PUlsed MAgnetic field (PUMA) project

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MID European XFEL

24.01.2022

Outline

- Pulsed Magnet experimental setup
- Pulsed Magnetic field research project

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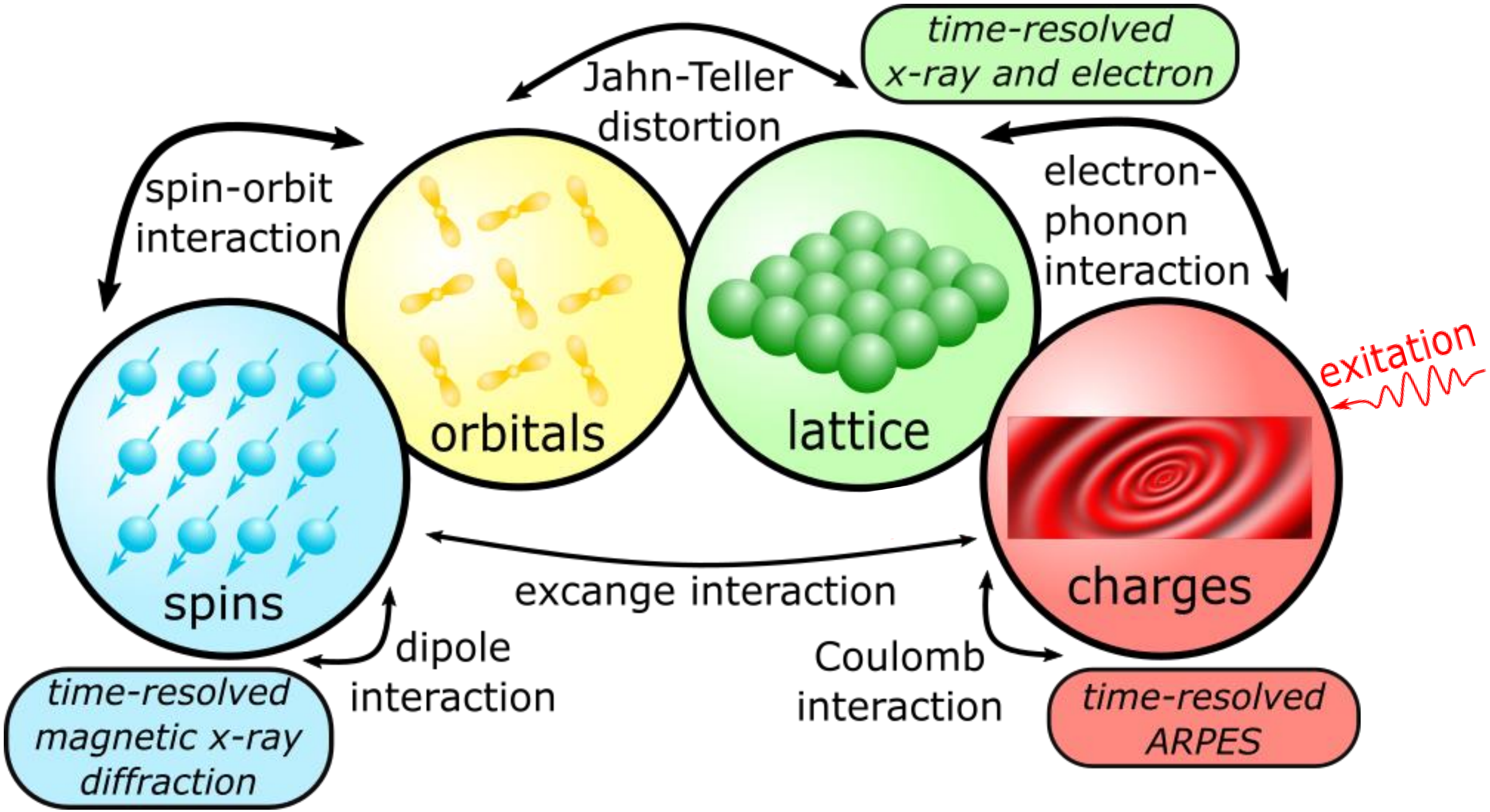
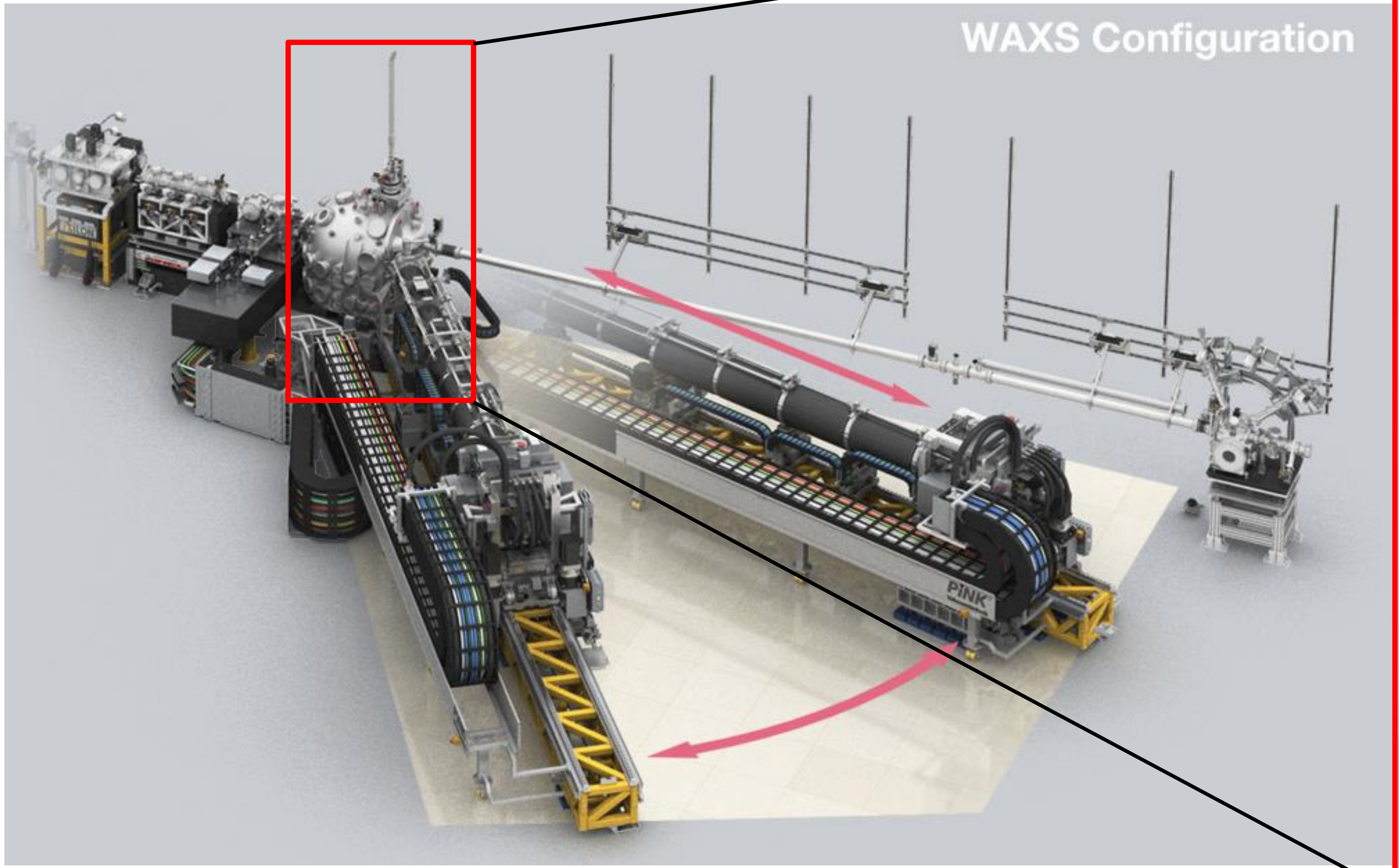
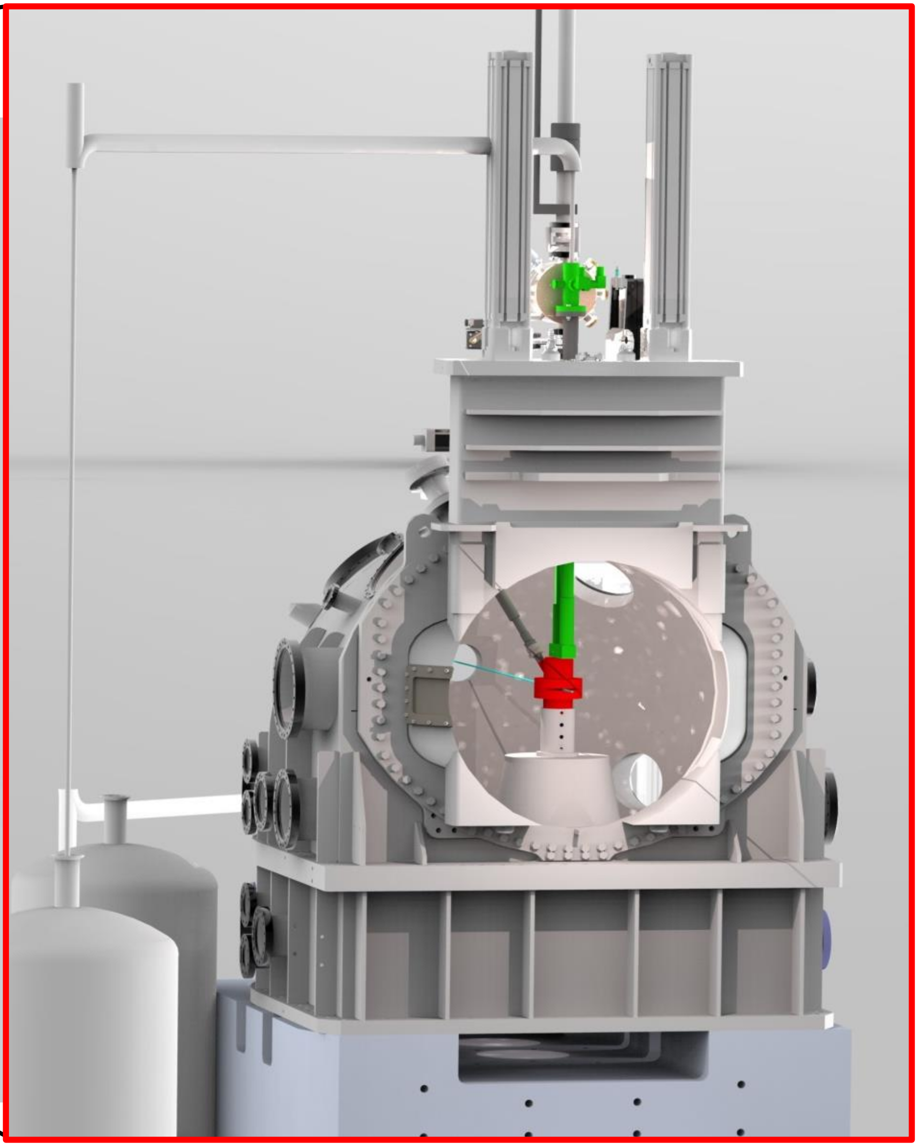
Motivation: Studying the couplings of fundamental degrees of freedom



