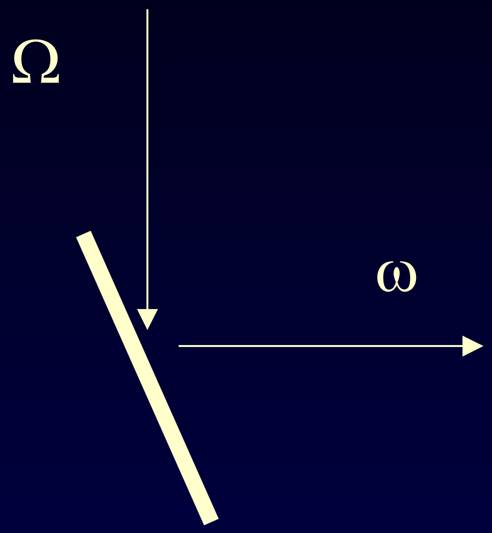
RESONANT X-RAY EMISSION: PREPARING SOLEIL



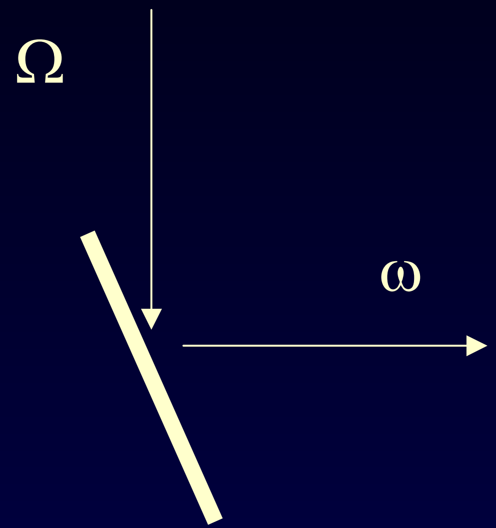
Workshop: Photon-in—Photon-out

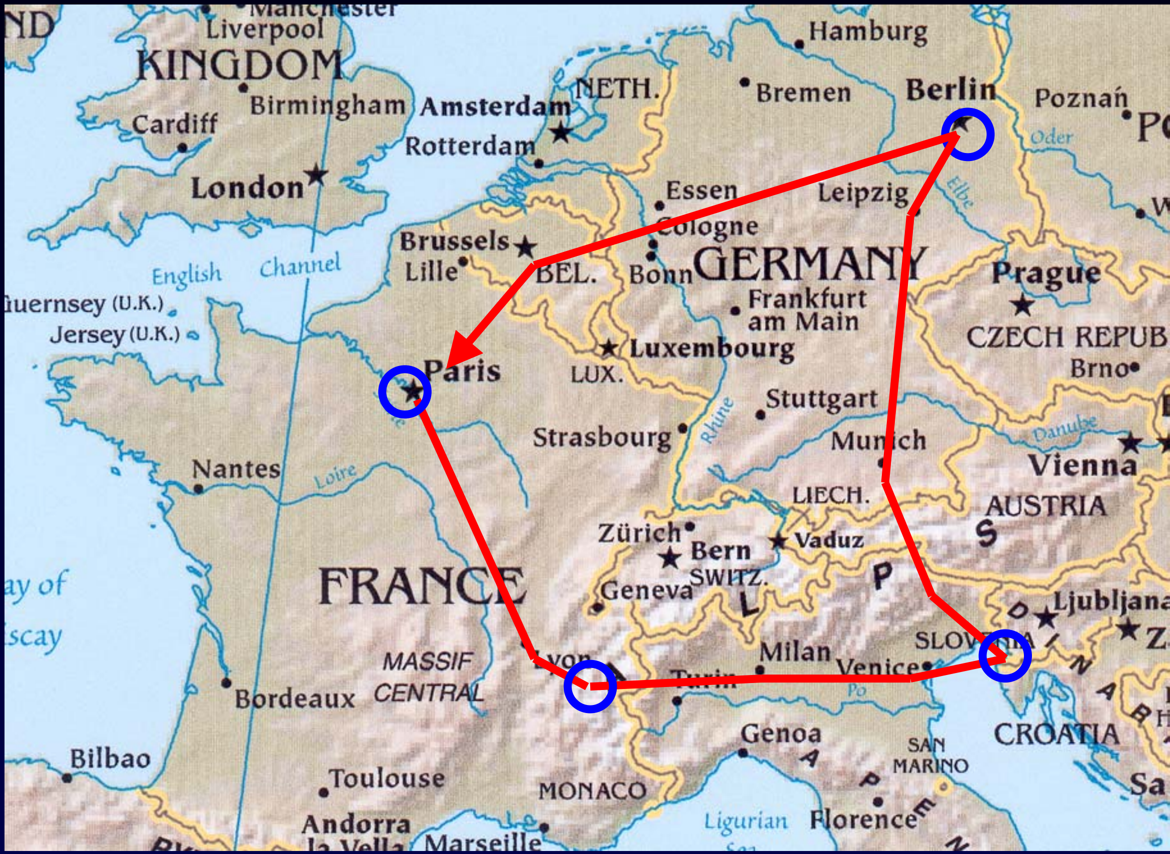
ALS 18/20-10-2004

Coryn F. HAGUE

Université Pierre et Marie Curie, Paris

RESONANT X-RAY EMISSION: PREPARING SOLEIL





Workshop: Photon-in—Photon-out

ALS 18/20-10-2004

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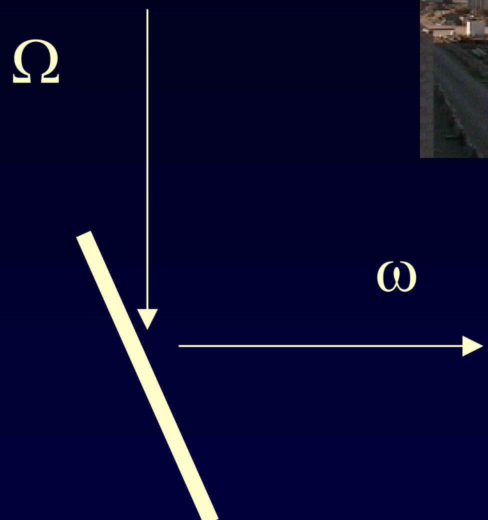

Workshop Photon-in—Photon-out

ALS 18/20-10-2004

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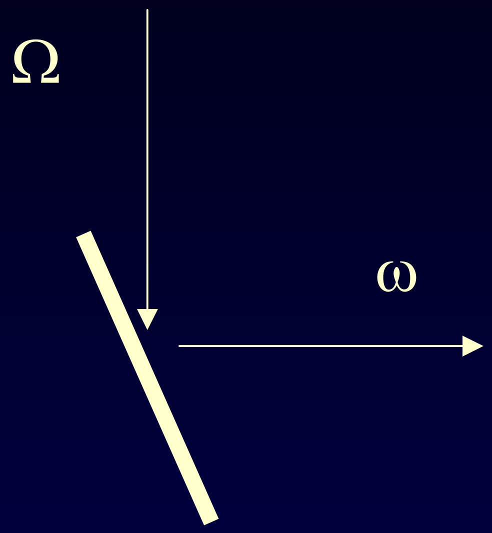


Renaud DELAUNAY

Jean-Michel MARIOT

Jean-Pascal RUEFF ←

Univ. P & M CURIE

Marino MARSI

Elettra

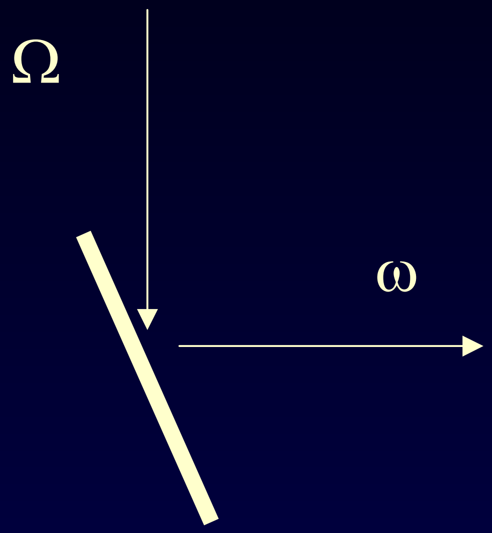
Maurizio SACCHI ←

LURE (SOLEIL)

Workshop: Photon-in—Photon-out

ALS 18/20-10-2004

RESONANT X-RAY EMISSION: PREPARING SOLEIL



RXES ONE OF THE TECHNIQUES WHICH BENEFITS MOST FROM SR

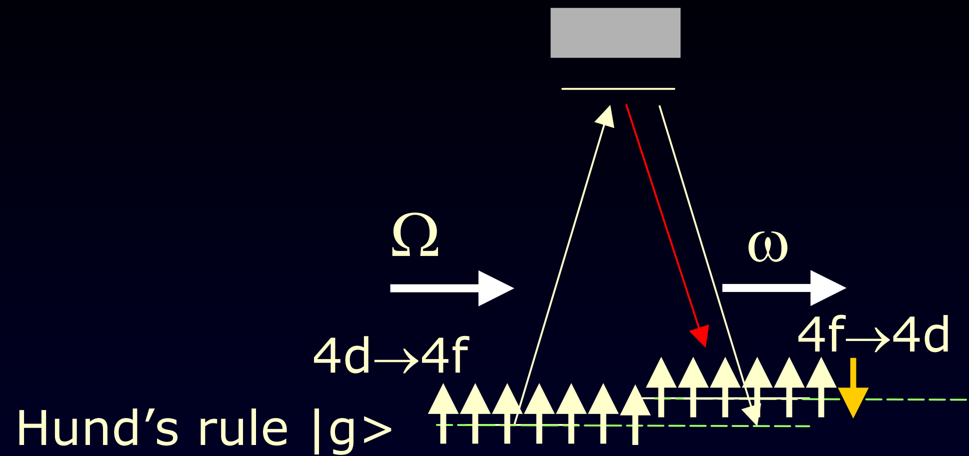
PREPARE FOR:

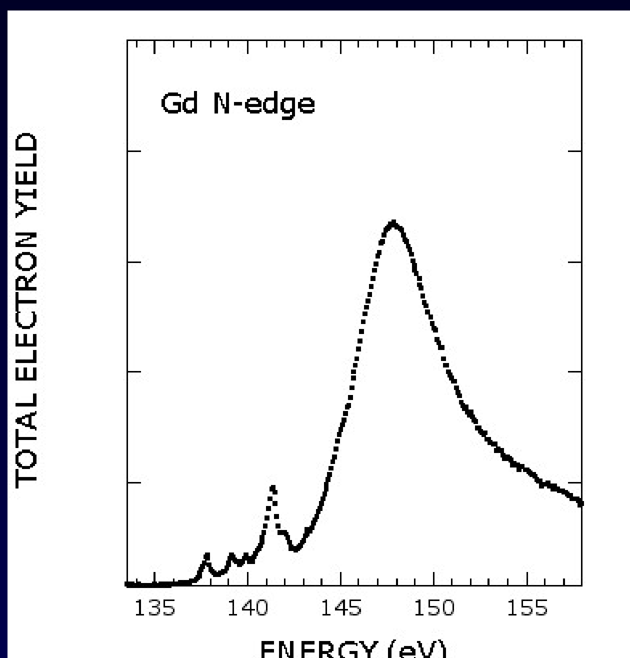
- GOOD RESOLUTION AND
- GOOD STATISTICS
- MORE USER FRIENDLY FOR MATERIALS SCIENCE.
- OVER MAXIMUM ENERGY RANGE OF MACHINE

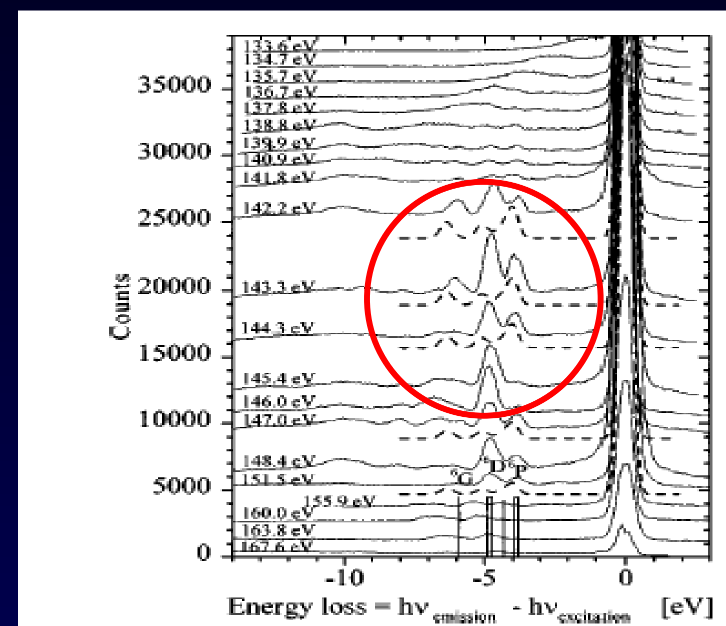
"TEXTBOOK" RESONANT X-RAY EMISSION

- Low energy excitations.

  Here spin flip in Gd.







Energy-loss spectra on $(Y,Gd)_2O_3$

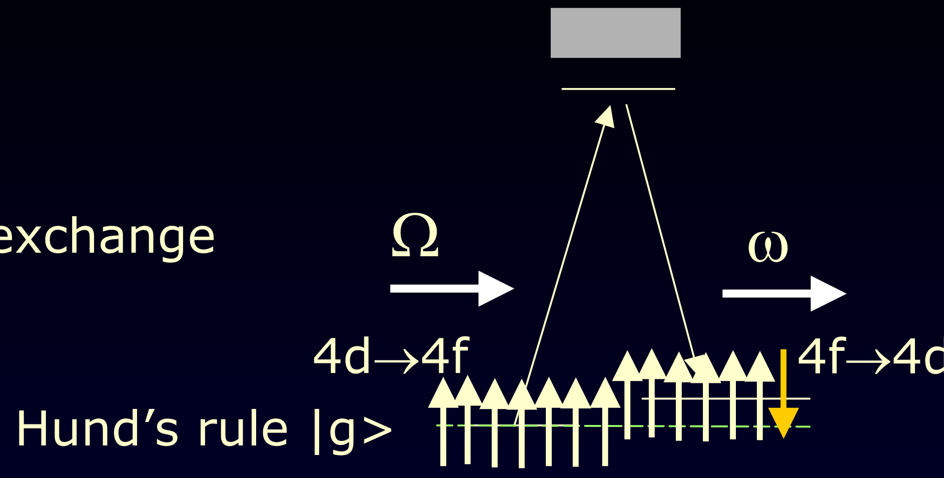
Moewes et al PRB 98

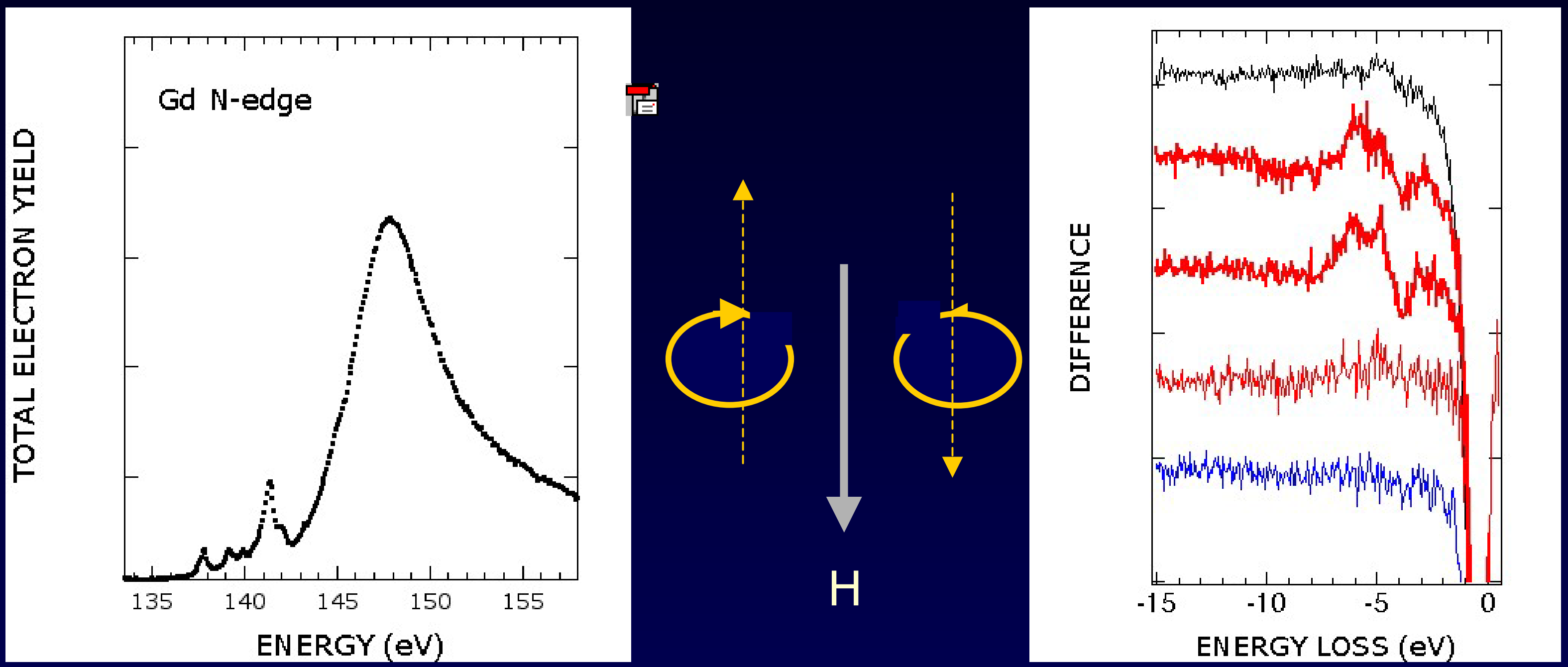
"TEXTBOOK" RESONANT X-RAY EMISSION

- Magnetism

  Here effect on spin flip

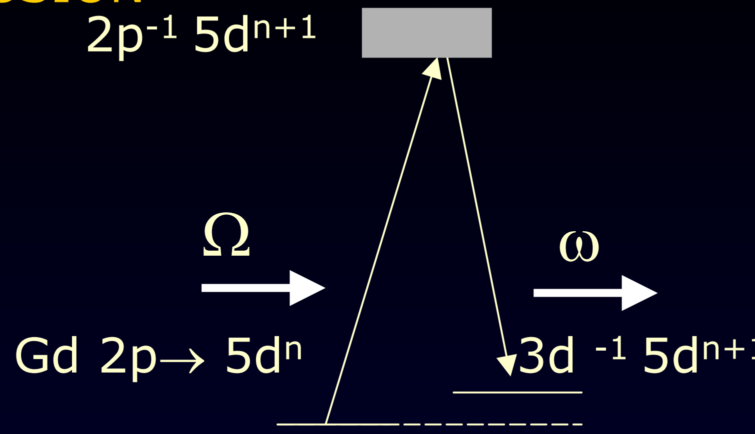
- MAGNETIC MATERIALS and exchange interactions





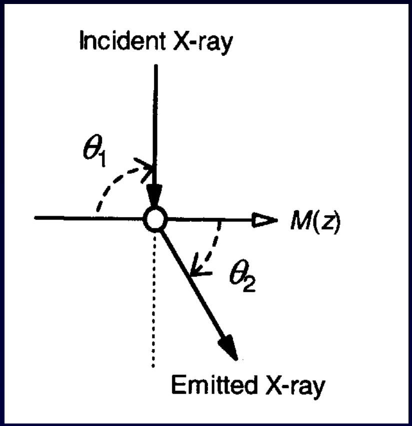
Mariot et al (Surf Sci Rev 2002) ELETTRA:Cipo

