Characterization of LaBr$_3$(Ce) Detectors for Picosecond (10^{-12}s) Lifetime Measurements

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WNPPC

Outline

1. $LaBr_3$(Ce) Detectors and the 8π
2. The project goal
3. Direct time optimization by signal processing
4. Indirect time optimization by Compton suppression
5. Summary and outlook

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The 8π

- 8π is an array of different detectors used for accurate nuclear lifetime measurements
- Located at TRIUMF in Vancouver
- These measurements provide tests of the standard model

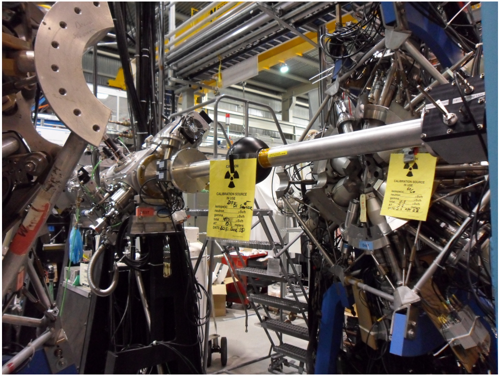

Figure 1: The 8π Array - Open

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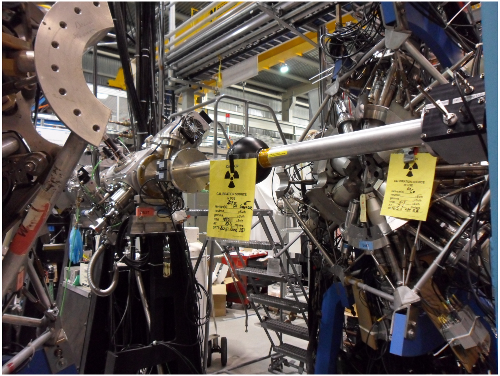
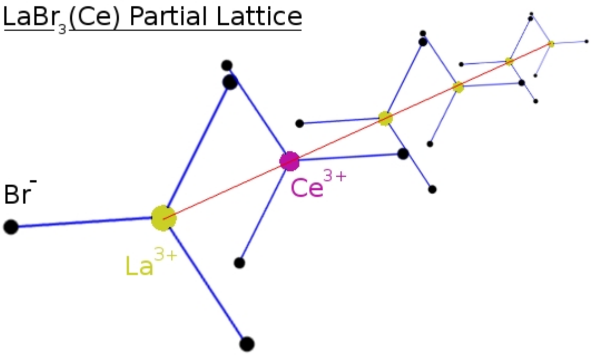


Figure 2: The 8π Array - Open

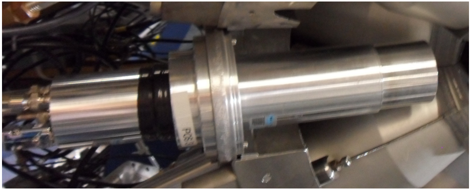
$LaBr_3(Ce)$

- Discovered in 2001
- 4f–5d electron excitation
- Stokes shift of 0.53 eV prevents reabsorbtion
- Emission on order of 3–4 eV - 'Bright' Scintillator



LaBr$_3$(Ce) Detectors and the 8π

- Good energy resolution and timing resolution of ≈250 pico-seconds!
- Installed in the 8π replacing the BaF fast-timing detectors



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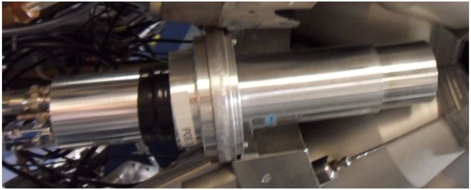
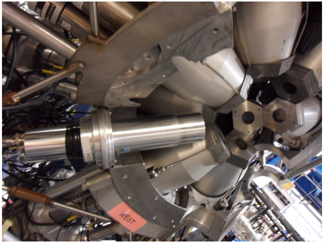




