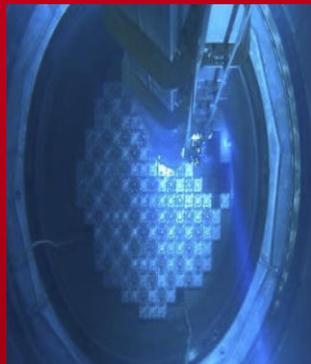


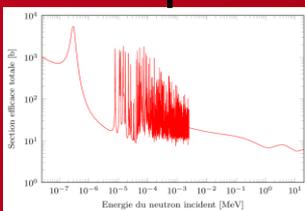
DE LA RECHERCHE À L'INDUSTRIE



Prediction ↔ Measurements
on reactor



Modelization



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Testing compound nucleus hypothesis across the O-17 nuclide excitation

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5th International Workshop On Nuclear Data Evaluation for Reactor
applications
(WONDER-2018)

8-12th October, 2018
Grand Hotel Roi René, Aix en Provence, France

- Purpose,
- Forces in attendance for the evaluation process,
- The work achieved,
- Some lessons and outlook.

NEW APPROACH TO NUCLEAR EVALUATION USING A SELF-CONSISTENT MULTICHANNEL MODELING METHODOLOGY

Work environment: code CONRAD (Code for Nuclear Reaction Analysis and Data Assimilation)

Strategy: development of a module TORA (TOol for Reactions Analysis)

- ❑ Easier management (CONRAD as a large C++ code)
- ❑ Philosophy-dedicated: a code written in a designed philosophy is not easy to transform; more efficient to start from scratch.
- ❑ TORA is being connected to CONRAD for evaluation purpose (doppler, resolution, etc);

Classic method

$$E_n^{lab}, \Gamma_n(E_n^{lab}), \Gamma_\alpha(E_n^{lab}), \Gamma_\gamma(E_n^{lab})$$

$(n, \text{tot}); (n, n); (n, n'); (n, \alpha); (n, \gamma)$

$$E_\alpha^{lab}, \Gamma_n(E_\alpha^{lab}), \Gamma_\alpha(E_\alpha^{lab}), \Gamma_\gamma(E_\alpha^{lab})$$

$(\alpha, \text{tot}); (\alpha, \alpha); (\alpha, \alpha'); (\alpha, n); (\alpha, \gamma)$

Unified approach

$$E_x^{CM}, \gamma_n^{CM}, \gamma_\alpha^{CM}, \gamma_\gamma^{CM}$$

Fit of a unique set of parameters without data reversal

$(n, \text{tot}); (n, n); (n, n'); (n, \alpha); (n, \gamma)$
 $(\alpha, \text{tot}); (\alpha, \alpha); (\alpha, \alpha'); (\alpha, n); (\alpha, \gamma)$

Any reactions observed/analysed simultaneously

Forces in attendance

SAMMY	REFIT	CONRAD		EDA	AMUR
			TORA		
ORNL N. Larson	Geel- M. Moxon	CEA Cadarache	CEA Cadarache	Los Alamos G. Hale	S. Kunieda
Reich-Moore Pseudo R- Matrix	Reich-Moore	Reich-Moore	Reich-Moore R Matrix (planned)	S-Matrix poles	R-Matrix
LAB incident particle	LAB incident particle	LAB incident particle	LAB inc. particles+CoM	CoM	(CoM)
Neutron+ charged particles	Neutron	Neutron + Charged particles (charged particles in validation)	Neutron+Charged particles	All channels	All channels

- Historically, neutron evaluations have conditioned incident neutron treatment evaluation codes (SAMMY, REFIT, CONRAD);
- Breakthrough in terms of accuracy in cross sections requires a self consistent multichannel modeling → TORA module in CONRAD

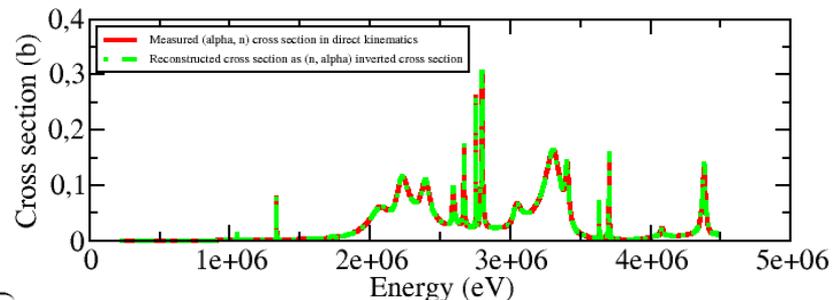
- ❑ Two reactions opened over reasonable energy range:
 - (n,α) reaction
 - (α,n) reaction
- ❑ CIELO project issues: 2 files (CIELO-1, CIELO-2)
 - JEFF3.3 → JEFF3.2 (G. NOGUERE contribution) ≠ CIELO-2
 - ENDFVIII.0 = CIELO-1
- ❑ Possibility to restart from CIELO-2 resonance parameters
- ❑ Caveat:
 - No (α, α) data used during the evaluation process
 - (n,α) channel fitted from (α,n) inverted data

