DAQ system of the dual-readout calorimeter for Future e+e- colliders.

Yun Eo

(supervisor Hwidong Yoo)

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 f_{em} event by event.

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

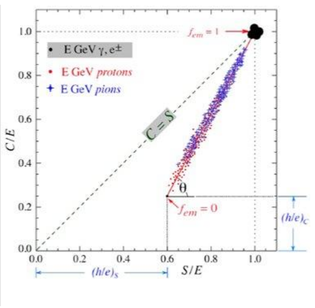
$$Q = E\left[f_{em} + \frac{1}{(e/h)_Q}(1 - f_{em})\right]$$

e.g. If $e/h = 1.3$ (S), 4.7 (Q)

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

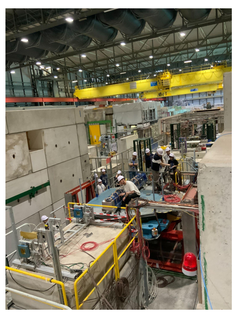
$$E = \frac{S - \chi Q}{1 - \chi}$$

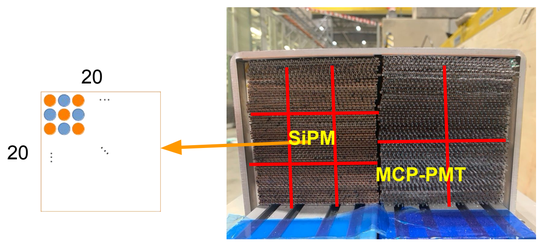
with $\chi = \frac{1 - (h/e)_S}{1 - (h/e)_Q}$



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.

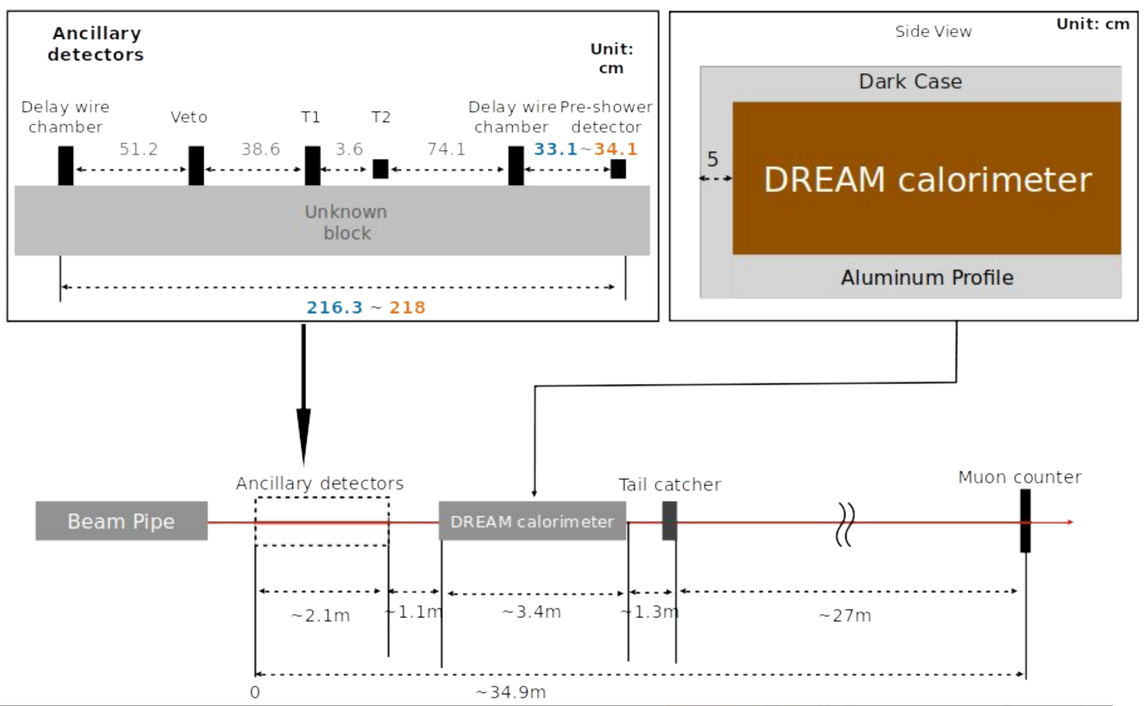




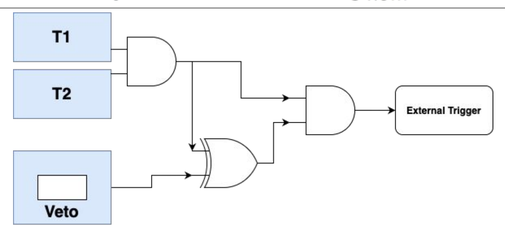
	Module 1		Module 2	
	T 1,2,4	T 3	T 1~4, 6~9	T5
readout	PMT	MCP-PMT	PMT	SiPM
# of channels	6	4	16	400

