Tau Identification at DØ

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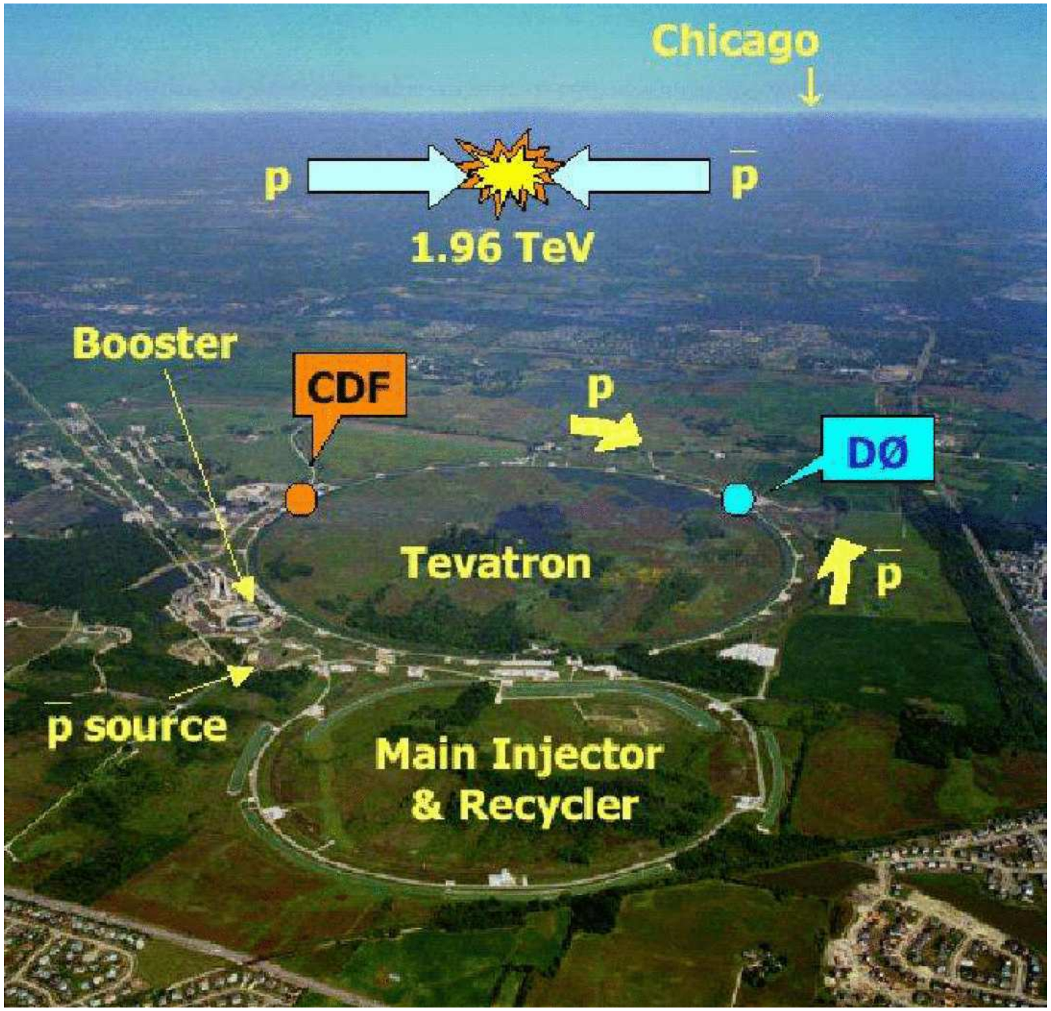
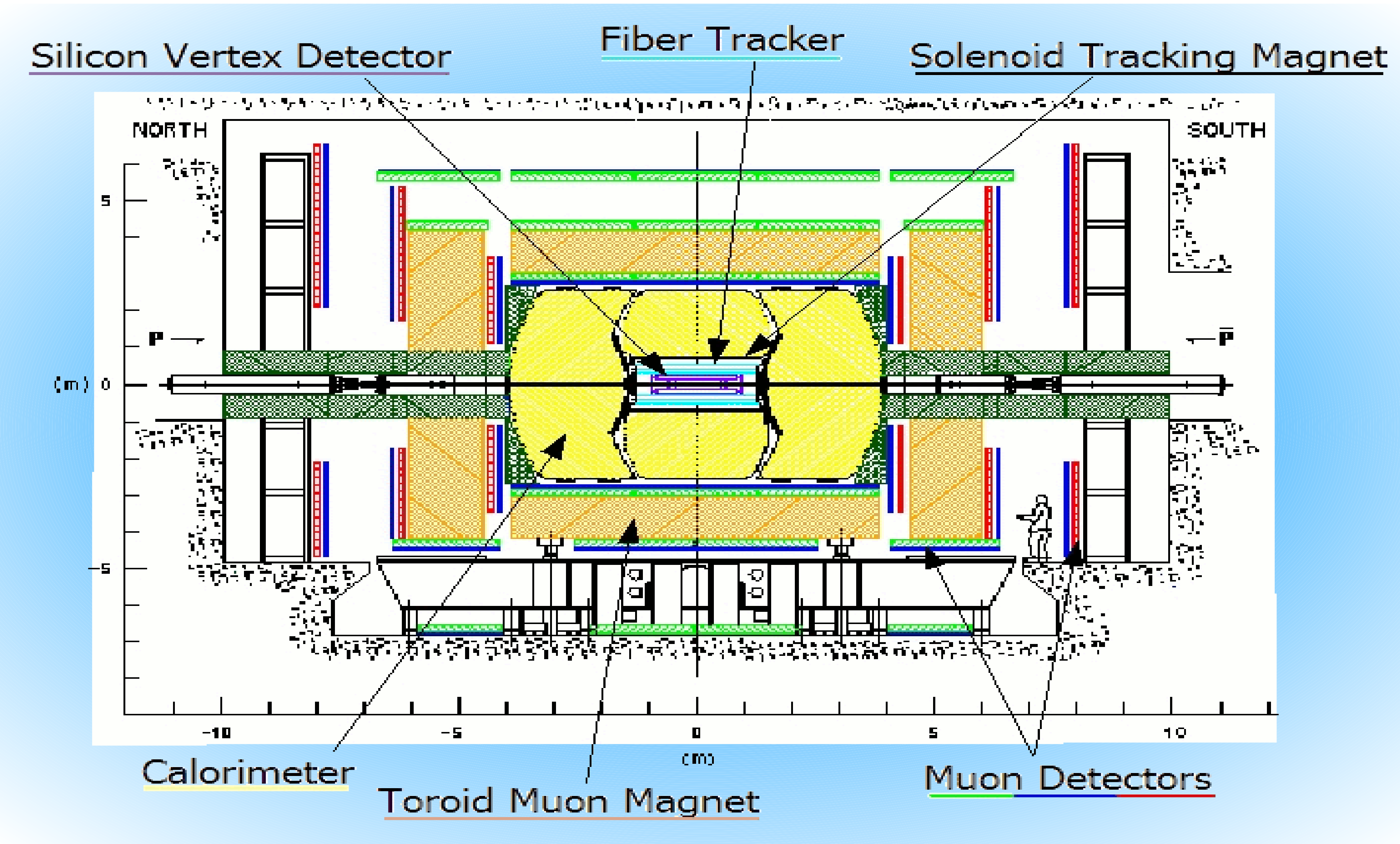
OUTLINE

