$\tau \to 3\mu$ Status Update

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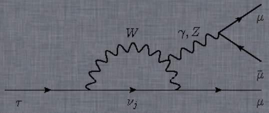

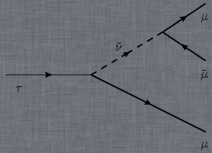

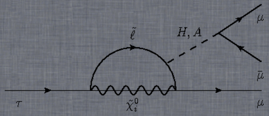

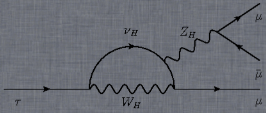

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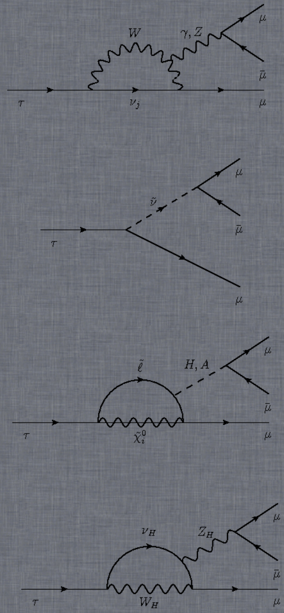

Status

1fb^{-1} analysis of $\tau \to \mu\mu\mu$ and $\tau \to p\mu\mu$ appeared in PLB.

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Searches for violation of lepton flavour and baryon number in tau lepton decays at LHCb ☆

LHCb Collaboration

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ABSTRACT

Searches for the lepton flavour violating decay $\tau^- \to \mu^-\mu^+\mu^-$ and the lepton flavour and baryon number violating decays $\tau^- \to \bar{p}\mu^+\mu^-$ and $\tau^- \to p\mu^-\mu^-$ have been carried out using proton–proton collision data, corresponding to an integrated luminosity of 1.0 fb^{-1}, taken by the LHCb experiment at $\sqrt{s} = 7$ TeV. No evidence has been found for any signal, and limits have been set at 90% confidence level on the branching fractions: $\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 8.0 \times 10^{-8}$, $\mathcal{B}(\tau^- \to \bar{p}\mu^+\mu^-) < 3.3 \times 10^{-7}$ and $\mathcal{B}(\tau^- \to p\mu^-\mu^-) < 4.4 \times 10^{-7}$. The results for the $\tau^- \to \bar{p}\mu^+\mu^-$ and $\tau^- \to p\mu^-\mu^-$ decay modes represent the first direct experimental limits on these channels.

2011 results:

1. Obtained limit for $\tau \to \mu\mu\mu$: 8.0×10^{-8}.
2. BaBar and Belle: $2.1(3.2) \times 10^{-8}$ at 90% CL.
3. For 2012 + 2011 planned to implement several improvements.

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MC Samples

1. In 2011 analysis one of the biggest contributions to the systematic error from MC was the reweighting the MC signal for the correct cross section.
2. For 2012 we solved this problem by simulating signal in 5 parts. One for each production channel(normalization to 1M events):

$$\tau \to \mu\mu\mu = \begin{cases} \mathrm{B} \to \tau \to \mu\mu\mu & 116,600 \\ \mathrm{B} \to \mathrm{D_s} \to \tau \to \mu\mu\mu & 87,200 \\ \mathrm{B} \to \mathrm{D} \to \tau \to \mu\mu\mu & 1,800 \\ \mathrm{D_s} \to \tau \to \mu\mu\mu & 750,600 \\ \mathrm{D} \to \tau \to \mu\mu\mu & 43,800 \end{cases}$$

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MC Generator Cuts

In order to reduce the number of unwanted events we introduced generator level cuts.

Signal sample[1]		Background sample(Dimuon)[2]	
$p_{t\mu}$	$> 250 MeV$	$p_{t\mu}$	$> 280 MeV$
p_{μ}	$> 2.5 GeV$	p_{μ}	$> 2.9 GeV$
		$m(\mu\mu)$	$< 4.5 GeV$
		DOCA$(\mu\mu)$	$< 0.35 mm$

Gain a factor of ~ 8 in statistics compared to 2011.

