# TENDL+EMPIRE Project

G. P. A. Nobre *et al.*
National Nuclear Data Center
Brookhaven National Laboratory
*CSEWG - Nuclear Data Weeks, November 6, 2017*

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*a passion for discovery*

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# New evaluations from EMPIRE & TENDL

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PSI

- During last mini-CSEWG ~ 50 new evaluations of short/long-lived isotopes were proposed from TENDL-2015

- Stable: $^{20,21,22}$Ne
- $t_{1/2} > 10^5$ years: $^{26m}$Al, $^{36}$Cl, $^{41}$Ar, $^{81}$Kr, $^{98}$Tc, $^{186m}$Re, $^{205}$Pb, $^{210m}$Bi
- $10^5 > t_{1/2} > 10^3$ years: $^{93}$Mo
- $10^3 > t_{1/2} > 100$ years: $^{32}$Si, $^{118m}$Ag, $^{158}$Tb, $^{209}$Po
- $100 > t_{1/2} > 10$ years: $^{35}$S, $^{63}$Ni, $^{121m}$Sn, $^{145}$Pm, $^{193}$Pt
- $10 > t_{1/2} > 1$ year: $^{55}$Fe, $^{109}$Cd, $^{144,146}$Pm, $^{171}$Tm, $^{204}$Tl, $^{208}$Po
- $1$ y$ > t_{1/2} > 1$ d: $^{37}$Ar, $^{45,47}$Ca, $^{49}$V, $^{51}$Cr, $^{54}$Mn, $^{71}$Ge, $^{75}$Se, $^{97}$Ru, $^{103}$Pd, $^{143}$Pm
$^{145}$Sm, $^{161}$Tb, $^{169}$Er, $^{175}$Yb, $^{181}$W, $^{185,191}$Os, $^{192,194m}$Ir, $^{203}$Hg, $^{210}$Po

Fusion, spallation
Medical, radiotracer
Spent nuclear fuel management
Gamma/beta/x-ray source

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$T_{1/2} = 2.0(2)$ seconds

$T_{1/2} = 6.3460(8)$ seconds

Fusion, spallation

Medical, radiotracer

Spent nuclear fuel management

Gamma/beta/x-ray source

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3

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# New evaluations from EMPIRE & TENDL

- We were tasked of reviewing these evaluations, assessing their quality, and determining whether they should be included into the ENDF/B-VIII.0 release

- Added to the analysis all nuclides with $T_{1/2}$ > 1 day and nuclides that "bridges gaps" between nuclei

- Performed "default" EMPIRE calculations, formatted into ENDF-6 files and generated 800+ plots for main reactions for all > 103 nuclides

- Compared with TENDL files

- Ran checking codes

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# List of nuclides analyzed

$^{20, 21, 22}$Ne, $^{26m}$Al, $^{31, 32}$Si, $^{35}$S, $^{36}$Cl, $^{37, 39, 41}$Ar, $^{41, 45, 47}$Ca, $^{49}$V, $^{51}$Cr, $^{54}$Mn, $^{55}$Fe, $^{63}$Ni, $^{64}$Cu, $^{69}$Zn, $^{70}$Ga, $^{71, 75}$Ge, $^{75, 81}$Se, $^{80}$Br, $^{79, 81}$Kr, $^{85}$Sr, $^{93}$Mo, $^{98}$Tc, $^{97}$Ru, $^{104}$Rh, $^{103, 109}$Pd, $^{108, 112, 113, 114, 115, 116, 117, 118m}$Ag, $^{107, 109}$Cd, $^{114}$In, $^{121m}$Sn, $^{122}$Sb, $^{121, 121m, 131, 131m}$Te, $^{128, 132, 132m, 133, 134}$I, $^{125, 127}$Xe, $^{131, 139}$Ba, $^{137, 137m}$Ce, $^{149}$Nd, $^{143, 144, 145, 146, 150}$Pm, $^{145, 146}$Sm, $^{159}$Gd, $^{158, 161}$Tb, $^{155, 157}$Dy, $^{163, 165, 169}$Er, $^{171}$Tm, $^{169, 175}$Yb, $^{175}$Hf, $^{181, 185}$W, $^{186m}$Re, $^{185, 191}$Os, $^{192, 194m}$Ir, $^{193}$Pt, $^{197, 197m, 203}$Hg, $^{204}$Tl, $^{205}$Pb, $^{210m}$Bi, $^{208, 209, 210}$Po, $^{245}$Pu, $^{247}$Cf

