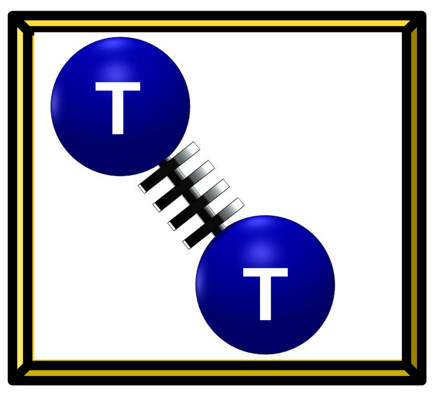
Understanding the Systematic Contribution from the KATRIN Rear Wall

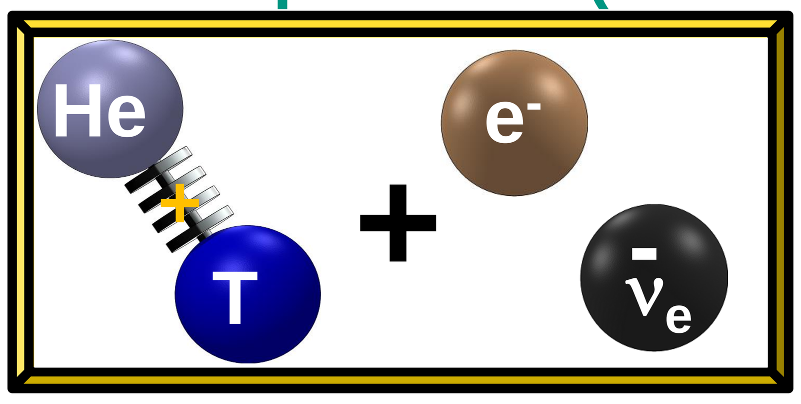
Byron A. Daniel*[1], Max Aker[2], Dominic Batzler[2], Gen Li[1], Kirsten McMichael[1], Shailaja Mohanty[2], Diana Parno[1], Rudolf Sack[2], Magnus Schlösser[2], Alessandro Schwemmer[3]
for the KATRIN Collaboration
[1]Carnegie Mellon University, [2]Karlsruhe Institute of Technology, and [3]Technical University of Munich *presenter email address: bdaniel@andrew.cmu.edu

KArlsruhe TRItium Neutrino Experiment (KATRIN) Direct Measurement of the Neutrino Mass



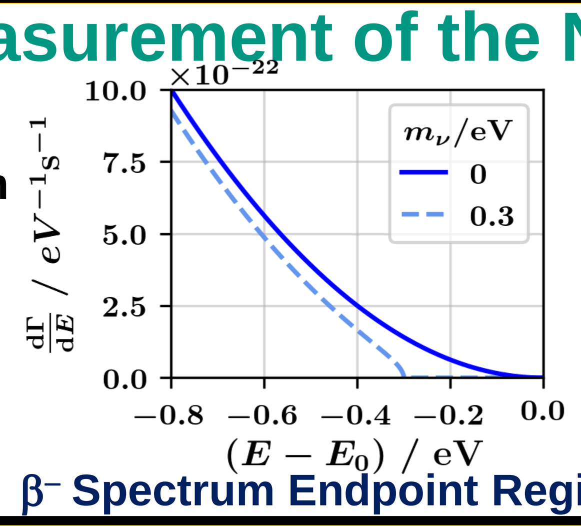
Molecular Tritium

Gaseous tritium undergoes β^- decay.



Molecular Tritium Decay Products

KATRIN measures the energy spectrum of the β^- near the endpoint.



β⁻ Spectrum Endpoint Region

The spectral shape near the endpoint is analyzed to determine the neutrino mass signature.

$m_\nu < 0.8$ eV/c^2 (90% C.L.)

