$\tau \to 3\mu$

Present limit : BR($\tau \to 3\mu$) > $4 \cdot 10^{-8}$

Is it possible to improve this limit in LHCb ?

How much ?

Parameters of DC06 Monte Carlo production

https://twiki.cern.ch/twiki/bin/view/LHCb/SettingsDc06?sortcol=0;table=3;up=0#sorted_table

CROSS SECTIONS

Min.Bias — $\sigma_{tot}(pp) = 102.9$ mb

$\sigma_{incl}(b\bar{b}) = 698\ \mu b$

$\sigma_{incl}(c\bar{c}) = 3643\ \mu b$

BRANCHING RATIOS

$Br(b \rightarrow \mu)_{incl} = 10.7\%$

$Br(b \rightarrow \tau)_{incl} = 2.9\%$

$Br(b \rightarrow D_s)_{incl} = 21\%$

$Br(D_s \rightarrow \tau\nu) = 6.4\%$

D_s PRODUCTION PROBABILITY FROM C

$P(c \rightarrow D_s) = 0.11$

Tau Production Cross Sections (4π geometry)

Main production channels

	Channel	Cross sections	
S1	$b \to \tau$ (excluding $b \to c \to \tau$)	$\sigma 1 = \sigma incl(bb) \cdot 2 \cdot Br(b \to \tau)incl$	40μb
S2	$b \to c \to \tau$ (cascade c-production)	$\sigma 2 = \sigma incl(bb) \cdot 2 \cdot Br(b \to Ds) \cdot Br(Ds \to \tau)$	19μb
S3	$c \to \tau$ (direct c-production)	$\sigma 3 \approx \sigma 4$	
S4	$Ds \to \tau$ (from direct c-production)	$\sigma 4 = \sigma incl(cc) \cdot 2 \cdot P(c \to Ds)incl \cdot Br(Ds \to \tau)$	51μb
S5	$X \to \tau$ (b&c excluding)		

Total $\sigma(\tau)$ = 110μb

Estimation of background yield

We assume that the main source of background is inclusive
$bb \to 2\mu$ events

Incl_b=DiMuon ~ 20M events

20M corresponds to luminosity = 3.9 pb^{-1}
(1/500 from the yield per year)

Signal events:
DC06-phys-v2-lumi2
31113001 – $\tau \to 3\mu$ ~50k events

Estimation of $\tau \to 3\mu$ yield

$\sigma_{tot}(\tau) = 110\ \mu b$

geometry LHCb acceptance $\varepsilon_{acc\_3\mu} = 27\%$

τ yield per year in LHCb geometry acceptance

(S1+S2+S3+S4 channels)

$N\tau(total) = 110\mu b \cdot 2fb^{-1} \cdot 0.27 = 5.9 \cdot 10^{10}$

However, separation of signals from background proved to be more effective for the Ds channel (S4-channel) .

Registration efficiency in S4-channel = 2.65%

Registration efficiency in S1&S2-channels ≈ 0.5 %

Therefore, our analysis was done mostly for S4-channel.

