# Are Symmetry Protected Topological States Immune to Dephasing?

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## Introduction

- The hallmark of *topology* in condensed matter systems: **topological phases** which feature **symmetry protected** dissipation-less channels via currents along the edge in 2D systems [1].
- These topological phases are theorized to be **robust** against disorder through symmetry protection $\longrightarrow$ **Conductance quantum maintained**!
- There is significant interest in employing materials manifesting topological phases for applications in **futuristic topological electronics**, where symmetry protection enables dissipation-less device operation. [2]
- Effects of **disorder** in practical settings on these phases remain to be seen; robustness under such disorder is key for enabling topological electronics.
- Phases of interest here are **quantum spin Hall** (QSH), hosting **helical edge modes** which are time-reversal invariant, and **spin quantum anomalous Hall** (SQAH), hosting **chiral edge modes**.

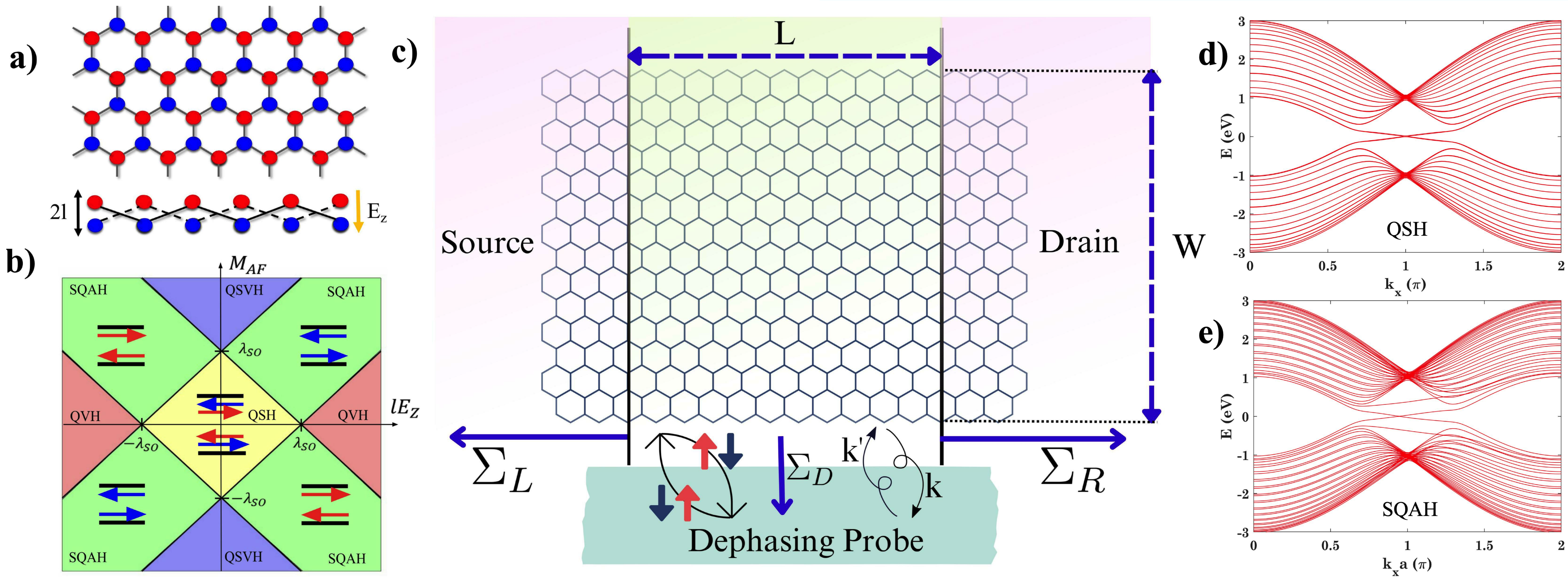
## Methods

- We work with a **tight-binding** lattice modelling a 2D Xene material [3].
- The **non-equilibrium Greens' function** (NEGF) formalism is used for the transport calculations [4].

$$G^R = [(E + \imath\eta)I - H - \Sigma_1 - \Sigma_2 - \Sigma_D]^{-1}; \qquad G^n = G^R(\Sigma_1^{in} + \Sigma_2^{in} + \Sigma_D^{in})G^A \tag{1}$$

- Dephasing can be added systematically using NEGF: momentum and spin dephasing independently introduced via $\Sigma_D = f_D(G^R)$ and $\Sigma_D^{in} = f_D(G^n)$, where $f_D$ introduces momentum or spin dephasing with the dephasing strength $D$.
- The **low energy Bloch hamiltonian** is given as,

