DEVELOPMENT OF A WAVEFORM-BASED CHARGED-PARTICLE COUNTING METHOD WITH A PLASTIC SCINTILLATOR AND A PMT

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Self-Introduction

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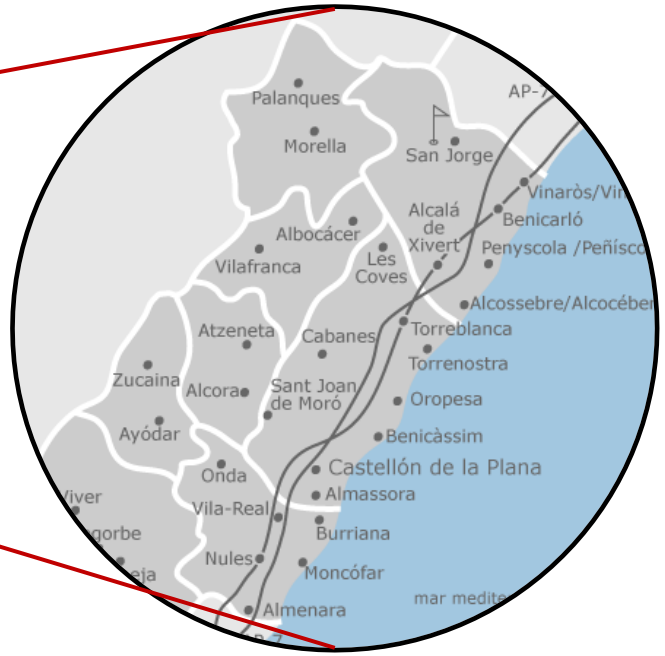


Self-Introduction

Universitat de València

Double Degree in Physics and Chemistry

IFIC Summer Student Programme:
IRIS Group

Universidad Francisco de Vitoria

Studies related to Philosophy, Literature, Anthropology and other disciplines

KEK SSP: Experiment and Goal

- **Experiment:** g-2.
  - **H2 Area:** Ultra slow muon production and reacceleration.

- **Goal:** measurement of the surface muon beam property, specially its polarisation and momentum districution.
  - Understand the detector's response to treat the data taken in April.

- **Measurement Principles:**

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

Most likely emitted in the muon spin axis

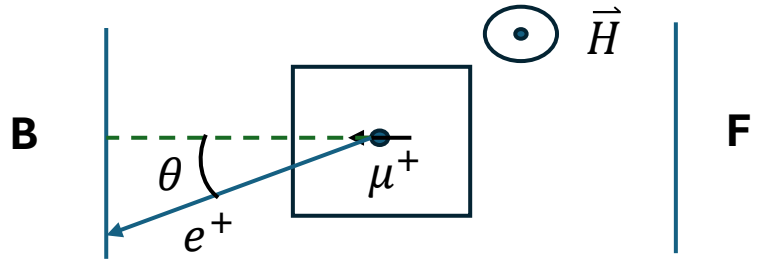


Figure 1. Scheme of the setup for measuring the assymetry.

KEK SSP: The Detector

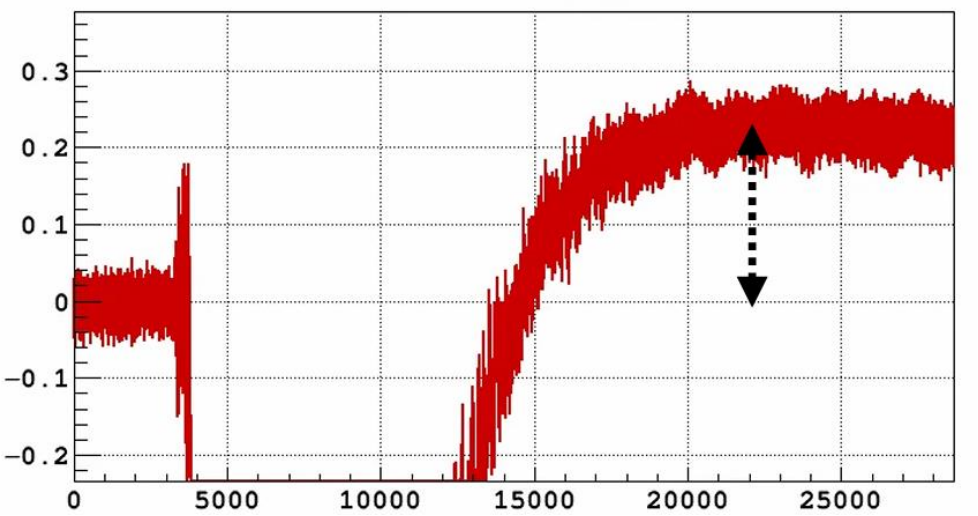


Figure 2. Distorsion of the PMT output.

$$I(t) = \frac{A}{RC} exp\left[\frac{-(t-t_0)}{RC}\right]$$

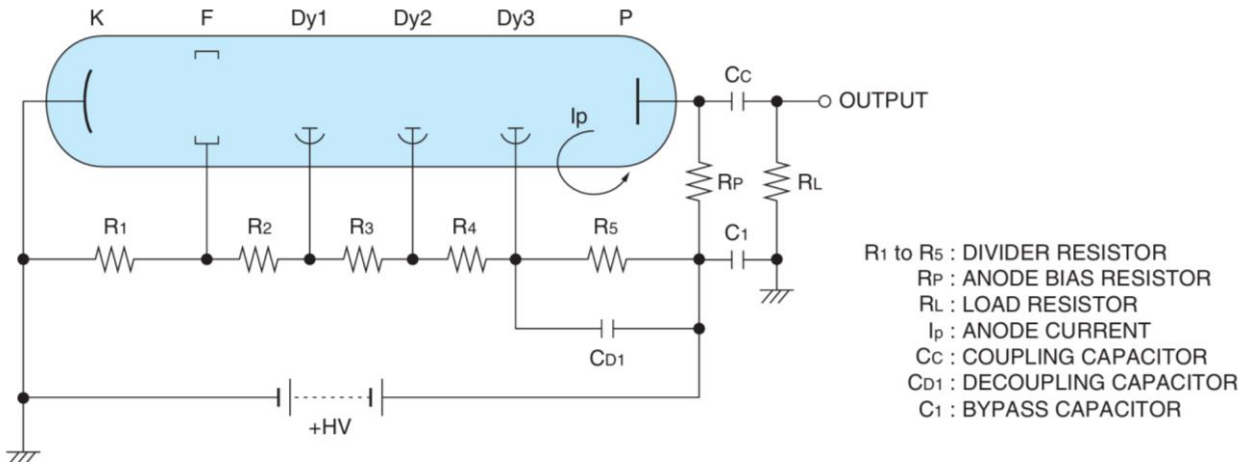


Figure 3. Hamamatsu Photonics K.K. (2017). *Photomultiplier tubes: Basics and applications* (4th ed., p. 87, fig. 5-4, "Voltage-divider circuit with grounded cathode"). Hamamatsu Photonics K.K.

