TAU RESULTS AT DØ

- tau identification in hadronic modes
- $Z \rightarrow \tau \tau$ cross section measurement
- R-parity violated susy with $\lambda_{133}$ coupling

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for the DØ collaboration

Tau04 workshop
September 17, Nara Japan
DØ detector

Tracking: silicon detector
Fiber tracker
2T magnetic field

Muon drift tubes scintillators

Shielding

Uranium absorber / Liquid Argon sampling calorimeters
**Tau identification in hadronic modes**

A tau candidate consists of:

- a calorimeter cluster found by simple cone algorithm (cone size $R=0.3$, isolation cone $R=0.5$)
- sub-clusters in the electromagnetic layers of the calorimeter, if $\pi^0$ are among the tau decay products
- tracks in an 0.5 cone consistent with tau mass
The hadronic $\tau$ candidate can be classified into 3 categories, according to the detector response:

- **type 1**: $\tau \rightarrow \pi \nu$, type: 1 track, CAL cluster, no EM sub-cluster
- **type 2**: $\tau \rightarrow \rho \nu$, type: 1 track, CAL cluster and EM sub-cluster
- **type 3**: 3 prongs, type: at least 2 tracks

**Early showers**

**Inter-cryostat region with less EM layers**
Neural networks for tau-Id

- three separate neural networks (NN), one for each tau type

- discriminating input variables based on shower shape, isolation, core, energy fractions, sub-clusters in the EM layers of the calorimeter, additional tracks found in an 0.5 cone not attached to the τ ... exploit the fact that τ are narrow, isolated jets with less associated particles than QCD jets

- most of input variables are ratios of energy to minimize dependence on E_T.

- used NN package from ROOT which uses vanilla back propagation method

- training samples:
  - **signal**: 100,000 MC single taus distributed uniformly in pseudo-rapidity and visible p_T overlaid on a minimum bias event
  - **background**: QCD jets in events with non isolated muons (data)
Neural networks for tau-ld

Background: tau candidates in events with non isolated muons

Efficiencies NN>0.8:

<table>
<thead>
<tr>
<th></th>
<th>type 1</th>
<th>type 2</th>
<th>type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>background</td>
<td>0.145 ± 0.014</td>
<td>0.042 ± 0.004</td>
<td>0.039 ± 0.02</td>
</tr>
<tr>
<td>(Z \to \tau\tau)</td>
<td>0.78 ± 0.03</td>
<td>0.74 ± 0.015</td>
<td>0.73 ± 0.02</td>
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</tbody>
</table>

scaled to branching ratios and QCD type fractions
overall arbitrary signal to background ratio
Some input variables of neural networks

Profile:

\[(E_{T1} + E_{T2})/E_T\]

Ratio of the transverse energies of the 2 most energetic towers in calorimeter cluster to the total transverse energy of the cluster.
Z→ττ cross section measurement

- Production dominated by q̅q
- Z→ττ : 3% of total Z production cross section
- Look at Z→ τe/hadr requiring a simple muon trigger
- Z→ τe/hadr ~0.14 fraction of Z→ττ

I high pT isolated , oppositely charged to the τ
Single muon trigger:
- L1: scintillator and wire requirement
- L3: track requirement with \( p_T > 10 \) GeV

Muon requirements:
- one isolated muon
- \( p_T(\mu) > 12 \) GeV/c

Tau requirements:
- NN output > 0.8
- cluster width < 0.25
- type 1 & 3: \( E_T(\tau) > 10 \) GeV, \( \Sigma p_T(trk) > 7 \) GeV
- type 2: \( E_T(\tau) > 5 \) GeV, \( \Sigma p_T(trk) > 5 \) GeV

