Event-Synchronized Data-Acquisition System for SPring-8 XFEL

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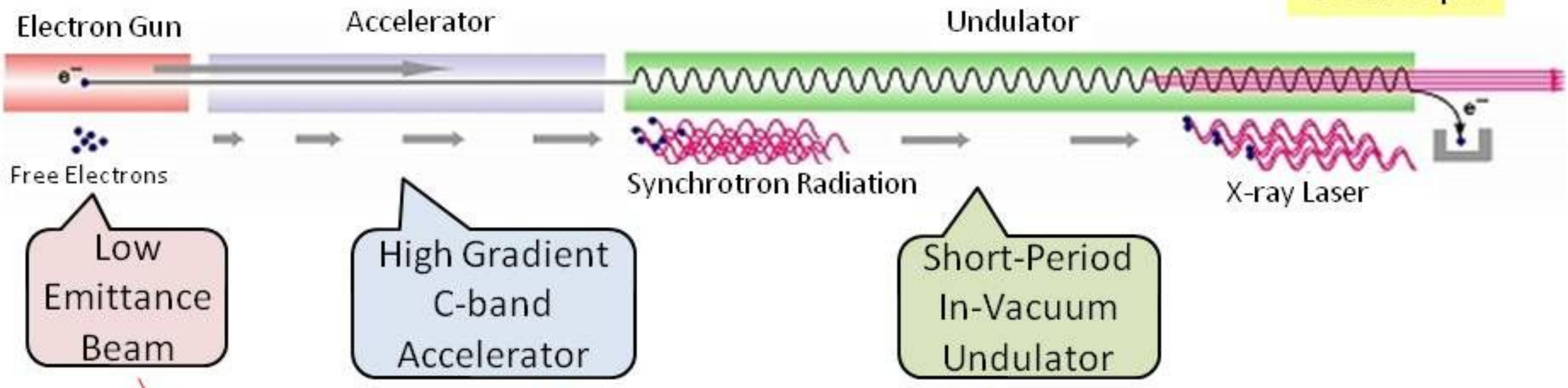
SPring-8 XFEL

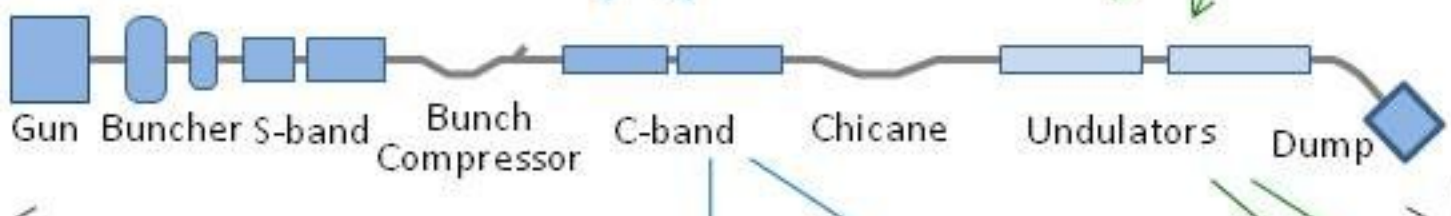
- SPring-8 XFEL will begin operation on 2011
  - aiming for < 0.1nm wavelength by 8-GeV LINAC
- 250MeV Prototype (SCSS): operating since 2006
  - successful for 50~60nm VUV Lasing

Towards the 8-GeV XFEL

- Compactness

Concept



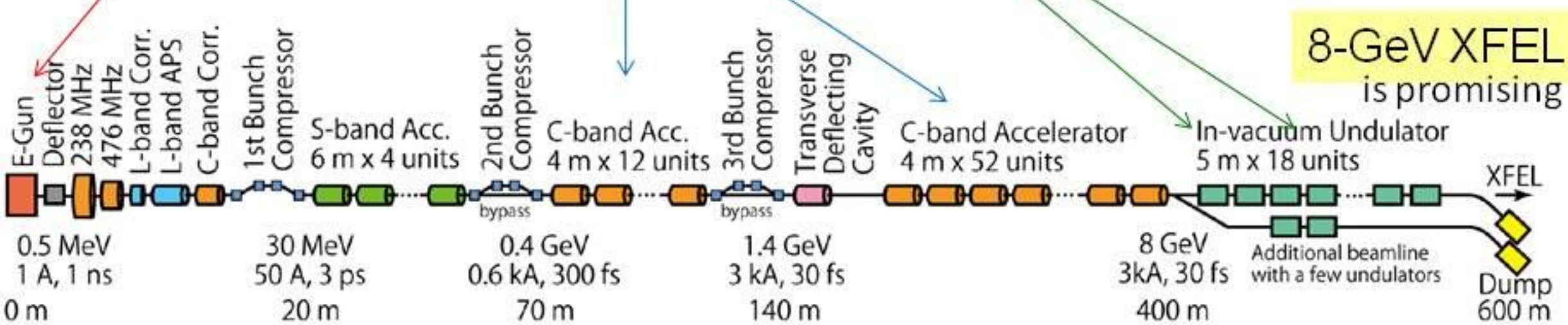


Demonstrated a high-performance FEL at

250MeV SCSS

~60m

8-GeV XFEL is promising



Why need '*Event-Synchronized*' DAQ ?

- For the XFEL system,

  the ***Stability of Laser Pulses*** is critically important.

  However,

  because XFEL is composed of a LINAC system,
  stability is not so easy to be achieved due to the
  pulsed operation for the equipment.

