MTCA.4 at Wendelstein 7-X

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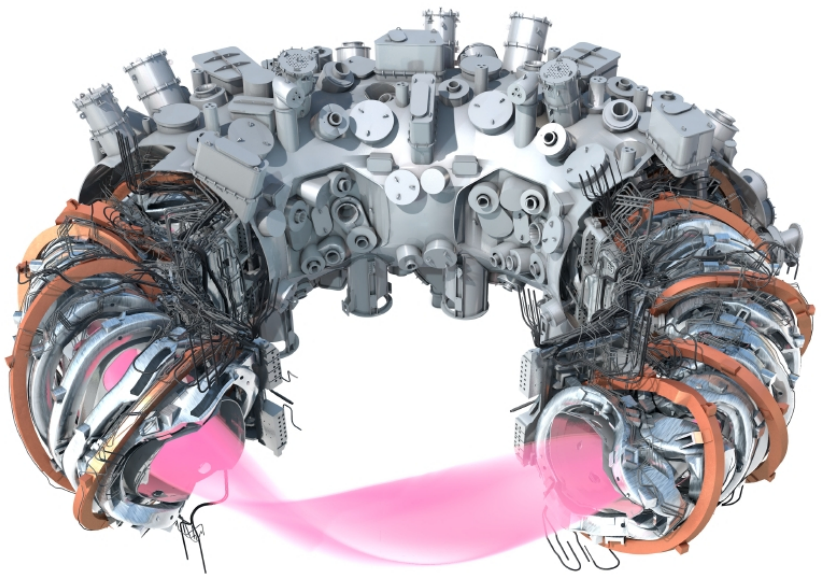
Overview

1. Wendelstein 7-X Introduction
2. MTCA.4/ATCA by Example
3. Outlook

Wendelstein 7-X (W7-X)

- is located in Greifswald (Germany) near the Baltic Coast
- employs about 400 scientists, engineers, administrative staff
- investigates the basics for energy production from nuclear fusion
- aims at quasi-continuous operation $\rightarrow$ goal: 30 min



Find out more at
http://www.ipp.mpg.de/w7x

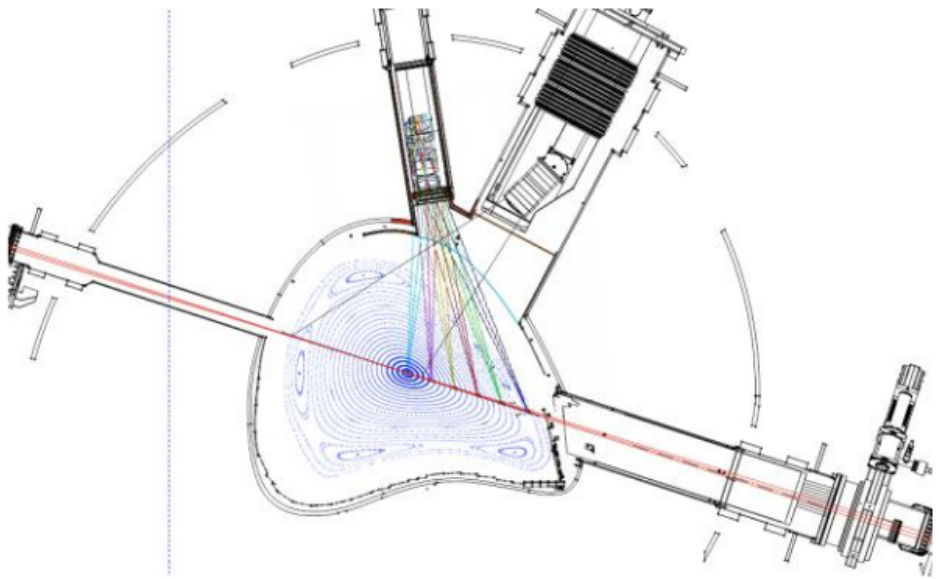
MTCA.4/ATCA by Example

- W7-X operates about 50 diagnostic systems to observe and analyze the experiment
- a wide range of different acquisition hardware used

- Diagnostic examples using MTCA.4 and ATCA hardware:
  - Thomson Scattering
  - Coil Isolation Supervision
  - Dispersion Interferometry
  - Magnetic Equilibrium

