Characterization of ParTI Phoswiches Using Charged Pion Beams

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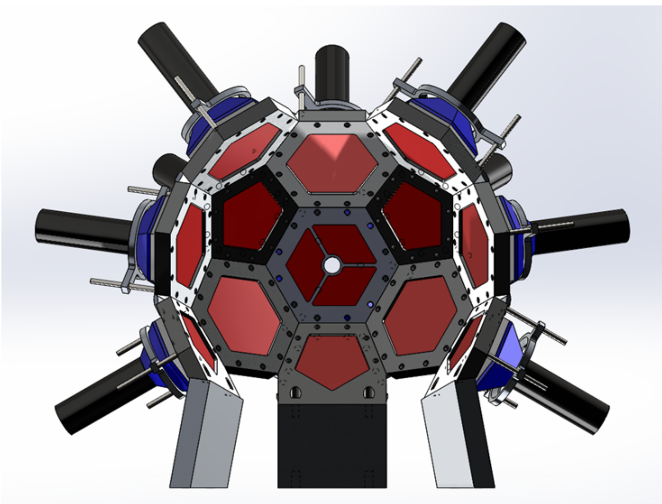
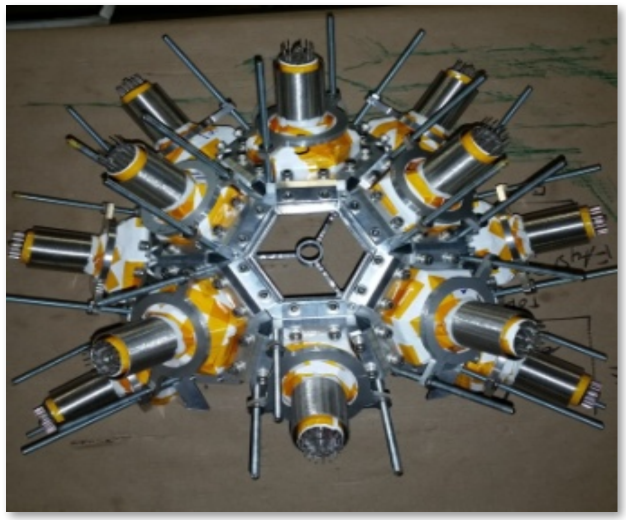
Motivation and Background

- Partial Truncated Icosahedron (ParTI) detector array consists of phoswiches and is designed to measure charged pions (π) emitted in pionic fusion reactions
- Pulse shape discrimination (PSD) particle identification (PID) can be achieved for light charged particles using fast vs. slow pulse shape discrimination
- π also identified by the characteristic decay pulse of their muon (μ) daughters
- 4 phoswiches at PSI
  - π^+, π^-, and proton beams

The ParTI Array

- ≈ 9” diameter
- 15 phoswiches
  - Each with own frame and angled tabs





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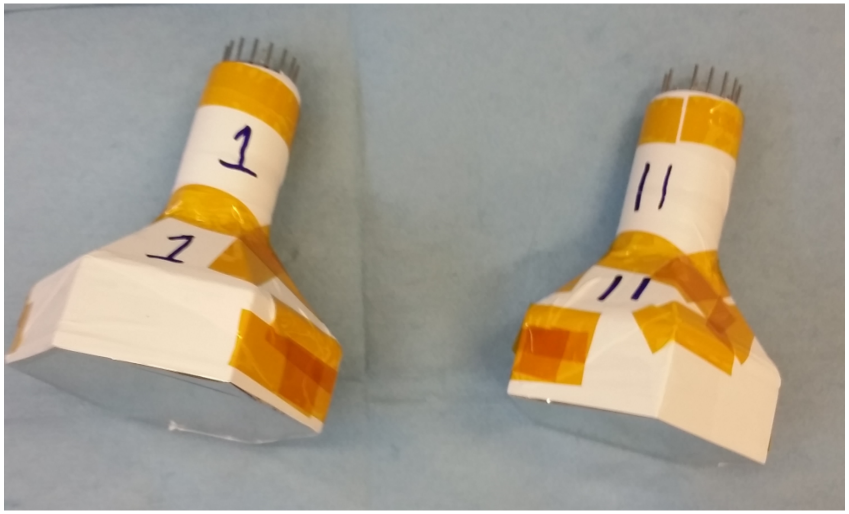
Phoswiches

