# APE group

- Giorgio Rossi

- **Staff** *(**IOM-CNR**, TASC)*:
  - Jun Fujii
  - Damjan Krizmancic
  - Giancarlo Panaccione
  - Piero Torelli
  - Ivana Vobornik

**Postdoctoral fellows:**
- Emilia Annese
- Manju Unnikrishnan

- **Former members**
  - Bo Zhou *(now @ Fudan University, Shanghai, China)*
  - Michael Hochstrasser *(now @ EU Patent Office, Amsterdam, NL)*
  - Luca Giovanelli *(now @ Uni. Marseille, F)*
  - Cinzia Cepek *(now @ TASC, I)*
  - Mikhail Galaktionov *(now @ Ioffe Inst., St. Petersburg, RU)*
  - Jörg Kröger *(now @ Uni. Kiel, D)*

- **PhD students** (2003-2009)
  - Carlos Viol *(now @Max-Planck-Institut für Mikrostrukturphysik, Halle, D)*
  - Francesco Maccherozzi *(now @ Diamond, UK)*
  - Mattia Mulazzi *(now @ Uni. Würzburg, D)*
  - Mauro Fabrizioli *(now @ Elettra, I)*

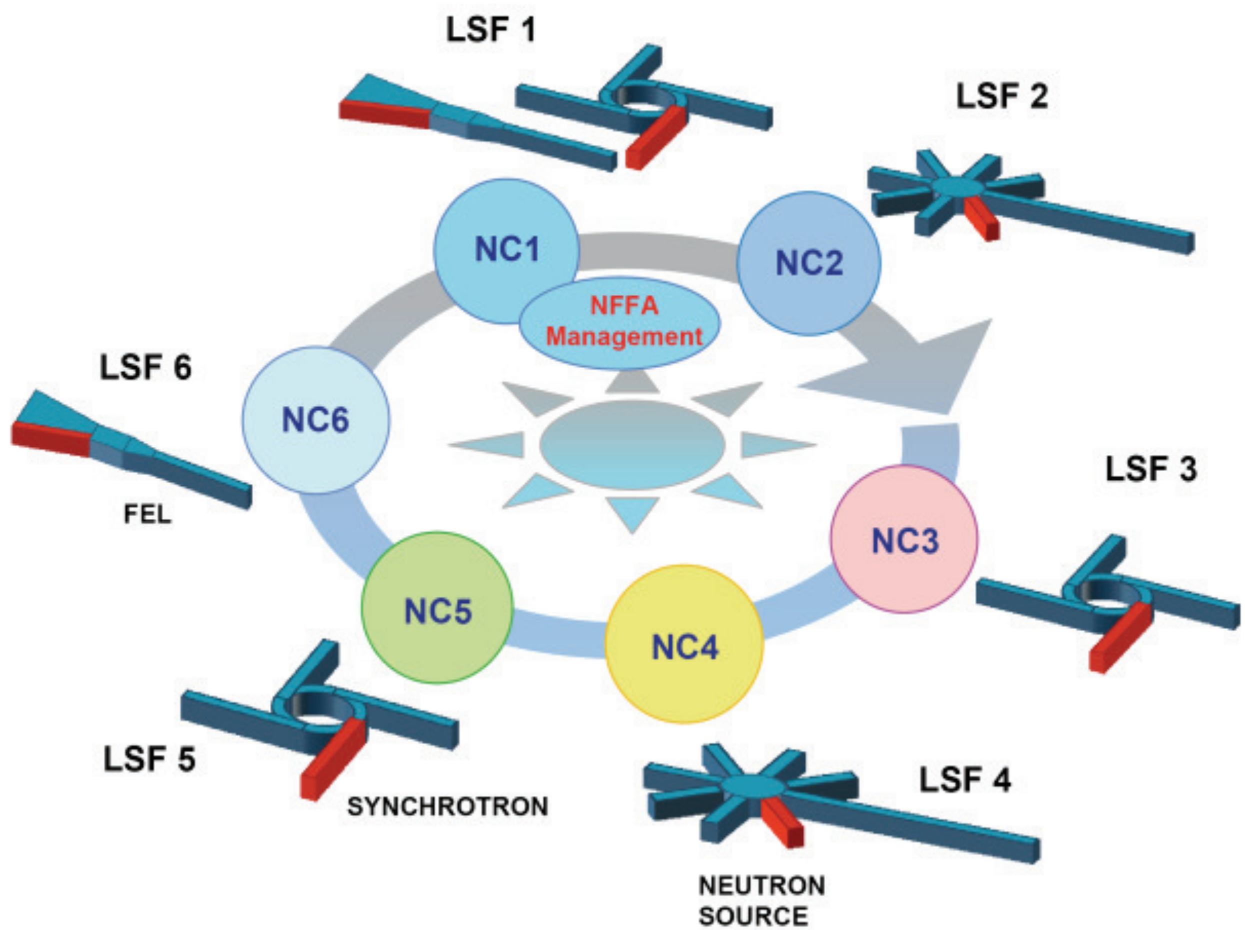
- **Laurea Thesis Students:**
  - 3-5 /year, mainly from Univ. Modena e Reggio Emilia
  - And Uni Milano (since 2013)

EUROPEAN COMMISSION
Community Research

# THE NFFA MISSION (www.NFFA.eu)

A DISTRIBUTED INFRASTRUCTURE LINKED TO ANALYTICAL LSFs

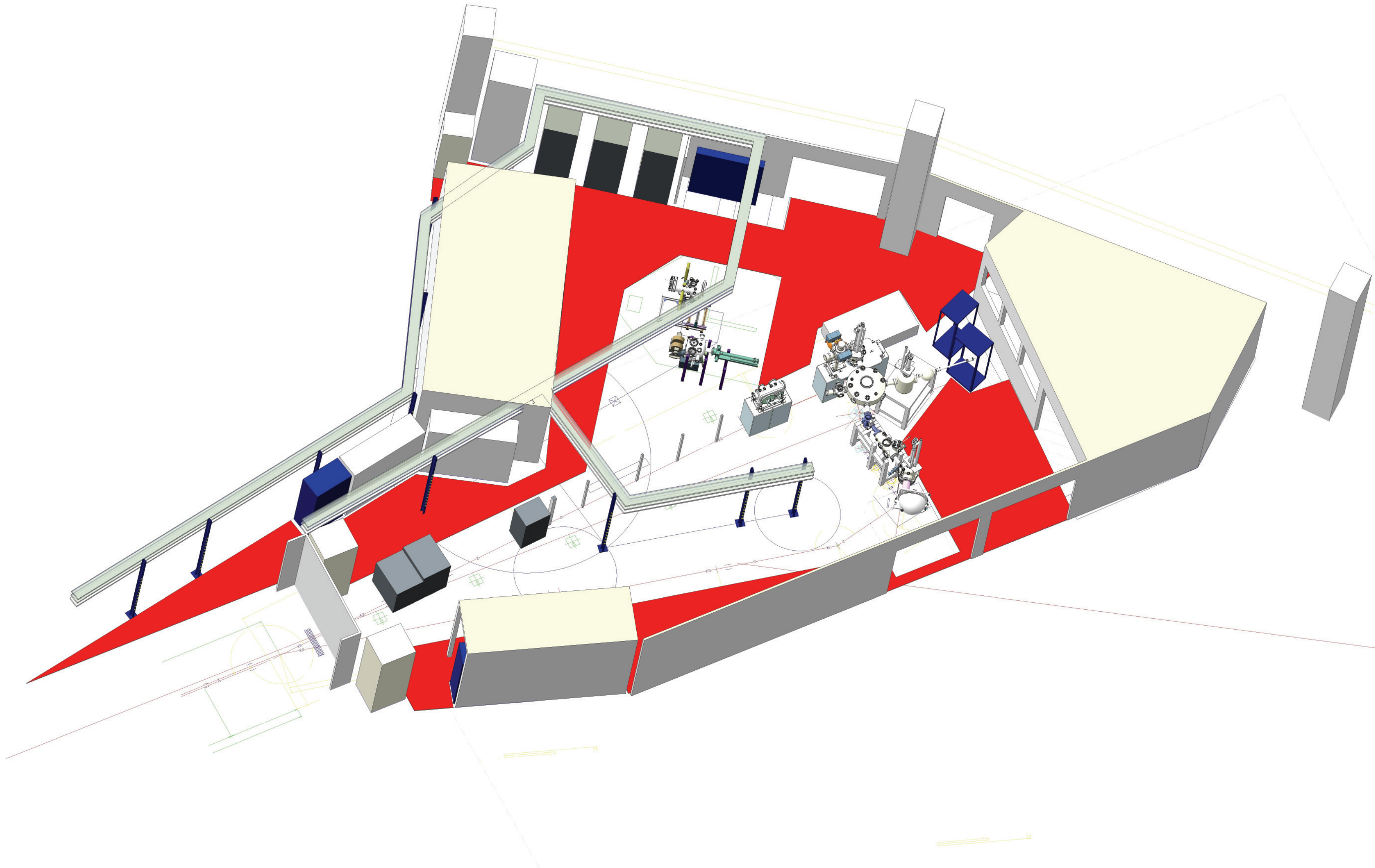
The NFFA Design Study supports the construction and operation of an ERIC consisting of Nanoscale Science Research Centers at European sites that already host Large Scale Facilities for Fine Analysis of matter.

