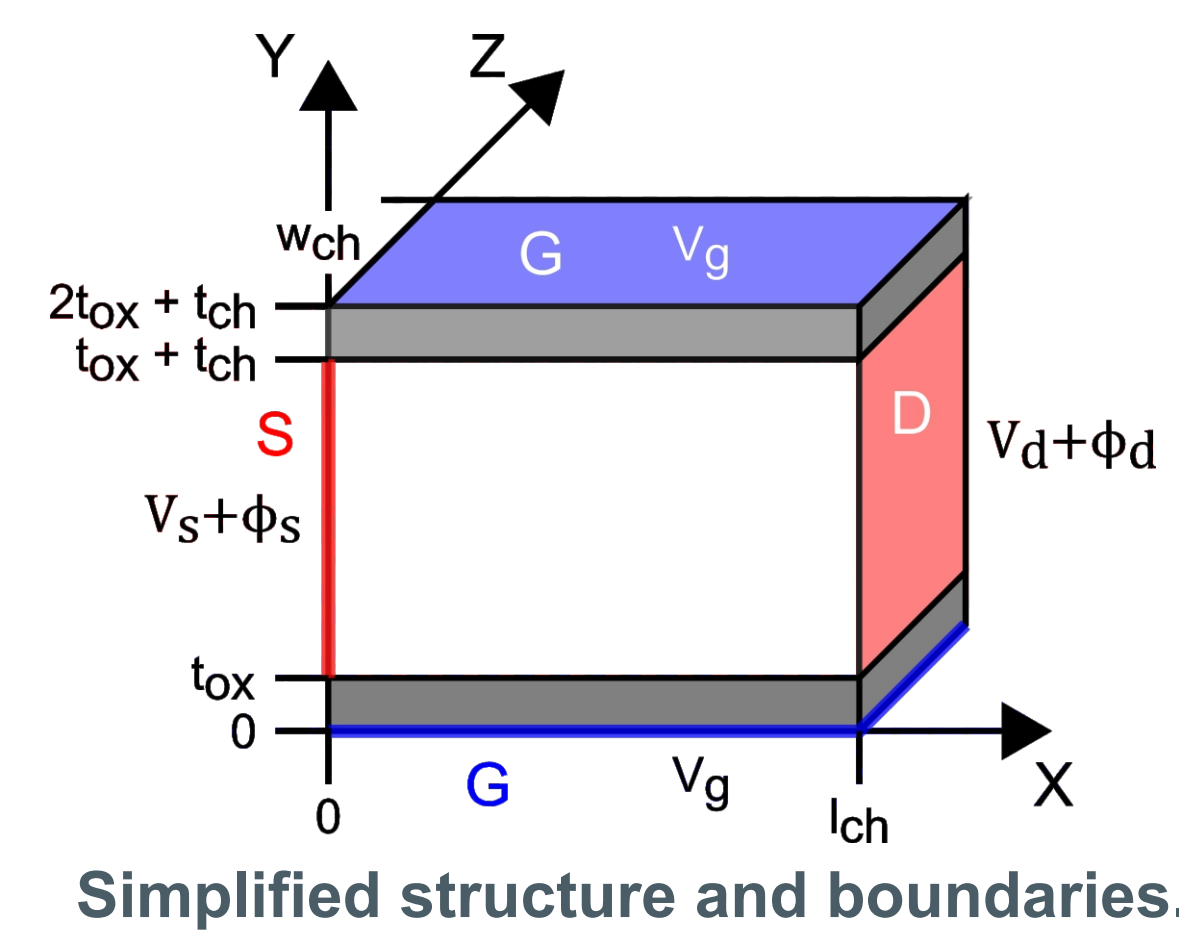


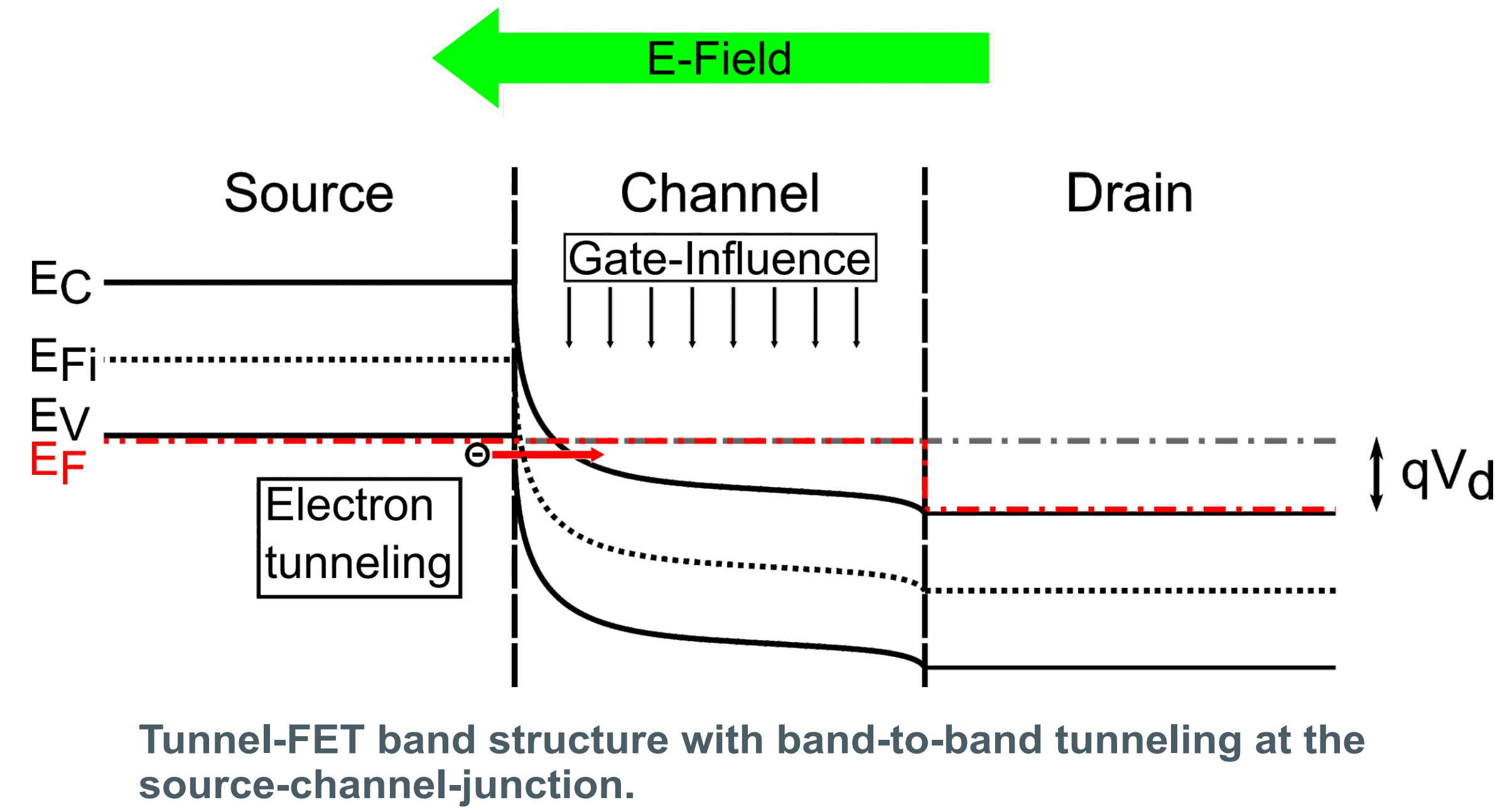
Analytical Two-Dimensional Model for Source/Drain Band-to-Band Tunneling in Silicon DG Tunnel-MOSFETs

- The Tunnel-FET is one of the promising device structures due its quantum effect based current transport mechanism to go below the SSlope of 60mV/dec from standard bulk MOSFETs [1].
- Our modeling approach applies an analytical framework for two-dimensionally solving the electrostatics in double-gate devices using the conformal mapping technique [2].
- From the 2D potential profile, using the WKB approximation the band-to-band tunneling current is analytically calculated.



Tunnel-FET Band-to-Band Tunneling

- Symmetric Tunnel-FET structure.
- Highly doped source and drain area.
- Intrinsic channel area.
- Band bending caused by the gate potential leads to a thin tunneling barrier between the source valence band and the channel conduction band.
- Electrons tunnel through the barrier (band-to-band tunneling).
- Ambipolar behavior at drain junction takes place for negative gate potential.
- In our model trap-assisted tunneling has been neglected.

