TENDL-2008: Talys Evaluated Nuclear Data Library

D. Rochman and A.J. Koning

Nuclear Research and Consultancy Group,

NRG, Petten, The Netherlands

November 19, 2008

Contents

Motivations: Do you remember 6 months ago ?

Experiments

(integral, differential)

Evaluation 1

(basic quantities)

Evaluation 2

(uncertainties)

Formatting

Checking

Library

Processing

(NJOY)

Benchmarks

(MCNP, Perturbation)

Evaluation

(basic quantities + uncertainties)

Motivations: Do you remember 6 months ago ?

Experiments → Evaluation 1 → Evaluation 2

(integral, differential) (basic quantities) (uncertainties)

Consequence: No more need of covariance files !

Well, apparently (and sadly) the world still is in need of covariance files

(*see Port-Jeff workshop, SG-26, ENDF/B-VII.1...*)

How can we help ?

(basic

(MCNP, Perturbation)

(NJOY)

Motivations: How to produce consistent (and reproducible) evaluations ?

Usual procedures in evaluations imply

- ☞ Start with nuclear codes (TALYS, GNASH, EMPIRE, SAMMY...)
- ☞ Format the output semi-manually to ENDF-6 file
- ☞ Compare with experimental cross sections
- ☞ Modify manually the ENDF-6 file
- ☞ Compare with integral tests
- ☞ Modify manually the ENDF-6 file
- ☞ ENDF-6 file ready

➳ More risky situation if we start from an existing evaluation !

Motivations: How to produce consistent (and reproducible) evaluations ?

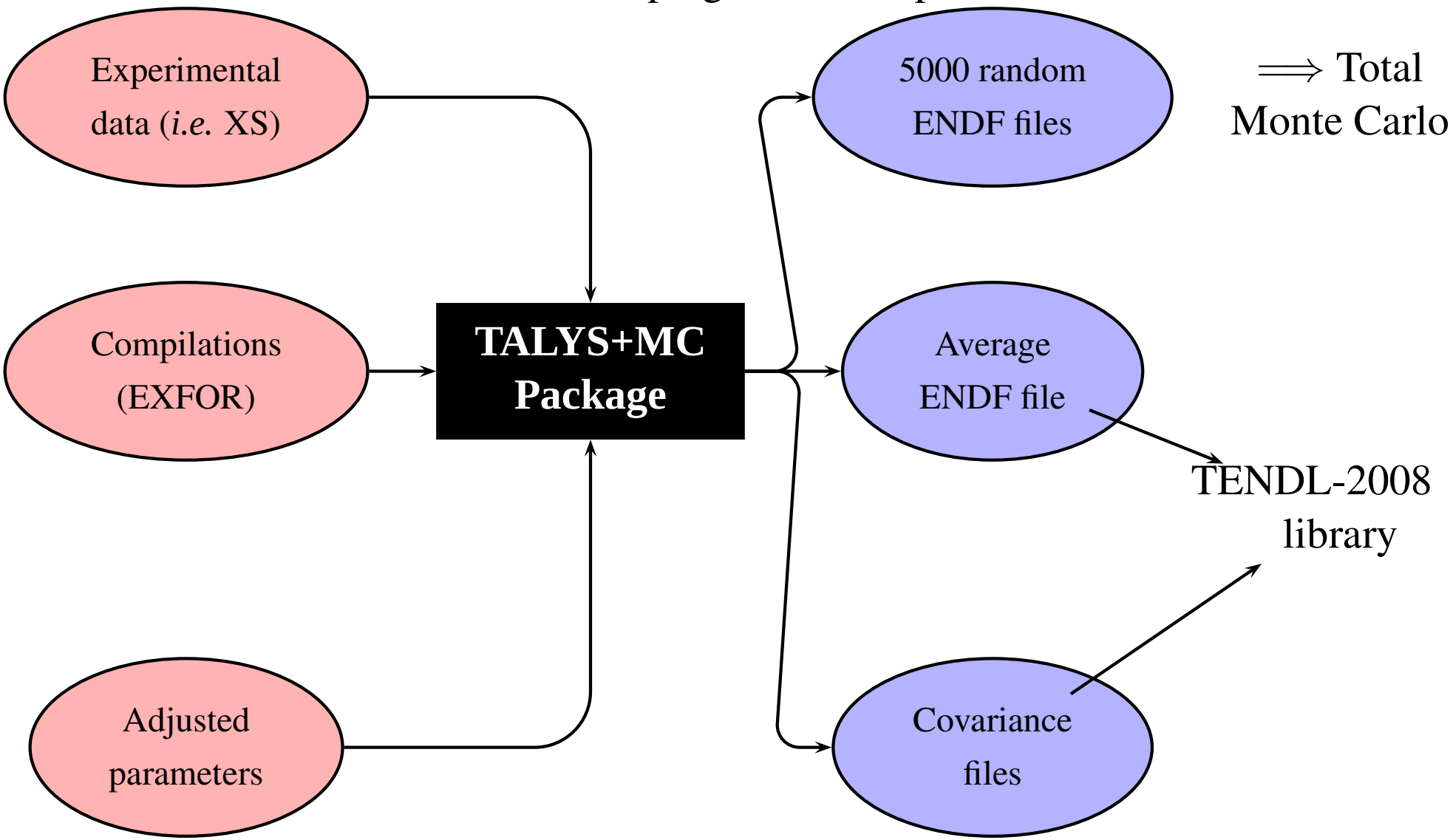
Consequences:

- ☞ What if (*later*) we want to update an evaluation keeping ”its best parts” ?
- ☞ What if we have forgotten what the best parts are ?
- ☞ What if we want to add sections (for heating, angular distribution, uncertainties...), or slight change of format ?
- ☞ Consistency, reproducibility, memory ?

➳ Should we do all of this semi-manually, with fading memories, year after year ?

