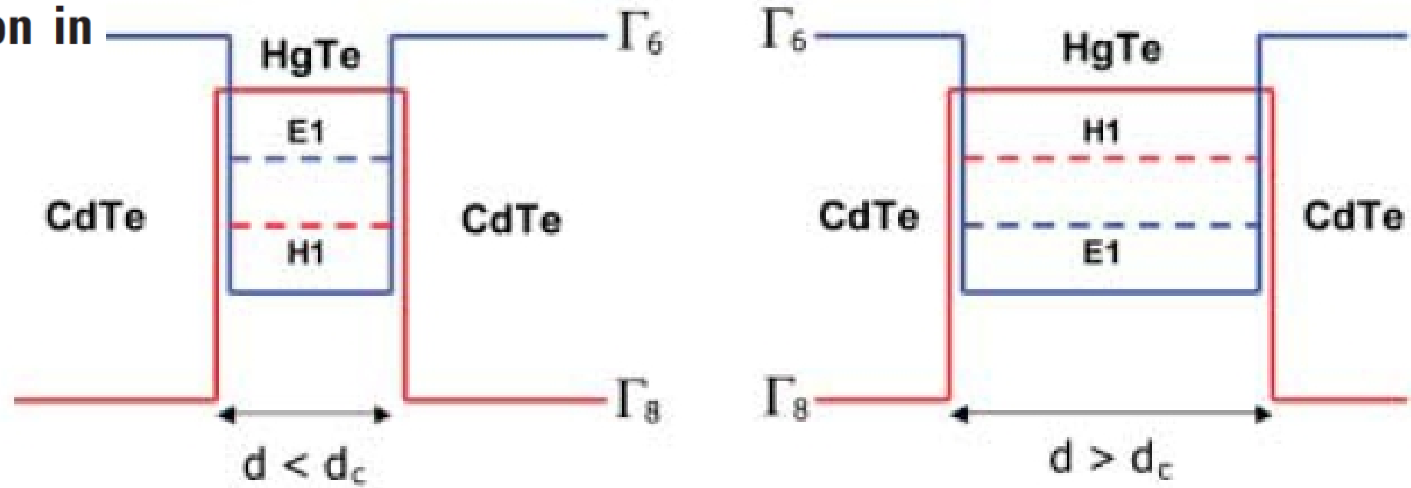
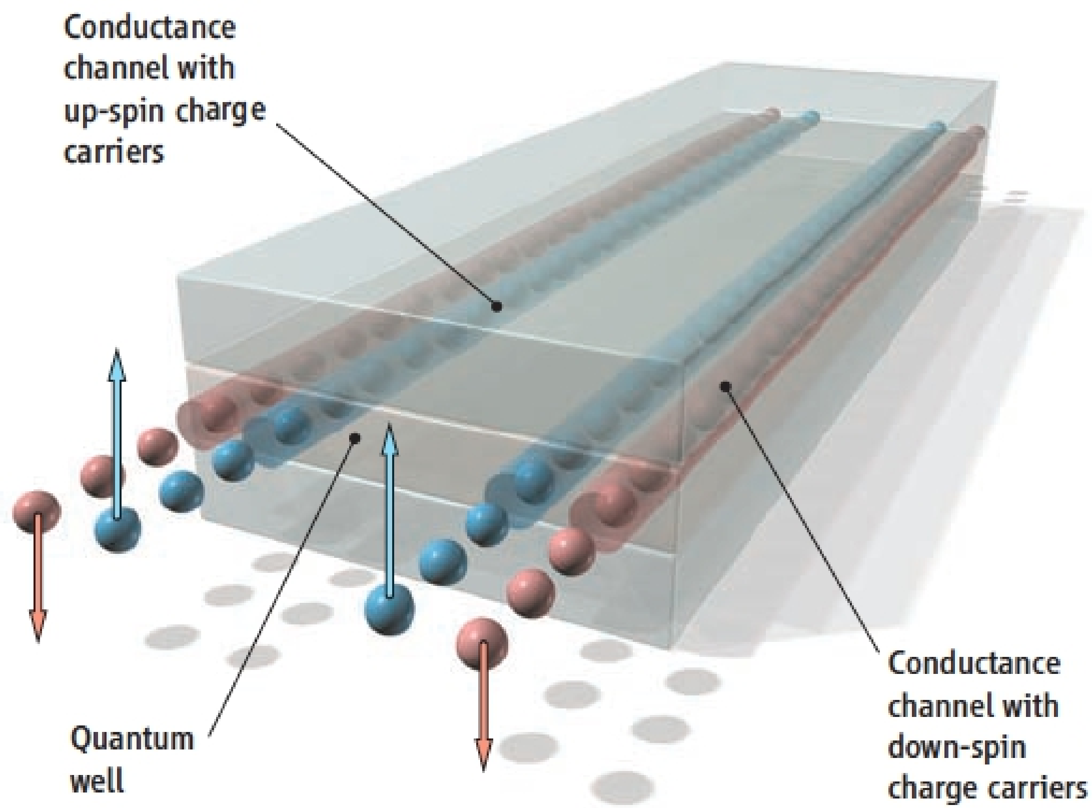
Quantum Spin Hall Effect and Topological Phase Transition in HgTe Quantum Wells

