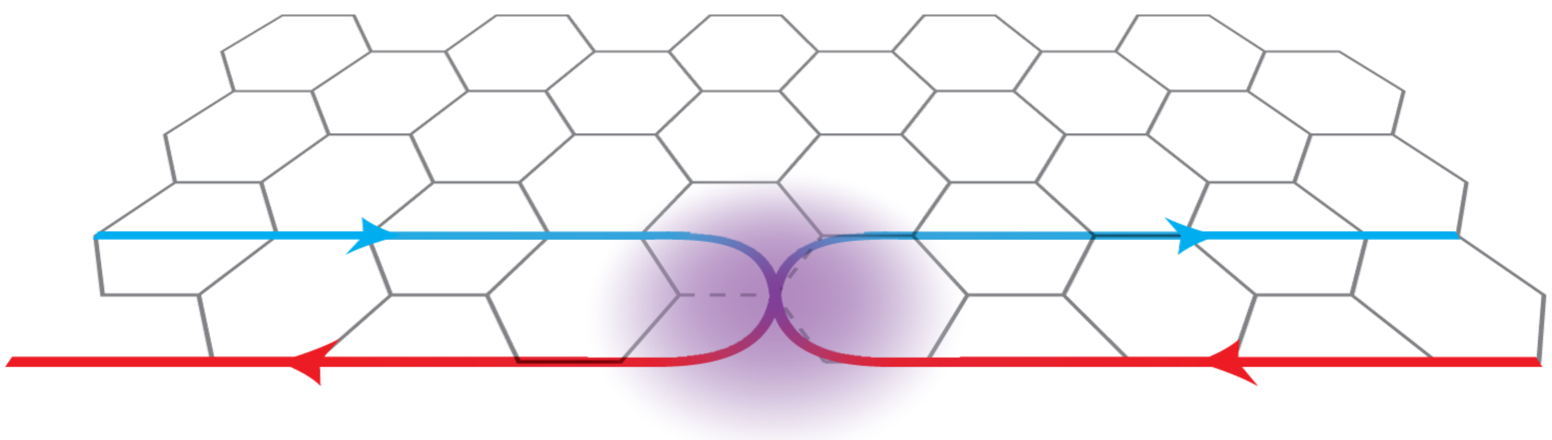
# Failure of Conductance Quantization in Two-Dimensional Topological Insulators due to Nonmagnetic Impurities

