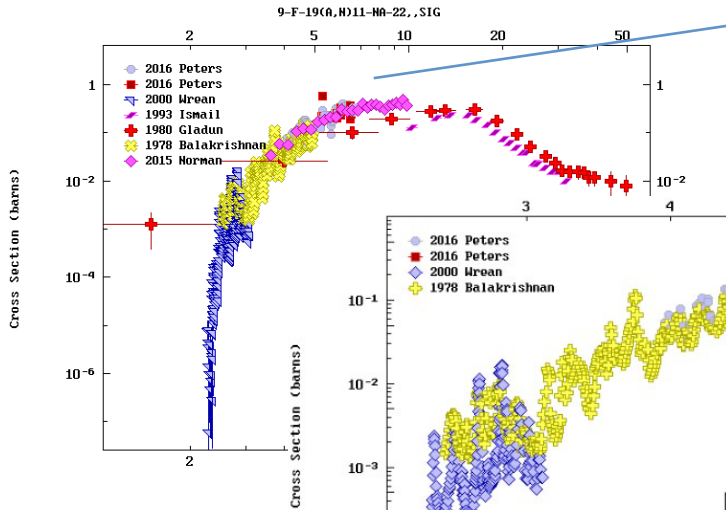# Progress on ^{19}F(alpha,n)

Vivian Dimitriou[1], Eleni Vagena[2]

[1]Nuclear Data Section, IAEA, Vienna, Austria
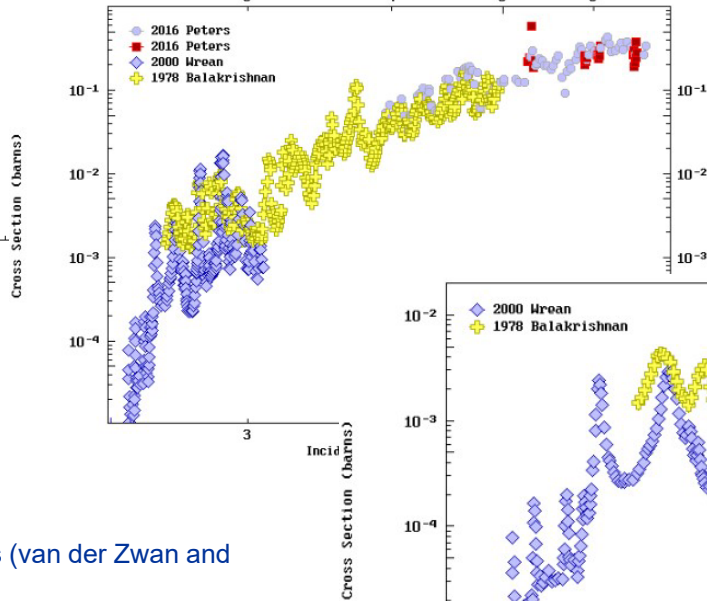[2]NCSR Demokritos, Athens, Greece
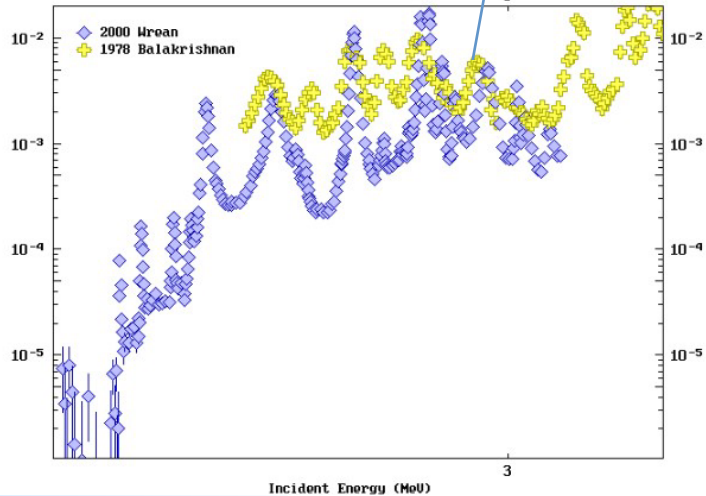
$^{19}F(\alpha,n)$: data needs

