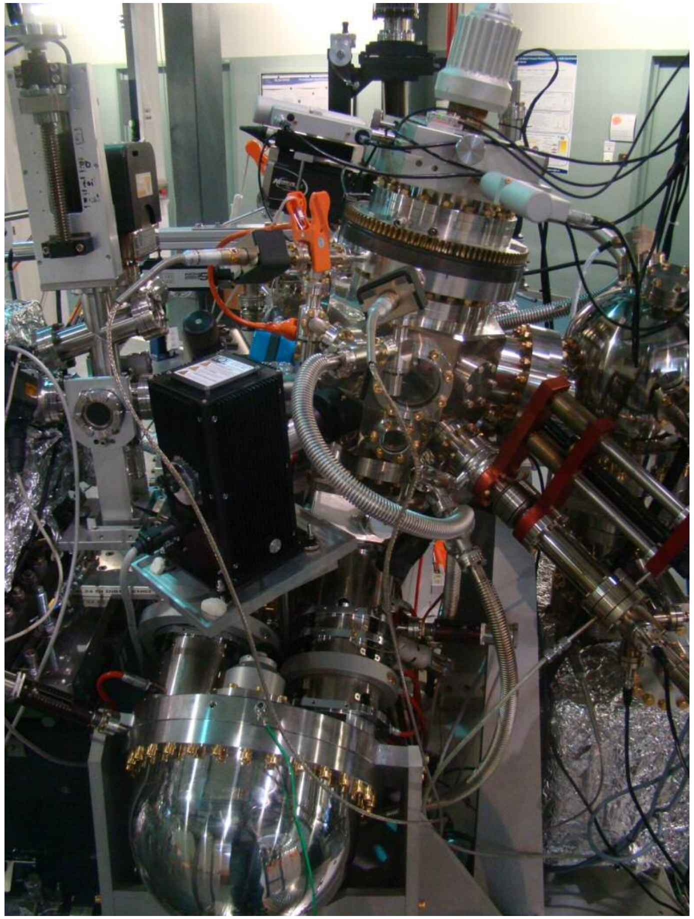
Working principles of LEEM-PEEM

Lucia Aballe

Michael Foerster



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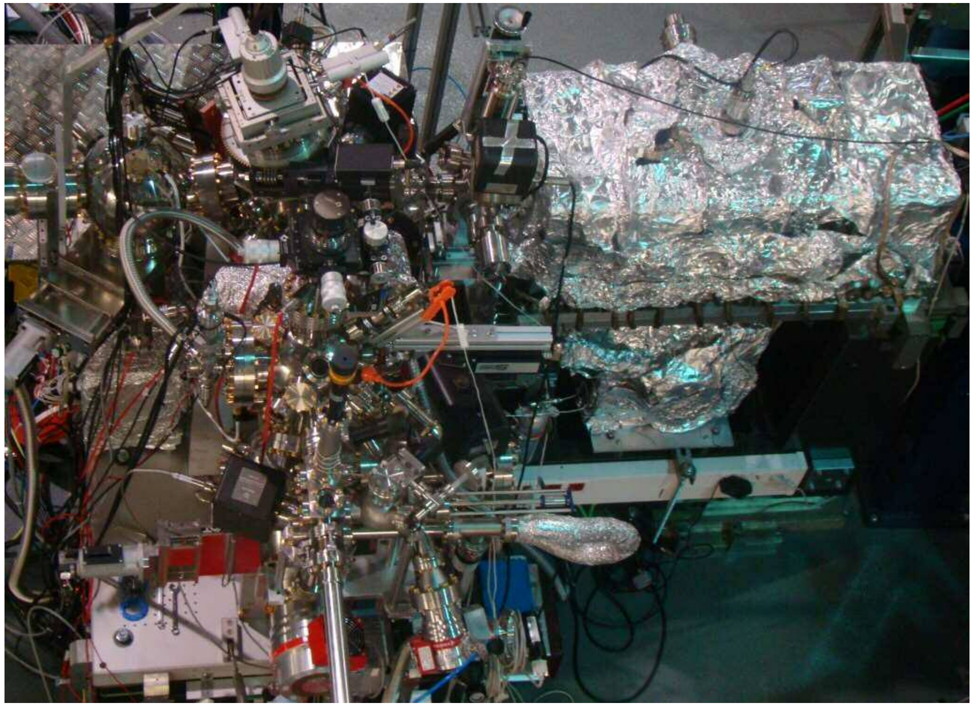
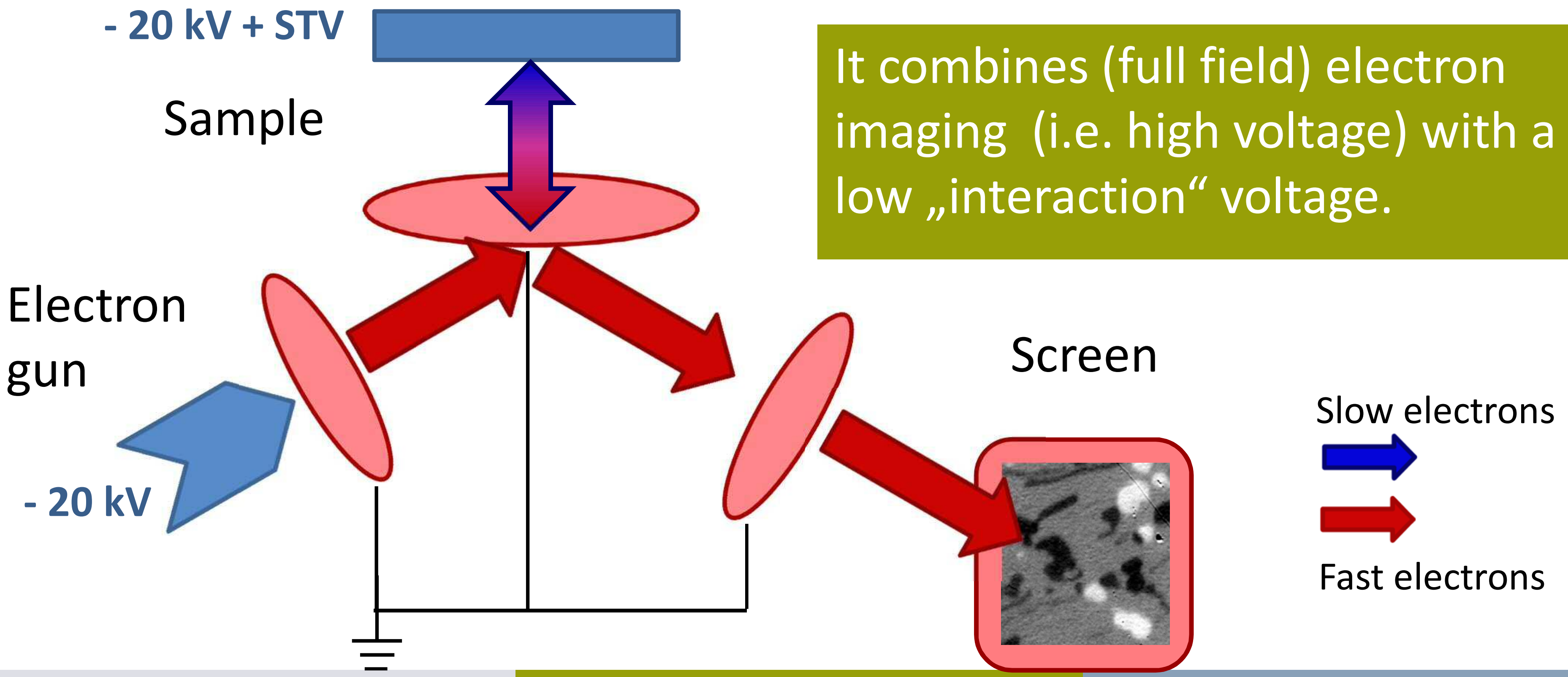
BL24 - PEEM

… it is connected to the synchrotron
… it is a LEEM
… it uses high Voltage



Low energy electron microscope (LEEM) (Bauer, 1962, 1985)

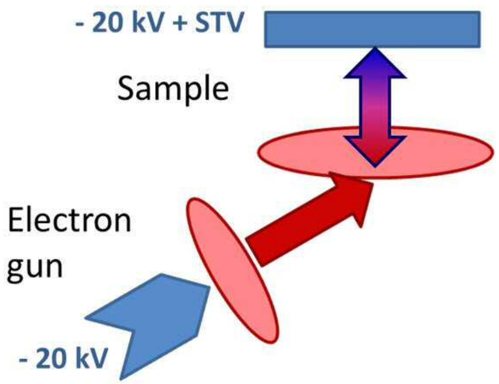
Cathode lense or immersion microscopy: electrons are accelerated by electric field between sample and the first lense (Objective).

