Secondary distribution addition and recent NZ evaluation progress

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Nuclear Data Week: Cross Section Evaluation Working Group (CSEWG)

Oct. 31- Nov. 4, 2022

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

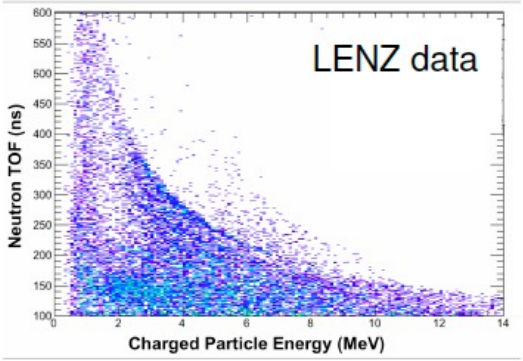
(n,x$_{tot}$)=(n,x$_{level}$)+(n,x$_{cont}$)
level: ground, 1st excited level, 2nd excited level, …

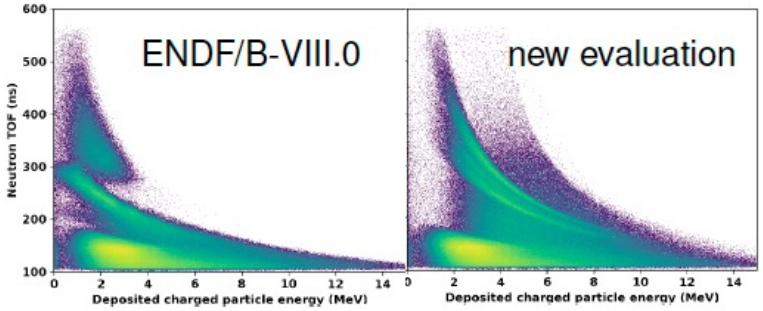
- Updated nuclei

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

- MCNP simulations

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





Courtesy H.I. Kim

CSEWG2020 presentation by H.I.Kim on "Angular and energy distributions update for structural materials

Production of consistent data sets

Courtesy H.I. Kim

- 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 with isotropic angular distributions
  - Cross sections for discrete levels but no data for continuum state
  - Inclusive or exclusive spectra
  - (No) Discrete 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 distribtuions for discrete levels were saved in MF4
  - Energy-angular distribtuions for continuum were exclusively saved in MF6
  - Photon trasitions were saved in MF12 for their multiplicity and MF14 for probability.

Update procedure

- Updating new angular distributions and energy spectra *Courtesy H.I. Kim*
  - 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

LANL-KAERI new evaluation ("nzv2") for nz reactions

-new calculations on 62 nuclei

-H1 and He4 distributions for MT=600-609 and MT=800-809

"New Evaluation on Angular Distributions and Energy Spectra for Neutron-induced Charged Particle Measurements" H.I. Kim, H.Y. Lee, T. Kawano, et al., Nucl. Instr. Meth. A 963, 163699 (2020)

Discrete levels for (n,p)

