High resolution RIXS from cuprates: results and perspectives

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Acknowledgments

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  and the staff of the ESRF- EXAFS group
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  (T. Schmitt and V. Strocov and coll.)

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  and the directors of Dptm of Physics

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  Claudia Dallera
  Giacomo Ghiringhelli
  Alberto Tagliaferri

- The EPFL group (M. Grioni and coll.)

- The theorists (J. van den Brink, L. Ament and coll.)

- All co-authors listed in the following viewgraphs

- All my students

Lay-out

PART 1 Cuprates

- History
- Spectroscopy of collective magnetic excitations
- The interplay between RIXS at various edges
- The cross fertilization with neutrons

PART 2 What do we need to do better ?

- The new project at the ESRF (RIXS + XMCD)

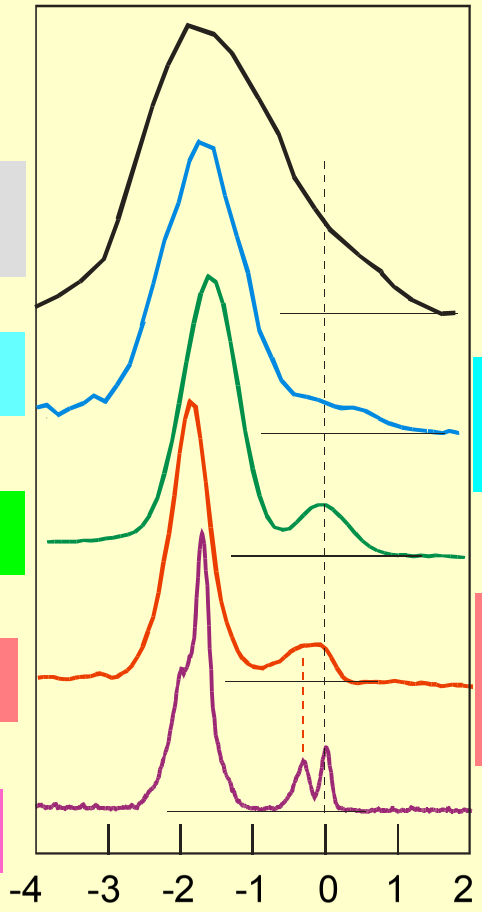
The importance of cuprates does not need to be demonstrated

Some history

Incident photon energy ~ 931 eV

La_2CuO_4 = LCO

La_2CuO_4 excited at Cu-3d



ΔE ~1.6 eV

K. Ichikawa *et al.*, J. Electron Spectrosc. Relat. Phenom. **78**, 183 (1996).

ΔE ~1.2 eV

L. C. Duda *et al.*, J. Electron Spectrosc. Relat. Phenom. **110–111**, 275 (2000).

ΔE ~0.8 eV

AXES @ ID08, 2003. G. Ghiringhelli *et al.*, Phys Rev Lett. **92**, 117406 (2004).

ΔE ~0.45 eV

AXES @ ID08, 2007. L. Braicovich *et al.*, arXiv:0807:1140v1, (2008).

ΔE ~0.13 eV

SAXES @ SLS, 2008. G. Ghiringhelli, L. Braicovich, T. Schmit *et al.*, unpublished

World record 2000

World record 2003

World record spring 2007

World record spring 2008

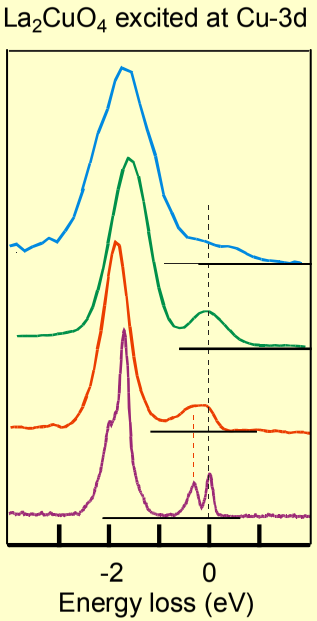
Uppsala

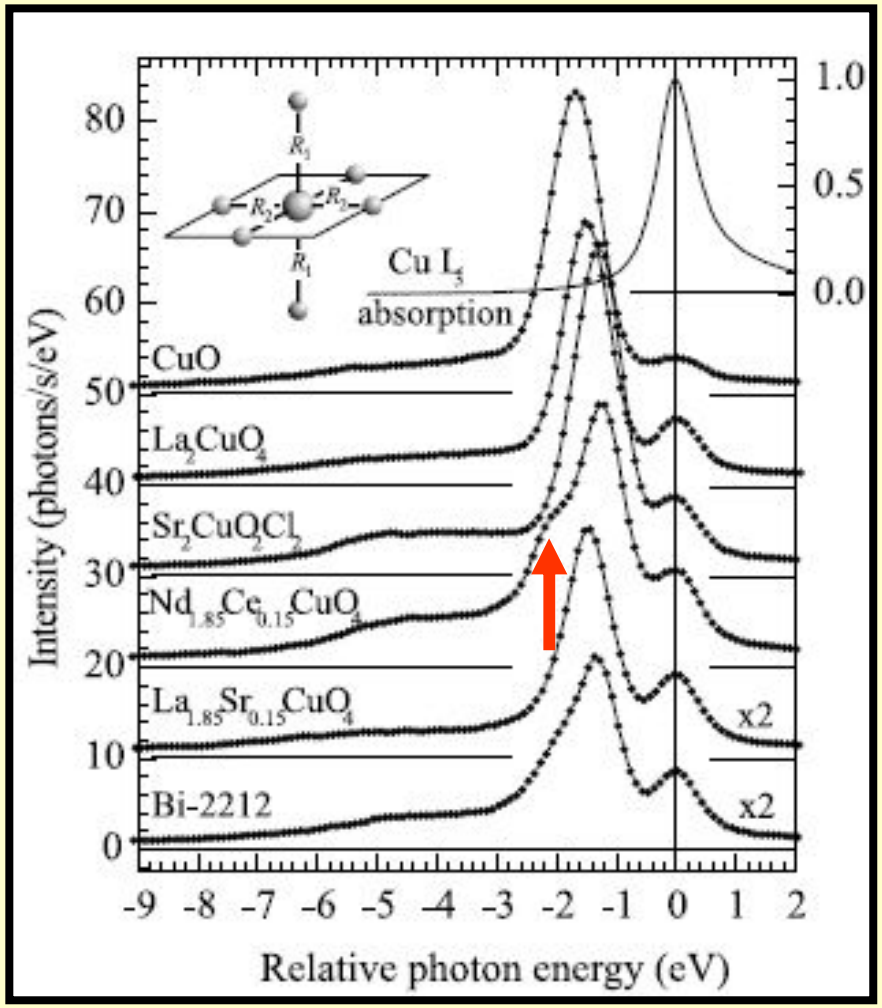
Milano

ESRF

SLS

Combined resolving power increase by a factor of 12





ESRF

First L2,3 evidence of the dd dependence on the structure

AXES @ ID08, 2003. G. Ghiringhelli *et al.*, Phys Rev Lett. **92**, 117406 (2004).

