

# Charged Lepton Flavour Violation

Overview of current experimental limits and future plans

Ann-Kathrin Perrevoort (Mu3e) | November 8, 2022

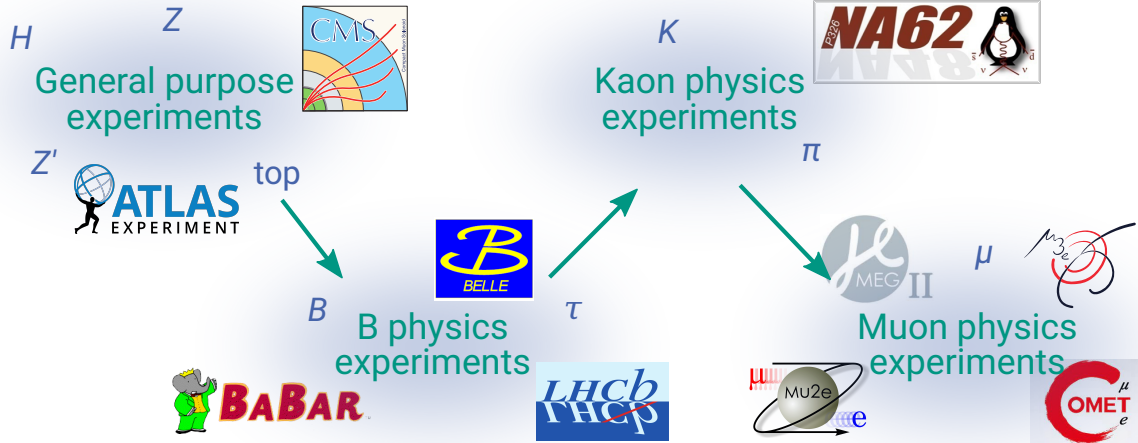


# Charged Lepton Flavour Violation - Experimental Overview

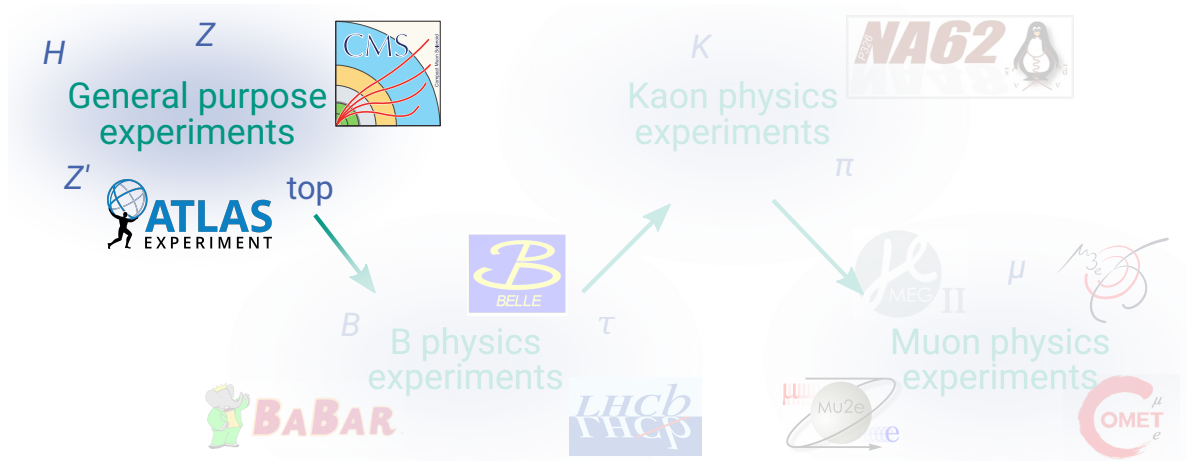
Observation of **Lepton Flavour Violation** in the charged lepton sector would be an unambiguous **sign of physics beyond the Standard Model** (and beyond neutrino oscillations)

Jonathan Kriewald will tell you more about cLFV in BSM models

# Charged Lepton Flavour Violation - Experimental Overview



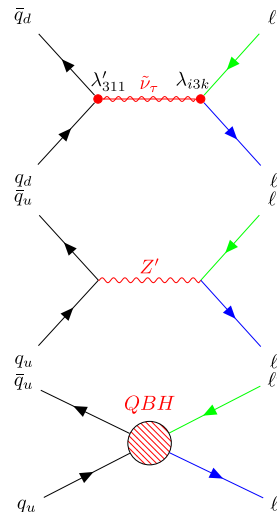
# cLFV Searches at the LHC



# cLFV Searches at the LHC

## Heavy $ll'$ Resonances

- CMS search for heavy  $e\mu$ ,  $eT_{\text{had}}$  and  $\mu T_{\text{had}}$  resonances [arXiv:2205.06709]
- Full Run 2 data set:  $138 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
- Interpretation as  $\tau$  sneutrino in RPV-SUSY,  $Z'$  and quantum black holes plus model-independent cross sections

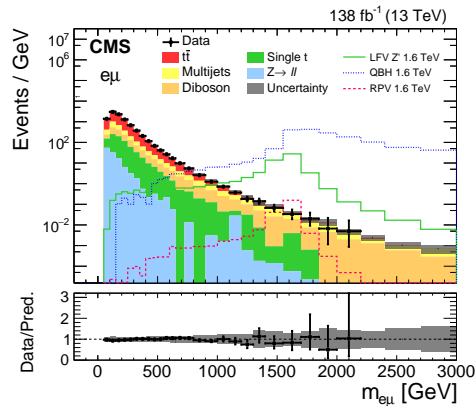


# cLFV Searches at the LHC

## Heavy $\ell\ell'$ Resonances

- CMS search for heavy  $e\mu$ ,  $e\mathcal{T}_{\text{had}}$  and  $\mu\mathcal{T}_{\text{had}}$  resonances [arXiv:2205.06709]
- No excess found in invariant ( $e\mu$ ) or collinear ( $\ell\mathcal{T}_{\text{had}}$ ) mass spectra
- Observed (expected) limits at 95% CL:

	RPV SUSY $\tilde{\nu}_\tau$ [TeV]		LFV $Z'$ [TeV]	QBH $m_{\text{th}}$ [TeV]
	$\lambda = \lambda' = 0.01$	$\lambda = \lambda' = 0.1$	$B = 0.1$	$n = 4$
$e\mu$	2.2 (2.2)	4.2 (4.2)	5.0 (4.9)	5.6 (5.6)
$e\mathcal{T}_{\text{had}}$	1.6 (1.6)	3.7 (3.7)	4.3 (4.3)	5.2 (5.2)
$\mu\mathcal{T}_{\text{had}}$	1.6 (1.6)	3.6 (3.7)	4.1 (4.2)	5.0 (5.0)

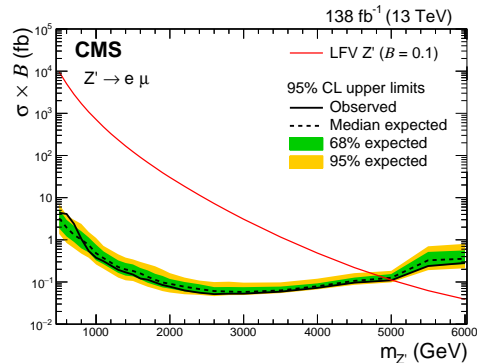


# cLFV Searches at the LHC

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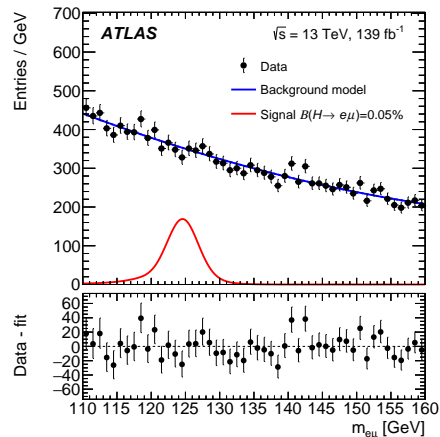
	RPV SUSY $\tilde{\nu}_\tau$ [TeV]		LFV $Z'$ [TeV]	QBH $m_{\text{th}}$ [TeV]
	$\lambda = \lambda' = 0.01$	$\lambda = \lambda' = 0.1$	$B = 0.1$	$n = 4$
$e\mu$	2.2 (2.2)	4.2 (4.2)	5.0 (4.9)	5.6 (5.6)
$e\mathcal{T}_{\text{had}}$	1.6 (1.6)	3.7 (3.7)	4.3 (4.3)	5.2 (5.2)
$\mu\mathcal{T}_{\text{had}}$	1.6 (1.6)	3.6 (3.7)	4.1 (4.2)	5.0 (5.0)



# cLFV Searches at the LHC

## LFV Higgs Decays

- ATLAS search for  $H \rightarrow e^\pm \mu^\mp$   
[Phys.Lett.B 801 (2020) 135148]
- Full Run 2 data set:  $139 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
- No excess in invariant  $m_{e\mu}$  spectra found
- $\mathcal{B}(H \rightarrow e\mu) < 6.2 \times 10^{-5} (5.9 \times 10^{-5})$  at 95 % CL

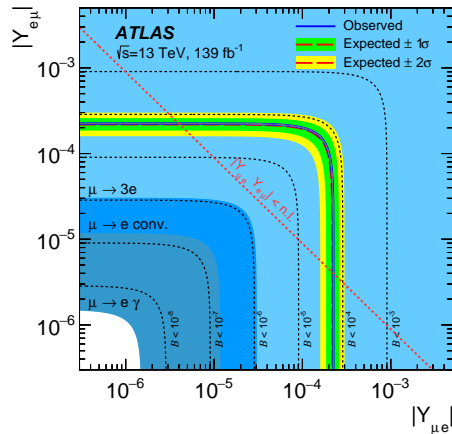




# cLFV Searches at the LHC

## LFV Higgs Decays

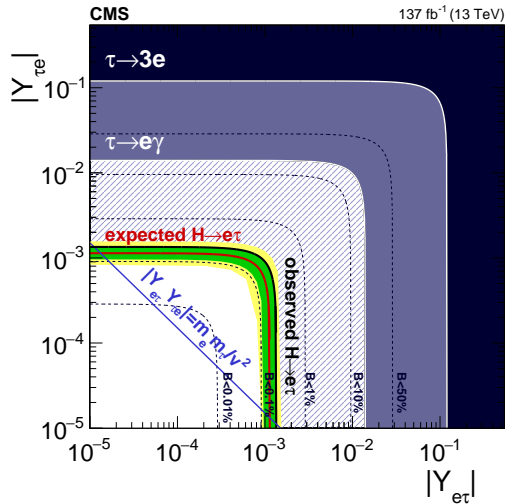
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# cLFV Searches at the LHC

## LFV Higgs Decays

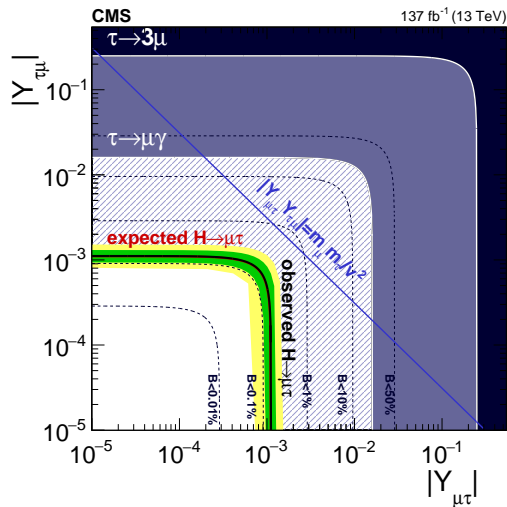
- CMS search for  $H \rightarrow e^\pm \tau^\mp$  and  $H \rightarrow \mu^\pm \tau^\mp$  [Phys.Rev.D 104 (2021) 032013]
- Full Run 2 data set:  $137 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
- Hadronic and leptonic ( $e\tau_\mu, \mu\tau_e$ ) tau decay modes
  
