Validation of new evaluations of the chromium isotopes

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U.S. DEPARTMENT OF ENERGY

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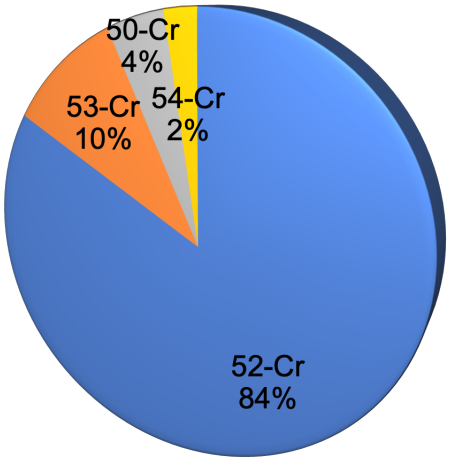
Summary of Cr evaluations



- Isotope and reactions to update?
  - *^{50,53}Cr: thermal and up to 10 keV; all reactions in fast region.*
  - *^{52,54}Cr: all reactions in fast region.*
  - *Reconstructed isotopic angular distributions in resonance region.*
- Motivation? Deficiencies in the current ENDF/B-VIII.0?
  - *Chromium is an important alloy in stainless steel. After recent evaluation of iron, it is essential to better constrain Cr files.*
  - *^{50,53}Cr: Cluster of capture resonances in the region 1-10 keV drive criticality in Cr-sensitive benchmarks. ENDF/B-VIII.0 followed data with inaccurate correction determination in this region (e.g., MS)*
- What new data/theory motivate a new evaluation/update?
  - *Appropriate normalization of Guber ^{53}Cr(n,g) data (ORNL) in the 1-10 keV region*
  - *Neutron and gamma ^{52}Cr inelastic data from Mihailescu (GEEL)*
  - *New soft-rotor dispersive optical potential for ^{50,52,54}Cr, interpolated as rigid rotor for ^{53}Cr*
- What validation testing has been/will be done?
  - *Chromium-sensitive benchmarks identified, in particular KBR-15 (HEU-COMP-INTER-005 k_∞) and ZPR-6/10 (PU-MET-INTER-002) with strong sensitivity to Cr – both are big outliers (11% and 2% in k, respectively)*
  - *Oktavian-Cr 14 MeV leakage: Not in SINBAD, new model developed in JSI*
  - *New evaluation greatly improves reactivity prediction and performs well for the 14 MeV benchmark*

Criticality benchmarks

List of chromium-sensitive benchmarks from the ICSBEP Handbook selected for the validation of new chromium evaluated files.

No.	ICSBEP Label	Short name	Common name	Comment
1	HEU-COMP-INTER-005	hci005-009	KBR-09(SS)	k_∞
2	HEU-COMP-INTER-005	hci005-010	KBR-10(Mo)	k_∞
3	HEU-COMP-INTER-005	hci005-015	KBR-15(Cr)	k_∞
4	HEU-COMP-THERM-011	hct011-001	RRC-KI-21x21-001	$SS_{cladding}$
5	HEU-COMP-THERM-011	hct011-002	RRC-KI-21x21-002	$SS_{cladding}$
6	HEU-COMP-THERM-011	hct011-003	RRC-KI-21x21-003	$SS_{cladding}$
7	HEU-COMP-THERM-012	hct012-001	RRC-KI-18x18-001	$SS_{cladding}$
8	HEU-COMP-THERM-012	hct012-002	RRC-KI-18x18-002	$SS_{cladding}$
9	HEU-COMP-THERM-013	hct013-001	RRC-KI-14x14-001	$SS_{cladding}$
10	HEU-COMP-THERM-013	hct013-002	RRC-KI-14x14-002	$SS_{cladding}$
11	HEU-COMP-THERM-014	hct014-001	RRC-KI-10x10-001	$SS_{cladding}$
12	HEU-COMP-THERM-014	hct014-002	RRC-KI-10x10-002	$SS_{cladding}$
13	HEU-COMP-THERM-022	hct022-001	SPERT-III	$SS_{cladding}$
14	HEU-MET-INTER-001	hmi001	ZPR-9/34	$SS_{reflector}$
15	HEU-MET-INTER-001	hmi001d	ZPR-9/34	$SS_{reflector}$
16	HEU-MET-THERM-016	hmt016	LACEF/Ni-Cr-Mo-Gd	
17	HEU-SOL-THERM-026	hst026-001	$RF_{Concrete}$	
18	IEU-COMP-THERM-005	ict005	KBR-21	k_∞
19	LEU-SOL-THERM-012	lst012-001	TRACY-203c	
20	MIX-COMP-FAST-001	mcf001	ZPR-6/7	
21	MIX-MET-FAST-008	mmf008-003	ZEBRA-8C/2	k_∞
22	PU-MET-INTER-002	pmi002	ZPR-6/10	$SS_{reflector}$

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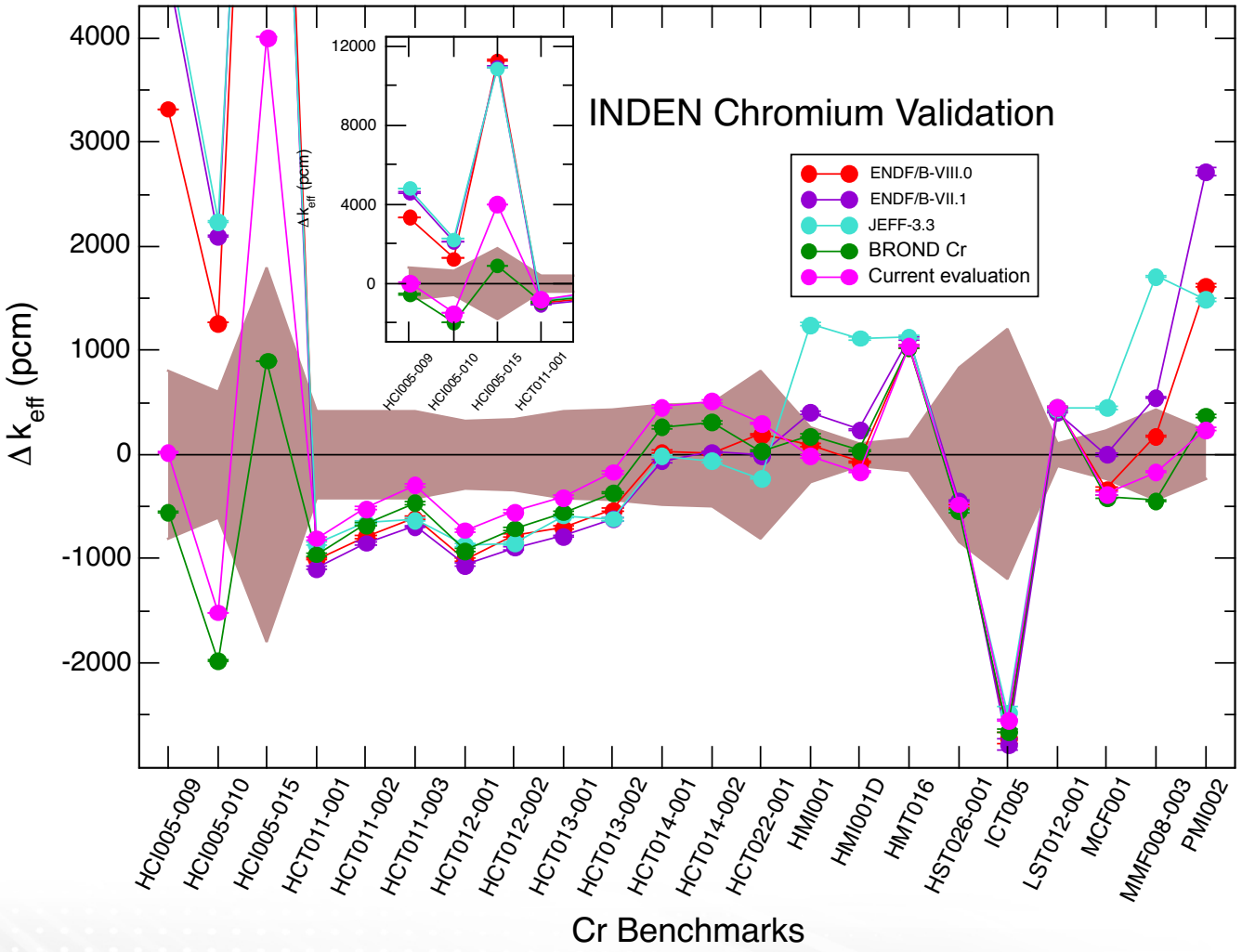
18	IEU-COMP-THERM-005	ict005	KBR-21	k_∞
19	LEU-SOL-THERM-012	lst012-001	TRACY-203c	
20	MIX-COMP-FAST-001	mcf001	ZPR-6/7	
21	MIX-MET-FAST-008	mmf008-003	ZEBRA-8C/2	k_∞
22	PU-MET-INTER-002	pmi002	ZPR-6/10	$SS_{reflector}$

