International Atomic Energy Agency

EXFOR for CIELO project: $^{16}O(n,\alpha)^{13}C$ and $^{13}C(\alpha,n)^{16}O$ data

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Introduction

- Collaborative International Evaluated Library Organisation = CIELO
- Coordinated now by WPEC Subgroup 40 (SG40) as a CIELO pilot project
- Starting 6 elements: ^{1}H ^{16}O, ^{56}Fe, ^{235}U, ^{238}U and ^{239}Pu
- NDS of IAEA is involved through:
  - EXFOR - revisiting Entries relevant to CIELO
  - coordination of NRDC to maintain EXFOR at level of completeness and quality
  - CRPs on “PFNS”, “Dosimetry”, “Damage and Gas production (Fe …)”
  - Data Development projects (Standards, U evaluation,)
  - organisation of proper Meetings
- NDS staff monitors the CIELO e-mails exchange, phone conferences, meetings ….

I. Recent history of EXFOR evolution for $^{16}O(n,\alpha)$ and $^{13}C(\alpha,n)$

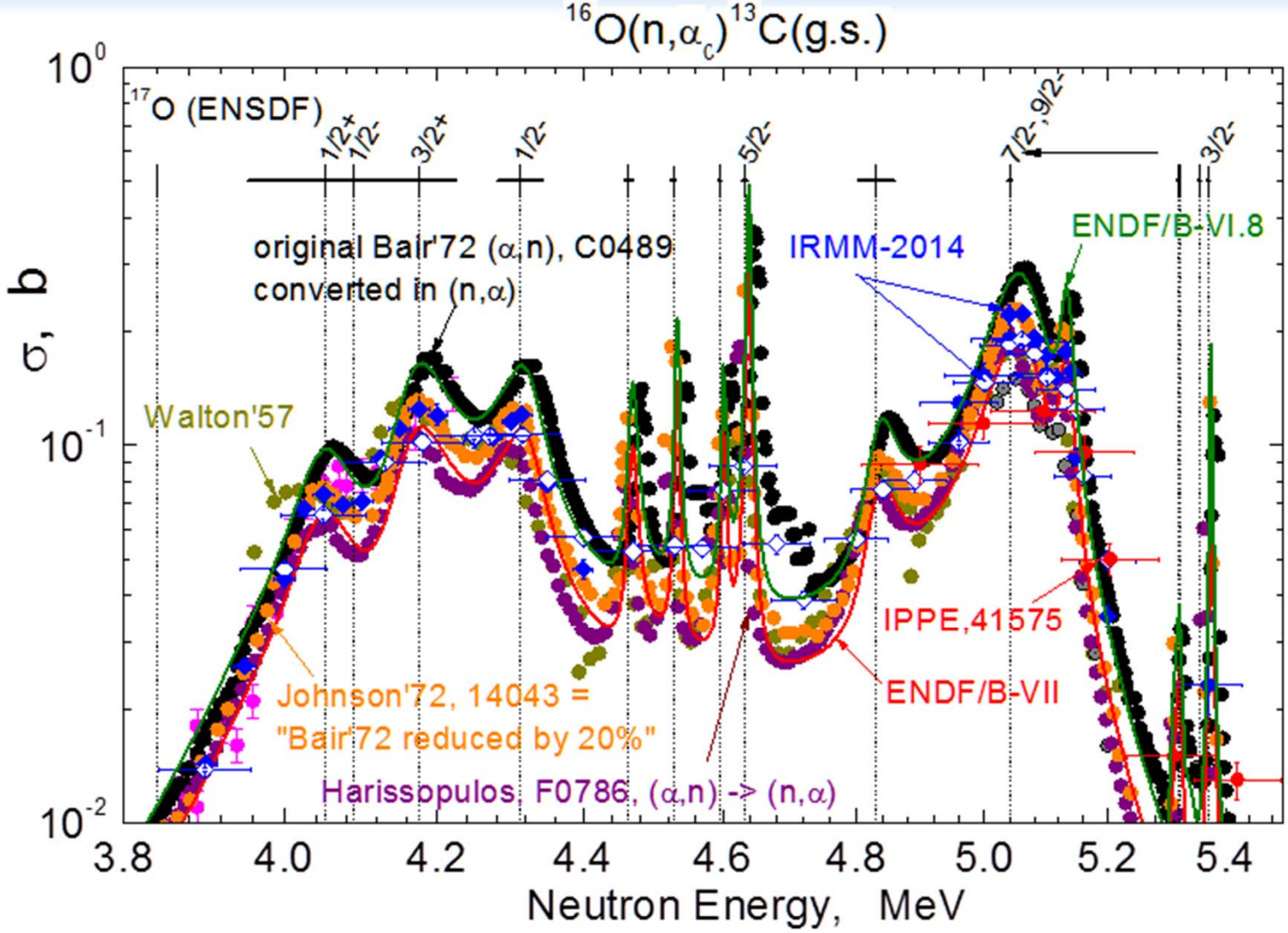
- 2012: IPPE, V. Khryachkov, 2011 - $^{16}O(n,\alpha)^{13}C$ data were included in June 2012
  (Entry 41575.002)

