The process of assembly
for the module of the dual-readout calorimeter

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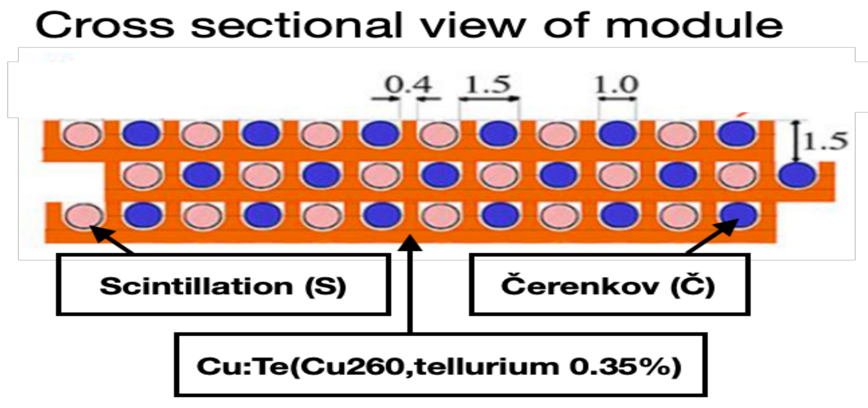
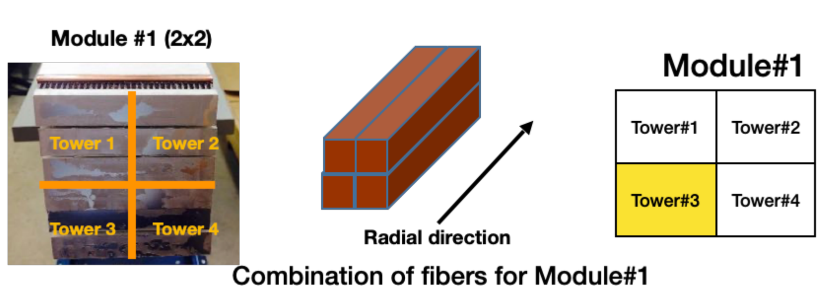
Dual-readout Calorimeter

- Dual-readout calorimeter has been proposed in IDA detector conceptual report(CDR) for future e^+e^-collider.
- Dual-readout calorimeter may offer high-quality energy measurement for both EM particles and hadrons.
- Deposited energy of shower components is measured in scintillating and čerenkov fibers.
- The detector uses two different channels; čerenkov fibers respond to mainly EM particles only, and scintillating fibers respond to both EM & hadronic particles.

Dual-Readout Calorimeter

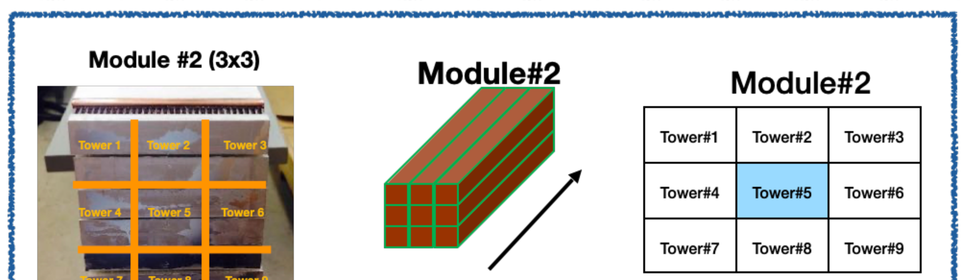
Cross sectional view of module





Combination of fibers for Module#1

	Tower #1	Tower #2	Tower #3	Tower #4
Scintillation fibers	Square / Single cladding	Round / Double cladding	Round / Single cladding	Round / Single cladding
Cherenkov fibers	Round / Single cladding			
Readout detector (2*4 ch)	2 PMTs	2 PMTs	2 MCP-PMTs	2 PMTs



