Dijet Azimuthal Decorrelations

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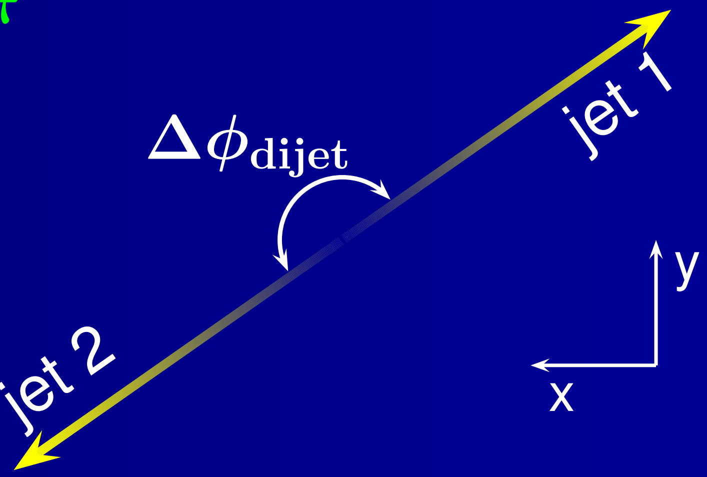
for the DØ Collaboration

$\Delta\phi$ Decorrelation

- Dijet production in lowest order pQCD
  - jets have equal p_T and $\Delta\phi_{\mathbf{dijet}} = \pi$



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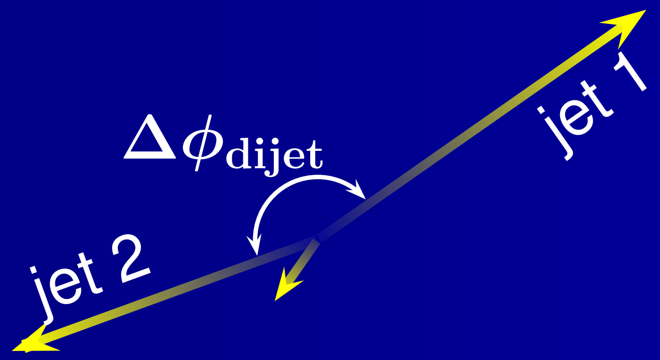
- Additional soft radiation causes small azimuthal decorrelations
  - $\boldsymbol{\Delta\phi_{\mathrm{dijet}} \sim \pi}$
  - divergent in fixed-order pQCD



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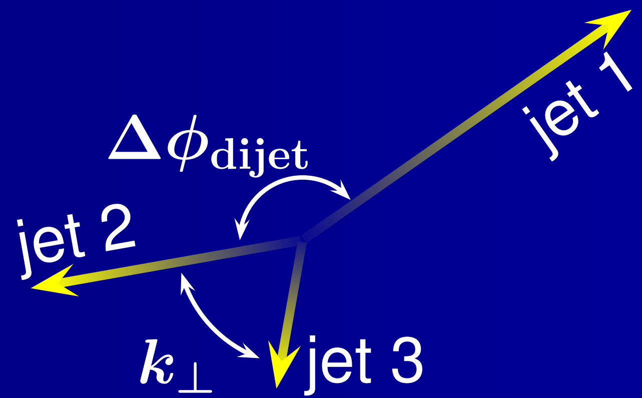

- Additional hard radiation can lead to large azimuthal decorrelations
  - $k_\perp$ large $\Rightarrow \Delta\phi_{\mathrm{dijet}} < \pi$
  - $2\pi/3 \leq \Delta\phi_{\mathrm{dijet}} < \pi$ for three-jet production

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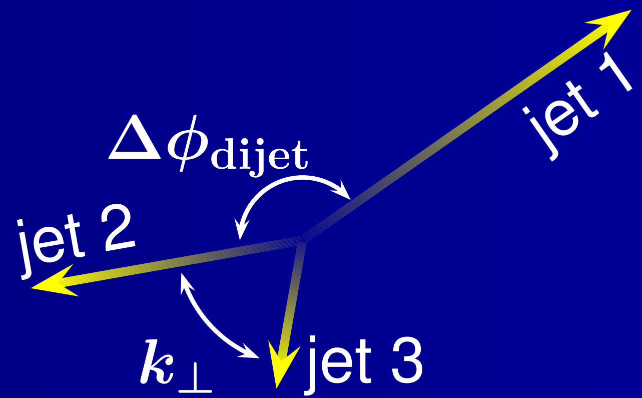

