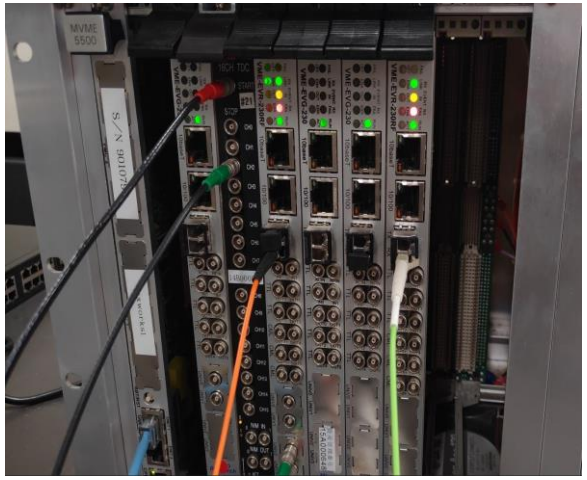
Upgrade plan of MicroTCA based event timing system at KEK LINAC

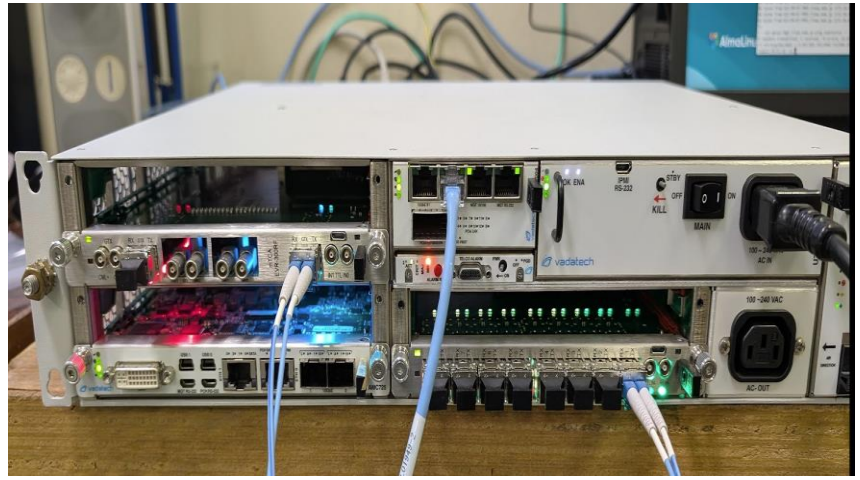
Di WANG
LINAC Control Group
KEK

20250829

Background: The Timing System Upgrade

- EVG & EVR from MRF company
  - Event Generator (EVG) sends event codes to Event Receivers (EVRs)
  - EVR generates trigger pulse to accelerator devices (BPM, magnet, etc.)
- KEK LINAC relies on a large, distributed timing system with over 100 Event Receivers (EVRs).
- The VME platform is stable but becoming obsolete; key components like the MVME5500/MVME6100 CPU are being discontinued.
- We are migrating our timing system from VME to the modern MicroTCA standard.