# List of nuclides analyzed

20, 21, 22Ne, 26mAl, 31, 32Si, 35S, 36Cl, 37, 39, 41Ar, 41, 45, 47Ca, 49V, 51Cr, 54Mn, 55Fe, 63Ni, 64Cu, 69Zn, 70Ga, 71, 75Ge, 75, 81Se, 80Br, 79, 81Kr, 85Sr, 93Mo, 98Tc, 97Ru, 104Rh, 103, 109Pd, 108, 112, 113, 114, 115, 116, 117, 118mAg, 107, 109Cd, 114In, 121mSn, 122Sb, 121, 121m, 131, 131mTe, 128, 132, 132m, 133, 134I, 125, 127Xe, 131, 139Ba, 137, 137mCe, 149Nd, 143, 144, 145, 146, 150Pm, 145, 146Sm, 159Gd, 158, 161Tb, 155, 157Dy, 163, 165, 169Er, 171Tm, 169, 175Yb, 175Hf, 181, 185W, 186mRe, 185, 191Os, 192, 194mIr, 193Pt, 197, 197m, 203Hg, 204Tl, 205Pb, 210mBi, 208, 209, 210Po, 245Pu, 247Cf

## No TENDL, EMPIRE only

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**Adopted TENDL**

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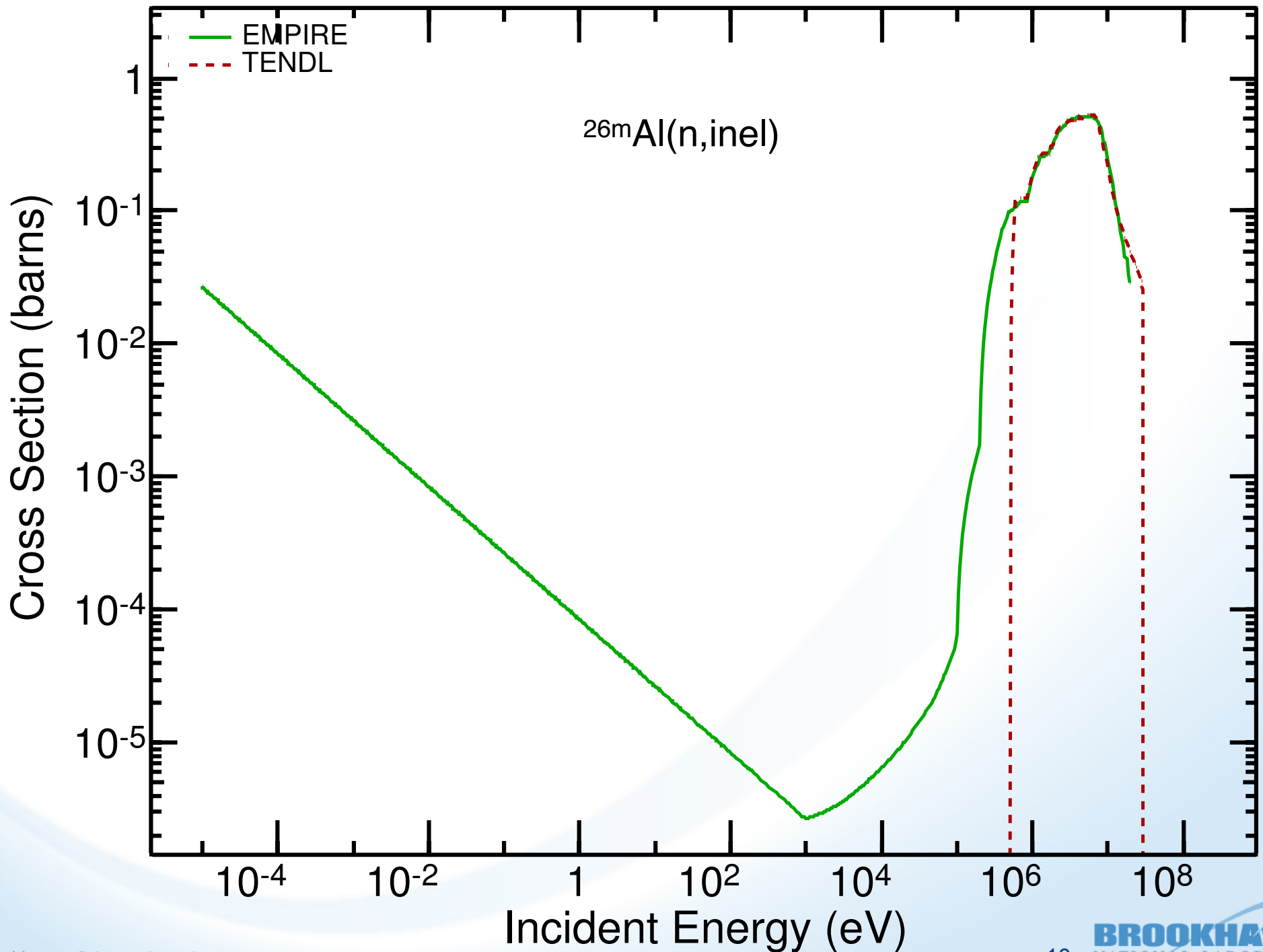
**Adopted TENDL**

