A Prototype Data Acquisition System of Abnormal RF Waveform at SACLA

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Outline

- Introduction
- Scheme of a DAQ system for abnormal RF waveforms
- Installation
- Summary

Introduction

SACLA

(Spring-8 Angstrom Compact Free Electron Laser)

SACLA has been operating for user experiments since March 2012.

In 2013
Total operation time
7000 hr
User Experimental time
3200 hr

SACLA is for the user experimental machine.

Data collection

- To maintain the scheduled user time as much as possible, we must reduce down time due to failure.
- To diagnose a failure source, it is necessary to collect data of many accelerator components.

- a data logging system with a cycle of several seconds
  - Environmental temperature, vacuum, interlock status, …
- an event-synchronized DAQ system in synchronization with the beam operation cycle
  - current maximum of 60 Hz
  - Bean currents, beam position, …
- RF waveform collection every 10 min

Motivation

- Abnormal RF waveforms may occur only a few times a day at all low-level RF of SACLA.
  - Sources of RF instability
    - electric discharge in a klystron tube
    - reflection in cavity
    - miss fire of thyratron
    - …

- We want to capture an abnormal waveform and predict the failure of components by taking statistics of failure event.

We developed a new DAQ system.

- captures an abnormal RF waveform that suddenly occurs
- stores the waveform in DB

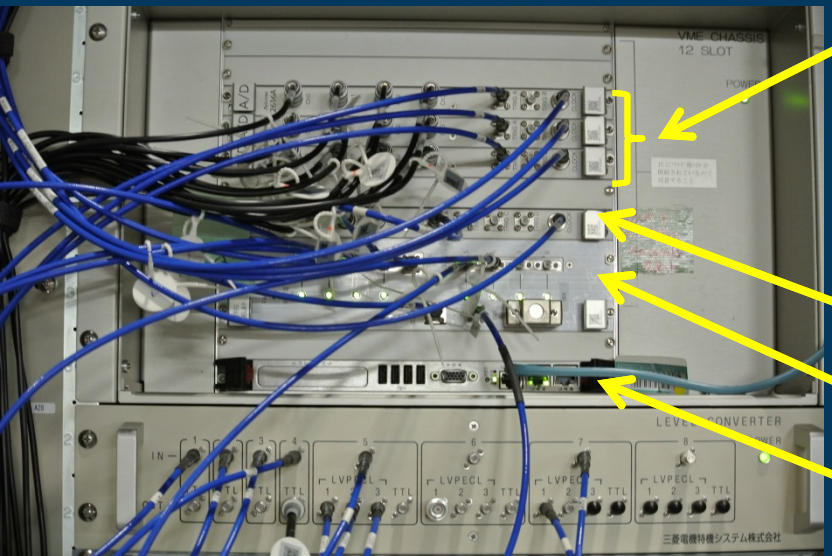
Scheme of a DAQ system of abnormal RF waveform

RF unit

The low-level RF system is composed of 74 RF units.

The klystron gallery

VME configuration of one RF unit



ADC board

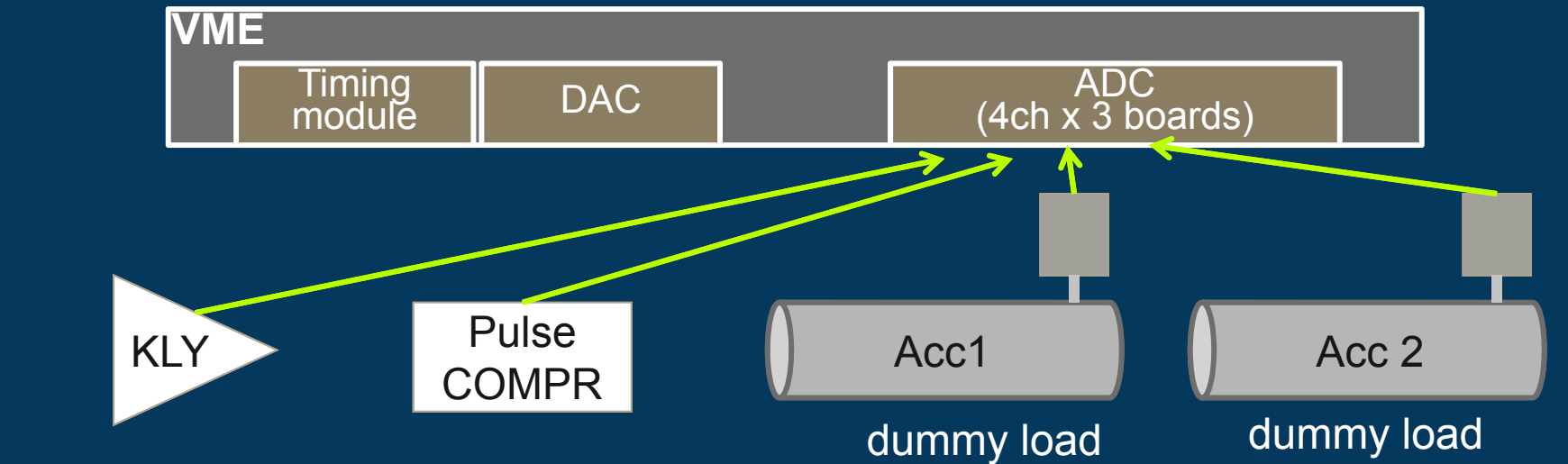
- The ADC board has 4 ch.
- 3 boards are implemented. (in total 12 ch)

DAC board

Trigger Delay Unit boad (timing module)

