Aerodynamic levitation and laser heating.

Current and future developments at the ILL

Louis HENNET

Cemhti

Conditions **E**xtrême et **M**atériaux :

Haute **T**empérature et **I**rradiation

ORLEANS – France

May 26 - 28, 2008

5th International Workshop on Sample Environment
at Neutron Scattering Facilities

Outline

Introduction

- I - Principle of the experiment

  - ✓ **Aerodynamic levitation**

- II - Various setups installed at the ILL

  - ✓ **WANS**
  - ✓ **SANS**
  - ✓ **INS**

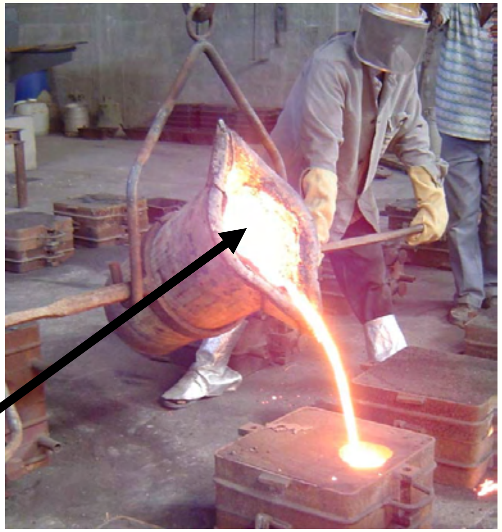
Conclusion

Why study molten materials?

- Fundamental interest
- Technological applications

Properties

?



Steel making industry

Glass blowing

Crystal growth

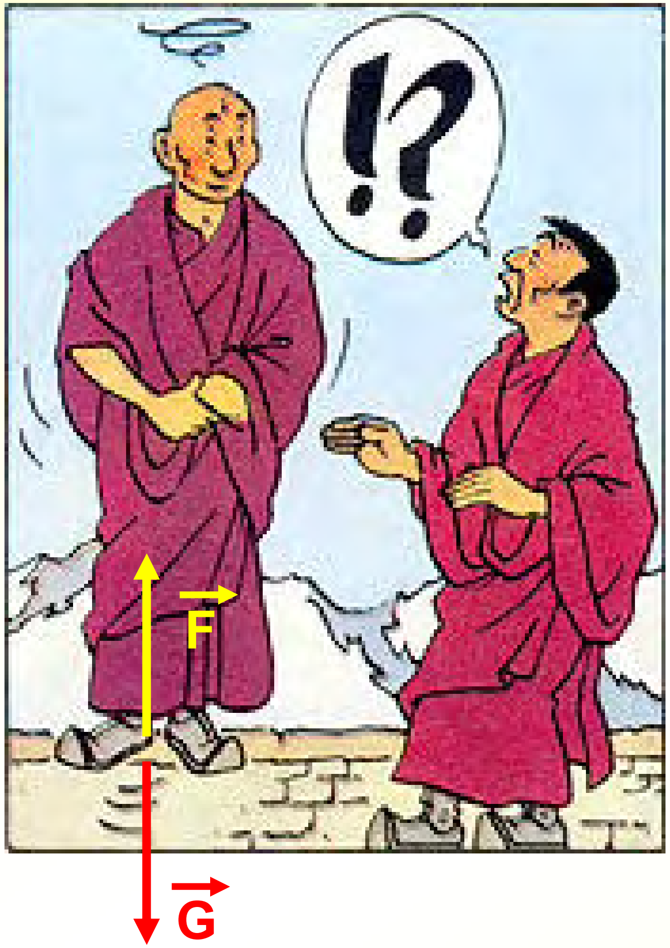
Difficult to use conventional furnaces

Difficulties to access very high temperatures
Possible interactions with the container
→ contamination of the sample

Levitation techniques

Various Advantages

- Possible to reach very high liquid temperatures (>3000°C)
- These methods maintain the sample purity
- Easy access to the supercooled state (few hundred degrees below the melting point)

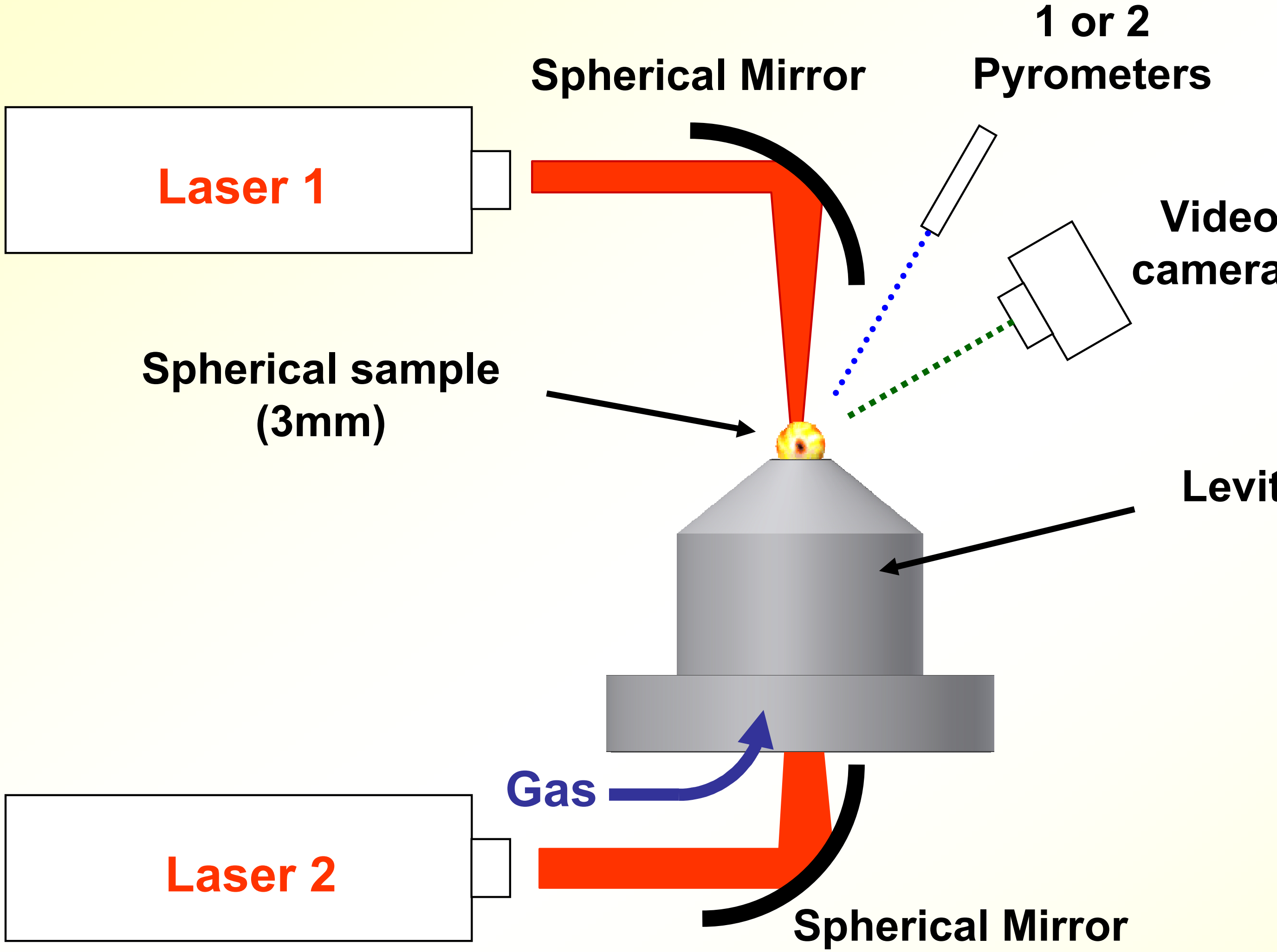


Various levitation techniques have been developed

The common principle is to apply a **force** to counteract the gravity

- Electromagnetic field
- Electrostatic field
- Acoustic wave
- Gas flow
  - → Gas film levitation
  - → Aerodynamic levitation

Aerodynamic levitation and CO_2 laser heating



Laser 1

Spherical Mirror

1 or 2 Pyrometers

Video cameras

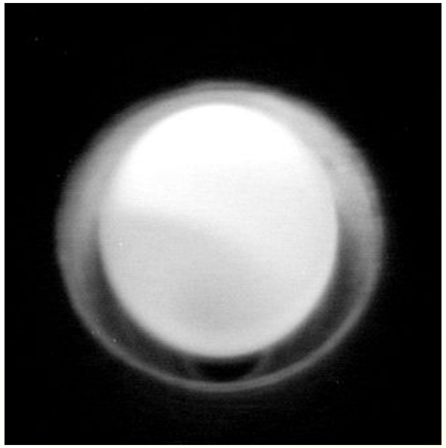
Spherical sample (3mm)