- Motivation
- Tau properties
- Tau Triggers
- Tau Reconstruction
  - Neural Networks
- Some Physics Results
- Conclusion

Fermilab




Silicon Vertex Detector
Fiber Tracker
Solenoid Tracking Magnet
NORTH
SOUTH
p
p̄
(m) 0
5
−5
−10
−5
0
5
10
(m)
Calorimeter
Toroid Muon Magnet
Muon Detectors

DØ detector

Why bother with taus?

- **Increase acceptance for channels with leptons:**
  - **Single lepton channel $\times$1.5 , 2 lepton channel $\times$2 , 3 lepton channel $\times$3**
- **Largest coupling of Higgs to leptons is to τ's**
- **Minimal SUSY models with large tanβ favor decays to τ's**
- **3rd generation lepto-quarks**

Tau Properties

Mass = 1.78 GeV, intermediate lifetime: $c\tau = 87\ \mu$m

All taus decay before reaching any detector

Final State	B.R. (%)	Decay type	
$e\nu_e\nu_\tau$	17.8	Leptonic	τ_e
$\mu\nu_\mu\nu_\tau$	17.4	35.2	τ_μ
$\pi/K\nu_\tau$	11.8	1-prong	
$\pi/K \geq 1\pi^0\nu_\tau$	36.9	48.7	τ_h
$\pi\pi\pi \geq 0\pi^0\nu_\tau$	13.9	3-prong	

Tau Triggers

- Single τ_h triggers
  - L1: track and CAL tower
  - L3: loose NN cut on CAL cluster
  - used with $\not\!\!E_T$ trigger for $W \rightarrow \tau\nu$ analysis
- Di-τ triggers
  - may be $\mu + \tau_h$, $e + \tau_h$ or $\tau_h + \tau_h$
  - analyses with di-τ triggers are at early stages
  - for $Z \rightarrow \tau\tau$ and H$\rightarrow \tau\tau$ single μ and single e triggers are used

All τ triggers add up to 2 Hz to tape @ 10^{32}/cm^2/sec

Tau candidate

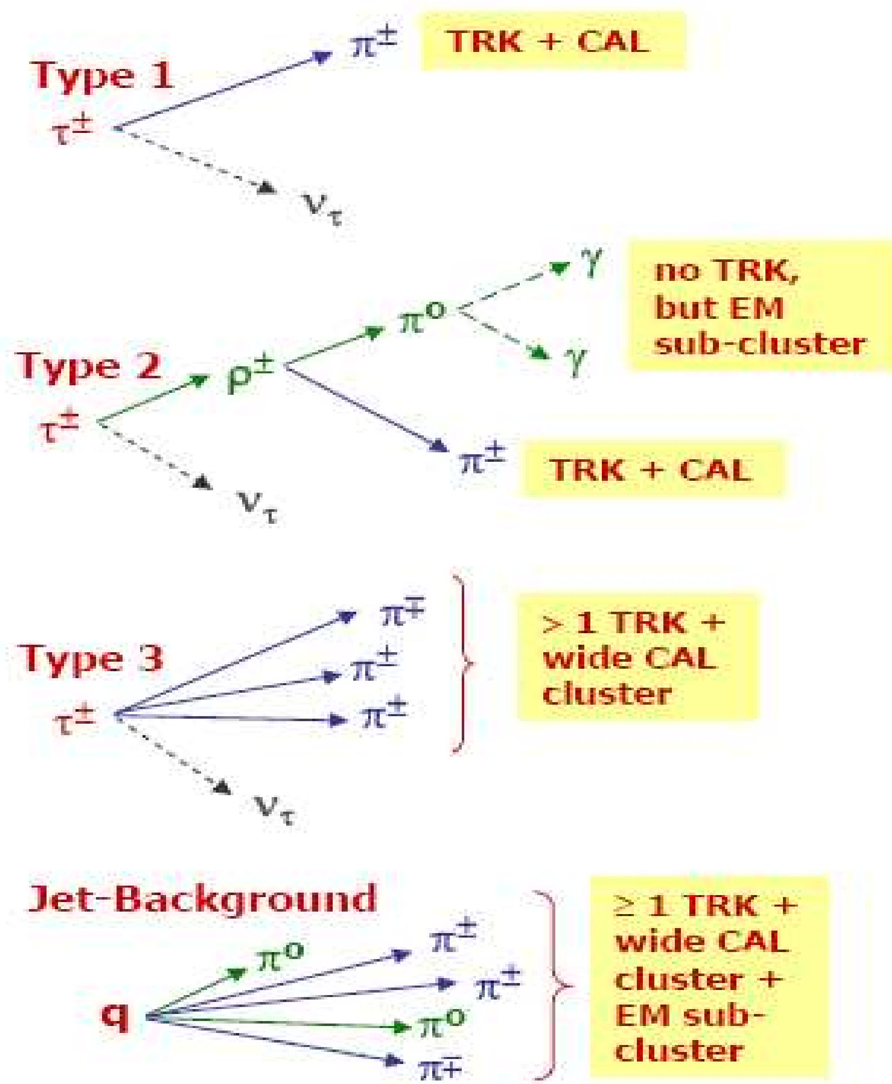
- **Calorimeter Cluster**: Simple Cone algorithm $R = 0.5$, core cone size $R_{core} = 0.3$. CAL cluster $rms < 0.25$

- **EM Sub-clusters**: Nearest Neighbour algorithm with seed in EM3 layer of CAL. EM cluster E $>$ 800 MeV

- **Tracks**: all tracks in 0.3 cone around the CAL cluster, compatible with τ decay. Highest track $p_T > 1.5$ GeV

