NEUTRONS
FOR SOCIETY

Sample environment for inelastic neutron scattering

Jiří Kulda

Institut Laue-Langevin, Grenoble, France

Sample environment

Temperature:

dilution insert	> 15 mK
Orange cryostat	1.5 - 300 K
cryofurnace	2 - 500 K
resistive heating	300 - 1400 K
optical (mirror)	*800 - 2000 K*

Pressure:

continuously loaded	*$p < 3$-5 kbar*
clamp	$p < 30$ kbar
uniaxial	$F < 10000$ N

ALL works down to $T \approx 2$ K!

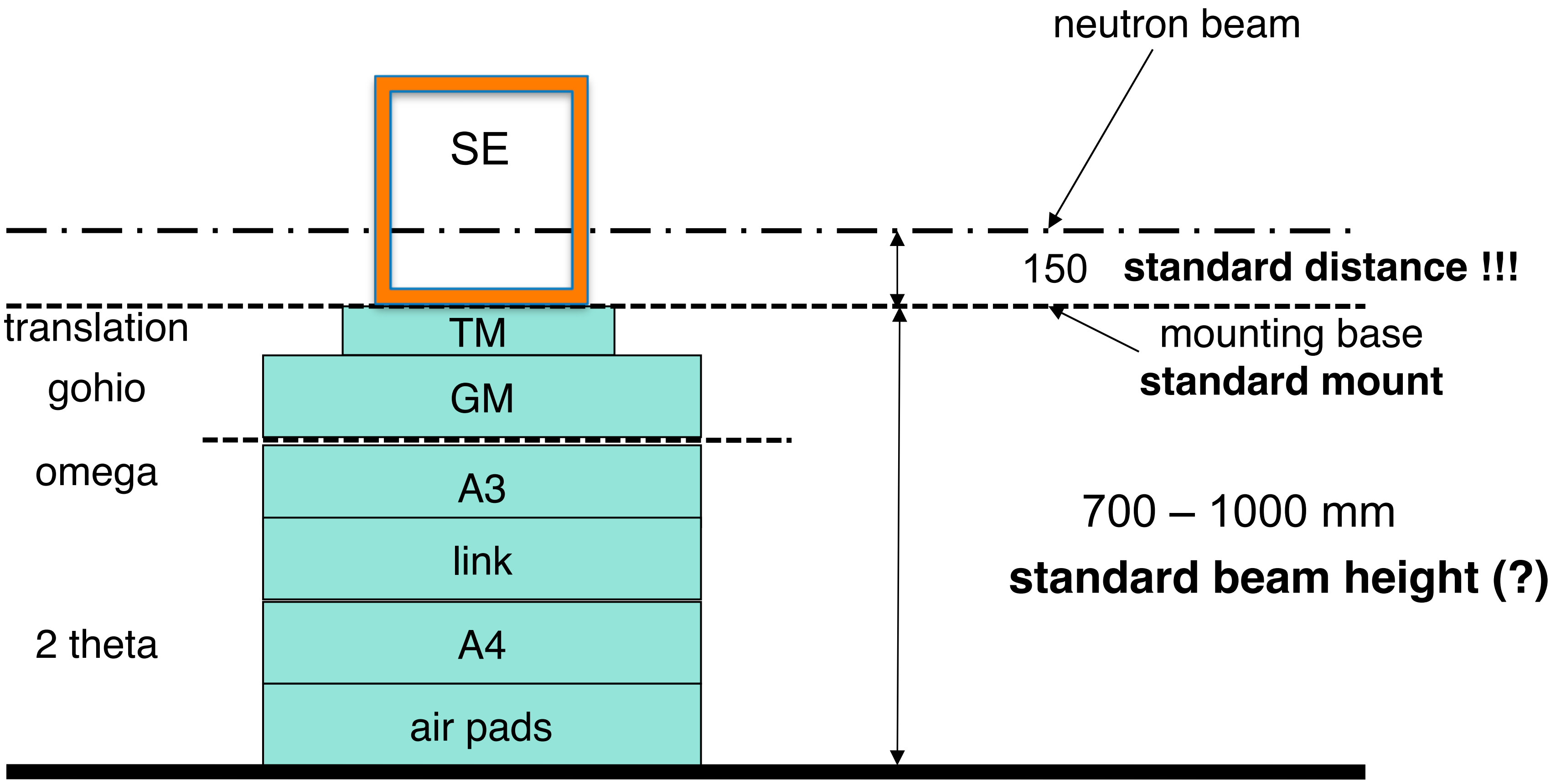
Paris-Edinburgh cell	$p < 100$ kbar $T > 4$ K

Magnetic field:

CRYOPAD	≈ 15 mG
cryomagnets	1 - 15 T
pulsed field	*< 40 T*

+ electric field, gas sorption, ...

Standard sample mounting system

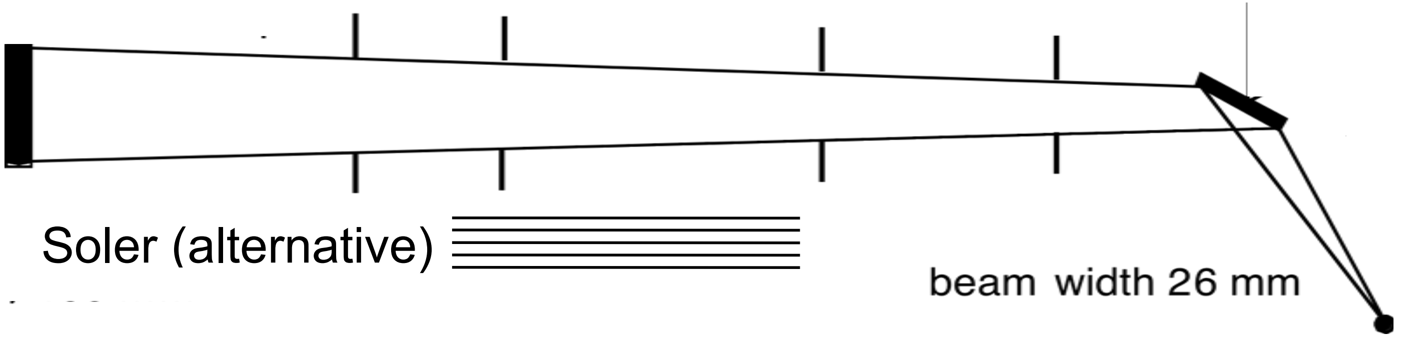


Layout of the talk

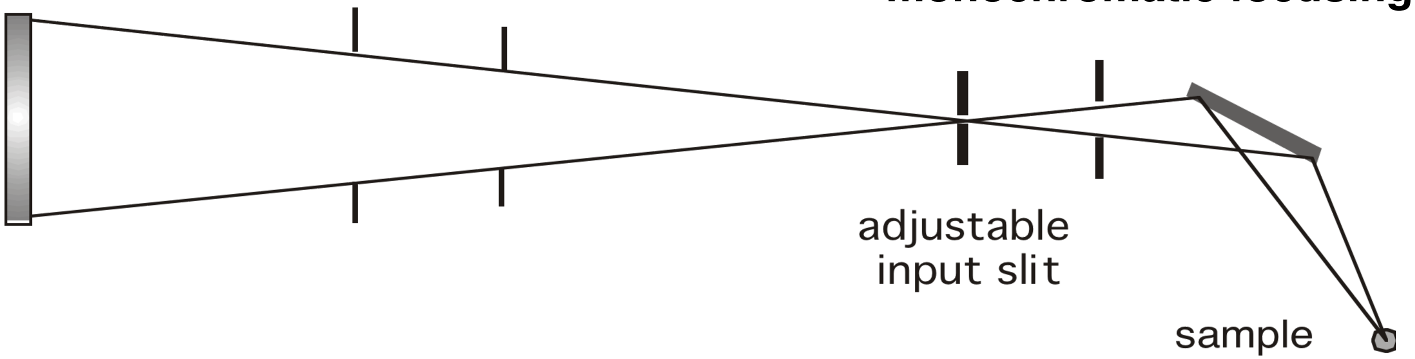
1. Optics
2. High pressures
3. Magnetic fields
    1. Zero field (CRYOPAD, MUPAD, ...)
    2. Conventional cryomagnets
    3. Ultra-high fields
4. Conclusions

TAS layout

"traditional" (... – 1999)



"modern" (2000 - ...)