P. Novelli, F. Taddei, A.K. Geim, and M. Polini, Phys. Rev. Lett. **122**, 016601 (2019)



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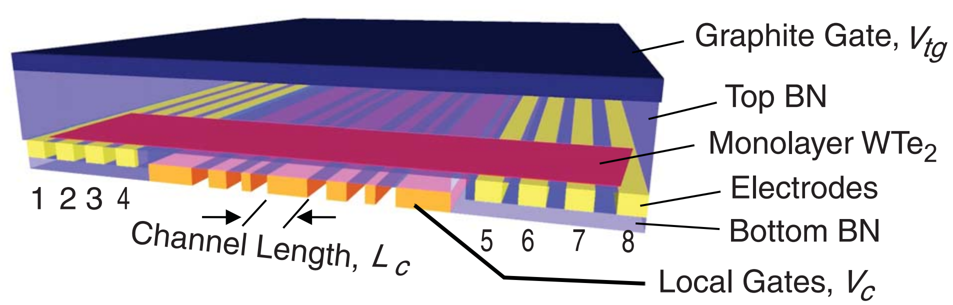
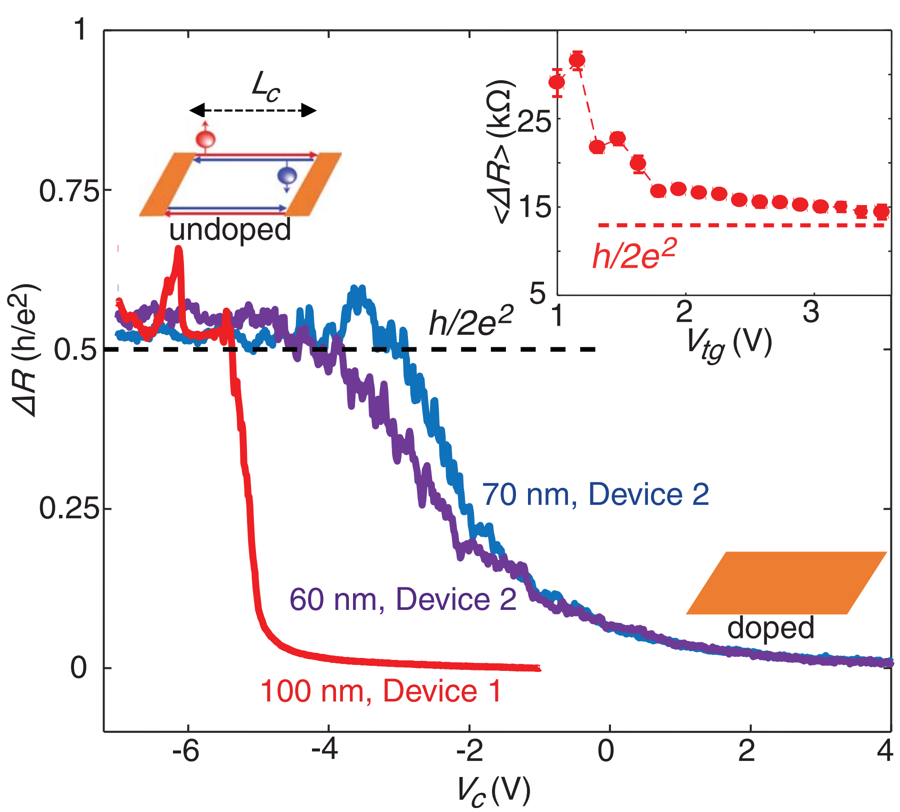
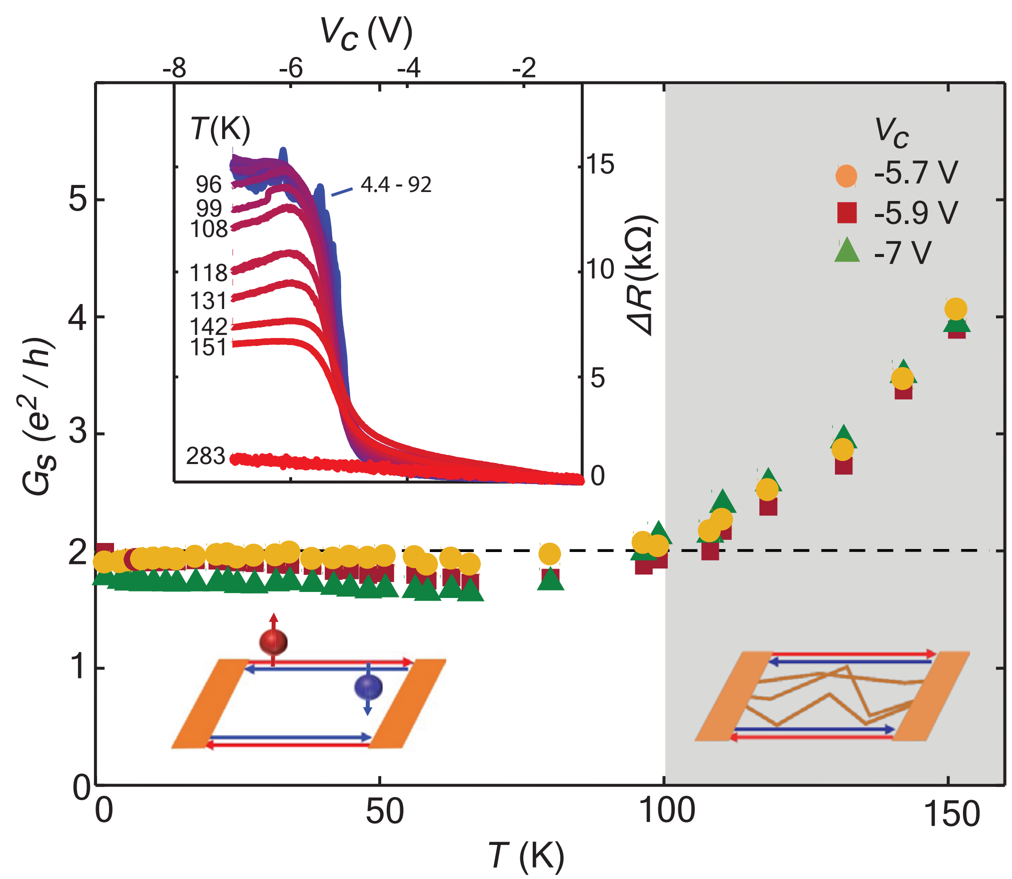
# Failure of conductance quantization in $WTe_2$




