Dijet Azimuthal Decorrelations vs NLO pQCD, Herwig and Pythia

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Outline

● Motivation
  ➔ Theoretical
  ➔ Experimental

● Analysis overview
  ➔ Data sample
  ➔ Corrections, unsmearing
  ➔ Systematics

● Results
  ➔ Comparisons to LO and NLO pQCD
  ➔ Comparisons to Monte Carlo generators
    ➔ Herwig and Pythia
    ➔ Impact of ISR, Tune A

● Summary and outlook

All results presented here are PRELIMINARY!
Theoretical Motivation

- In $2 \rightarrow 2$ scattering, partons emerge back-to-back $\rightarrow$ additional radiation introduces decorrelation in $\Delta \Phi$ between the two leading partons/jets
  - Soft radiation: $\Delta \Phi \sim \pi$
  - Hard radiation: $\Delta \Phi < \pi$

- $\Delta \Phi$ distribution is directly sensitive to higher-order QCD radiation

- Testing fixed-order pQCD and parton-shower models across $\Delta \Phi$:
  - $\Delta \Phi \sim \pi$:
    - FO calculations unstable
    - PS Monte Carlo’s applicable
  - $2\pi/3 < \Delta \Phi < \pi$:
    - First non-trivial description by $2 \rightarrow 3$ tree-level ME
    - $2 \rightarrow 3$ NLO ME calculations became available recently (NLOJET++)
  - $\Delta \Phi < 2\pi/3$ (3-jet “Mercedes”)
    - $2 \rightarrow 4$ processes and higher

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Experimental Motivation

- Observable: $\Delta \Phi$ distribution between the two leading jets normalized by the integrated dijet cross section

$$\frac{1}{\sigma_{\text{dijet}}} \cdot \frac{d\sigma_{\text{dijet}}}{d\Delta \Phi}$$

- Advantages:
  - $\Delta \Phi$ is a simple variable, uses only the two leading jets
  - No need to reconstruct any other jets!
  - Jet direction is well measured
  - Reduced sensitivity to jet energy scale

$M_{jj} = 1206$ GeV
Analysis Overview

● Data sample:
  ➔ \( \sim 150 \text{ pb}^{-1} \) used in analysis
  ➔ At least two jets reconstructed with cone \( R=0.7 \)
  ➔ Require that two leading jets are central: \( |y_{\text{jet1,2}}|<0.5 \)
  ➔ Jet \( p_T \)’s in the region of full trigger efficiency
  ➔ Running conditions, jets, vertex, missing \( E_T \) satisfy quality requirements

● Corrections for:
  ➔ Cut efficiencies
  ➔ Jet energy scale
  ➔ Resolution smearing (unfolding)

● \( \Delta \Phi \) distribution measured only for \( \Delta \Phi>\pi/2 \) to avoid jet overlaps
• Good agreement between data and MC with full detector simulation (MC slightly low)
• Average $<n_{\text{jet}}>$ increases towards low $\Delta \Phi$, as expected
Resolution Unfolding

- Unfolding procedure:
  - Start with the $\Delta \Phi$ spectrum obtained for jets reconstructed at hadron level in events from Pythia
  - Smear this spectrum according to measured resolutions in $\Delta \Phi$ (from MC) and $p_T$ (from data)
  - Reweight the resulting spectrum to fit the data

- Correction = unsmeared spectrum / smeared spectrum
  (bin-by-bin, after reweighting)
  - Includes effects of jet reordering due to smearing in $p_T$
  - Shapes similar in all $p_T$ ranges
  - Unfolding corrections not huge
  - Work in progress
- Jet energy scale still results in a substantial uncertainty
  - But, fractionally, much smaller than in the case of the absolute cross sections
  - A new jet energy scale determination, with significantly smaller uncertainties, is propagating through the analyses
- Other sources:
  - Vertex efficiency
  - Unfolding (under study)
- Estimated uncertainties:
  - ~5% ($\Delta \Phi \sim \pi$) to ~25% ($\Delta \Phi \sim \pi/2$)
Results: Dijet Azimuthal Decorrelations

- Recap:
  - Central jets $|y| < 0.5$
  - Second-leading $p_T > 40$ GeV
  - Leading jet $p_T$ bin thresholds:
    - $75, 100, 130, 180$ GeV