Specifically dedicated to testing chromium

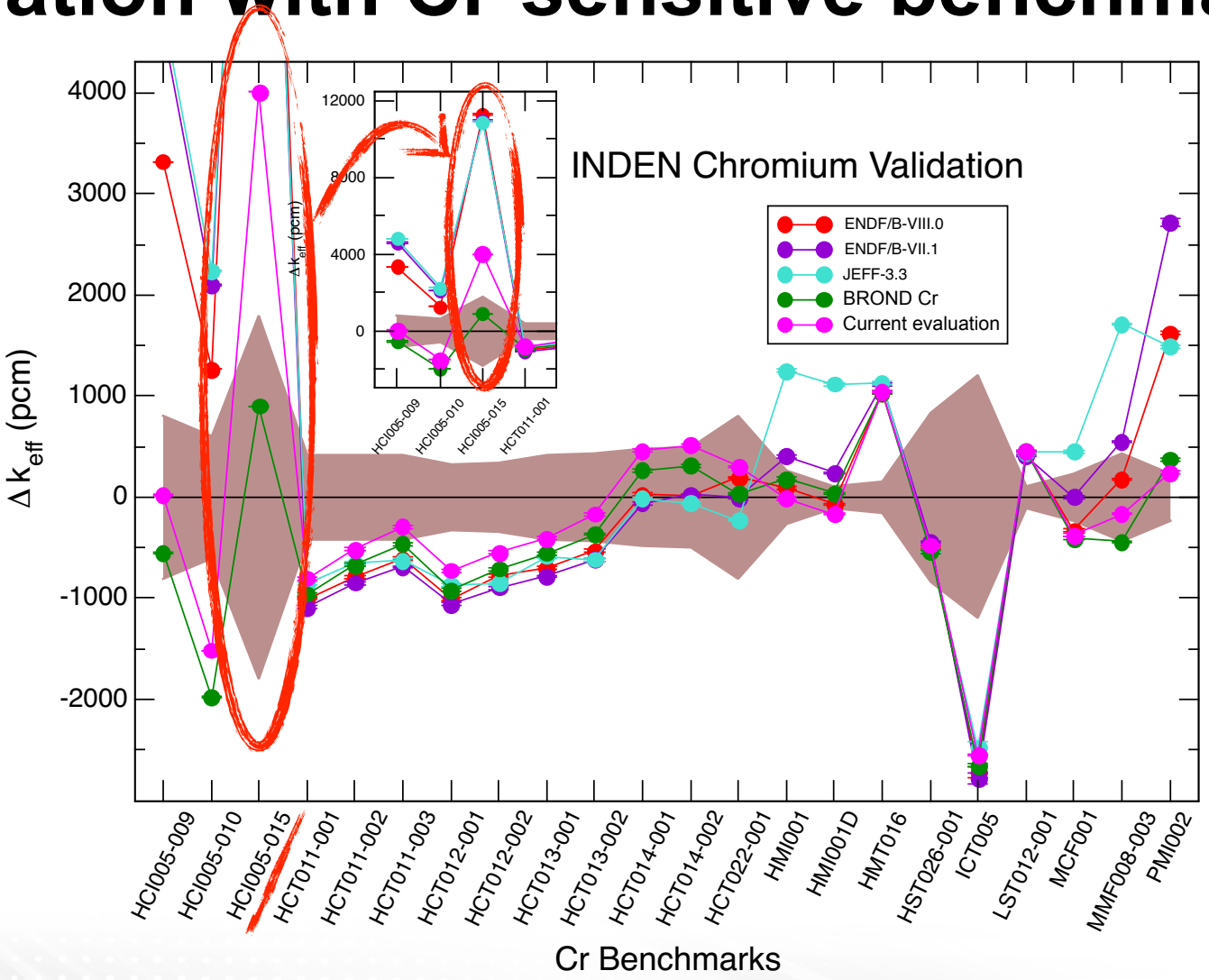
Notorious outlier for a long time

Validation with Cr-sensitive benchmarks



Major improvement in the performance in criticality benchmarks sensitive to chromium