**No TENDL, EMPIRE only**

**Adopted EMPIRE**

# Results

- TENDL: Problems at low energies for scattering on excited targets

- ENDF-6 format: documentation of "superelastic" Q-value is unclear

- EMPIRE vs. TENDL:
  - EMPIRE does proper deformed coupled-channel calculations: better results for rare-earths
  - Codes make different choices of levels to couple
  - If there are no experimental resonances TENDL creates more realistic-looking resonances but these can be misleading (format does not distinguish between "artificial" and "real" ones)
  - In some cases generated resonances in TENDL seem to be orders of magnitude too high.

- Incorporated: 28 from TENDL, 75 from EMPIRE

$^{26m}Al(n,inel)$

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1.920000+8 5.554420-1 1.940000+8 5.527130-1 1.960000+8 5.502130-11323 3  1   130
1.980000+8 5.477411-1 2.000000+8 5.454910-1                            1323 3  1   131
                                                                       1323 3 099999
1.302600+4 2.576365+1          0          0          0         01323 3  2     1
0.000000+0 0.000000+0          0          0          1      2851323 3  2     2
        285          2                                                 1323 3  2     3
1.000000-5 0.000000+0 5.128063+5 0.000000+0 5.128063+5 2.874505+01323 3  2     4
5.500000+5 2.875390+0 5.913100+5 2.875320+0 6.000000+5 2.875170+01323 3  2     5
6.500000+5 2.866840+0 6.600490+5 2.864950+0 7.000000+5 2.856660+01323 3  2     6
7.500000+5 2.841360+0 8.000000+5 2.824140+0 8.500000+5 2.800800+01323 3  2     7

