Upsilon production and μ-tagged jets in DØ

Horst D. Wahl

Florida State University

(DØ collaboration)

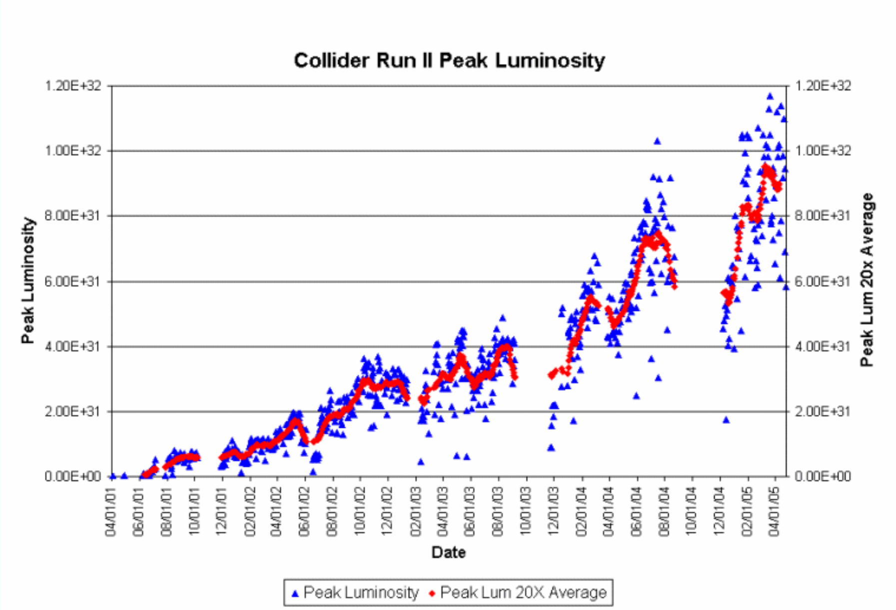
29 April 2005

DIS 2005

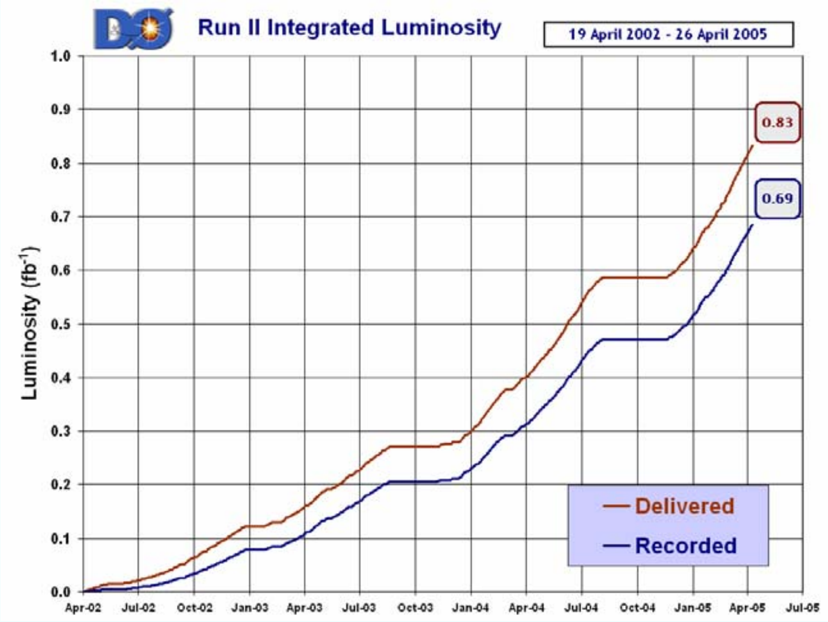
27 April to 1 May 2005

Madison

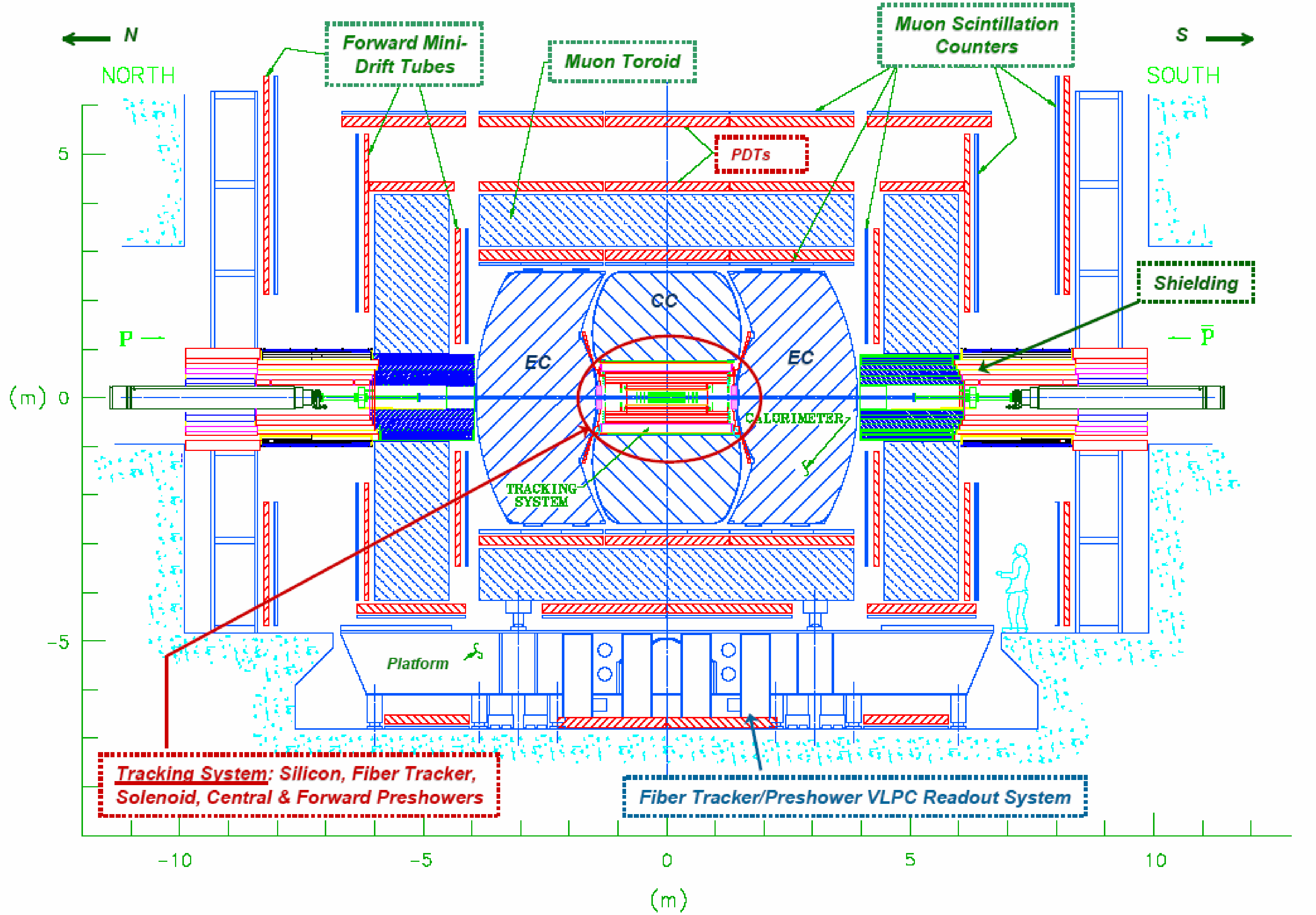
- Outline:
  - Tevatron and DØ detector
  - Upsilon ϒ(1S)
  - High p_t jets with μ tag
  - Summary



