

FNSNF



UNIVERSITÉ
DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique
de la matière condensée

Condensed Matter Physics Experiments Relevant to Accelerator Development

Daniel Mazur
Université de Genève



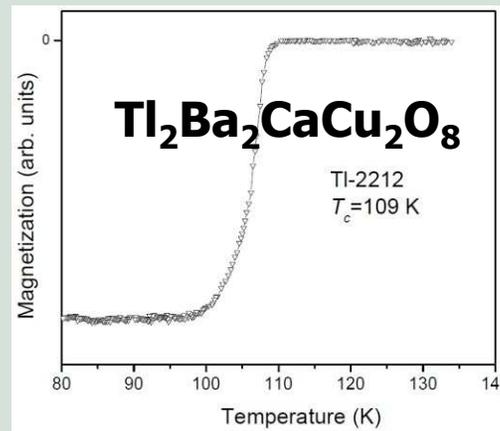
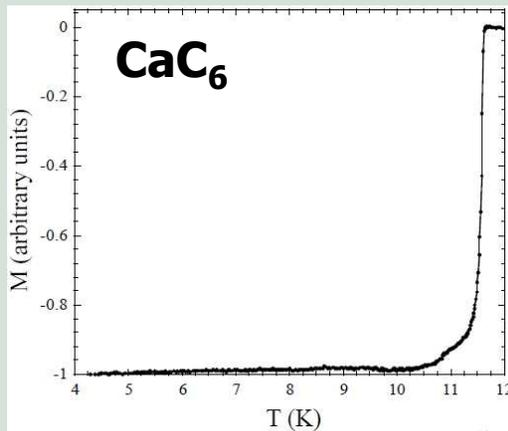
Synopsis

An Overview:

- Superconductivity ...
measurements of CaC_6 and High- T_C cuprate Tl-2212 at Argonne Nat'l Lab
- Nanostructures ...
fabrication of templates for metal atomic chains on Silicon (001) surface at the University of Geneva, Switzerland
- Photoemission spectroscopy ...
puzzling surface state of the bi-layered lanthanum-strontium manganite at the Advanced Photon Source at ANL
- Thin films and auxiliary techniques ...
overview of surface modification and analytic techniques employed
- Building a laboratory from scratch ...
new group at the University of Geneva, Switzerland

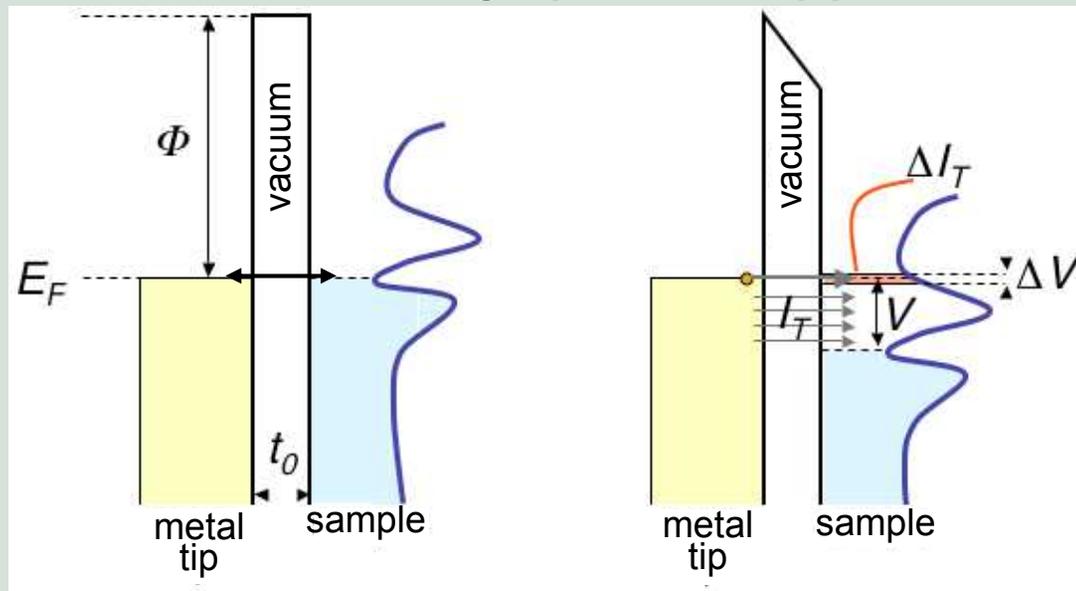
Superconductivity

Emerging Materials Group at ANL: Superconductors



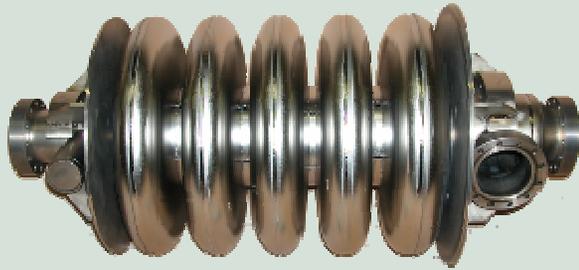
... and
 $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$

Tunneling spectroscopy

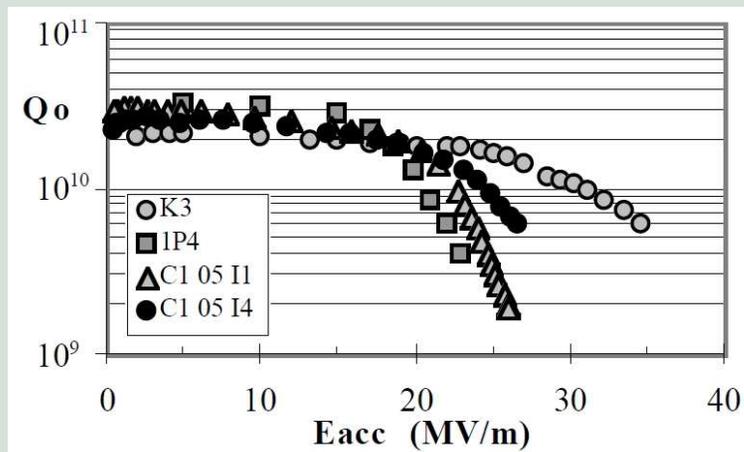


Superconductivity

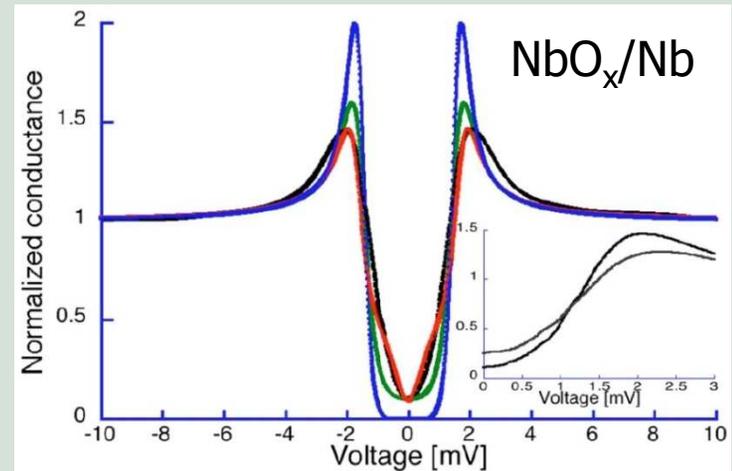
Niobium SRF cavities



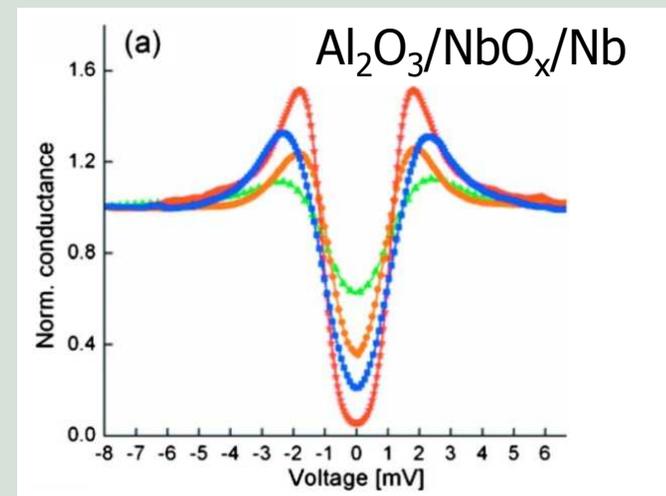
Real-life Q factor



FNAL, ANL and IIT collaboration

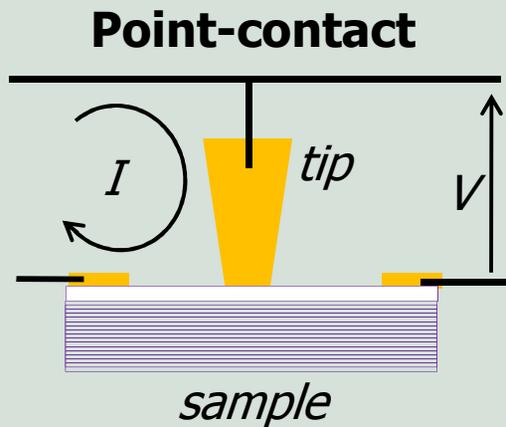
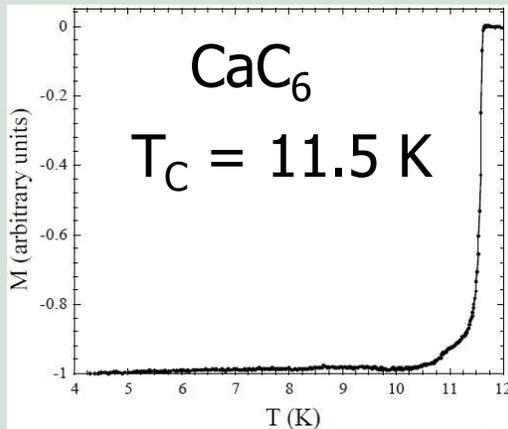


Proslir T. et al, APL 92 (2008) p.201505



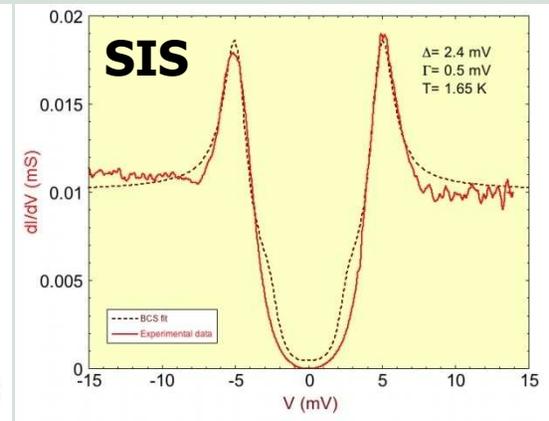
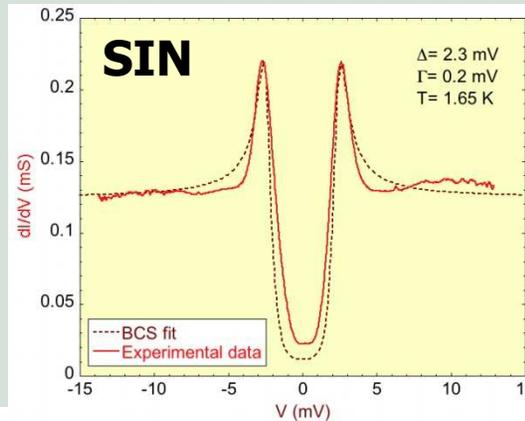
Proslir T. et al, APL 93 (2008) p.192504

