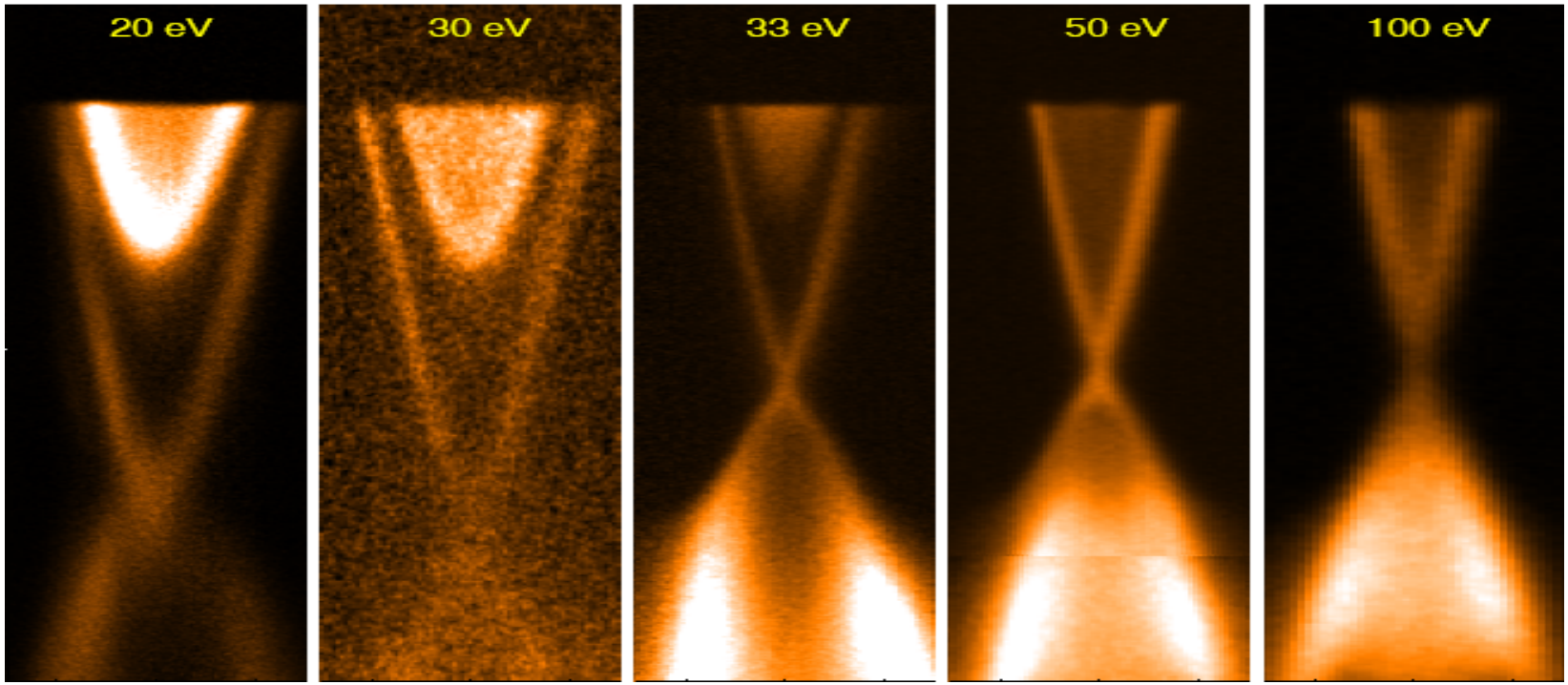
Photoemission induced gating of topological insulator



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Photoemission-induced gating of topological insulators

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The recently discovered topological insulators exhibit topologically protected metallic surface states which are interesting from the fundamental point of view and could be useful for various applications if an appropriate electronic gating can be realized. Our photoemission study of Cu-intercalated Bi_2Se_3 shows that the surface-state occupancy in this material can be tuned by changing the photon energy and understood as a photoemission-induced gating effect. Our finding provides an effective tool to investigate the new physics coming from the topological surface states and suggests intercalation as a recipe for synthesis of a material suitable for electronic applications.

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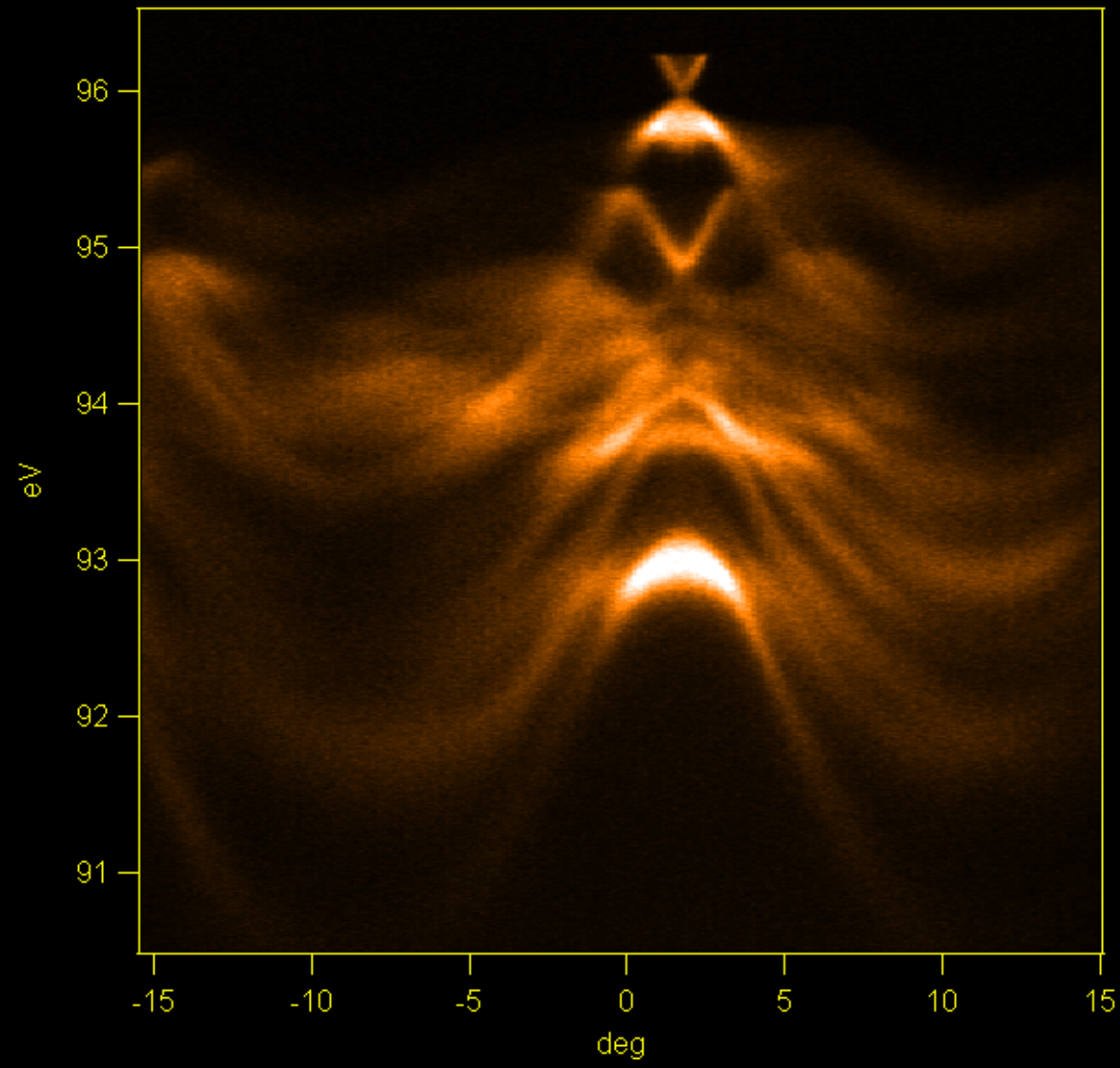
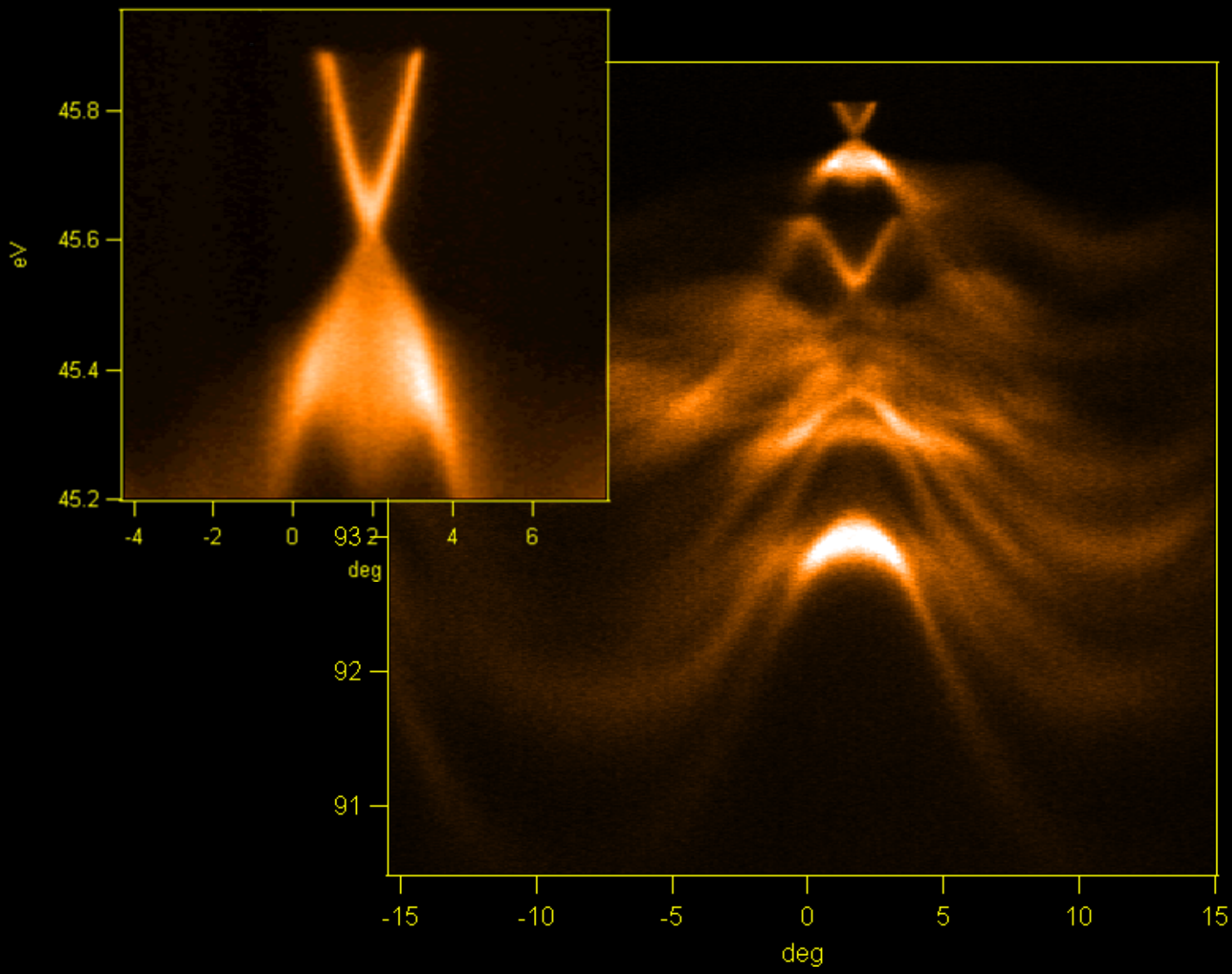
Plan