- Tevatron – data taking
  - peak luminosity in 2005 above 10^{32} cm^{-2} s^{-1}
  - DØ collected > 690 pb^{-1}
  - Results shown use 150 – 300 pb^{-1}

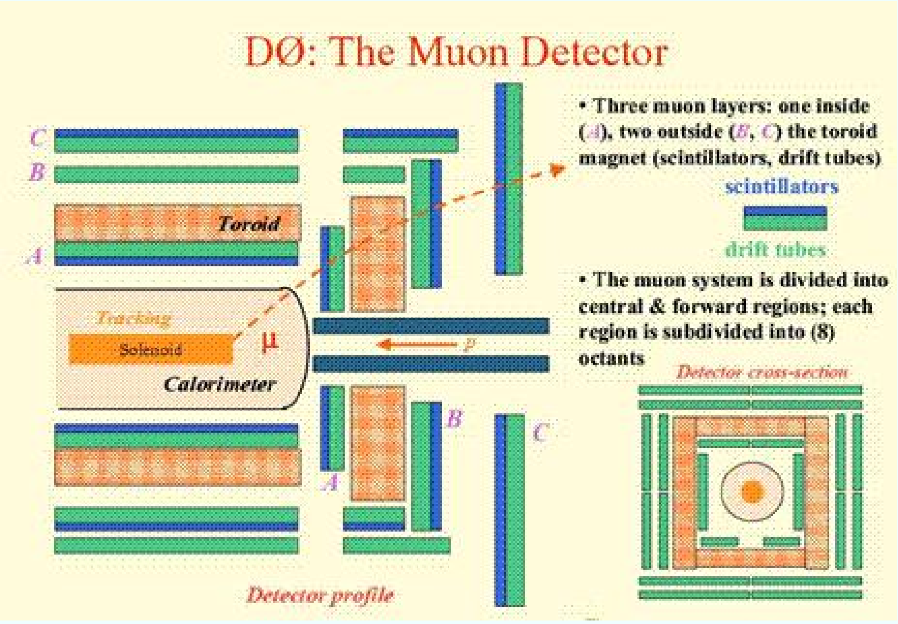


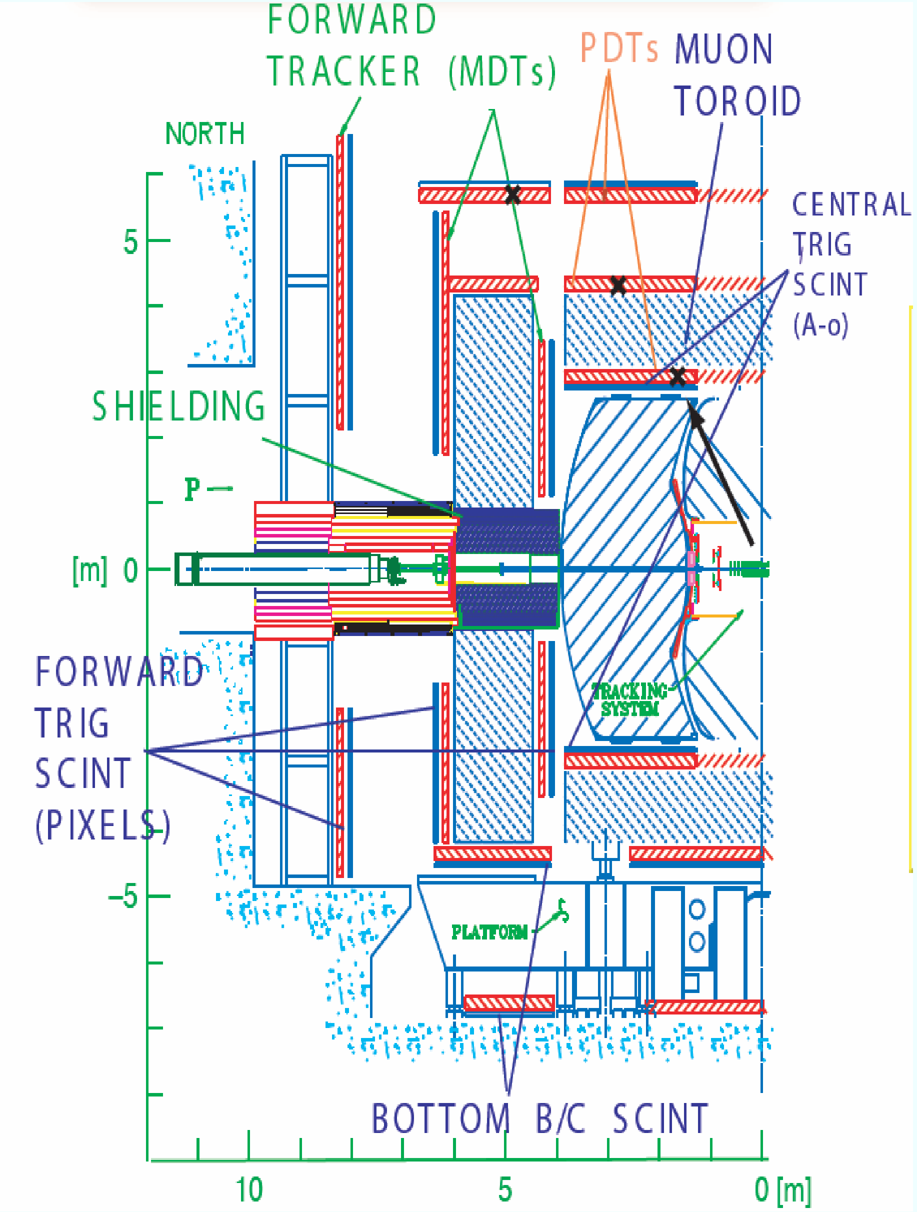
The DØ Detector



DØ muon Detector

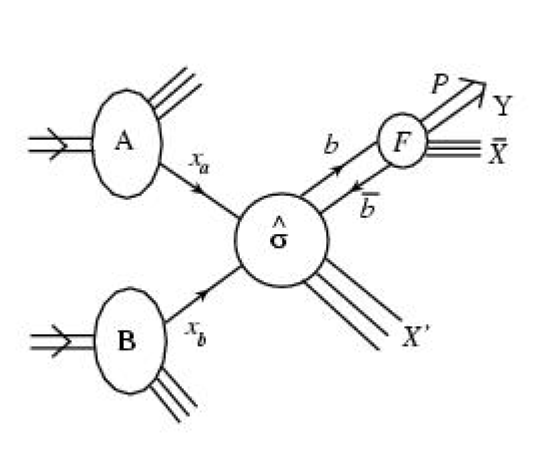
- 3 layers
  - Drift tubes and scintillation counters
  - One layer (A) inside of 1.8 T toroid
- Good coverage:
  - Central $|\eta| < 1$ PDT
  - Forward $1 < |\eta| < 2$ MDT
- Fast and efficient trigger





Upsilon production

- Quarkonium production is window on boundary region between perturbative and non-perturbative QCD
- Factorized QCD calculations to O(α^3) (currently employed by PYTHIA)
- color-singlet, color-evaporation, color-octet models
- Recent calculations by Berger et al. combining separate perturbative approaches for low and high-p_t regions
  - Predict shape of p_t distribution
  - Absolute cross section not predicted



- Υ(1S) production at the Tevatron:
  - 50% produced promptly
  - 50% from decay of higher mass states (e.g. $\chi_b \rightarrow \Upsilon(1S)\gamma$)

Analysis Overview

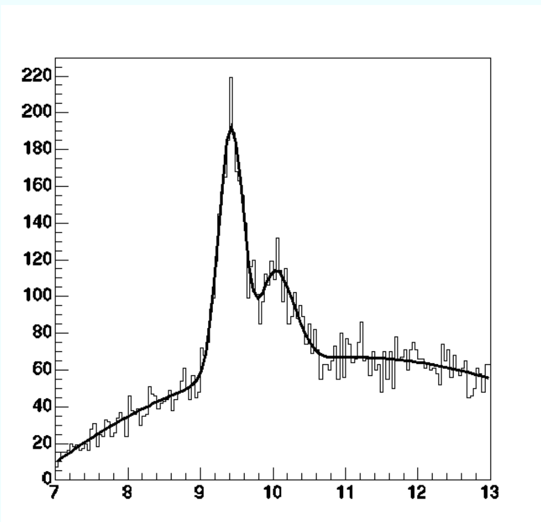
- Sample selection
  - 159 ± 10 pb^{-1} taken with dimuon trigger
  - Opposite sign muons with hits in all three layers of the muon system, matched to a track in the central tracking system (with hit in SMT)