Temperature dependence of the undoped channel conductance.

$$\Delta R = R(V_c) - R(V_c = -1\text{V})$$




S. Wu, V. Fatemi, Q.D. Gibson, K. Watanabe, T. Taniguchi, R.J. Cava, and P. Jarillo-Herrero, Science **359**, 76 (2018)

# Existing mechanisms

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## Interaction-mediated scattering

Thomas L. Schmidt, Stephan Rachel, Felix von Oppen, and Leonid I. Glazman,
Phys. Rev. Lett. **108**, 156402 (2012)

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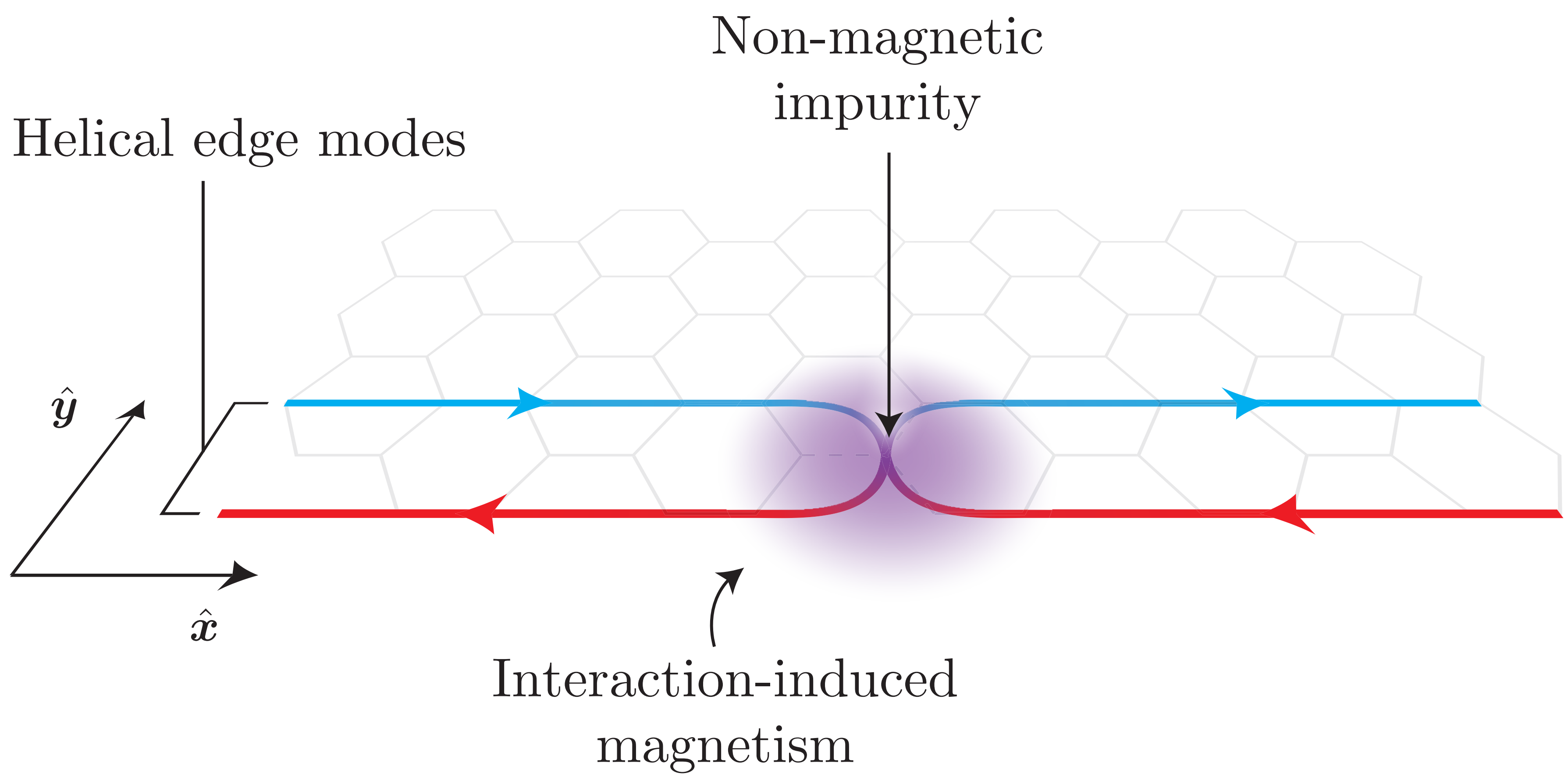
## Spontaneous breaking of time-reversal symmetry