  ⇒ Shot-by-shot measurement to understand behavior

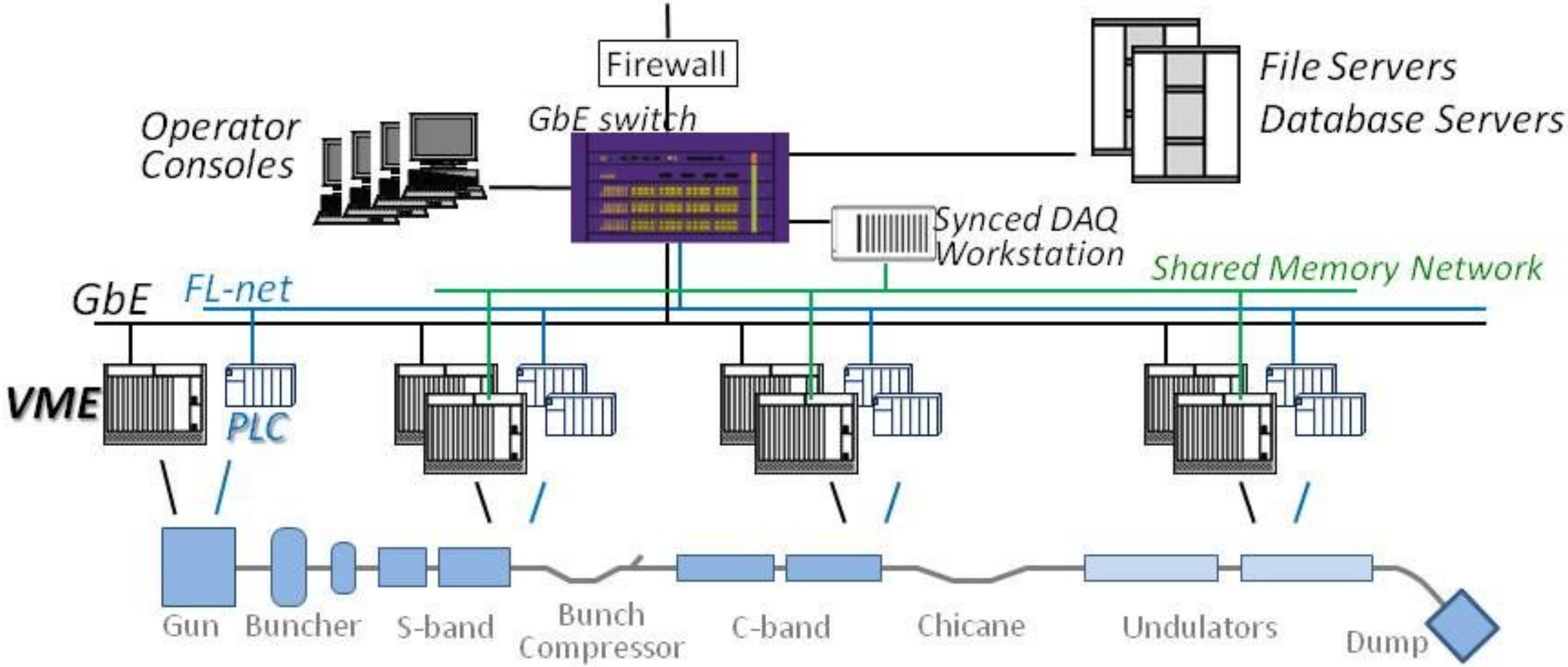
  ⇒ Feedback correction for beam energy and trajectory

- Investigation of the causes of problems/malfunctions for stable and reliable operation.

  * History of shot-by-shot data.

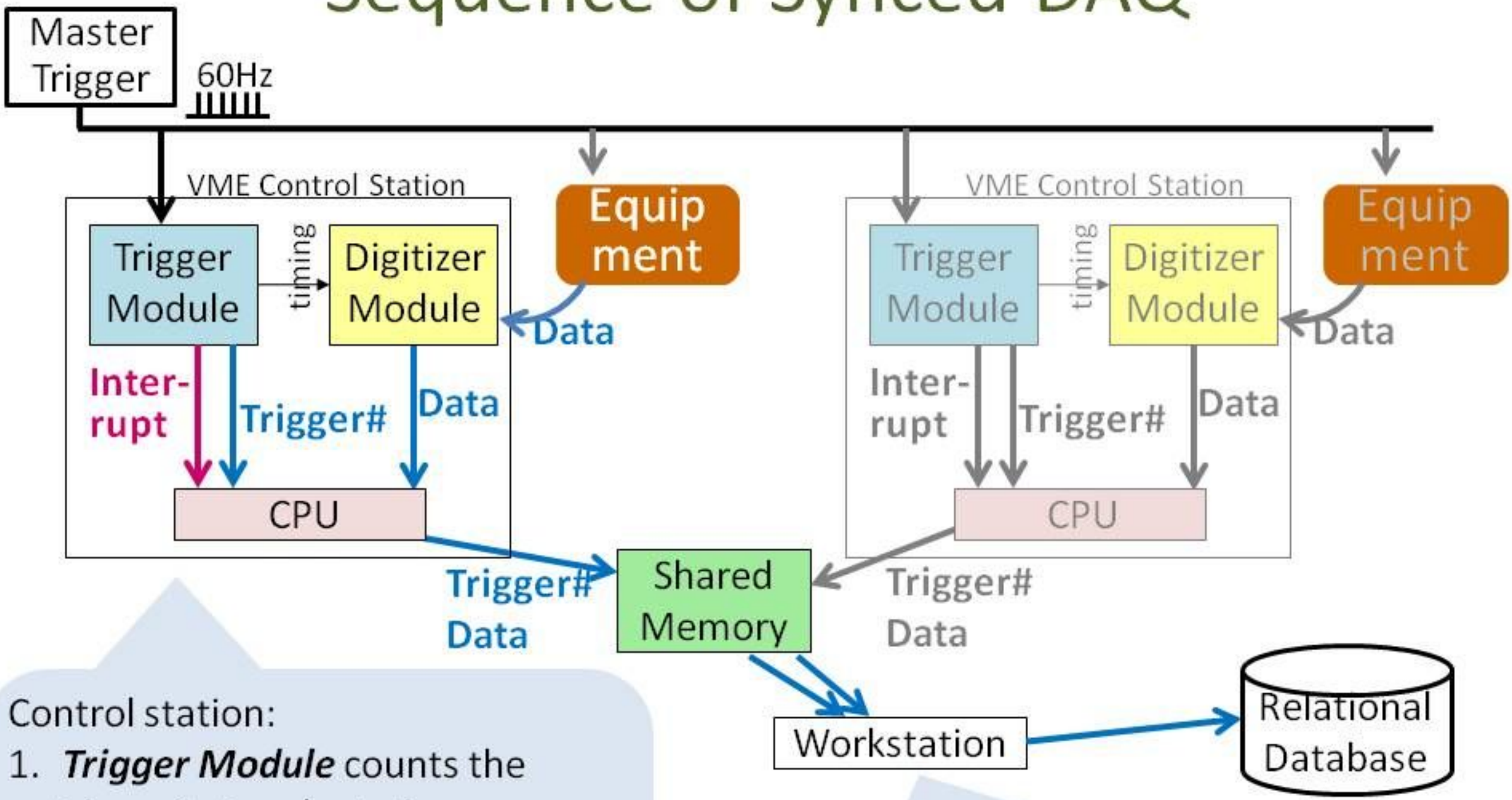
Overview of the control system of SCSS

Distributed system based on the SPring-8 controls.