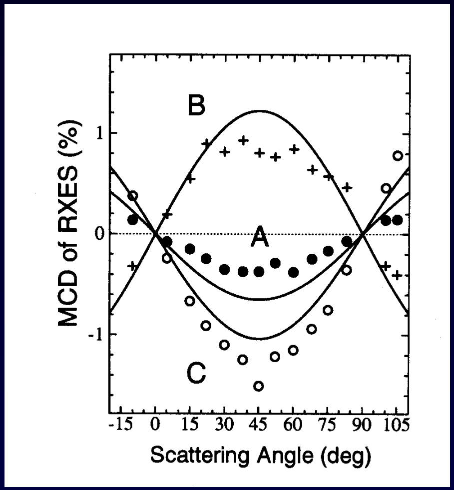
“TEXTBOOK” RESONANT X-RAY EMISSION

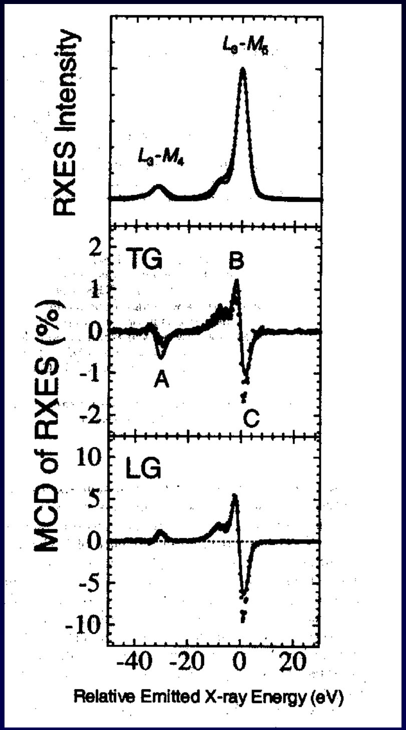


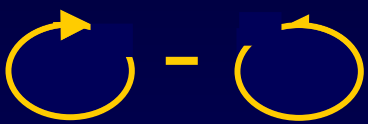
- Magnetism

  Here at Gd L-edge





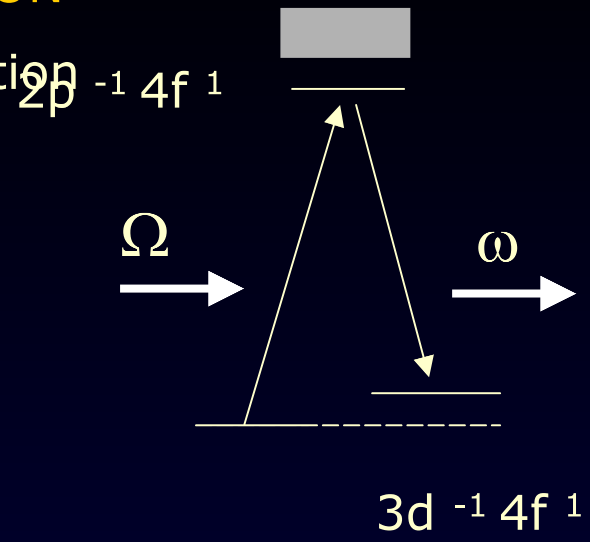


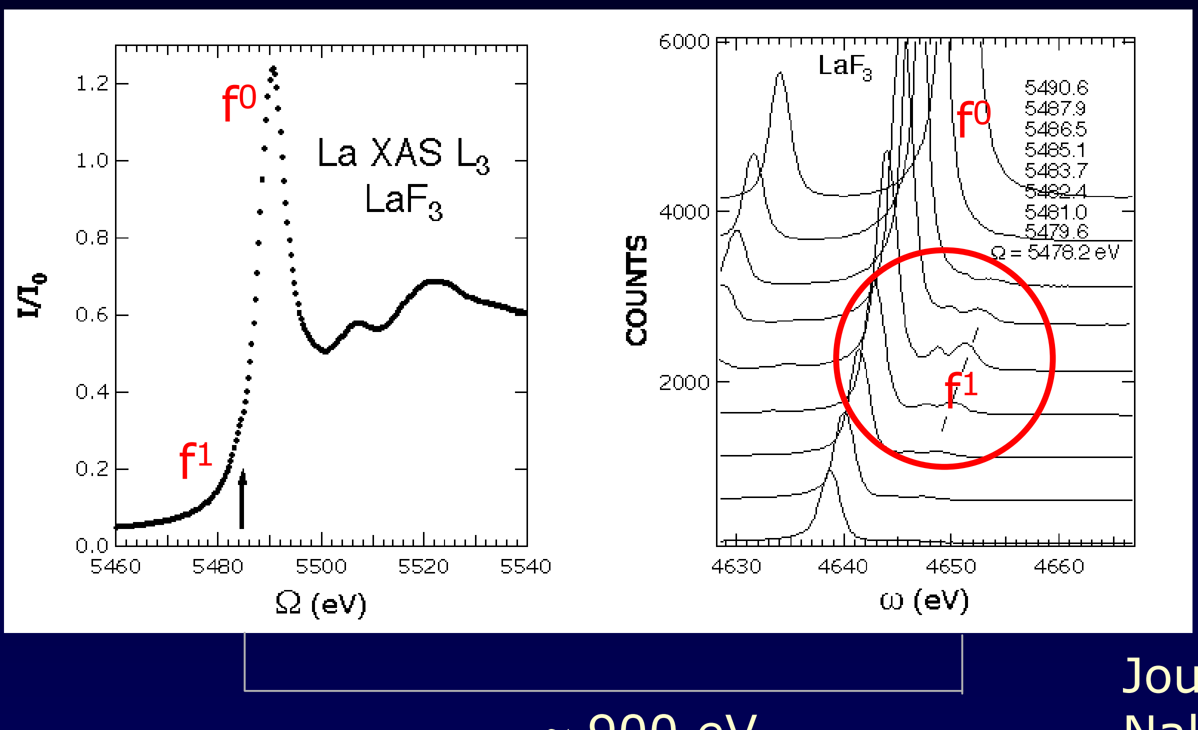


Fukui et al. J. Phys. Soc. Jpn 2001

"TEXTBOOK" RESONANT X-RAY EMISSION

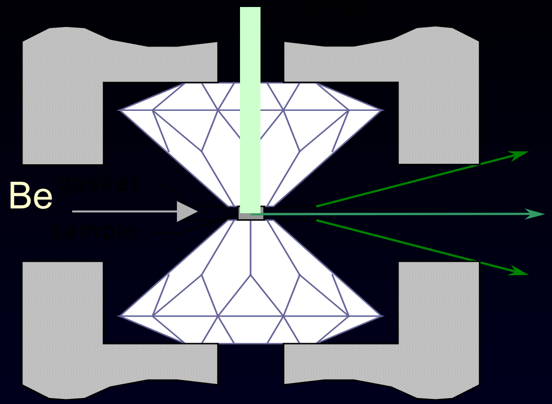
- Details of pre-edge structure in transition metal oxides useful for MATERIALS SCIENCE
- Highlighting pre-edge structure e.g. quadrupole transitions in lanthanides.





Journel et al. PRB 2002
Nakazawa et al. PRB 2003

FAVORITE PHASE TRANSITIONS:



$\gamma \rightarrow \alpha$ transition (first order) in Ce

- fcc $\rightarrow$ fcc 14% contraction
- $\gamma \rightarrow \alpha$: 8 GPa (80kbar) 300 K

(changing temp not a clean experiment)

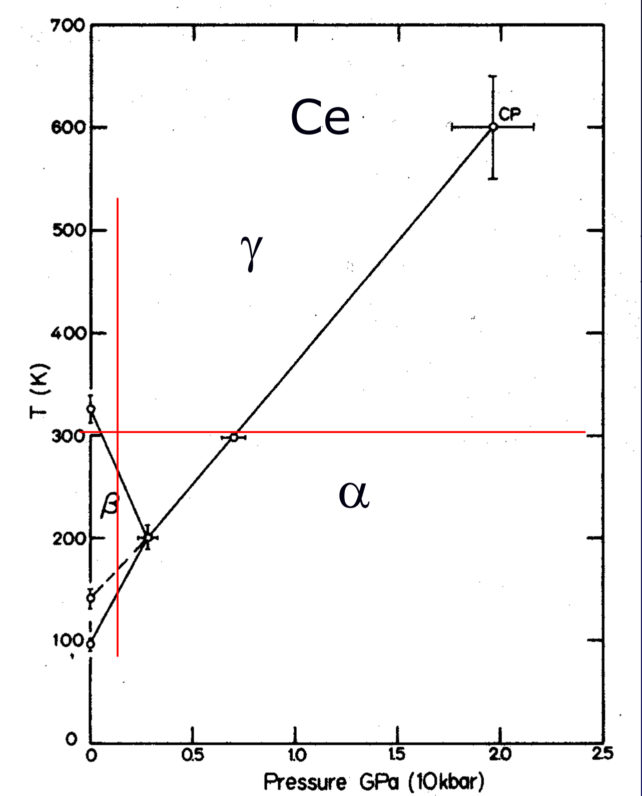
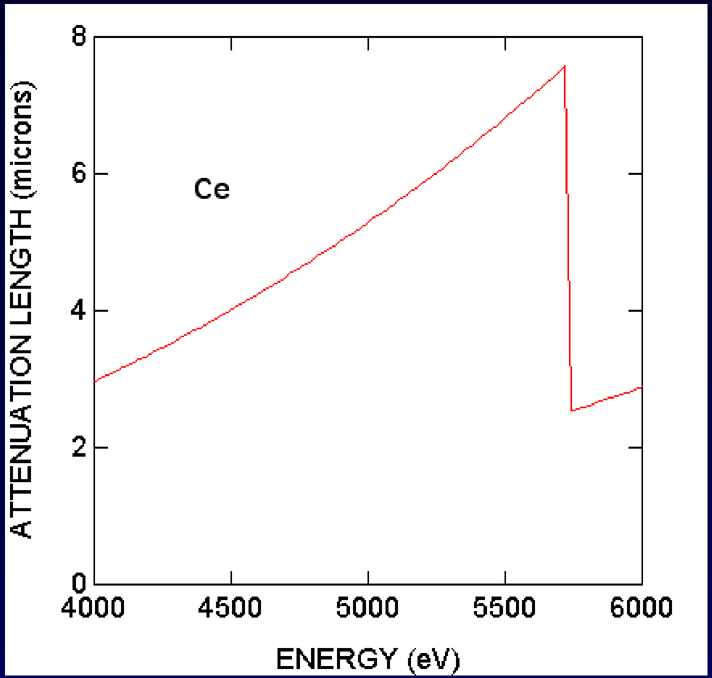


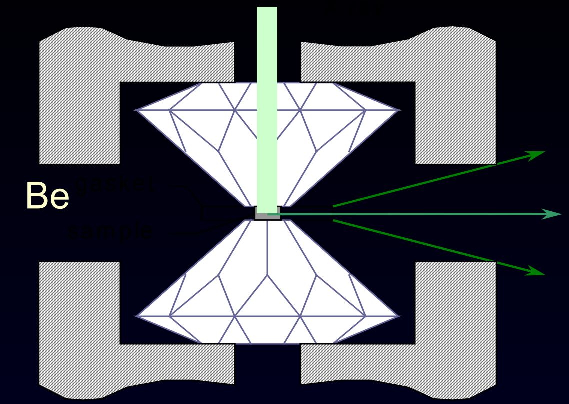
Fig. 1. *P–T* phase diagram of cerium metal (from ref. [1]).

