NEUTRONS FOR SCIENCE

FlatCone

Mapping diffuse scattering in single crystals

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Acknowledgements

FlatCone:

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J. Saroun	NPI AS CR, Rez near Prague
P. Flores, S. Roux, S. Baudoin,C. Menthonex, F. Descamps, J. Locatelli, J.-P. Vernier,P. Thomas, F. Lapeyre, F. Horst	ILL
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D. Mrazek, B. Lukas	Polovodice, Prague
P. Steffens, M. Boehm, A. Hiess	ILL
D. Hohlwein	HMI Berlin
L.-P. Regnault	CEA Grenoble
H.-B. Braun	University College Dublin
J. Hlinka, S. Kamba, J. Petzelt	Inst. of Physics AS CR, Prague
A. Boothroyd, A. Lewtas	Oxford University

Plan of the talk

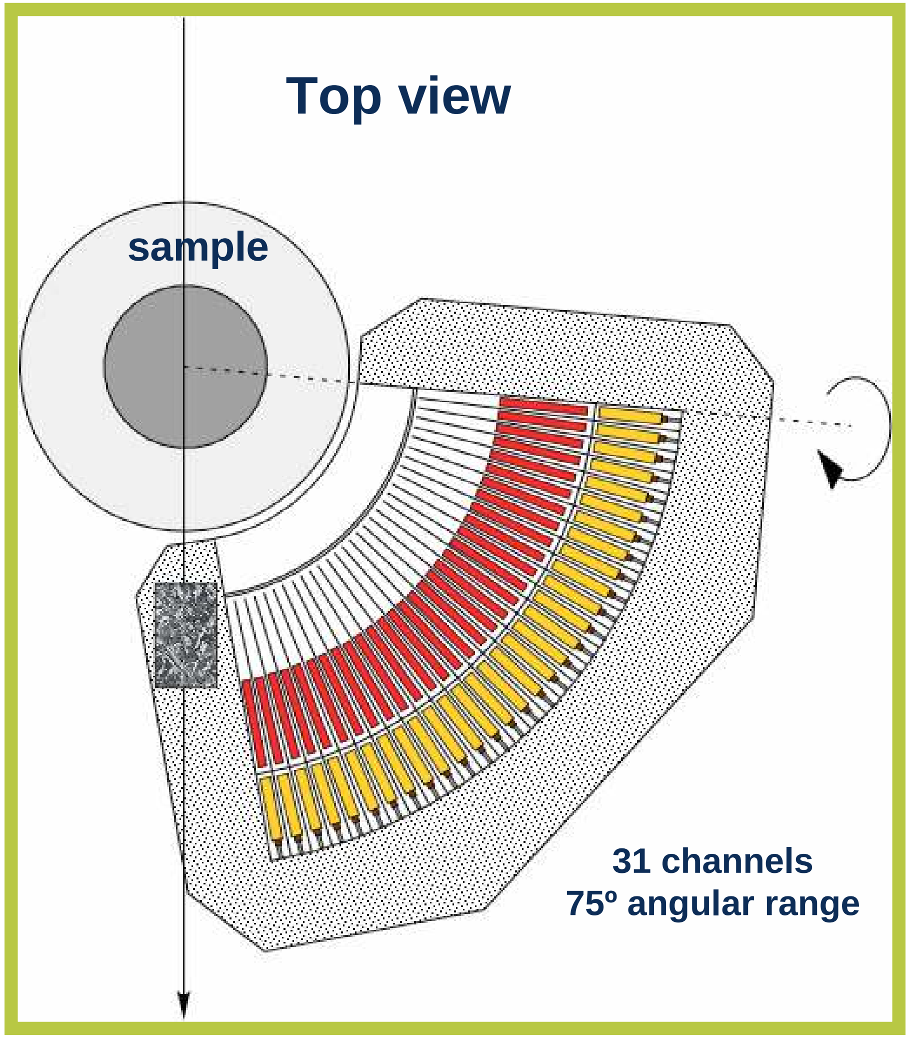
1. *FlatCone* concept and hardware
2. *FlatCone* software
3. Experimental data examples
4. Conclusions

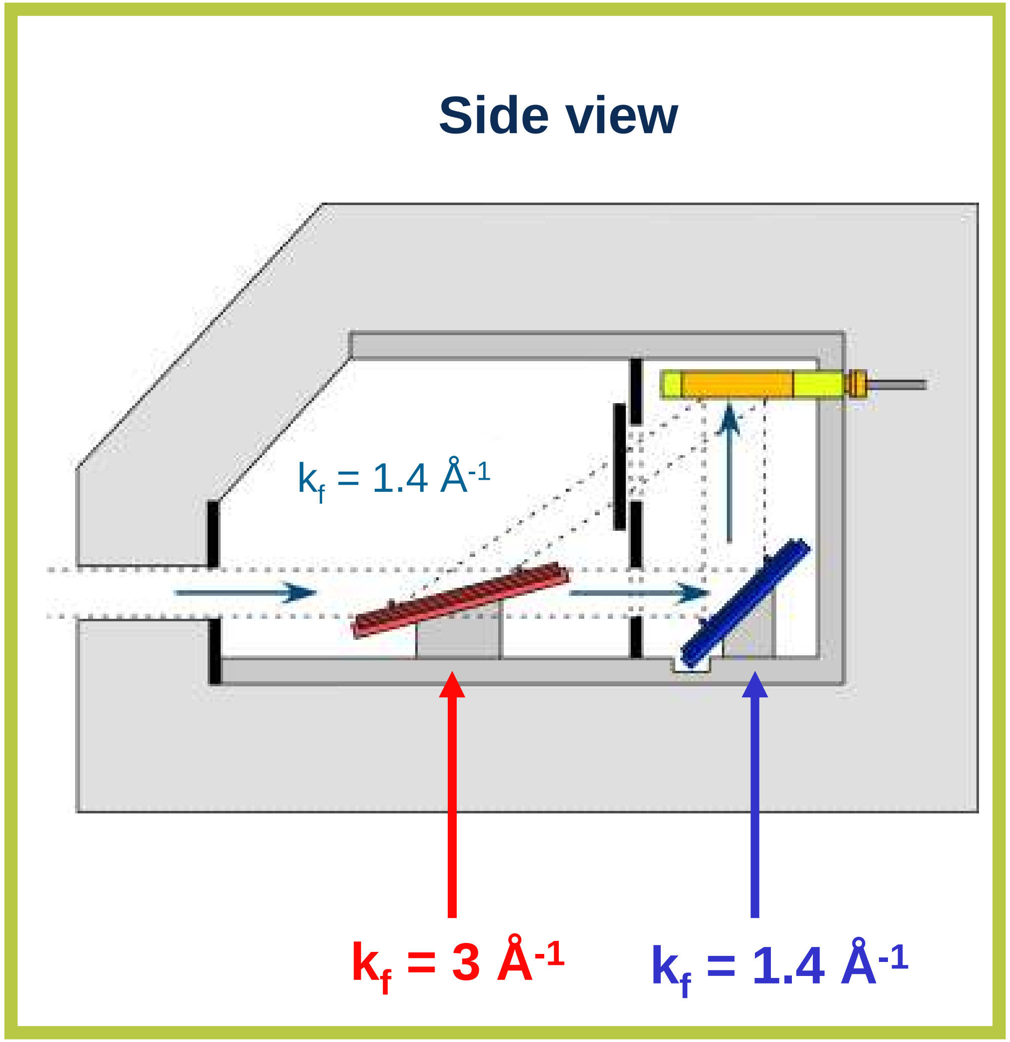
FlatCone multianalyzer

(ThirtyThree Axis Spectrometer)

• angular coverage	75 deg
• pixel width	1.3 deg
• no. of pixels	31
• SA distance	765 & 1000 mm
• analyzer crystals	Si 111
• cold neutrons	k_f = 1.4 Å^{-1}
	ΔE = 0 - 10 meV
• thermal neutrons	k_f = 3 Å^{-1}
	ΔE = 0 - 40 meV

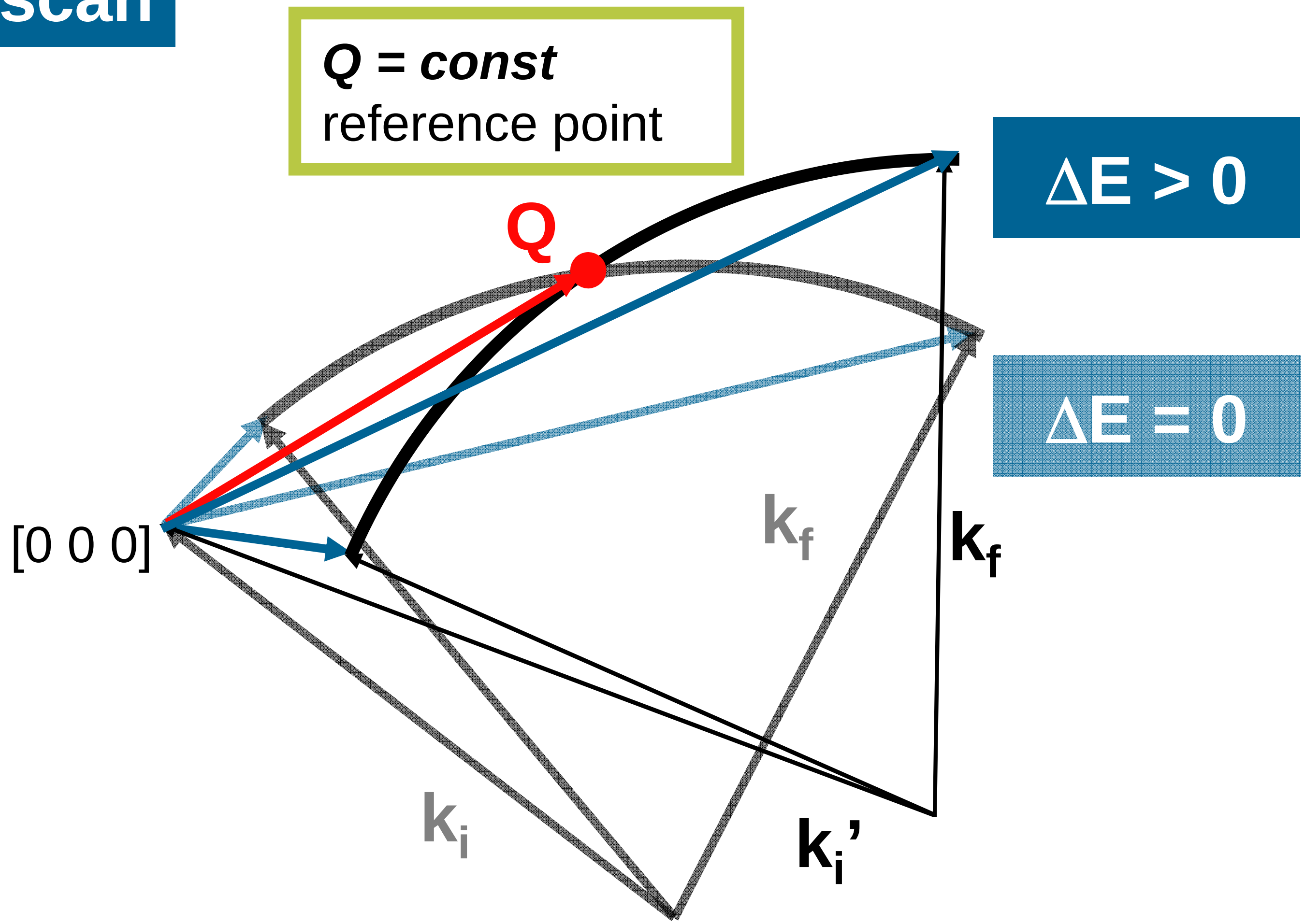
FlatCone (II)


Top view
sample
31 channels
75º angular range


Side view
k_f = 1.4 Å^{-1}
k_f = 3 Å^{-1}
k_f = 1.4 Å^{-1}

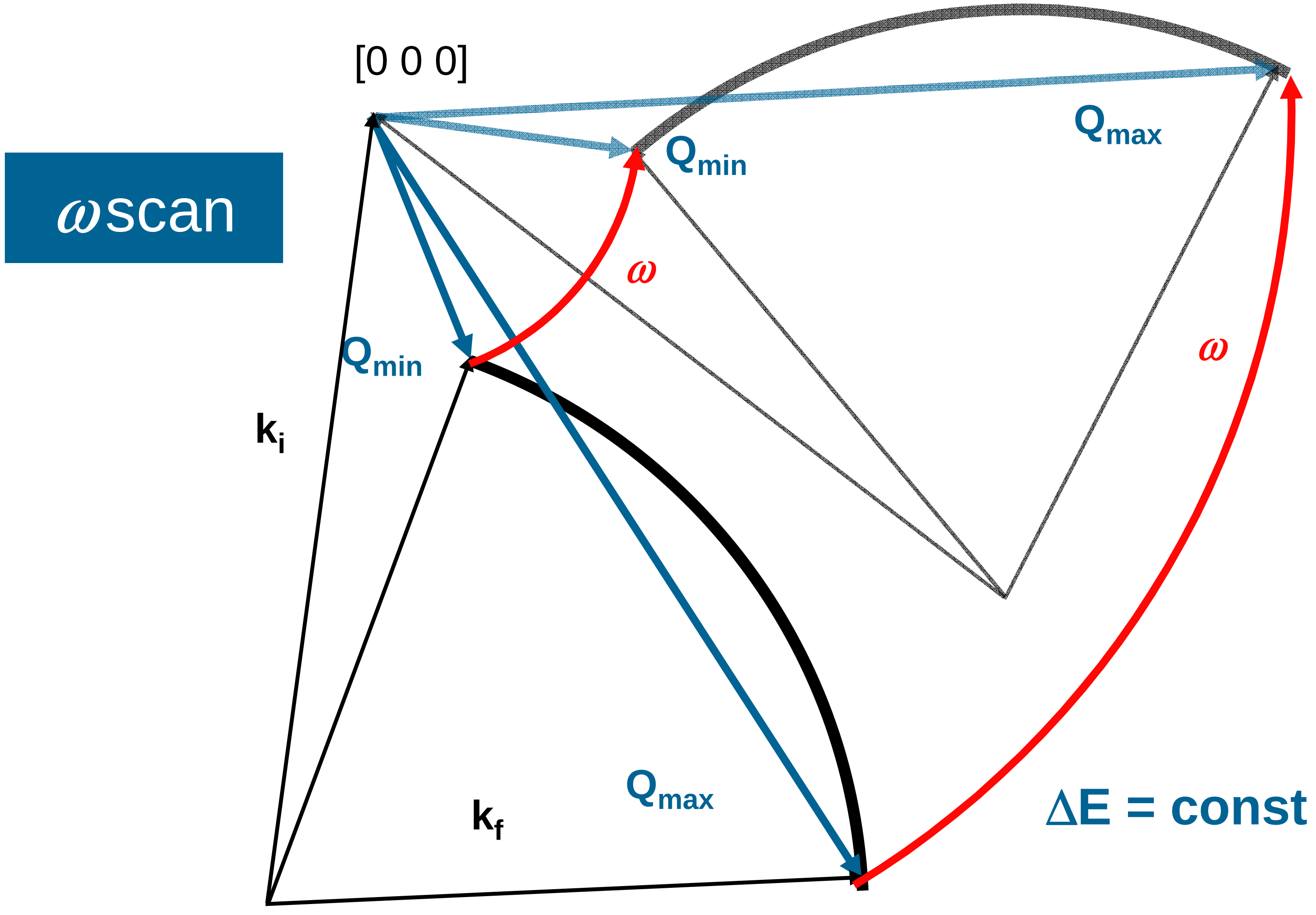
FC scan modes (I)

