Development of Water Cherenkov Detector for the J-PARC H-Dibaryon Search Experiment
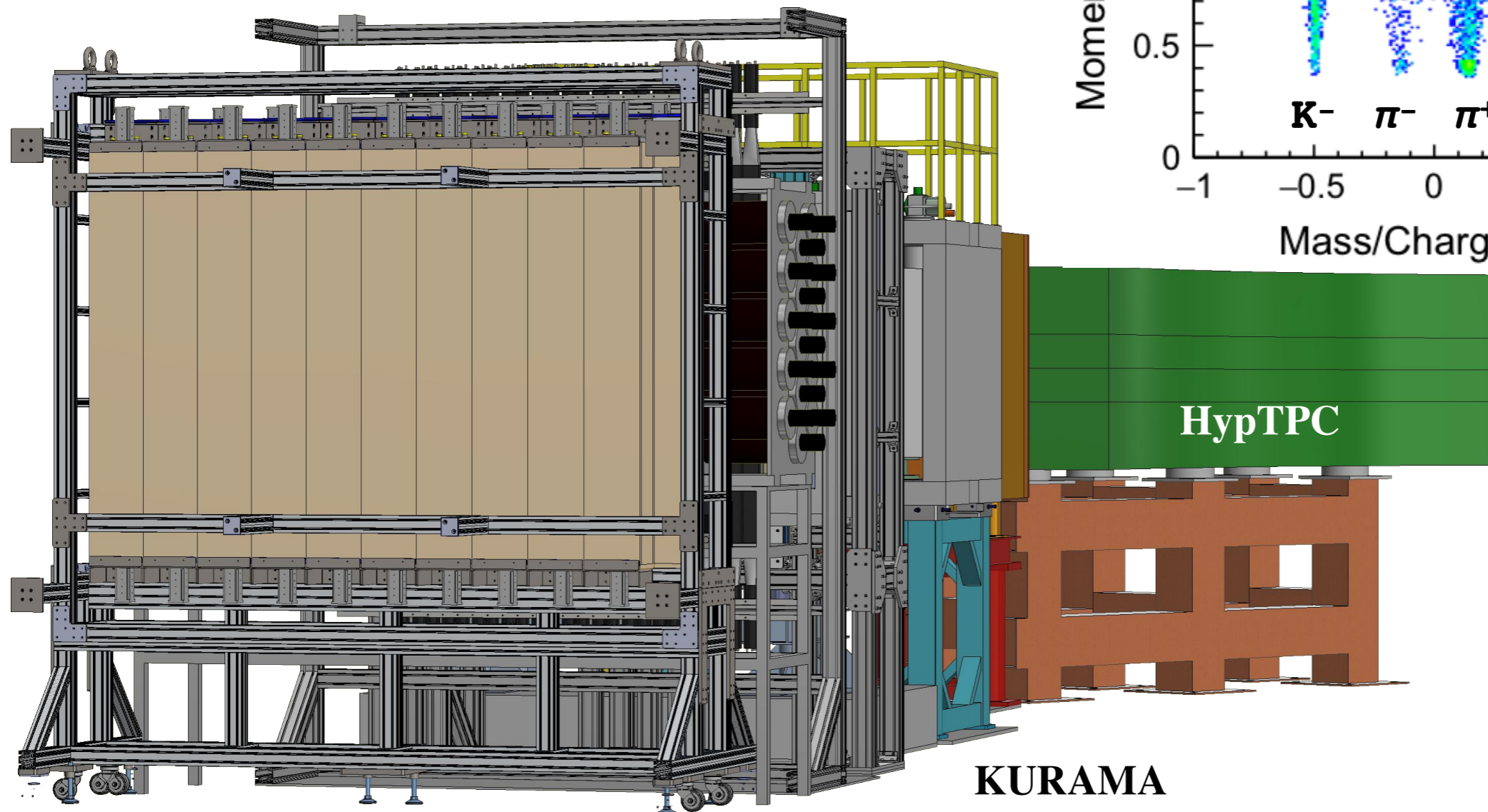
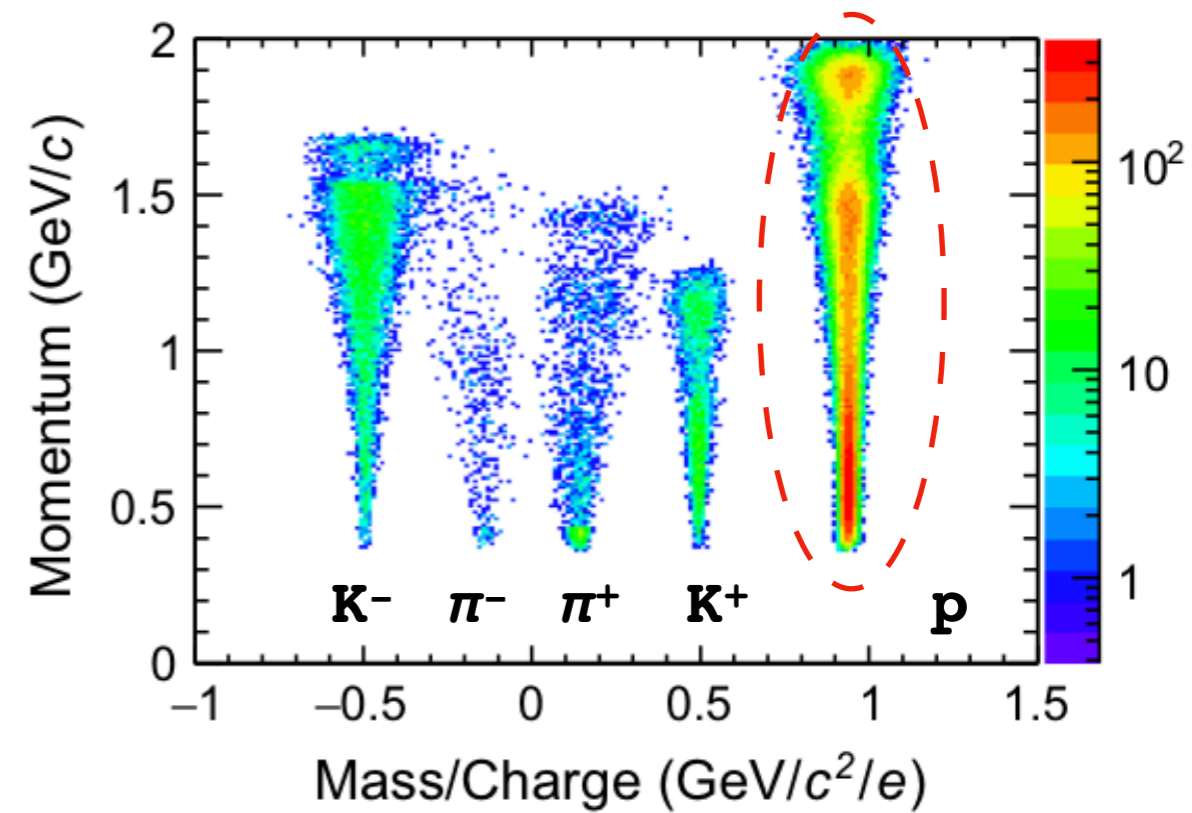Sungwook Choi

Dept. Of Physics, Korea University

J-PARC E42 Experiment

- **E42 Water Cherenkov Detector :** Suppressing protons from kaons in online-trigger system
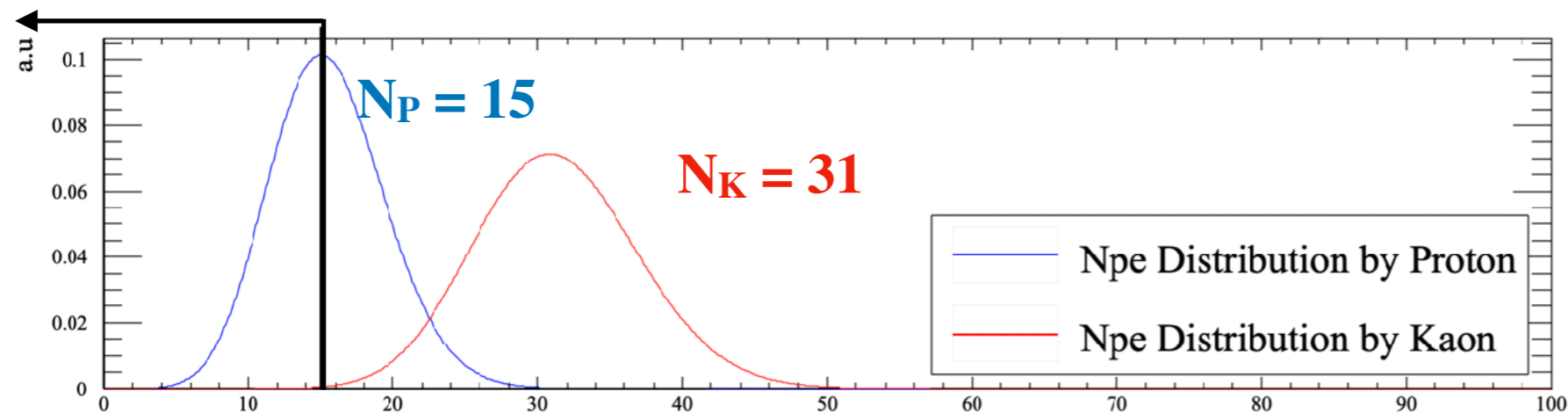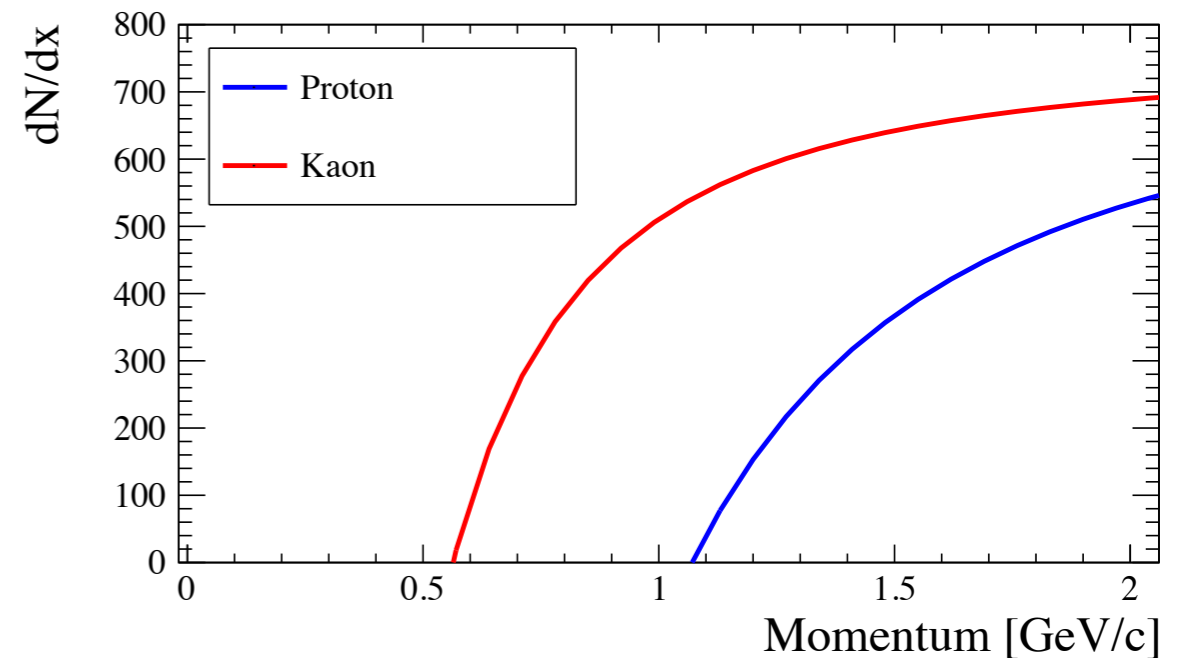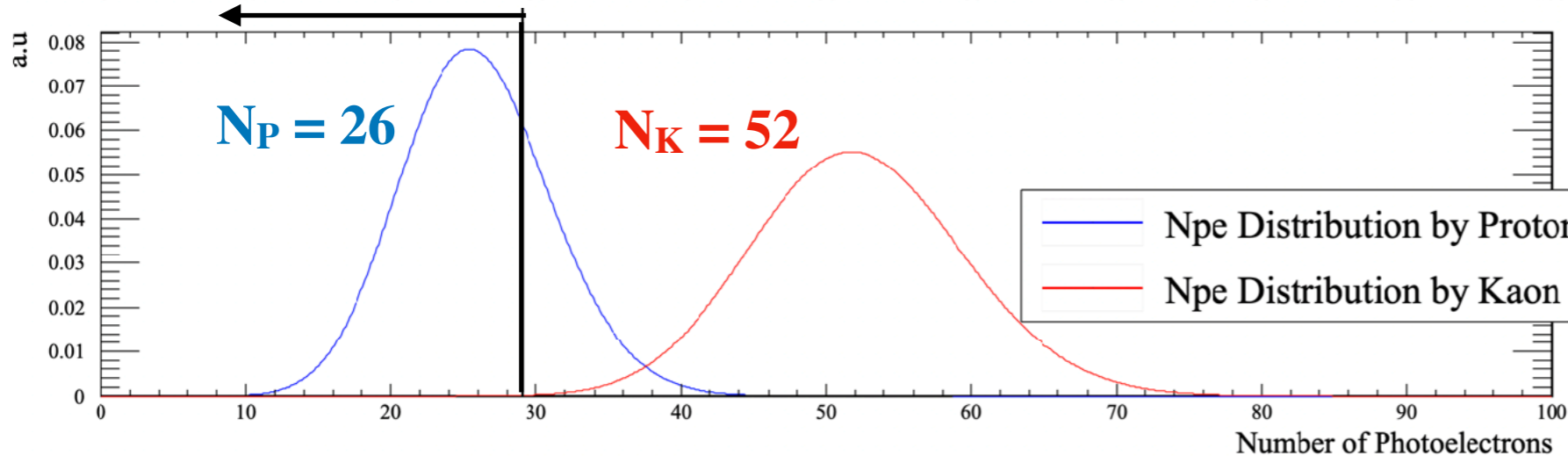

HypTPC

KURAMA
Spectrometer

PID Strategy of WC

- Protons and kaons will be discriminated by the difference in their photon yield

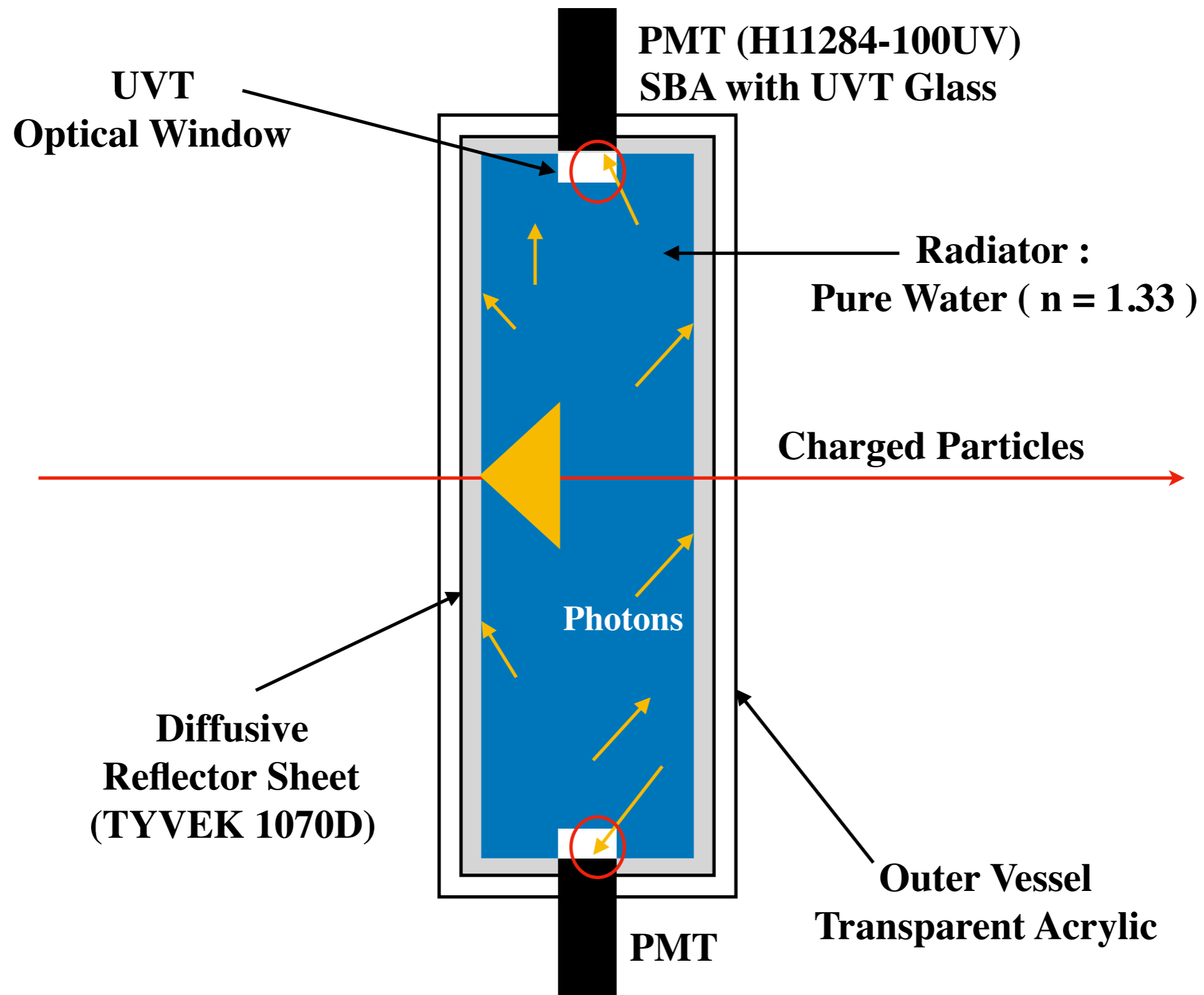$$\frac{d^2 N}{dx d\lambda} = \frac{2\pi z^2 \alpha}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2}\right)$$