KEK SSP: Simulation of the PMT Output

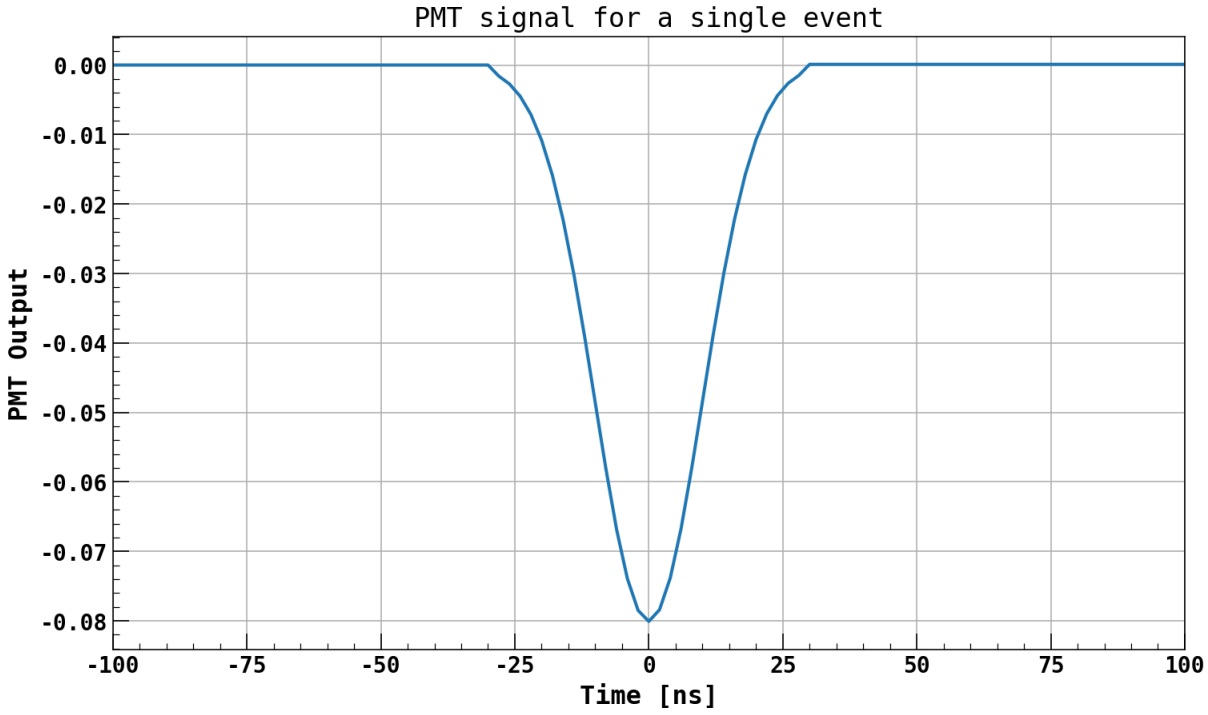


Figure 4. Simulated output for a single event.

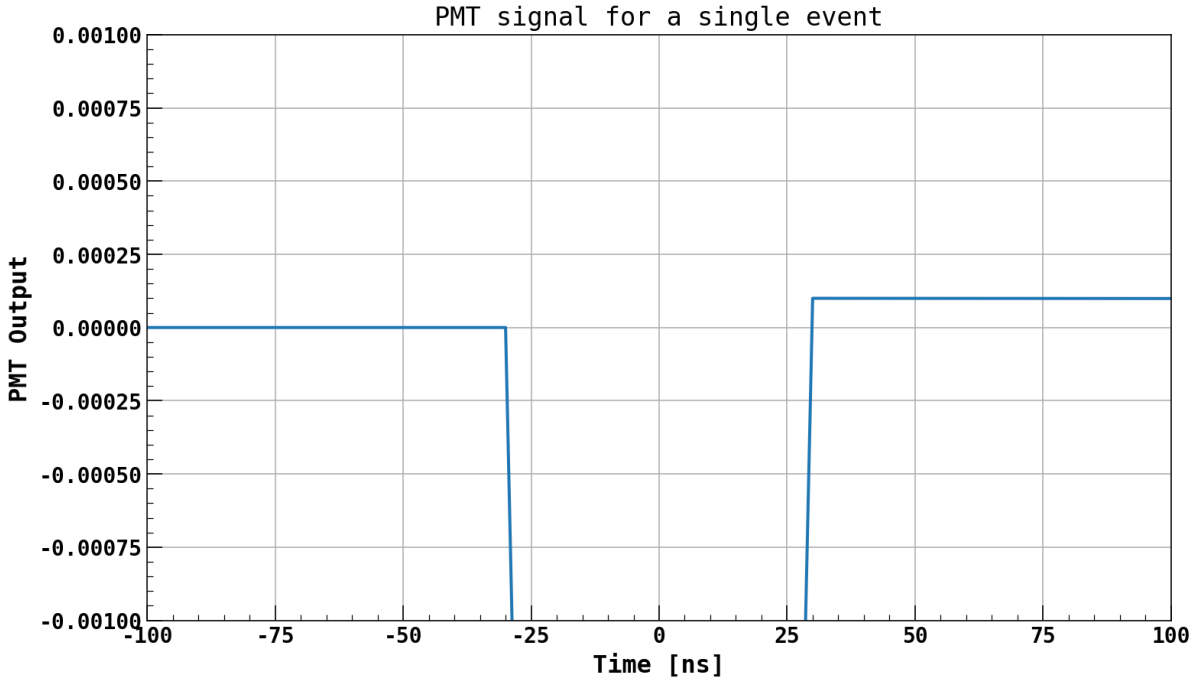
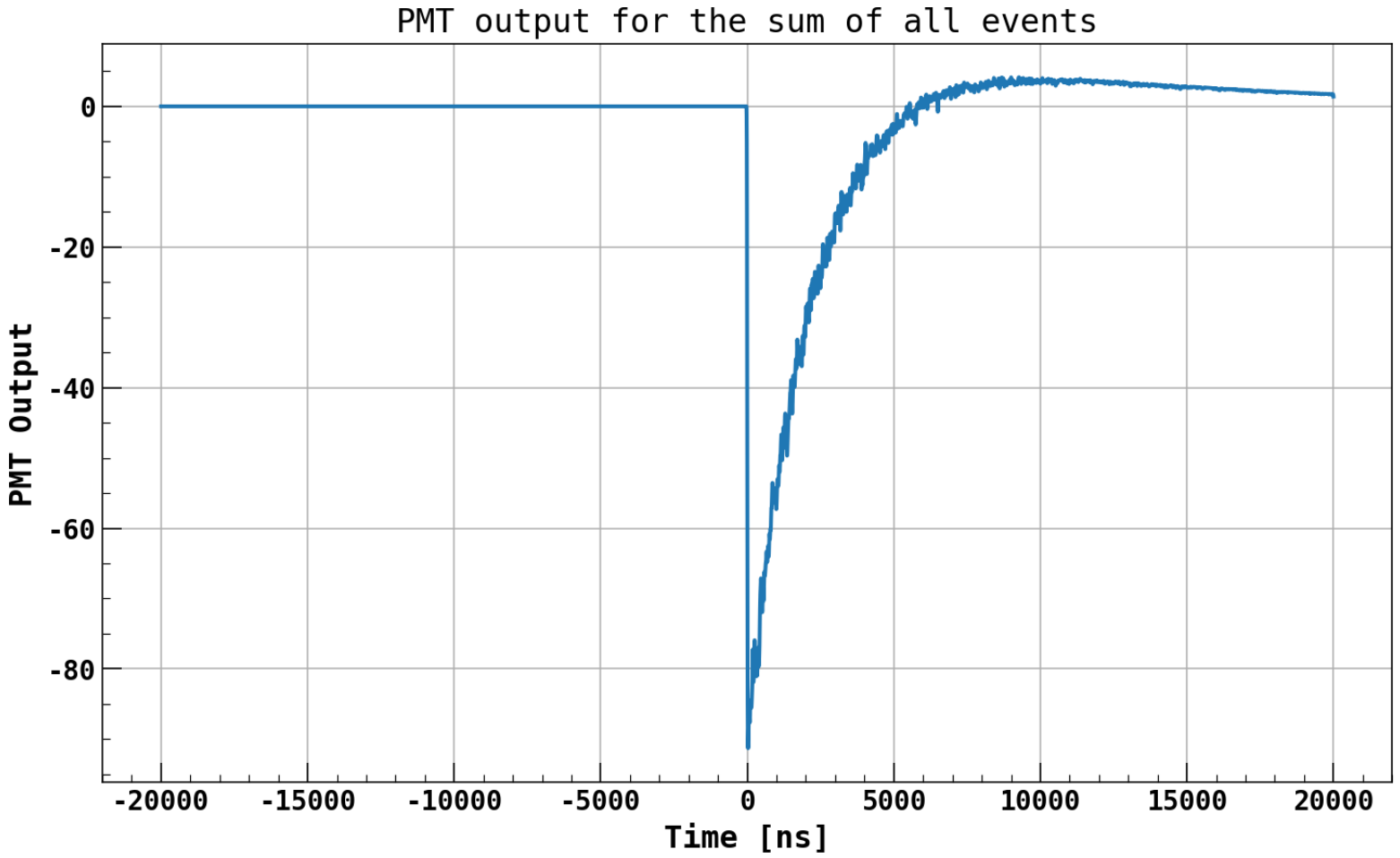


Figure 5. Zoomed-in simulated output for a single event.

