

LA-UR-16-23112

Status of Cross Section Progress for $^{235,8}\text{U}$, ^{239}Pu , ^{56}Fe , ^{16}O

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LANL

(with CIELO collaboration ... “whole world coming together”-Koning)

WPEC Subgroup 40, OECD, Paris, May 9-13, 2016

Overview comments on CIELO progress

Progress on our understanding of 1H , 16O , 56Fe , 235U , 238U , and 239Pu :

- a variety of different teams and approaches
- experiments & theory advanced

A set of starter files has been created via a USA-IAEA-Europe collaboration

- this suite of (ENDF/B-VIII.beta1) files, taken together (with a new H2O scattering kernel), appears to model integral criticality fairly well. Validation testing ongoing (including SG39 support); future refinements planned
- other CIELO collaborations will provide alternative options, e.g. a European JEFF3.3-testing suite (including CEA/BIII+IRSN files) coming.
- Need to add/refine covariances
- These analyses will be documented in the coming year, including journal articles in Elsevier's Nuclear data Sheets (January 2018)

Perspectives on CIELO progress

We knew changing the “big 6” nuclides would be a major challenge

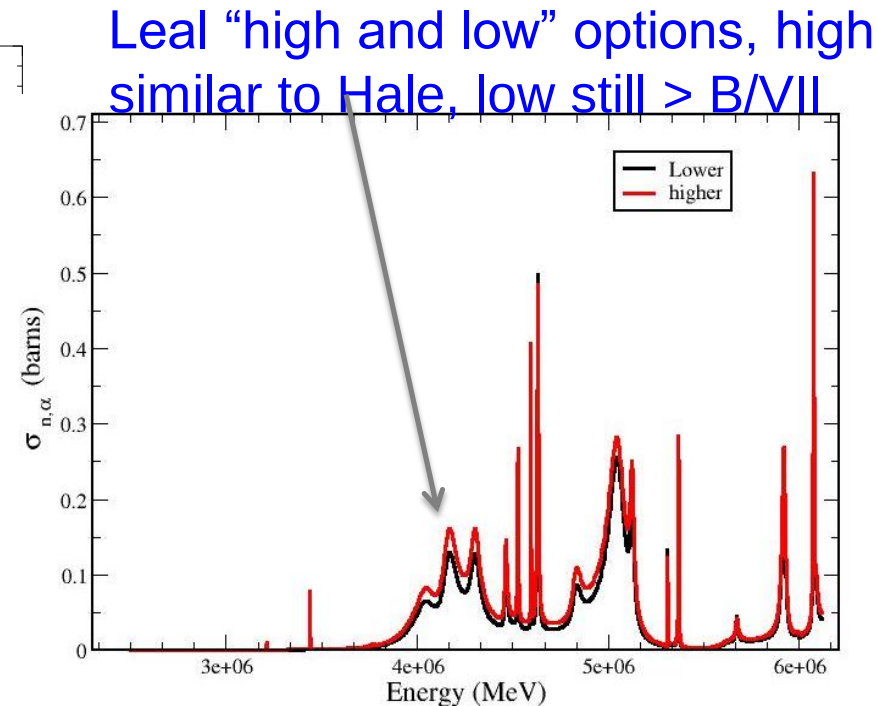
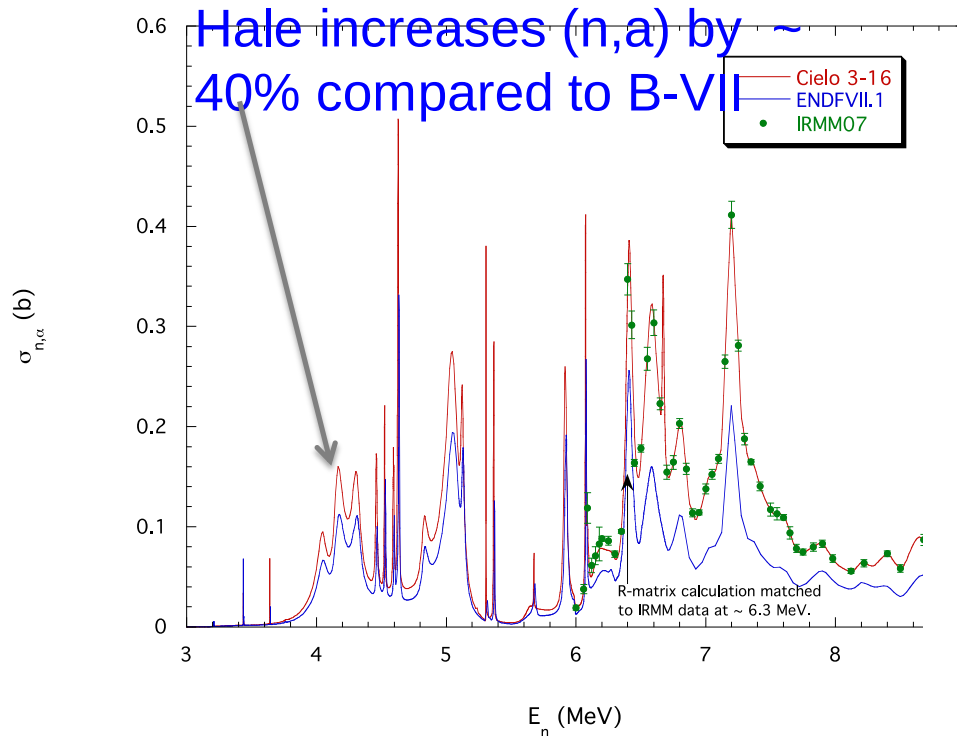
- indeed, this was the motivation to take advantage of international experts