$LaBr_3$(Ce) vs BaF Detector Energy Resolution

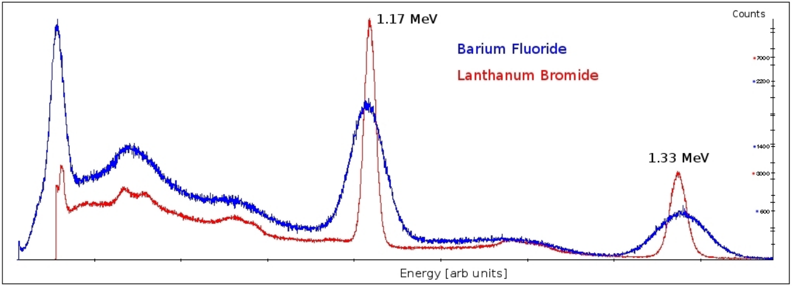
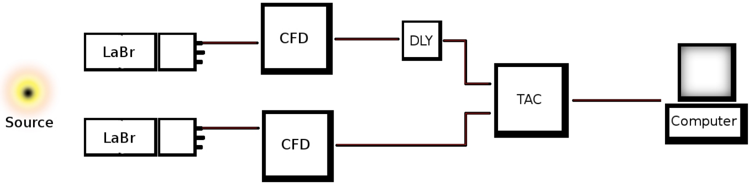


Figure 3: BaF vs $LaBr_3$(Ce) ^{60}Co Energy Spectra

How to test the 8π timing resolution

- Many types of radioactive decay emit multiple gamma rays
- ^{60}Co for example mainly emits 2 gamma rays within a picosecond of eachother



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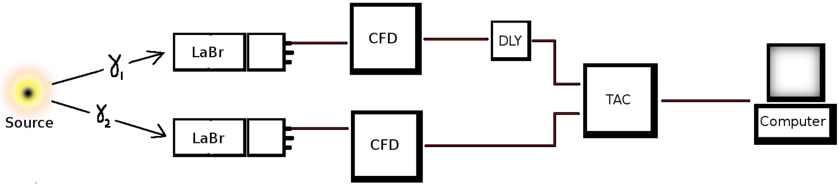
$$^{60}Co \rightarrow {}^{60}Ni + e^- + \text{(gammas)}$$



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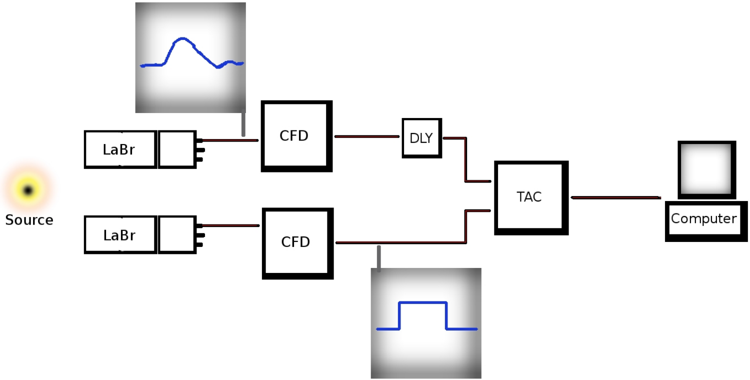

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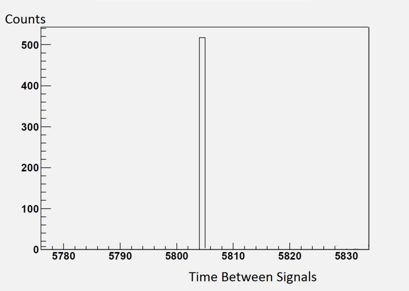
- When both are detected in the 8π array one can insert a delay in one of the detectors to measure the time between detections