Superconductivity: Ca-doped Graphite

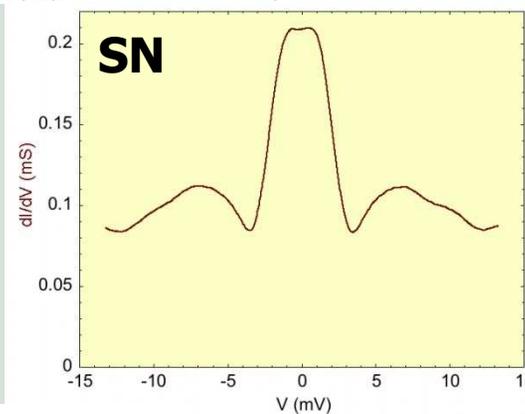


same method as used by
Thomas Proslie

Measured superconducting gap 40% larger than other studies, implied strong (!) coupling



tunneling



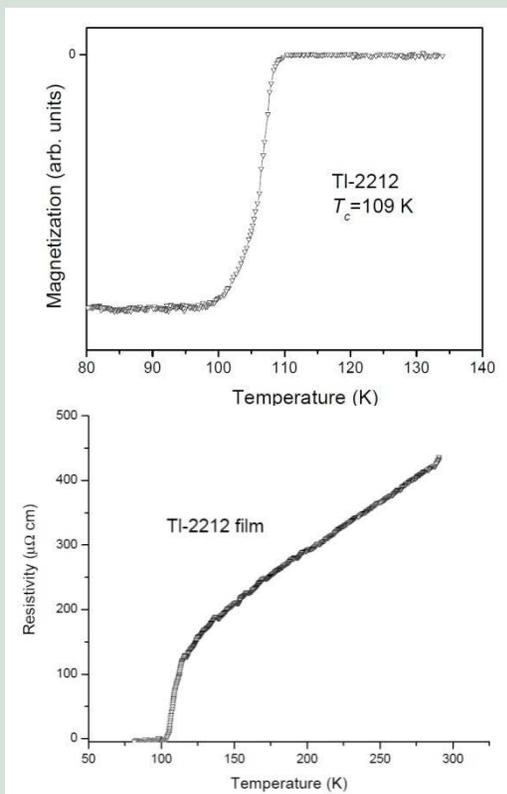
Andreev reflection

Kurter C, Ozyuzer L, Mazur D et al, PRB 76 (2007) p.220502

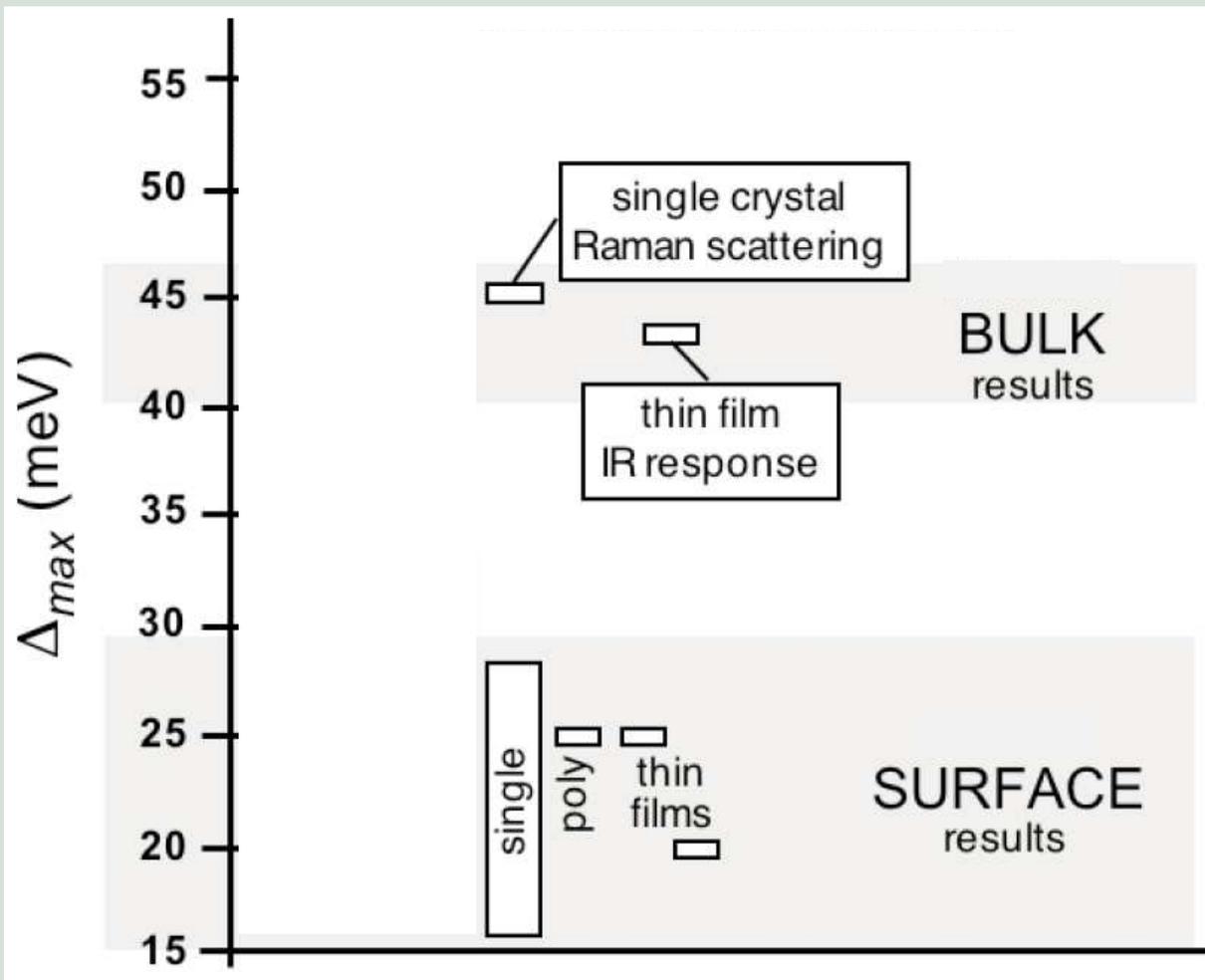
Superconductivity: Thallium cuprate



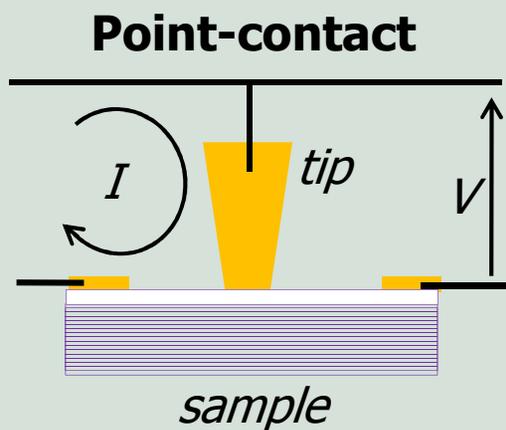
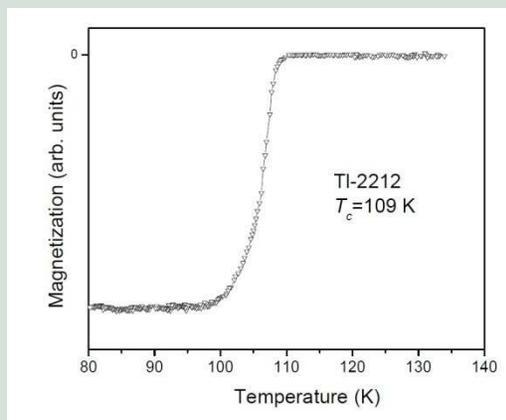
$$T_c = 103\text{-}108 \text{ K}$$



