INSULATOR-TO-METAL SWITCH VIA THE FIELD-DRIVEN COLLAPSE OF THE MOTT GAP

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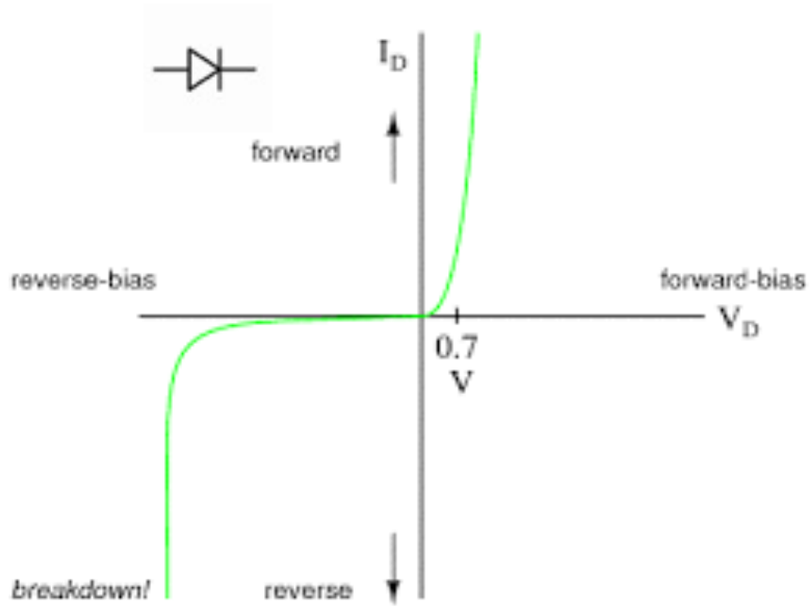
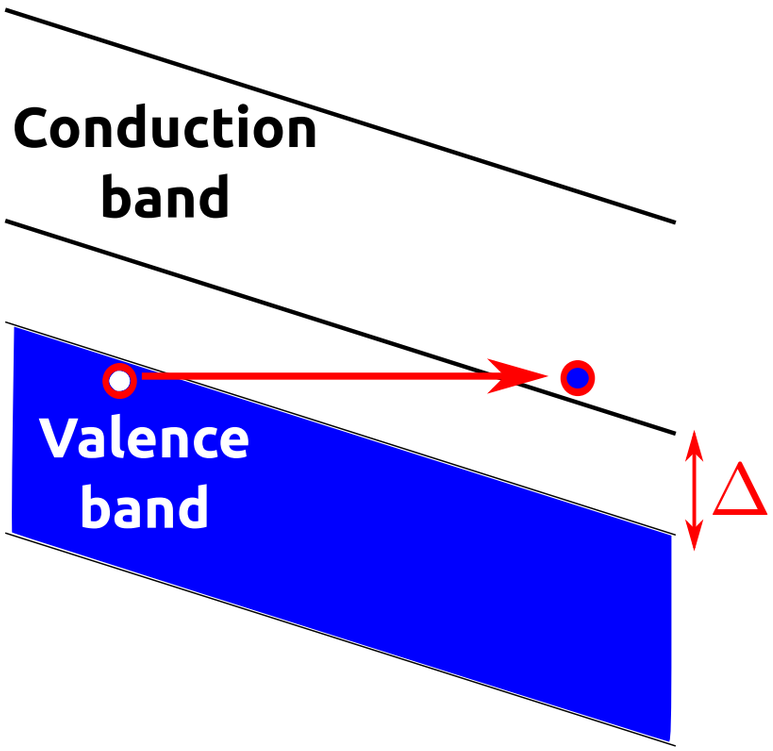
Control of the conductive properties of materials

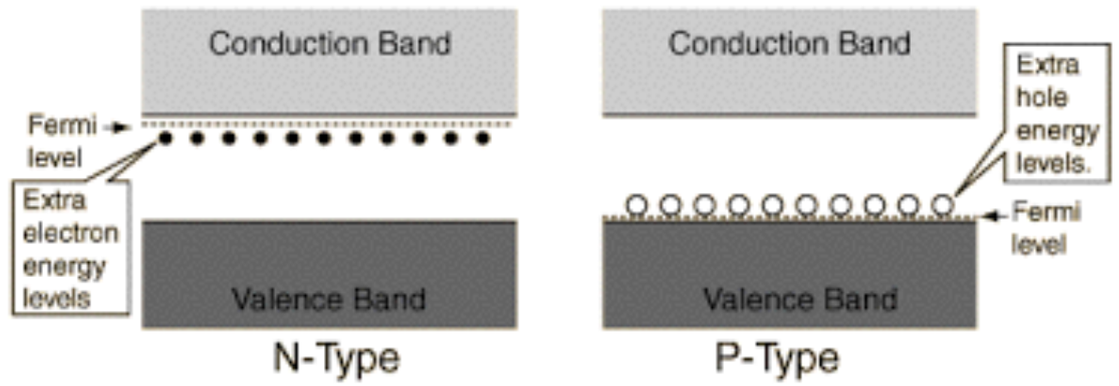
Semiconductor based electronic devices



* Quantum tunneling

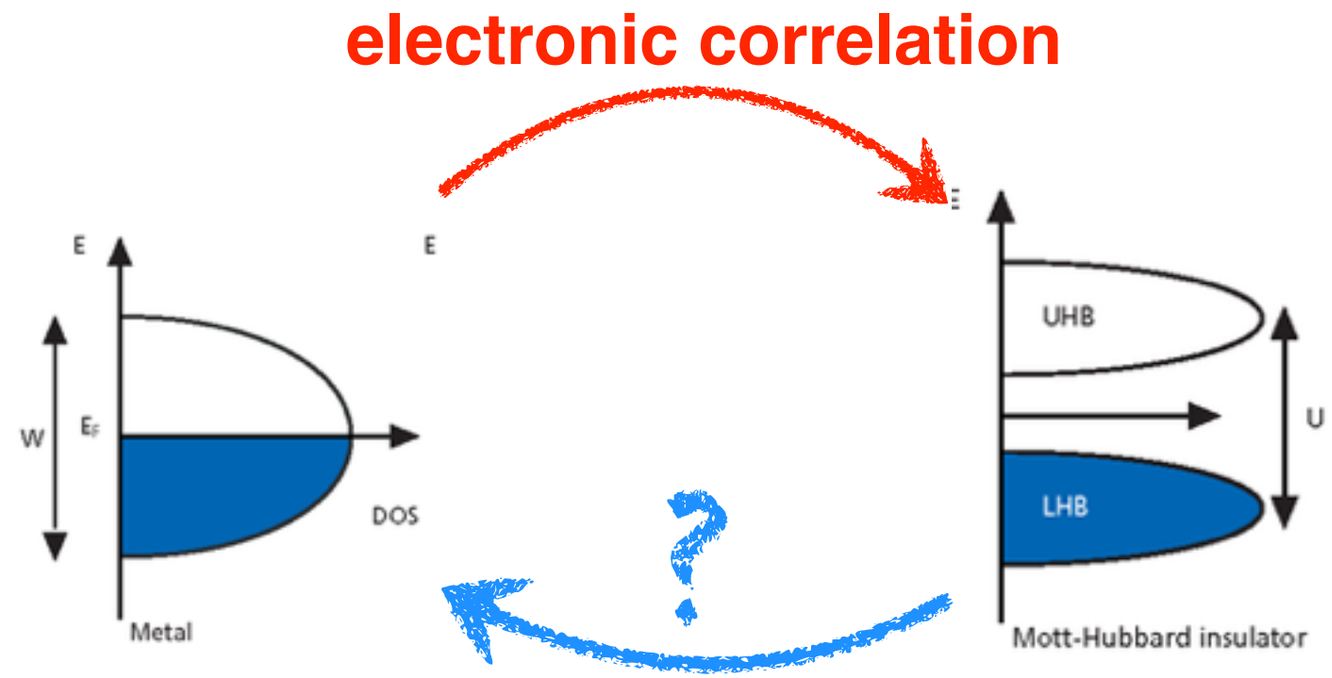


* Chemical doping



Why Correlated Materials?