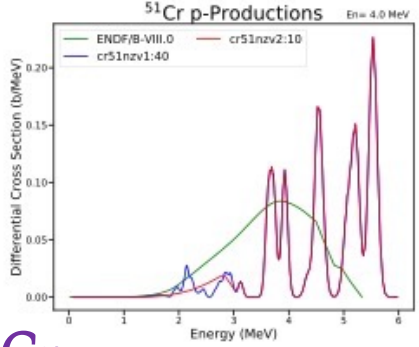
Nucleus	nzv1	nzv2	en80	nucleus	nzv1	nzv2	en80	nucleus	nzv1	nzv2	en80
^{27}Al	20	20	20	^{52}Cr*	32	10	0	^{65}Cu*	31	10	0
^{28}Si	14	14	14	^{53}Cr*	24	10	0	^{64}Zn*	40	10	0
^{29}Si	16	16	16	^{54}Cr*	17	10	0	^{65}Zn*	40	10	0
^{30}Si	6	6	6	^{54}Fe	34	34	34	^{66}Zn*	32	10	0
^{31}Si	1	1	1	^{56}Fe	10	10	10	^{67}Zn*	26	10	0
^{32}Si	1	1	1	^{57}Fe	18	18	18	^{68}Zn	8	8	0
^{35}Cl	30	30	30	^{58}Fe	17	17	17	^{69}Zn	17	17	17
^{36}Cl	16	16	16	^{56}Co*	40	10	–	^{70}Zn	1	1	0
^{37}Cl*	18	10	0	^{57}Co*	30	10	–	^{73}As*	40	10	0
^{39}K *	35	10	0	^{58}Co	40	40	40	^{74}As*	40	10	0
^{40}K *	40	10	0	^{59}Co*	27	10	0	^{90}Zr	12	12	12
^{41}K *	30	10	0	^{56}Ni*	32	10	–	^{91}Zr	6	6	6
^{46}Ti*	40	10	0	^{57}Ni*	40	10	–	^{92}Zr	1	1	1
^{47}Ti*	28	10	0	^{58}Ni*	40	10	0	^{93}Zr	17	17	17
^{48}Ti*	35	10	0	^{59}Ni*	40	10	0	^{94}Zr*	10	10	10
^{49}Ti*	25	10	0	^{60}Ni*	40	10	0	^{95}Zr	16	16	16
^{50}Ti	9	9	0	^{61}Ni*	40	10	0	^{96}Zr	3	3	3
^{49}V	40	40	40	^{62}Ni*	25	10	0	^{107}Ag*	40	10	0
^{50}V*	40	10	0	^{63}Ni	26	26	26	^{109}Ag	31	31	31
^{51}V*	35	10	0	^{64}Ni*	14	10	0	^{180}Ta*	40	10	0
^{50}Cr*	40	10	0	^{63}Cu*	23	10	0	^{181}Ta*	36	10	0
^{51}Cr*	40	10	0	^{64}Cu	40	40	40	^{197}Au*	32	10	0

* employed different numbers of discrete levels between nzv1 and nzv2

Discrete levels for (n,α)

Nucleus	nzv1	nzv2	en80	nucleus	nzv1	nzv2	en80	nucleus	nzv1	nzv2	en80
^{27}Al	20	20	20	^{52}Cr*	40	10	0	^{65}Cu*	25	10	0
^{28}Si	16	16	16	^{53}Cr*	40	10	0	^{64}Zn*	36	10	0
^{29}Si	20	20	20	^{54}Cr*	35	10	0	^{65}Zn*	40	10	0
^{30}Si	12	12	12	^{54}Fe	24	24	24	^{66}Zn*	23	10	0
^{31}Si	15	15	15	^{56}Fe	19	19	19	^{67}Zn*	40	10	0
^{32}Si	1	1	1	^{57}Fe	39	39	39	^{68}Zn*	31	10	0
^{35}Cl	21	21	21	^{58}Fe	10	10	10	^{69}Zn	18	18	18
^{36}Cl	32	32	32	^{56}Co*	40	10	–	^{70}Zn	1	1	0
^{37}Cl	6	6	6	^{57}Co*	34	10	–	^{73}As*	40	10	0
^{39}K*	39	10	0	^{58}Co	40	40	40	^{74}As*	23	10	0
^{40}K*	40	10	0	^{59}Co*	40	10	0	^{90}Zr	9	9	9
^{41}K*	31	10	0	^{56}Ni*	24	10	–	^{91}Zr	40	40	40
^{46}Ti*	40	10	0	^{57}Ni*	25	10	–	^{92}Zr	40	40	40
^{47}Ti*	40	10	0	^{58}Ni*	31	10	0	^{93}Zr	27	27	27
^{48}Ti*	25	10	0	^{59}Ni*	40	10	0	^{94}Zr	40	40	40
^{49}Ti*	40	10	0	^{60}Ni*	30	10	0	^{95}Zr	9	9	9
^{50}Ti*	26	10	0	^{61}Ni*	40	10	0	^{96}Zr	10	10	10
^{49}V	40	40	40	^{62}Ni*	27	10	0	^{107}Ag*	40	10	0
^{50}V*	28	10	0	^{63}Ni	28	28	28	^{109}Ag	2	2	2
^{51}V*	35	10	0	^{64}Ni	1	1	0	^{180}Ta*	40	10	0
^{50}Cr*	40	10	0	^{63}Cu*	40	10	0	^{181}Ta*	33	10	0
^{51}Cr*	40	10	0	^{64}Cu	40	40	40	^{197}Au*	40	10	0

