4th SuperB Collaboration Meeting

La Biodola, May 31st-June 4th 2012

Lepton number violation in τ and B decays

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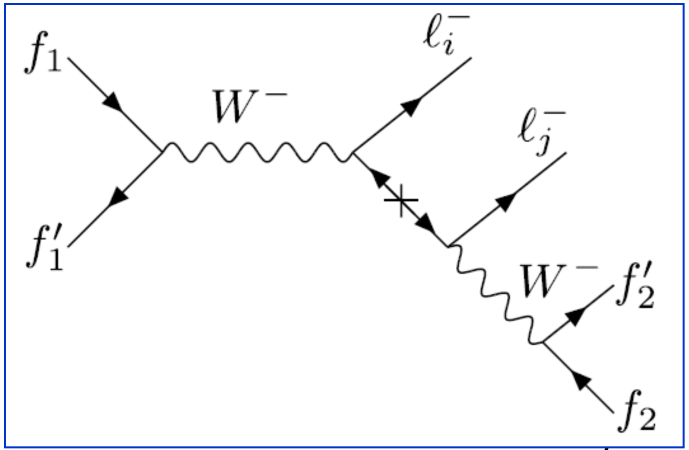
Motivations

- Masive neutrinos can be Dirac or Majorana
- Lepton number violation ($|\Delta L|=2$) signals of Majorana neutrinos

$$\left\{\begin{array}{l}
\bullet\ (A,Z) \rightarrow (A,Z+2)e^- e^- \\
\bullet\ M_1^{\pm} \rightarrow M_2^{\mp} l^{\pm} l'^{\pm}, \quad (M = meson) \\
\bullet\ \tau^{\pm} \rightarrow l^{\mp} M_1^{\pm} M_2^{\pm} \\
\bullet\ \Sigma^- \rightarrow \Sigma^+ e^- e^-, \ \ \Xi^- \rightarrow p \mu^- \mu^- \\
\bullet\ l^- \rightarrow l'^+ \quad conversion\ in\ nuclei \\
\bullet\ pp,\ p\bar{p} \rightarrow l^{\pm} l'^{\pm} X
\end{array}\right.$$

- Very light neutrinos $\rightarrow \langle m_{ll'} \rangle = \Sigma_i U_{il} U_{l'i} m_i$,
- Very heavy neutrinos $\rightarrow \Sigma_k V_{lk} V_{l'k} / m_k$,
- Resonant neutrinos $\rightarrow \Sigma_k V_{lk} V_{l'k} m_k / \Gamma_N$

