Digital Signal Processing

for

HPGe Detectors

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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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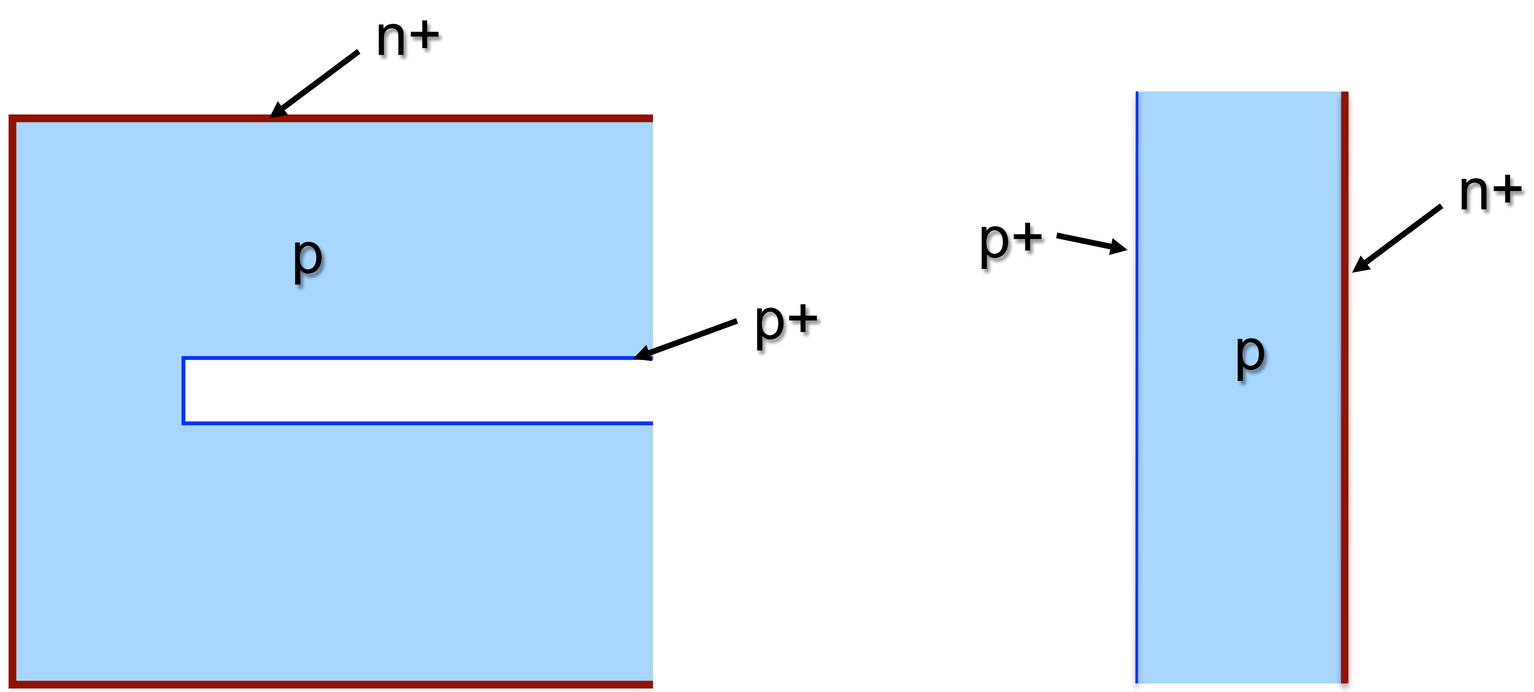
HPGe Detectors

- Hyper-Pure Ge (HPGe) detectors are the “gold standard” for gamma-ray spectroscopy
  – Unsurpassed energy resolution
  – Indispensible to in-beam nuclear structure studies for many decades
- Made from a single large crystal pulled from molten hyper-pure Ge
- Operated as a large reverse-biased diode; up to 5 kV bias
  - No current flows until a gamma ray interacts with an electron in the Ge, lifting its energy above the band gap of the Ge semiconductor
  - This electron scatters off other electrons, creating many electron-hole pairs; each pair takes ~ 3 eV in energy
  - The electrons and holes separate in the strong electric field and are collected at the electrodes
  - The resulting charge pulse is proportional to the deposited gamma-ray energy, and is amplified and digitized
- Operated at cryogenic temperatures to prevent thermal generation of electron-hole pairs

HPGe Detectors

Historically, there have been two designs, both cylindrical:
Coaxial and Planar.