Inversion relying on the compound nucleus hypothesis:

$$\sigma(n, \alpha)(E_n) = \sigma(\alpha, n)(E_\alpha) \frac{(2I_\alpha + 1)(2I_{^{13}\text{C}} + 1) \lambda_n^2}{(2I_n + 1)(2I_{^{16}\text{O}} + 1) \lambda_\alpha^2}$$

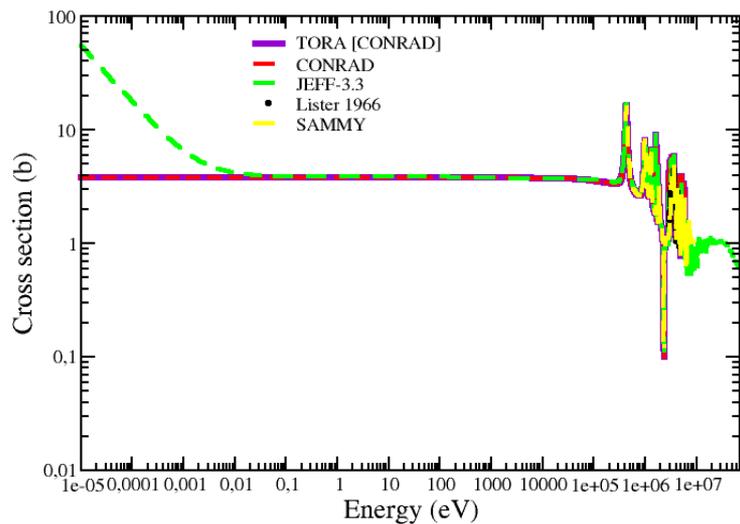
Surrogate cross section

