Irradiation Test of Opt. Transceivers for CDCFE → TRG

Hanwook Bae and Yu Nakazawa

KEK, Institute of Particle and Nuclear Studies (IPNS)

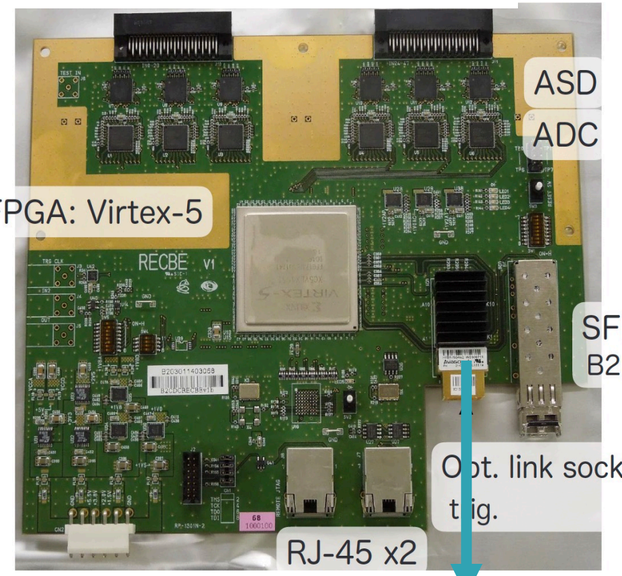
Current CDCFE and Triggers

- Currently, CDCTRG receives the hit information from the front-end electronics
  - The merger boards receive the data firstly and simplify signals
  - Then, the TSF modules get the simplified information and find the track segments for further CDCTRG processes.

- The front-end boards send the signal through the MPO cables with 3.2 Gbps speed.
  - The optical module in the front-end side **survives for the 300 Gy dose** (The **manufacture** for the modules is **terminated** 👉 No spares!)

- The CDC team planned upgrading the front-end boards

Current CDCFE board



CDC Merger

CDCTRG (TSF)

From Nakazawa-san's slides: Link

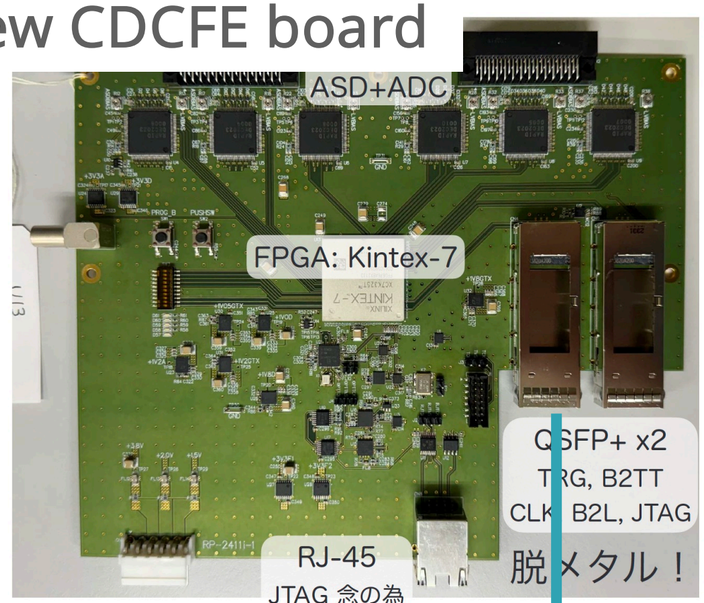
Upgrade of CDCFE

- The new CDC front-end board has upgraded FPGAs and optical transceiver
  - New optical transceiver: **Replaceable** QSFP+ modules with **40 Gbps**
  - Easy replacement and more detailed information to CDCTRG

- With the new boards, the TSF module will receive **the full CDC information** without merger boards
  - e.g., ADC information for all the wires in the track segments

- We tested the resistance of the various QSFP+ modules in the market against the gamma and neutron rays
  - Requirements: It should survive for **1000 Gy dose** of gamma and **10^{12} 1MeV-equivalent** thermal neutrons
    (This requirement corresponds to **the dose for 10 years** at the Belle II radiation condition)

