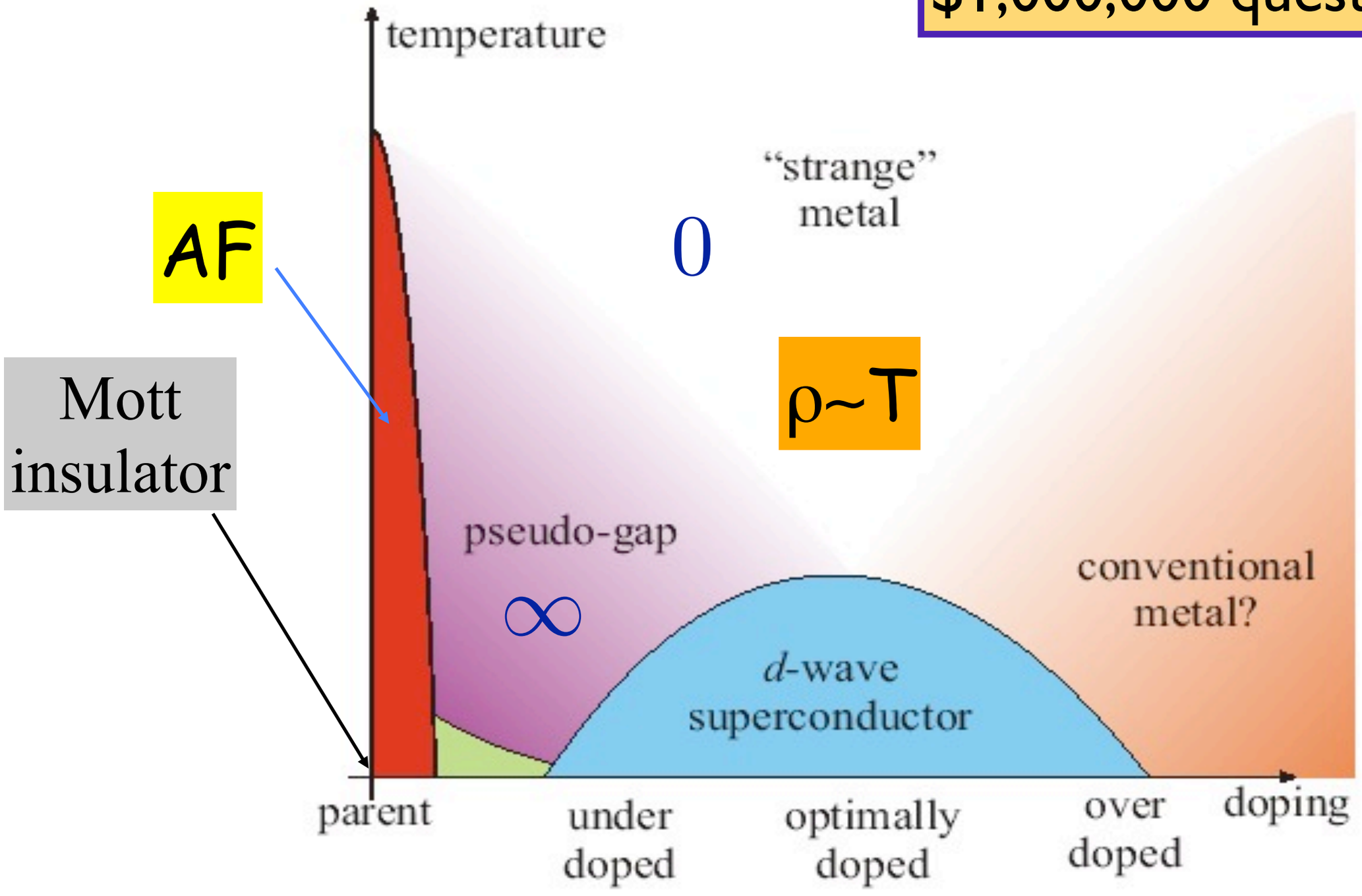
Why is the T_c region `dome'-shaped?

$1,000,000 question?



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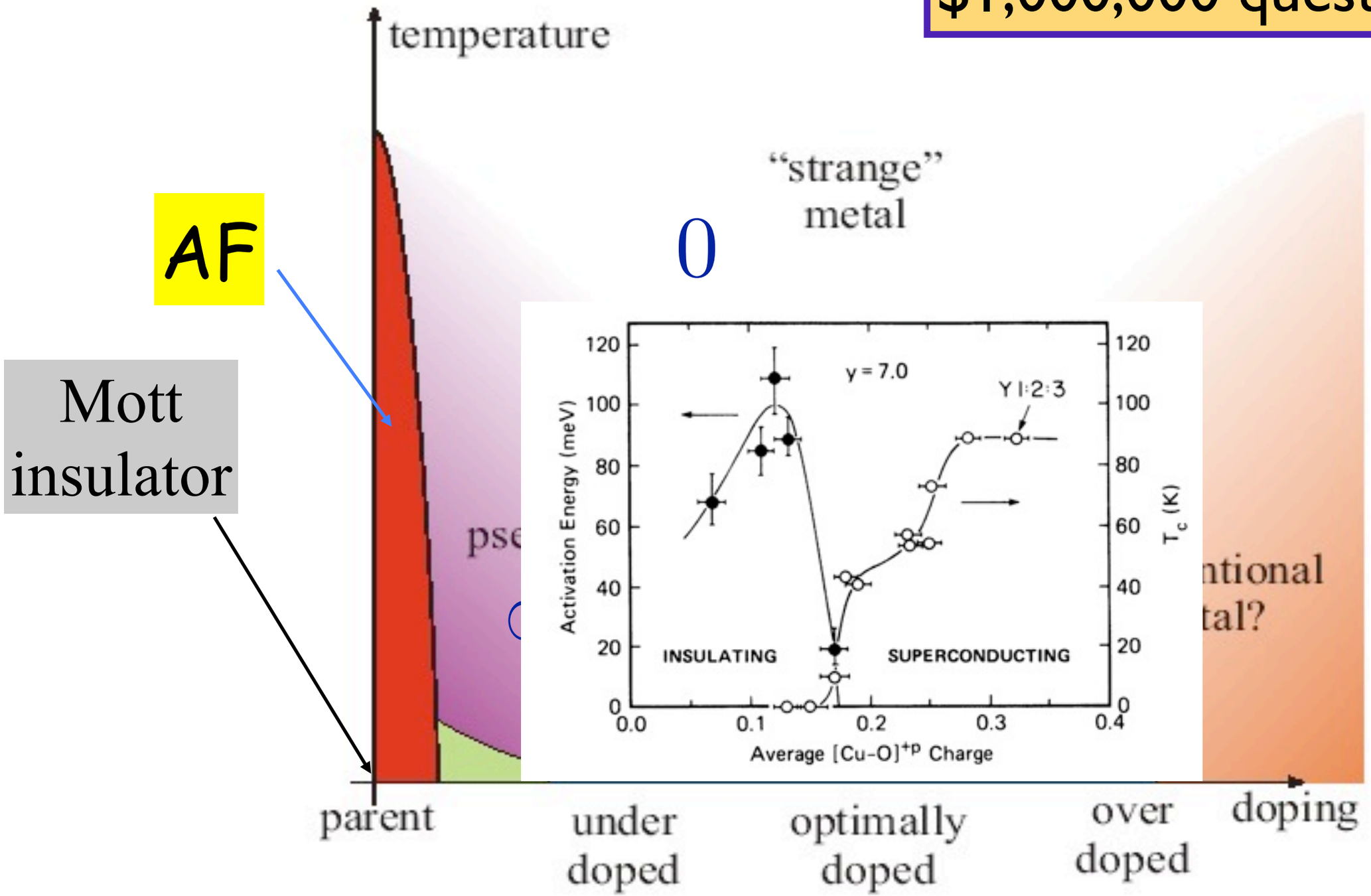

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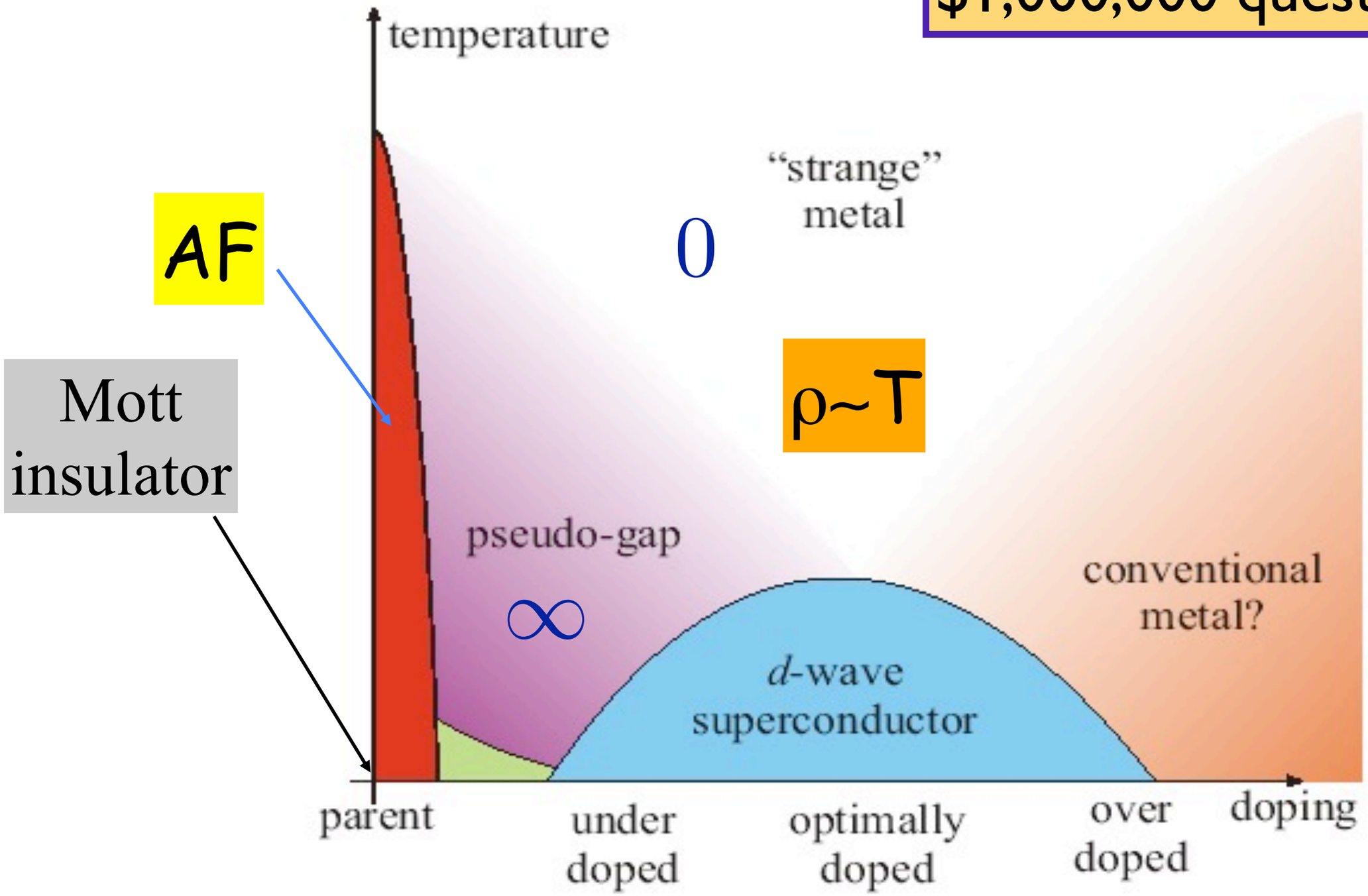
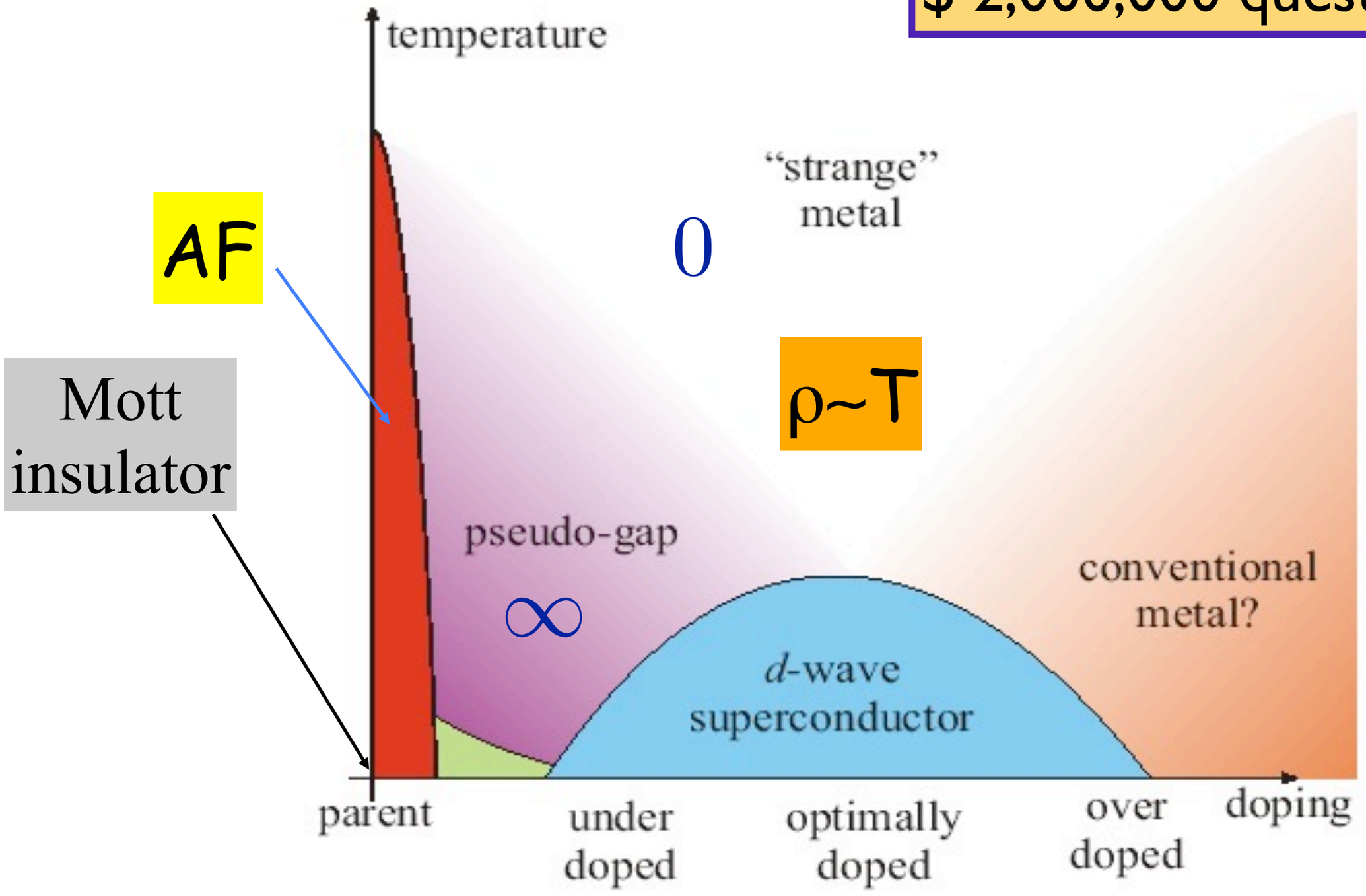