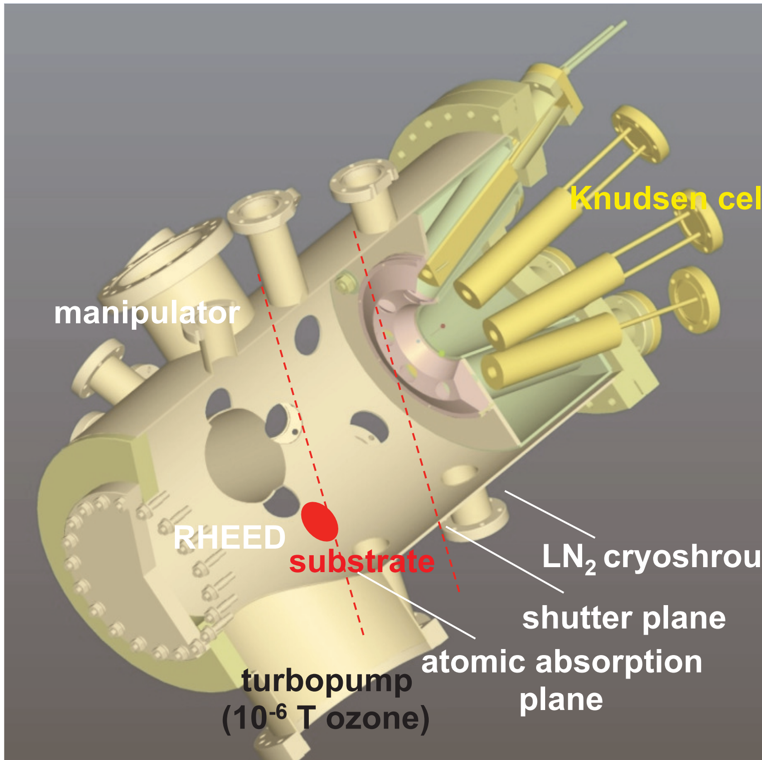





SEVENTH FRAMEWORK PROGRAMME

NFFA DP1 – IOM : New layout of APE beamline with integration of MBE-Oxides and new synthesis and characterization chamber: thin films, in situ/in operando characterization and spectroscopy/magnetometry






**<u>Oxide molecular beam epitaxy</u>** (MBE)

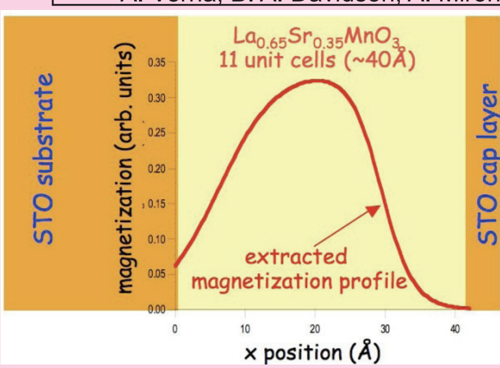
- ***Enabling technology,*** like semiconductor MBE in the 1970s, for realization of thin film heterostructures (quantum wells, modulation doping, etc.)

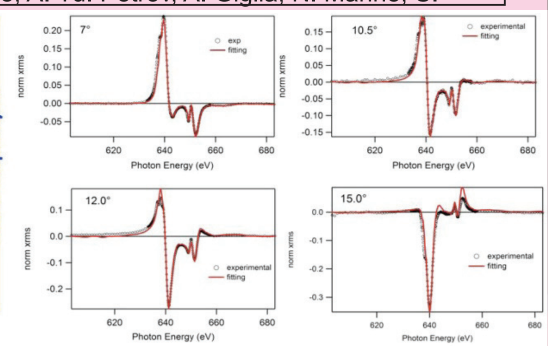
  * *atomic precision and purity* superior to competing growth techniques *
- Oxide MBE at TASC designed completely in-house with support of ***TASC instrument development group***
- one of only 4 such systems in the world
- study device mechanisms in **newly emerging field of oxide electronics**
- exploits ***large scale facilities for applied research*** via dedicated instrumentation physically connected to synchrotron beamlines

# FROM IN SITU TO IN OPERANDO

*Determining magnetization profiles at surfaces and interfaces using interference effects in resonant magnetic scattering*

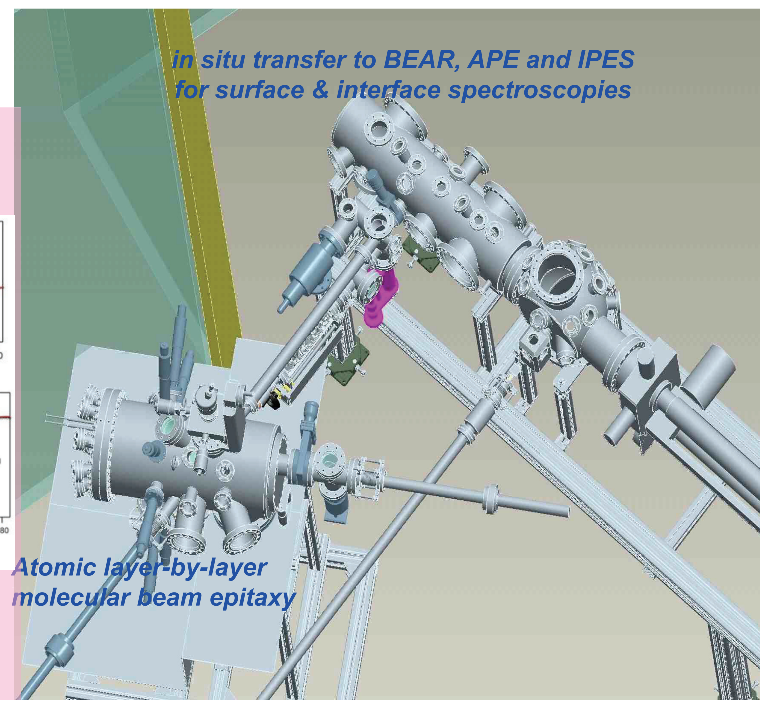
A. Verna, B. A. Davidson, A. Mirone, A. Yu. Petrov, A. Giglia, N. Mahne, S.