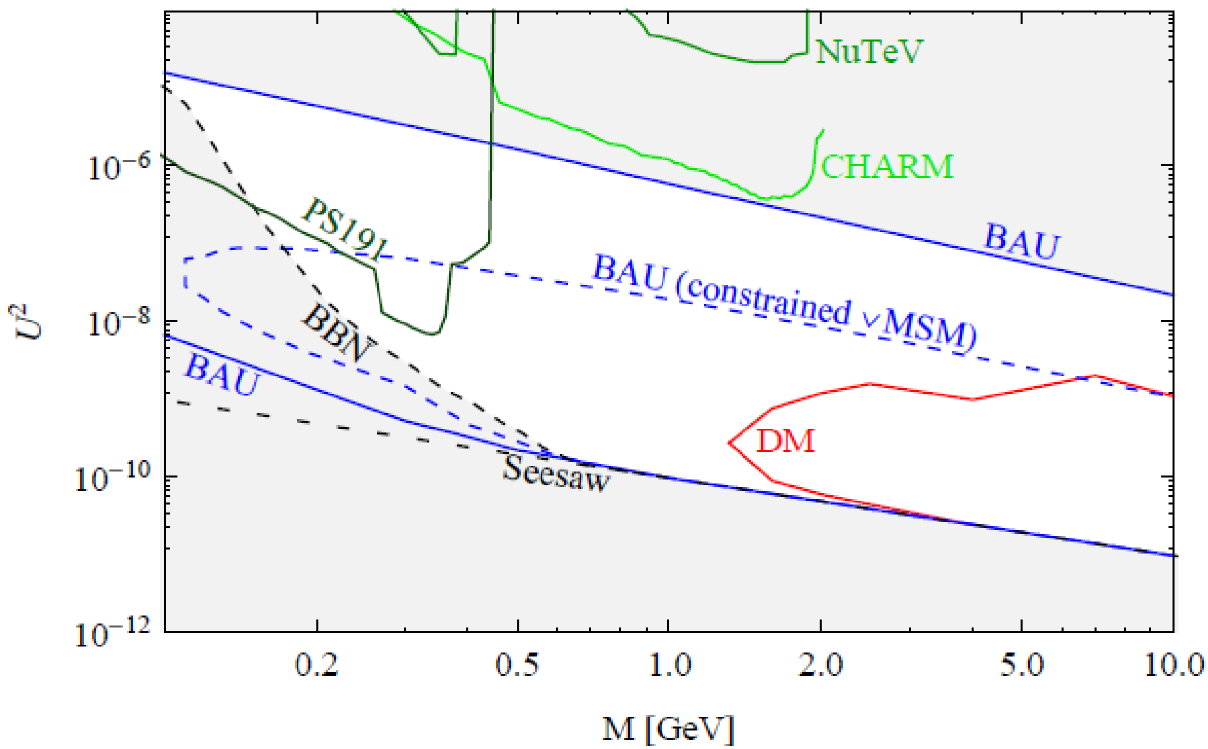


♦ Neutrino minimal Standard Model (νMSM), 3 right-handed singlets:

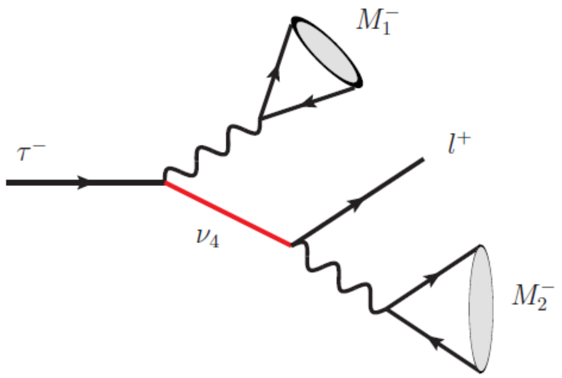
$$\nu_l = \sum_{i=1}^{3} U_{li}\nu_i + \sum_{N=4}^{n+4} V_{lN}\nu_N$$

* Asaka & Shaposhnikov, PLB620, 17 (2005);
* Shaposhnikov & Tkachev, PLB639, 414 (2006);
* Canetti, Drewes and Shaposhnikov, 1204.3902 1204.4186

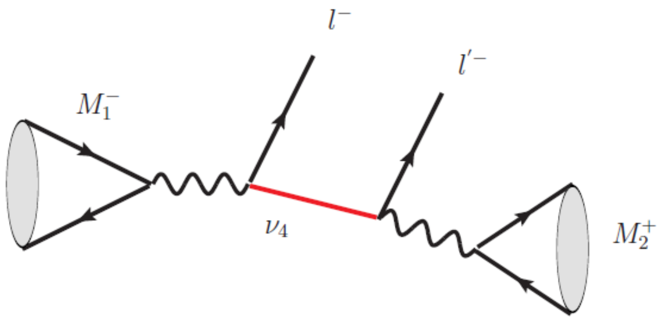
$$M = m_{N_{2,3}} \sim O(1GeV), \qquad BAU$$



3-body decays of mesons and τ's



$$\sim G_F^2 V_{\tau 4} V_{l4} m_4 F_{RES} V_{M_1}^{CKM} V_{M_2}^{CKM} f_{M_1} f_{M_2}$$



$$\sim G_F^2 V_{l4} V_{l'4} F_{RES} V_{M_1}^{CKM} V_{M_2}^{CKM} f_{M_1} f_{M_2}$$

