Study of transistor performance of carbon nanotube networks

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Study of transistor performance of carbon nanotube networks

(1) Modeling carbon nanotube transistor – one problem or many different problems?

(2) Influence of channel geometry

(3) Conductivity vs. density

(4) Conclusion

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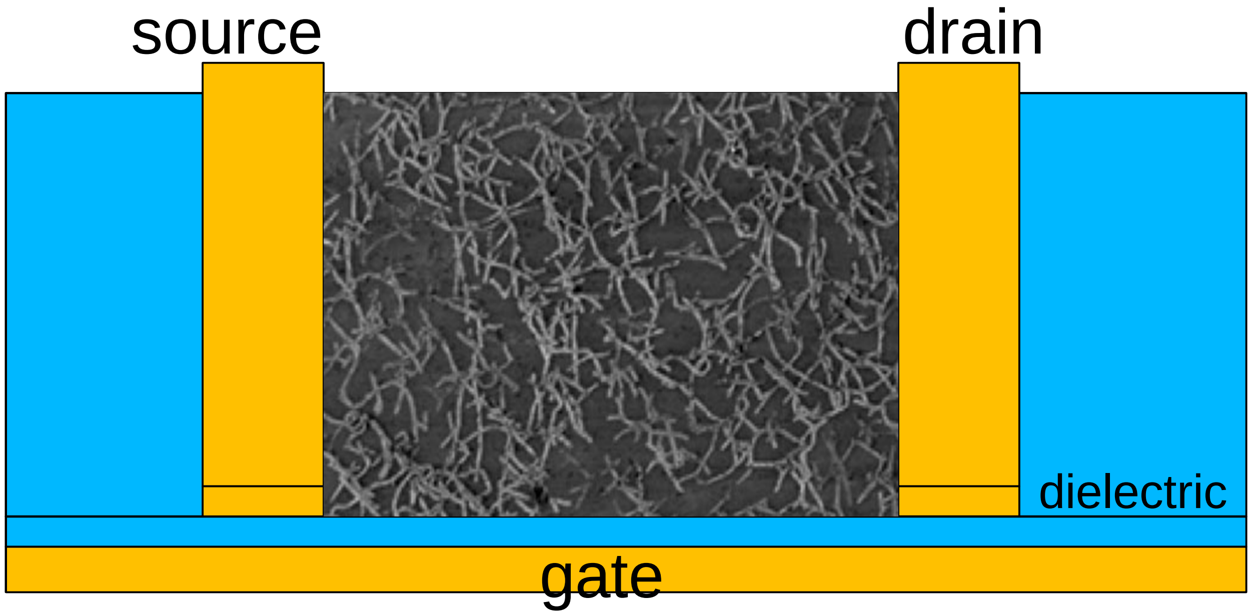
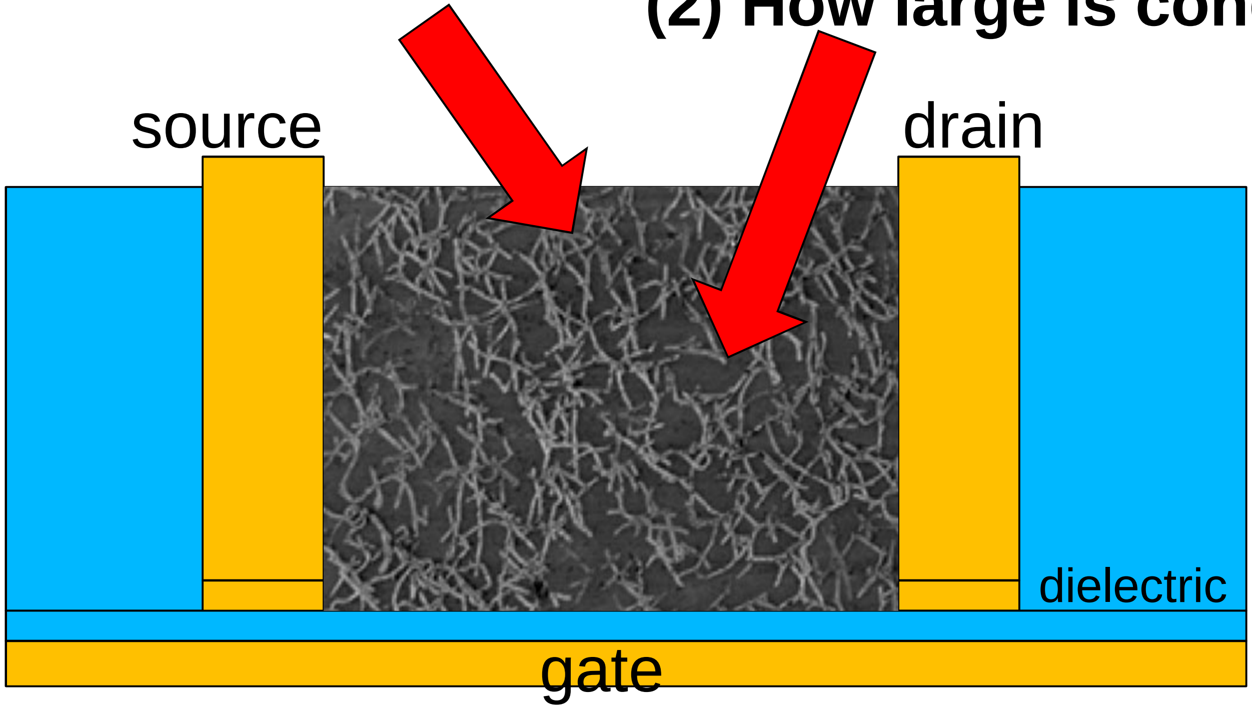
We develop a models for transport properties of random rod-like particle networks.



