Identification of τ lepton at the DØ experiment

Romain MADAR[a]

[a]Service de Physique des Particules
CEA Saclay, Irfu/SPP - France

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Overview

1. **Motivations**
2. **τ lepton properties & reconstruction**
3. **Understanding of τ_{had} object**
   - τ_{had}/jet discrimination
   - τ energy calibration
4. **Identification improvements**
   - New discriminating observables
   - Multivariate analysis optimization
5. **Conclusions and outlooks**

Motivations

SUSY SM extention

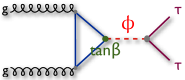
- $\tilde{q}$, $\tilde{g}$,
- weak gauginos, ...

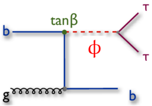
$\Big\}$ cascade decays can end with τ's

Higgs sector of MSSM After $SU(2)_L \times U(1)_Y$ symmetry breaking :

1. 3 neutral Higgs fields $\phi \equiv (H^0, h, A)$,
2. 2 charged Higgs fields H^+, H^-.

For the neutral Higgs search :



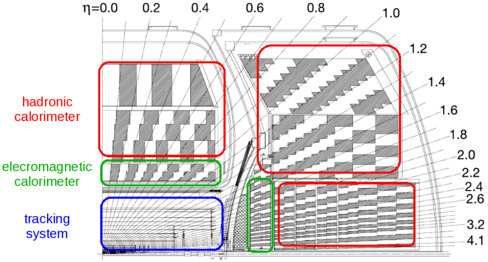


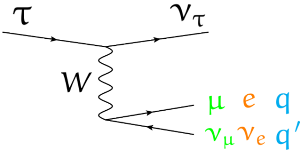
- ϕ decays in $\tau\tau$ (10%) and $b\bar{b}$ (90%)
- but $b\bar{b}$ final state : multijet bkg

$$\boxed{\text{Sensitive process : } p\bar{p} \to \phi \to \tau\tau}$$

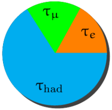
The τ lepton and its reconstruction

Physical properties : $m_\tau = 1.78$ GeV, $c\tau_{\text{life}} = 87\ \mu\text{m}$





BR_τ

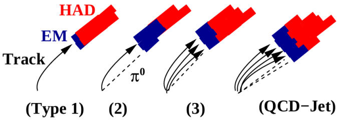


We will focus on **hadronic decay of τ** : τ_{had}

Reconstruction and DØ τ type definition for <u>hadronic</u> decay :

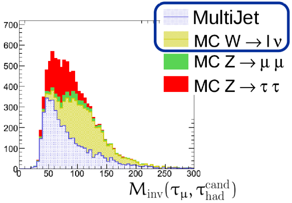
- DØ type 1 ≡ 1 trk, HAD deposit $\sim \tau^\pm \rightarrow \pi^\pm \nu_\tau$
- DØ type 2 ≡ 1 trk, EM and HAD deposit $\sim \tau^\pm \rightarrow \rho^\pm (\rightarrow \pi^0 \pi^\pm)\nu_\tau$
- DØ type 3 ≡ at least 2 trks, HAD deposit $\sim \tau^\pm \rightarrow a_1^\pm (\rightarrow \pi^\pm \pi^\mp \pi^\pm)\nu_\tau$

Identification of true τ



$\tau_{had} \approx$ narrower jet with lower track multiplicties

Jets could have the same experimental signatures as hadronic τ and need to be removed.



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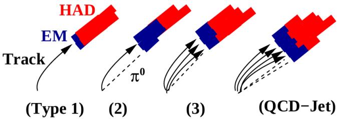

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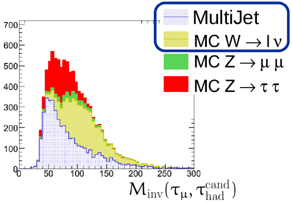
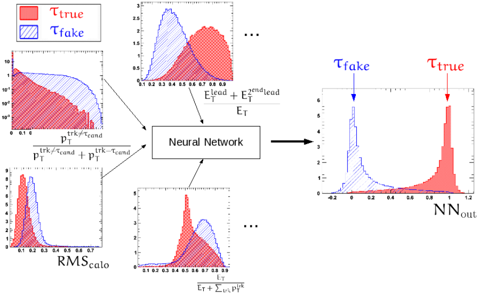


~ 12 discrimating observables

- track isolation,
- calo isolation,
- shower shape,
- trk-cal correlations.



E_τ calibration : "E/p correction"

Known effect

The calorimeter response is slightly different in the simulation and in data.
$\tau_{measured} \equiv \{\gamma, \pi^\pm\}$ energy **needs a relative correction**.

