Study of scintillator based muon detector

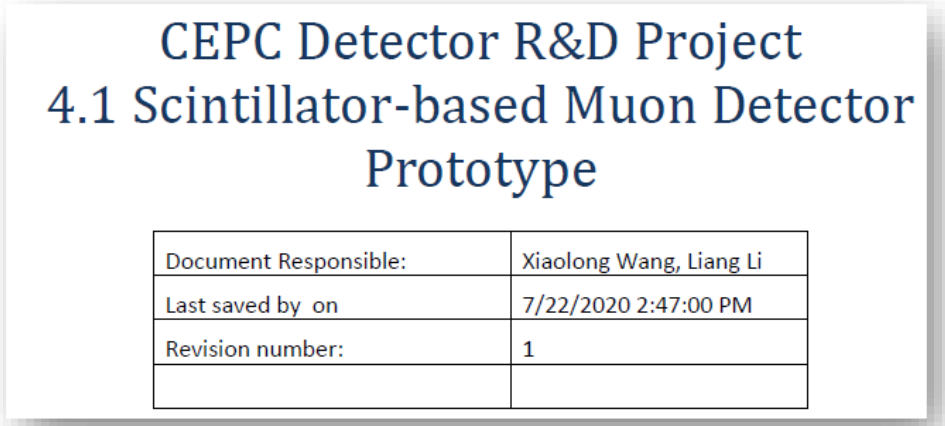
Xiaolong Wang, Hongyu Zhang

Fudan University, Shanghai

CEPC Plenary meeting, 7/22/2020

Subprojects of R&D

1. SiPMs and Scintillator strips procurement
2. WLS fiber and optical couplings
3. Time/spatial resolution measurements
4. Radiation Hardness of SiPM and scintillator
5. Prototype construction: Multi-layer detectors



CEPC Detector R&D Project
4.1 Scintillator-based Muon Detector Prototype

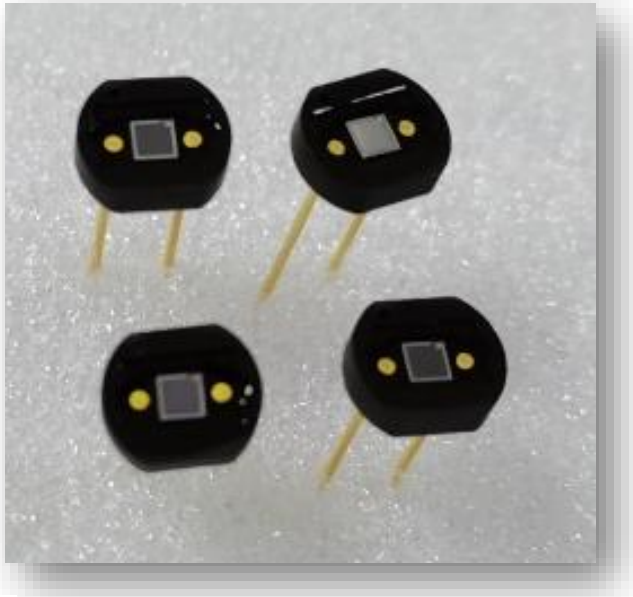
Document Responsible:	Xiaolong Wang, Liang Li
Last saved by on	7/22/2020 2:47:00 PM
Revision number:	1

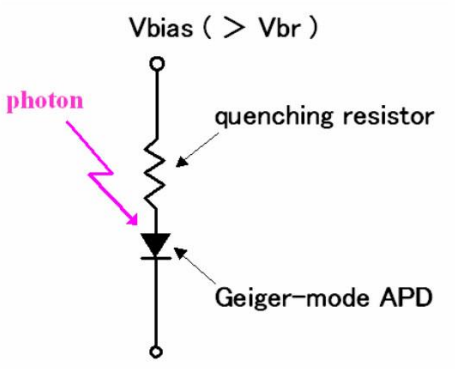
SiPM, scintillator and fibre

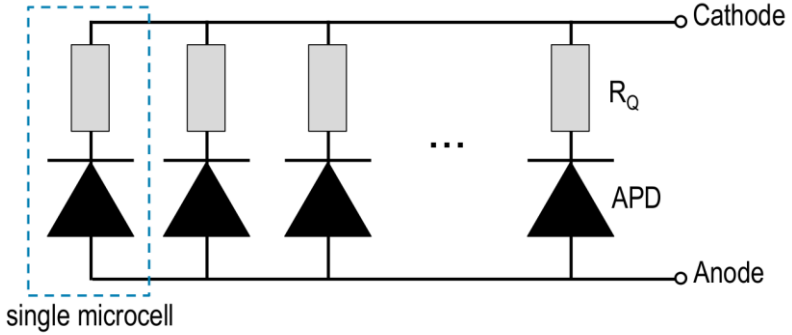
- SiPM: Hamamatsu S13360-13**CS
  - Or MPPC, aka Multi-pixel photon counter
- Scintillator: provided by 高能科迪 (Gao Neng Ke Di Company)
  - Geometry: $1cm \times 4cm \times 1.5m$
  - Plastic scintillator extruded.
- Fibre: wave-length-shift fibre,
  - Wave-length-shift (WLS) fibre by Saint-Gobain
  - $D = 1\ mm$
- Some materials sent to SJTU for a separate study.

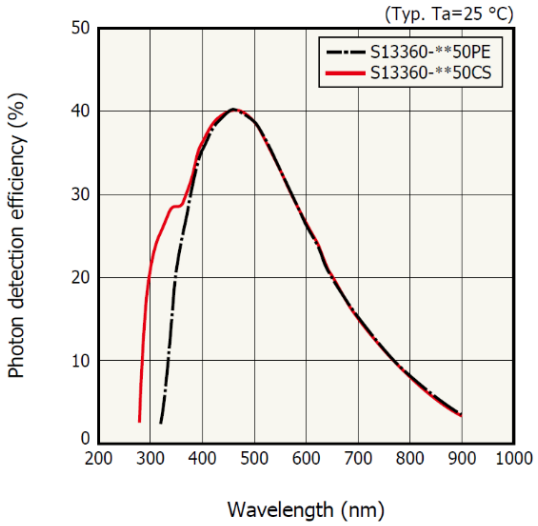
MPPC

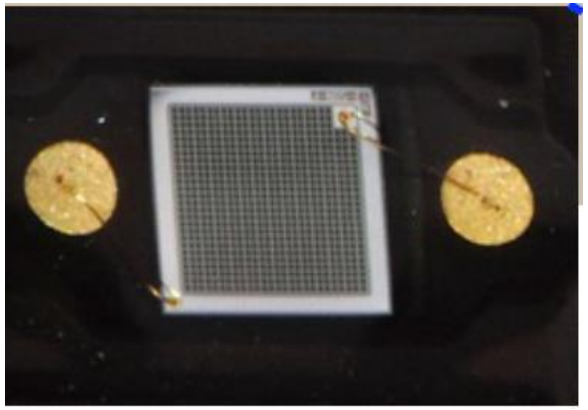
- Hamamatsu MPPC of 25, 50 and 75μm pixel pitch
  - 50μm type has 667 pixels.
- Effective Photo-sensitive area: $1.3\ cm \times 1.3 cm$.
- Terminal capacitance 60 pF.
- Spectral response range 270 to 900 nm.