(1) At which density CNT network conducts?

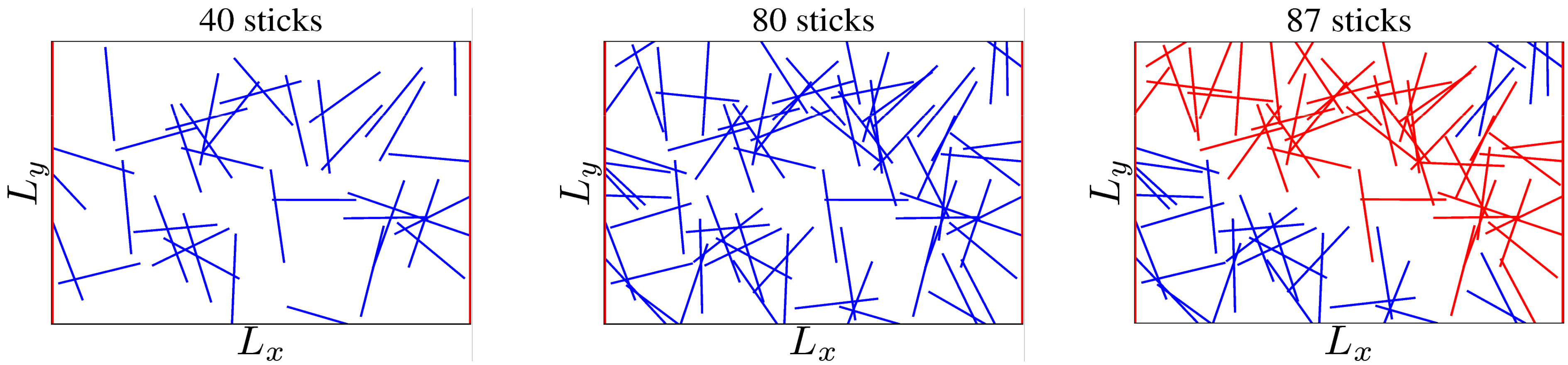
One wants conduction only through semiconductive CNTs!

(2) How large is conductivity?



At which density CNT network conducts?