!This works in the RR region

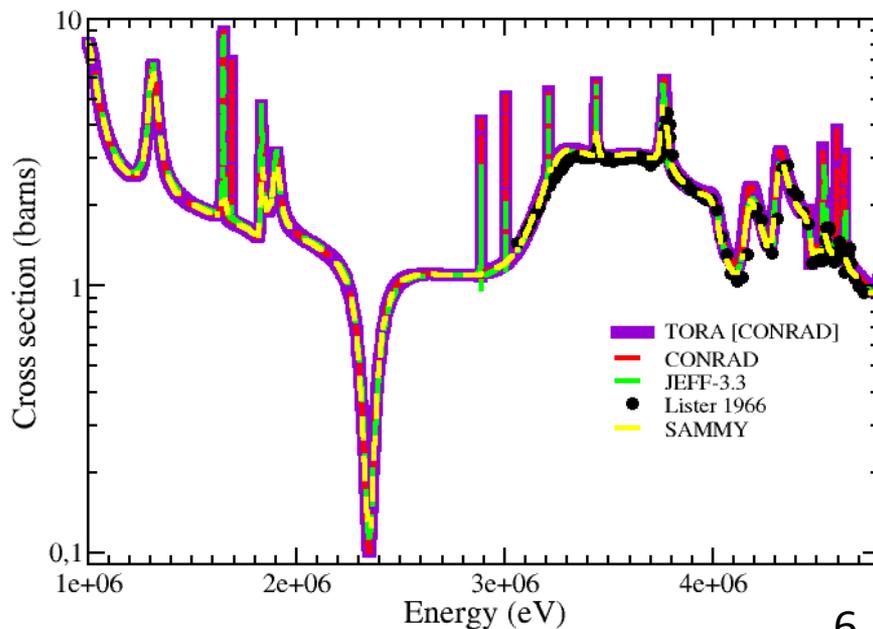


Numerical validation: neutron elastic channel

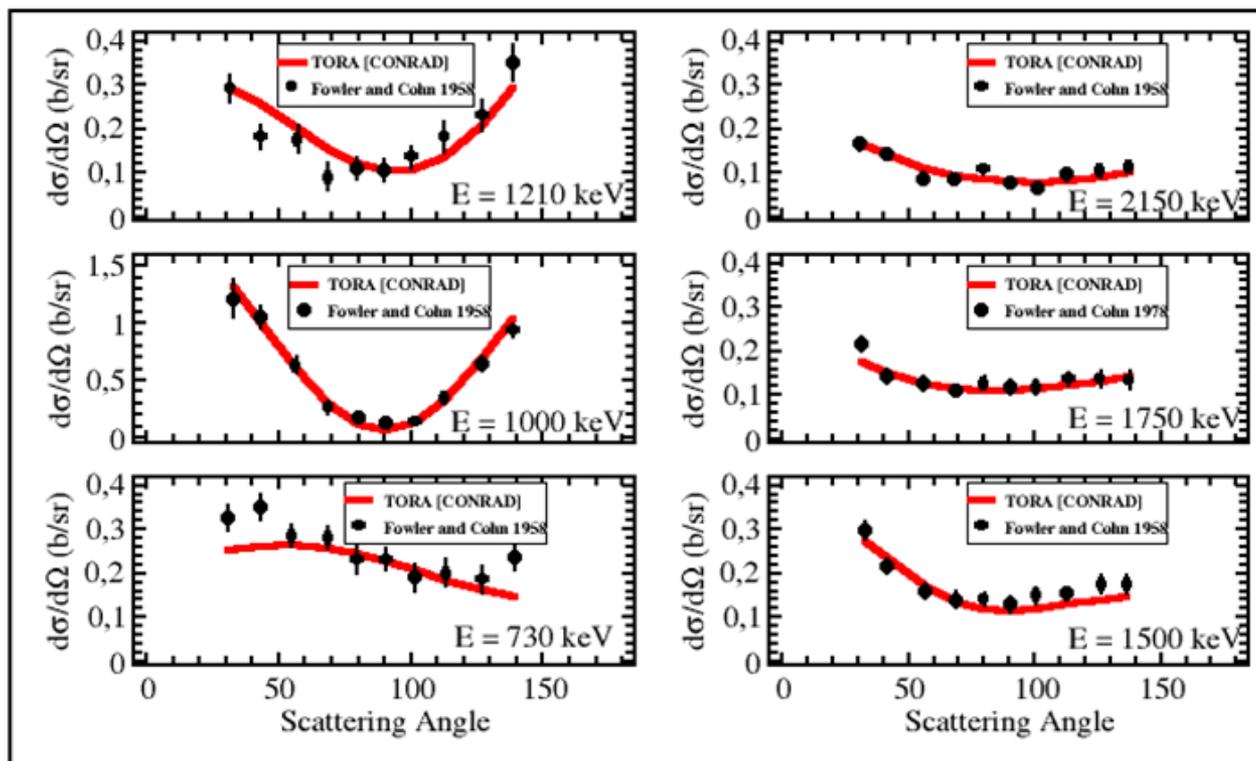
$^{16}\text{O}(n, \text{El})$ cross section



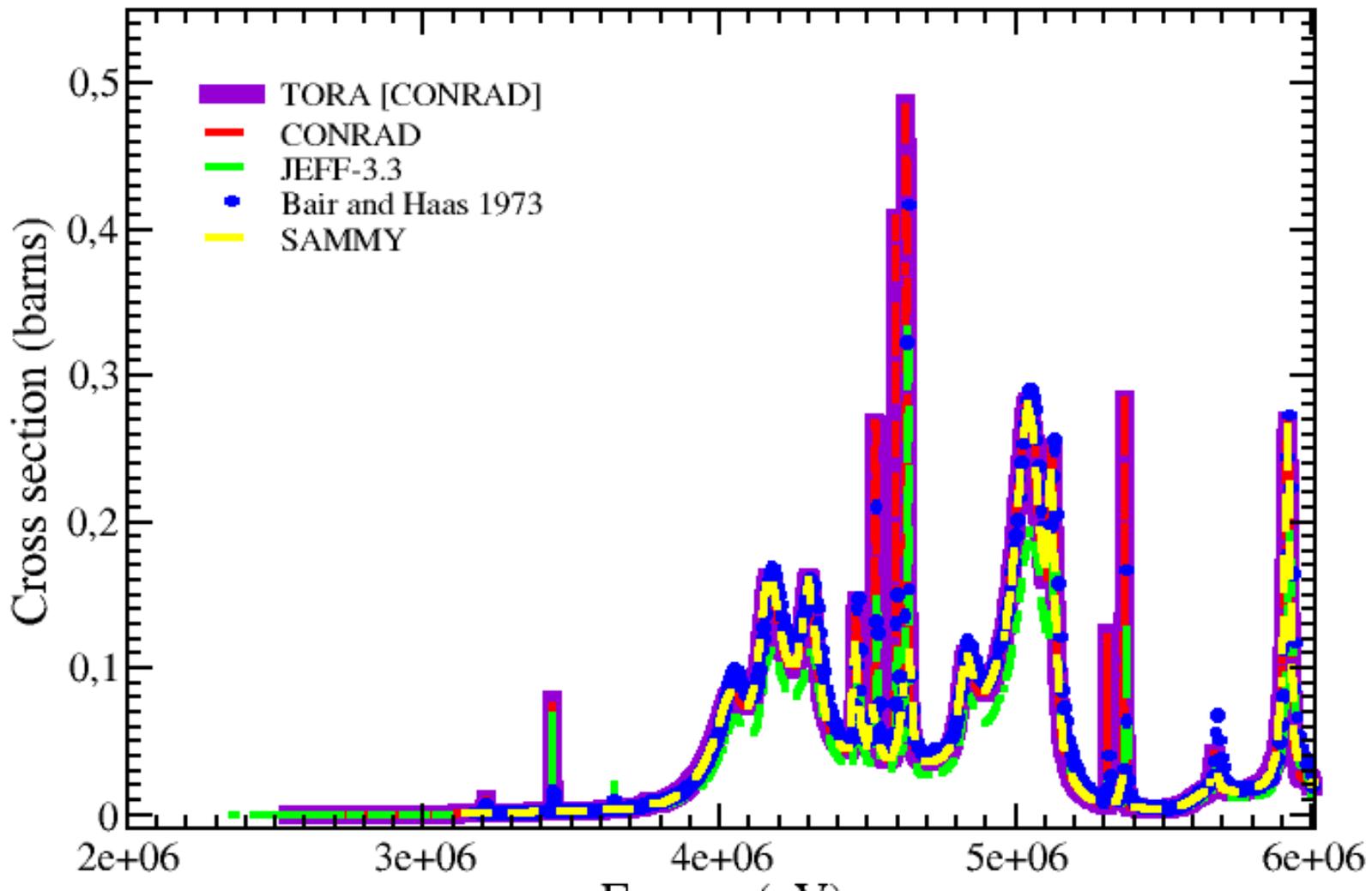
$^{16}\text{O}(n,n)^{16}\text{O}$ cross section