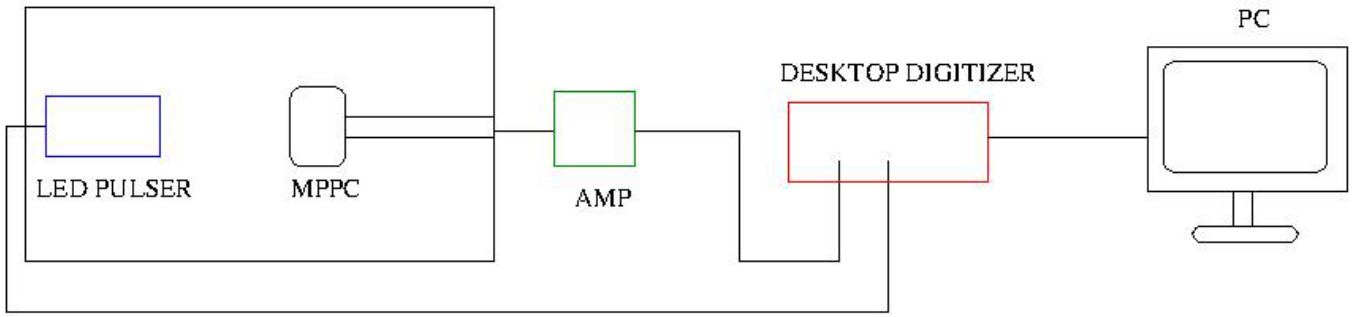


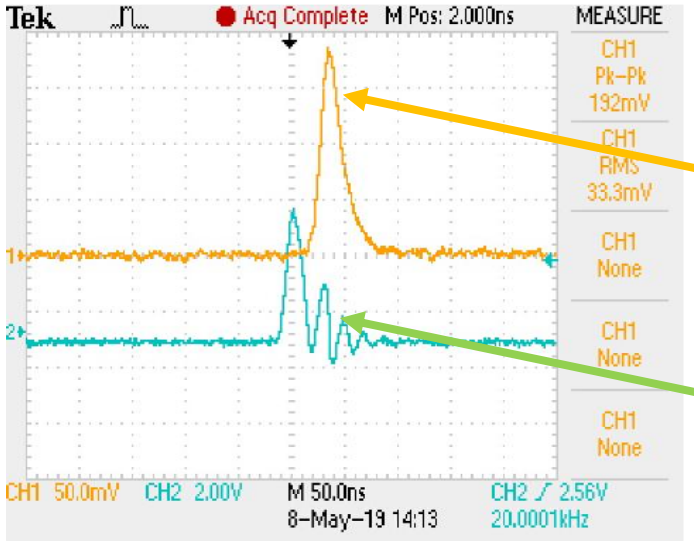




Setup for MPPC study

- A blue LED diode is as a photon source.
- A pulse generator is used to make a pulse light source, and as a trigger too.
- A pre-amplifier circuit is used to for MPPC signal.
- A high voltage power supply is used to drive the MPPC

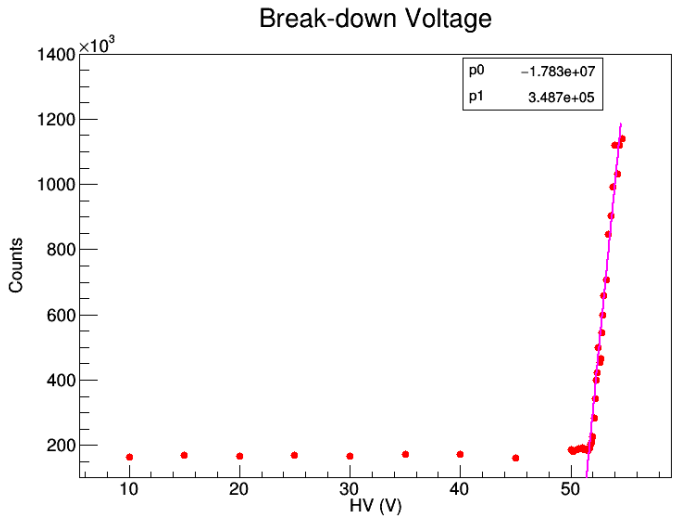


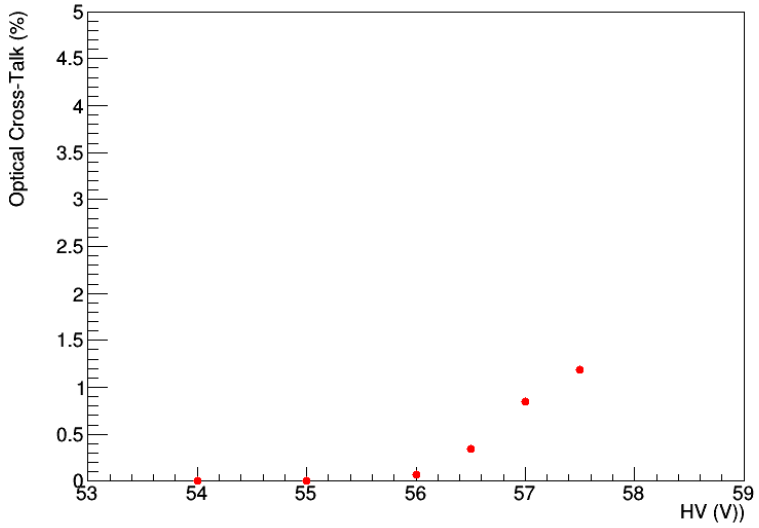


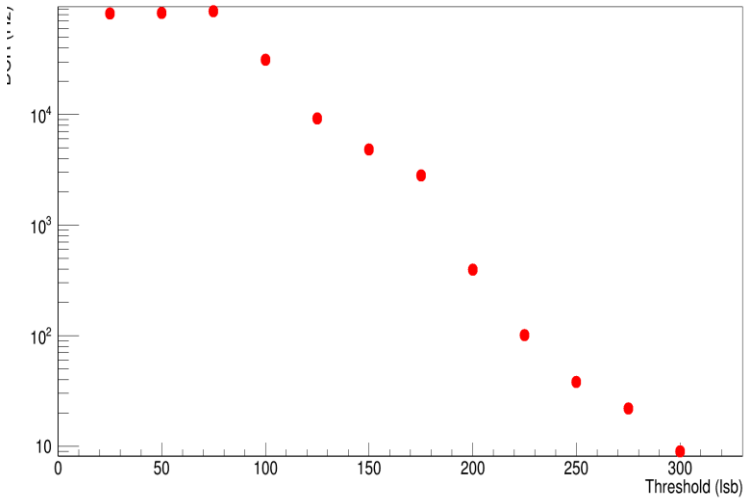
Study of MPPC paramters (I)

