

2019 NSF STC Virtual Site Visit  
February 8, 2019

## Theme 1: Nano-electronics

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Fischer



Louie



Bokor



Yablonovitch



Javey



Jing Kong



Del Alamo



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STANFORD  
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THE UNIVERSITY OF  
TEXAS AT EL PASO

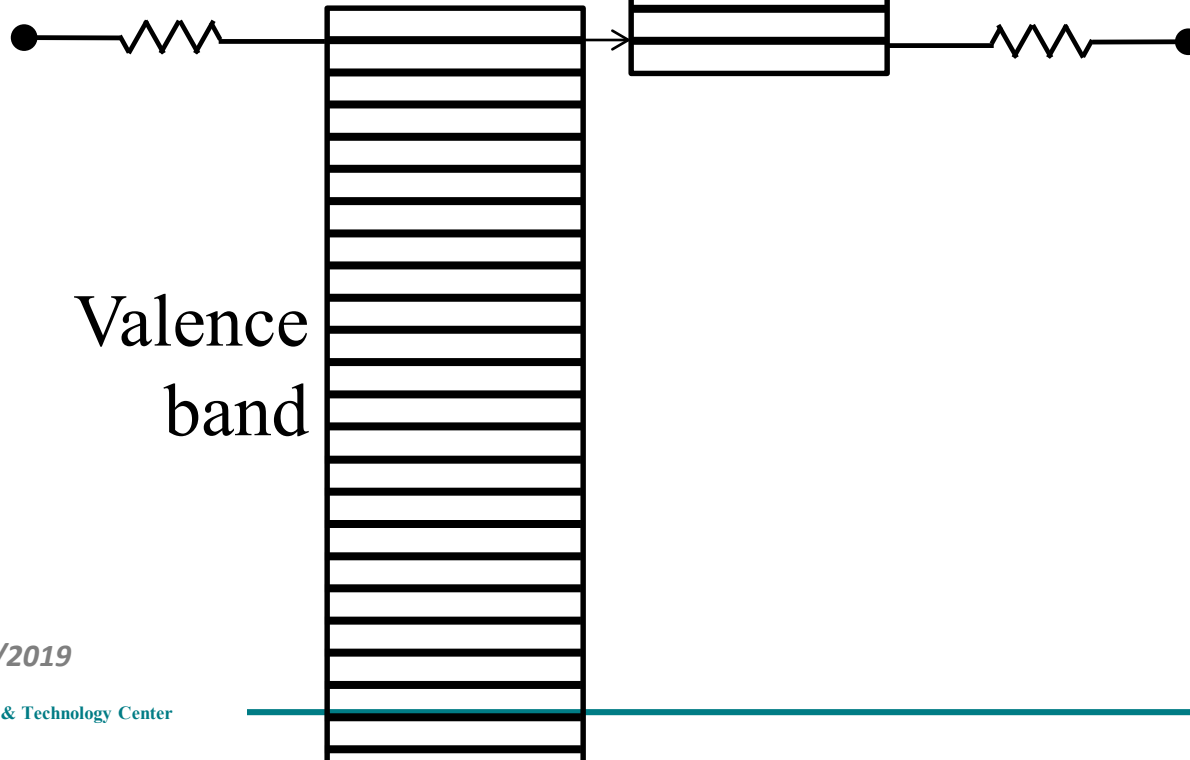
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Electronics Science

Preferred  
TFET  
Switching  
Principle:



