# Self-Introduction 自己紹介

## Denzel Goh ゴー･デンゼル

## KEKSSP Summer Programme 2025

# SINGAPORE

Young, multi-cultural and multi-religious country in Southeast Asia

4 official languages

Imperial College London

# Hobbies/Interests

Physics (who would have thought?)

Astronomy and Stargazing

Art, Music, Coffee

# Overview of projects in Hadrons

| Week 1, 3&4 | Week 2 | Weeks 5-7 | Week 8 |
| --- | --- | --- | --- |
| • Particle Interactions in Scintillator with Dr. Mifuyu Ukai<br>• Further guidance by Dr. Yamamoto Takeshi, Doctoral students Ryoh Imamoto and Seong Chesu | • Further lectures by Dr. Kyoichiro Ozawa<br>• Additional simulation tasks on C++/ROOT | • Testing of apparatus for E16 experiment<br>• Semiconductor detectors with Prof. Dr. Kazuya Aoki<br>• SAMIDARE board (for GEM Trackers) with Doctoral student Nagafusa Shunnosuke | • Report and Presentation |

# Why understand scintillators and interaction of radiation with them?

Motivation: Improve **resolution!**
- width in signal peaks seen (i.e. standard dev / FWHM)

Investigate the various factors affecting energy resolution of the peak
- are certain materials suitable for strange hadron experiments?

Many applications to improving precision in high-energy physics experiments

Finding combination that optimizes balance of computation time and precision

# Scintillators

Work by luminescence

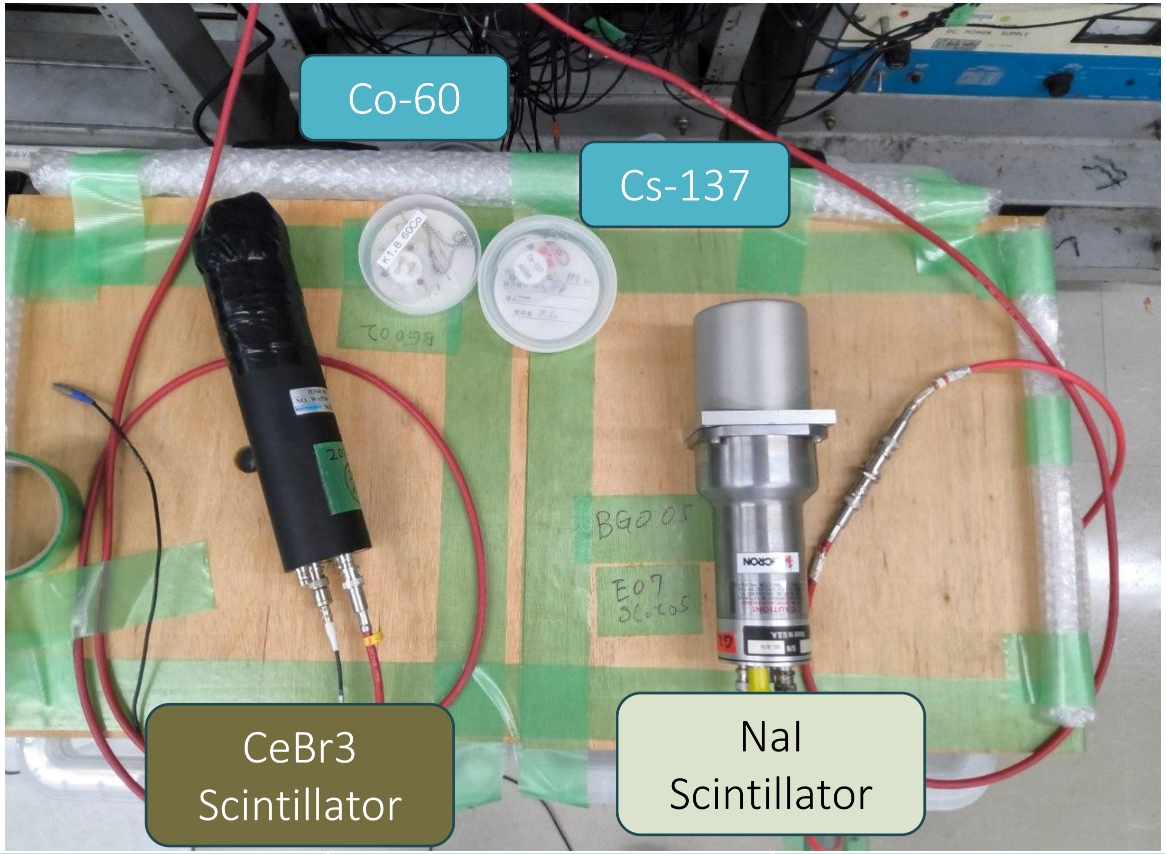
- excitation and de-excitation processes

Energy of incident radiation is detected when radiation loses energy through interactions with the scintillator crystal

Ideal characteristics:

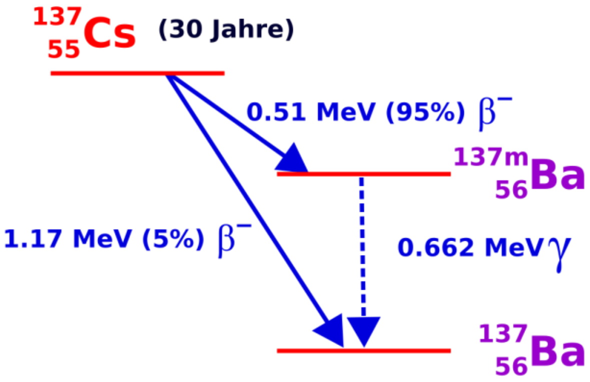
- Linear response
- High light yield
- High Quantum Efficiency

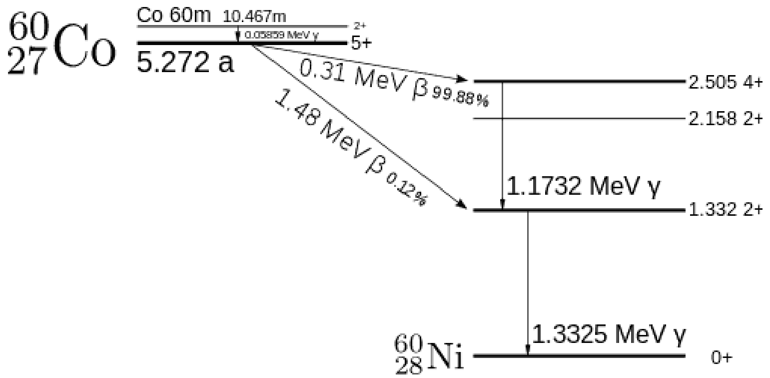
(Many other pros and cons not written here)



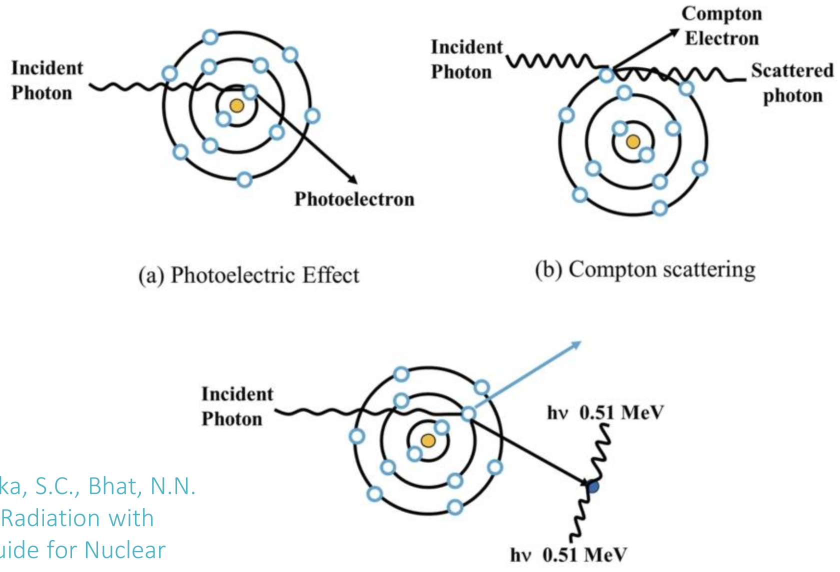

| Inorganic Material: | NaI | CeBr3 |
|---|---|---|
| Length of Cs-137 signal | 1011 +/- 14 ns | 136 +/- 1 ns |
| Decay time (literature) | ~250ns | ~17 ns |
| Resolution | Relatively high | Relatively low |

