Light Element Evaluations

from LANL-EDA R-matrix analyses

Report of evaluation status

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Outline

- **LANL EDA Code**
  - Simultaneous fit of all reaction/scattering data in R-matrix approach
- **LANL evaluations**
  - ENDF/B-VIII.0
  - Recent improvements
  - Gaps

LANL-EDA code

- **R-matrix formalism [Wigner(1947)]**
  - Unified description of many reactions
  - Ensures unitarity & probability conservation
- **Capabilities**
  - Any projectile: n, p, D, T, ^{3}He, α, …
  - Any target: H, He, Li, Be, B, C, N, O, F, …
  - All data fit ***together, at the same time***
    - Elastic, inelastic, rearrangement, breakup, capture
  - All observables
    - Cross sections: elastic, reaction, total
    - Angular distributions/excitation functions
    - Polarization observables
    - Spectra 2➔3, 2➔4
    - Capture/electromagnetic
- **High-fidelity fit:**
  - Typical chi-squared: χ^2/dof ~ 1.2 – 1.5

Channel	a_c (fm)	l_{max}
t+^{4}He	4.02	5
n+^{6}Li	5.0	3
n+^{6}Li*	5.5	1
d+^{5}He	6.0	0

Reaction	Energy Range (MeV)	# Pts.	Observables
^{4}He(t,t)^{4}He	E_t=0 - 14	1661	σ(θ), $A_y(t)$
^{4}He(t,n)^{6}Li	E_t = 8.75 - 14.4	37	σ_{int}, σ(θ)
^{4}He(t,n)^{6}Li*	E_t =12.9	4	σ(θ)
^{6}Li(n,t)^{4}He	E_n = 0 - 4	1406	σ_{int}, σ(θ)
^{6}Li(n,n)^{6}Li	E_n = 0 - 4	800	σ_T, σ_{int}, σ(θ), $P_y(n)$
^{6}Li(n,n')^{6}Li*	E_n = 3.35 - 4	8	σ_{int}
^{6}Li(n,d)^{5}He	E_n = 3.35 - 4	2	σ_{int}
Total		3918	13

- **Unified, simultaneous fit**
  - describe all data together
  - fit quantum mechanical amplitudes, not cross sections
- **Built-in Quality Assurance**
  - Normalization constrained
    - Weed-out underestimated exp'l uncertainties
- ***Superior to single-channel or polynomial fitting***

LANL Light Element Evaluations

	H1	H2	H3	He3	He4	Li6	Li7
n	VIII.0	VII.1	VII.1	VII.1	VII.1	VIII.0	VII.1
p	VII.1	VII.1	VII.1	VII.1	2011*	VII.1	2001**
d		VII.1	VII.1, 2018	VII.1	2011	VII.1	2003**
t			VII.1	VII.1	2011*	VII.1	--*
^{3}He				2001	2011*	VII.1	--
α					2011*	--	--

- **Roman numerals refer to ENDF versions**
- **Years refer to locally available files that have not yet been submitted to ENDF**

* Nuclei for which LLNL evaluations have been put into ENDF/B-VIII.0

** Nuclei for which LLNL evaluations replaced existing LANL evaluations in VIII.0

Evaluation revision criteria

- **Improvement to existing LANL evaluations welcome**
  - Primary concern: eliminate evaluation ‘gaps’
    - gaps in recommended energy range 0 < E < 20 MeV (higher for some)
    - gaps in reactions available (spectra, capture, etc.)
- **Review criteria for evaluation revisions**
  - For reactions without existing evaluation
    - describes “well” the available data
    - covers recommended energy range
    - ENDF-6 compliant
  - For reactions with existing evaluation
    - “complete” (as above)
    - accepted for extension of energy range (appended to existing evaluation)
    - ***substantial*** improvement over existing evaluation requires
      - improved fidelity of data fit
      - improved method/approach of proposed eval.
        - » better theory; simultaneous description of more data; etc.

NB: simpler approaches (such as single-channel curve fitting) offering substantially improved description of data will be accepted

Status of existing LANL evaluations ENDF/B-VIII.0

Highlights

1. p+t, p+^{3}He, p+^{6,7}Li
2. d+d, d+t, d+^{3}He
3. t+t, t+^{6}Li
4. n+^{6}Li, n+^{12}C, n+^{13}C
5. ^{9}Be system
6. ^{15}N system
7. n+^{16}O

Existing LANL evaluations

A	System	Channels	Energy Range (MeV)
2	N-N	p+p; n+p, γ+d	0-40 0-40
3	N-d	p+d; n+d	0-4
4	^{4}H; ^{4}Li	n+t; p+^{3}He	0-20
	^{4}He	p+t; n+^{3}He; d+d	0-11; 0-10; 0-10
5	^{5}He	n+α; d+t; ^{5}He+γ	0-28; 0-10
	^{5}Li	p+α; d+^{3}He	0-24; 0-1.4

A	System (Channels)
6	^{6}He (^{5}He+n, t+t); ^{6}Li (d+^{4}He, t+^{3}He); ^{6}Be (^{5}Li+p, ^{3}He+^{3}He)
7	^{7}Li (t+^{4}He, n+^{6}Li); ^{7}Be (γ+^{7}Be, ^{3}He+^{4}He, p+^{6}Li)
8	^{8}Be (^{4}He+^{4}He, p+^{7}Li, n+^{7}Be, p+^{7}Li*, n+^{7}Be*, d+^{6}Li)
9	^{9}Be (^{8}Be+n, d+^{7}Li, t+^{6}Li); ^{9}B (γ+^{9}B, ^{8}Be+p, d+^{7}Be, ^{3}He+^{6}Li)
10	^{10}Be (n+^{9}Be, ^{6}He+α, ^{8}Be+nn, t+^{7}Li); ^{10}B (α+^{6}Li, p+^{9}Be, ^{3}He+^{7}Li)
11	^{11}B (α+^{7}Li, α+^{7}Li*, ^{8}Be+t, n+^{10}B); ^{11}C (α+^{7}Be, p+^{10}B)
12	^{12}C (^{8}Be+α, p+^{11}B)
13	^{13}C (n+^{12}C, n+^{12}C*)
14	^{14}C (n+^{13}C)
15	^{15}N (p+^{14}C, n+^{14}N, α+^{11}B)
16	^{16}O (γ+^{16}O, α+^{12}C)
17	^{17}O (n+^{16}O, α+^{13}C)
18	^{18}Ne (p+^{17}F, p+^{17}F*, α+^{14}O)

Status of existing LANL evaluations ENDF/B-VIII.0

Proton induced

- **p-001_H_003.endf** **[T(p,x)Y]**
  - MF3(x-sec): 2(el), 50(n_0), 650(d_0) (<20 MeV)
  - MF6(E-ang): 2, 50, 600
- **p-002_He_003.endf** **[^{3}He(p,x)Y]**
  - MF3: 2(el), 50(n_0), 650(d_0) (<20 MeV)
  - MF6: 2, 50, 650
- **p-002_He_004.endf** **[^{4}He(p,x)Y]**
  - LLNL
- **p-003_Li_006.endf** **[^{6}Li(p,x)Y]**
  - MF3: 2 750 ($^3He_0$) (<2.5 MeV)
  - MF6: 2 750
- **p-003_Li_007.endf** **[^{7}Li(p,x)Y]**
  - LLNL

Status of existing LANL evaluations ENDF/B-VIII.0
Deuteron induced

- **d-001_H_002.endf** **[D(d,x)Y]**
  - MF3(x-sec): 2(el), 50(n0), 600(p0) (<10 MeV)
  - MF6(E-ang): 2, 50, 600 (<10 MeV)
- **d-001_H_003.endf** **[T(d,x)Y]**
  - MF3: 2 50(<40 MeV) 51 (<10 MeV)
  - MF6: 2 50 51 (same energies)
- **d-002_He_003.endf** **[^{3}He(d,x)Y]**
  - MF3: 2 600 (<14 MeV)
  - MF6: 2 600
- **d-003_Li_006.endf** **[^{6}Li(d,x)Y]**
  - MF3: 2 50 600 800(a0) (<5 MeV)
  - MF6: 2 50 600 800
- **d-003_Li_007.endf** **[^{7}Li(d,x)Y]**
  - LLNL