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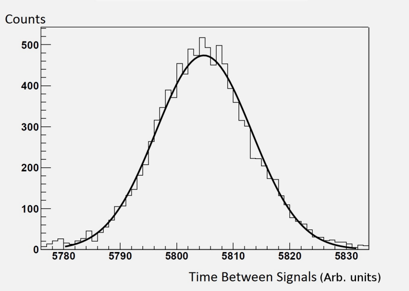

The Project Goal

- The goal of my project is to set up these LaBr detectors with optimal timing resolution
- First step is to process the detector signal as accurately as possible

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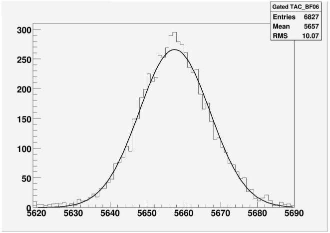

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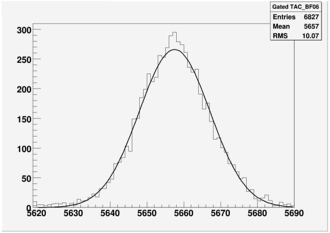

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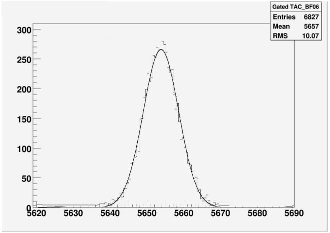

Constant Fraction Discriminator

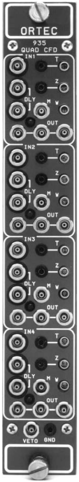

Figure 4: CFD Module

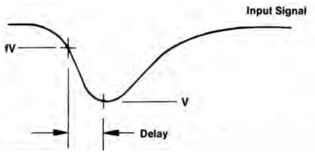

Figure 5: CFD Process

Constant Fraction Discriminator

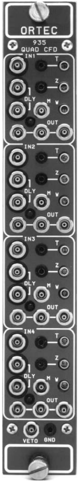

Figure 6: CFD Module

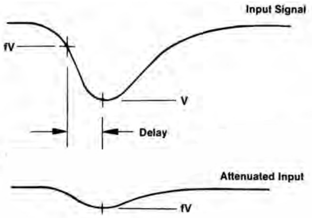

Figure 7: CFD Process

Constant Fraction Discriminator

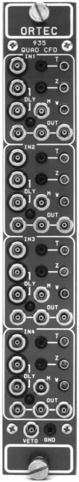

Figure 8: CFD Module

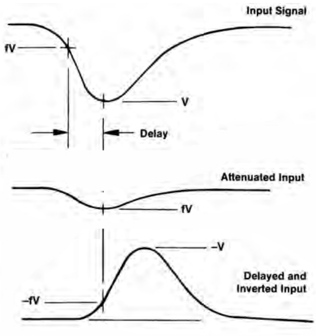

Figure 9: CFD Process

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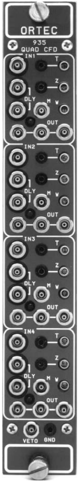