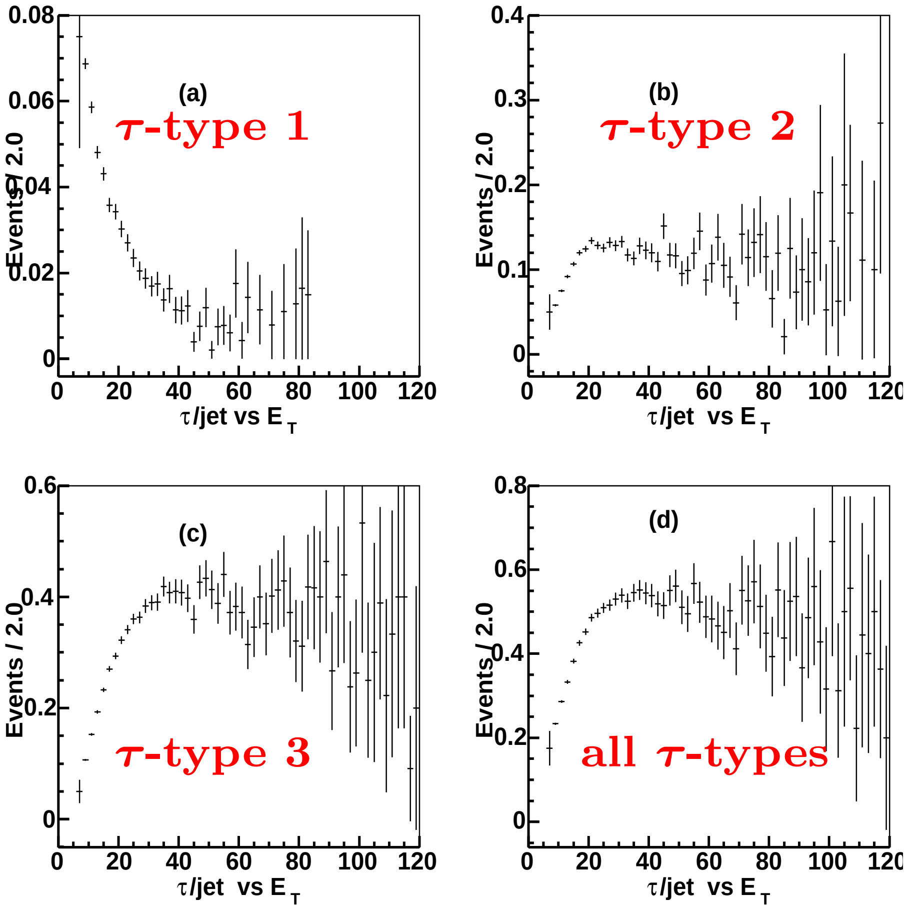
Three types of τ-candidates:

1. one track + CAL cluster, no EM sub-clusters
2. one track + CAL cluster, some EM sub-clusters
3. >1 tracks + CAL cluster

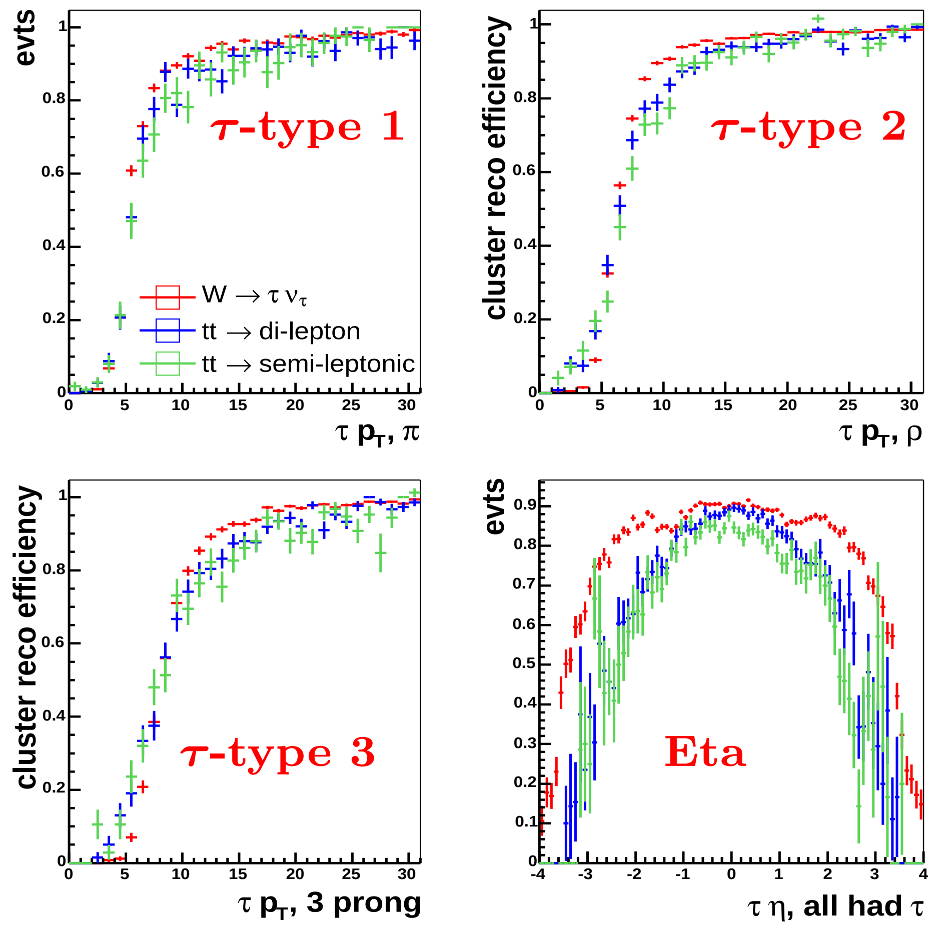


Reconstruction Efficiencies

Jets faking taus (data)



Taus (MC)



Neural Networks for τ-id

- **three separate anti-jets NNs, one for each type**
- **one Neural Network to reject electrons, NN_e**
- **training samples:**
  - **signal: taus from MC**
  - **background: jets in events with a non-isolated μ from data (NN), electrons from MC (NN_e)**
- **Note: most input variables are ratios of energies to minimize dependence on E_τ**

NN Input variables

- **isolation parameters**: $caliso = (E_T^\tau - E_T^{core})/E_T^{core}$
  $trkiso = \Sigma p_T^{trk}/\Sigma p_T^{\tau_{trk}}$
  $em12isof = (E^{EM_1} + E^{EM_2})/E^\tau$