Conduction  
band

2d quantum  
Density of States  
 $\sim 10^{13}$  states/cm<sup>2</sup>eV

Valence  
band



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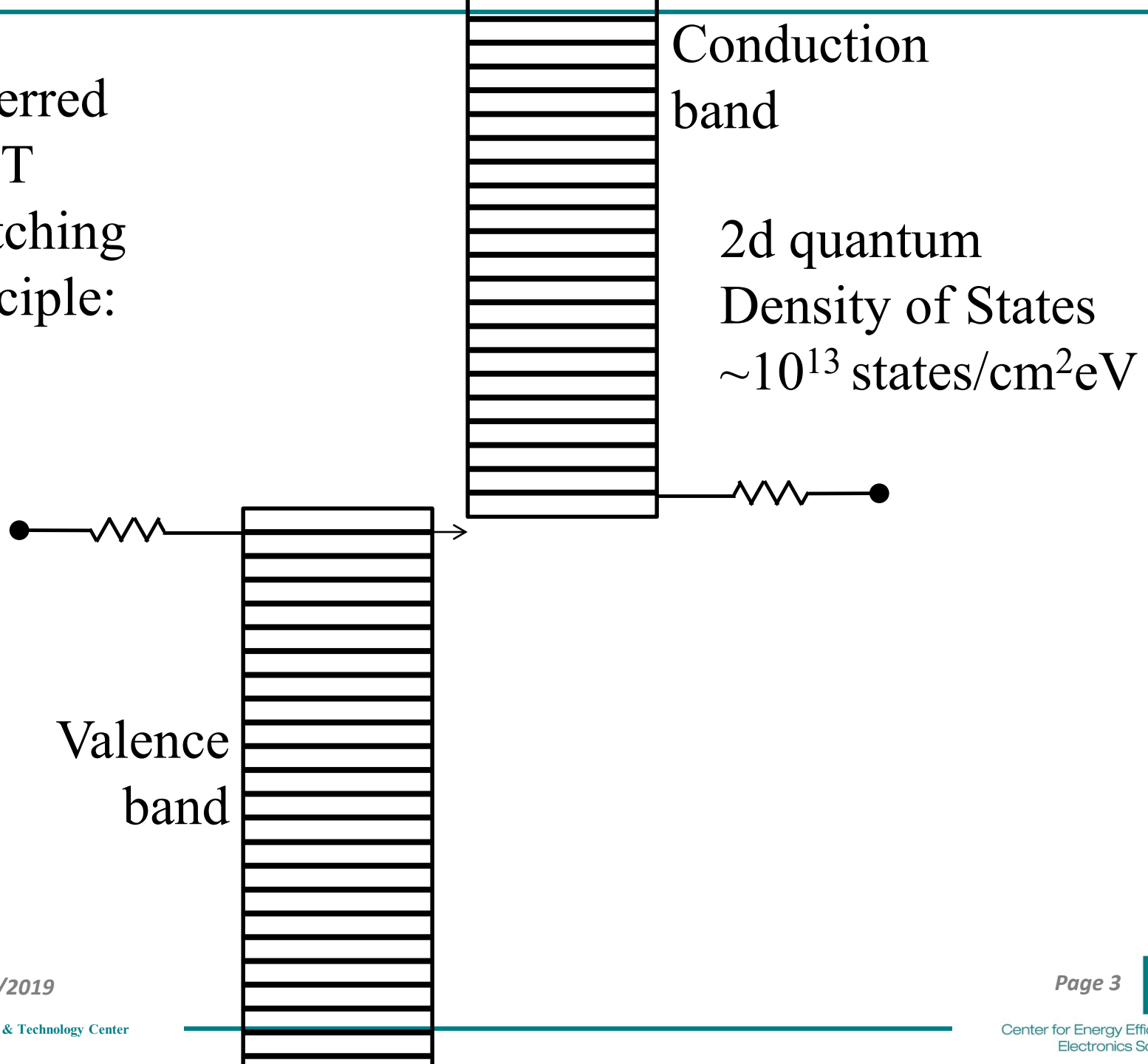
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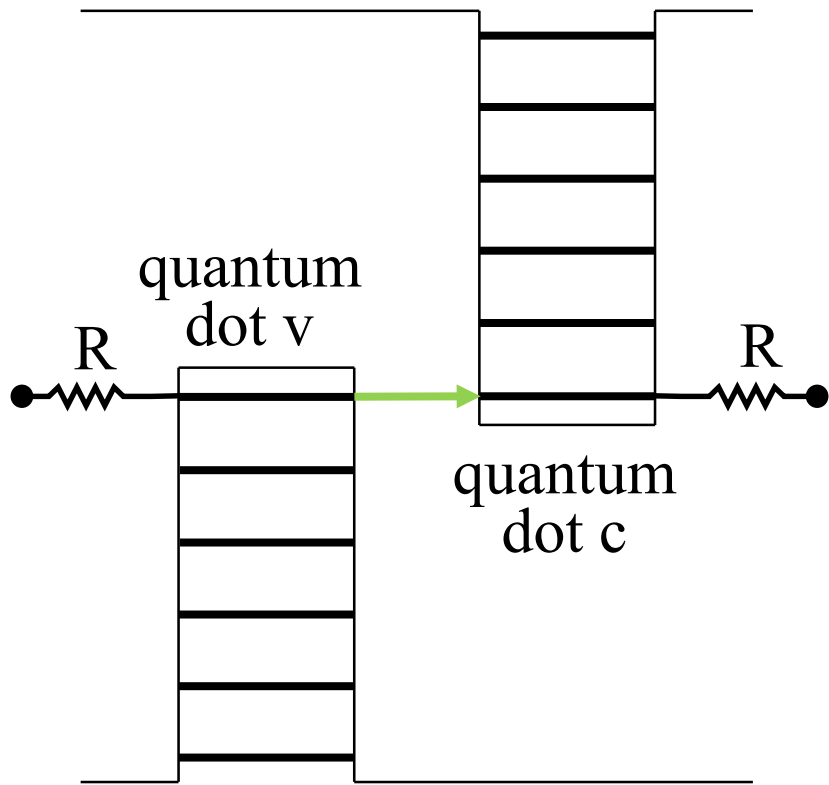


