Lecture #8

FORM C
APPROVED FOR USE IN
PURDUE UNIVERSITY

Hadronic Calorimeters

Heavy particles like protons do not emit Bremsstrahlung. Neutral particles like neutrons do not ionize matter as they pass through it.

We measure the energy of hadronic particles (like protons and neutrons) by detecting the charged and electromagnetic debris from nuclear collisions.

eg, $n + p \rightarrow n + \Delta^+$

$\hookrightarrow \pi^0 p$

$\hookrightarrow \gamma\gamma$

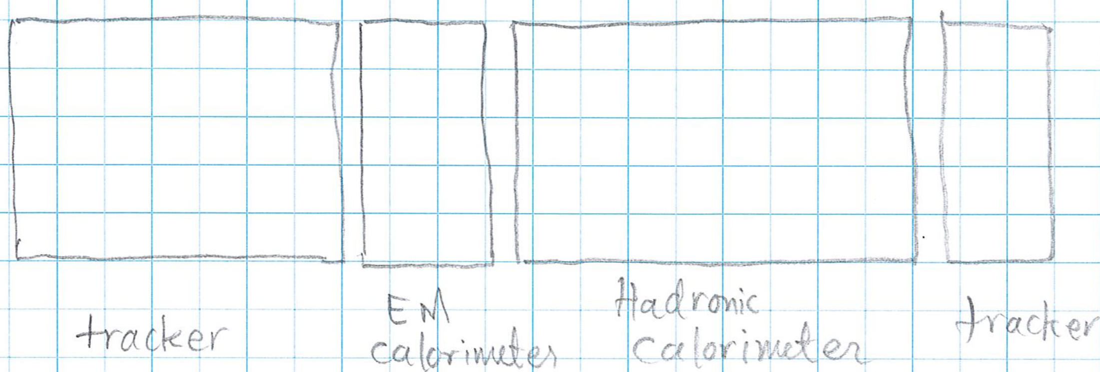
Then detect the γ via their electromagnetic interactions.

Similar to electromagnetic shower but the characteristic length is λ_I rather than X_0.

Example: Lead $X_0 = 0.5612$ cm
$\lambda_I = 17.59$ cm

Hadronic showers are larger and have larger statistical fluctuations.

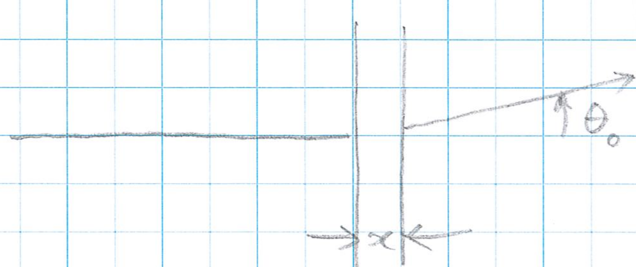
Particle classification



	tracker	EM calorimeter	Hadronic calorimeter	tracker
Photon	No	Yes	No	No
electron	Yes	yes	No	No
proton	Yes	yes	yes	No
neutron	yes	maybe	yes	No
⊛ muon	yes	yes	yes	yes
Nutrino	no	no	no	no

Multiple Scattering

Even if charged particles don't interact, they will scatter from the material they pass through



$$\sigma_{\theta_0} = \frac{13.6 \text{ MeV}}{\beta c p} z \sqrt{\frac{x}{X_0}} \left(1 + 0.038 \log\left(\frac{x}{X_0}\right)\right)$$

Example : Proton through silicon

$p = 400$ MeV/c

$\beta = p/E = \dfrac{p}{\sqrt{p^2 + m^2}} = \dfrac{1}{\sqrt{1 + m^2/p^2}} = 0.392$

Silicon , $x = 300\ \mu m$, $\rho = 2.329\ g/cm^3$

$X_0 = 21.82\ g/cm^2 \Rightarrow 9.370$ cm

So $x/X_0 = 0.0032$

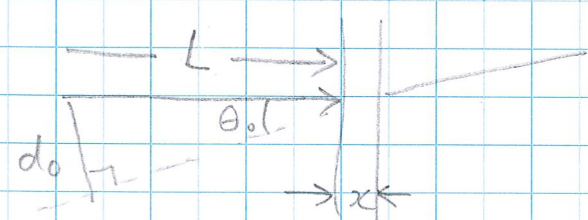
$\sigma_{\theta_0} = 0.0038$ rad $= 0.22°$

If $p = 200$ MeV

$\beta = 0.209$

$\sigma_{\theta_0} = 0.82°$ (.014 rad)

How much uncertainty does this introduce?



$\sigma_{d_0} \approx L\,\sigma_{\theta_0}$

If $L \sim 5$ cm then $\sigma_{d_0} = (50\text{ mm})(.014)$

$= 0.7$ mm.

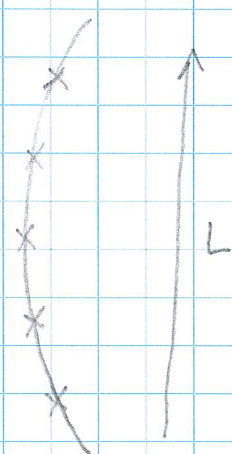
Momentum measurement

In a magnetic field, charged particles will travel in a helix with radius

$$r\,[m] = \frac{p\,[GeV]}{0.3\,B\,[T]}$$

or $p\,[GeV] = 0.3\,B\,[T]\,r\,[m]$

Momentum resolution



For N measurements

$$\left.\frac{\sigma_{p_T}}{p_T}\right|_{meas} = \frac{\sigma\, p_T}{0.3\,B\,L^2}\sqrt{\frac{720}{N+4}} \qquad \text{for } N \gtrsim 10$$

Multiple scattering also degrades the momentum resolution

$$\left.\frac{\sigma_{p_T}}{p_T}\right|_{MS} = 0.045\,\frac{1}{B\sqrt{L X_0}}$$

$$\left(\frac{\sigma_{p_T}}{p_T}\right)^2 = \left(\frac{\sigma_{p_T}}{p_T}\right)^2_{meas} + \left(\frac{\sigma_{p_T}}{p_T}\right)^2_{MS}$$