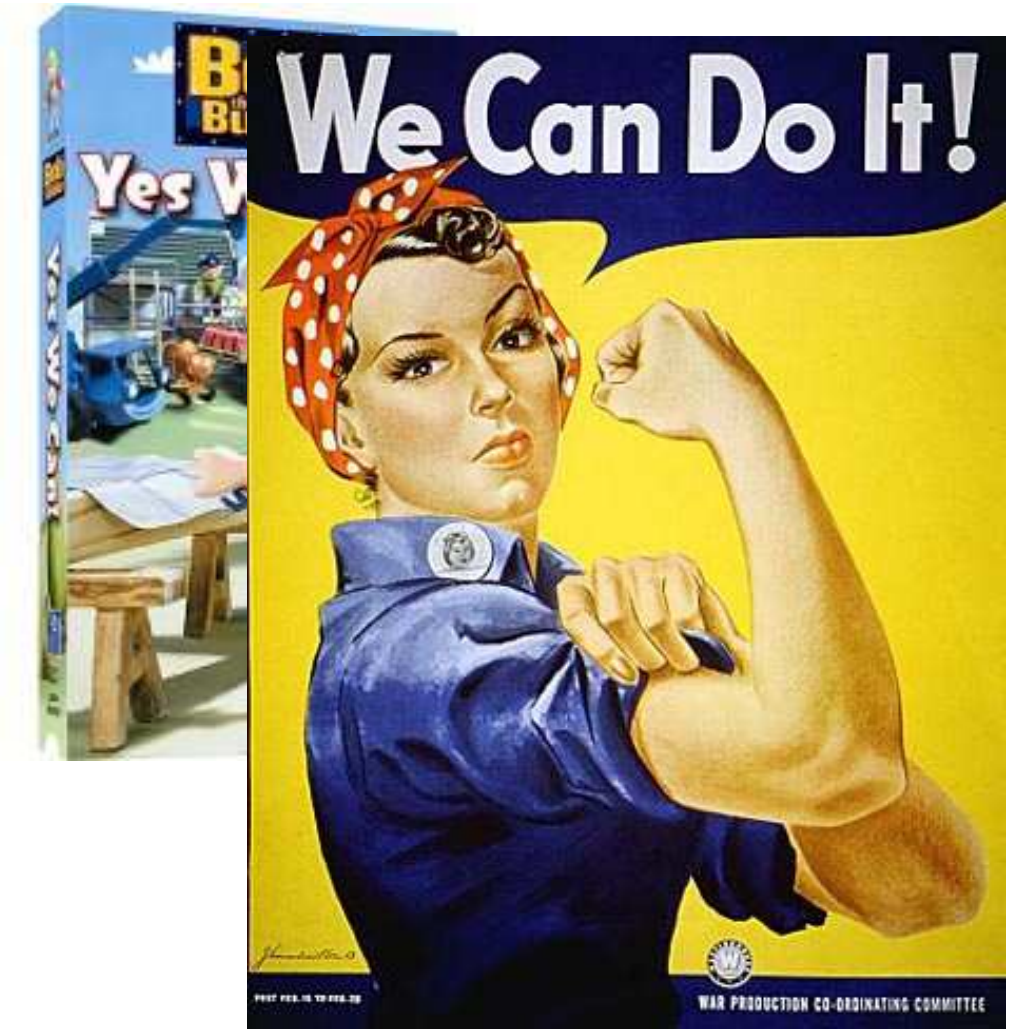
Concept: TALYS + Monte Carlo = TENDL-2008

Maximization of automation while keeping detailed input



Can we do it ? Can we do it for more than one isotope ?

Can we do it ? Can we do it for more than one isotope ?



Can we do it ? Can we do it for more than one isotope ?

Is TENDL-2008 available (free access) ?

Is TENDL-2008 available (free access) ?

Yes !

Here

Here

Here

www.talys.eu/tendl-2008

Here

Here

Here

Is TENDL-2008 available ? Yes !

- Neutrons: ENDF files up to 20 MeV, plots, ACE files, processed covariances (187 energy groups)
- Protons, Deuterons, Tritons, Helium-3, Alphas : ENDF files up to 200 MeV, ACE files
- Photons: ENDF files up to 200 MeV

For comparison:

	Neutron	Proton	Deuteron	Triton	Alpha	Helium-3	Photon
TENDL-2008	**348**	**344**	**336**	**339**	**342**	**338**	**327**
(JEFF-3.1)	*381*	*26*					
(ENDF/B-VII.0)	*393*	*48*	*5*	*3*			*163*

Content 2: TENDL-2008 Neutron library: ^{19}F to ^{209}Po

A total number of **348** isotopes, **267** stables and **81** radioactives nuclides

Z=9	^{19}F						
Z=10	^{20}Ne	^{21}Ne	^{22}Ne				
Z=11	^{23}Na						
Z=12	^{24}Mg	^{25}Mg	^{26}Mg	^{27}Mg			
Z=13	^{27}Al						
Z=14	^{28}Si	^{29}Si	^{30}Si	^{31}Si	^{32}Si		
Z=15	^{31}P						
Z=16	^{32}S	^{33}S	^{34}S	^{36}S			
Z=17	^{35}Cl	^{36}Cl	^{37}Cl				
Z=18	^{36}Ar	^{38}Ar	^{39}Ar	^{40}Ar	^{41}Ar		
Z=19	^{39}K	^{40}K	^{41}K				
Z=20	^{40}Ca	^{41}Ca	^{42}Ca	^{43}Ca	^{44}Ca	^{45}Ca	^{46}Ca ^{48}Ca
Z=21	^{45}Sc	^{46}Sc					
Z=22	^{46}Ti	^{47}Ti	^{48}Ti	^{49}Ti	^{50}Ti		
Z=23	^{49}V	^{50}V	^{51}V				
Z=24	^{50}Cr	^{51}Cr	^{52}Cr	^{53}Cr	^{54}Cr		

Z=25	^{53}Mn	^{54}Mn	^{55}Mn				
Z=26	^{54}Fe	^{56}Fe	^{57}Fe	^{58}Fe			
Z=27	^{57}Co	^{59}Co	^{60}Co				
Z=28	^{58}Ni	^{60}Ni	^{61}Ni	^{62}Ni	^{63}Ni	^{64}Ni	
Z=29	^{63}Cu	^{64}Cu	^{65}Cu	^{66}Cu			
Z=30	^{64}Zn	^{66}Zn	^{67}Zn	^{68}Zn	^{70}Zn		
Z=31	^{69}Ga	^{71}Ga					
Z=32	^{70}Ge	^{72}Ge	^{73}Ge	^{74}Ge	^{76}Ge		
Z=33	^{75}As						
Z=34	^{74}Se	^{76}Se	^{77}Se	^{78}Se	^{80}Se	^{82}Se	
Z=35	^{79}Br	^{81}Br					
Z=36	^{78}Kr	^{80}Kr	^{82}Kr	^{83}Kr	^{84}Kr	^{85}Kr	^{86}Kr
Z=37	^{85}Rb	^{87}Rb	^{88}Rb				
Z=38	^{84}Sr	^{86}Sr	^{87}Sr	^{88}Sr	^{89}Sr	^{90}Sr	
Z=39	^{89}Y	^{90}Y	^{91}Y				

