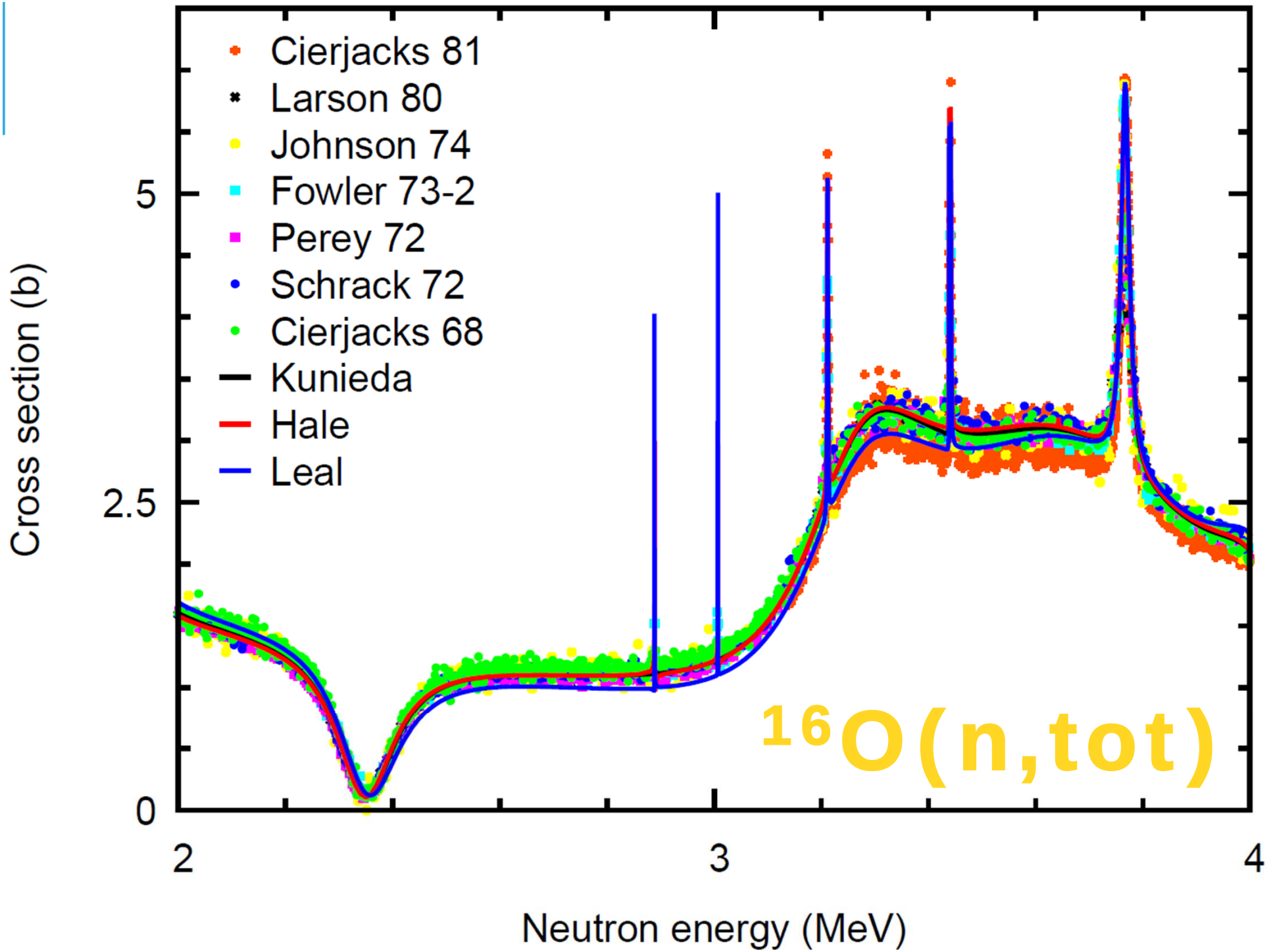
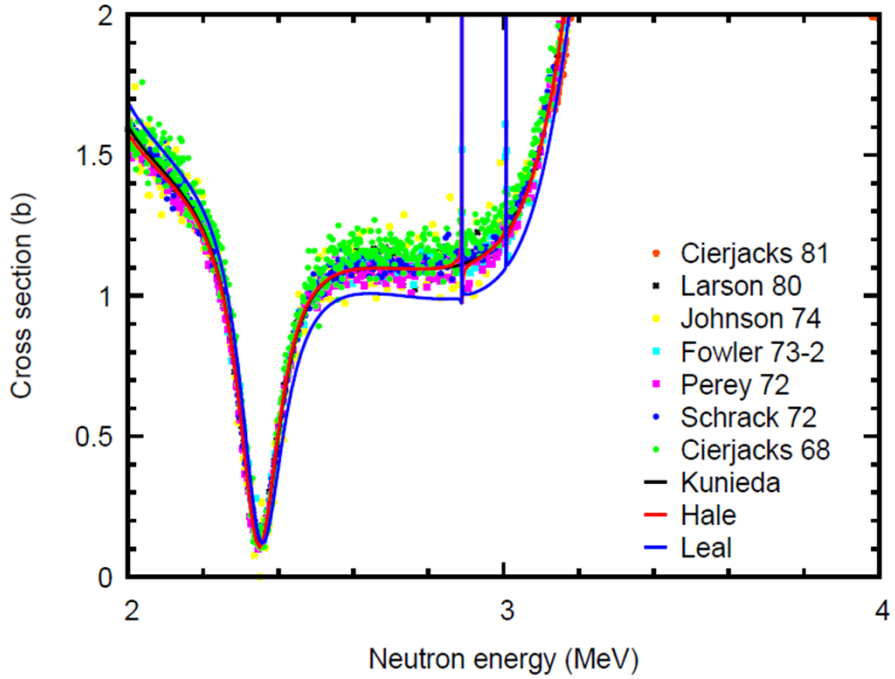
$n + {}^{16}O$