- Break-down Voltage: the voltage MPPC statrts to work
- Dark Current Rate (DCR):
  - Major nosie due to the thermally generated electrons in absence of light
  - Typical DCR is maximum 81 KHz at $V_{OP} = 56\ V$, threshold = 0.5 p.e.
- Optical Cross Talk (OCT)

$$OCT = \frac{(DCR)_{1.5p.e.}}{(DCR0)_{0.5p.e.}}$$

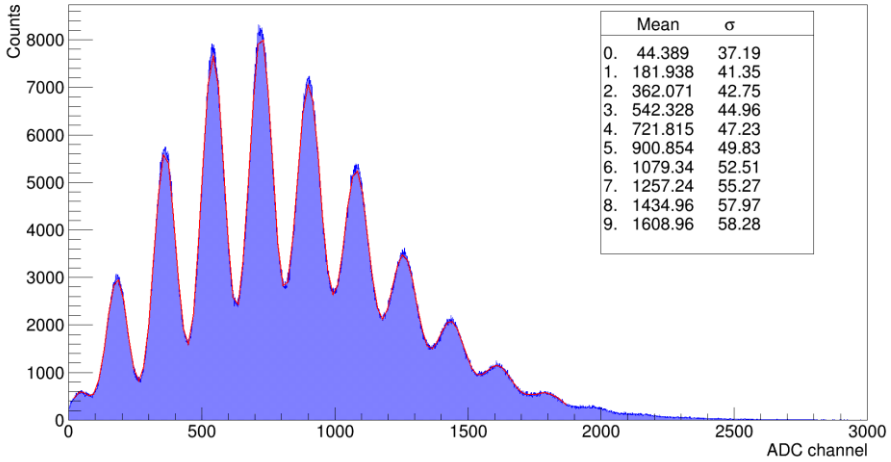


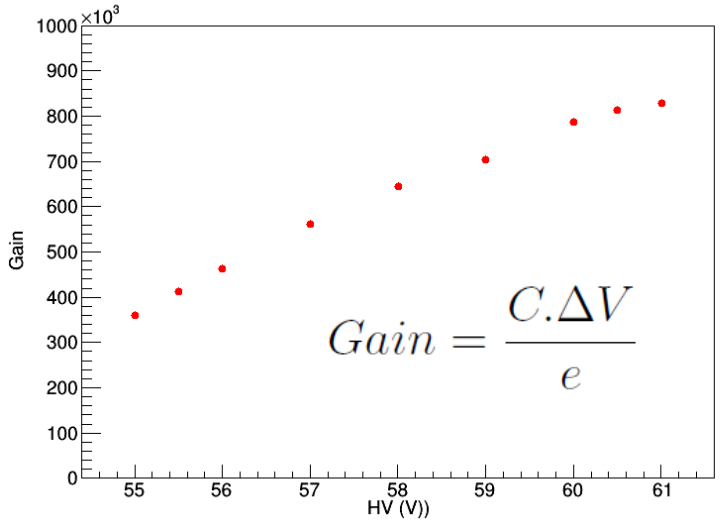


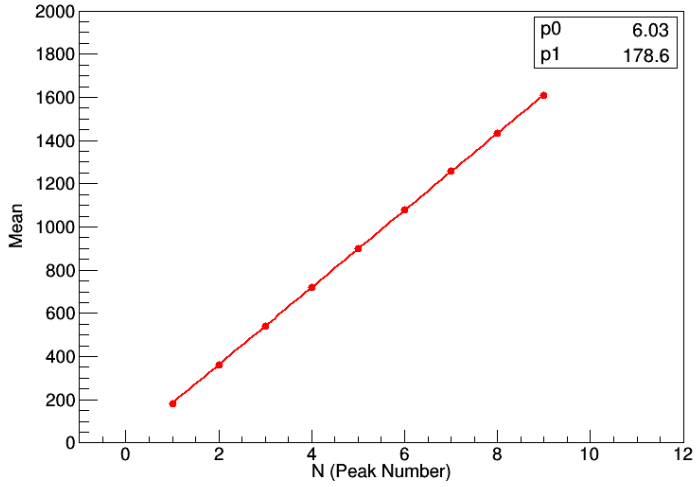


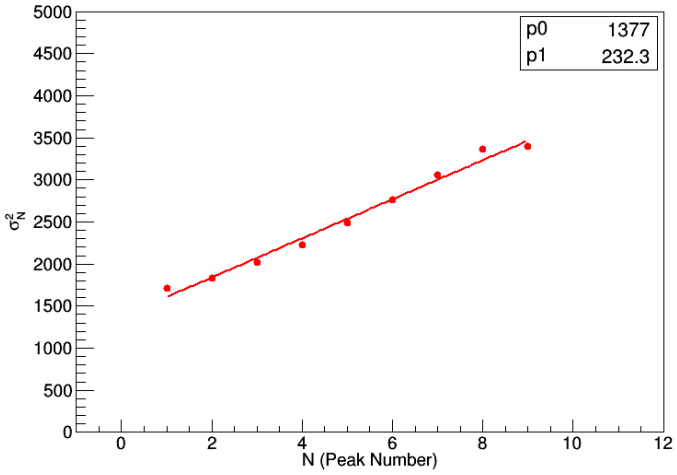
Study of MPPC paramters (II)

- ADC measurement with $HV = 57.0\ V$.
- Up to 11 p.e. could be seen.
- Fit to the photon spectrum
- The gain: 5.5×10^5at $57.0\ V$



