MicroTCA for photon beamlines — on-the-fly scans with spec

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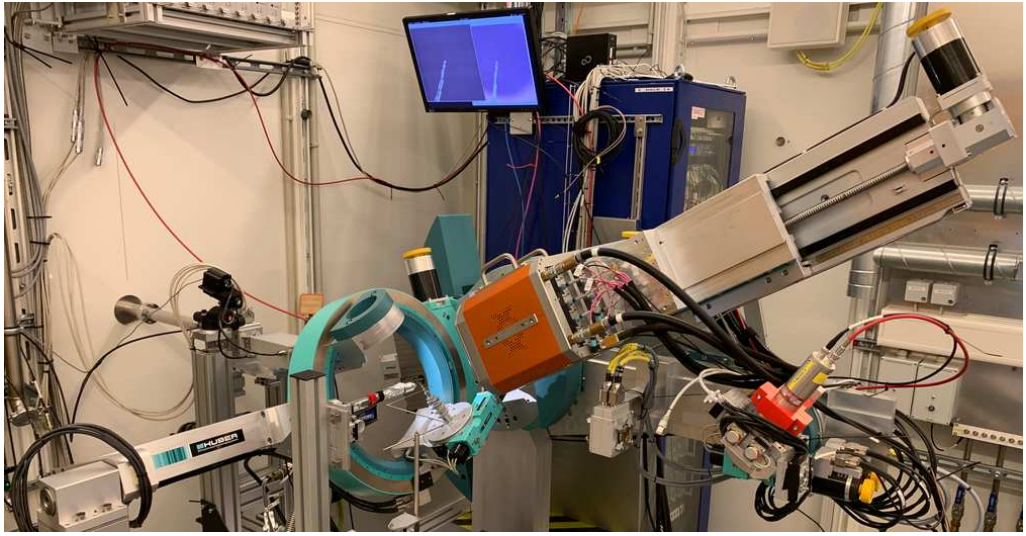
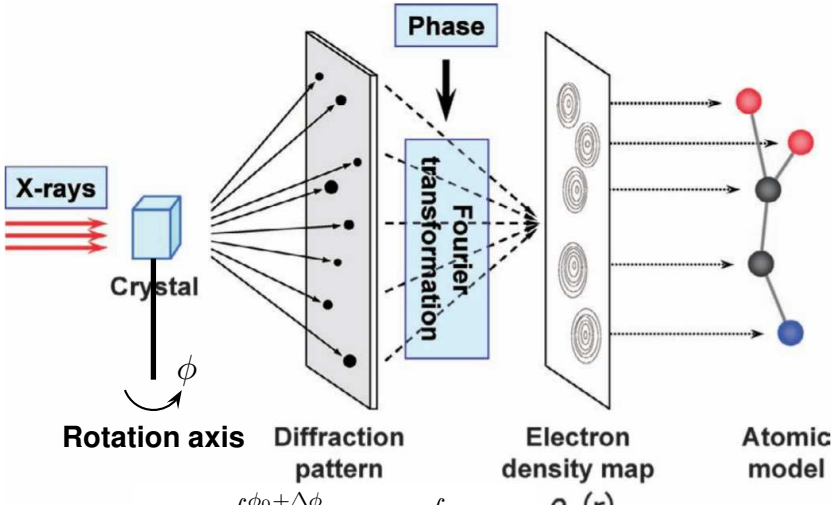
Outline

- Introduction — beamline P24
- MTCA hardware at P24
- Software
- On-the-fly scans

Four circle diffractometer at P24



Single crystal diffraction



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

MTCA.4 hardware in use at P24

4 channel HV source: CAENels HV-PANDA

HV-PANDA

panda_gui

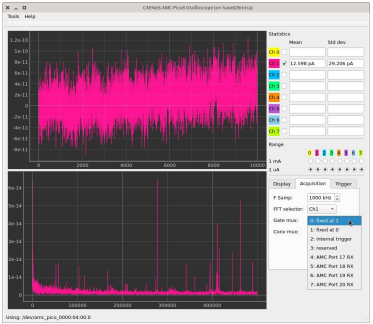
- 4 channel HV source
- positive or negative polarity
- Interlock functionality

- Python based GUI for setting output voltages and ramp rates
- Output current can be displayed
- Based on PyQt4 (needs to be updated!)
- Command line iterface also available

