Advancing Timing Resolution of Strip Scintillators for Electromagnetic Calorimeters

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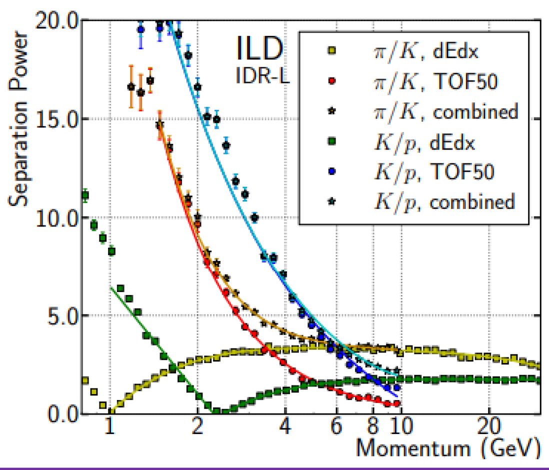
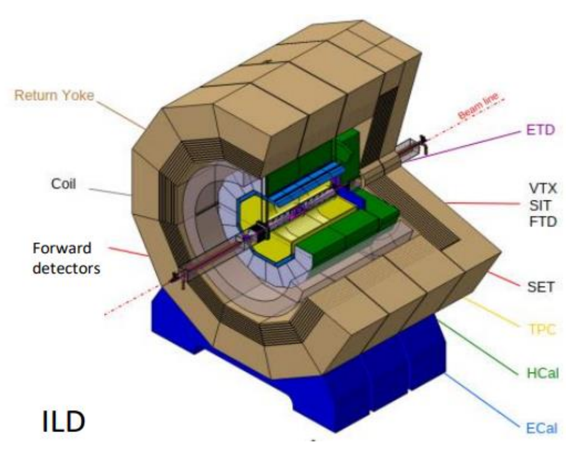
Introduction

- Precise measurement of particle flow (PF) is crucial in next-generation collider experiments, such as the proposed Linear Collider Higgs Factory.
- Recent research's focus on PF calorimetry and lepton identification, rather than hadron identification.
- Particle ID in the jets is also relevant however, dE/dx curves cross at p-K-π separation. [1]
- Combination of a modest TOF detector can cover this hole.
- Combine with a measurement of its dE/dx and PID by TOF.[2]
- we focus on equipping fine-segmented electromagnetic calorimeters with better than 100ps time resolution.



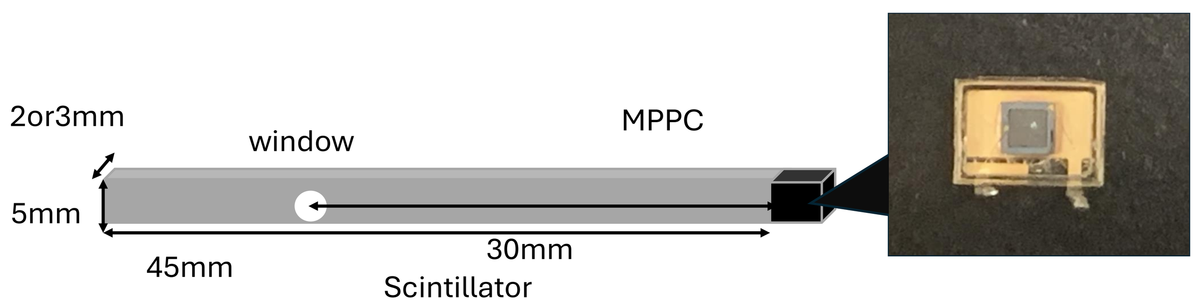
ECal using strip scintillator

- The electromagnetic calorimeter in the ILD [3] detector of the next-generation accelerator, ILC, with high-precision time measurement.
- cells with a size of 5 mm x 5 mm and adding it to each cell.
- employing scintillator strips arranged orthogonally to ensure both positional resolution and a reduced number of readout channels.