G. Ghiringhelli, N. B. Brookes, E. Annese, H. Berger, C. Dallera, M. Grioni, L. Perfetti, A. Tagliaferri, and L. Braicovich

Resonant X-Ray Raman Spectra of Cu *dd* Excitations in $Sr_2CuO_2Cl_2$

Pieter Kuiper,* J.-H. Guo, Conny Såthe, L.-C. Duda,† and Joseph Nordgren
Department of Physics, Uppsala University, Box 530, S-751 21 Uppsala, Sweden

J. J. M. Pothuizen, F. M. F. de Groot, and G. A. Sawatzky
Laboratory of Solid State Physics, Materials Science Center, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

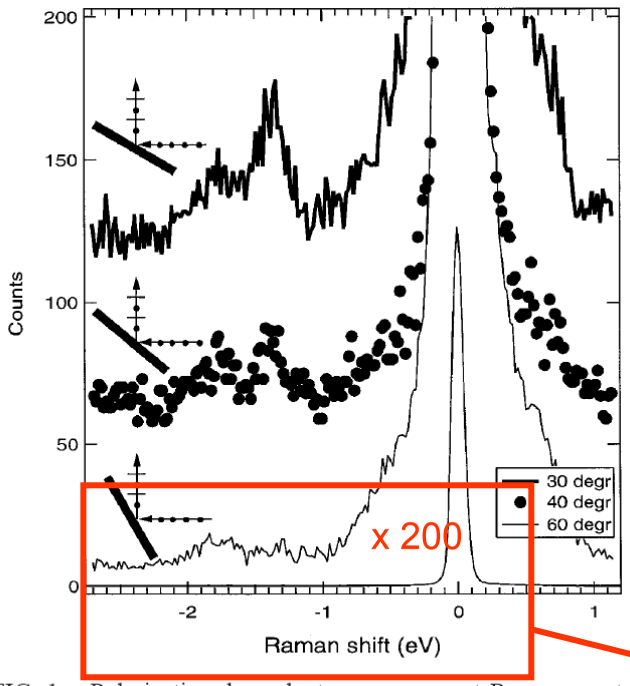


FIG. 1. Polarization-dependent x-ray resonant Raman spectra at the Cu M_3 resonance (74 eV). The angle between the emission direction and the sample normal is 30°, 40°, and 60°, from top to bottom. The last spectrum is also shown reduced by a factor of 200.

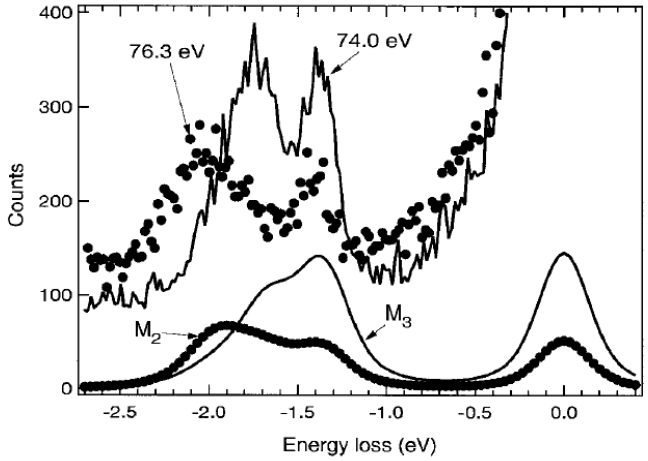


FIG. 3. X-ray resonant Raman spectra at the Cu M_3 and M_2 resonances (74 and 76.3 eV). The emission direction is in the direction of the incident polarization and makes an angle of 40° with the sample normal.

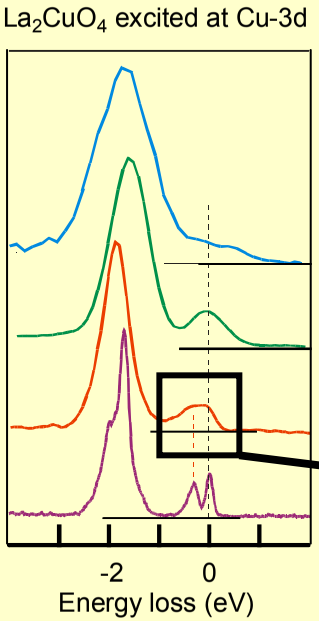
Very small cross section

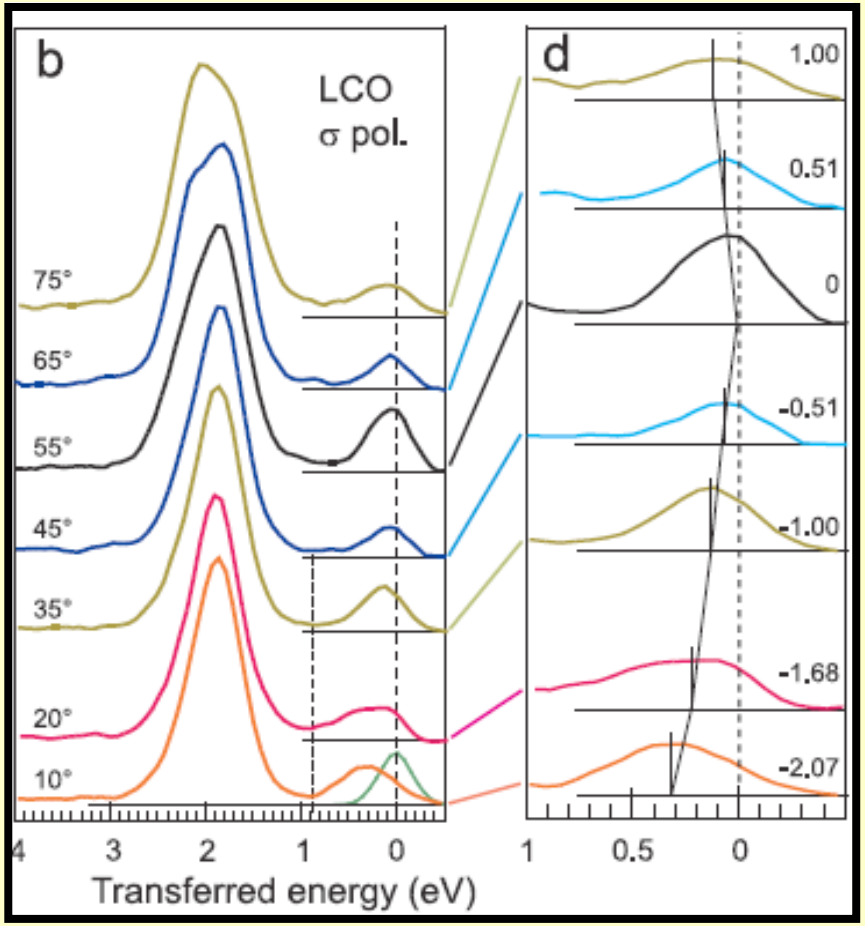
Essentially no K of the photon
(< 7% of the BZ around (0,0))