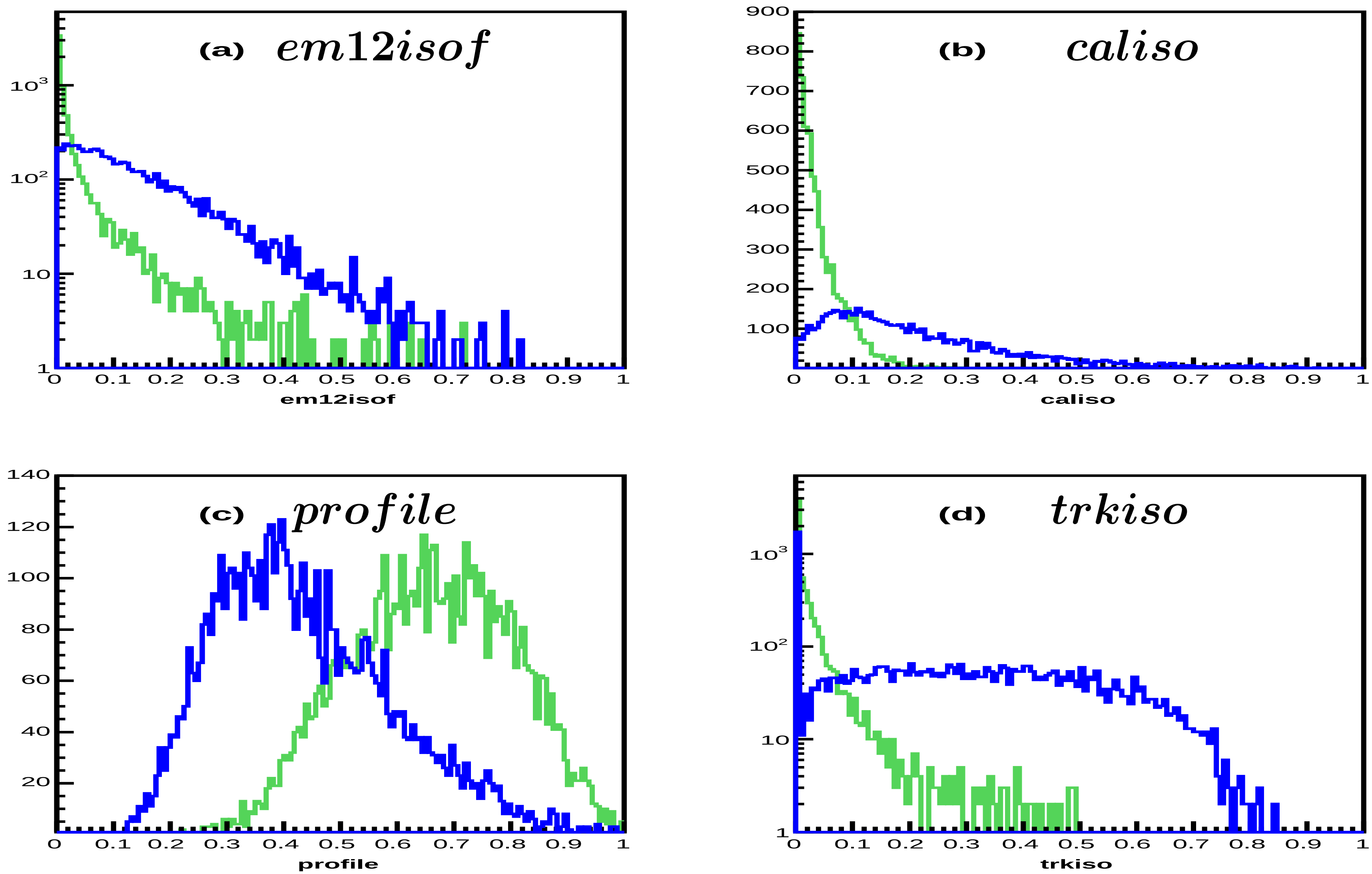
- **shower shape parameters**: rms
  EM $and\ hadronic\ fractions$
  $profile = (E_T^{tower1} + E_T^{tower2})/E_T^\tau$
  $emprofile = E_T$ EM subclusters/$E_T^{EM_3}$

- **CAL - track correlations**: $E_T^\tau/(E_T^\tau + \Sigma p_T^{\tau_{trk}})$
  $\delta\alpha$ = angle between $\Sigma\tau$-tracks and ΣEM-subclusters

where τ_{trk} (trk) are tracks assoc. (unassoc.) with τ in R<0.5
E^{EM_i} is E in ith layer of EM calorimeter

