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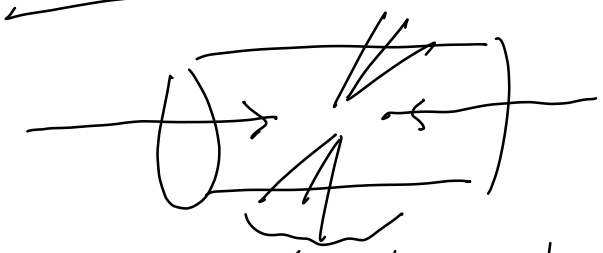
Lecture 10



Last time: LHC beam colliding protons

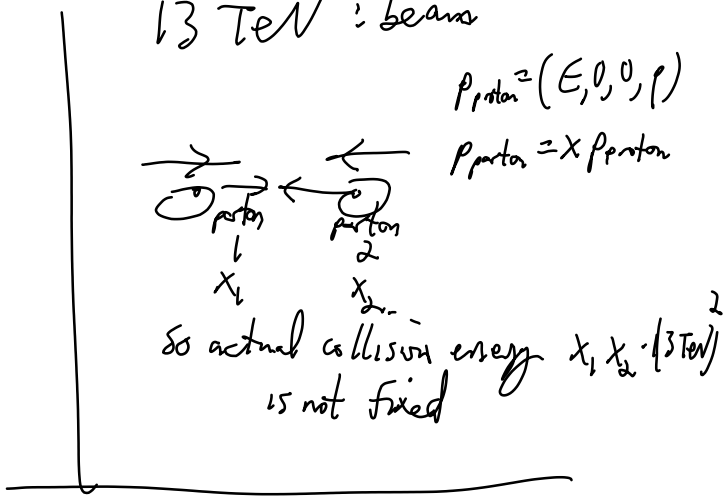
This time (et seq)

↓

products of collisions → spray of particles

- energies
- momenta
- charge
- identity

} recorded by detector



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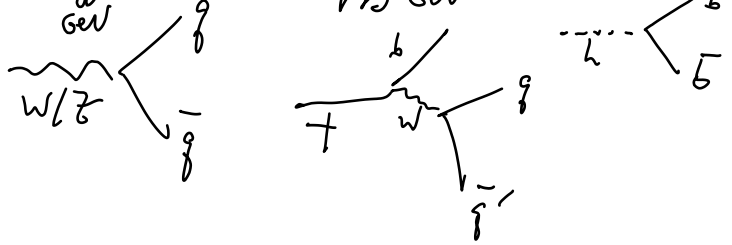
- detector stable particles

fully recorded
- $e^{\pm}$ (essentially massless)
- γ
- $\mu^{\pm}$
- hadrons (protons, neutrons, pions, kaons, ...)
  - charged
  - neutral

"missing energy"
- neutrinos

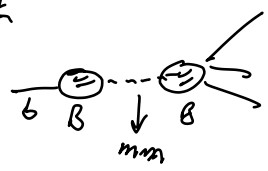
- other particles decay (nearly) instantaneously to detector stable ptcls.

e.g. W/Z 80 GeV, 90 GeV, tops 175 GeV, Higgs 125 GeV



- few are metastable

e.g. b quark



displaced vertex

c quark, τ leptons

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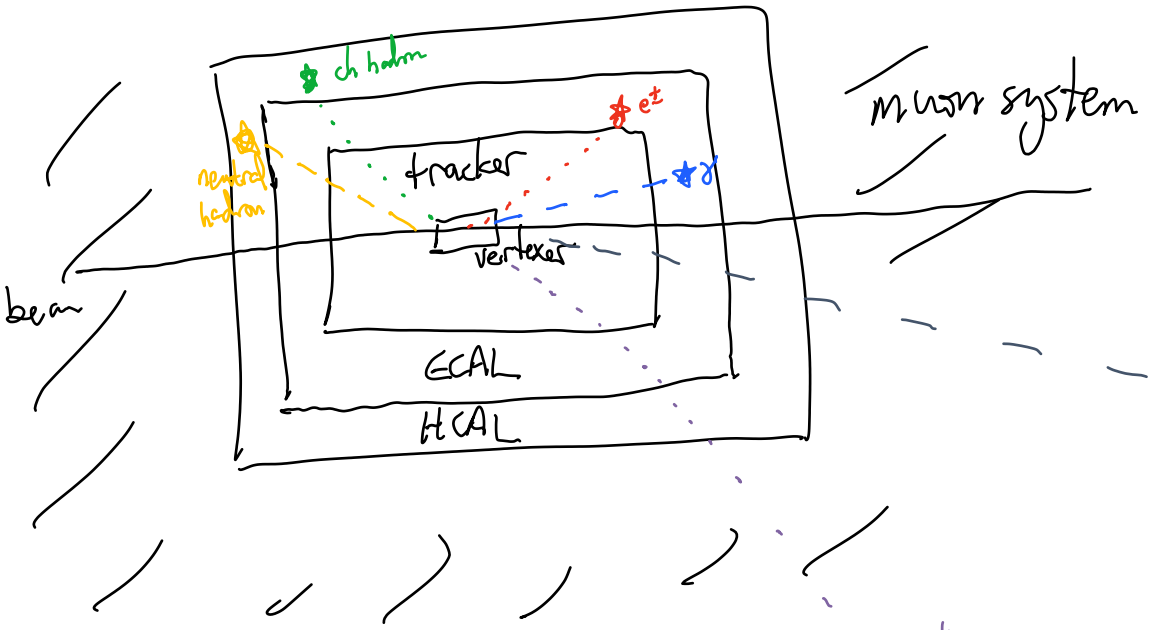
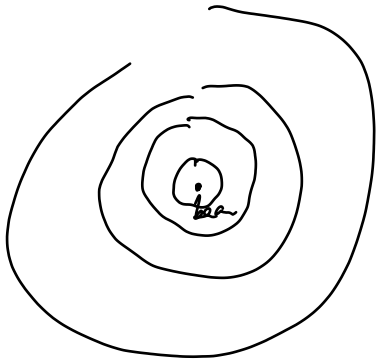
Detector design