KEK SSP: Simulation of the PMT Output

Figure 6. Simulated output for a beam with 10^5 muons.



KEK SSP: Simulation of the muon precession phenomena

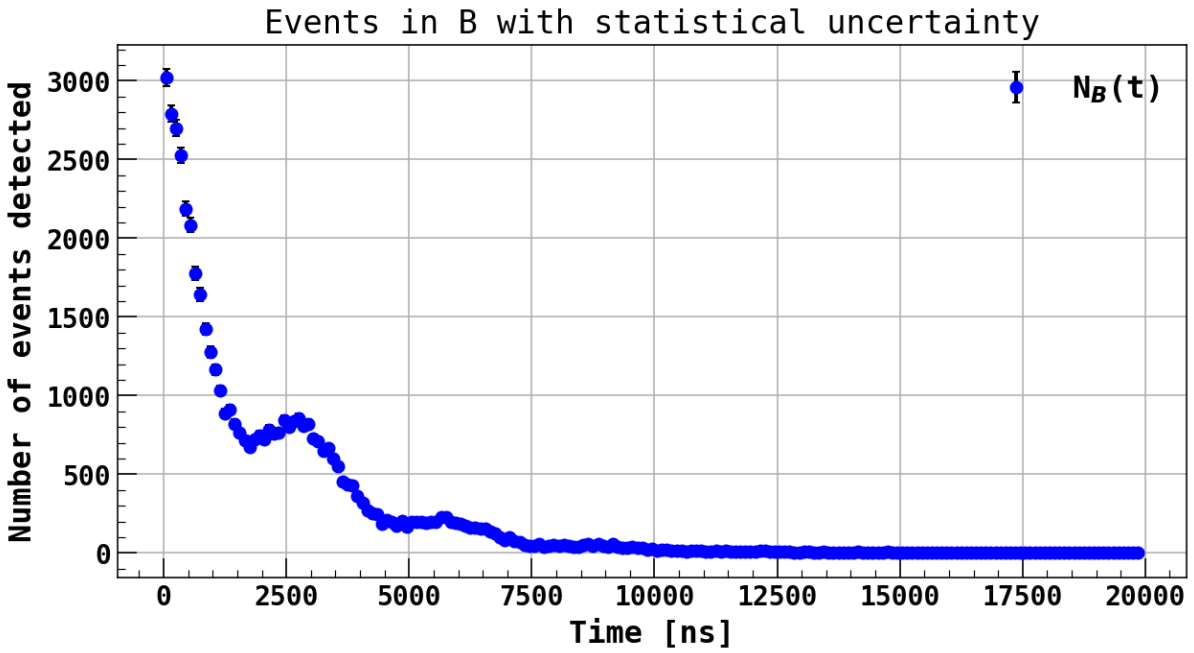


Figure 7. Simulated events detected by B with its statistical uncertainties.

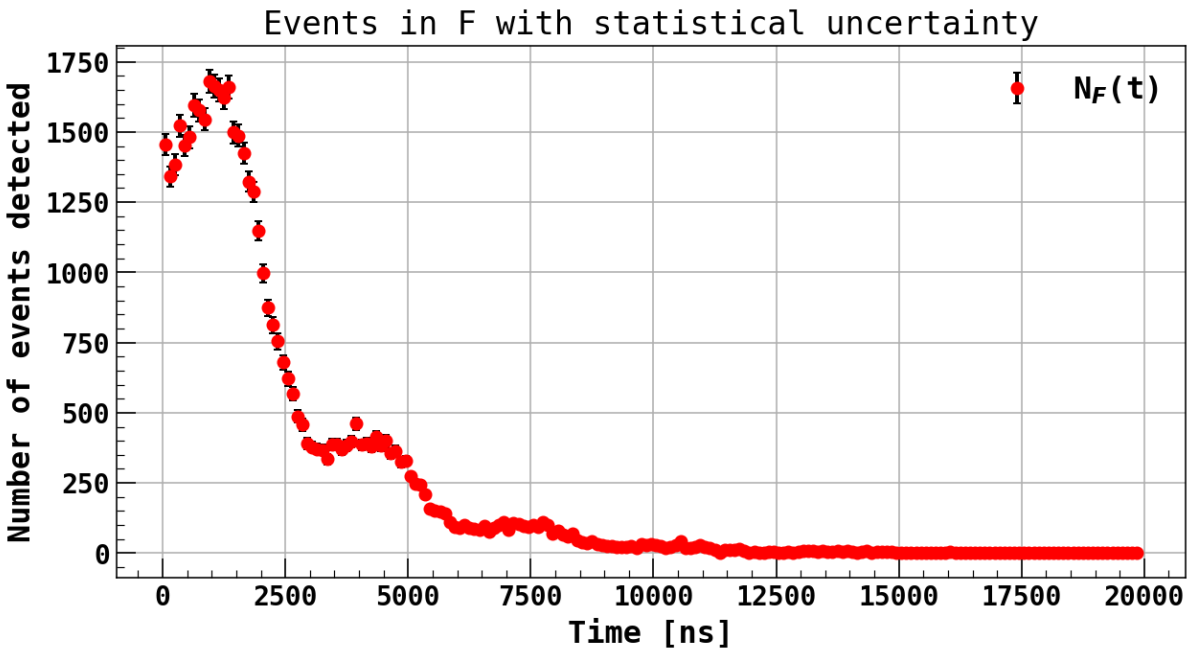


Figure 8. Simulated events detected by F with its statistical uncertainties.