"unsuccessful metals" ⟷ Mott insulators



electric-field

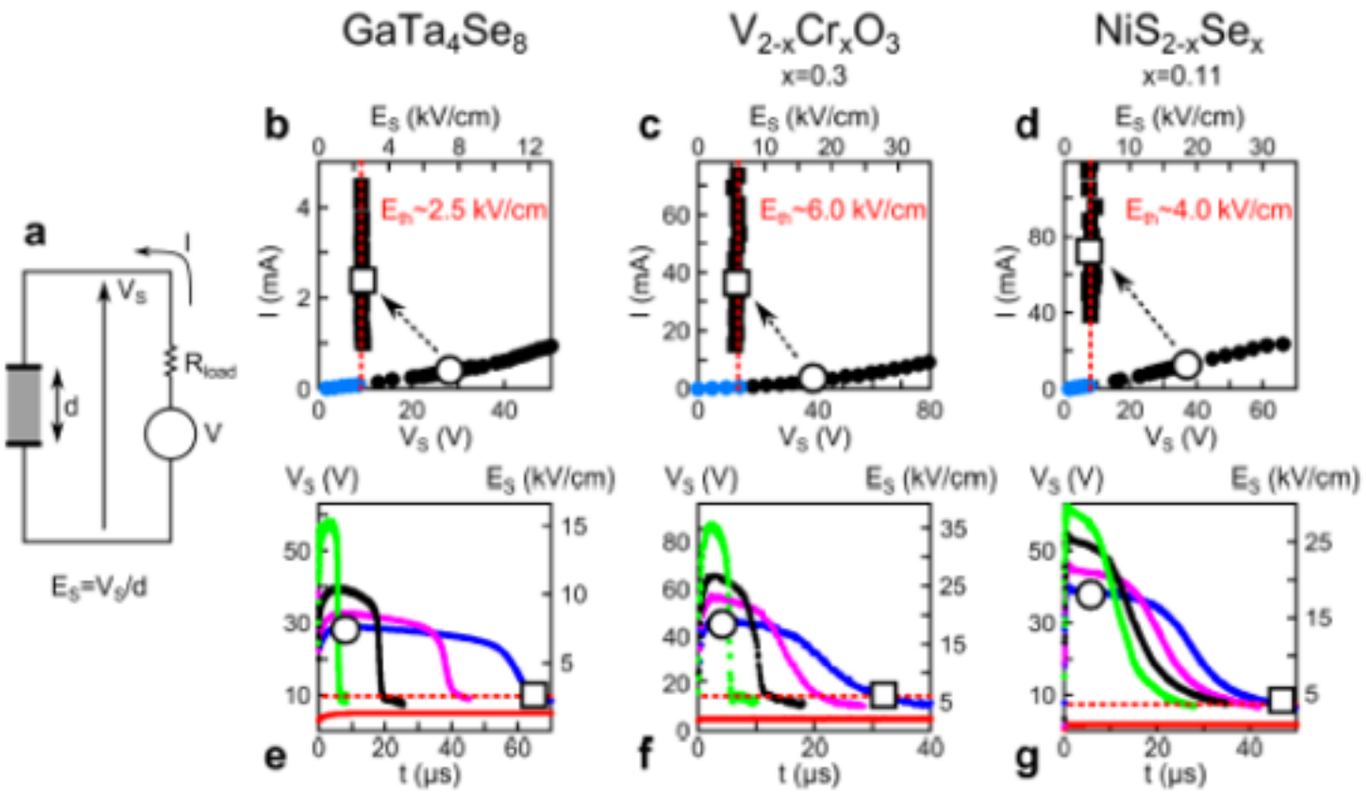
Unlock a huge number of frozen carriers

Huge potential for Mott based microelectronic devices!

Inoue & Rozenberg Adv. Funct. Mater. '08
Janod et al Adv. Funct. Mater. '15,

Insulators-to-Metal switch in correlated insulators

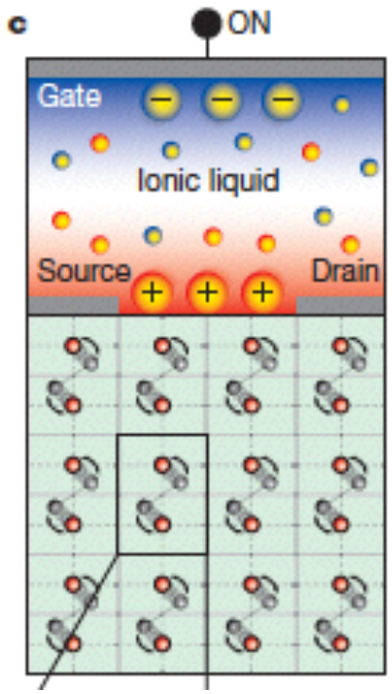
Resistive switch experiments



Abrupt switch at fields much smaller than the gap

Guiot et al NatComm ’13
Stoilar et al AdvMat ‘13

Electric-Double-Layer-Transistor



VO2

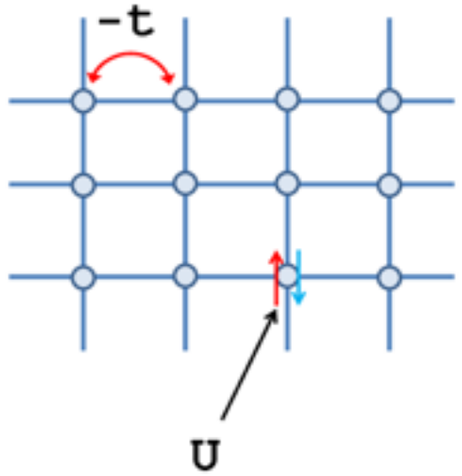
bulk delocalisation above the electrostatic screening length

