Isolation: Part I

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Overview

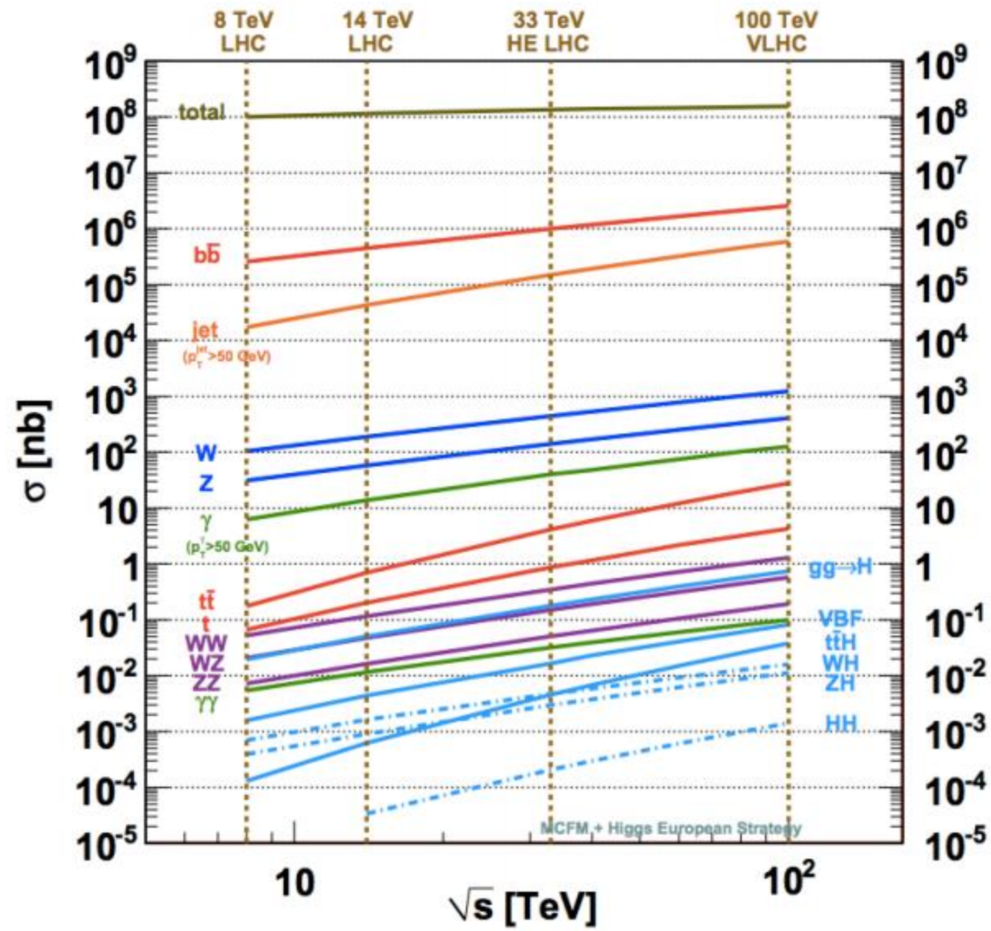
- Why is isolation useful?
- What is isolation?
- How can we calculate it for a lepton?

Proton-Proton Collisions

- Two protons collide and produce particles
- Quarks or gluons become a jet of hadrons due to confinement, producing many colored particles
- What if we are interested in a colorless process, e.g. $Z \rightarrow 2l$?
- How do we separate colored from colorless physics?

Relative Cross Sections

- $W \rightarrow l\nu$ and $Z \rightarrow 2l$ are the first colorless production and decay processes
- Colored interactions are much more prevalent (6 orders of magnitude)



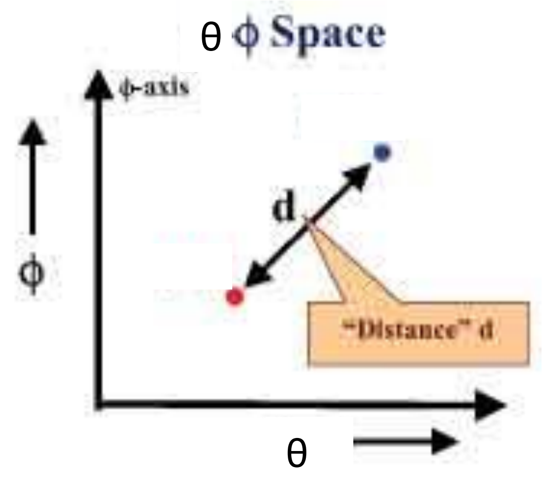
Why Isolation is Useful

- We expect jets from colored interactions. A colored particle should have many other particles nearby
- Isolation is a strong signature of colorless physics
- Finding isolated leptons can help identify certain processes
  - Decay of W or Z to lepton(s) is colorless
  - Useful in identifying Drell Yan, also for Higgs ($H \rightarrow ZZ$ and $H \rightarrow WW$)

