Lecture 10

Last time: LHC beam colliding protons

This time (et seq.)

Products of collisions → spray of particles
- energies
- momenta
- charge
- identity

13 TeV: beam
Proton= (E,0,0,1)
Proton=x Proton

So actual collision energy \( x_1 x_2 (3.16)^2 \) is not fixed

https://rutersconnect-my.sharepoint.com/personal/shih_physics_rutgers_edu/_layouts/15/Doc.aspx?sourcedoc={1c8418de-3e15-43ad-8ded-ca103e6850ff}&action=edit&wd=target%28Physics 694 Lecture 10.one%7C2f2…
Detector stable particles
- $e^+$ (essentially massless)
- $\gamma$
- $\mu^+$
- Hadrons (protons, neutrons, pions, kaons, ...)

Fully (charged neutral)

- Neutrinos
- Missing energy

Other particles decay instantaneously to detector stable particles:

- $W$, $Z$
- Tops
- Higgs 125 GeV

Few are metastable
- $b$ quark
- Displaced vertex

e.g., $b \rightarrow c \ell
\nu\nu^\prime$
Detector design

- \( \mu \) \& ch. hadrons, neutral hadrons, \( \nu \)
- Tracker has very high resolution
- Calorimeter is much lower resolution spatially pixelated into "towers" like a digital image!
Detector coordinates:

\[ p^\mu = (E, px, py, pz) = (E, \rho \cos \phi \sin \theta, \rho \sin \phi \sin \theta, \rho \cos \theta) \]

\( \theta \) not ideal b/c of special relativity.

Instead define rapidity
\[ \gamma = \frac{1}{2} \log \left( \frac{E + p_z}{E - p_z} \right) \]

\( E \) and \( p_z \) are added under boosts in \( z \) direction.

Imported by longitudinal momenta of initial state unknown @ LHC.

Pseudorapidity:
\[ \gamma \rightarrow \eta \text{ in massless limit} \]
\[ \eta = \frac{1}{2} \log \left( \frac{p - p_z}{p + p_z} \right) = \frac{1}{2} \log \left( \frac{1 + \cos \theta}{1 - \cos \theta} \right) = \log \left( \cosh \frac{\theta}{2} \right) \]

\( \eta \leftrightarrow \theta \)

\( \eta \)'s of pfts must balance! \( \rightarrow \) any imbalance

Neutrinos < detector measurement
New missing pfts.
Jets @ LHC

Much of physics @ LHC concerns jets

hadron colliders → QCD → quarks & gluons

QCD Jet

$\Delta R = \sqrt{\Delta y^2 + \Delta y^2}$

$R \sim 0.4 - 0.6$
Jet mass

Jets have mass (not coming from decays)

What about heavy unstable particles?

Many decay to jets

\[ \Delta R \sim \frac{2m}{\Delta \eta} \]

(kinematics)
\( m_{\text{top}} = 175 \text{ GeV} \)

\( p_T^t = 500 \text{ GeV} \)

\( \delta R \sim 0.7 \), "fat jets"

interesting question

Top

vs.

Acq

how to tell apart?

"jet tagging"