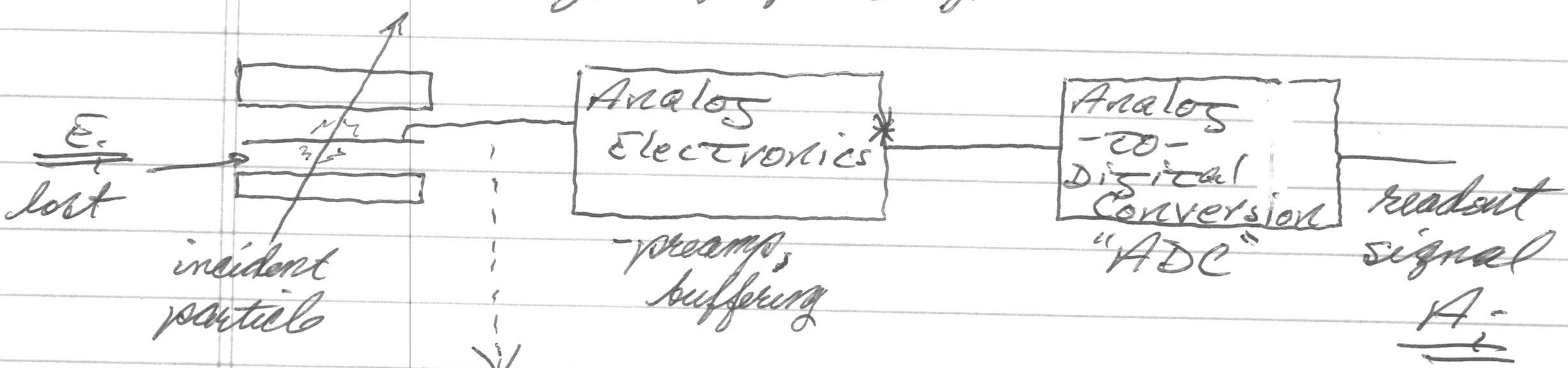
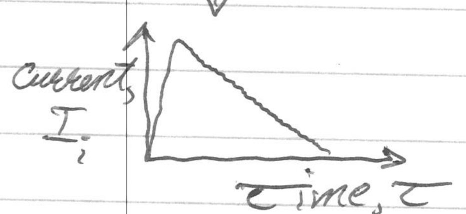
Calibration + Monitoring

Signals retrieved from detector elements and ultimately digitized, e.g.





total charge $Q_i = \int I_i \, d\tau$

For LAr, $Q_i \propto E_i$ ($i \to$ ith detector element)

Design electronics so it's linear

$$A_i \propto Q_i \propto E_i$$

- May not be perfectly achievable

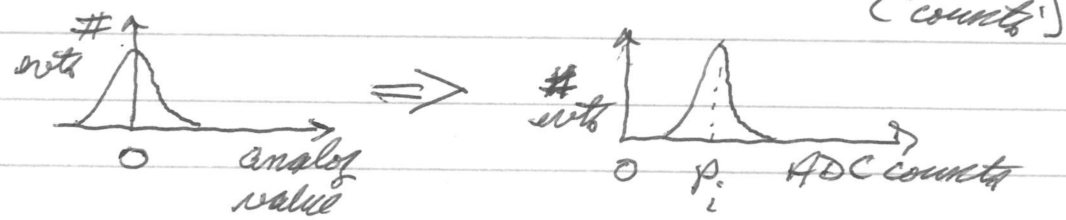
* for scintillator, electrode + preamplifier electronics replaced by PMT + electronics

For a linear detector and electronics:

$$\boxed{E_i = \alpha_i (A_i - P_i)}$$

P_i = "pedestal"

- a signal added at digitization stage to ensure a positive value in ADC units ('counts')



- can set approximate value
- measure precisely in events with no particles

A_i = observed "signal" in # ADC counts
- actual signal is excess above pedestal $(A_i - P_i)$