Jianhui Wang, Yigal Meir, and Yuval Gefen,
Phys. Rev. Lett. **118**, 046801 (2017)

# Our idea




- At an edge of a 2DTI, a **nonmagnetic** short-range impurity can effectively act as a magnetic one due to its dressing via on site e-e interactions
- The latter favor the formation of a **local magnetic moment** with non-zero in-plane components
- These cause spin mixing and hence **back-scattering**

# Mean field model

$$\mathcal{H} \simeq t \sum_{\langle ij \rangle, \alpha} c_{i\alpha}^{\dagger} c_{j\alpha} + i\lambda \sum_{\langle\langle ij \rangle\rangle, \alpha, \beta} \nu_{ij} c_{i\alpha}^{\dagger} \sigma_{\alpha\beta}^{z} c_{j\beta}$$

$$+ \frac{U}{2} \sum_{i,\alpha,\beta} c_{i\alpha}^{\dagger} (n_i \mathbb{I}_{\alpha\beta} - \boldsymbol{m}_i \cdot \boldsymbol{\sigma}_{\alpha\beta}) c_{i\beta}$$

$$- \frac{U}{4} \sum_{i} (n_i^2 - |\boldsymbol{m}_i|^2)$$

# Mean field model

Kane-Mele model

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Hartree-Fock expansion of the Hubbard model

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Hartree-Fock expansion of the Hubbard model

Local mean electron density

$$n_i = \langle \sum_\alpha c^\dagger_{i\alpha} c_{i\alpha} \rangle$$

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Hartree-Fock expansion of the Hubbard model