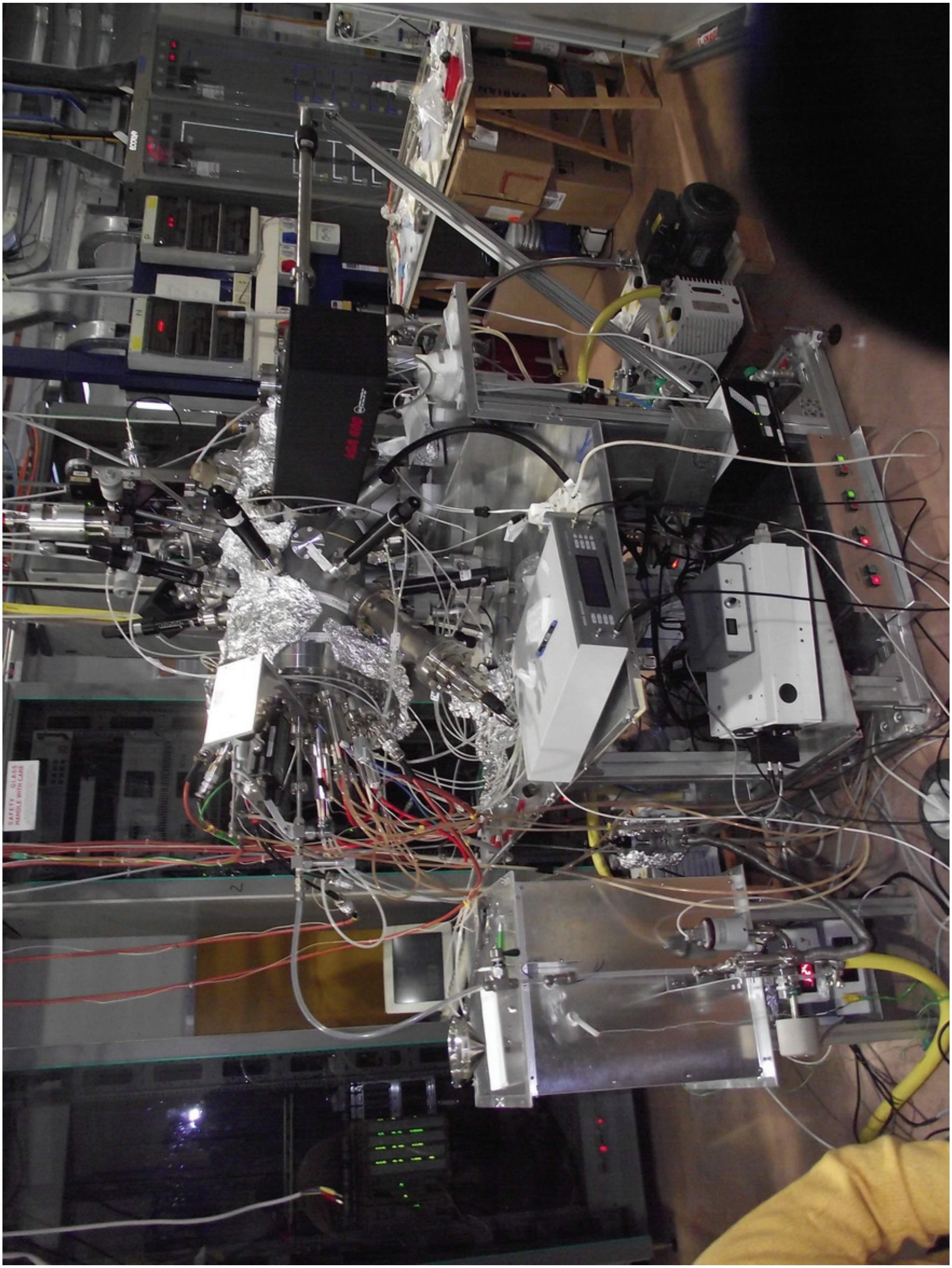



<u>Left</u>: extracted magnetization profile that generates fits shown on right. Note presence of 2 "dead layers", one at each interface.

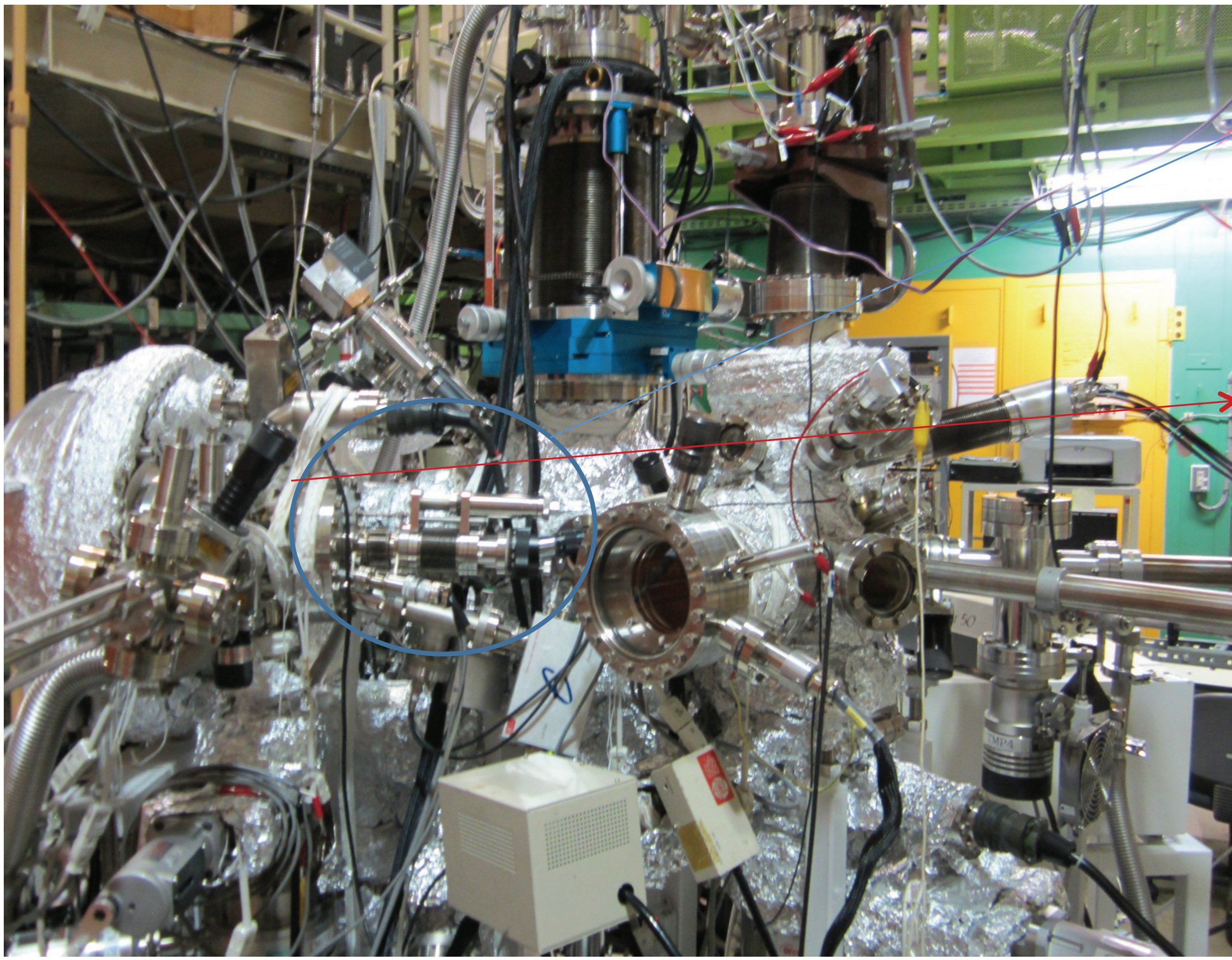
<u>Right</u>: fits (red lines) to XRMS spectra (open circles) from 11uc LSMO film, taken at different incidence angles and 200K. Film





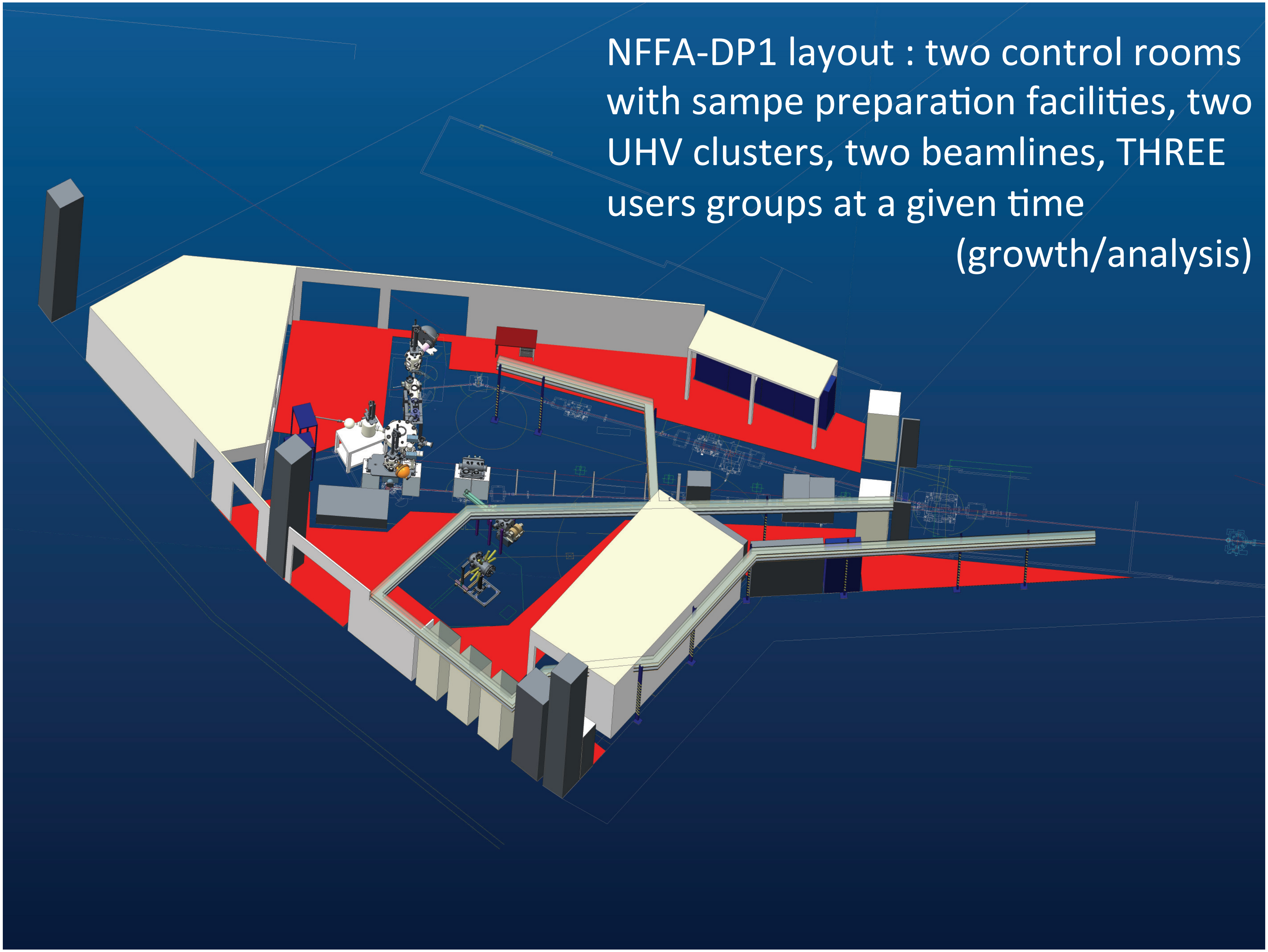
- UPGRADE:
- New analyser broad (45°) acceptance, 1meV energy resolution, 0.1° angular resolution
- VLEED vectorial detector for High. Res. SP
- High flux XMCD