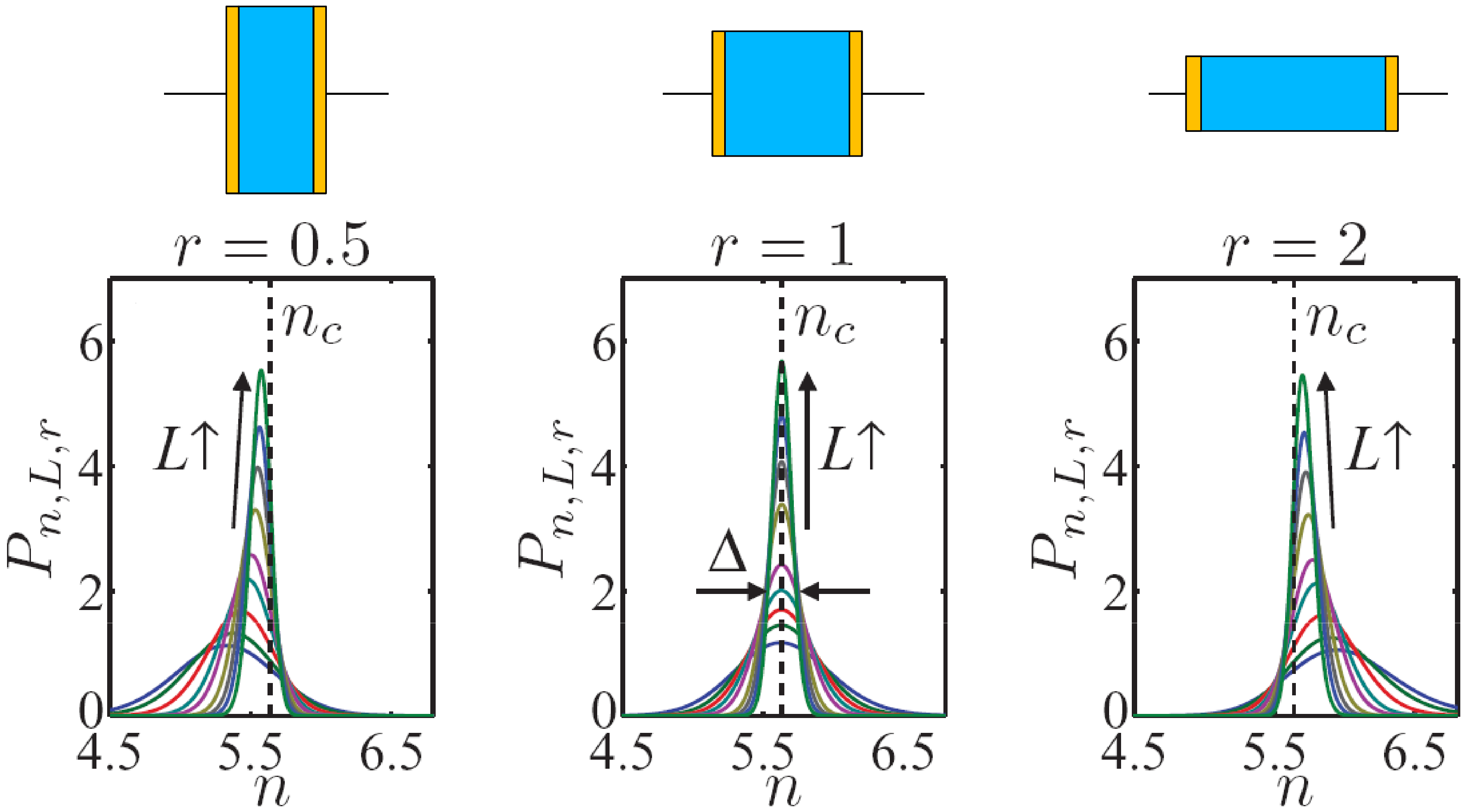
(1) Percolation problem



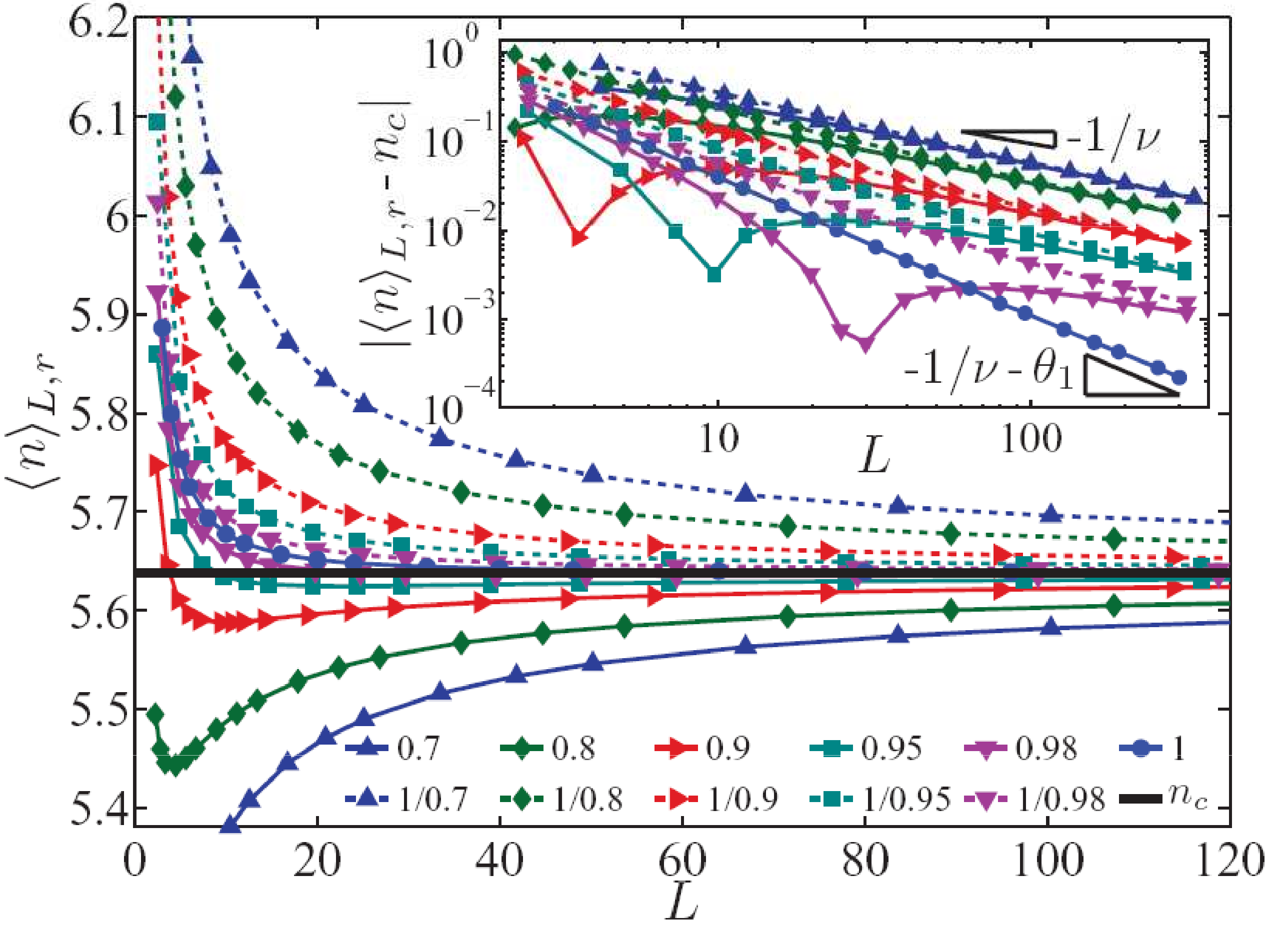
(2) Systems are finite – this is also statistical problem

There is average percolation density and variance.

Influence of channel geometry on probability that system of size L starts to conduct at density n :



Average percolation density can have a minimum for certain system aspect ratios!