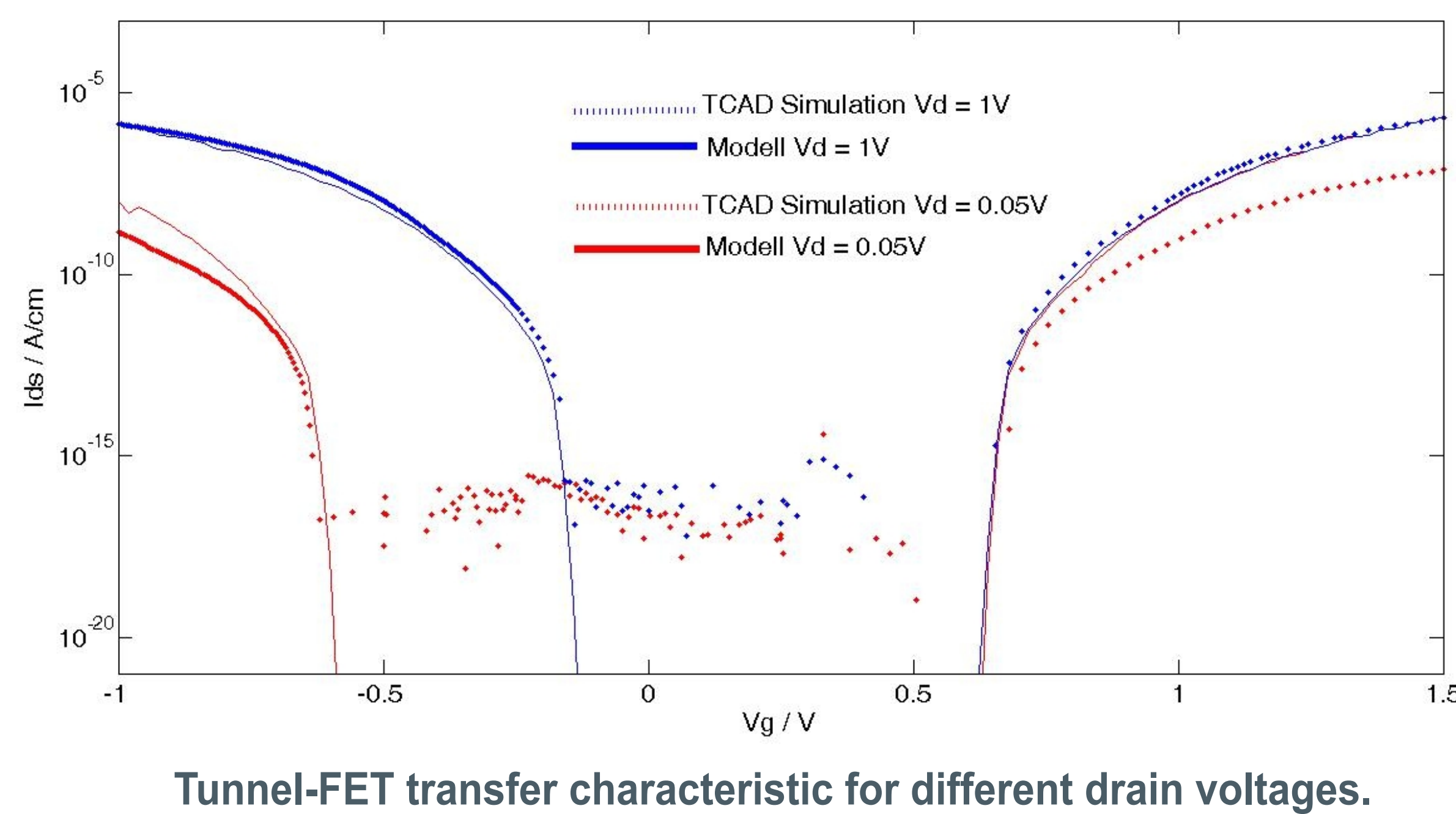
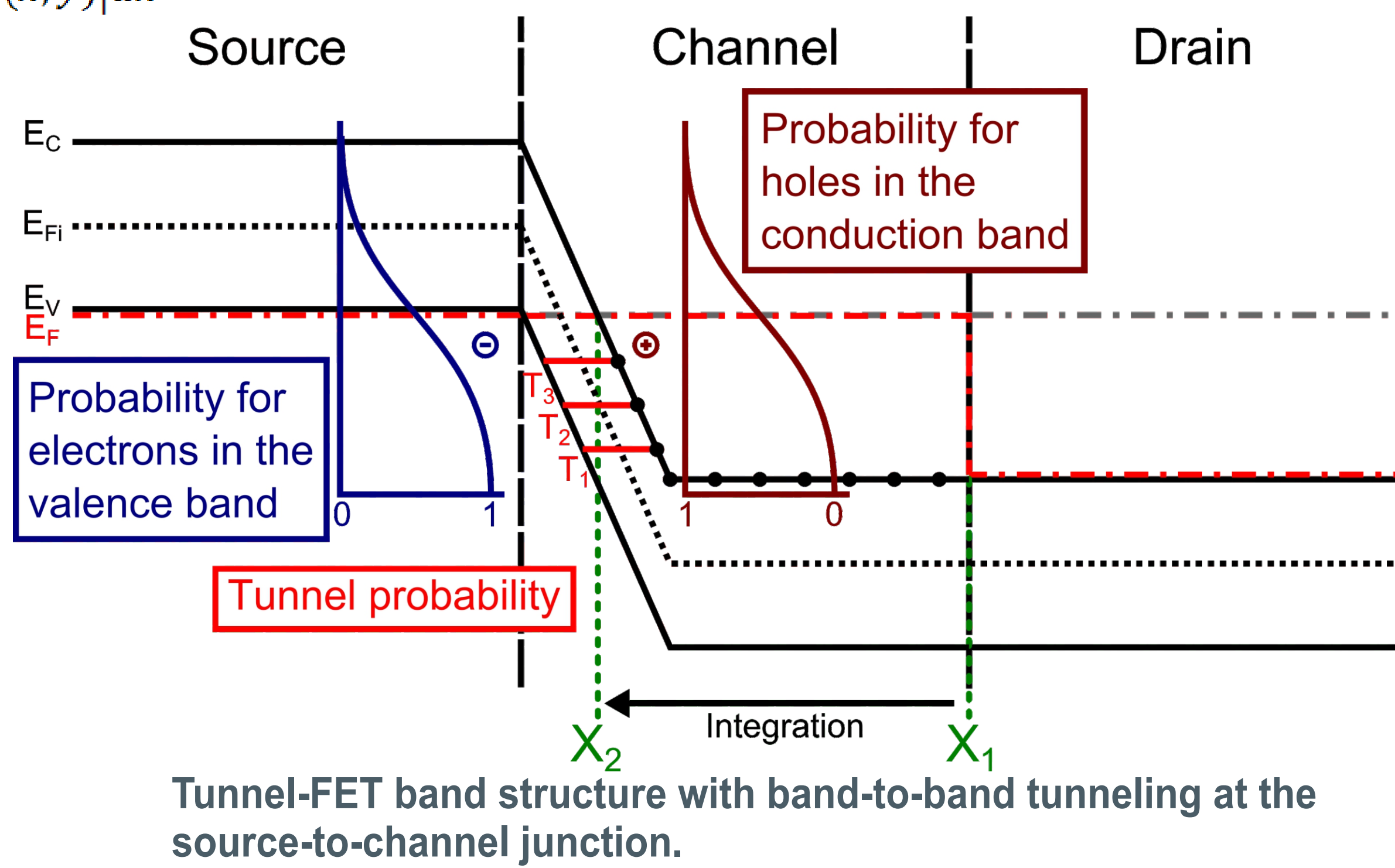


