Network for Computational Nanotechnology (NCN)
US Berkeley, Univ.of Illinois, Norfolk State, Northwestern, Purdue, UTEP

Introduction to RTDs: Relaxation Scattering in the Emitter

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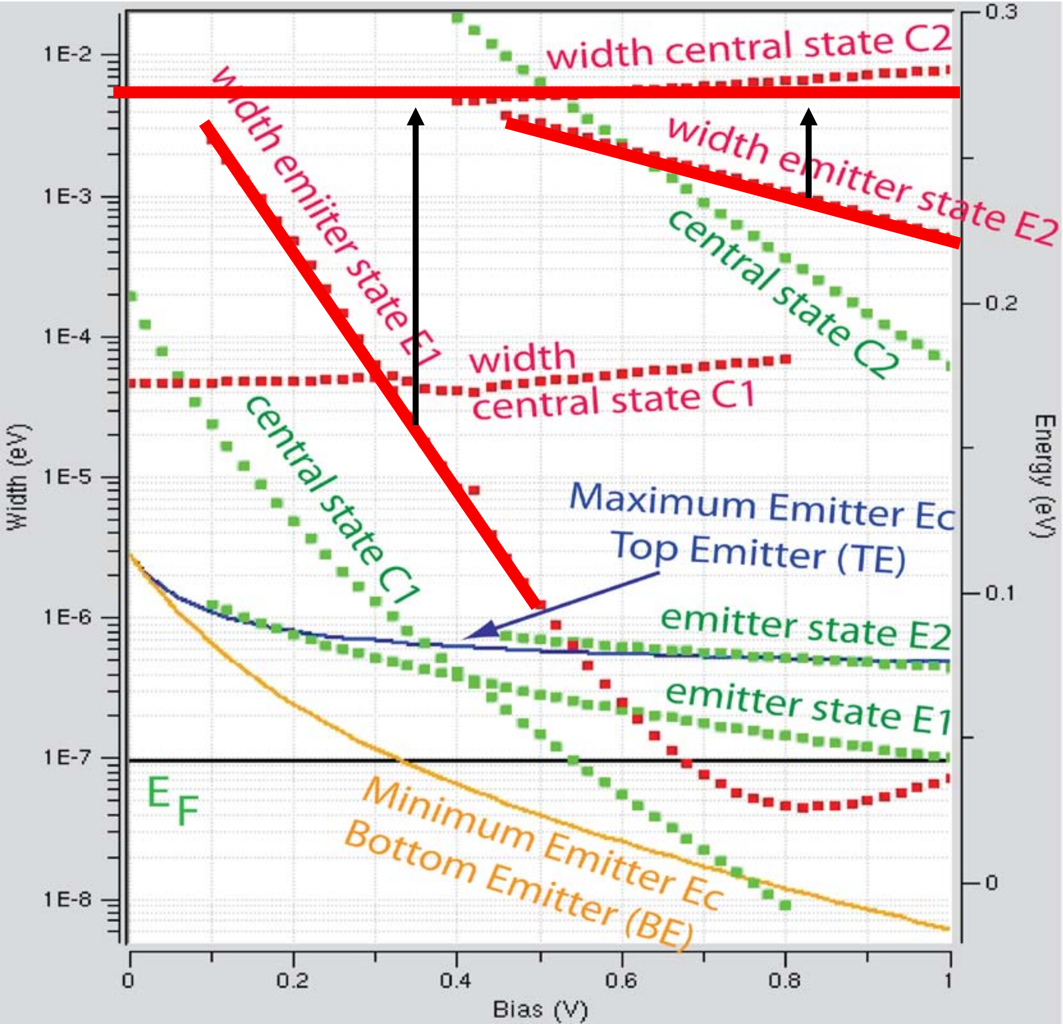
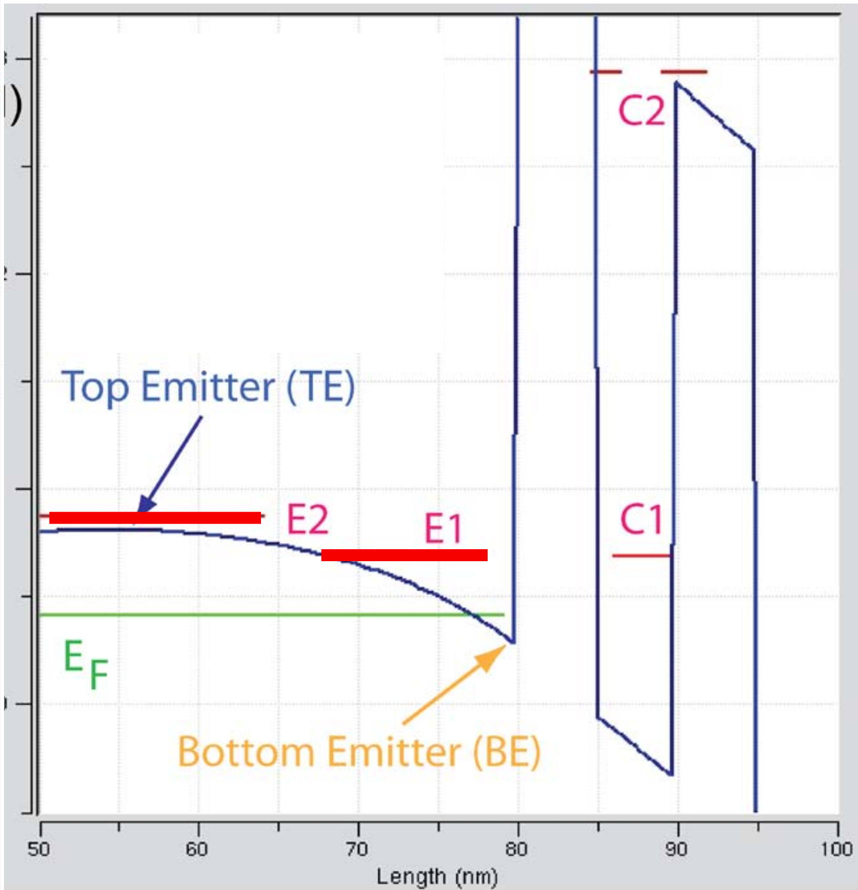
Resonance Widths / Lifetimes in the Emitter