Q = const scan



compatibility with classical TAS

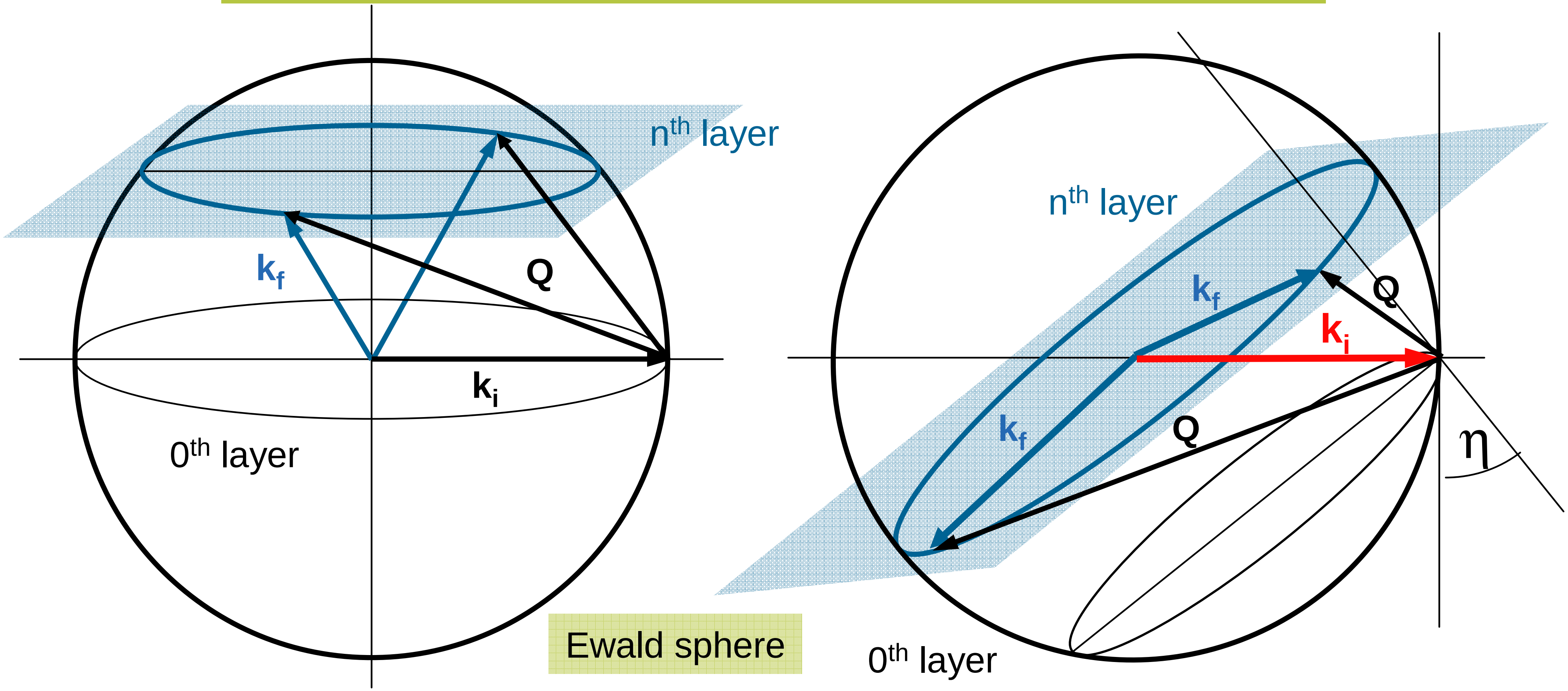
FC scan modes (II)



- **essential for mapping Q,E space:**
  sweeps a plane in reciprocal space at ΔE = const

FC geometry

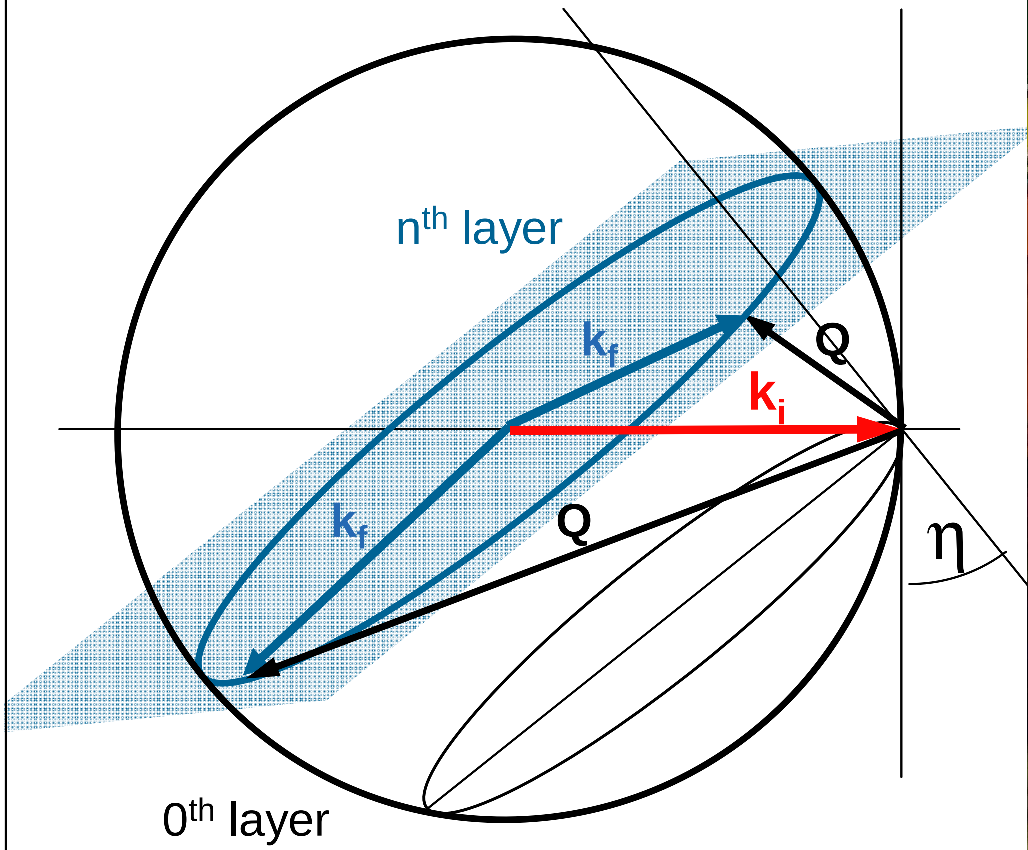
- **access to n^{th} layer scattering with a linear multidetector**



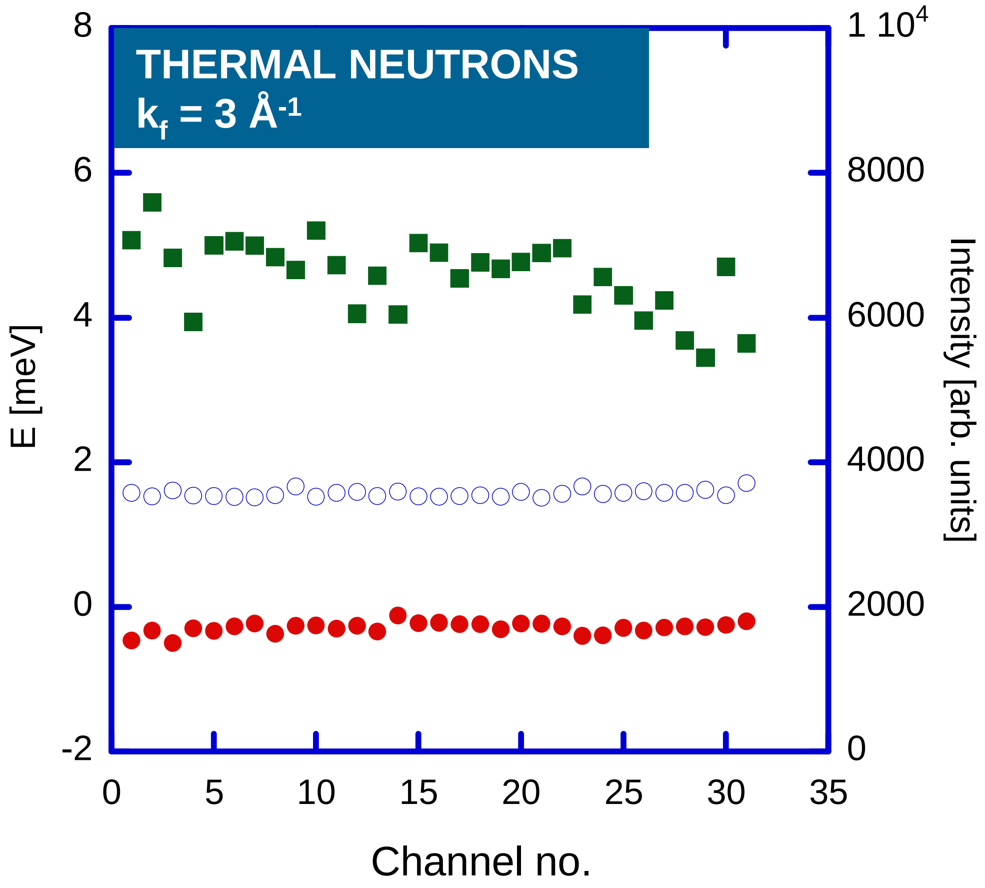
- **conventional rotating crystal method:**
  k_f's form a cone
  out of equatorial plane

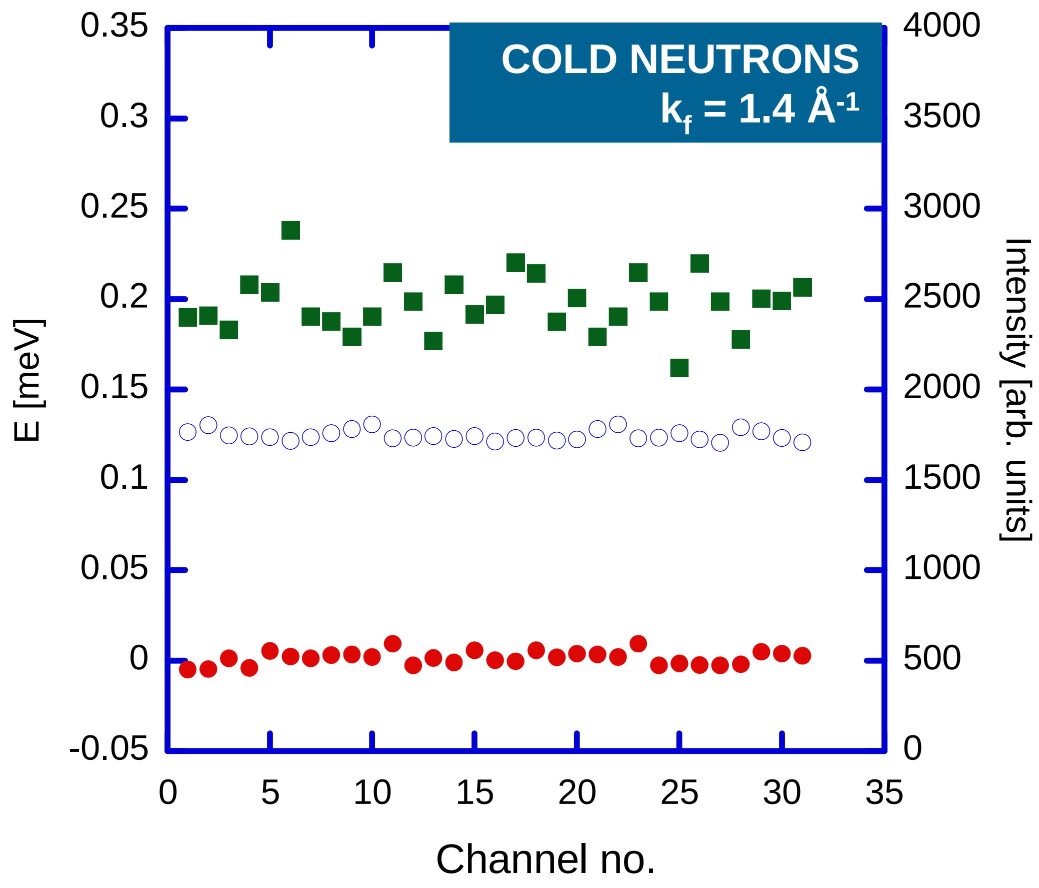
- **tilt crystal to bring k_i into n^{th} layer:**
  k_f's become coplanar
  forming a "flat cone"

FC tilted geometry



Vanadium data





- peak intensity spread ± 8% (rms)
- energy resolution
  - 1.55(4) meV measured
  - 1.40 meV calculated
- energy baseline 0±0.05 meV

- peak intensity spread ± 6% (rms)
- energy resolution
  - 0.125(3) meV measured
  - 0.120 meV calculated
- energy baseline 0±0.004 meV

FC background (IN20)

FlatCone & IN20 Si111, July 2006

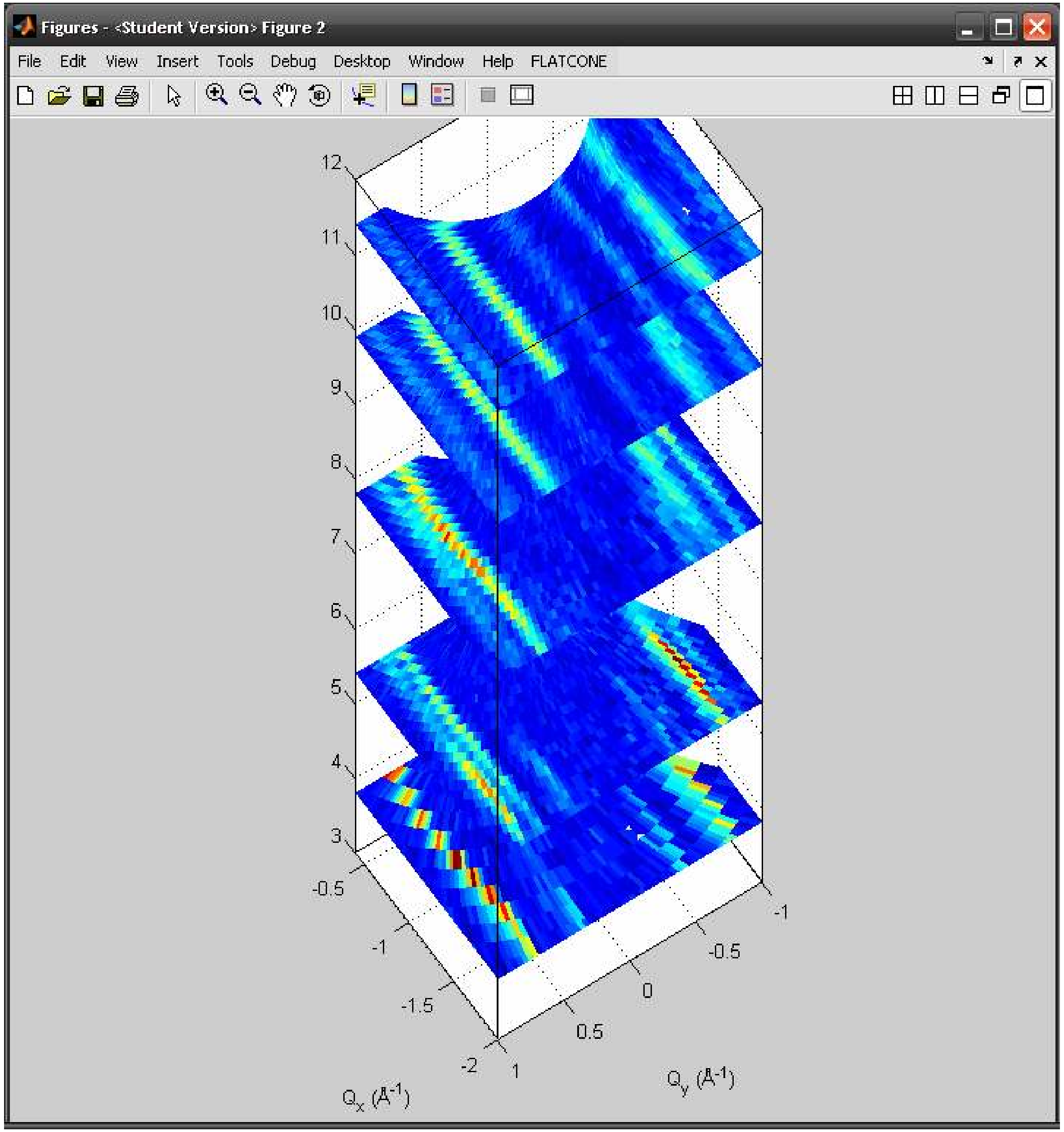
• P= 58.3 MW, H13 & OS closed:	3 cts/channel/6000 sec (all Poissonian)
• EN = 15 meV, empty Orange:	14 cts/channel/100sec
• EN = 15 meV, $CuGeO_3$ in Orange:	50 cts/channel/100 sec

IN20 Heusler/Heusler, July 2006

• EN = 15 meV, empty Orange:	25 cts/100 sec (NSF)
	11 cts/100 sec (SF)