1.100000+7 1.753210+0 1.200000+7 1.763470+0 1.300000+7 1.753220+01323 3  1    14
1.400000+7 1.759190+0 1.500000+7 1.768730+0 1.600000+7 1.779440+01323 3  1    15
1.700000+7 1.790670+0 1.800000+7 1.802170+0 1.900000+7 1.813790+01323 3  1    16
2.000000+7 1.825360+0                                                  1323 3  1    17
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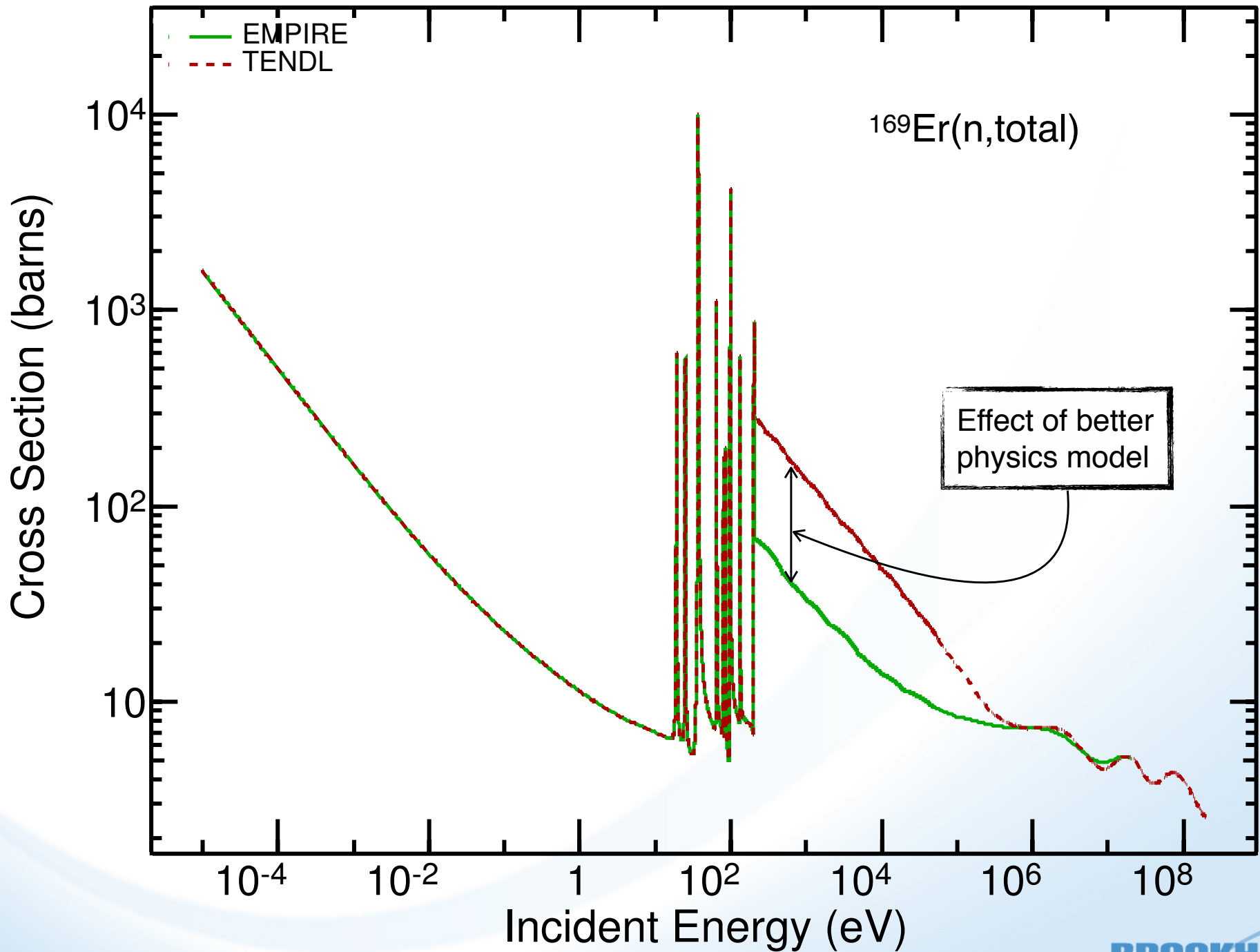
