DØ Jet Results

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Sinaia, Romania

Outline

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- Motivation for Jet Physics
- Tevatron and the DØ Experiment

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- Dijet Cross-section
- Dijet Azimuthal Decorrelations
- μ-Tagged Jets Cross-Section

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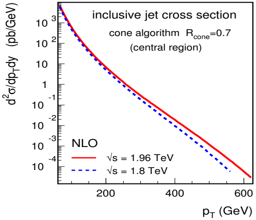
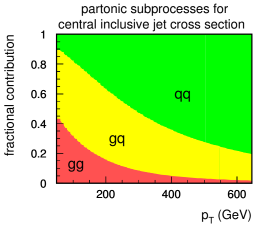
- Matrix Element Method

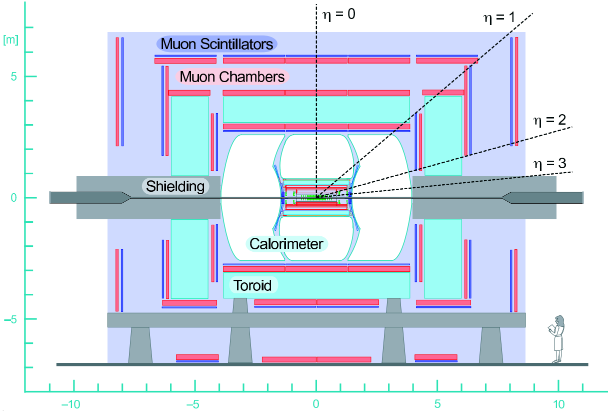
Motivation

- Tevatron upgrade ($1.8\,\mathrm{TeV} \Rightarrow 1.96\,\mathrm{TeV}$) extends the reach of jet p_T. (Increase in cross-section of 300% for $p_T = 500\mathrm{GeV}$ jet).
- Inclusive jet cross-section directly sensitive to strong coupling constant α_S, PDFs and pQCD matrix elements.
- Sensitivity to gluon PDFs.
- Dijet azimuthal decorrelations directly sensitive to higher order QCD radiation.
- Place to search for new physics!



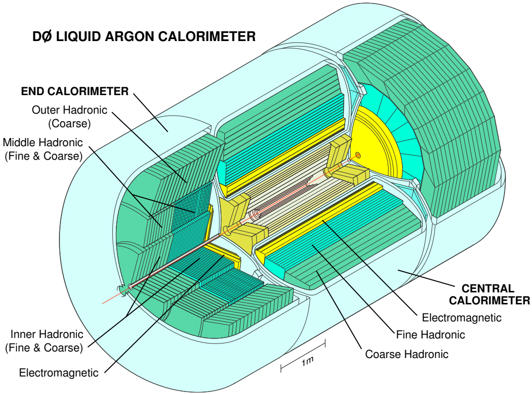


Tevatron and DØ Detector



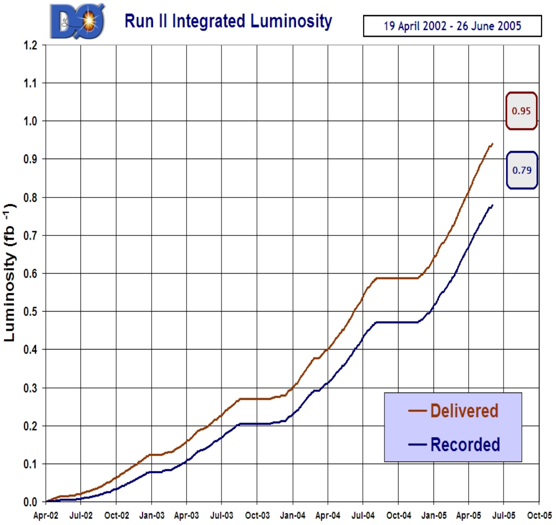
- $\sqrt{s} = 1.96$TeV, Luminosities $> 10^{32}\text{cm}^{-2} \cdot \text{s}^{-1}$
- DØ upgraded for Run II 396 ns bunch spacing (Trigger, DAQ).
- New tracking system in 2T magnetic field.
- Upgraded Muon Chambers and Calorimeter electronics.