Arjan Plompen

EC-JRC-IRMM, SN3S unit

www.jrc.ec.europa.eu


Cierjacks 81
Larson 80
Johnson 74
Fowler 73-2
Perey 72
Schrack 72
Cierjacks 68
Kunieda
Hale
Leal
Cross section (b)
0
2.5
5
2
3
4
Neutron energy (MeV)
16O(n,tot)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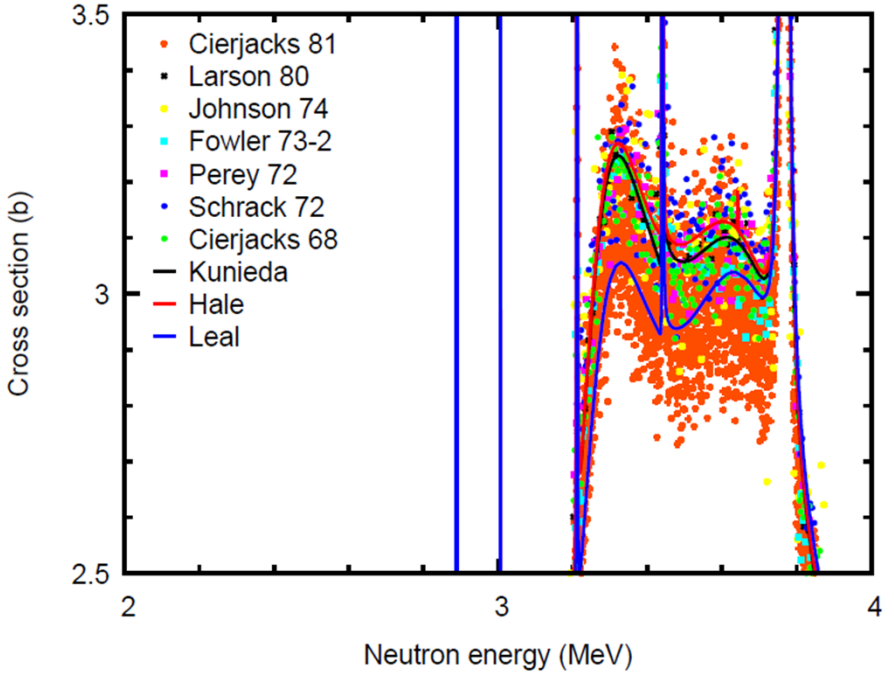
Kunieda
Hale
Leal
Cross section (b)
Neutron energy (MeV)


Cierjacks 81
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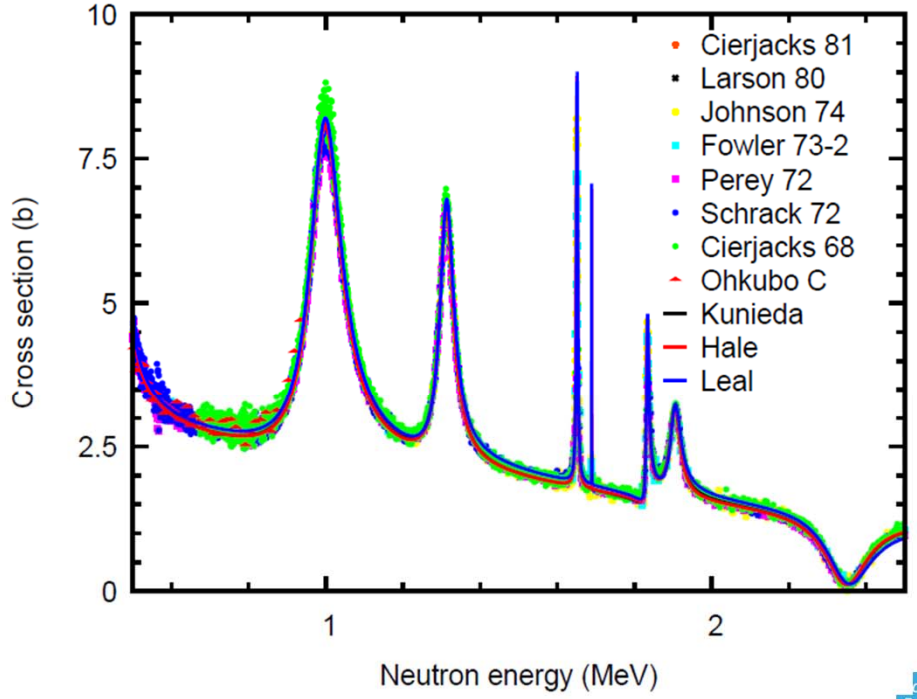
Kunieda
Hale
Leal
Cross section (b)
Neutron energy (MeV)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Johnson 74
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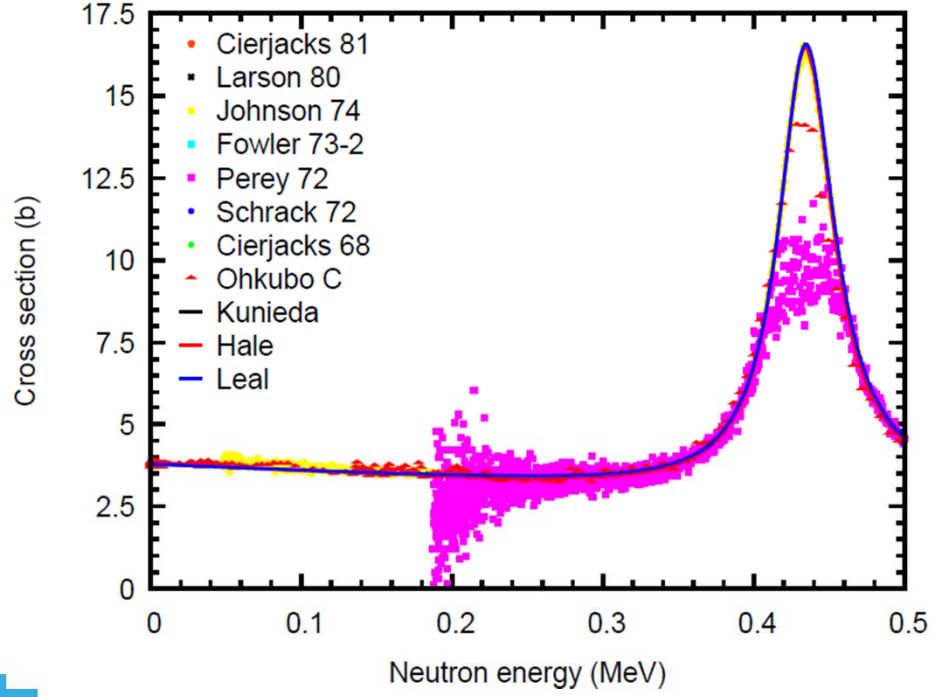
Ohkubo C
Kunieda
Hale
Leal
Cross section (b)
Neutron energy (MeV)


Cierjacks 81
Larson 80
Johnson 74
Fowler 73-2
Perey 72
Schrack 72
Cierjacks 68
Ohkubo C
Kunieda
Hale
Leal
Cross section (b)
Neutron energy (MeV)

