Report on $\tau \to p\ell\ell$

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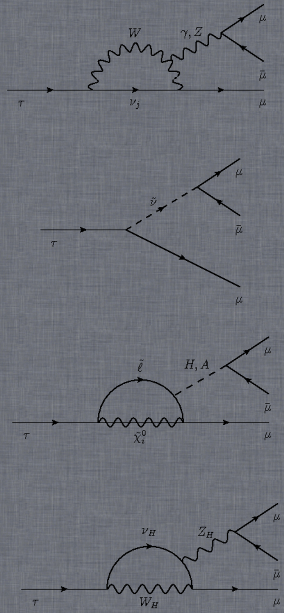


Motivation

MC & data

Preselection

- Geometric & Topology
- PID

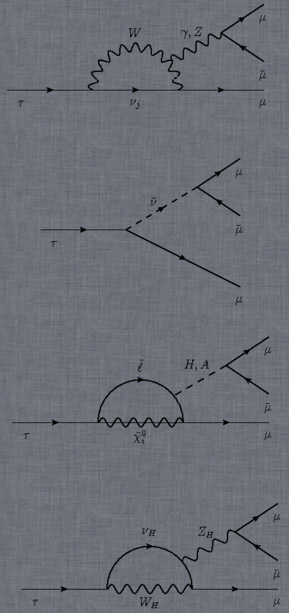
Selection

Fits

systematics

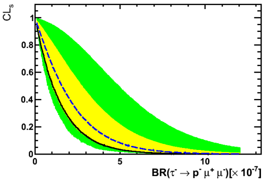
- MC systematics

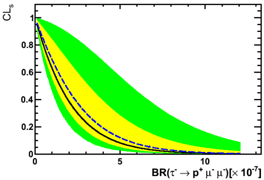
Results



Motivation

- Each of studied decay: $\tau^- \to p\ell^-\ell^-$ or $\tau^- \to \bar{p}\ell^-\ell^+$ violates Lepton and Baryon numbers.
- However the quantity: $\Delta|B-L|=0$, which is predicted by many NP models, ex. R-parity violating SUSY.
- LHCb searched for this decays($\ell=\mu$) using 2011 data.





Limits 90% CL: (can we do better?)
$\mathcal{B}(\tau^- \to p^+\mu^-\mu^-) < 4.4 \times 10^{-7}$
$\mathcal{B}(\tau^- \to \bar{p}^+\mu^+\mu^-) < 3.3 \times 10^{-7}$

Data Set used in this analysis.

Available data:
The MC signal samples used:

Decay	Generated events
$\tau^- \to p\mu^-\mu^-$	207000
$\tau^+ \to \bar{p}\mu^+\mu^+$	212000
$\tau^- \to \bar{p}\mu^+\mu^-$	212000
$\tau^+ \to p\mu^-\mu^+$	217000
$\tau^- \to pe^-e^-$	185000
$\tau^+ \to \bar{p}e^+e^+$	198000
$\tau^- \to \bar{p}e^+e^-$	191000
$\tau^+ \to pe^-e^+$	187000

Table: Simulated MC signal samples.

Data Set used in this analysis.

Available data:
Data: $472 fb^{-1}$ (run 1-6, on and off peak).
MC bck samples: Run 1-6

Background type	$\sigma[nb]$	$L[fb^{-1}]$
$e^- e^+ \to \tau\tau$	0.92	471
$e^- e^+ \to uu/dd/ss$	1.09	746
$e^- e^+ \to cc$	1.3	860
$e^- e^+ \to B\bar{B}$	1.1	1190

Table: MC background samples used in this analysis.

Preselection

We divide our pre selection cuts into two categories:

- Geometric & Topology
- PID

Geometric & Topology

The following selections are applied to data and MC samples:

- Trigger logic: (L3OutDch $\|$ L3OutEmc)&BGFMultiHadron.
- Pass the 1N skim.
- Events are divided into two hemispheres using the thrust axis:

$$thr = MAX\left(\frac{\sum_{i=0}^{n} |A \cdot P_i|}{\sum_{i=0}^{n} \sqrt{P_i \cdot P_i}}\right) \tag{1}$$

- Total charge =0 and opposite sign of the two hemispheres is required.

Geometric & Topology

The following selections are applied to data and MC samples:

- On the signal side we require 3 charged tracks from GoodChargeLoose list.
- Tag side is single charge track form the same list. 85% eff. in SM decays.
- A loose kinematic cuts are also applied:

Variable	Cut
P_t	$> 0.1 GeV$
P	$<10 GeV$
θ	$(0.41; 2.46)$

Table: Cuts applied for each track in the event.

Geometric & Topology

we found the following efficiencies:

Decay	ϵ_{Geo}	$\pm\delta\epsilon_{Geo}$
$\tau \to pe^- e^-$	35.3 %	0.1 %
$\tau \to \overline{p}e^+ e^-$	35.3 %	0.1 %
$\tau \to \overline{p}\mu^- \mu^-$	39.4 %	0.1 %
$\tau \to p\mu^- \mu^+$	39.3 %	0.1 %

Table: Efficiencies for signal MC.