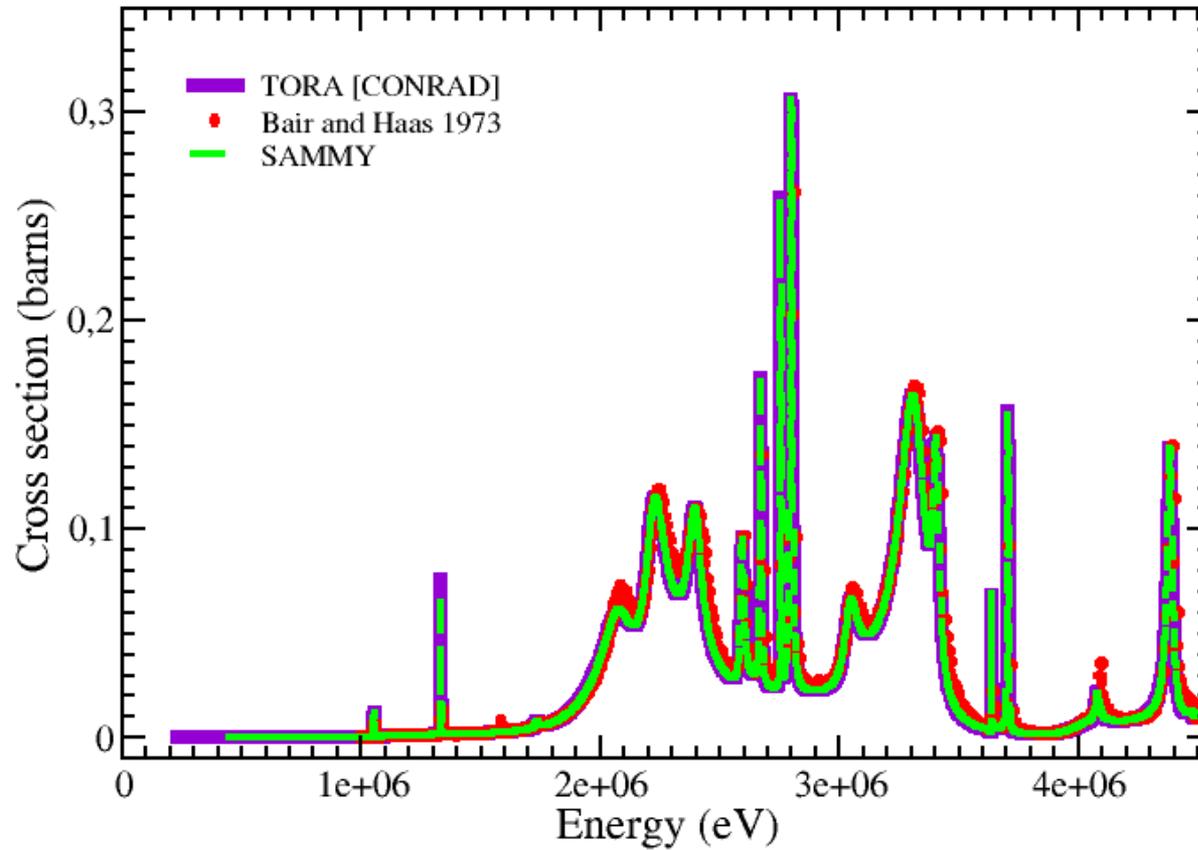
$^{16}\text{O}(n, \text{El})$ differential cross section