DØ Calorimeter



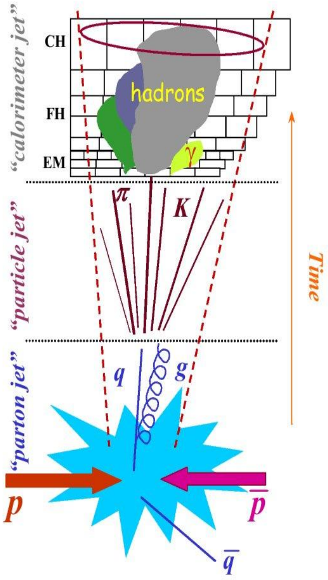
- Uranium-Liquid Argon Calorimeter
- Uniform hermetic coverage $|\eta| \leq 4.2$ $[\eta \equiv -\ln\tan(\theta/2)]$
- Fine segmentation (up to $|\eta| < 3.2$) $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$

Luminosity



- Here we present data collected between 2002 and 2004.
- Data taking efficiency is at stable 85-90%.
- **Tevatron already reached 1fb^{-1}!** Run IIa finishes soon, Run IIb with upgraded accelerator and detector.

Jets



- Calorimeter jet
  - Interaction of hadrons with calorimeter.
  - Collection of calorimeter cell energies.
- Particle jet
  - After hadronization and fragmentation.
  - Effect of hadronization is soft $\Rightarrow$ allows comparison between particle and parton jets.
- Parton jet
  - Hard scattering.
  - Additional showers.

Run II Cone Jet Algorithm

- Uses particles as **seeds**:
  - Experiment - calorimeter clusters (above given threshold).
  - MC - stable particles.
  - pQCD - partons.
- Uses 4-vector scheme:
  - p_T instead of E_T.
  - rapidity $y = \frac{1}{2} \ln \frac{E+p_z}{E-p_z}$ instead of pseudorapidity η.
- Combines 4-vectors within a cone of radius $R_\mathsf{cone} = 0.7$ in $y \times \phi$

$$\Delta R = \sqrt{\Delta^2 y + \Delta^2 \phi} < R_\mathsf{cone} \, .$$

- Calculates jet axis - iterates until the solution is stable.
- Adds midpoints between jets as additional seeds $\Rightarrow$ infrared safe.
- Removes identical solutions, and treats overlapped jets.

Jet Energy Calibration

- Measured energy is corrected to particle level using the following decomposition:

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

where

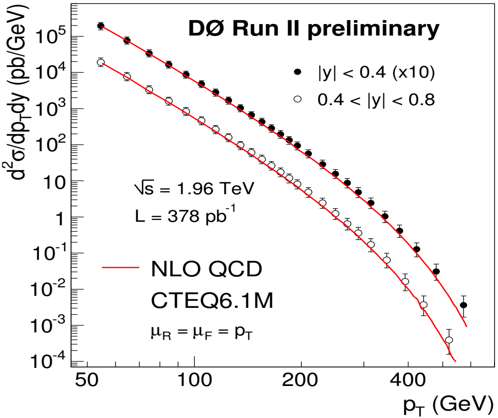
  - **Offset** (O) is energy due to previous events, multiple interactions, noise, etc.
  - **Response** (R) is calorimeter response to jets (measured in $\gamma +$ jet events).
  - **Showering** (S) is fraction of energy inside the jet cone after showering in the calorimeter.

- Jet Energy Scale (JES) is the dominant uncertainty of the measurement.

Inclusive Jet Cross-section: Method

- Events selected using inclusive jet triggers in separate
  - **Central region**: $\mid y \mid < 0.4$
  - **Higher rapidity region**: $0.4 < \mid y \mid < 0.8$
- These results correspond to the integrated luminosity of $L = 378 \mathrm{pb}^{-1}$.
- Predictions of next-to-leading order (NLO) pQCD are computed using NLOJET++.
- CTEQ 6.1M PDFs are used and scale choices of $\mu_\mathrm{r} = \mu_\mathrm{f} = p_\mathrm{T}$.