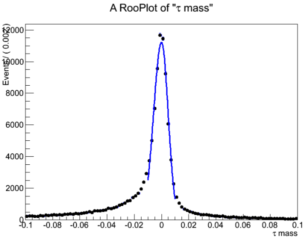
where we used:

$$\varepsilon = \frac{n+0.5}{k+1}, \delta\varepsilon = \sqrt{\frac{(n+0.5)(k-b+0.5)}{(k+2)(k+1)^2}}$$ [1]

[1] arXiv0908.0130

Energy constrain fit

We applied an Energy constrain fit for τ reconstruction(signal hemisphere is constrain to have $E_{cm}/2$ energy. This improves the mass resolution by $5-10\%$ depending on the decay mode.



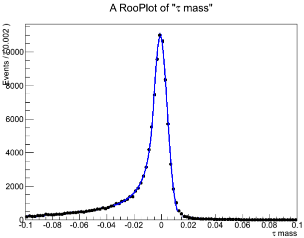
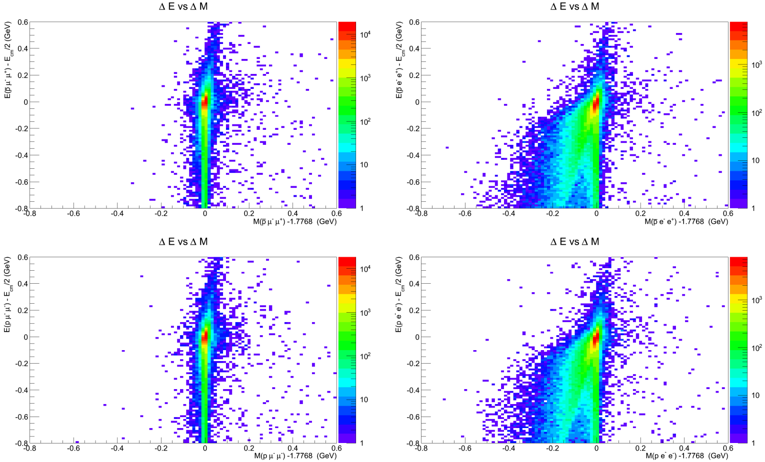


Figure: Fits to $\tau \rightarrow pe^-e^+$ mass. Left- with energy constrain. Right with Geo constrain.

Signal distribution.



PID

- We used the standard BaBar classifiers for the PID cuts.

Decay	e Classifier	μ Classifier	p Classifier	$\epsilon_{PID\|GEO}$
$\tau \to p\mu^-\mu^-$	DNA	BDTLoose	LooseKM	$34.5 \pm 0.1\%$
$\tau \to \bar{p}\mu^+\mu^-$	DNA	BDTLoose	LooseKM	$35.3 \pm 0.1\%$
$\tau \to pe^-e^-$	TightKM	DNA	LooseKM	$54.7 \pm 0.1\%$
$\tau \to \bar{p}e^+e^-$	TightKM	DNA	LooseKM	$55.1 \pm 0.1\%$

Table: Classifiers and efficiencies after the PID cut. DNA = does not apply

Selection

- Selection was optimised in order to get the best upper limit. For the optimisation the CLs method was used.
- The optimisation is done to reach the best separation of signal+background like hypothesis and background only hypothesis. We used the following figure of merit:

$$\Delta LQ = 2ln(Q_{SB}) - 2ln(Q_B)$$

where,

$$Q_{SB} = \prod \frac{P(s_i + b_i, s_i + b_i)}{P(s_i + b_i, b_i)}$$
$$Q_B = \prod \frac{P(b_i, s_i + b_i)}{P(b_i, b_i)}.$$

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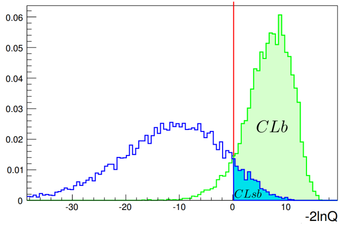
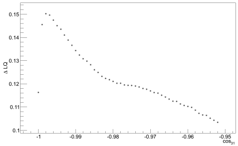
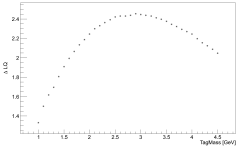
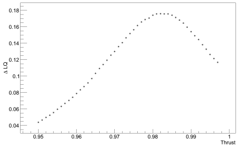
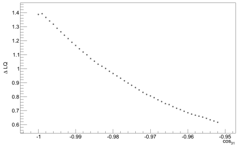


