Optimization of 500MHz Pixie-16 for Fast Time Measurement

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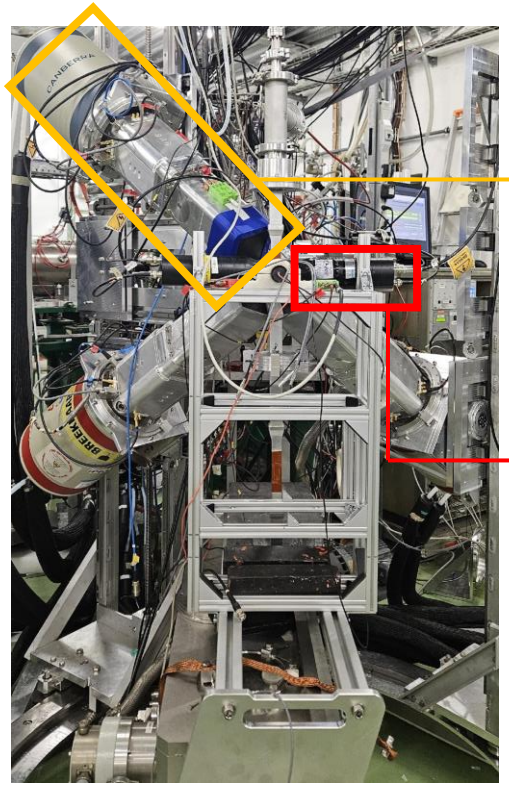
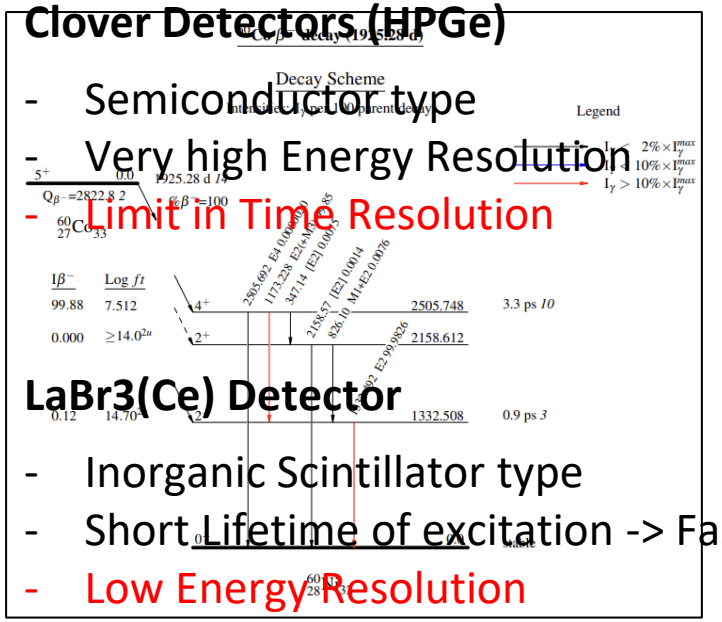
Why Fast Time Measurement?

- Lifetimes of excited nuclear states is used to understand **Nuclear Structure** and **Transition Matrix Elements**
- Magnitude of lifetime is in wide range: femtoseconds (10^{-15}) to years



Clover Detectors (HPGe)

- Semiconductor type
- Very high Energy Resolution
- Limit in Time Resolution



LaBr3(Ce) Detector

- Inorganic Scintillator type
- Short Lifetime of excitation -> Fast Time Measurement!
- Low Energy Resolution

Analogue & Digital Data Acquisition

Analogue

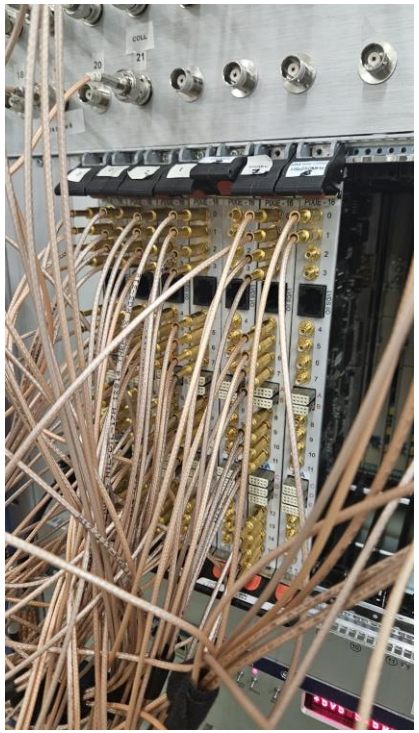
Higher Time Resolution
(Charge & Discharge of Capacitor)

