AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Field induced phase transition in Ca_2FeReO_6 double perovskite

an XMCD study in 30T pulsed magnetic field

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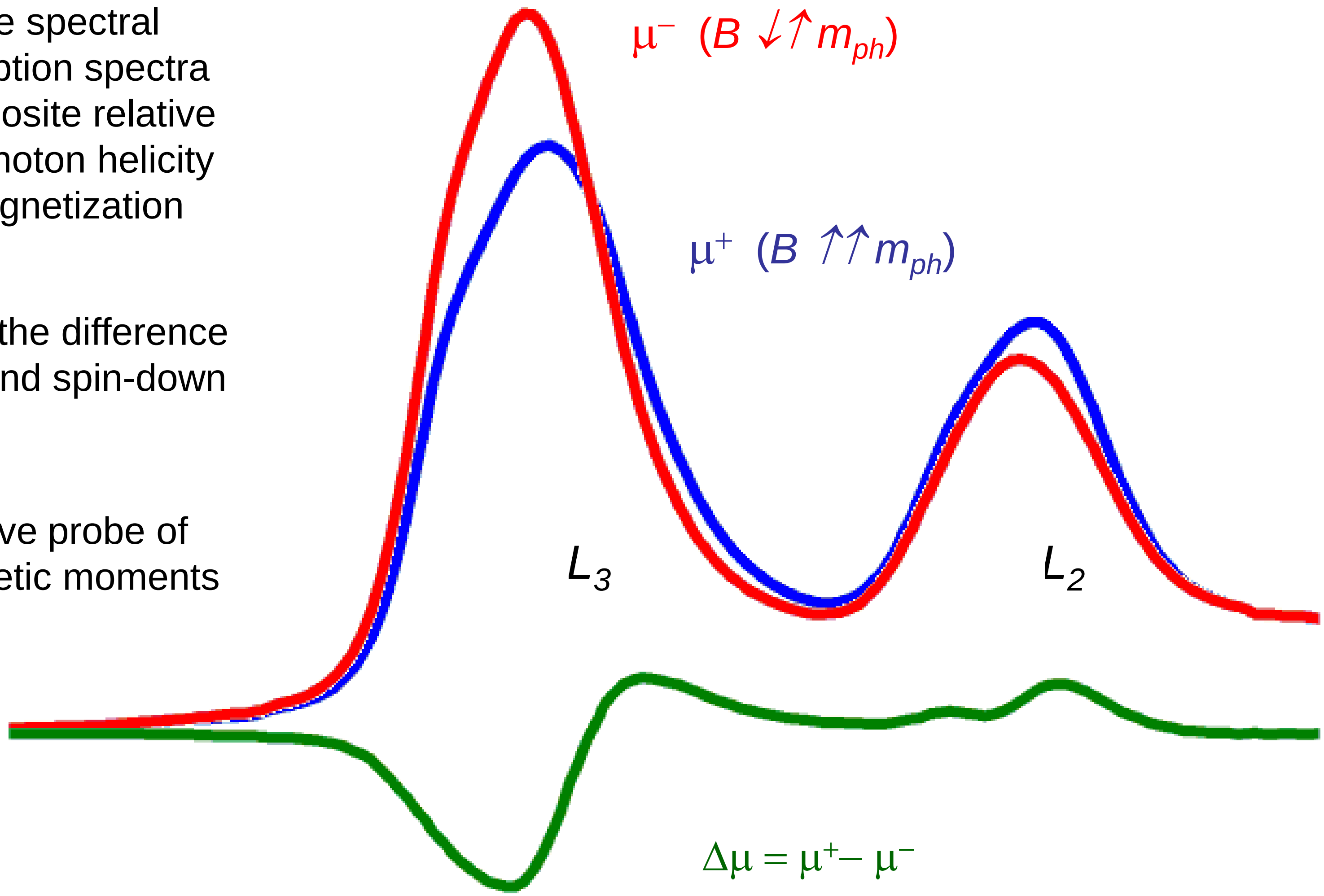
X-ray Magnetic Circular Dichroism

Difference in the spectral shape of absorption spectra acquired at opposite relative orientation of photon helicity and sample magnetization

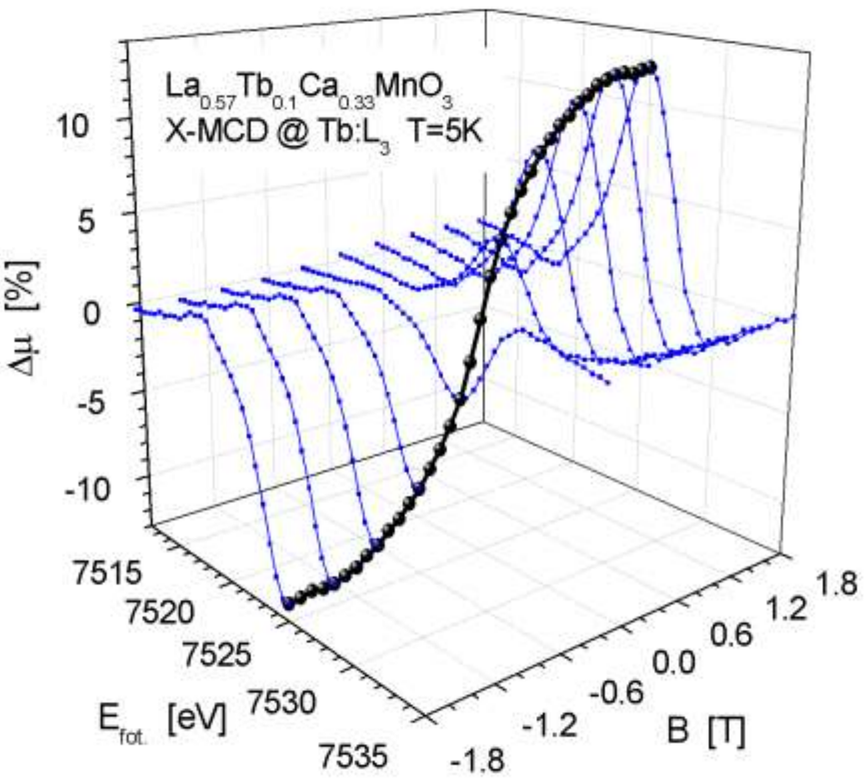
Proportional to the difference in the spin-up and spin-down DOS above E_F

Element selective probe of localized magnetic moments



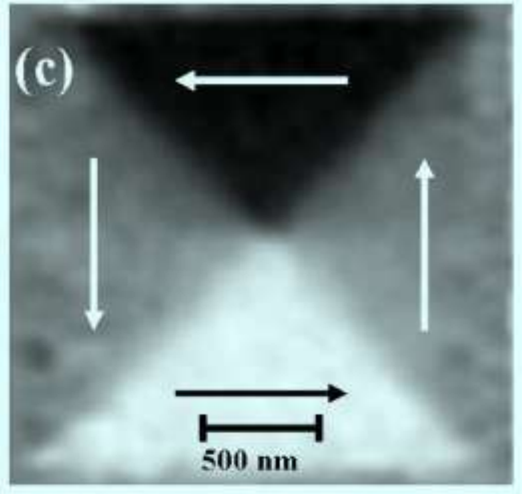
XMCD magnetometry & imaging

Assuming no change in the spectral shape element specific *M(B,P,T)* profiles can be measured



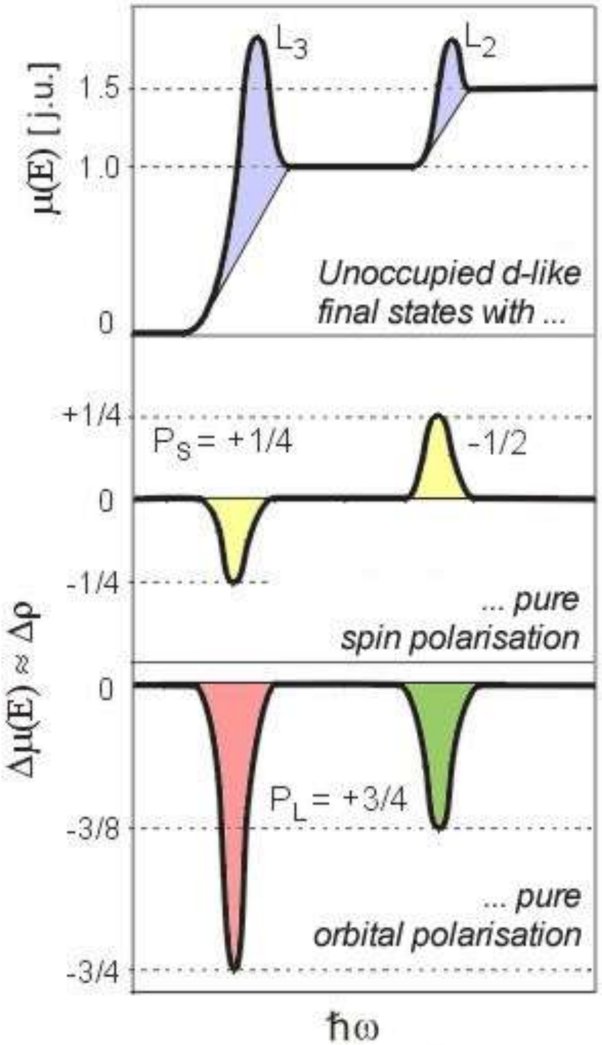
M.Sikora et al., J. Magn. Magn. Mat. 272-276, 2148 (2004)

High resolution, element specific imaging of magnetic domains



M.Bolte et al., Phys. Rev. Lett. 100, 176601 (2008)

