Studies of $W \to \tau\nu$ production at the FNAL Tevatron

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- $W \to \tau\nu$ at DØ
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Introduction

Two compelling reasons to study $W \to \tau\nu$ events at the Tevatron:

- Provide a relatively clean sample of events with τ-leptons and thus an opportunity to study the detector response to τ's. Detection of τ's at the Tevatron is considerably more difficult than of e's or μ's. Main characteristics are narrow jets with low track multiplicity.
  Final states with τ's can be of great importance in Higgs and SUSY searches.

- The ratio of $W \to \tau\nu$ to $W \to e\nu$ production cross sections tests lepton universality, a fundamental concept in the Standard Model.

$W \rightarrow \tau\nu$ at CDF

Starting samples selected by two triggers in run 0 and one trigger in run 1a:

$\not{E}_T$ Trigger (run 0)

- $\not{E}_T$ >25 GeV
- electromagnetic E_T >8 GeV in most energetic calorimeter cluster (c.c.)

τ Trigger (run 0, 1a)

- $\not{E}_T$ >20 GeV
- τ trigger cluster $|\eta| < 1.1$
  - Charged track $P_T > 4.8$ GeV/c
  - track matched to c.c. with $E_T > 10$ GeV
  - c.c. with had/em>0.125 and
  - number of calorimeter towers ≤2
    towers have $\Delta\phi$ =15° and $\Delta\eta = 0.2$.

$W \to \tau\nu$ at CDF (cont'd)

Offline selections (run 0):

- seed track $P_T > 5$ GeV/c within 10° of c.c.
- additional tracks with $P_T > 1$ GeV/c included in cluster if within 30° of seed track.
- $\not{E}_T$ >25 GeV for $\not{E}_T$ trigger, $\not{E}_T$ >20 GeV for τ-trigger
- τ cluster $E_T(\tau) > 15$ GeV
- No clusters with E_T >10 GeV other than τ
- No clusters with E_T >5 GeV for $\Delta\phi > 150^\circ$ from τ
- From charged tracks $P_T(\tau) > (15 + (\#\ tracks) \times 2.5)$ GeV/c
- Remove events satisfying electron or muon selection cuts.

$W \to \tau\nu$ at CDF (cont'd)

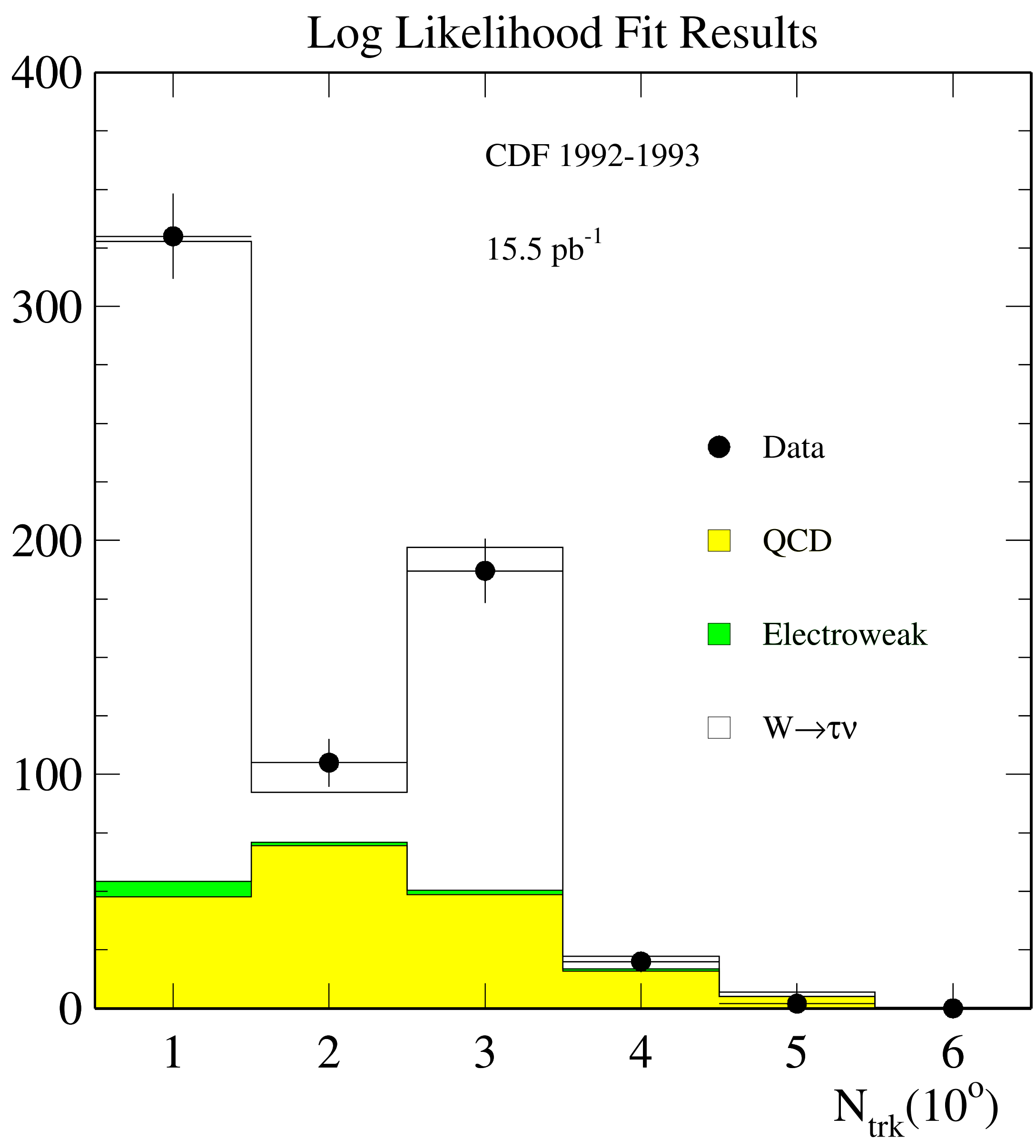
Offline selections (run 1a)
same as run 0 but adding:

- $E_T(\tau) > 20$ GeV
- $\not{E}_T > 25$ GeV, significance > 2.4
- $|Z - vertex| < 60$ cm
- track isolation, no track with $P_T > 1$ GeV in annulus 10° - 30°

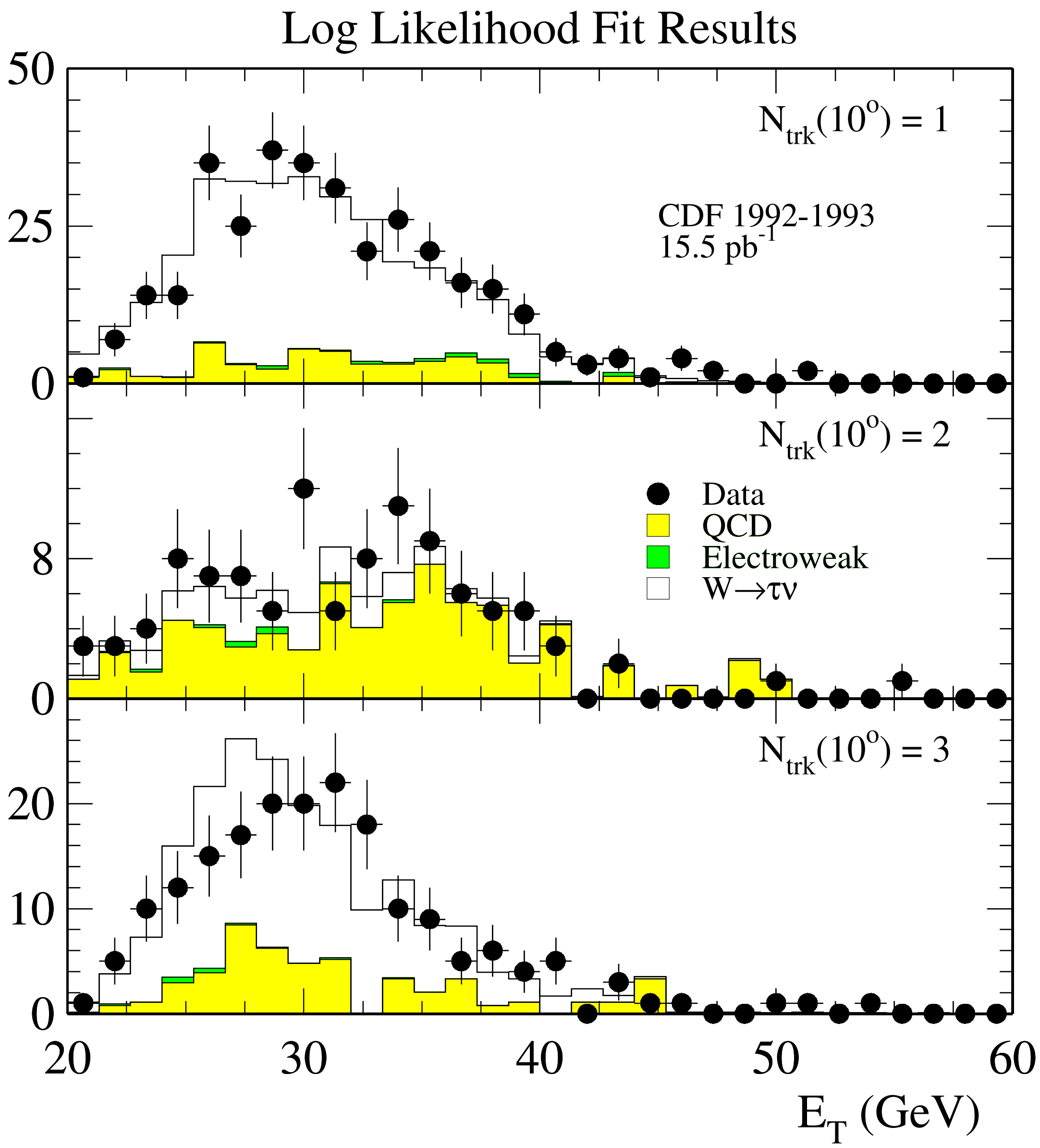
run 0: $\int \mathcal{L} dt$=4.05 pb^{-1}, τ-candidates=284 (166)
after bkg. sub 105

run 1a: $\int \mathcal{L} dt$=15.5 pb^{-1}, τ-candidates= 625 (525)
after bkg. sub ≈400

