INSULATOR–TO–METAL SWITCH IN CORRELATED INSULATORS VIA THE FIELD–DRIVEN COLLAPSE OF THE MOTT GAP

Giacomo Mazza

École Polytechnique & Collège de France @ Paris

w/ **Adriano Amaricci**, **Massimo Capone**, **Michele Fabrizio**

International School for Advanced Studies @ Trieste

arXiv 1602.03138

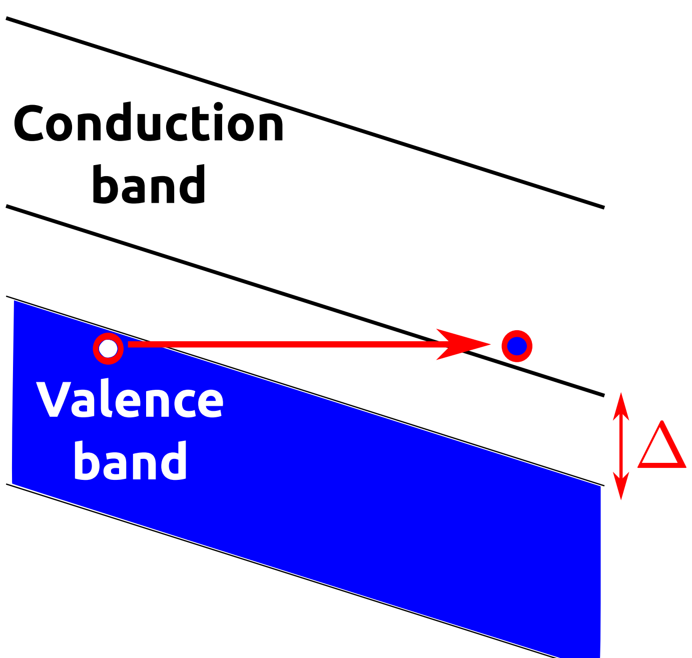
IMPACT 2016, Cargèse

Control of the conductive properties of materials

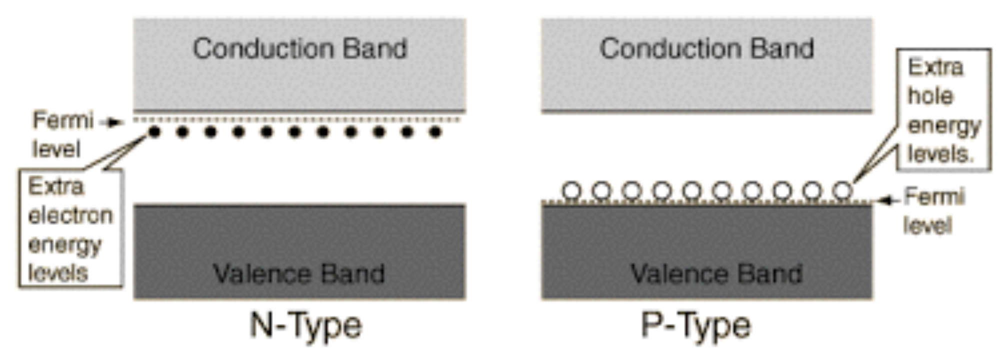
Building block of almost every electronic device

Semiconductors

Quantum tunneling



Chemical doping

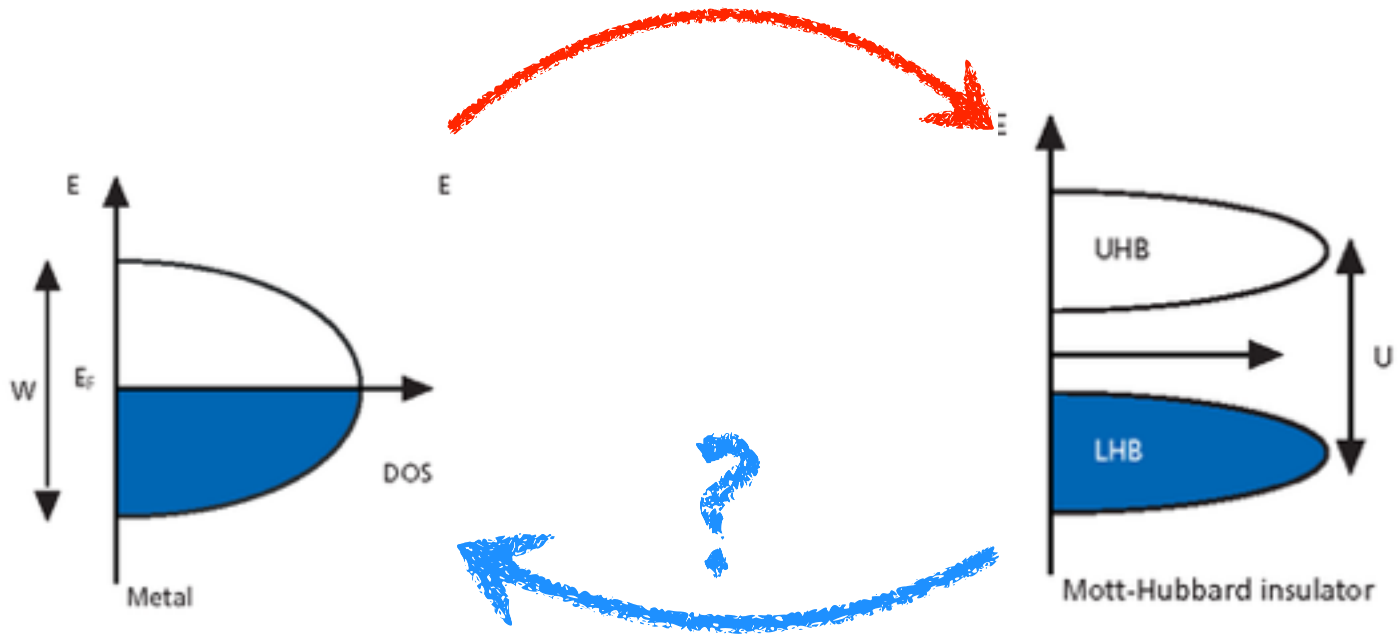


Why Correlated Materials?

Extremely tunable materials with rich phase diagram
(doping,temperature,pressure)

Mott insulators ⟷ “unsuccessful metals”