Figure 10: CFD Module

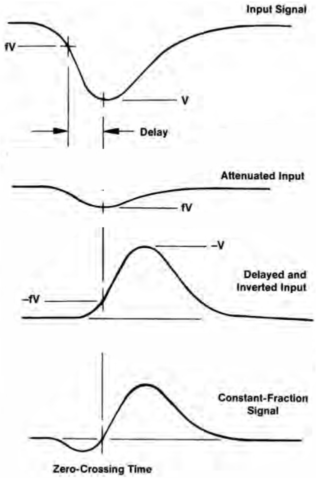


Figure 11: CFD Process

Constant Fraction Discriminator

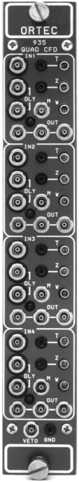


Figure 12: CFD Module

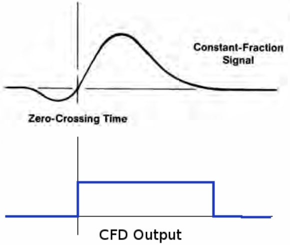


Figure 13: CFD Process

Detector Signal Optimization

- Using a Constant-Fraction Discriminator (CFD) we determine singal timing

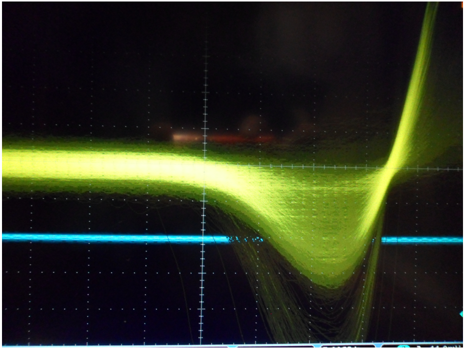
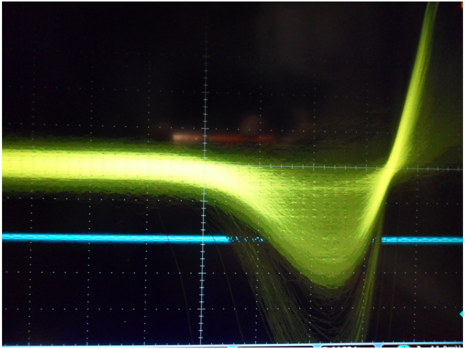


Figure 14: CFD Superimposes Delayed-Inverted Signal

Detector Signal Optimization

- Using a Constant-Fraction Discriminator (CFD) we determine singal timing
- We must adjust settings: Zero-Crossing; Delay-Length



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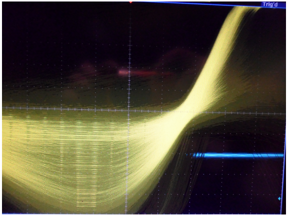


Figure 15: Well adjusted delay

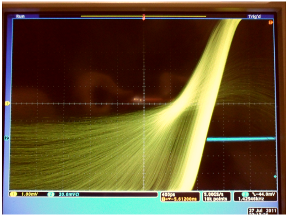


Figure 16: Too long a delay

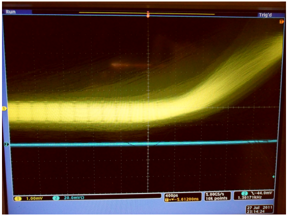
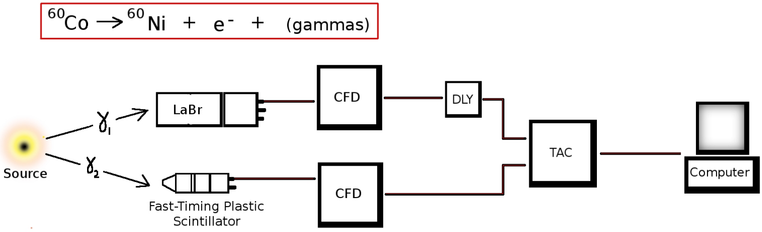


Figure 17: Too short a delay

Our Setup

- Make use of a high-precision plastic timing scintillator
- Timing uncertainty is negligible compared to LaBr



Optimization Results

Collecting and fitting ^{60}Co spectra with different CFD delay lengths allows us to determine which setting is optimal