8 channel picoammeter: CAENels PICO-8

PICO-8
8 channel 1MSPS, 20bit

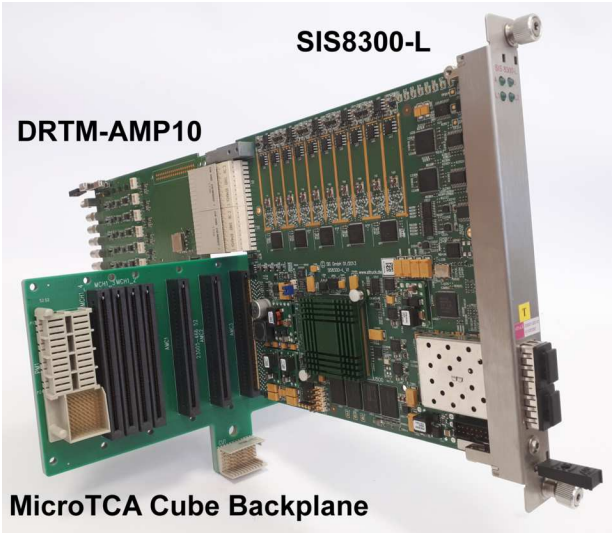
- MSK firmware framework
- Newer version with ZYNC UltraScale+ FPGA



Oscilloscope GUI

- Python based GUI, based on PyQt4
- User can select MLVDS line for gate and trigger
- Other nice features like FFT

SIS8300KU with γ spectroscopy firmware



Based on Struck SIS8300KU:

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

Digital IO

SIS8864 64bit GPIO

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

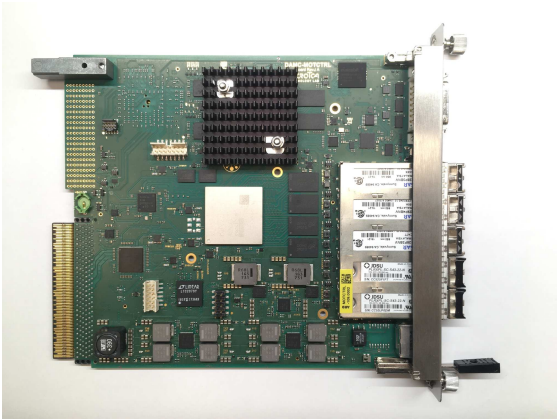
MTCA based motion controller

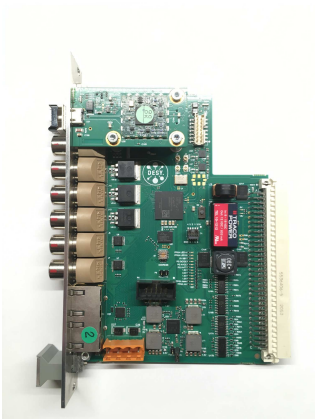
- Up to 48 stepper motors
- Programmable trigger signals
- Synchronization of many cards (μs precision)
- Heterogeneous Processing:
  - Zynq UltraScale+ (XCZU2EG) with 2GB DDR4 32-bit (runs interface software for external control system)
  - Kintex (XC7K160) with 4GB DDR3 64-bit (real time processing)
- 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.)

New MTCA based motion controller

MTCA.4 based motion controller and motor driver adapter card:





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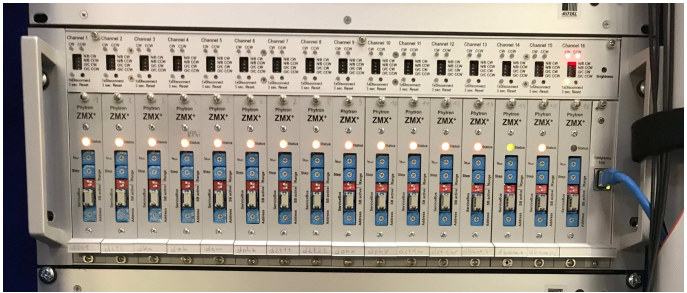
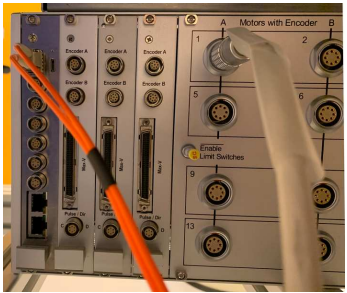
ZMX motor driver crate

One 4U crate for 16 axes:





Left: Front panel
Right: Close up of rear panel, with motor and encoder connectors, adapter card

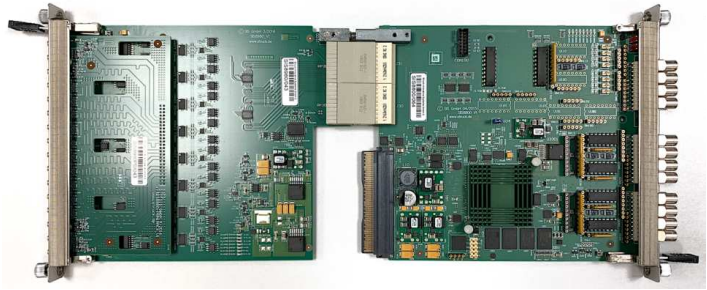
MTCA based motion controller — trigger signals

