

XXXVIII International Symposium on Multiparticle Dynamics

ISMD 2008

15-20 September 2008



Multiplicities and Underlying Event

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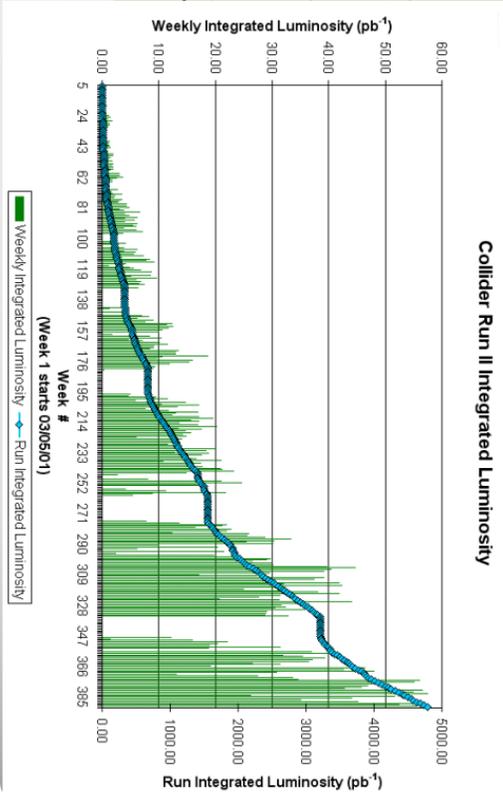
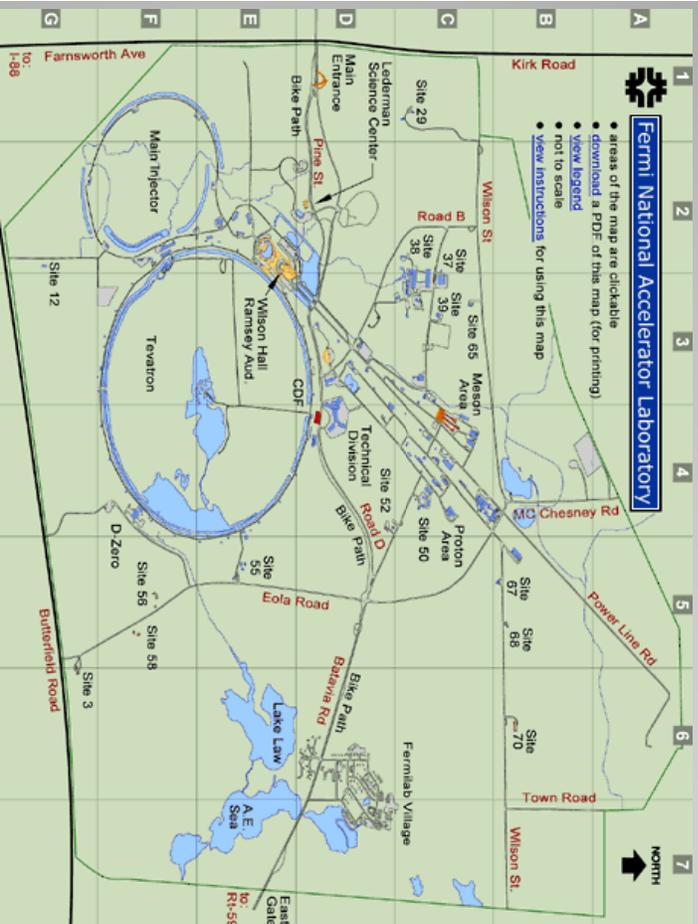
(On behalf of the CDF Collaboration)