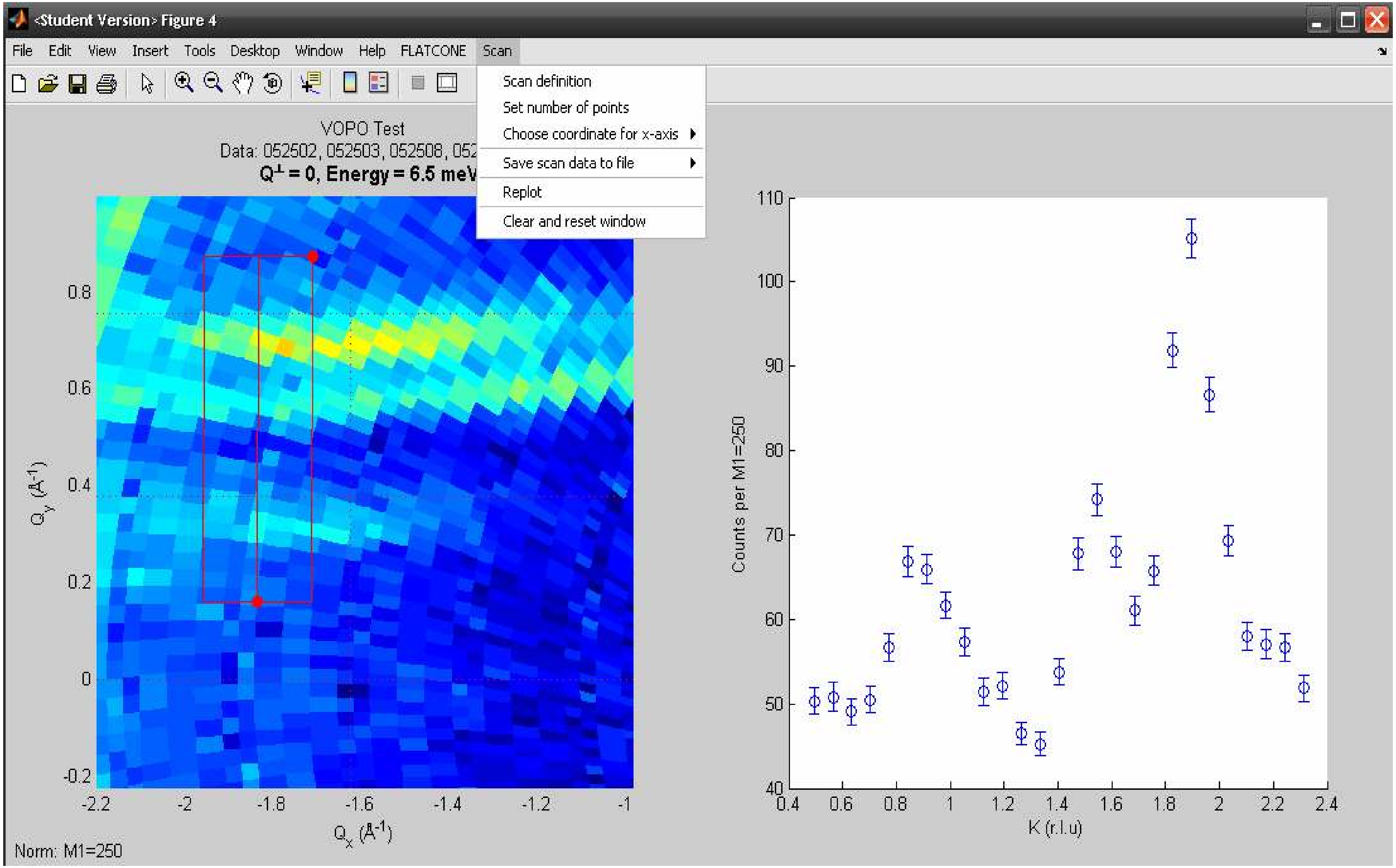
Data visualisation (I)

ViewFC MATLAB script *(P. Steffens)*

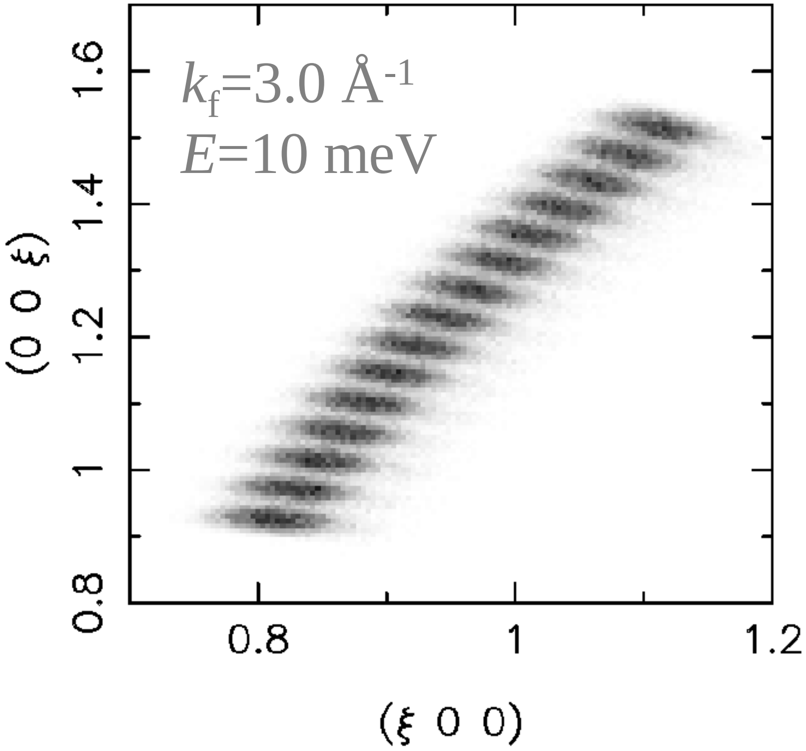


- addition, subtraction, combination, normalization of data sets
- display of intensity maps on linear and logarithmic scale
- extraction of linear scan data (interpolation, integration, projection)
- cuts through sets of $E = const$ maps

Data visualisation (II)

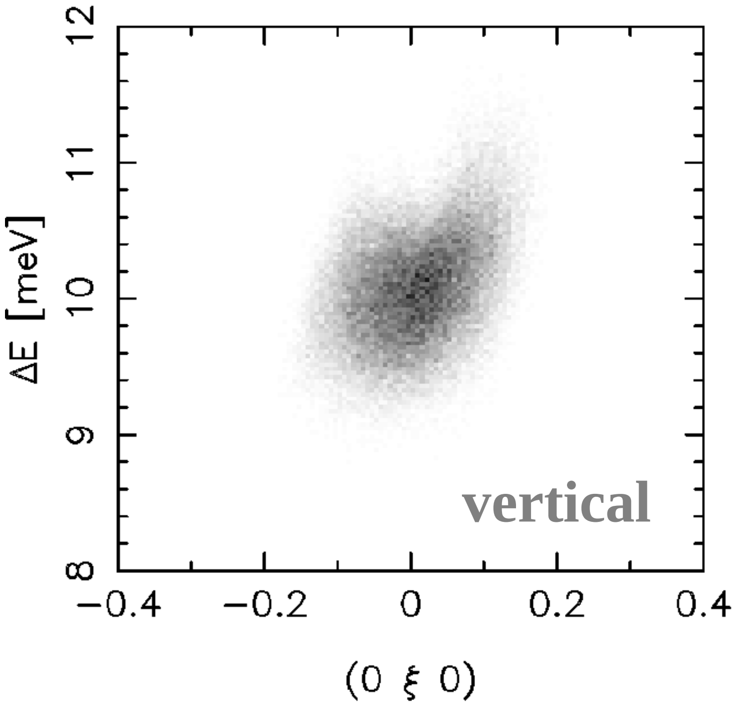


Flat-cone resolution



Primary spectrometer: **IN20**

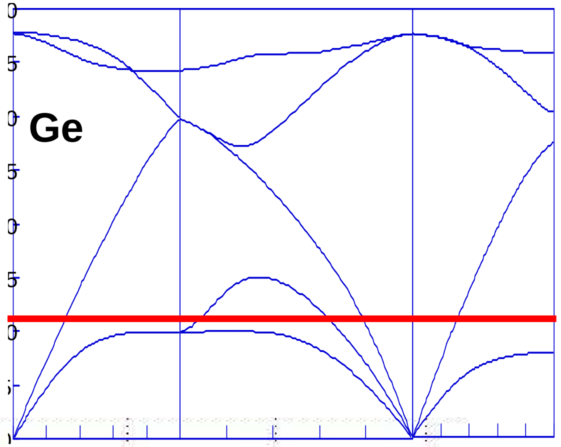
Multianalyzer: **flat-cone**
bent single crystals (Si), 1 cm wide
$2\theta_S$ range = 15º

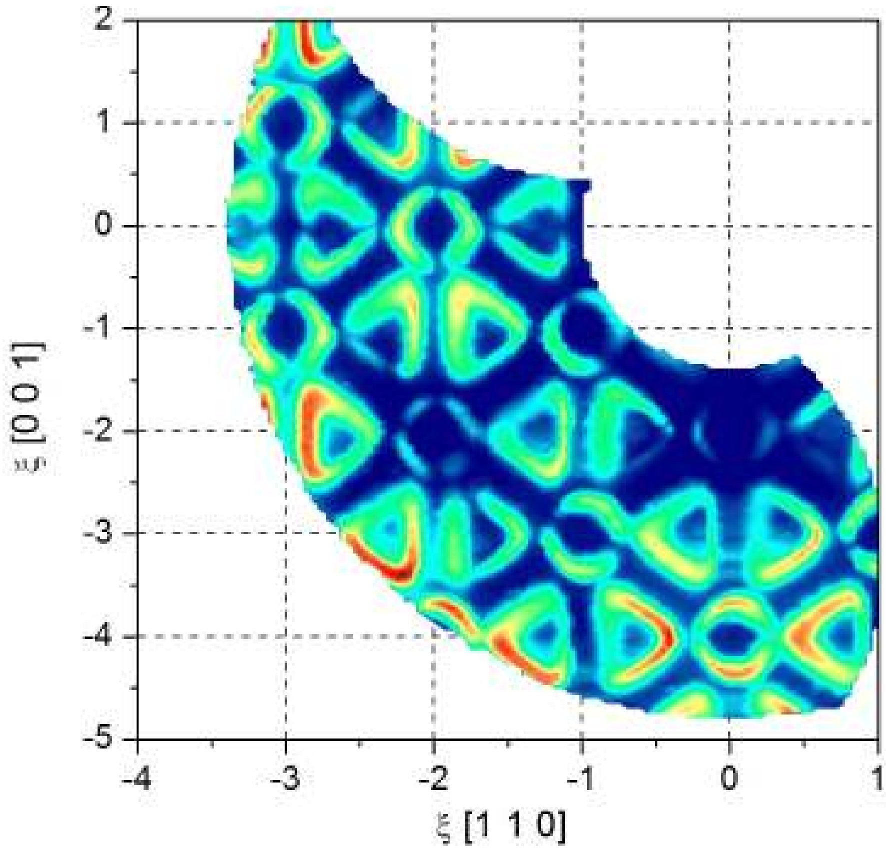


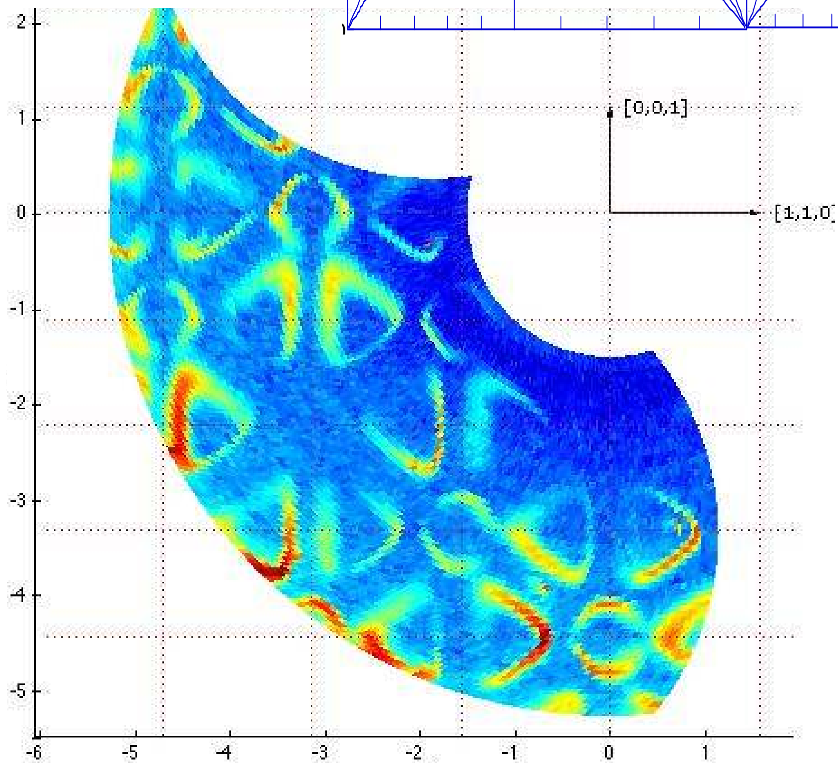
focused R_A = 3.3 m

FC map simmulation

- •MC ray-tracing simulations using ***RESTRAX***
- •4D convolution with $S(Q,E)$ from BCM (bond-charge model)
- •IN8 thermal beam, Si111 / FC , k_f = 3 Å¹
- •Ge single crystal 4 x 4 x 10 mm³

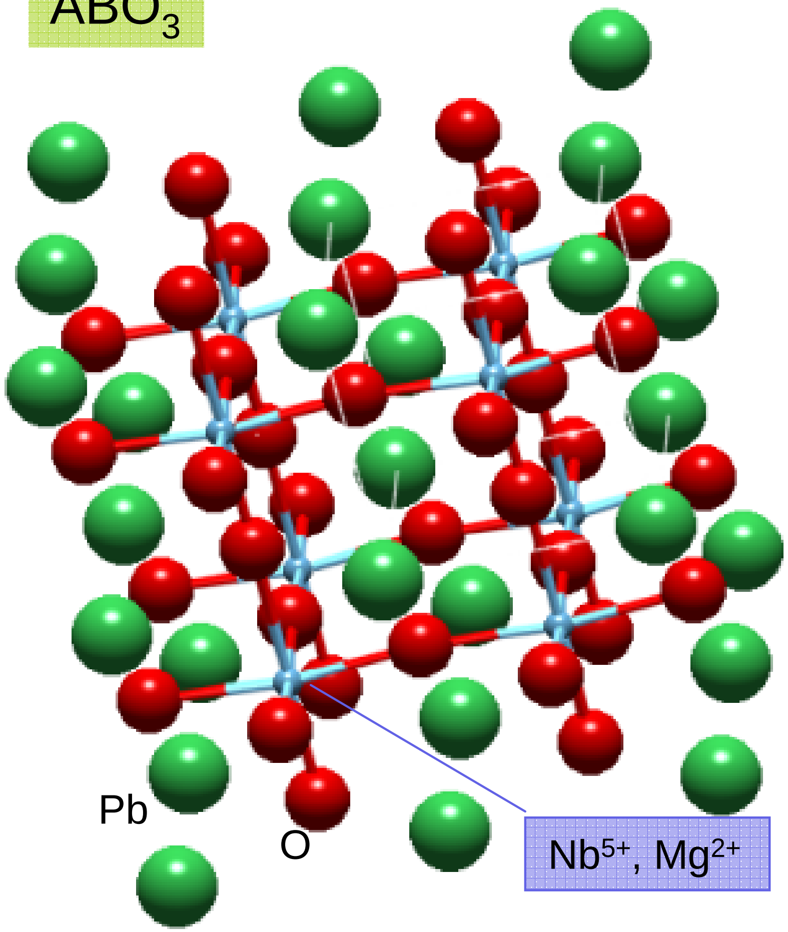




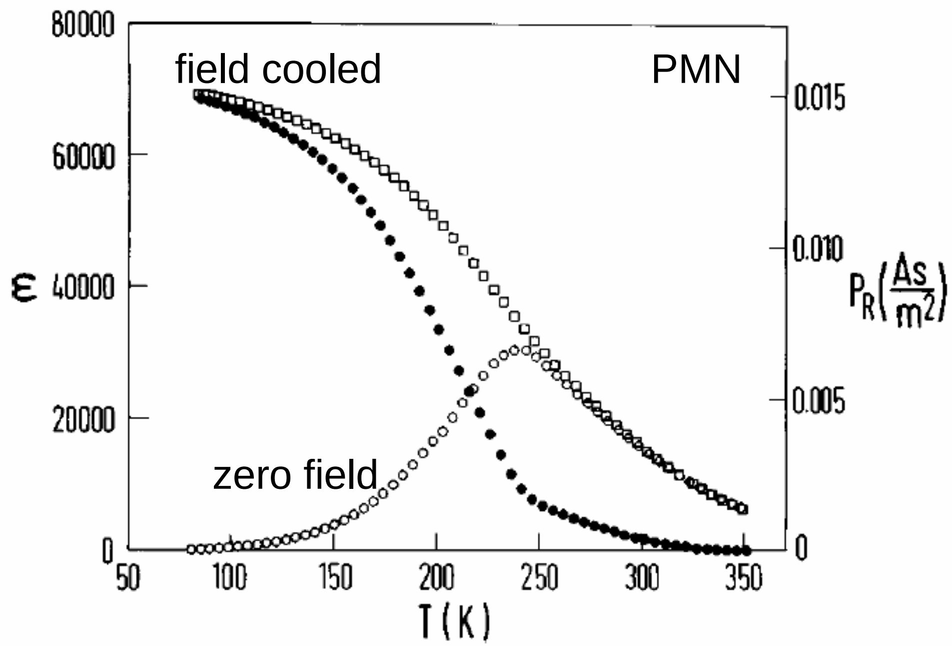


Relaxor ferroelectrics

ABO_3



- "ferroelectrics with a diffuse phase transition"
- giant dielectric permitivity
- strong piezoelectricity