Later we will discuss a new design, "Point Contact" detectors



Closed-end coaxial

Planar

HPGe Detectors

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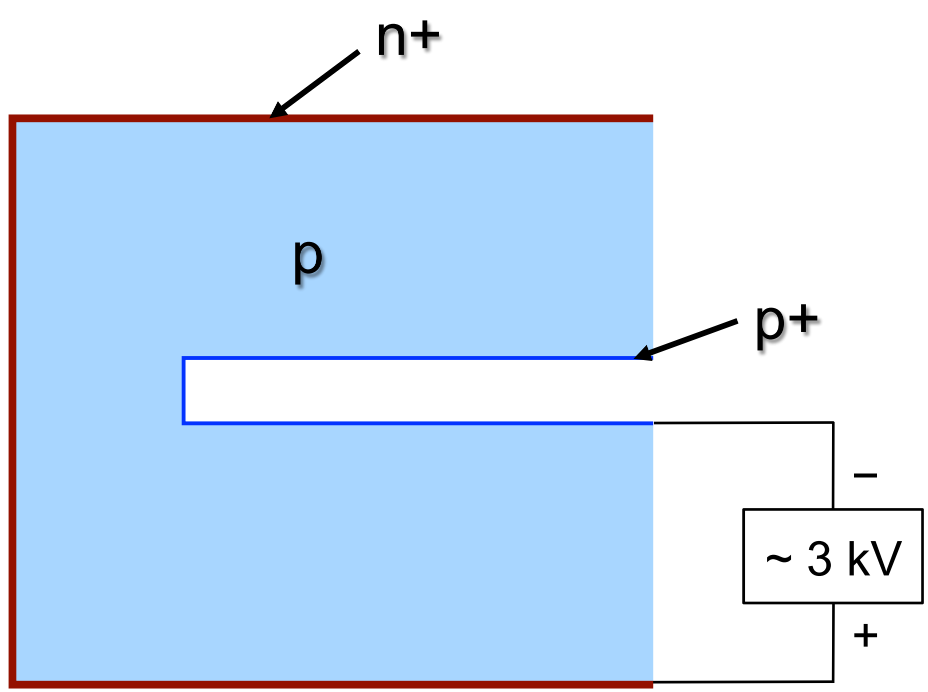
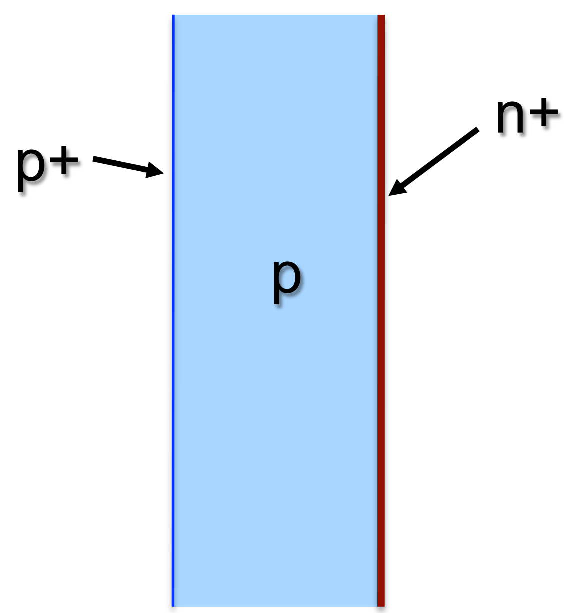


Closed-end coaxial



Planar

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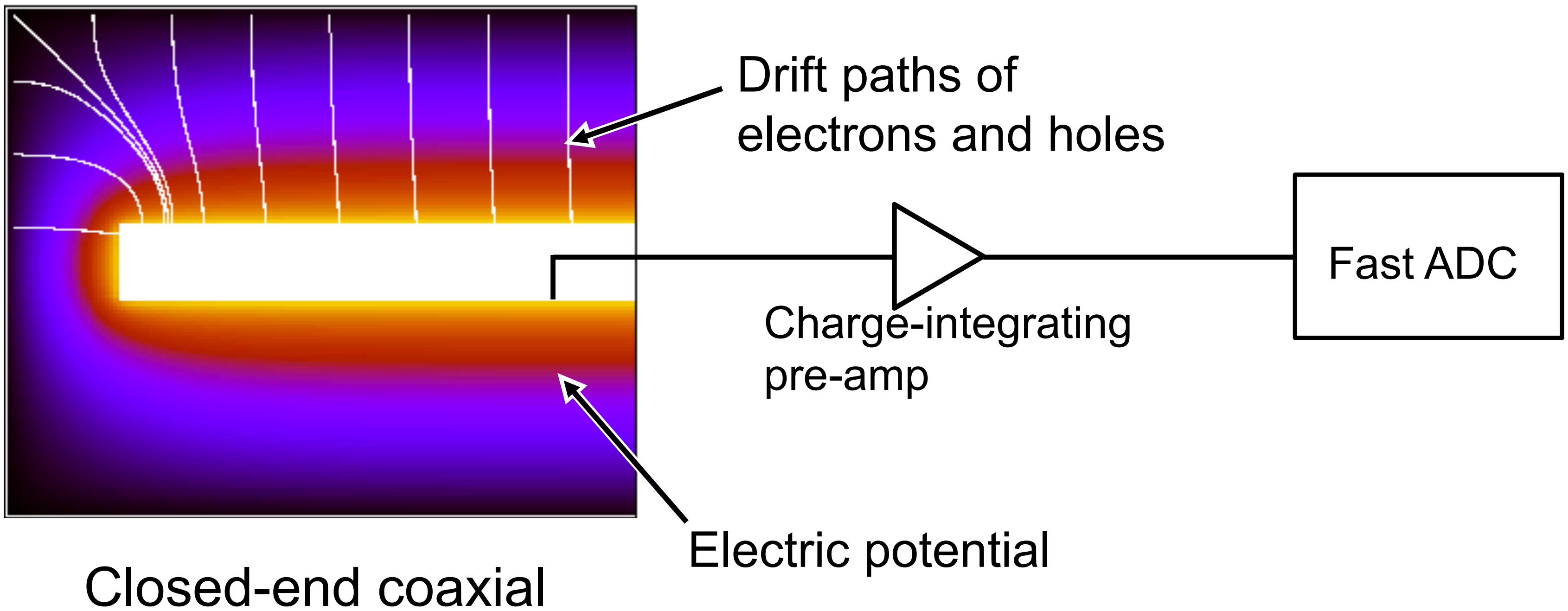
HPGe Detectors