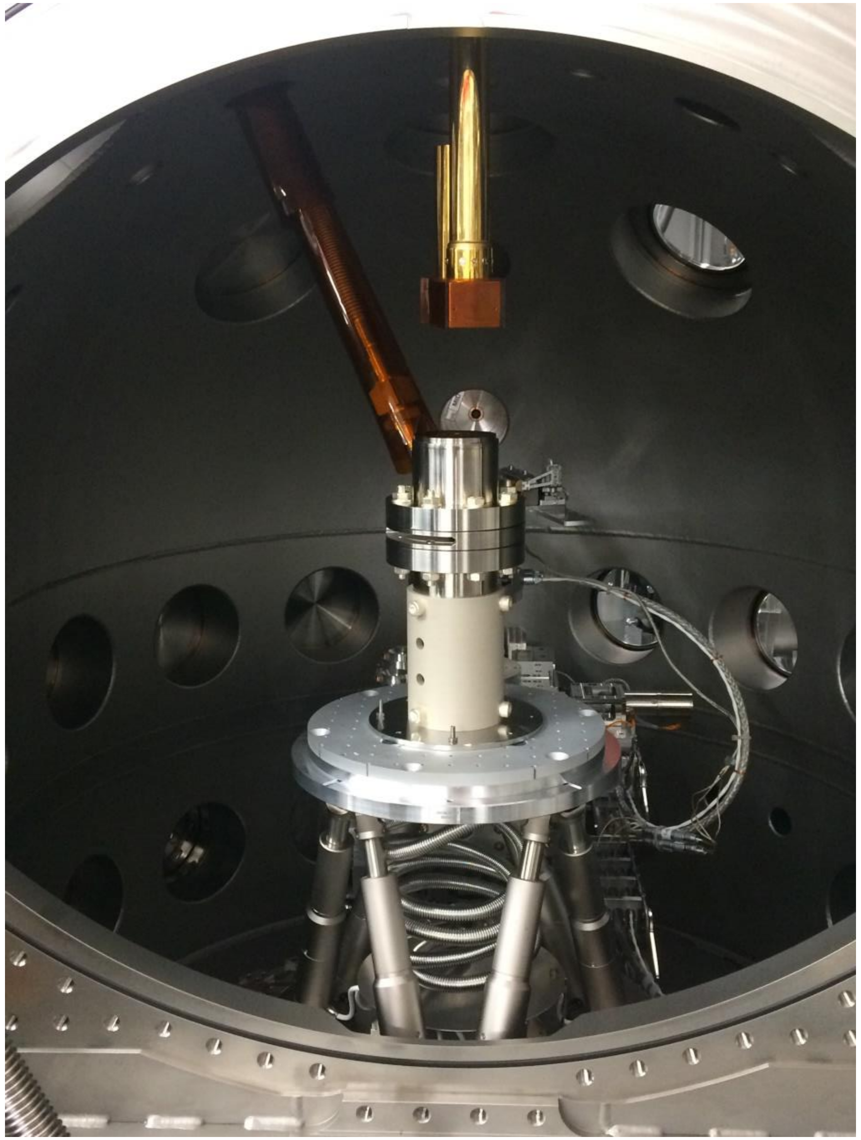
Pulsed magnetic field & helium flow cryostat

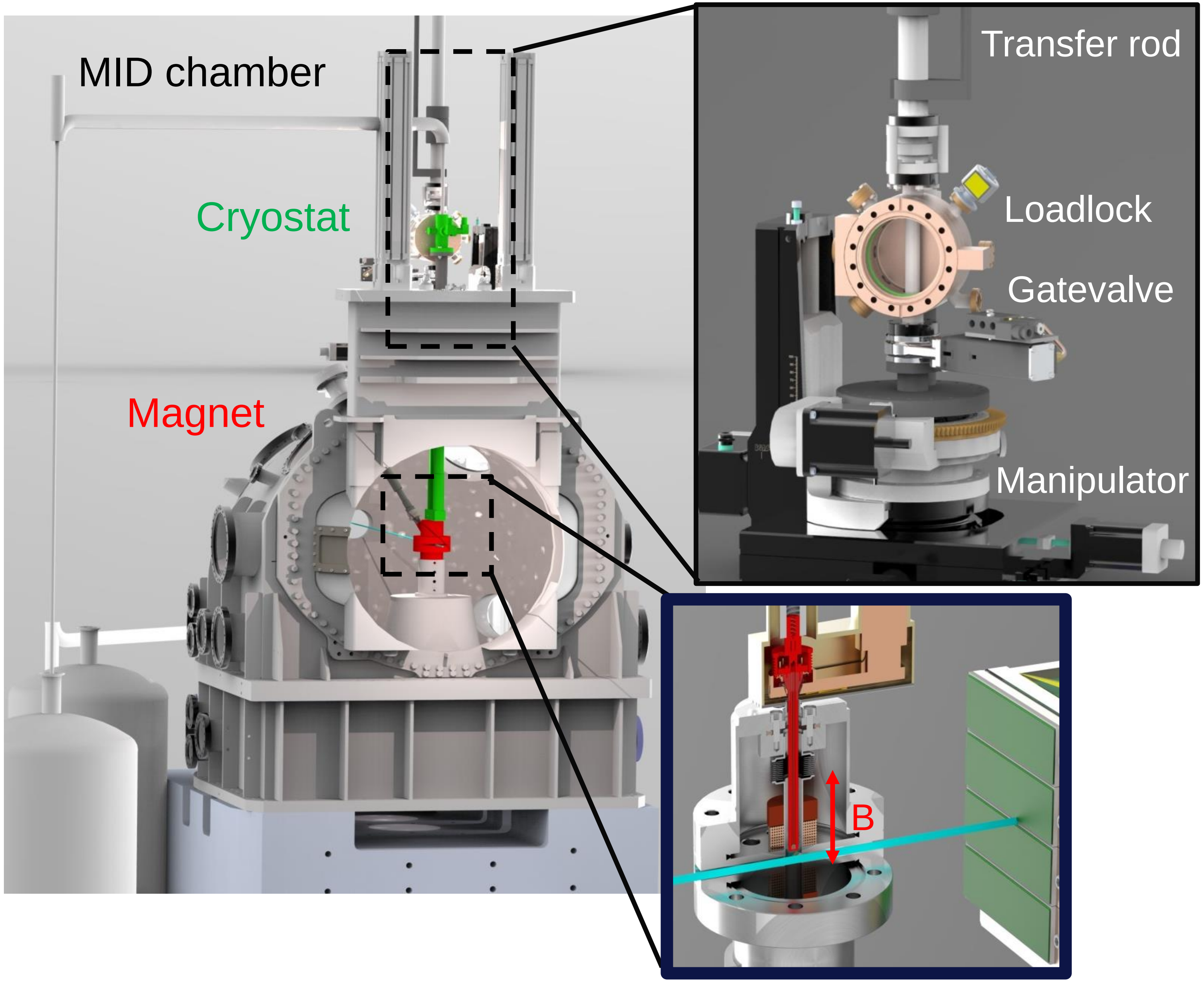
MID chamber





Pulsed magnetic field & helium flow cryostat



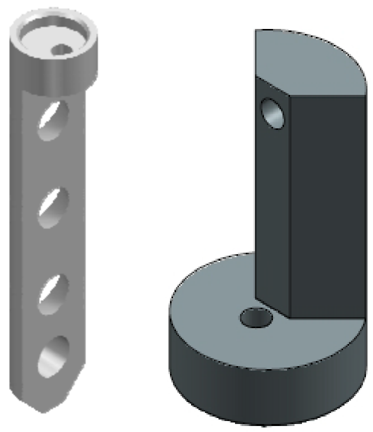


General PUMA setup characteristics

Sample-holders

Materials
Copper / Saphir (Al_2O_3)