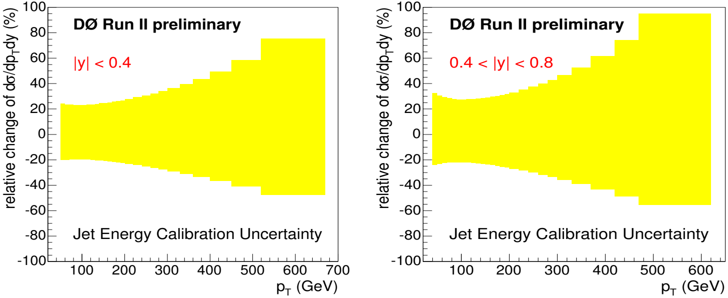
Inclusive Jet Cross-section: Results



- Two rapidity ranges ($| y | < 0.4$ cross-section is scaled by 10).
- Cross-section in $0.4 < | y | < 0.8$ falls slightly more steeply towards higher p_{T}'s.

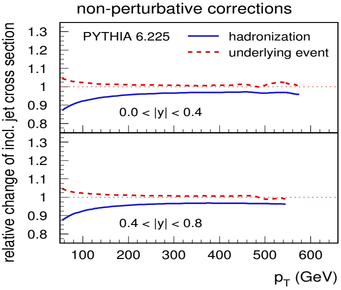
Experimental Uncertainties

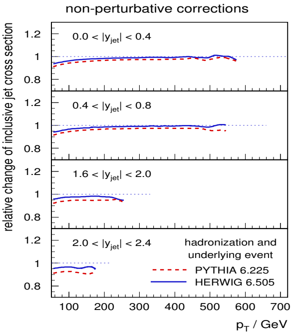
- Largest uncertainty coming from Jet Energy Calibration.
- Reconstruction inefficiencies (trigger, vertex, . . .).



Non-perturbative effect

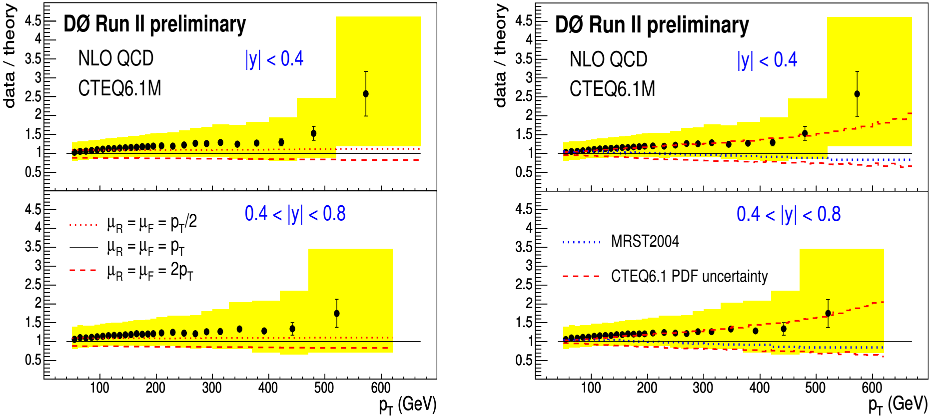
- Effects of hadronization and underlying event:
  - studied in MC by a “switch off”.
  - consistent results were found in PYTHIA and HERWIG
- Effects of hadronization and underlying event have opposite directions and are both below 5% for $p_{\mathrm{T}} > 150\mathrm{GeV}$



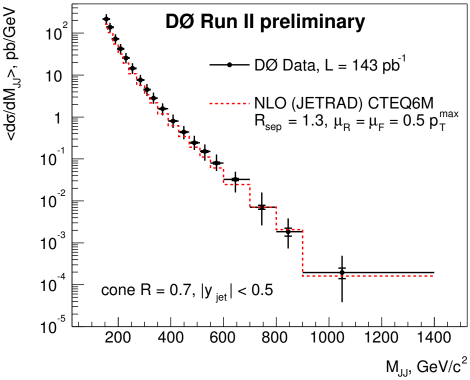


Data – Theory Comparison

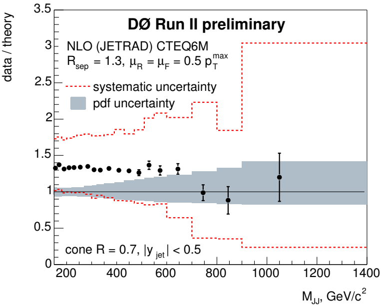
- Scale dependence of NLO (dotted and dashed lines) (left).
- Theoretical uncertainty coming from PDFs (right).
- Total experimental uncertainty in yellow.