- No excess in BDT distributions found
- $\mathcal{B}(H \rightarrow e\tau) < 0.22(0.16)\%$  at 95 % CL
- $\mathcal{B}(H \rightarrow \mu\tau) < 0.15(0.15)\%$  at 95 % CL



# cLFV Searches at the LHC

## LFV Higgs Decays

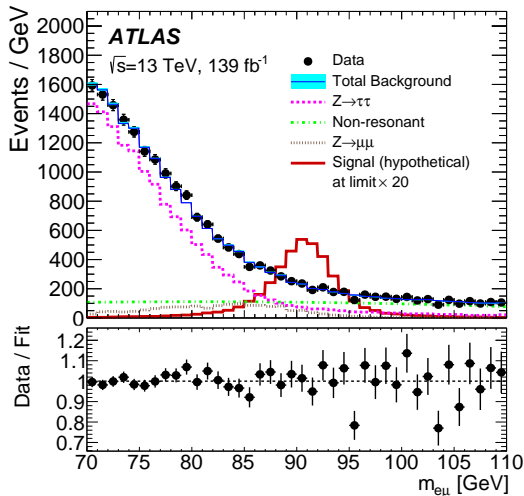
- CMS search for  $H \rightarrow e^\pm \tau^\mp$  and  $H \rightarrow \mu^\pm \tau^\mp$  [Phys.Rev.D 104 (2021) 032013]
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# cLFV Searches at the LHC

## LFV Z Decays

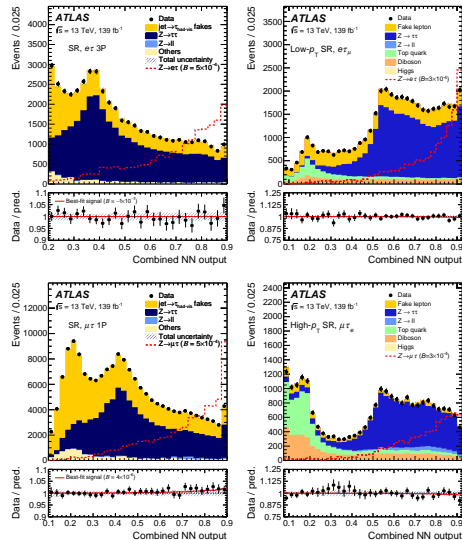
- ATLAS search for  $Z \rightarrow e^\pm \mu^\mp$   
[arXiv:2204.10783]
- Full Run 2 data set:  $139 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
- No excess in invariant  $m_{e\mu}$  spectra found
- $\mathcal{B}(Z \rightarrow e\mu) < 2.62 \times 10^{-7} (2.37 \times 10^{-7})$  at 95% CL



# cLFV Searches at the LHC

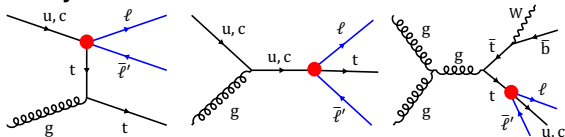
## LFV Z Decays

- ATLAS search for  $Z \rightarrow e^\pm \tau^\mp$  and  $Z \rightarrow \mu^\pm \tau^\mp$   
[Nature Phys. 17 (2021) 819 & PRL 127 (2021) 271801]
- Full Run 2 data set:  $139 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
- Hadronic and leptonic ( $e\tau_\mu$ ,  $\mu\tau_e$ ) tau decay modes
- No excess in neural net classifier distribution found
- $\mathcal{B}(Z \rightarrow e\tau) < 5.0 \times 10^{-6}$  ( $6.0 \times 10^{-6}$ ) at 95 % CL
- $\mathcal{B}(Z \rightarrow \mu\tau) < 6.5 \times 10^{-6}$  ( $5.3 \times 10^{-6}$ ) at 95 % CL

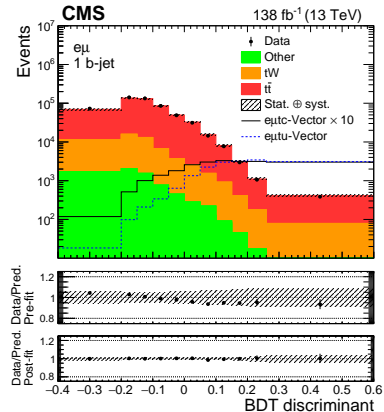


# cLFV Searches at the LHC

## LFV top Decays

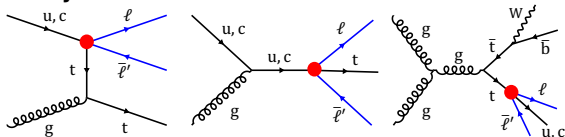


- CMS search for  $q \rightarrow e^\pm \mu^\mp t$  production and  $t \rightarrow e^\pm \mu^\mp q$  decay ( $q = u, c$ ) [JHEP 06 (2022) 082]
- Full Run 2 data set:  $138 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
- Selected events with 1  $b$ -jet
- No excess in BDT distribution found
- Interpretation as vector, scalar and tensor effective 4-fermion interactions
- $\mathcal{B}(t \rightarrow e\mu u) < 0.13 \times 10^{-6} \mid 0.07 \times 10^{-6} \mid 0.25 \times 10^{-6}$  at 95 % CL
- $\mathcal{B}(t \rightarrow e\mu c) < 1.31 \times 10^{-6} \mid 0.89 \times 10^{-6} \mid 2.59 \times 10^{-6}$  at 95 % CL

