

Requirements on a MTCA based beamline control system

Martin Tolkiehn

Deutsches Elektronen-Synchrotron

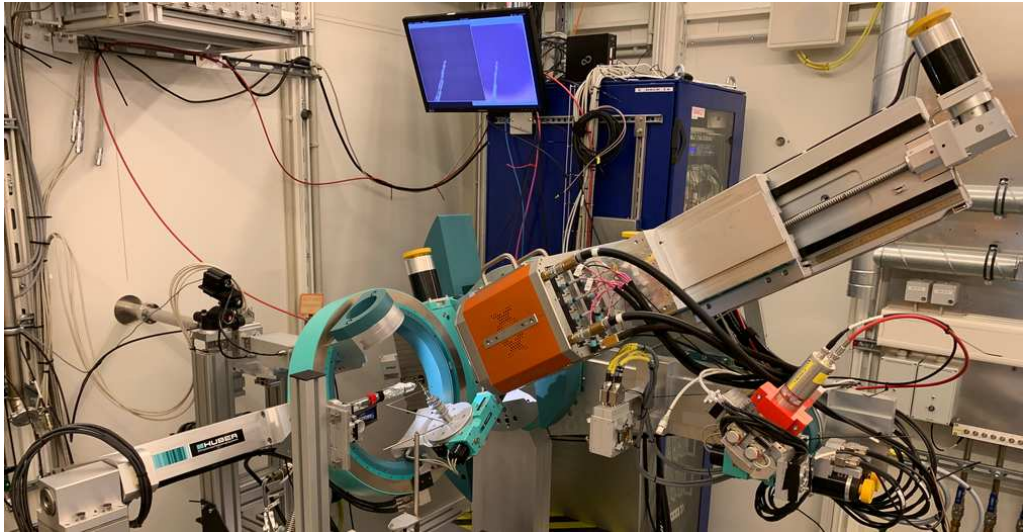
Ein Forschungszentrum der Helmholtz-Gemeinschaft