$O(n^2)$ complexity for n detectors

Digital

Flexibility & Scalability

Time Resolution should be optimized



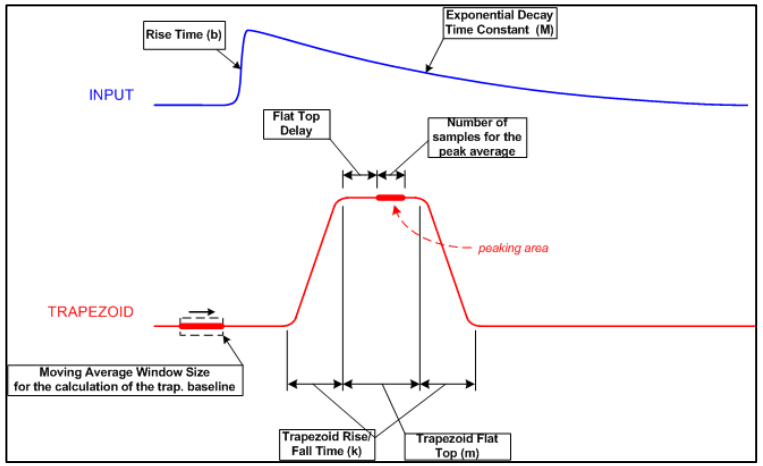
How Data are Collected

- CFD and Trapezoidal Filter
- What is a “Good Parameter”?

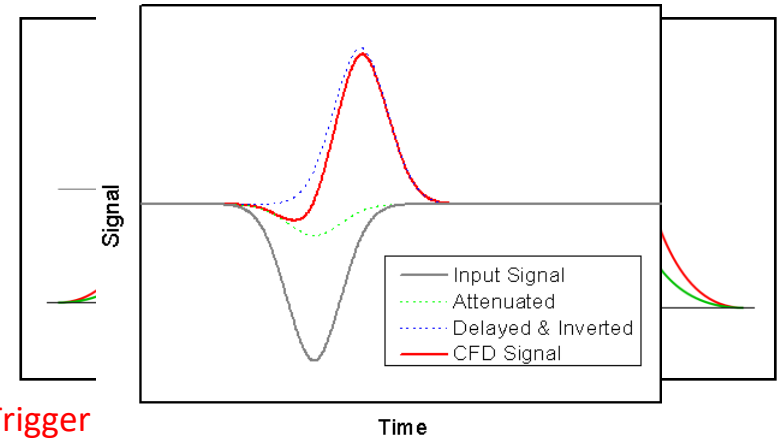
Constant Fraction Discriminator

CFD & Trapezoidal Filter

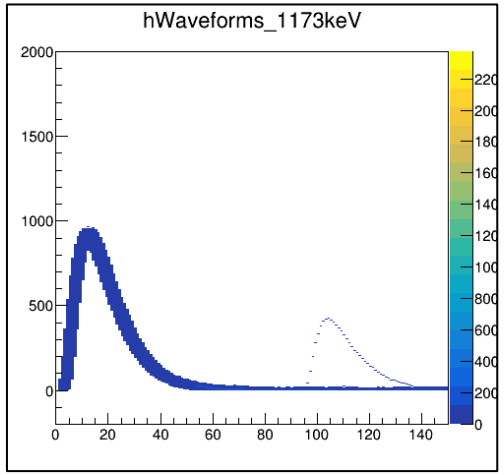
Energy?



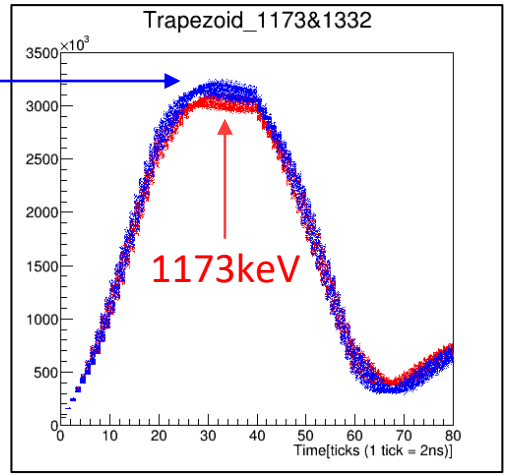
Time?