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$\Delta\phi_{\mathrm{dijet}}$ is directly sensitive to higher-order QCD radiation without explicitly measuring third and fourth jets $\Rightarrow$ test $\mathcal{O}(\alpha_s^4)$ calculations

The Observable

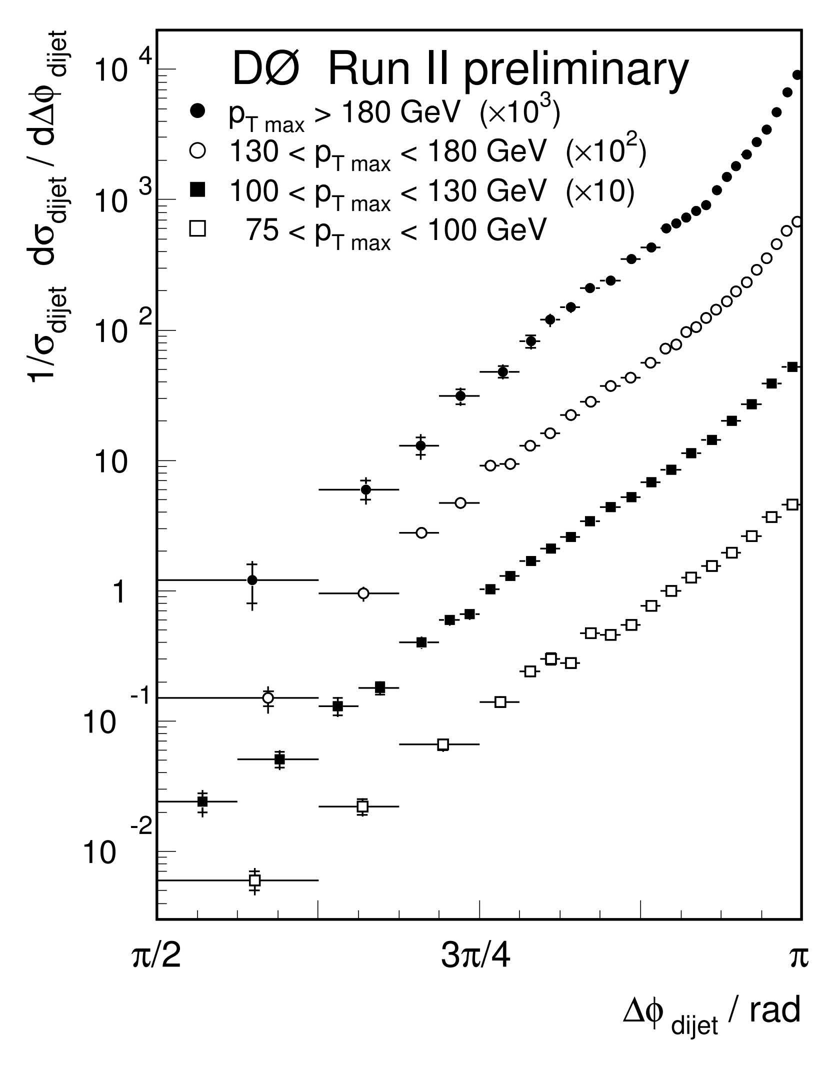
- ϕ decorrelation is a *three-jet observable*
- Three-jet NLO pQCD calculations are now available (NLOJET++)
  - Same theory calculation used in previous talk
- Tree-level pQCD calculations with up to six jet production are also available (ALPGEN)
  - Used extensively in top and higgs analyses
- We can also test parton shower models in HERWIG, PYTHIA, ...

The Measurement

- Inclusive Dijet Sample
  - Discussed in previous talk
- Observable: $\frac{1}{\sigma_{\text{dijet}}} \cdot \frac{d\sigma_{\text{dijet}}}{d\Delta\phi_{\text{dijet}}}$
- Results are fully corrected to particle level, including unsmearing in p_T and position (< 20 mrad for $p_T > 80$ GeV)
- Systematic uncertainties dominated by jet energy calibration. The energy scale contributes $\approx 7\%$ near π and up to 23% at $\pi/2$ (larger at small $\Delta\phi_{\text{dijet}}$ due to p_T reordering).

