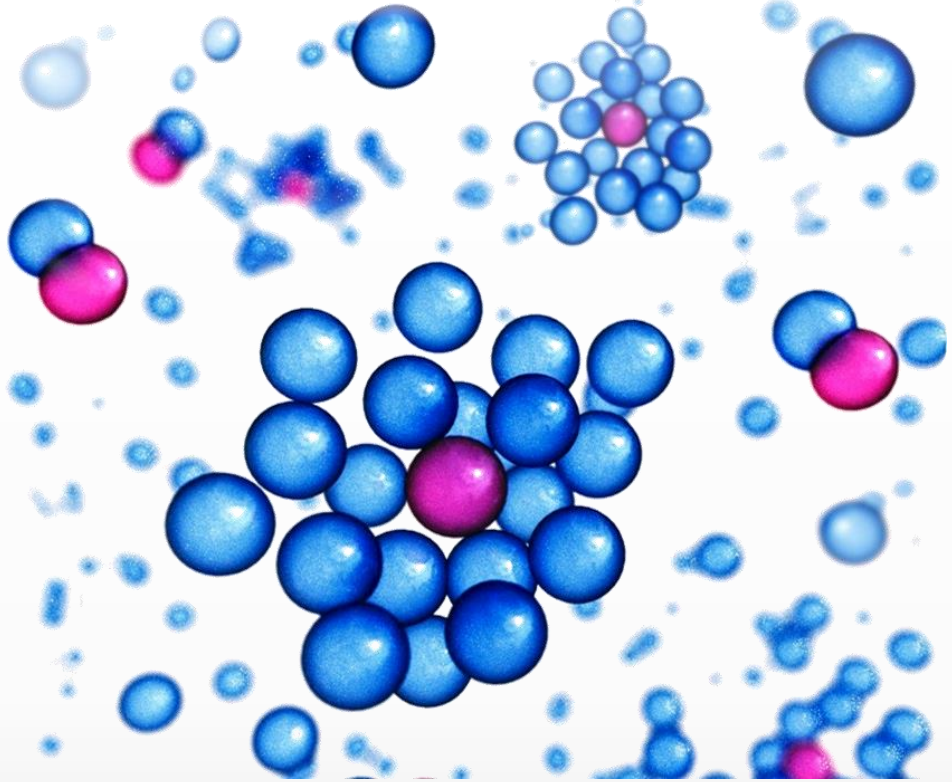

Observation of a Smooth Polaron–Molecule Transition in a Degenerate Fermi Gas

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Oriana K. Diessel, Jonas von Milczewski, Richard Schmidt, Yoav Sagi

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PRX **10**, 041019 (2020)

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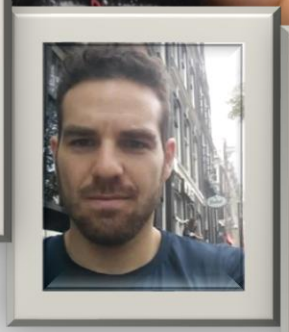


Meny Menashes

Yigal Ilin

Anastasiya Vainbaum

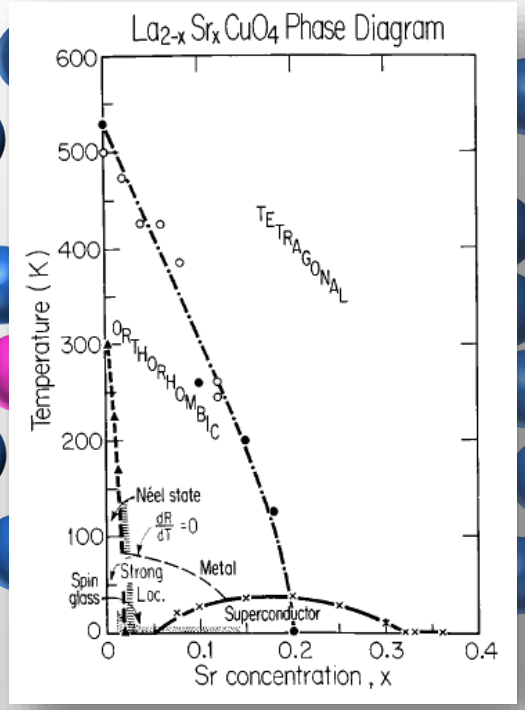
Oded Zilberman

Oriana Diessel

Jonas von Milczewski

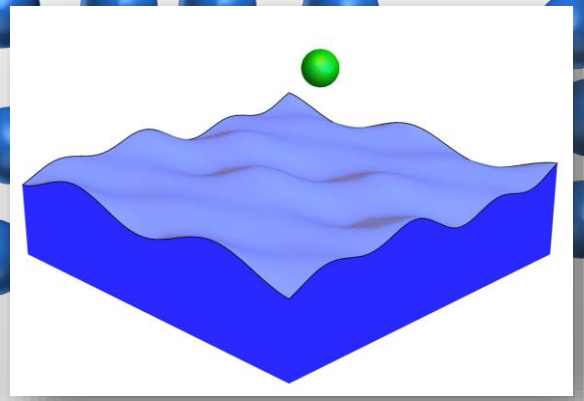
2. Fermi impurity problem

high-T_c superconductors



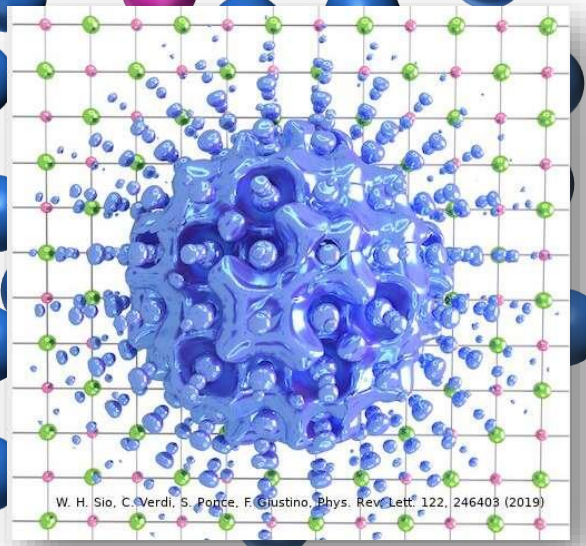
N. F. Mott, JPCM **5**, 3487 (1993)

Helium 3



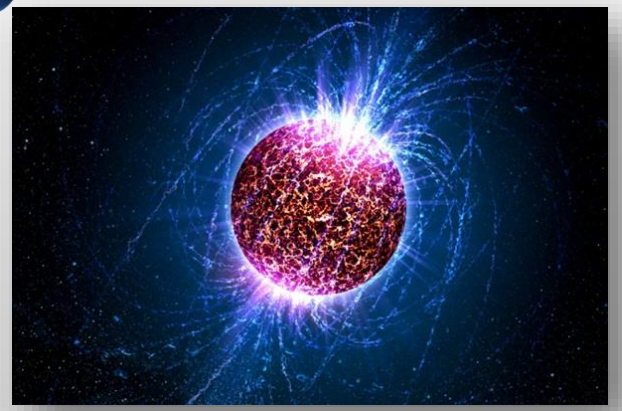
M. I. Dykman, K. Kono, D. Konstantinov, M. J. Lea, PRL **119**, 256802 (2017)

semiconductors



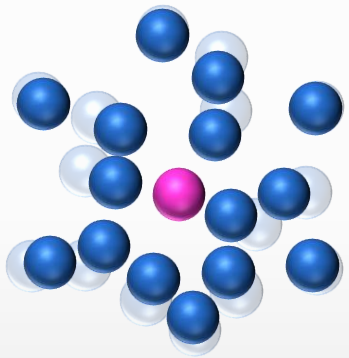
W. H. Sio, C. Verdi, S. Poncé, F. Giustino, PRL **122**, 246403 (2019