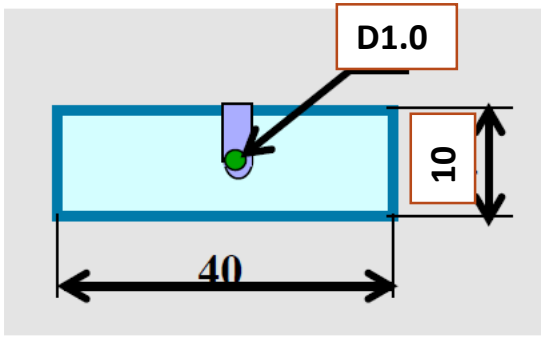


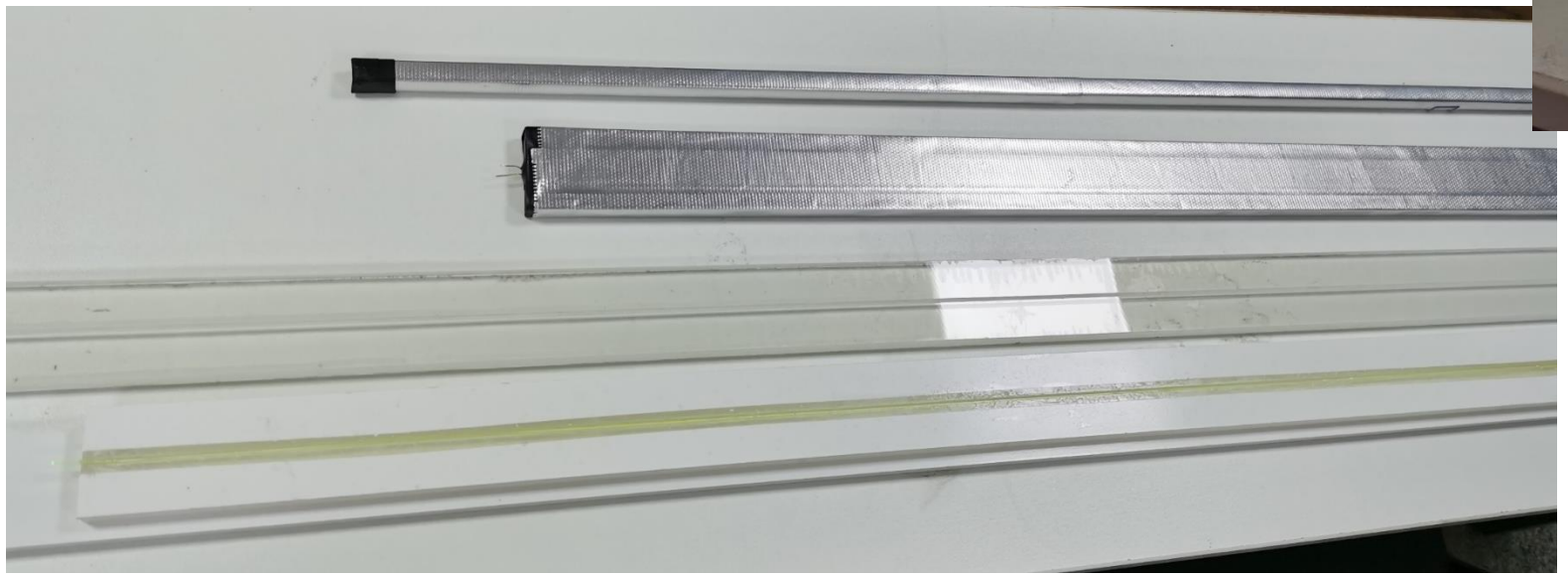




Plastic scintillator

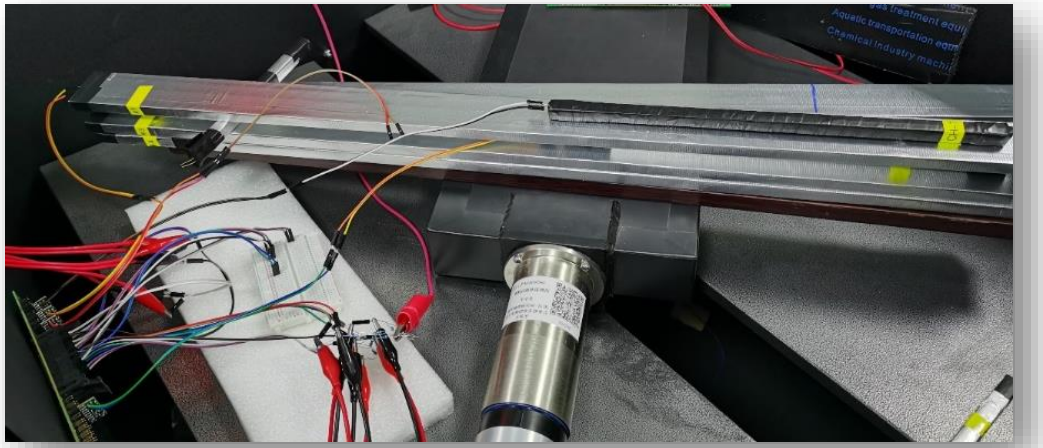
- Purchased in China
- Geometry: $1cm \times 4cm \times 1.5m$
- Reflective cover: Teflon
- Groove for WLS fibre is sawed into the top surface
- Structure is like Belle II endcap KLM.

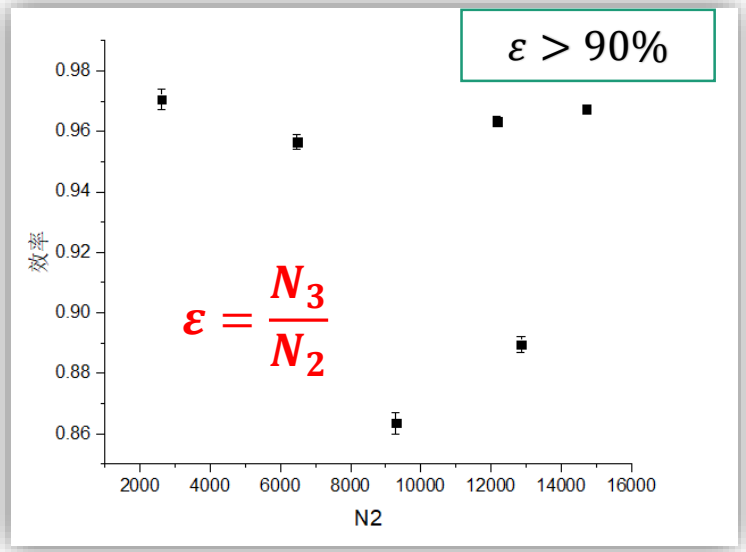


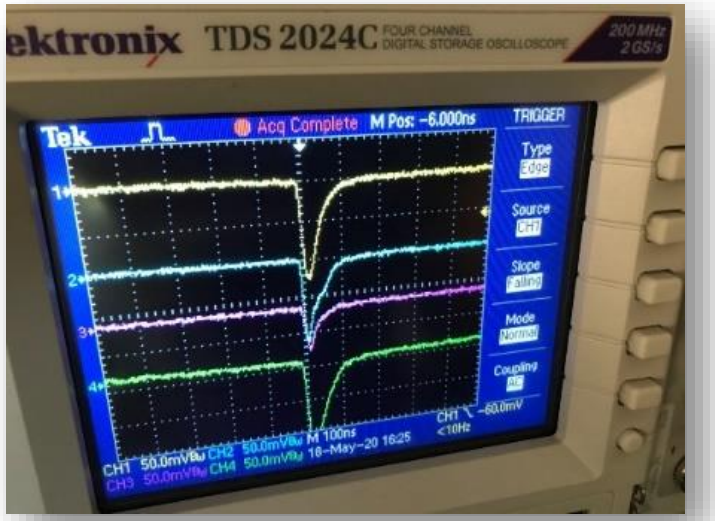


Testing setup

- FE readout designed from Belle II
- Pre-amplifier: ~ 10
- Cut to be $75\ cm$ to fit in a dark box.
- Test with cosmic rays.
- Small strip for trigger, close to the position of fibre.