$N_P = 15$ $N_K = 31$

Threshold : 15 Npe

Proton Rejection Ratio : 46 %
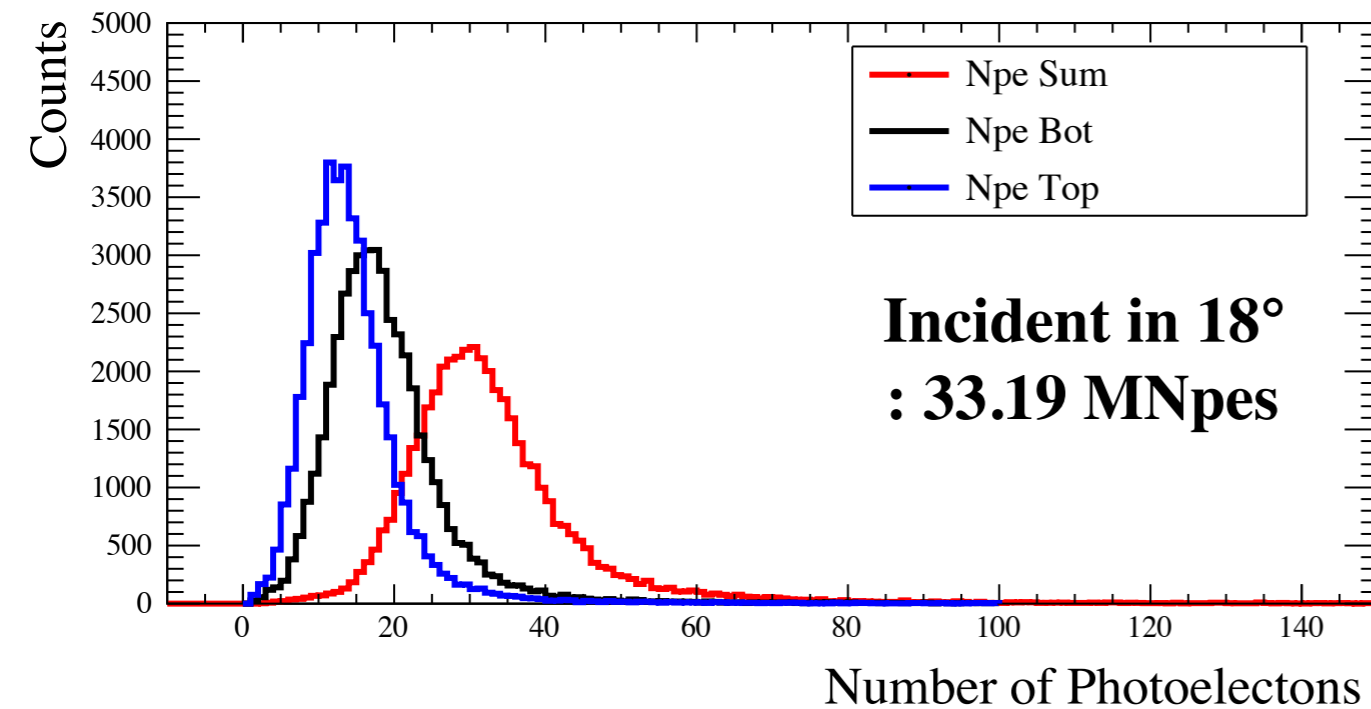
Kaon Survival Ratio : 99.9 %
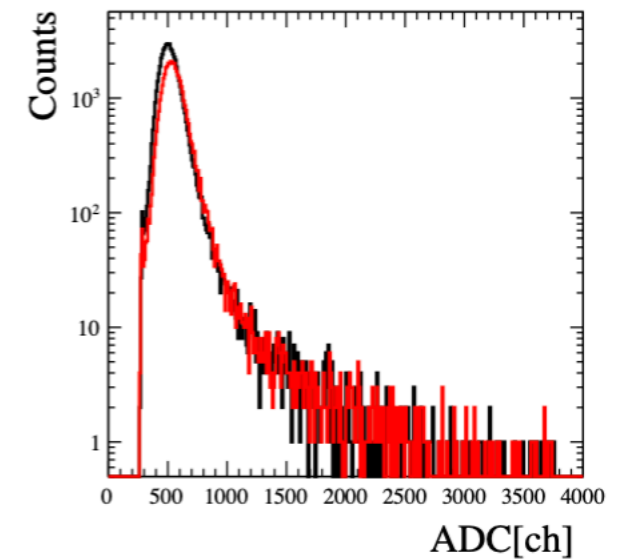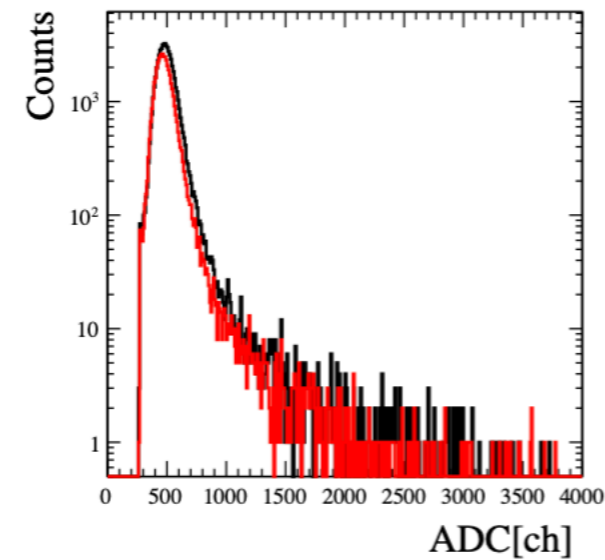
$N_P = 26$ $N_K = 52$

Threshold : 29 Npe

Proton Rejection Ratio : 73 %

Kaon Survival Ratio : 99.9 %

Prototype Water Cherenkov Detector

PMT (H11284-100UV)
SBA with UVT Glass

UVT
Optical Window

Radiator :
Pure Water (n = 1.33)

Charged Particles

Photons

Diffusive
Reflector Sheet
(TYVEK 1070D)

Outer Vessel
Transparent Acrylic

PMT

Prototype WC Cosmic Ray Test

Incident in vertical : 32.09 MNpes
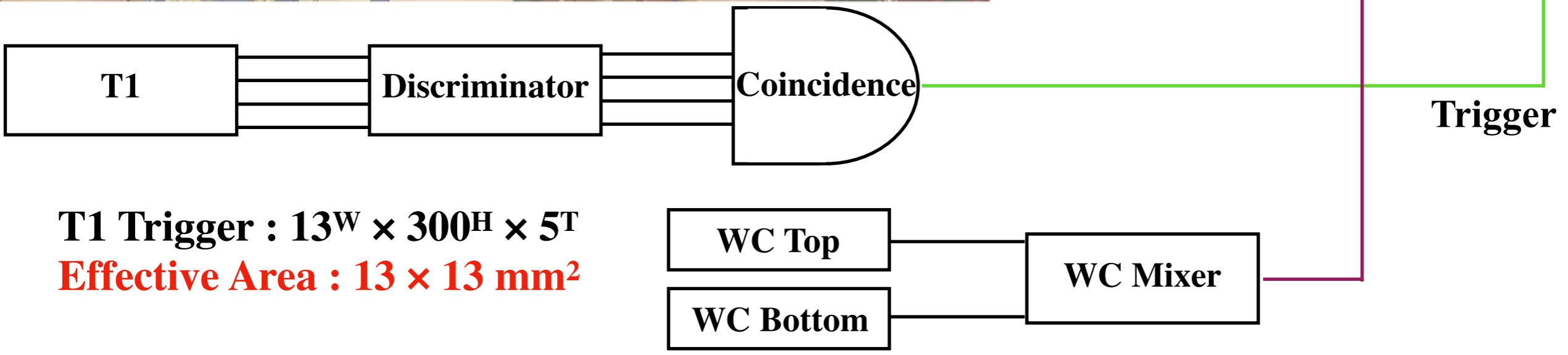
Incident in 18° : 33.19 MNpes
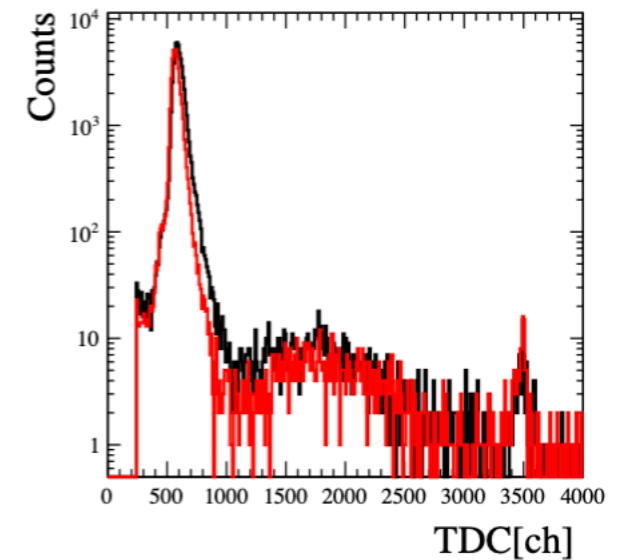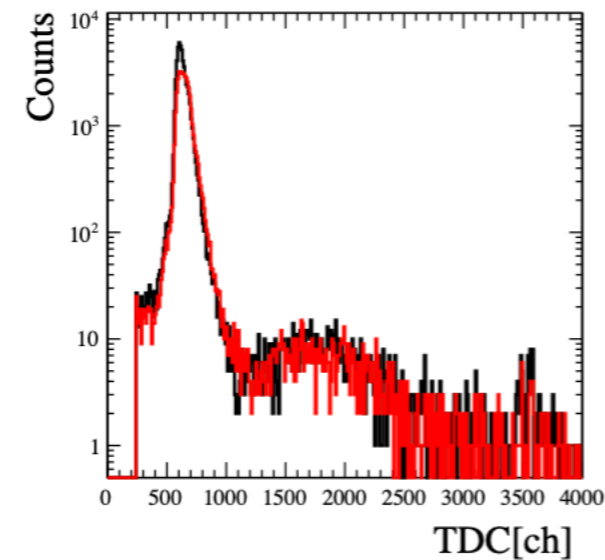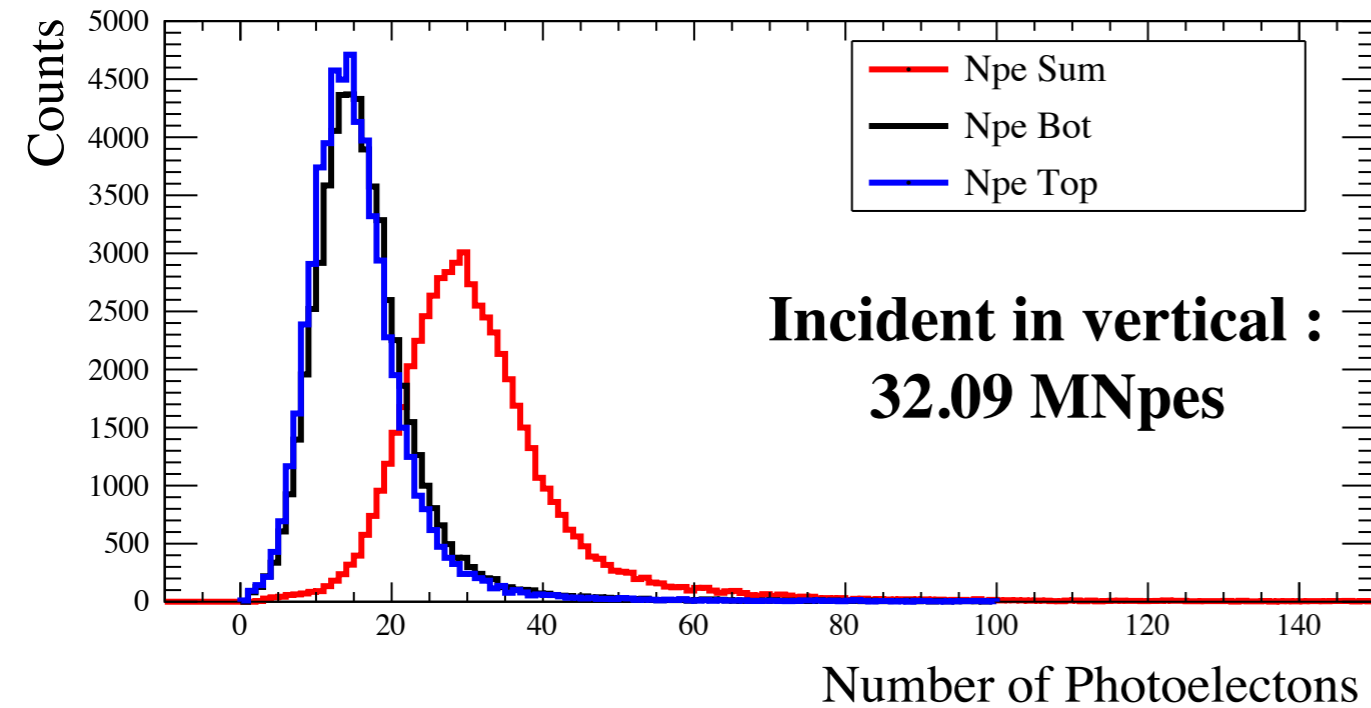
Schematic Design

Outer Vessel : 257^W × 207^H × 1880^T [mm]

Inner Vessel : 214^W × 164^H × 1810^T [mm]

A (0.32 : 1)

B

Inner Vessel

Outer Vessel

B (0.32 : 1)

PMT Holder

Water Filling Part

A
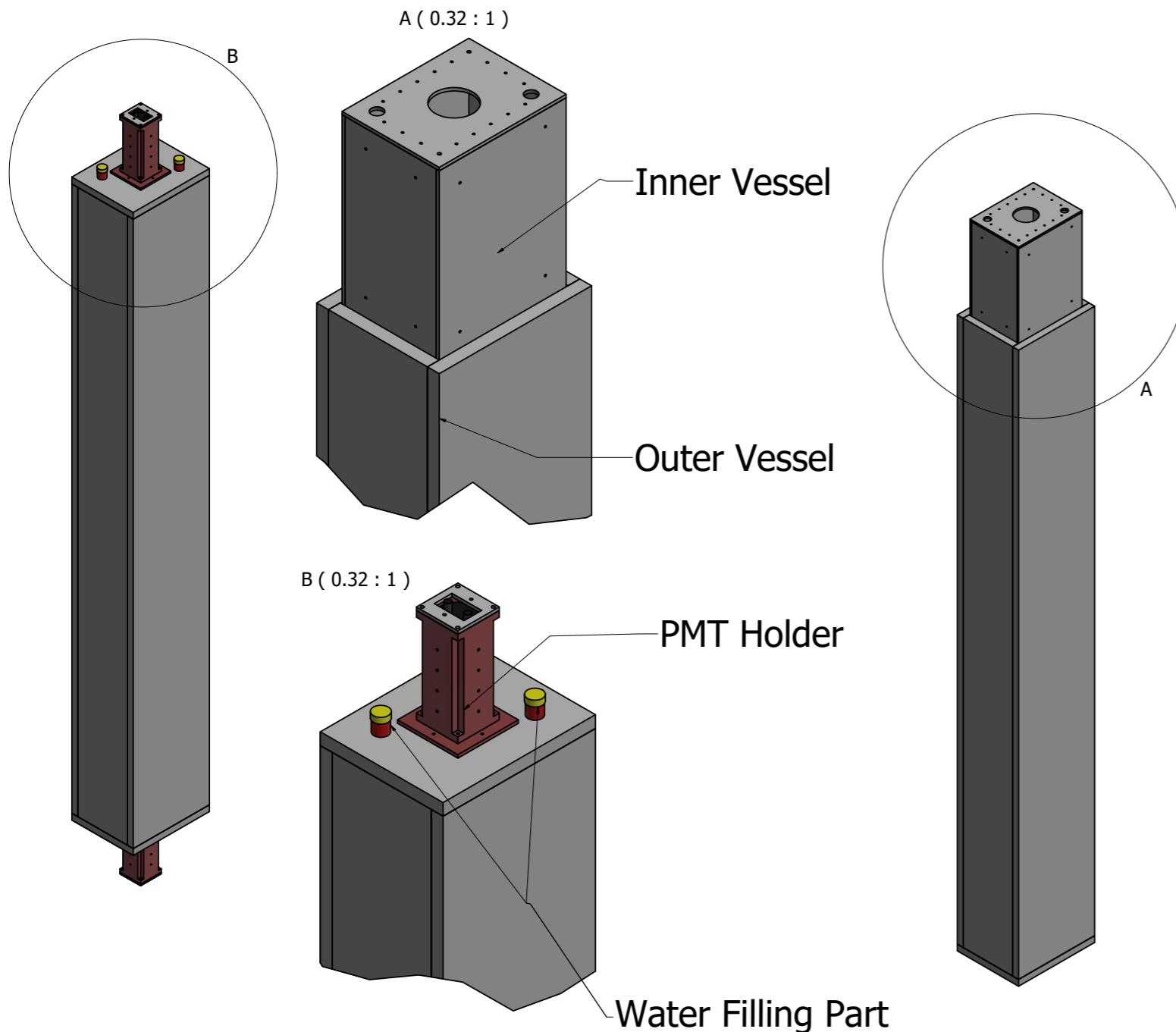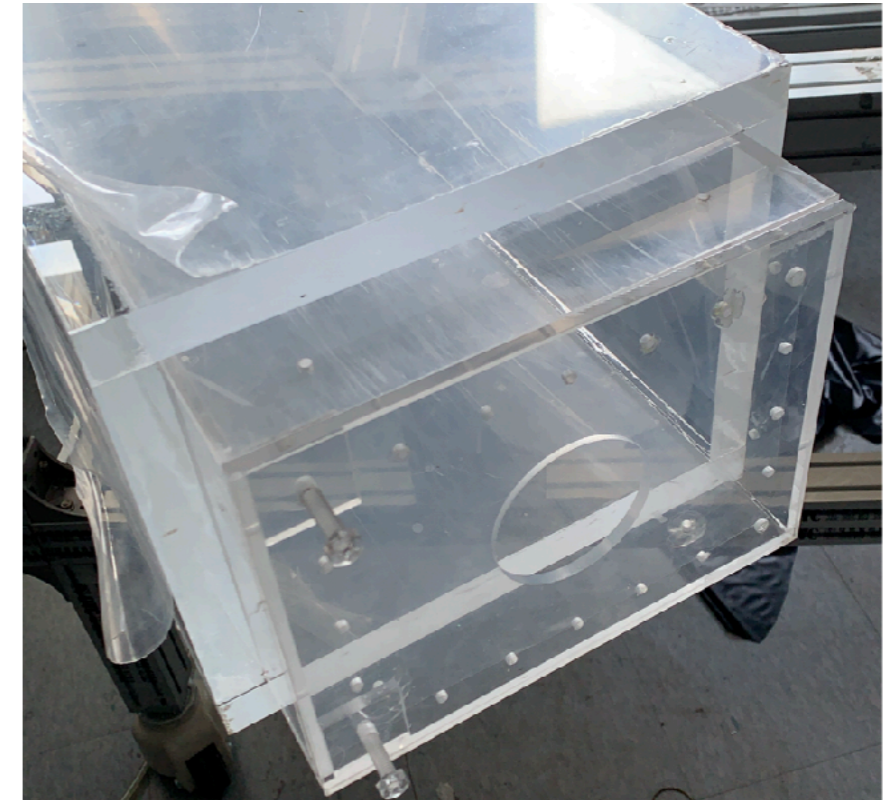
- Two layer system for the detector maintenance