Diagnostic Goal

- acquisition of light from monochromatic IR lasers scattered on the free electrons of the plasma
  $\rightarrow$ information about electron temperature and density

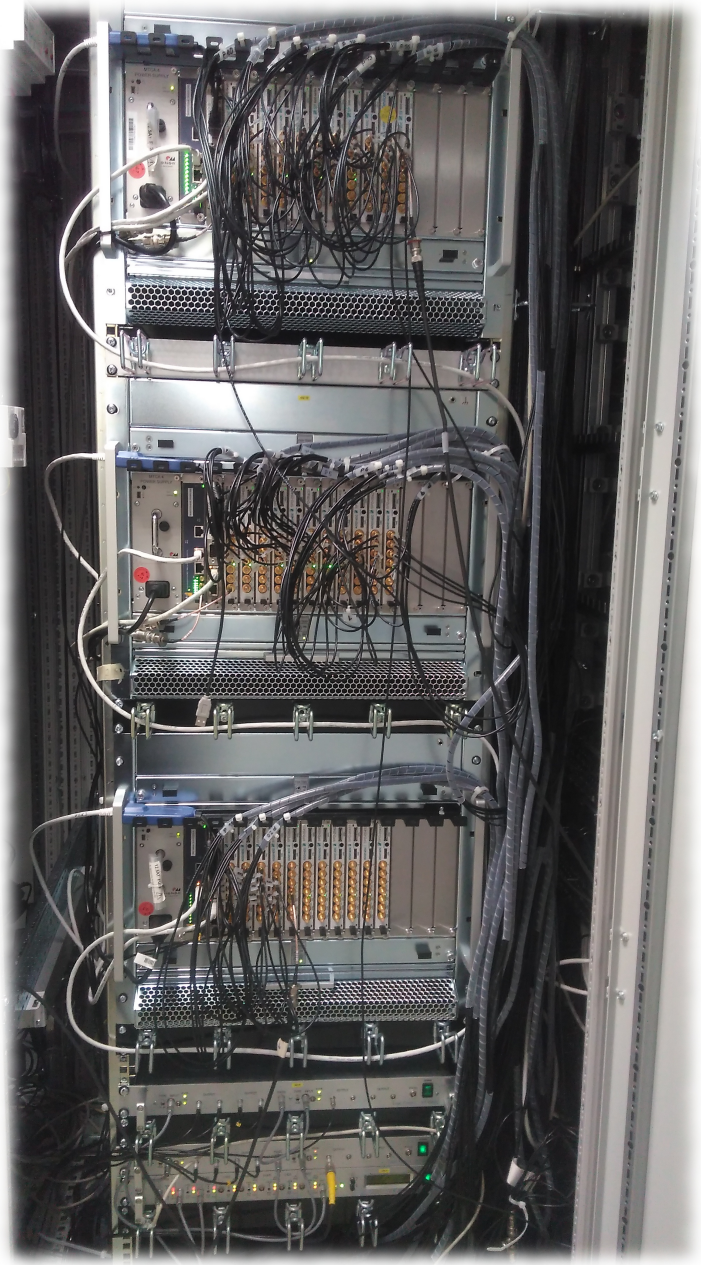


Acquisition Parameters

- Number of channels: 220
- Sample Frequency: 1 GHz
- Acquisition Method: pulsed (triggered by laser pulses)
- 2000 samples acquired on each pulse

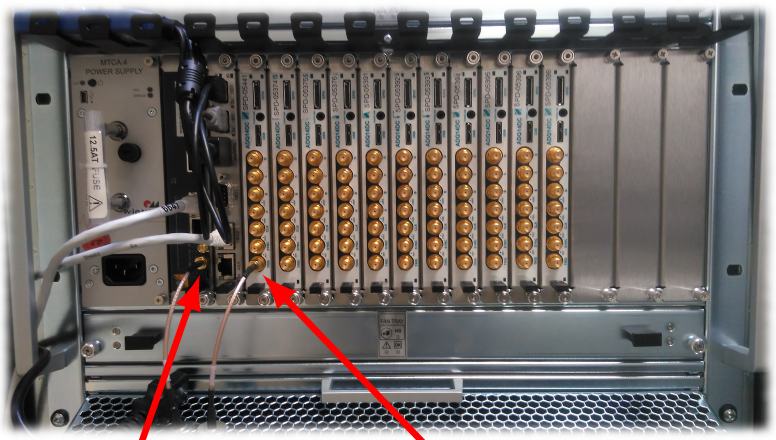
Hardware

- 5x 12-slot Schroff MTCA.4 shelf
- in each shelf:
  - 1x Concurrent AM-90X CPU
  - 11x SPDevices ADQ14DC-4C