2026年9月16日

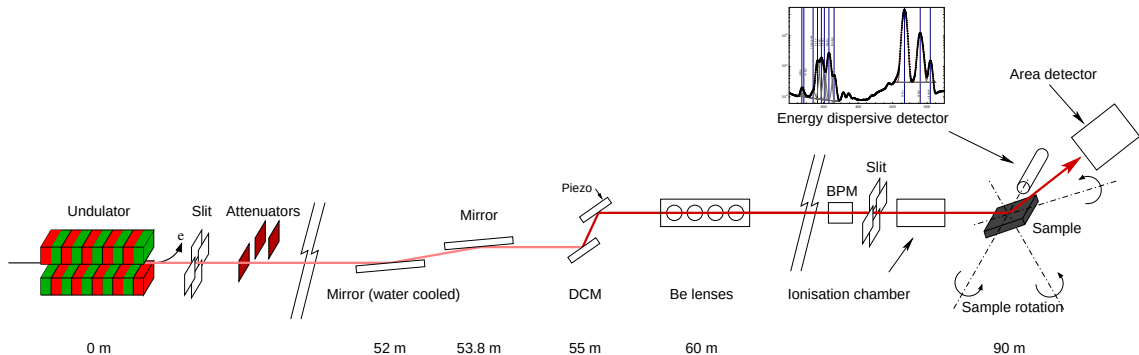


- Introduction — beamline P24
- Available MTCA hardware
- Applications

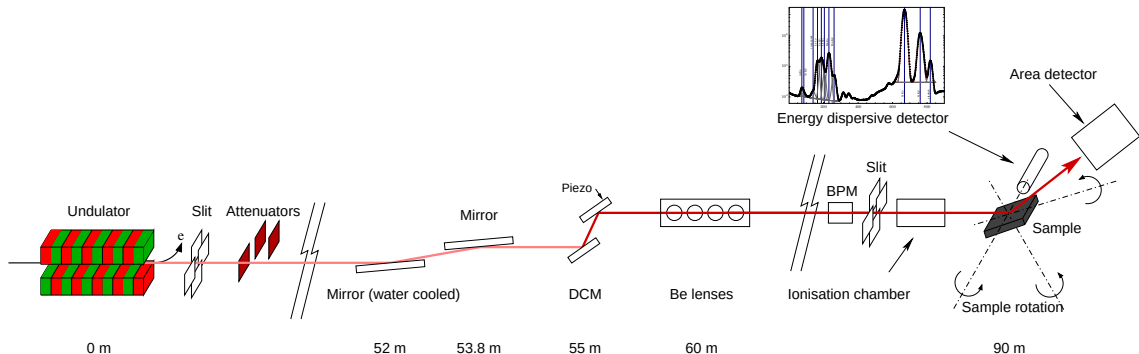
Four circle diffractometer at P24



Chemical crystallography beamline P24

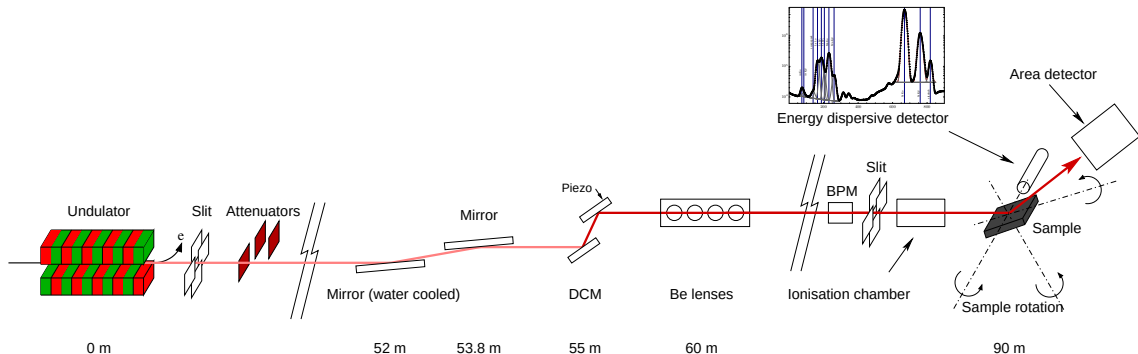


Chemical crystallography beamline P24



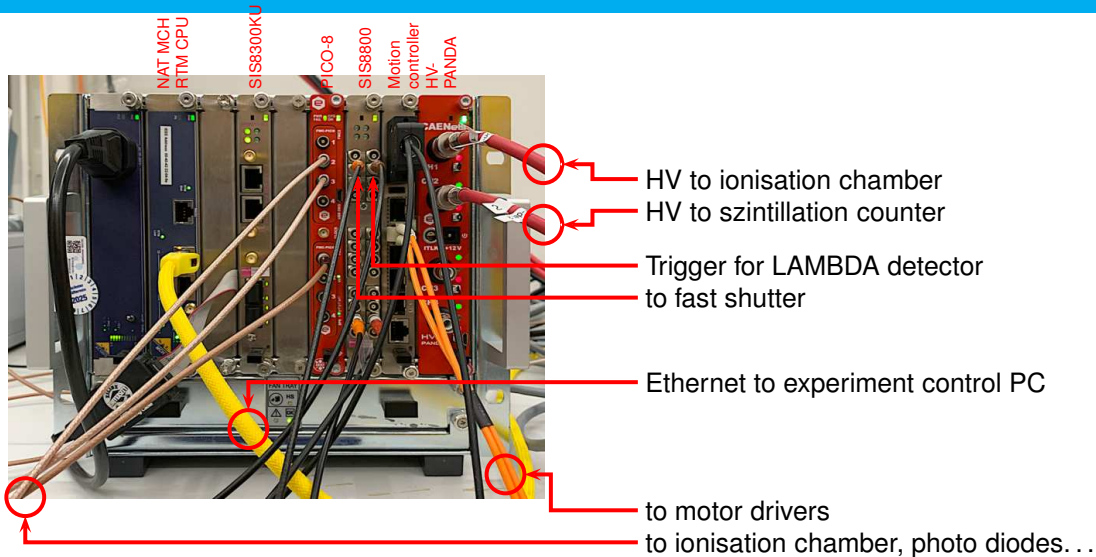
- Motion controller
- Piezo controller
- GPIO (Attenuators, CRLs, ...)
- HV supply, Picoamp. meter (Ionisation chambers)
- Precise detector triggering
- Spectroscopy system
- Szintillation detector read out
- other...

Chemical crystallography beamline P24



- Coordinated movement (different axes, DCM+Undulator...)
- Feedback loops (e.g. Monochromator stabilization)
- Automatic attenuator insertion
- Scans (step scans and on-the-fly scans) — synchronization!

MTCA.4 hardware in use at P24



Ionisation chamber readout



CAENels HV-PANDA

- 4 channel HV source
- positive or negative polarity
- Interlock functionality
- **obsolete!**



CAENels PICO 1M4

- 4 channel picoamp meter
- FMC-Carrier is needed
- Software is needed!