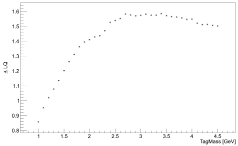
Optimisation results

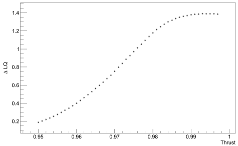












Efficiency after the selection

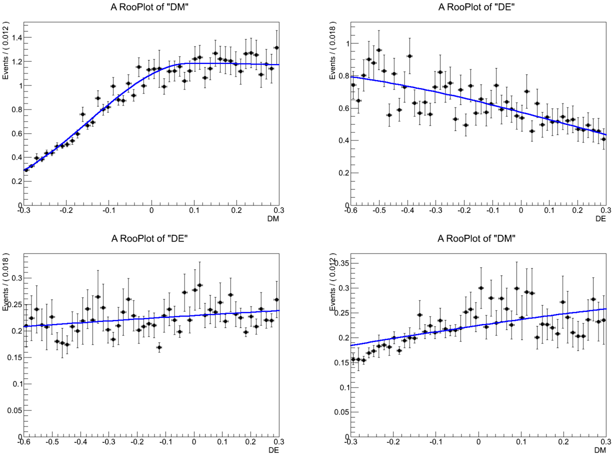
Decay	$\epsilon_{Sel\|PID}$	$\pm\delta\epsilon_{Sel\|PID}$
$\tau \rightarrow pe^{-}e^{-}$	41.8%	0.2%
$\tau \rightarrow \overline{p}e^{+}e^{-}$	47.7%	0.2%
$\tau \rightarrow \overline{p}\mu^{+}\mu^{-}$	75.2%	0.2%
$\tau \rightarrow p\mu^{-}\mu^{+}$	79.0%	0.2%

Table: Efficiencies for signal MC.

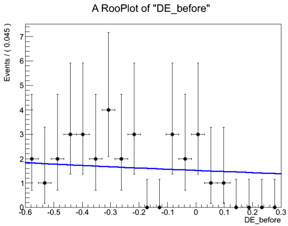
Background and fits

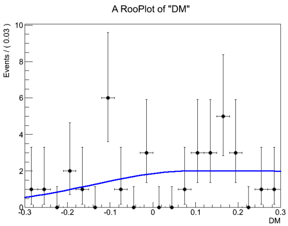
- Because only few events from $B\bar{B}$ background survive the geometric cut we will not consider this in further analysis.
- We used the PID weighting procedure as in $\tau \to \mu\mu\mu$ to determined the pdf shape. We consider 3 types of background: QED, *udsc* , $\tau\tau$.
- QED samples are evaluated directly on data.
- We sum the bck pdf and preform an Unbinned maximum likelihood fit to data side band to determine the expected number of bck events.

Fits to MC background



Fits to data


A RooPlot of "DE_before"
Events / (0.045)
DE_before


A RooPlot of "DM"
Events / (0.03)
DM

Expected background

Decay	Expected	Error
$\tau^- \to pe^-e^-$	0.30	0.09
$\tau^- \to \overline{p}e^+e^-$	1.08	0.13
$\tau^- \to \overline{p}\mu^+\mu^-$	0.81	0.15
$\tau^- \to p\mu^-\mu^-$	0.49	0.14

Table: Number of expected events in the signal window.

Systematics

We define three types of systematics:

- MC related
- Background systematics
- Luminosity systematics.

MC Systematics

Considered systematics:

- Signal systematics, limited MC statistics.
- τ BR.
- PID
- Tracking efficiency.

MC Systematics

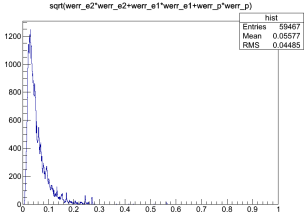
τ BR.

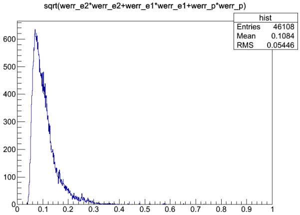
TAUOLA takes the SM branching fractions from PDG 2006. The systematic uncertainty related to the branching fraction errors is evaluated as a quadrature sum of the individual BF uncertainties weighted by their relative fraction.

MC Systematics

PID efficiency

The PID systematics is evaluated in a conservative way. We sum squared errors for each track on the tag side. Because the distribution is asymmetric the error is defined at 68% coverage.





MC Systematics

—	$\tau \to \bar{p}e^+e^-$	$\tau \to pe^-e^-$	$\tau \to \bar{p}\mu^+\mu^-$	$\tau \to p\mu^-\mu^-$
Total eff.	9.3	8.1	11.0	10.3
MC statistics	0.46	0.54	0.39	3.8
Tau BR	0.7	0.7	0.7	0.7
PID sig side	2.34	3.1	7.0	7.8
PID tag side	0.9	0.9	0.0	0.0
Tracking eff.	1.0	1.0	1.0	1.0
Total	2.7	3.4	7.1	7.9

Table: Total efficiency and systematic uncertainties expressed in relative percent

Expected UL at 90% CL

Decay	Expected UL
$\tau^- \to p e^- e^-$	3.2×10^{-8}
$\tau^- \to \bar{p} e^+ e^-$	4.0×10^{-8}
$\tau^- \to \bar{p} \mu^+ \mu^-$	3.5×10^{-8}
$\tau^- \to p \mu^- \mu^-$	2.5×10^{-8}

Table: Expected upper limits at 90% CL.

Conclusions

- Analysis in pretty good shape.
- Supporting documentation 20, pages, needs just polishing.
- With this presentation we ask to start an AWG review.