

# State of Empire

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# Developers

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**EMPIRE** is a comprehensive, easy to use, nuclear reaction code for nuclear data evaluation.

- ✓ R. Capote (IAEA, Vienna)
- ✓ B. Carlson (ITA, Sao Jose dos Campos, Brazil)
- ✓ M. Herman (BNL, US)
- ✓ T. Kawano (LANL, US)
- ✓ P. Oblozinsky (BNL, US)
- ✓ M. Sin (Univ. Bucharest, Romania)
- ✓ A. Trkov (IAEA, Vienna)
- ✓ V. Zerkin (IAEA, Vienna)



# Recent developments (2.19b29 Lodi)

- ✓ Automatic fit of Optical Model Potential (Spherical, CC, and DWBA)
- ✓ Discrete collective states embedded in the continuum
- ✓ Sensitivity calculations
- ✓ Covariances
  - ✓ Coupling to KALMAN
  - ✓ Monte-Carlo approach
- ✓ Normalization of  $\Gamma_\gamma$  to the experimental data
- ✓ Mixed (exclusive/inclusive) spectra in high energy evaluations
- ✓ Adjustment of energy dependence of model parameters
- ✓ Support for NJOY code
- ✓ Improved numerical stability and bug fixes

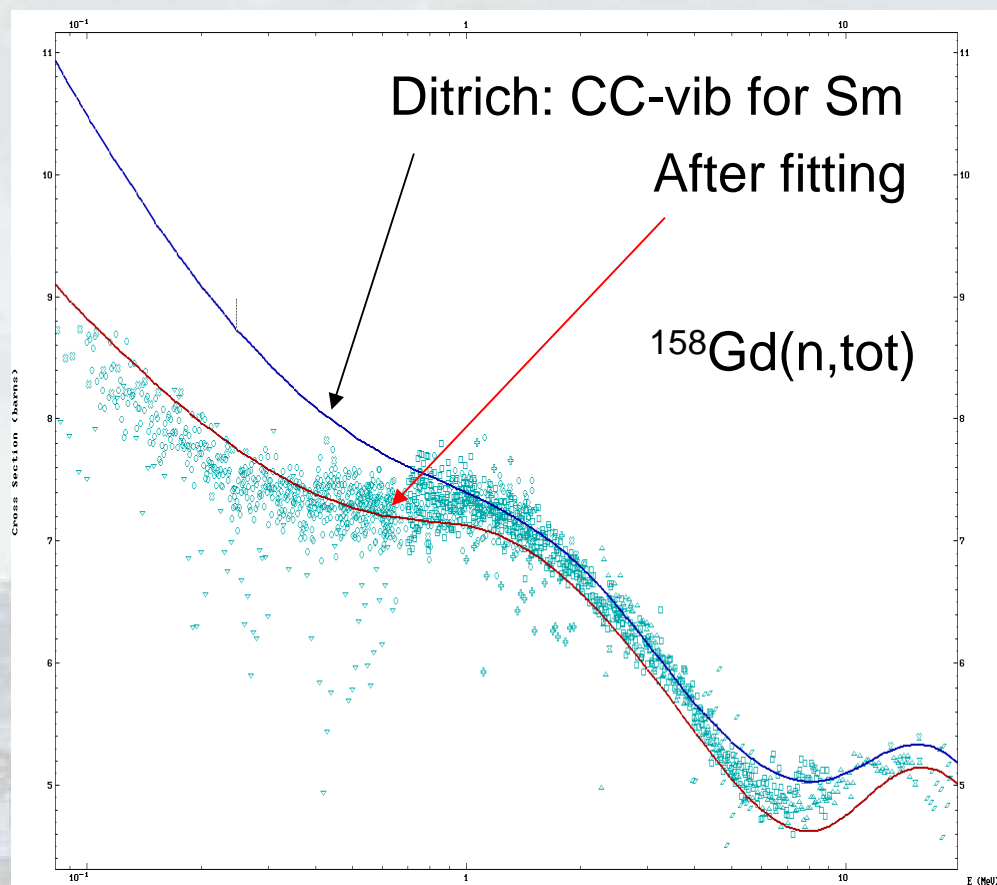
**Ultimate goal: EMPIRE input = ENDF evaluation**



# Automatic fit of Optical Model Potential

Developed by B. Carlson

- ✓ Calculations done totally within EMPIRE
- ✓ Spherical, CC-vibrational, CC-rotational, and DWBA
- ✓ Simple input
  - automatic retrieval and selection of experimental data
  - automatic energy grid
  - Typical input:  
**FITOMP 2**  
**FITRVV 0 200 (default+-2MeV)**





# Exclusive/inclusive spectra

## ✓ Conventional approach

- ✓ exclusive spectra up to 20 MeV
- ✓ inclusive spectra (MF/MT=3/5 and MF/MT=6/5) above 20 MeV

- ✓ Disadvantage: abrupt change of representation for some reactions (e.g.,  $(n,2n)$ ,  $(n,3n)$ , ...)