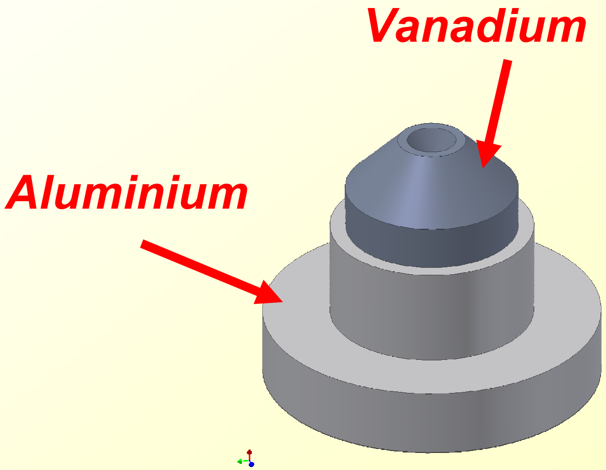
Levitator

Gas

Laser 2

Spherical Mirror





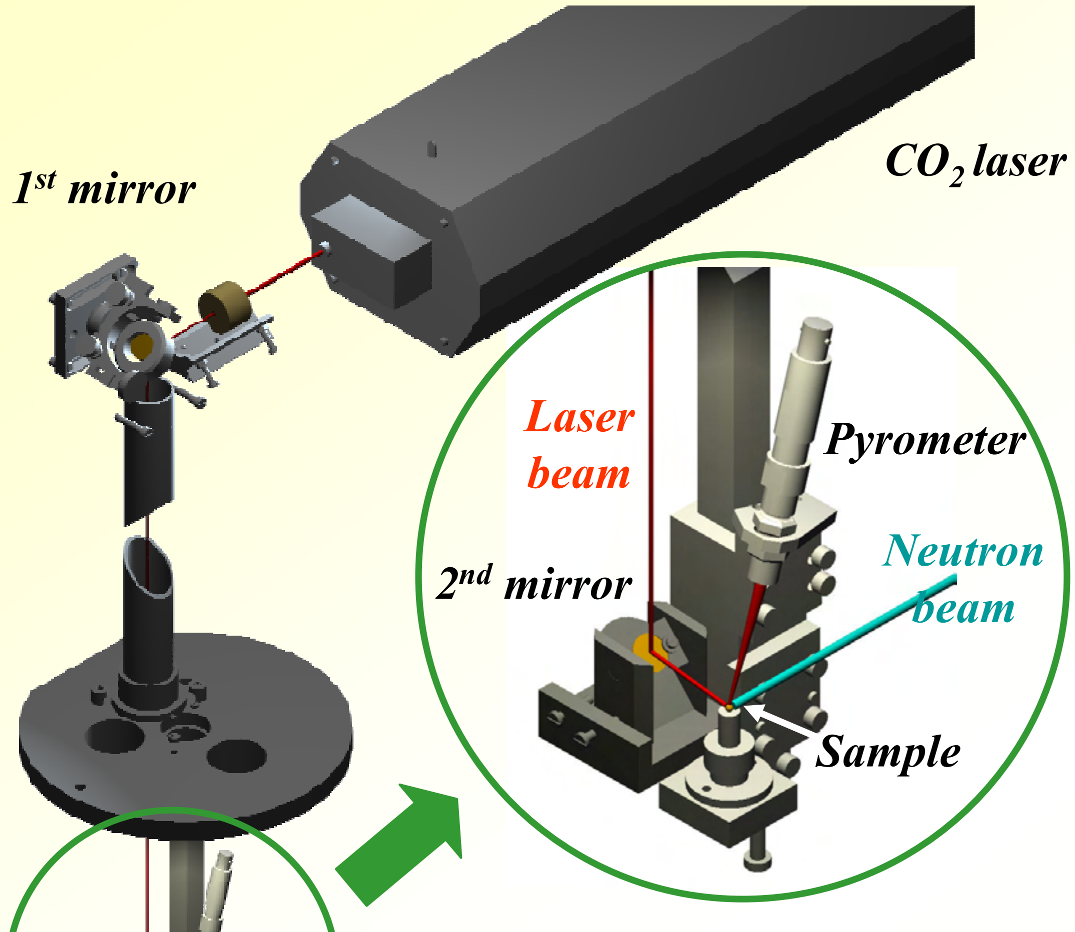
Vanadium

Aluminium

For neutron diffraction

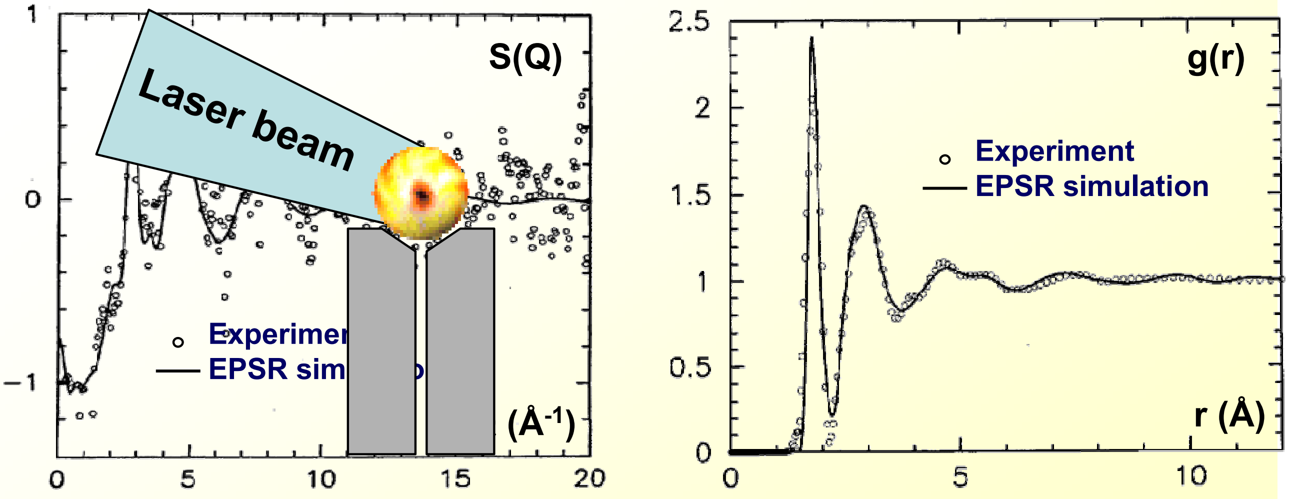
Neutron Diffraction

SANDALS diffractometer @ ISIS




1st levitation setup installed at the SANDALS instrument 8 years ago. (developed with UWA)

Liquid Al_2O_3 (2250°C)



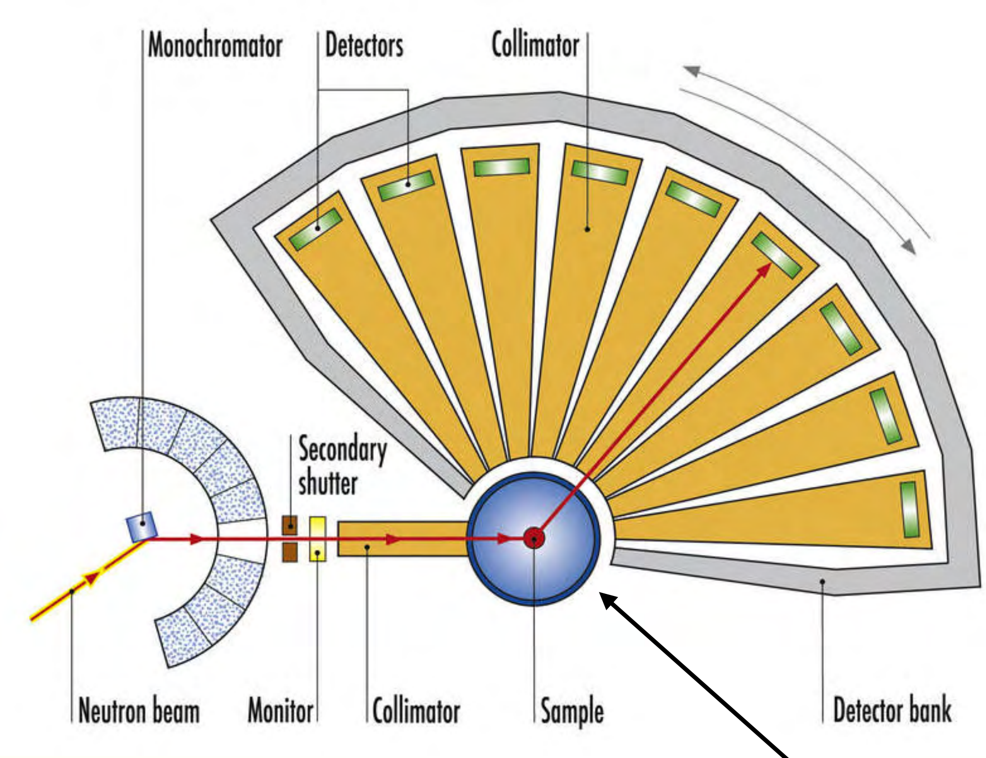
C. Landron, L. Hennet, T. Jenkins, G.N. Greaves,
J.P. Coutures, A Soper,
Phys. Rev. Lett. 86, 4839 (2001)