- ARPES of Bi_2Se_3
- Photoemission induced gating
- Model (simple explanation)
- Conclusions

Bi_2Se_3 as seen by ARPES



Bi_2Se_3 as seen by ARPES



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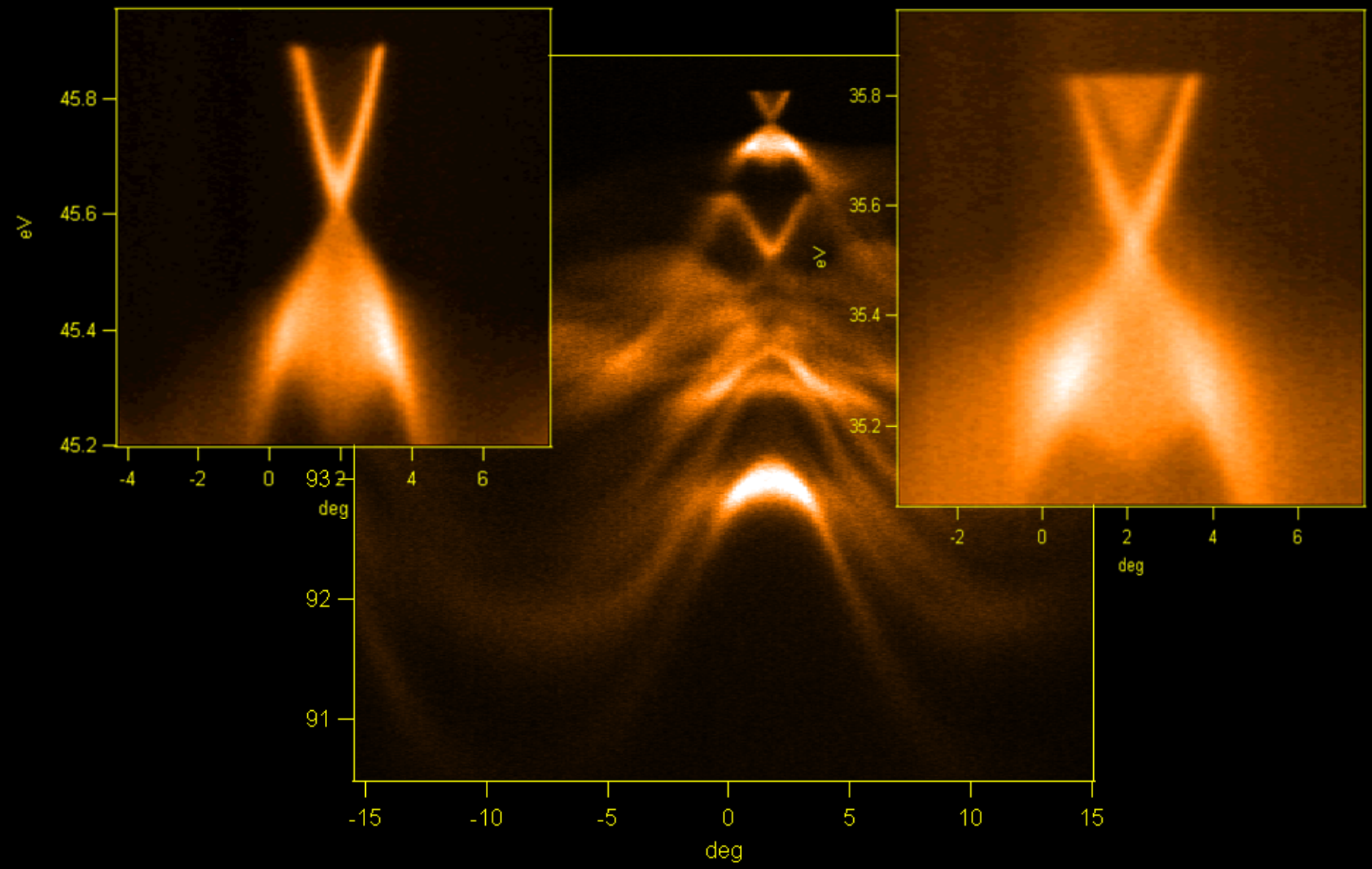
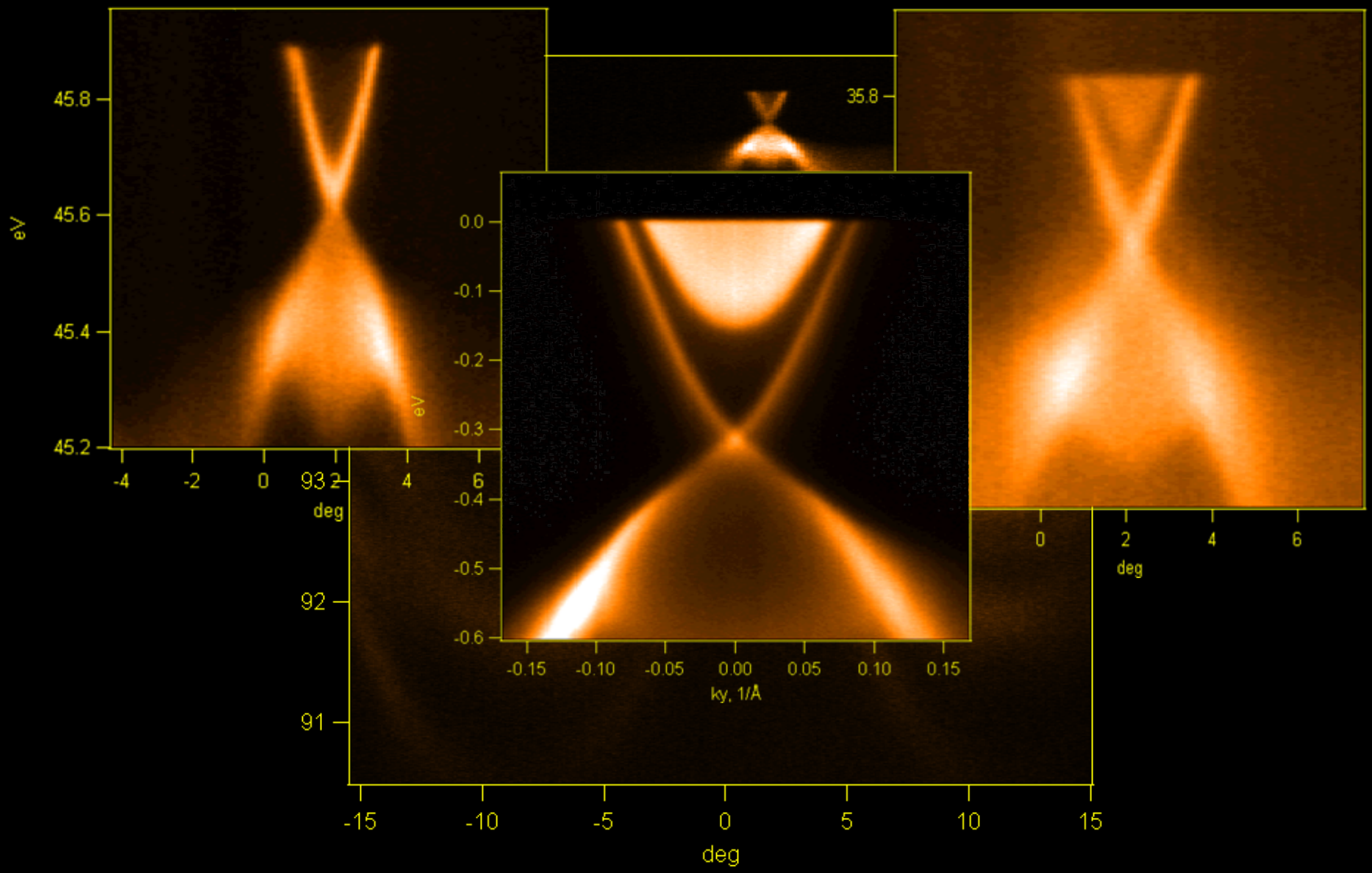