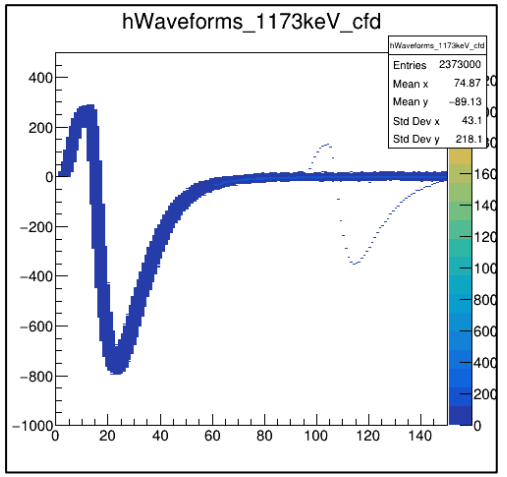


Trigger



1332keV

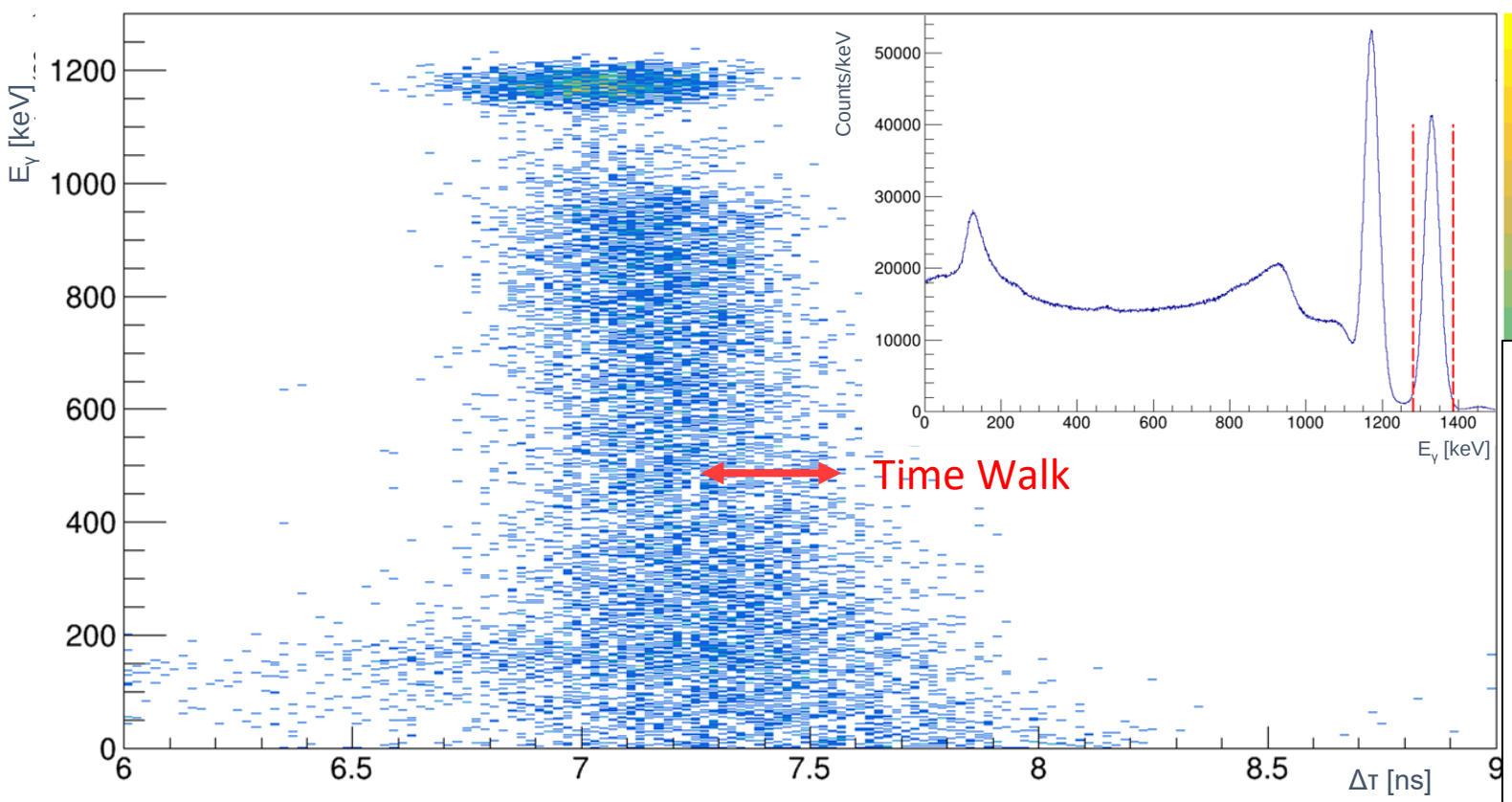


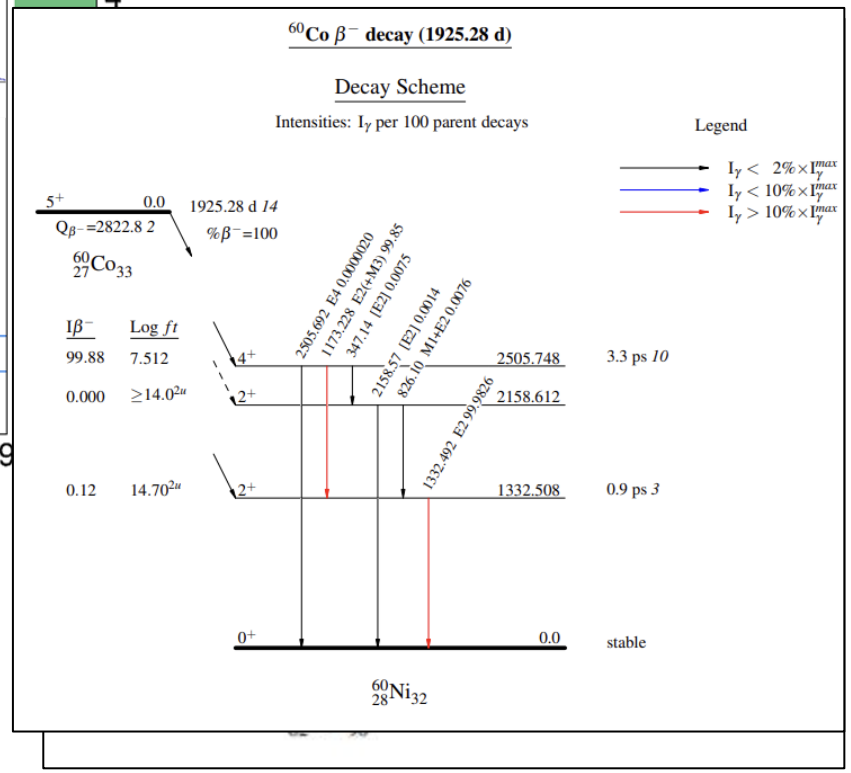


http://lmu.web.psi.ch/docu/manuals/bulk_manuals/software/TDC/set_cfd.html

