Current Status and Upgrade Plan of the Data-Acquisition System at SACLA

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Outline

- Overview of SACLA
  - X-ray Free Electron Laser
  - Current Status of SACLA
- SACLA Data Acquisition System
  - Experimental Requirement
  - Front-end Section
  - Data transfer and Accumulation Section
  - Analysis Section
- Future Plan
  - Analysis using External Supercomputers
  - Next Generation Detector and FE System

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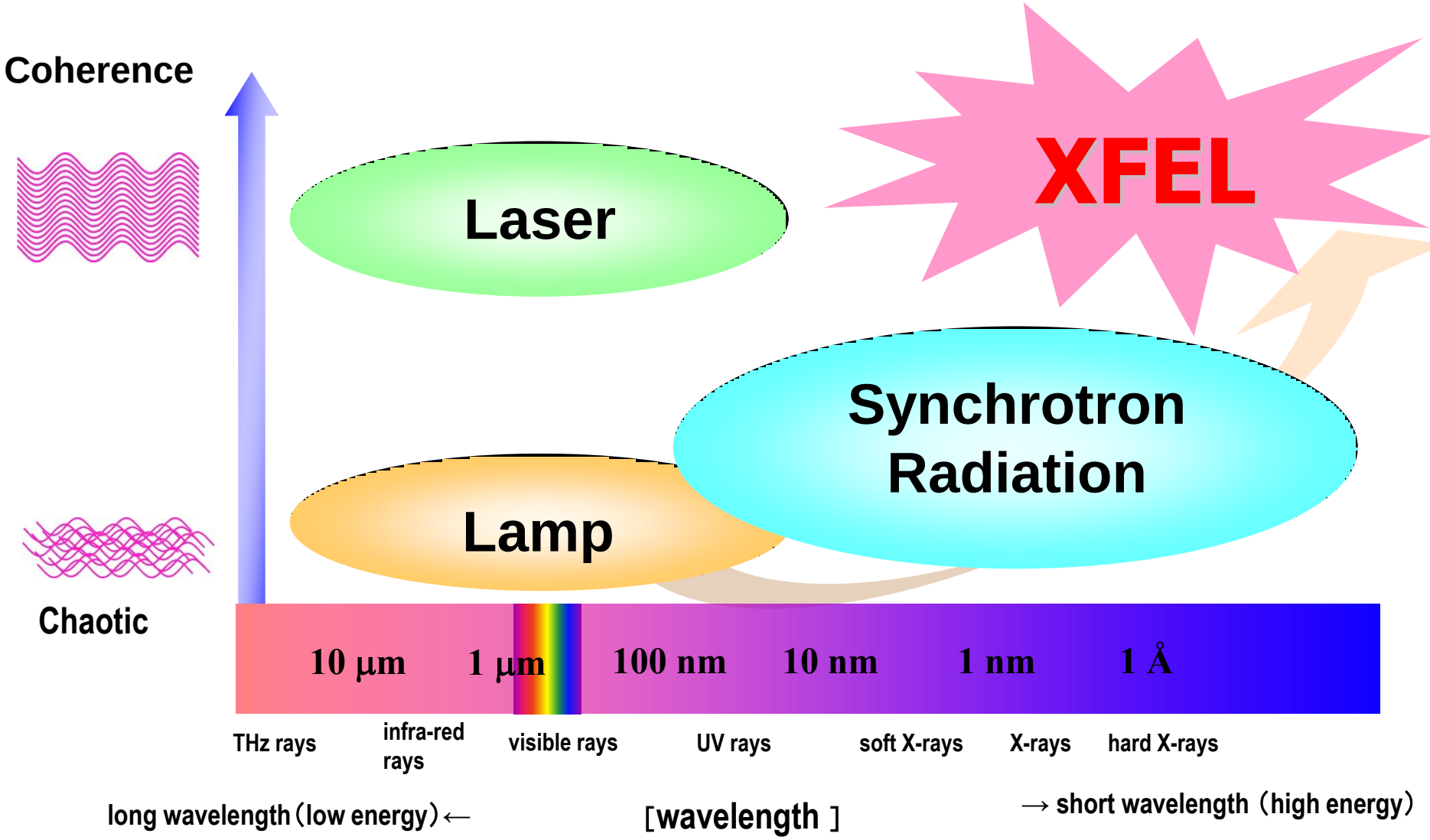
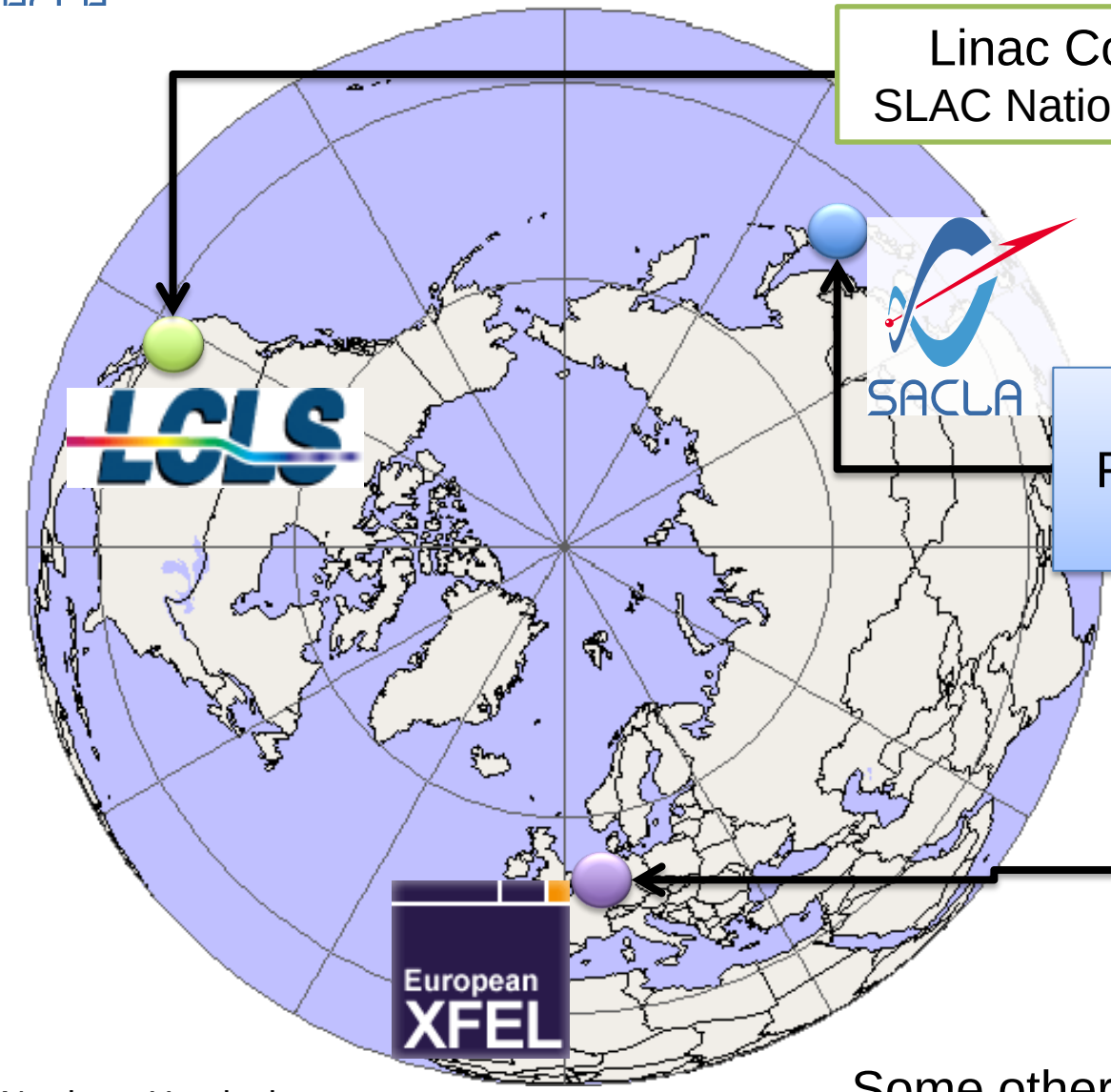
X-ray Free Electron Laser (XFEL)



X-ray Free Electron Laser Facilities



Linac Coherent Light Source (LCLS),
SLAC National Accelerator Laboratory, USA

First lasing in April 2009
Public Beam Time from Oct. 2009

SPring-8 Angstrom Compact Free Electron Laser (SACLA),
RIKEN SPring-8 Center, Japan