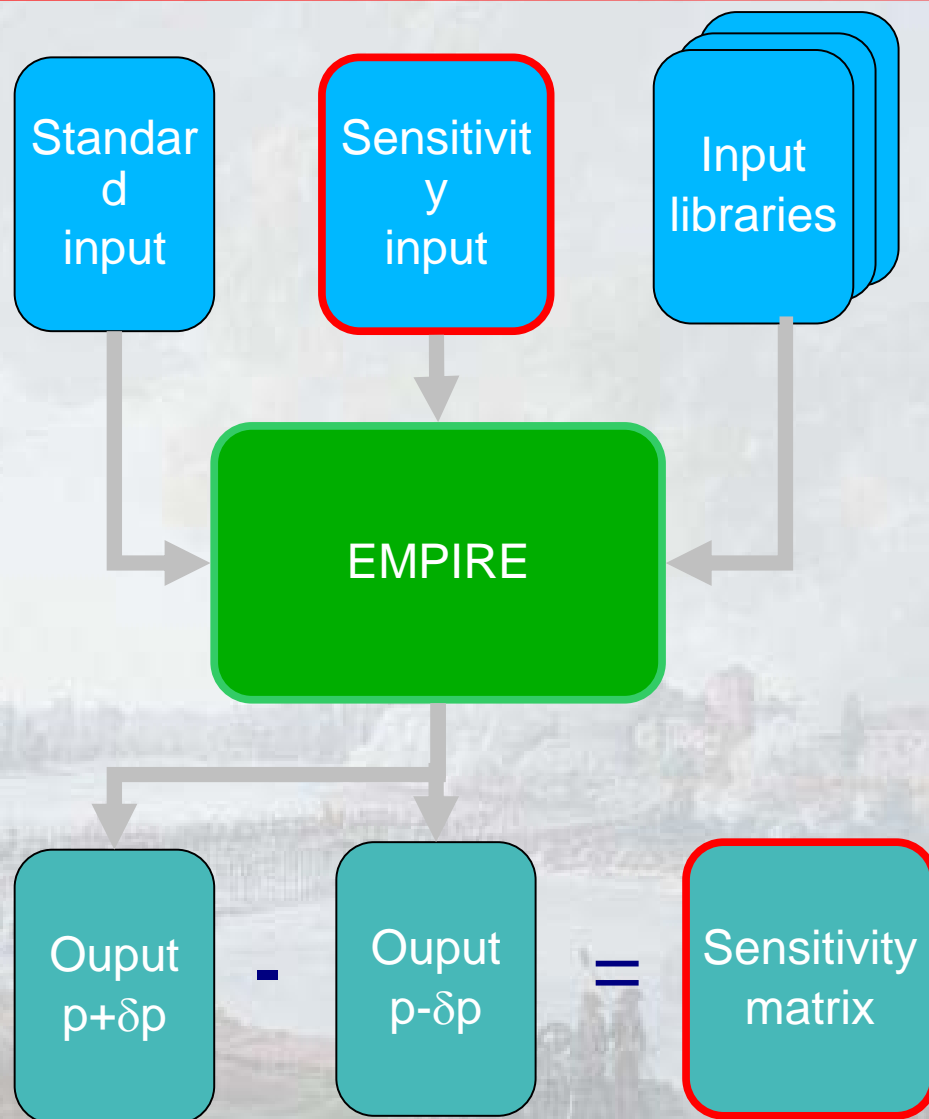
## ✓ EMPIRE approach

- ✓ exclusive spectra for all reactions up to a given number of emissions (e.g.,  $(n,g)$ ,  $(n,n')$ ,  $(n,2n)$ ,  $(n,np)$ , ... for 2 emissions)
- ✓ inclusive spectra for higher emissions (e.g.,  $(n,3n)$ ,  $(n,2np)$ , ...)