B. Andrei Bernevig,[1,2] Taylor L. Hughes,[1] Shou-Cheng Zhang[1]*





Schematic of the spin-polarized edge channels in a quantum spin Hall insulator.

Quantum Spin Hall Insulator State in HgTe Quantum Wells

Markus König,[1] Steffen Wiedmann,[1] Christoph Brüne,[1] Andreas Roth,[1] Hartmut Buhmann,[1] Laurens W. Molenkamp,[1*] Xiao-Liang Qi,[2] Shou-Cheng Zhang[2]

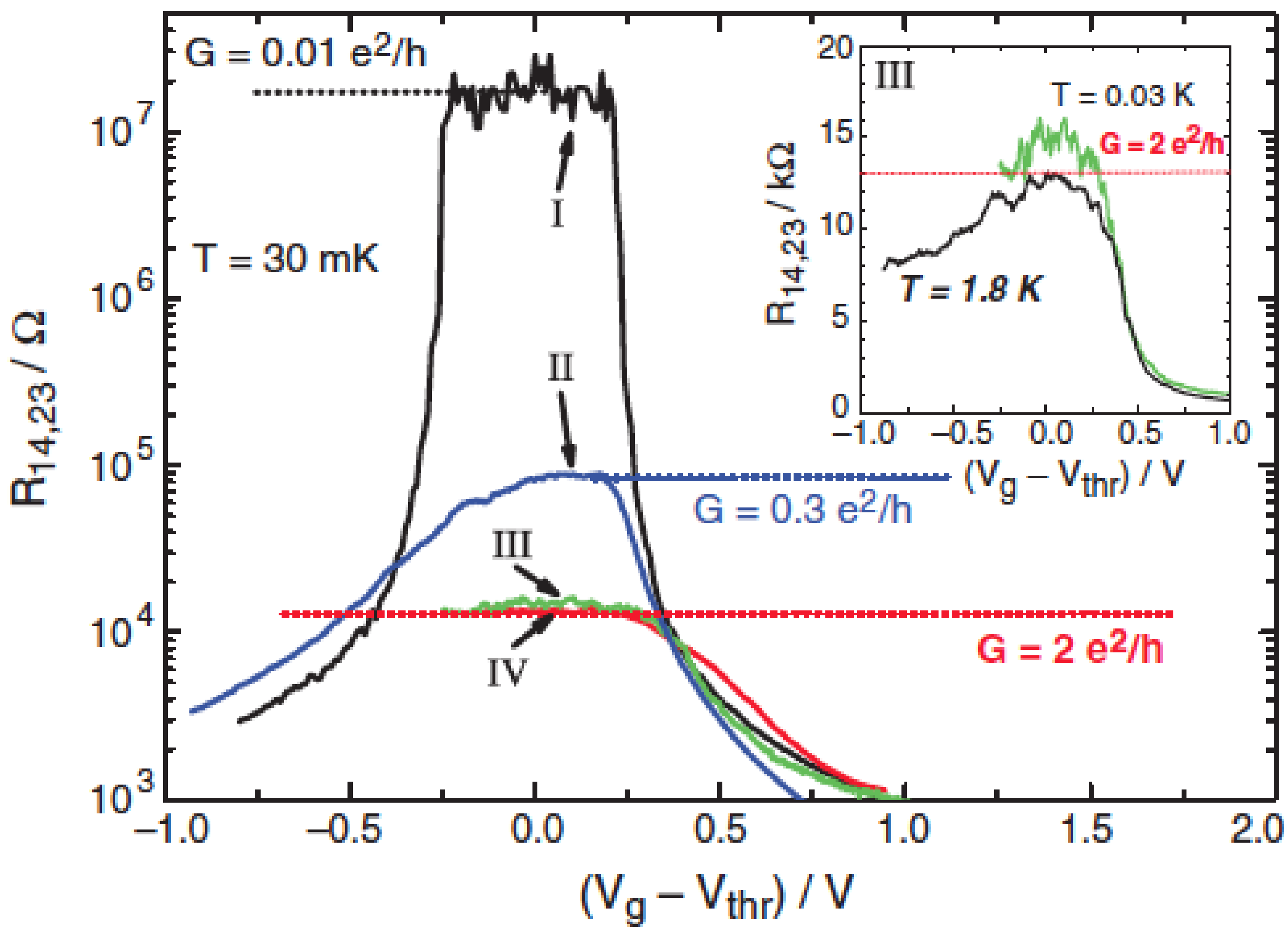


Fig. 4. The longitudinal four-terminal resistance, $R_{14,23}$, of various normal (d = 5.5 nm) (I) and inverted (d = 7.3 nm) (II, III, and IV) QW structures as a function of the gate voltage measured for B = 0 T at T = 30 mK. The device sizes are (20.0 × 13.3) μm^2 for devices I and II, (1.0 × 1.0) μm^2 for device III, and (1.0 × 0.5) μm^2 for device IV. The inset shows $R_{14,23}(V_g)$ of two samples from the same wafer, having the same device size (III) at 30 mK (green) and 1.8 K (black) on a linear scale.

Nonlocal Transport in the Quantum Spin Hall State

Andreas Roth,[1] Christoph Brüne,[1] Hartmut Buhmann,[1] Laurens W. Molenkamp,[1]* Joseph Maciejko,[2,3] Xiao-Liang Qi,[2,3] Shou-Cheng Zhang[2,3]