Sum Rules



B.T.Thole et al., PRL 68 (1992) 1943
P.Carra et al., PRL 70 (1993) 694

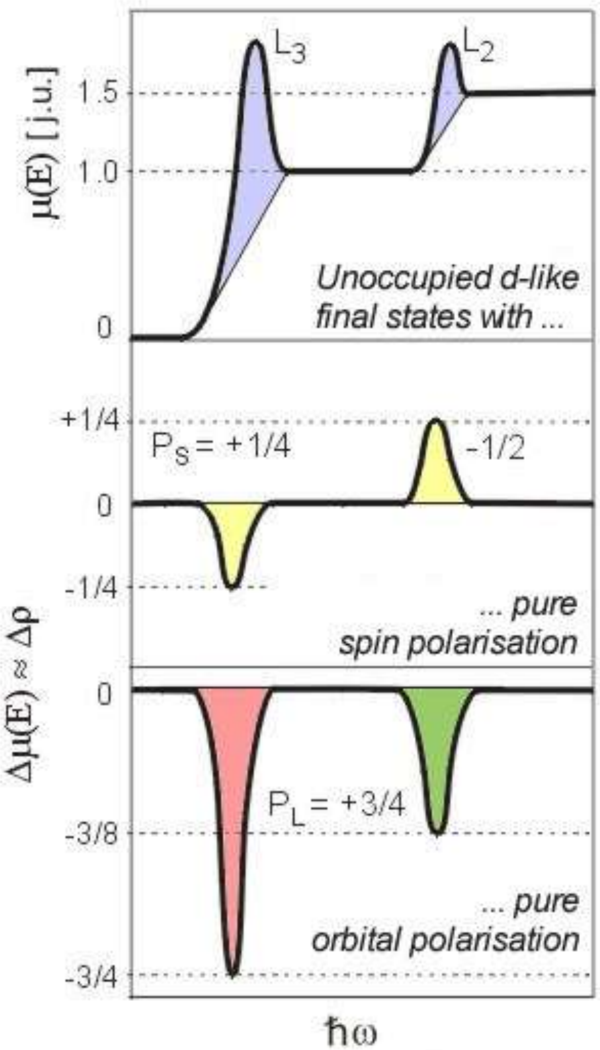
$$L_z = -(4/3)\cdot n \cdot \frac{\int_{L_3+L_2} (\Delta\mu)\, dE}{\int_{L_3+L_2} (\mu_0)\, dE}$$

$$S_z = -n \cdot \frac{\int_{L_3} (\Delta\mu)\, dE - 2\int_{L_2} (\Delta\mu)\, dE}{\int_{L_3+L_2} (\mu_0)\, dE}$$

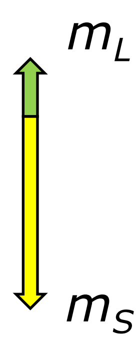
where ***n*** denotes the number of holes in the final states

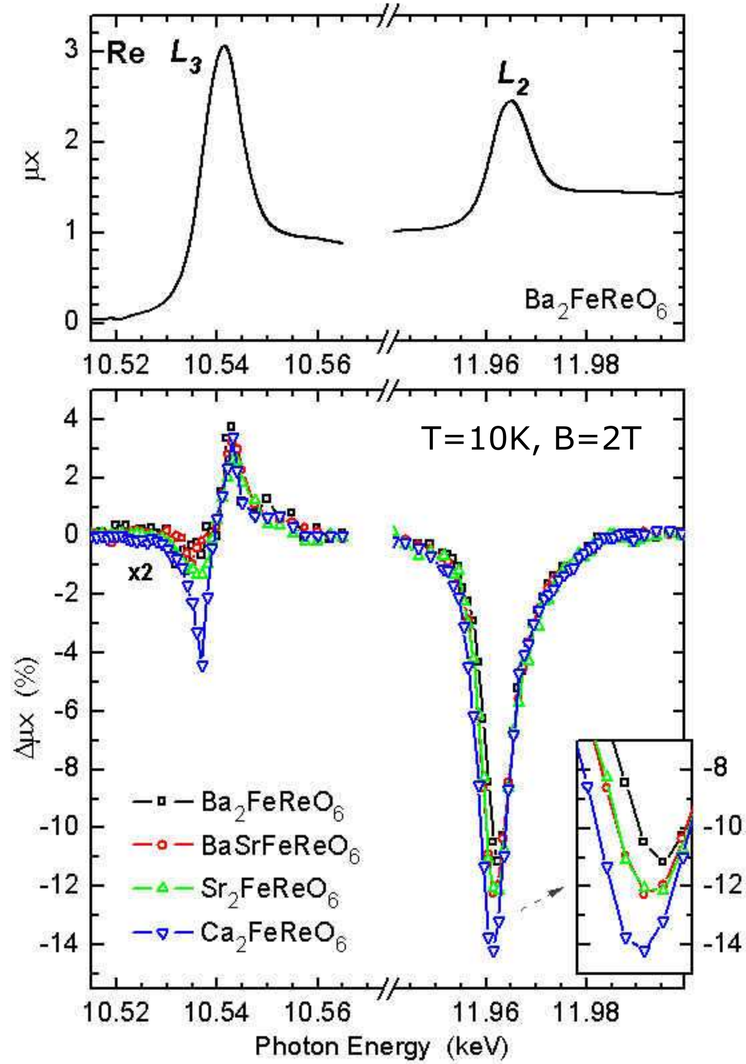
Full spectra necessary at the energy step ~ lifetime broadening

Sum Rules for Re $L_{2,3}$-edges



$$\frac{m_L}{m_S} \approx \frac{L_z}{2S_z} \sim -\frac{1}{3}$$



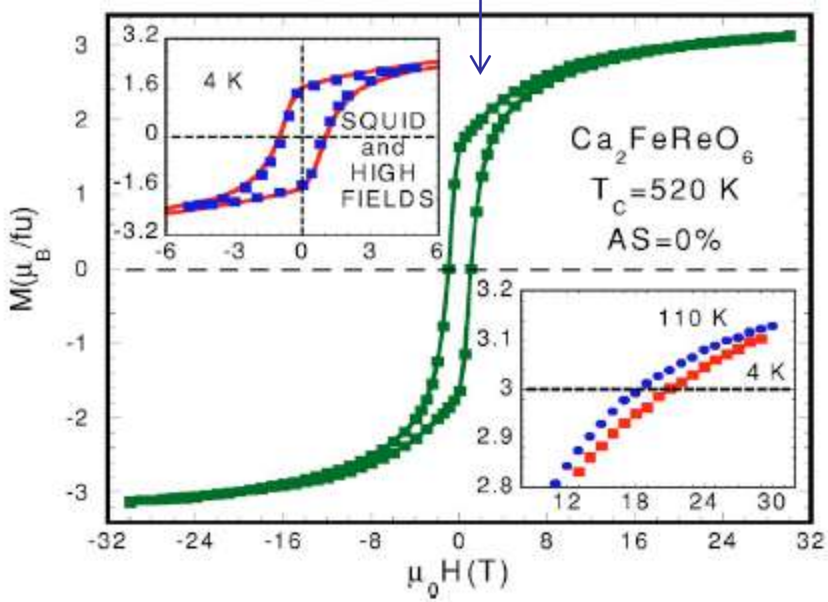


M.Sikora et al., Appl. Phys. Lett. 89, 062509 (2006)

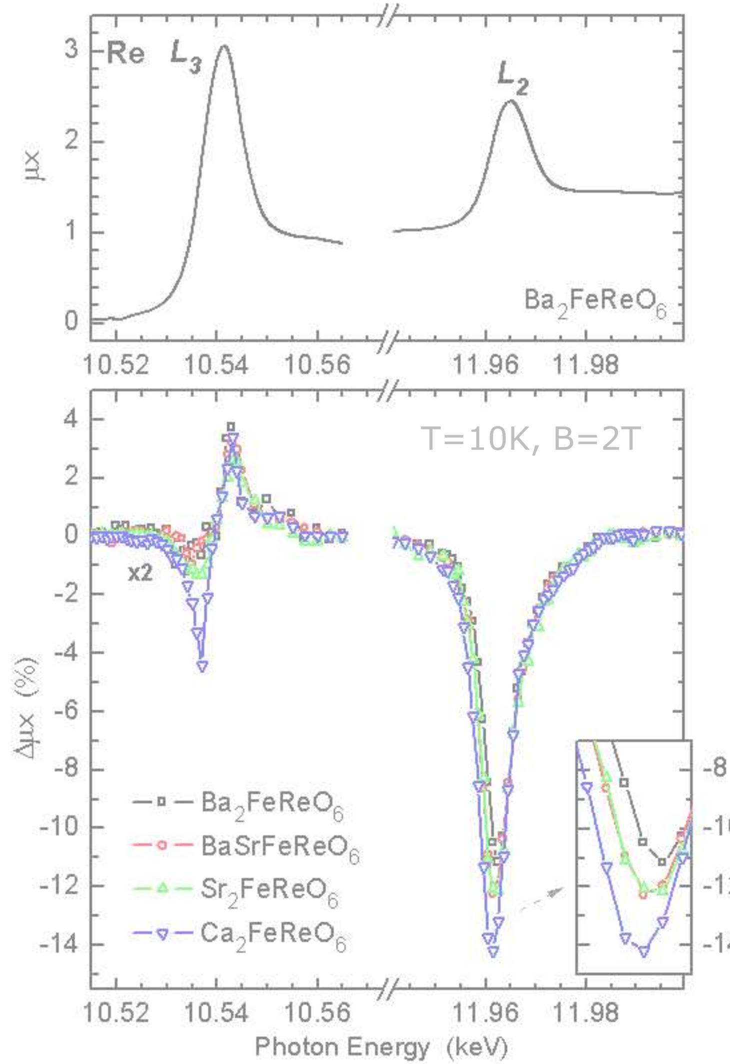
Need for high magnetic field

High magnetocrystalline anizotropy
→ high saturation magnetization
and coercive field

2T



J.M.deTeresa et al., Appl. Phys. Lett. 90, 252514 (2007)