Validation with Cr-sensitive benchmarks



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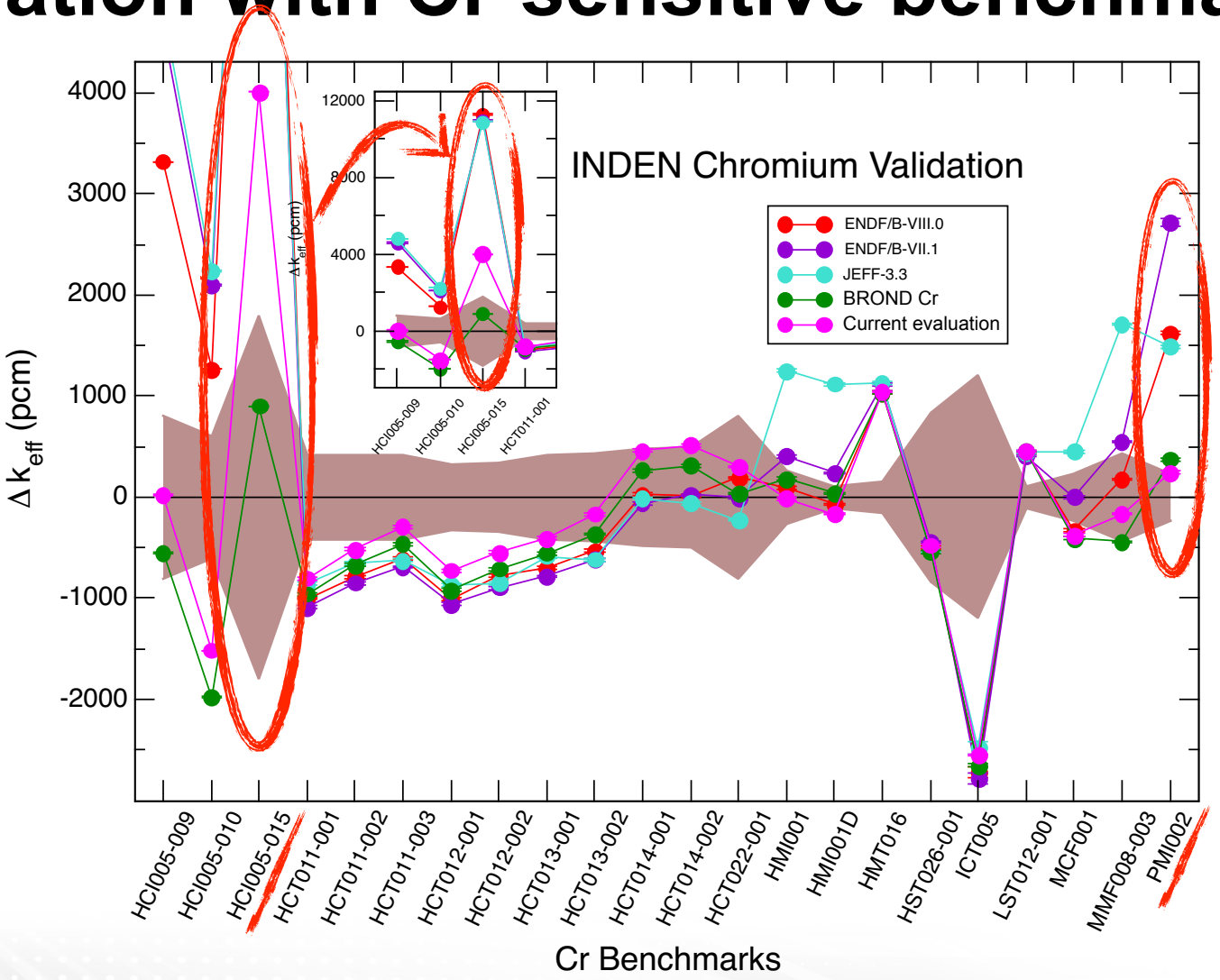

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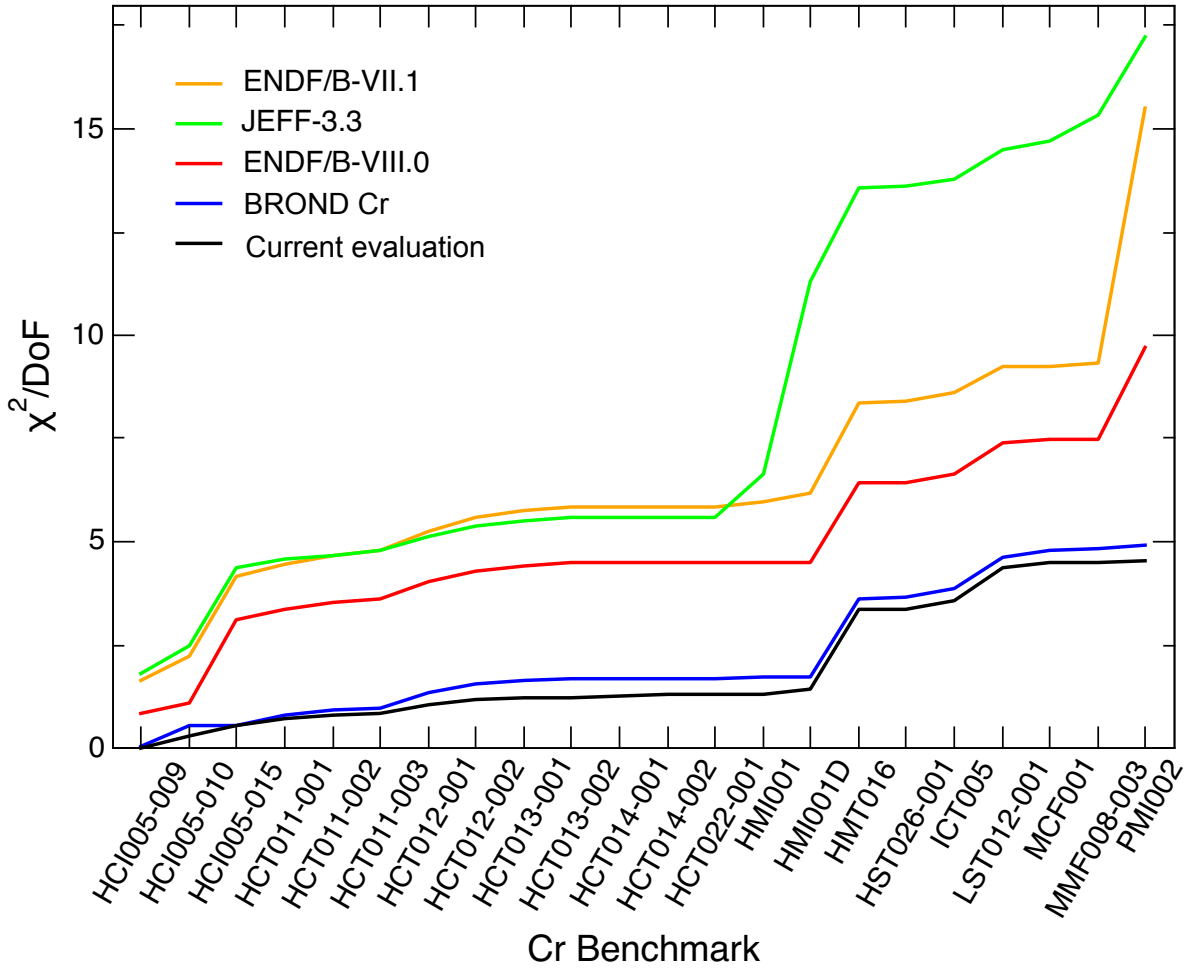

Major improvement in the performance in criticality benchmarks sensitive to chromium

But this wasn’t the end of the story…

- Oktavian-Cr leakage experiment (40 cm diameter chromium sphere) is not in SINBAD.
- New model was developed by Bor Kos (JSI) based on previous work by A. Milocco with explicitly modelled source:
    - Analysis in time-domain is crucial – subsequent conversion into the energy domain.
    - Resolution-broadening is needed to reproduce the elastic peak (asymmetric resolution function?).