$$F_{RES} \sim \left(q^2 - m_4^2 + i m_4 \Gamma_4\right)^{-1}$$

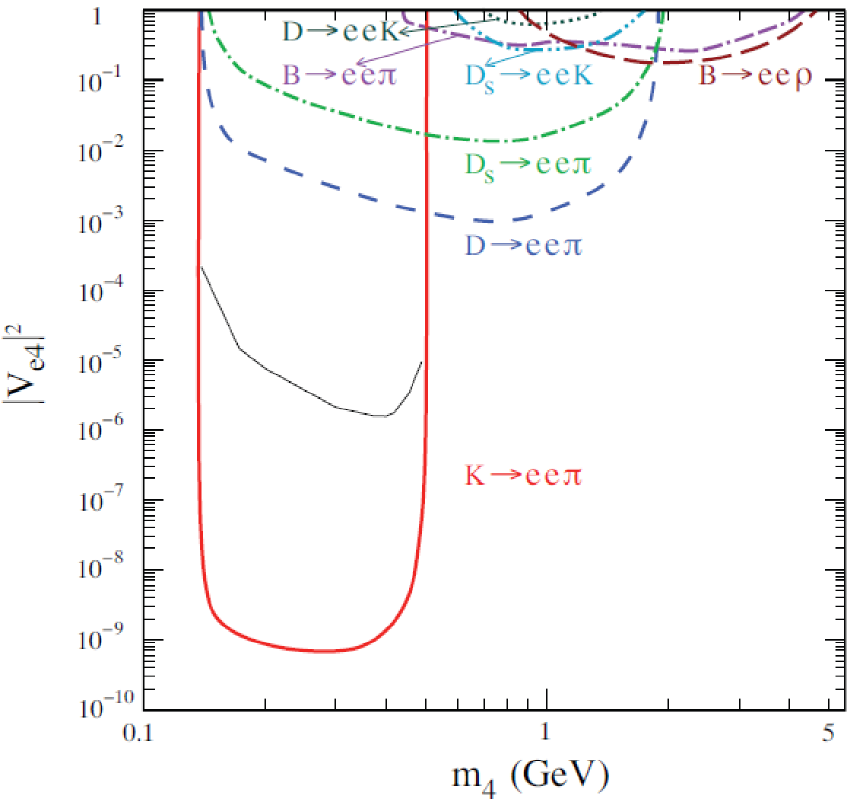
Resonance enhancement

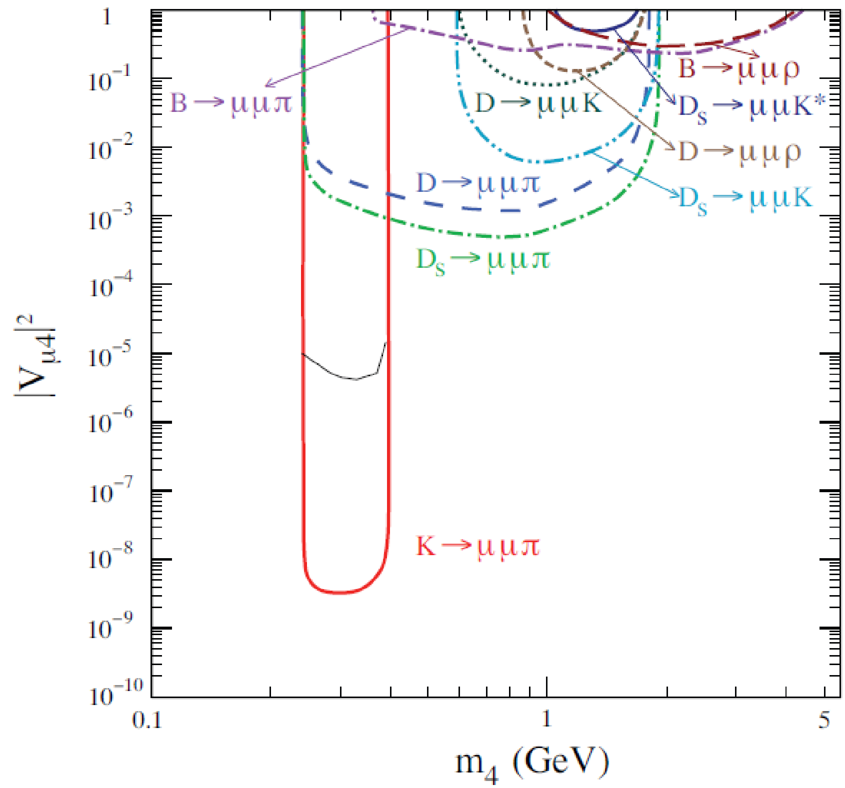
Atre, Han, Pascoli, & Zhang, JHEP **0905**, 030 (2009)
Helo, Kovalenko, & Schmidt, NPB853, 80 (2011)
Zhang & Wang, EPJC **71**, 1715 (2011)
Gribanov, Kovalenko & Schmidt, NPB607, 355 (2001).