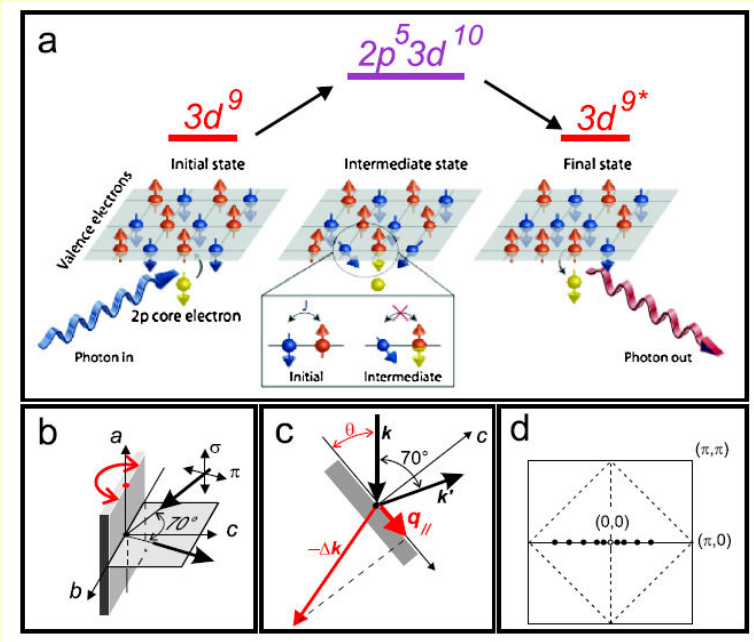
FIRST EVIDENCE OF DISPERSION

ESRF

AXES @ ID08 (ESRF)
fall of 2007.
L. Braicovich *et al.*,.



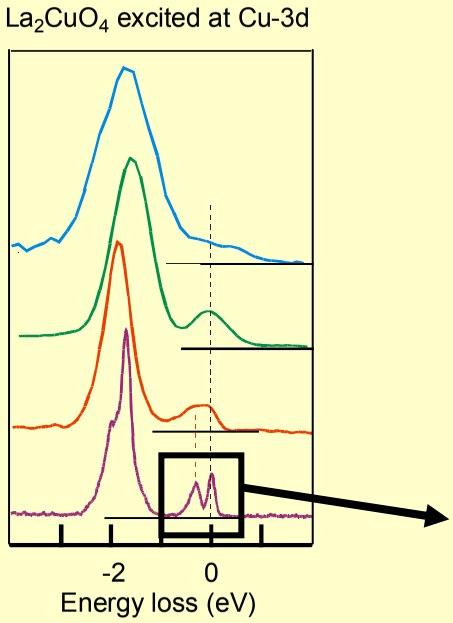




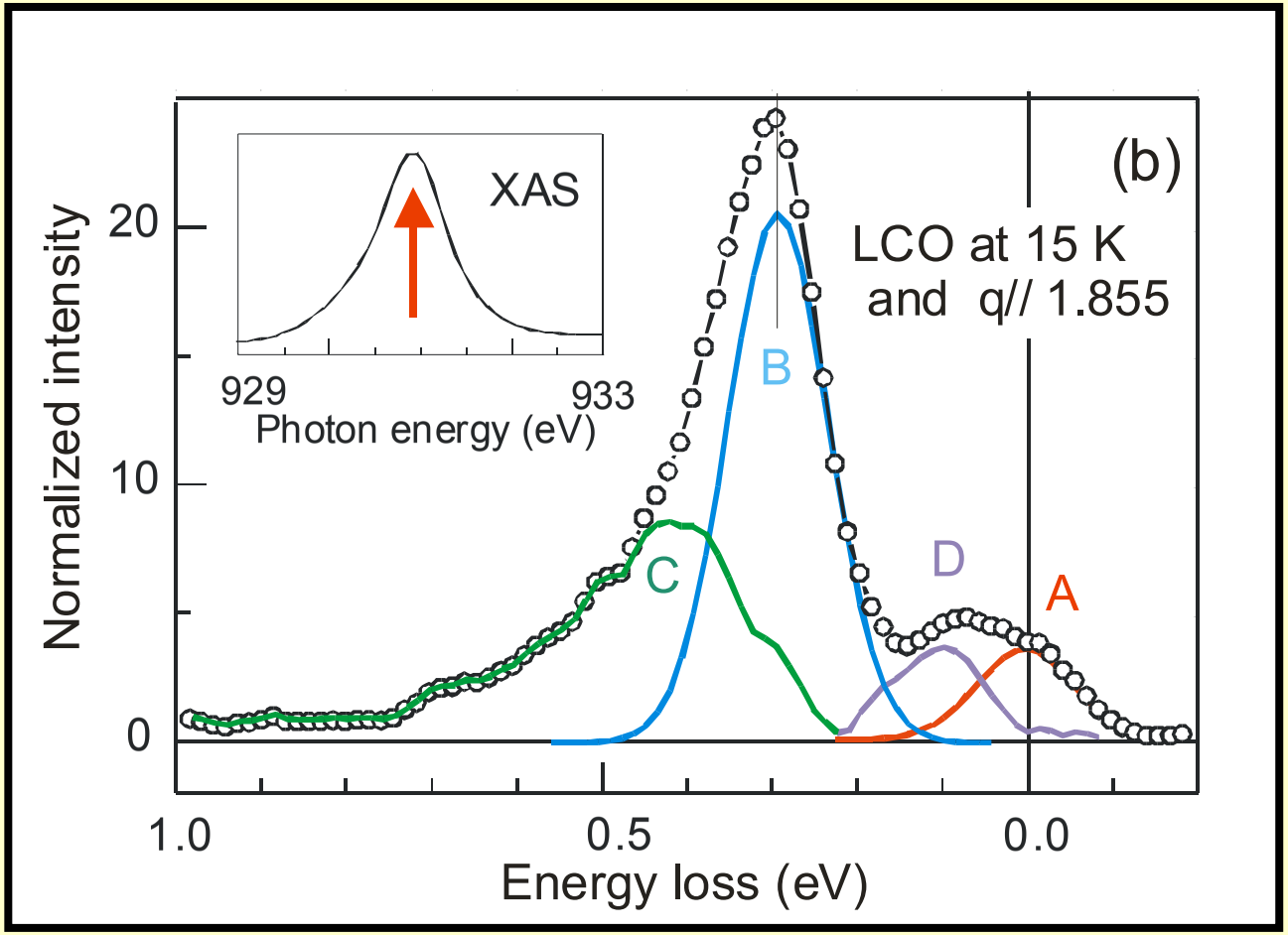
L. Braicovich, L. J. Ament, V. Bisogni, F. Forte, C. Aruta, G. Balestrino, N. B. Brookes, G. M. De Luca, P. G. Medaglia, F. Miletto Granozio, M. Radovic, M. Salluzzo, J. van den Brink, and G. Ghiringhelli
Phys. Rev. Lett. **102**, 167401 (2009)

FIRST Disentangling of magnon and bimagnon

SLS



SAXES @ ADRESS
(SLS)
fall of 2008.

