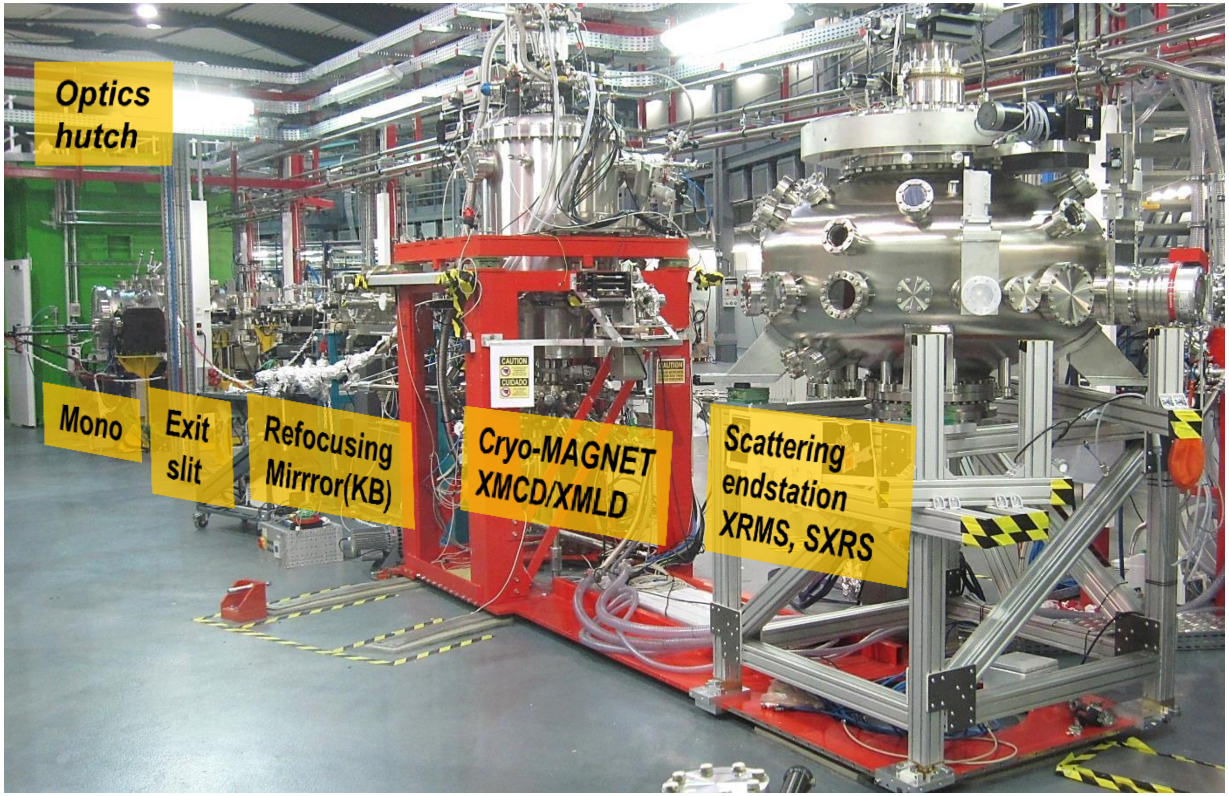
BOREAS, Beamline Of REsonant Absorption and Scattering

Scientific Case ***Soft x-rays: 80-4000 eV, Apple II, 3 VLS-grating mono, two endstations for XAS, XMCD/ XMLD, and XRMS***

- **Beamline performance, status, commissioning**
- **Hector endstation**
- **MaReS endstation**
- **In-house and user results**



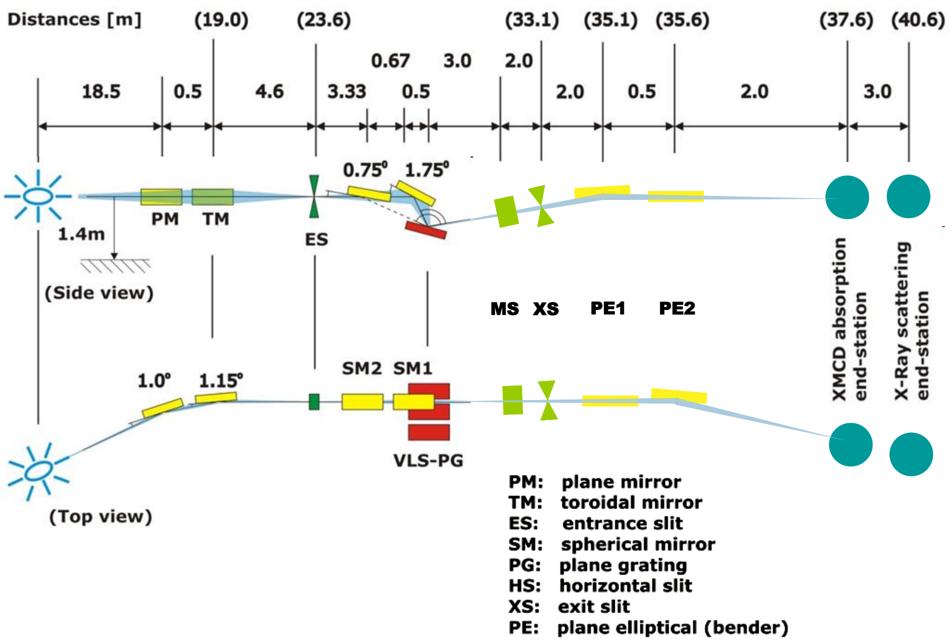
Scientific Case

Beamline designed for soft x-ray polarization-dependent spectroscopy and scattering: XAS,XMCD-XMLD, XRMS

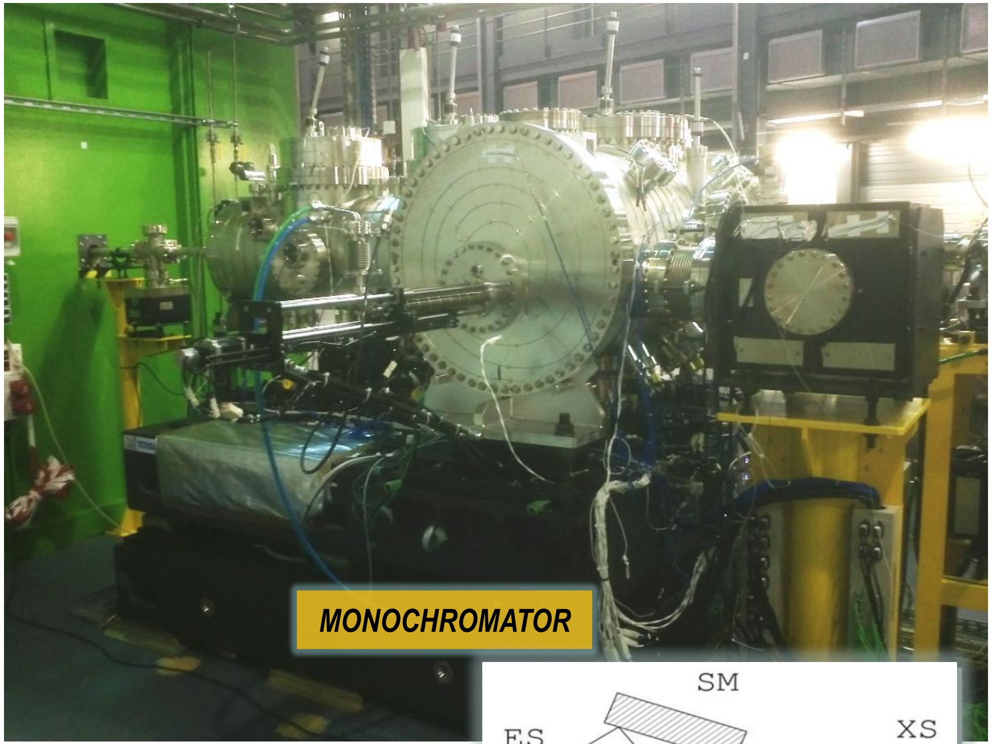
highlights

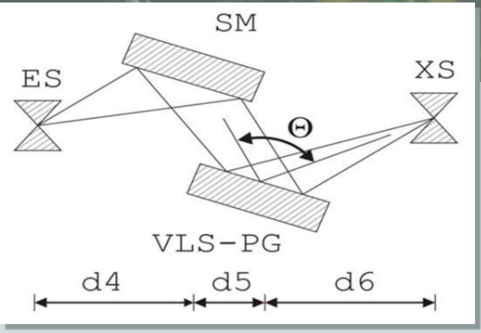
- ***Full x-ray polarization control (APPLE-II)***
- ***Extended soft x-ray range: 80-4000 eV (high flux, resolving power)***
- ***Variable x-ray beam size and focal distance (KB system)***
- ***(ES1) High-field SC vector magnet: 6T, 2T with 1.5K-370K sample temp.***
- ***(ES2) UHV scattering chamber, 2T magnet, large access, 20K-350K***

optical layout



extra slides: theoretical photon flux, range

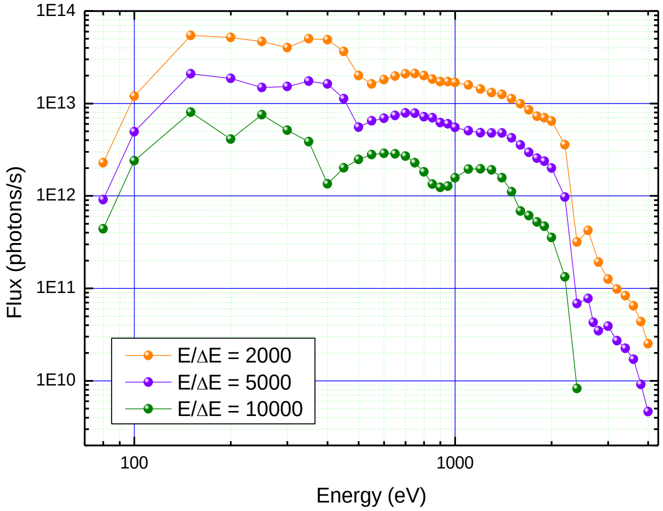




- *Monochromator chamber :*
  3 plane VLS gratings
  2 spherical mirrors
  (mechanics by Toyama co.)