$^{16}O(n,tot)$

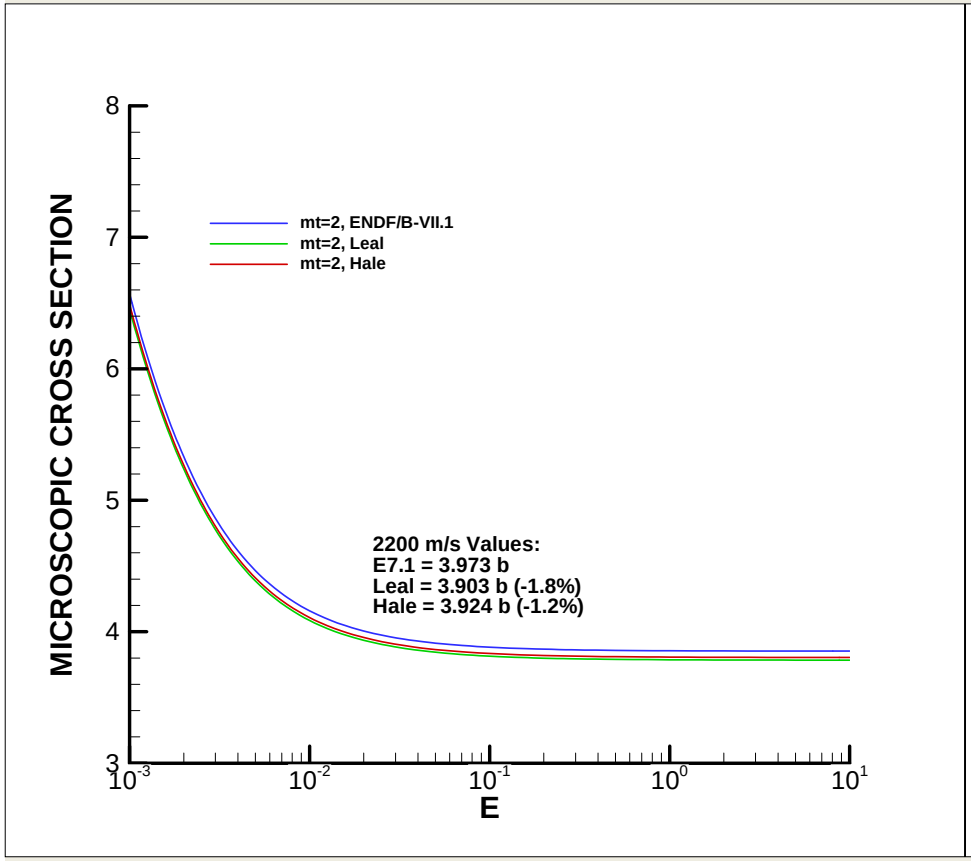
The Hale and Kunieda evaluations are very close. They appear to be determined by the Schrack, Cierjacks-68 and Perey data between 2 and 4 MeV.

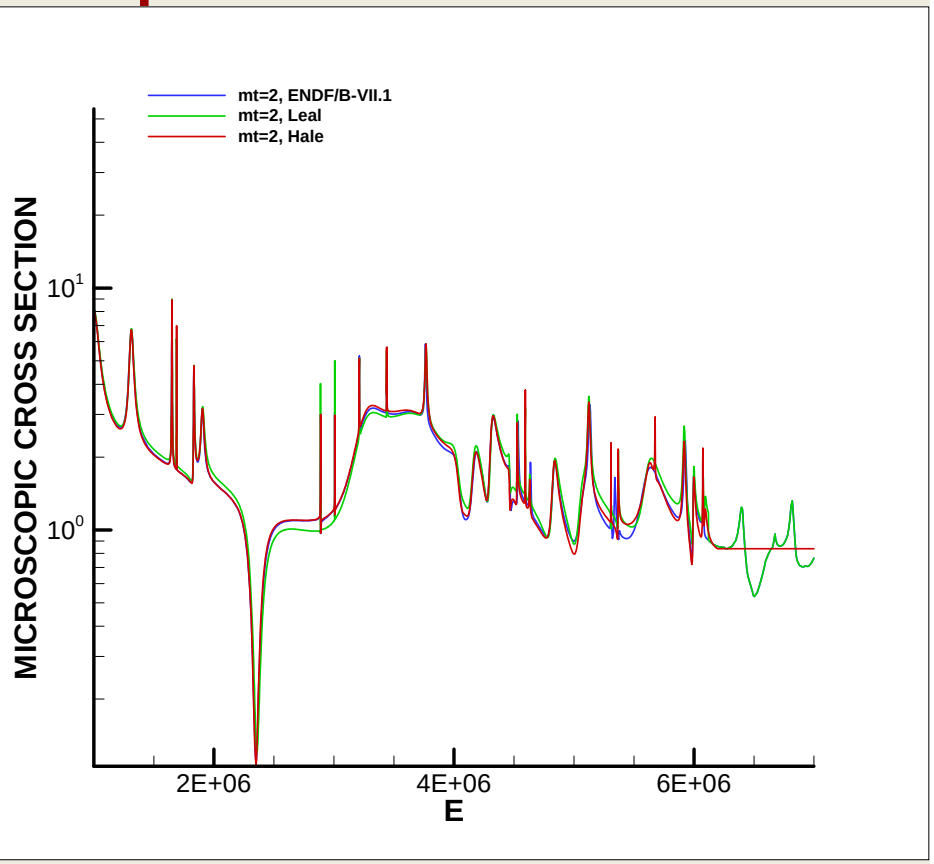
The Leal evaluation is below Hale and Kunieda in the range above the (n,a) threshold in an energy dependent way. It is in better agreement with the average of Cierjacks-80 and somewhat below. This is obscured by the scatter in the latter data.

From 0.1 to 2 MeV the three evaluations and the data appear to agree with each other. Differences appear minor. However, the resonance integral shown by Trumbull places Leal above Hale. This is the result of Leal's evaluation being above Hale's in the region from 0.1 to 2.3 MeV.

The transition to the recommended value for energies below 10 keV is almost made. Some further improvement is still possible, in particular for Kunieda and Hale.