- 2014: IRMM, G. Georginis, 2007 - $^{16}O(n,\alpha)^{13}C$ data were not available since 2007
  (Entry 23040.003)
  during communication within CIELO project (spring 2014)
  the original data were received from author – ***in prelim***

- 2014: ORNL, J.K. Bair and F.X. Haas, 1973 - $^{13}C(\alpha,n)^{16}O$ data are available in
  (Entry C0489.002)
  STATUS (NACRE) Data probably scanned by NACRE from Fig. 3 in PR/C,7,1356,1973
  during communication within CIELO project (spring 2014)
  the (original) data of Bair-and-Hais'73 were provided by G. Hale - ***in prelim***

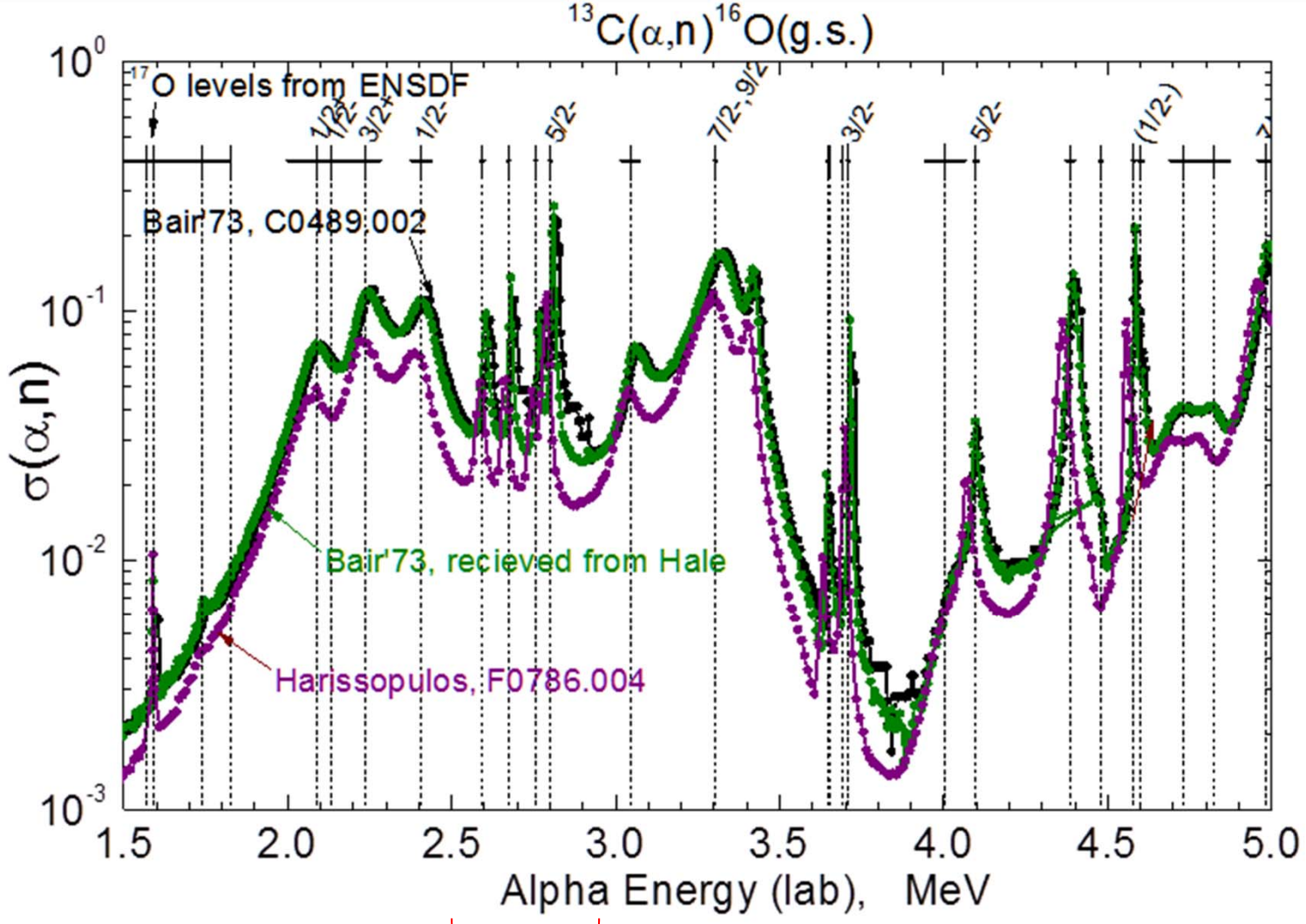
- 2014: ORNL, C.H. Johnson, ORNL, 1973 - $^{16}O(n,\alpha)^{13}C$ data available in
  (Entry 14043.002):
  ANALYSIS (WSP) Data are those from J.K. Blair, ORNL-4659, p.38
  but reduced by 20 % due to new analysis
  STATUS (CURVE) Data taken from Fig. 1
  REACTION (8-O-16(N,A)6-C-13,,SIG) – should at least has DERIV !
  Our final decision – delete this Entry as non-author or non-original data
  (see also N.Otuka presentation "Data corrected or derived by other than authors")