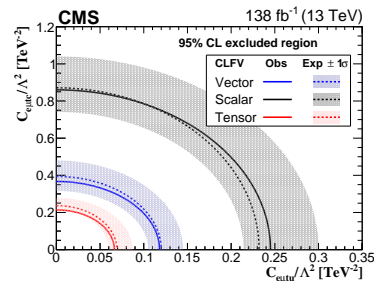


# cLFV Searches at the LHC

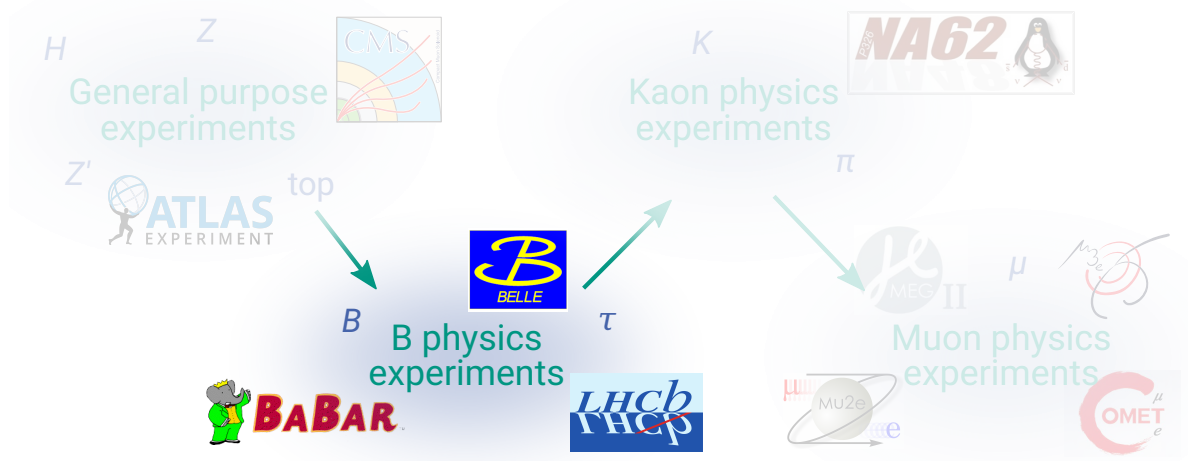
## LFV top Decays



- CMS search for  $q \rightarrow e^\pm \mu^\mp t$  production and  $t \rightarrow e^\pm \mu^\mp q$  decay ( $q = u, c$ ) [JHEP 06 (2022) 082]
- Full Run 2 data set:  $138 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 13 \text{ TeV}$
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# cLFV Searches at $B$ -Physics Experiments

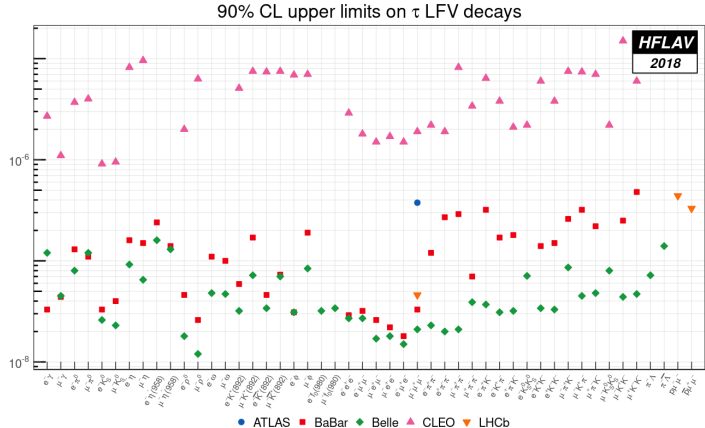




# cLFV Searches at $B$ -Physics Experiments

## LFV $\tau$ Decays

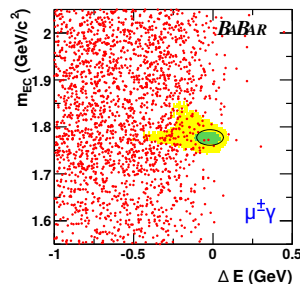
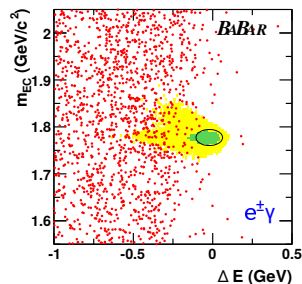
- Exclusion limits for LFV  $\tau$  decays range between  $10^{-6}$  and  $10^{-8}$  set by BaBar, Belle, CLEO, LHCb, ATLAS and CMS
- Overview from HFLAV 2018 [Eur.Phys.J. C (2021) 81:226]  $\rightarrow$
- Sensitivities in the range of  $10^{-9}$  to  $10^{-10}$  expected for Belle II
- BaBar results on  $\tau \rightarrow b\gamma$  and Belle results  $\tau \rightarrow lll$



# cLFV Searches at $B$ -Physics Experiments

## LFV $\tau$ Decays

- BaBar search for  $\tau^\pm \rightarrow e^\pm \gamma$  and  $\tau^\pm \rightarrow \mu^\pm \gamma$  [PRL 104 (2010) 021802]
- $963(7) \times 10^6$   $\tau$  decays near  $\Upsilon(4S)$ ,  $\Upsilon(3S)$  and  $\Upsilon(2S)$
- No significant excess found
- $\mathcal{B}(\tau^\pm \rightarrow e^\pm \gamma) < 3.3 \times 10^{-8}$  at 90 % CL
- $\mathcal{B}(\tau^\pm \rightarrow \mu^\pm \gamma) < 4.4 \times 10^{-8}$  at 90 % CL