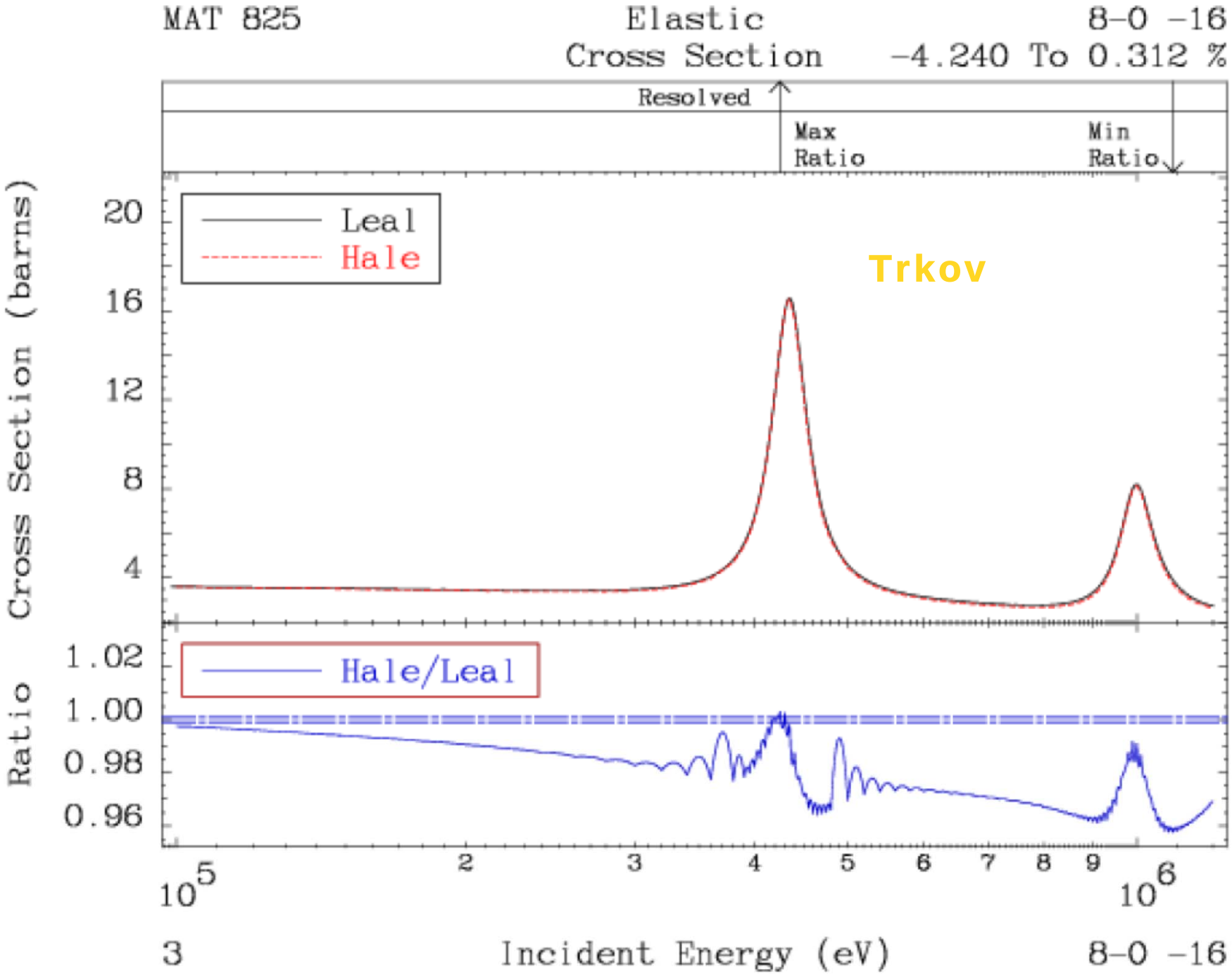
Cross Section Comparisons - I

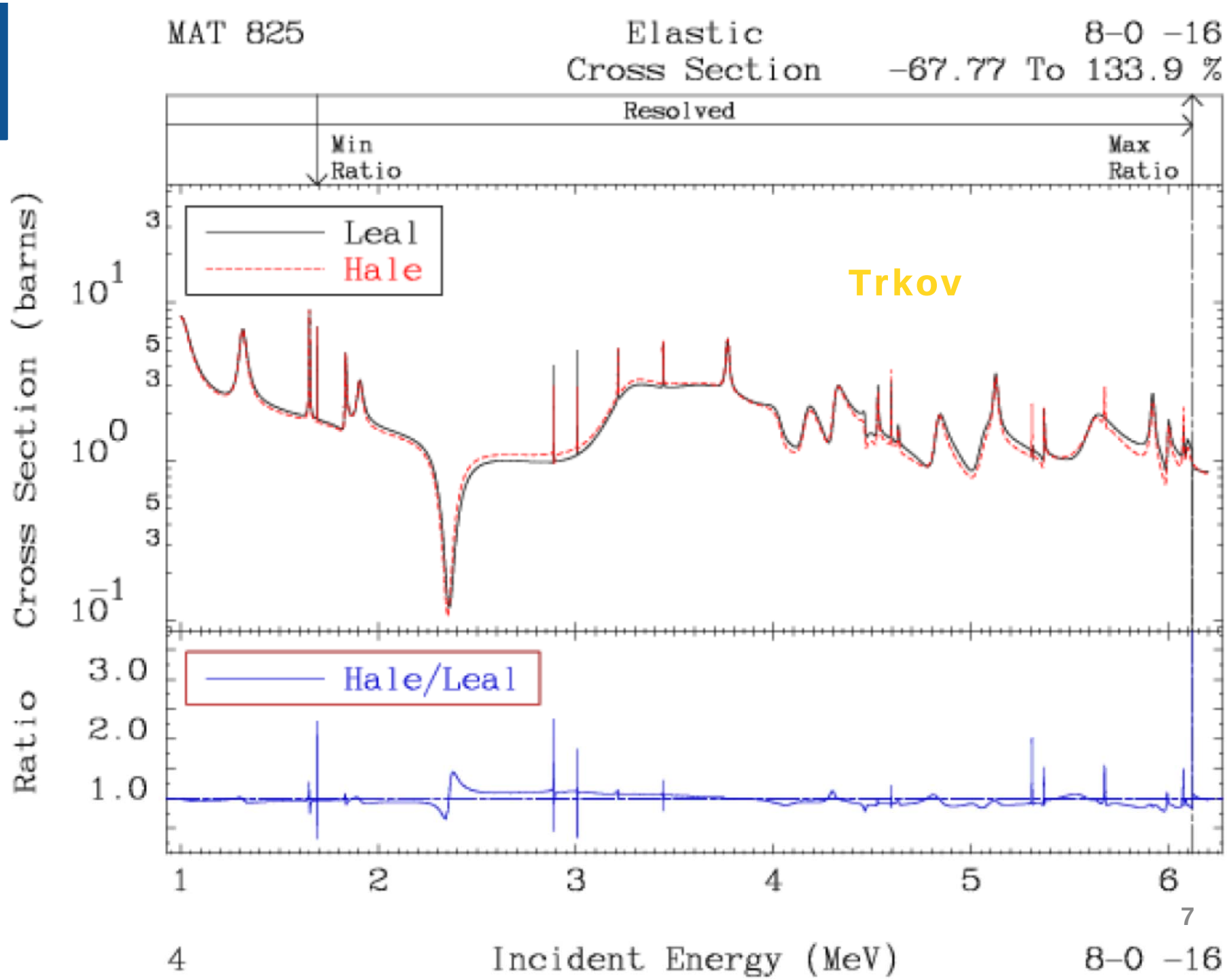




	Total		Elas. Scat.		Capture		(n,alpha)	
	2200 m/s	Res. Int.	2200 m/s	Res. Int.	2200 m/s	Res. Int.	2200 m/s	Res. Int.
ENDF/B-VII.1	3.973	64.255	3.973	62.781	1.900E-04	7.835E-04		0.198
Leal	3.903	63.563	3.903	62.087	9.334E-05	2.761E-04		0.200
Hale	3.924	60.747	3.924	60.617				0.130

All cross sections broadened to 293.6 K


MAT 825
Elastic
Cross Section
8-0 -16
-4.240 To 0.312 %
Resolved
Max Ratio
Min Ratio
Leal
Hale
Trkov
Cross Section (barns)
20
16
12
8
4
Hale/Leal
Ratio
1.02
1.00
0.98
0.96
10^5
2
3
4
5
6
7
8
9
10^6
3
Incident Energy (eV)
8-0 -16


MAT 825
Elastic
Cross Section
8-0 -16
-67.77 To 133.9 %
Resolved
Min Ratio
Max Ratio
Leal
Hale
Trkov
Cross Section (barns)
Hale/Leal
Ratio
Incident Energy (MeV)
8-0 -16

Open points total cross section

Needs accurate new measurements (plateau 3.5 MeV, 1st reson.) See later the presentation by Y. Danon.