Content 2: TENDL-2008 Neutron library: ^{19}F to ^{209}Po

Z=40	^{90}Zr	^{91}Zr	^{92}Zr	^{93}Zr	^{94}Zr	^{96}Zr			
Z=41	^{93}Nb	^{94}Nb	^{95}Nb						
Z=42	^{92}Mo	^{93}Mo	^{94}Mo	^{95}Mo	^{96}Mo	^{97}Mo	^{98}Mo	^{99}Mo	^{100}Mo
Z=43	^{98}Tc	^{99}Tc							
Z=44	^{96}Ru	^{98}Ru	^{99}Ru	^{100}Ru	^{101}Ru	^{102}Ru	^{104}Ru	^{105}Ru	^{106}Ru
Z=45	^{103}Rh	^{104}Rh	^{105}Rh						
Z=46	^{102}Pd	^{104}Pd	^{105}Pd	^{106}Pd	^{108}Pd	^{110}Pd			
Z=47	^{107}Ag	^{109}Ag	^{111}Ag						
Z=48	^{106}Cd	^{108}Cd	^{109}Cd	^{110}Cd	^{111}Cd	^{112}Cd	^{113}Cd	^{114}Cd	^{116}Cd
Z=49	^{113}In	^{115}In							
Z=50	^{112}Sn	^{114}Sn	^{115}Sn	^{116}Sn	^{117}Sn	^{118}Sn	^{119}Sn	^{120}Sn	^{122}Sn	^{124}Sn
Z=51	^{121}Sb	^{123}Sb	^{124}Sb						
Z=52	^{120}Te	^{122}Te	^{123}Te	^{124}Te	^{125}Te	^{126}Te	^{128}Te	^{130}Te	
Z=53	^{126}I	^{127}I	^{129}I	^{130}I	^{131}I				
Z=54	^{124}Xe	^{126}Xe	^{128}Xe	^{129}Xe	^{130}Xe	^{131}Xe	^{132}Xe	^{133}Xe	^{134}Xe	^{135}Xe	^{136}Xe
Z=55	^{133}Cs	^{134}Cs	^{135}Cs	^{137}Cs							

Content 2: TENDL-2008 Neutron library: ^{19}F to ^{209}Po

Z=56	^{130}Ba	^{132}Ba	^{133}Ba	^{134}Ba	^{135}Ba	^{136}Ba	^{137}Ba	^{138}Ba	^{139}Ba	^{140}Ba
Z=57	^{138}La	^{139}La	^{140}La							
Z=58	^{136}Ce	^{138}Ce	^{139}Ce	^{140}Ce	^{142}Ce	^{143}Ce	^{144}Ce			
Z=59	^{141}Pr	^{142}Pr	^{143}Pr							
Z=60	^{142}Nd	^{143}Nd	^{144}Nd	^{145}Nd	^{146}Nd	^{147}Nd	^{148}Nd	^{150}Nd		
Z=61	^{146}Pm	^{147}Pm	^{148}Pm	^{149}Pm	^{151}Pm					
Z=62	^{144}Sm	^{147}Sm	^{148}Sm	^{149}Sm	^{150}Sm	^{151}Sm	^{152}Sm	^{154}Sm		
Z=63	^{151}Eu	^{152}Eu	^{153}Eu							
Z=64	^{148}Gd	^{152}Gd	^{153}Gd	^{154}Gd	^{155}Gd	^{156}Gd	^{157}Gd	^{158}Gd	^{160}Gd	^{161}Gd
Z=65	^{159}Tb									
Z=66	^{156}Dy	^{158}Dy	^{160}Dy	^{161}Dy	^{162}Dy	^{163}Dy	^{164}Dy	^{165}Dy		
Z=67	^{165}Ho									
Z=68	^{162}Er	^{164}Er	^{166}Er	^{167}Er	^{168}Er	^{170}Er	^{171}Er			
Z=69	^{169}Tm	^{171}Tm								
Z=70	^{168}Yb	^{169}Yb	^{170}Yb	^{171}Yb	^{172}Yb	^{173}Yb	^{174}Yb	^{176}Yb		
Z=71	^{175}Lu	^{176}Lu	^{177}Lu							

Content 2- TENDL-2008 Neutron library: ^{19}F to ^{209}Po

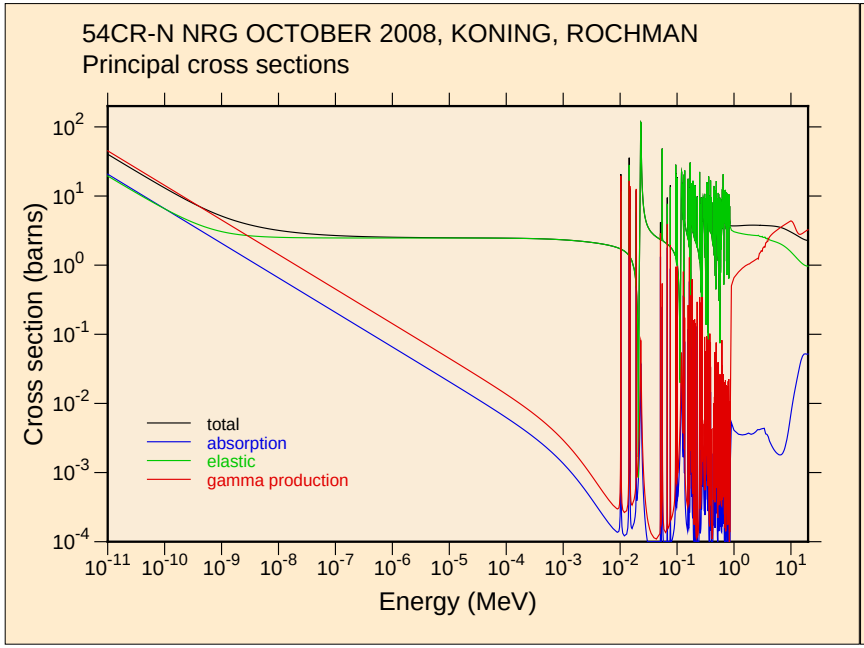
Z=72	^{174}Hf	^{176}Hf	^{177}Hf	^{178}Hf	^{179}Hf	^{180}Hf	^{181}Hf		
Z=73	^{180}Ta	^{181}Ta	^{182}Ta						
Z=74	^{180}W	^{182}W	^{183}W	^{184}W	^{186}W				
Z=75	^{184}Re	^{185}Re	^{187}Re	^{188}Re					
Z=76	^{184}Os	^{186}Os	^{187}Os	^{188}Os	^{189}Os	^{190}Os	^{191}Os	^{192}Os	^{193}Os
Z=77	^{191}Ir	^{193}Ir	^{194}Ir						
Z=78	^{190}Pt	^{192}Pt	^{194}Pt	^{195}Pt	^{196}Pt	^{198}Pt			
Z=79	^{197}Au								
Z=80	^{196}Hg	^{198}Hg	^{199}Hg	^{200}Hg	^{201}Hg	^{202}Hg	^{204}Hg		
Z=81	^{203}Tl	^{204}Tl	^{205}Tl						
Z=82	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb					
Z=83	^{209}Bi								
Z=84	^{209}Po								

