An Overview of the Status of Lead Evaluations in ENDF/B-VIII.0 and JEFF 3.3

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Introduction

- A new effort is under way to reevaluate neutron interaction data for incident neutron energies corresponding to resolved resonances in the isotopes of lead.
- Lead is a ubiquitous material in the nuclear industry. Lead possesses not only high photon attenuation properties, which make it almost a universal choice as a gamma-ray shielding material, but also desirable neutronic qualities that find applications in advanced reactor designs.
- Stemming from the work of Subgroup 26 of the Working Party on Nuclear Data Evaluation Cooperation (WPEC) of the OECD/NEA, lead has been identified as a significant contributor to the uncertainty of nuclear systems calculations.

Isotope	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb
abundance	1.40%	24.10%	22.10%	52.40%
spin	0+	0+	1/2-	0+

Background ENDF/B-VIII.0

- In ENDF/B-VIII.0 the evaluations for ^{204}Pb, ^{206}Pb, and ^{207}Pb are credited to A.J. Koning. The evaluations were done primarily based on a theoretical analysis using the nuclear model code TALYS.
- For ^{204}Pb, evaluated resonance parameters in the range of 10^{-5} eV to 50 keV were adopted from the JENDL3.3.
- The resonance parameters for ^{204}Pb are described as corresponding to the Reich-Moore formalism, while the flag in File 2 is set to represent the Multilevel Breit-Wigner (MLBW) formalism. This may change the interference patterns observed in the cross sections.
- The resonance evaluations for ^{206}Pb and ^{207}Pb are Reich-Moore resolved resonance parameters covering the energy ranges 10^{-5} eV to 900 keV and 10^{-5} eV to 450 keV, respectively. These evaluations were adopted from the ENDF/B-VI.8 library.
- The ENDF/B-VIII.0 evaluation for ^{208}Pb is credited to M. Chadwick and P. Young. The Reich-Moore resolved resonance parameters were adopted from the ENDF/B-VI evaluation.