* employed different numbers of discrete levels between nzv1 and nzv2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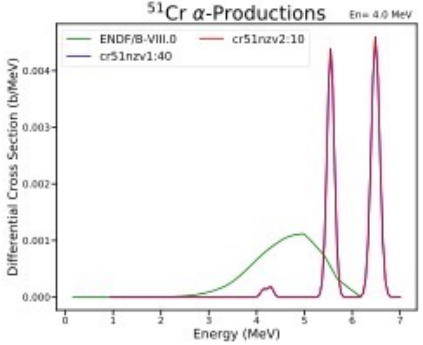
Differential Cross Section (b/MeV)
Energy (MeV)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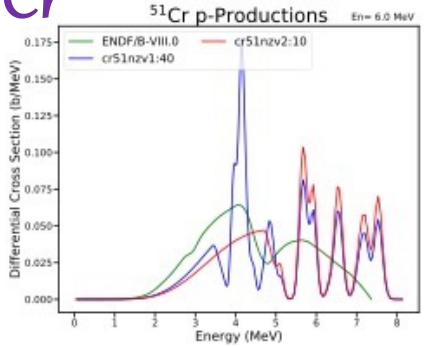
cr51nzv1:40
Differential Cross Section (b/MeV)
Energy (MeV)

52Cr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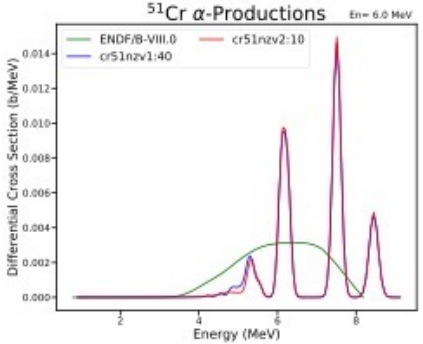
Energy (MeV)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En= 6.0 MeV
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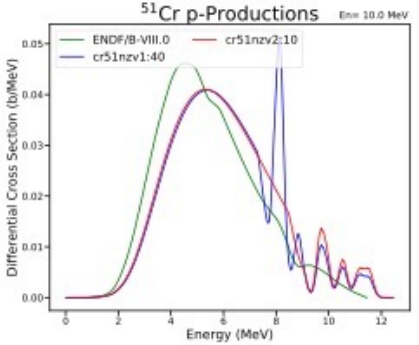
Differential Cross Section (b/MeV)
Energy (MeV)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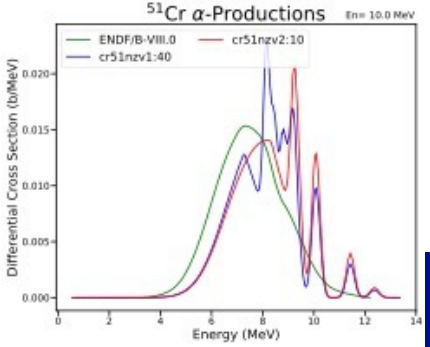
Differential Cross Section (b/MeV)
Energy (MeV)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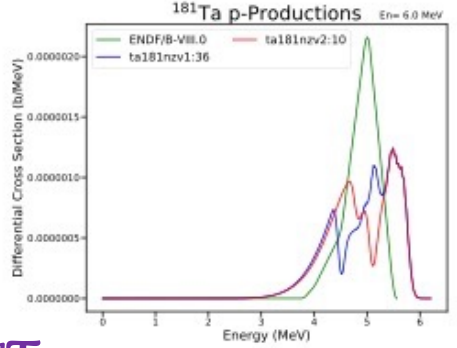
En= 10.0 MeV
ENDF/B-VIII.0
cr51nzv2:10
cr51nzv1:40
Differential Cross Section (b/MeV)
Energy (MeV)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En= 6.0 MeV
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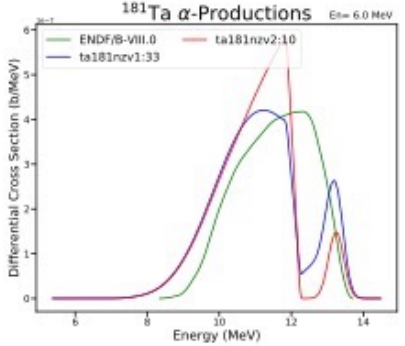
Differential Cross Section (b/MeV)
Energy (MeV)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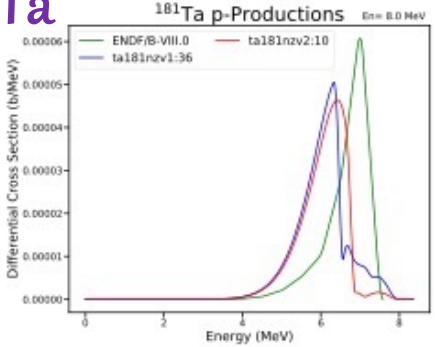
ta181nzv1:33
Differential Cross Section (b/MeV)
Energy (MeV)

