# Introduction

- Dual-readout calorimeter
  - Two components of hadron showers.
    - em component.
    - non-em component.
  - Responses of calorimeter to these components are not same (e/h ≠ 1)
  - cerenkov light almost exclusively is produced by em component
  - Dual-readout method
    - measure fem event by event.
- 2022 August test beam
  - We tested Dual-readout calorimeter in CERN north area in this August
  - Our module has two modules
    - module 1 : 3 PMT Towers & 1 MCP-PMT Tower
    - module 2 : 8 PMT Towers & 1 SiPM Tower
  - Our module require 426 channels.
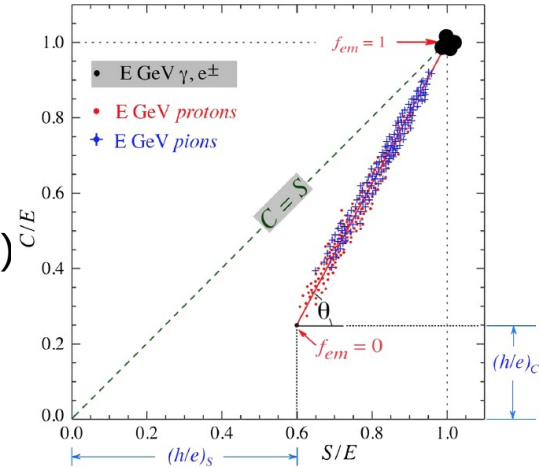
$$S = E \left[f_{em} + \frac{1}{(e/h)_S} (1 - f_{em}) \right]$$

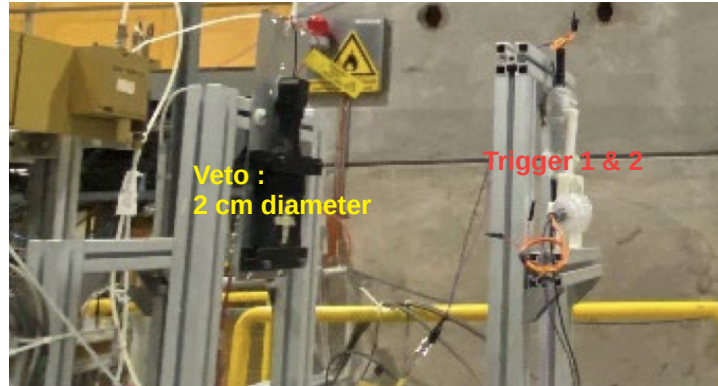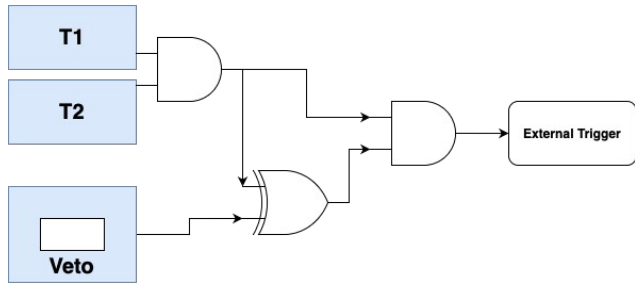$$Q = E \left[f_{em} + \frac{1}{(e/h)_Q} (1 - f_{em}) \right]$$

$$e.g. \, \text{If} \quad e/h = 1.3 \, (S), \, 4.7 \, (Q)$$

$$\frac{Q}{S} = \frac{f_{em} + 0.21 \, (1 - f_{em})}{f_{em} + 0.77 \, (1 - f_{em})}$$