- Reflector sheet is attached to inner wall of the inner vessel
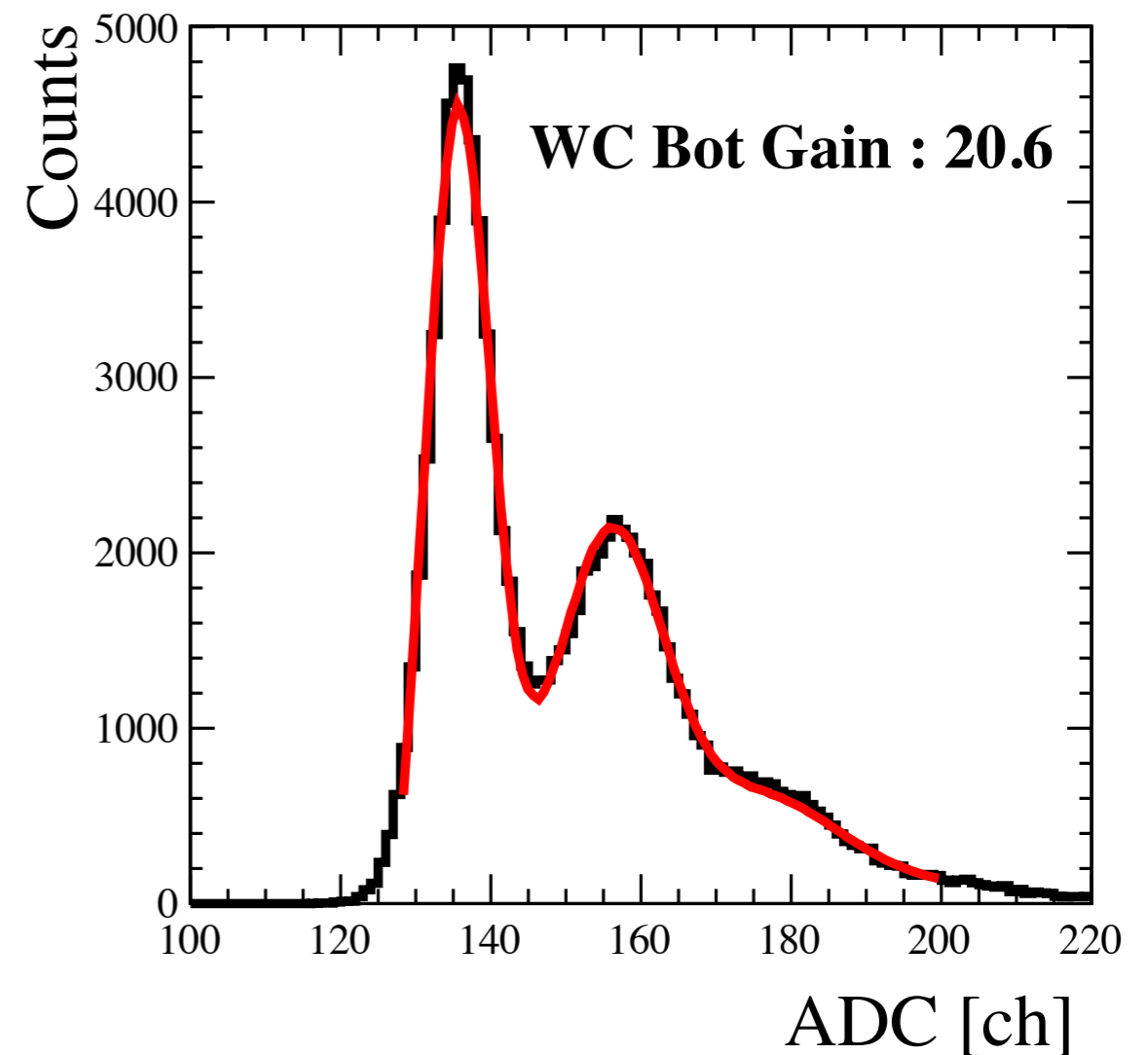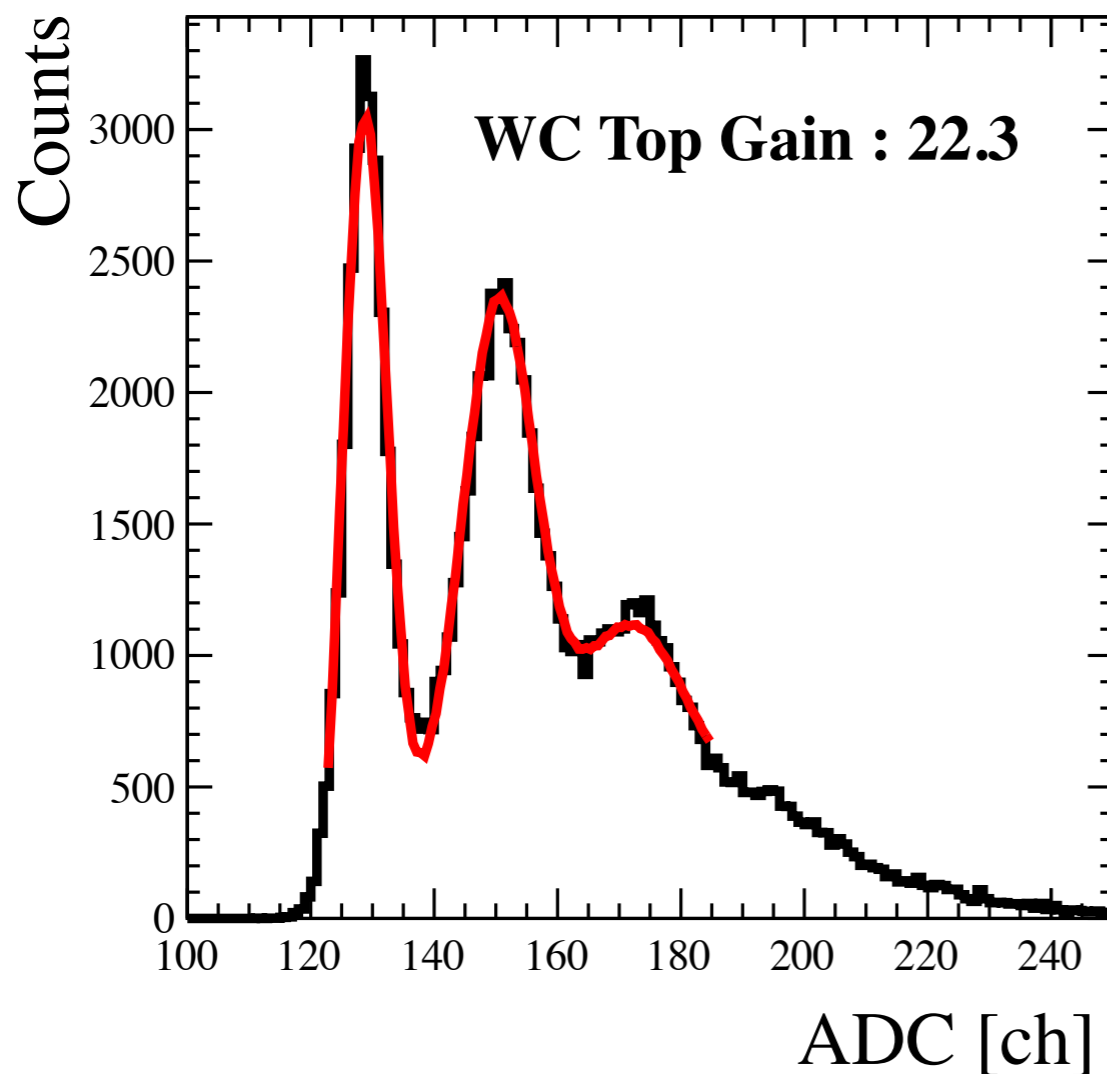
- PMT Holder also designed
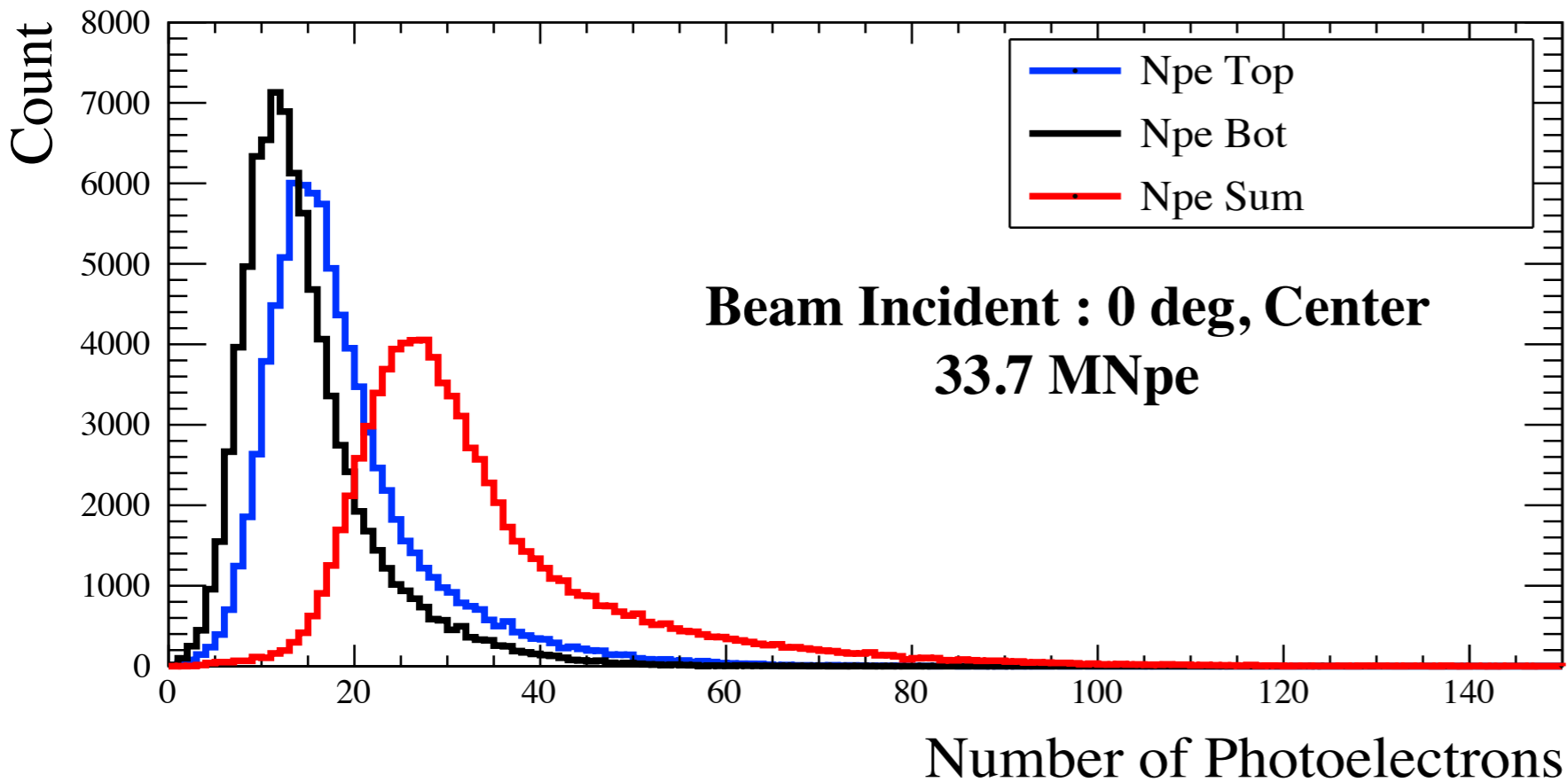
WC Beam test with e⁺ beam

460 MeV

T3

WC

T1

WC Sum

WC Top

T1 — Discriminator — Coincidence — Trigger

T1 Trigger : 13ᵂ × 300ᴴ × 5ᵀ
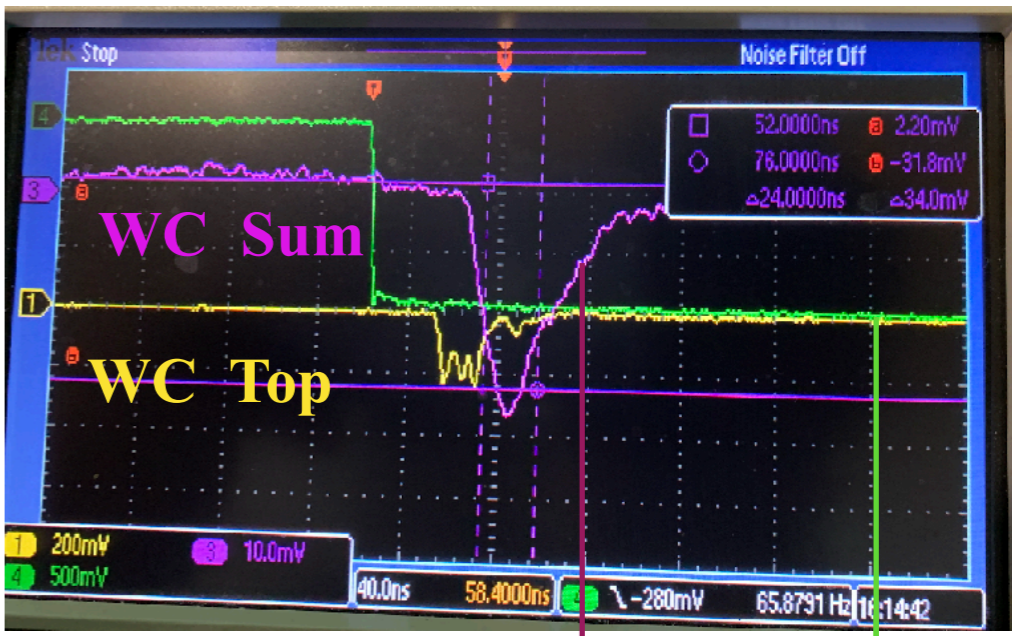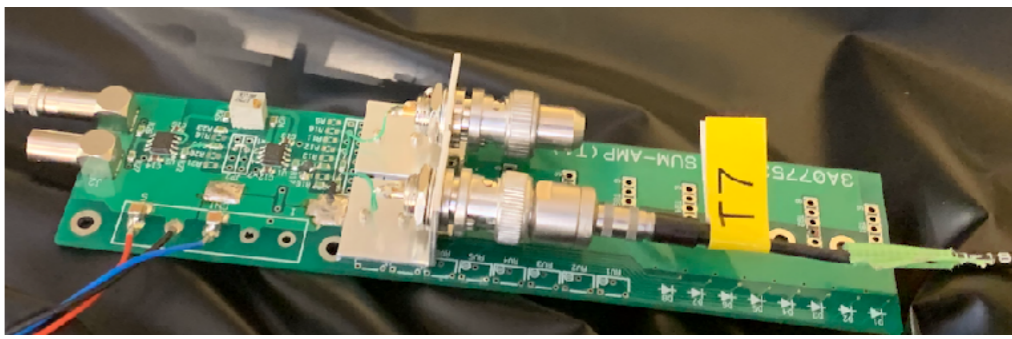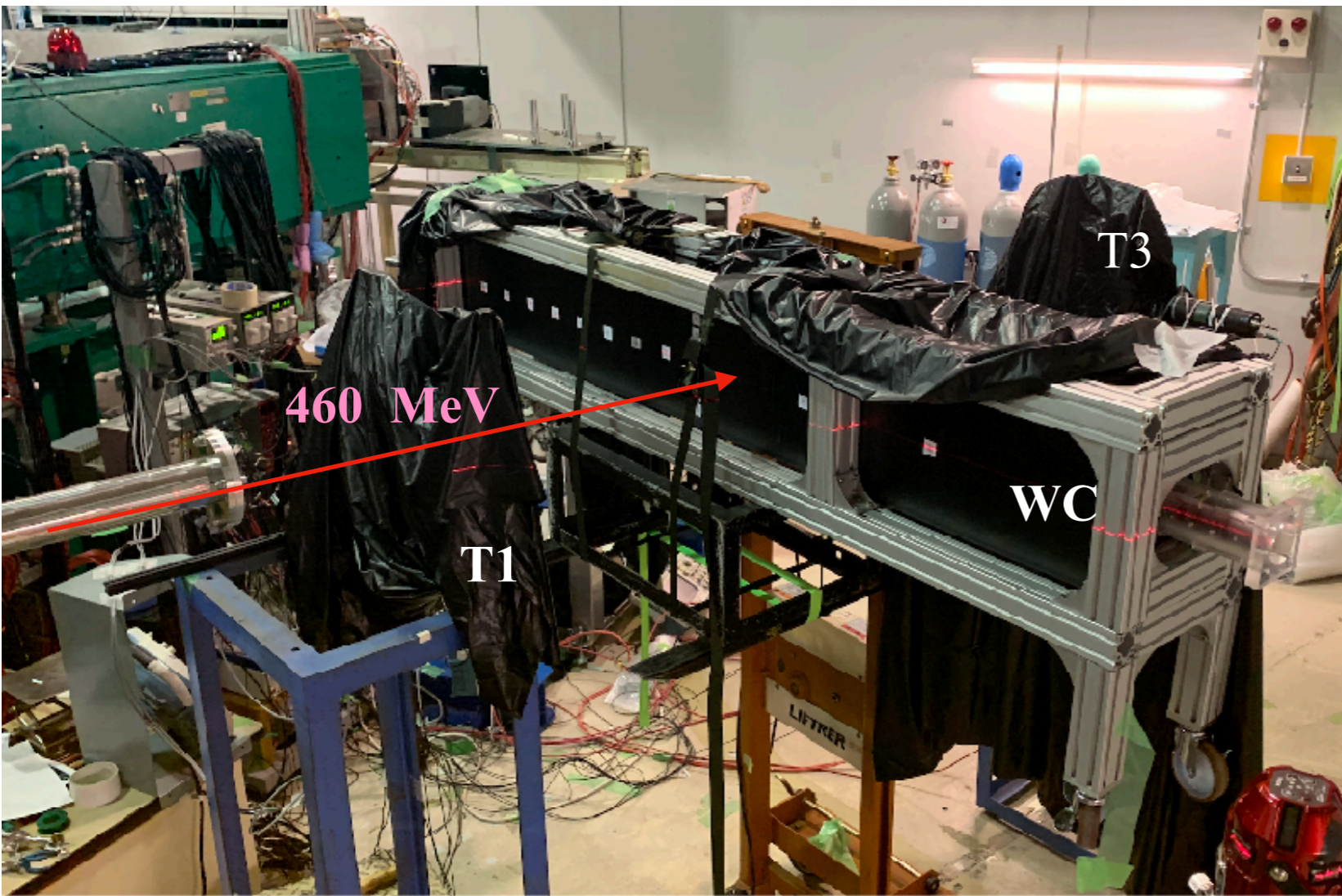
Effective Area : 13 × 13 mm²
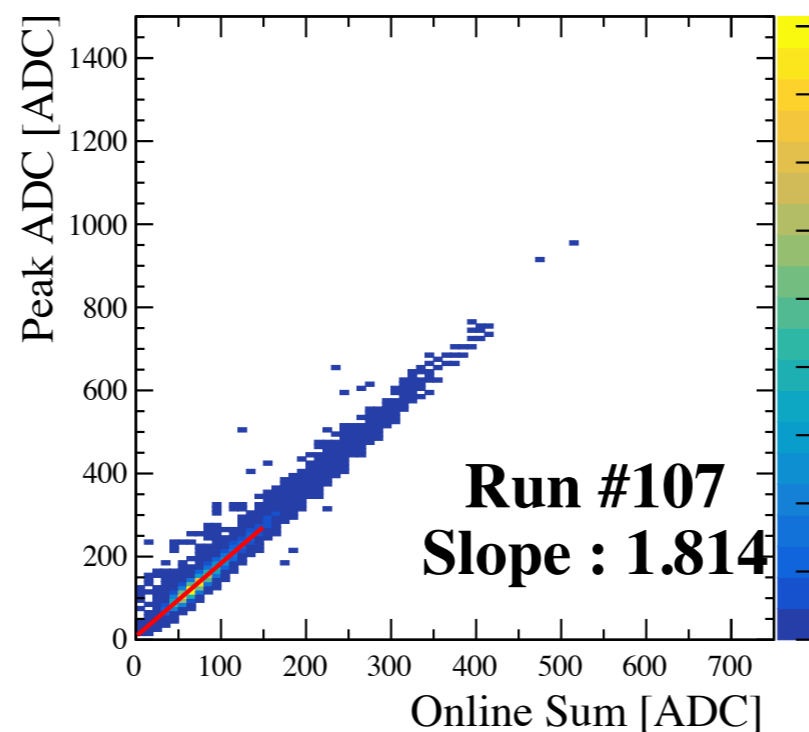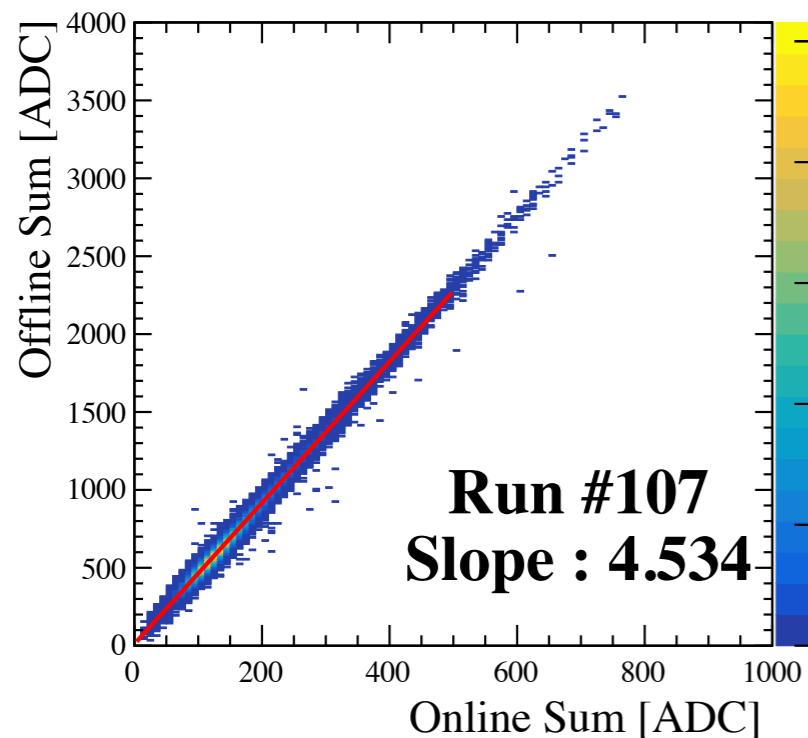
WC Top
WC Bottom — WC Mixer