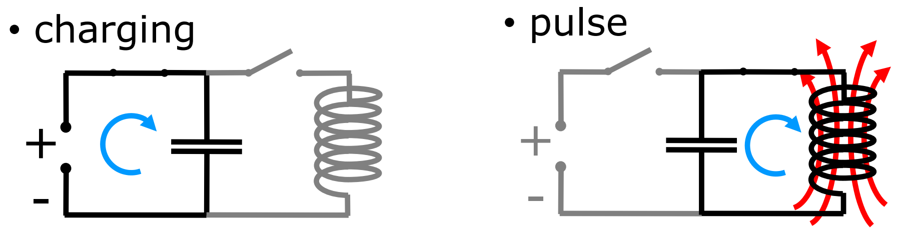


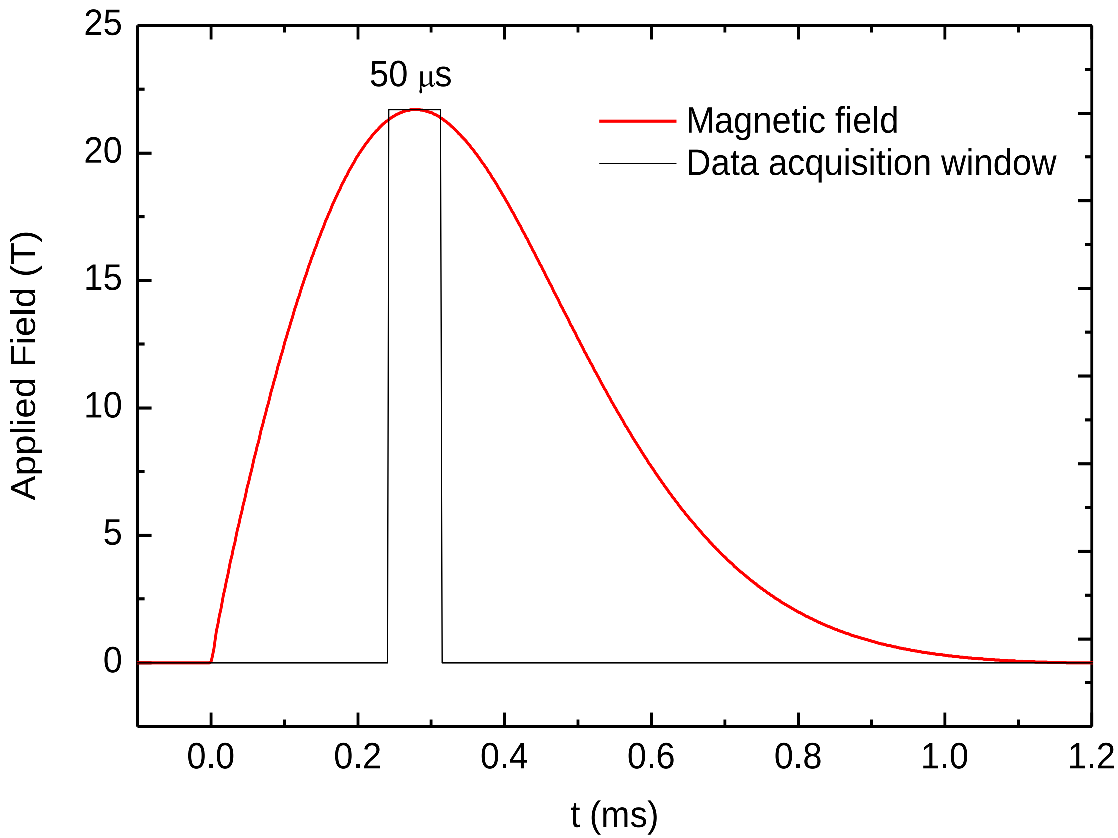
M.Sikora et al., Appl. Phys. Lett. 89, 062509 (2006)

Pulsed magnetic field generation

High, steady field magnets are huge and very expensive
Max. at SR facility:
17T at Spring-8

Higher field may be generated at low cost using pulsed technique
Max. at SR facility:
40T at Spring-8
30T at ESRF



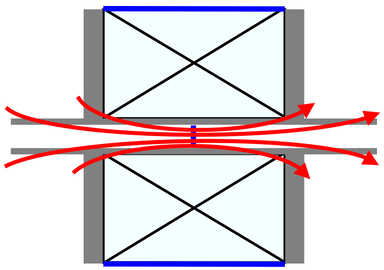


Portable pulsed field setup at ESRF

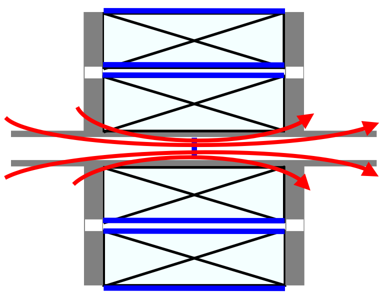
High duty cycle minicoil

C = 1 mF L = 20 μH
U = 2650 V I = 13 000 A

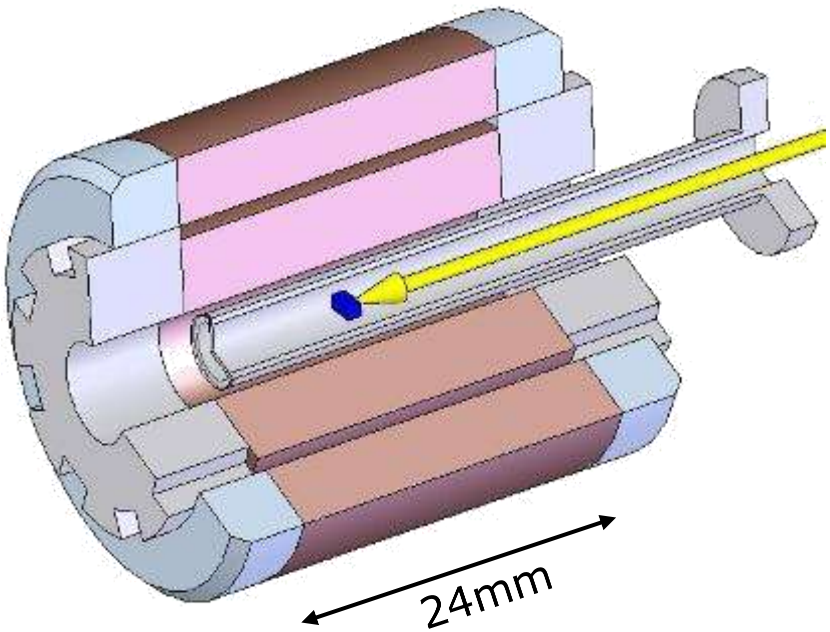
- monolithic



- slit coil



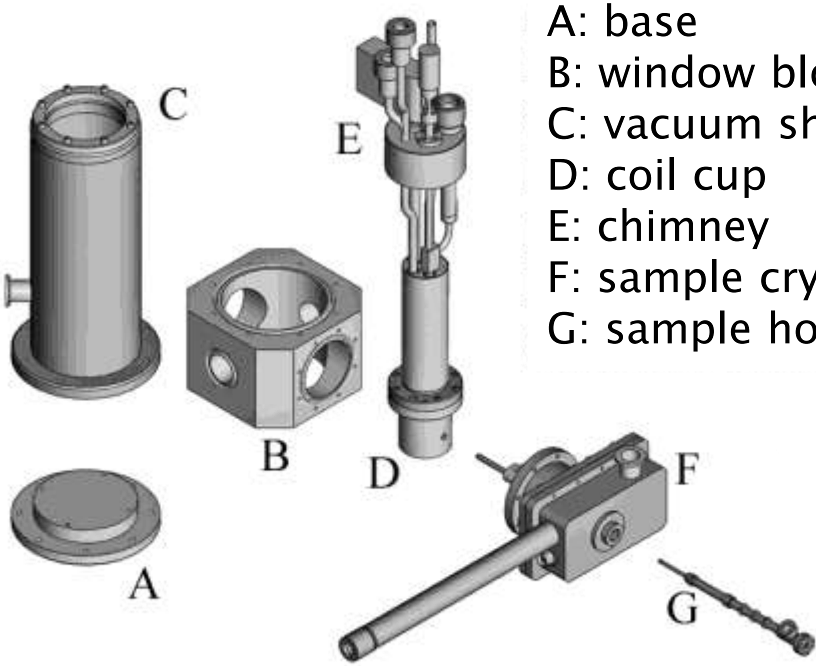
cooling surface



Duty cycle: $1 \cdot 10^{-4}$ rep. rate: 6/min
B = 30 (38) T at working T: 120K

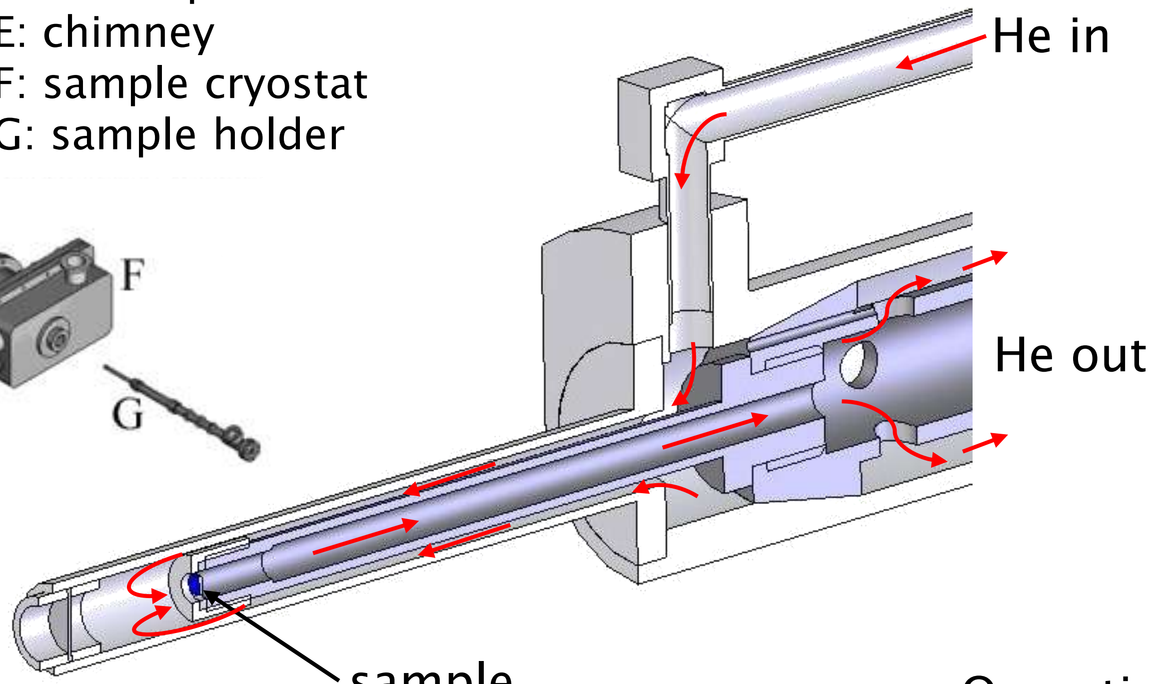
P. J. E. M. van der Linden et al., Rev. Sci. Inst. 79, 075104 (2008)

Portable pulsed field setup at ESRF



A: base
B: window block
C: vacuum shroud
D: coil cup
E: chimney
F: sample cryostat
G: sample holder