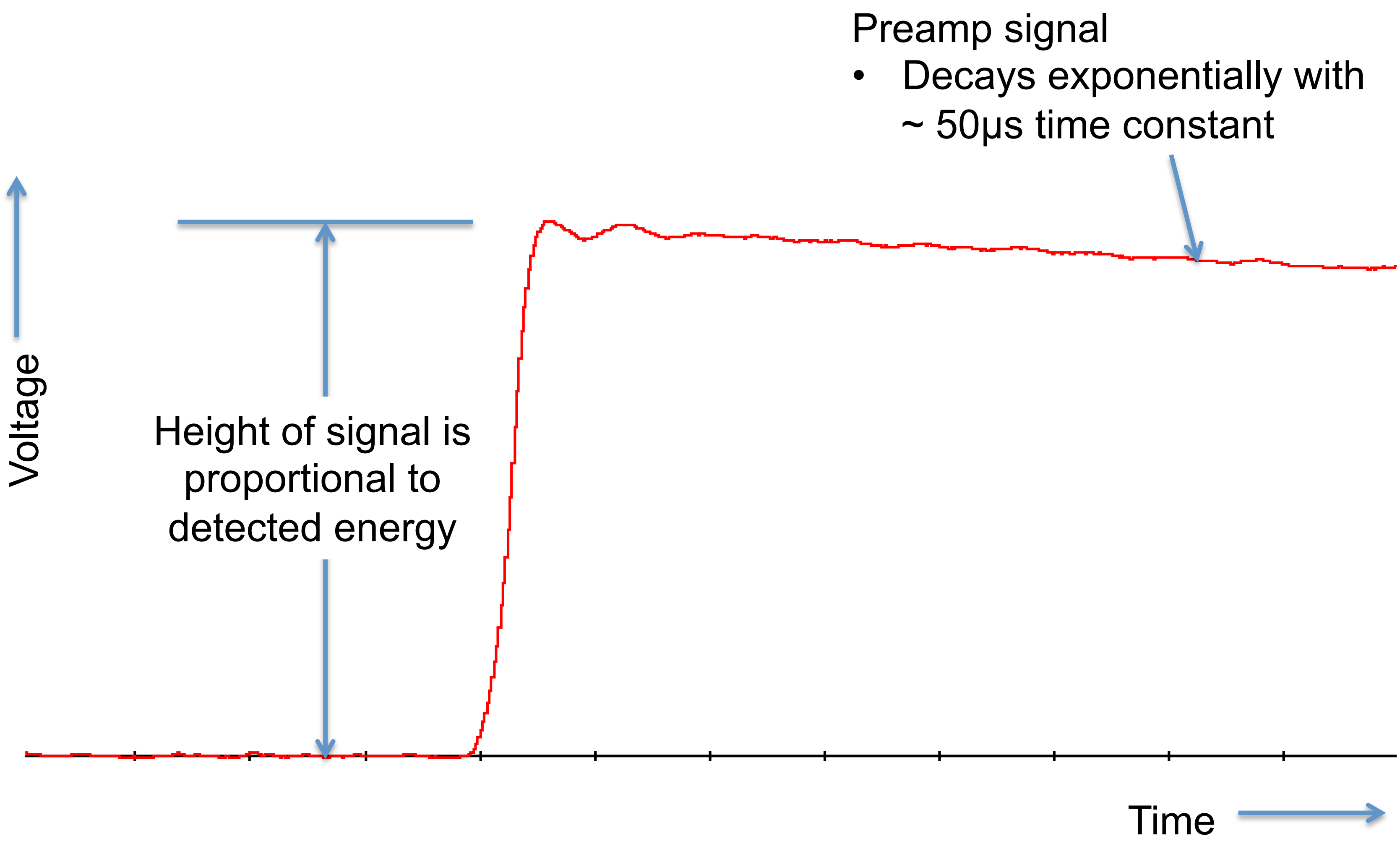


Signal Processing

Once the preamplifier signal/waveform has been digitized, need to process the data to extract interesting numbers, e.g.

- Amplitude
  - Gives energy, so we want it to be as accurate as possible
- Timing
- Pulse-shape analysis to select specific types of events
- Noise filtering and/or reduction
- Pile-up rejection and/or correction