It has been very hard work to utilize improved physics, especially

- ^{235}U (PFNS, & 100keV-2.25 keV n,g physics-motivated capture changes, drive the need for many other changes)
 - *Confidence to proceed because of independent consistent DANCE & RPI data*
- ^{16}O (changes for low-energy scattering and (n,a) have significant impacts)
- ^{56}Fe – many RR and fast advances, but it is proving tricky to reconcile basic data, ENDF fidelity representations, & integral performance
- ^{238}U ... easier; able to use quality new resonance analysis
- ^{239}Pu ... easier; partly because we have made few changes beyond SG34

Examples of convergence of opinion

(1) Oxygen-16 (n,alpha)



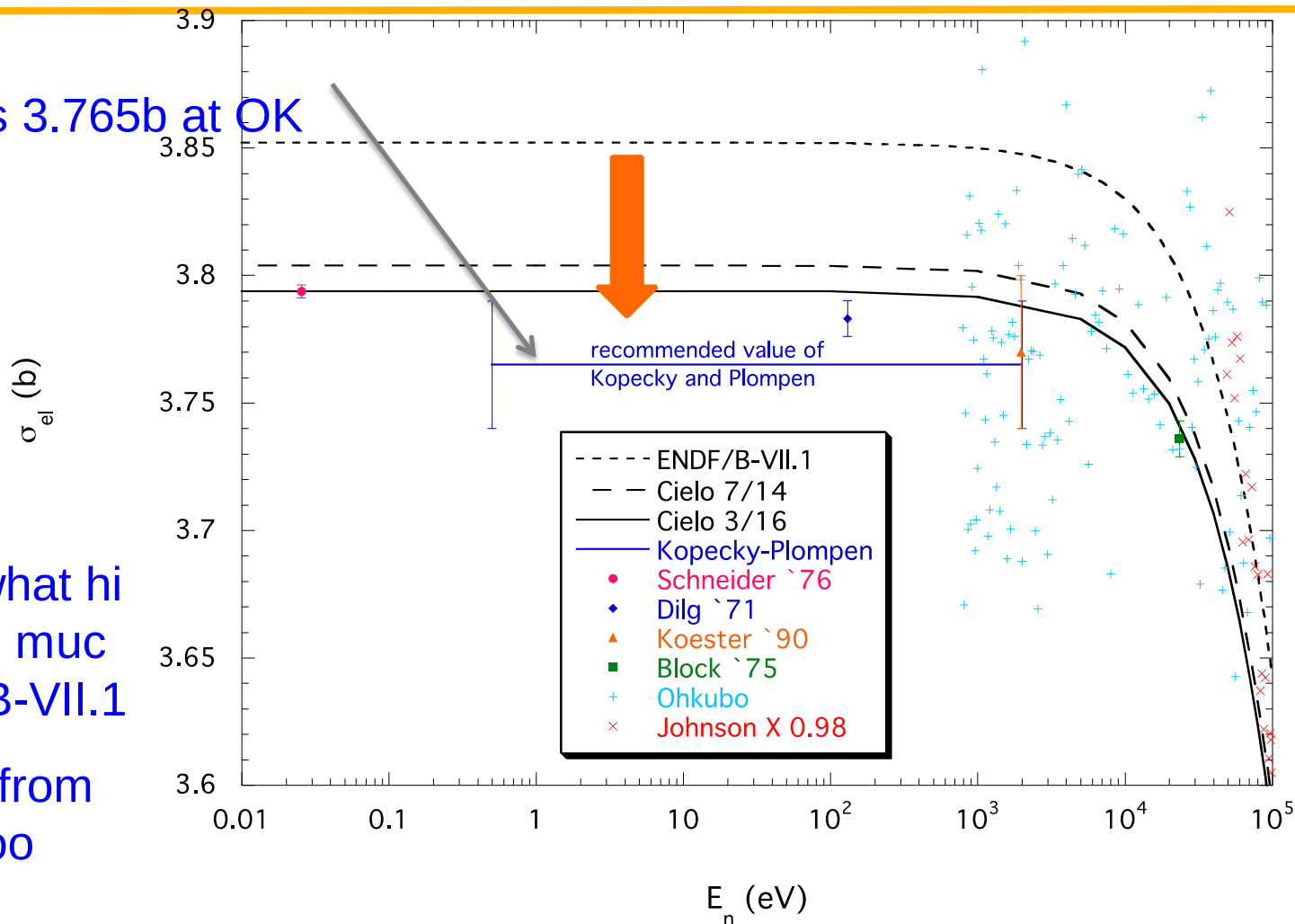
Hale file is in accordance with IRMM (Georginis et al.) conclusions

Future “confirmatory” experiments beginning at various labs, including Los Alamos

Examples of convergence

Oxygen-16 low-energy elastic scattering

Leal adopts 3.765b at OK



Hale's somewhat higher, but both much lower than B-VII.1

Note insights from Chalk River too

Examples of convergence

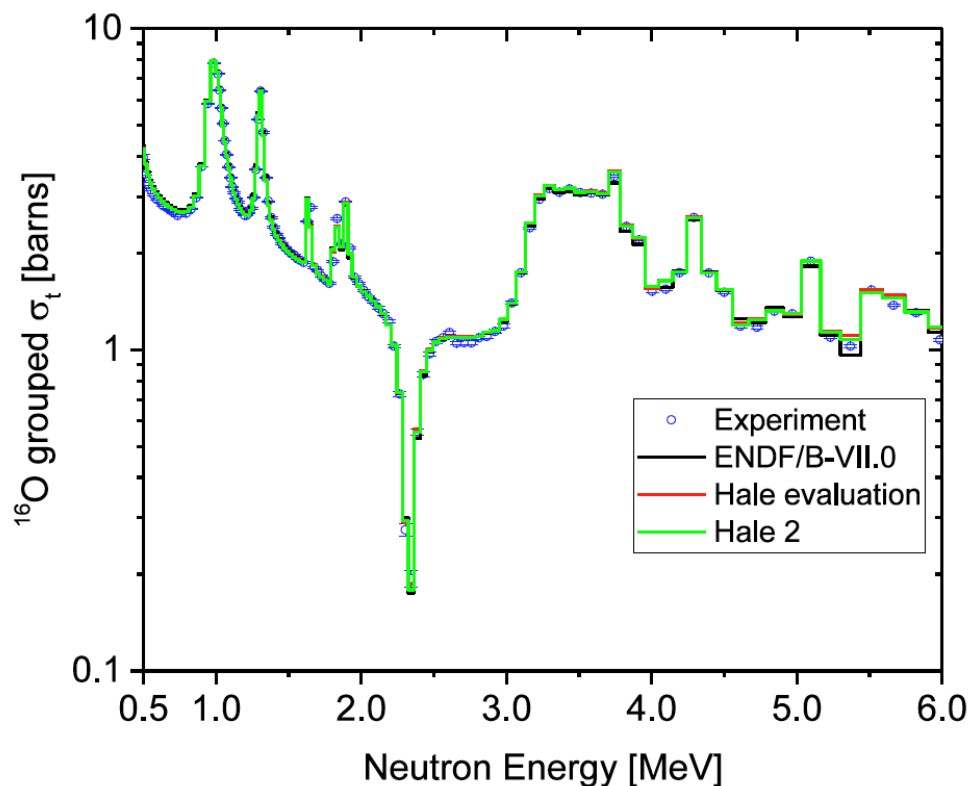
Oxygen-16 total cross section, normalization determined from RPI experiment