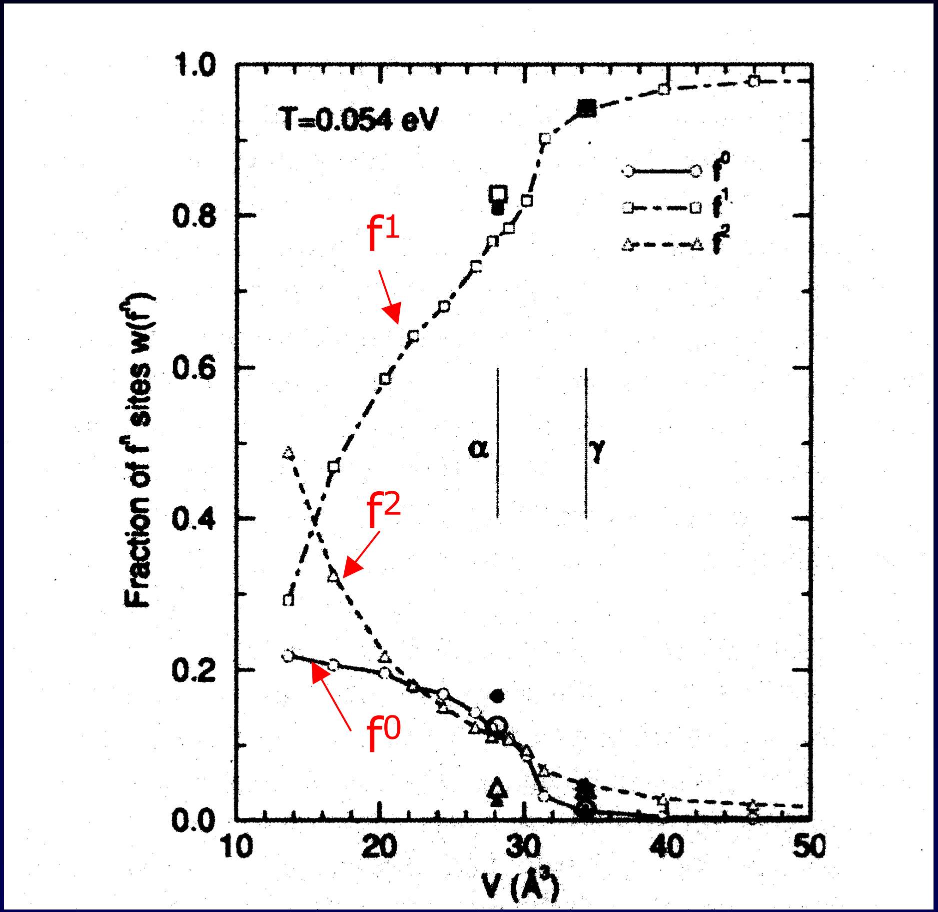
At Ce 2p edge:



FAVORITE PHASE TRANSITIONS:

$\gamma \rightarrow \alpha$ transition (first order) in Ce





Theory
Held et al PRL 2001
McMahan et al PRB 2003

- LDA+DMFT:

PREDICT A QUASI PARTICLE RESONANCE IN THE 4f SPECTRUM ACCOMPANIED BY RAPID GROWTH IN DOUBLE OCCUPANCY AS THE γ to α TRANSITION IS CROSSED

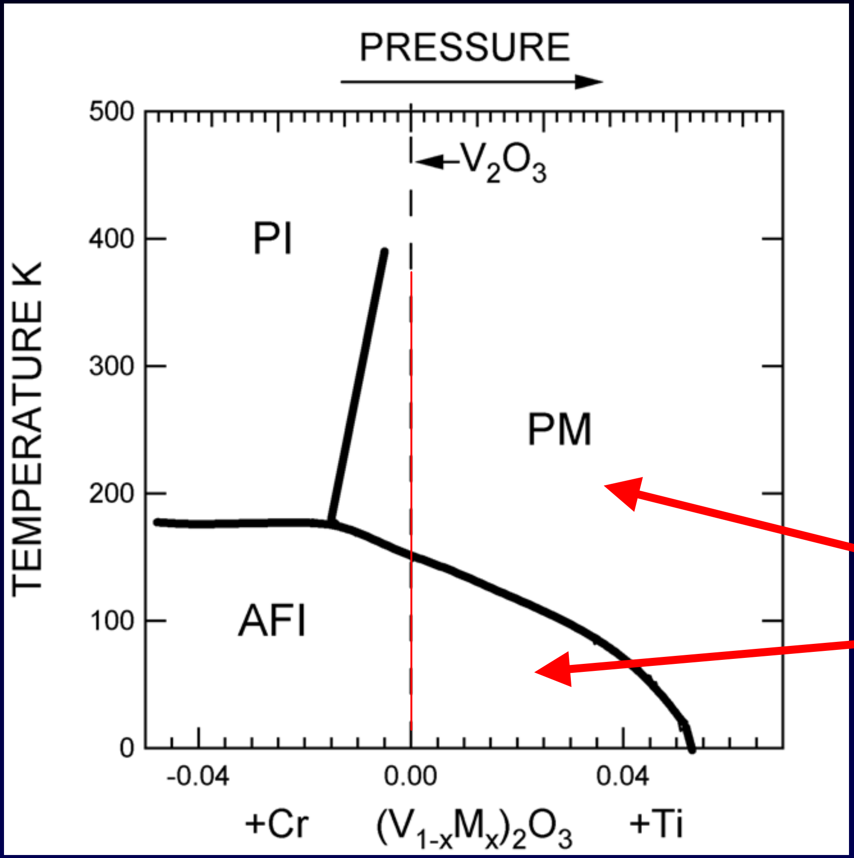
Expt.

See Rueff et al PRL 2004

FAVORITE PHASE TRANSITIONS:

metal→insulator transition (first order) in V_2O_3

V_2O_3
McWhan 1972



M-I transition induced by:
Temperature
Pressure
Non-stoichiometry
Alloying

Notorious surface effects

Corundum

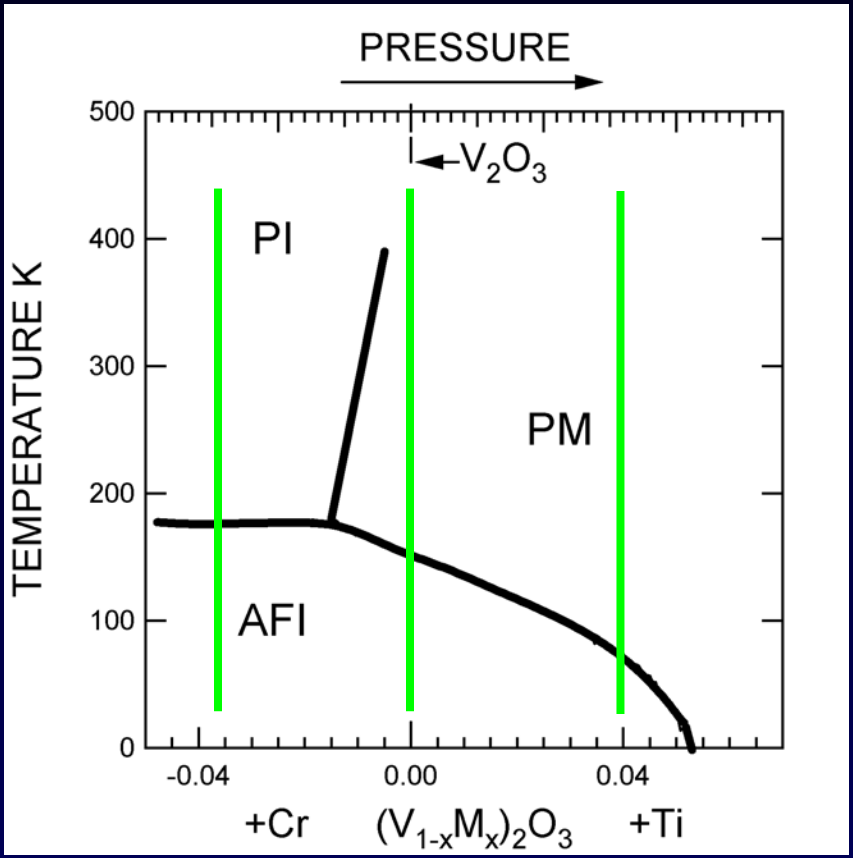
Monoclinic

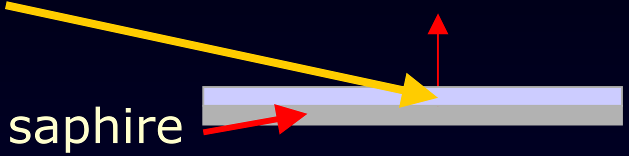
FAVORITE PHASE TRANSITIONS:

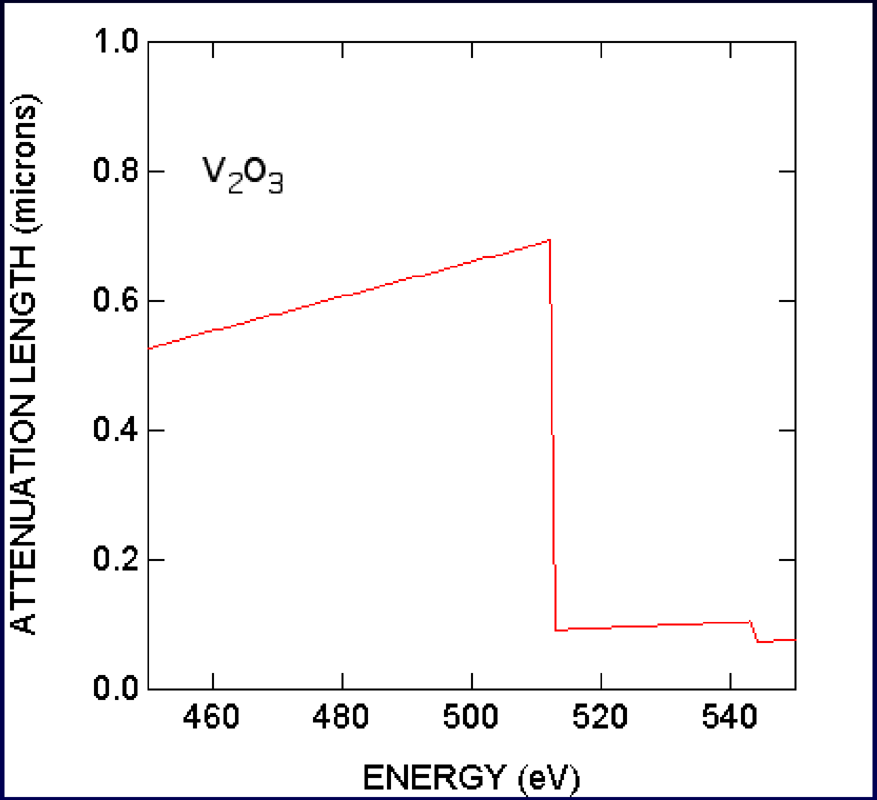
metal→insulator transition (first order) in V_2O_3

