Multi-isotope Experimental Validation of Calorimetric Electron Capture Spectral Theory

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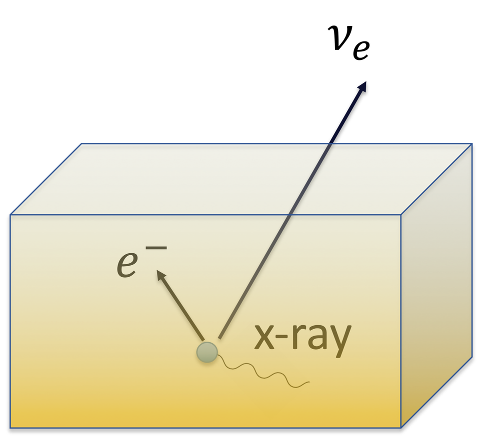
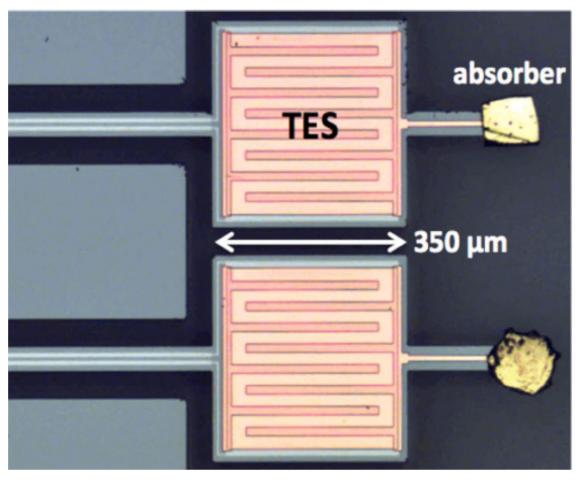
LA-UR-19-26573

Motivation

Electron capture is a 2-body reaction. A measure of the excited atom's energy is a measure of the neutrino's energy.

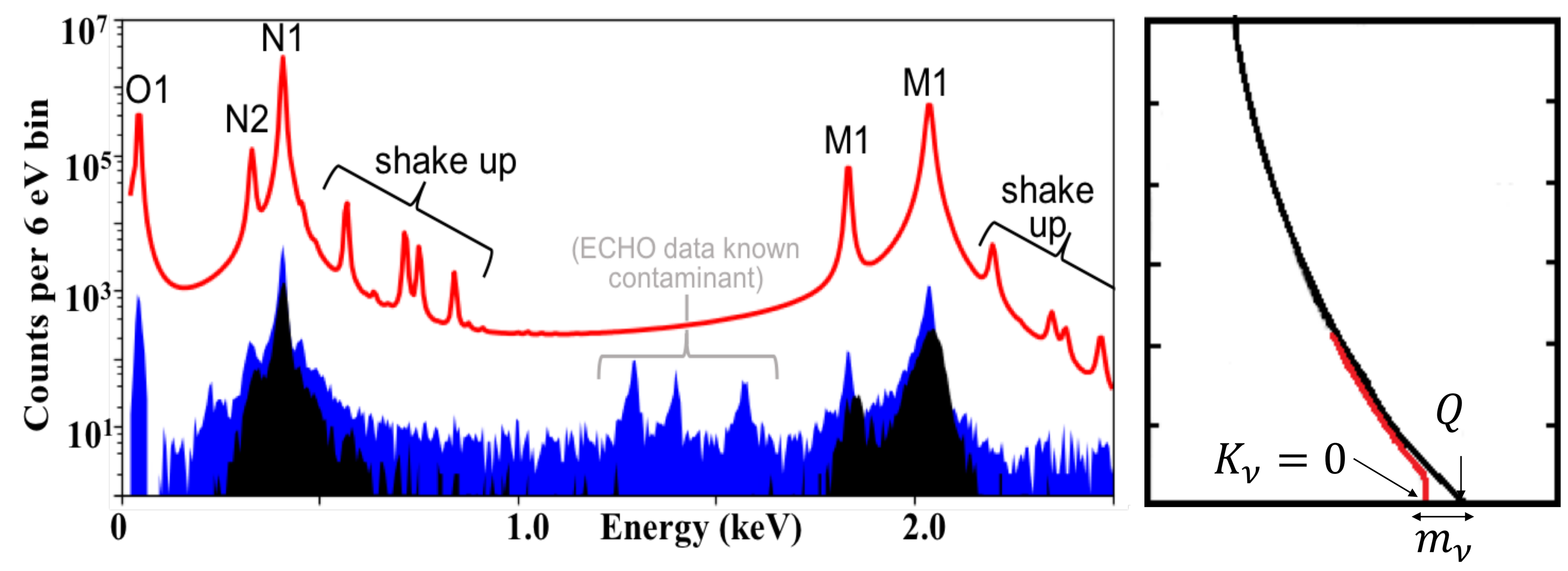
$$^{163}\text{Ho} \rightarrow {}^{163}\text{Dy}^* + \nu_e \rightarrow {}^{163}\text{Dy} + \nu_e + \underbrace{(\text{electrons, photons, phonons})}_{E_{atom} = Q - E_\nu}$$