Some NN input variables

Signal (MC τ) and Background (jets from data) for τ-type 1



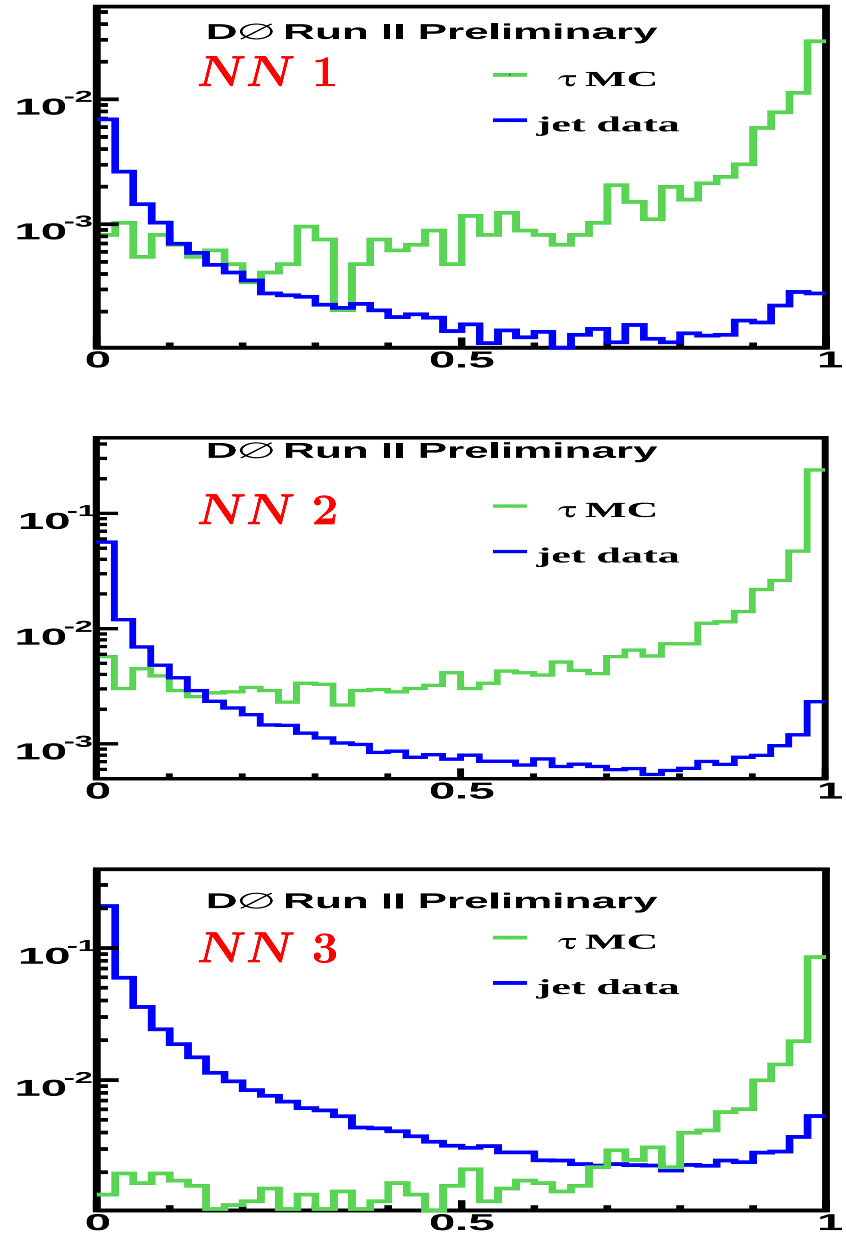
Jet-τ discrimination

Efficiencies (%)

$20 < E_T^\tau < 40$ GeV, $|\eta^\tau| < 2.5$

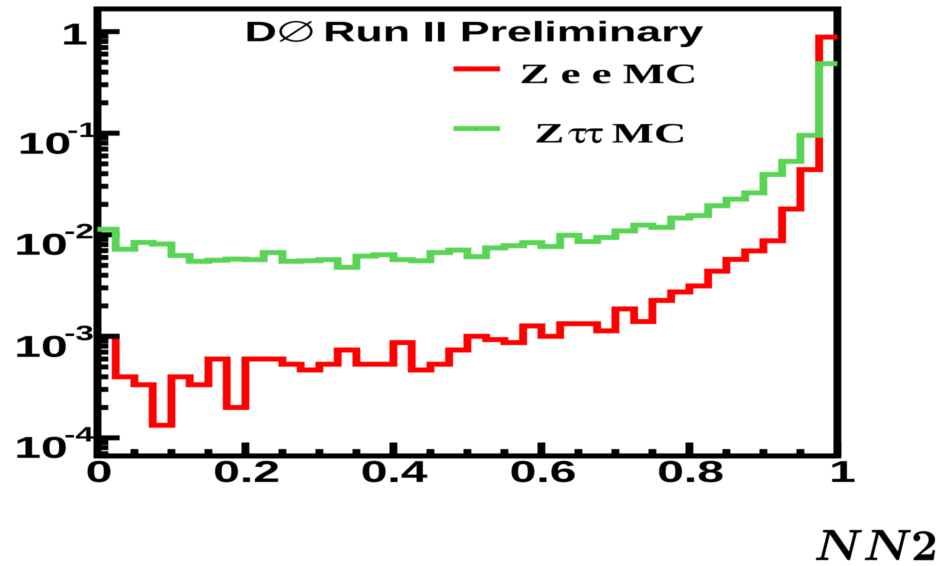
τ-type	1	2	3	all
jets	2	12	38	52
τ	11	60	24	95
$NN > 0.9$				
jets	0.06	0.24	0.80	1.1
τ	7	44	16	67

Note: $NN \rightarrow 1$ for signal
$NN \rightarrow 0$ for bkg



e-τ discrimination

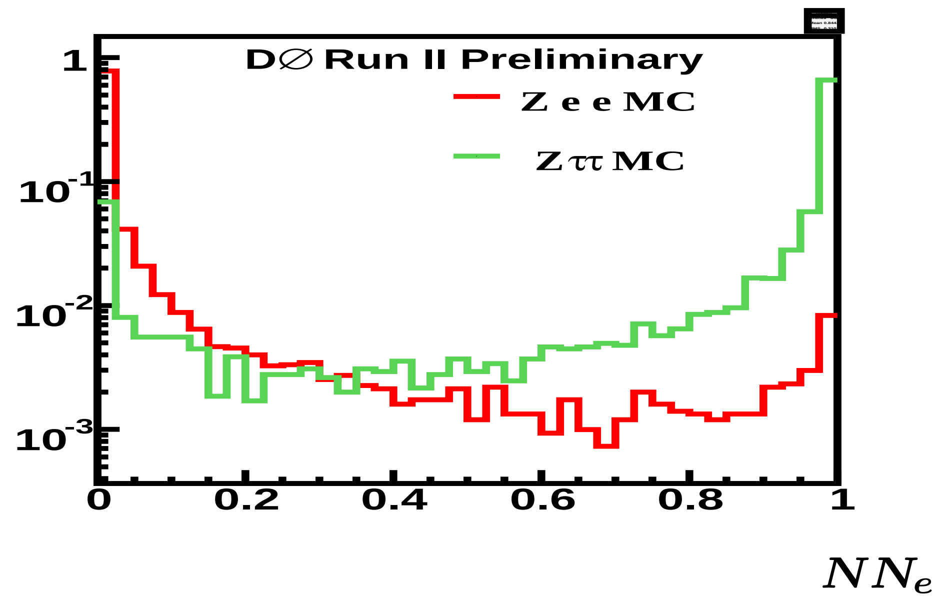
- electrons make nice type-2 tau candidates
- NN_e trained with electrons as background



Efficiencies (%)

$20 < E_T^\tau < 40$, $|\eta^\tau| < 2.5$

	$NN2 > 0.9$	$NN_e > 0.5$
e	98	3.4
τ	44	38



μ-τ discrimination

Efficiencies (%)