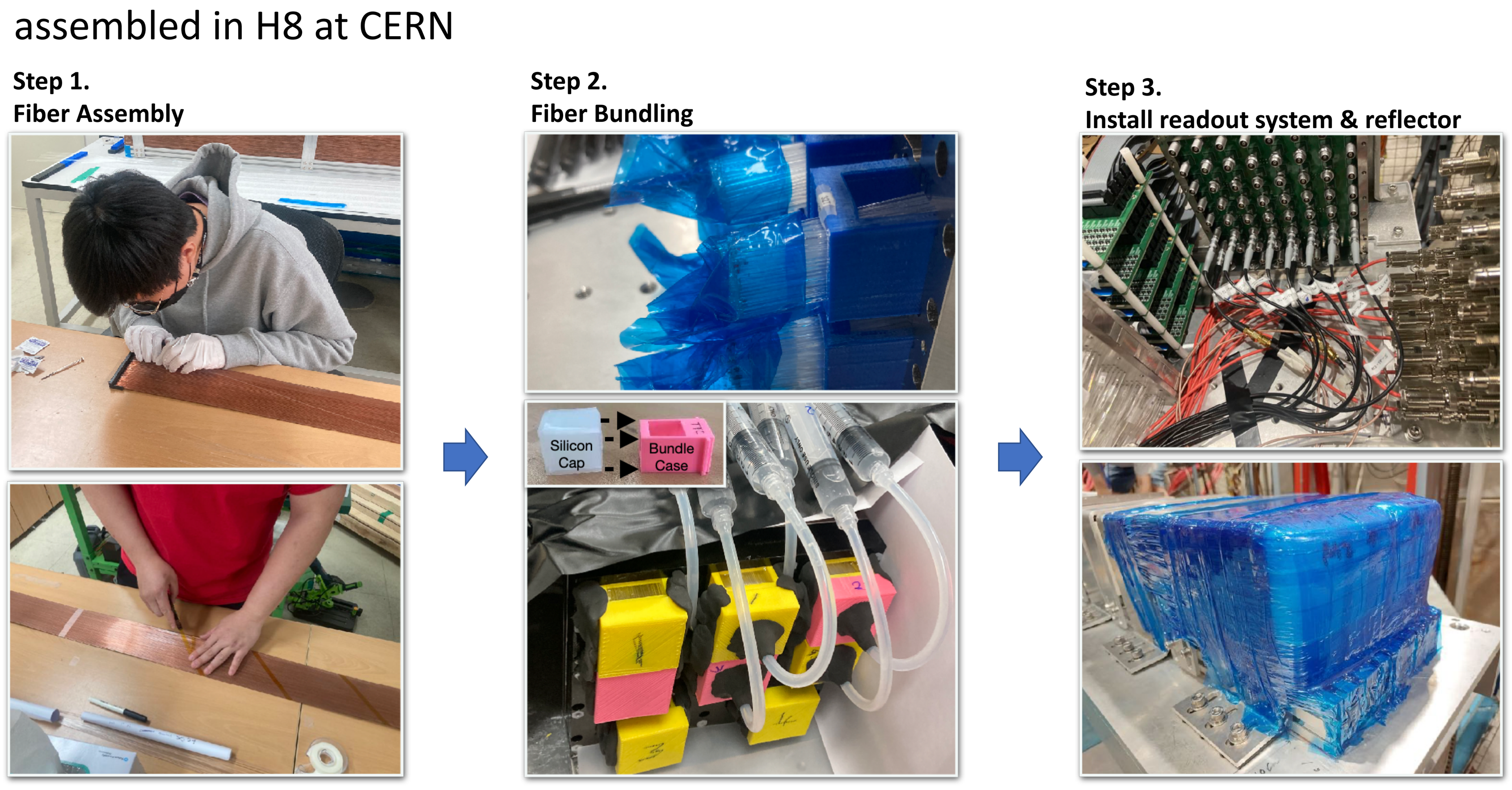
Combination of fibers for Module#2

	Tower #1~4 and #6~9	Tower #5
Scintillation fibers	Round / Single cladding	Round / Single cladding
Cherenkov fibers	Round / Single cladding	Round / Single cladding
Readout detector (400+16 ch)	16 PMTs	400 SiPMs