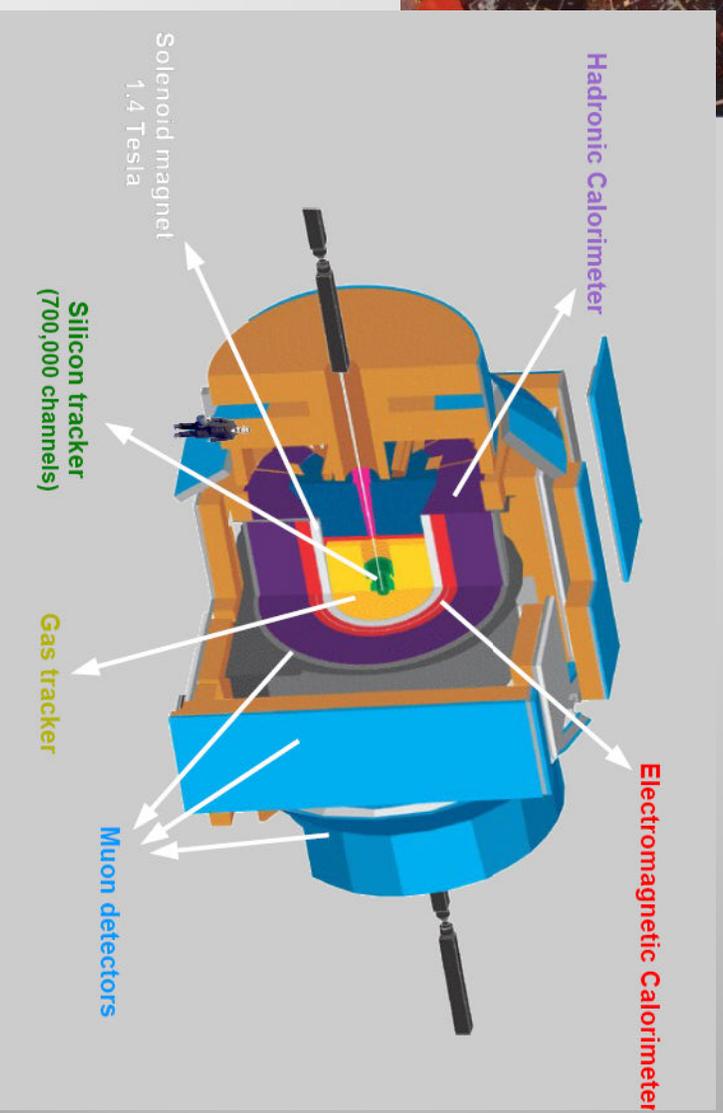
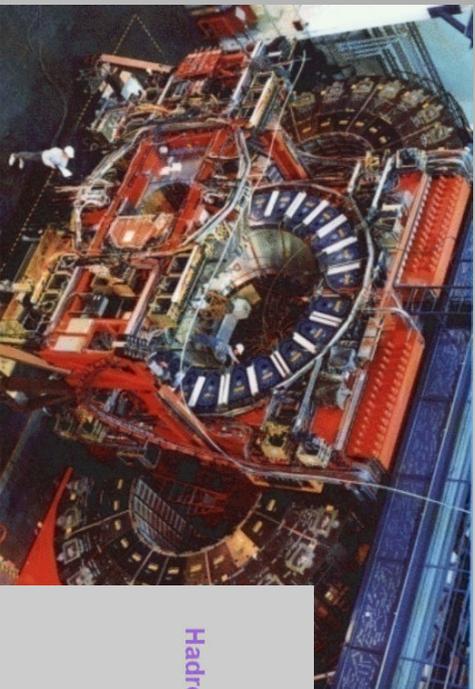
Motivation

- Finding *new* physics requires a good understanding of the *old* Physics and discriminating it from the complicated background.
- Looking at the *Minimum Bias Event* and the *Underlying Event* are important ways to look at the *softer* physics.

Tevatron



Collider Detector at Fermilab (CDF)