- Phoswich – 2 scintillating components, PMT
  - EJ-212 scintillating plastic
    - Fast response
  - CsI(Tl) crystal
    - Slow response
- Sensitive to charged and neutral particles
  - PID by energy deposition in 2 components



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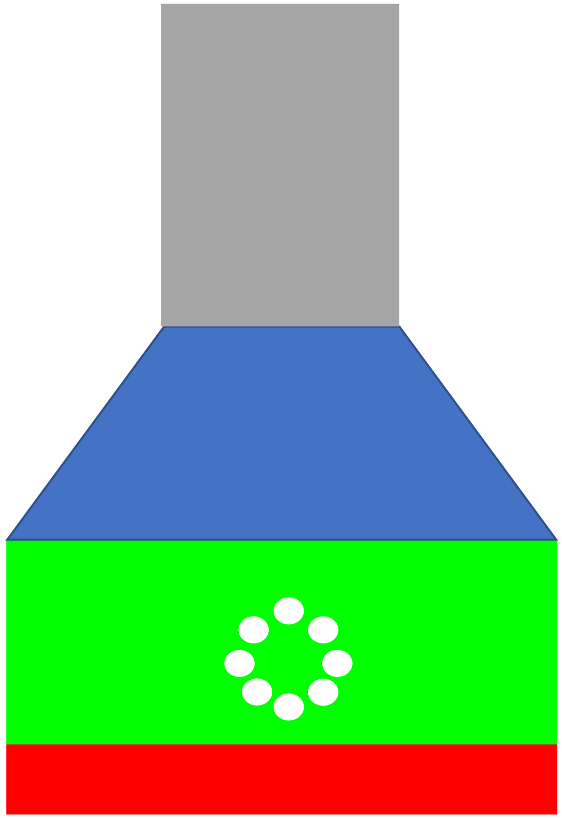
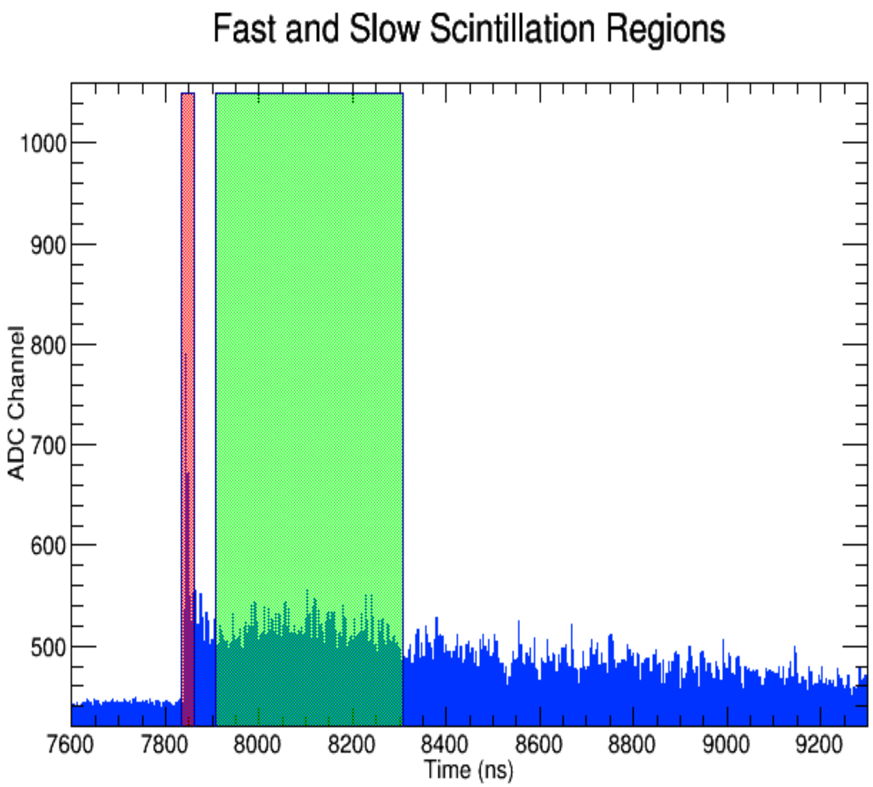
Particles and Phoswiches