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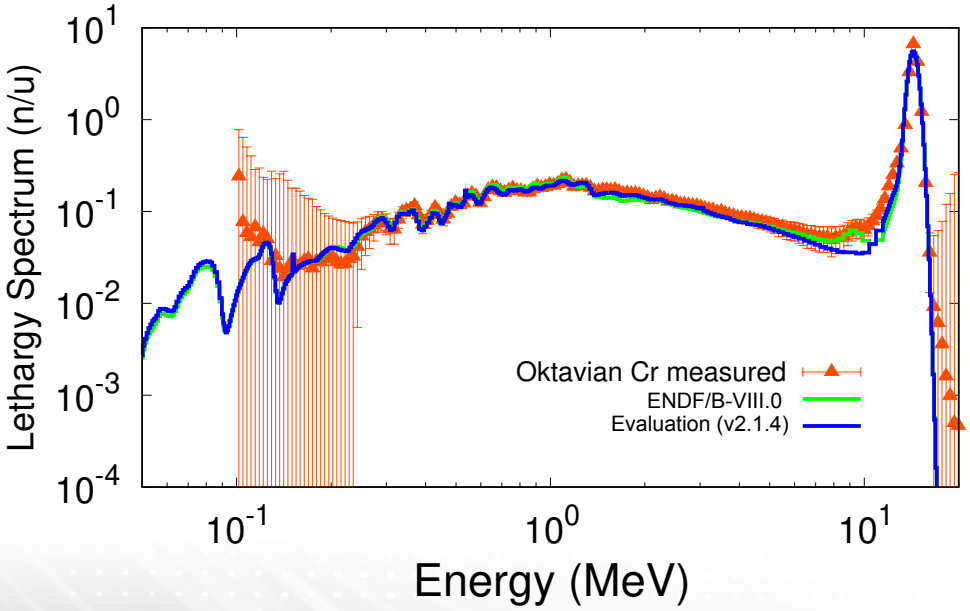

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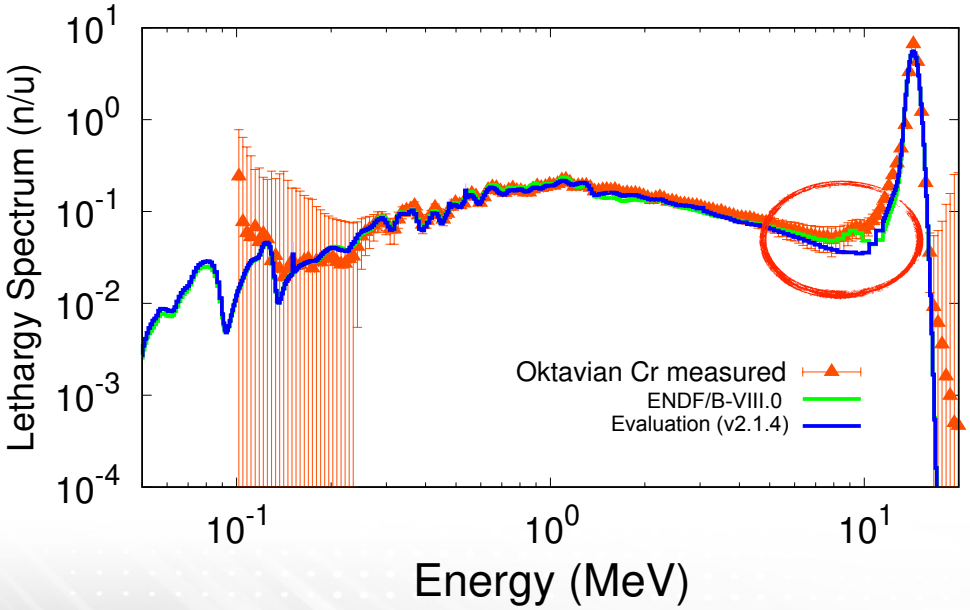

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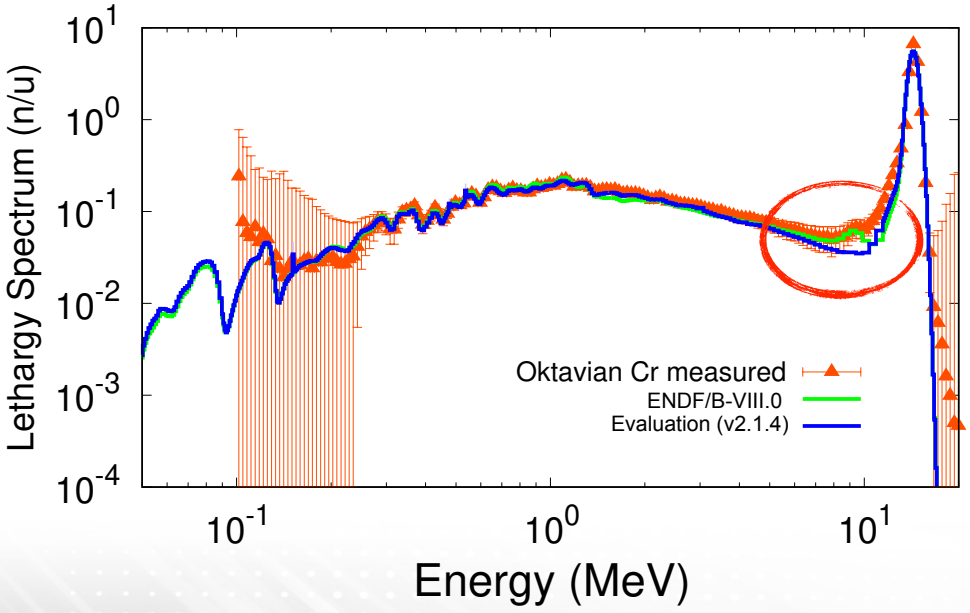