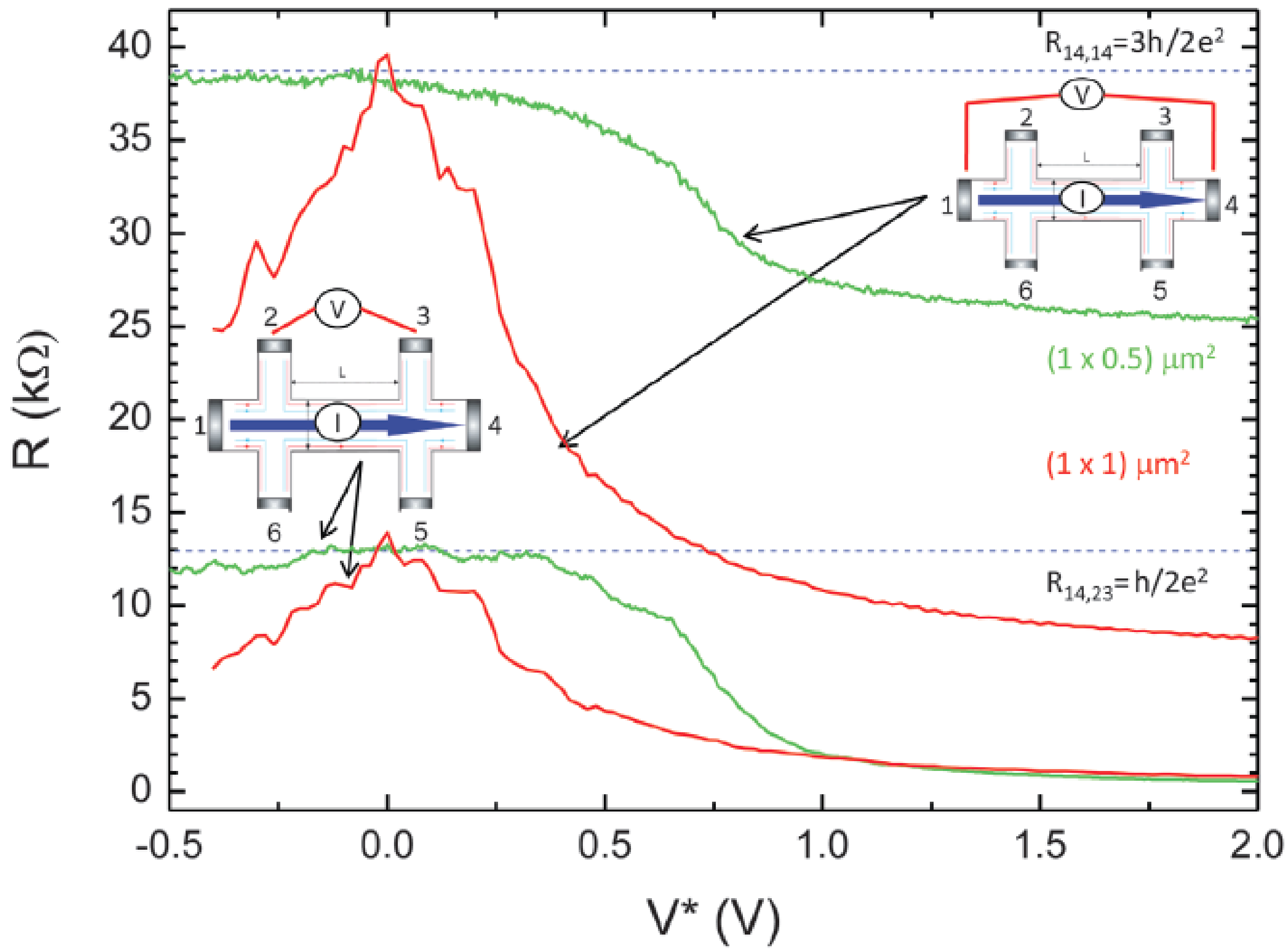


Fig. 1. Two-terminal ($R_{14,14}$) (top two traces) and four-terminal ($R_{14,23}$) (bottom traces) resistance versus (normalized) gate voltage for the Hall bar devices D1 and D2 with dimensions (length × width) as indicated. The dotted blue lines indicate the resistance values expected from the Landauer-Büttiker approach.

Classification of Topological Insulators and Superconductors

Andreas P. Schnyder*, Shinsei Ryu†, Akira Furusaki** and Andreas W. W. Ludwig‡

Periodic table for topological insulators and superconductors

Alexei Kitaev

TABLE 2. Summary of the *main result of this paper*: listed are again the ten symmetry classes of single particle Hamiltonians (from TABLE 1) classified in terms of the presence or absence of time-reversal symmetry (TRS) and particle-hole symmetry (PHS), as well as sublattice (or "chiral") symmetry (SLS) [17, 18, 19]. The last three columns list all possible topologically non-trivial