Top Pair Production Cross Section using τ+jets events

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for the DØ Collaboration.

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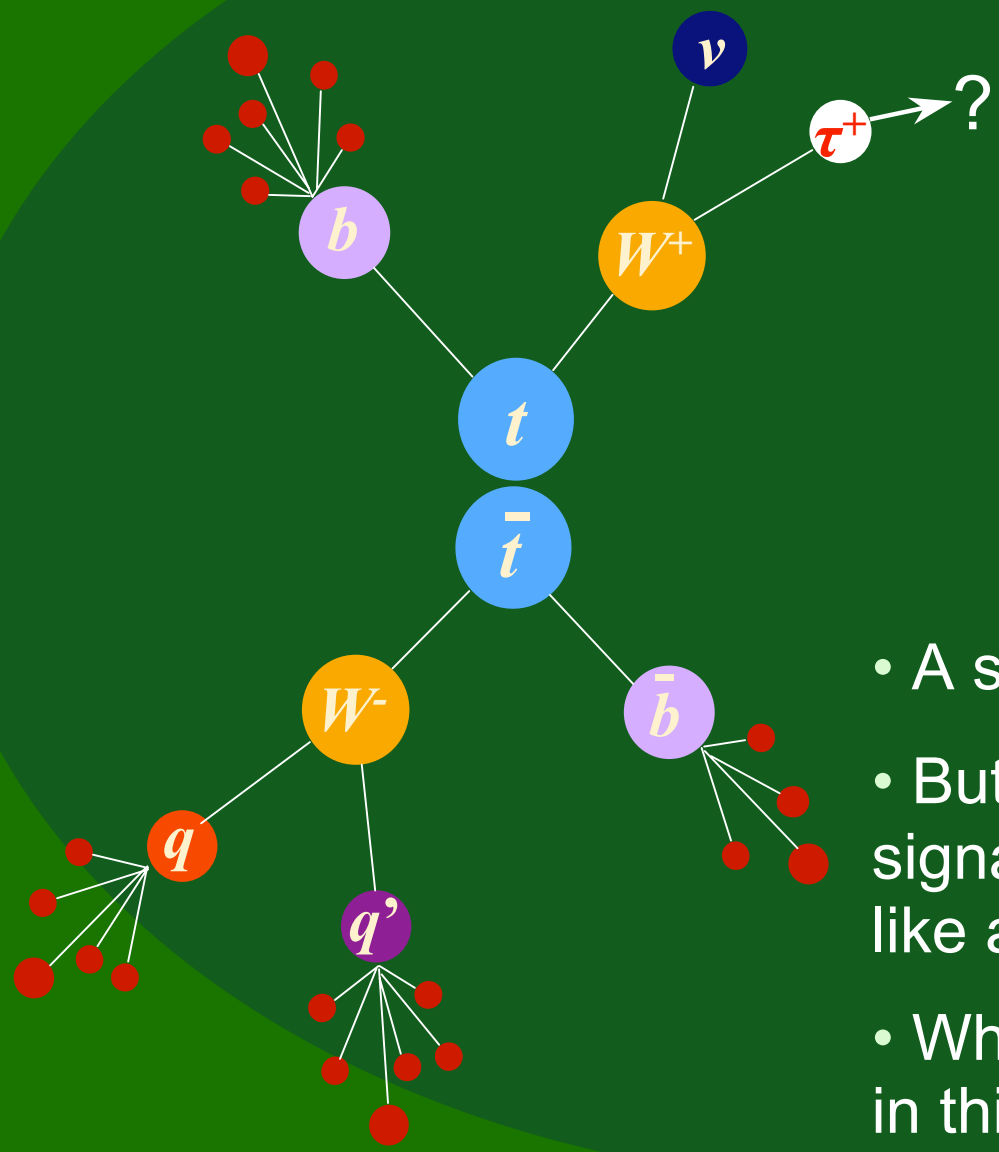
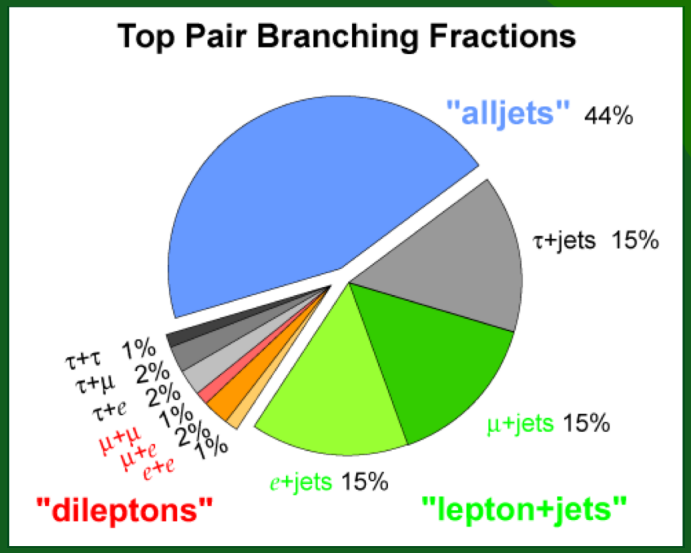
Introduction