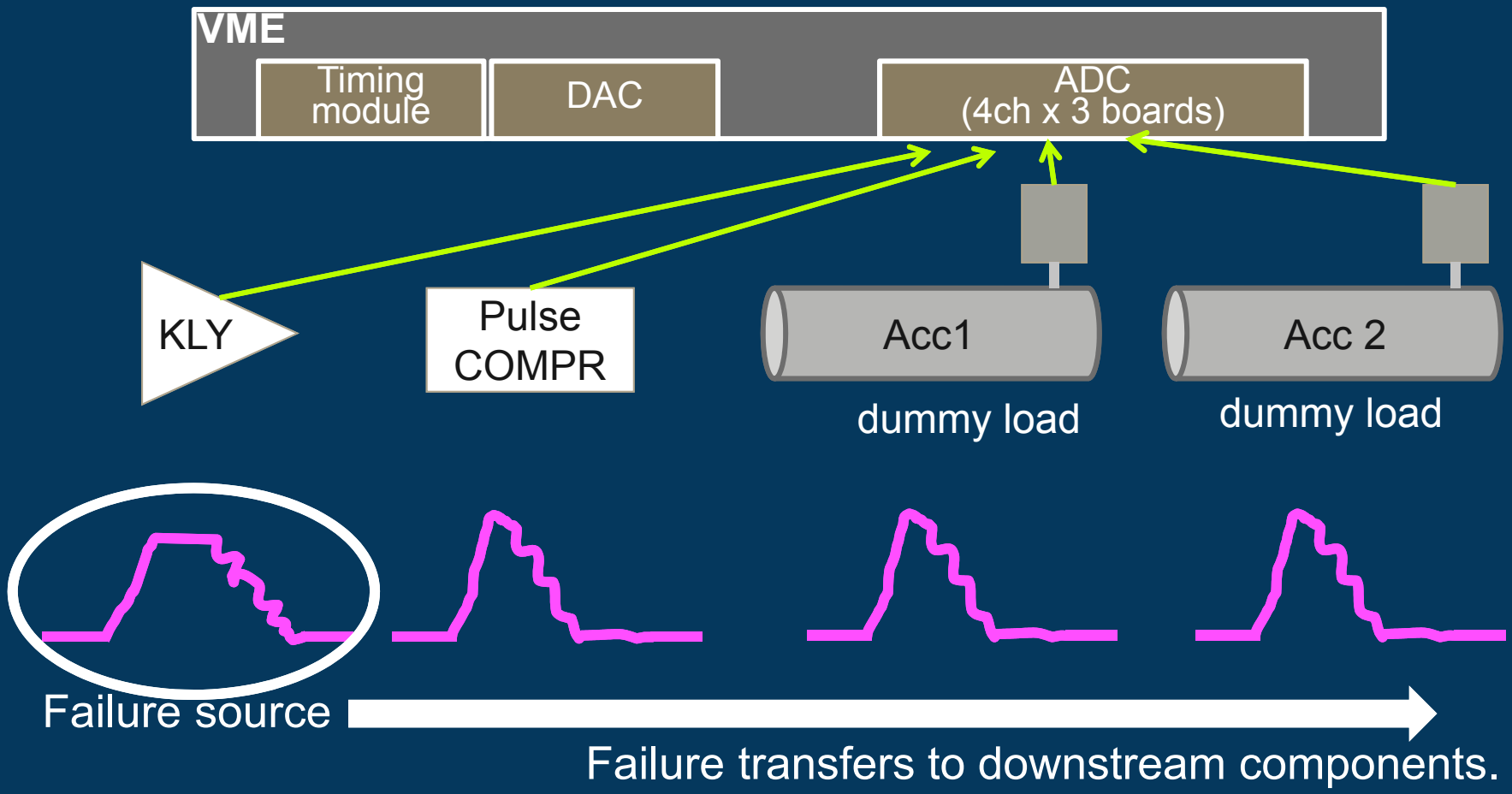
Multi-core CPU board

Identification of failure source



All waveforms are normal.

Identification of failure source



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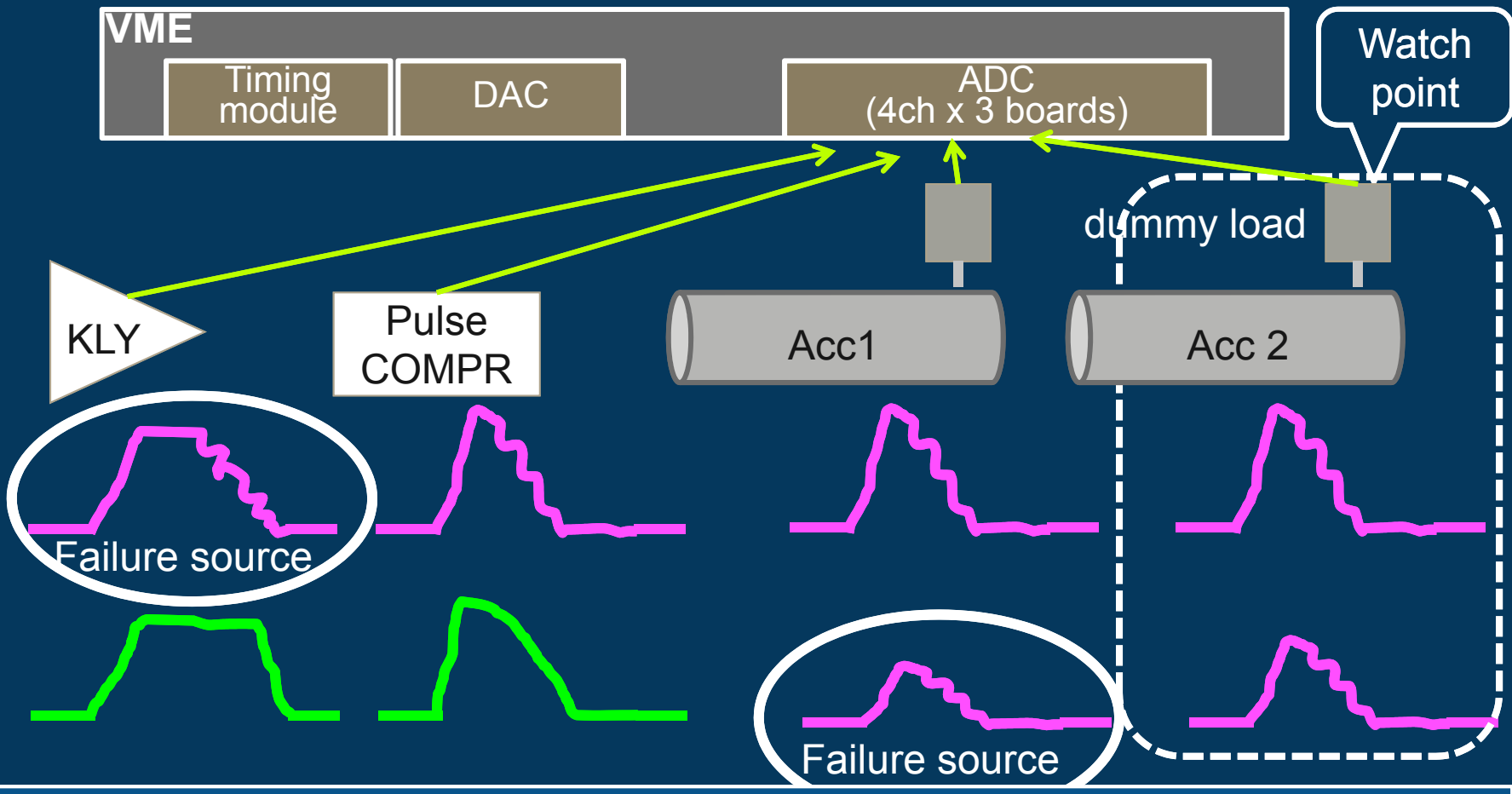
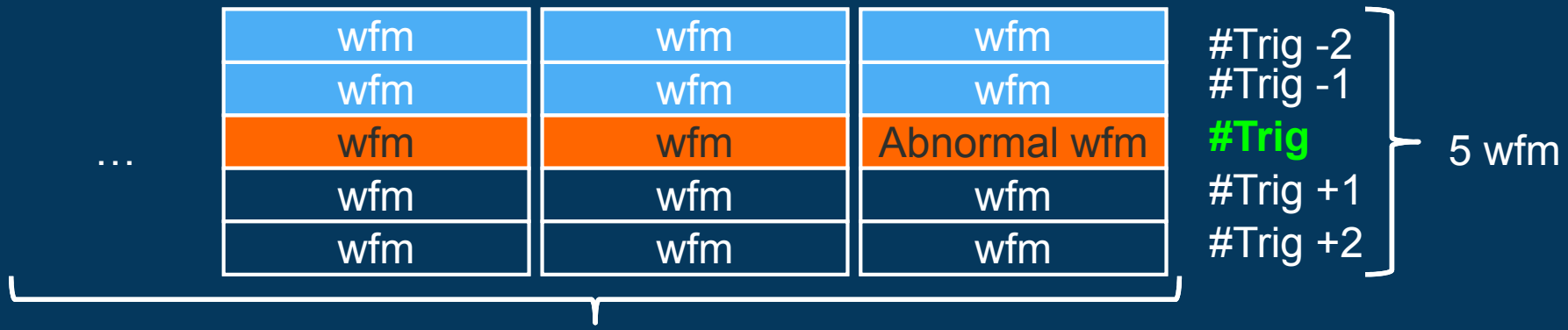