# Decay Energies



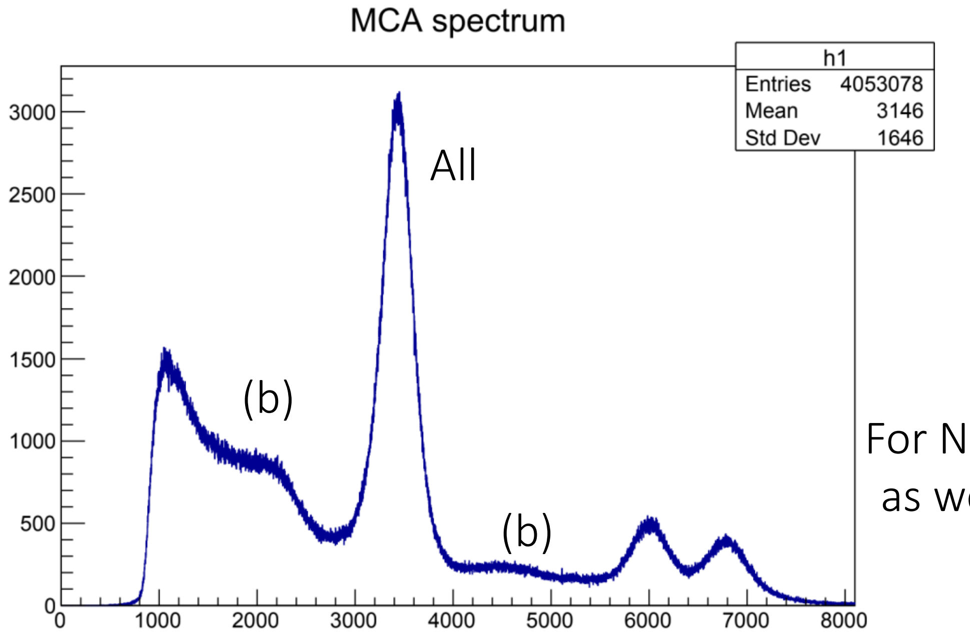

# Interaction of Gamma Rays with matter and Detection




(a) Photoelectric Effect

(b) Compton scattering

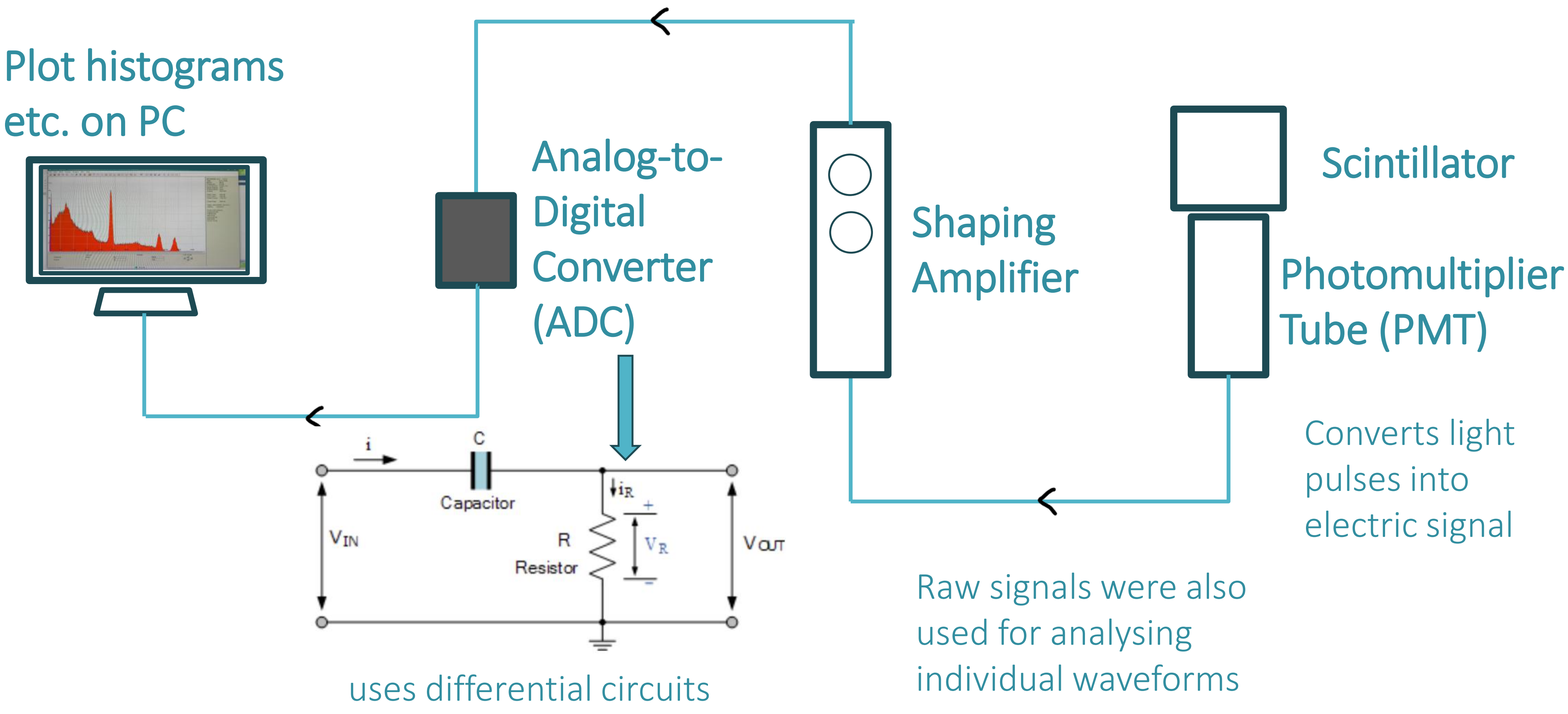
(c) Pair Production




For NaI: Peaks not as well resolved.

Tandon, P., Prakash, D., Kheruka, S.C., Bhat, N.N. (2022). Interaction of Ionizing Radiation with Matter. In: Radiation Safety Guide for Nuclear Medicine Professionals. Springer, Singapore. https://doi.org/10.1007/978-981-19-4518-2_3

# Data-taking




RC circuit diagram from https://www.electronics-tutorials.ws/rc/rc-differentiator.html

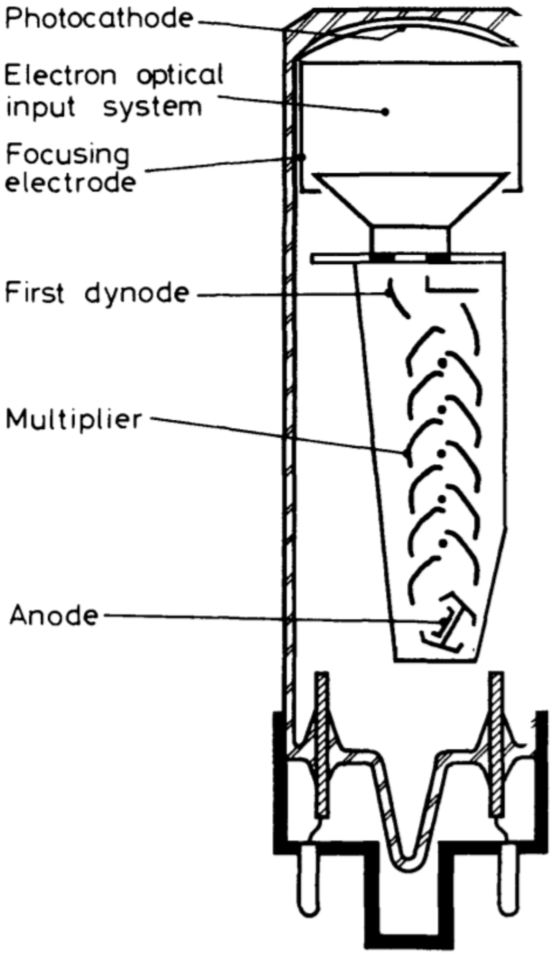
Sodium Iodide crystal

Applied Potential Difference (-1200V to -1800V)