neutron stars

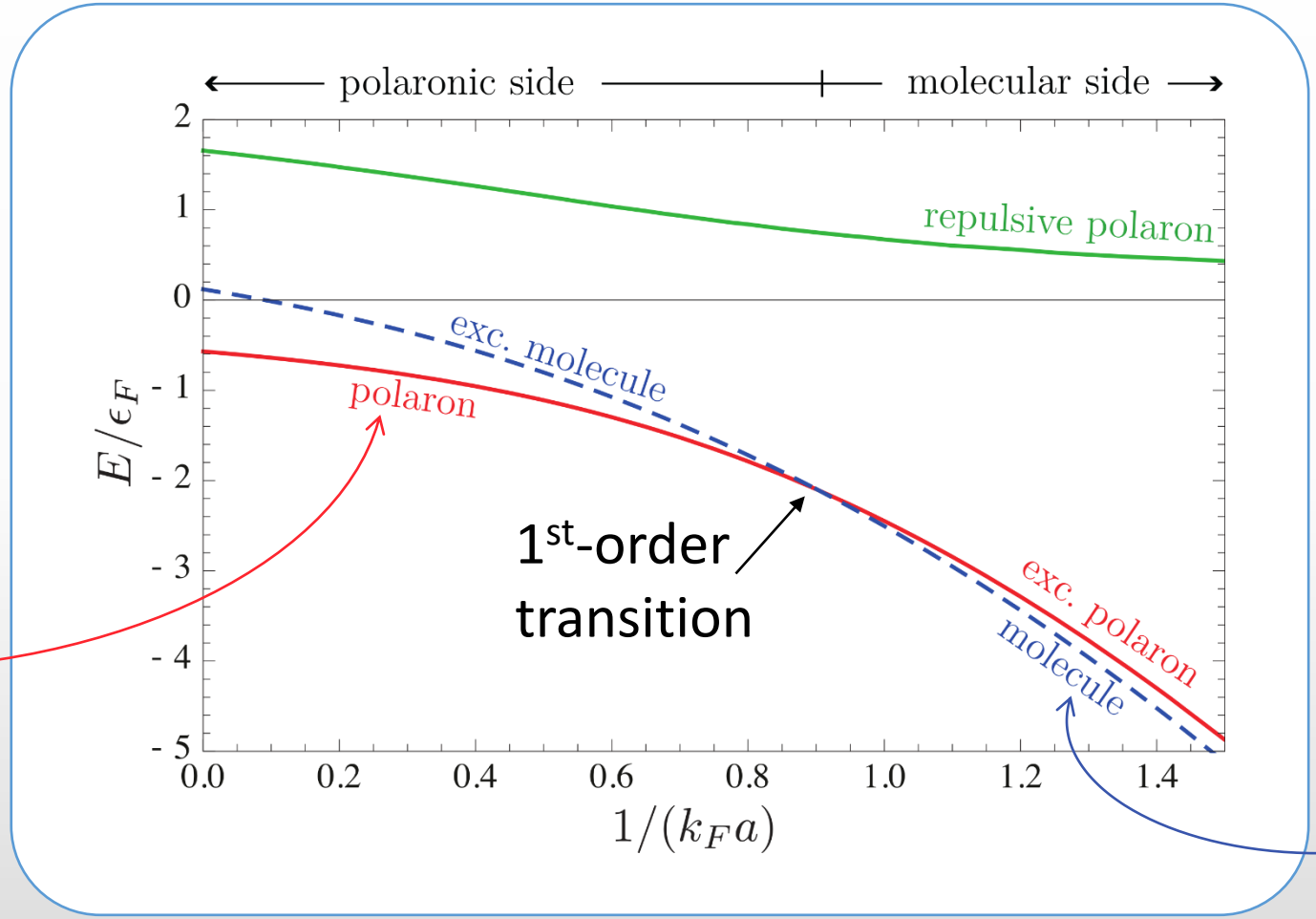


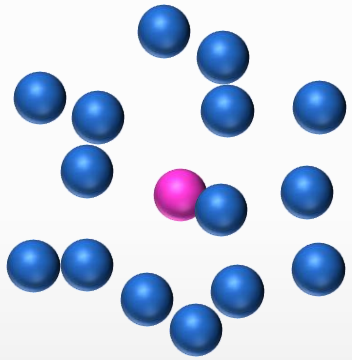
M. Kutschera & W. Wójcik, PRC **47**, 1077 (1993)

2. Fermi impurity problem



polaron



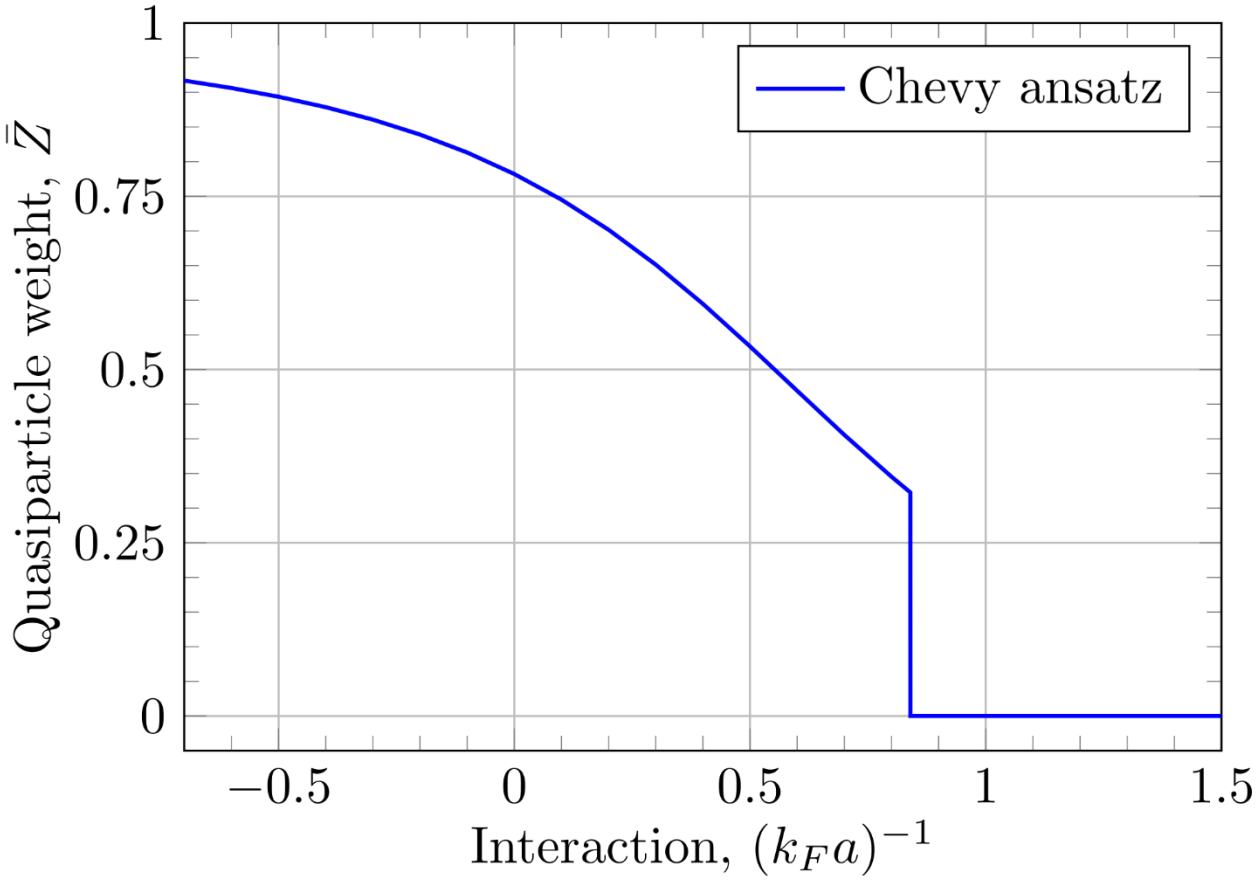


molecule

increasing interaction

N. Prokof'ev & B. Svistunov, PRB **77**, 020408 (2008)
M. Punk, P.T. Dumitrescu, W. Zwerger, PRA **80**, 053605 (2009)
R. Schmidt & T. Enss, PRA **83**, 063620 (2011)