A failure of upstream components certainly transfers the most downstream dummy load.
We set only the downstream dummy load as a watch point of abnormal detection.
When ADC board detects abnormal waveform, the board collects all waveforms.
The failure sources are included.

The number of waveform

- ADC board takes not only the abnormal waveform but also previous and following waveforms of the abnormal one.
  - Abnormality is one shot ? or propagation error ?

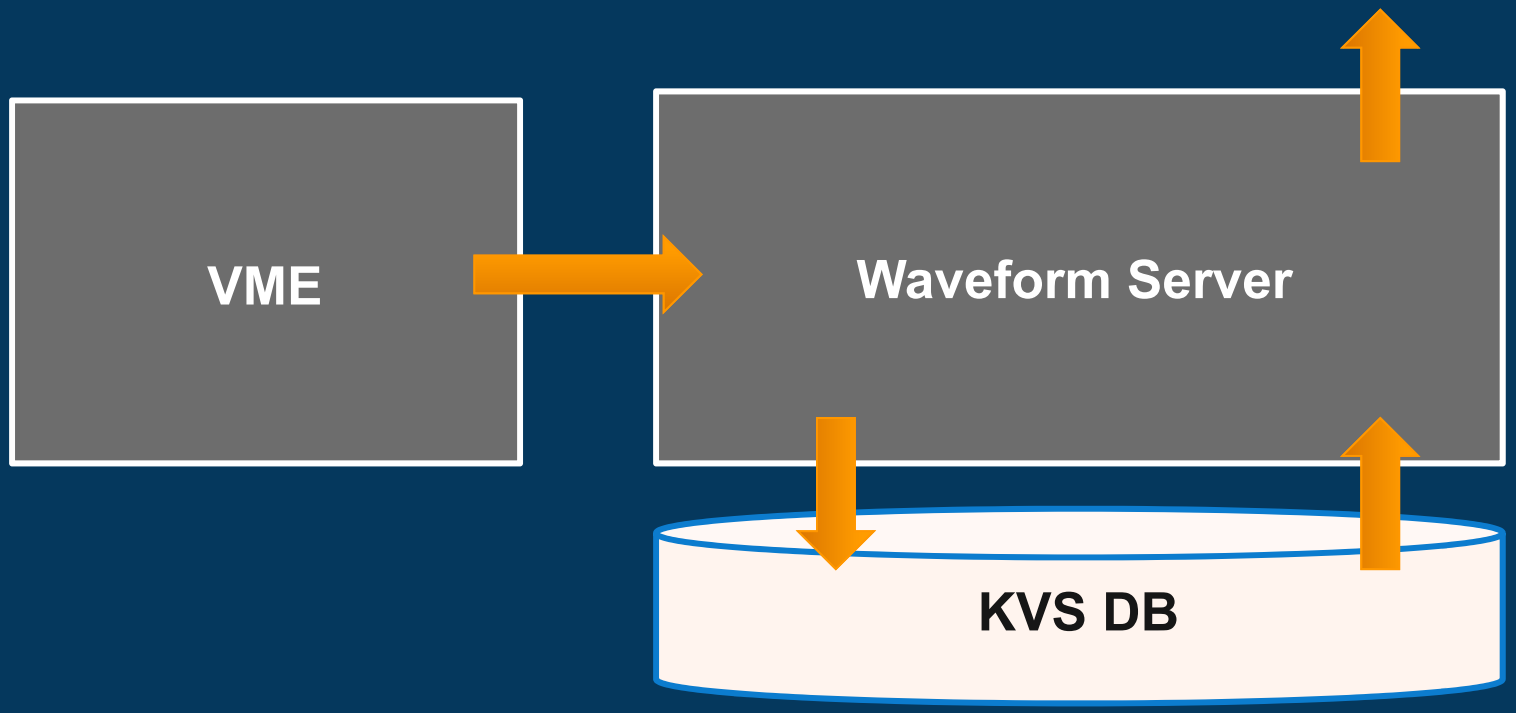


5 waveforms * 4ch * 3 boards = 60 waveforms at one abnormality of one RF unit.