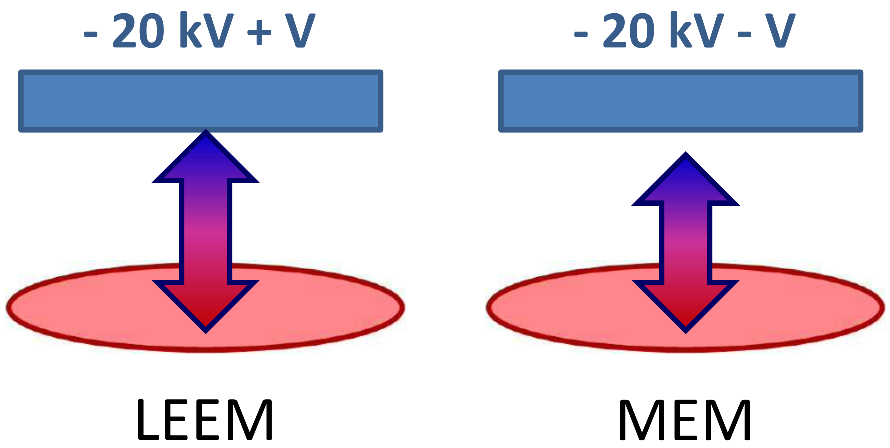


It combines (full field) electron imaging (i.e. high voltage) with a low „interaction“ voltage.

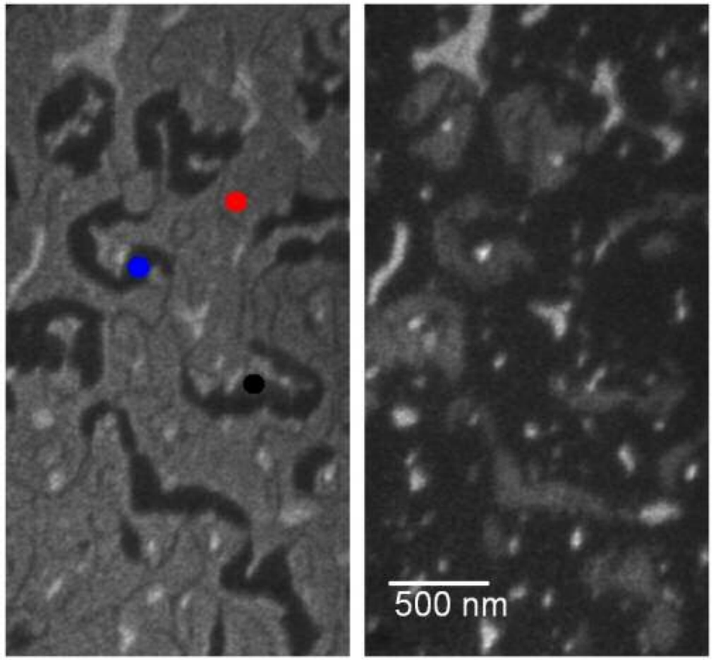
Start voltage STV

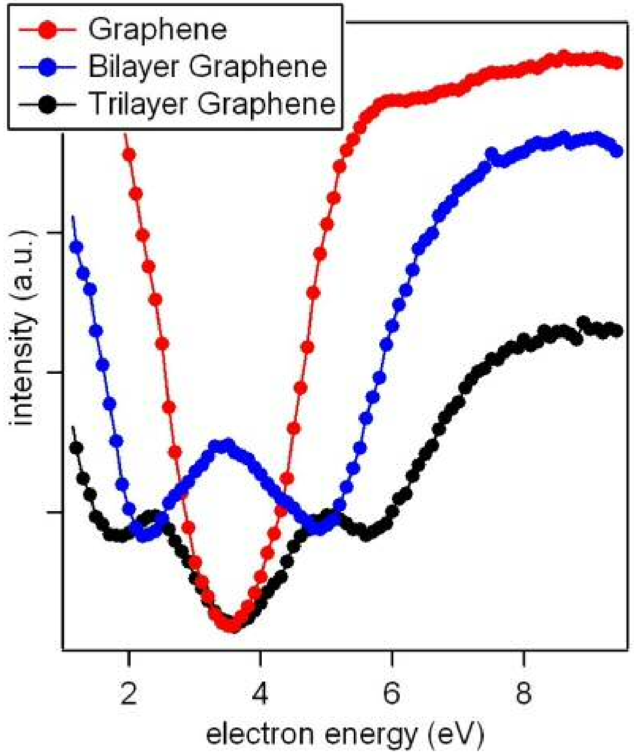
- The voltage offset STV between the e-gun and the sample is called **Start Voltage.** It defines the kinetic energy of the electrons arriving at the sample.
- Varying the start voltage between -5 until +100 V, different contrast mechanisms are accesible (work function, quantum confinement).
- For negative STV, the electrons do not reach the sample. The sample is acting as electrostatic mirror (mirror electron microscopy (MEM)).





Quantum confinement





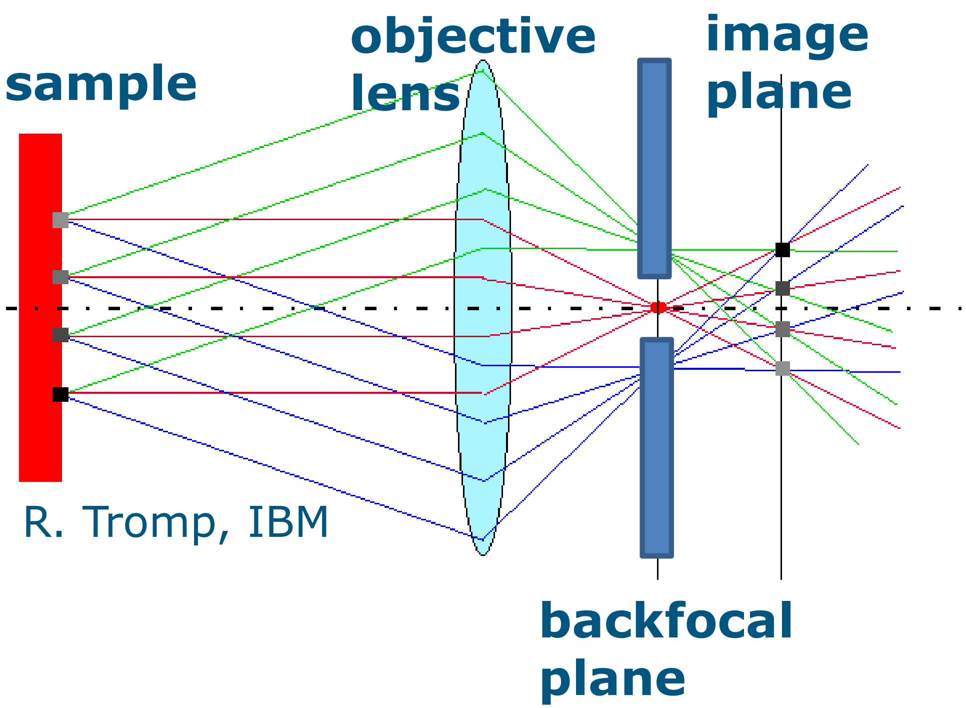
IV- LEEM: counting atomic layers in graphene
P. Merino & J.A. Martin-Gago (ICMM)

Aberrations and resolution

- The spatial resolution is limited by several effects to typically < 10nm in LEEM. (approaching 1 nm in new aberration corrected type)
- **Spherical aberration:** electron far off center of the optical axis are deviating (Contrast Aperture)
- **Chromatic aberration (in XPEEM):** electrons with different energy are deviating (Energy Analyzer)
- **Diffraction limit**

