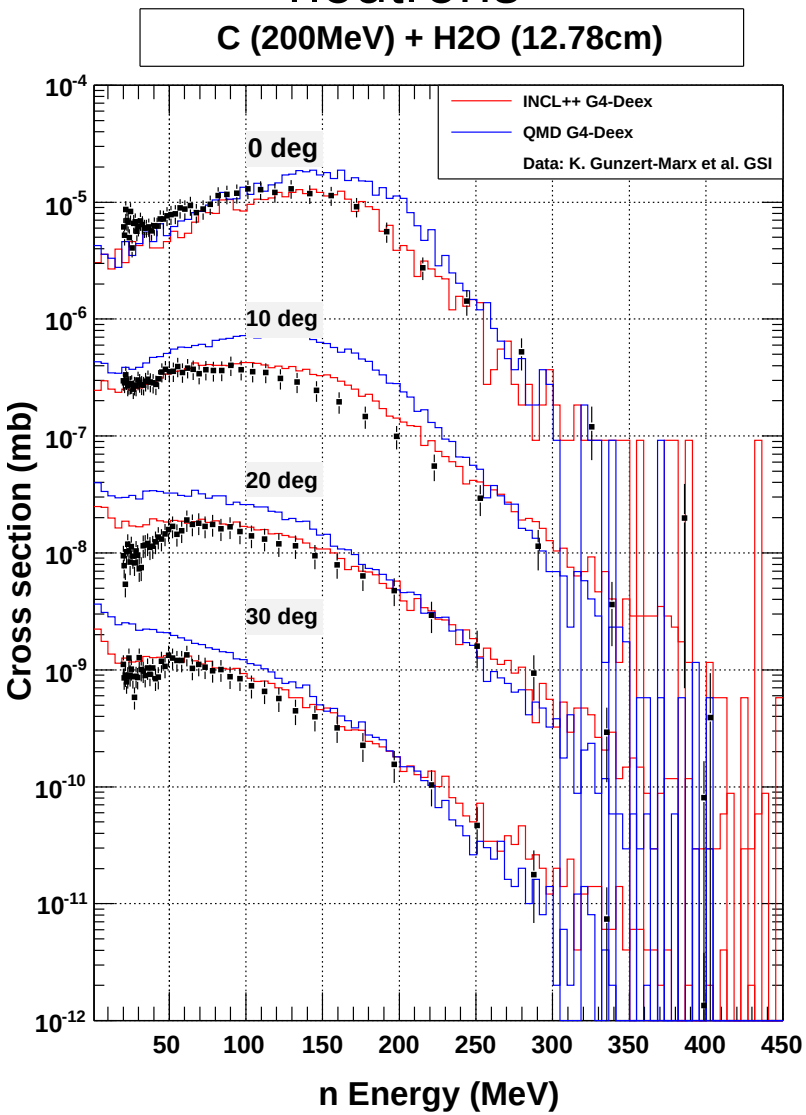
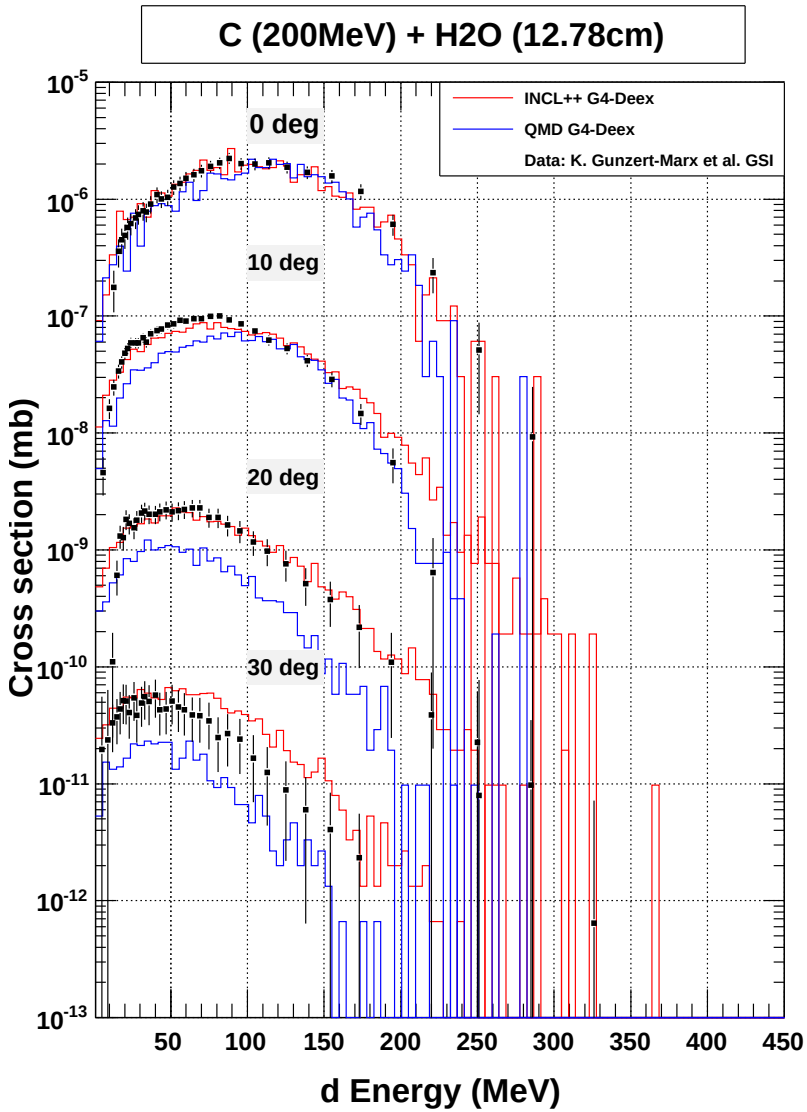
thick-target results