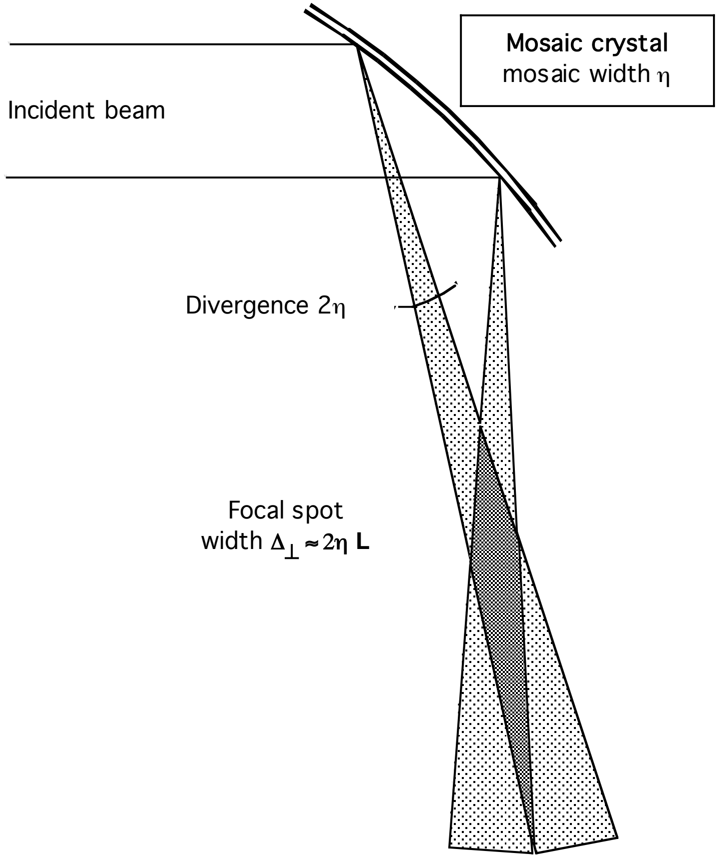


intensity gain ≈ 30x

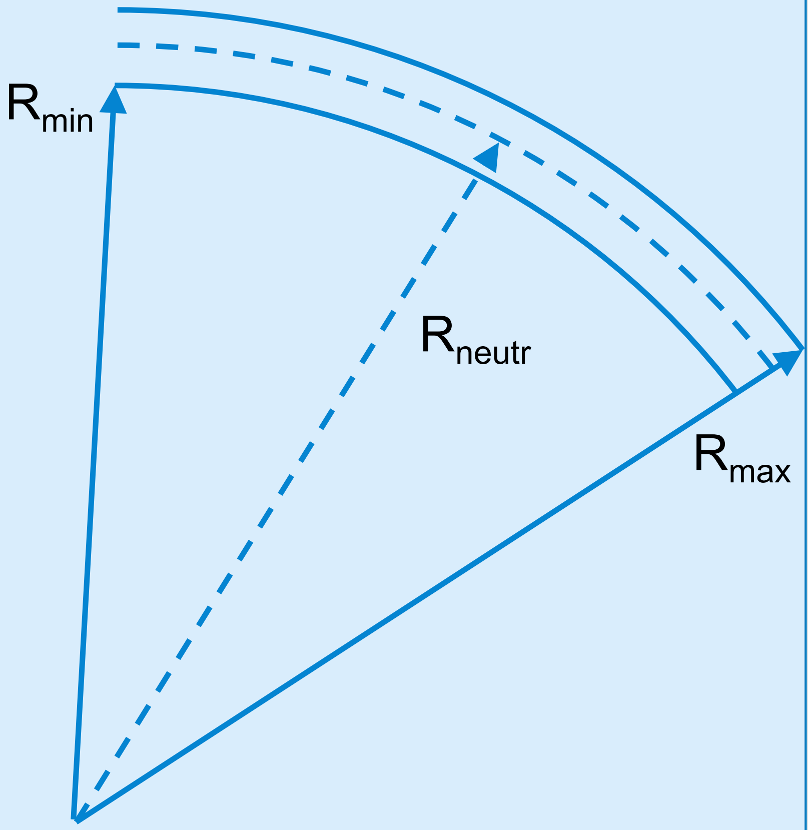
sample size > 1 cm3 ➔ 100 mm3

Focusing properties

mosaic crystal



gradient crystal



common centre of curvature

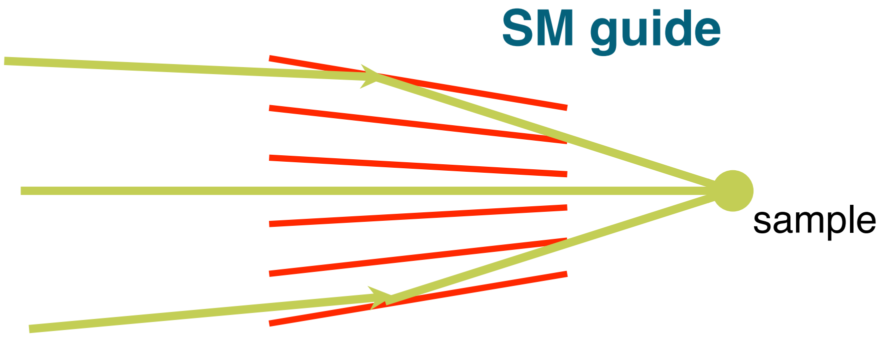
= common focal point

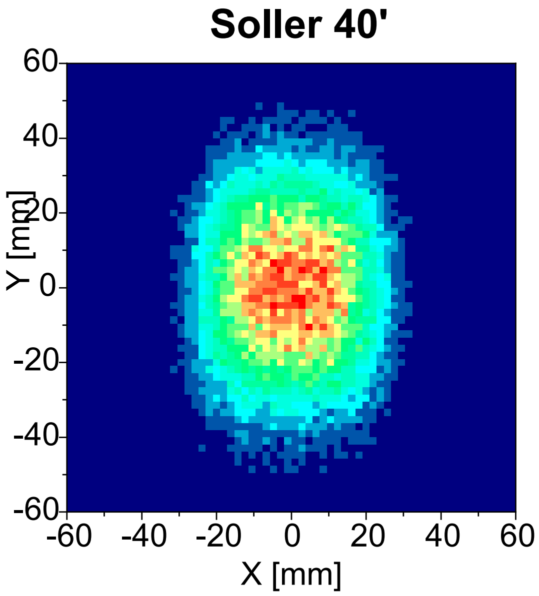
Kulda & Saroun, Nucl. Inst. Meth. A379 (1996) 155

SM microfocusing

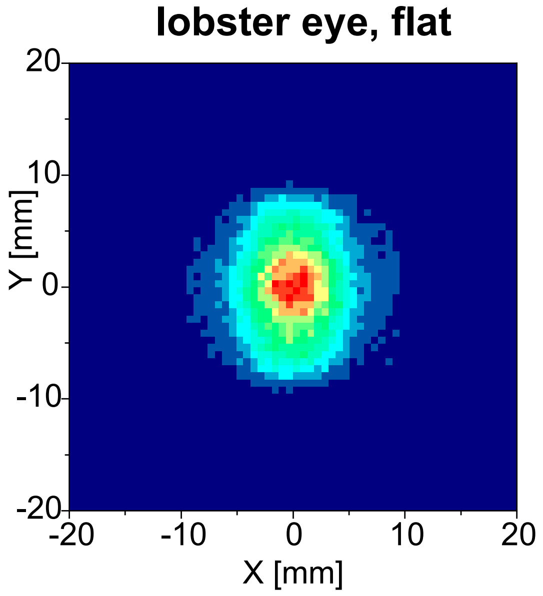
2D lobster eye optics:

- PG 002, *k*=1.55A^{-1}
- supermirror *m*=3
- 11 x 15 slits (HxV)
- length = 300 mm
- sample distance = 300 mm



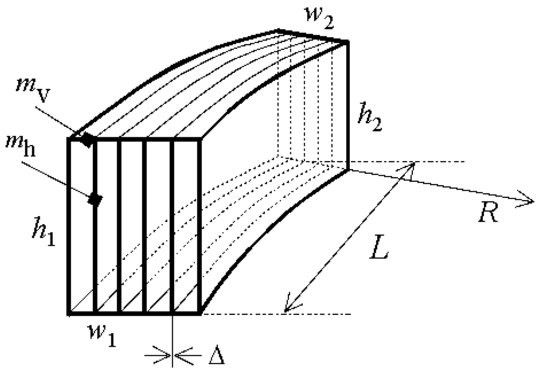


Φ = 0.9·10^6 / mm^2



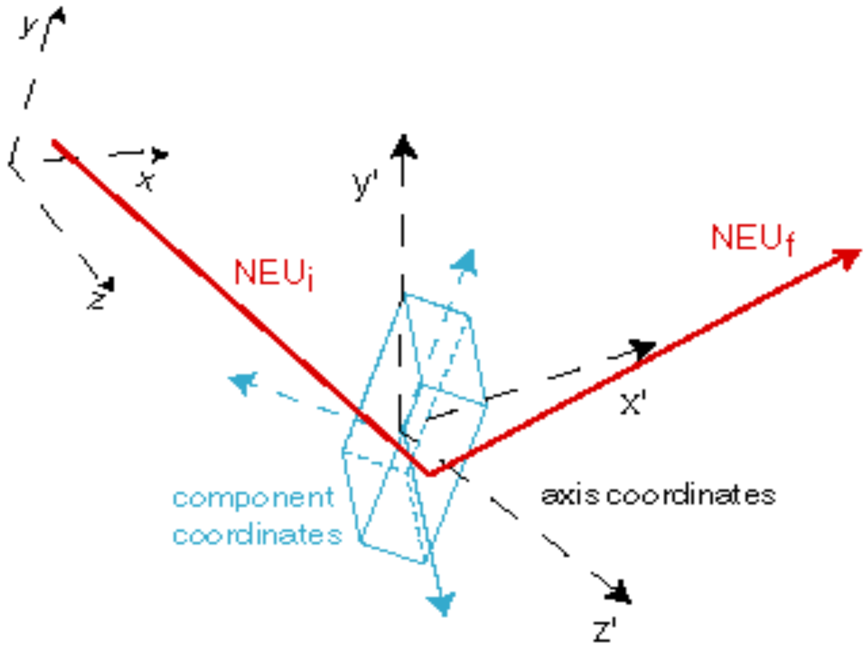
Φ = 9.5·10^6 / mm^2

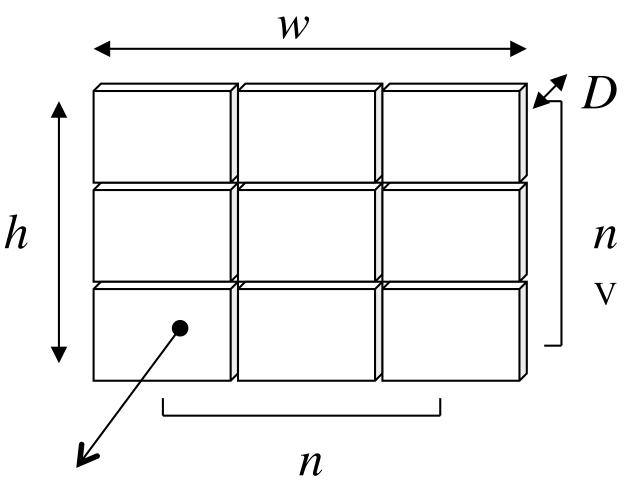
RESTRAX



- neutron ray-tracing or multi-Gaussian convolution
- diffraction/reflection optics of neutron instruments
- realistic crystal description (mosaic, elastically bent)
- highly optimized F77/F95 code

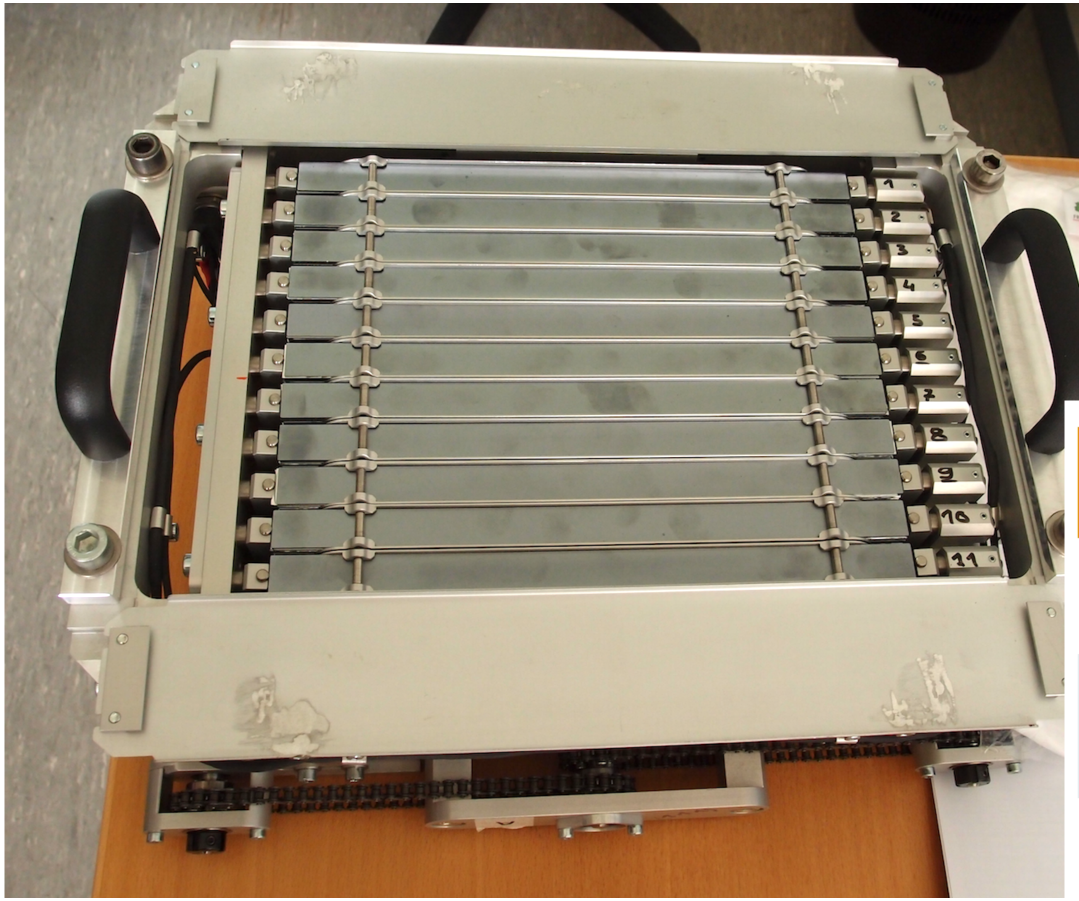
http://omega.ujf.cas.cz/restrax





$\eta_H,\ \eta_V,\ \chi,\ d^{\mathrm{H}}_{hkl},\ Q_{hkl},\ \mu,\ \ldots$

Si (111) vers. PG(002)