May 26 - 28, 2008

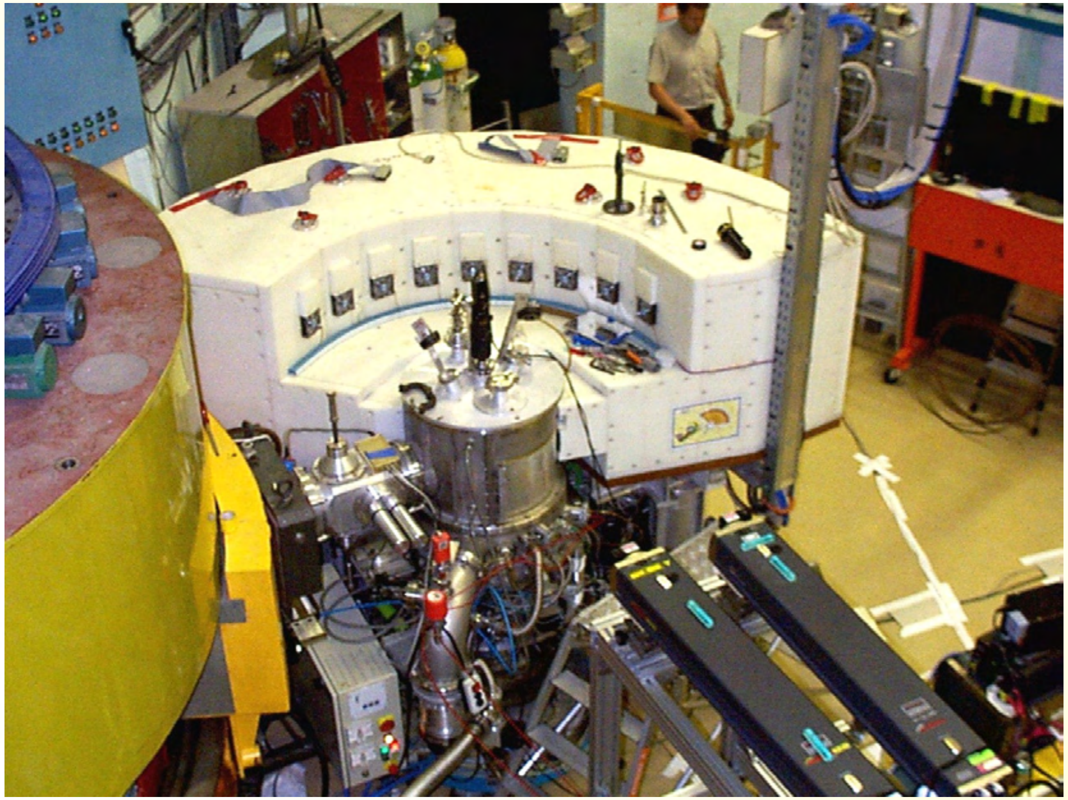
Good agreement with x-ray measurements

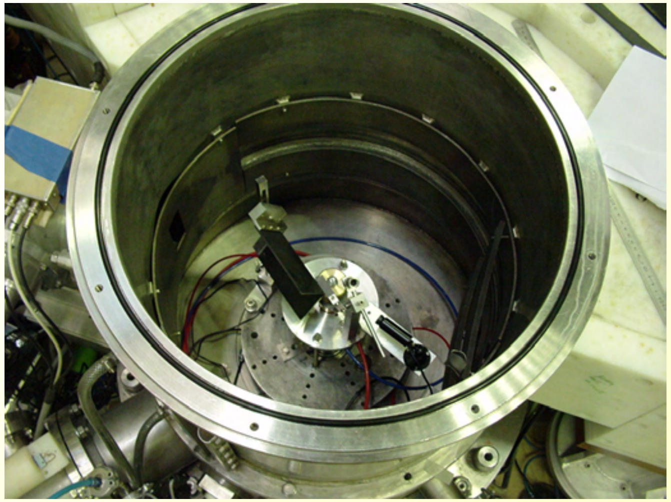
Neutron Diffraction

D4C diffractometer @ ILL

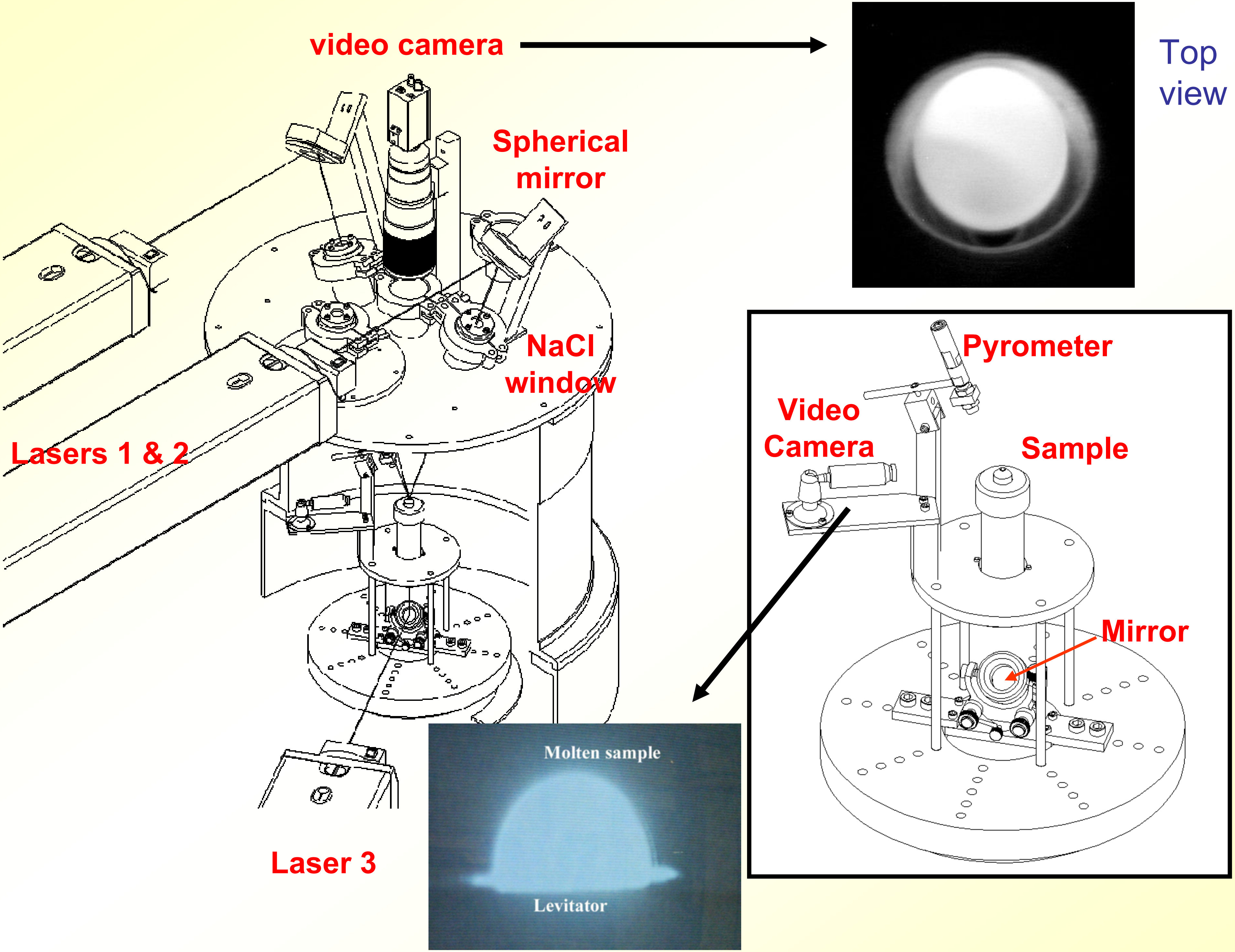


Instrument Layout





May 26 - 28, 2008


video camera
Spherical mirror
NaCl window
Lasers 1 & 2
Laser 3
Top view
Pyrometer
Video Camera
Sample
Mirror
Molten sample
Levitator