Issues

- 10 MHz Reference clock distribution over backplane for synchronization of all ADC cards to central W7-X time system
  → solved with MCH Firmware upgrade provided by N.A.T.
- Trigger distribution over backplane to avoid individual cables to each ADC card
  → solved with ADQ14 Firmware Upgrade provided by SP Devices
- some temperature and voltage sensors unavailable via MCH
  → solved by MCH firmware upgrade (FPGA & MMC)



Coil Isolation Supervision

Diagnostic Goal

- detection of possible RF emission in case of HV discharges on the superconducting coil system using five RF antennas
  $\rightarrow$ prevention of severe damage to the superconducting coils

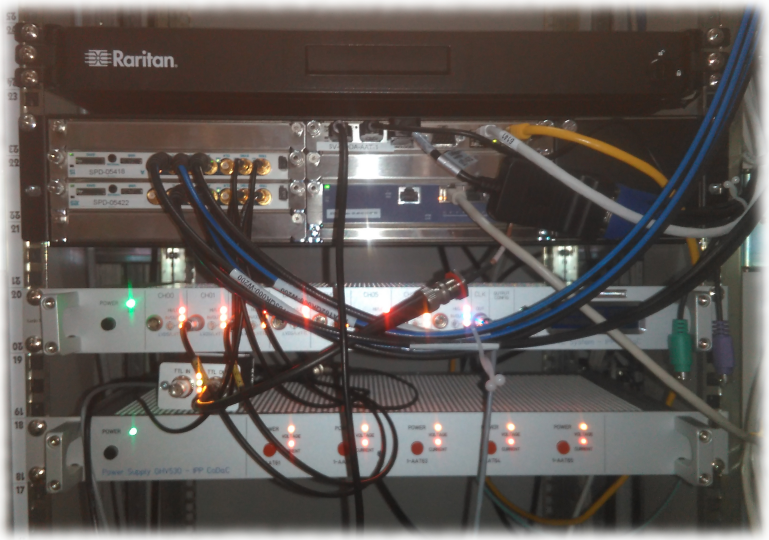
Coil Isolation Supervision

Acquisition Parameters

- Number of channels: 5
- Sample Frequency: 1 GHz
- Acquisition Method: pulsed (triggered by threshold)
- variable number samples on each pulse (1μs to 10ms)