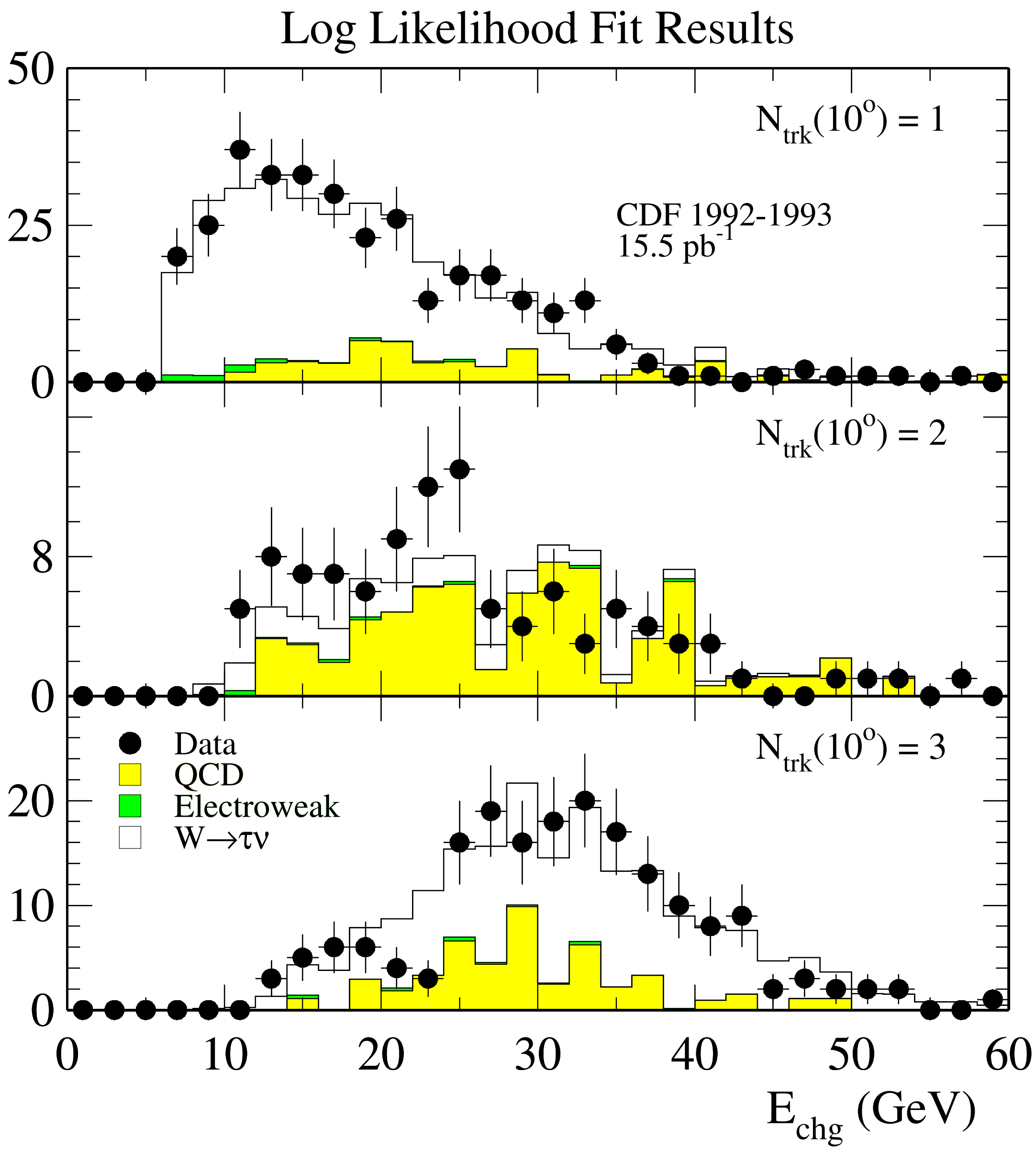
CDF τ candidates



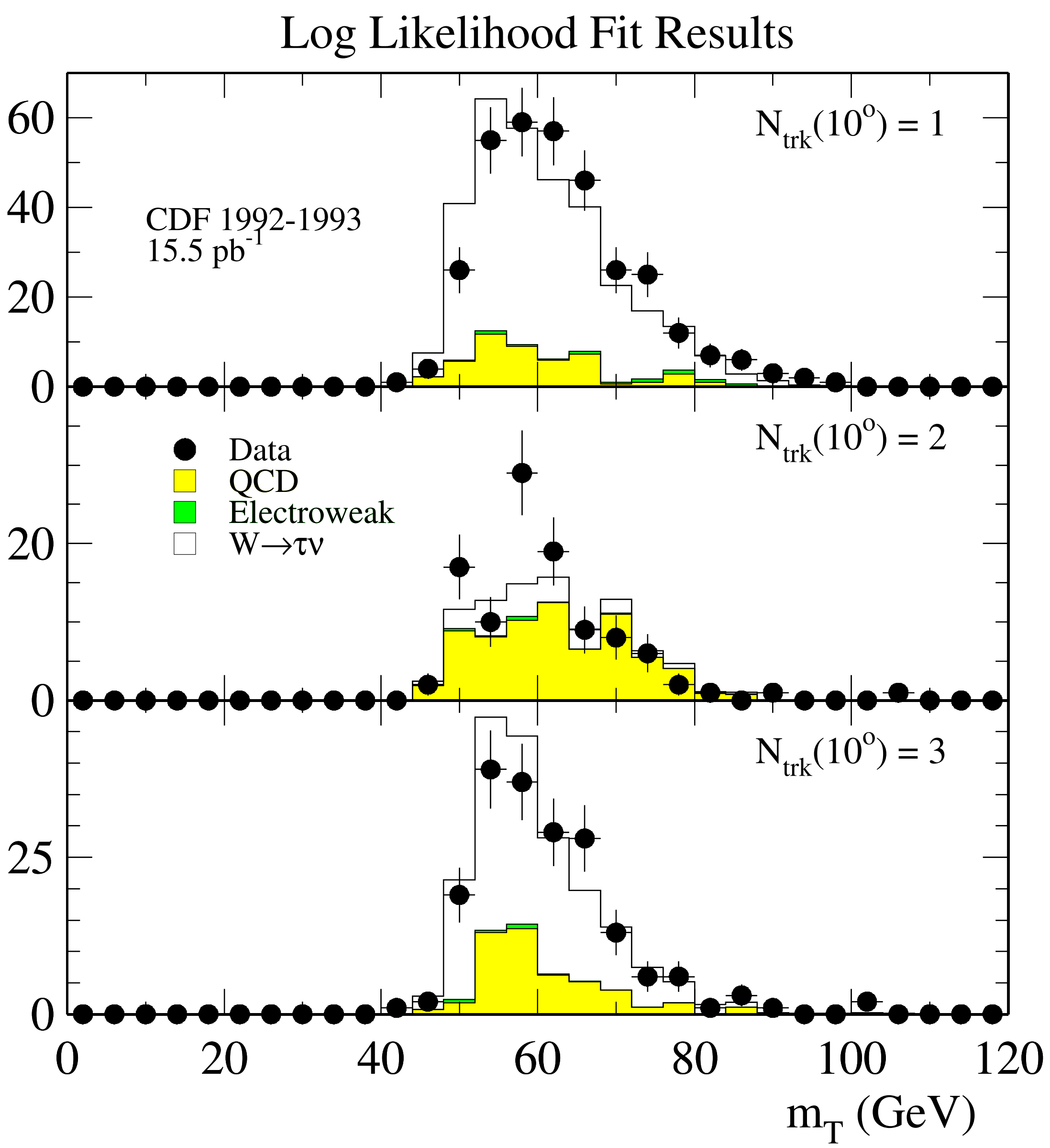
CDF τ candidates