Local mean electron density

$$n_i = \langle \sum_{\alpha} c^{\dagger}_{i\alpha} c_{i\alpha} \rangle$$

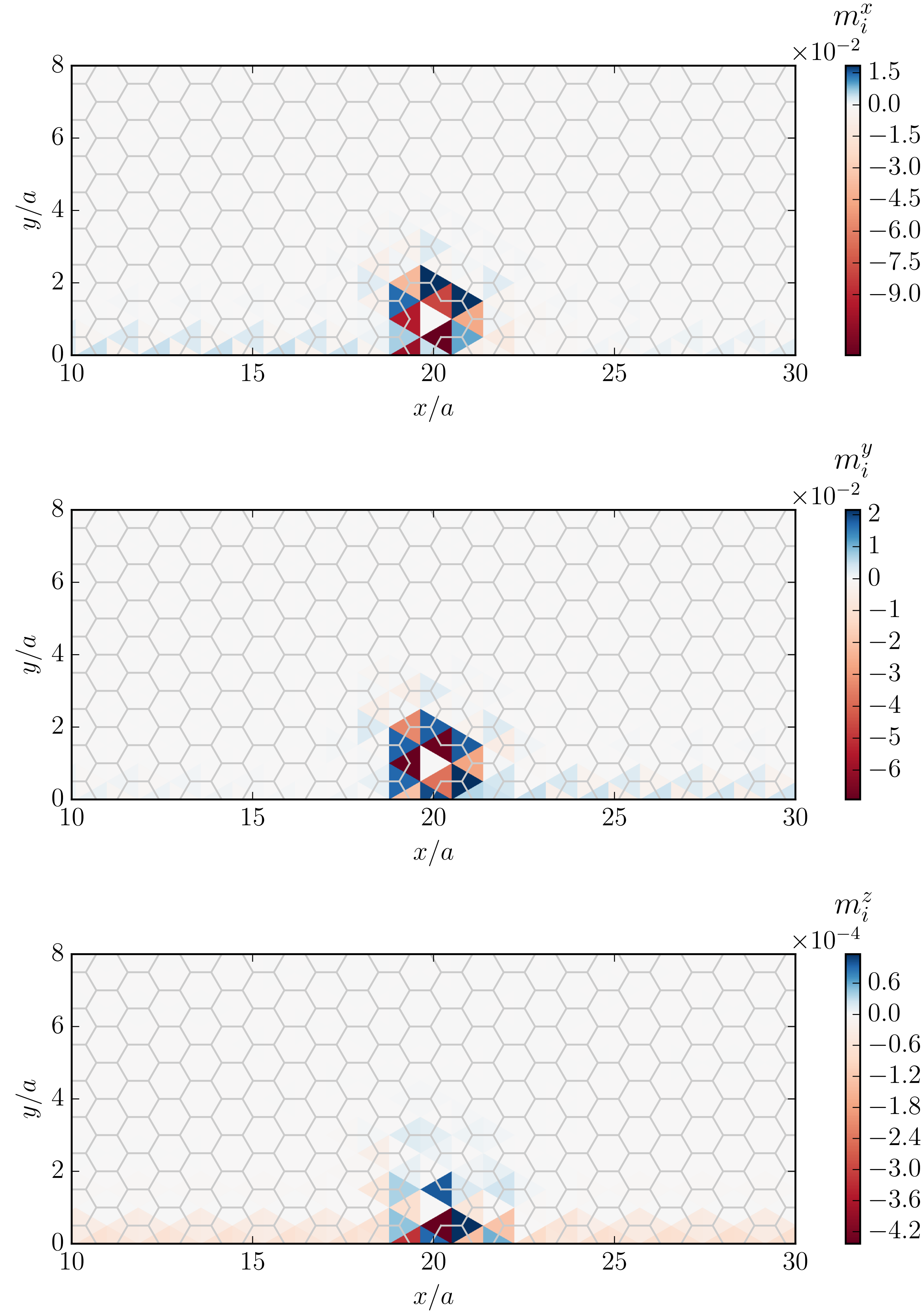
Local mean spin polarization

$$\boldsymbol{m}_i = \langle \sum_{\alpha,\beta} c^{\dagger}_{i\alpha} \boldsymbol{\sigma}_{\alpha\beta} c_{i\beta} \rangle$$