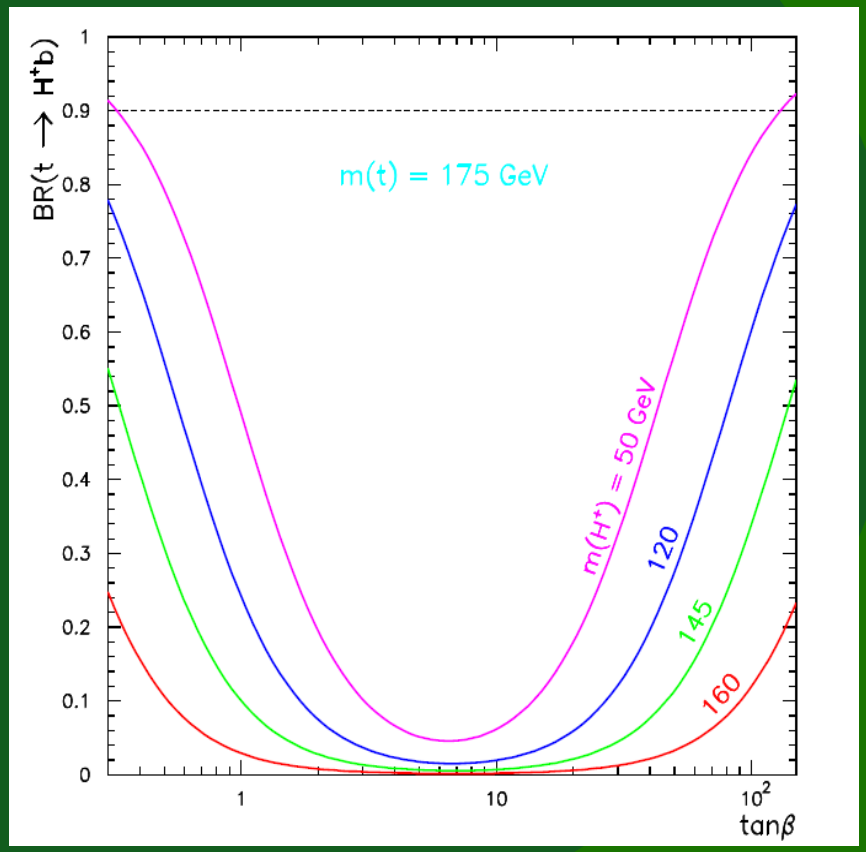
- A sizable branching fraction
- But the τ's experimental signature is faint: it's looks either like a μ or like a narrow jet.
- Why measure the cross section in this difficult channel?

Motivation

- A first measurement at DØ

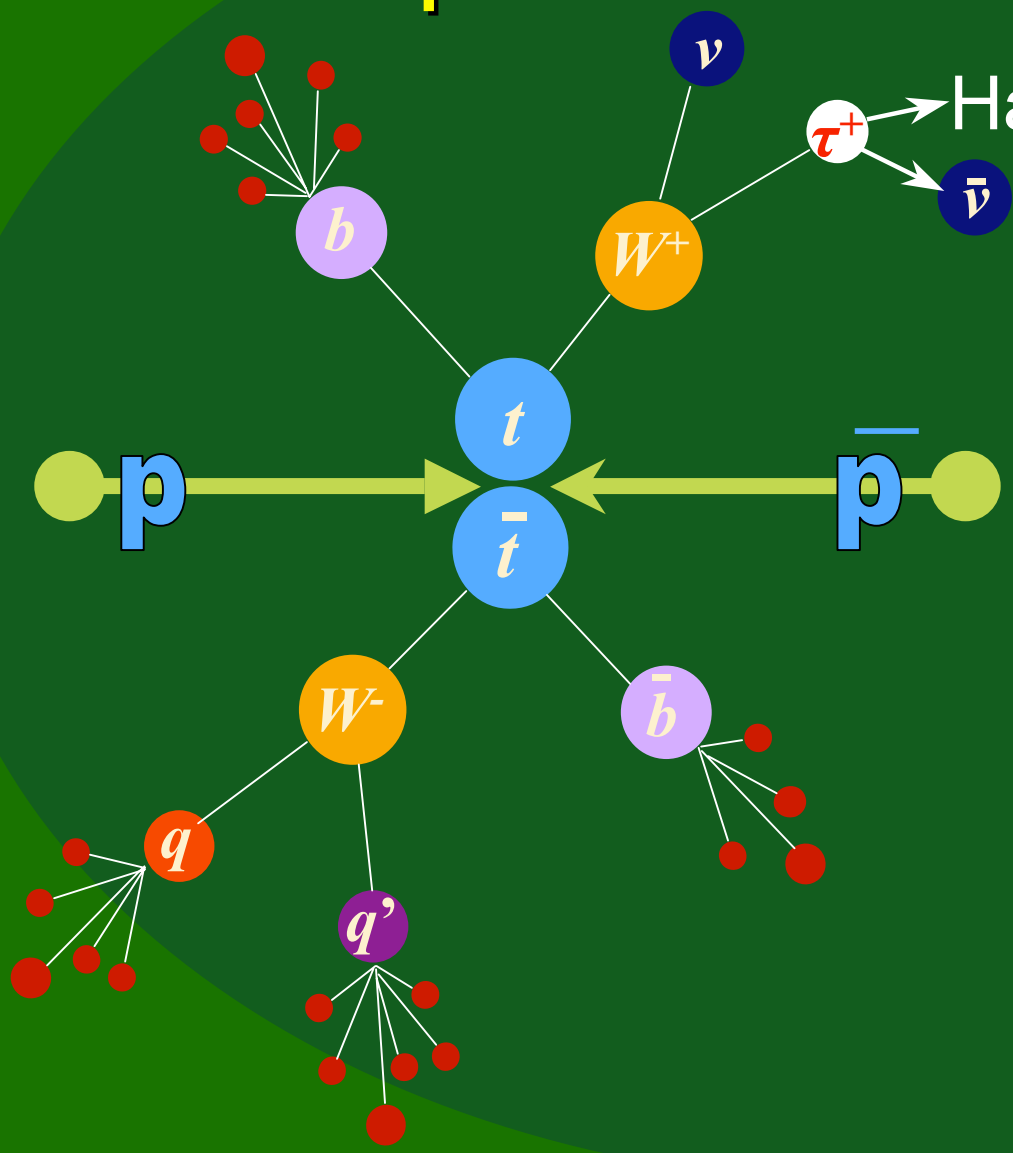
- As τs are the heaviest leptons, this channel is particularly sensitive to new physics involving the Higgs.