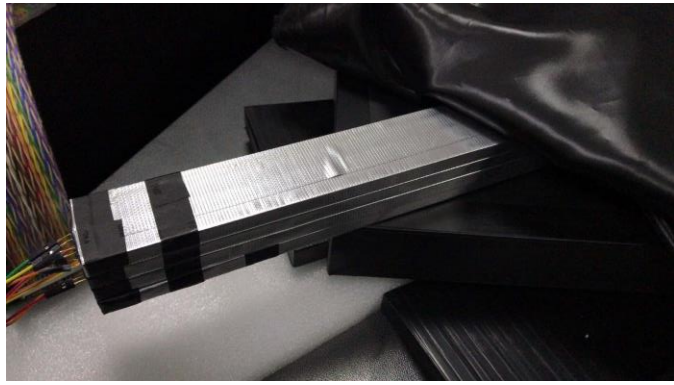


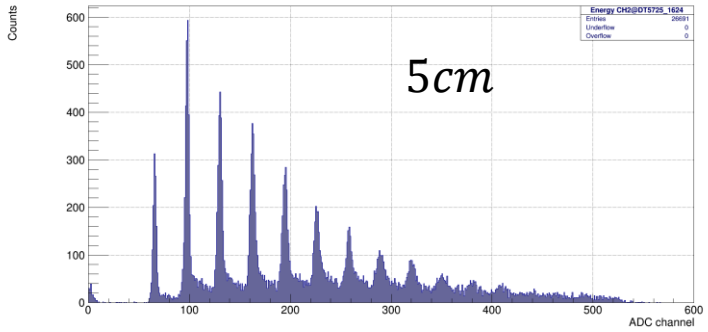


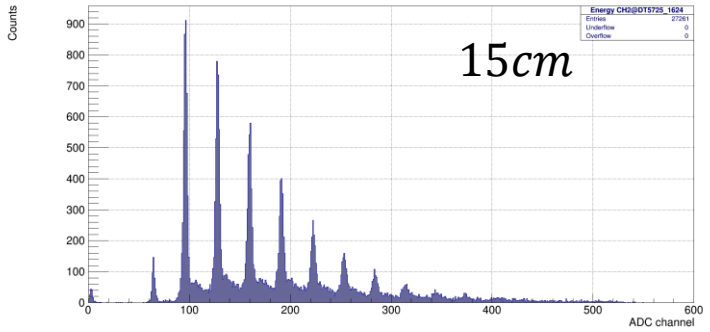


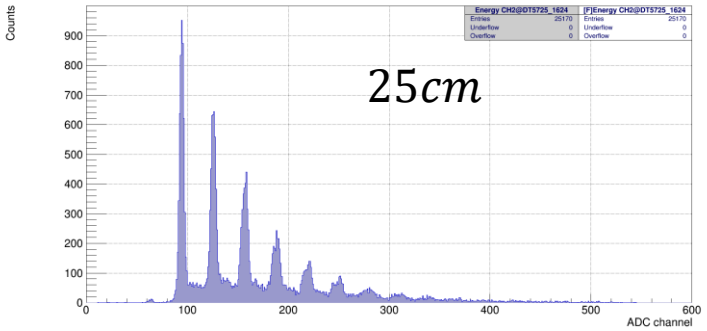
ADC distributions from different position

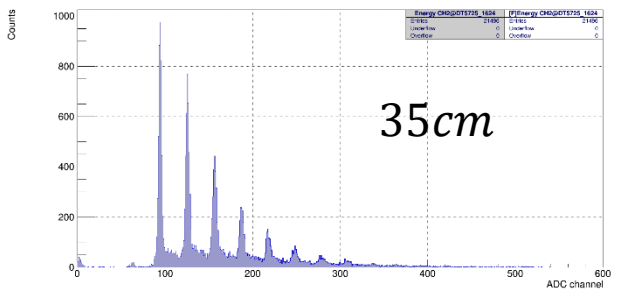
- Test on 75 cm strip.
- Trigger CR signals at different postion: $L = 5, 15, 25 \ldots cm$ from the near end.