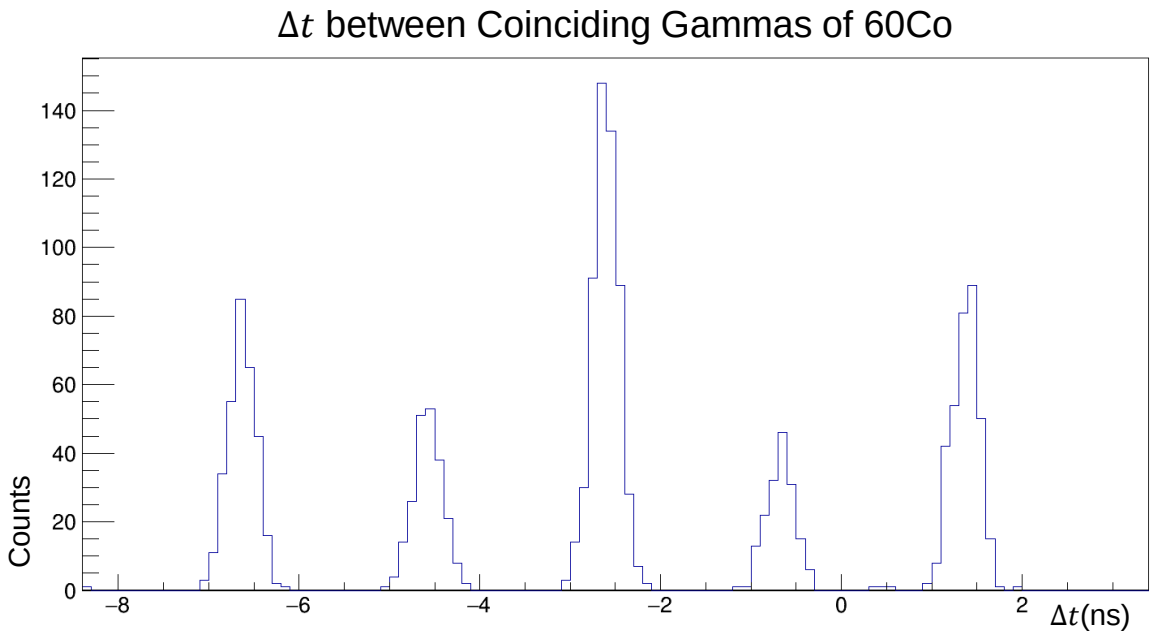
Mutti, Paolo & Jentschel, M. & Ruiz-Martinez, E & Ratel, Justin & Rey, F & Urban, Waldemar. (2023). A NEW FAST TRIGGERLESS ACQUISITION SYSTEM FOR LARGE DETECTOR ARRAYS.

What is a “Good Parameter”?