I. Summary of EXFOR data for $^{16}O(n,\alpha)$



neutron measurements, $^{16}O(n,\alpha)^{13}C$, are less accurate and have worse resolution than alpha ones, $^{13}C(\alpha,n)^{16}O$, which can be converted in $^{16}O(n,\alpha)^{13}C$ (below En = 5.6 MeV)

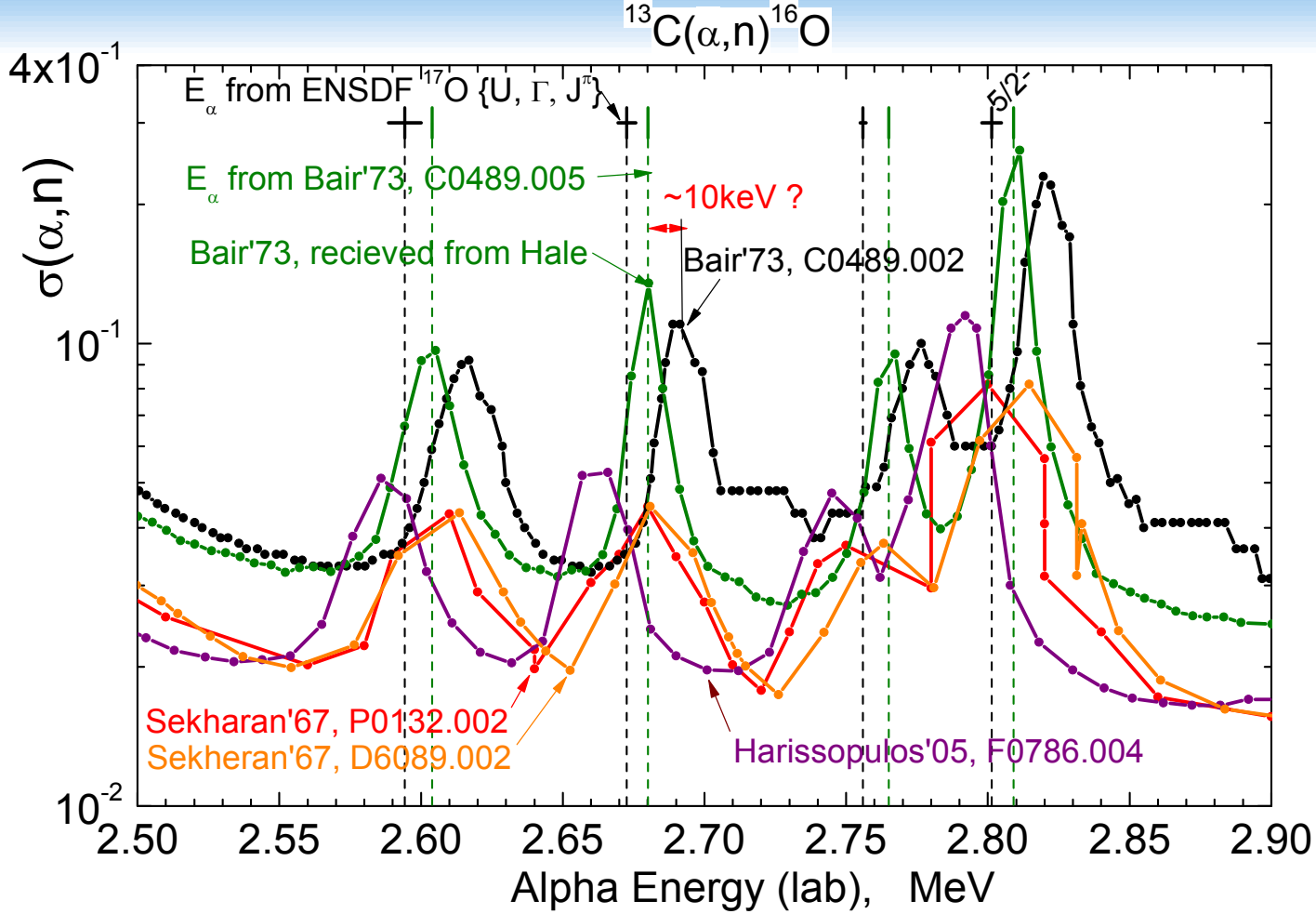
I. Summary of EXFOR data for $^{13}C(\alpha,n)$



