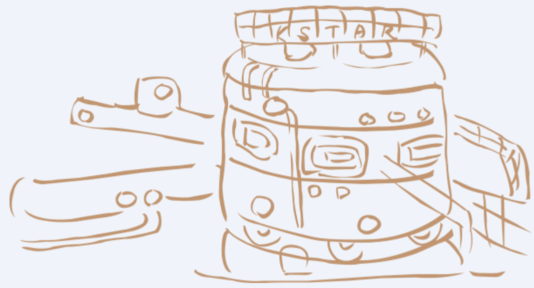

MicroTCA.4 based data acquisition system for KSTAR Tokamak

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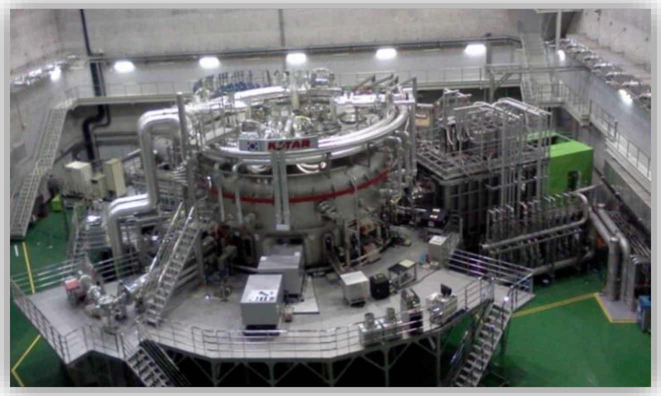
Outline

- Overview
- Background
- Develop and evaluation
- Application use case
- Summary and conclusions

Overview the KSTAR control system

❑ Development of a steady-state-capable advanced superconducting tokamak to establish the scientific and technological base for an attractive fusion reactor as a future energy source



KSTAR main facility

- **KSTAR parameters**

Major radius, R_0 / Minor radius, a	1.8 m / 0.5 m
Elongation, κ / Triangularity, δ	2.0 / 0.8
Plasma volume	17.8 m^3
Plasma surface area / cross section	56 m^2 / 1.6 m^2
Plasma shape	DN, SN
Plasma current, I_P	2.0 MA
Toroidal field, B_0	3.5 T
Pulse length	300 s
β_N	~5.0
Plasma fuel	H, D-D
Superconductor	Nb_3Sn, NbTi
Auxiliary heating /CD	~ 28 MW
Cryogenic	9 kW @4.5K

❑ Control system features

- **EPICS** is a basic control system, middleware, **MDSplus** is for an experimental data
- Most plant control system use the **Linux**, but VxWorks and Windows still run
- Collection of **heterogeneous hardware platform**, such as, VME, VXI, PXI, cPCI, PLC etc.
- Five network interface; **M**achine, **E**xperimental data, **R**eal time, **I**nterlock and **T**iming network.
- QT based **KSTAR widget toolkit** for the operator interface

Background & Motivation

❑ Driving us to investigate the next generation control system

- A variety of control platforms have emerged the maintenance issue
- Control team involved developing a local control system as well as central system I&C
- Mission to find the next generation control platform according to a long term operation plan
- High performance open architecture based modular design allows flexible reconfiguration of system functionality

❑ Functional enhancement on MicroTCA

- Have been paying attention to xTCA as a candidate for a new standard to real time controller
- An extension of MTCA initiated by the Physics community, MTCA.4, provides high precision clock and trigger through the backplane, intelligent system management interface, modular structure of high-speed links, and allows flexible reconfiguration of system functionality
- For the systematic standardization of a fast controller at KSTAR, we adopt the MTCA.4 standard.

Perform the integration test with COTS products

❑ Investigation of MTCA ecosystem

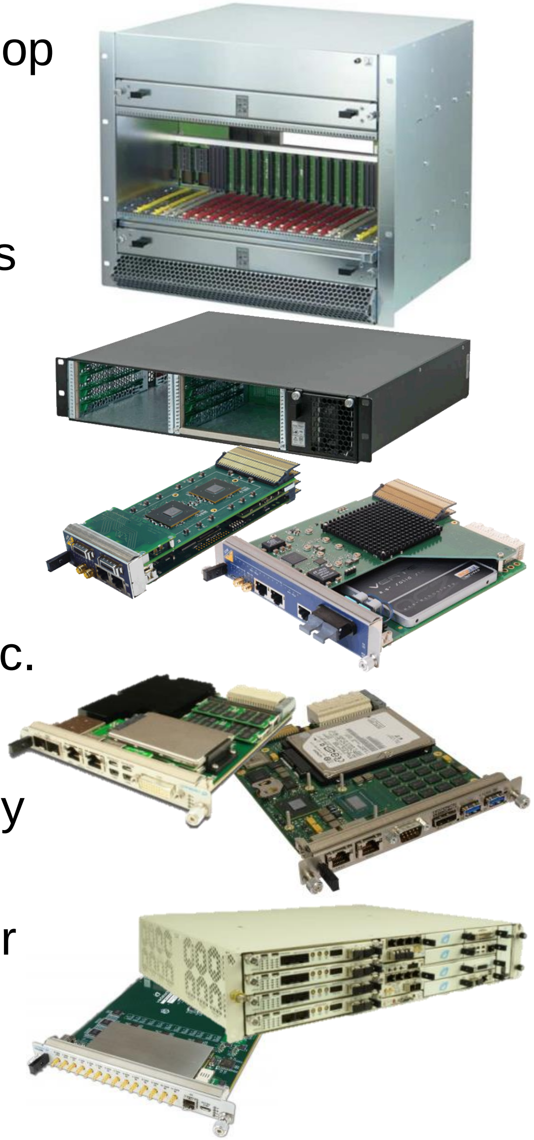
- Not yet plenty of products be shown, but enough to develop a control system what we want to do now
- Inspired the rear transition module and modularity design
- Need a technical support as like a conventional standards once in a while

❑ System use case

- 12-slot crate for the high density channel input system without redundancy scheme → Magnetic diagnostic
- Small form factor for a low channel density → MSE diagnostic, interferometer, In-vessel coil P/S controller, etc.