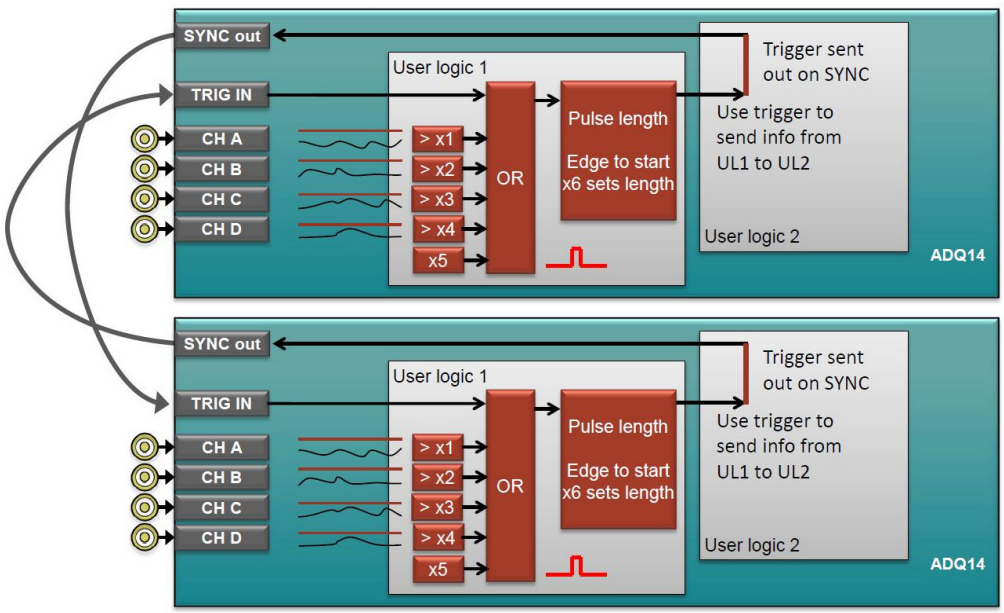
Hardware

- 1x 6-slot powerBridge RackPak MTCA.4 shelf
- 1x Concurrent AM-90X CPU
- 2x Signal Processing Devices ADQ14DC-4C



Issues

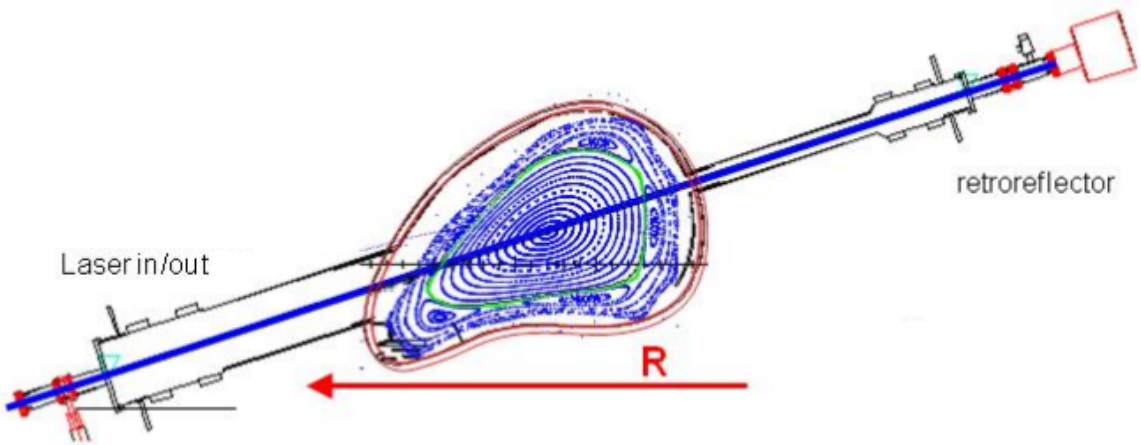
- triggering of acquisition by threshold violation on *any* of the five input channels distributed over *two* ADC boards
  $\rightarrow$ solved with custom firmware developed by SP Devices



Source: Daisy-chained level trigger, SP Devices, Sweden (2017)

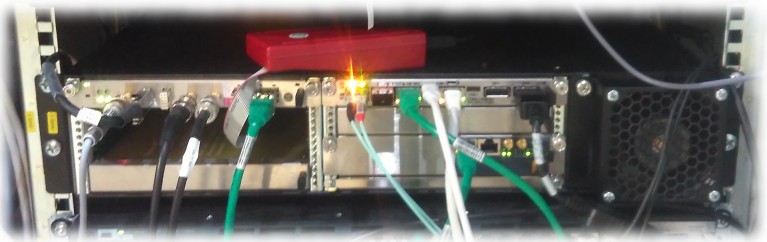
Diagnostic Goal

- measurement of line integrated electron density from plasma induced changes in the optical path length



Acquisition Parameters

- Number of channels: 2
- Sample Frequency: 50 MHz
- Acquisition Method: continuous (limited by experiment program - currently max. 100s)