Bi_2Se_3 as seen by ARPES



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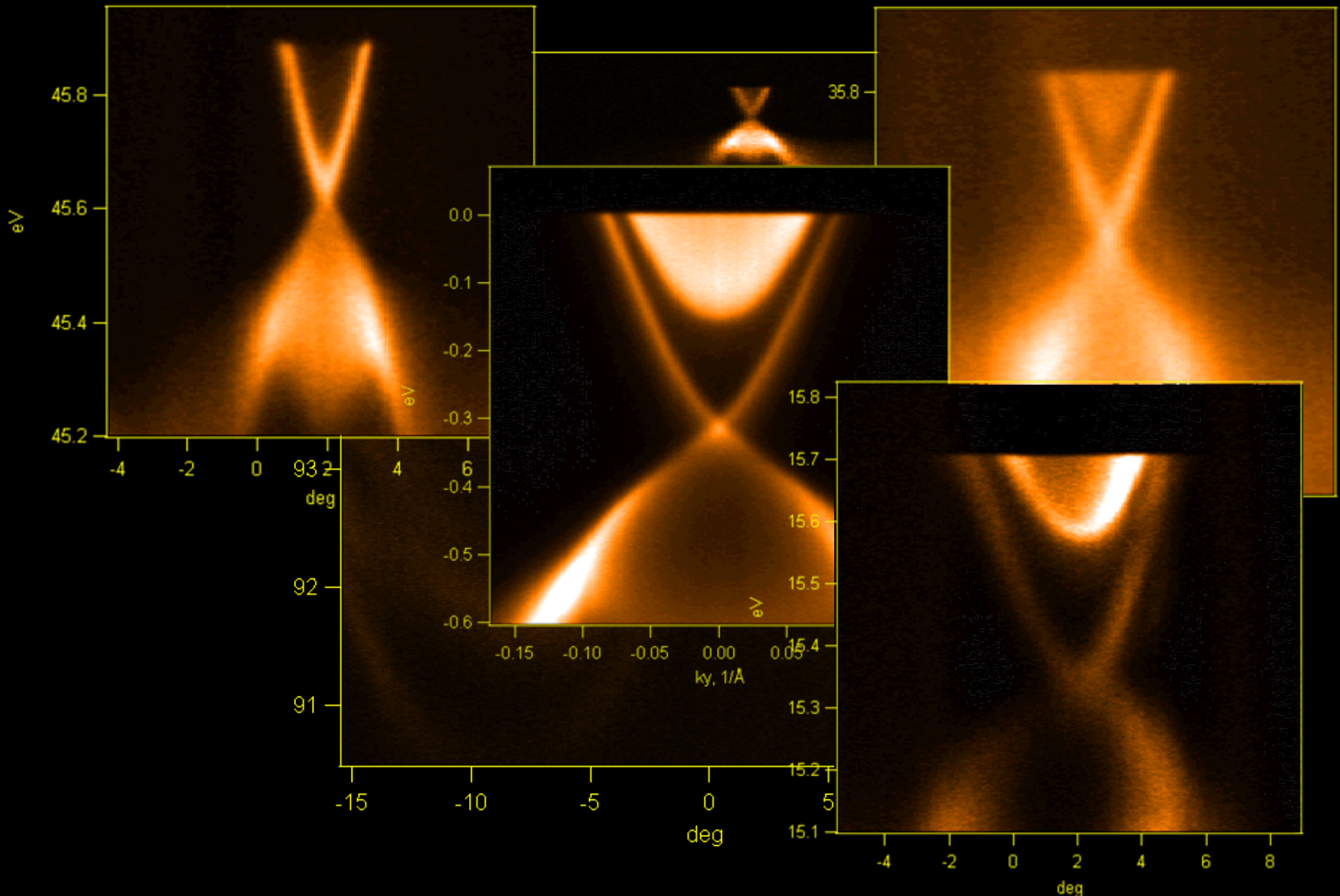

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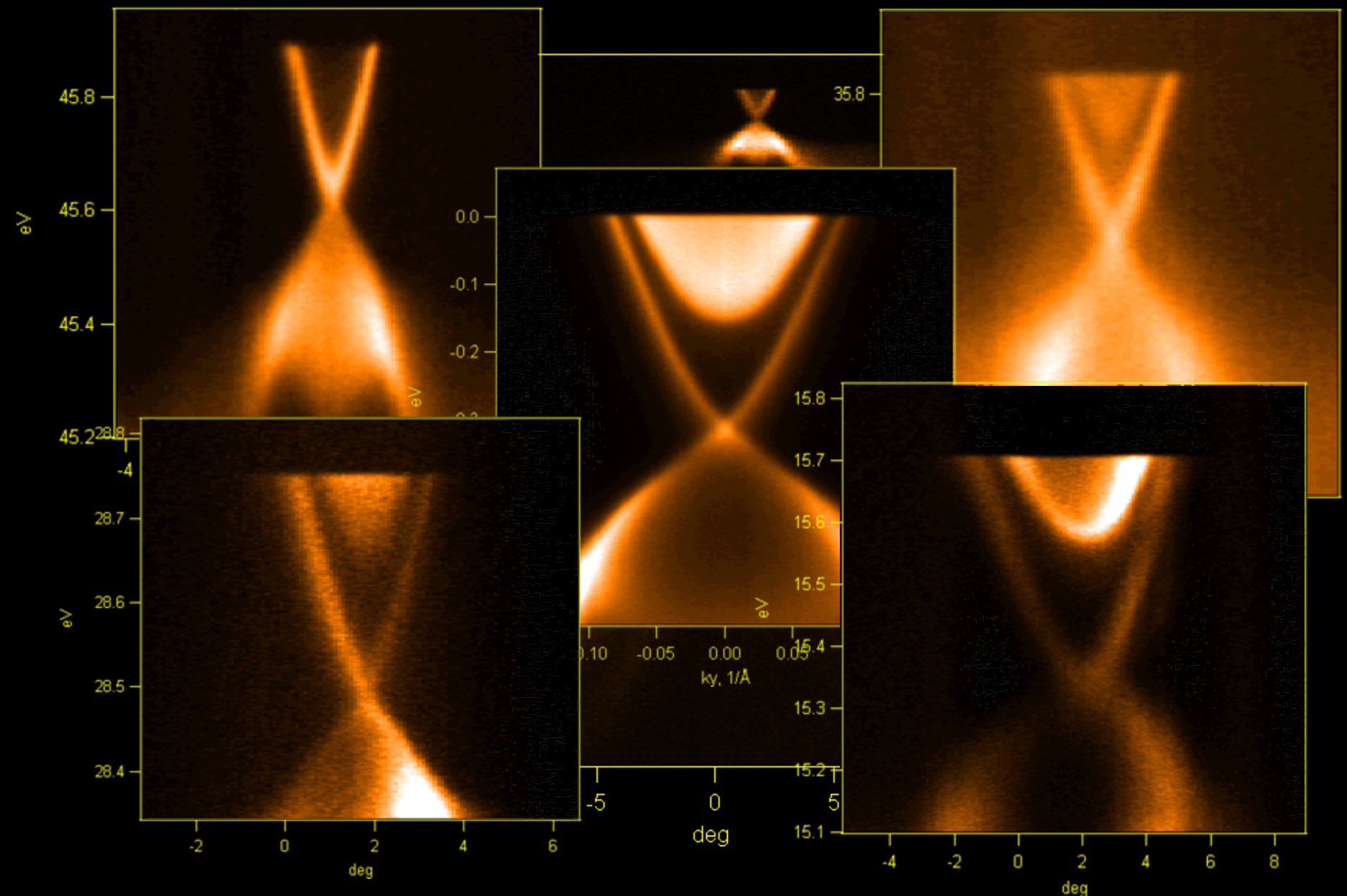