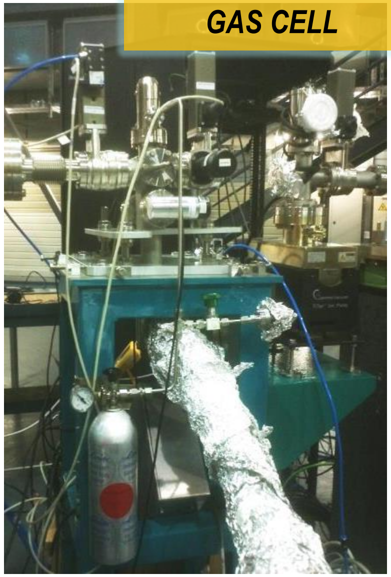
GRATING MIRROR COMBINATIONS	
80 – 300 (800) eV	SM1+LEG
250 – 600 (1400) eV	SM2+LEG
380 -1700 eV	SM1+MEG
950 - 3000 eV	SM2+MEG
600 – 2100 eV	SM1+HEG
1900 – 4500 eV	SM2+HEG

Photon flux (calculated)

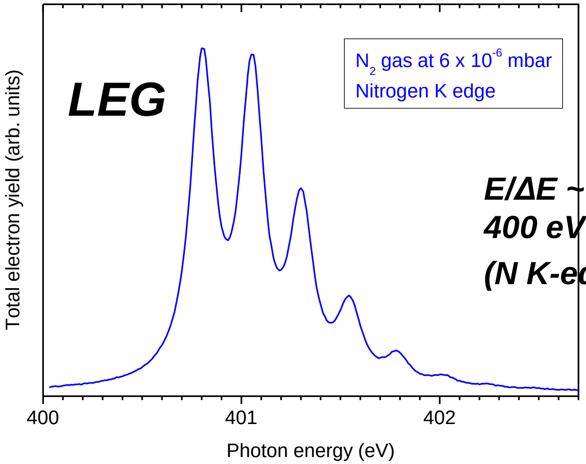


LEG: 200 l/mm, laminar, Ni coated [35nm}+Cr binding layer
MEG: 800 l/mm, blazed (mech. Ruled + ion beam etch), Rh [35nm]
HEG: 1200l/mm, blazed, Au [35nm]

BL performance–resolution LEG



Resolving power (ES=15/XS=15)



E/ΔE ~7000 at 400 eV

(N K-edge)

I zero: AXUV100 (IRD) absolute diode,

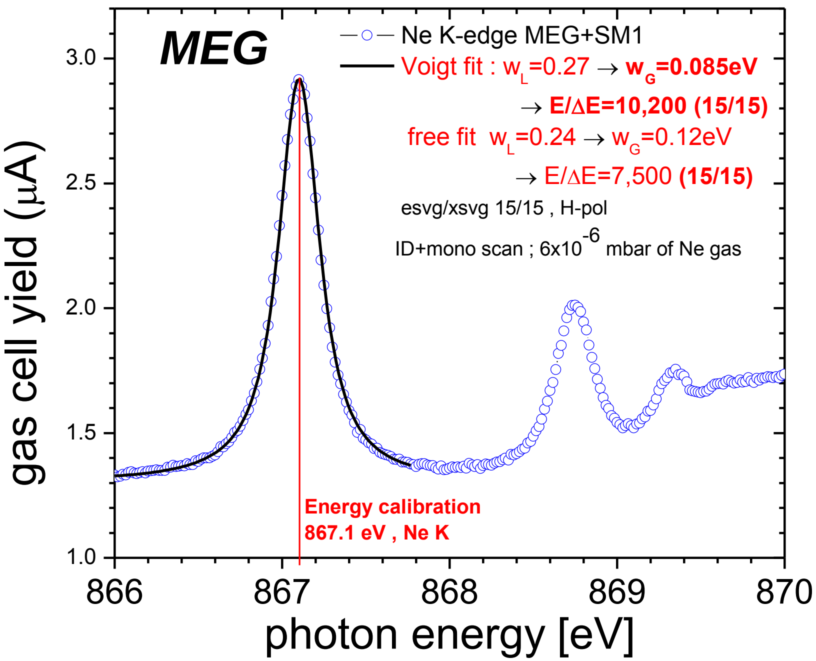
photon flux

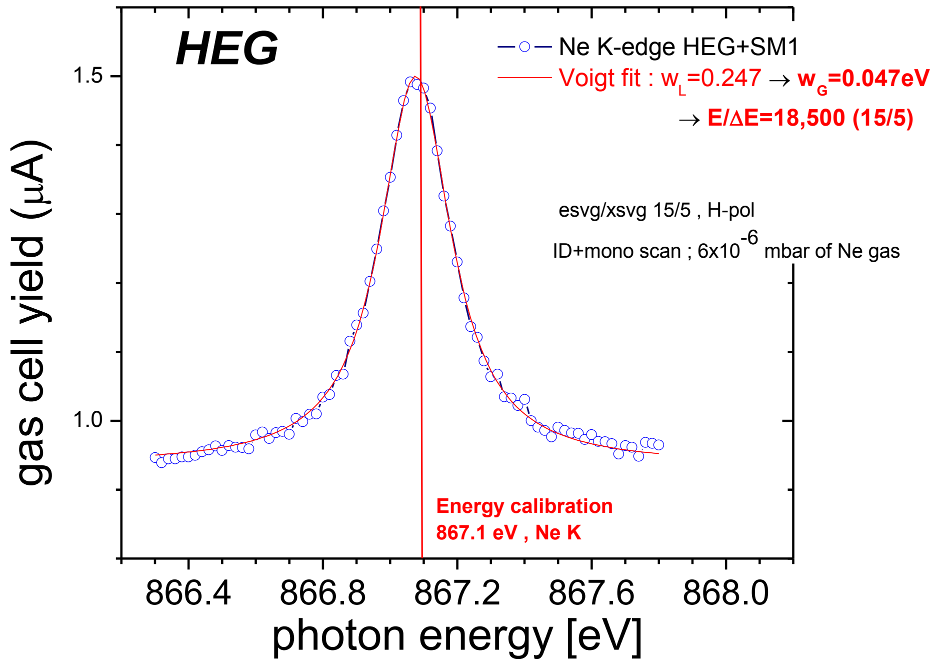
hv	I_{SR}	Diode current	flux
500eV	70µA	17.3 µA	7.8×10^{11} photons/s(*)
(*) : Circular polarization, ES=15um; XS=5um; Extrapolates to 4-5x10^{12} photons/s at I_{SR}=400µA			

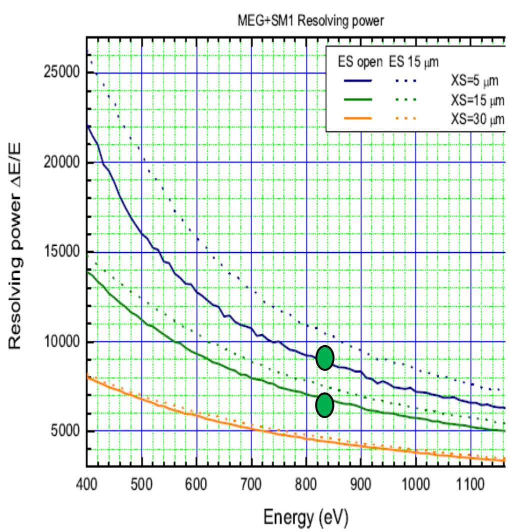
Beam size (micron)

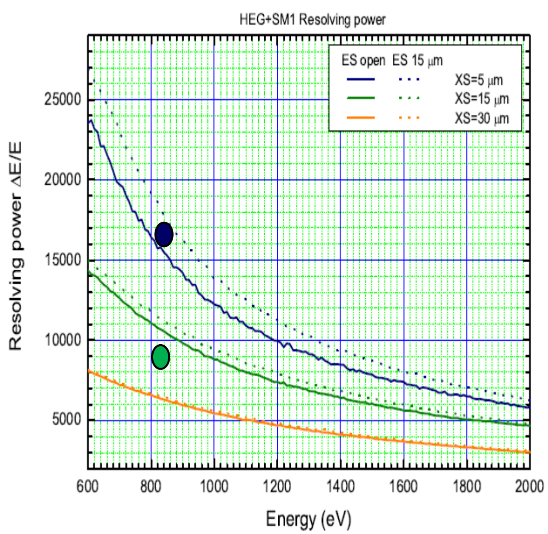
Element	Vertical	Horizontal
exit slit	10	250
ES1	600	250

BL performance–resolution MEG, HEG



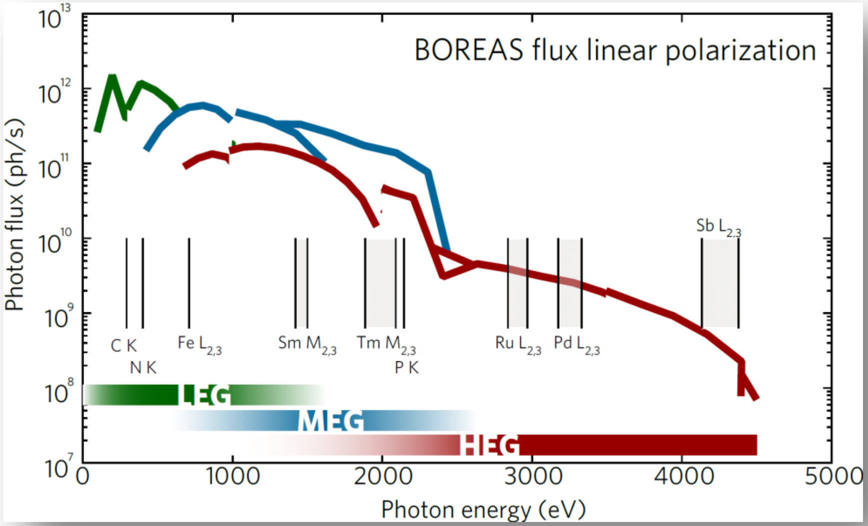


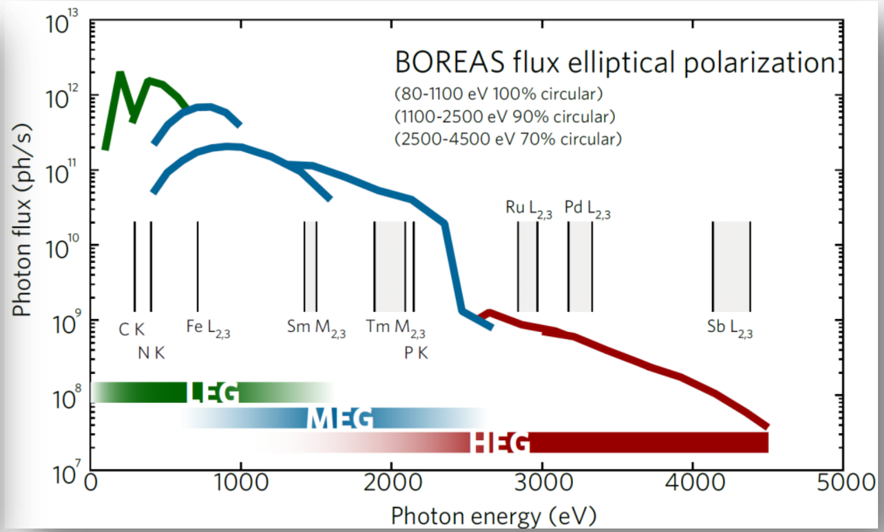




- *At 15/5 slits, MEG and HEG single Lorentzian width is 0.26(8) and 0.25(4) eV*
- *Width smaller literature Ne K natural width, 0.27+/- 0.02 eV [Floreano et al, RSI]*
- ***Instrumental resolution ~10,000*** *for* ***15/15 μm slits*** *and ~* ***20,000*** *for* ***15/5 μm,***
- ***Confirmed resolution performance of conceptual design***