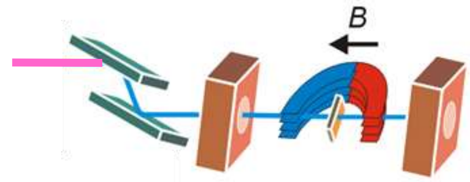
Continous flow sample cryostat

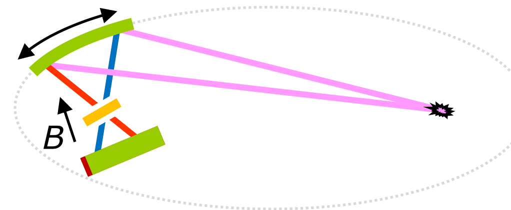


Operating temperature 5–300K

P. J. E. M. van der Linden et al., Rev. Sci. Inst. 79, 075104 (2008)

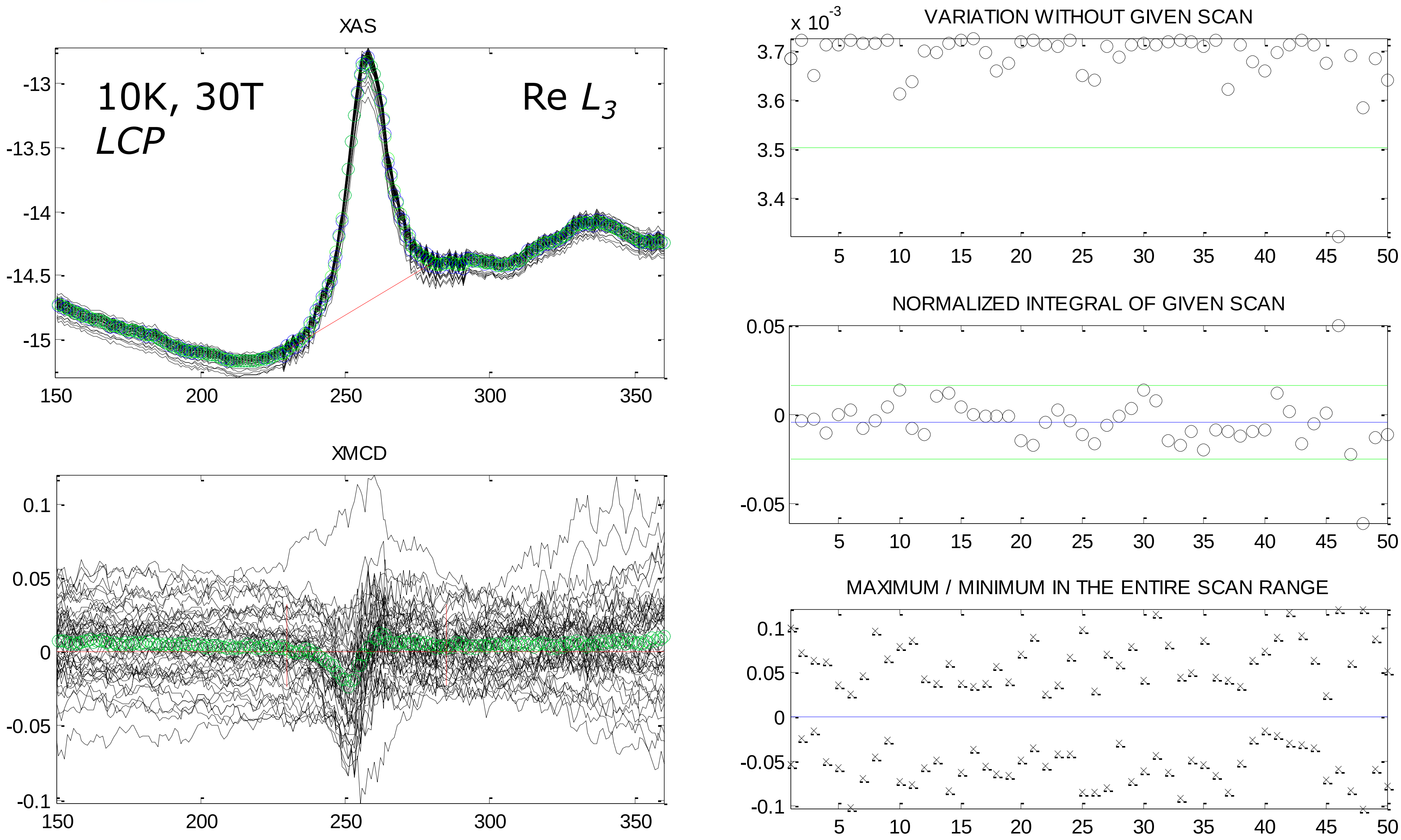
Pulsed fields at ED beamline



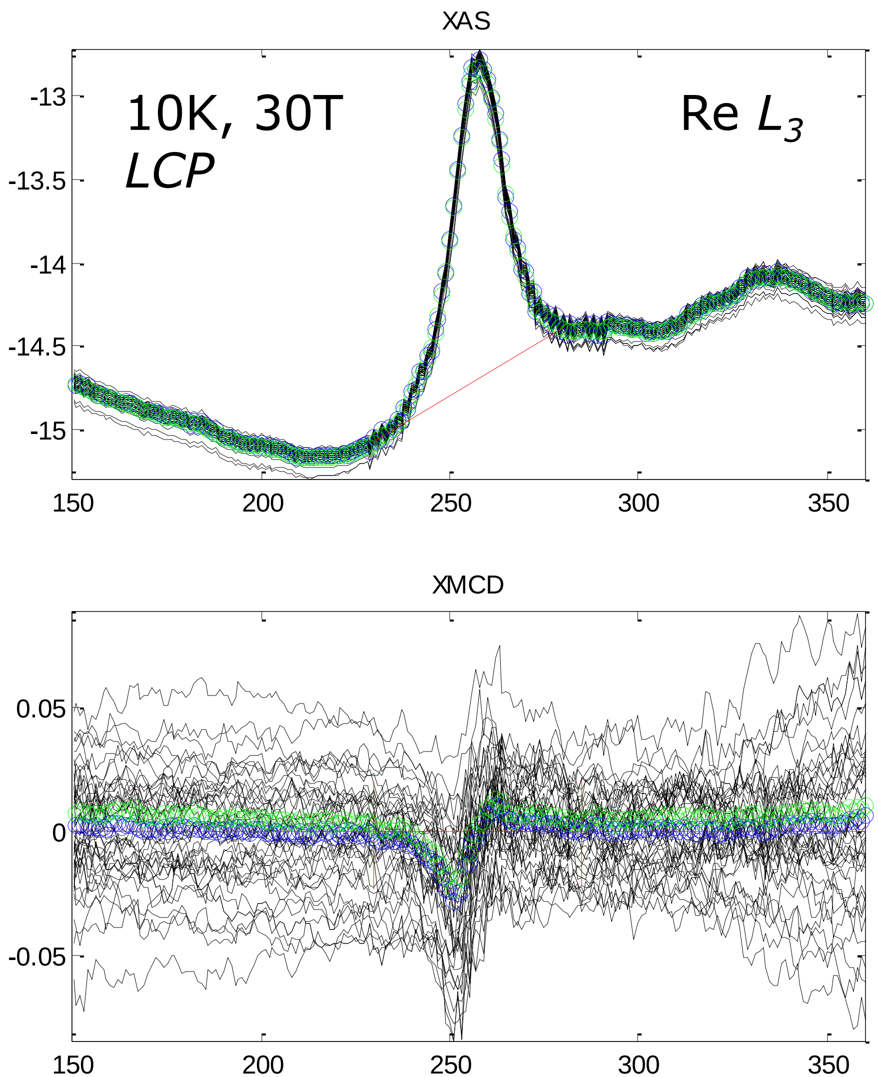


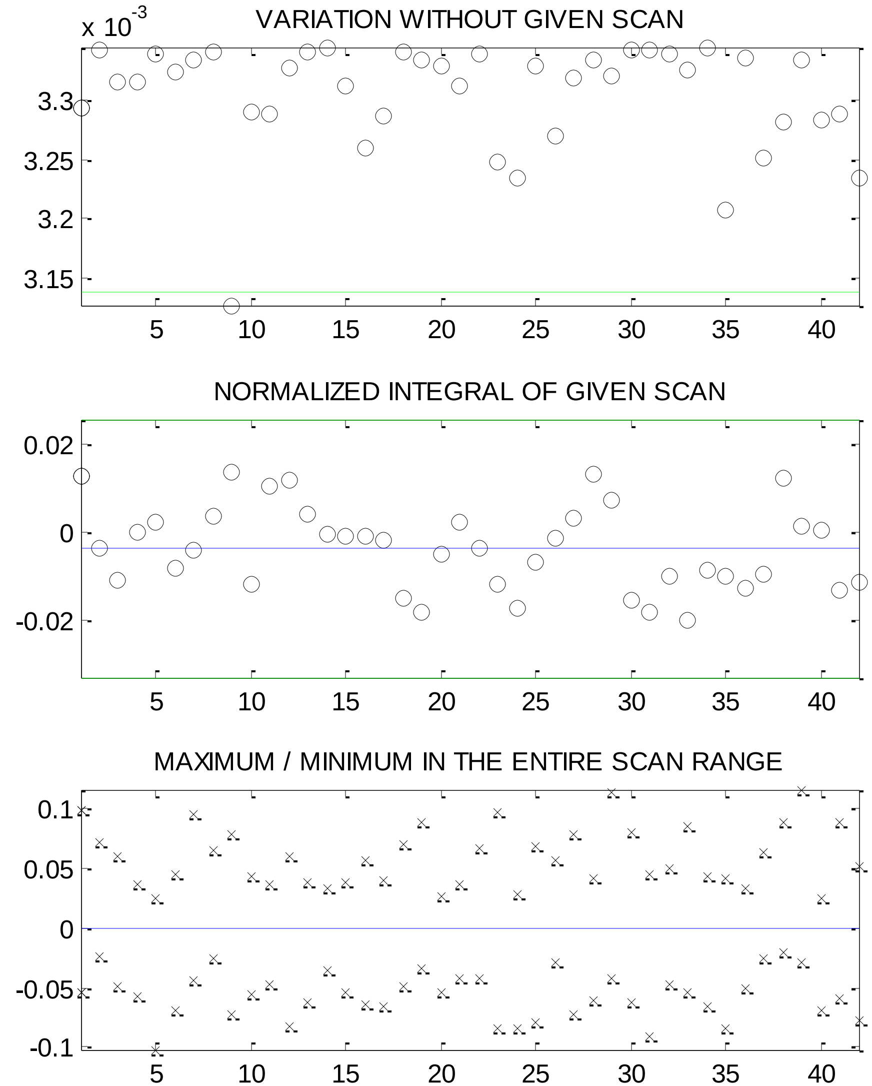
Beamline type	**Monochromatic**	**Energy dispersive**
Circular polarization	**ID**, QWP	QWP
Spectral distortions *sample or beam related*	**Sensitive** for highly non-homogenous samples only	**Sensitive** to beam motions, **very sensitive** for non-homogenous samples
Detection techniques	Transmission, **fluorescence, TEY**	Transmission only?
Systematic errors *due to ring current decay*	higher	**low**
Number of pulses per spectrum	at least 50	**1**