- The MSSM predicts a charged Higgs.
If its mass is low enough, $t \rightarrow H^+b$ will compete with the SM $t \rightarrow W^+b$ decays.



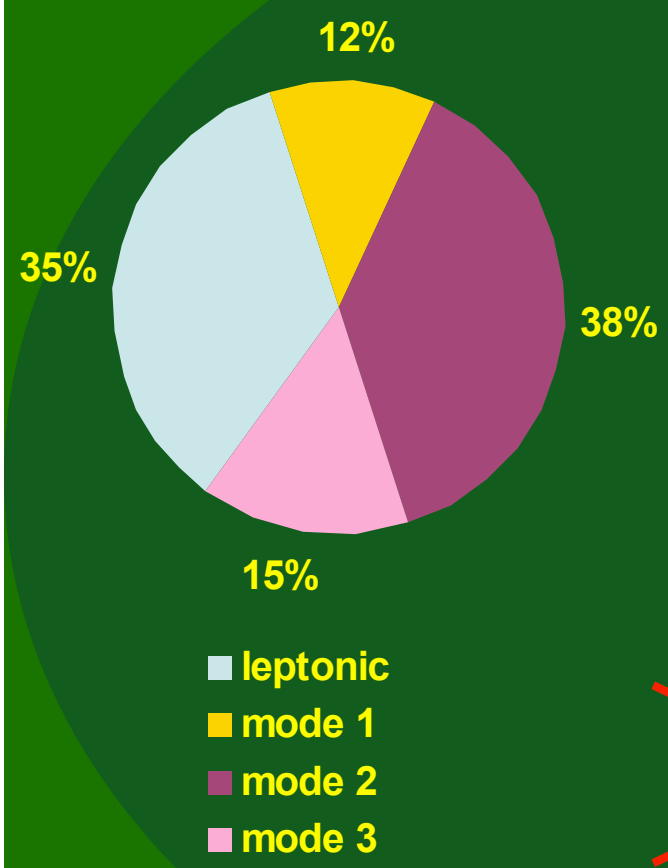
→ Disappearance searches

Experimental Signature

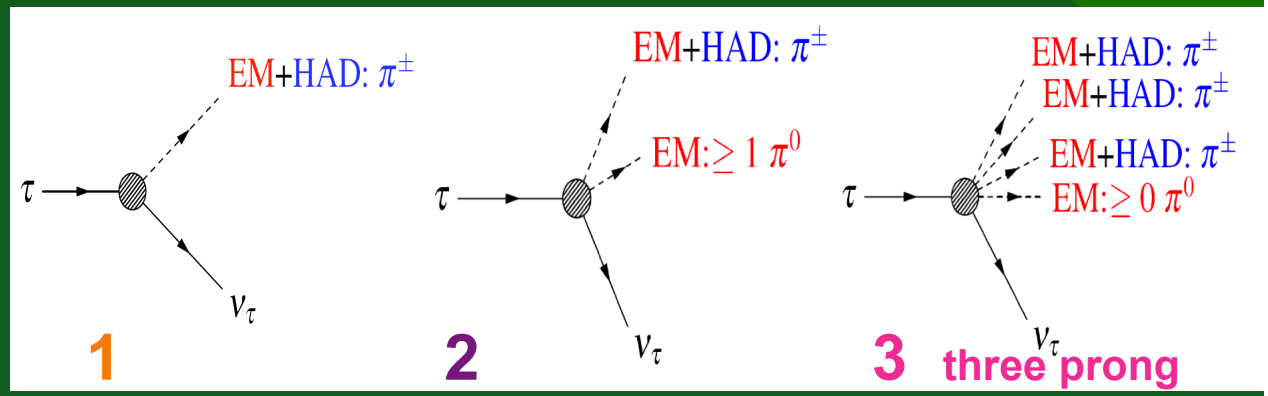


- **4 jets**
- 2 displaced vertices
- Hadronic τ
- Energy imbalance

τ Decays & Candidates



Decay Modes:



Candidates:

All τ candidates contain a narrow isolated jet (simple cone algorithm, $\Delta R=0.3$) matched with:

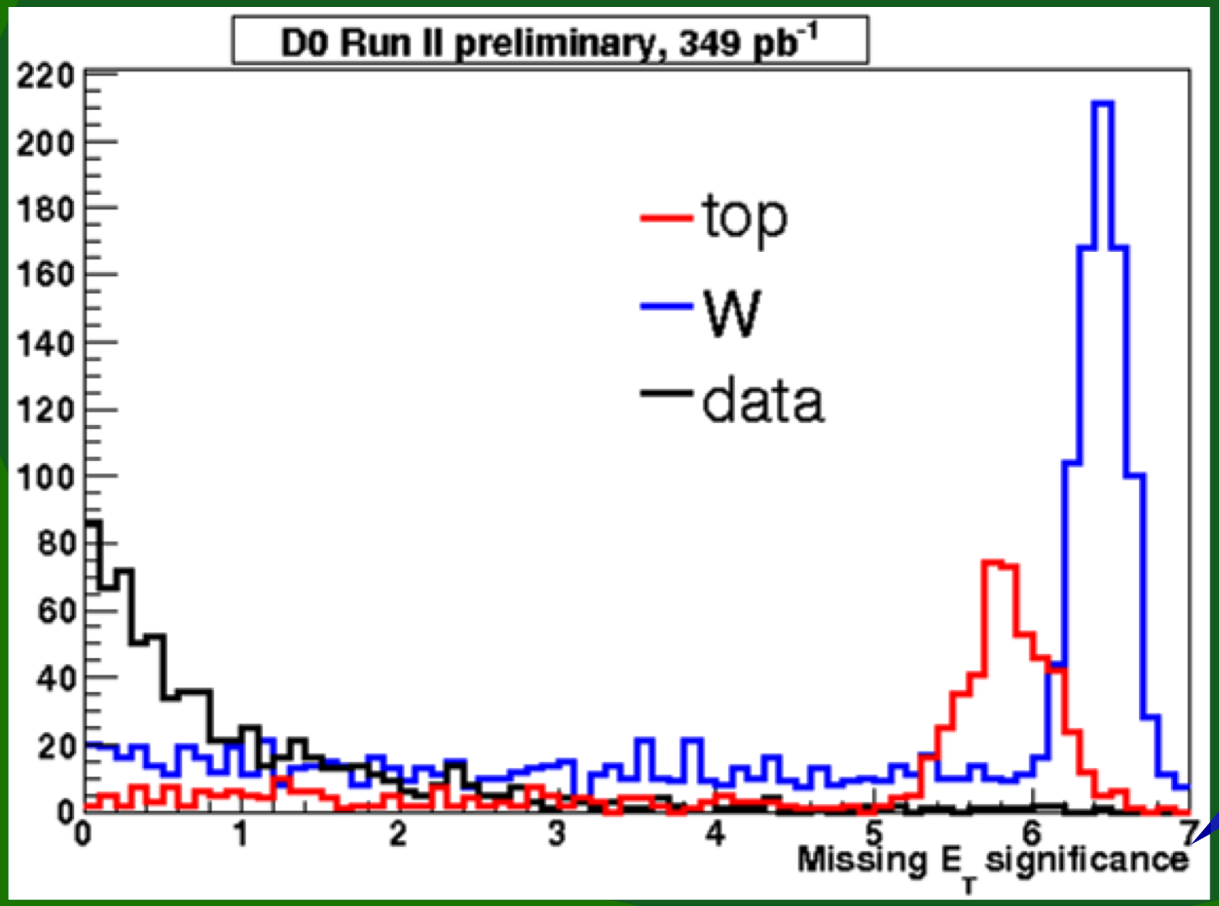
~~Type 1~~	Type 2	Type 3
~~1 charged track~~	1 charged track	>1 charged track
	≥1 EM sub cluster	Used in analysis

For each candidate type, a neural net was trained to distinguish between true τs (from MC) from fakes (from data). Inputs: isolations, energy deposition profiles, angles.

The NN performance on real τs was verified using $Z \rightarrow \tau\tau$ data.

Missing E_T Significance

A key tool is the determination of the missing E_T resolution for each event, based on the detailed resolutions of its reconstructed objects (jets, electrons, unclustered energy).



[redacted] = [redacted] / σ[redacted]

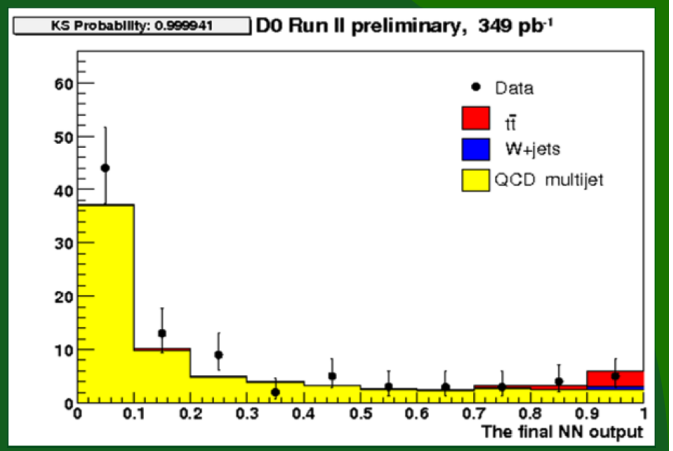
Corresponds to the probability that the entire energy imbalance is a mismeasurement.

Analysis Flow & Overview

Preselected dataset
- Multijet trigger
- veto *e* and *μ*
- ≥4 jets
- $S_{MET}>3$

***b*-tag vetoed dataset**
- **no** tight *b*-tags
- τ with $NN_\tau>0.95$

***b*-tagged dataset**
- tight *b*-tag



τ-vetoed dataset
- τ with $0.5>NN_\tau>0$
- **no** τs with $NN_\tau>0.8$

τ fake rates in multijets

Signal dataset
- τ with $NN_\tau>0.95$

95% multijets

Analysis NN training

Multijet background

X-section measurement

Doesn't use τ–ID

Multijets and Fake τs

The selected sample contains ~95% by multijet events, where a random jet is reconstructed as a τ.