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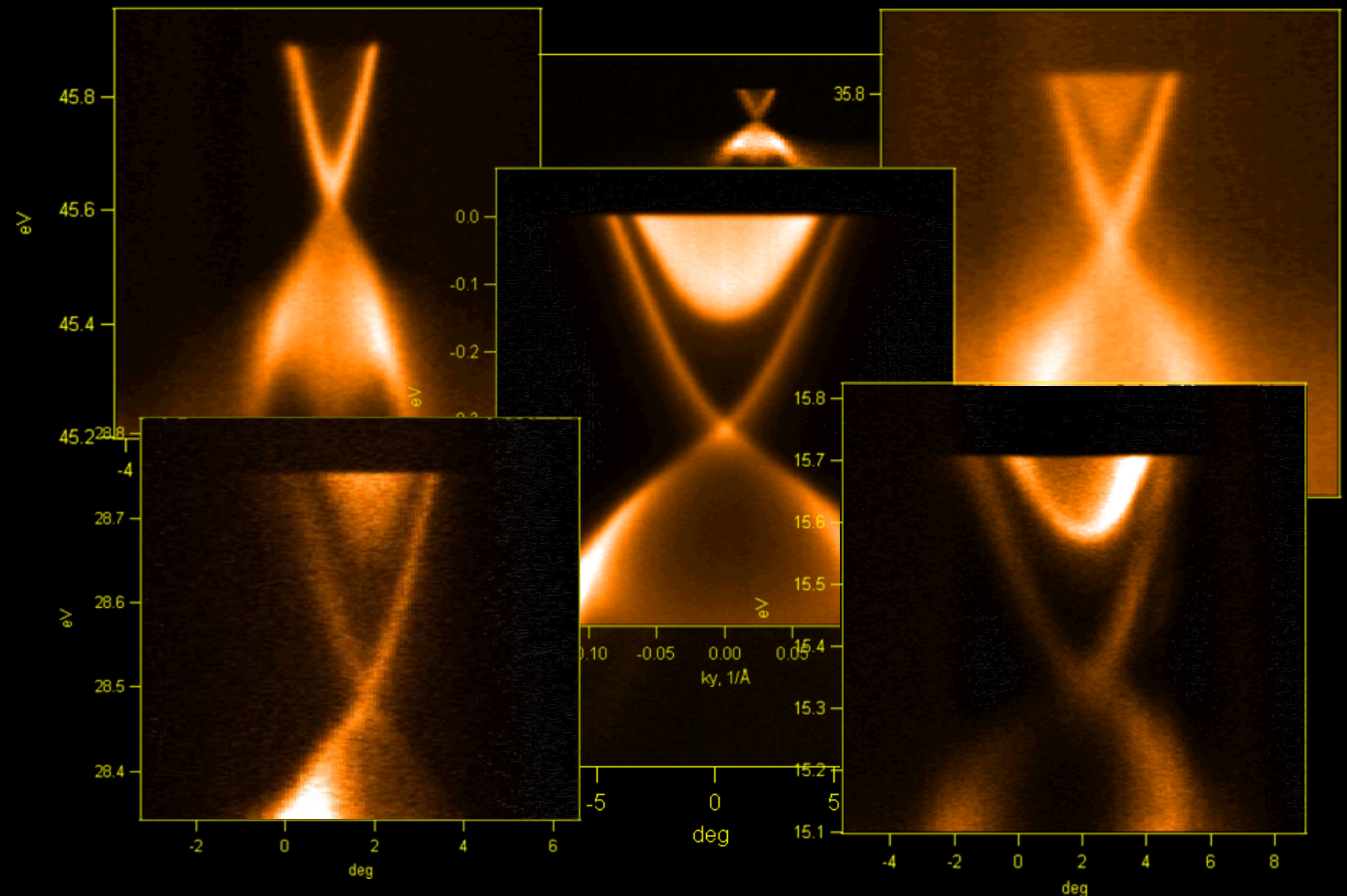

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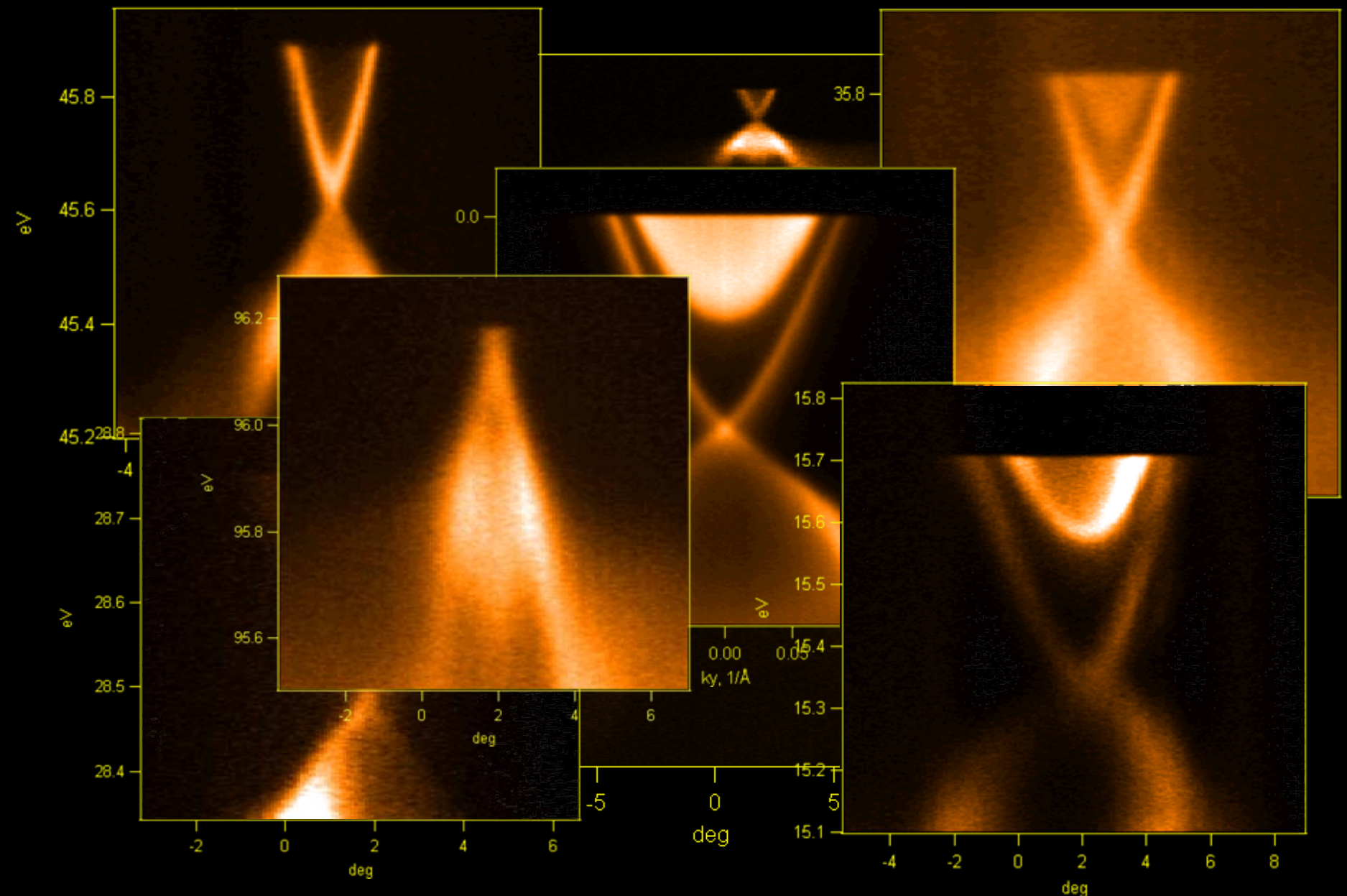
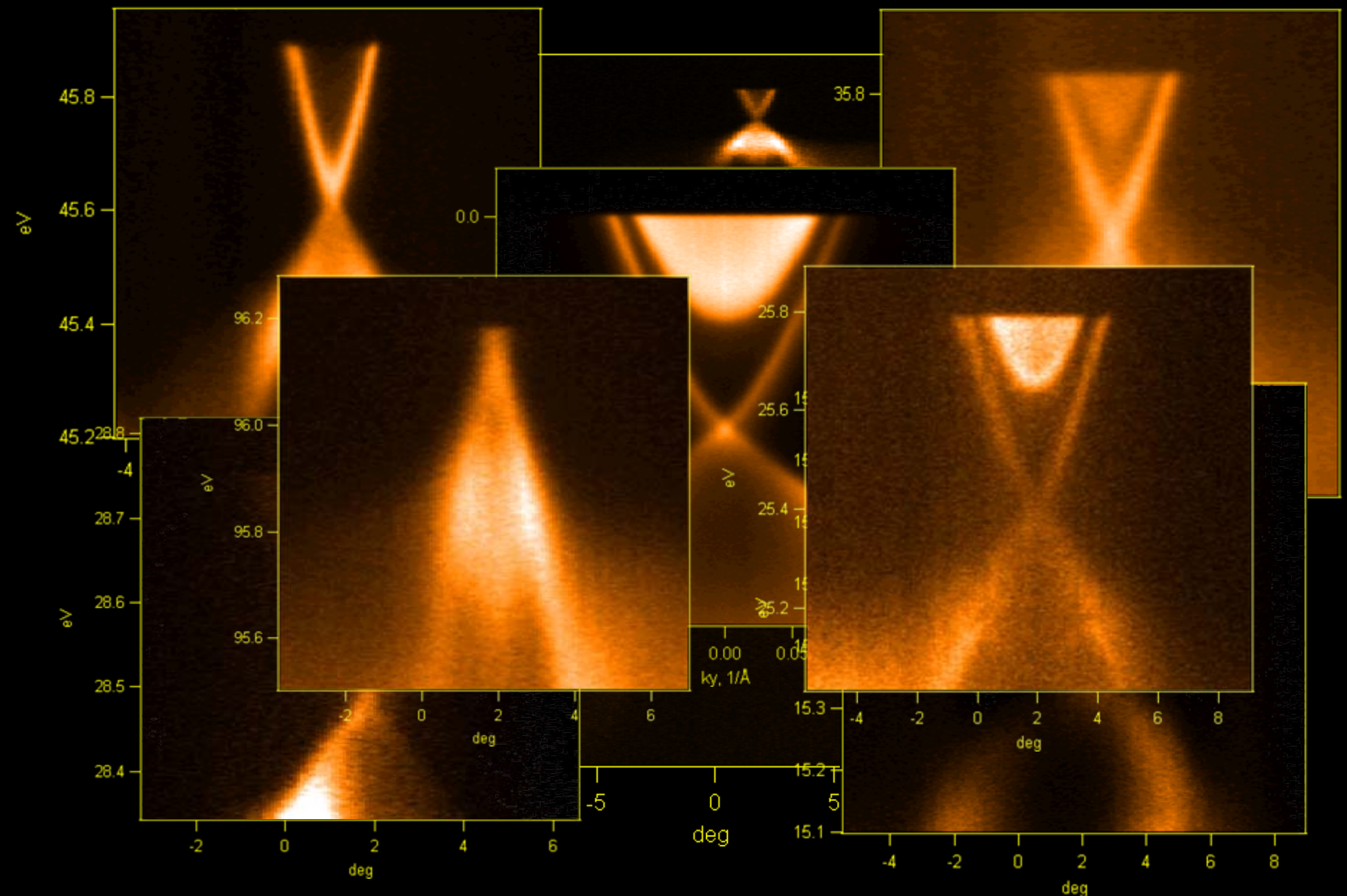
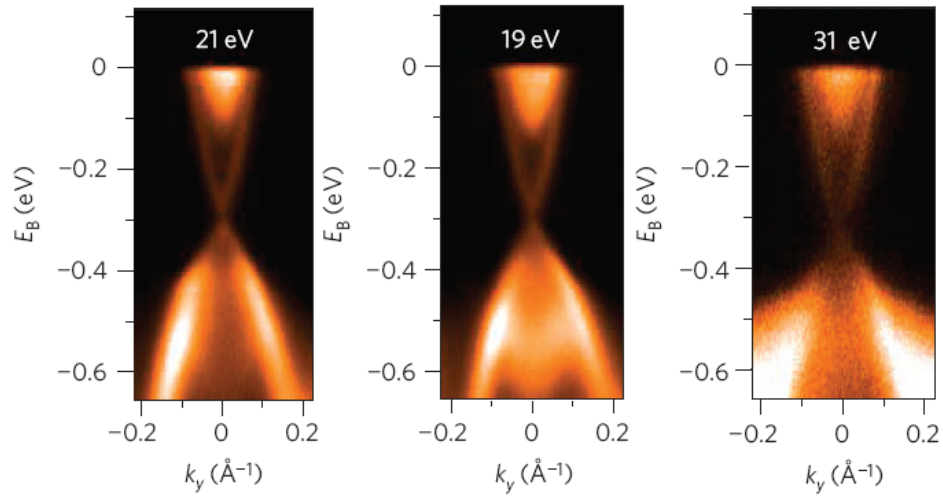
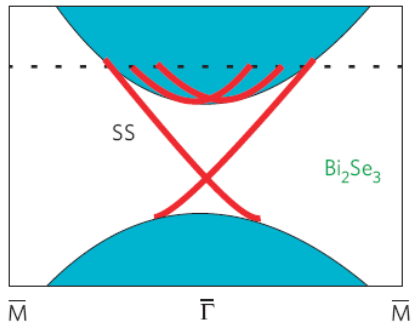