# VLEED



Linear+rotary+tilt
for target adjusting
position

Vieport needed
For the target
Transferring is the same
Used for checking with
Pirometer temperature
during annealing


NFFA-DP1 layout : two control rooms with sampe preparation facilities, two UHV clusters, two beamlines, THREE users groups at a given time (growth/analysis)

# FERMI at the ELETTRA LABORATORY

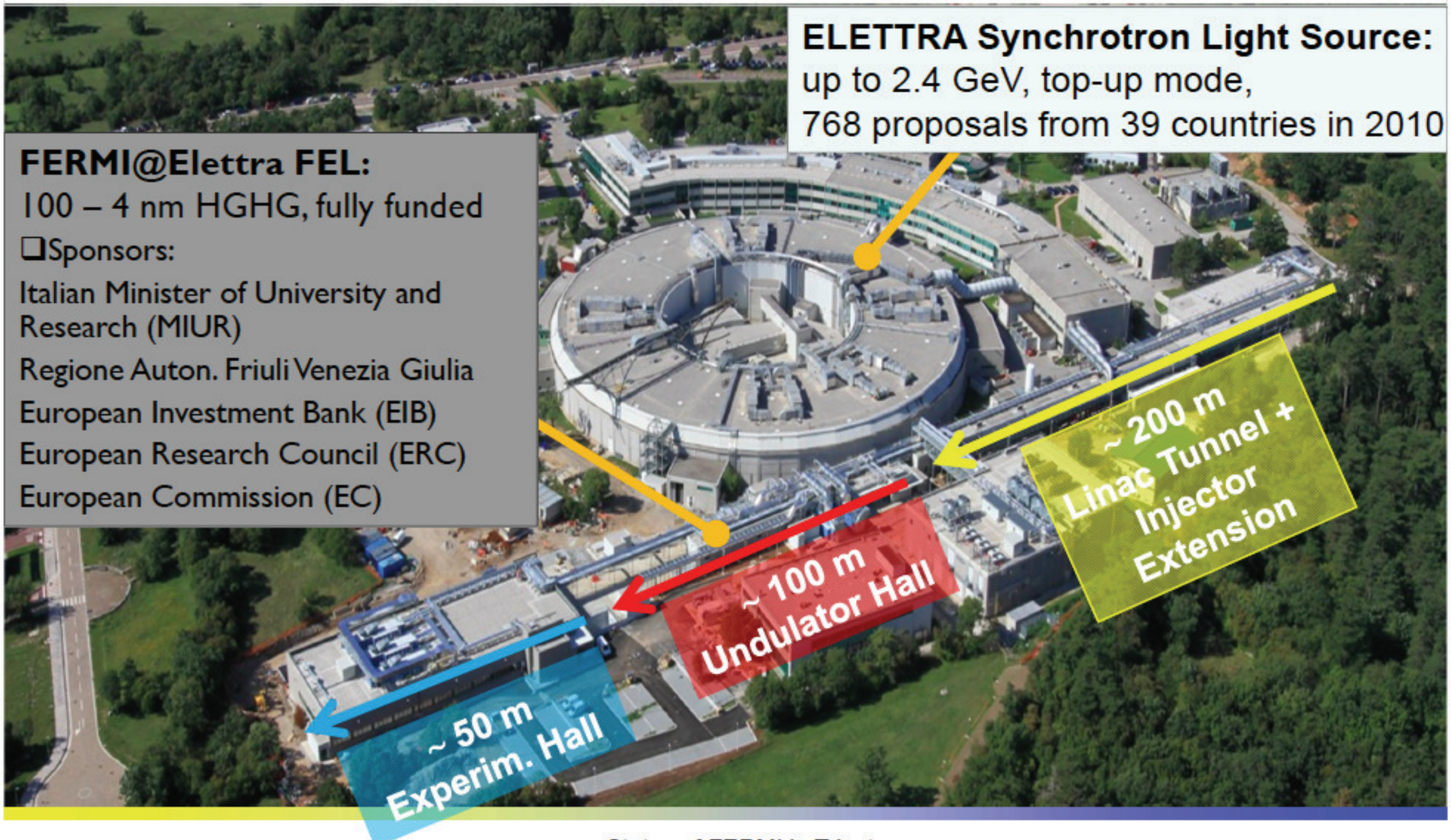
SINCROTRONE TRIESTE is a nonprofit shareholder company of national interest, established in 1987 to construct and manage synchrotron light sources as international facilities.

**ELETTRA Synchrotron Light Source:**
up to 2.4 GeV, top-up mode,
768 proposals from 39 countries in 2010

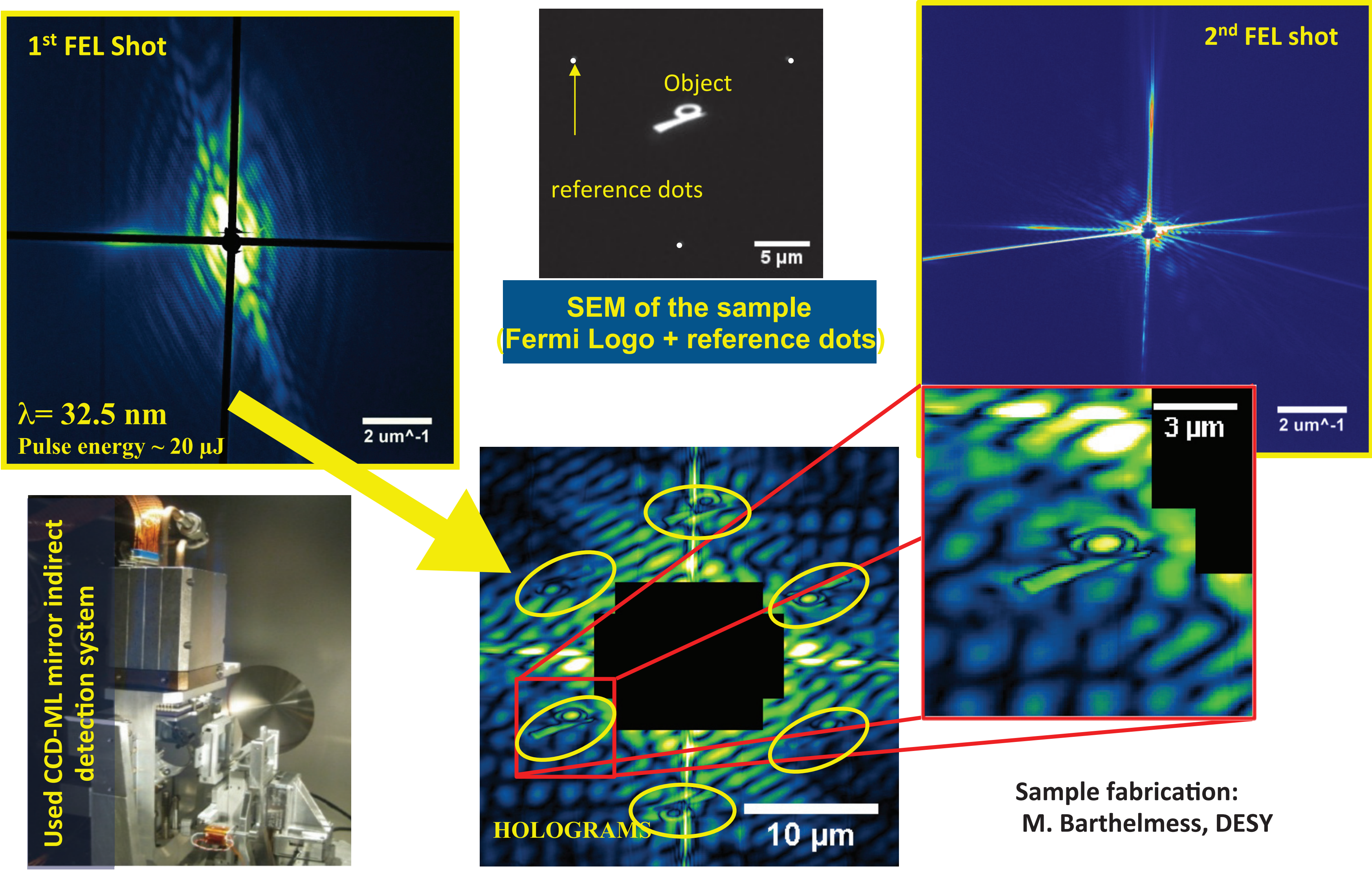
**FERMI@Elettra FEL:**
100 – 4 nm HGHG, fully funded