CDF τ candidates



CDF τ candidates



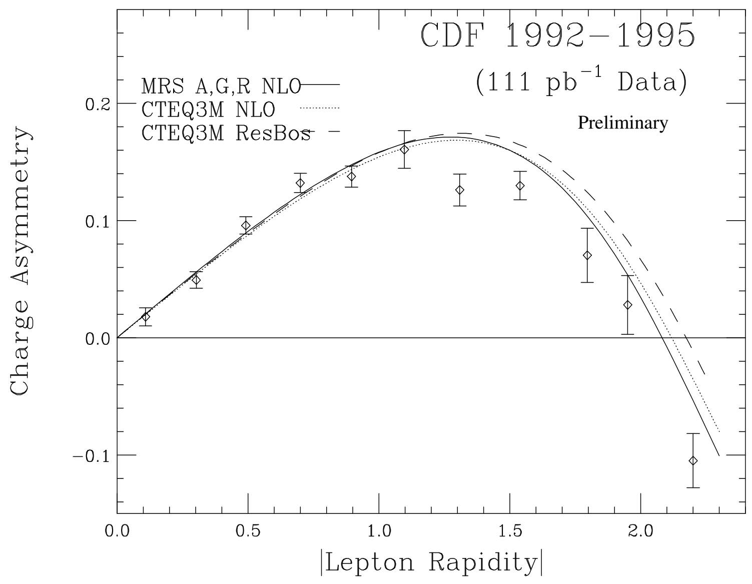
CDF $W \to \tau\nu$ Analysis Summary

PRL 68, 3398 (1992)