Situation with Δ_{max} observed in Tl-2212

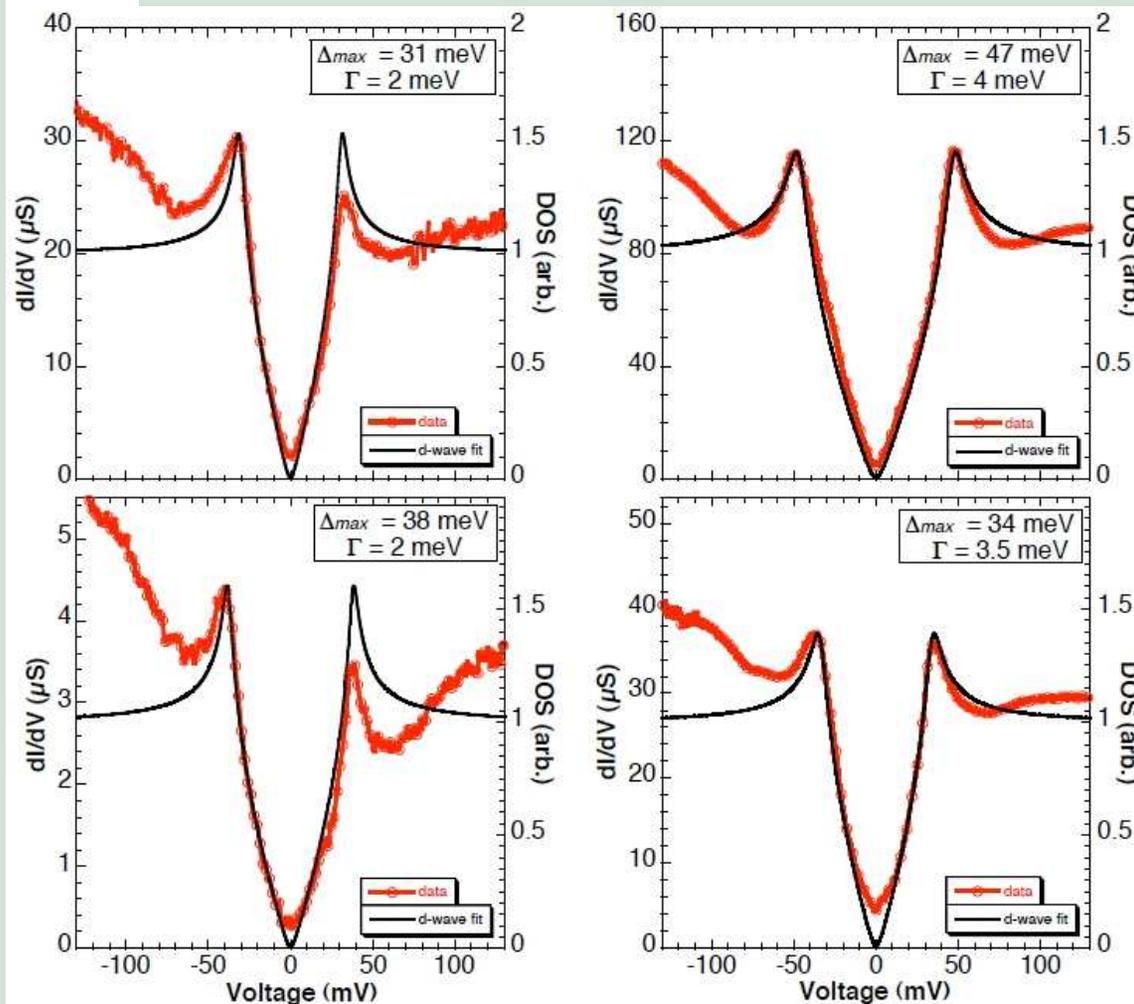


Superconductivity: Thallium cuprate



SIN

tunnel dI/dV curves and d-wave fits

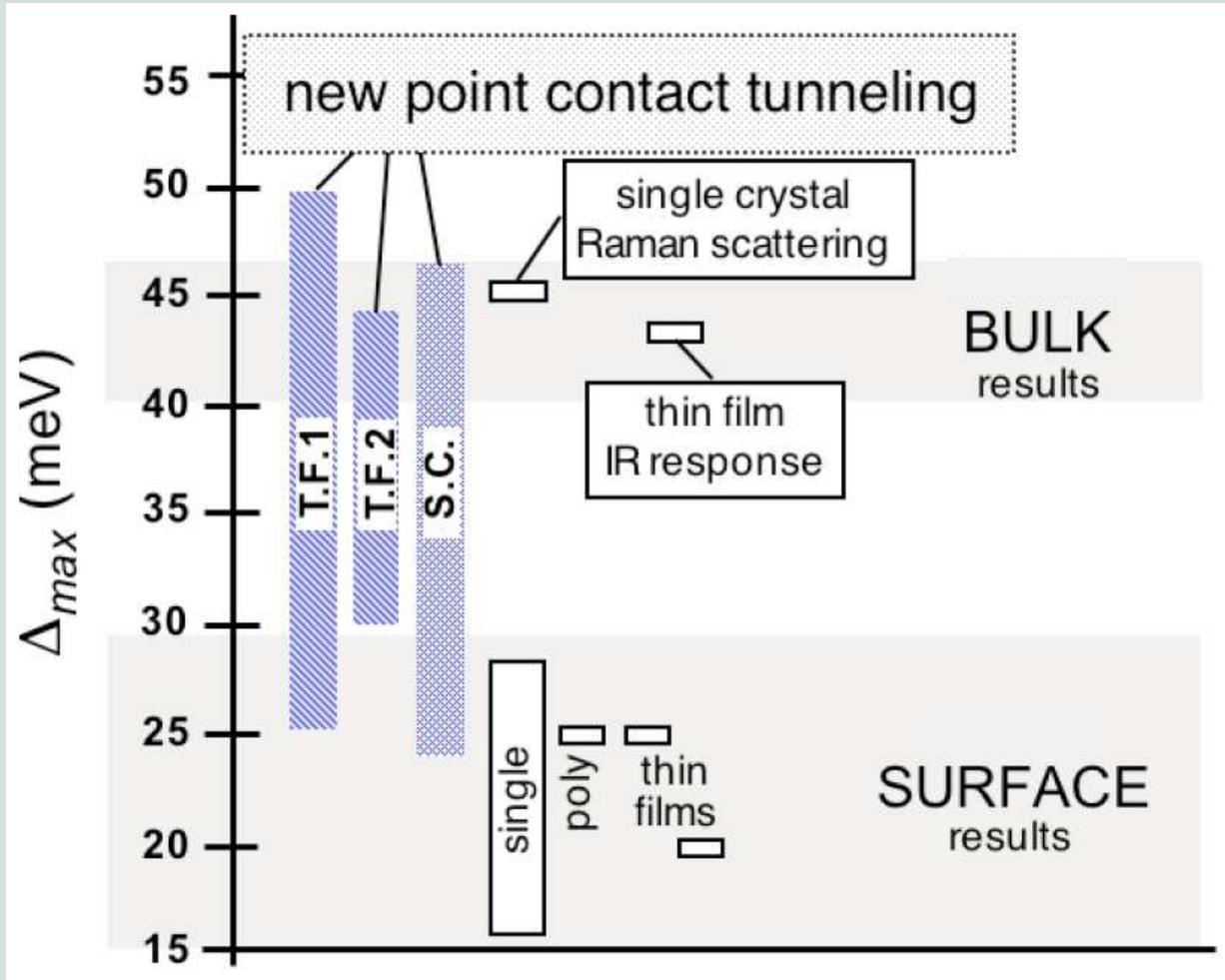
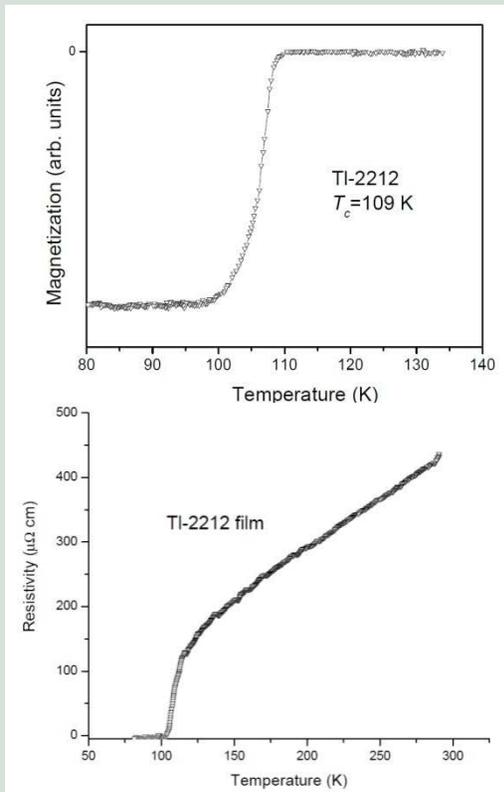


Superconductivity: Thallium cuprate



$$T_c = 103\text{-}108 \text{ K}$$

Conclusion regarding Δ_{max} in Tl-2212:
It is a normal member of the cuprate family



Milestone - nanostructures

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measurements of CaC_6 and High- T_C cuprate Tl-2212 at Argonne Nat'l Lab
- Nanostructures ...
fabrication of templates for metal atomic chains on Silicon (001) surface
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Nanostructures

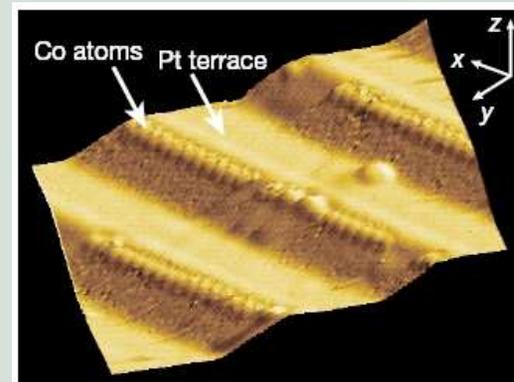
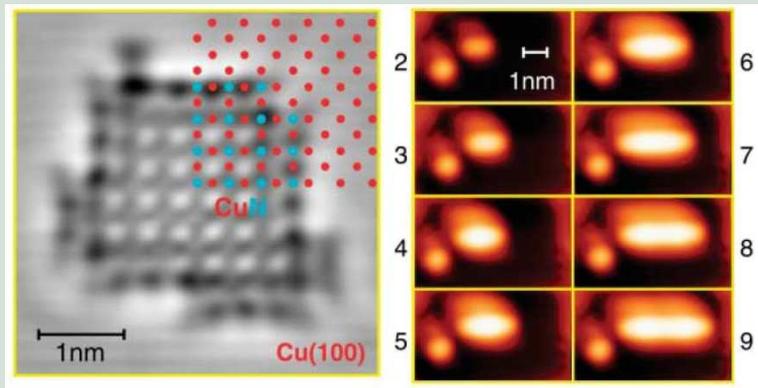
Atomic chain and its electrons



- Failure of fermi liquid theory
- Luttinger liquid description
- signal traveling as an isolated excited state, importance of localized states, Coulomb energy
- very few experimental systems are available to test predictions of 1D theories (2DEGs, Mn on CuN, ...)

Mn on CuN: Hirjibehedin C.F. et al, Science 312 (2006) p.1021

Co on vicinal Pt: Gambardella P. et al, Nature 416 (2002) p.301



Nanostructures

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Chain suspended vs deposited on a substrate

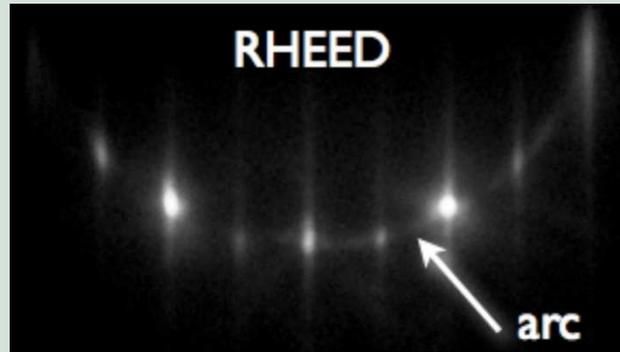
Support:

- Rigid (opposed to suspensions)
- Topography => adsorption sites (in plane, step edges)
- Much better way to build devices

Interaction:

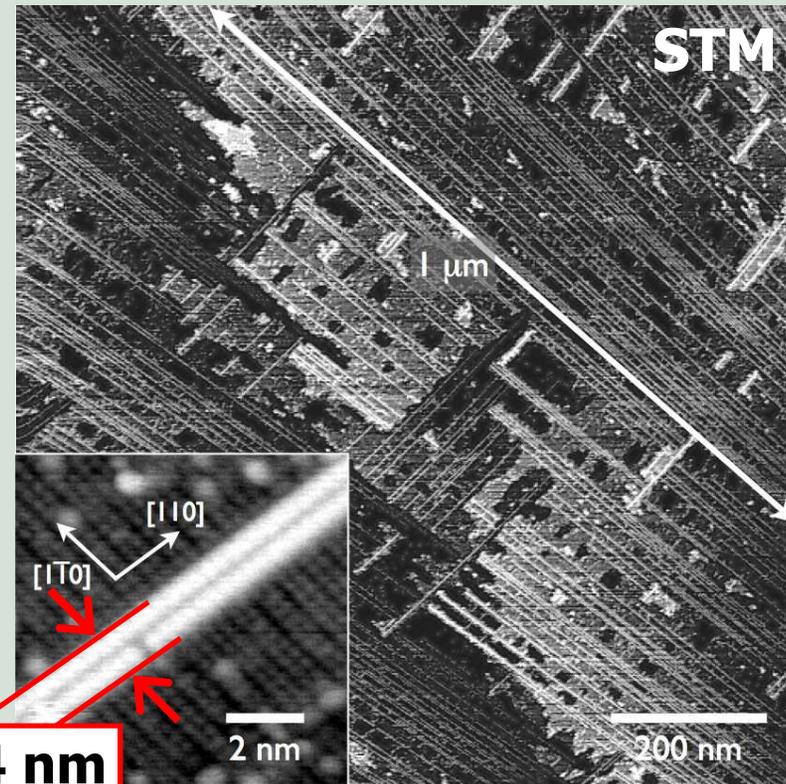
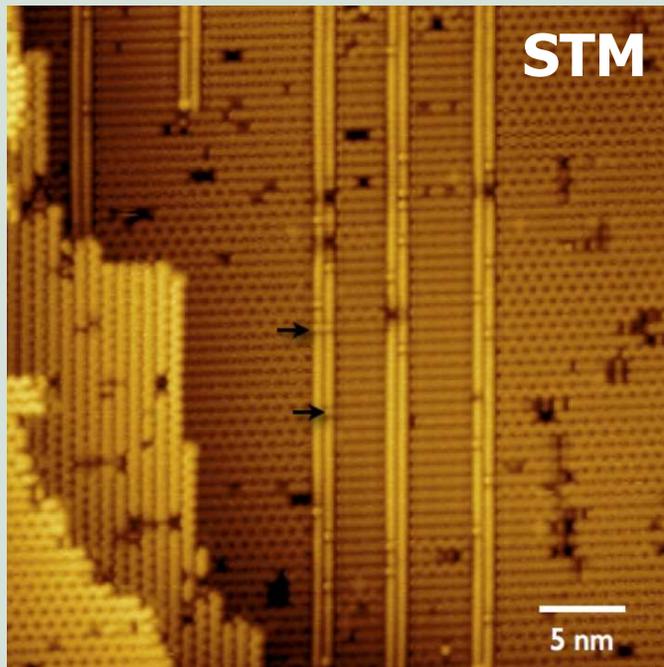
- Strong interaction causes a shift of electronic levels of deposited material.
- Semiconductor gives a chance that deposit levels are in band gap, so there is no mixing.

Nanostructures – Bismuth nanolines as templates



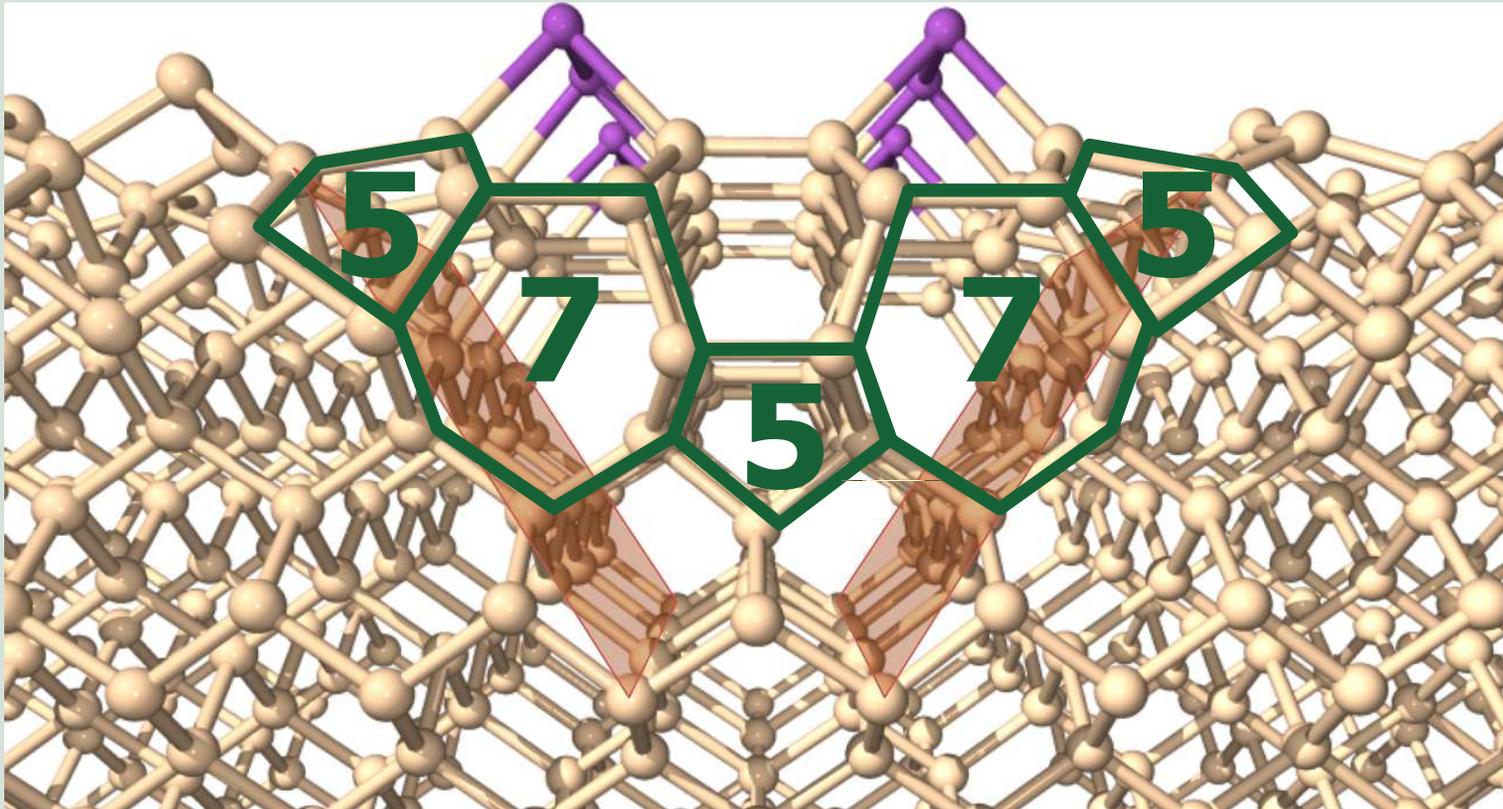
Bismuth nanolines:

- constant width, long length, no kinks
- few defects, limited only by terraces
- self-assembled, stable up to 500°C



Review Article: *J. Mat. Sci.* **41** (14) 4568 (2006).

Nanostructures – Bismuth nanolines as templates



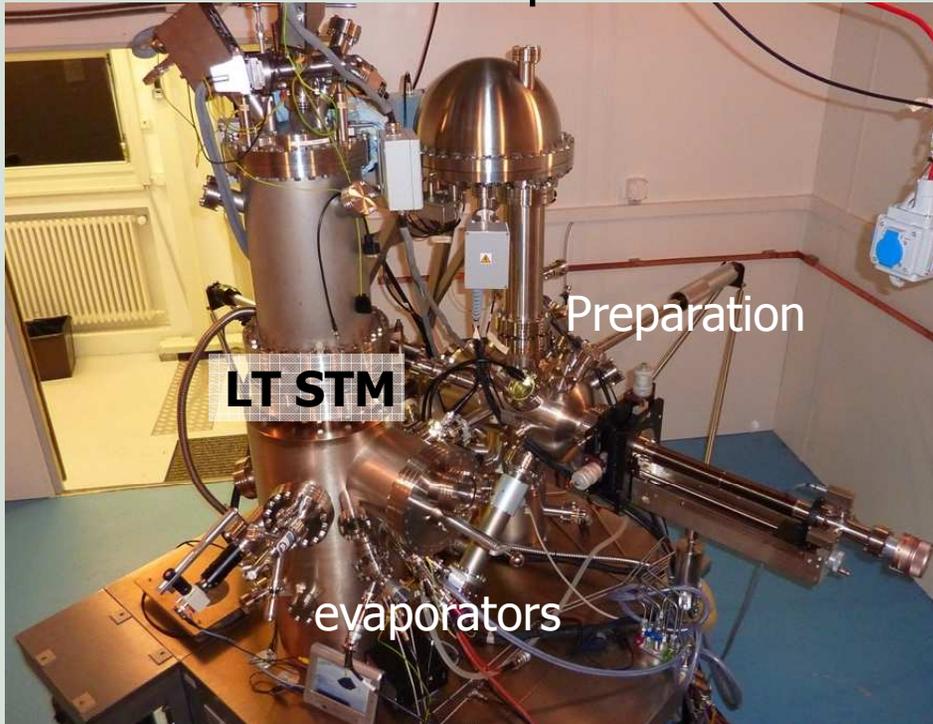
Proposed answer:

- Double-core "Haiku" structure, with 5- and 7-membered rings of Silicon
- Thermodynamically stable. 0.37 eV/ Bi dimer better than next best structure

Phys. Rev. Lett. **88** 226104 (2002).

Nanostructures – LT STM at the Uni de Genève

Omicron Low-temperature STM



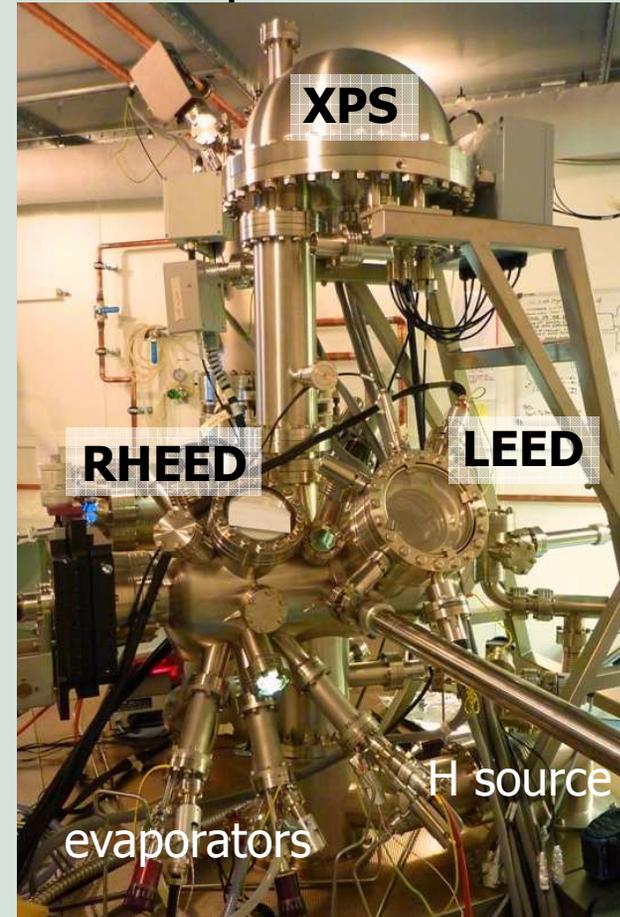
Preparation:

sample temperatures: 77K to ~1500K
2 K-cell evaporators, H beam source

STM:

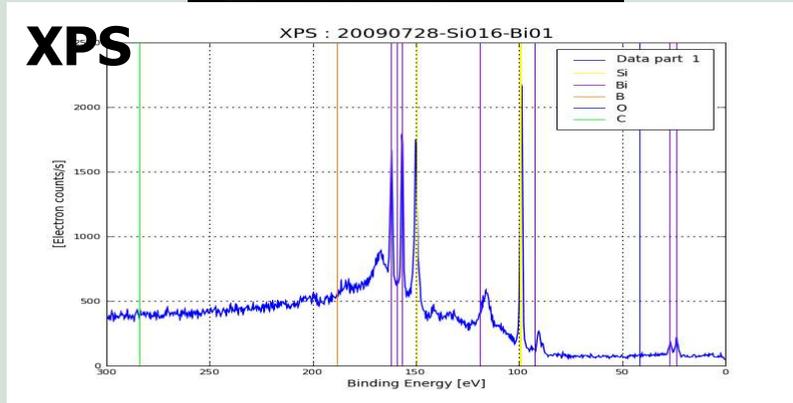
tip and sample temperature: 2K to 300K
K-cell evaporator, e-beam evaporator for on-the-spot deposition