BL performance– flux (commissioning)





Linear polarization

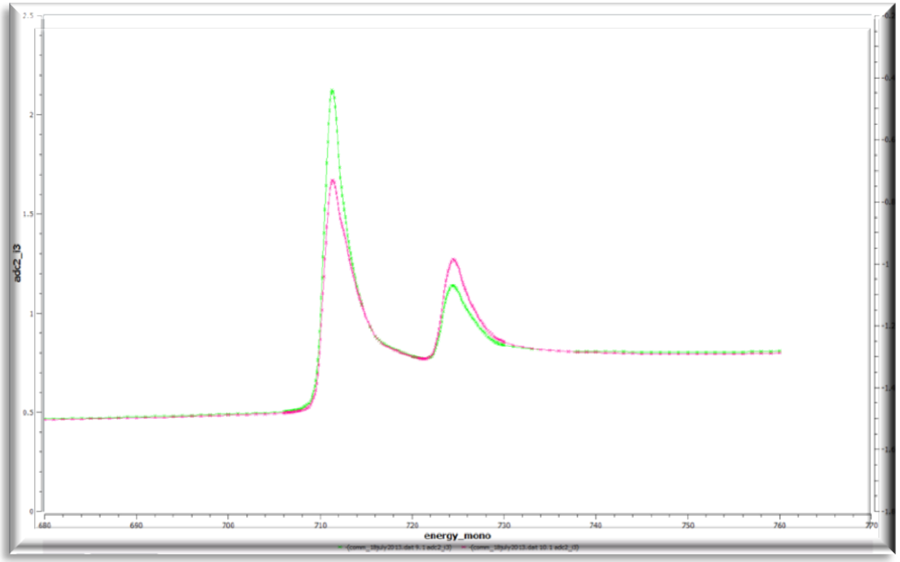
Circular & elliptical polarization

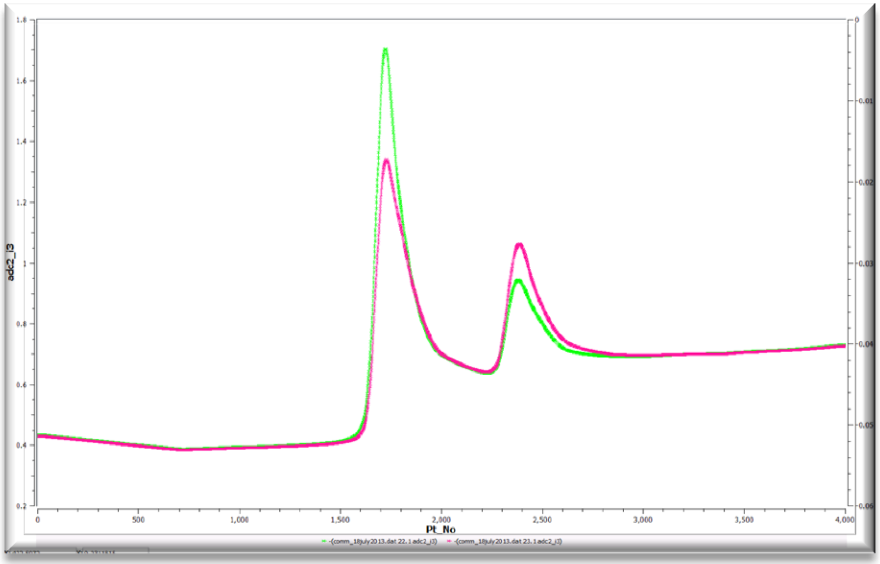
- **Considerably high flux with good resolution in the high energy range (>1.5 keV)**

  Typically 1st ID harmonic 100-1100 eV ; 3rdh : 1000-2500 eV approx. ; 3rd, 5th , … for E>2000 eV

- **Spectral purity**: ID harmonics x grating orders coincidences can be relatively intense

BL commissioning– continuous scans





Step scan, variable step:
Finest res. 0.050 meV
Total time: 17min 30sec
Normalized

Continuous scans
0.050meV resolution everywhere
Total time : 2min
Not normalized

- Continuous scans can more efficiently use acquisition, benefiting of high frequency sampling
- As important as time saving, is quality of sucessive measurements.

BL optics summary – performing to specs

ELEMENT	STATUS	HIGHLIGHTS, INCIDENCES
Monochromator	READY	Works well, reprod.~10 meV, **analyzing energy instabilities** **- Grating exchange prob⟶ solved, back to motorized mode**
diagnostics, gas cell, foils	READY	- Work well; LEG, MEG energy calibration; HEG calibration
re-focusing mirrors (KB)	CONSERVATIVE OPERATION, COMMISSIONING FORESEEN END DEC'13	- Pitch works; benders fixed at nominal ES1 focus; - **Two translations blocked** (but beam aligned through) - **Conservative operation (beam focus so far OK). Variable beam size/focus commissioning July 2013**
Signal normalization	READY	Works fine, either last KB mirror or Io mesh (gold evaporator)
High Flux	Performance confirmed	**LEG flux 8x10^{11}photons/s at 500eV** **MEG, HEG provide expected high flux on large hv range**
High Resolution	Performance confirmed	Resolving power : >7,000 at 400 eV (LEG) ; 7,500 – 20,000 at Neon K edge (867.1 eV) with LEG+SM2, MEG+SM1, HEG+SM1**; Ru L,… HEG+SM2**
Spectral Purity	Under commissioning, analysis	- Considerably intense harmonics, half orders (expected, not a big issue for now; choose harmonic,…) - **Future ⟶ harmonic rejection mirror system, filters**
Undulator, Control	Under commissioning, analysis	- **Analysis of x-ray polarization (Fe film, polarimeter?)** - **Linear polarization angle control** - **Continuous scans (mono, mono+ID) : in progress**

BL endstations update – XMCD magnet

First endstation, "HECTOR" high-field magnet

- Running full experiments since May 2012

- performing according to specs (6Tesla, 1.5K)

Upgrades from May:

- Final cabling

- Electrometer stack

- Improved vacuum scheme (safe if supply failure)

- Enhanced control, macros

- Safety: signs, plastic chains, "field on" flashing lights

Upgraded capabilities, equipment:

- upgraded with transmission detection (Oct'2012), transmission sample holders

- upgraded equipment: heating stage, evaporators, wobble stick, gas lines, ion gun, quartz balance

In progress upgrades:

- Fluorescence detection (Feb'2012)

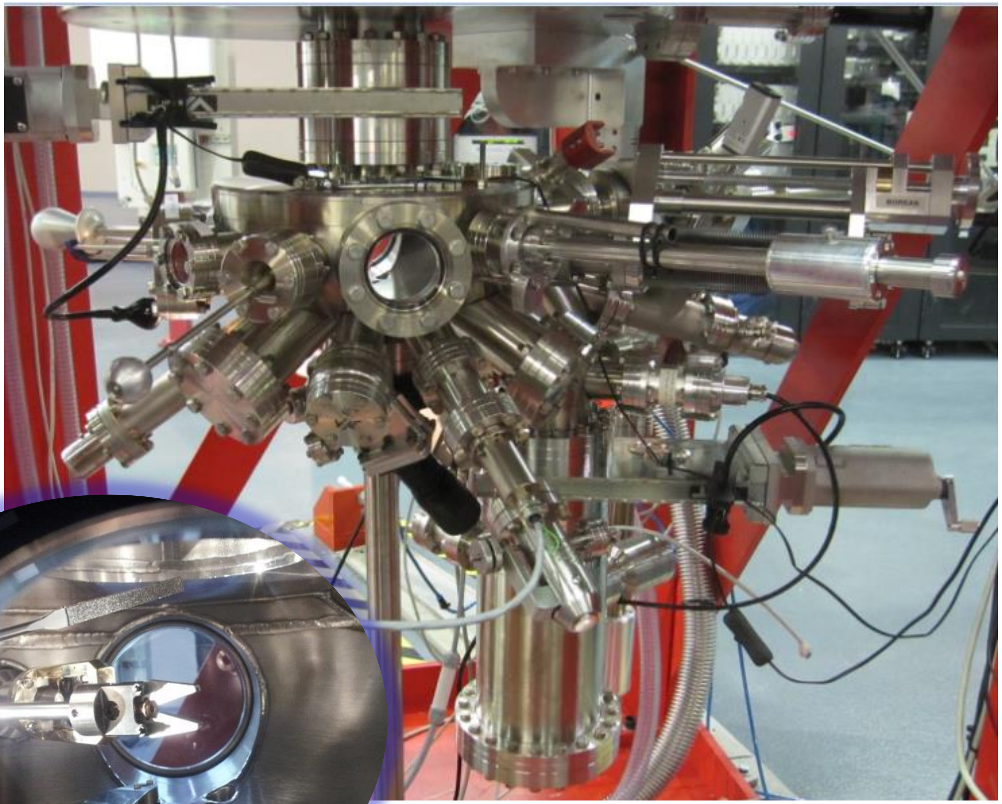
- Dock for travelling suitcase, STM

- Motorization of transmission diode

- Anti-condensation, other upgrades if funded

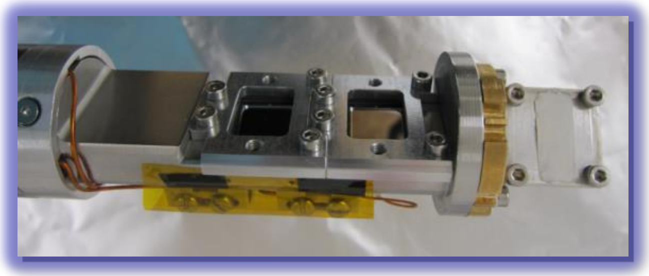
BL endstations update – magnet equipments

- ***Installed equipment: heating stage, metal evaporator, wobble stick, gas lines, leak valve, quartz balance***