RPI measurement made *after*
Hale evaluation completed

Agrees to <1% - confirmation

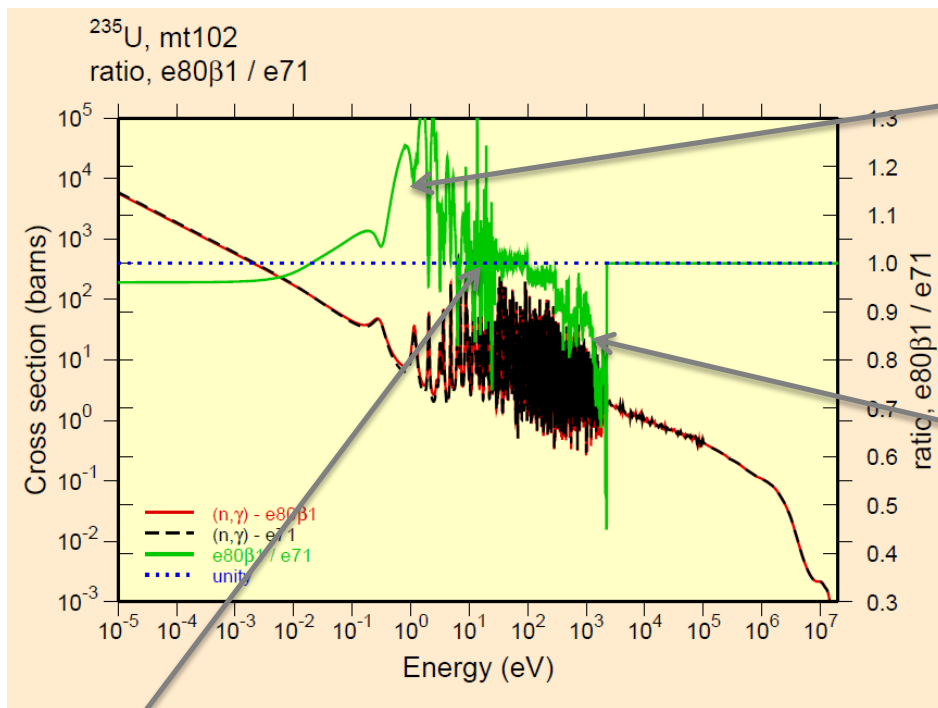
Resolves 3-4 % normalization
uncertainties