Preparation

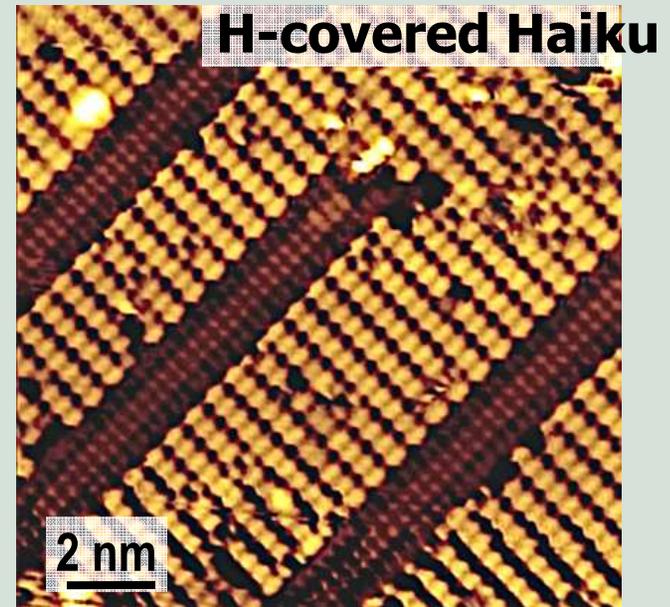
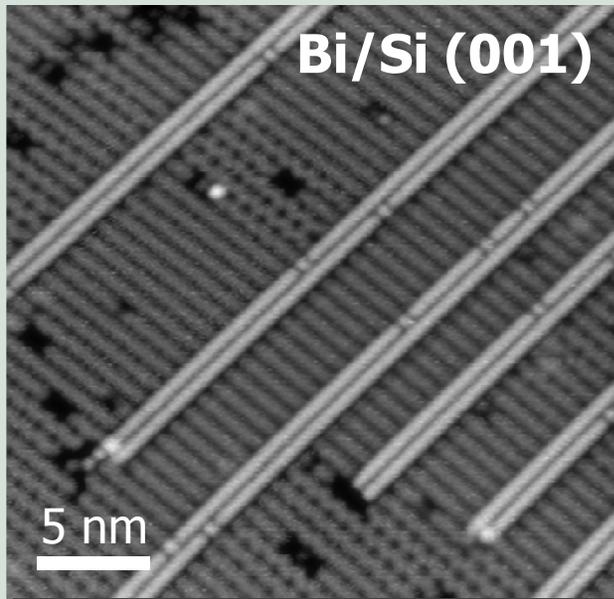
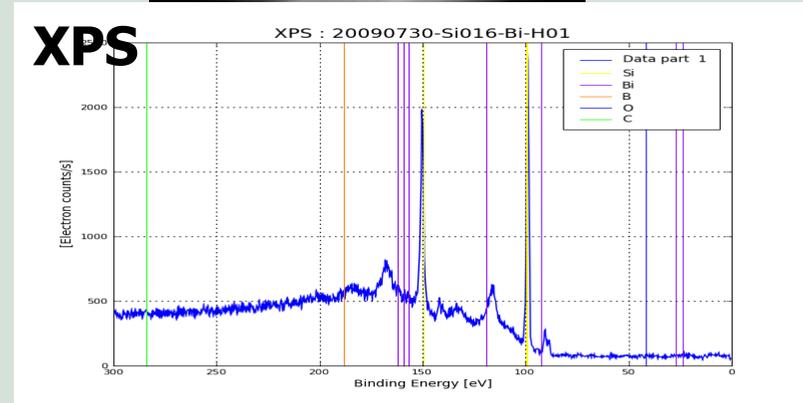


Nanostructures

after Bi deposition

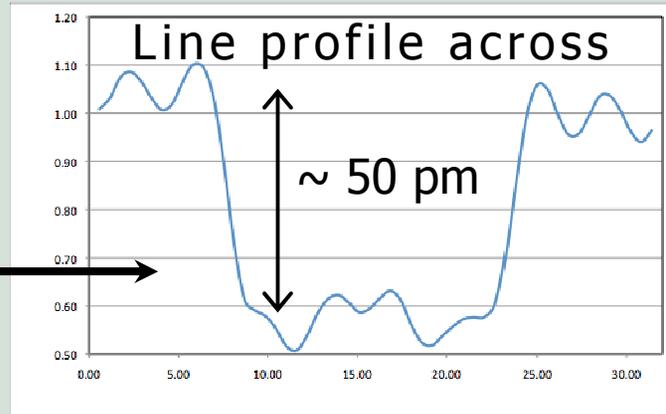
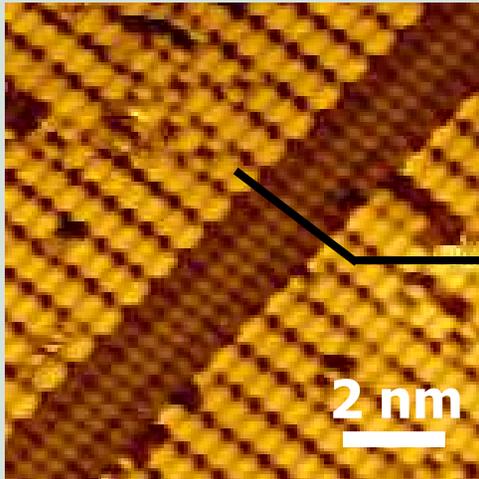


after H exposure



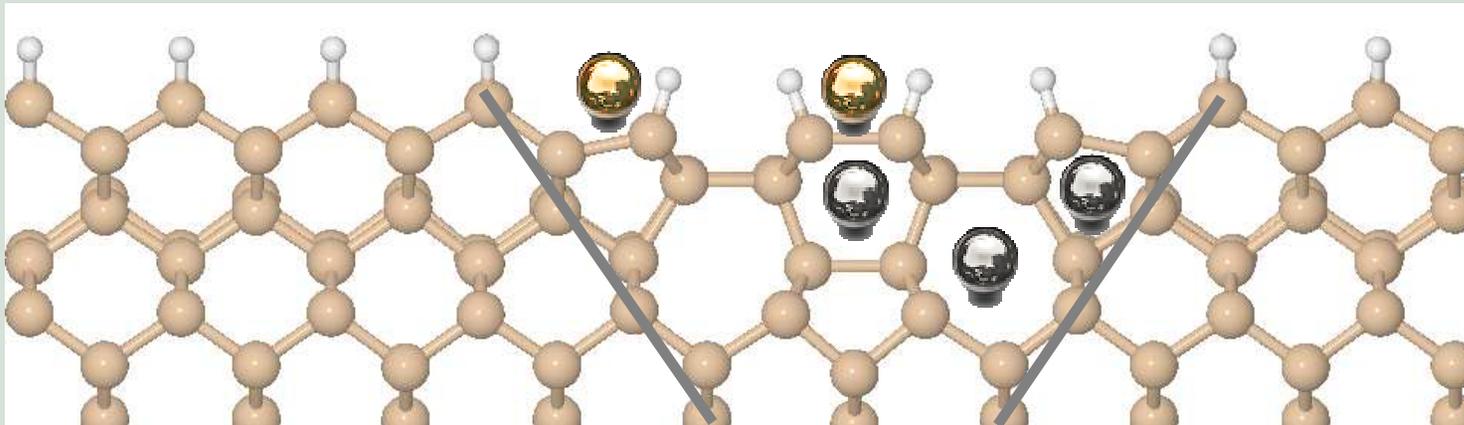
STM

Nanostructures – the potential of H-saturated « Haiku »



- trench depth agrees with modeling
- structure inside trench is a purely electronic effect (DFT)

« Haiku » stripes as templates



Milestone - Photoemission

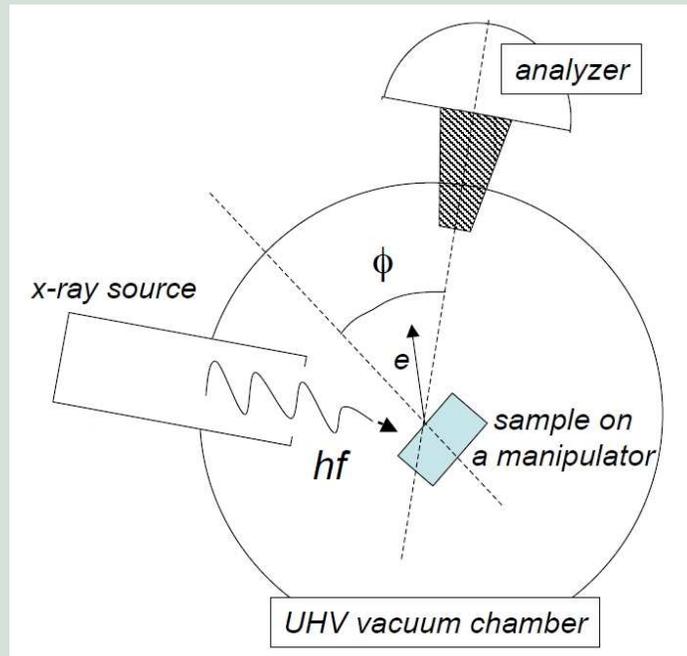
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Photoemission

