UE/MinBias with Calorimeters

• **Motivations**
  – Large acceptances
  – Detects neutral and charged particles
  – Precise direction and energy reconstruction

• **Challenges**
  – No direct single particle reconstruction hadronic final state
    • Except for high energy isolated particles
  – Particle energy is spread
    • Especially laterally
  – Poor quality response to low energetic particles
    • Large signal fluctuations
    • Acceptance and calibration highly intertwined
Solutions

• Topological cell clusters
  – Collect cell signals into energy blobs
    • Suppresses noise
    • Follows particle shower development – especially for isolated particles
  – Apply local calibrations depending on cluster shapes
    • Calibrate “photon/electron–like” clusters differently than hadronic clusters
    • Provides calibrated input to jet finding
  – Reasonable “picture” of original event Et flow
    • Allows to reconstruct event (and jet!) shapes

• Use observables least affected by calorimeter inefficiencies
  – Focus for the rest of this
Longitudinal Et Flow

• Original idea developed August 2009
  – FNAL visit with P. Skands
  – Major motivation: can we learn something about color flow/connections between (hard) scattered partons and the rest of the event
    • Radiation, even MPIs?

• Interesting topologies
  – Di–jets
    • E.g., expect soft Et flow between leading and sub–leading jet and remnant ~ similar
  – Photon + jet(s)
    • Lack of color connections in the photon
Jet-Jet and Photon-Jet final states

- We require the two leading hard objects to be reconstructed in different $\eta$ hemispheres (one in the positive $\eta$ and one in the negative $\eta$ hemisphere). The hemisphere with the leading jet will be called the "towards" region, while the one with the sub-leading jet or the leading photon the "away" region.

- Isolation cut: hard objects are required to be reconstructed in the central region, while we look at the $E_T$ deposited in $\eta$ strips closer to the beam remnants.
Event Selections (P8)

- Prompt Photon

  **TOPOLOGY CUTS:**
  - both jet and photon pt > 20 GeV
  - jet is good
  - $\Delta \Phi > 2.9$
  - opposite $\eta$ hemispheres
  - $|\eta| < 0.8$ for both jet and photon

- Di-jets

  **TOPOLOGY CUTS:**
  - both jets with pt > 20 GeV
  - both jets are good
  - $\Delta \Phi > 2.9$
  - opposite $\eta$ hemispheres
  - $|\eta| < 0.8$ for both jets.

- Detector effects
  - Acceptance $E > 1$ GeV
  - Gaussian Fluctuations

  $\sigma = \sqrt{a^2 E + c^2}$
Average Et Flow

\[ \frac{dE_T}{d\eta} \ (\text{GeV/0.5}) \]

\[ N_{\text{vertex}} = 1 \]

di-jet

prompt photon

3/10/2011  \[ -|\eta_{\text{subleading}} | \]  P. Loch, Oregon UE Workshop 2011  \[ |\eta_{\text{leading}} | \]
Average Et Flow

$dE_T/d\eta$ (GeV/0.5)

$N_{\text{vertex}} = 1$

di-jet

prompt photon
Average Et Flow

$\frac{dE_T}{d\eta} \ (\text{GeV}/0.5)$
Average Et Flow

\[
dE_T/d\eta \ (\text{GeV}/0.5)
\]

\[N_{\text{vertex}} = 5\]

di-jet

prompt photon

3/10/2011

P. Loch, Oregon UE Workshop 2011
Average Et Flow

$dE_T/d\eta$ (GeV/0.5)
Deep Inelastic Scattering (1)

photon-gluon fusion (photo-production)

$e^+ \rightarrow \gamma + q + \bar{q}$

$Q^2 \gg 0$

$k_{T,n} \gg k_{T,n-1} \gg \ldots \gg k_{T,1}$

$x_n < x_{n-1} < \ldots < x_1$

meson-like system (resolved photon)

$e^+ \rightarrow e^+ + q + \bar{q}$

$Q^2 \approx 0$

$x = x_n \ll x_{n-1} \ll \ldots \ll x_1$

(no ordering in $k_T$)

photon fragmentation region

DGLAP evolution in $Q^2$

proton remnant

BFKL evolution in $\log(x)$

proton remnant
Deep Inelastic Scattering

Hadronic center-of-mass in DIS at HERA
Deep Inelastic Scattering (3)
pp at LHC: QCD 2→2

\[ k_{T,n}^2 \gg k_{T,n-1}^2 \gg \cdots \gg k_{T,1}^2 \]
\[ x_n < x_{n-1} < \cdots < x_1 \]

\[ Q^2 \gg 0 \]

DGLAP evolution in \( Q^2 \)

proton remnant

LHC parton kinematics

\[ x_{1,2} = (M/14 \text{ TeV}) \exp(\pm y) \]
\[ Q = M \]

M = 10 TeV

M = 1 TeV

M = 100 GeV

M = 10 GeV

BFKL? HERA

fixed target

Thursday, March 10, 2011
pp at LHC: prompt photon
pp at LHC: soft QCD (UE,