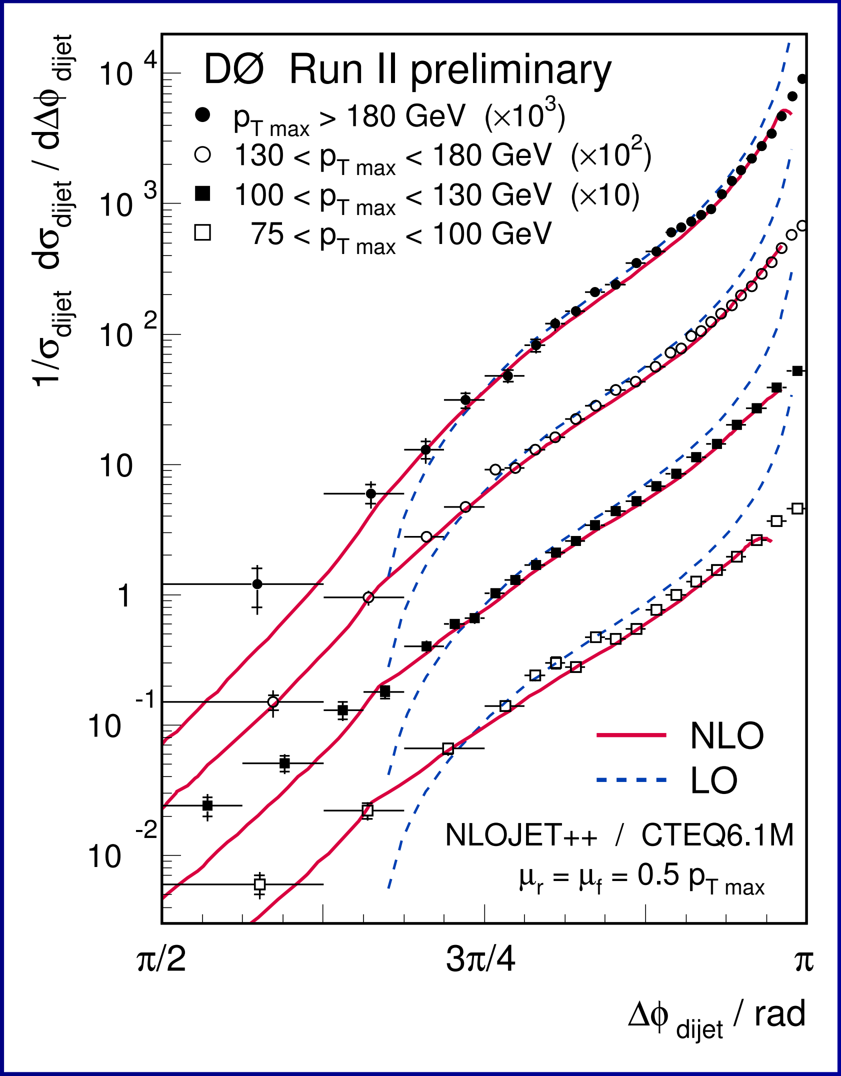
The Measurement

- Inclusive Dijet Sample
  - Four bins in leading jet p_T: 75, 100, 130, 180 GeV
  - Second leading jet: $p_T > 40$ GeV
  - Both leading jets central: $|y_{\mathrm{jet}}| < 0.5$
- Increased $\Delta\phi$ correlation with larger $p_{T\,max}$