PMT Gain Measurement

$$S_{real}(x) = const. \times \left[\left\{ \frac{1-w}{\sigma_0\sqrt{2\pi}} exp\left(-\frac{(x-Q_0)^2}{2\sigma_0^2}\right) + w\theta(x-Q_0)\times\alpha exp[-\alpha(x-Q_0)] \right\} e^{-\mu} + \sum_{n=1}^{\infty} \frac{\mu^n e^{-\mu}}{n} \times \frac{1}{\sigma_1\sqrt{2\pi n}} exp\left(-\frac{(x-Q_0-nQ_1)^2}{2n\sigma_1^2}\right) \right]$$

WC Top Gain : 22.3

WC Bot Gain : 20.6
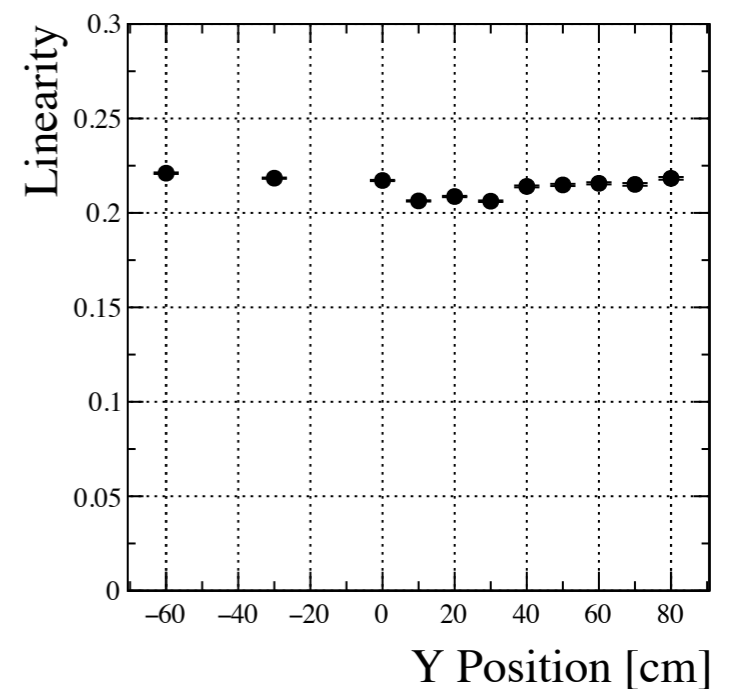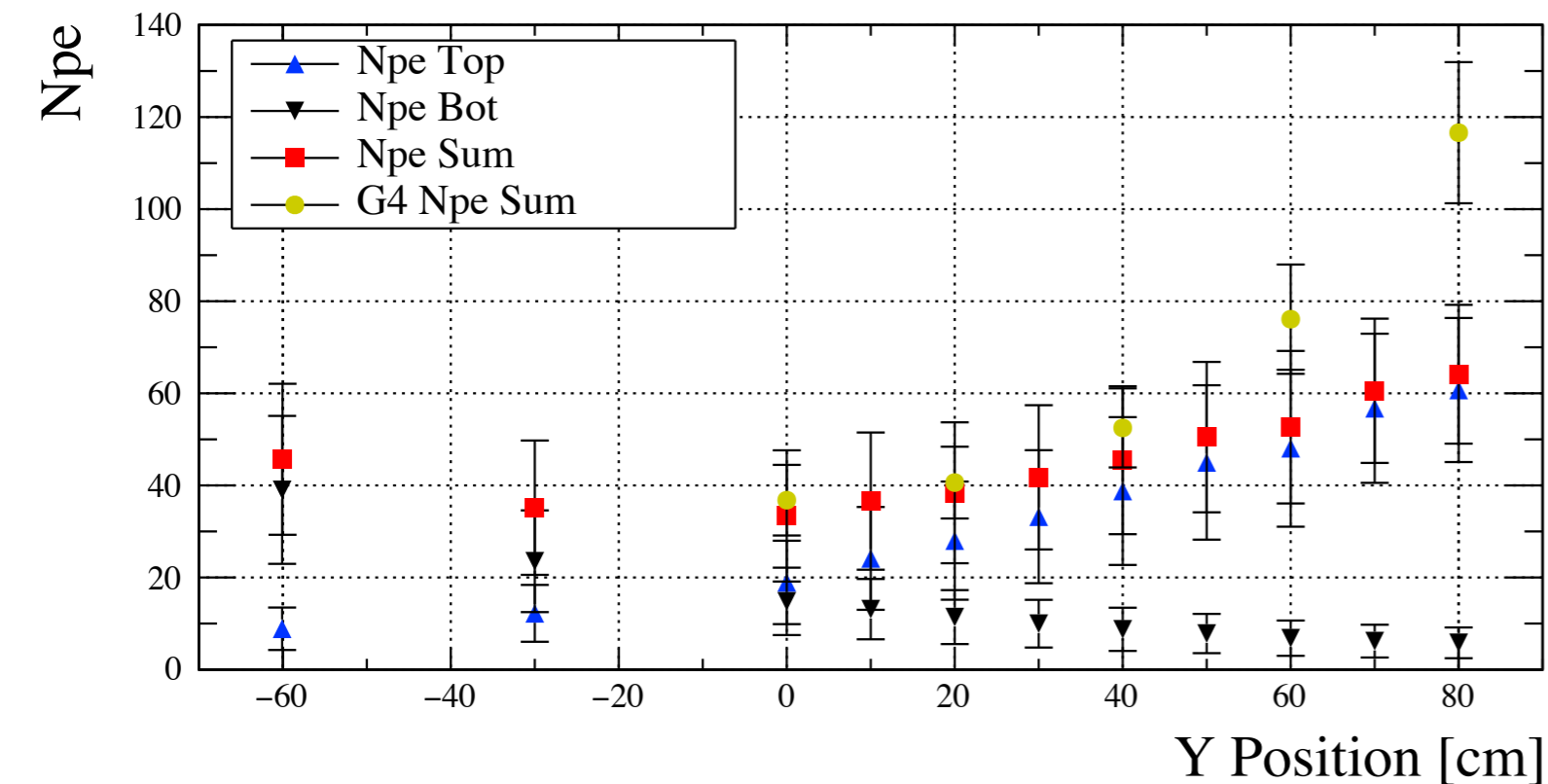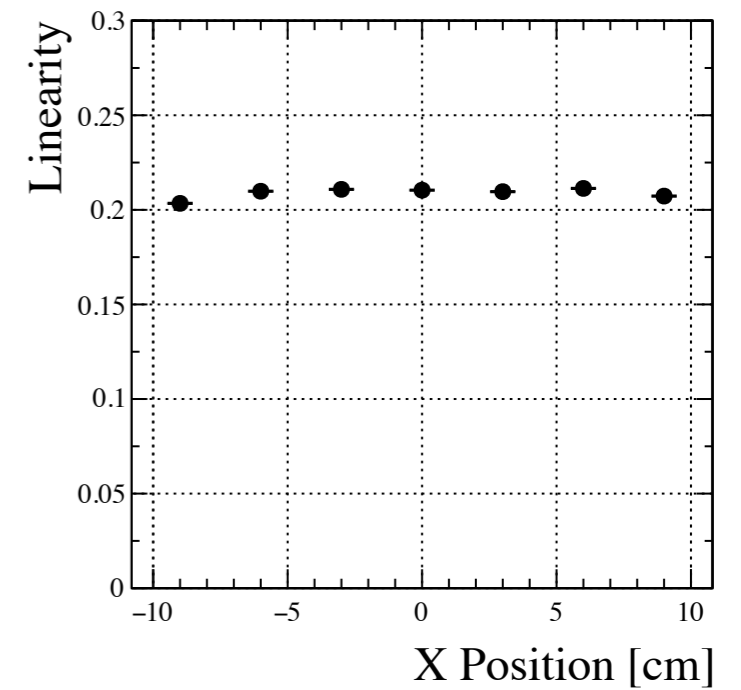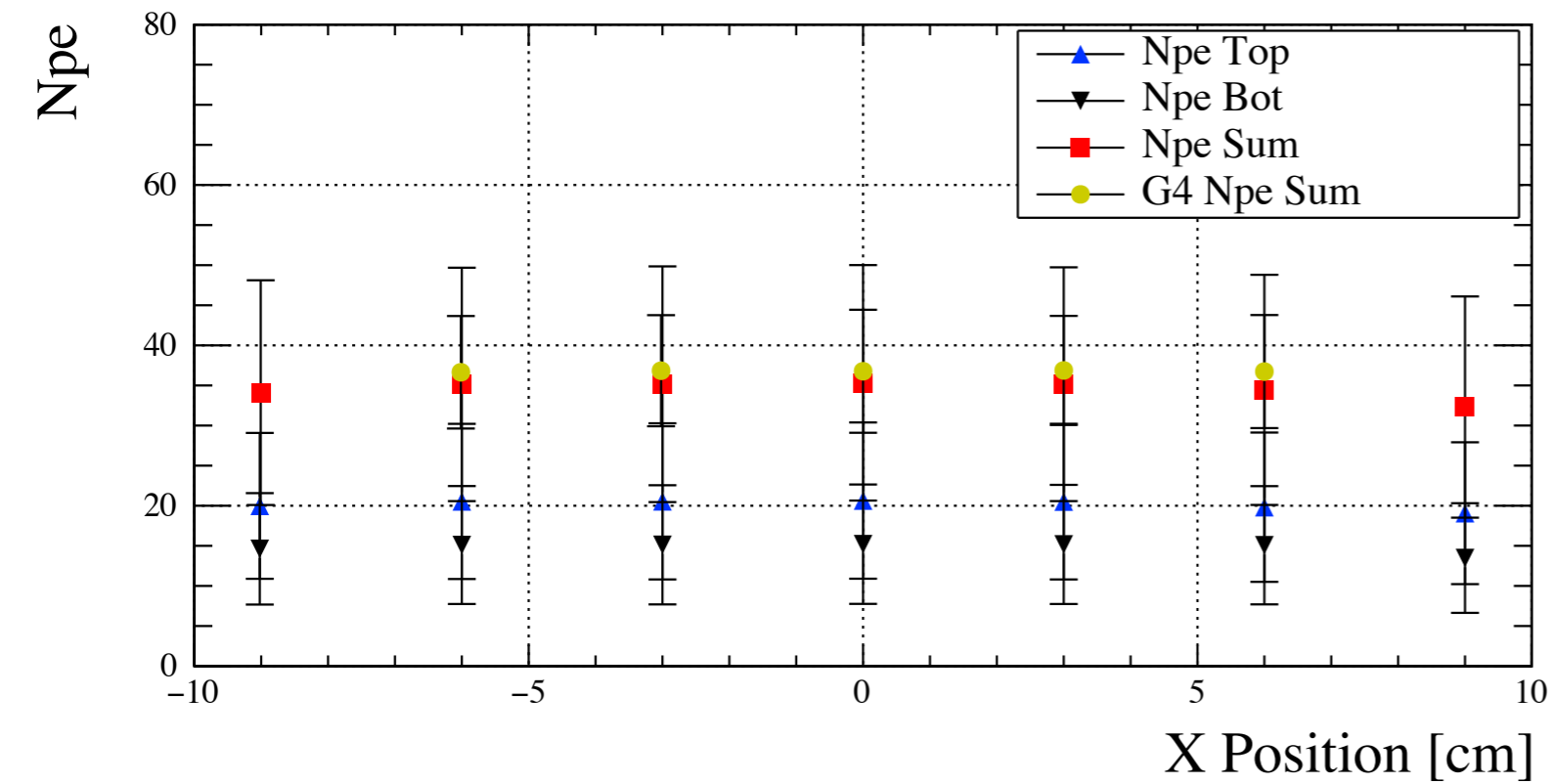
Analysis

Beam Incident : 0 deg, Center
33.7 MNpe

- Npe values were scanned along each axis and by differing incident angle by 15°

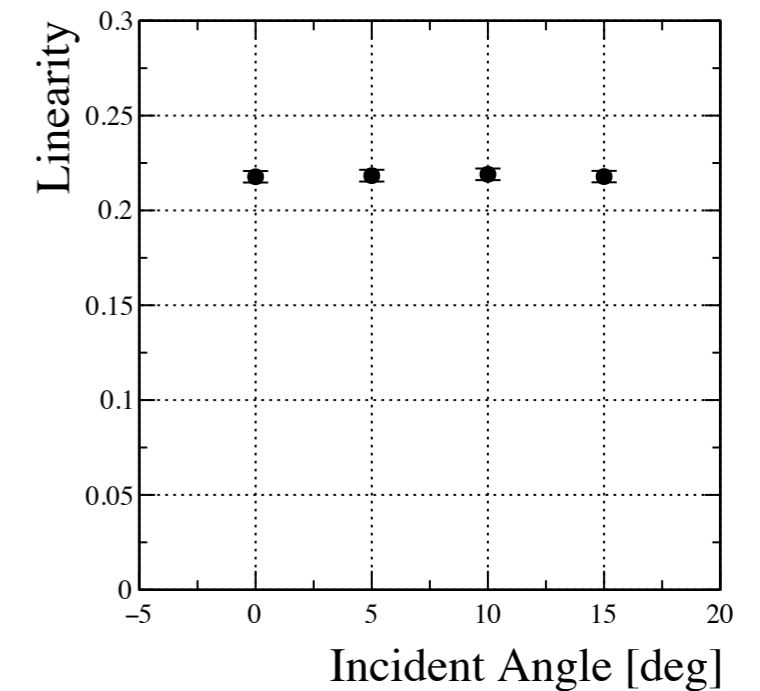Run #107
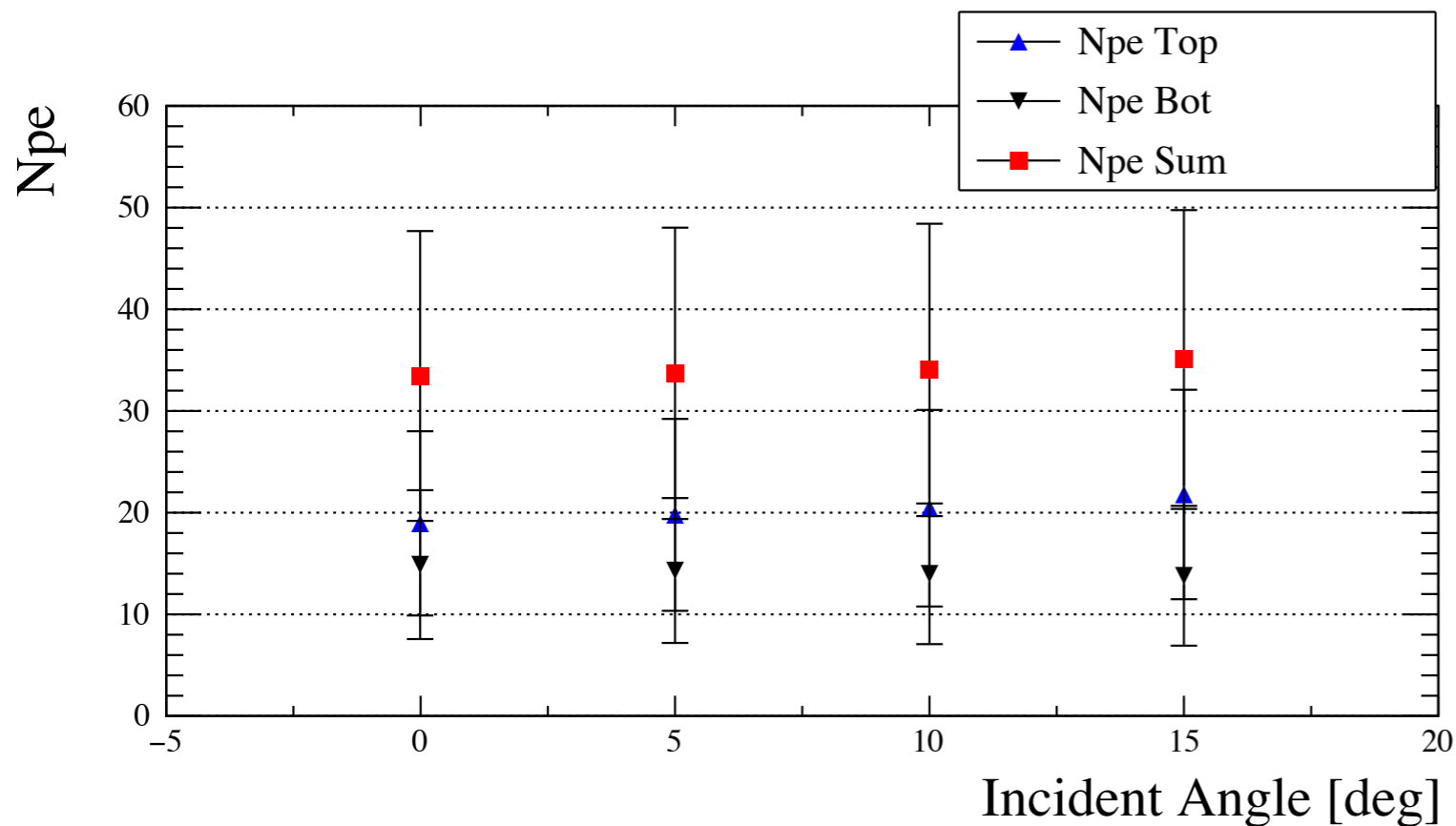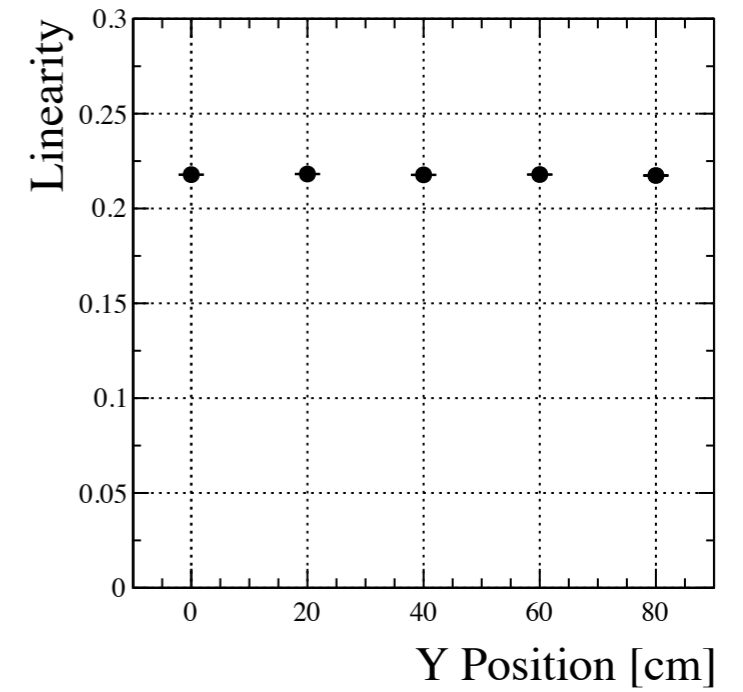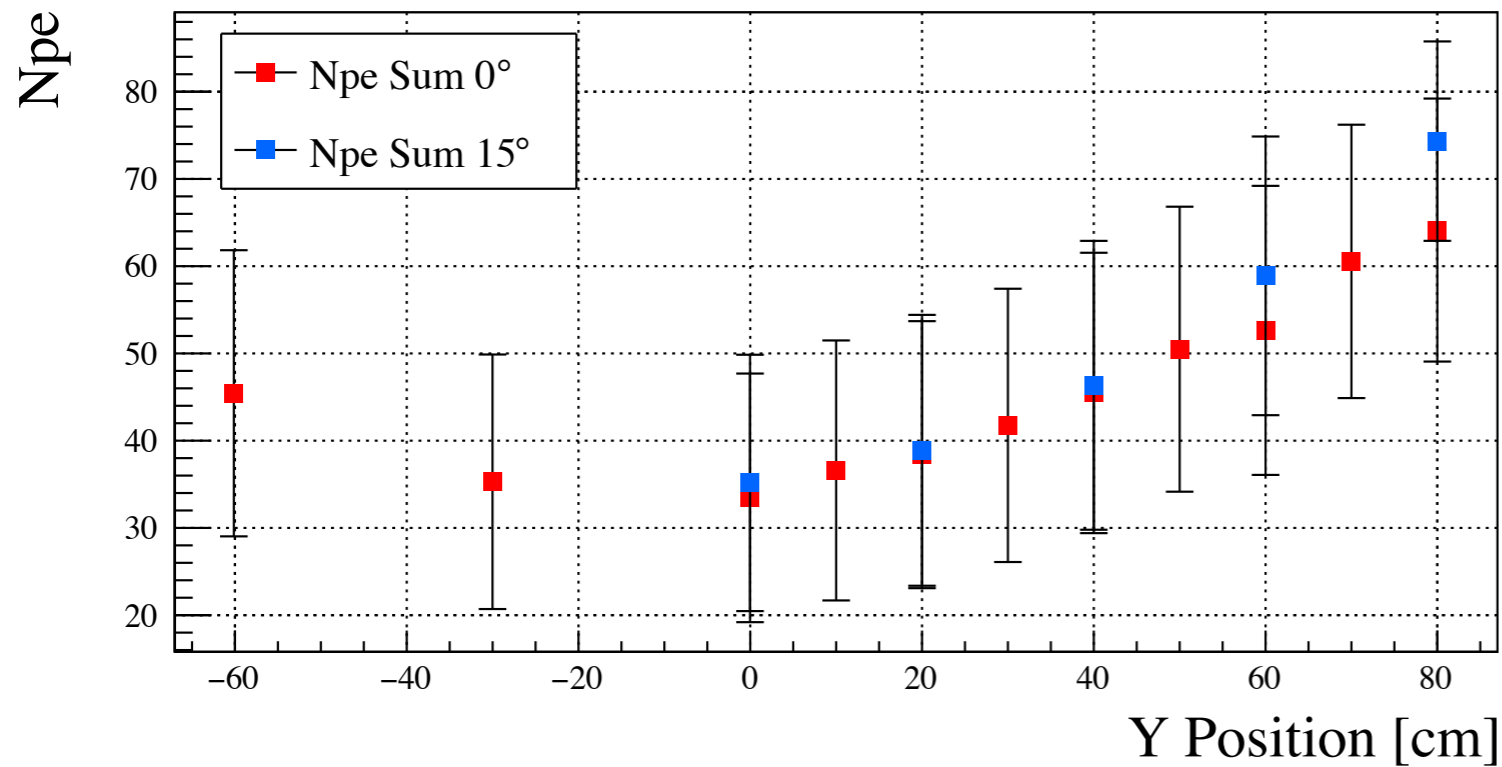Slope : 4.534