First lasing in June 2011
Public Beam Time from March 2012

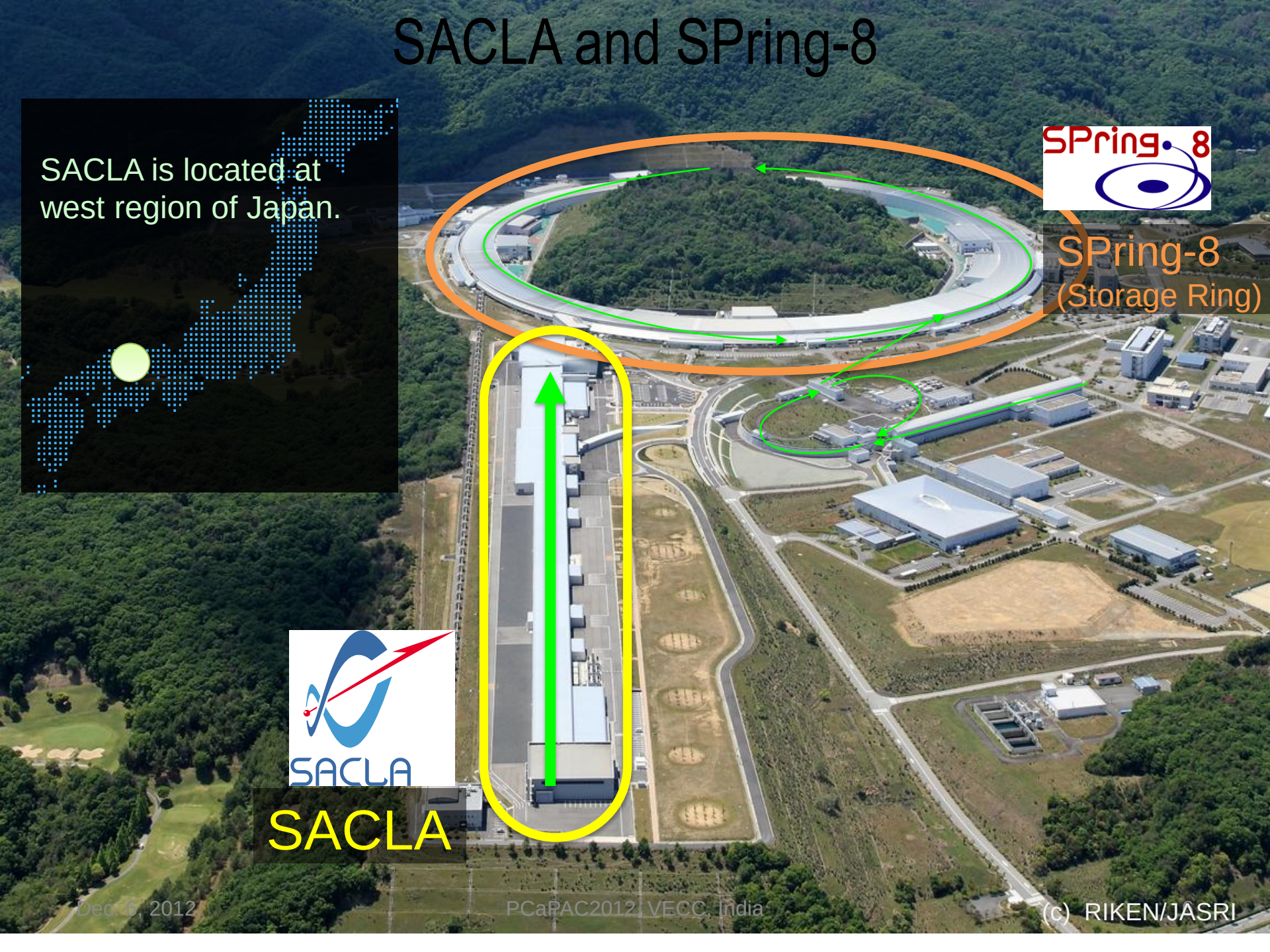
European XFEL,
Germany

Under construction

Northern Hemisphere

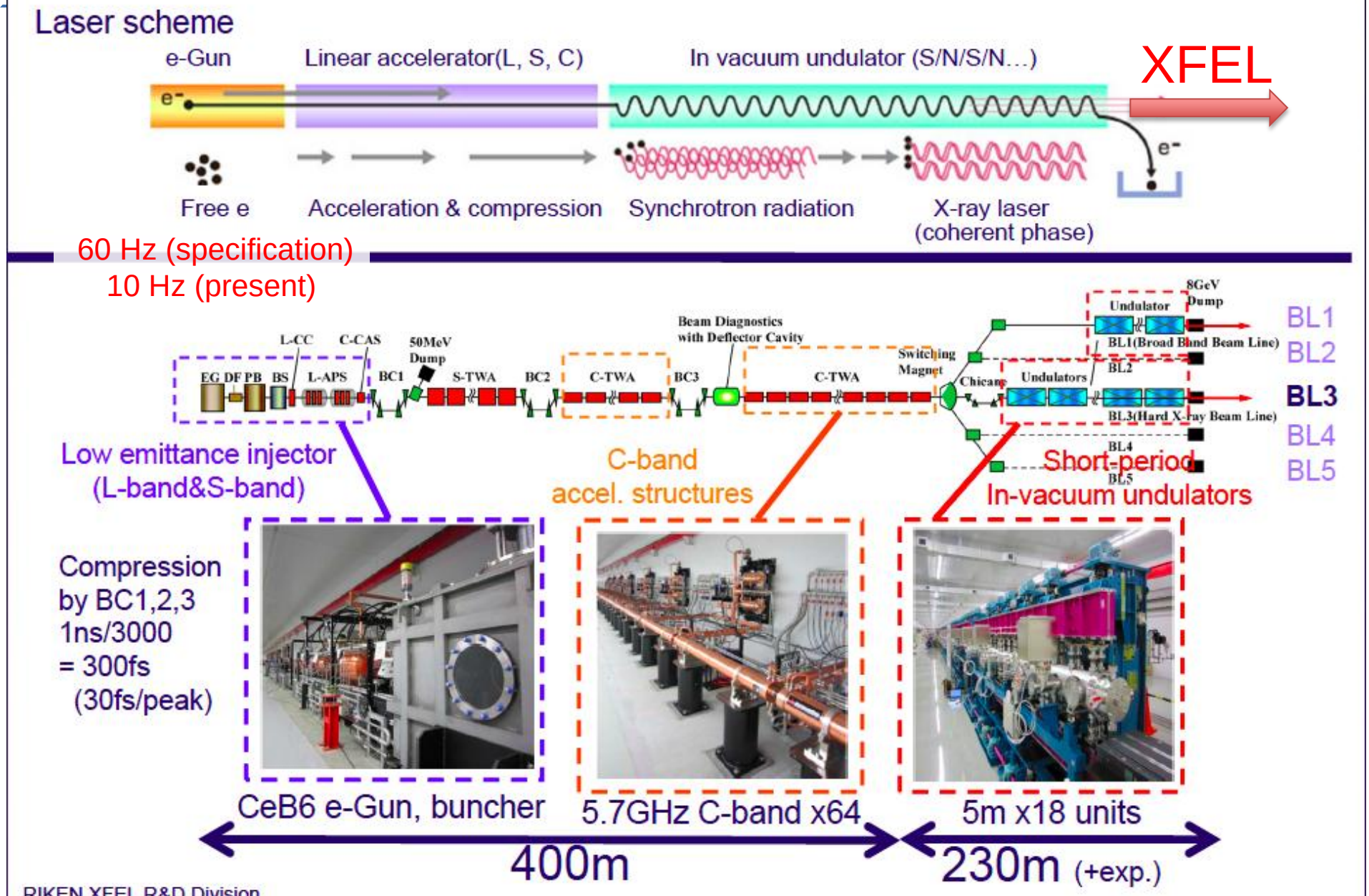
Some other facilities are under planning.

SACLA and SPring-8

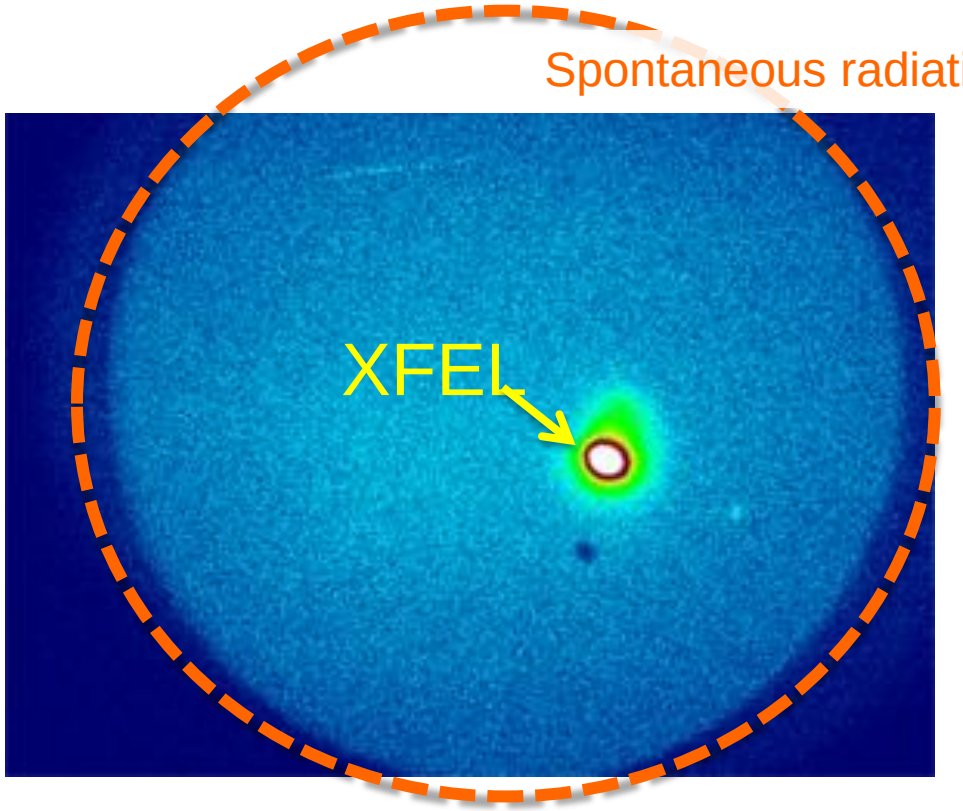


(c) RIKEN/JASRI

Characteristic Components at SACLA



First Lasing on June 7, 2011

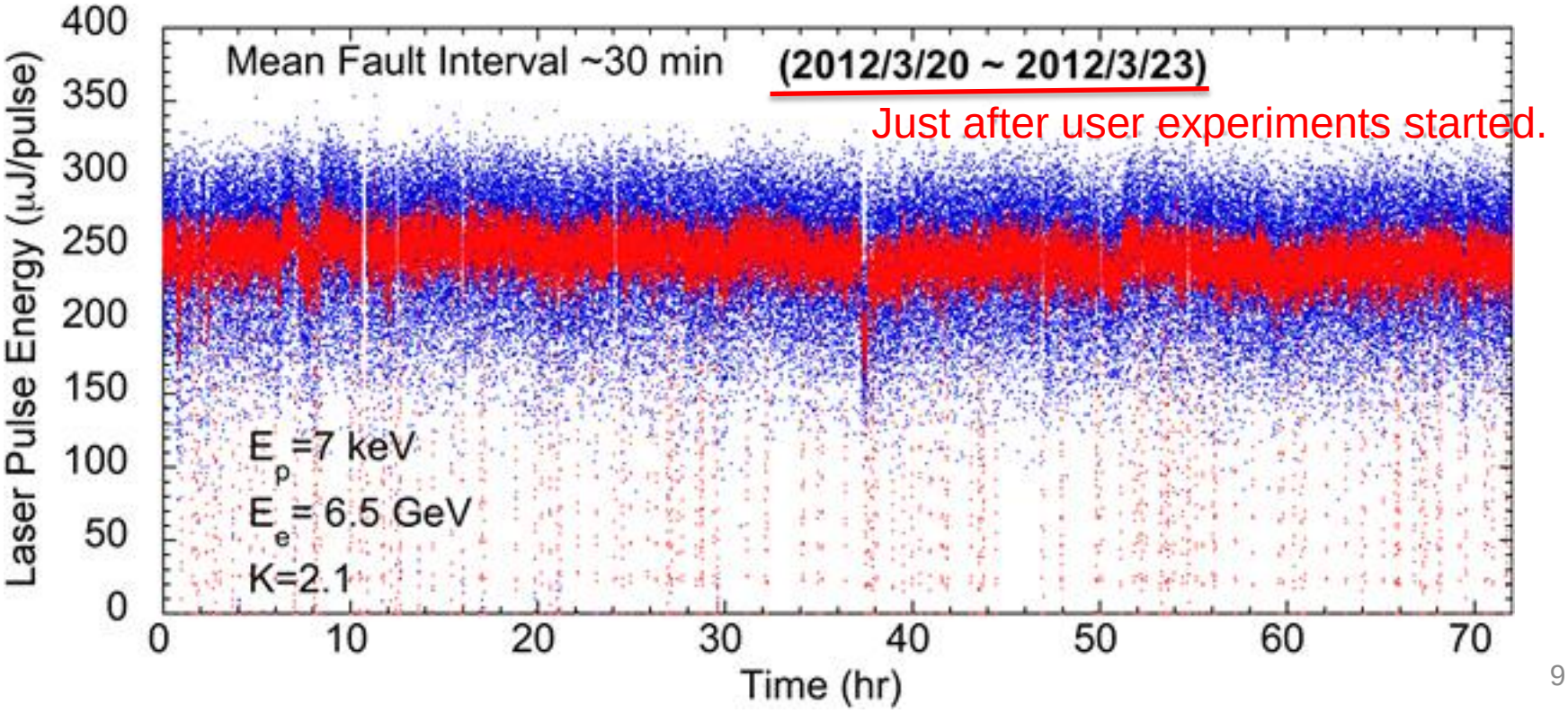


First XFEL image acquired
by the SACLA DAQ system.

Group photograph of
SACLA development staff.

User Experiments Started

- We have delivered XFEL for user experiments from March 2012.
  - 25 experiments (March 2012 – July 2012)
  - 27 experiments (October 2012 – March 2013)



Current Status of SACLA

Location		SPring-8 site, JAPAN
		700 m long
Components	Electron source	e-gun
	Acceleration tube	L-band (x1), S-band (x4), C-band (x64)
	Light source	in-vacuum undulator (x18)
Beam condition	Energy	8 GeV (max.)
	Emittance	0.77 – 1.1 pimm.mrad
	Repetition rate	60 Hz (spec.) / 10 Hz (present)
XFEL condition	Energy	5 – 15 keV (2.4 – 0.8 Å, tunable)
	Power/pulse	280 uJ/pulse (max.)
	Pulse width	6 – 30 fs

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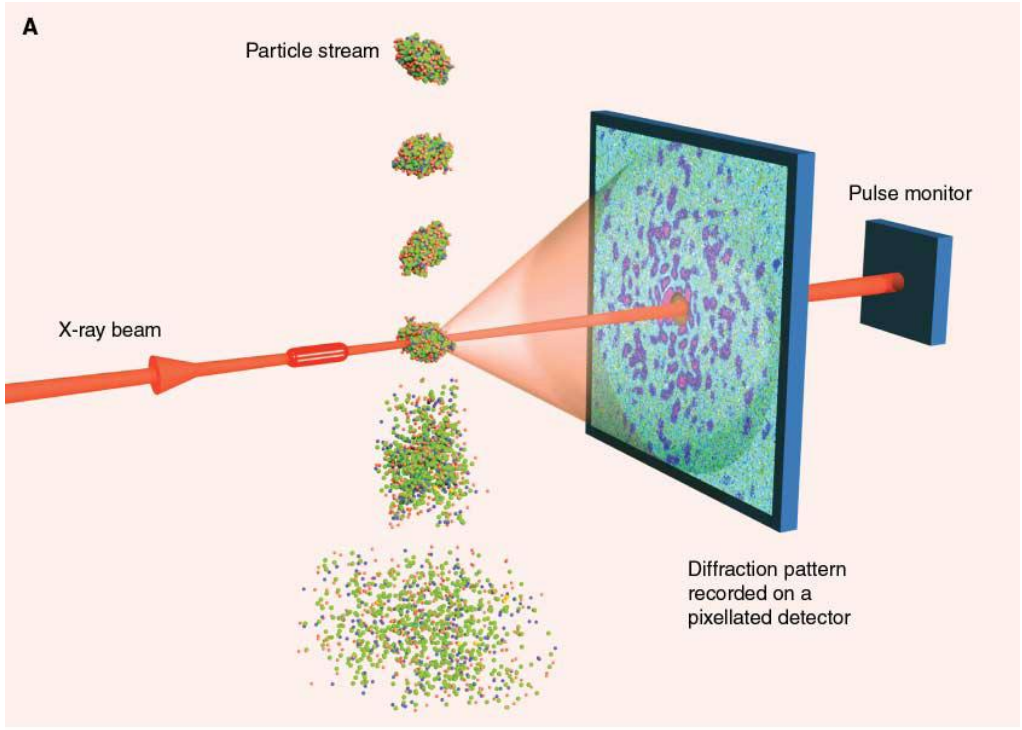
Scientific Application: Coherent X-ray Diffraction Imaging (CXDI)



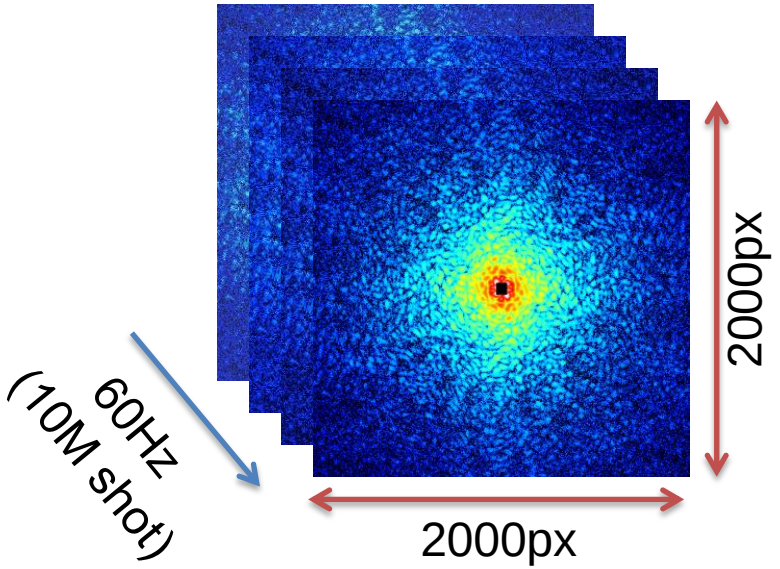
One of motivation is life science.