Nakano et al Nature ‘12

Insulators-to-metal switch beyond semiconductor physics

Breakdown in Mott-Hubbard Insulators

Simplest description of a correlated insulator

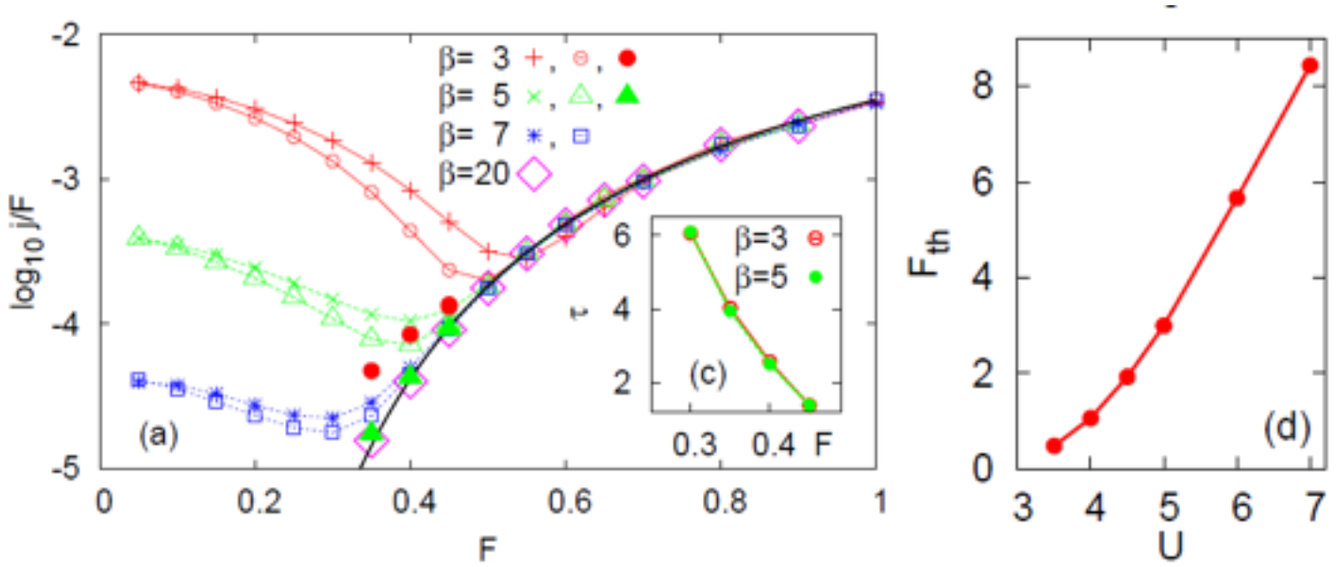


dielectric breakdown
not too different from semiconductors!

* Tunnel across the Mott-Hubbard gap

T. Oka et al PRL ’03
S. Okamoto PRB ’08
M. Eckstein et al PRL ’10
M. Eckstein et al. PRB ’14
G. Mazza et al. PRB‘15

Eckstein et al PRL 105,146404



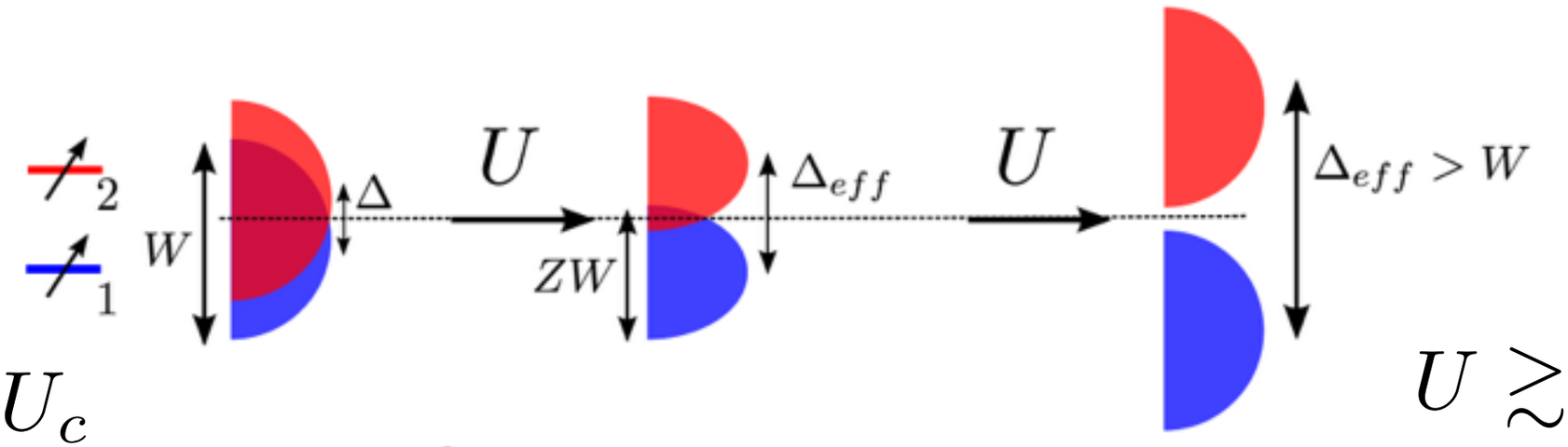
Possible alternative route to the dielectric breakdown

Mott insulator coexisting with a metastable metal

Model: Two bands + crystal field + U

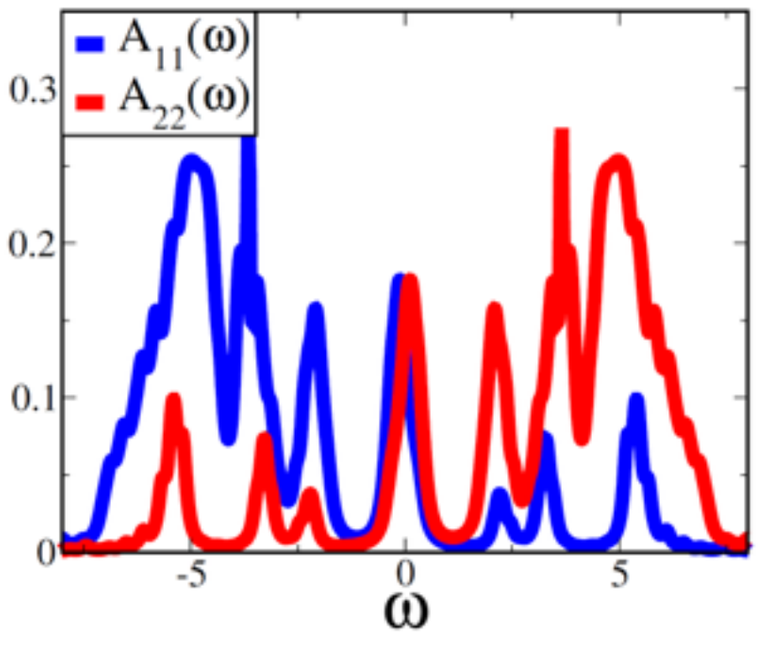
Effects of e-e correlation

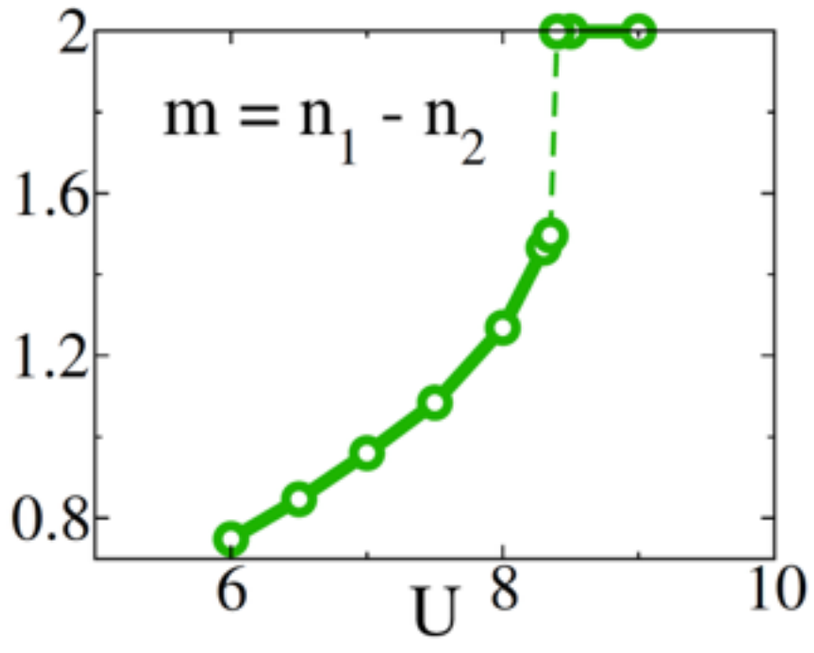
- Shrinking coherent quasiparticles $W \to ZW$
- Enhancement of the crystal field $\Delta \to \Delta + Um$