Status of existing LANL evaluations ENDF/B-VIII.0

Triton induced

- **t-001_H_003.endf** **[T(t,x)Y]**
  - MF3: 2 16(2n) (<2.2 MeV Rmat/data; >2.2, <20 extrap)
  - MF6: 2 16
- **t-002_He_003.endf** **[^{3}He(t,x)Y]**
  - MF3: 2 28(np) 650(nd) (<3 MeV Rmat/data; >3, <20 extrap)
  - MF6: 2 28 650
- t-002_He_004.endf [^{4}He(t,x)Y]
  - LLNL
- **t-003_Li_006.endf** **[^{6}Li(t,x)Y]**
  - MF3: 2 22(nα) 650 (<4 MeV Rmat/data; >4, <20 MeV extrap)
  - MF6: 2 22 650
- t-003_Li_007.endf [^{7}Li(t,x)Y]
  - LLNL

Status of existing LANL evaluations ENDF/B-VIII.0

Neutron induced

```
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 0 - N - 1 LANL        EVAL-APR16 HALE, PARIS                      25 1451
  1-H -  1 LANL        EVAL-JUL16 G.M.Hale                        125 1451
  1-H -  2 LANL        EVAL-FEB97 P.G.Young,G.M.Hale,M.B.Chadwick  128 1451
  1-H -  3 LANL        EVAL-NOV01 G.M.Hale                        131 1451
  2-He-  3 LANL        EVAL-MAY90 G.Hale,D.Dodder,P.Young         225 1451
  2-He-  4 LANL        EVAL-SEP10 Hale                            228 1451
  3-Li-  6 LANL        EVAL-JAN17 G.M. Hale                       325 1451
  3-Li-  7 LANL        EVAL-AUG88 P.G.Young                       328 1451
  4-Be-  7 LANL        EVAL-JUN16 I.Thompson, P.R.Page            419 1451
  4-Be-  9 LLNL,LANL   EVAL-OCT09 G.HALE,PERKINS ET AL,FRANKLE    425 1451
  5-B - 10 LANL        EVAL-FEB17 G.M.Hale                        525 1451
  5-B - 11 LANL        EVAL-MAY89 P.G.Young                       528 1451
  6-C - 12 LANL,ORNL   EVAL-AUG15 G.M. Hale, P.G. Young, C.Y. Fu  625 1451
  6-C - 13 LANL,       EVAL-AUG15 G.M. Hale, M.W. Paris           628 1451
  7-N - 14 LANL        EVAL-JUN97 M.B.Chadwick,P.G.Young          725 1451
  7-N - 15 LANL        EVAL-SEP83 E.Arthur,P.Young,G.Hale         728 1451
  8-O - 16 LANL        EVAL-DEC16 Hale,Paris,Young,Chadwick       825 1451
```

Ongoing/planned evaluation work

- **LANL**
  - Commit existing charged-particle evaluations to ENDF/A trunk
    - protons: ^{4}He, ^{7}Li
    - deuterons: ^{3}H, ^{4}He, ^{7}Li
    - tritons: ^{4}He
    - ^{3}He's: ^{3}He, ^{4}He
    - alphas: ^{4}He
- **LLNL**
  - energy extensions
  - missing evaluations

```
alphas/a-003_Li_006.endf
deuterons/d-001_H_002.endf
deuterons/d-001_H_003.endf
deuterons/d-002_He_003.endf
deuterons/d-002_He_004.endf
deuterons/d-003_Li_006.endf
helium3s/h-003_Li_006.endf
helium3s/h-003_Li_007.endf
protons/p-001_H_003.endf
protons/p-002_He_003.endf
tritons/t-001_H_003.endf
tritons/t-003_Li_006.endf
```

- **ORNL**
  - n+^{16}O resonance parameters
  - SAMMY advances
    - $B_c = -\ell$ boundary condition
    - capture
    - closed-channel effects
  - comprehensive resonance anal.
  - Normalization work for ^{16}O(n,a)
- **JAEA**
  - multichannel fits
    - n+^{16}O (^{17}O system)
    - p+^{7}Li
  - ^{17}O system agrees closely with LANL/EDA normalizations

Thank you!

Follow-on material

ENDF/B-VIII.0 evaluation custodians

```
==> alphas-VIII_0_owners.txt <==
  2-He-  4 LLNL       EVAL-DEC99 R.M.White,D.A.Resler,S.I.Warshaw  228 1451
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  1-H -  3 LANL       EVAL-JAN95 G.M.HALE  AND M.DROSG             131 1451
  2-He-  3 LANL       EVAL-FEB01 G.M.HALE                          225 1451
  3-Li-  6 LANL       EVAL-JUN04 P.R.PAGE                          325 1451
  3-Li-  7 LLNL       EVAL-NOV10 P. Navratil, D. A. Brown          328 1451
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  1-H -  1 LANL       EVAL-JUL16 G.M.Hale                          125 1451
  1-H -  2 LANL       EVAL-FEB97 P.G.Young,G.M.Hale,M.B.Chadwick    128 1451
  1-H -  3 LANL       EVAL-NOV01 G.M.Hale                          131 1451
  2-He-  3 LANL       EVAL-MAY90 G.Hale,D.Dodder,P.Young           225 1451
  2-He-  4 LANL       EVAL-SEP10 Hale                              228 1451
  3-Li-  6 LANL       EVAL-JAN17 G.M. Hale                         325 1451
  3-Li-  7 LANL       EVAL-AUG88 P.G.Young                         328 1451
  4-Be-  7 LANL       EVAL-JUN16 I.Thompson, P.R.Page              419 1451
  4-Be-  9 LLNL,LANL  EVAL-OCT09 G.HALE,PERKINS ET AL,FRANKLE      425 1451
  5-B - 10 LANL       EVAL-FEB17 G.M.Hale                          525 1451
  5-B - 11 LANL       EVAL-MAY89 P.G.Young                         528 1451
  6-C - 12 LANL,ORNL  EVAL-AUG15 G.M. Hale, P.G. Young, C.Y. Fu    625 1451
  6-C - 13 LANL,      EVAL-AUG15 G.M. Hale, M.W. Paris             628 1451
  7-N - 14 LANL       EVAL-JUN97 M.B.Chadwick,P.G.Young            725 1451
  7-N - 15 LANL       EVAL-SEP83 E.Arthur,P.Young,G.Hale           728 1451
  8-O - 16 LANL       EVAL-DEC16 Hale,Paris,Young,Chadwick         825 1451
```