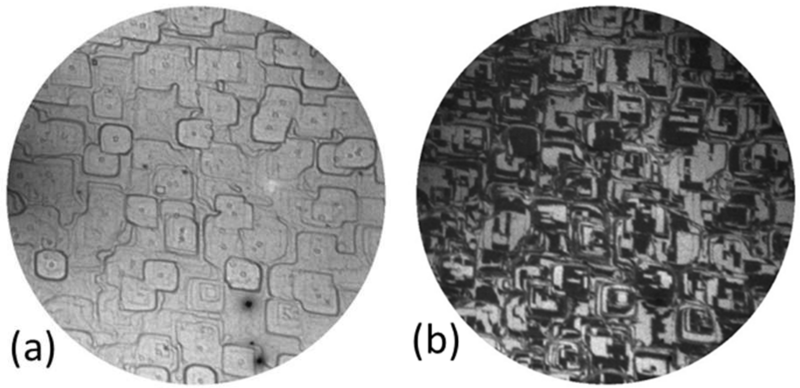
Contrast aperture and dark field

- To reduce the spherical aberration, the **Contrast Aperture** (CA) is introduced into a backfocal (diffraction) plane



R. Tromp, IBM

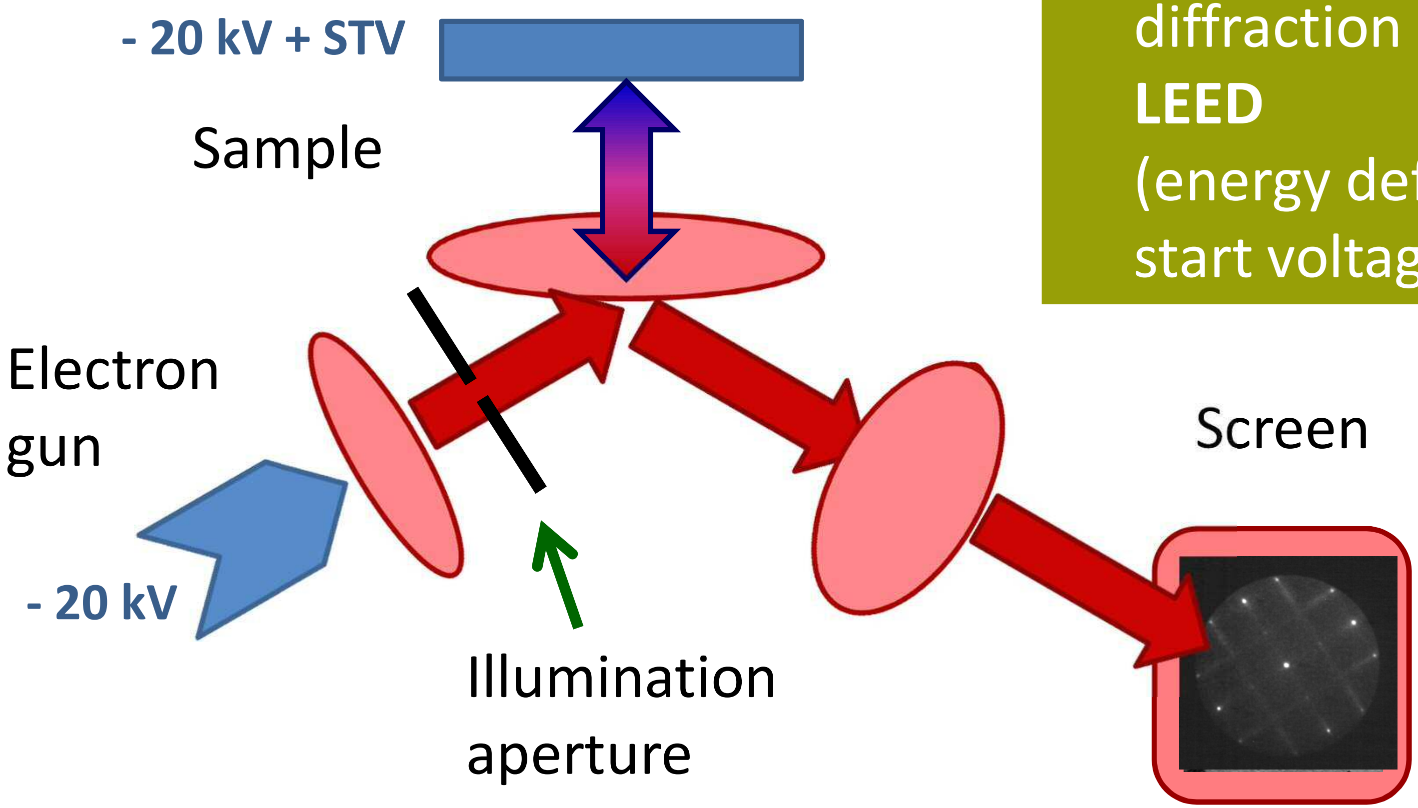
- **Darkfield imaging**: using diffracted electron beam for the image



L. Martin, M. Monti, J. Marco, J. Figuera (IQFR-CSIC, Instituto de Química Física "Rocasolano")

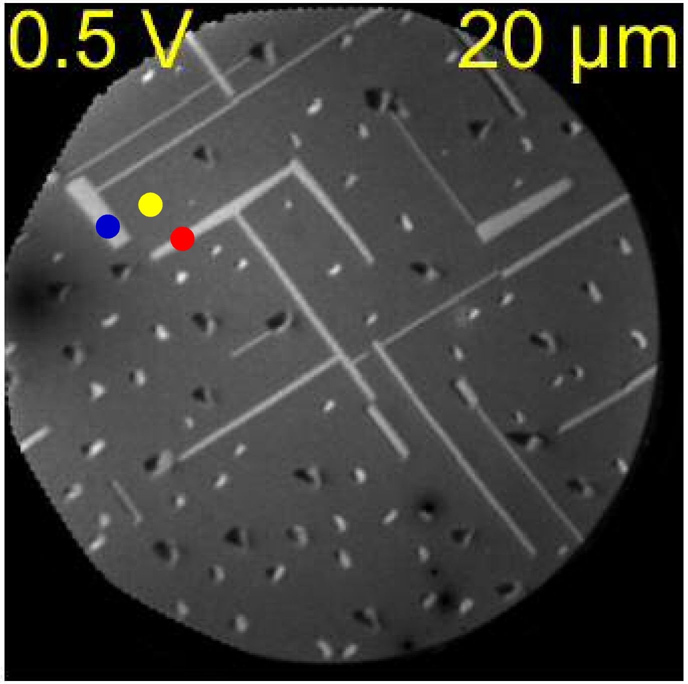
LEED

- We can also image a diffraction plane, i.e. **LEED** (energy defined by the start voltage)

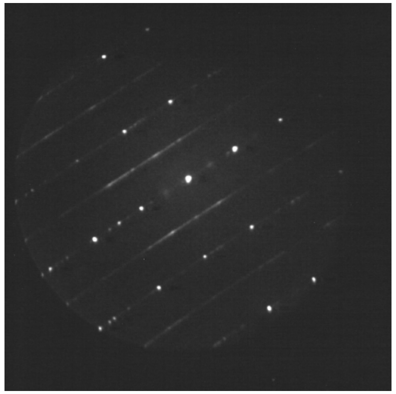


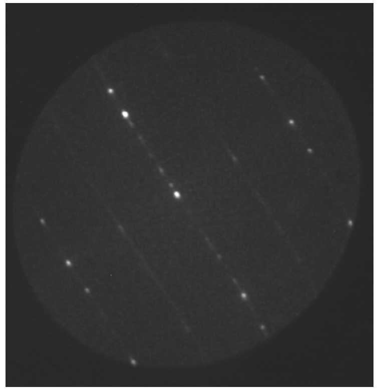
Illumination aperture

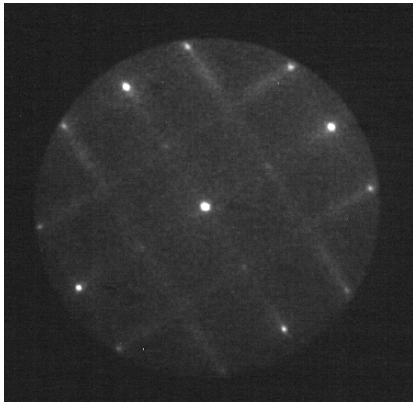
- In LEED mode we can define the area of which the diffraction pattern is taken (down to 0.5um) by the **Illumination aperture**



(J.I. Flege, et al University of Bremen)