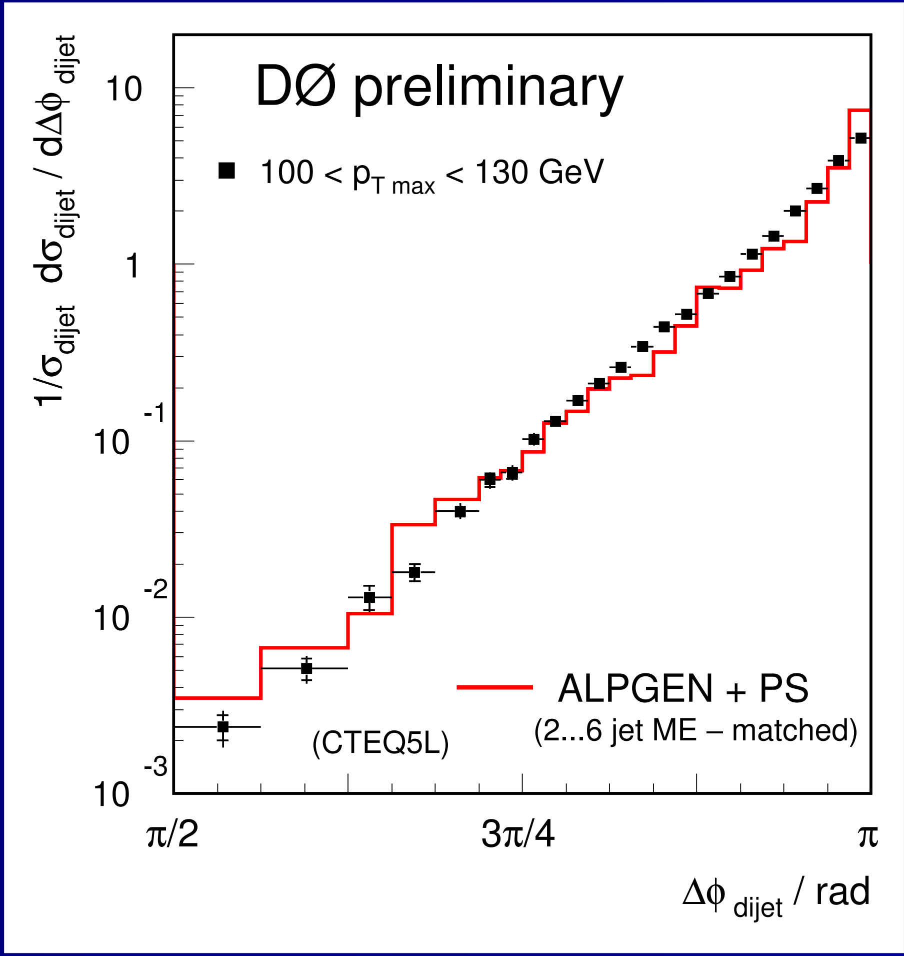
Theory Comparison – NLOJET++

- $$\frac{1}{\sigma_{\mathbf{dijet}}}\Big|_{\mathbf{(N)LO}} \; \frac{d\sigma_{\mathbf{dijet}}}{d\Delta\phi_{\mathbf{dijet}}}\Big|_{\mathbf{(N)LO}}$$
- LO pQCD (in 3-jet prod.)
  - Poor agreement
    no phase space at $< 2\pi/3$
  - divergent at $\Delta\phi_{\mathbf{dijet}} = \pi$
- NLO pQCD (in 3-jet prod.)
  - Good description over large range
  - Tree-level only for $\Delta\phi_{\mathbf{dijet}} < 2\pi/3$
  - divergent at $\Delta\phi_{\mathbf{dijet}} = \pi$



Theory Comparison – ALPGEN

- Tree-level production for $2 \longrightarrow 2, 3, \ldots, 6$ jets
- Uses PYTHIA parton showers
- Mangano's matching applied to properly add multiplicity bins
- Reasonable description of the data