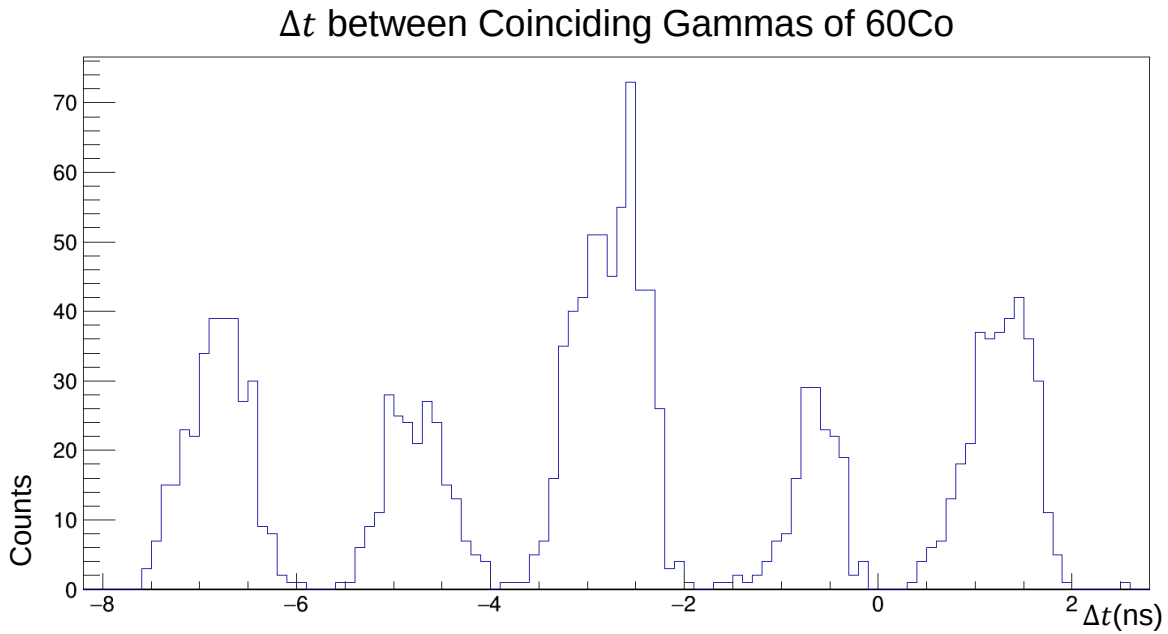




Current Status



Ex 1) CFD Scale = 0.4 / CFD Delay = 7 ns



Ex 2) CFD Scale = 0.7 / CFD Delay = 50 ns

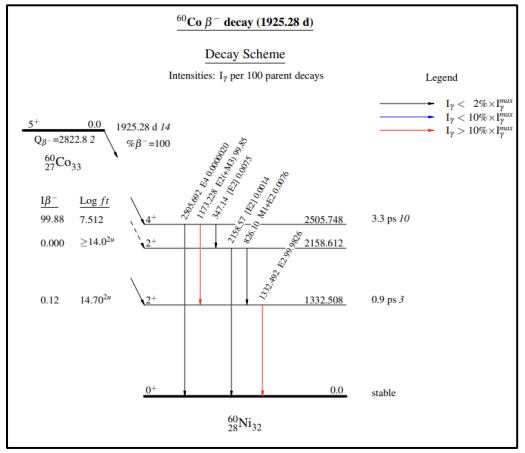
How Data are Calibrated

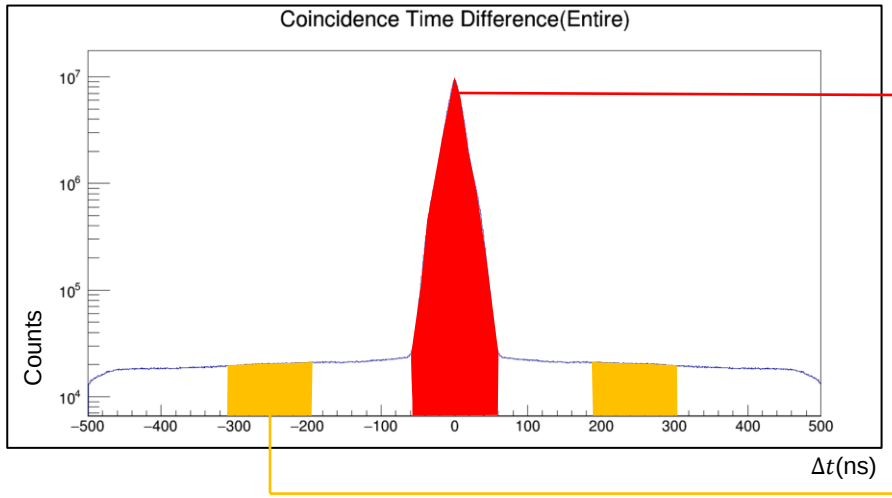
- Time Calibration

Time Calibration (^{60}Co)

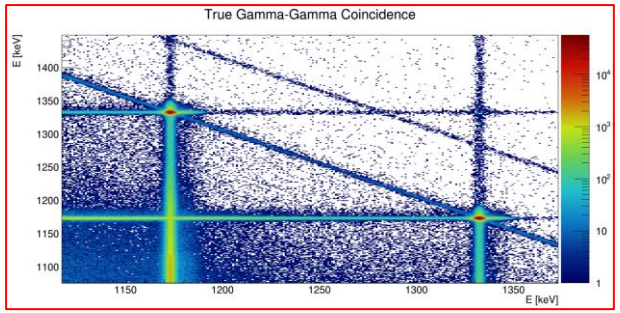
Data gathered in a specified time interval (TIM_REF) are considered as one event even though they are not simultaneous in reality