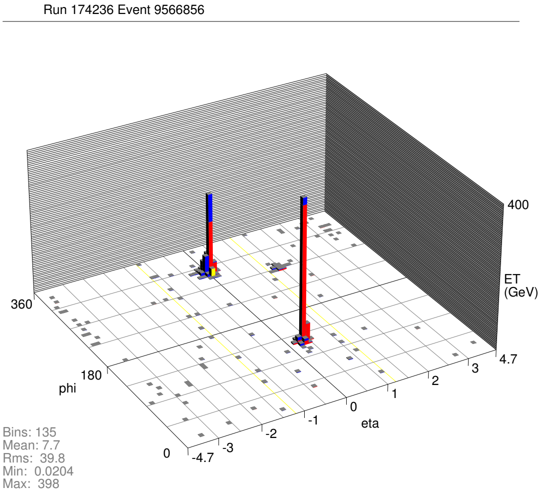
Dijet Cross-section Measurement (Dijet Mass)



- **Dijet cross-section as a function of dijet invariant mass.**
- Smaller statistics: $L = 143\text{pb}^{-1}$.



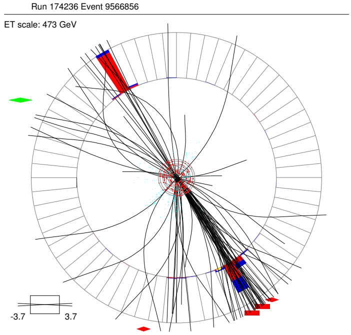
Highest p_T Event

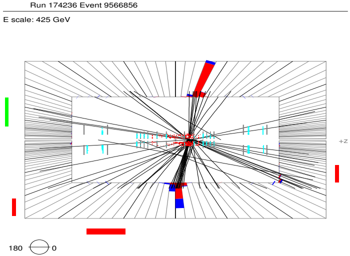


	1[st] jet	2[nd] jet
p_T	631 GeV	560 GeV
$y_{\rm jet}$	0.14	-0.17
$\phi_{\rm jet}$	2.10	5.27

$M_{\rm jj}$ = 1208GeV

mE_t: 20.8
phi_t: 295 deg

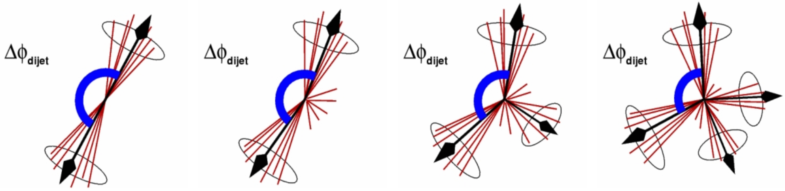




Dijet Azimuthal Decorrelations - Motivation

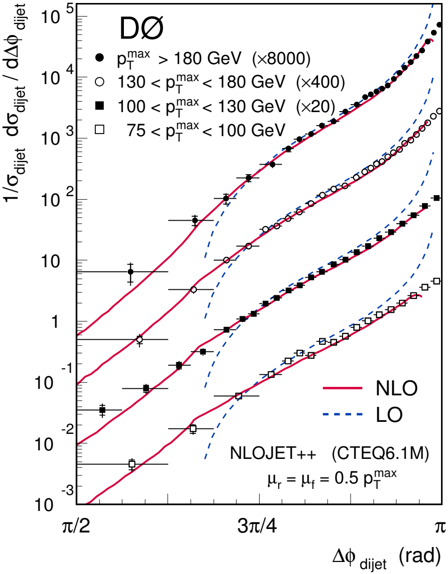
- **Dijet production in lowest order pQCD**
  - jets have equal p_T and $\Delta\phi_{\text{dijet}} = \pi$
- **Additional soft radiation causes small azimuthal decorrelations**
  - $\Delta\phi_{\text{dijet}} \sim \pi$
- **Hard radiation can lead to larger decorrelations**
  - $2/3\pi \leq \Delta\phi_{\text{dijet}} < \pi$ for three-jet production
  - $\Delta\phi_{\text{dijet}} < 2/3\pi$ for four-jet production