Data treatment 1



Data treatment 2

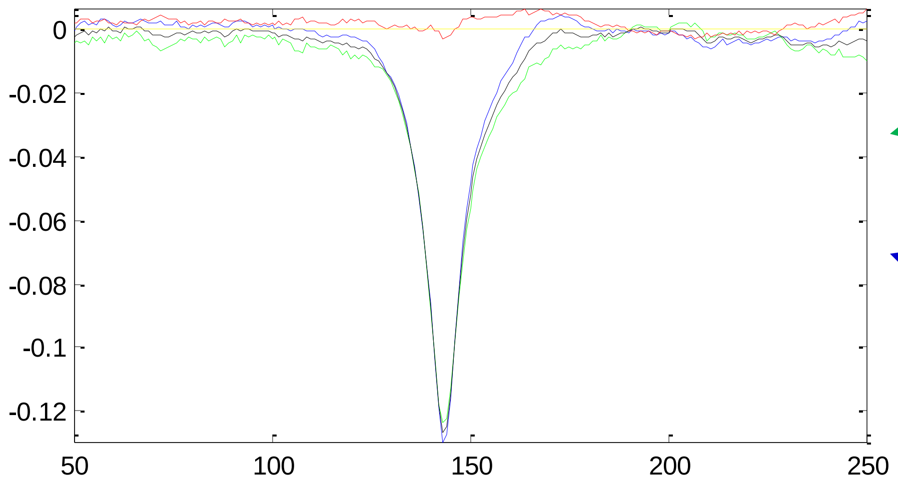


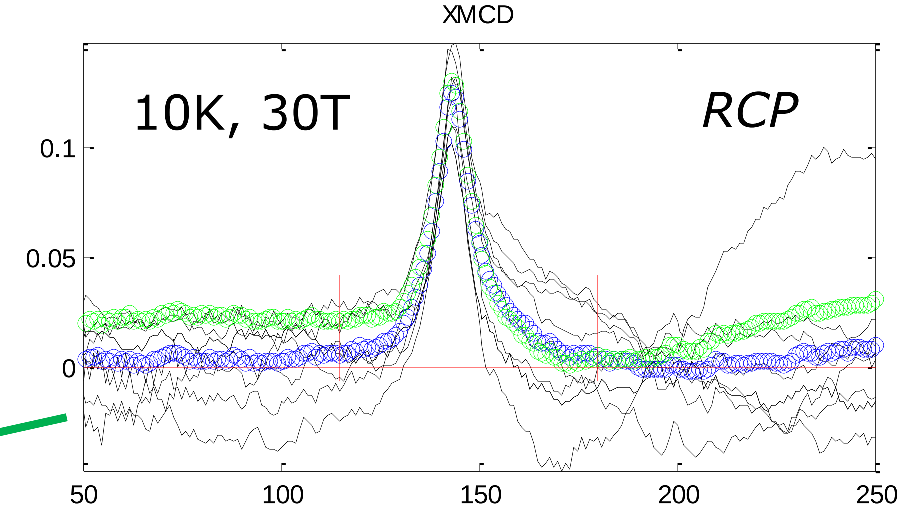


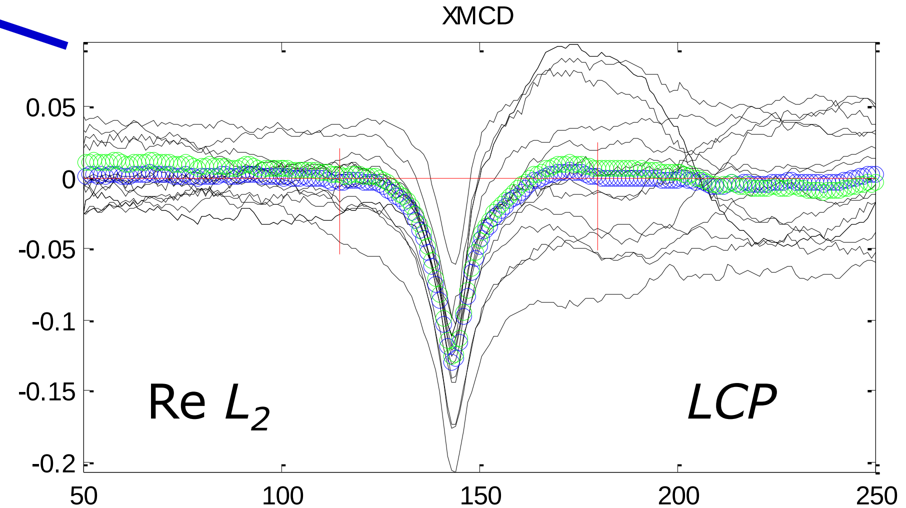
Data treatment 3

Left & right CP comparison

Systematic error



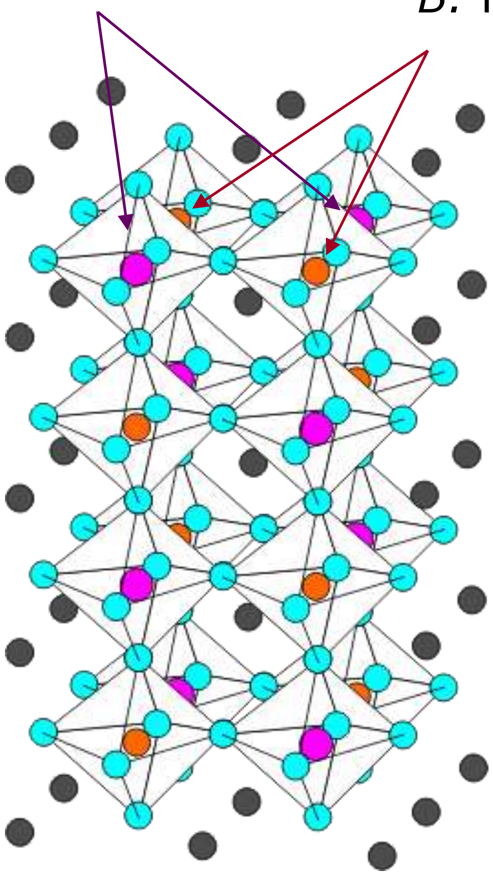




Double perovskites: $A_2BB'O_6$

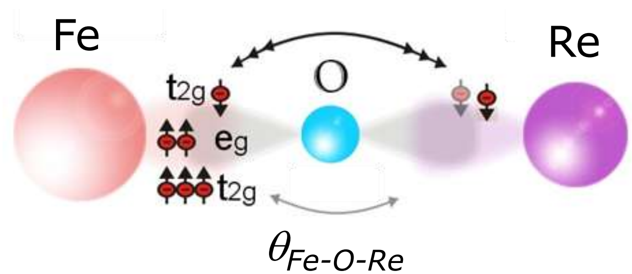
B′: Mo,Re,W,Os

B: Fe,Cr,Mn



Half doped B site: regularly stacked BO_6 and $B'O_6$ octahedra

Ferrimagnetic, metallic double-exchange-like interaction

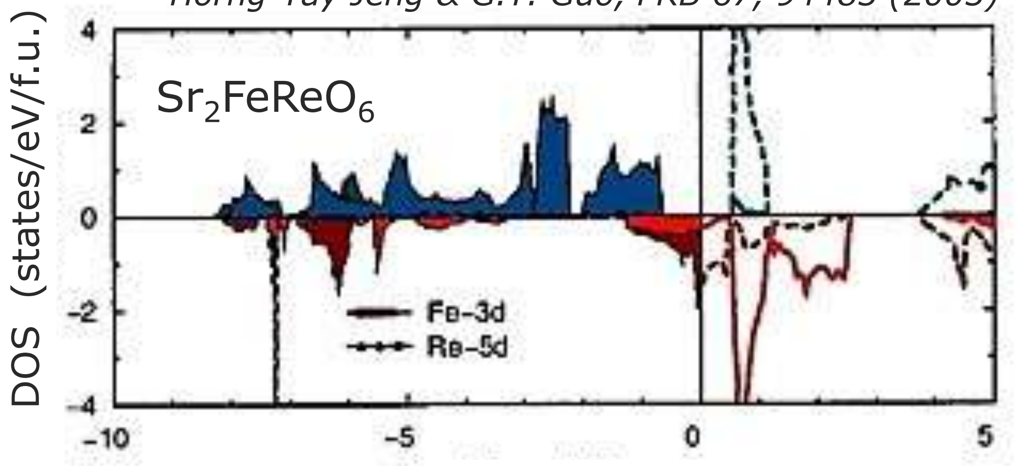


Magnetoresistive double perovskites

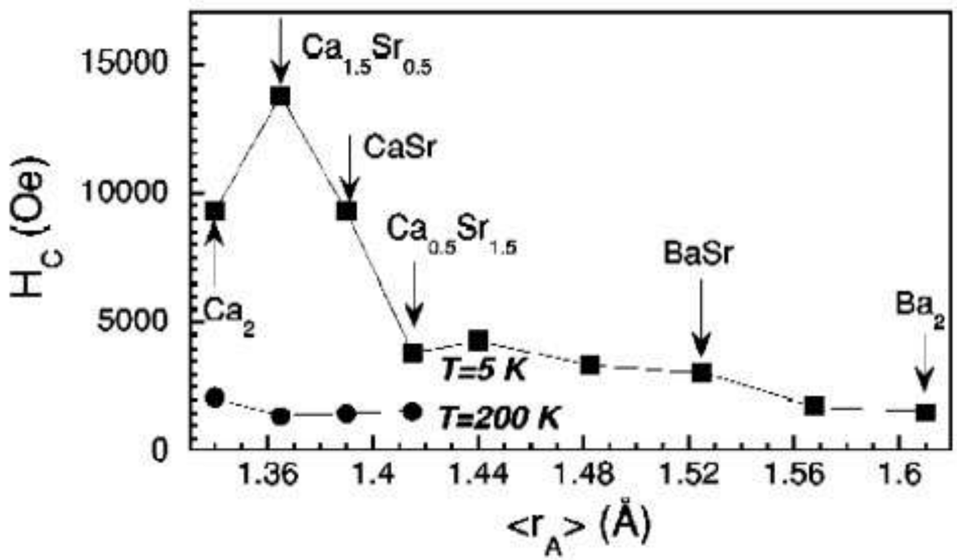
Ferrimagnetic half metals
100% spin polarization

T_C ~ 400-750K

Horng-Tay Jeng & G.Y. Guo, PRB 67, 94483 (2003)



J.M. De Teresa et al., Phys. Rev. B 69, 144401 (2004)



Ca_2FeReO_6 reveals:

High coercivity at low T

Magnetoresistive double perovskites

Horng-Tay Jeng & G.Y. Guo, PRB 67, 94483 (2003)