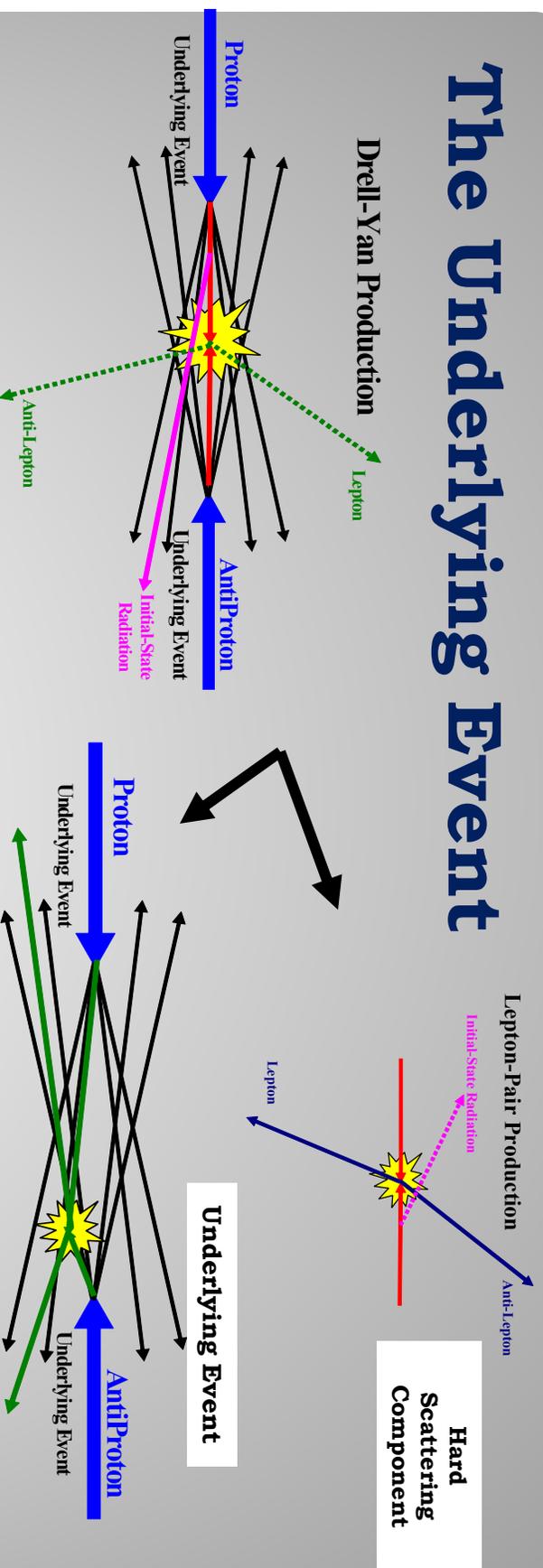


Minimum Bias Event

- Events collected with a trigger that is **not very restrictive** – ideally with totally inclusive trigger.
- In principle contains all types of interactions proportionally to their natural production rate.

*At the Tevatron about 1% of min-bias events contain a jet with 10 GeV transverse energy. At the LHC we expect this fraction **increase** by more than a factor of 10.*

The Underlying Event



Everything except the two outgoing hard scattered components.
(Beam-beam remnants, multiple parton interactions...)

Density of particles in the UE in jet events is about a **factor of two** larger than the density of particles in a typical MB collision at the Tevatron. At the LHC the difference might be even greater.

From an experimental point of view, on an event by event basis, it is impossible to separate these two components.

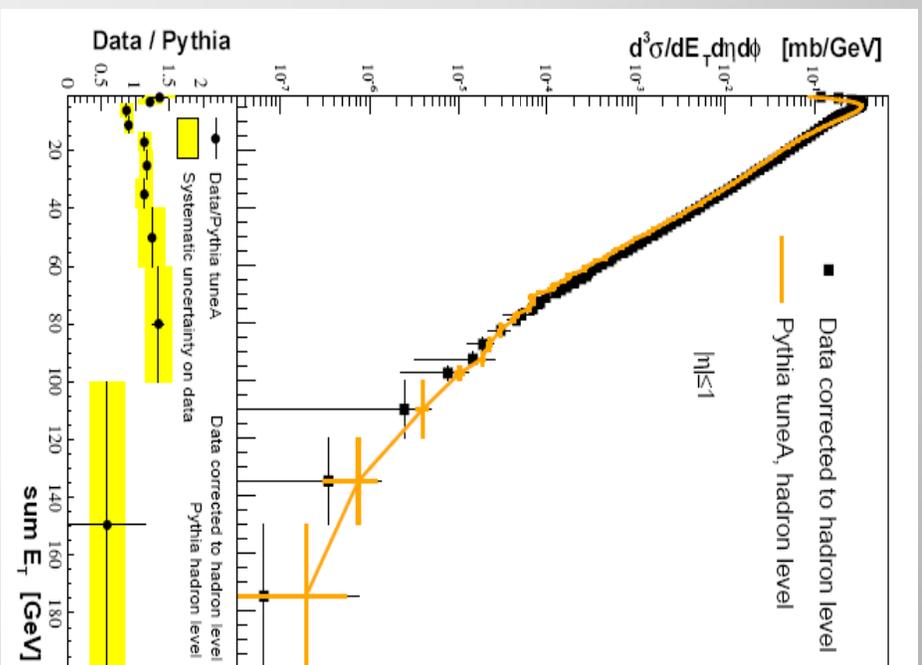
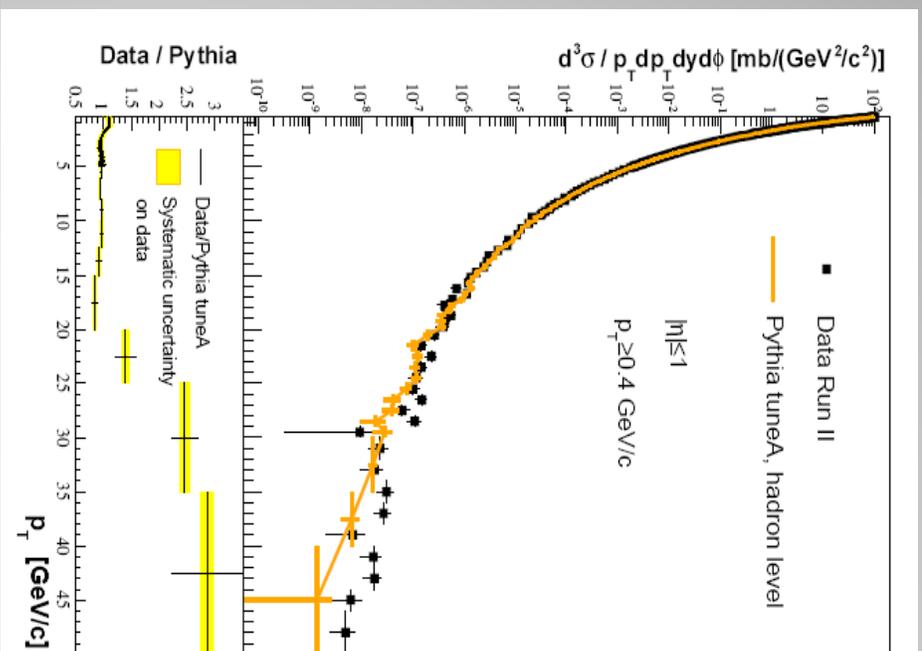
However, modeling these softer physics is very **important**.