In-situ cleaver, wobble stick scrapper (file), ash tray

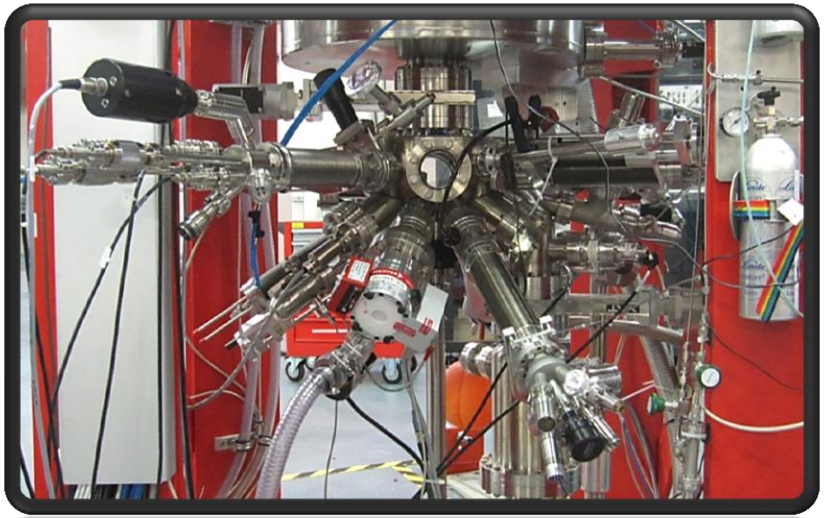
Transmission arm



e-beam heating stage

Demanding surface science user&in-house experiments put strong needs for these and further surface science equipment: turbo pump in preparation chamber, multi-sample loading upgrade for load-lock, LEED, evaporation screen, enhanced fluorescence detection (funding needed)

endstation 1 – upgrades at *Hector*



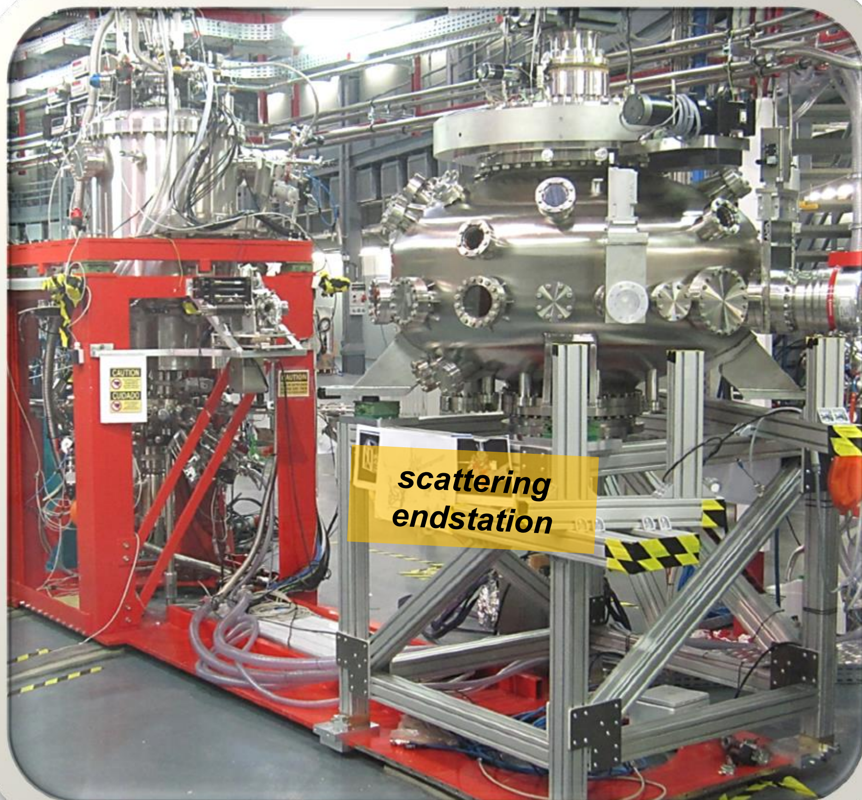
Vector magnet:
6T , 2T (3D)
Temp.: 2K – 350K
sample contacts

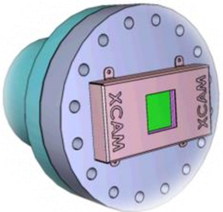
- Temperature control macros ; 3D mode integration (new gui)
- Transmission diode arm (motorized)
- Quadruple metal evaporator, organic evaporator, heating stage, ion gun
- Turbo, LEED/AES prep-ch upgrades (warranting good surface science)
- Fluorescence diode: diode + 2 HV grids for e^- repulsion (foil option)
- Many more types of sample holders, clips;
- In progress: bias, HV batteries, ...enhancing TEY detection

Fluorescence diode assembly designed and built at ALBA (installed end Feb'2013)

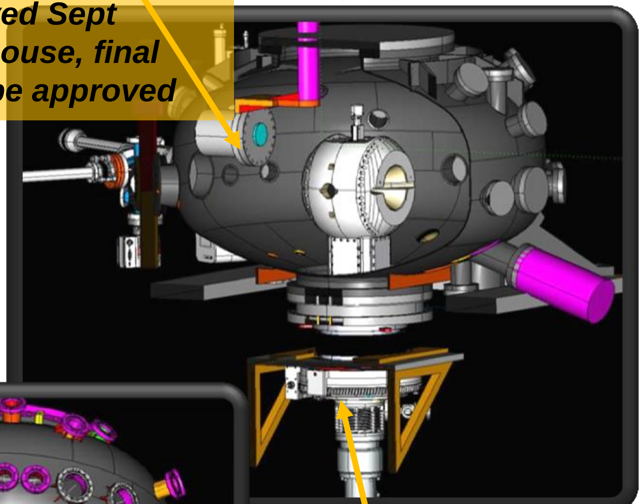
endstation 2– status scattering (MaReS)

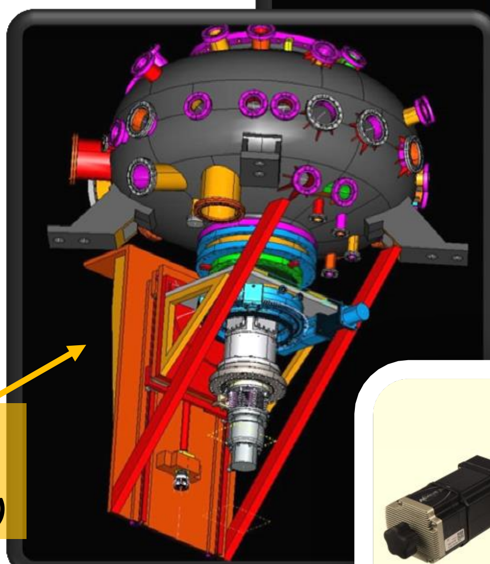
Final assembly mid 2014, Commissioning end 2014, official users Jan' 2015



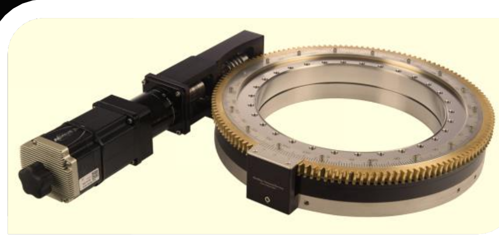


In-vacuum custom CCD:
- XCAM, DDR to be approved Sept
- Arm in-house, final design to be approved





Magnet rotation (delivery July, McAllister) . Under commissioning

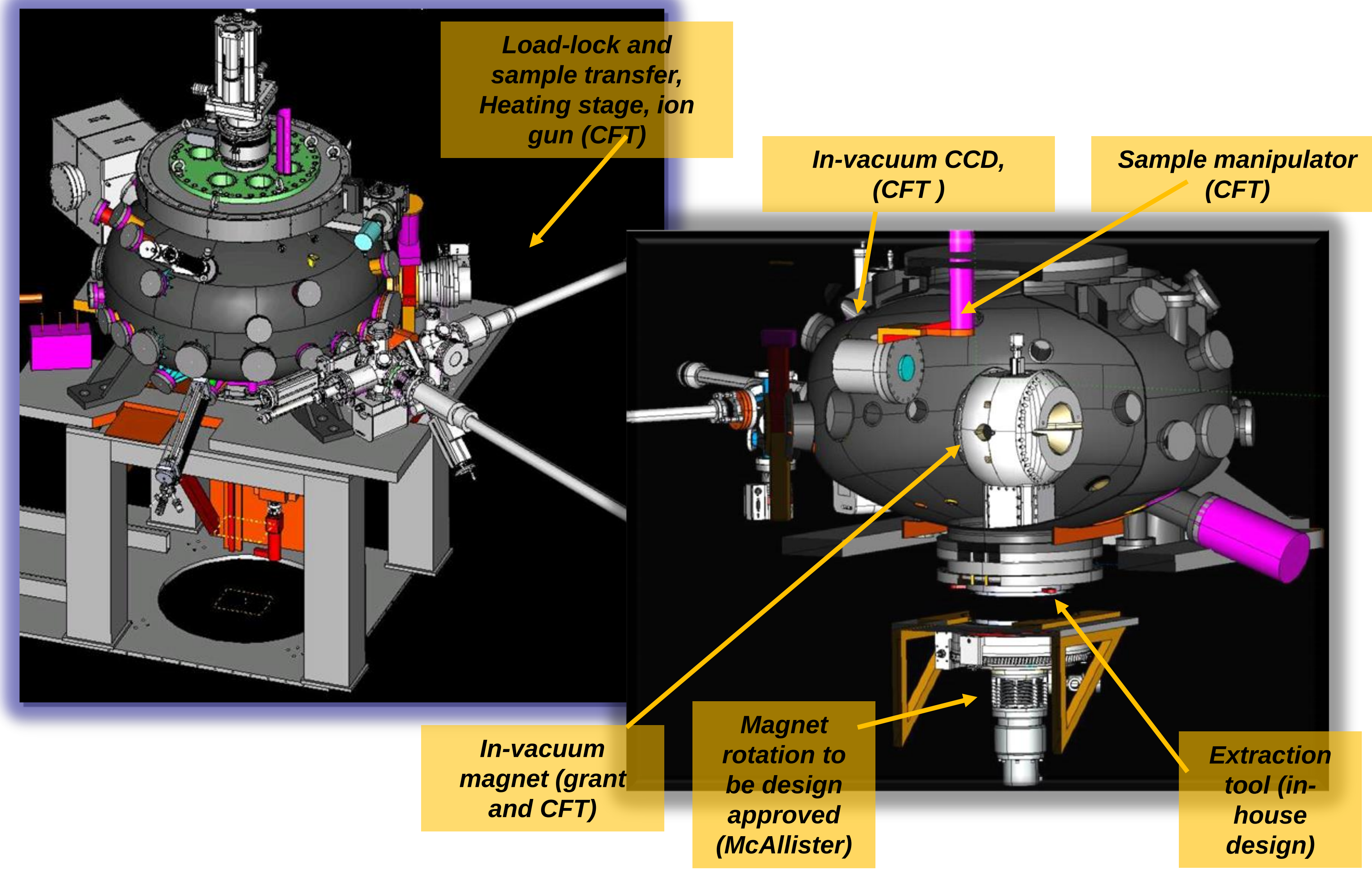


Extraction tool (detailed final design in progress)

- Assembly, tests, commissioning
- Cabling, control (pool) under progress
- Designs, CCD CFT in progress