[1] $X \to \tau \to 3\mu$, $\mathrm{D_s} \to \eta(\mu\mu\gamma)\mu\nu$, $\mathrm{D_s} \to \phi(\mu\mu)\pi$
[2] $c\bar{c}$, $b\bar{b}$

Normalization channel

As last year we will use $\mathrm{D_s} \to \phi(\mu\mu)\pi$. Events are split into 2 categories:

1. *cc* $\to \mathrm{D_s} \to \phi(\mu\mu)\pi$ 897,000
2. *bb* $\to \mathrm{D_s} \to \phi(\mu\mu)\pi$ 103,000

We avoid reweighting of the samples as in 2011.

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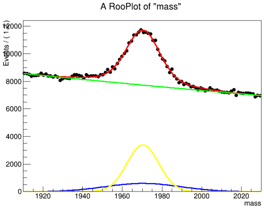
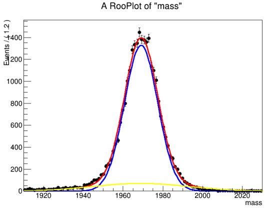
Mass correction

$D_s \to \phi(\mu\mu)\pi$ in data.



- mean = $1970.3 \pm 0.9 MeV$

$D_s \to \phi(\mu\mu)\pi$ in MC.

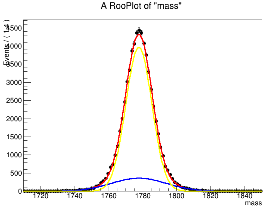


- mean = $1969.1 \pm 0.60 MeV$

- $m_{\tau\to3\mu} = \frac{1970.3}{1969.1} \times 1777.7 = 1778.8 \pm 1.1 MeV$

  In agreement with 2011.

Fit $\tau \to \mu\mu\mu$ in MC.



- mean = $1777.7 \pm 0.4 MeV$

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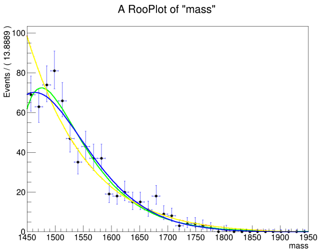
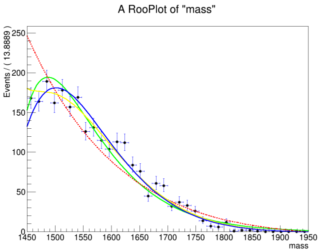
Peaking backgrounds

1. The dominant background source of peaking background in this analysis is $\mathrm{D_s} \to \eta(\mu\mu\gamma)\mu\nu$
2. In 2011 we suffered from lack of MC statistics.
3. Thanks to generator cuts our pdfs became more stable.



PID:0.65; 0.725,GEO:−0.48; 0.05



PID:0.725; 0.0.86,GEO:0.35; 0.65

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Normalization

For the normalization of background samples($c\bar{c}$ and $b\bar{b}$) we used generator cuts efficiencies and corrected the nominal cross section accordingly:

$$\mathcal{L} = \frac{N_{MC}}{\varepsilon_{acc} \times \varepsilon_{gen} \times \sigma LHCb}$$

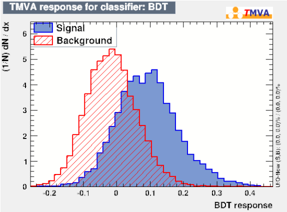
The obtained luminosities(per 1M events):

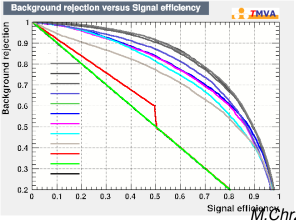
1. $\mathcal{L}_{cc} = 0.25 \pm 0.04 pb^{-1}$
2. $\mathcal{L}_{bb} = 1.20 \pm 0.15 pb^{-1}$

Dominant uncertainty from the cross section.