- By looking at Min-Bias and Underlying Event data.
- By looking at the **correlation** between $\langle P_T \rangle$ and charged multiplicity to discriminate different scenarios.

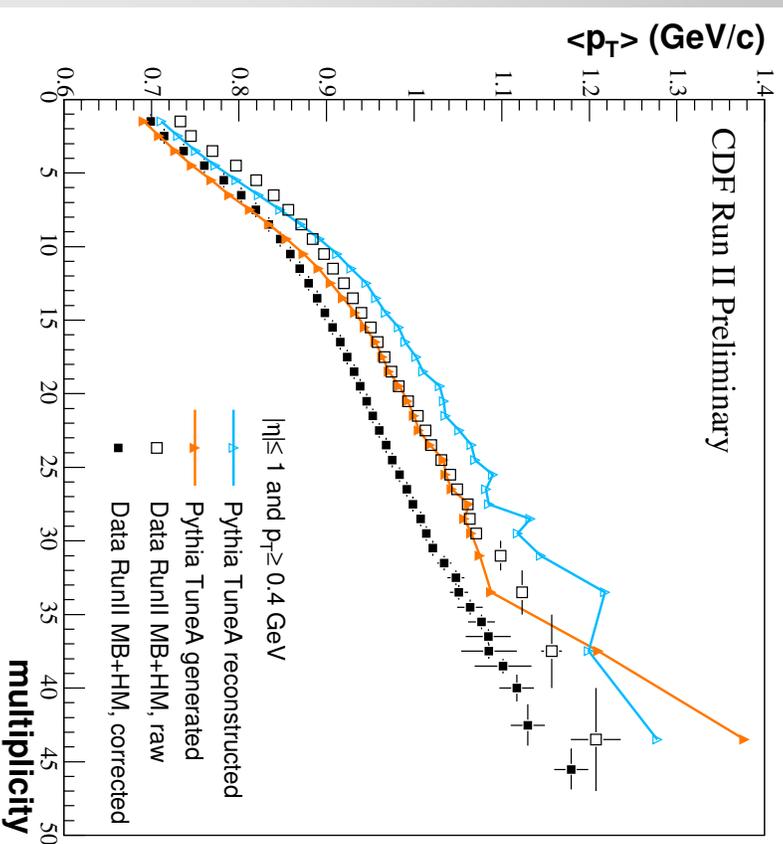
- Precision measurements of hard interactions where soft effects need to be subtracted.
- Jet cross-section, missing energy, isolation...
- QCD Monte-Carlo tuning.

Higher the precision, higher the accuracy of physics measurements.

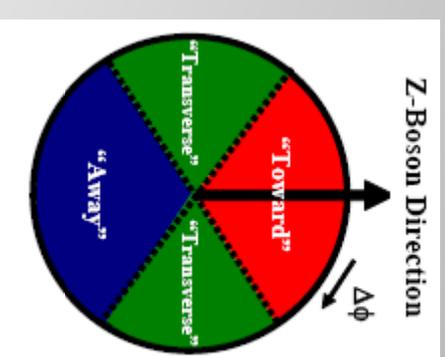
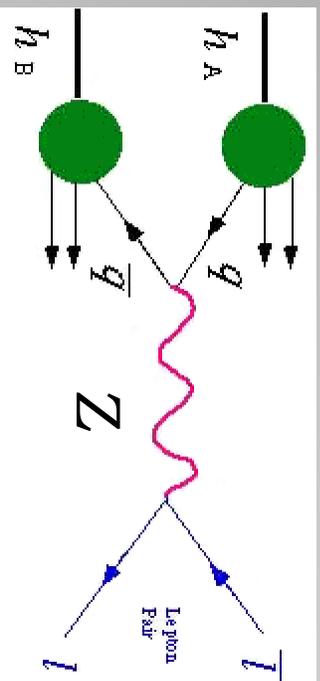
Min-Bias Cross Sections