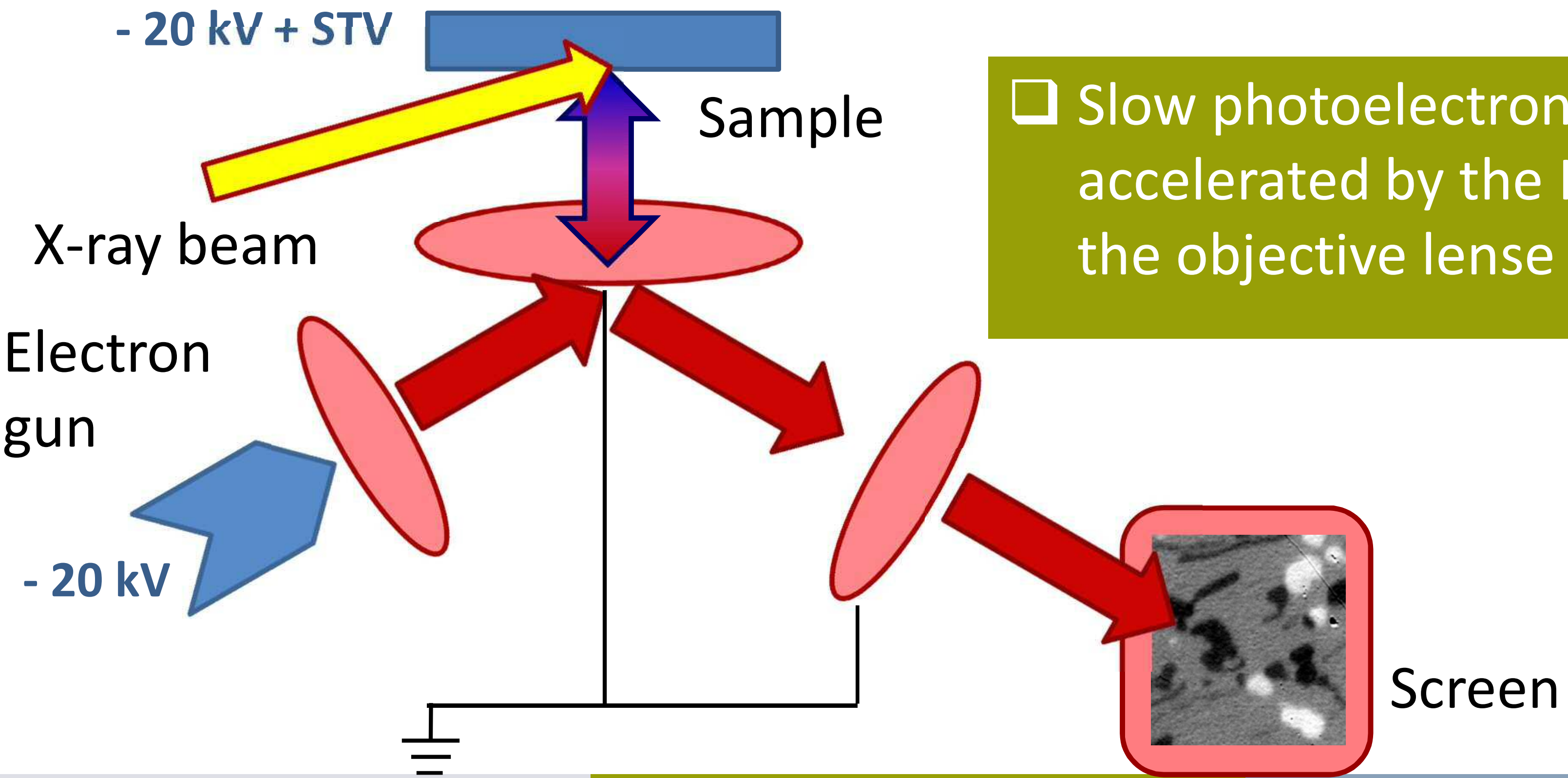


LEEM modes and sensitivity

Mode	Parameter/ tool	Contrast/ sensitivity
❑ LEEM ❑ MEM ❑ LEED ❑ u-LEED ❑ DF-LEEM	❑ STV ❑ Projector settings ❑ Contrast aperture ❑ Illumination aperture	❑ Topography ❑ Workfunction ❑ Quantum confinement ❑ Structure

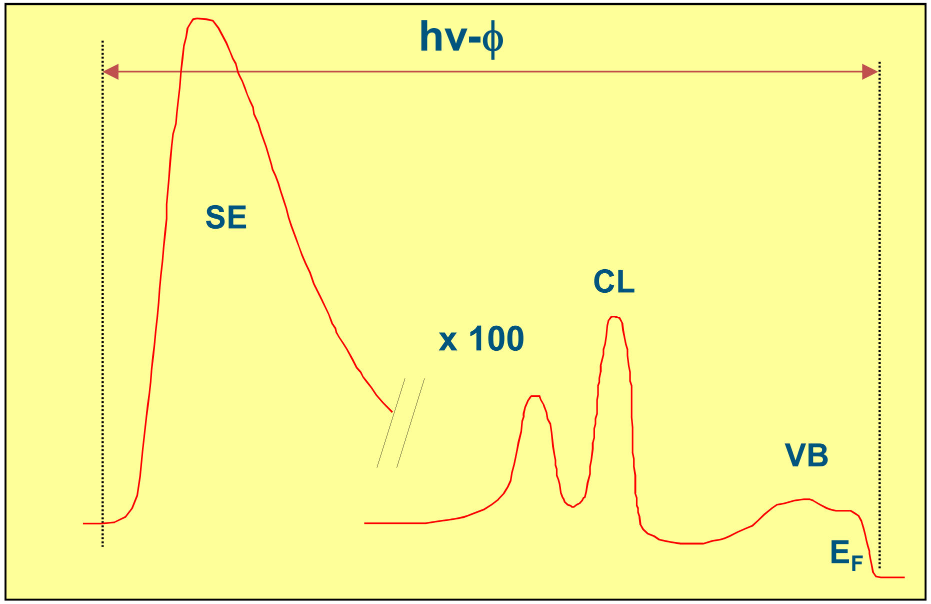
From LEEM to PEEM

- ❑ Technically „easy“: just replace e-gun by photons (UV lamp, laser or Synchrotron)
- ❑ Photo Emission Electron Microscope (PEEM or XPEEM with X-rays)