High quality samples holding oxygen with careful choice of compensating sample. Several thicknesses are required.

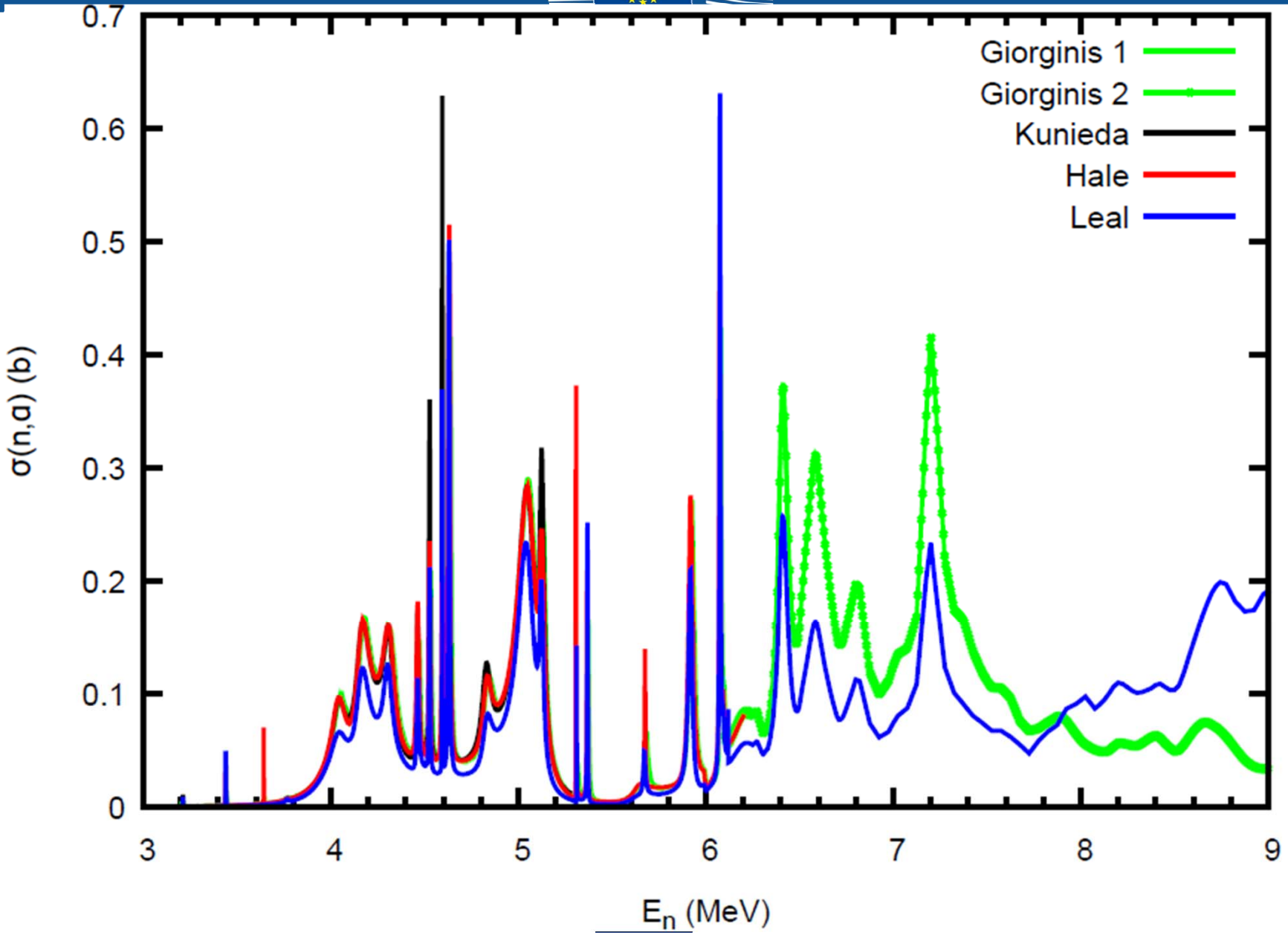
Avoid water absorption and moisture or ice on the surface. Humidity and temperature control are required.

Control of and a low background are essential.

High resolution needed for the first resonance: non-saturating sample with all of the above.

Open points $^{16}O(n,a)$

Giorginis recommendations vs Kunieda, Hale and Leal



Open points $^{16}O(n,a)$ and $^{13}C(a,n)$

$^{16}O(n,a)$ measurement

Independent result needed for checking normalization.

Improved resolution compared to IRMM/IPPE. See later Chadwick.