let look more carefully in this interval, next slide ->

Observation: known (α,n) cross sections are notably (50%) different !!!

I. Difference between EXFOR and (original) Bair-and-Haas data



1. - Bair' data received from Hale in 2014 differ from Bair'73 available in C0489.002
   - Peaks position (C0489.002) cf. Res. Energies (C0489.005) is shifted by ≈ 10 keV – Digitizat. Syst. Error ?
2. - K.K. Sekharan et al. (P0132.002, 155 points) :
   STATUS (CPX) Data from CPX compiled in 1964/67 by F.K. McGowan et al.
   HISTORY (19830620T) Converted to EXFOR format by IAEA-NDS.
   - K.K. Sekheran et al. (D6089.002, 290 points):
   STATUS (CURVE)fig.2

II. Reaction inversion (detailed balance), Q-values and thresholds: implementation in the EXFOR database

1. **Detailed balance**:

- for the time reversible nuclear reaction

$$i\ \{\ \mathrm{n} + {}^{16}\mathrm{O}\ \} \leftrightarrow {}^{17}\mathrm{O} \leftrightarrow f\ \{\ \alpha + {}^{13}\mathrm{C}\ \}$$

- cross section relation between forward $i \rightarrow f$ and backward $f \rightarrow i$ reactions (in c.m. system) follows the principle of detailed balance

In our case of interest it will look:

$$\sigma_{16O(n,\alpha)} = \sigma_{13C(\alpha,n)} \frac{m_\alpha {m_C}^2}{(m_\alpha + m_C)^2} \frac{(m_n + m_O)^2}{m_n {m_O}^2} \frac{E_\alpha}{E_n}$$

where neutron energy

$$E_n = (E_\alpha \frac{m_C}{m_\alpha + m_C} + Q_{(n,\alpha)}) / \frac{m_O}{m_n + m_O}$$

and reaction $Q_{(n,a)}$ = *2.21561 MeV* , calculated from masses – lonely parameter used

2. Concerns from recent experience: Q values for ^{139}I β-decay *(LiveChart, M.Verpelly)*:

- Atomic Mass eval. 2012 = 7185 (you see on Livechart table)
- Atomic Mass eval. 2011 = 7117 (you see on Mass Chain) or minus 68 keV (!)
- ENSDF = 6806 (you see on Decay plot) or minus 379 keV (!!)

3. Reaction Q and Threshold – would be useful to calculate/display on retrieval page (?)

Summary

✓ CIELO project will essentially rely on experimental data available now in EXFOR

✓ Involvement of NDS and NRDC in the project gives additional chance for revisiting of the relevant EXFOR Entries

✓ First results:

- original IPPE and IRMM numerical $^{16}O(n,\alpha)^{13}C$ cross sections were received
- original 1973 ORNL numerical $^{13}C(\alpha,n)^{16}O$ cross sections were received but in 2014
- comparison of original and digitized ORNL data discovered 10 keV systematic shift

  (it also seen from comparison of resonance energies and XS peaks stored in Subentries of one Entry - are there other such suspicious Entries with contradicting information ?)
- other old resonances cross section data could be still available in the input files for SAMMY, REFIT, CONRAD …
- implement in the EXFOR retrieval system (using reliable reference mass tables)
  -> inversion of reaction cross sections using detailed balance principle
  -> calculator of reaction Q values and Thresholds