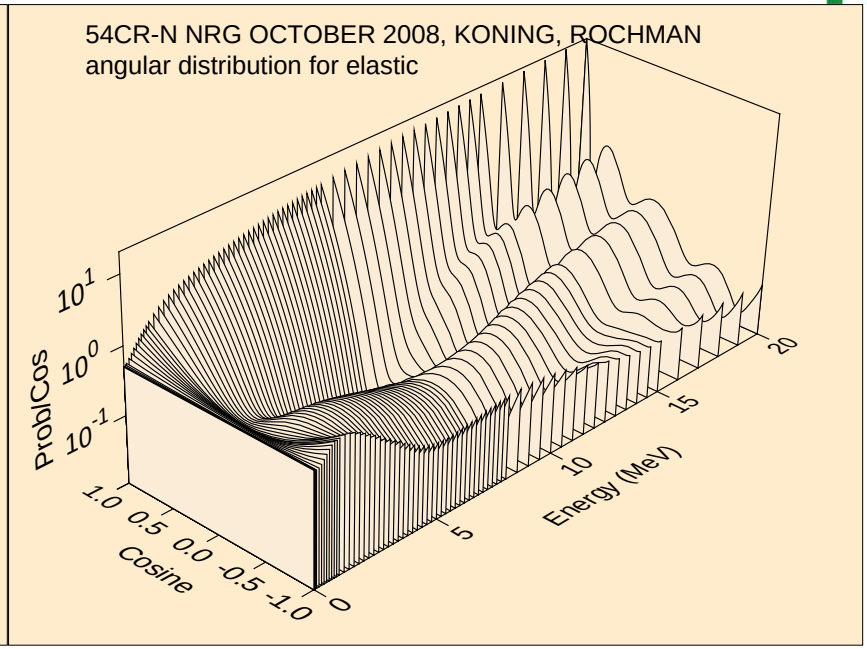
Content 3- TENDL-2008 Neutron library: from MF-1 to MF-34

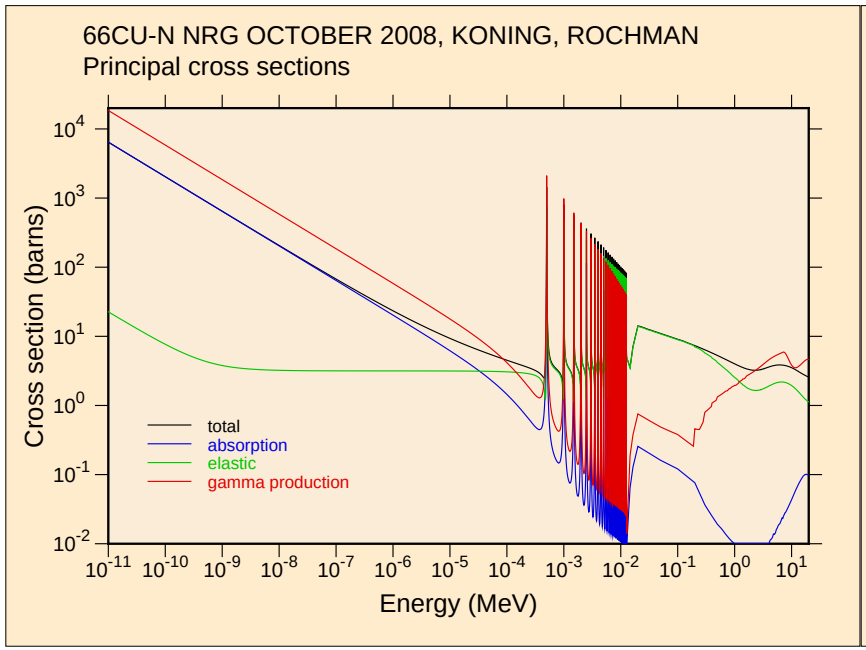
Content of a typical file up to 20 MeV (out of 348 files):

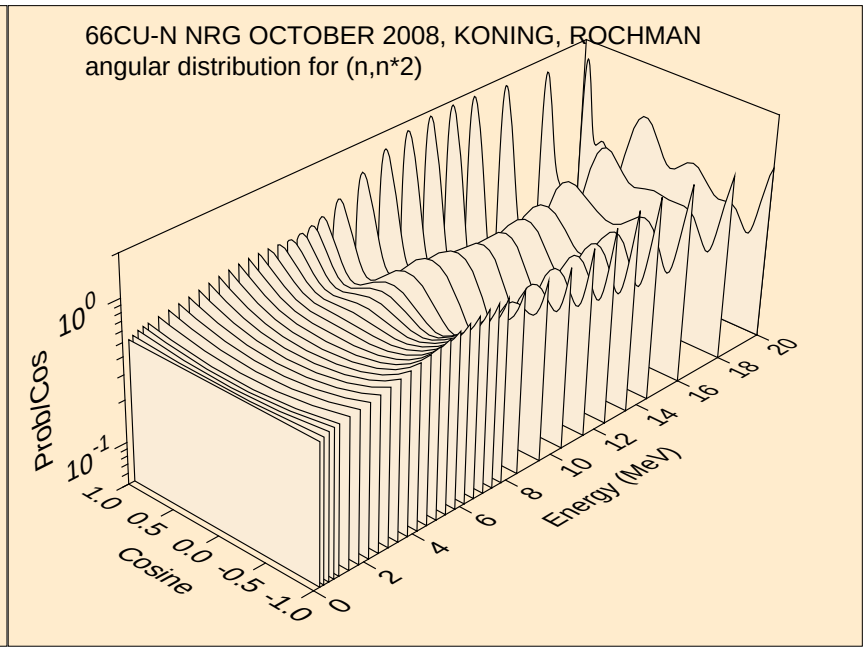
- MF-1: Description
- MF-2: Resonance parameters (Reich-Moore)
- MF-3: Cross sections (n,tot), (n,el), (n,non), (n,inl$_i$), (n,2n), (n,3n), ..., (n,γ), (n,p$_i$), (n,α_i)
- MF-4: Elastic angular distribution (Legendre Polynomials)
- MF-6: Double differential distributions and spectra for (n,2n), (n,inl$_i$), (n,γ),(n,p$_i$), (n,α_i)
- MF-32: Resonance parameter covariances (with R')
- MF-33: Cross section covariances (with cross correlation)
- MF-34: Elastic angular distribution covariances (up to the 6^{th} Legendre polynomial coefficient)