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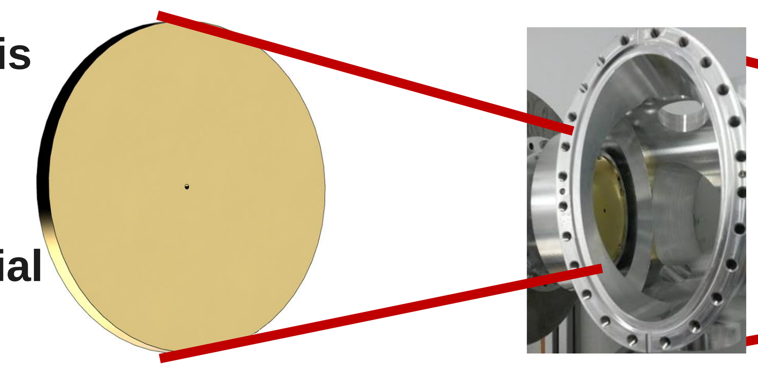
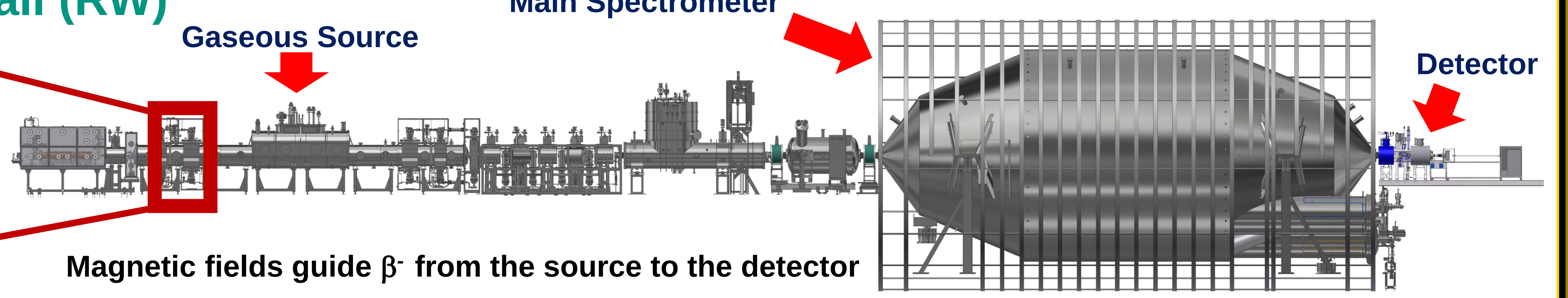
Introduction to the KATRIN Rear Wall (RW)

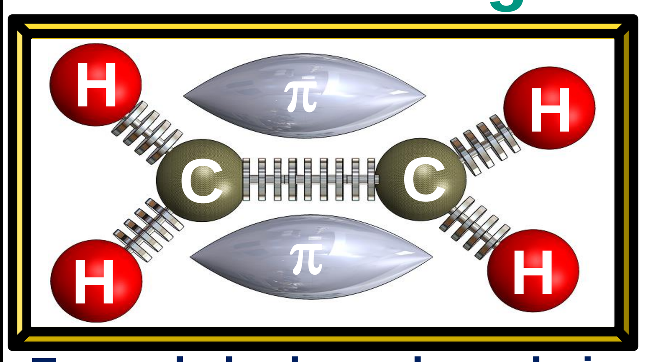
A bias voltage is applied to the RW to help to control the starting potential of electrons in the gaseous source.


Gold RW Surface The Rear Wall (RW)



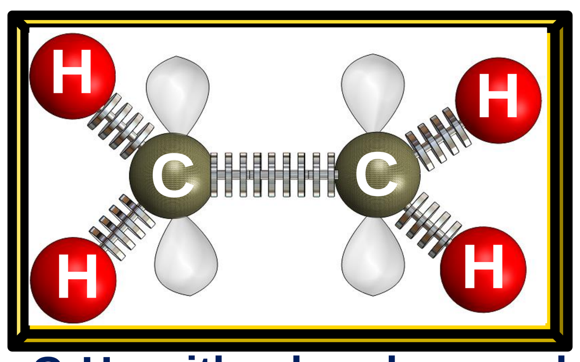
Magnetic fields guide β^- from the source to the detector

A Possible Origin for the RW Systematic



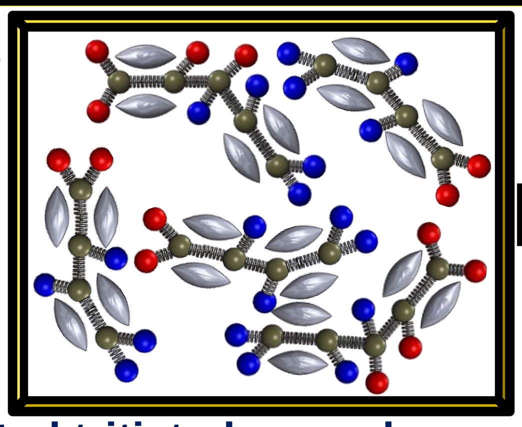
Example hydrocarbon chain (C_nH_m) pre-existing on RW