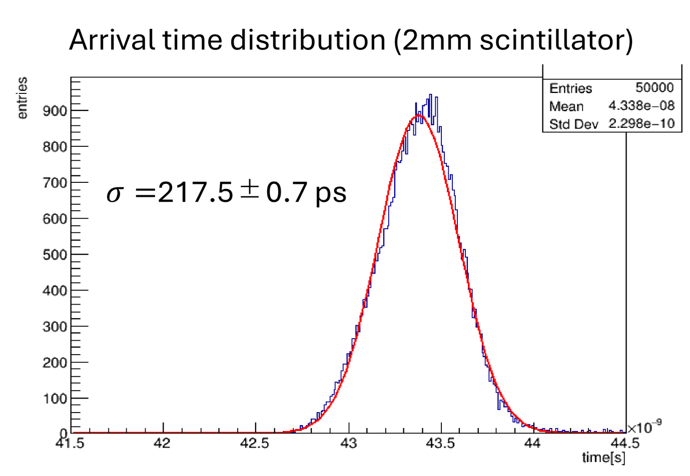


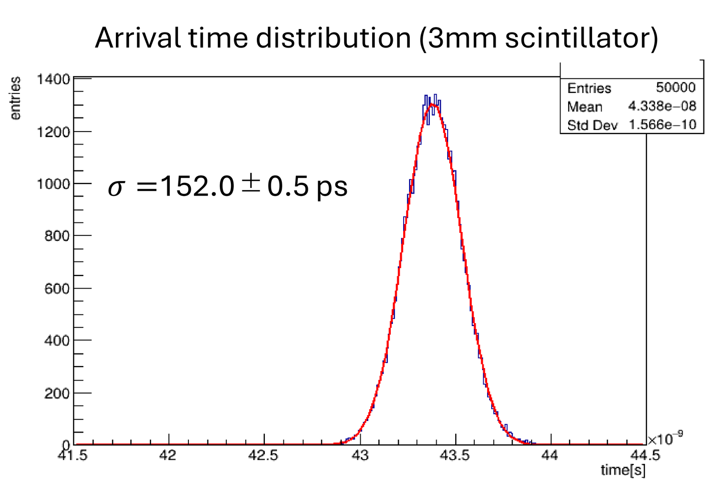
Picosec-Laser test

- Tested using a picosecond laser in lab.
- scintillator : 45mm × 5mm × 2or3mm
  wrapped with a reflective material
- MPPC : 1 mm × 1 mm and a pixel size of 25 μm
  one side readout
- Oscilloscope : bandwidth 500MHz, sampling rate10Gsa/s
  The trigger is the signal from the laser driver
- Read out measured using an oscilloscope as 20% of pulse height timing.



- Arrival time were measured.

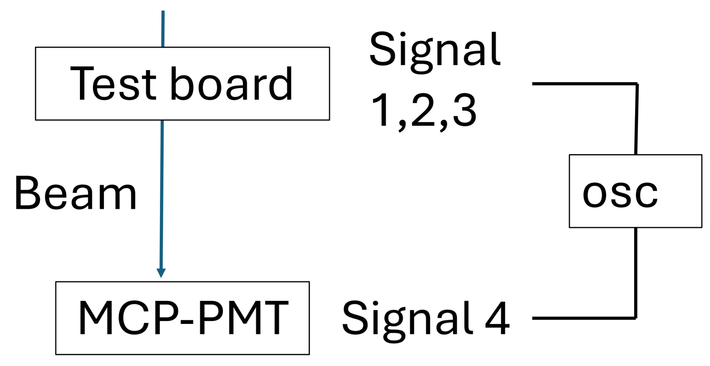


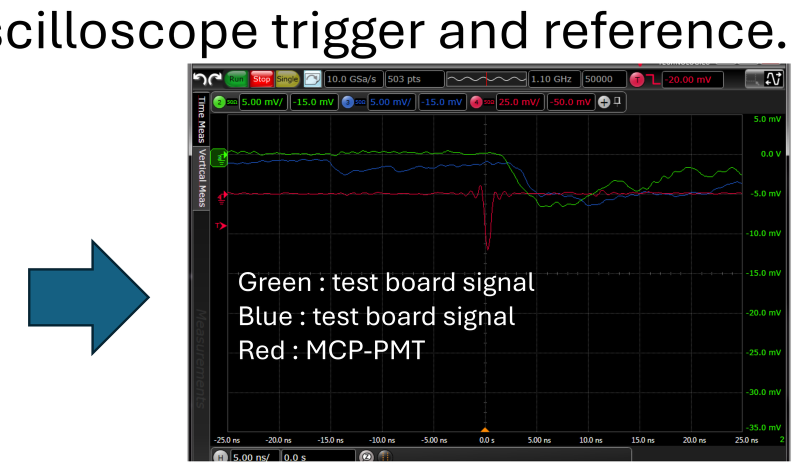


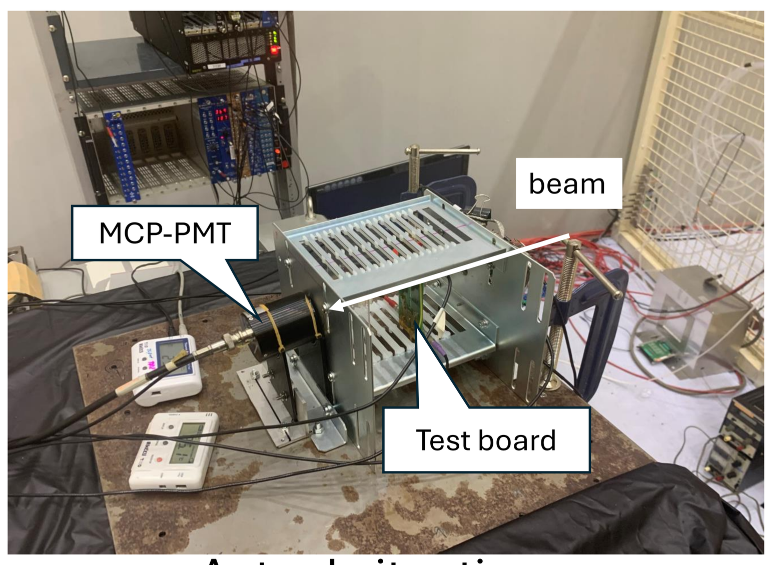
- Based on these results, We are testing the different configuration of the MPPC and scintillator for improved resolution.