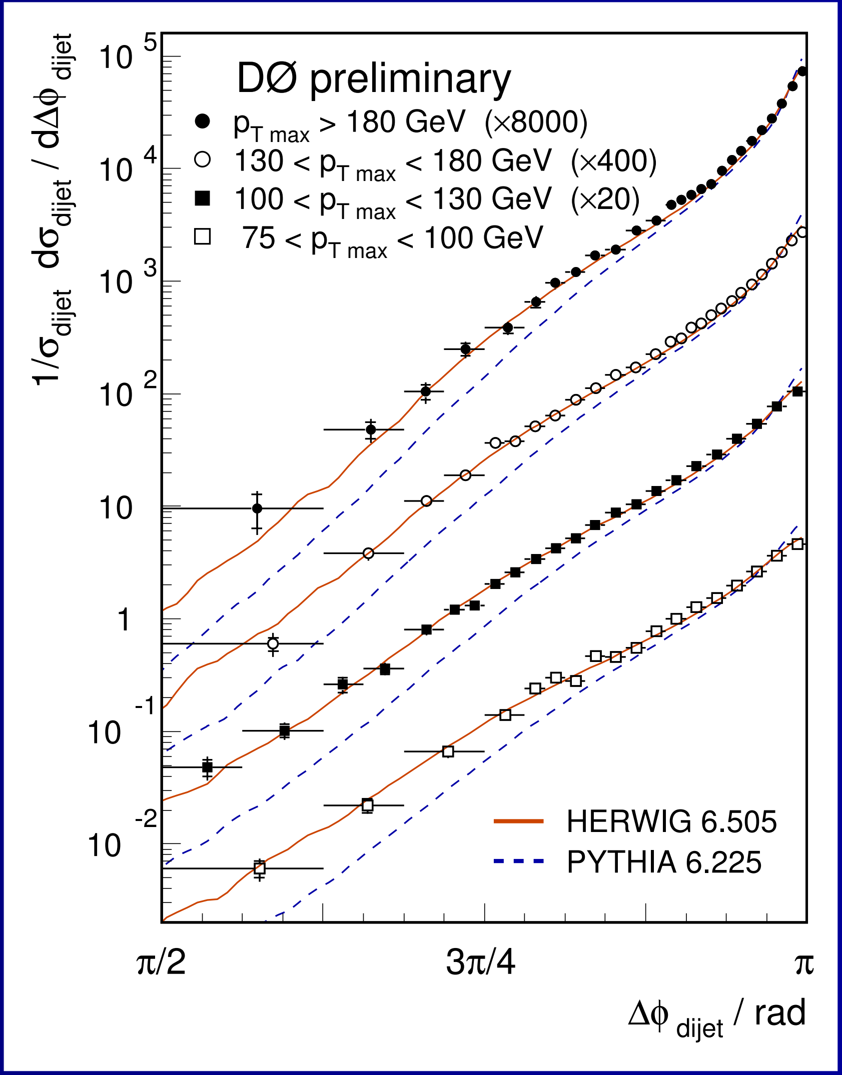


Event Generator Comparisons

Third and fourth jets are generated via parton showers (uses soft and collinear approximations)

- HERWIG v6.505
  - very good description
- PYTHIA v6.225
  - poor description

(default parameters)



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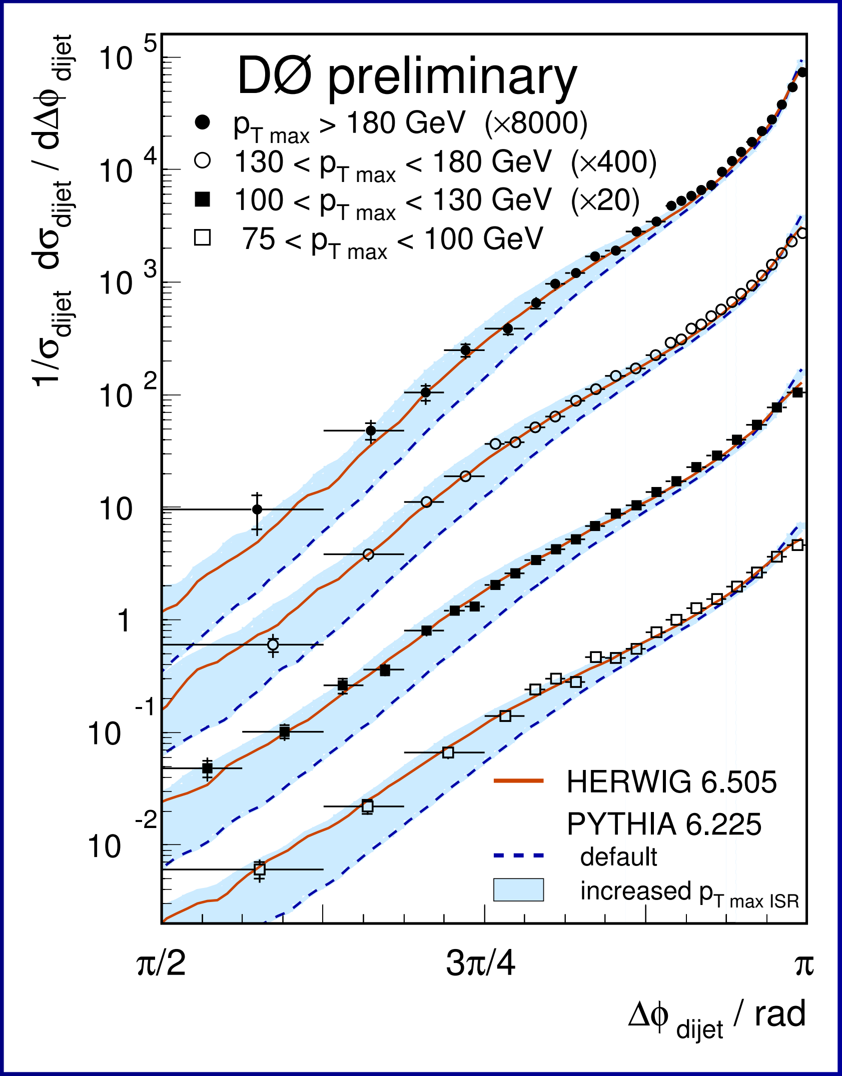
    PARP(67)=1 $\Rightarrow$ 4
  - improves description



