Enhanced Resonant Positron Annihilation due to Nonfundamental Modes in Molecules*

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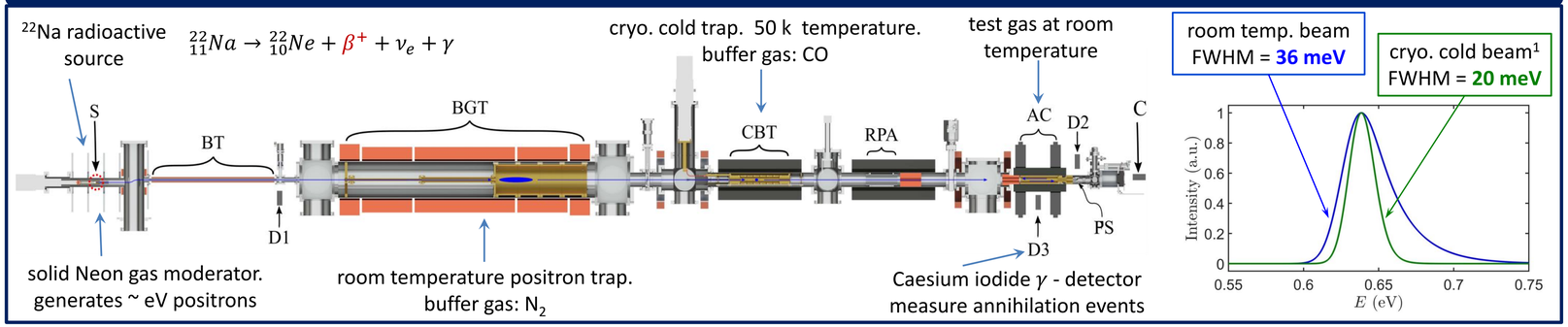
Introduction & Objectives

Here we investigate the low-energy (< 0.5 eV) positron-molecule annihilation spectra.

- ✓ We use detailed knowledge of (i) room temperature beam and (ii) cryogenically cold beam to analyze features of the spectra.
- ✓ We know the dipole and quadrupole interactions of positron with *fundamental vibrational modes* in the molecule as they have been observed.
- ○ The question is, are there any interactions *beyond the fundamental vibrational modes*?

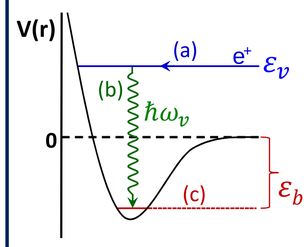
UCSD Slow and Cold Positron Beamline



Positron-Molecule Bound State

An incident positron can excite a vibrational mode and temporarily occupy a bound state in the molecule, leading to enhanced annihilation.

--- known as **V**ibrational **F**eshbach **R**esonances (**VFR**)



(a) e⁺ energy $\varepsilon = \varepsilon_v$

(b) e⁺ excites molecular vibration $\hbar\omega_v$

(c) e⁺ - molecule binding energy ε_b

$$\varepsilon = \varepsilon_v = \hbar\omega_v - \varepsilon_b$$

$\varepsilon_b = 64 \pm 2\ meV$

Gribakin and Lee model[2]

normalized annihilation rate:

$$Z_{eff}^{(res)}(\varepsilon) = c\,\Gamma^a \frac{\Gamma_v^e}{\Gamma^{tot}} f(\varepsilon_v - \varepsilon)$$

a constant — experimental beam distribution

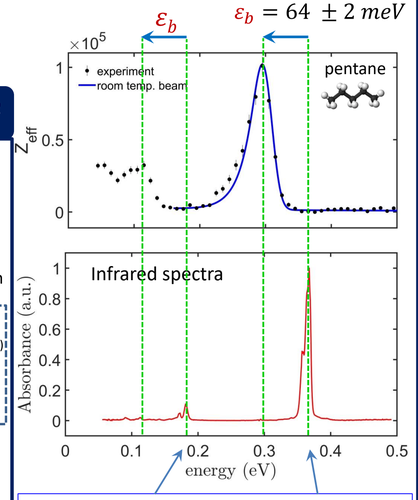
Γ^a, annihilation rate ⇒ depends on ε_b, (constant for a molecule)