New CDCFE board

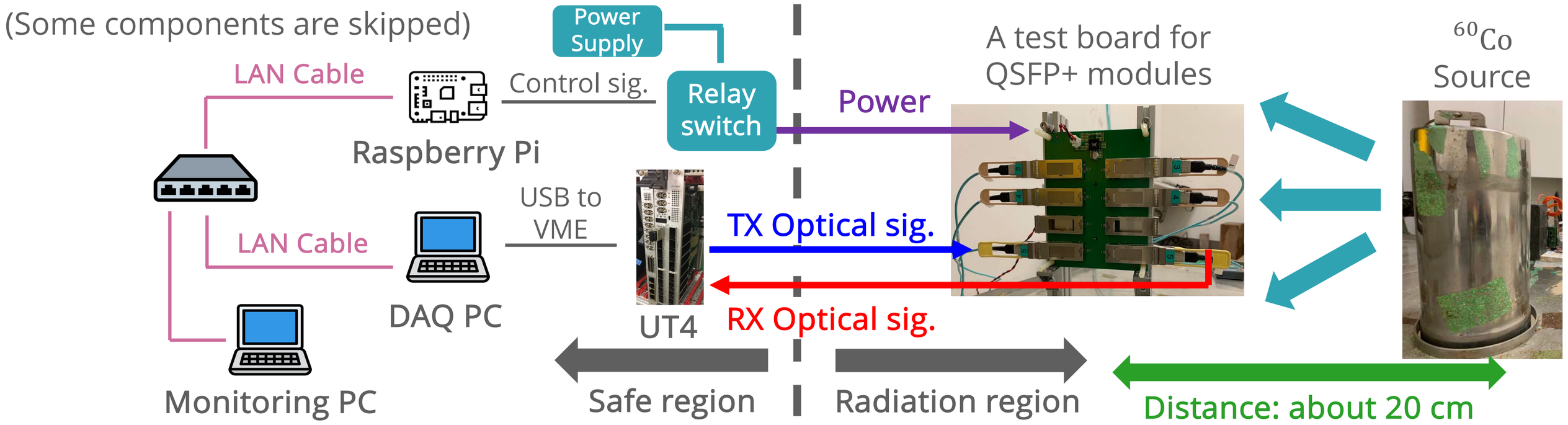


From Nakazawa-san's slides: Link

CDCTRG (TSF)

Gamma Irradiation Test: Configuration

- We performed the irradiation test with gamma rays at the facility of Science Tokyo Univ.
  - ^{60}Co in the source emits the 1.17 and 1.33 MeV gamma-rays. Dose rate: 100-200 Gy / hour
  - We check the stability of optical links with a loopback configuration through the test board.
  - Optical modules on the test board are power-cycled per every 100 Gy doses



Gamma Irradiation Test: Results by Models

- We tested various models for the modules. Two modules meet our requirements
  - Considering the selling agencies, we selected the **Dell-compatible model from FS.com**

Model & Manufacture	Sample pair number / Lethal dose					Resistance at least
	#1	#2	#3	#4	#5	
FiberJapan 8515	500 (PC)	650	1400 (PC)	1300 (PC)	1500 (PC)	> 400 Gy
FiberJapan 85-015	1400 (PC)	1300 (PC)	1100 (PC)	1256 (PC)	1200 (PC)	> 1000 Gy
FS.com FS compatible QSFP-SR4-40G	500 (PC)	400 (PC)	500 (PC)	400 (PC)	400 (PC)	> 300 Gy
FS.com Dell compatible QSFP-SR4-40G	1300 (PC)	1400 (PC)	1300 (PC)	1200 (PC)	1200 (PC)	> 1100 Gy
FS.com Cisco compatible QSFP-SR4-40G	1000 (PC)	1190 Survived	Not tested			> 900 Gy
FS.com Avago compatible QSFP-SR4-40G互換	1000 (PC)	1156 Survived	1300 (PC)	1200 (PC)	1300 (PC)	> 900 Gy

- Color of figures indicates the dose rate (100 Gy/h and 200 Gy/h)
- (PC) means the corresponding sample dead after the power-cycle
- In the (PC) case, we consider the dose in the previous successful power-cycle as the final resistance as a conservative approach