electronic correlation



electric-field

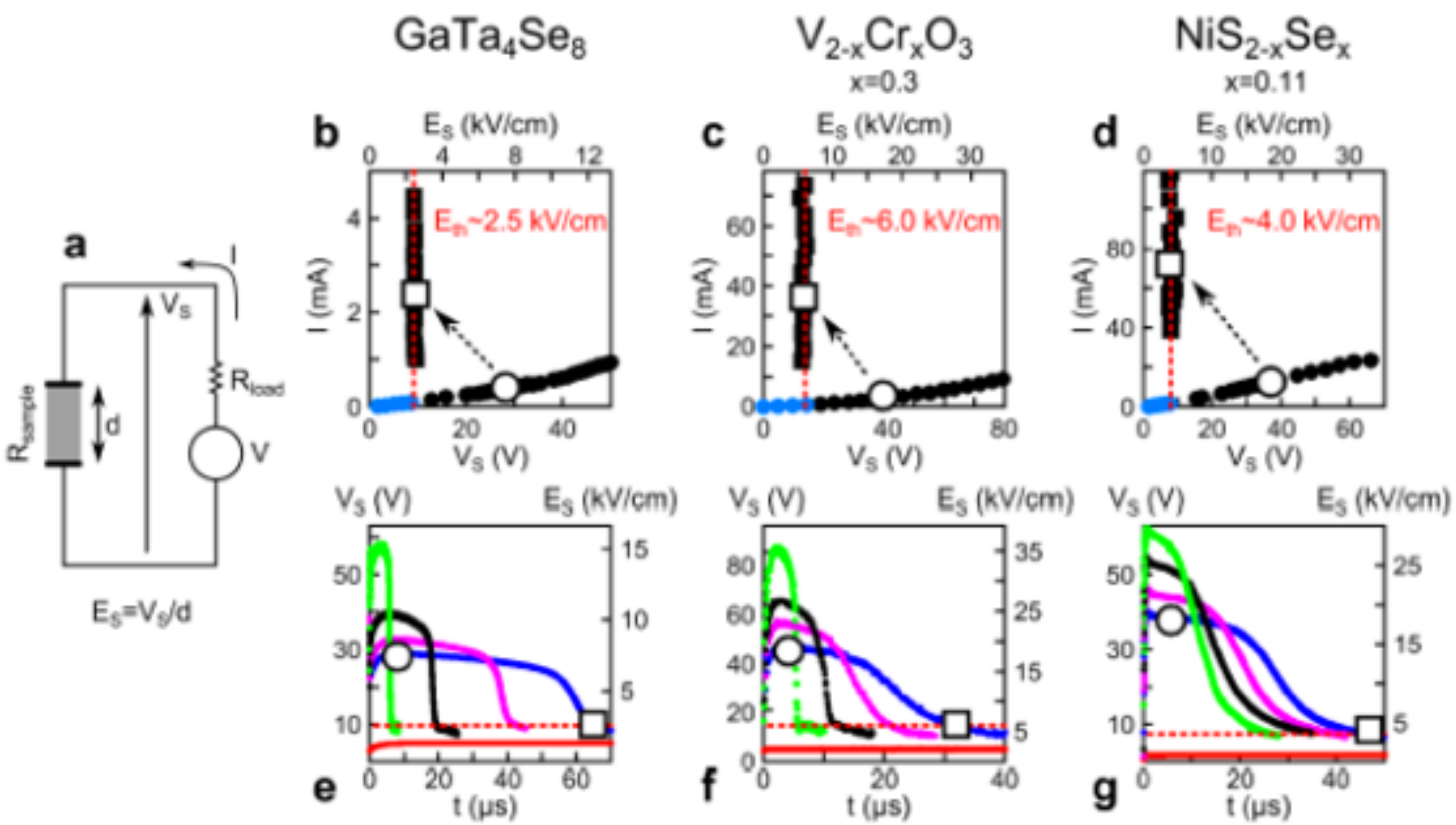
Unlock a huge number of frozen carriers

Huge potential for Mott based microelectronic devices!

see Inoue & Rozenberg Adv.Func.Mat ‘08

Insulators-to-Metal switch in correlated insulators

Resistive switch experiments

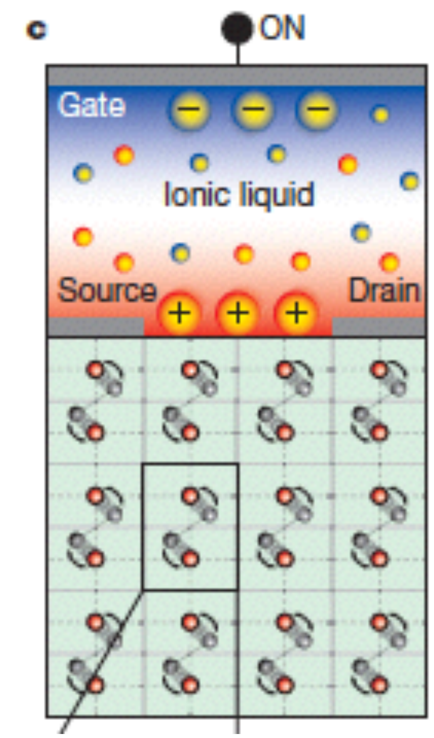


Abrupt switch at fields much smaller than the gap

Guiot et al NatComm '13
Stoilar et al AdvMat '13

cf. E. Janod talk

Electric-Double-Layer-Transistor



VO2

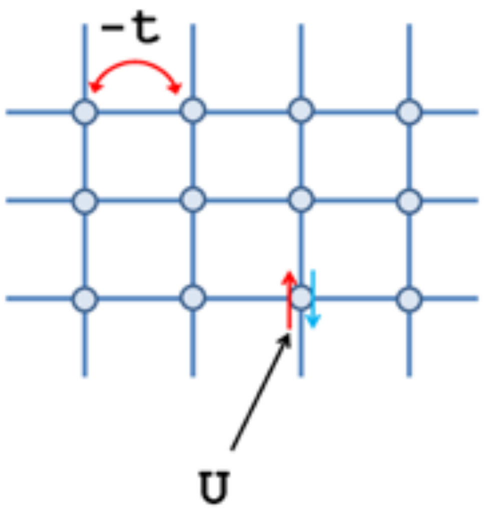
bulk delocalisation beyond the electrostatic screening length

Nakano et al Nature '12

Insulators-to-metal switch beyond semiconductor physics

Breakdown in Mott-Hubbard Insulators

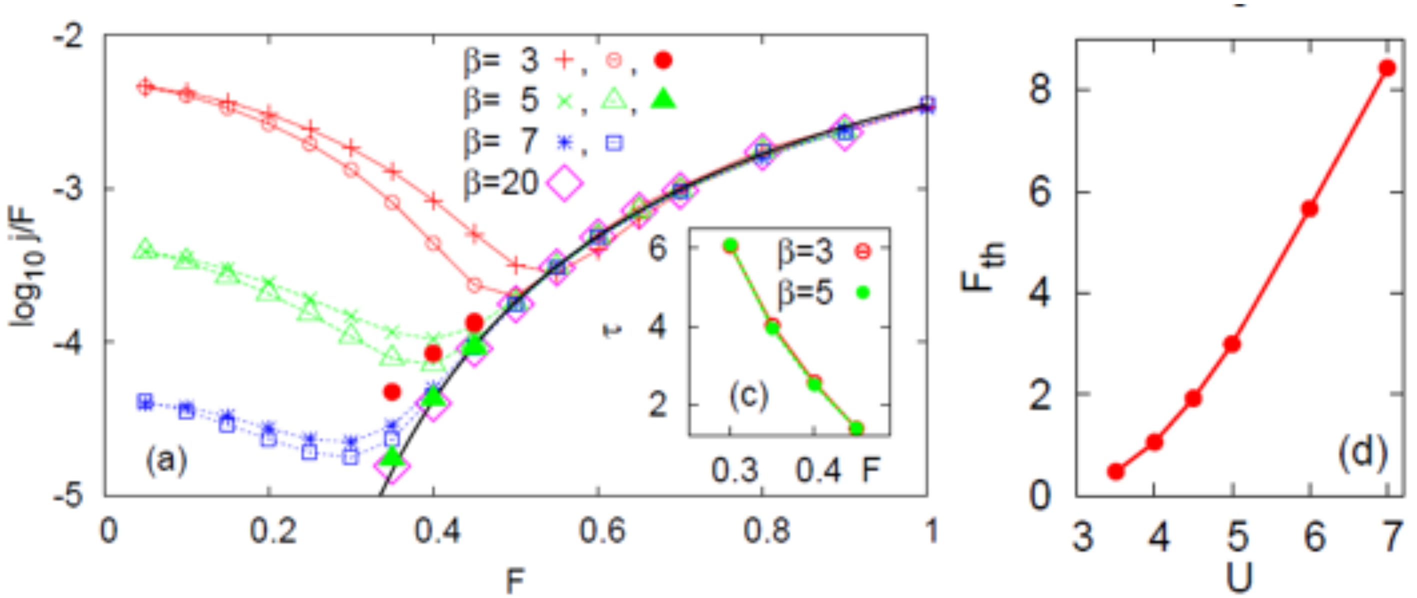
Simplest description of a correlated insulator phase behave <u>not differently to semiconductors</u>