$$E = \frac{S - \chi Q}{1 - \chi}$$

$$\text{with} \quad \chi = \frac{1 - (h/e)_S}{1 - (h/e)_Q}$$

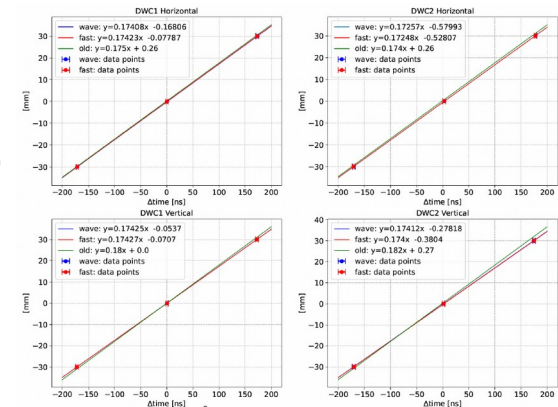# Anciliary detector

- Trigger

- Delay wire chamber
  - Delay wire chamber (DWC) is gas chamber that used on the SPS extracted lines to measure beam profiles.
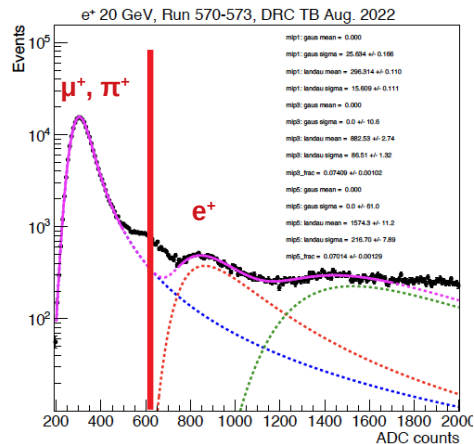- Calibration
  - 3 channel (L/U, C, R/D) that goes to known position for calibration.
    - Left/Up (L/U) : (-30, 30) mm
    - Center (C) : (0, 0) mm
    - Right/Down (L/U) : (30, -30) mm

Ancillary detector

- Pre-shower
  - Identify the particles from beam.
    - 1 MIP : pions & muon
    - more than 3 MIP : positron
  - 5.1 mm(~1X0) thickness of lead plate is attached in front of scintillator.

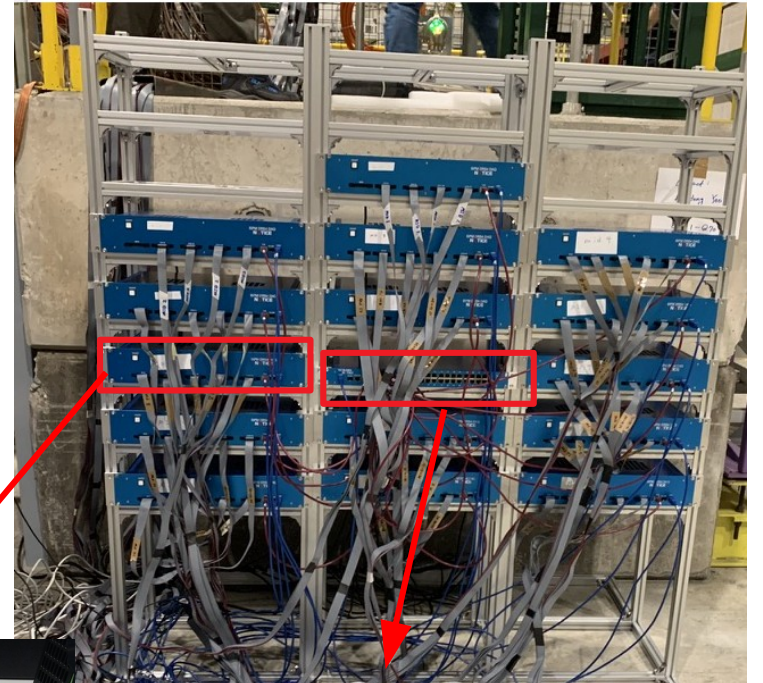- Tail catcher
  - To detect whether shower leakage is exist.