Side view

Some experimental results

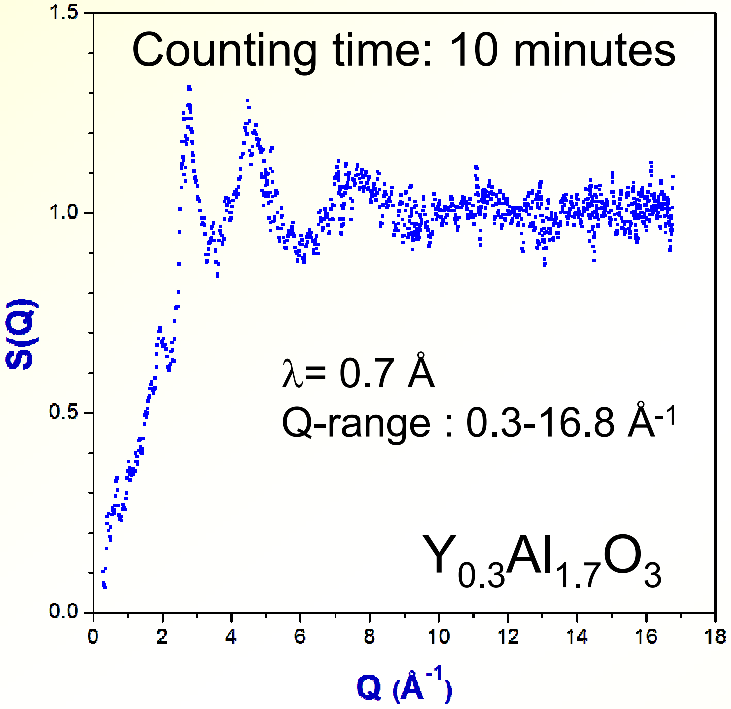
$(Y_20_3)_x$-$(Al_20_3)_{1-x}$

x=0.15

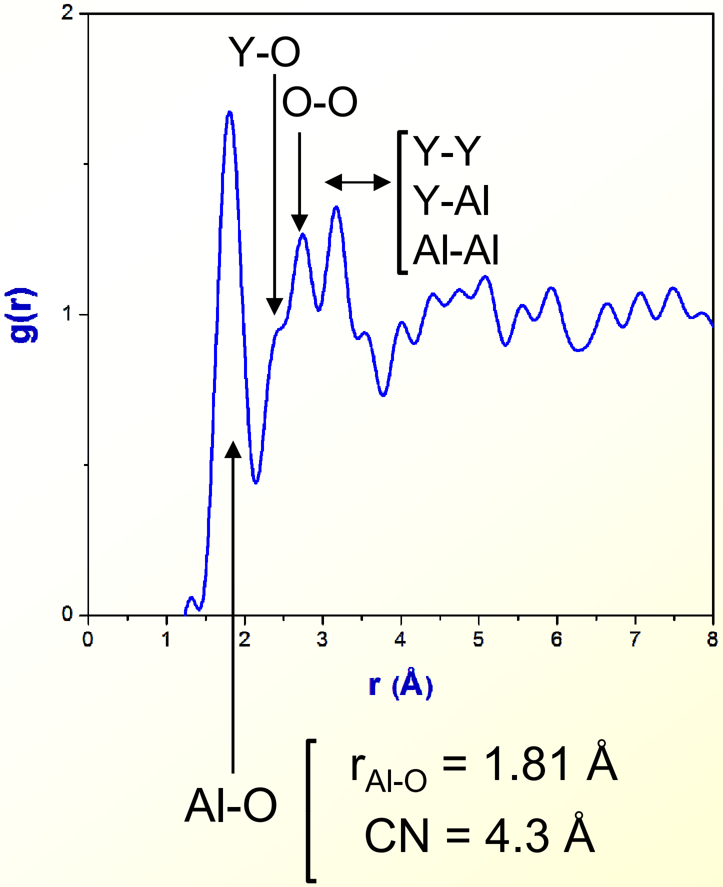
(Melting point : 1840°C)

Contrary to x-rays, it's difficult to make very fast neutron scattering measurements

Possible to obtain good statistics with relatively short counting times



Statistics are relatively good in spite of the small sample size (2.8mm).

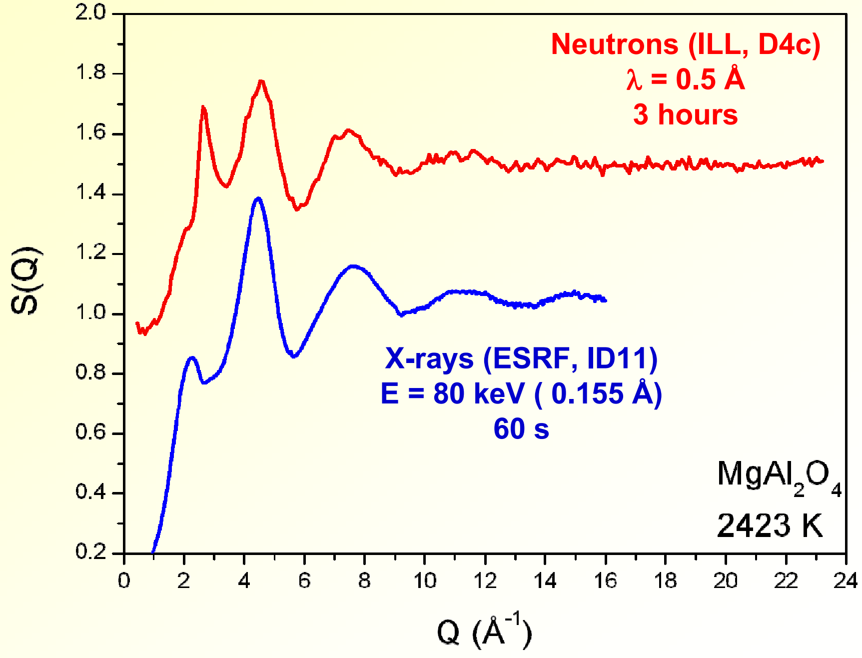


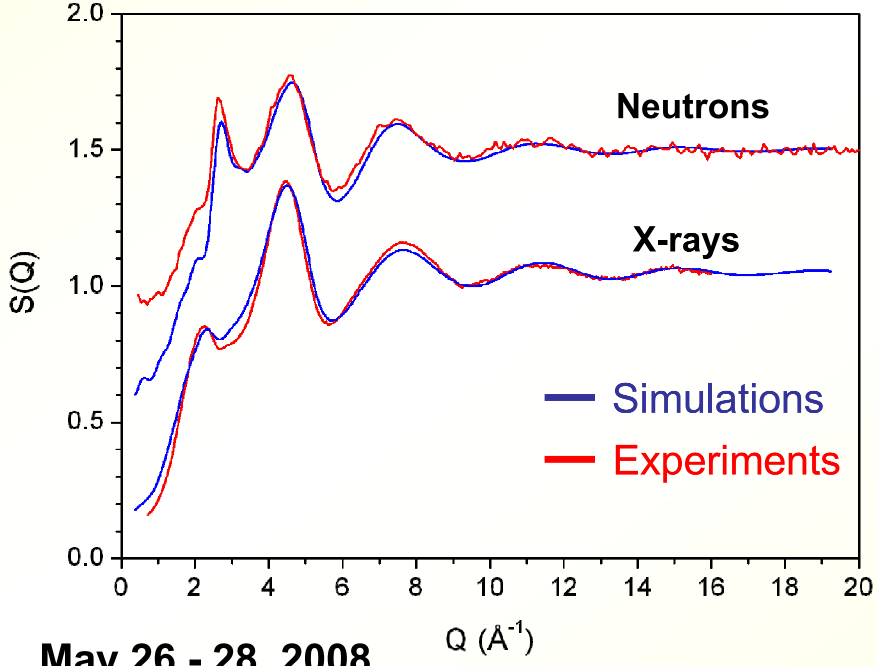
Calculations give results in agreement with x-ray and NMR experiments