<u>Tunnel across the Mott-Hubbard gap</u>

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



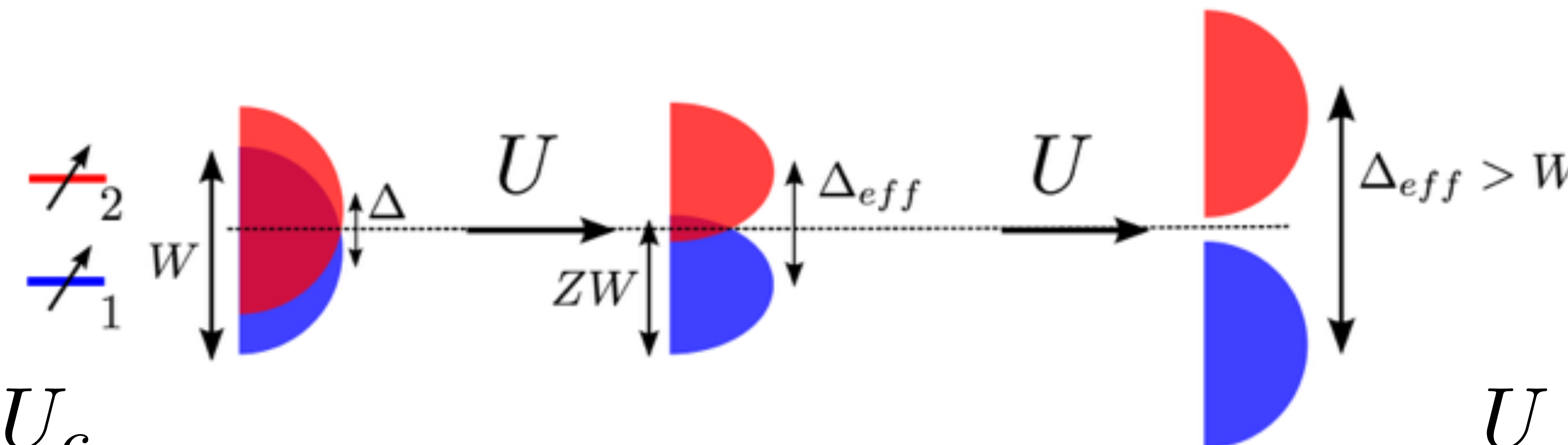
Possible alternative route to the dielectric breakdown

Mott insulator coexisting with a metastable metal

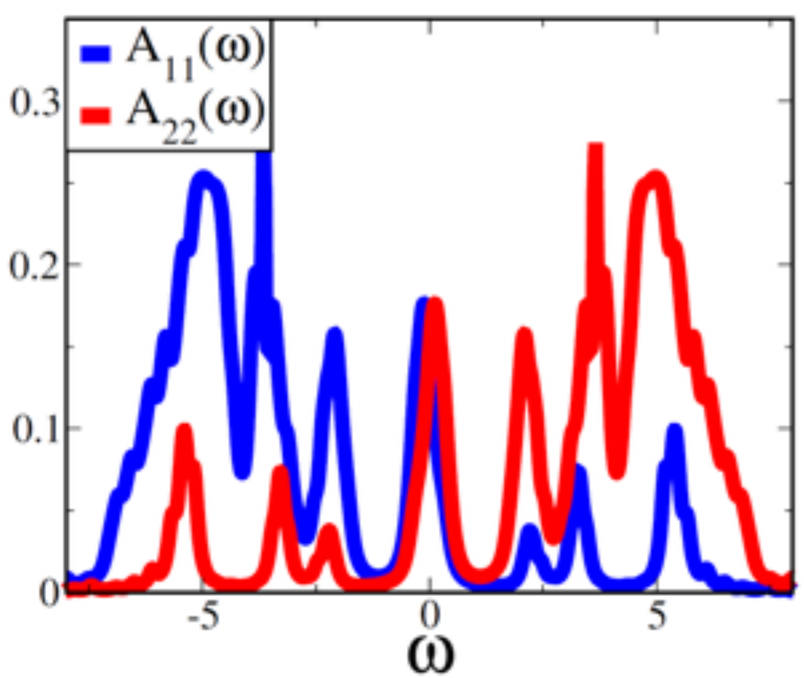
Two bands model w/ crystal field splitting