γ-γ Coincidence of 60Co source (1173 keV & 1332 keV) is used for time calibration

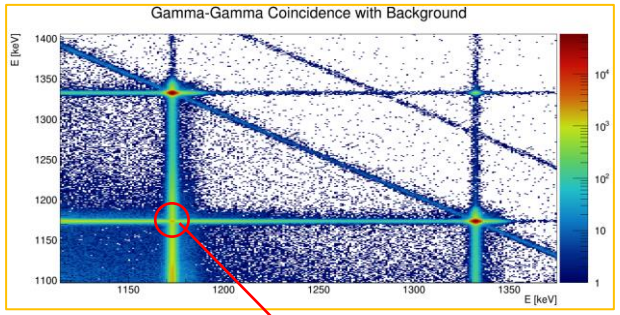




Prompt Time Gate



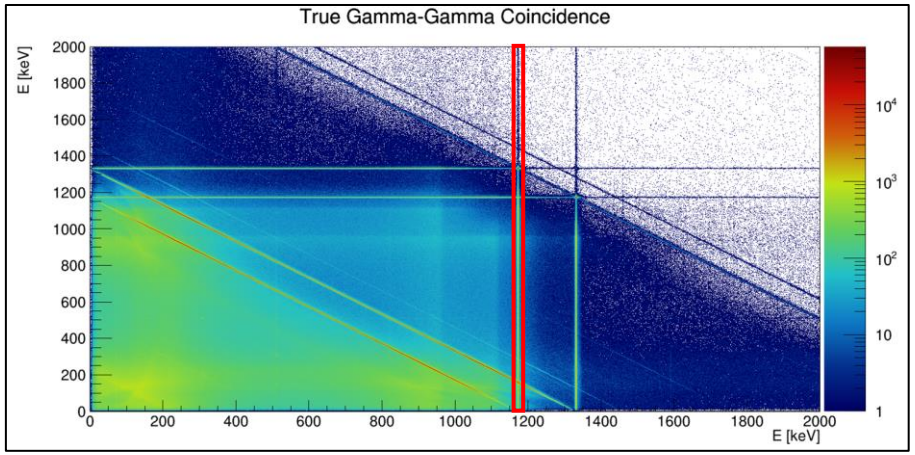
Background Time Gate

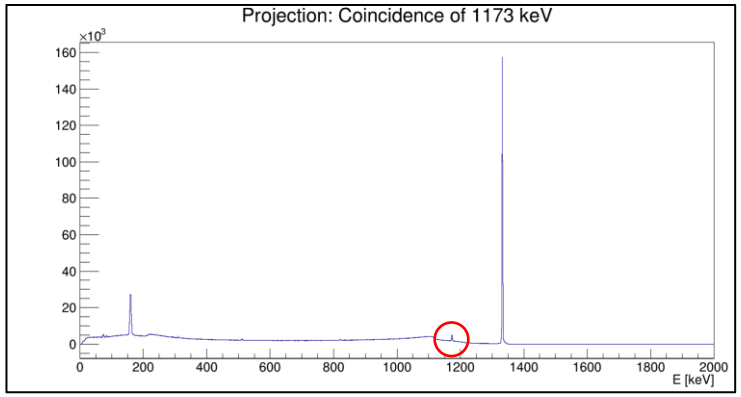


Self-Coincidence: Evidence of Background

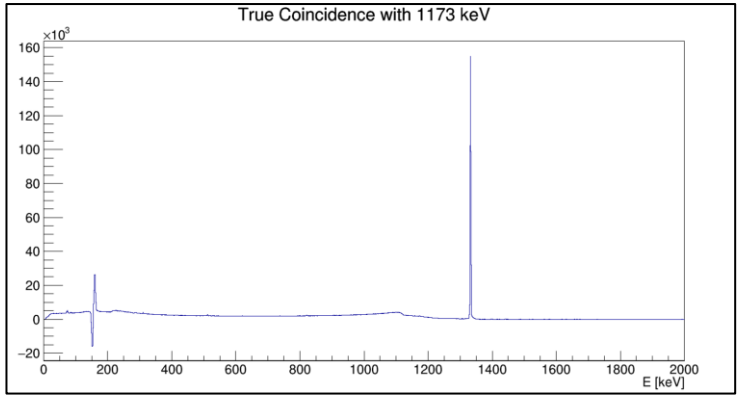
Time Calibration (^{60}Co)

If the time gate is properly set, true coincidence spectrum can be obtained by gating in energy