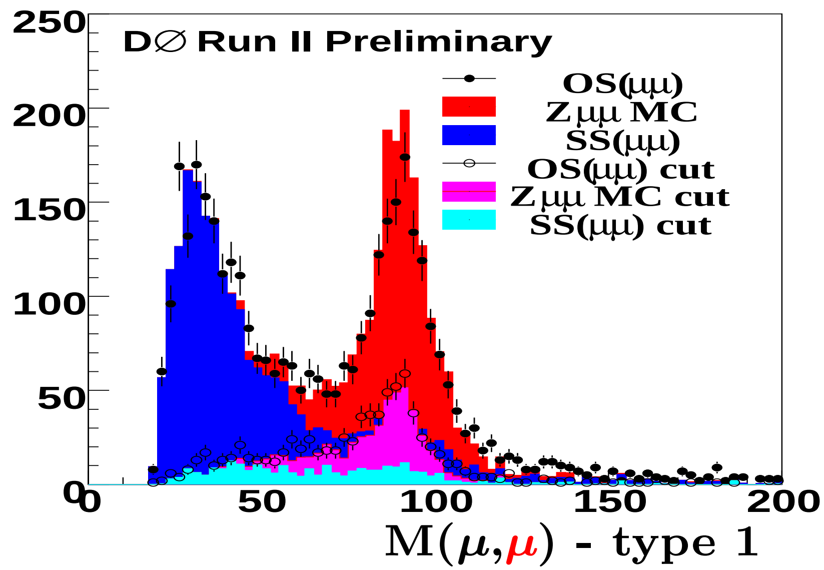
$p_T^{\tau_{trk}} > 10$, $|\eta^\tau| < 2.5$

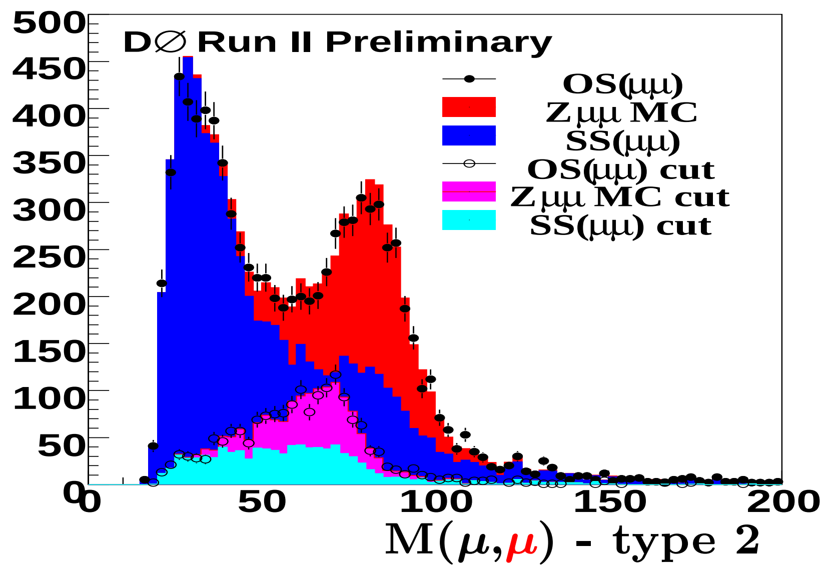
$NN > 0.9$		
τ-type	1	2
μ	2.5	3.1
no μ id	0.4	0.8
$\mathcal{R}_\mu > 0.4$	0.2	0.4
τ	5.5	35

$\mu \equiv$ misidentified as τ

$\mathcal{R}_\mu = E_T^\tau(1 - fch)/p_T^{trk}$

where $fch \equiv E_T$ fraction in CH cal.

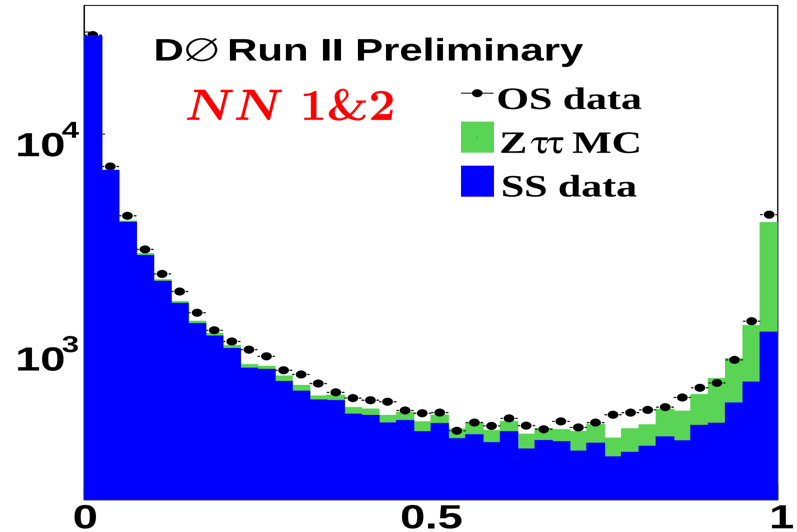




NN on $\mu + \tau$ data

Event Selection

μ	$p_T > 12$ GeV	$\|\eta_d\| < 1.7$
	only 1 μ	
τ	$E_T > 10$ GeV	$\|\eta_d\| < 2.5$
	$\mathcal{R}_\mu > 0.4$	
	$\|\phi_\mu - \phi_\tau\| > 2.7$	