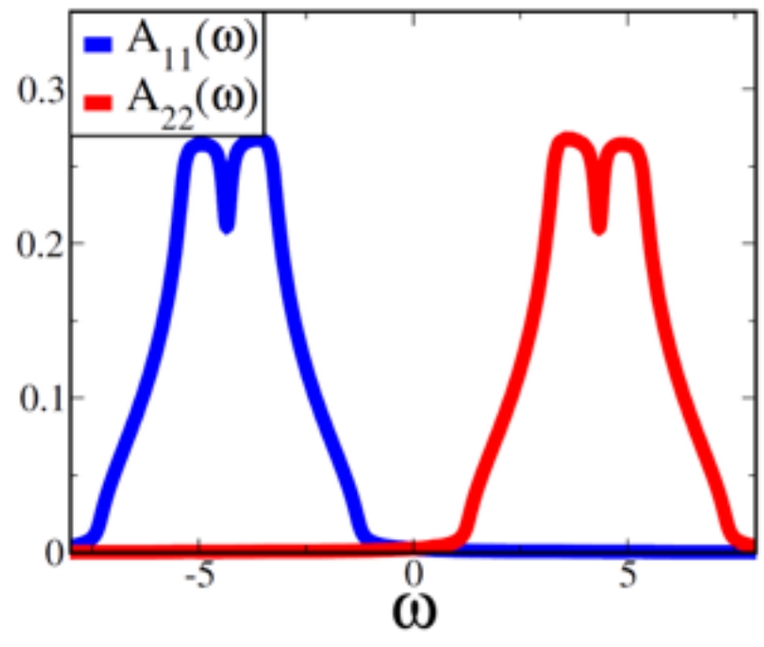


$U \lesssim U_c$

$U \gtrsim U_c$

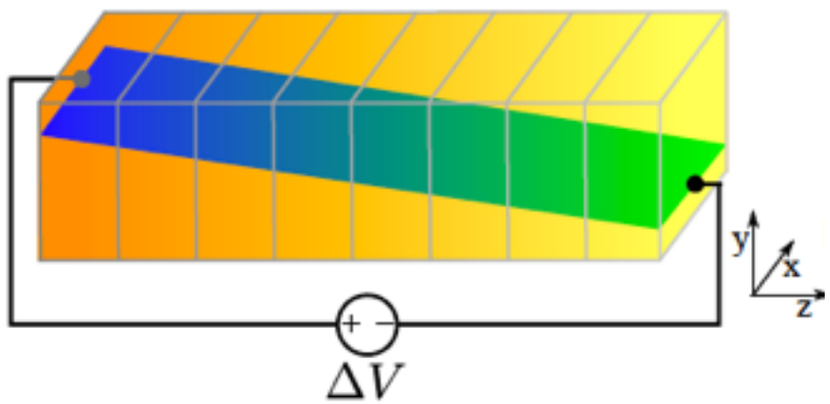


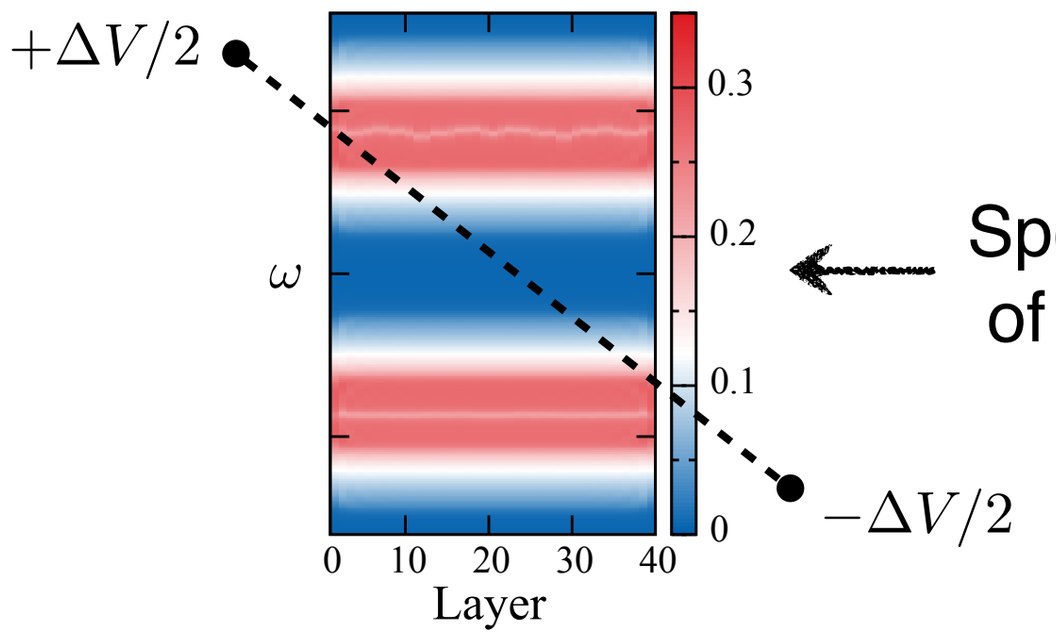




First-order MIT (DMFT)
Metal-Insulator Coexistence

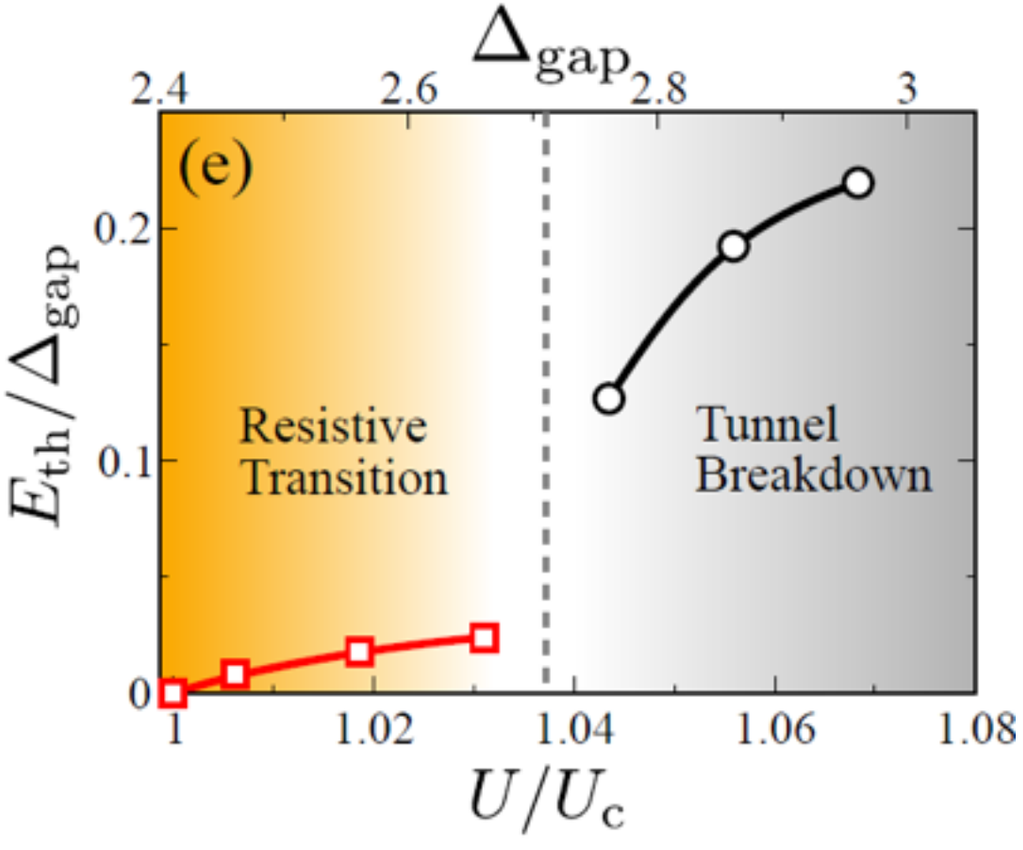
Insulating slab w/ applied electric field