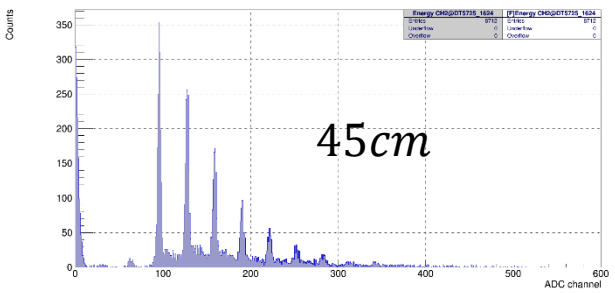


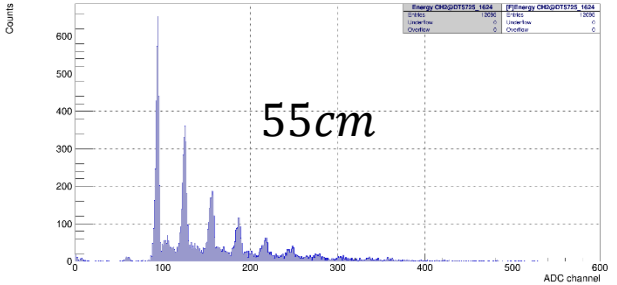


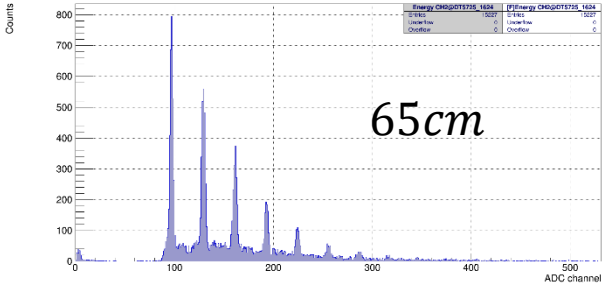






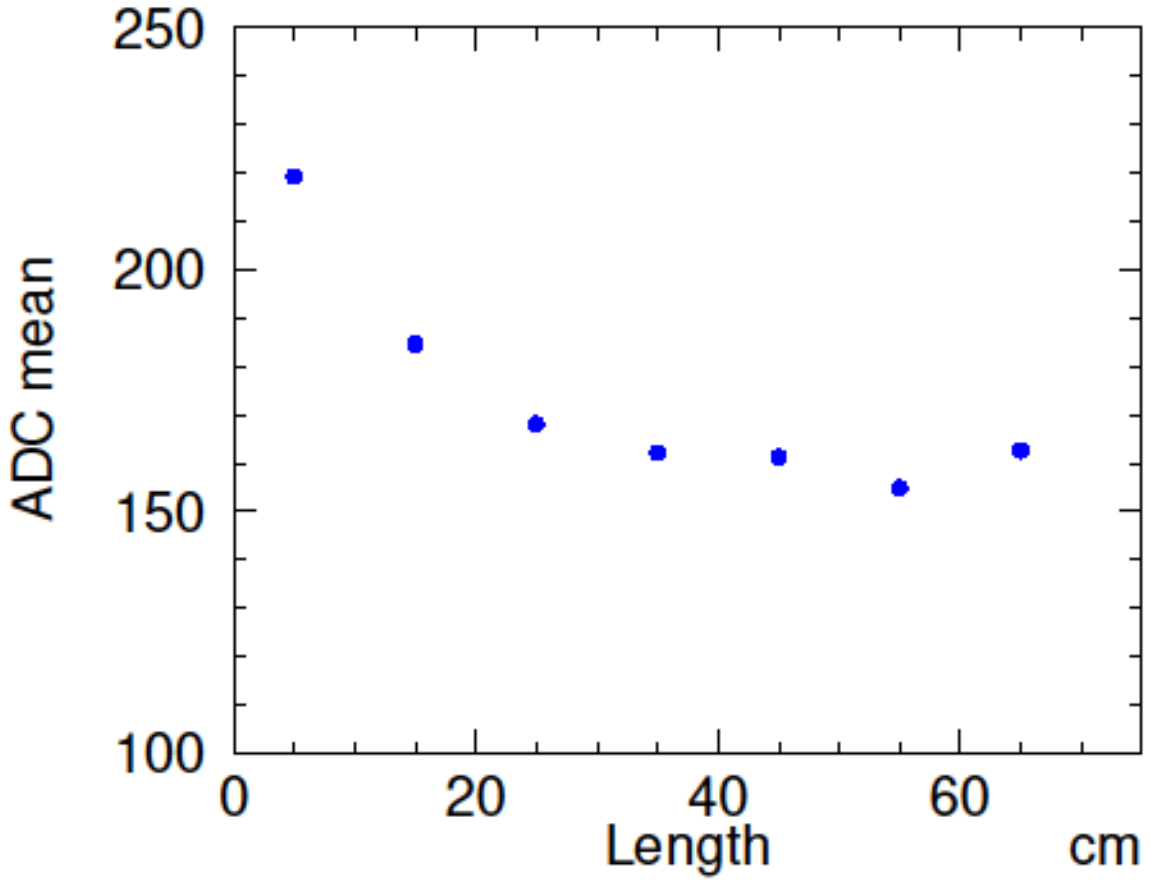






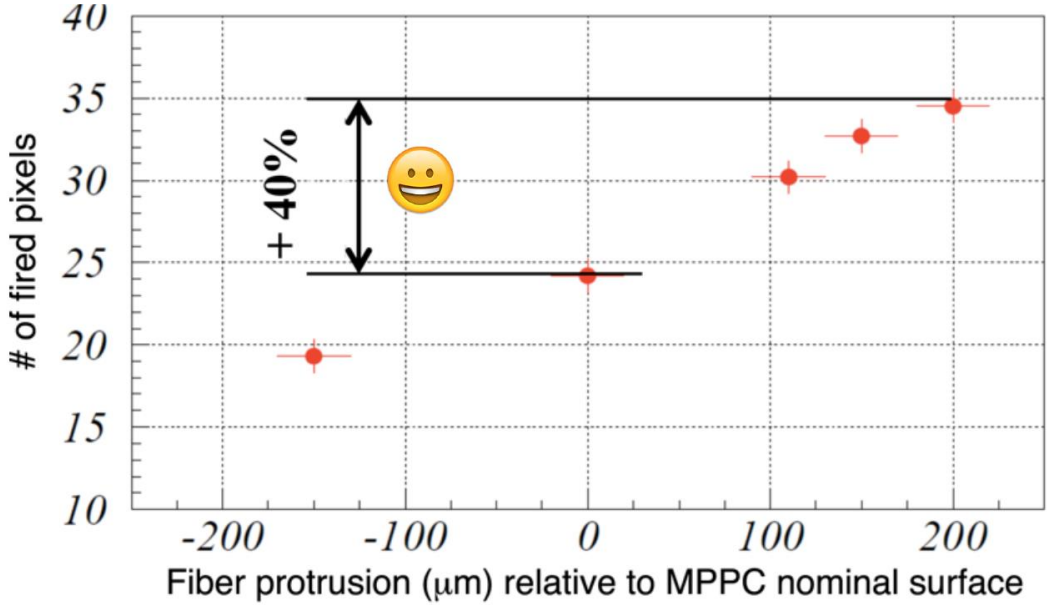
ADC vs. length

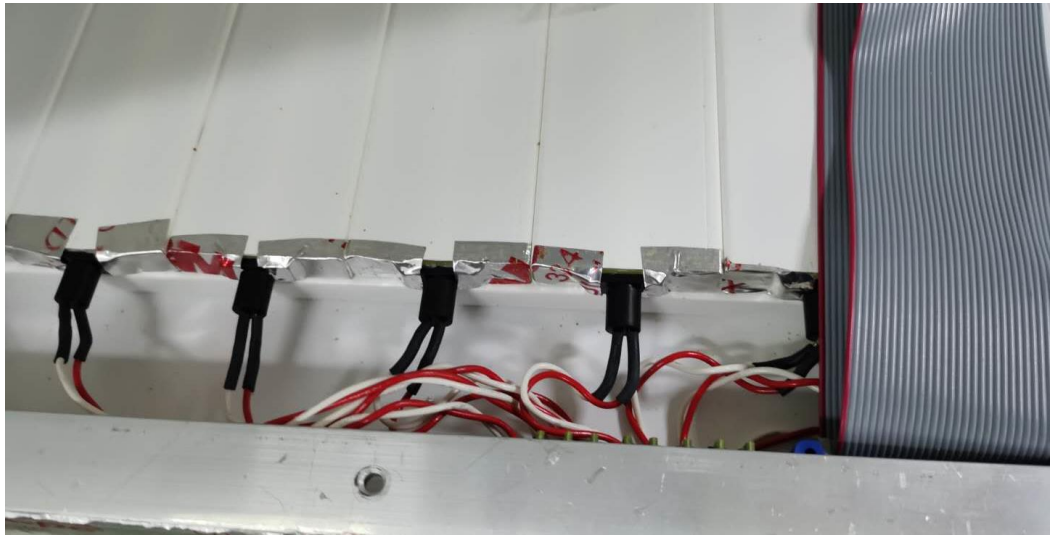
- Get the means from the distributions.
- The errors are not so accurate, too small.
- Near end is much better, no obvious difference since $L = 25\ cm$