❑ Optical link to a remote computing system

- To avoid unexpected malfunction caused by a high energy source
- Design flexibility for a distributed control as well as sensor centric controller
- Several COTS provides high end solution



Design and development

KSTAR

❑ Design approach and consideration

- Simultaneous two point streaming data transmission for current plasma control system.
- Standalone operation capability for a small size diagnostics
- Perform not only for DAQ, but also for an actuator controller
- Collaboration with the experts and keep the compatibility with current working system

DESY

D-tAcq Solutions

(주)시드코어 SEEDCORE

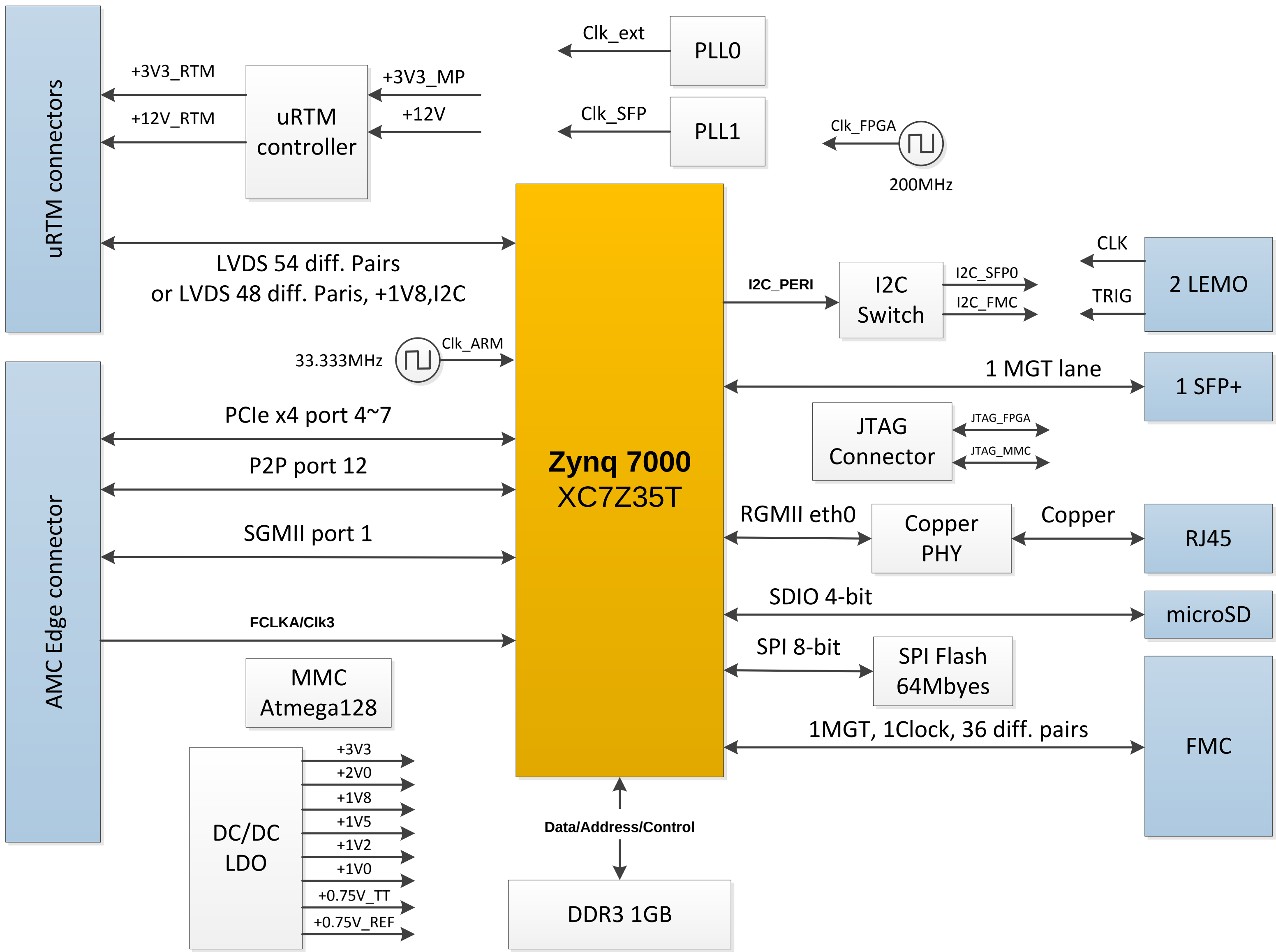
✓ **MMC from DESY**

✓ **Manufacture a rear side carrier board, supports present analogue Interface modules**