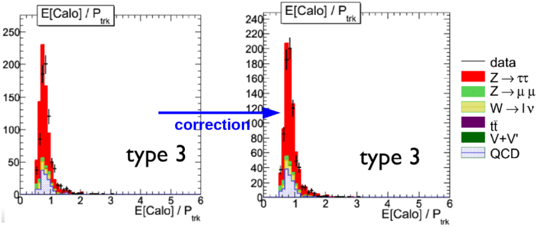
Correction method

Use the track energy as reference to correct simulation event by event :

$$\left(\frac{E}{p}\right)_{MCcorr} = \left(\frac{E}{p}\right)_{MC} \times \frac{\langle E/p \rangle_{data[Z \to \tau\tau]}}{\langle E/p \rangle_{MC}}$$

with

- $E/p \equiv E^{calo}/p^{trk}$
- $\langle E/p \rangle \equiv$ average value.



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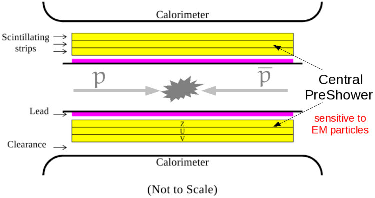
Central PreShower (CPS) for type 2

Physical idea. Exploit specific resonance of τ **type** 2 decay : $\tau^{\pm} \to \rho^{\pm}\nu \to \pi^{\pm}\pi^{0}\nu$. Use Central PreShower detector with fine segmentation : $\Delta\phi_{\mathrm{CPS}} \simeq 0.1 \times \Delta\phi_{\mathrm{calo}}$

$$\boxed{\mathrm{CPS}_{\mathrm{cluster}} \approx \pi^{0} \;,\; \mathrm{trk} \approx \pi^{\pm}}$$



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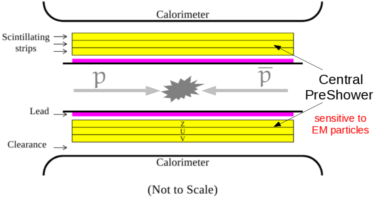
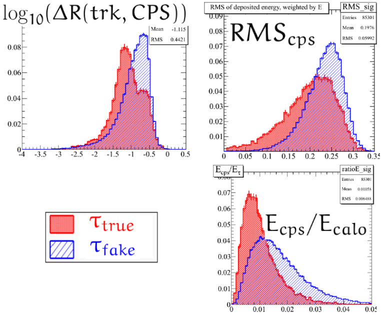
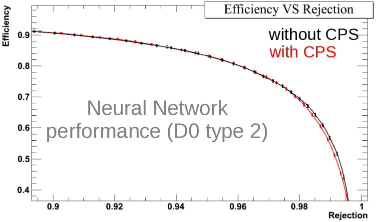
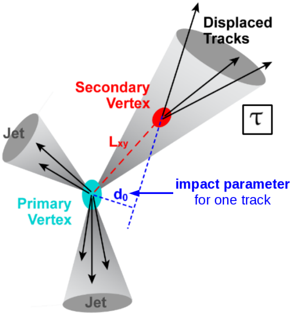






No significant improvement

τ is a long lived particle



Use impact parameter to remove jets faking τ more efficiently.
(large $c\tau_{\mathrm{life}} \Rightarrow$ large d_0)

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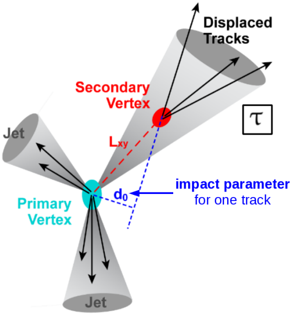

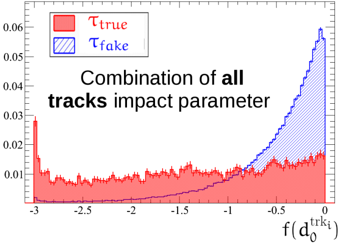

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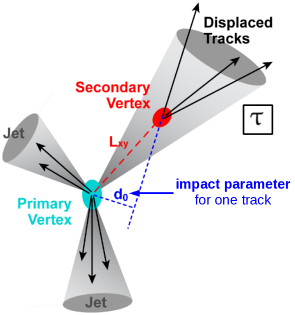

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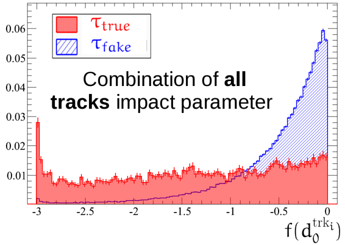
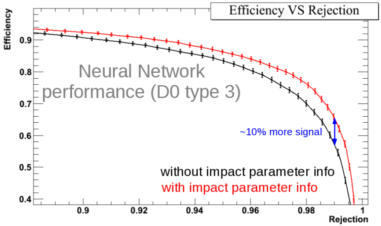


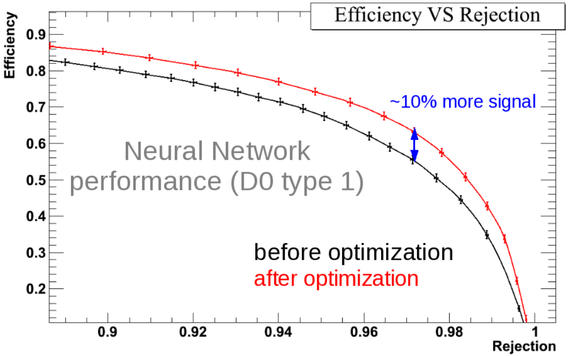


Clear improvement in performance !