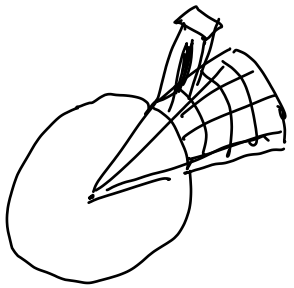
$e^{\pm}$ γ ch. hadrons, neutral hadrons, ν

$\mu^{\pm}$





- Tracker has very high resolution
- Calorimeter is much lower resolution spatially pixelated into "towers" like a digital image!



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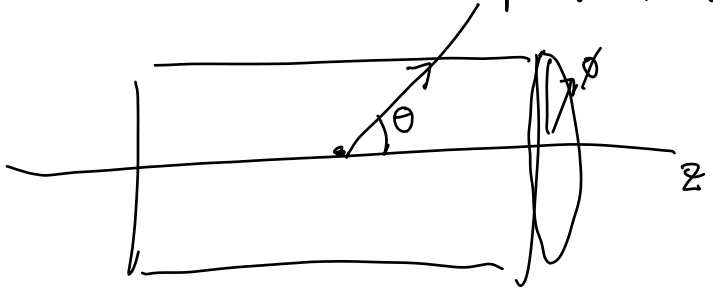
Detector coordinates

$p^\mu = (E, p_x, p_y, p_z) = (E, p\cos\phi\sin\theta, p\sin\phi\sin\theta, p\cos\theta)$



θ not ideal b/c of special relativity

instead define rapidity $y = \frac{1}{2}\log\left(\frac{E+p_z}{E-p_z}\right)$

- additive under boosts in z direction
- important b/c longitudinal momentum of initial state unknown @ LHC

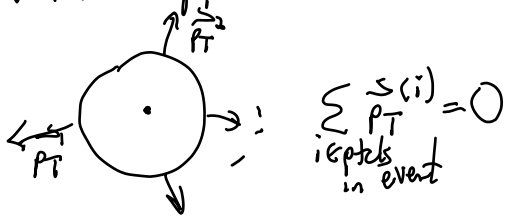
$$p^\mu = p_T(\cosh y, \cos\phi, \sin\phi, \sinh y)$$

pseudorapidity → y in massless limit

$$\eta = \frac{1}{2}\log\frac{p+p_z}{p-p_z} = \frac{1}{2}\log\frac{1+\cos\theta}{1-\cos\theta} = \log\cot\frac{\theta}{2}$$

transverse momentum

initial state $\vec{p}_T = 0$



$\sum_{i\text{ptcls in event}} \vec{p}_T^{\,(i)} = 0$

$\eta \leftrightarrow \theta$

$\vec{p}_T$'s of ptcls must balance! → any imbalance = neutrinos / detector mismeasurement / new invisible ptcls