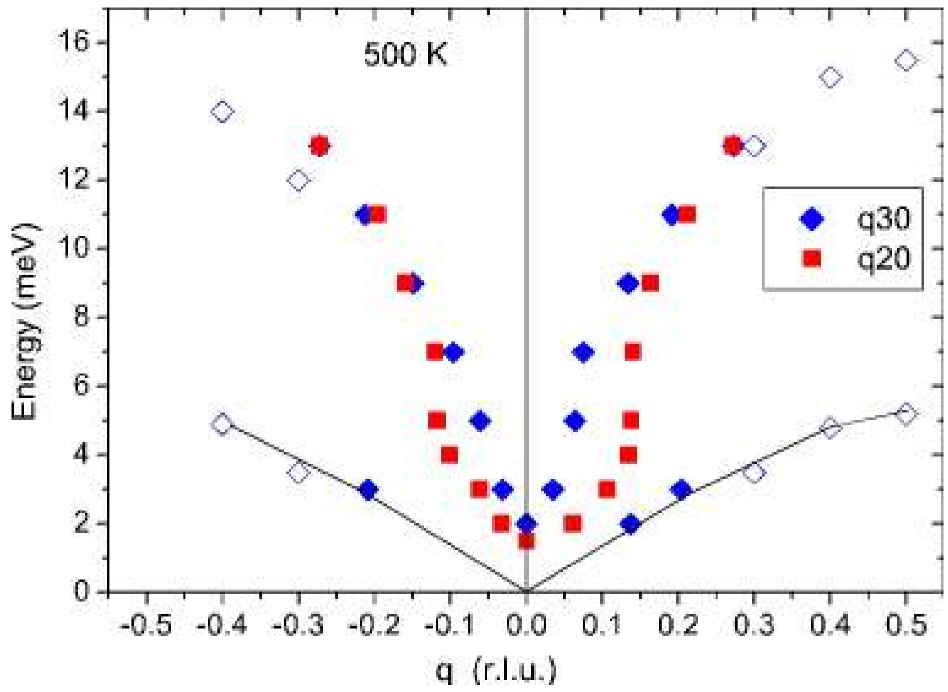


- PMN ($Pb(Mg_{1/3}Nb_{2/3})O_3$)
- PZN-8%Pt ($Pb(Zn_{1/3}Nb_{2/3})O_3$ with 8% $PbTiO_3$)