- Nonproliferation, spent fuel management, homeland security
  - Non-destructive assay of clean or spent nuclear fuel (UF_6, PuF_4, etc)
  - Alphas from alpha-emitters (Am, Bk, Cf, Cm, Np, Pu, Th, U) with alpha-decay energies < 6.5 MeV
- Rare-event experiments
  - Low-background measurements
  - Alphas from radioactive natural background (U and Th decay chains, Rn emanation)
  - Alpha energies < 9 MeV
- Fusion technologies

Cross sections derived from thick-target yield data

9-F-19(A,N)11-NA-22,,SIG

Legend (top-left plot):
- 2016 Peters
- 2016 Peters
- 2000 Wrean
- 1993 Ismail
- 1980 Gladun
- 1978 Balakrishnan
- 2015 Norman

Legend (middle plot):
- 2016 Peters
- 2016 Peters
- 2000 Wrean
- 1978 Balakrishnan

Legend (bottom-right plot):
- 2000 Wrean
- 1978 Balakrishnan
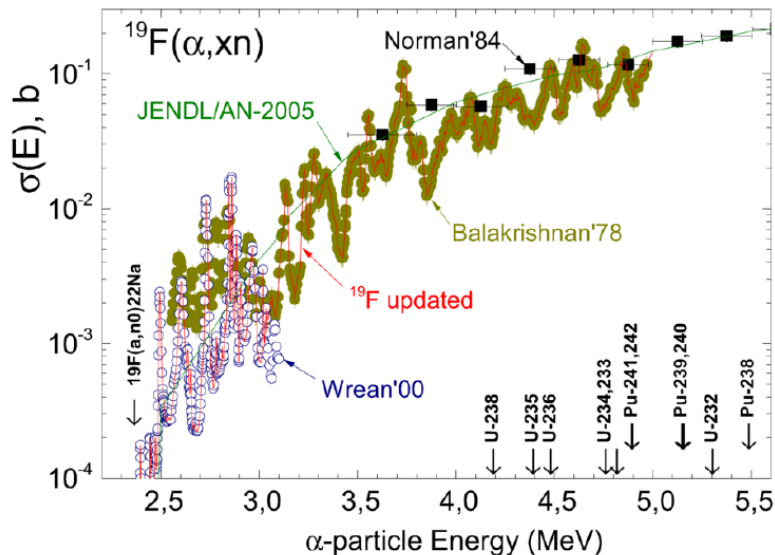
Wrean: sys.unc. 8%
Balakrishnan: syst. Unc. 15%

Other data:
0 deg excitation functions (van der Zwan and Geiger 1977)
(a,n), (a,p0,1) angular distributions
(a,el) excitation functions at given angle