1) Fast plastic (red)
2) Slow CsI(Tl) (green)
3) Light Guide (blue)
4) PMT (grey)
5) Particle from reaction (black)
6) Photons emitted from scintillators (white)



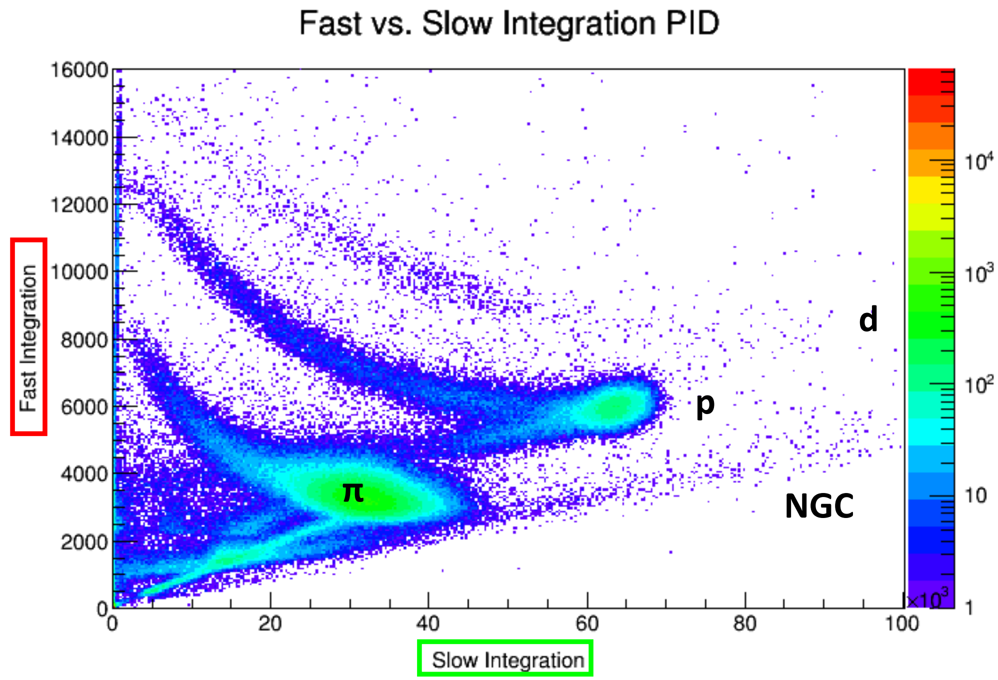
Fast and Slow Integration – How it works

- Energy deposited by particles
  - Photon response
  - Photons converted to cascade of $e^{+/-}$
  - Voltage generated on PMT
    - Converted to counts of photons/time
- Each pulse has 2 regions
  - Fast (red)
  - Slow (green)
- Integrate area under each region