By accumulating and analyzing 10 M shot of X-ray diffraction image of proteins, we can reconstruct structure of proteins using CXDI technique.

K. J. Gaffney and H. N. Chapman, Science 316, 1444 (2007)

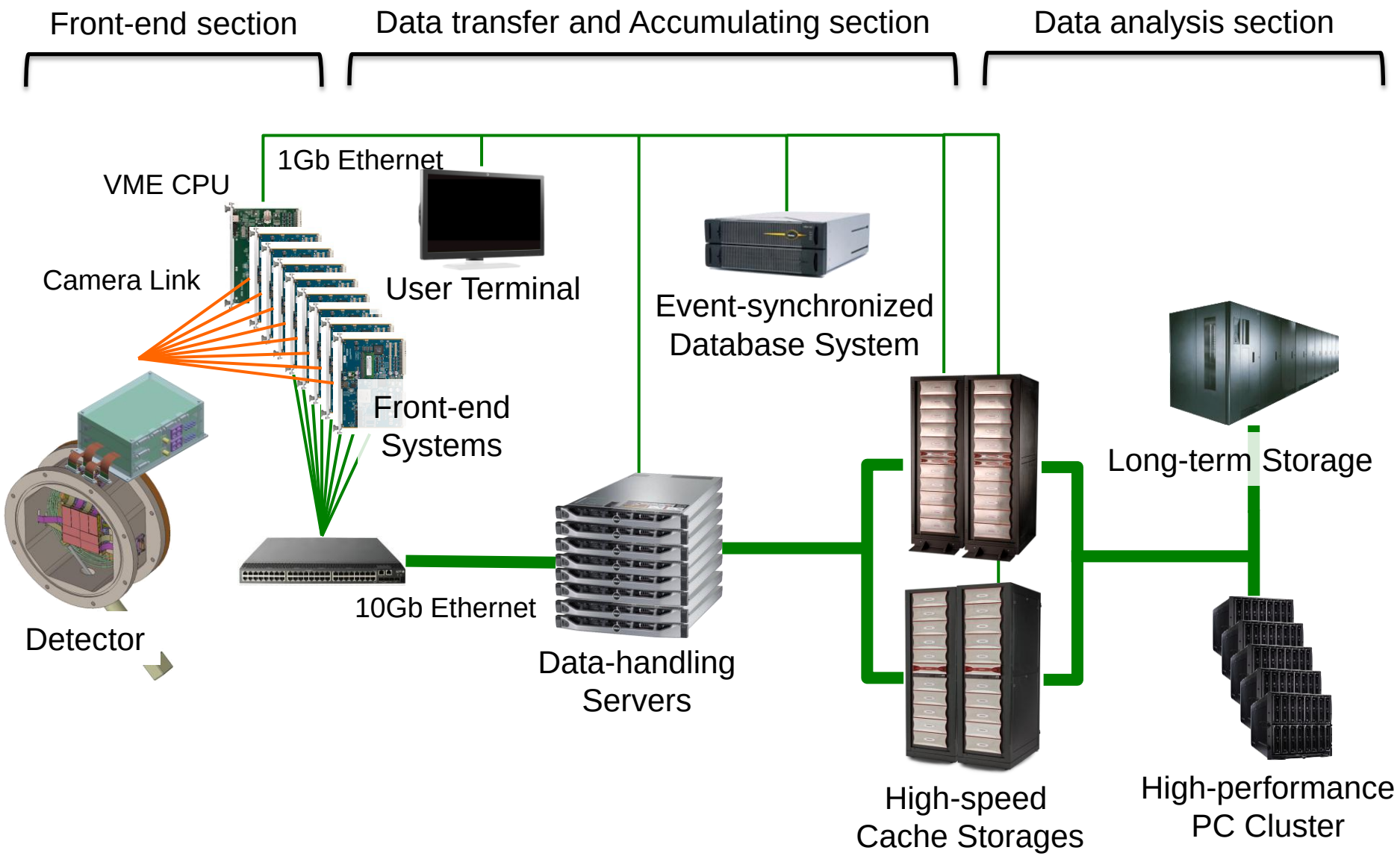
Experimental Requirement

- Experimentalist need to acquire X-ray 2D image;
  - 2000x2000 resolution
  - 16 bit data depth
  - 60 Hz repetition rate
  - 10,000,000 shot

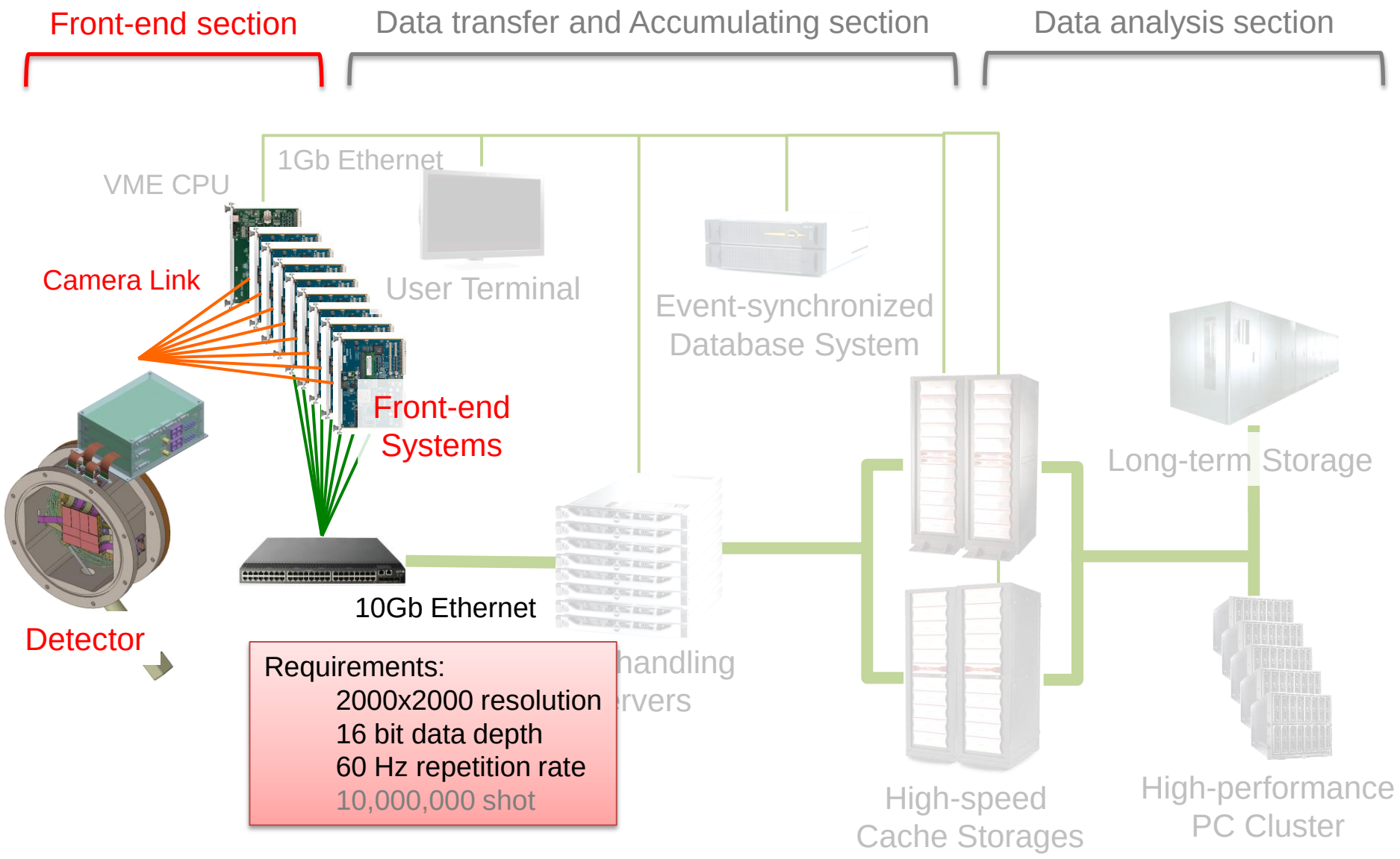


- To accomplish experimentalists' requirement, we have developed dedicate X-ray sensors and DAQ system.

Overview of the SACLA DAQ System



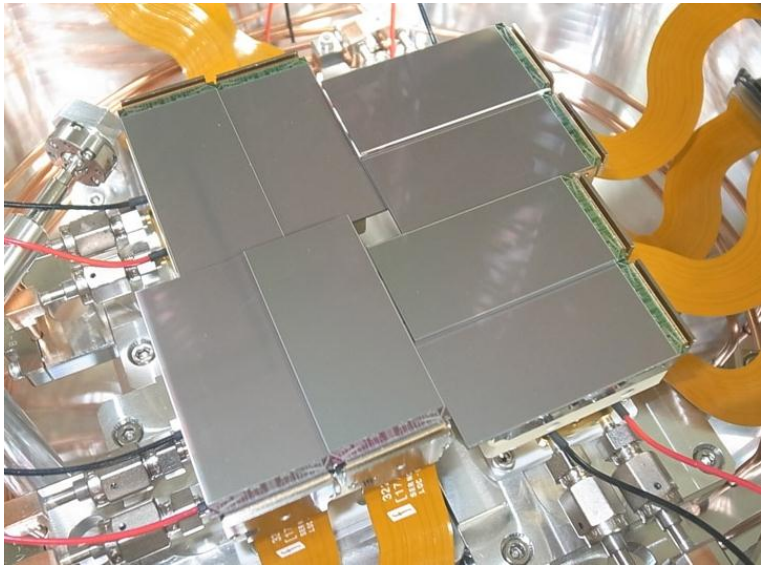
Detector and Front-end System



Multi-Port CCD (MPCCD) Sensor

Single MPCCD Sensor

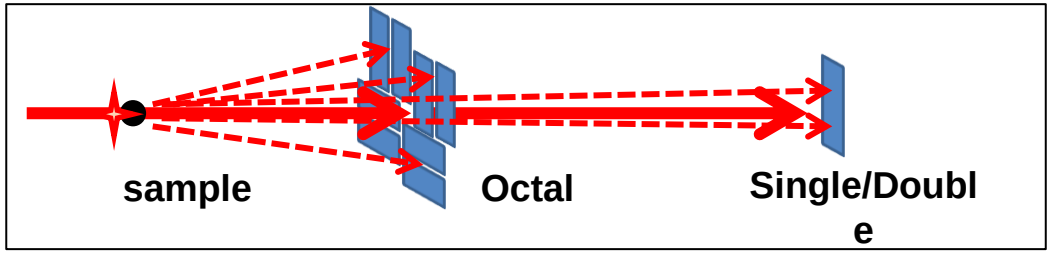
x8



Octal MPCCD Sensor

Resolution : 1024x512 px
Data depth : 16 bit
Repetition rate : 60 Hz (max.)