    - p_t (μ) > 3 GeV and |η (μ)| < 2.2
  - At least one isolated μ
  - ~ 46k ϒ(1S) events
- Analysis
  - ($\mu^+\mu^-$) mass resolution functions obtained from J/ψ and MC studies
  - Fit ($\mu^+\mu^-$) mass spectra for different y and p_t bins, assuming 3 ϒ states and background
  - Get efficiencies and uncertainties

Fitting the Signal

- Signal: 3 states (ϒ(1S), ϒ(2S), ϒ(3S)), described by Gaussians with masses m_i, widths (resolution) σ_i, weights c_i ,(i=1,2,3)
  - Masses $m_i = m_1 + \Delta m_{i1}$(PDG), widths $\sigma_i = \sigma_1 \bullet (m_i/m_1)$, for i=2,3
  - free parameters in signal fit: m_1, σ_1, c_1, c_2, c_3
- Background: 3rd order polynomial

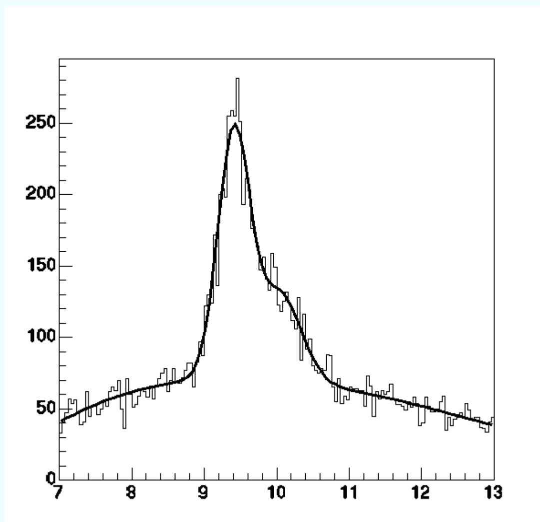
PDG: m(ϒ(1S)) = 9.46 GeV

m(ϒ) = 9.423 ± 0.008 GeV



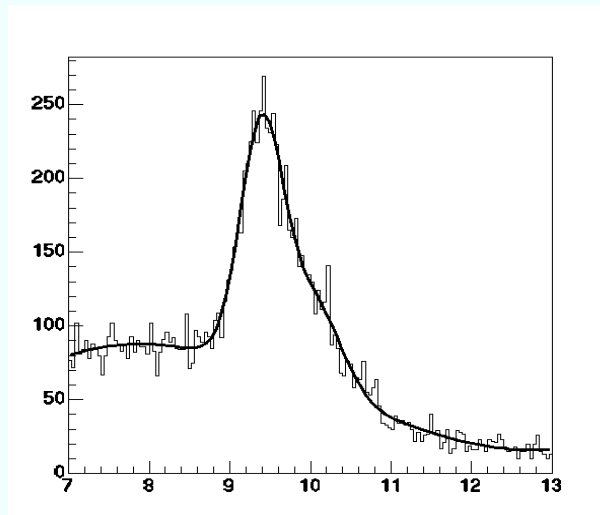
$0 < |y^{\Upsilon}| < 0.6$

m(ϒ) = 9.415± 0.009 GeV



$0.6 < |y^{\Upsilon}| < 1.2$

m(ϒ) = 9.403 ± 0.013 GeV



$1.2 < |y^{\Upsilon}| < 1.8$

All plots: 3 GeV < p_t(ϒ) < 4 GeV

Efficiencies, correction factors…

- Cross section

$$\frac{d^2\sigma(\Upsilon(1S))}{dp_t \times dy} = \frac{N(\Upsilon)}{L \times \Delta p_t \times \Delta y \times \varepsilon_{acc} \times \varepsilon_{trig} \times k_{dimu} \times k_{trk} \times k_{qual}}$$