Run #107
Slope : 1.814

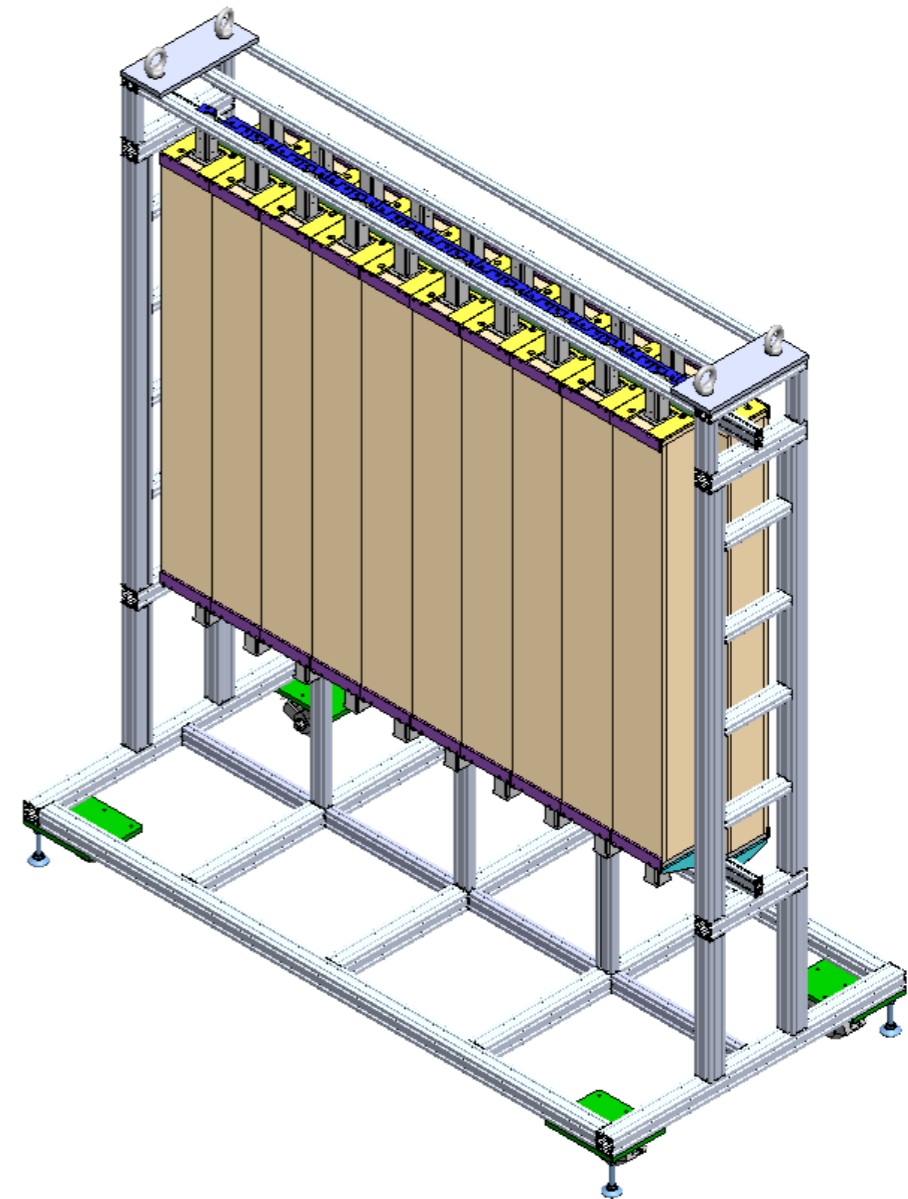- Linearity between online and offline sum and correlation with Peak ADC were also scanned.

Position Dependency

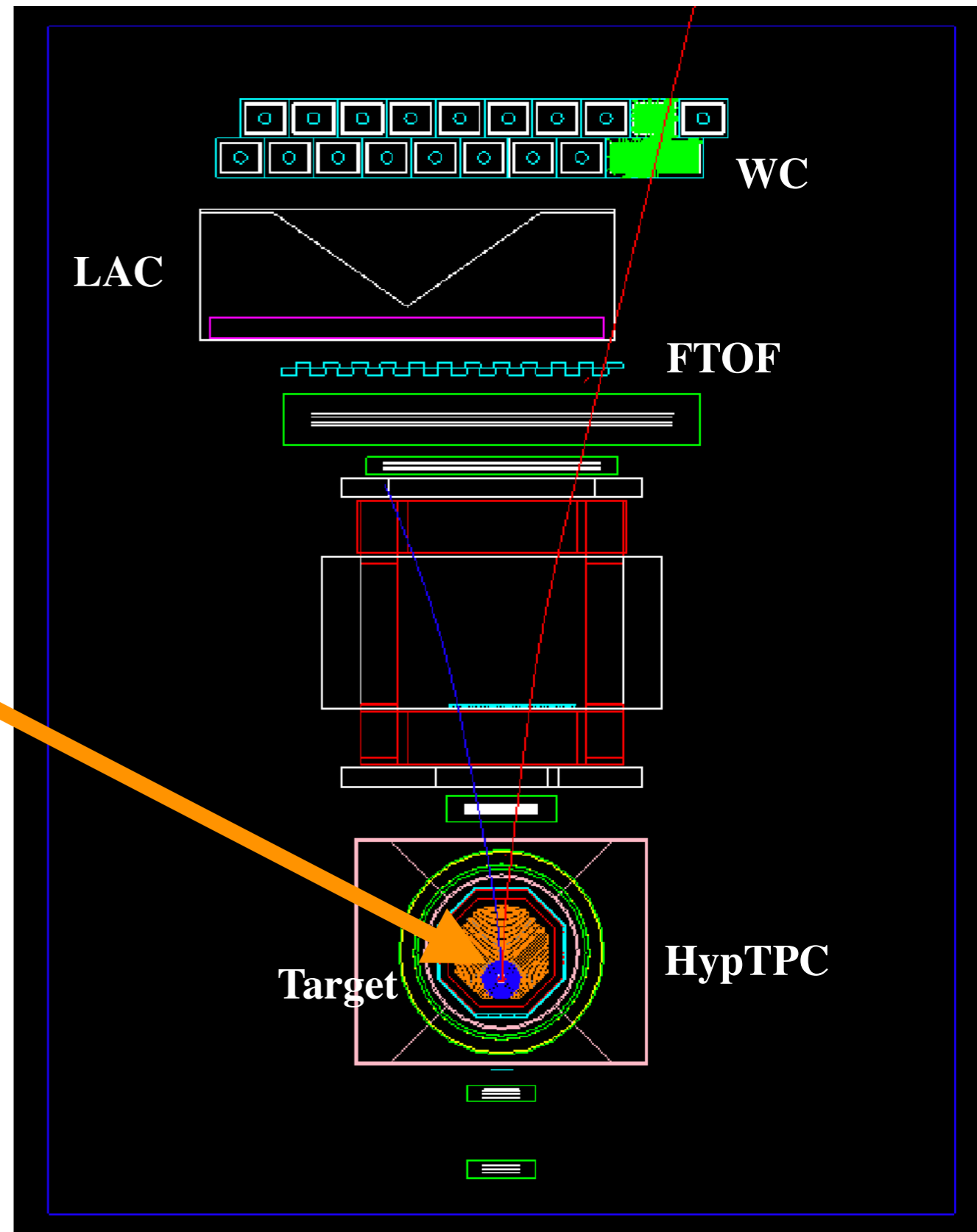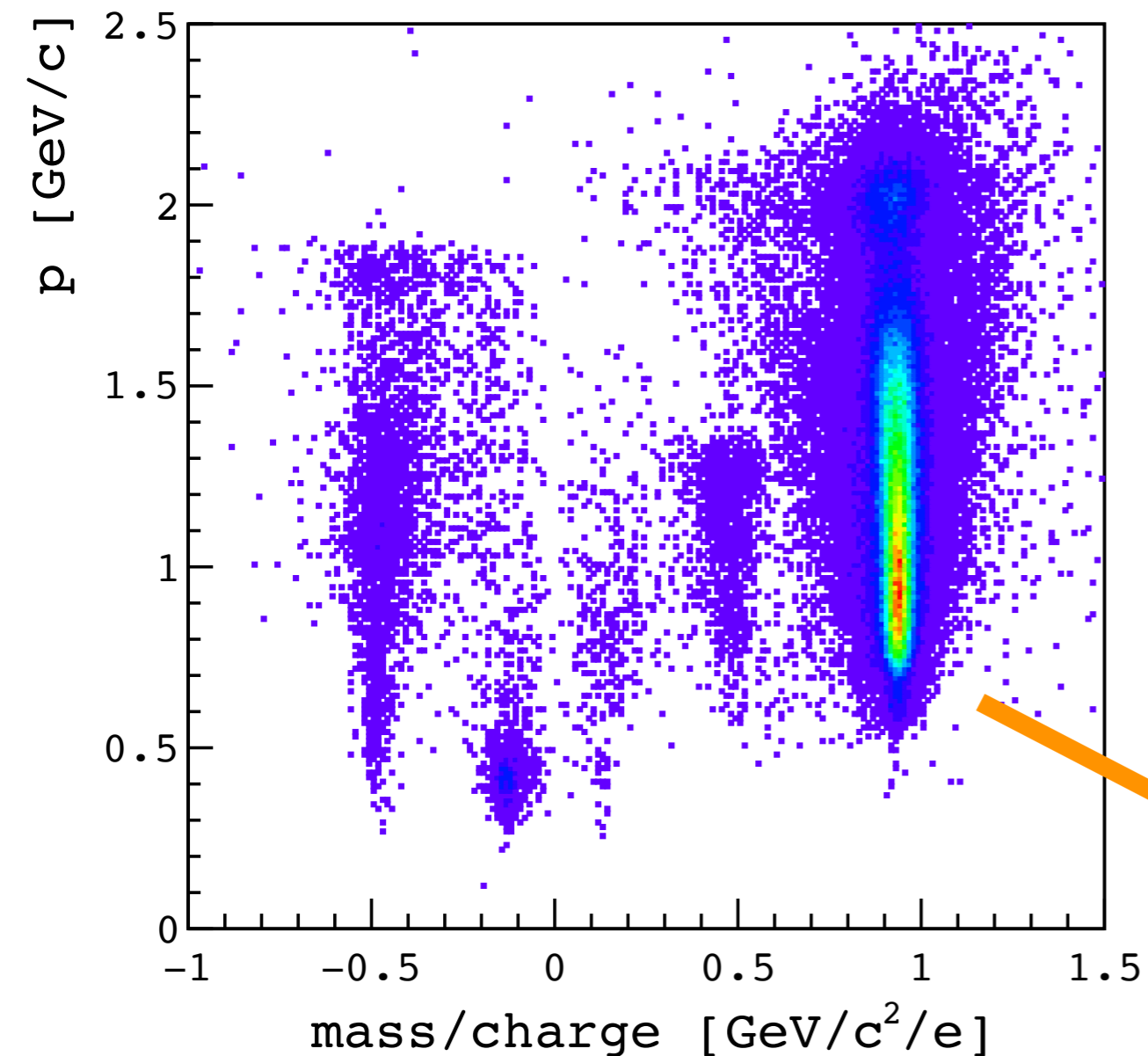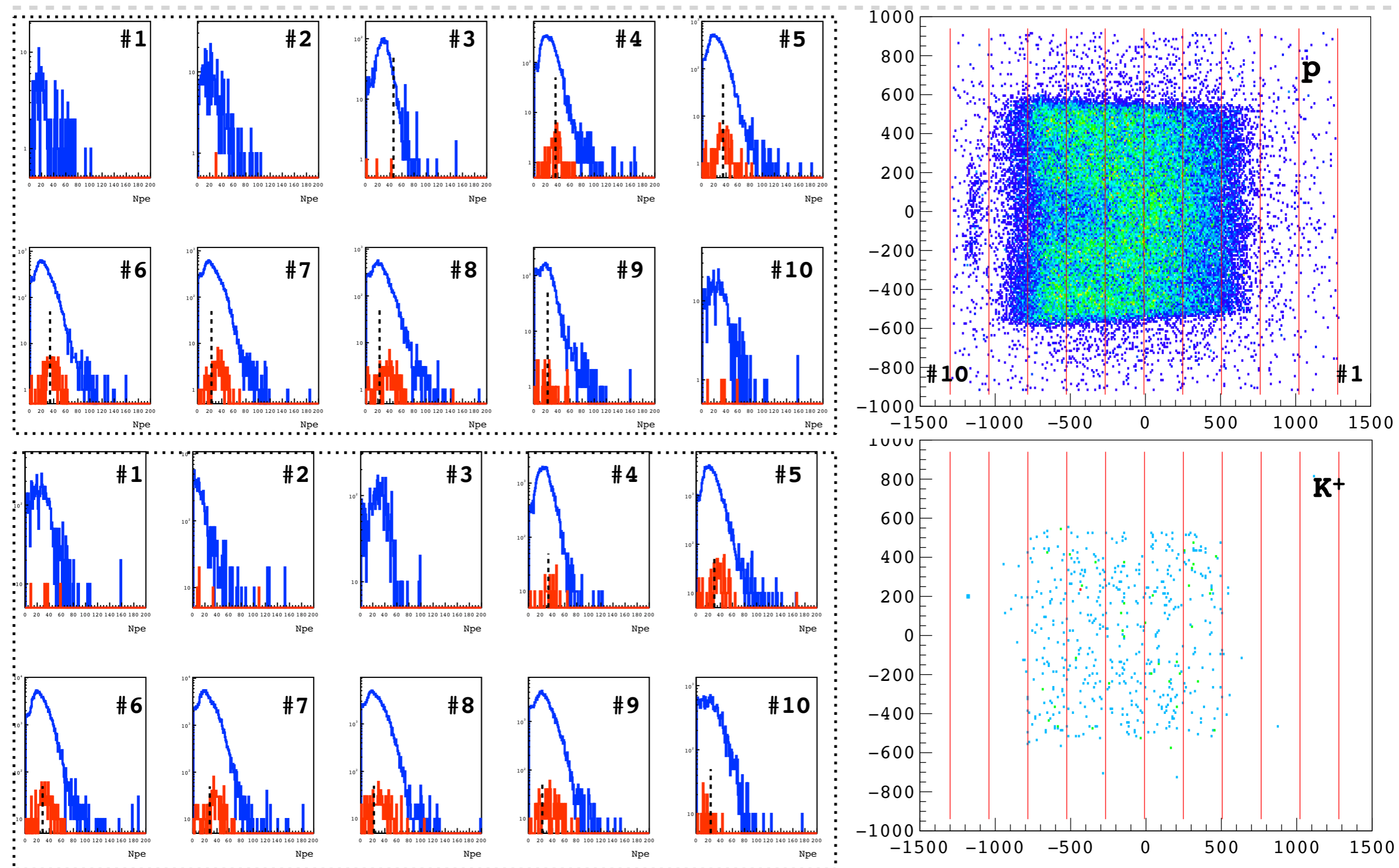# Incident Angle Dependency