Data libraries
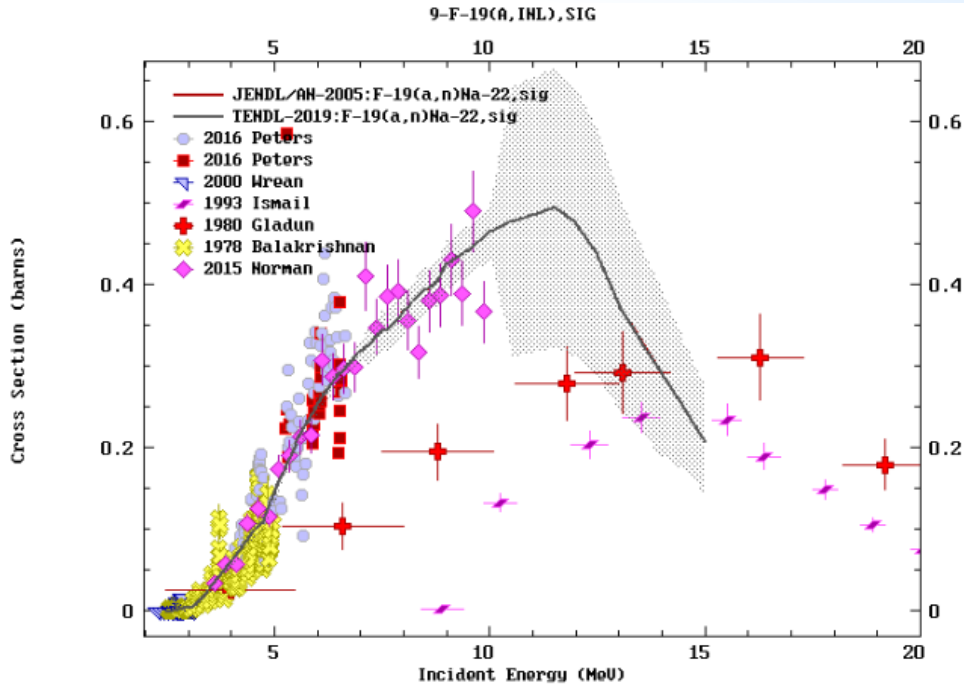
Fit to exp. Cross sections
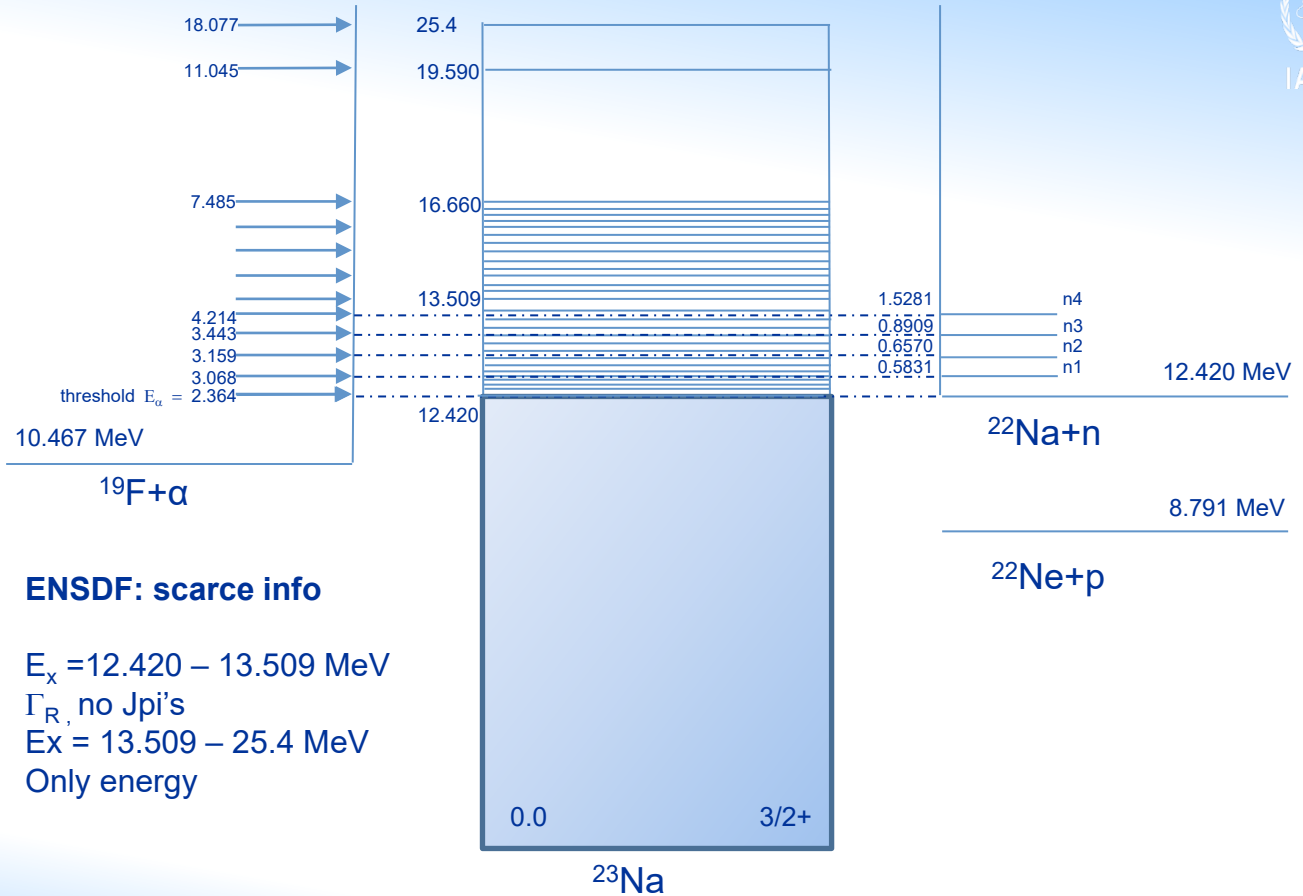