$(Mg0)_x$-$(Al_20_3)_{1-x}$

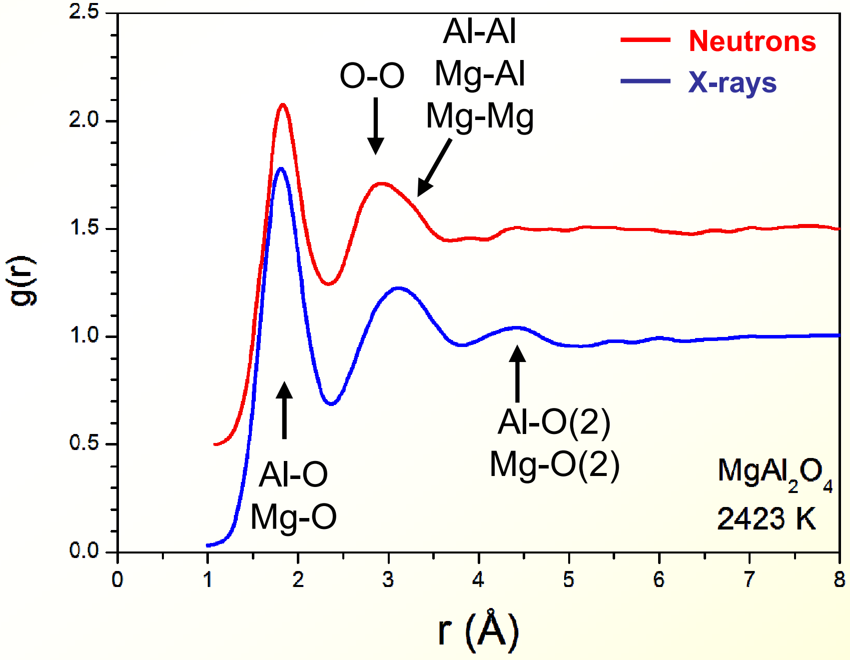
x=0.5

Structure factors





Pair distribution functions

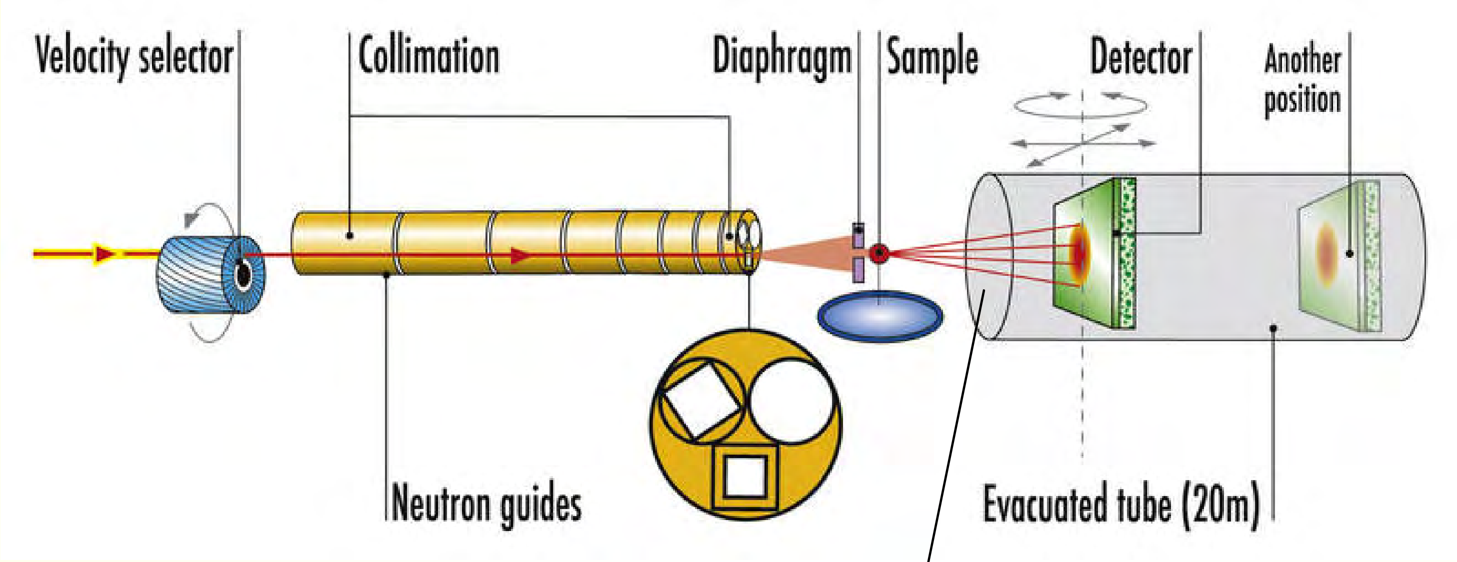


Good agreement with x-rays
with MD simulations

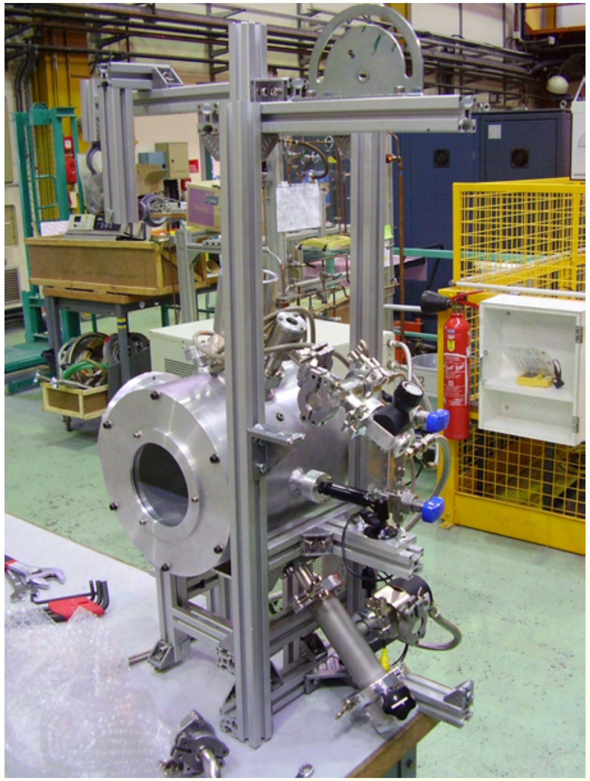
With this setup, it is possible to obtain reliable structural information in the liquid state