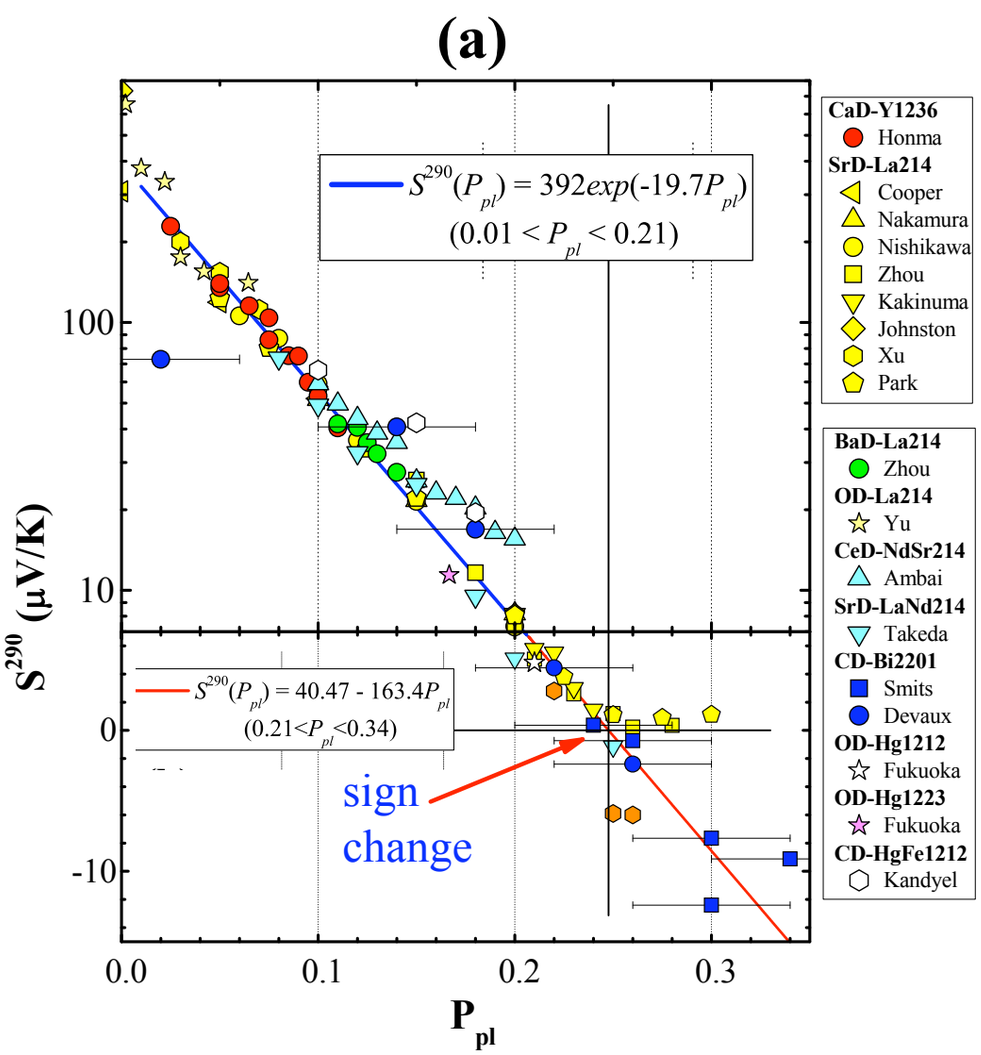
Why is the T_c region `dome'-shaped?

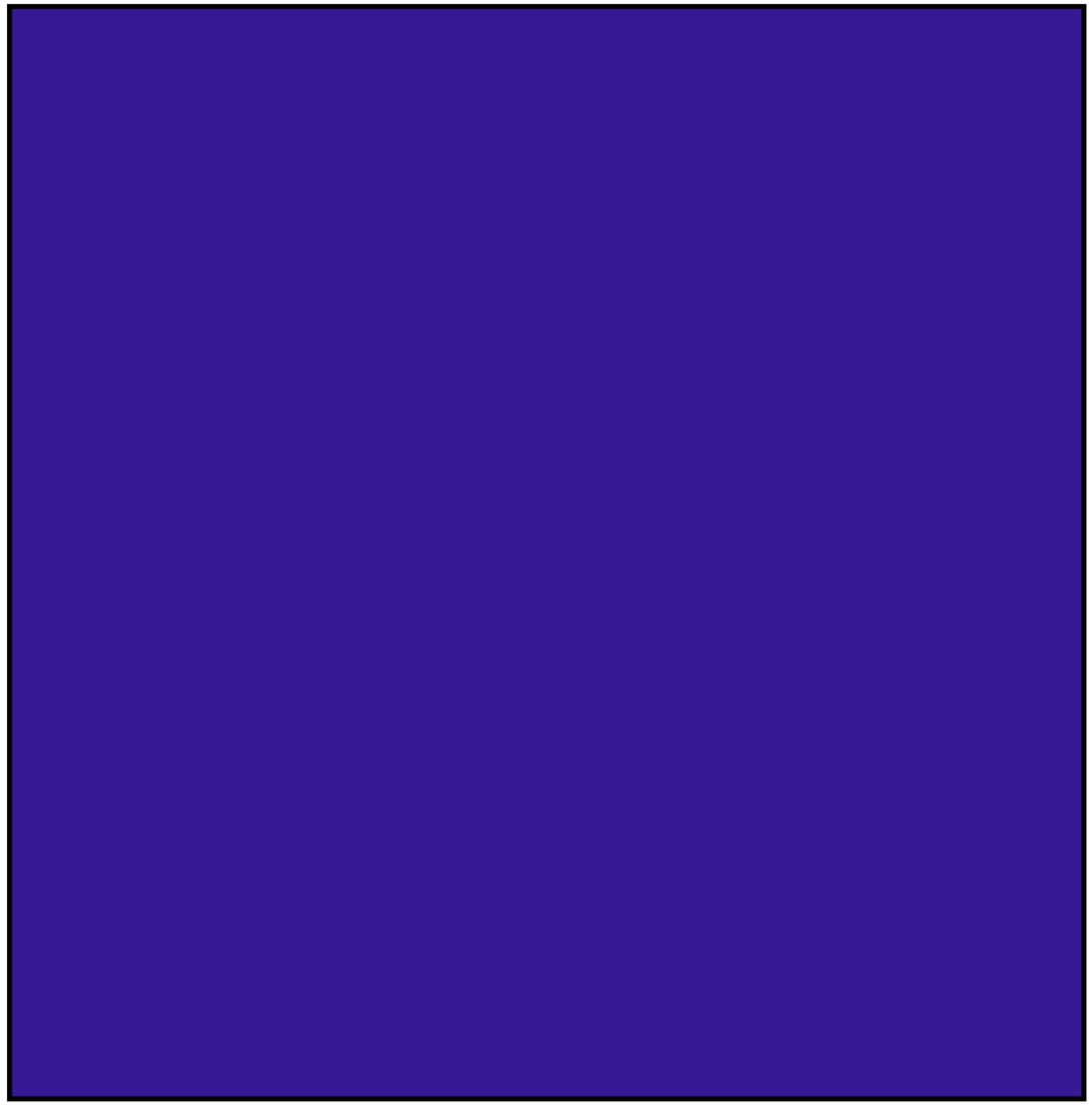
$ 2,000,000 question?



How does Fermi Liquid Theory Breakdown?

