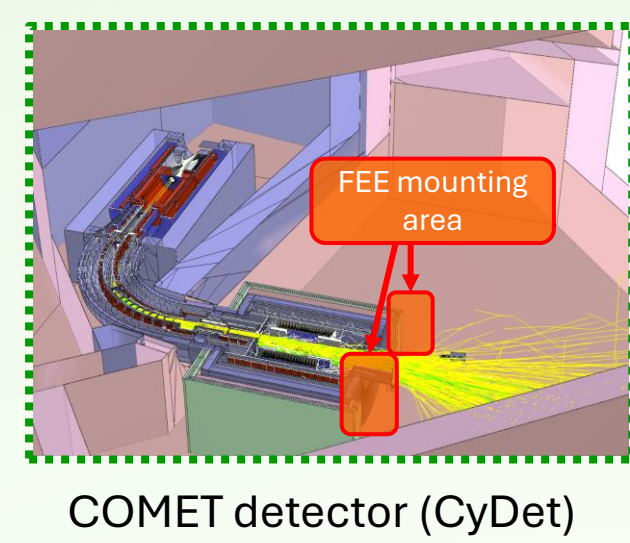


Partial restart of a distributed data acquisition system

Motivation

- Modern detector systems employ a vast number of Front-End Electronics (FEEs).
 - These FEEs can occasionally exhibit instability, necessitating a system restart.
 - FEEs mounted close to detectors are exposed to radiation-induced SEUs, which can cause failures during data taking.
- In the COMET Phase-I experiment at J-PARC, SEU-induced FEE failures are expected every 7.2 minutes.
 - Restarting the entire DAQ system for every failure would introduce significant dead time.
- On the other hand,
 - Temporary loss of a small number of FEEs has little impact on detector acceptance.
 - The loss of a small number of FEEs does not significantly affect the physics analysis.



Partial restart of FEEs during data taking can improve the DAQ live time.

An implementation of automatic partial FEE restart

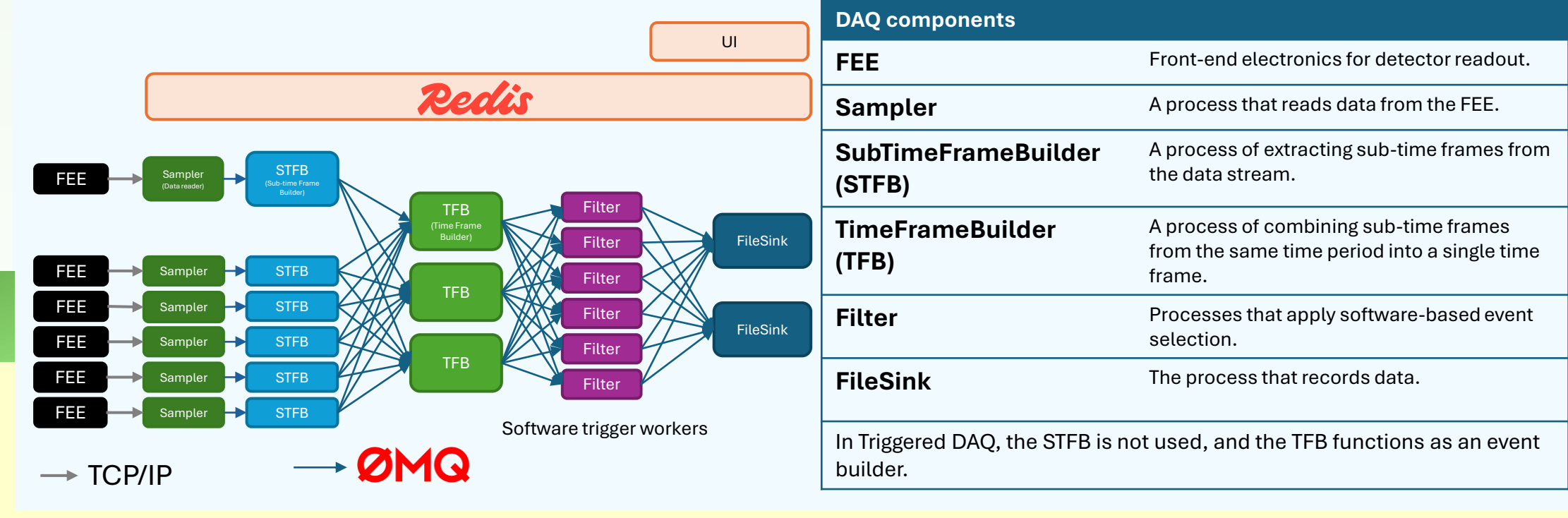
To achieve this mechanism, we developed the following components.