181Ta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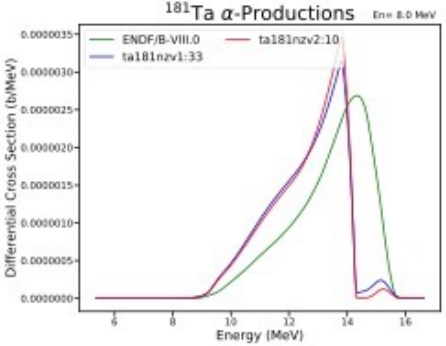
Differential Cross Section (b/MeV)
Energy (MeV)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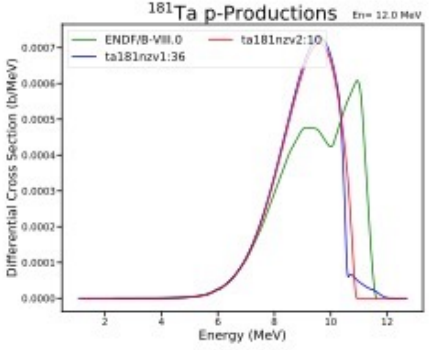
En= 8.0 MeV
ENDF/B-VIII.0
ta181nzv2:10
ta181nzv1:33
Differential Cross Section (b/MeV)
Energy (MeV)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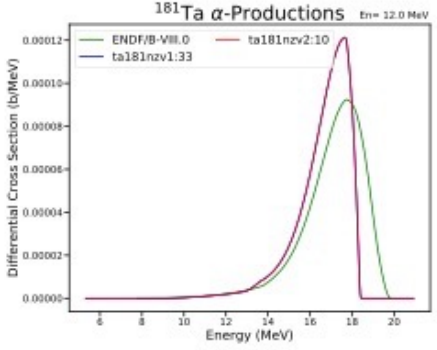
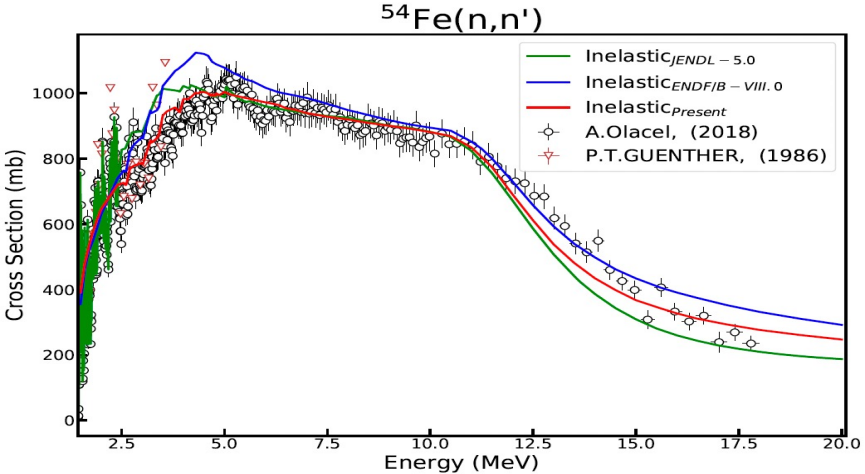
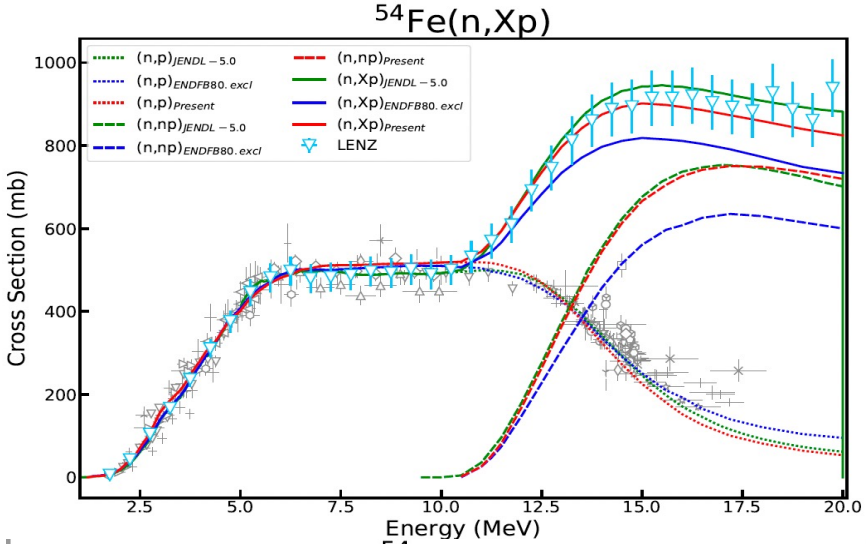
Differential Cross Section (b/MeV)
Energy (MeV)