A waveform data size is 16KB.

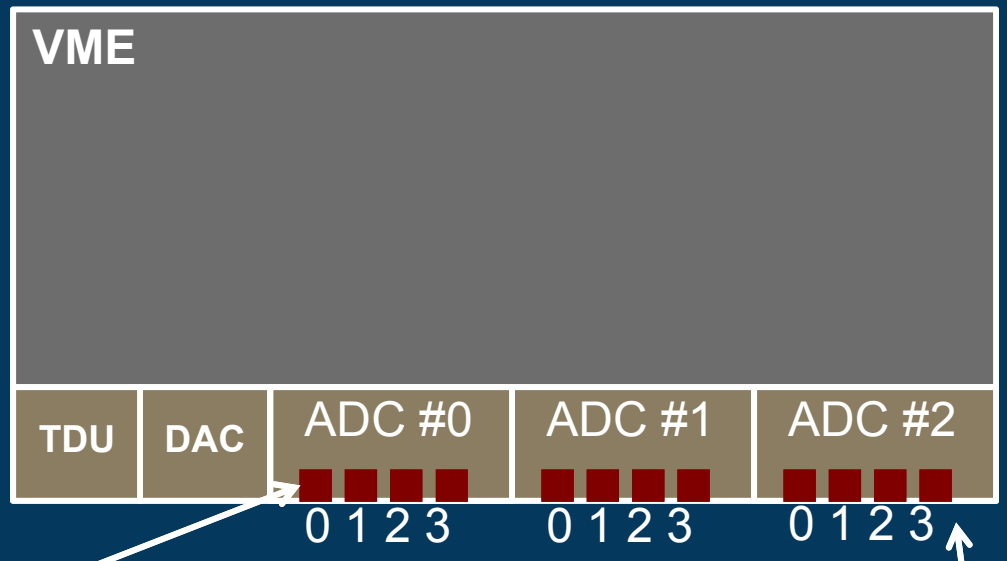
- resolution : 16-bits, sampling number : 8K

A DAQ system

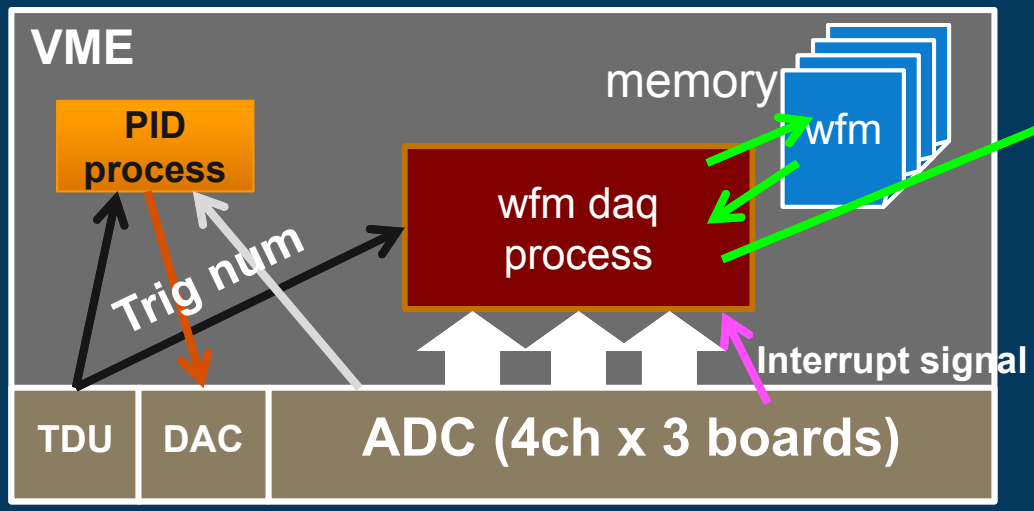


A DAQ system signal name

Each ADC channel is assigned a human-readable signal name.
It is a feature of MADOCA control framework.