- VME controllers for fast controls.
- Shared-memory network for Synced DAQ

Sequence of Synced DAQ



Control station:

1. ***Trigger Module*** counts the trigger# at each station.
2. CPU reads data from the Digitizer module when triggered.
3. Puts a set of ***"trigger# and data"*** on the ***shared memory***.

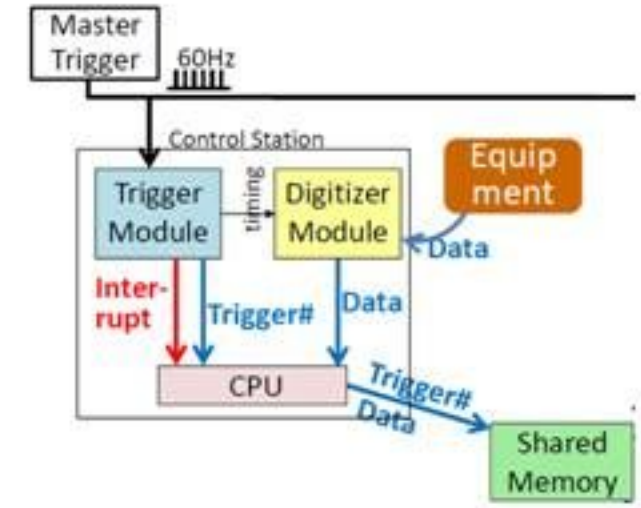
Event Builder :

Collects data having ***same trigger#***, stores them together to the Database .

⇒ *Online synchronization*

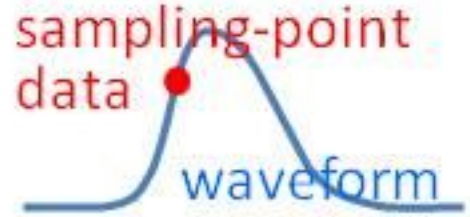
VME modules

- Reflective Memory as a network shared-memory
  - Real-time data-sharing at distributed system