Universal sign change of thermopower





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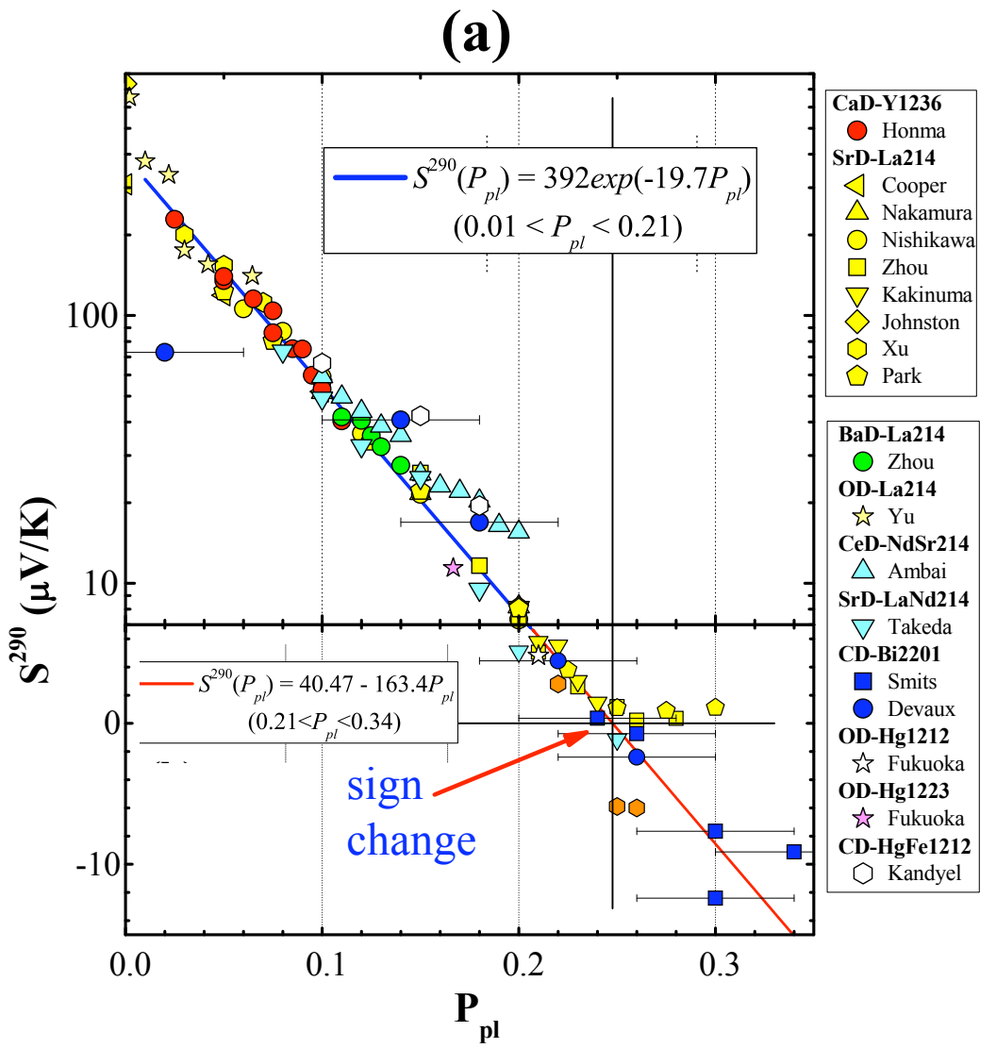
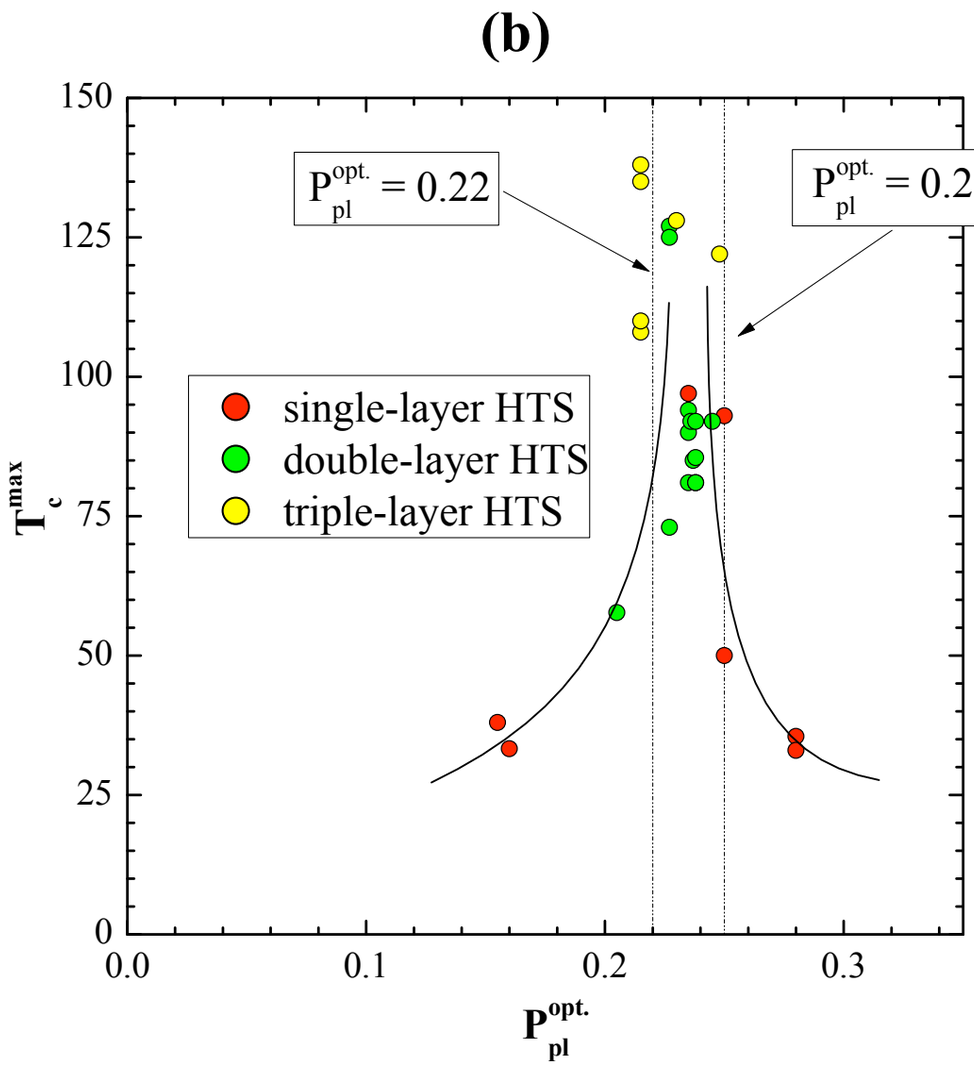
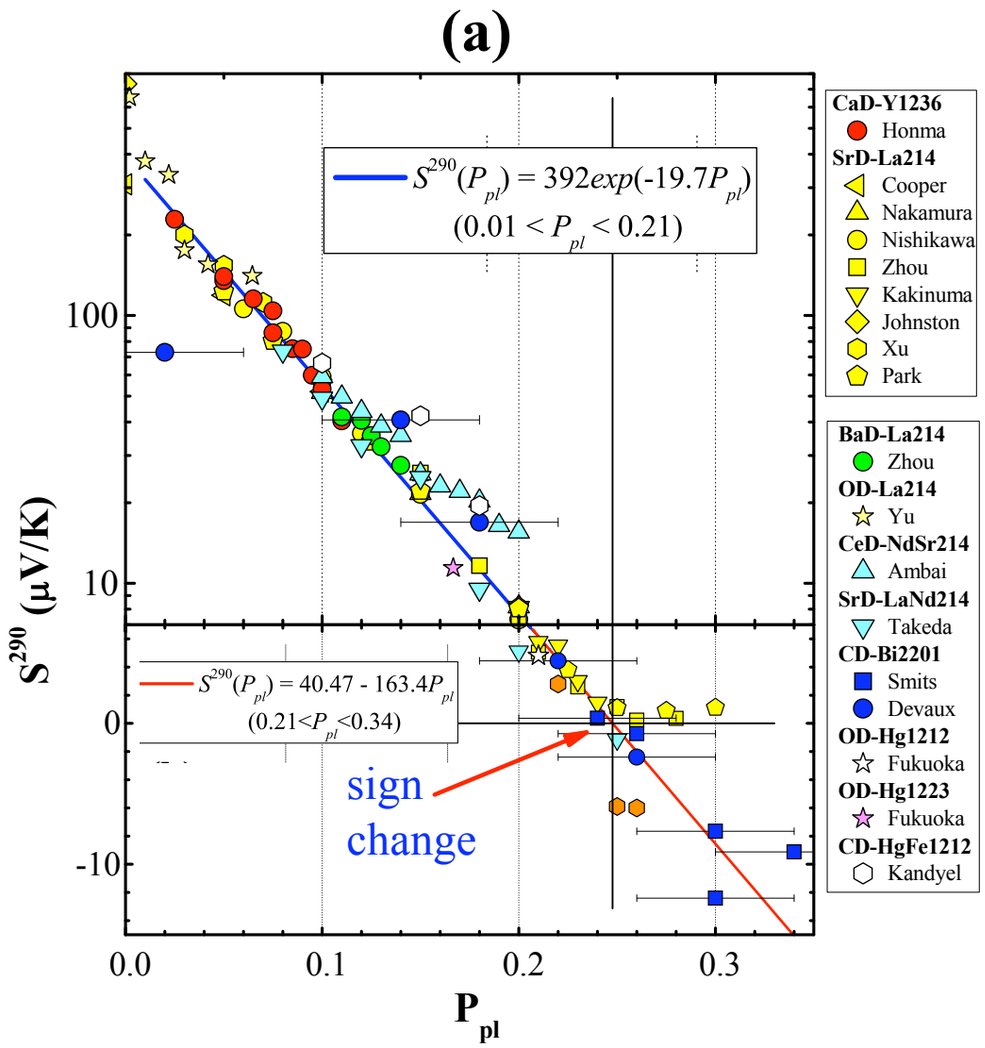
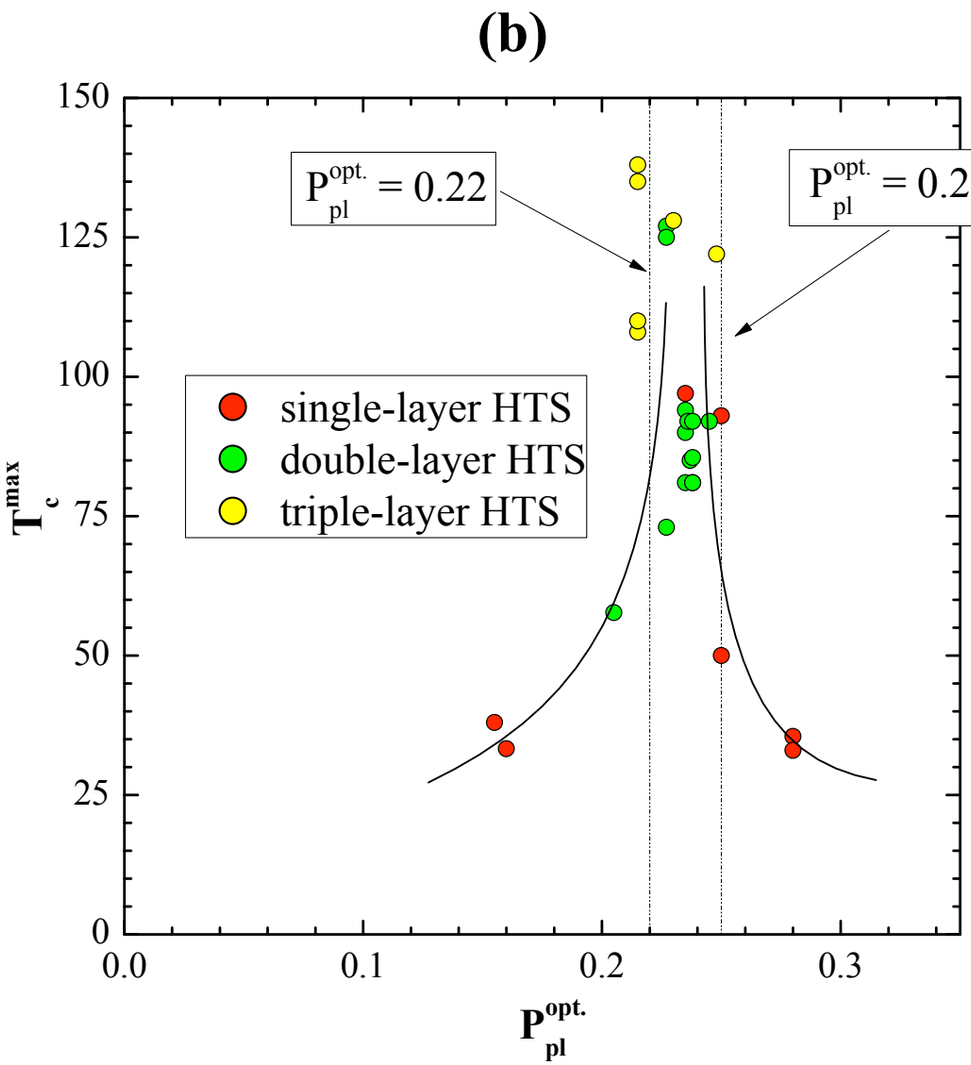




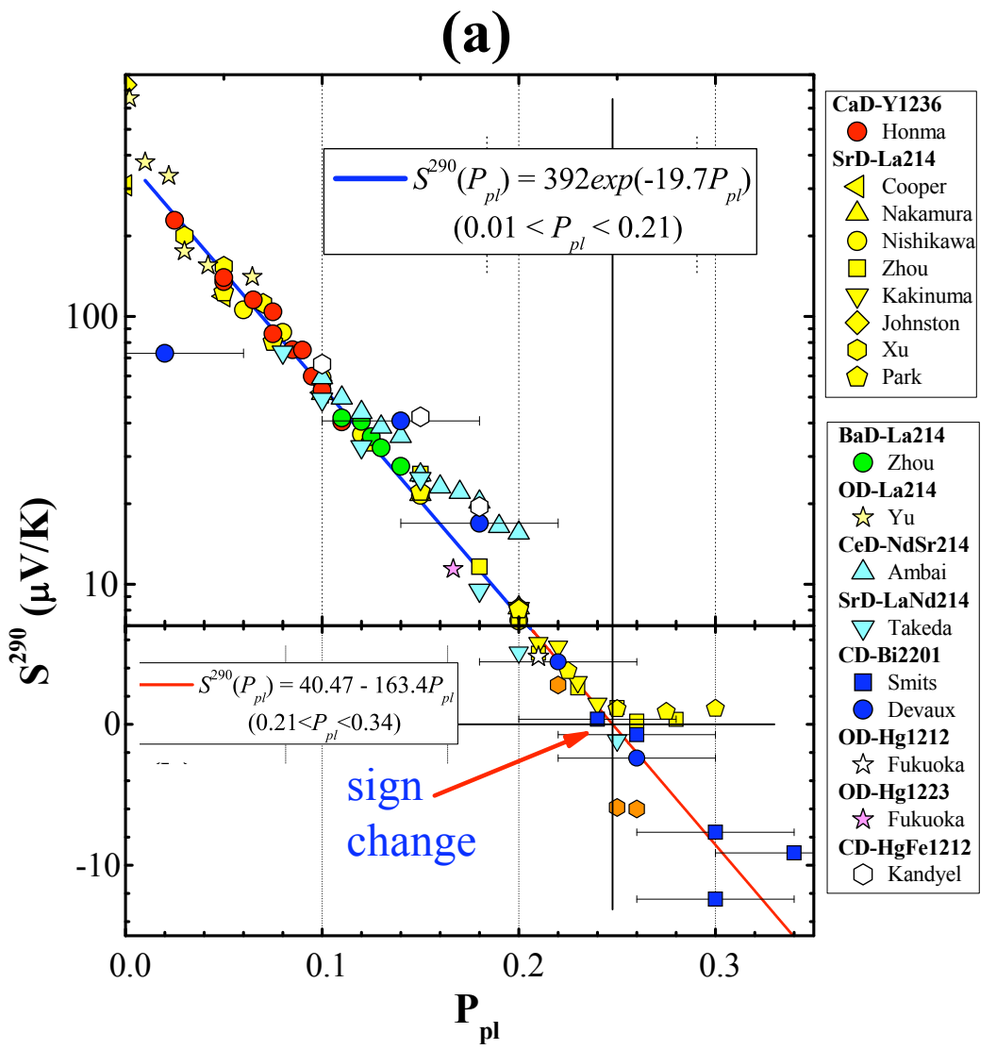
Universal sign change of thermopower

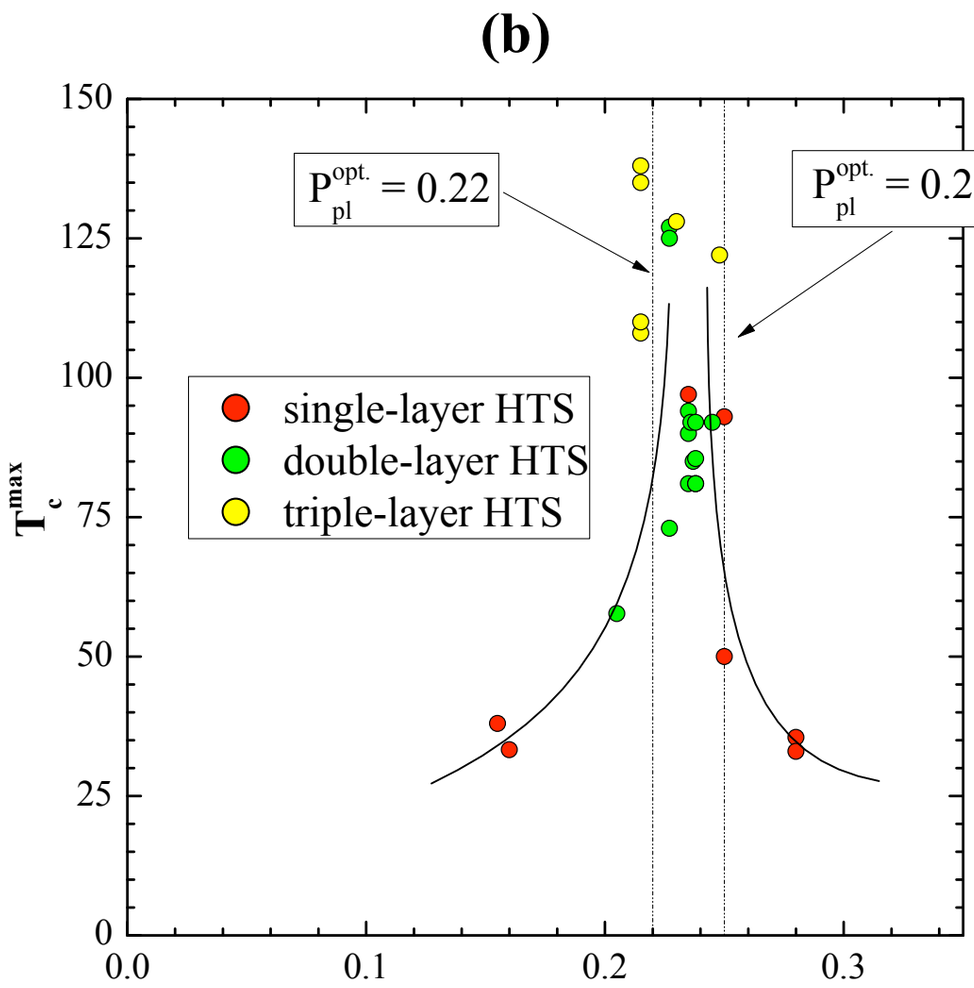




$$1 - \frac{T_c}{T_c^{\max}} = 82.6(x - 0.16)^2.$$

Universal sign change of thermopower





$$1 - \frac{T_c}{T_c^{max}} = 2.6(x - 0.16)^2.$$

How valid is the thermopower doping scale?