Defining Isolation

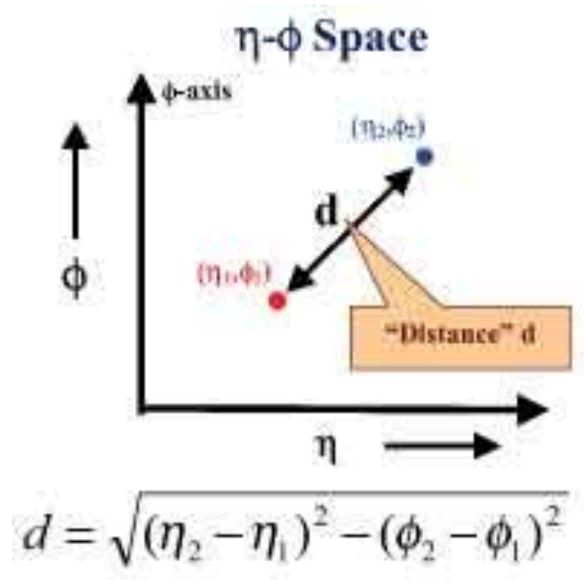
- Isolated means "not much other stuff" nearby
- To quantify this notion, we might define a cone in the CoM frame with (ϑ, φ) and measure the energy inside

  $d^2 \leq (\Delta\varphi)^2 + (\Delta\vartheta)^2$
- Pick an energy cutoff to define isolation
  - Cutoff defined relative to lepton p_t; high p_t = more energy allowed in the cone
  - $E_{rel} = \frac{1}{P_T} \sum E_T\,(ECAL) + E_T(HCAL) + P_T(TRK)$
- This doesn't quite work. We don't know $p_{z,}$ so we can't find the CoM frame in θ



Isolation Cone

- Choose cone in (η, φ) instead
- η is invariant under boosts in the z-direction
- Define distance
  $d^2 = (\Delta\varphi)^2 + (\Delta\eta)^2$
- Choose appropriate radius R. If $\mathrm{R} \geq d$ then the particle is within the cone
- Default radii: 0.4 for ECAL, HCAL, 0.3 for tracker [1]



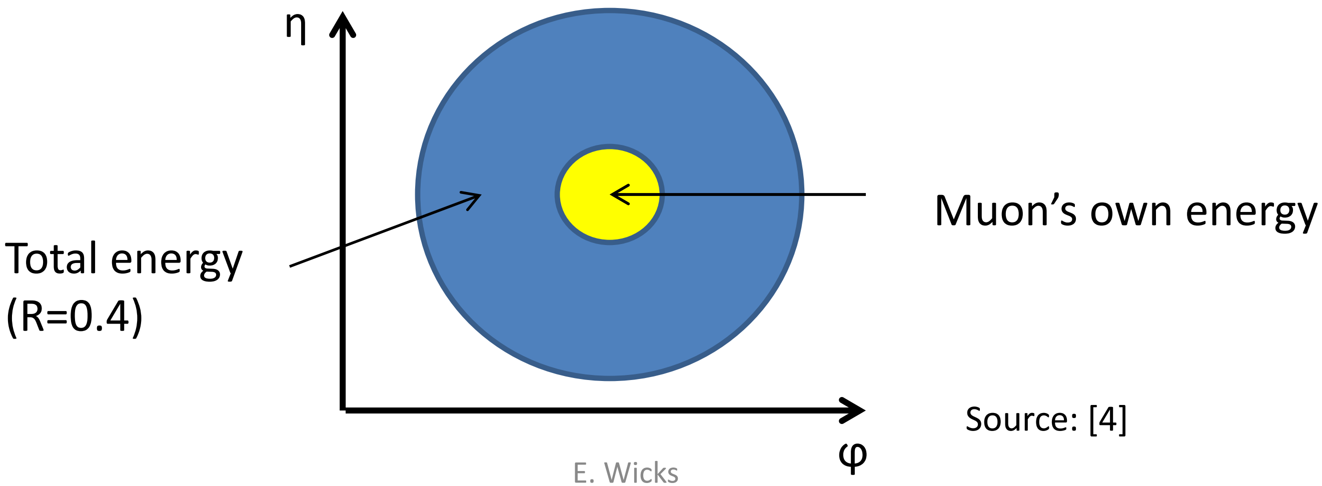
[2]