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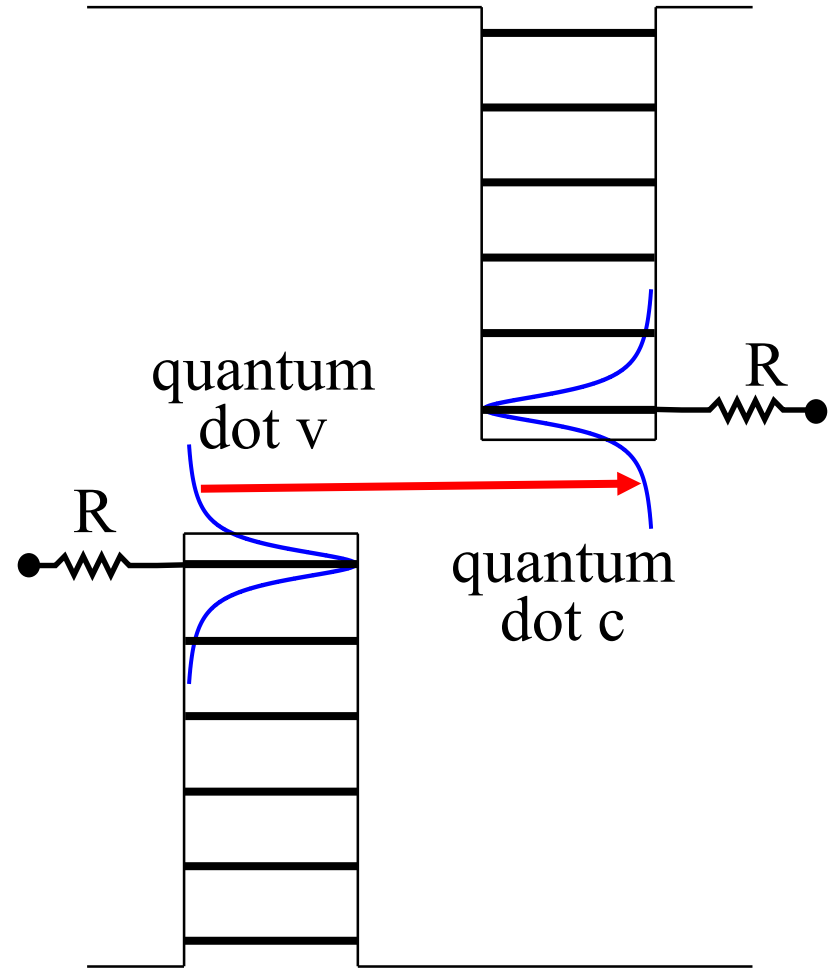
## Challenges to the Ideal "Energy-Filtering" t-FET:

1. Conductance becomes Intrinsically Handicapped at  $V_{sd} < 100\text{mVolts}$ , and it's really harmful.
2.  $D_{it}$  is a severe problem, not because of the gate efficiency, but because of On/Off ratio.
3. Coulomb Blockade demands greater contact linewidth broadening, penalizing voltage.
4. Phonon broadening.
5. Phonon-assisted tunneling.
6. Dopants create an extrinsic bandtail.
7. There is further harm to the On/Off ratio caused by "Inverse Auger", or "Impact Ionization" leakage.
8.  $D_{it}$  is a severe problem, not because of the gate efficiency, but because of On/Off ratio.