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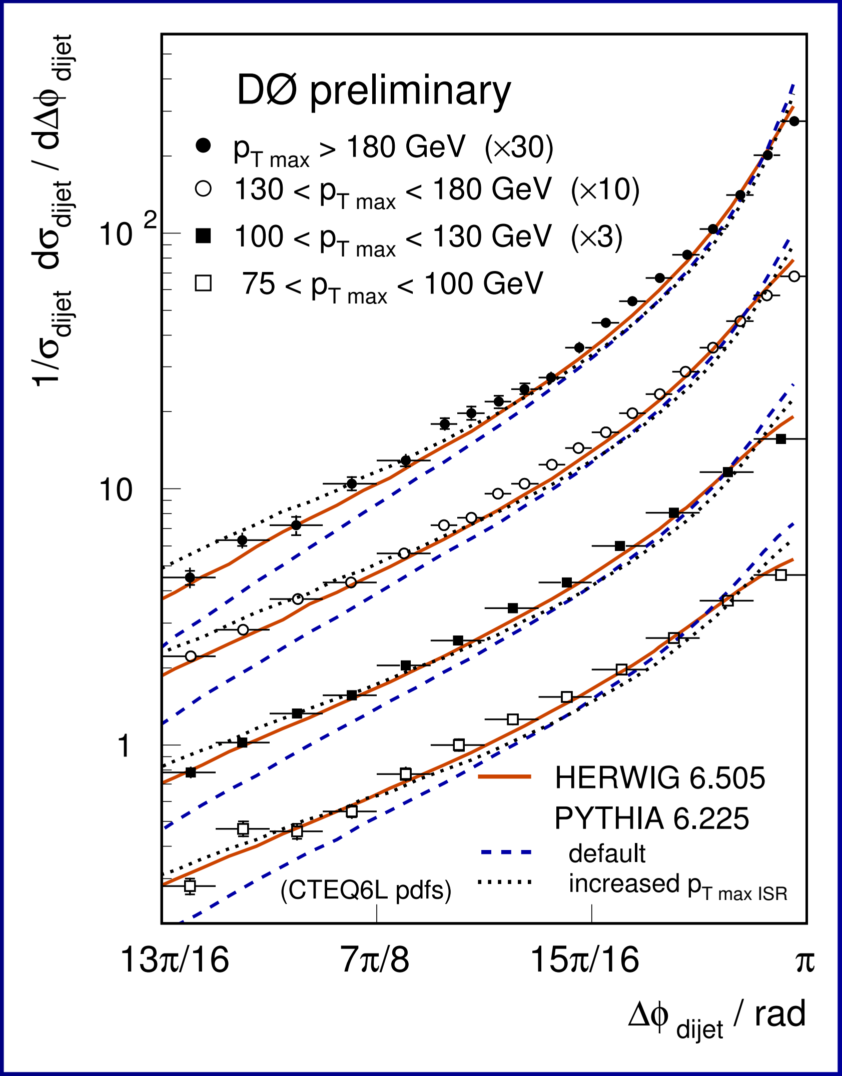


Conclusions

- The DØ collaboration has measured the azimuthal decorrelation between the two leading jets at $\sqrt{s} = 1.96$ TeV
- NLO pQCD describes the data very well
- LO pQCD fails to describe the data, but a tree-level calculation with up to six jet production is adequate
- HERWIG v6.505 with default parameters describes the data
- PYTHIA v6.225 with default parameters does not characterize the data, however, PYTHIA has many handles. In particular, increasing the maximum virtuality of the ISR shower significantly improves agreement at low $\Delta\phi_{\mathbf{dijet}}$.