Ferrimagnetic half metals
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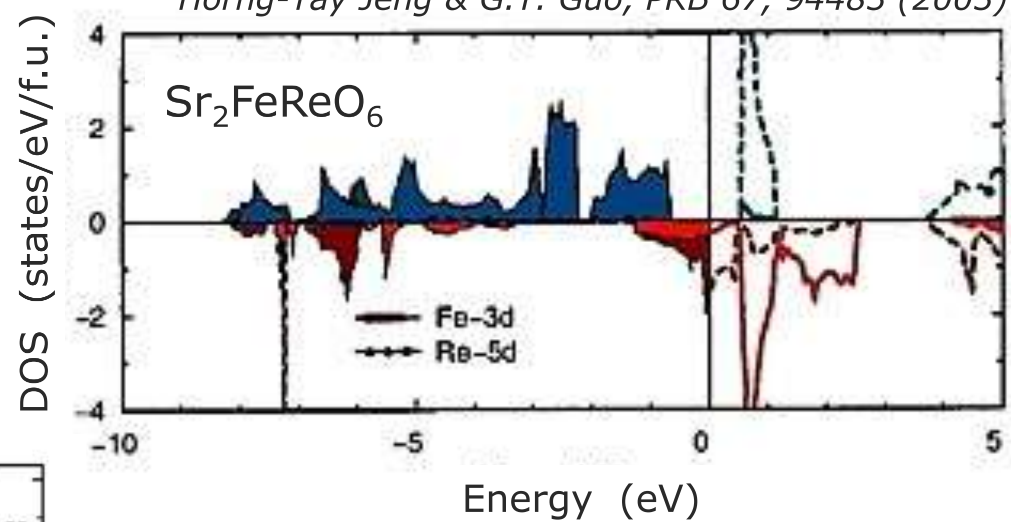
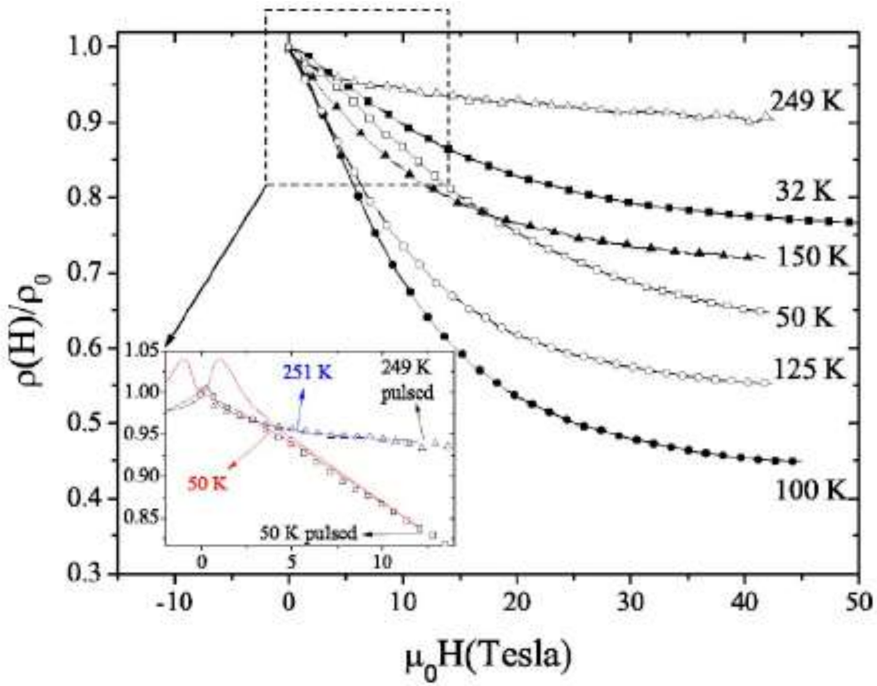




Ca_2FeReO_6 reveals:

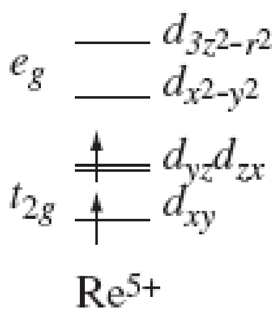
High coercivity at low T

Large magnetoresistance

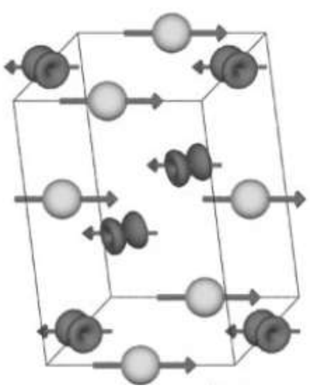
Phase coexistence at T<150K

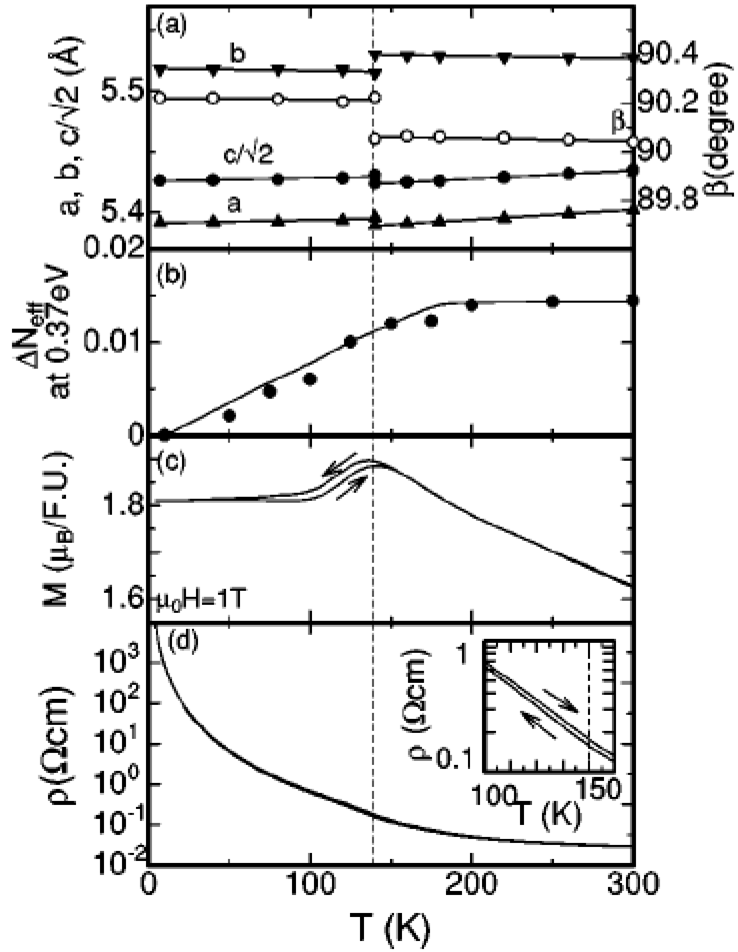
D. Serrate et al., Phys. Rev. B 75, 165109 (2007)

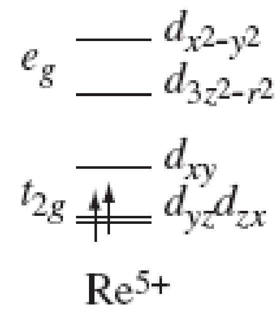
Phase transition in Ca_2FeReO_6



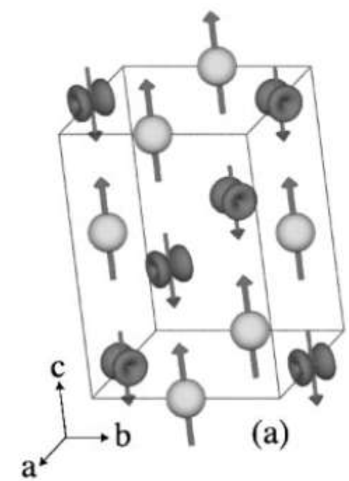
below T_S







above T_S

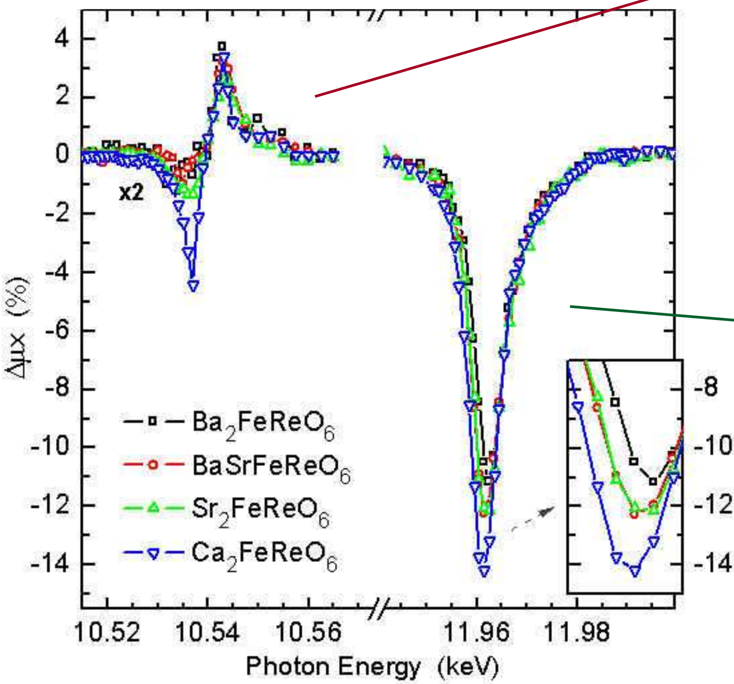


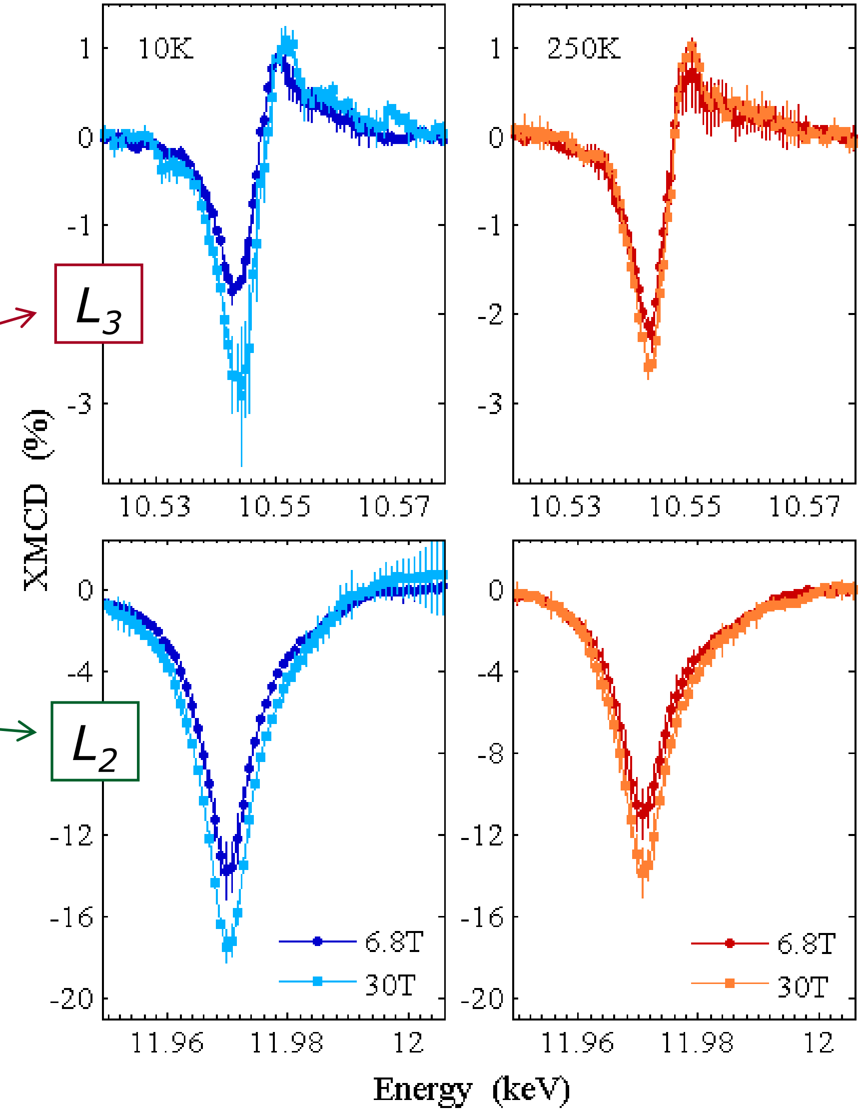
H. Kato et al., Phys. Rev. B 65, 144404 (2002)
K. Oikawa et al., J. Phys. Soc. Japan 72, 1401 (2003)