Simakov et al., NDS 137 (2017) 190

IAEA evaluation of cross-section data:
- Up to 3 MeV adopt Wrean data
- From 3 to 5 MeV adopt Balakrishnan et al data

Goal

- Perform an evaluation up to 9 MeV incident alpha energies – for applications
- Produce ENDF files

18.077

11.045

7.485

4.214
3.443
3.159
3.068
threshold E_{α} = 2.364

10.467 MeV

$^{19}F+\alpha$

25.4

19.590

16.660

13.509

12.420

0.0   3/2+

^{23}Na

1.5281
0.8909
0.6570
0.5831

$^{22}Na+n$

n4
n3
n2
n1

12.420 MeV

8.791 MeV

$^{22}Ne+p$

ENSDF: scarce info

E_x = 12.420 – 13.509 MeV
Γ_R, no Jpi's
Ex = 13.509 – 25.4 MeV
Only energy

R-matrix analysis

- AZURE2
  - Alpha incident energy up to 5 MeV
  - Channels: alpha+^{19}F; n+^{22}Na g.s.; p+^{22}Ne g.s.
  - Channel radius:$1.4*(A_1^{1/3}+A_2^{1/3})$
  - L=4
  - Background poles

Parameter	Channel radii (fm)
$\alpha_c(^{19}F+\alpha)$	5.96
$\alpha_c(^{22}Na+n)$	5.32
	Atomic mass (μu)
M_n	1.00866
M_α	4.00260
M_{19F}	18.9984
M_{22Na}	21.9944
Q	-1952 MeV

$$^{19}F + \alpha$$
$$(E_{lab} = 5000 \text{ keV})$$

Reaction Products	Q-Value (keV)	Threshold (keV)
$^{23}Na + \gamma$	10467.3243 *20*	0
$^{22}Ne + p$	1673.216 *18*	0
$^{19}F + \alpha$	0	0
$^{22}Na + NN$	-1952.46 *13*	2349.66 *16*
$^{15}N + 2\alpha$	-4013.7991 *10*	4830.3664 *13*

ENSDF 2022: ^{23}Na

E_α(MeV)	E_x (MeV)	Jpi	Γ_α (eV)
2.363	12.419	(7/2+,5/2+)	116(20)
2.446	12.488	(13/2+)	5000(2000)
2.612	12.625		25000
2.630	12.64		10000(5000)
2.738	12.729		130000(2000)
2.824	12.8		6000(3000)
2.846	12.818		5000(2000)
2.882	12.848		11000(5000)
2.887	12.852		9000(4000)
2.978	12.927		6000(3000)
3.156	13.074		12000(4000)
3.289	13.184		9000(4000)
3.304	13.196		9000(4000)
3.366	13.248		10000(5000)
3.404	13.279		14000(7000)
3.474	13.337		8000(4000)
3.549	13.399		13000(6000)
3.623	13.46		23000(11000)
3.682	13.509		10000(5000)

(α,p_0) measurements Schier et al, 1976

E_α	E_x	Jpi
1.318	11.556	1/2+
1.492	11.700	1/2 +-
1.507	11.712	3/2-
1.879	12.019	1/2+,5/2+
1.954	12.081	1/2+-
2.002	12.121	1/2-
2.081	12.186	5/2+
2.102	12.203	5/2+
2.199	12.284	1./2+,1/2-
2.319	12.383	3/2-
2.402	12.451	7/2-
2.45	12.491	3/2+
2.538	12.564	3/2+,3/2-
2.639	12.647	3/2-
2.742	12.732	5/2+,7/2-
3.036	12.975	1/2+,7/2-
3.165	13.082	1/2+,7/2-
3.266	13.165	5/2+,7/2-
3.308	13.200	7/2-,9/2+
3.361	13.243	5/2+,5/2-
3.548	13.398	3/2-,7/2-
3.735	13.552	1/2-,5/2+
3.87	13.664	5/2+,7/2-
4.115	13.866	1/2-,7/2-
4.186	13.925	3/2-,5/2+
4.344	14.056	3/2-,7/2-
4.5	14.184	3/2-,3/2+
4.616	14.280	3/2-,3/2+
4.704	14.353	1/2+,7/2-
4.825	14.453	1/2+,7/2-
4.895	14.511	1/2-,9/2+