KEK SSP: Simulation of the PMT Output

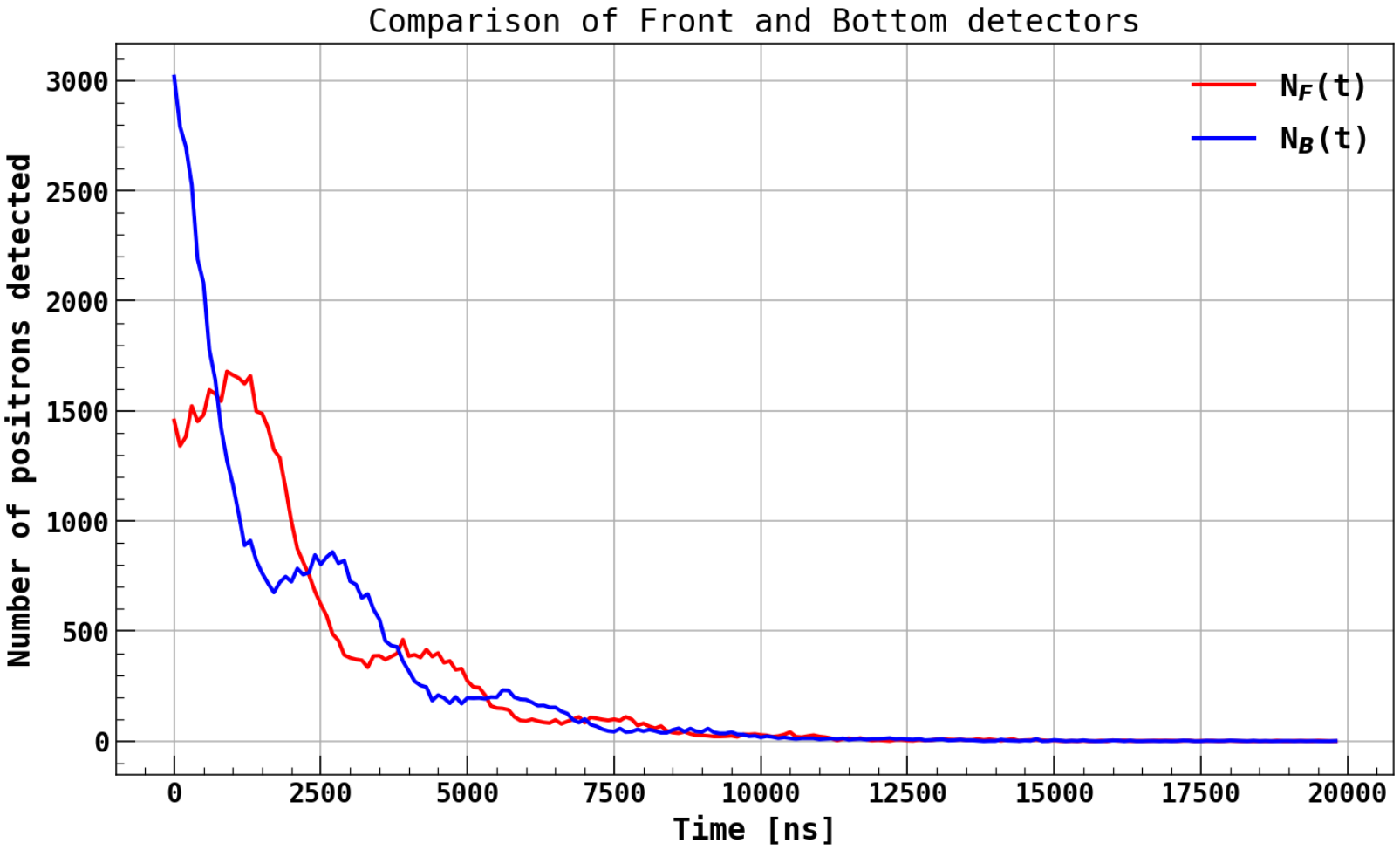


Figure 9. Comparison of the number of events detected by each detector as a function of time.

KEK SSP: Simulated Asymmetry Plot

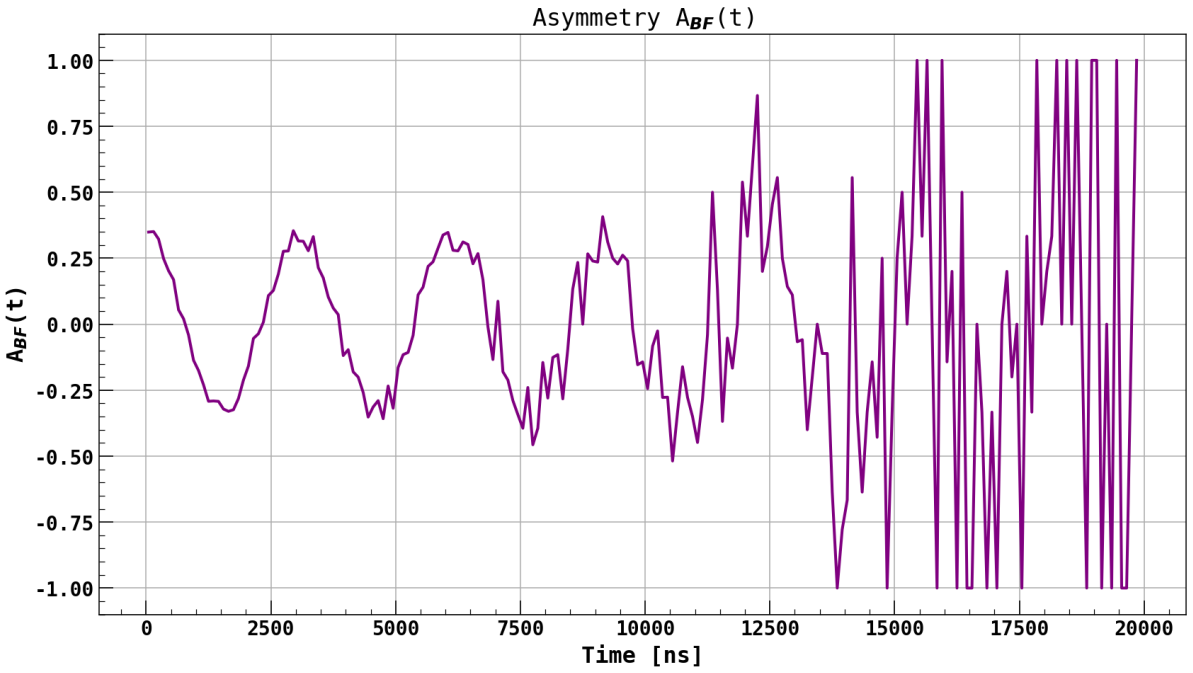


Figure 10. Simulated asymmetry between B and F for $\alpha_{bal} = 1$.

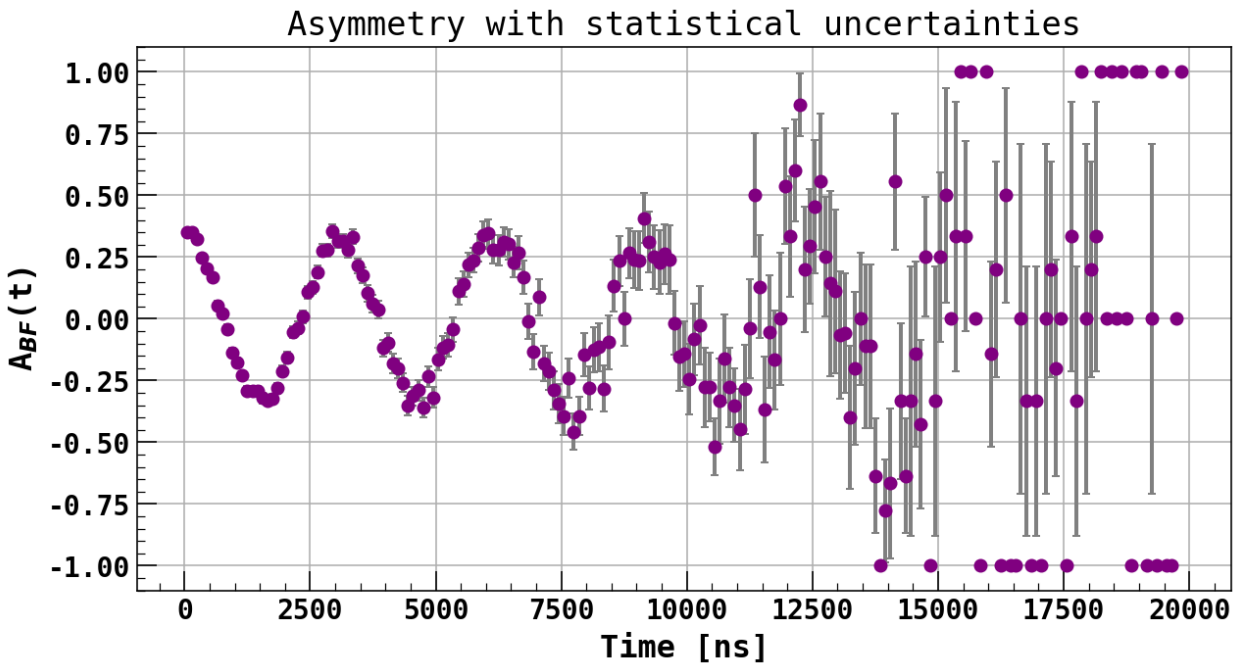
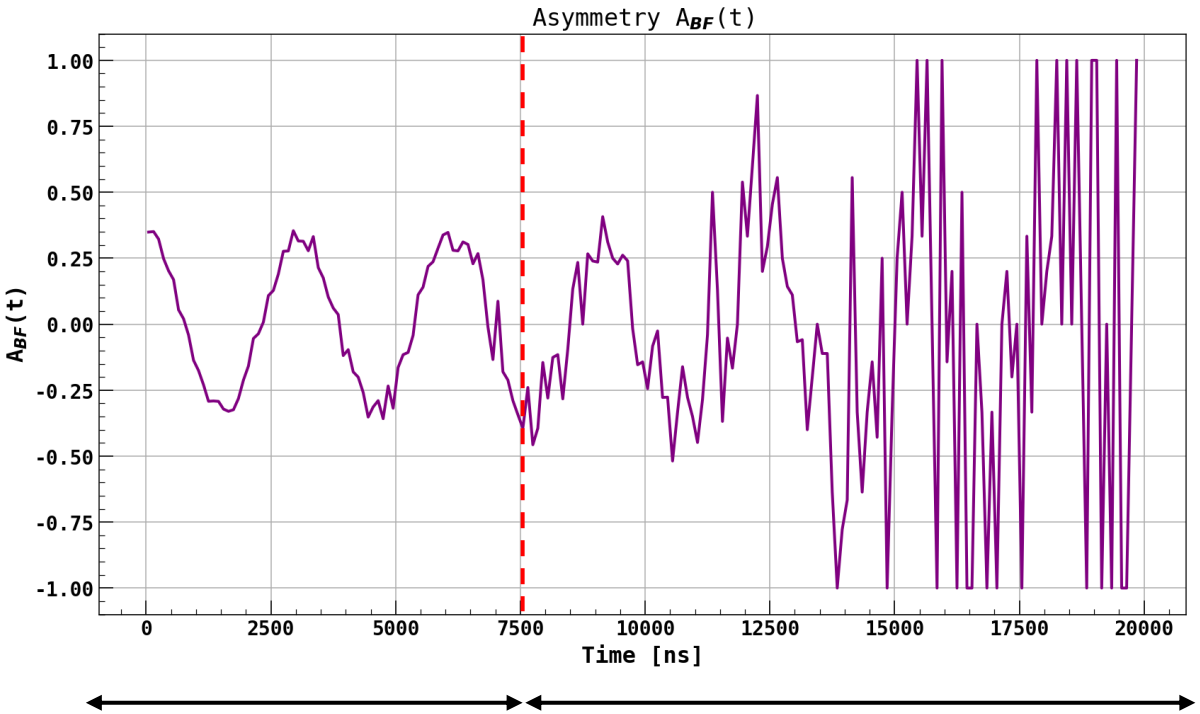