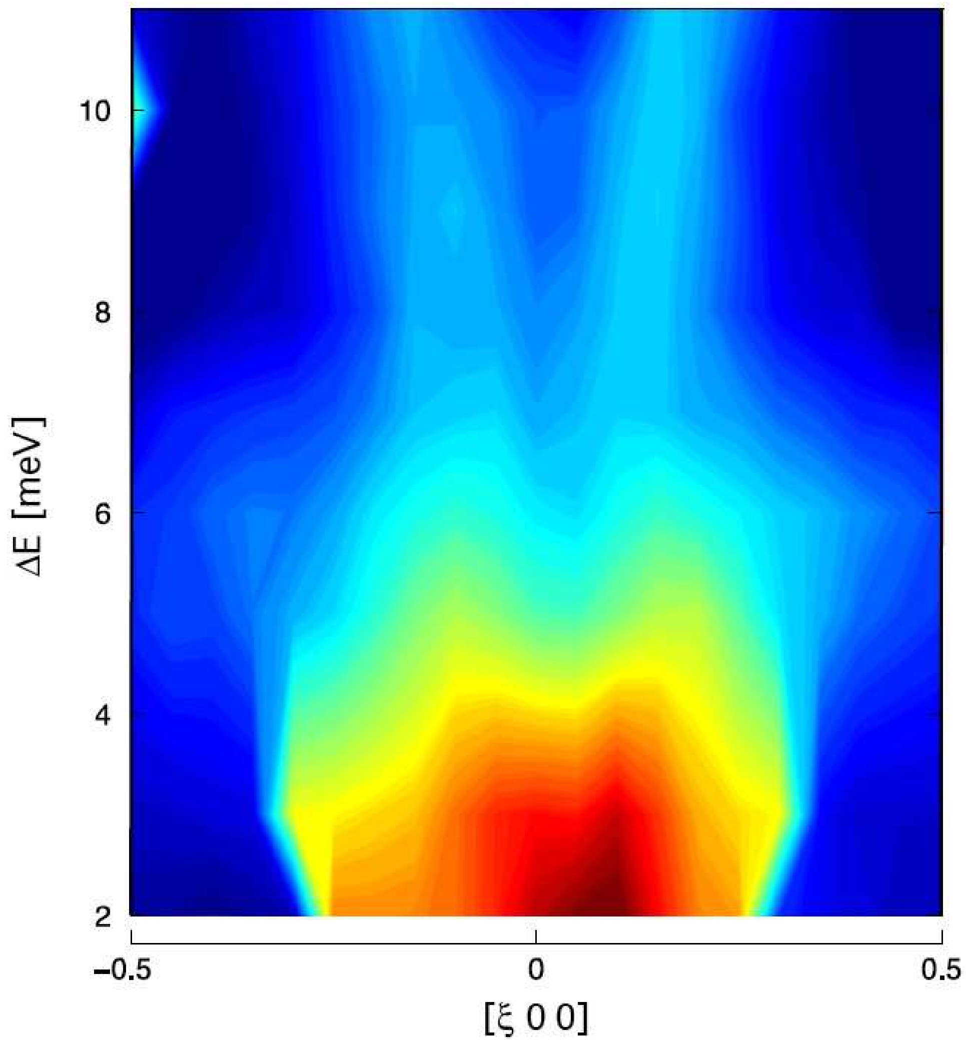
“Waterfall” anomaly

PMN
cut through 3D (**Q**,E) data from FC

PZN-8%Pt
from E = const TAS scans

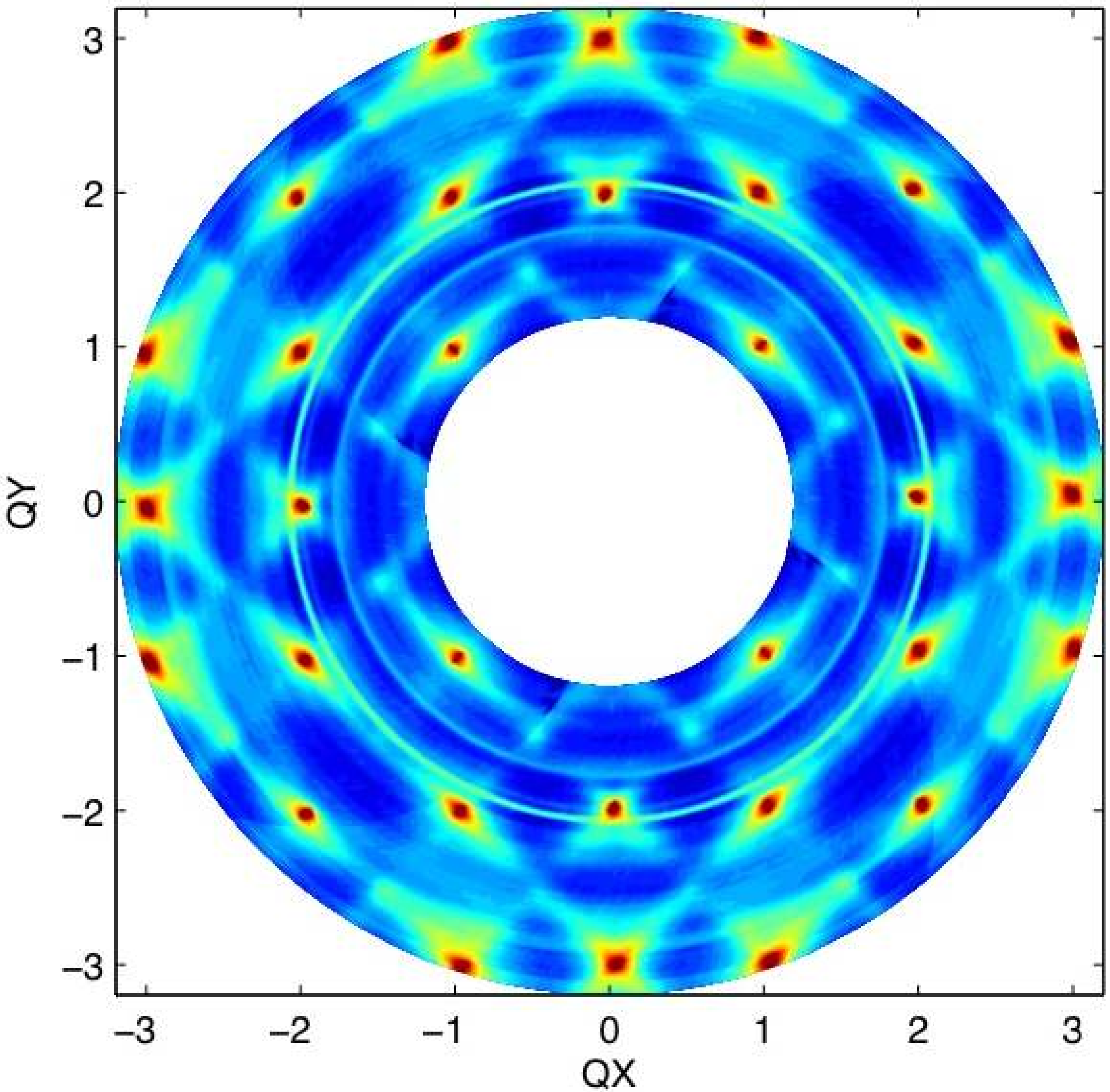


J. Hlinka et al., Phys. Rev. Lett. 91 (2003) 107602



Elastic diffuse scattering

PMN
T = 20K

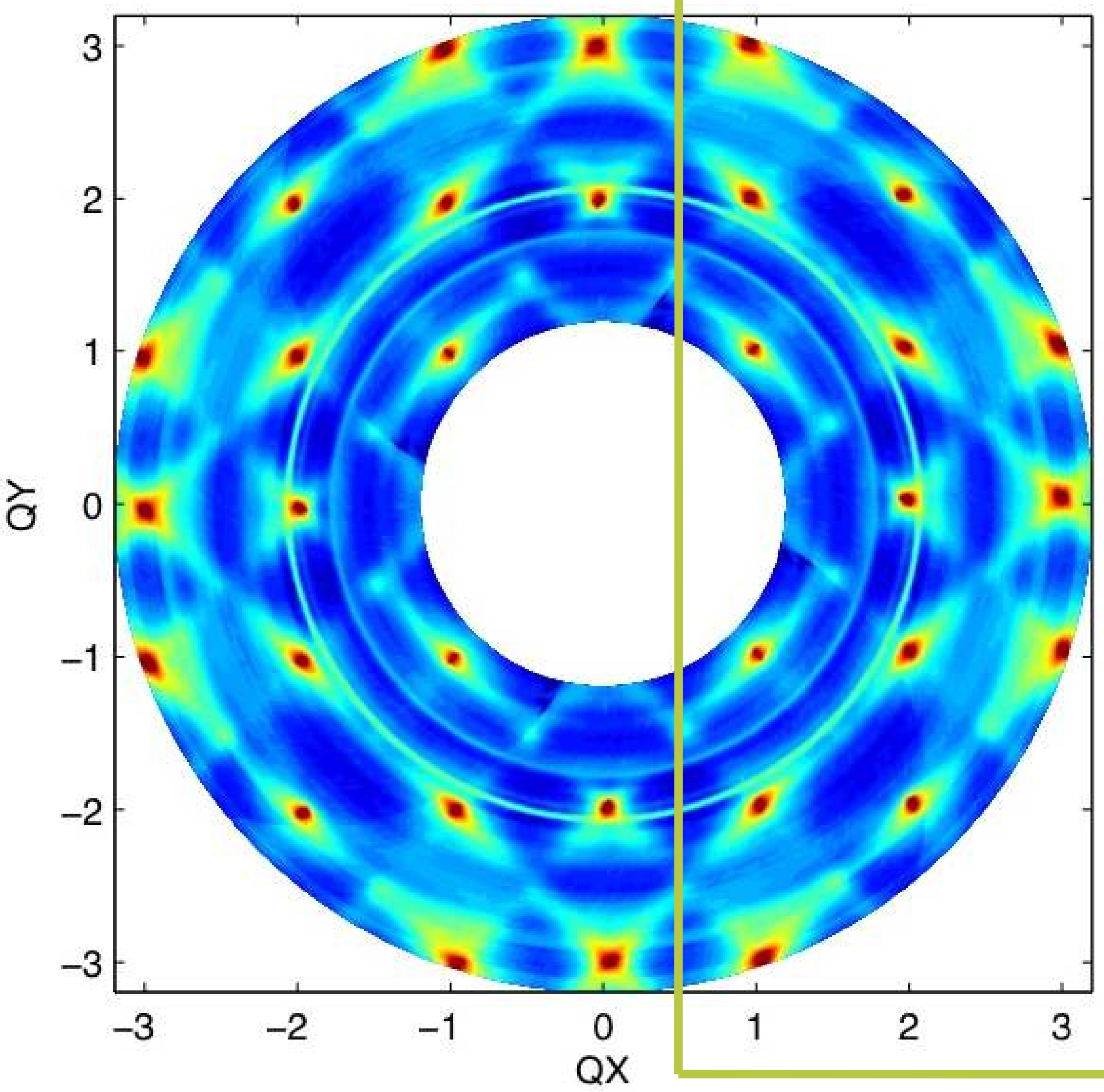


ΔE = 0 meV
k_f = 3 Å^{-1}

IN20
t_{exp} = 14 sec
t_{tot} = 2.5 hours
62 x 360 pixels

Elastic diffuse scattering

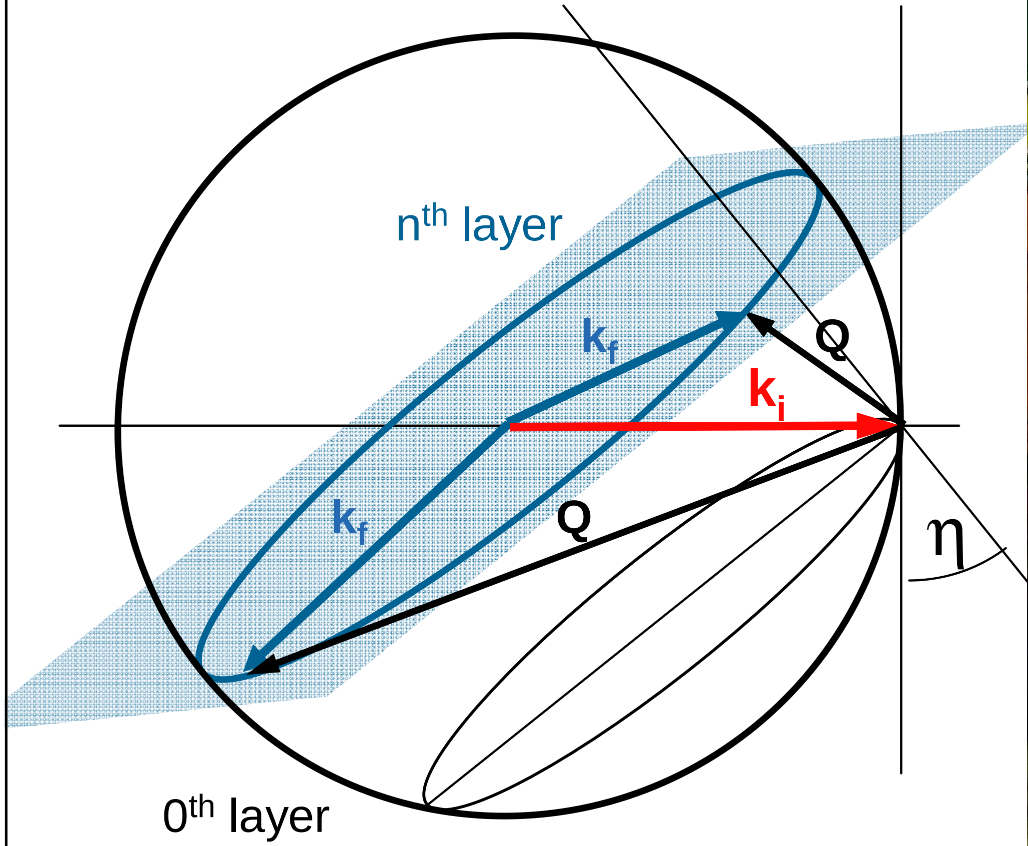
PMN
T = 20K



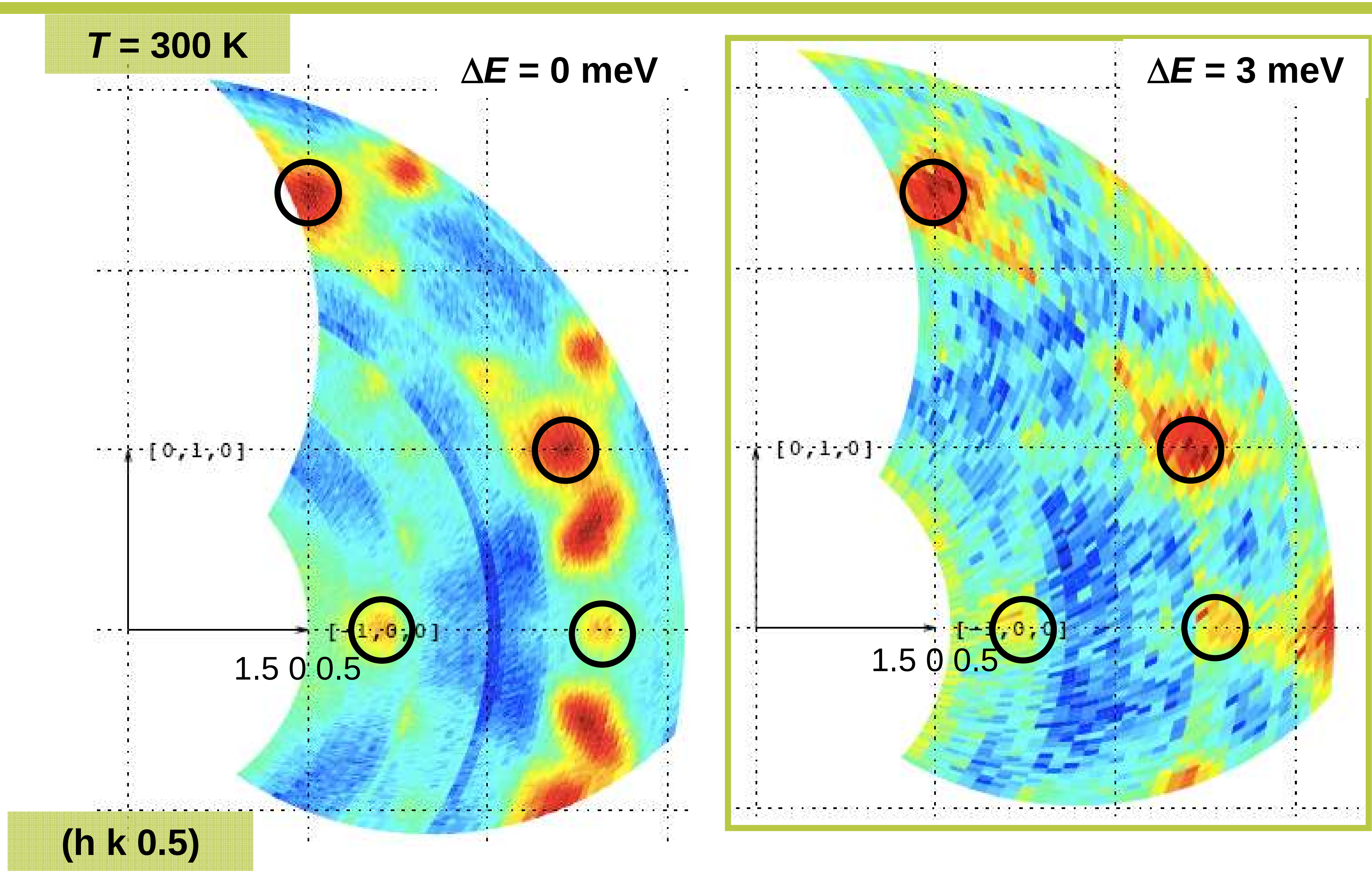
?