IN1, IN8, IN20, ThALES

Monochromator			
Crystal	**W x H (mm^2)**	**ki/$Å^{-1}$**	**flux/10^8 n $cm^{-2}s^{-1}$**
PG (002) double focusing, three faces	233x197	2.662 4.1	2.0 6.5
Cu (200) variable double-focusing, anisotropic mosaic (h:25', v:10')	233x197	4.1 7.0	4.6 3.0
Si (111) bent perfect crystals, fixed horiz. curvature optimized for k=3.5$Å^{-1}$	180x197	2.662 4.1	0.8 3.4

monochromatic flux ≈ 1/3 PG

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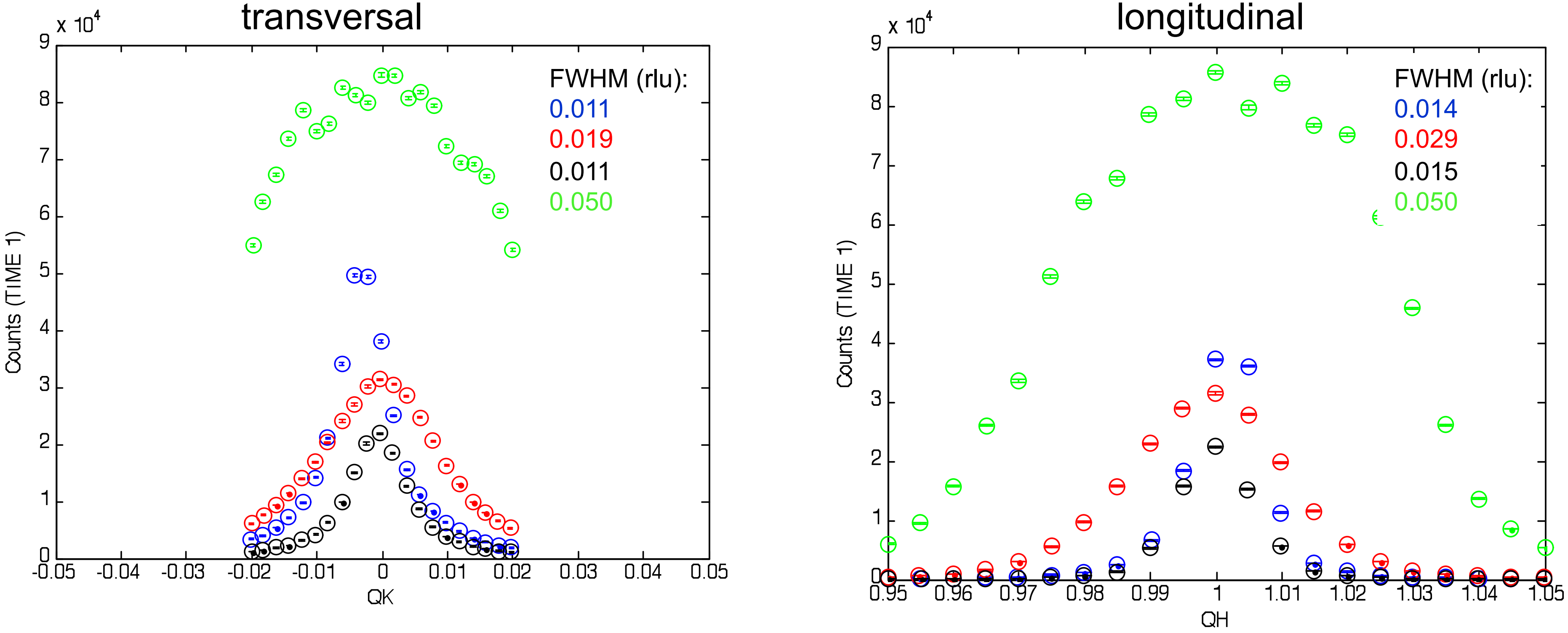
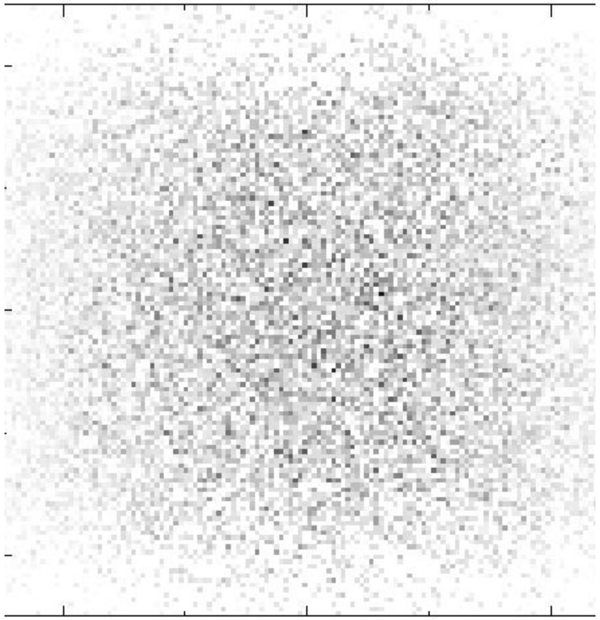
Si (111) vers. PG(002)

Bragg width (PMN 100)



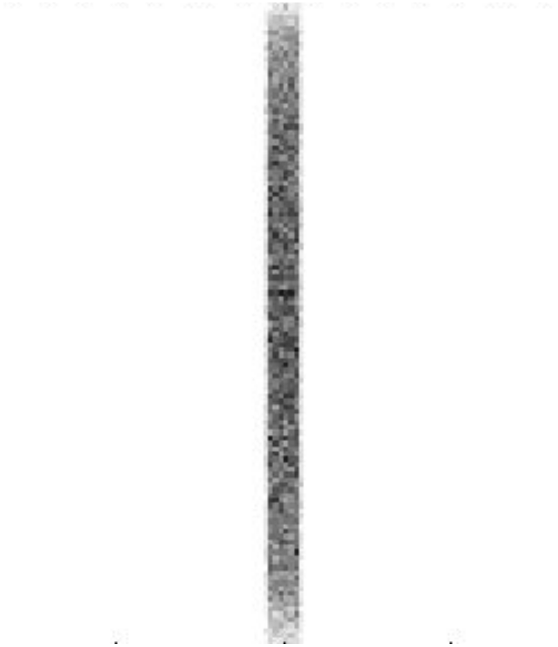
PG-PG	open	DTR 40
PG-PG	40’ – 40’	DTR 40
Si-Si	open	DTR 10
Si-Si	40’ – 40’	DTR 40

Microfocusing crystal optics



PG002 horizontal focus
(RESTRAX ray-tracing)

Paris-Edinburgh
High pressure cell



Si111 horizontal focus
(RESTRAX ray-tracing)

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High pressures

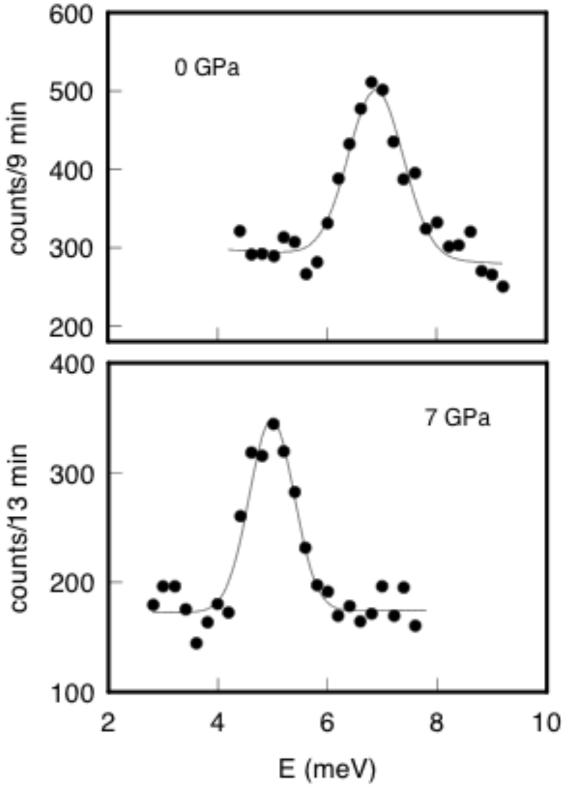
Paris-Edinburgh cell

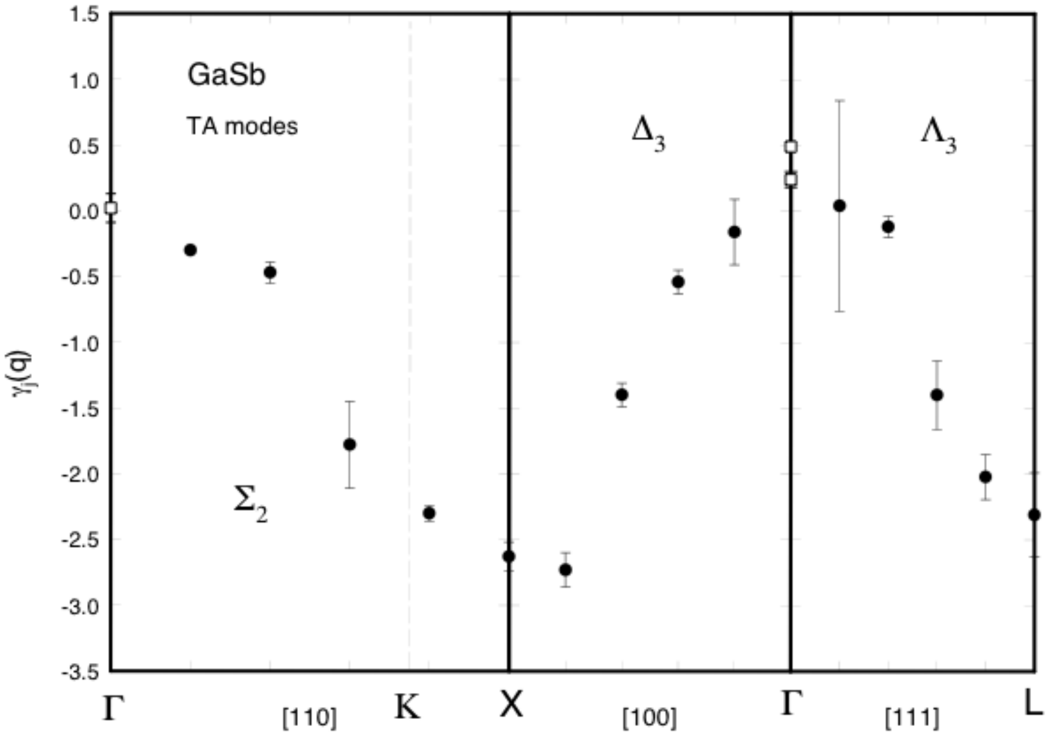
ILL version

- pressure < 8 GPa
- temperatures > 4 K
- sample volume < 40 mm^3

GaSb negative Grueneisen parameter

X-point TA phonon in GaSb at 0 and 7 GPa



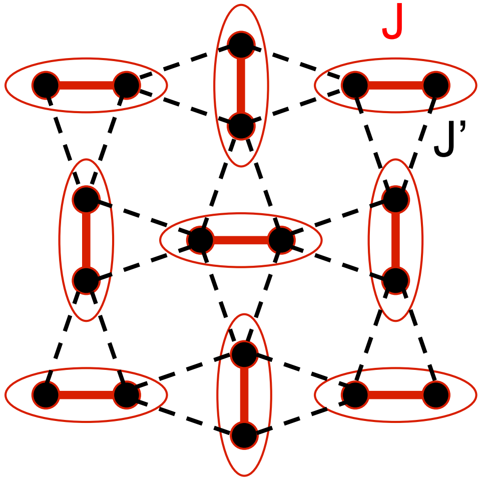


S.Klotz, M.Braden, J. Kulda, P.Pavone, B.Steininger
phys. stat. sol. (b) 223 (2001) 441

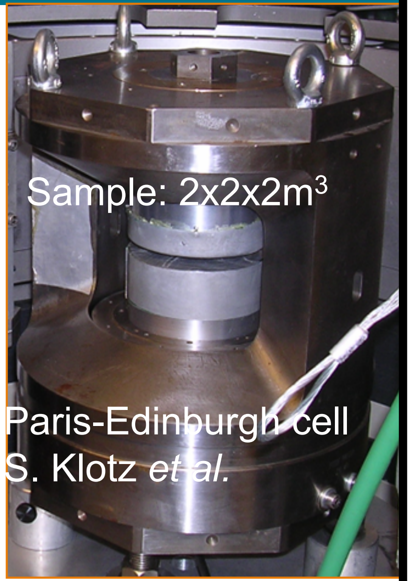
High-pressure Studies of Quantum Magnets