Spectral density of the insulator

Ground state evolution across the <u>field driven insulator-to-metal transition</u> (real space DMFT)



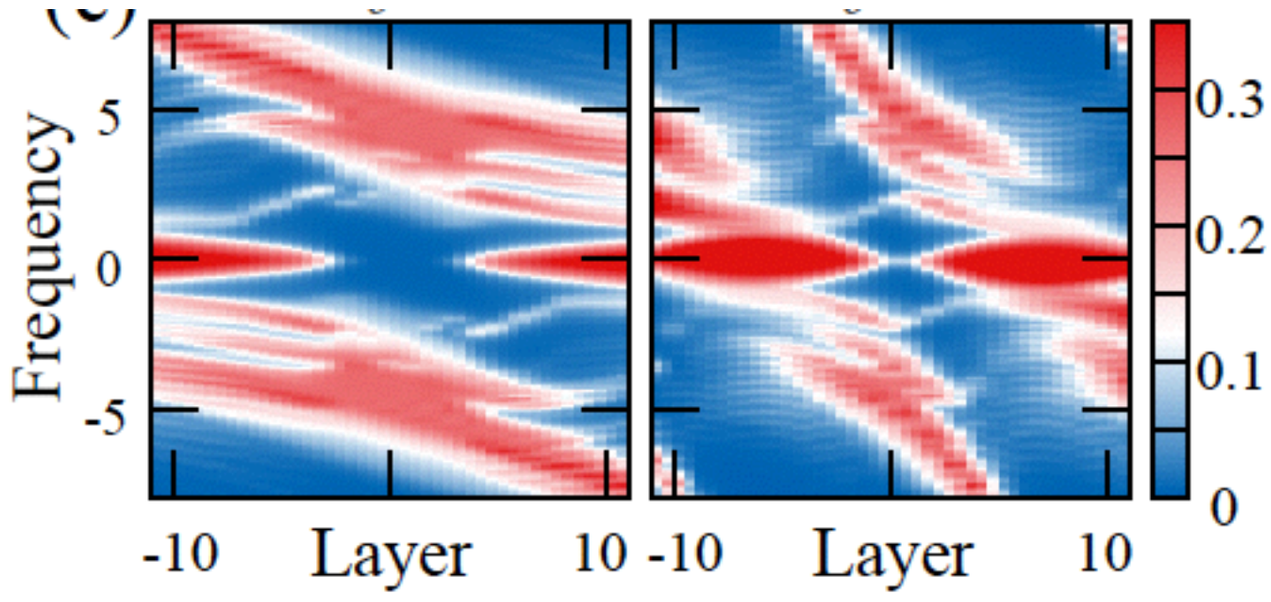
Different mechanisms IN and OUT the metal-insulator coexistence region!

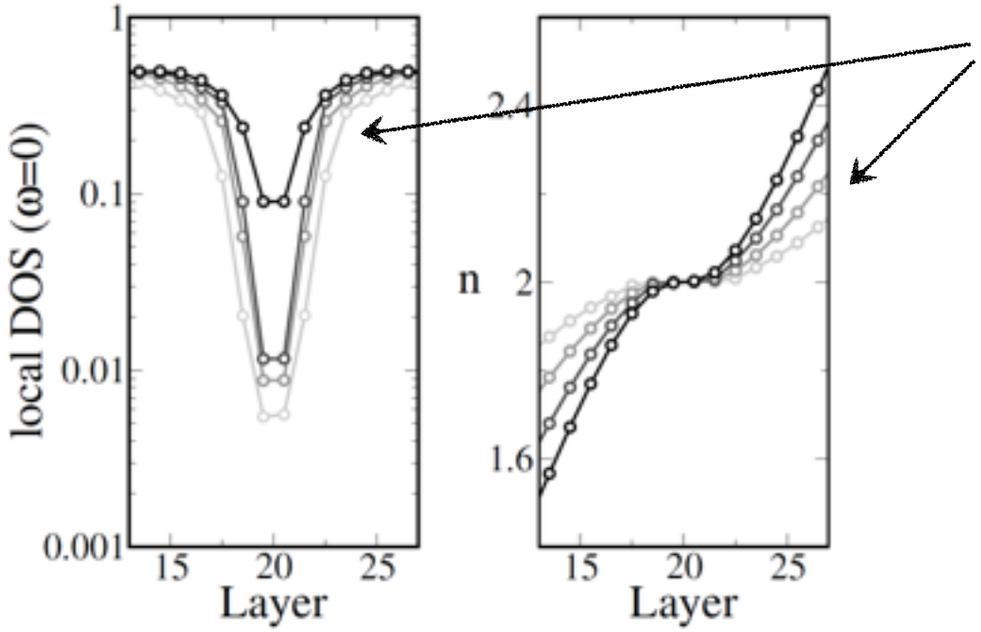
Field-induced insulator-to-metal transition