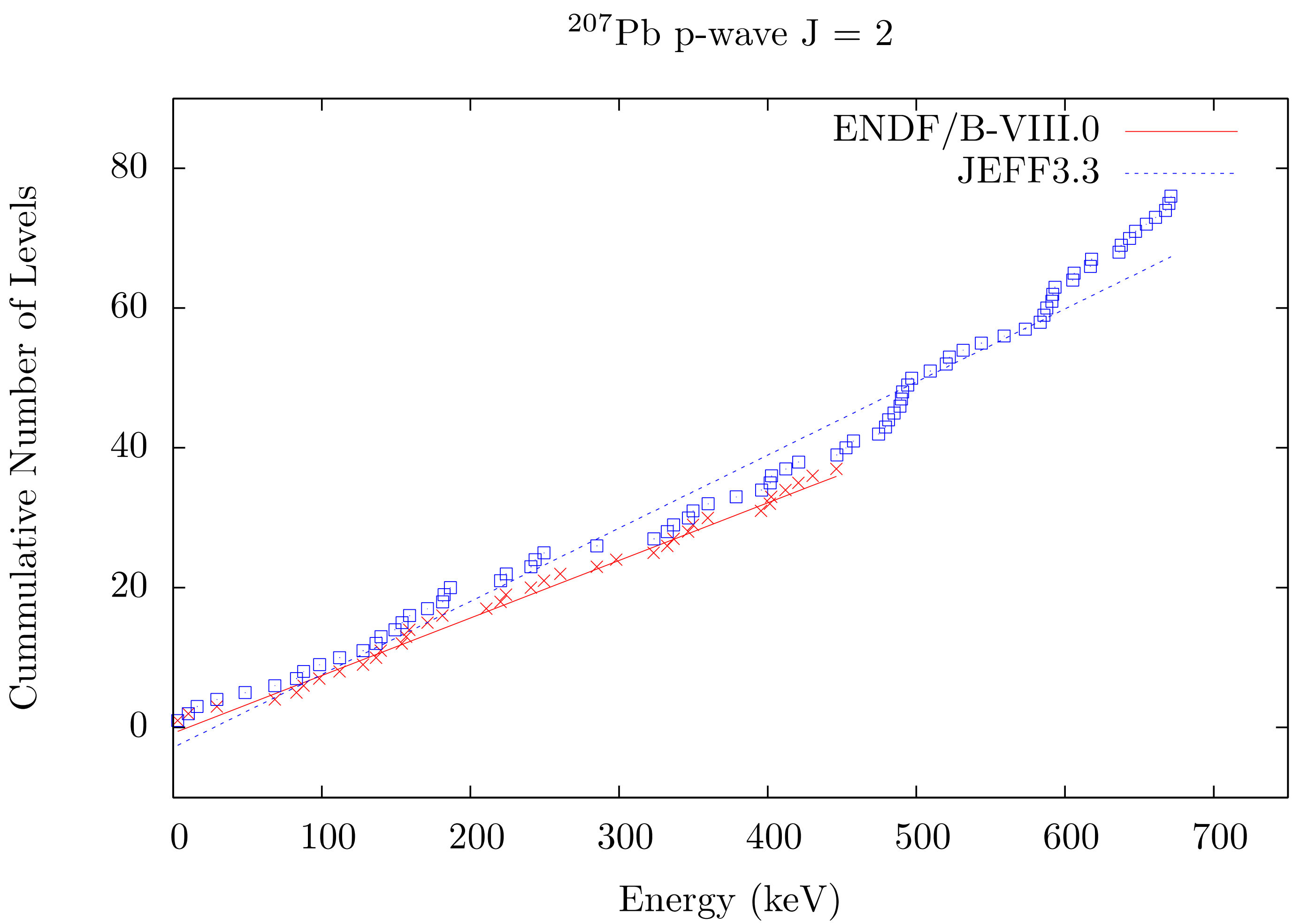
Background JEFF-3.3

- The ^{204}Pb evaluation in JEFF3.3 is overall credited to D. Rochman and A.J. Koning and results from some modifications made to JEFF3.2 of the JEFF3.1 files. In particular the resolved resonance region, File 2, is based on the *Atlas of Neutron Resonances* up to 900 keV. However, only the part up to 100 keV is used in the file.
- Resonance parameter uncertainties were first taken from the Atlas and then increased to compensate for the scattering radius and to match integral measurements.
- In JEFF3.3 the evaluations for ^{206}Pb, ^{207}Pb, and ^{208}Pb are all referenced to A. Plompen and G. Zerovnik.
- Systematically, the resolved resonance region for all three evaluations was taken from JENDL-4.0 and evaluated by N. Iwomoto.

Select Properties of the Evaluations of the Isotopes of Lead

	^{204}Pb			^{206}Pb		
Isotope	Atlas	ENDF	JEFF	Atlas	ENDF	JEFF
ENDF number		8225			8231	
Thermal capture (mb)	703 ± 35	661	703	26.6 ± 1.2	29.78	26.53
Thermal scattering (b)	n/a	11.20	11.16	10.85 ± 0.11	11.26	10.85
RRR (keV)	1 000	50	100	900	900	820
	^{207}Pb			^{208}Pb		
Isotope	Atlas	ENDF	JEFF	Atlas	ENDF	JEFF
ENDF number		8234			8237	
Thermal capture (mb)	622 ± 14	711.86	620.14	0.23 ± 0.02	0.230	0.230
Thermal scattering (b)	n/a	10.77	11.51	11.50 ± 0.15	11.40	11.46
RRR (keV)	700	475	680	1 000	1 000	1 000