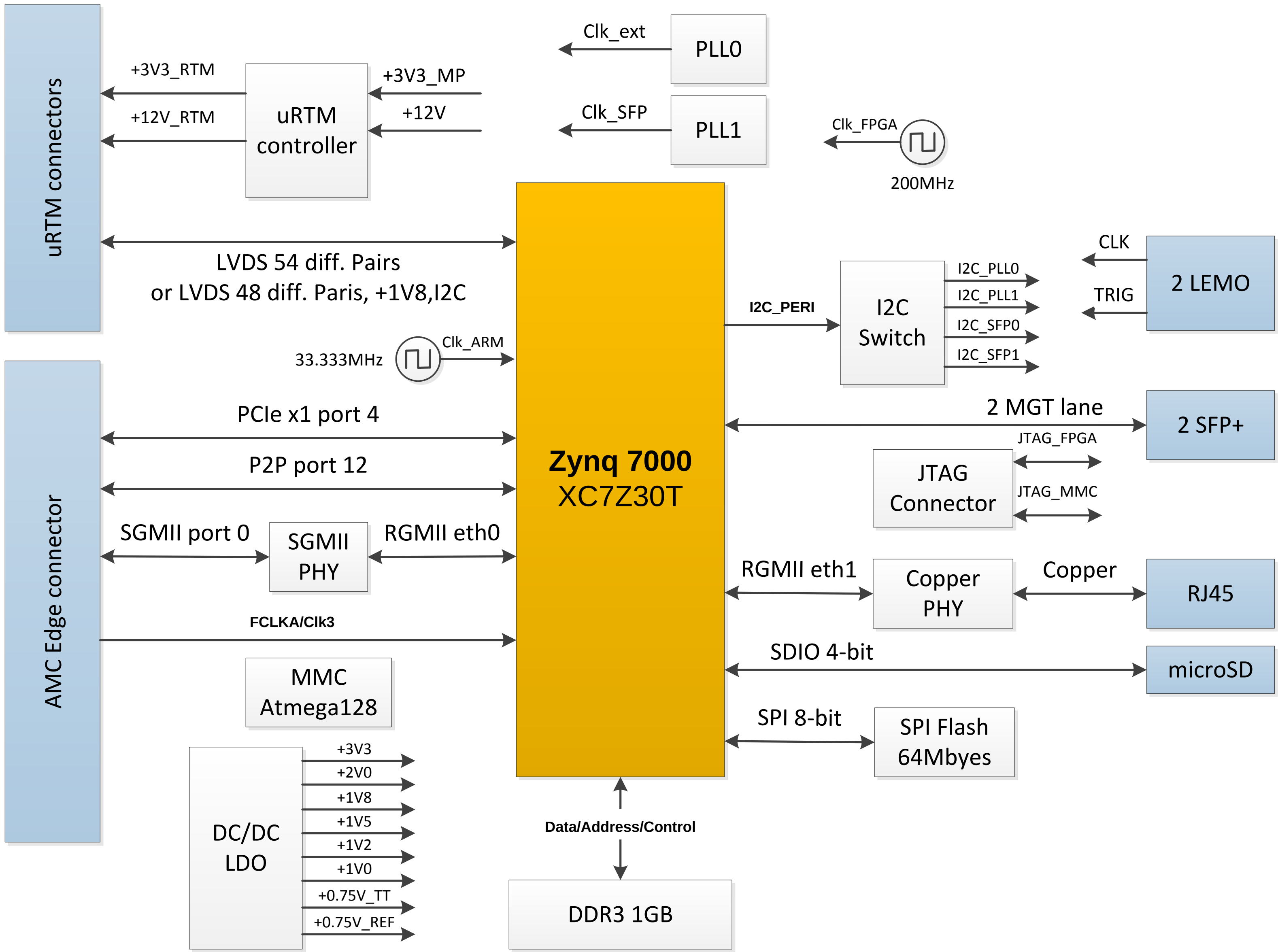
✓ **Retain current software architecture on target side**

	KMCU-Z35	KMCU-Z30
FPGA	XC7Z35T	XC7Z30T
Memory	1GB DDR3	←
Font I/F	- 1 x LPC FMC site - 1 x SFP+ - Ethernet - RJ45 - microSD - LEMO CLK/TRIG	n/a 2 x SFP+ ← ← ←
Backplane I/F	- PCIe x4 (port 4-7) - Ethernet port-0	PCIe x1, port 4 ←
Zone 3	Class D1.0.	←

KSTAR Multi-function Control Unit : K-Z35



KSTAR Multi-function Control Unit : K-Z30



Assembled KMCU Z30, Z35 and uRTM

❑ Appearance of the manufactured MTCA.4 modules

MicroTCA rear transition module
(ACQ400-MTCA-RTM2):
- Carrier board for various input/output module.
- Two mountable sites supports elongated FMC