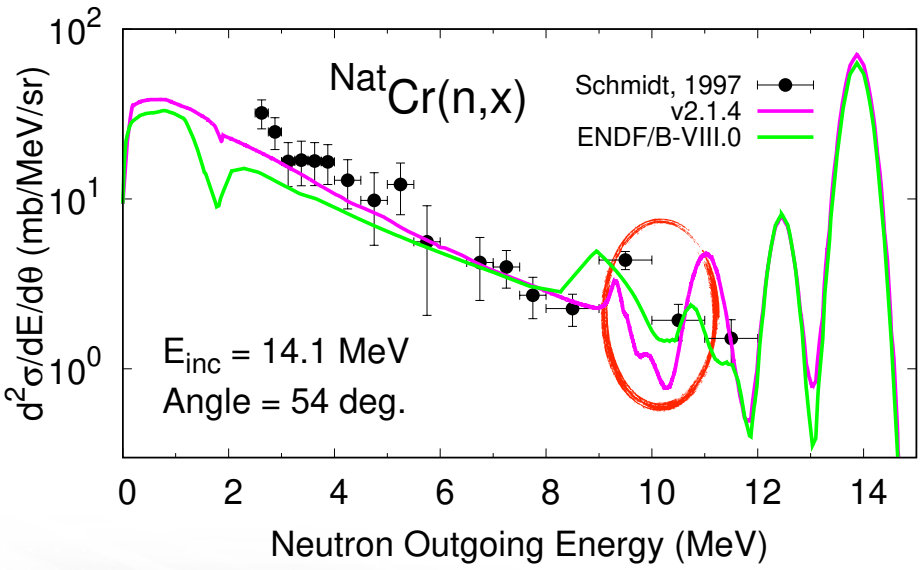

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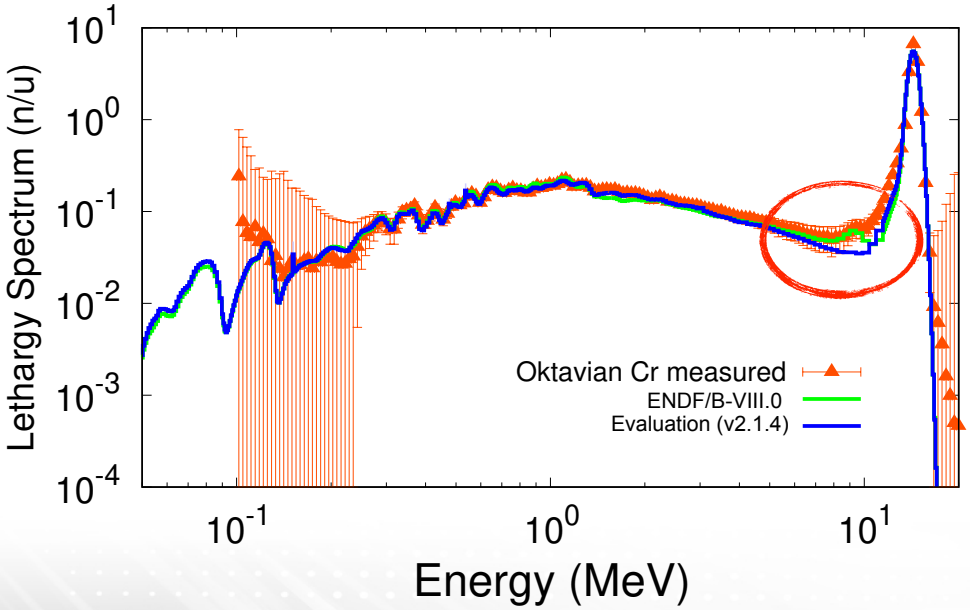

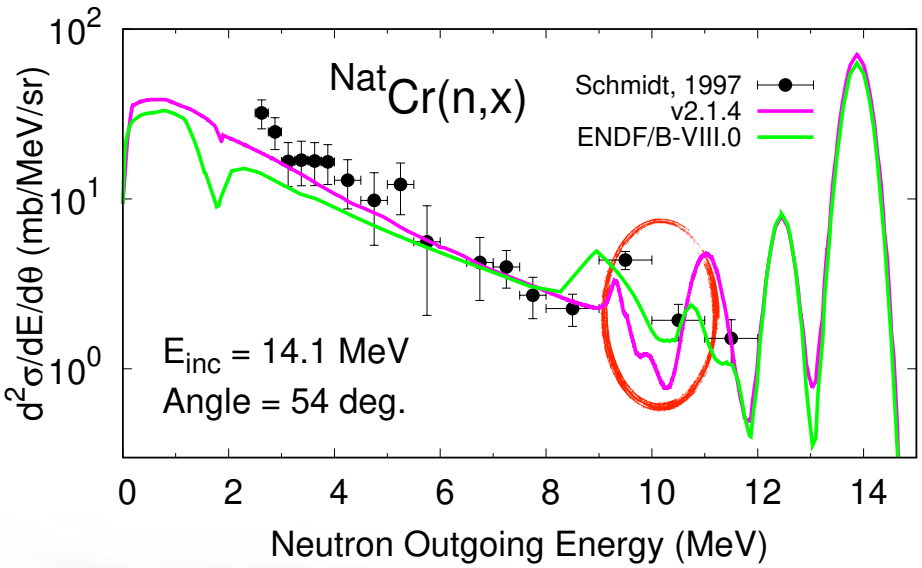

Oktavian-Cr leakage experiment calls for minor adjustment in inelastic neutron spectra