neutrons



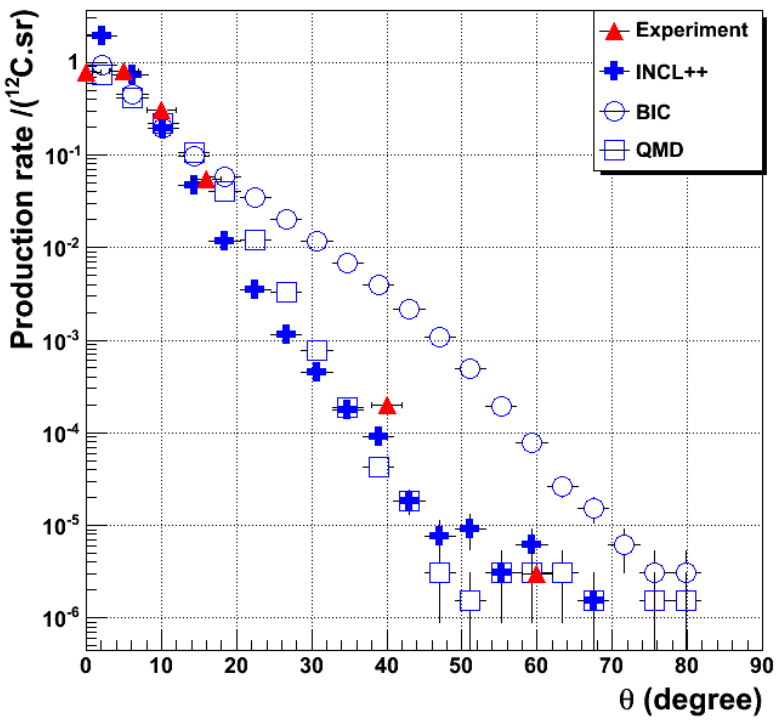
deuterons ($\times$0.33?!)



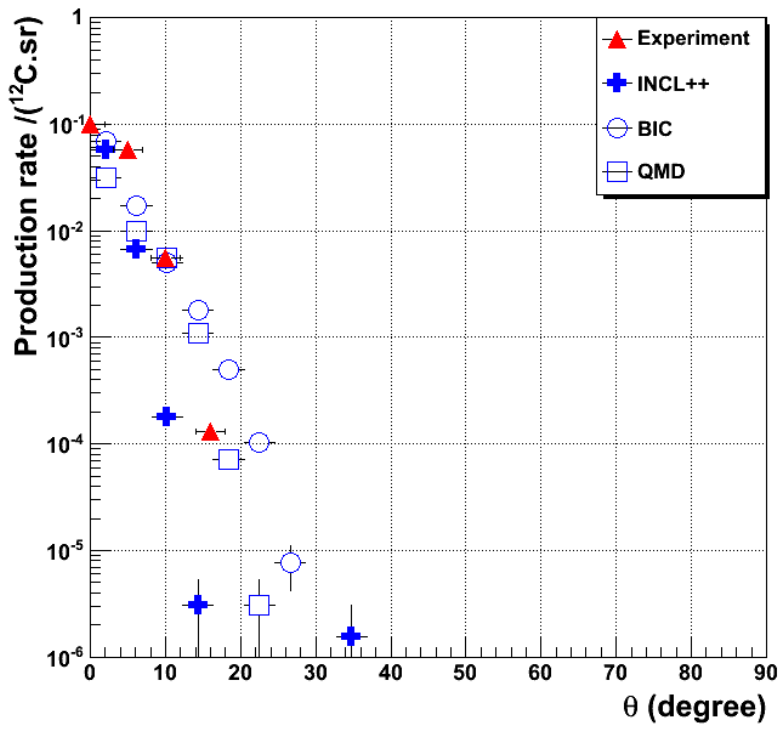
K. Gunzert-Marx *et al.*
New J. Phys. 10 (2008) 075003