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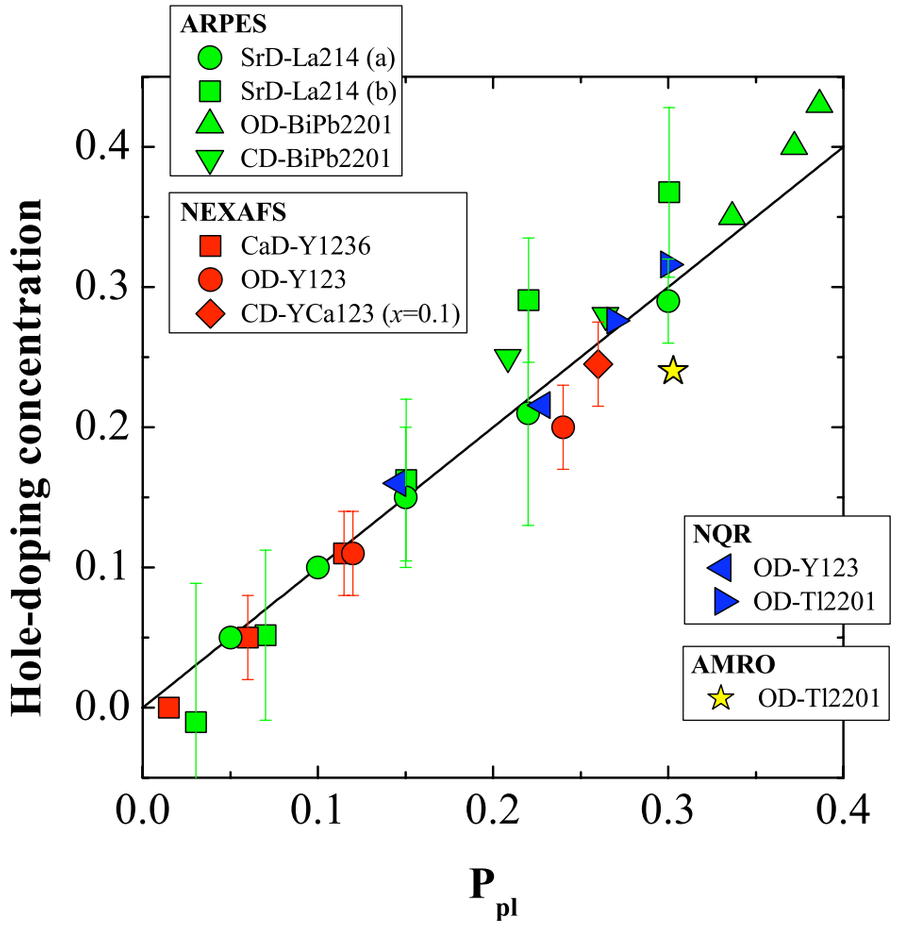
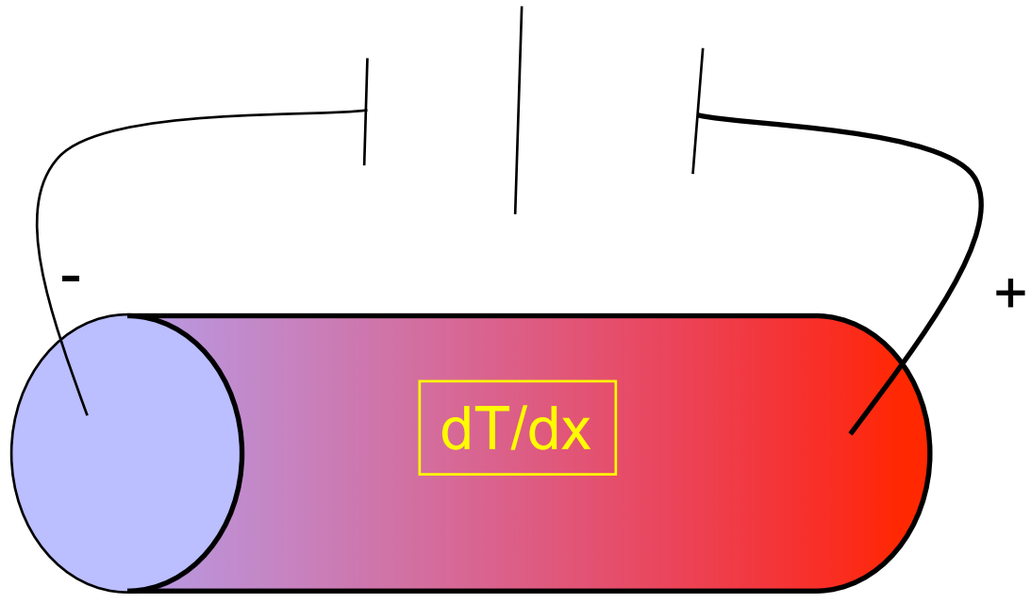


Why?



$S = V/\Delta T$

entropy per carrier

particle-number conservation

Thermopower Primer

$$S = -\frac{k_B}{e}\beta\frac{L_{12}}{L_{11}}$$

$$L_{ij} = \int_{-\infty}^{\infty} d\omega(-\frac{\partial f(\omega)}{\partial\omega})\tau^i(\omega)\omega^{j-1}$$

$$\tau(\omega) = \frac{1}{N}\sum_{\mathbf{k},\sigma}(\frac{\partial\epsilon_{\mathbf{k}}}{\partial k_x})^2 A^2(\mathbf{k},\omega)$$

spectral function

1.) τ must be symmetric about the chemical potential for S=0

2.) but if *A* is momentum-independent, S=0 by particle-hole symmetry

G. Beni, Phys. Rev. B vol. 10, 2186 (1973).

Exact calculation of S for atomic (t=0) limit of Hubbard model

$$S = -\frac{k_B}{e} \ln \frac{2x}{1-x}$$

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$$\ln \frac{x}{2-x}$$

vanishes at half-filling

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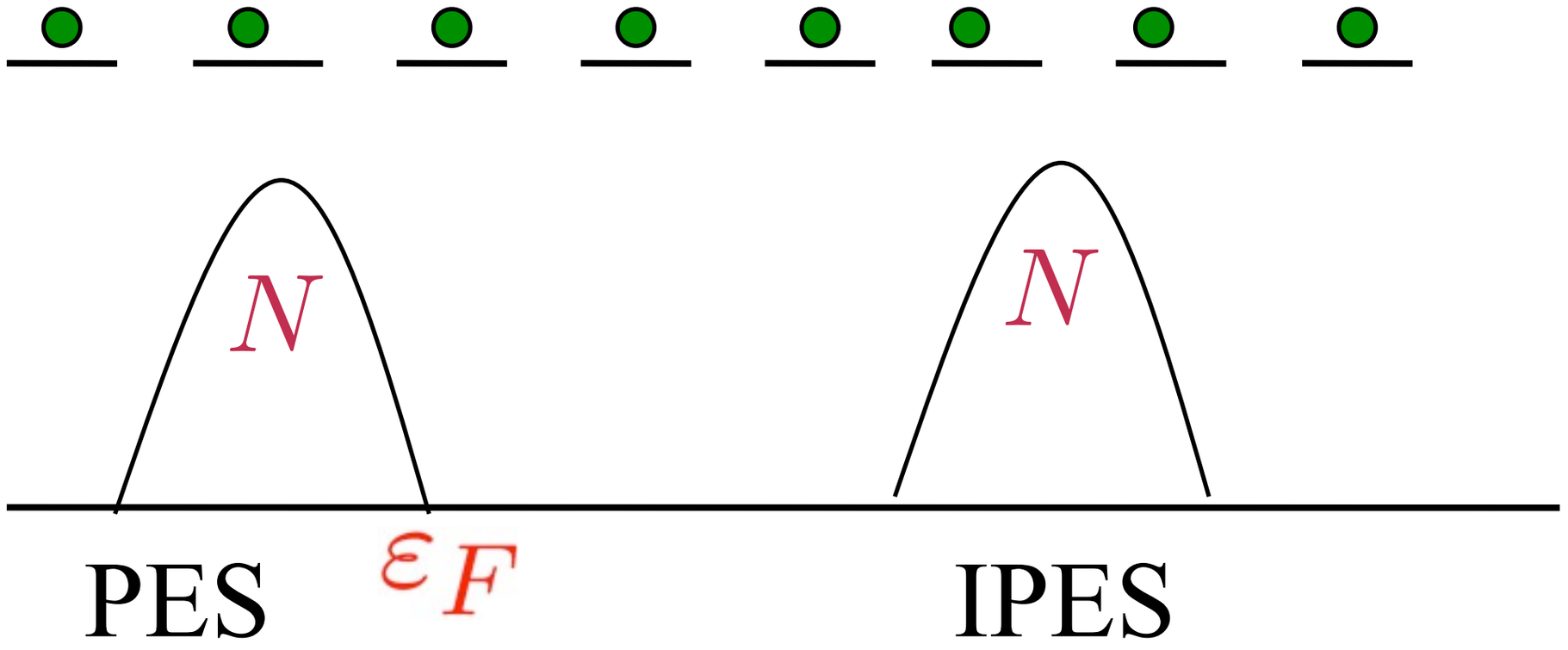
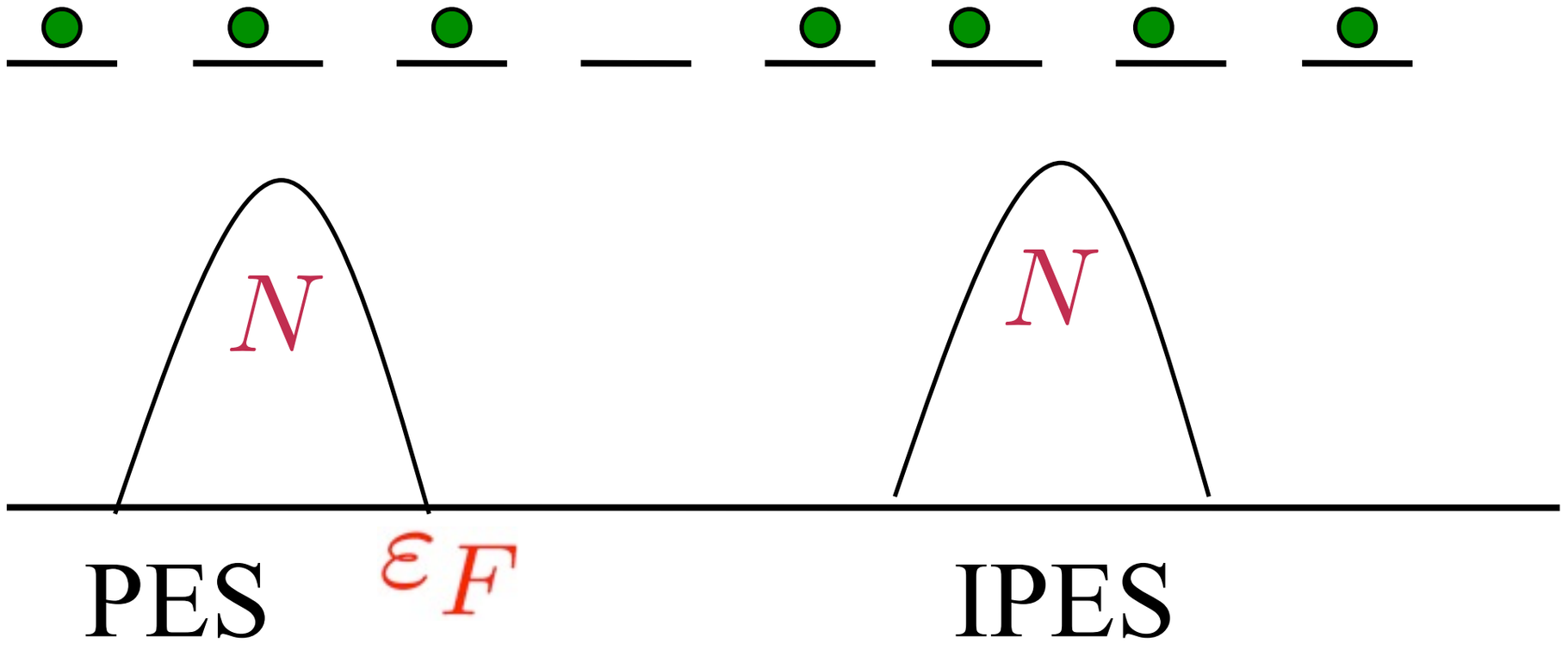
$$\ln \frac{x}{2-x}$$

vanishes at half-filling

S=0 when x=1/3; WHY?

What is so special about 2x and 1-x?