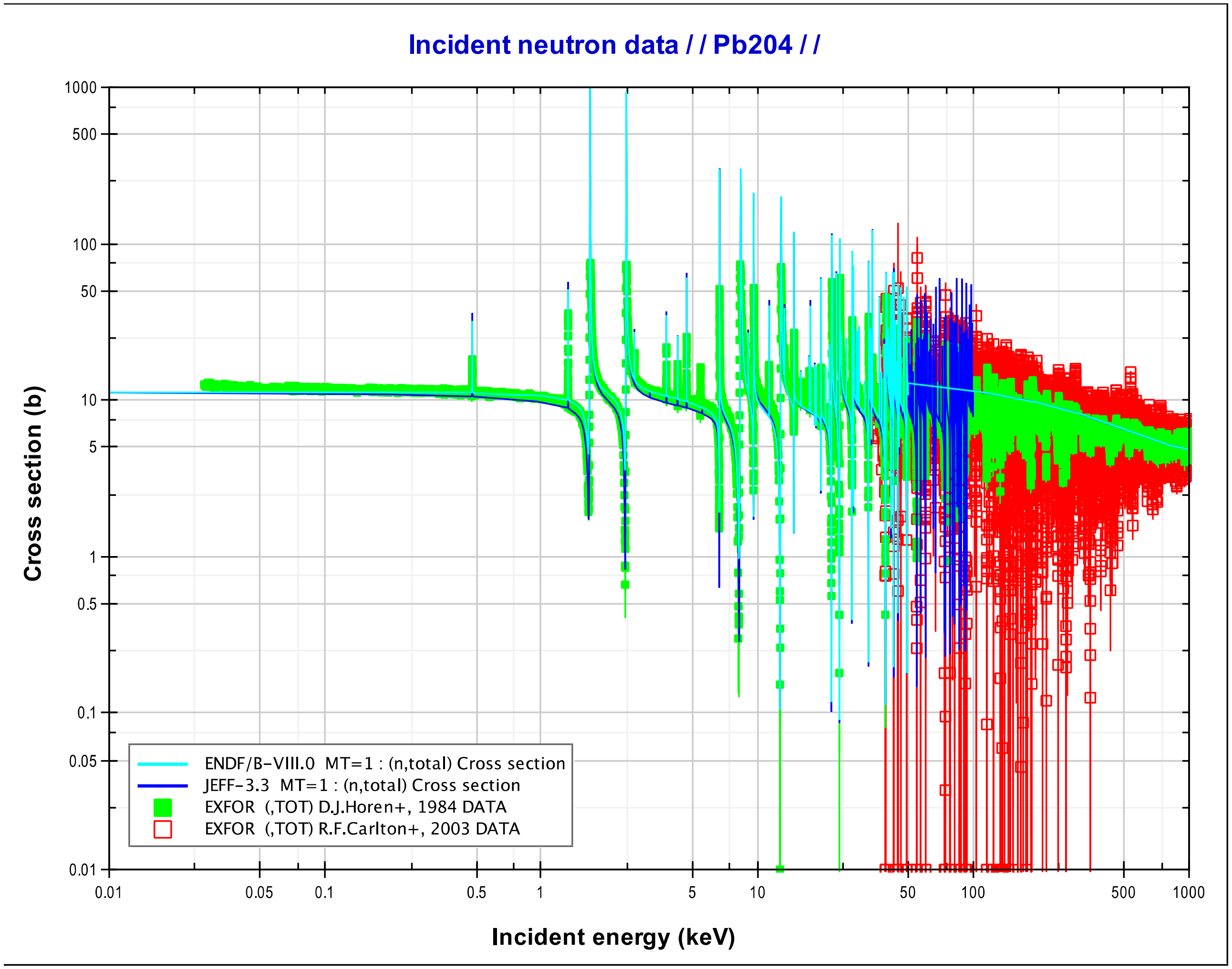
Cumulative number of levels compared to the line of best fit