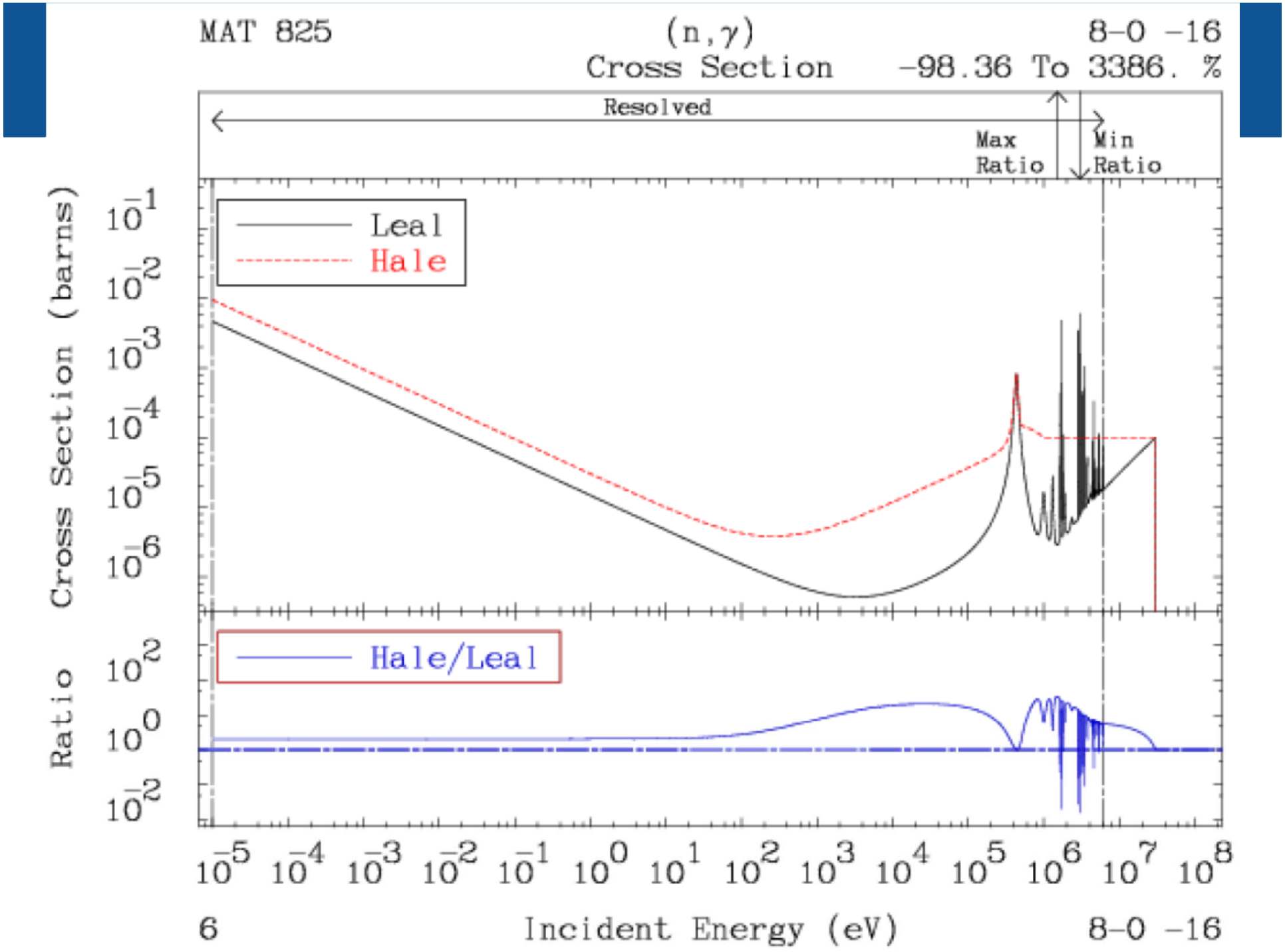
$^{13}C(a,n)$ measurements

Existing results all have issues.

New measurement(s) needed to confirm conjectures.

They may be plausible conjectures, but that's all they are.

Guard: ^{13}C target quality during experiment, energy-dependent efficiency (detector model, angular distribution), reliable principles.


MAT 825
(n,γ)
Cross Section
8-0 -16
-98.36 To 3386. %
Resolved
Max Ratio
Min Ratio
Leal
Hale
Hale/Leal
Cross Section (barns)
Ratio
Incident Energy (eV)
6
8-0 -16

Cece Lubitz (Unrelated to the Lufthansa pilot): April 15, 2015

We're now in a position where we can check the current Hale and Leal versions of O16 to see if they have any undesirable trends with either oxygen absorption or with leakage (ATLF). Gerry's (n,α) cross section is larger than Luiz', reflecting their different interpretations of the experimental data. The difference is large enough so that one (or possibly both) **should exhibit a trend with oxygen absorption**, i.e., a non-flat linear fit to a plot of calculated Keff C/E versus oxygen absorption. **The trend with leakage is a non-specific indicator of problems with the overall absorption**. Restricting the leakage to above-thermal, "AT", increases the sensitivity to the higher-energy cross sections.

For this exercise we need two different versions of U235 which include the new softer prompt-fission neutron spectrum (PFNS), and ENDF71 is the logical choice because it has been so extensively benchmarked in the past:

1. To go with Hale's "high-n-alpha" version we want ENDF71 with the new lower-mean-energy PFNS replacing the current one. Andrej Trkov informed us that it already exists at https://www-nds.iaea.org/CIELO/data/u235g6_endf.zip. We expect Its increased reactivity to more-or-less cancel the opposite effect from the oxygen. The question is whether that can be done without introducing either of the aforementioned trends.

2. To go with Leal's "low-n-alpha" version we again want ENDF71 including the new lower-energy PFNS, but with the reactivity gain canceled by some combination of small adjustments as was done for Pu239 by Paul Romano and me. This will make the Leal oxygen solely responsible for changes to the average reactivity.

For this exercise we should resolve disagreements resulting from different collections of benchmarks. We can have different sets, but if they differ in their implications that should be ironed out. It would be nice if Steven, Paul, Skip, and anyone else with a benchmarking capability had some kind of "agreement" since the goals of CIELO will only be reached with a huge benchmarking effort. Maybe a CIELO-BMK group?

WPEC Subgroup 40 (CIELO)
May 2015

O16 Items

C. R. Lubitz

#1 Agree on one or more ***defined collections*** of integral benchmarks

- Agreement between calculated eigenvalues and the integral benchmarks is an objective measure of their ***utility*** (not accuracy).
- That agreement ***and particularly the trends*** with leakage and absorption, depend on what benchmarks we compare to, so we all need to be using the same collections.

#2 Freeze the thermal scattering cross section at ~3.765 barns

- That number is well-defined by low-energy measurements, give or take some unexplained divergence in the coherent scattering results.
- There is nothing to be gained by letting it be altered by high-energy measurements.
- Agree that all future evaluations will lie between 3.76 and 3.77.

#3 Remeasure the 0-1 MeV cross section

- The new RPI data will help define where we end up above 0.5 MeV. Their data diverge from ENDF71 down near 0.5 MeV.
- We need a similar current look at the 0-1 MeV region, to augment the Ohkubo data.
- The latter is widely used but had problems with the aluminum resonances in the Al2O3 sample and it now contains a moisture "correction" with no experimental basis.

#4 Figure out what the total cross section really is between 3.3 and 3.8 MeV

- Plots of measured O16 cross sections fluctuate wildly in this region. Why?
- One possibility is that there are narrow resonances which cannot be seen but contribute to the resolution-limited measured data.
- Some kind of high-resolution technique is needed.
- Other explanations? Fixes?

#5 Require that all changes to existing cross sections, not only O16, be accompanied by a ***trend analysis*** of the ***absorption rates*** and ***leakage***.

- Why? Because It's ***easy*** to fix problems with the overall reactivity, <Keff>. The simplest is to replace a "high-reactivity" isotopic cross section set with a "lower-reactivity" version (or vice versa).
- Unfortunately, it is ***difficult*** to do that without introducing ***trends***.

#6 Recommendation

- It seems reasonable to require that ***every*** isotopic evaluation in CIELO be trend-free before it is considered as a candidate for the "mix and match" effort to keep the benchmark <Keff> C/E equal to 1.0.
- We should not rely on "canceling trends".

#7 Kahler's recent leakage trends

- E71+G6PFNS k = 1.0010 + ***0.0073****ATLF
- Softening the spectrum to which E71 U235 was adjusted ***degrades the adjustment***.
- E71+G6PFNS+Hale O16 k = 1.0004 + ***0.0051****ATLF
- If subtracting these estimates is legitimate it says Hale O16 is k = 0.9994 - ***0.0022****ATLF.
- That looks pretty good. We also need the ***absorption trend*** to help with the (n,α) cross section.
- We need similar data on Leal's new O16 evaluation.

Thank you

We are very far from

THE END

Gery Hale:

Here are my comments on 16O, especially with regard to the new total cross section measurements from Danon we recently heard about.

The evaluation we submitted in June of last year is similar in many ways to ENDF/B VI.8. For that reason, since the total cross section was preserved in the evaluation that finally became ENDF/B VII.1, it is not surprising that the agreement with the new RPI measurement of the total cross section looks similar for VII.1 and the LANL Cielo file. Our **latest evaluation is somewhat better in the "window",** and **somewhat worse at energies above about 4.5 MeV**. Adding these total cross section data to the analysis would **likely decrease the total cross section somewhat in the 2.5-3.5 MeV** region, which because of the often-noted anti-correlation effect of unitarity in this region, would **tend to raise the fitted (n,alpha)** cross section at these energies. This would make the disagreement even worse with experiments that favor the lower normalization scale for the reaction cross section.