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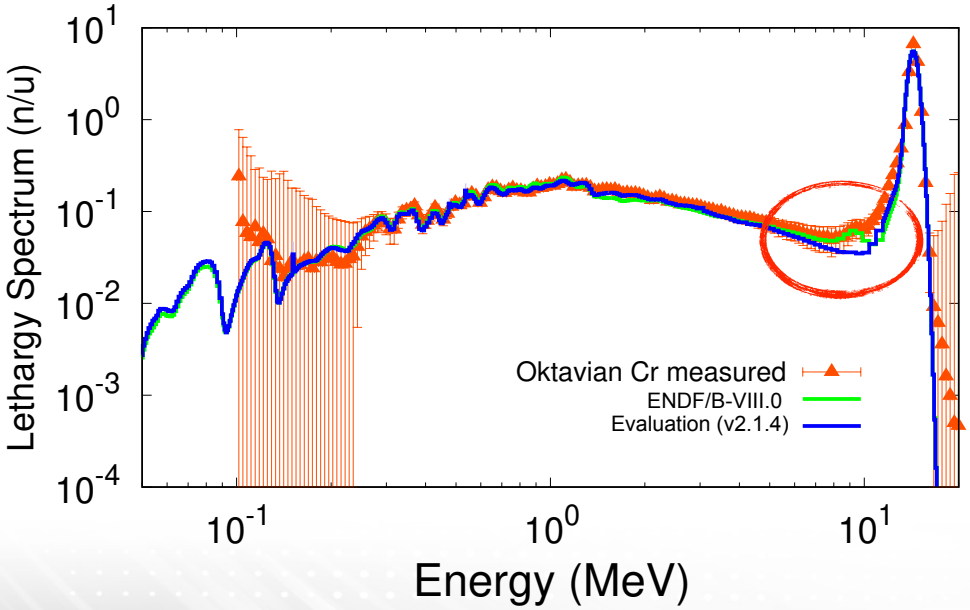
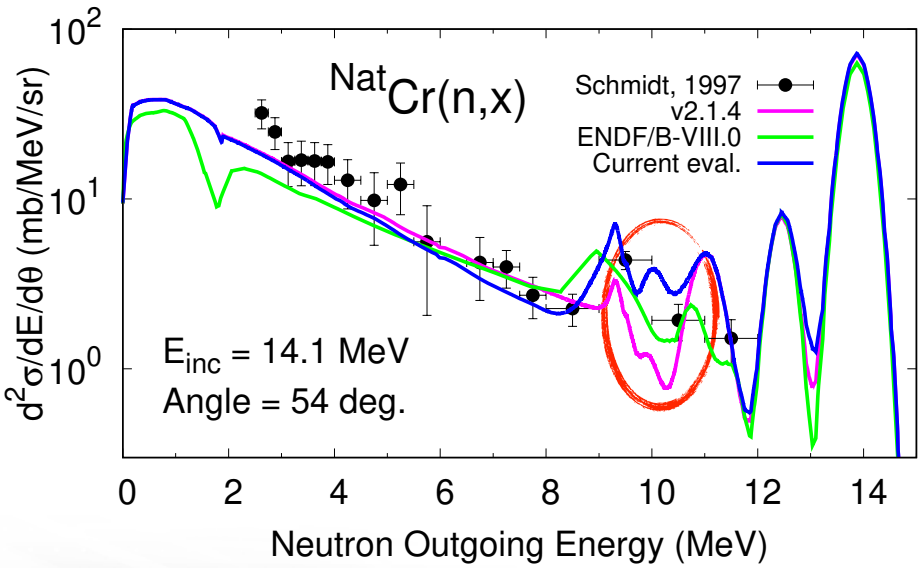
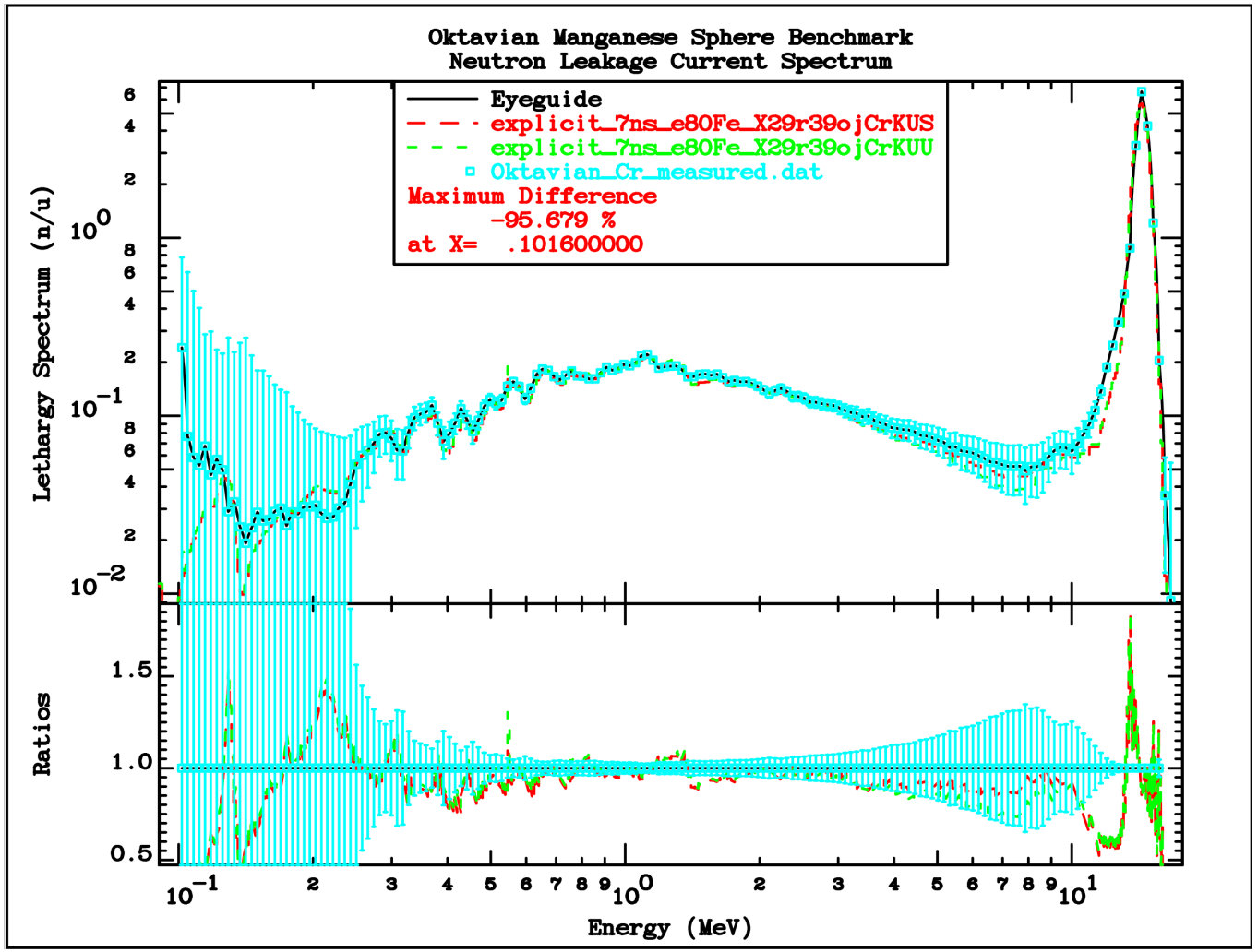




Oktavian-Cr leakage experiment calls for minor adjustment in inelastic neutron spectra