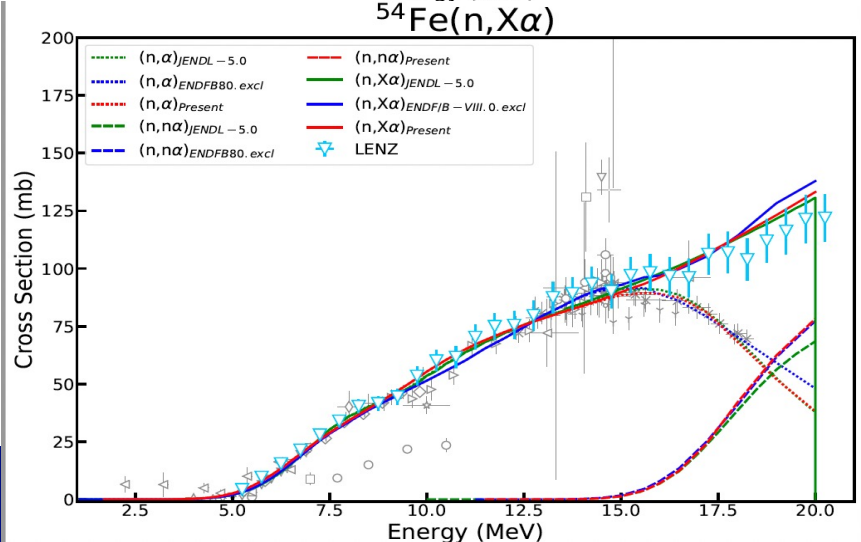

181Ta α-Productions
En= 12.0 MeV
ENDF/B-VIII.0
ta181nzv2:10
ta181nzv1:33
Differential Cross Section (b/MeV)
Energy (MeV)