ΔE = 0 meV
k_f = 3 Å^{-1}

FC tilted geometry

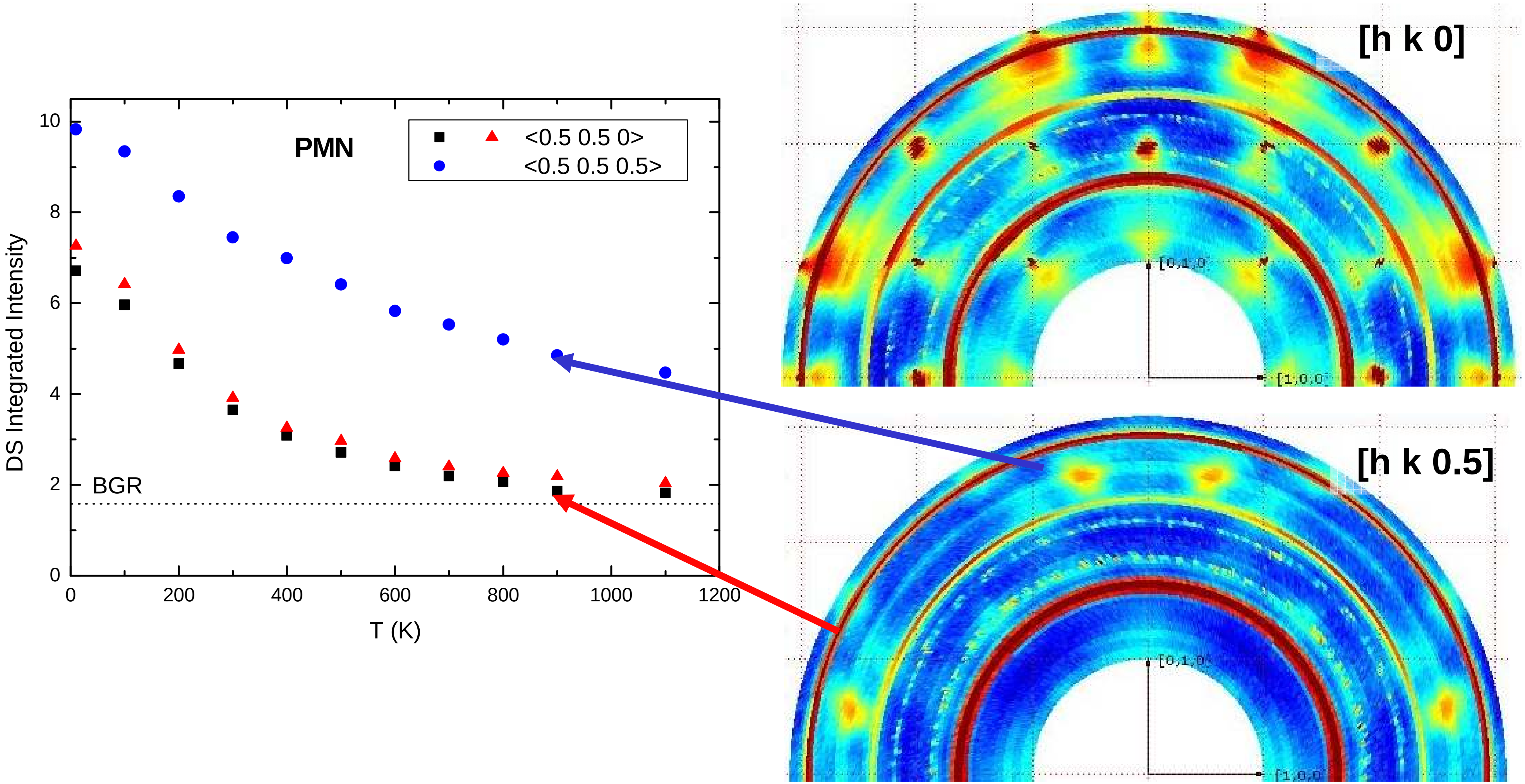


PMN diffuse scattering



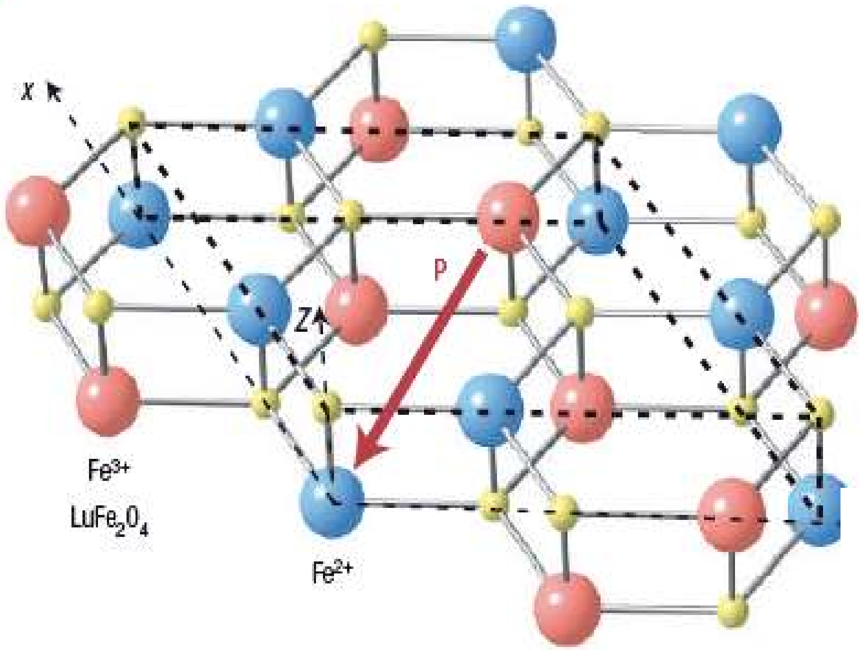
PMN elastic diffuse scattering

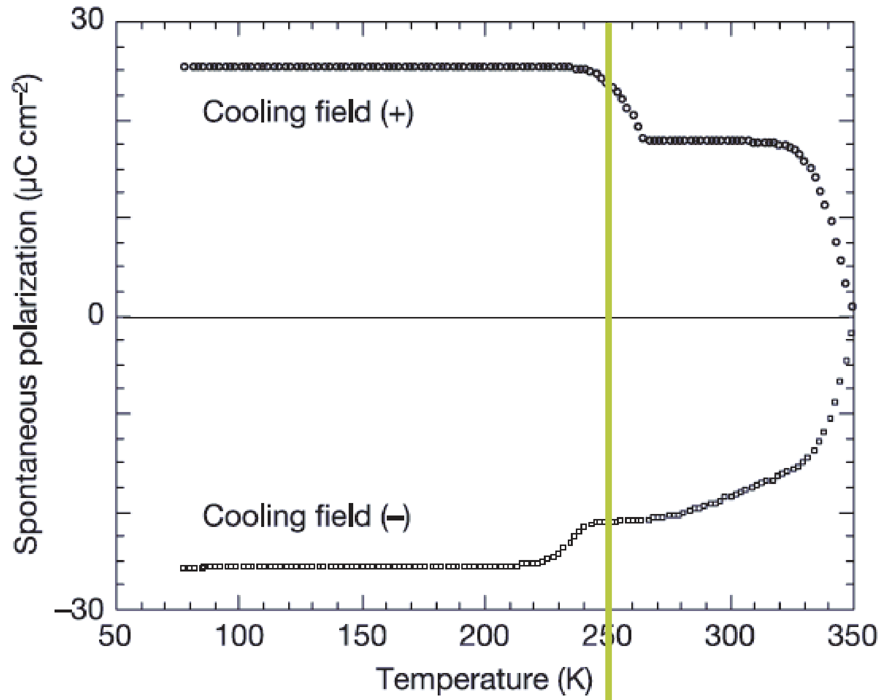
PMN
T = 900 K

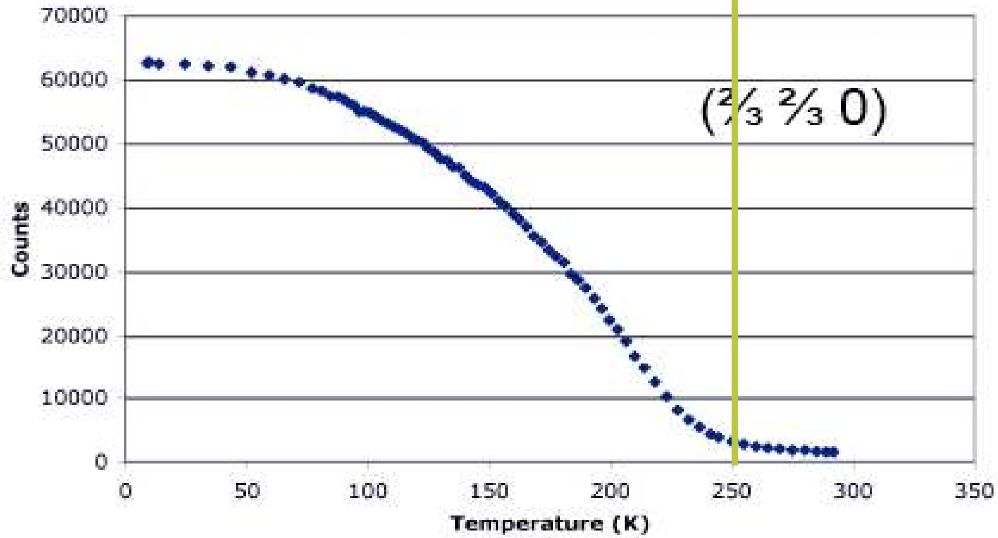


$LuFe_2O_4$

electric polarization



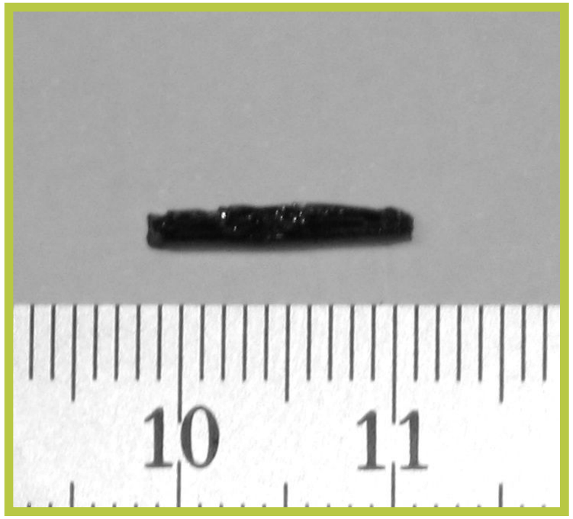


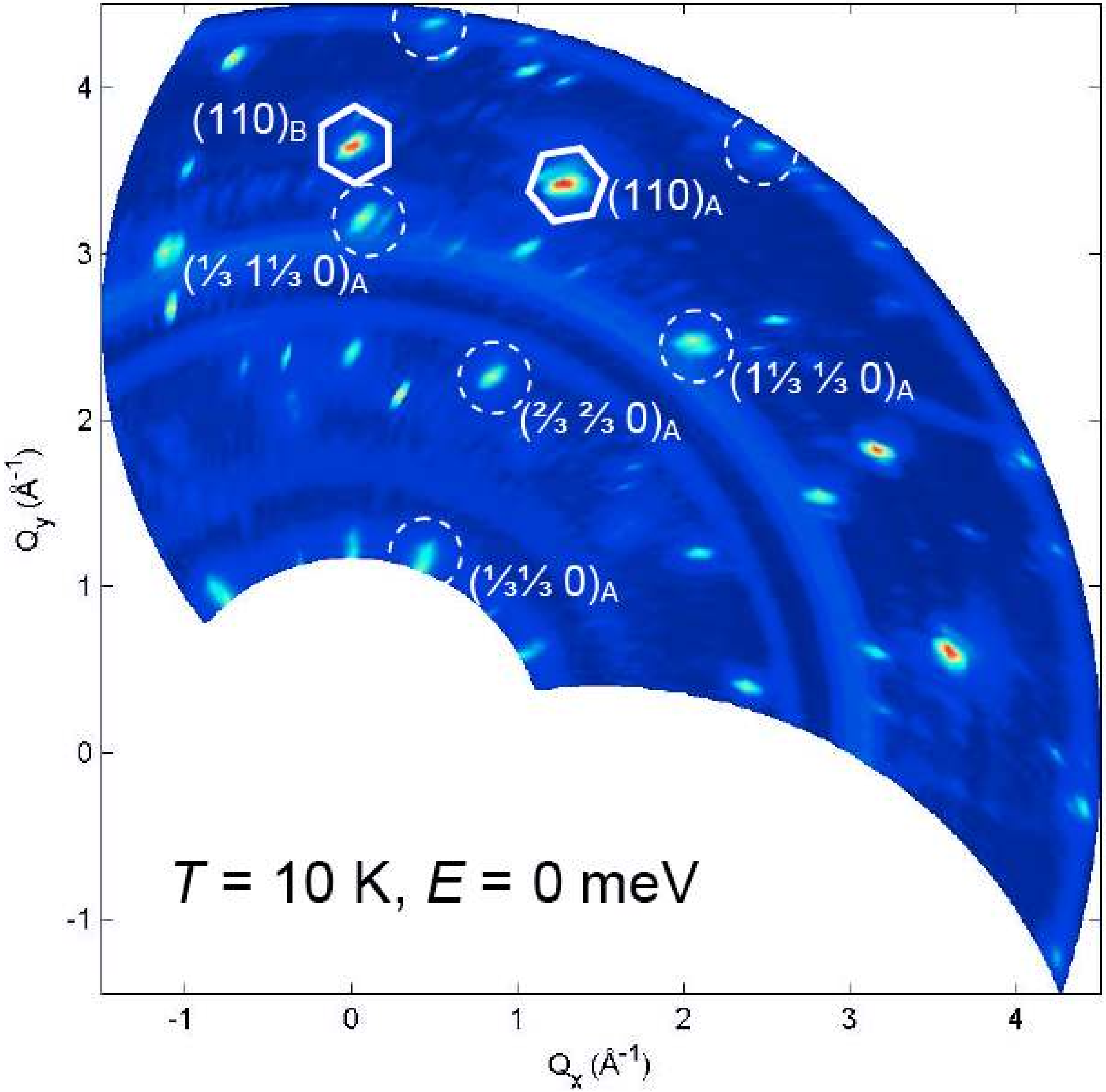


sublattice magnetization

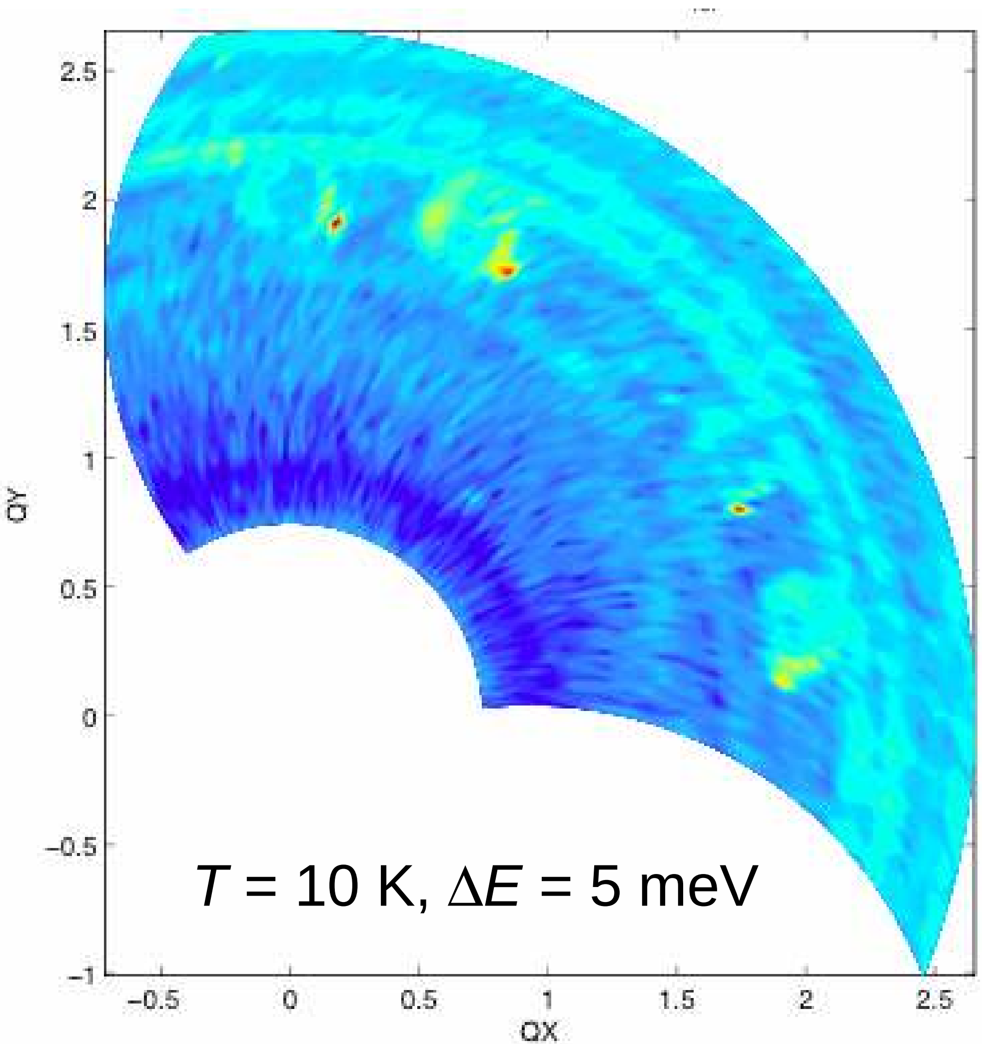
IN20 FC $LuFe_2O_4$

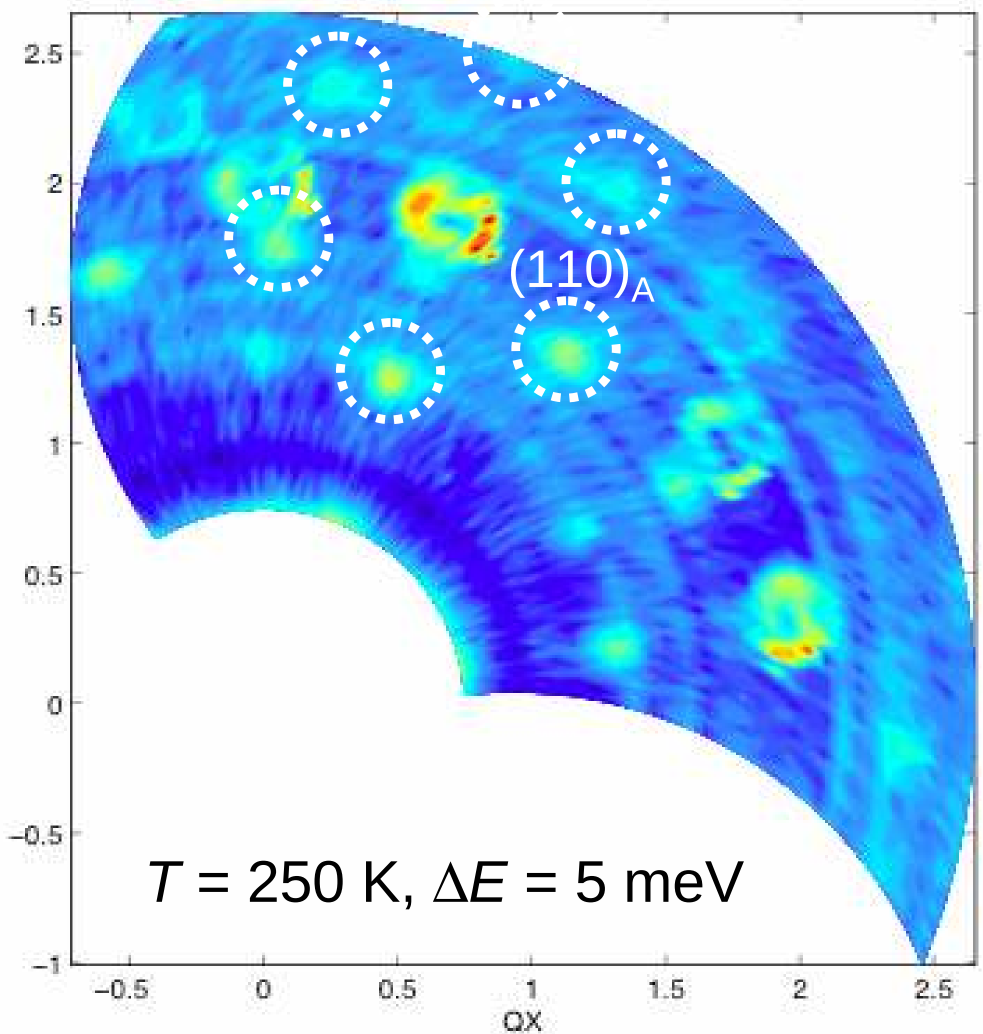
sample B
m ≈ 80 mg
*hk*0 plane
T = 10K
ΔE = 0 meV





IN20 FC $LuFe_2O_4$





magnon gap > 5 meV

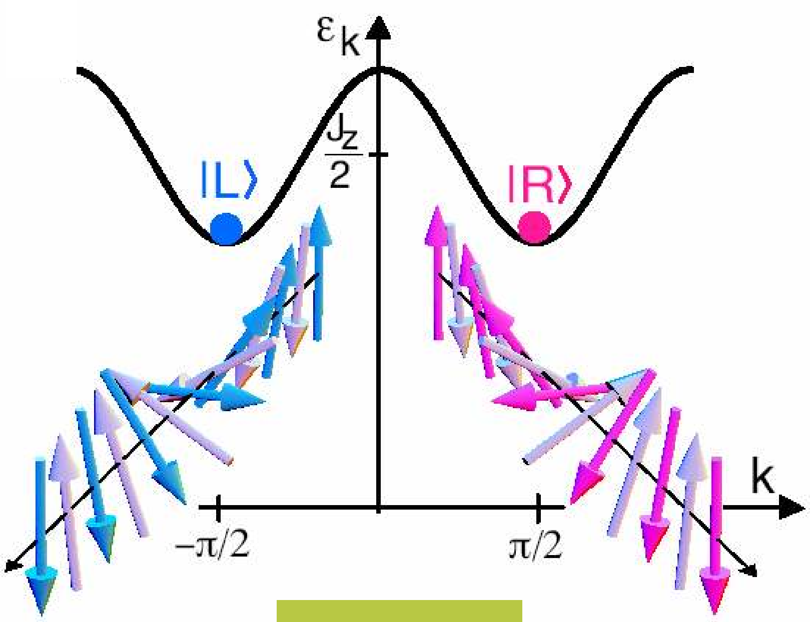
A.Boothroyd, D.McMorrow, H.Lewtas, J. Kulda, ILL Exp. report 4-01-689