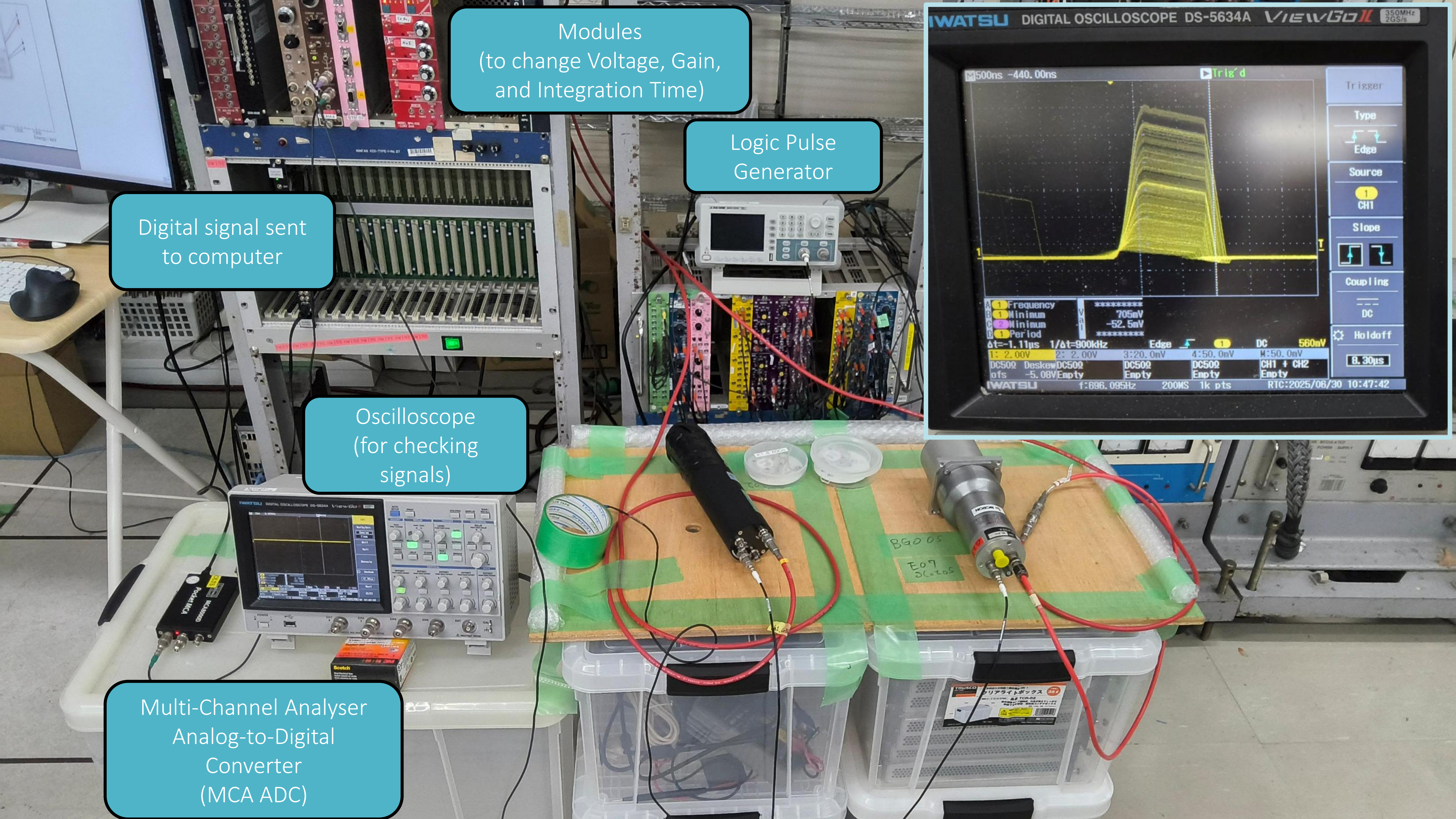
Photomultiplier Tube

Incident gamma radiation on scintillator crystal

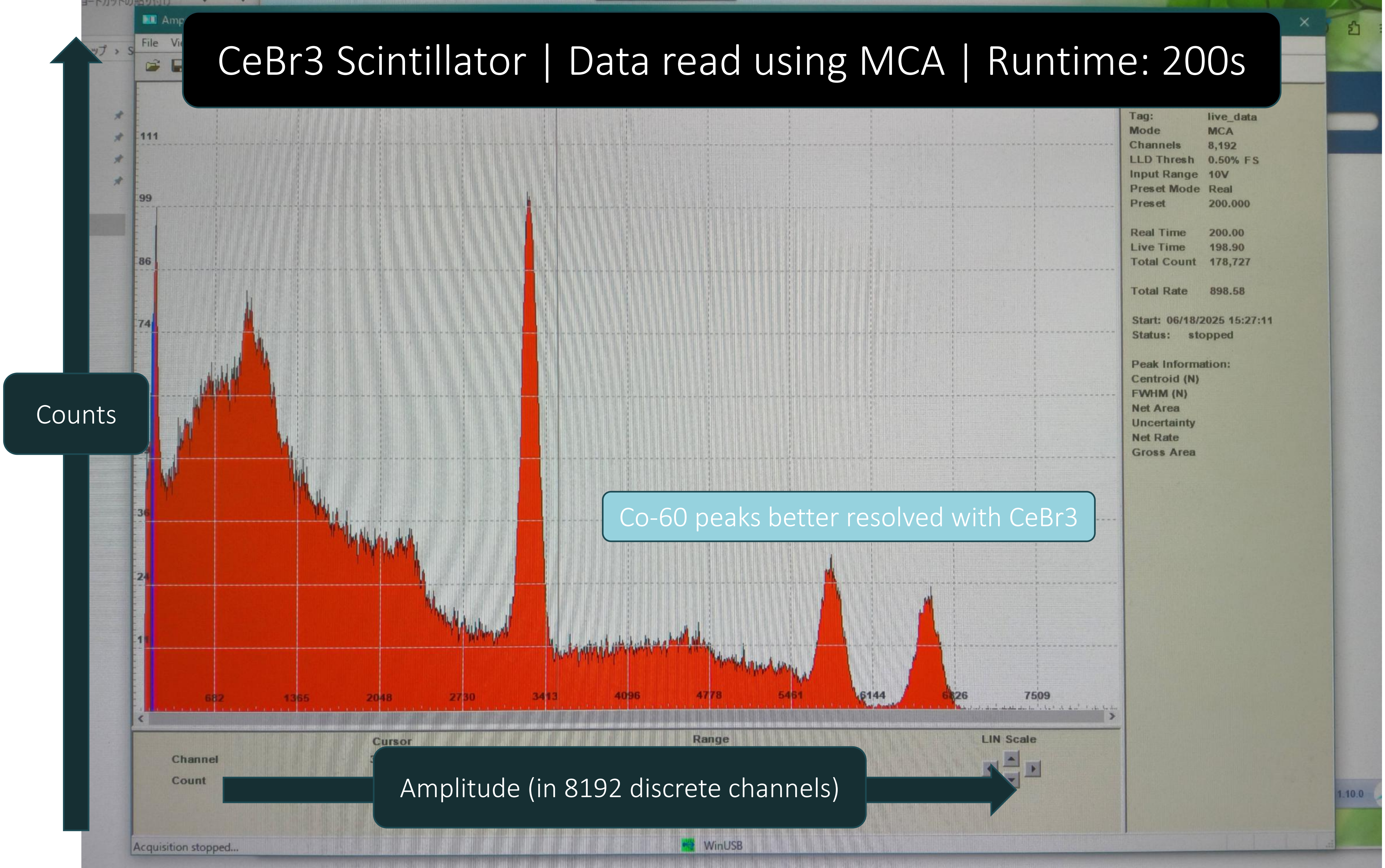
1. Photoelectric Effect
2. Compton Scattering
3. Pair Production