- Towards larger $p_T$, $\Delta \Phi$ spectra more strongly peaked at $\sim \pi$
  - Increased correlation in $\Delta \Phi$

- Distributions extend into the “4 final-state parton regime”, $\Delta \Phi < 2\pi/3$

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MC4RUN2 Workshop, 11 May 2004
**Comparison to Fixed-Order pQCD**

- **Leading order (dashed blue curve)**
  - clear limitations
  - Divergence at $\Delta \Phi = \pi$
    - need soft processes
  - No phase-space at $\Delta \Phi < 2\pi/3$
    - only three partons

- **Next-to-leading order (red curve)**
  - Good description over the whole range, except in extreme $\Delta \Phi$ regions

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**D0 data**
- $p_{T_{\text{max}}} > 180$ GeV ($\times 10^3$)
- $130 < p_{T_{\text{max}}} < 180$ GeV ($\times 10^2$)
- $100 < p_{T_{\text{max}}} < 130$ GeV ($\times 10$)
- $75 < p_{T_{\text{max}}} < 100$ GeV

- $\Delta \phi_{\text{dijet}} / \text{rad}$

- $1/\sigma_{\text{dijet}} \cdot d\sigma_{\text{dijet}} / d\Delta \phi_{\text{dijet}}$

- $p_{T_{\text{max}}} > 180$ GeV ($\times 10^3$)
- $130 < p_{T_{\text{max}}} < 180$ GeV ($\times 10^2$)
- $100 < p_{T_{\text{max}}} < 130$ GeV ($\times 10$)
- $75 < p_{T_{\text{max}}} < 100$ GeV

- $\mu_r = \mu_f = 0.5 \cdot p_{T_{\text{max}}}$
Testing the radiation process:
- 3rd and 4th jets generated by parton showers
  - Soft and collinear approx.

HERWIG 6.505 (default)
- Good overall description!
- Slightly too high in mid-range

PYTHIA 6.223 (default)
- Very different shape
- Too steep dependence
- Underestimates low $\Delta \Phi$

**Graph:**
- $\sigma_{dijet}$ vs $\Delta \phi_{dijet}$
- DØ preliminary
- $p_{T_{\text{max}}} > 180$ GeV ($\times 100$)
- $75 < p_{T_{\text{max}}} < 100$ GeV

**Legend:**
- HERWIG 6.505
- PYTHIA 2.223
- CTEQ6L (PDFs)

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Impact of ISR in Pythia

- $\Delta\Phi$ distributions are sensitive to the amount of initial-state radiation
  - Plot shows variation of PARP(67) from 1.0 (current default) to 4.0 (previous default, Tune A)
  - PARP(67) controls the scale of parton showers
  - Intermediate value suggested

- More PYTHIA tuning possible!

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Most of variation from PARP(67)

- Sensitivity to soft underlying event small

HERWIG prediction with CTEQ5L (parameterized) not as good as with CTEQ6L

- $|y_{jet,2}| < 0.5$, $p_{T\text{ jet}_2} > 40$ GeV
- $100$ GeV < $p_{T\text{ jet}_1} < 130$ GeV
- $130$ GeV < $p_{T\text{ jet}_1} < 180$ GeV
Summary and Outlook

- The $\Delta \Phi$ distribution has been measured for central jets in four $p_T$ regions using 150 pb$^{-1}$ of DØ Run II data
  - Sensitive to higher-order QCD processes
  - Test of 3-jet NLO pQCD at Tevatron
    - good agreement for most of $\Delta \Phi$ range
  - Prospects for tuning parton-shower Monte Carlo’s
    - Herwig doing well, sensitivity to ISR in Pythia

- Plans, hopes, dreams:
  - Extend the measurement to lower $p_T$ values
    - More sensitivity to initial-state gluons
    - A handle on quark vs gluon induced showers
  - Extend to forward rapidities for one of the jets
    - Probe even smaller values of $\Delta \Phi$
    - More sensitivity to initial-state gluons
  - Extend to b-tagged jets
    - Probe gluon$\rightarrow$bbar splitting
    - Interesting overlap with top, Higgs physics…

Frixione, Nason, Webber