WC Mass Production

- WC is now on mass production for the installation at J-PARC beam line

- WC K+ beam test J-PARC, Nov.2020

E42 Geant4 Simulation
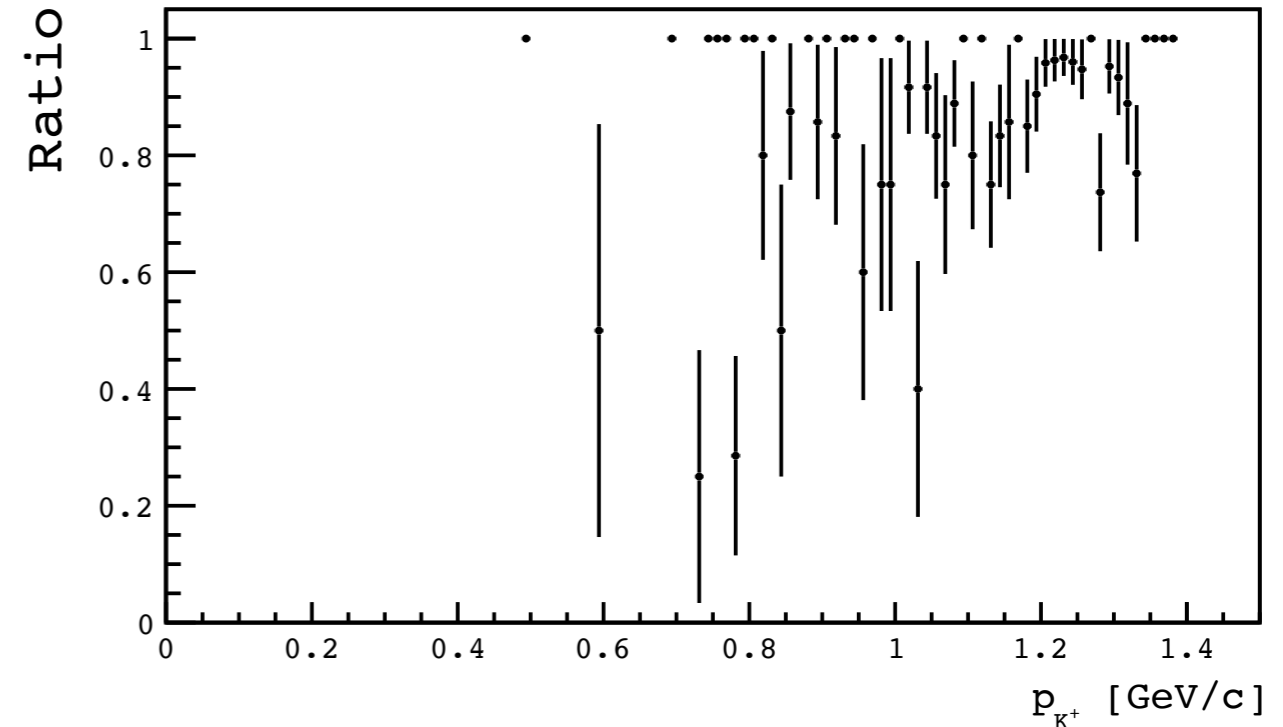

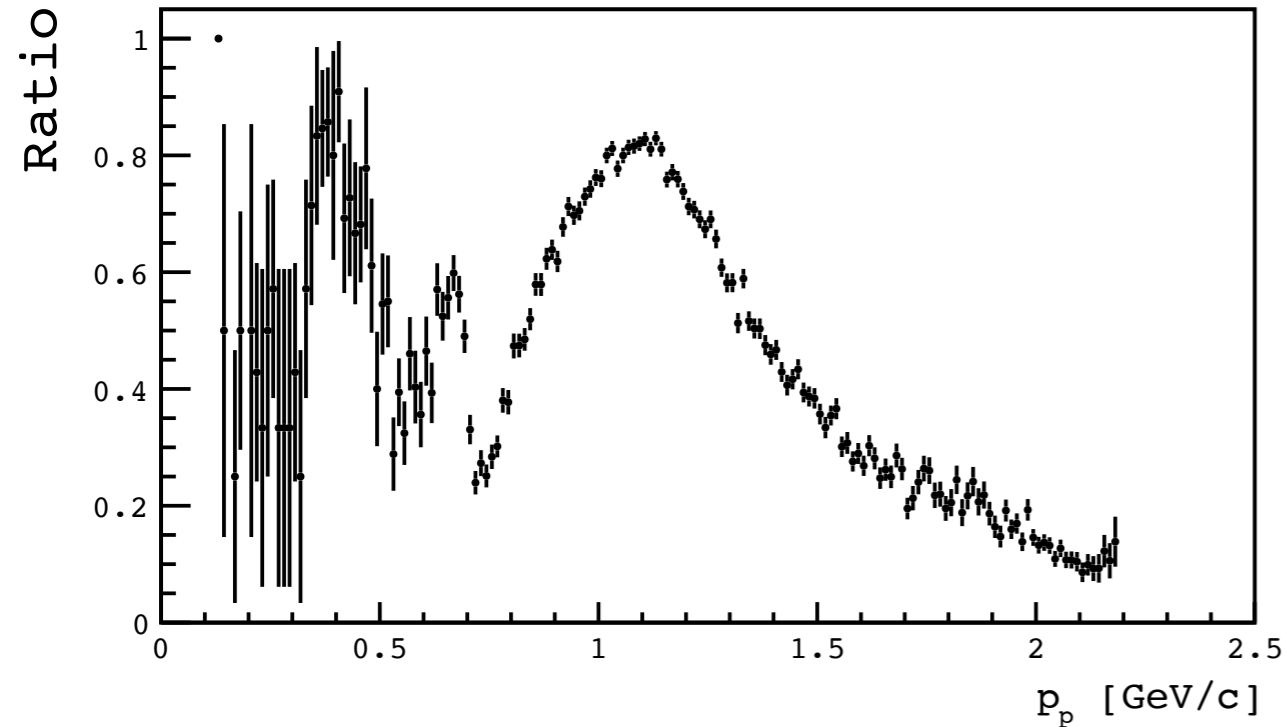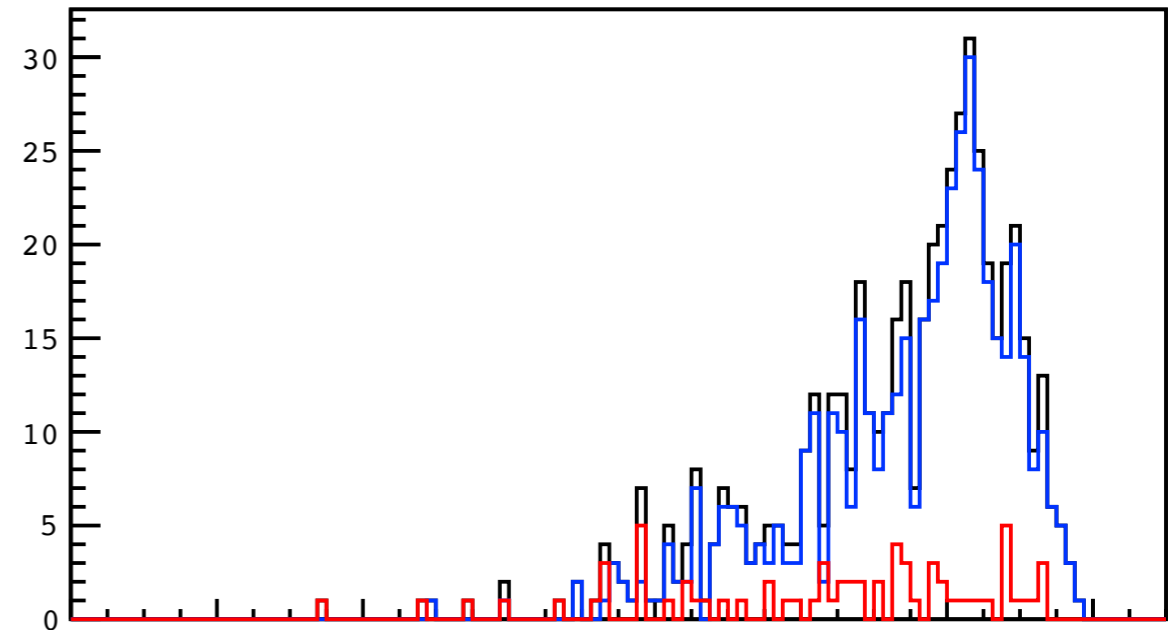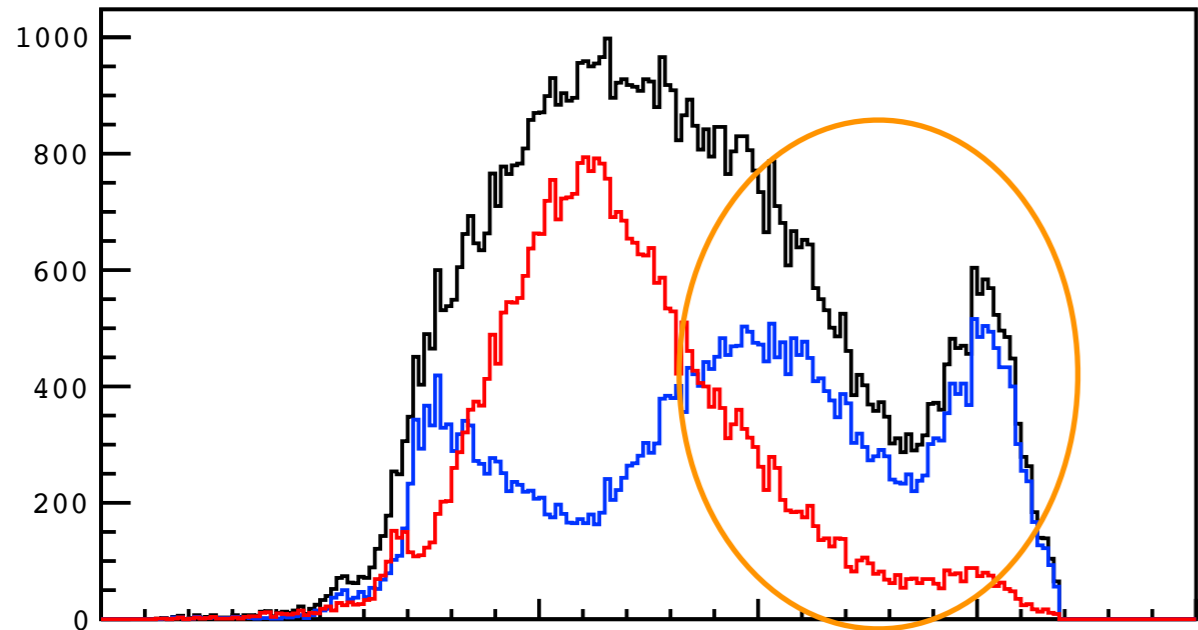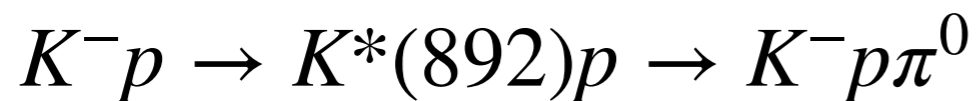- Proton rejection efficiency estimation with E42 Geant4 Simulation, using E07 (K⁻,K⁺) data
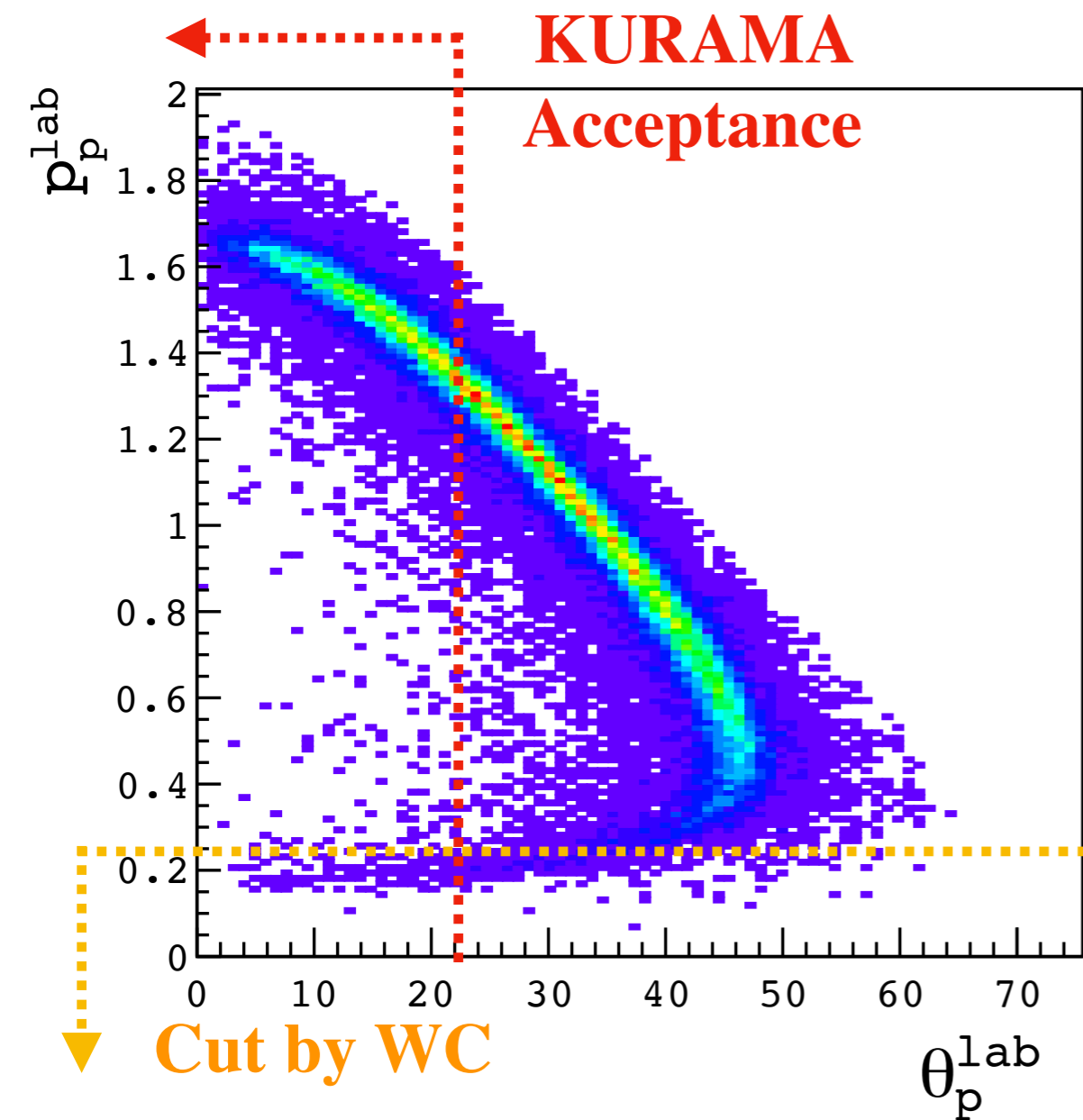
Npe Distribution p/K+

Proton Rejection Efficiency

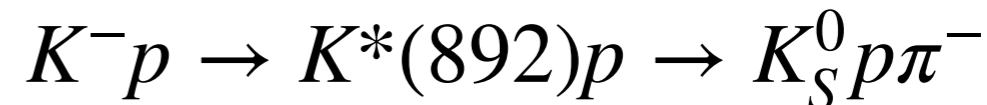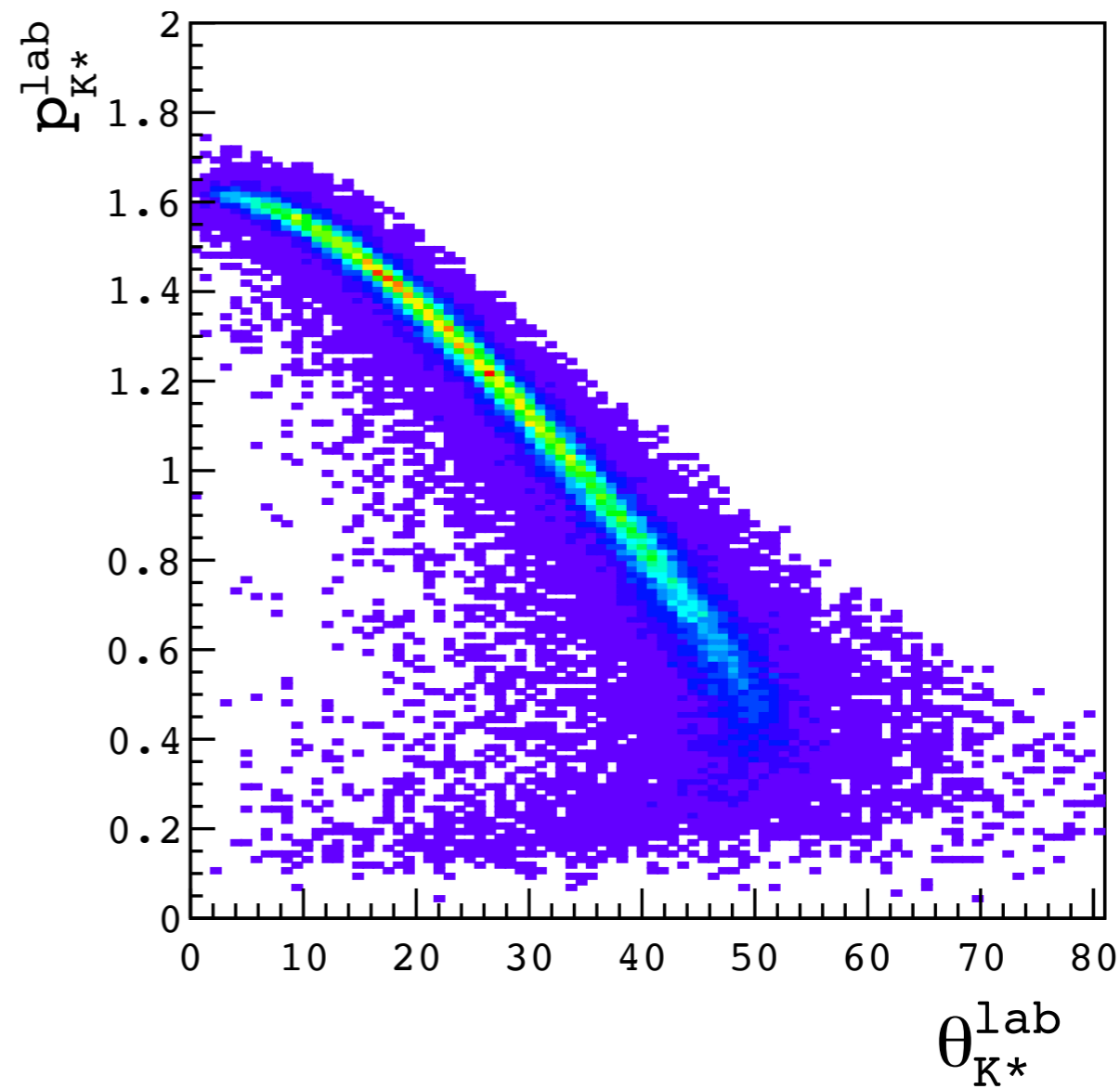**Proton Rejection Ratio : ~ 46 %**