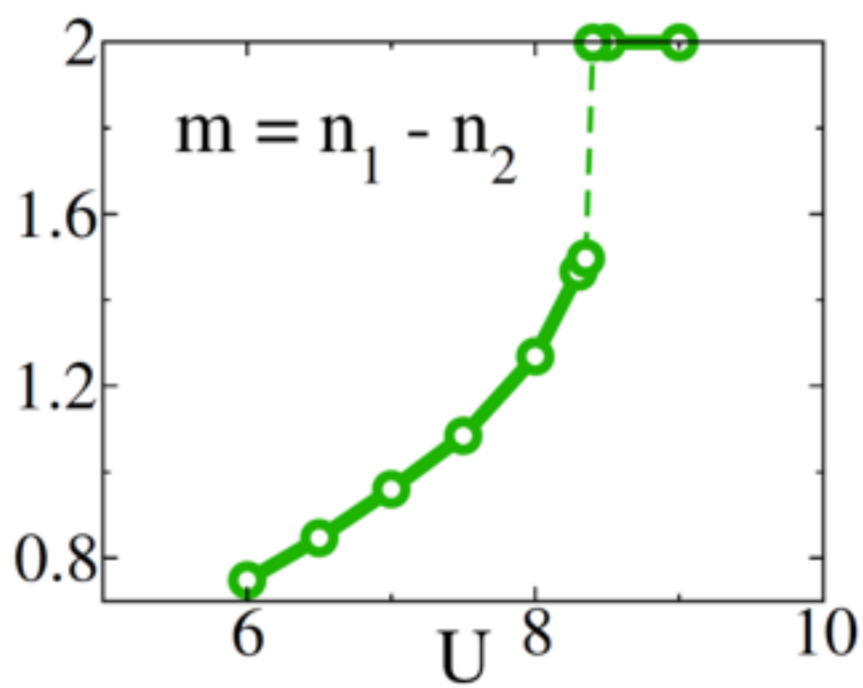
Effects of e-e correlation

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

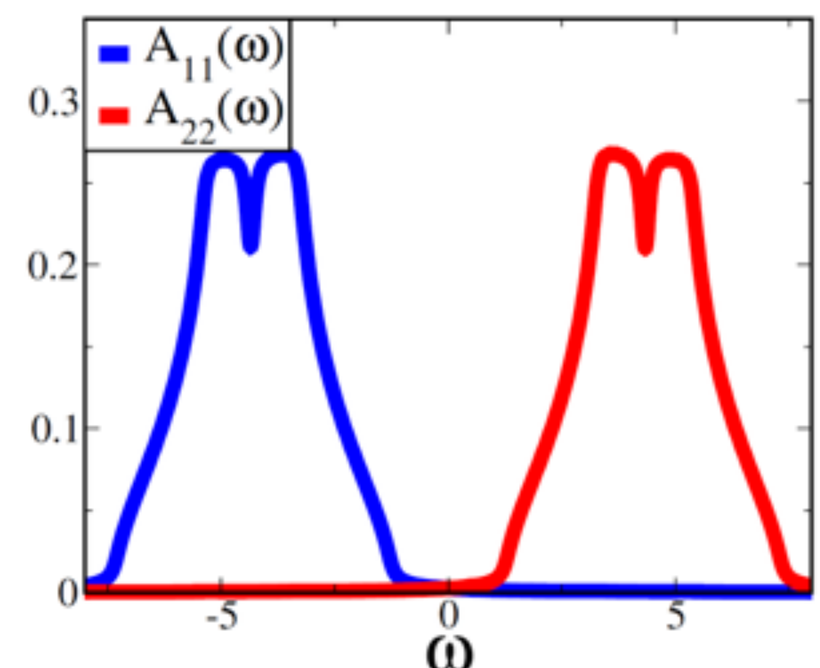


$U \lesssim U_c$





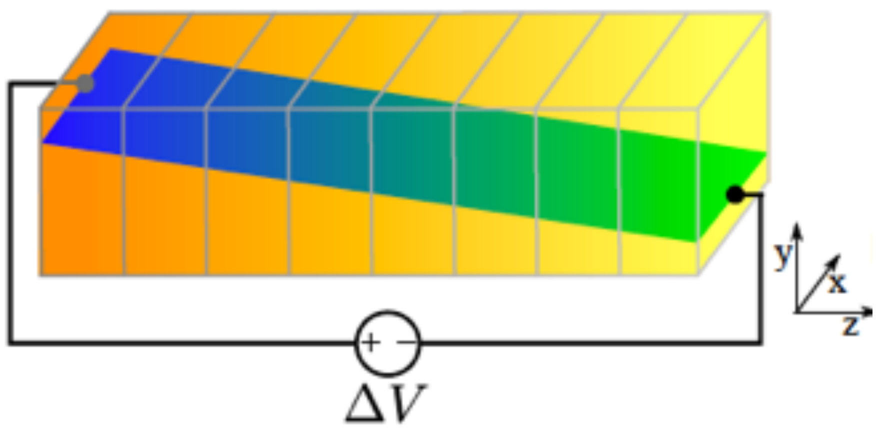
$U \gtrsim U_c$

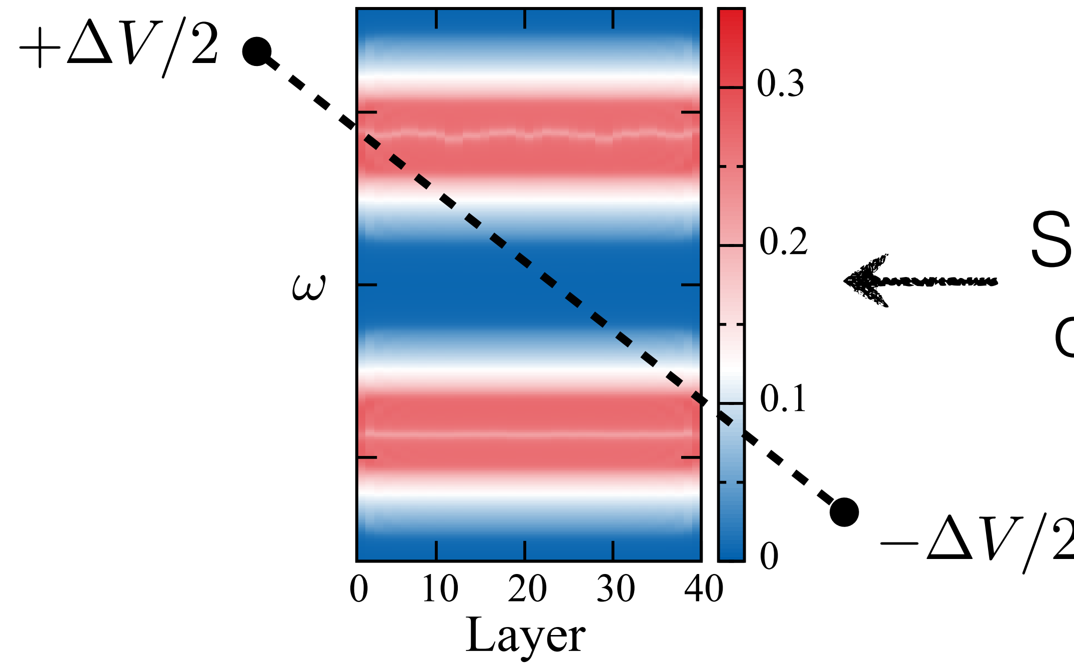


First-order MIT (DMFT)

Metal-Insulator Coexistence

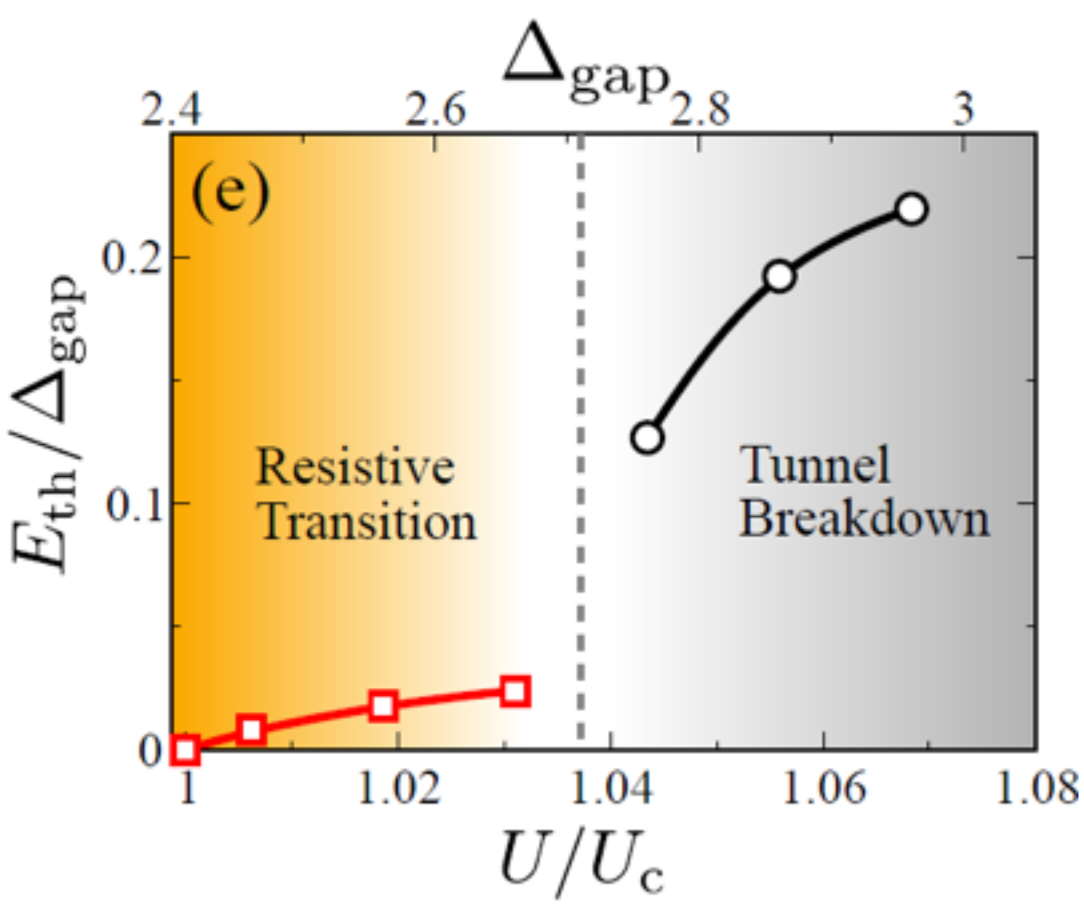
Insulating slab w/ applied electric field