- Improvements to the TimeFrameBuilder (EventBuilder)**
 - The TimeFrameBuilder (EventBuilder) must handle incomplete time frames (events).
 - A malfunctioning FEE stops sending its detector data.
 - The TimeFrameBuilder reports its status, success rate, the IDs of FEEs that did not send data, and the number of lost segments.
- Watchdog**
 - Detection of FEE anomalies based on notifications from the database. DAQ process control
 - Execution of a recovery program with configuration parameters
- Communication connection management**
 - ZeroMQ can handle disconnection and reconnection automatically.
 - Sampler uses sockets to read FEE data. Socket connections are opened and closed according to state transitions.

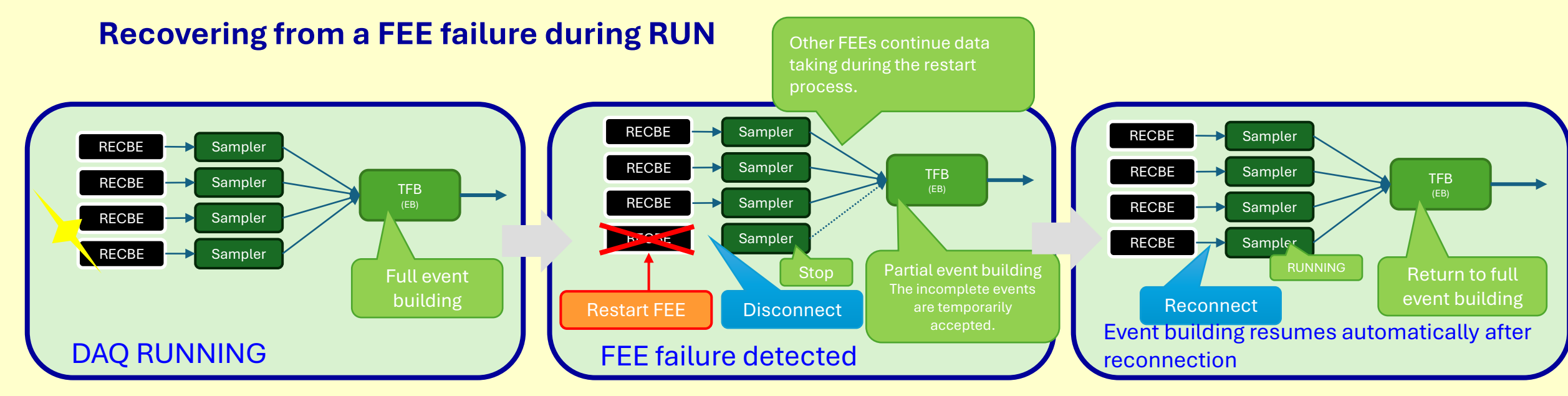
NestDAQ: A distributed DAQ system

FairMQ[2] with ZeroMQ[3] + Redis[4] + Semi-automatic self-configuration
 → NestDAQ[5] (Network-based streaming DAQ)

- A DAQ software framework for streaming readout developed under the SPADI Alliance[6].
- Semi-automatic configuration based on simple configuration parameters
 - Endpoints and links are defined by simple configuration parameters.
- Control and management: Redis
- Inter-process communication: ZeroMQ
- State machine: FairMQ