L luminosity
y rapidity
ε_{acc} accept.•rec.eff.
ε_{trig} trigger

k_{dimu} local muon reconstruction
k_{trk} tracking
k_{qual} track quality cuts

	$0.0 < y < 0.6$	$0.6 < y < 1.2$	$1.2 < y < 1.8$
ε_{acc}	0.15 - 0.26	0.19 – 0.28	0.20 - 0.27
ε_{trig}	0.70	0.73	0.82
k_{dimu}	0.85	0.88	0.95
k_{trk}	0.99	0.99	0.95
k_{qual}	0.85	0.85	0.93

Results: $d\sigma(\Upsilon(1S))/dy \times B(\Upsilon(1S) \rightarrow \mu^+\mu^-)$

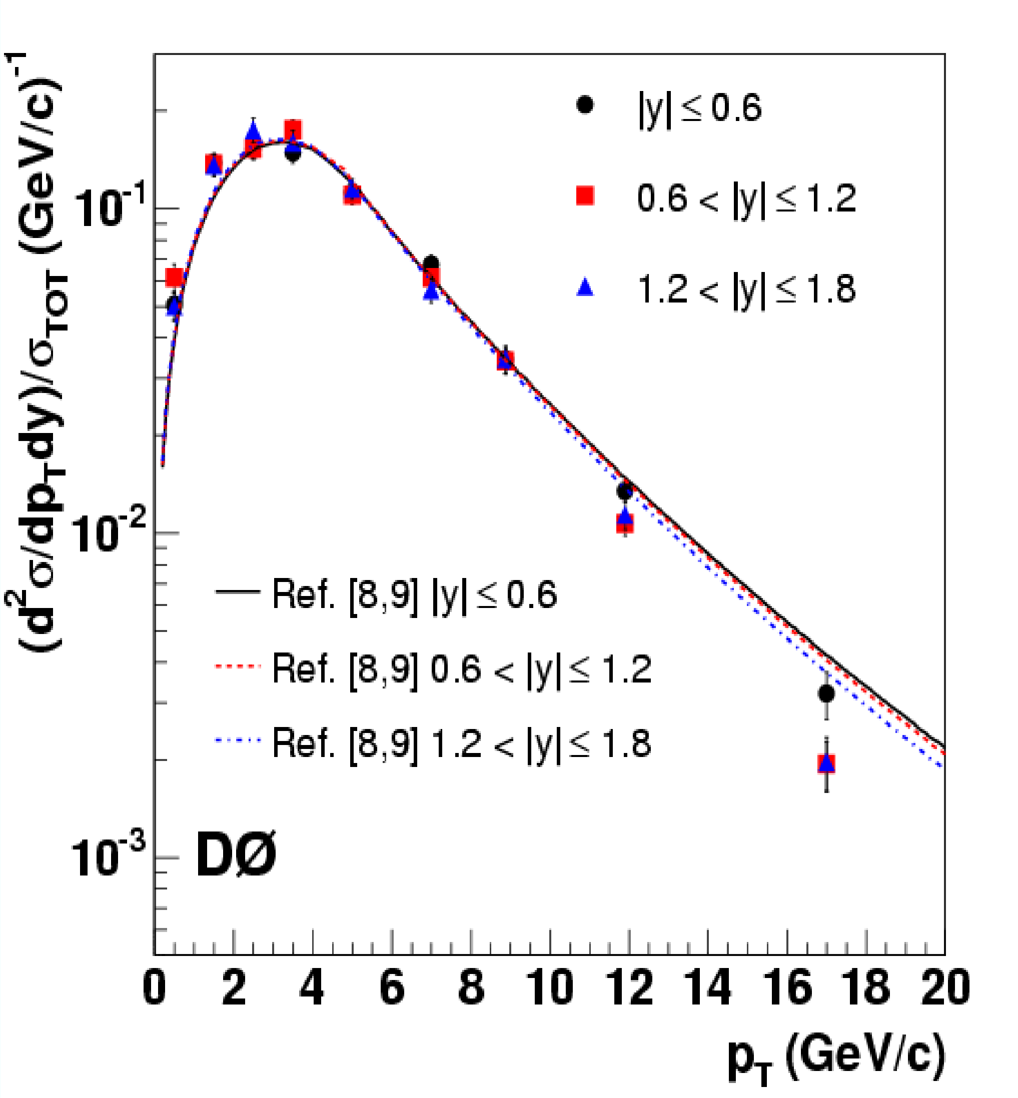
$0.0 < y_\Upsilon < 0.6$	732 ± 19 (stat) ± 73 (syst) ± 48 (lum) pb
$0.6 < y_\Upsilon < 1.2$	762 ± 20 (stat) ± 76 (syst) ± 50 (lum) pb
$1.2 < y_\Upsilon < 1.8$	600 ± 19 (stat) ± 56 (syst) ± 39 (lum) pb
$0.0 < y_\Upsilon < 1.8$	695 ± 14 (stat) ± 68 (syst) ± 45 (lum) pb

CDF Run I:

$0.0 < y_\Upsilon < 0.4$ 680 ± 15 (stat) ± 18 (syst) ± 26 (lum) pb

for central y bin, expect factor ~ 1.11 increase in cross section from 1.8 TeV to 1.96 TeV (PYTHIA)

