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CoH_3

The Coupled-Channels and Hauser-Feshbach Code

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Statistical Model Code for Compound Nuclear Reactions

- A main tool for calculating nuclear reactions for $A > 20$, $E_n > 1$ keV (above resolved resonance region)
- Provide complete information of nuclear reactions
  - reaction cross sections
  - energy and angular distributions of secondary particles

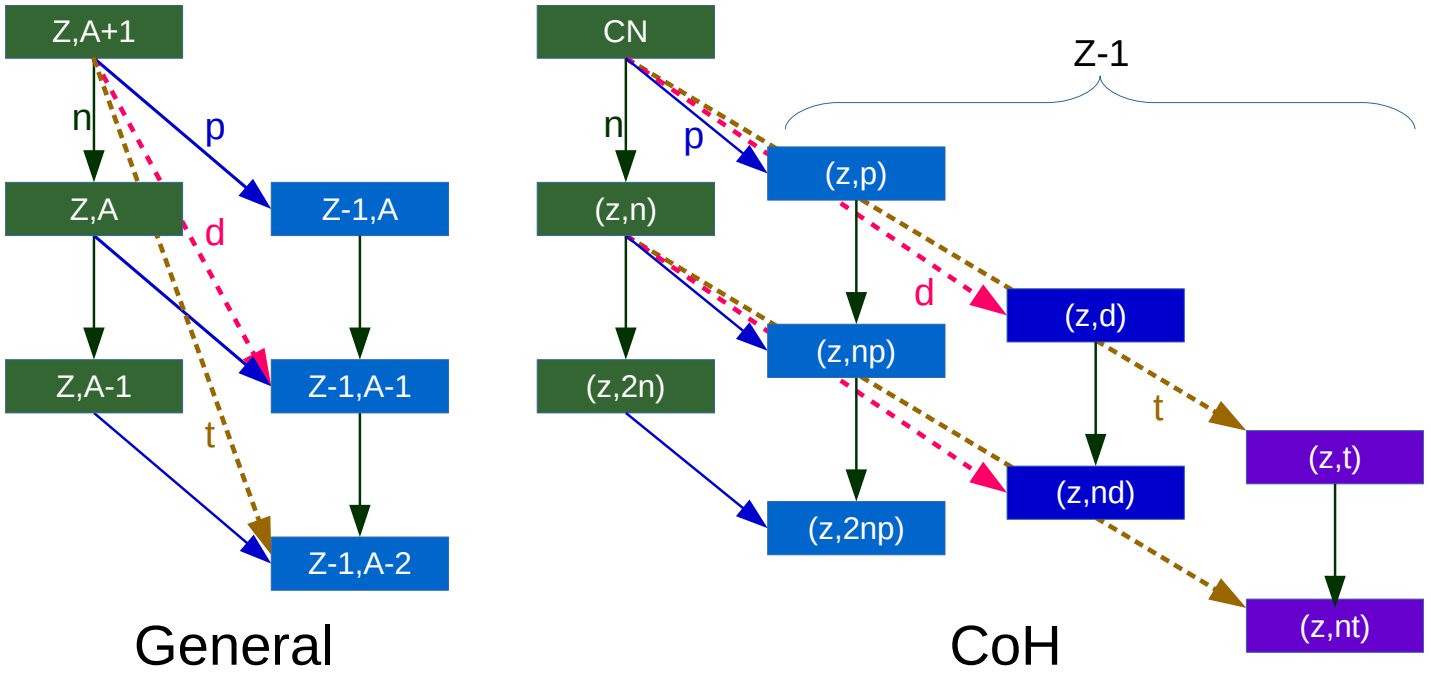
CoH_3: Coupled-Channels Hauser-Feshbach code

- 45,000 lines C++ code
- internal optical model / coupled-channels solver
- compound nucleus decay by deterministic or Monte Carlo method
- exclusive reaction cross sections and spectra [JNST **47**, 462 (2010)]

Modules and Models Employed in CoH_3

- Optical Model
  - spherical and deformed (rotational or vibrational model)
  - DWBA for direct inelastic scattering
- Compound Reaction
  - Moldauer's width fluctuation correction with LANL parameters [NDS **118**, 183 (2014)]
  - Engelbrecht-Weidenmüller transformation with direct channels [PRC **94**, 014612 (2016)]
  - Gilbert-Cameron level density [JNST **43**, 1 (2006)]
- Pre-equilibrium Reaction
  - 2-component exciton model
  - (FKK MSD/MSC still external code)
- Prompt Fission Neutron Spectrum
  - advanced Madland-Nix model including pre-fission neutrons
- Direct/Semidirect Capture [PRC **75**, 054618 (2007)]
- Mean-Field Model (FRDM and Hartree-Fock-BCS) [EPJ **146**, 12004 (2017)]