Min-Bias Correlation Study



Underlying Event Studies with Drell-Yan



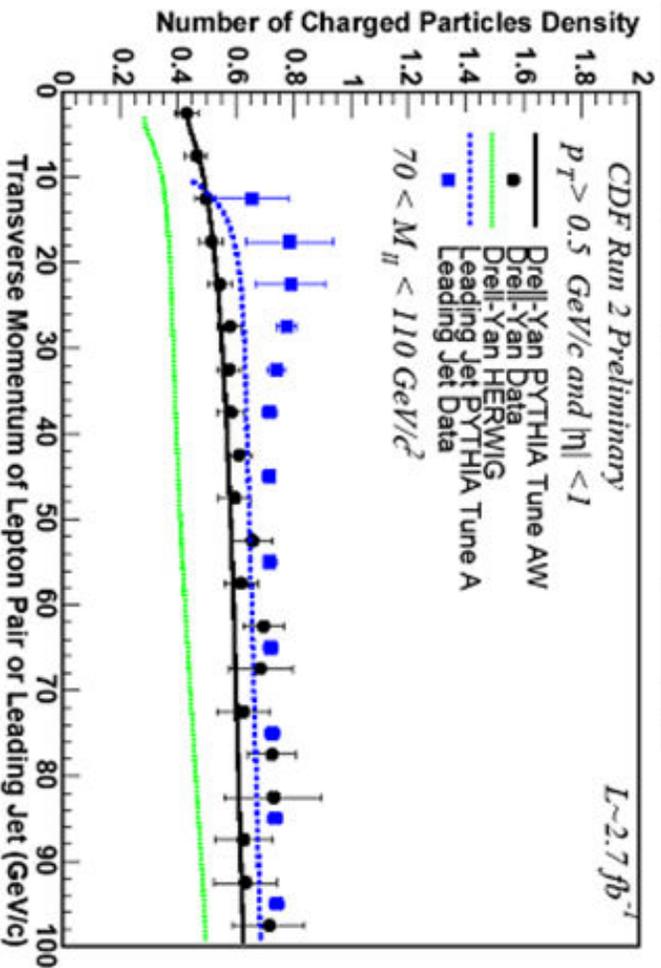
Azimuthal angle $\Delta\phi$ relative to the Z boson.

- Charged Particles with $p_T > 0.5 \text{ GeV}/c$ and $|\eta| < 1$
- Using events with the lepton pair invariant mass in the Z region: $70 < M(l\bar{l}) < 110 \text{ GeV}/c^2$

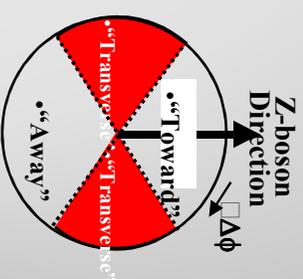
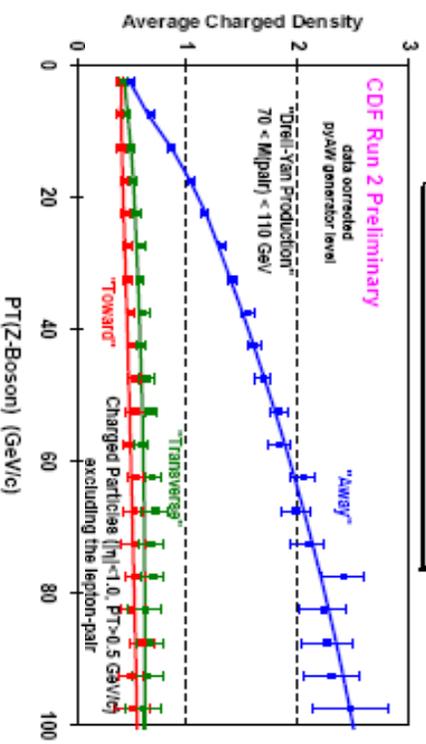
$|\Delta\phi| < 60^\circ$ as Toward
 $60^\circ < |\Delta\phi| < 120^\circ$ as Transverse
 $|\Delta\phi| > 120^\circ$ as Away