Isolating parameters

1. In 2011 we used the isolation parameter developed for $B^0_s \to \mu\mu$. For 2012 data we optimised the isolation parameter for our channel based on MVA(BDT).
2. Instead of training on isolating vs non-isoalting tracks we train on combinatorial background vs signal.
3. We see big improvement compared to old isolation.





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Ensemble Selection

1. In the last few years people winning leading machine learning contests started to combine their classifiers to squeeze the best out of them.
2. This technique/method is know as Ensemble Selection or Blending.
3. The plan for $\tau \to \mu\mu\mu$ is to take it to the next level.
4. Combine not only different channels, but also different τ sources(slide 4).

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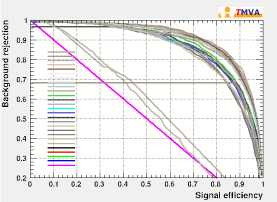
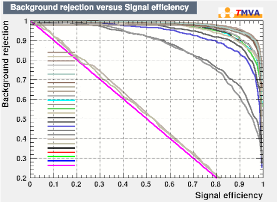
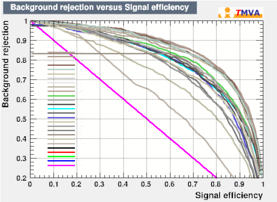
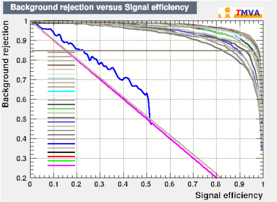
Ensemble Selection





- $\mathrm{B} \to \mathrm{D} \to \tau$
- $\mathrm{D} \to \tau$





- $\mathrm{B} \to \mathrm{D_s} \to \tau$
- $\mathrm{D_s} \to \tau$

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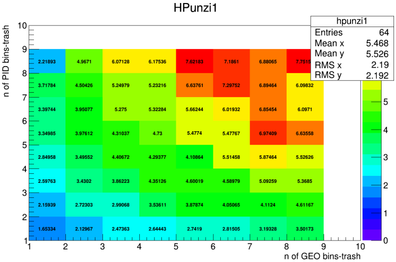
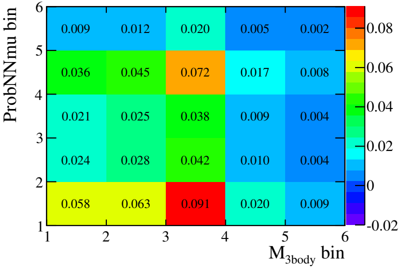
Binning optimisation

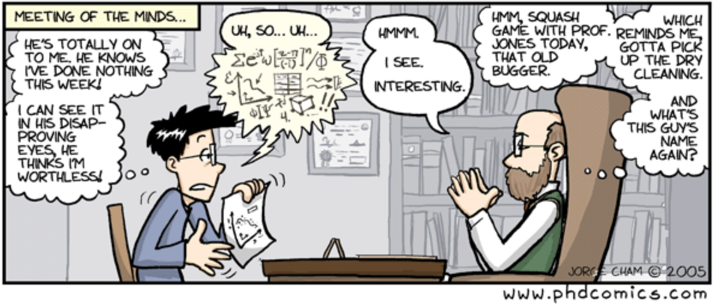
For the 2011 analysis we had two classifiers: *PIDNN* and M_{GEO}. Each of them we optimised separately. For the 2012 analysis we are performing a simultaneous 2D optimisation.