Examples 1

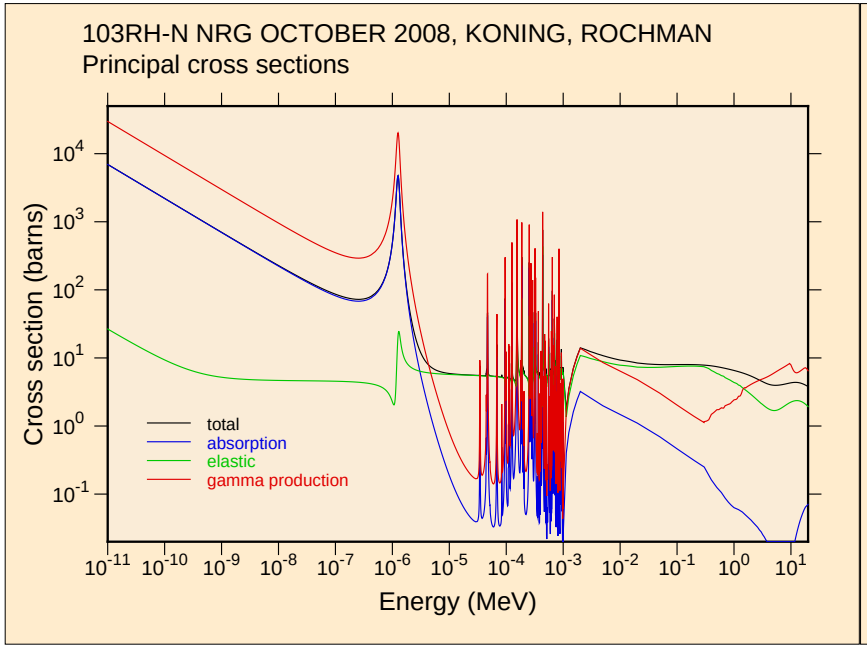

54CR-N NRG OCTOBER 2008, KONING, ROCHMAN
Principal cross sections
Cross section (barns)
Energy (MeV)
total
absorption
elastic
gamma production

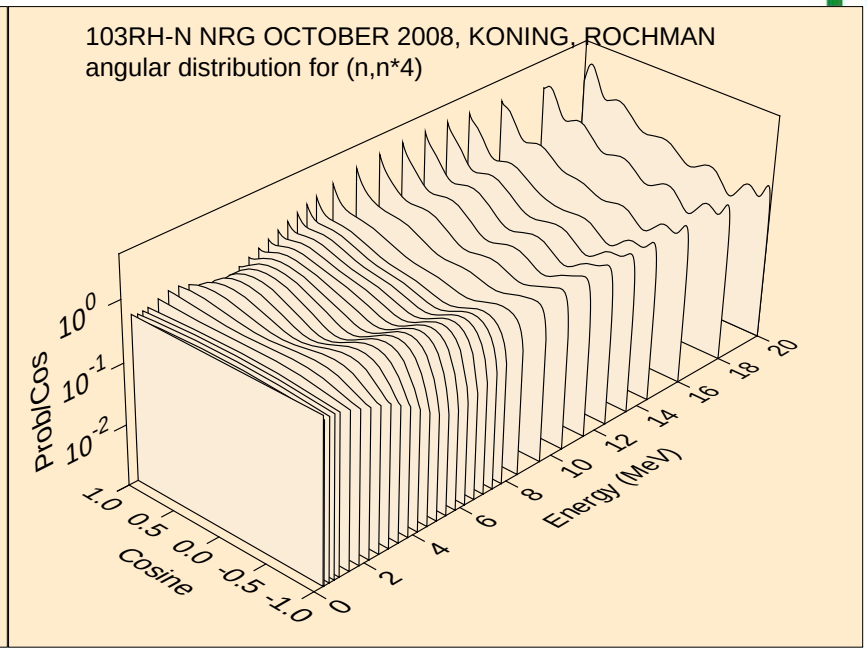

54CR-N NRG OCTOBER 2008, KONING, ROCHMAN
angular distribution for elastic
ProbCos
Cosine
Energy (MeV)

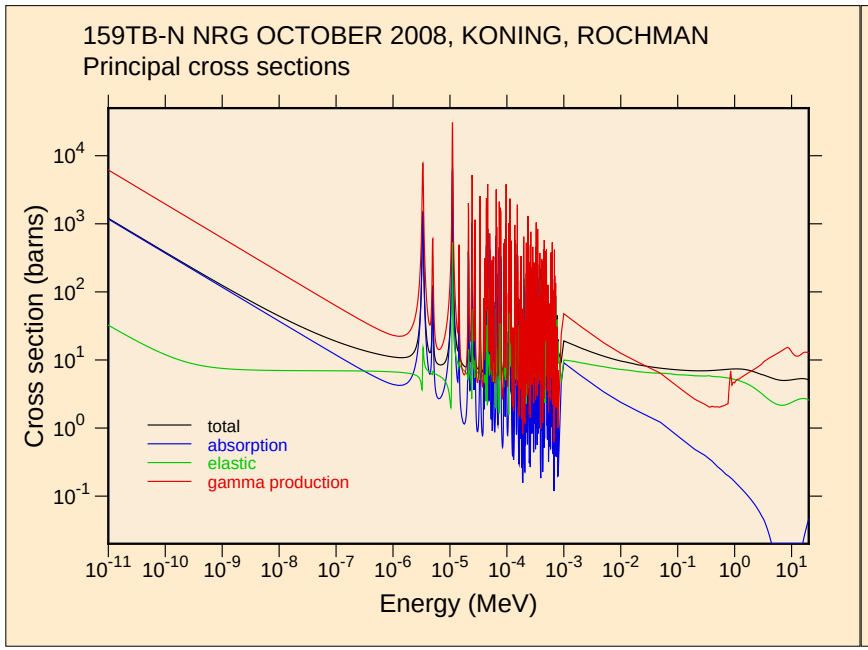

66CU-N NRG OCTOBER 2008, KONING, ROCHMAN
Principal cross sections
Cross section (barns)
Energy (MeV)
total
absorption
elastic
gamma production