# Numerical results: magnetization

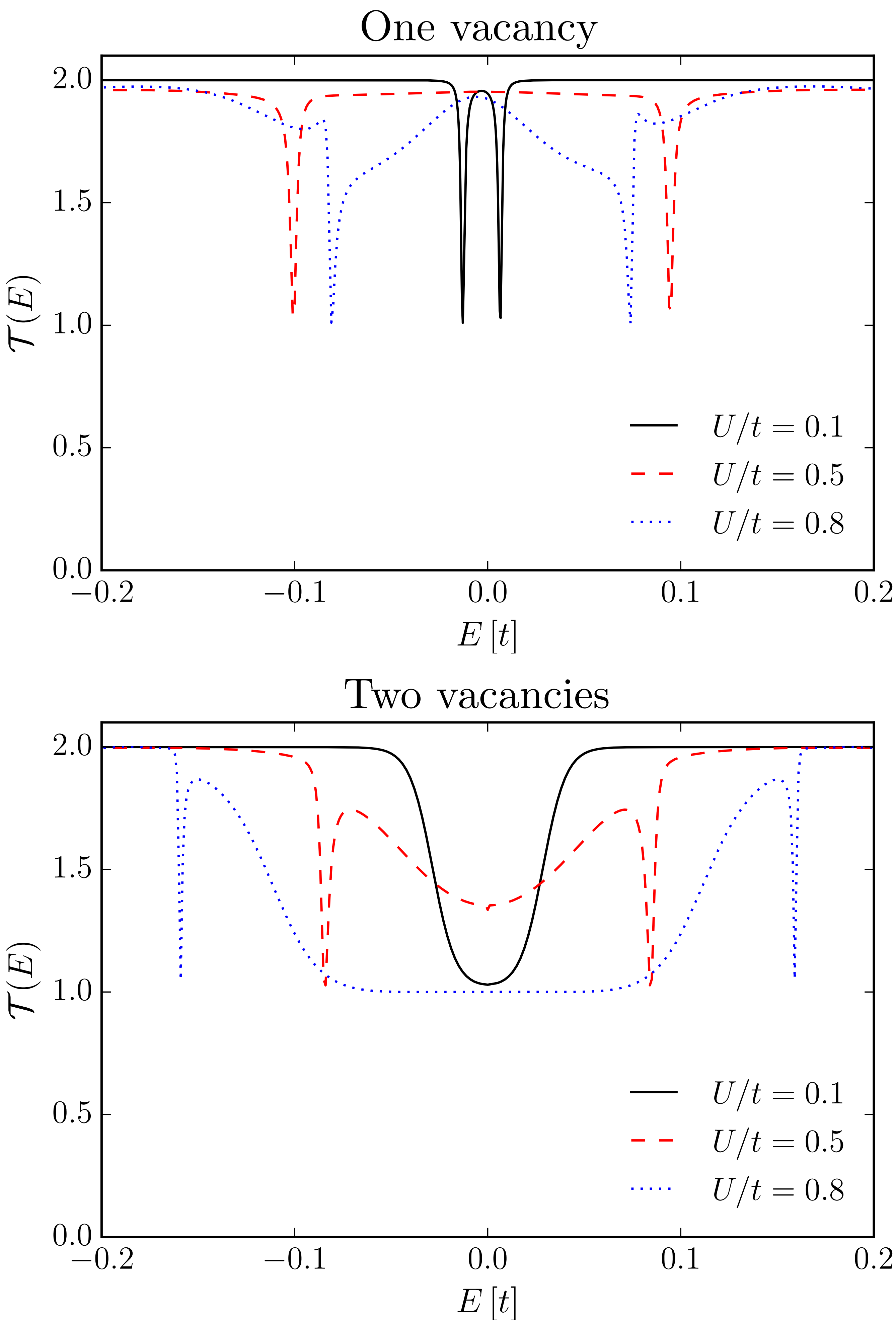
**The in-plane components are those leading to spin-mixing and hence back-scattering.**

Numerical results in this figure have been obtained by setting $\lambda/t = 0.09$ and $U/t = 0.1$