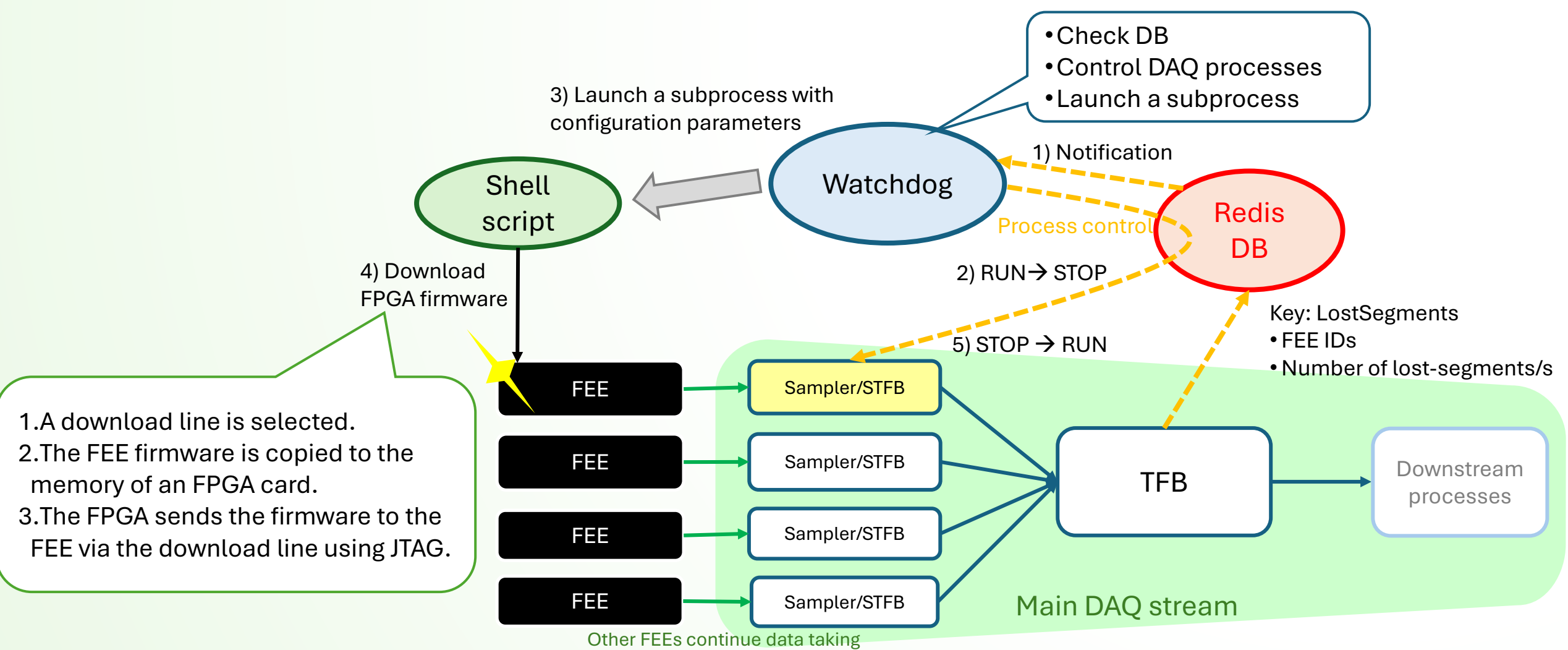


Recovering from a FEE failure during RUN

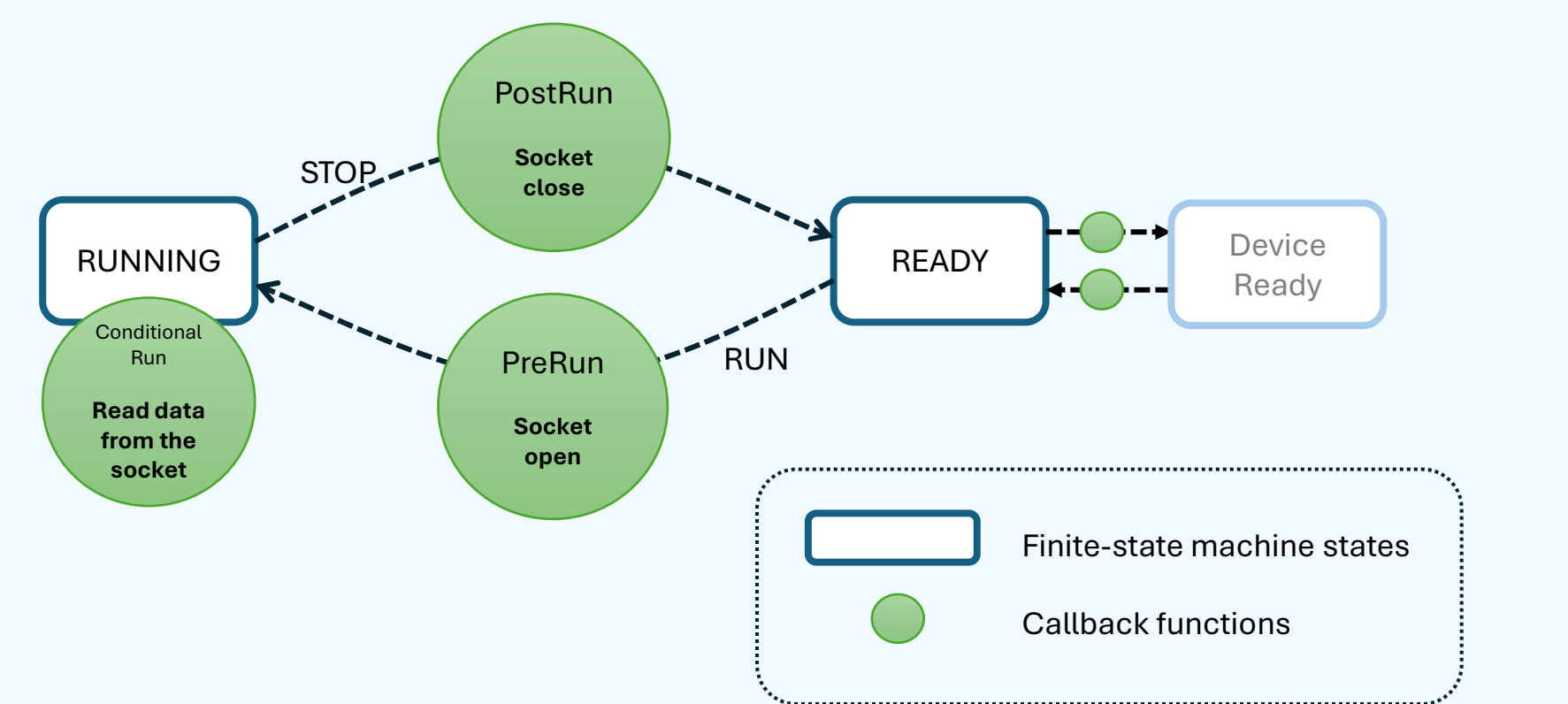


Sequence of partial FEE restart

The recovery procedure is automatically triggered by the watchdog process.