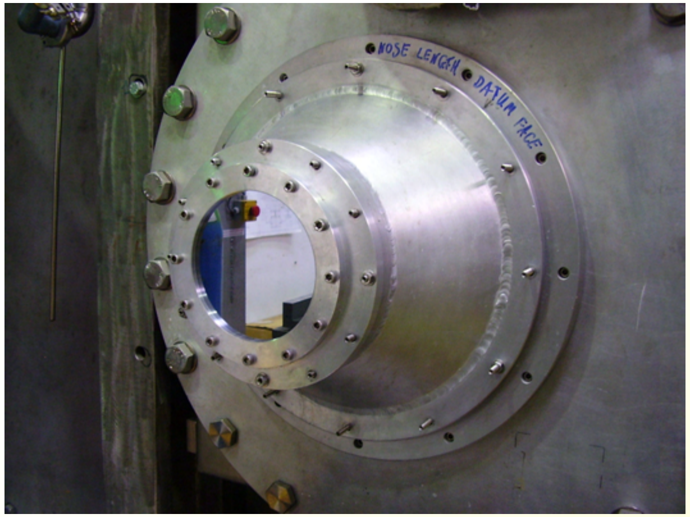
Small Angle Neutron Scattering

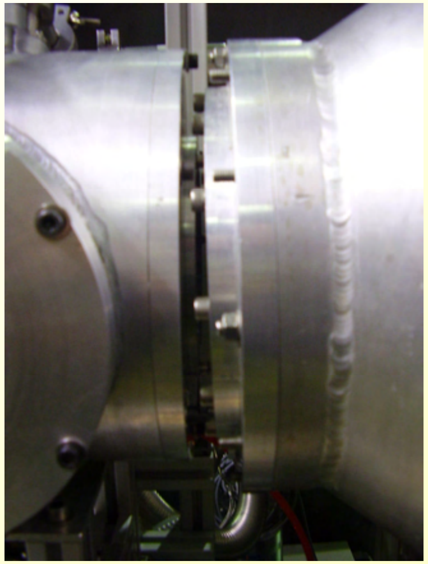
D22 instrument @ ILL

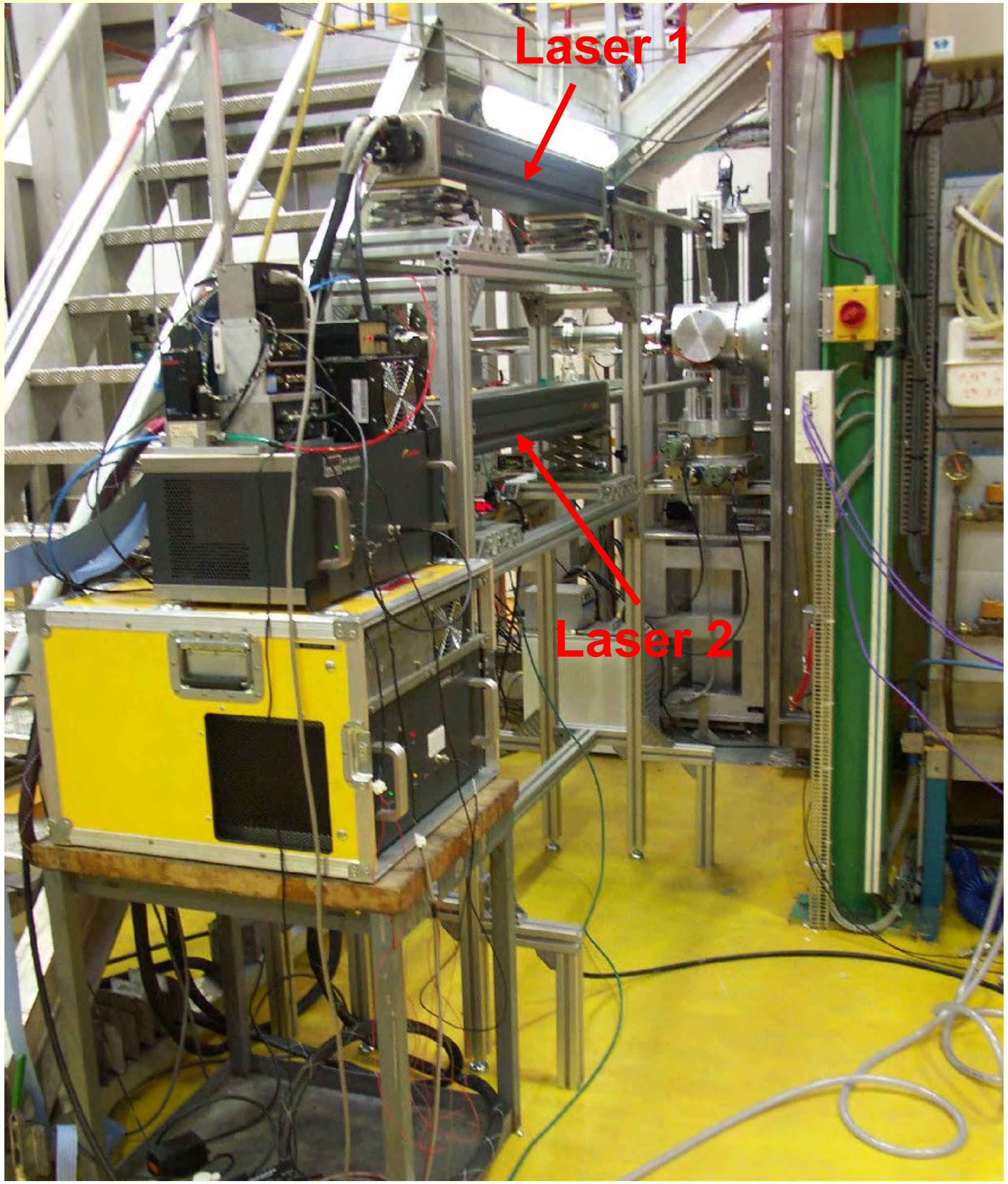


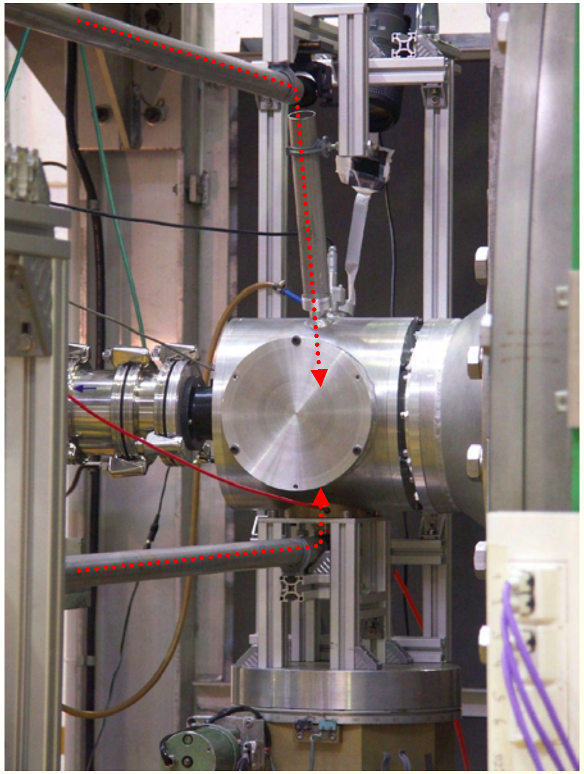
Instrument Layout

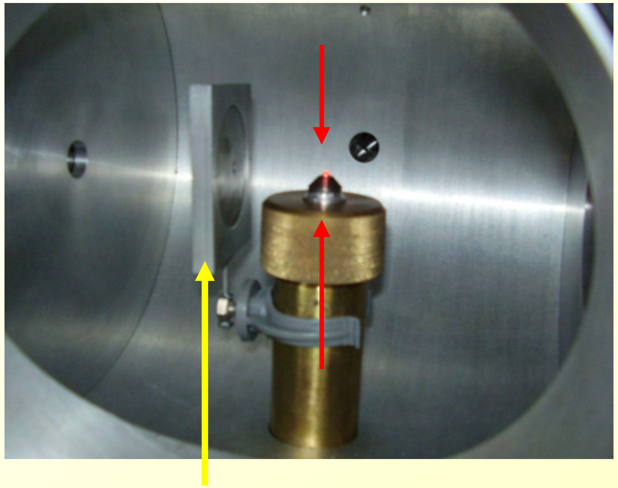




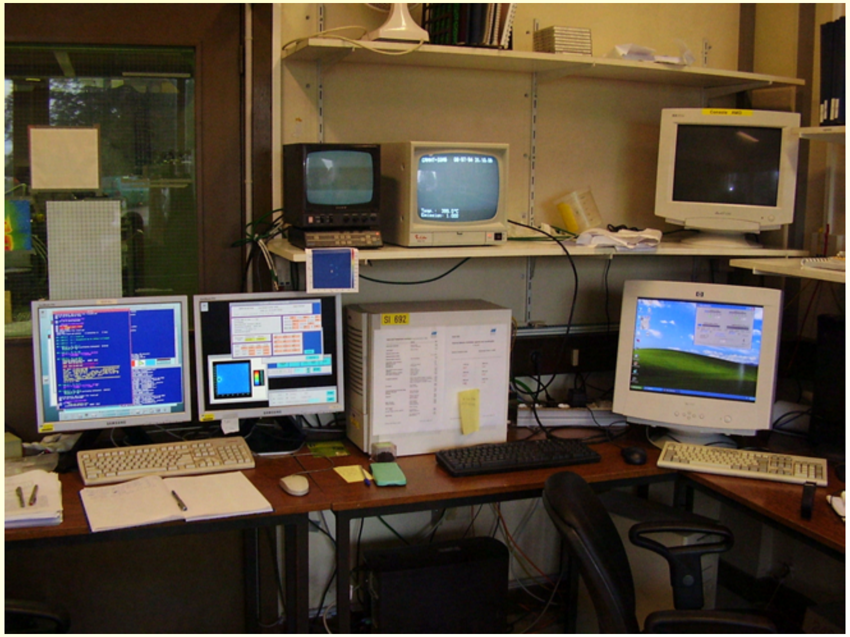




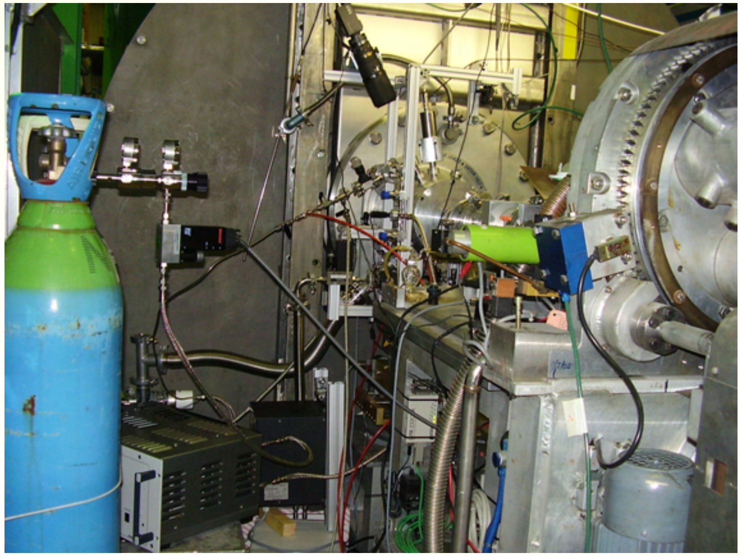




Diaphragm (Cd)



All is controlled from outside.

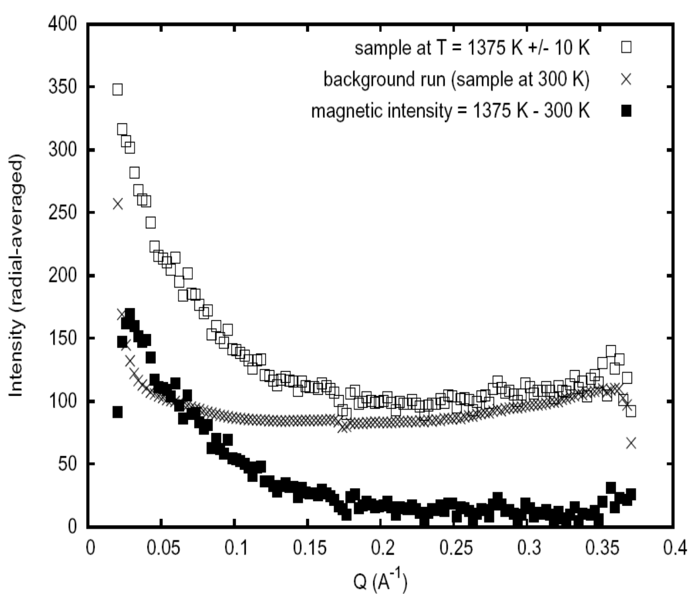


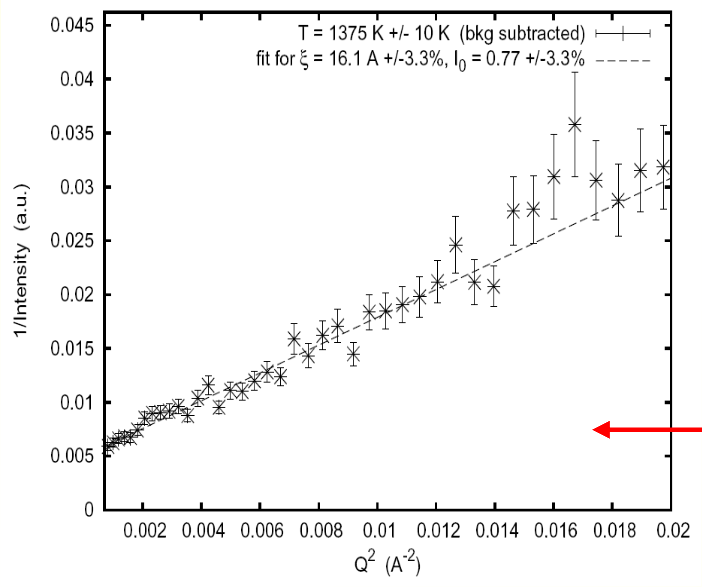
Limited space around the experiment
Lot of equipments

The next job is to optimize the configuration of the setup

Magnetic critical scattering in solid $Co_{80}Pd_{20}$

H. E. Fischer *et al*, J. Phys.: Condens. Matter 19 (2007) 415106





$$I(Q) = I_0 \frac{1}{\kappa^2 + Q^2}$$

$$\kappa = \frac{1}{\xi}$$

$$\boxed{\frac{1}{I(Q)} = \frac{1}{I_0}\left(\frac{1}{\xi^2} + Q^2\right)}$$

Magnetic correlation length :

$$\xi(t) = \xi_0 t^{-\upsilon}$$

$$t = \frac{T - T_c}{T_c}$$

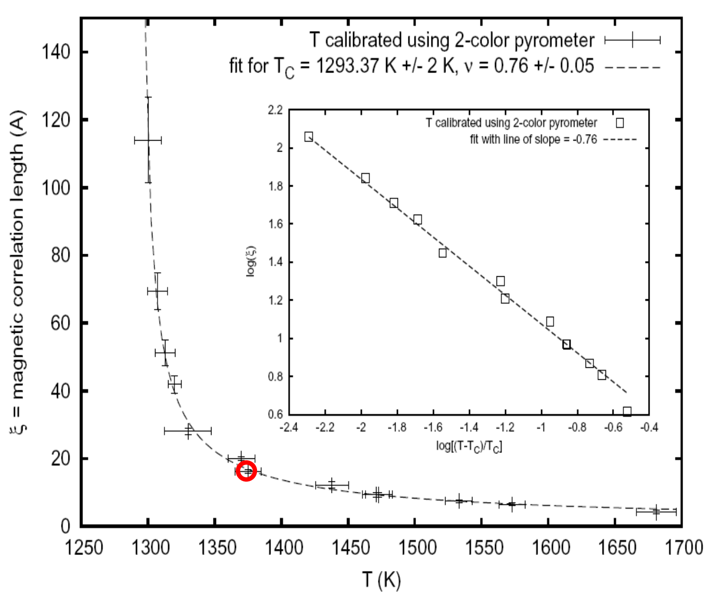
T_c = Ferromagnetic transition temperature