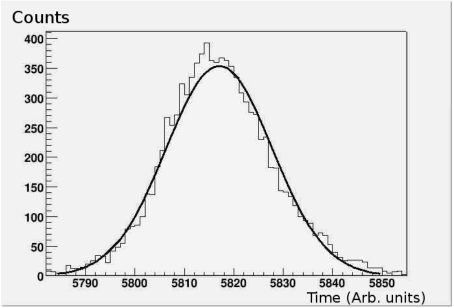


Figure 18: Poor-resolution Setting

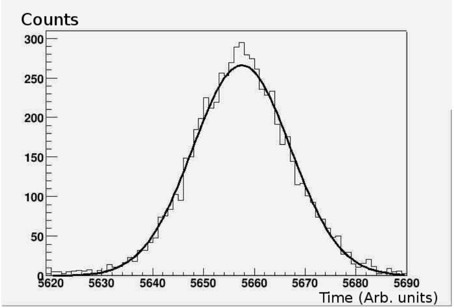


Figure 19: Good-resolution Setting

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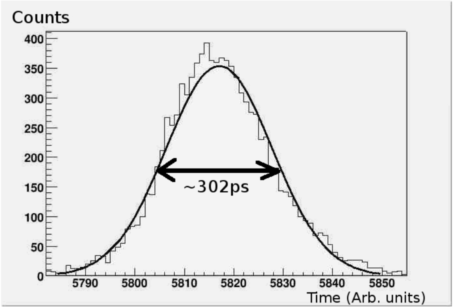


Figure 20: Poor-resolution Setting

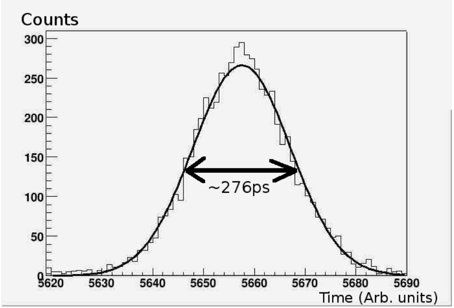


Figure 21: Good-resolution Setting

Optimization Results

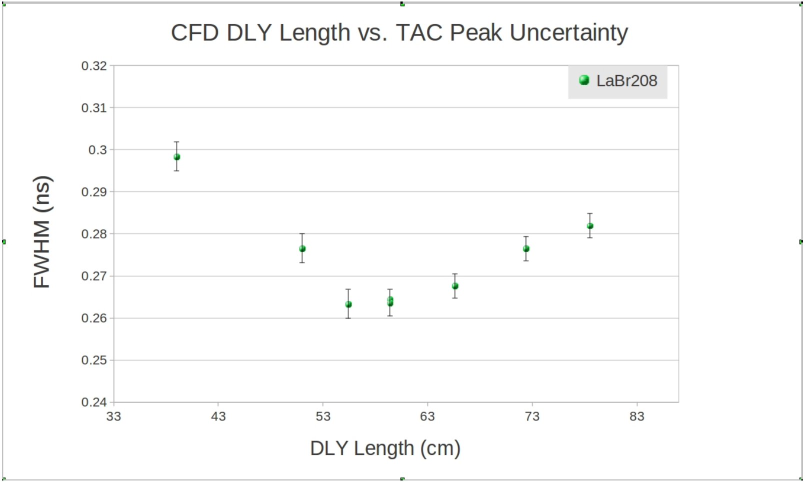


Figure 22: Comparison of CFD Delay Settings for Timing Optimization

Cross-Detector Scattering

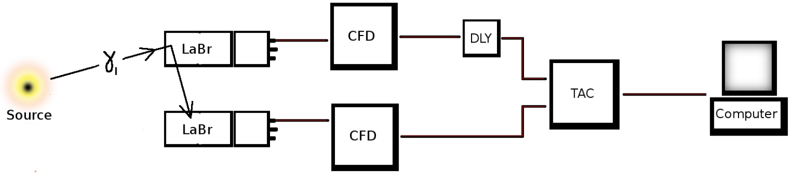


Figure 23: Possible Scattering Problem

Compton Suppression to Increase Time Resolution

- Peak of interest often lies on a Compton background
- Compton scattered gamma rays might be detrimental to timing resolution due to their increased time-of-flight
- This effect has not yet been investigated in the 8π