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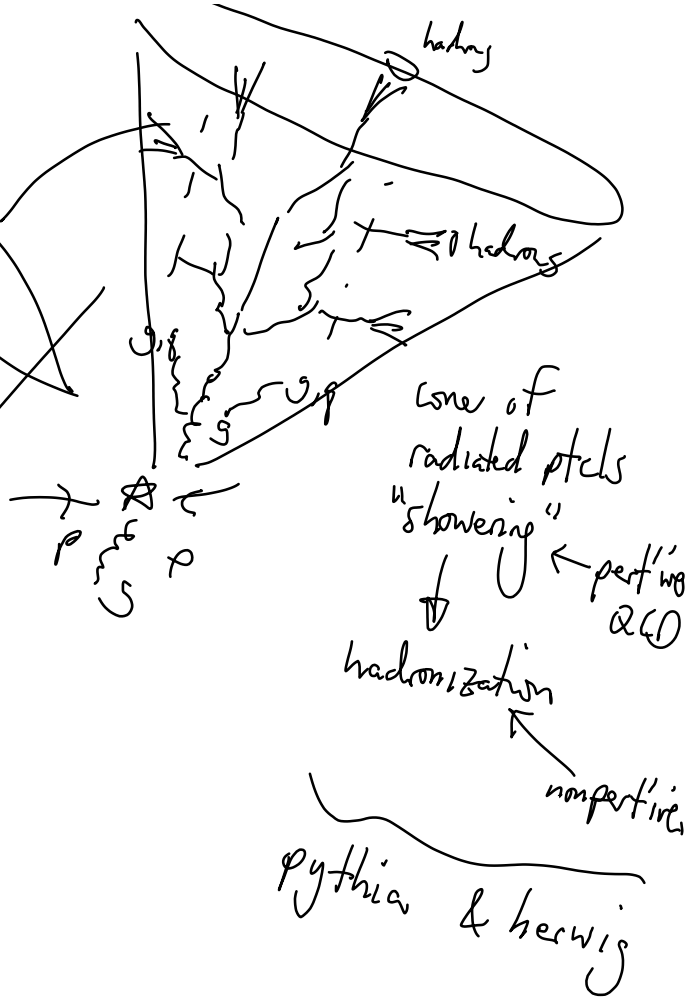
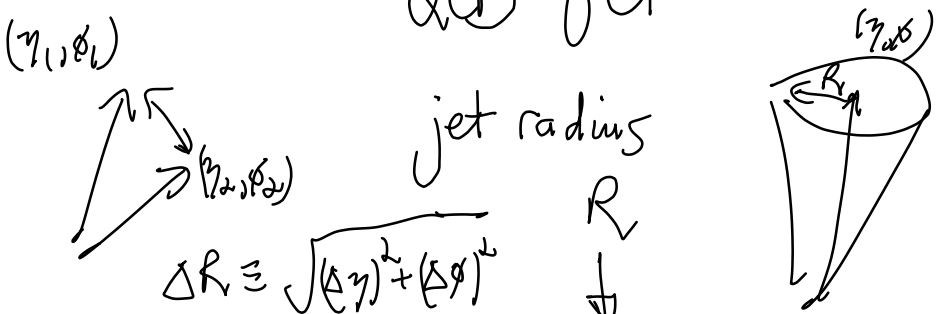
Jets @ LHC

Much of physics @ LHC concerns jets

hadron colliders → QCD → quarks & gluons



QCD jet



jet radius R

$\Delta R \equiv \sqrt{(\Delta\eta)^2+(\Delta\phi)^2}$

$R \sim 0.4 - 0.6$

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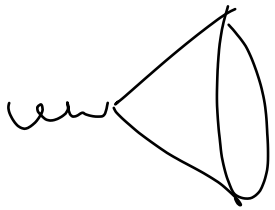
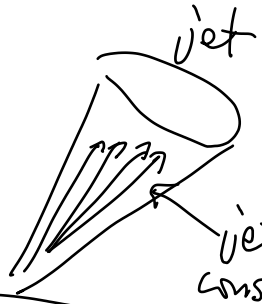
jet mass



jets have mass (bk not coming from decays)

$\langle m^2 \rangle \propto \# p_T^2 R^2$



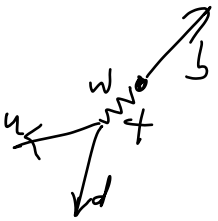
$\hat{p}_{jet} = \sum_{i \in jet\ const.} \hat{p}_i$

$m_{jet} = \sqrt{E_{jet}^2 - p_{jet}^2}$ ← jet mass

What about heavy unstable ptcls?

↓

Many decay to jets



boosted → $\bar{t}$

$\Delta R \sim \frac{2m}{p_T}$ (kinematics)

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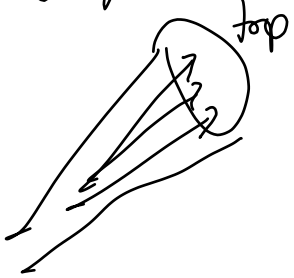
Ex: $m_{top} = 175$ GeV

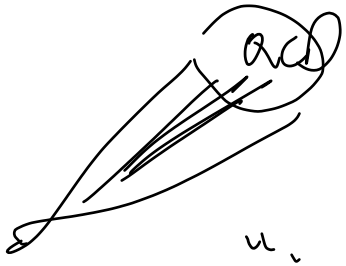
$p_T \geq 500$ GeV

$\Delta R \sim 0.7$ "fat jets"

interesting question



vs.



how to tell apart? "jet tagging"