Conclusions

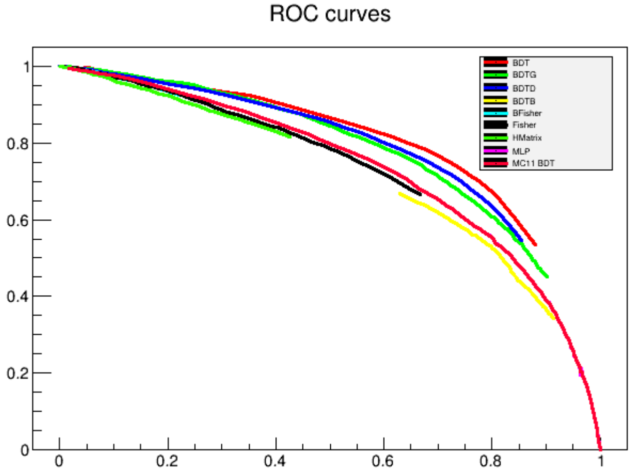
1. Analysis is well underway.
2. MC samples are almost there.
3. Hope to improve the selection.
4. $\tau \to p\mu\mu$ mode will be studied in parallel.



BACKUP

$B \to \tau$

We really suck in selecting this channel.



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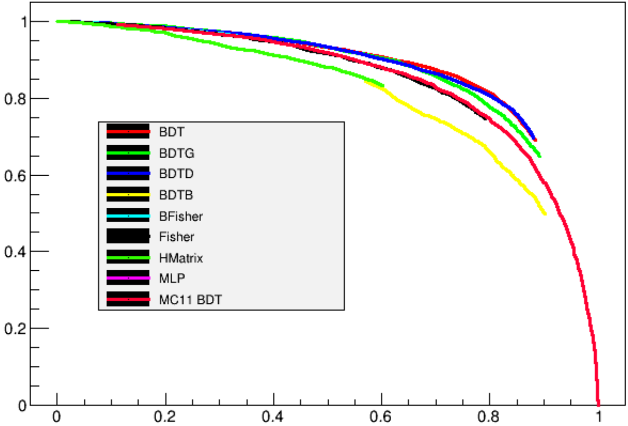
$B \to D_s \to \tau$

On the biggest contributing channel we are quite optimal.

ROC curves



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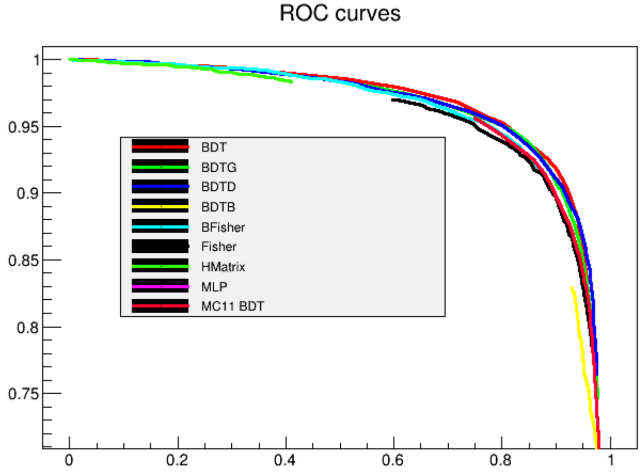
$D_s \to \tau$

On the biggest contributing channel we are quite optimal.



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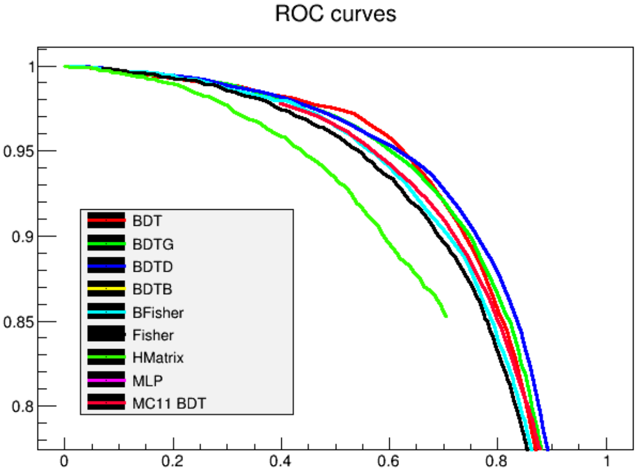
$B \to D^+ \to \tau$

On the biggest contributing channel we are quite optimal.