SIS8864 64bit GPIO

- 2x 32 channels on front panel (direction programmable)
- PCIe, GbE
- Synchronization with other devices via MLVDS

Struck SIS8800 multi channel scaler + SIS8980



SIS8980 + SIS8800 multi channel scaler

- Replacement for SIS3820
- 16 channels on front panel
- 16 channels via RTM (discriminator RTM)
- Synchronization with other devices via MLVDS
- BSP from Struck

SIS8300KU with γ spectroscopy firmware



Based on Struck SIS8300KU:

- 10 Channels 16 bit, 125MS/s
- XCKU040-1FFVA1156C Kintex Ultrascale FPGA
- 4x PCIe Gen3, 2GB DDR4 RAM
- MLVDS for synchronization
- RTM with DC coupling and amplifier
- *AI based noise removal*
- 125eV energy resolution at shaping times $< 1\mu s$!

MTCA based motion controller

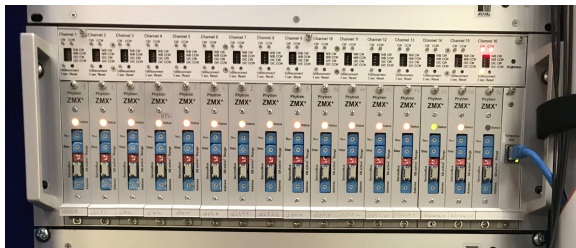
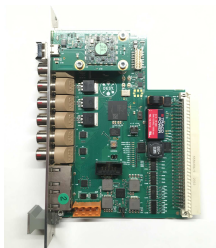


- Up to 48 stepper motors
- Programmable trigger signals
- Synchronization of many cards (μs precision)
- Heterogeneous Processing:
 - Zynq UltraScale+ (XCZU2EG) with 2GB DDR4 32-bit (runs interface software for external control system)
 - Kintex (XC7K160) with 4GB DDR3 64-bit (real time processing)
- Based on open source FWK firmware framework
- Future: CANopen CIA 402 over EtherCAT
- Supported by spec (Future: EPICS, Tango, ...)
- Will be commercially available...

DESY-ITT funded project in collaboration with DESY-MSK
(N. Radakovic, M. Fenner, M. Randall, Ç. Gümüş et al.)

ZMX motor driver crate

One 4U crate for 16 axes:



Left: ZMX adapter board (4 pieces required!)

Middle: Close up of rear panel with adapter card, motor and encoder connectors

Right: Front panel with 16 Phytron ZMX motor driver modules

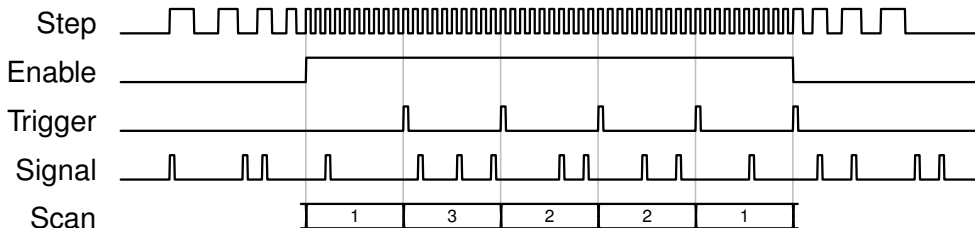
MTCA based motion controller — trigger signals

- Different trigger signals (MLVDS or front panel GPIO) can be defined
- For every trigger signal a start and end event or a duration can be defined.
- These events can be rising and/or falling edge of
 - motor moving signal
 - motor step signal (forward, backward or both directions, division is possible)
 - encoder step signal
 - software trigger