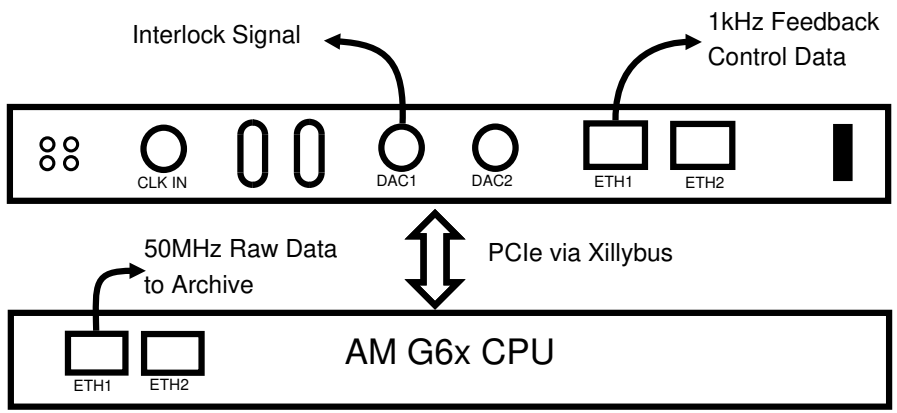


Hardware

- 1x 6-slot powerBridge RackPak MTCA.4 shelf
- 1x Concurrent AM-G6x CPU
- 1x Struck SIS8300

Issues

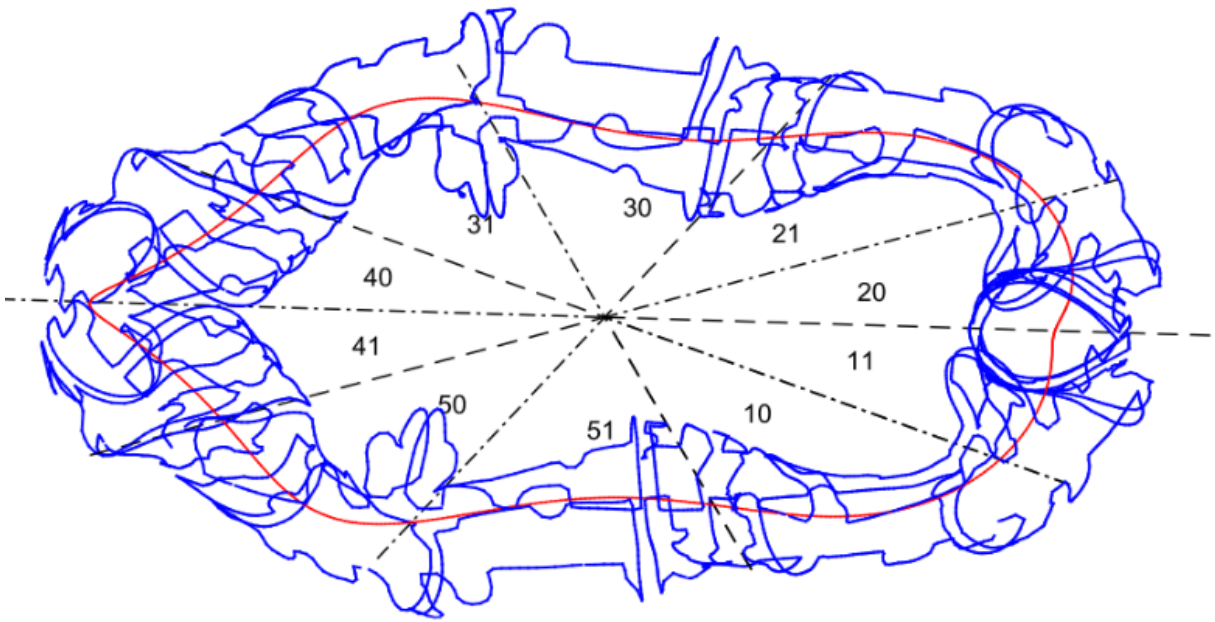
- custom FPGA firmware for density feedback control and interlock generation
  - developed in-house[1]
  - PCIe interface to CPU realized with Xillybus FPGA IP core
- AM-G6x 10Gbit network interface
  - about 2 Gbit/s streaming data rate required for continuous operation
  - initially SFP module detection failed
    $\rightarrow$ solved with BIOS updated of CPU module



[1] Real-time dispersion interferometry for density feedback in fusion devices, K.J. Brunner et al, 2018, https://doi.org/10.1088/1748-0221/13/09/P09002

Diagnostic Goal

- measurement of changes of the magnetic flux of the plasma using a system of magnetic coils
  $\rightarrow$ information about the plasma energy