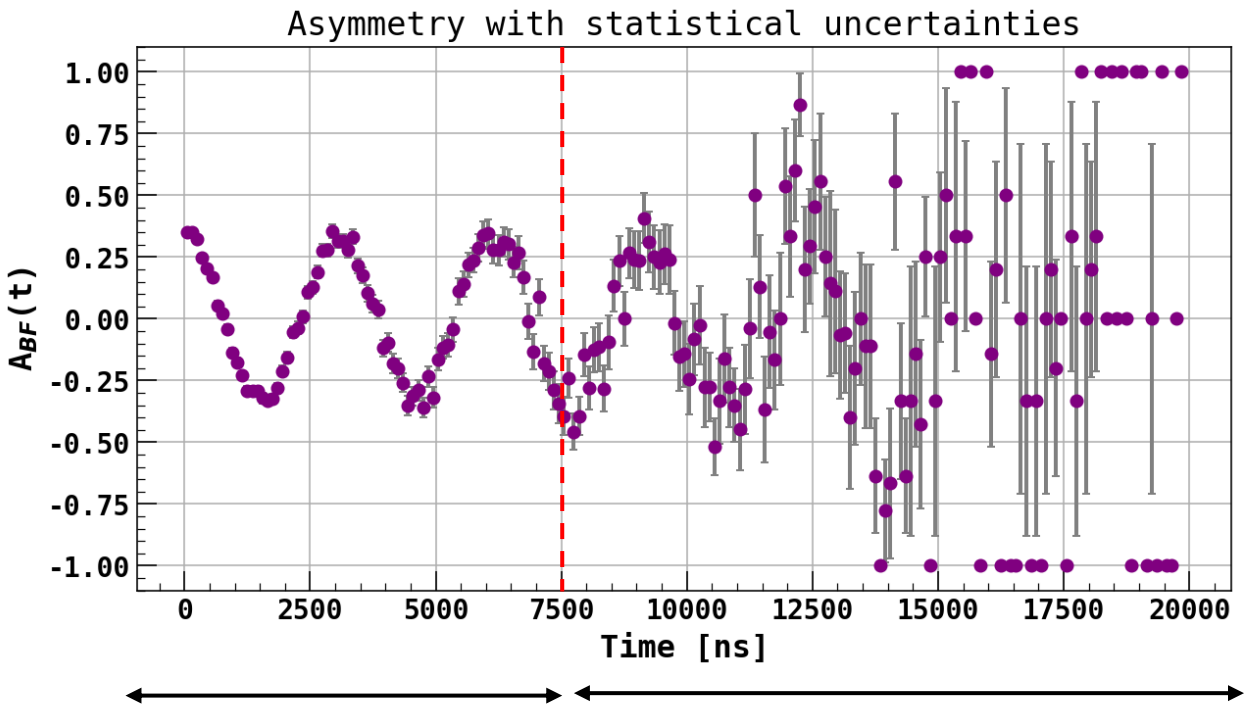
Figure 11. Statistical uncertaintity of each point of the asymmetry plot.

$$A_{BF} = \frac{N_B - \alpha_{bal} N_F}{N_B + \alpha_{bal} N_F} \rightarrow \sigma_{A_{BF}} = \frac{2\alpha_{bal}}{(N_B + \alpha_{bal} N_F)^2} \sqrt{N_F N_B (N_F + N_B)}$$

KEK SSP: Simulated Asymmetry Plot



Reliable data Unreliable data



Reliable data Unreliable data

$$A_{BF} = \frac{N_B - \alpha_{bal} N_F}{N_B + \alpha_{bal} N_F} \rightarrow \sigma_{A_{BF}} = \frac{2\alpha_{bal}}{(N_B + \alpha_{bal} N_F)^2} \sqrt{N_F N_B (N_F + N_B)}$$