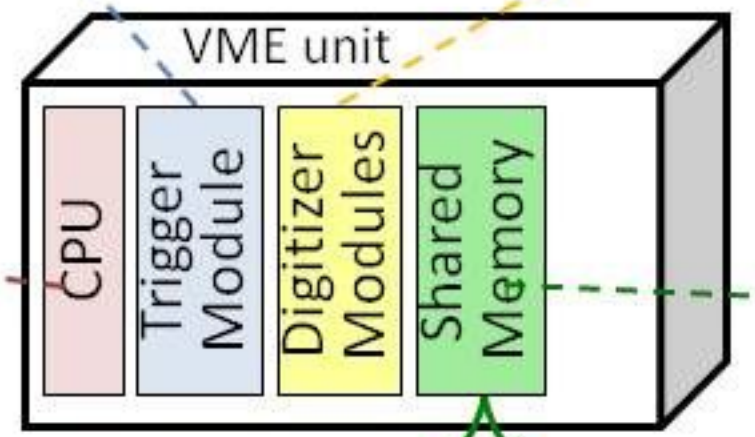


Trigger Module:
ARKUS Axvme4900
Interrupt Register

Digitizer Module:
Advanet Advme2616
Waveform Digitizer



CPU: SVA041
OS: Solaris9



Shared Memory:
VMEVMI-5565
Reflective Memory

Other Shared-memory

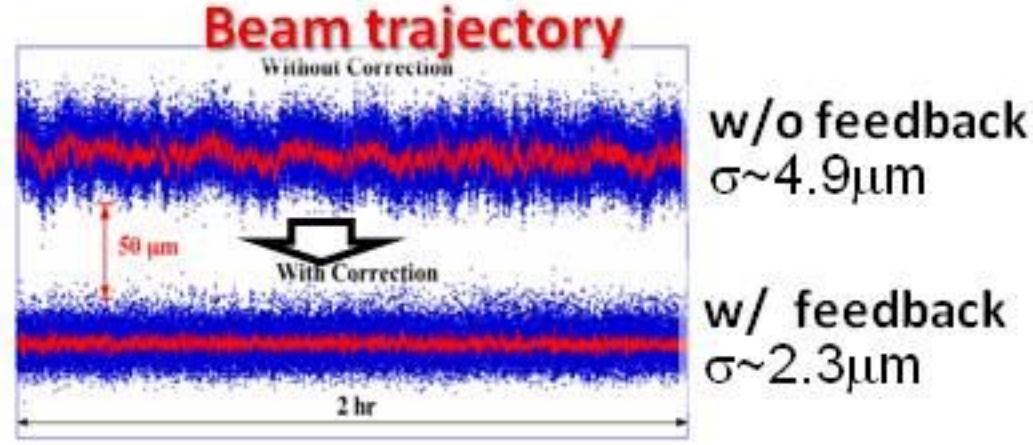
Other Shared-memory

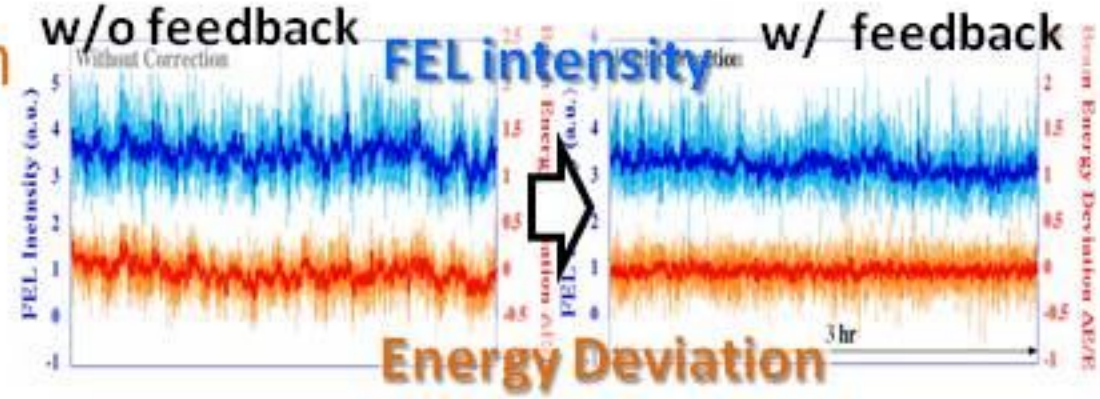
For Monitor System and Feedback Correction

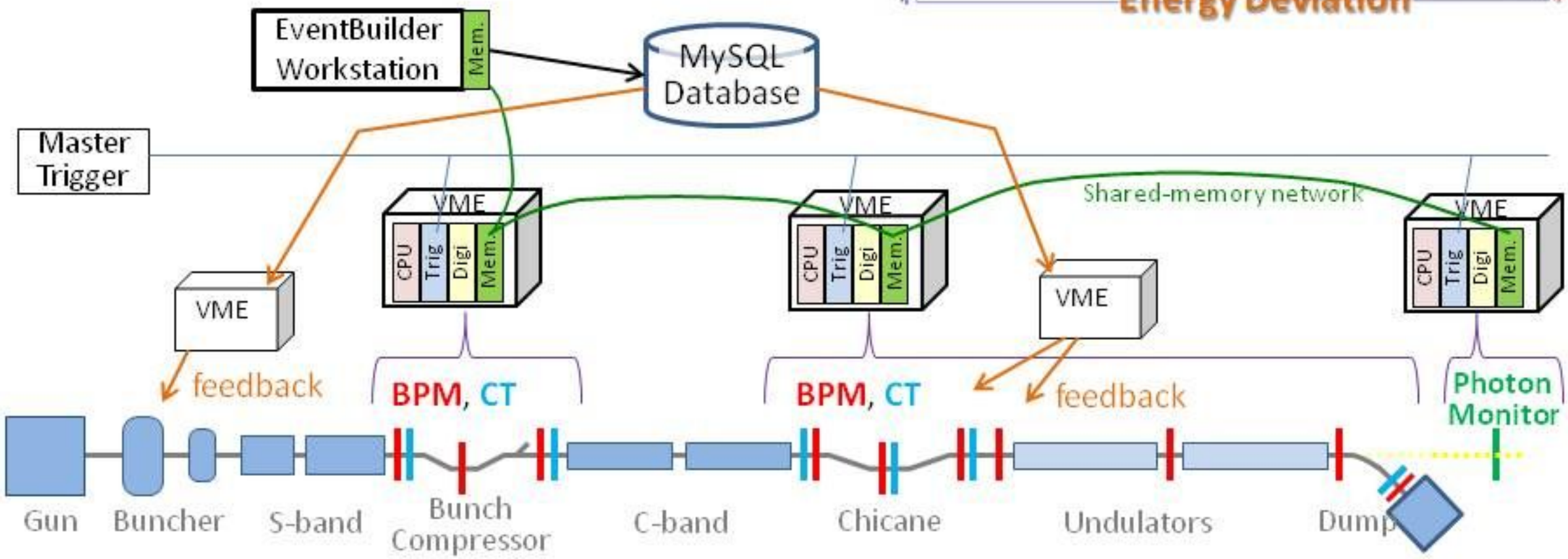
- 3 VME-units.
- 54 channels of sampling-point data from CTs, BPMs and photon monitors.
- Successful up to 60Hz of beam cycle.
  - Data rate ~60kB/sec

Data are utilized for feedback correction of beam energy and trajectory.

⇒ Quite effective for stabilization.