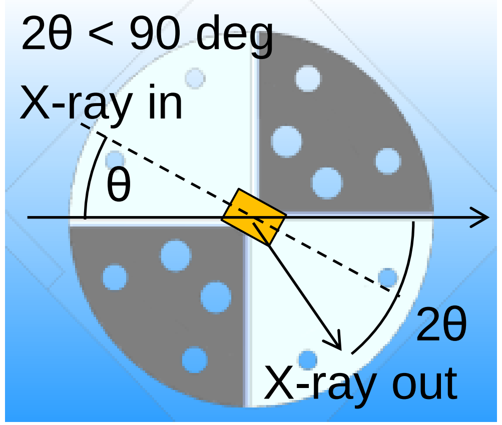
for transmission

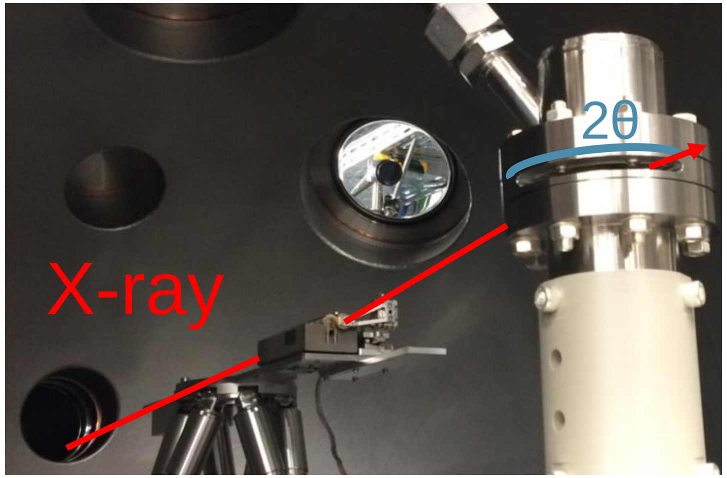


for reflection

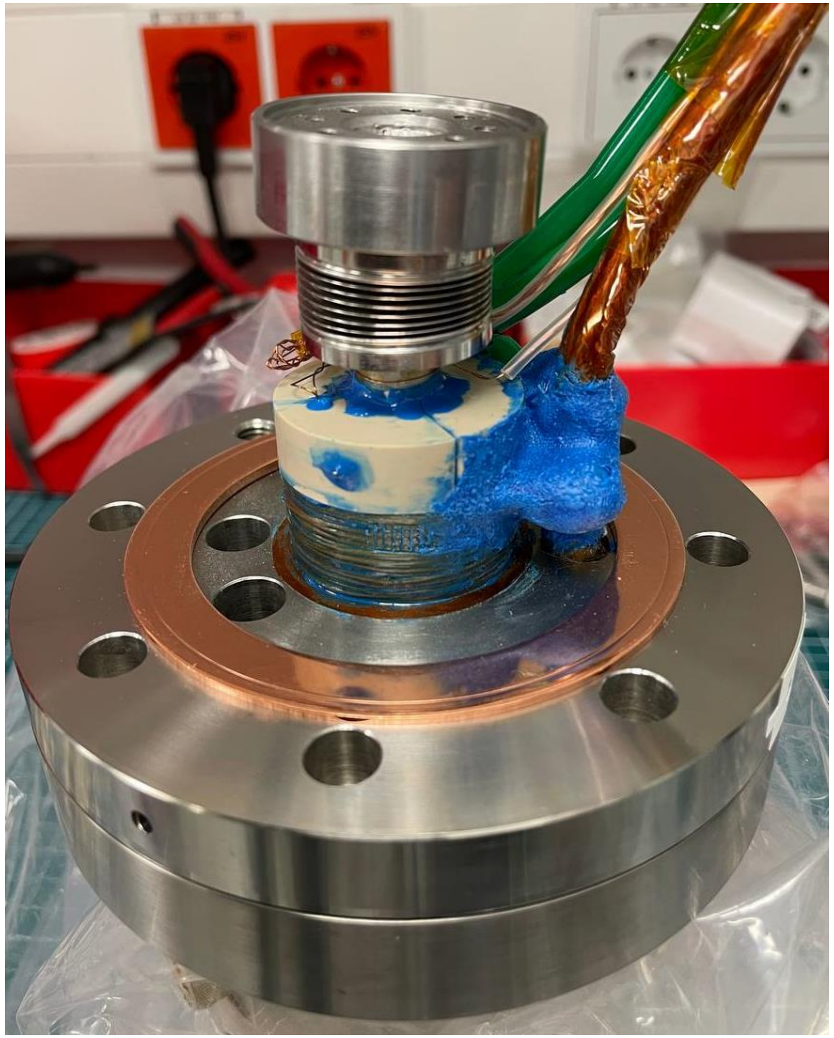
- **Liquid helium flow-cryostat for 7K to 300K**
- Multiple sample-holders available
- Magnetic scattering: θ-2θ horizontal geometry
- θ-rotation ~ 180 deg, 2θ detection up to 50 deg
- 4 electrical contacts for resistivity measurements
- **Miniature coils for pulsed high magnetic field**
  - Up to 15 T vertical magnetic field pulse of 1 ms duration
  - Repetition rate 1 pulse every 5 – 10 seconds
- For more detailed information visit poster James Moore (#50 on Wed)

Scattering geometry

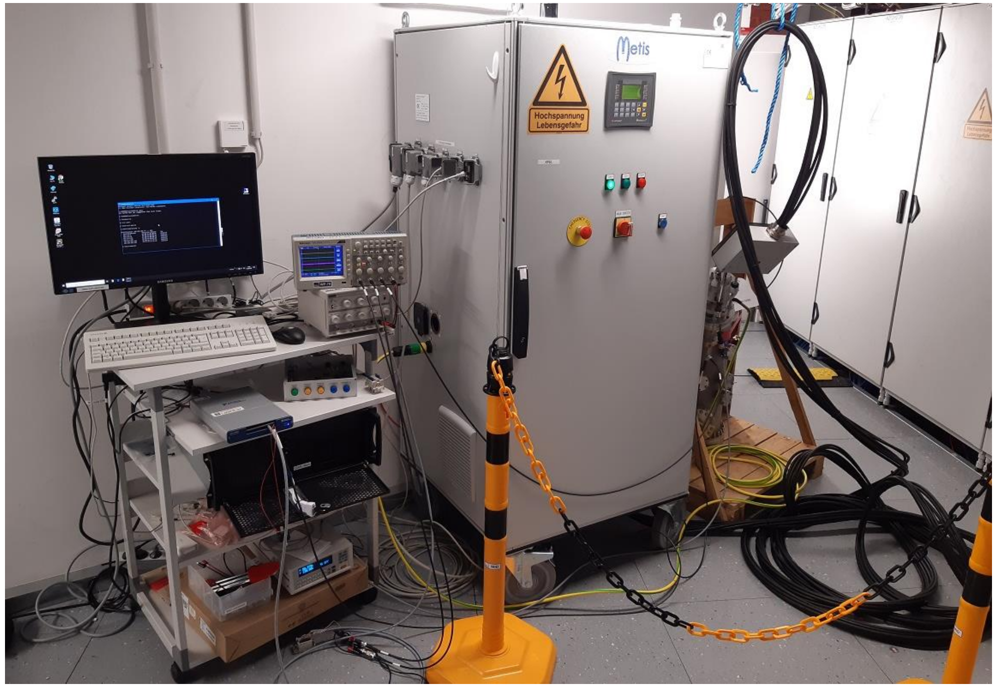




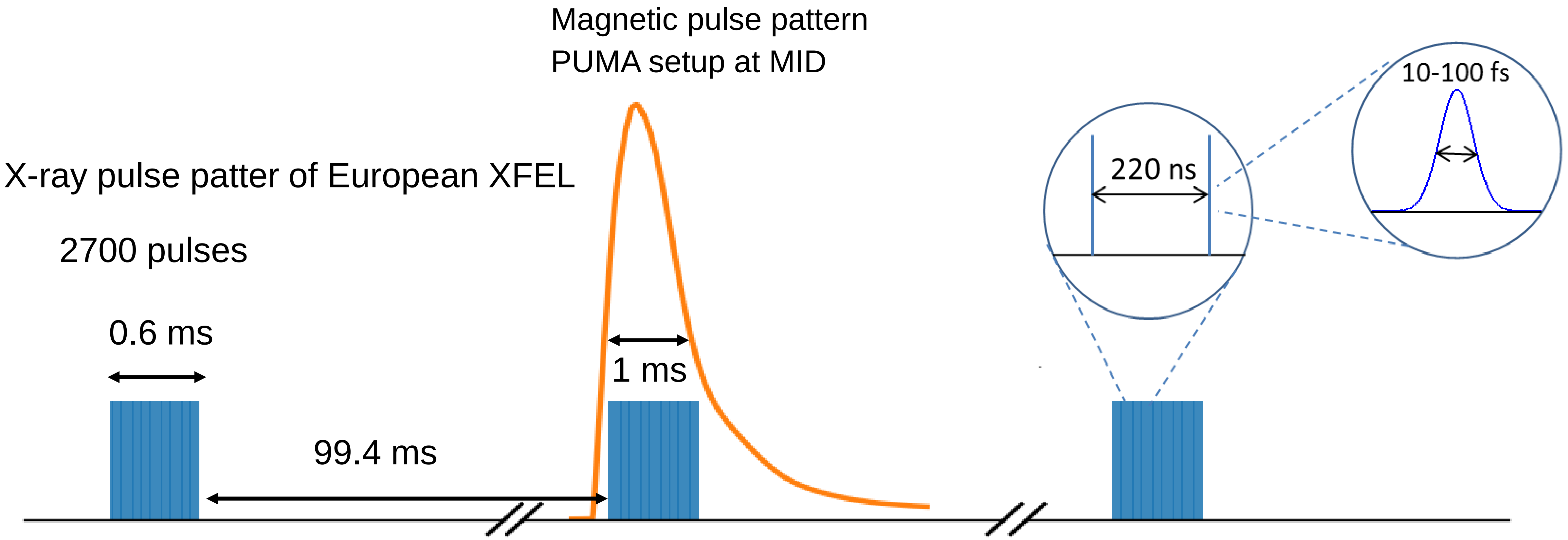
Pulsed high magnetic field coil



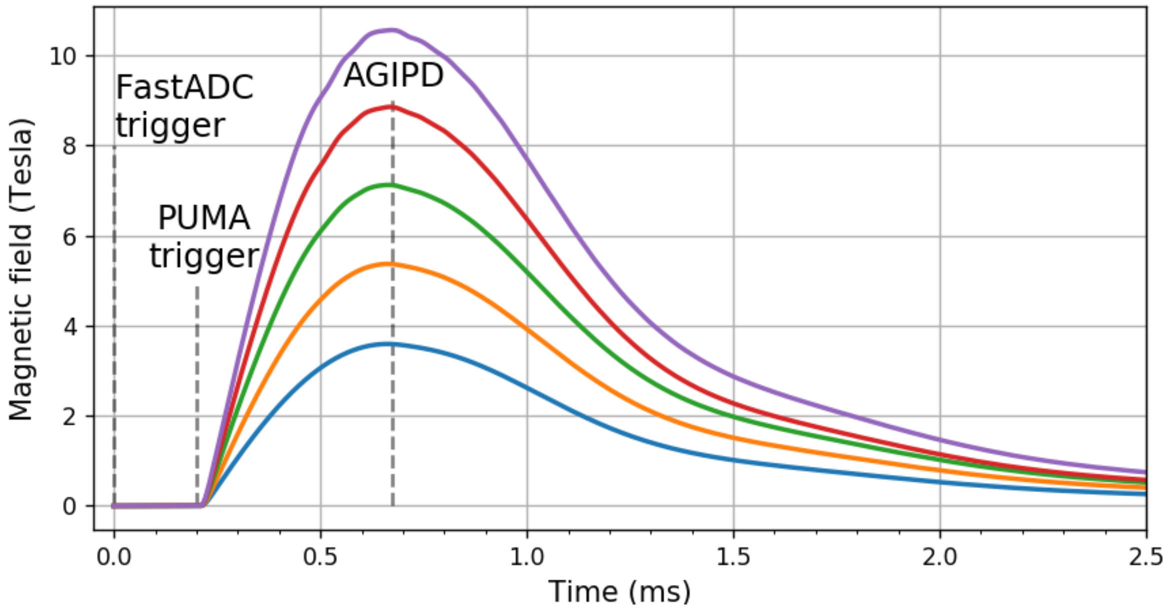
- In-house made split-pair coil by James Moore (SEC group)
- Temperature sensor and pickup coil right above the sample position
- Liquid nitrogen cooled to dissipate heating during a magnet pulse
- Commercial magnetizing unit - 3kV capacitor bank
- Software operation and synchronisation control