V_2O_3 THIN FILM
Sass et al (Univ. Göttingen)

Epitaxially grown on $\alpha-Al_2O_3$







MAIN FEATURES OF SOLEIL

E = 2.76 GeV

2π = 354 m

I (multi-bunch) = 500 mA

Emittance H = 3.7 nm.rad V = 37pm.rad

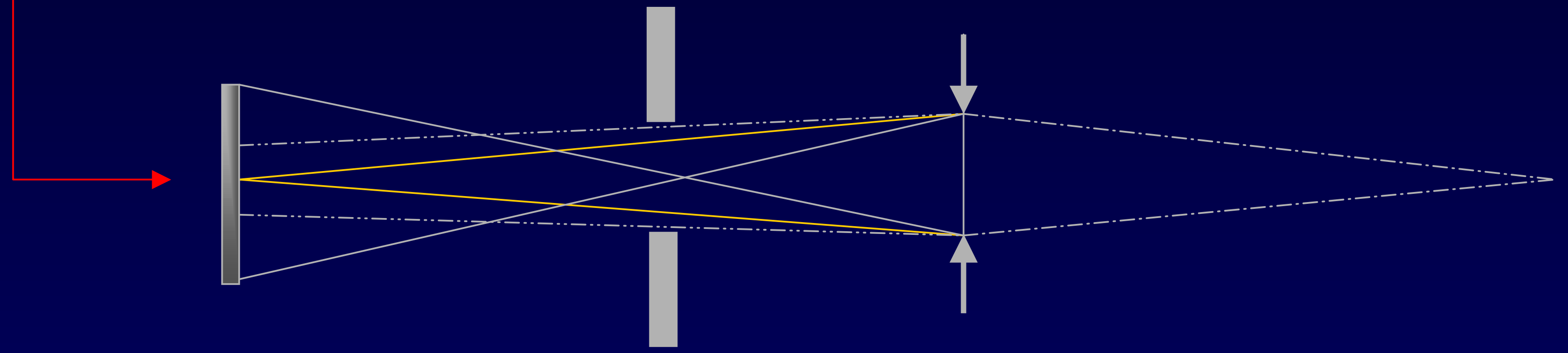
Straight sections:

4x12 m 12x6m 8X3.5 m

- Low energy resonant inelastic x-ray scattering
- High energy resonant inelastic x-ray scattering

WHAT ARE THE SPECIFIC REQUIREMENTS?

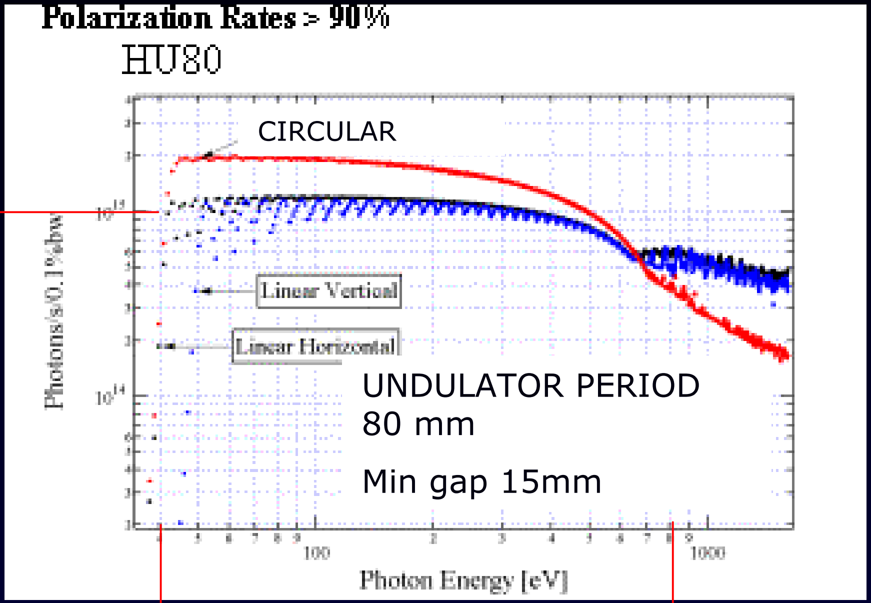
- VERY HIGH INCIDENT FLUX and VARIABLE POLARIZATION
- HIGH PERFORMANCE MONOCHROMATORS (high emittance) and MICROFOCUS to OPTIMIZE ACCEPTANCE
- EFFICIENT X-RAY SPECTROMETERS
- MATCHED RESOLVING POWER FOR Ω and ω
- VERY HIGH STABILITY (Beam and Analyzer particularly for Magnetic measurements)



UNDULATOR(s)

APPLE II

10^15/s (0.1%BW)



40 eV

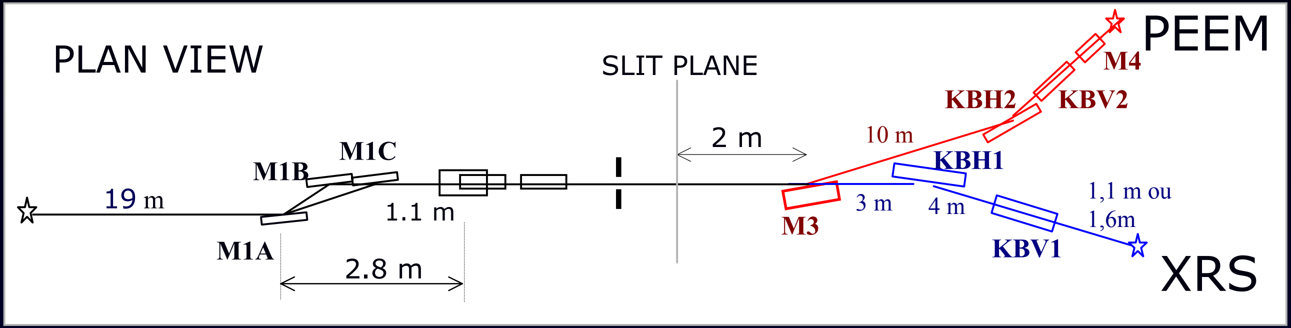
800 eV

Low energy resonant inelastic x-ray scattering

High energy resonant inelastic x-ray scattering

LOW ENERGY MONOCHROMATOR

Lagarde and Polack (SOLEIL)

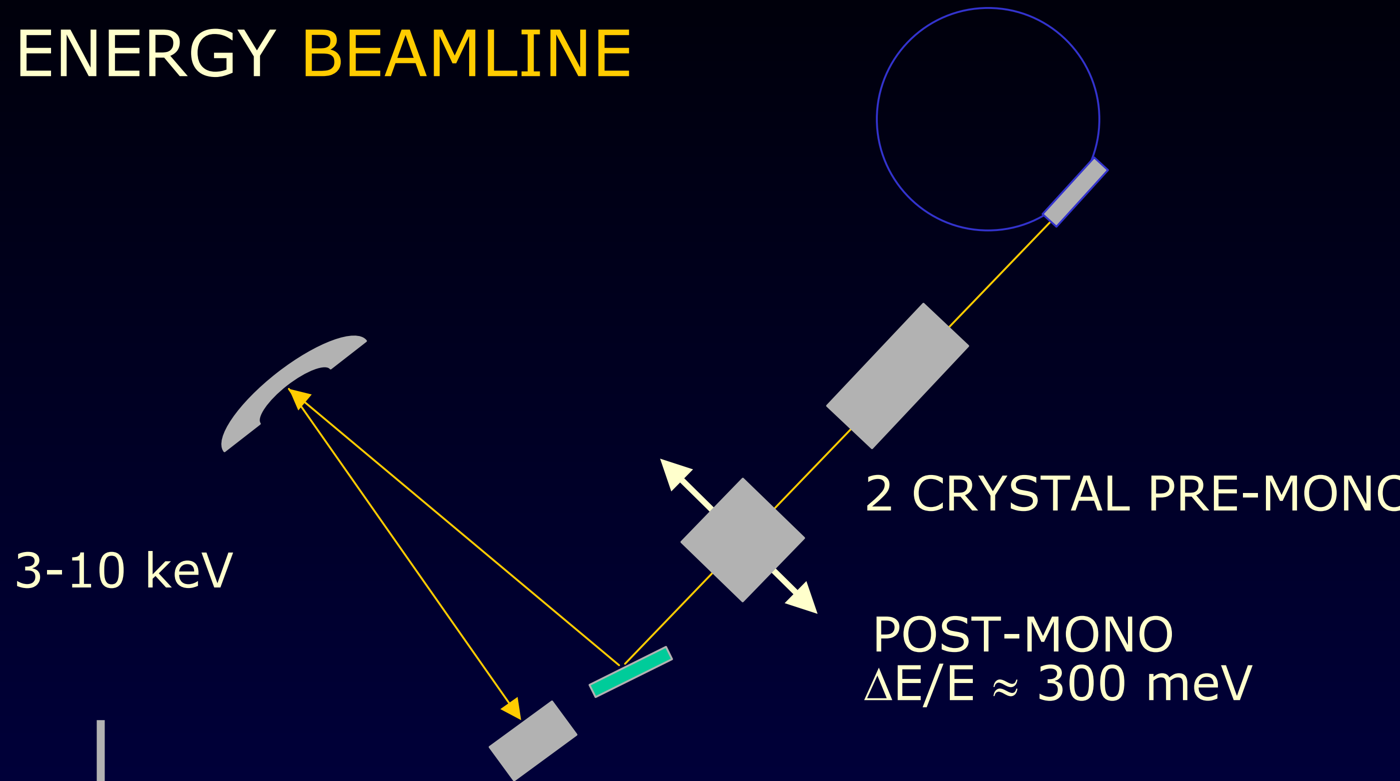


- 2 sets of constant included angle +
- 3 gratings
- No entrance slit 20 µm slit for E/ΔE=3000
- Fixed slit position (source for KB).
- KB demagnification 1/10.