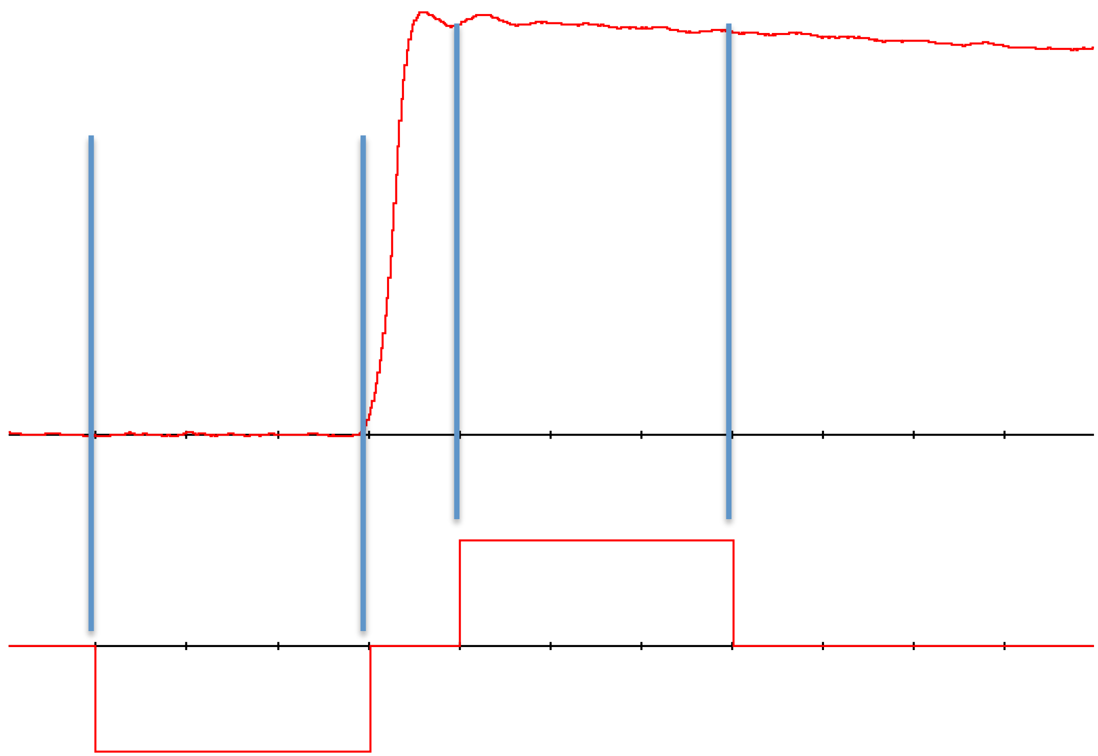
Extracting Signal Amplitude



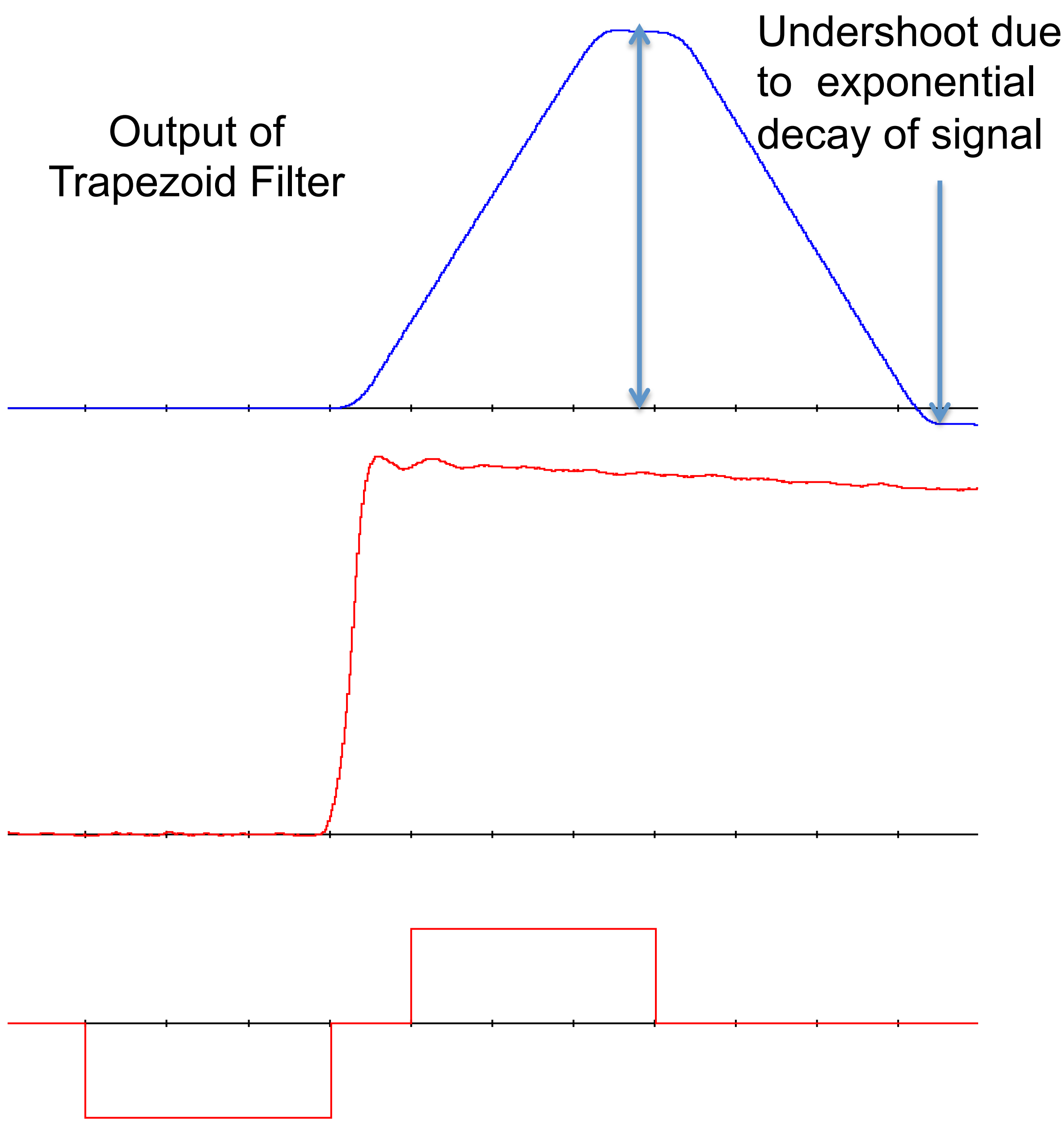
Extracting Signal Amplitude

But the signal has noise…

- Need to integrate signal for several microseconds to determine amplitude more precisely
- Use “Trapezoid Filter”