BL endstations update – scattering chamber

"MaReS" endstation concept



BL endstations update – scattering chamber

Multiaxis C6 cryomanipulator

Manufacturer: VG Scienta

reflectometer rotary feedthroughs

Sample circle

Detector flanges, detector circle

Manufacturer: PINK

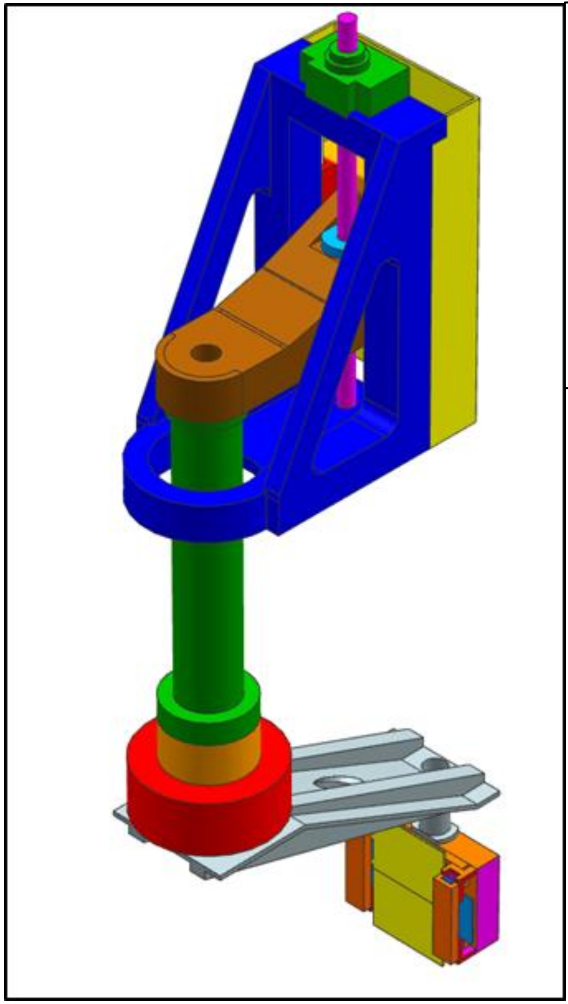
Large UHV vessel (photo of manufacturing at VCS factory in Italy)

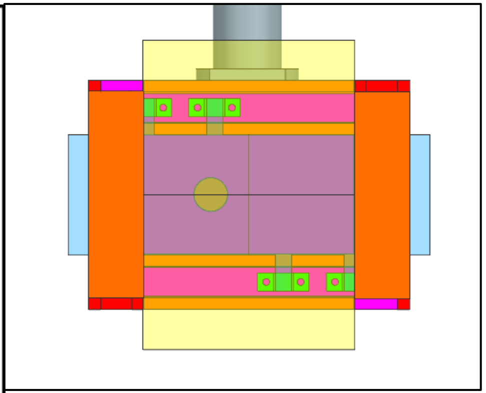
Manufacturer: VCS

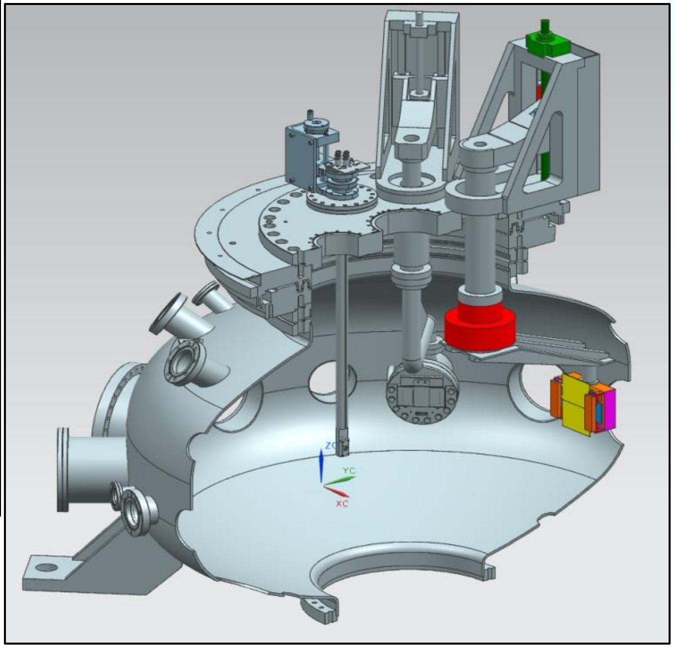
In-vacuum large access HTS magnet

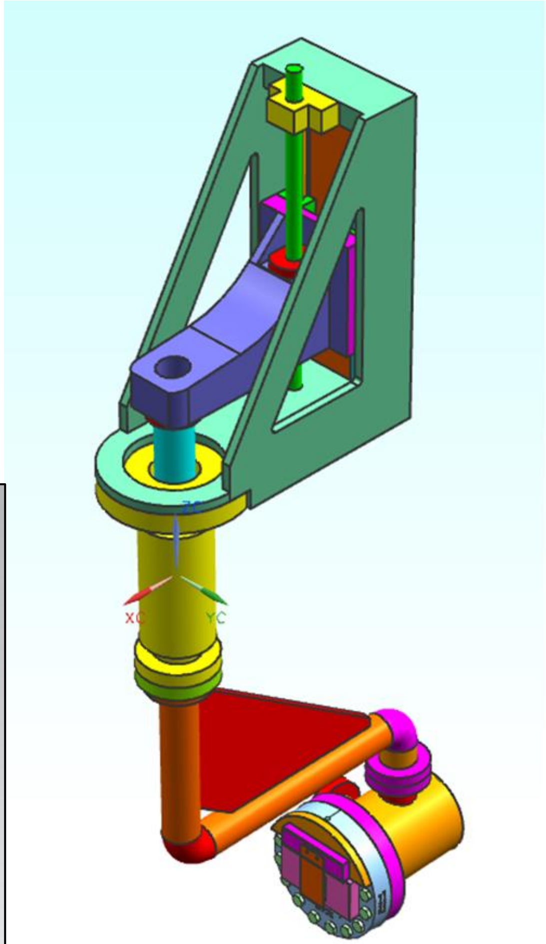
Manufacturer: HTS-110

Endstation 2 – detector arms

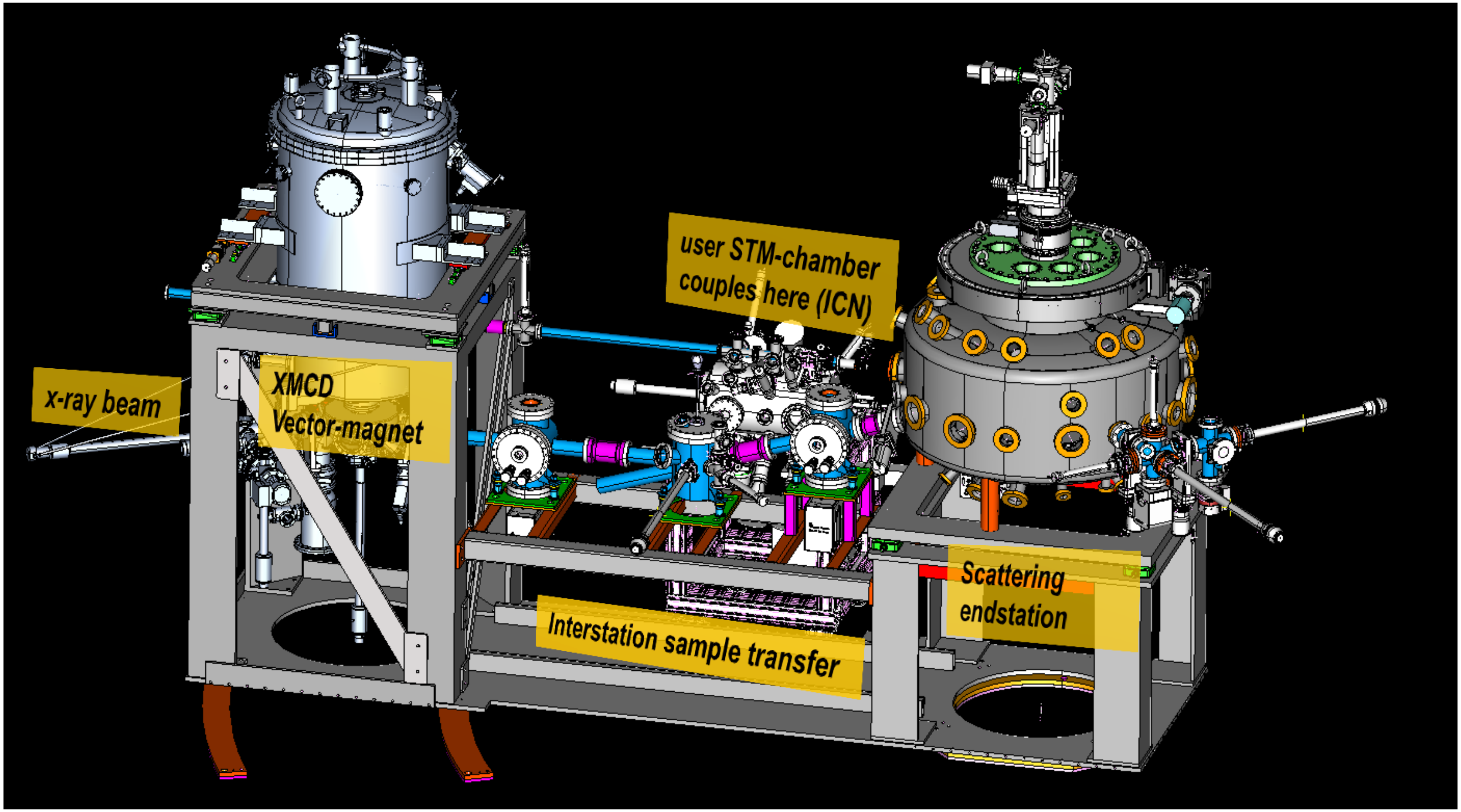








Interstation transfer line & STM– status

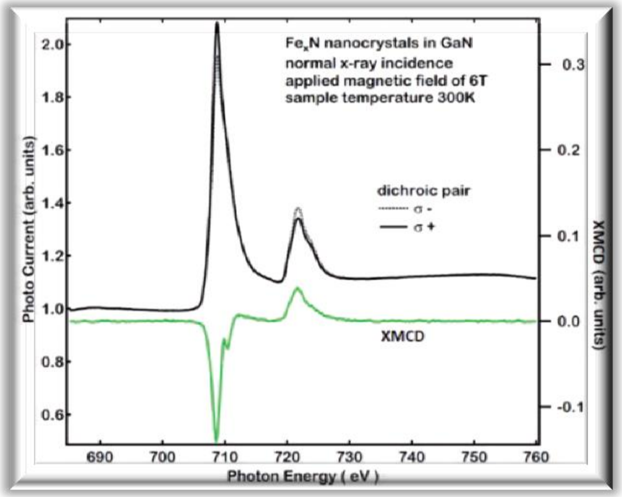


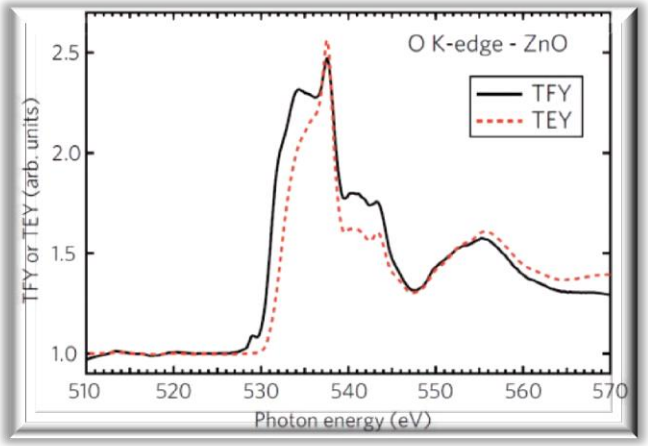
- Most elements bought
- Support on design
- System working Dec 2013 or early 2014

user results

User proposal, ext. cycle, Feb-March 2013

- *Magnetic semiconductors, delicate sample mounting*
- *Fluorescence diode used for the first time*
- *Interest of Partial Fluorescence yield for dilute systems*