- Muon counter
  - To detect muon from beam or shower.
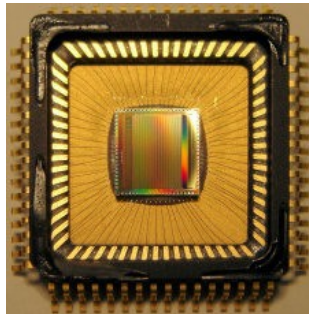

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DAQ & TCB boards

- DAQ board
  - One board can cover 32 channels.
  - Use DRS4 chip.
  - Use 16 pin Ribbon cable
- TCB board
  - Control the setting value of DAQ boards and the trigger system.
  - Connect DAQ boards with TCP/IP cable, cover 40 ch DAQ.
- All boards connected with PC using USB3 line
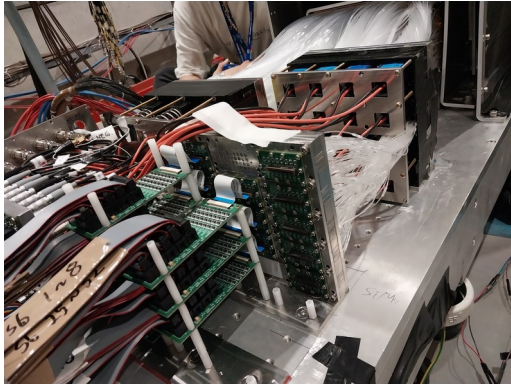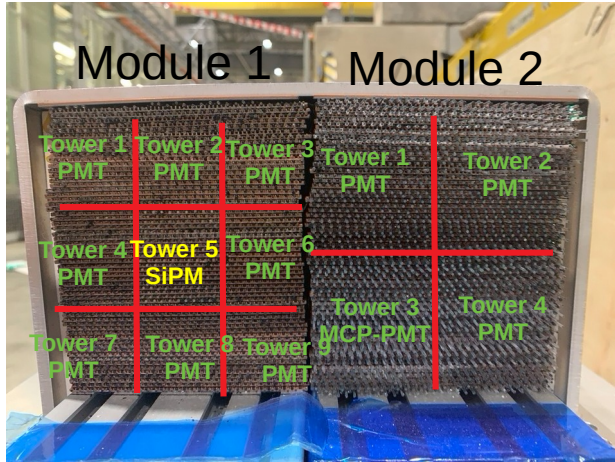

16 pin ribbon cable

DRS4 chip

DAQ board

TCB board

	Generic PMT	MCP-PMT	Auxilary detector	SiPM
channels	22	4	11	400
DAQ		2		13

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Readout system

Module 1   Module 2

Tower 1 PMT, Tower 2 PMT, Tower 3 PMT, Tower 1 PMT, Tower 2 PMT
Tower 4 PMT, Tower 5 SiPM, Tower 6 PMT
Tower 7 PMT, Tower 8 PMT, Tower 9 PMT, Tower 3 MCP-PMT, Tower 4 PMT

PMT & MCP-PMT(26ch)

☀ → PMT sensor board → Ribbon cable → DAQ system

Anciliary detector(11ch)

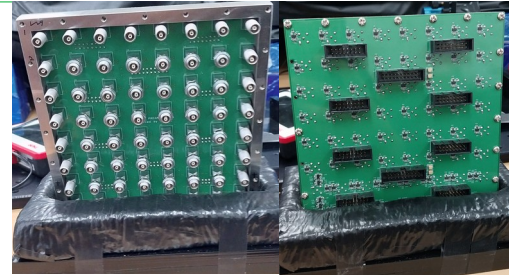☀ Extention cable → PMT sensor board → Ribbon cable → DAQ system
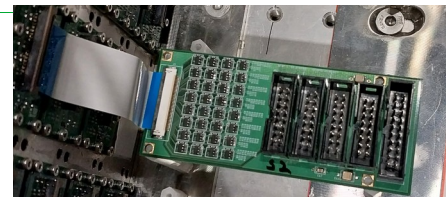
64 ch   x2
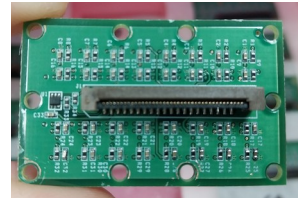
SiPM(400ch)

☀ → pre-amp board → Ribbon cable → DAQ system

x13   x13

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	Generic PMT	MCP-PMT	Auxilary detector	SiPM
channels	22	4	11	400