Multi-Particle Emission and Exclusive Cross Section

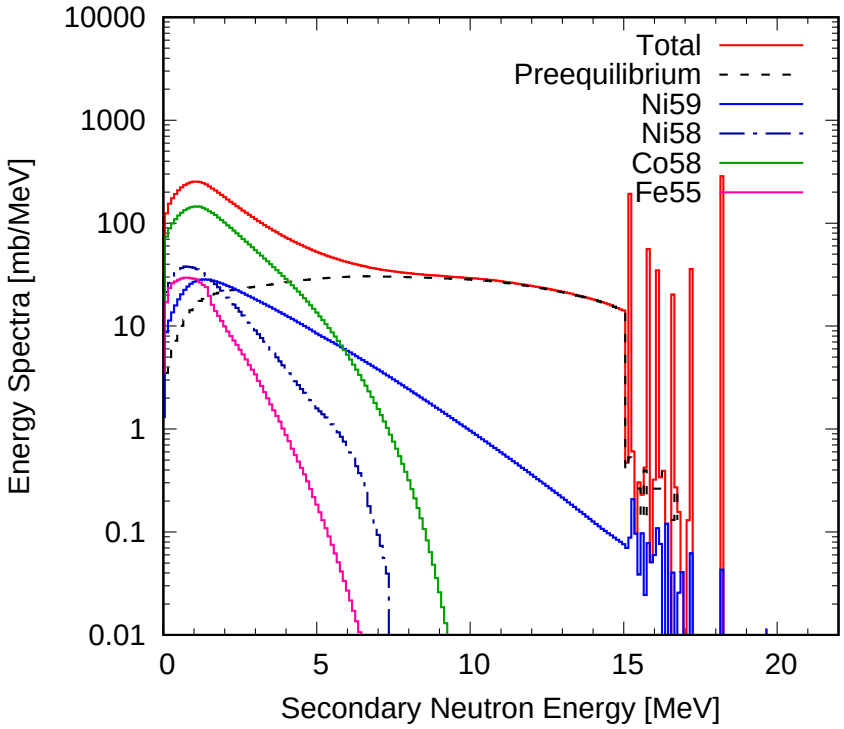


- Nucleus objects for (n,d) and (n,np) channels are different
- The current versioin of CoH_3 is slow at high energies, because a large number of CN object emerge

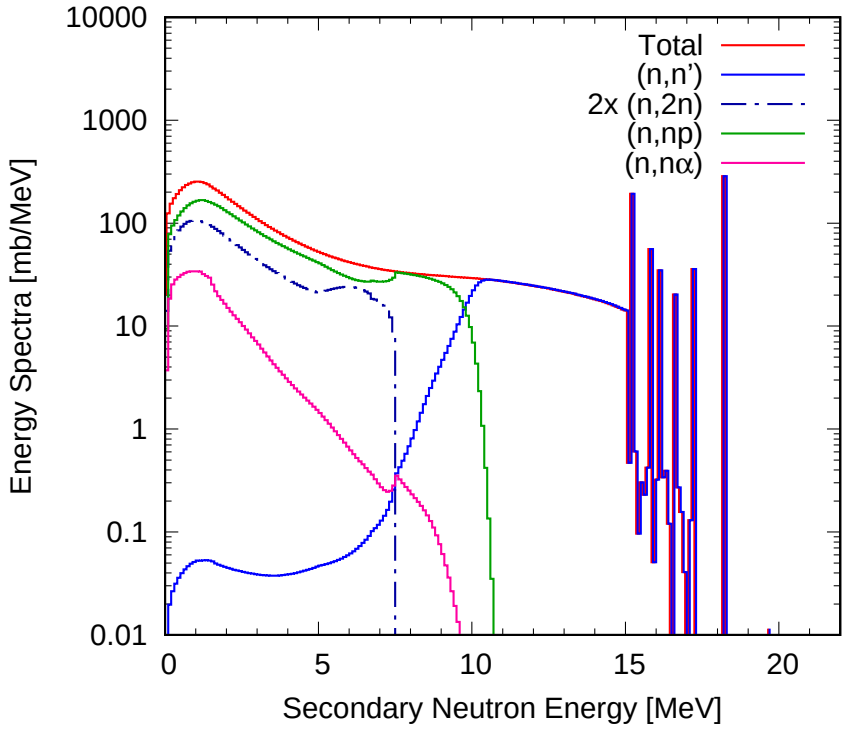
Exclusive Particle Emission Spectrum

n (20 MeV) + ^{58}Ni

Inclusive $\phi(E)$



Exclusive $\psi(E)$



$$\Phi = \phi_{PE} + \phi_{n'x} + \phi_{npx} + \phi_{2nx} + \ldots = \psi_{1n} + \psi_{np} + 2\psi_{2n} + \ldots$$