Charged Particle Multiplicity

Transverse Region Charged Particle Density: $dN/d\eta d\phi$

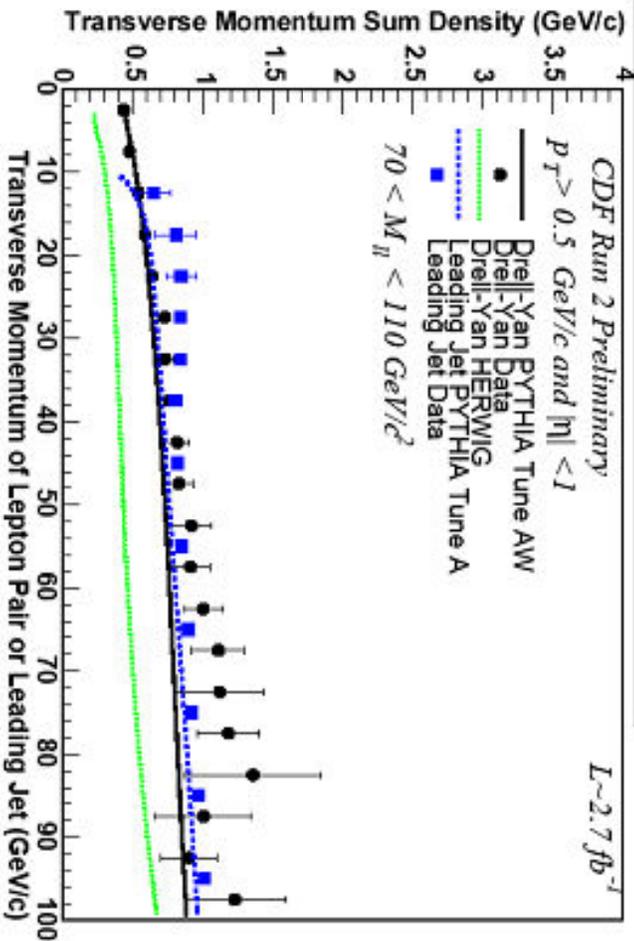


Charged Particle Density: $dN/d\eta d\phi$

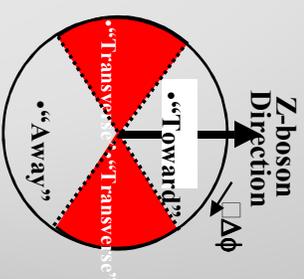
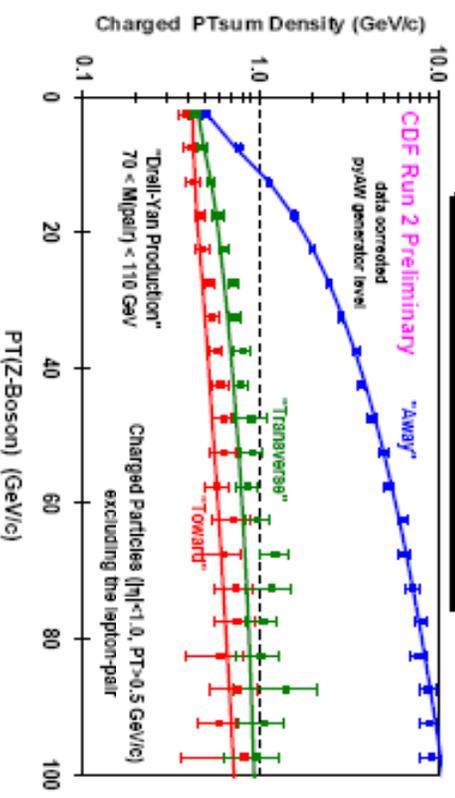


Charged Transverse Momentum Sum

Transverse Region Charged p_T Sum Density: $dp_T/d\eta d\phi$



Charged PTsum Density: $dP_T/d\eta d\phi$

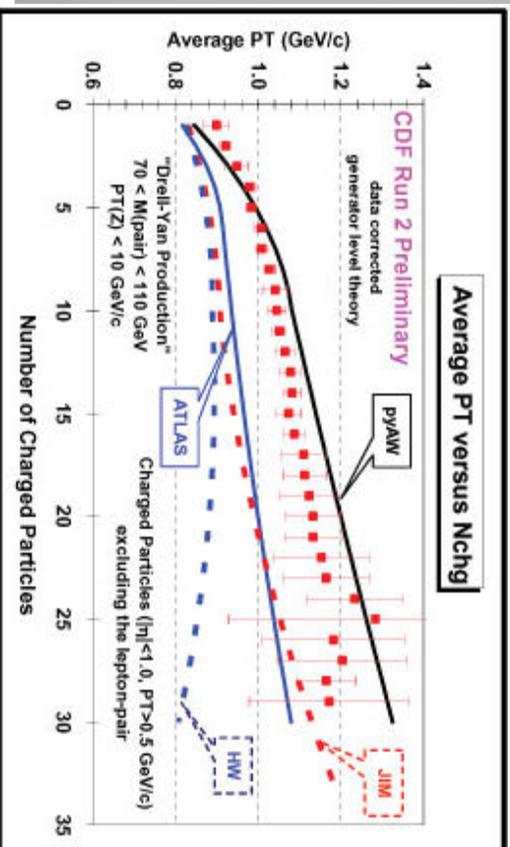
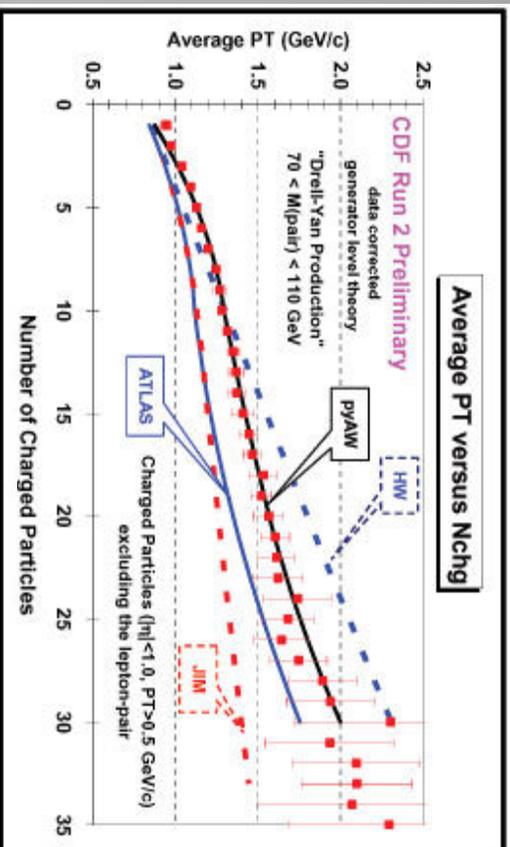