- All fibers are installed on stacked copper plates, called tower structures.
- Copper plate: grooving with a milling machine
- Optical fiber
  1) Čerenkov fiber: round-shaped with single cladding
  2) Scintillating fiber: round-shaped with single cladding & double cladding, square-shaped with single cladding
- Module 1
  - 4 readout towers
  - tower 3 is connected to MCP-PMT
- Module 2
  - 9 readout towers
  - central tower is connected to 416 SiPM ch
- Other towers are equipped with generic PMT

Procedure of Assembly

- 3 steps to build dual-readout calorimeter
- All steps are performed at Yonsei university
- Installation readout system & reflector is disassembled after working test and re-assembled in H8 at CERN



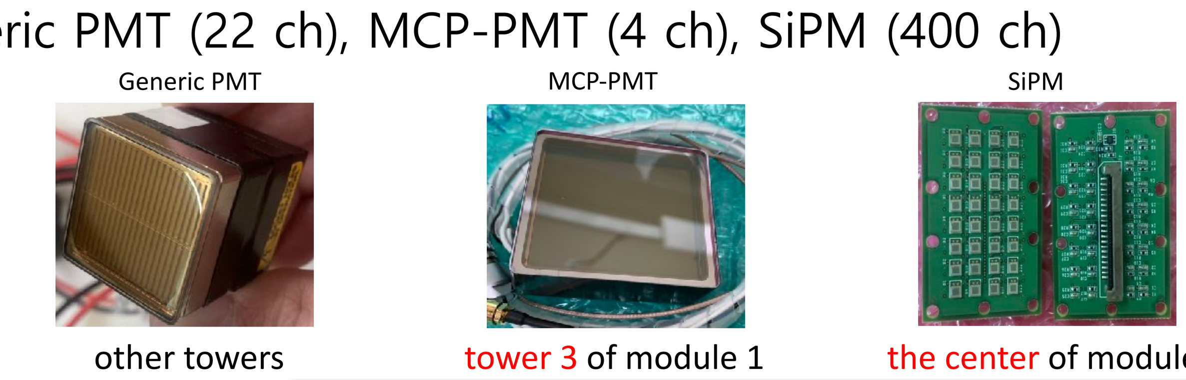
- Fibers are put in the grooves of the copper plate
- **Taping** to block the escaping fibers

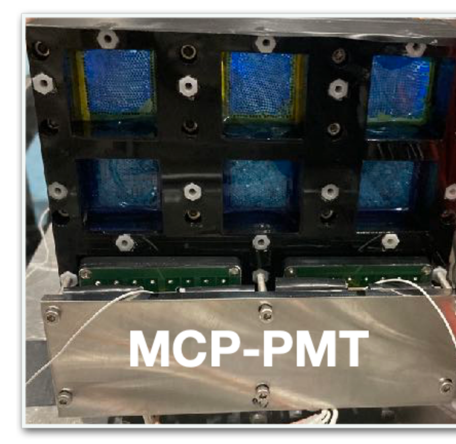
- We used **3d-printed bundle case**
- Fiber bundle of each tower is glued by **epoxy**