Spectral density of the insulator

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



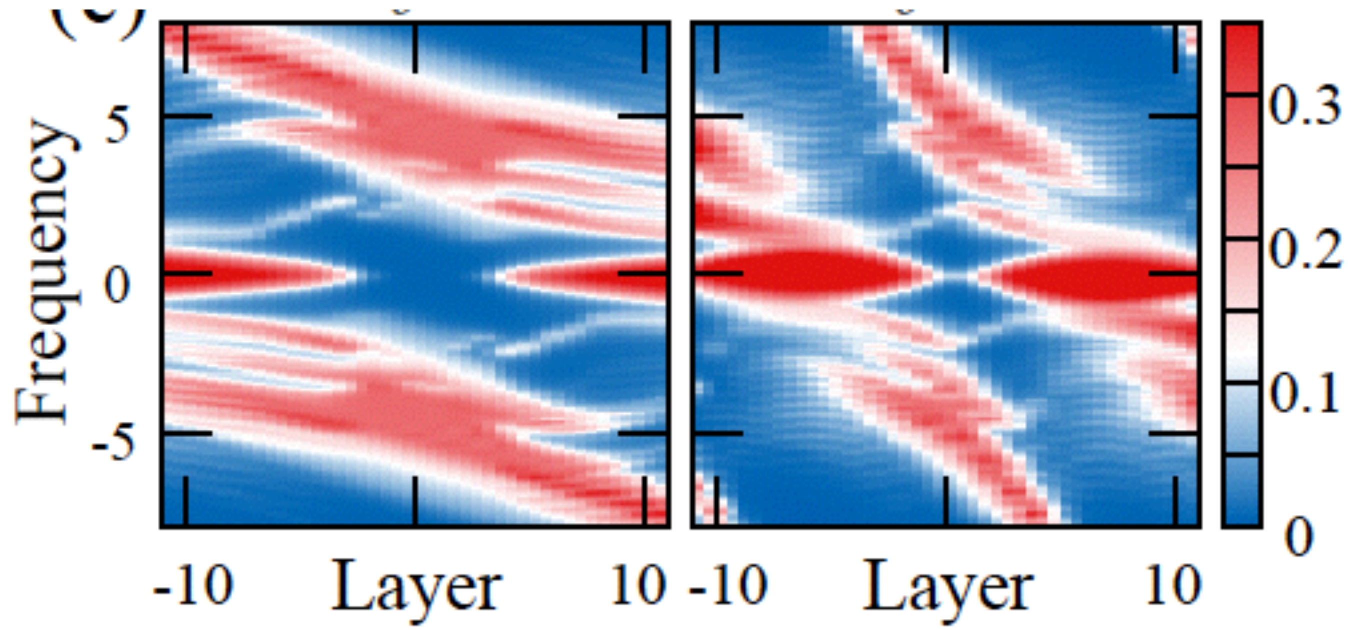
<u>Different mechanisms in and out the metal/insulator coexistence region</u>

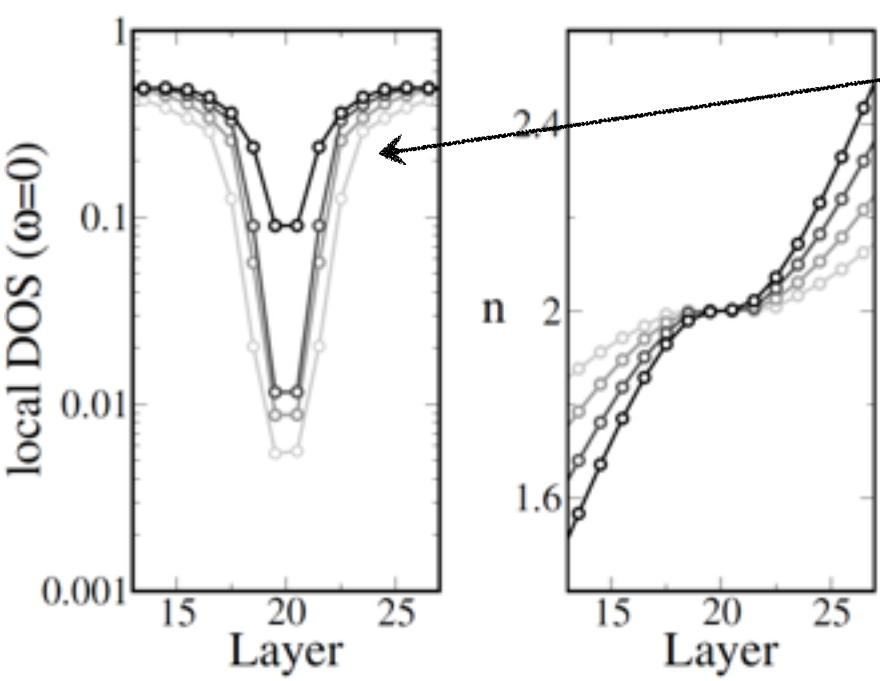
Field-induced insulator-to-metal transition