Low and high field XMCD

L_3 shape altered by B & T

L_2 shape unchanged

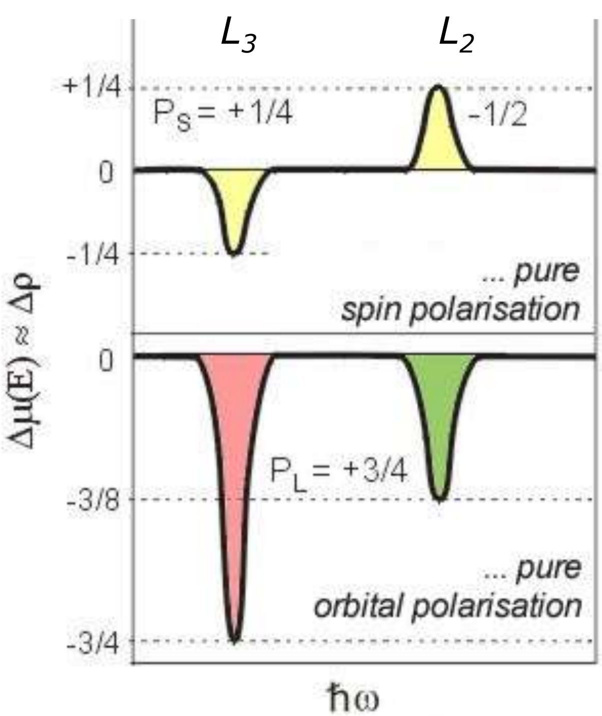


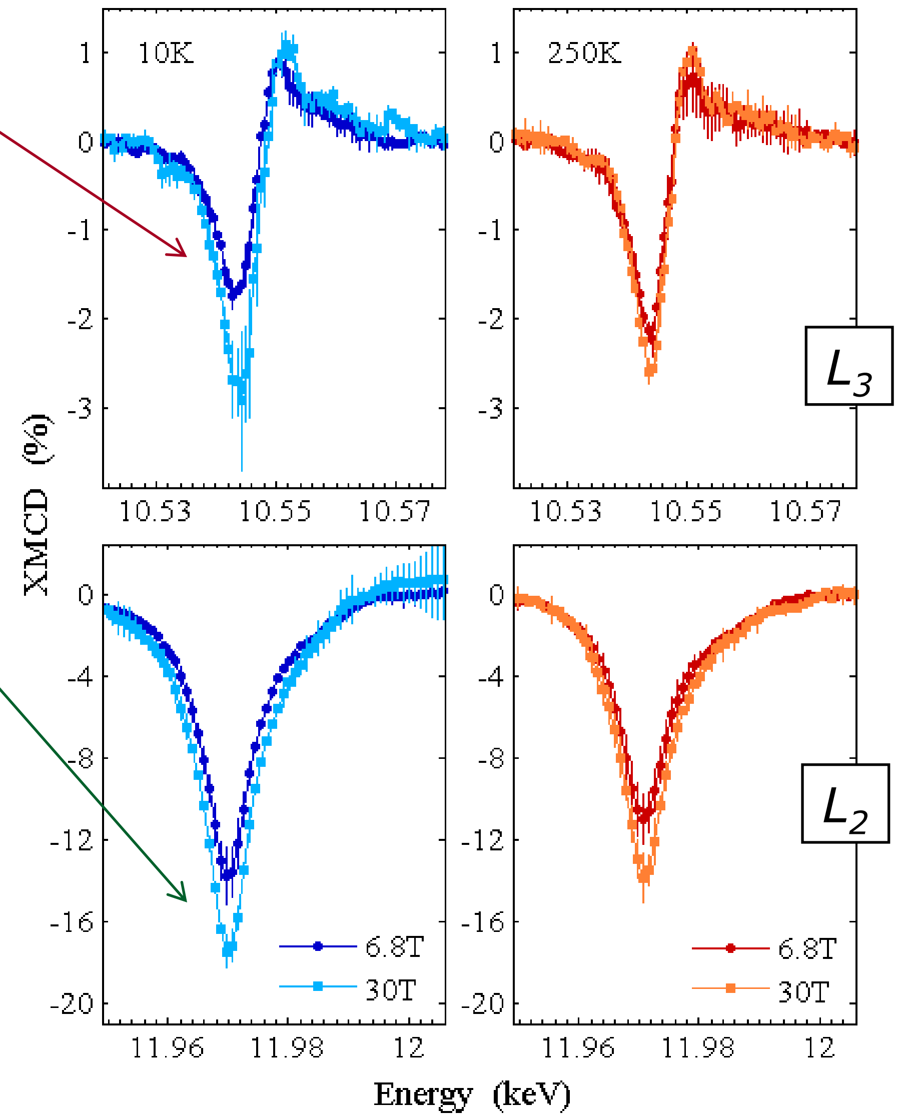


m_L/m_S evolution

Stronger L_3 → *higher* absolute m_L/m_S

Simillar increase of L_2 *(XMCD integral)*
→ m_L *follows bulk magnetization*





m_L/m_S evolution over *B-T* space

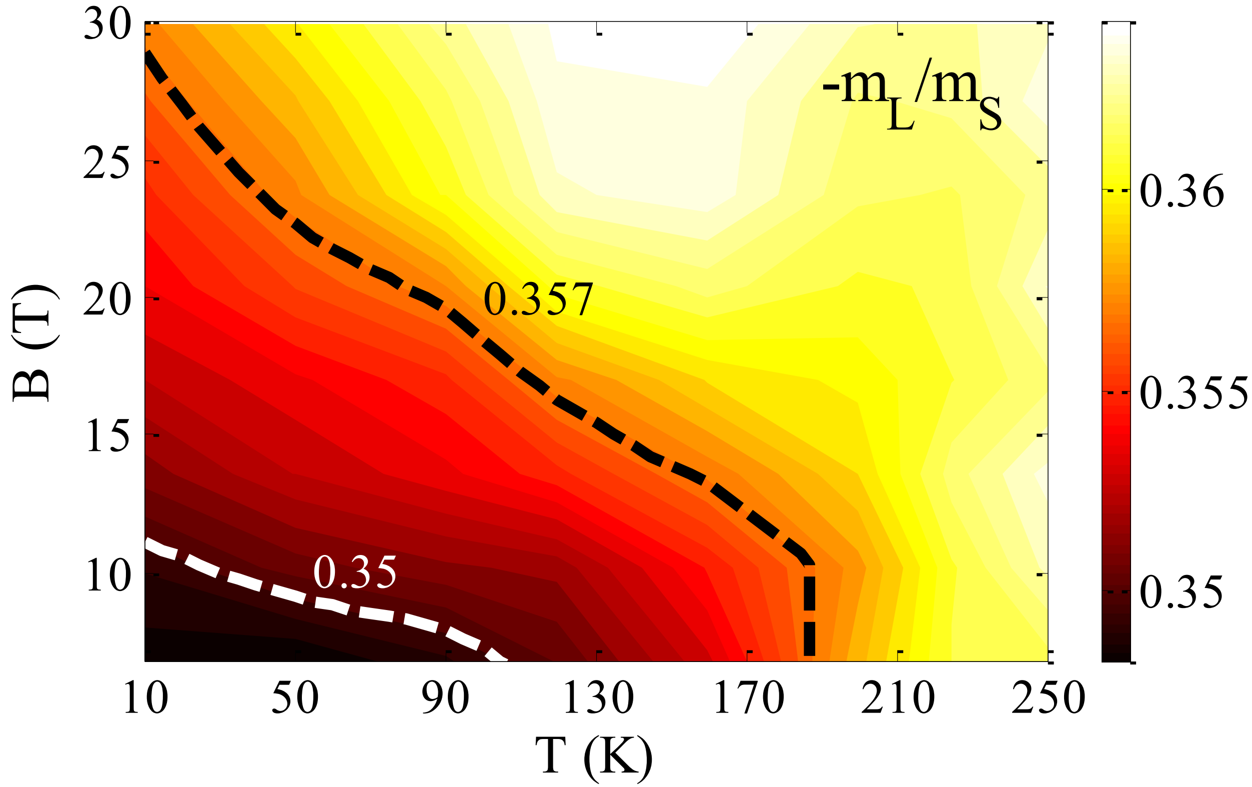
Within statistical error margin →

T<100K
m_L/m_S evolution
Induced by magn. field
→ phase coexistence

T>200K
constant m_L/m_S
→ single phase

Unique m_L/m_S expected for given electronic configuration

Relative increase of the absolute m_L/m_S ratio in 'metallic' phase

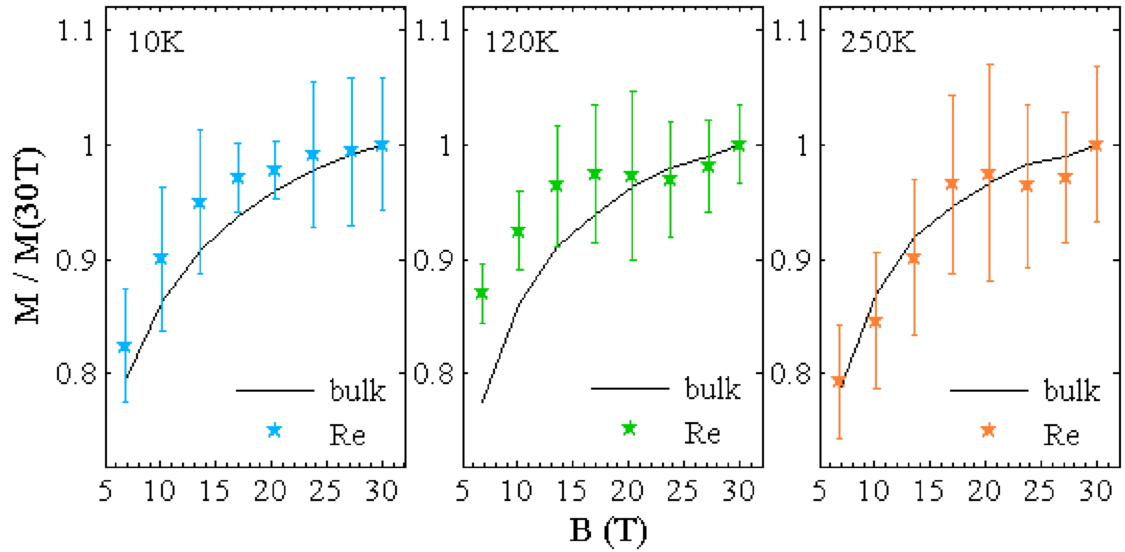


Re & bulk magnetization evolution

M(B) profiles normalized at 30T

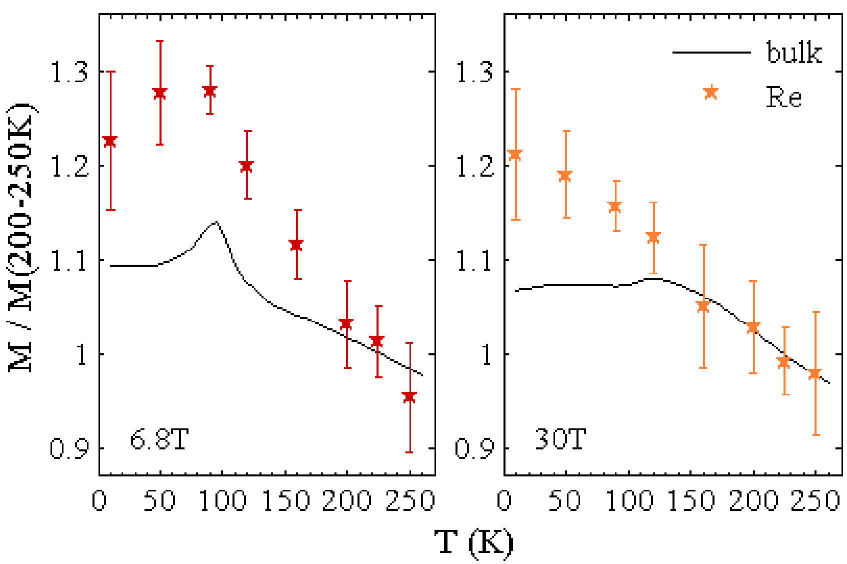
→ collinear magn. *T* > 200K

→ excess of Re magnetization at low fields for *T* <150K



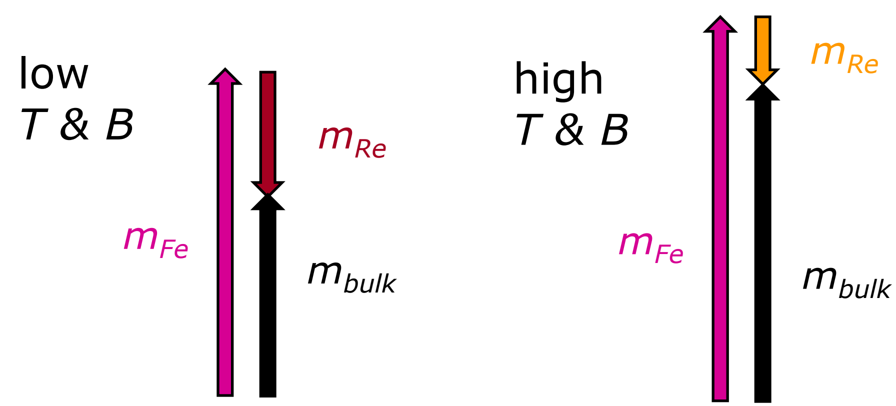
M(T) normalized at high *T*

→ excess of Re magnetization at low temperatures & fields



May be explained by charge redistribution

→ increase in Re population at low *T* & *B*



m_L & bulk magnetization evolution

M(B) profiles normalized at 30T