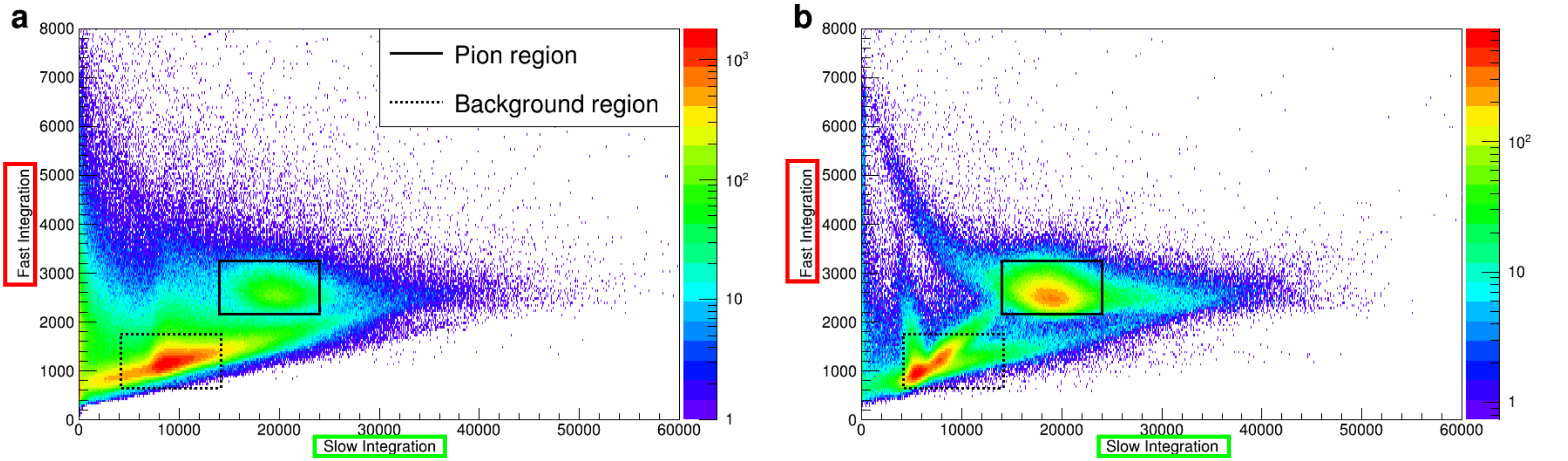
Fast vs. Slow Integration – PID

- Yields PID lines
  - Based on relative energy lost
  - Photons produced proportional to energy deposit
  - Energy deposited unique to particle



Muon Decay Trigger

- Implemented in place of a singles trigger
- Trigger occurs only on possible π-candidate events
  - Only if CFD is triggered 2nd time



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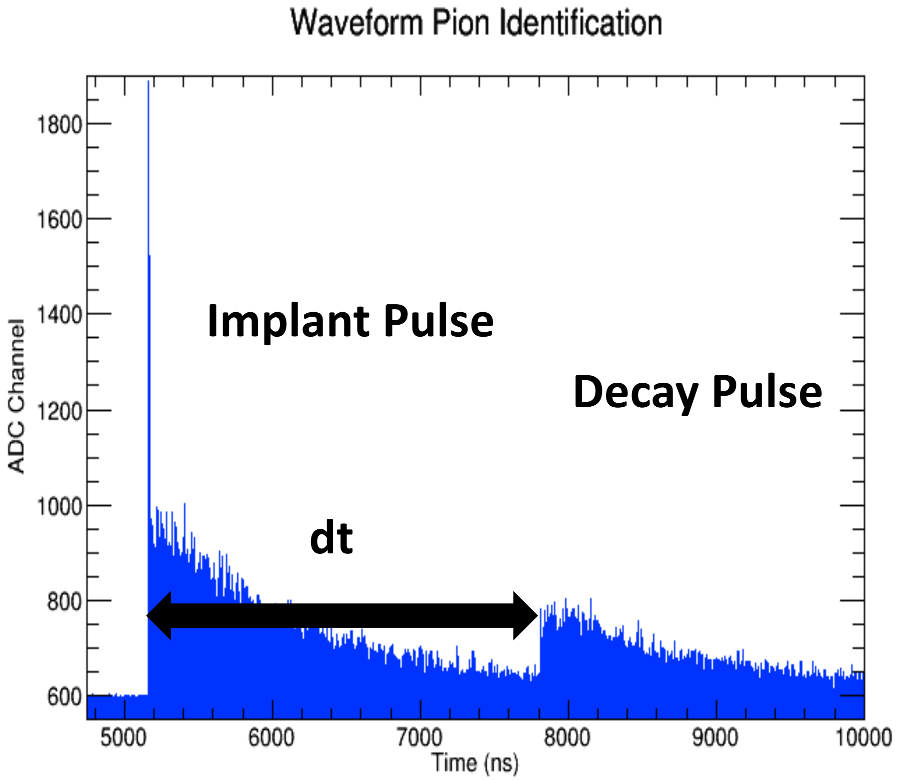
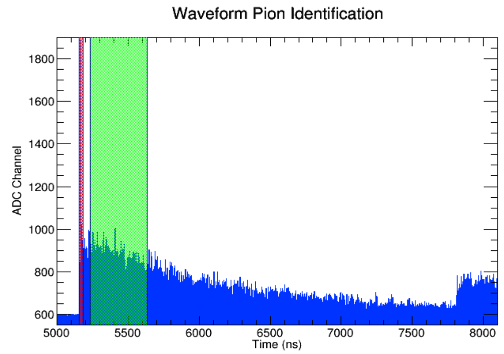
Detecting π Through Digitized Waveforms