- Width of E1 varies exponentially with bias! => truly bound state!
- Electron sheet density in the emitter is 10^{10}-10^{12}/cm^2
  => strong electron-electron and electron-phonon scattering
  => state is broadened

$$\tau = 0.1 ps$$

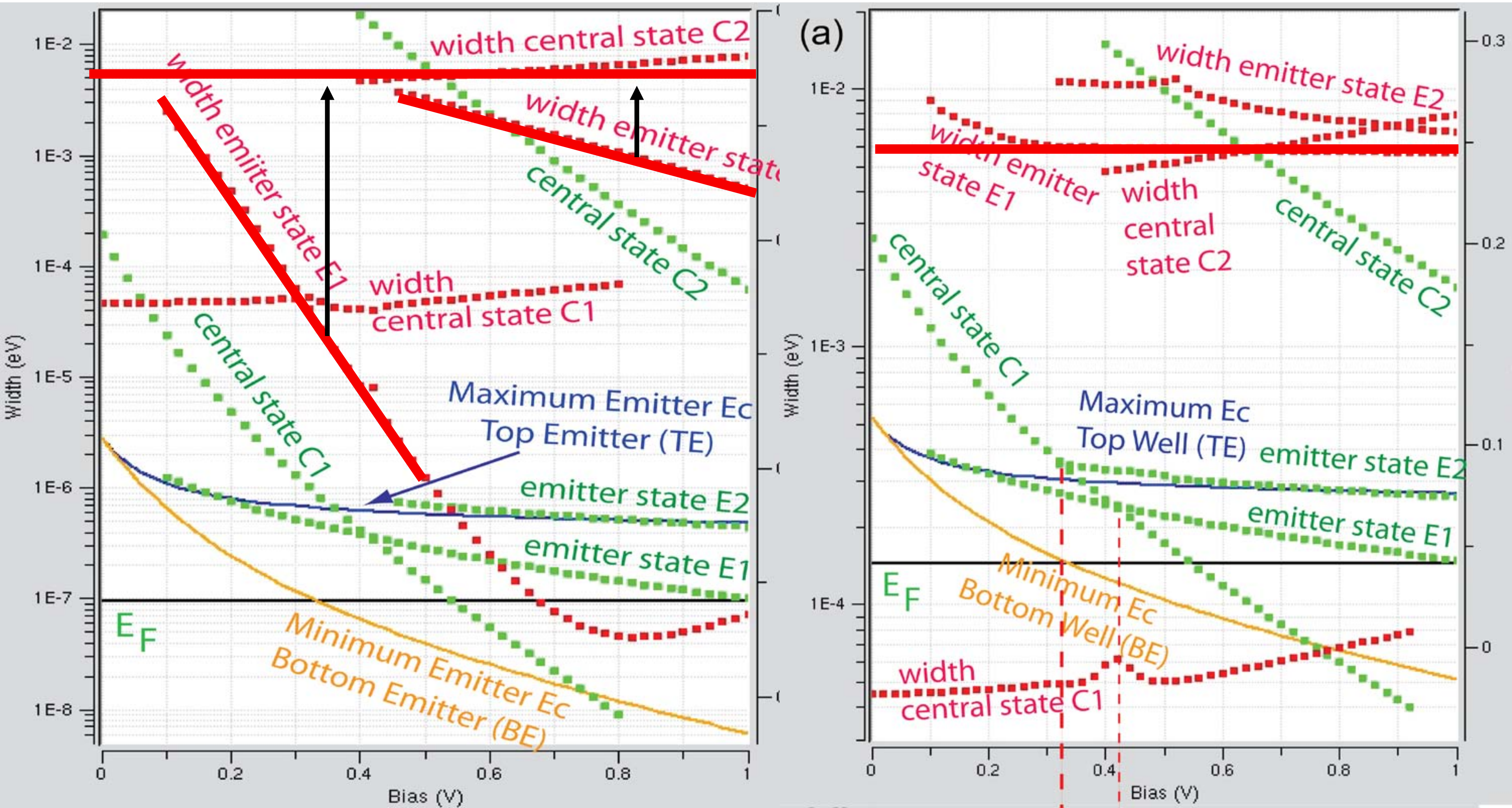
$$\Gamma = \hbar/2\tau = 6.6 meV$$