A DAQ system
VME



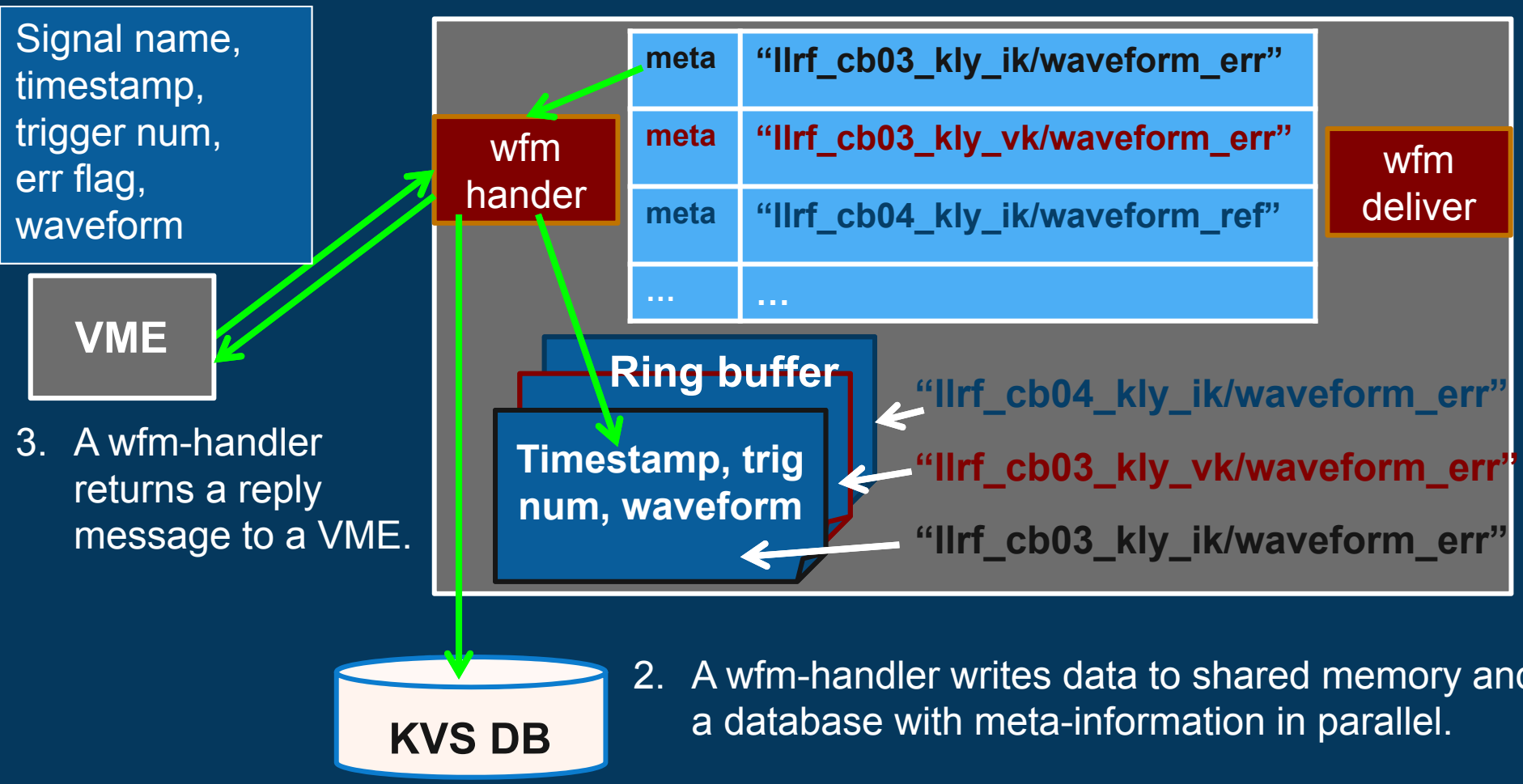
Waveform Server

1. When an ADC board detects an abnormal waveform, the board issues an interrupt signal to a DAQ process.
2. The process takes a timestamp, a trigger number, …

3. The process takes the abnormal waveforms, the previous and the following waveforms (ex. 60 waveforms) and write waveforms on memory.
   - To prevent blocking VMEbus access from the PID process , the DAQ process takes each waveform data at a 500-ms interval.
4. The process sends each waveform with a signal name, a timestamp, a trigger number.

A DAQ system
Waveform Server

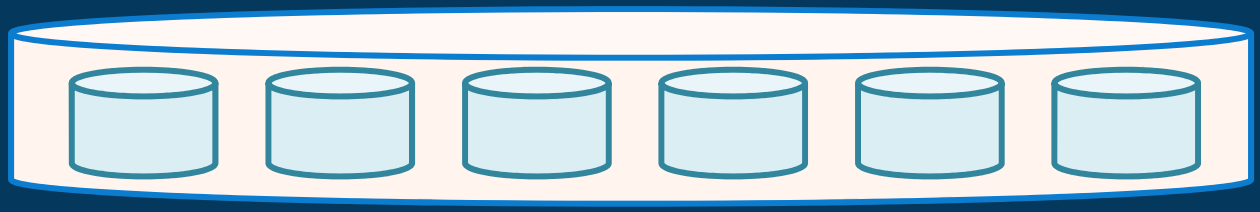
1. When a wfm-handler receives data from a VME, the process takes meta information according to signal name from a signal table (shm).



3. A wfm-handler returns a reply message to a VME.

2. A wfm-handler writes data to shared memory and a database with meta-information in parallel.

A DAQ system
Database



- requirements
  - high write performance
  - fault tolerance
  - Valuable length data

We adopted Apache Cassandra.

MADOCA II (Next Generation of MADOCA) adopted Cassandra.

Cassandra can efficiently handle time-series.

Cassandra's data structure

DATA

row-key : "xfel_llrf_sb_1_iq_acc_2_dload_ta_i/waveform_err:20140918"

Column name	Column value
1411012800200100:trig	12345678
1411012800200100:err	1 ← abnormal
1411012800200100:wfm	Waveform data (binary)
….	….

row-key : "xfel_llrf_cb01_1_iq_acc_1_dload_ta_i…veform_err:20140919"

Column name	Column value
1411012800401760:trig	12355678
1411012800401760:err	0 ← normal
1411012800401760:wfm	Waveform data (binary)
….	….

One row-key provides the information of one day's signal.

The row-key name is formed from a signal name in addition to a date string.

A name is formed from a timestamp in addition to key word such as "trig", "err", and "wfm".