Beam test with scintillation lights

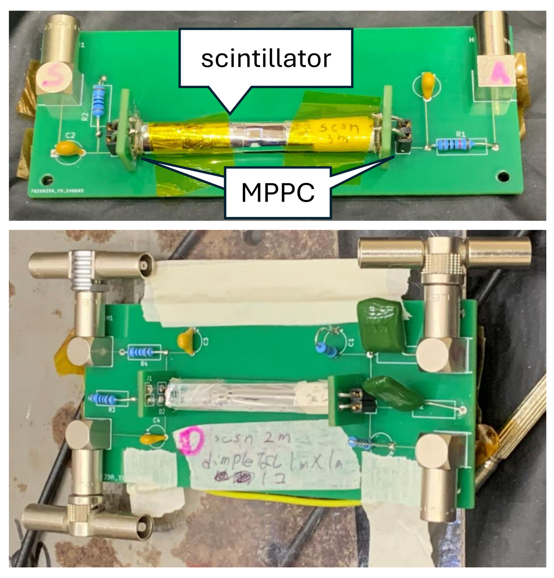
- tested using a 3 GeV electron beam in AR KEK beam line (6/17~6/21).
- scintillator : length 45mm,width 5mm thickness 2 or 3mm.
  Compared with the readout from the dimples.
  Dimple in the center and MPPC read it out from there.
  wrapped with a reflective material.
- MPPC : 1 × 1 mm or 1.4 × 1.4 mm sensitive area and 25μm pixel size
  3 × 3mm sensitive area and a pixel size of 50μm (series only)
  each one in parallel or connect in series.
  In parallel case, use the average arrival time of both sides.
- MCP-PMT : fast time response, high time resolution as time reference.[4]
  The rise time is 669.6±0.3ps,about 3 times faster than Scintillator.
  Use the signal as an oscilloscope trigger and reference.







Actual situation

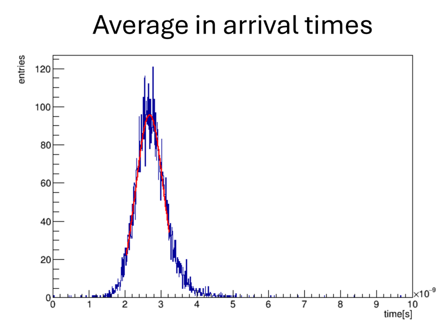


Test Board (Series and parallel)

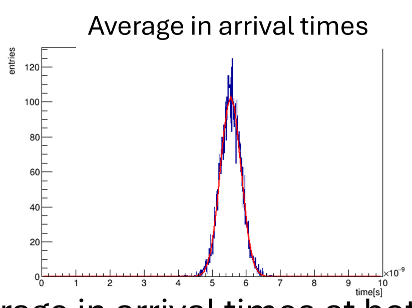
Result

- **parallel read out**
  The resolution is determined by range of the average in both side.
- **series read out**
  Use a 3mm scintillator and connect the MPPC in series to read out.

	Configurations	resolution
parallel	1×1mm MPPC 2mm scintillator	384.3±10.1ps
	1.4×1.4mm MPPC 3mm scintillator	377.1±5.1ps
	1×1mm MPPC 2mm dimple	551.6±5.9ps
series	1.4×1.4mm MPPC 4 in series 2 on each side (1 readout)	420.4±3.9ps
	1.4×1.4mm MPPC 2 in series 2 on each side (2 readout parallel)	299.5±2.5ps
	3×3mm MPPC 2 in series1 on each side (1 readout)	322.4±2.2ps



average in arrival times at both sides
1.4×1.4mm MPPC and 3mm scintillator



average in arrival times at both sides
1.4×1.4mm MPPC and 3mm scintillator
2 in series 2 on each side

- Compared to dimples, increased MPPCs in dual side readout improve resolution.
- Timing resolution is improved by connecting in series.
- Series connection improved resolution, but overall resolution was high and did not meet the target.

Summary and Next

- We tested various configuration to try to improve the timing resolution , and found that series connection tended to improve it.
- However , time resolutions of a scintillator strips are measured and found to be not better than 100ps.
  We are also attempting to improve the resolution by using other configuration(such as thicker scintillator and larger MPPCs).

references

[1] Charged Hadron Identification with dE/dx and Time-of-Flight at Future Higgs Factories(2021)
[2] Time-of-flight technologies (2021)
[3] ILD detector for ILC (2009)
[4] MICROCHANNEL PLATE-PHOTOMULTIPLIER TUBES (HAMAMATSU)