❑Sponsors:

Italian Minister of University and Research (MIUR)
Regione Auton. Friuli Venezia Giulia
European Investment Bank (EIB)
European Research Council (ERC)
European Commission (EC)

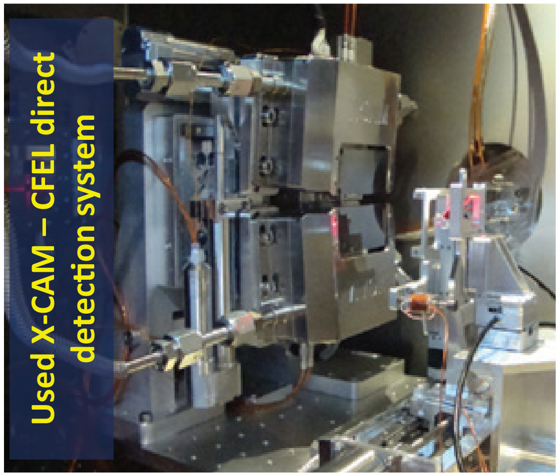


## DiProI: Single Shot Holography (on behalf of the DiProI team)



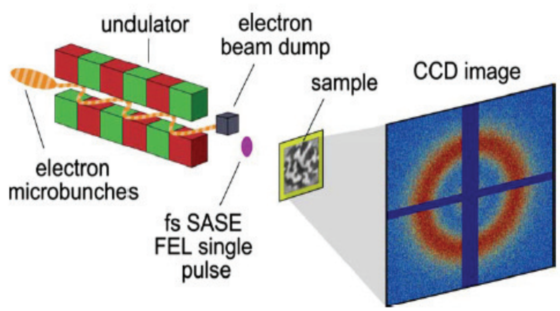

Sample fabrication:
M. Barthelmess, DESY

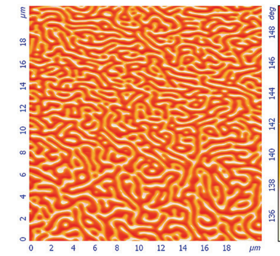
# DiProI: Magnetic - Resonant CDI

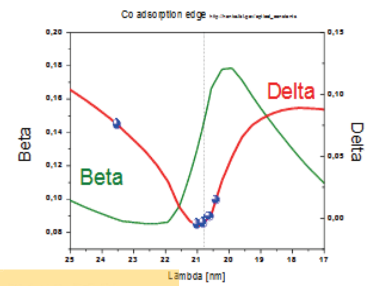



**Single-pulse resonant magnetic scattering using a soft x-ray free-electron laser**

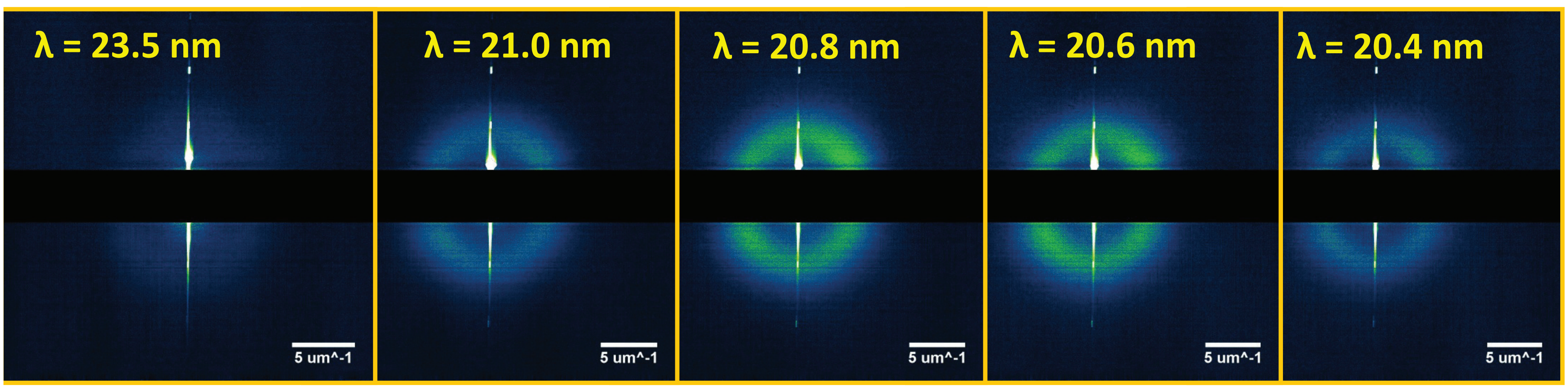
C. Gutt,[1] S. Streit-Nierobisch,[1] L.-M. Stadler,[1] B. Pfau,[2,3] C. M. Günther,[2,3] R. Könnecke,[2,3] R. Frömter,[4] A. Kobs,[4] D. Stickler,[4] H. P. Oepen,[4] R. R. Fäustlin,[1] R. Treusch,[1] J. Feldhaus,[1] E. Weckert,[1] I. A. Vartanyants,[1] M. Grunze,[5,6] A. Rosenhahn,[5,6] T. Wilhein,[7] S. Eisebitt,[2,3] and G. Grübel[1]






**Co/Pt multilayer sample, Courtesy C. Gutt et al (DESY)**



# PIK proposal (X-FEL, Fermi)

# ULTRASPIN

## (ULTRAfast spectroscopy with SPIN Polarization)

## A CONTRIBUTION TO THE DISCUSSION OF THE USERS CONSORTIUM for PES at XFEL

(Giorgio Rossi, Aug. 17th 2012)


Consortium

G. Panaccione, J. Fujii, P. Torelli (Istituto Officina dei Materiali IOM-CNR, Trieste)
M. Medici (Univ. Modena e Reggio Emilia)
F. Offi (Dip. Fisica Univ. Rome III and CNISM)
G. Cautero (Detectors and Instrumentation Laboratory , ELETTRA)

Collaborators

D. Pescia, A. Vaterlaus, Y. Acremann (ETH-Zuerich, Switzerland)
F. Sirotti (SOLEIL, France)

Interest in performing pilot experiments

C.H. Back (Univ. Regensburg, Germany)
C.M. Schneider (FZ-Juelich, Germany)
M. Kiskinova (Elettra)