3. Hallmark of the first-order transition



- A. Schirotzek, …, M. W. Zwierlein, PRL **102**, 230402 (2009)
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- M. Cetina, …, E. Demler, Science **354**, 96 (2016)
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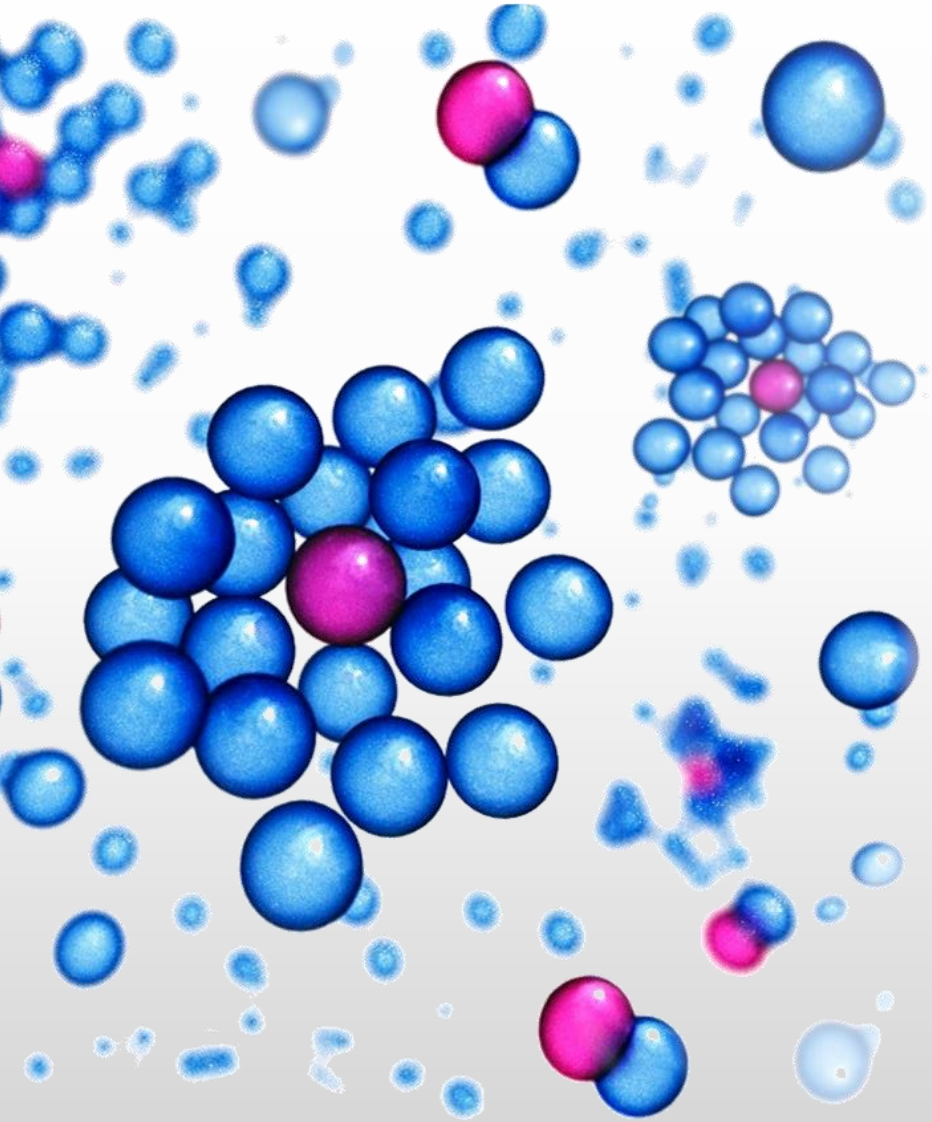
- Z. Yan, …, M. W. Zwierlein, PRL **122**, 093401 (2019)

F. Chevy, PRA **74**, 063628 (2006)
M. Punk, P.T. Dumitrescu, W. Zwerger, PRA **80**, 053605 (2009)

4. Observation of a smooth transition



We developed:

- Raman spectroscopy with high-sensitivity fluorescence detection
- Theoretical model of many impurities at $T > 0$

We found:

- Finite impurity density leads to a smooth transition
- Finite temperature enhances this effect
- Polarons and molecules coexist around the transition

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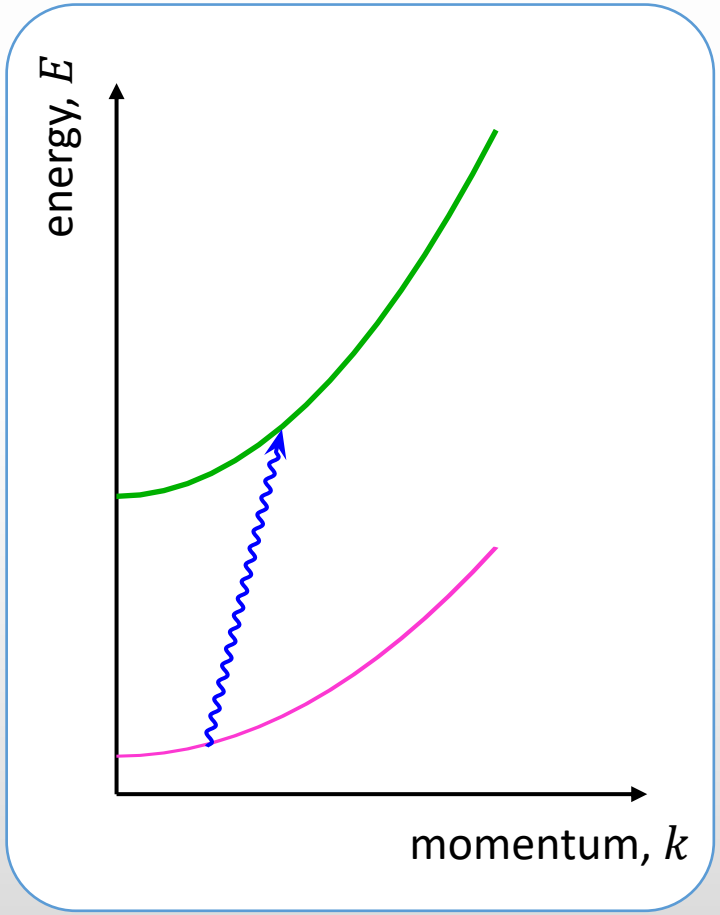
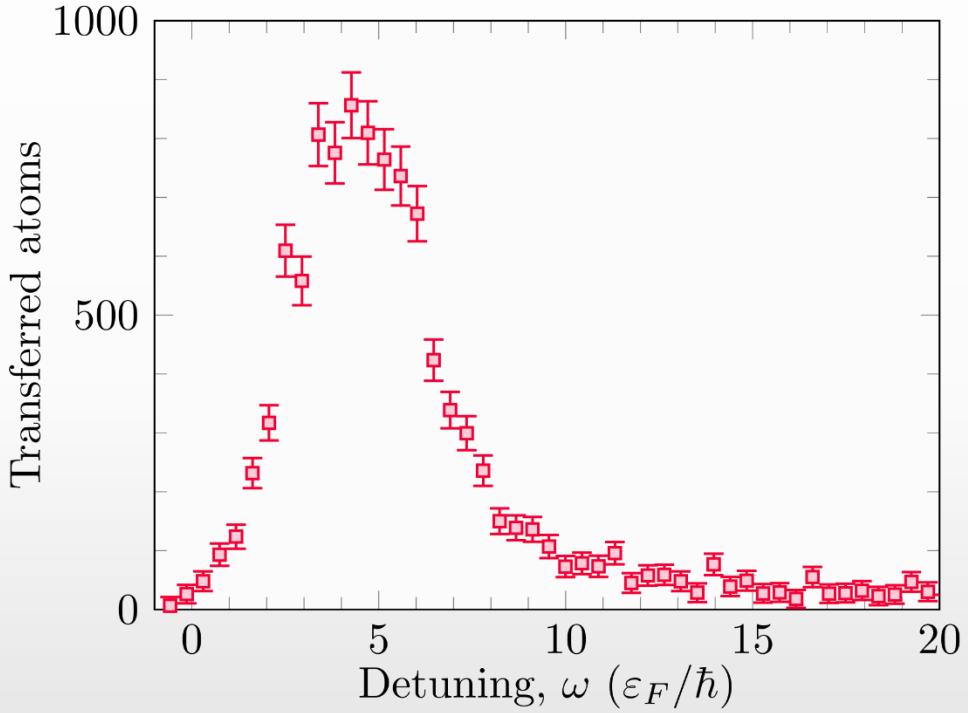
5. Raman spectroscopy