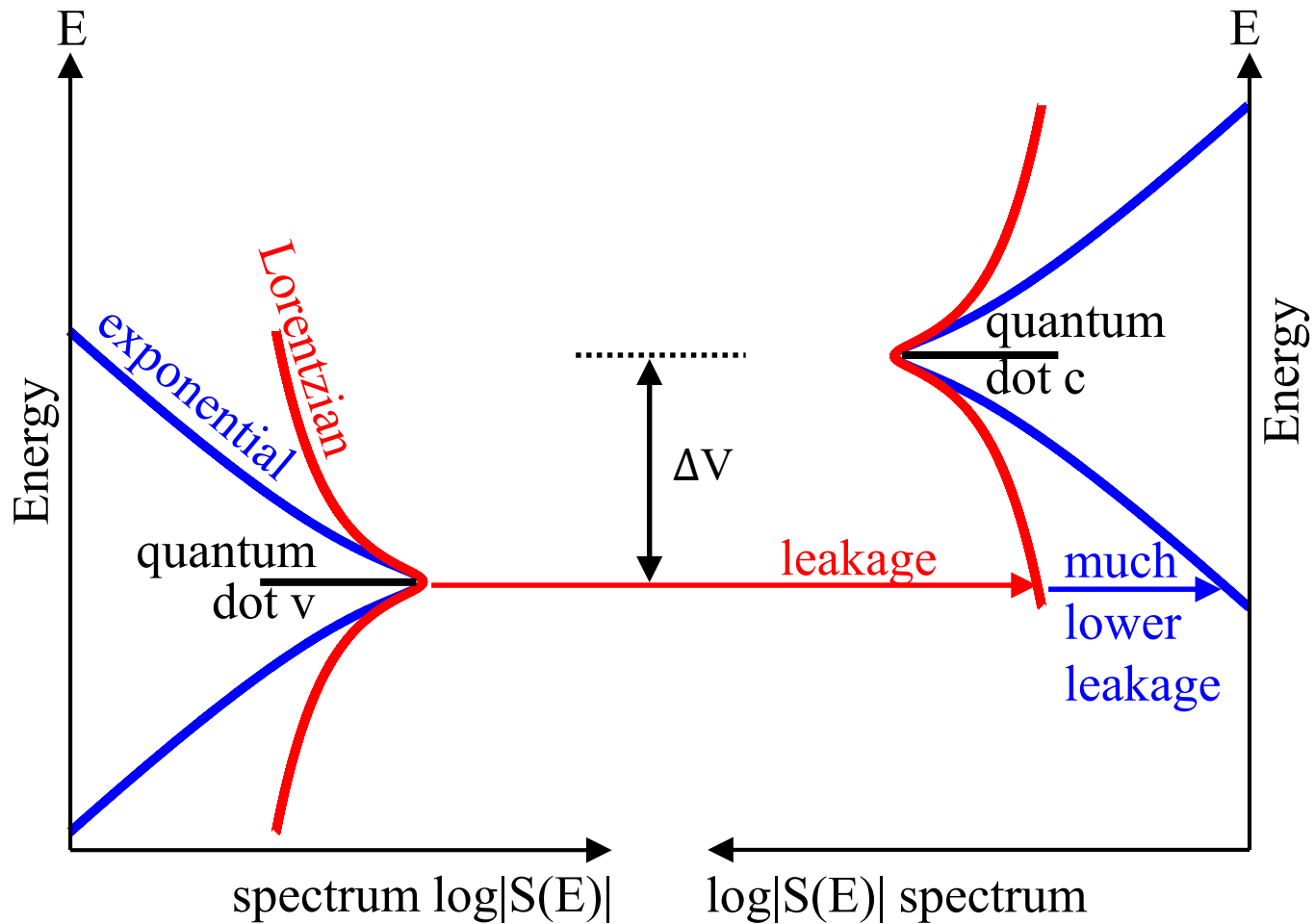




(a) aligned