$\Rightarrow$ **$\Delta\phi_{\text{dijet}}$ is sensitive to higher order QCD radiation without explicitly measuring third and fourth jets!**



Azimuthal Decorrelations - The Measurement

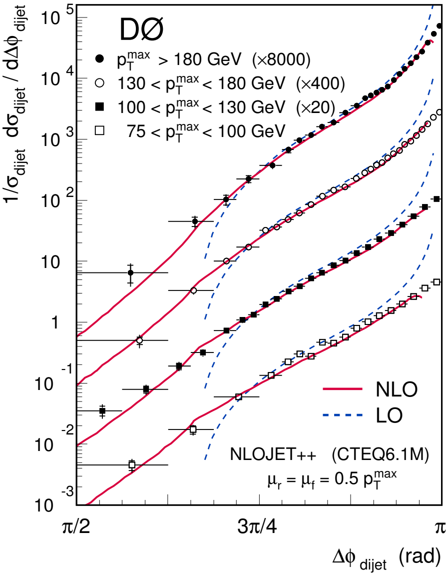
- Observable: $\frac{1}{\sigma_{\text{dijet}}} \cdot \frac{d\sigma_{\text{dijet}}}{d\Delta\phi_{\text{dijet}}}$
- **Inclusive dijet sample:**
  - Selected by jet triggers
  - Four bins in leading jet p_T: 75, 100, 130, 180 GeV.
  - Second leading jet: $p_T > 40$GeV.
  - Both leading and second leading jets central: $|\, y \,| < 0.5$.



Accepted by PRL, hep-ex/0409040

LO and NLO Theory Comparison - NLOJET++

- $\frac{1}{\sigma_{\text{dijet}}}\bigg|_{\text{(N)LO}} \frac{d\sigma}{d\Delta\phi_{\text{dijet}}}\bigg|_{\text{(N)LO}}$
- CTEQ6.1M
- Scales: $\mu_r = \mu_f = 0.5 p_T^{\text{max}}$.
- **LO pQCD** in 3-jet production
  - Poor agreement.
  - Divergent at π.
- **NLO pQCD** in 3-jet production
  - Good agreement over large range.
  - Divergent at π.

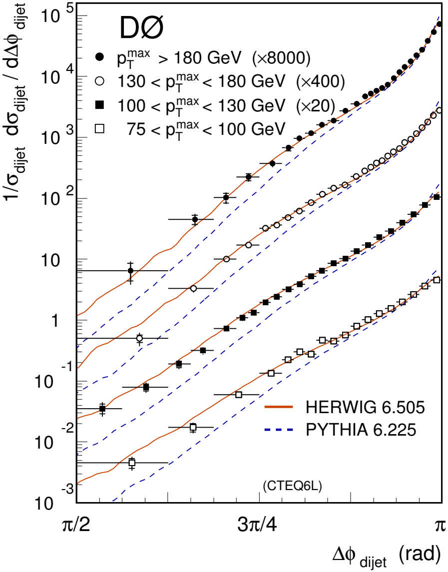


Event Generator Comparisons

Herwig v6.505 vs. Pythia v6.225
LO pQCD + parton showering

- **Herwig:**
  - Very good description.
- **Pythia**
  - Poor agreement.
  - But many parameters to adjust. . .
  - Adjusting maximal virtuality of ISR.