Calculating Isolation

- We can use tracks, ECAL, and HCAL deposits
- Sum up the energy in the cone
- Make some corrections
  - Subtract the particle's own energy
  - Particle flow, pileup, neutral energy…
- If cone energy is less than the cutoff energy, then the particle is isolated

Muon Footprint

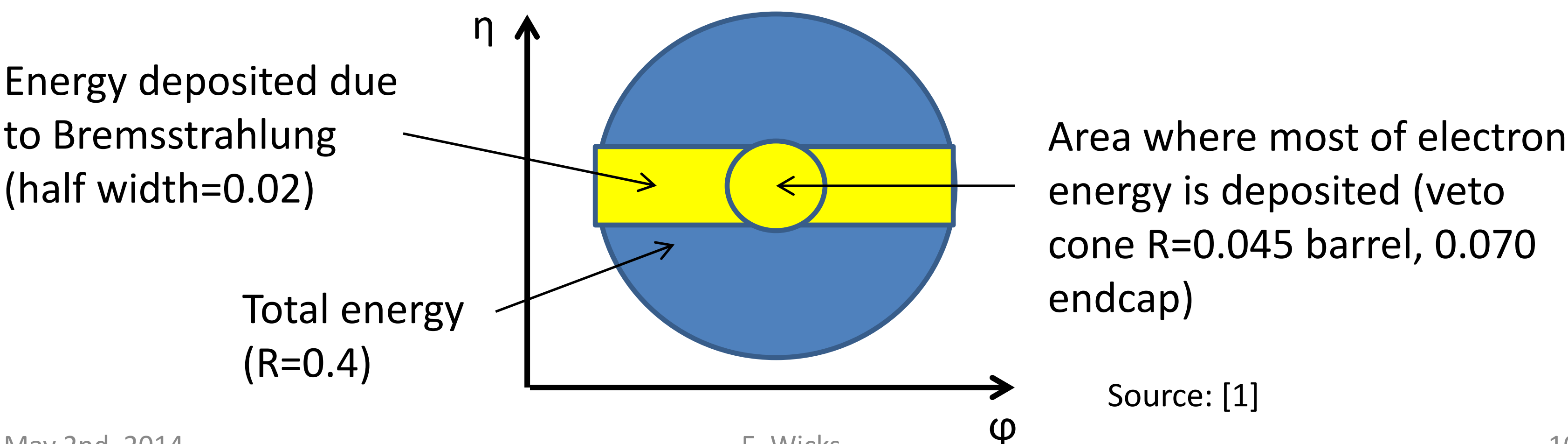
- Want to subtract muon's own energy
- The muon's own energy is deposited in a small cone (MIP)
- Small cone on the order of the Moliere radius (99% of the energy is within $3R_M$)



Source: [4]

Electron Footprint

- Electron is not a MIP, loses most energy through radiation
  - There is a wide swath in φ due to brem
- In the ECAL, an electron loses all energy within a few radiation lengths X_0
  - Get a concentrated small cone of energy
- The diagram below (ECAL) is called the “Jurassic cone”



Source: [1]

Summary

- Isolation enables us to find leptons that come from colorless interactions
- Isolation is defined through relative energy contained in a cone in the (η, φ) plane
- The energy of the lepton itself (as well as other energy corrections) must be subtracted from the cone to obtain the energy from colored sources

References

1. https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideEgammaIsolation
2. http://www.phys.ufl.edu/~rfield/cdf/chgjet/etaphi_space.jpg
3. http://www.t2.ucsd.edu/twiki2/pub/UCSDTier2/ParticlePhysics2013/lecture23.pdf
4. https://twiki.cern.ch/twiki/bin/viewauth/CMS/MuonIsolation