Kuperus 1965

^{19}F$(\alpha,\alpha_0)^{19}$F resonance parameters — Cseh et al, 1984

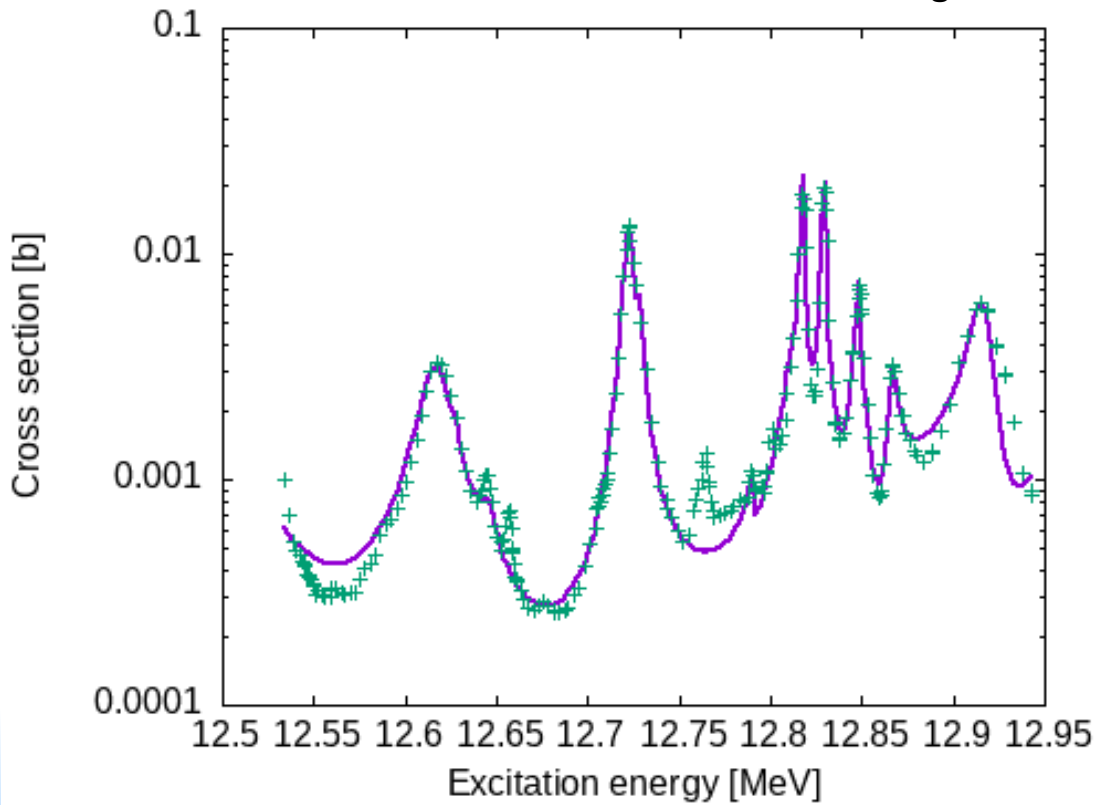| E_α a) (MeV)	E_x b) (MeV)	l_α	J^π	Γ_α/Γ c)	Γ c) (keV)	γ_α^2 (keV)
2.513	12.544	2	3/2+, 5/2+	0.23, 0.16	6.6	76, 52
2.632	12.642	0	1/2+	0.17	11	15
		1	1/2-, 3/2-	0.21, 0.11	13	34, 18
2.737	12.729	2	3/2+, 5/2+	0.17, 0.12	12	44, 31
2.813	12.791	2	3/2+, 5/2+	0.065, 0.045	11	12, 9
2.846	12.819	1	1/2-, 3/2-	0.37, 0.20	3.4	8.4, 4.5
2.873	12.841	2	3/2+, 5/2+	0.11, 0.074	17	27, 19
2.887	12.852	0	1/2+	0.11	5.5	2.3
		1	1/2-, 3/2-	0.12, 0.064	12	8.4, 4.5
3.126	13.050	2	3/2+, 5/2+	0.14, 0.097	9	9, 6.2
3.151	13.071	1	1/2-, 3/2-	0.39, 0.21	6.8	8.5, 4.6
3.156	13.075	2	3/2+, 5/2+	0.21, 0.15	12	18, 12
3.250	13.153	2	3/2+, 5/2+	0.18, 0.12	11	11, 7.5
3.302	13.195	0	1/2+	0.90	6.3	9
3.359	13.243	3	5/2-, 7/2-	0.15, 0.11	12	24, 18
3.467	13.332	2	3/2+, 5/2+	0.24, 0.17	23	18, 12
3.567	13.422	3	5/2-, 7/2-	0.07, 0.053	15	8.3, 6.3
3.621	13.459	1	3/2-	0.69	22	20