quantum ground states as a function of symmetry class and spatial dimension d. The symbols $\mathbf{Z}$ and $\mathbf{Z}_2$ indicate that the space of quantum ground states is partitioned into different topological sectors labeled by an integer ($\mathbf{Z}$), or a $\mathbf{Z}_2$ quantity (two sectors only), respectively.

System	Cartan nomenclature	TRS	PHS	SLS	$d=1$	$d=2$	$d=3$
standard (Wigner-Dyson)	A (unitary)	0	0	0	-	$\mathbf{Z}$ QHE	-
	AI (orthogonal)	+1	0	0	-	-	-
	AII (symplectic)	−1	0	0	-	$\mathbf{Z}_2$ QSH	$\mathbf{Z}_2$
chiral (sublattice)	AIII (chiral unit.)	0	0	1	$\mathbf{Z}$	-	$\mathbf{Z}$
	BDI (chiral orthog.)	+1	+1	1	$\mathbf{Z}$	-	-
	CII (chiral sympl.)	−1	−1	1	$\mathbf{Z}$	-	$\mathbf{Z}_2$
BdG (mean-field superconductors)	D	0	+1	0	$\mathbf{Z}_2$	$\mathbf{Z}$	-
	C	0	−1	0	-	$\mathbf{Z}$	-
	DIII	−1	+1	1	$\mathbf{Z}_2$	$\mathbf{Z}_2$	$\mathbf{Z}$
	CI	+1	−1	1	-	-	$\mathbf{Z}$

Tristan Cren : topological superconductors ; Benoit Douçot : classification