with high-sensitivity fluorescence detection





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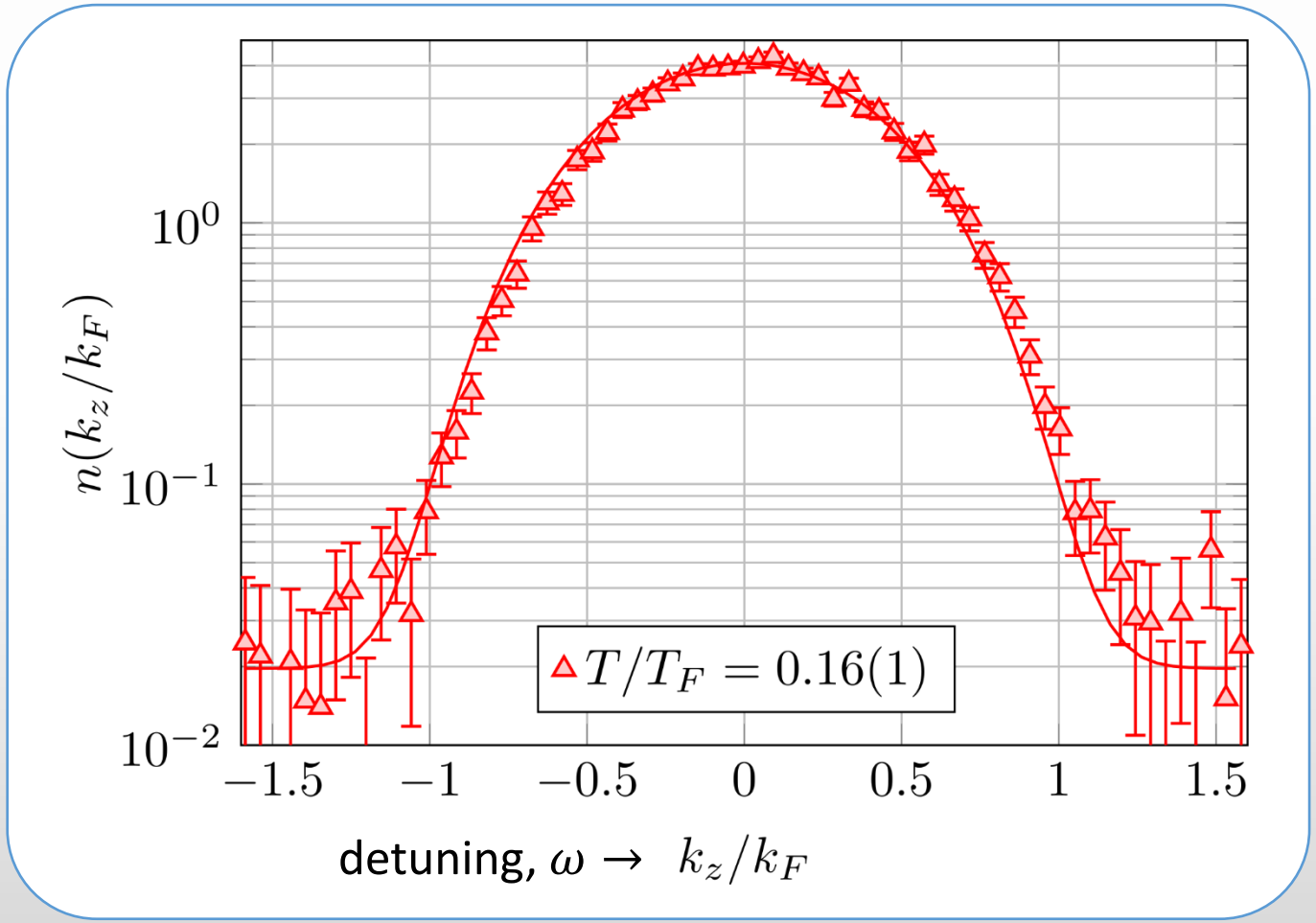
5. Raman spectroscopy

of weakly-interacting atoms



For weakly-interacting atoms:

$$\hbar\omega = \frac{2\hbar^2}{m}\left(\bar{q}^2 + \bar{q}k_z\right)$$

Raman spectrum reveals the momentum distribution

in situ

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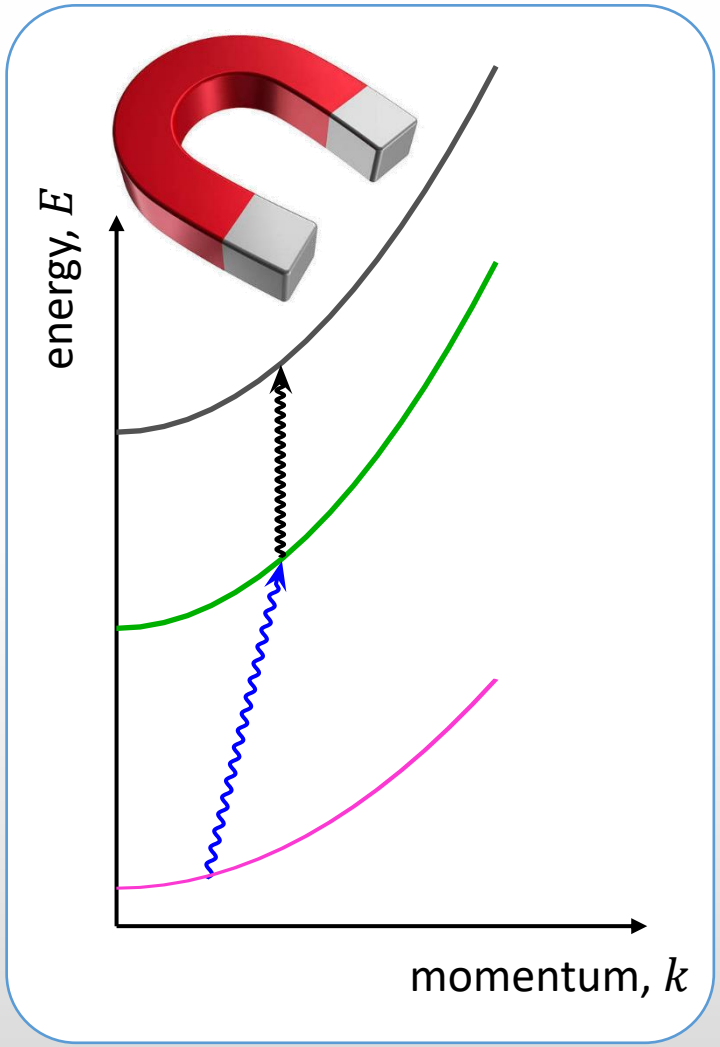
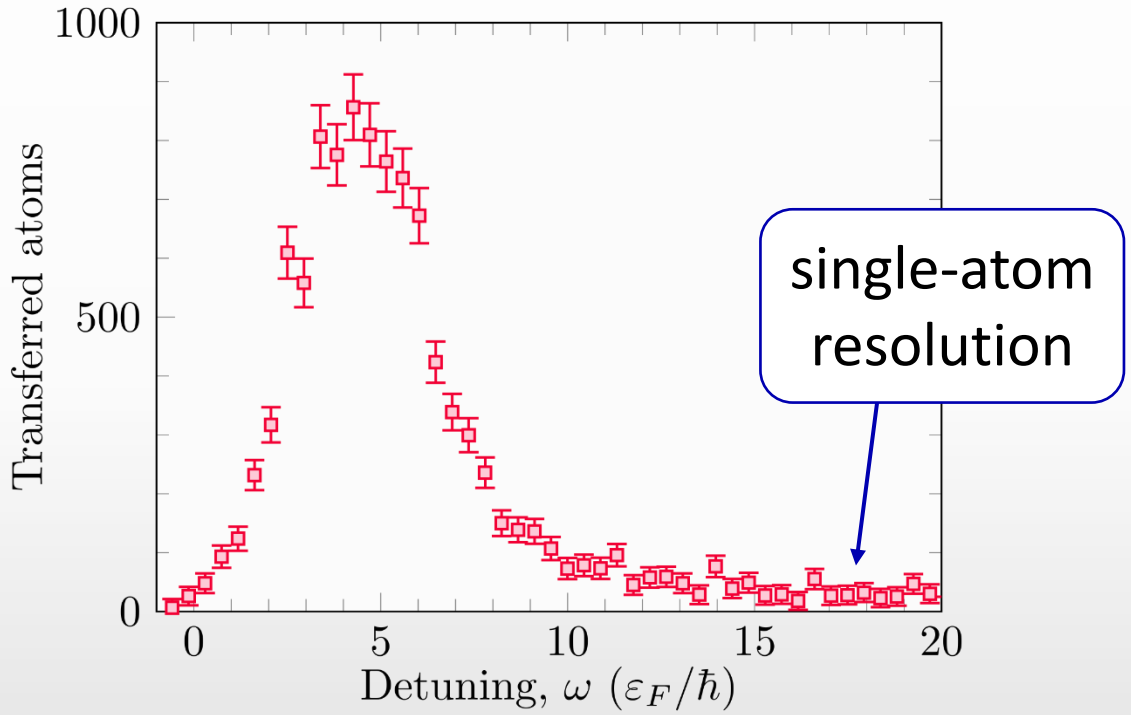
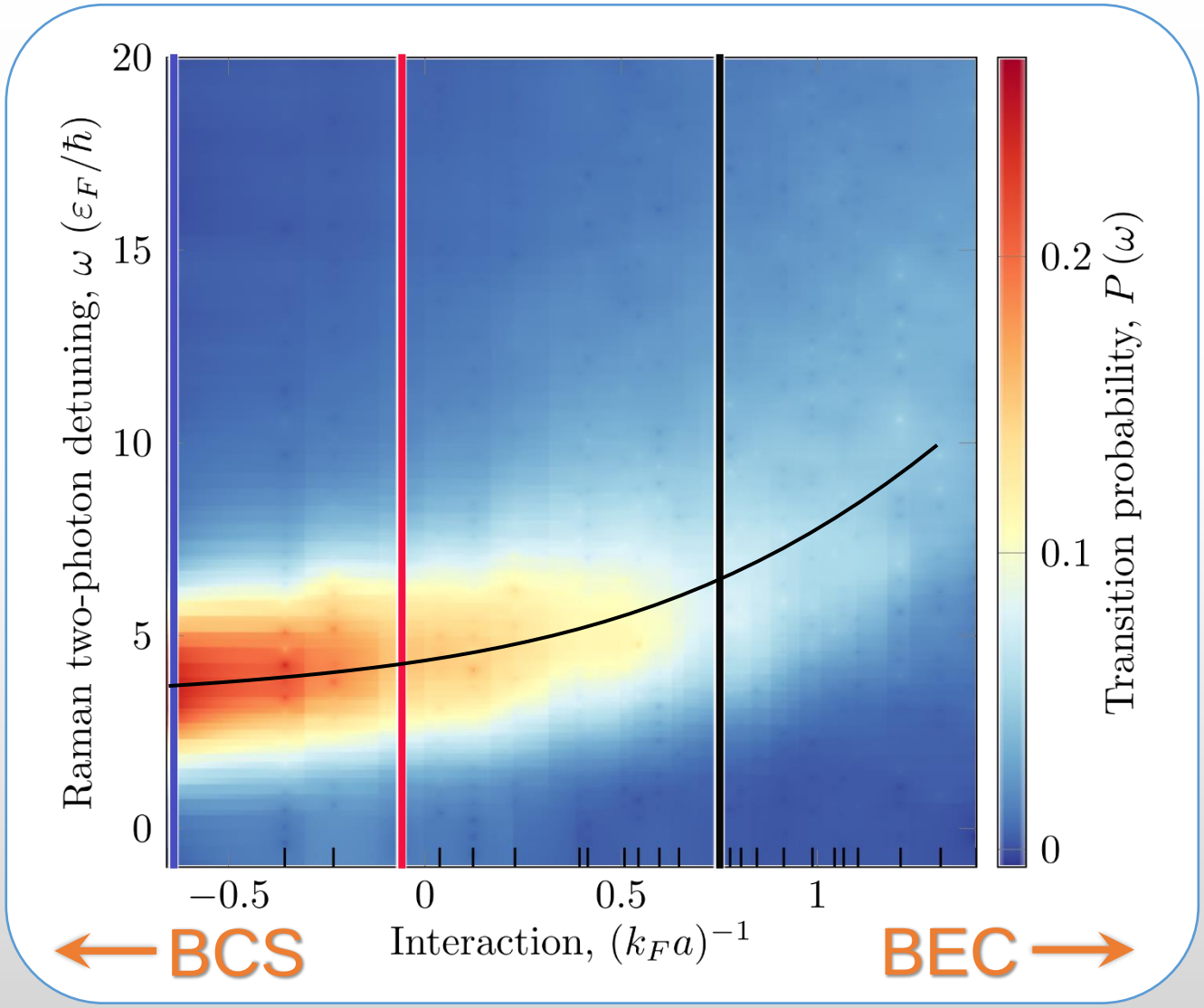
6. High-sensitivity Raman spectroscopy