Energy balance equation of photoemission

$$hf = BE + KE^{vacuum} + \Phi_{sample} = BE + KE^{analyzer} + \Phi_{analyzer}$$

PE Spectroscopy instrument diagram



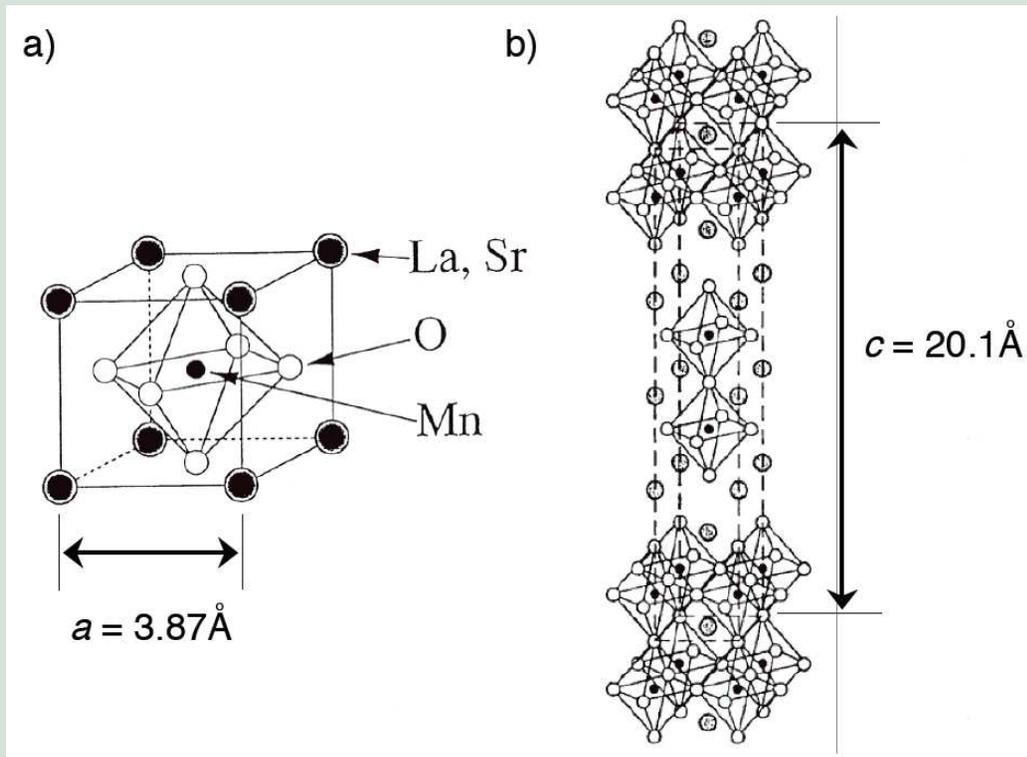
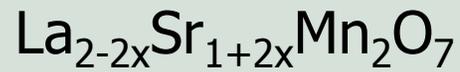
Energy range: Ultra-Violet (PES, UPS) or X-ray (XPS)

Angular resolution: ARPES/ARUPS, ARXPS, X-ray photoelectron diffraction (XPD)

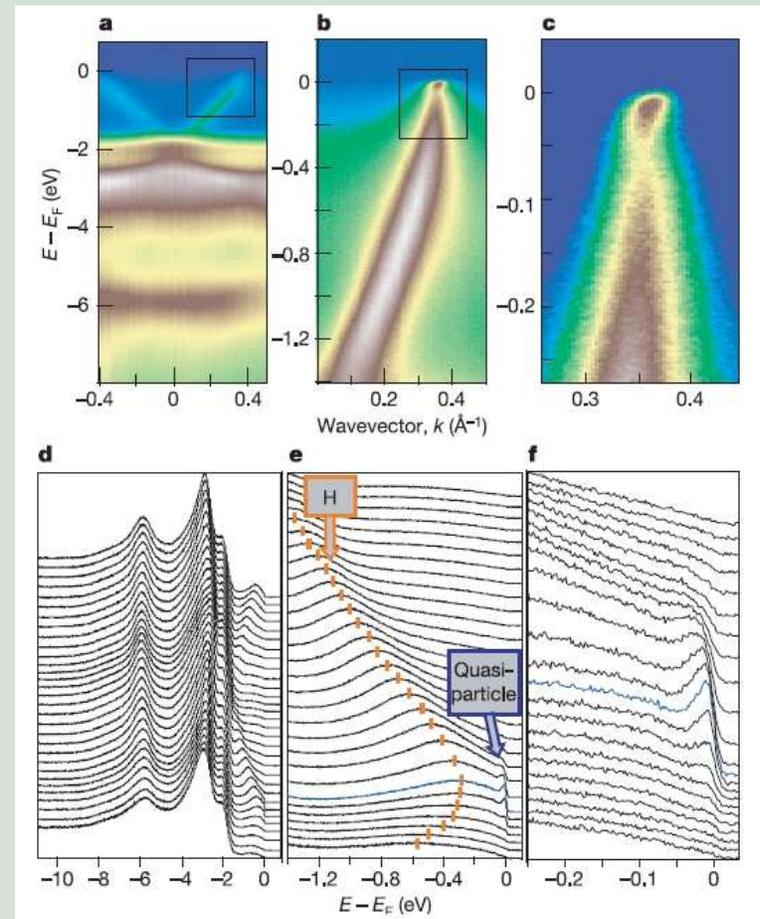
UPS: valence band mapping

XPS: chemical depth profiling

Photoemission spectroscopy - LSMO



ARPES on $x=0.36$ and $x=0.40$

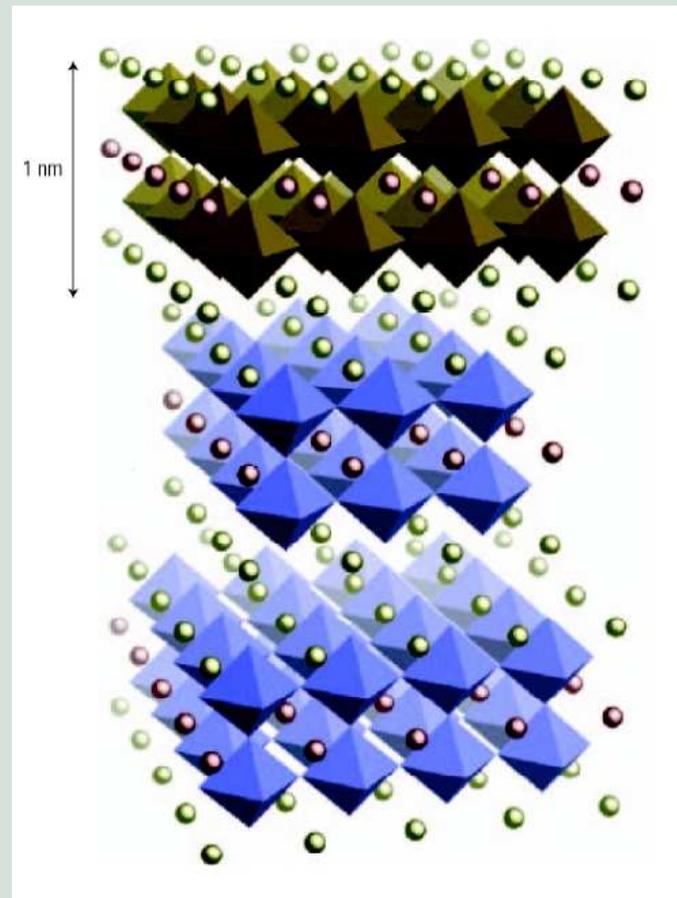
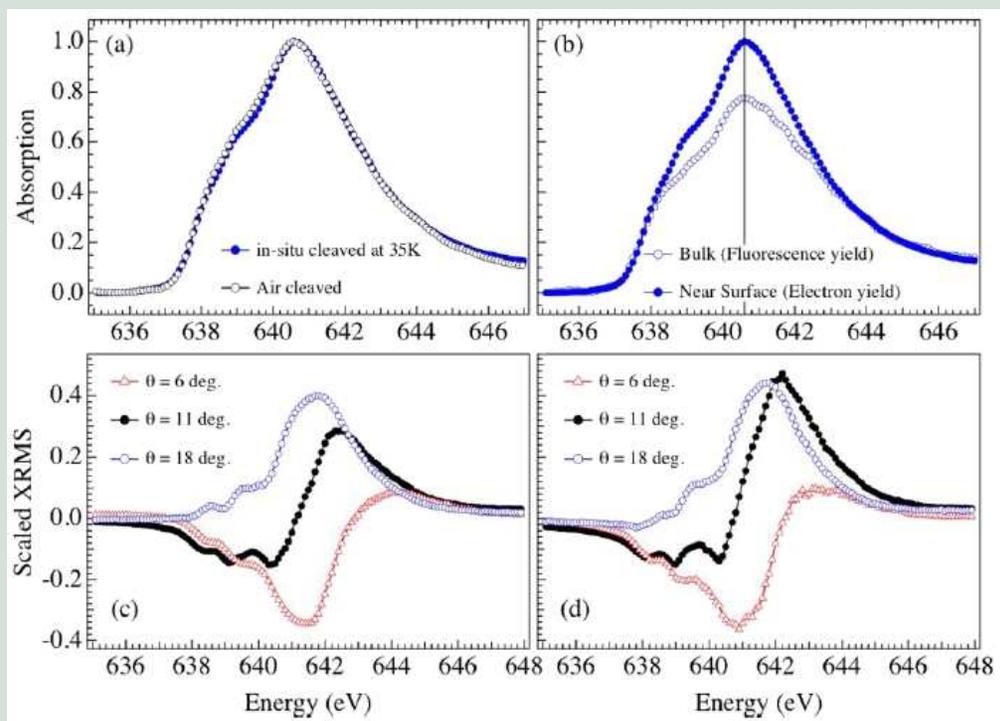


Mannella N. et al, Nature **432** (2005) p.474

UV ARPES had been employed with promising results by others.

Photoemission spectroscopy - LSMO

Magnetic scattering at Argonne APS beam line

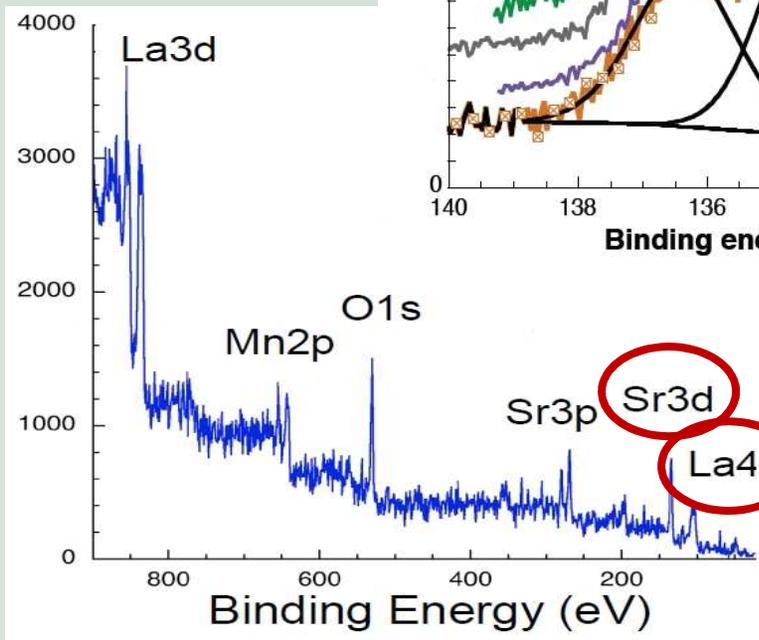
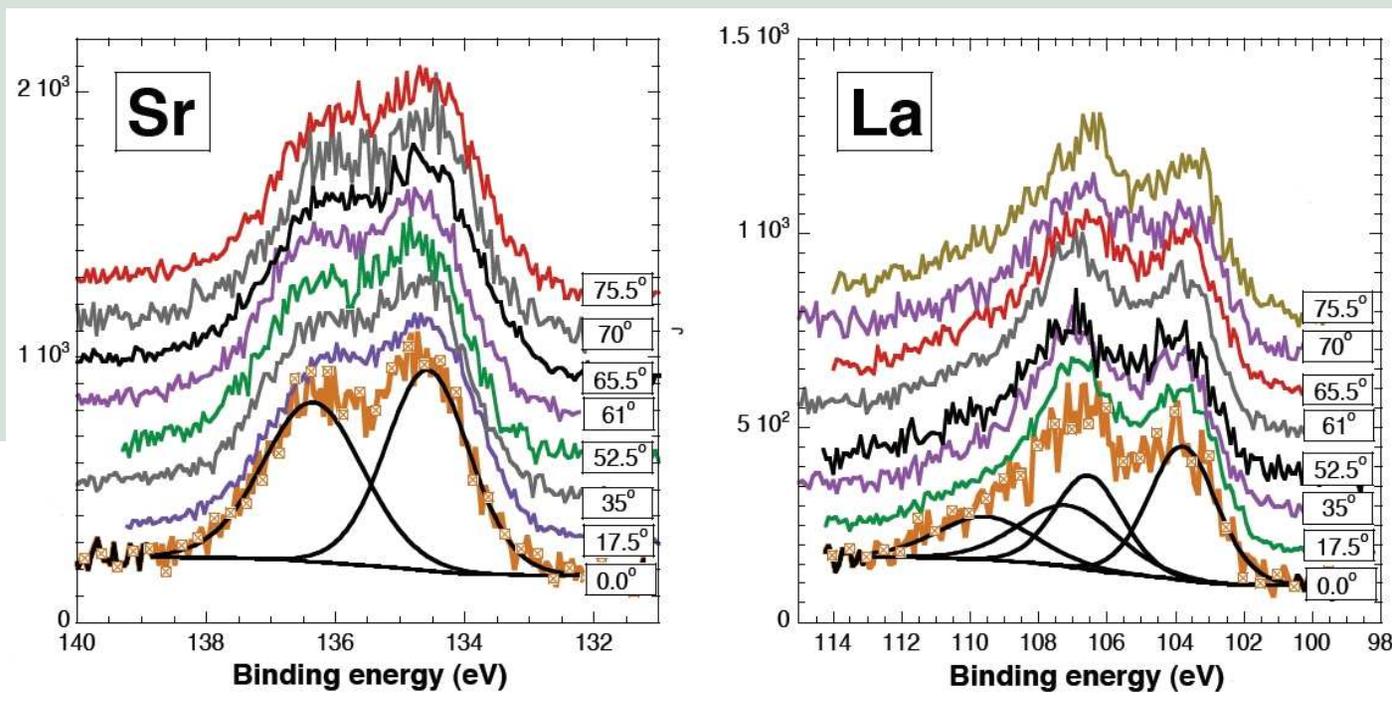