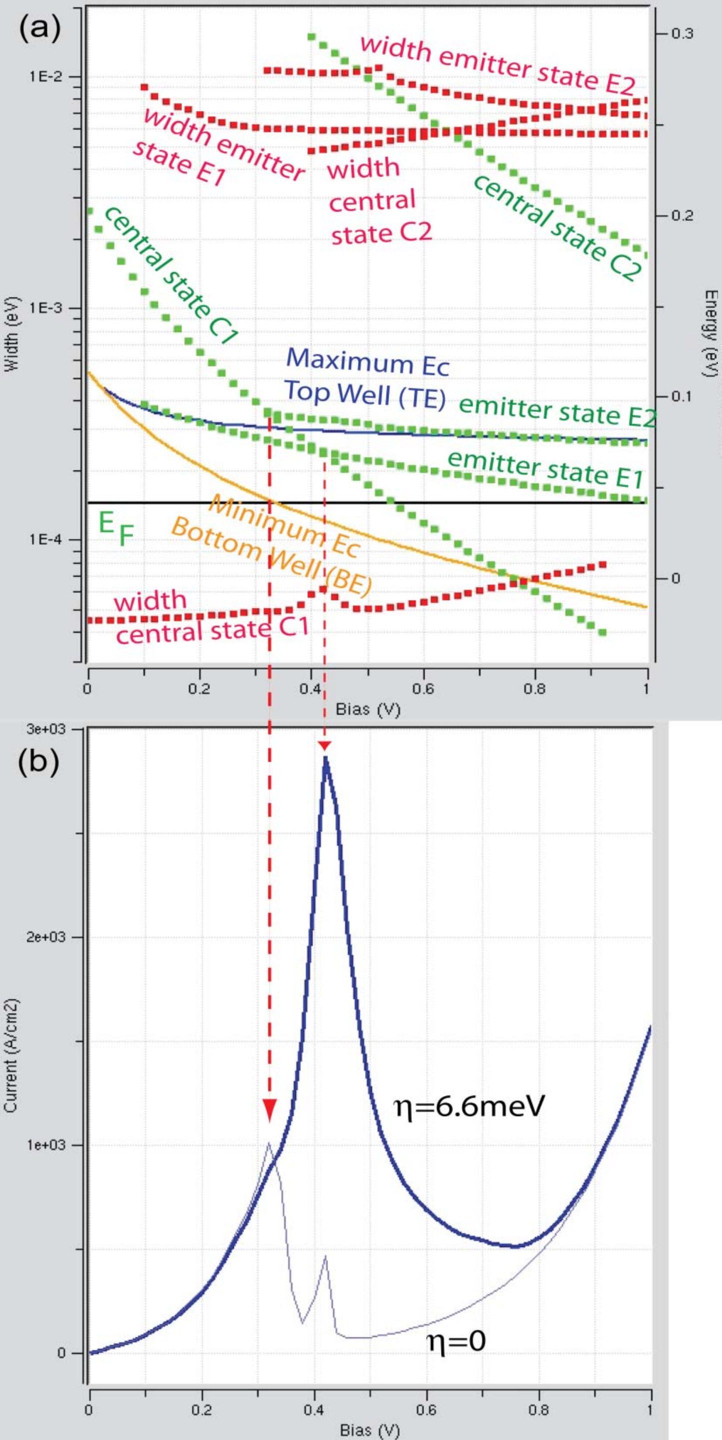


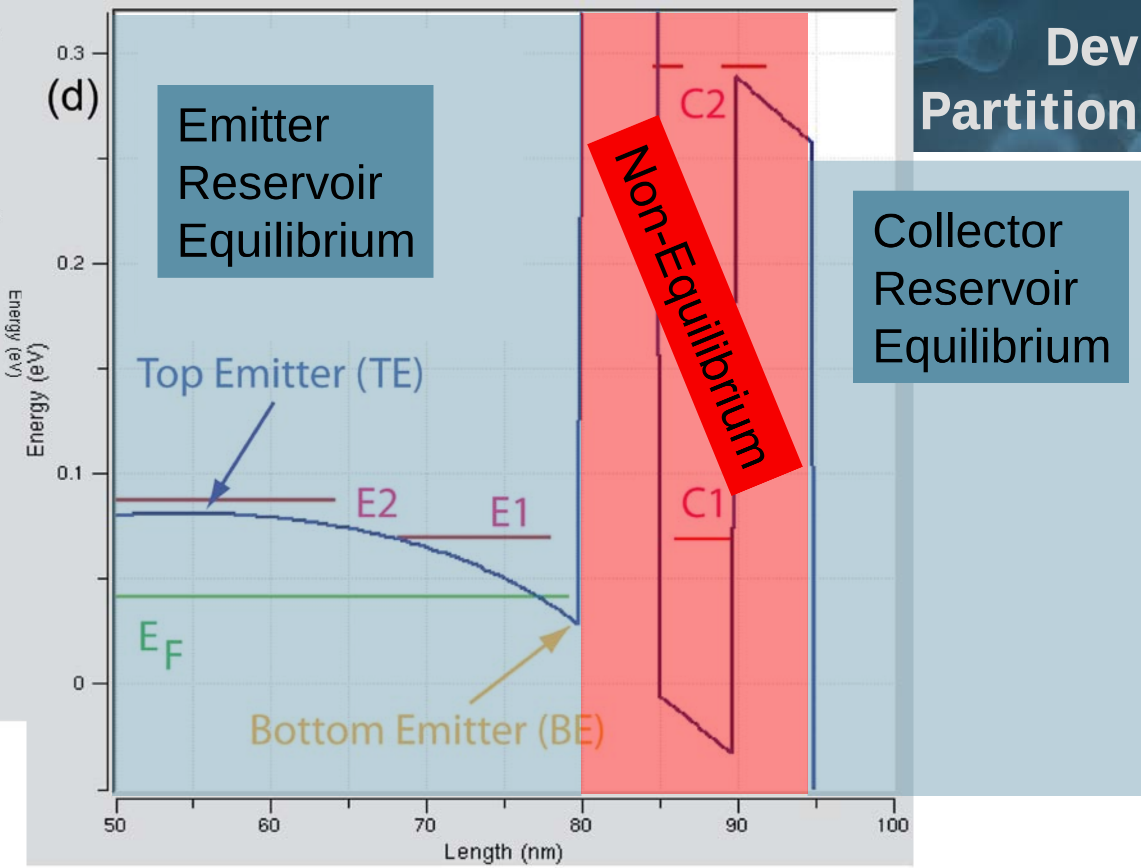
Relaxation in the Emitter - η=6.6meV

- NEMO [APL94] introduced the relaxation in the reservoirs $\eta = \hbar / 2\tau = 6.6 meV$
- Mimics the broadening through scattering
- Critical item in the understanding of RTD transport