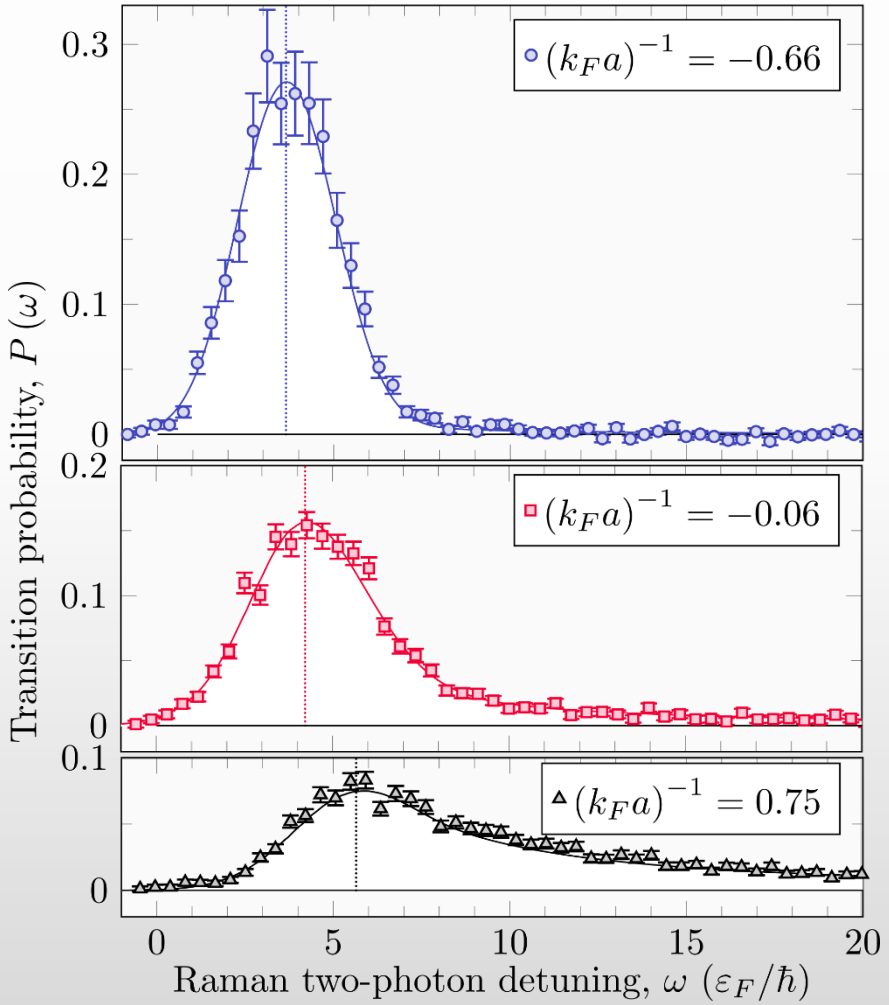




C. Shkedrov, Y. Florshaim, GN, A. Gandman, Y. Sagi, PRL **121**, 093402 (2018)

7. Raman spectroscopy of strongly-interacting imbalanced Fermi gas





