# Nuclear Reaction Codes Development

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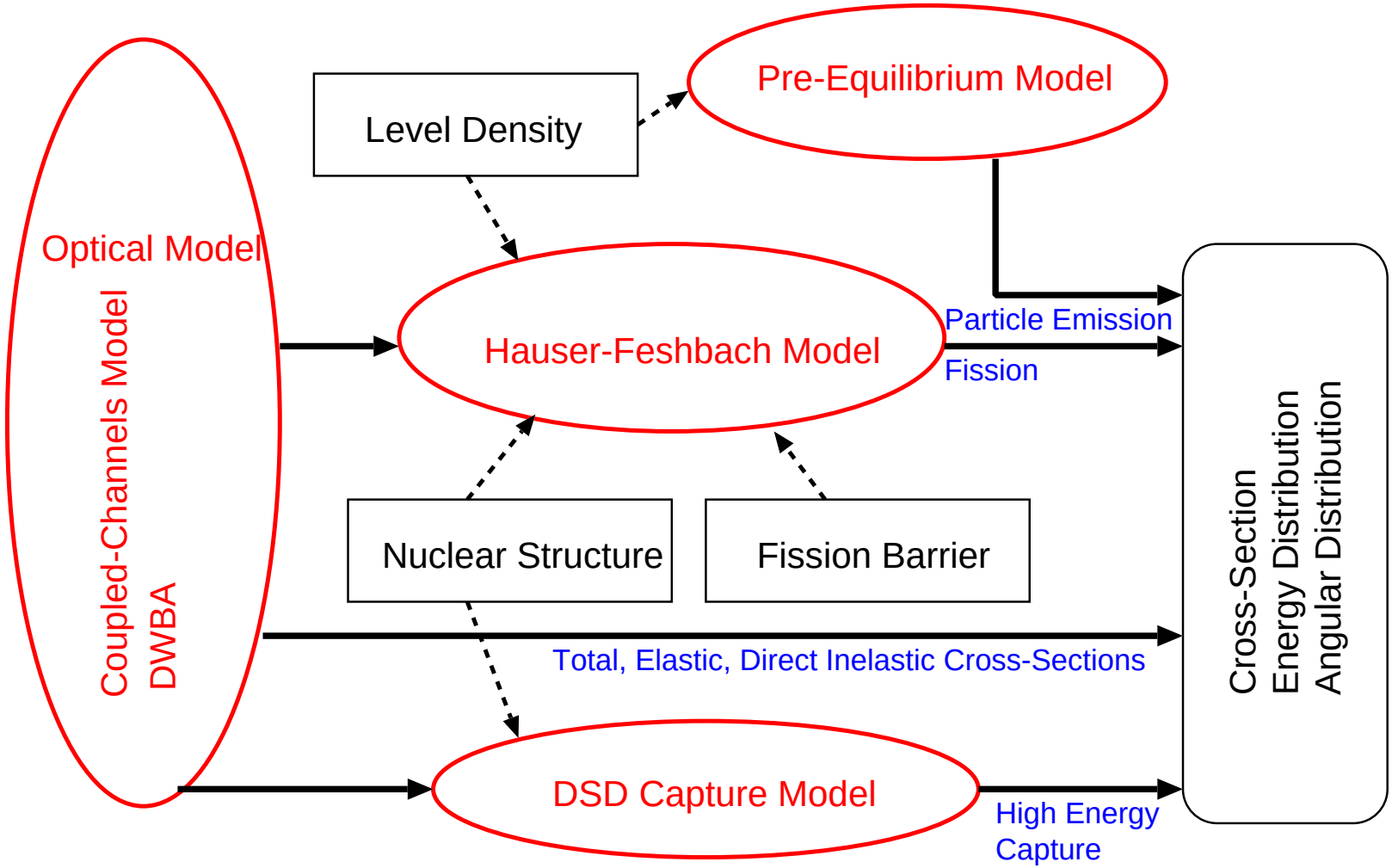
# Nuclear Reaction Theories above Resonance Region



# Optical Model / CC Model

## Status

- Coupled-Channels code, ECIS, is widely used.
- There are also many optical model codes available.
  - SCAT2, DWUCK4, CoH, ELIESE-3, CCOM, TWOSTP, etc.

## Recent Topics and Issues

- Coding of ECIS is so tight, and it is almost impossible to make any modification to this code.
- A new compact module (Fortran95) for spherical calculations is available (LANL), which is a part of DSD module.
- A consistent treatment of deformation effect in the coupled-channels method and the Hauser-Feshbach model is needed.

# Hauser-Feshbach Model

## Status

- Extensive efforts have been paid to make the HF codes in many countries.
  - GNASH, McGNASH (LANL), EMPIRE-2 (BNL/IAEA), TALYS (NRG, Petten)
  - more new codes are also available in Japan and China.

## Recent Topics and Issues

- The HF has been used for several decades, and it is known that the calculated quantities agree fairly well with experimental observables, when a reasonable parameter set is chosen.
- A full Monte-Carlo approach to calculate an exclusive cross section is feasible. The technique make us possible to evaluate a correlated $\gamma$ and neutron emission, which is needed by an active interrogation technique.
- Further efforts needed to improve model parameters
  - Level densities — well-understood systematics or microscopic approach
  - Fission barriers — nuclear structure calculation, fission dynamics
  - $\gamma$-ray strength function — well-understood systematics or microscopic approach

# Pre-Equilibrium Model

## Status

- We still rely on a classical exciton model, because :
  - the classical model works well in many cases (cf. PRECO).
  - quantum-mechanical models have not been well understood yet.
    - TUL model in EMPIRE for $n$ and $p$ emissions
    - FKK/NWY one-step model in GNASH calculation (optional)
- McGNASH has an interface to a hybrid model, DDHMS.
- GEANIE experiments at LANSCE revealed an importance of PE spin physics.

## Recent Topics and Issues

- Theoretical development in the quantum mechanical pre-equilibrium reaction is still needed.
- A high-performance computer will help a fully microscopic multi-step reaction calculations.
- The model also requires up-to-date nuclear structure calculations.

# General Remarks Relevant to Code Development

- Coding Style
  - We can take advantages of modern computer languages to write a code — Fortran90/95, C, C++
- Interface to Model Parameters
  - IAEA has organized an international collaboration to compile a nuclear reaction model input parameter library, RIPL, and US has been involved in this project deeply. Many of model codes have an interface to this library.
- International Collaboration
  - International (or inside USA) collaborations on the code development are one of the key issues to improve our capability to predict unknown cross sections.
  - A framework in which model codes are freely exchangeable is needed.