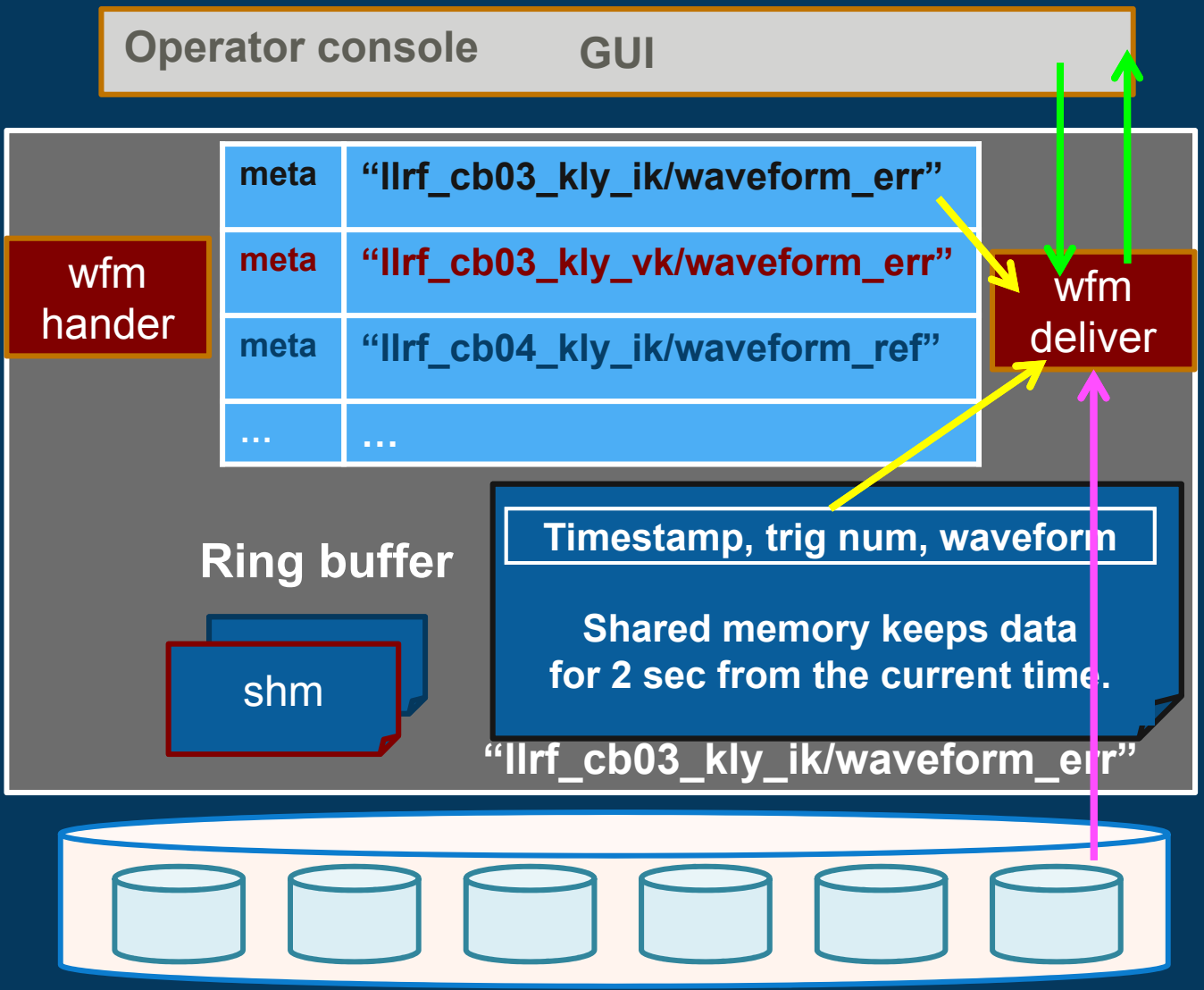
Cassandra cluster eventual consistency

- Cassandra can construct multi node clustering to achieve a redundant system.
- The time required for guaranteeing consistency is as much as 1 sec *.
  - When the data are taken from a cluster with 6 nodes and a replication factor of 3.

To prevent this inconsistency, the waveform server is designed as a cache server.

* M. Kago, et al, “Development of a Scalable and Flexible Data Logging System Using NoSQL Databases”, ICALEPCS2013

A DAQ system readout from a cache



1. A GUI requires waveform with a signal name and a timestamp.
2. A wfm-deliver takes waveform from shared memory or Cassandra in accordance with a timestamp that the GUI required,
3. and sends the data to the GUI.

Installation

At test stand

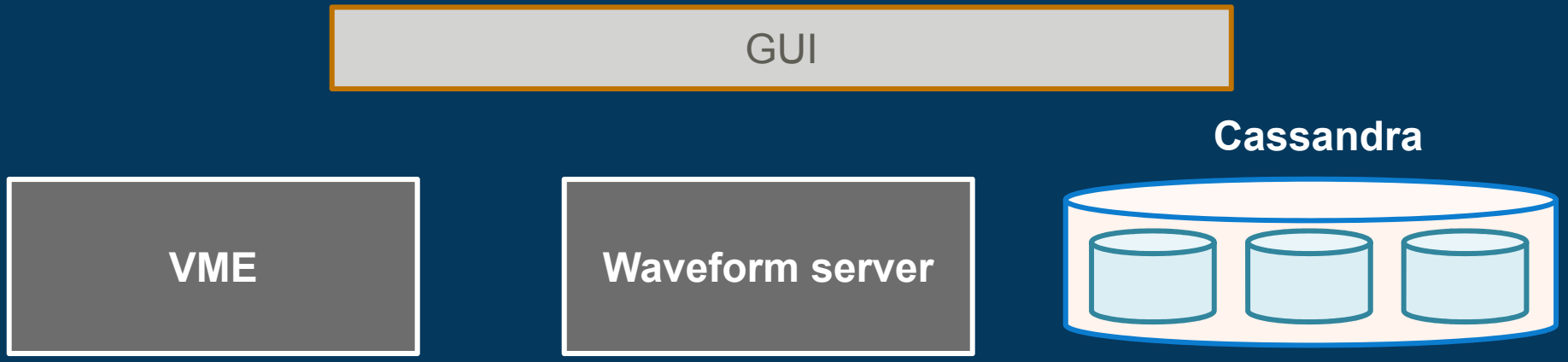
- We tested a prototype system with a minimum configuration to ensure the performance of the low-level RF VME system.
  - One VME set
  - Cassandra cluster
    - 3 node, replication factor of 2

SACLA has one set of low-level RF test stand.

- It is set real accelerator structures, kly, modulator, control system, ...

performance

- The time to take 16KB of waveform data from an ADC channel = ~1 ms.
- The round trip time (@ a waveform with 16 KB)
  - VME ~ a waveform server ~ Cassandra = ~10 ms
  - GUI ~ a waveform server = ~ 3 ms
  - GUI ~ a waveform server ~ Cassandra = ~ 6 ms



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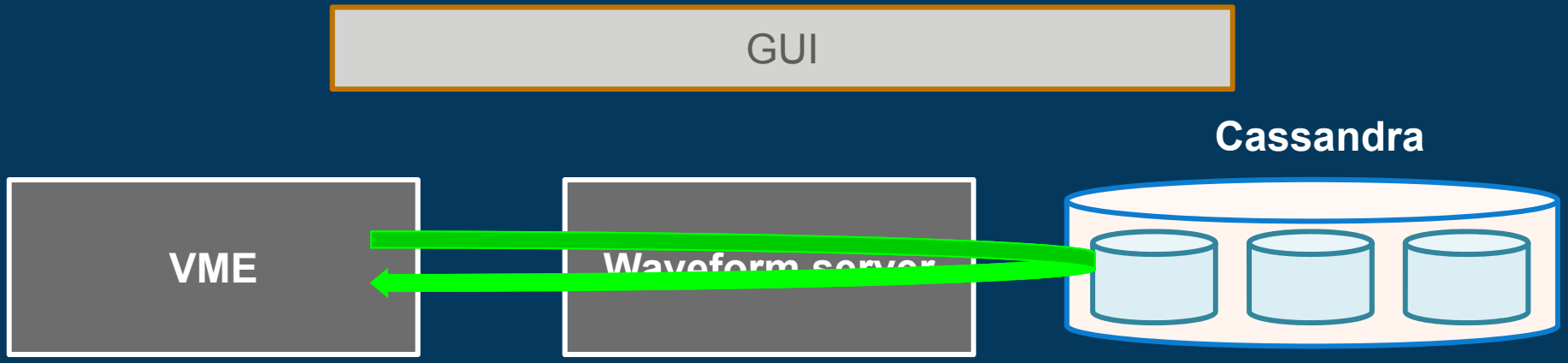