Upper limits from charged mesons

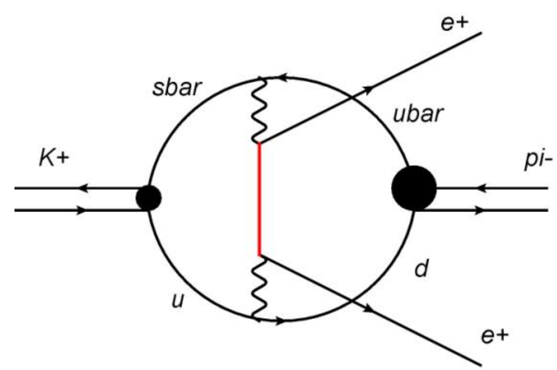
$K^+ \to \pi^- e^+ e^+$	6.4×10^{-10}			
$K^+ \to \pi^- \mu^+ \mu^+$	3.0×10^{-9}	PDG		
$K^+ \to \pi^- e^+ \mu^+$	5.0×10^{-10}			
$D^+ \to \pi^- e^+ e^+$	1.9×10^{-6}	$D_s^+ \to \pi^- e^+ e^+$	4.1×10^{-6}	
$D^+ \to \pi^- \mu^+ \mu^+$	2.0×10^{-6}	$D_s^+ \to \pi^- \mu^+ \mu^+$	14×10^{-6}	
$D^+ \to \pi^- e^+ \mu^+$	2.0×10^{-6}	$D_s^+ \to \pi^- e^+ \mu^+$	8.4×10^{-6}	BABAR1
$D^+ \to K^- e^+ e^+$	0.9×10^{-6}	$D_s^+ \to K^- e^+ e^+$	5.2×10^{-6}	
$D^+ \to K^- \mu^+ \mu^+$	10×10^{-6}	$D_s^+ \to K^- \mu^+ \mu^+$	13×10^{-6}	
$D^+ \to K^- e^+ \mu^+$	1.9×10^{-6}	$D_s^+ \to K^- e^+ \mu^+$	6.1×10^{-6}	
$B^+ \to \pi^- e^+ e^+$	2.3×10^{-8} BABAR2	$B^+ \to D^- e^+ e^+$	2.6×10^{-6} Belle	
$B^+ \to \pi^- \mu^+ \mu^+$	10.7×10^{-8} BABAR2	$B^+ \to D^- \mu^+ \mu^+$	1.8×10^{-6} Belle	
	1.3×10^{-8} LHCb		6.9×10^{-7} LHCb	
$B^+ \to \pi^- e^+ \mu^+$	1.3×10^{-6} BABAR2	$B^+ \to D^- e^+ \mu^+$	1.1×10^{-6} Belle	
$B^+ \to K^- e^+ e^+$	3.0×10^{-8} BABAR2	$B^+ \to D_s^- \mu^+ \mu^+$	5.8×10^{-7} LHCb	
$B^+ \to K^- \mu^+ \mu^+$	6.7×10^{-8} BABAR2	$B^+ \to D^{*-} \mu^+ \mu^+$	2.4×10^{-6} LHCb	
$B^+ \to K^- e^+ \mu^+$	2.0×10^{-6} BABAR2			

BABAR1: J. P. Lees et al, PRD 84, (2011)
BABAR2: J. P. Lees et al, arXiv: 1202.3650
Belle: O. Seon et al, PRD 84 (2011)
LHCb: R. Aaij et al, PRL 104 (2011); arXiv: 1201.5600





-Atre, Han, Pascoli & Zhang, JHEP 0905, (2009);
-Helo, Kovalenko and Schmidt, NPB 853, (2011)