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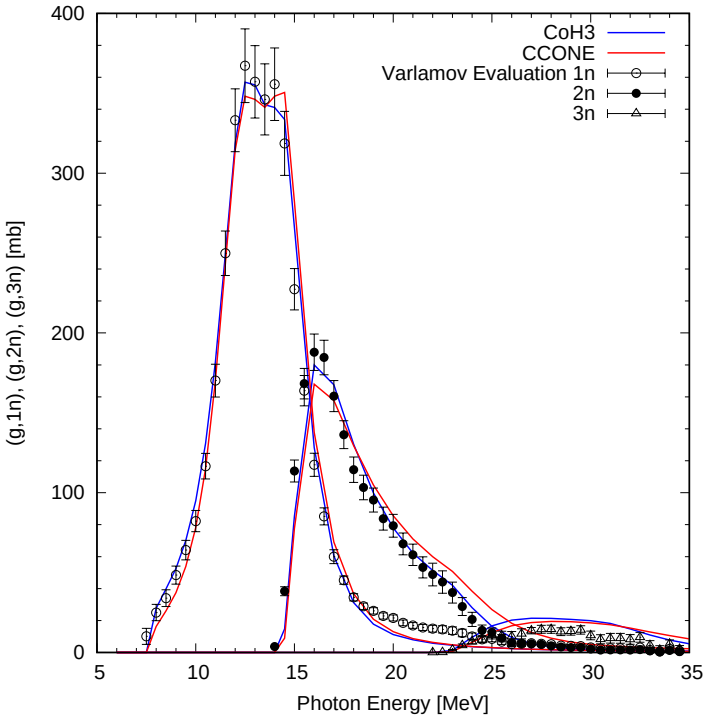
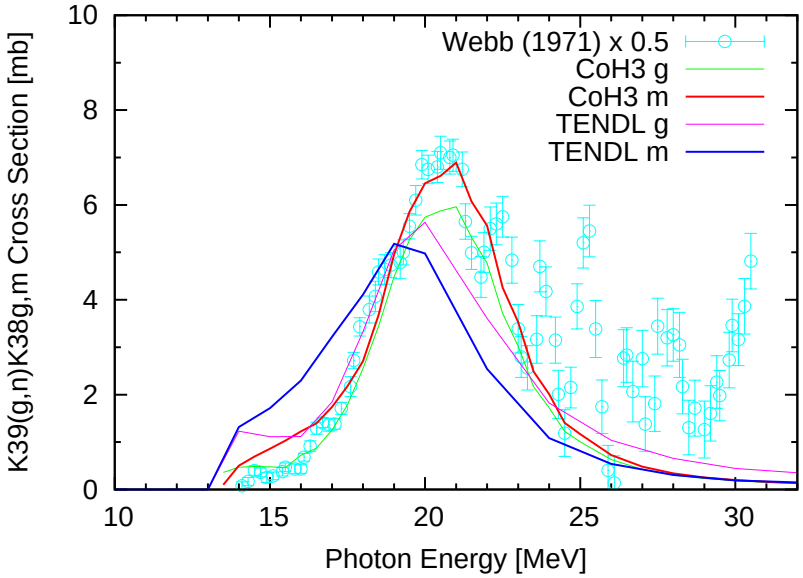
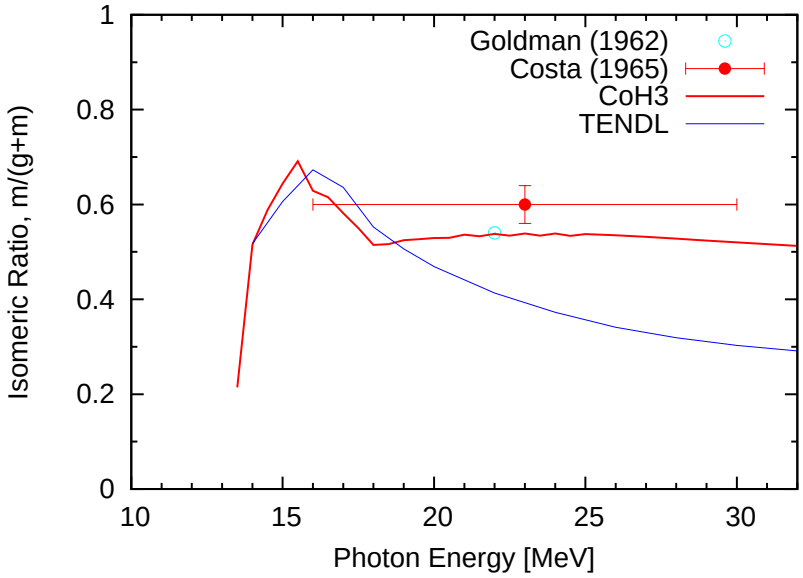
Photonuclear Reactions



- pre-equilibrium process in the photo-reaction not so well established

[NDS **163**, 109 (2020)]





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Crucial Development Needed for Isotope Production

Pre-equilibrium reaction

- PE plays an important role at high energies
  - Exciton model works when phenomenological parameters are well-tuned, but crude approximations are always involved
  - New development of quantum mechanical models ongoing at CEA and LANL, although at moderate pace
  - There a wide unexplored area in the composite particle emission

Nuclear level densities

- The nuclear level density is the most important physical quantity for predicting unknown IP cross section
  - It could have the largest uncertainties in the high energy reactions
  - Experimental data of nuclide production in the vicinity of the target reactions essential