Grouped Cross Section



Examples of convergence, but open problems remain

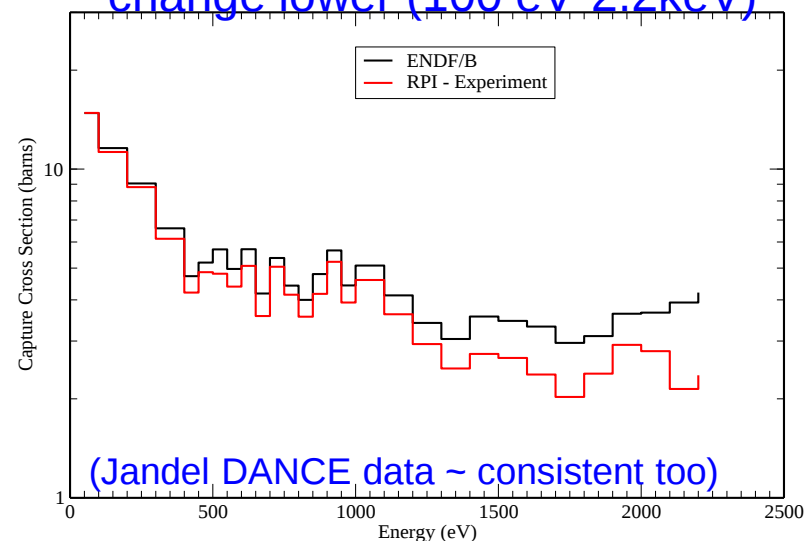
U235 capture



IAEA/ORNL new analysis increases capture (thermal - 20eV)

- Motivated by modeling thermal crits
- Includes alpha data from Brooks, supporting this increase

RPI & LANL data motivating this change lower (100 eV-2.2keV)