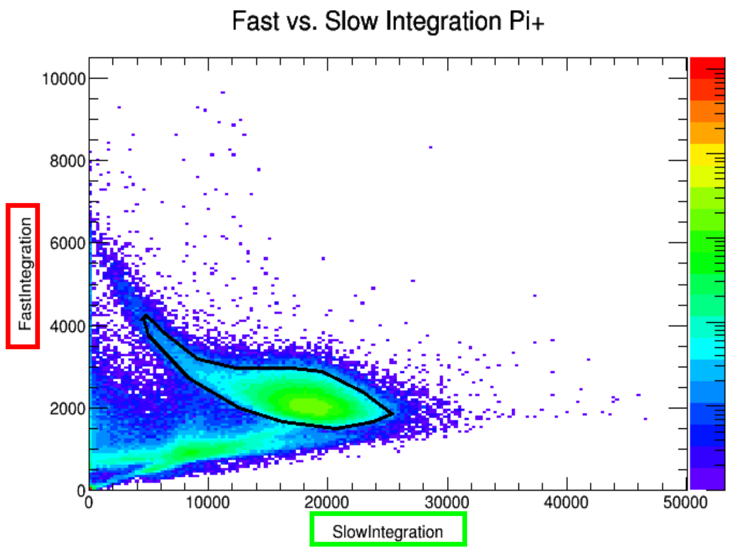
- π decay not easily detectable
  - 26 ns mean lifetime
  - 4.12 MeV energy deposit
- $\pi^+ \rightarrow \mu^+ + \nu_\mu \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$
- $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu \rightarrow e^- + \bar{\nu}_e + \nu_\mu$
  - 2197 ns μ mean lifetime
  - Up to 50 MeV energy deposit
  - 2nd pulse in waveform
    - Decay in detector
    - Difference = dt