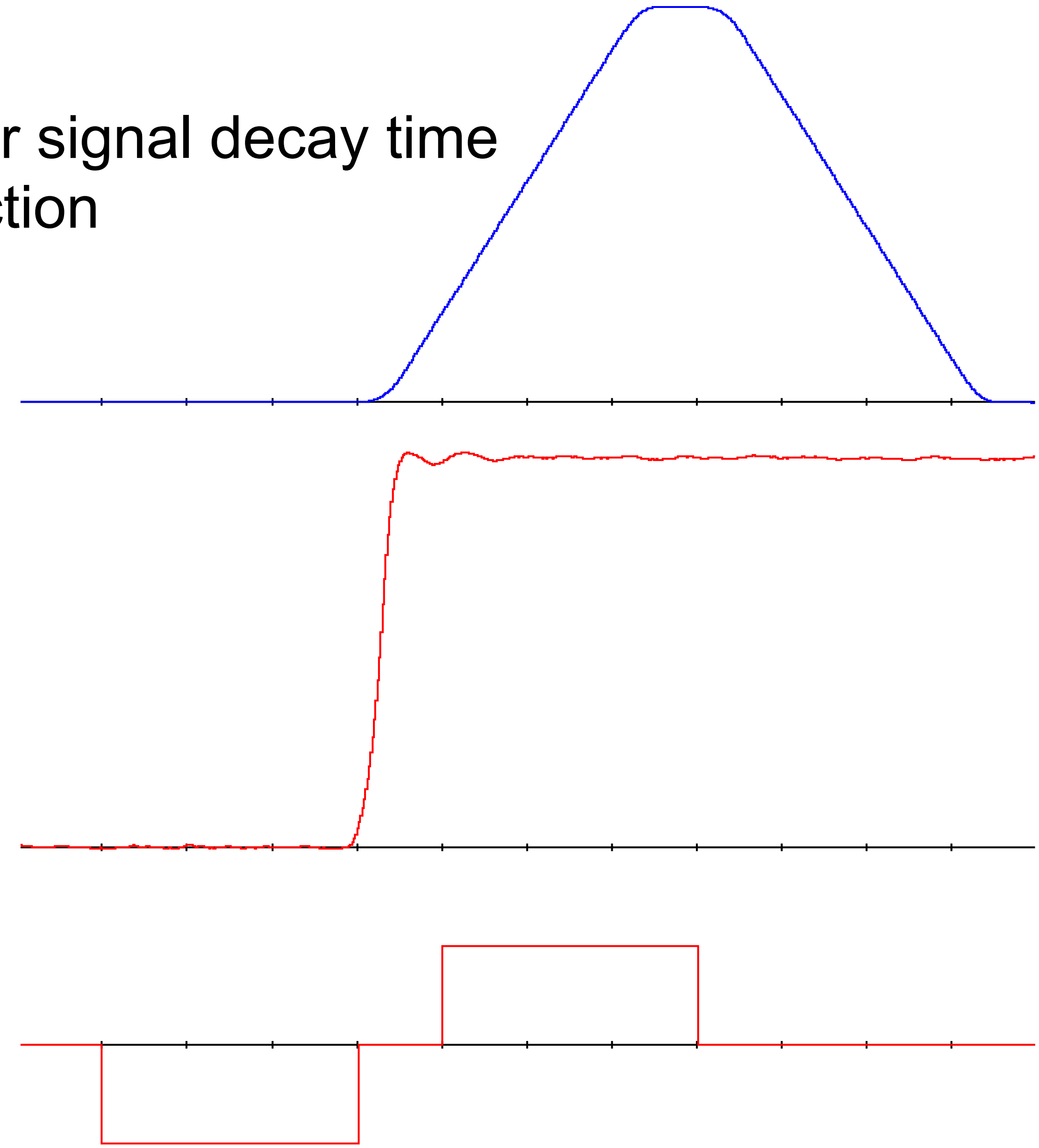


Extracting Signal Amplitude



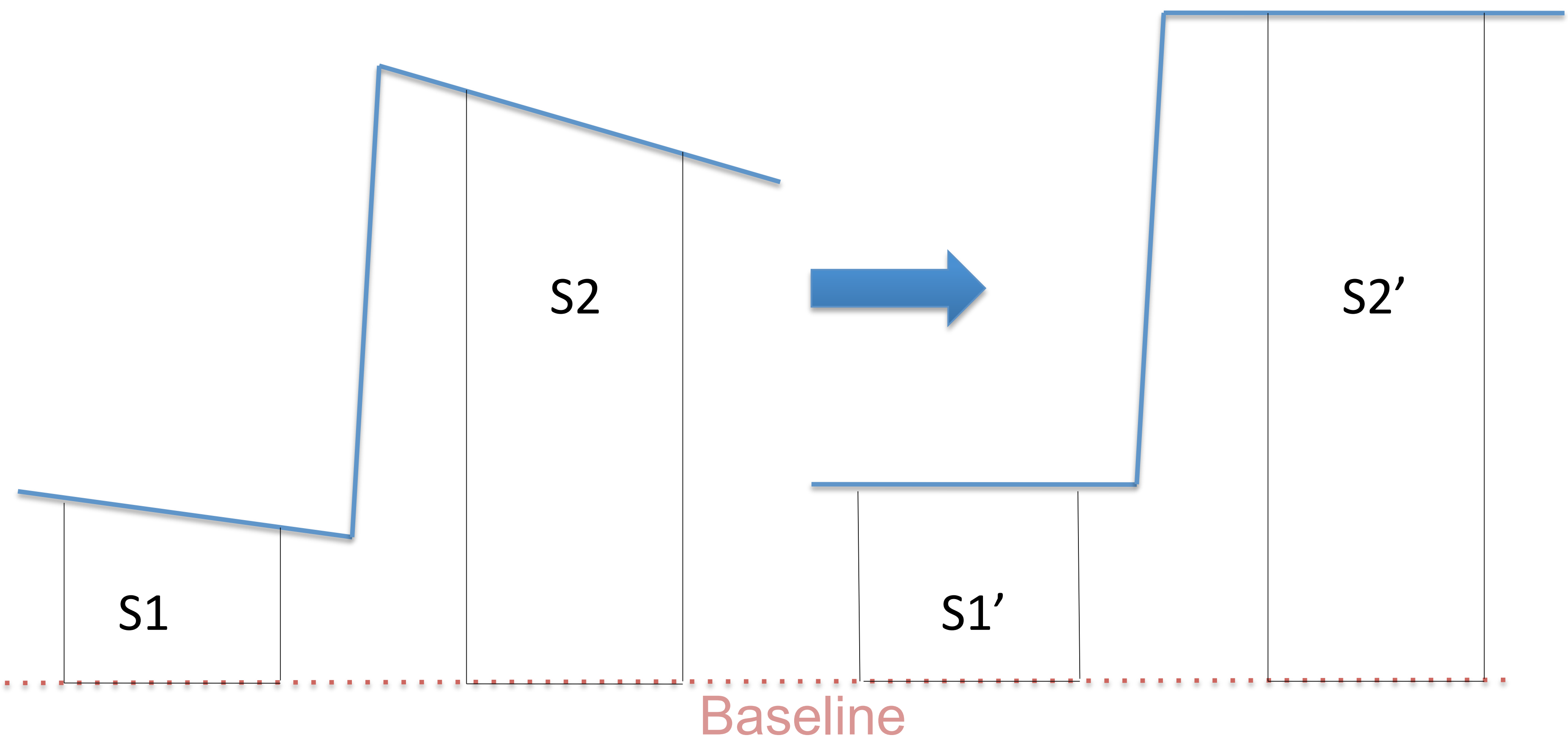
Extracting Signal Amplitude

- Need to correct for signal decay time
- “Pole-zero” correction



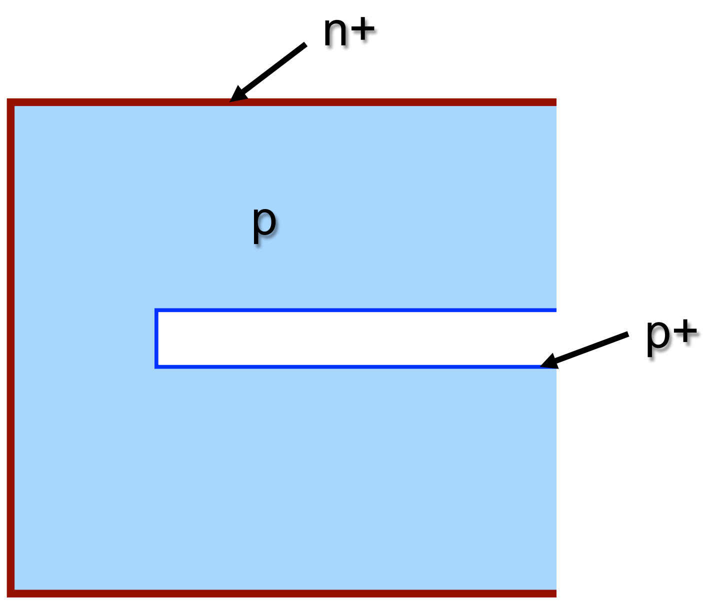
Trapezoid and P/Z Correction

- Need to know the baseline (asymptote) and signal decay time constant tau
- E ~ S2' – S1'

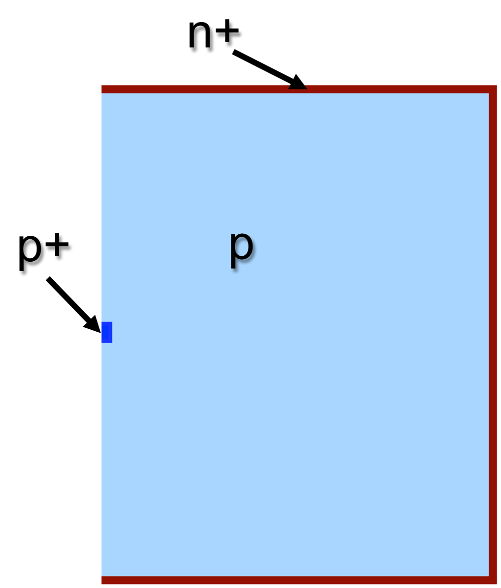


Point Contact Detectors

- No deep hole; small point-like central contact
- Length is shorter than standard coaxial detector
- Excellent discrimination between single-interaction and multiple-interaction events
- Excellent resolution at low energies