We are **anxious to add these measurements** (not the binned data) to our analysis to see what their effect might be, but we are gratified that the initial comparison does not seem to indicate any major problems with the evaluation. **Hopefully, we will have additional (n,alpha) data coming from Los Alamos** in the next year or so. In the meantime, **we are working on extending the existing LANL file above 6 MeV, and including the Geel (n,alpha) data in our analysis, following Giorginis' recommendations about normalizations, etc.**

Oscar Cabellos about NDEC (presentation follows):

According to your request on a CIELO-BMK group, I would like to take this opportunity to inform you of a new framework for nuclear data verification, benchmarking and validation that we have recently started developing at the Data Bank (under JEFF and larger Nuclear Data activities). The Nuclear Data Evaluation Cycle (NDEC) platform aims to be a systematized workflow for handling, diagnosing and validating nuclear data files under the different steps involved in the production of nuclear data libraries: format verification, processing, experimental differential validation and experimental integral benchmarking. Although it is still in the prototype version, many of its aspects are already operational.

In particular, concerning processing and integral Benchmarking, NDEC is currently able to handle default processing with NJOY-2012, PREPRO-2012/15 and AMPX/SCALE6.2. NDEC (through a complementary tool also developed at NEA, called NDaST) will also be able to discriminate from over 4000 ICSBEP available input cases, and select the appropriate criticality benchmarks that are sensitive to a particular nuclide or reaction channel given a sensitivity threshold. These functionalities will allow us in principle to provide well-defined quantitative criteria for a "tailored" integral validation of a complete library, nuclide by nuclide, for a specific application (criticality).

The status of NDEC and preliminary results will be presented in the upcoming NEA Nuclear Data Week in Paris, on April 27-30 2015. We think NDEC would be extremely useful for the CIELO initiative, NDEC could be presented in the WPEC/CIELO meeting with a first example of NDEC treatment of Fe-56.

My best regards

Oscar

Roberto Capote:

My first comment is that **new U5 PFNS strongly favors Gerry's O-16**.

It is also true that the **ATLF slope is worse (even with Gerry's O-16)**. As you said if we assume that everything else is frozen, then we may conclude that softer PFNS lead to worst integral benchmarks. However, this conclusion depends critically on assuming that all our cross sections are frozen.

We do have significant differences coming both to U-235 capture (from SG-29 and new experiments) as well as to U-235 inelastic (from new optical model potentials and better compound nucleus decay). Therefore we have to check new U-235 cross-section evaluations.

Right now we got a new file from **BRC that is not performing well due to big differences in capture (as pointed out in earlier Andrej's report)** as well as too soft U5 PFNS (softer than G6). One possible test will be to replace JENDL-4 fission completeley (with G6 PFNS and fission cross sections) and repeat your checks with the (JENDL-4 + modified fission) file. That should show the impact of elastic/inelastic cross section and capture on benchmarks with the new PFNS keeping the fission cross sections from neutron standards. We have further work to do on U-235 cross section file.

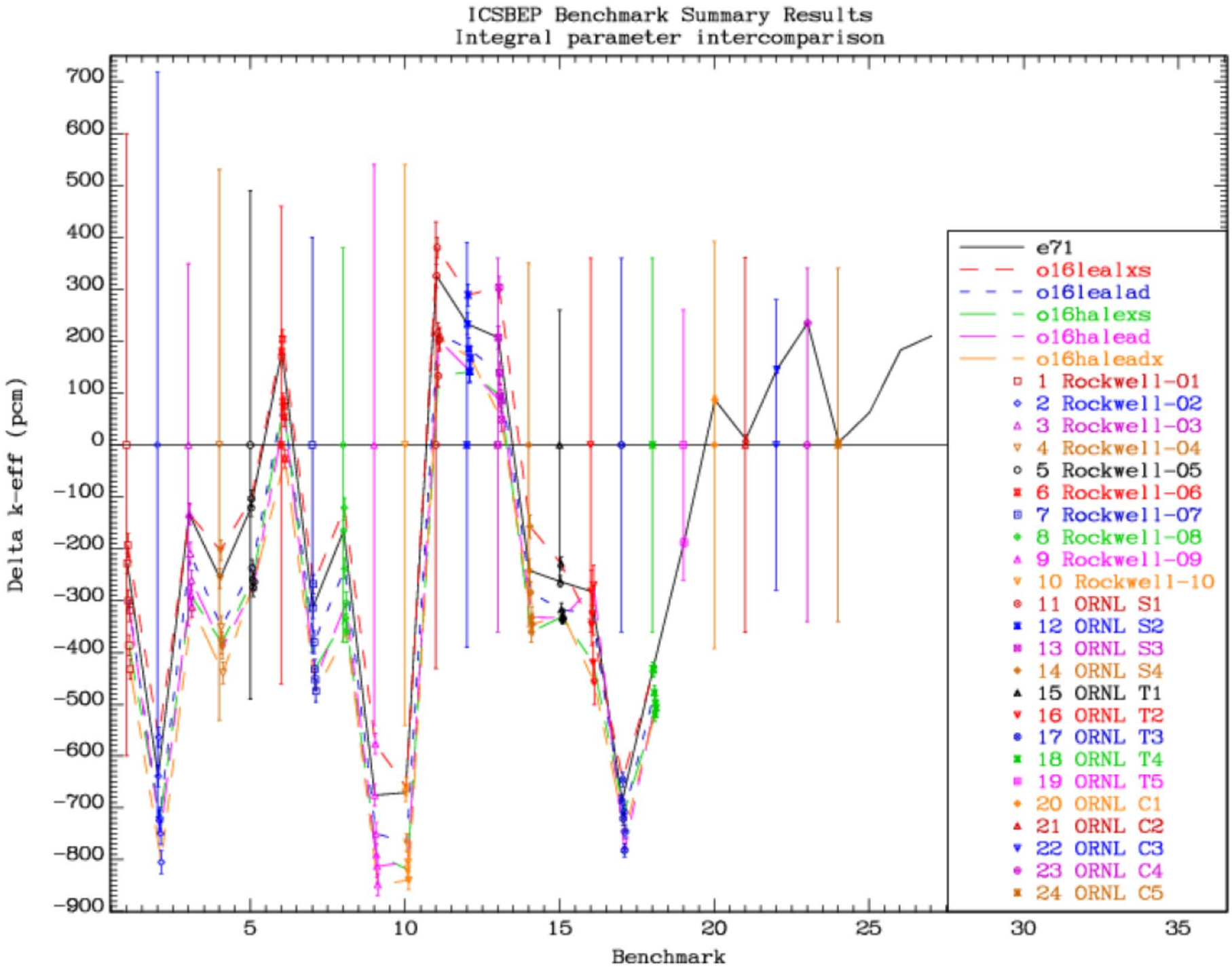
Andrej Trkov

The analysis of **thermal solution benchmarks** indicates that **some reactivity gain due to the softer PFNS can be compensated by lowering the inelastic cross section**. This is supported by recent evaluations of other actinides using advanced nuclear models.