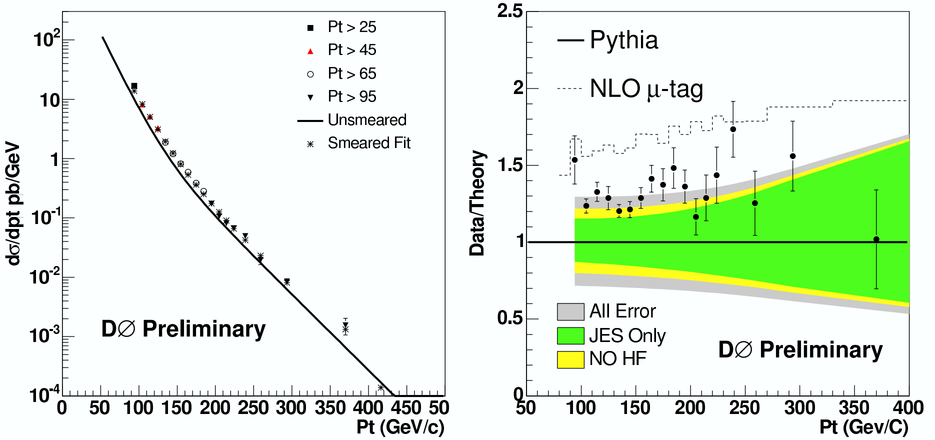
$\Rightarrow$ Significant improvement!



High p_T μ-Tagged Jets Cross-Section: Method

- Cone 0.5 jets, $L = 294$ pb^{-1}, rapidity of $|y| < 0.5$
- **At least one of two leading jets has muon within the 0.5 cone.**
- Correct for Jet Energy Scale of μ-tagged jets.
- Unsmearing applied to access particle level cross section.
- Restrict on jets with μ from Heavy Flavours: correct for μ's from π's and K's ($c\tau$'s of 7.8m and 3.7m).
- p_T-dependent HF fraction obtained from full Monte Carlo.
- Muon reconstruction: central tracker, outer Muon Chambers, toroidal field.
- Largest uncertainties from HF fraction, muon reconstruction efficiencies, unsmearing ansatz form, luminosity, JES.

High p_T μ-Tagged Jets Cross-Section: Results



- Data divided by LO Pythia.
- Compared to NLOJET++ × [Pythia's μ-tagged fraction].
- **$\approx 1\sigma$ deviation of data from both Pythia and simple NLO.**

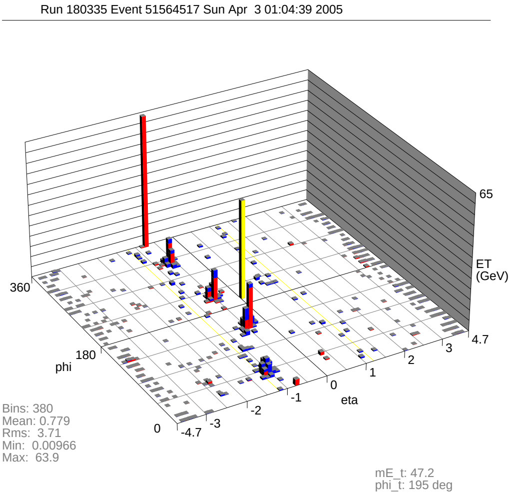
Top Quark Mass Measurements

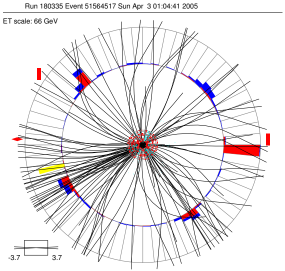
- In general, Top Quark is a nice QCD laboratory with different systematical effects than pure QCD processes.
- Jet Energy Scale uncertainties are the main systematics in Top Quark Mass measurements.
- We expect 6 jets in the all jets channel, 4 jets in lepton+jets channel and 2 b-jets in dilepton channels.

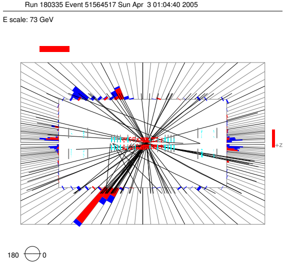
$\Rightarrow$ We deal with a **multijet environment!**

- As a result, Jet Energy Scale derived in low multiplicity photon+jet and dijet events may be different from the in-situ one which may be obtained from fitting the W mass in $t\bar{t}$ events.
- We have $p\bar{p} \to t\bar{t} \to bW^+\bar{b}W^-$.
- Here we present results from the lepton+jet channel using two different techniques.
- We find the in-situ derived JES consistent with the standard from photon+jet.

e+jets Top Candidate Event







Ideogram Method

- 2D Likelihood used to fit the Top Mass and JES from the m_W, BG separation via likelihood discriminant.
- b-tagged analysis performing kinematics fit and using resulting $w_i \equiv \exp(\frac{1}{2}\chi^2)$ weights.
- $\geq$ 4jets, Use information from all jet permutations.