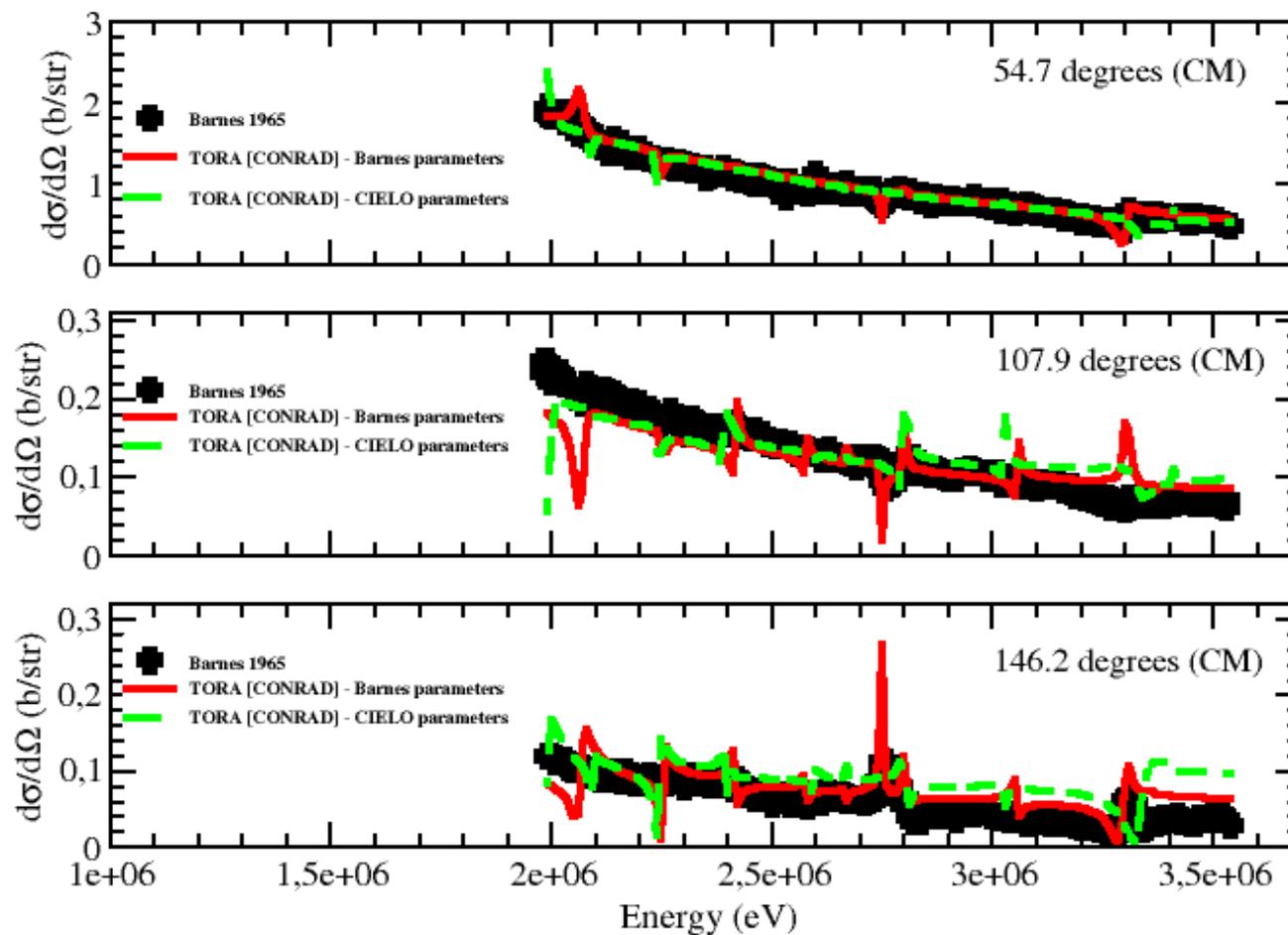
$^{16}\text{O}(n,\alpha)^{13}\text{C}$ cross section