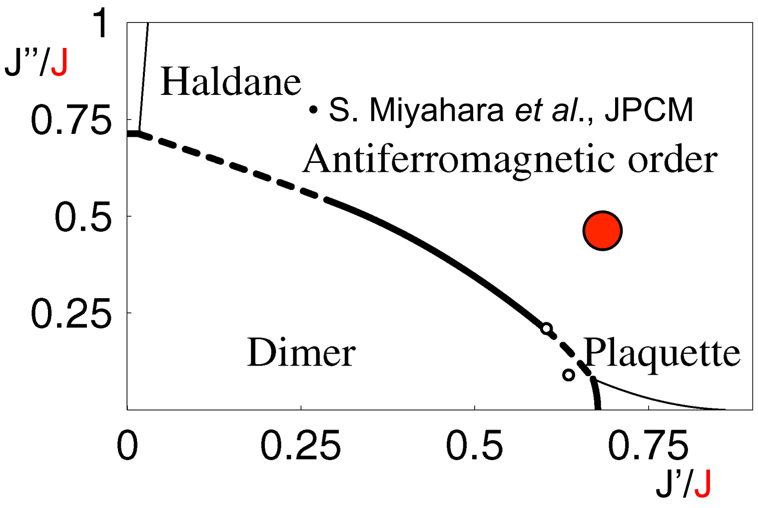
Shastry-Sutherland compound $SrCu_2(BO_3)_2$

- pressure-control of exchange interactions
- INS measurements of elementary excitations
- magnetic and structural phase transitions

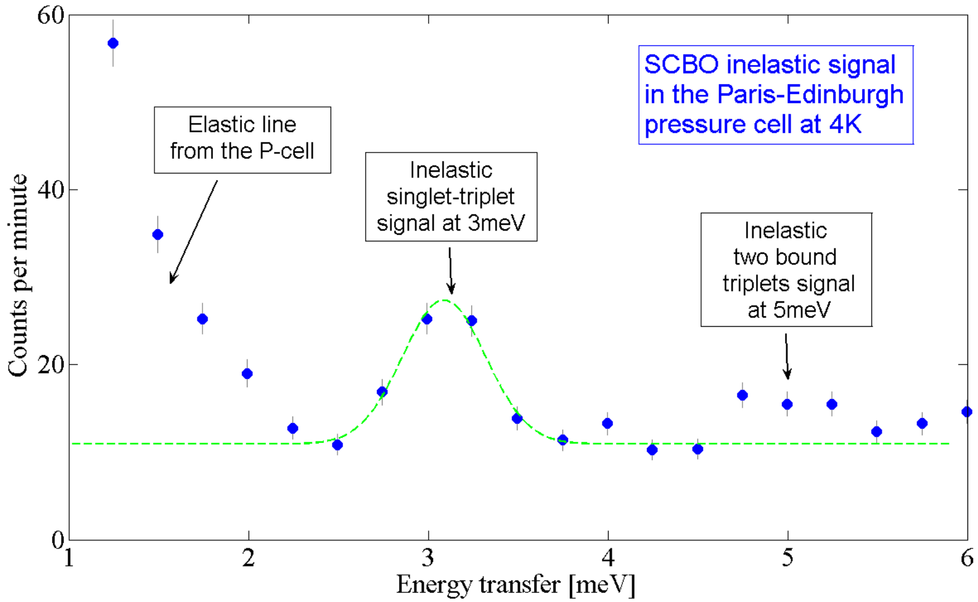


S=1/2 $SrCu_2(BO_3)_2$





• S. Miyahara *et al.*, JPCM



SCBO inelastic signal in the Paris-Edinburgh pressure cell at 4K

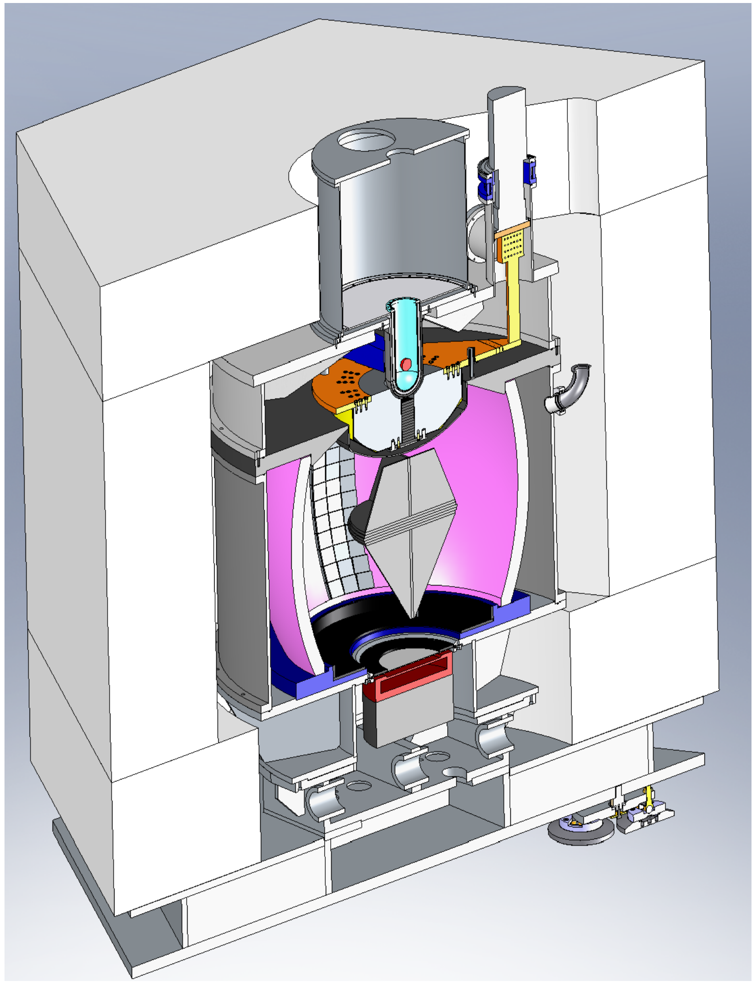
Elastic line from the P-cell

Inelastic singlet-triplet signal at 3meV

Inelastic two bound triplets signal at 5meV

M. Zayed, H.M. Rønnow, EPF Lausanne
Ch. Rüegg, UCL
S. Klotz, G. Hamel, IMPMC Paris
K. Conder, Th. Strässle, PSI

Chemical spectroscopy



ILL/Spain co-funding

A. Ivanov et al., ILL 2009-2011

IN1 *LAGRANGE*

Be-filter/PG-analyzer

$\Delta E < 1000$ meV

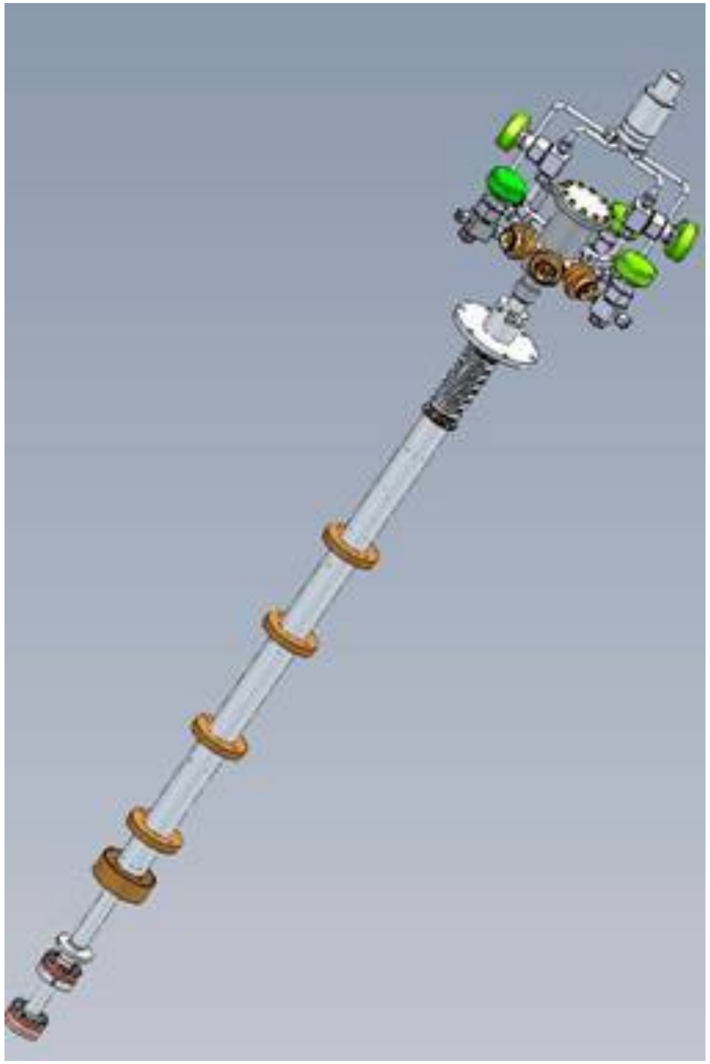
	BeF	Lagrange
solid angle [sr]	**0.06**	**2.5***
ΔE [meV]	**3**	**0.75**
transmission	**0.7**	**0.5**
background	**1**	**1/30 – 1/10**

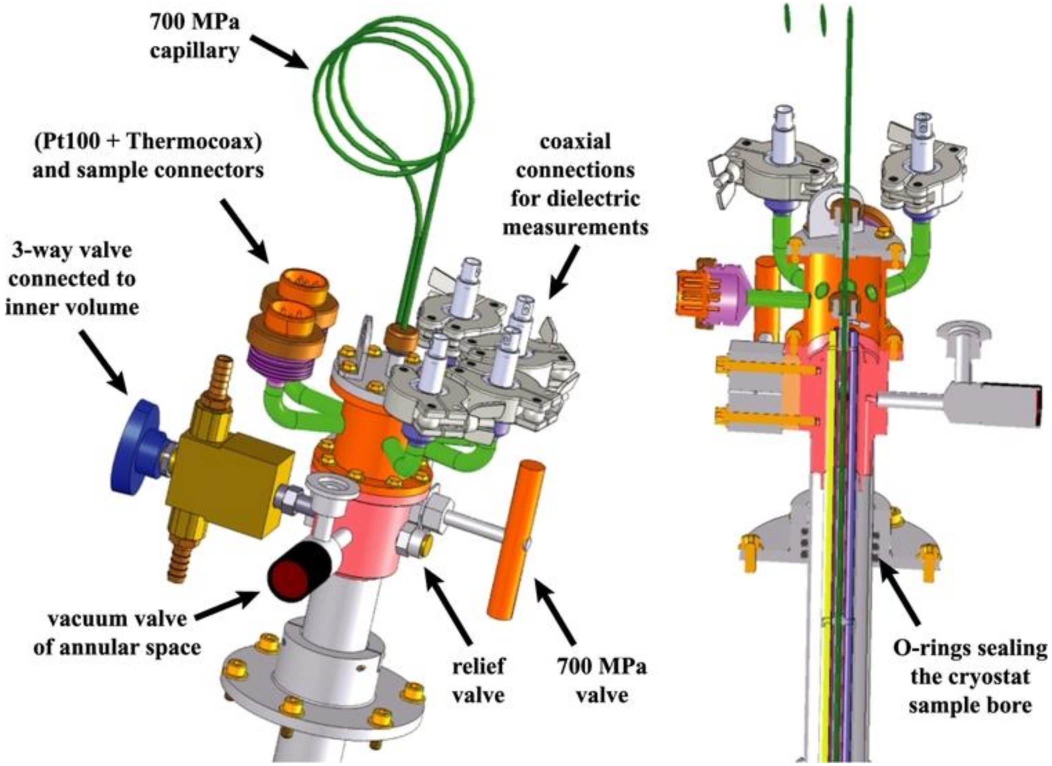
*) IN5 ≈ 1.8 sr

Samples down to
10 μg H
10 mg C

^{1}H : $\sigma_{\text{inc}} \approx$ 80 barn

Gas handling





gas sorption Lagrange

- pressure 80 (< 700) bar
- temperatures 1.5 – 550 K
- sample space ø 49 mm & 70 mm