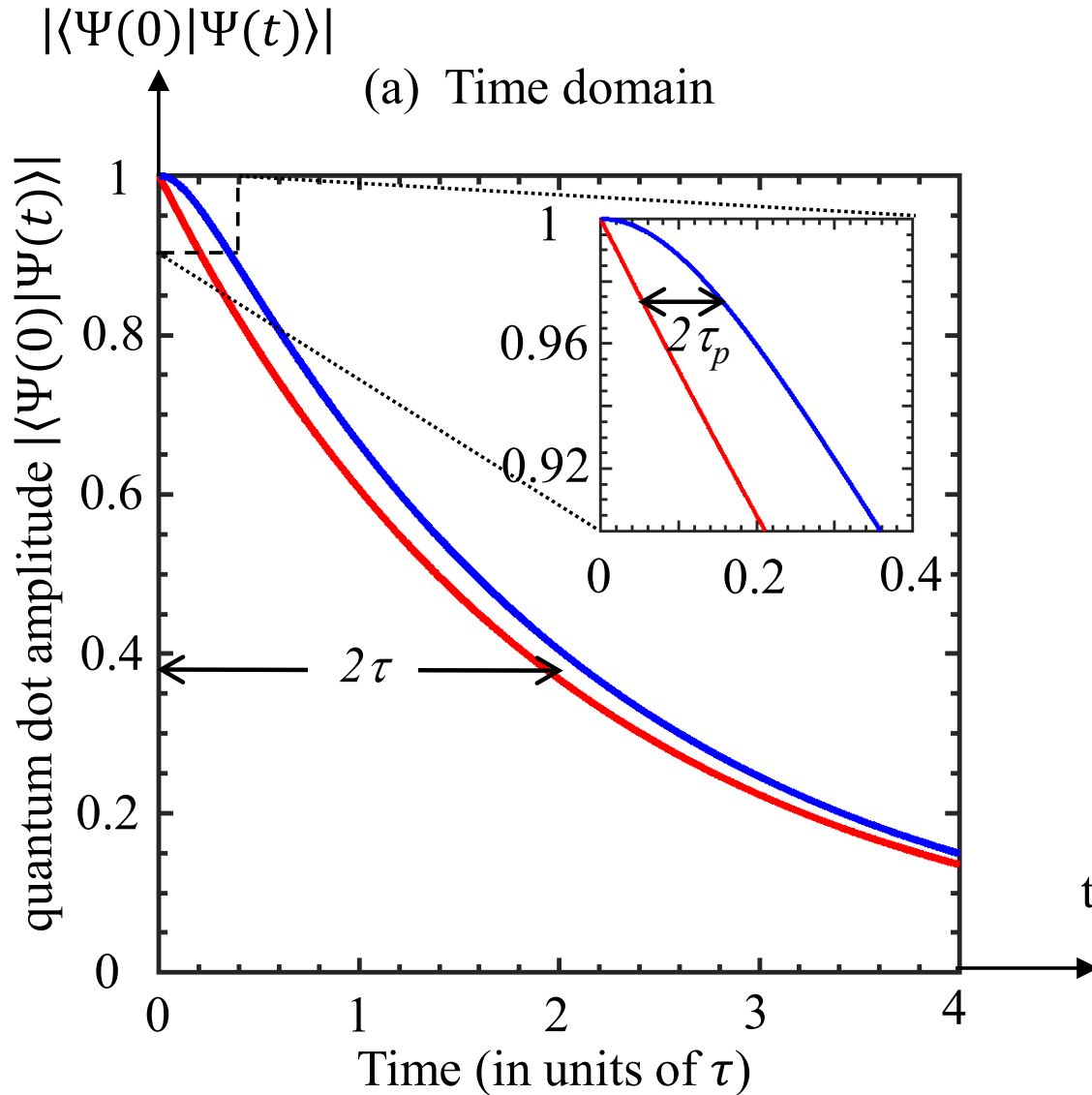
(b) misaligned



(b)