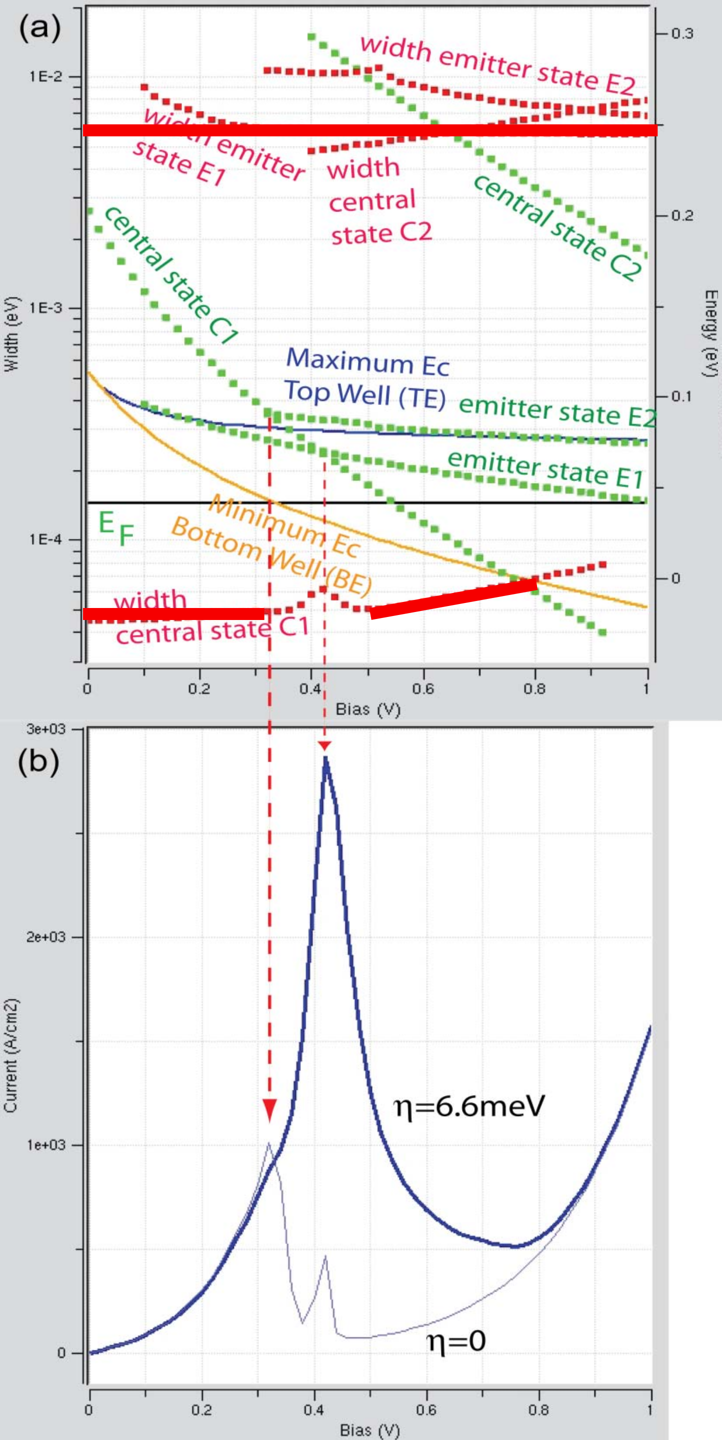
Device Partitioning

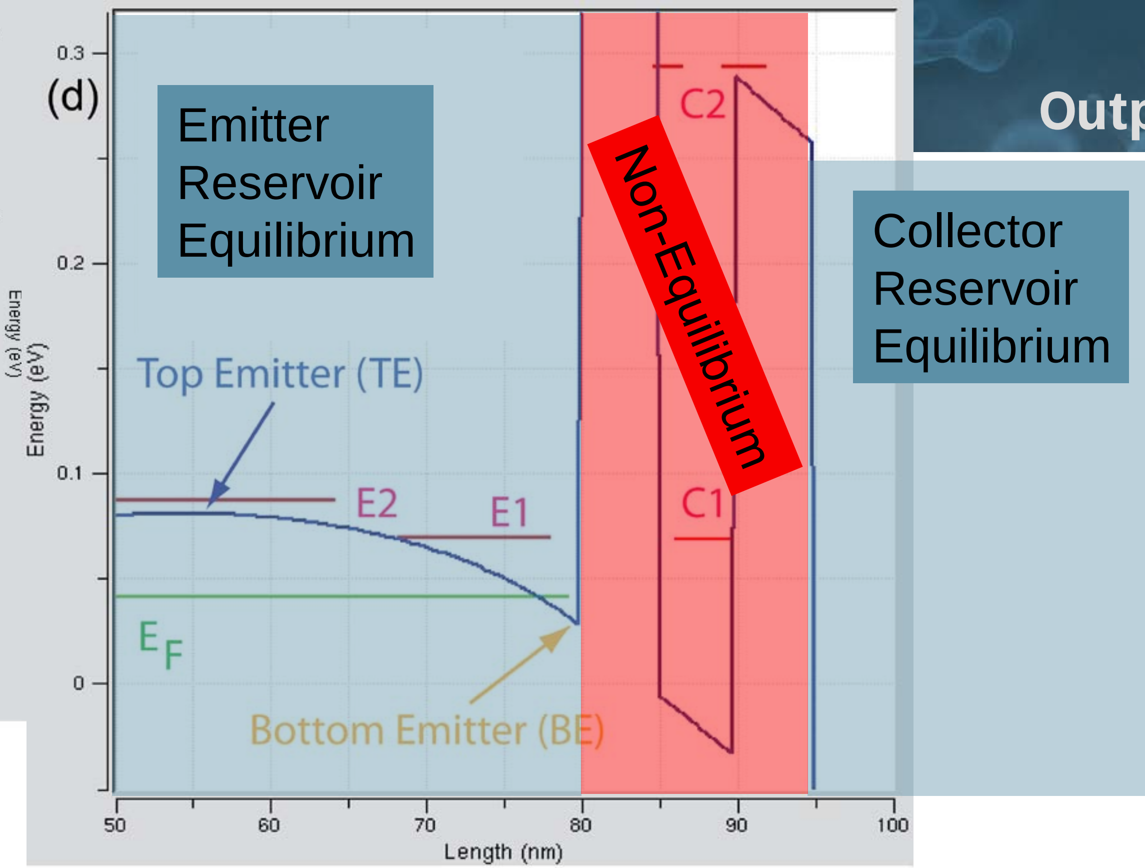




- Emitter and collector ASSUMED to be in equilibrium
  => Reservoirs => STRONG scattering
- iη=i 6.6meV is added to Hamiltonian in reservoirs
  => non-Hermitian
  => current not conserved AND NOT computed
  => only compute equilibrium charge
- Central device region treated with NEGF
  => non-equilibrium charge and current