Single-sensor data rate is
60 MB/s. (0.5 Gbps)

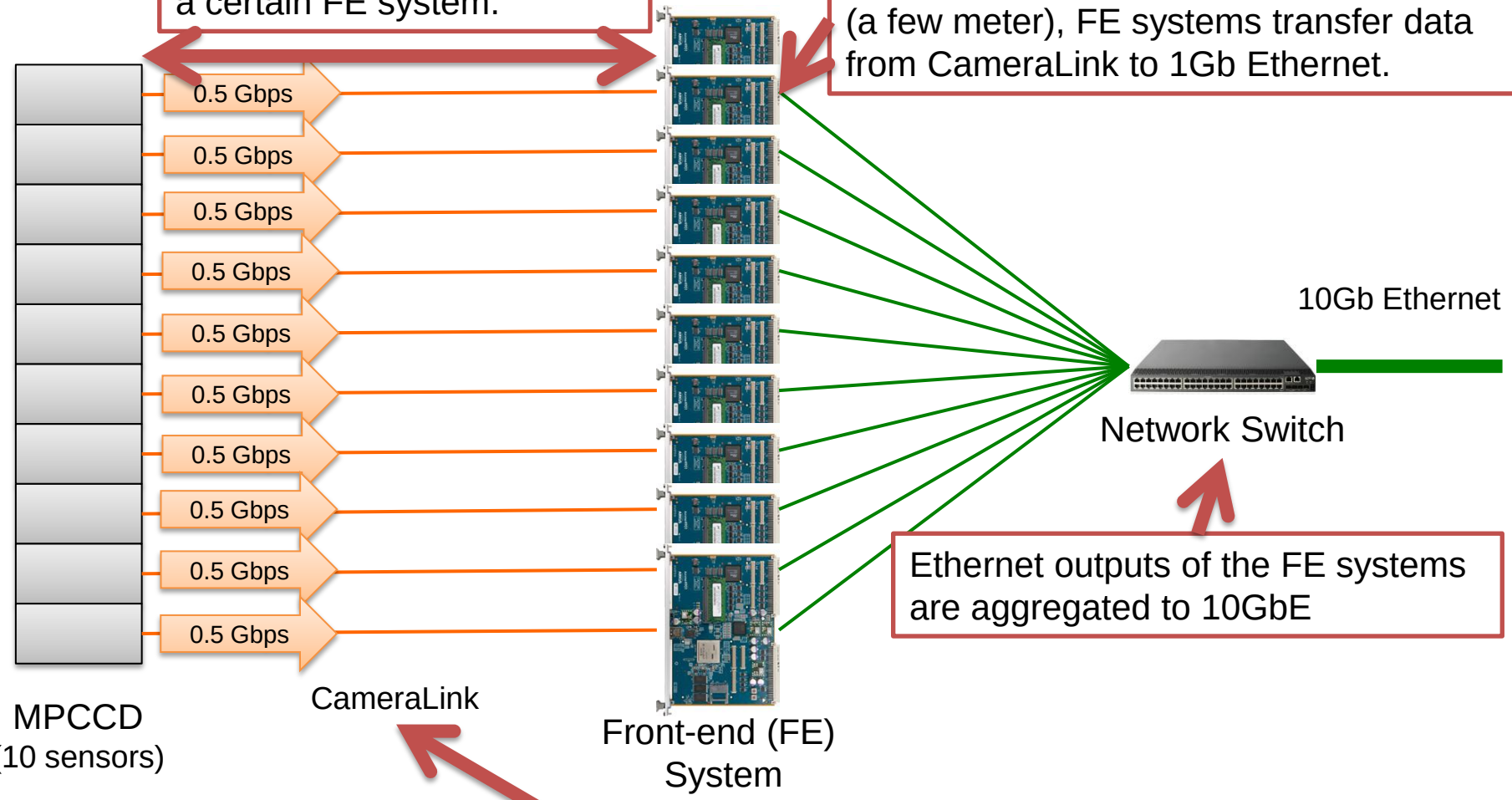


We use octal and single/double simultaneously.
Total data rate is 600 MB/s.（5 Gbps）

Front-end System and Data Transfer

One sensor corresponds to a certain FE system.

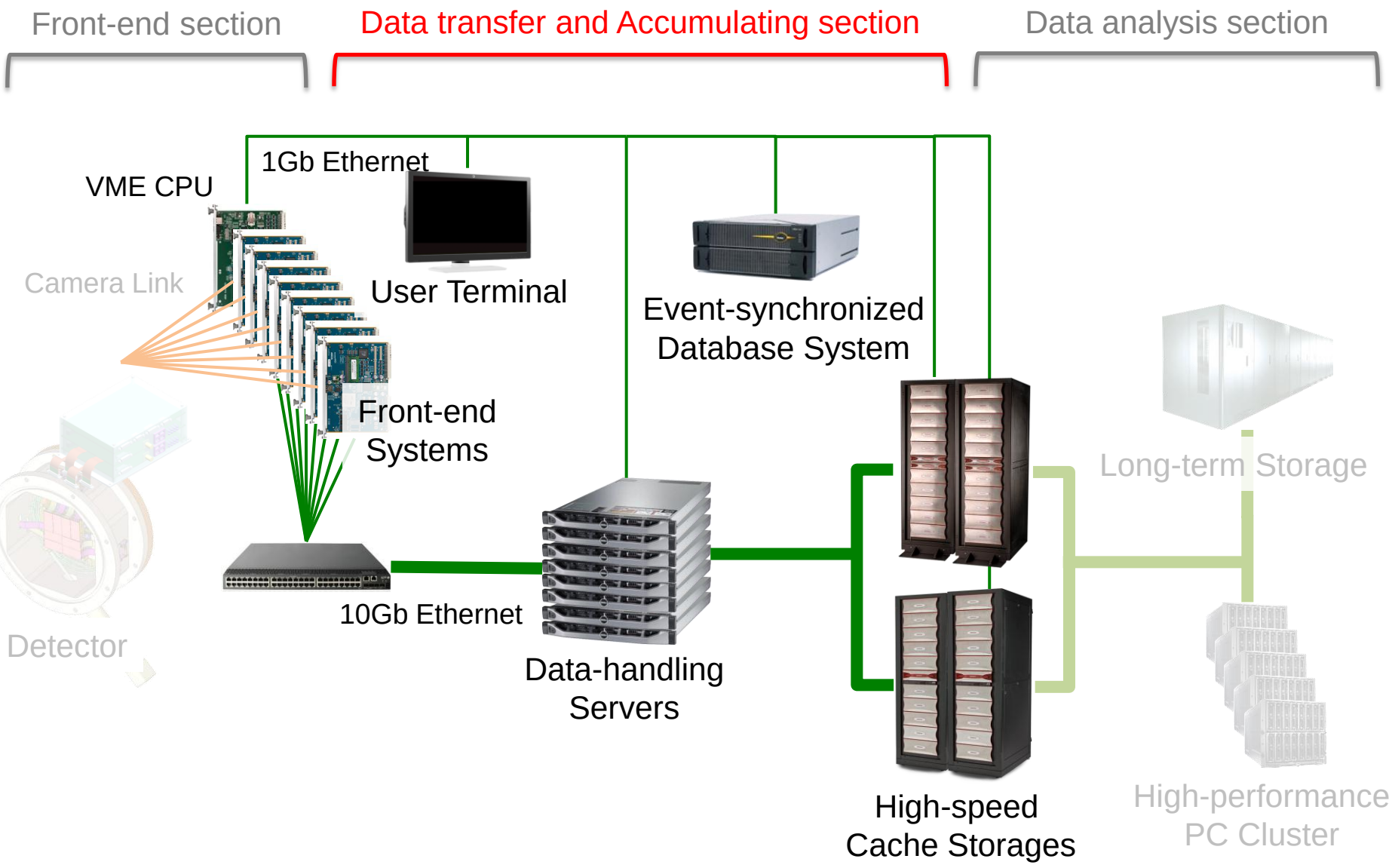
Since range of the CameraLink is short (a few meter), FE systems transfer data from CameraLink to 1Gb Ethernet.



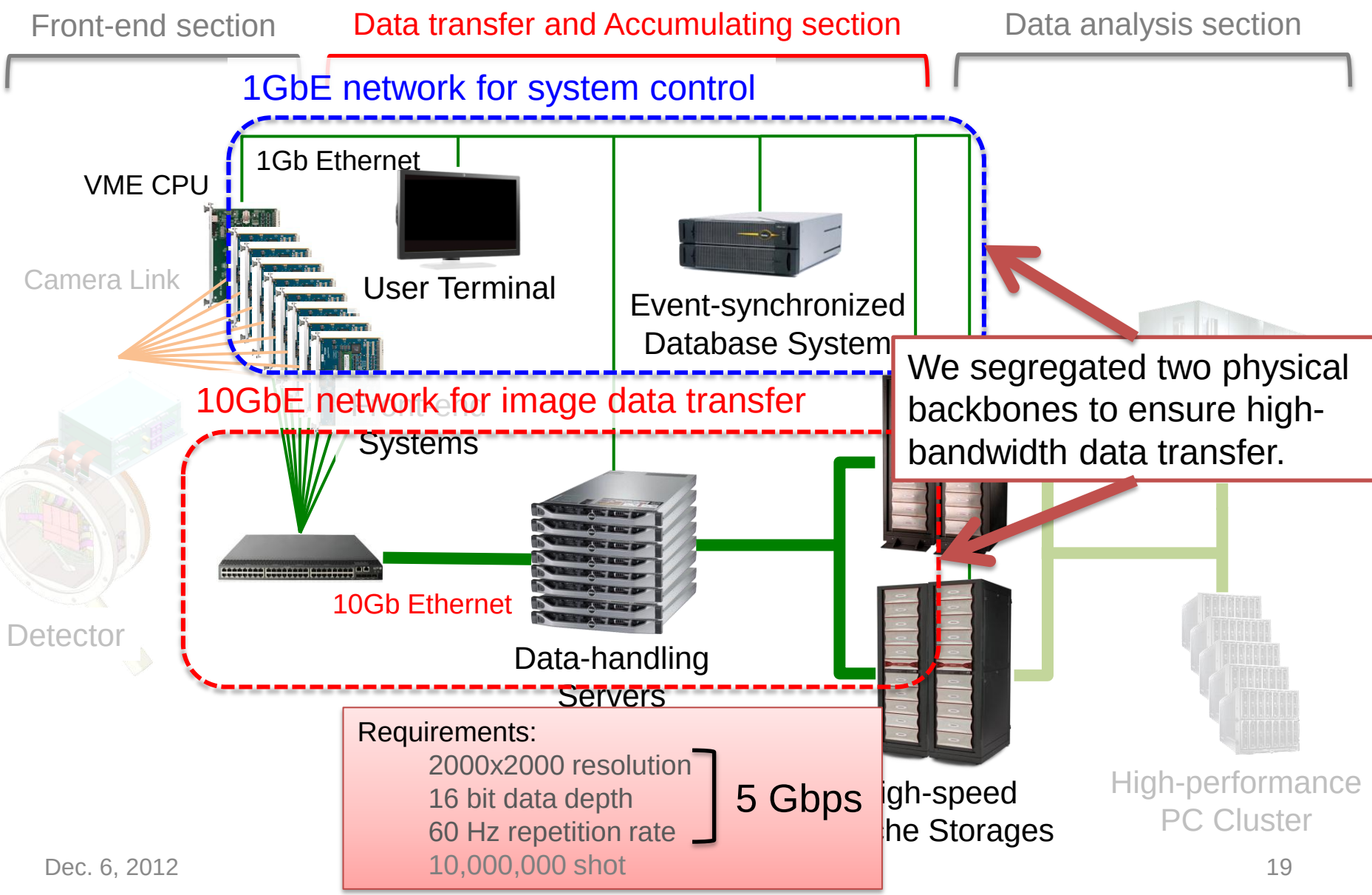
Ethernet outputs of the FE systems are aggregated to 10GbE

We choose CameraLink as digital interface between MPCCD and FE system.
Because we can use other commercial cameras.