Gamma Irradiation Test: Results per Lot-Numbers

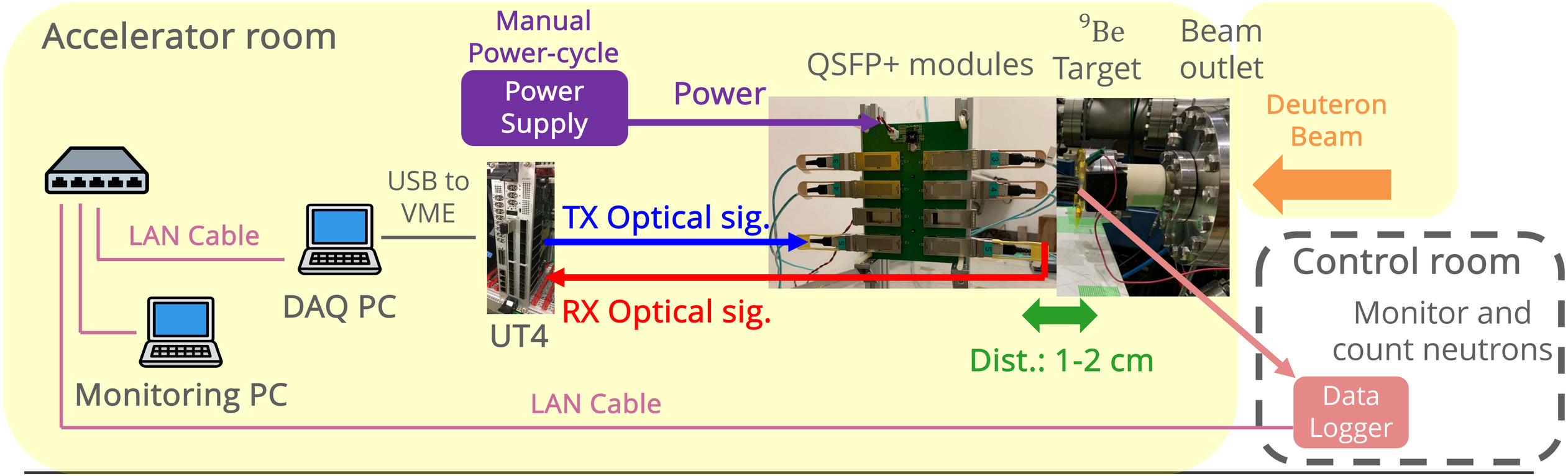
- We performed another test to check the dependency of the lot numbers.
  - The module model is “Dell compatible QSFP-SR4-40G” from FS.com
- Three module pairs from two different lot number has been tested
  - Dose rate and total dose: 40 Gy/hour for 32 hours: 1280 Gy

- Result: No significant variations and **all pairs** from the both lot numbers **can meet our requirements**.
  - Some pairs showed unstable link status during the test, but after power-cycling at the end of test, all modules established the stable link!

Lot. No. of Dell-compatible QSFP-SR4-40G modules	Sample pair number / Lethal doses			Resistance at least
	#1	#2	#3	
CG2409245468	> 1280 Gy	1200 Gy	1200 Gy	1200 Gy
CG2408268338	1200 Gy	1100 Gy	1200 Gy	1100 Gy

Neutron Irradiation Test: Configuration

- We performed the irradiation test at the TANDEM accelerator of Kobe University.
  - It shoots 3-MeV deuterons to $^{9}\mathrm{Be}$ targets, which makes 2-MeV neutrons through $^{9}\mathrm{Be}(d,n)^{10}\mathrm{Be}$
  - We measured the number of neutrons with probes at the $^{9}\mathrm{Be}$ target (Total dose: 10^{12} neutrons)



Neutron Irradiation Test: Results

- As we considered the optical transceiver is not affected much by the neutrons, we tested two pairs of the optical transceiver
  - The module model is “Dell compatible QSFP-SR4-40G” from FS.com

- We irradiated 10^{12} neutrons to the module, and there were **no optical link instability during the test**.
  - The module was normal after the irradiation test.

- The both modules **meet our requirements** for the resistance against the neutron rays

Summary

- We performed irradiation tests for the optical modules with the gamma and neutron-rays, which will be used between the CDCFE and CDCTRG link for the new CDCFE.

- Gamma ray test:
  - 1st test to confirm what model we will use: “Dell compatible QSFP-SR4-40G” from FS.com is good.
  - 2nd test to check the lot-number dependency: There may be dependency, but not large and all lots we tested meet our requirements. (We will buy the tested lots)

- Neutron ray test to confirm the neutron-ray-resistance of the selected module
  - The module meets our requirements for the neutron rays.

- We successfully selected the model for the optical modules, which can endure the Belle II radiation conditions for 10 years.

Backup Slides