# cLFV Searches at $B$ -Physics Experiments

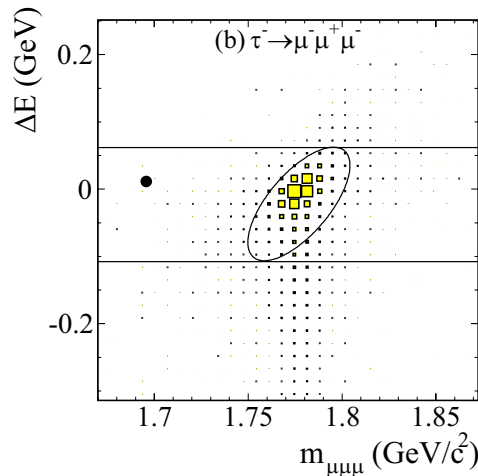
## LFV $\tau$ Decays

- Belle search for  $\tau^- \rightarrow \ell^- \ell^+ \ell^-$   
[Phys.Lett.B 687 (2010) 139–143]
- 782 fb<sup>-1</sup> of  $e^+e^-$  collision data near  $\Upsilon(4S)$

- No significant excess found

Observed UL at 90 % CL

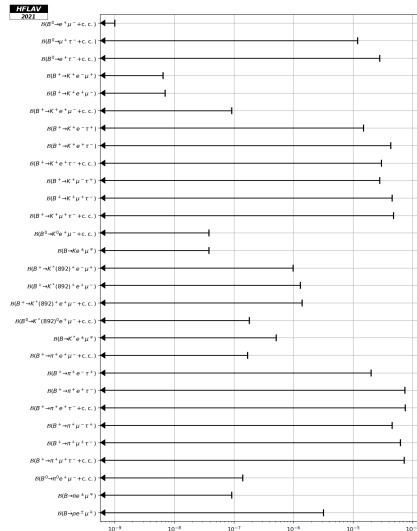
$\mathcal{B}(\tau^- \rightarrow e^- e^+ e^-) < 2.7 \times 10^{-8}$	$\mathcal{B}(\tau^- \rightarrow \mu^- \mu^+ \mu^-) < 2.1 \times 10^{-8}$
$\mathcal{B}(\tau^- \rightarrow e^- \mu^+ \mu^-) < 2.7 \times 10^{-8}$	$\mathcal{B}(\tau^- \rightarrow \mu^- e^+ e^-) < 1.8 \times 10^{-8}$
$\mathcal{B}(\tau^- \rightarrow e^+ \mu^- \mu^-) < 1.7 \times 10^{-8}$	$\mathcal{B}(\tau^- \rightarrow \mu^+ e^- e^-) < 1.5 \times 10^{-8}$



# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

- Exclusion limits for LFV  $B$  meson decays range between  $10^{-4}$  and  $10^{-9}$  set by BaBar, Belle, CLEO and LHCb
- Overview from HFLAV 2021 [arXiv:2206.07501]  $\longrightarrow$
- Recent LHCb results on  $B^0 \rightarrow K^{*0} \ell^\pm \ell'^\mp$  and  $B_{(s)}^0 \rightarrow p \mu^-$



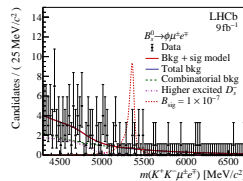
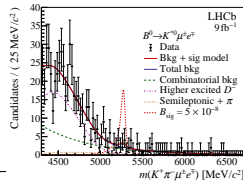
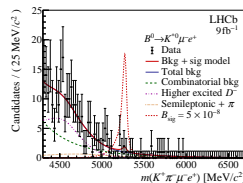
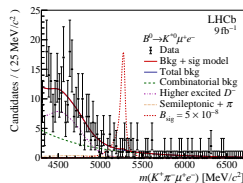
# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

- LHCb searches for  $B^0 \rightarrow K^{*0} e^\pm \mu^\mp$ ,  $B_s^0 \rightarrow \phi e^\pm \mu^\mp$  and  $B^0 \rightarrow K^{*0} \mu^\pm \tau^\mp$   
[arXiv:2207.04005 & arXiv:2209.09846]
- Run 1 + Run 2 data set:  $9\text{fb}^{-1}$  of  $pp$  at  $\sqrt{s} = 7, 8, 13\text{TeV}$
- Final states with  $K^{*0} \rightarrow K^+ \pi^-$ ,  $\phi \rightarrow K^+ K^-$  and  $\tau \rightarrow \pi^- \pi^+ \pi^- (\pi^0) \nu_\tau$
- Normalisation modes  $B^0 \rightarrow J/\psi K^{*0}$  and  $B_s^0 \rightarrow J/\psi \phi$  with  $J/\psi \rightarrow \mu\mu$  and  $B^0 \rightarrow D^- D_s^+ \rightarrow K^+ \pi^- \pi^- K^+ K^- \pi^+$
- No excess in invariant/corrected  $m_{B(s)}$  spectra found