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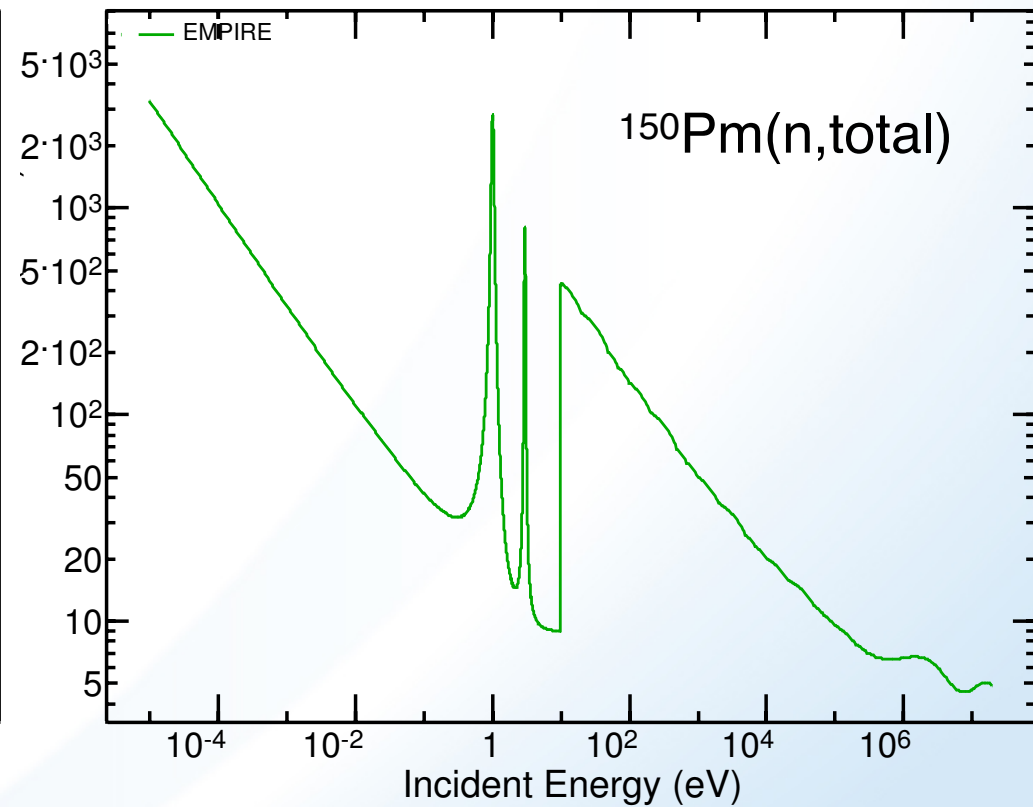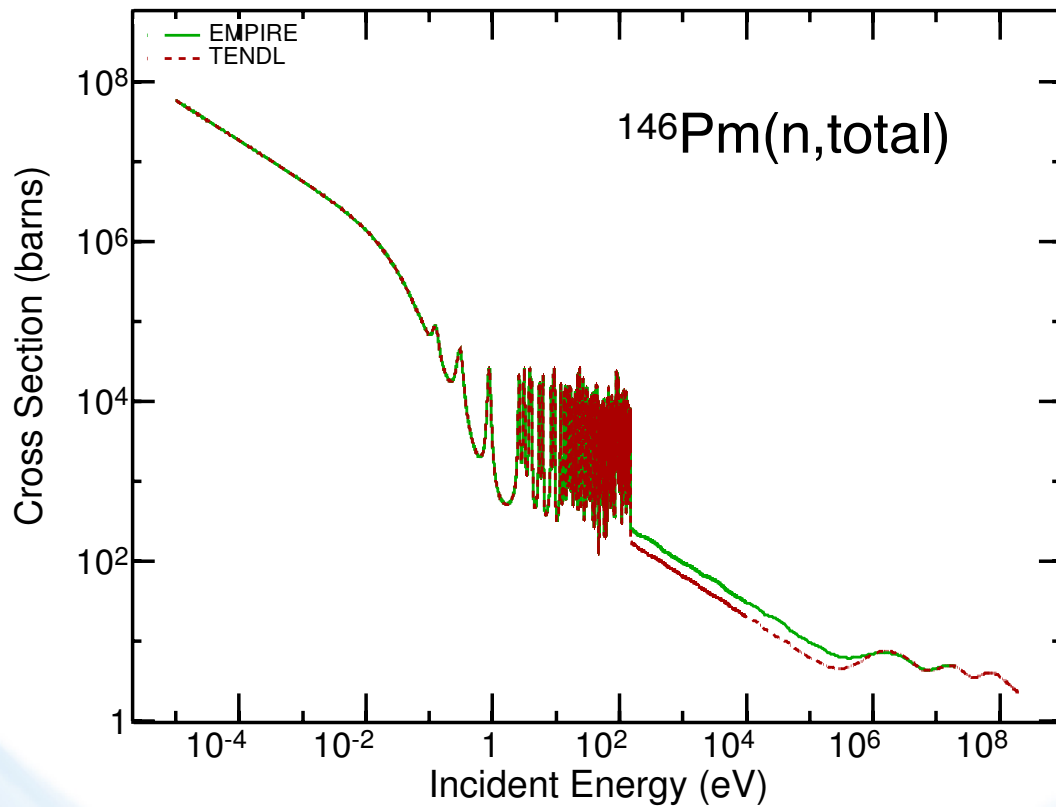
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169Er(n,total)

EMPIRE
TENDL

Effect of better physics model

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# Better-looking…



… but does not contain more experimental info.

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