N
N
PES
ε_F
IPES


N
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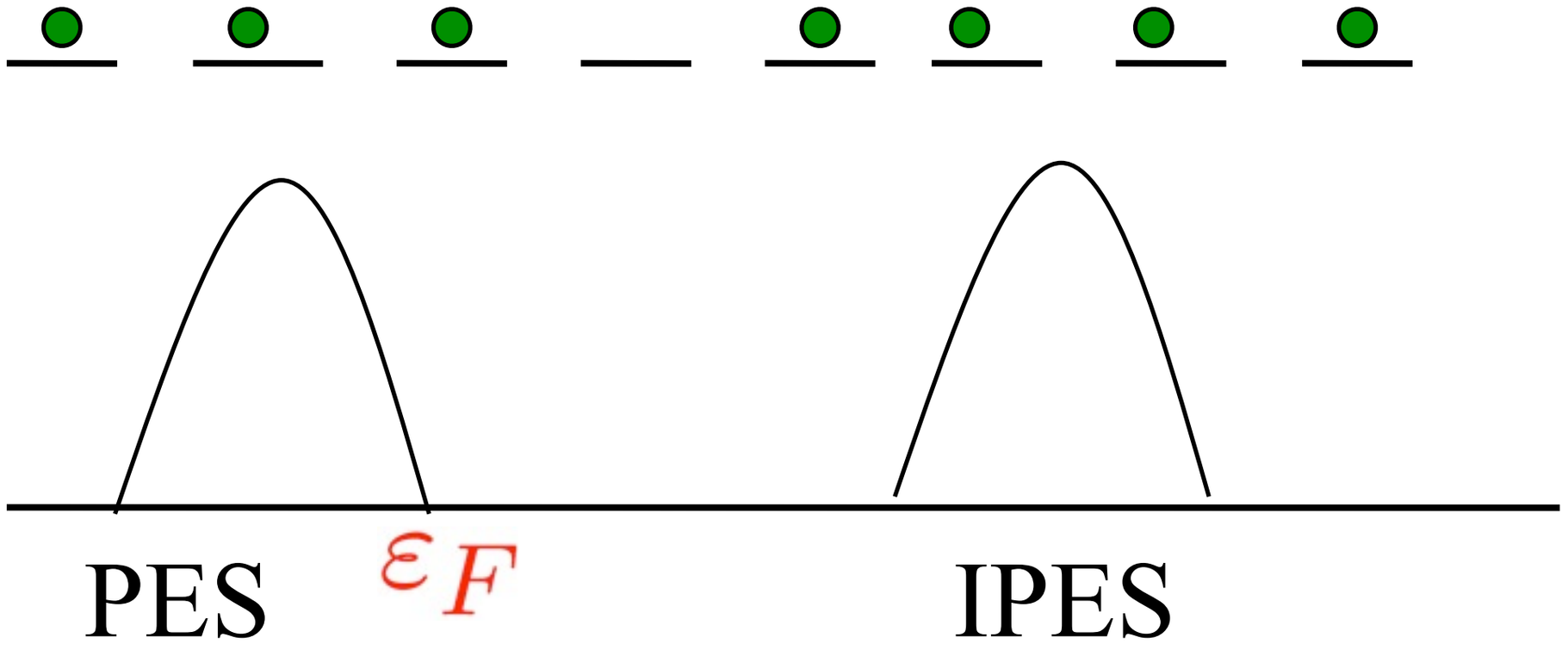
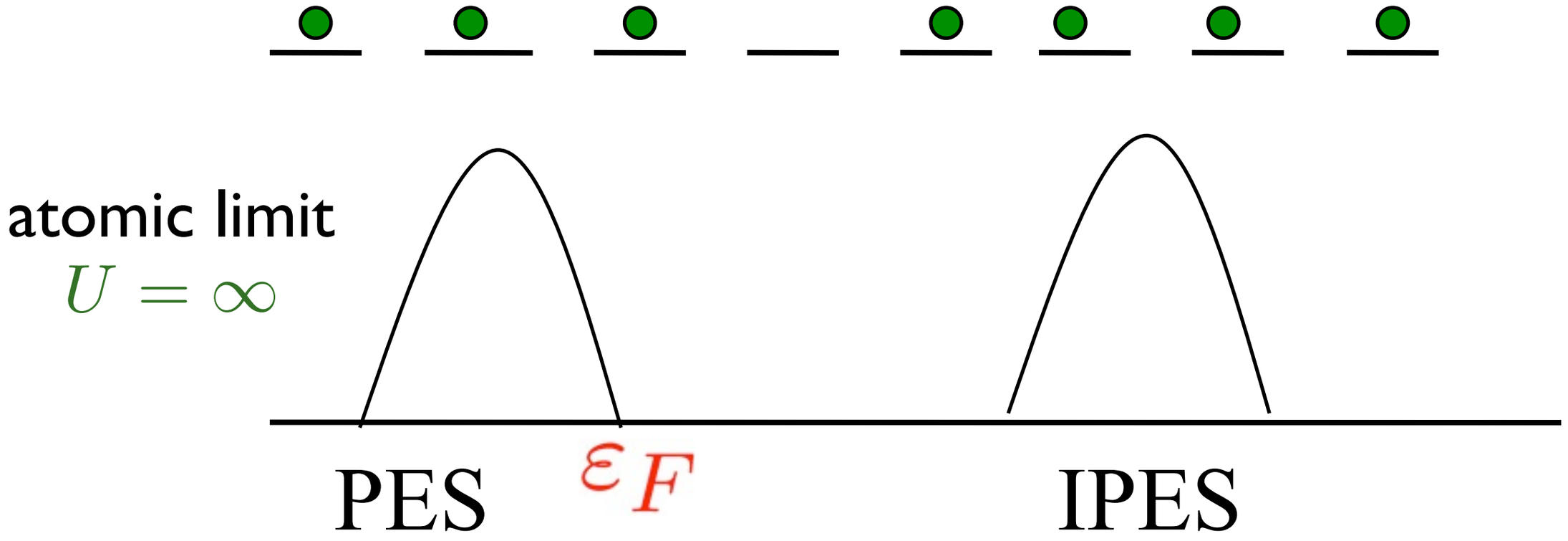
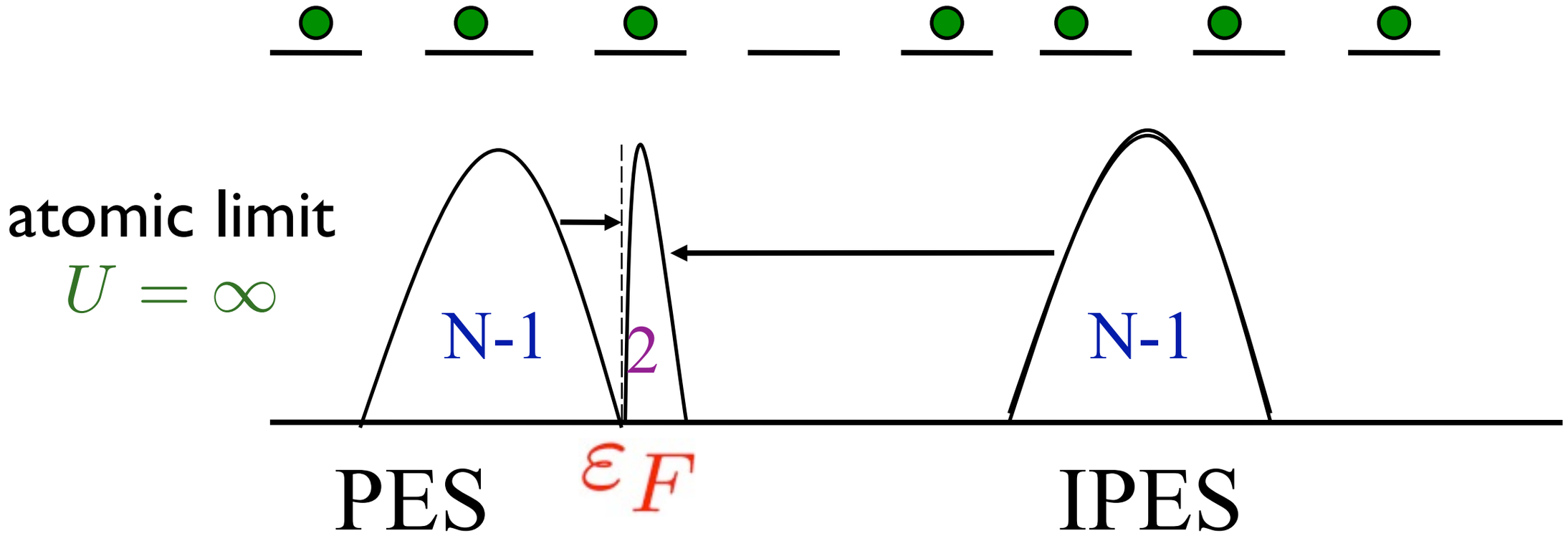
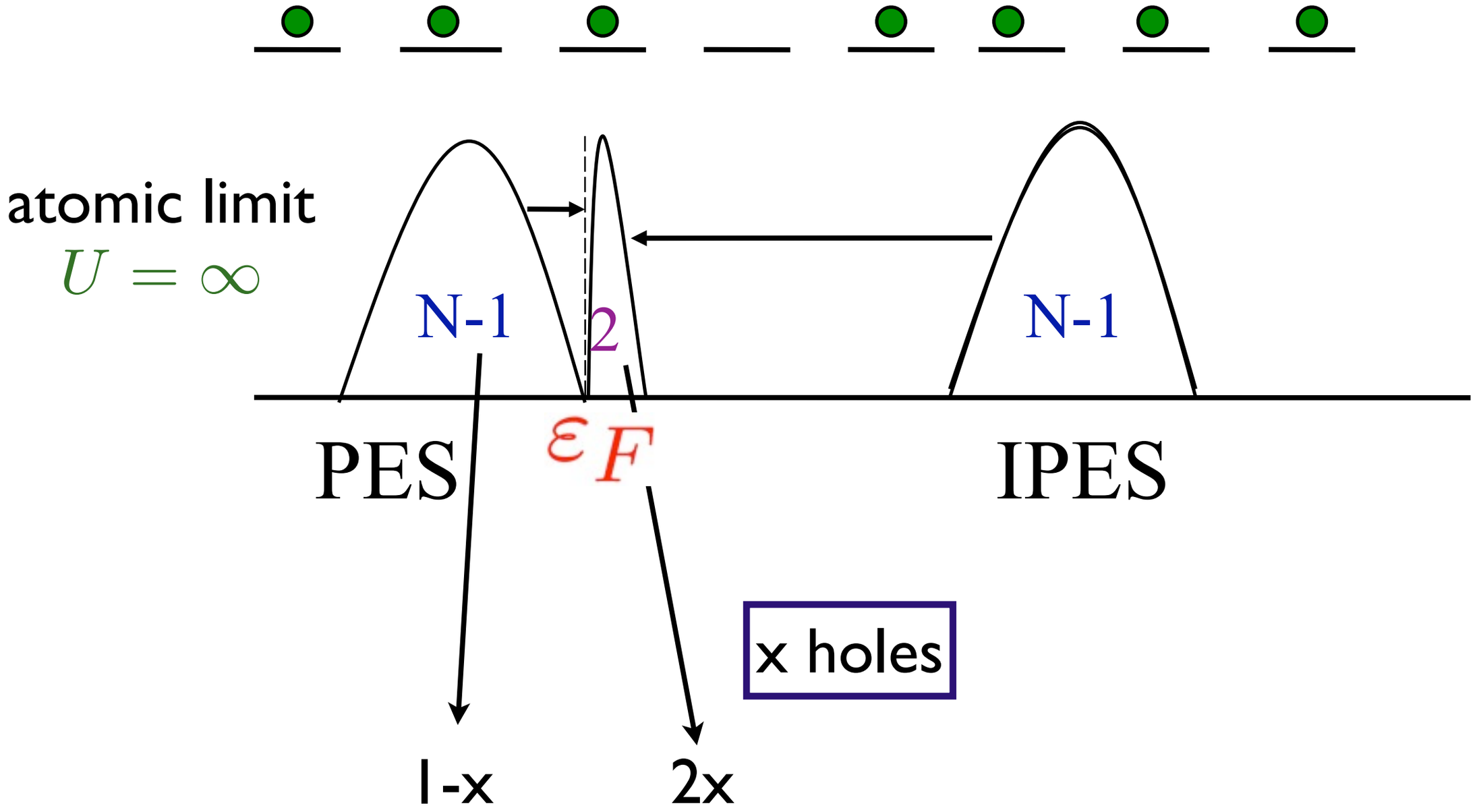
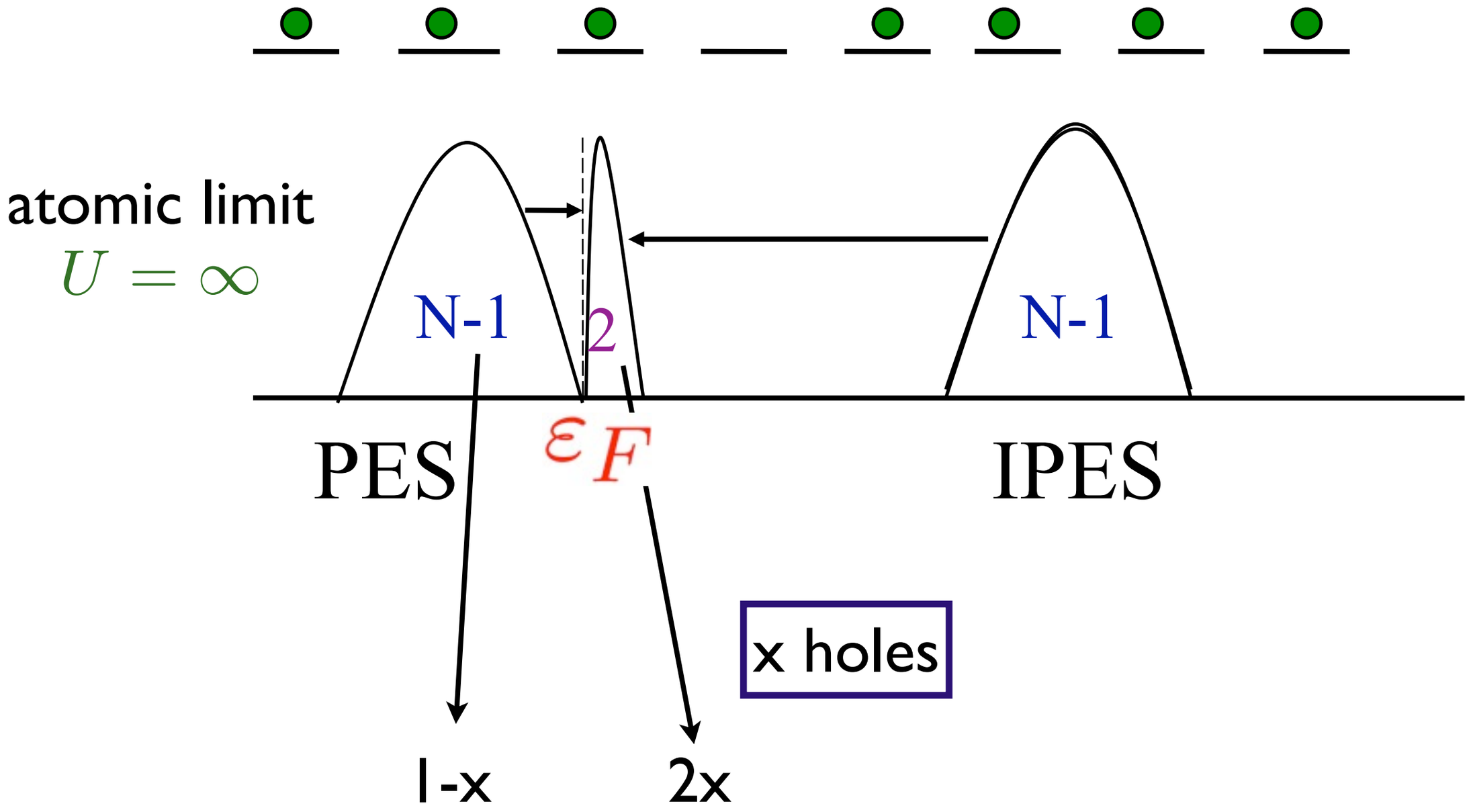