New evaluation ("present") using new data on ^{54}Fe

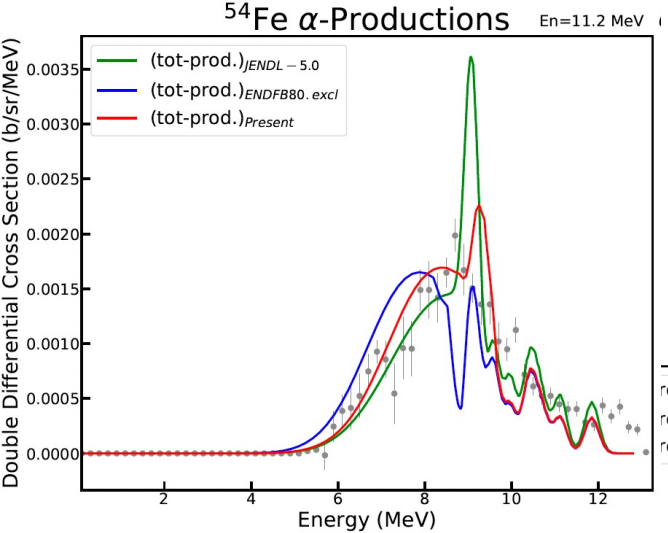
- Possible ways
  - Partial update
    - Re-evaluation for only (n,n') and (n,np) cross sections
    - Reconstructing other channels
  - New evaluation
    - New evaluation through model parameterizations
    - Reproducing all channels carefully
- Present work (New evaluation)
  - code: Empire + CoH_3
  - CCOMP
    - Adjusted OMP from Spherical Koning local OMP (RIPL ID. 1414)
    - CC (β_2 = 0.15) calculation with DWBA
  - Gilbert-Cameron level density and PCROSS
  - Angular distributions with energy-dependent anisotropy for emitted charged particles by CoH_3 (out of this talk)