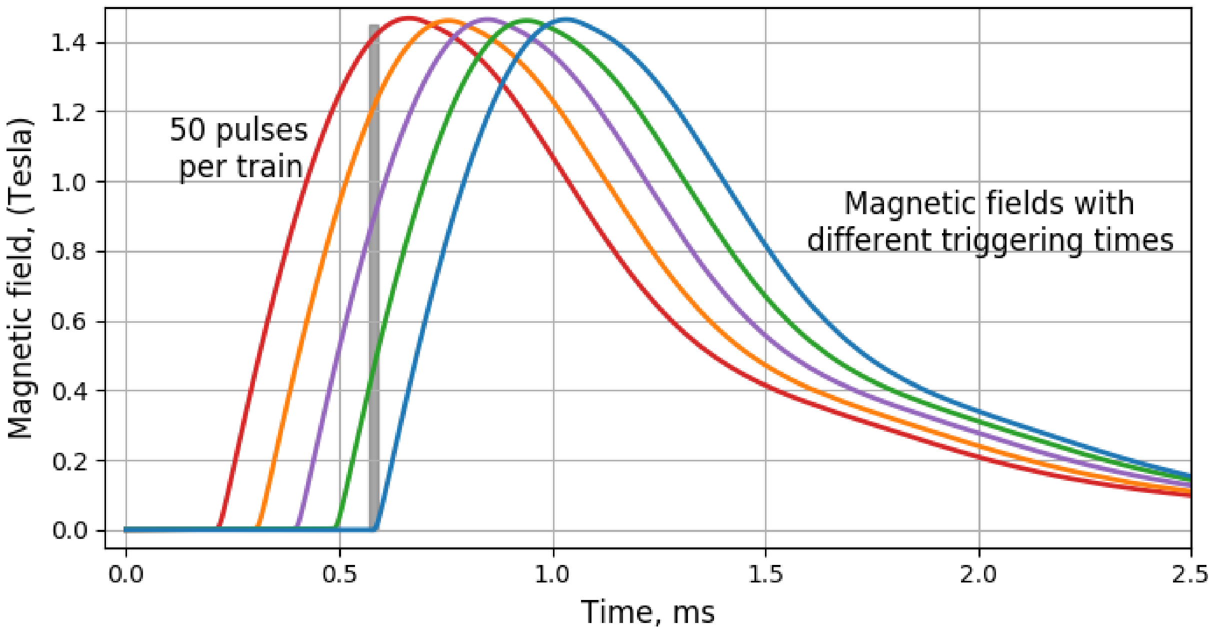


European XFEL Temporal Structure for Magnetic Measurements



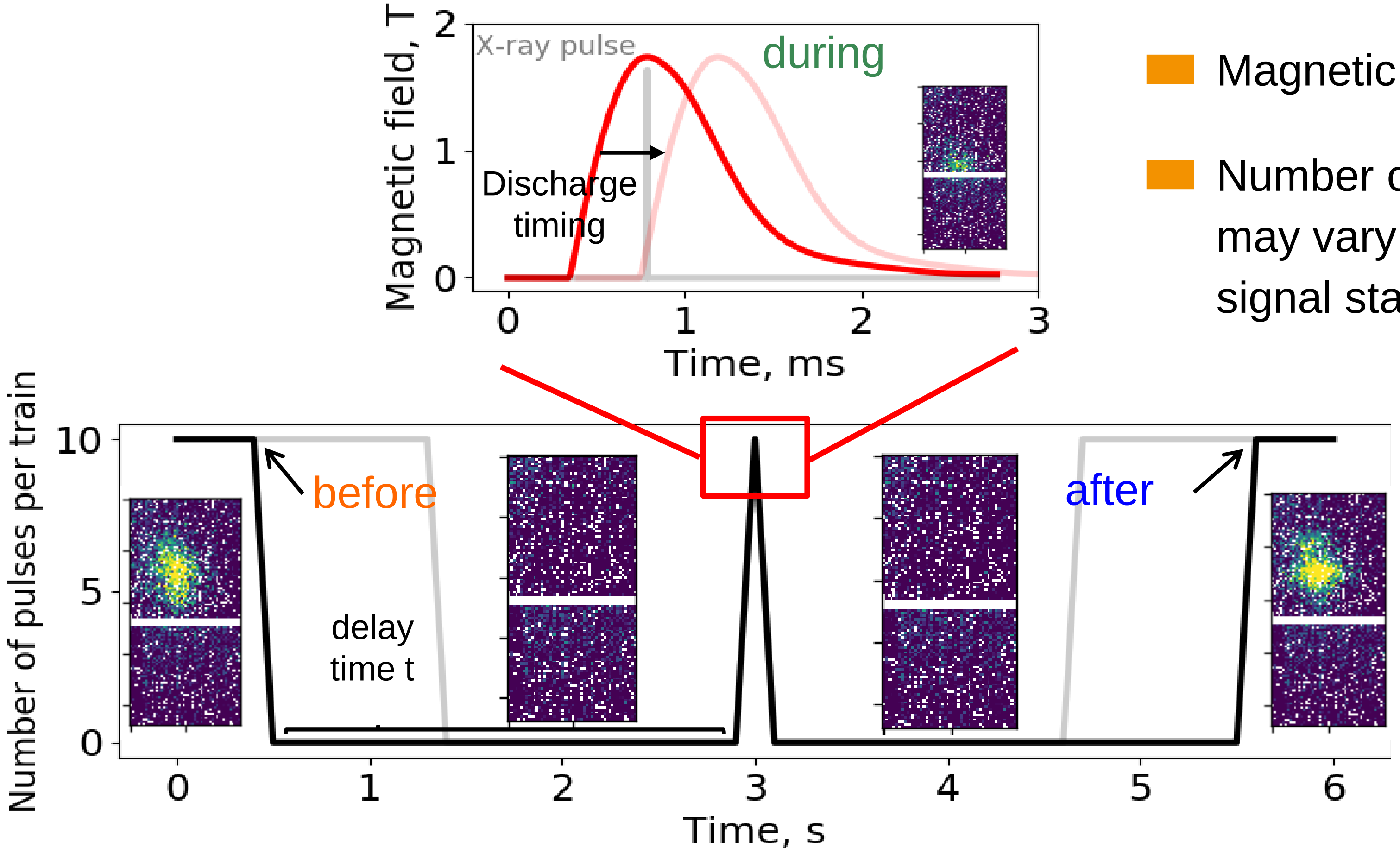
Magnetic and X-ray pulses synchronization





- PUMA trigger timing for discharge strongly connected with X-rays timing and so with AGIPD
- Magnetic pulse length is always constant, independently of power
- Variable PUMA trigger delays to observe sample in different states of dynamical process

Full Pulsed Magnet setup operation



- Magnetic discharge contain one train
- Number of pulses within train with discharge may vary depending on sample damage and signal statistics
- Track intensity and position of reflection before, during and after magnetic discharge
- Minimum delay time t is 100 ms, which corresponds to time between trains

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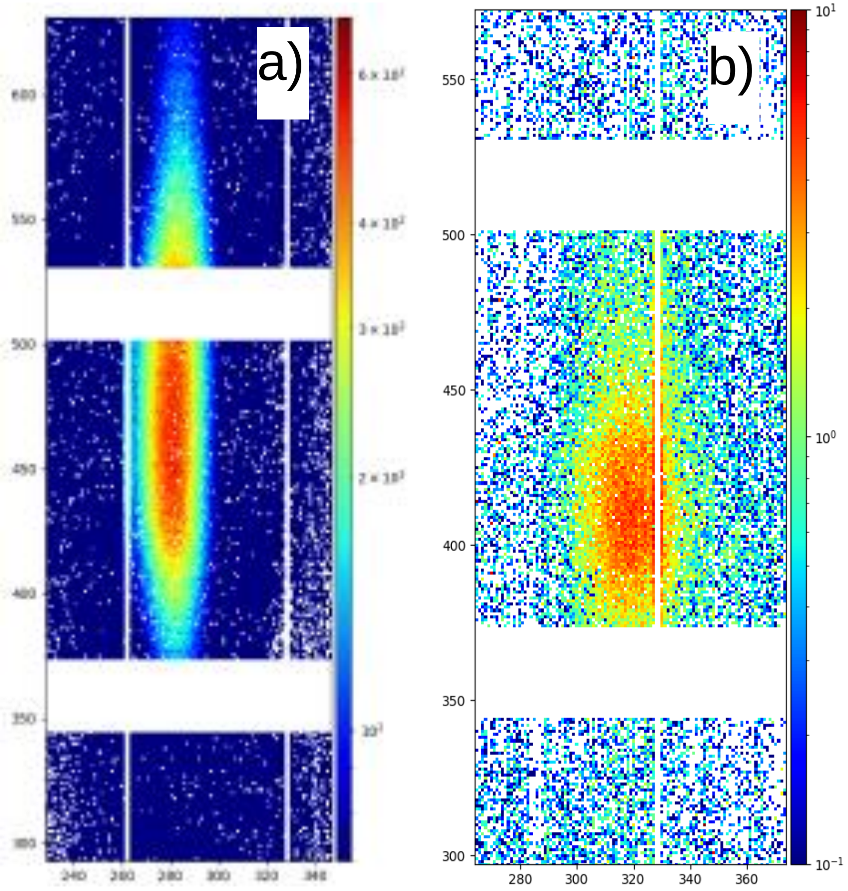
PUMA experiments