- ❑ Slow photoelectrons are accelerated by the HV of the objective lense

From LEEM to XPEEM

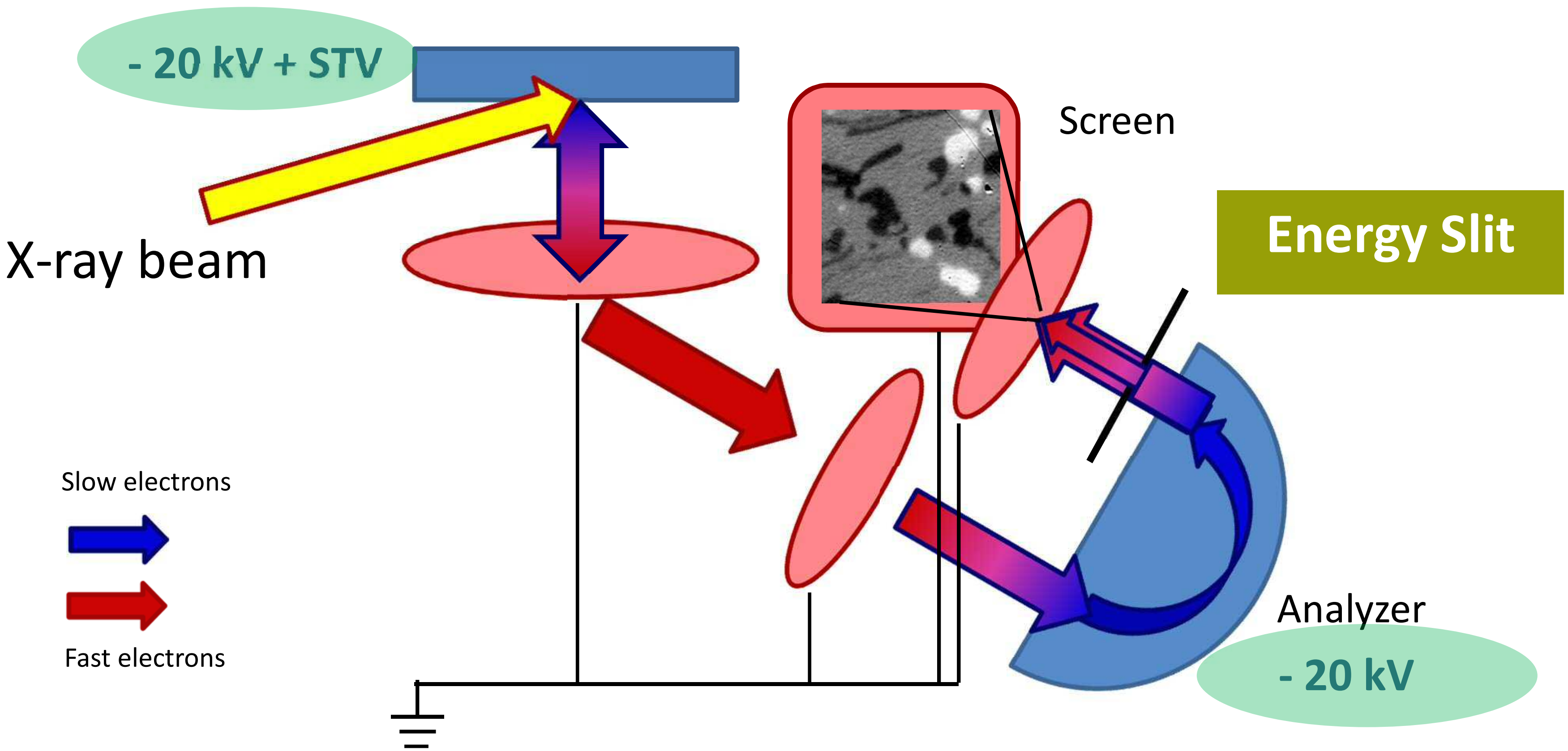


Kinetic Energy (eV)

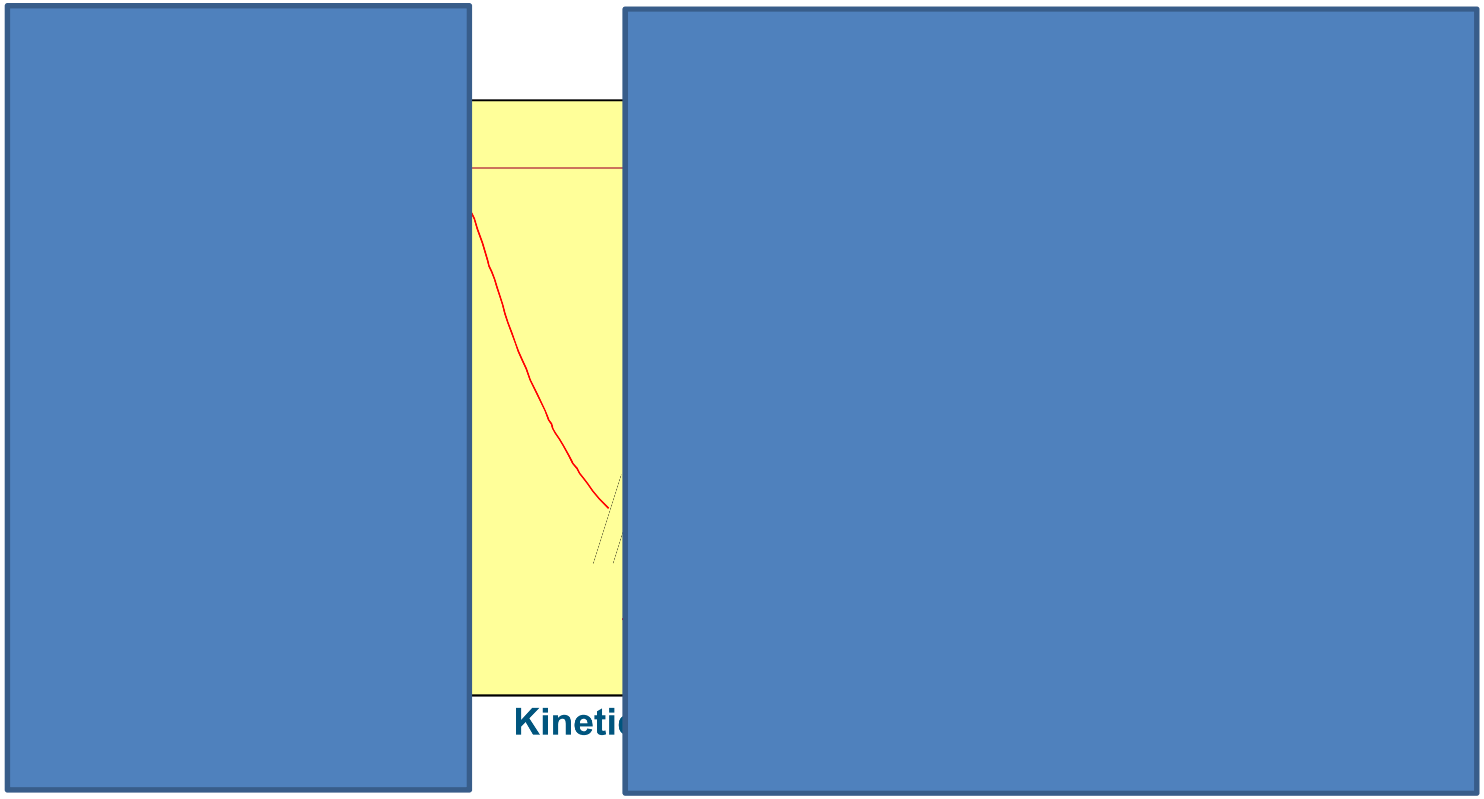
- Under synchrotron X-ray illumination, all kind of electrons come out of the sample, but mainly low energy secondaries

From LEEM to XPEEM

- Adding an electron analyzer and energy slit: **spectroscopic LEEM/PEEM** (note that STV is sample offset)



How to select the electrons we want?



Changing STV moves the electron spectrum through the fixed acceptance window (energy slit):
STV = kinetic energy of accepted electrons (XPS)

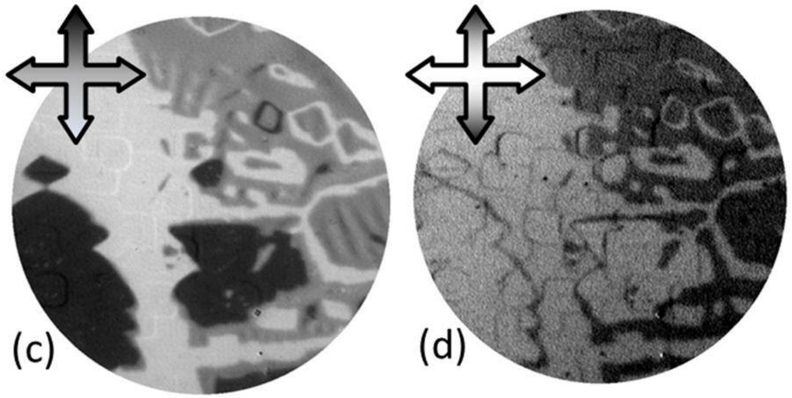
Benefits of X+PEEM

- scanning hν : XAS, EXAFS
- scanning STV (const. hν) : XPS
- diffraction mode: ARPES

- Elemental
- Chemical
- Magnetic: XMCD/XMLD
- Directional (orbitals) nXLD

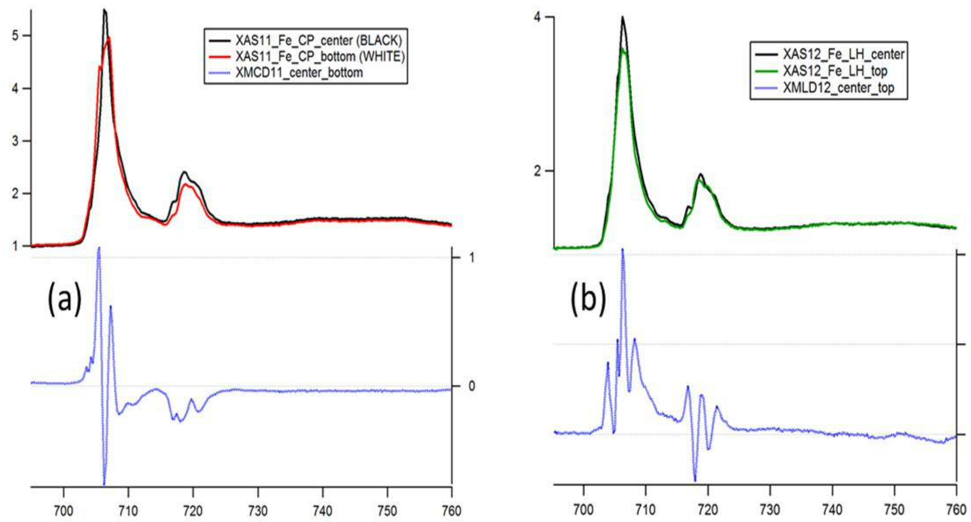
- Photon energy
- Polarization
- Kinetic Energy (STV)