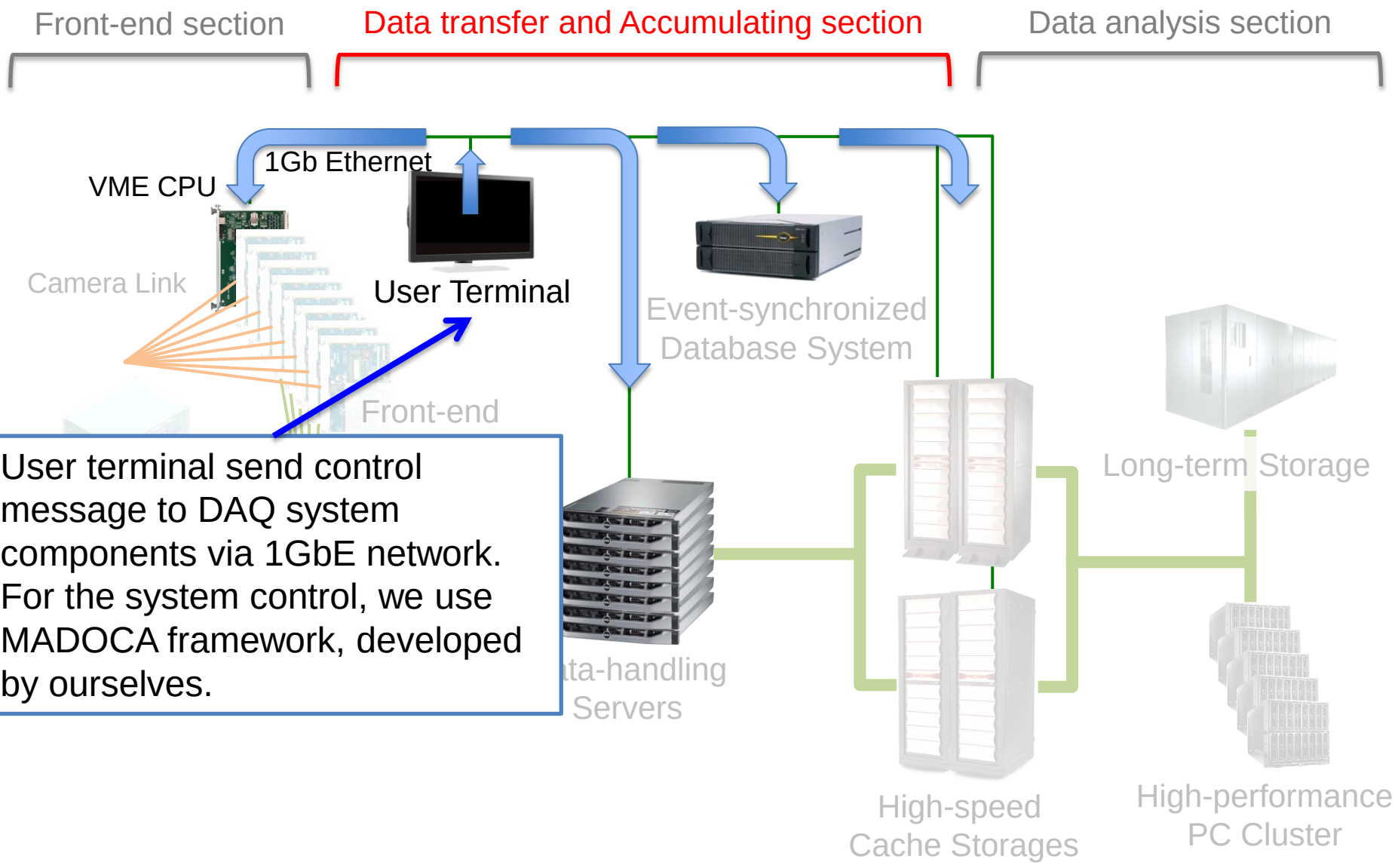
Overview of the SACLA DAQ System



DAQ Network

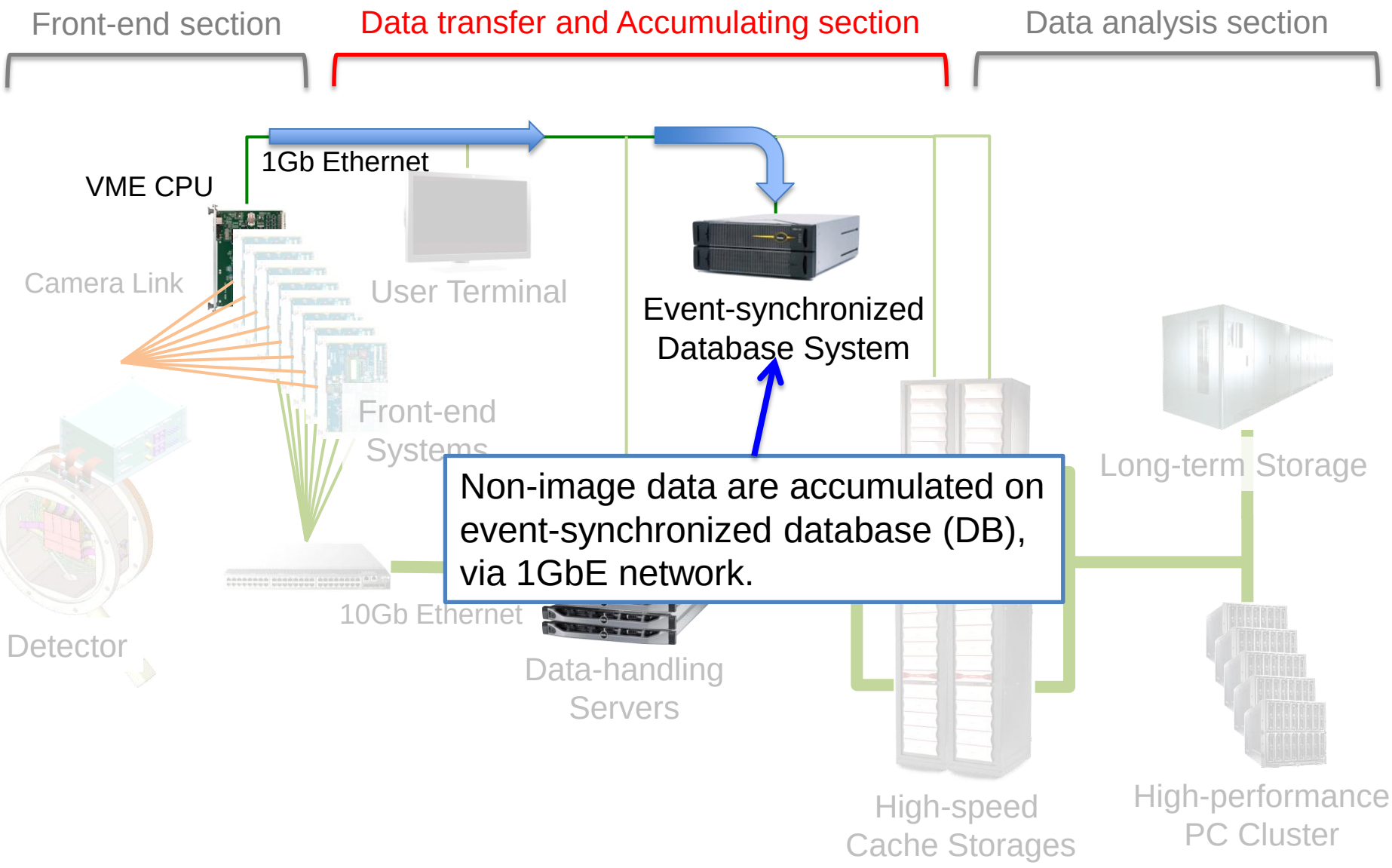

Front-end section
Data transfer and Accumulating section
Data analysis section
1GbE network for system control
1Gb Ethernet
VME CPU
Camera Link
User Terminal
Event-synchronized
Database System
10GbE network for image data transfer
Systems
10Gb Ethernet
Data-handling
Servers
Detector
We segregated two physical backbones to ensure high-bandwidth data transfer.
Requirements:
2000x2000 resolution
16 bit data depth
60 Hz repetition rate
10,000,000 shot
5 Gbps
igh-speed
he Storages
High-performance
PC Cluster

System Control via 1GbE Network

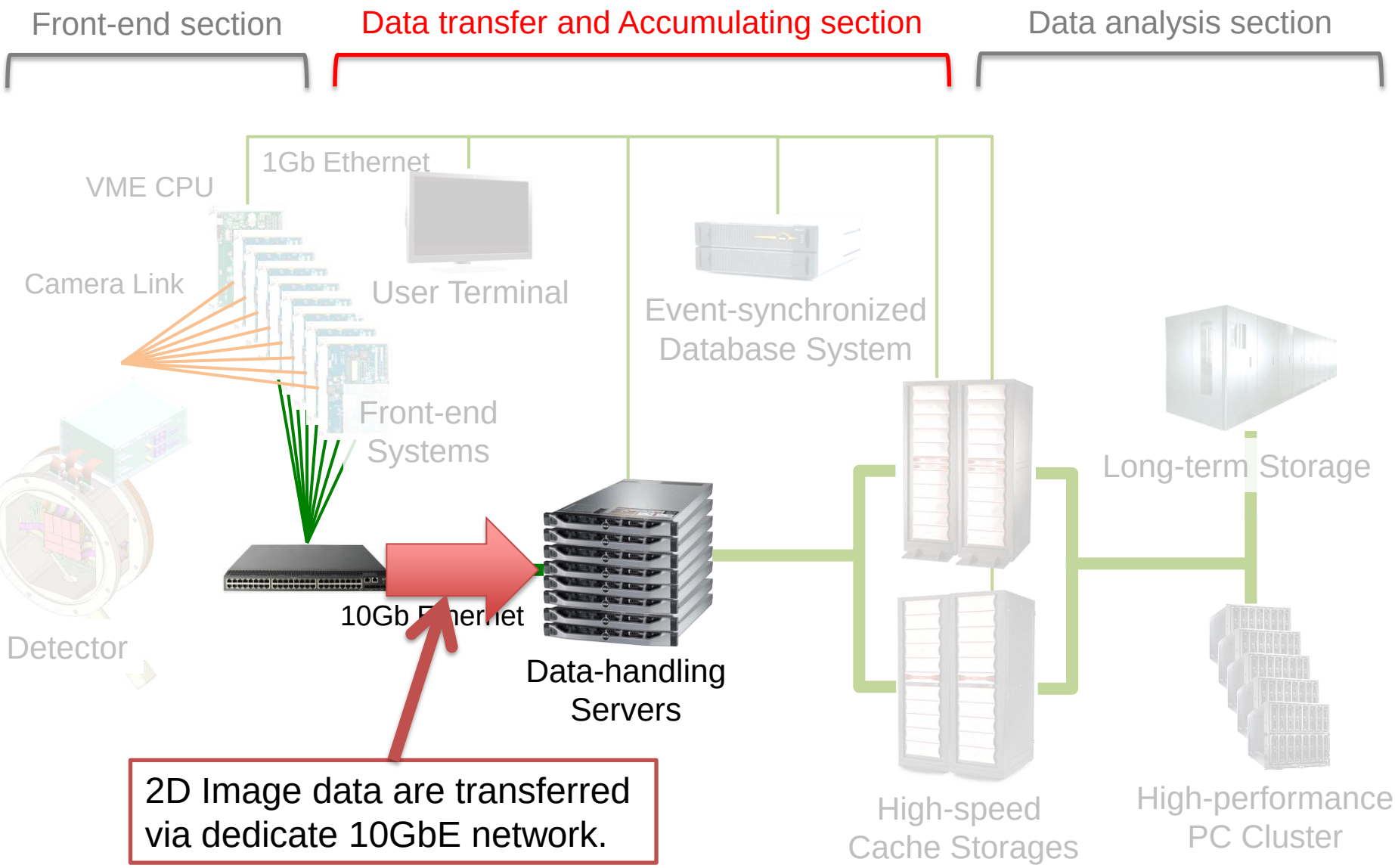


User terminal send control message to DAQ system components via 1GbE network. For the system control, we use MADOCA framework, developed by ourselves.