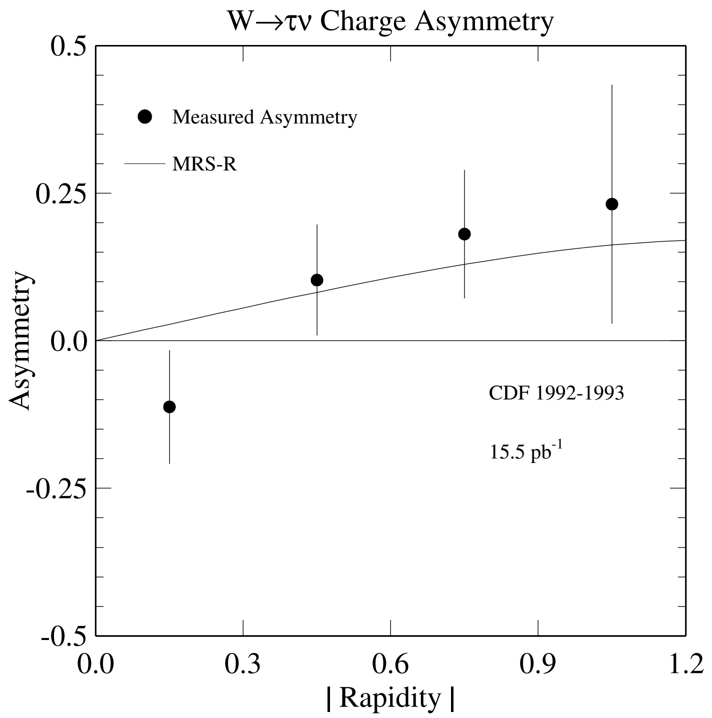
	$\not\!\!E_T$ Sample	τ Sample
Number of Events		
$W \to \tau\nu$ Data Sample	207	77
QCD Background	$63 \pm 3 \pm 8$	$26 \pm 2 \pm 4$
$Z \to \tau\tau$ Background	7 ± 2	4 ± 1
$W \to e\nu$ Background	5 ± 1	
$A \cdot \epsilon(W \to \tau\nu)$		
$A(W \to \tau\nu)$	0.396	
Br($\tau \to$ hadrons $+\nu$)	(64.5 ± 2)	
$\epsilon(W \to \tau\nu)$	0.0636	.0679
$A \cdot \epsilon(W \to \tau\nu)$	0.0161	.0172
Systematic Error on $A \cdot \epsilon$		
M. C. Statistics	± 0.0005	± 0.0005
N_{tower}, $\mathrm{P}_T(\tau)$ cuts		$\pm .0008$
B.R.(correlated)	± 0.0007	± 0.0004
E- Scale(correlated)	± 0.0006	± 0.0012
$\int \mathcal{L} dt$		
Int. Luminosity	(4.015 ± 1.315) pb^{-1}	
$\sigma \cdot Br$		
$\sigma \cdot Br(W \to \tau\nu)$	$2.04 \pm 0.22 \pm 0.18$nb	$2.08 \pm 0.40 \pm 0.26$nb
$\sigma \cdot Br(W \to \tau\nu)$(comb.)	2.04 ± 0.27nb	
$\sigma \cdot Br(W \to e\nu)$	$2.36 \pm 0.02 \pm 0.07$nb	

$$\boxed{g_\tau^W / g_e^W = 0.97 \pm 0.07}$$

CDF W Charge Asymmetry



run 1a+1b



run 1a

$W \to \tau\nu$ at DØ

τ trigger (run 1b):

- Single interaction event (determined by TOF detector). Reduces the effective luminosity to 16.8 pb^{-1}.
- $\not\!\!E_T$ >15 GeV
- $0.05 < EMF < 0.95$ (EMF = electromagnetic energy fraction)
- leading narrow jet $E_T > 20$ GeV, $|\eta| < 0.9$
- No other jet with $E_T > 15$ GeV within 140° - 220° of leading jet ϕ or within 30° of $\not\!\!E_T$ direction.

τ-bkg trigger

- Single interaction event
- leading jet $E_T > 20$ GeV
- $0.05 < EMF < 0.95$

$W \rightarrow \tau\nu$ at DØ (cont'd)

Offline selection criteria:

- $\not{E}_T$ >25 GeV
- $|Z - vertex|$ <60 cm (*)
- no good electrons or muons (*)
- no jet with $E_T > 8$ GeV within 30° of $\not{E}_T$ direction
- no jet with $E_T > 8$ GeV with 140° - 220° of τ
- no jet with $E_T > 15$ GeV
- τ-jet $25 < E_T < 60$ GeV, $|\eta| < 0.9$ (*)
- τ-jet width $\mathcal{W}$ <0.25 (*)
- τ-jet profile $\mathcal{P}$ >0.55.

run 1b: $\int \mathcal{L}dt$=16.8 pb^{-1}, τ-candidates= 1202

after bkg. sub. 980

(*) = cuts to select QCD bkg. sample

DØ τ-jet variables

τ-jet width:

$$\mathcal{W} = \sqrt{\sum_{i=1}^{n} \frac{(\phi_i - \phi)^2 E_T^i}{E_T^{jet}} + \sum_{i=1}^{n} \frac{(\eta_i - \eta)^2 E_T^i}{E_T^{jet}}}$$

where $i = 1 \ldots n$ indicates the calorimeter η-ϕ tower number, the sum is over all towers in the jet, and E_T^{jet} is the total E_T of the jet.

τ-jet profile:

$$\mathcal{P} = \frac{E_{T1} + E_{T2}}{E_T^{jet}}$$

E_{T1} and E_{T2} are the E_T of the two leading towers within the jet.