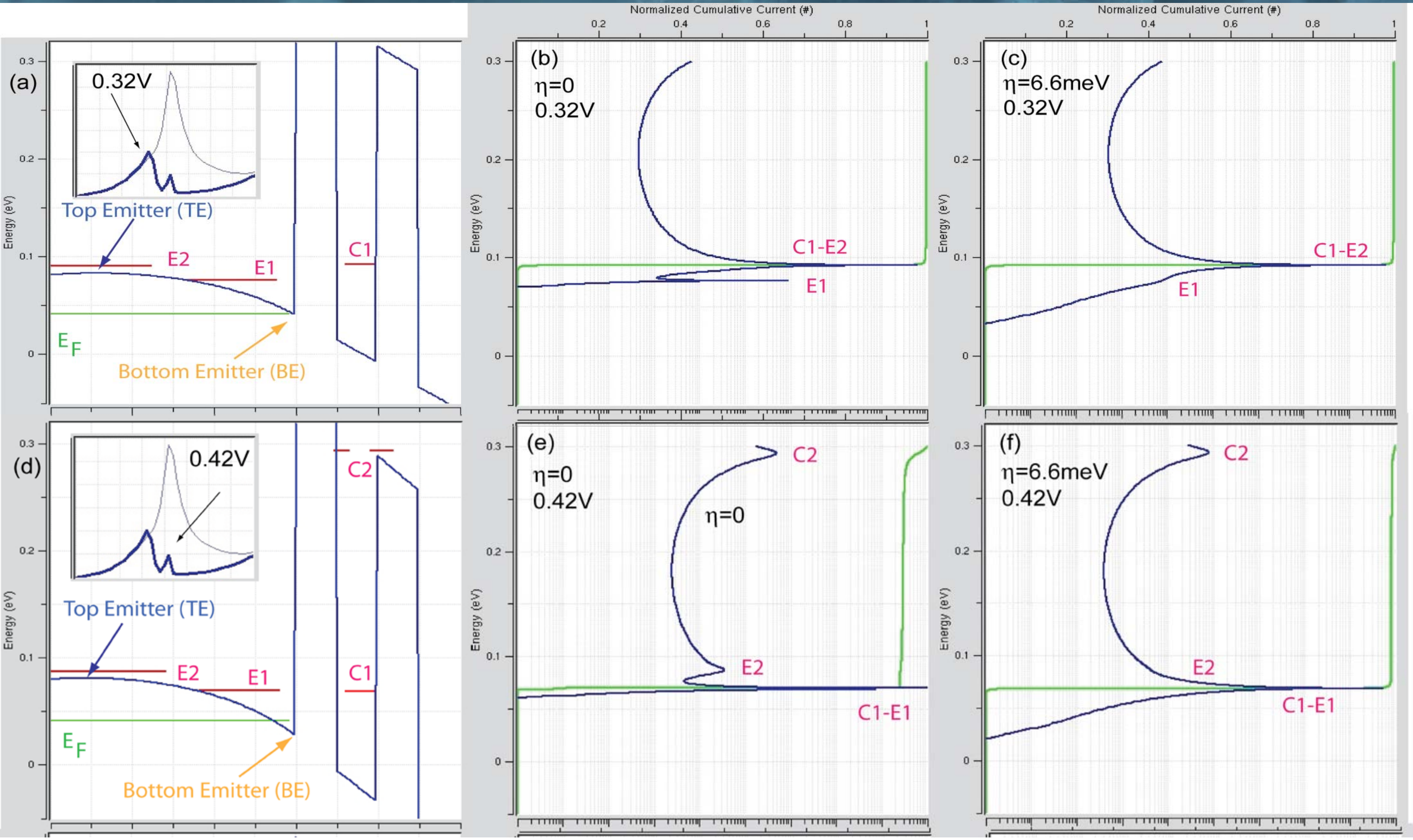
I-V Output

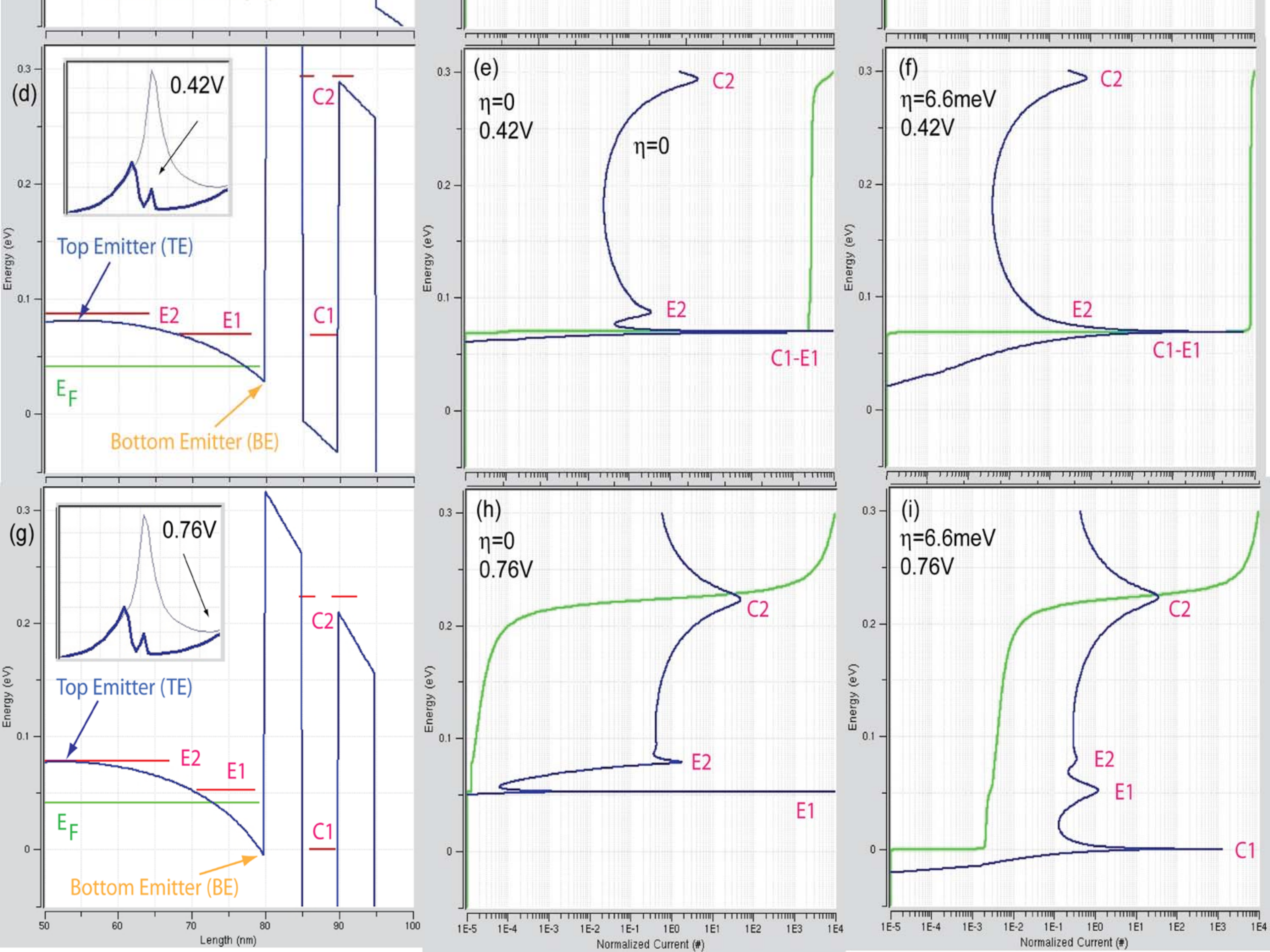




- Central resonance C1 almost unaffected
- Emitter resonances E1 significantly broadened >6.6meV
- The relatively narrow central resonance is probing the states in the emitter
- Overall current increases

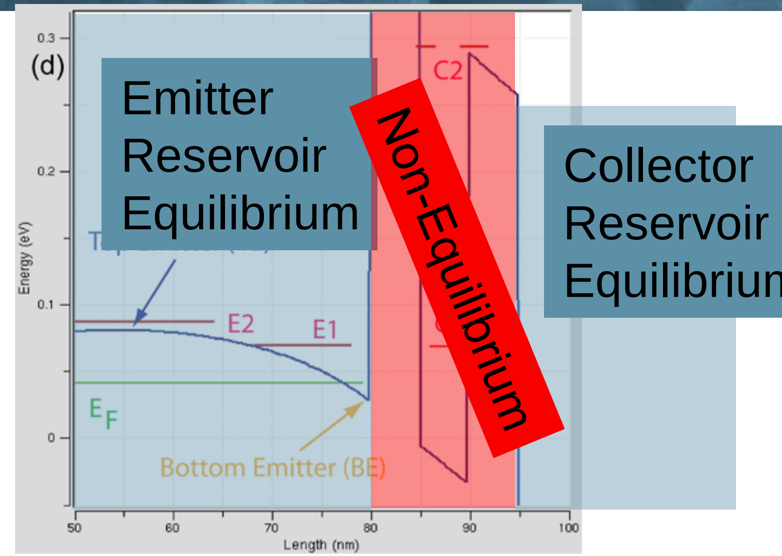