→ collinear magn. T > 200K

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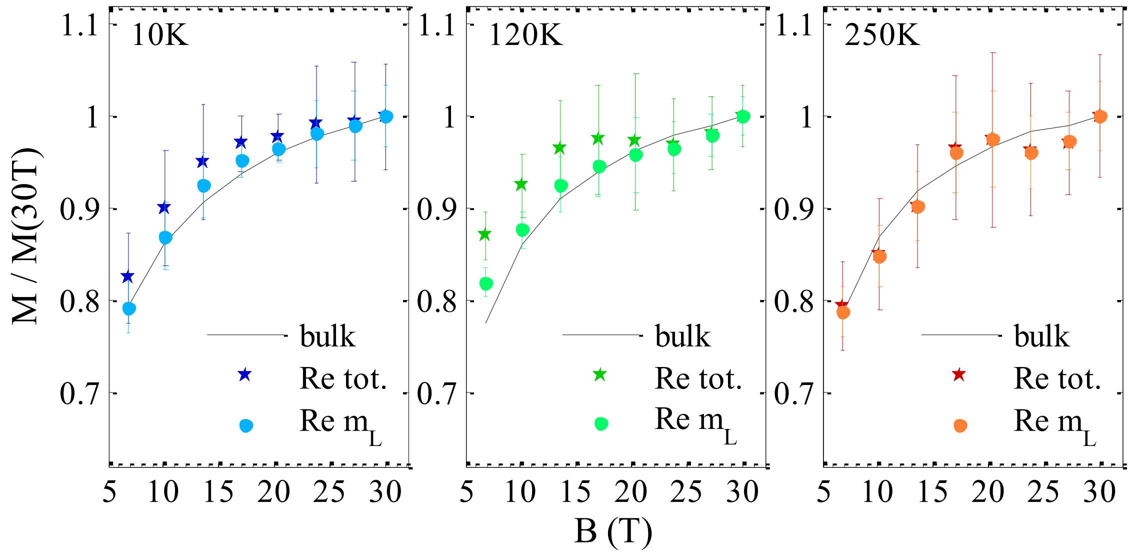
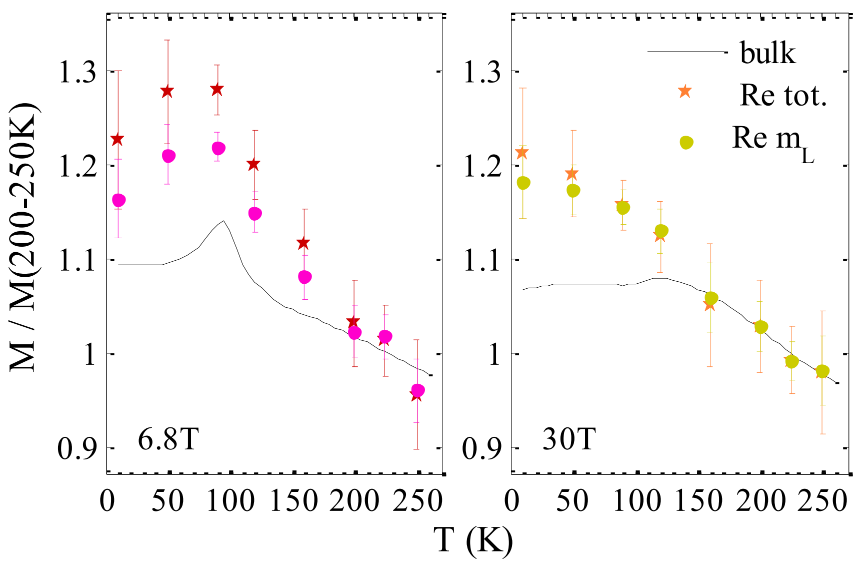
M(T) normalized at high *T*

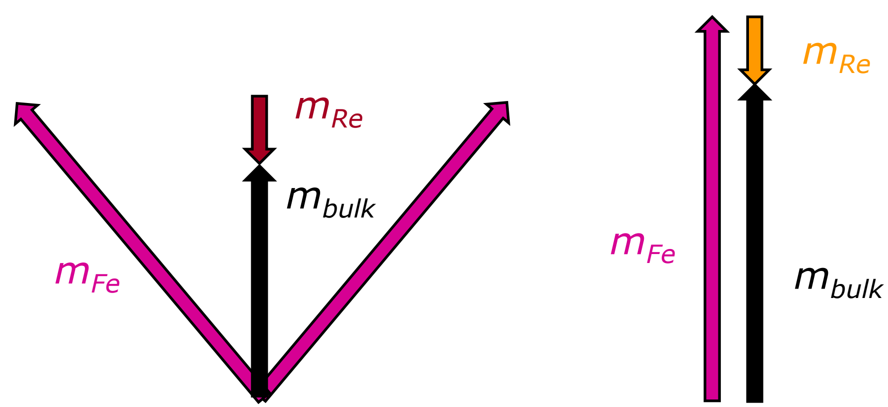
→ excess of Re magnetization at low temperatures & fields





… or by non-collinear allignment

→ decrease of projected M_{Fe}



Conclusions and perspectives

Re $L_{2,3}$ XMCD spectra acquired up to 30T over wide T range: 10-250K

Field induced phase transition observed in Ca_2FeReO_6, confirmed phase coexistence

Phase transition associated with charge redistribution and …

… non-colinear allignment in insulating (low B & T) phase

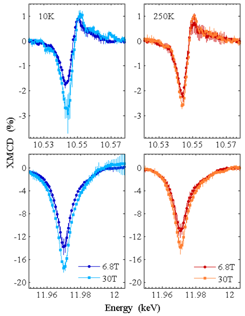
XMCD spectroscopy succesfully combined with pulsed generation of magnetic field

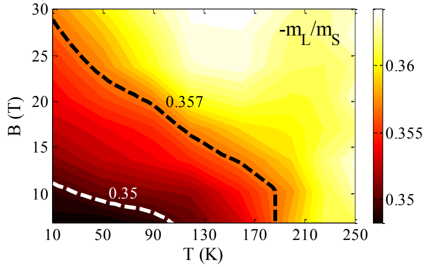
A number of 20-50 pulses per spectrum is sufficient

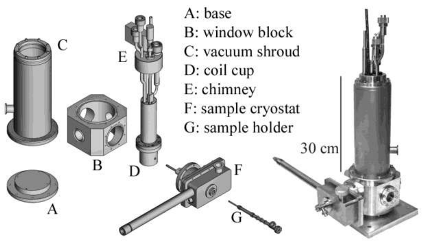
Reliable but complex setup

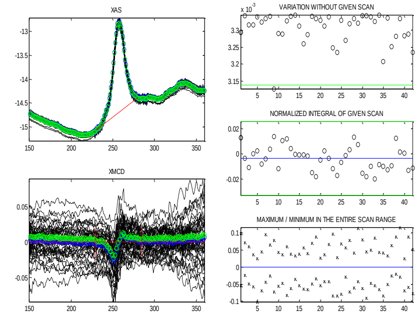
(quick reparation time)

Automatic data selection (correction) techniques to be developed









With help from

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