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On-the-fly scans with SIS8800: flysetup and flyscan

```
MCS Fly Scan Setup using SIS8800-MCS (MCA unit 0)

Select allowed fly scan motors: [tth] [th] [chi] [phi] [dtesth] dtestv2>

Configure allowed fly scan motors: tth th chi phi dtesth m7
Use manual value for steps per unit for FLY motor (phi)? NO
Motor pulses per degree/mm (phi)? ---
MCS counter number for channel advance and prescaling (phi)? < [50] 51>

Start mode? ON START
Word size? 1 2 [4]

Enabled channels? [1:sec] [2:mon] [3:det] [4:gpio]
Normalization counter? 1:sec 2:mon 3:det 4:gpio [none]

Other counters to read during counting? ---
Switch directions in mesh scans? YES

Specify scan time argument as seconds per BIN
Specify intervals argument as INTERVALS
Behavior if too many intervals? ABORT
Channel advance for motorless scans? INTERNAL TIMEBASE

Screen output mode? ALL LINES
Maximum lines to include in screen output? 20

| Counter or M-LVDS inputs can be used as MCS channel advance. Counters
| are 1 to 32. Select falling edge M-LVDS 0 to 7 with 40 to 47. Rising
| edge 0 to 7 are 50 to 57.

L/R arrows, ^B/^F, ^A/^E browse, <space> selects, <tab> enters/cycles.
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Thanks to G. Swislow,
Certified Scientific Software
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```
195.FOURC> flydscan m7 -1 1 2000 .001
Sweeping m7 from -0.7945 to 1.2075 with duration 2s
Prescaling to 2
Using MCS counters 1 3 4
Counting 0.001s per 0.001

Moving to start position ...

Setting m7 backlash to 0 (from 50)

Estimated 2001 points, 2 seconds

Scan 13 Tue Sep 02 12:32:34 2025 **NO DATA FILE** fourc user = tolkiehn
flyscan m7 -0.794 1.206 2000 0.001

# Motor 7 Detector Monitor Seconds GPIO 1
2000 1.2060 656 0 0.00531992 2

Restoring m7 backlash to 50 (from 0)
Returning m7 to 0.206

196.FOURC> mca_par("report2")

Struck SIS8800 (fw 1.0B sn 64) 2048 Mb

Enabled counters ("counters") = 1 3 4 (0xd)
Chan Adv counter ("prescale_counter") = 50 (M-LVDS 0 rising edge)
Prescale ("prescale") = 2
Dwell ("dwell") = External (0.001 sec)
Start mode ("start_mode") = On start (0)