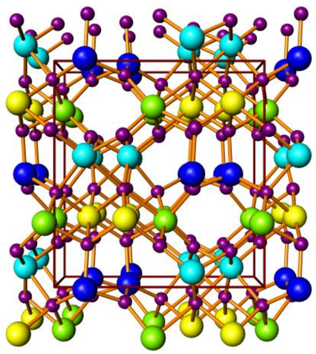


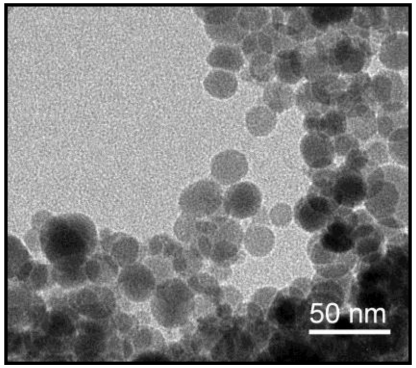


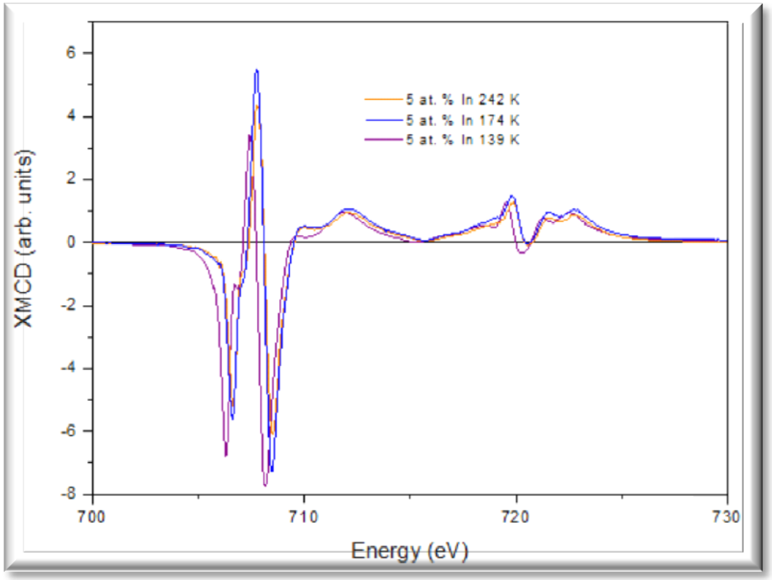
Courtesy I. Kowalik, D. Arvinitis et al, IFW-Lund Univ - Imdea

User proposal, 2012 round

- *ε-Fe2O3 along transition from collinear magnetic (CM) to incommensurate magnetic structures*







Courtesy of M. Gich et al, ICMAB-CSIC (more on his talk)

- **Co-based oxide single crystals**

J. Padilla (co-directed PhD, J.Herrero- ICMAB)

XMCD studies, phase transitions

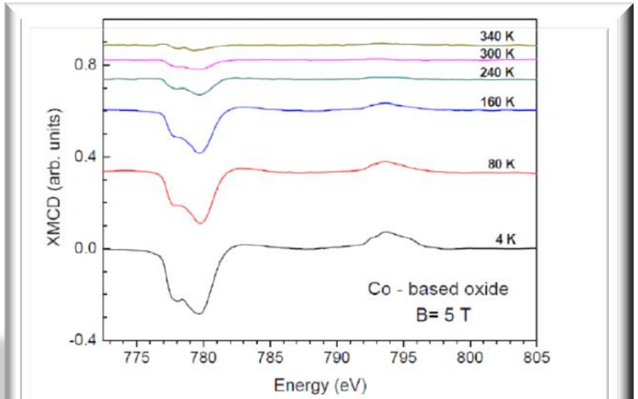
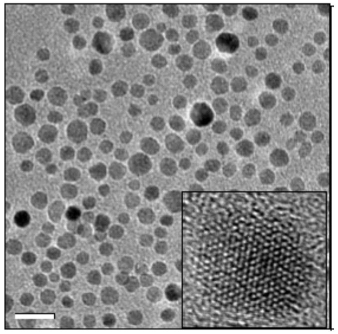


Figure 13: MCD spectra at different temperatures from a ferromagnetic bulk Co-oxide sample under an applied field of 5 Tesla in the HECTOR cryomagnet.

Courtesy J. Padilla, J.L. Garcia Muñoz et al

- **HTS with embedded NPs, (2012, user exp 0180)**

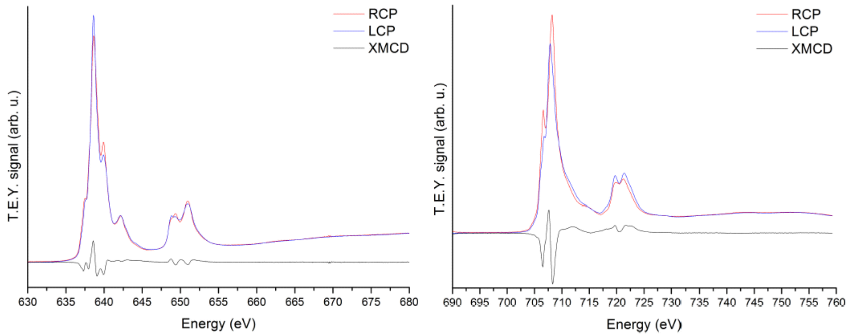
E. Solano et al, UAB-ICMAB-ALBA BL29



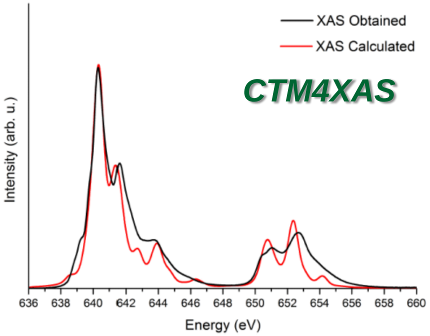
Chapter 9

Synchrotron XAS & XMCD

Contents



(a) $MnFe_2O_4$-T Mn edge (b) $MnFe_2O_4$-T Fe edge



Early results presented at MRS2013, publiction in preparation

Fe di-nuclear molecular magnets, preliminary measurements

J. Giner et al, ICMAB –UAB- BL29

José Giner Planas,*[a] Florencia Di Salvo,[a] Min Ying Tsang,[a] Francesc Teixidor,[a] Clara Viñas,[a] Núria Aliaga-Alcalde,[a] Eliseo Ruiz,[b] Duane Choquesillo-Lazarte[c]

[a] Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Campus de la UAB, Bellaterra (Spain).
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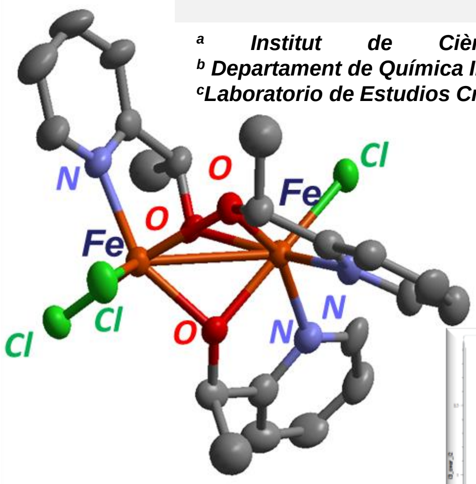
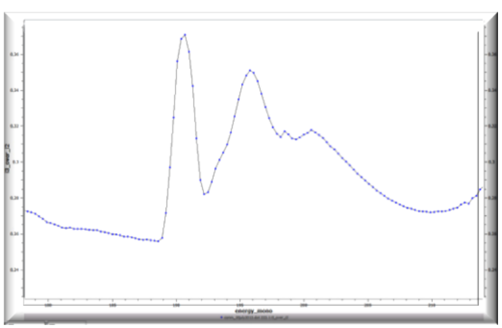
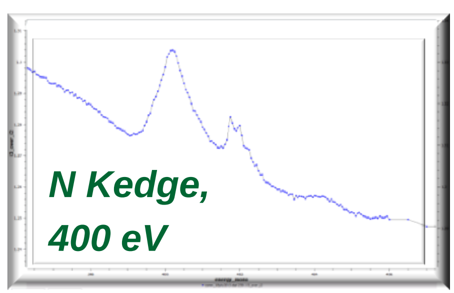
[c] Laboratorio de Estudios Cristalográficos, IACT-CSIC, Armilla, Granada (Spain)



Cl L1 edge, 200 eV
(20 time attenuated flux)