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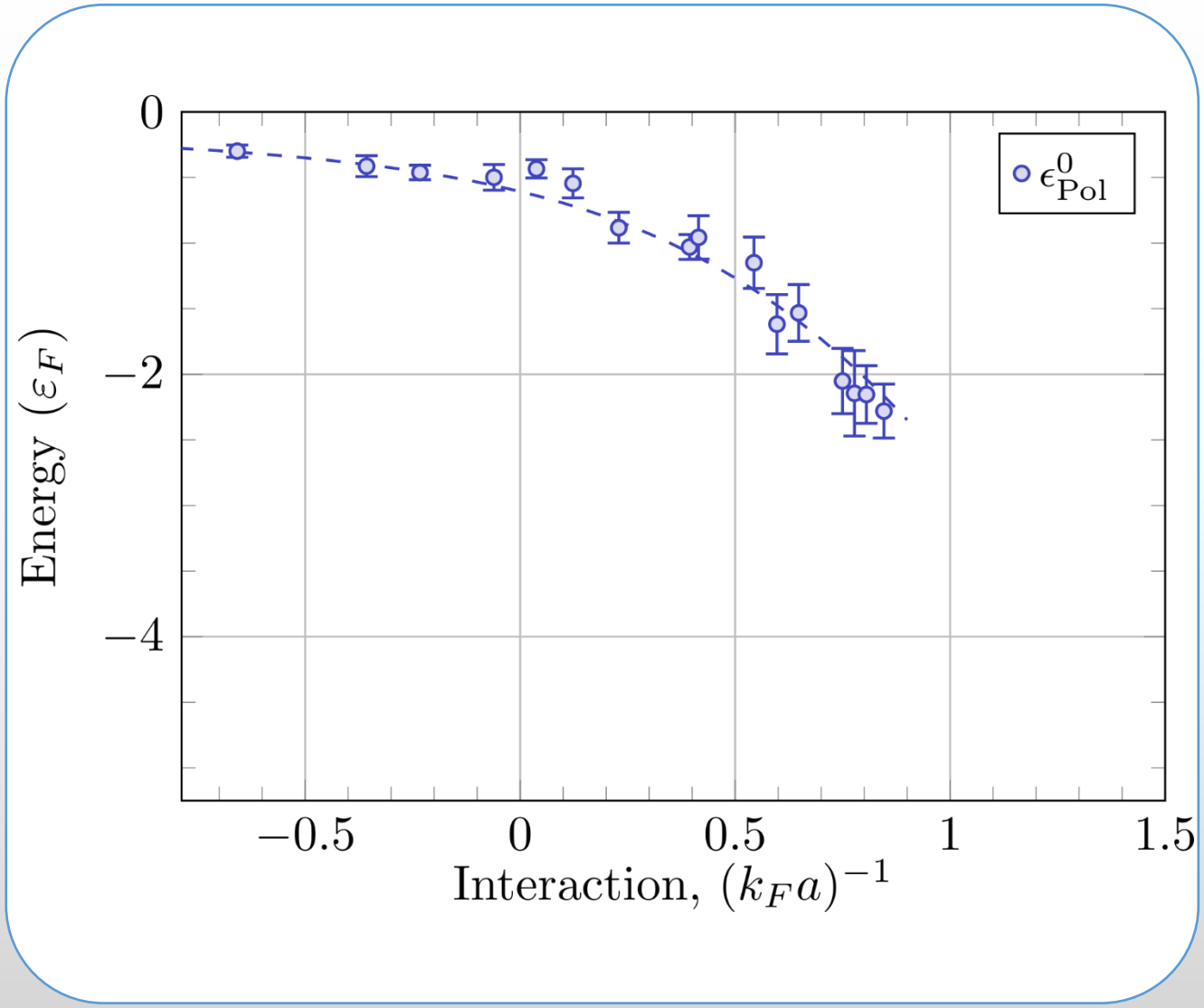
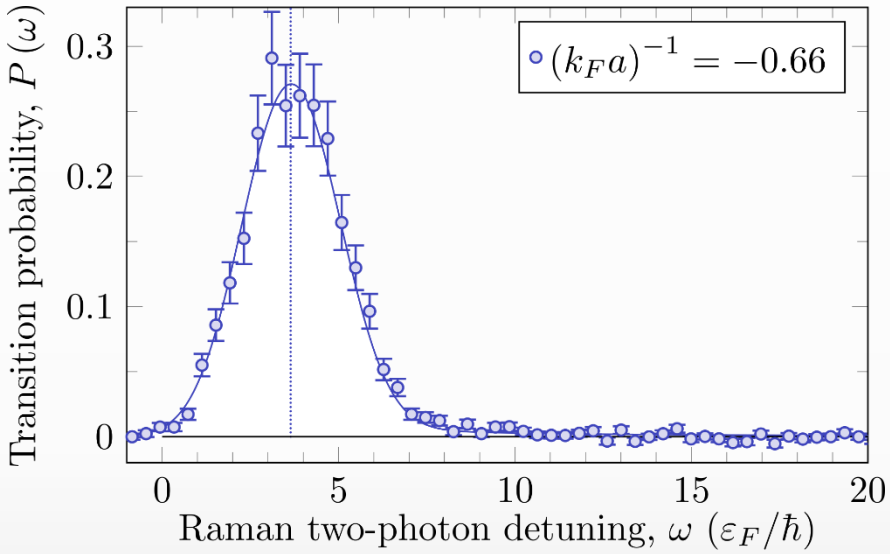
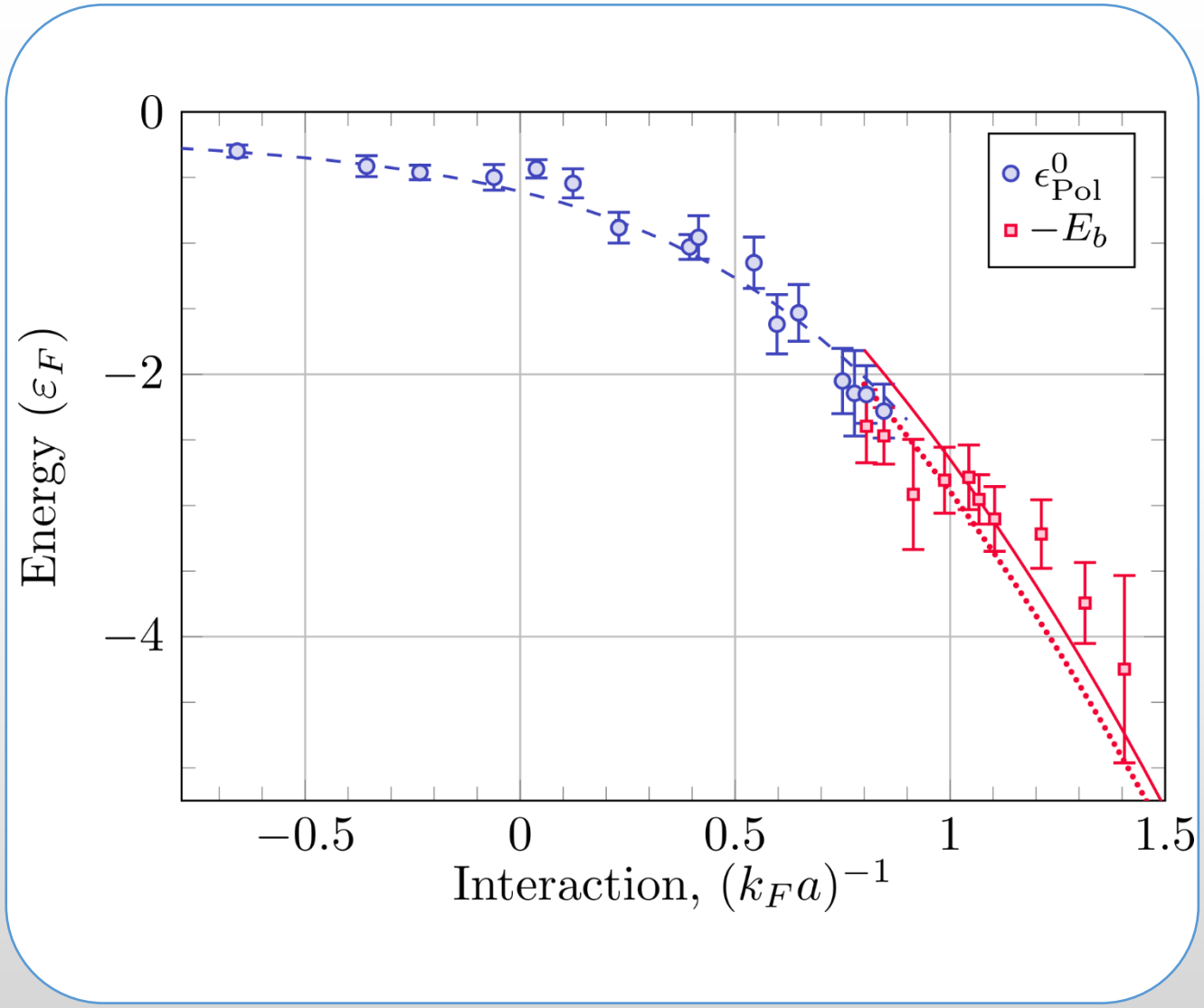
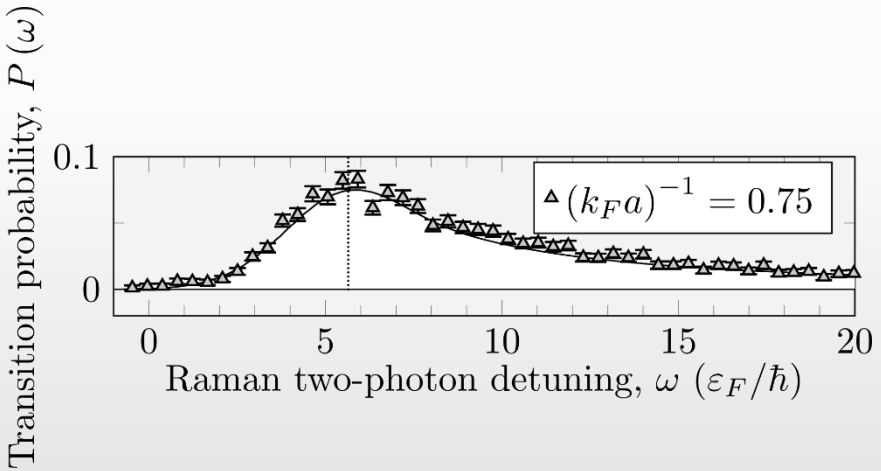
8. Zero-momentum polaron energy