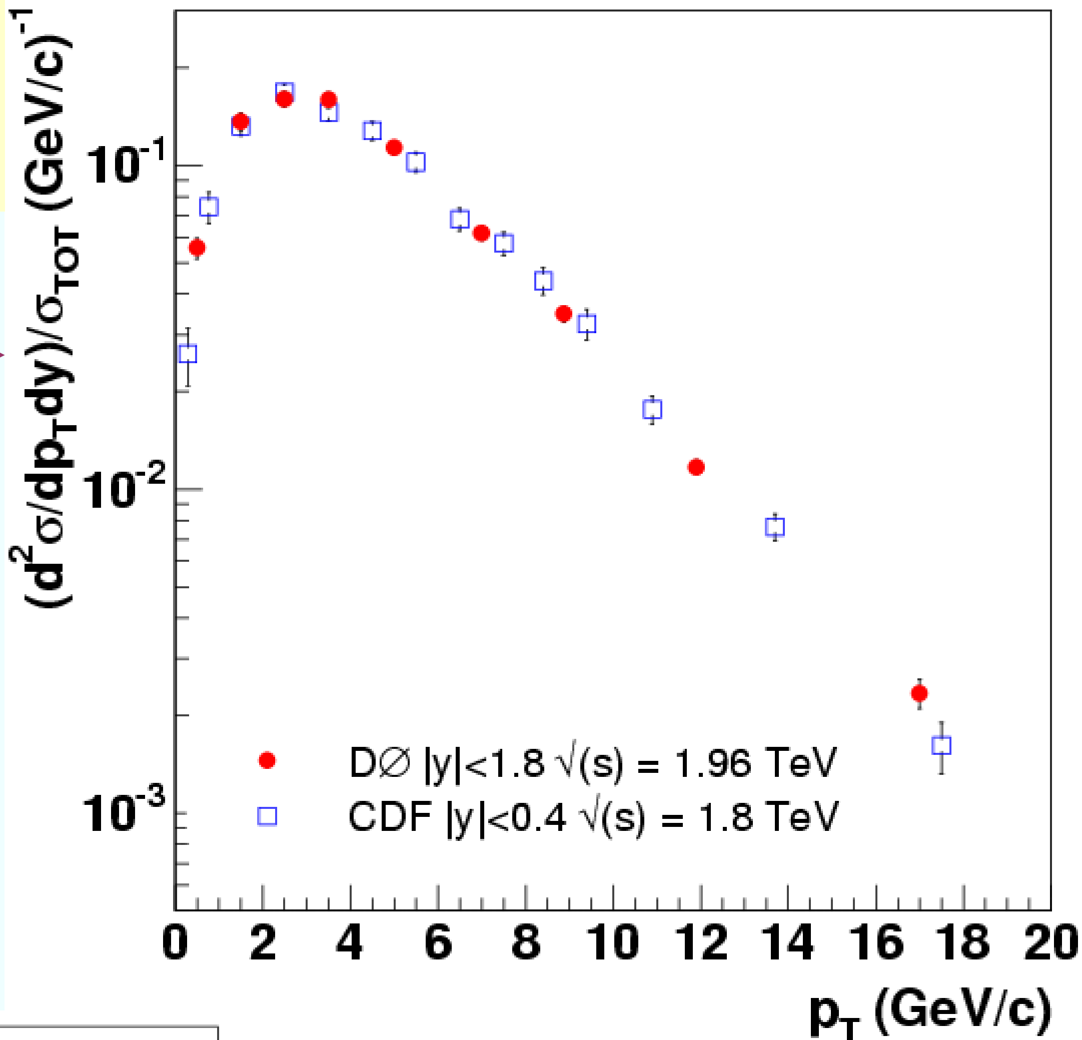
Normalized Differential Cross Section



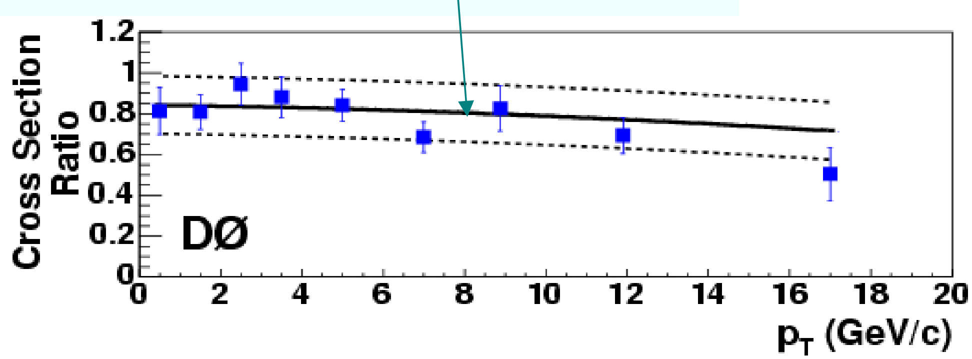
- shape of the p_t distribution does not vary much with ϒ rapidity
- Reasonable agreement with calculation of Berger, Qiu, Wang

Comparison with previous results

only statistical uncertainties shown



PYTHIA



$\sigma(1.2 < y^\Upsilon < 1.8)/\sigma(0.0 < y^\Upsilon < 0.6)$

band = uncertainties of relative normalization

μ-tagged jet cross section

- Data sample:
  - 294 ± 18 pb^{-1}
  - Standard jet triggers
  - Standard (y,φ) ($R = 0.5$) cone jets in $|y_{jet}| < 0.5$
    - Standard jet quality cuts, standard jet energy scale correction
  - Jet tagged with medium quality muon: $\Delta R(\mu, jet) < 0.5$
  - Additional quality cuts to reduce fake muons from punch-through
  - 4660 μ-tagged jets
- Analysis:
  - Establish jet energy scale correction for μ-tagged jets
  - Determine resolution for μ-tagged jets
  - "Unsmear" resolution
  - Determine efficiencies
  - Extract heavy flavor component