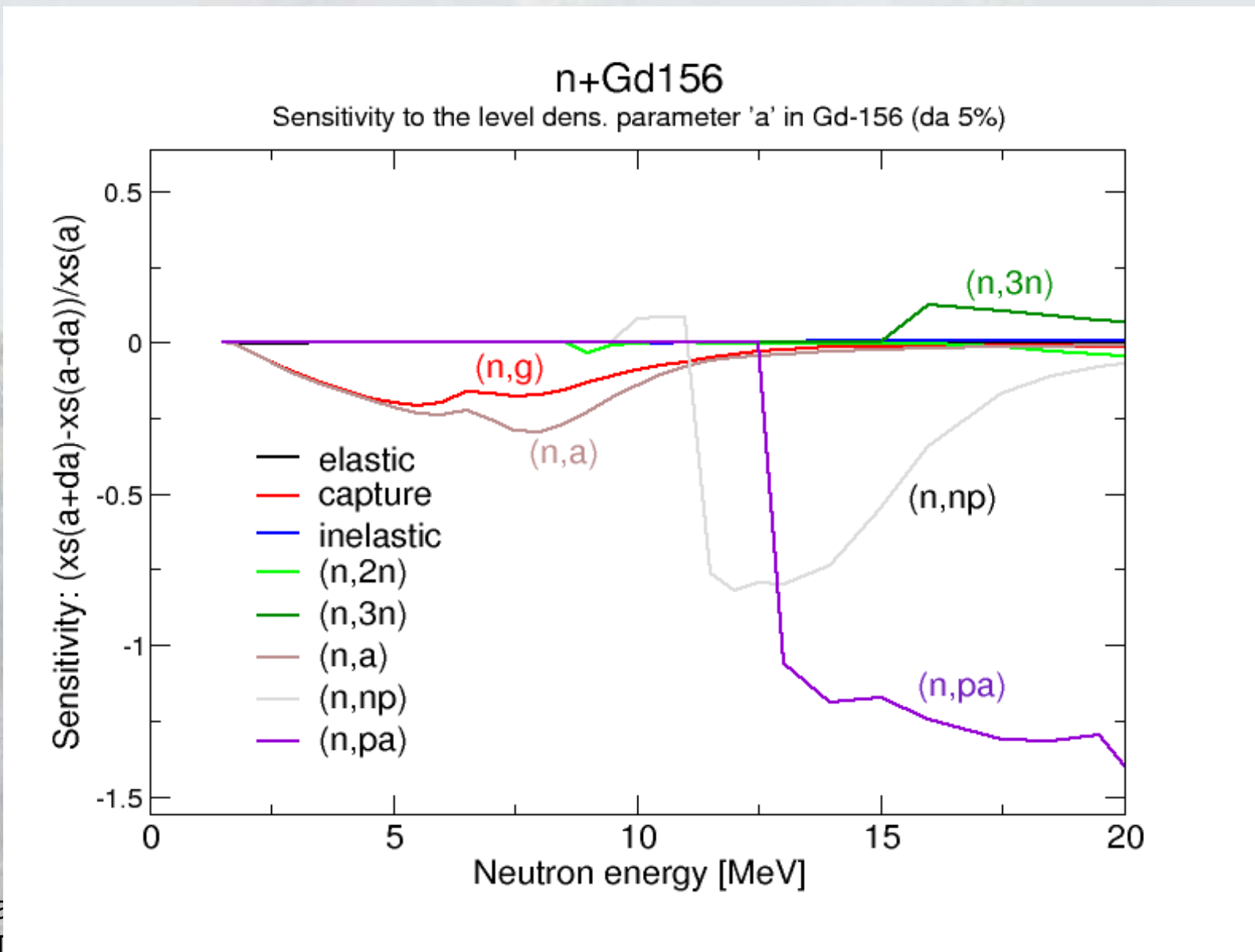
# Sensitivity calculations

- ✓ Sensitivity matrix needed for covariance calculations with KALMAN implemented in EMPIRE-2.19b29
- ✓ almost any model parameter can be varied (including energy dependent ones)
- ✓ sensitivity of all reaction cross sections to each varied parameter are determined
- ✓ Calculation time: 0.5 to 7 h





# Example of the sensitivity





# New quality in data fitting!

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- ✓ Sensitivity matrix tells us
  - ✓ to which parameter particular cross section is sensitive
  - ✓ what potential damage to other cross sections we do changing this parameter
- ✓ Sensitivity matrix does it
  - ✓ in compact, easy to analyse, form
  - ✓ with less manual effort
  - ✓ faster !
- ✓ More in presentation on EMPIRE-KALMAN





# Conclusions

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State of the EMPIRE is good!