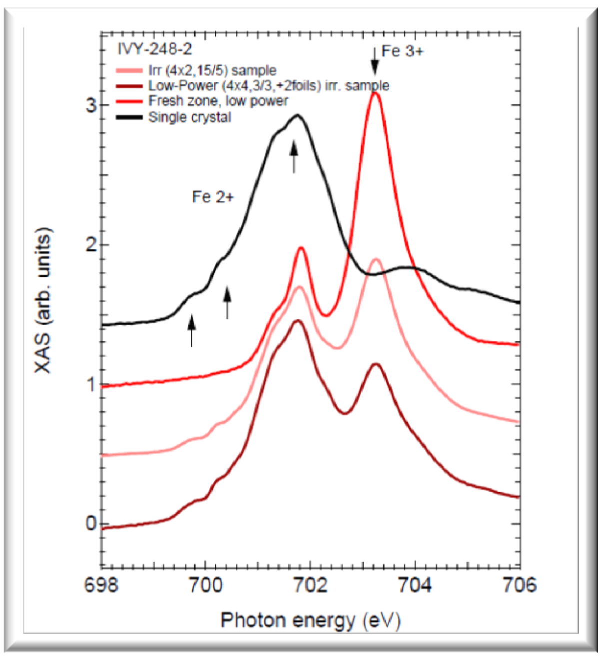
C Kedge, 290 eV





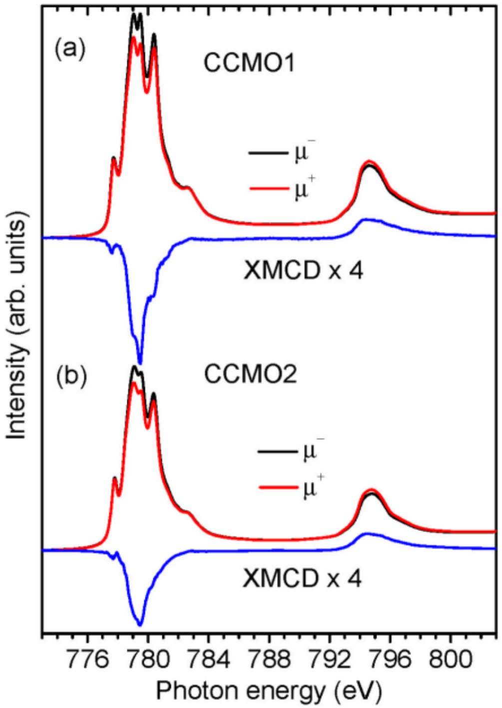
N Kedge, 400 eV

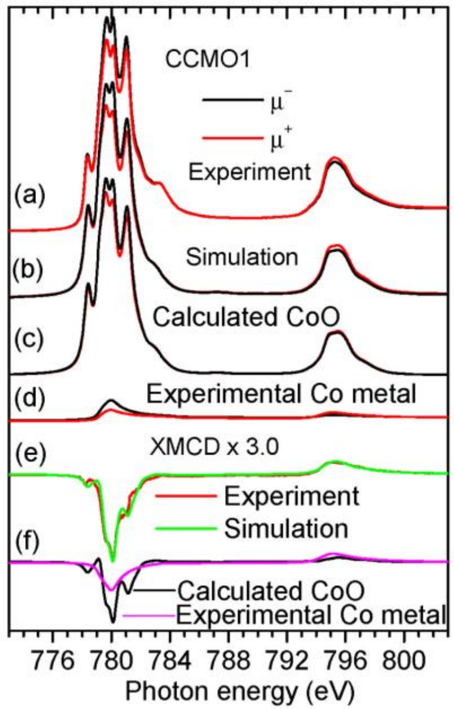
Fe L2,3

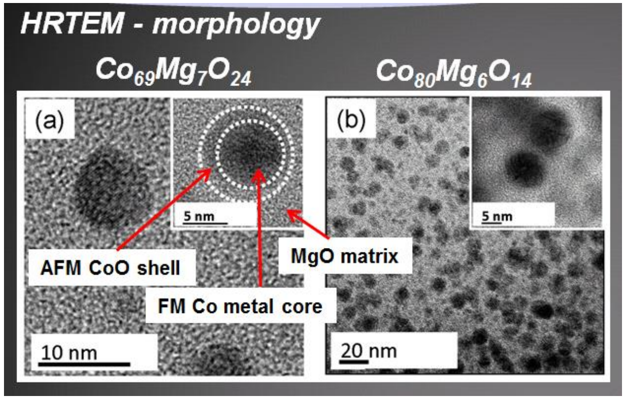


Giant Exch Bias Co-CoO granular systems

Nanjing University / MPI CPfS Dresden / CELLS-ALBA (E. Pellegrin, BL29)



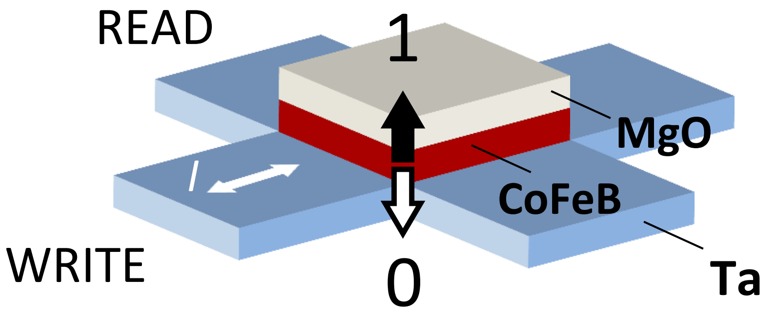


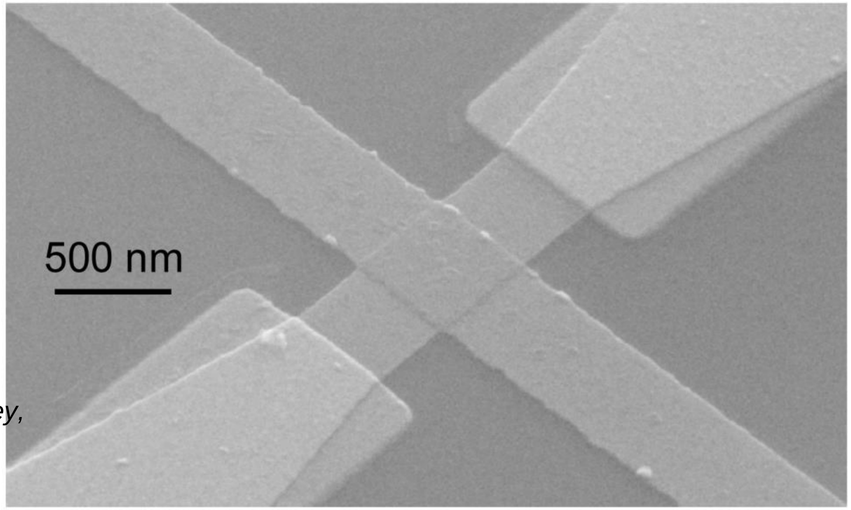


- ***Uncompensated rotatable Co2+ spins in nominally AFM CoO shell stabilized by MgO matrix.***
- ***Metallicity cancels CoO FM contribution***
- ***30% Co metal + 70% ferromagnetic Co2+ in dichroic spectrum.***
- ***Larger part of ferromagnetic signal stems from CoO shell***

1st BL29 publication, to appear in Nanoscale.

Motivation: Magnetization switching by in-plane current injection

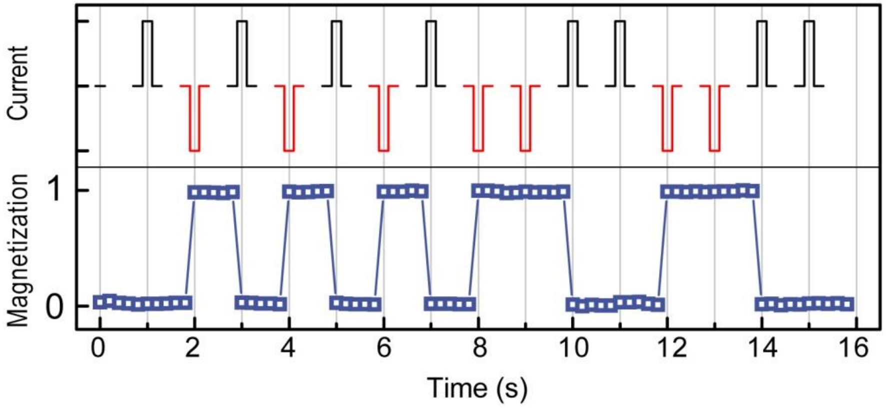




Can Onur Avci, Kevin Garello, Corneliu Nistor, Mihai Miron, Sylvie Godey, Belen Ballesteros, Aitor Mugarza, and Pietro Gambardella
Catalan Institute of Nanotechnology (ICN)

Alessandro Barla
CNR – ISM Trieste

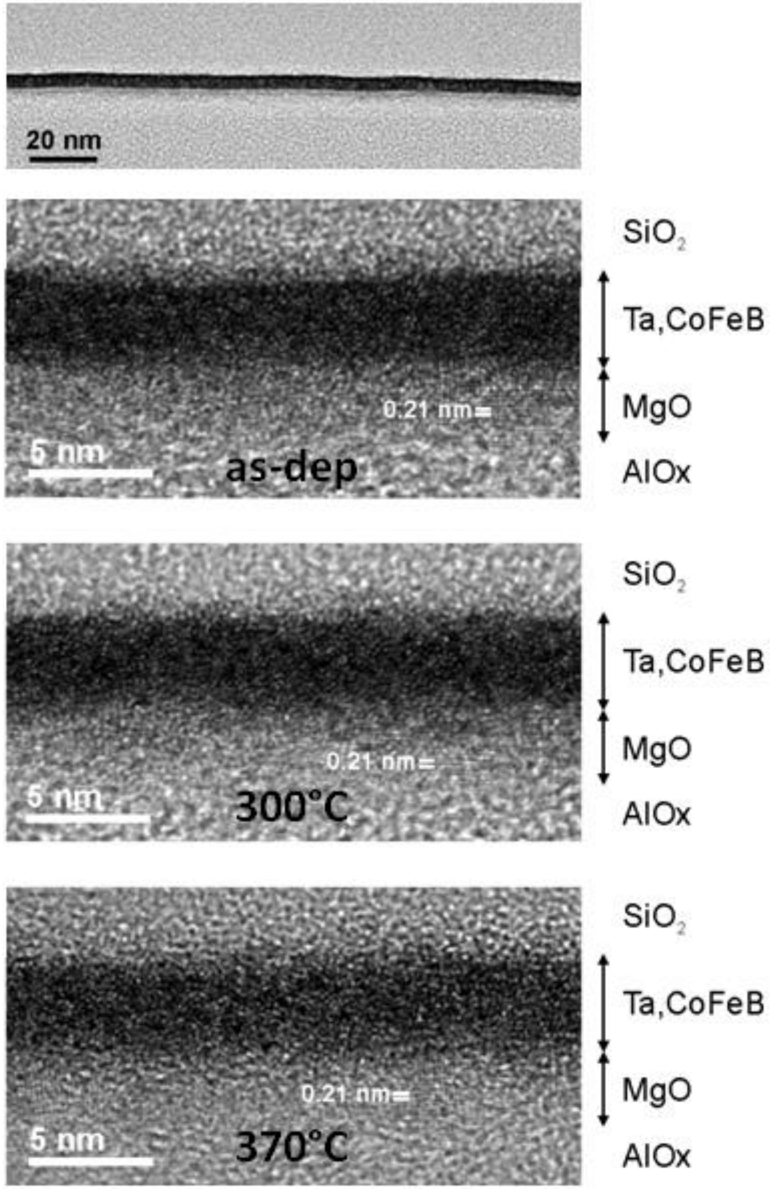
Manuel Valvidares, Eric Pellegrin
Boreas beamline, ALBA