Observed UL at 90 % CL

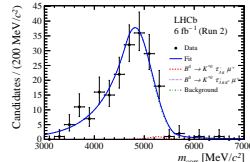
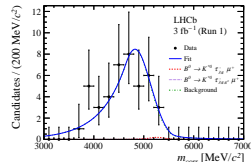
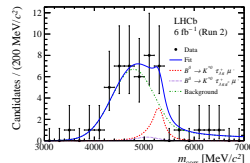
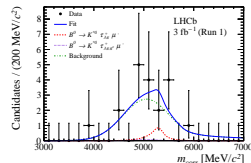
$\mathcal{B}(B^0 \rightarrow K^{*0} e^\pm \mu^\mp) < 10.1 \times 10^{-9}$	$\mathcal{B}(B_s^0 \rightarrow \phi e^\pm \mu^\mp) < 16.0 \times 10^{-9}$
$\mathcal{B}(B^0 \rightarrow K^{*0} e^- \mu^+) < 5.7 \times 10^{-9}$	$\mathcal{B}(B^0 \rightarrow K^{*0} \mu^- \tau^+) < 1.0 \times 10^{-5}$
$\mathcal{B}(B^0 \rightarrow K^{*0} e^+ \mu^-) < 6.8 \times 10^{-9}$	$\mathcal{B}(B^0 \rightarrow K^{*0} \mu^+ \tau^-) < 8.2 \times 10^{-6}$



# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

- LHCb searches for  $B^0 \rightarrow K^{*0} e^\pm \mu^\mp$ ,  $B_s^0 \rightarrow \phi e^\pm \mu^\mp$  and  $B^0 \rightarrow K^{*0} \mu^\pm \tau^\mp$   
[arXiv:2207.04005 & arXiv:2209.09846]
- Run 1 + Run 2 data set:  $9 \text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s}=7,8,13 \text{ TeV}$
- Final states with  $K^{*0} \rightarrow K^+ \pi^-$ ,  $\phi \rightarrow K^+ K^-$  and  $\tau \rightarrow \pi^- \pi^+ \pi^- (\pi^0) \nu_\tau$
- Normalisation modes  $B^0 \rightarrow J/\psi K^{*0}$  and  $B_s^0 \rightarrow J/\psi \phi$  with  $J/\psi \rightarrow \mu\mu$  and  $B^0 \rightarrow D^- D_s^+ \rightarrow K^+ \pi^- \pi^- K^+ K^- \pi^+$
- No excess in invariant/corrected  $m_{B(s)}$  spectra found



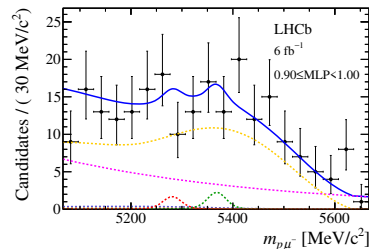
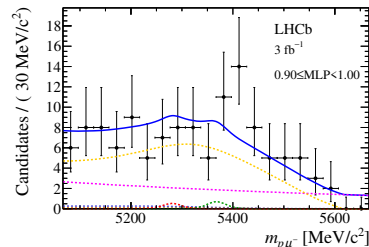
Observed UL at 90 % CL

$\mathcal{B}(B^0 \rightarrow K^{*0} e^\pm \mu^\mp) < 10.1 \times 10^{-9}$	$\mathcal{B}(B_s^0 \rightarrow \phi e^\pm \mu^\mp) < 16.0 \times 10^{-9}$
$\mathcal{B}(B^0 \rightarrow K^{*0} e^- \mu^+) < 5.7 \times 10^{-9}$	$\mathcal{B}(B^0 \rightarrow K^{*0} \mu^- \tau^+) < 1.0 \times 10^{-5}$
$\mathcal{B}(B^0 \rightarrow K^{*0} e^+ \mu^-) < 6.8 \times 10^{-9}$	$\mathcal{B}(B^0 \rightarrow K^{*0} \mu^+ \tau^-) < 8.2 \times 10^{-6}$

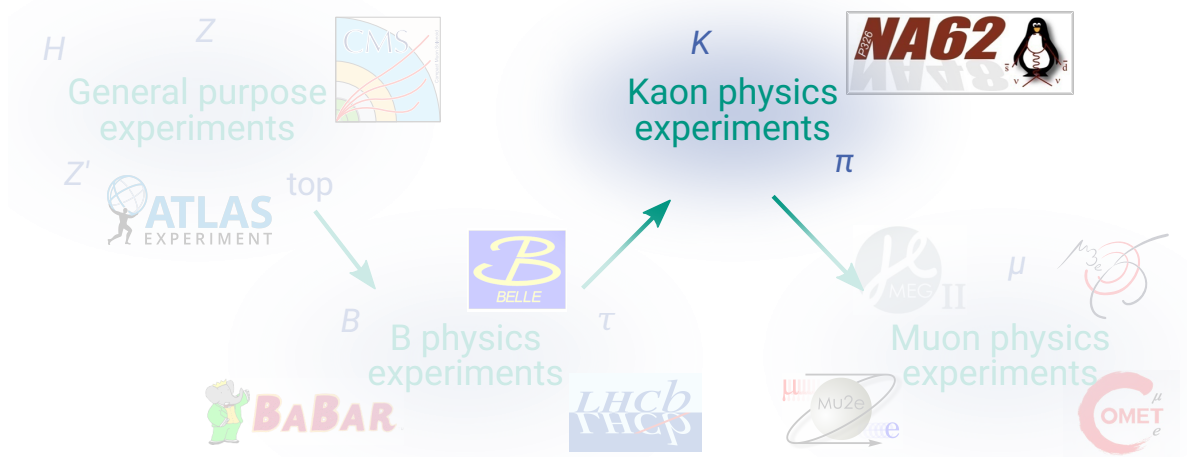
# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

- LHCb search for  $B_{(s)}^0 \rightarrow \rho\mu^-$  [arXiv:2210.10412]
- Run 1 + Run 2 data set:  $9\text{ fb}^{-1}$  of  $pp$  at  $\sqrt{s}=7,8,13\text{ TeV}$
- Normalisation modes  $B^0 \rightarrow K^+\pi^-$  and  $B^+ \rightarrow J/\psi K^+$  with  $J/\psi \rightarrow \mu\mu$
  