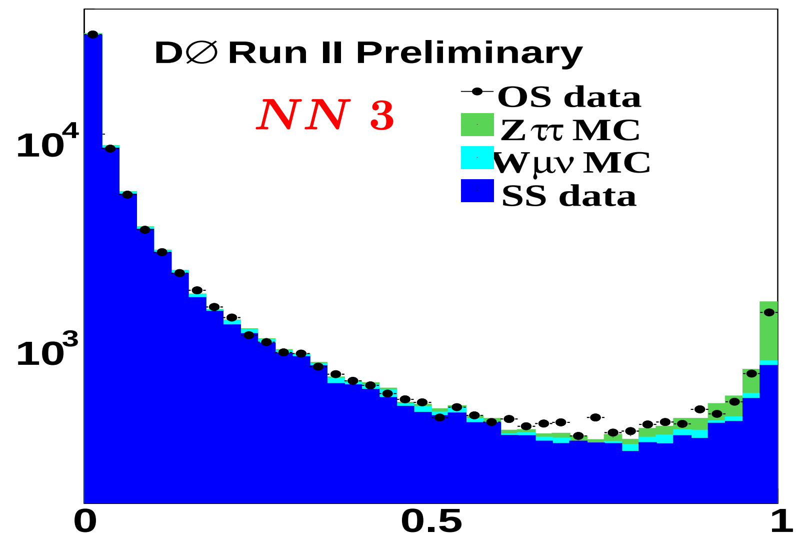


Data: no trigger selection applied

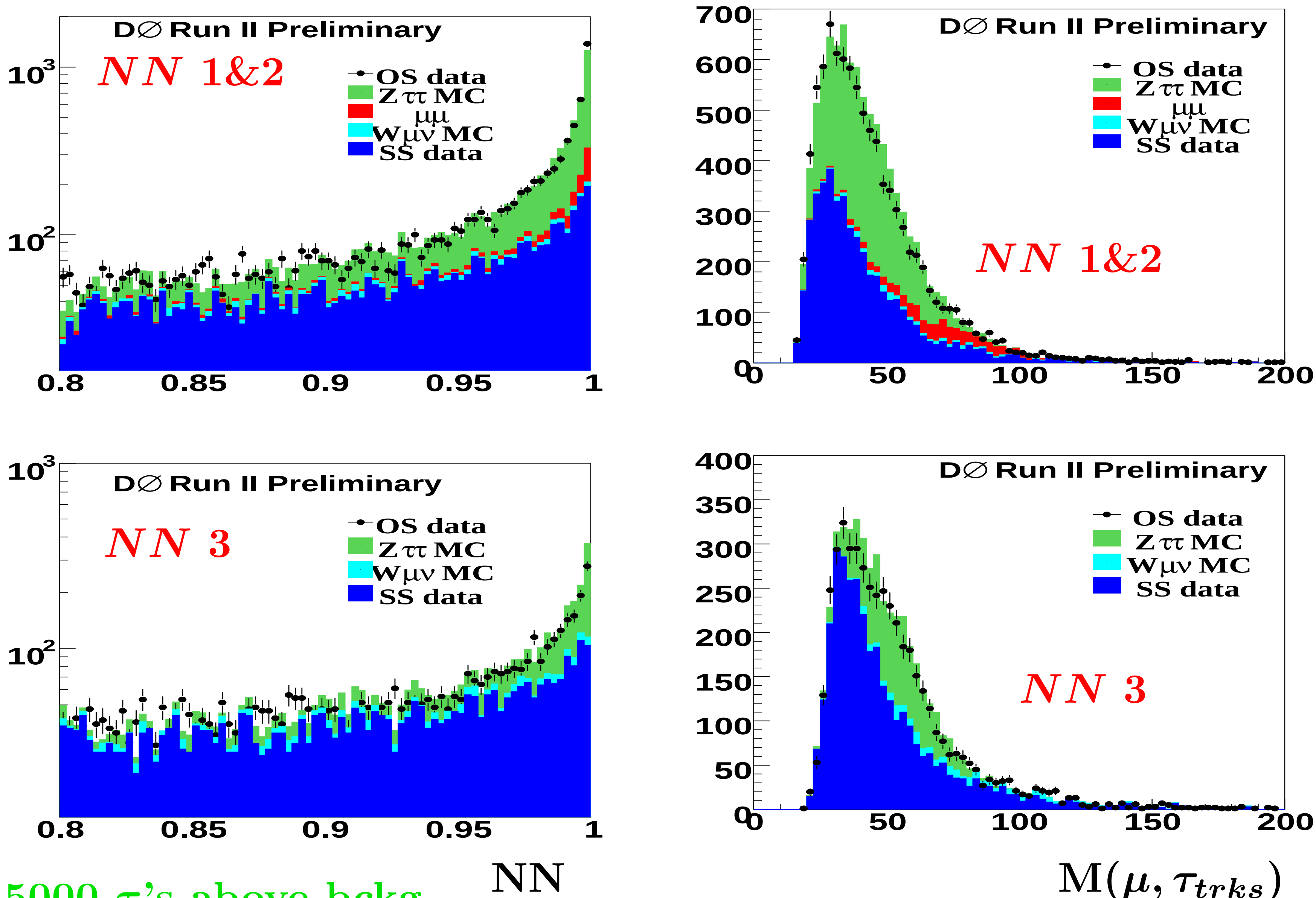
MC : uncorrected for trigger ϵ

normalized to OS data

$\int Ldt \approx 630$ pb^{-1}



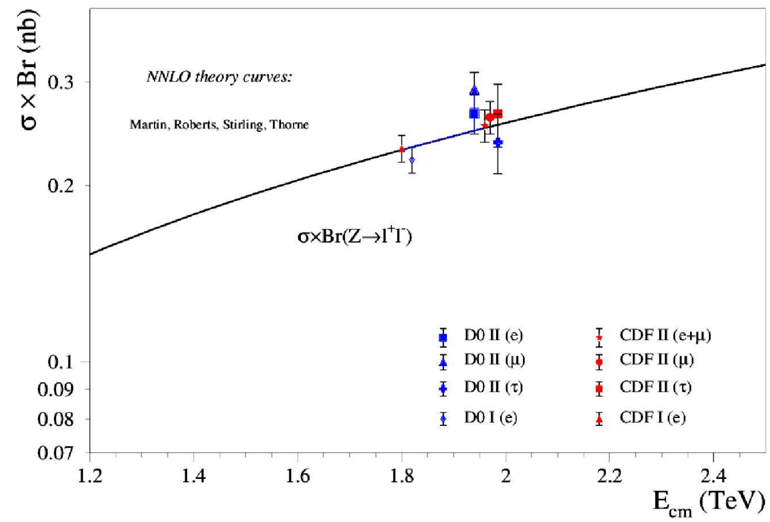
$\mu + \tau$ data after $NN > 0.8$

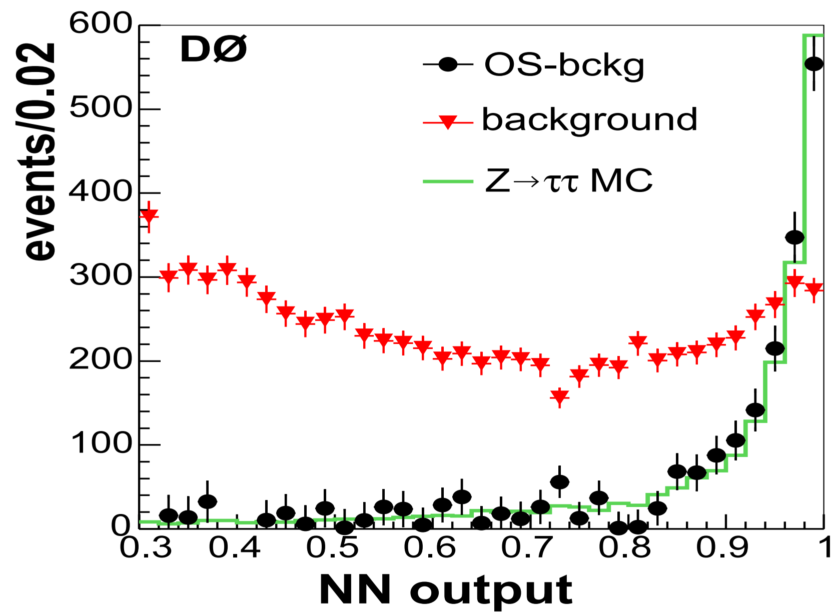


$\approx$ 5000 τ's above bckg.