Magnetic Equilibrium

Acquisition Parameters

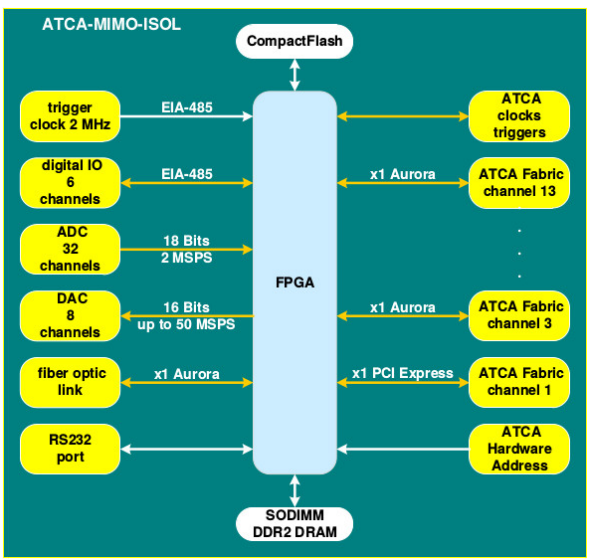
- Number of channels: 294
- Sample Frequency: 2 MHz
- Acquisition Method: continuous (limited by experiment program - currently max. 100s)

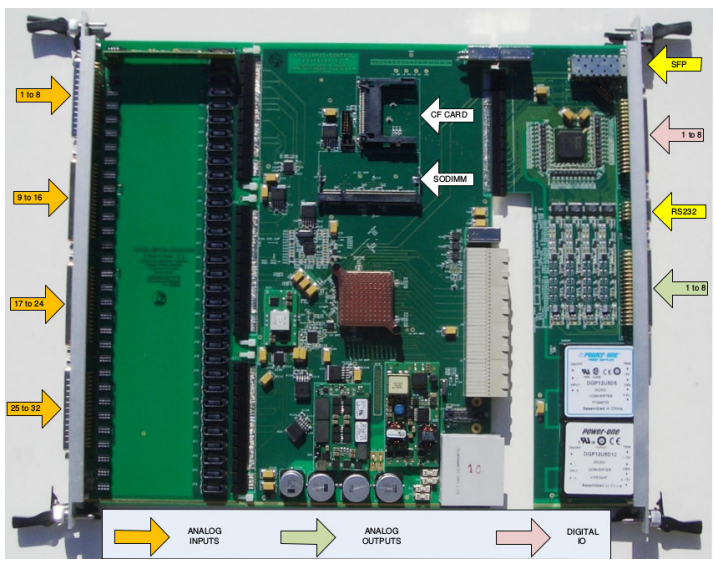
Hardware

- 10x 2-slot Artesyn Centellis 2000 ATCA shelf
- in each shelf:
  - 1x IST ATCA-MIMO-ISOL board
  - 1x RTM board for external clock & trigger
  - 1x eicSys EATCA-PCIe-EX ATCA to PCIe expansion board

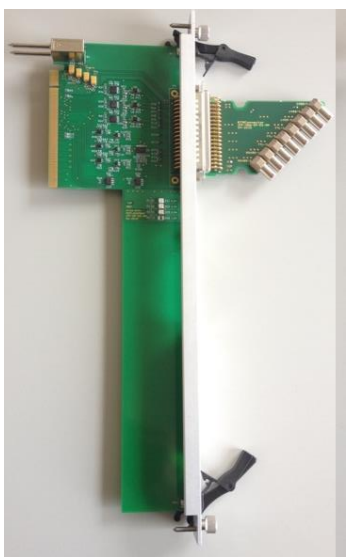
Issues

- two firmware versions:
  1. Standard version (32 channels, 16 Bit)
  2. Interlock version (6 channels, 18 Bit + Interlock Data)
- custom development of RTM board at IPP (SimpleRTM)
  $\rightarrow$ simple I/O for gate and clock triggers





Source: ATCA-MIMO-ISOL User Manual V1.0, IST, Portugal



SimpleRTM, IPP

Outlook

Extension of existing systems

- Thomson Scattering: 480 channels
- Interferometry: 10 channels

Camera Support

- development of Camera Link and GigE Vision interface boards on MTCA FMC carrier
- FPGA based real-time image processing for supervision tasks

Additional Custom Boards

- further board developments based on FMC carrier (e.g. W7-X Bolometer)

Thank you
for your attention!