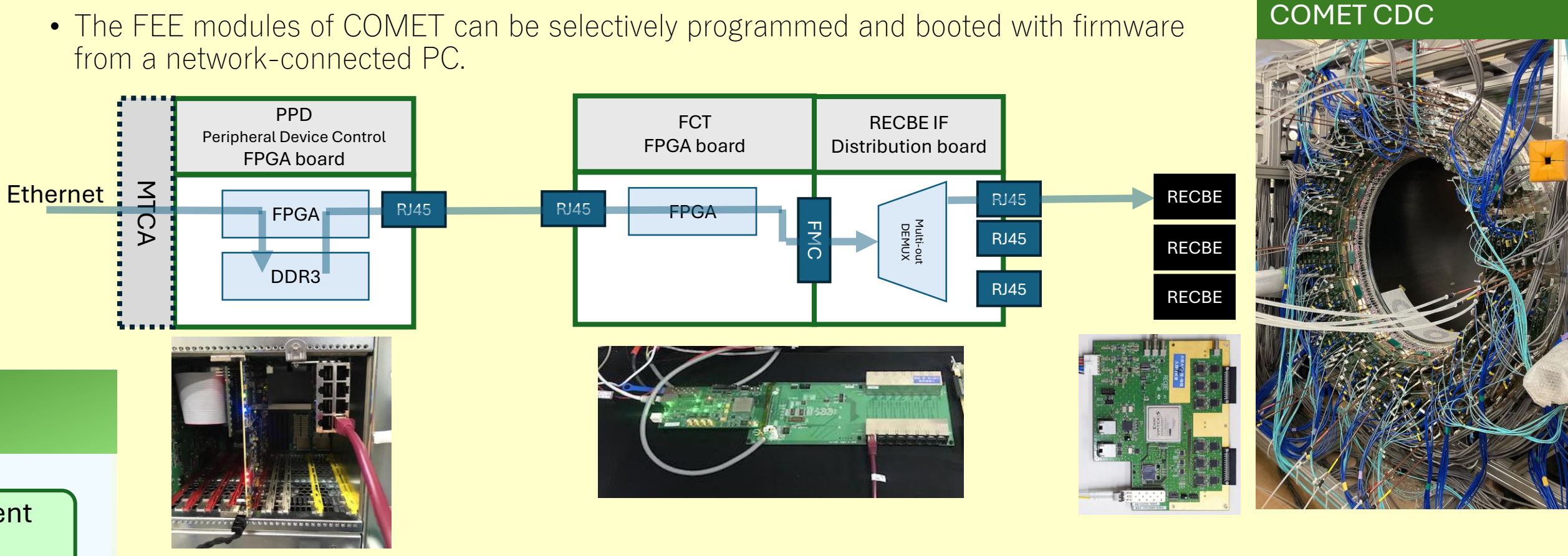
In the Sampler, the socket used to read the FEE is opened and closed according to state transitions.