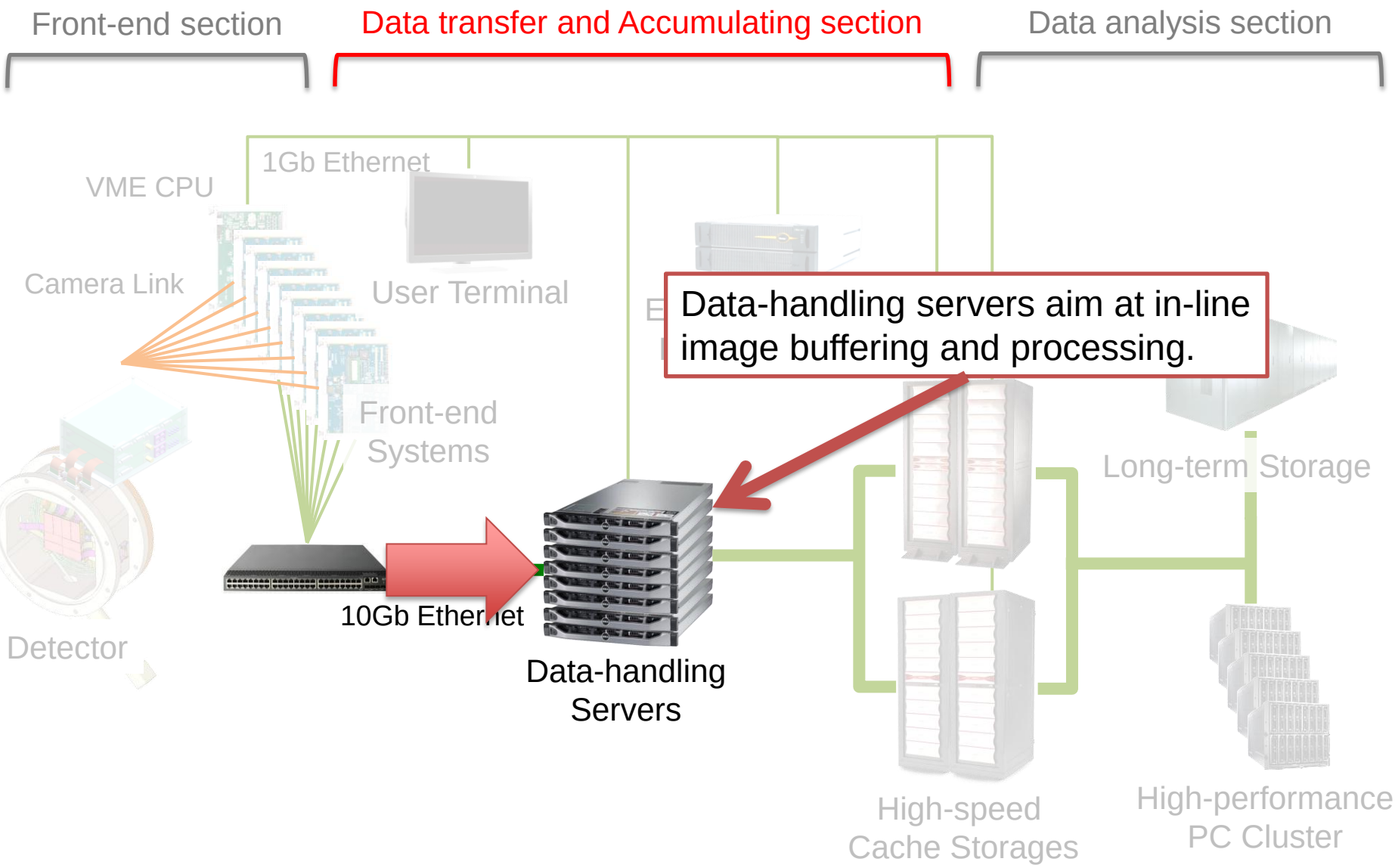
Event-synchronized Data Acquisition



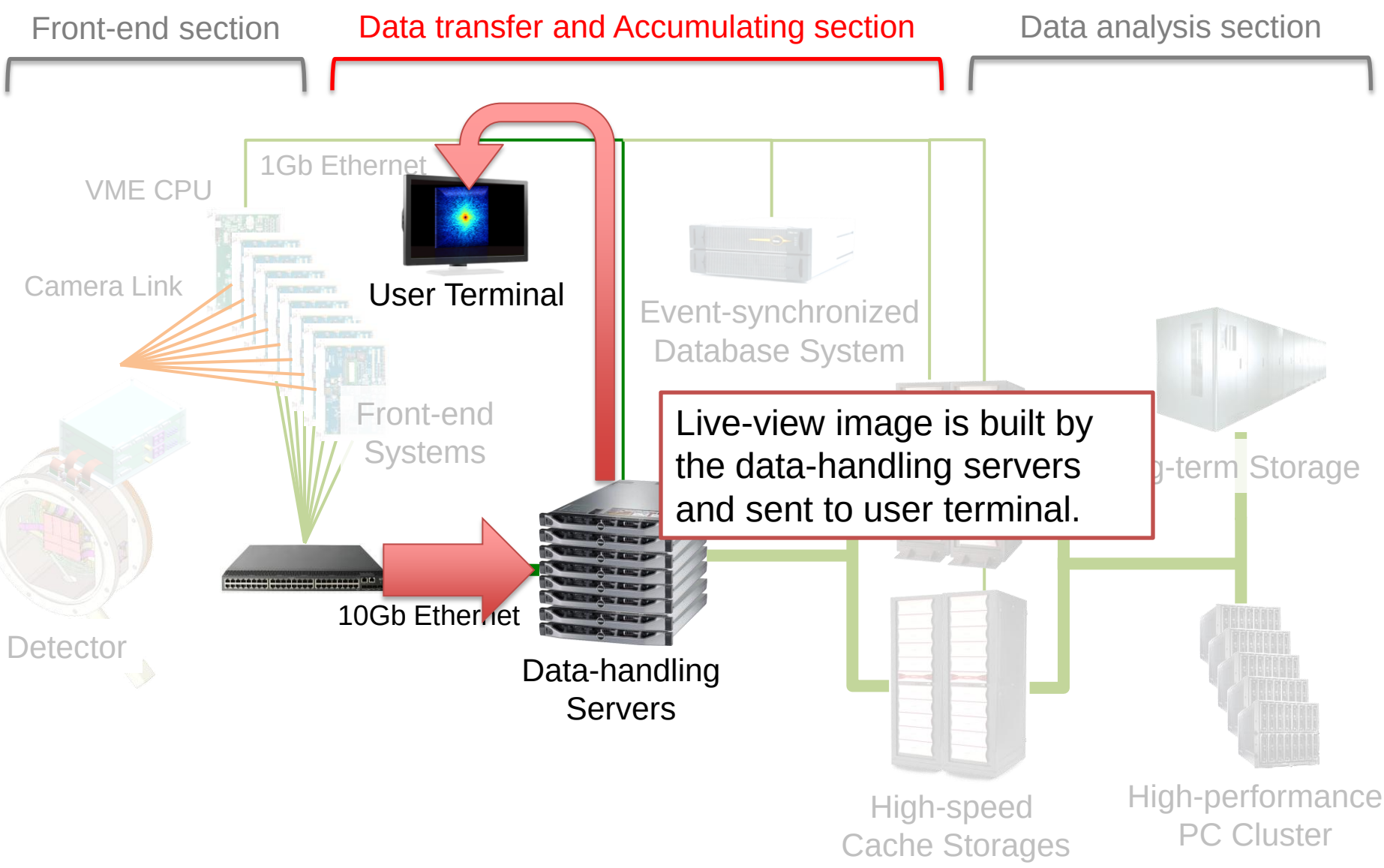
2D Image Data Transfer



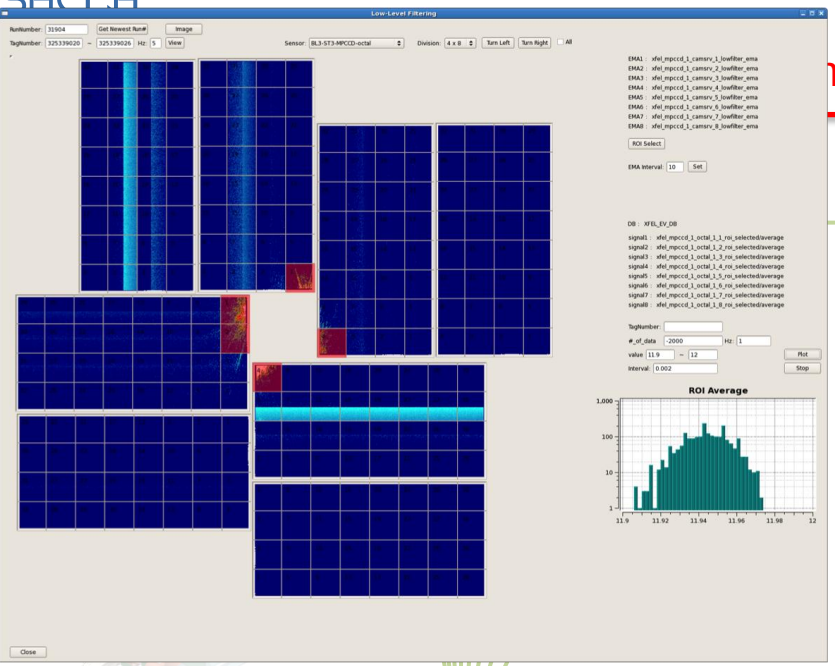
In-line Data Handling



In-line Data Handling: Live View



In-line Data Handling: Low-level Filtering



nd Accumulating section

Data analysis section

Event-synchronized
Database System

Long-term Storage

Detector

10Gb Ethernet

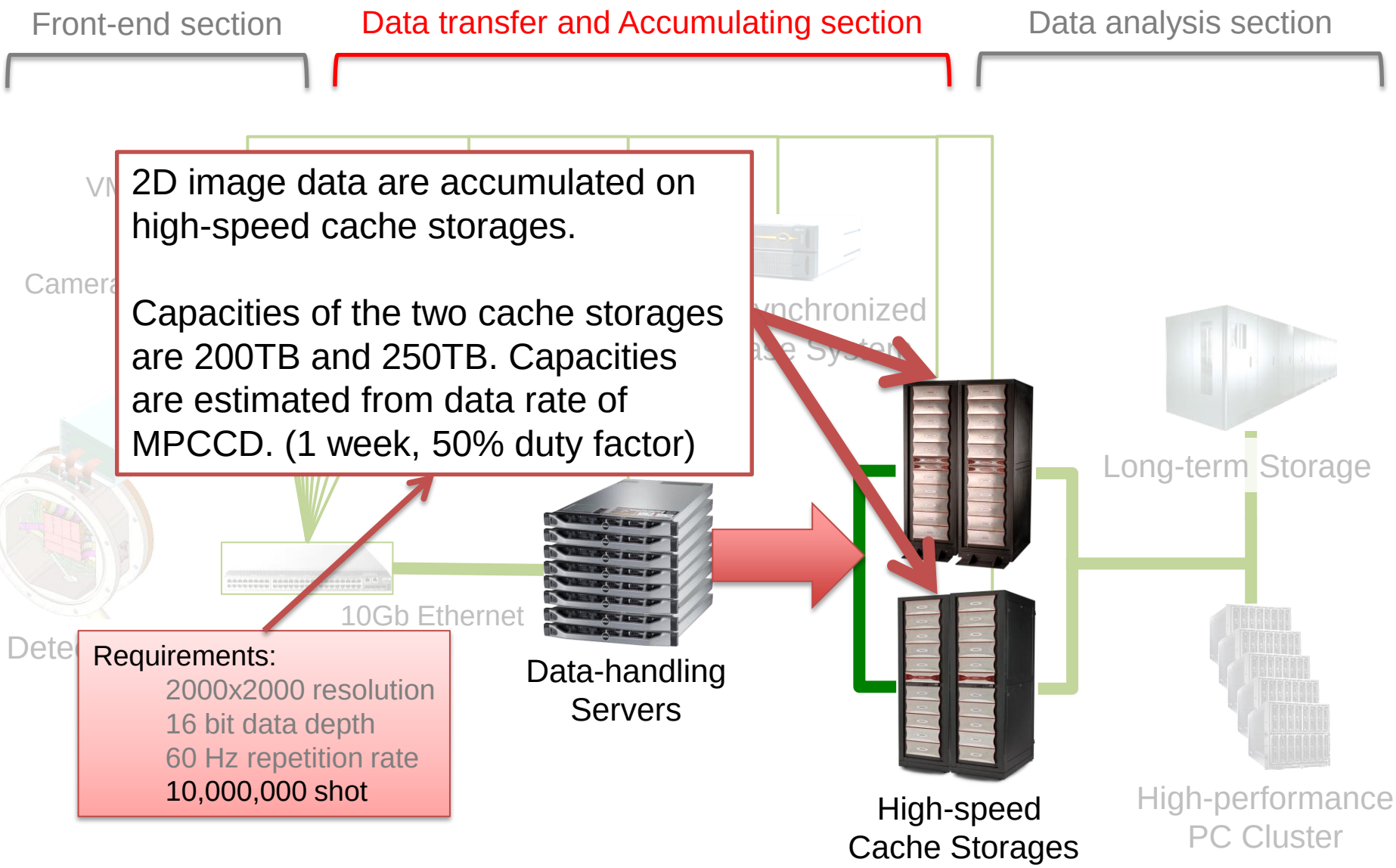
Data-handling
Servers

Data-handling server also perform low-level filtering, shot by shot.
Filtering results are recorded on the event-synchronized database.