KMCU Z35

KMCU Z30

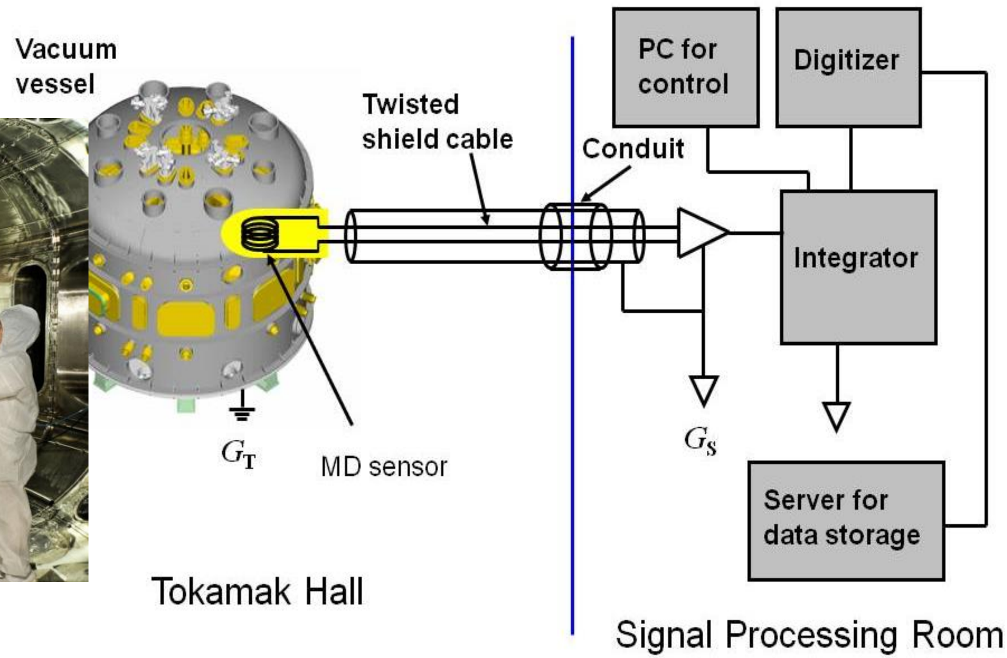
Target application use case #1

❑ Magnetic diagnostics for KSTAR

- Studies on the plasma characteristics in the equilibrium state, MHD phenomena due to the magnetic fluctuations and plasma disruption, and for **control of plasma shape and position** in the equilibrium state

❑ Over 400 sensors are installed in the Vaccuum vessel

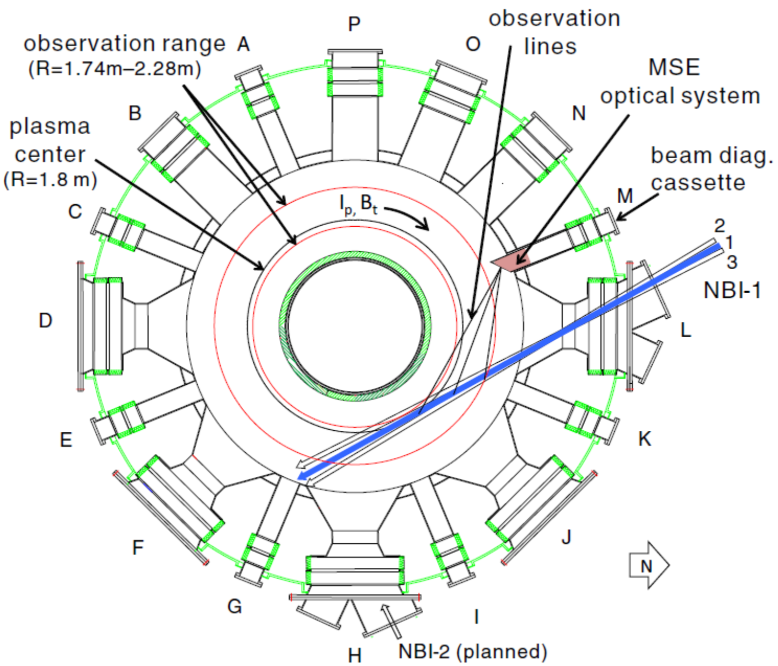
- Rogowski coils, Flux Loops, Magnetic field probes, Lock mode coils, Saddle loops, Mirnov coils, Diamagnetic Loops, Vessel current monitors, Halo current monitors, etc.



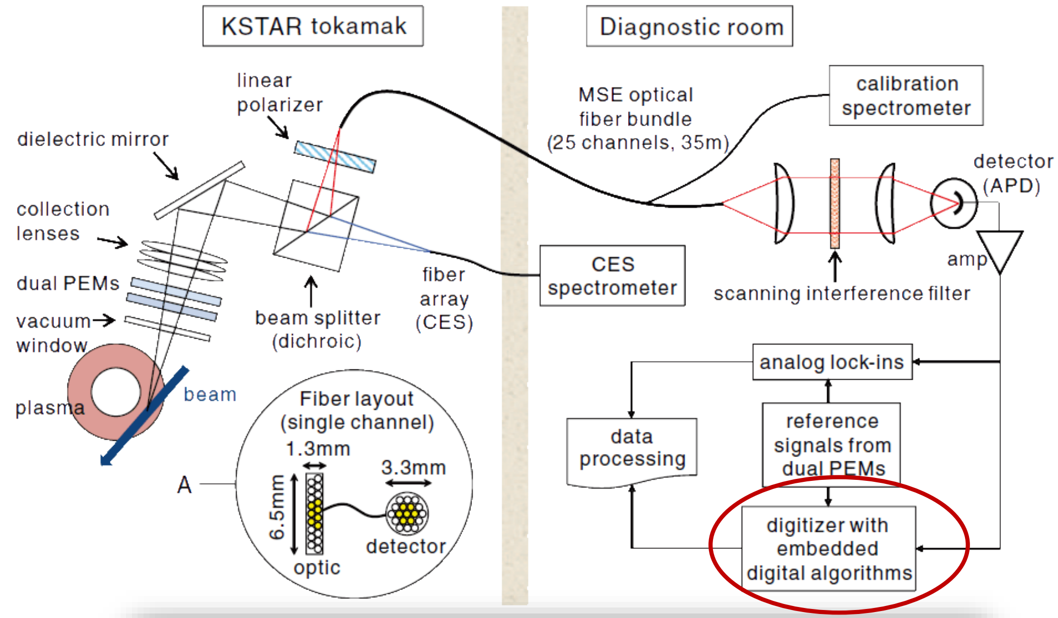
Target application use case #2

❑ A multichord photo-elastic modulator based MSE system

- The Motional Stark Effect(MSE) diagnostic is used to measure the radial magnetic pitch angle profile in neutral beam heated plasma.