Nature ***476****, 189 (2011)*

User results spotlight: spintronics

Optimization of material parameters



Stack composition:

HM/FM/Ox

HM = heavy metal (Pt, Ta, W, …)

FM = ferromagnet (Co, CoFeB, …)

Ox = 0xide (AlOx, MgO,…)

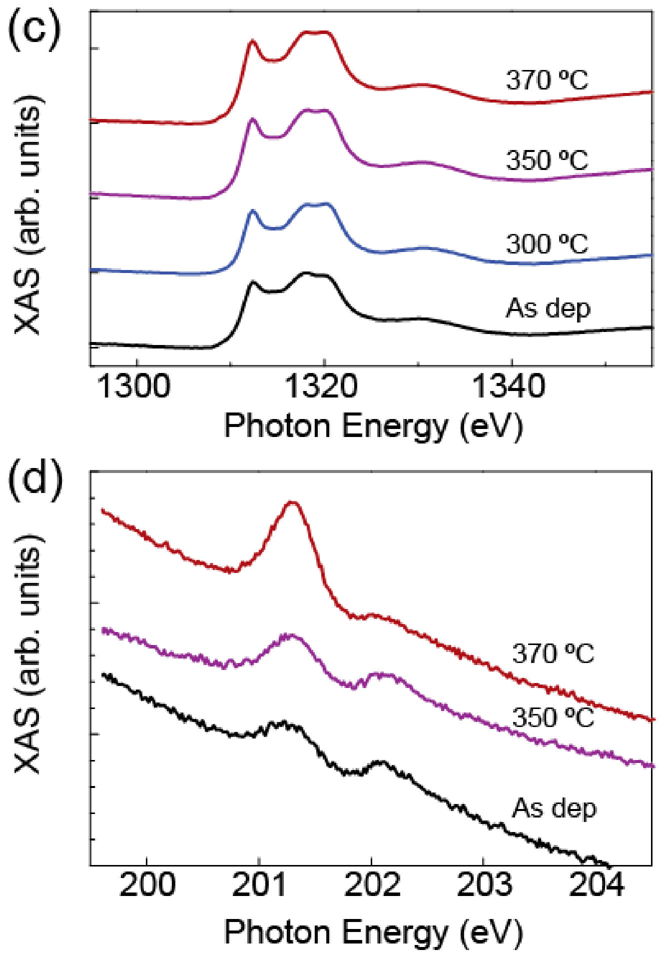
Thickness

Annealing conditions

Magnetization

User results spotlight: spintronics

Chemical sensitivity afforded by XAS



Quality of oxide barrier:

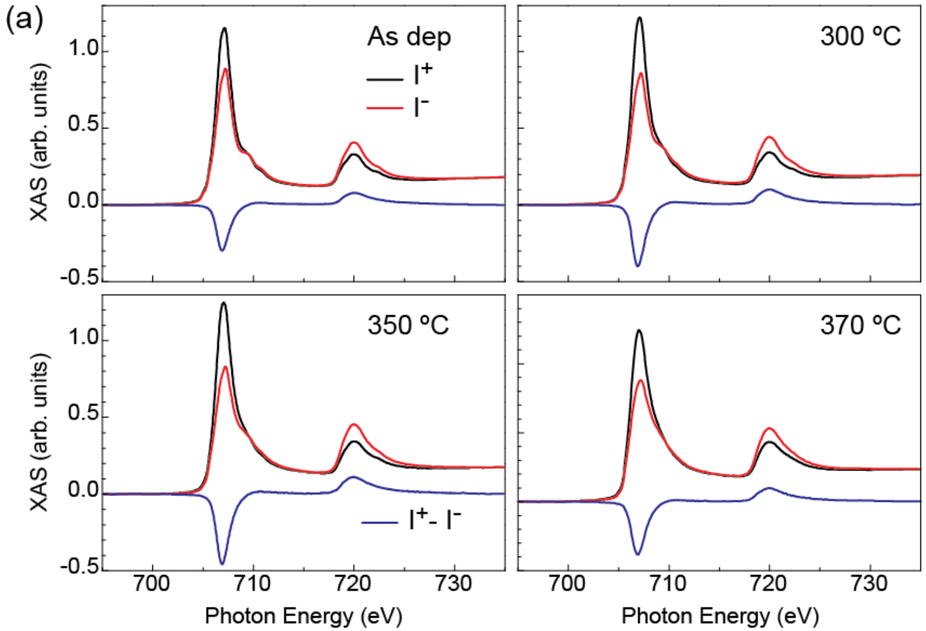
XAS at the K edge of Mg

Diffusion of B from the FM to the oxide:

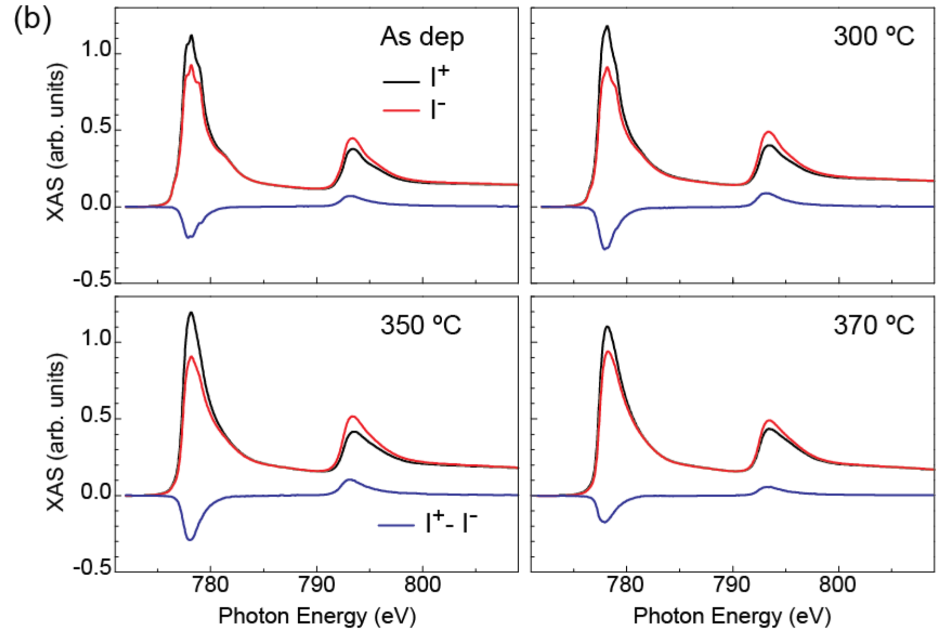
XAS at the K edge of B

Element-resolved magnetic moments measured by XMCD

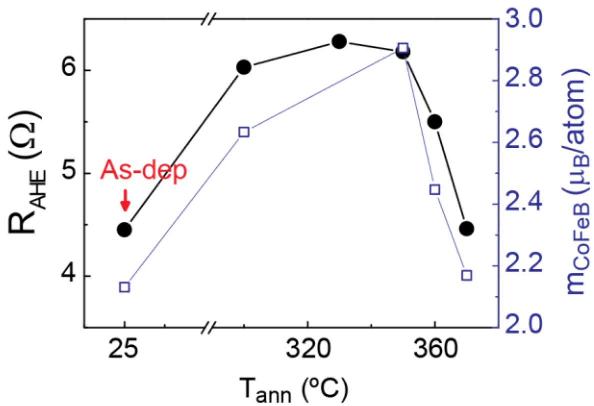
Fe



Co



Magnetization measured by the anomalous Hall effect



Magnetic moments measured by XMCD

User results spotlight: spintronics

User conclusions

Several ultrathin magnetic films (0.5 – 1 nm) were measured by XAS and XMCD

The energy range of the beamline is very convenient

The signal-to-noise ratio is comparable to that of other synchrotron sources in Europe

XMCD spectra are acquired in a reasonable time

It would be nice to have better online software to perform quick analysis of the spectra

These measurements are helping us to optimize the fabrication of magnetic layers for current-induced switching applications.

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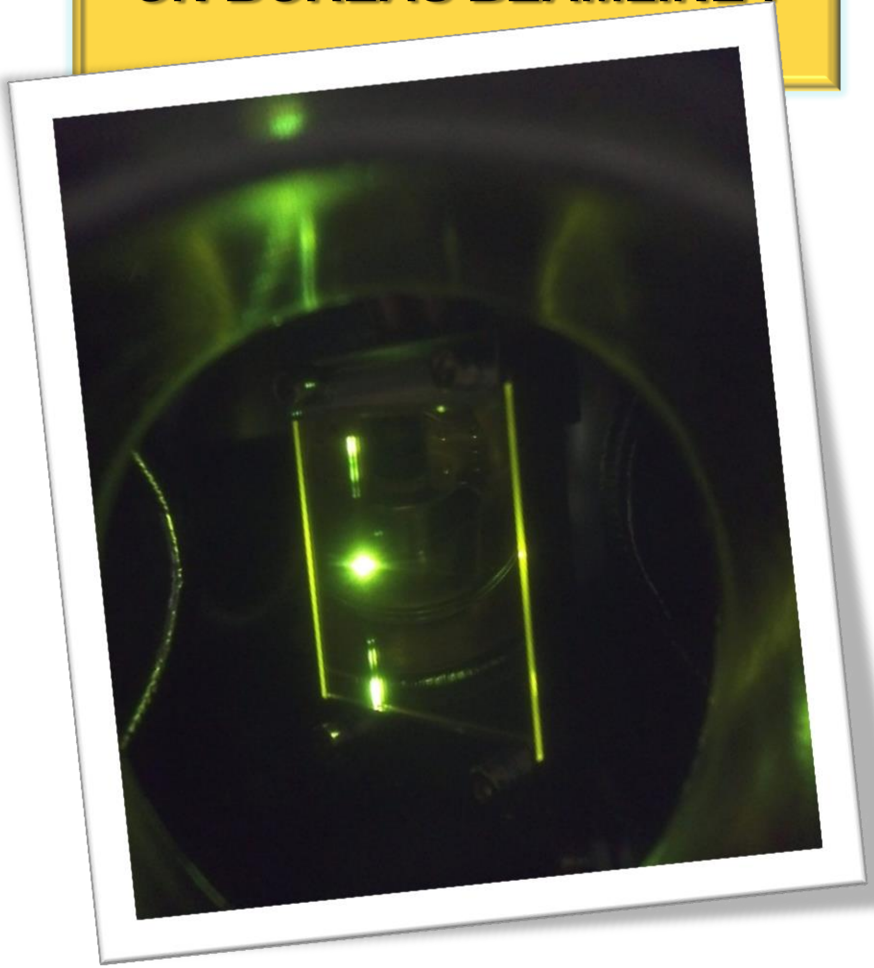
THANKS FOR YOUR ATTENTION AND ADVICE ON BOREAS BEAMLINE !



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