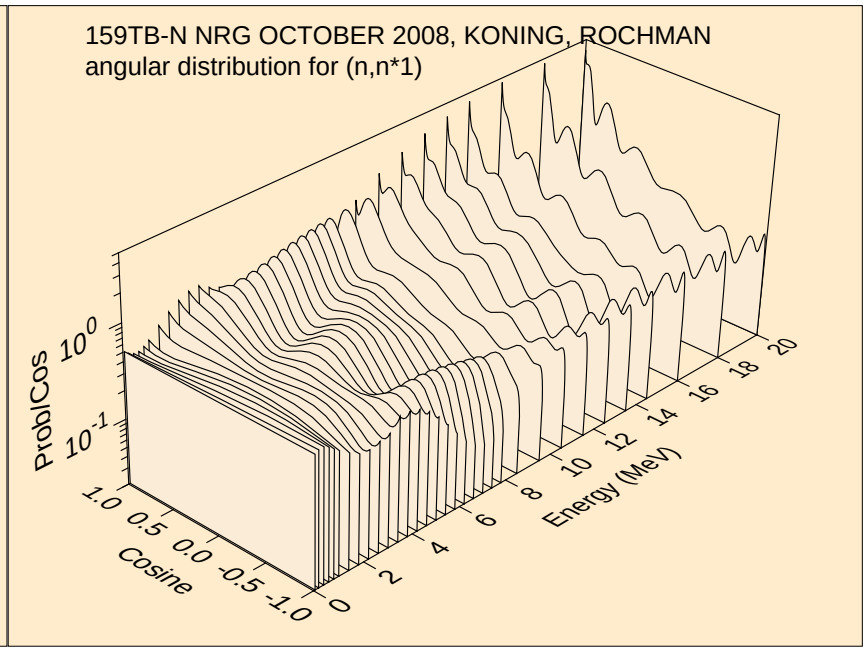

66CU-N NRG OCTOBER 2008, KONING, ROCHMAN
angular distribution for (n,n*2)
ProbCos
Cosine
Energy (MeV)

Examples 2

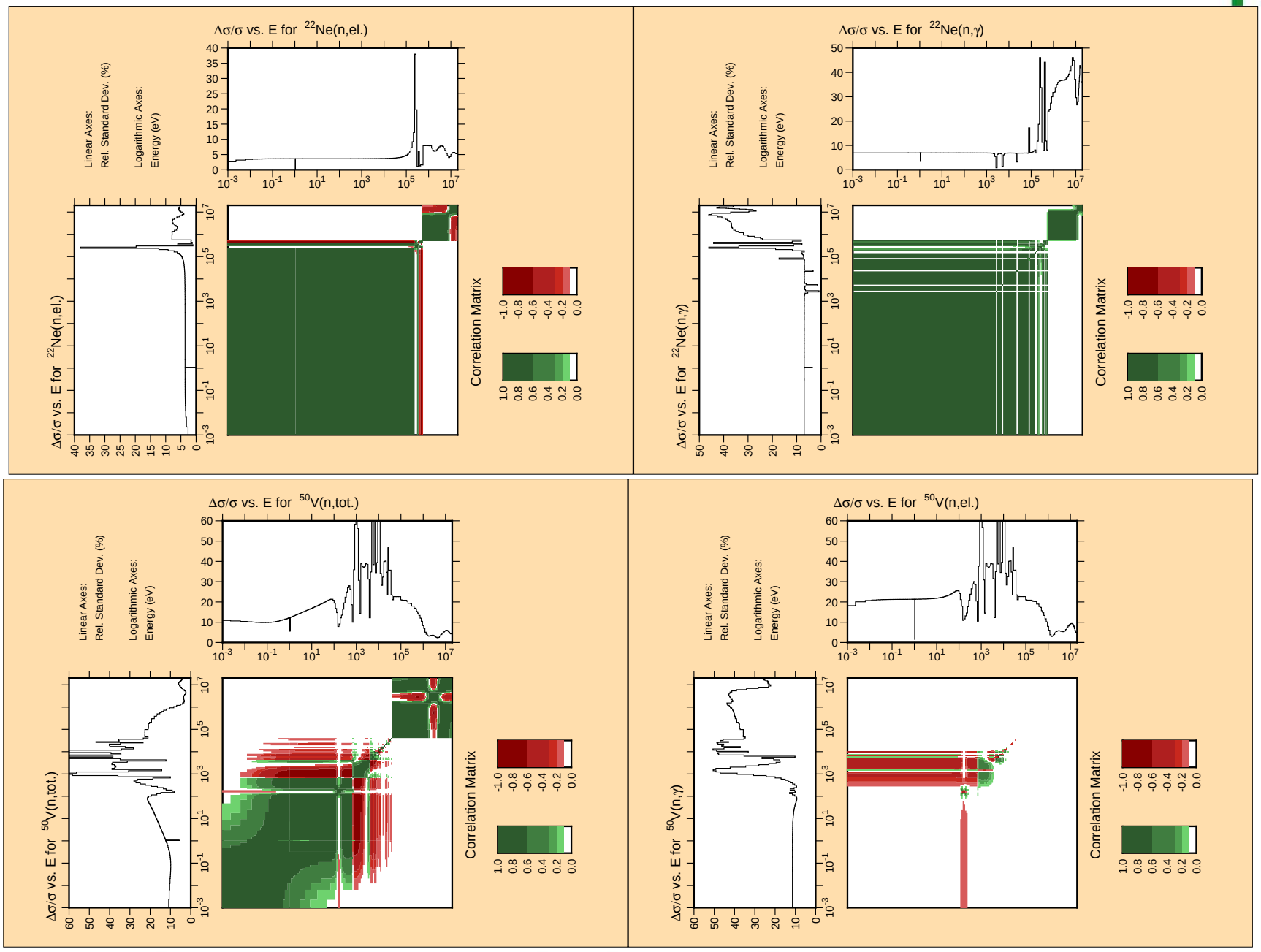

103RH-N NRG OCTOBER 2008, KONING, ROCHMAN
Principal cross sections
Cross section (barns)
Energy (MeV)
total
absorption
elastic
gamma production