Low energy resonant inelastic x-ray scattering

High energy resonant inelastic x-ray scattering

HIGH ENERGY BEAMLINE



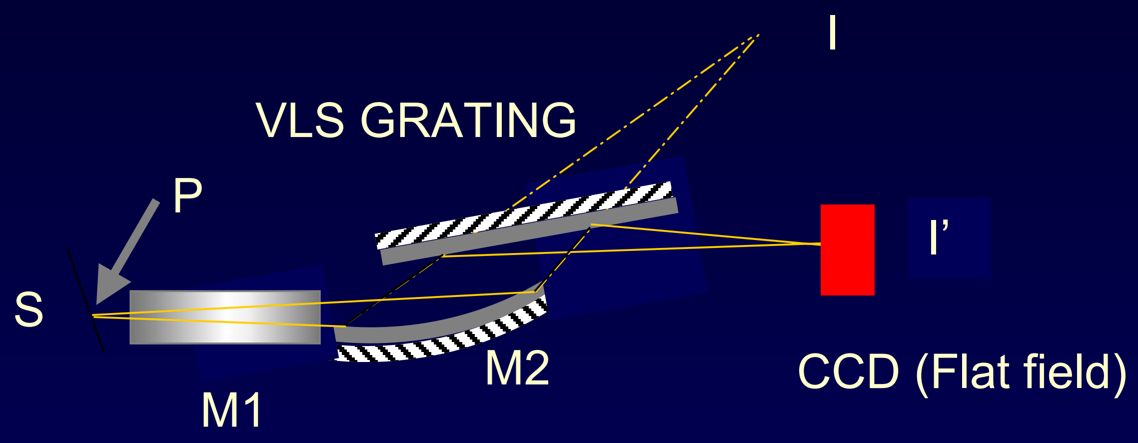
- Low energy resonant inelastic x-ray scattering
- High energy resonant inelastic x-ray scattering

FLAT-FIELD GRATING SPECTROMETER

- GOOD RESOLVING POWER
- GOOD ACCEPTANCE (slitless)
- GOOD DETECTION EFFICIENCY (CCD)
- EASY ENERGY CALIBRATION (Flat-field)
- TRANSPORTABLE

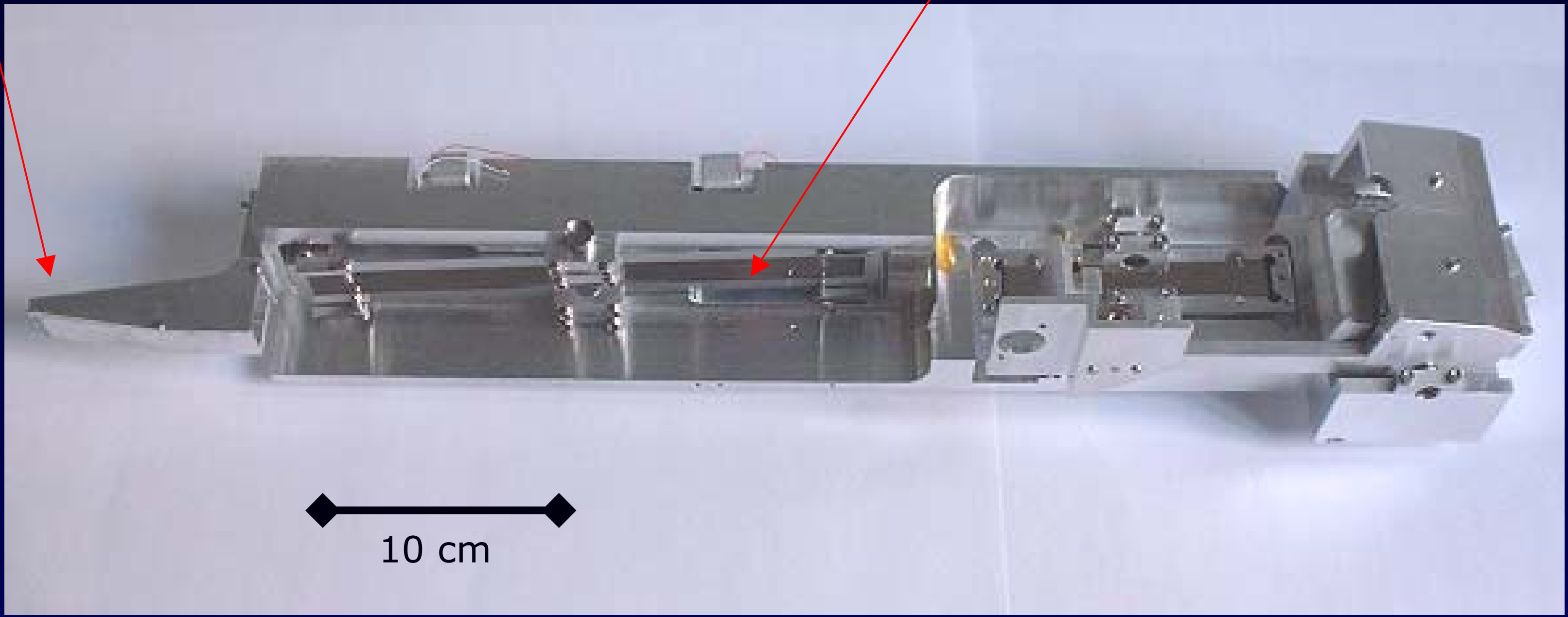
HETTERICK-UNDERWOOD PRINCIPLE (In coll. Jim Underwood)

Low energy resonant inelastic x-ray scattering



FLAT-FIELD GRATING SPECTROMETER

- GOOD RESOLVING POWER
- GOOD ACCEPTANCE (slitless but requires microfocus)
- GOOD DETECTION EFFICIENCY (CCD) (horizontally focusing mirror)
- EASY ENERGY CALIBRATION
- TRANSPORTABLE

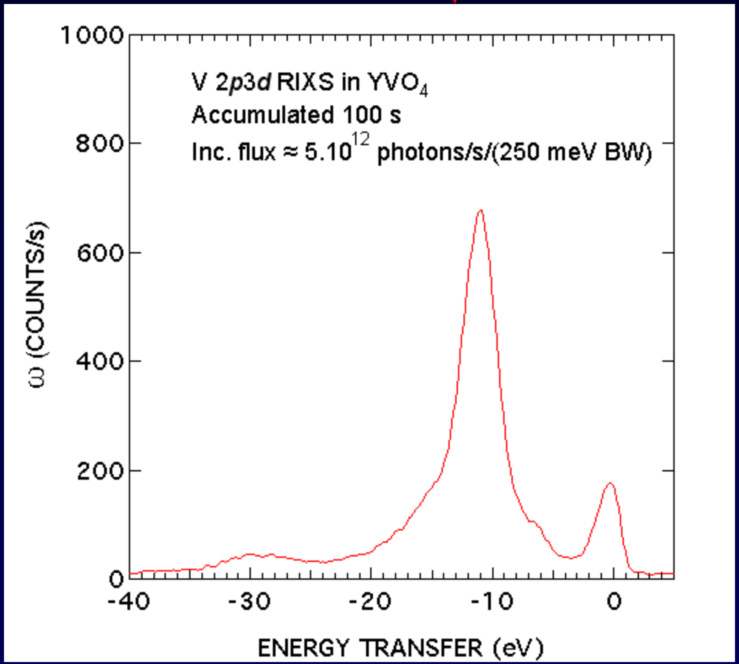


PERFORMANCE

- GOOD RESOLVING POWER (potentially)
- GOOD ACCEPTANCE (slitless)
- GOOD DETECTION EFFICIENCY (CCD)
- EASY ENERGY CALIBRATION
- TRANSPORTABLE

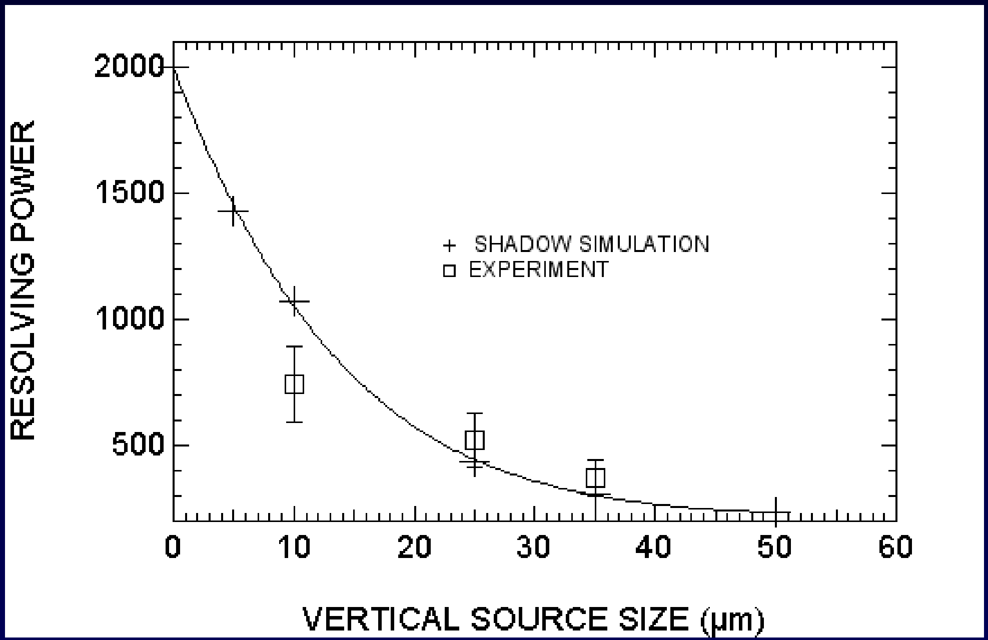
BESSY U41-PGM
monochromator (Petersen type)
exit slit 100 µm
BL resolving power > 2000
FOCUS SIZE 35 µm