Backup Slides

DØ Calorimeter

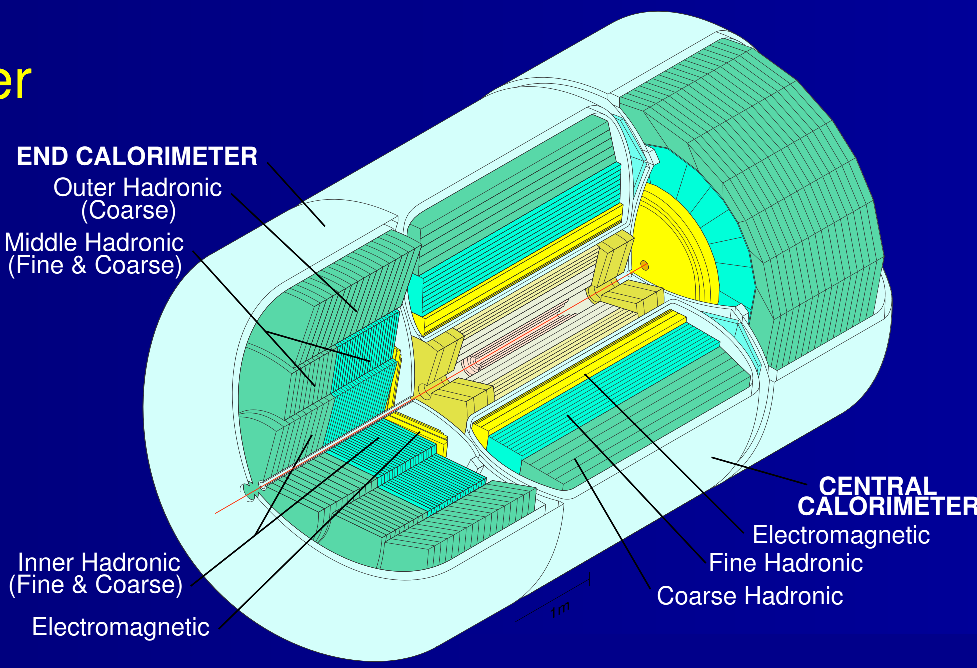
- Uranium–Liquid Argon Calorimeter

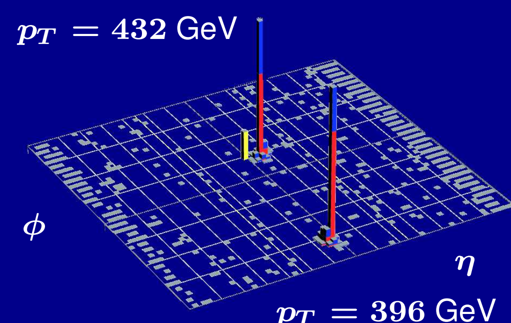
  stable, uniform response, radiation hard

- Compensating: $e/\pi \approx 1$
- Uniform hermetic coverage

  $|\eta| \leq 4.2$ $[\eta \equiv -\ln\tan(\theta/2)]$

- Longitudinal Segmenation:
  - 4 EM Layers ($21X_0$)
  - 4–5 Hadronic Layers (6λ)
- Transverse Segmentation:
  - $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$ in EM_3
  - $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$ otherwise





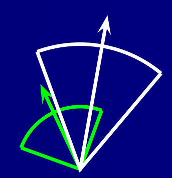
Cone Jet Definition

- Run I
  - Add up towers around a “seed”
  - Iterate, using “jets” as seeds, until stable
  - Jet quantities: E_T, η, ϕ

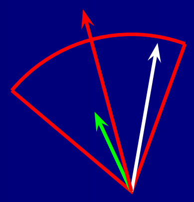
    $$E_T^{\text{jet}} = \sum_{R_i \le 0.7} E_T^{\text{tower}}$$