Spin soliton chirality

pure Ising AFM

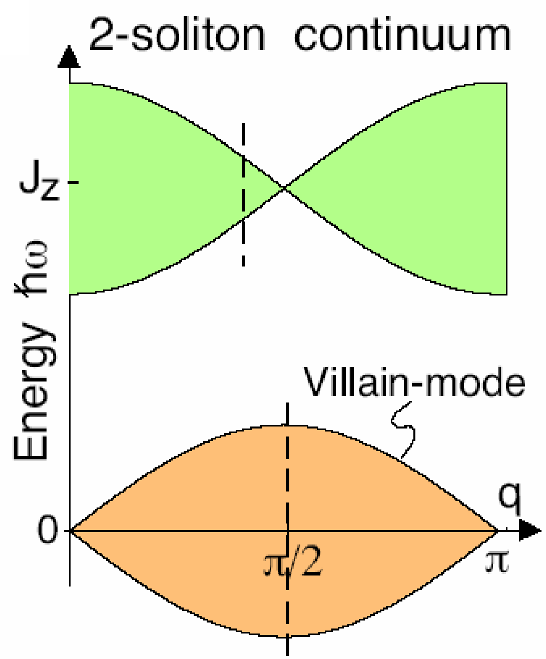
domain walls

transverse exchange
&
quantum fluctuations

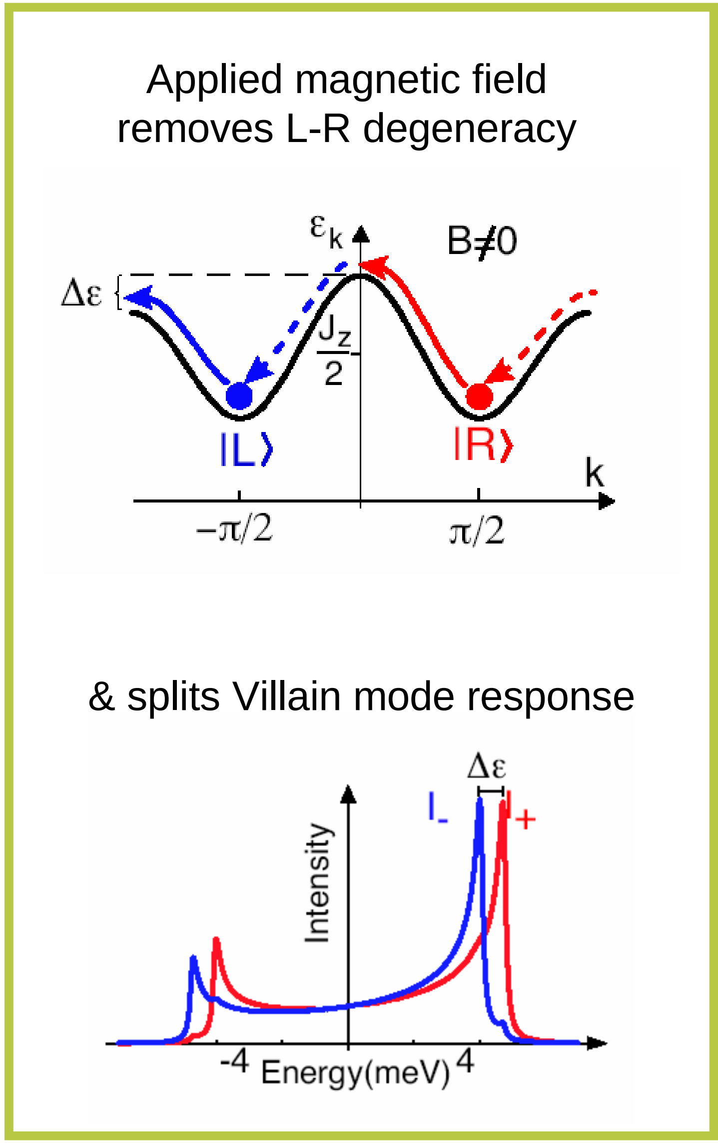


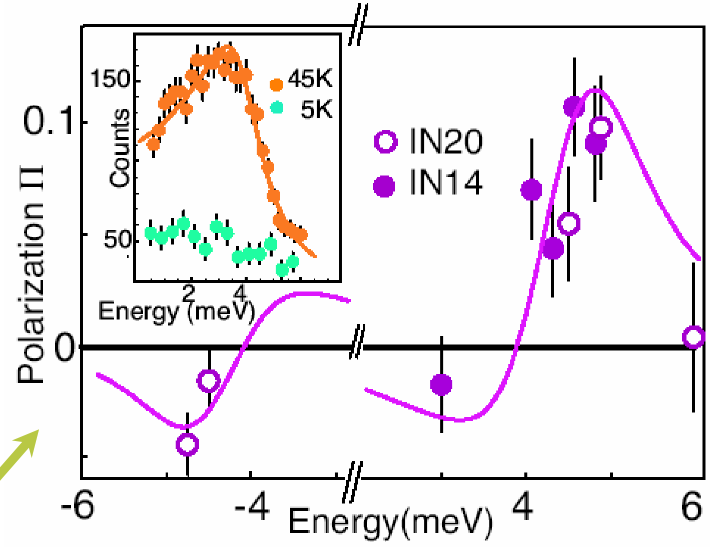
solitons

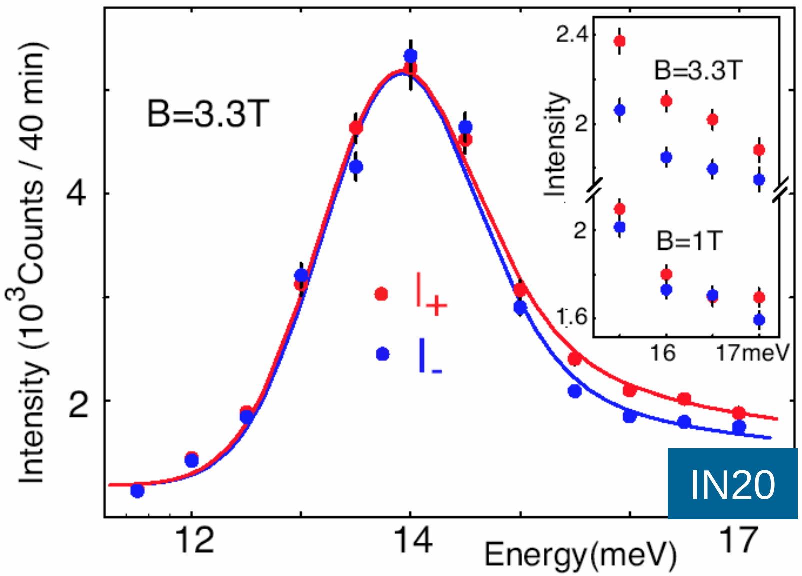
Neutron response of a quantum 1D spin-half AFM



CsCoBr$_3$ data



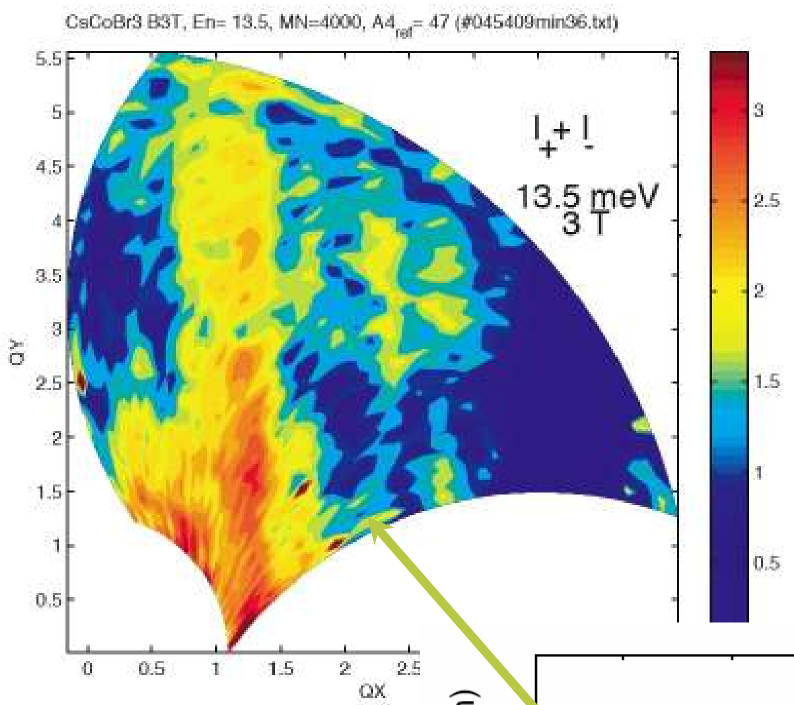




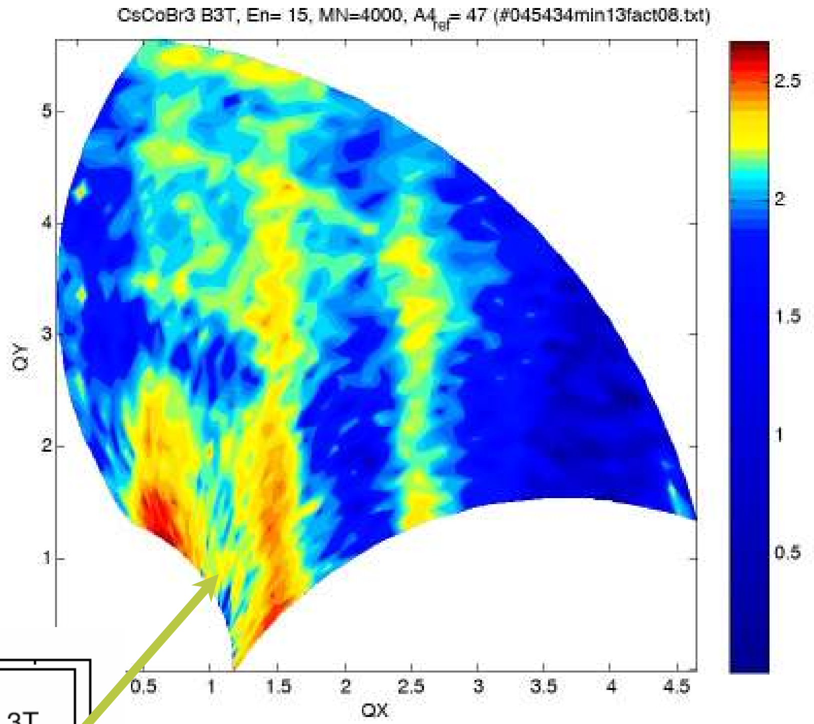
H.B. Braun, J. Kulda, P. Boni, B. Roessli, D. Visser, Nature Physics 1 (2005) 1038

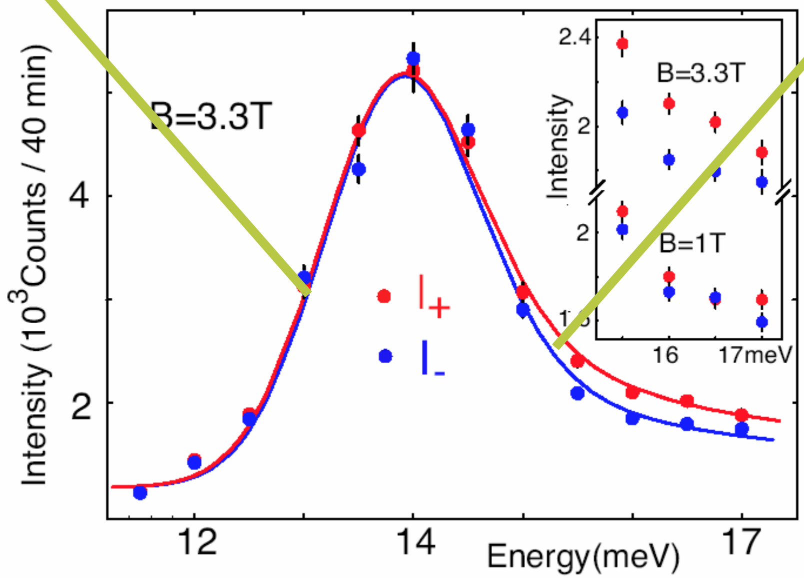
IN20 *FlatCone*

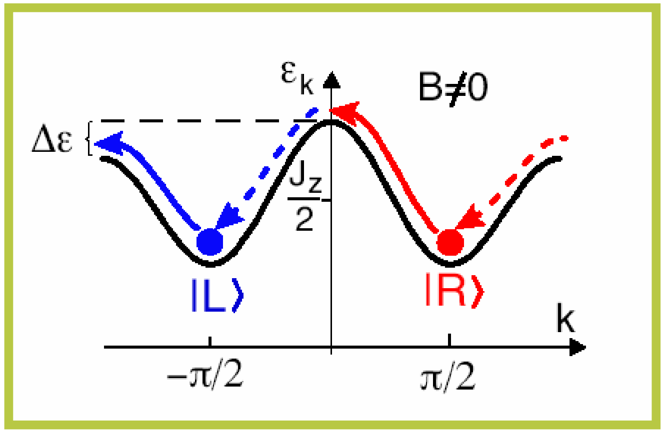
$CsCoBr_3$



IN20
FlatCone
B = 3.3 T
unpolarized

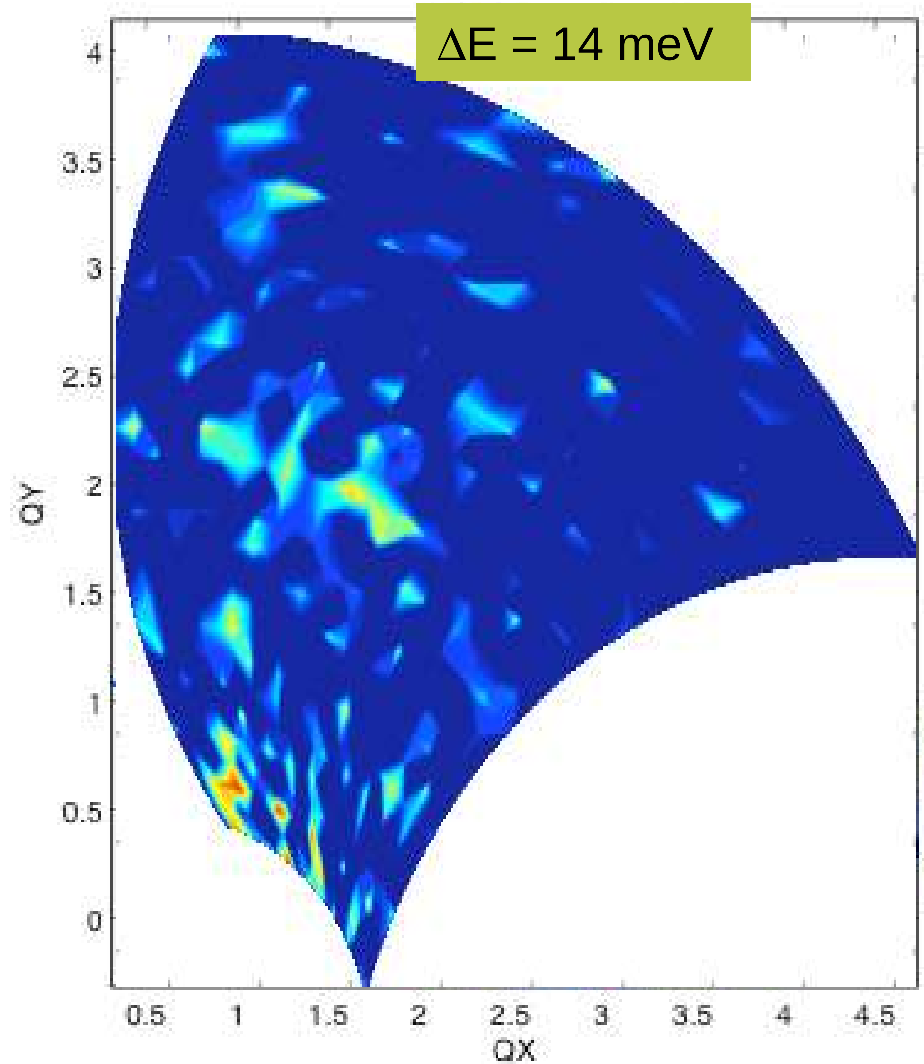


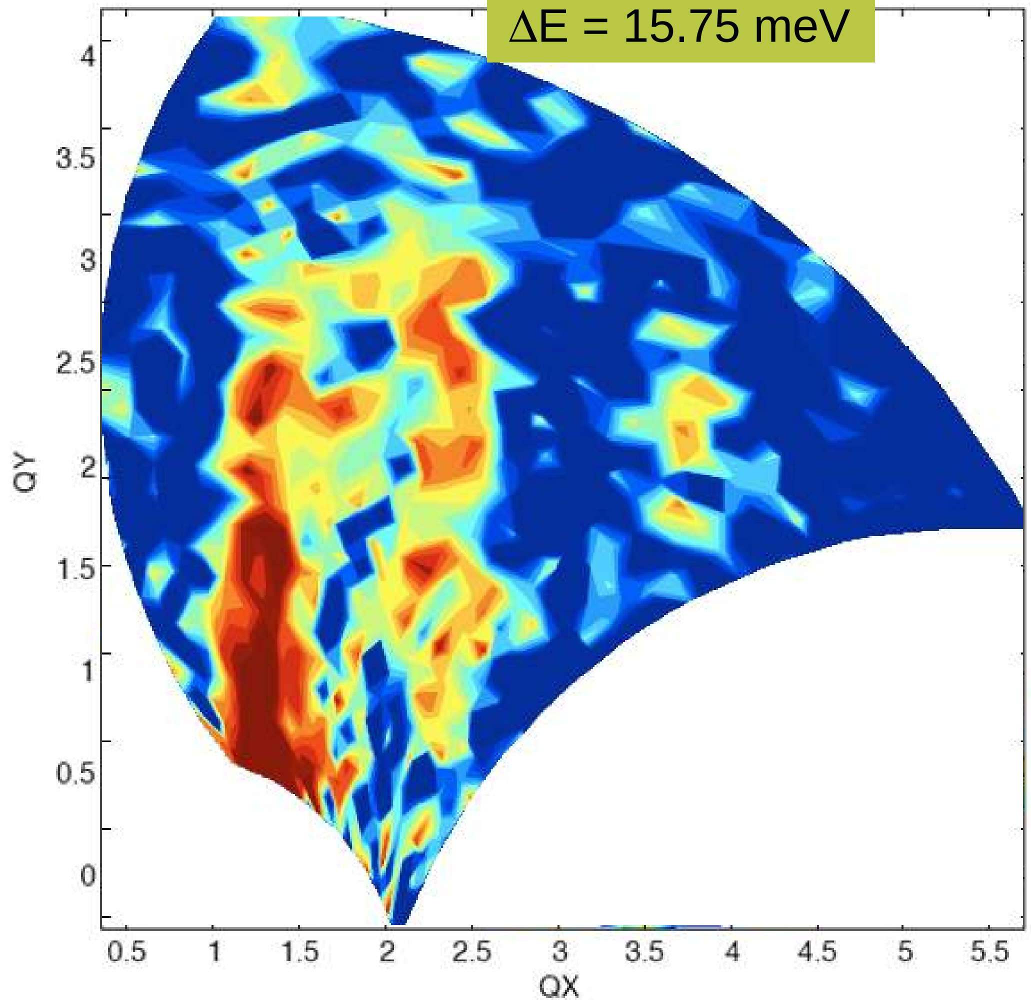




IN20 FC $CsCoBr_3$

Two-soliton continuum, B = 3T, T = 40K, *h0l* plane, $\Delta I = I_+ - I_-$





H.-B. Braun, J. Kulda, ILL Exp. report 4-01-695

Summary

- highly efficient mapping of inelastic response at *ΔE = const*
- diverse scan modes available
- luminosity/channel ≈ 1/3 of TAS
- transverse resolution *ΔQ ≈ 1/2 TAS*
- good signal/noise
- routine operation on IN14, IN20