# Time and lenght scales in magnetism

Source:
Swiss FEL Science case

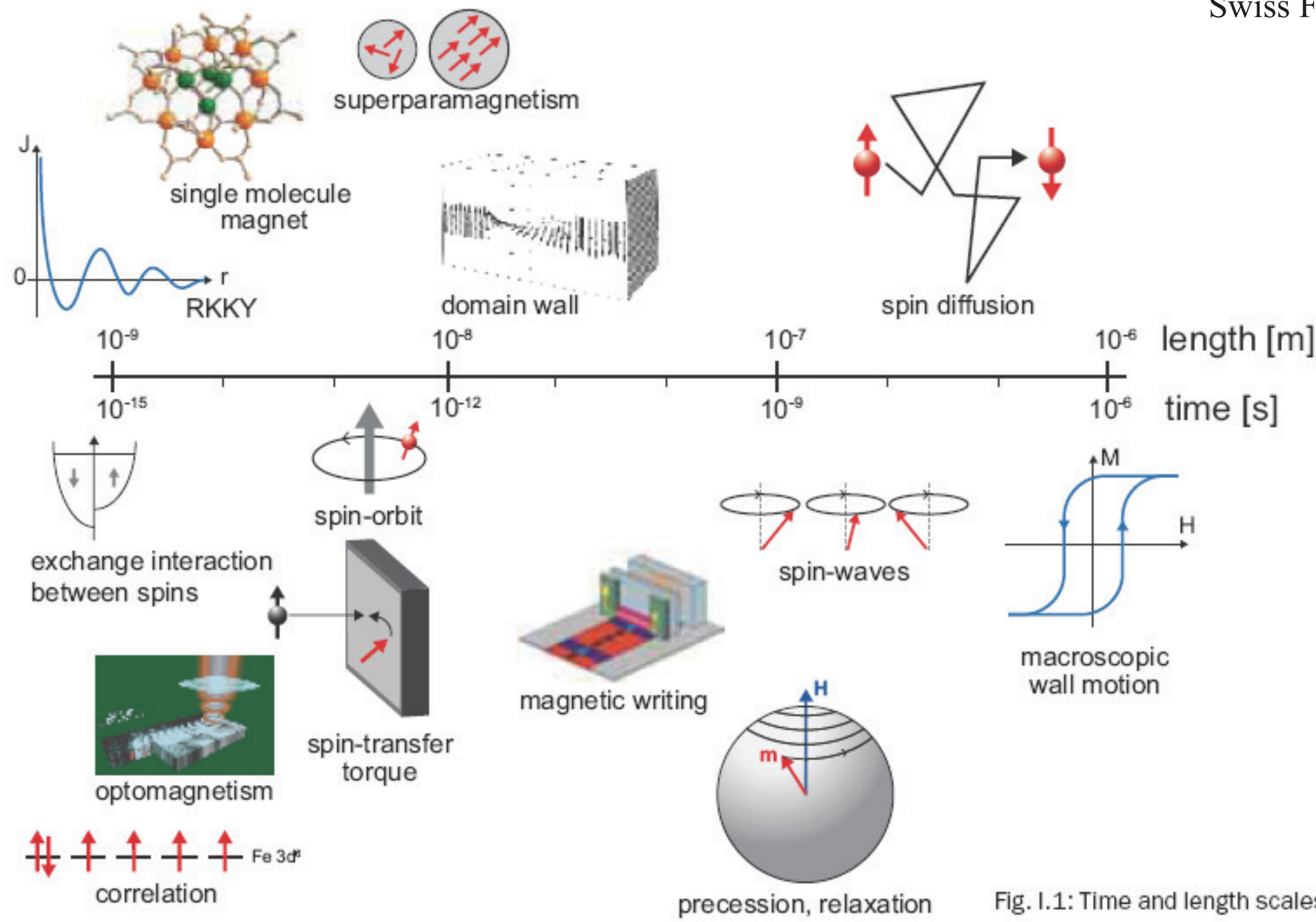
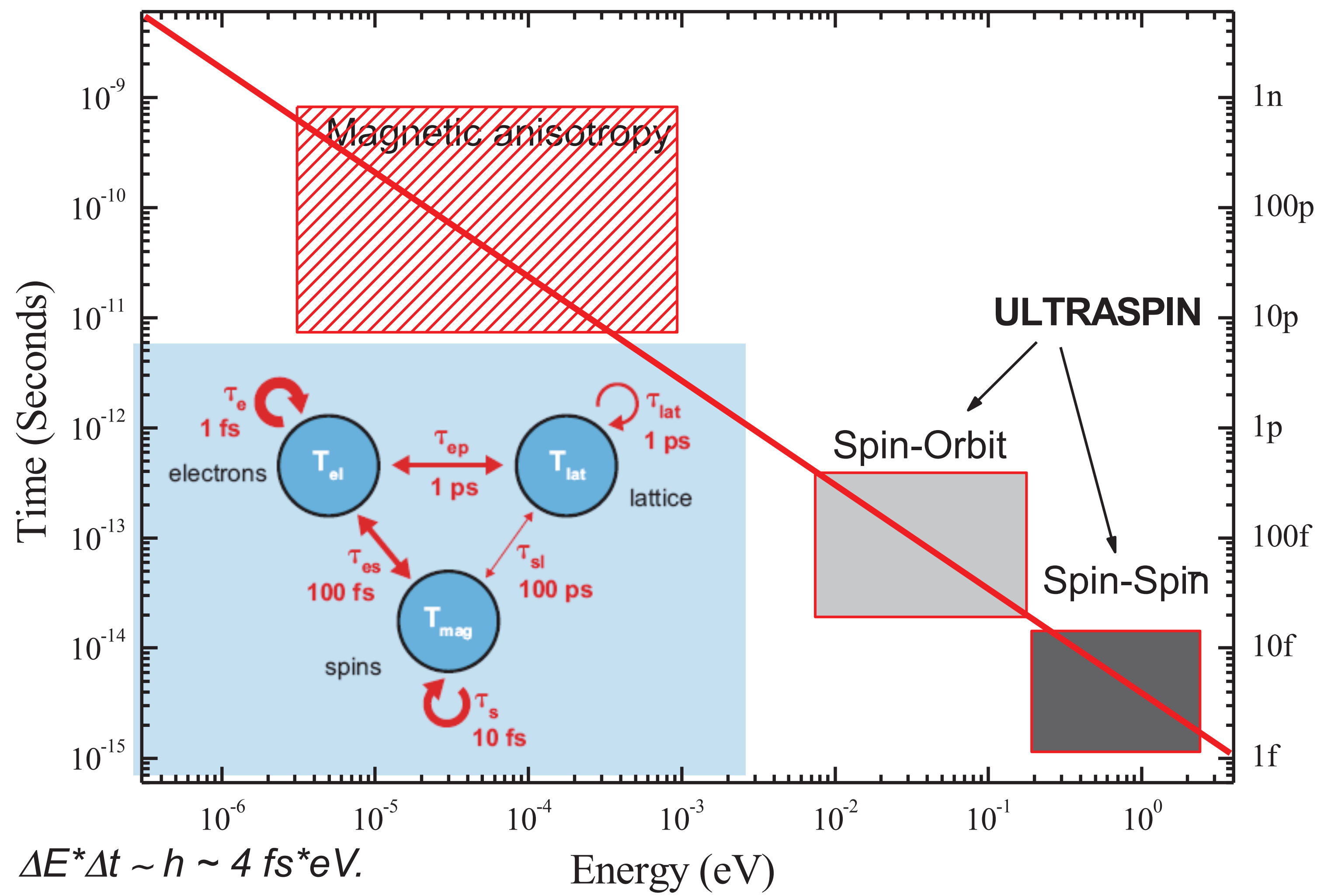



Fig. I.1: Time and length scales in magnetism.

| | |
|---|---|
| Electrostatic crystal-field interaction of oriented 3d-orbitals with neighboring ions | ~ 1 eV → τ ~ **5 fs** |
| Inter-electronic exchange energy *J* arising from the Pauli principle | ~ 5 eV → τ ~ **1 fs** |
| Correlation energy, responsible within an atom for enforcing Hund's rules | ~ 5 eV → τ ~ **1 fs** |

| | |
|---|---|
| Spin-orbit interaction between the electron spin and its orbital motion | 1–100 meV → τ ~ **50–5000 fs** |
| Jahn-Teller interaction, which stabilizes an elastic distortion to avoid a degenerate electronic ground-state | ~ 50 meV → τ ~ **100 fs** |
| Spin-wave energy, at intermediate wave-vector | 1–1000 meV, → τ **5–5000 fs** |

# Time-energy relation of fundamental interactions in solids




$\Delta E^{*}\Delta t \sim h \sim 4\ fs^{*}eV.$

# Femtosecond laser pulses :

Pump-probe Kerr-effect experiment with 60 fs pulses

(*E. Beaurepaire, J.C. Merle, A. Daunois, and Y.-Y. Bigot, Phys. Rev. Lett. 76, 4250 (1996).*)