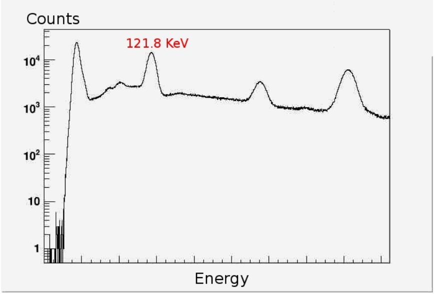


Figure 24: Europium Energy Peaks of Interest

How to Test the Effect of Suppression

- We take advantage of the the ^{152}Eu state with a half-life of $\approx$1.4 ns
- By fitting the time signal we can make measurements of this already known lifetime
- This was measured with varying amounts of suppression material

Figure 25: Scattering Setup

Suppressed and NonSuppressed Timing Spectra

What we have so far... (one of many acquisitions)

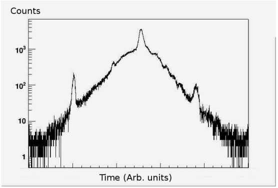


Figure 26: Compton Suppressed ^{152}Eu Time Spectra

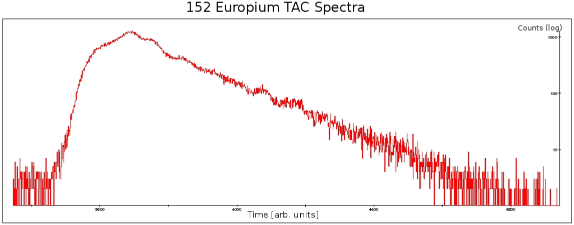
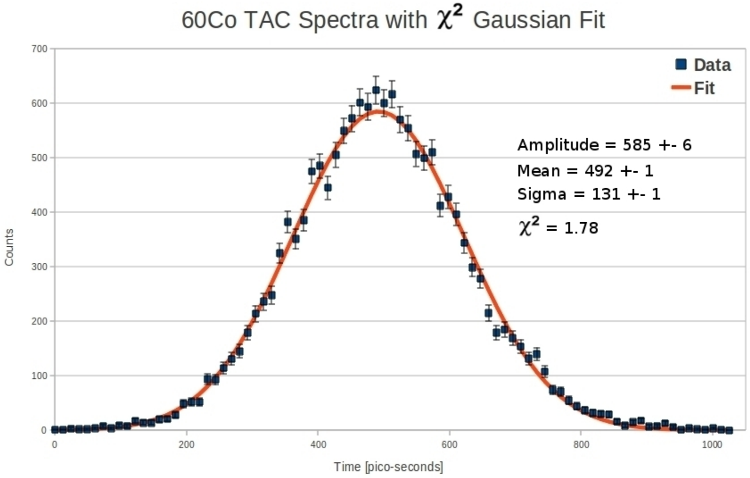


Figure 27: Gated ^{152}Eu Time Spectra

Latest Results

- Recently finished creating a program which performs a 3-parameter χ^2 regression to fit time-resolution data to a gaussian
- Successfully fit ^{60}Co data

Latest Results



Compton Suppression - Worse Results

- Compton suppressed and non-suppressed Europium data was examined
- It appears on first look, however, to conflict with our assumption about the effect of shielding...
- To understand this effect better more experimental investigation may be required

Summary and What's Next

- The $LaBr_3$(Ce) signal processing has been optimized and the fit data looks good
- Suppression vs NonSuppression data has been collected over a period of 2 months at TRIUMF
- Further investigation into the queer effect Compton suppression has had will likely take place in March at TRIUMF
- The Europium time-data will be fit to a skew-gaussian in order to extract a half-life
- This same analysis will also be done for a ^{207}Bi dataset which was acquired last fall
- With this we hope to test the limits of the LaBr detectors, understand the effect of cross-detector scattering and improve the abilities of the 8π

Thank You

for your attention and to all those who contributed

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Nuclear Group

TRIUMF

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