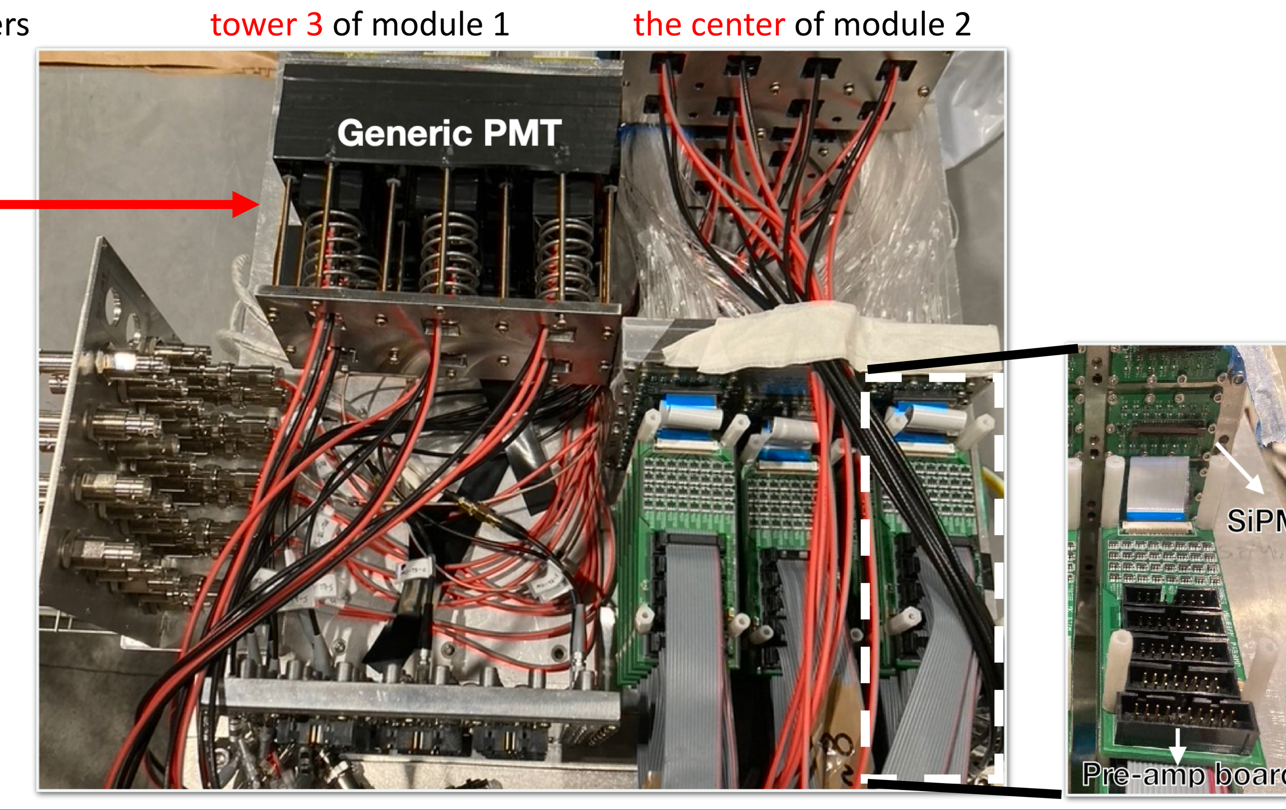
- All readout systems are **installed on towers** & **connected to the DAQ system**

Readout System Installation

- We used 3 types of photomultiplier for checking the characteristic of dual-readout calorimeter
  - Generic PMT (22 ch), MCP-PMT (4 ch), SiPM (400 ch)



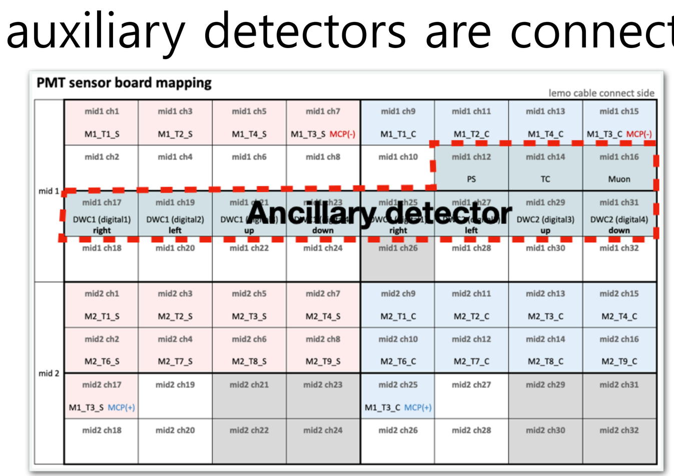




- We stacked the PMTs layer by layer to compose the readout system

DAQ Connection

- We made **mapping** for cable connection with DAQ team
- Also, auxiliary detectors are connected to PMT sensor board with LEMO cable