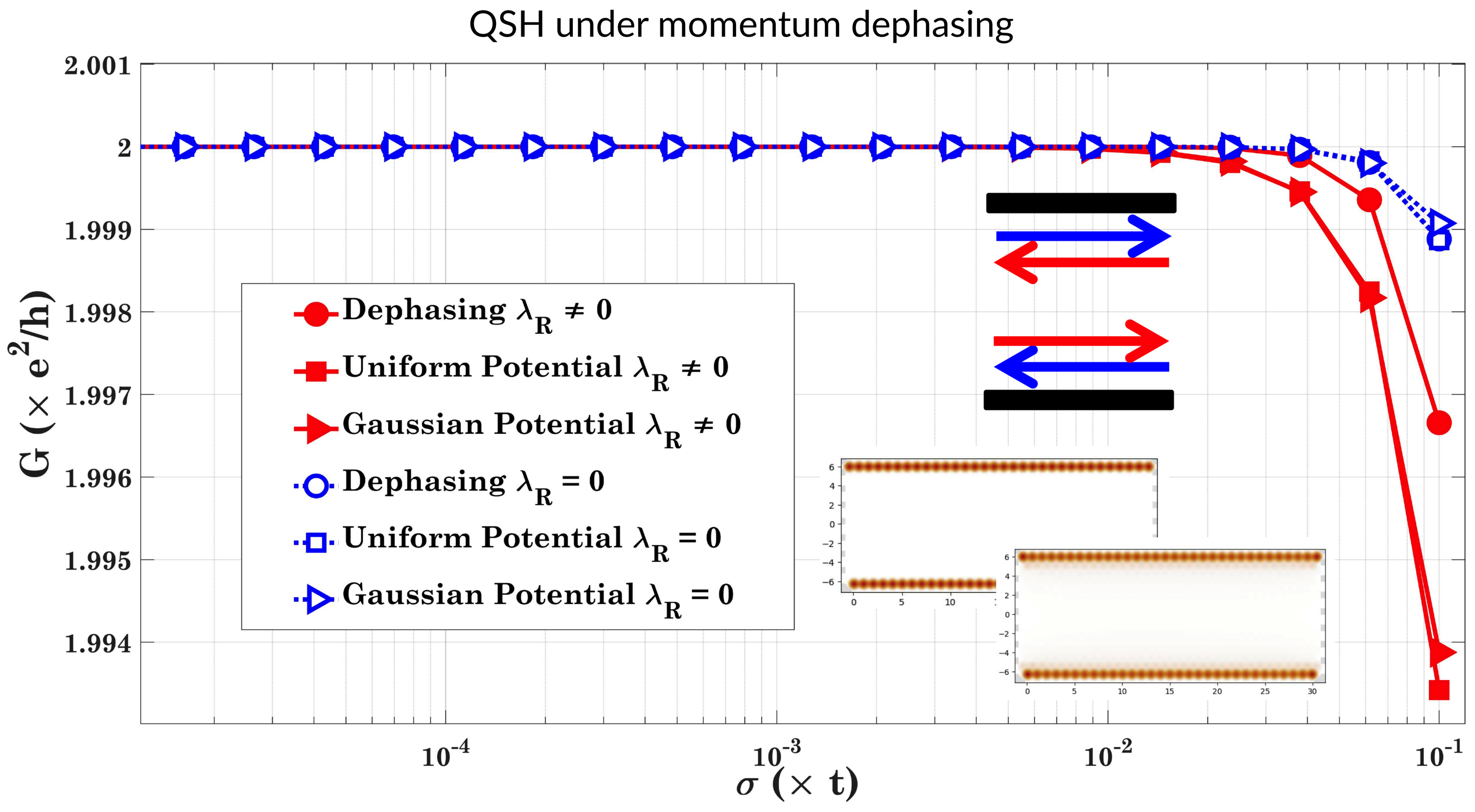
$$\mathcal{H}(\mathbf{k}) = \underbrace{\hbar v_f(k_x\tau_z\sigma_x + k_y\sigma_y)}_{\text{NN hopping}} + \underbrace{\lambda_{SO}\sigma_z\tau_z s_z}_{\text{SO coupling}} + \underbrace{\lambda_R(\sigma_x s_y\tau_z - \sigma_y s_z)}_{\text{Rashba spin-mixing}} + \underbrace{\Delta\sigma_z}_{\text{Alt. potential}} + \underbrace{M_{AF}\sigma_z s_z}_{\text{AFM interaction}} \tag{2}$$