As an **ad-hoc exercise** I already have a file, which is essentially the "**u235g6**" evaluation, in which the inelastic data were taken from JENDL-4.0

In document [2] in the U235 tab on the web page a report has been available for some time, which describes the benchmark analysis with these data, but it is limited to the thermal solution benchmarks.

You may also note **some preliminary (and incomplete) work on the O-16 data, which is available in the report in the O16 tab. I was interested in the impact of the differences in angular distributions between the Leal and Hale evaluations**.


ICSBEP Benchmark Summary Results
Integral parameter intercomparison
Delta k-eff (pcm)
Benchmark
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
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10
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35
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o16lealad
o16halexs
o16halead
o16haleadx
1 Rockwell-01
2 Rockwell-02
3 Rockwell-03
4 Rockwell-04
5 Rockwell-05
6 Rockwell-06
7 Rockwell-07
8 Rockwell-08
9 Rockwell-09
10 Rockwell-10
11 ORNL S1
12 ORNL S2
13 ORNL S3
14 ORNL S4
15 ORNL T1
16 ORNL T2
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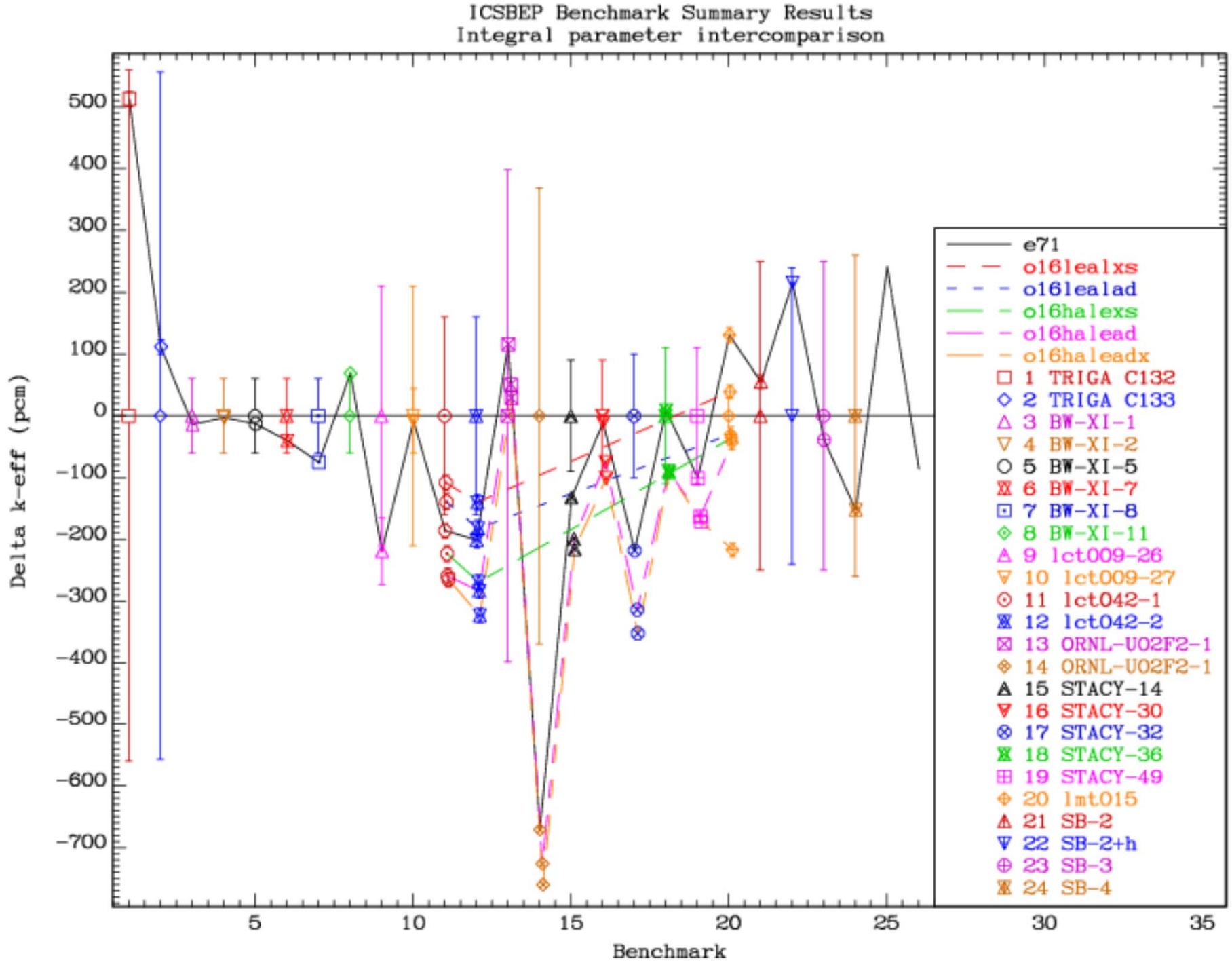
21 ORNL C2
22 ORNL C3
23 ORNL C4
24 ORNL C5


ICSBEP Benchmark Summary Results
Integral parameter intercomparison
Delta k-eff (pcm)
Benchmark
500
400
300
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100
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-100
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-600
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25
30
35
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o16lealad
o16halexs
o16halead
o16haleadx
1 TRIGA C132
2 TRIGA C133
3 BW-XI-1
4 BW-XI-2
5 BW-XI-5
6 BW-XI-7
7 BW-XI-8
8 BW-XI-11
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10 lct009-27
11 lct042-1
12 lct042-2
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14 ORNL-U02F2-1
15 STACY-14
16 STACY-30
17 STACY-32
18 STACY-36
19 STACY-49
20 lmt015
21 SB-2
22 SB-2+h
23 SB-3
24 SB-4

Benchmarking

1. *Perceived to be the effect of changes to total and angular distribution.*
2. *Main difference Hale evaluation and B-VII.1 is $^{16}O(n,a)$! Or is it?*
3. *Resonance integral has Leal>Hale (tot+el.). Is this perhaps all that matters?*
4. *Still not used new NEA capabilities highlighted by J.Dyrda, N.Soppera, I.Hill, M.Bossant, O. Cabellos (sensitivities to quick check main effects on most sensitivite benchmarks).*

More general benchmarking and the final file.

1. *CIELO/A: Compensating effects from other CIELO nuclides should be investigated before solving potential problems on a nuclide-by-nuclide basis.*

2. *It is good to investigate the sensitivities that allow tweaking CIELO/A into CIELO/B with good performance a suite of benchmarks.*

3. *In doing point 2 above, avoid the confusion with CIELO/A files and preferably do the final tweaking as late as possible. Otherwise progress in understanding is limited and may even be lost altogether.*