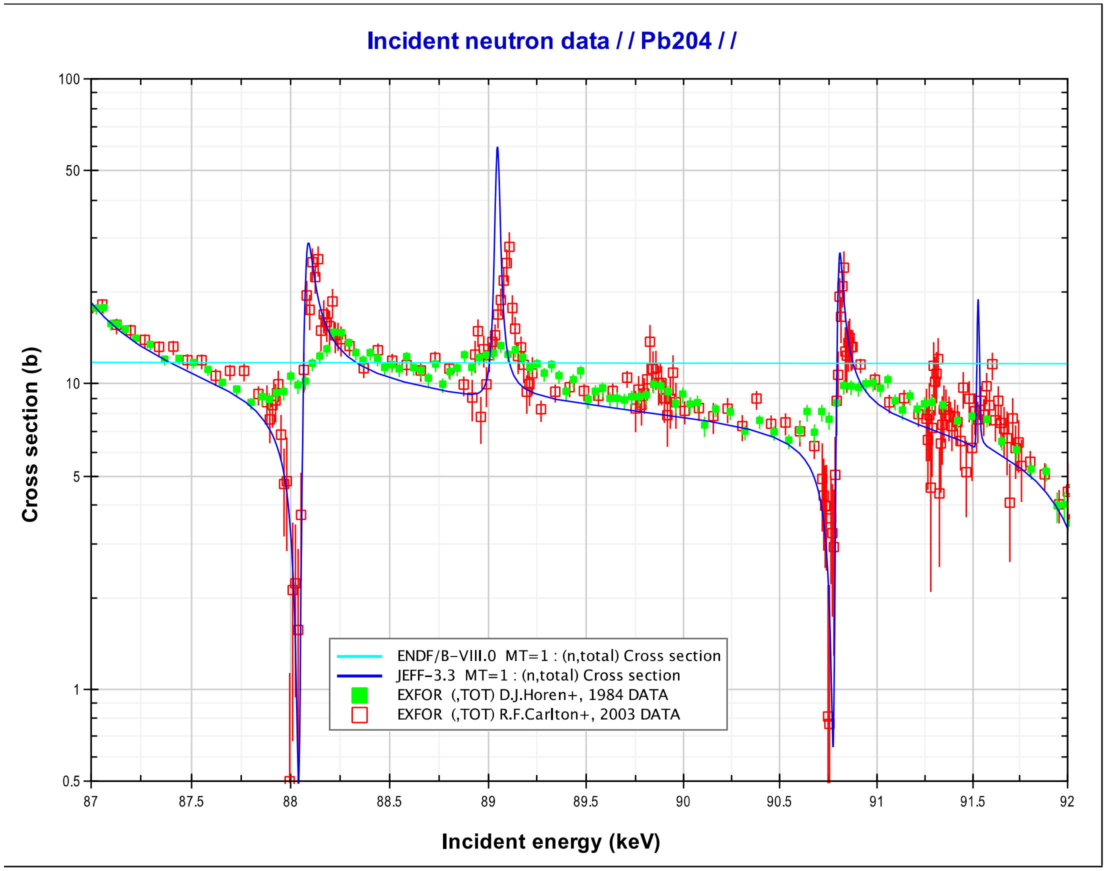
Spin Group Calculation for ^{207}Pb + ^{1}n System

	Spin				
Neutron	½+				
Target	½-				
Total	0-	1-			
Partial wave	Angular Momentum	Spin	Total Angular Momentum		
s-wave	0+	0-	0-		
		1-	1-		
p-wave	1-	0-	1+		
		1-	0+	1+	2+
d-wave	2+	0-	2-		
		1-	1-	2-	3-
f-wave	3-	0-	3+		
		1-	2+	3+	4+

ENDF and JEFF evaluations of ^{204}Pb on differential experimental data of Horen and Carlton