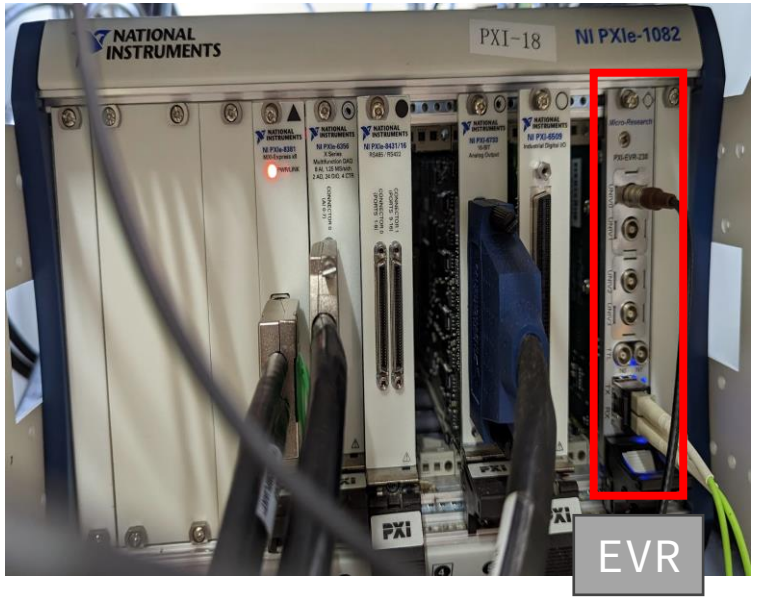


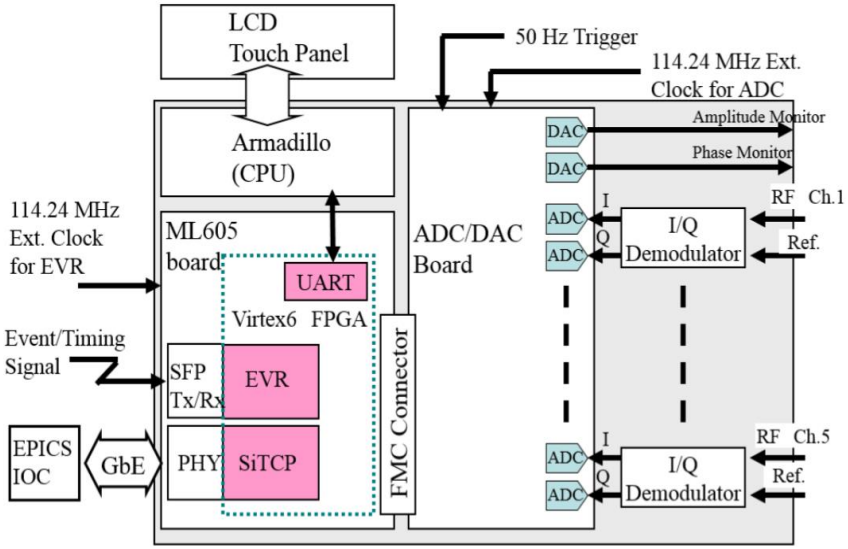
Considerations Before Upgrade

From	To	Note
VME-EVG-230	VME-EVR-230	In Ope
VME-EVG-230	VME-EVR-230RF	In Ope
VME-EVG-230	PXI-EVR-230	In Ope
VME-EVG-230	Home-made EVR	In Ope
VME-EVG-230	MTCA-EVR-300RF	??
VME-EVG-230	MTCA-EVR-300U	??
VME-EVG-230	VME-EVR-300	??
MTCA-EVG-300	MTCA-EVR-300U	○
MTCA-EVG-300	MTCA-EVR-300RF	○
MTCA-EVG-300	VME-EVR-300	○
MTCA-EVG-300	VME-EVR-230RF	??
MTCA-EVG-300	VME-EVR-230	??
MTCA-EVG-300	PXI-EVR-230	??
MTCA-EVG-300	Home-made EVR	??

Combination table of EVG and EVR

- Various EVR types are used
  - PXI-EVR-230 for pulsed magnet control
  - Home-made EVR (Virtex6 FPGA) for RF monitor
  - SINAP EVR
- We need to consider
  - Compatibility between timing module generations
  - Compatibility among various form factors



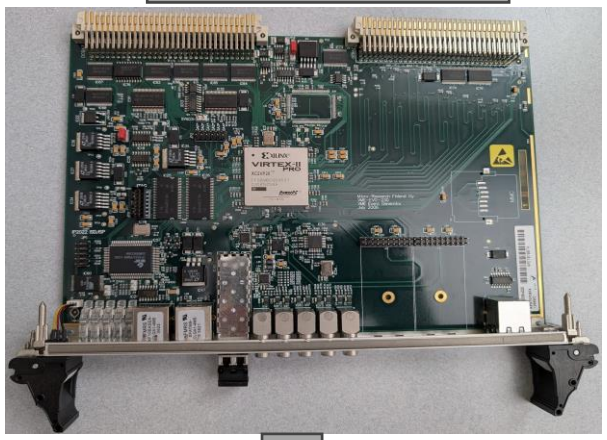


What MicroTCA + MRF 300 Series Offers

- **VME**
  - **Proven stable**: has been proved reliably in accelerator environments
  - **Long lifecycle**: has been running for decades
  - **EPICS integration**: tightly coupled with mainstream control systems framework - EPICS
- **MicroTCA**
  - **Modern, Stable**: redundant design (MCH, PM, CU) for high stability
  - **Long-term support**: with an active market
  - **System management**: health monitoring, alarm and remote diagnostics via MCH/IPMI
  - **High bandwidth backplane**: Support high-speed data acquisition
  - **Hot-swap feature:** maintainability
- **MRF 230 Series**
  - **Trigger events**: distribution of event codes on a stimulus
  - **Sequencers**: support for complex, pre-programmed event sequences
  - **Timestamp distribution logic**: provides global timestamp for synchronized data acquisition
  - **AC line synchronization**: locked to mains cycle for periodic operations (50/60 Hz)
  - **EPICS IOC integration**: mature EPICS drivers (mrfioc2) and database support, widely deployed
- **MRF 300 Series**
  - **Delay compensation**: compensate transmission delay
  - **Flip-Flot output**: Pulse generator X for set, X+1 for reset. Interlock logic possible
  - **Embedded EVR**: upstream event link, suitable for post-mortem analysis