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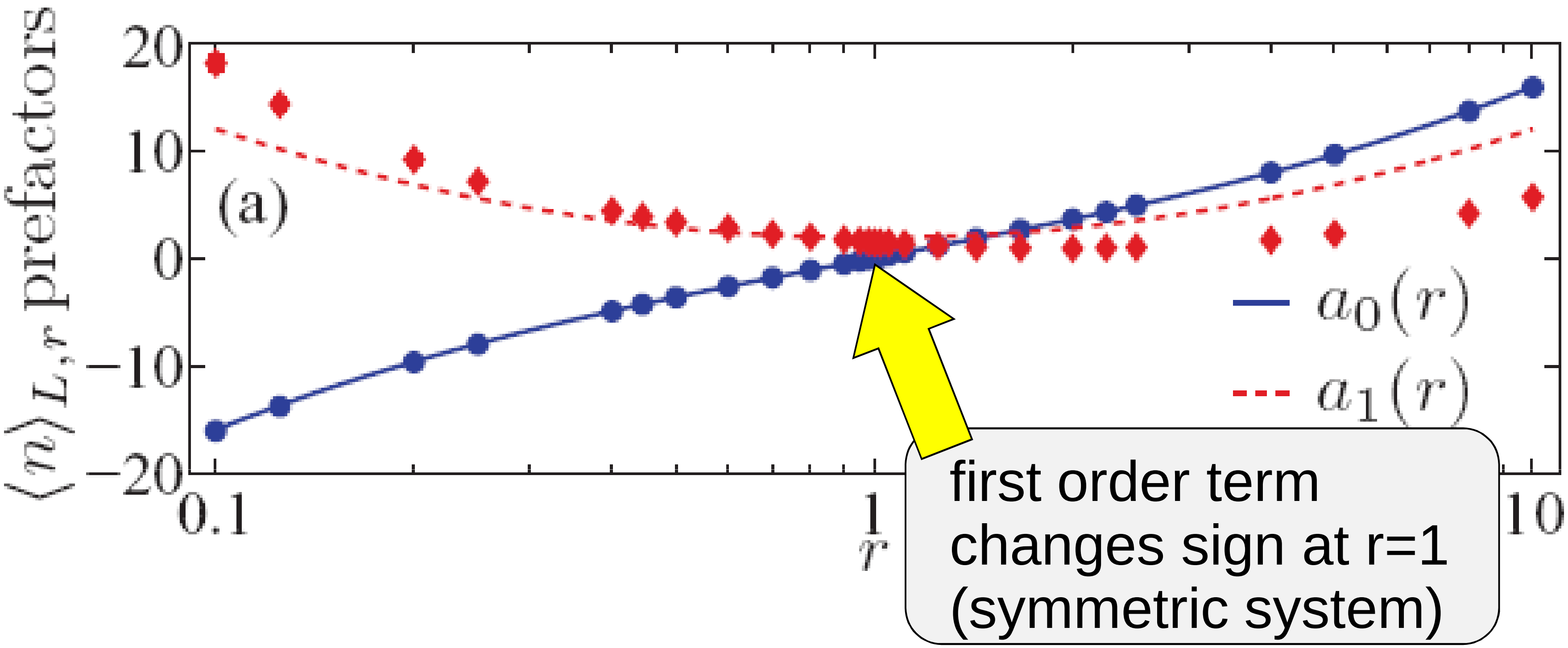
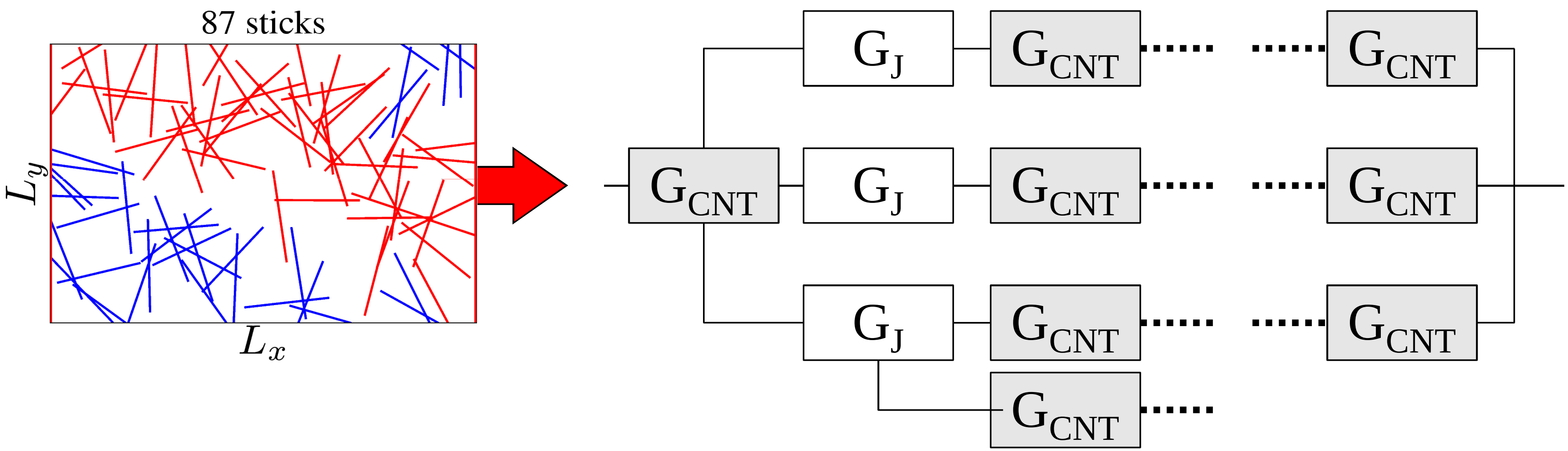
Dependence of average percolation density on system aspect ratio *r*:

$$\langle n \rangle_{L,r} = n_c + L^{-1/\nu} \sum_{i=0}^{\infty} a_i(r) L^{-\theta_i}$$



Conductivity vs. density

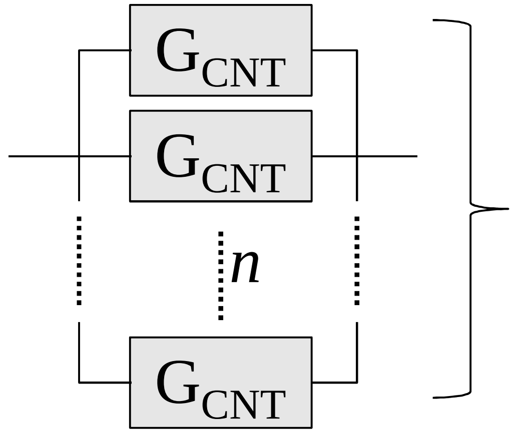


CNT is replaced with resistor network

G_{CNT} - conductance of one CNT
G_J - conductance of junction

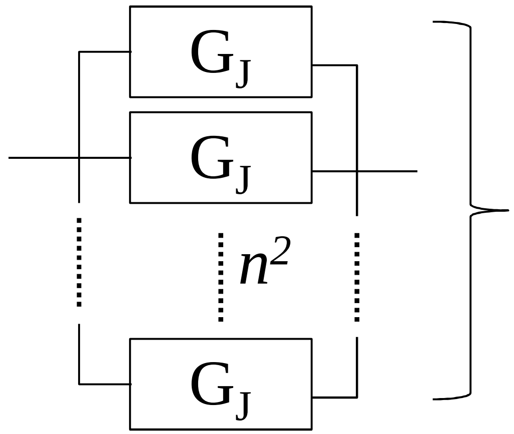
Conductivity vs. density

(1) $G_J \longrightarrow \infty,\ n \longrightarrow \infty$



$G \sim n\, G_{\mathrm{CNT}}$