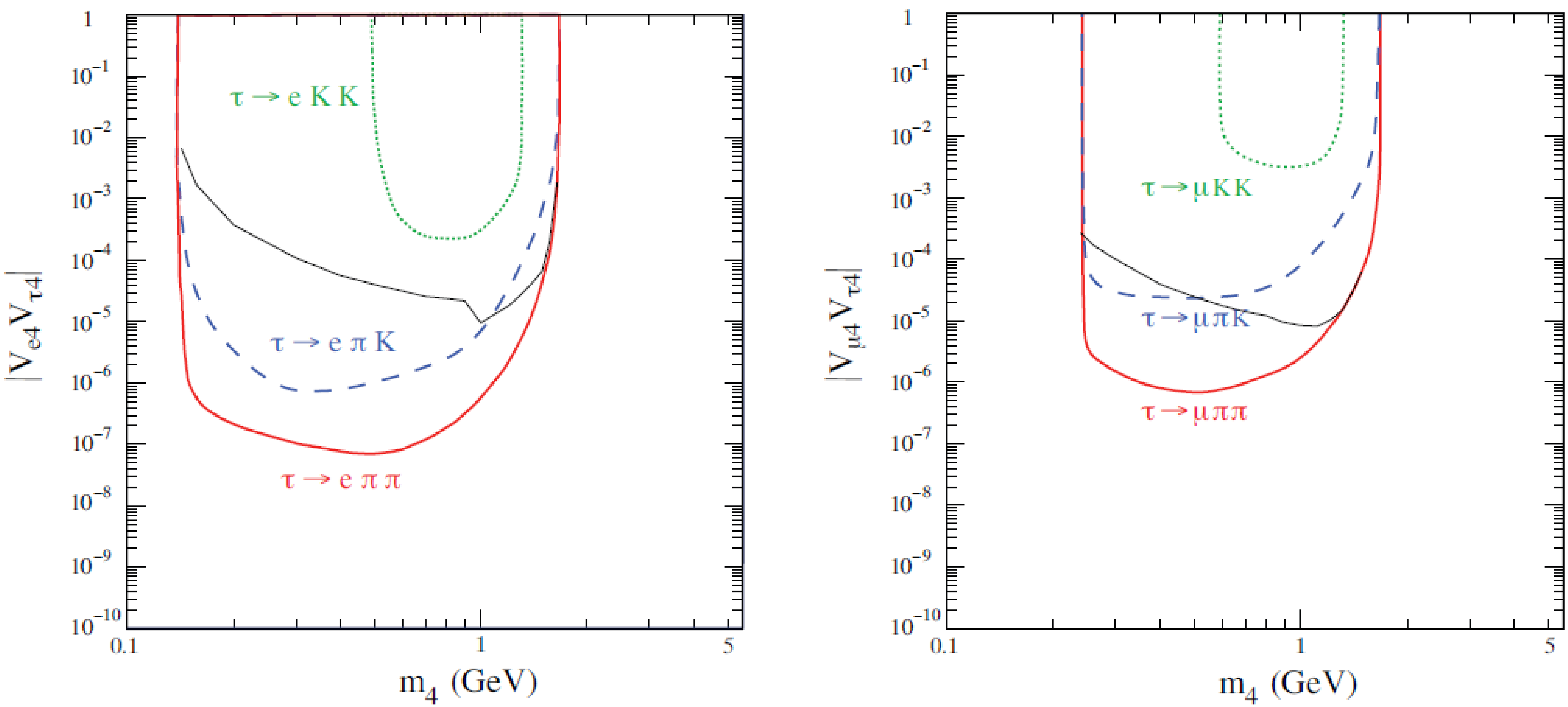
Important for charm and bottom

A. Ali,A.Borisov,M.Sidorova,2006

Current limits from tau leptons

Belle: PLB 682, 355 (2010), (90 % C.L.).

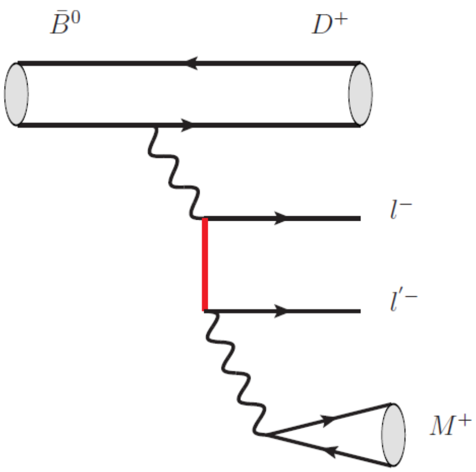
	$\mathcal{B}(\times 10^{-8})$
$\tau^- \to e^+\pi^-\pi^-$	8.8
$\tau^- \to e^+\pi^-K^-$	6.7
$\tau^- \to e^+K^-K^-$	6.0
$\tau^- \to \mu^+\pi^-\pi^-$	3.7
$\tau^- \to \mu^+\pi^-K^-$	9.4
$\tau^- \to \mu^+K^-K^-$	9.6



Atre, Han, Pascoli, & Zhang, JHEP **0905**, 030 (2009)
Helo, Kovalenko, & Schmidt, NPB**853**, 80 (2011).