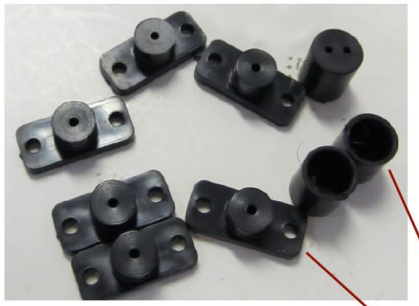


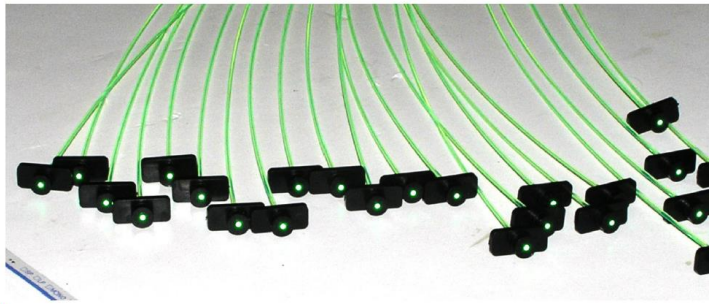
Some problems

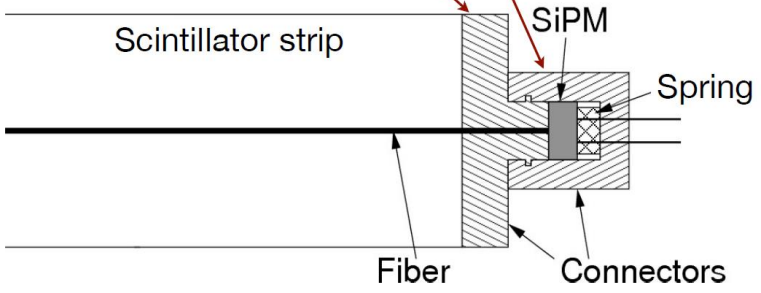
- Electronic noise.
- Coupling between fibre and MPPC:
  - Belle II uses small item to hold fibre and MPPC to get good coupling.
  - We don’t have it now, and the coupling is poor.
  - The coupling needs to be improved!

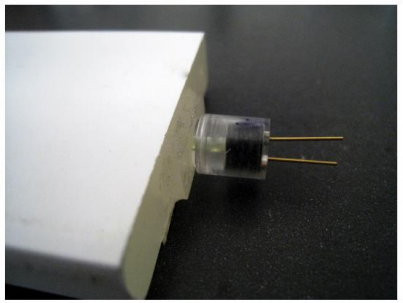












Time calibration at Belle II

- Fudan Group in charge of KLM time calibration.
- Good time resolution would be important for next generation experiment with high luminosity.
- The first item of a large size subdetector is due to pass length, mainly from cable length.

$$T_{\text{record}} = T_0 + T_{\text{fly}} + T_{\text{prop}} + T_{\text{collect}} + T_{\text{cable}}$$

From VXD and CDC

Based on MC and extrapolate hits

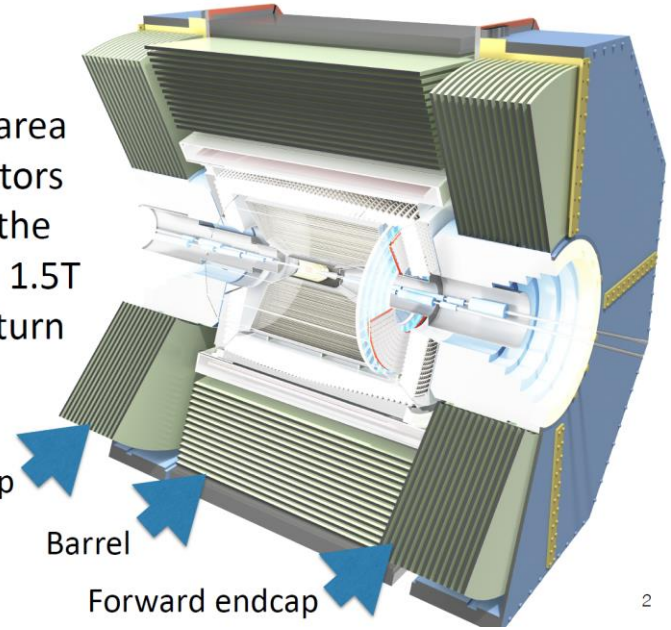
Local position over effected light speed

Time of SiPM collect photon
is related to signal energy and number of photon.
Ignored for now.

Time on cable, determined by cable length. Need to be corrected.

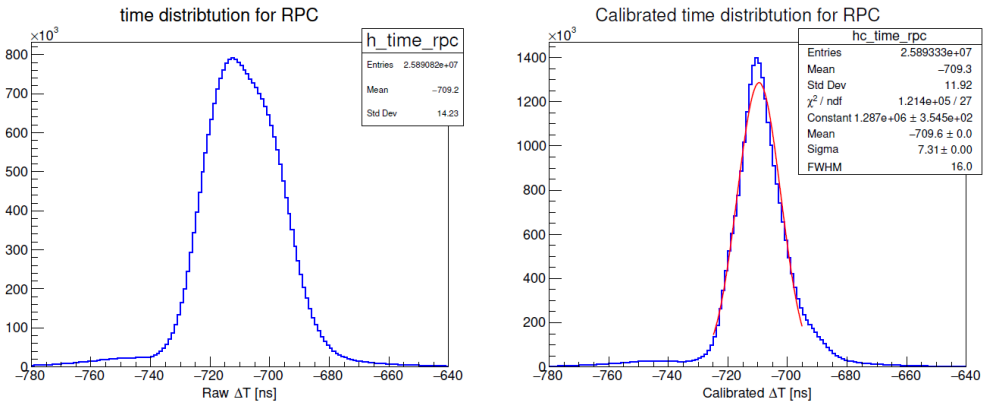
The KLM ("K_L–Muon detector")

consists of large-area thin planar detectors interleaved with the iron plates of the 1.5T solenoid's flux return yoke.



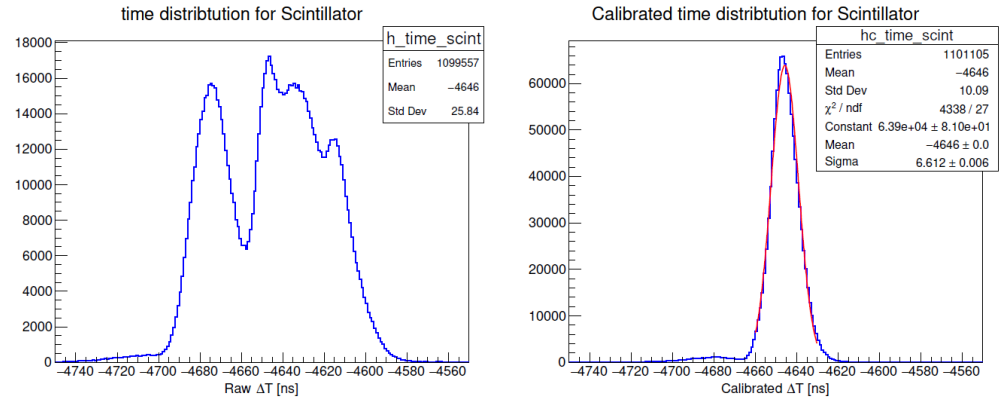
Time resolution after calibration

- Three subsystems of KLM: RPC in BKLM, scintillator in BKLM and scintillator in EKLM
- The time resolutions achieved: $6.6ns, 7.3ns, 3.8ns$
- Resolution of readout is $\sim 1ns$
- Still possible to improve it in the future.