(2) $G_{CNT} \longrightarrow \infty\ ,\ n \longrightarrow \infty$



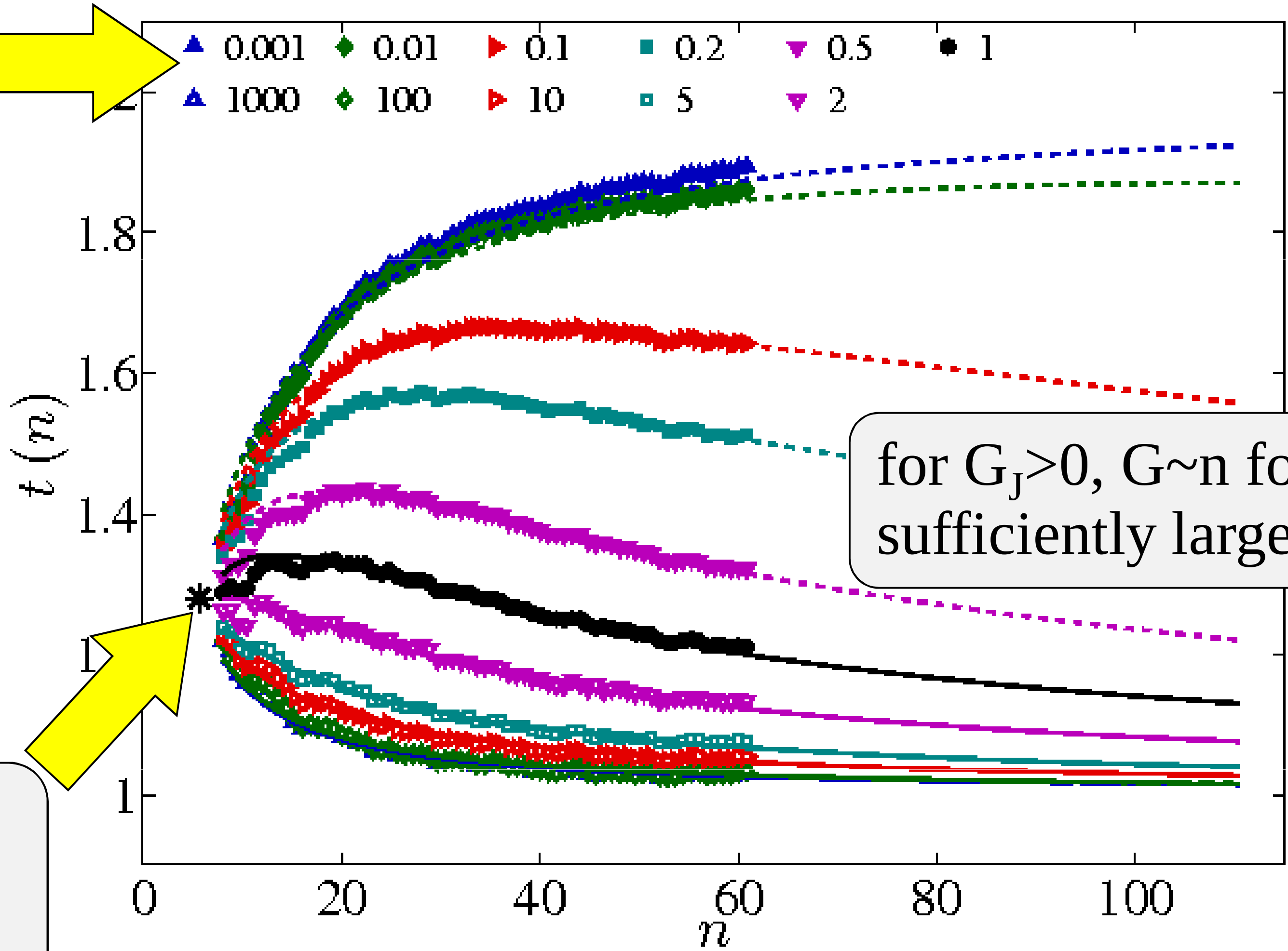
$G \sim n^2\, G_{\mathrm{J}}$

(3) $n \longrightarrow n_c$ (percolation)

$G \sim (n - n_c)^t,\ t = 1.28$

Conductivity vs. Density - exponent $G \sim (n - n_c)^{t(n)}$

G_J / G_{CNT}



for $G_J > 0$, G~n for sufficiently large n

exponent at percolation threshold

Conductivity vs. density (general expression)