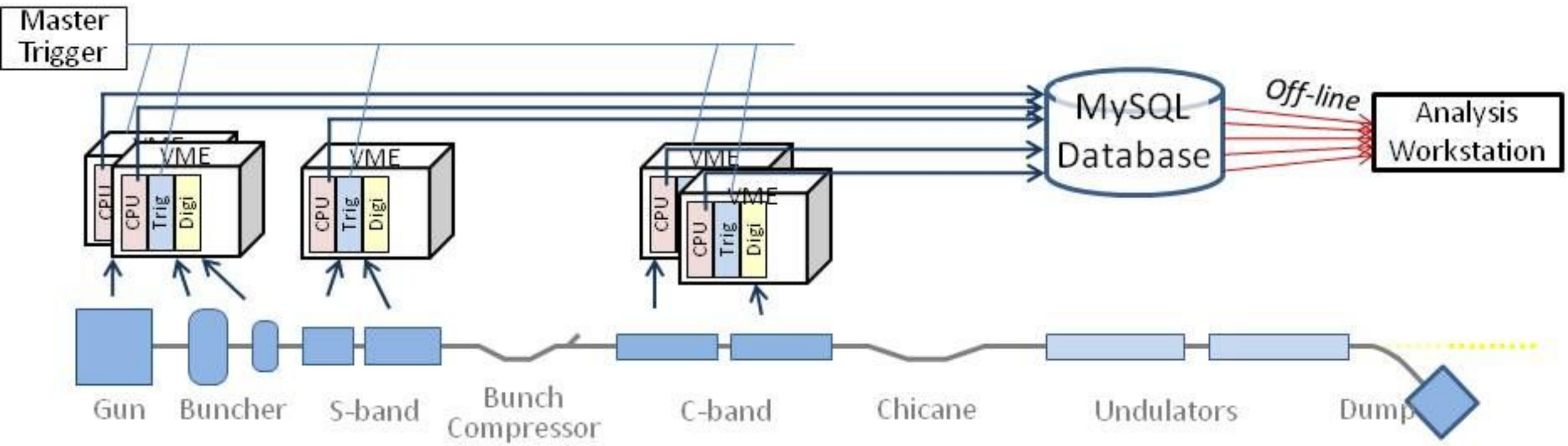


For RF System

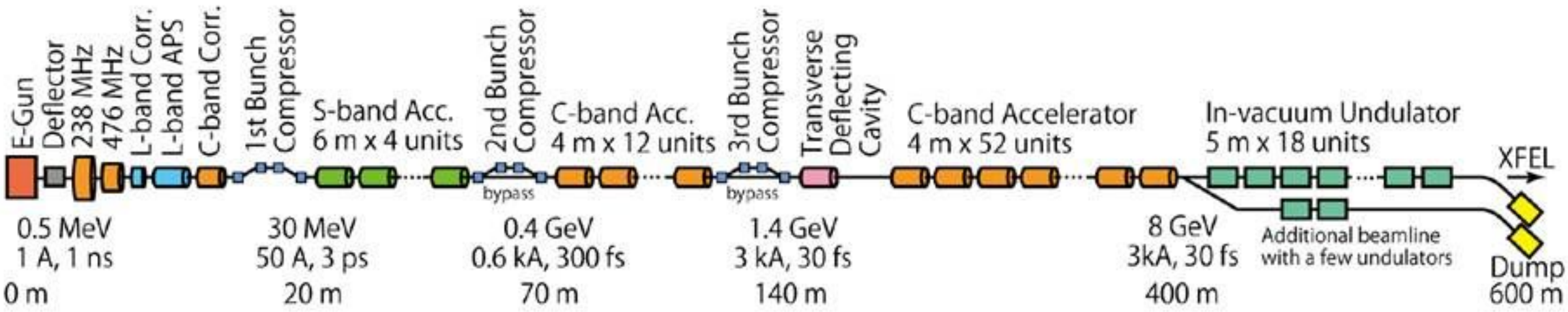
Valuable for the investigation of problems/malfunctions.
⇒ History of all equipment 'in the same shot'

- Reflective-Memory is unnecessary. (i.e. no real-time analysis)
  ⇒ Suppress the cost for many RF units, e.g. at the 8-GeV XFEL.
- *Event-synchronization* can be done at *off-line analysis* process.
  – Search the data having same trigger# from DB

Successful with 6 VMEs,
48 sampling-point signals up to 60Hz, 25 waveforms at 0.1Hz.
  – Data rate ~60kB/sec



At the 8-GeV XFEL …



- More than 70 VMEs for the RF units
- ~30 VMEs for monitor systems

⇒ ~ x10 of channels for Synced DAQ than SCSS

Data rate will be ~1.2 MB/sec in total.

Same scheme as SCSS will be operational by simply scaling up the number of units.

Summary

- Our Event-synchronized DAQ with VME-based distributed-system contributes quite effectively to stabilize the beam at SCSS Prototype Accelerator.

