Nuclear data completion for analog simulations

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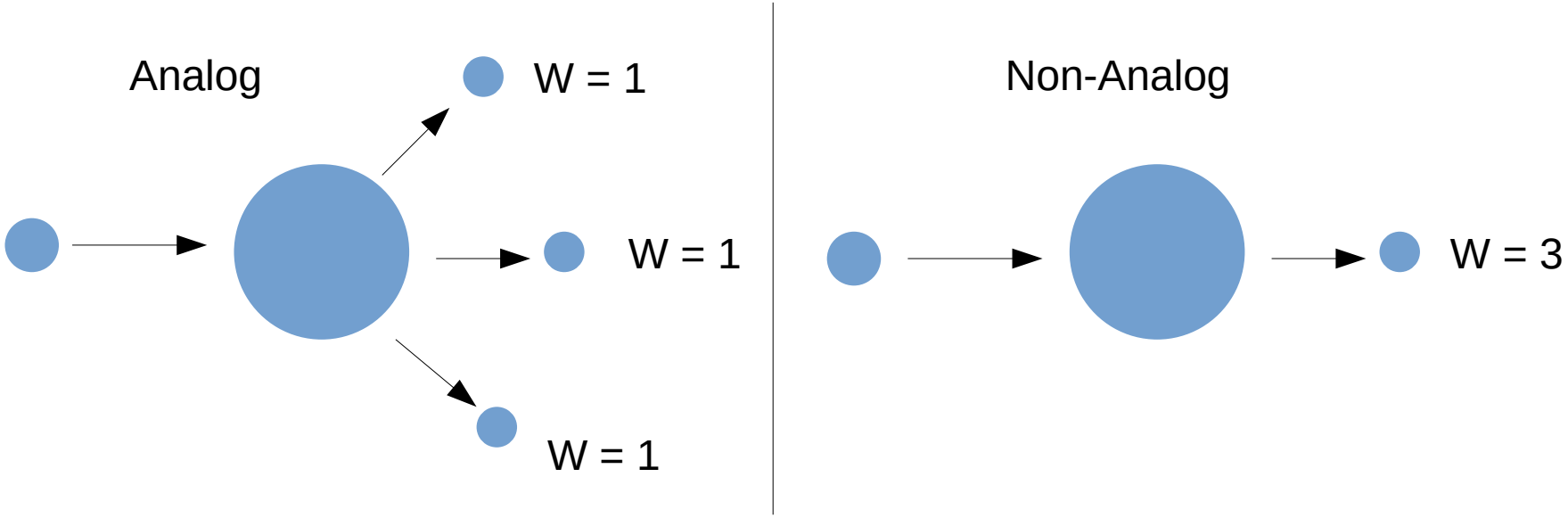
Outline

- Analog versus non-analog simulations
- Inelastic reactions
- Neutron capture

Analog versus non-analog simulation

- Nuclear reactions such as (n,n') (n,g) (n,2n) (n,f) can produce more than 2 particles, and these are correlated in energy and angle.
- Analog simulation requires data for each particle produced.
- Non-analog simulation only requires averaged data.
- Application : detector simulations & particle coincidence.

  Example : STEREO experiment → inverse beta reaction + (n,g).



Inelastic reaction (n,n'g)