Layout of the talk

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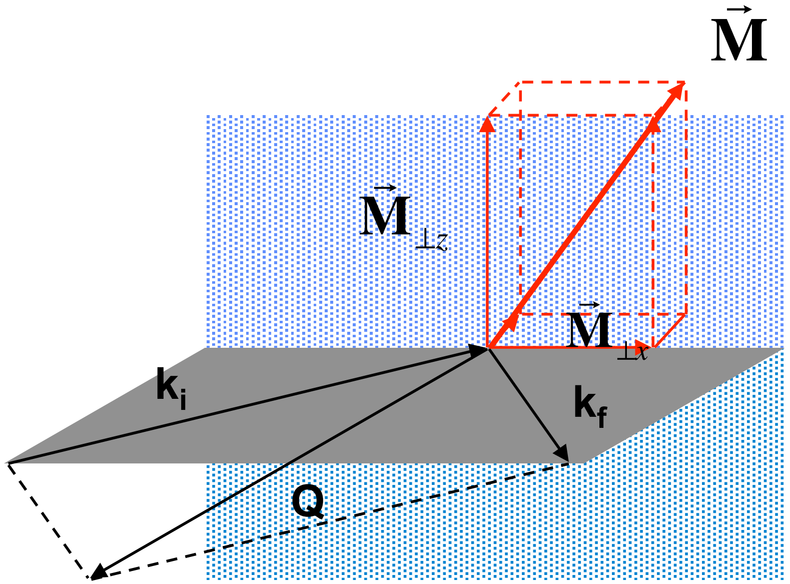
Magnetic scattering

$$\vec{M}(\vec{Q}) = \sum_j \vec{M}_j(Q)\exp(i\vec{Q}\vec{r}_j)\exp(-W_j)$$

- only projection of **M⊥Q** contributes

$$\vec{M}_\perp(\vec{Q}) = \vec{e}_Q \times \vec{M}(\vec{Q}) \times \vec{e}_Q$$



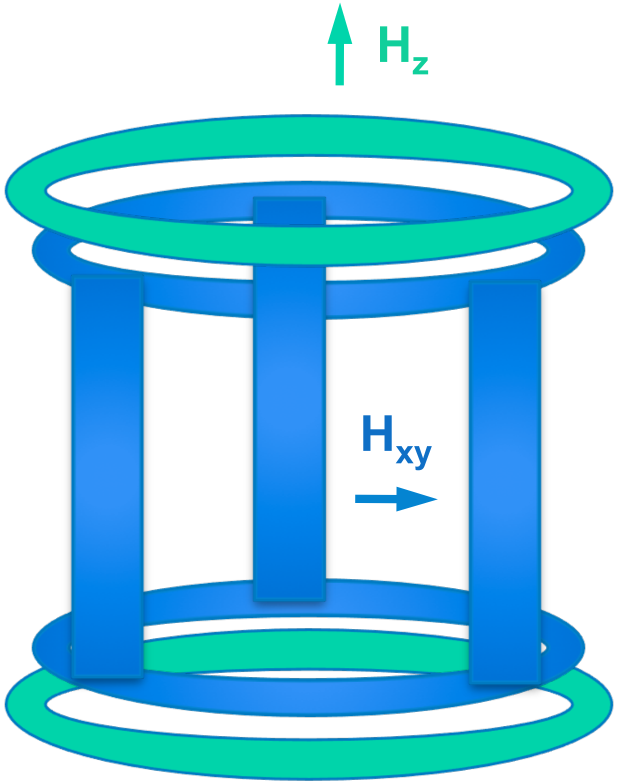
"Moon's golden rule":

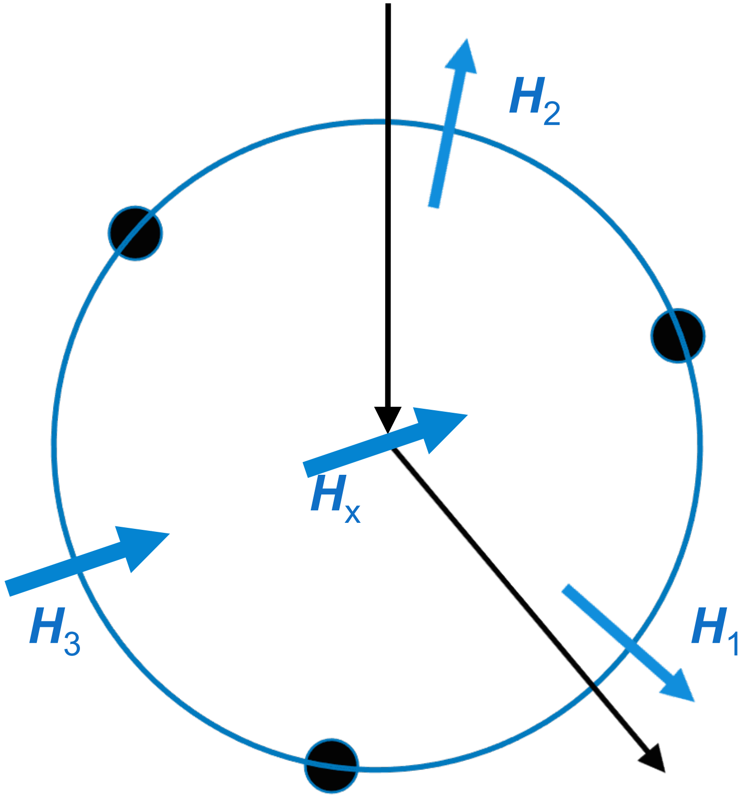
$\vec{M}_\perp \parallel \vec{\sigma}_n$ non spin-flip (NSF) U^{++}, U^{--}