- Different trigger signals 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
- Trigger signals can be routed to MLVDS or front panel GPIO (3.3V or 5V)

Typical application:

- Generate a 20ns pulse every 10 forward steps (or encoder pulses) of a motor
- Generate a gate signal whenever a certain motor is moving

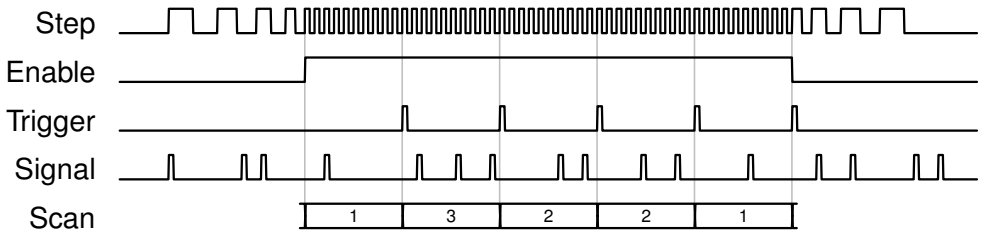
Struck SIS8800 multi channel scaler + SIS8980



SIS8980 + SIS8800 multi channel scaler

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

Continuous scans with SIS8800



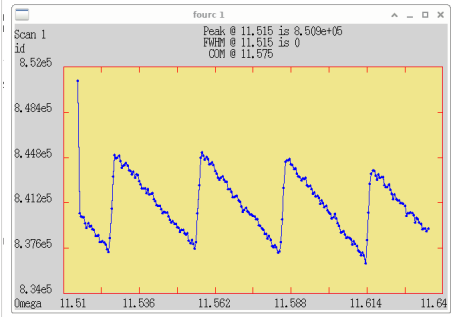
- Step signals are generated by motion controller and send to MLVDS
- Enable and Trigger signals are available at the front panel or MLVDS
- Synchronization with other devices is possible
  (e.g. fast shutter, SIS8300, PICO-8, LAMBDA, . . .)
- Supported by spec (`flyscan`)

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.
Up/down arrows, ^P/^N/^G and <return> navigate the menu.
Use q or ^D to save and quit, x or ^C to quit and not save.
```

Thanks to G. Swislow,
Certified Scientific Software
www.certif.com

```
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
```

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197.FOURC>
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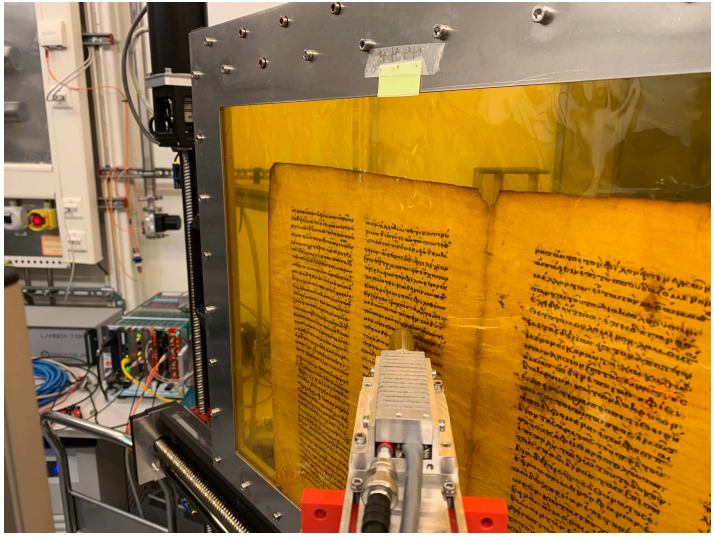
FLuorescence mapping



- Reconstruction of deleted text from old handwritings
- $100\mu m$ resolution
- Two SDD detectors (front and back)
- Full spectrum is saved for every point
- Continuous scans: Full double page can be scanned in a few hours
- Next experiment planned in spring 2026...

Conclusion

Advantages of MTCA:

- Based on modern protocols (PCIe, Ethernet)
- Fast data transfer (>1GB/s)
- Variety of modules commercially availabe, many open source solutions
- One crate can control the whole experiment
- Remote management
- Price: Comparable or lower than VME

Conclusion

- A synchrotron beamline can be controlled with MTCA
- New motion controller works very good
- Old VME base electronics can be replaced
- PETRA IV will be operated with MTCA!