$N\tau(Ds \to \tau) = 51\mu b \cdot 2fb^{-1} \cdot 0.27 = 2.7 \cdot 10^{10}$

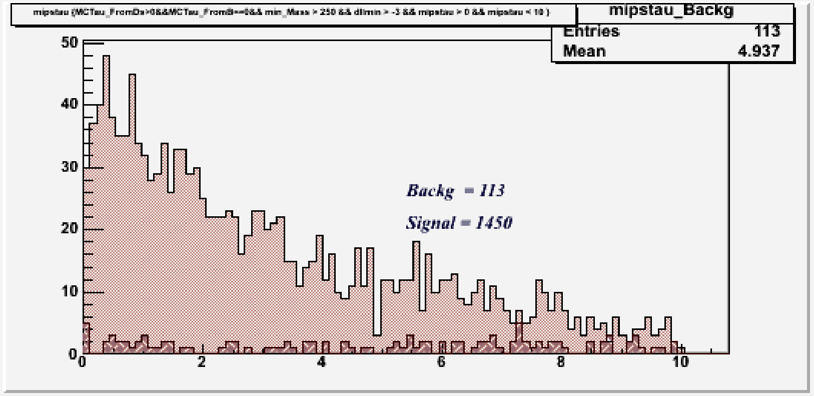
If $BR(\tau \to 3\mu) = 10^{-8}$

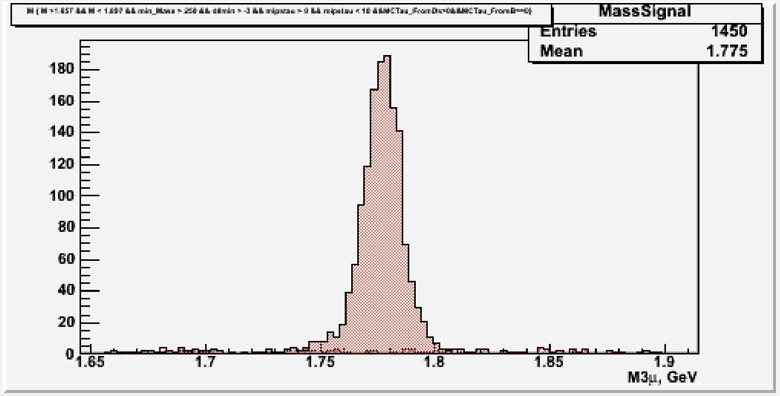
then number of detected $N(\tau \to 3\mu)$ =

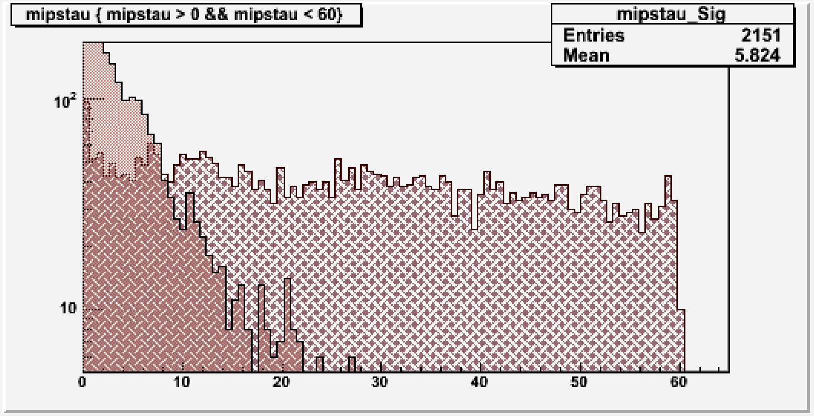
$= (2.65\% \cdot 2.7 \cdot 10^{10} + 0.5\% \cdot 3.2 \cdot 10^{10}) \cdot BR(\tau \to 3\mu) =$

= 9 events per $2fb^{-1}$.

min_Mass > 250 && dllmin > -3 && mipstau > 0 && mipstau < 10







mipstau > 0 && mipstau < 10

Background and Signal after the cut:
min_Mass > 250 && dllmin > -3 && mipstau > 0 && mipstau < 10
Rejection / Efficiency in mass window $M\tau \pm 30$ Mev.

*Rej = 16144/112 = 144.1 .   Signal Eff = (1361/2012) * 100% = 67.64%*

Backg.root . Input = 14810 / 16304
Signal.root . Input = 51693 / 6175

Sun Dec 14 23:01:23 2008

Step-by-step cut application

Backgound after stripping cuts Nbg = 16144

Ds sample with stripping cuts applied Nsg = 2012

	Variable	Nbg	Nsg	Backg. Rej.	Signal Eff.[%]
1	Minmass(2μ) > 250 Mev	5976	2000	2.7	99.4
2	dLL (μ) > -3	1910	1620	8.5	80.5
3	0 <IPS(τ) < 10	112	1361	144	67.7
4	Cos(dira) > 0.99999	41	957	394	47.6
5	0.07 < tdot < 1.0	39	954	414	47.4
6	13GeV < maxP (μ) < 100GeV	31	845	521	42
7	0.3GeV < minPT (μ) < 5GeV	8	721	2018	35.8
8	L0	1	625	16144	31

Nbg – number of BG in mass window m_τ ±120 MeV

Nsg – number of signals in mass window m_τ ±30 MeV after BG subtraction

Step-by-step cut application

Backgound After stripping Nbg = 16144

Ds sample with stripping cuts applied Nsg = 2012

	Variable	Nbg	Nsg	Backg. Rej.	Signal Eff.[%]
1	Minmass(2μ) > 250 Mev	5976	2000	2.7	99.4
2	dLL (μ) > -3	1910	1620	8.5	80.5
3	0.6 < IPS(τ) < 10	102	1163	158	57.8
4	Cos(dira) > 0.99999	31	770	521	38.3
5	0.07 < tdot < 1.0	30	768	538	38.2
6	13GeV < maxP (μ) < 100GeV	24	692	673	34.4
7	0.3GeV < minPT (μ) < 5GeV	2	585	8072	29.1
8	L0	0	506	∞	25.2

Nbg – number of BG in mass window m_τ ±120 MeV

Nsg – number of signals in mass window m_τ ±30 MeV after BG subtraction

Results

Background rejection and signal efficiency after all cuts applied.