PES
ε_F
IPES


atomic limit
$U = \infty$
PES
ε_F
IPES

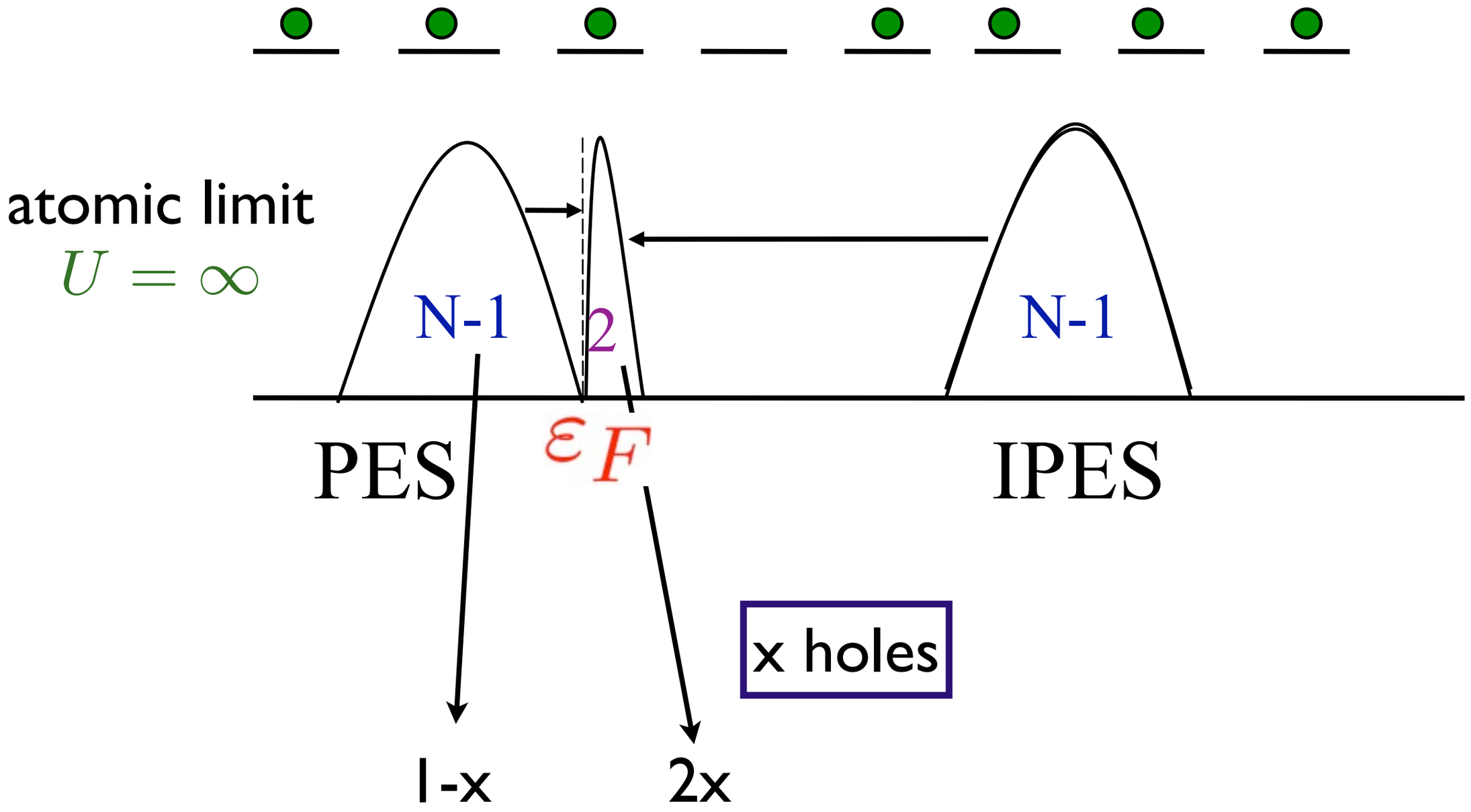

atomic limit
$U = \infty$
N-1
2
N-1
PES
ε_F
IPES


atomic limit
$U = \infty$
N-1
2
N-1
PES
ε_F
IPES
x holes
1-x
2x



criterion for vanishing of thermopower

LESW above ε_F = LESW below ε_F



criterion for vanishing of thermopower

LESW above ε_F = LESW below ε_F

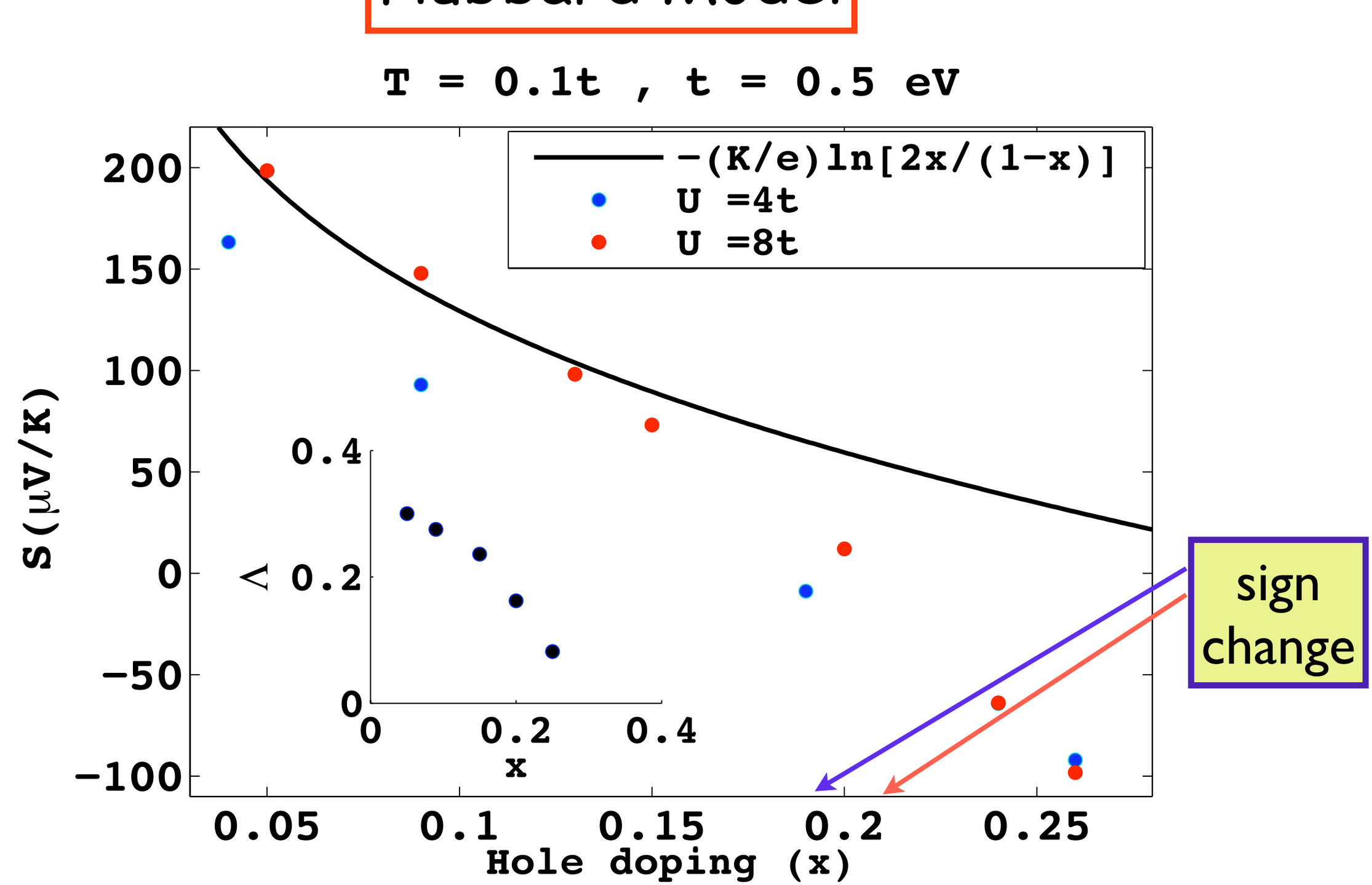
2x=1-x → x=1/3!

$$S \approx -\frac{k_B}{e} \ln \frac{\mathcal{L}}{1-x}$$

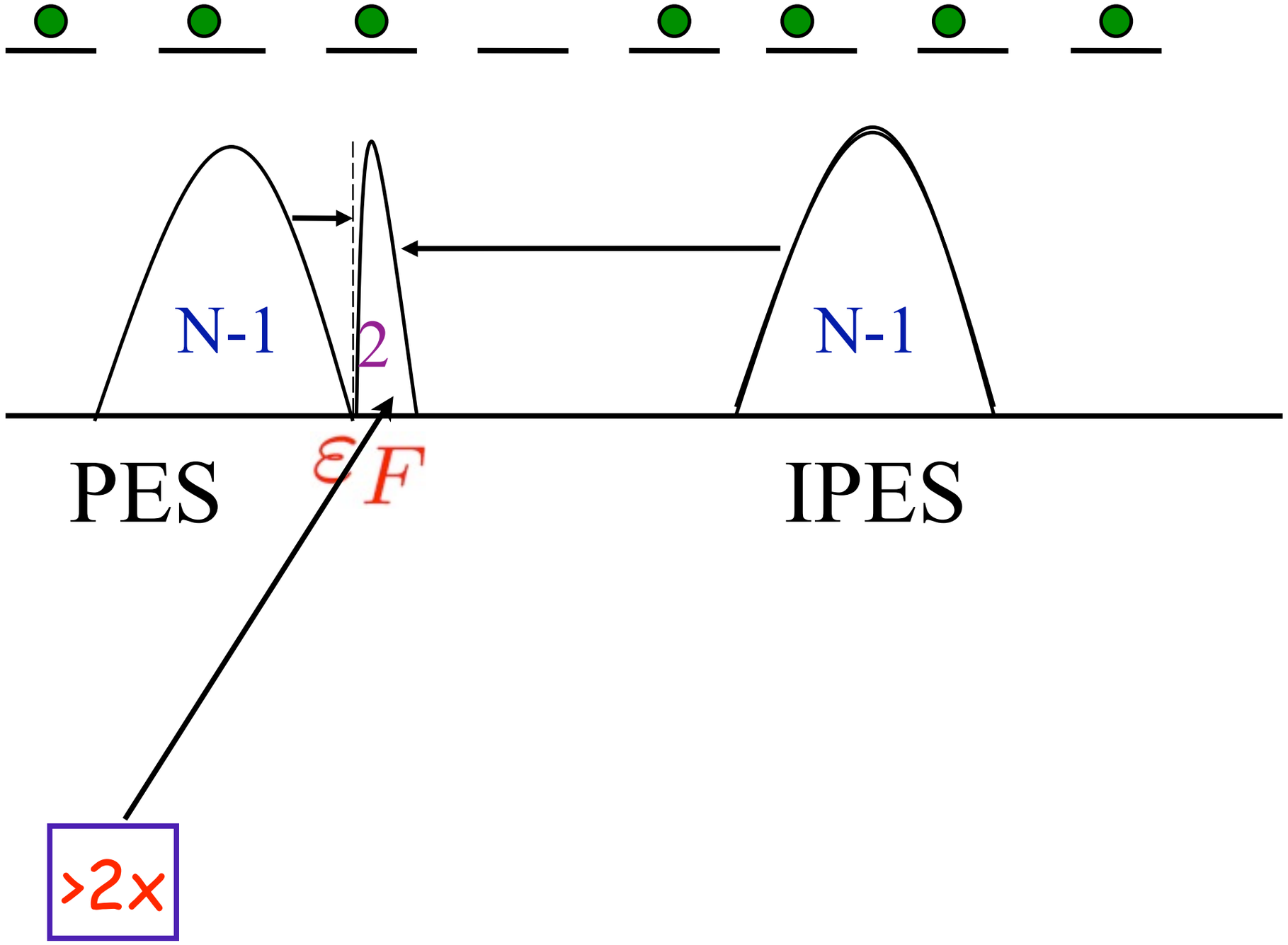
S must change sign before x=1/3
(atomic limit)