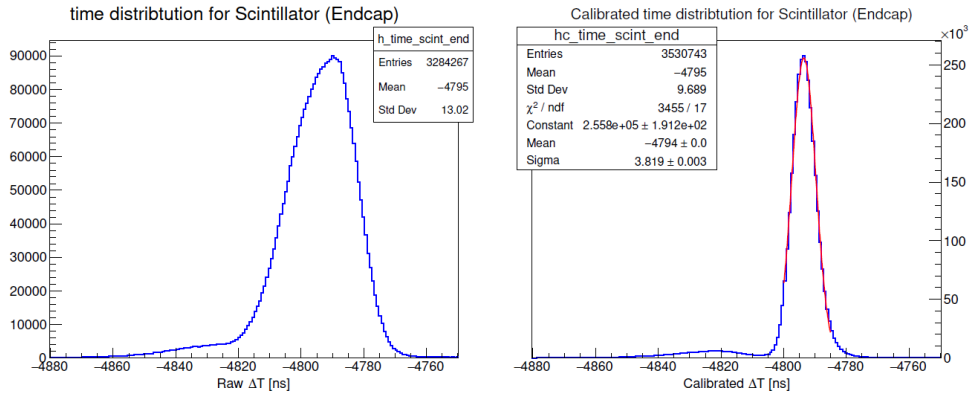
(a) (b)

FIG. 11: Global ΔT distribution before (a) and after (b) calibration for RPC.



(a) (b)

FIG. 12: Global ΔT distribution before (a) and after (b) calibration for BKLM scintillator.

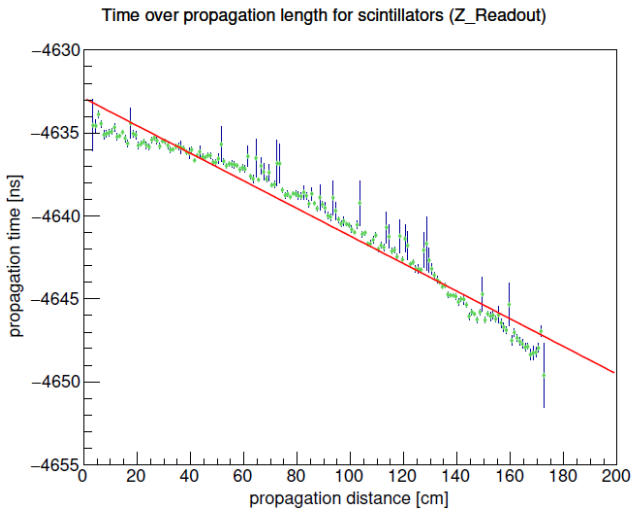


(a) (b)

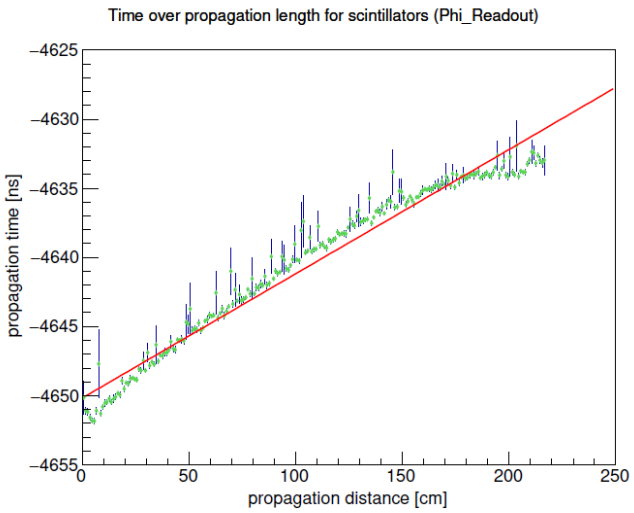
FIG. 13: Global ΔT distribution before (a) and after (b) calibration for EKLM scintillator.

β of light in materials

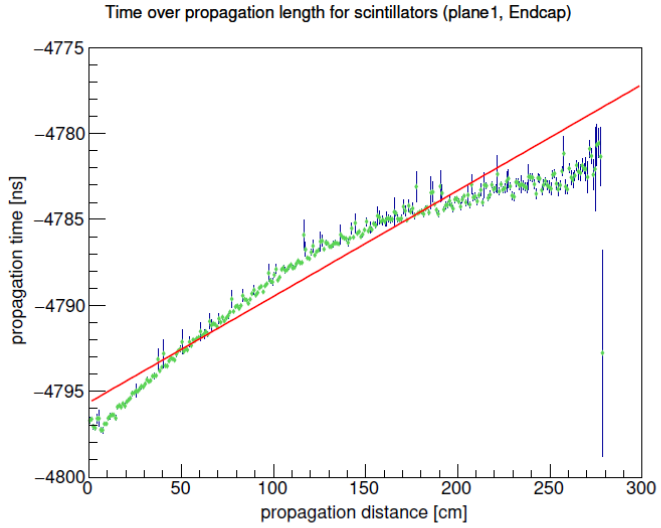
- Propogation time in a strip: scintillator and fibre
- Get $\beta \sim 0.5$



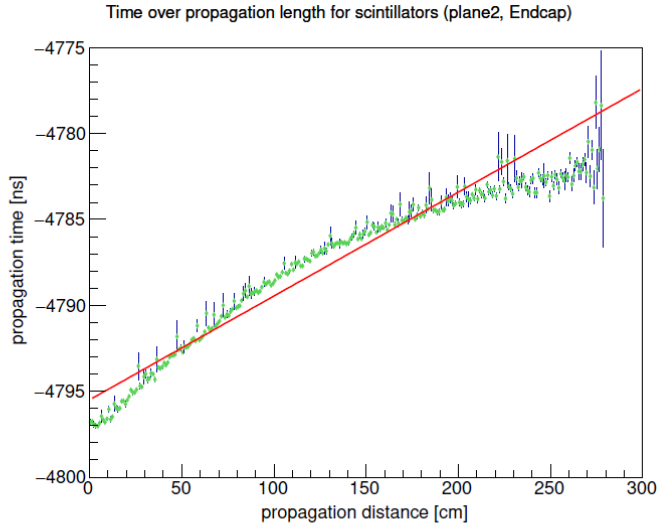
(a)



(b)



(a)



(b)

Summary

- Items got for muon detector R&D:
  - Scintillator, WLS fibre, MPPC, FE readout
- Systems setup for testings:
  - efficiency, ADC (light collection), …
- Study of MPPC parameters has been performed.
- Time calibration for Belle II KLM, which yields experience for CEPC muon detector.
- Two problems: noise from readout, coupling between MPPC and fibre.
  - Noise is mainly due to the power supply and no good ground.
- Plans:
  - More studies on scintillator, test with Belle II scintillator from Fermilab
  - Test with Kuraray WLS fibre, $D = 1.2mm$
  - Improve the quality of scintillator with company
  - Prototype construction: Multi-layer detectors
  - Precise time measurement
  - Unite more institutions for R&D?