Event selection:
- the \( \tau \) candidate has opposite sign to the \( \mu \) (type 3 & 2 tracks: 2 same sign tracks only)
- \( |\phi(\tau) - \phi(\mu)| > 2.5 \)
• QCD w/ mainly from $b\bar{b}$ not removed by isolation requirement
  - removed by subtracting equal sign (ES) $-\tau$ pairs from opposite sign (OS) distributions, corrected by a factor of 4% for the excess of OS over ES expected for QCD background
• $Z/\gamma^*\rightarrow \mu\mu$ with one misidentified as a $\tau$
  - removed by applying a cut on the $E$ deposited in the coarse hadronic layers around the track, should deposit more $E$ in the coarse hadronic layers than a $\tau$
• $W\rightarrow \nu+\text{jets}$ with one jet misidentified as a $\tau$
  - estimate contribution in data sample with one isolated, $p_T(\ ) > 20$ GeV/c, $0.2<NN<0.8$, $|\phi(\tau)-\phi(\ )|<2$, where we don’t expect much $Z\rightarrow\tau\tau$ signal.
  - expect excess of OS events because high percentage of $W\rightarrow \nu+\text{jets}$ comes from quark jets
  - solve equations to estimate $N_W$

\[
N_W + N_{QCD} = N_{OS} + N_{ES} \\
0.26 N_W + 0.02 N_{QCD} = N_{OS} - N_{ES}
\]

known OS/ES excesses
Extracting $\sigma^* \text{Br}$ measurement

- the total background in OS events is estimated by summing $1.04 \times \text{ES}$, $W \rightarrow \nu (MC)$, $Z/\gamma^* \rightarrow$
- Data = OS - estimated background

8562 $\tau^-$ pairs selected with NN cut $> 0.3$
1946 OS $\tau^-$ pairs selected with NN cut $> 0.8$

- $48 \pm 14$ $W \rightarrow \nu + \text{jets}$
- $81 \pm 17$ $Z/\gamma \rightarrow$
- $909 \pm 18$ QCD $w/\mu$

final selection 1946 events with $\sim 55\%$ background

Event efficiencies for the different types of $\tau$ (including branching ratios):

- * type 1 : 0.35 %
- * type 2 : 1.61 %
- * type 3 : 0.79 %
Selected tau, muon transverse momenta and invariant masses

- Tau transverse momentum
- Muon transverse momentum
- Invariant tau track + muon mass
Check input distributions of NN

Fit $Z \rightarrow \tau\tau$
content in OS
- $\tau$ pairs
($|\varphi(\tau) - \varphi(\mu)| > 2.7$)
from $p_T$ shape

Tau candidate $p_T$ after NN cut

Cluster width after NN cut

$\Sigma p_T$ additional tracks / $\Sigma p_T$
all tracks after NN cut

Cluster profile after NN cut
Result on $\sigma \cdot \text{Br}$ for $Z \to \tau\tau$

\[ \text{BR} = \frac{N_{\text{evts}}}{N_{\text{total}}} \frac{N_{\text{bkg}}}{Ldt} \]

- $N_{\text{evts}}$: number of events observed
- $N_{\text{bkg}}$: number of background estimated
- $\int Ldt$: luminosity: $207\pm13.5$ pb$^{-1}$
- $\epsilon_{\text{total}}$: total efficiency
  \[ \epsilon_{\text{total}} = \epsilon_{\text{evt}} \epsilon_{\text{trig}} \Delta(\text{MC-data}) \]
  \[ = (0.0275\pm0.0004) \times (0.65\pm0.02) \times (0.925\pm0.032) \]

\[ \sigma \cdot \text{Br}(Z \to \tau\tau) = 256 \pm 16(\text{stat}) \pm 17(\text{sys}) \pm 16(\text{lumi}) \text{ pb} \]
R-parity violating supersymmetry with $\lambda_{133}$ coupling

Extension of MSSM superpotential

$\mathcal{W} = ijk (L_i L_j) E_k^c + ijk (Q_i L_j) D_k^c + ijk (U_i^c U_j^c D_k^c)$

violates conservation of R-parity

$R_p = (1)^{L+2B+3S}$

Susy particles produced in association with gauge couplings mainly $\tilde{t}_2 \tilde{t}_1^\pm$

LSP decays in SM particles:

Final states with $\lambda_{133}$ coupling:

- 2 $\tau$ + 2 electrons + $\slashed{E}_T$
- 3 $\tau$ + 1 electron + $\slashed{E}_T$
- 4 $\tau$ + $\slashed{E}_T$

→ Look for 2 isolated electrons plus at least 1 hadronic $\tau$
Event selection

* 2 electrons with $M_{ee} > 18 \text{ GeV/c}^2$
* $M_{ee} < 80 \text{ GeV/c}^2$
* at least one hadronic τ of type 1 or 2, identified with NN cuts, veto on electrons and muons applied

* $E_T / \sqrt{SE_T} > 1.5$
  → signal exhibits moderate $E_T$
  → takes into account statistical fluctuations of QCD jets
  mismeasurements
  → removes Z Drell-Yan with low $E_T$

0 events selected for $1 \pm 1.32$ expected from SM and instrumental backgrounds
Excluded at 95% C.L.:

\[ m(\tilde{\tau}^0_1) < 66 \text{ GeV}/c^2, m(\tilde{\tau}^\pm_1) < 119 \text{ GeV}/c^2 \text{ for } \tan\beta = 10, > 0, m_0 = 80, A_0 = 0 \]

mSUGRA parameter space with stau lighter than \( \tilde{\tau}^\pm_1 \), expect additional taus from the cascade: \( \tan\beta = 10, > 0, m_0 = 80, A_0 = 0 \)

\(~ 2 - 4 \text{ events selected in signal}~\)
Preliminary studies for $\sigma(t\bar{t})$ in lepton + $\tau$ channel, $Higgs \rightarrow \tau\tau$, R–Parity violating susy stop $\rightarrow \tau b$, trilepton mSUGRA at high $\tan(\beta)$ underway!

Backup slides
Systematic errors on $\sigma \cdot \text{Br}(Z\to \tau\tau)$ and RPV susy search with $\lambda_{133}$ coupling

<table>
<thead>
<tr>
<th>$\sigma \cdot \text{Br}(Z\to \tau\tau)$</th>
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<tbody>
<tr>
<td>cluster width cut &lt; 1 %</td>
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<tr>
<td>Energy scale 2.5 %</td>
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<tr>
<td>NN (excluding energy scale) 2.6 %</td>
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<tr>
<td>QCD background 2 %</td>
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<tr>
<td>$W\rightarrow \nu +$ jets background 1.7 %</td>
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<tr>
<td>$\epsilon_{\text{data}}/\epsilon_{\text{MC}}$ (from $\tau-$Id) 2.5 %</td>
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<tr>
<td>$\epsilon_{\text{data}}/\epsilon_{\text{MC}}$ (from $-\text{Id}$) 2.5 %</td>
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<tr>
<td>Trigger 2 %</td>
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<td><strong>Total 6.3 %</strong></td>
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</tbody>
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- systematic errors on signal were obtained by rescaling in MC $E_T$ and input variables distributions and recalculate NN output after rescaling
- systematic errors for backgrounds:
  - QCD : error of OS/ES estimate
  - $W\rightarrow \nu +$ jets : difference $N_W$ data / MC predicton

<table>
<thead>
<tr>
<th><strong>RPV search with $\lambda_{133}$</strong></th>
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<tbody>
<tr>
<td>Luminosity 6.5 %</td>
</tr>
<tr>
<td>backgrounds 5% – 8%</td>
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<tr>
<td>$\epsilon_{\text{data}}/\epsilon_{\text{MC}}$ (from $\tau-$Id) 12.5 %</td>
</tr>
<tr>
<td>$\epsilon_{\text{data}}/\epsilon_{\text{MC}}$ (from electron-$\text{Id}$) 2 %</td>
</tr>
<tr>
<td>Trigger up to 7 %</td>
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<td><strong>~ 20 % for signal</strong></td>
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- $\epsilon_{\text{data}}/\epsilon_{\text{MC}}$ (from $\tau-$Id) determined from NN efficiency in data using fit on pT shape to estimate $Z\rightarrow \tau\tau$
- errors on background processes from cross sections errors