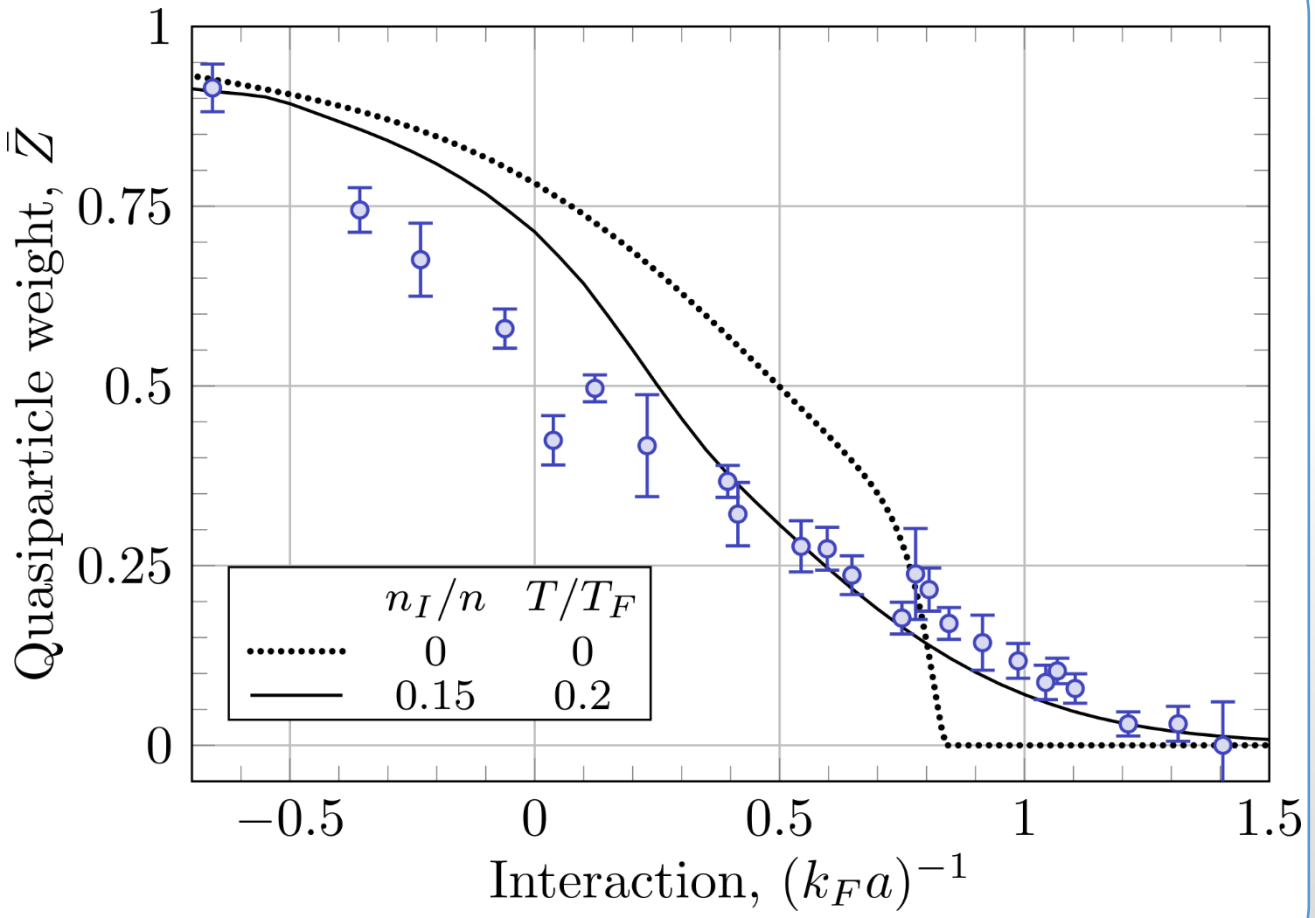


9. Molecule binding energy

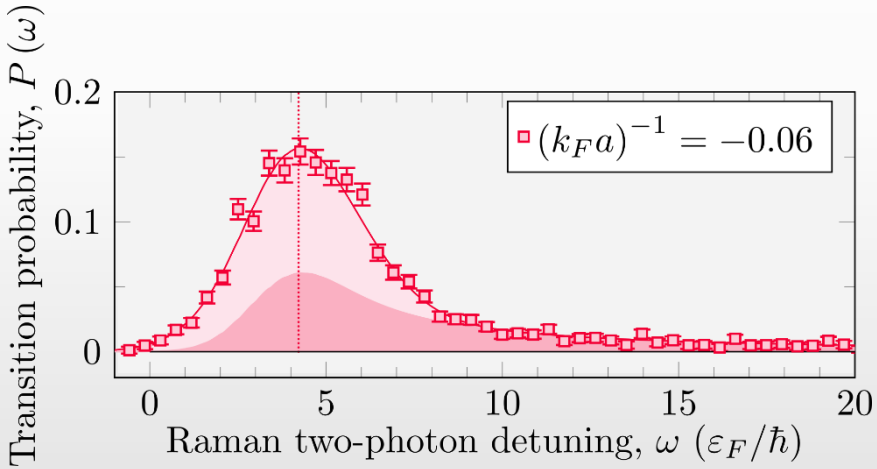




10. Quasiparticle weight

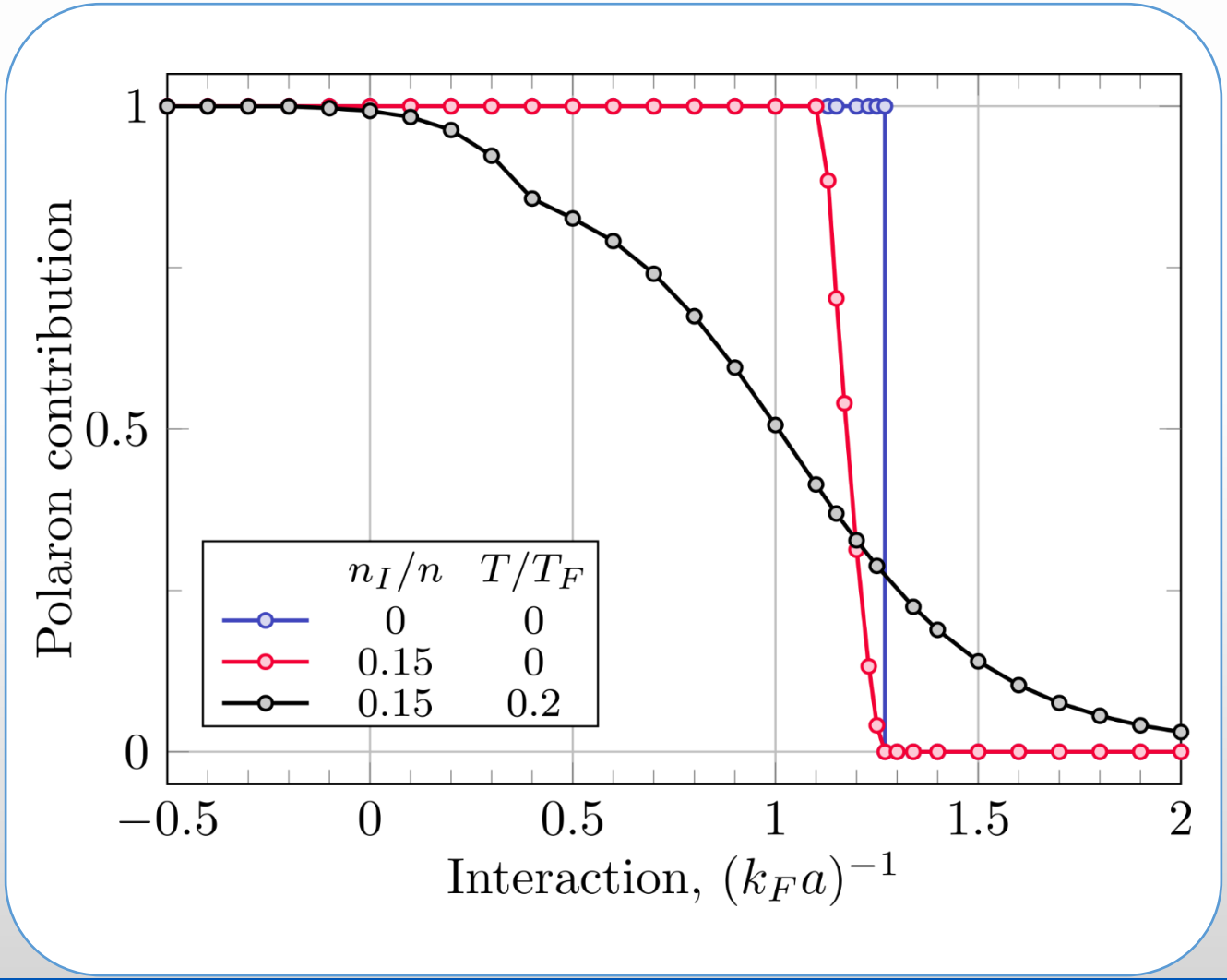


$$P(\omega) = \bar{Z} P_{\mathrm{coh}}(\omega_{;T_p,\epsilon^0_{\mathrm{pol}},m^*}) + (1-\bar{Z}) P_{\mathrm{bg}}(\omega_{;T_{\mathrm{bg}},E_b})$$



11. Fermi polaron model

- polaron and molecule variational wave-functions
- populated at finite temperature



12. Summary

Thank you!

1. Smooth polaron–molecule transition is a direct consequence of coexistence for $n_I > 0$, amplified in $T > 0$

2. High-sensitivity Raman spectroscopy enabled momentum-dependent probing and extraction of the quasiparticle residue

3. Outlook: repulsive polaron, Raman injection spectroscopy

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