Preamp board mapping

		Down steam side
S5-mid15		C5-mid7
S4-mid14	S6-mid10	C4-mid6
S3-mid13	SC-mid11	C3-mid5
S2-mid12	C6-mid8	C2-mid4
S1-mid9		C1-mid3

Shielding PMT

- We put lead bricks in dark case to **protect PMTs from beam**

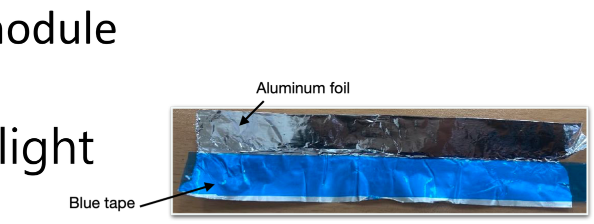
Reflector

- Čerenkov light is nearly exactly prompt, so reflected light retains good time information.
- Čerenkov light also has no signal penalty in the longer path length of the reflected light because attenuation length is long.

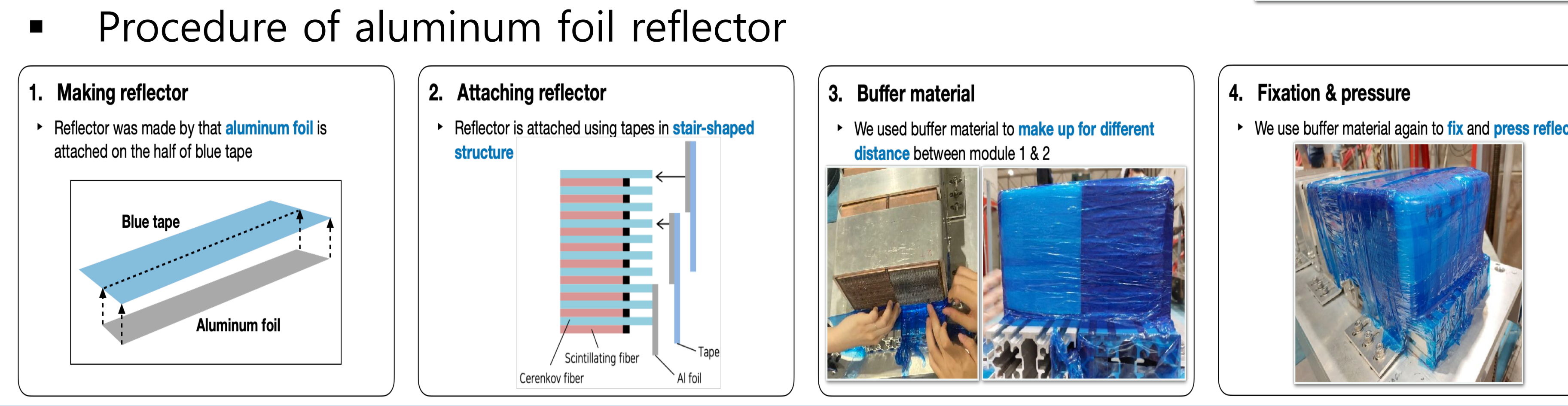
Light	Scintillating light	Čerenkov light
Quantity	Bright	Not bright
Speed	Slow (~2 ns)	Fast (~0 ns)
Attenuation lengths	Small (~3m)	Long (6~10m)

Scintillating fiber: block the light
Čerenkov fiber: reflect the light which gives the depth of light in the module

- Aluminum foil is a good material to reflect čerenkov light



- Procedure of aluminum foil reflector



Conclusions & Next Step

- Dual-readout calorimeter is **a novel, innovative, possibly more cost-effective design** for the future collider.
- We **built** 2 dual-readout calorimeter modules & **tested** them in August at CERN
- The first importance is **optical contact between fiber and readout system**
- **Shielding readout system** is the second importance