Two Migration Strategy

VME EVG 230



MTCA EVR 300

Path A: **Replace EVRs first**

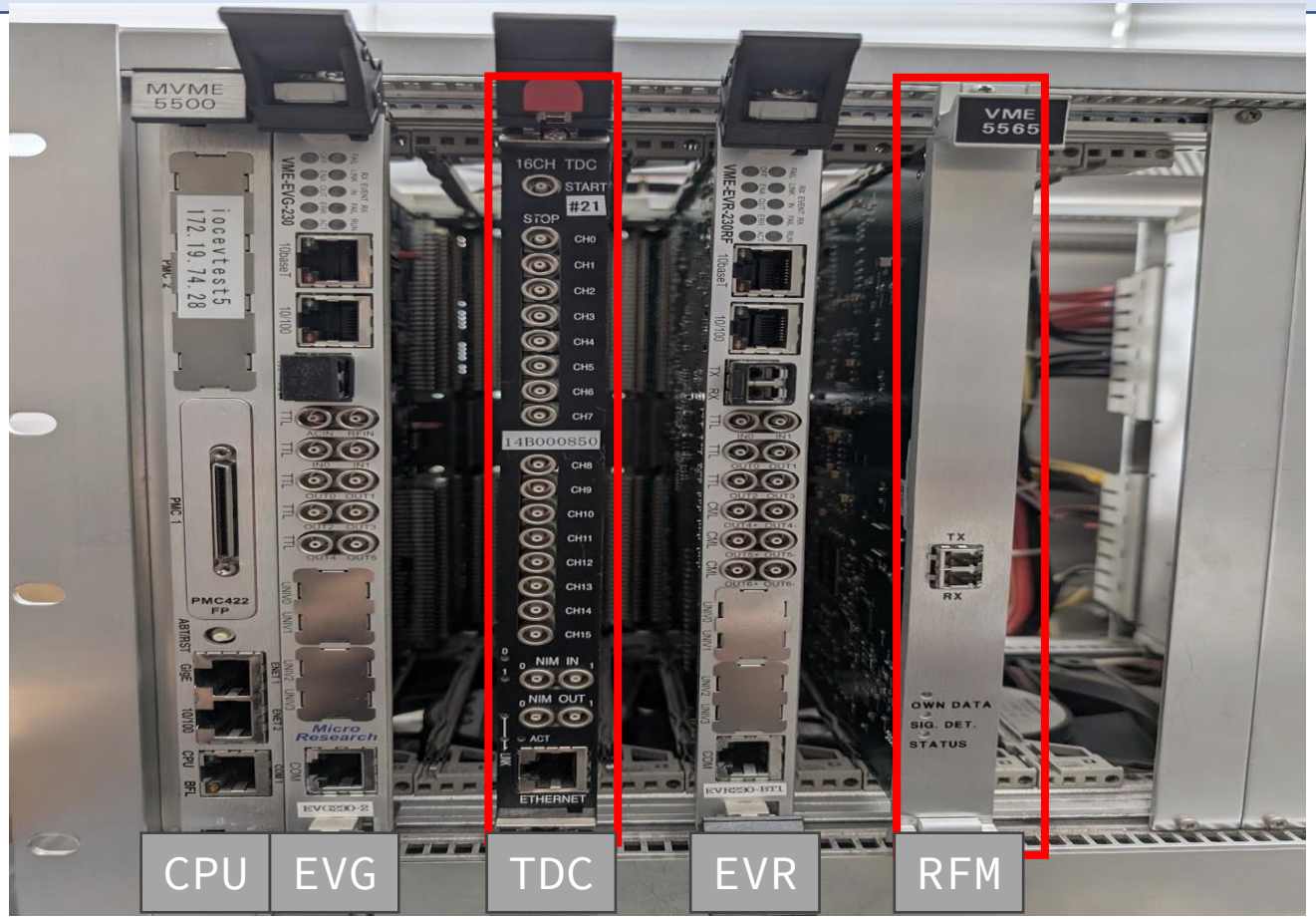
- Ultimate goal: fully non-VME timing system
- Chosen approach: **replace EVG first**
  - Remove VME from the “heart” of the timing system
  - Deploy the latest EVG software stack from the start
  - Unlock advanced functionality of the MRF 300 series
  - Simplify subsequent EVR migration and system expansion

