The Underlying Event in Hard Interactions at the Tevatron pbar-p Collider

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for

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Godparents: Rick Field, Franco Rimondi, Rick Tesarek

chief godparent, but I have to provide the refreshments
This is a study performed by Valeria Tano on Run 1 data.

Long-blessed and presented at many conferences/workshops.

Valeria has left the field and we’re trying to get this publication out to formally document the study.
- and to be able to use it in databases such as JetWeb
- of interest for LHC tunes, for example.

Orthogonal and complementary to Run 1 studies that Rick Field did.
- sets the stage for Rick’s Run 2 work.

Two drafts have been generated (CDF6768) and questions of godparents and interested CDF collaborators (i.e. Torontonians) have been answered.
- webpage is
  http://www.pa.msu.edu/~huston/ue_paper/ue_paper.htm
Motivation

- Inclusive jet cross sections at CDF are compared to NLO QCD calculations at the parton level.
- The (mostly) non-perturbative underlying event has to be subtracted in order for the comparison to be made.
- The assumption made by CDF is that the underlying event measured in an active (class 12 vertex) should be subtracted.
- This analysis sought to check this assumption and to understand how well Monte Carlo programs predicted the event structure.
- In this analysis, we used the Run I inclusive cross section data but restricted there to be only 1 vertex of class 10,11 or 12 in the event.

By definition there is at least one jet in the central rapidity region; we construct 2 cones (R=0.7) at the same rapidity as the lead jet and 90 degrees away in phi. One of these cones has more energy (max cone) and one has less (min cone).
We choose to work with charge track momenta rather than calorimeter energies due to the uncertainties in the CDF low energy calorimeter response.

We use charged tracks with \( p_T > 0.4 \) GeV/c in the central rapidity region, correcting for track reconstruction efficiency.

The lead jet used in this analysis has to be within \( |\eta| < 0.5 \); thus the centroid of the min/max cones are also within that range.

On the right is shown the momentum contained in the max, min and max-min cones compared to Herwig and Pythia.
Tuning

- Working with Rick Field, we tried using one of his Pythia tunes, which resulted in better agreement.

- Common features:
  - min cone is flat over range of inclusive jet data
  - max cone rises
  - both in reasonable agreement with MC predictions
look at distributions

- Look at distributions of momentum in max+min cones for different lead jet bins
- Contains contributions from underlying event plus gluon radiation
  - double-log enhanced
    - basis of parton shower Monte Carlos
  - single-log enhanced
    - partially in MC’s; new area of much theoretical effort
    - expect major contribution when \( \log \left( \frac{E_T^{\text{jet}}}{E_T^{\text{cones}}} \right) \) is large

Conclusion
- Pythia and Herwig ain’t so bad
Another observable: Swiss cheese

- Subtract energy in 2 (3) leading jets in central region and compare to MC

almost perfect agreement for 3-jets subtracted; no contribution from \textit{NLO final state} for this configuration
Study was repeated at 630 GeV, where qualitatively similar behavior is found (but tune works better for Pythia)

Energy extrapolation from 1800 GeV to 630 GeV useful; probably last time anyone looks at 630 GeV data

Swiss cheese
Swiss cheese at 630 GeV

- Agreement is reasonably good for both Monte Carlos
Minimum bias events

- Look at charged track multiplicity, $p_T$ distribution
- Pythia’s model of DPS does much better than Herwig at describing the high $p_T$ end
Ditto at 630 GeV

- Track multiplicity well-defined
- Could describe high $p_T$ tail better
Underlying event subtraction at 1800 GeV

- Sum of momentum inside a random cone of radius 0.7 in high quality (class 12) vertex min bias events is a reasonable approximation for the momentum in the min cone in jet events
Compare to Rick’s Run I analysis

Transverse Region vs Transverse Cones

Field-Stuart-Haas

Pt track in max and min cone

$0 < P_T(\text{charged jet#1}) < 50$ GeV/c

Add max and min cone:

- $2.1$ GeV/c $+$ $0.4$ GeV/c $= 2.5$ GeV/c.
- Multiply by ratio of the areas:
  
  $2.5$ GeV/c $/ (1.36) = 3.4$ GeV/c.

The two analyses are consistent!
Plans

- Submit to Los Alamos and then to PRD
- Go back to Santa Barbara and work on my tan
- ...and while I’m talking, let me give website for Santa Barbara workshop where I’ve been keeping track of developments
  - http://www.pa.msu.edu/~huston/santa_barbara/collider04.html
- Developing/improving tools for use in Run II as well as answering Big Questions
  - for example, now both Herwig and Pythia authors are working on understanding photon+jet balancing differences
  - last week, Rick was visiting and very useful discussions of the type of physics in this paper
    ▲ his sister was off in Mexico with Jane Fonda but he still refused my request to have a party at her house
  - all talks are stored in pdf format as well as streaming video