ENDF/B-VIII.0 evaluation custodians (cont.)

```
==> protons-VIII_0_owners.txt <==
  1-H -  1 LANL       EVAL-FEB98 G.HALE                             125 1451
  1-H -  2 LANL       EVAL-FEB97 P.G.YOUNG,G.M.HALE,M.B.CHADWICK   128 1451
  1-H -  3 LANL       EVAL-SEP01 G. M. HALE                         131 1451
  2-He-  3 LANL       EVAL-OCT83 G.HALE                             225 1451
  2-He-  4 LLNL       EVAL-DEC99 R.M.White,D.A.Resler,S.I.Warshaw  228 1451
  3-Li-  6 LANL       EVAL-AUG01  G.M.HALE                          325 1451
  3-Li-  7 LLNL       EVAL-SEP10 P. Navratil, D.A. Brown            328 1451
  4-Be-  9 LANL       EVAL-NOV88 P.G.Young, E.D.Arthur              425 1451
  5-B - 10 LANL       EVAL-AUG05   P.R.PAGE                         525 1451
  6-C - 12 LANL       EVAL-JUN96 M.B.CHADWICK AND P.G.YOUNG         625 1451
  6-C - 13 LANL       EVAL-DEC04  P.R.PAGE                          628 1451
  7-N - 14 LANL       EVAL-AUG97 M.B.CHADWICK & P.G.YOUNG           725 1451
  8-O - 16 LANL       EVAL-JUN96 M.B.CHADWICK AND P.G.YOUNG         825 1451
==> tritons-VIII_0_owners.txt <==
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  2-He-  3 LANL       EVAL-AUG01 G.M.HALE                           225 1451
  2-He-  4 LLNL       EVAL-DEC99 R.M.White,D.A.Resler,S.I.Warshaw  228 1451
  3-Li-  6 LANL       EVAL-SEP01 G.M.HALE                           325 1451
  3-Li-  7 LLNL       EVAL-JUN16 I.Thompson, P.Navratil, D.Brown   328 1451
```
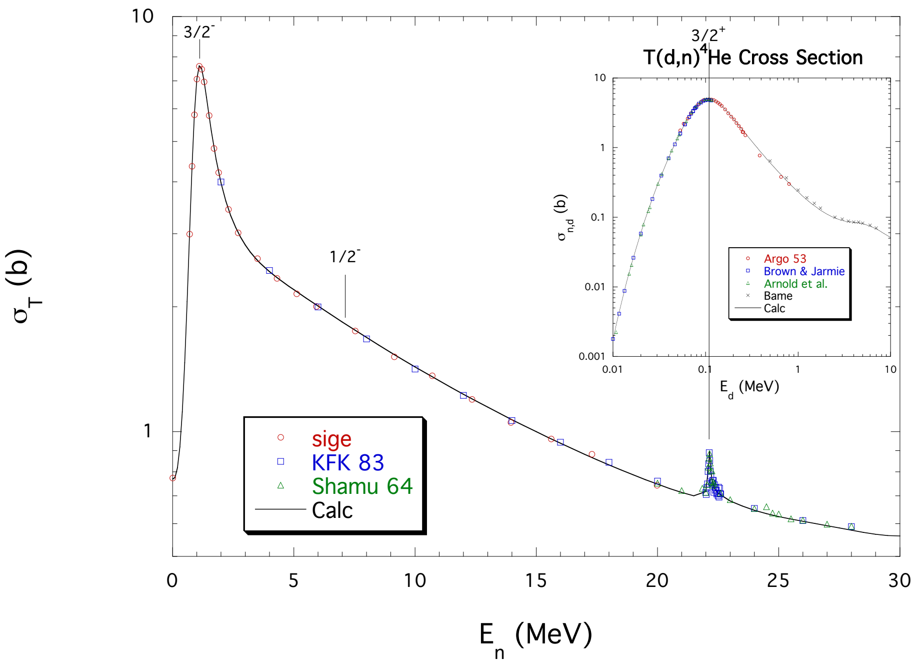

T(d,n)α evaluation (I)

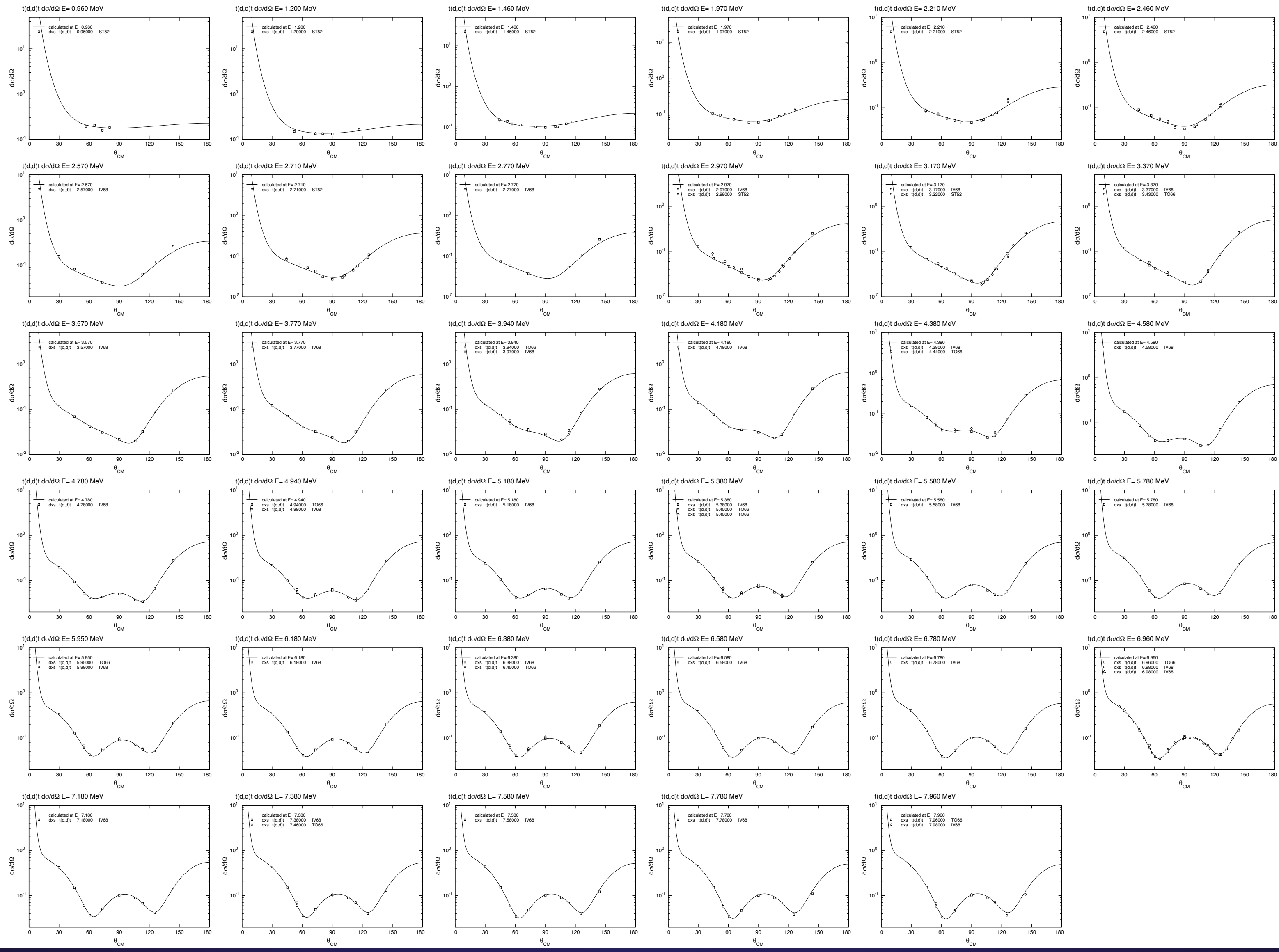
- **Simultaneously fits all known low-E data**
  - neutron & charged-particle channels
  - polarization (distinguishes partial waves, etc.)
- **High-fidelity X^2 ~ 1.5 below 10 MeV**
- **All resonances/partial waves included**
- **EDA also provides covariance matrices**

channel	a_c (fm)	l_{max}
n+^{4}He	3.0	5
γ+^{5}He	60	1
d+^{3}H	5.1	5
n+^{4}He*	5.0	1

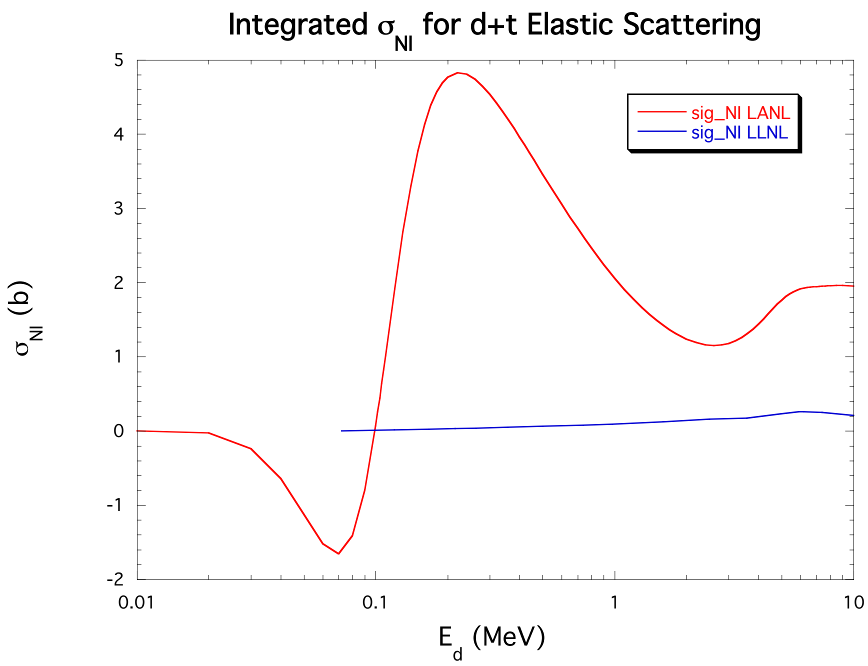
Reaction	Energies (MeV)	# data points	# data types
^{4}He(n,n)^{4}He	E_n = 0 – 40	817	2
^{3}H(d,d)^{3}H	E_d = 0 – 8.6	700	6
^{3}H(d,n)^{4}He	E_d = 0 – 30	1185	14
^{3}H(d,γ)^{5}He	E_d = 0 – 8.6	17	2
^{3}H(d,n)^{4}He*	E_d = 4.8 – 8.3	10	1
total		2729	25



