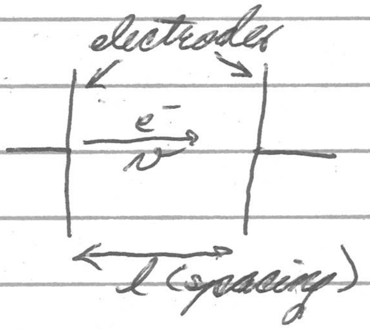
oise

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

- semiconductor detectors
- photodiodes
- ionization chambers

Consider

$$\underline{\underline{i = \frac{nev}{l}}}$$



What are sources of fluctuation in this current?

$$\langle di \rangle^2 = \left(\frac{ne}{l}\langle dv\rangle\right)^2 + \left(\frac{ev}{l}\langle dn\rangle\right)^2$$

velocity fluctuations → due to "thermal noise" ⊕ number fluctuations → eg. current flow in semiconductor

'shot noise' each emission is random & uncorrelated with others

Thermal Noise

Consider a resistor.

- spectral noise power density vs. frequency

$$\frac{dP_n}{df} = 4\boxed{k}T$$

Boltzmann constant

Using $P = V^2/R = I^2R$, we get spectral densities:

$$\frac{dV_n^2}{df} = 4kTR \qquad (\equiv e_n^2)$$

$$\frac{dI_n^2}{df} = \frac{4kT}{R}$$

To get the ~~variance in velocities~~ total noise

$$v_{on}^2 = \int_0^\infty \boxed{e_n^2}\,\boxed{A^2(f)}\,df$$

~~en~~

frequency response of system

Total noise ⇒ increase with bandwidth

→ Note: small bandwidth → large rise times

→ making faster pulse will increase noise

Shot Noise

Spectral density

$$i_n^2 = 2\,\underbrace{\boxed{e}}_{\text{electron charge}}\,I \quad \propto \text{ average current } (I)$$

Follows from fact that electrons come independently of each other

→ if have a conductor
  - fluctuations in charge density
  - fields extract more charge readily
    ∴ little noise

Pulse Shaping

Two objectives

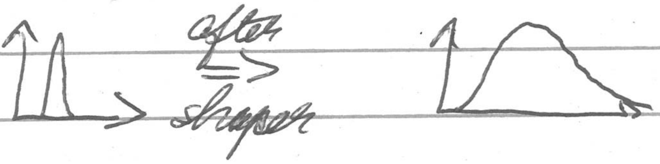
1) reduce bandwidth

frequency domain

→ 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

time domain

→ 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 assess data as it comes (and before rejected)

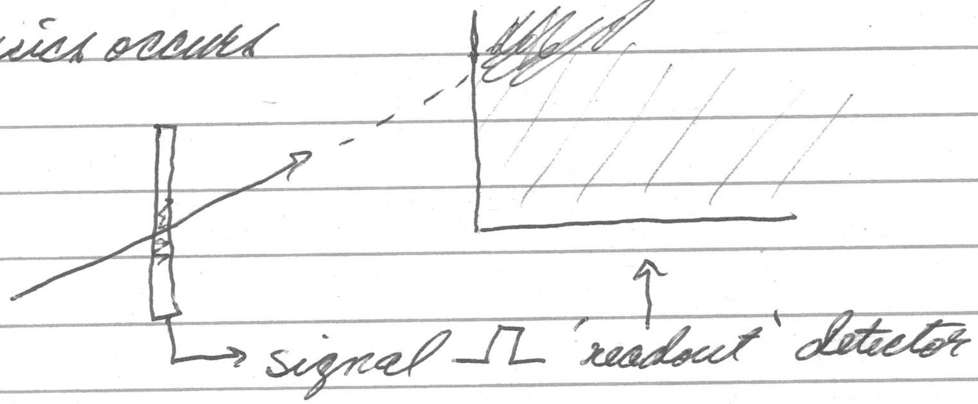
There are several components

- 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



Often more sophisticated

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

particle identification

The Trigger Logic

One may have several different criteria

→ if have a track
a cluster
cluster that is narrow
cluster above 10 GeV

use logical AND to combine

track AND cluster AND (>10 GeV) AND narrow = "*electron*"

One can also combine basic criteria

muon AND electron

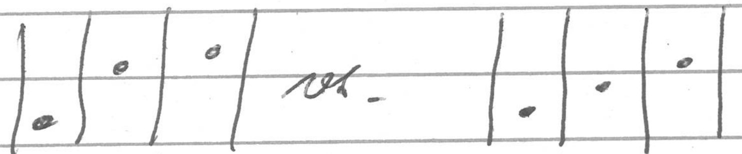
(2 electrons) OR (1 electron AND 1 track)

Structure of the trigger dictated by final states looking for

Triggering Levels

Often, triggers are hardware-based

- coincidence earlier
- might be able to use hardware for basic decisions



curved → low momentum track

straight → high momentum

Compare to lookup table: ~ p_T selection

- fast triggers, not very sophisticated, or lack full detector information

Software triggers

→ digitize data
→ fast algorithms reconstruct data
- much slower, more accurate decisions