- Modifications for Run II
  - Use 4-vector scheme

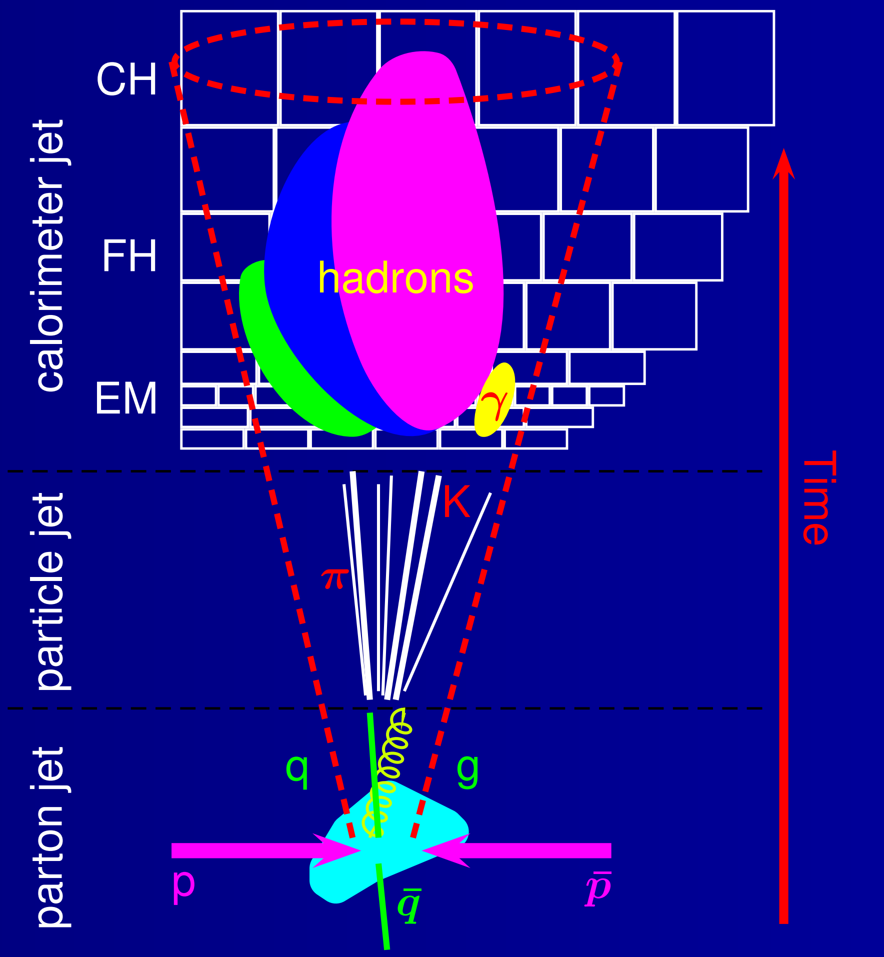
    p_T instead of E_T



  - Add midpoints between jets as additional seeds
  - Infrared safe



  - $\Delta R = \sqrt{\Delta y^2 + \Delta\phi^2}$
- Correct to particle jets...

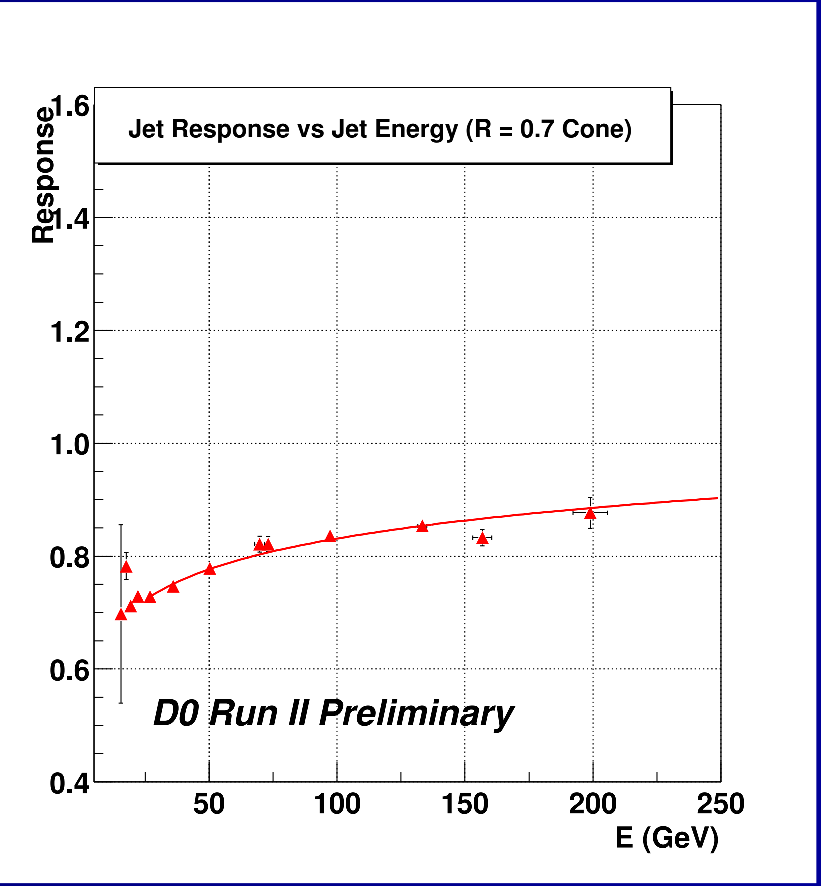


Jet Energy Scale

- Measured jet energy is corrected to particle level

$$E_{corr} = \frac{E_{uncorr} - O}{R\,S}$$

- O energy due to previous events, multiple interactions, noise, etc
  minimum bias events
- R calorimeter response to hadrons (dead material, non-linearities, etc)
  E_T imbalance in $\gamma + jet$ events
- S net fraction of particle–jet energy remaining inside jet cone after showering in calorimeter
  jet transverse shapes



- Large statistical uncertainties and substantial systematic uncertainties (increase with energy due to extrapolation).
  $\gamma + jet$ statistics up to 200 GeV

Soft Physics