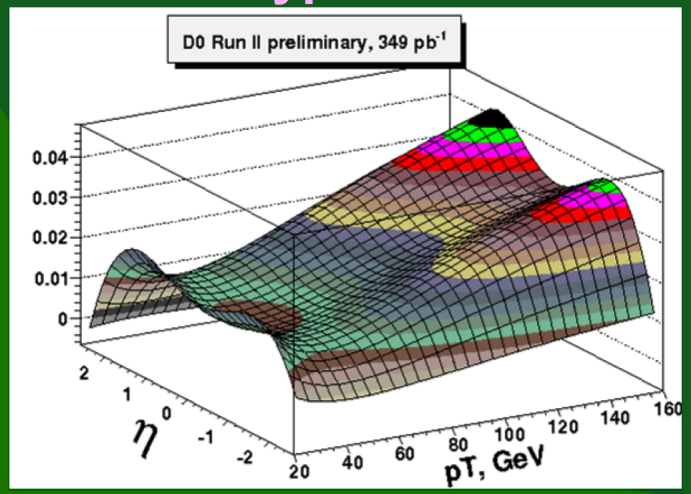
What's the probability that a jet fakes a τ ?

The *b*-vetoed sample is ~99.8% multijets, effectively all τs are fake.

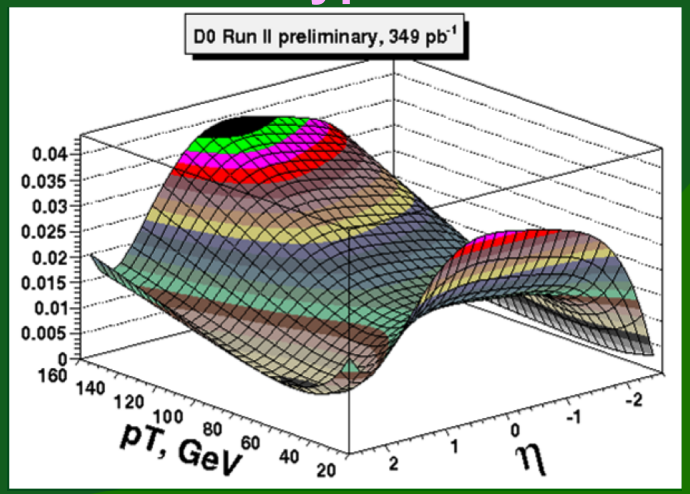
$$[redacted]\eta,[redacted] = [redacted]\tau \mid [redacted]\eta,[redacted] = \frac{[redacted]_{\tau}(\eta,[redacted])}{[redacted](\eta,[redacted])}$$

Fit the ratio, and treat the two types as independent channels.

Type 2



Type 3



Estimating the Multijet Background

Preselected dataset

- Multijet trigger
- veto e and μ
- $\geq$4 jets
- S_{MET}>3

***b*-tag vetoed dataset**

- **no** tight *b*-tags
- τ with NN_{τ}>0.95

***b*-tagged dataset**

- tight *b*-tag

τ fake rates in multijets

Multijet background

From the probability that an jet fakes a τ in a sample similar to our signal sample, we derive the probability that a *b*-tagged preselected data event will pass τ ID:

$$[illegible] = 1 - \prod_{i} \left(1 - [illegible](\eta^{i}, [illegible]^{i})\right)$$

And estimate the multijet background from data.

Event Level NN

Even after requiring a tight *b*-tag and τ–ID, the selected sample contains ~95% by multijet events.

That's too much background for a cross section measurement.

An event-level neural net was trained to separate signal and the τ–vetoed sample.

The neural net inputs were:

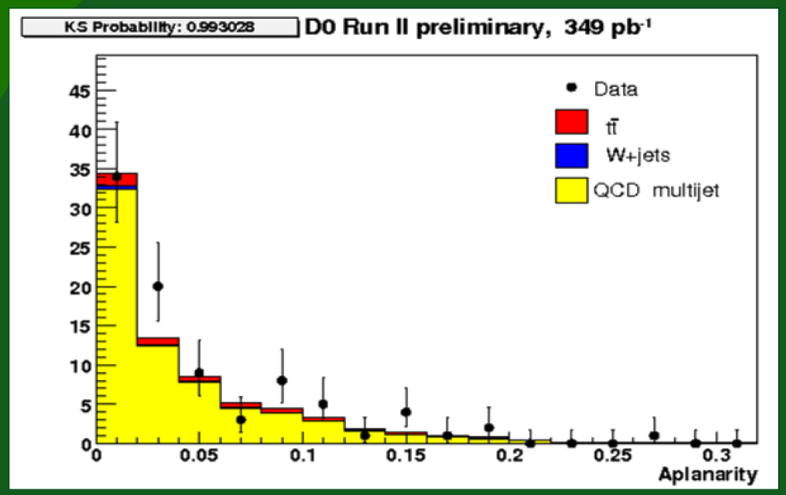
- Topological variables
  - Aplanarity, sphericity, centrality
  - Sum of object energies
- A χ^2 like variable
  for the best assignment

$$\blacksquare = \left(\frac{\blacksquare_{\blacksquare} - \blacksquare_{\blacksquare}}{\sigma_{\blacksquare}}\right)^{\blacksquare} + \left(\frac{\blacksquare_{\blacksquare} - \blacksquare_{\blacksquare}}{\sigma_{\blacksquare}}\right)^{\blacksquare}$$