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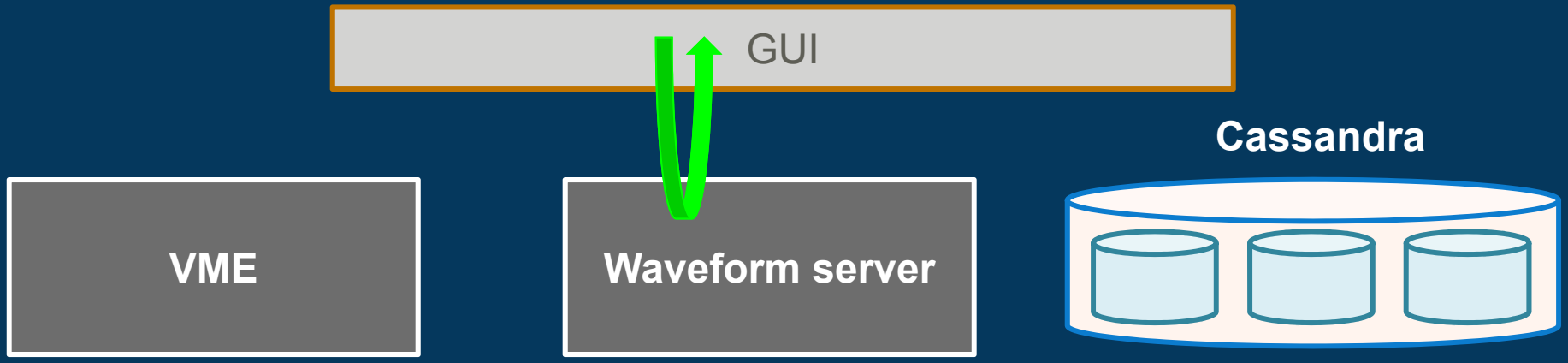

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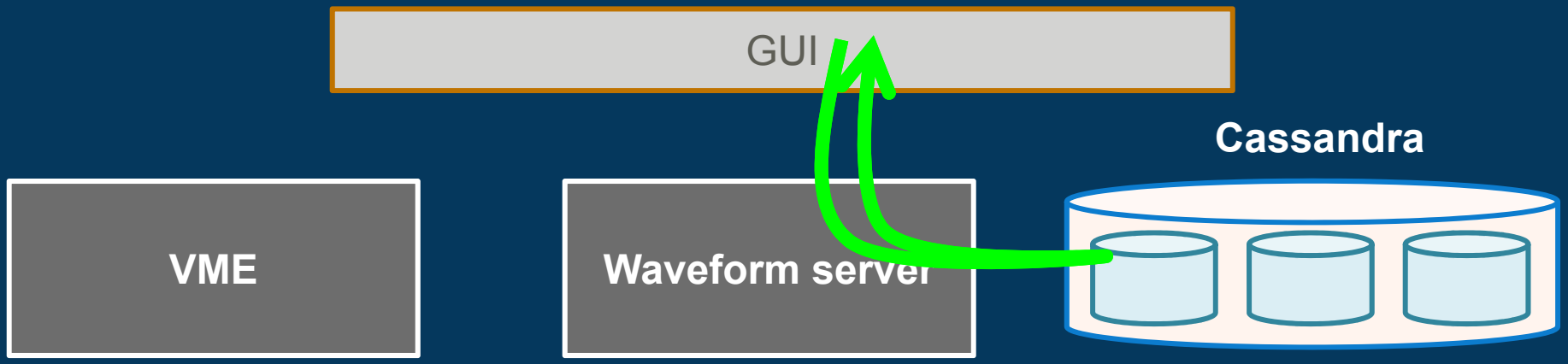


- A CPU load of a DAQ process running on a VME < 1%
  - The DAQ process doesn't prevent other processes.