MTCA EVG 300

VME EVR 230

Path B: **Replace EVG first**

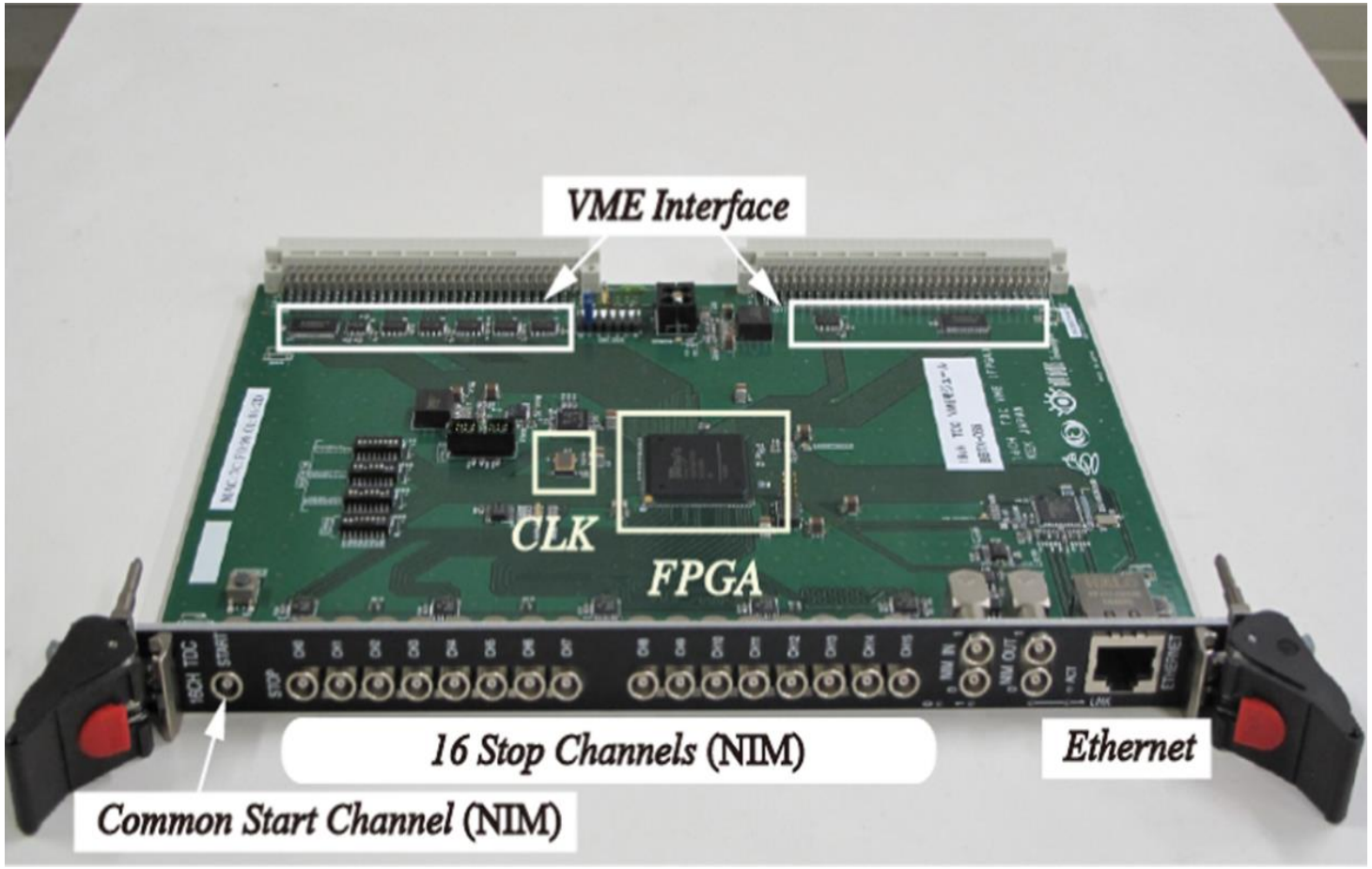
Other Considerations Before Upgrade



- Besides of MRF timing modules, timing system also use auxiliary VME modules
- Home-made TDC (Time-to-digital Converter)
- Reflective memory (VME-5565) from Abaco