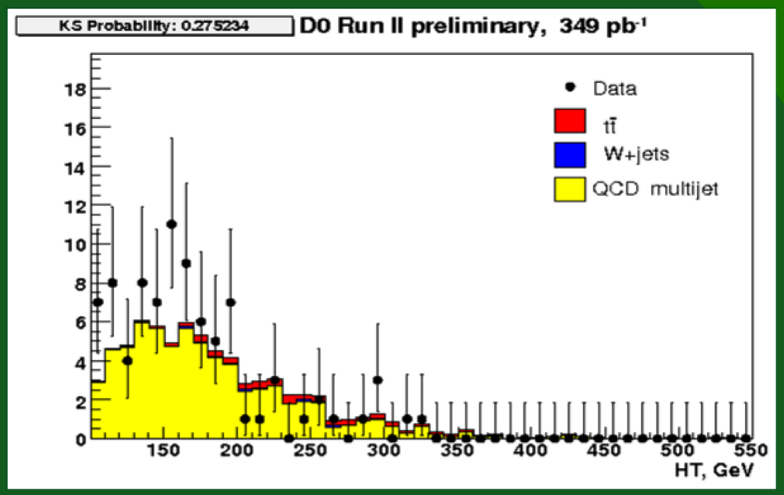
- For the leading *b*-tagged jet
  - Its transverse momentum
  - Significance of its secondary vertex displacement

Event Level NN - II

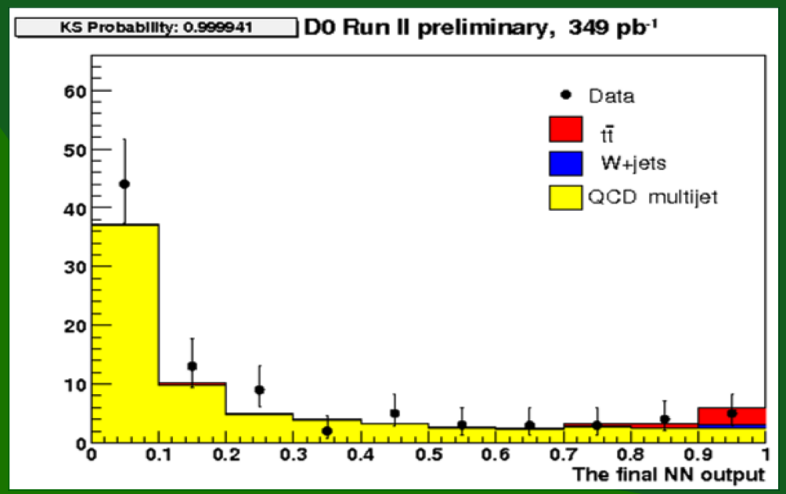
Sample control plots and NN output distributions

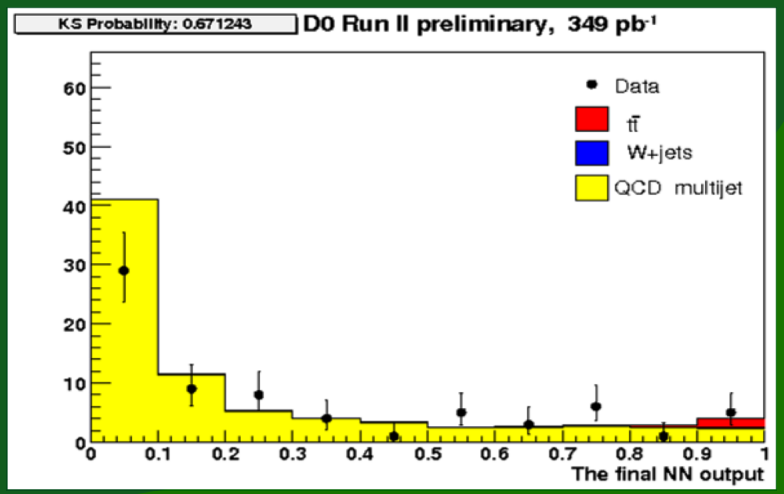


Type 2



Type 3





Extracting the Cross Section

Channel	N^{obs}	$\mathcal{B}$	Bakgrounds		$\varepsilon(t\bar{t})$ (%)
type 2	5	0.1	$W \to \tau\nu$	0.60±0.03	1.57±0.01
			fakes	2.41±0.09	
type 3	5	0.1	$W \to \tau\nu$	0.27±0.01	0.73±0.01
			fakes	2.33±0.09	

The cross section is measured as $\sigma = \frac{[redacted]}{\varepsilon_{[redacted]}[redacted](\to \tau + [redacted])\int [redacted]}$

For type 2: $\sigma_{[redacted]}(\tau + [redacted]) = [redacted]$

And for type 3: $\sigma_{[redacted]}(\tau + [redacted]) = [redacted]$

Combined: $\sigma_{[redacted]}(\tau + [redacted]) = [redacted]$

Systematic Uncertainties

Source	Type 2 τ	Type 3 τ
Jet Energy Calibration	[redacted]	[redacted]
Primary Vertex	± [redacted]	± [redacted]
MC statistics	[redacted]	[redacted]
Trigger	+[redacted] −[redacted]	+[redacted] −[redacted]
Branching Ratios	± [redacted]	+[redacted] −[redacted]
Multijet fake τ rate	± [redacted]	± [redacted]
W→ $\tau\nu$	± [redacted]	± [redacted]
b-tagging	[redacted]	[redacted]

Summary and Outlook

- DØ performed a preliminary measurement of the top pair production cross section in the τ + jets channel, using on the 350 pb^{-1}.