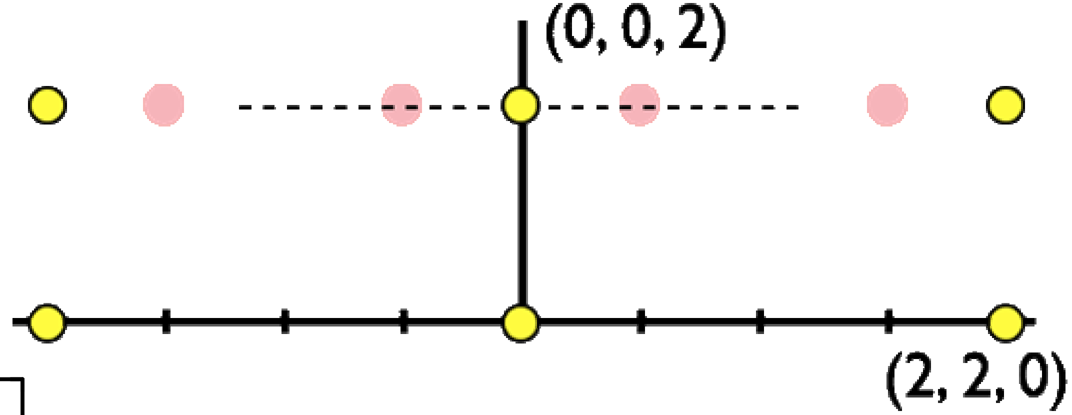
• angular coverage	75 deg
• pixel width	1.3 deg
• no. of pixels	31
• SA distance	765 & 1000 mm
• analyzer crystals	Si 111
• cold neutrons	$k_f = 1.4$ Å^{-1}
	$\Delta E = 0 - 10$ meV
• thermal neutrons	$k_f = 3$ Å^{-1}
	$\Delta E = 0 - 40$ meV

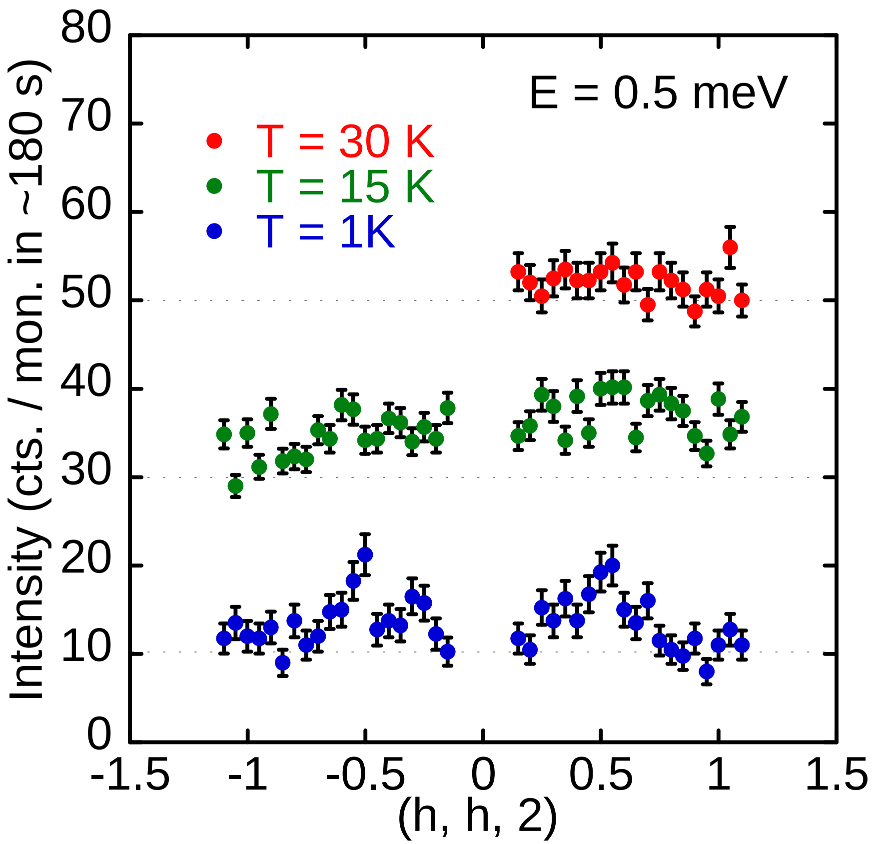
Pending:

- polarization analysis insert - ^{3}He filter
- vacuum sample chamber

UBe_{13}

TAS-IN14 $k_f = 1.5 Å^{-1}$

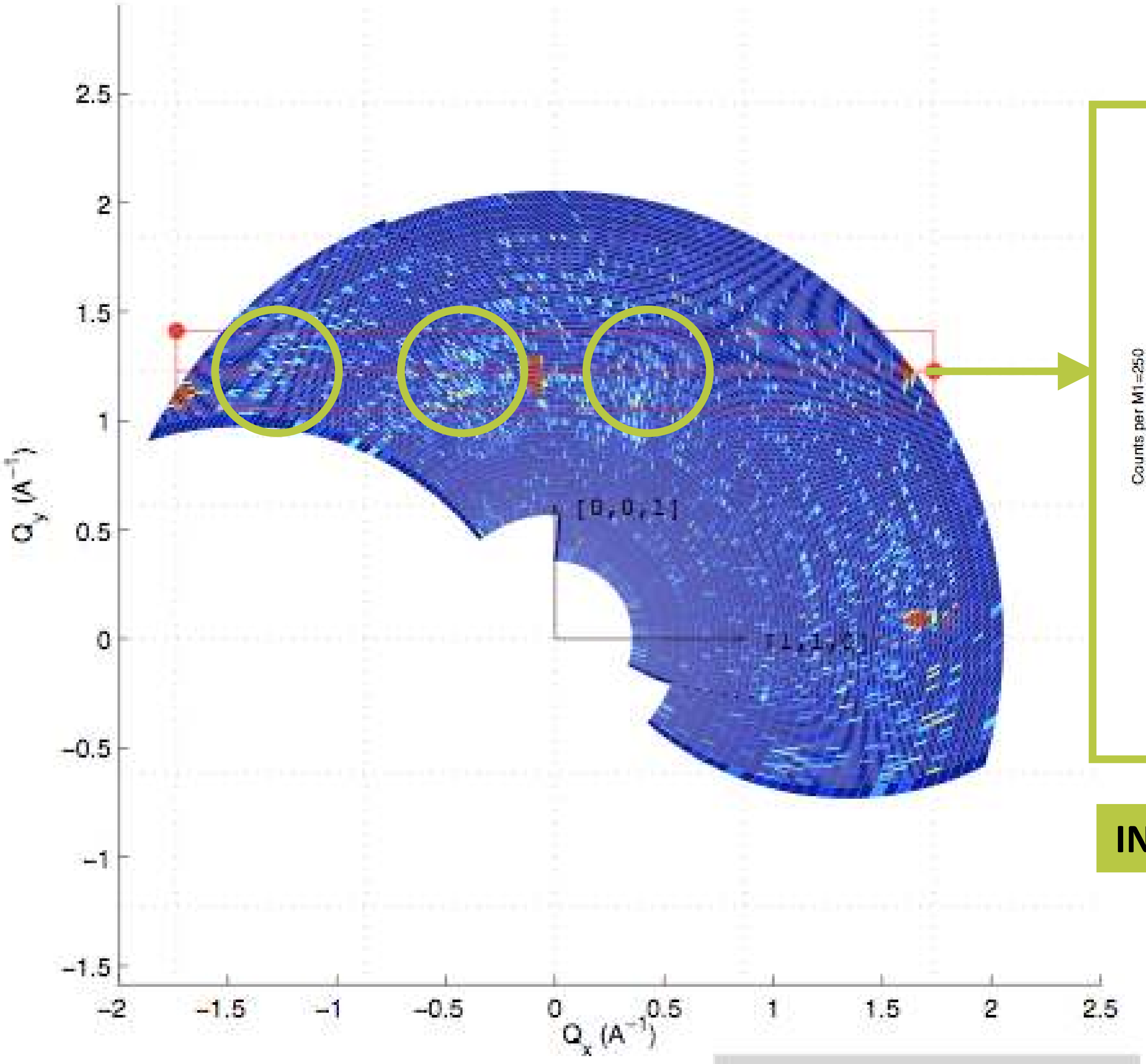


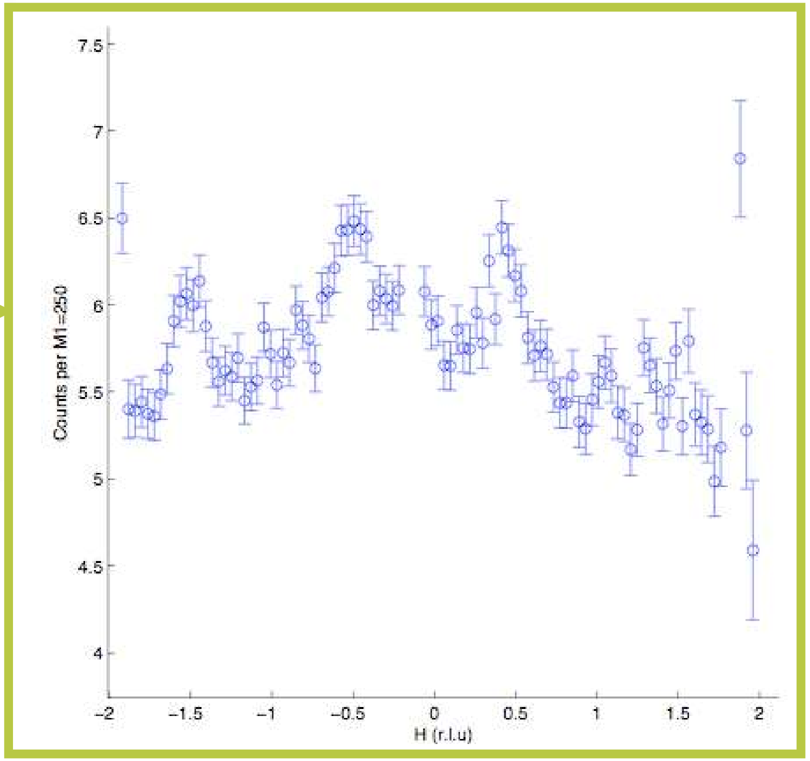


- scattering observed at (1/2 1/2 2) but not at (1/2 1/2 0)
- longitudinal fluctuations build up below ~30 K in pure and Th-doped UBe_{13}

A.Hiess, O.Stockert, Z.Fisk, ICNS-2009

UBe_{13}

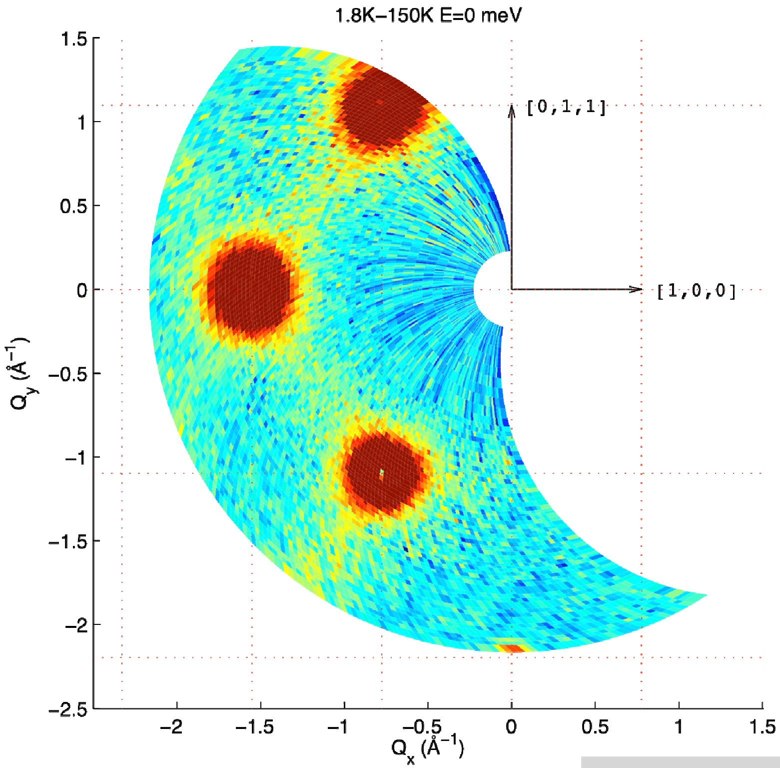


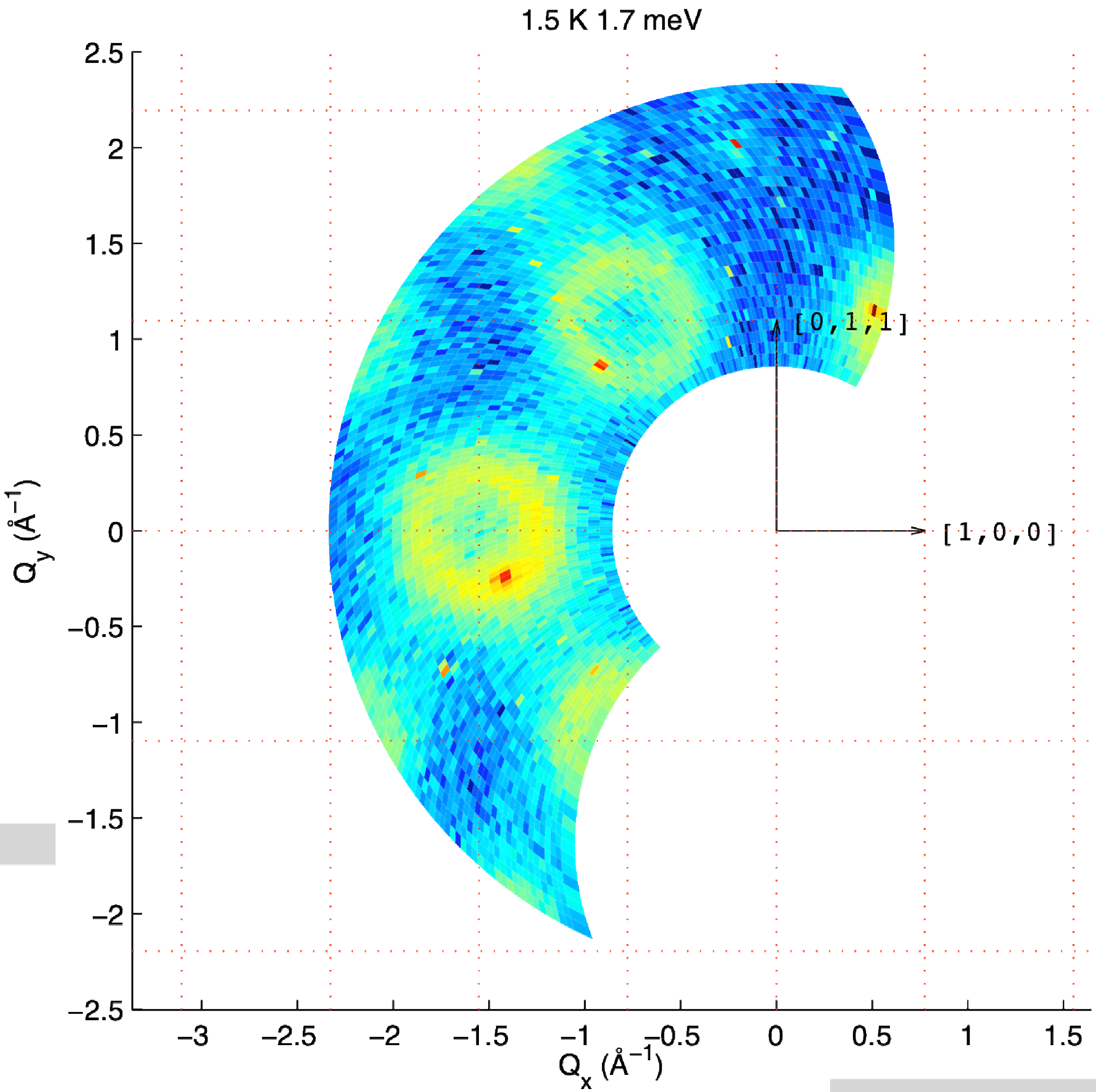


IN14 *FC* $k_f = 1.4$ $Å^{-1}$

A.Hiess, O.Stockert, Z.Fisk, ICNS-2009

$CoAl_2O_4$





IN14 *FC* k_f = 1.4 $Å^{-1}$

V ≈ 0.5 cm^3; ≈ 5 h/map

O. Zaharko, N. Christensen, M. Boehm and F. Yokaichiya unpublished, 2009

FlatCone & polarized neutrons

MagicPastis:

- hybrid of “Magic box” and PASTIS coils
- no blind angles
- magnetised mu-metal