Bi_2Se_3 as seen by ARPES

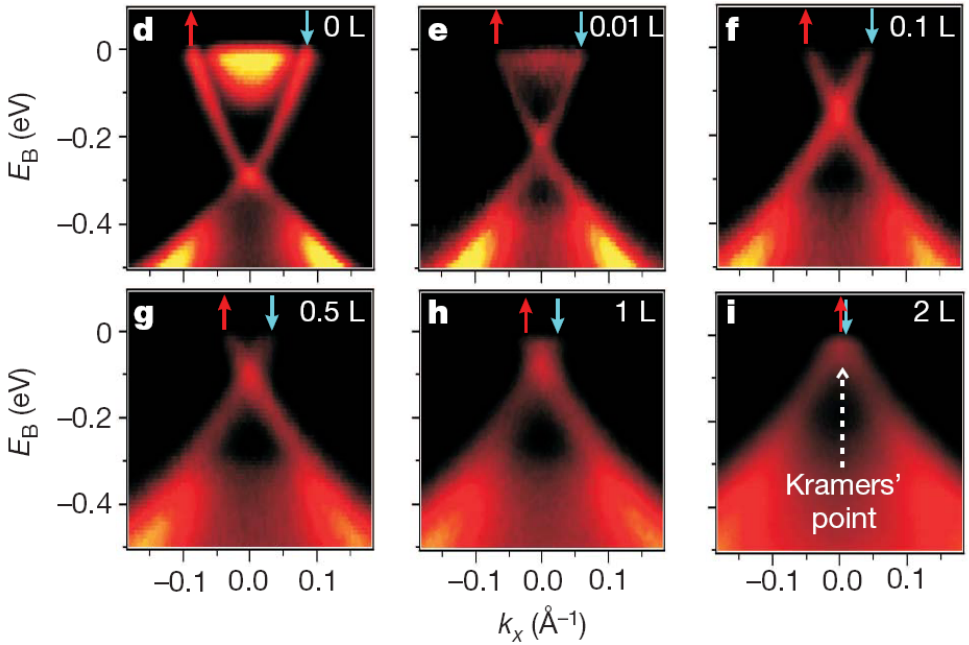


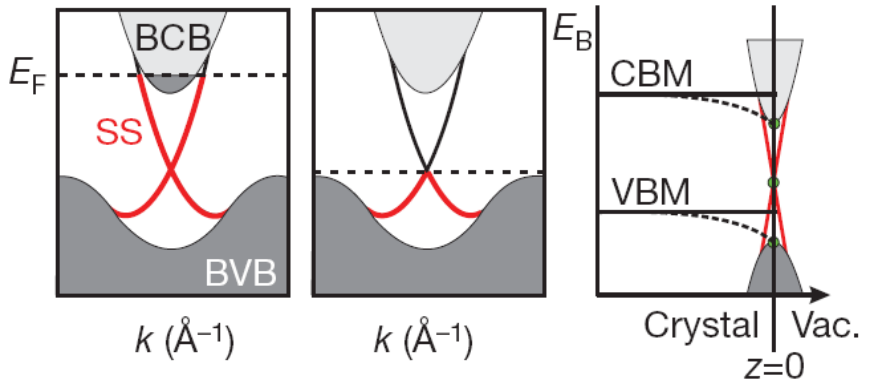
ARPES on Bi_2Se_3





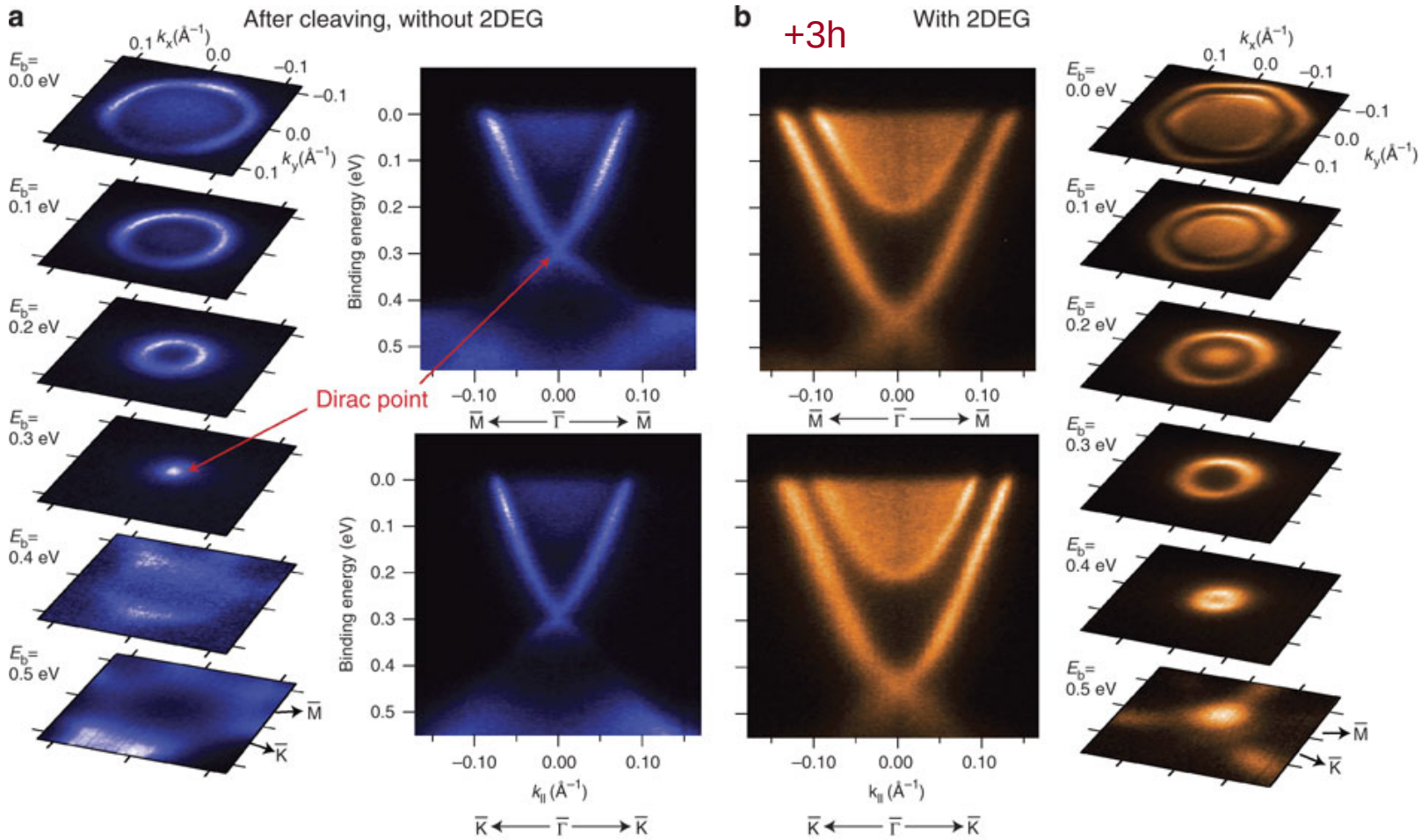
Xia *Nature Physics* 2009





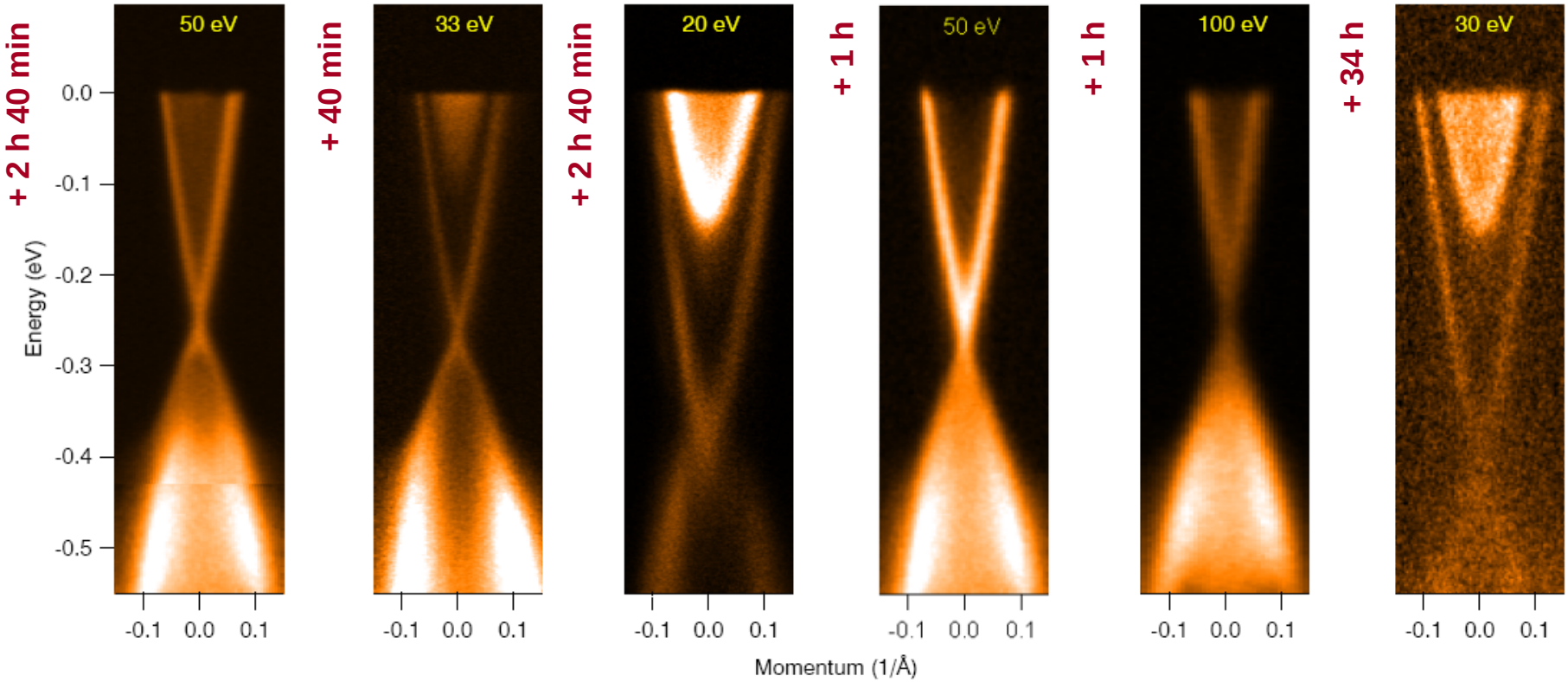
Hsieh *Nature* 2009

ARPES on Bi_2Se_3



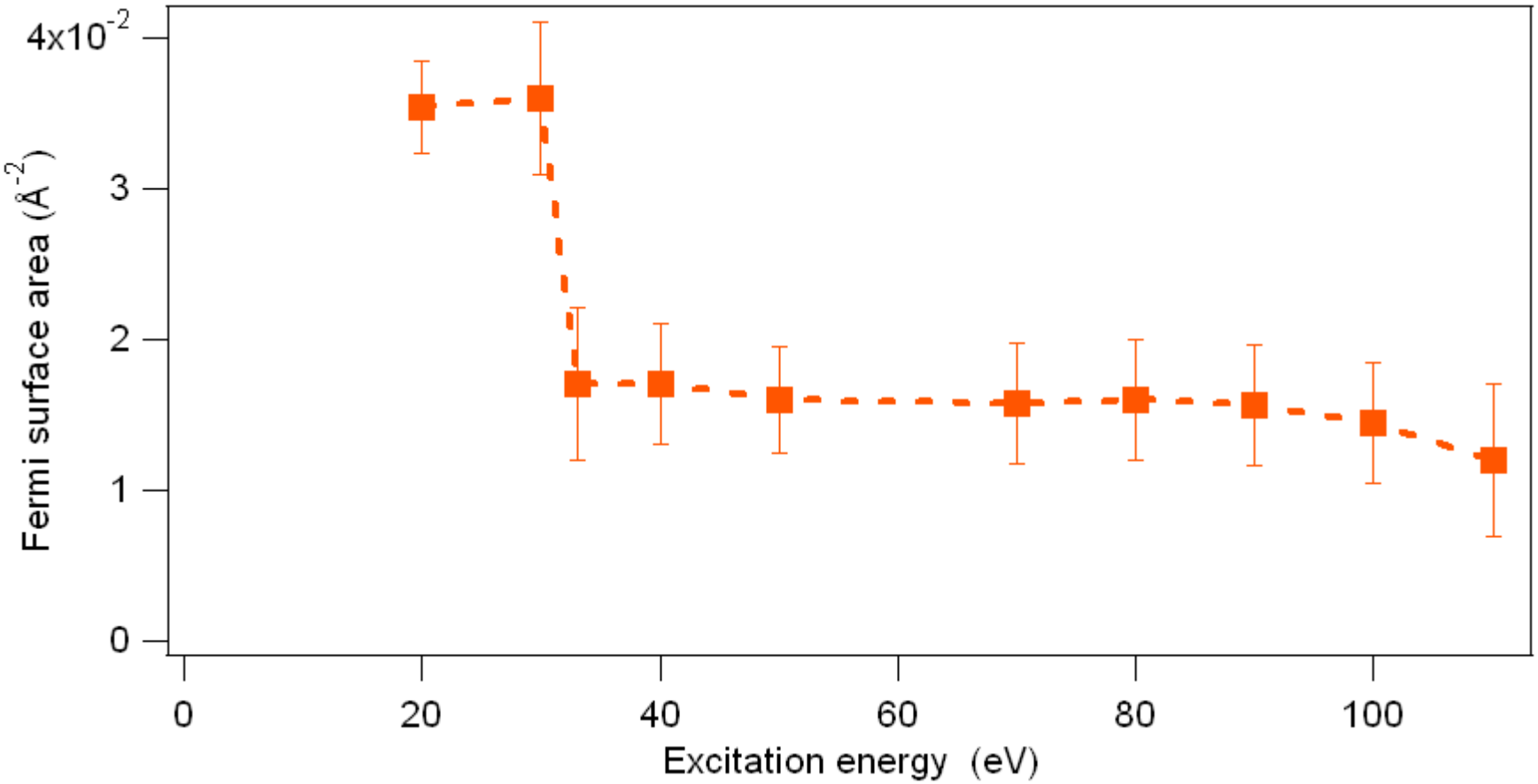
Bianchi *Nature Commun.* 2010

$Cu_xBi_2Se_3$



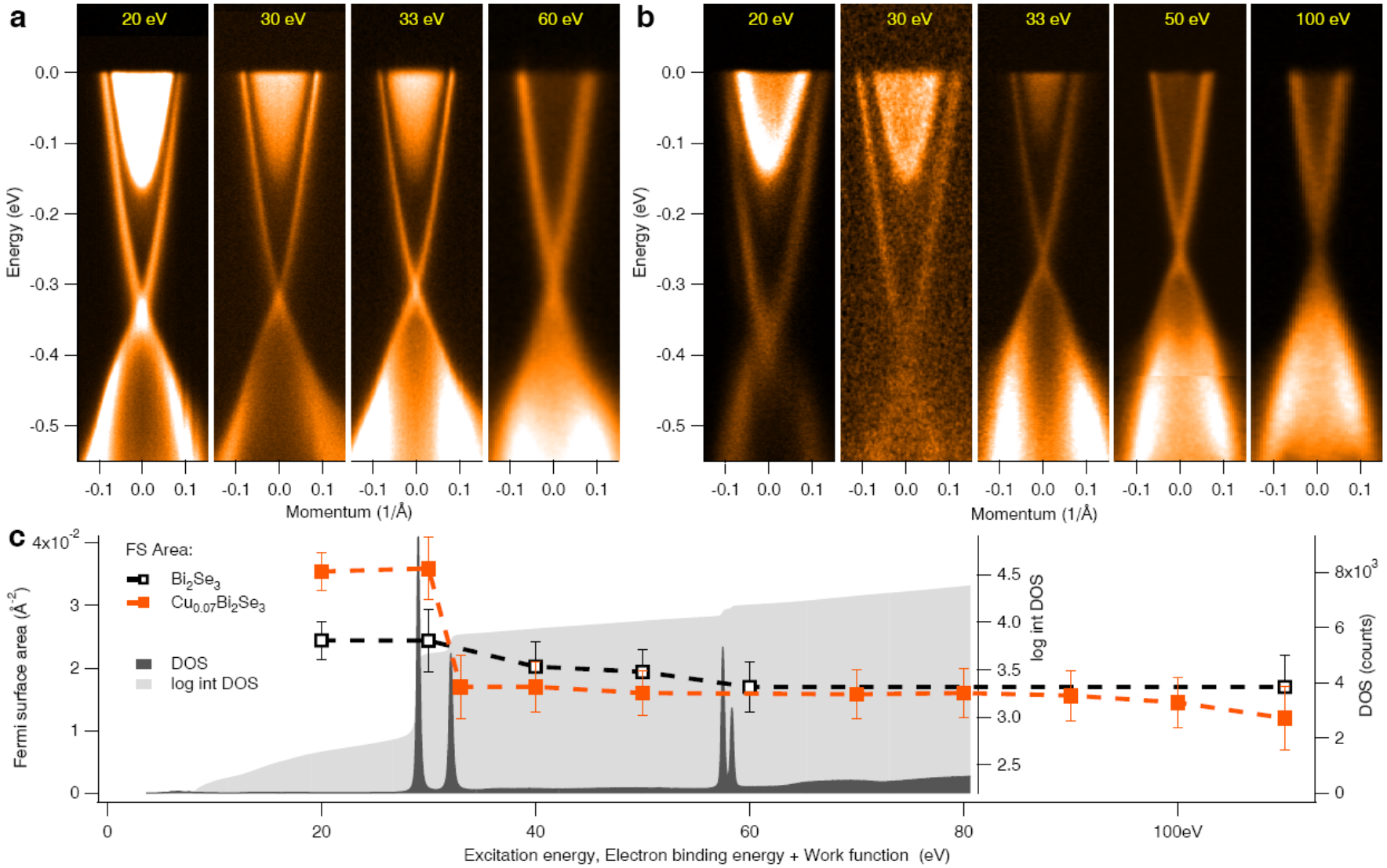
Kordyuk *PRB* 2011

$Cu_xBi_2Se_3$



Kordyuk *PRB* 2011

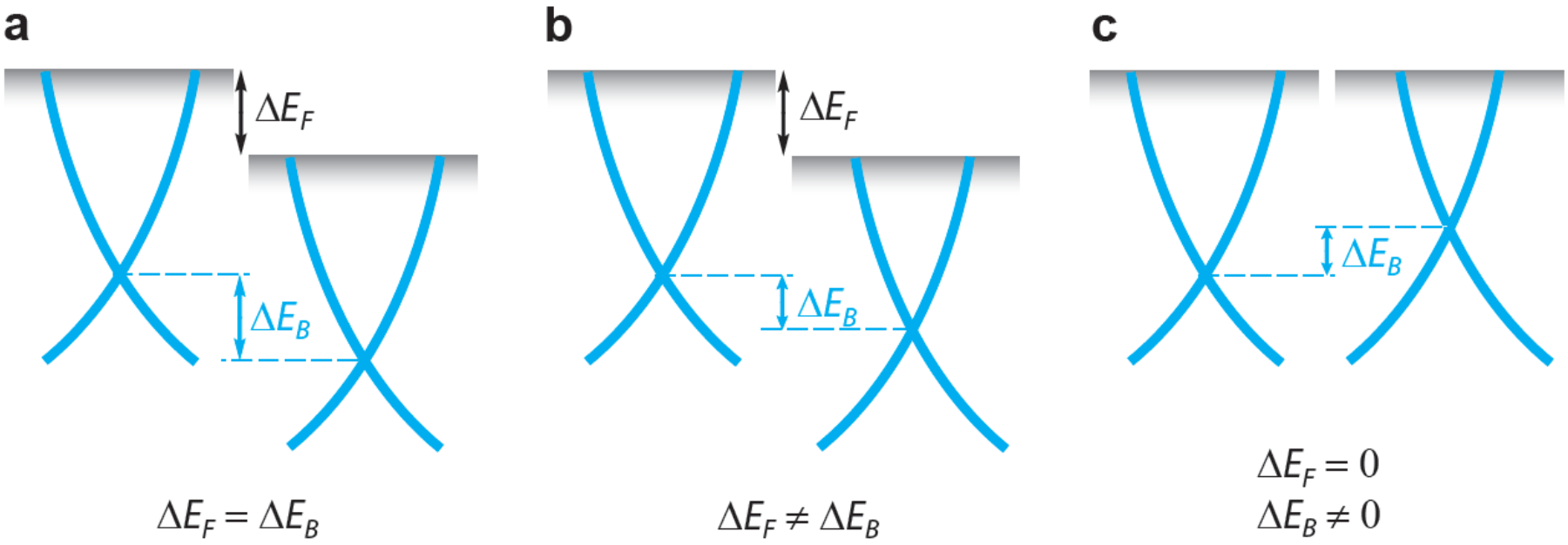
Bi_2Se_3 $Cu_xBi_2Se_3$



$5d_{5/2}$ and $5d_{3/2}$

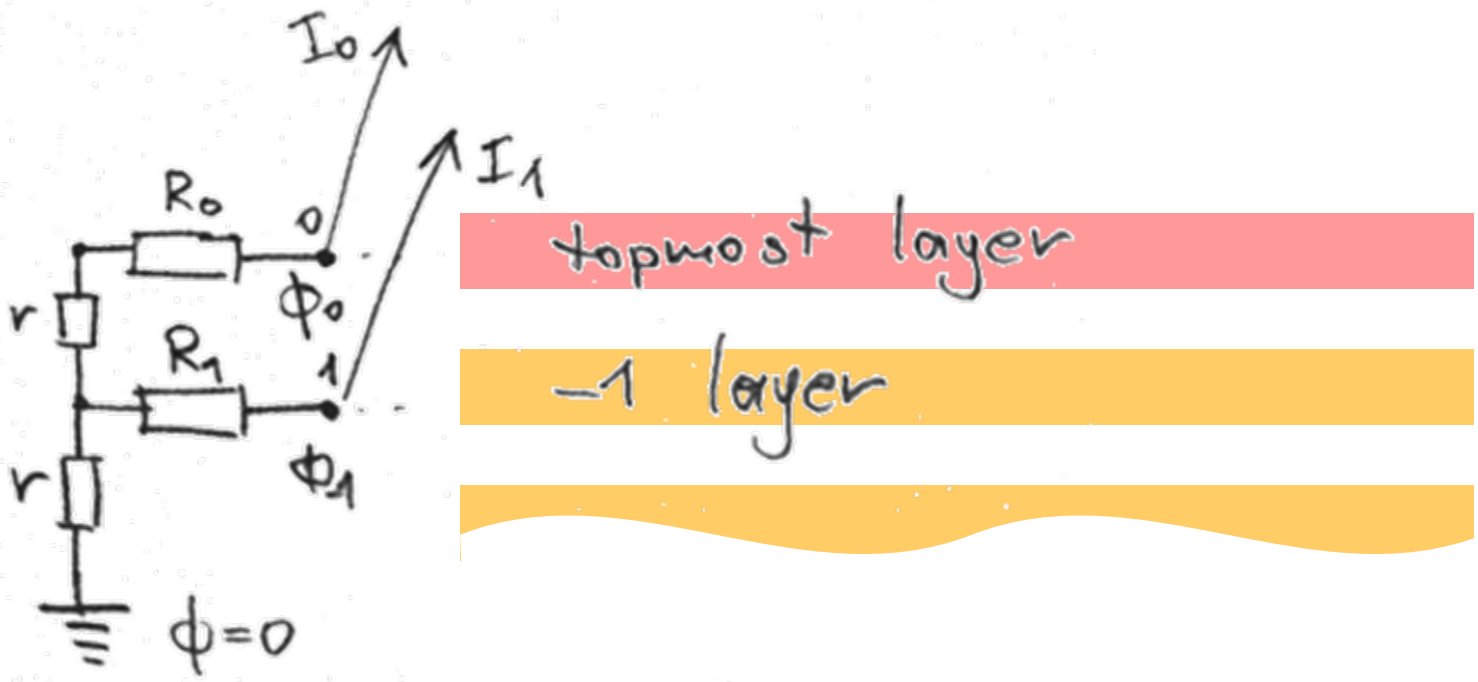
Kordyuk *PRB* 2011

Gating *vs* Charging



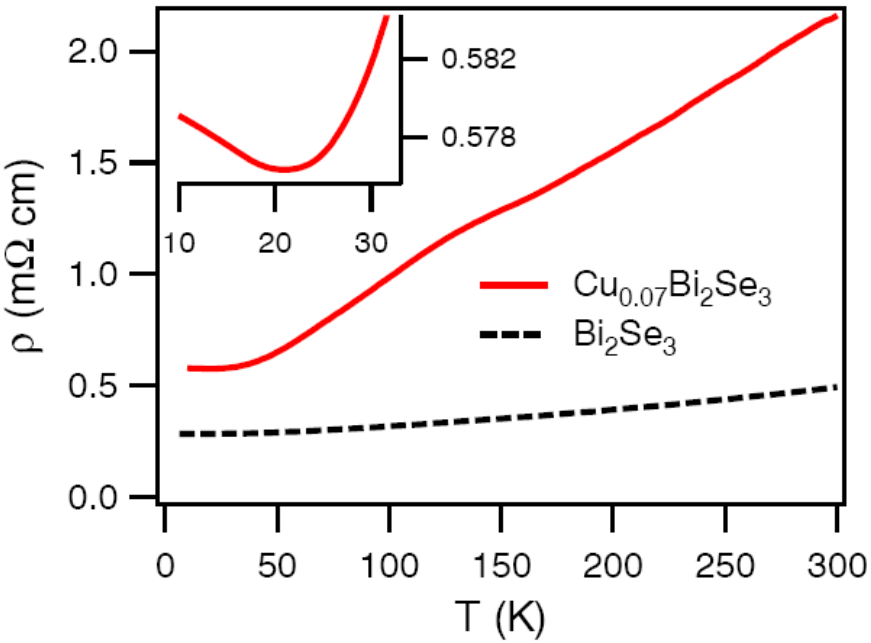