Conduction band edge, transmission, and current density



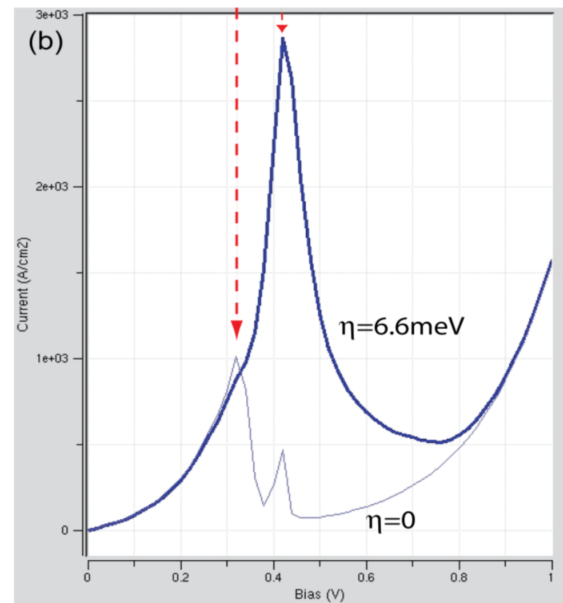


(d)
0.42V
Top Emitter (TE)
E2
E1
C2
C1
EF
Bottom Emitter (BE)
(e)
η=0
0.42V
η=0
C2
E2
C1-E1
(f)
η=6.6meV
0.42V
C2
E2
C1-E1
(g)
0.76V
Top Emitter (TE)
E2
E1
C2
C1
EF
Bottom Emitter (BE)
(h)
η=0
0.76V
C2
E2
E1
(i)
η=6.6meV
0.76V
C2
E2
E1
C1
Energy (eV)
Length (nm)
Normalized Current (#)