	Nbg	Signal efficiency	
		S4 (Ds $\rightarrow \tau$)	S1+S2
A	1	2.65%	0.5%
B	0	2.14%	0.4%

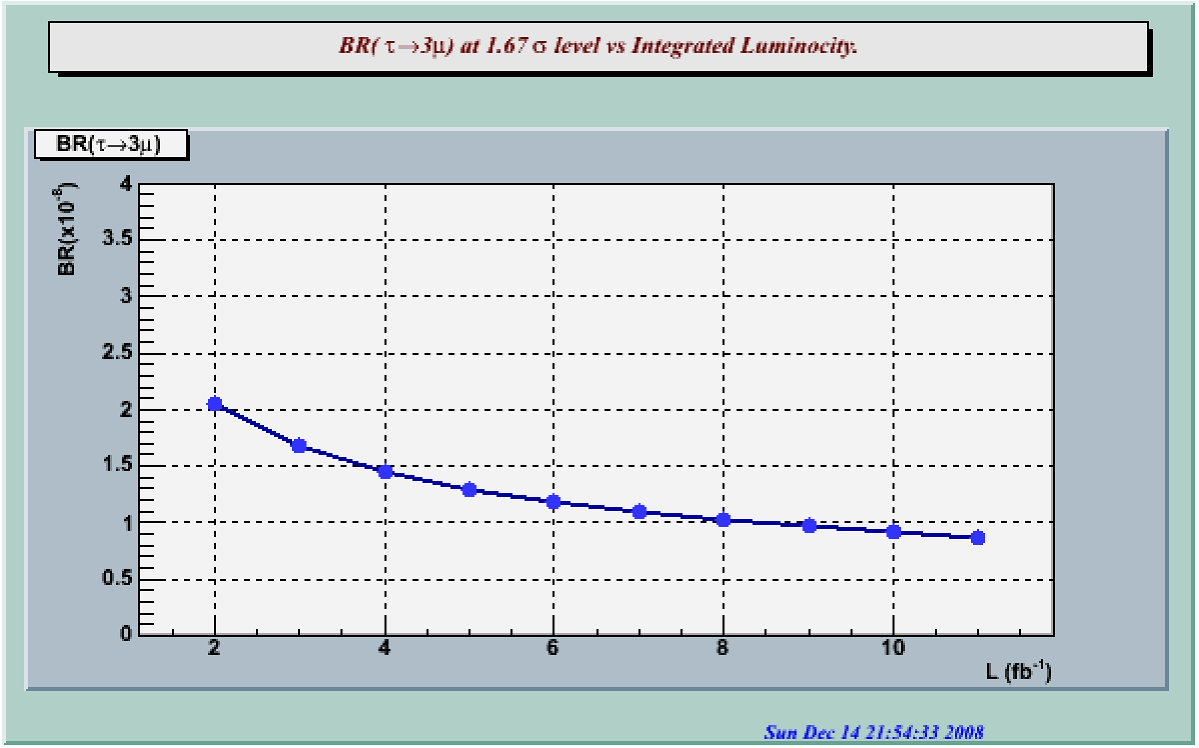
Nbg – number of Bg events in mass window m_τ = ±120 MeV
Signal efficiency in m_τ = ±30 MeV

Hopefully, the efficiency could be increased by a factor of 2 optimizing the preselection cuts

Results

After cuts Nbg = 1 in mass window m_τ = ±120 MeV
At L = $2fb^{-1}$ Nbg = 500 in mass window $m\tau$ = ±120 MeV
At L = $2fb^{-1}$ Nbg = 125 in mass window $m\tau$ = ±30 MeV ($1.67 \cdot \sqrt{125} = 18$)

At L = 2fb-1 Nsg = 18 in mass window $m\tau$ = ±30 MeV at $BR(\tau \rightarrow 3\mu) = 2 \cdot 10^{-8}$



Hopefully, the UL can be pushed down by a factor of 2 by increasing the signal efficiency optimizing preselection cuts

Conclusion

The present analysis shows that
at LHCb it might be possible
to reach sensitivity up to
$BR(\tau \rightarrow 3\mu) = 10^{-8}$
at L = 5-8 fb-1