K+ Survival Ratio : ~ 90 %

K*(892) Kinematics

$$K^-p \to K^*(892)p \to K^-p\pi^0$$

Total Cross Section : 0.849 mb

$$K^-p \to K^*(892)p \to K^0_S p\pi^-$$

Total Cross Section : 1.402 mb

Dalitz Plot
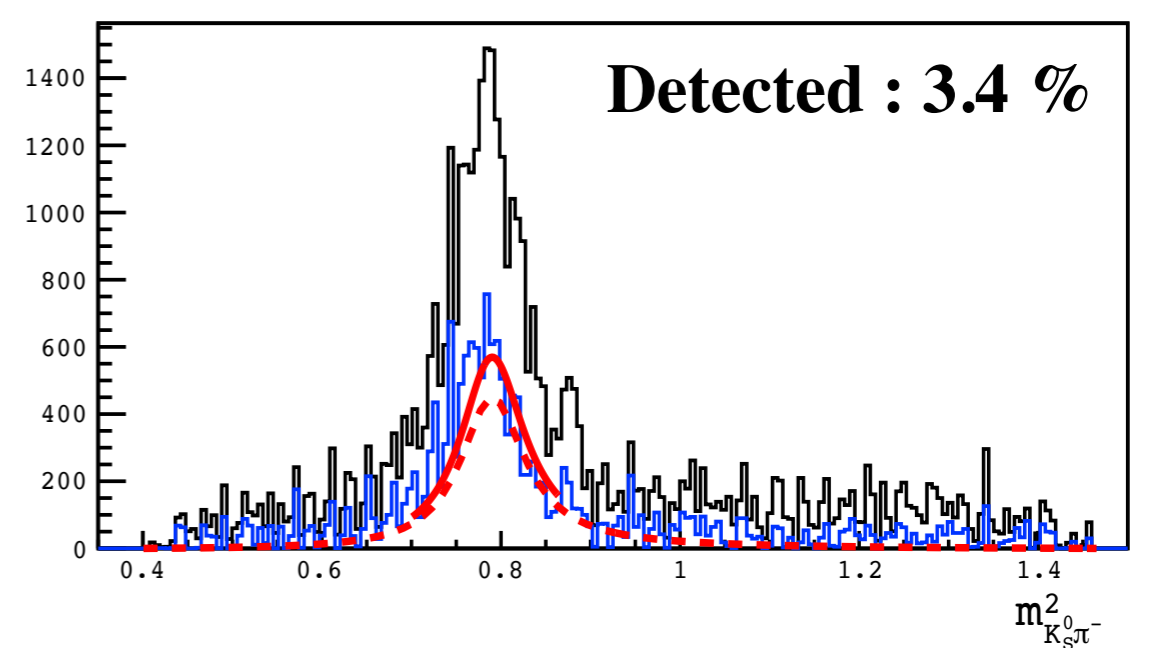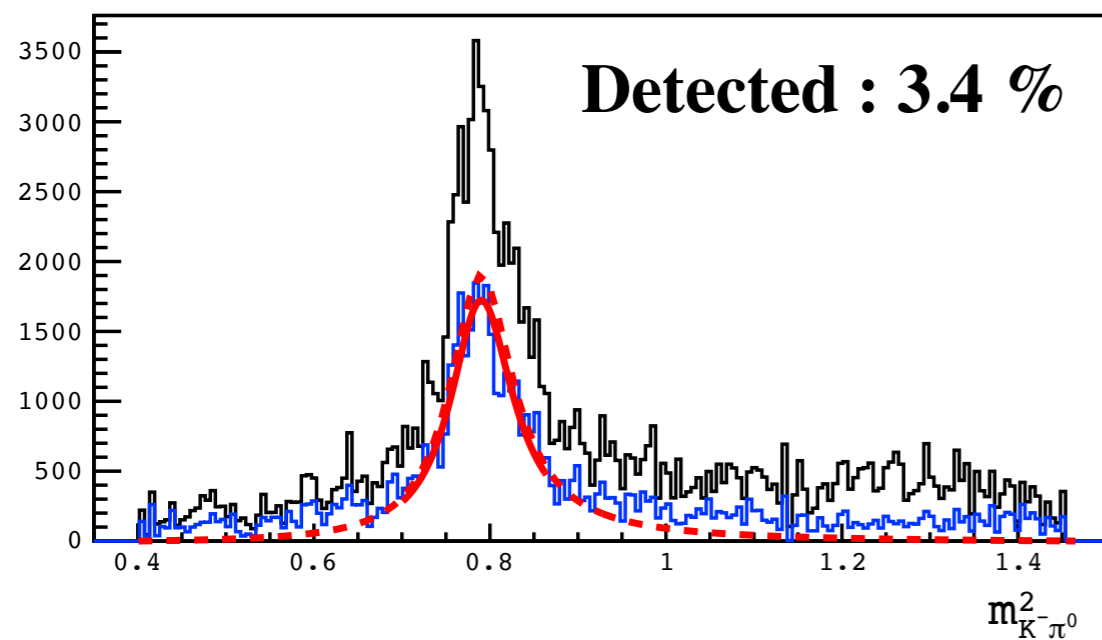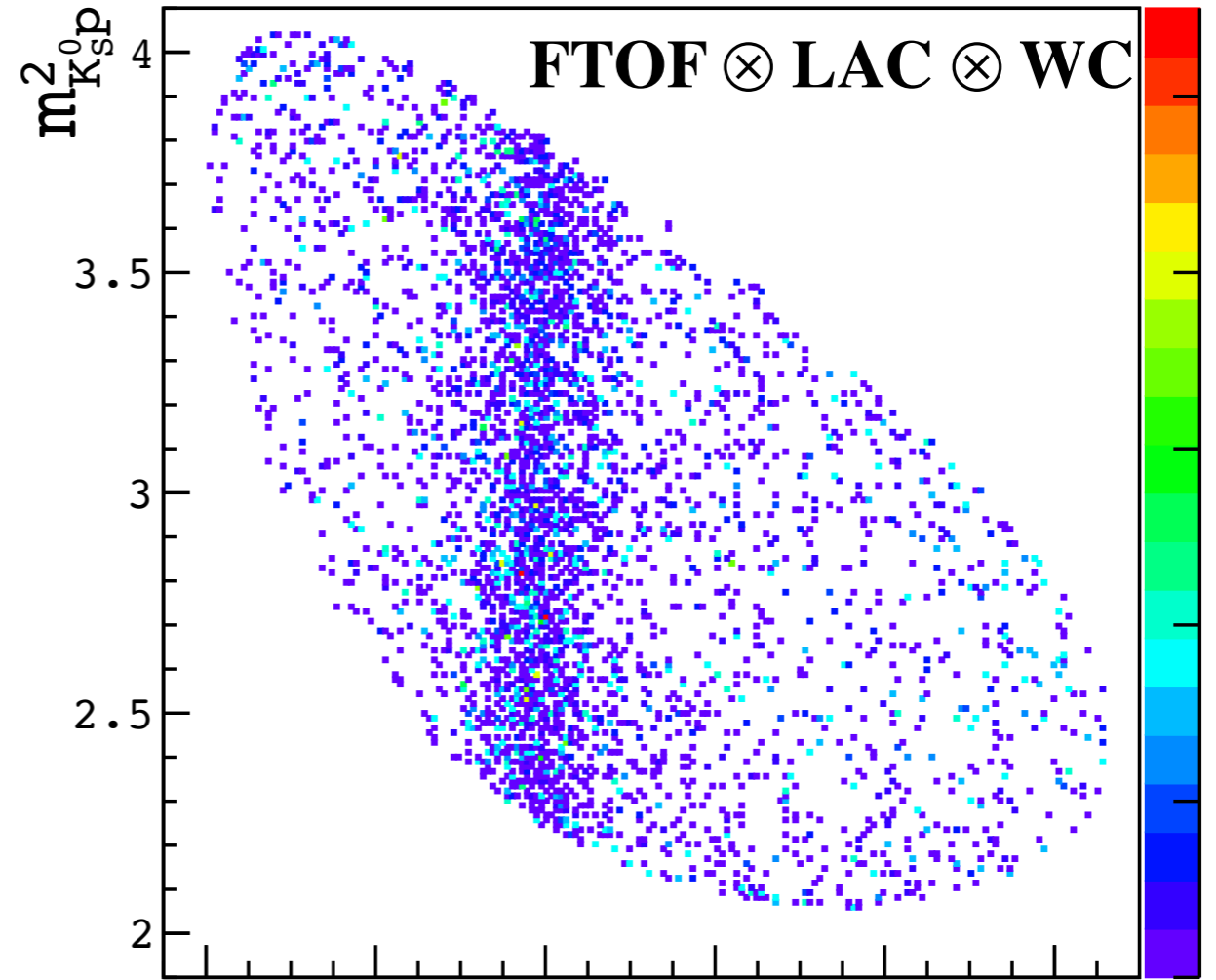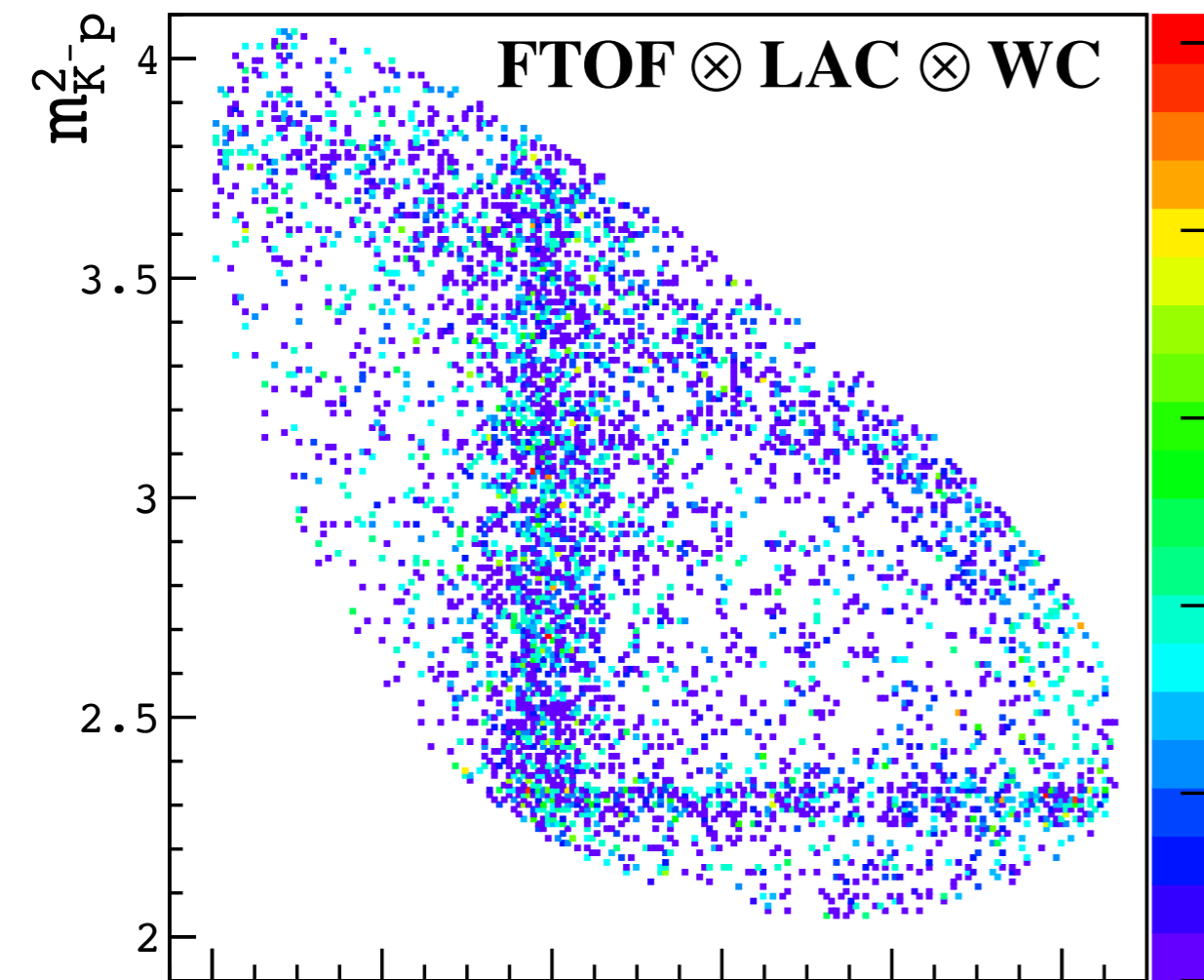
Yield Estimation

$$Y = F_{K^-} \times n_{target} \times d\sigma$$

E42 Beam Flux : 120k /s

K*(892) induced
Total Cross Section : 2.252 mb

Estimated K*(892) Yield

- **Diamond Target :** $\sim 8.2M$ / day

$$K^-p \rightarrow K*(892)p \rightarrow K^-p\pi^0 \quad : \sim \textbf{3M / day}$$

$$K^-p \rightarrow K*(892)p \rightarrow K^0_S p\pi^- \quad : \sim \textbf{5M / day}$$

- **$\sim 100k/day$ K*(892) can be detected via $K^-p \rightarrow K^-p\pi^0$**

- **$\sim 170k/day$ K*(892) can be detected via $K^-p \rightarrow K^0_S p\pi^-$**

Summary

- Water Cherenkov detector is developed for J-PARC E42 in order to separate protons and kaons in online trigger.

- WC was tested by irradiating 460 MeV e+ beam at ELPH and confirmed good performance of WC and the mixer logic
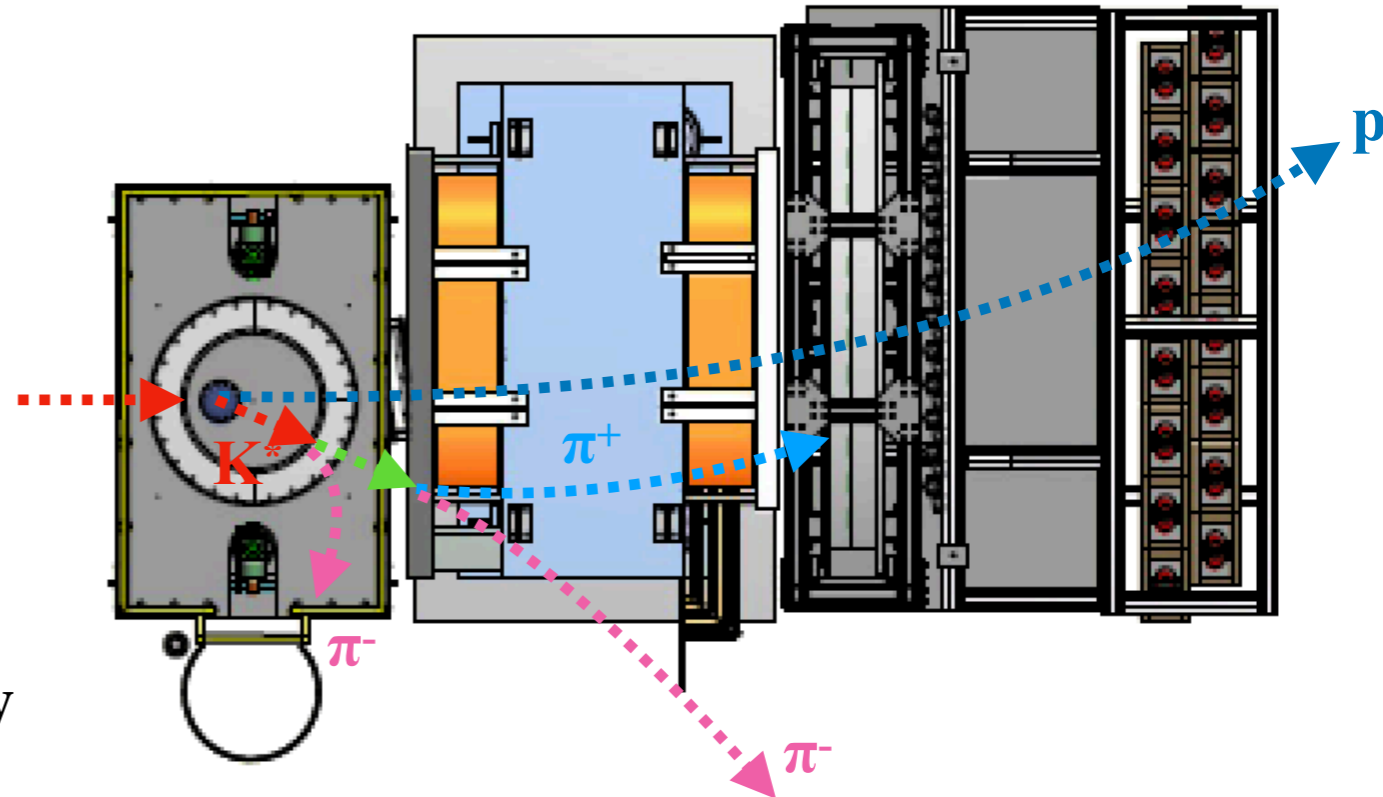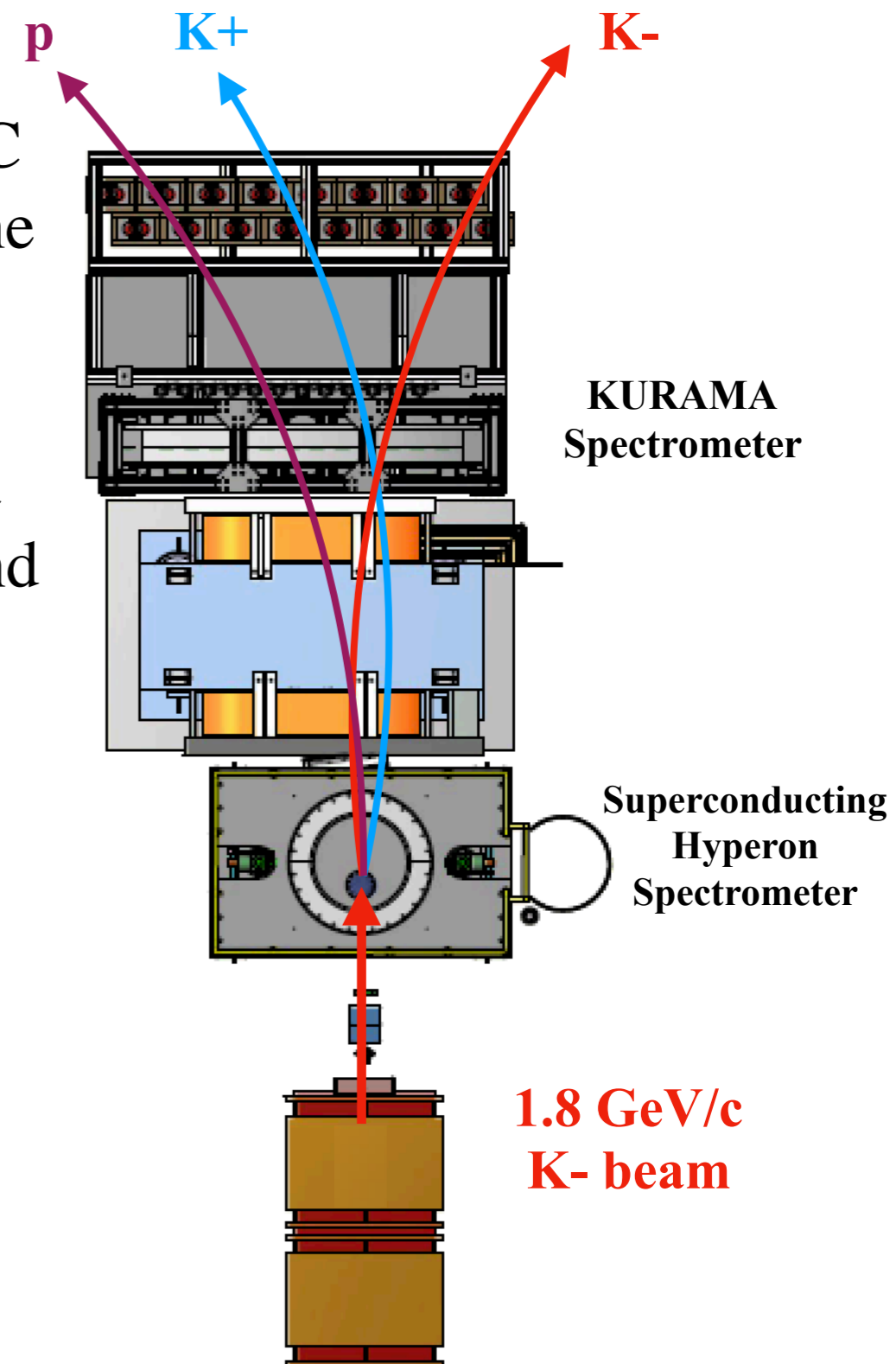
- **~ 6.8k/day** K*(892) events can be obtained at current beam intensity according to preliminary yield estimation results