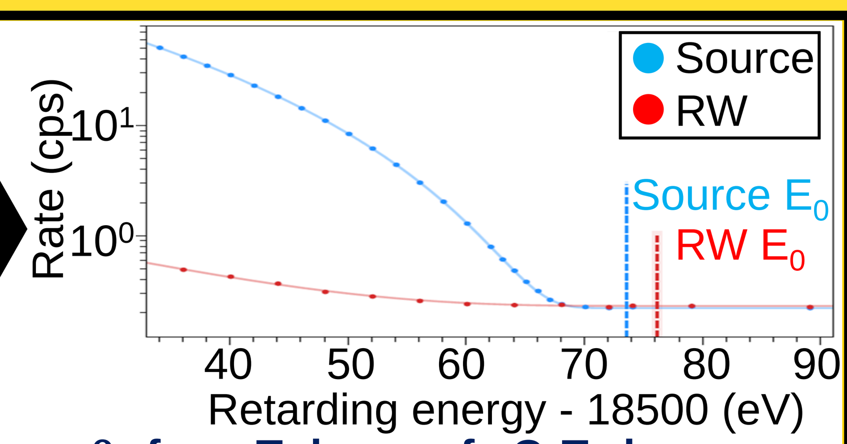
During KATRIN operations, electrons bombard the unknown C_nH_m, breaking the π-bonds and the C_nH_m.



C_nH_m with π-bond opened by electron bombardment

Tritium bonds to the newly opened π-bonds resulting in amorphous structure.

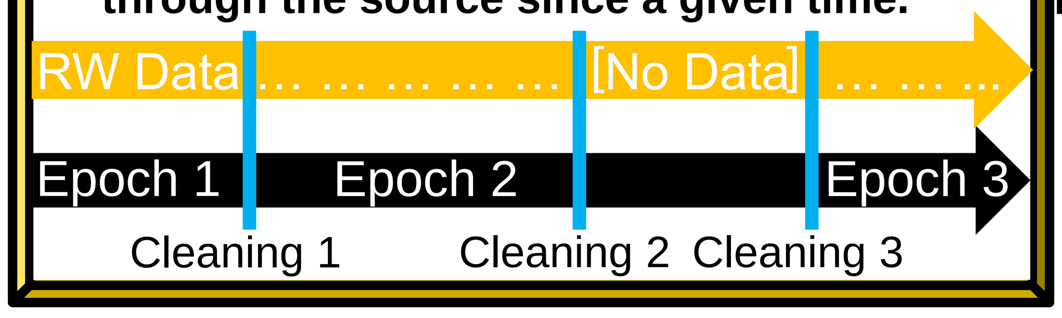

Newly created tritiated amorphous hydrocarbon (aC_nT_m) on RW



β^- from T decay of aC_nT_m have a different spectrum than β^- from source

Analyzing RW Systematic via Measuring the Rate and Spectrum from RW β^- Events

- We divide our RW data into epochs between surface cleanings with UV and ozone.
- Integral flow is the total tritium circulated through the source since a given time.



- RW rate measurements are performed whenever there is no tritium in the gaseous source (e.g., between KATRIN Neutrino Mass Campaign "KNM" etc).
- For these measurements, we count the rate above a fixed retarding energy threshold.
- From these measurements, we found the RW rate has a predictable growth during epochs.