$$U \gg U_c$$

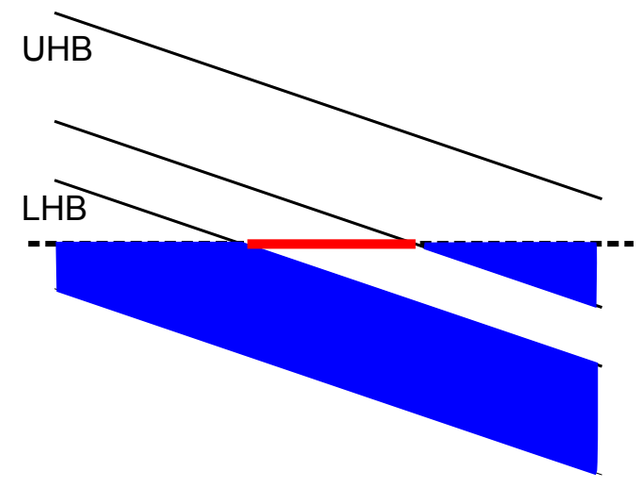
increasing Electric Field

Rigid tilt of the insulating gap





- inhomogeneous metal
- charge redistribution



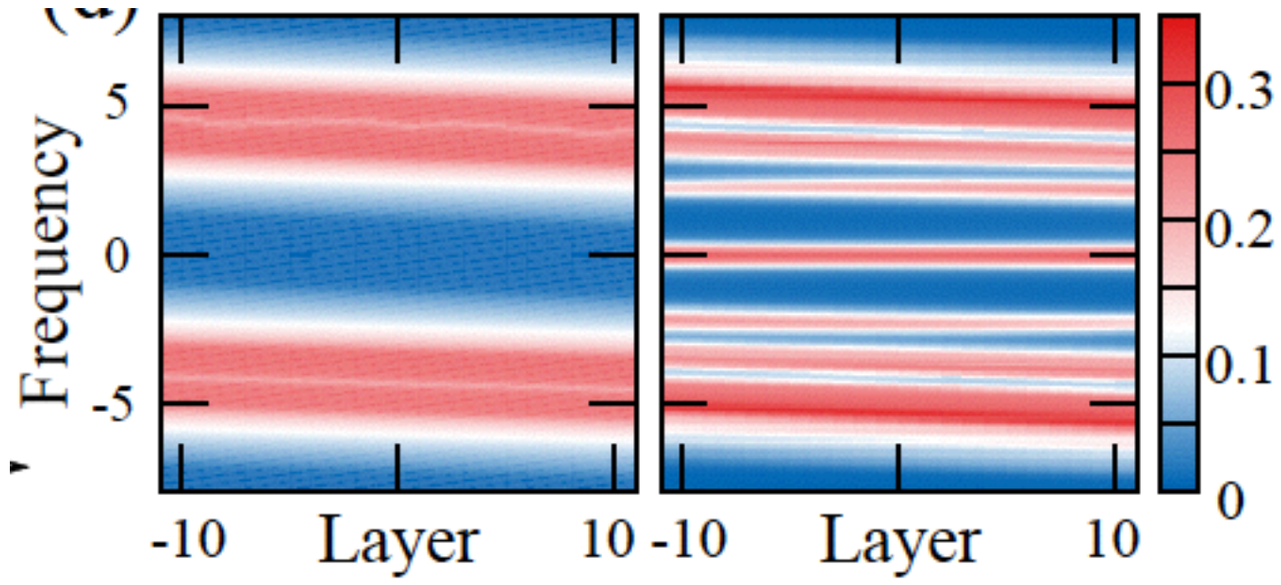
“equilibrium picture” of tunnel-like conductive channel

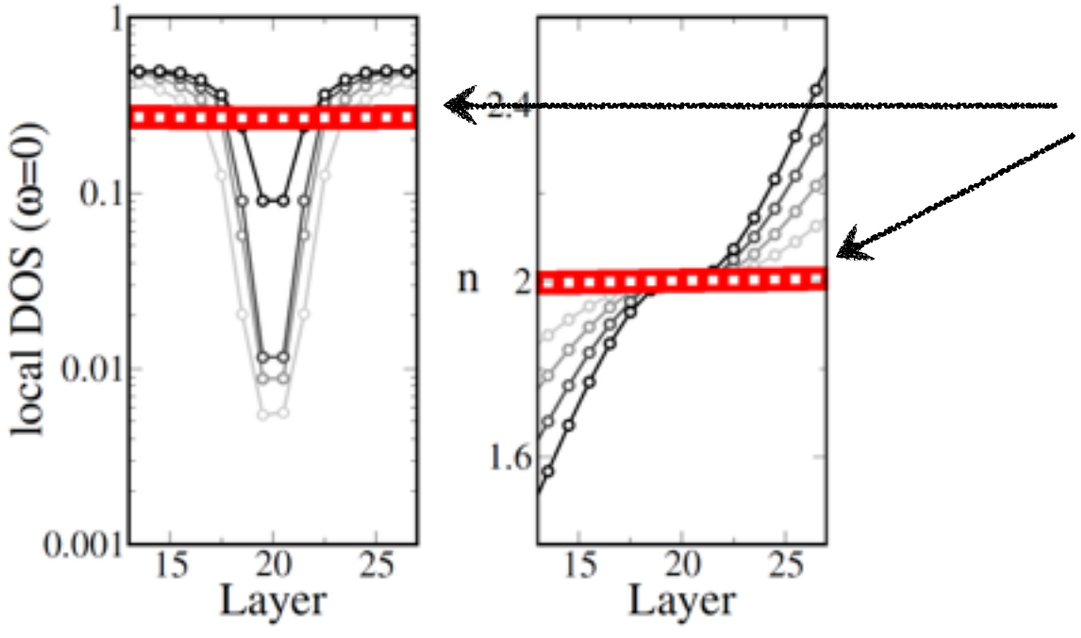
Field-induced insulator-to-metal transition