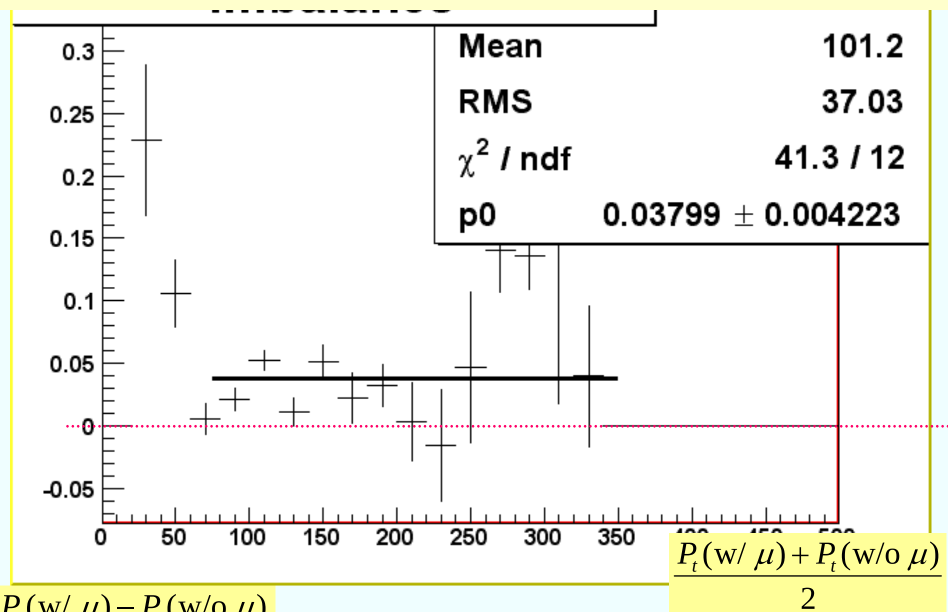
Efficiencies….

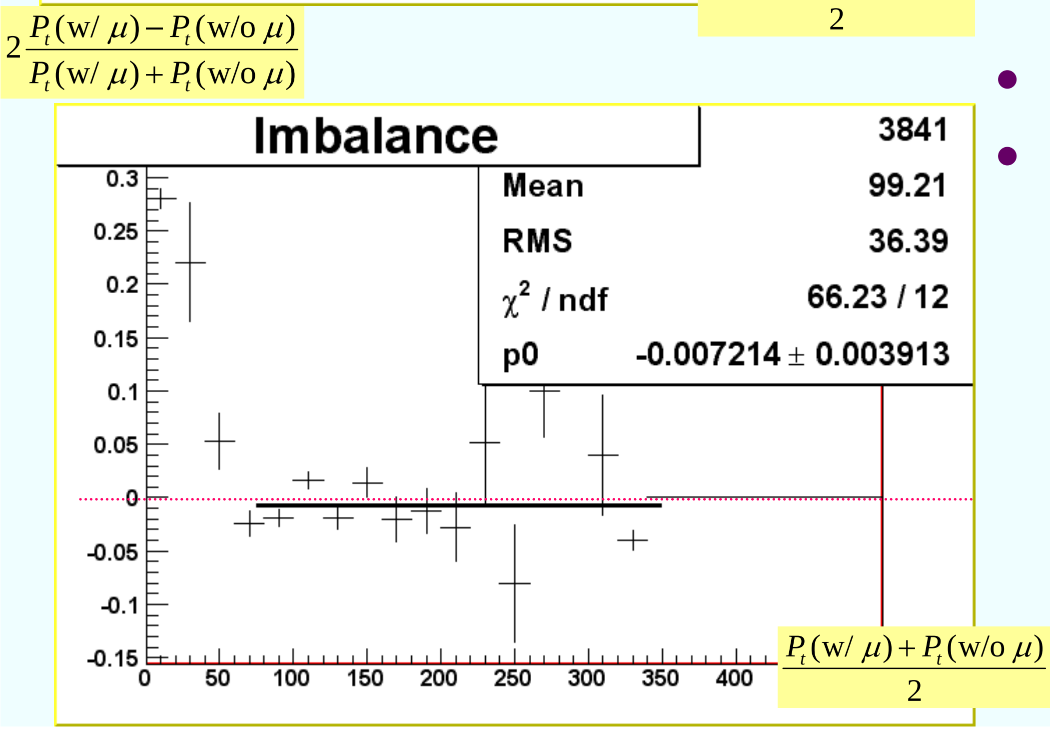
$$N = \varepsilon_T \varepsilon_{PV} \varepsilon_j \varepsilon_\mu (f_{HF\to\mu} \sigma_{HF} + f_{bg\to\mu} \sigma_{bg}) L \Delta p_t$$

efficiency	detail	value
ε_T	Trigger Eff	1.000
ε_{PV}	Primary Vertex: |z| < 50cm, ≥ 5tracks	0.84 ± 0.005
ε_μ	μ Eff (geom, μ det., tracking, match)	0.37 ± 0.05
ε_j	Jet Eff (jet quality cuts)	0.99 ± 0.01
$f_{bg\to\mu}$	Frac background $\to \mu$ (P_t > 4 GeV)	p_t dependent
$f_{HF\to\mu}$	Frac heavy flavor $\to \mu$ (P_t > 4 GeV)	p_t dependent