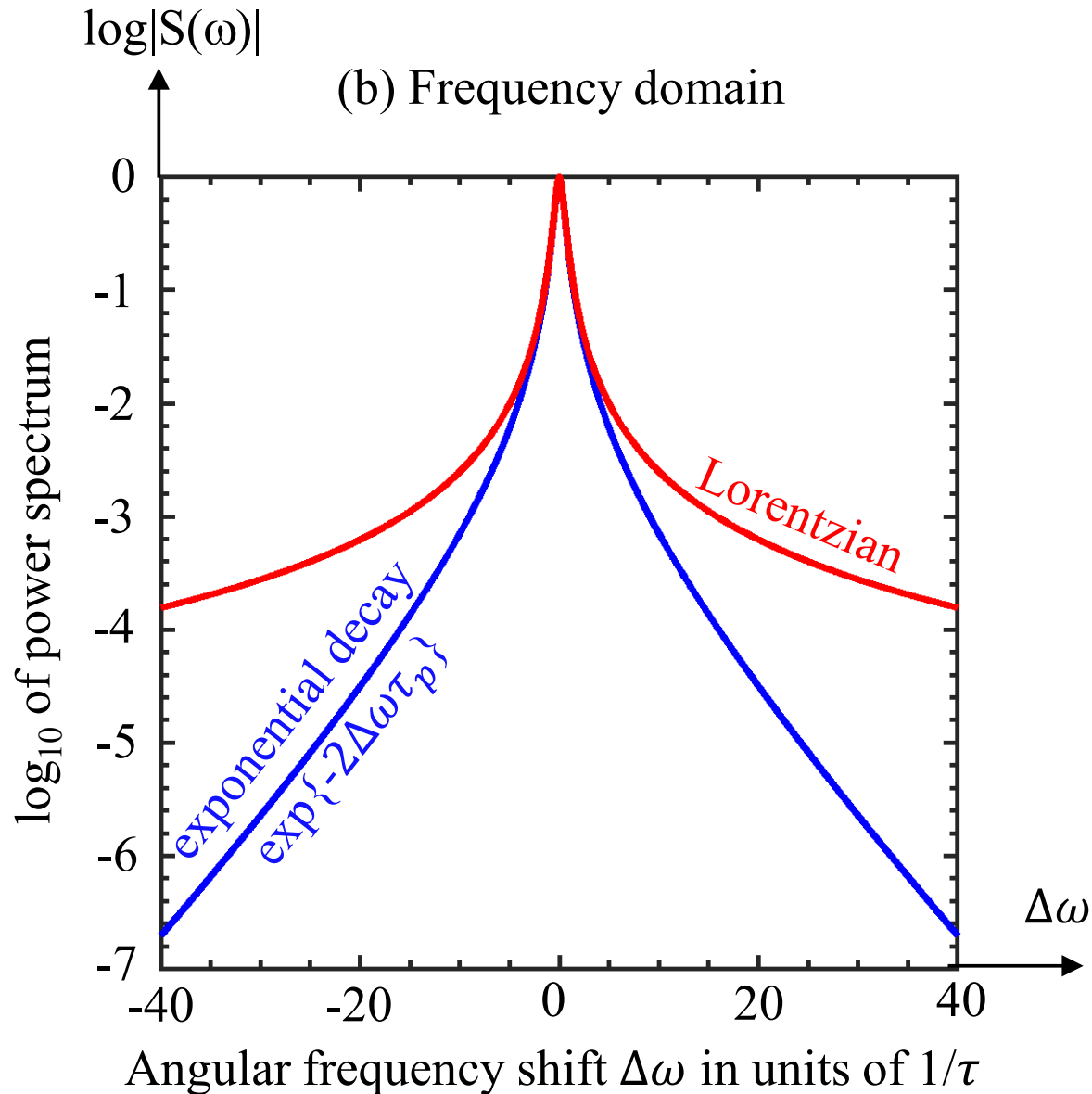
For Lorentzian spectral tails,  
 you can never turn off the tunnel-FET

What happens in reality is not exponential decay:



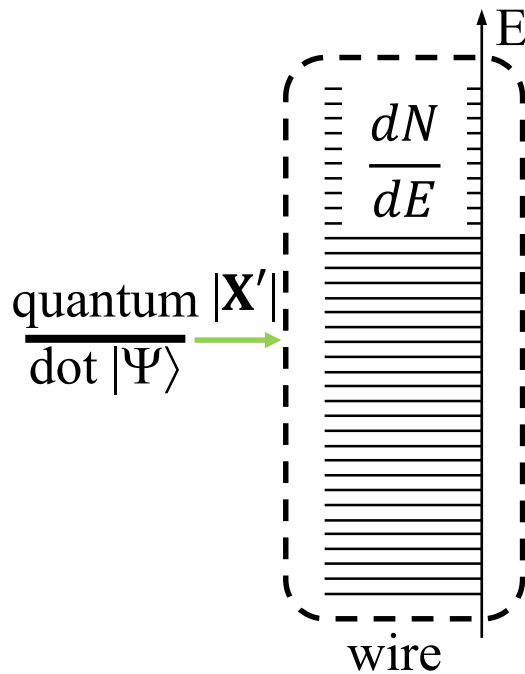
There is an initial parabolic period of time  $2\tau_p$  !