T(d,n)α evaluation (II)
Angular distributions T(d,el)

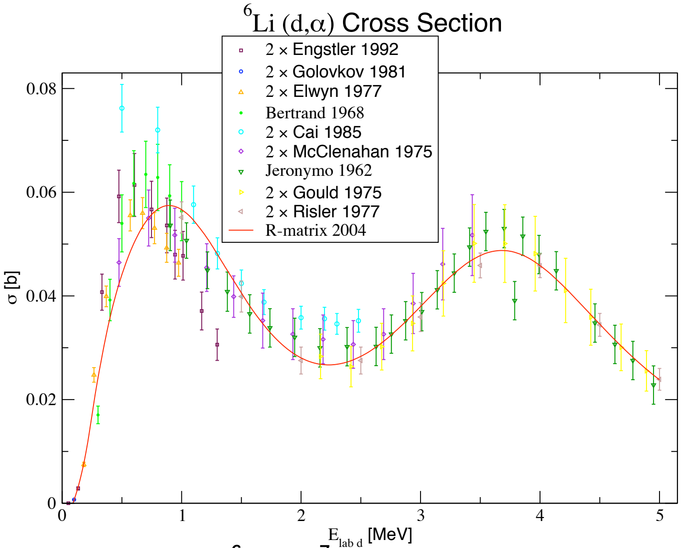


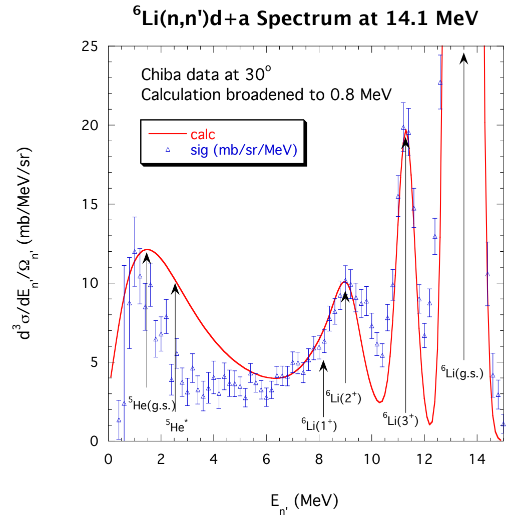
T(d,n)α evaluation (II)
σ_{NI} T(d,el) nuclear plus interference

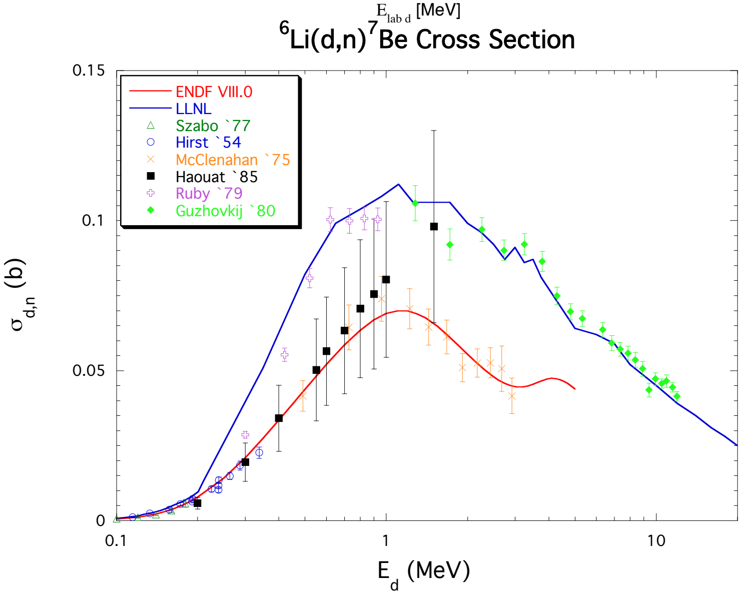


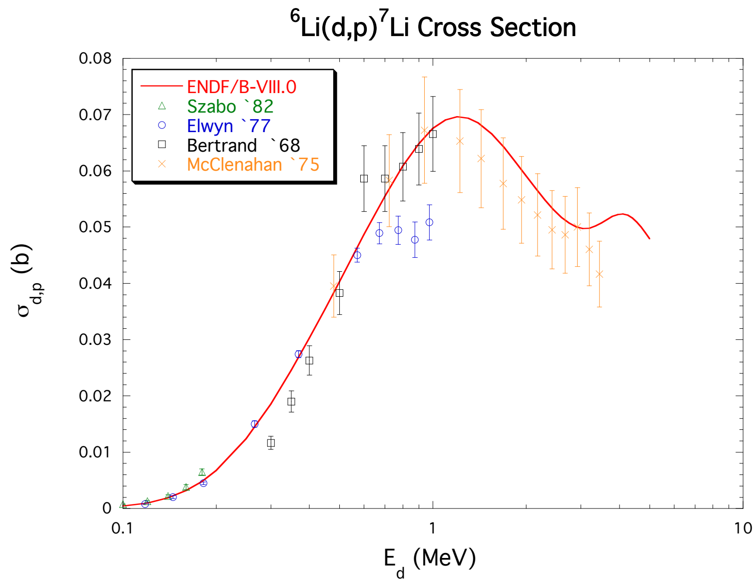
- **Nuclear + interference cross section**
  - requires multichannel fit
  - strong energy dependence
  - not necessarily > 0

^{6}Li
deuterons, neutrons









Uncertainties from chi-squared minimization

$$\chi^2_{\text{EDA}} = \sum_i \left[\frac{nX_i(\mathbf{p}) - R_i}{\Delta R_i}\right]^2 + \left[\frac{nS-1}{\Delta S / S}\right]^2 \quad \begin{cases} R_i,\ \Delta R_i = \text{relative measurement, uncertainty} \\ S,\ \Delta S = \text{experimental scale, uncertainty} \\ X_i(\mathbf{p}) = \text{observable calc. from res. pars. } \mathbf{p} \\ n = \text{normalization parameter} \end{cases}$$

Near a minimum of the chi-squared function at **p** = **p**$_0$:

$$\begin{aligned} \chi^2(\mathbf{p}) &= \chi^2_0 + (\mathbf{p}-\mathbf{p}_0)^{\mathrm{T}}\mathbf{g}_0 + \tfrac{1}{2}(\mathbf{p}-\mathbf{p}_0)^{\mathrm{T}}\mathbf{G}_0(\mathbf{p}-\mathbf{p}_0) \\ &= \chi^2_0 + \Delta\chi^2. \end{aligned} \quad \begin{cases} \chi^2_0 = \chi^2(\mathbf{p}_0) \\ \mathbf{g}_0 = \nabla_{\mathbf{p}}\chi^2(\mathbf{p})\big|_{\mathbf{p}=\mathbf{p}_0} \approx 0 \\ \mathbf{G}_0 = \nabla_{\mathbf{p}}\mathbf{g}(\mathbf{p})\big|_{\mathbf{p}=\mathbf{p}_0} \end{cases}$$

Conventions:

1) previous: $\Delta\chi^2 = 1 \implies$ Very small uncertainties $\delta p_i = (C^0_{ii})^{1/2} \sim \mathcal{O}(N_p^{-1/2})$