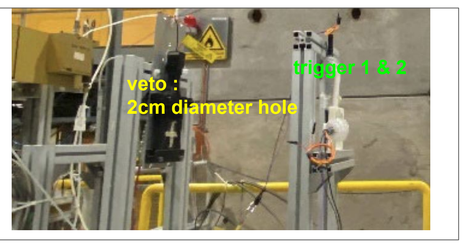
Ancillary detector

- The purpose of ancillary detector is identifying particles without DREAM calorimeter (possible to select unbiased events)

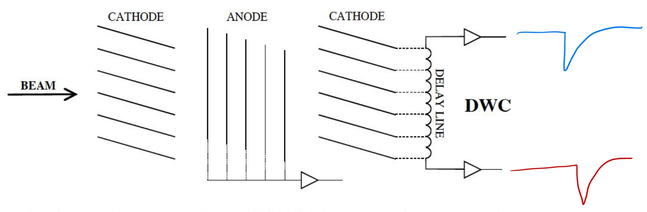


- trigger



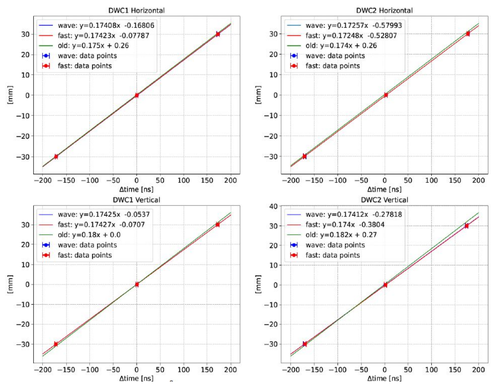


- delay wire chamber



- Delay wire chamber (DWC) is gas chamber that used on the SPS extracted lines to measure beam profiles.
- Two cathode planes provide X and Y positions
  - Measurement based on the delay gained along a delay line
- Each DWC have the 4 channels

$$x = \alpha \Delta t + \beta$$

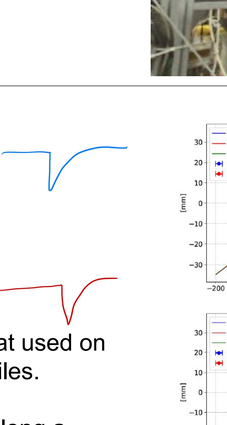


- pre-shower
  - Identify the particles from beam.
    - 1 MIP : pions & muon
    - more than 3 MIP : positron
  - 5.1 mm(~1X_0) thickness of lead plate is attached in front of scintillator.

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
- Put some pulses at each channels by using function generator.

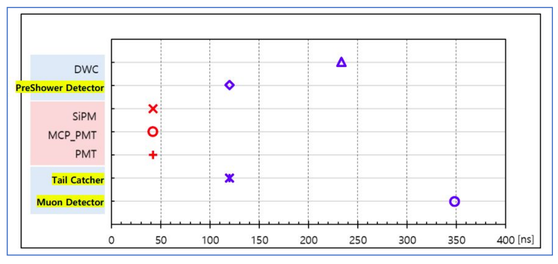
- tail-catcher
  - To detect whether shower leakage exist



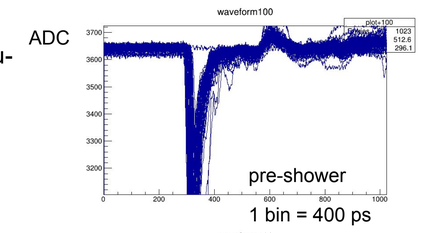
- muon counter
  - To detect muon from beam or shower.

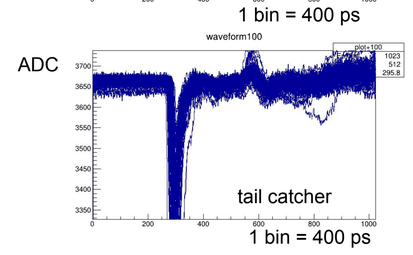
Time window

- Trigger delay
  - cable & trigger logic : ~ 185.51 ns.
  - DAQ latency : ~ 100 ns
  - DAQ software delay : 77 ns
  - total : ~ 358 ns
- We can put all signal in 400 ns time window.