DØ Data Based Monte Carlo

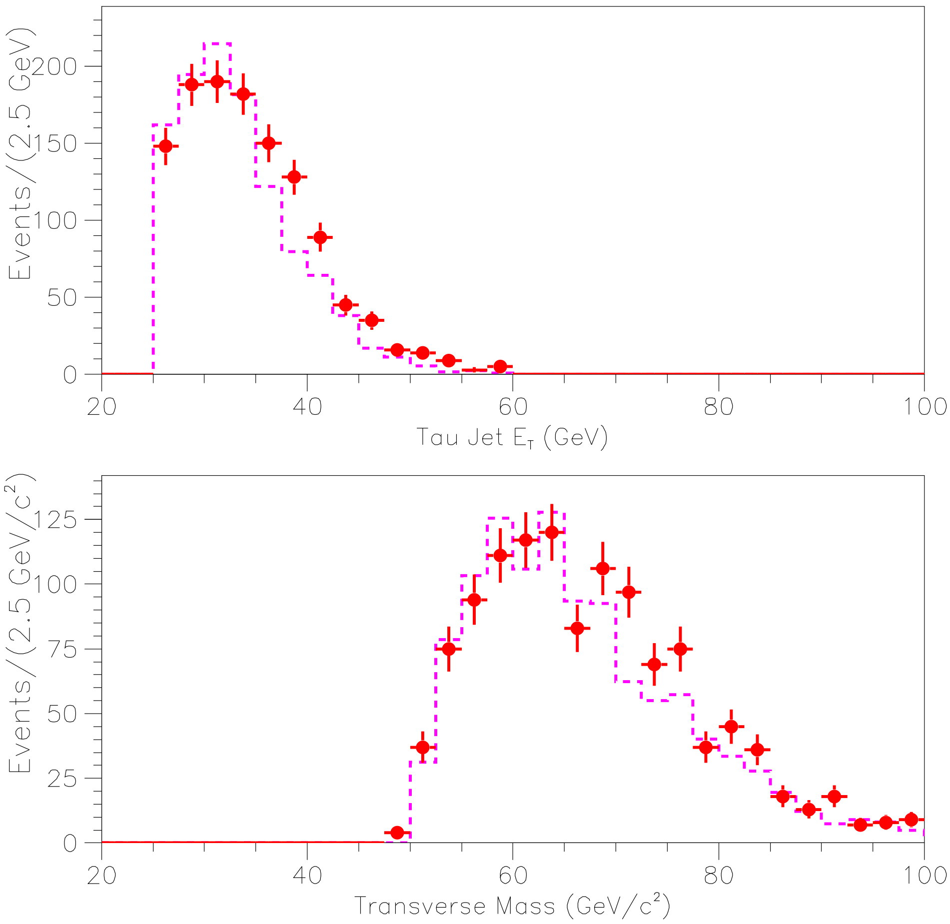
τ identification in DØ depends critically on calorimetric information. Understanding of selection efficiency requires careful modelling of underlying event and calorimeter noise.

Instead of a standard event generator for the signal use a data based Monte Carlo (DBMC):

- Select $W \to e\nu$ events in same fiducial volume used for $W \to \tau\nu$ events.
- Remove from the event all the data associated with the electron
- replace electron with a τ having same 4-momentum
- let τ decay hadronically and run decay products through DØ Geant
- merge τ data with the rest of event.

This procedure should reproduce the distribution of $W \to \tau\nu$ events. Statistics, however, limited by the number of $W \to e\nu$ events from single interactions (10,000).

DØ τ candidates

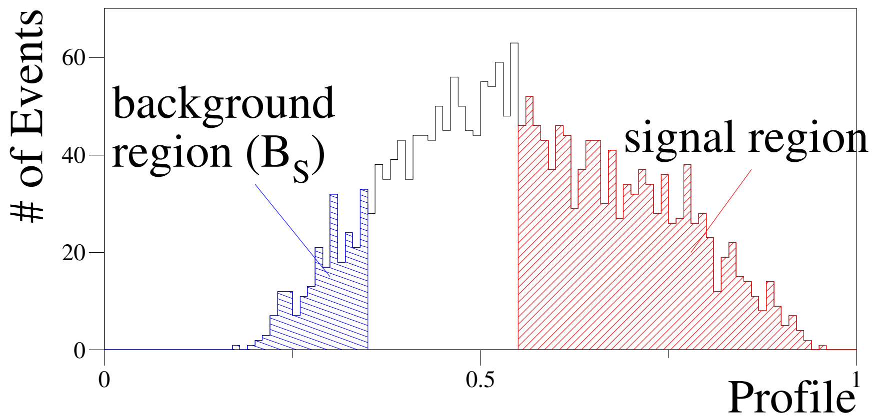


E_T and transverse mass distributions from τ-DBMC.

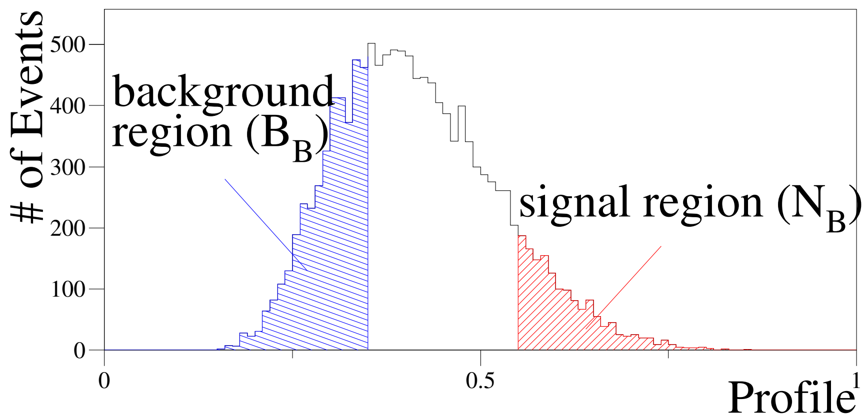
Points with error bars are data before background subtraction.