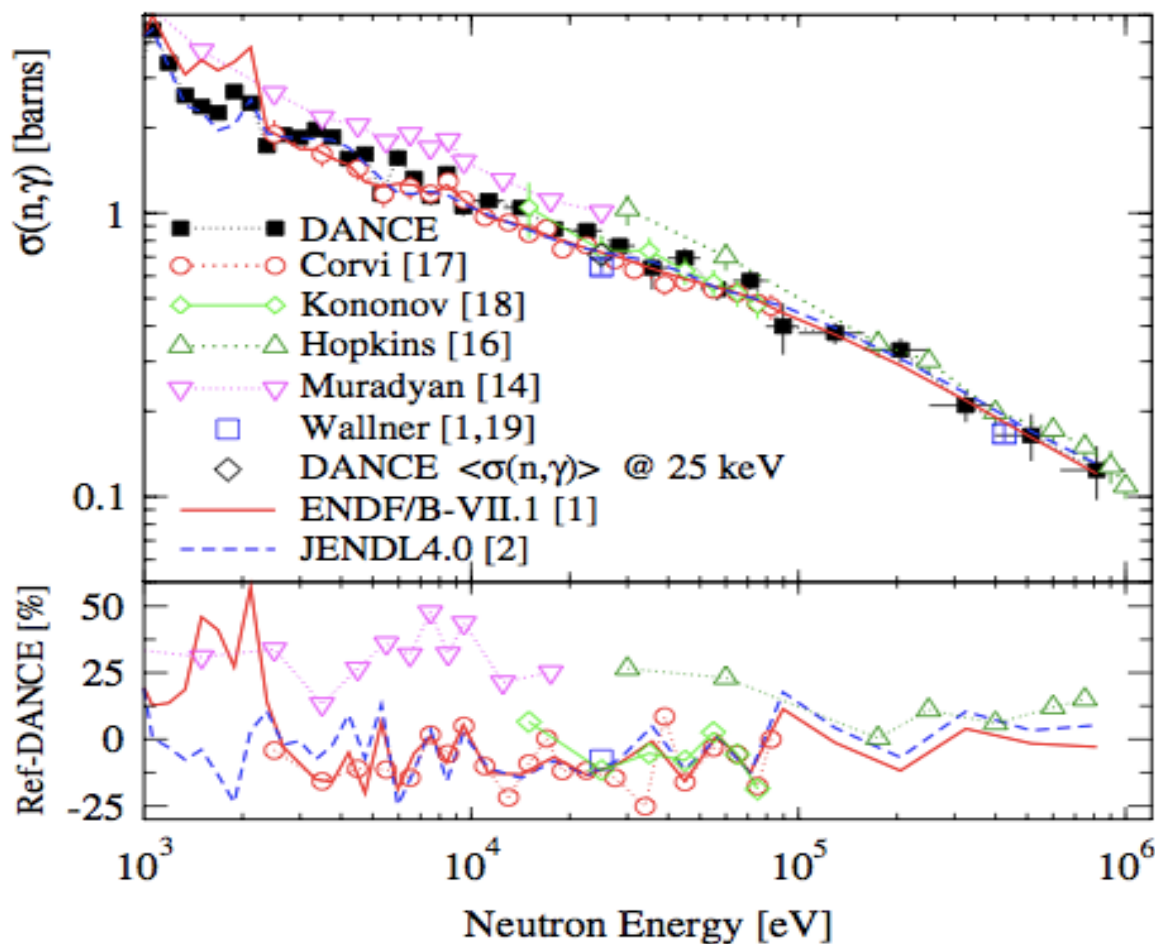


Future work needed on 20-100 eV region?:

- Do alpha c/f data support a capture increase?
- Impacts on LANL intermediate crits, HMI6 (Zeus) and HCI3 (Comet); See Wu SG39 “stress test”

^{235}U capture at higher energies (>10s of keV)

- No changes yet



Discrepancy between
Jandel & Wallner (25 keV)

We are considering modest
changes in ~ 2.25 -10s keV
(e.g. sens. of Comet HMI-6)
Since EALF ~ 5 -80 keV for HMI 1-4

Examples of convergence

^{235}U and ^{239}Pu PFNS

Thermal PFNS – IAEA/ENDFVIII.beta1
and CEA/BIII evaluations ~ agree

Thermal ^{235}U $E_{\text{av}}=2.00$ MeV,
not 2.03 MeV

Both use thermal ^{239}Pu $e_{\text{av}} \sim 2.10$ MeV
(tentative, until we obtain new data)

Other perspectives of a softer ^{239}Pu thermal PFNS (IAEA, Neudecker)

- but this is not yet adopted.
- considered in the future
- Future resonance analysis can capture
use new Mosby LANL capture

Examples of convergence 235U and 239Pu PFNS

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Thermal 235U $E_{av}=2.00$ MeV,
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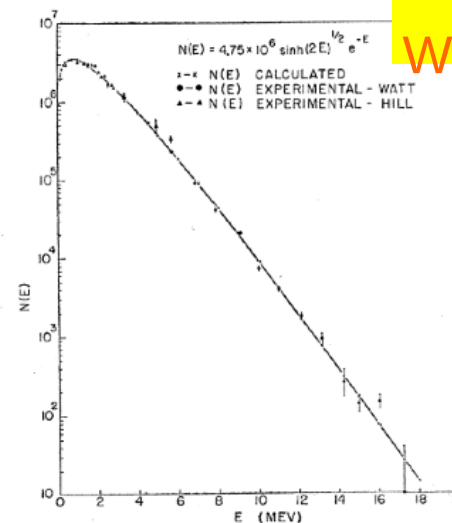


FIG. 4. Energy spectrum of fission neutrons. The calculated curve is based on the assumption of a Maxwellian distribution in the center-of-mass system for the neutrons emitted by a fission fragment.

Watt 1952 PRC paper

Watt: $N(E) \sim \exp(-E/a) \cdot \sinh(\sqrt{b \cdot E})$

$E_{av} = (3/2)(1 + a \cdot b/6)$.