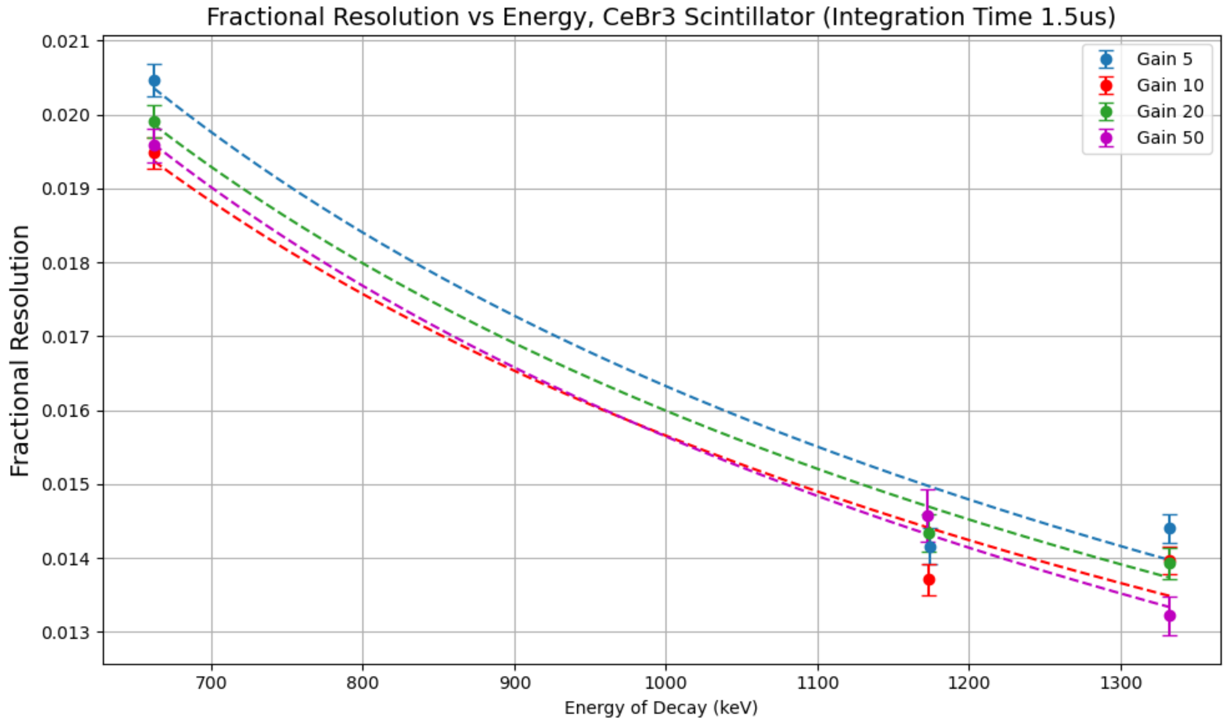

Photomultiplier schematic diagram
(From W. R. Leo, 1994)

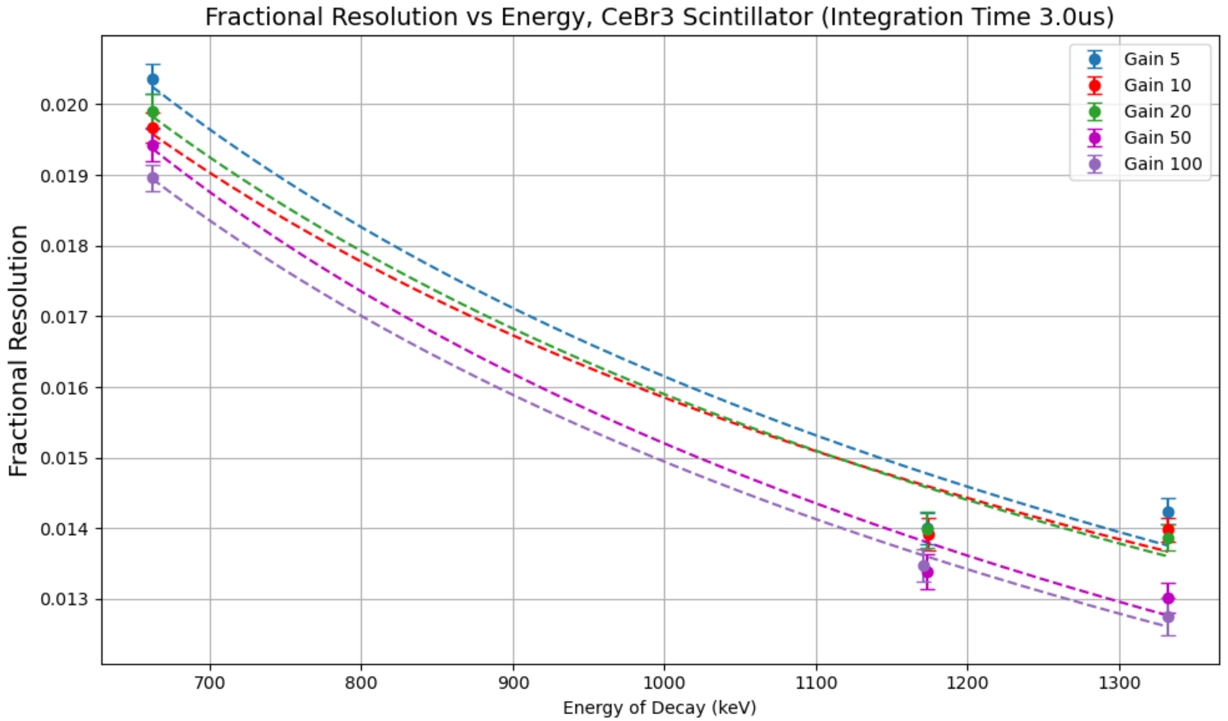

Modules
(to change Voltage, Gain, and Integration Time)
Logic Pulse Generator
Digital signal sent to computer
Oscilloscope (for checking signals)
Multi-Channel Analyser Analog-to-Digital Converter (MCA ADC)
IWATSU DIGITAL OSCILLOSCOPE DS-5634A

# CeBr3 Scintillator | Data read using MCA | Runtime: 200s



# Effect of Gain & Integration Time on Resolution




Data presented for CeBr3.

General trend: Improved resolution (i.e. lower fractional resolution) with increasing Gain. Very slight improvement in resolution with higher integration time.

Best fit curve $A + \frac{B}{\sqrt{E}}$ needs more decay sources for improved significance.