- Shot-by-shot data will also be useful to investigate the cause of problems or malfunctions in the equipment.

- The same scheme will be implemented to the 8-GeV XFEL at SPring-8.

backup

Table 1: Achieved SASE FEL performance

Item	**Achieved value**
Wavelength	50~60 nm
Laser Pulse Energy	30~40μJ
Repetition Rate	20 Hz (60 Hz[*1])
Pulse Energy Fluctuation (STD)	~10%, 14~15%[*2]
Laser Profile Radius (FWHM)[*3]	3 mm
Pointing Stability[*3]	~5% of Laser Radius
Average Spectrum Width (FWHM)	0.6~1%

*1 60 Hz was tested only in the machine study.
*2 ~10% is for a short period and 14~15% is over the beam operation.
*3 16-m downstream of the source point.

Troubles

- Early days (2006~)
  - Short circuit of the dummy tube cathode heater in the electron gun
  - Vacuum leakage of the S-band APS
  - Electric circuit damage of the PFN (pulse forming network) high voltage charger

- Recently (2007~)

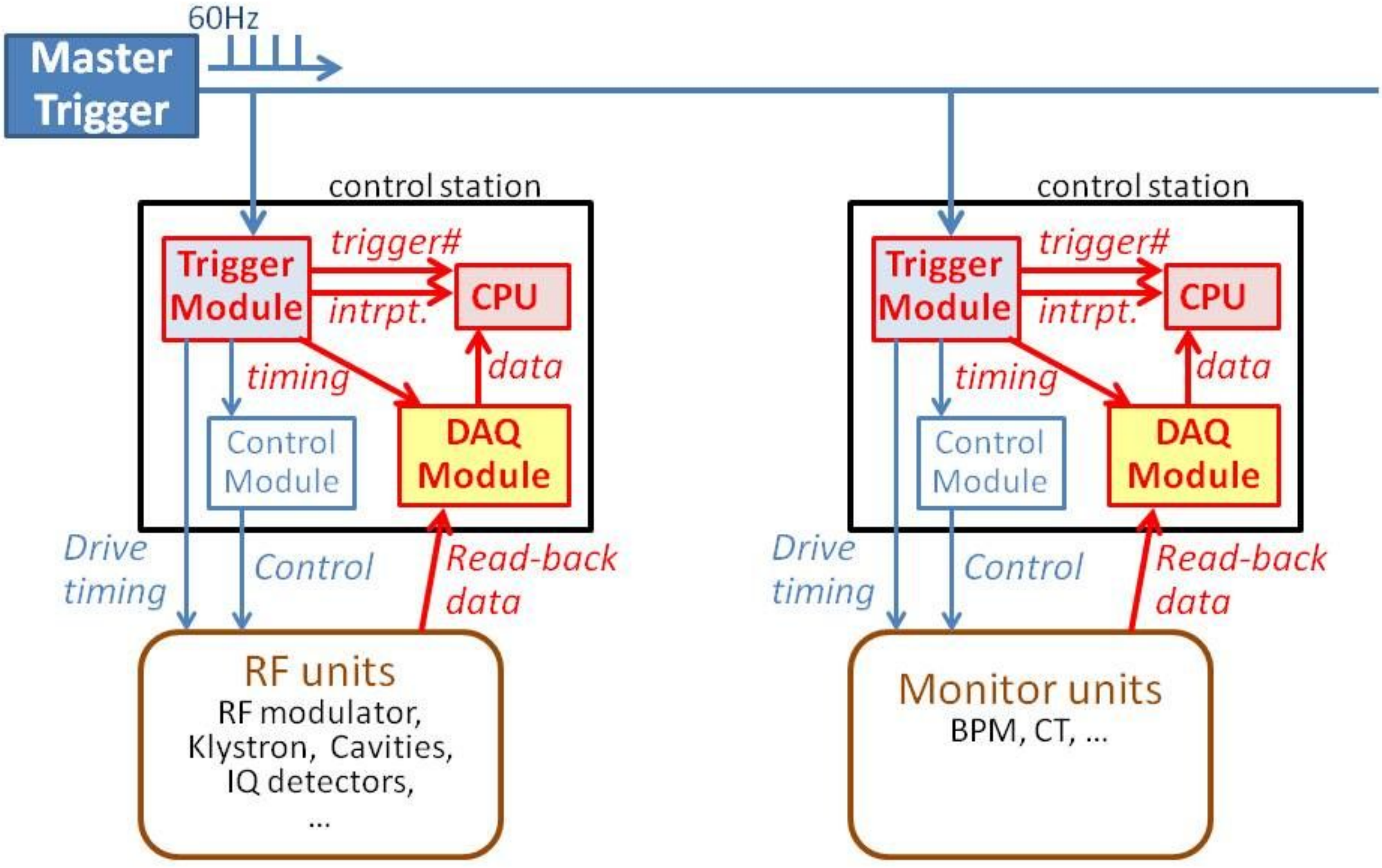
  Minor troubles only
  - Short circuits of some power cables
  - Failures of the solid-state amplifiers
  - Failures of the thyratrons
  - ...