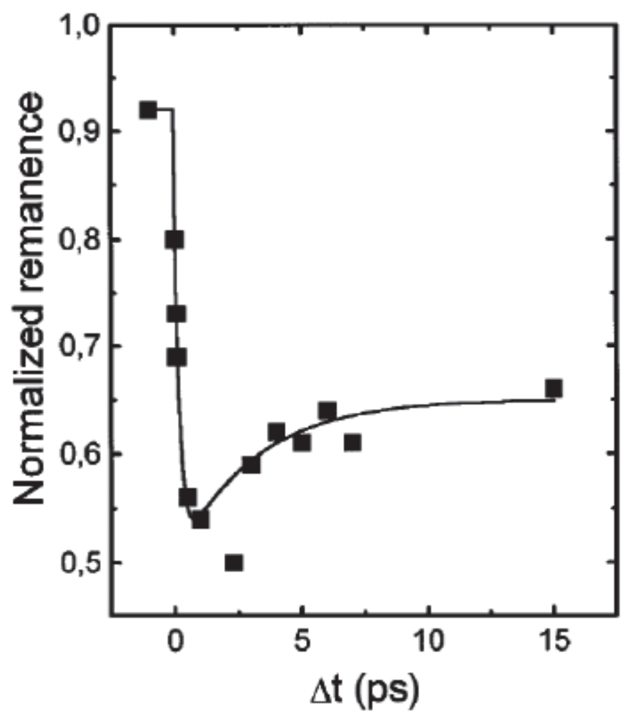
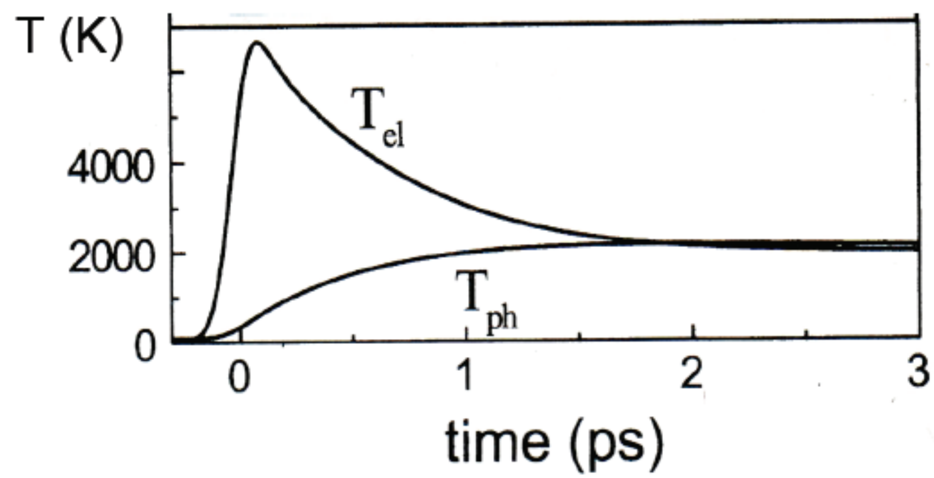



Fig. I.6. Sub-picosecond demagnetization of a Ni film following an optical laser pulse, observed with the magneto-optical Kerr effect [8]. This observation stimulated much speculation on the as yet unanswered question of how angular momentum can be transferred so efficiently from the spin system to the lattice.

Electrons and lattice are not in thermal equilibrium during a 60 fs heating pulse.



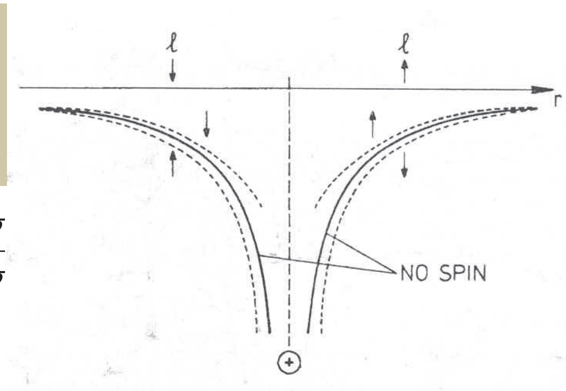

Demagnetization on a subpicosecond time scale seems possible.

Courtesy of A. Vaterlaus, Y.Acremann, ETHZ Zurich

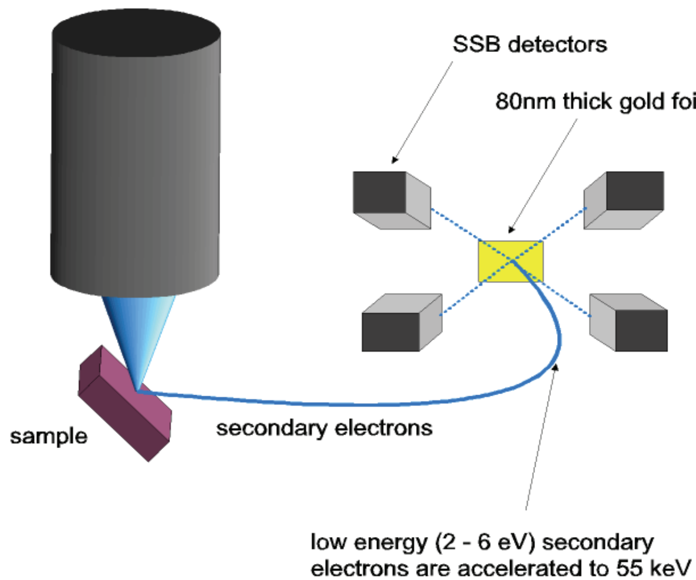
# Principles of spin polarization analysis with Mott scattering

Electron Scattering at 60 kV of
spin polarized photoelectrons:
spin-orbit induced asymmetry in scattered electron

$$P = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow} = \frac{\sigma_\uparrow - \sigma}{\sigma_\uparrow + \sigma}$$




X-rays or FEL Radiation




Spin polarization of
secondary electron (low energy)
directly proportional to
long range magnetization

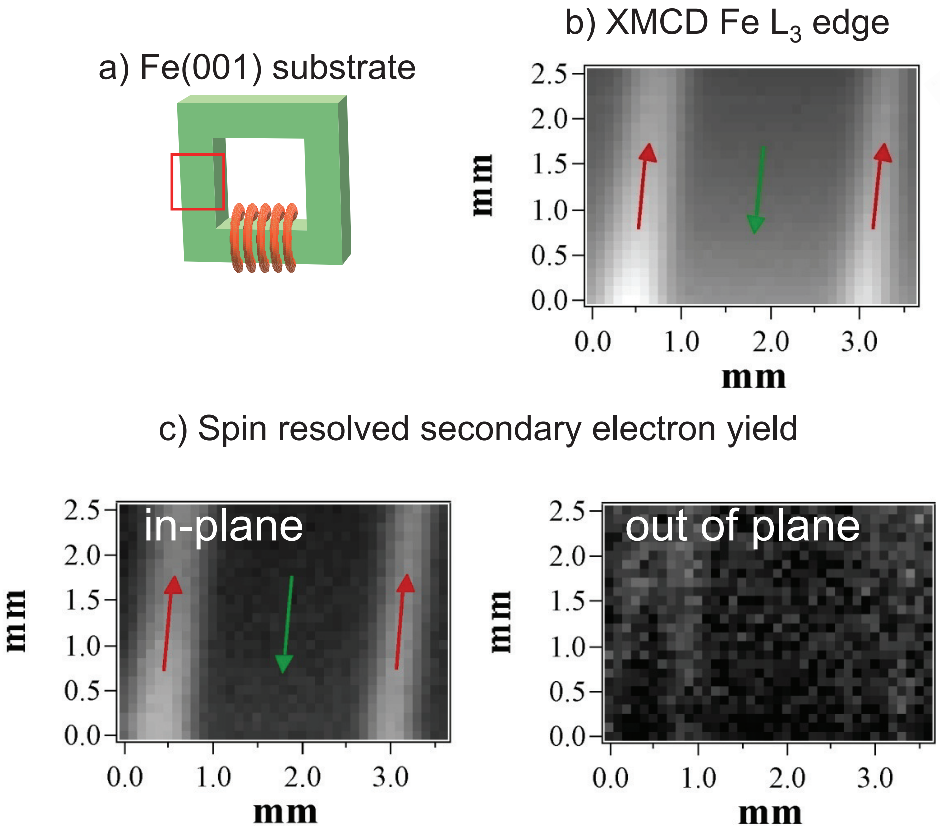
$$P_x = \frac{1}{2S_{eff}}\left(\frac{D_1 - U_1}{D_1 + U_1} + \frac{D_2 - U_2}{D_2 + U_1}\right) \quad P_y = \frac{1}{S_{eff}}\left(\frac{L_1 - R_1}{L_1 + R_1}\right) \quad P_z = \frac{1}{S_{eff}}\left(\frac{L_2 - R_2}{L_2 + R_2}\right)$$

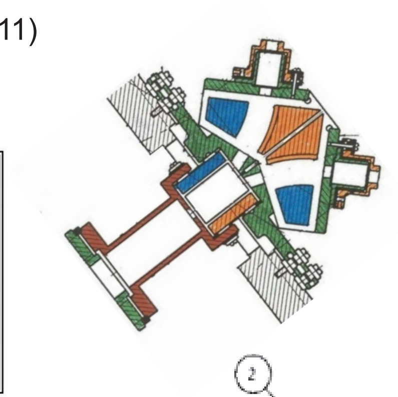
Differential measurement
(reduced space charge effects)

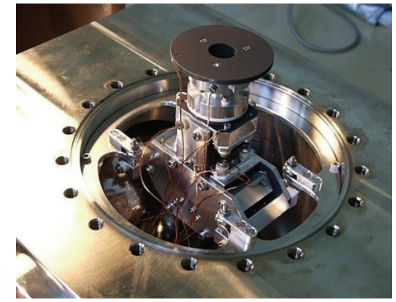
Spin polarization
along quantization axis