The advantage of a calorimetric measurement (conceptual drawing at left): no need to know fluorescent yield, because all atomic decay energy is thermalized and measured as heat. Microcalorimeter Transition Edge Sensors (right) provide the required energy resolution (< 10eV FWHM at 2 keV) for a kinematic neutrino mass measurement.

The endpoint region is most sensitive to the neutrino mass.
Need a validated theory to extract neutrino mass without systematic uncertainty!

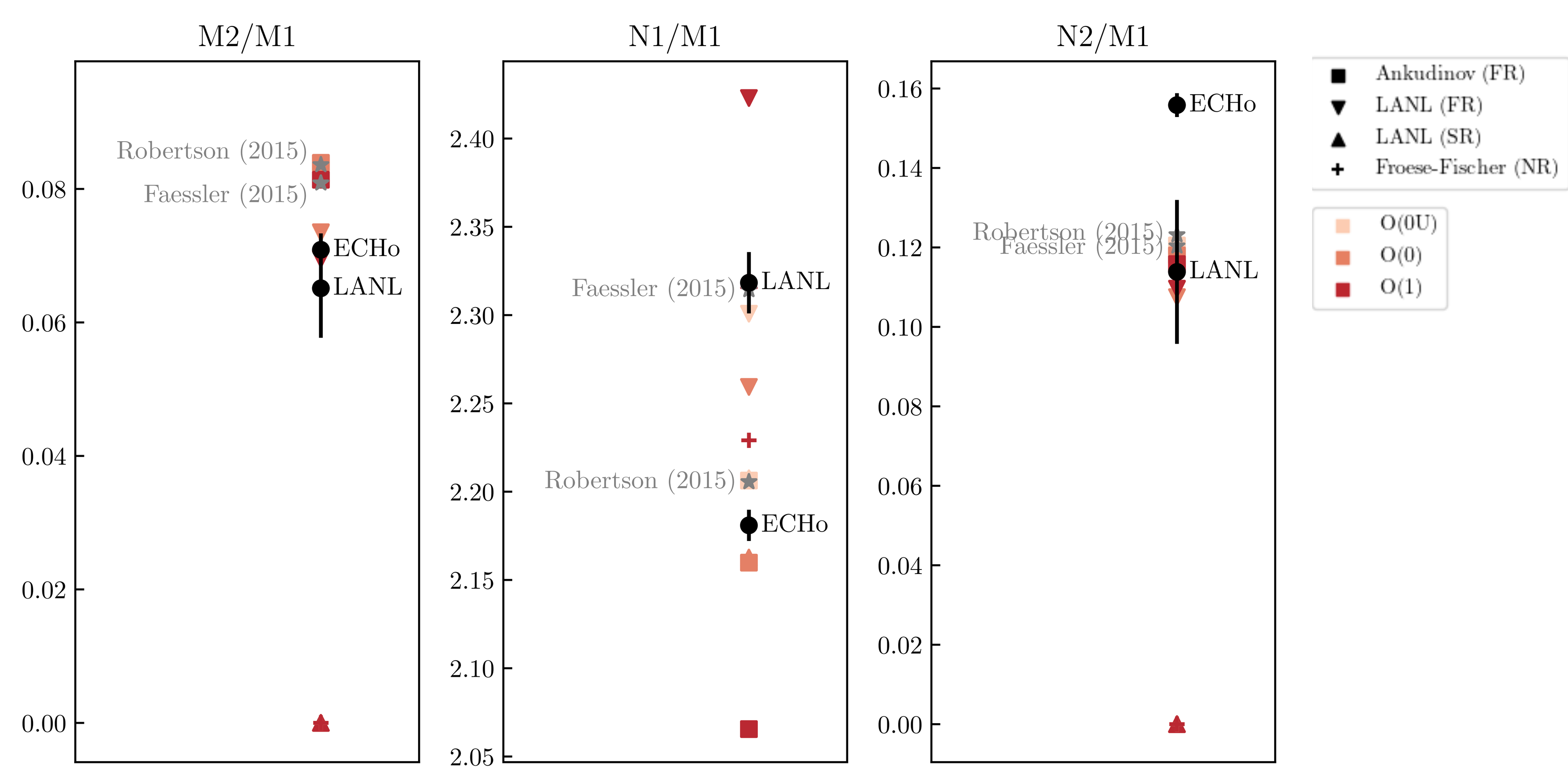


(Left) Theoretically calculated spectrum with 10^7 decays (red) with current ^{163}Ho data (LANL, black. ECHo, blue). (Right) Conceptual drawing of the spectral endpoint, showing sensitivity to the kinematic neutrino mass.

Validating a theory…

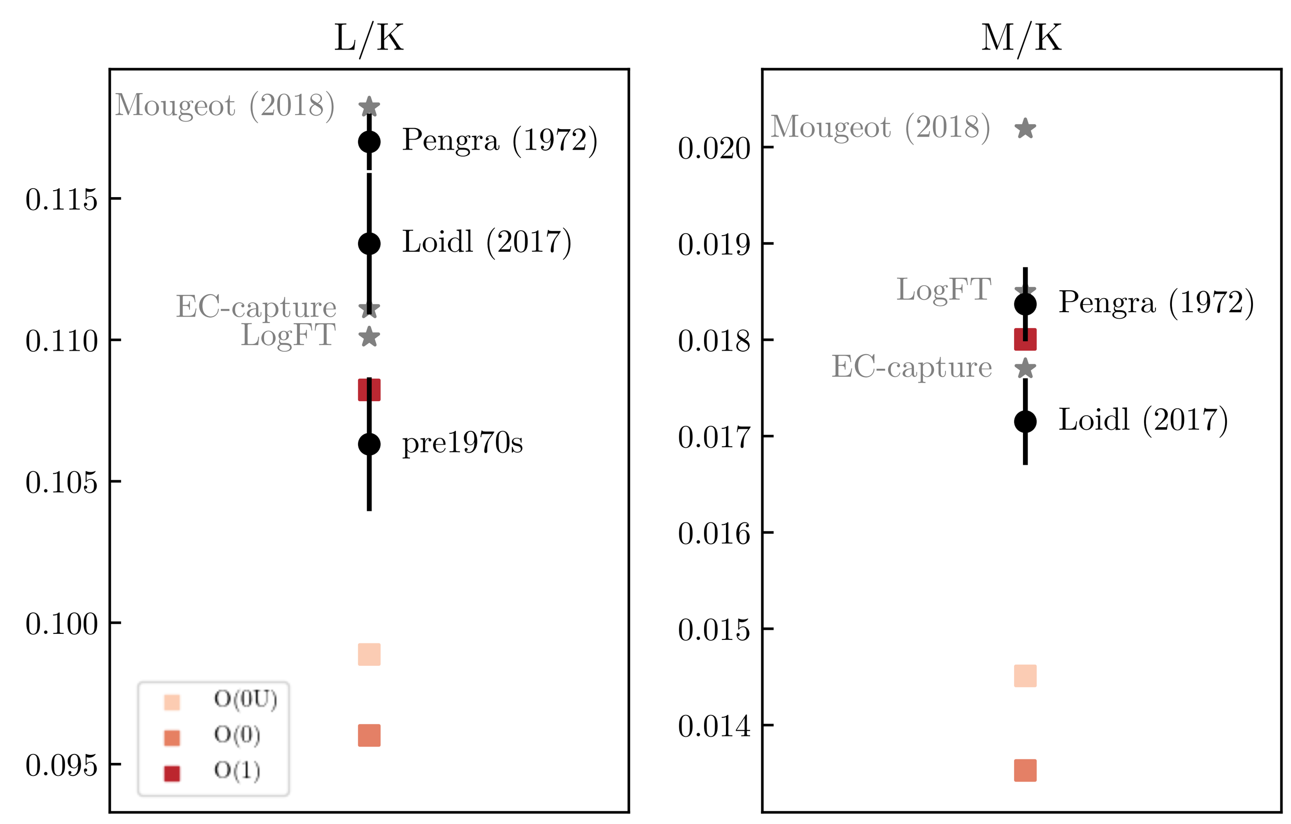
- Comparing theoretical predictions on features far from the end point
- Using theory on other isotopes