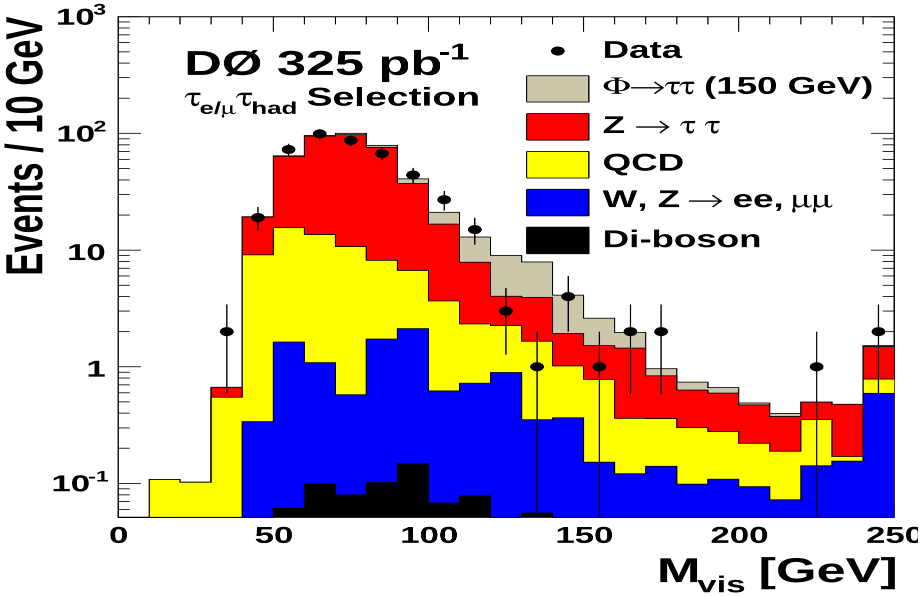
$Z/\gamma^* \rightarrow \tau\tau$ cross section

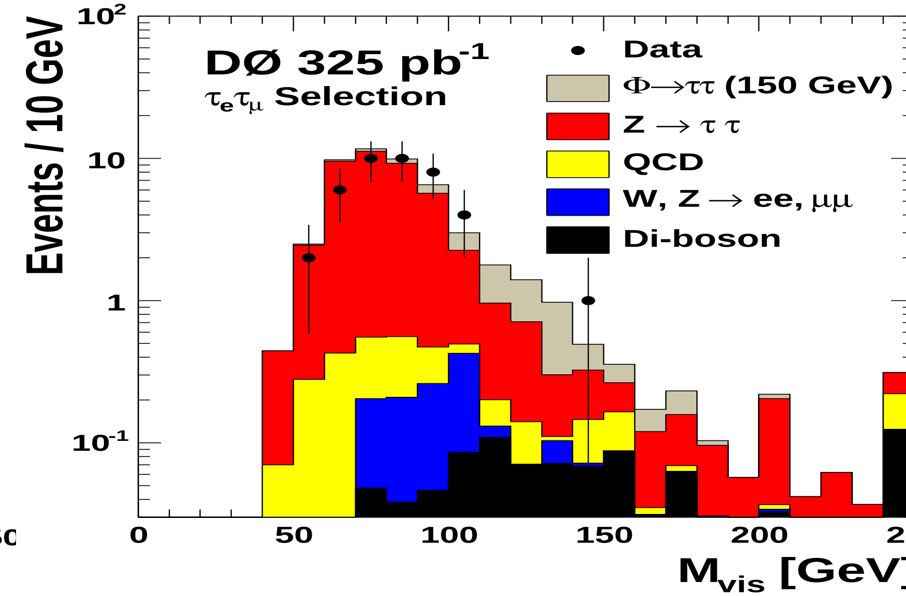
Channel	$Z \rightarrow \tau_\mu \tau_{h,e}$
Event Selection	$p_T^\mu > 12,\ E_T^\tau > 10$ $\lvert\phi_\mu - \phi_\tau\rvert > 2.5,$ $NN > 0.8$
$\int Ldt$	226 pb^{-1}
Data	2008 events
Background	1084 ± 69
$\sigma \cdot BR$	$237 \pm 15_{stat}$ $\pm 18_{sys} \pm 15_{lum}$ pb
Published	PRD 71, 072004 (2005)





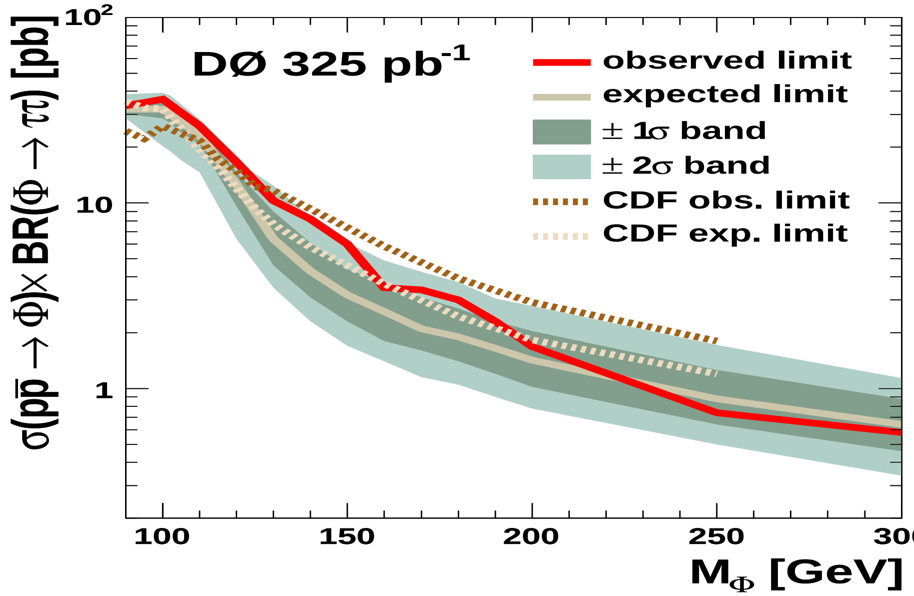
Neutral Higgs→ $\tau\tau$ Search





submitted to PRL

arXiv (hep-ex/0605009)



Conclusions and Outlook

- **Jet rejections of 99% or better can be achieved with τ efficiencies near 65%**

- **Misidentified e's and μ's can be reduced to low levels**

- **Measurements with τ lepton channels at Tevatron can ultimately achieve a few % precision**

- **Taus are an important handle in the search for new physics at the Tevatron and LHC**