Measurement of the Underlying Event Activity in Proton-Proton Collisions at 900 GeV

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Goals

- Investigate properties of spectators and multiple parton interaction components of the hard QCD scattering process in proton-proton collisions at 900 GeV.
- Use the direction of both the leading track and the leading jet.
- Report comparisons of uncorrected data and full detector simulation for different underlying event model predictions.

Definitions

- Hard proton-proton collision can be divided into three components:
  - 2-to-2 hard scattering subprocess
  - Multiple parton interactions (MPI)
  - Fragmenting partons that do not participate in the perturbative interactions (spectators)
- Importance first demonstrated at the SPS.
- Detailed UE studies by the CDF collaboration for the Tevatron.

Modelling

- All models predict that the contribution from MPI to the hard scattering process is:
  - The same for proton-proton and proton-antiproton collisions
  - It grows with increasing center-of-mass energy.
- Energy dependence of the MPI cross sections are not very well understood yet
  - Models agree with the data at the Tevatron center-of-mass energies
  - Predict very different results at other energies

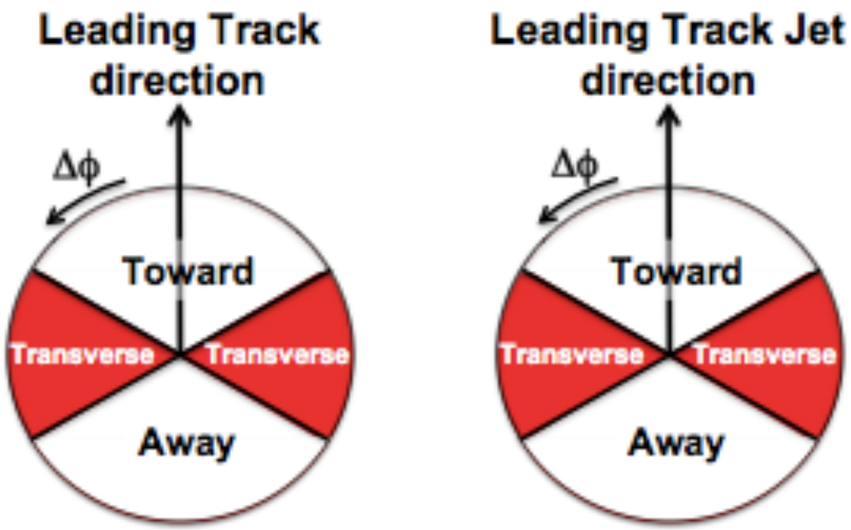
Methodology

- Define areas of phase space that are particularly sensitive to UE modeling
  - Direction of the leading track
  - Direction of the leading track jet
- Interaction scale is provided by the transverse momentum of the leading charged object(track or track jet)
- Study of the energy dependence of MPI by comparing uncorrected data with different QCD Monte Carlo model predictions after full GEANT4 simulation

Strategy

- Hard scattering collision topology:
  - Outgoing hadrons follow the kinematics of the underlying 2-to-2 hard scattering subprocess.
  - Leading objects (track or track jet) are likely to arise from the hard scatter.
- Direction of the leading object defines three regions of interest in η-ϕ space:
  - Toward and Away: dominated by the hard 2-to-2 parton-parton scattering.
  - Transverse:
    - Roughly perpendicular to the plane of the hard 2-to-2 parton-parton scattering
    - Sensitive to the modeling of the underlying event

Topology



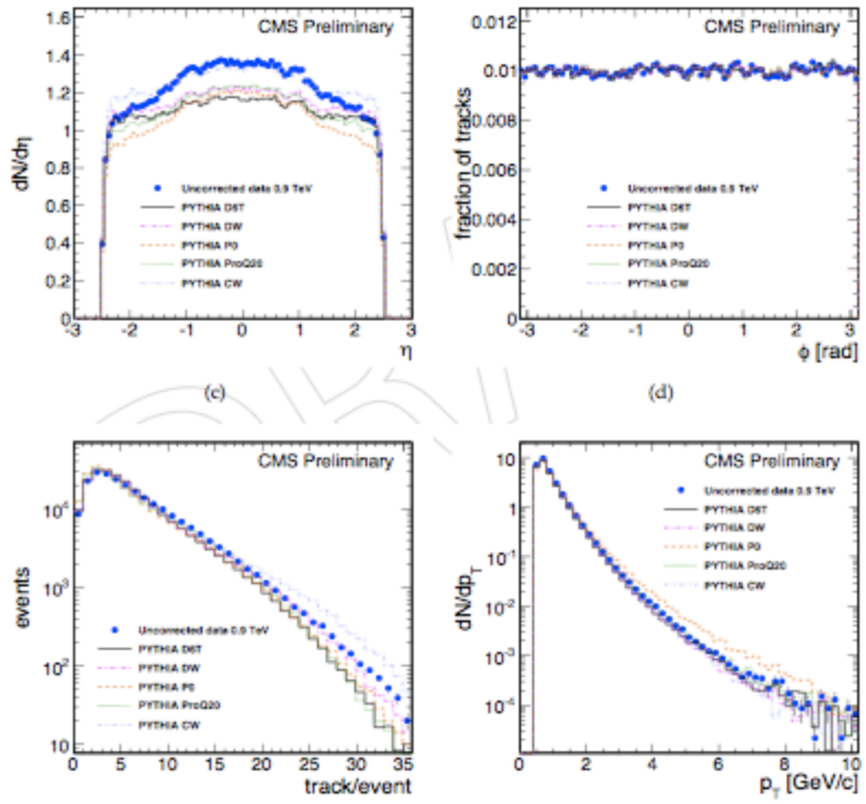
- $\Delta\phi = \phi - \phi 1$
  - $\phi 1$: azimuthal angle of the leading track
  - ϕ: azimuthal angle of any other track in the event
- $|\eta| < 2$ applies to the tracks in the three regions
- Toward region is defined as $|\Delta\phi| < 60^\circ$
- away region is defined with $|\Delta\phi| > 120^\circ$
- transverse regions are defined with $60^\circ < |\Delta\phi| < 120^\circ$
  - combined η-ϕ area of $8\pi/3$