Freeland J.W. et al, Nature Mat. 4 (2005) p.62

Angle-Resolved XPS called to establish, if this is a chemical effect.

Photoemission spectroscopy - LSMO

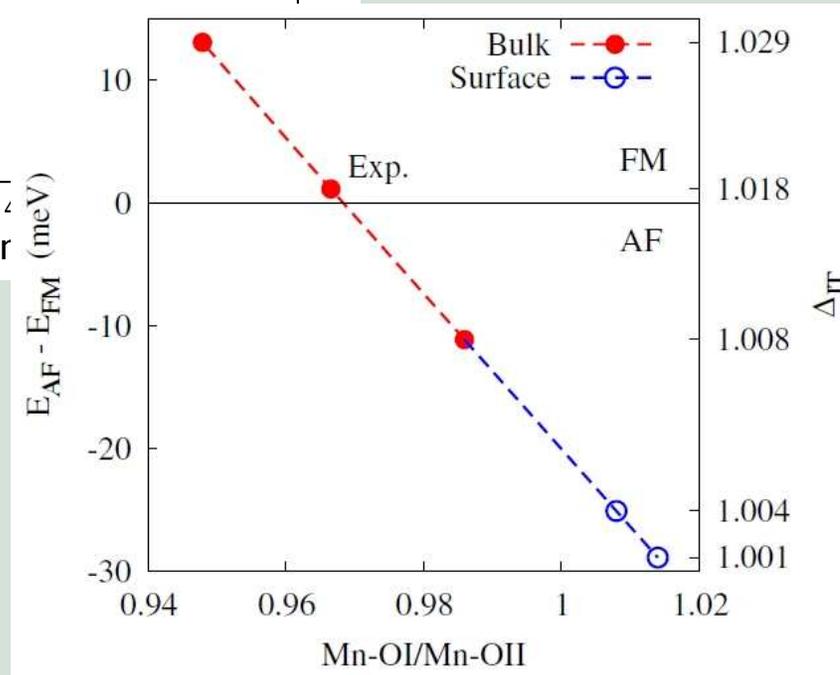
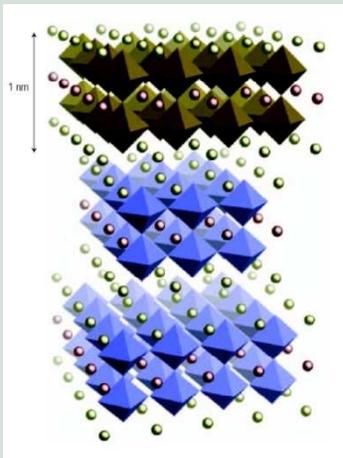
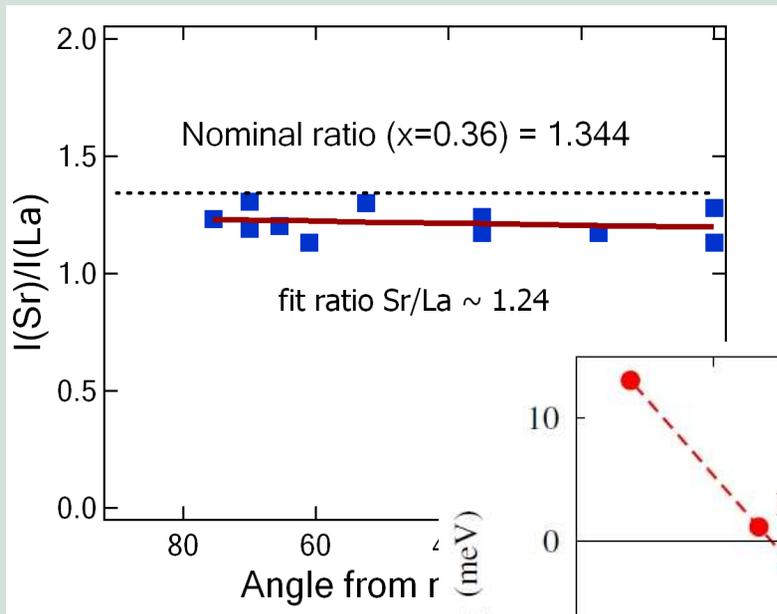
Angular dependence of XPS



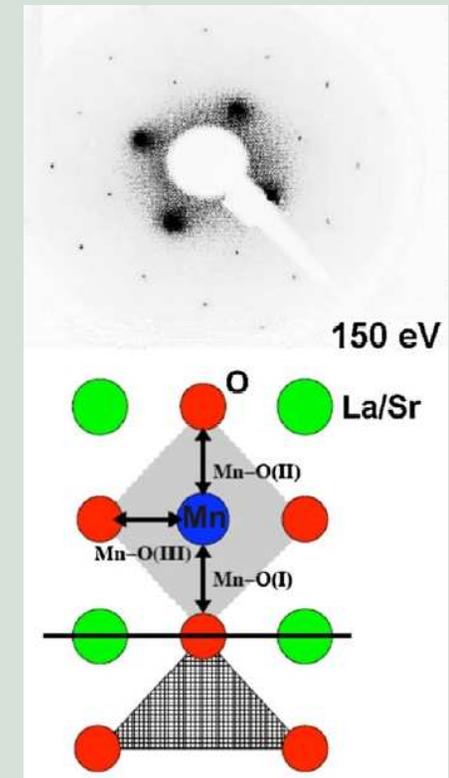
Sr 3d & La 4d
Peaks at near energies = info depth match

Photoemission spectroscopy

XPS depth profile of LSMO $x=0.36$



LEED experiment aided by modeling



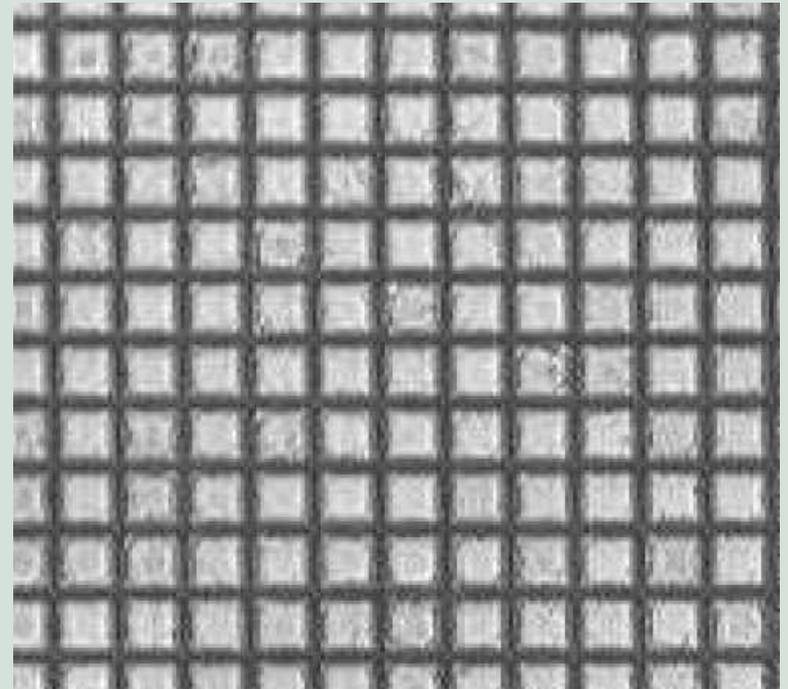
Nascimento V. B. et al, PRL 103 (2009) p.227201

Milestone - last

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- Nanostructures ...
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- Thin films and auxilliary techniques ...
overview of surface modification and analytic techniques employed
- Building a laboratory from scratch ...
new group at the University of Geneva, Switzerland