$\vec{M}_\perp \perp \vec{\sigma}_n$ spin-flip (SF) U^{+-}, U^{-+}

3D diagonal polarisation analysis

Triple-dutch & Helmholtz coils

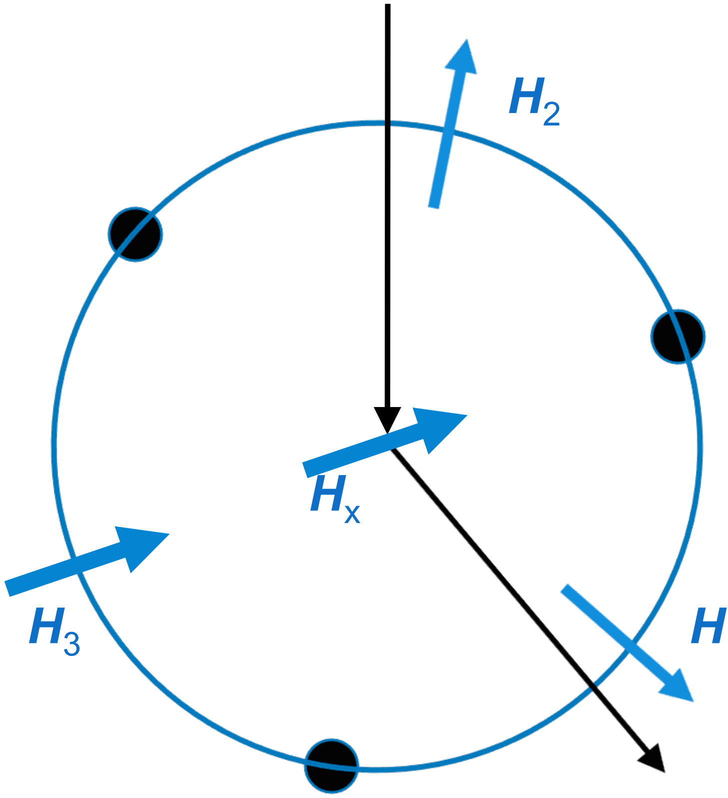


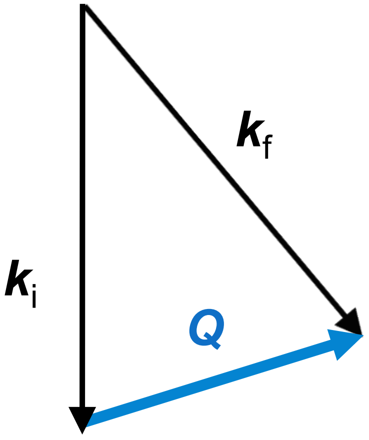


compose guiding field
in any direction in 3D

3D diagonal polarisation analysis

Elastic scattering

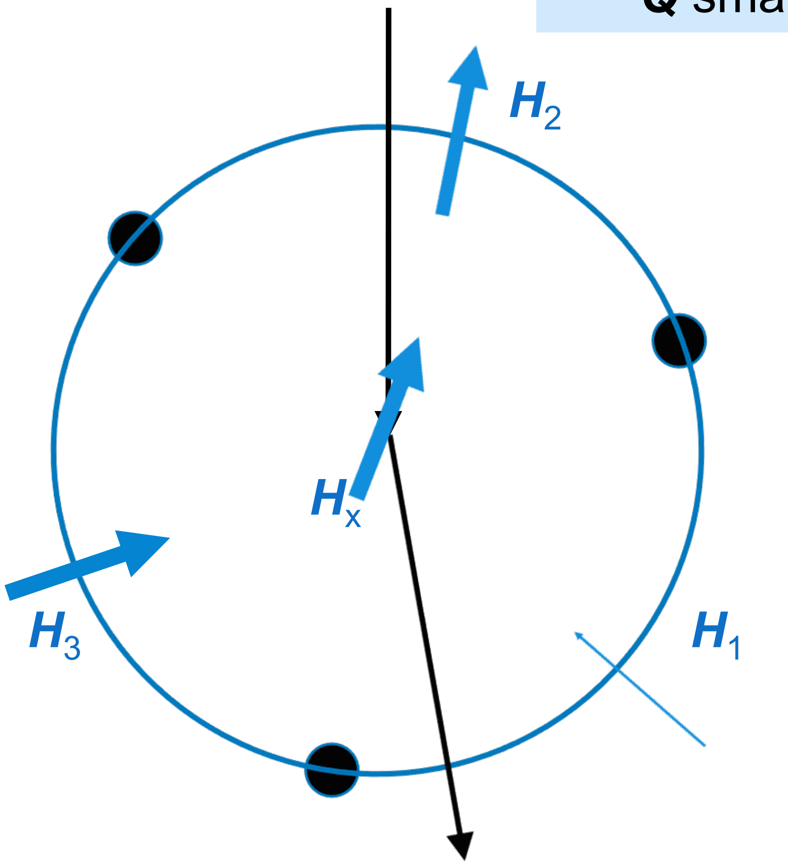


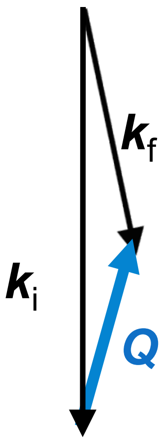


easy current distribution optimisation

3D diagonal polarisation analysis

Deep inelastic scattering
$\boldsymbol{Q}$ small, ΔE large





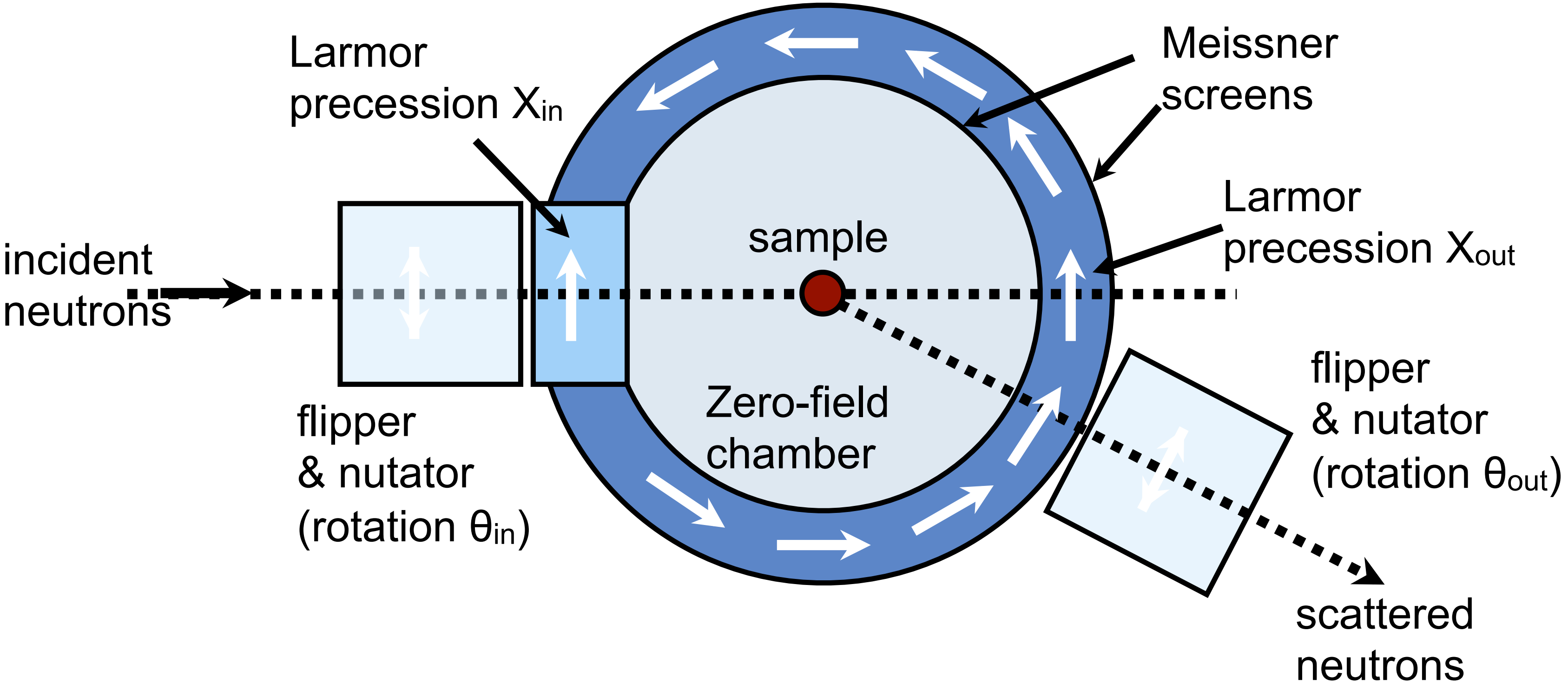
patological current distributions

- small or missing fields
- anomalies close to pilars

>> use zero-field environment

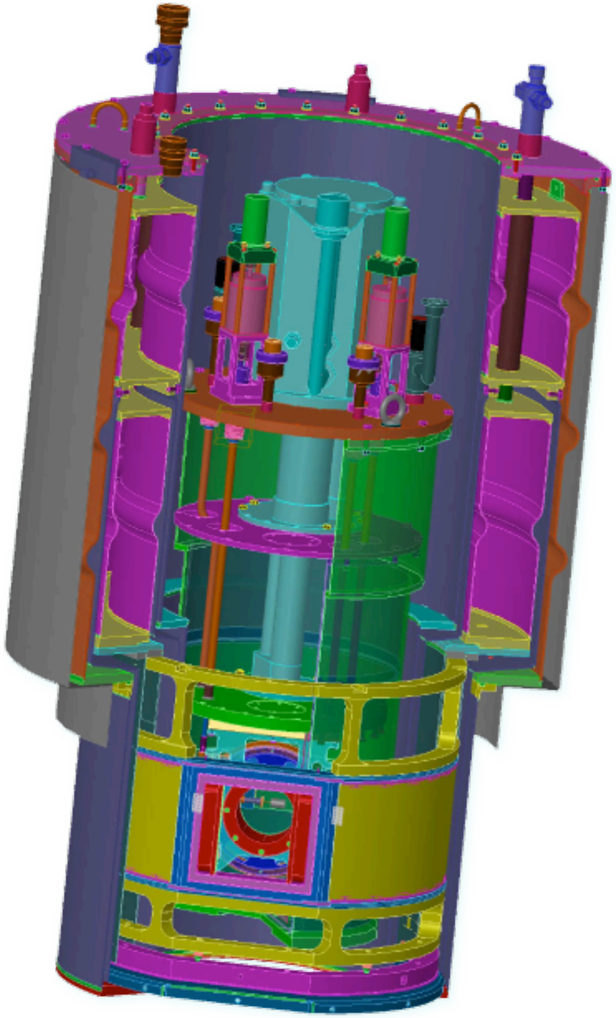
CRYOPAD scheme

CRYOPAD II



F. Tasset et al., Physica B 267}268 (1999) 69

CRYOPAD design



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Specifications

- 10T for reasonable cost, reliability
- dilution fridge insert (obviously)
- ease of use

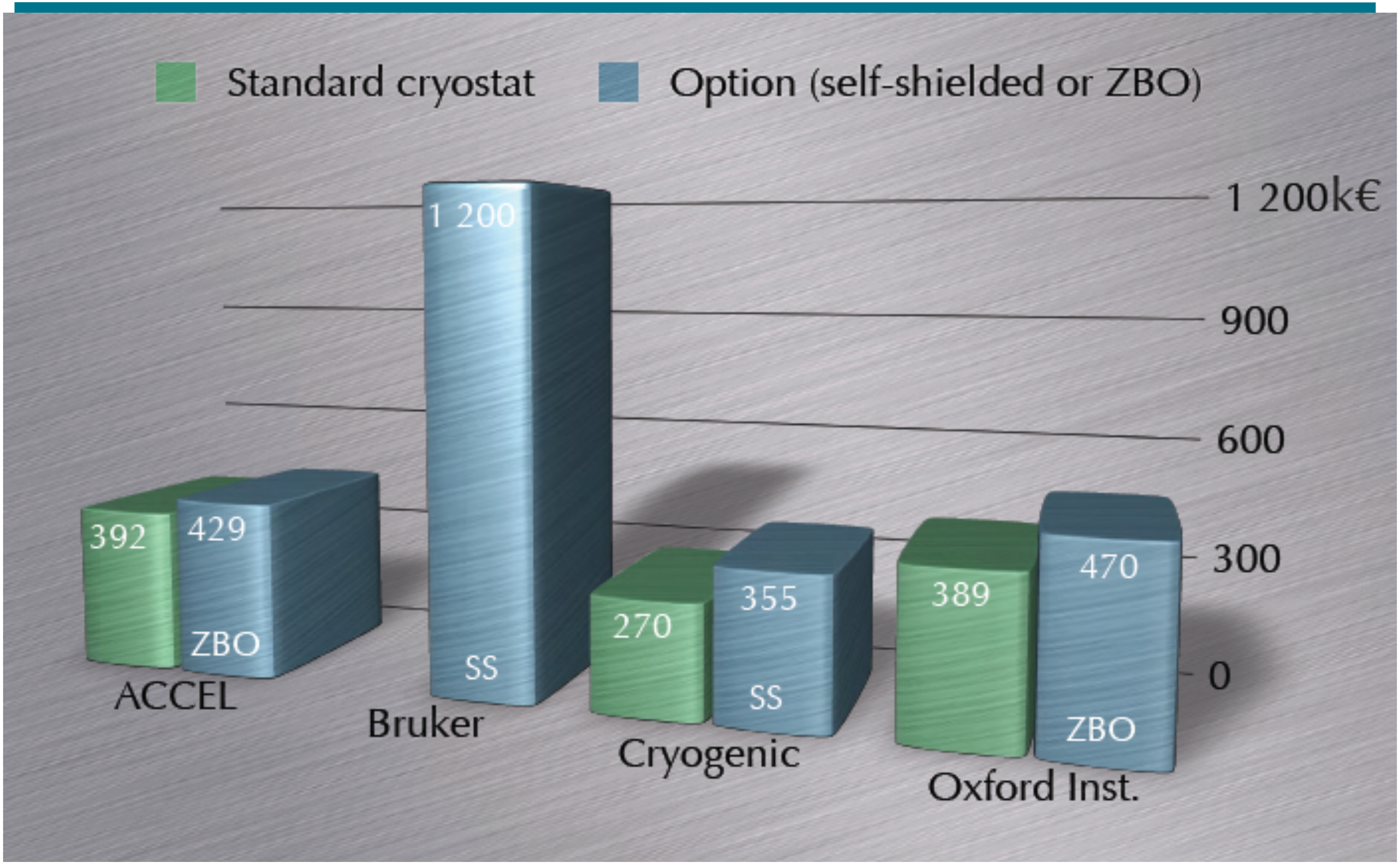
  zero-boil-off: we save 25k€ LHe per year, simplify the use
  cost doubles? NOT! +20%
  Reliability? reservoir system reasonable (moving, quenching ..)
  BUT: prototype! time scale? other risks? life time?

- with or without self-shielded option

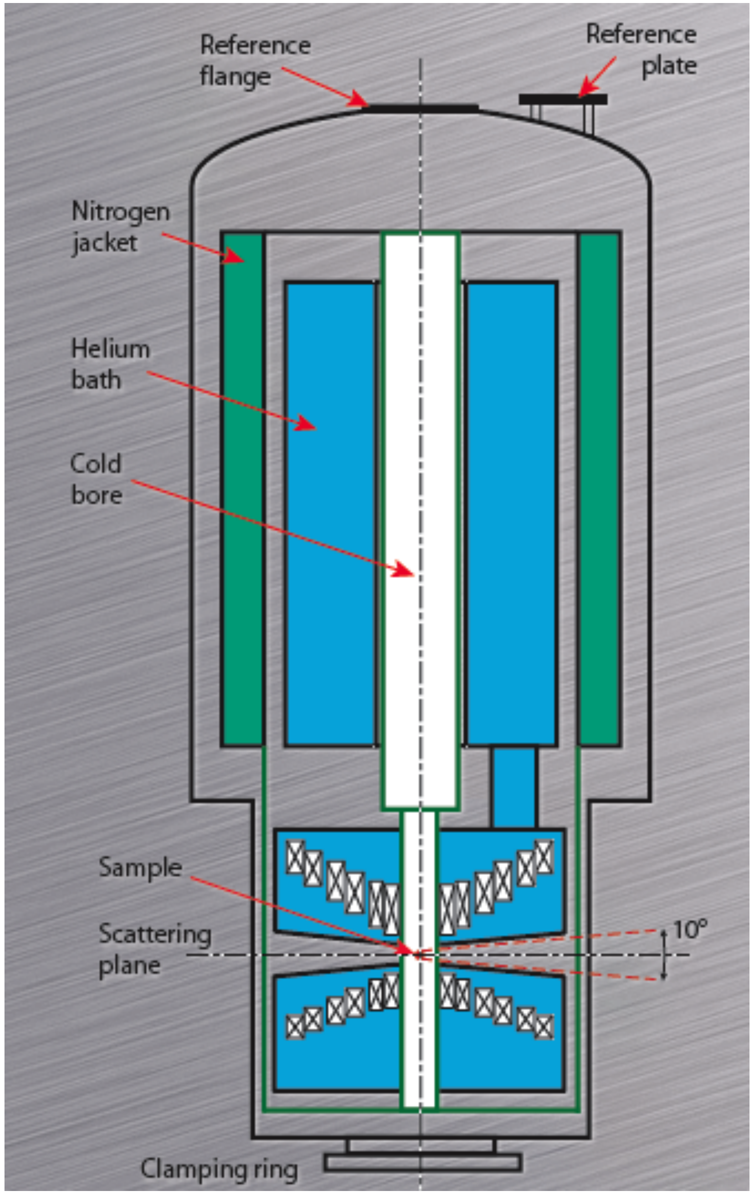
  stray field is reduced by a factor ≈50
  BUT the cost doubles, diameter & weight increases
  WAIT FOR FUTURE