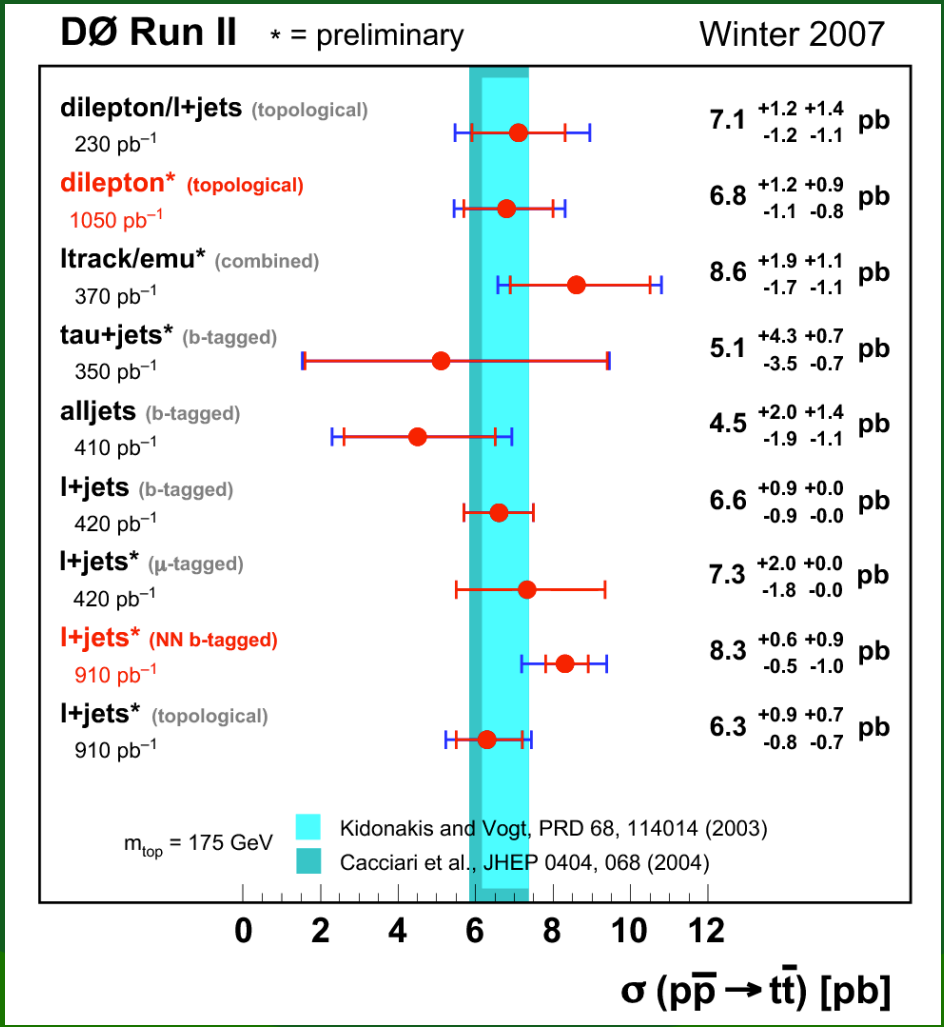
$$\sigma_{\blacksquare}(\tau + \blacksquare) = \blacksquare.\blacksquare\blacksquare^{+\blacksquare.\blacksquare\blacksquare}_{-\blacksquare.\blacksquare\blacksquare}(\blacksquare)^{+\blacksquare.\blacksquare\blacksquare}_{-\blacksquare.\blacksquare\blacksquare}(\blacksquare) \pm \blacksquare.\blacksquare\blacksquare(\blacksquare)$$

- Working on many improvements for the final measurement:
  - Using the complete Run IIa dataset: 1 fb^{-1} worth of data
  - Analysis techniques (*b*-tagger, S_{MET}, simulation, tests, JES)
  - Oriented towards a H+ search (e.g. *e*-veto)

Back up slides

Other D Cross Section Measurements

$$\sigma_{\text{[redacted]}}(\tau + \text{[redacted]}) = \text{[redacted]}^{+\text{[redacted]}}_{-\text{[redacted]}}(\text{[redacted]})^{+\text{[redacted]}}_{-\text{[redacted]}}(\text{[redacted]}) \pm \text{[redacted]}(\text{[redacted]})$$