$^{13}\text{C}(\alpha,n)^{16}\text{O}$ cross section



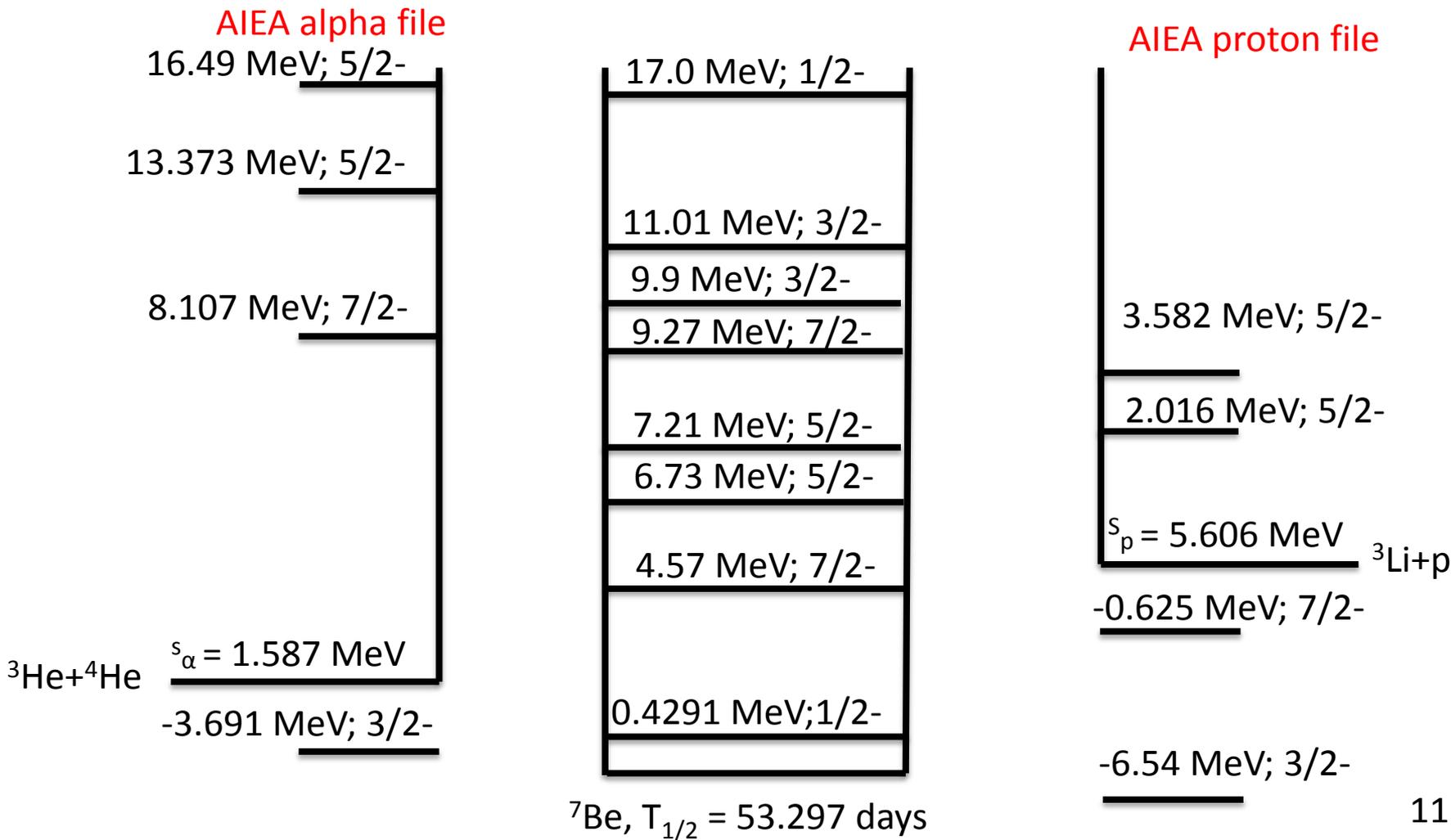
PRELIMINARY RESULTS

 $^{13}\text{C}(\alpha,\alpha)^{13}\text{C}$ differential cross section


Formal validation of the alpha differential channel

Formal validation of elastic scattering of the charged particles channel: ${}^7\text{Be}$ /AIEA test case

□ Simulation in progress (not presented here)



${}^7\text{Be}^*$ reference

AIEA alpha file	${}^7\text{Be}^*$	AIEA proton file	JPI
E (MeV)	E (MeV)	E (MeV)	
	17.0		1/2-
	11.1		3/2-
	9.9		3/2-
	9.27		7/2-
7.770	7.21	7.87	5/2-
6.428	6.73	6.529	5/2-
4.165	4.57	4.266	7/2-
	0.4291		1/2-
-0.94	0.	-0.80	3/2-

Conclusion: - Level energies are in reasonable agreement;
 - The ground state is below Fermi energy;
 - One level missing (429 keV).