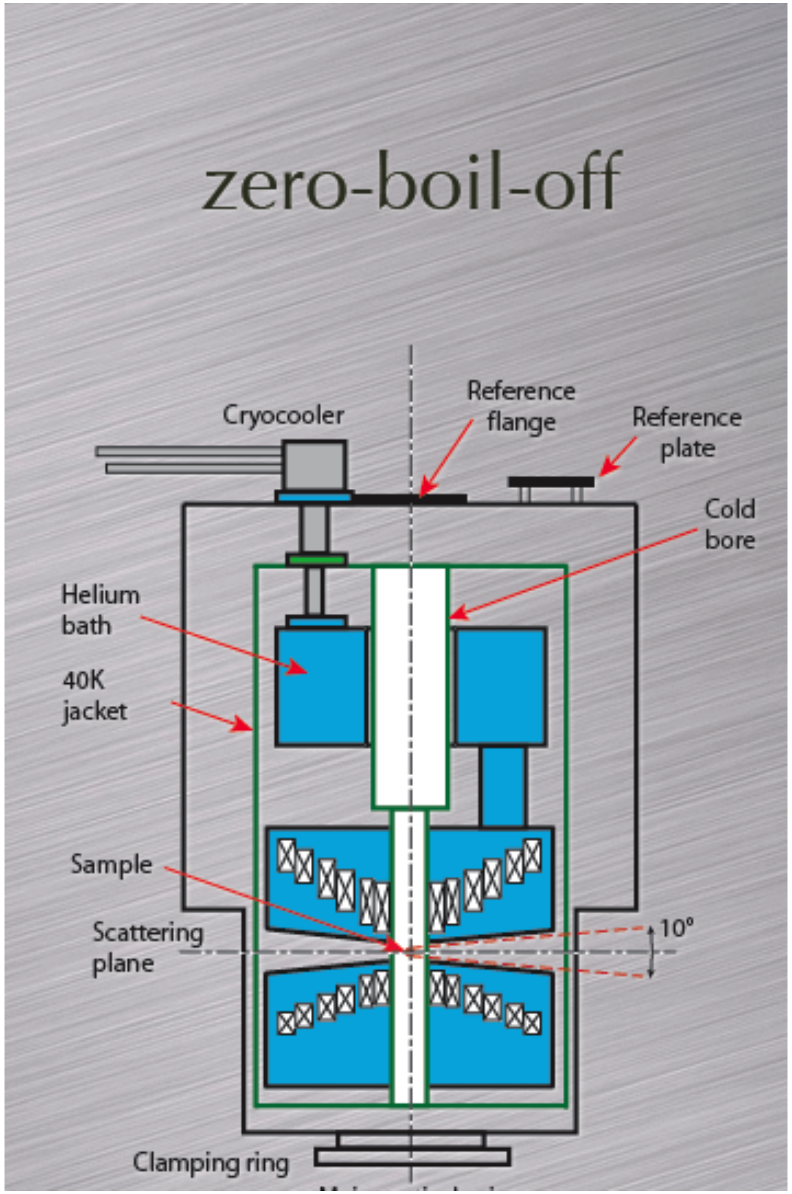
- asymmetric field for polarised neutron beams
- large samples (10mm width, 30mm height)
- large horizontal access: Al rings *vers.* pillars

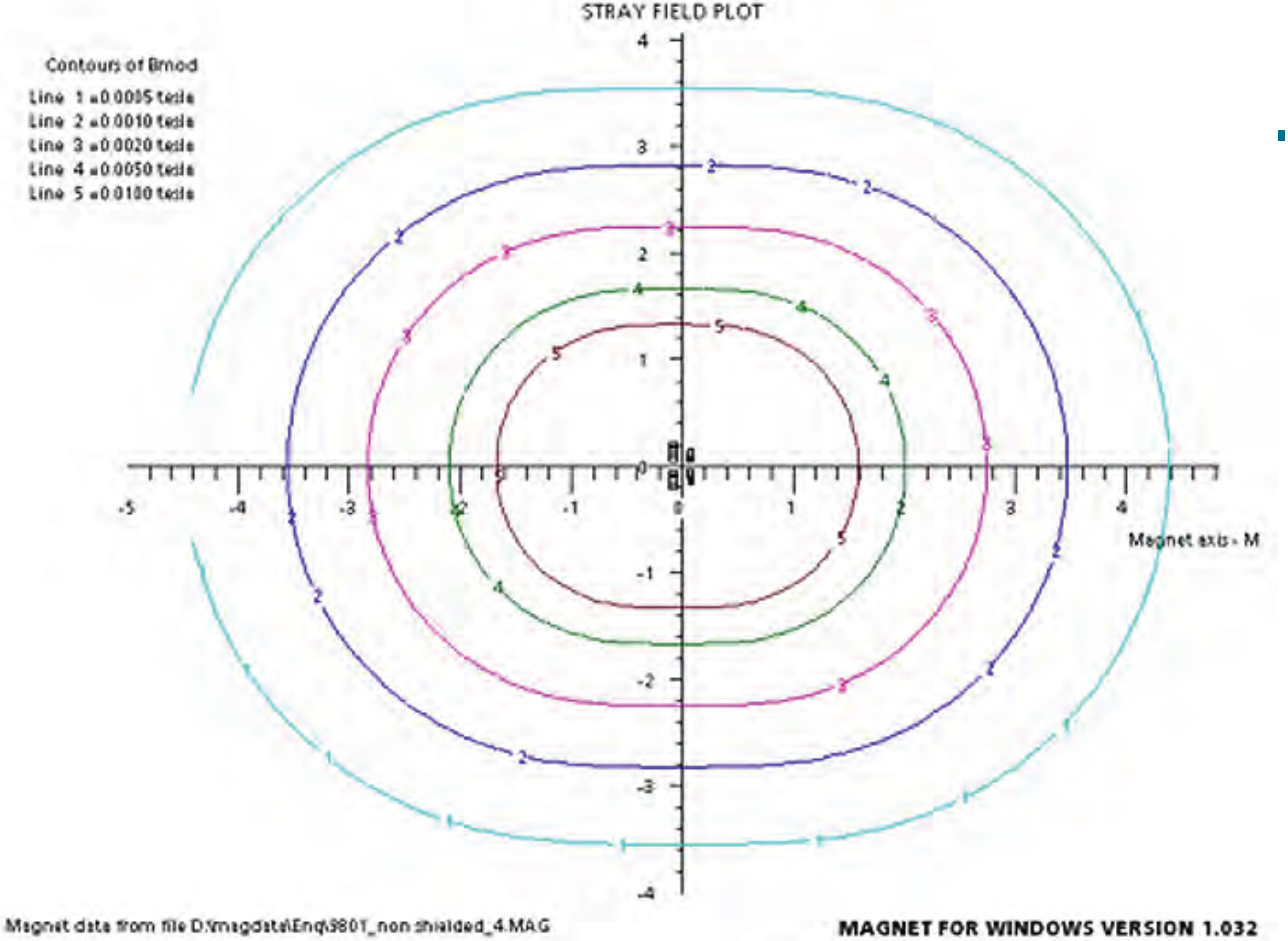
Price tags

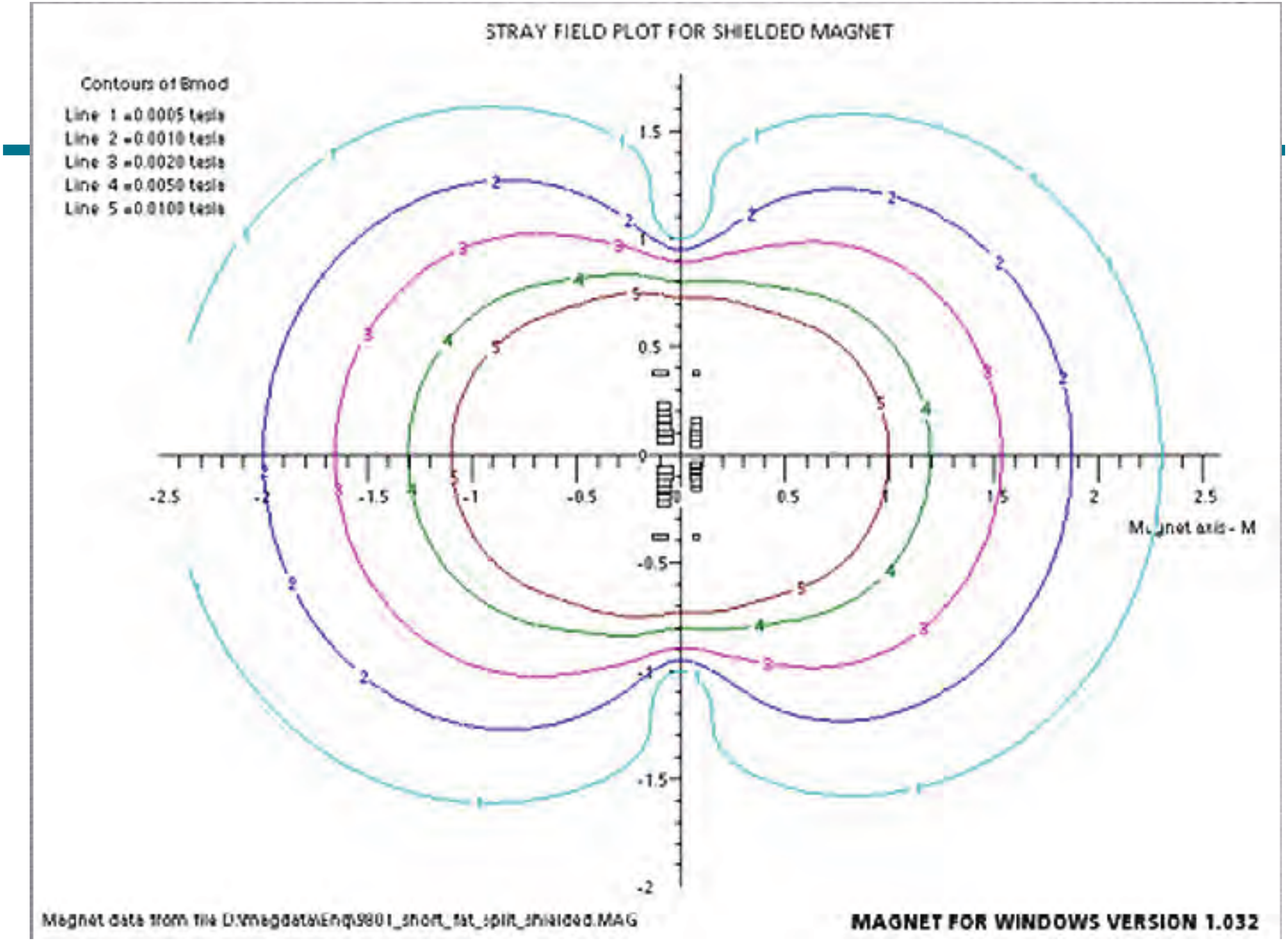

Standard cryostat
Option (self-shielded or ZBO)
1 200k€
900
600
300
0
392
429
ZBO
ACCEL
1 200
SS
Bruker
270
355
SS
Cryogenic
389
470
ZBO
Oxford Inst.