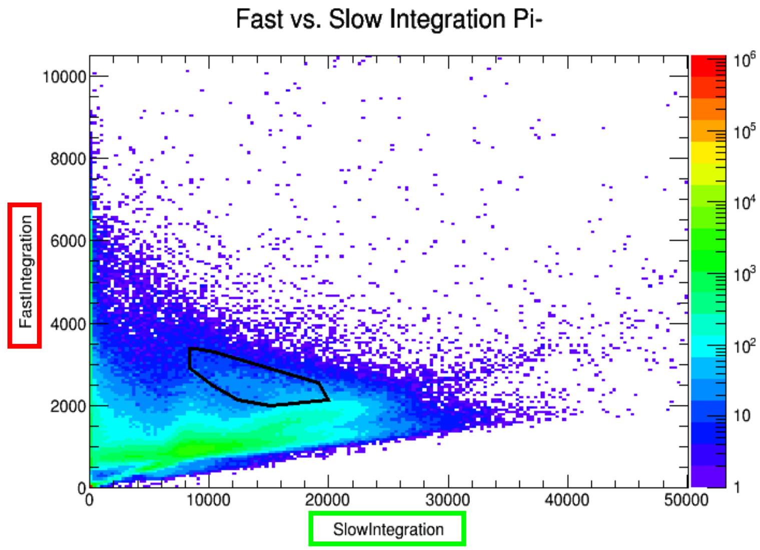


Fast vs. Slow Integration for Implant Pulse

- Cuts gate π section
  - Analyze π decay inside gate

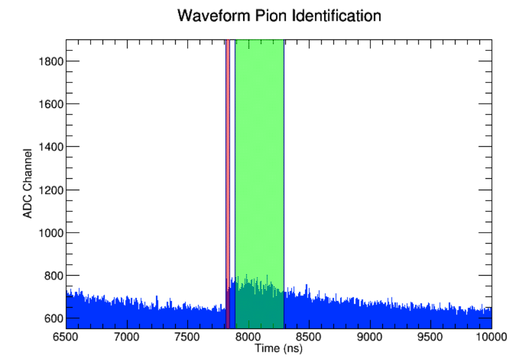


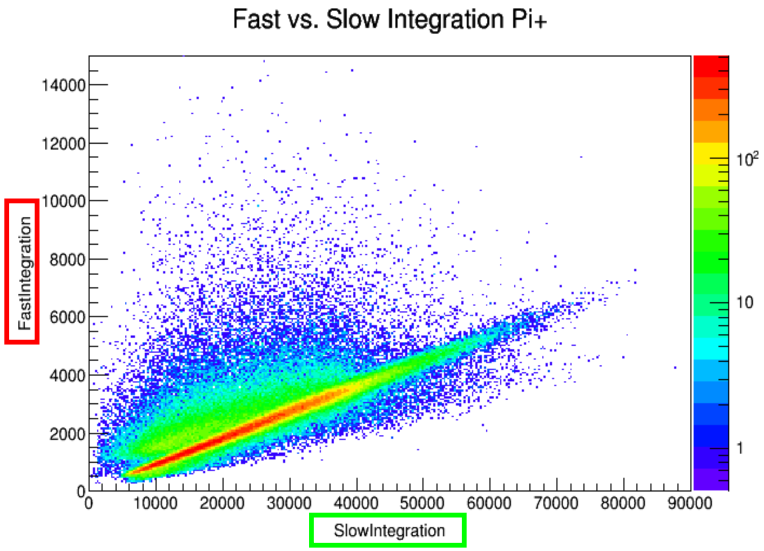


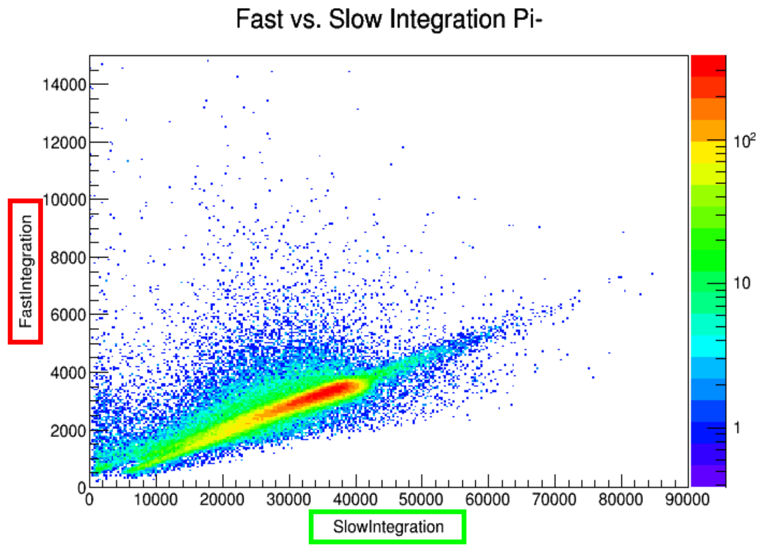


Fast vs. Slow Integration for Decay Pulse

- PSD on decay pulse