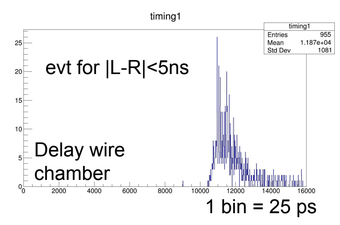


- Run 578
  - 160 GeV mu-

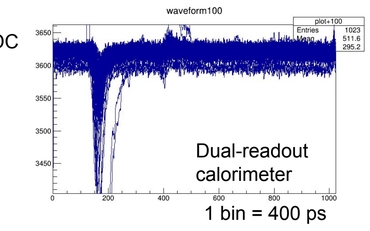




evt



ADC



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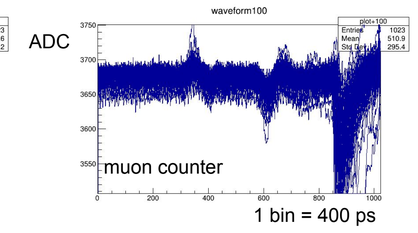
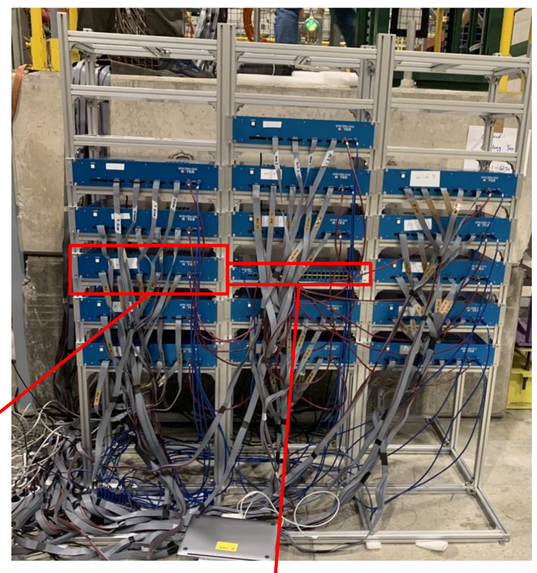
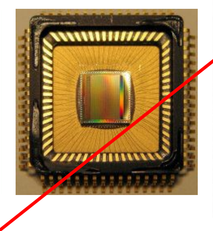


DAQ system

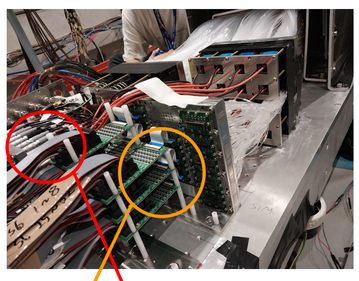
- DAQ board
  - One board can cover 32 channels.
  - Use DRS4 chip.
  - Use 16 pin Ribbon cable
- TCB board
  - Control the setting value of DAQ boards and the trigger system.
  - Connect DAQ boards with TCP/IP cable, cover 40 ch DAQ.
- All boards connected with PC using USB3 line



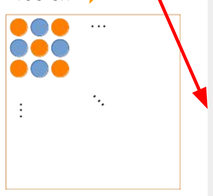
- specification of DRS4 chip
  - DRS (Domino Ring Sampler) based on SCA (Switched Capacitor Arrays)
  - Channel number of input and trigger: 8 + 1 ch
  - Sampling frequency: 1~5 GSPS (1 ns ~ 200 ps/sampling depth)
  - Number of sampling depth: 10 bit - Power consumption: max. ~40 mW/ch



Readout system

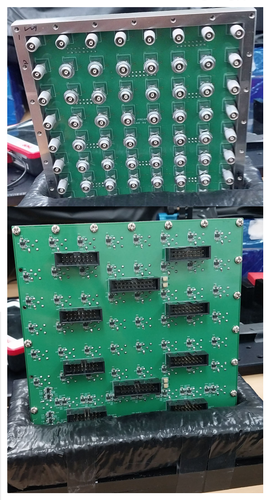


400 ch



- Module 1 (10 ch)
  - tower 1, 2, 4
  - tower 3
- Module 2 (16 ch)
  - tower 1 ~4, 6 ~9
- ancillary detector (11 ch)
  - DWC 1 & 2 (8 ch)
  - 3 ch for PID

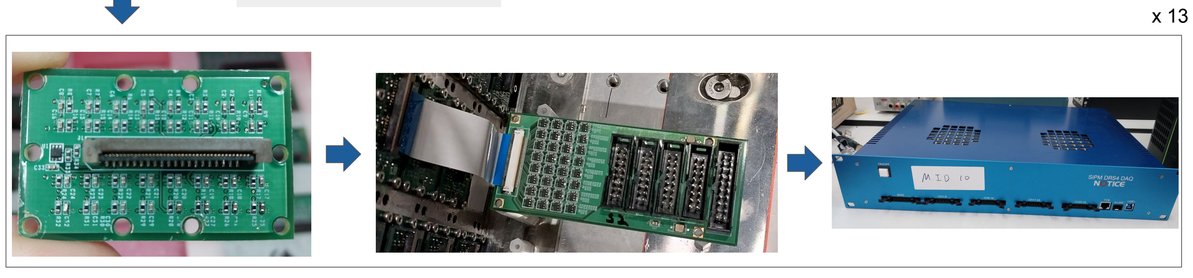
64 ch



x 2

detector	# of channels	# of DAQ
PMT	22	2
MCP-PMT	4	
Ancillary detector	11	
SiPM	400	13
total	437	15

x 13



Summary

- The KFC-DREAM (Korea Future Collider Dual-REAdout Method calorimeter) collaboration had first test beam at August 2022 in CERN north area.
- Ancillary detector
  - The rules of Ancillary detectors are particle identification and triggering the events without using dual-readout calorimeter.
    - trigger : triggering the event
    - muon counter & pre-shower : particle identification
    - delay wire chamber : align the beam
  - All signal is in the 400 ns time window
- DAQ system
  - DAQ system consists of 15 DAQ boards and 1 TCB board, it can cover the 480 channels.
  - Our readout system had 437 channels.
    - PMT & MCP-PMT : 26 ch, Ancillary detector : 11 ch, SiPM : 400 ch