2) improved: $\Delta\chi^2 = \frac{1}{2}\Delta\mathbf{p}^{\mathrm{T}}\mathbf{G}_0\Delta\mathbf{p} \le \Delta\chi^2_{\max}$,

$$P(\Delta\chi^2|k) = \left[2^{\frac{k}{2}}\Gamma(\tfrac{k}{2})\right]^{-1}\int_0^{\Delta\chi^2_{\max}} t^{\frac{k}{2}-1}e^{-\frac{t}{2}}dt = \text{CL (e.g.} \sim 0.68 \text{ for } 1\text{-}\sigma),\ 0.95 \text{ for } 2\text{-}\sigma, \text{etc.}$$

$$\Delta\chi^2_{\max} \approx k = \langle \Delta\chi^2 \rangle.$$

$$\delta p_i \sim (N_p C^0_{ii})^{1/2}$$

Covariance

The parameter covariance matrix is $\mathbf{C}_0 = 2\mathbf{G}_0^{-1}$, and so first-order error propagation gives for the cross-section covariances

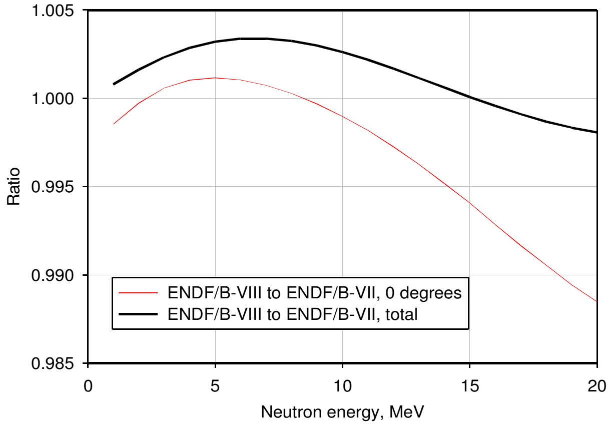
$$\begin{aligned}\chi^2(\mathbf{p}) &= \chi_0^2 + (\mathbf{p}-\mathbf{p}_0)^{\mathrm{T}}\mathbf{g}_0 + \tfrac{1}{2}(\mathbf{p}-\mathbf{p}_0)^{\mathrm{T}}\mathbf{G}_0(\mathbf{p}-\mathbf{p}_0) \\ &= \chi_0^2 + \Delta\chi^2.\end{aligned} \quad \begin{cases} \chi_0^2 = \chi^2(\mathbf{p}_0) \\ \mathbf{g}_0 = \nabla_{\mathbf{p}}\chi^2(\mathbf{p})\big|_{\mathbf{p}=\mathbf{p}_0} \approx 0 \\ \mathbf{G}_0 = \nabla_{\mathbf{p}}\mathbf{g}(\mathbf{p})\big|_{\mathbf{p}=\mathbf{p}_0} \end{cases}$$

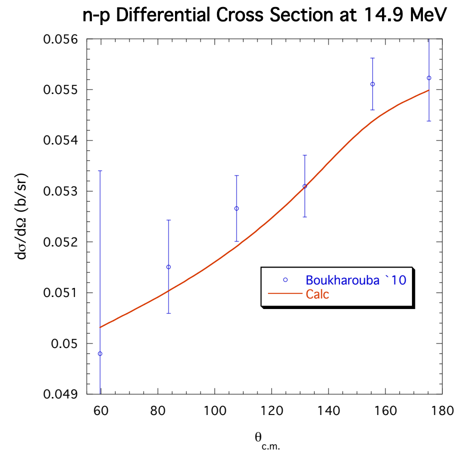
$$\begin{aligned}\mathrm{cov}[\sigma_{\mathrm{i}}(E)\sigma_j(E')] &= \left[\nabla_{\mathbf{p}}\sigma_{\mathrm{i}}(E)\right]^{\mathrm{T}}\mathbf{C}_0\left[\nabla_{\mathbf{p}}\sigma_{\mathrm{j}}(E')\right]\Big|_{\mathbf{p}=\mathbf{p}_0} \\ &= \Delta\sigma_{\mathrm{i}}(E)\Delta\sigma_{\mathrm{j}}(E')\rho_{ij}(E,E').\end{aligned}$$

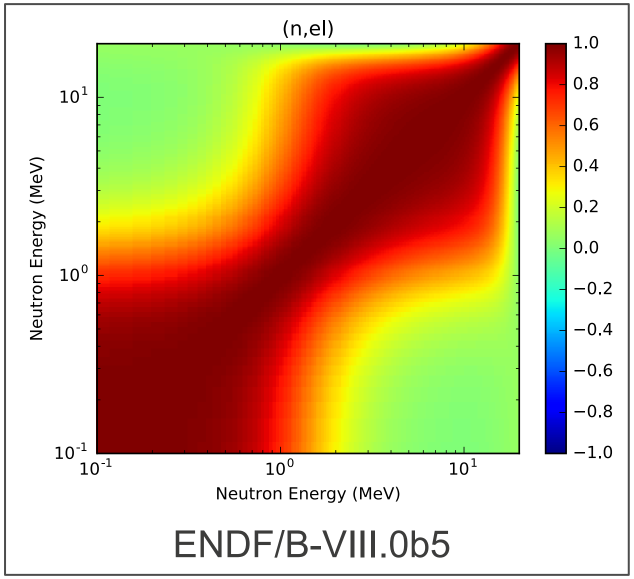
observable uncertainties

correlation coefficient

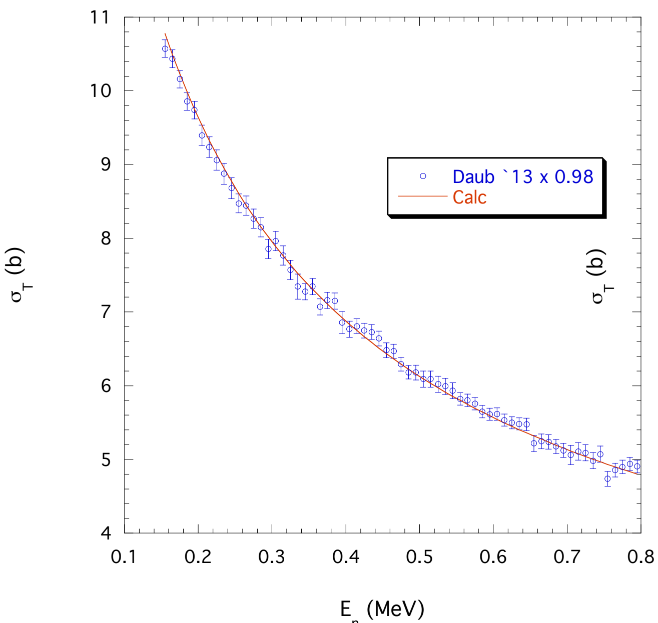
Evaluation 1: `n-001_H_001`



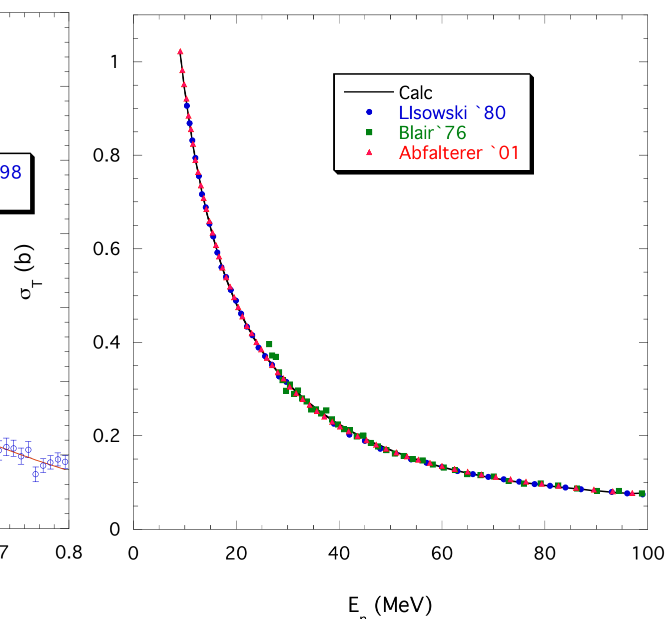




n-p Total Cross Section



n-p Total Cross Section



Partitions:

$pp(\ell \leq 3); np(\ell \leq 3);$
$\gamma d(\ell \leq 1); nn(\ell \leq 3)$

36 channels $(J^\pi LS)$

$\chi^2/\mathrm{dof} \simeq 0.9$

Evaluation 2: `n-003_Li_006`

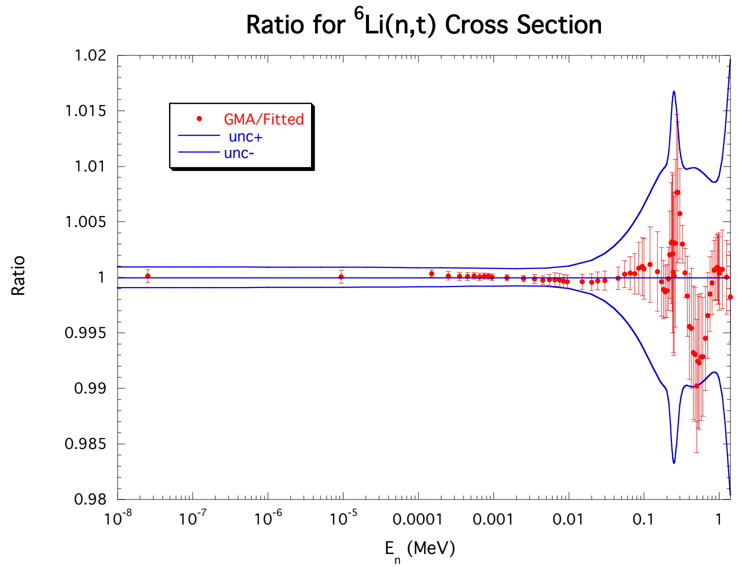
Partitions :

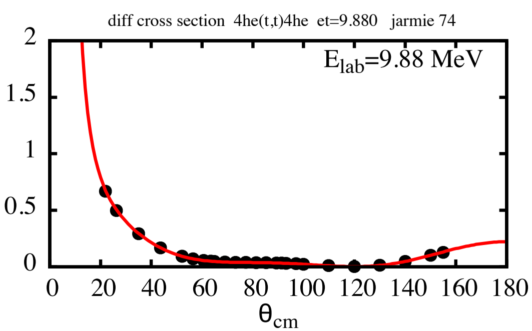
$t^4\mathrm{He}(\ell \leq 5); n^6\mathrm{Li}(\ell \leq 3);$

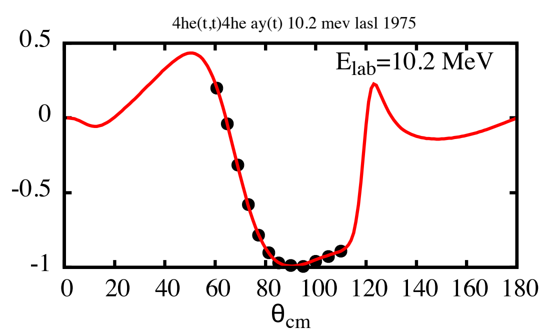
$n^6\mathrm{Li}^*(\ell \leq 1); d^5\mathrm{He}(\ell = 0)$