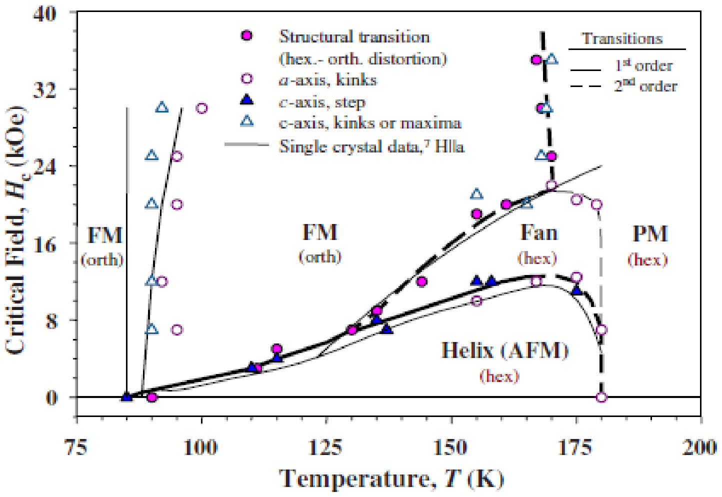


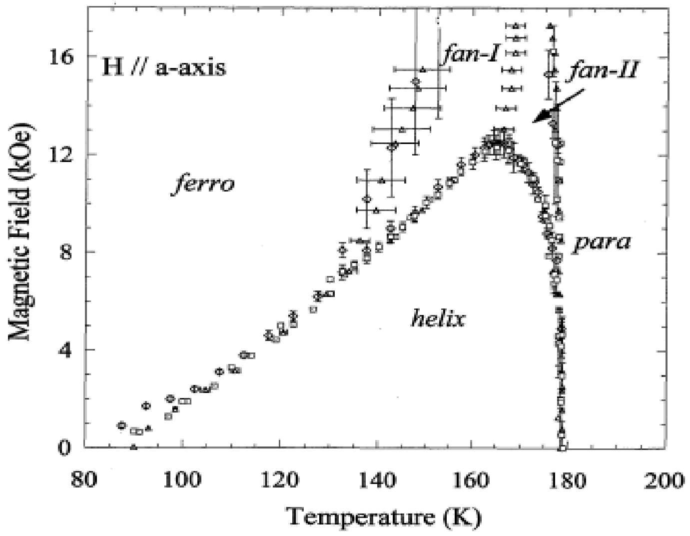
(a) fundamental Cr (002) reflection
(b) CDW peak (00 2-2σ) of Cr
measured by AGIPD

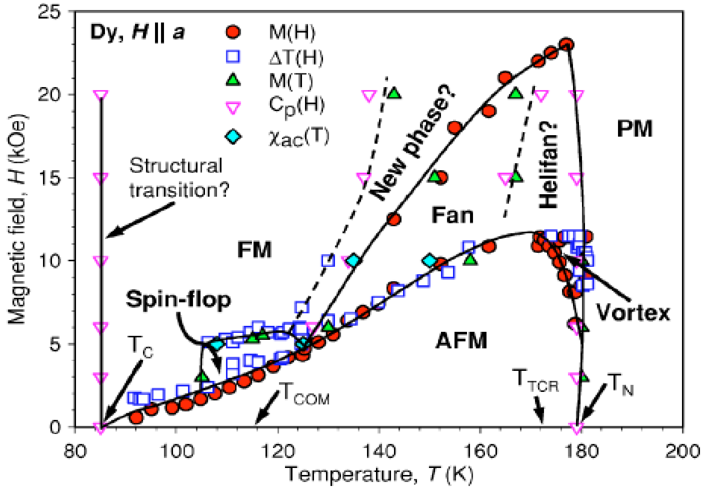
- Samples: Silicon, Chromium, Dysprosium
- X-ray energy 10.5 -11 keV
- AGIPD angle range 2θ from 20.7° to 50.45°
- Maximum applied magnetic field ~ 12 Tesla
- Lowest applied temperature ~20K
- Sample – detector distance 3 and 7.5 meters

Research of Dy phase diagram using PUMA

- Helical antiferromagnetic (AF) structure (c axis) below T_N = 179 K in zero magnetic field
- Ferromagnetic (F) below T_C = 89 K with easy magnetization direction in plane (a axis)
- Strong depends T_N (H)
- Both first and second order phase transition
- Interplay between helix and fan antiferromagnetic phases
- Time resolved observation of phase transition dynamics

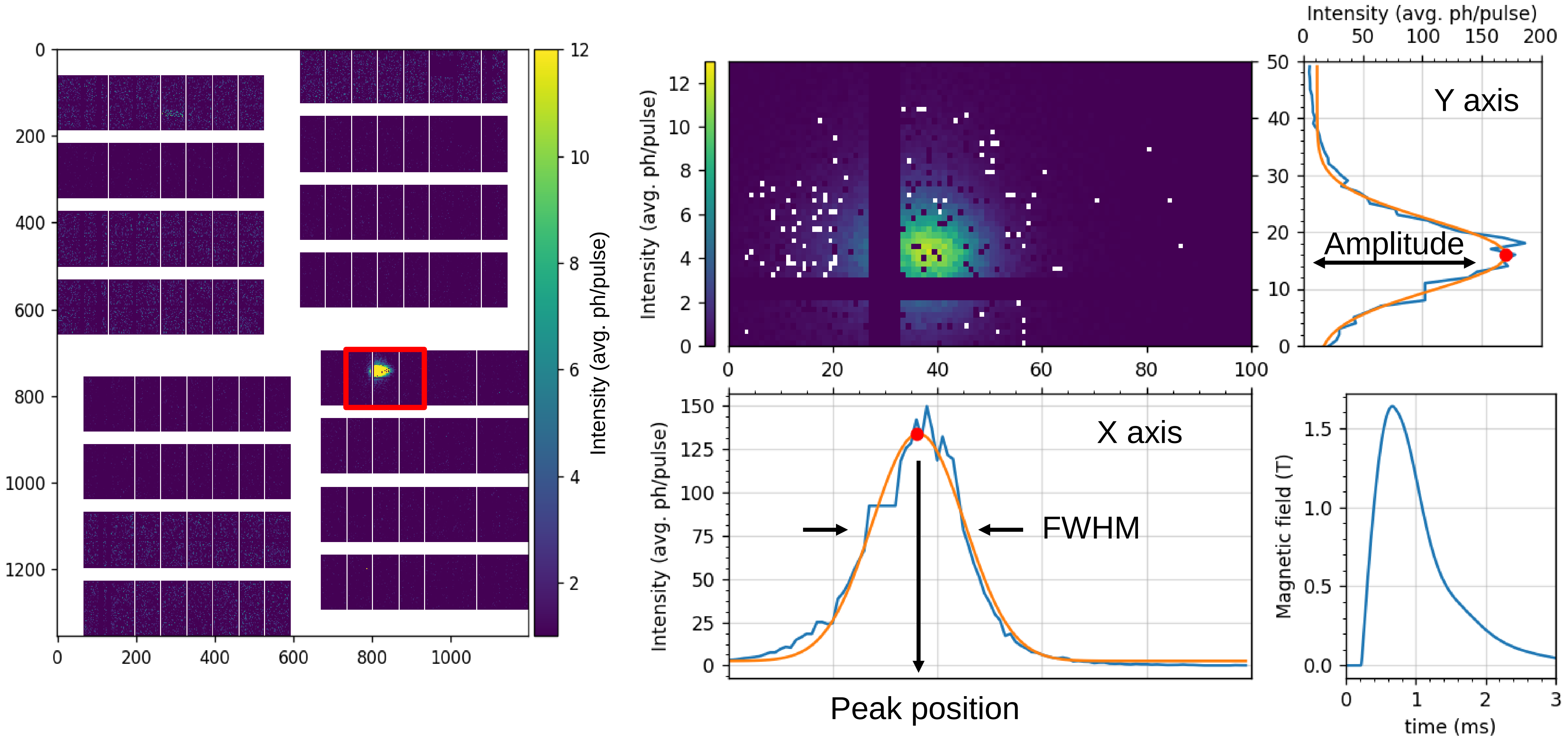






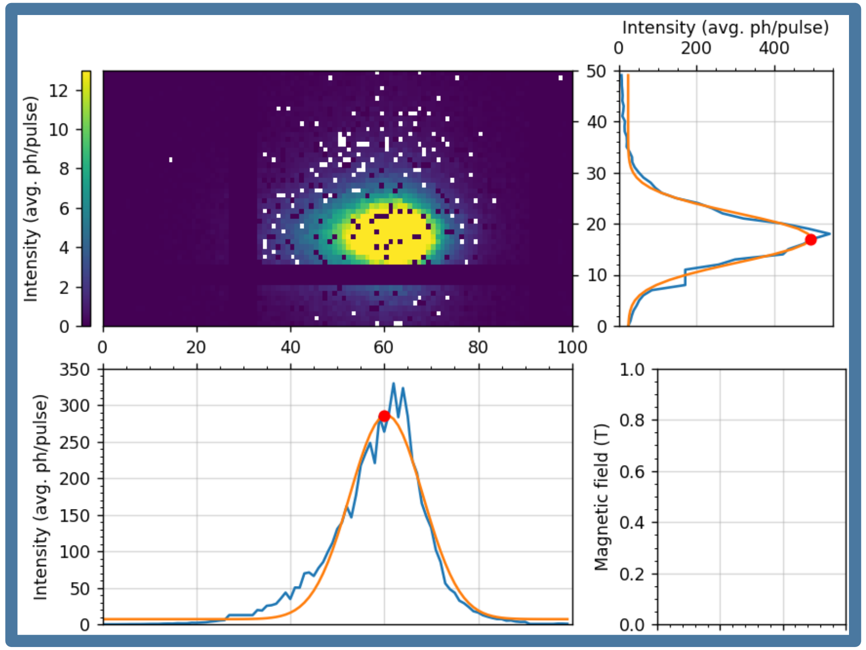
- Yoshtoshi Kida et al, J. Phys. Soc. Jpn **68 No. 2**, 650 (1999) (DOI: 10.1143/JPSJ.68.650)
- A. S. Chernyshov et al, Phys. Rev. B **71**, 184410 (2005) (DOI: 10.1103/PhysRevB.71.184410)
- A. S. Chernyshov et al, Phys. Rev. B **77**, 094132 (2008) (DOI: 10.1103/PhysRevB.77.094132)