Spectromicroscopy



"images with spectral contrast"

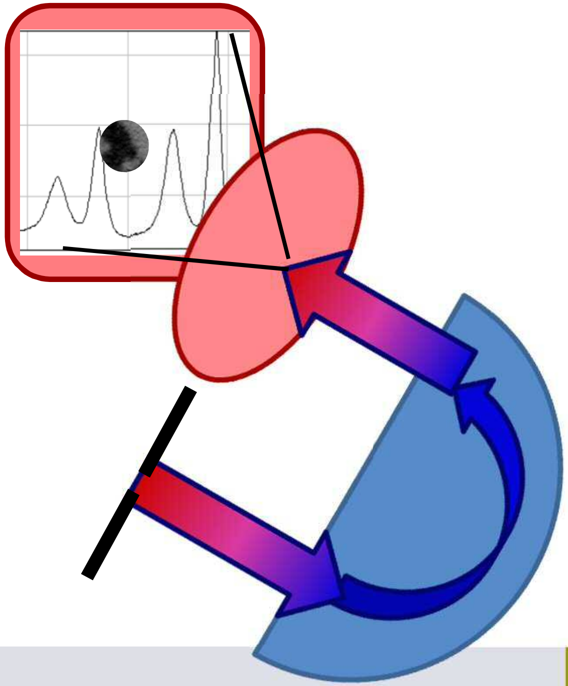
"spectroscopy with spatial resolution" (pixel by pixel)

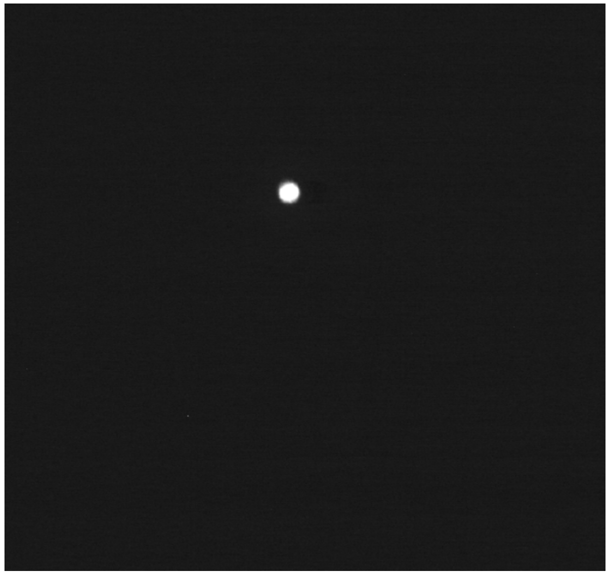


L. Martin, M. Monti, J. Marco, J. Figuera
(IQFR-CSIC, Instituto de Química Física "Rocasolano")

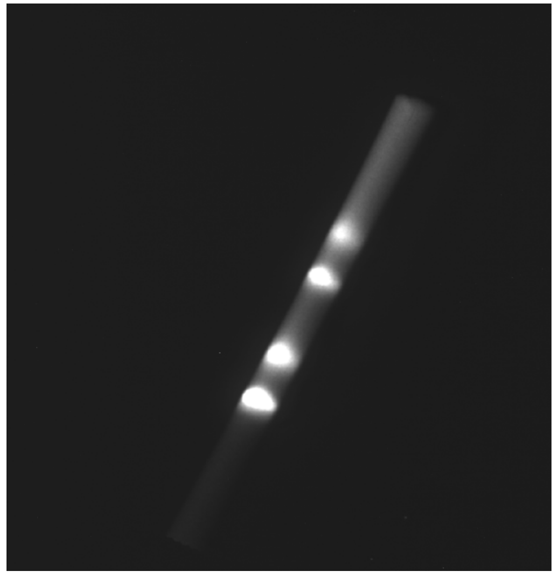
Dispersive plane

- Microscope works best with low kinetic energy, at high STV, transmission is much lower
- For XPS, we get better statistics and energy resolution when we image the **Dispersive Plane** of the analyzer and obtain spatial resolution by an aperture in an image plane **(Selected Area)**