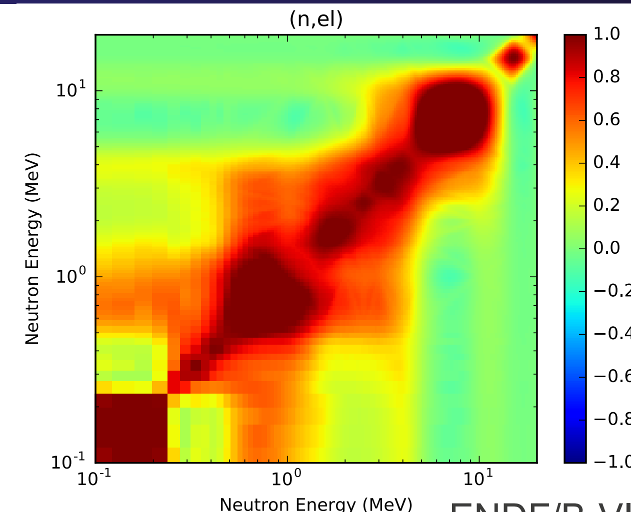
41 channels $(J^\pi LS)$

$\chi^2/\mathrm{dof} = 1.36$

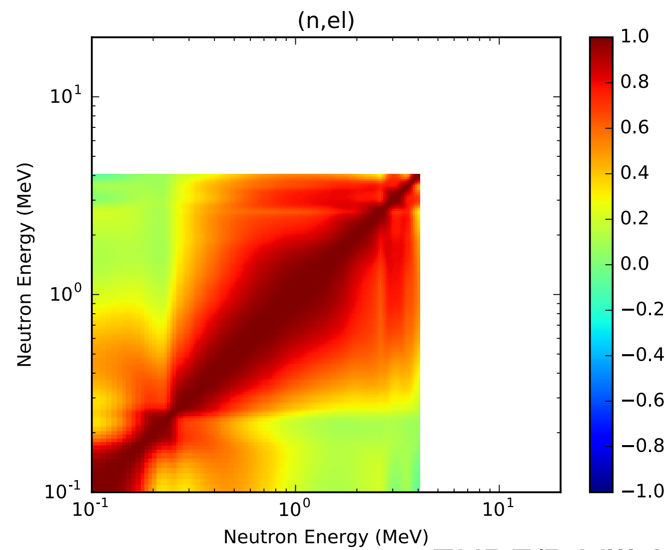






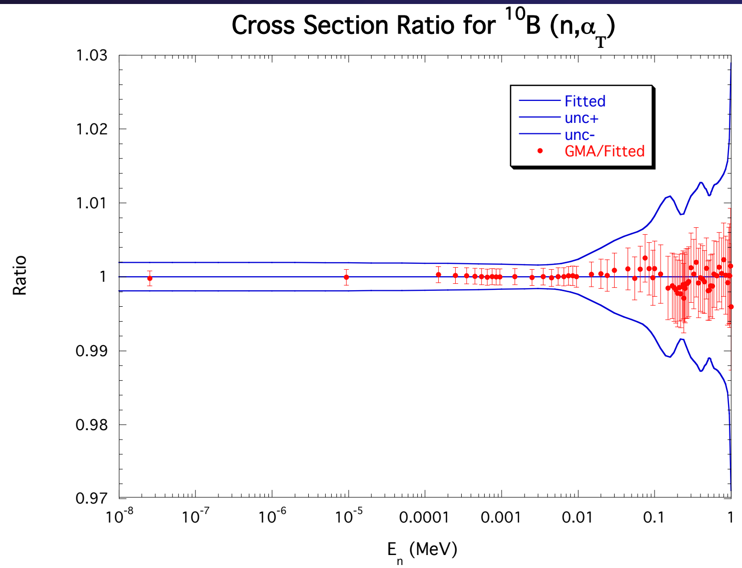


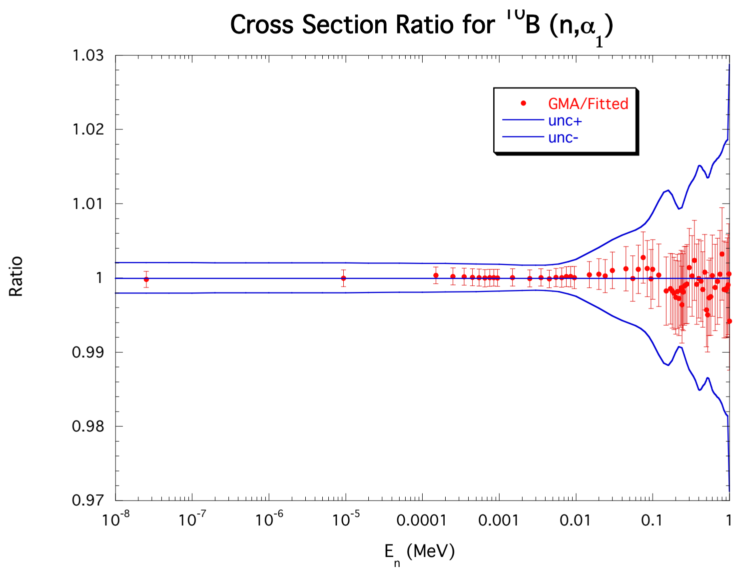
ENDF/B-VII.1



ENDF/B-VIII.0b5

Evaluation 3: `n-005_B_010`





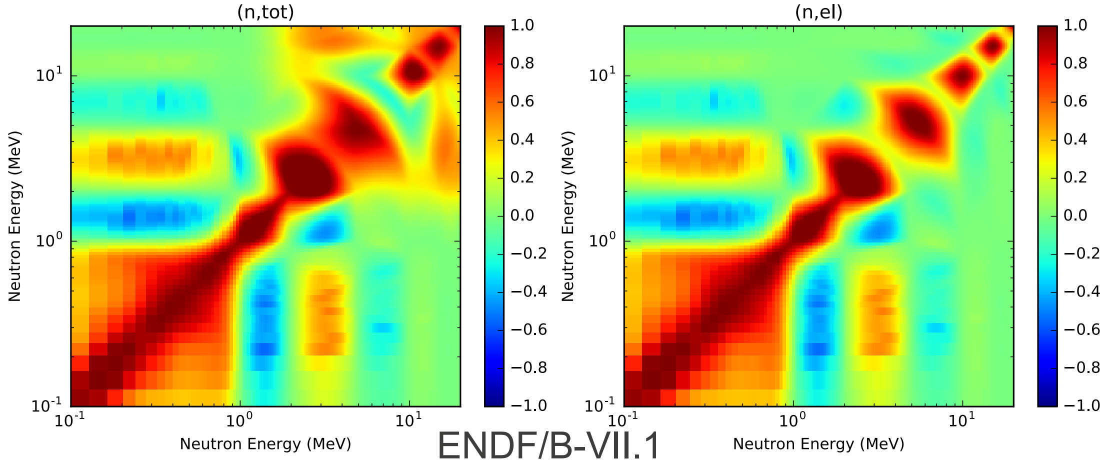
Partitions :