(a) "Charging" of the whole sample due to absence of a good Ohmic contact between the surface of the sample and an electron analyser appears as a shift, ΔE_F, of the Fermi level, E_F, of the sample under illumination in respect to its equilibrium position or to the E_F of the analyser.
(b) The most general case: the light induced photovoltage does both affect the surface charge region and create the charge of the sample.
(c) "Gating": in case of a highly conductive surface (and poorly conductive or insulating sample volume), its Fermi level remains equal to E_F of the analyser and the only observed photovoltage effect is the surface states gating.

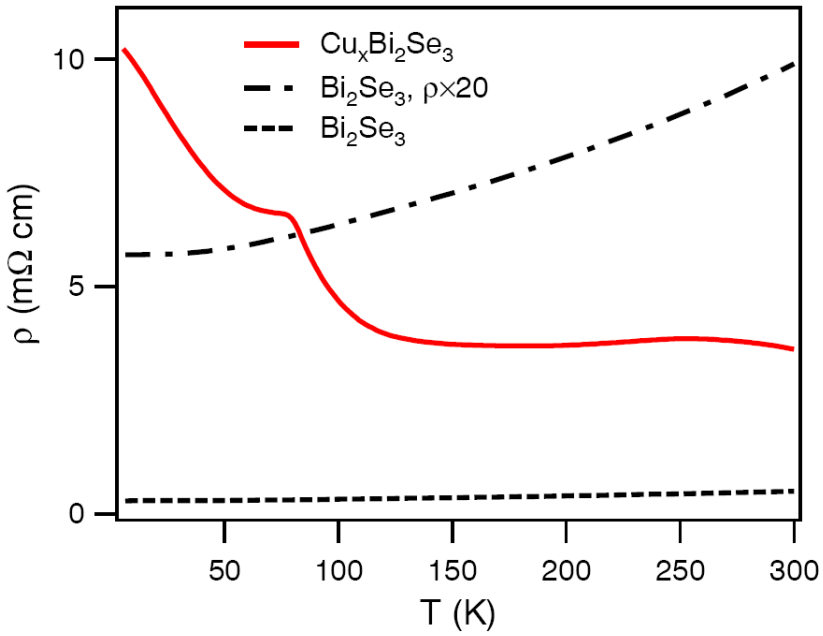
instead of a model