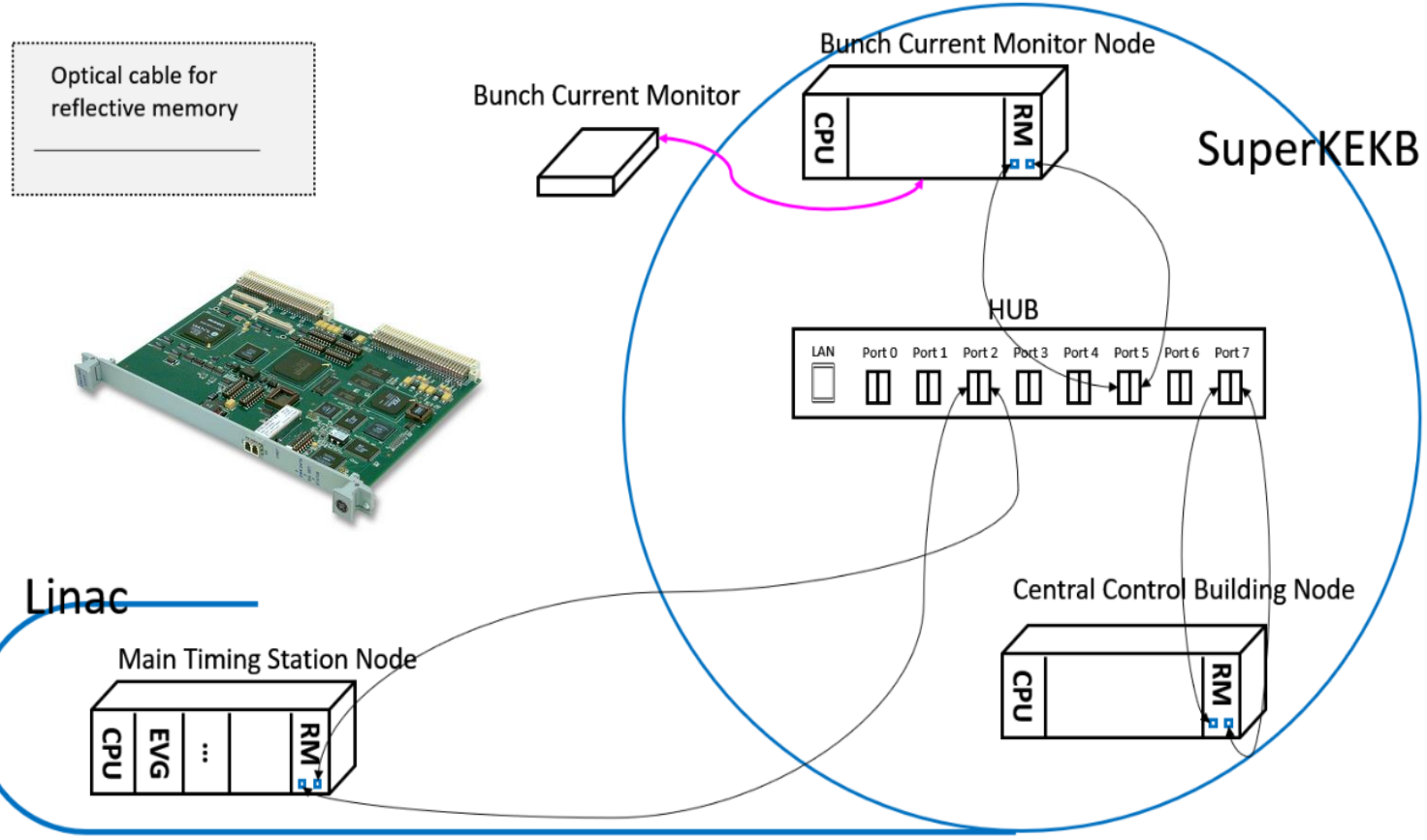
Other Considerations Before Upgrade

- 16 channel
- 32 bit counter with 1 ns resolution
- Usage
  - For EVG: Measure phase of AC line and synchronize events with AC line
  - For EVR: Measure and log EVR trigger delay for diagnosis
- Need to develop (or purchase?) TDC module of AMC form factor



Other Considerations Before Upgrade

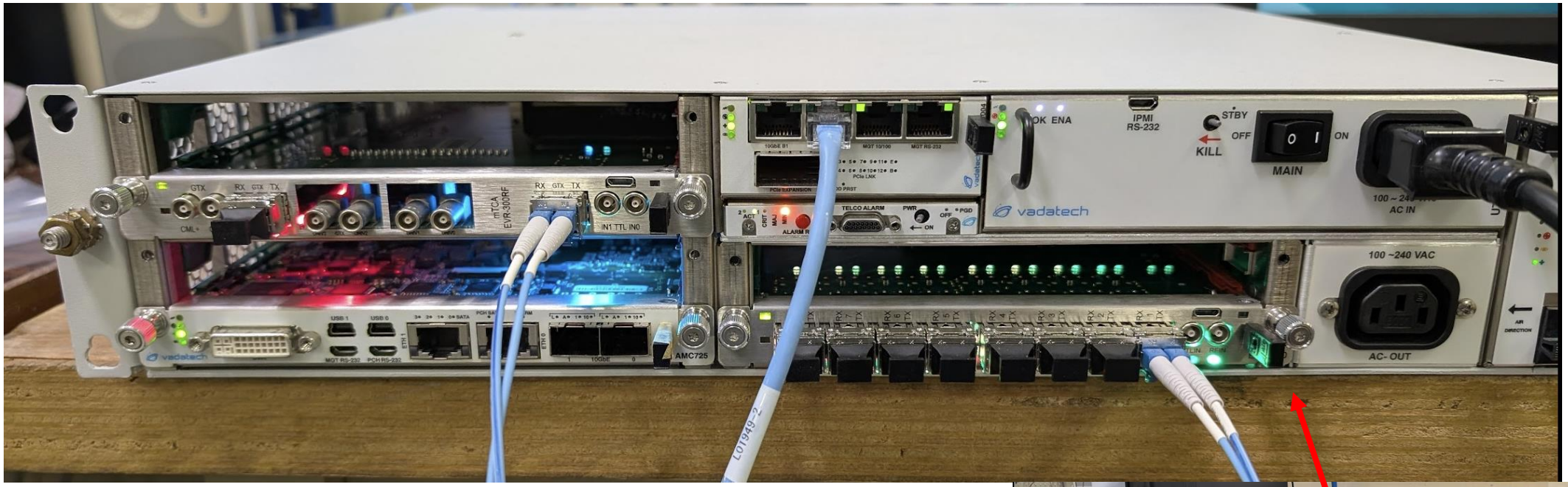
- Fiber-optic connected nodes
- data written into SDRAM of local nodes is broadcasted to other nodes
- Bunch current monitor in SuperKEKB ring share data with bucket selection node.
- Bucket selection node decide next injection bucket
- Main timing station node apply the change
- Vendor provides RFM of 3 form factor: VME, PCIe, PMC
- AMC carrier for PMC is needed
  - COTS from N.A.T. and VadaTech is available