$$U \gg U_c$$

increasing Electric Field

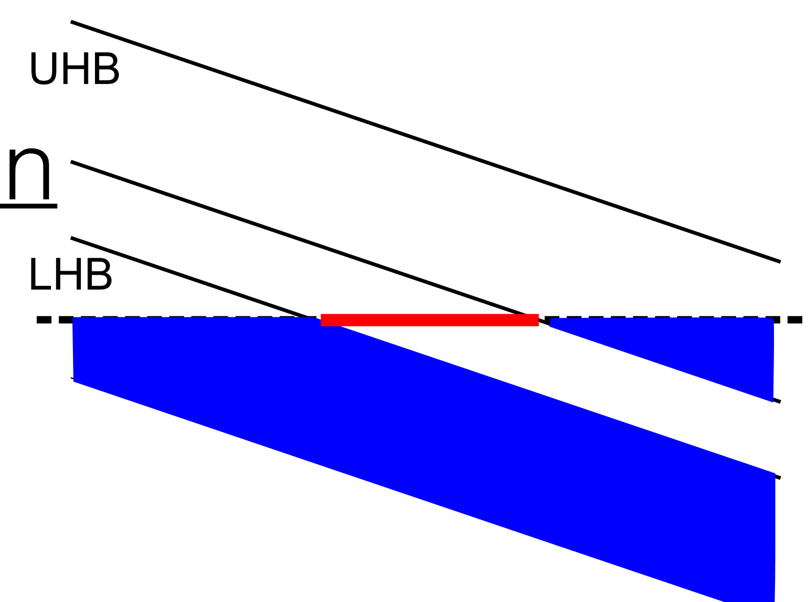
Rigid tilt of the insulating gap





<u>inhomogeneous metal</u>

<u>charge redistribution</u>



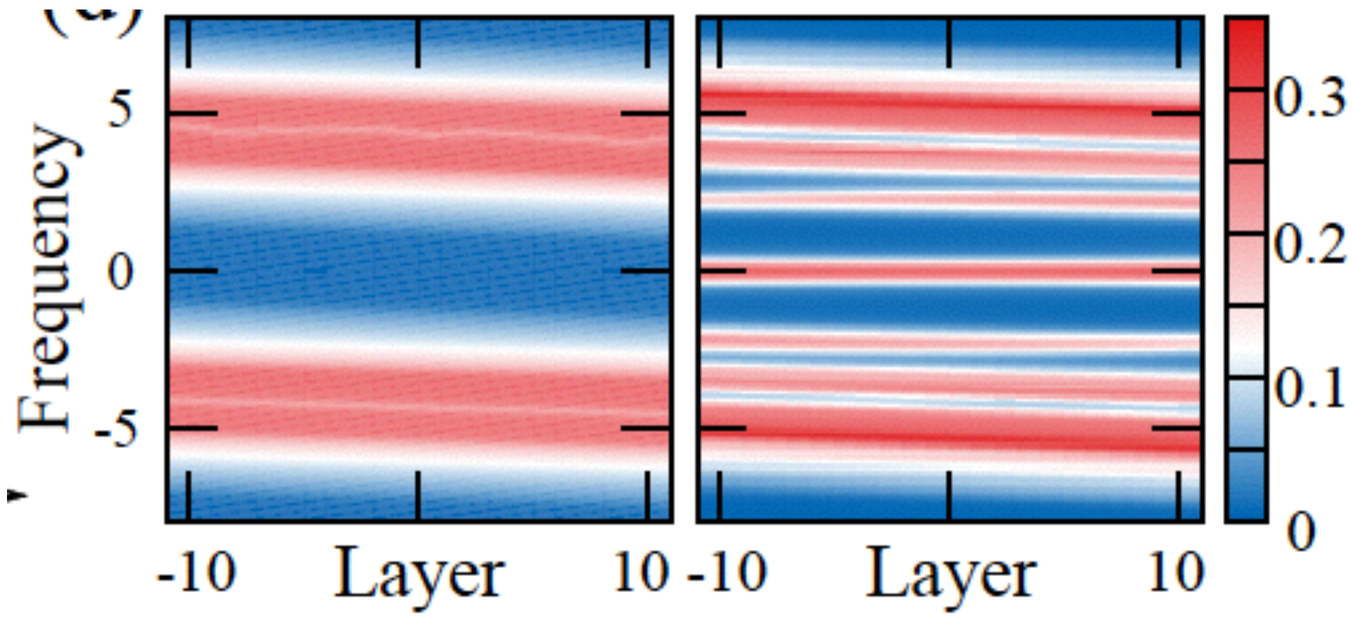
“equilibrium” formation of tunnel-like conductive channel

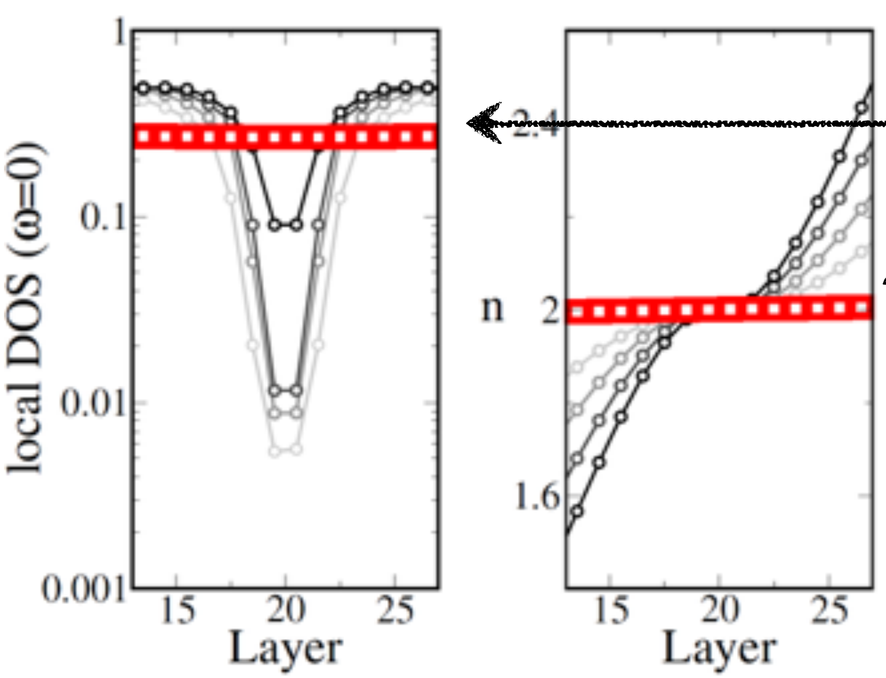
Field-induced insulator-to-metal transition