Overall efficiency = 0.31 ± 0.05

Jet energy scale for μ-tagged jets

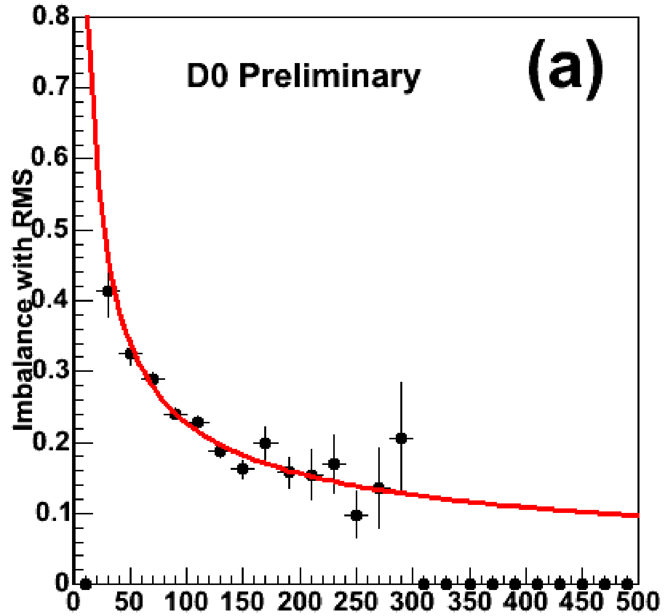




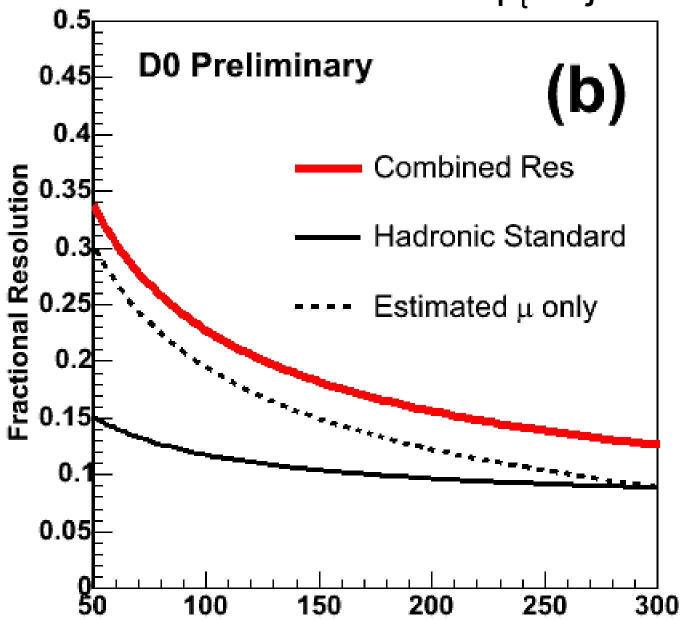
- P_t imbalance in events with 2 jets (one with, one without μ)

$$2\frac{P_t(\text{w.}\mu)-P_t(\text{no }\mu)}{P_t(\text{w.}\mu)+P_t(\text{no }\mu)}$$

- find 3.8% offset,
  not strongly p_t dependent
  for p_t in (75, 250 GeV)
- Scale energies of μ-tagged jets
- Order-randomized imbalance used to get resolution



p_t of jet



p_t of jet

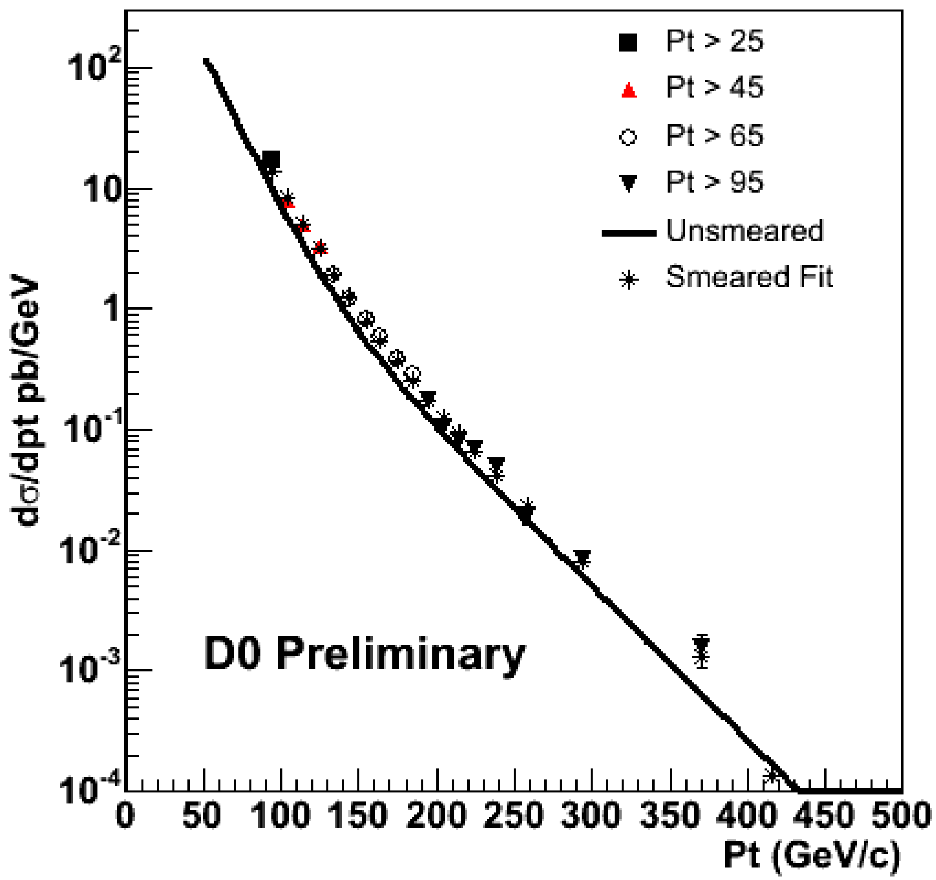
Resolution

- Neutrinos in μ-tagged jet ⇒ resolution worse than for jets without μ
- Take rms of order-randomized imbalance
- Parameterize, Fit (fig. (a))
- Subtract (in quadrature) resolution for jets without μ ⇒ obtain resolution for μ-tagged jets (fig. (b))
- Fit:

$$\left(\frac{\sigma}{P_t}\right)^2 = \left(\frac{N}{P_t}\right)^2 + \left(\frac{S}{\sqrt{P_t}}\right)^2 + C^2$$

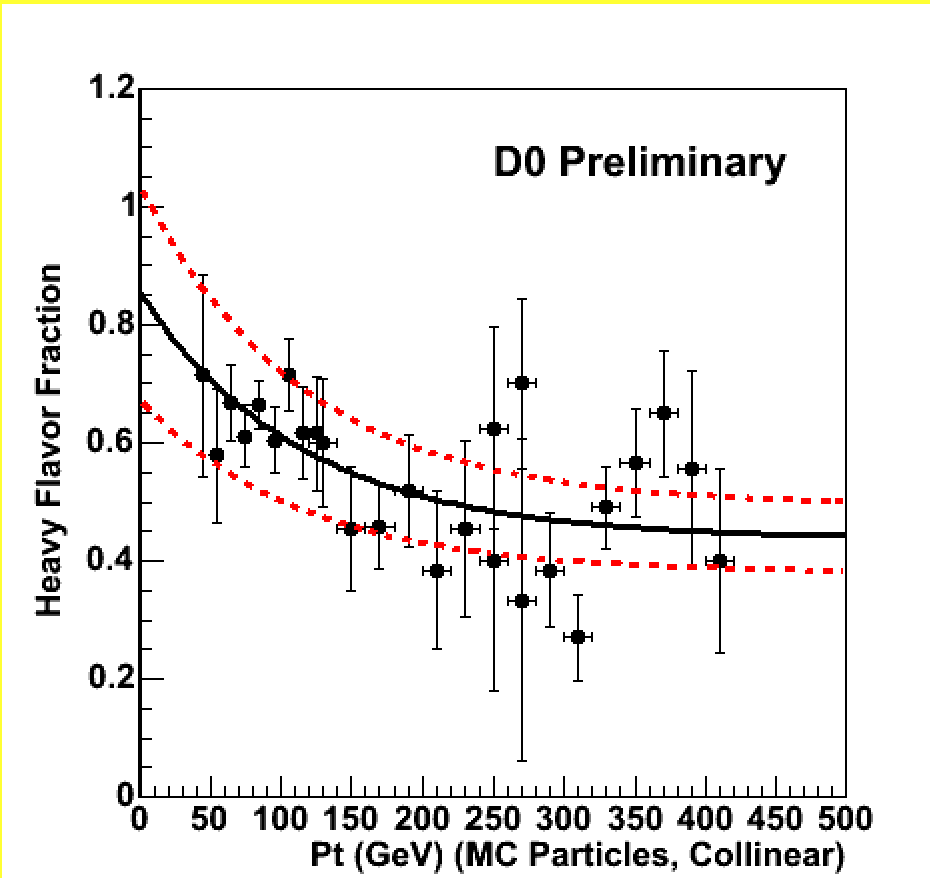
  - N = 7.7 ± 4.1
  - S = 1.9 ± 0.1
  - C = 0.0 ± 0.1
- Resolution parameterization used in "unsmearing"