Research of Dy phase diagram using PUMA

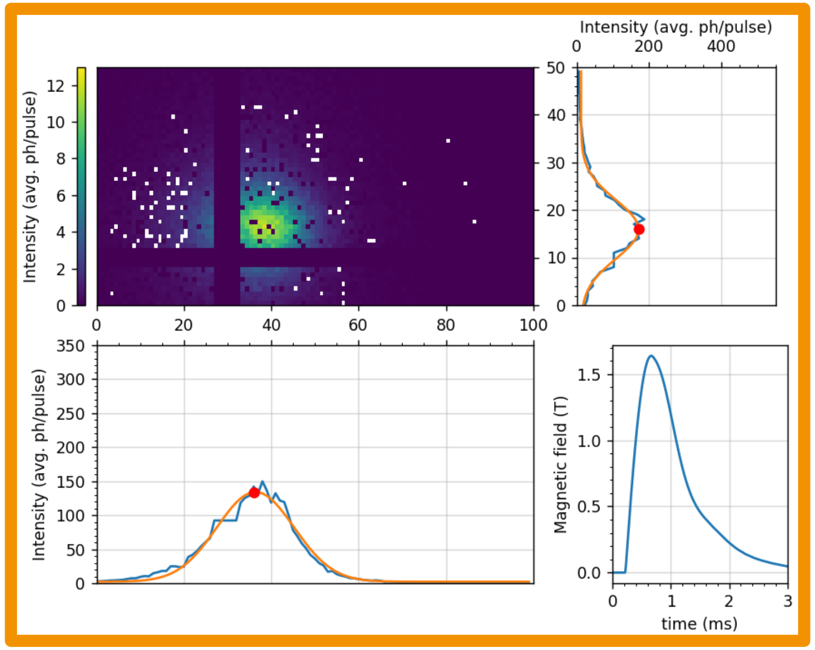


Research of Dy phase diagram using PUMA

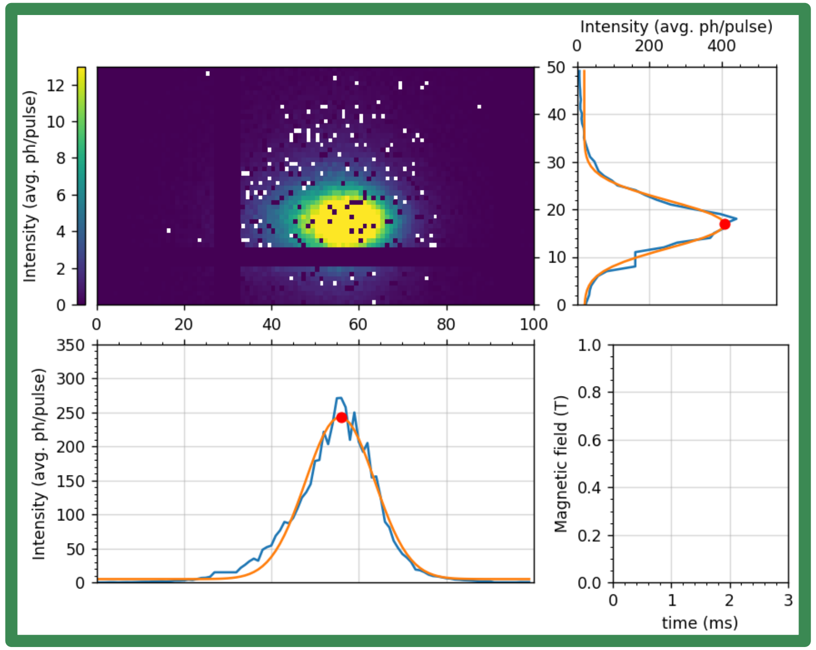
Before discharge

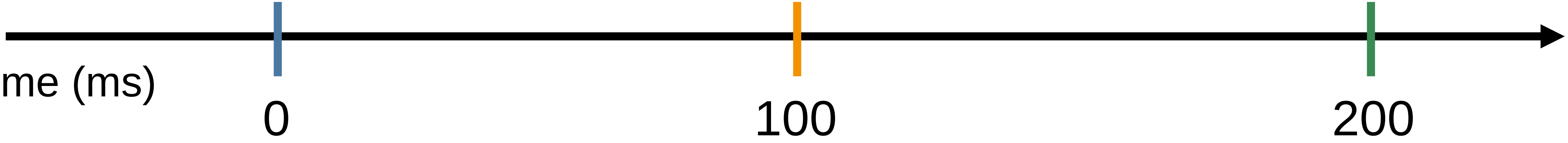


During discharge



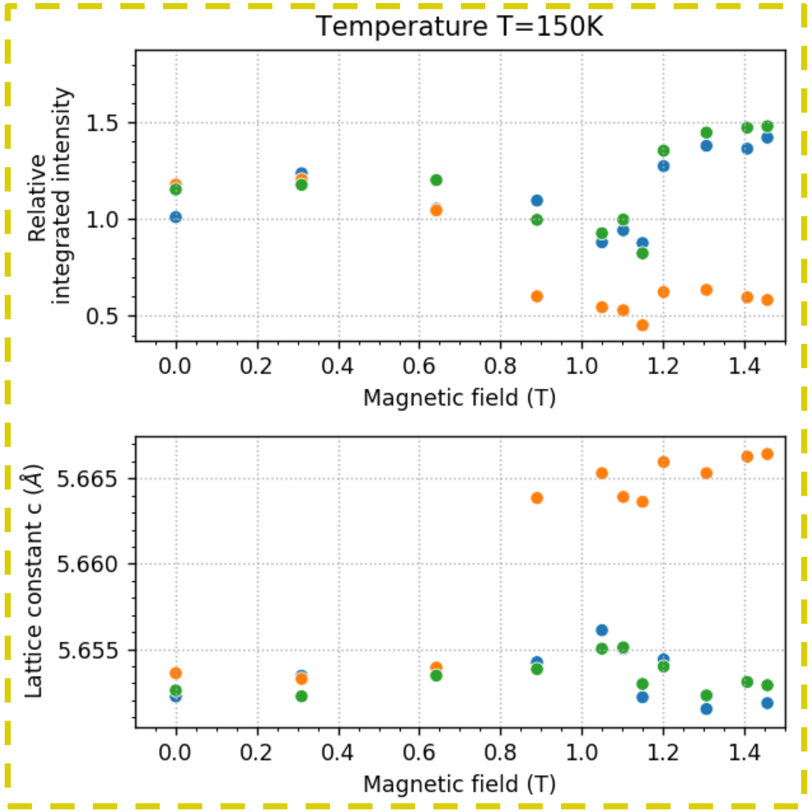
After discharge

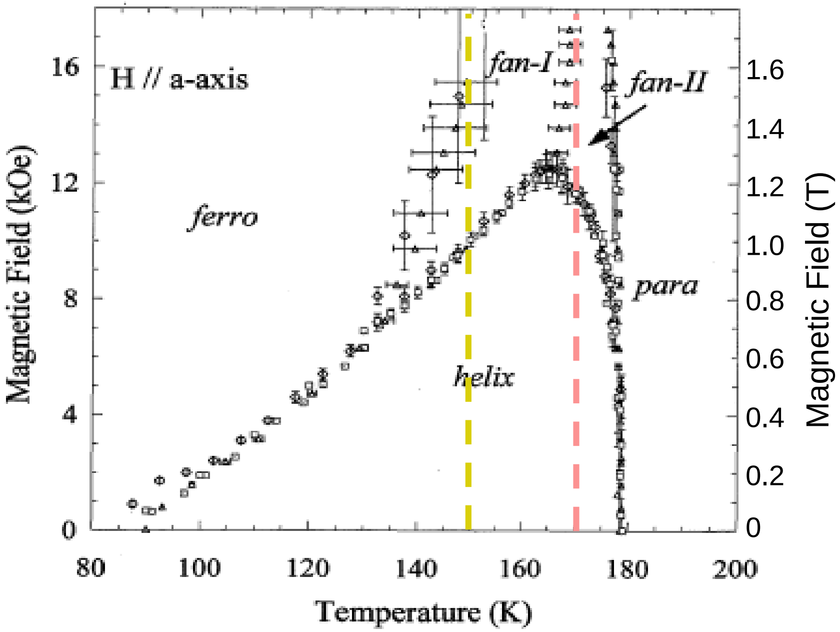


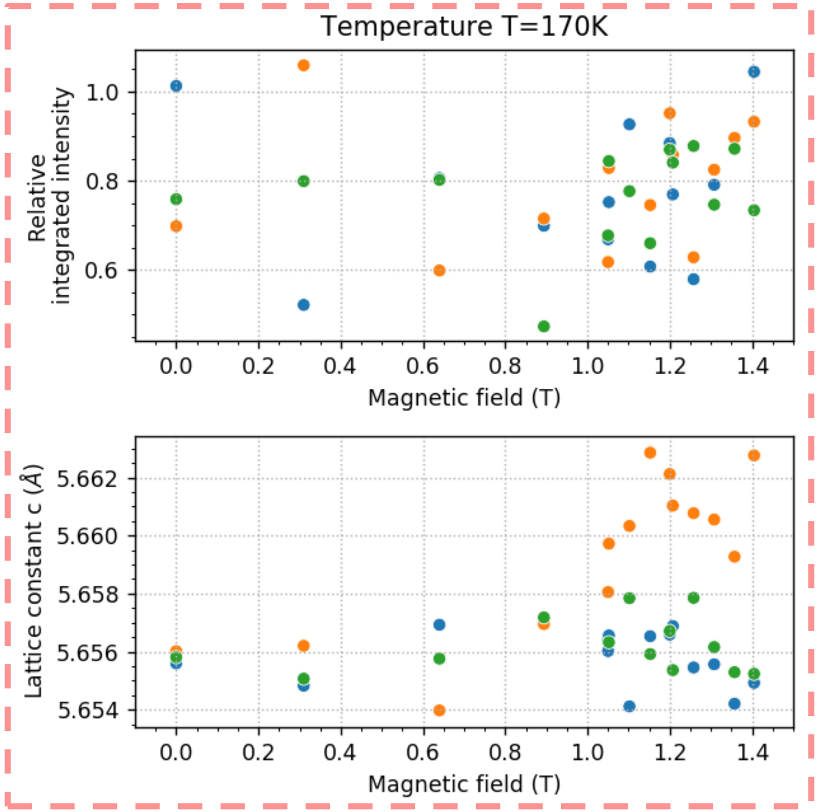


Next magnetic pulse in 20s

Dependence of Dy(002) reflection parameters on the magnetic field







Measurement
- before
- during
- after discharge

Yoshtoshi Kida et al, J. Phys. Soc. Jpn **68 No. 2**, 650 (1999) (DOI: 10.1143/JPSJ.68.650)