$R_1 >> R_0, r$

$Cu_xBi_2Se_3$





ρ_c = 7–38 Ω cm at 10 K

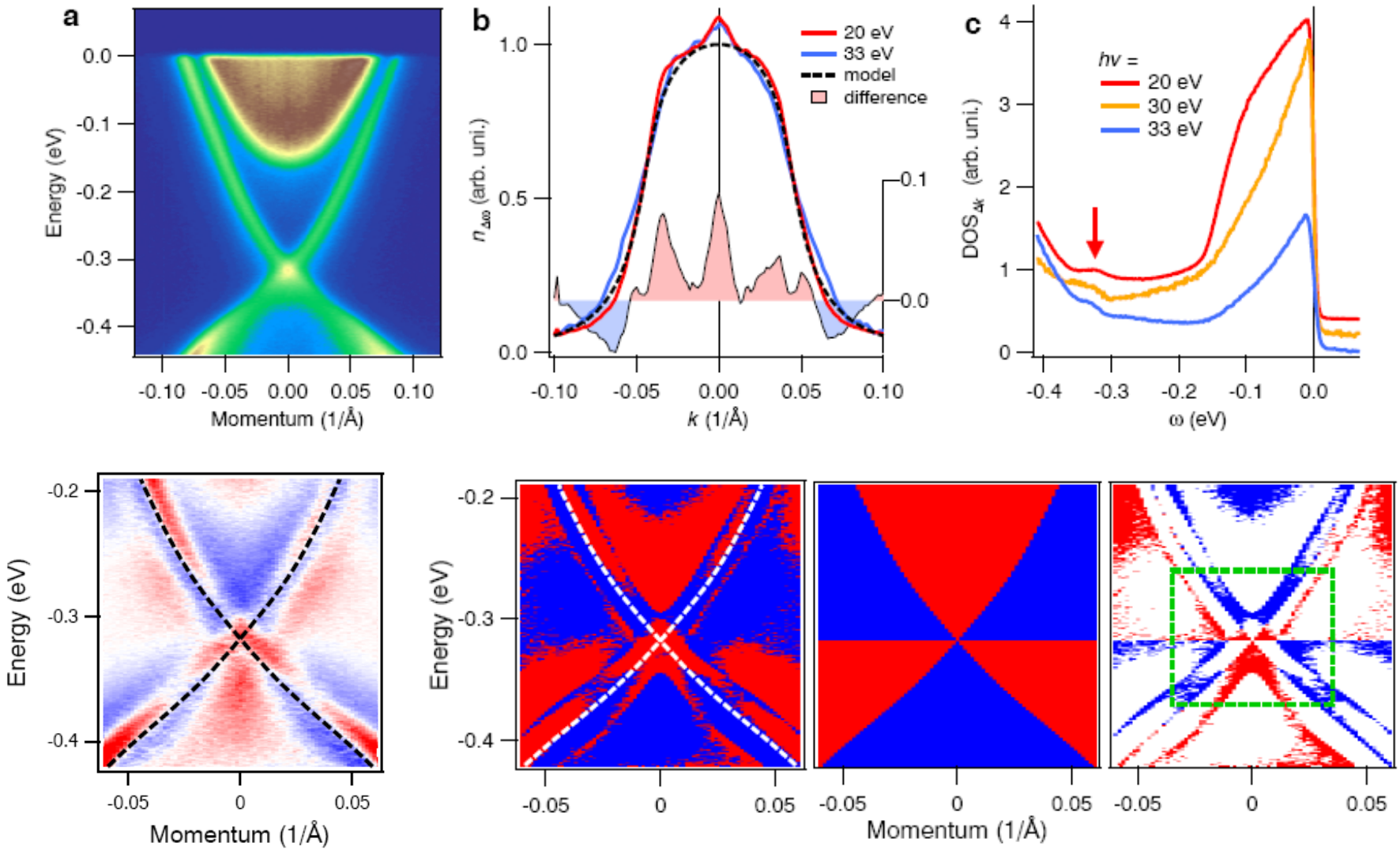
10–18 mΩ cm at 300 K

Bauch, Hess 2010

Conclusions

- We observe the effect of photoemission induced gating of the topological surface states on $Cu_xBi_2Se_3$ that may stimulate the use of the topological insulators in electronics.
- The observed enhancement of the effect by Cu intercalation shows the way to control it from the material side.
- While the peculiarities caused by the presence of the topologically protected surface states have to be understood, the very fact that the photovoltage effect has been observed directly for the compound in which the surface states dispersion can be measured in details and controlled opens opportunity to study the microscopic mechanisms of the surface photovoltage effects on semiconducting surfaces and interfaces.
- Detailed dependences of the effect on temperature, doping, and flux intencity are needed to make a model.

Future work


a
Energy (eV)
0.0
-0.1
-0.2
-0.3
-0.4
-0.10 -0.05 0.00 0.05 0.10
Momentum (1/Å)
b
$n_{\Delta\omega}$ (arb. uni.)
1.0
0.5
0.0
0.1
0.0
20 eV
33 eV
model
difference
-0.10 -0.05 0.00 0.05 0.10
k (1/Å)
c
$DOS_{\Delta k}$ (arb. uni.)
4
3
2
1
0
hv =
20 eV
30 eV
33 eV
-0.4 -0.3 -0.2 -0.1 0.0
ω (eV)
Energy (eV)
-0.2
-0.3
-0.4
-0.05 0 0.05
Momentum (1/Å)
Energy (eV)
-0.2
-0.3
-0.4
-0.05 0 0.05
-0.05 0 0.05
-0.05 0 0.05
Momentum (1/Å)