τ ID Signal Efficiencies

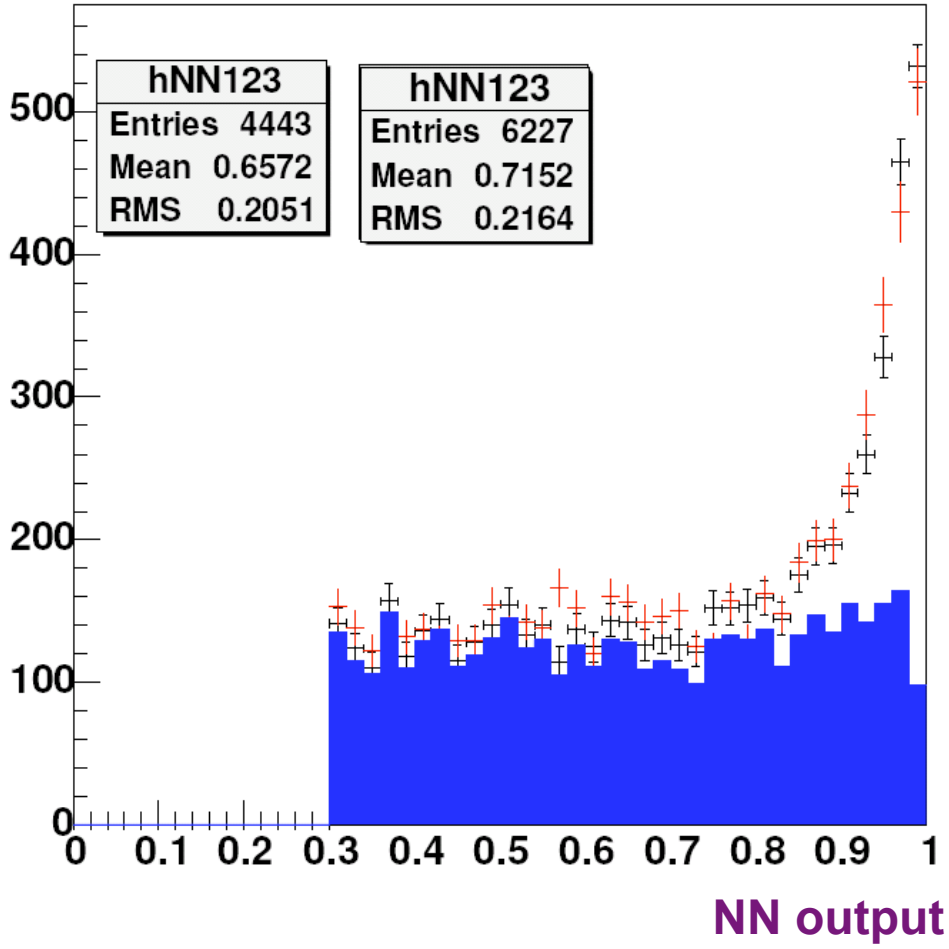


Figure 21: NN distributions for τ candidates from os (red error bars), es (solid blue), and prediction from es+$Z \rightarrow \tau\tau$ Monte Carlo (black error bars).

Trigger and Preselection

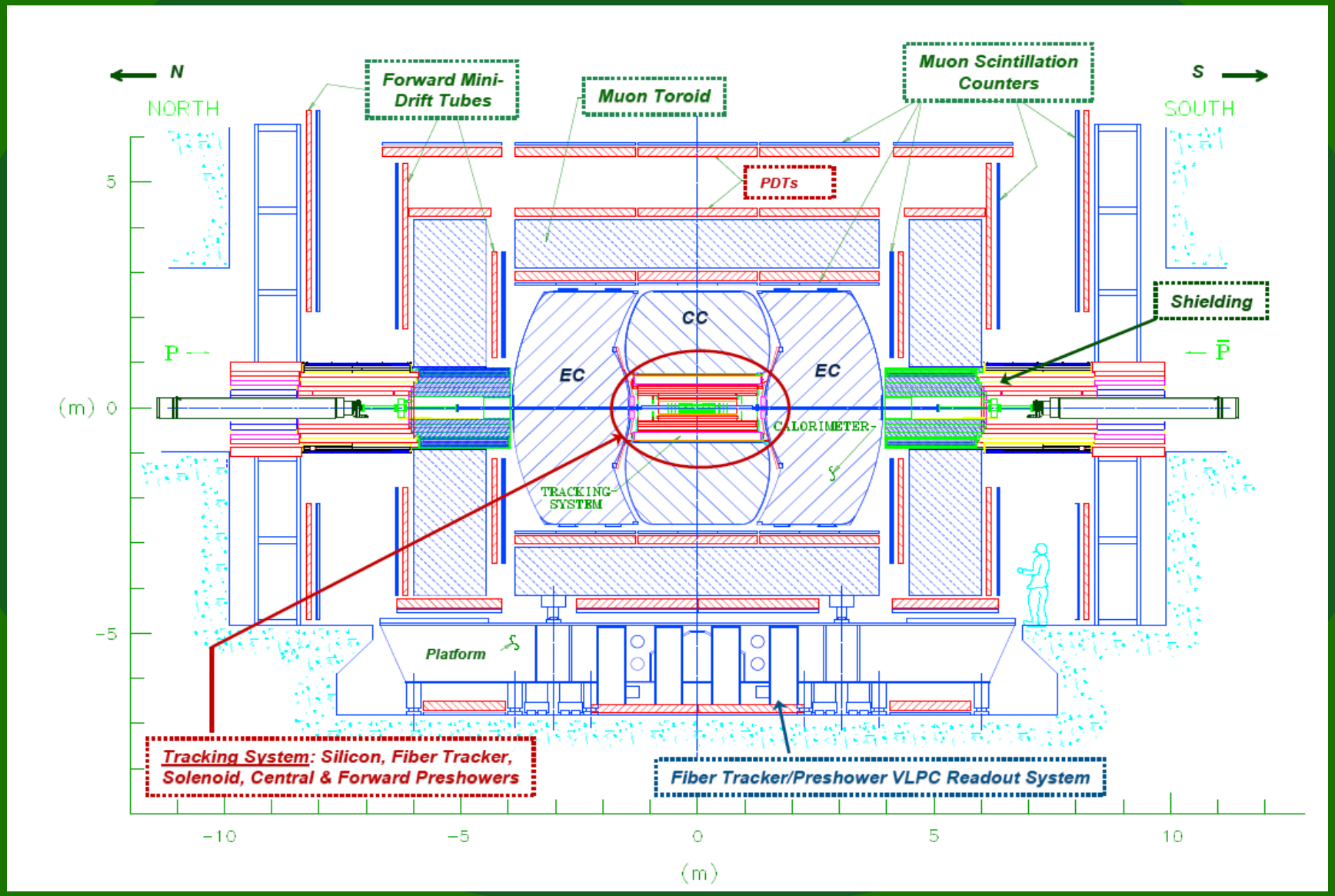
Trigger

We used a four jet trigger.

The exact jet requirements vary between DØ's three trigger levels.

The trigger efficiency for signal events is >90%.

Preselection

- Require a tau candidate
- Veto isolated electrons and muons
- At least four jets with E_T>8GeV
- Missing E_T significance > 3

The DØ Detector