Coincidence of 1173 keV w/ Background



True Coincidence of 1173 keV

- ❑ Compton Effect
- ❑ Plateau of Compton Effect
- ❑ Photopeak

Can also check the accuracy of efficiency curve

Summary

- Lifetimes of excited nuclear states is used to understand **Nuclear Structure** and **Transition Matrix Elements**

- LaBr3(Ce) is a good detector for fast time measurement

- Digital system is considered to be used for its convenience, but has tradeoff of resolution

- Time resolution & Energy resolution of data can be optimized by CFD & Trapezoidal Filters
  - Search for Optimization Criteria and Optimization is being done

- After getting the good data, calibration is rather simple! (and familiar)

Thank you for Your Attention

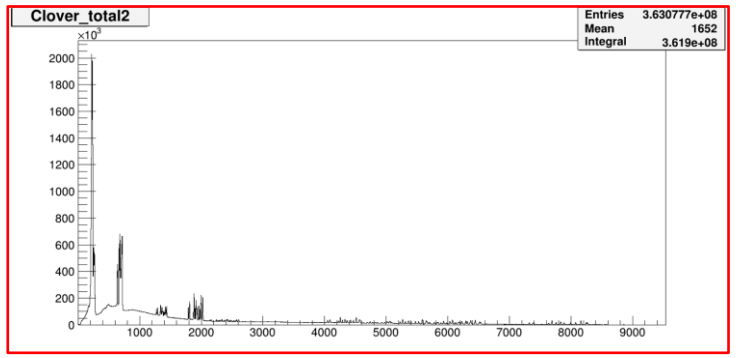
Any Question?

Backup Slides

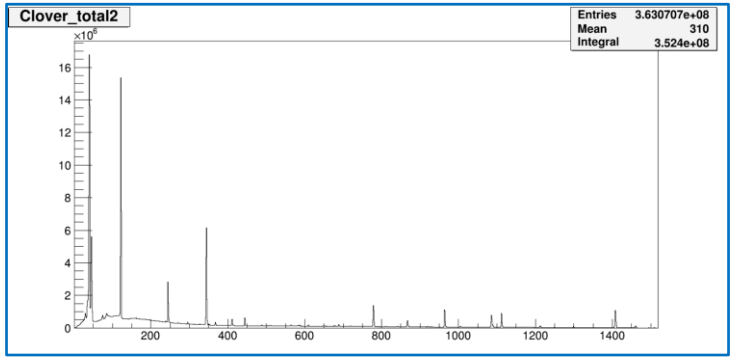
Just in Case

Energy Calibration (^{152}Eu) & Efficiency Curve

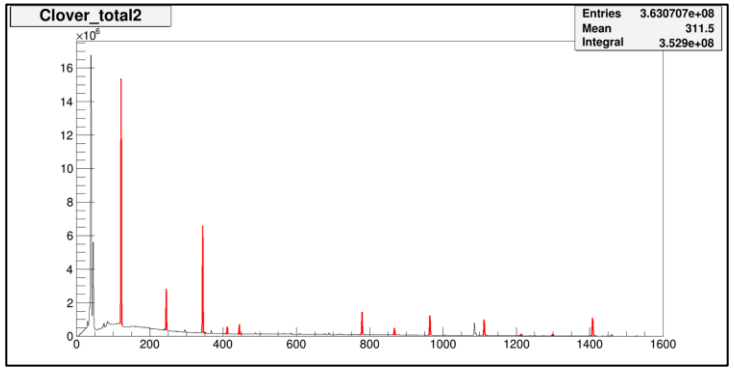
It is basically matching channel no. with known spectrum energy