^{12}C + 25 mm PMMA, 95 *A*MeV fragment angular distributions

$Z = 2$



$Z = 4$

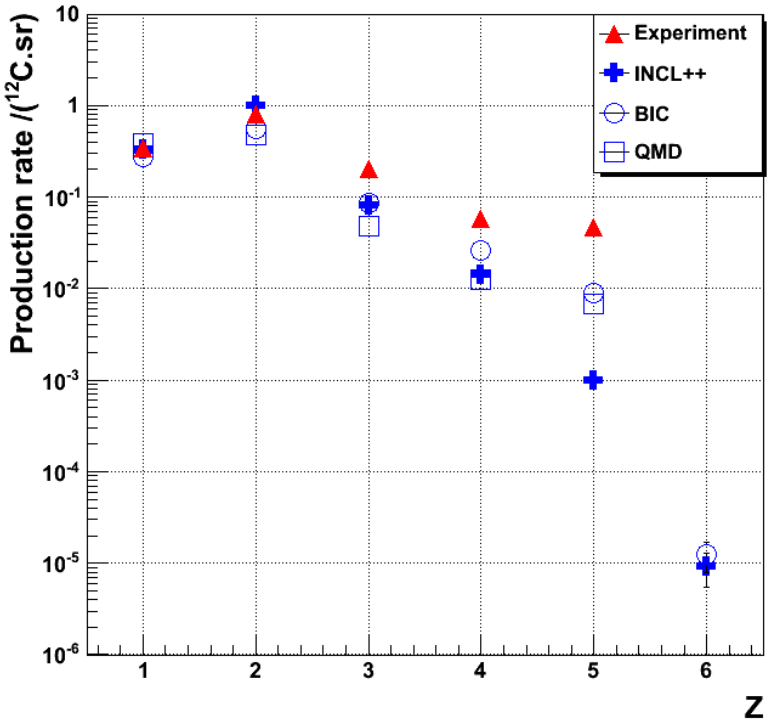


B. Braunn *et al.*

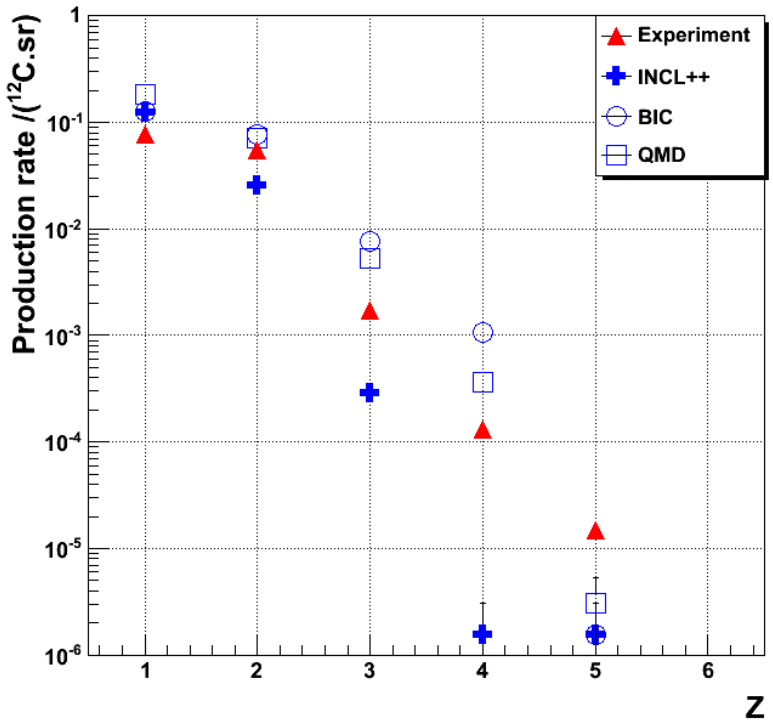
Nucl. Instr. Meth. B269 (2011) 2676–2684

^{12}C + 25 mm PMMA, 95 *A*MeV
charge distributions

$\theta = 5°$



$\theta = 16°$



B. Braunn *et al.*

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nucleus-nucleus extension: conclusions

new INCL++ v5.1: encouraging results!

future plans:

- refine the present treatment?
- conceive a new, symmetrical approach?
  - collision of two potential wells

the INCL++ team

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- Sylvie Leray
- Davide Mancusi

University of Liège, Belgium

- Joseph Cugnon