Nuclear Data Week 2020

Angular and energy distributions update for structural materials

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Dec. 1. 2020

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Summary

- Isotope and reactions to update
  - Updating angular and/or energy distribution for 62 materials (Ni, Fe, Zn, Cr, . . .)
  - Published in *Nucl. Instr. Meth.* **A 963**, 163699 (2020)
- Motivation
  - No/partial information for discrete levels of (n,p) and (n,α) reactions cross sections in the Current ENDF/B-VIII.0
  - Large discrepancies for Monte Carlo simulations on angular distributions of the LENZ experiment.
- New data/theory
  - Angular distributions of Hauser-Feshbach formalism in CoH_3
  - LENZ measurements for several structural materials, such as Fe, Ni,. . .
- Validation
  - Angular distributions measured at LENZ detector compared to those of new evaluations

Deficiencies in the current ENDF/B-VIII.0

- Status in the current ENDF/B-VIII.0

Status of evaluations on (n,x) reactions (x=p,d,t,α)

	A	B	C	D
p	189	265	9	94
α	163	273	25	96
d	18	246	4	289
t	14	227	3	313

(total: 557 nuclei)

A: (n,x$_{level}$) and (n,x$_{cont}$) B: (n,x$_{tot}$) only
C: (n,x$_{level}$) or (n,x$_{cont}$) D: no data

(n,x$_{tot}$)=(n,x$_{level}$)+(n,x$_{cont}$)

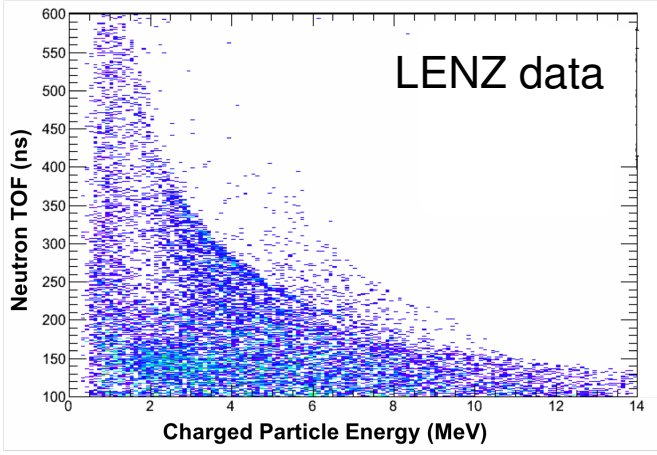
level: ground, 1st excited level, 2nd excited level, . . .

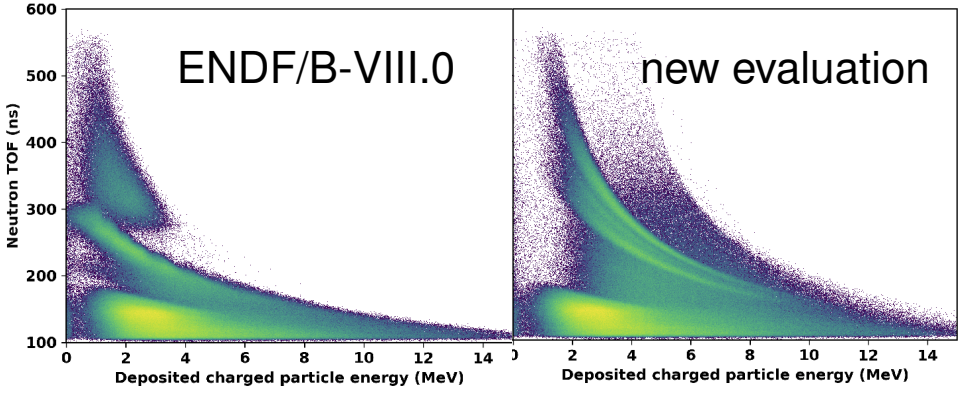
- Updated nuclei

  62 materials including Ni, Fe, Zn, Cr, . . .

- MCNP simulations

(Brass target: 65 % ^{nat}Cu + 35 % ^{nat}Zn)





Production of consistent data sets

- Inconsistent data in the current ENDF/B-VIII.0
  - Cross sections and double differential cross sections (DDX) for total (n,p) and (n,α) without data of discrete levels
  - Cross sections for discrete levels but no data for continuum state
  - Cross sections for discrete levels with isotropic angular distributions
  - Inclusive or exclusive spectra
  - (No) γ emissions for discrete levels of (n,p) and (n,α)
- Consistent data in new evaluations
  - The cross sections in MF3 if available were not changed.
  - Discrete levels and continuum state were separately saved in MF3
  - Angular distributions for discrete levels were saved in MF4
  - Energy-angular distribtuions for continuum were exclusively saved in MF6
  - Photon transitions were saved in MF12 for their multiplicity and MF14 for probability.