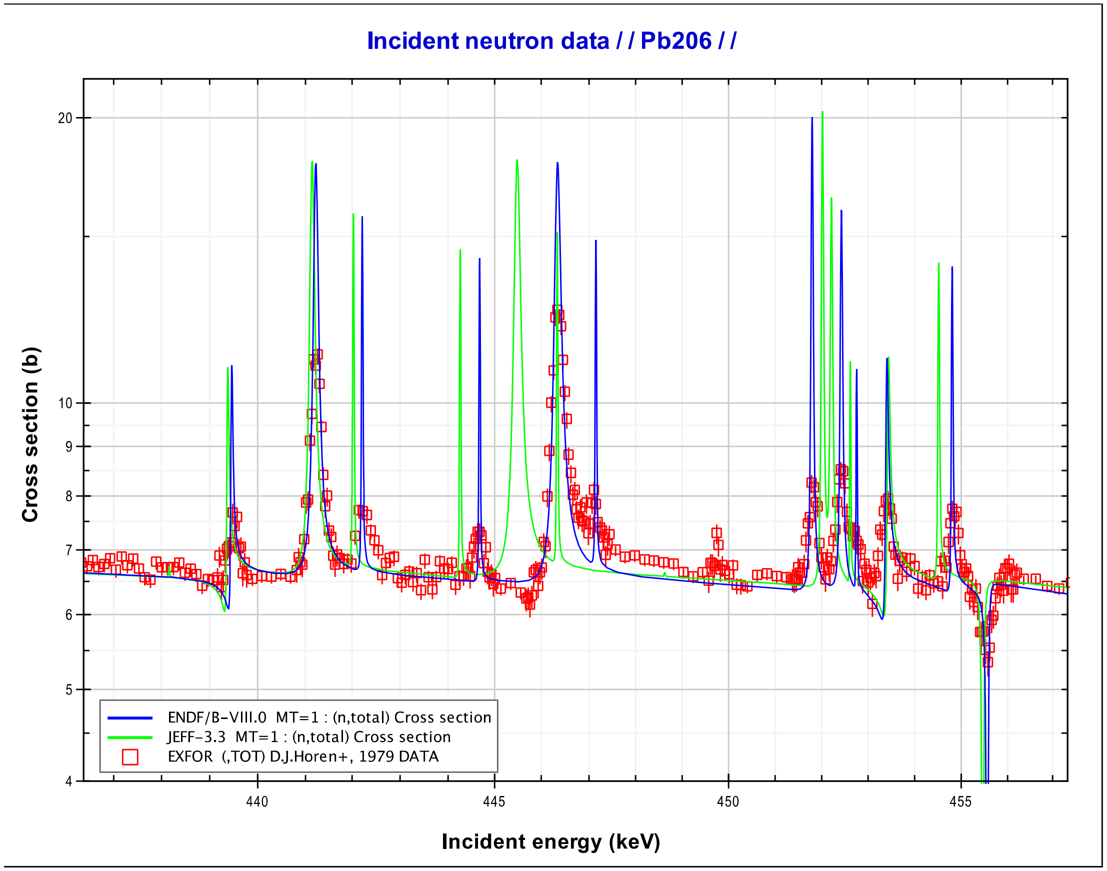


ENDF and JEFF evaluations of ^{204}Pb on differential experimental data of Horen and Carlton



No experimental corrections have been applied to the ENDF and JEFF cross sections; therefore, it appears that the fit to the Horen et al. [15] experimental data is poor.

Plot of the ENDF and JEFF evaluations of ^{206}Pb on differential experimental data of Horen



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Future work (1/2)

- Having the correct spin group structure for ^{207}Pb, we have the foundation to begin a careful reevaluation of the vast amounts of differential data in the EXFOR database.
- Based on the availability and the quality of the differential data, it is the authors' intention to significantly extend the resolved resonance region of the ^{204}Pb evaluation and to increase the upper energy limit of the resolved resonance range in ^{206}Pb and ^{207}Pb to at least the limit in the Atlas.
- Having the proper spin group structure will allow important resonance parameter statistics, such as the Wigner distribution, the Porter Thomas distribution, and the Dyson Mehta Δ_3, to be kept track of.
- Angular distributions of neutron scattering from lead play an important role in practical applications. For this reason, in the reevaluation of the resonance region, the authors plan to develop high-fidelity angular distributions based on the resonance parameters through the Blatt and Biedenharn formalism.

Future work (2/2)

- Working together to evaluate all of the isotopes of lead simultaneously, will also produce a joint covariance file that will accurately reflect the cross-correlations between the different isotopes of lead that naturally arise for the analysis of non-monoisotopic samples in differential measurements.
- A large body of integral and semi-integral measurements, such as thick sample transmission, are available for validation of the new evaluations of lead. It is the authors' intention to incorporate some of these measurements into the new resonance parameter evaluation with the use of the SAMINT code. An independent set of integral experiments will be kept as a cross validation set to evaluate the improvement in the performance through the inclusion of integral experiments.

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