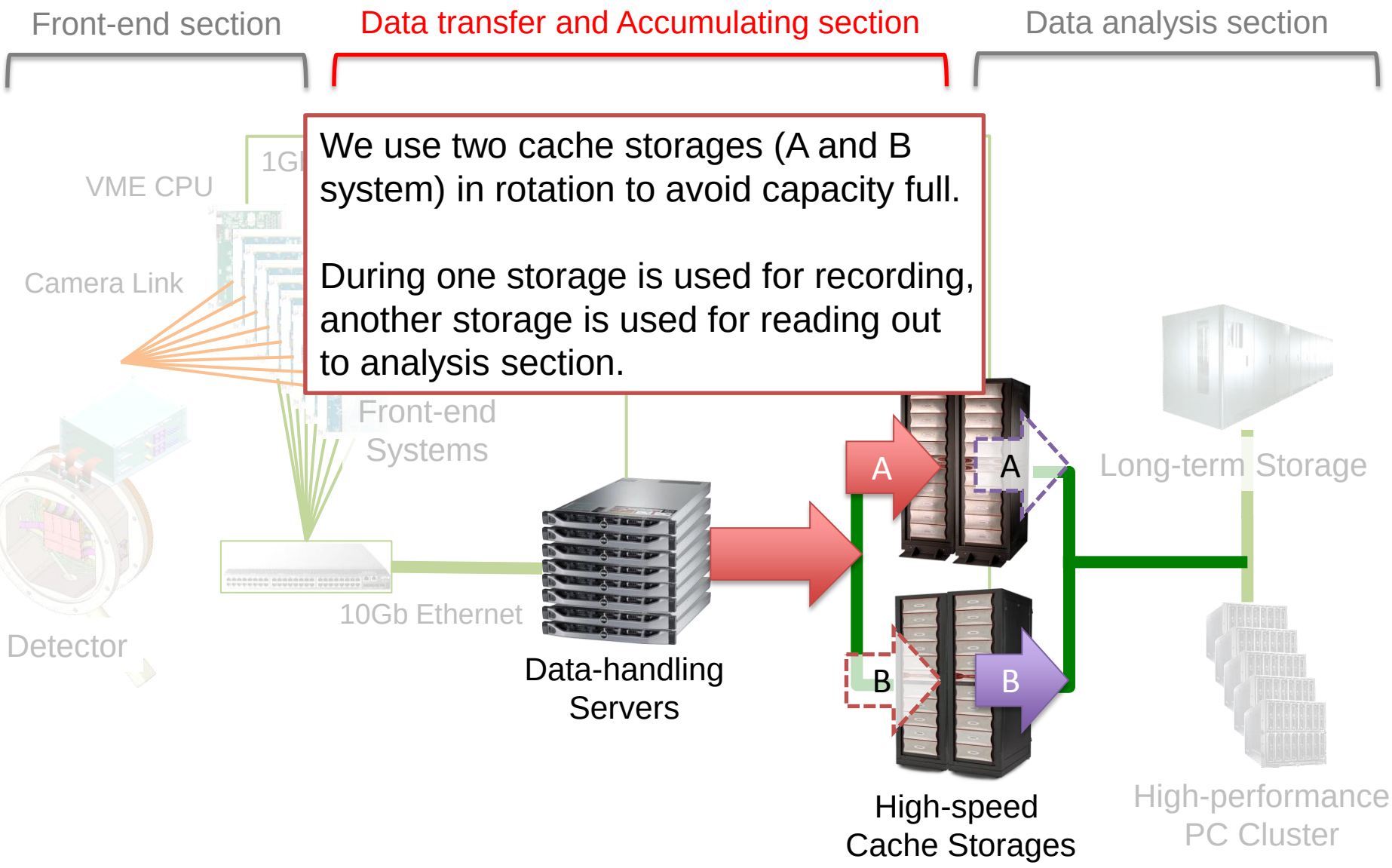
High-speed
Cache Storages

High-performance
PC Cluster

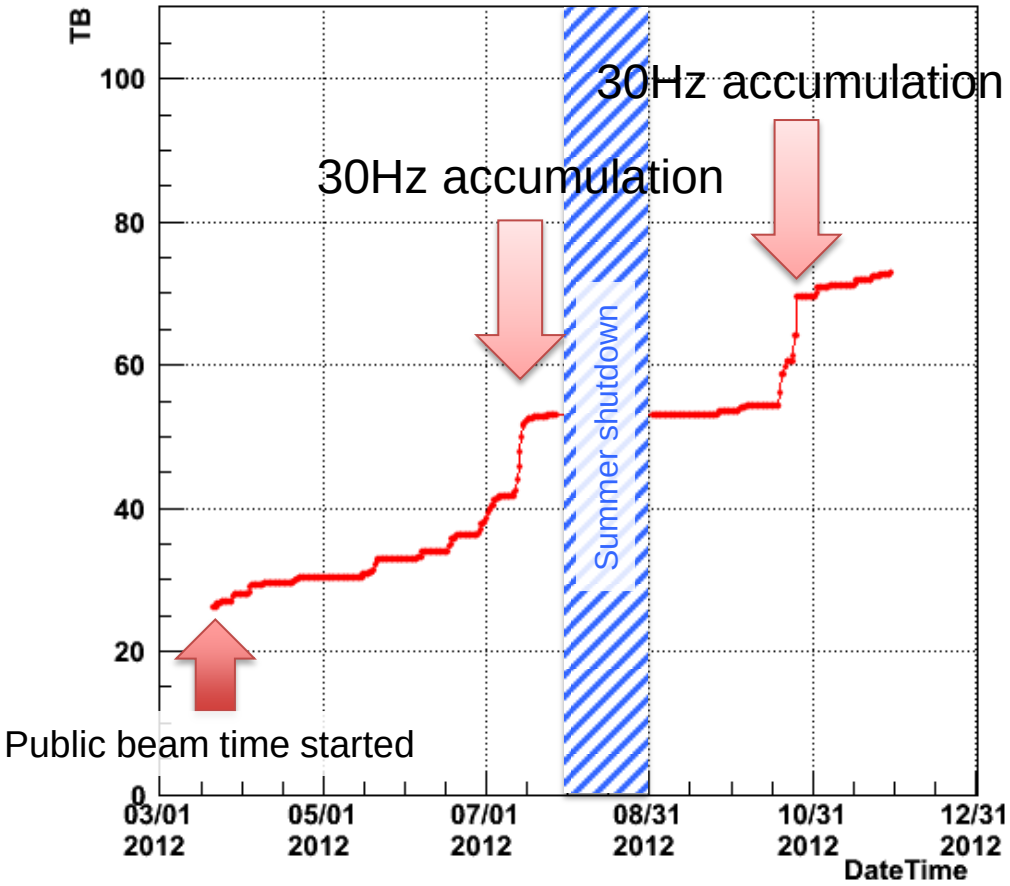
2D Image Data Recording



2D Image Data Recording



Statistics of Storage Usage

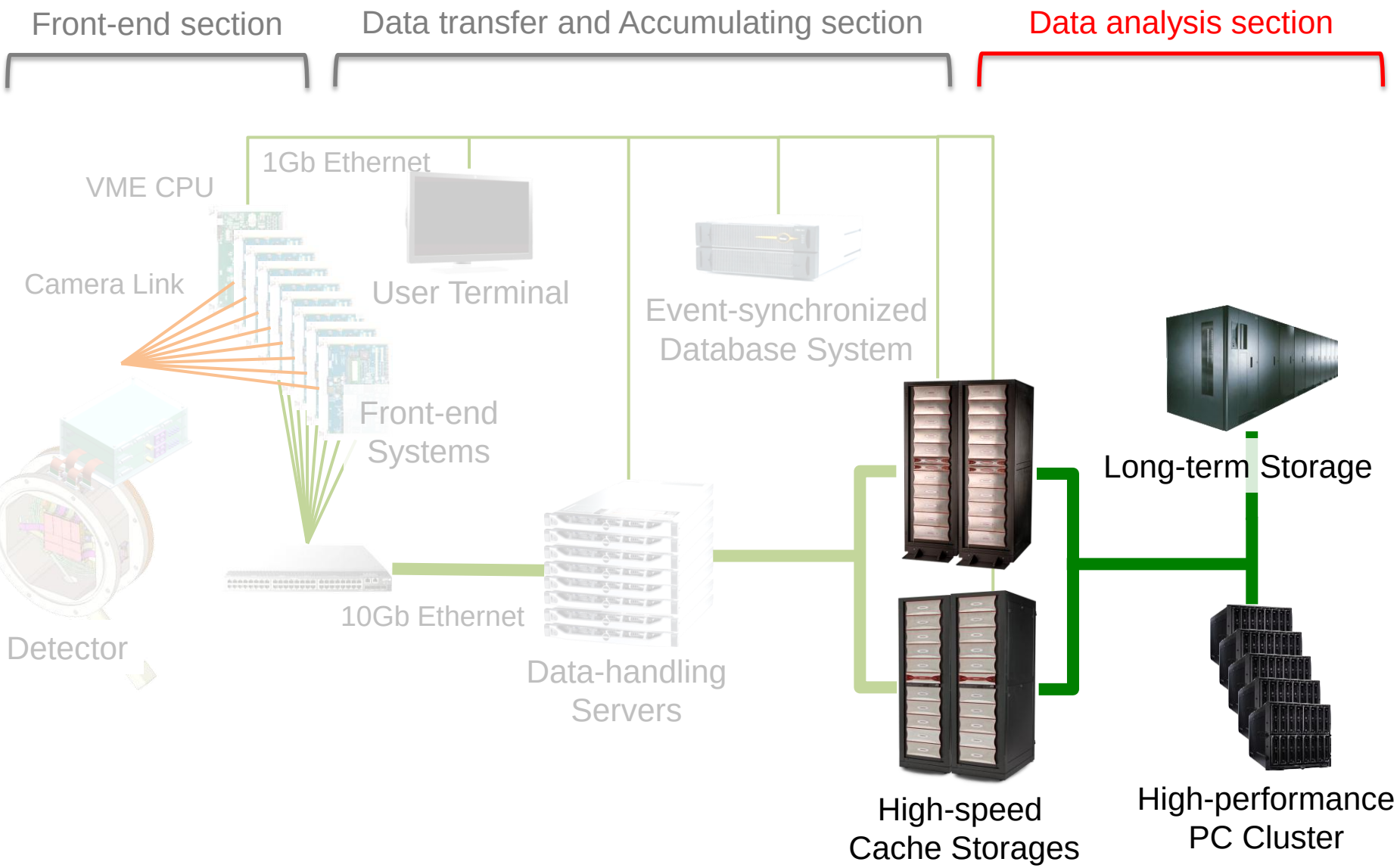


From March 2012, experimental data are accumulated without fatal trouble.

At present, repetition rate of XFEL is 10 Hz. Thus accumulation rate is relatively low than that we expected.

The DAQ system can perform at 10/30/60 Hz. 30 Hz mode is already used by a few experiments.

Overview of the SACLA DAQ System

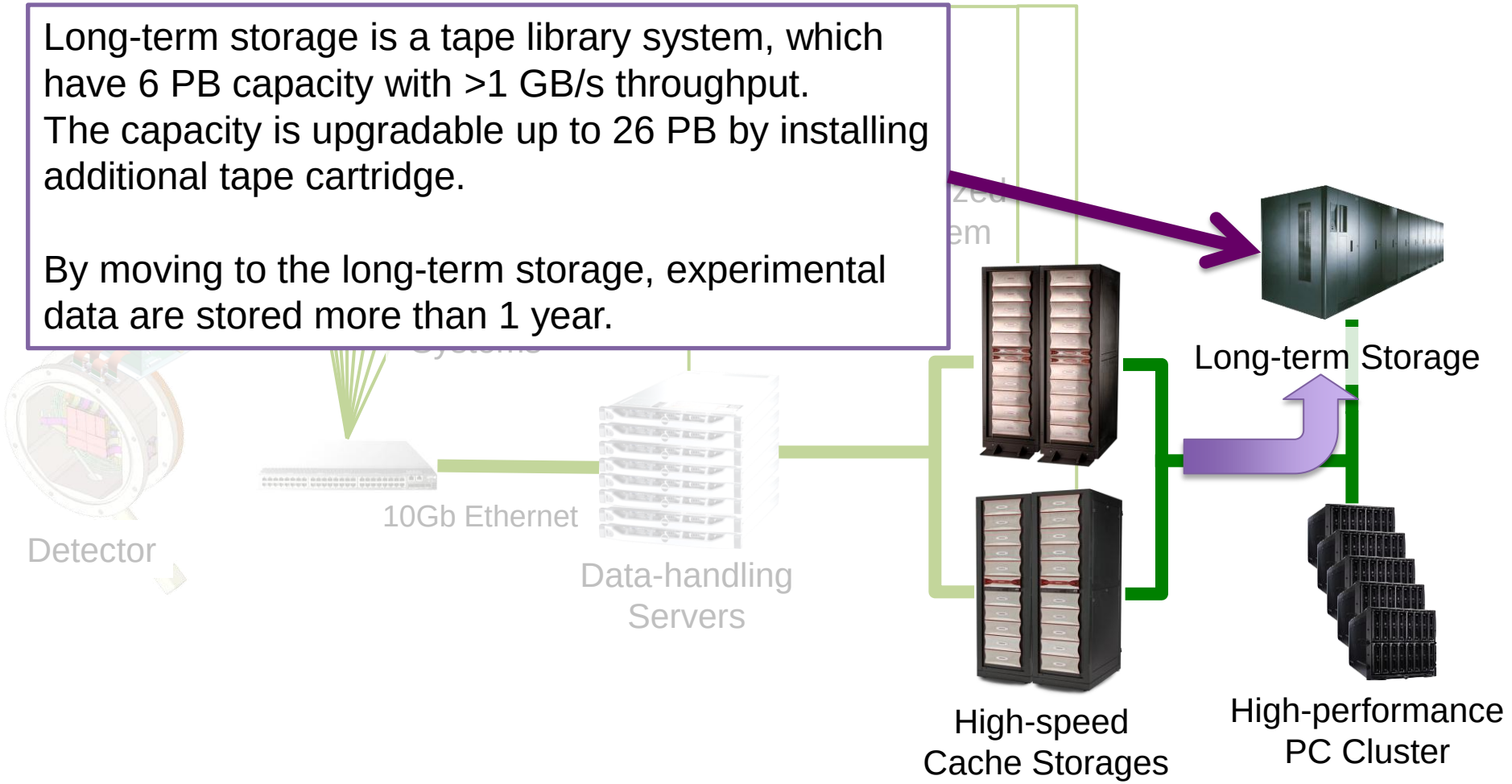


Long-term Data Storage

Front-end section | Data transfer and Accumulating section | Data analysis section

Long-term storage is a tape library system, which have 6 PB capacity with >1 GB/s throughput.
The capacity is upgradable up to 26 PB by installing additional tape cartridge.

By moving to the long-term storage, experimental data are stored more than 1 year.

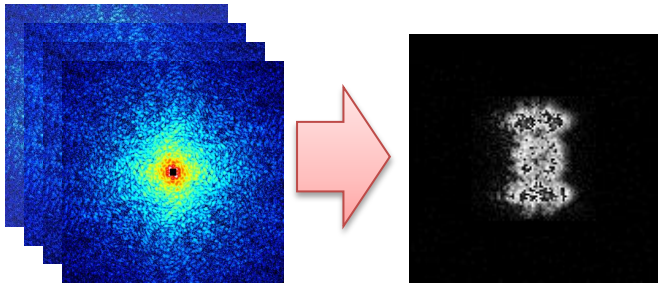


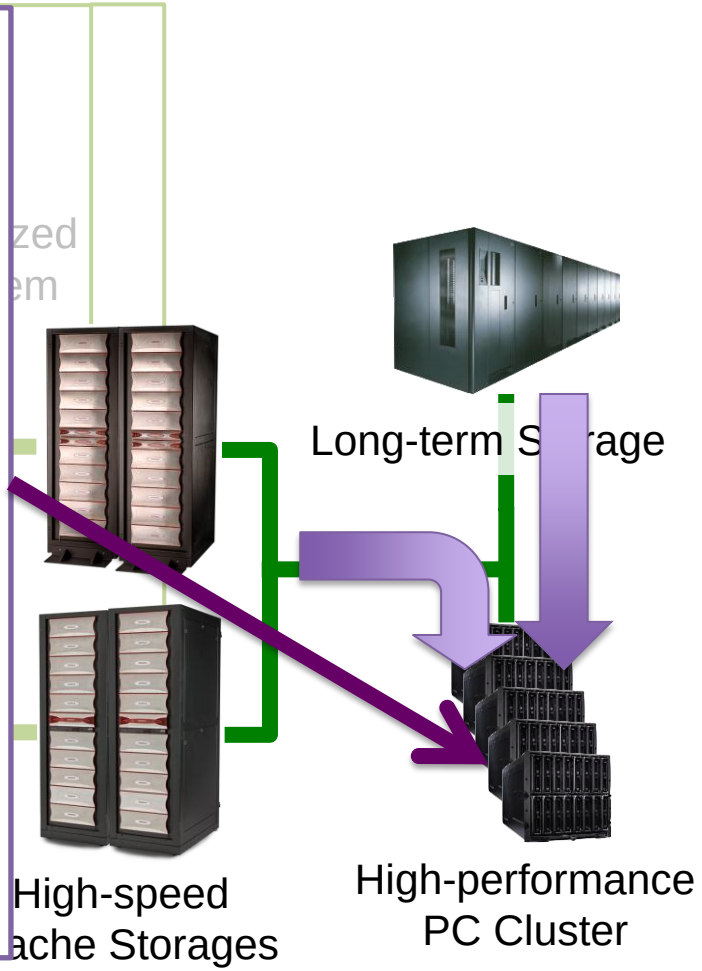
High-performance PC Cluster

Front-end section | Data transfer and Accumulating section | Data analysis section

High-performance PC cluster (HPC) is 13 TFLOPS Intel-based PC Cluster system.
The HPC is not only for off-line analysis, but for instant visualization during the experimental period.