Multivariate analysis optimization

- Change training sample from current DØ NN_τ : add τ_{cand} of low p_T,
- larger training sample,
- More epochs,
- More nodes.

} τ_{true}/τ_{fake} differences described in more details



Overview

Conclusions & outlooks

General :

- τ lepton is a key object to probe new physics as well as SM physics, (see Kathy and Melvin's talks).
- Understand these objects is an experimental challenge.

Last results for the DØ experiment :

- Use Central PreShower : no significant improvement,
- Use the decay length information : $\sim 10\%$ improvement.
- Optimize Multivariate analysis : $\sim 10\%$ improvement.

Future plans :

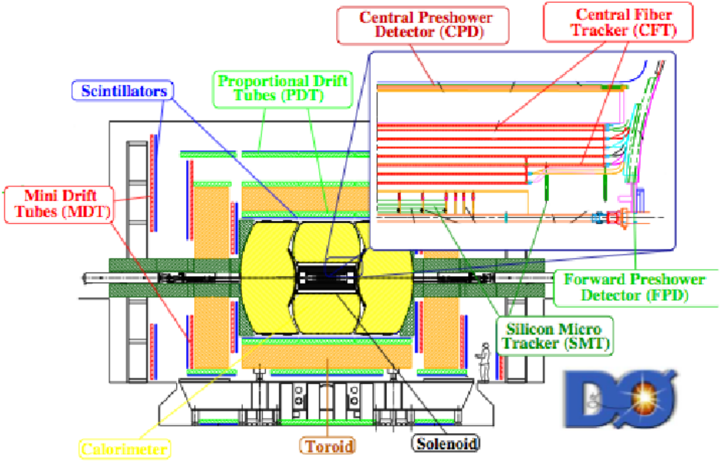
- Large contamination of electrons : finer segmentation of PreShower could provide strong discriminant.

BACKUP SLIDES

DØ detector

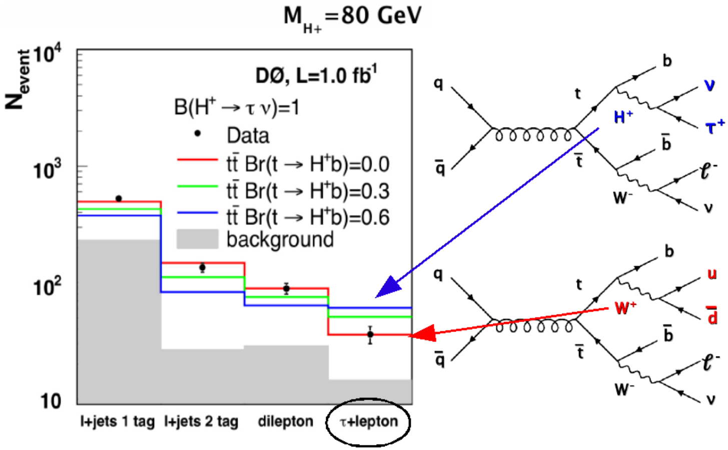
Multi purpose detector:

μ id, EM id, jets, taus, $\not{E}_T$, b-jets tagging



MSSM charged Higgs

Charged higgs bosons via $t\bar{t}$ events



Identification efficiency correction

Problem : ID efficiency ($\epsilon_{ID} \equiv \frac{N[\tau_{NN>cut}]}{N[\tau_{true}]}$) is better in MC than in data.

Solution : Measure ID eff in data and correct the simulation :

1. Build a pure τ data sample $\mathcal{S} \equiv \text{Data} - \sum_i \text{Bkg}_i \approx Z\tau\tau_{data}$,
2. All τ^{cand} from $\mathcal{S}$ is **assumed** to be a true τ : $\epsilon_{ID}^{data} = \frac{N[\tau_{NN>cut}]}{N_{tot}}$,
3. Correct the simulation to have $N_{MCcorr}[\tau_{NN>cut}] = N_{data}[\tau_{NN>cut}]$:

$$N_{MCcorr}[\tau_{NN>cut}] = \frac{\epsilon_{ID}^{data}}{\epsilon_{ID}^{MC}} \times N_{MC}[\tau_{NN>cut}]$$