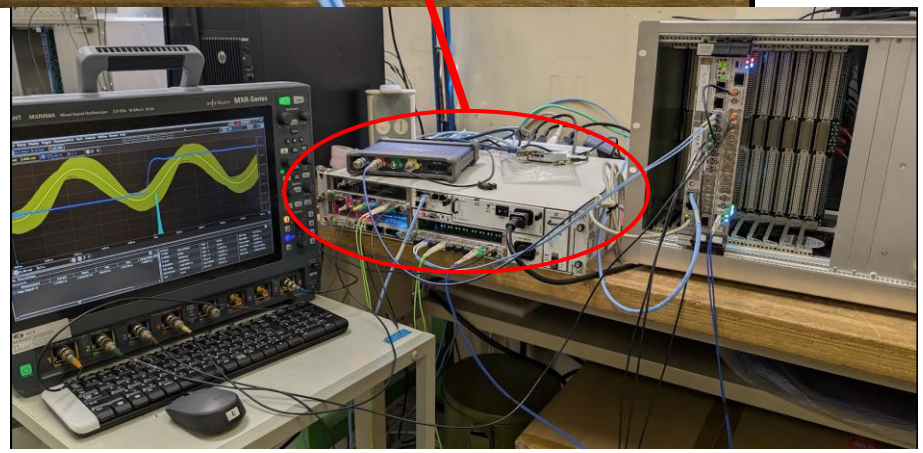
Phased Upgrade Plan

- Phase 0 – Test & Validation <- WE ARE STILL HERE!
  - Install MTCA-EVG-300 + VME-EVR-230 in a lab or test stand
  - Verify event stream compatibility with VME modules
  - Validate EPICS IOC support, monitoring, and operator interface
  - Run long-term stability tests before touching production
  - Keep software continuity
- Phase 1 – Deploy MTCA EVG
  - Replace VME EVG with µTCA EVG in the production system
  - Fallback to legacy EVG if unexpected issues arise
- Phase 2 – Mixed Environment
  - Gradually phase out VME EVRs at selected devices
  - Operate in mixed mode (MTCA-EVG-300 → VME-EVR-230 + MTCA-EVR-300)
- Phase 3 – Full Migration
  - Replace all remaining VME EVRs with MTCA EVRs
  - Activate more advanced MTCA features