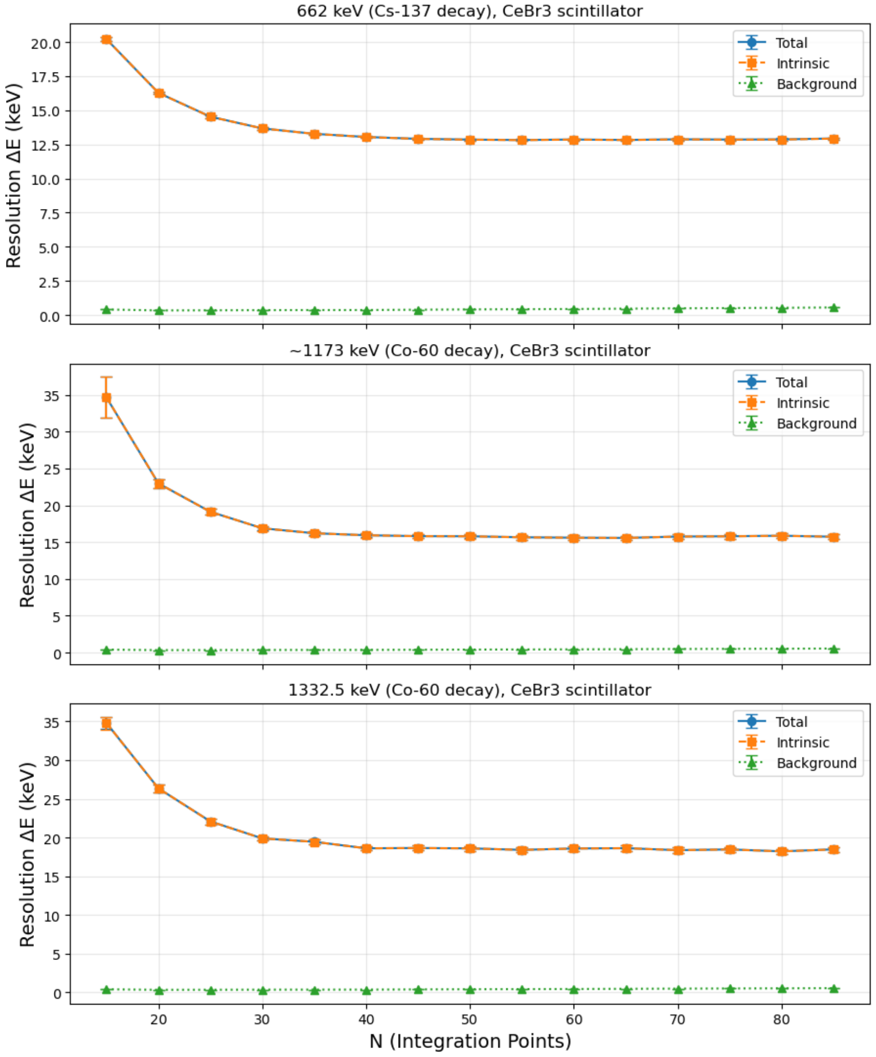
# Integrating raw waveforms – how many points (N) should we integrate?

Integrating gives us the signal in terms of "channels"

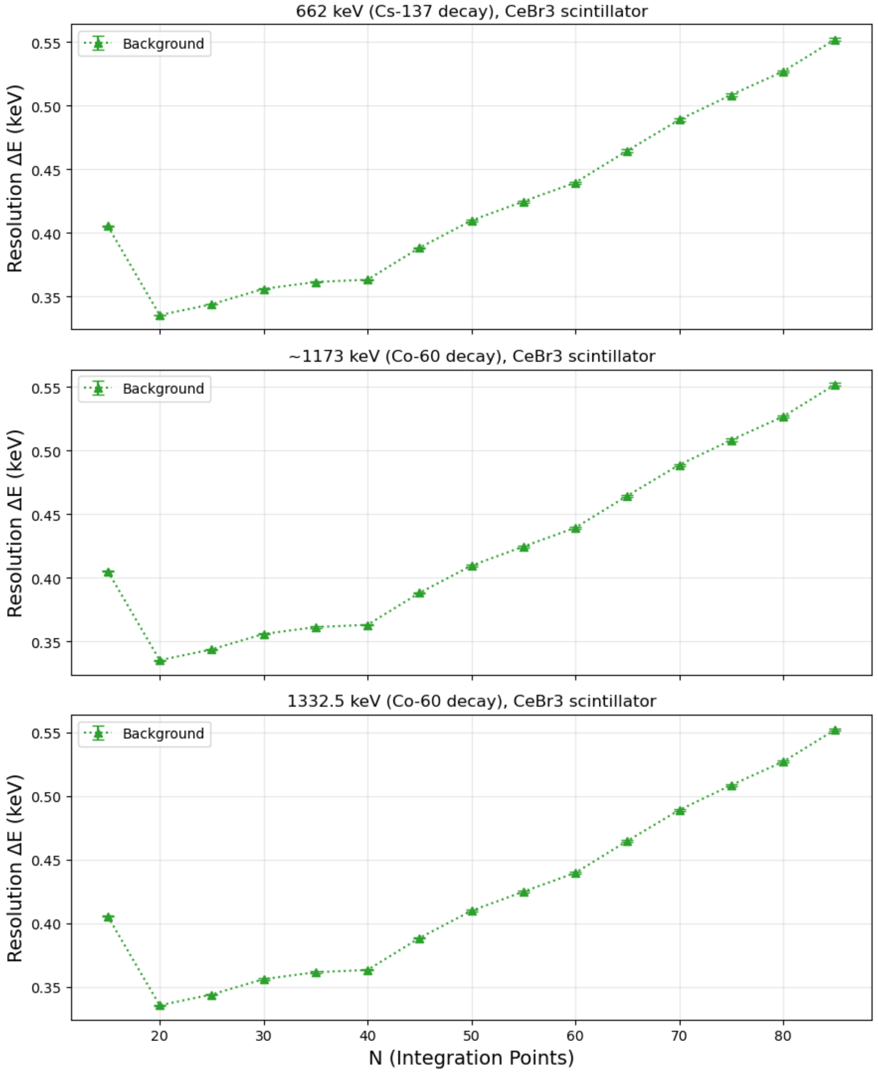
Make energy calibration functions -> convert channels to energy

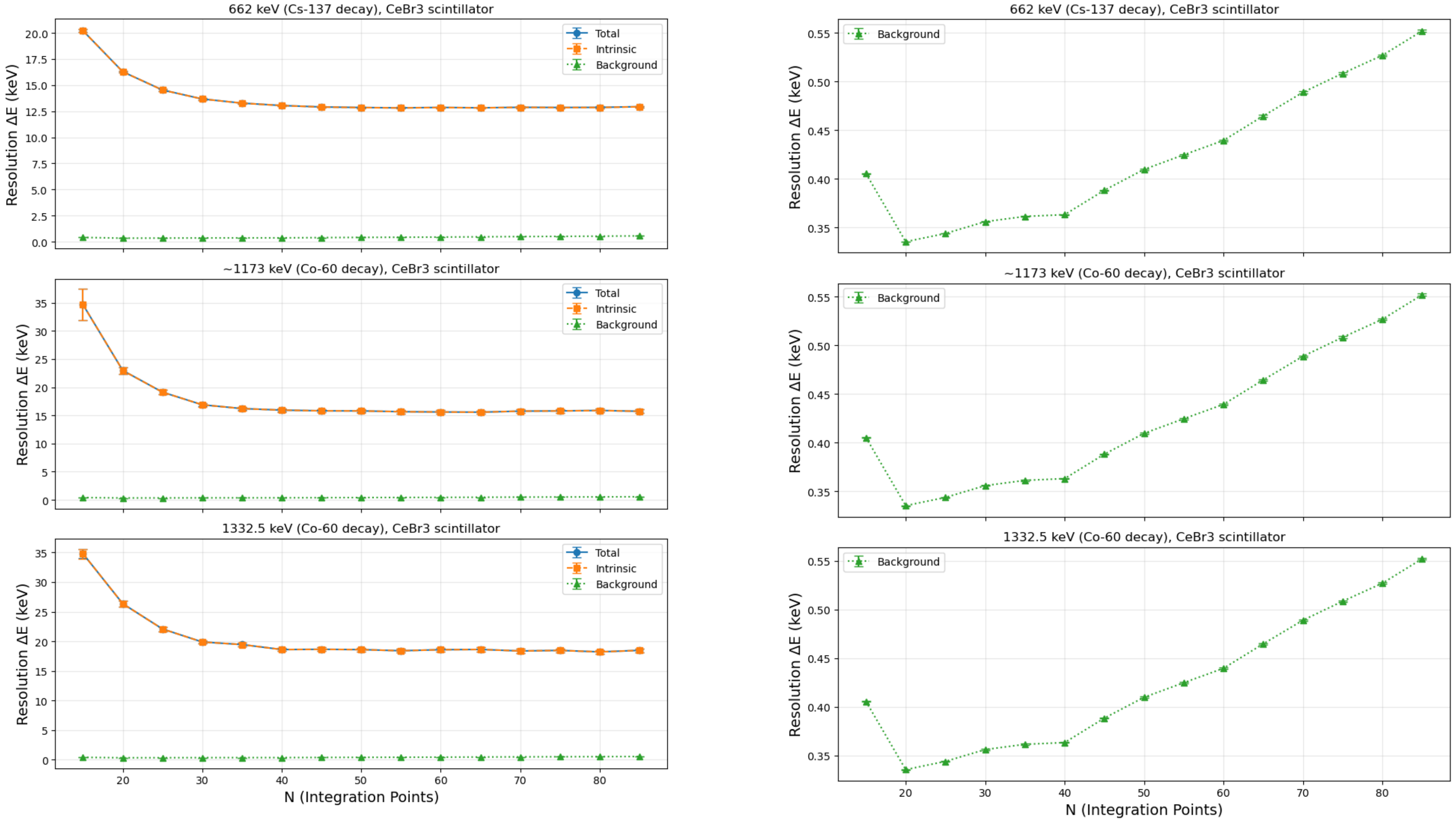
Find contribution of intrinsic factors and background to the peak resolutions