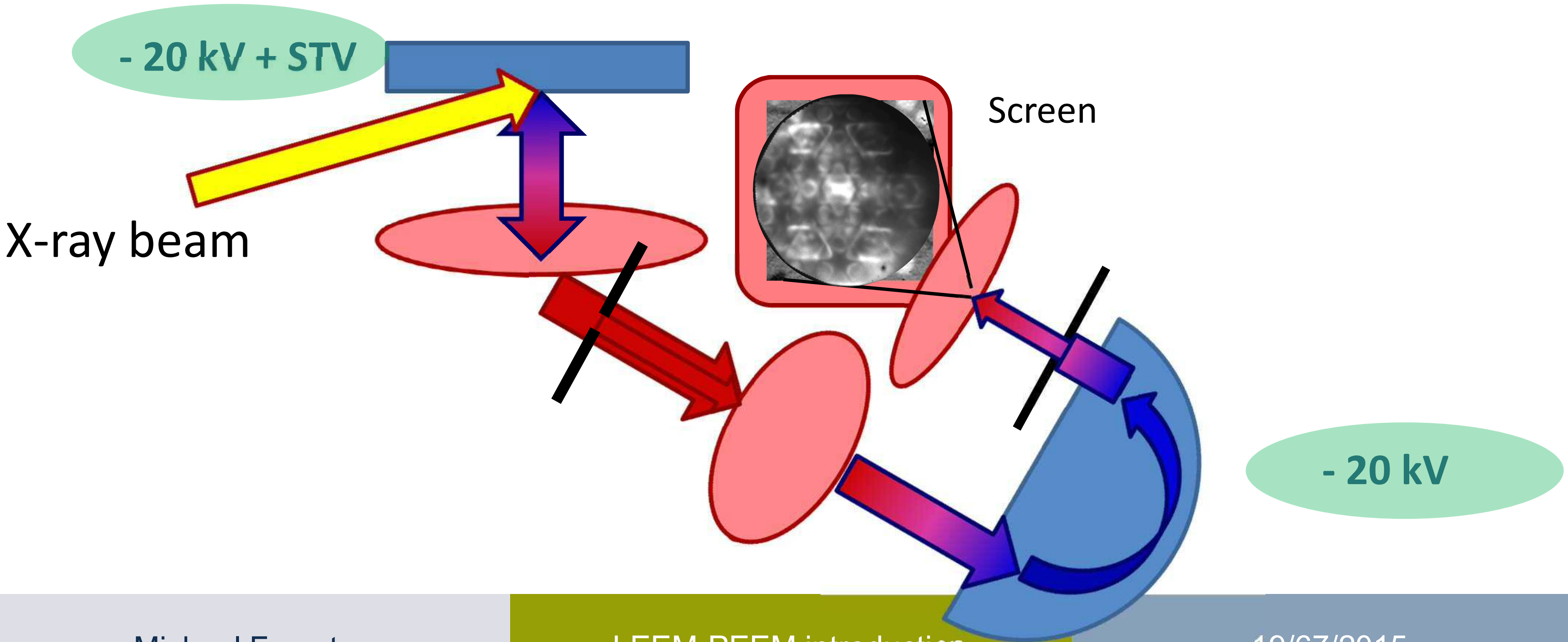
SA in image



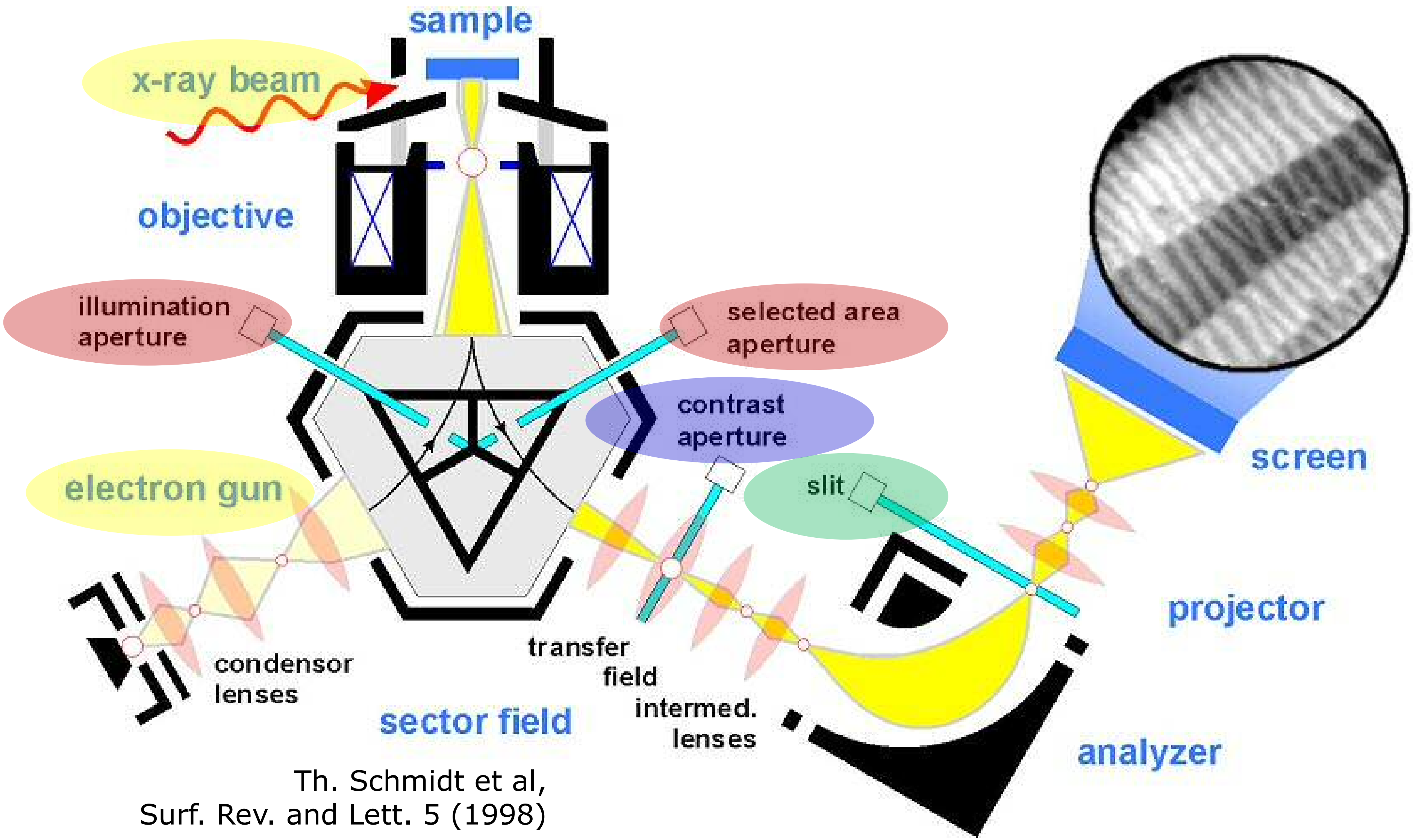
Dispersive image on detector

ARPES with selected area

- ❑ Microscope in diffraction mode for angle resolved Photoemission spectroscopy (ARPES)
- ❑ Image k_x-k_y at constant energy (ΔE ca. 200meV)
- ❑ Spatial resolution by selected area aperture

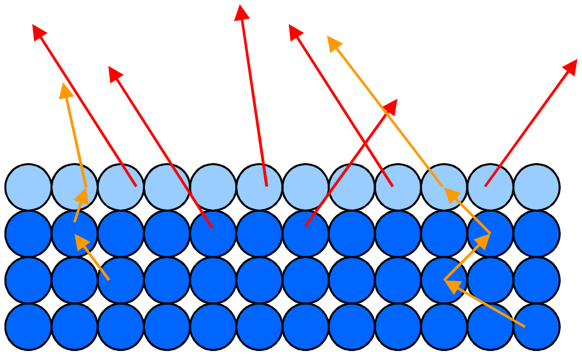


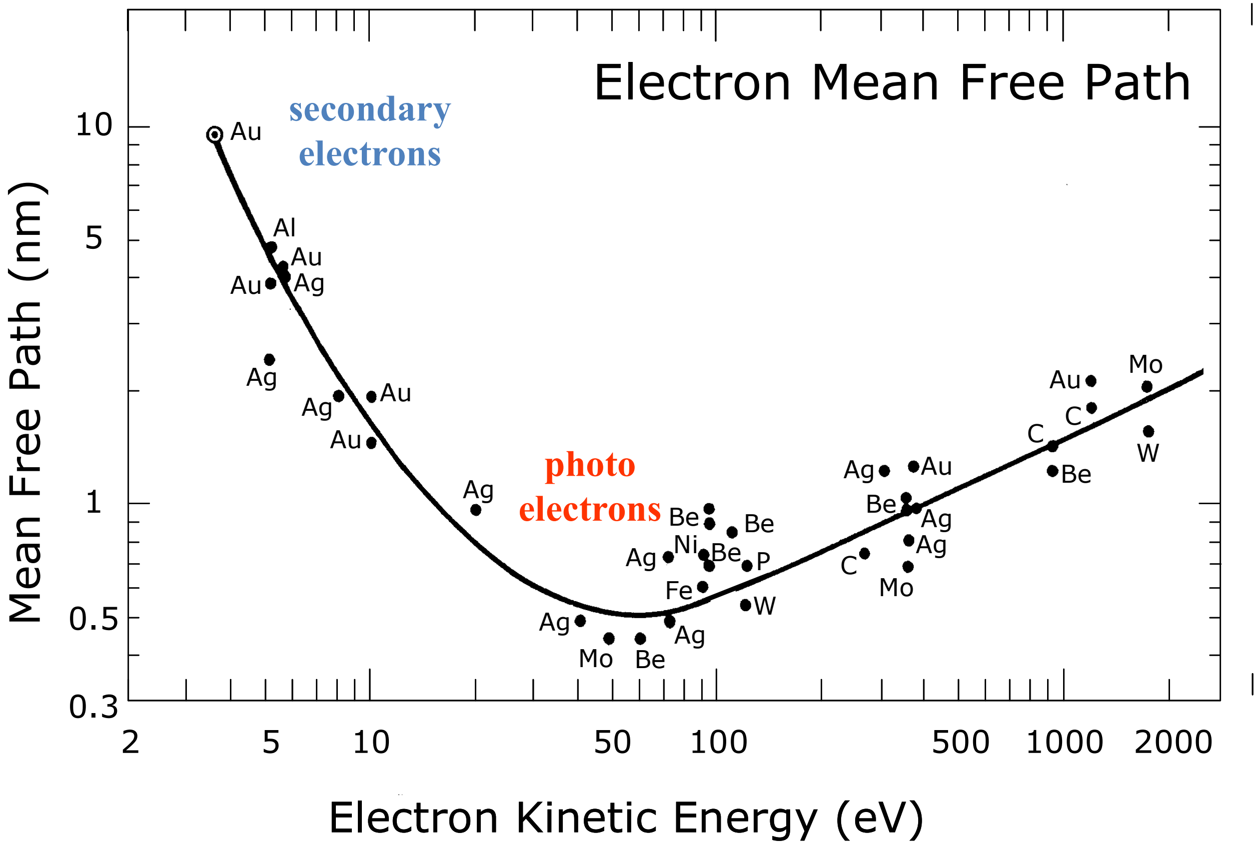
A more complete picture



Th. Schmidt et al,
Surf. Rev. and Lett. 5 (1998)