$$U \gtrsim U_c$$

increasing Electric Field

Abrupt closing of the gap

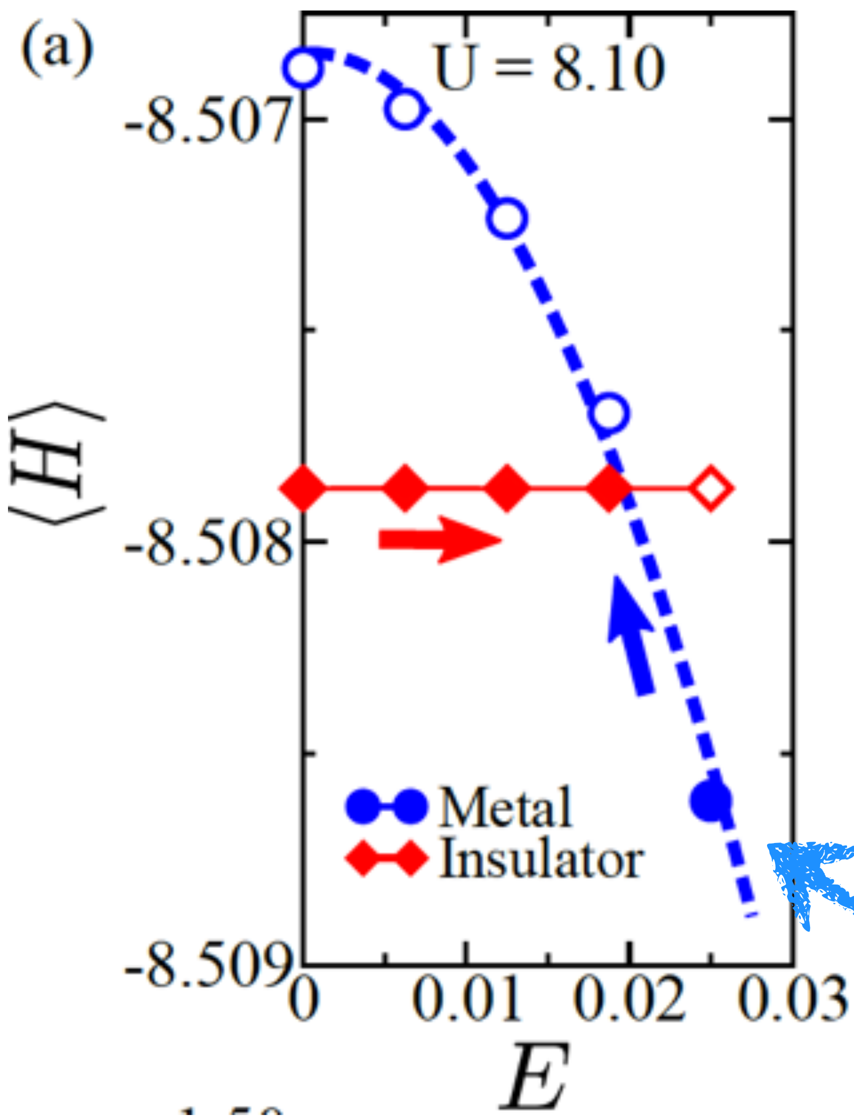




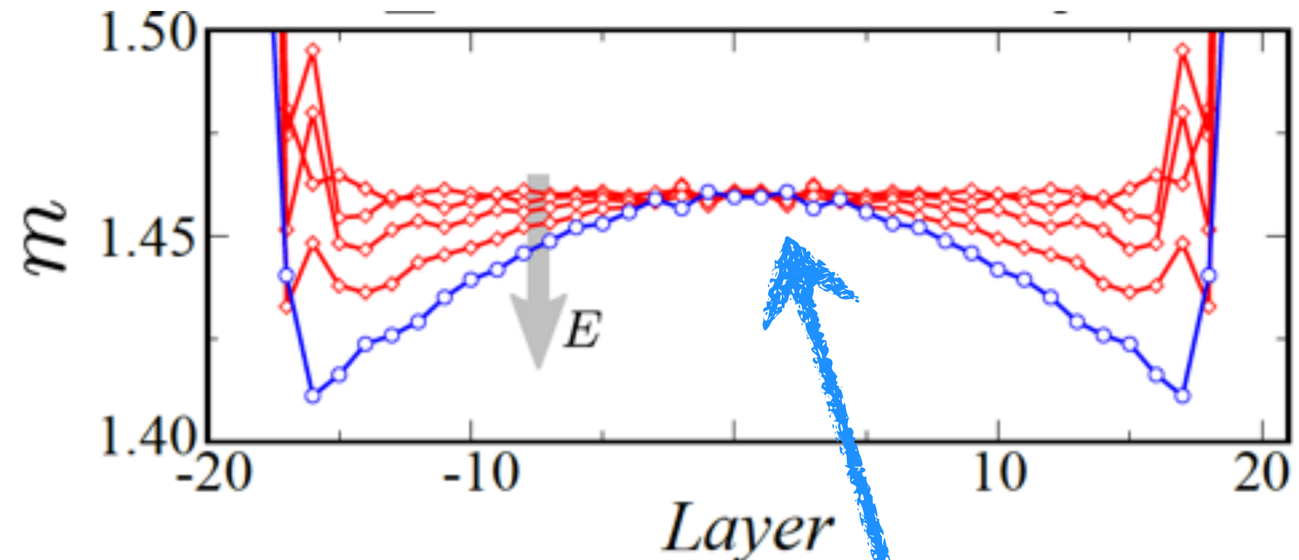
<u>Homogenous conductive states</u>

First-order insulator-to-metal transition!

INS–MET hysteresis loop VS electric field



Orbital polarisation VS field



The electric field <u>reduces the effect of the correlation</u>

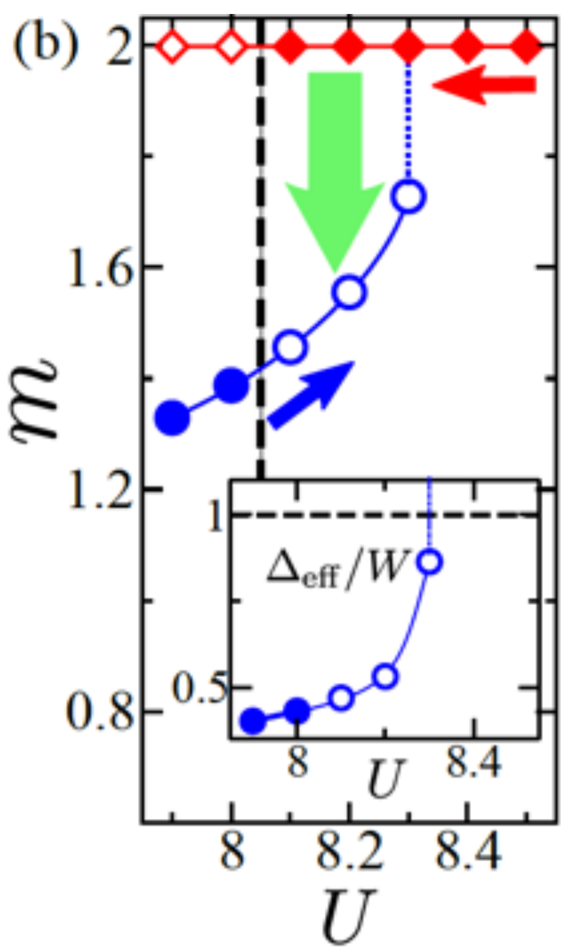
Energy gain within the <u>linear response regime</u>!

