Karlsruher Institut für Technologie

Vorlesung:

Teilchenphysik I (Particle Physics I)

Summary 04-05: Particle Detectors

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Summary: passage of particles through matter

- Charged Particles:
  - ionization along trace in matter → free charges
    → visible light from de-exitation
    falling ~β^2 below minimum at $\beta\gamma \approx 4$, slow rise above,
  - Bremsstrahlung dominant process for $E > E_{crit}$, relevant scale radiation length X_0
  - multiple scattering limits position resolution
  - Cherenkov light: above threshold $\beta > 1/n$, cherenkov cone $\cos(\varphi)=1/(\beta n)$
  - transition radiation proportinal to γ

- Photons:
  - photo effect dominant below 0.1 MeV
  - Compton effect dominant between 0.1 and 1 MeV
  - pair production dominant above 1 MeV, relevant scale 9/7 X_0
- hadrons
  - hadronic interactions with nucleons produce mostly pions and photons from decay of neutral pions, scale is the hadronic interaction length λ_{int}

Interplay of photon radiation and pair production leads to electromagnetic shower

hadronic shower from hadron; satellites due to neutral hadrons,
electromagnetic component from π^0 decays

Summary Detector Systems

- **Tracking detectors:**
  precise measurement of momentum and origin of charged particles
  with as little impact as possible on particle.

Typical technologies:

- Gaseous detectors, e. g. drift chambers
- Semiconductor detectors, e. g. silicon strips and pixel detectors

Momentum resolution:

- measurement of transverse momentum by fit of a helix to measured points;
- relative resolution inverse proportional to track length squared, magnetic field and square root of the number of detector layers, proportional to position resolution on track points :

$$\frac{\Delta_{p_t}}{p_t} = \frac{8\,p_t}{0.3BL^2} \cdot \Delta_s$$

typical values: $\frac{\Delta p_t}{p_t} \simeq 10^{-3} \cdot p_t\,[\mathrm{GeV/c}]$

- multiple scattering in material in front of detector layers degrades resolution and causes early interactions (photon conversion, knock-on electrons, early start of showers)

Summary Detector Systems

- **Calorimeters:**
  - sampling calorimeters
    separate absorber and active material
  - homogeneous calorimeters
    absober is active material

  relative resolution proportion to 1/√E
  plus a noise term (prop 1/E) and a constant term:

$$\frac{\Delta E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

- **Particle Flow**

  Combination of tracking + calorimetry + myon system to improve energy resolution on jets