$$\sigma_{intrinsic} = \sqrt{\sigma_{total}^2 - \sigma_{background}^2}$$




Background Plots





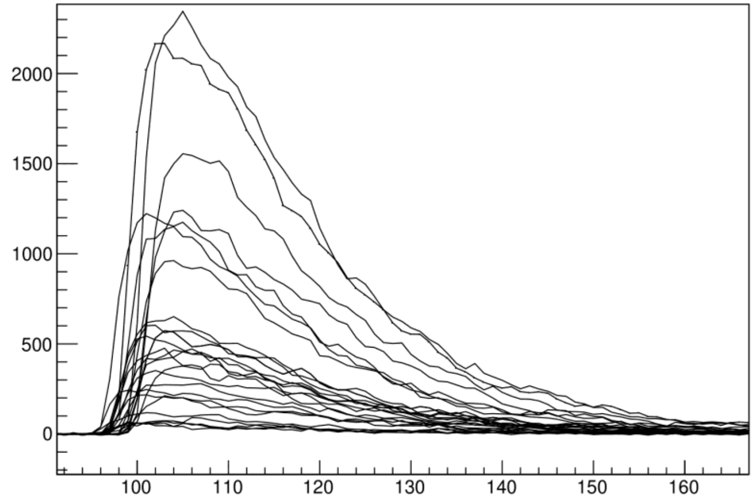

Expect background contribution to resolution to be proportional to sqrt(N)

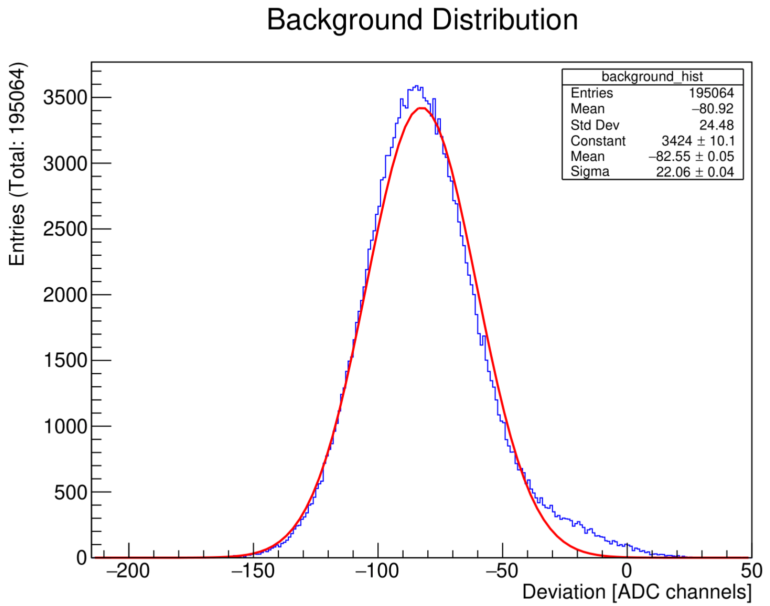
My results show a linear relationship and even a spike at lower N

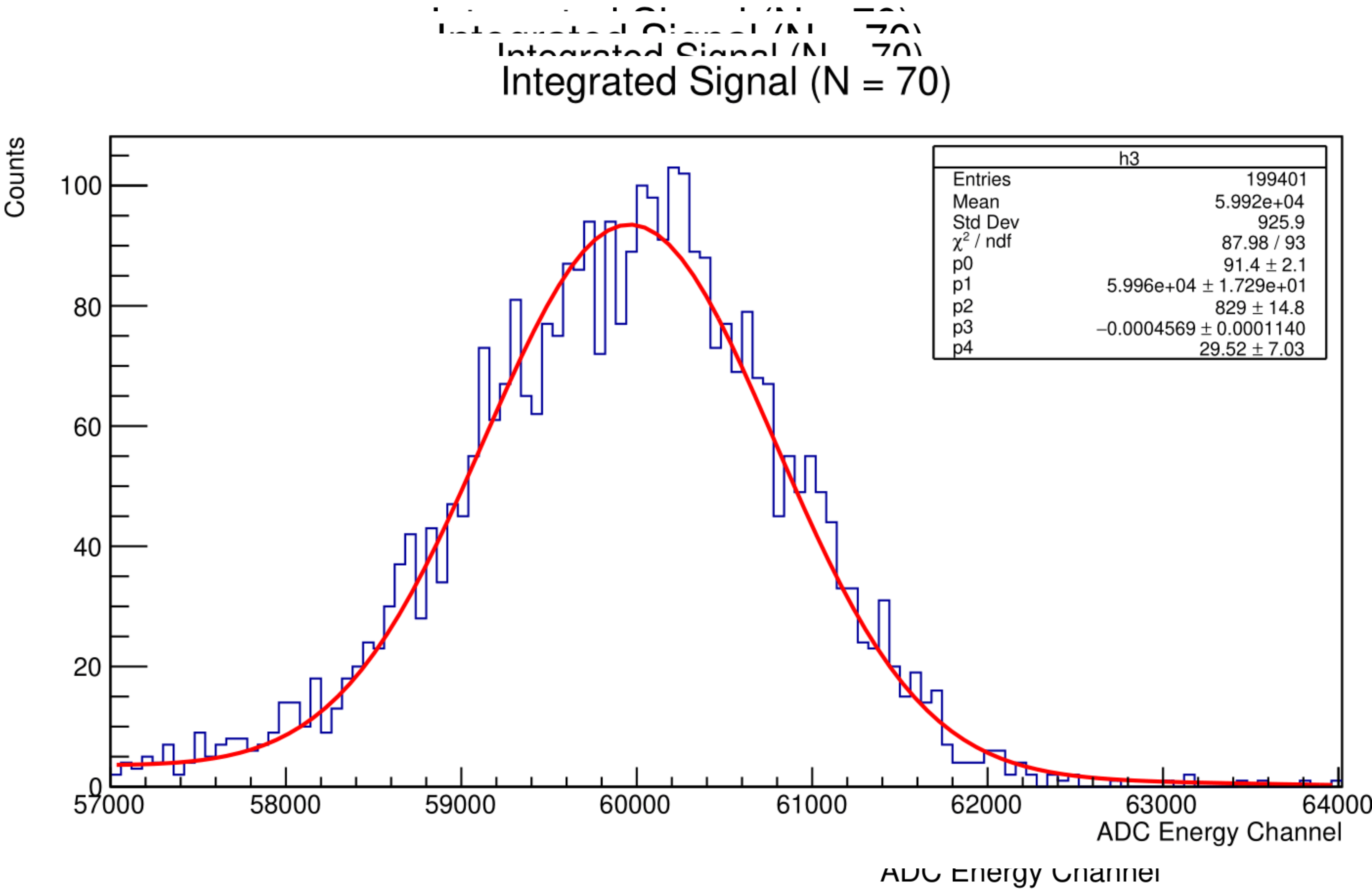
-> Could be due to subtracting baselines at the wrong time

# Example CeBr3 raw signals

- Integrate → Area



# Learning points

Deviation likely caused by subtraction of baseline from integrals

- Potentially another reason could exist

A deep physics understanding of particle interactions is needed to detect radiation

Signal processing is a sophisticated, multi-layer process

Every result, every waveform, every anomaly you see in a detector has an explanation.