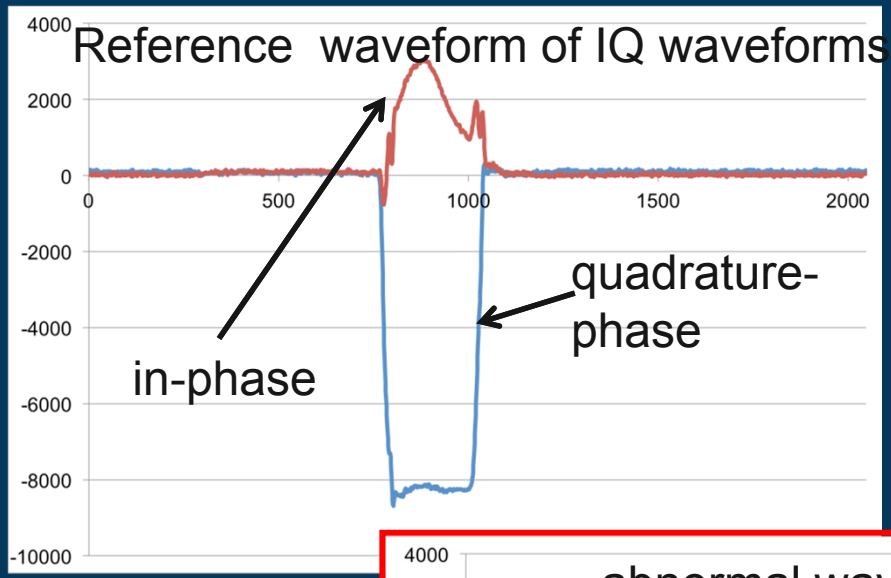
Install to injection part

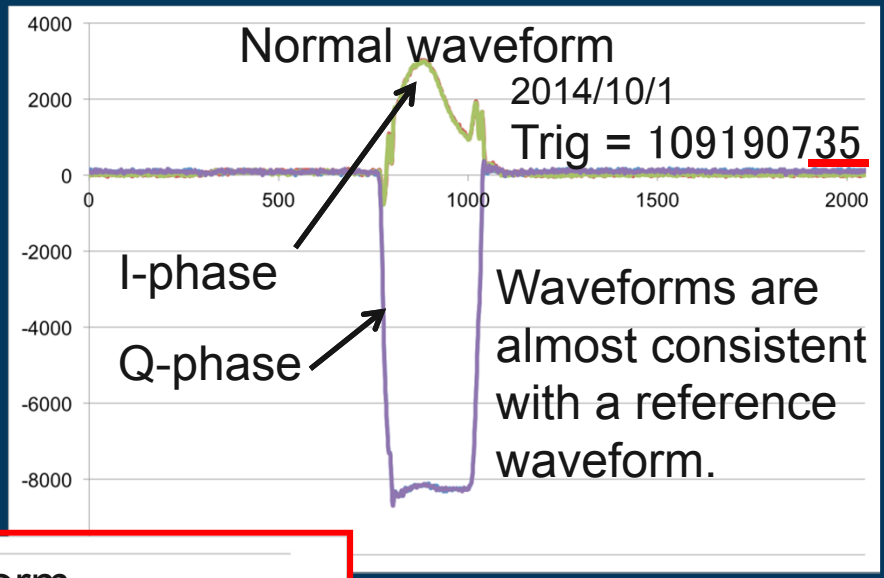
- We installed the DAQ system into the injection part on Sep 26, 2014.
  - 5 VMEs
  - The Cassandra cluster is 6 nodes and a replication factor of 3.

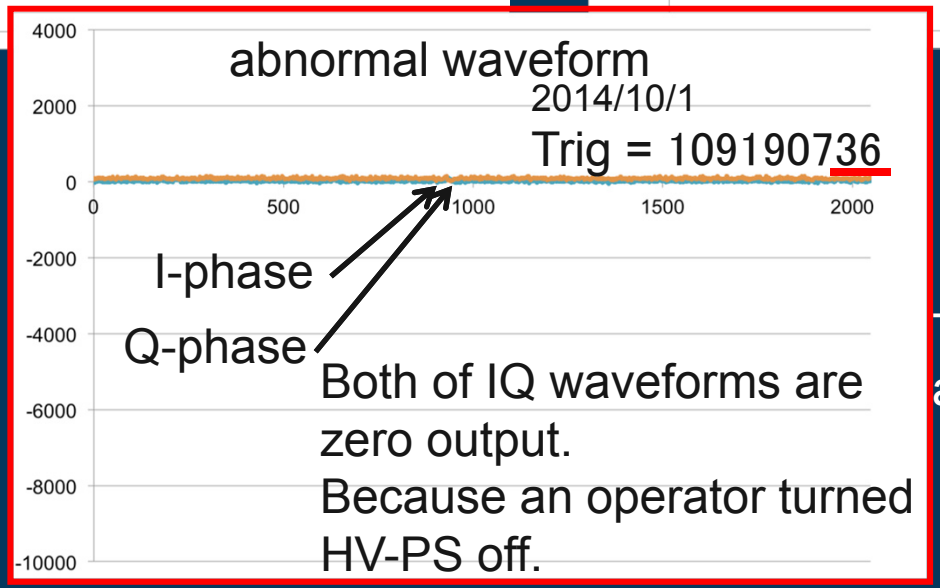
The injection part of SACLA is stable.
We have not captured a “good” abnormal waveform yet…

An example of capture

Dummy load waveform of C-band correction at the commissioning







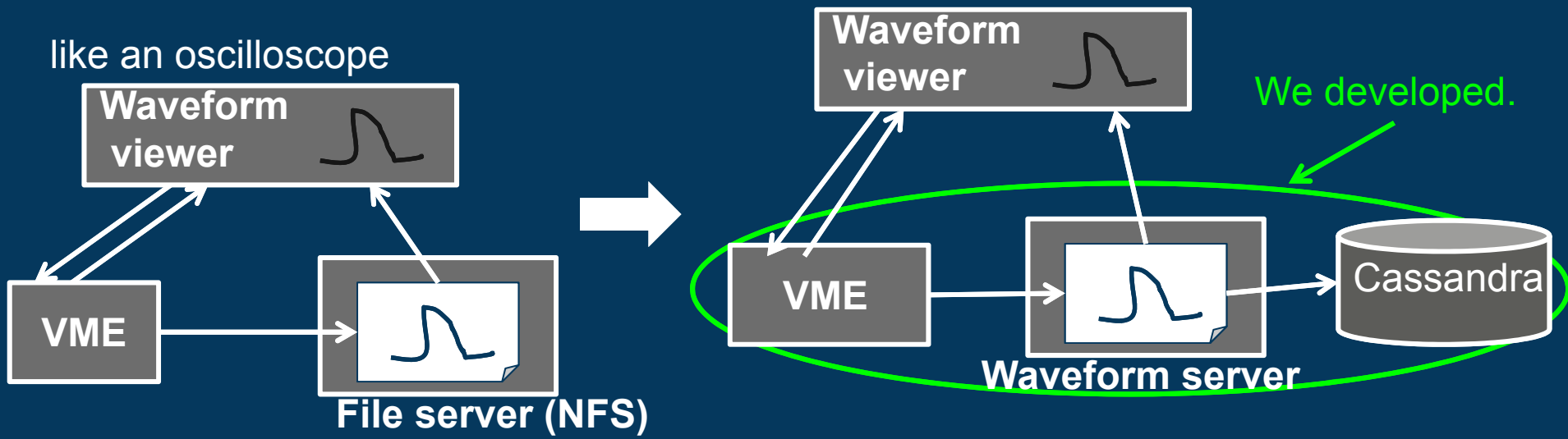
The DAQ system can catch abnormal waveform!

Future plan

- We will take waveforms from all low-level RF VMEs.
  - 74 VMEs
  - In total,
    - 12 ch /VME * 74 VMEs = ~ 800 waveforms

Future plan contn'd

- Application to a waveform viewer
  - Currently a waveform viewer displays waveform with 3 ~ 4 Hz refresh rate.
    - A VME takes waveform and writes the data as a file on a NFS.
    - The waveform viewer reads out the file and display waveform .
    - The timing delay occurs between export and readout out the file.
  - We will upgrade the viewer by using the DAQ system.



Summary

- We developed a DAQ system for abnormal RF waveforms.
- The system consists of
  - VME that detects abnormal waveform
  - Cassandra database system
  - A waveform server.
- We installed the system into injection part of low-level RF control system in September 2014.
- The DAQ system works well.
- We will take waveforms from all low-level RF VMEs.

Thank you.