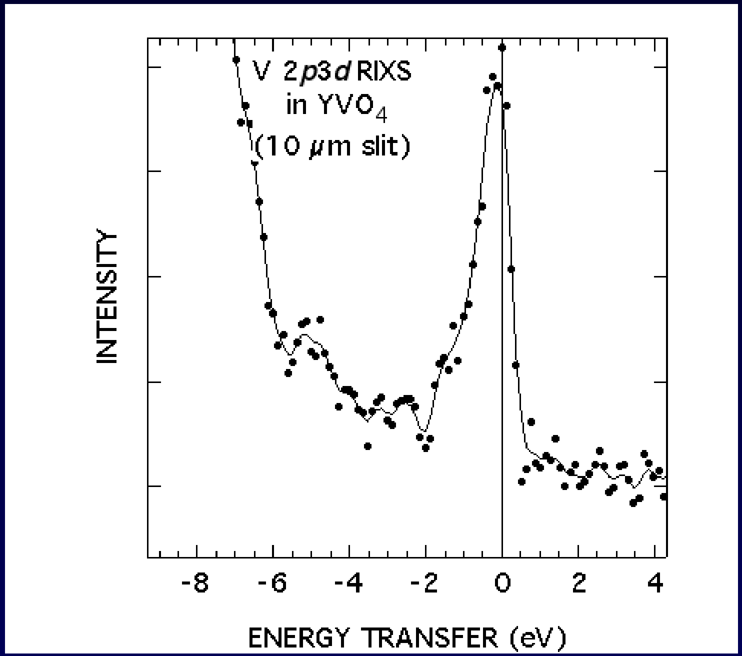
RIXS at V L_3 edge



PERFORMANCE

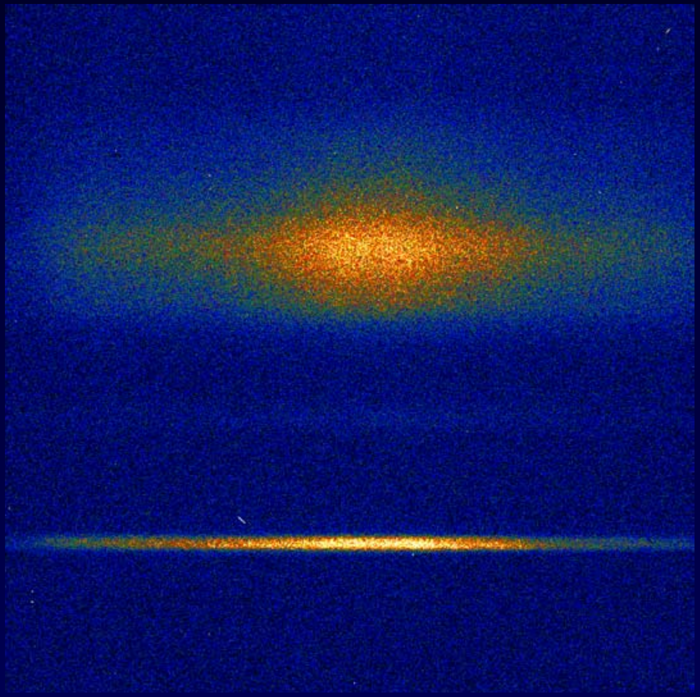
- TRANSPORTABLE
- GOOD RESOLVING POWER (potentially)
- GOOD DETECTION EFFICIENCY (CCD)
- EASY ENERGY CALIBRATION

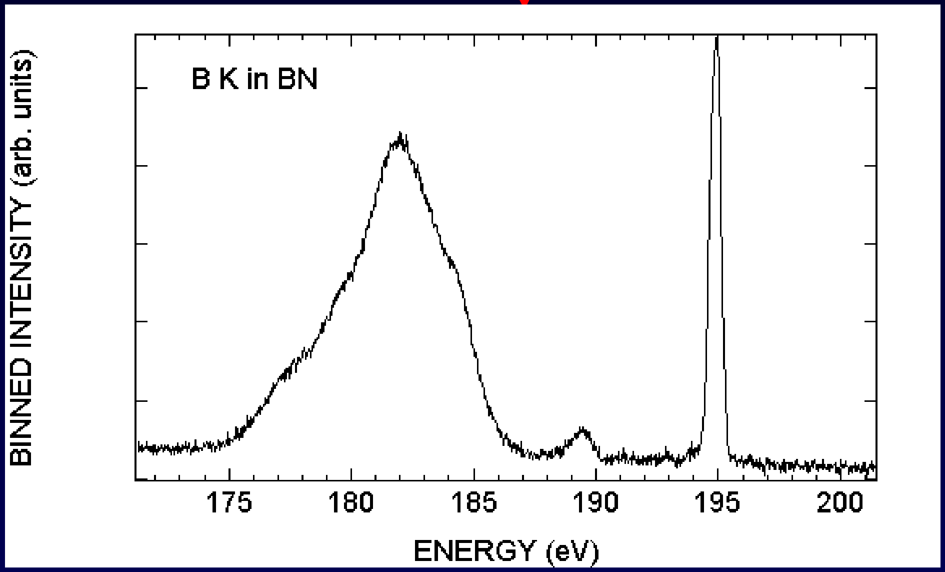




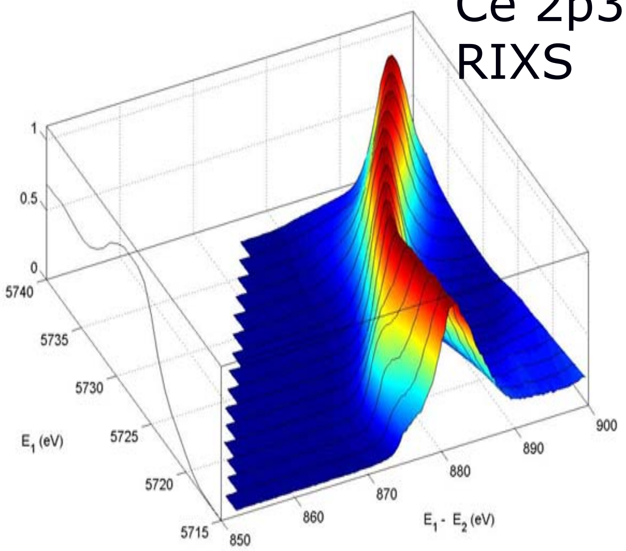
PERFORMANCE

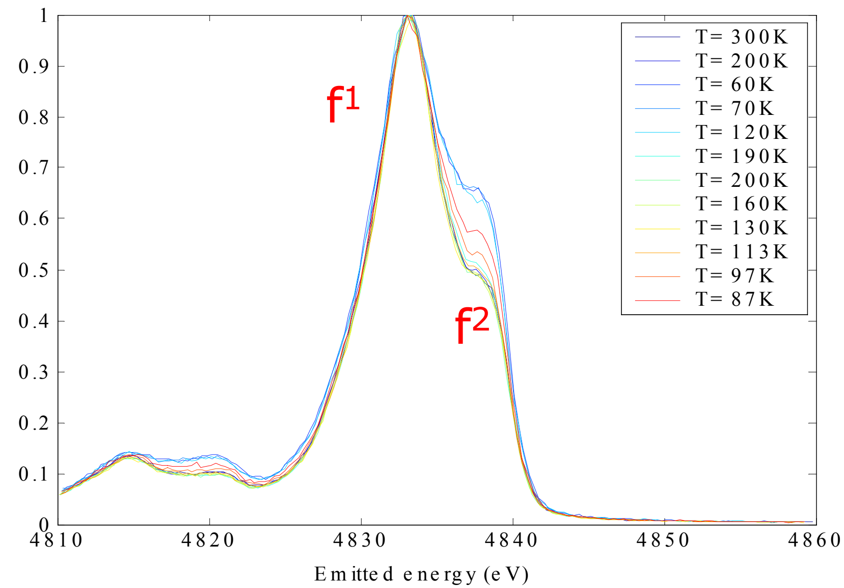
- TRANSPORTABLE
- GOOD RESOLVING POWER
- GOOD S/N (CCD) by using binned mode
- EASY ENERGY CALIBRATION