Important of planning layout early

- Prevent hidden coding errors -> Saves time

# Next course of action

Re-take data with my improved code

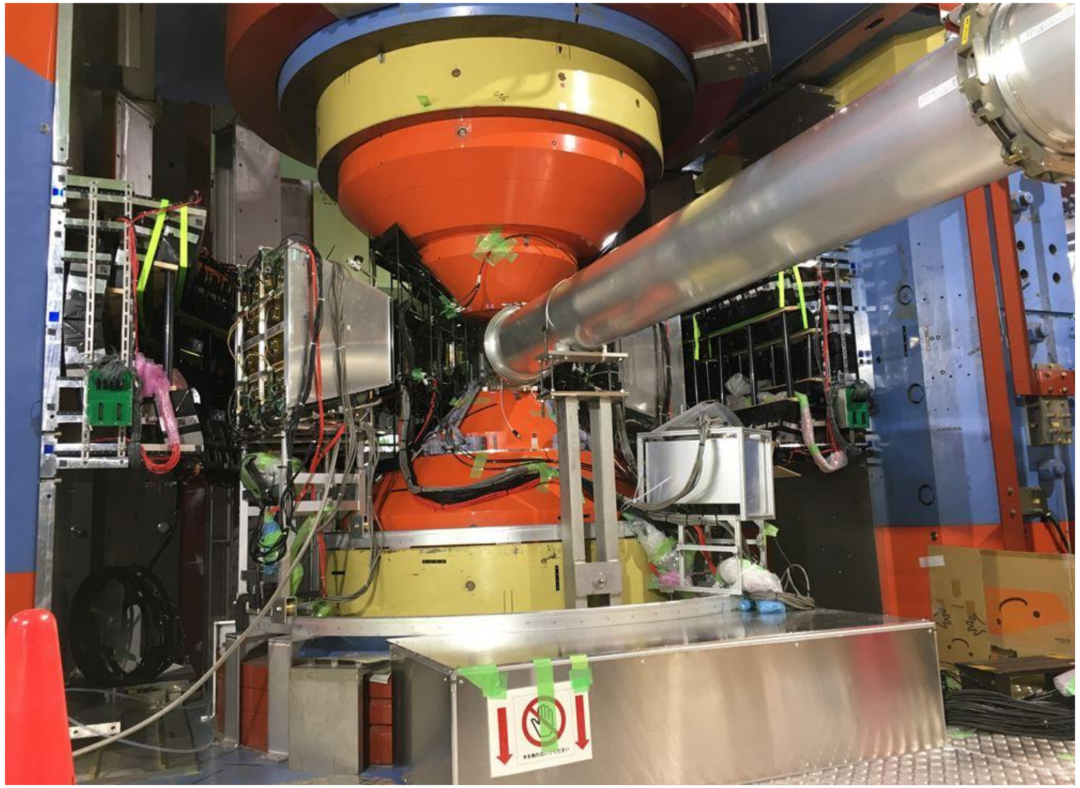
Simulate list-wave compression

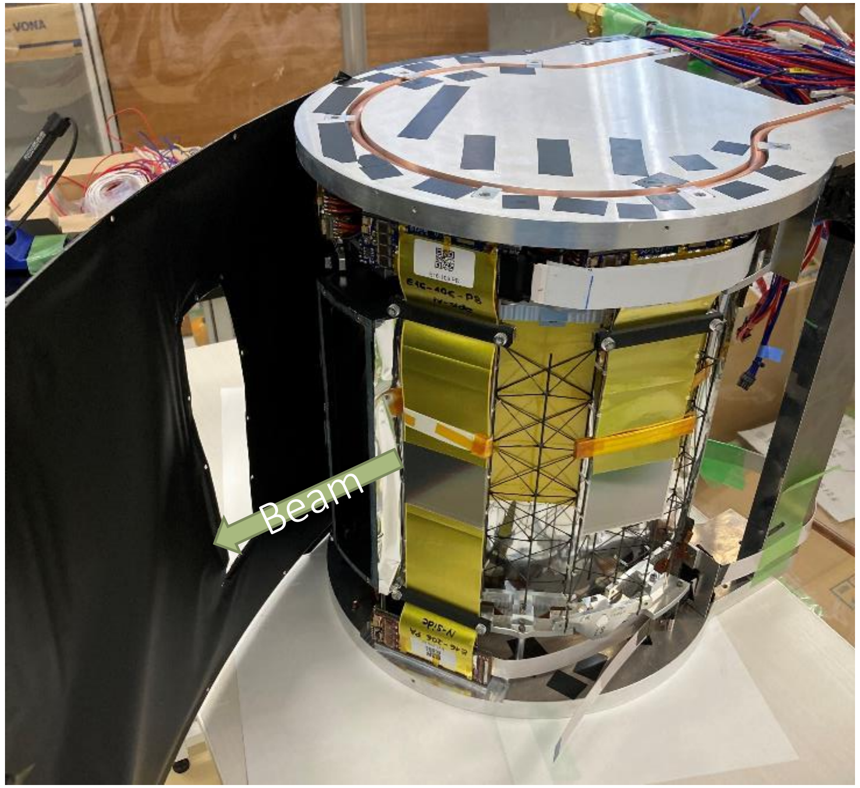
- Investigate optimal sampling rate for data precision and file sizes

Organise all plots (for NaI and CeBr3 detectors) prior to starting the report

# A Brief Summary of E16-related projects

1. Silicon Tracking System calibration - with Prof. Aoki Kazuya
2. SAMIDARE boards with Doctoral student Nagafusa Shunnosuke (Kyoto U.)





# E16 experiment

Spontaneous Chiral Symmetry Breaking

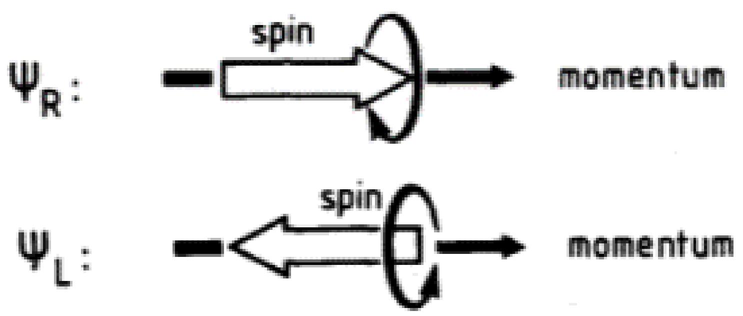
- Origin of mass in hadrons!