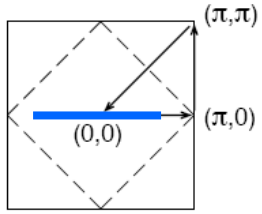


L. Braicovich, J. van den Brink, V. Bisogni, M. Moretti Sala, L. Ament, N.B. Brookes, G.M. de Luca, M. Salluzzo, T. Schmitt, and G. Ghiringhelli (to be published)

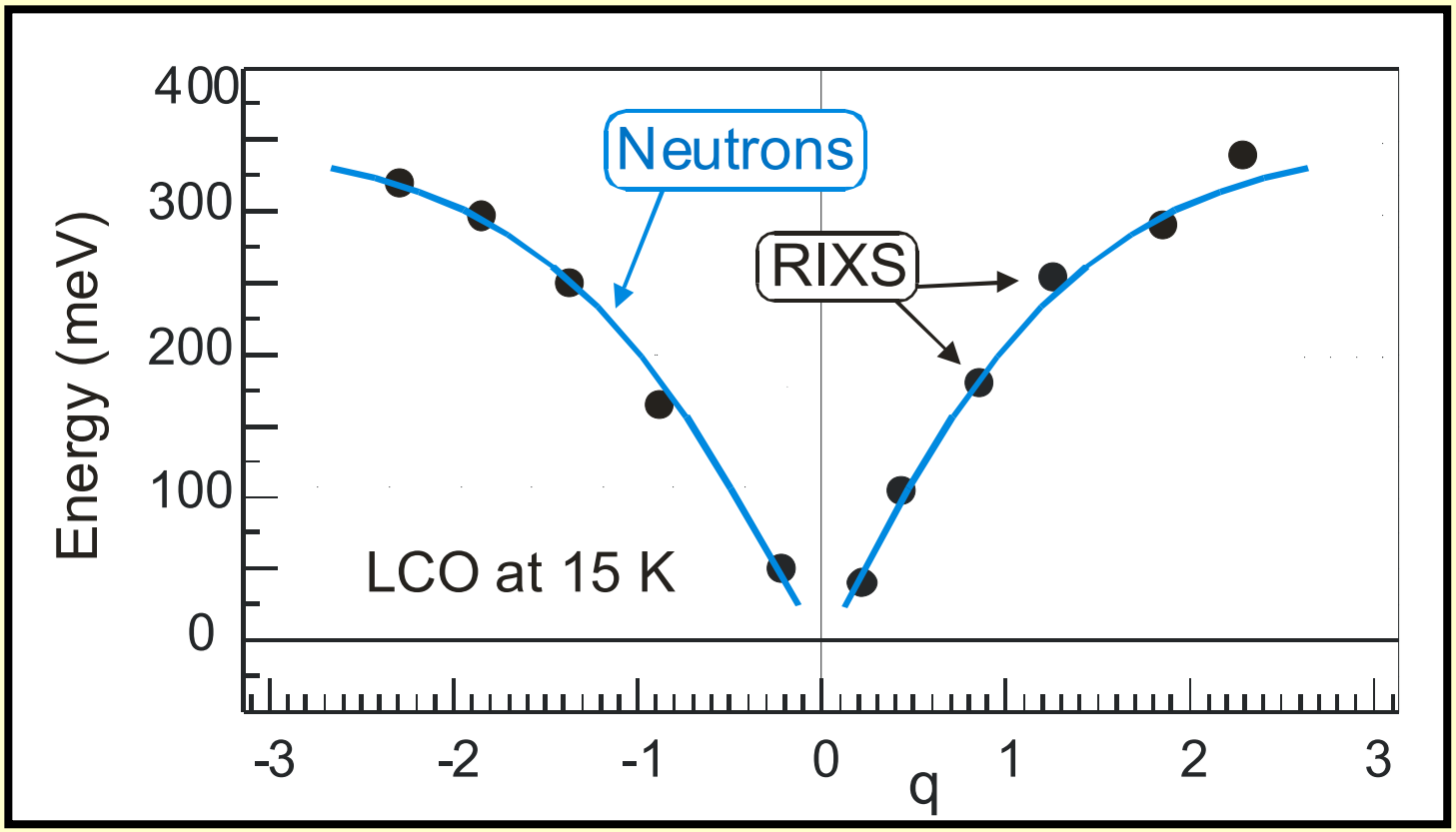
Milan + The Netherland + ESRF + SLS + Naples

RIXS by

L. Braicovich, J. van den Brink, V. Bisogni, M. Moretti Sala, L. Ament, N.B. Brookes, G.M. de Luca, M. Salluzzo, T. Schmitt, and G. Ghiringhelli (to be published)