Top view of the KSTAR tokamak showing locations of a set of neutral beam from the NBI-1 on port L and observation lines of MSE diagnostic in the beam diagnostic cassette on port M.

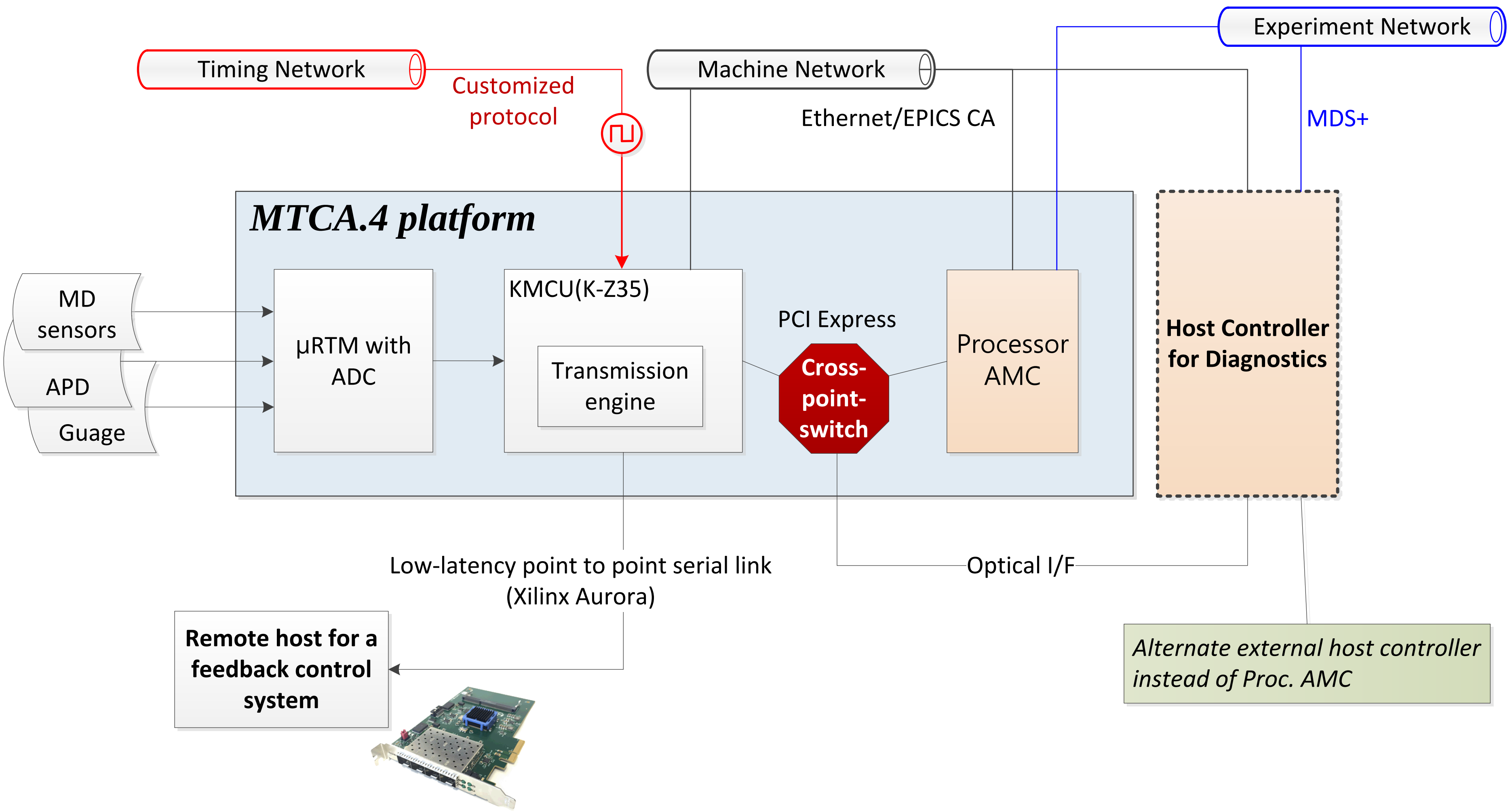


Courtesy J. Chung

System architecture of a typical DAQ system

❑ Block diagram of generic data acquisition system

- Supports two way transmission for real time plasma control



System configuration and interface

❑ Evaluate and functional test purpose

MCH with optical PCIe uplink option:

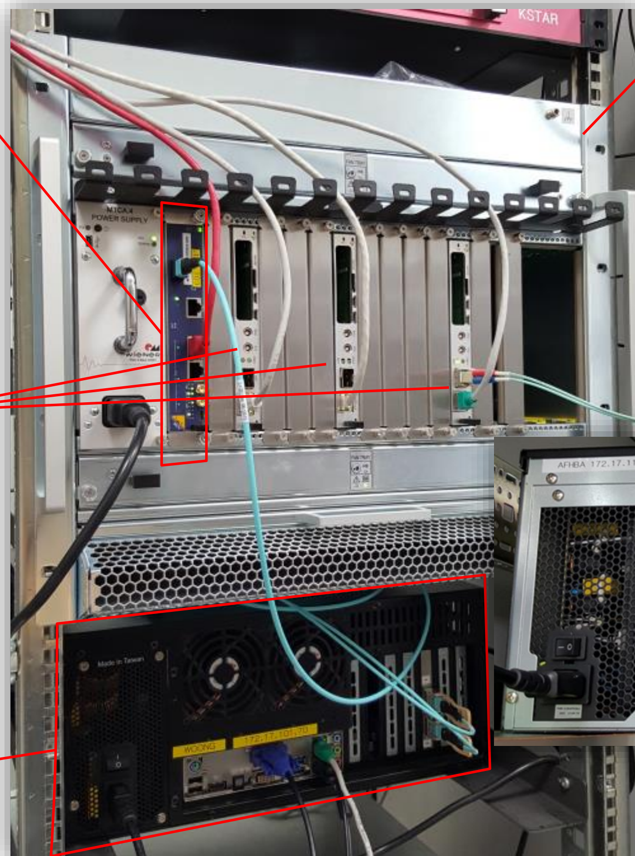
- PCIe x8 Gen3 (Max. x16)

Three KMCU-Z35:

- Use front panel Ethernet

Host controller:

- Intel® i7-3770@ 3.4GHz, 8 Core, 8GB RAM, 128GB SSD



12-slot MTCA.4 crate with single P/S

2nd data link:

- PCIe x1 Gen1 (will switch to x4, Gen2)

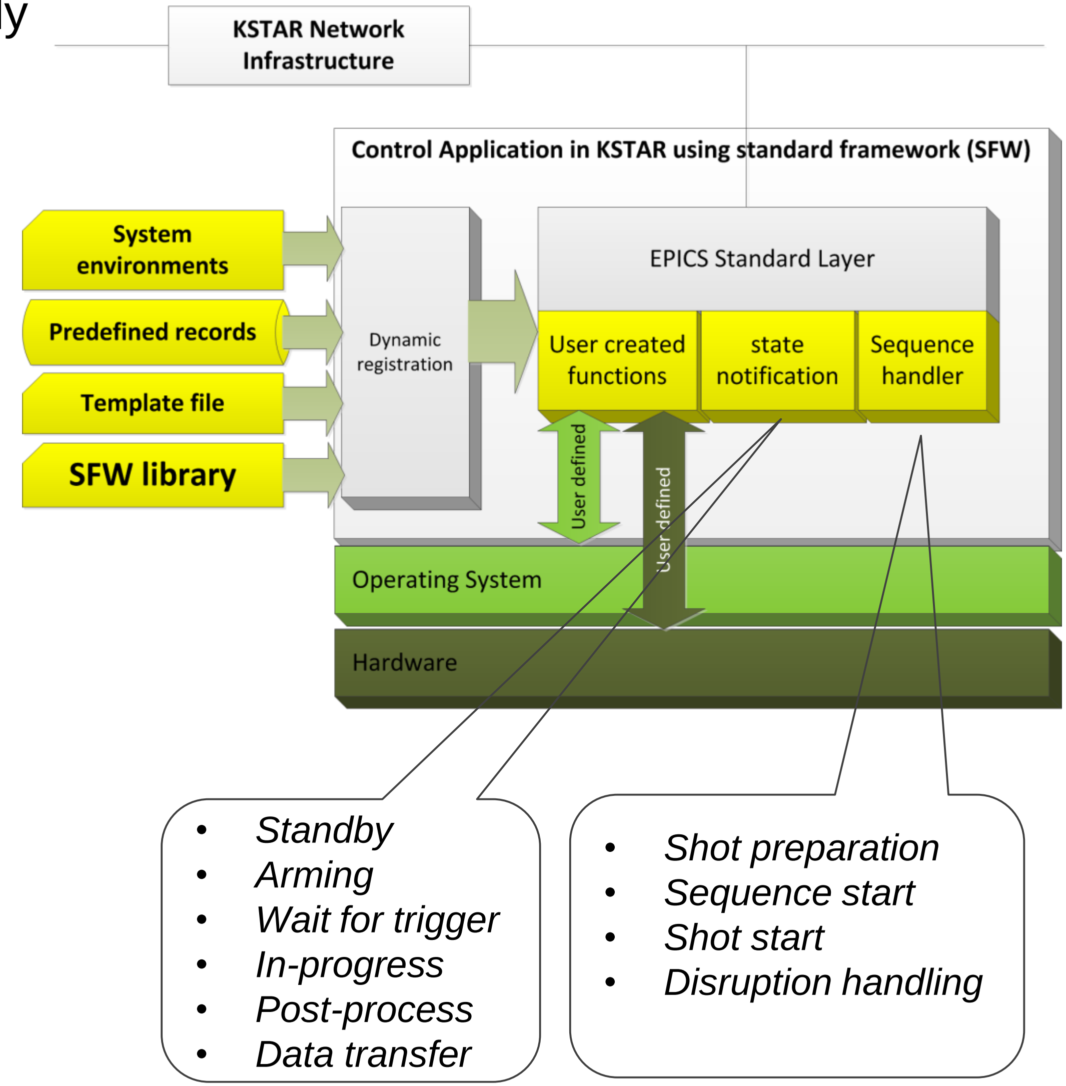
Remote side 2nd data receiver:

- Intel® i7-3960X@ 3.3GHz, 12 Core, 16GB RAM, 1TB HDD

Basic software architecture for DAQ system

❑ Standard EPICS library for diverse control systems

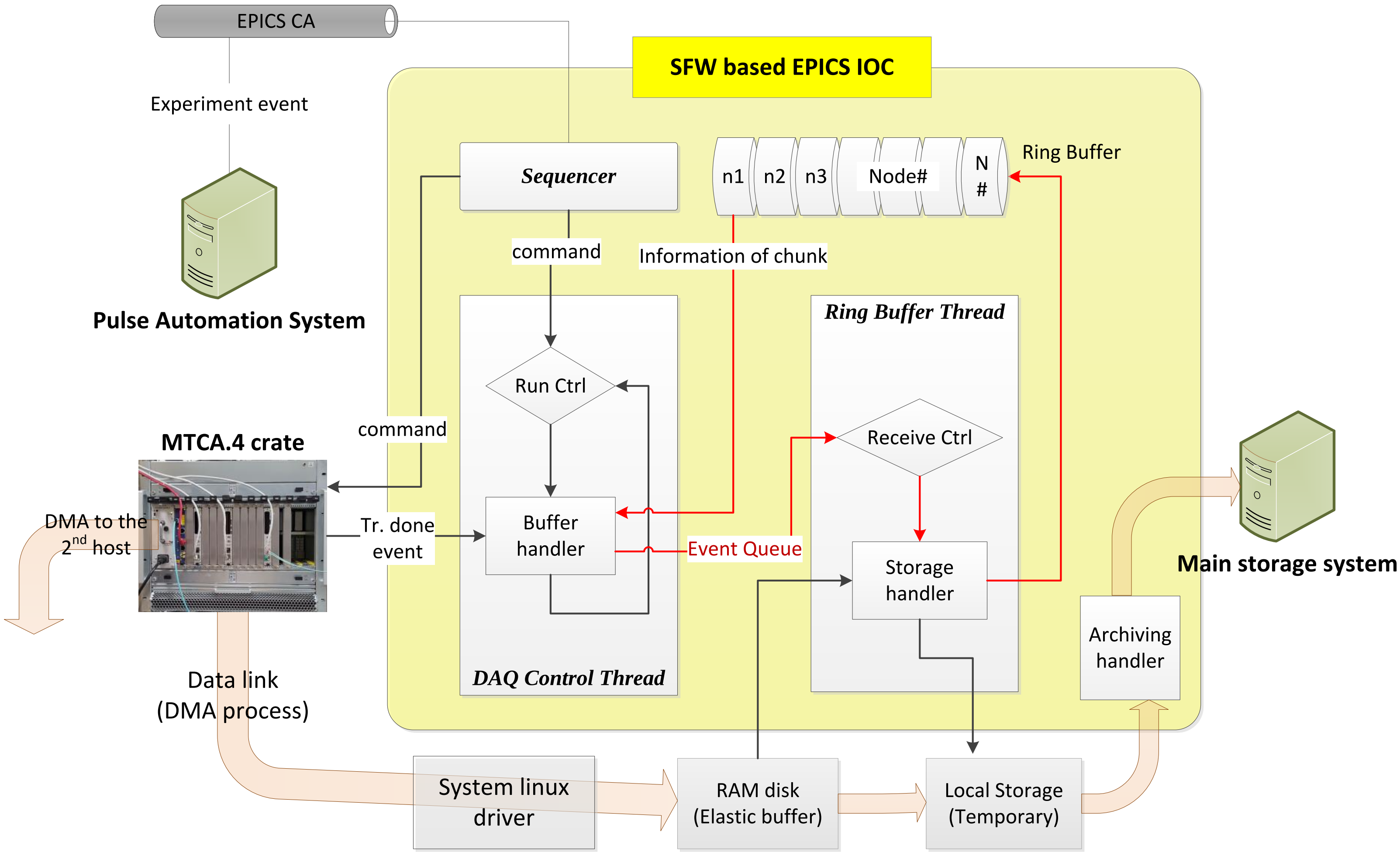
- First implementation at 2010 for only DAQ system
- Over 20 systems use the **SFW**
- EPICS device support based non-blocking software architecture
- Local system should identify its operating status.
- Nominal functions for generic tasks
- Functional enhancement for a real time performance using EPICS extension