$$U \gtrsim U_c$$

increasing Electric Field

Abrupt closing of the gap

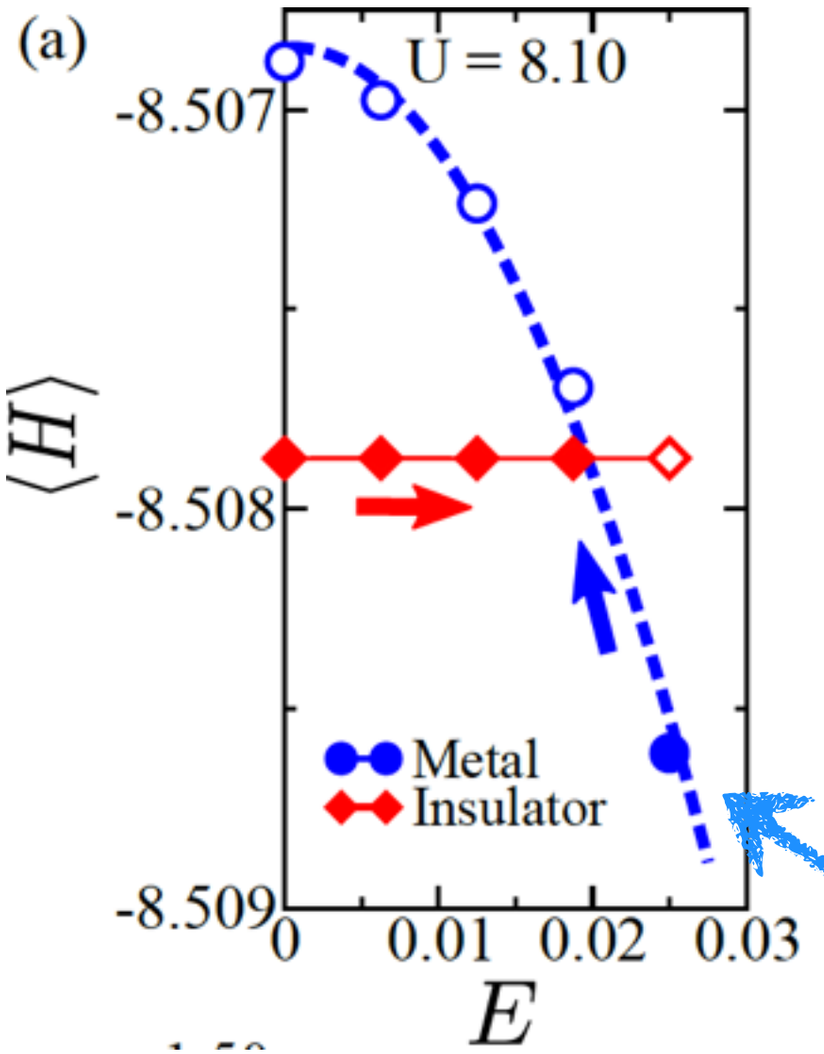




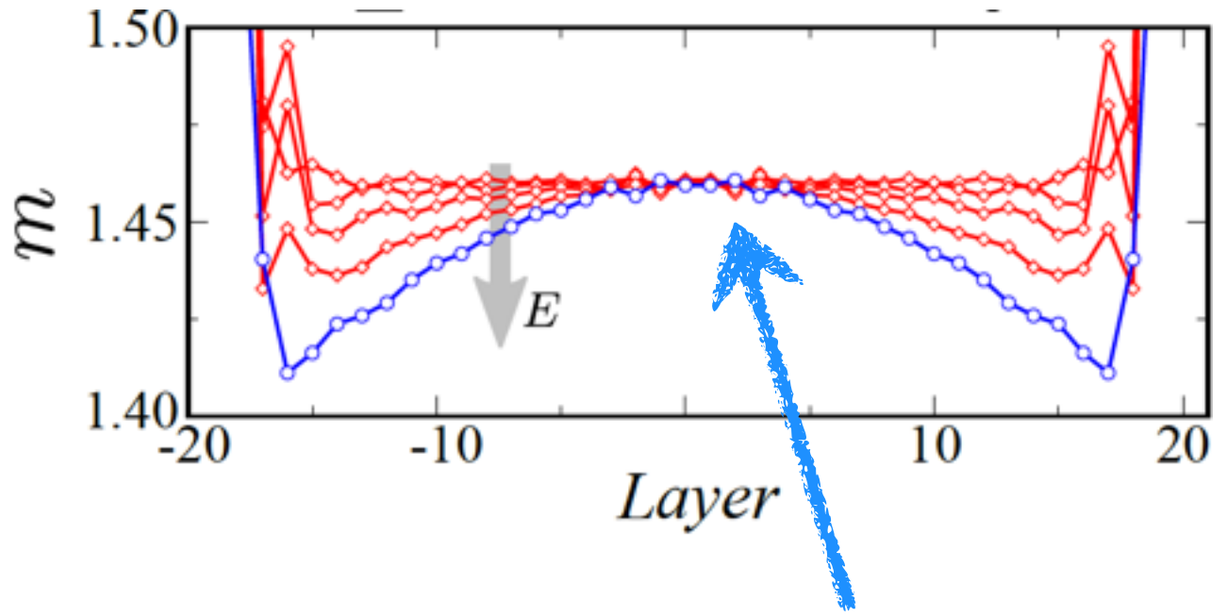
- Homogenous conductive states
- No charge redistribution

First-order insulator-to-metal transition!

INS-MET hysteresis loop VS electric field



Orbital polarisation VS field



The electric field reduces the effect of correlations

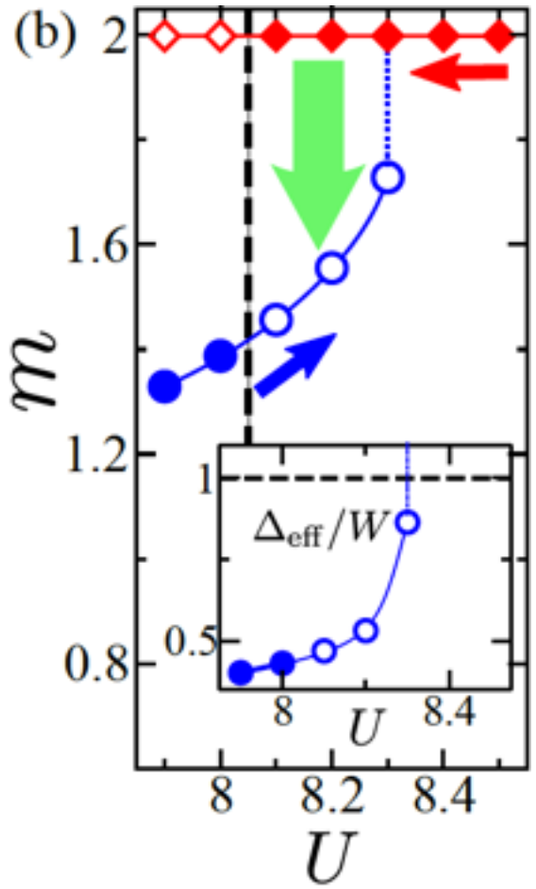
Energy gain within the linear response regime