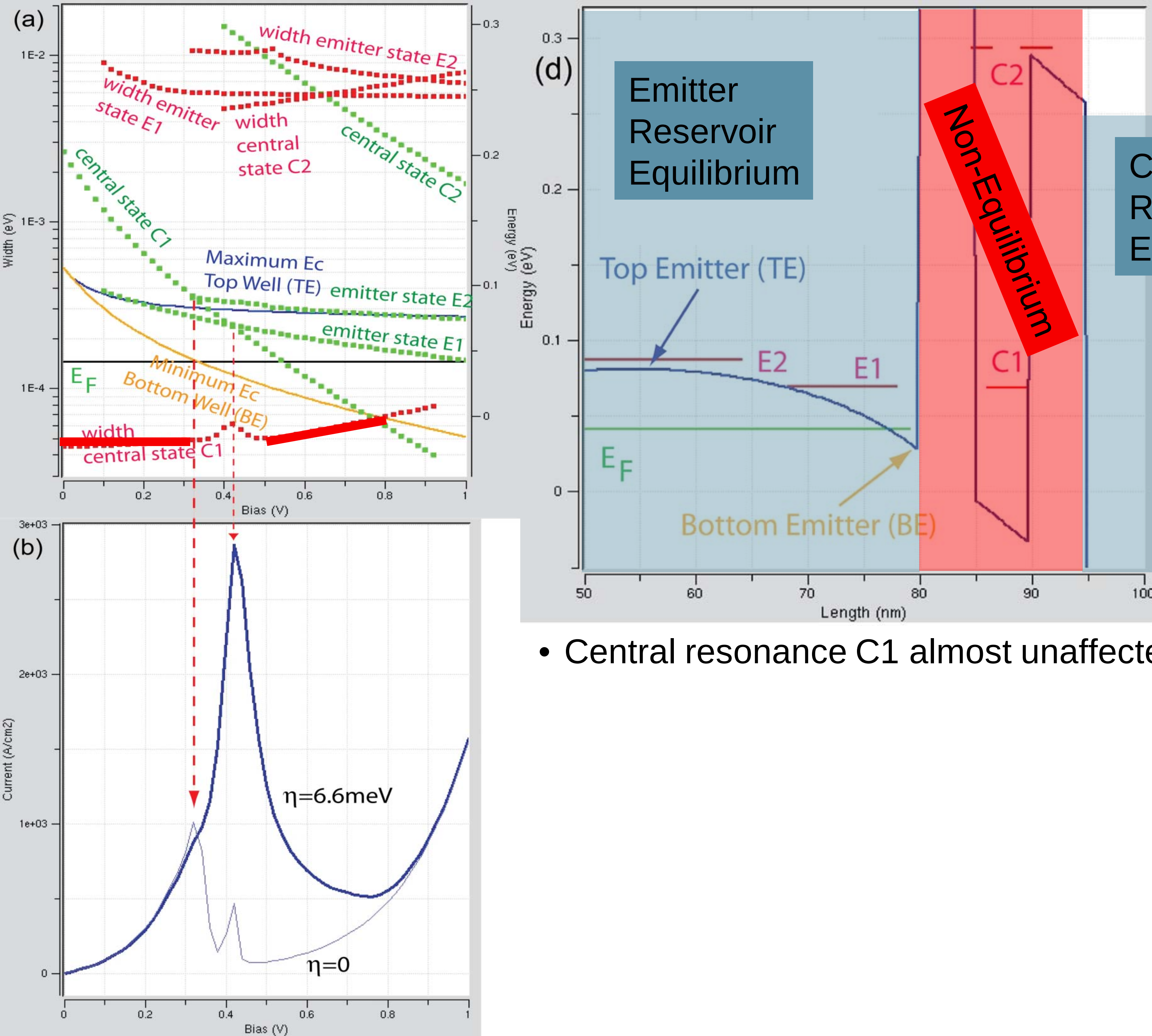
Conclusions



- Realistic doping profiles
  => triangular quantum wells in the emitter.
  => confined states in the emitter
  very long lifetime / very narrow states in the mathematically ideal case
- High electron density in the emitter, Equilibirum conditions!
  => strong equilibrating scattering
  => states are broadened
- NEMO introduced an empirical broadening model
  » Partition the device into reservoirs and NEGF region
  » Reservoirs are non-Hermitian – compute charge only
  » Central NEGF region sees effects of thermalized states
- For typical high performance InGaAs/InAlAs RTDs: set the relaxation to η=*6.6meV*
  => scattering time of about t=0.1ps.
- The relaxation rate should not be used to match experimental data on a one-time basis.



I-V Output



- Central resonance C1 almost unaffected