Experimental data

- (alpha,el): Cseh et al, 1984; excitation function at 5 angles; no info on syst. Unc.
- (alpha,n): Wrean and Kavanagh, 2000: up to 3 MeV, fine resolution <0.5 keV, norm. unc. 8%
- (alpha,p): Schier et al, 1976: angular dsitributions at ~20 angles; absolute norm. 25%

- Normalizations in R-matrix analysis: free
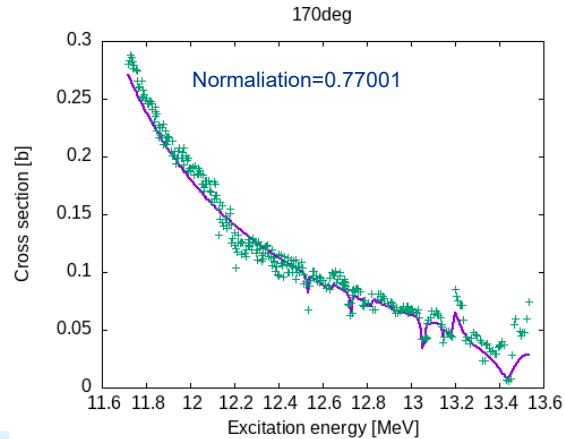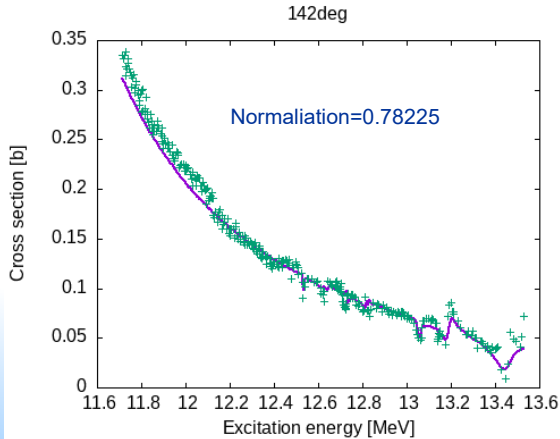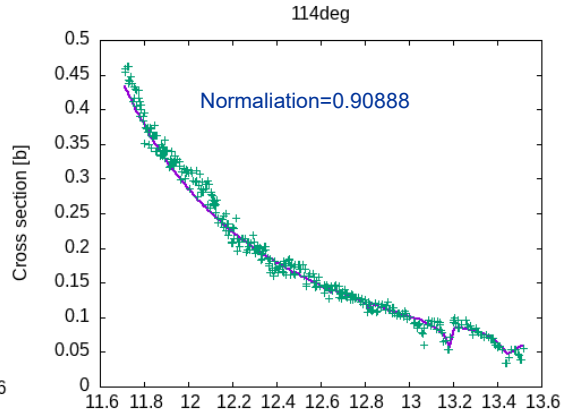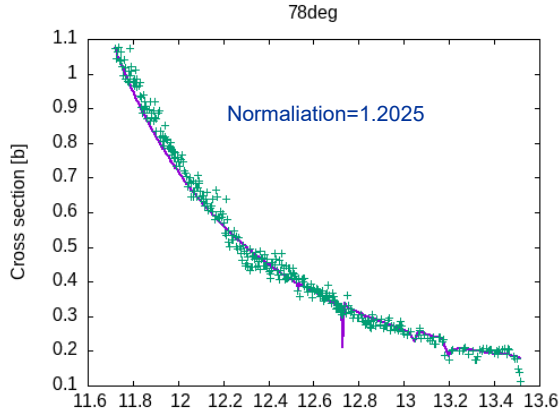
Results up to ~3 MeV