SLS



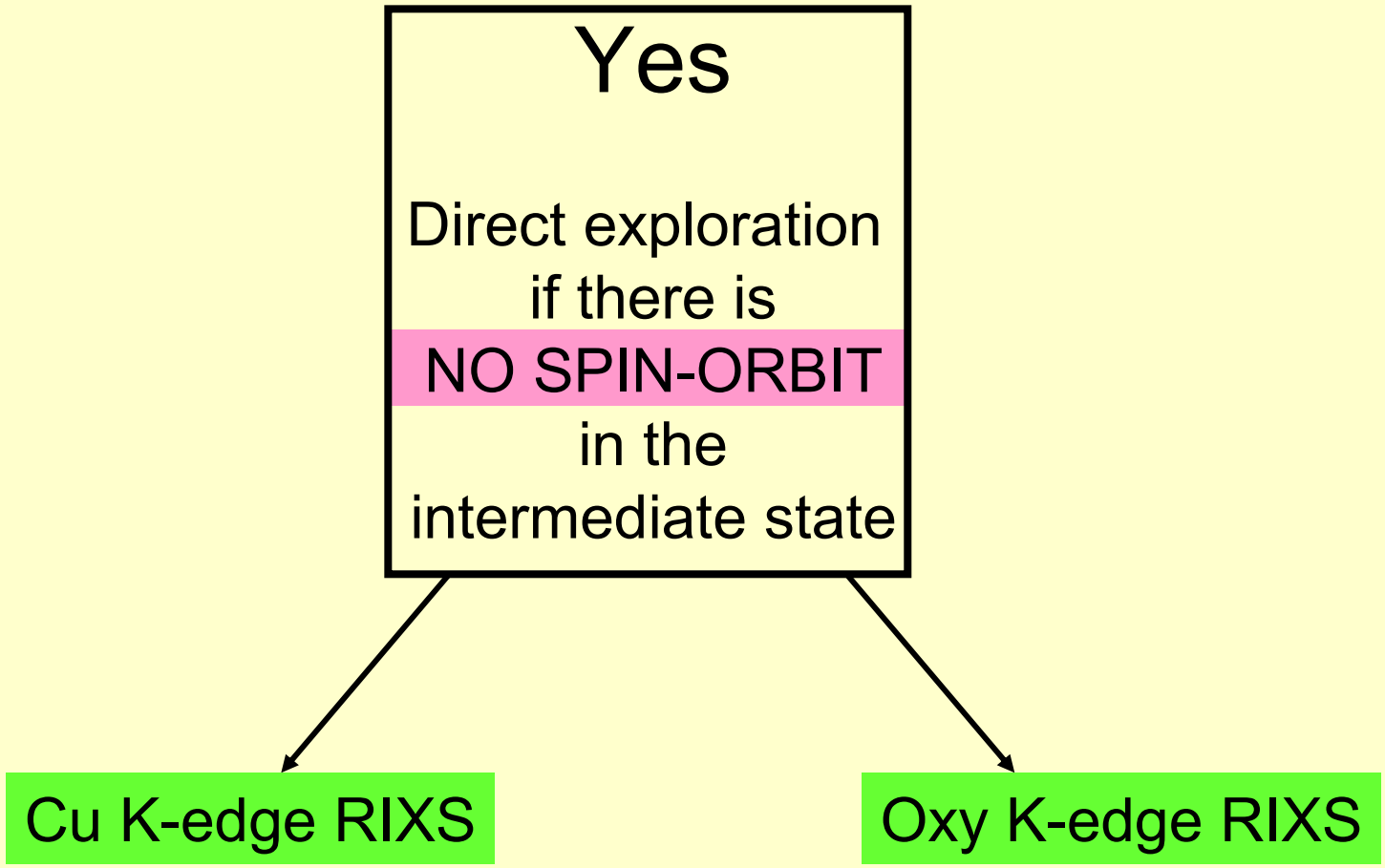
Neutrons by

R. Coldea,[1,2] S. M. Hayden,[3] G. Aeppli,[4] T. G. Perring,[2] C. D. Frost,[2] T. E. Mason,[1] S.-W. Cheong,[5] and Z. Fisk[6]

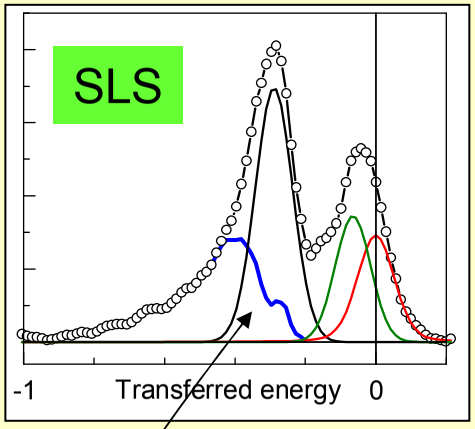
VOLUME 86, NUMBER 23 PHYSICAL REVIEW LETTERS 4 JUNE 2001

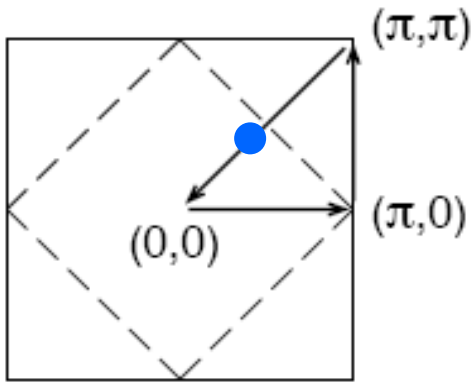
What about bimagnons ?

Any other way to explore bimagnons ?



(J. Hill et al.)

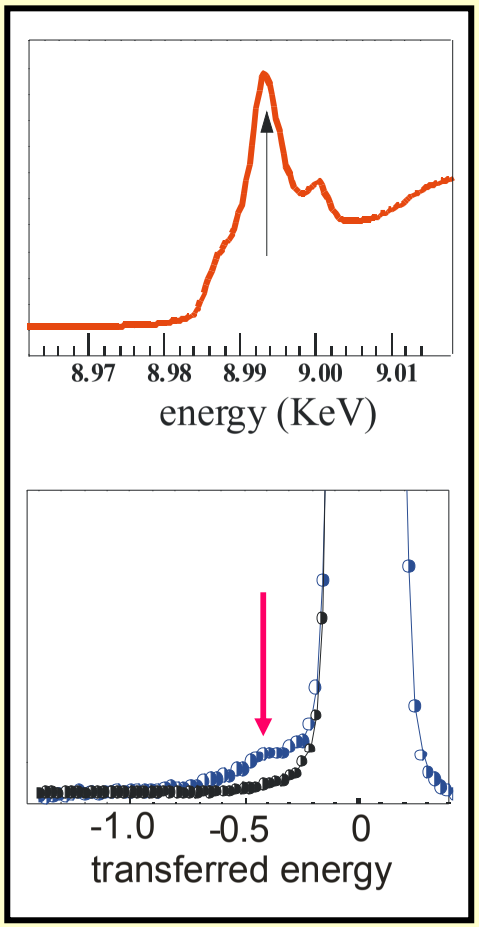


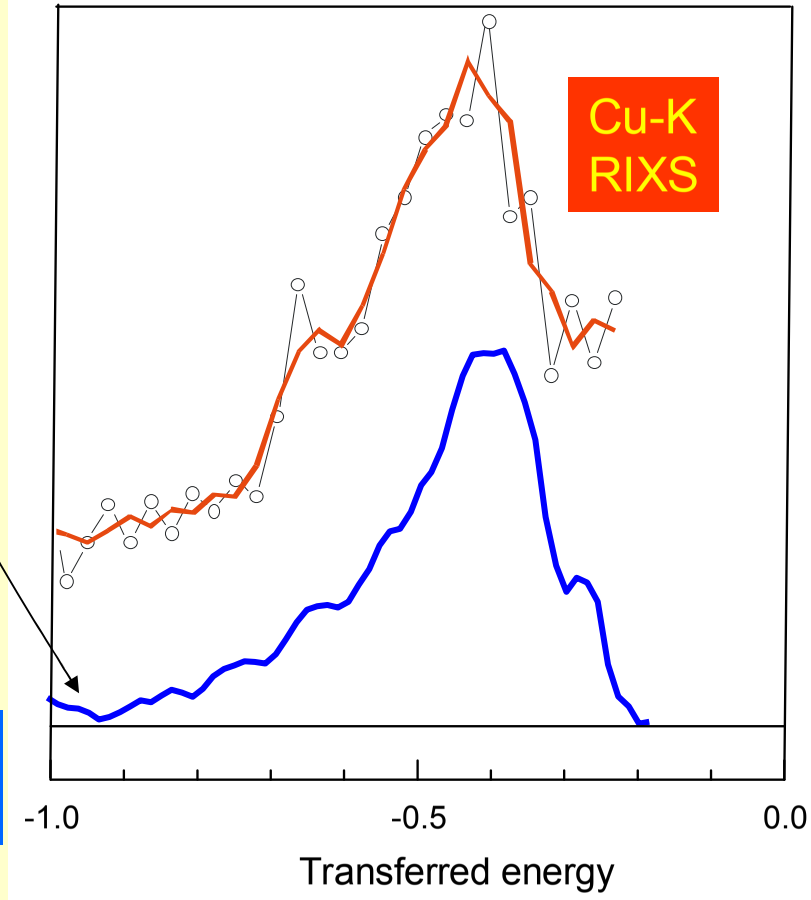


ESRF

Cu-K RIXS

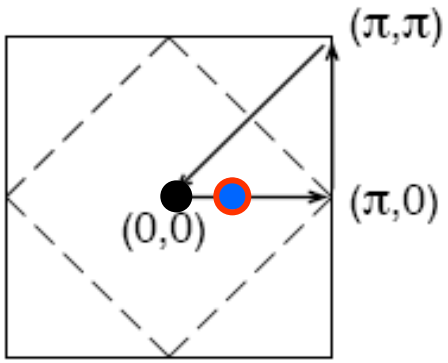
ID16 – ID12 – Milano coll.
V. Bisogni, L. Simonelli et al.