Bounds on the product $V_{l4}V_{\tau 4}$ only

4-body decays of neutral B mesons



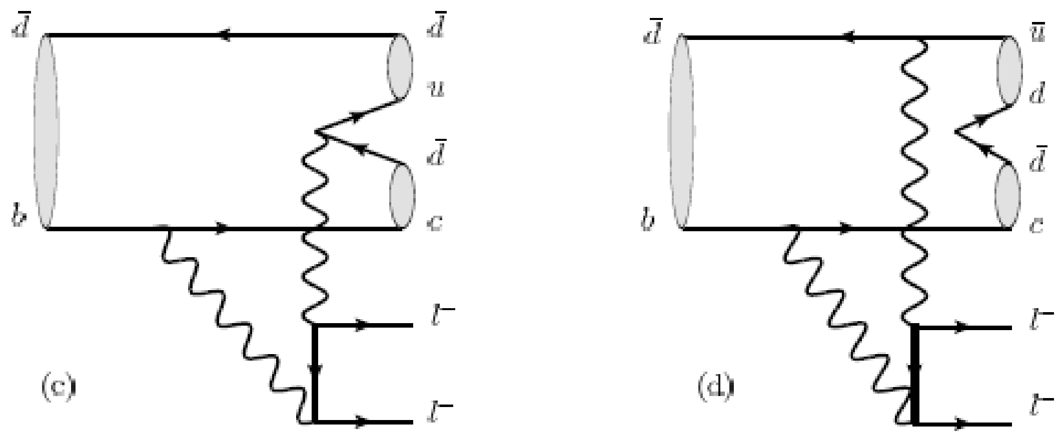
$$\sim G_F^2 V_{lN} V_{l'N} F_{RES} V_{cb}^{CKM} V_{ud}^{CKM} f_\pi F_+^{B\to D}(Q^2)$$

Cabibbo allowed

Different dynamics

Delepine, GLC, Quintero, PRD84 (2011)

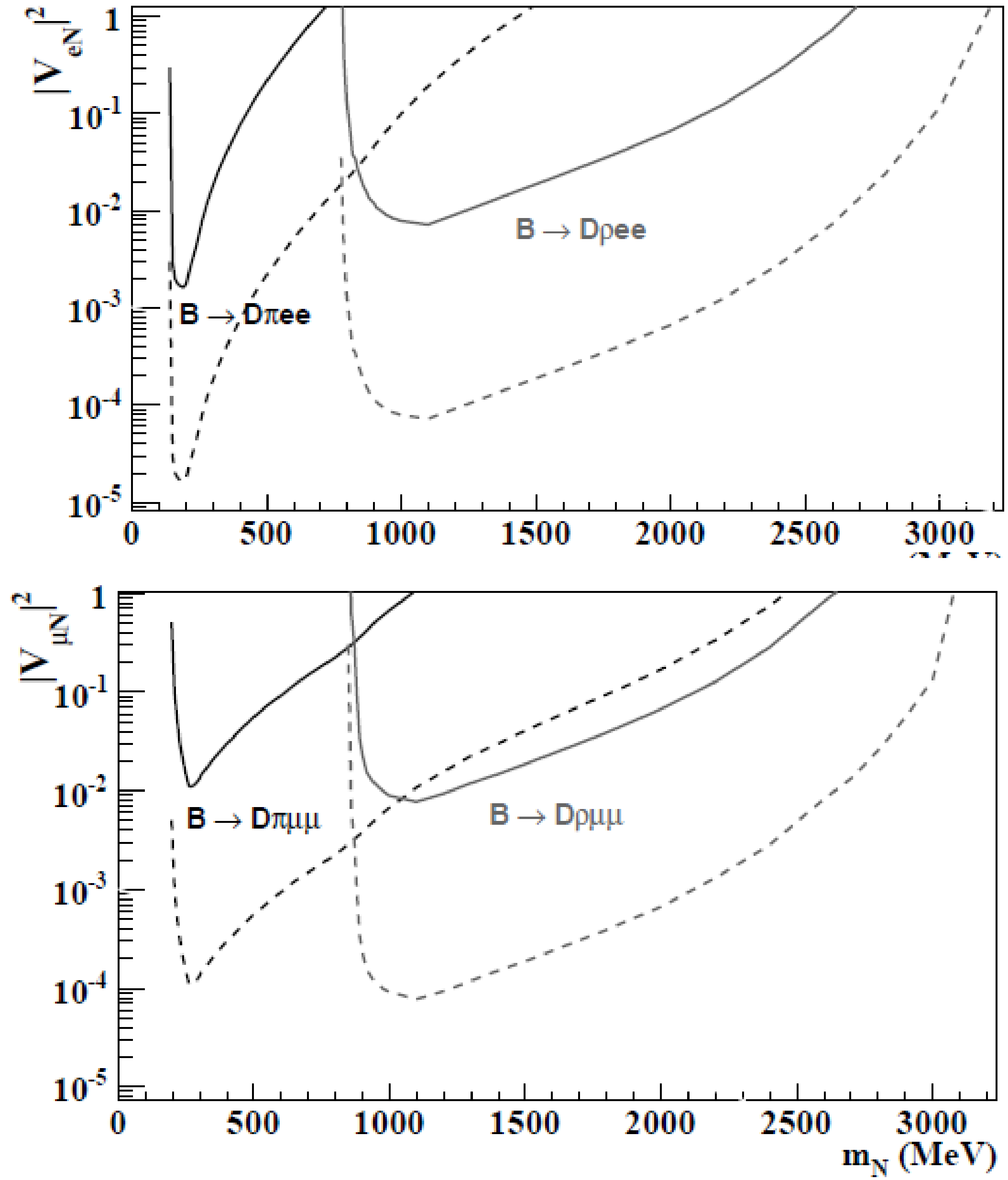
Disadvantage:
loop contributions
difficult to evaluate
reliably