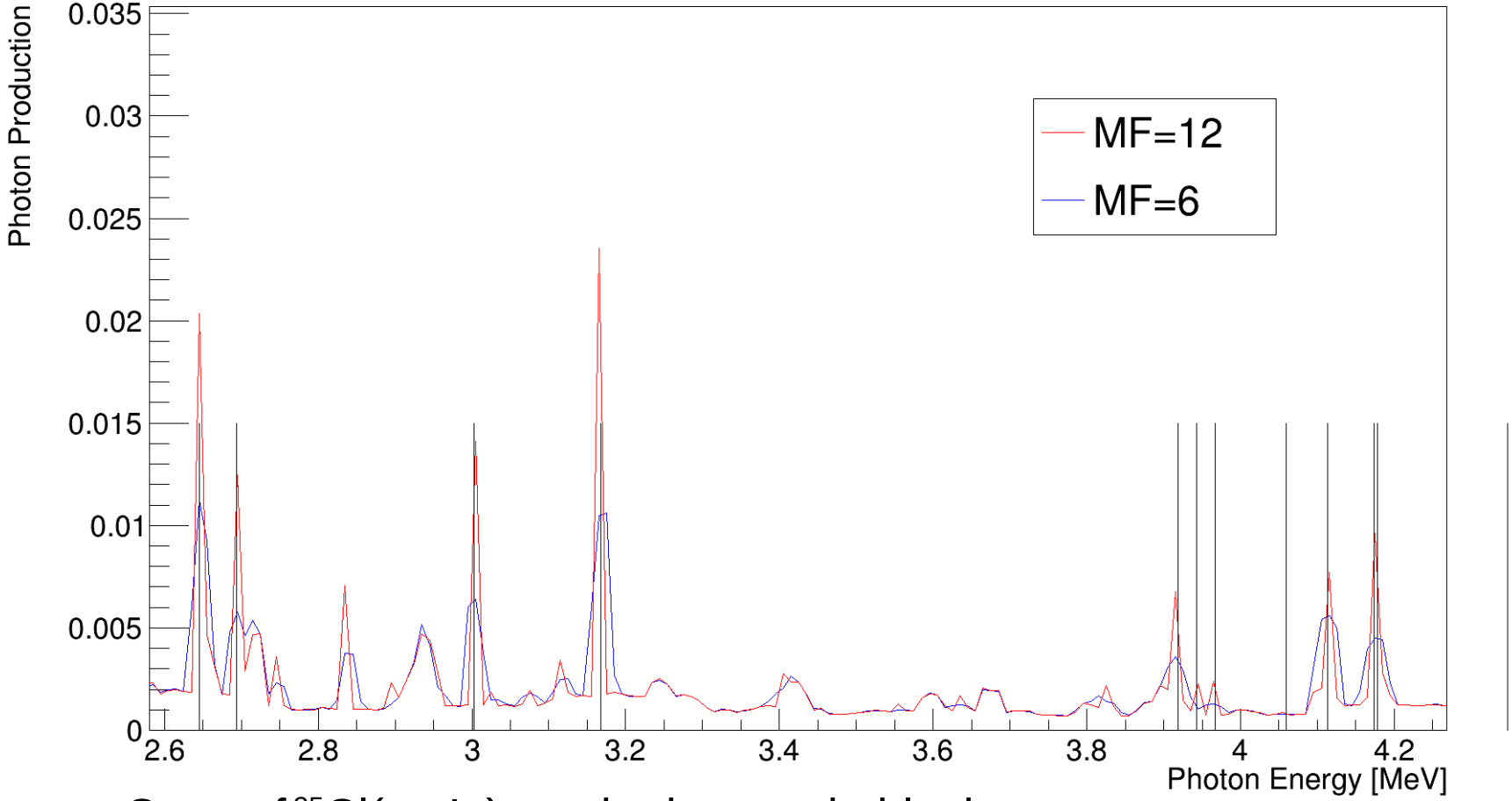
- The creation of MF=12 files for 47 isotopes of the JEFF3.3 library has allowed to test photon cascades in TRIPOLI-4
- TRIPOLI-4 produces the same average spectra using both formats (MF=12 for analog vs MF=6 for non-analog)
- Correlations between the emitted photons have been verified using MF=12, however, center of mass corrections are not possible with this format, this option should thus be made available
- This results were presented in the JEFF Meeting of 2020.
- PHITS (JAEA – T. Ogawa) was used to compare results, it is specialized in nuclear reactions, Event Generator Mode = analog
- Correction in data stored in the PHITS code for the improvement of the ^{27}Al(n,n'g) simulation.

MF=12 added to JEFF3.3

Mg27
Al26
P31
P32
S32
S33
S34
S35
Ar38
As73
Se77
Ru100
Cs134
Sm150
Sm151
Gd153
Dy160
Dy165
Er168
Os189
Hg200
Np237

22 isotopes for which the declares excited states in MF=3 do not coincide with the declares excited states in MF=12.