ν = Critical exponent

T_C = 1293 K

ν = 0.76

(1272 K and 0.7 in the literature)

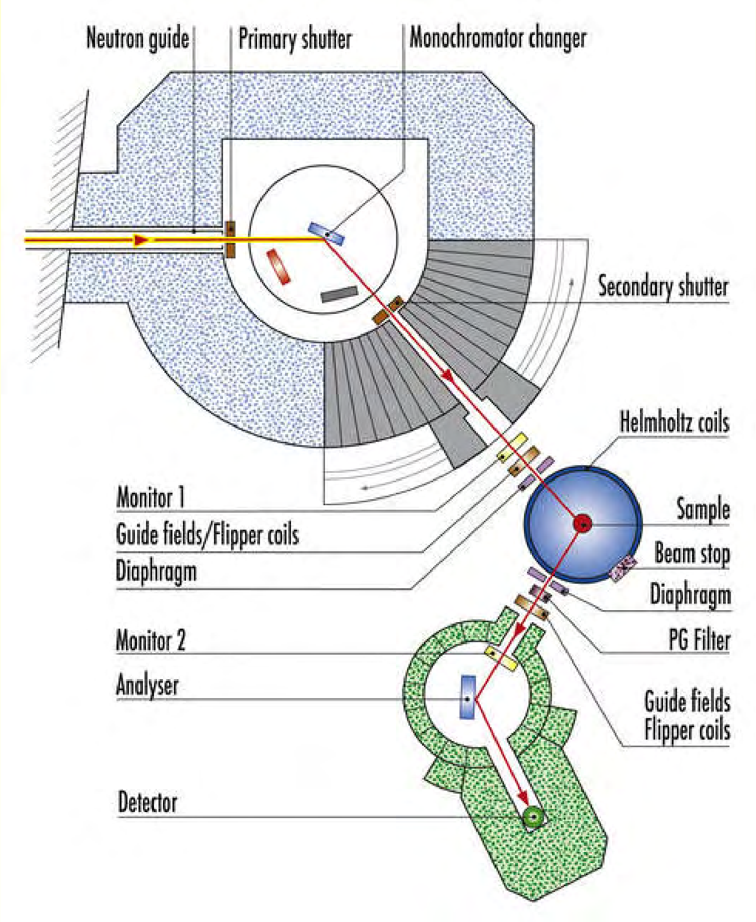


New experiments are planed to study the liquid state

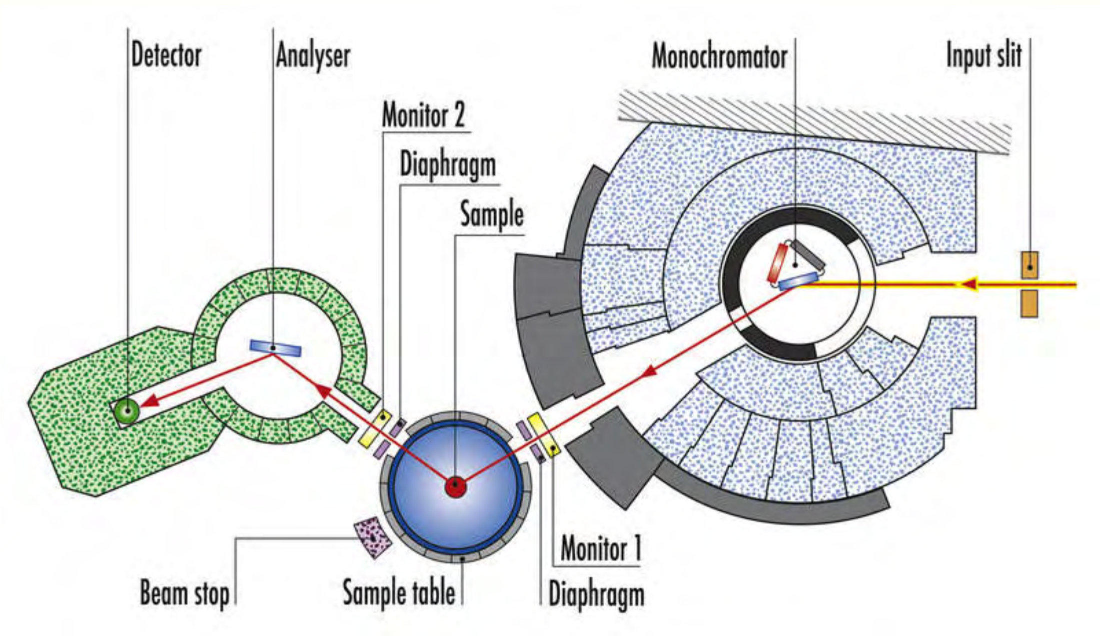
Inelastic Neutron Scattering

IN22 and IN8 instruments @ ILL

TAS spectrometers



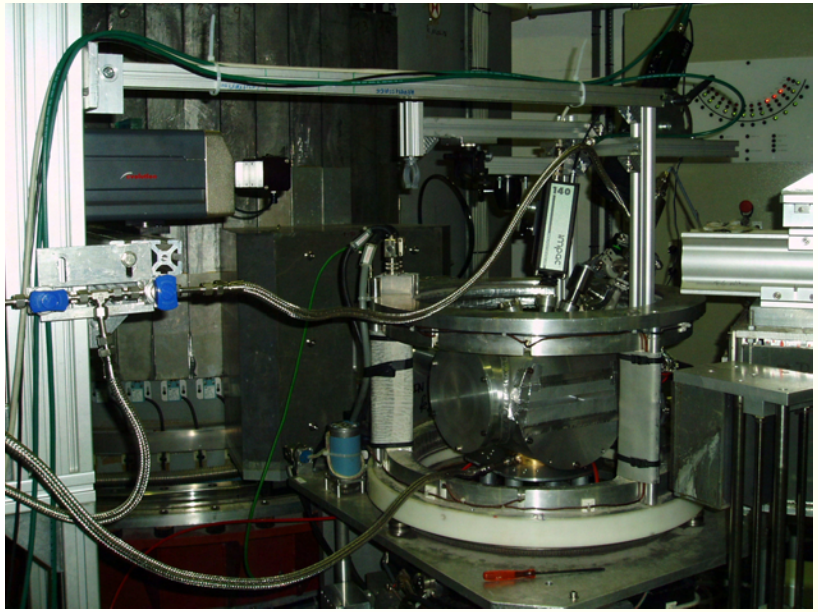
IN22



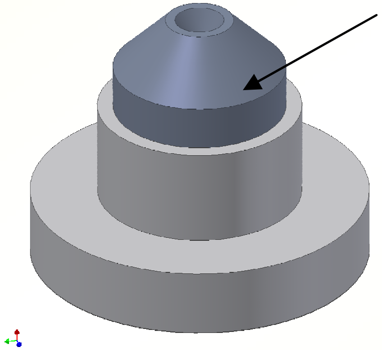
IN8

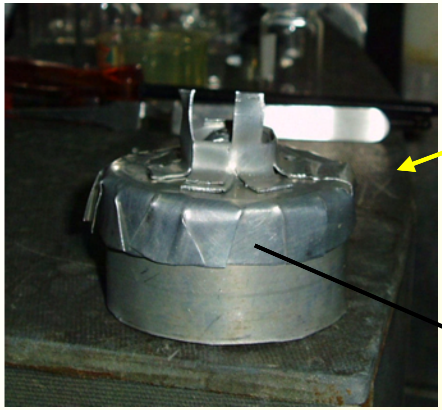
Instruments Layout

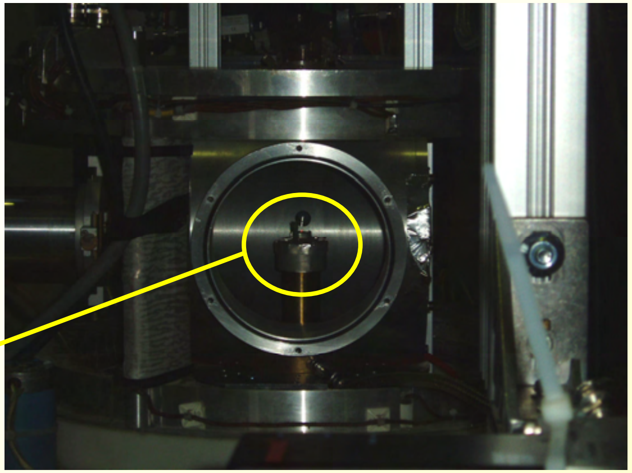
May 26 - 28, 2008



Fixed K_i (the lasers don't move)







Cd shielding on the brass parts

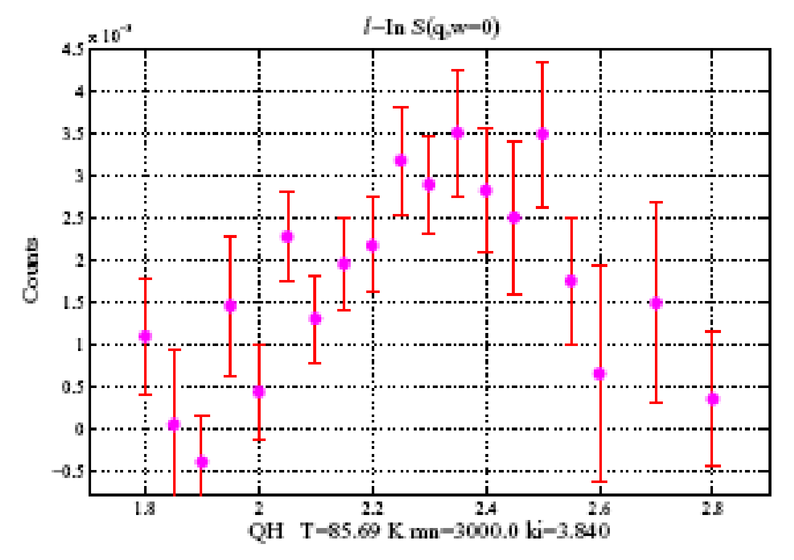
First measurements on liquid In

(E. Farhi et al)