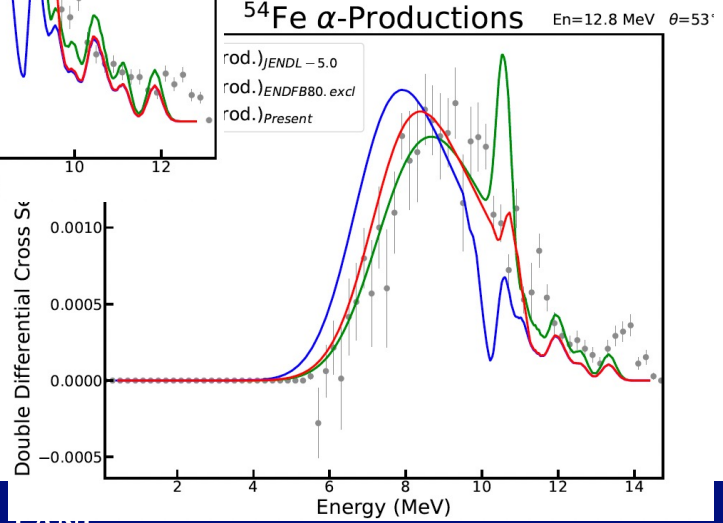


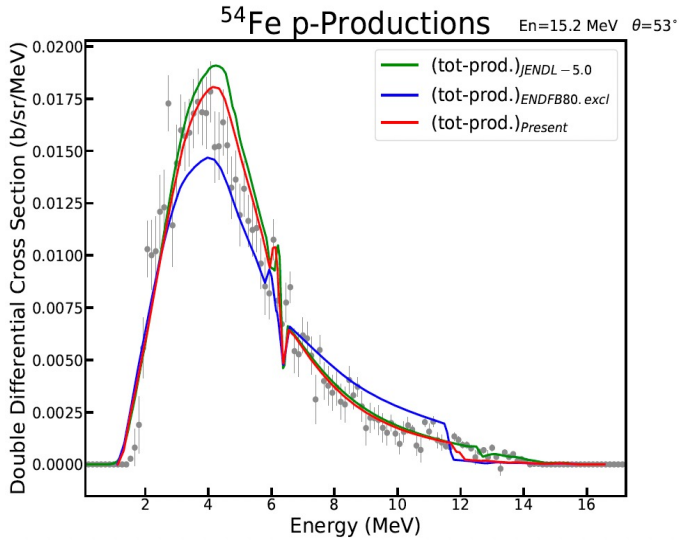


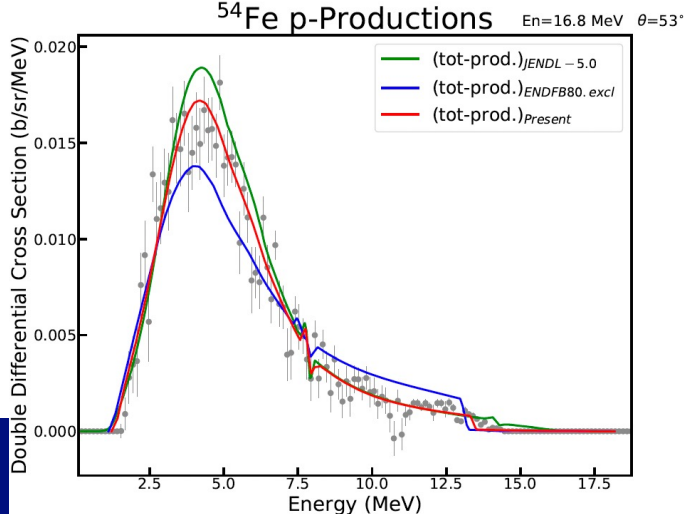


Production cross section measured at 53 degrees compared with new evaluation ("present"), ENDF, and JENDL

