Detectors in Particle Physics

- Interaction of radiation with matter
  - Tracking detectors
    - Wire chambers
    - Silicon Detectors
  - Calorimeters
    - Electromagnetic calorimeters
    - Hadron calorimeters
Interaction of radiation with matter

- Any high energy particle passing through neutral matter will cause the matter to be ionized and/or "excited"
  - Primary mechanism by which particle detectors work
  - To first approximation independent of particle type
    MIP = minimum ionizing particle
  - Energy loss due to ionization is relatively small
dE/dx-resolution:
(159 samples)
µ-pairs: 2.8 %
min. ion. π: 3.2 %
Electromagnetic interactions with matter

- If a charged particle undergoes a hard electromagnetic interaction with a nucleus – Brehmstrahlung results:

\[ e + Z \rightarrow e + \gamma + Z \]

characterized by radiation length
\[ 1_{\text{rl}} = 0.35 \text{ cm of W} \]
\[ 1_{\text{rl}} = 1.76 \text{ cm of Fe} \]
\[ 1_{\text{rl}} = 304 \text{ m of air} \]

Chernkov and transition radiation also possible

- High energy \( \gamma \) rays can "pair produce"

\[ \gamma + Z \rightarrow e^+e^-Z \]

- Compton scattering is also possible

\[ \gamma + e \rightarrow \gamma + e \]
Hadronic Interactions with matter

- Hadrons (such as $\pi^\pm$, $K_{long}^0$, n, p) can interact via the strong force with the nucleus, e.g.

$$\pi^+ + N \rightarrow N + \pi^+ + \pi^0$$

- Characterized by "interaction length"
  (mean free path between inelastic collisions)

$$\lambda_I = 17 \text{ cm of Fe}$$

$$\lambda_I = 9.5\text{cm of W}$$
Tracking Chambers

- Wire
  - Ionization (electrons) drifted in an electric field to wires
  - High field at wires cause an avalanche (gain $10^4$ to $10^6$)
  - Two-fold ambiguity for each "hit"
  - Spatial resolution $\sim 100 \, \mu m$

- Silicon
  - Uses electron-hole pairs formed in
  - Spatial resolution $\sim 10 \, \mu m$
OPAL Jet Chamber
Run: event 9780  Date 980728  Time 75611
Ebeam 94.331  Evis 169.3  Vtx (-0.03, 0.10, 0.30)  Muon (N=2)  Sec Vtx (N=0)  Fdet (N=1)  SunE- 0.0
Bz=0.027  Bunchlet 1/1  Thrust=0.9619  Aplan=0.0001  Oblat=0.2652  Spher=0.1051

Event type bits
4 Low mult presel
7 LL Isolated Lepton
17 Heavy lept IsolTrk
22 5 photon muon veto
35 "Phys1" selection
16 2D type physics
16 Unlabeled QG, Exc.

Quark Net 2003
David Strom – UO
Silicon Detectors

- ~ 24,000 electron hole pairs are produced by a MIP
- Electrons drift to anode and are detected by low-noise amplifier
- Holes are collected at cathod
- Complicated geometry is needed for double-sided readout
Electromagnetic and hadronic calorimeters

- Calorimeters are designed to completely stop particles and measure all of their energy. This causes electromagnetic and hadronic showers.

- Detector of finite size $\Rightarrow$ use dense materials.

- There are two main types:
  - Sampling
  - Crystal
Run: event 7652: 45765

Cirek (N= 58 SumE= 88.7) Ecal (N= 72 SumE= 119.5)
Ebeam 86.161 Vtx (-0.06, 0.06, 0.02)
Heal (N=20 SumE= 12.9) Muon (N= 1)

\[
\begin{align*}
  &WW \rightarrow q q \ q q \\
  \text{jet-jet 1, mass} = & 85.1 \pm 0.7 \text{ GeV} \\
  \text{jet-jet 2, mass} = & 84.2 \pm 1.6 \text{ GeV}
\end{align*}
\]
Try your hand at identifying events on your own at

http://www.hep.man.ac.uk/u/wyatt/events/home.html

which was produced by Terry Wyatt at Manchester University

(May not work well with internet explorer)