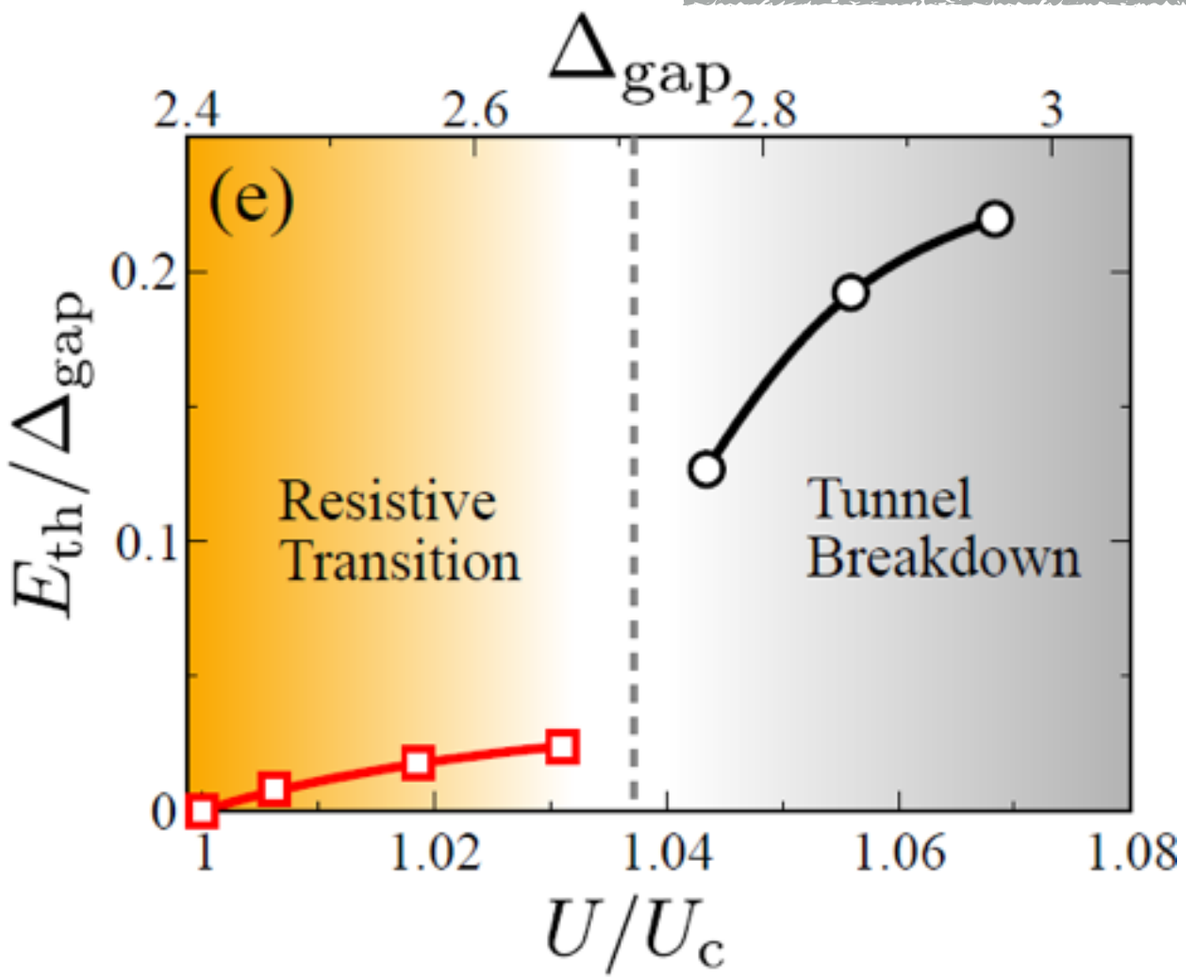
$$\delta\langle H\rangle \propto E^2$$

Relatively small electric field is able to induce the switch between the two competing phases!

Different routes for the Mott insulator metallisation

Rigid modification of the insulator (only one stable phase)



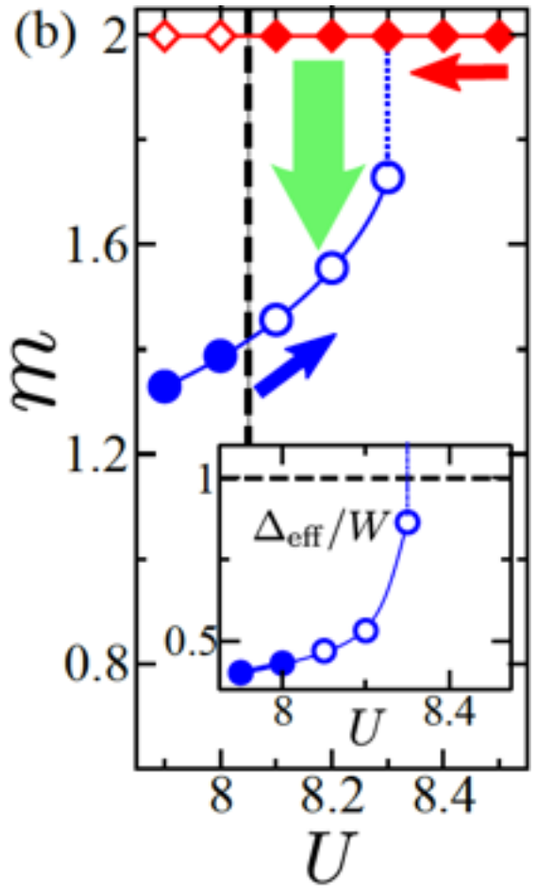


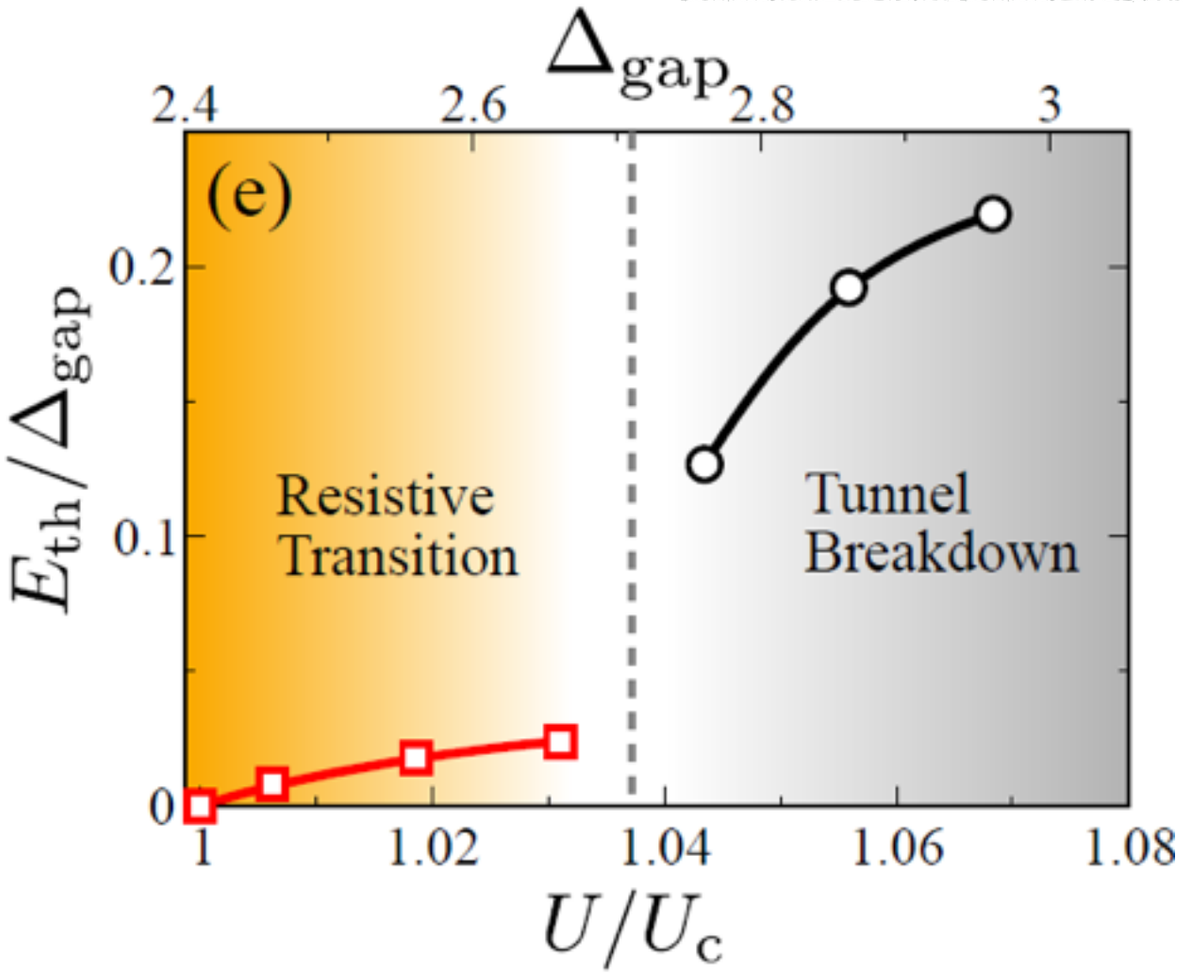
Switch between two competing phases

Qualitative and quantitative different IMT!

Different routes for the Mott insulator metallisation

Rigid modification of the insulator (only one stable phase)





Switch between two competing phases

Qualitative and quantitative different IMT!

Thank you