CIELO-2 parameters/ Neutron LAB reference

J^π	E_n (eV)	Γ_n (meV)	Γ_α (meV)	Γ_γ (meV)
1/2+	-3.4775E+06	3.8978E+09	0.000000E+00	1.795800E+02
3/2-	-1.1573E+06	2.8406E+07	0.000000E+00	2.836600E+02
5/2-	-3.193900E+05	4.436100E+04	0.000000E+00	3.355000E+02
3/2-	4.341000E+05	4.421600E+07	0.000000E+00	2.500000E+02
7/2-	3.007100E+06	8.374100E+04	0.000000E+00	2.500000E+02
5/2-	3.211700E+06	1.747700E+06	6.418900E+03	2.500000E+02
3/2+	3.286600E+06	3.215800E+08	1.596200E+05	2.500000E+02
5/2+	3.438500E+06	4.806600E+05	1.496600E+04	2.500000E+02
5/2-	3.441500E+06	1.525800E+06	8.385500E+03	2.500000E+02
3/2-	3.485300E+06	7.141500E+08	1.831700E+04	2.500000E+02

CIELO-2 parameters translated (TORA) to Alpha LAB reference

J^π	E_α (eV)	Γ_n (meV)	Γ_α (meV)	Γ_γ (meV)
1/2+	-7.1747e+06	4.32314e+09	0.00000e+00	1.99176e+02
3/2-	-4.3205e+06	3.15057e+07	0.00000e+00	3.14614e+02
5/2-	-3.2897e+06	4.92018e+04	0.00000e+00	3.72111e+02
3/2-	-2.3628e+06	4.90410e+07	0.00000e+00	2.99463e+03
7/2-	8.02343e+05	9.28790e+04	0.00000e+00	2.77281e+02
5/2-	1.05403e+06	7.11935e+03	1.93841e+06	2.77281e+02
3/2+	1.14617e+06	3.56672e+08	1.77038e+05	2.77281e+02
5/2+	1.33303e+06	5.33111e+05	1.65991e+04	2.77281e+02
5/2-	1.33672e+06	1.69230e+06	9.30055e+03	2.77281e+02
3/2-	1.39060e+06	7.92080e+08	2.03158e+04	2.77281e+02

CIELO-2 parameters/ $^{17}\text{O}^*$ frame

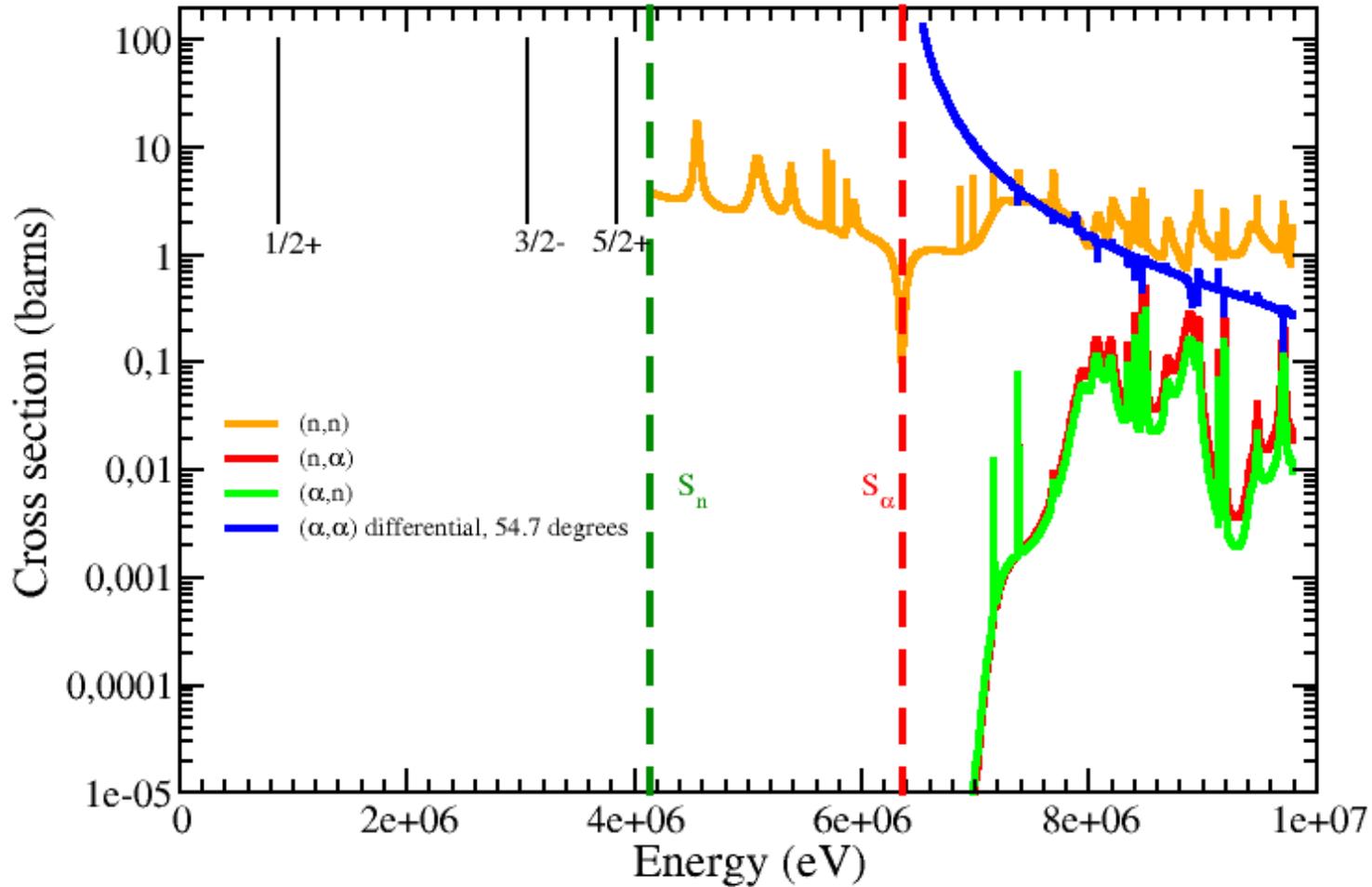
J^π	E_r (eV)	Γ_n (meV)	Γ_α (meV)	Γ_γ (meV)	Γ (meV)
1/2+	8.726778e+05	3.666579e+09	0.000000e+00	1.689271e+02	3.666579e+09
3/2-	3.055241e+06	2.672093e+07	0.000000e+00	2.668330e+02	2.672119e+07
5/2+	3.843446e+06	4.172947e+04	0.000000e+00	3.155978e+02	4.204506e+04
3/2-	4.552238e+06	4.159307e+07	0.000000e+00	2.539833e+03	4.159560e+07
7/2-	6.972606e+06	7.877342e+04	0.000000e+00	2.351698e+02	7.900858e+04
5/2-	7.165069e+06	1.644025e+06	6.038126e+03	2.351698e+02	1.650298e+06
3/2+	7.235526e+06	3.025036e+08	1.501512e+05	2.351698e+02	3.026539e+08
5/2+	7.378415e+06	4.521468e+05	1.407820e+04	2.351698e+02	4.664601e+05
5/2-	7.381237e+06	1.435288e+06	7.888065e+03	2.351698e+02	1.443411e+06
3/2-	7.422439e+06	6.717860e+08	1.723042e+04	2.351698e+02	6.718034e+08