Surface methods overview

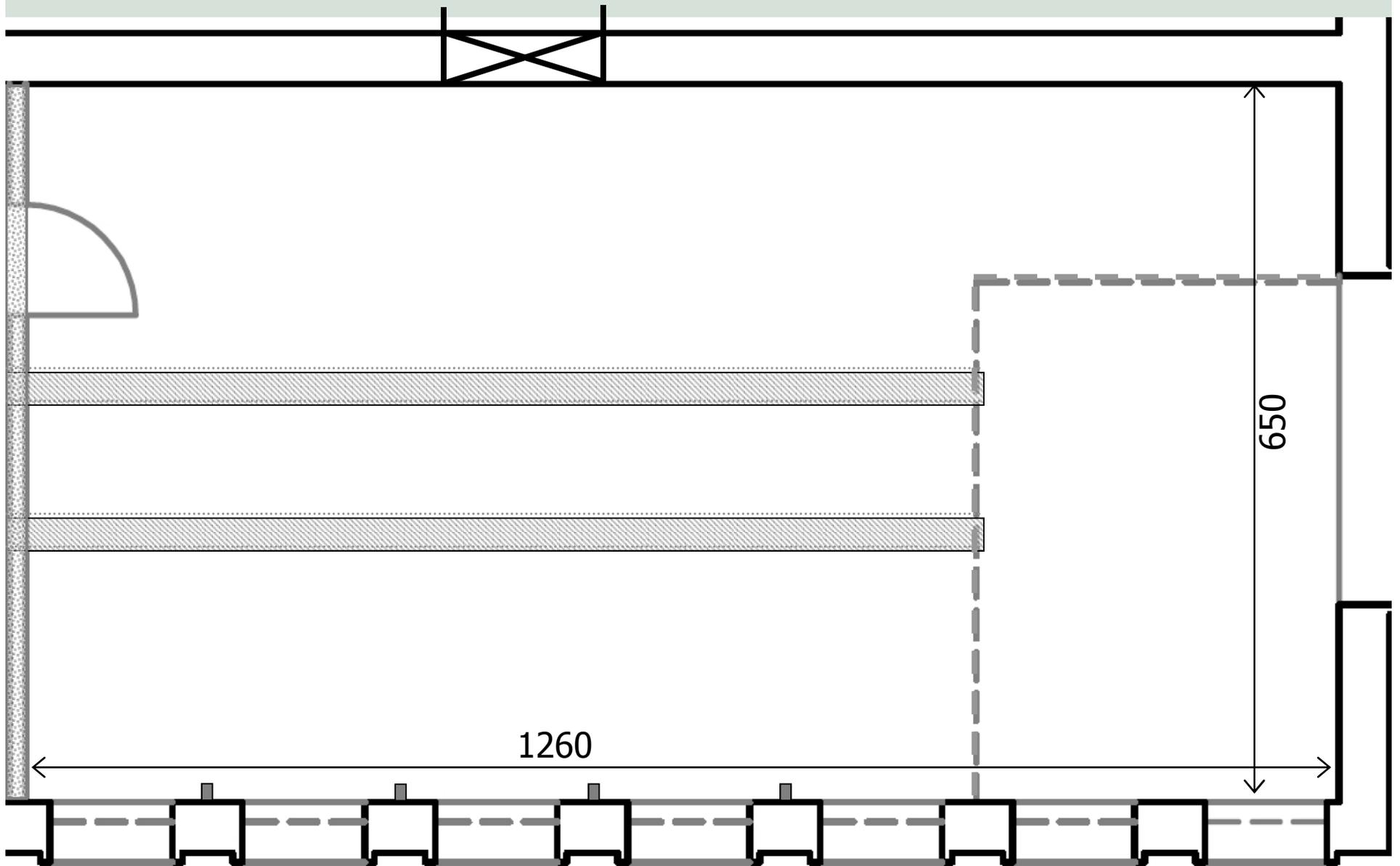
- Surface cleaning:
UHV cleaving, flash-heating
Argon sputtering
- Thin films :
magnetron sputtering (Au deposition)
evaporation (Bi, Au)
pulsed laser deposition (SrTiO₃ on LSMO)
- Patterning :
photolithography + Ar plasma etching
Focused Ion Beam (FIB)
- STM tip making :
DC and AC electrochemical etching (Au, Ir, Pt/Ir, W)



FIB of Au/SrTiO₃/LSMO(x=0.36)
array 80x80 of 2µm x 2µm patches

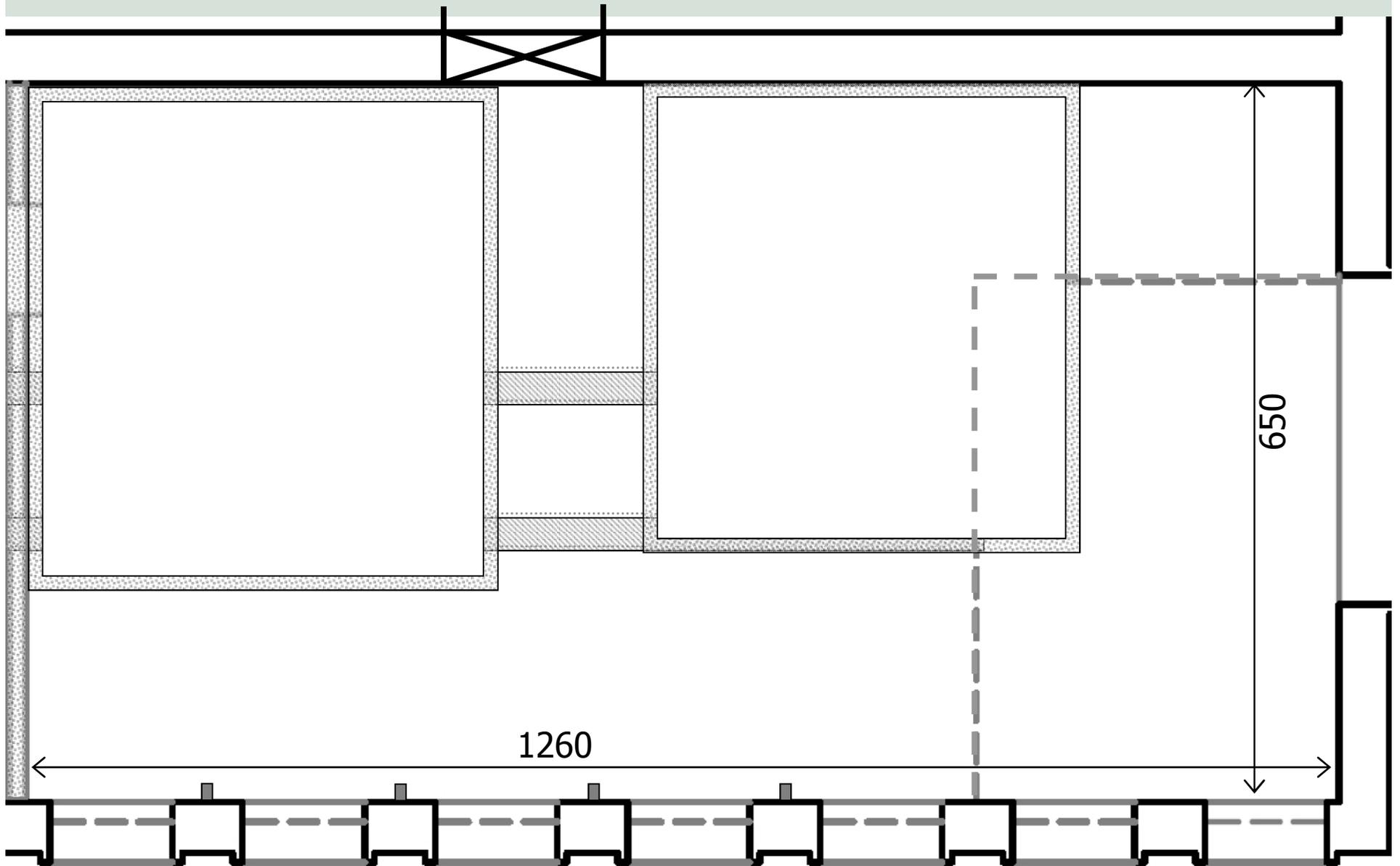
New group, new laboratory

1:50



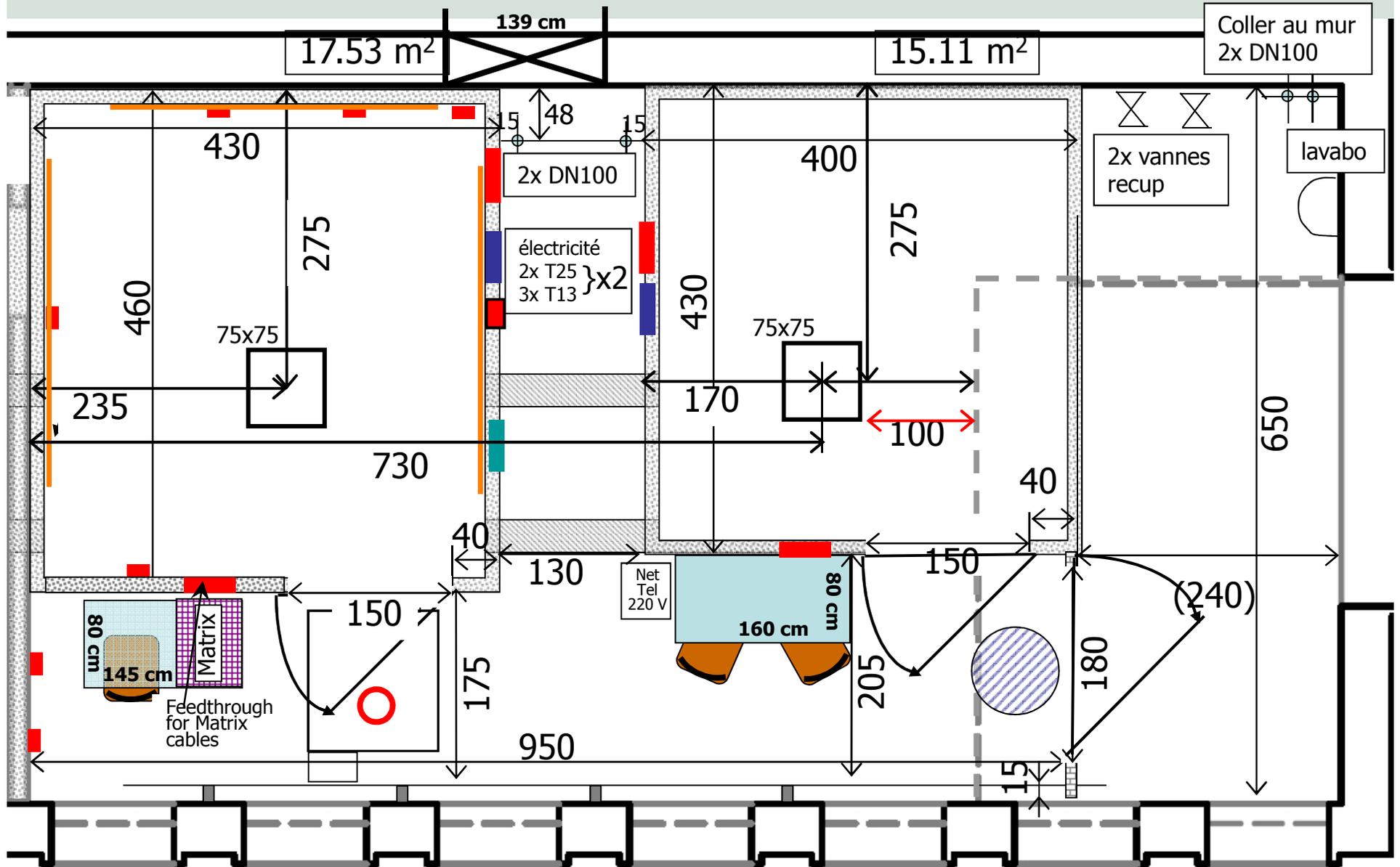
New group, new laboratory

1:50



New group, new laboratory

1:50



Acknowledgements

STM group Uni Genève



Christoph Renner
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Nabil Nectoux



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Cihan Kurter
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Hong Zheng
John W. Freeland
... and many more

Surface Physics Lab in Prague

Katerina Veltruska
Vladimir Matolin



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DE GENÈVE**

FACULTÉ DES SCIENCES
Département de physique
de la matière condensée



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