  - Possible way to ID π

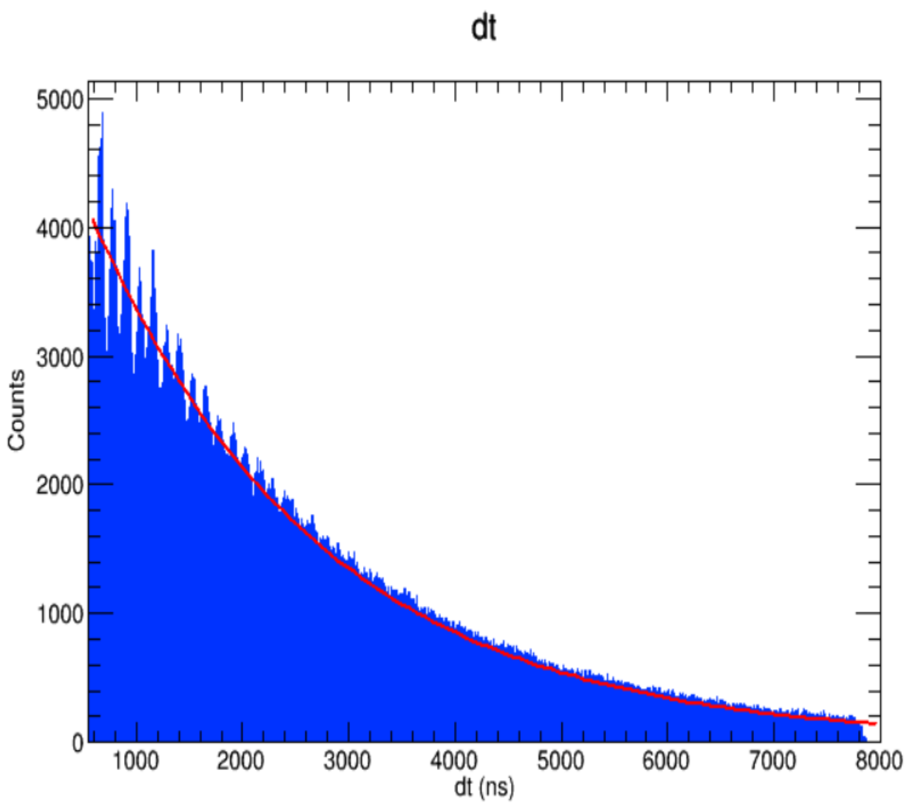






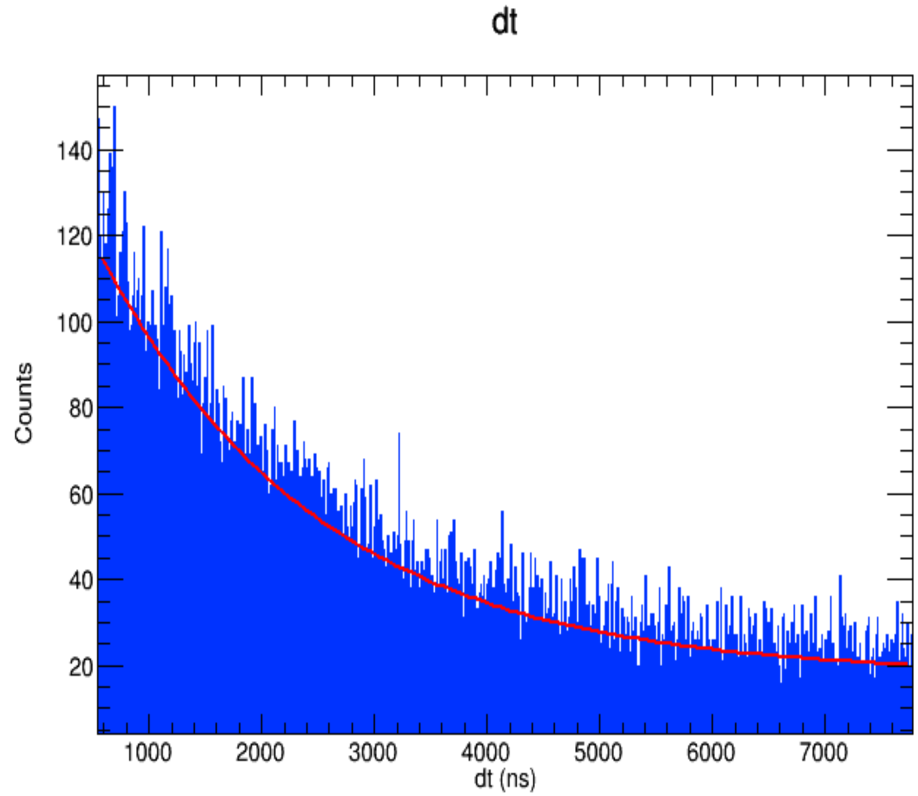
dt and Decay Curves for π^+

- dt corresponds to the time of survival for a muon
- Plotting dt
  - Exponential curve (red)
  - Generated decay constant
    - λ_{μ}=4.55 E −4 ns^{-1}
    - λ_{π^+}=4.57 E−4 ± 3.83 E−7 ns^{-1}