Observables

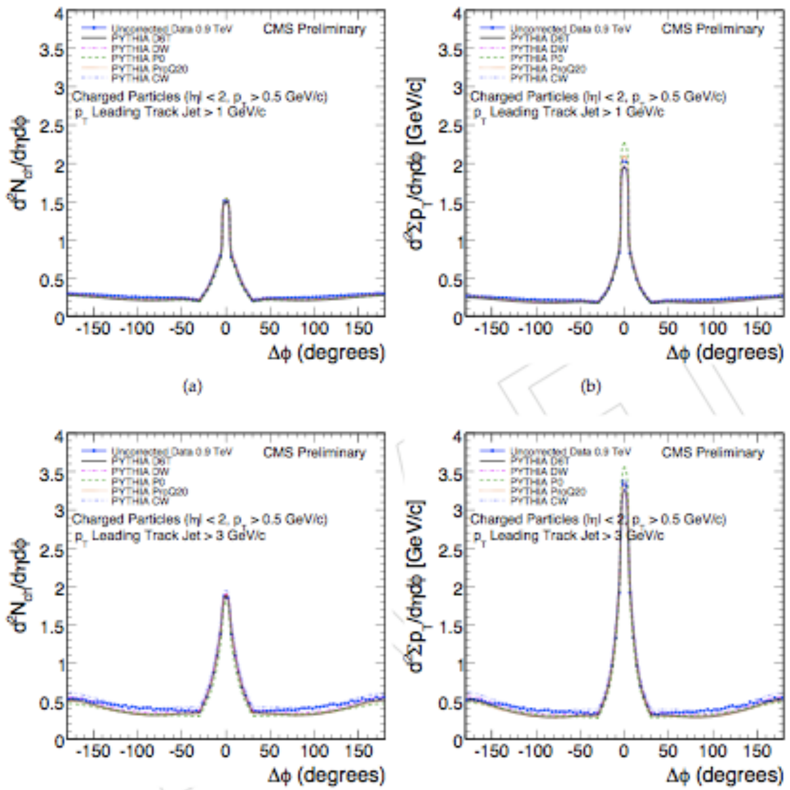
- Two variables used to describe UE activity:
  - Transverse charged particle density
    - Number of tracks in the transverse region divided by its area in η-ϕ space.
  - Transverse charged ∑ pT density
    - Scalar sum of track transverse momenta in the transverse region divided by its area in η-ϕ space.
- Jets constructed by clustering reconstructed tracks using the SisCone algorithm
  - The leading track jet is the highest pT jet constructed from tracks with pT > 0.5 GeV/c and $|\eta| < 2.5$, and a clustering radius of R = 0.5

Results

- Uncorrected data are compared with PYTHIA tunes D6T, CW, DW, Pro-Q20 and P0



(c) (d) (e) (f)



(a) (b) (c) (d)

Pythia Tunes

- The perturbative 2-to-2 parton-parton differential cross section diverges like $1/\hat{p}_T^4$
- PYTHIA regulates this cross section by including a smooth cut-off $1/\hat{p}_T^4 \to 1/(\hat{p}_T^2 + p_{T0}^2)^2$
- PYTHIA parameterizes this energy dependence of the cutoff as $p_{T0}(E_{cm}) = p_{T0}(E_0)(E_{cm}/E_0)^\epsilon$
- E_0 = PARP(89); p_{T0} = PARP(82); ε = PARP(90)

Conclusions

- Charged multiplicity and the charged scalar ∑ pT profiles in the transverse region lay above most of the predictions of all the considered PYTHIA tunes in the transverse region, with CW (a special version of DW with slightly increased MPI rate) giving the best description.
- Our data definitely favor a steep MPI energy dependency: $\varepsilon \simeq 0.25$ along the lines of the tune DW or the even higher ε values of CW.
- Lower ε values adopted for example tune D6T ($\varepsilon = 0.16$) are ruled out.
  - Confirmed by the recent RHIC UE analysis in proton-proton collisions at 200 GeV.