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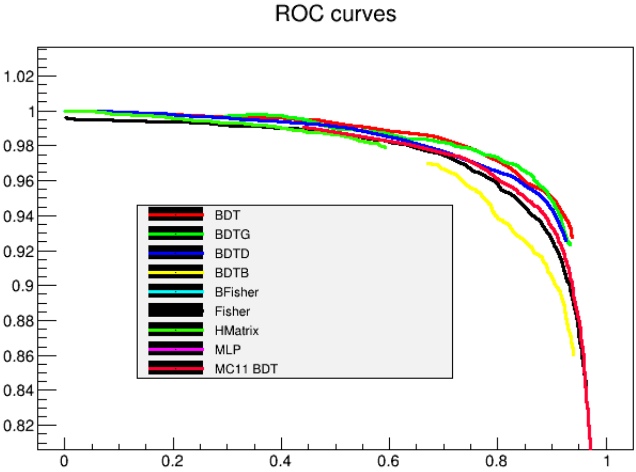
$D^+ \to \tau$

On the biggest contributing channel we are quite optimal.



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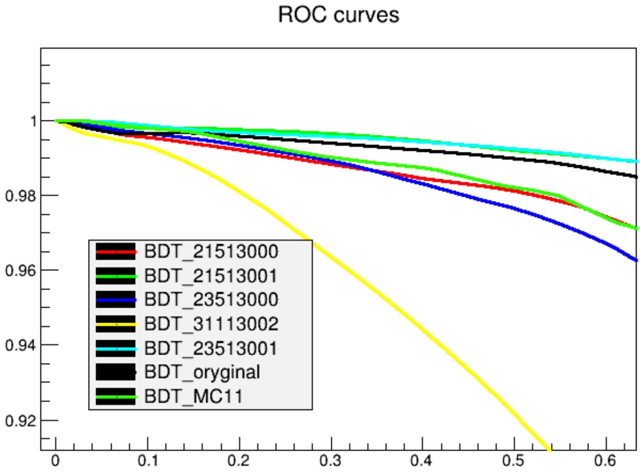
Comparison on mix sample

On the biggest contributing channel we are quite optimal.



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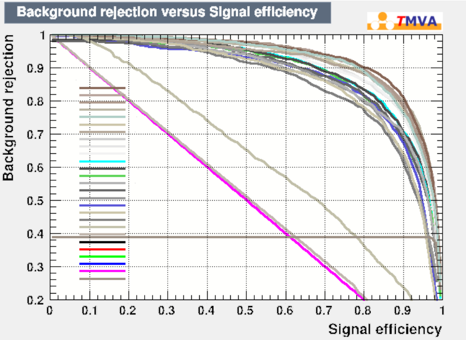
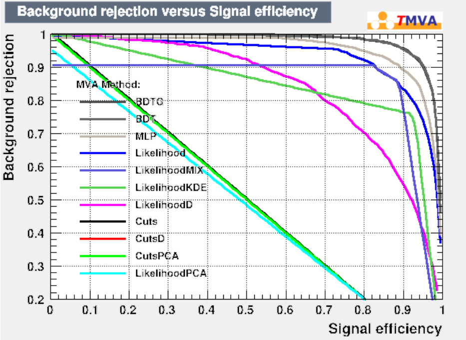
Conclusions on TMVA

- Each of the signal components is enormously larger than MVA trained on mix.
- Method looks very promising if we can find a nice blending method(work for next week).
- Mayby discusion on TMVA/MatrixNet/Neurobayes is next to leading order effect compared to this method?

Comparison on mix sample





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