α_i = calibration constant

Note: The detector + electronics may not be linear
- more complex expression with more constants to establish

Calibrating Cell Energies

For linear situation

$$\boxed{\alpha_i = f_{samp}\, C_Q\, C_{ADC}}$$

Ionization System

f_{samp} = sampling fraction, set by detector construction

C_Q = energy per charge constant

C_{ADC} = charge per ADC count

Units: $E_i = \frac{eV}{C} \cdot \frac{C}{ADC}\left[ADC - ADC\right] = eV$

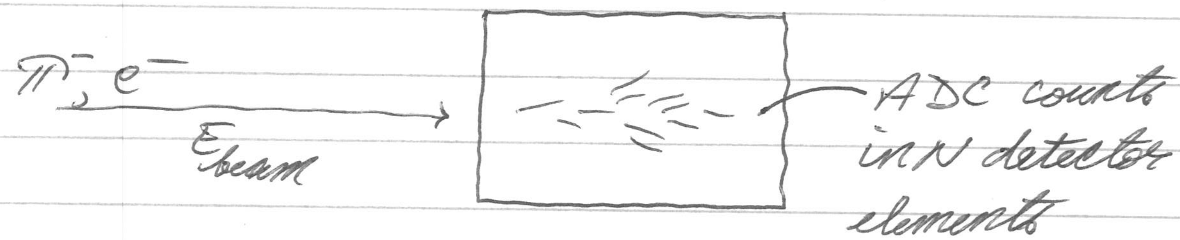
The constants C_Q + C_{ADC} can change with time for many reasons:

- impurity in LAr
- → analogous parameter for scintillator changes for ageing of scintillator, change in gain of photodetector
- changes in analog electronics
- pedestal shifts @ ADC

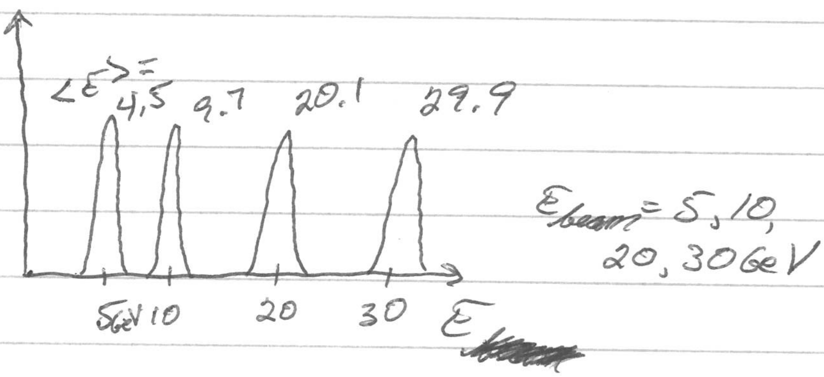
∴ Very important to monitor + correct for.

Test Beam Calibration

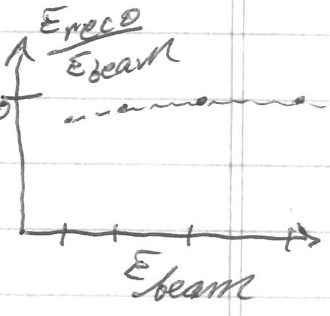
Prior to beam, can place detector elements in a 'test beam'



Observe: (example)



- Can use to establish sampling weights f_{samp}^{-1}
- Verify that electronics gives signal expected
  - establish initial C_Q + C_{ADC} values if same electronics as final detector
- Establish linearity (and non-linearities) of detector + electronics