TRIPOLI-4® photon production results



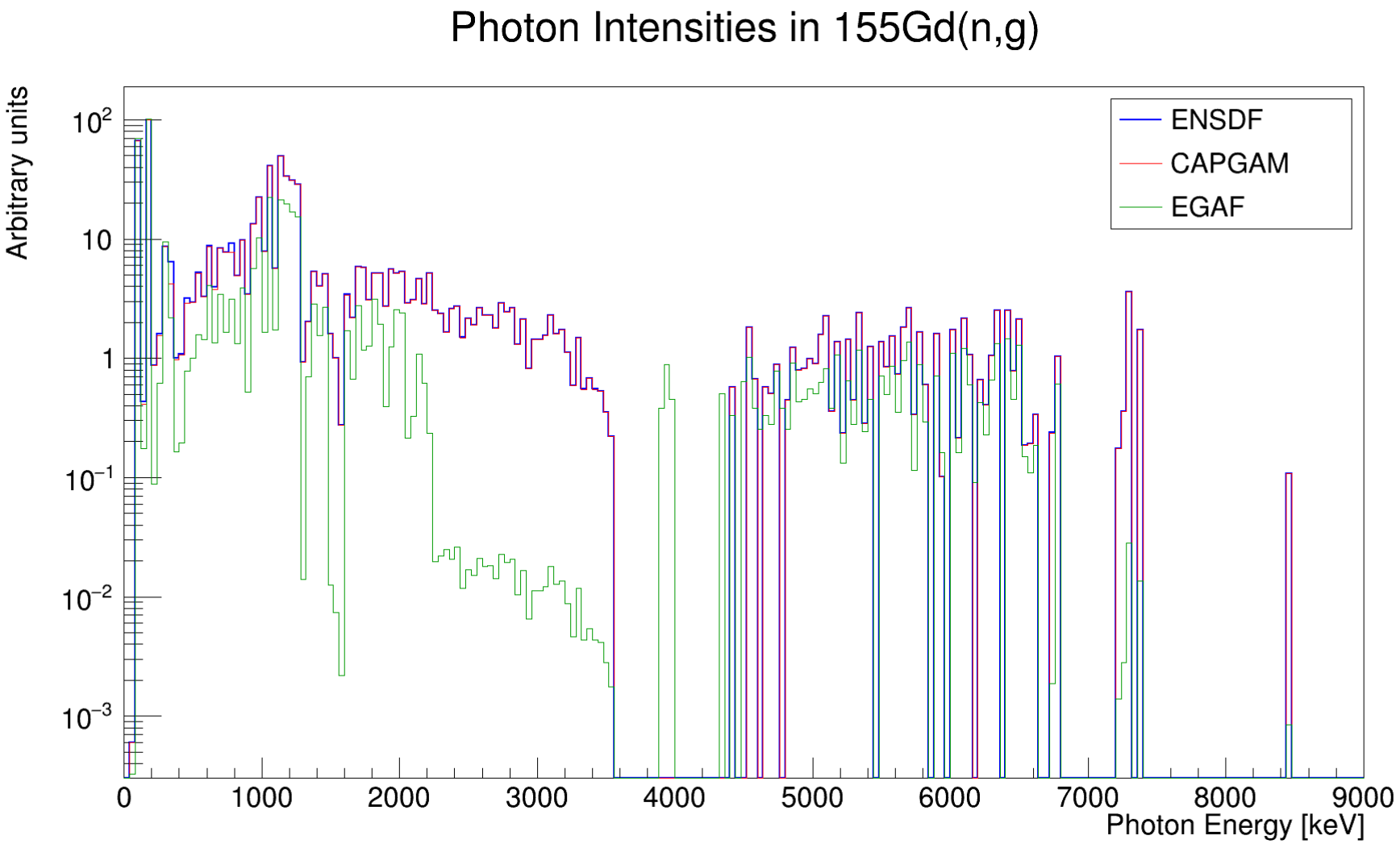
Case of ^{35}Cl(n,n'g), excited states in black

MF=12 is analog, MF=6 is non-analog but differences in peak width come from center of mass considerations

Nuclear data for neutron capture (n,g)