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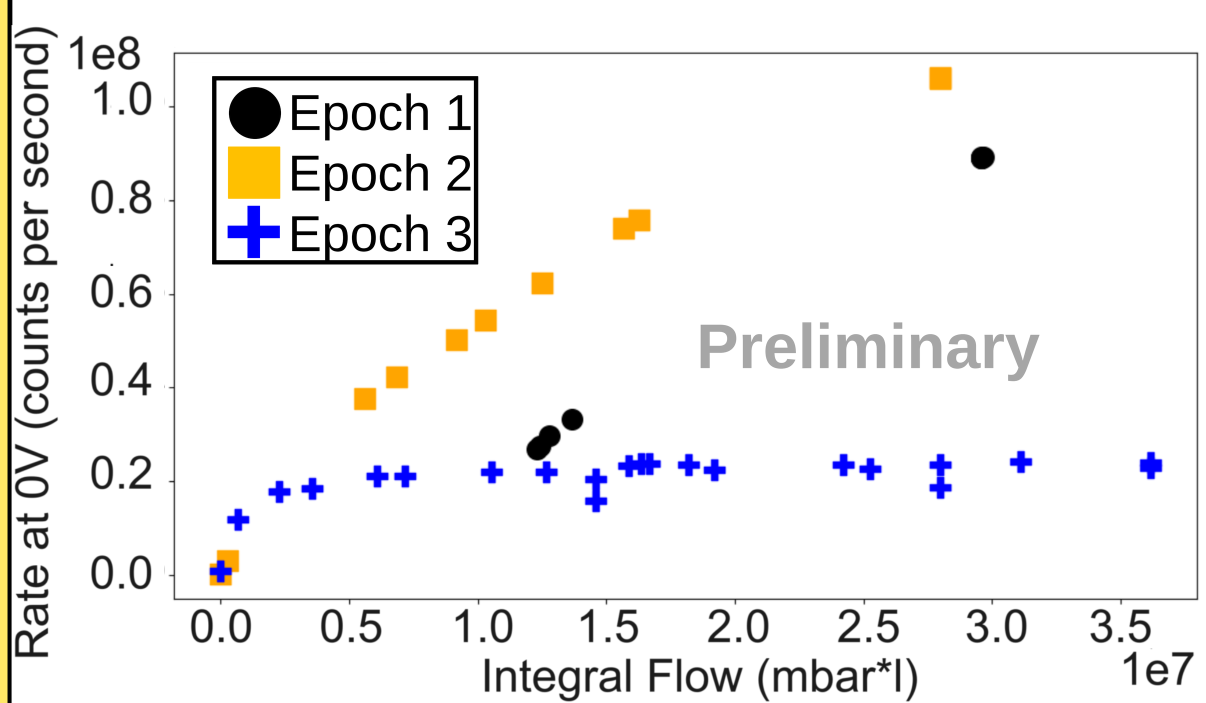
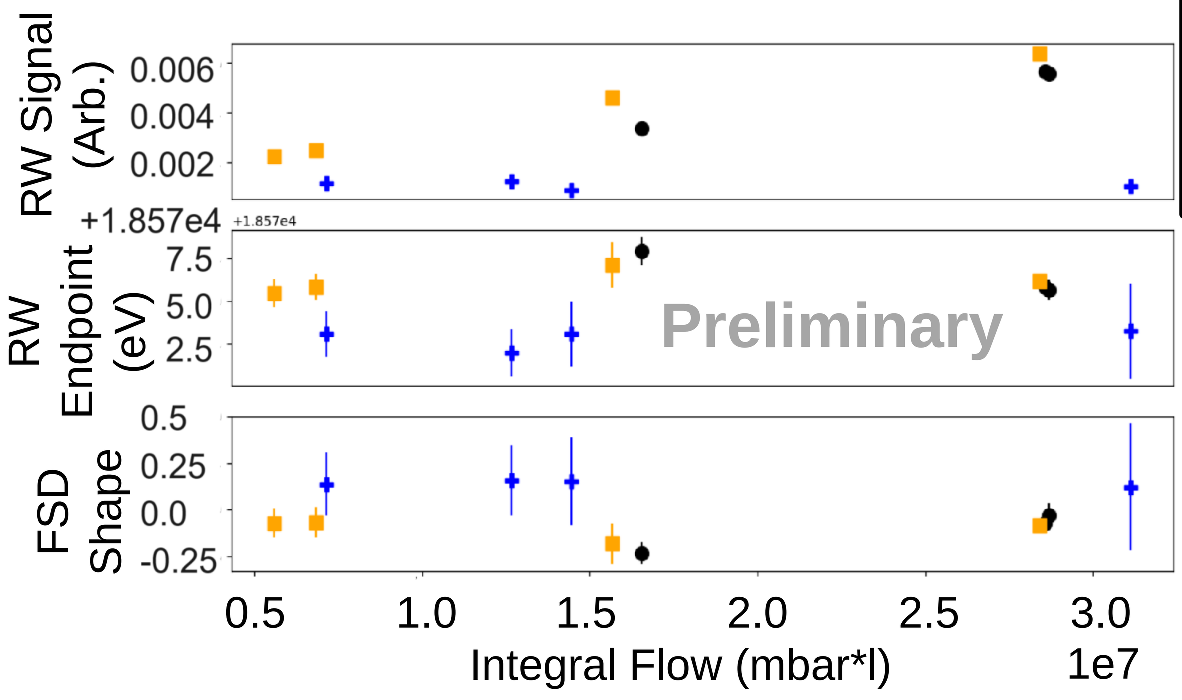
- RW spectrum measurements are performed by varying the retarding energy threshold to scan the RW β^- spectrum and then fitting a model to that RW β^- spectrum.
- Our goal is to find a minimal set of parameters for the RW spectrum model.
- The RW spectrum parameters are signal, endpoint, and FSD shape.
- The FSD shape compares the Final State Distribution (FSD) of the RW substance to that of T_2.