Dependence of Dy(002) reflection parameters on the magnetic field

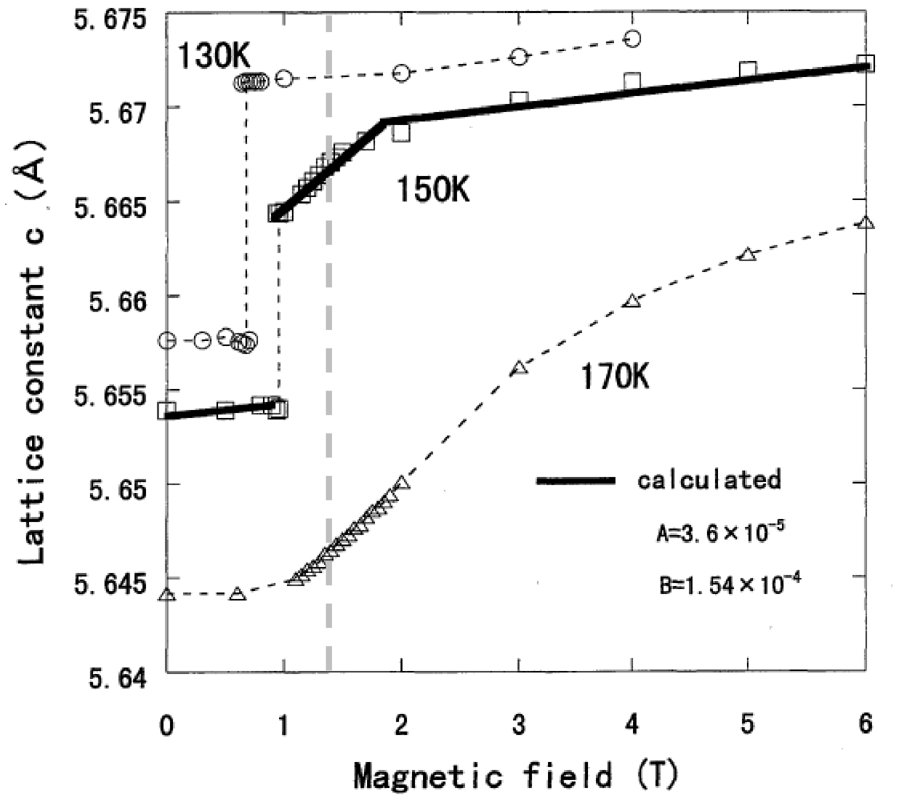
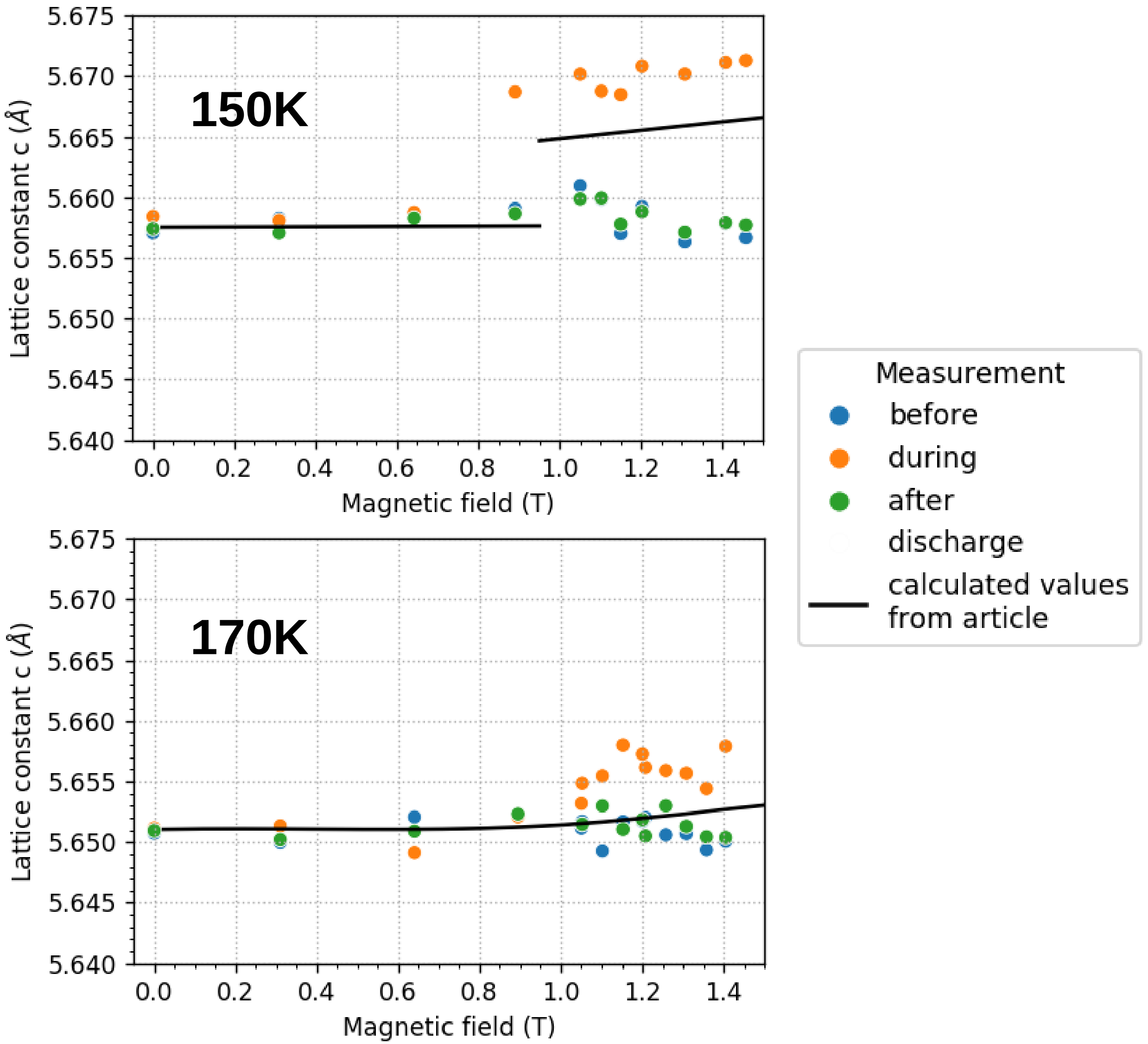


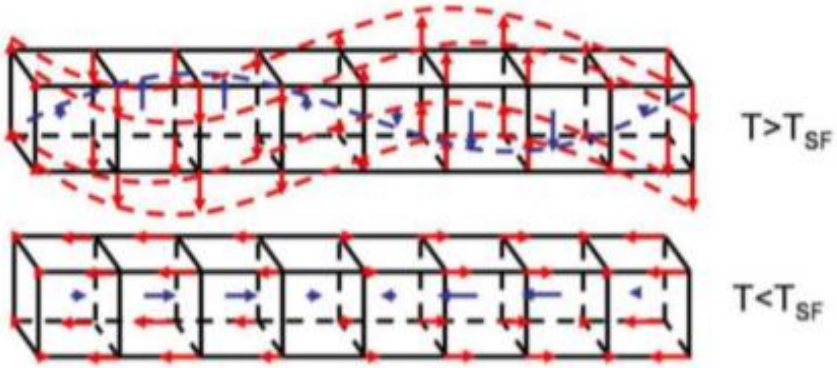
Fig. 3. The magnetic field dependence of the c lattice parameter obtained by the (006) reflections at the temperature of 130, 150 and 170 K. A solid line at 150 K is the result of fitting (see text).