Underlying Event in Drell-Yan Summary

- Observed excellent agreement with PYTHIA Tune AW predictions.
- Close match with leading jet underlying event results – perhaps indicating an universality of underlying event models independent of hard scattering event.

Mean p_T vs Charged Multiplicity

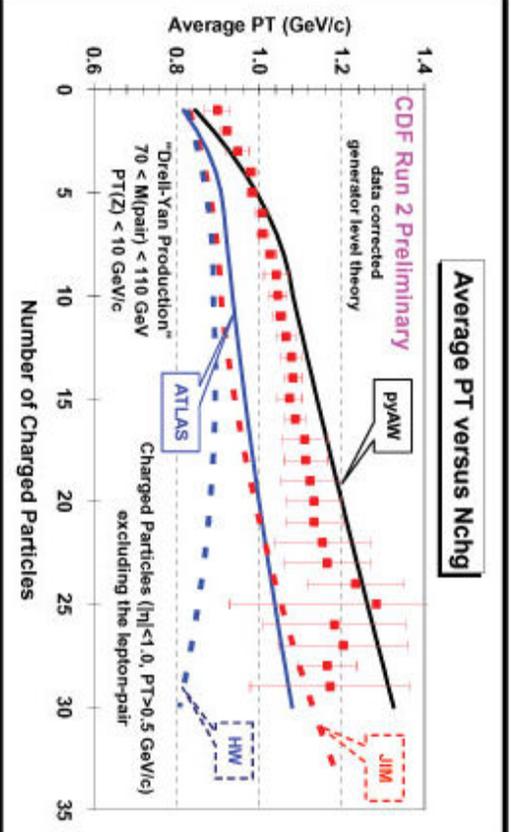
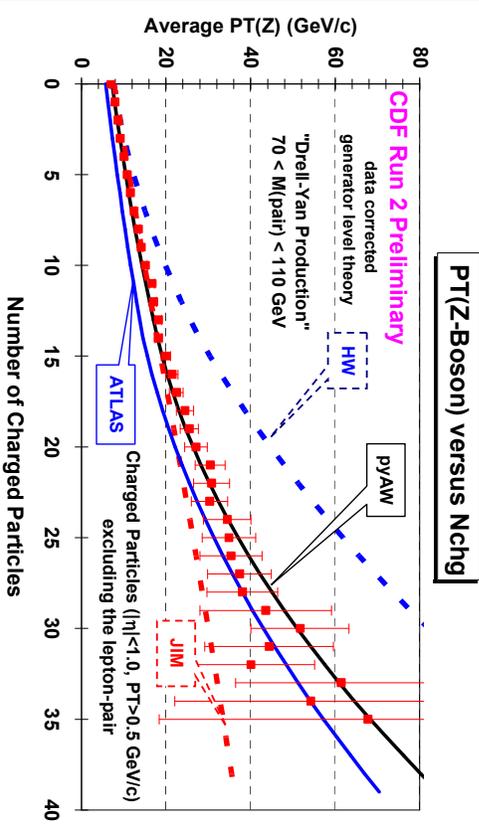
Fermilab
Result of
the Week



$\langle p_T \rangle$ versus N_{chg} is a measure of the amount of **hard versus soft** processes contributing and it is **sensitive** to the modeling of the multiple-parton interactions.

Mean p_T vs Charged Multiplicity

Fermilab
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$\langle p_T \rangle$ versus N_{chg} is a measure of the amount of **hard versus soft** processes contributing and it is **sensitive** to the modeling of the multiple-parton interactions.