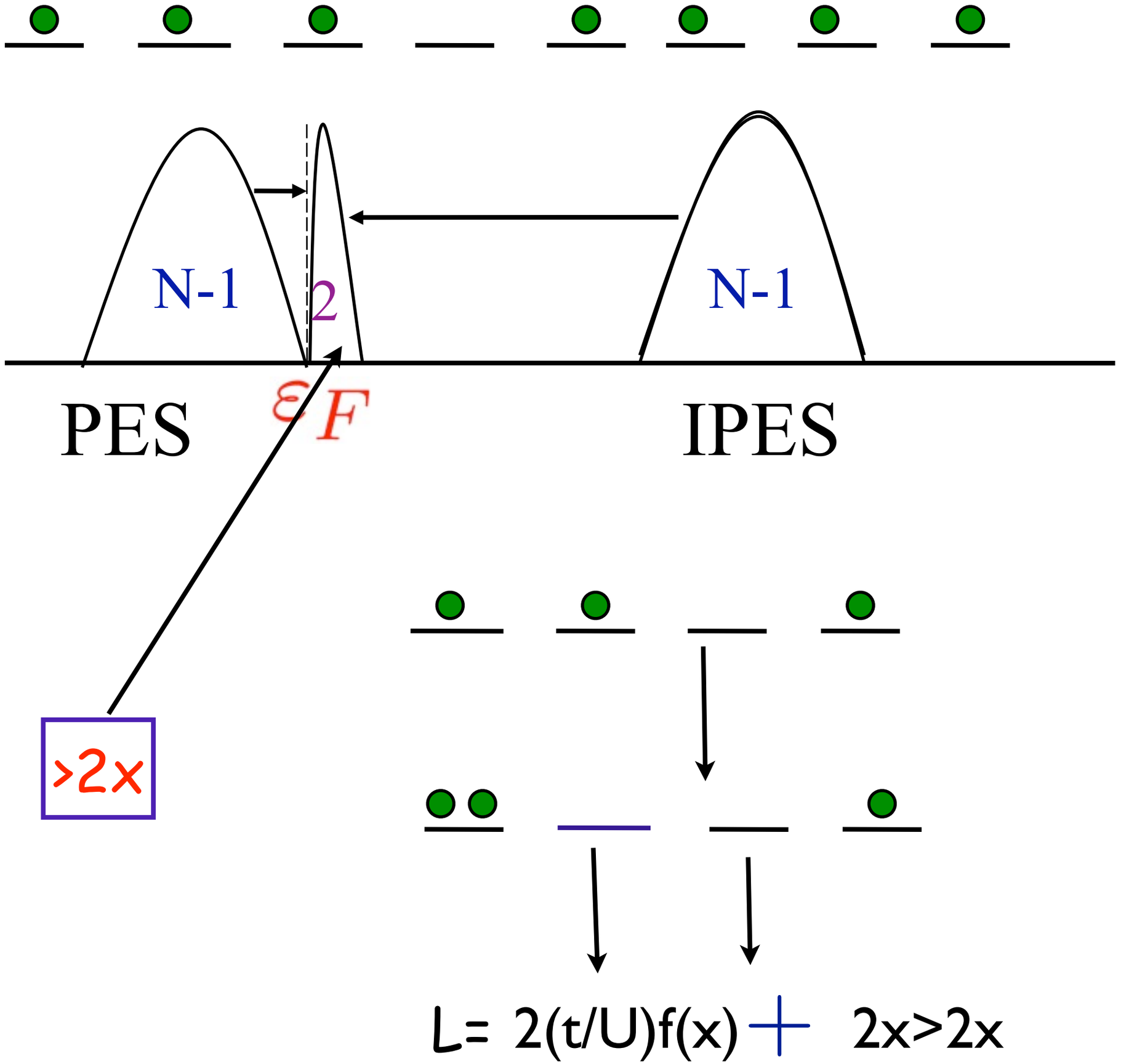
experiments: x_c=.24

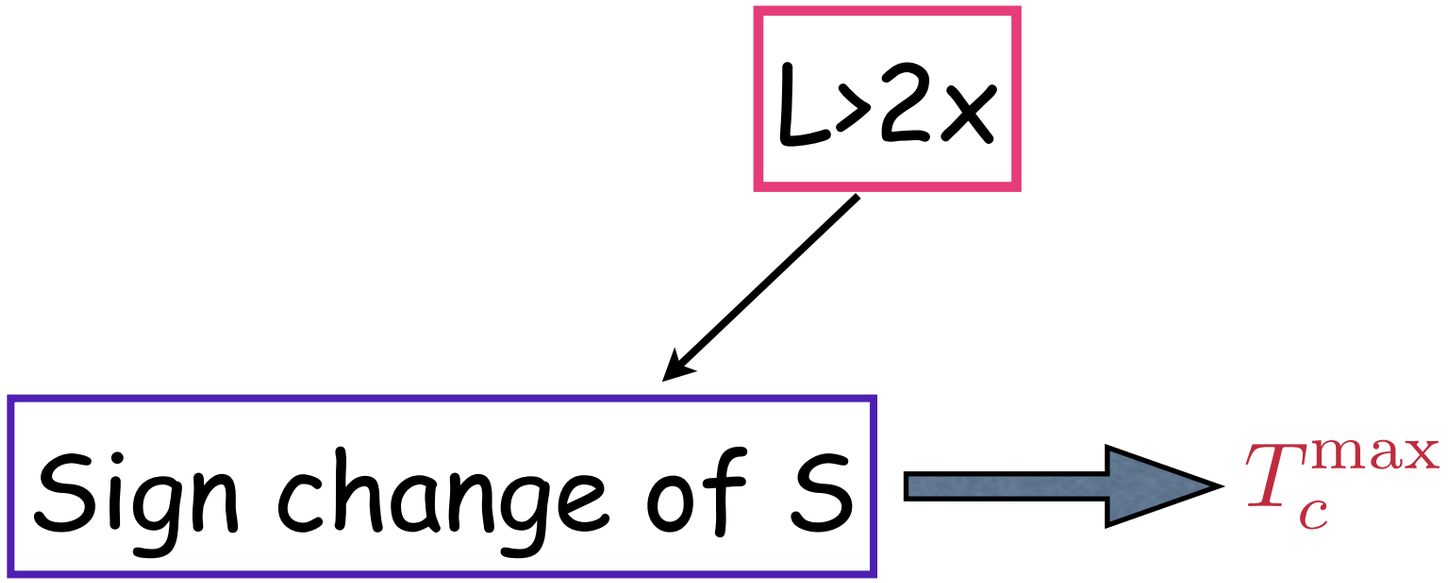
Hubbard Model

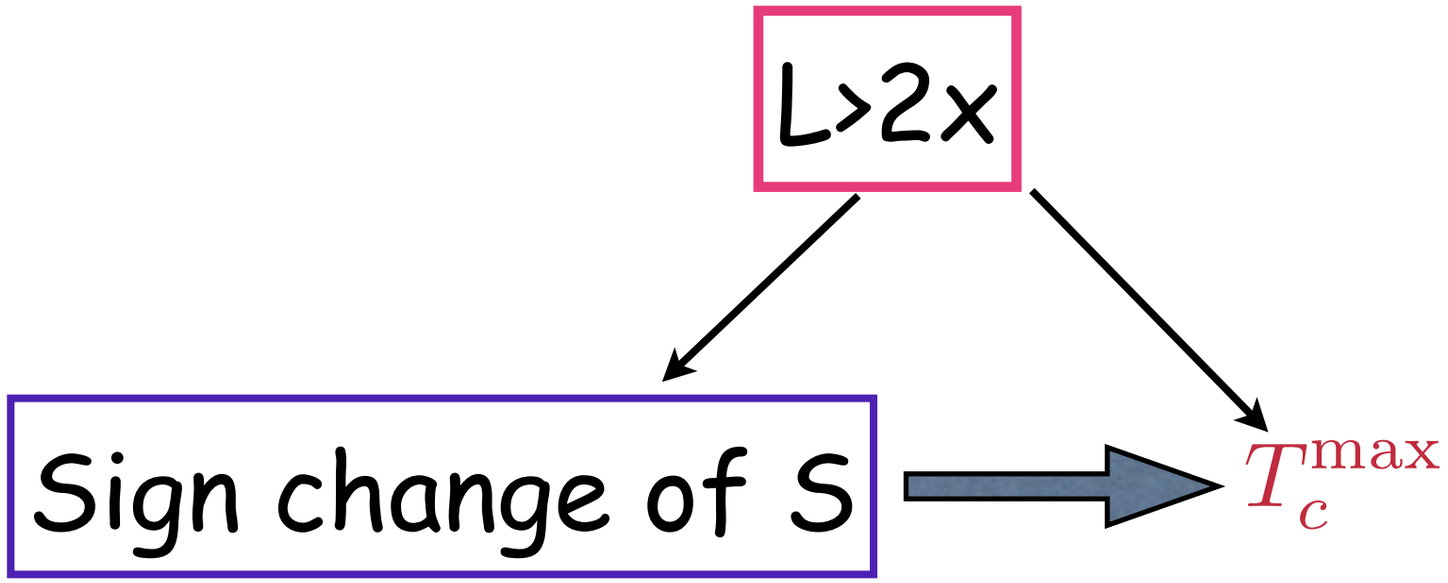


arXiv:0807.2854

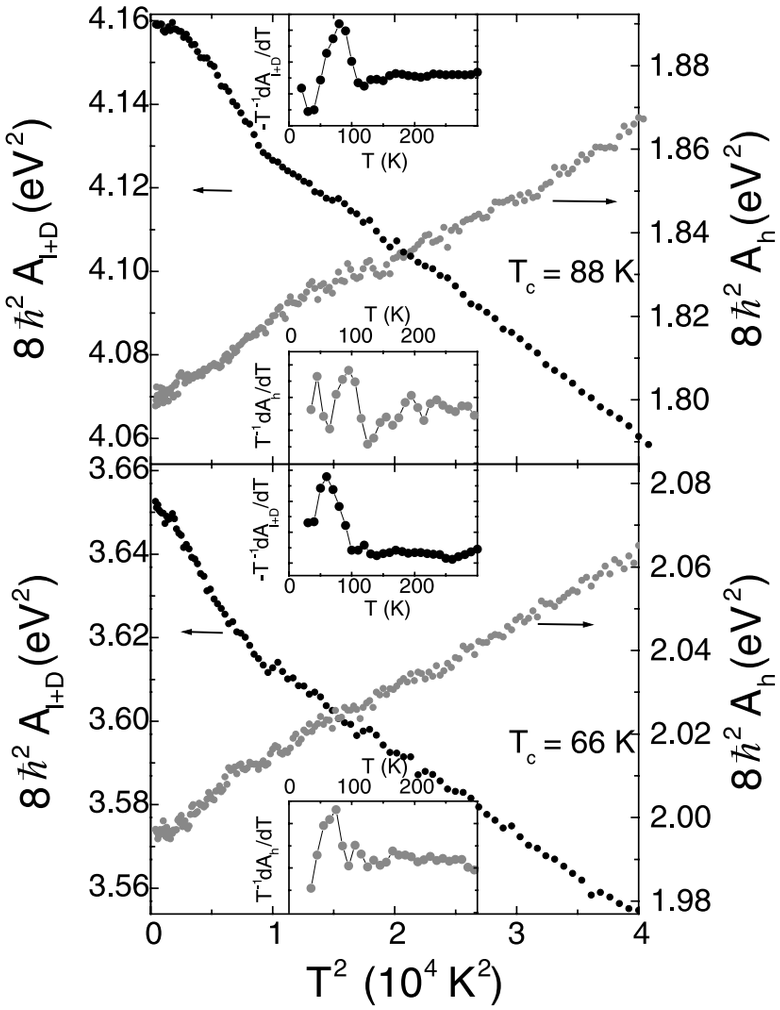

N-1
2
N-1
PES
ε_F
IPES
>2x

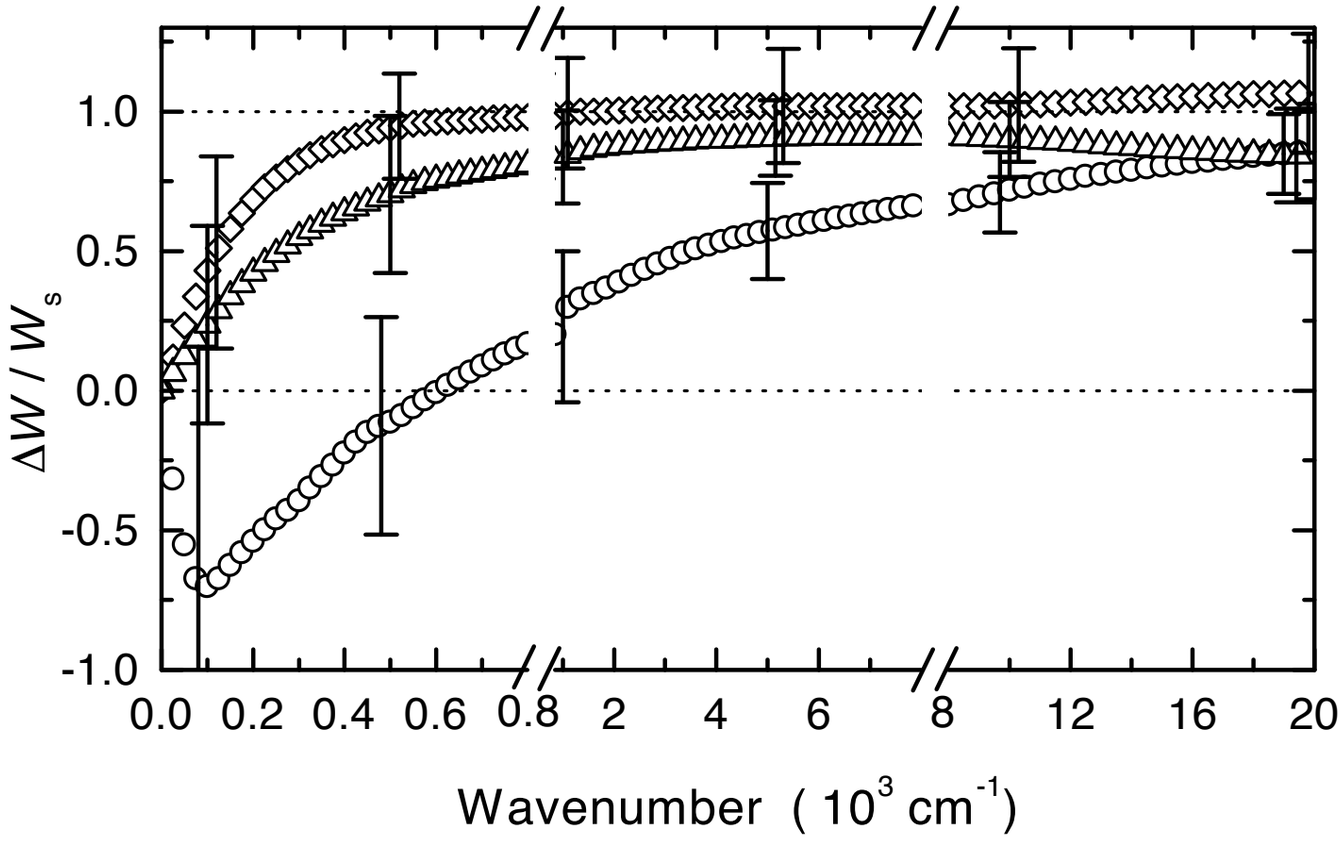

N-1
2
N-1
PES
ε_F
IPES
>2x
L= 2(t/U)f(x) + 2x>2x


L>2x
Sign change of S
$T_c^{\max}$

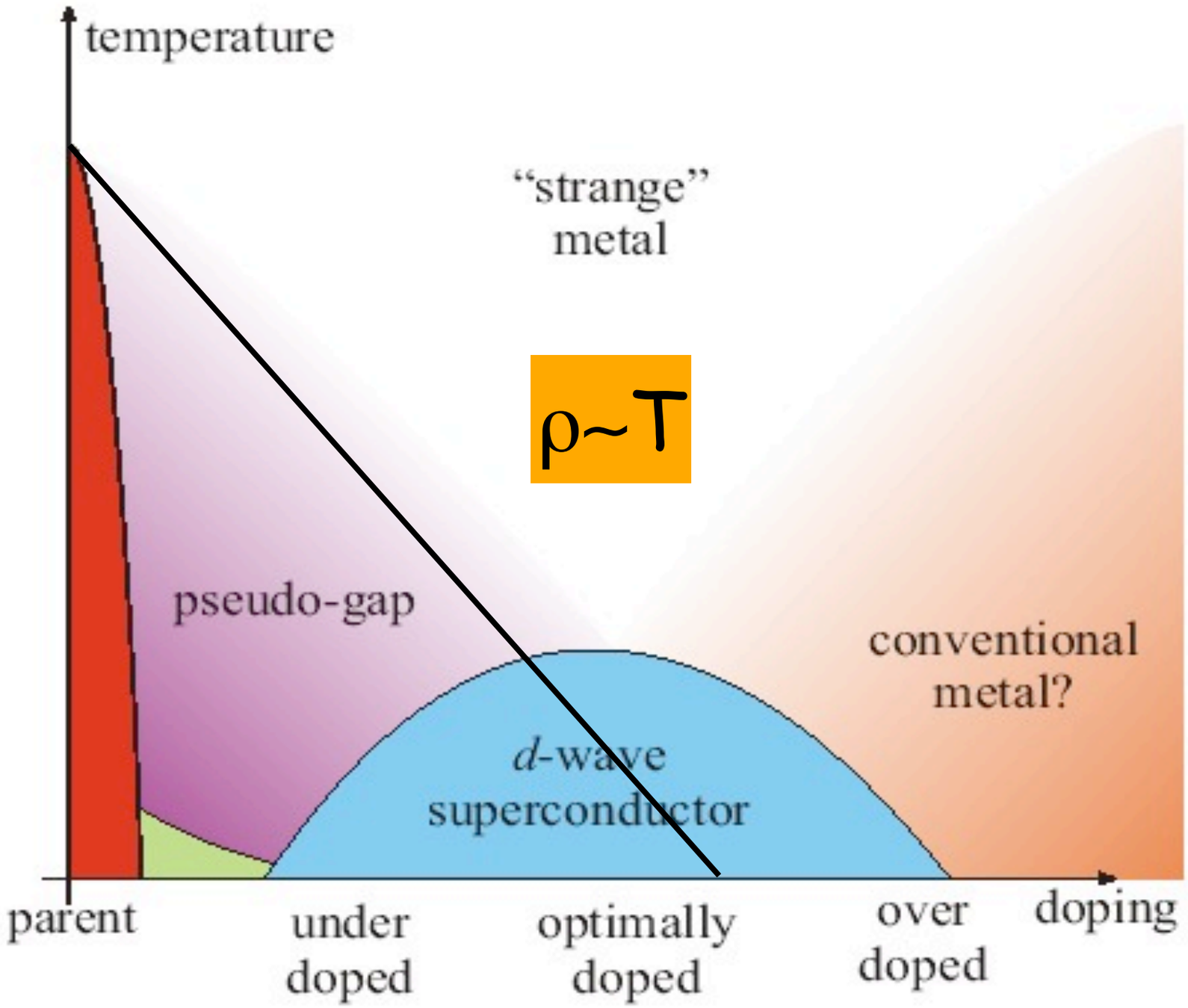

L>2x
Sign change of S
$T_c^{\max}$

similar to optical data



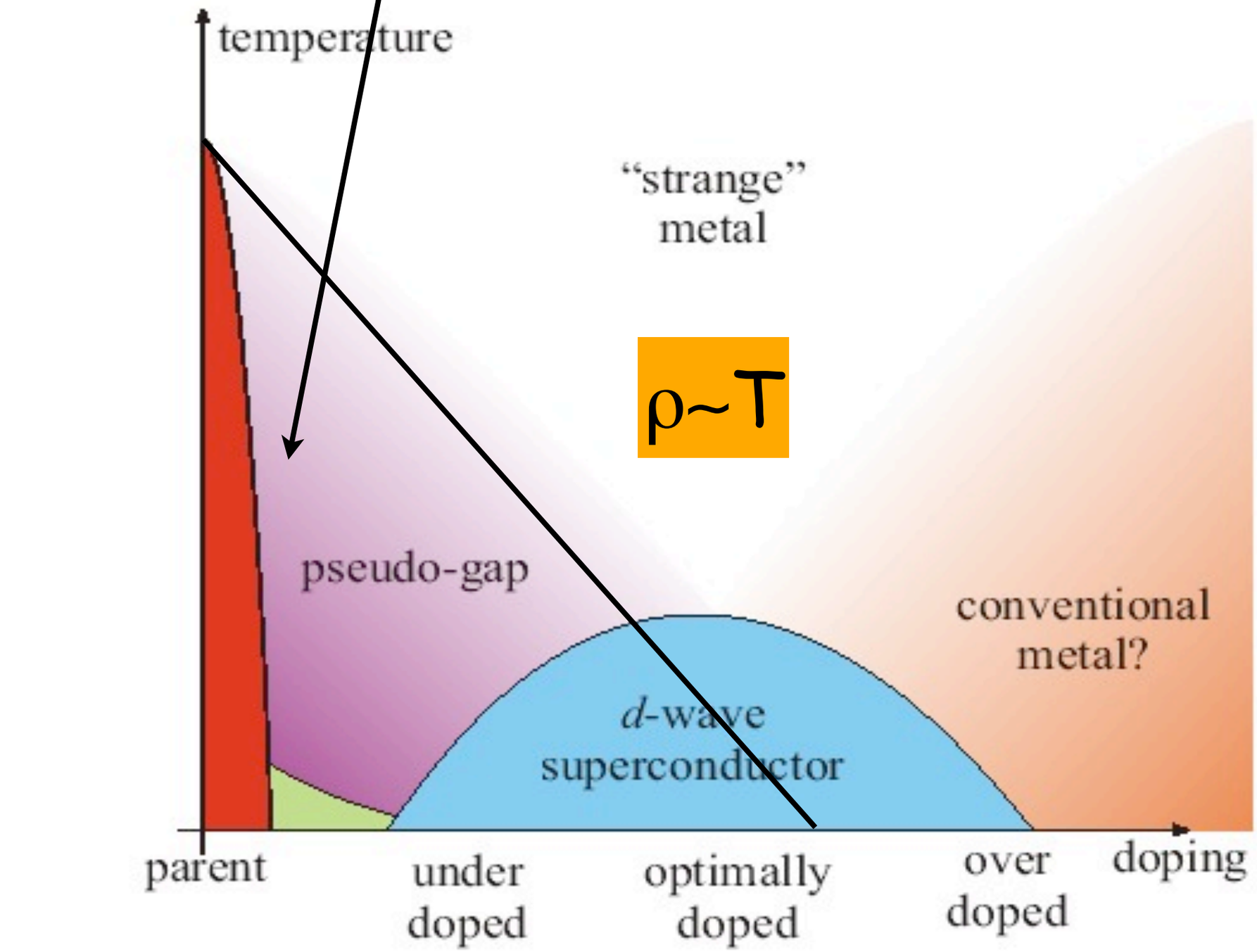


Experimental Prediction:



Experimental Prediction:

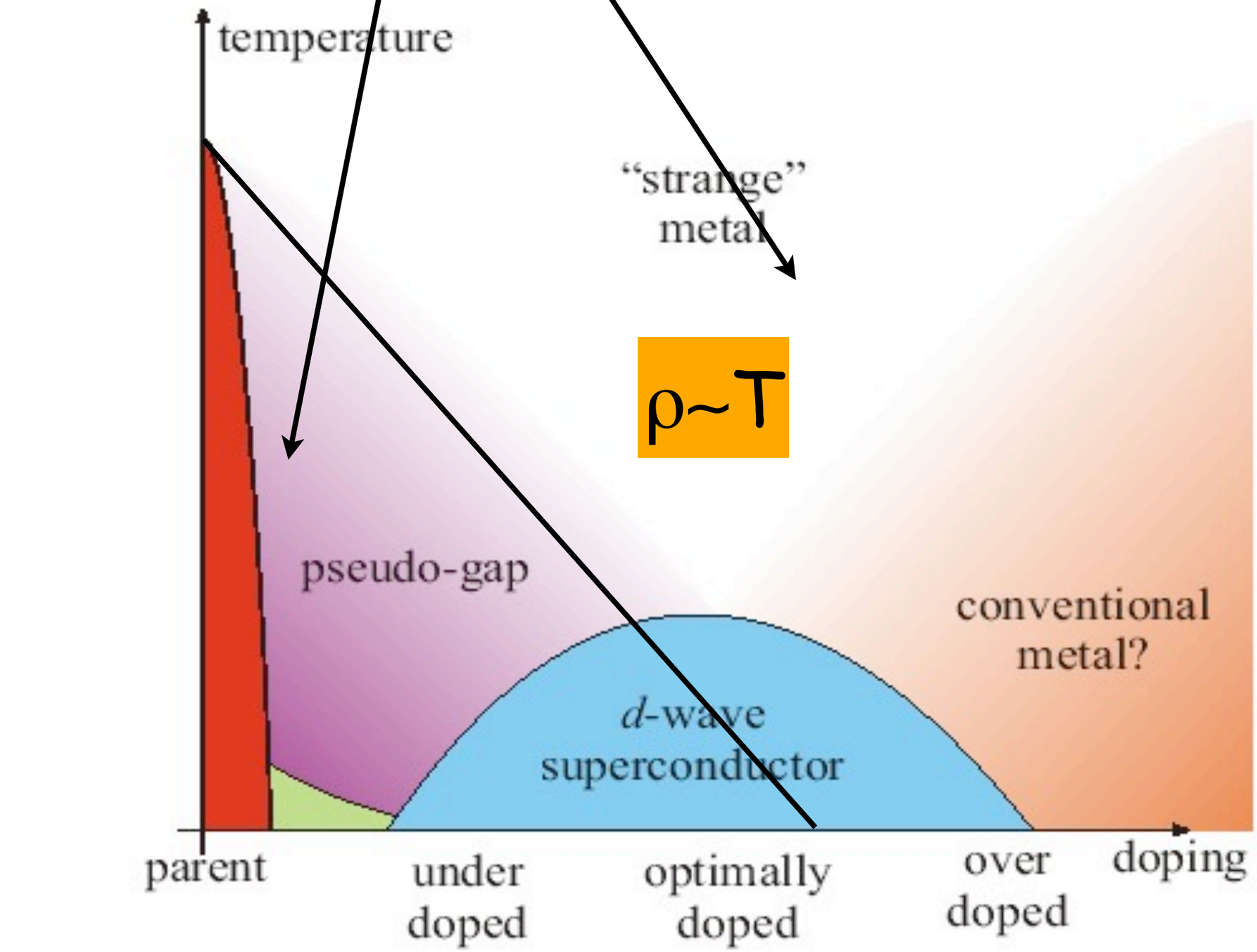
$L/n_h > 1$



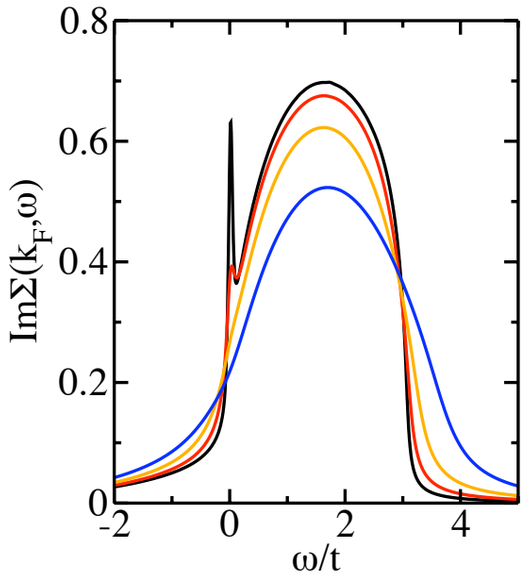