This fixes leakage…



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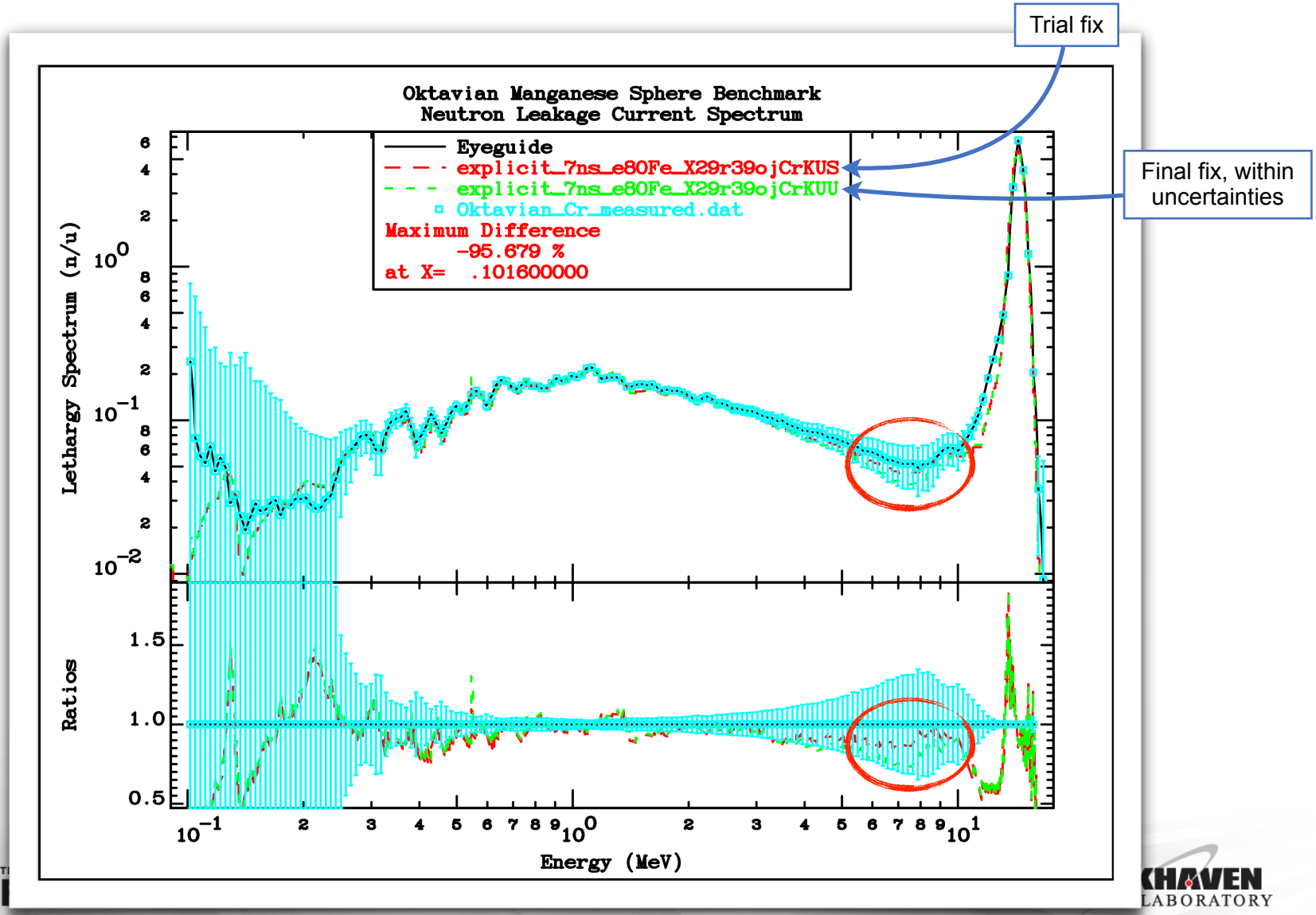
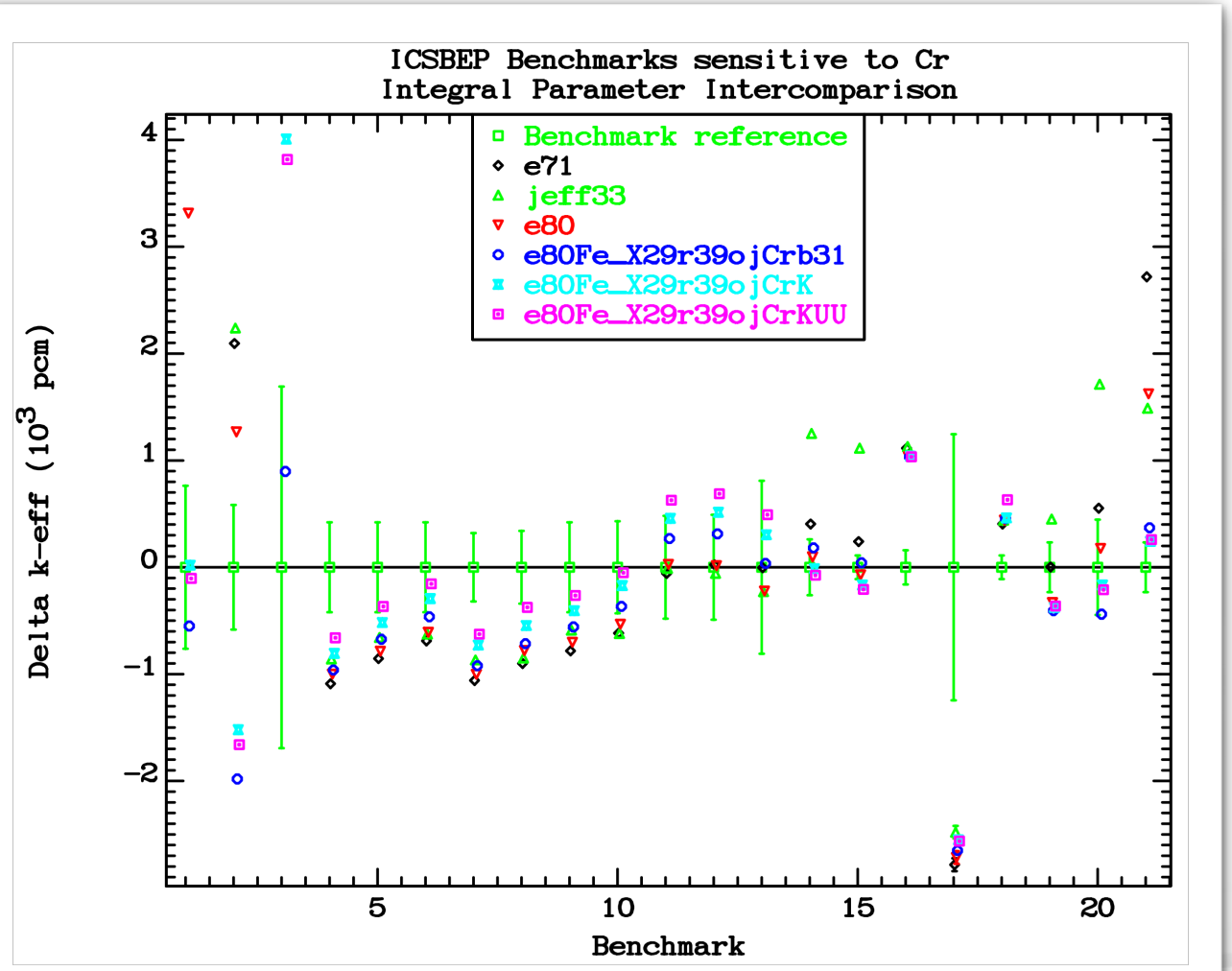


… and doesn't break criticality.