Moving Forward to LHC

- The UE measurement plan at the LHC benefits from the solid experience of the CDF studies.
- Predictions on the amount of activity in transverse region at the LHC are based on extrapolations from lower energy data (mostly from the Tevatron).
- All the UE models have to be tested and adjusted at the LHC, in particular we know very little about the energy dependents of MPI in going from the Tevatron to the LHC.

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From The Times

September 10, 2008

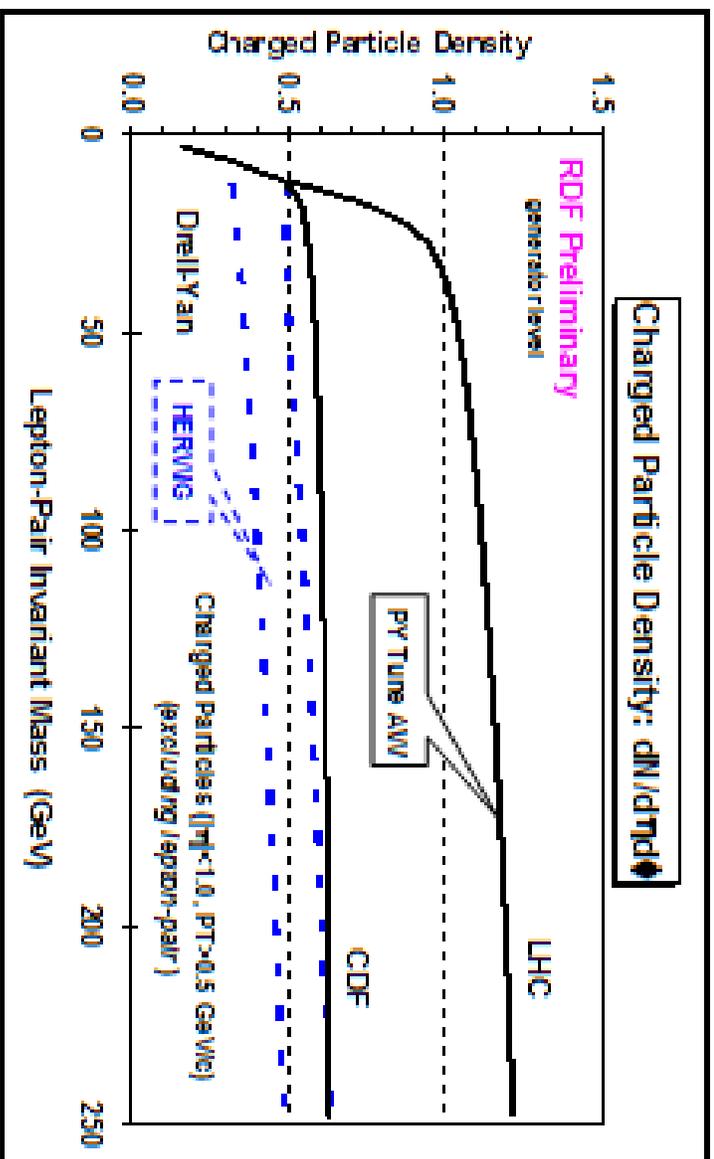
Scientists cheer as protons complete first circuit of Big Bang machine

Step by step...

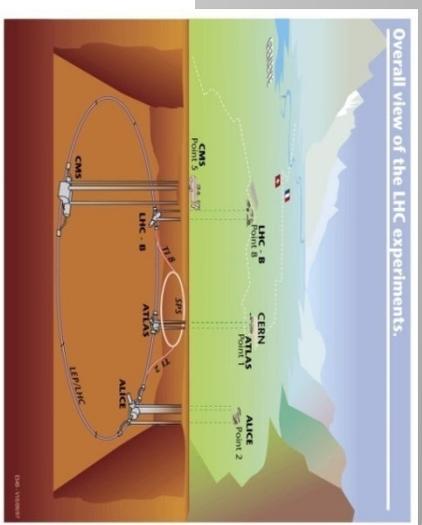
1. **The first pb^{-1} of collected data:** Mainly to calibrate the different analysis tools, look at min-bias data.
2. **With 10 pb^{-1} and a partially calibrated detector:** Look at underlying event observables, take control of systematics.
3. **Extending the statistics to 100 pb^{-1} :** Distinguish between differences of the investigated underlying models.

The Underlying Event in LHC

Drell-Yan Production in LHC



Underlying Event much more active at LHC



Conclusions

One will learn a lot about the energy dependence of the underlying event (i.e. multiple parton interactions) by comparing the Tevatron results with the LHC. Early analyses in LHC would be geared towards tuning the QCD Monte Carlo models.



As seen in Madison, WI