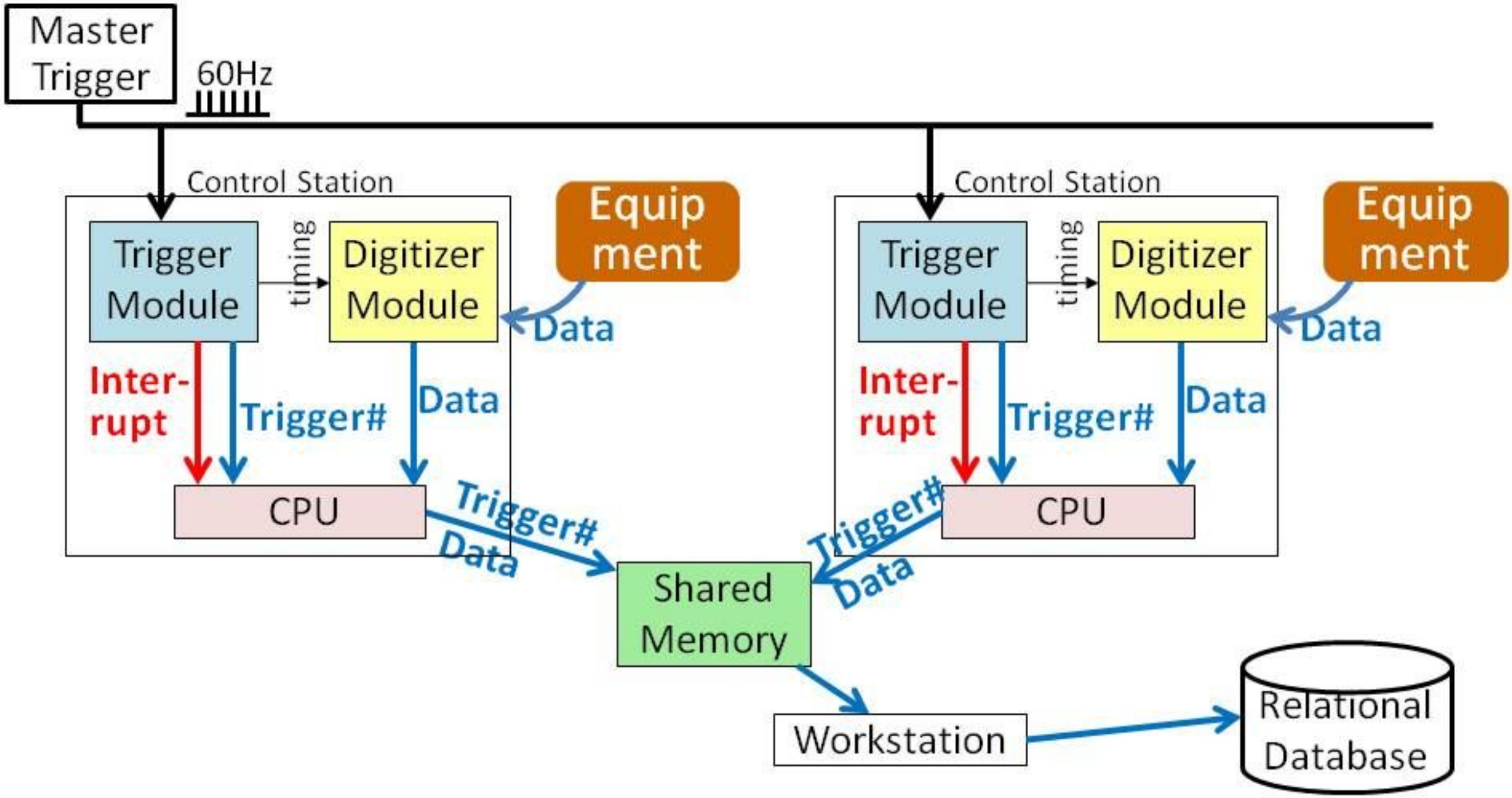
Conceptual Design

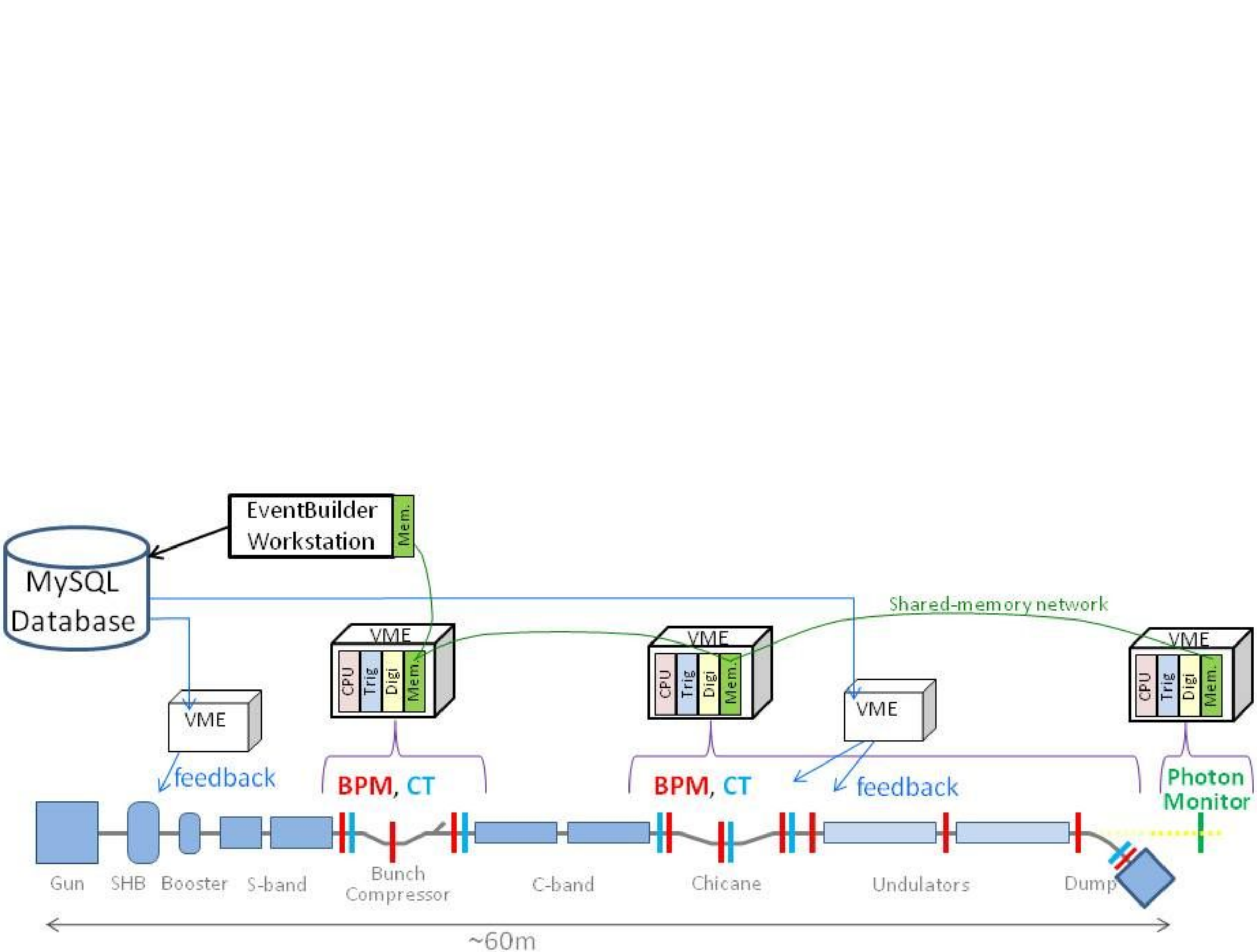
- Equips are driven with the Master Trigger timing.
- Deliver the Master Trigger timing to each station.
- Count the trigger number at each station.
- Read data from equipment when trigger arrives.