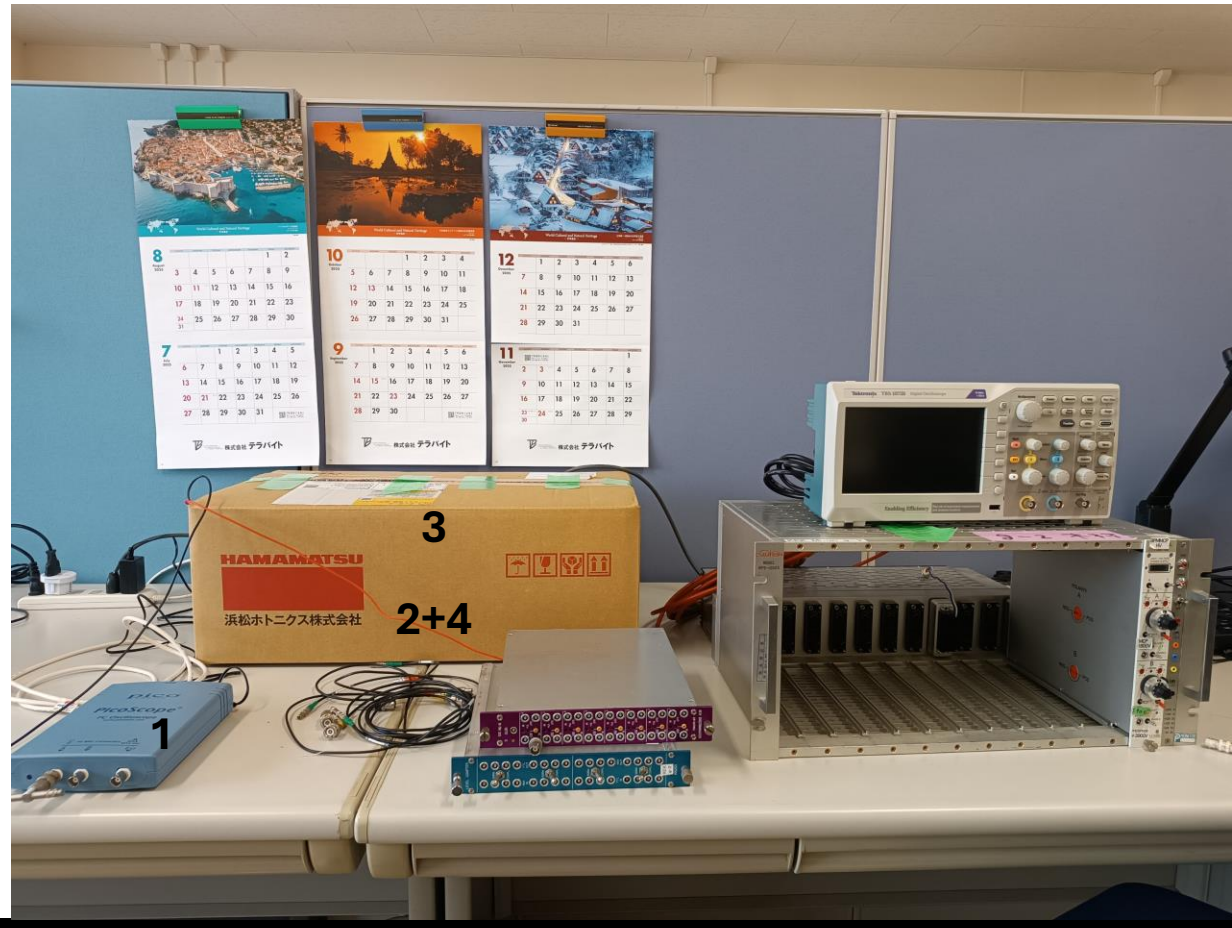
KEK SSP: Setup of the Plastic Scintillator + PMT

Material:

1. **PicoScope 3206**
2. **Nanosecond Pulsed Laser Diode System (NPL45B)**
3. **Black boxes**
4. **Plastic Scintillator + PMT**

❑ **Milestones:**

- ❑ Measure the number of events per unit of time and suface for different thresholds.
- ❑ Average the group of waveforms taken and observe the detector distortion of the right tails.
- ❑ Characterise the distorsion signal and learn how to correct it using a laser.



KEK SSP: Characterisation of the detector

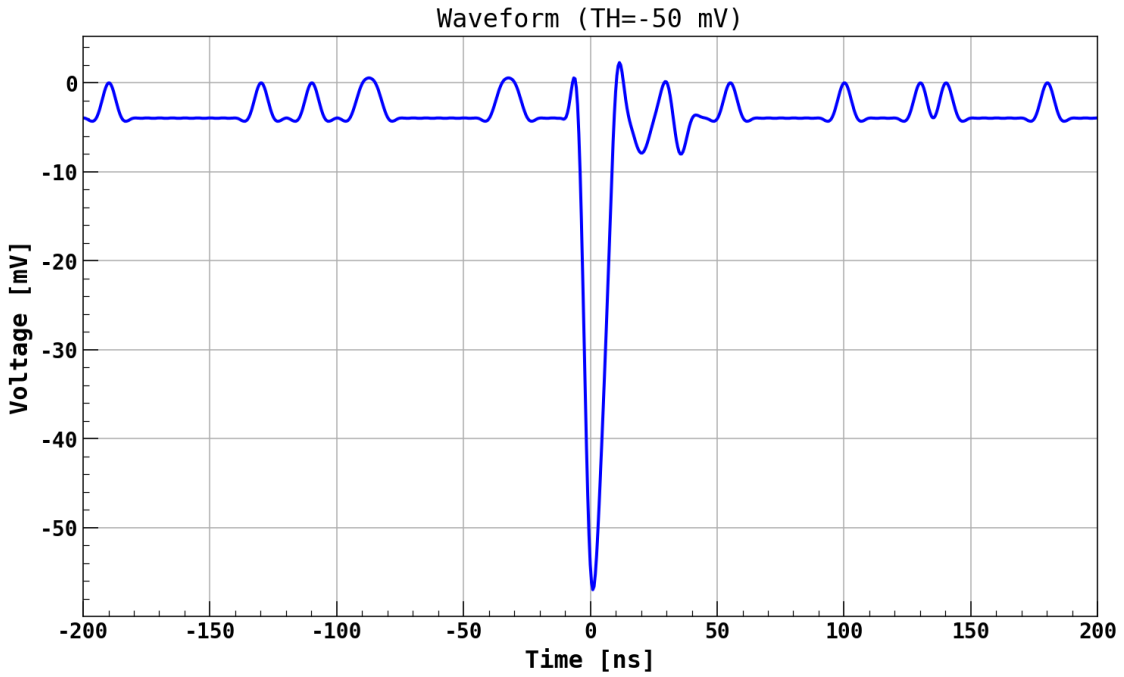


Figure 12. Experimental data for the detection of 1 muon in cosmic rays.

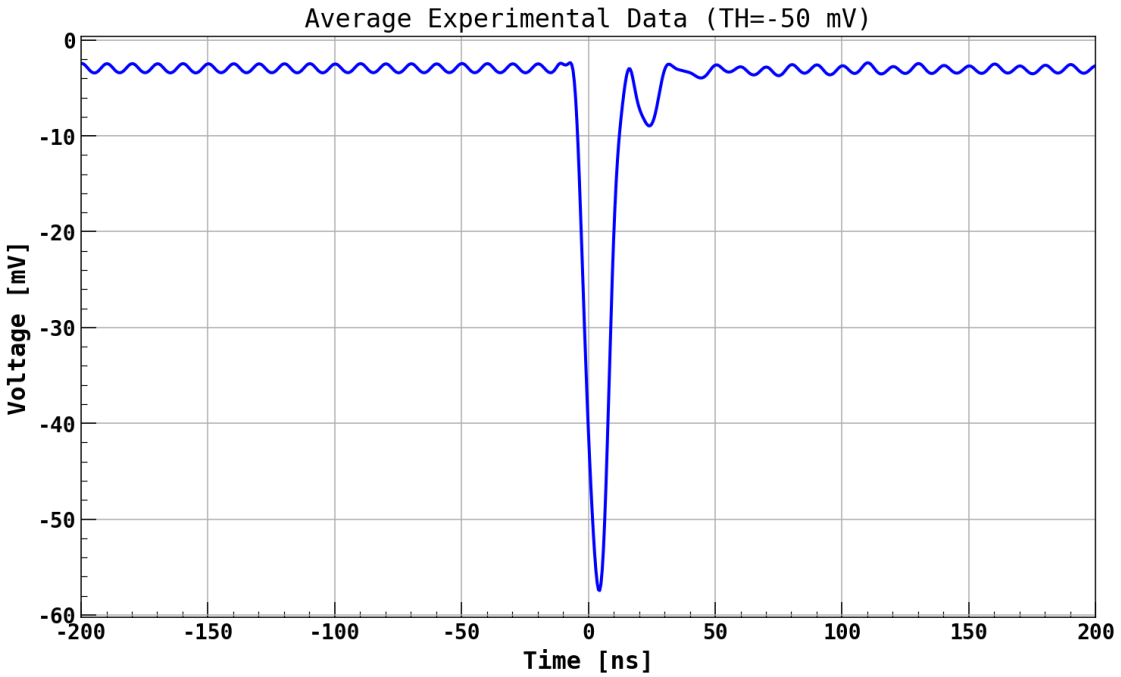


Figure 13. Average of the experimental data (10^4 waveforms).