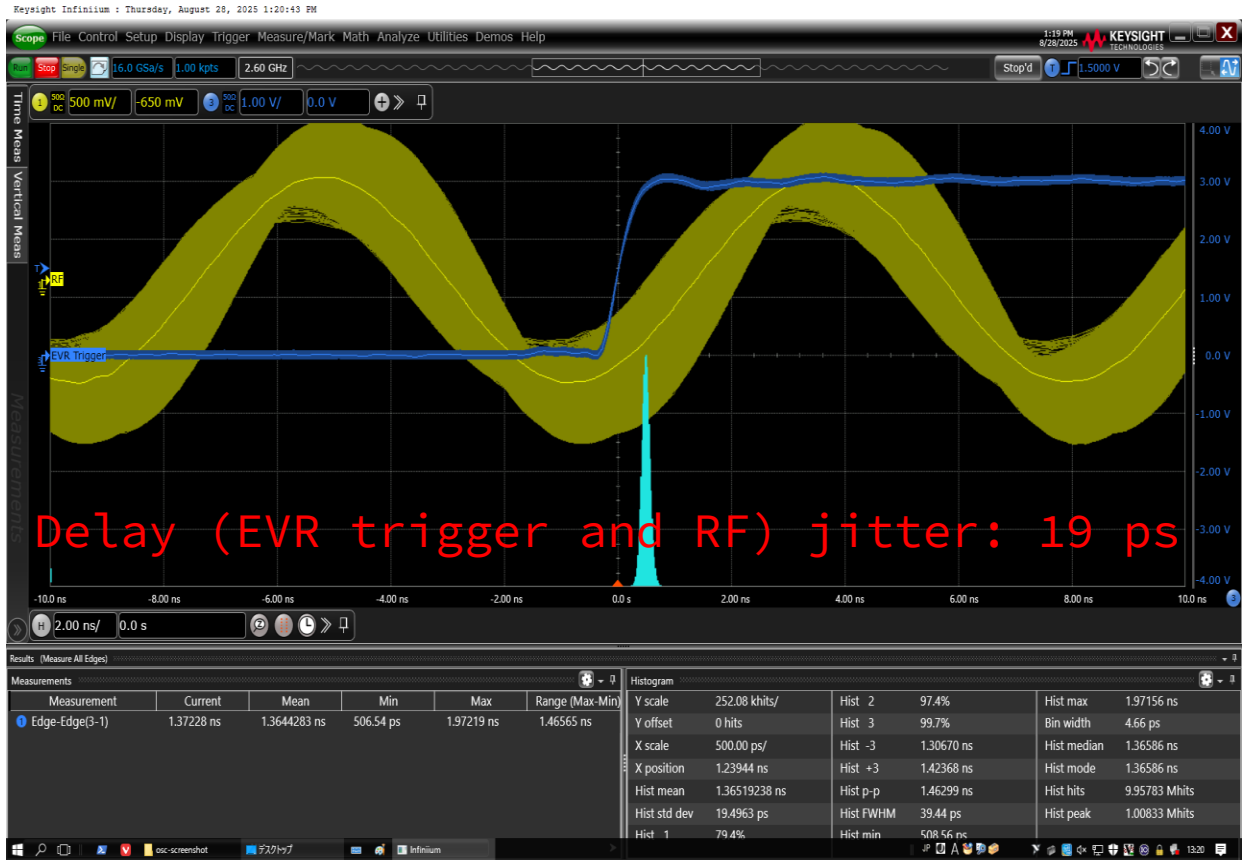
Test Bench



- VadaTech Chassis: VT814
- VadaTech MCH: UTC004
- VadaTech CPU: AMC725
  - Preinstalled Fedora OS & reinstall AlmaLinux 9
  - EPICS 7 & mrfioc2 (EPICS module) on NFS
- MRF MTCA-EVM-300
- MRF MTCA-EVR-300RF, VME-EVR-230RF, VME-EVR-300