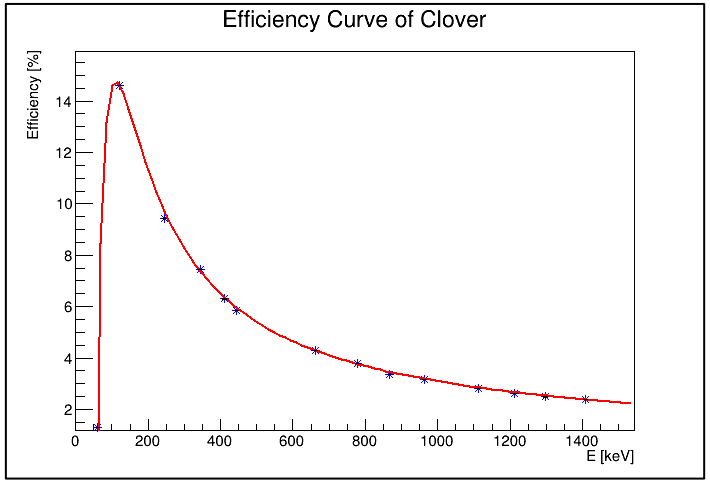


<Uncalibrated 152Eu Data>



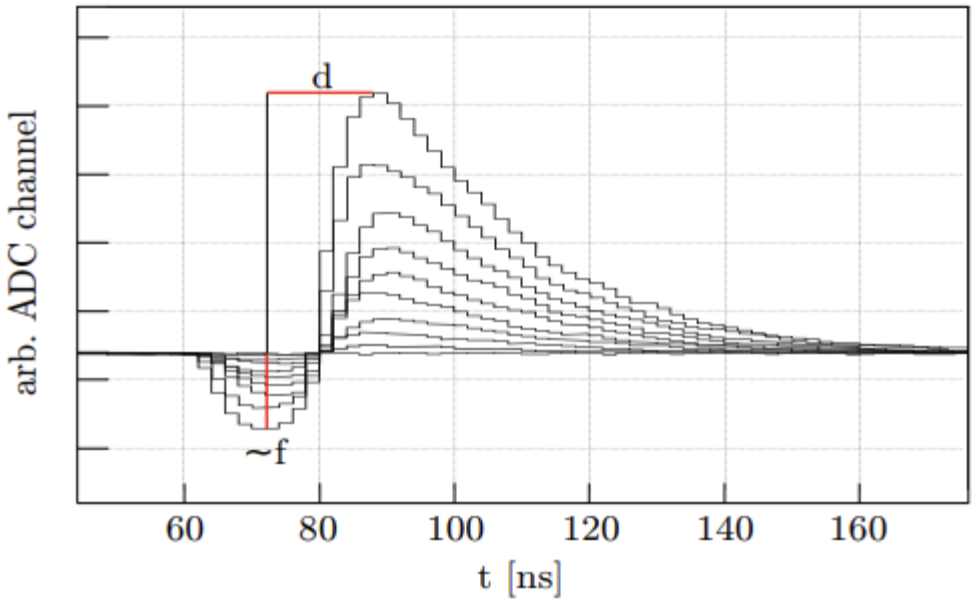
<Calibrated 152Eu Data>





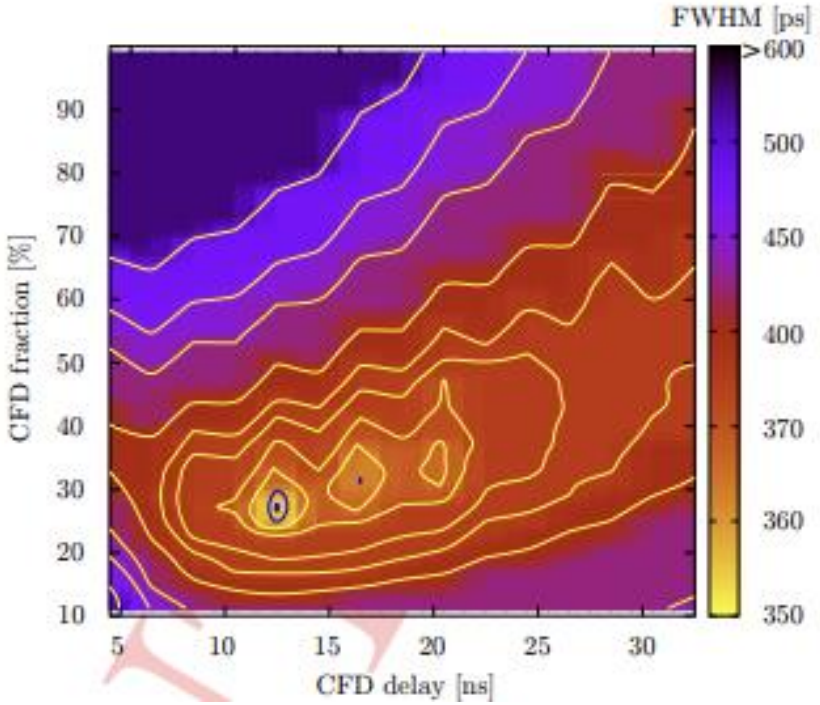
$$\epsilon(E) = \frac{P_1 + P_2 \ln(E) + P_3 \ln(E)^2 + P_4 \ln(E)^3 + P_5 \ln(E)^4}{E}$$

I. A. Alnour, H. Wagiran, N. Ibrahim, S. Hamzah, W. B. Siong, M. S. Elias; New approach for calibration the efficiency of HpGe detectors. *AIP Conference Proceedings* 12 February 2014; 1584 (1): 38–44. https://doi.org/10.1063/1.4866101



Several digitally CFD shaped signals recorded by a CAEN V1730 digitizer module

Reference 2D Histogram for CFD Optimization



Harter, Andreas & Weinert, M. & Knafla, Lukas & Régis, J.-M & Esmaylzadeh, Arwin & Ley, M. & Jolie, J.. (2023). Investigating timing properties of modern digitizers utilizing interpolating CFD algorithms and the application to digital fast-timing lifetime measurement.