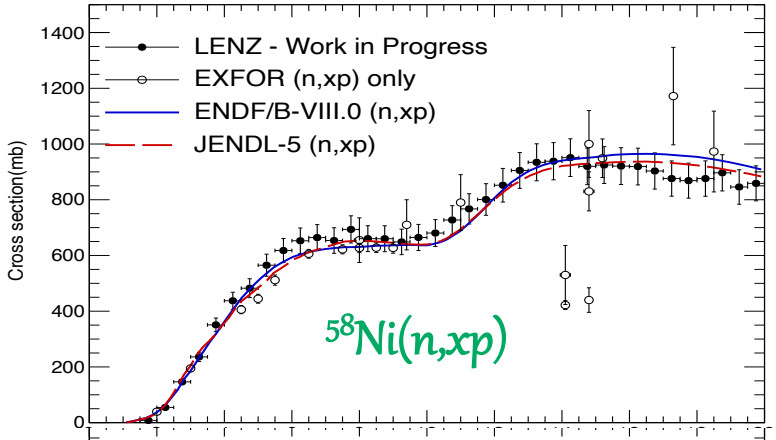


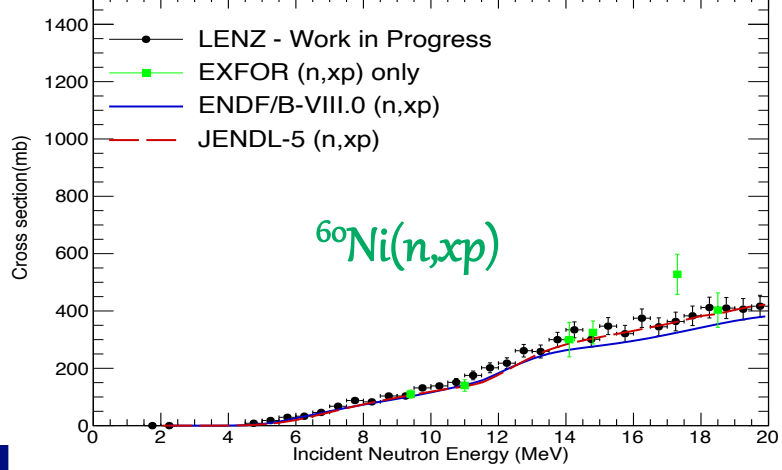


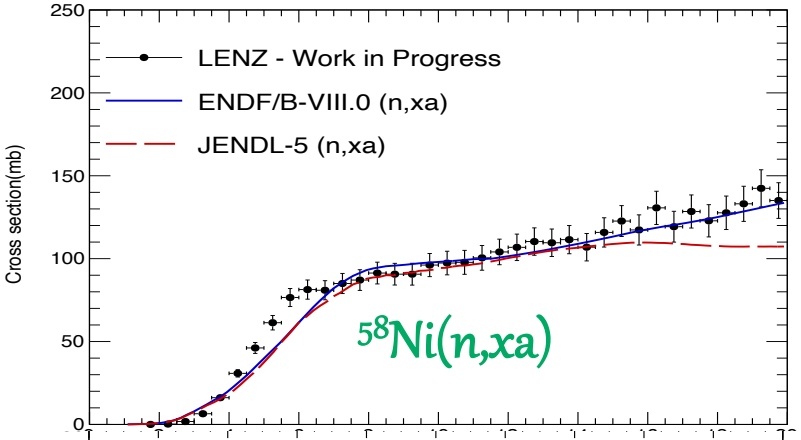


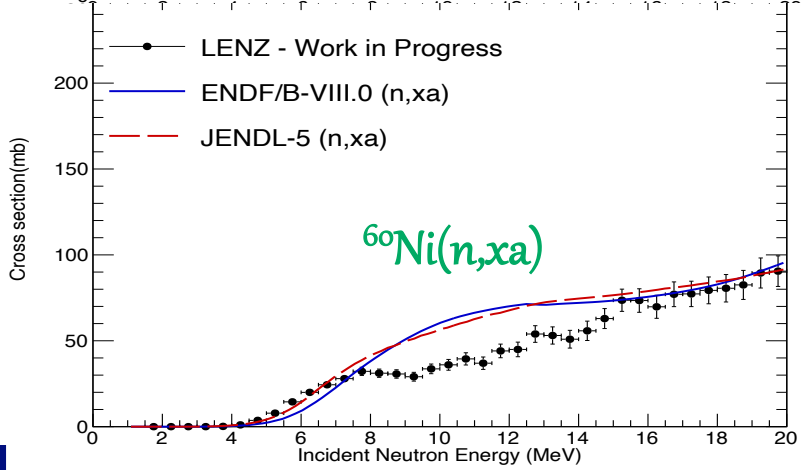


New LENZ data on stable Ni– new evaluation is in progress









Plans for secondary distribution for ENDF/B-VIII.1

- we're closely working with LLNL and BNL for merging both efforts into the new ENDF release
  - making decisions on how to consistently merge the secondary distribution files over a broad range of nuclei
  - expect the energy balances for those channels will be improved with this effort
- LANL-KAERI plans to complete new evaluation based on new experimental LENZ data of Fe-54, Fe-56 and Ni-58, Ni-60
  - will update cross sections for (n,p) MT=103, (n,np) MT=28, (n,d) MT=104, (n,α) MT=107, and (n,nα) MT=22
  - will update differential cross sections of discrete states for protons in MT=600-609 and alphas in MT=800-809

Acknowledgement

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KAERI 한국원자력연구원 Korea Atomic Energy Research Institute