For a large experiment (eg. ATLAS, DØ), only test some modules
- calibrate others relative to these

in situ Calibration

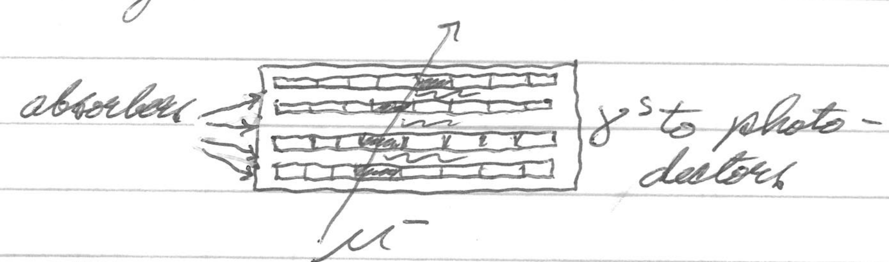
Need to establish calibration of the running detector

- You can't rely on a priori calculations or simulations!

Testing sensitivity to signal in active medium:

Scintillator:

- radioactive sources (helps monitor ageing)
- cosmic rays



→ $\frac{dE}{dx}\big|_\mu$ observed per cell

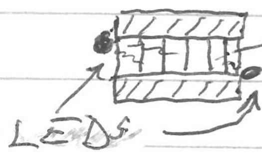
LAr

- purity monitors (also radioactive sources)
- temperature monitoring + adjustment

Testing downstream electronics

- for photodetectors

  - use light-emitting diodes (LED's)

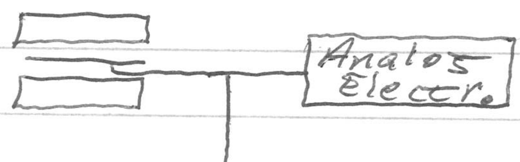


→ Each cell has eg. PMT

→ pulse of known size emitted by LED

- for ionization detectors

  - electronic charge injection



There will be channel-to-channel variations

- some time dependence to correct for

$\therefore \alpha_i = \alpha_i(t)$

Cryogenic Calorimeters

Above devices useful when measuring $E >> MeV$

If want sensitivity in eV range, need other approach

- Generally important when looking for non-electromagnetic matter at low E

  WIMPs, neutrinos

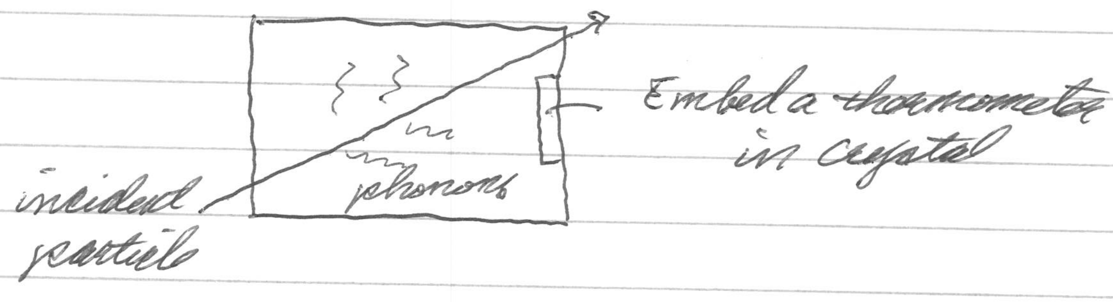
- Need to rely on mechanisms that permit energy transitions at low E

- phonons (to 10^{-5} eV @ 0.1 K)
- Cooper pairs
  - bound states of antialigned e^-s at low temperature
  - in superconductors
  - to 10^{-4} eV to 10^{-3} eV

- To prevent normal thermal photon signals: Operate at mK

Phonon Detectors

Use a medium such as a crystal
- the 'absorber'



Examples:

TeO_2 @ 15mK

$\sigma_E = 4.2\,keV$ for 5MeV α particle

Si @ 20mK

$\sigma_E \sim 0.1\,eV$

For a WIMP:

- energy transfer to struck nucleus ~10keV
- can use scintillator which operates at low temperature (eg. $CaWO_4$)

∴ measure scintillation and phonons