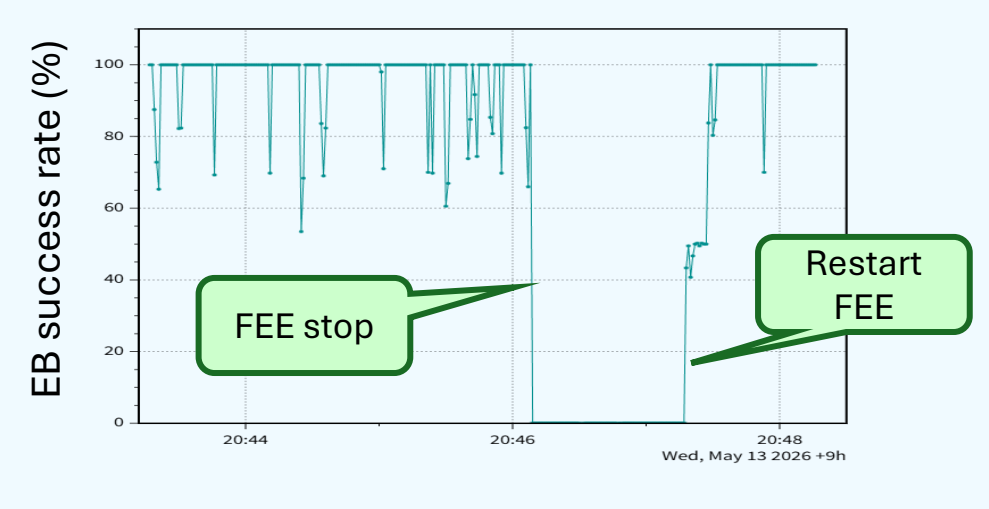
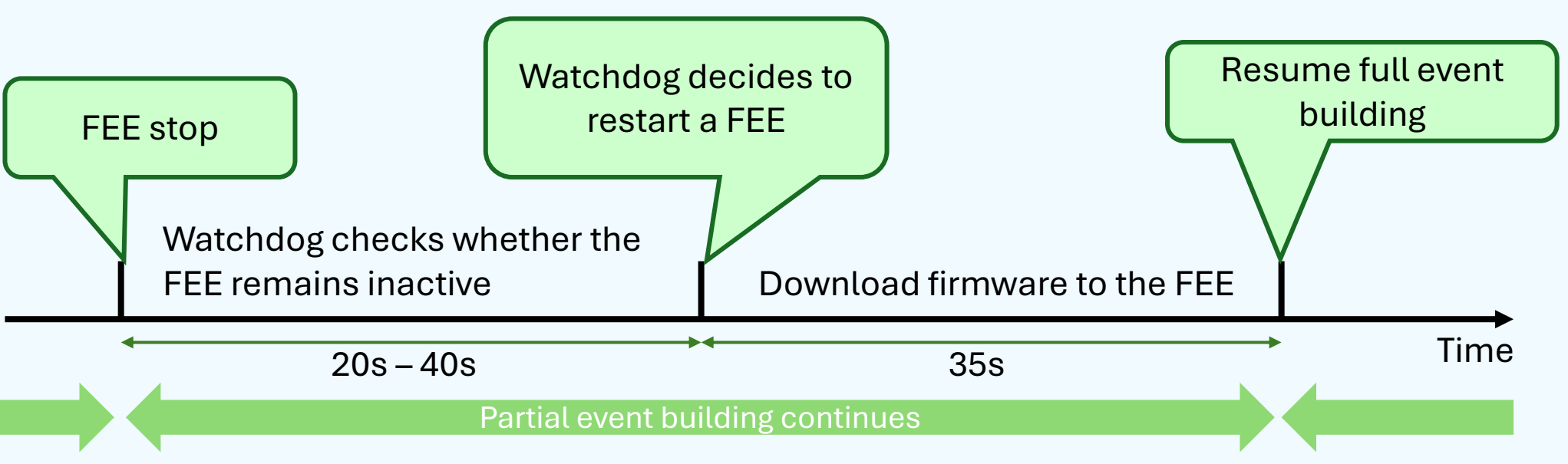
An applied system, COMET Cylindrical Drift Chamber (CDC)

- COMET: An experiment searching for charged lepton flavor violation via $\mu N \rightarrow eN$ conversion at J-PARC.
 - The goal of the COMET Phase-I experiment is to achieve a sensitivity of $O(10^{-15})$.
- The front-end electronics are mounted close to the detector to achieve a good signal-to-noise ratio.
 - The electronics will be exposed to radiation from the beam.
- The CDC is one of the main detectors of the COMET Phase-I experiment. Signals from the chamber are read out by an FEE board called RECBE.

FPGA firmware downloading by remote JTAG



Timeline of the partial restart sequence



Summary

- We implemented a partial FEE restart mechanism on NestDAQ.
- The system was applied to and tested on the COMET CDC detector system.
 - The system successfully recovered from FEE failures within approximately one minute.
 - Compared with restarting the entire DAQ system, the proposed method is expected to improve the DAQ live time by approximately 14% under the assumption of an MTBF of 7.2 minutes due to FEE SEUs.
 - The anomaly detection time can be further reduced by improving the detection algorithm.
- Global DAQ interruption is avoided during FEE recovery.

References

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- [2] "FairMQ: C++ Message Queuing Library and Framework," [Online]. Available: <https://github.com/FairRootGroup/FairMQ>
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- [5] Y. Igarashi et al., "Implementations of Streaming DAQ on Actual Detector Systems," IEEE Trans. Nucl. Sci., vol. 72, no. 3, pp. 421-428, 2025. DOI: 10.1109/TNS.2024.3506783
- [6] "SPADI Alliance," [Online]. Available: <https://spadi-alliance.rcnp.osaka-u.ac.jp/>