Unsmearing correction



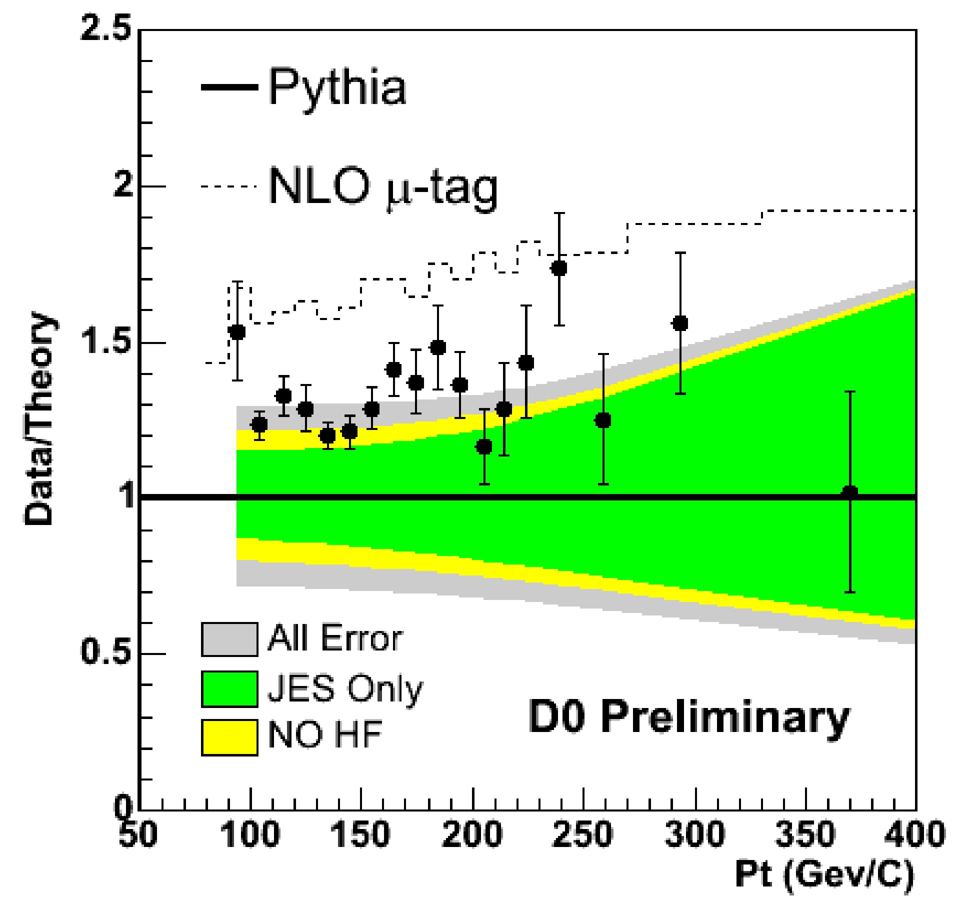
- Fit data to convolution of "ansatz function" with resolution
- Obtain unsmearing correction factors for p_t bins (ratio of unsmeared to smeared ansatz)
  - 0.65 to 0.77, smooth variation with p_t
- Used two different ansatz functions
  - estimate of systematic error: <5% for p_t > 100 GeV

HF fraction of μ-tagged jet sample



- Sample of jets with μ-tagged jets contains jets with μ from non-HF sources (e.g. π, K decays…)
- Use PYTHIA with standard DØ detector simulation to find HF fraction of jets tagged with muons vs (true) p_t
- Fit with $O + N\, e^{-Pt/k}$
  - O = 0.44 ± 0.06
  - N = 0.42 ± 0.12
  - k = 114 ± 68

Data vs theory



- Use PYTHIA (with standard DØ MC) to find μ-tag fraction of jets and HF fraction of jets tagged with muons .
- NLO: NLOJET++ (with CTEQ6M) multiplied by PYTHIA μ-tagged HF fraction
- Uncertainties:
  - Multiplicative factors
  - "JES": jet energy scale
  - "NO HF": HF fraction uncertainty set to 0

Summary

- ϒ(1S) cross-section
  - Presented measurement of ϒ(1S) cross section • BR(→μμ) for 3 different rapidity bins out to y(ϒ) = 1.8, as a function of p_t(ϒ)
  - First measurement of ϒ(1S) cross section at $\sqrt{s}$ = 1.96 TeV.
  - Cross section values and shapes of $d\sigma/dp_t$ show only weak dependence on rapidity.
  - $d\sigma/dp_t$ is in good agreement with published results (CDF at 1.8 TeV)
  - Normalized $d\sigma/dp_t$ in good agreement with recent QCD calculations (Berger at al.)

- μ-tagged jet cross section:
  - Measured $d\sigma/dp_t$ in central rapidity region $|y|<0.5$ for μ-tagged jets originating from heavy flavor (estimating HF contribution by MC)
  - Resulting HF-jet cross section values lie between PYTHIA and simple NLO calculation
  - Future:
    - Reduce systematic uncertainties
    - Find data driven method of estimating HF fraction (p_t^{rel} ,imp. par...?)
    - Try other jet-tagging methods (sec. vertex, impact par., ..)