Surface sensitive





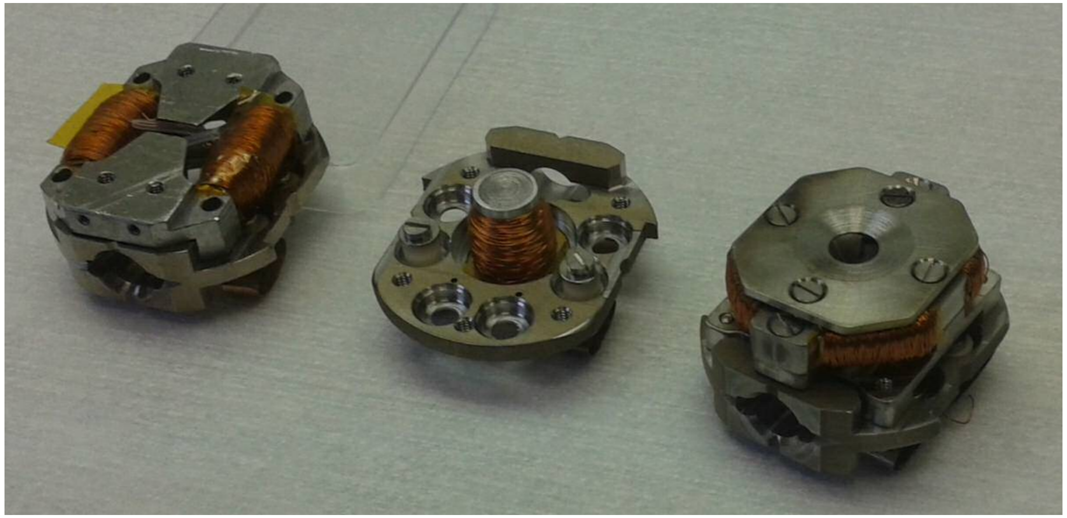
X ray penetration depth >> Electron escape depth

Sample environment

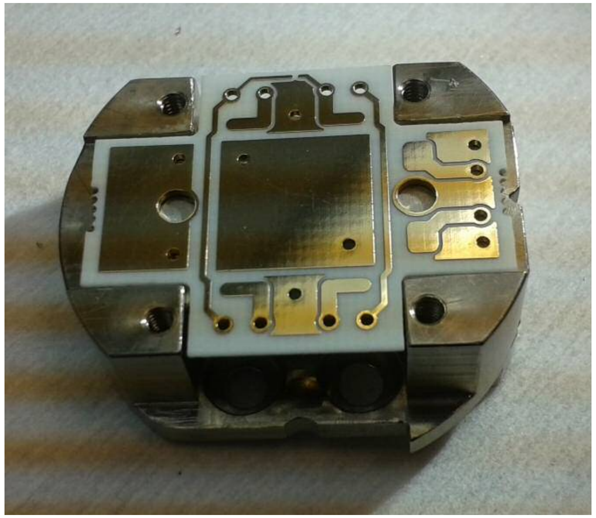
- Requirements: UHV compatible, reasonable large, flat and not too insulating
- Standard options: sputter cleaning, heating (>1500 K), cooling (>150K), low pressure gas exposure, in situ metal evaporation
- All electronics connected to the sample must float on HV

Customized environment @ALBA

- In situ magnetic fields: OOP, IP, biaxial IP (small)
- In situ electrical poling: OOP or in-plane electrodes



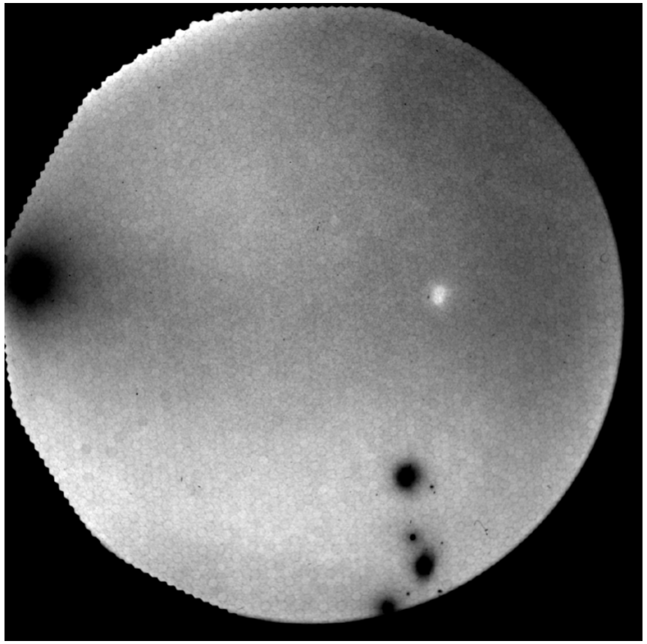
Based on design from BESSY (F. Kronast)



Based on design from SLS

Keep in mind

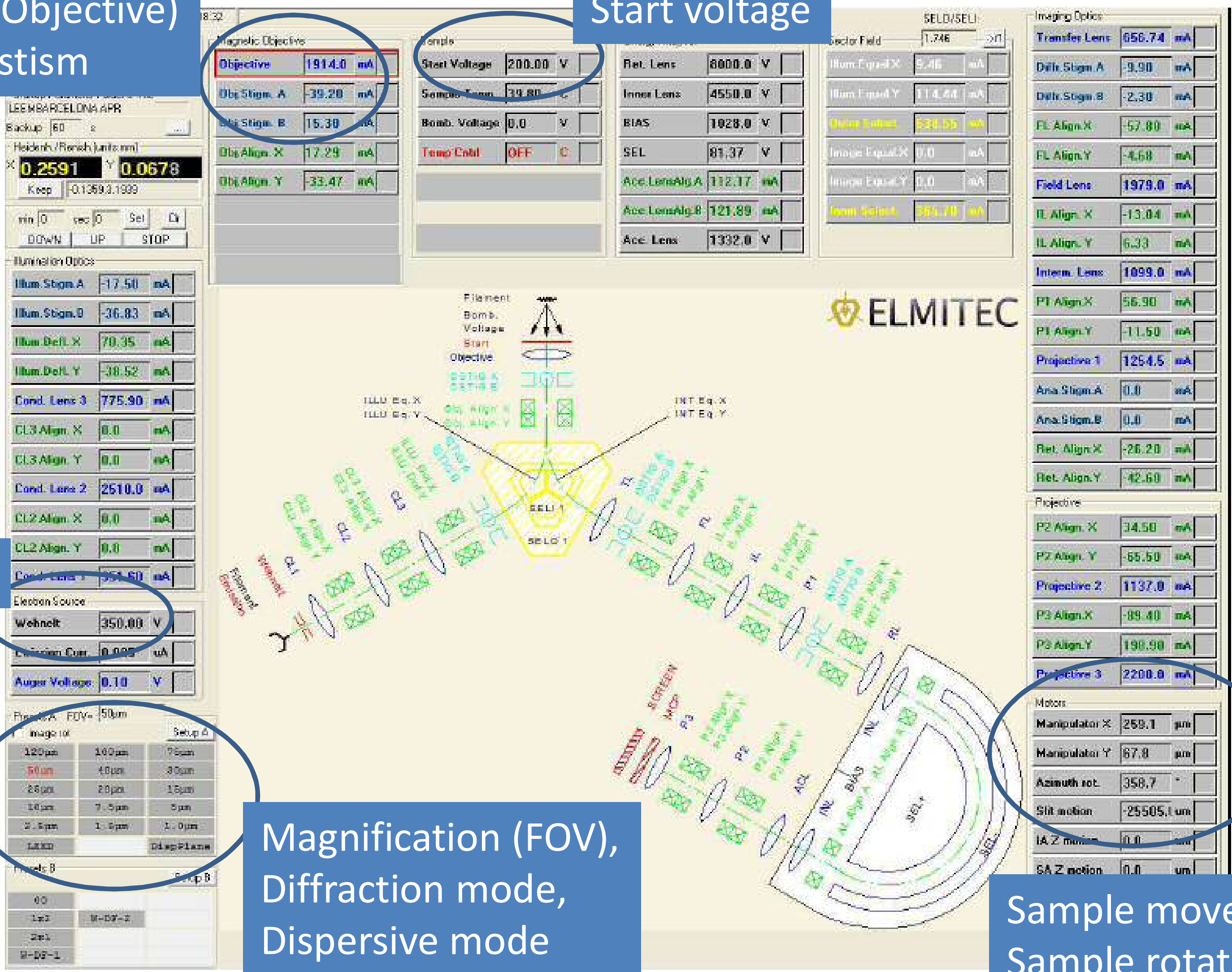
- UHV system with sample transfers, many pumps and valves
- High voltage between sample and lense (20 kV in ca. 2mm), risk of discharges, clean, flat samples, sufficient degassing (the day before)
- Detector overexposure and damage (there is an automatic protection, but it works only when camera is run in the proper way)
- Take normalization image



The control panel

Focus (Objective)
Stigmastism

Start voltage



e-gun intensity

Magnification (FOV),
Diffraction mode,
Dispersive mode

Sample movement
Sample rotation

Thank you‘s

Laura Campos
User office
Sergi Puso, Sergio Vicente, Gemma Rosas (Systems)
Salvador Ferrer
Alba Staff

The speakers:
Juan de la Figuera
Florian Kronast

You!