- No excess in invariant  $m_{\rho\mu^-}$  spectra found
- $\mathcal{B}(B^0 \rightarrow \rho\mu^-) < 2.6 \times 10^{-9} (1.9 \times 10^{-9})$  at 90 % CL
- $\mathcal{B}(B_s^0 \rightarrow \rho\mu^-) < 12.1 \times 10^{-9} (7.0 \times 10^{-9})$  at 90 % CL



# cLFV Searches at Kaon Physics Experiments





# cLFV Searches at Kaon Physics Experiments

## LFV Kaon and Pion Decays

- Exclusion limits for LFV  $K$  and  $\pi$  decays range between  $10^{-10}$  and  $10^{-12}$  set by BNL E865, BNL E871, KTeV and NA62
- Recent NA62 results on  $K^+ \rightarrow \pi^- e^+ \mu^+$ ,  $K^+ \rightarrow \pi^+ e^+ \mu^-$  and  $\pi^0 \rightarrow e^+ \mu^-$

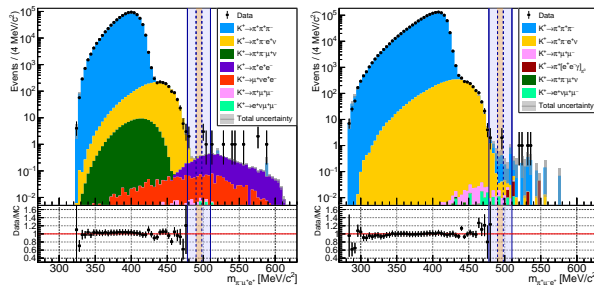
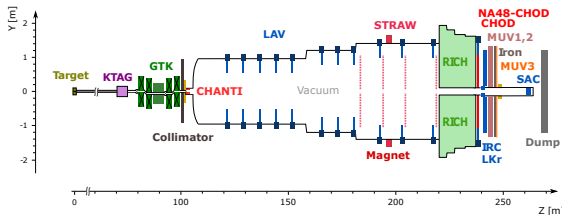
Observed UL at 90 % CL

$\mathcal{B}(K^+ \rightarrow \pi^- e^+ \mu^+)$	$< 4.2 \times 10^{-11}$	NA62
$\mathcal{B}(K^+ \rightarrow \pi^+ e^+ \mu^-)$	$< 6.6 \times 10^{-11}$	NA62
$\mathcal{B}(K^+ \rightarrow \pi^+ e^- \mu^+)$	$< 1.3 \times 10^{-11}$	BNL E865
$\mathcal{B}(K_L^0 \rightarrow e^\pm \mu^\mp)$	$< 4.7 \times 10^{-12}$	BNL E871
$\mathcal{B}(K_L^0 \rightarrow \pi^0 e^\pm \mu^\mp)$	$< 7.6 \times 10^{-11}$	KTeV
$\mathcal{B}(K_L^0 \rightarrow \pi^0 \pi^0 e^\pm \mu^\mp)$	$< 1.7 \times 10^{-10}$	KTeV
$\mathcal{B}(\pi^0 \rightarrow e^+ \mu^-)$	$< 3.2 \times 10^{-10}$	NA62
$\mathcal{B}(\pi^0 \rightarrow e^- \mu^+)$	$< 3.8 \times 10^{-10}$	BNL E865
$\mathcal{B}(\pi^0 \rightarrow e^\pm \mu^\mp)$	$< 3.6 \times 10^{-10}$	KTeV

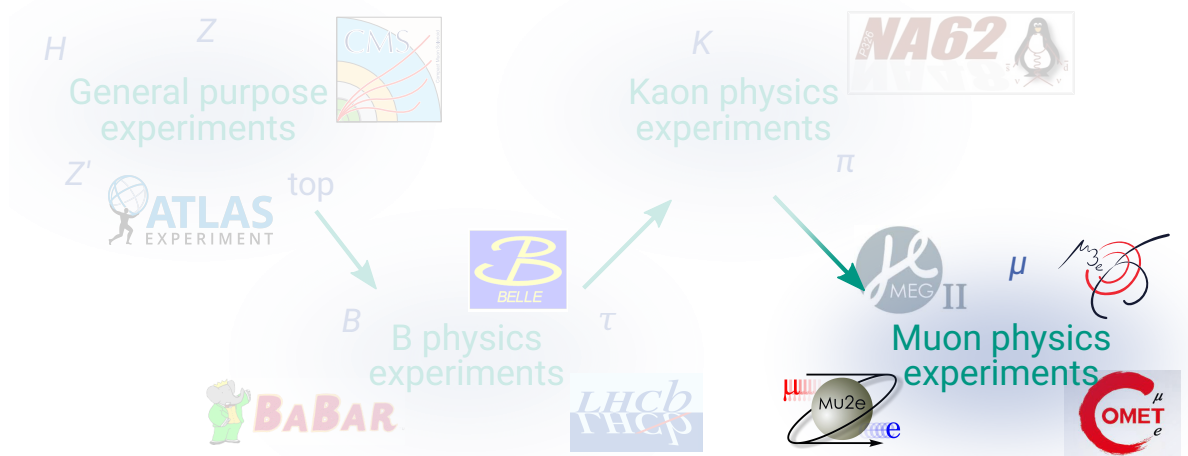
# cLFV Searches at Kaon Physics Experiments

## LFV Kaon and Pion Decays

- NA62 search for  $K^+ \rightarrow \pi^- e^+ \mu^+$ ,  $K^+ \rightarrow \pi^+ e^+ \mu^-$  and  $\pi^0 \rightarrow e^+ \mu^-$  with  $\pi^0$  from  $K^+ \rightarrow \pi^+ \pi^0$  [PRL 127 (2021) 12 131802]
- $8.3 \times 10^5$  SPS spills collected in 2017/18
- Normalisation channel  $K^+ \rightarrow \pi^+ \pi^+ \pi^-$
- No excess in invariant  $m_{\pi e \mu}$  spectra found
- $\mathcal{B}(K^+ \rightarrow \pi^- e^+ \mu^+) < 4.2 \times 10^{-11}$  at 90 % CL
- $\mathcal{B}(K^+ \rightarrow \pi^+ e^+ \mu^-) < 6.6 \times 10^{-11}$  at 90 % CL
- $\mathcal{B}(\pi^0 \rightarrow e^+ \mu^-) < 3.2 \times 10^{-10}$  at 90 % CL