Results

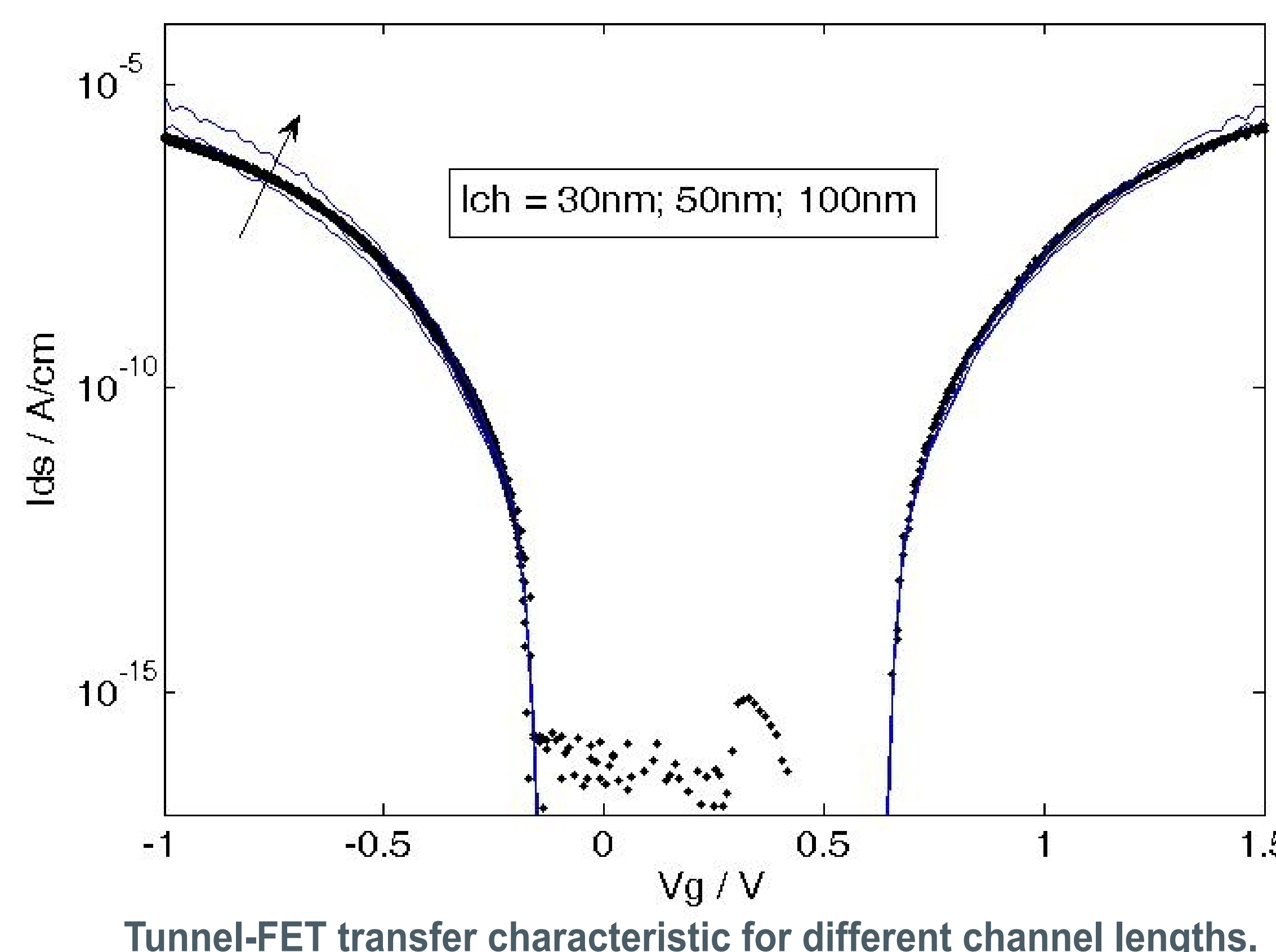
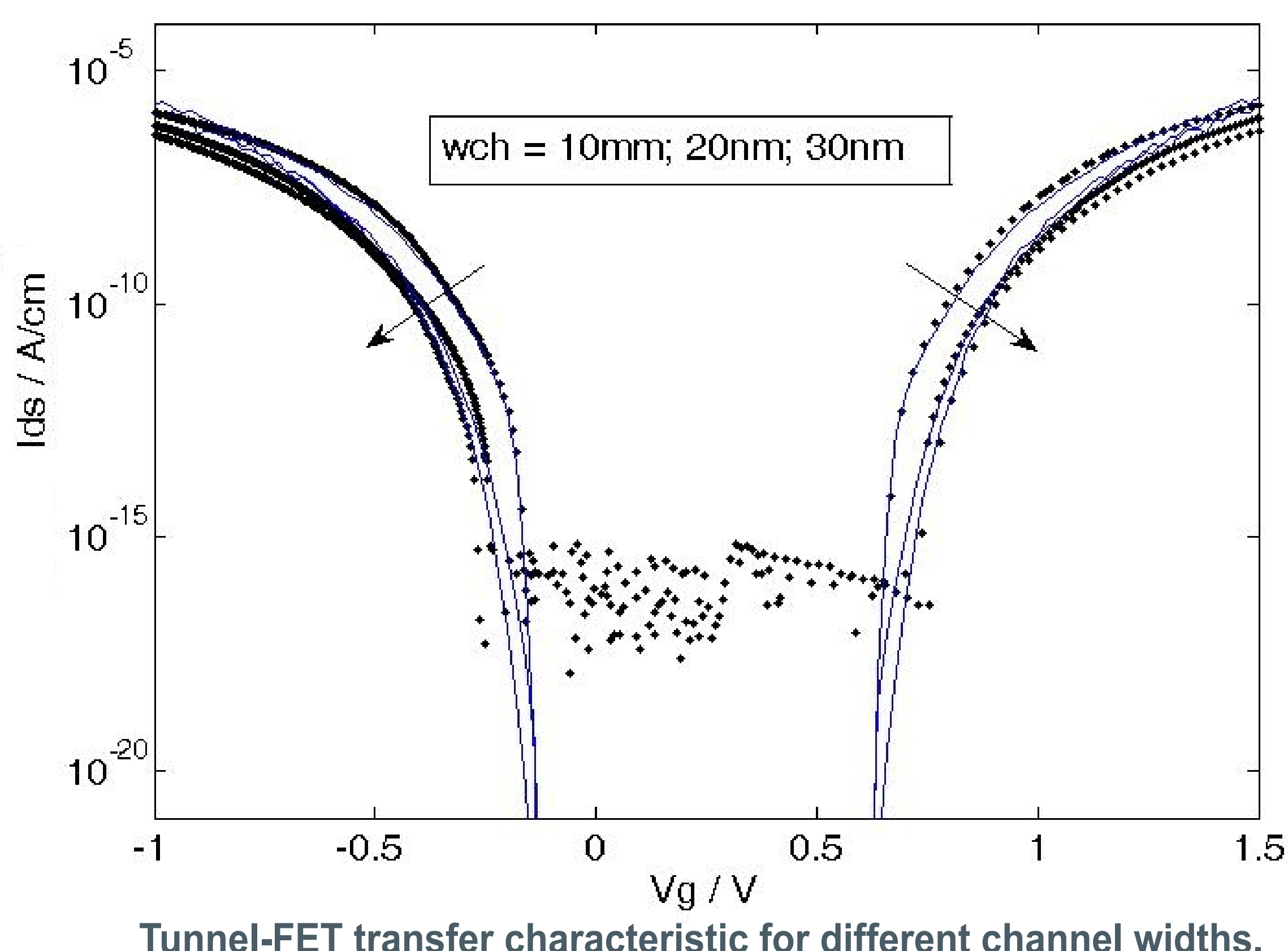
- Tunneling current calculation with Fermi distributions for electrons and holes in source and channel, respectively, and a quasi-2D analytical model for the band-to-band tunneling probability:

$$J_{\text{tun},s}(x, y) = \frac{\mu_n * N_c * q^2 * |\vec{E}|}{k * T} \int_{x_1}^{x_2} T_s(\vec{E}, x) * f_{m,s,con,n}(x, y) * f_{m,s,con,p}(x, y) * |\vec{E}(x, y)| dx$$

Area	Symbol	Value
Source Area:	N_s	$1,5 * 10^{20} \text{ cm}^{-3}$
	ϕ_s	$-0,53 \text{ V}$
Channel Area	μ_r	6
	μ_i	4
	m_c	$0,26 * m_0$
	m_p	$0,26 * m_0$
	N_{ct}	$1,02 * 10^{10} \text{ cm}^{-3}$
	N_c	$2,8 * 10^{19} \text{ cm}^{-3}$
	N_v	$2,65 * 10^{19} \text{ cm}^{-3}$
Gate Area	V_g	$-1 \text{ V} < V_g < 1,5 \text{ V}$
	ϵ_{ox}	1nm
	Drain Area	V_d
N_d		10^{20} cm^{-3}
ϕ_d		$-0,523 \text{ V}$



- Tunnel-FET transfer characteristic for modified model parameters.
- Comparing the results with simulations from TCAD-Sentaurus.



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References

[1] Woo Young Choi, Byung-Gook Park, Jong Duk Lee, Tsu-Jae King Liu: Tunneling Field-Effect Transistors (TFETs) With Subthreshold Swing (SS) Less Than 60 mV/dec. IEEE Electron Device Letters, vol.28, no.8. 2007.

[2] M. Schwarz, T. Holtij, A. Kloes, B. Iniguez: Analytical Compact Modeling Framework for the 2D Electrostatics in Lightly Doped Double-Gate MOSFETs, Solid-State Electronics, no. 69, pp. 72-84, 2012.

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