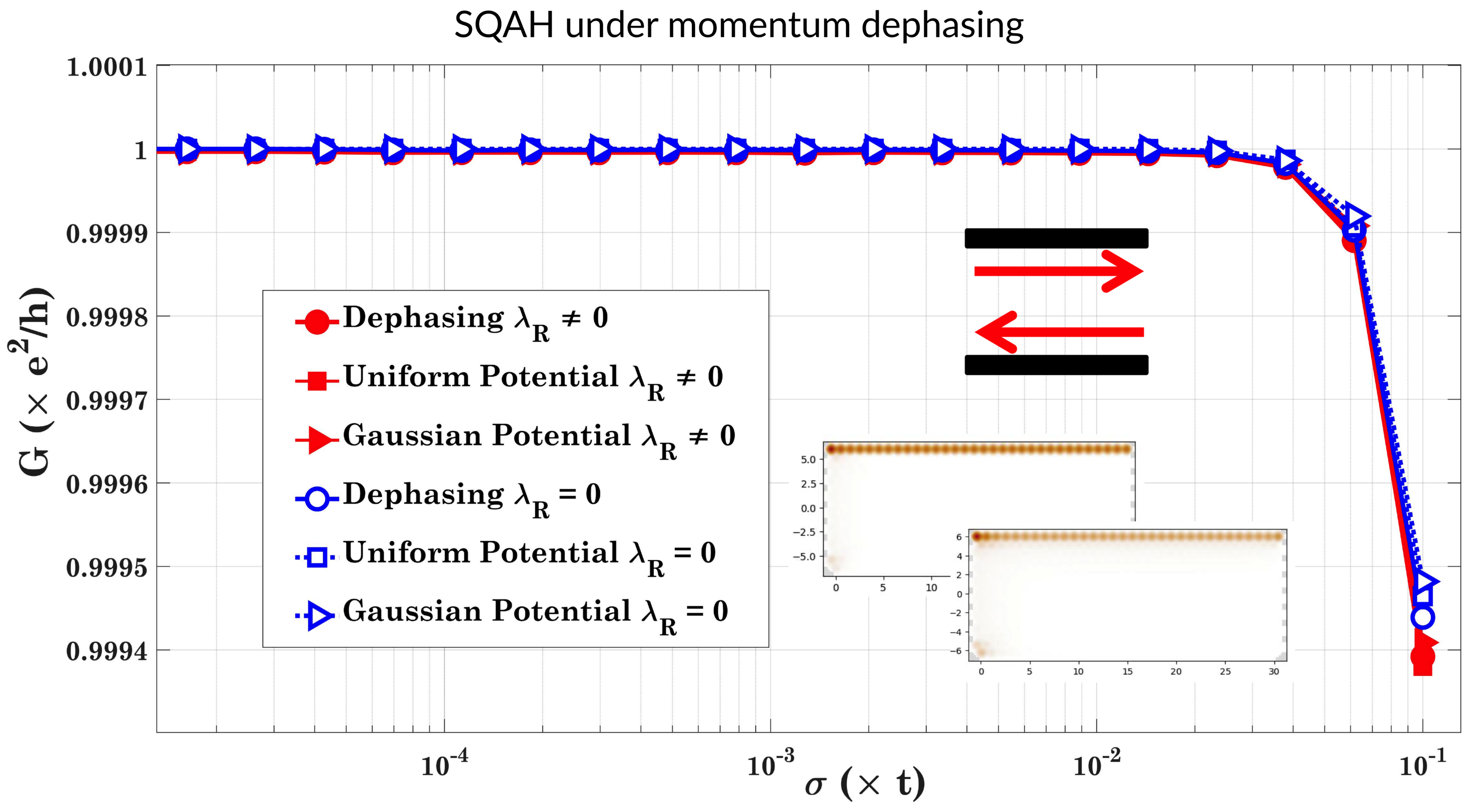

## Results: Momentum Dephasing

- Dephasing is added through the NEGF method and conductance response is computed.
- Impurity potentials followed by sample averaging is also performed as a comparison ($D = \sigma^2$) [4].
- There is a **worst-case** drop of $0.05\%$ for QSH with $\lambda_R = 0eV$, and $0.06\%$ for SQAH. With $\lambda_R = 15meV$, the QSH decay is $0.3\%$
- Rashba mixing worsens the conductance for QSH, but **not** for SQAH. Helical and chiral modes! The spin texture imposed by the Rashba term at the Fermi surface causes different effects on the QSH and SQAH phases, hence explaining this behaviour.
- **The self-consistent Born approximation** may fail above $D \sim 10^{-2}t^2$