Evolution of the RW rate

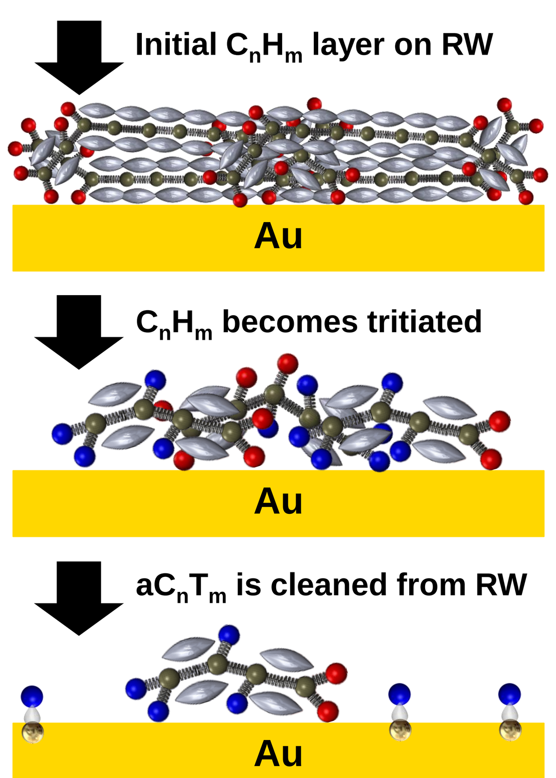


Evolution of the RW spectrum

- The RW rate and signal have consistent behavior across epoch 1 and 2.
- In epoch 3, the RW signal and rate are lower and more stable than in epochs 1 and 2.
- The RW endpoint and FSD shape have -0.96 correlation coefficient.

How Can We Model the RW Contaminant?

Non-Mitigated RW Surface(s)



Mitigated RW Surface

- Possible Model: A big, initial C_nH_m layer that *later* saturates with tritium.

1. Tritium bonds to the open pi bonds in the C_nH_m creating aC_nT_m.
2. UV and ozone cleaning removes the chemisorbed tritium and some of the aC_nT_m beneath (*Fusion Science and Technology* 80.3-4 (2024): 303-310.).
3. The aC_nT_m has been almost removed. We see that there is limited accumulation of tritium activity (T adsorbs poorly on Au).

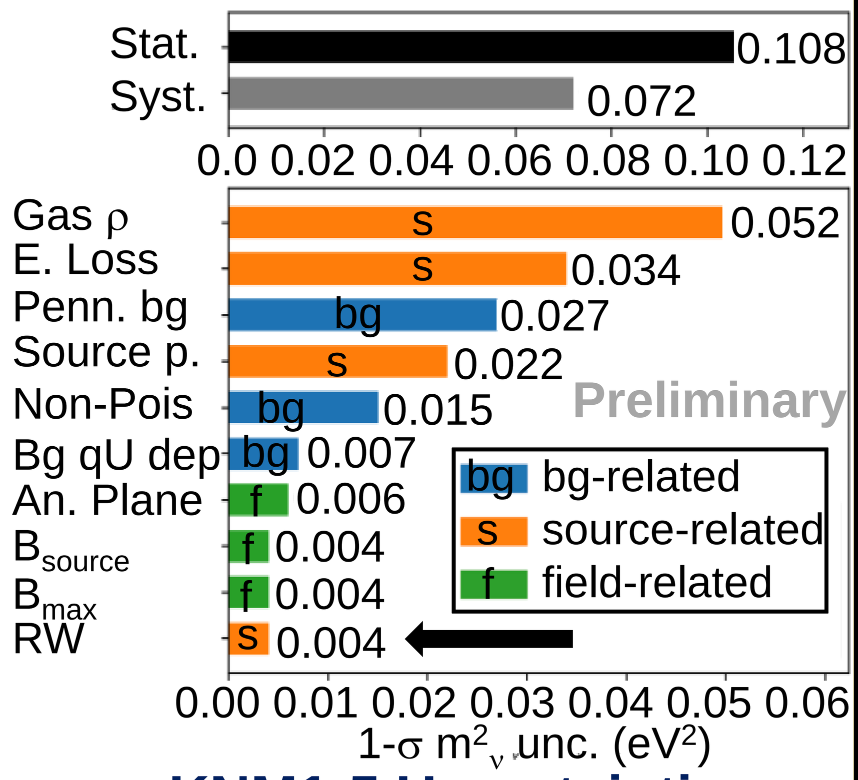
Conclusions and Further Studies:

Conclusion:

- The RW tritium spectrum has a systematic effect on the neutrino mass which can be addressed by including the RW spectrum in neutrino mass fits.
- This systematic effect has been successfully mitigated.

Further Studies:

- We plan to next determine the RW uncertainty for KATRIN datasets post KNM1-5.



KNM1-5 Uncertainties

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