Astrophysics database (Ajzenberg-Selove)			CIELO-2		
J^π	E_λ (eV)	Γ (meV)	J^π	E_λ (eV)	Γ (meV)
1/2+	8.70e+05	1.27e-03	1/2+	8.7267e+05	3.6665e+09
1/2-	3.05e+06	2.74	3/2-	3.0552e+06	2.6721e+07
5/2-	3.84e+06	$\leq 1.3e+01$	5/2+	3.8434e+06	4.2045e+04
3/2-	4.55e+06	4.0e+07	3/2-	4.5522e+06	4.1595e+07
7/2-	6.97e+06	$< 1.0e+06$	7/2-	6.9726e+06	7.9008e+04
5/2-	7.16e+06	1.38e+06	5/2-	7.1650e+06	1.6502e+06
3/2+	7.202e+06	2.80e+08	3/2+	7.2355e+06	3.0265e+08
5/2+	7.3792e+06	6.4e+05	5/2+	7.3784e+06	4.6646e+05
5/2-	7.3822e+06	9.6e+05	5/2-	7.3812e+06	1.4434e+06
3/2-	7.559e+06	5.00e+08	3/2-	7.4224e+06	6.7180e+08

Conclusion:

- Two wrong J^π attributions;
- Small $T_{1/2}$ for CIELO base \rightarrow Fitted bound resonance parameters are only rescaling negative resonance parameters;
- Energies are in correspondance (except the 10th of CIELO which is slightly lowered).

O-17 compound nucleus



Some lessons - Perspectives

Lessons:

- ❑ CoM amplitudes are incident particle-energy independent $\Gamma_c = 2P_c \gamma^2 c$;
- ❑ CoM framework fit results in unique set of resonance parameters;
- ❑ CoM framework avoids inconsistent results;
- ❑ CoM framework allows multiple scientific areas to talk;
- ❑ CoM framework is definitively the way to overpass current evaluations best accuracy.

Perspectives:

- Some valuable feedback on $^{17}\text{O}^*$ neutron evaluation;
- Supply the capability to achieve simultaneously multipurpose evaluation files; eg

JEFF-3.3 (Neutron, $^{17}\text{O}^*$)=JEFF-3.2+G.NOGUERE

JEFF-3.3 (alpha, $^{17}\text{O}^*$) = TENDL 2017;

Different origins result likely in inconsistencies.

Thank you for your
attention