QSH under momentum dephasing



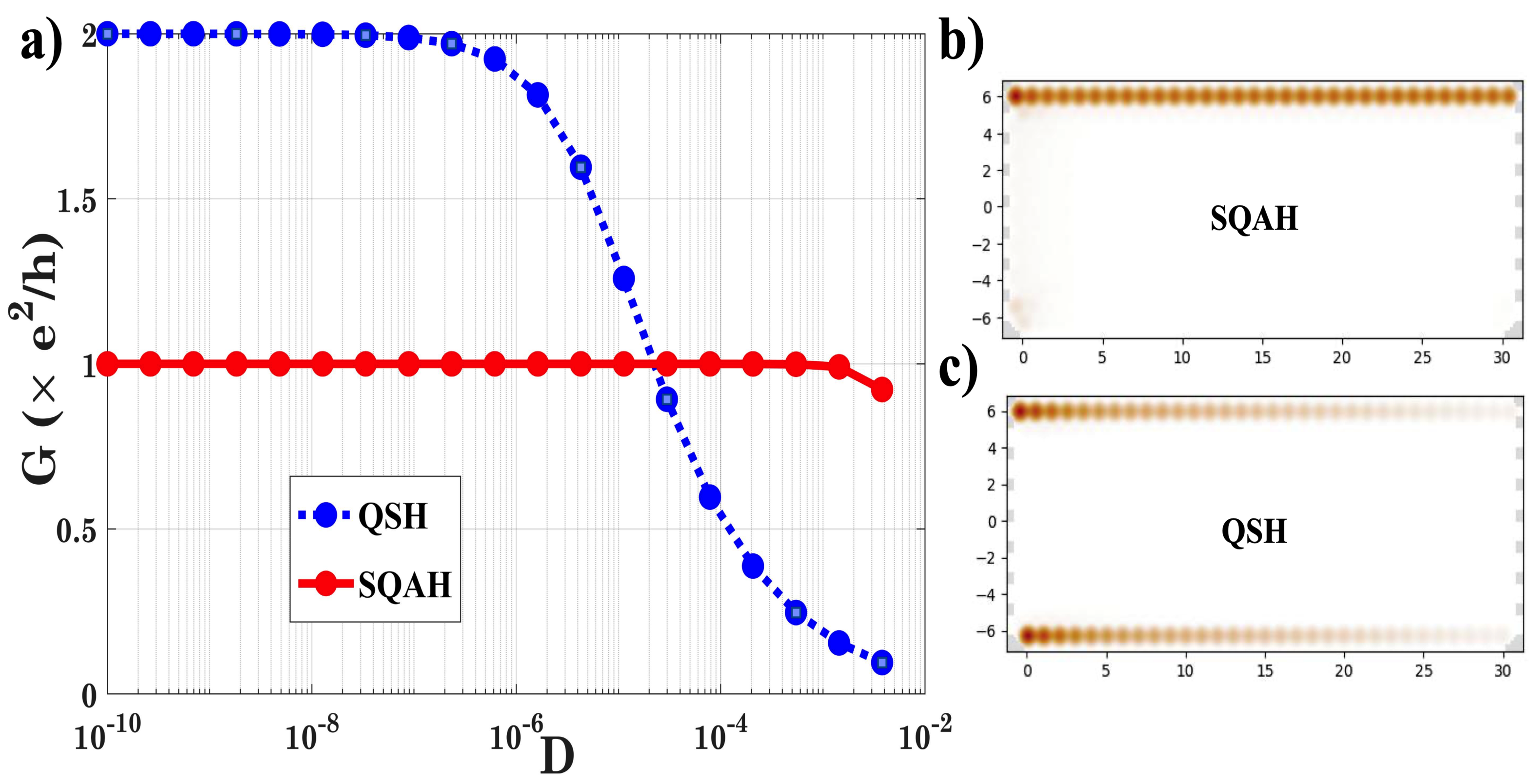

SQAH under momentum dephasing



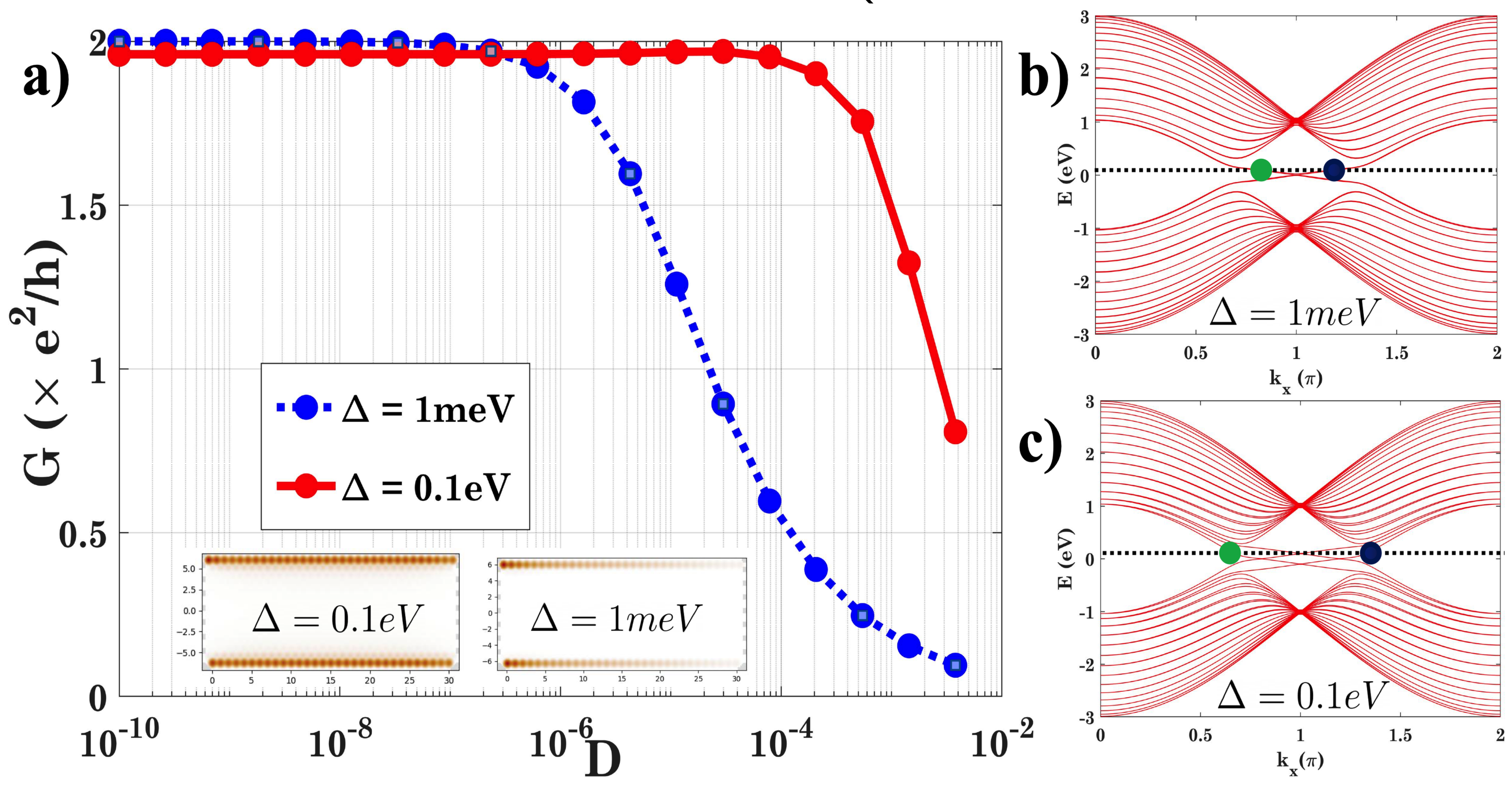

## Results: Spin Dephasing

- Magnetic impurities are simulated as spin dephasing, and QSH and SQAH cases are compared.
- Effect of the **staggered sublattice potential** $\Delta$ for the QSH case is studied.
- These results would be expected even without magnetic impurities owing to current induced gap opening in **interacting** TIs [5], or with random Rashba interactions [6].

Comparison of QSH and SQAH under spin dephasing




Effect of $\Delta$ for QSH




## Conclusions

- Both the QSH and SQAH phases are robust again strictly relaxation of momentum.
- Under spin relaxation, the QSH phase breaks down due to **backscattering**, but the SQAH phase remains intact. **Choice of phase parameters** is indeed important in QSH.
- Many effects, such as interactions [5] and random spin-mixing [6] can lead to spin relaxations, thereby destroying the QSH phase in experiments.
- Thus, we propose the **SQAH phase as a candidate** for futuristic low-power topological electronics.

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## References

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