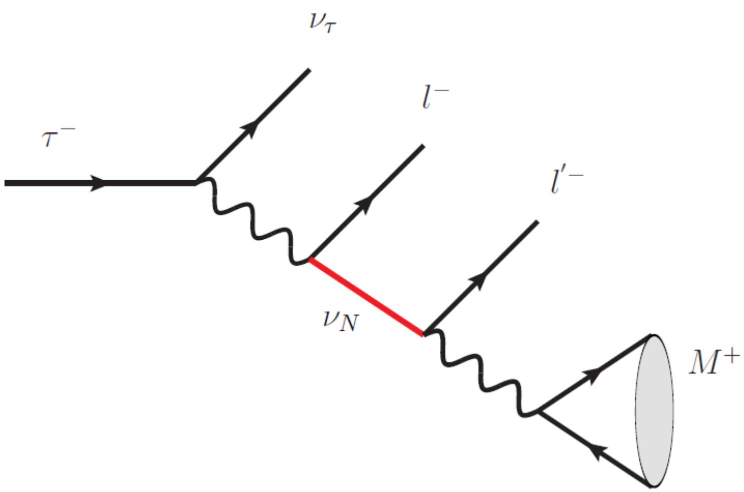
Current upper limits for 4-body decays

Channel	BR (UL)	Collaboration
$D^0 \to \pi^-\pi^-\mu^+\mu^+$	2.9×10^{-5}	E791 (2001)
$D^0 \to \pi^-\pi^- e^+ e^+$	1.1×10^{-4}	E791 (2001)
$D^0 \to \pi^-\pi^-\mu^+ e^+$	7.9×10^{-5}	E791 (2001)
$D^0 \to K^-\pi^-\mu^+\mu^+$	3.9×10^{-4}	E791 (2001)
$D^0 \to K^-\pi^- e^+ e^+$	2.1×10^{-4}	E791 (2001)
$D^0 \to K^-\pi^-\mu^+ e^+$	2.2×10^{-4}	E791 (2001)
$D^0 \to K^-K^-\mu^+\mu^+$	9.4×10^{-5}	E791 (2001)
$D^0 \to K^-K^- e^+ e^+$	1.5×10^{-4}	E791 (2001)
$D^0 \to K^-K^-\mu^+ e^+$	5.7×10^{-5}	E791 (2001)
$B^- \to D^0\pi^+\mu^-\mu^-$	1.5×10^{-6}	LHCb (2012)

- $B^0 \rightarrow D^- \, l^+ \, l'^+ \, M^-$ decays
- BR ~ 10^{-6} solid (10^{-8} dashed)
- Lattice Fermilab & MILC, arXiv: 1202.6364 ; BABAR, PRL 104 (2010)