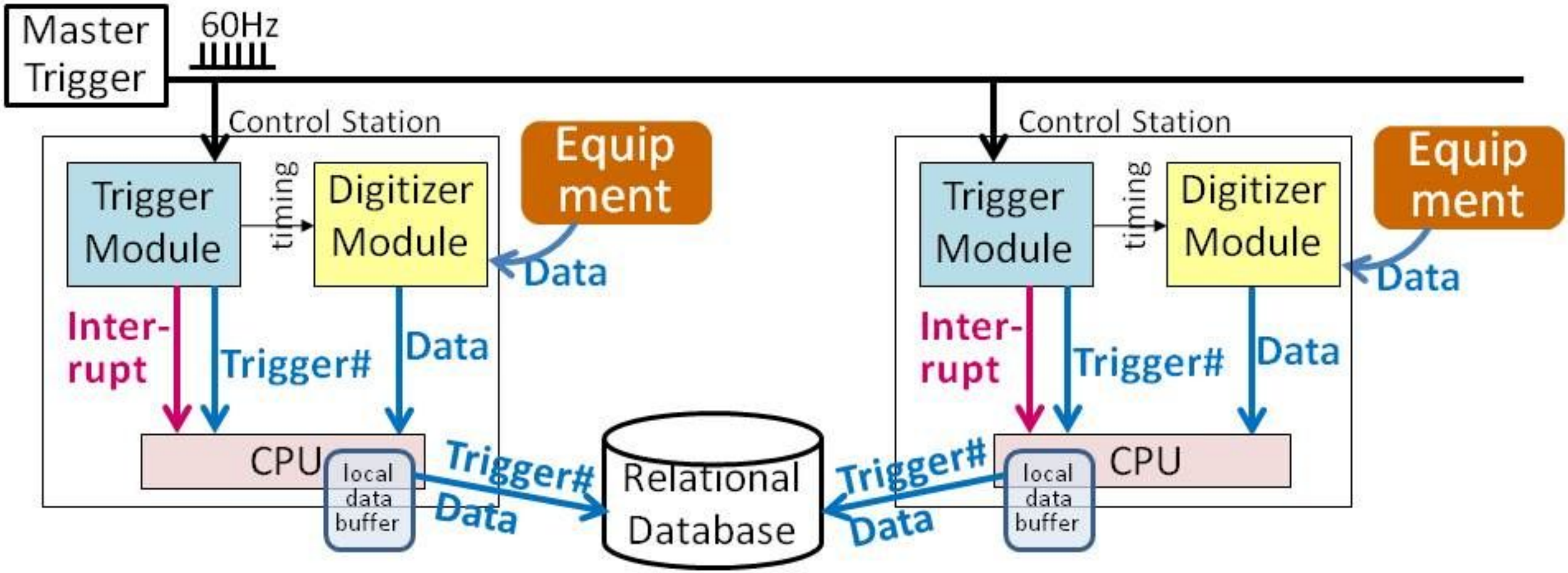
- Solaris
- VME
- Relational DB

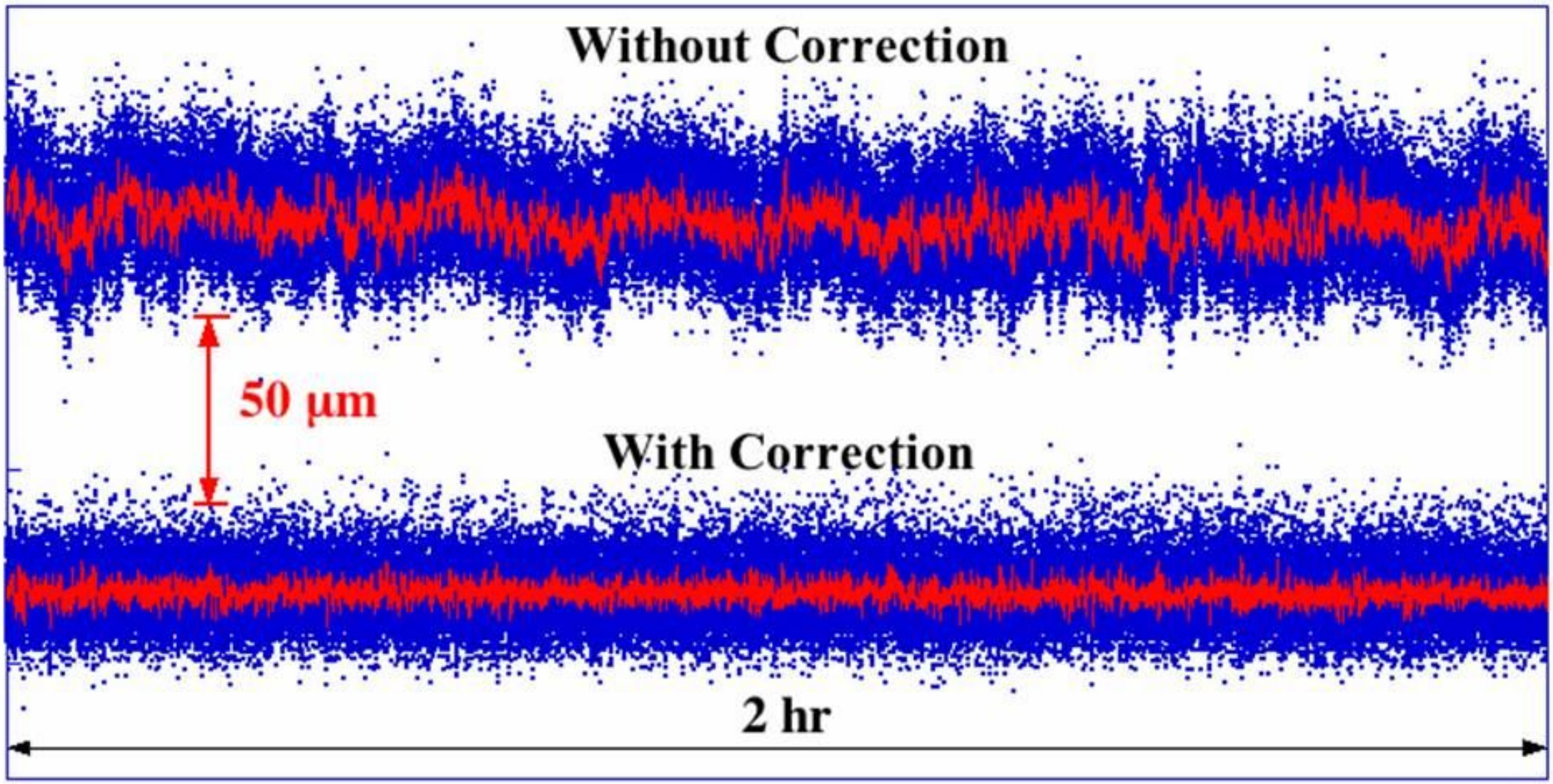
Conceptual Design of the Event-Synchronized DAQ




Master Trigger
60Hz
Control Station
Trigger Module
timing
Digitizer Module
Equip ment
Data
Inter-rupt
Trigger#
Data
CPU
Trigger#
Data
Control Station
Trigger Module
timing
Digitizer Module
Equip ment
Data
Inter-rupt
Trigger#
Data
CPU
Trigger#
Data
Shared Memory
Workstation
Relational Database


EventBuilder
Workstation
Mem.
MySQL
Database
Shared-memory network
VME
CPU
Trig
Digi
Mem.
feedback
BPM, CT
BPM, CT
feedback
Photon
Monitor
Gun
SHB
Booster
S-band
Bunch
Compressor
C-band
Chicane
Undulators
Dump
~60m


Master Trigger
60Hz
Control Station
Trigger Module
timing
Digitizer Module
Equip ment
Data
Inter-rupt
Trigger#
Data
CPU
local data buffer
Trigger#
Data
Relational Database
Trigger#
Data
Control Station
Trigger Module
timing
Digitizer Module
Equip ment
Data
Inter-rupt
Trigger#
Data
CPU
local data buffer


Without Correction
50 μm
With Correction
2 hr

Without Correction

FEL Inetnsity (a.u.)

6 5 4 3 2 1 0 -1

Beam Energy Deviation ΔE/E

2.5 2 1.5 1 0.5 0 -0.5 -1

With Correction

FEL Intensity (a.u.)

6 5 4 3 2 1 0 -1

3 hr

Beam Energy Deviation ΔE/E

2.5 2 1.5 1 0.5 0 -0.5 -1