KEK SSP: Characterisation of the detector

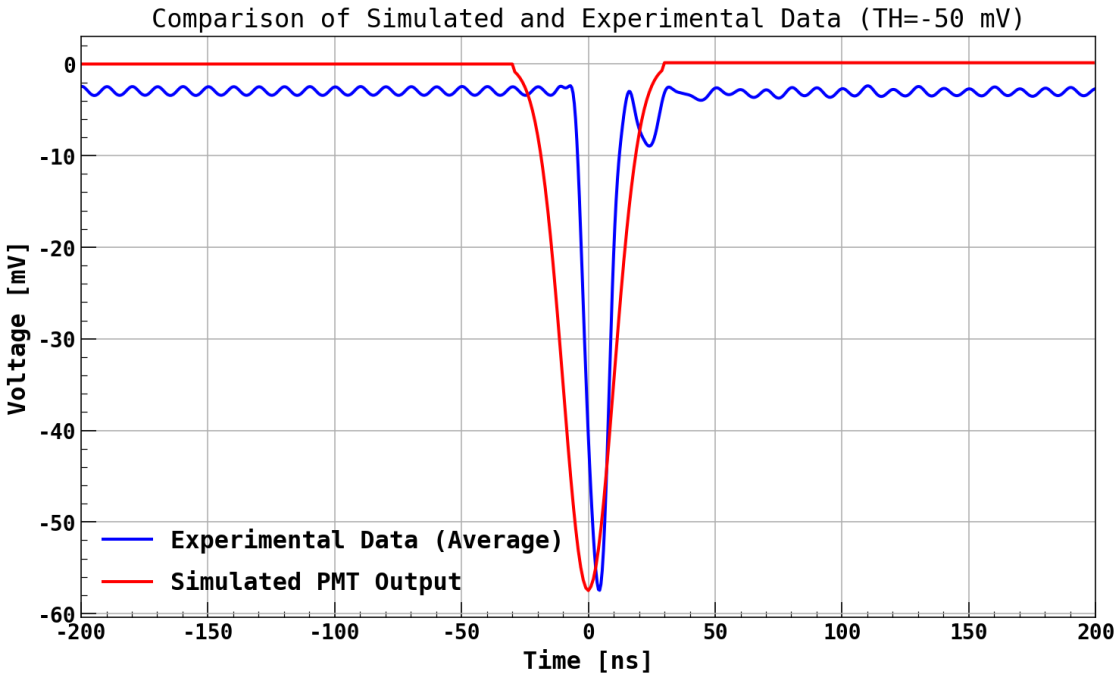


Figure 14. Comparison of the average of the waveforms and the simulated output for a threshold of $-50\,mV$.

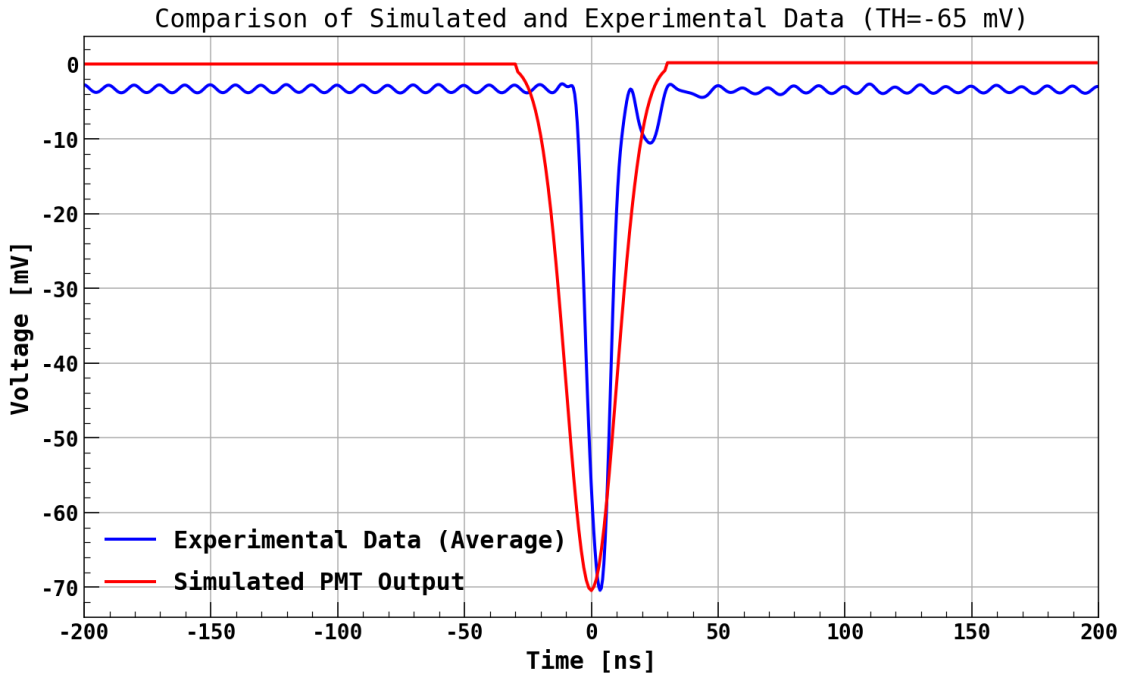


Figure 15. Comparison of the average of the waveforms and the simulated output for a threshold of $-65\,mV$.

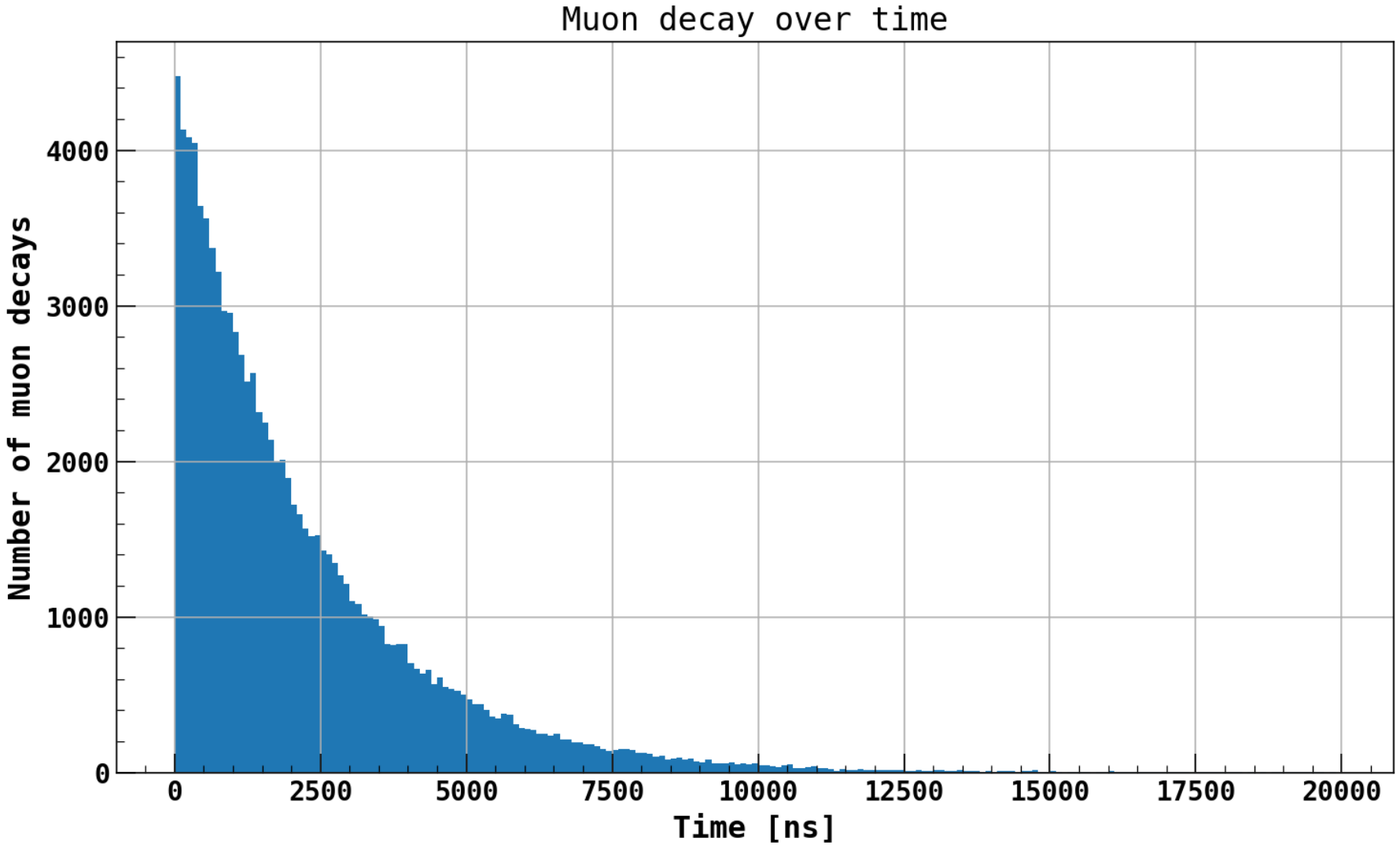
Thank you!