The initial parabolic decay rescues the tFET concept:

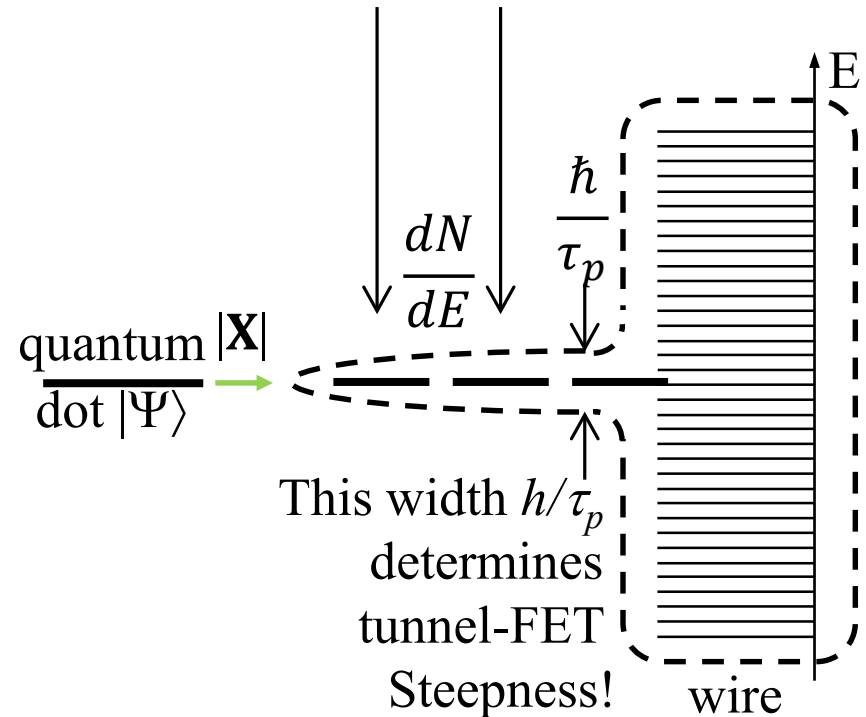




We are setting forth, for the first time, the requirement: that the wires connecting to a tunnel FET should consist of 1-d conductors of heavy effective mass, a narrow band metal that can only be achieved by a metallic, graphene nano-ribbon