DØ τ candidates
$\mathcal{P}$ distributions

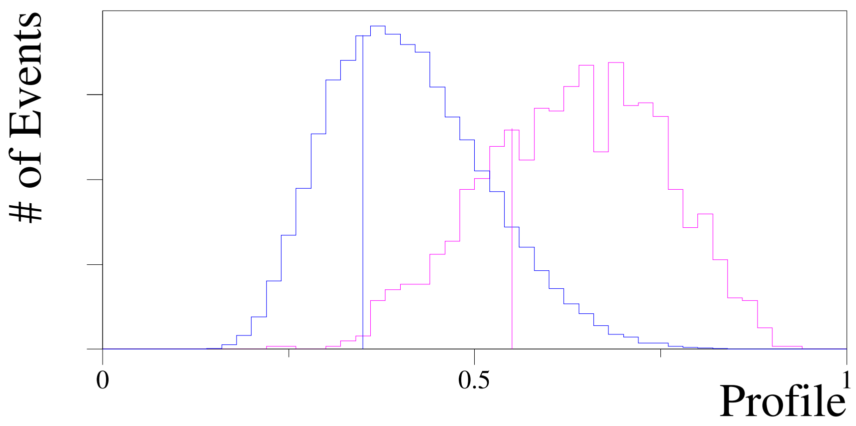
data



QCD



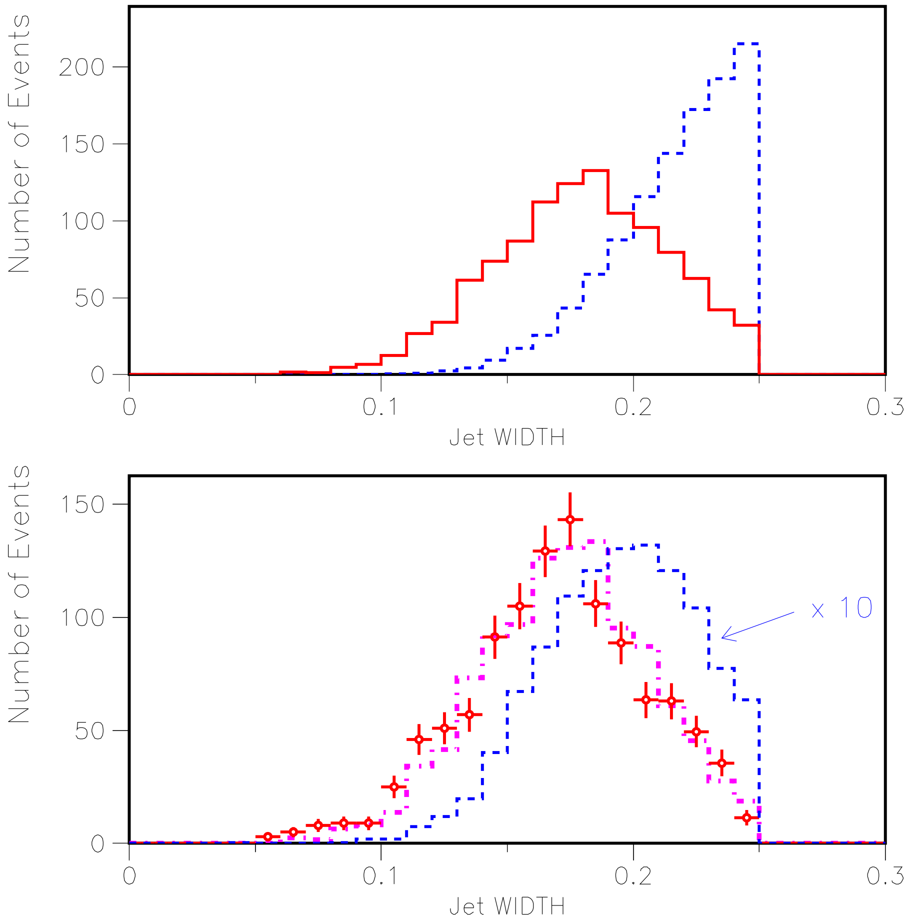
τ-DBMC



DØ τ candidates

- QCD

- DBMC



$\mathcal{W}$ distributions before and after $\mathcal{P} > 0.55$ cut

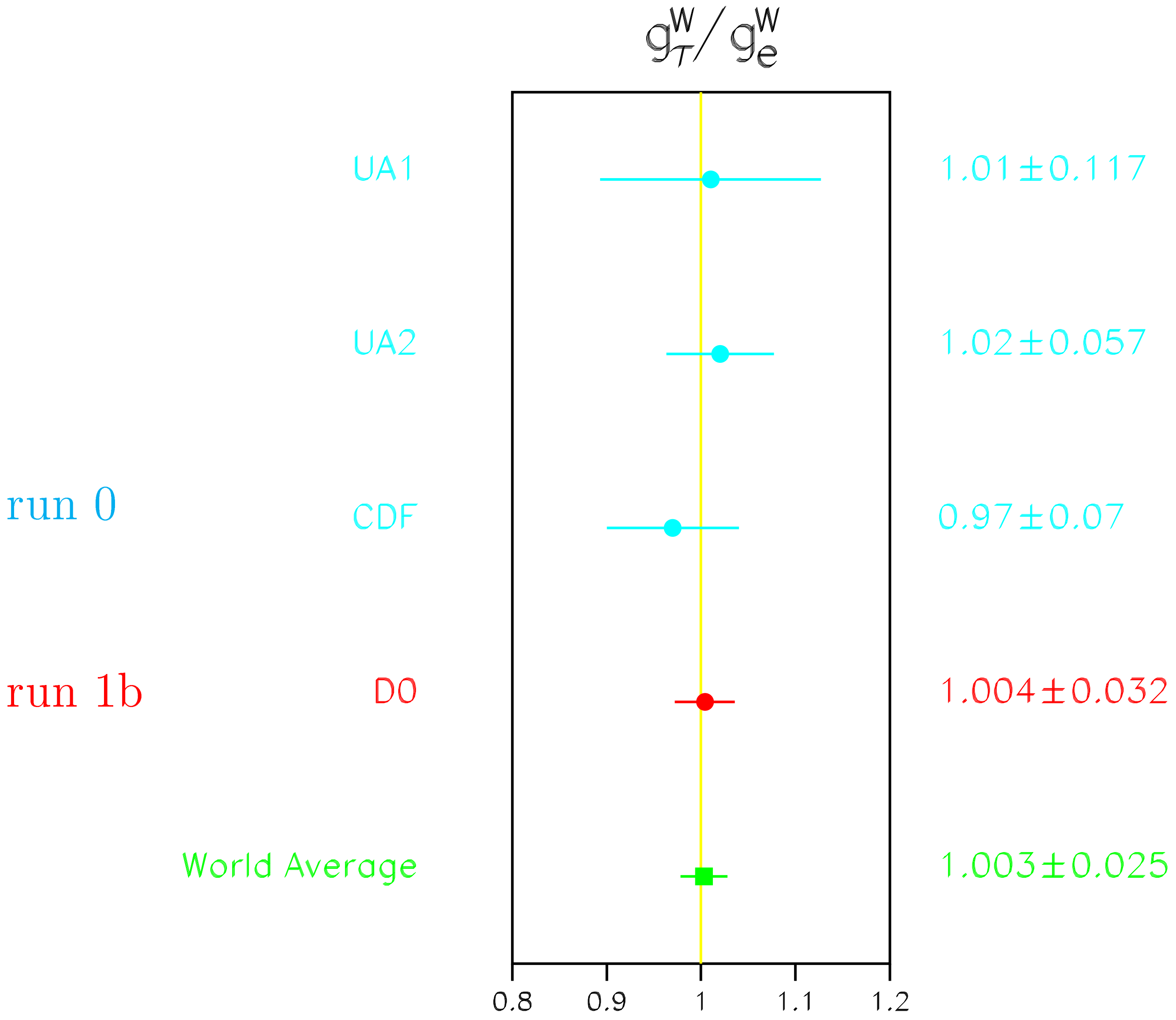
Points with error bars are τ-data after background subtraction.

DØ $W \to \tau\nu$ Analysis Summary

Number of Events	
$W \to \tau\nu$ Data Sample	1202
QCD Background	$106 \pm 7 \pm 5$
Noisy Events	81 ± 14
$Z \to \tau\tau$ Background	32 ± 5
$W \to e\nu$ Background	3 ± 1
$A \cdot \epsilon(W \to \tau\nu)$	
$\mathrm{Br}(\tau \to \text{hadrons} + \nu)$	(64.5 ± 2) %
$A(W \to \tau\nu)$	0.290
$\epsilon(W \to \tau\nu)$	0.127
Correction to $W \to e\nu$ fiducial cuts	1.03
$A \cdot \epsilon(W \to \tau\nu)$	0.0379
Systematic Error on $A \cdot \epsilon$	
Monte Carlo Statistics	± 0.0010
Branching ratios	± 0.0008
Energy Scale	± 0.0011
$\int \mathcal{L} dt$	
Integrated Luminosity	(16.84 ± 0.91) pb^{-1}
$\sigma \cdot Br$	
$\sigma \cdot Br(W \to \tau\nu)$	$2.38 \pm 0.09 \pm 0.10$nb
$\sigma \cdot Br(W \to e\nu)$	$2.36 \pm 0.02 \pm 0.07$nb

$$\boxed{g_\tau^W / g_e^W = 1.004 \pm 0.019 \pm 0.026}$$

Summary of g_τ^W/g_e^W measurements



Conclusions

CDF and DØ are able to separate τ's decaying hadronically from a very large background of QCD jets. Identified samples were used by DØ to get the world's most accurate measurement of g_τ^W/g_e^W.

CDF was able to observe W charge asymmetry in $W \to \tau\nu$ events.

Detector upgrades and higher luminosity for the next run (starting April 2000) give great prospects for detecting τ's as signatures of SUSY or Higgs production.