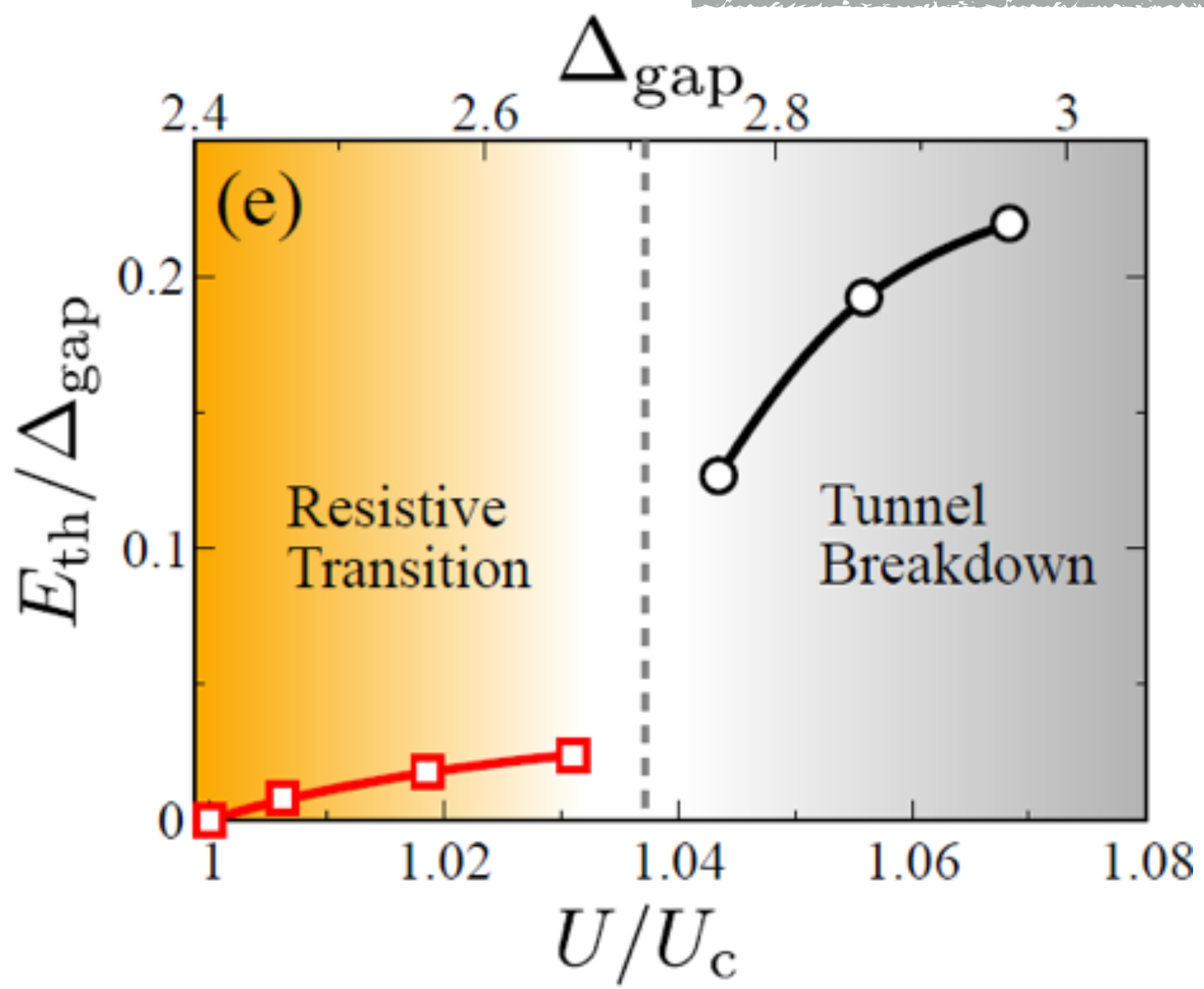
$$\delta\langle H\rangle \propto E^2$$

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

Different routes for the Mott insulator metallisation

Rigid modification of the insulator (only one stable phase)



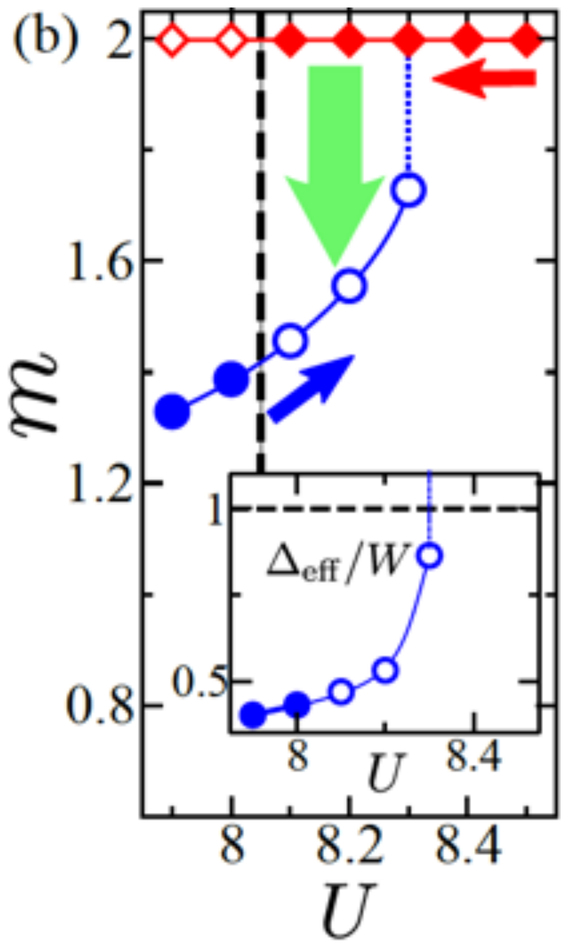


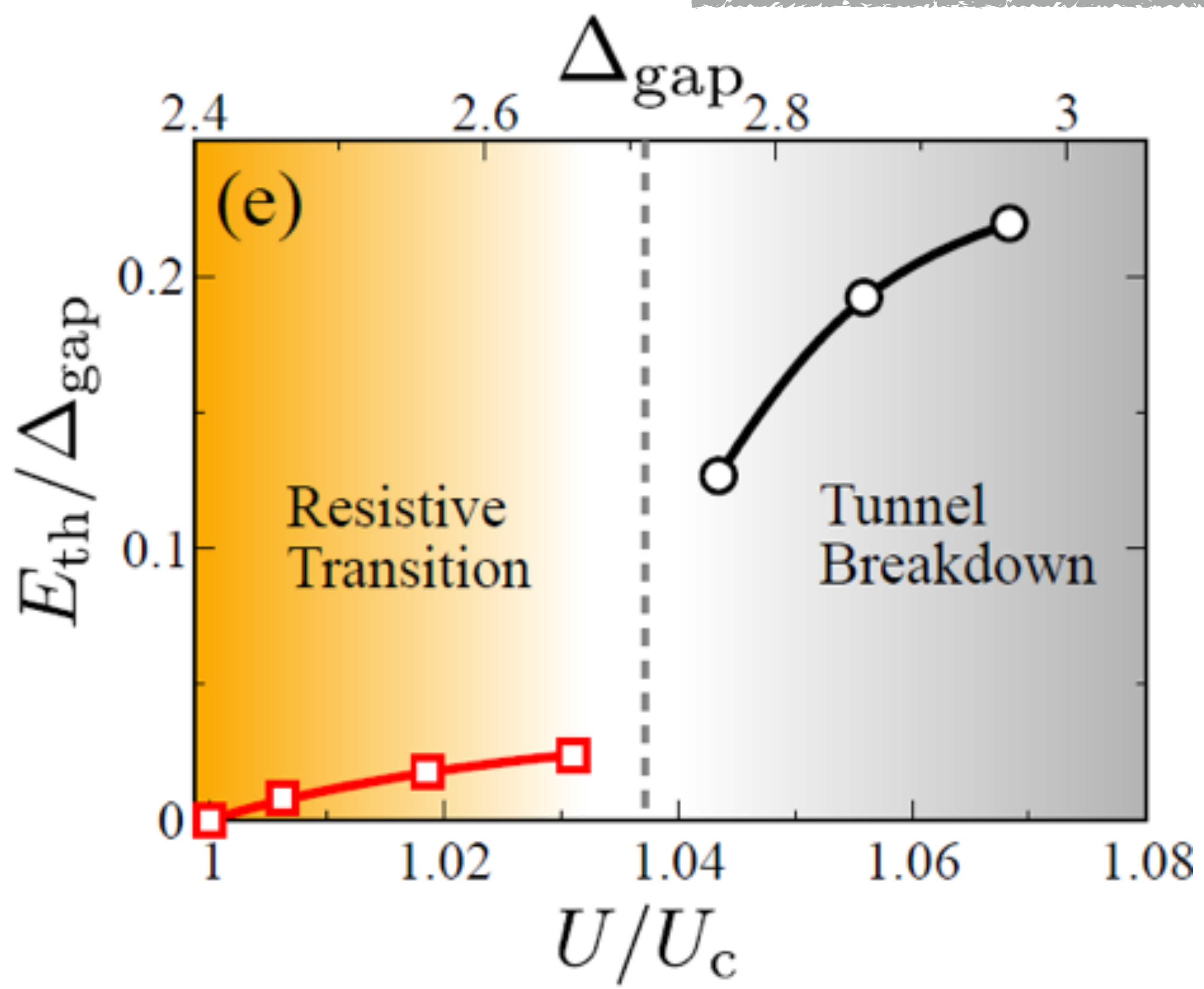
Switch between two competing phases

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!

Non-equilibrium description needed!