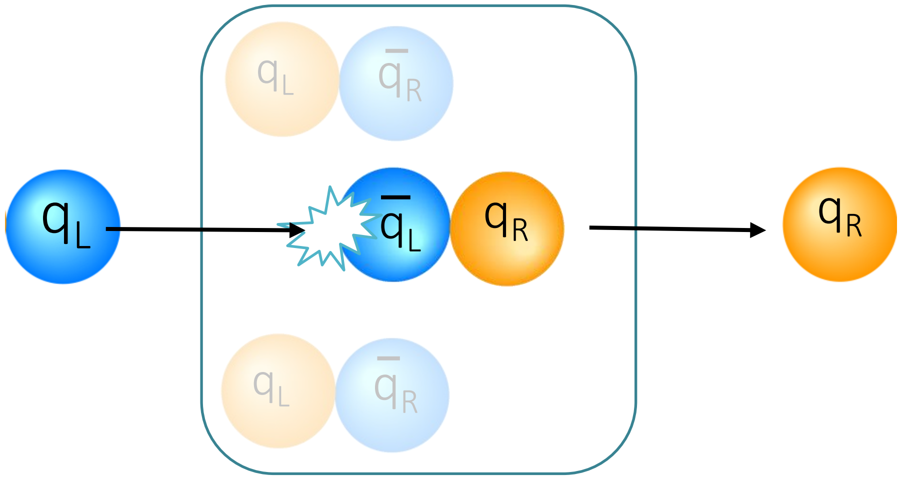
Mass loss in **p + A → ρ/ω/ϕ → e⁺e⁻** reaction

- Temperature and density dependent

$$\psi_R \rightarrow \psi'_R = \psi_R e^{i\alpha}$$

$$\psi_L \rightarrow \psi'_L = \psi_L e^{-i\alpha}$$



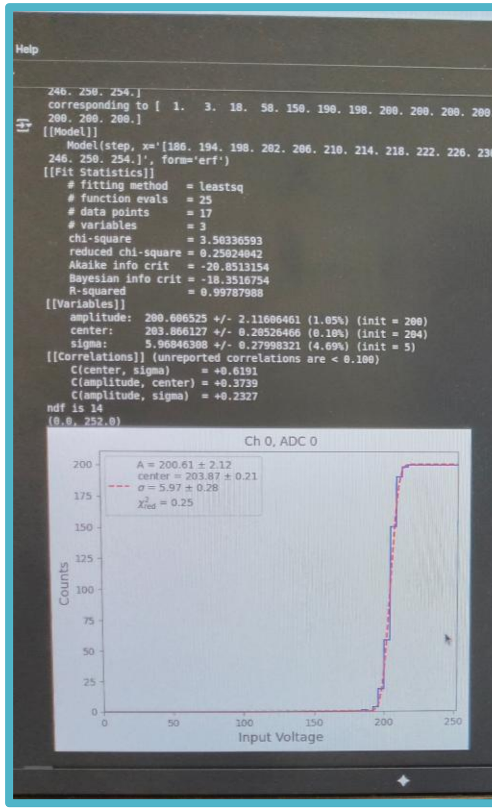




If lagrangian unchanged upon chiral exchange -> R-L values conserved

# Progress

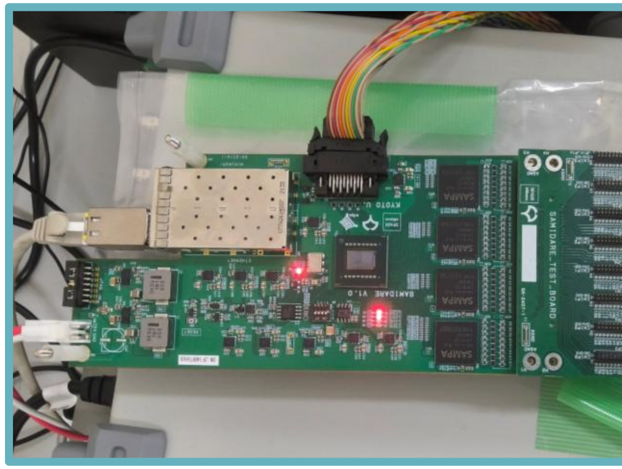
## STS calibration experiment

- Threshold voltage for each channel-ADC
  - *Preliminary data taken*
- Database of over 4000 detector response plots
  - *Yet to begin*




## SAMIDARE testing

- Data-taking voltage inputs with triggers
  - *Some data taken*
- Plotting of data readout response curve
  - *Yet to begin*




Thank you for listening!
ご静聴いただき
ありがとうございました!

# Photo credits

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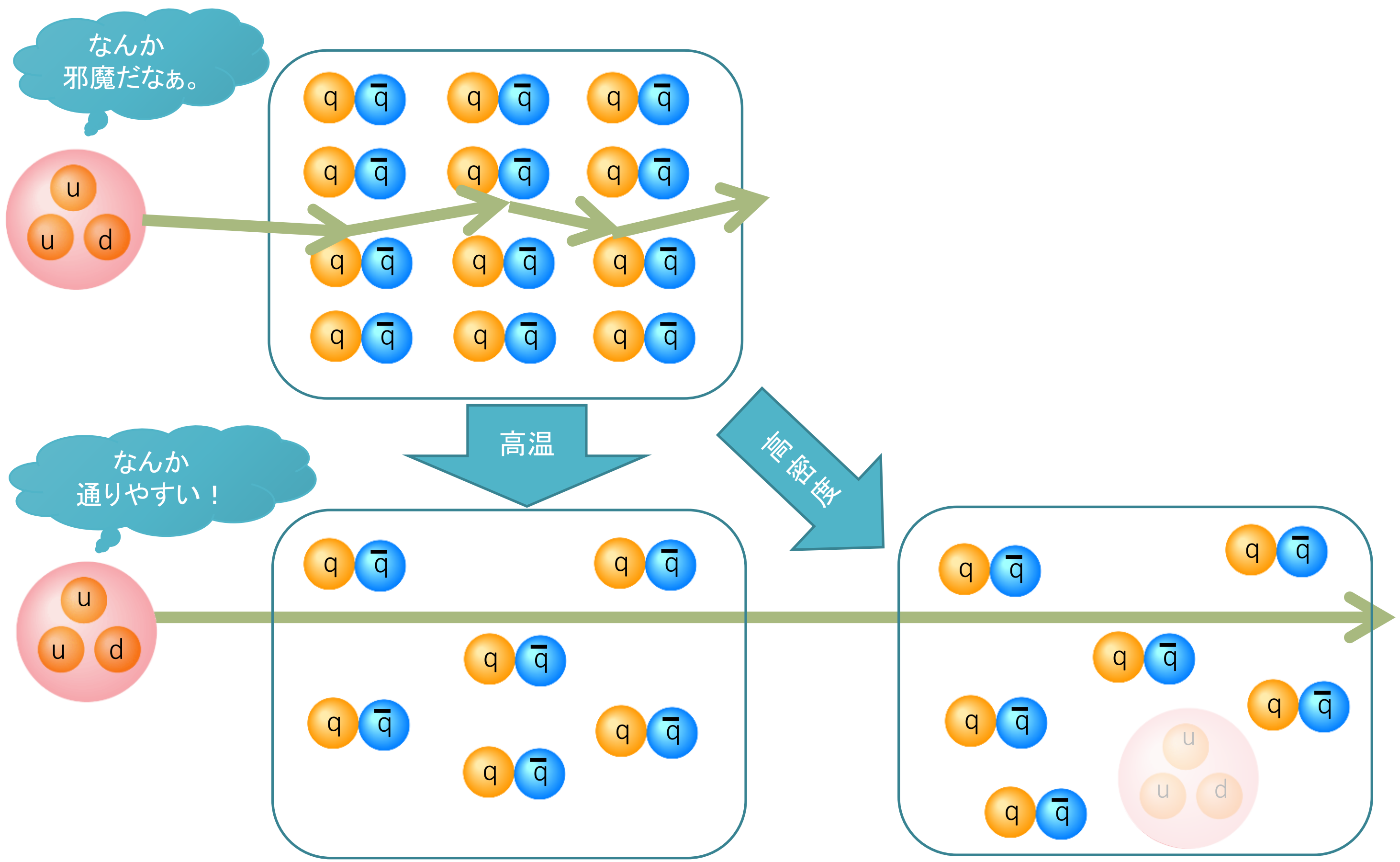
Bishan Park HDB Flats:
- Solaman Soh on Pexels

Cobalt-60 decay diagram:
- Nuclear power [dot] com

E16 setup in Hadron Hall, Quark chirality and Interactions:
- Dr. Aoki Kasuya’s introduction sldies

# Backup slides / photo bank

# Temperature and Density affects ($\sum$ *invariant mass*)!



# Formation of exotic nuclei

Kaon experiments

Lambda baryons…

Iso-spin → Eventually led into QCD

Nucleon-nucleon interactions:
n,p are the same!


Two states of same particle!
→ Isospin