$$\mathcal{L}_{\text{evt}} \equiv \sum_{i=1}^{24} w_i \Big\{ (1 - P_{\text{evt}}) BG$$

$$+ P_{\text{evt}} \cdot \left[P^{\text{ntag}}_{\text{correct}} \cdot G \otimes BW + (1 - P^{\text{ntag}}_{\text{correct}}) \cdot BG^{\text{ntag}}_{\text{combi}} \right] \Big\} ,$$

where G is detector resolution function, BW Breit-Wigner and BG the background shape.

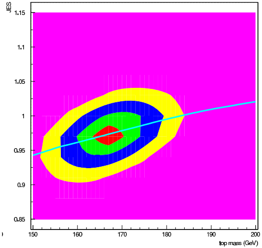
- **Combined e+jets and μ+jets channels** with 370 fb^{-1}:
  $m_t = 171.3 \pm 3.7$ (stat + JES)$^{+2.7}_{-0.0}$ (res. JES)$^{+1.0}_{-1.7}$ (syst) GeV.
  fitted JES factor $= 1.024 \pm 0.024$.

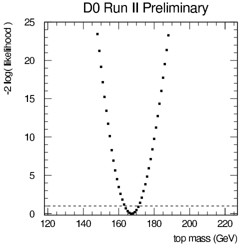
Matrix Element Method

- Analytical matrix element $|\mathcal{M}_{fi}|^2$ for the $t\bar{t}$ production is used to compute a cross section as a function of m_t and JES parameter which enters jet transfer function via the variable $E_{\text{jet}}/\text{JES} - E_{\text{parton}}$.
- Event-by-event signal probability based on computed LO $\sigma_{t\bar{t}}$.
- Exactly 4 jets, BG separation using VECBOS Wjjjj description; assume $p_{\text{T}}^{t\bar{t}} = 0$.
- Likelihood maximised w.r.t. m_t and JES; fitted signal fraction $f_{t\bar{t}}$. $\mathcal{L} \equiv \prod_{i=1}^{n} P_{\text{evt}}(x_i, m_t, \text{JES})$
  $P_{\text{evt}}(x, m_t, \text{JES}) \equiv f_{t\bar{t}} P_{t\bar{t}}(x, m_t, \text{JES}) + (1 - f_{t\bar{t}}) P_{\text{BG}}(x, \text{JES})$
- 16D phase space integration, convolution with jet transfer functions and detector acceptance function.
- **Combined lepton+jets result** using 320 fb^{-1} data: $169.5 \pm 4.4\ (\text{stat} + \text{JES})^{+1.3}_{-1.3}\ (\text{syst})$ GeV.

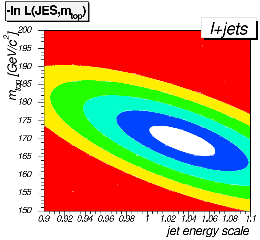
Latest DØ Top Mass l+jets Results

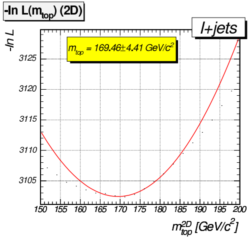
Ideogram:





Matrix Element:





Summary and Conclusion

The DØ Collaboration has measured the inclusive jet cross-section and the azimuthal decorrelations at $\sqrt{s} = 1.96$TeV.

- Increase of $\sqrt{s}$ from 1.8TeV extends the p_{T} range by 150GeV.
- **Inclusive jet cross-section** presented in central region with $L = 378\text{pb}^{-1}$, **dijet cross-section** with $L = 143\text{pb}^{-1}$.
- NLO pQCD describes the data.
- **Dijet azimuthal decorrelations** sensitive to higher order radiation effects.
- NLO pQCD describes the data very well.
- Parton shower models tested in Herwig and Pythia.
- **μ-Tagged Jets Cross-Section** shows 1σ deviation from theory.

We present competitive results on Top Quark Mass measurements in the lepton+jets channel using simultaneous fit of m_t and Jet energy Scale parameters.