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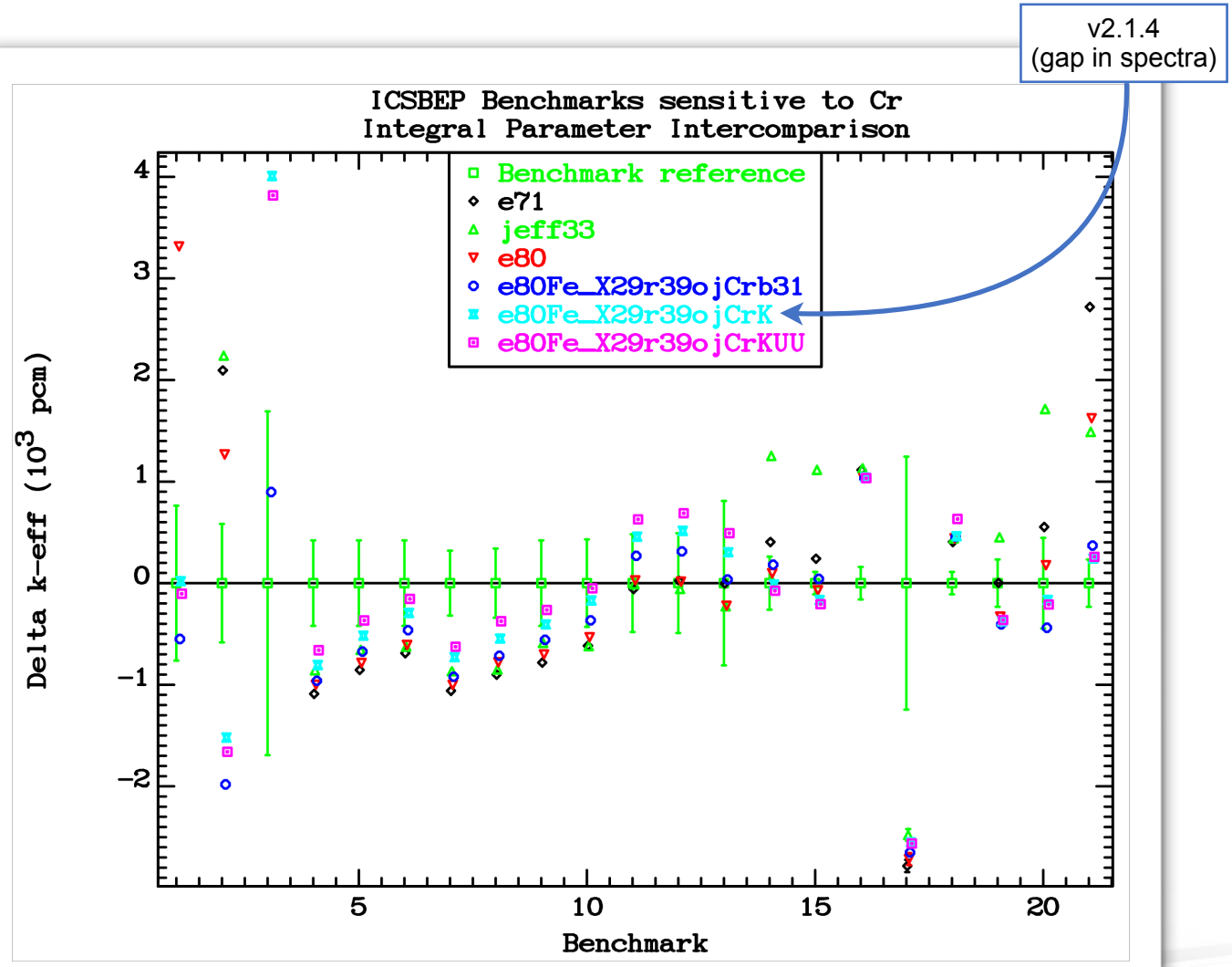

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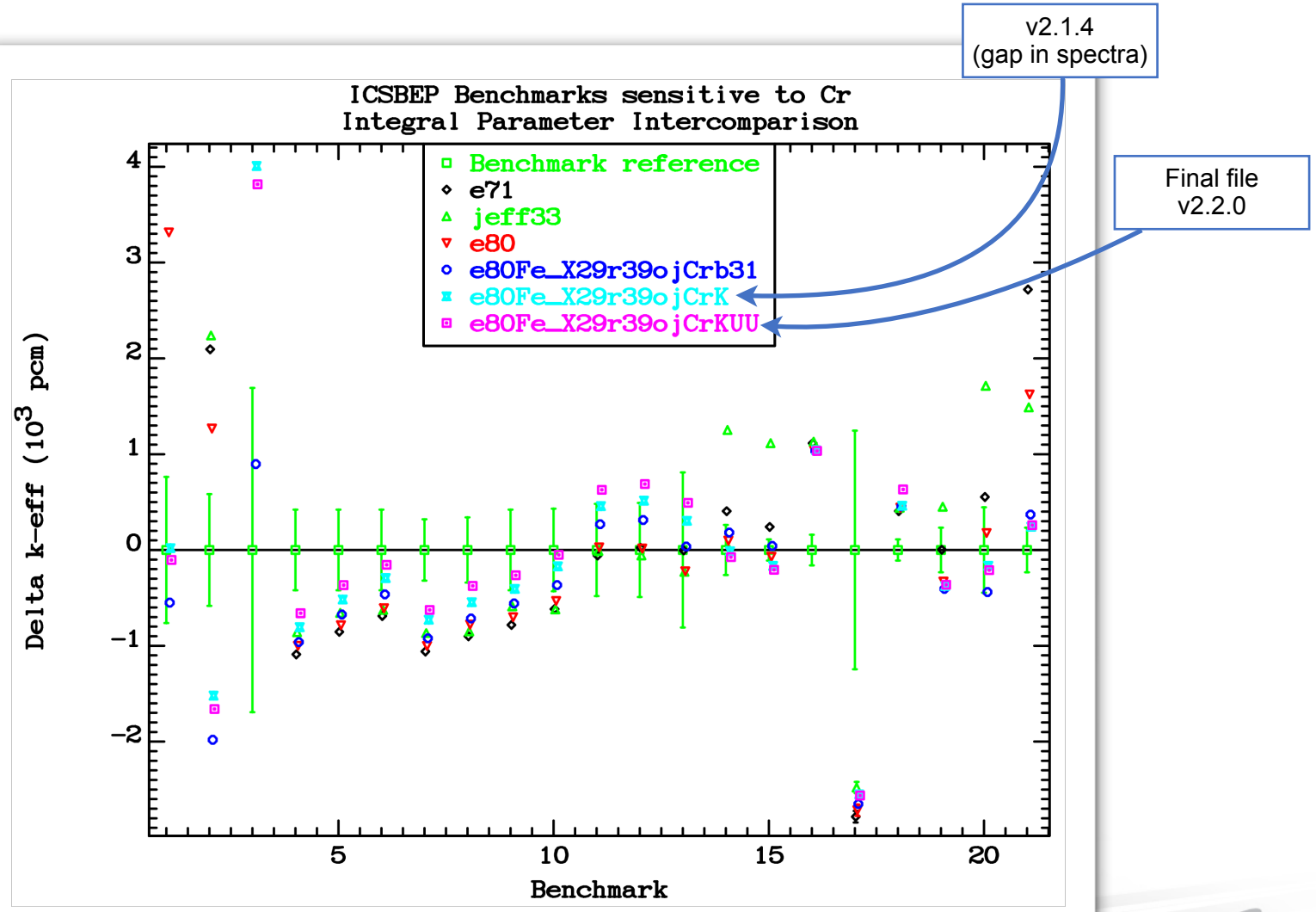

Conclusion

- **New evaluated files** for stable chromium isotopes represent a major improvement compared to existing files: Data agreement and Performance
- **Oktavian benchmark** revealed the need for minor adjustment in inelastic neutron spectra in the initial trial evaluation. The change was implemented and good performance was achieved.
- Importance of complementary benchmarks that can probe different energy regions and different reactions
- New evaluations of Cr isotopes perform well for
  - suite of Cr-sensitivity criticality benchmarks improving substantially the outliers (**PMI-002 is now within uncertainty**)
  - 14 MeV leakage benchmarks.
- **Submitted** to ENDF/B library and IAEA for testing and distribution
- **Article** in final stages of preparation to be submitted to Nuclear Data Sheets

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