MCS channels ("npts") = 2001
Passes ("passes") = 1
Word size ("word_size") = 4 bytes
Input mode ("input_mode") = 0
Output mode ("output_mode") = 1
Invert inputs ("invert_inputs") = 0x0
Invert output ("invert_outputs") = 0xf
LNE Delay/Width logic ("lne_delay_logic") = Off
Reset time("reset_time") = 0 ns

Elapsed channels ("elapsed_channels") = 2001
Elapsed passes ("elapsed_passes") = 1.00
Elapsed time ("elapsed_time") = 2.18 sec
Data rate = 32000 bytes/sec

197.FOURC> █
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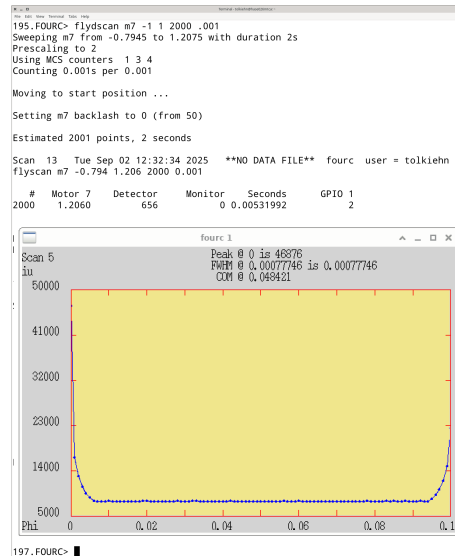
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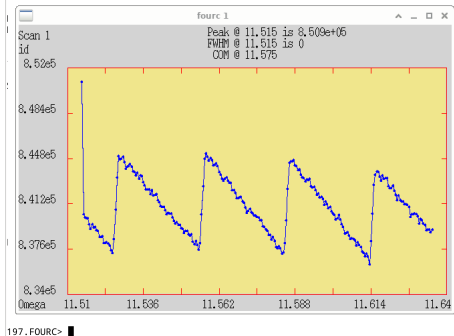
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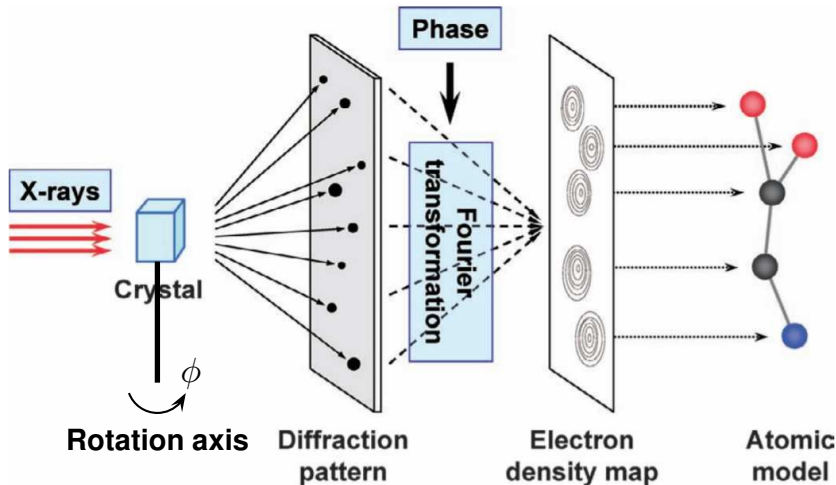
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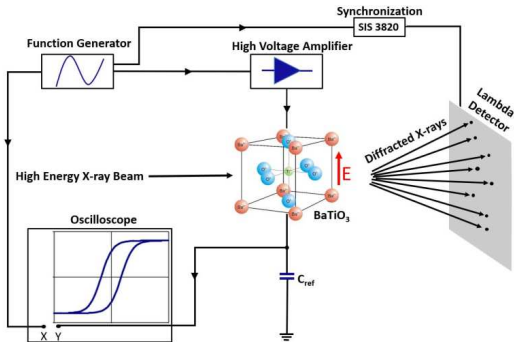
Single crystal diffraction



$$I_{\text{int}} = \int_{\phi_0}^{\phi_0 + \Delta\phi} I d\phi = \int I \omega dt$$

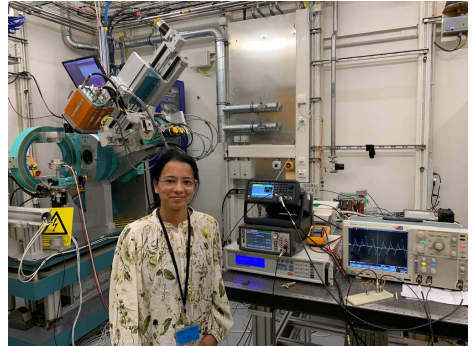
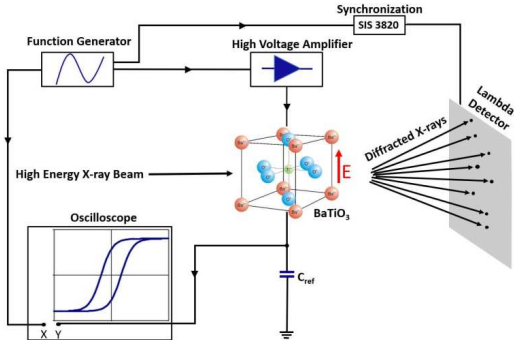
In-situ measurements with applied fields

Investigation of ferroelectric materials:



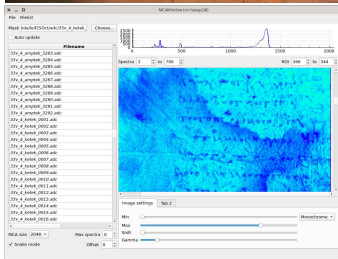
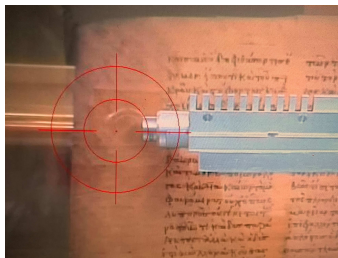
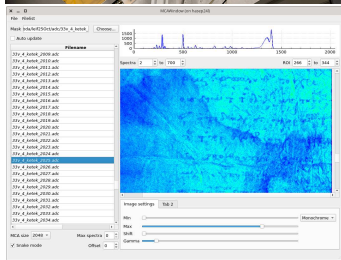
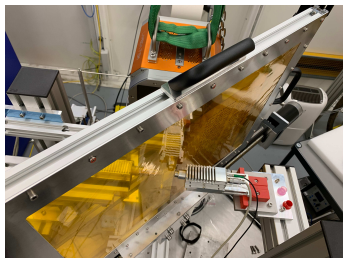
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Investigation of ferroelectric materials:



No MTCA-Solution yet. . .

Fast X-ray fluorescence mapping



- Recovering erased text from old manuscripts
- $100\mu m$ resolution
- Two SDD detectors (front and back)
- Full spectrum is saved for every point
- Continuous scans with down to 2ms per point
- Data visualisation shown here:
Ca fluorescence recorded with back and front detector

DESY R-20251616 EC „Fast scanning X-ray fluorescence mapping of the Vienna Basilica Palimpsest“
© FWF Project „The Vienna Basilica Palimpsests“ (PAT9022724)

Conclusion

- A synchrotron beamline can be controlled with MTCA
- New motion controller works very good
- Old VME base electronics can be replaced
- However: Some MTCA components are already at end of live!