Update procedure

- Updating new angular distributions and energy spectra
  - Adopting cross sections from ENDF/B-VIII.0
    - Cross sections of ENDF/B-VIII.0 for (n,p) and (n,α) if data available, where threshold energies are recalculated using mass data by Audi2012 and FRDM2012
  - Adding new data
    - Cross sections of discrete levels and continuum state if no data available, where cross sections of (n,p$_{tot}$) and (n,α_{tot}) are normalized to those of ENDF/B-VIII.0.
  - Adding/Replacing new data
    - Angular distributions of discrete levels and continuum state if no data or isotropic data available
    - Exclusive energy spectra if no data or inclusive spectra available.
- Code: CoH$_3$
- Formatting: DeCE
- Processing: NJOY2016
- Simulation: MCNP-6.2

Angular distribution of Hauser-Feshbach formalism in CoH_3

Blatt-Biedenharn Formalism:

$$\left(\frac{d\sigma}{d\Omega}\right)_{ab} = \sum_L B_L P_L(\cos\theta_b) \ ,$$

where the Legendre coefficient,

$$\begin{aligned} B_L &= \frac{1}{4k_a^2}\frac{(-)^{I_B-I_A+s_b-s_a}}{(2s_a+1)(2I_A+1)} \\ &\times \sum_J (2J+1)^2 \frac{1}{N_J} \sum_{l_a j_a} \sum_{l_b j_b} W_{ab} \\ &\times \{X_{l_a j_a} X_{l_b j_b} + Y_{l_a j_a, l_b j_b}\} \ , \end{aligned}$$

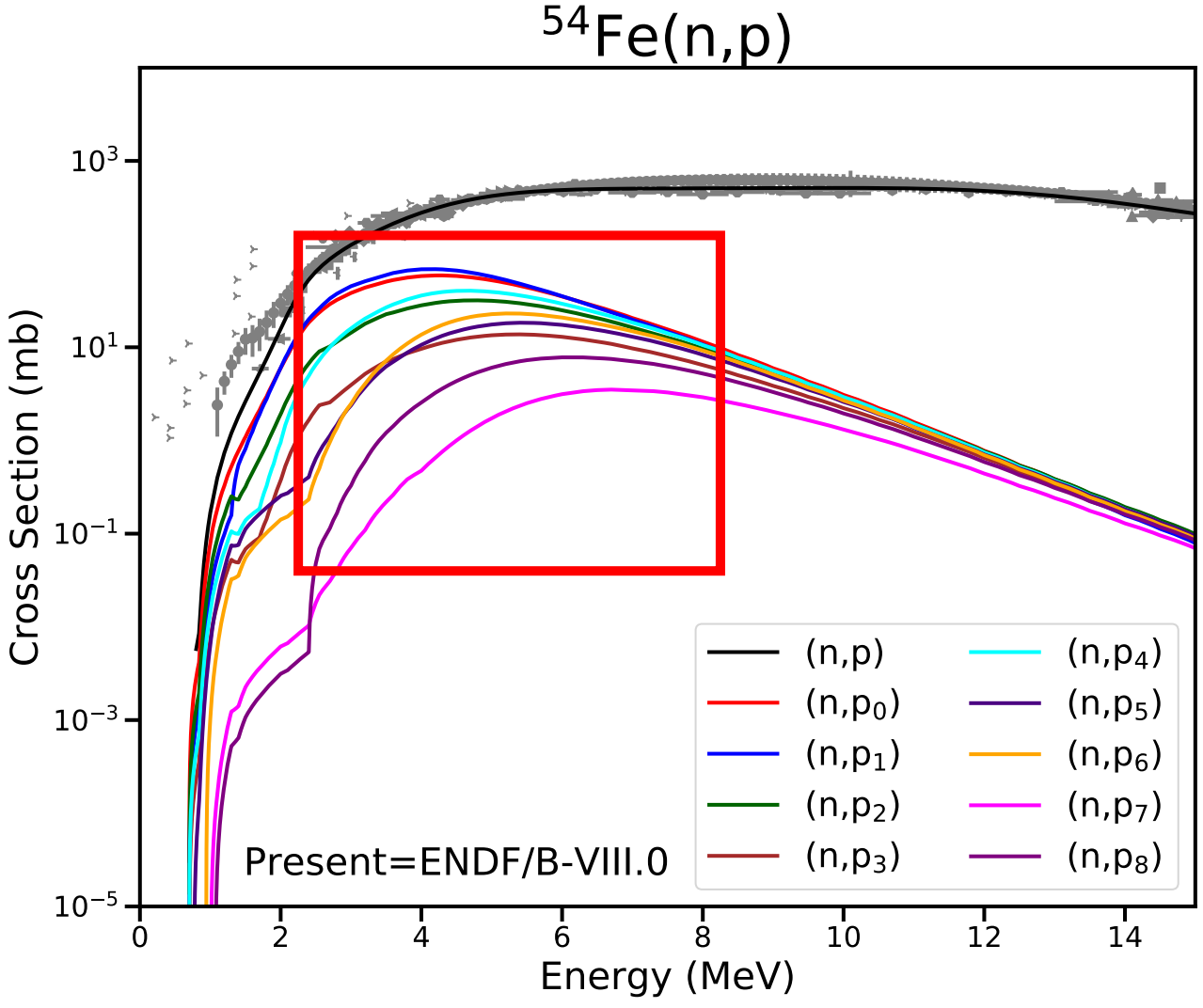
is explicitly calculated.