Since the stored 2D image data are reciprocal lattice space, we have to analyze to extract real-space image.
By performing instant visualization, we can determine whether the experimental conditions need to changed.





Current Status of SACLA DAQ System

- SACLA DAQ system consists of three section.
  - Front-end section
  - Data transfer and accumulating section
  - Data analysis section
- We have developed each component of DAQ system to satisfy experimental requirements.
  - 2000x2000 / 16bit / 60 Hz / 10 M shot
- Experiments are successfully performed from March 2012.
  - Typical experiments use 10 Hz mode. Some experiments use 30 Hz mode (vs. XFEL is 10 Hz).
- Off-line analysis are currently underway by each experiment group.

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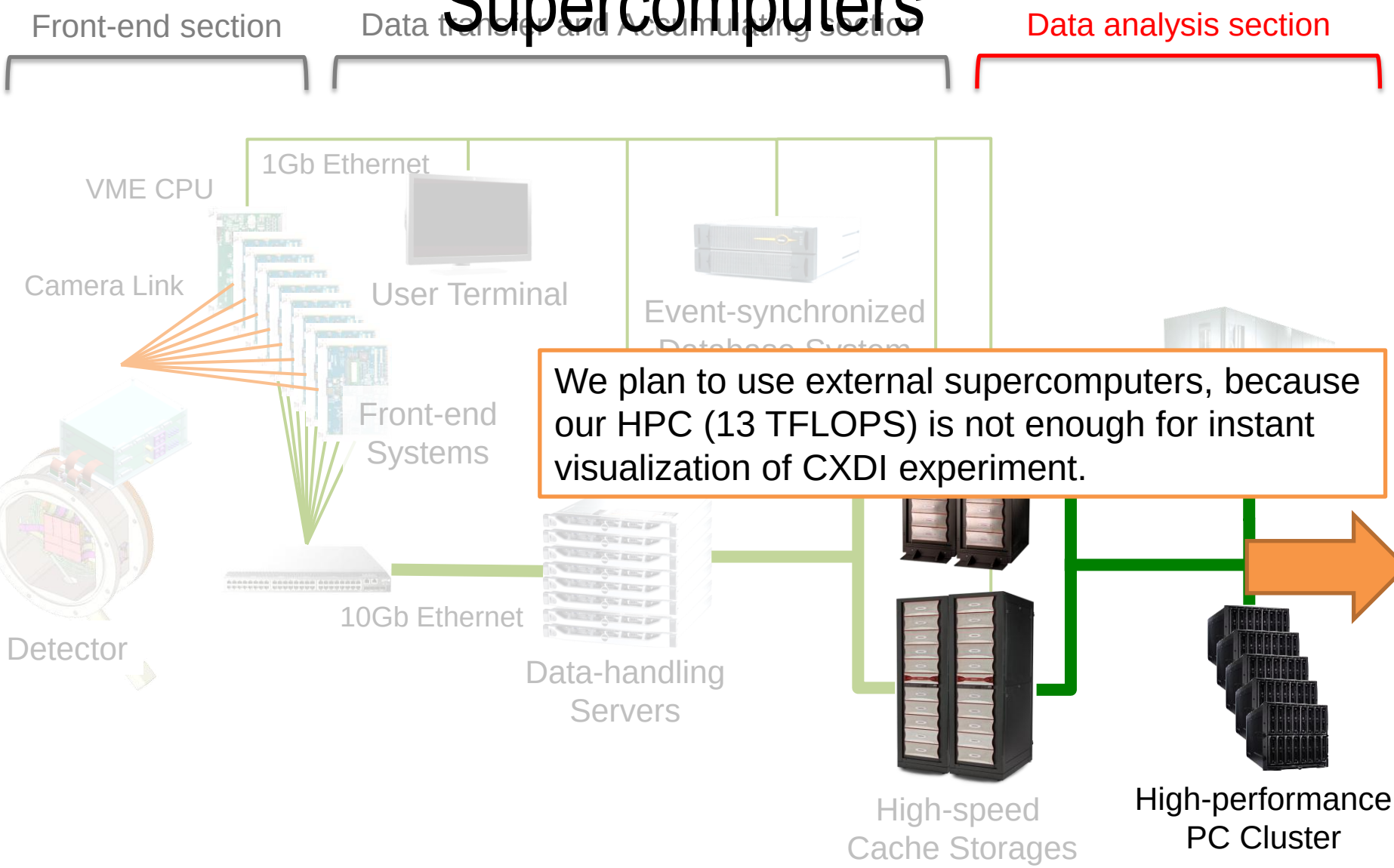
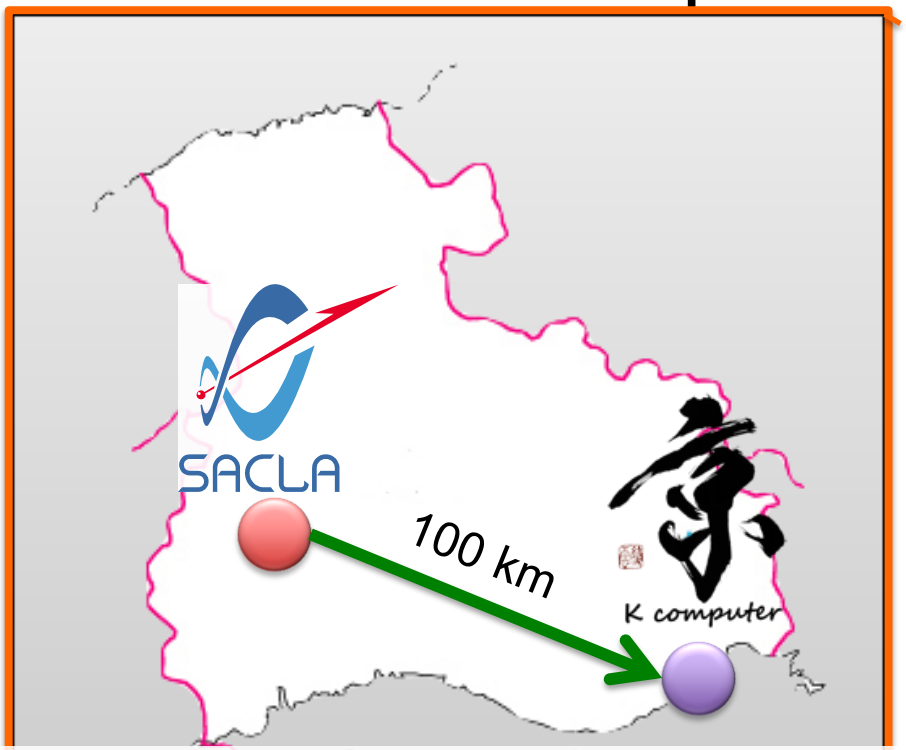
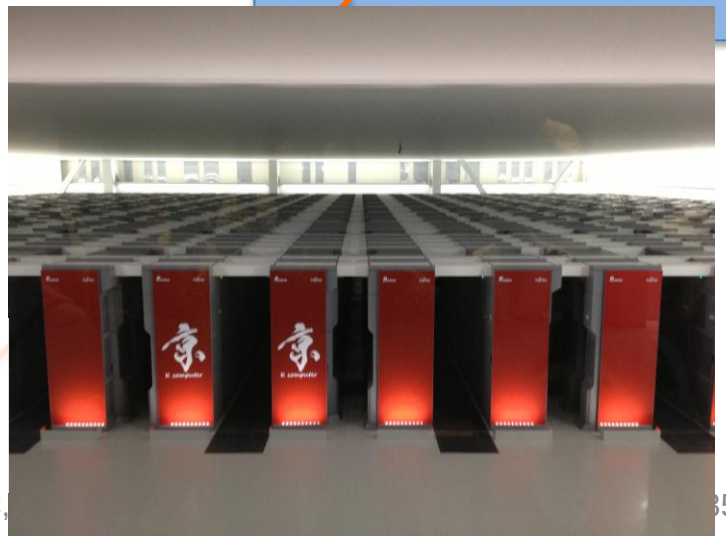
Future Plan: Analysis using External Supercomputers



Future Plan : Analysis using External Supercomputers





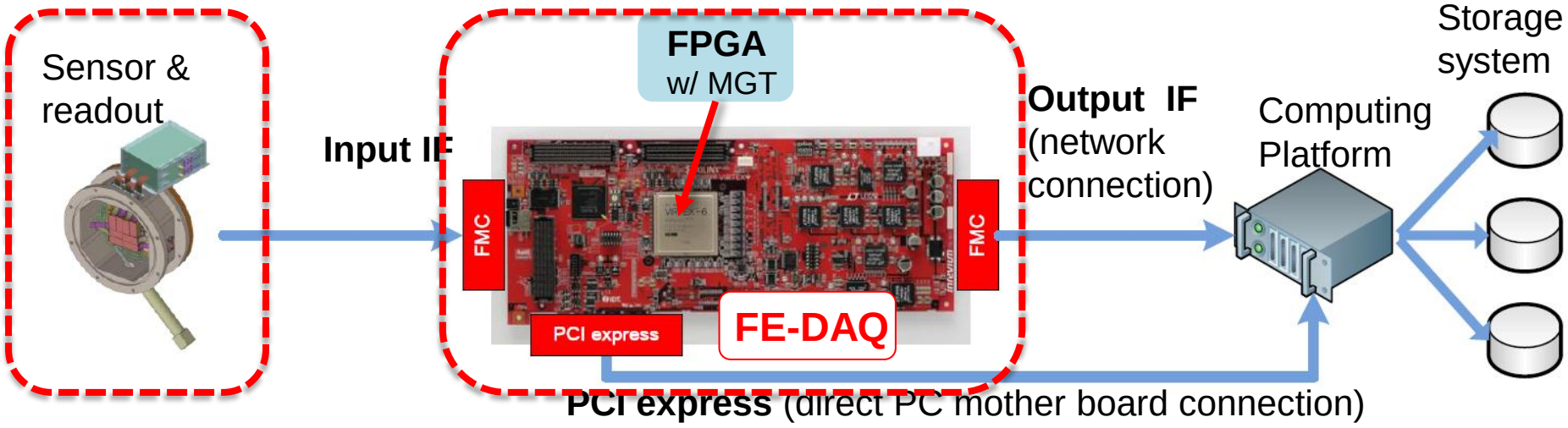
We plan to use the “K Computer” (10 PFLOPS), which is 100-km apart from SACLA, for the on-line visualization.

We already carried out a preliminary data-transfer from SACLA to K computer. We achieved 6.4 Gbps bandwidth, which satisfy the experimental data rate.

Future Plan: New Detector and FE System

To achieve higher data depth and large resolution, we started developing next generation SOI X-ray image sensor, named “SOPHIAS”.
The SOPHIAS have 1024x2048 and 32 bit data depth. Data rate becomes x8 higher (480 MB/s) than that of MPCCD (60 MB/s), and we plan to use 40 SOPHIAS sensors simultaneously (up to 20 GB/s).

We also started developing new FE system supporting up to 2.5 GB/s data rate, which satisfy requirements of SOPHIAS sensor readout.



T. Hatsui et al., International Workshop on Semiconductor Pixel Detectors for Particles and Imaging (PIXEL2012).
C. Saji et al., International Workshop on Semiconductor Pixel Detectors for Particle and Imaging (PIXEL2012).

Summary

- Overview of SACLA
  - Key component
    - e-gun, C-band accelerator, in-vacuum undulator
  - Successfully established
    - First lasing on June 2011
    - Experiments with our DAQ system started on March 2012
- SACLA Data Acquisition System
  - Requirement
    - 2000x2000, 16bit, 60Hz, 10M shot
  - We have developed detector and DAQ system
    - MPCCD: 1024x512px, 16bit/px, 8+2 sensors
    - DAQ: 5 Gbps, 200+250TB cache, 6PB long-term storage
- Future Plan
  - Analysis using External Supercomputers
    - preliminary test bandwidth is 6.4Gbps (> 5Gbps, by 10 MPCCD sensors)
  - Next Generation Detector and FE System
    - 2048x1024px, 32bit/px SOI sensor, and 2.5 Gbps FE