Cryogenics

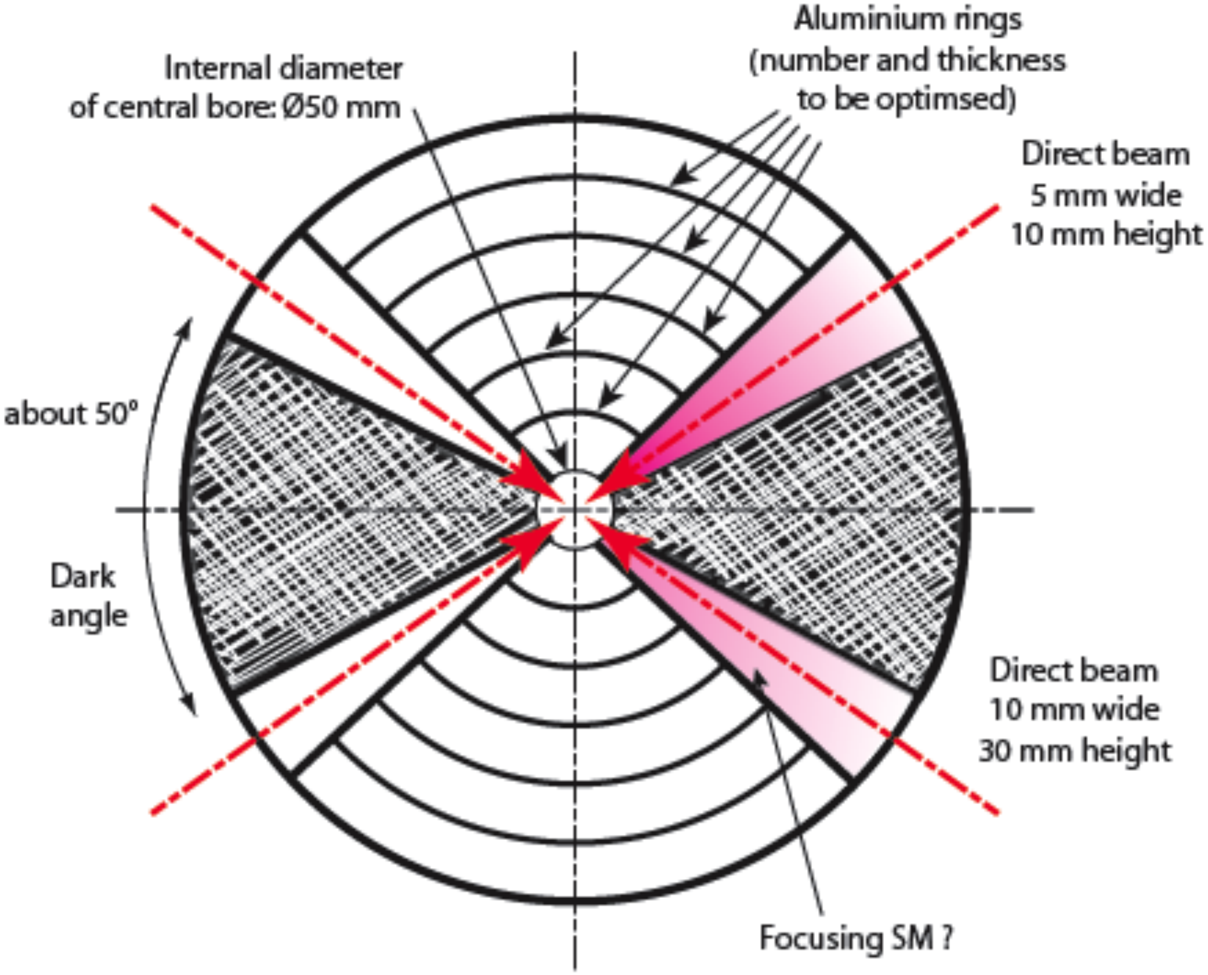

Reference flange
Reference plate
Nitrogen jacket
Helium bath
Cold bore
Sample
Scattering plane
10°
Clamping ring


zero-boil-off
Cryocooler
Reference flange
Reference plate
Cold bore
Helium bath
40K jacket
Sample
Scattering plane
10°
Clamping ring


STRAY FIELD PLOT
Contours of Bmod
Line 1 = 0.0005 tesla
Line 2 = 0.0010 tesla
Line 3 = 0.0020 tesla
Line 4 = 0.0050 tesla
Line 5 = 0.0100 tesla
4
3
2
1
0
-1
-2
-3
-4
-5
-4
-3
-2
-1
0
1
2
3
4
Magnet axis - M
Magnet data from file D:\magdata\Enq\9801_non shielded_4.MAG
MAGNET FOR WINDOWS VERSION 1.032


STRAY FIELD PLOT FOR SHIELDED MAGNET
Contours of Bmod
Line 1 = 0.0005 tesla
Line 2 = 0.0010 tesla
Line 3 = 0.0020 tesla
Line 4 = 0.0050 tesla
Line 5 = 0.0100 tesla
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
Magnet axis - M
1
2
3
4
5
Magnet data from file D:\Magdata\Eng\9801_short_fat_split_shielded.MAG
MAGNET FOR WINDOWS VERSION 1.032

Beam layout



Here is a design with two pillars [*]. In this case, one could reduce the thickness of the Al rings. The question is to determine how much. I guess that to a first approximation it is proportional to the relative proportion of angle covered. The gain might be of the order of 20%–30% maximum.

The problem I see is the implementation of the supermirrors. As they would be installed inside the cryomagnet, they cannot be removed between experiments or cycles. They would be in the direct beam, leading to a production of background. On the other hand, they might help you increase the flux when using small samples.

[*] On this sketch, the pillars are not well drawn and might cut the incident beam. This sketch is for helping discussions only

10T recondensation magnet

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Ultra-high magnetic fields > 20 T

Scientific case

- normal state of high-Tc superconductors
- quantum limit of certain metals
- nature of hidden order in URu_2Si_2
- static and dynamic correlations in true Bose-Einstein condensates
- spin supersolidity
- nature of correlations at and in between the plateau phases of the two-dimensional Shastry-Sutherland lattice $SrCu_2(BO_3)_2$
- static and dynamic correlations in quadrupolar spin-nematic Luttinger liquids
- origin of electric polarisation changes at 20-30 T in certain multiferroics
- evolution of magnetic order near charge order melting in $Na_{0.5}CoO_2$ near 30 T.

HIFI – ***HI***gh-***FI***eld Diffraction/Spectroscopy

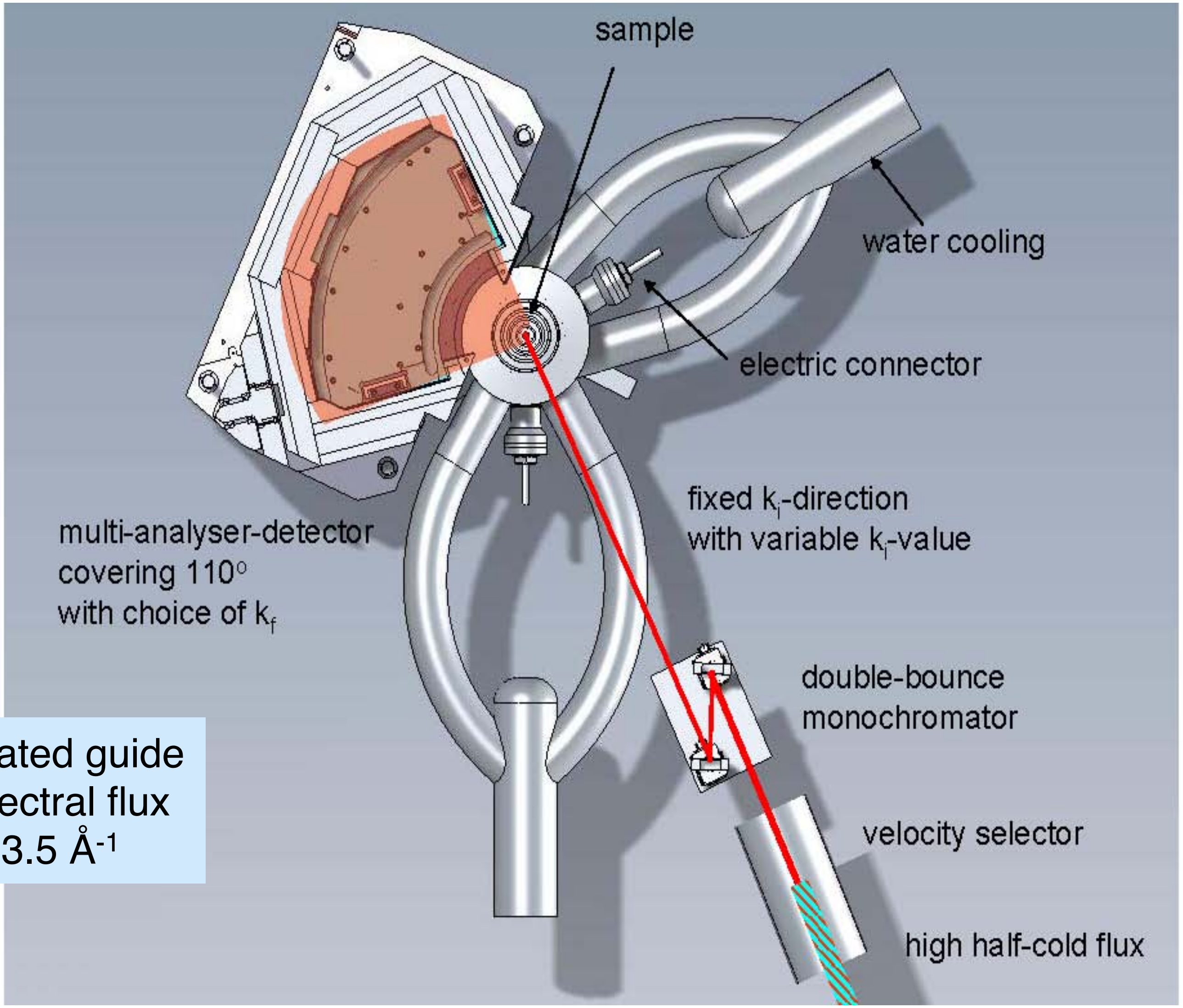
ILL/ESRF high-field installation

B ≈ 30-35 T

P_{el} ≈ 40 MW

power plant cost
≈ 10 - 15 M€

electricity cost
≈ 10 M€/yr



ILL7 dedicated guide
high bi-spectral flux
k_i =1.1-3.5 Å^{-1}

UHF magnet Oxford Instruments

New era in high field superconducting magnets – opening new frontiers in science, nanotechnology and materials discovery

08 January 2018

Oxford Instruments is delighted to congratulate our partners at the National High Magnetic Field Laboratory (NHMFL) on the successful demonstration of a 32 Tesla all-superconducting user magnet on 8th of December 2017. Achieving this major milestone is a step change in high field, compact magnets and important for research into new science and materials discovery. It enhances our understanding and knowledge of superconducting and nanomaterials, leading to new nano-devices and applications.

The 32 T superconducting system is made from two primary sections, an outsert section delivering 15 Tesla in a 250 mm wide bore magnet developed by Oxford Instruments Nanoscience (OINS) using advanced Low Temperature Superconductor (LTS) materials operating at 4.2 Kelvin and an insert section delivering 17 Tesla in 34 mm cold bore developed by our colleagues at NHMFL using advanced High Temperature Superconductor (HTS) materials manufactured by Superpower Inc. Both sections were integrated by NHMFL team in a cryogenic system developed by OINS.

32 T solenoid >> ≈ 22 - 25 T split coil (?)

key enabling technology: Bi-2212 round wire

Bi-2212 = $Bi_2Sr_2CaCu_2O_{8+x}$

OXFORD
INSTRUMENTS

size, weight & operation costs
≈ “normal” self-shielded cryomagnet

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Recommendations

Strategic decisions:

- unification of mechanical interfaces
- adapted beam optics
- cryogenic policy: **wet** *vers*. **dry**
- non-magnetic environment

& progressive procurement policy

NEUTRONS
FOR SOCIETY

NEUTRONS for Europe
USER MEETING
2018

ILL & ESS
European User Meeting
10-12 October 2018
Grenoble - France

See you in
DAYS
148

3
Days

6
Events

15
Keynote Speakers