103RH-N NRG OCTOBER 2008, KONING, ROCHMAN
angular distribution for (n,n*4)
ProbICos
Cosine
Energy (MeV)

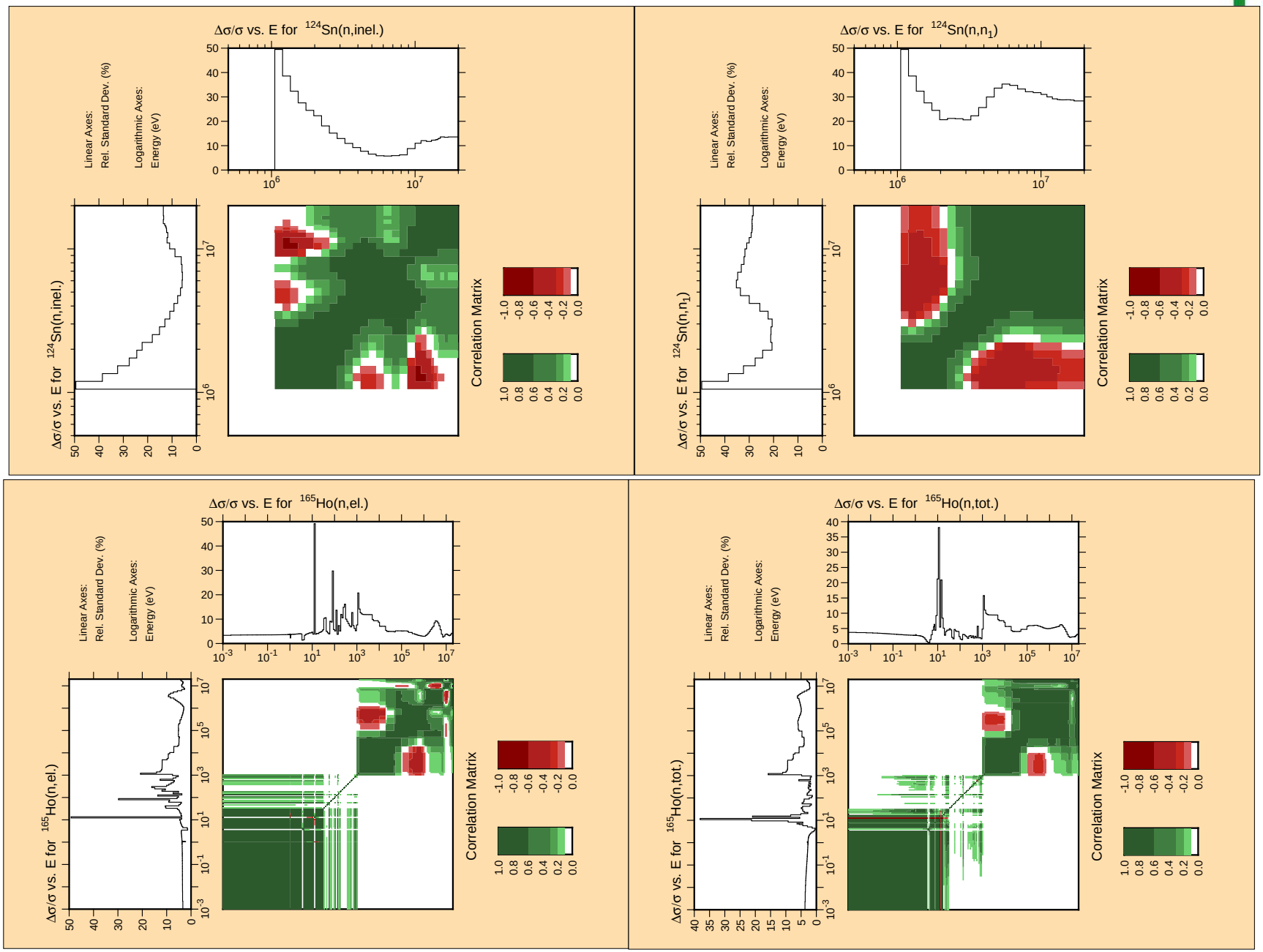

159TB-N NRG OCTOBER 2008, KONING, ROCHMAN
Principal cross sections
Cross section (barns)
Energy (MeV)
total
absorption
elastic
gamma production


159TB-N NRG OCTOBER 2008, KONING, ROCHMAN
angular distribution for (n,n*1)
ProbICos
Cosine
Energy (MeV)

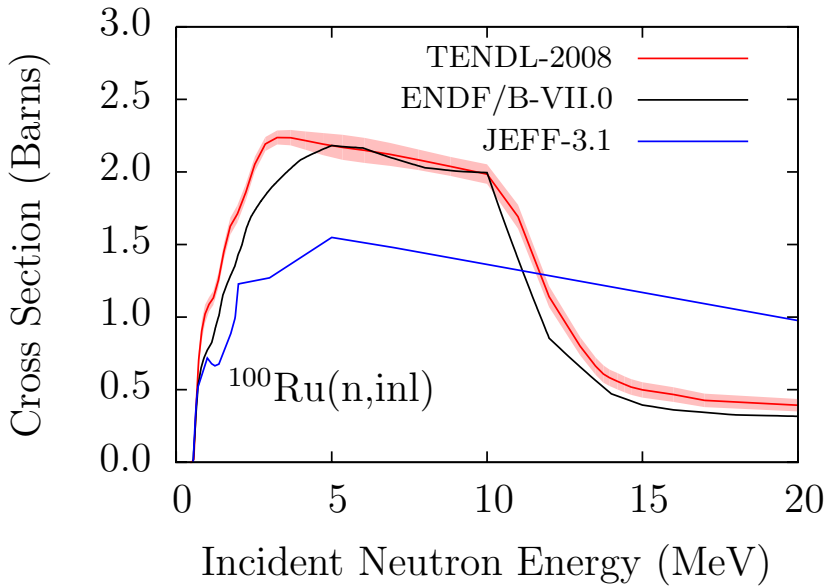
Examples 3 (with the latest ERRORJ)