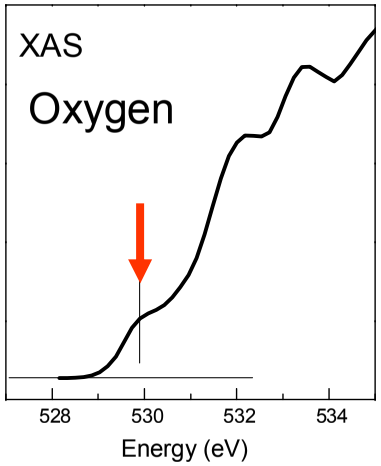




Cu-L3 RIXS

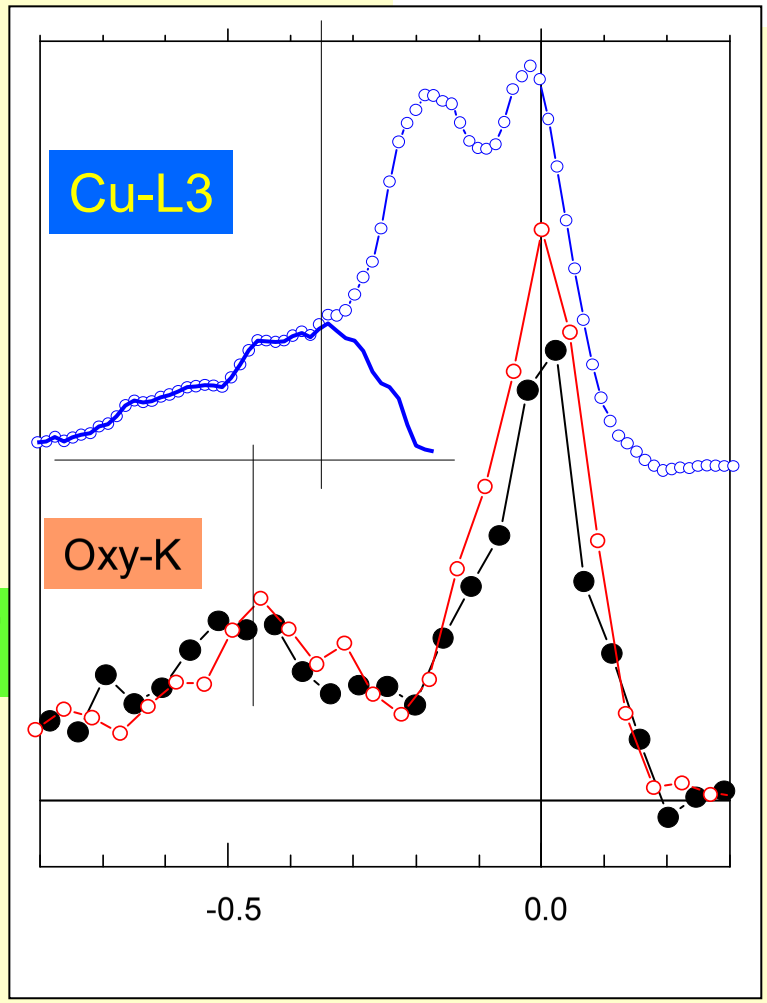
Go to Oxygen K-edge (ESRF)





SLS

ESRF



Different sampling !!!!

Summarizing part I

The highlight is the DISPERSION at all edges (in particular SOFT x-rays)

Cross fertilization with neutrons

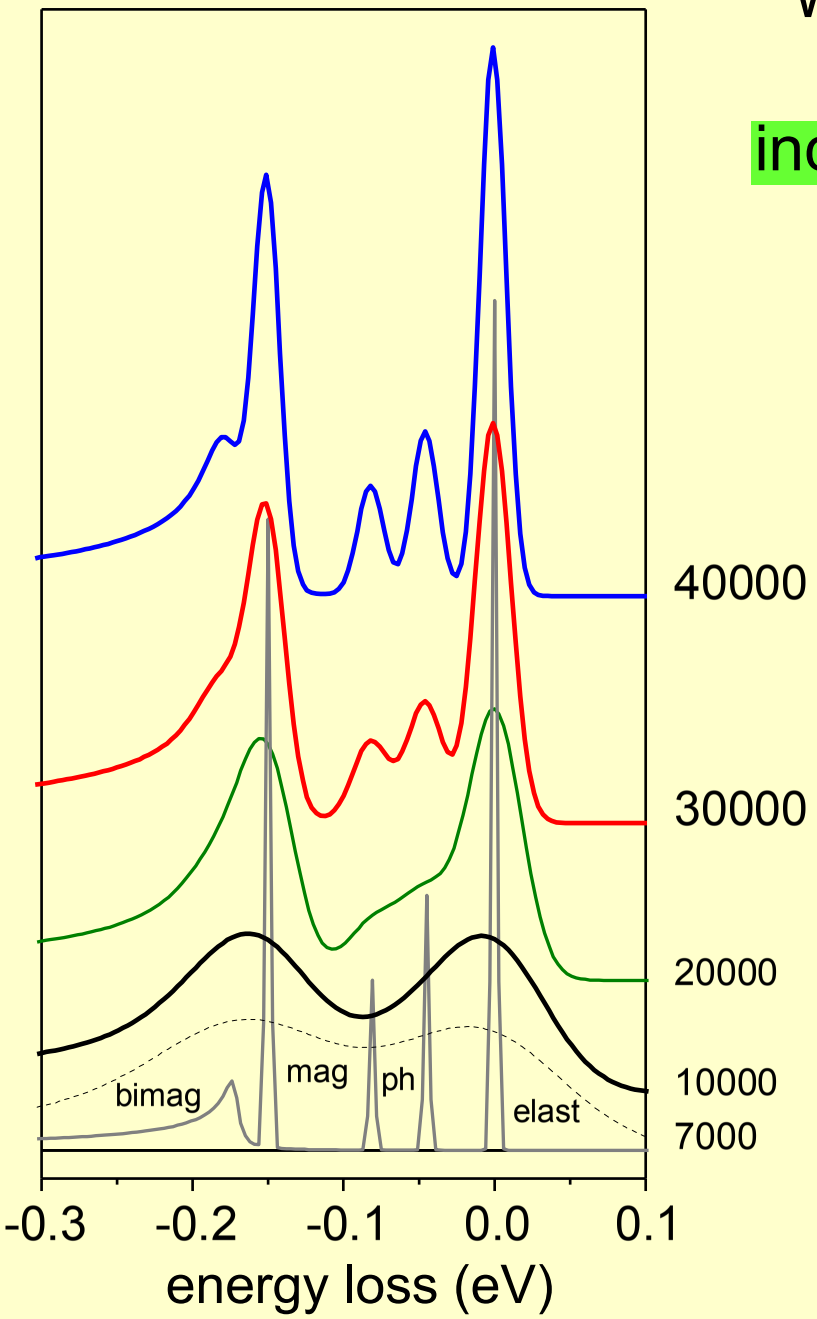
Very small samples (a few monolayers)