Experimental Prediction:

$L/n_h > 1$

$L/n_h = 1$



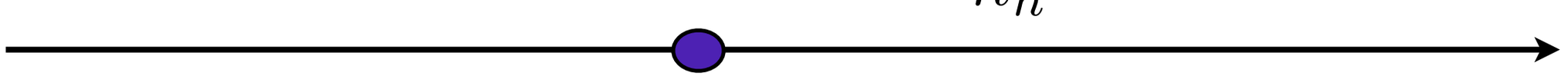
Luttinger surface



FL

$$\frac{L}{n_h} = 1$$

$$\frac{L}{n_h} > 1$$



φ_i is irrelevant

charge 2e boson is the new degree of freedom

1.) only $e - \varphi$ interactions are relevant

2.) φ_i is homogeneous with no bare dynamics

Luttinger surface

FL

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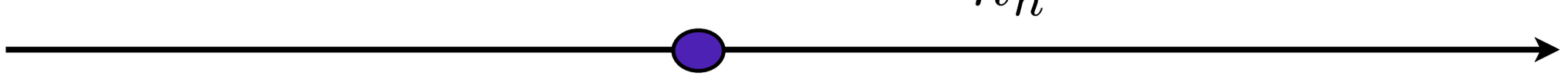

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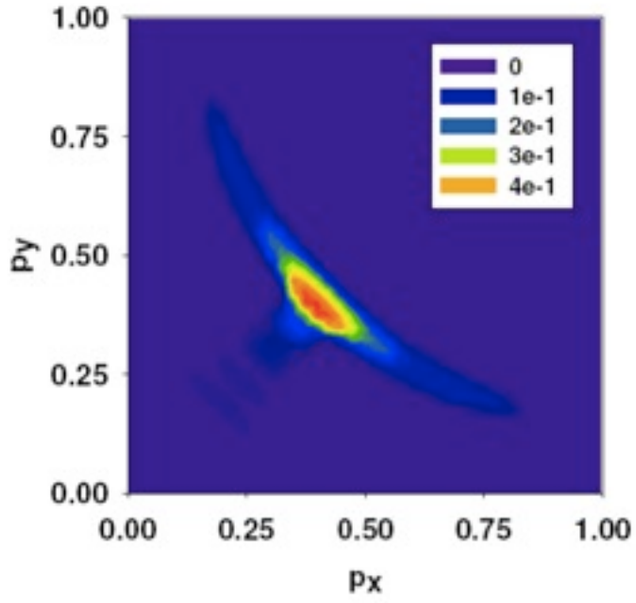

FL

$$\frac{L}{n_h} = 1$$

$$\frac{L}{n_h} > 1$$

g_c

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