BACKUP

BACKUP: Probability Density Function

$$W(\theta) \; \alpha \; [1 + a_{as}(\varepsilon) \cos(\theta)]$$

BACKUP: Muon Decay Histogram



BACKUP: Transient Response for RC Circuit

The intensity output is an ideal pulse:

$$I(t) = A\delta(t - t_0) \longrightarrow Q = \int_{t_0}^{+\infty} I(t)dt = A$$

ODE:

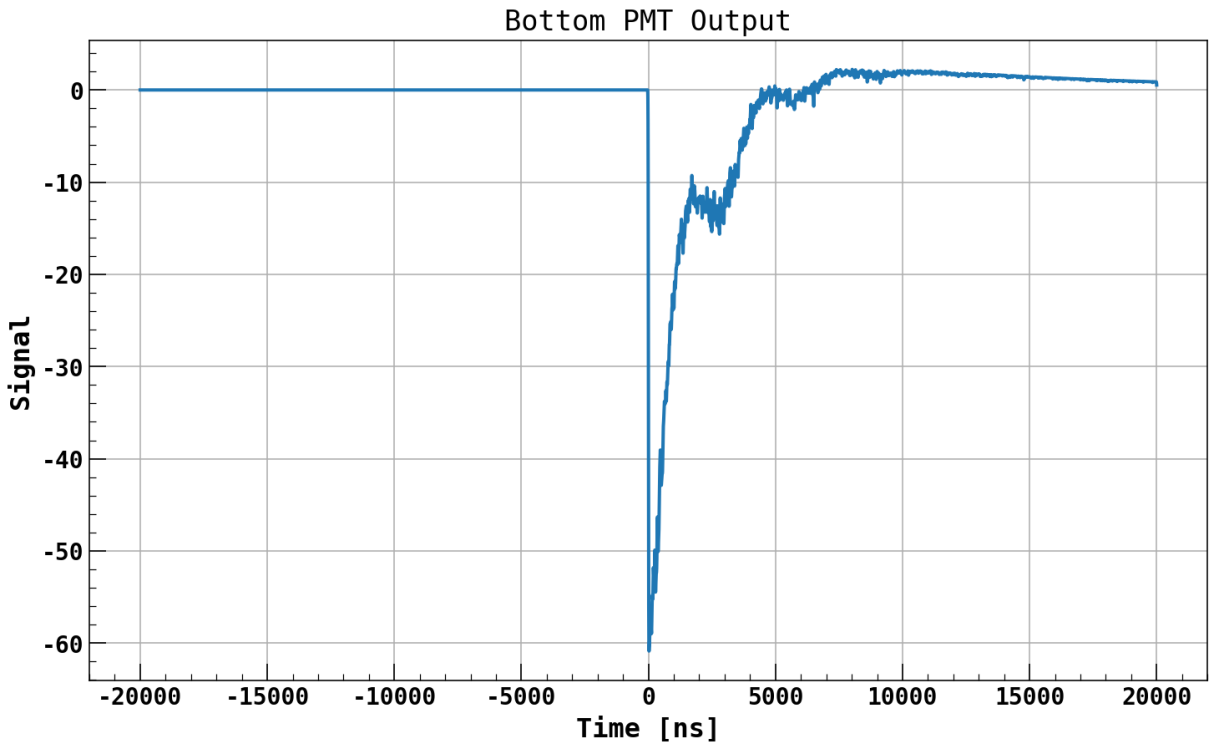
$$\frac{dV(t)}{dt} + \frac{1}{RC}V(t) = \frac{I(t)}{C} \longrightarrow I(t) = \frac{A}{RC}exp\left[\frac{-(t - t_0)}{RC}\right]$$

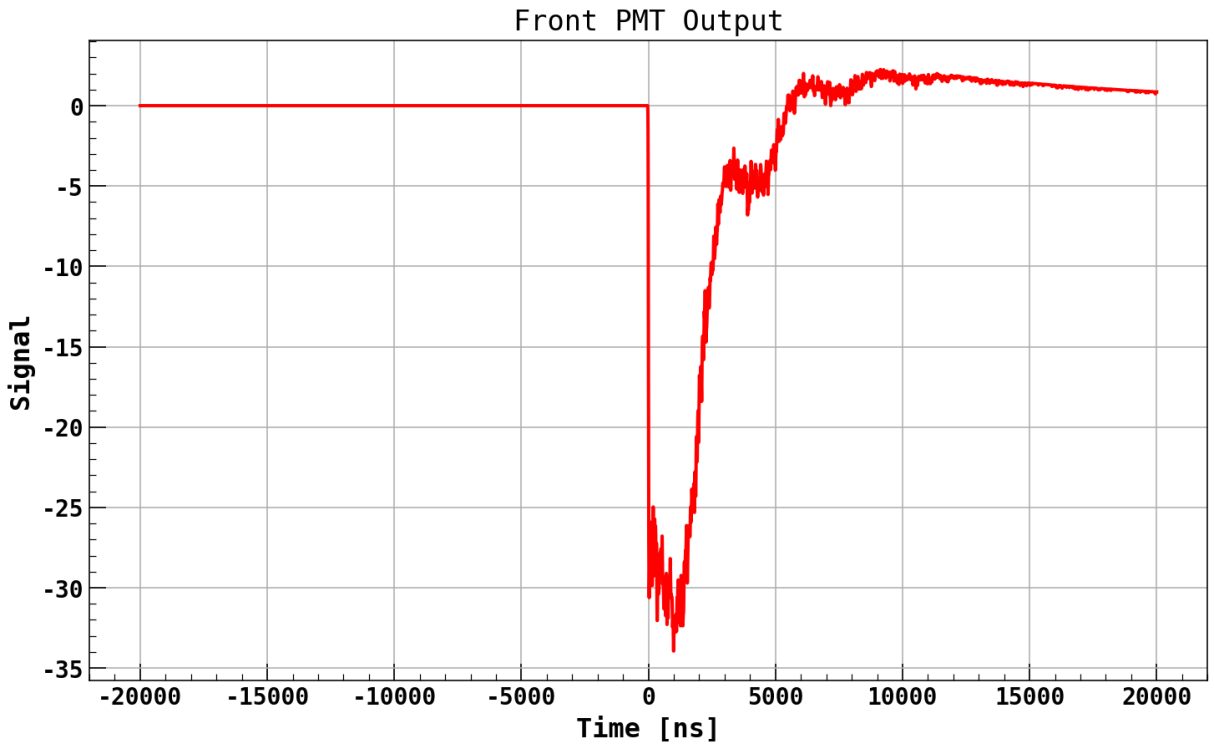
BACKUP: Poisson Distributions and Statistical Uncertainties

$$P(r) = \frac{\mu^r e^{-\mu}}{r!} \longrightarrow \sigma = \sqrt{\mu}$$

$$\mu =< N_i(t) > \approx N_i(t) \longrightarrow \sigma \approx \sqrt{N_i(t)}$$

BACKUP: B and F PMT Output





BACKUP: SAFETY TEST