P-type Coaxial



P-type Point Contact

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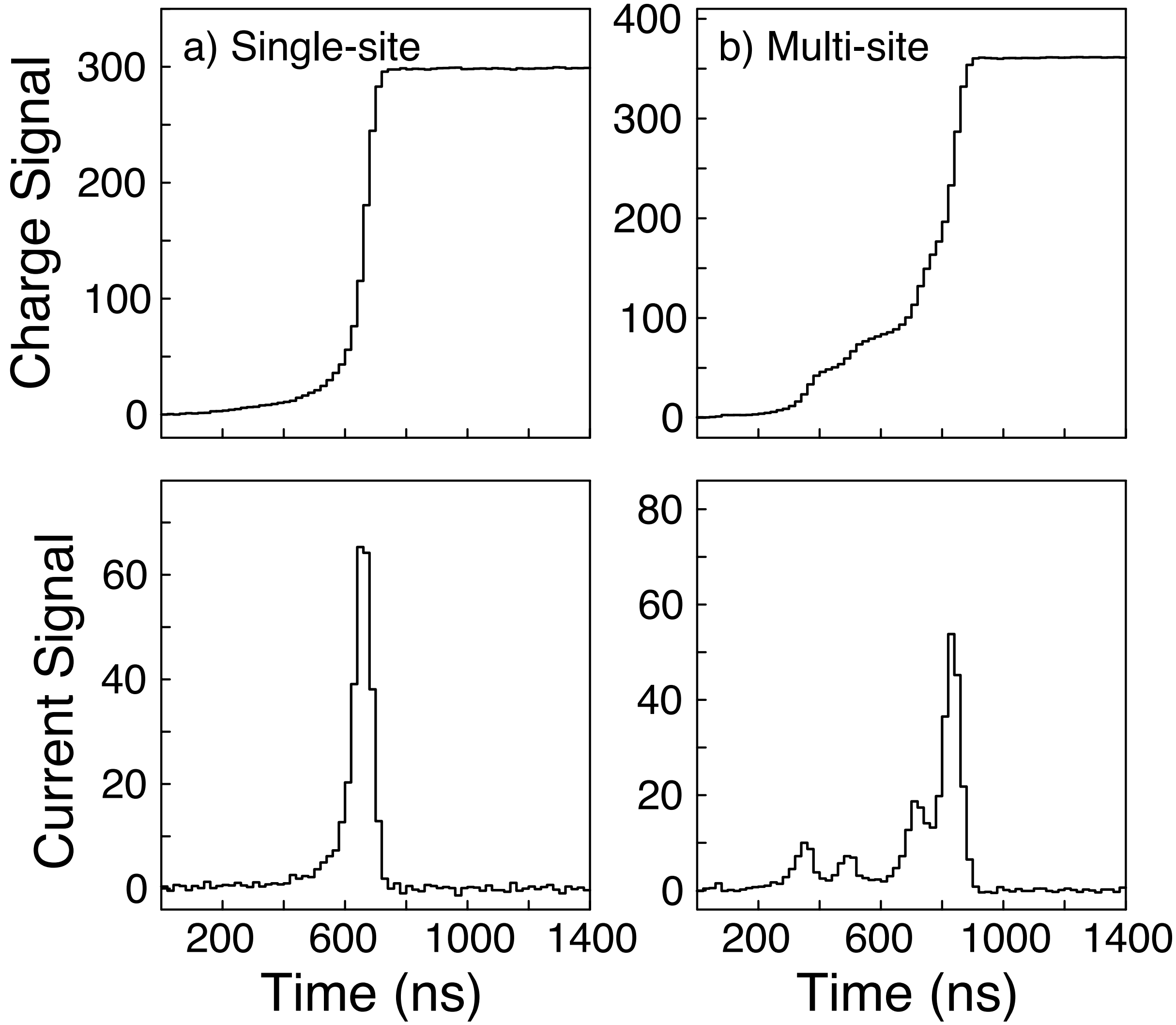
Pulse-Shape Response

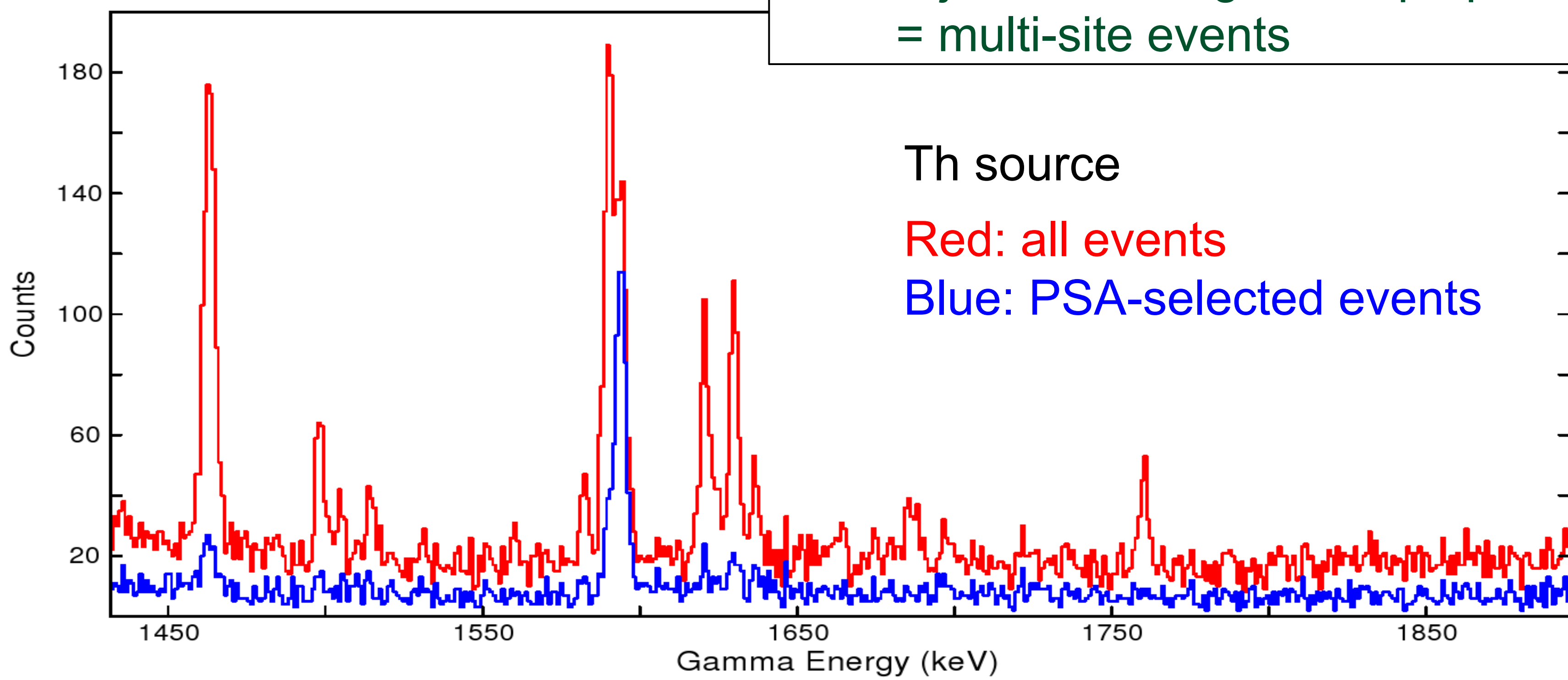
Point Contact detectors are ideal for discrimination between single-site and multi-site events (or determining the number of interactions)