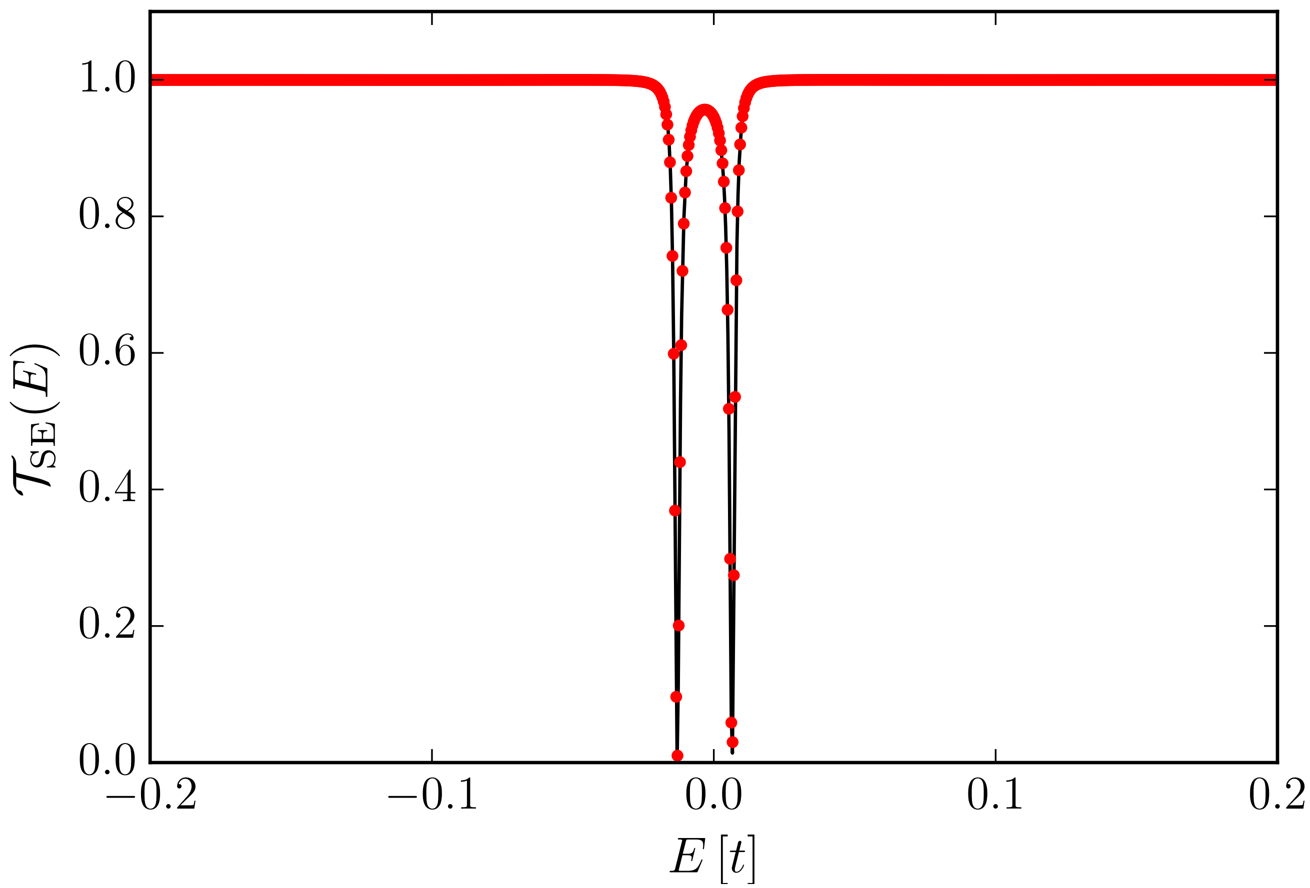
# Numerical results: conductance

Numerical results in these figures:
$\lambda/t = 0.09$ ($\delta g \approx 0.93$ t).
Since on-site e-e interactions produce a spin polarization with in-plane components near the vacancy, **back-scattering events occur at the same 2DTI edge and lead to the breakdown of conductance quantization.**