- WC is in mass-production and 1.8 GeV/c K- beam test is scheduled in Nov. 2020 at J-PARC

p   K+   K-

KURAMA Spectrometer

Superconducting Hyperon Spectrometer

1.8 GeV/c K- beam

Back Up

Prototype WC Cosmic Ray Test
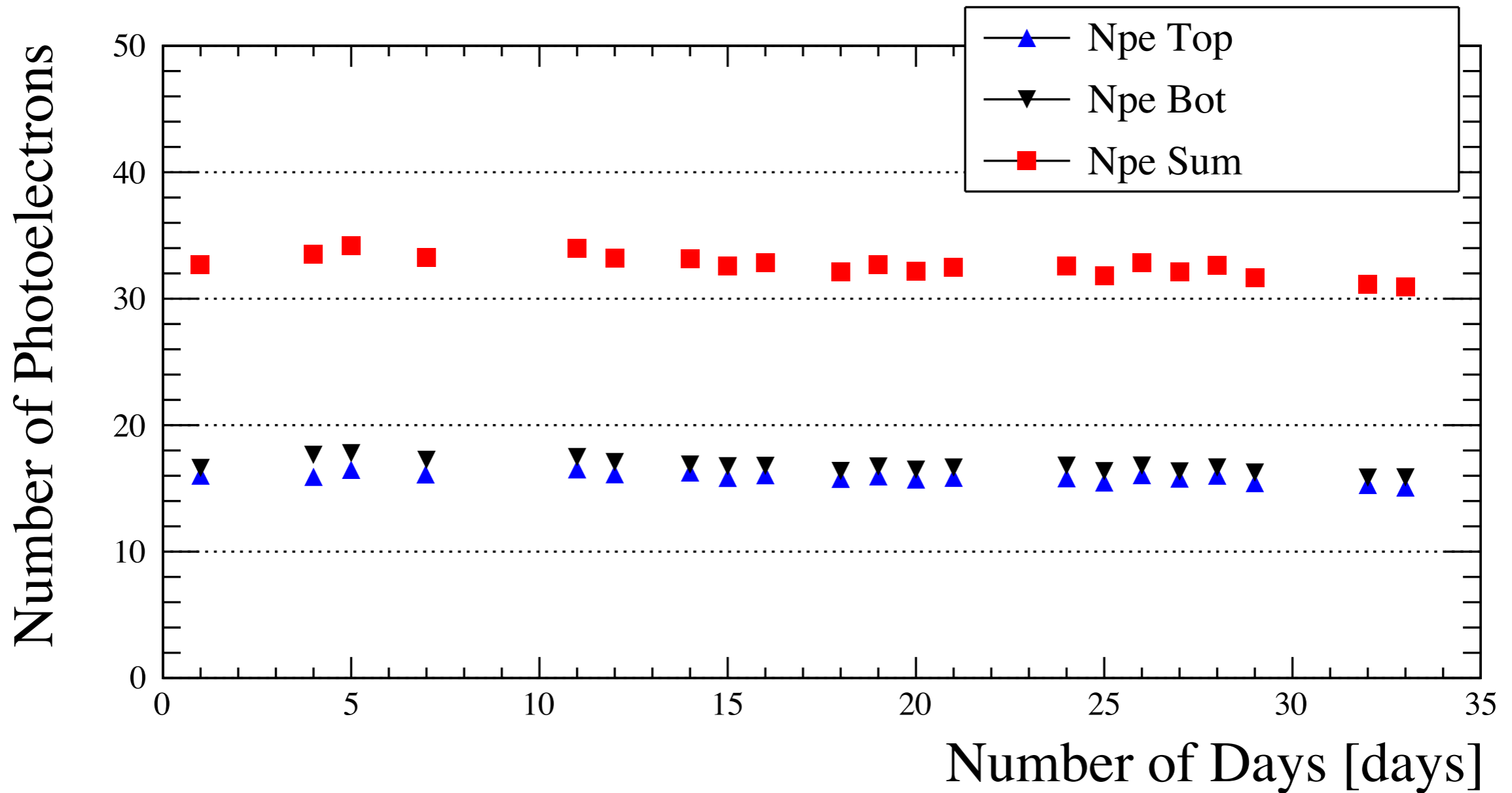
- Npe of each channel were monitored during 35 days, corresponds to the requested beam time of E42
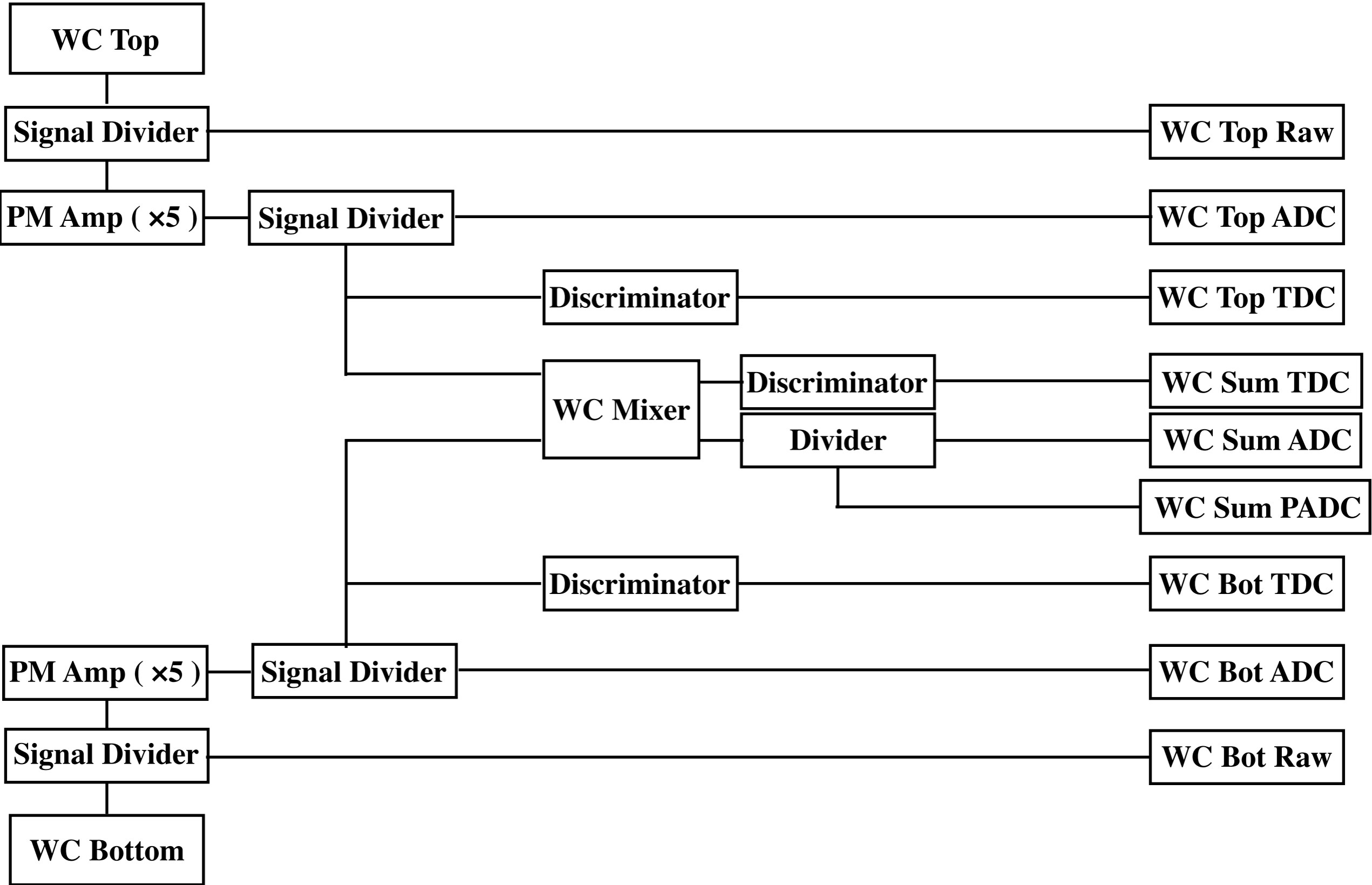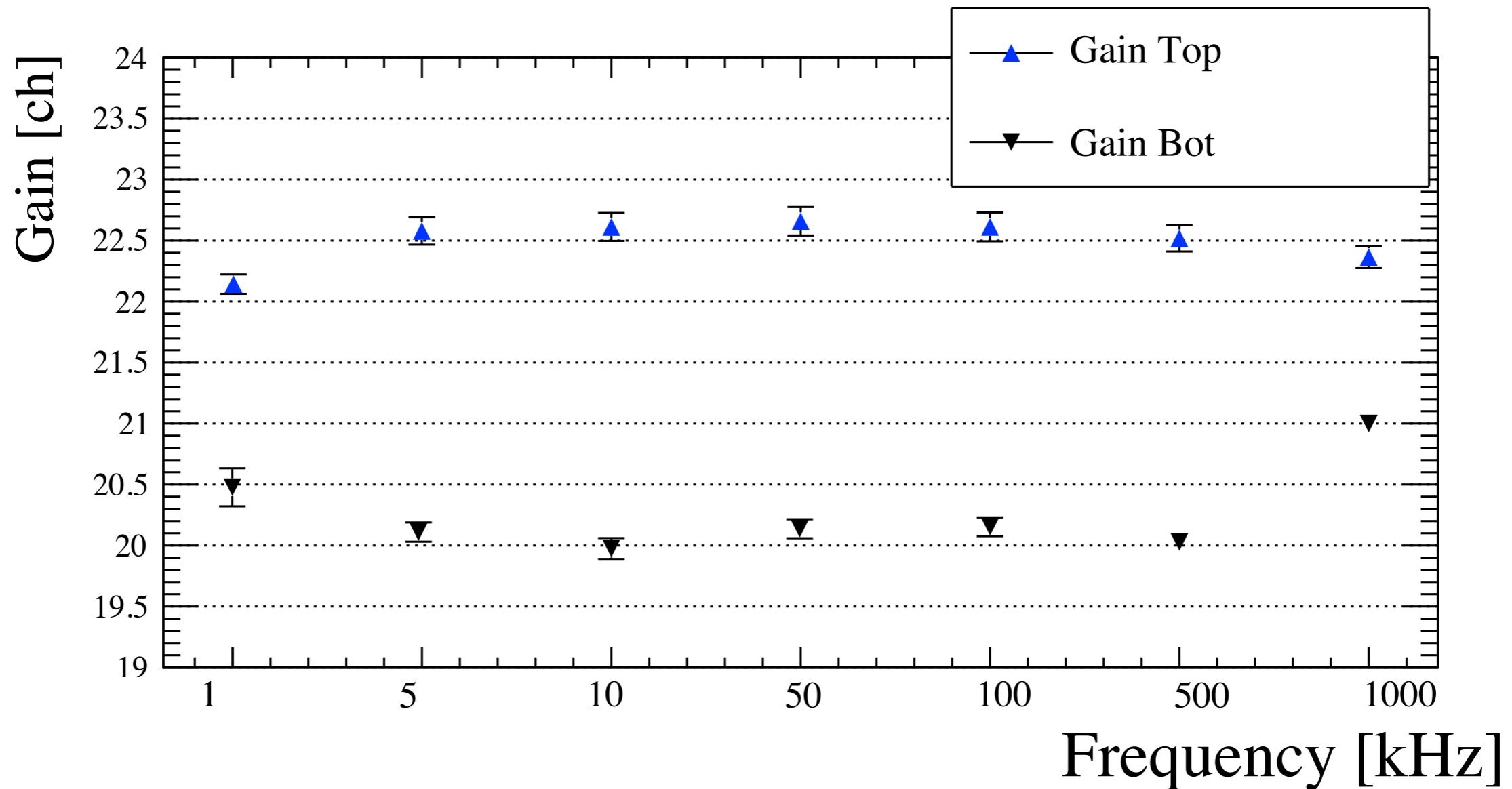
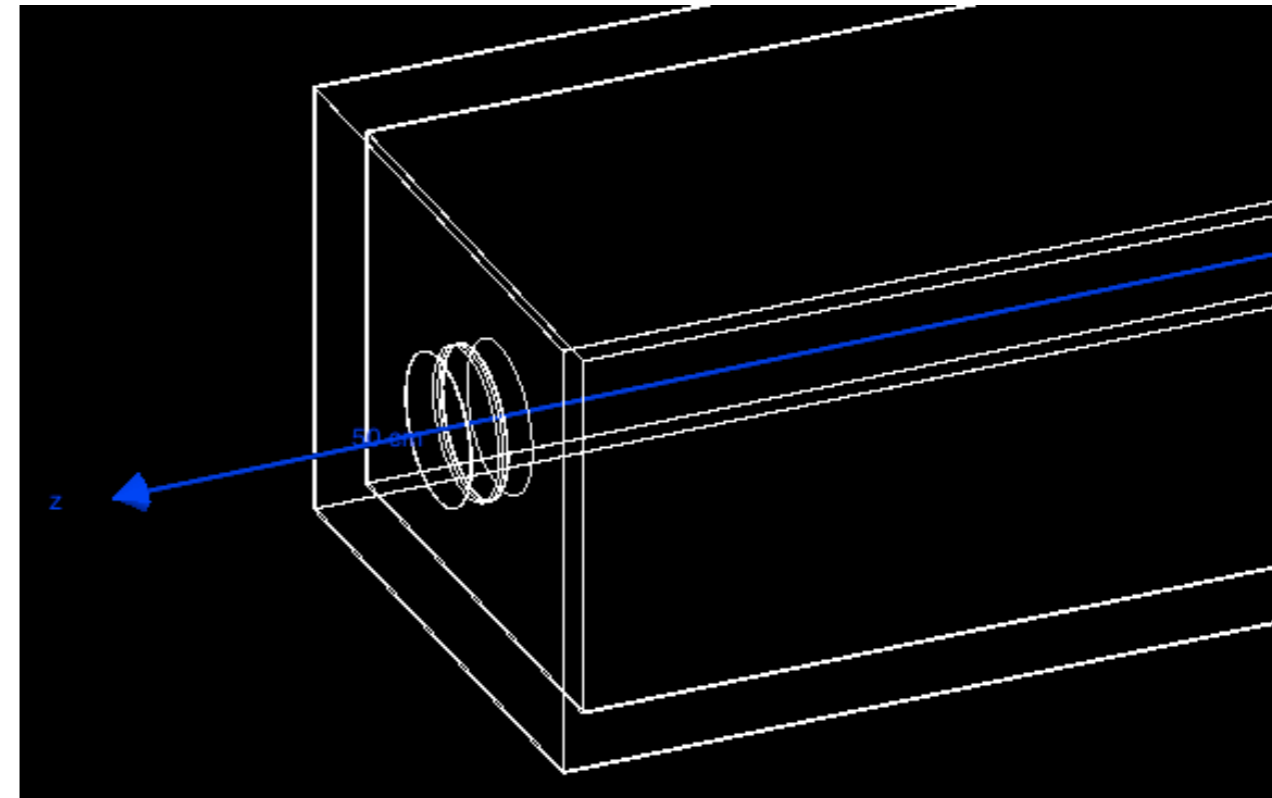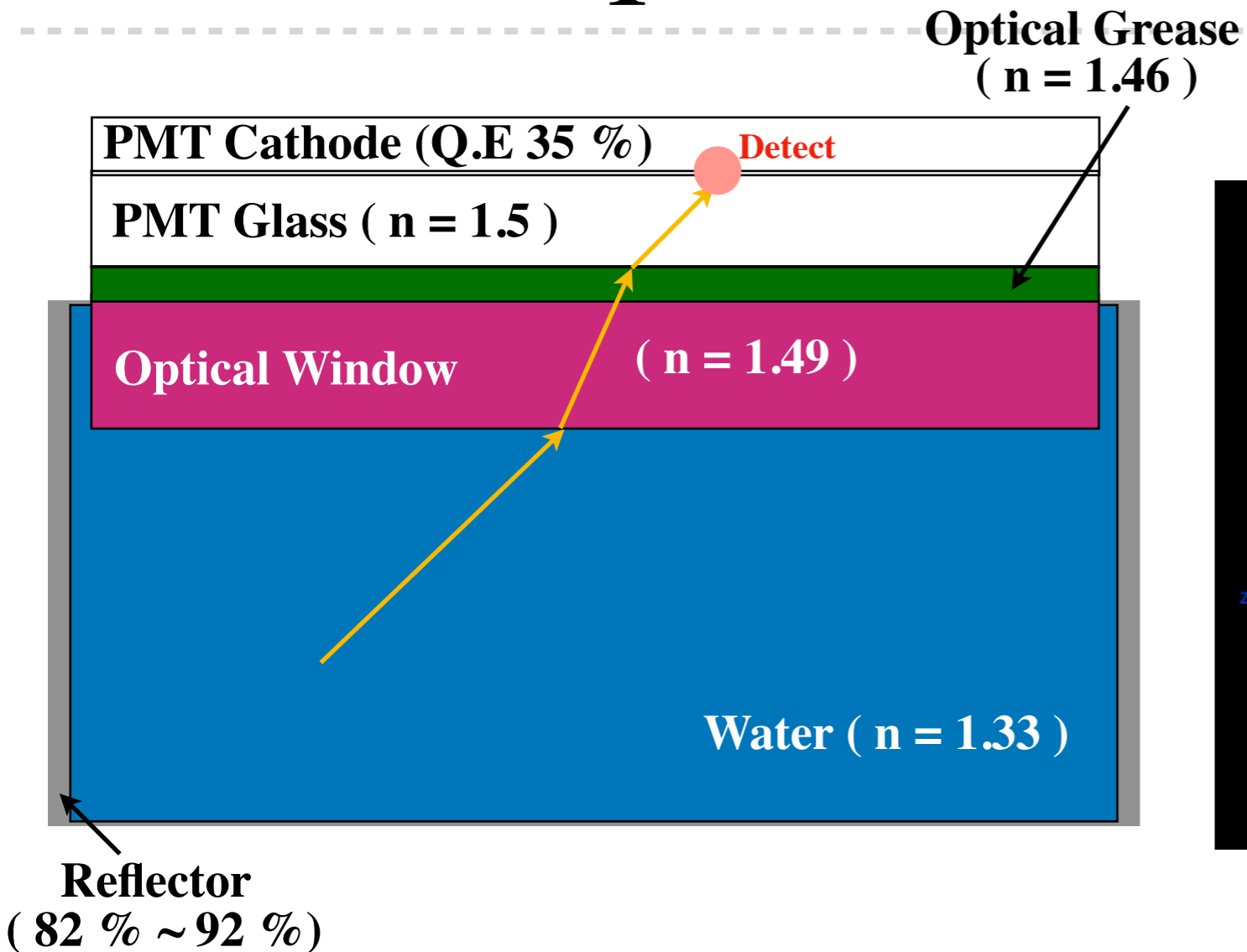# ELPH Beam Test Electronics

PMT Gain Measurement

- Gain of PMT was scanned by LED light source to figure out its stability, by differing the LED driving frequency from 1kHz to 1MHz

- Each gain was set as **22.3** and **20.6**, respectively

Geant4 Optical Simulation

Optical Grease
(n = 1.46)

PMT Cathode (Q.E 35 %)   **Detect**

PMT Glass (n = 1.5)

Optical Window   **(n = 1.49)**

Water (n = 1.33)

Reflector
(82 % ~ 92 %)

- Main Parameter : Reflectivity of diffusive reflector, set as from **92 %** to **98 %**

- PMT cathode as a sensitive detector

- **Hit and Miss method**
  Generated random number > QE value : Counts the photon