Pulse-Shape Response

95% efficiency for double-escape peak
= single-site events

99% rejection of single-escape peak
= multi-site events



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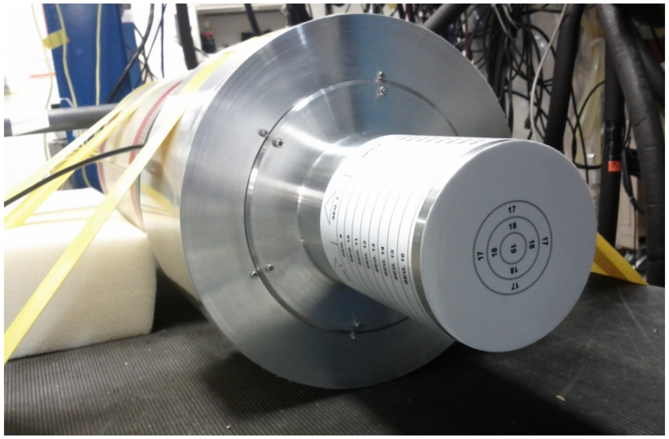
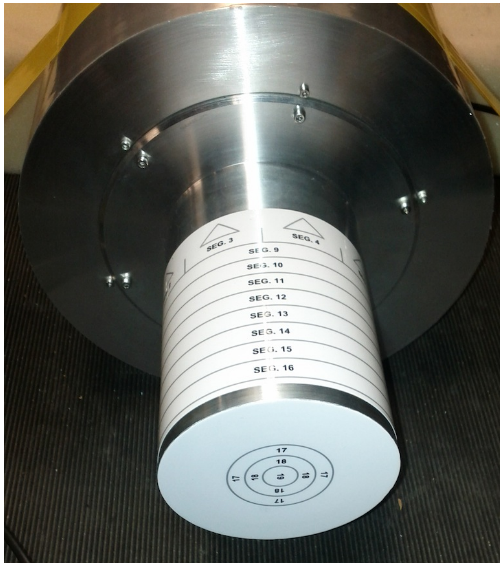
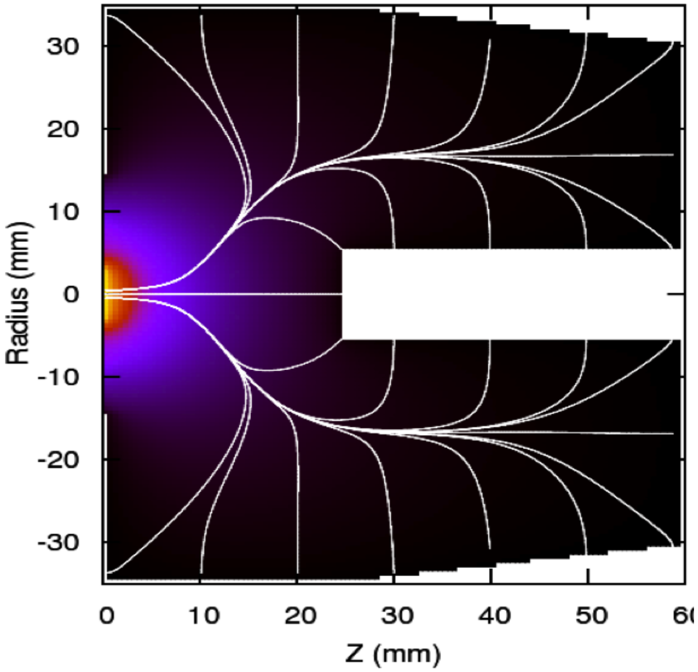
“Inverted-Coaxial” Point-Contact Detector

- Designed and developed here at ORNL
- Drift of charges is radically different from a normal coaxial detector
- Very long drift times, ~ 2 μs
- A segmented prototype has recently been produced by Canberra France







Am "SuperPulses"

- Finely collimated Am source, directed at known location on the detector surface
- Select events with 60 keV in a single hit segment
- Use PSA to select only single-site events
- Time-align events to a common time
- Take average signal to reduce noise to negligible level