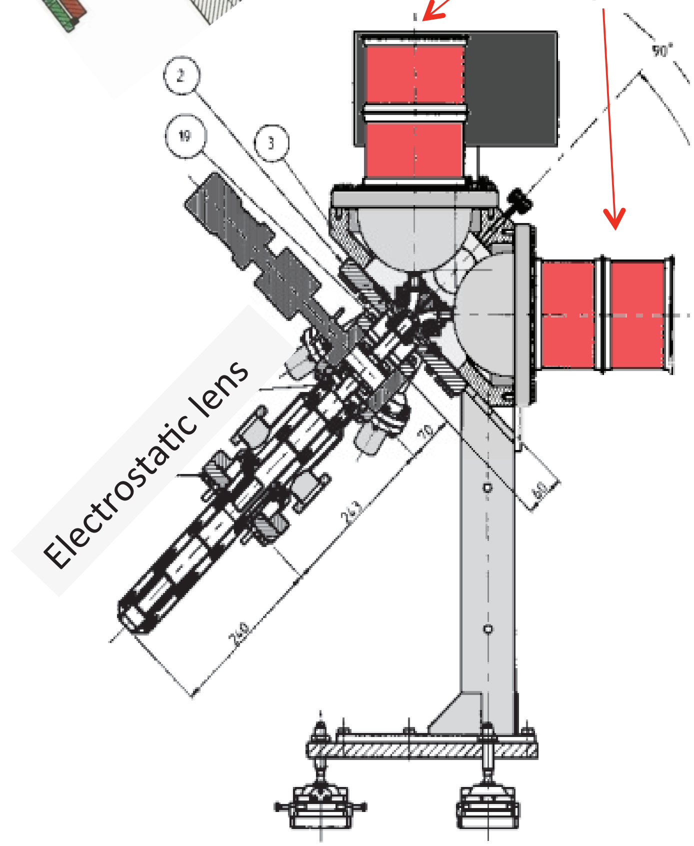
# Vectorial twin-mott detectors @ APE beamline

J. Fujii et al., Phys. Rev. B **73**, 214444 (2006), M. Medici et al. (2011)








Spin resolved secondary electron yield
Measurement of both in-plane and out of plane spin polarization

V.N. Petrov et al. Rev. Sci. Instruments 72, 3728 (2001)

# Ultraspin: Methodology and Developments (0-24 months)

a) Design and implementation of ultrafast readout electronics
(adapted layout following schemes operational at ETH,Zurich and SOLEIL)

b) Feasibility and design of energy and time resolved experiments (TOF-Spin)
(space charge limit)

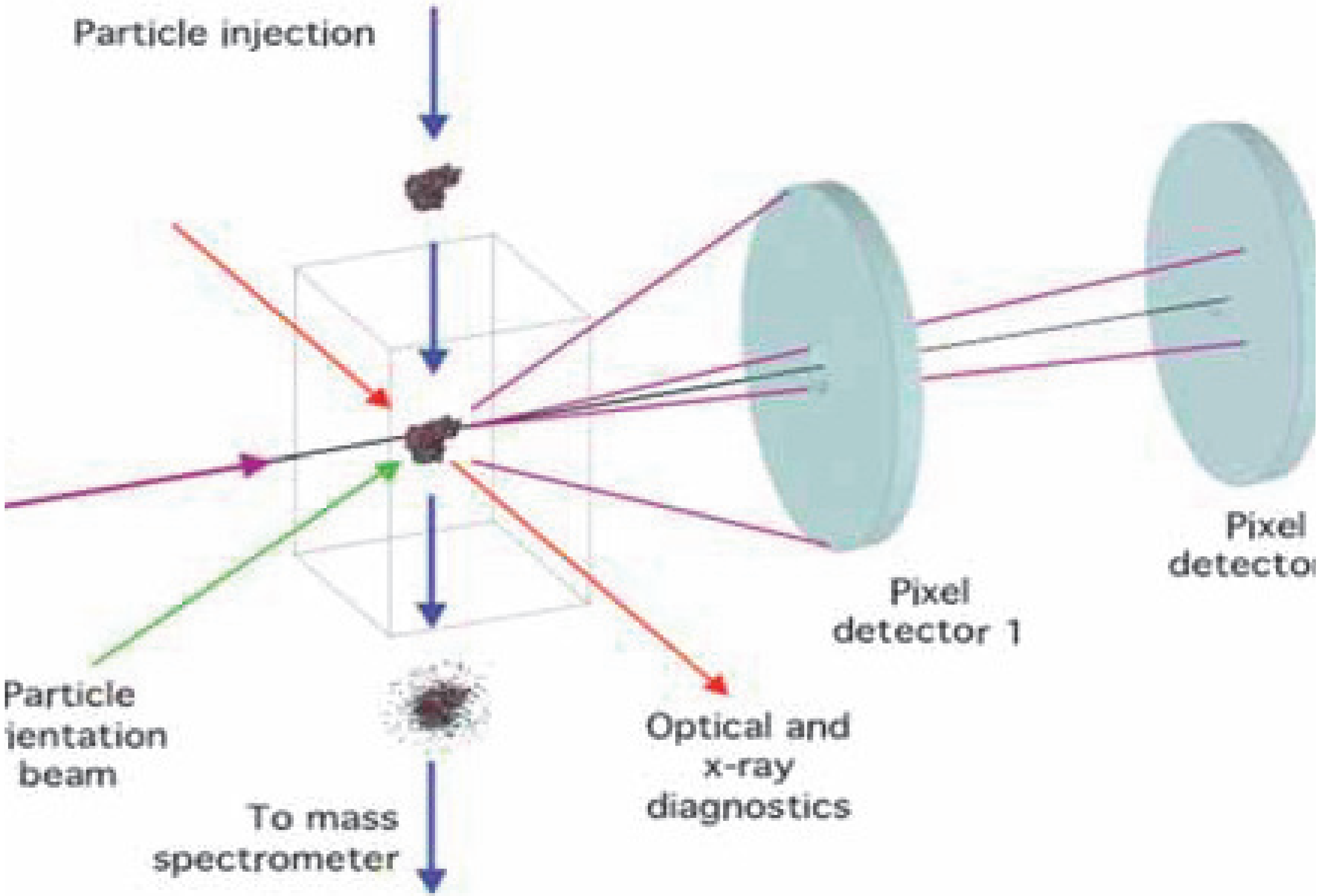
c) Test experiments @ Fermi (applied to nanostructrures, thin films, interfaces)

Total yield and total yield pump and probe experiments (ultrafast demagnetization)

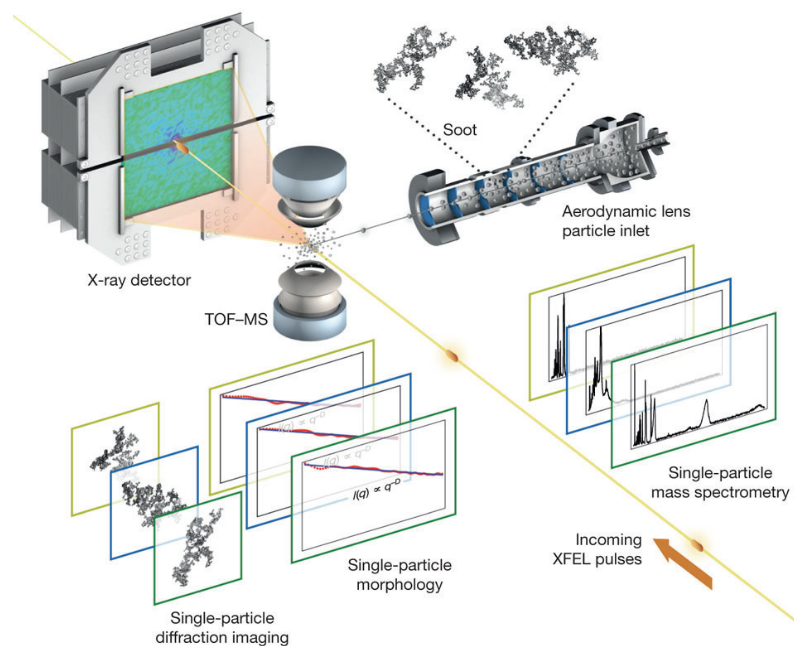
Comparison electron-out (spin polarization) and photon-out (XMCD-reflectivity)
(disentangling spin and orbit contribution)

d) Conceptual design of a whole experimental station adapted to X-FEL

PROGETTO NOXSS UNIMI  X-ray Single Shots of Nano Objects
(PRIN 2012 ?)



Schematic of concurrent imaging, morphology and spectroscopy of single soot particles in flight.




ND Loh *et al. Nature* **486**, 513-517 (2012) doi:10.1038/nature11222

nature