4-body decays of τ's

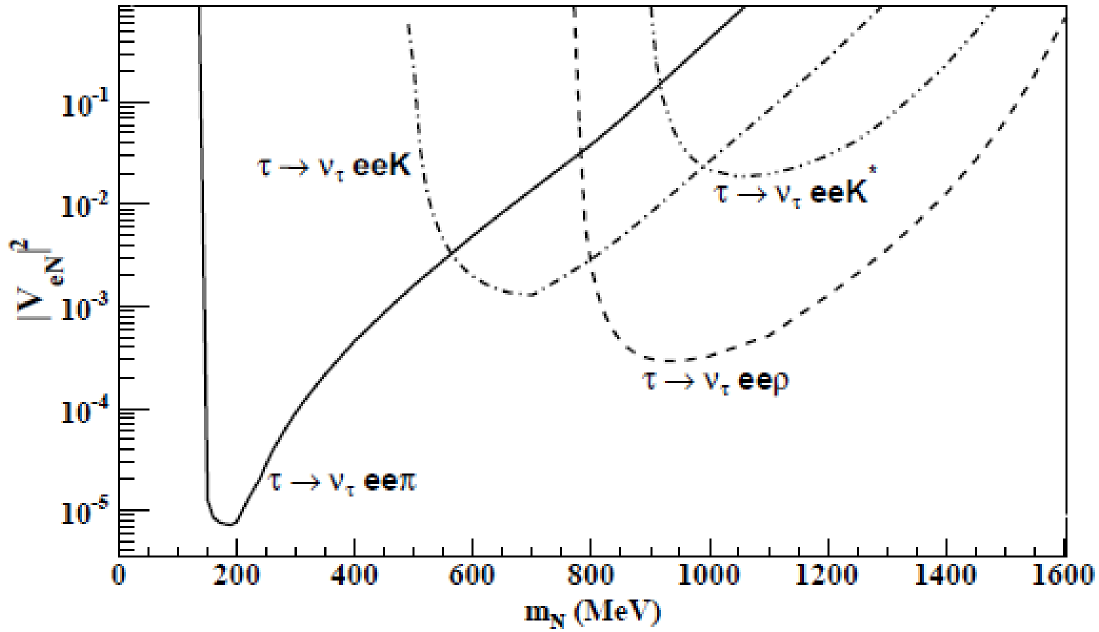


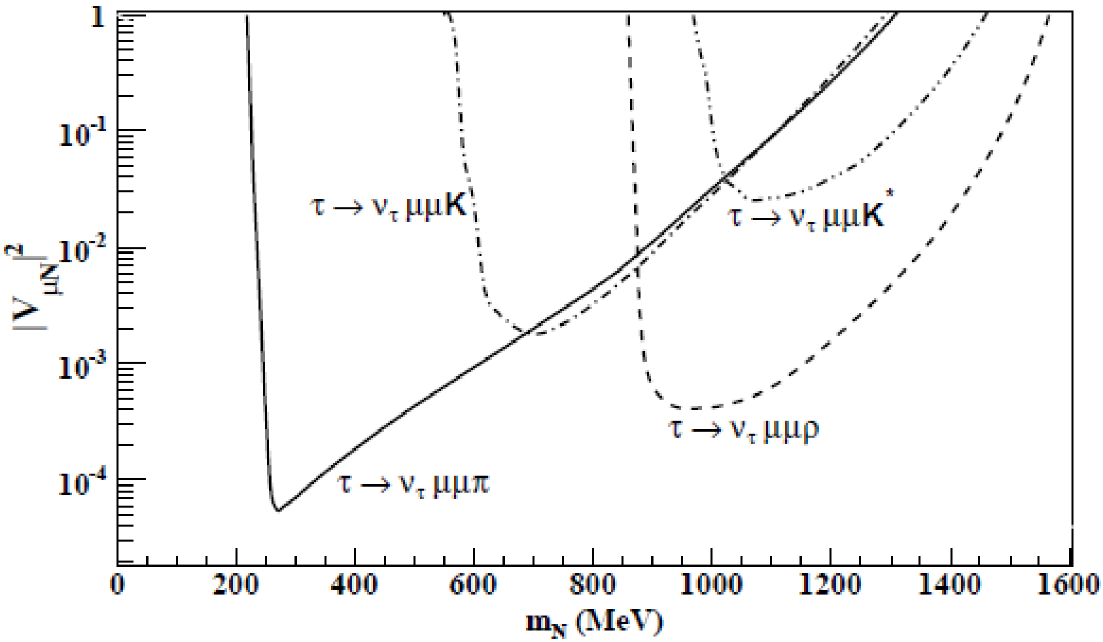
$$\sim G_F^2 V_{lN} V_{l'N} F_{RES} V_M^{CKM} f_M$$

Advantages:

- Access to V_{lN}^2 contrary to 3-body decays ($\sim V_{\tau 4} V_{l4}$)
- Leptonic couplings other than $V_{\tau N}$ and compare to meson decays
- Absence of loop contributions

Quintero & GLC, PRD85, 076006 (2012)





No UL's reported so far

Plots assume: BR($\tau \to \nu llM$) < 10^{-7}

Summary and Conclusions

- Effects of resonant Majorana neutrinos can be searched at superflavor factories. Strong limits on parameter space can be derived from τ & B meson decays.

- Limits from 4-body decays can be competitive and complementary to searches in 3-body decays

- 4-body τ decays are cleaner than charged meson decays (loop-effects pollution)

Decay within detector, L_{dec}: $P=1-\exp(-L_{dec}\,\Gamma_N)$

L_{dec}=10 mt, $\tau\to\pi ee$, $\pi\mu\mu$ (solid line)

Atre et al, JHEP (2009)