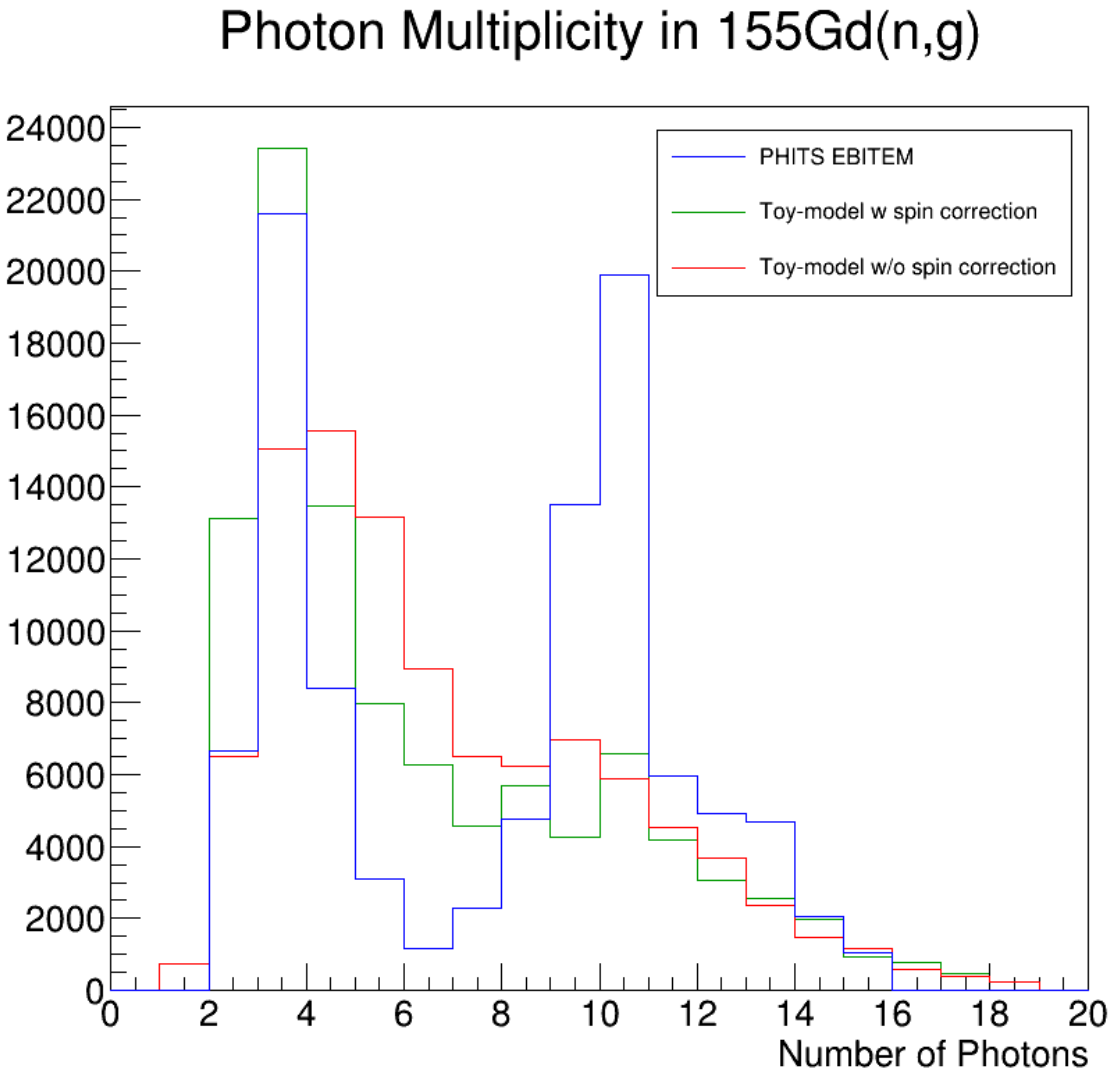
- The ENSDF, CAPGAM and EGAF libraries contain photon intensities for thermal (n,g)
- The MF=6 file contains the average photon multiplicity according to the incident energy + a distribution for discrete photons + a distribution continuum photons → not adapted to analog simulation
- The RIPL-3 library contains all the necessary information for the (n,g) simulation (excited states, transition probabilities, spin-parity, etc) → creation of a toy-model algorithm to simulate photon cascades
- The DICEBOX (AIEA) code simulates this reaction using photon strength functions + level densities + structure data → it produces the reference results to compare with the toy-model algorithm

Measured gamma production spectrum of ^{155}Gd(n,g)



Interval [2 : 5] MeV presents incompatibilities

Toy-model Monte Carlo for ^{155}Gd(n,g)