Ce 2p3d RIXS





Ce: |int> = 2p(4f5d)$^{n+1}$

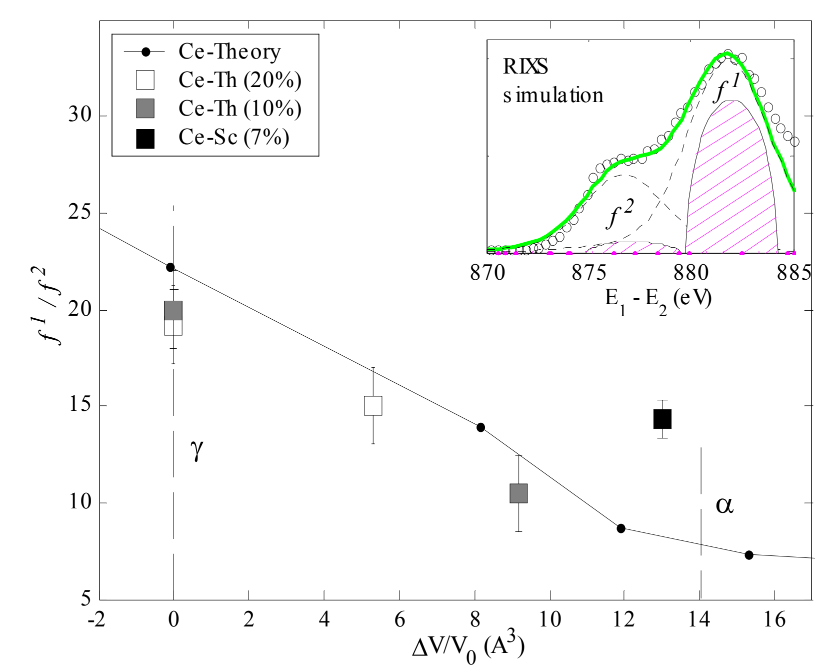
|f> = 3d(4f5d)$^{n+1}$

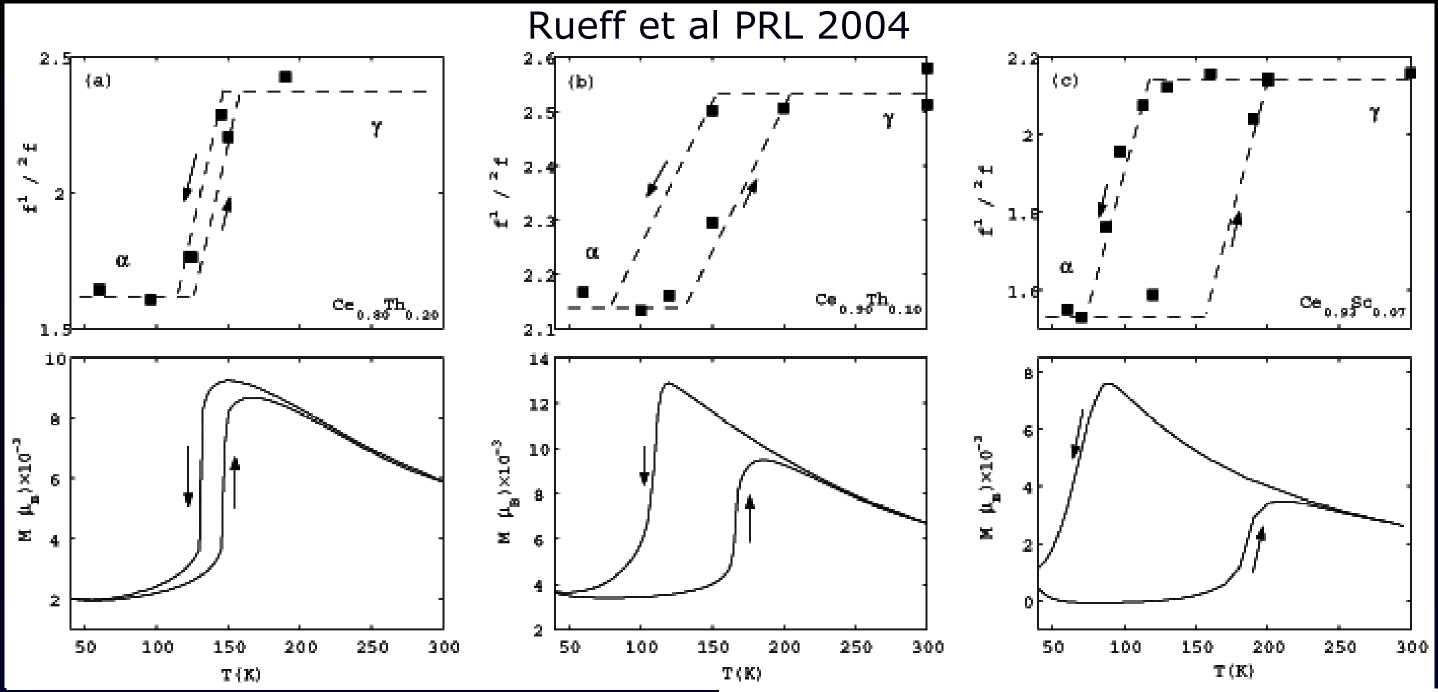
" Chemical" pressure + temperature

Ce-Th

Ce-Sc

Rueff et al PRL 2004
MacMahan et al PRB 2003





Ce: |int> = 2p(4f5d)$^{n+1}$

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Ce-Th

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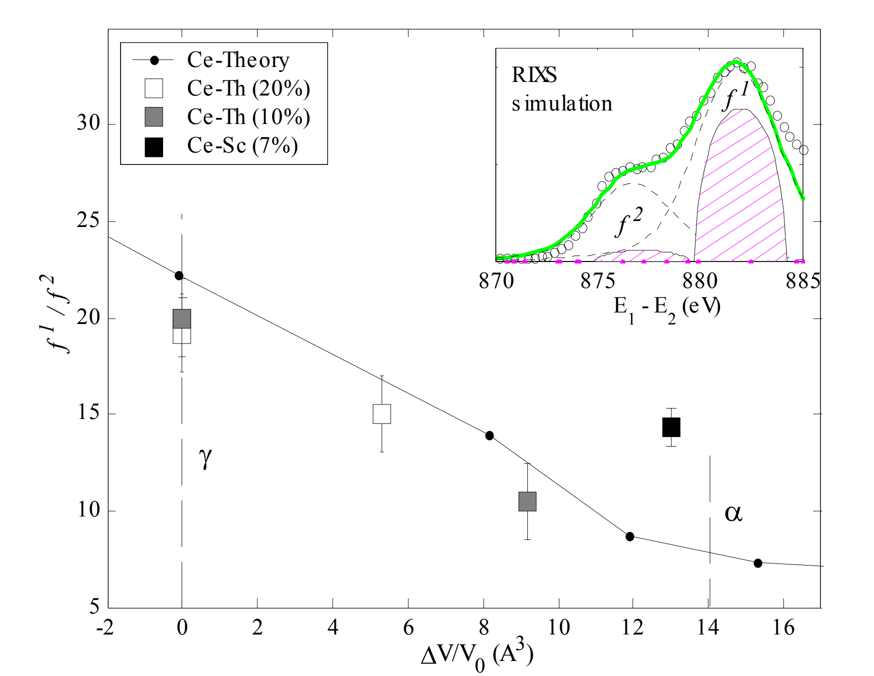
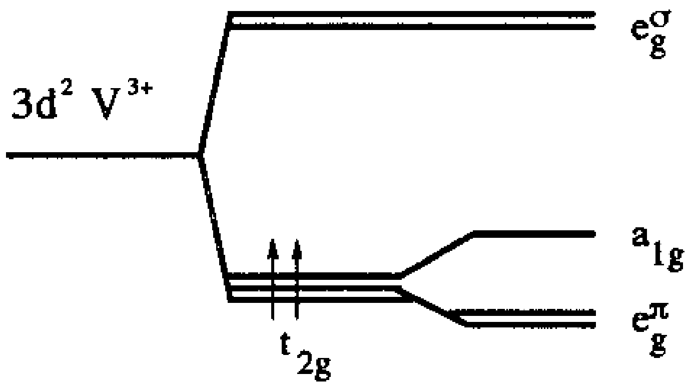
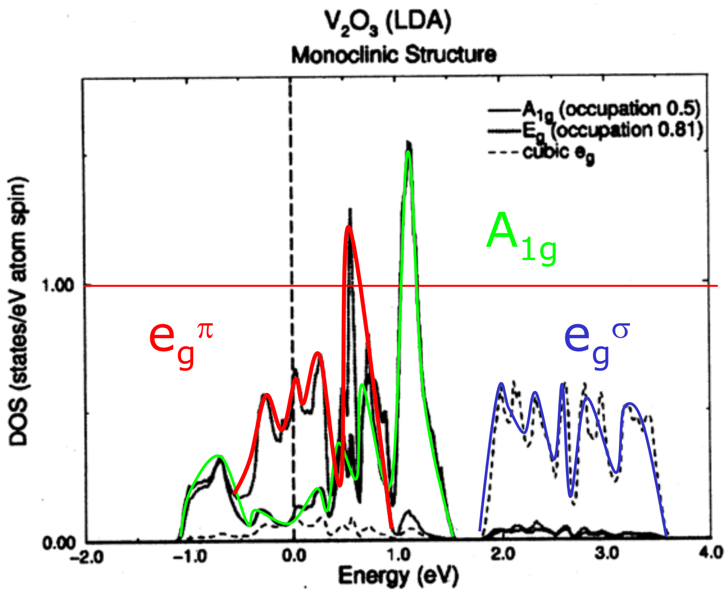
MacMahan et al PRB 2003

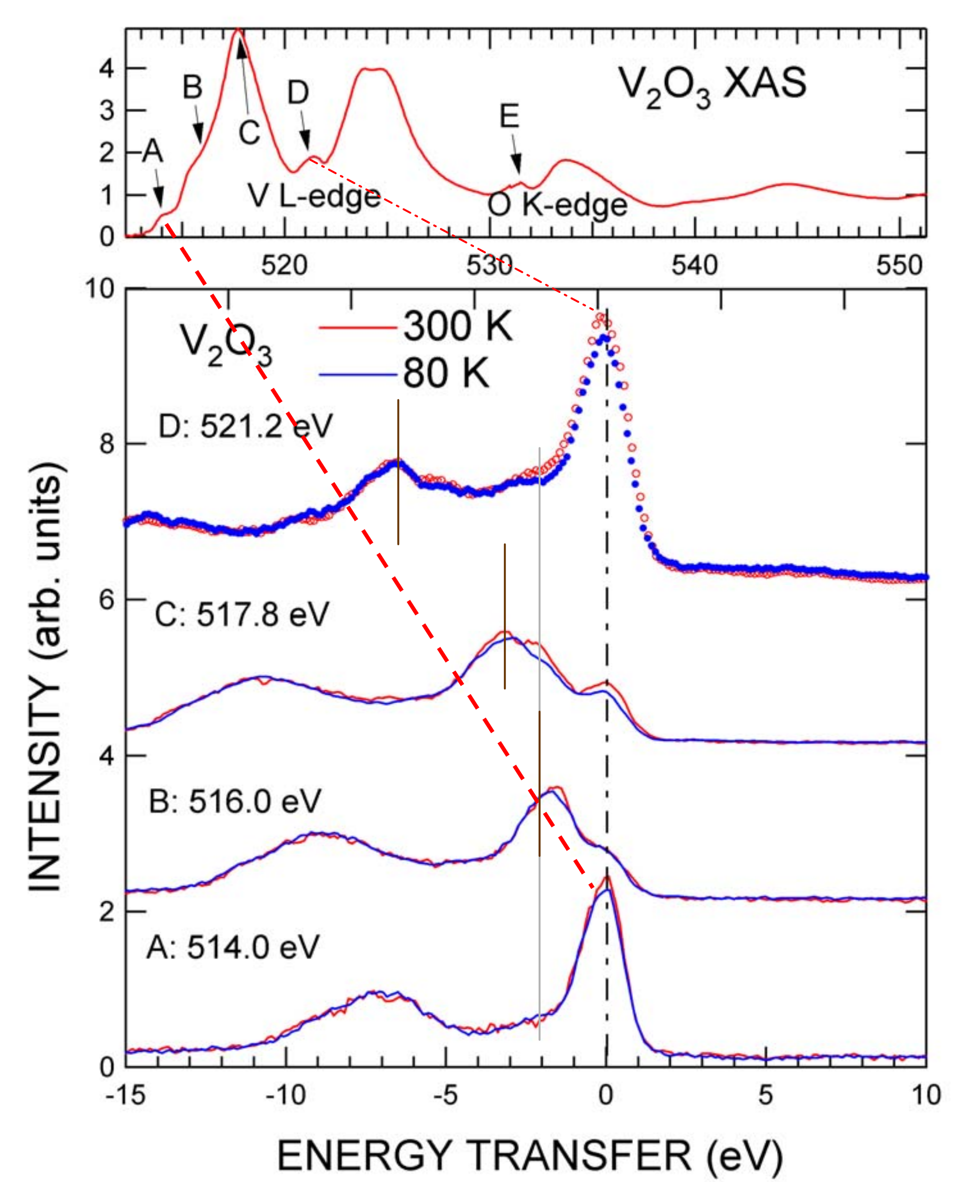


Marsi et al. (unpublished)



S.Yu. Ezhov et al. PRL 1999





See also Held et al. PRL 2001 (LDA+DMFT)

RESONANT X-RAY EMISSION: PREPARING SOLEIL

TO SUMMARIZE:

FIRST EXPERIMENTS AT SOLEIL ARE EXPECTED 2007

THERE'S A DEMAND IN MATERIALS SCIENCE FOR:

- "GOOD" RESOLVING POWER (i.e. ≈ 1000 (low energies), 5000 (high energies) + GOOD STATISTICS
- GOOD ENERGY CALIBRATION
- *RESONANT* INELASTIC SCATTERING

- VERY HIGH RESOLVING POWER AT LOW ENERGIES WILL ENTAIL A THIRD BL

THANKS TO:

A. Rogalev ESRF
S. Turchini Elettra
S. Heun Elettra
C. Jung Bessy
S. Eisebitt Bessy

J.H. Underwood CXRO
R.C. Perera CXRO

FINANCIAL SUPPORT:

CNRS
LURE

Jinghua Guo for the invitation