# Thank you!

# More numerical results: fit with analytical model




$E_a$ Position of the dips

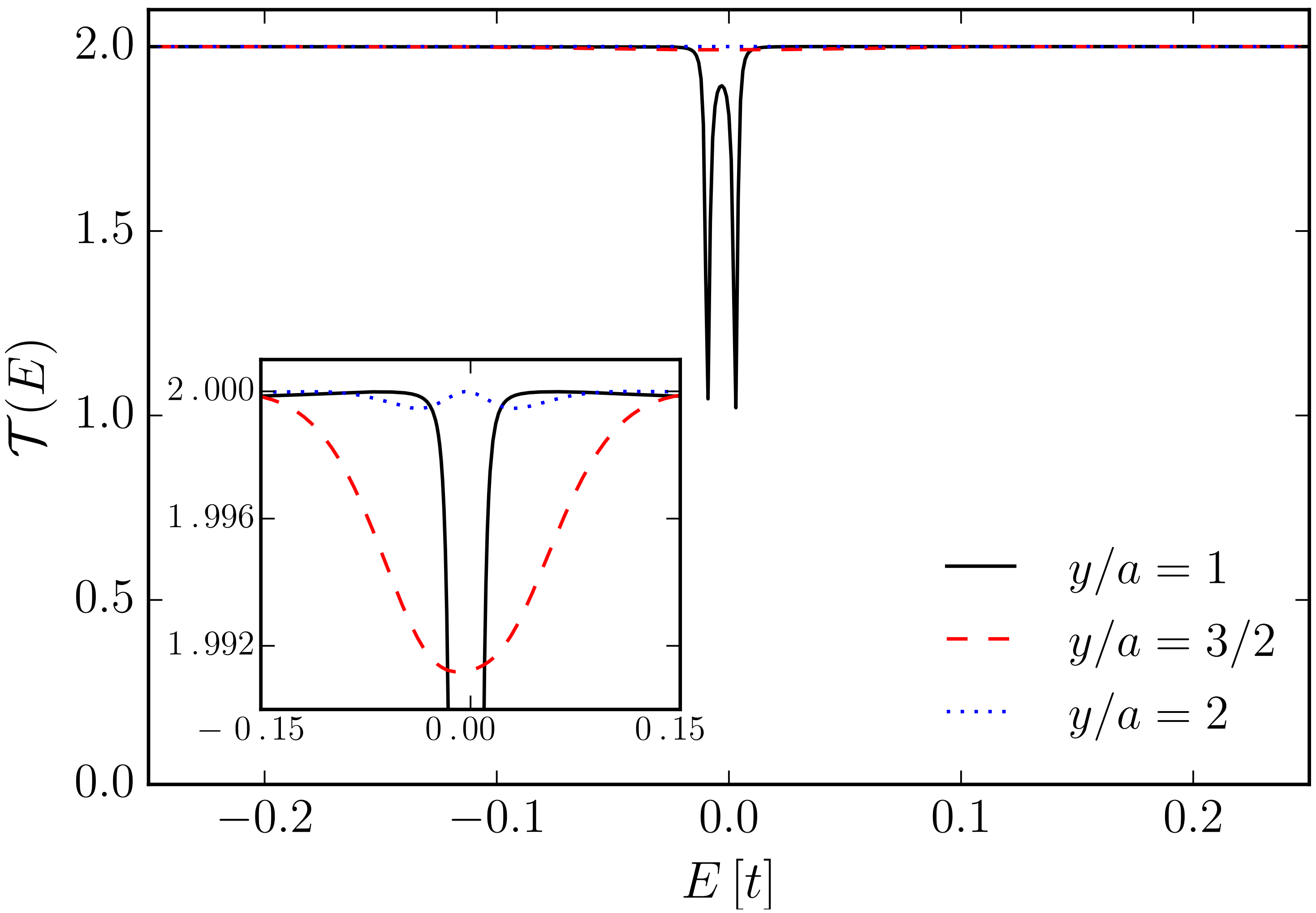
$\tilde{\gamma}$ Controls dips's width

$\alpha$ Controls dips's depth

$$\mathcal{T}_{\mathrm{SE}}(E) = 1 - (1 - \alpha^2)\frac{\tilde{\gamma}^2}{(E^2 - E_{\mathrm{a}}^2)^2 + \tilde{\gamma}^2}$$

X. Dang, J.D. Burton, and E.Y. Tsymbal, J. Phys.: Condens. Matter **28**, 38LT01 (2016)

# More numerical results: dependence on the position of the vacancy




Numerical results in this figure have been obtained by setting $\lambda/t = 0.09$ and $U/t = 0.1$