Γ_v^e, elastic rate ⇒ depends on mode energy $\hbar\omega_v$ and IR intensity

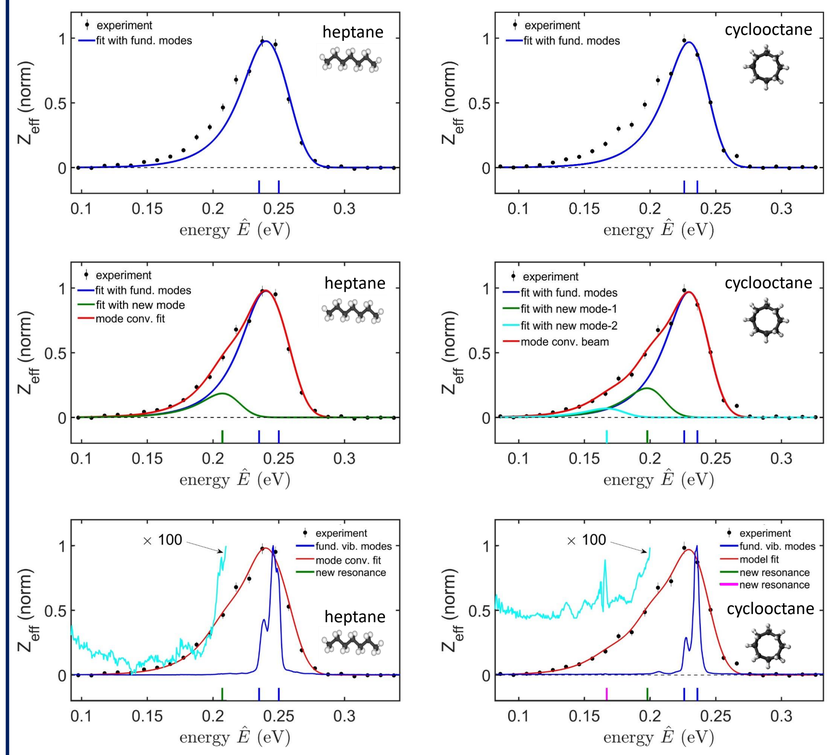
$$\Gamma^{tot} = \Gamma_v^e + \Gamma^a$$

$\Gamma_v^e \gg \Gamma^a$

$\frac{\Gamma_v^e}{\Gamma^{tot}} \approx 1$

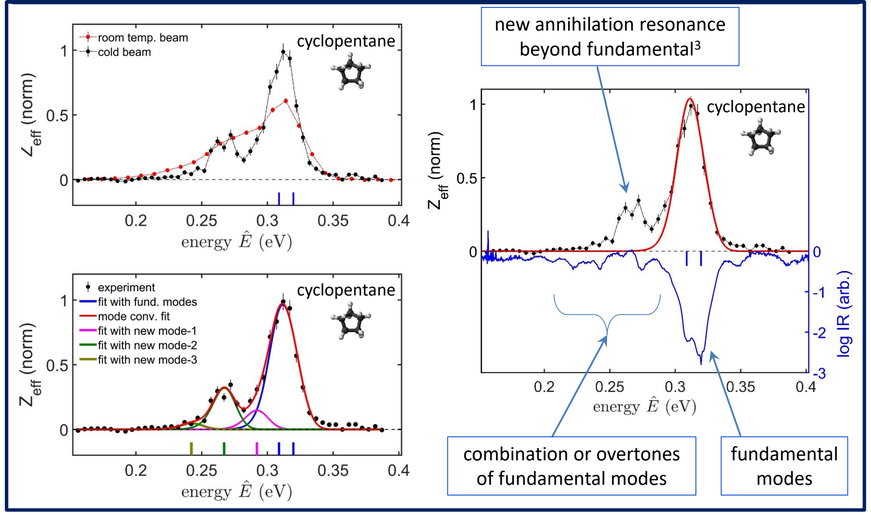


Room Temp. Beam Annihilation Resonances Beyond Fundamental



- IR activity near the New VFR is ~ 100 times smaller than the fundamentals
- But sufficient enough $\left(\frac{\Gamma_v^e}{\Gamma^{tot}} \sim 1\right)$ to produce a resonance

Cryo. Cold Beam Annihilation Resonances Beyond Fundamental



Conclusions and Outlook

- *Enhanced* VFR interactions of positrons with *other than fundamental modes* have been observed.
- Appears to be a *generic effect* – similar features are observed for several molecules, both rings and chains.
- What is the mechanism for the enhanced annihilation?
- New resonances are only near a few specific energies – is there a "selection rule"?

References:

1. M. R. Natisin, J. R. Danielson, and C. M. Surko, Appl. Phys. Lett. 108, 024102 (2016).
2. G. F. Gribakin and C. M. R. Lee, Phys. Rev. Lett. 97, 193201 (2006).
3. S. Ghosh, J. R. Danielson and C. M. Surko, Phys. Rev. Lett., 125, 173401 (2020).

UCSD Positron Group Website: **http://positrons.ucsd.edu/**

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