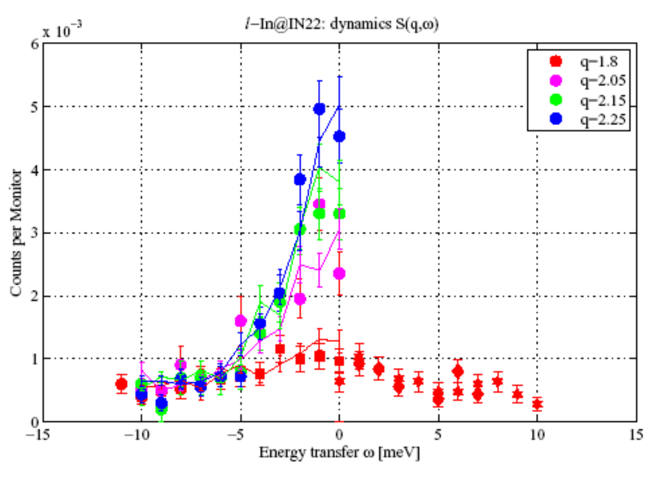
Small samples : 2 mm → Not the best case
Relatively high absorption : σ_{abs}=194 barns

Melting point 156.6°C → **Why do we need levitation ?**

If we use a furnace, it generates lot of scattering



Static structure factor S(q, ω = 0) of *l*-In at T=180 °C.



Measured and simulated quasi-elastic signal S(q, ω) around the first peak of *l*-In at T=180 °C.
Decrease of the width of the QENS line

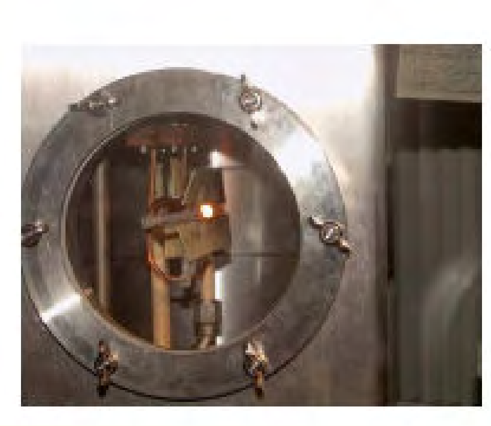
New experiments are planed with bigger samples

Results obtained on liquid Ni

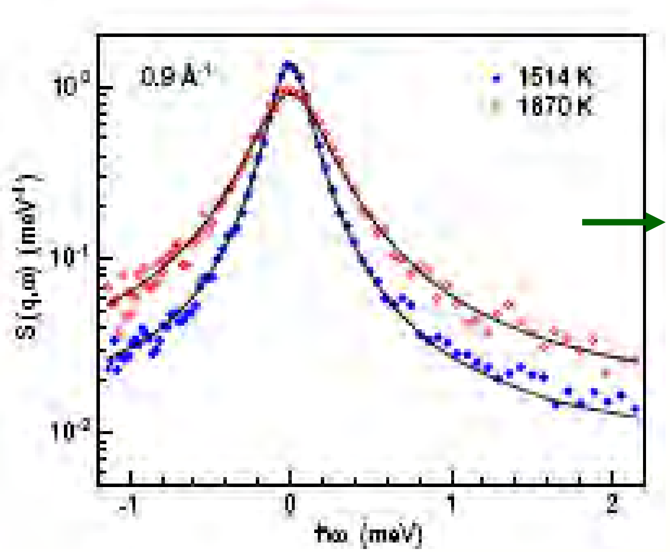
By A. Meyer *et al*

PAUL SCHERRER INSTITUT PSI

FOCUS instrument
(TOF spectrometer)

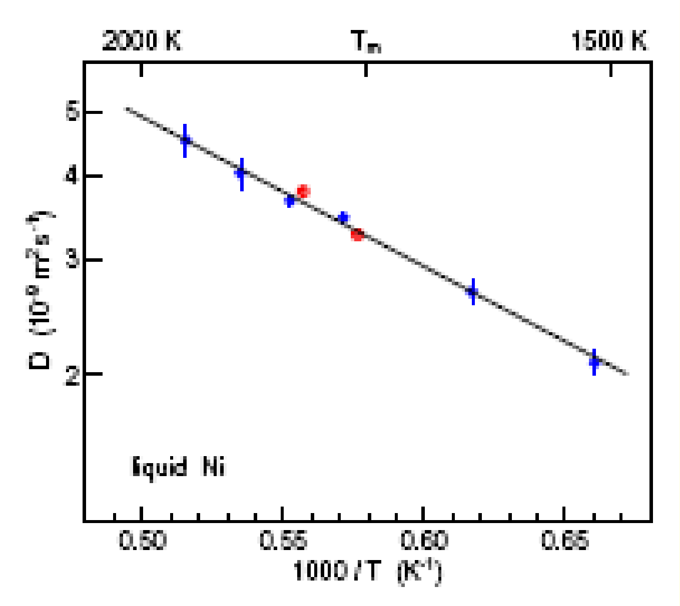


Electromagnetic levitation
6-8mm samples



QENS spectra of liquid Ni

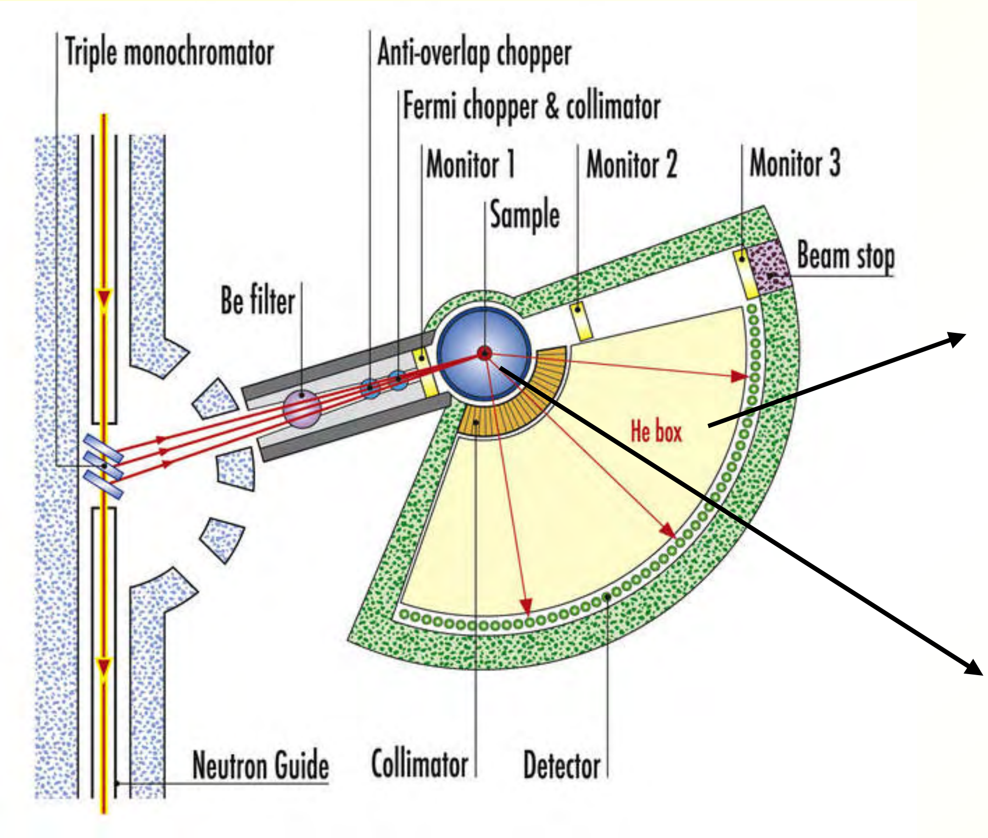
→ Self Diffusion coefficient D



The temperature dependence of D can be described with an Arrhenius law.

Future plan

Design of a new setup @ IN6 (ILL)



Instrument Layout

Enough space for putting the lasers and the levitator

Conclusion

- We have developed various devices to study the structure and the dynamics of high temperature levitated liquids using
  WANS
  SANS
  INS

- The future plans are to
  - Optimize the existing setups (Sample size…)
  - Develop another system for TOF spectrometers :

(In collaboration with the Sample Environment Group at ILL)

Collaborators

CEMHTI - CRMD
ORLEANS

Séverine BRASSAMIN
Jean-François BRUN
Viviana CRISTIGLIO
Marlène LEYDIER
Irina POZDNYAKOVA
David L. PRICE
Marie-Louise SABOUNGI
Didier ZANGHI

ILL
GRENOBLE

Simon BAUDOIN
Gabriel J. CUELLO
Emmanuel FARHI
Henry E. FISCHER
Monica JIMENEZ-RUIZ
Roland MAY
Pierre PALLEAU
Louis-Pierre REGNAULT

Thank you for your attention