Comparisons of Theory and Experimental ^{163}Ho Ratios



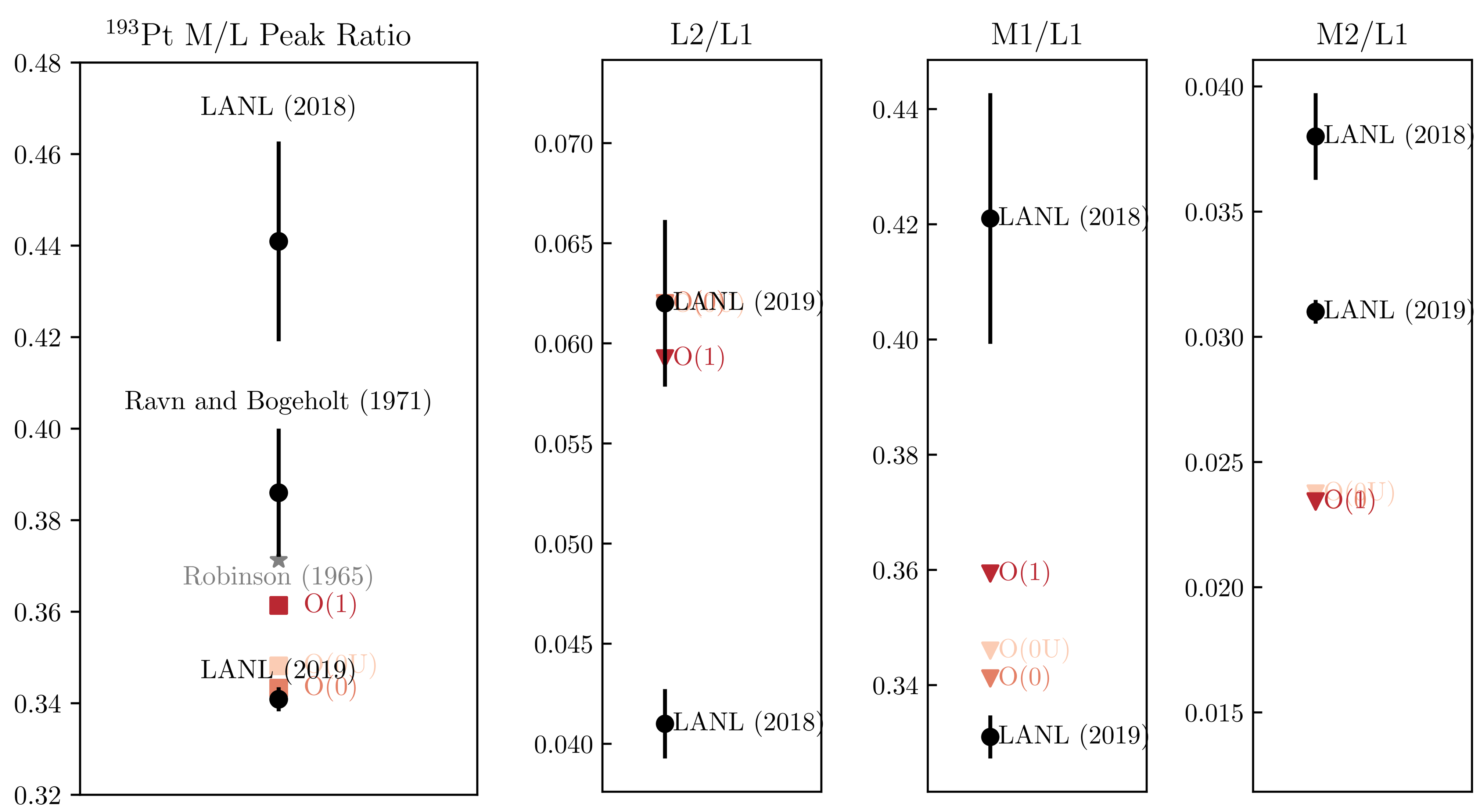
^{163}Ho Peak Ratios are not experimentally well-constrained.
Theoretical calculations of the peak ratios vary significantly based on atomic structure code generating orbital wave functions AND order of antisymmetrization.

Comparisons of Theory and Experimental ^{55}Fe Ratios



Modern ^{55}Fe Peak Ratios agree best with EC-capture calculations.
Better energy resolution → Better theoretical evaluations
L1/K and L2/K instead of L/K

Comparisons of Theory and Experimental ^{193}Pt Ratios



Year	Reference	L partial half-life	Q value	^{193}Pt Source	Notes
1953	Swan, et al. [207]	1 hour – 74 days		X[1]	^{193m}Pt was the object of this research not ^{193}Pt
1956	Naumann [208]	< 100 years		Y[2]	
1969	Hopke and Naumann [209]	620 ± 250 years	60.8 ± 3 keV	Y	This reference tells us to disregard values from [210]
1971	Hopke and Naumann [211]	94 ± 30 years		Y	Half-life calculation dependent on 60.8 ± 3 keV Q-value
1971	Ravn and Bogeholt [205]	73 ± 9 years		Y	
1983	Jonson, et al. [212]		56.6 ± 0.3 keV	Z[3]	This reference quotes 56.6 ± 0.3 keV in the text and 56.3 ± 0.3 keV in the abstract
1988	Babu and Rao [213]		54.5 ± 4.3 keV	Y	This work reanalyzes data from [209]

[1]Platinum foils (0.012% ^{190}Pt, 0.8% ^{192}Pt, 32.8% ^{194}Pt, 33.7% ^{195}Pt, 25.4% ^{196}Pt, 7.2% ^{198}Pt) subjected to gamma irradiation.
[2]^{192}Pt-enriched sample irradiated at Materials Testing Reactor at Arco, Idaho for 6 months
[3]Platinum extracted from the 1-kg lead target used at the ISOLDE facility at CERN

Q value of ^{193}Pt EC must be better known. Varying Q by 10% can change a theoretical calculation by 6%.