Implementation result

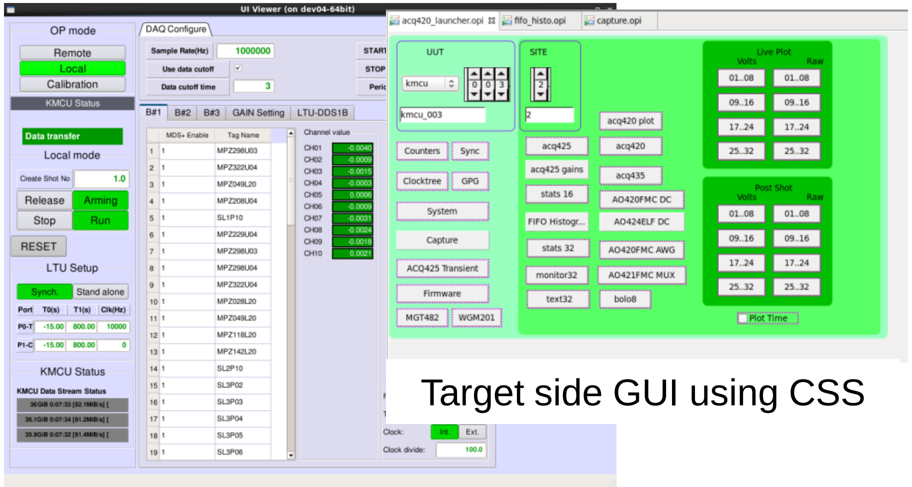
❑ Host side SFW based target application

- Internal Sequencer synchronized to the Pulse Automation System (PASS)
- Entire procedure automatically performed with a given interval time



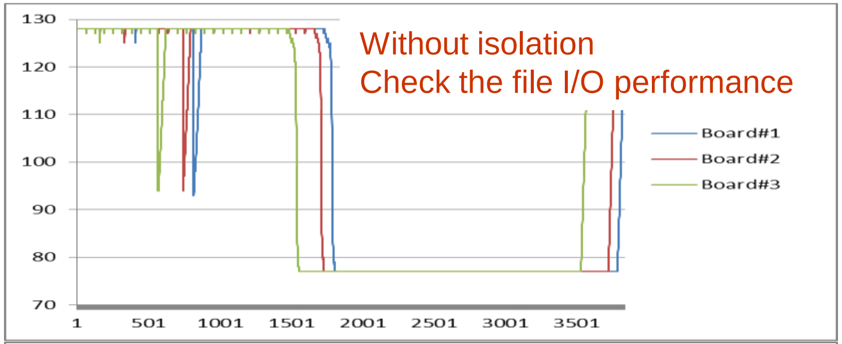
K-Z35 streaming data transmission and archiving

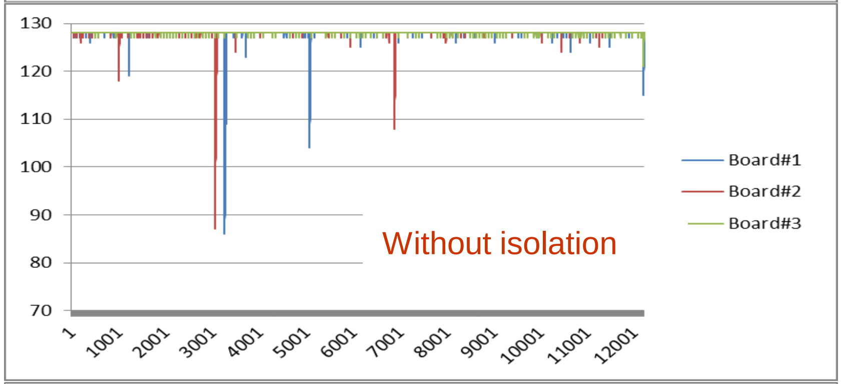
- **Evaluate the streaming data acquisition function with two way transmission in concurrent**
- **Test system condition:**
  - Scientific Linux 7.2 (3.10.0-327 64bit)
  - EPICS R3.14.12.2 with RT patch
  - Isolation CPU 0-5, general task: 6,7
  - Combined SSD, HDD
  - 1MSPS, 12bit resolution, over 100s duration, 64ch*3 ≈ 370MB/s
  - Number of ring buffer node 128

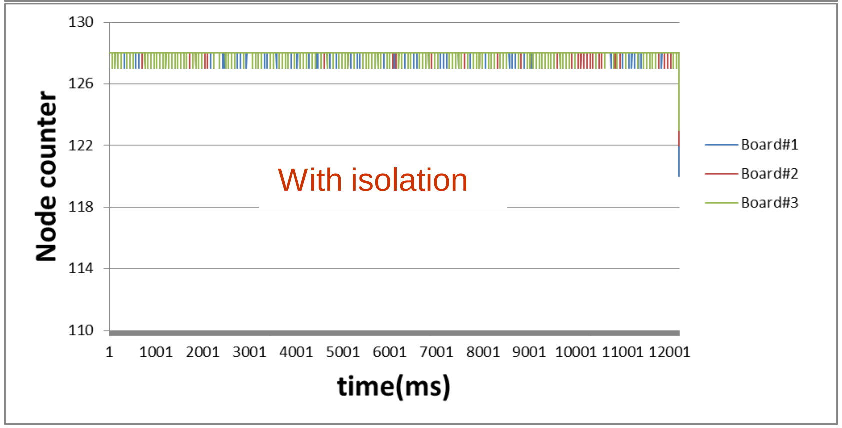


Target side GUI using CSS

QT based Operator Interface







Summary and Future work

- KSTAR has been investigating the next generation control platform and new standards both hardware and software infrastructure
- KSTAR adopt the MTCA.4 standard for the systematic standardization of a fast controller and real time diagnostics
- Implement the Xilinx SOC architecture based AMC, and under commissioning for magnetic diagnostics
  - Result of a successful international collaboration
- Realize a new streaming data transfer function for plasma control system as well as diagnostics
- Under consider the K-series AMCs for a small size diagnostics and control system by means of standalone operability