ten be a limiting factor for sensors making precision measurements with small signals

- semiconductor detectors
- photodiode
- ionization chamber

Consider

\[ i = nev \]

\[ \text{electrode} \]

\[ \text{spacing} \]

What are sources of fluctuation in this current?

\[ <d_i^2> = \left( \frac{ne <dv>}{2} \right)^2 + \left( \frac{ev}{2} <dn> \right)^2 \]

- velocity fluctuations
- number fluctuations
- due to thermal noise

- shot noise each carrier is random and uncorrelated with others
Thermal Noise

Consider a resistor.
- spectral noise power density vs. frequency

\[ \frac{dP_n}{df} = 4kT \]

Boltzmann constant

Using \( P = V^2/R = I^2R \), we get spectral densities:

\[ \frac{dV_n^2}{df} = 4kT \]
\[ \frac{dI_n^2}{df} = \frac{4kT}{R} \]

To get the root mean square noise:

\[ V_{no}^2 = \int c_n \delta f \cdot \delta f \]

Total noise \( \rightarrow \) increase with bandwidth.
- Note: small bandwidth \( \rightarrow \) large rise times
- fast capsule will release noise
Shot Noise

Spectral density

\[ n^2 = 2QI \quad I \text{ average current} \]
\[ Q \text{ electron charge} \]

Follows from fact that electrons come independently of each other

- If have a conductor
- fluctuations in charge density
- yield detect more charge density
- little noise
Pulse Shaping

Two objectives

1) reduce bandwidth
   - too much will let in more noise components
   - signal only has restricted range of bandwidth
   - often need to "slow down" pulse to do this

2) constrain duration of pulse
   - if pulse too long = sequential pulses overlap
   - reduce low frequency components

The competing criteria lead to high + low pass constraints on pulse shape
   - optimization
Triggering + Data Acquisition

In many experiments:

- rate of events too high to record all
- some discrimination between noise and particle physics processes is needed
- mechanism to synchronize readout across detector elements
- need to access data as it comes (and filter)

There are several components:

- criteria for whether to readout
- logic for making decision
- timing + control scheme for
- levels of triggering
Trigger Criteria

At fundamental level, need to know when physics occurs

coincidence

signal \rightarrow \text{readout detector}

Often more sophisticated:

- energy threshold
- track segment identified
- isolation measurement (for jets)
- shower shape: cone for jets

identification
The Trigger Logic

One may have several different criteria

- if have a track
  a cluster
  cluster that is narrow AND
  cluster about 10 GeV to combine

track AND cluster AND (>10 GeV) AND vertex
= "electron"

One can also combine basic criteria

muon AND electron

(2 electrons) OR (electron AND 1 track)

Structure of the trigger dictated by final states looking for
Triggering

Often, triggers are hardware-based.

- Considering earlier,
  - Might be able to use hardware for basic decisions.

<table>
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<td>curved</td>
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<tr>
<td>low momentum</td>
<td>high momentum</td>
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<tr>
<td>track</td>
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- Compare to lookup table: p selectors

- Fast triggers, not very sophisticated, or lack full detector information.

Software triggers

- Digitize data
- Fast algorithms reconstruct data
  - Much slower, more accurate decisions.