dt and Decay Curves for π^-

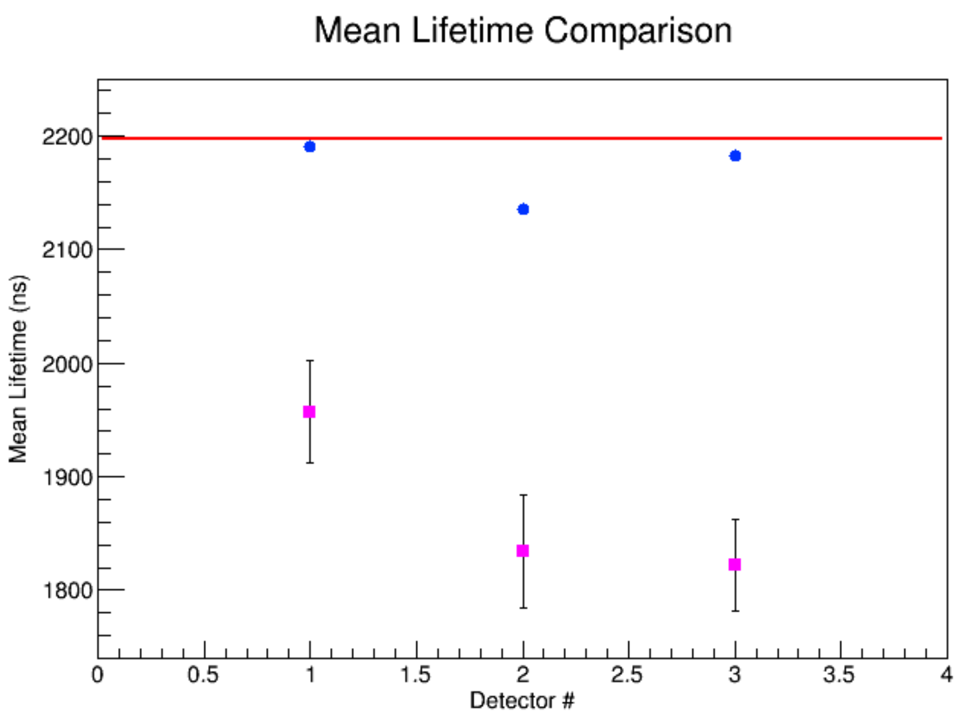
- Generated decay constant
  - λ_μ = 4.55 E−4 ns^{-1}
  - λ_{π^-} = 5.11 E−4 ± 1.27 E−5 ns^{-1}



Mean Lifetime of the Decaying Particle

- Inverse of decay constant
  - $\tau_\mu = 2197\ ns$ (red)

π^+ (blue)	π^- (magenta)
$\tau_1 = 2190 \pm 2\ ns$	$\tau_1 = 1957 \pm 51\ ns$
$\%\ error_1 = 0.32\%$	$\%\ error_1 = 10.9\%$
$\tau_2 = 2136 \pm 2\ ns$	$\tau_2 = 1832 \pm 47\ ns$
$\%\ error_2 = 2.78\%$	$\%\ error_2 = 16.6\%$
$\tau_3 = 2182 \pm 3\ ns$	$\tau_3 = 1822 \pm 42\ ns$
$\%\ error_3 = 0.68\%$	$\%\ error_3 = 17.1\%$



Conclusions

- Using decay trigger increases the selectivity for π by an order of magnitude
- Fast vs. Slow PID methods for the phoswiches allow for π identification and separation from other light charged particles
- Decay curves for μ daughter can be reproduced by focusing on the π implant region to further identify the original presence of a π in its PID region

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