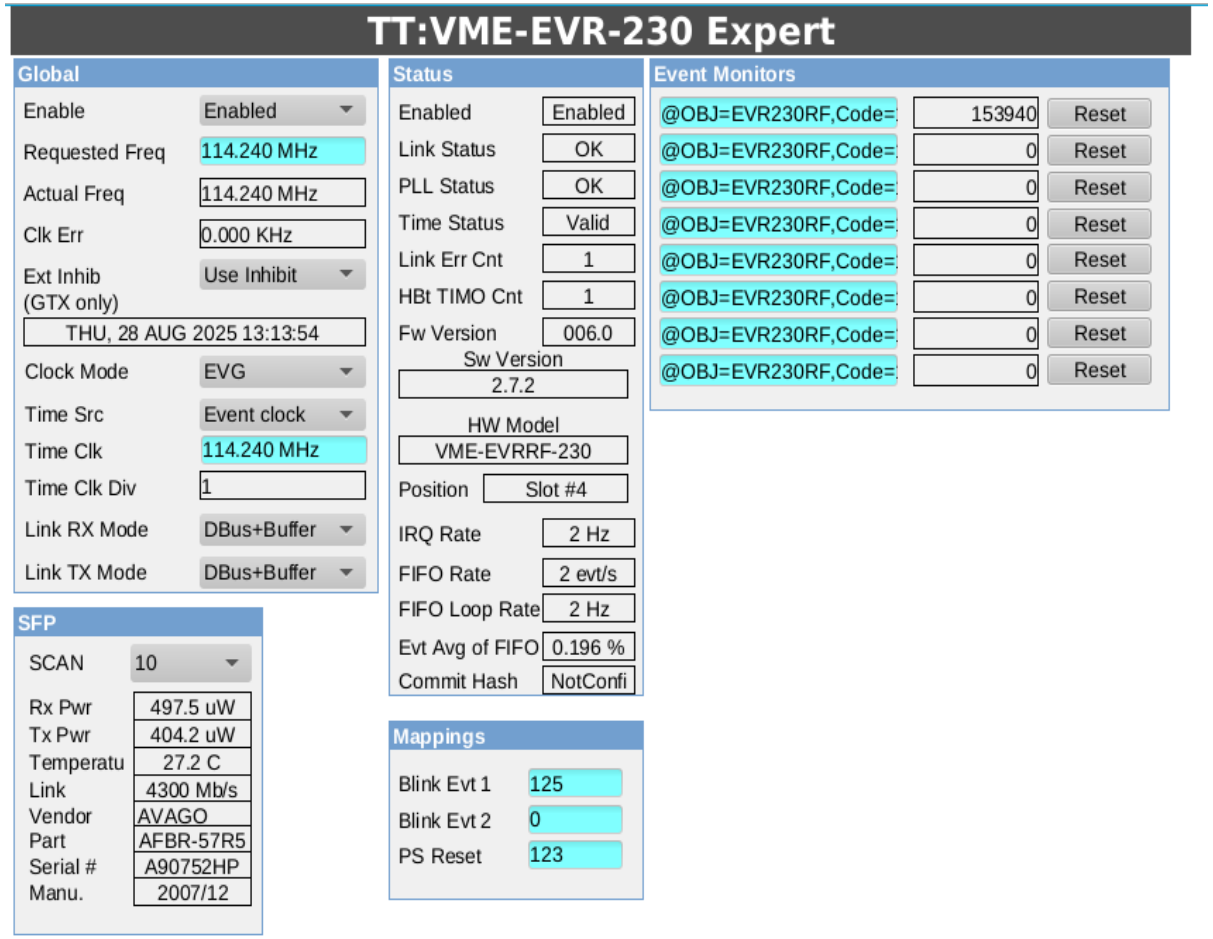
Early Results



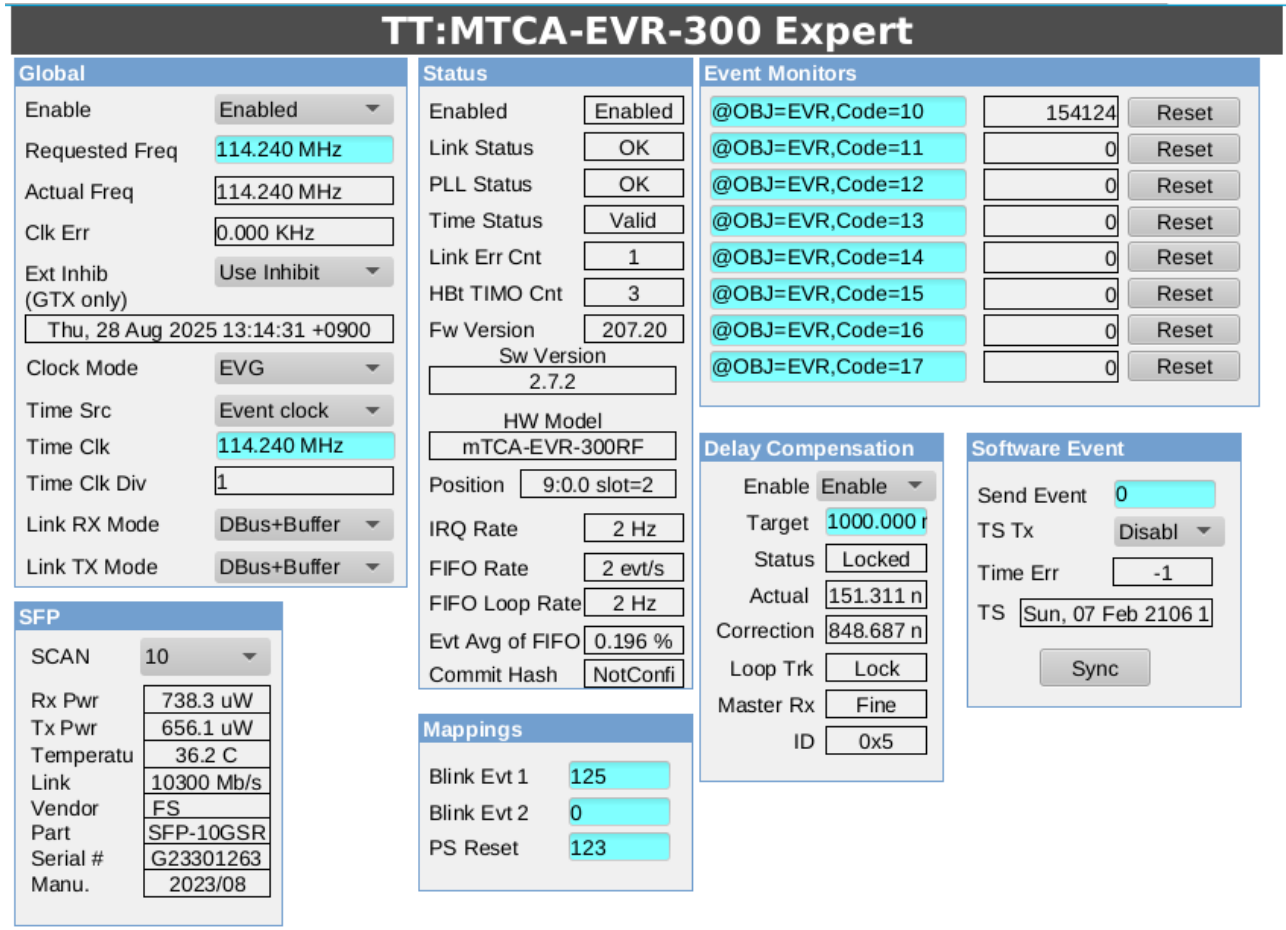
SuperKEKB MR Requirement: <30 ps

Front panel can only output half of event clock, which is 114 MHz/2 = 57 MHz
EVR can output 114 MHz on backplane TCLKA/B

Early Results



OPI VME-EVR-230



OPI for MTCA-EVR-300

Keep EPICS PV name and OPI consistency for various of form factors

Summary & Future Work

- Upgrade plan defined
  - Goal is a fully non-VME timing system with MTCA + MRF 300 modules
  - Phased migration approach ensures safety and compatibility
- Compatibility validated
  - Event code distribution tested and confirmed functional
  - Jitter performance within requirements – no degradation observed
- Next migration tasks
  - Replace remaining VME-based timing modules (TDC/RFM) with MTCA versions
  - Develop new Linux driver for MTCA TDC/RFM modules
  - Integrate into EPICS and conduct system-level tests
- Final target
  - A robust, maintainable, and future-proof MTCA timing system
  - Smooth transition for operators with improved monitoring and reliability