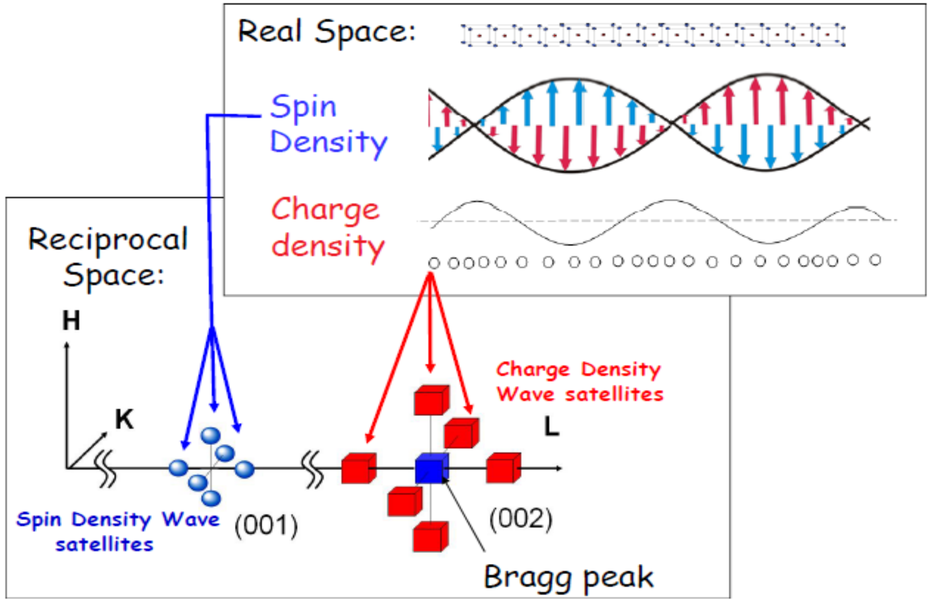


Yoshtoshi Kida et al, J. Phys. Soc. Jpn **68 No. 2**, 650 (1999) (DOI: 10.1143/JPSJ.68.650)

Study of charge and spin density waves dynamics in Cr

- Antiferromagnetic below T_N = 311 K
- Spin-flip transverse to longitudinal wave at 122 K
- Connection between charge and spin density waves
- Magnetic field induced domain structure dynamics

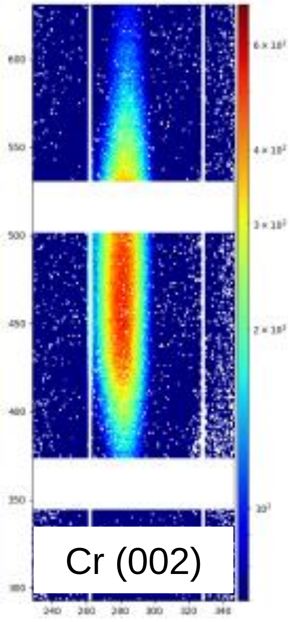


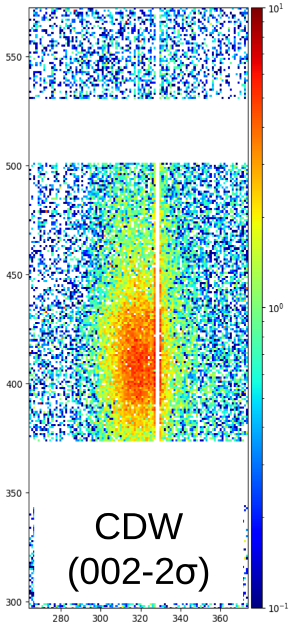


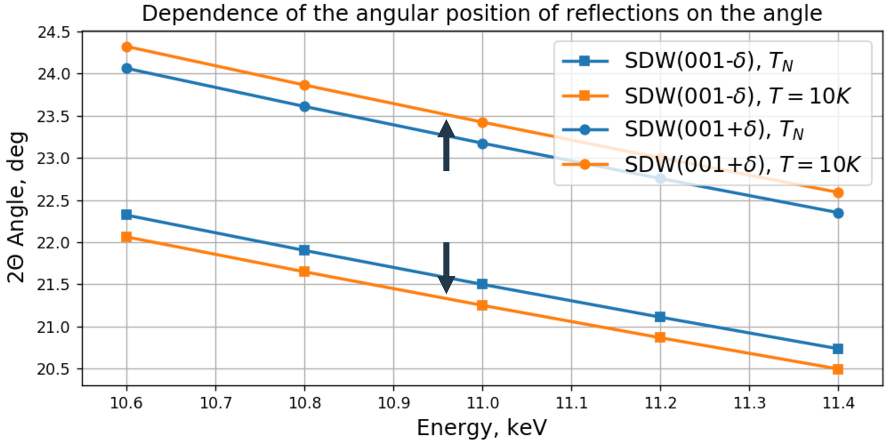
- V. L. R. Jacques et al, Phys. Rev. B **89**, 245127 (2014) (DOI: 10.1103/PhysRevB.89.245127)
- O. G. Shpyrko et al, Nature Vol **447**, 68 (2007) (DOI: 10.1038/nature05776)

Study of temperature dependence of SDW satellites Cr (001±δ)

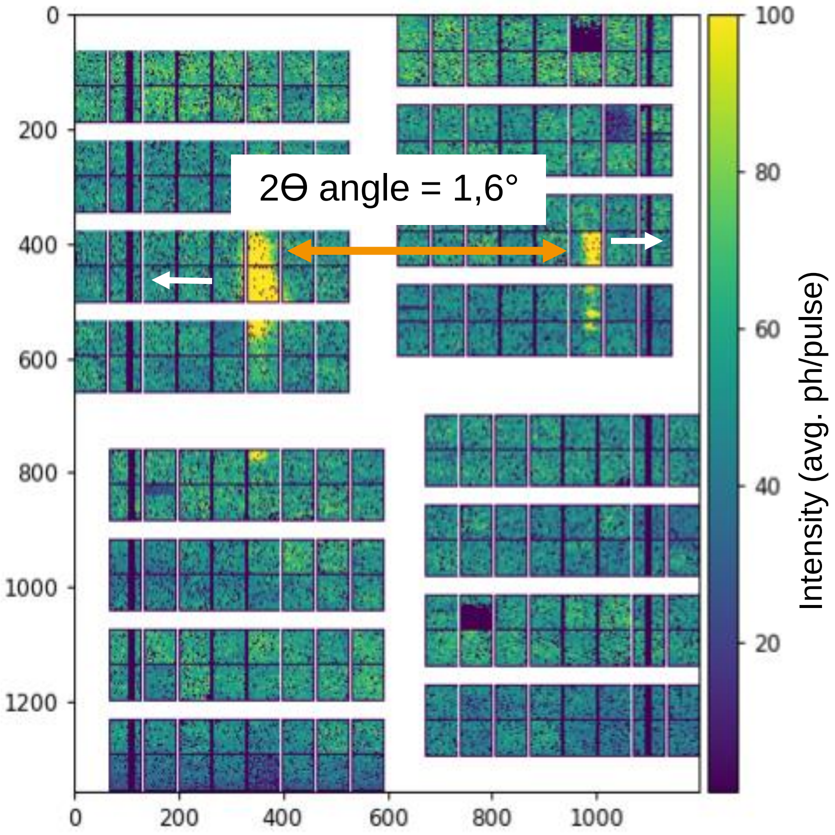
h k l	Θ angle	2Θ angle
0 0 2	22.79°	45.58°
$0\ 0\ 2-2\delta$	21.66°	43.33°
$0\ 0\ 1-\delta$	11.7°	23.41°



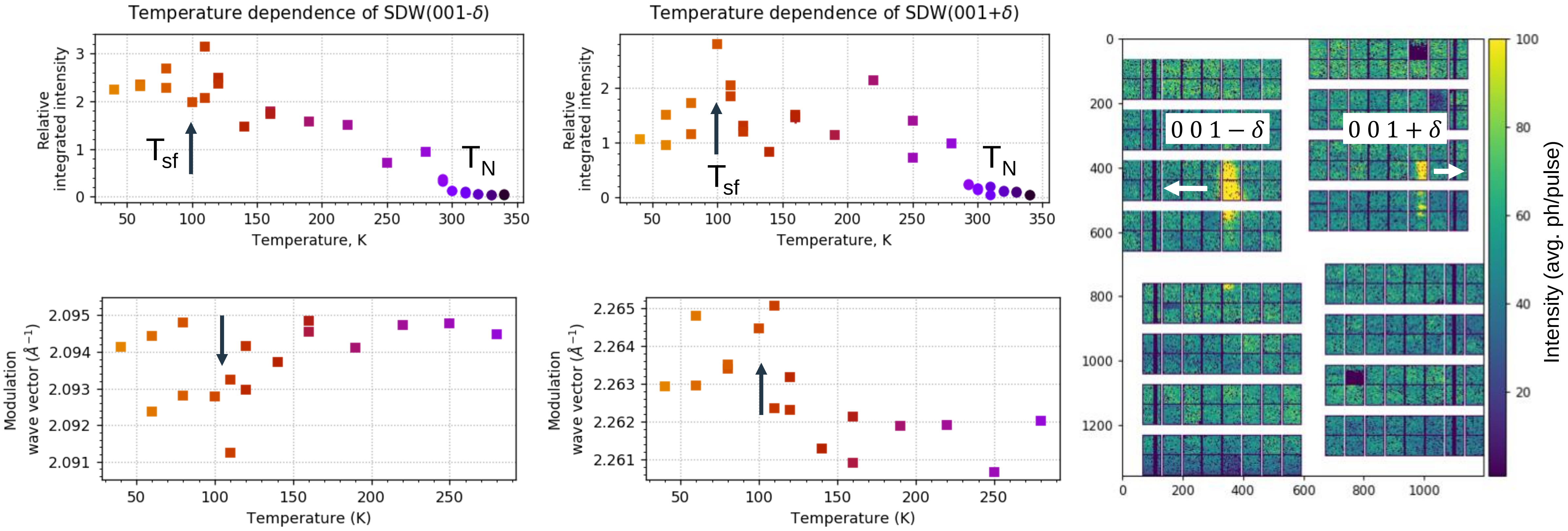




h k l	Θ angle	2Θ angle
$0\ 0\ 1+\delta$	11.7°	23.41°
$0\ 0\ 1-\delta$	10.9°	21.72°
	Δ = 0.8°	Δ = 1.67°



Study of temperature dependence of SDW satellites Cr (001$\pm\delta$)



Thank you!

Software

Christopher Youngman

Riccardo Fabbri

Robert Schaffer

Marijan Stupar

Andrea Parenti

Bruno Fernandes

Scientific advice

Anders Madsen

Gerhard Grübel

Cornelius Strohm

Vincent Jacques

David Le Bolloc'h

Engineering

James Moore

Iker Lobato

Konstantin Sukharnikov

Alexander Bartmann

Gabriele Ansaldi

Andreas Schmidt

Experiment

Jorg Hallmann

Ulrike Bosenberg

Johannes Moller

Roman Schayduk

Alexey Zozulya

Markus Scholz

Angel Rodriguez-Fernandez

Felix Brausse

Lu Wei

Dieter Lott

Vasilii Bazhenov

Robin Schubert

Mark Busch

Rainer Behn

Scattering geometry for Cr(111)