$cf.$

$$\begin{aligned} B_L^{\rm HF} &= \frac{1}{4k_a^2}\frac{(-)^{I_B-I_A+s_b-s_a}}{(2s_a+1)(2I_A+1)} \\ &\times \sum_J (2J+1)^2 \frac{1}{N_J} \\ &\times \sum_{l_a j_a} \sum_{l_b j_b} X_{l_a j_a} X_{l_b j_b} \ . \end{aligned}$$

Many codes employ B_L^{HF} multiplied by width fluctuation.

Angular distributions on ^{54}Fe(n,p) measured at LENZ experiment



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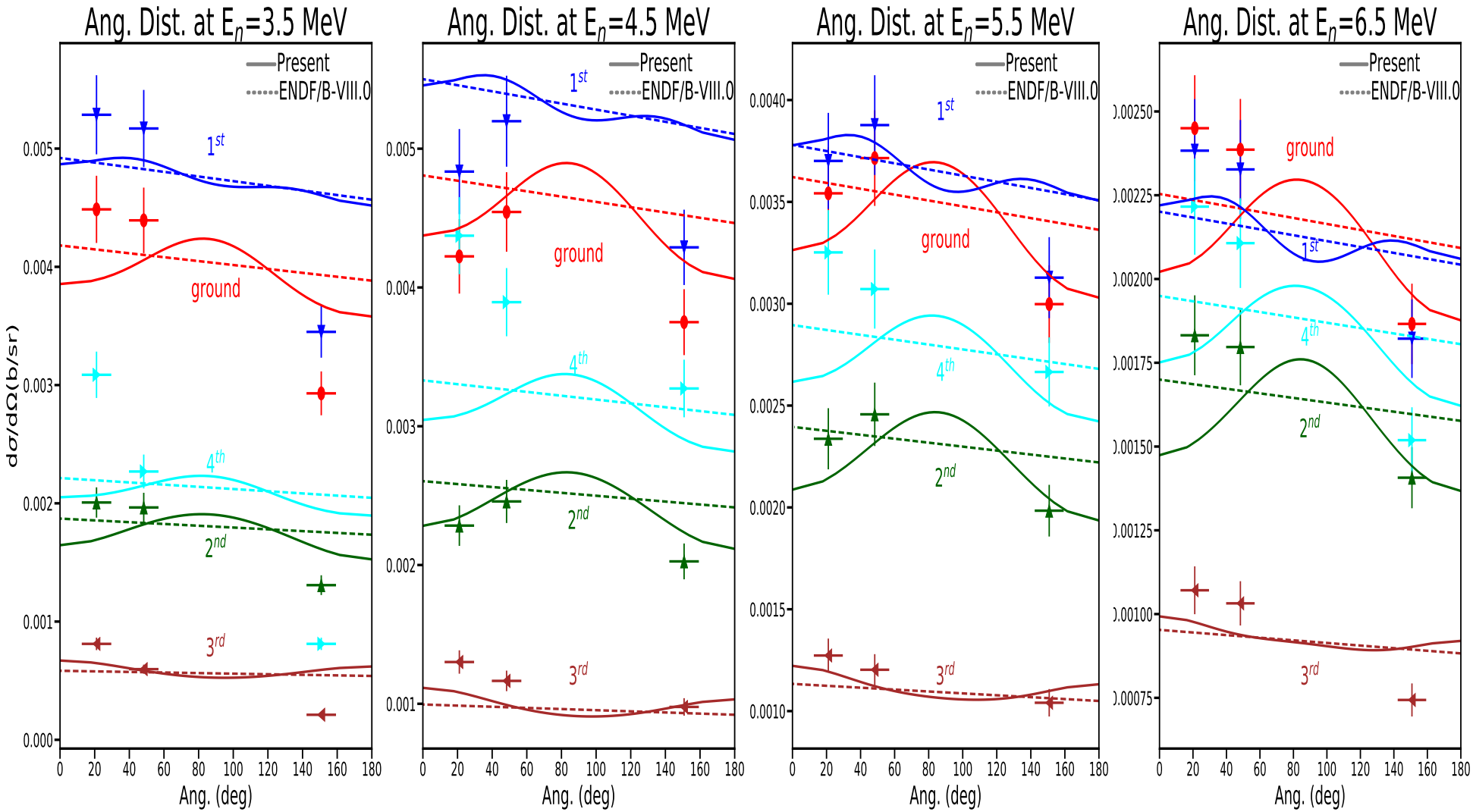

Angular distributions on ^{54}Fe(n,p) measured at LENZ experiment