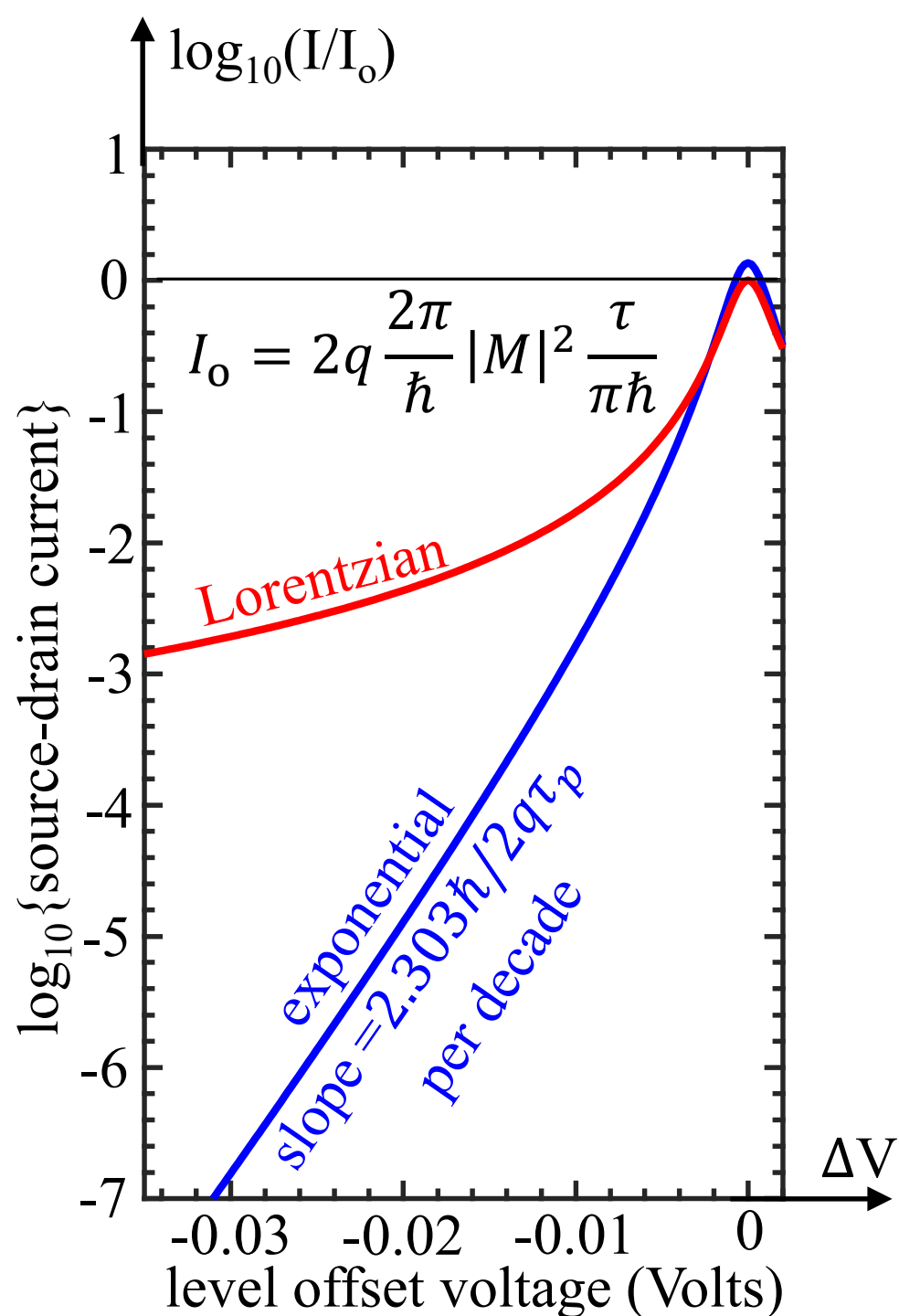


Lorentzian  
straight  
Fermi's  
Golden  
Rule

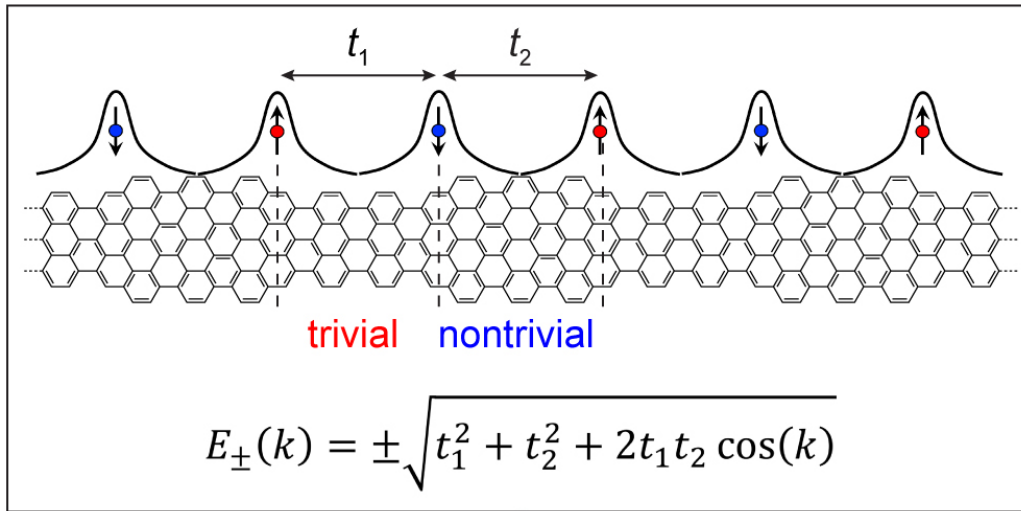


initial  
parabolic  
decay  
for a  
time  $\tau_p$

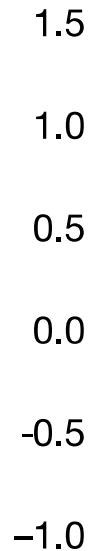
The predicted tFET  
I-V curves.



# Engineering Metallic GNRs from Topological Superlattices



**c**



$$E_g = 2 |t_1 - t_2|$$

Semiconductor Band Structure for:

$$t_1 \neq t_2 ; E_g > 0$$

Metallic Band Structure for:

$$t_1 = t_2 ; E_g = 0$$



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### New Requirement:

8. Prevent the Lorentzian lineshape by requiring narrow-band, heavy-effective-mass connecting leads to the tunneling device.

This has implications for other areas of scientific spectroscopy.