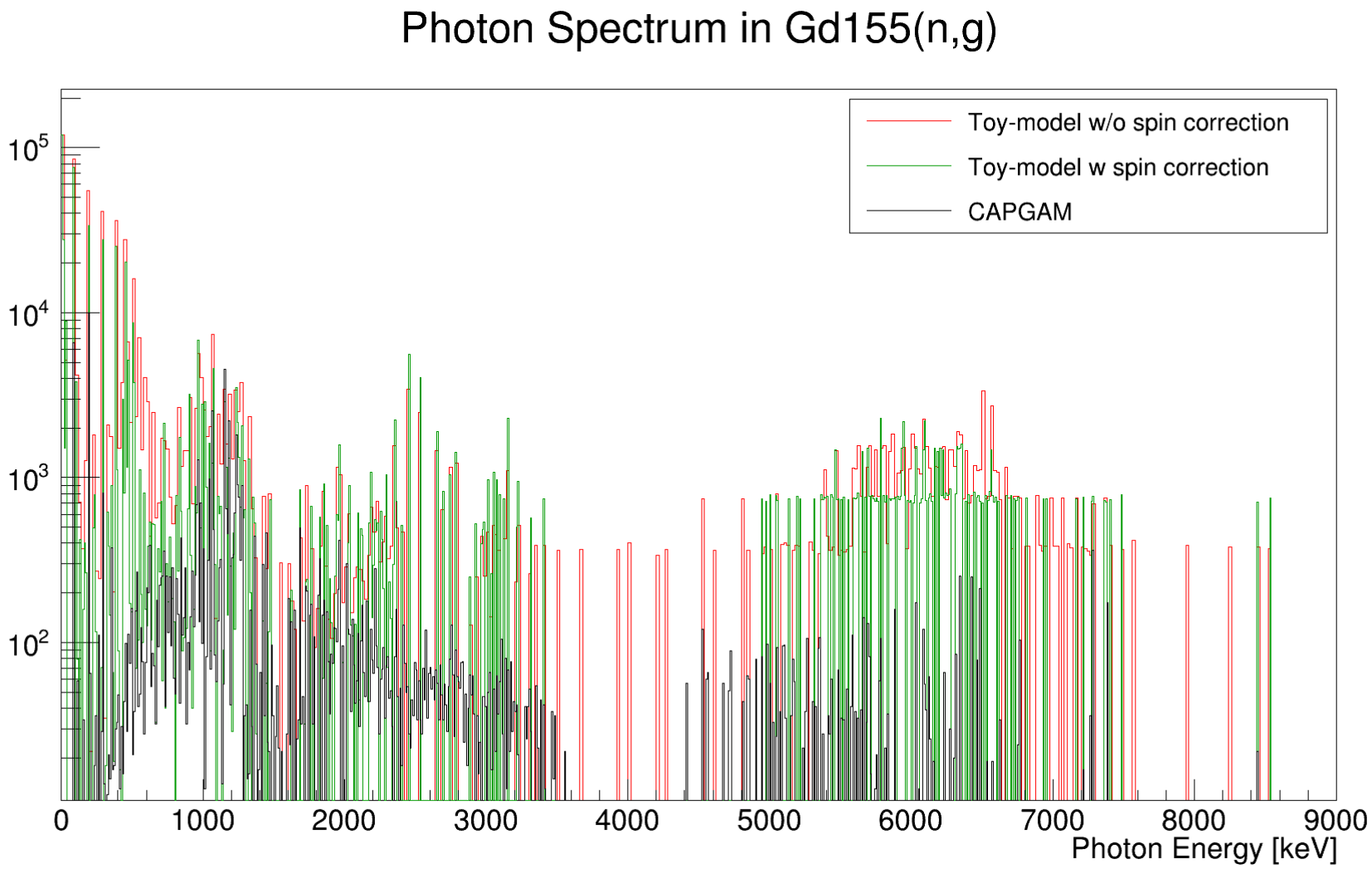
Gamma multiplicity at 10^{-5} eV

JEFF33 / MF6	3.99
ENDFB8 / MF6	3.92
JENDL4 / MF6	4.05
Forced mult.	3.80
W spin correction	5.87
W/o spin correction	6.40
PHITS	7.38

Spin correction :

Transitions must have
$| J_i - J_f | < 3$

Toy-model Monte Carlo for ^{155}Gd(n,g)



La correction de delta spin élimine les photons d'énergie [3 : 5] MeV

Conclusion

- 22 nuclear evaluations have been completed in their MF=12 file, 47 others can also be added

- Discussions in progress with the PHITS team to correct gamma multiplicities in ^{155}Gd(n,g) et ^{198}Hg(n,g)

- DICEBOX uses PSF + LD + structure data for the (n,g) simulation → realistic production of gamma spectra for discrete and continuous regimes, serves as reference to test the toy-model

- The (n,g) simulation only with JEFF3.3 and ENSDF cannot reproduce the expected spectra (correlations, multiplicities)

Thank you