Goal: monolayer sensitivity

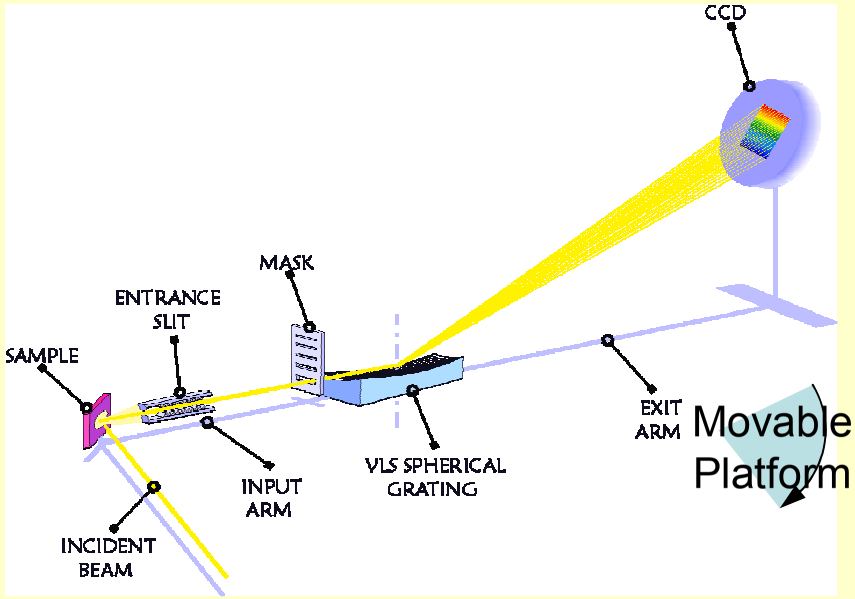
Dramatic expansion of the field with respect to neutrons

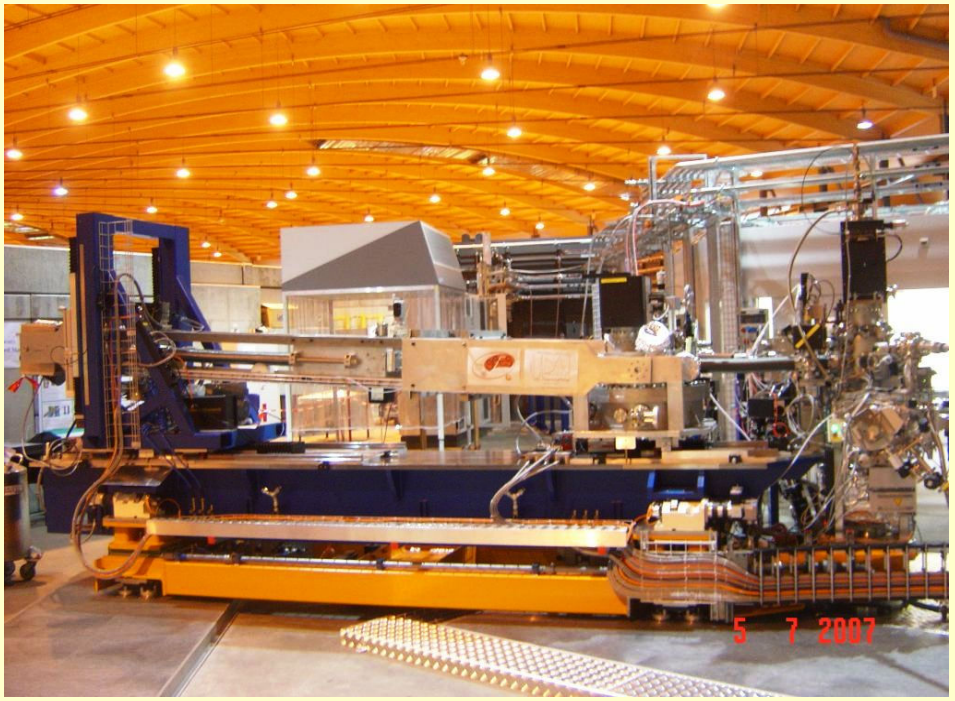
What do we need ?
A considerable
increase of resolution
in the soft range

Around
½ of
the BZ



ESRF + Milano
goal

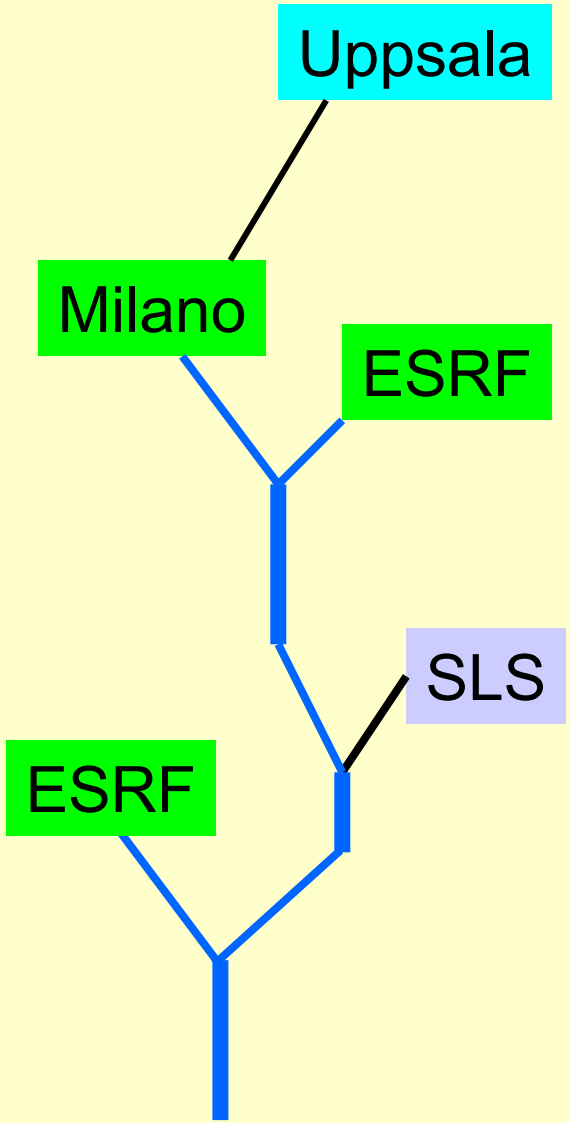




SAXES, a high resolution spectrometer for resonant x-ray emission in the 400–1600 eV energy range

G. Ghiringhelli, A. Piazzalunga, C. Dallera, G. Trezzi, and L. Braicovich
Dipartimento di Fisica, Politecnico di Milano, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy
T. Schmitt, V. N. Strocov, R. Betemps, and L. Patthey
Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
X. Wang and M. Grioni
Institut de Physique des Nanostructures, Ecole Polytechnique Fédéderale de Lausanne, CH-1015 Lausanne,
REVIEW OF SCIENTIFIC INSTRUMENTS **77**, 113108, 2006

Scaling up by a factor of 2 i.e. 10 meters spectrometer


Uppsala
Milano
ESRF
SLS
ESRF

Evolution of BL8 of the ESRF in a new ambitious project

Framework: Electronic and magnetic properties of matter.

Goal: To understand the interplay between the electronic, spin and orbital degrees of freedom which determine the physical properties of materials.