• Broadhead, ORNL, PHYSOR2004)

Watt's $a=1$, $b=2$ gives

$E_{av}=2.00$ MeV

Both use thermal 239Pu $e_{av} \sim 2.10$ MeV
(tentative, until we obtain new data)

Other perspectives of a softer 239Pu
thermal PFNS (IAEA, Neudecker)

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Examples where open questions remain

- These differences of opinion will be documented
-

Magnitude of actinide inelastic scattering

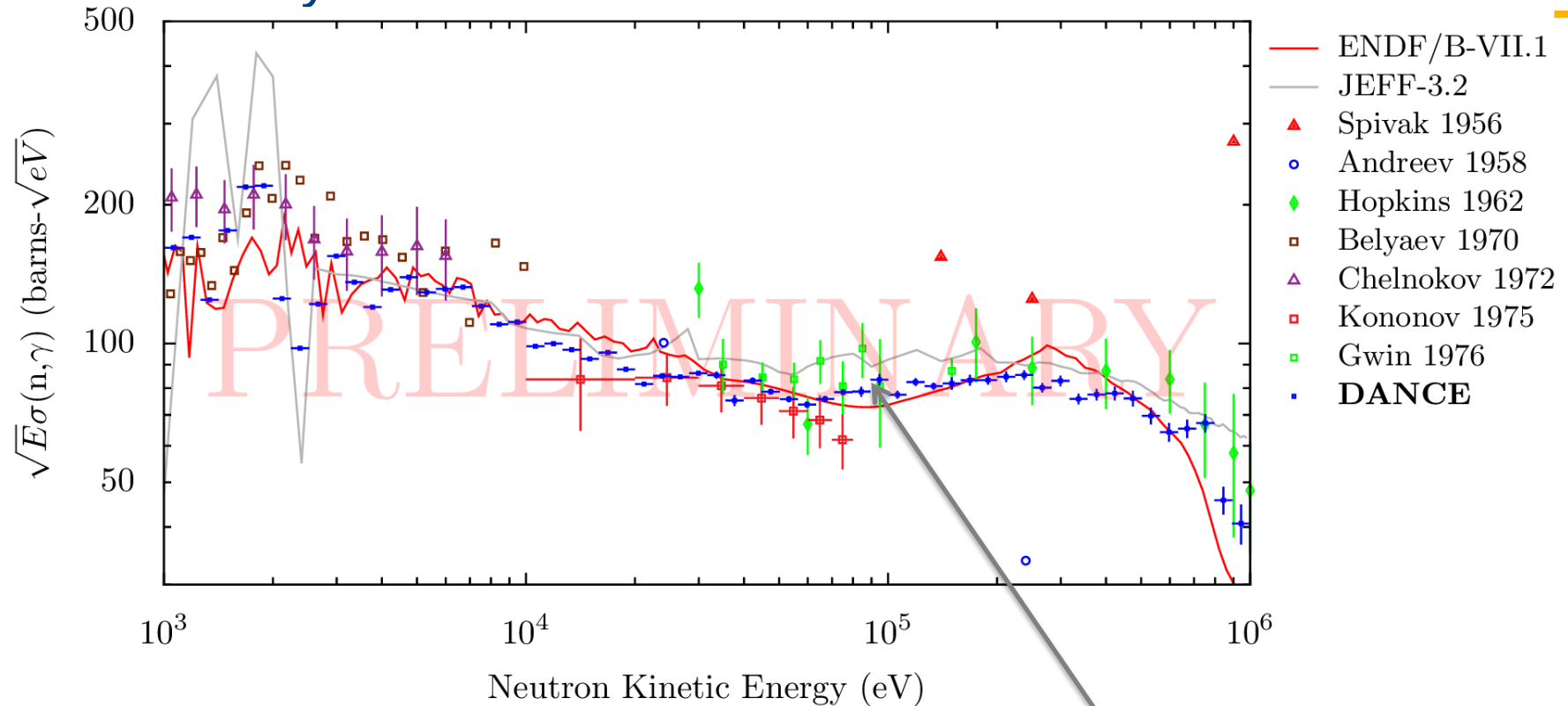
- Still differences between ENDFVIII.beta1 & JEFF3.3testing files?