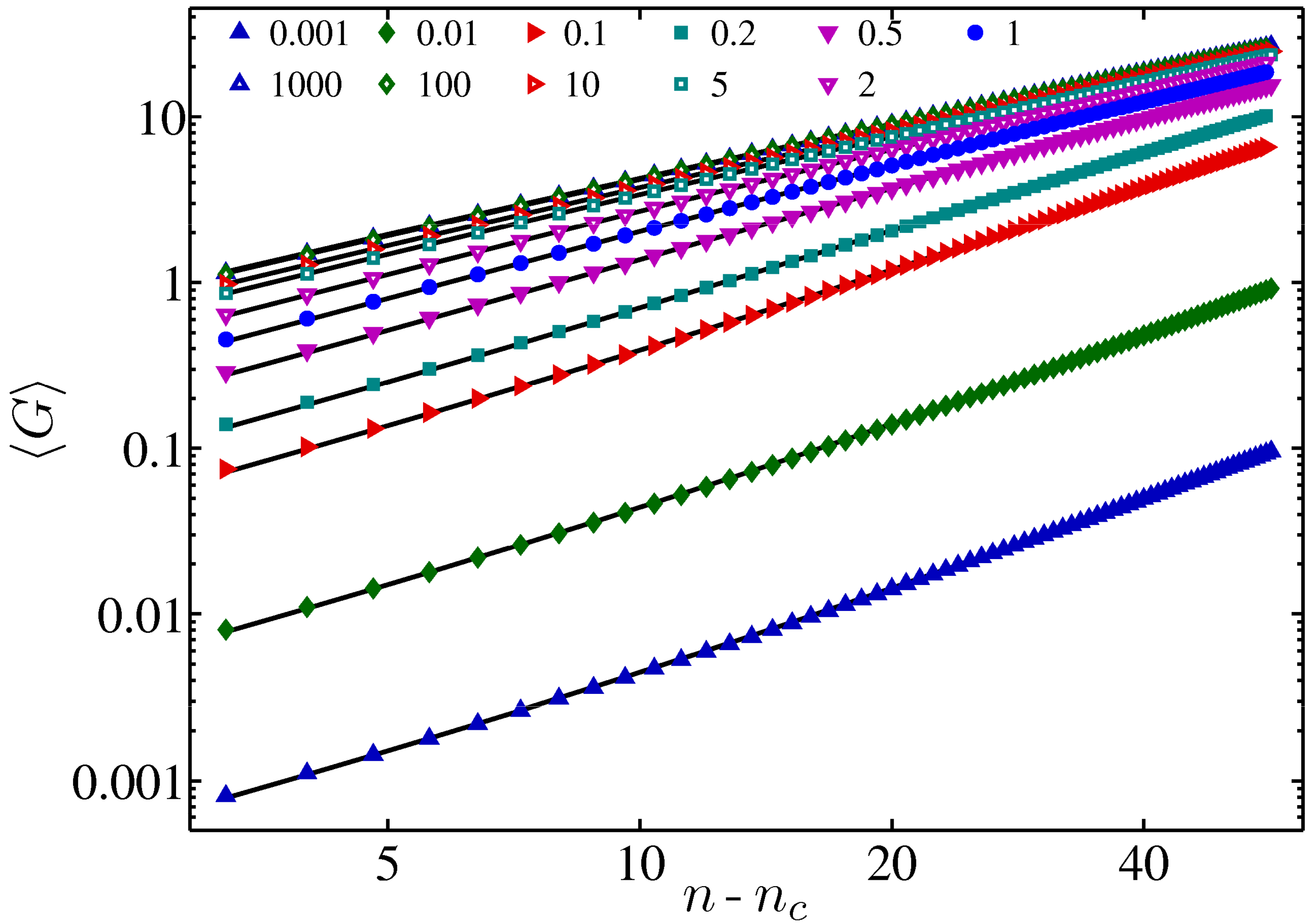
(1) $G_J \rightarrow \infty$, $n \rightarrow \infty$, $G \sim n\, G_{CNT}$

(2) $G_{CNT} \rightarrow \infty$, $n \rightarrow \infty$ $G \sim n^2 G_J$

(3) $n \rightarrow n_c$ (percolation) $G \sim (n - n_c)^t$, $t=1.28$

$$\frac{1}{G} \approx \frac{a}{(n - n_c)^t} \left(\frac{G_J}{G_{CNT}} \frac{1}{n^{1-t}} + \frac{1}{n^{2-t}} \right)$$

Comparison of model & simulation for $G_J / G_{CNT} = 10^{-3} - 10^{3}$



Conclusions:

- channel geometry is important

- magnitude of conductivity is determined by interplay/interchange of percolation and networking effects

Thank you!

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