an **Wrean-Kavanagh 2000**

(a,a) **Cseh et al 1984**

$^{19}F(a,p)$ **Schier et al 1976**
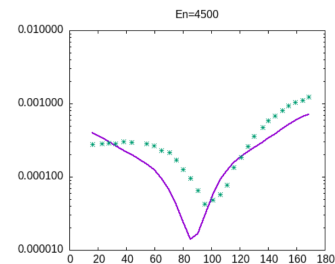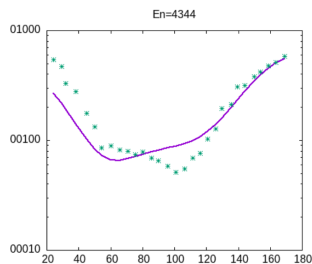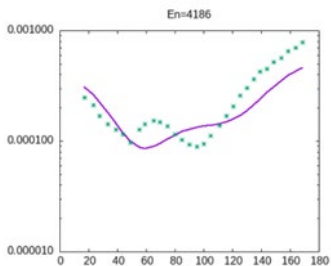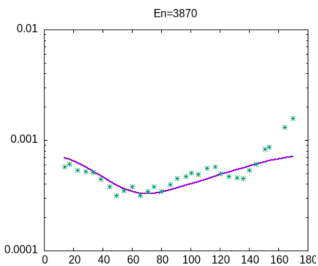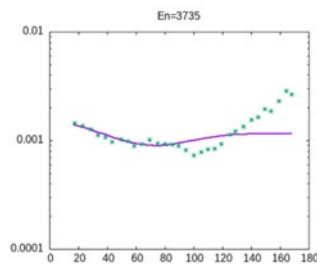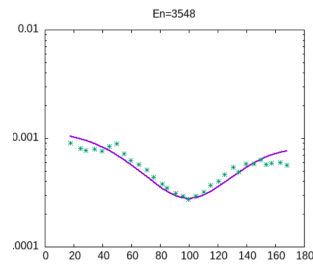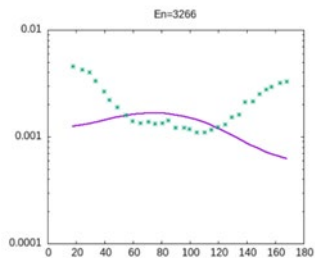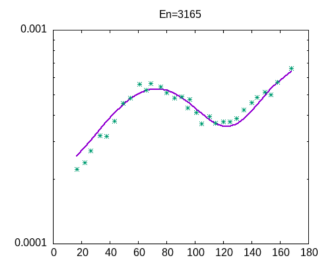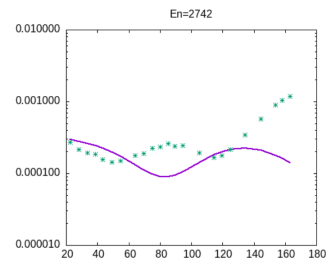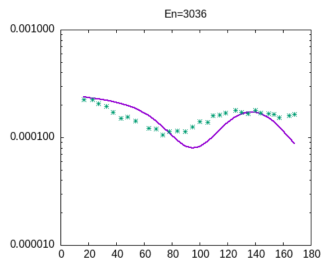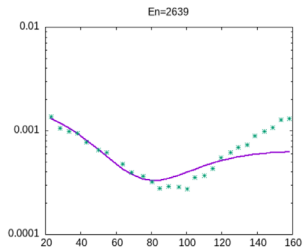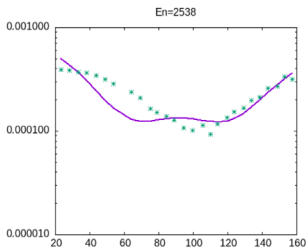
Excitation energy(MeV)

Work in progress –to do

- Complete R-matrix analysis up to 5 MeV with a chi2 ~ 2 – Nov 23

- Extend to 5 MeV: Add Balakrishnan et al data and partial (alpha,n) channels – release complete analysis

- Extend to 9 MeV: consider statistical model

- Expecting new NPL data up to higher energies (than 9 MeV)

- Perform R-matrix analysis with SAMMY too

- Produce ENDF files

Thank you!