Actinide capture

- ^{238}U uncertainties further reduced, largely confirming standard
- ^{235}U questions in 20-100 eV, & in the 10s-100s of keV range
- ^{239}Pu new DANCE capture data, but will largely influence a future evaluation (more time needed to include in res. analysis)

Various questions in resonance evaluation of ^{56}Fe

Preliminary Results for ^{239}Pu from DANCE



- Investigating structures in keV region
- Plan: complete analysis by end of this FY
- What will be the impact on criticality calculations?

How will these data impact modeling
intermediate & fast Pu crits?

- Studied in coming months

56Fe iron advances - BNL, IAEA, ORNL, IRNS, China

- VIII.beta1 uses most precise and most recent experimental data between resonance region and 4 MeV (Berthold data for total, new Geel (Negret, Plompen) data for inelastic, and old but not used before data by Dupont for inelastic, Kinney data for elastic angular distributions)
- It uses IRDFF file for dosimetry activation cross sections
- Dispersive Lane optical model > 4 MeV; modeling to 150 MeV
- Informed by semi-integral data from RPI (neutron emission and capture)
- Provides better reproduction of inelastic (China & BNL ~ agree)
- Chinese file predicts n,xn particularly well

Ongoing IRSN 56Fe resonance analysis - we will study it (JEFF is testing it; ENDF/B-VIII.beta1 presently uses a mod. to JENDL)

Much valuable data testing done (esp. Kahler, Trkov, Hill, CEA ...)

Conclusions:

- Fast bare ~ good
 - Fast reflected ~ good (but we may make U8 reflectors a bit more reactive)
 - Thermals ~ good, for U and Pu
 - Intermediate (Bigten) ~ good
 - Intermediate (Zeus, Comet, Planet) – worse (driven by cap decr. in 100eV-2 keV; ~1000 pcm incr for HMF6)
- (Now we are studying ^{235}U n,g in the 10-100 eVs and 10s of keV region)*
- We welcome future Japanese FCA sodium void testing of VIII.beta1
 - Some intermediate Pu assemblies over-calculated. (lower Pu cap might help)

Conclusions on CIELO collaboration

CIELO has stimulated healthy collaborations

Enabled significant progress on these evaluations

- enabled large changes to new regional evaluation files, ENDF, JEFF, ..

We welcome feedback from:

- Integral validation data testers
- Adjustment SG39 project insights
- Sensitivity tools like NEA's NDaST

Will complete pilot CIELO SG40 project by May 2017; documentation in 2018

- IAEA considering long term plan for reaction data network

Nuclear never ends ...

Plus Ultra : there is more beyond

(motto of the great scientific pioneers
of the 16th & 17th Century)

Francis Bacon's *Novum Organum*
(1620): Straits of Gibraltar flanked
by the colossal pillars of
Hercules.

Inscription: “Many shall pass too and
fro and knowledge shall be
increased”



CIELO ND2018 papers

- Sometimes authors may want separate papers to get credit for first-authorship. OK
 - Big VIII paper versus CIELO paper issues: CIELO can focus on more reaction physics
-

- Cover summary paper - `MBC draft. Many co-authors?
- 16O. Plompen (IRMM-LANL-KAPL-RPI-IRSN-Japan-LLNL-Chalk River et al bigger paper? (or separate papers by Hale, Leal,?)
- 235U, 56Fe, (O16) – Leal resonance analyses
- 238U – Scbx resonance analysis, capture and inelastic scattering
- 235,8U IAEA RPI ... fast analyses (incl LANL PFNS work, but no need for LANL co-authorship); same paper or separate 235U RR (Pigni-Trkov)?
 - Separate Devlin et al 235U PFNS paper?
 - Separate Chinese 235U paper, eg on alpha c/f evaluation?
- CEA 235,8U and 239Pu fast evaluations
- 56Fe+minor isotopes, BNL-IAEA –RPI ...;same paper or separate 56Fe RR (Pigni-Trkov)? Same paper or separate Chinese paper?
- 239Pu One paper or Separate Mosby DANCE capture paper?

CIELO ND2018 papers

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- Kawano. Capote, Romain et al, theory on inelastics and differences in actinides?
- Neudecker et al., ? Publication of PFNS .. Including those not adopted?