RIXS XMCD

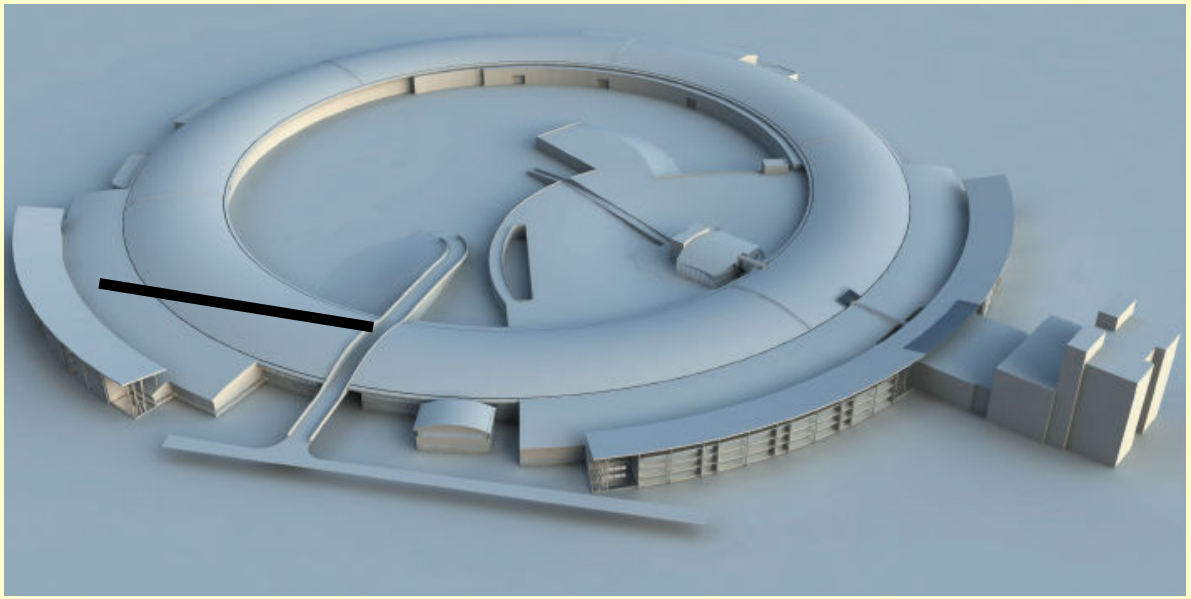
Need of a very long beam-line (typically 120 m) probably with two monochrom. (RIXS and XMCD)

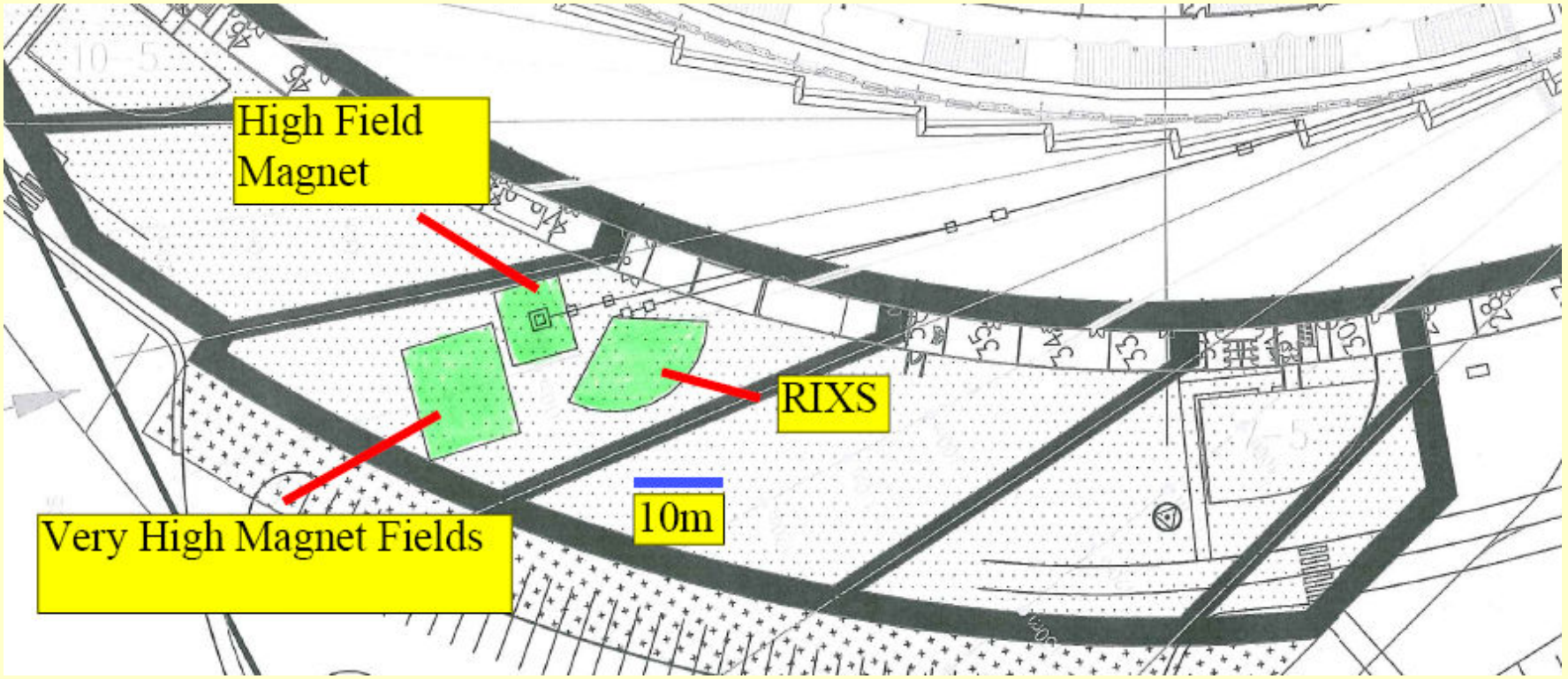
Need of a new building

ESRF Upgrade:

Magnetism “village”
Increased flux.
Increased stability.
Long beamline with space
for experimental infra-structure
even with small beams.
New instruments.

High DC magnetic field lab.?





RIXS: very high combined energy resolution (at least 30000).
Beam sizes (e.g. 3 x 50 microns)
A LOT OF SPACE around the instrument AND AROUND THE SAMPLE for q dependent measurements and
experimental facilities e.g. a high magnetic field.

"XMCD": small spots microns. Space for instrumentation, sample preparation e.g. pulsed laser deposition

An intelligent combination of technologies will allow unique performances of the instruments

The perspective is to tell something really new in the medium period

Past and future of the collaboration with Milano Politecnico

1995 — AXES at the ESRF (Advanced X-ray Emission Spectroscopy)

2007-8 — SuperAXES = SAXES
at SLS (SAXES = success)

2010 — AXES rebuilding at the ESRF

2013 — New RIXS project at the ESRF
ARES (Advanced REsonant Scattering)

Greek name of the God of war
No war. "Wars are not won but only lost" (W. Churchill)
Fair competition

time

MAKE PHYSICS NOT WAR