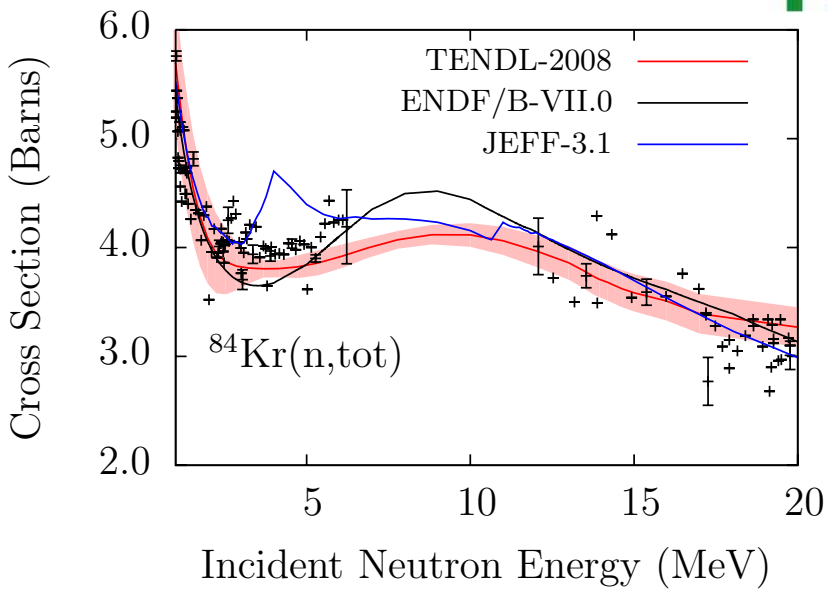


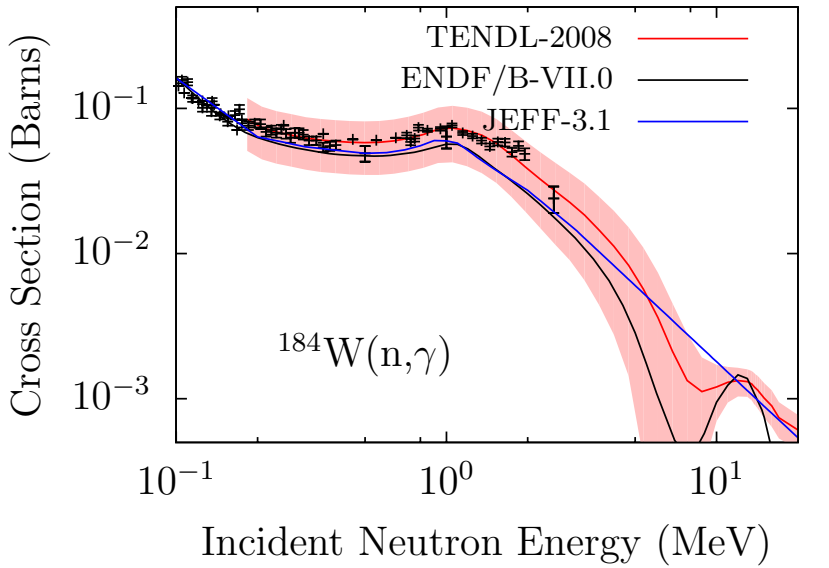
Examples 4 (with the latest ERRORJ)

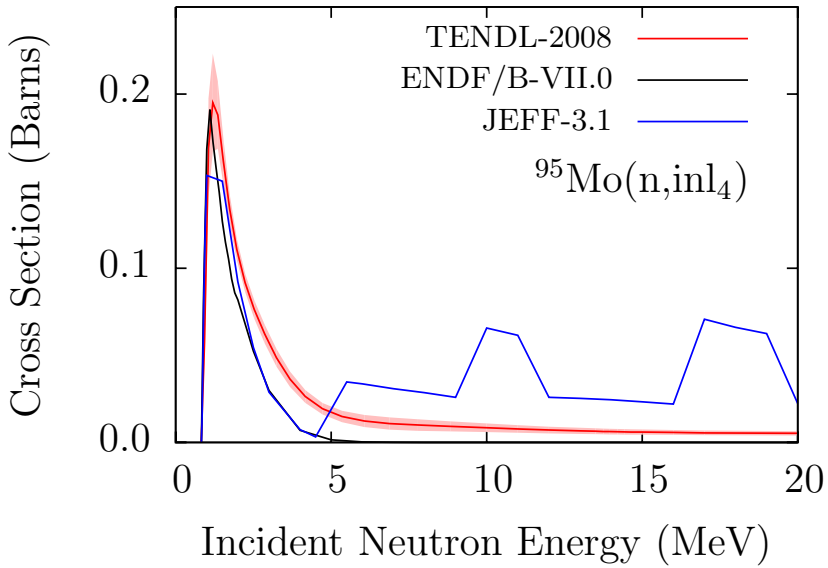


Examples 5


TENDL-2008
ENDF/B-VII.0
JEFF-3.1
^{100}Ru(n,inl)
Cross Section (Barns)
Incident Neutron Energy (MeV)


TENDL-2008
ENDF/B-VII.0
JEFF-3.1
^{84}Kr(n,tot)
Cross Section (Barns)
Incident Neutron Energy (MeV)


TENDL-2008
ENDF/B-VII.0
JEFF-3.1
^{184}W(n,γ)
Cross Section (Barns)
Incident Neutron Energy (MeV)


TENDL-2008
ENDF/B-VII.0
JEFF-3.1
^{95}Mo(n,inl$_4$)
Cross Section (Barns)
Incident Neutron Energy (MeV)

Discussion

- Only large-scale library for transport created with a consistent approach
- Unprecedent complete and consistent covariance data set (348 !)
- All information in TALYS input files + experimental data
  $\Longrightarrow$ *ENDF-6 library is becoming an intermediate step (not a starting point)*
- Partial adjustment to experimental data and uncertainties
  $\Longrightarrow$ *but AK claims that some evaluations already better than JEFF-3.1*
- Tritons, helium-3, alphas files ready even if not used by codes
- If new information arrive: automatic updates

Feedback appreciated !

Future improvements

- Better fitting isotope per isotope (for stable ones)
- Necessity of “error-free” EXFOR
- From 300 to 3000 nuclides and from 20 to 200 MeV
- Photon library will come with covariances
- TALYS Actinides on their way

Future improvements

- Better fitting isotope per isotope (for stable ones)
- Necessity of “error-free” EXFOR
- From 300 to 3000 nuclides and from 20 to 200 MeV
- Photon library will come with covariances
- TALYS Actinides on their way

- **Finally**, ENDF-6 files are not starting points anymore !

(is that a good idea ?)

Buzz Light-year: - *This is no time to panic, sheriff !*
Sheriff Woody: - *This is perfect time to panic !*