$n^{10}\mathrm{B}(\ell \leq 1); \alpha^7\mathrm{Li}(\ell \leq 3);$

$\alpha^7\mathrm{Li}^*(\ell \leq 1); t^8\mathrm{Be}(\ell \leq 2)$

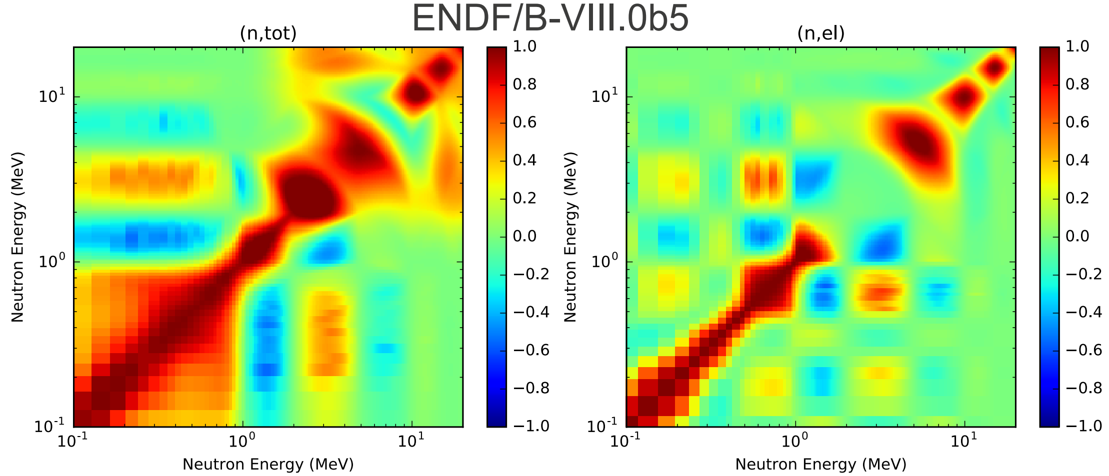
32 channels $(J^\pi LS)$

$\chi^2/\mathrm{dof} = 1.14$

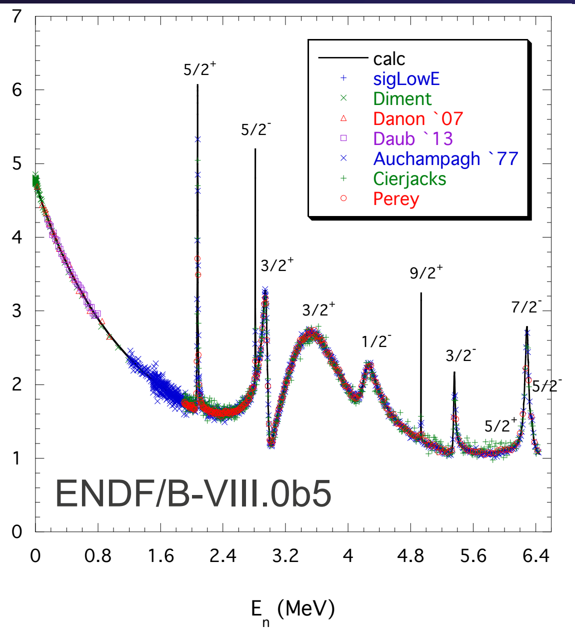


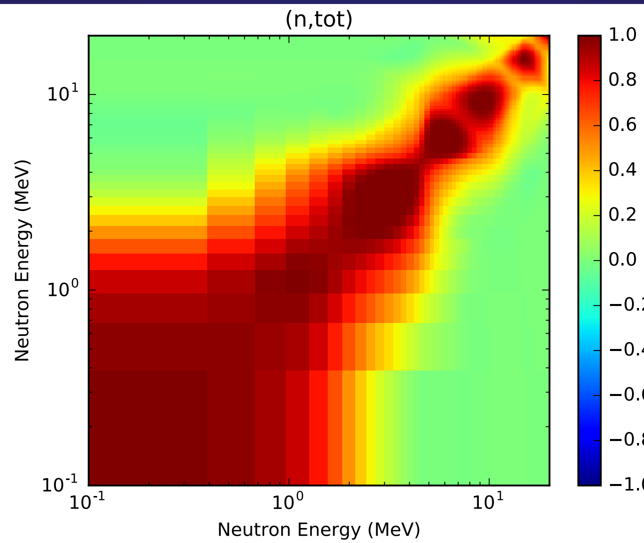
ENDF/B-VII.1

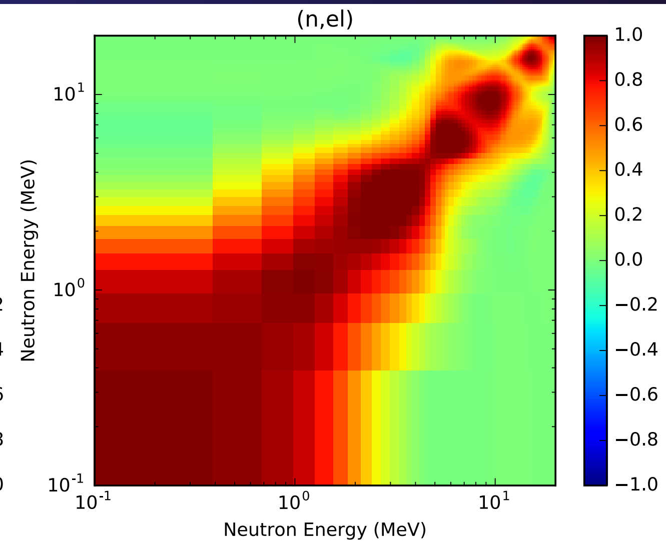
ENDF/B-VIII.0b5



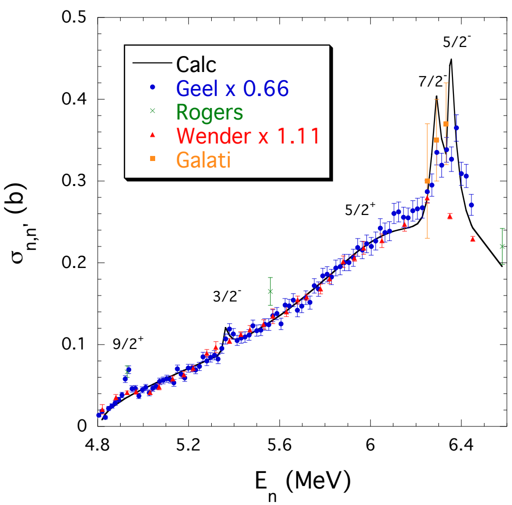
Evaluation 4: n-006_C_012







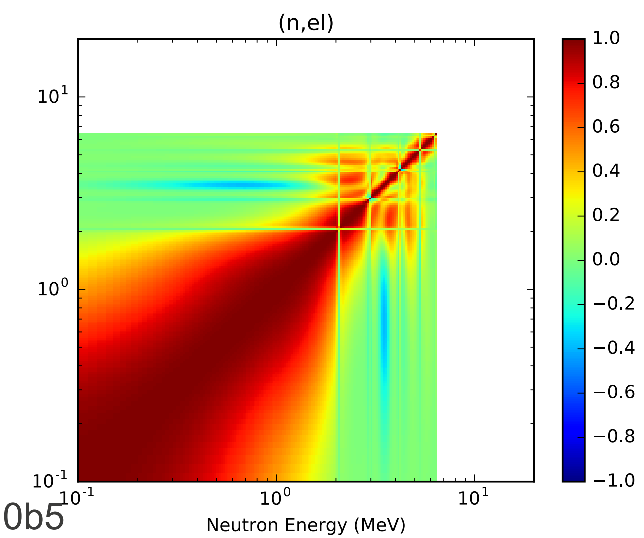
ENDF/B-VII.1



channel	a_c (fm)	l_{max}
n+^{12}C(0$^+$)	4.6	4
n+^{12}C*(2$^+$)	5.0	1
γ+^{13}C	50	1

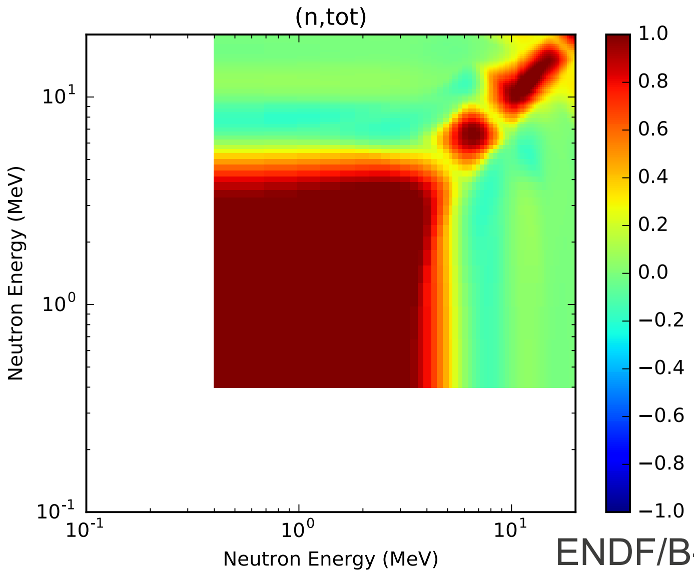
Reaction	Energies (MeV)	# data points	Data types
^{12}C(n,n)^{12}C	E_n = 0 – 6.45	6940	σ_T, $\sigma(\theta)$, $A_n(\theta)$
^{12}C(n,n')^{12}C*	E_n = 5.3 – 6.45	443	σ_{int}, $\sigma(\theta)$
^{12}C(n,γ)^{13}C	E_n = 0 – 0.199	7	σ_{int}
total	4994	7390	5

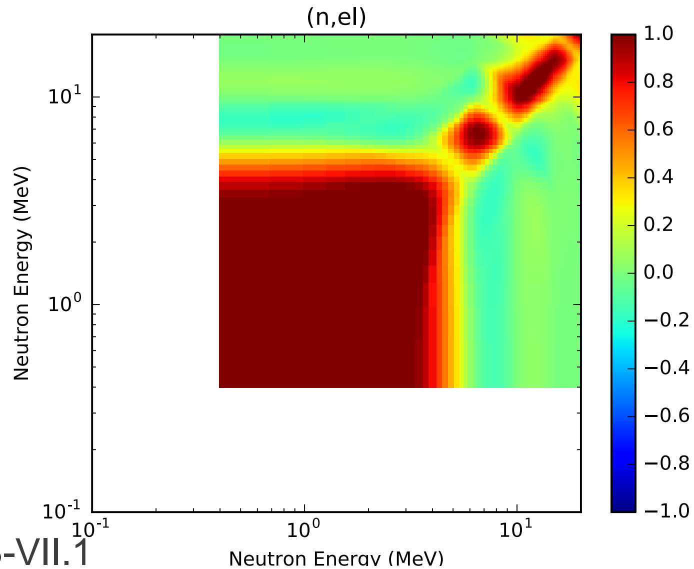
χ^2 per degree of freedom = 1.54



ENDF/B-VIII.0b5

Evaluation 5: `n-008_O_016`

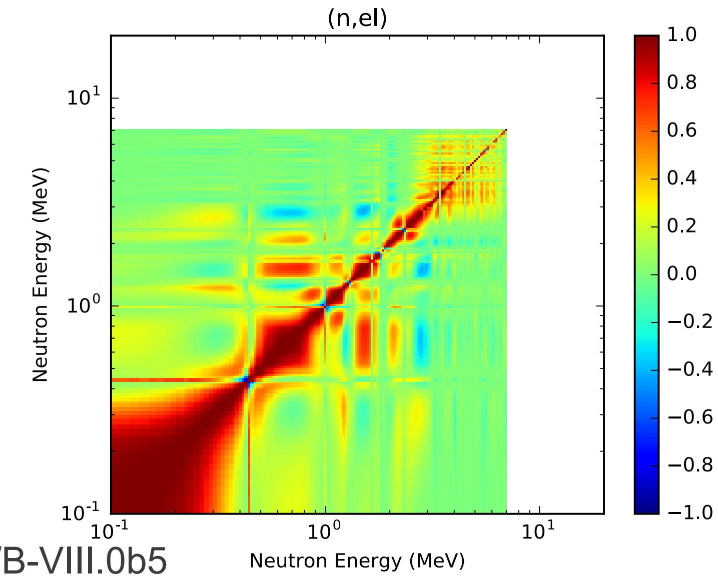




ENDF/B-VII.1

channel	a_c (fm)	l_{max}
n+^{16}O	4.4	4
α+^{13}C	5.4	5

Reaction	Energies (MeV)	# data points	Data types
^{16}O(n,n)^{16}O	E_n = 0 – 7	2540	σ_T, $\sigma(\theta)$, $P_n(\theta)$
^{16}O(n,α)^{13}C	E_n = 2.35 – 5	672	σ_{int}, $\sigma(\theta)$, $A_n(\theta)$
^{13}C(α,n)^{16}O	E_α = 0 – 5.4	870	σ_{int}
^{13}C(α,α)^{13}C	E_α = 2 – 5.7	1168	$\sigma(\theta)$
total		5250	8



χ^2 per degree of freedom = 1.68

ENDF/B-VIII.0b5

Outlook

- **Short term**
  - publish existing evaluations (including, of course, charged-particle) absent from ENDF/B
    - including all R-matrix & normalization parameters (Ian T.'s talk)
    - *Caveat Emptor*: EDA5 & 6 – relativistic parametrization
  - use existing EDA5
- **Medium term**
  - continue development on EDA6 (modern-language successor to EDA5)
    - primary objectives:
      - extend light-element analyses/covariance to $E_n \leq 20$ MeV
      - charged particles
      - spectra
  - Likelihood-based fitting with Bayesian approach
- **Long term**
  - modern-language modular/OO structure will allow
    - experimental acceptance, efficiency, general IRF capabilities (comparable to SAMMY)
    - integrated, ***homogeneous*** optimization with integral benchmarks & other evaluation codes
      - avoids 'optimization via email' situation that currently obtains