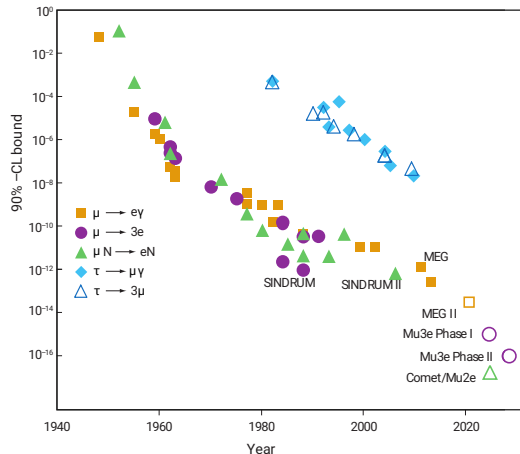
# cLFV Searches at Muon Physics Experiments



# cLFV Searches at Muon Physics Experiments

## LFV $\mu$ Decays

- High-intensity muon sources paired with dedicated high-precision experiments
- Current exclusion limits on LFV  $\mu$  decays range between  $10^{-12}$  and  $10^{-13}$
- Sensitivities in the range of  $10^{-15}$  to  $10^{-17}$  expected for near-future experiments
- Plans for  $\mu \rightarrow e\gamma$ ,  $\mu \rightarrow eee$ ,  $\mu N \rightarrow eN$  and  $\mu \rightarrow eX$  searches



Adapted from [Ann.Rev.Nucl.Part.Sci 58 (2008) 315–341]

# cLFV Searches at Muon Physics Experiments

## LFV $\mu$ Decays

- MEG and MEG II search for  $\mu^+ \rightarrow e^+ \gamma$
- Continuous  $\mu^+$  beam at PSI
- Mono-energetic  $e^+$  and  $\gamma$
- Background from accidental combinations

- Current limit

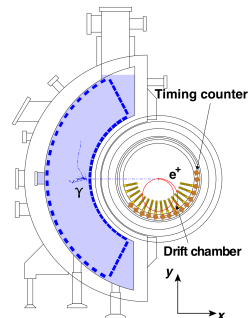
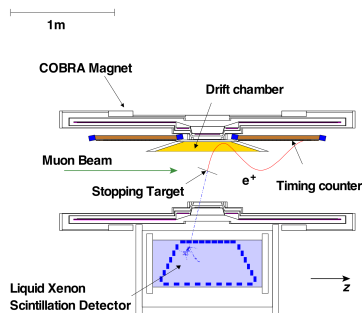
$$\mathcal{B}(\mu^+ \rightarrow e^+ \gamma) < 4.2 \times 10^{-13} \text{ at } 90 \% \text{ CL}$$

[Eur.Phys.J.C 76 (2016) 8, 434]

- MEG II running with expected sensitivity

$$\mathcal{B}(\mu^+ \rightarrow e^+ \gamma) < 6 \times 10^{-14} \text{ at } 90 \% \text{ CL}$$

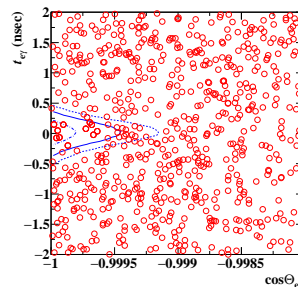
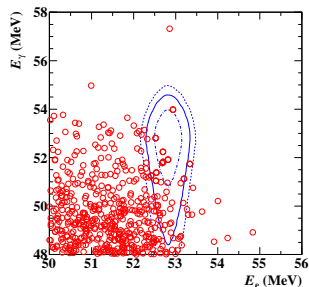
[Eur.Phys.J.C 78 (2018) 5, 380]



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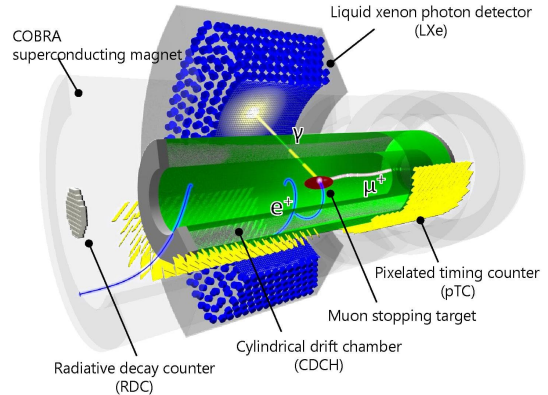
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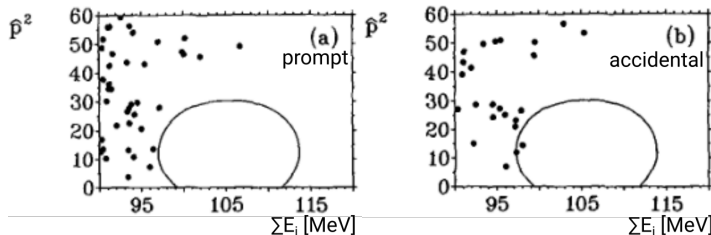
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# cLFV Searches at Muon Physics Experiments

## LFV $\mu$ Decays

- Search for  $\mu^+ \rightarrow e^+ e^- e^+$
  - Continuous  $\mu^+$  beam at PSI
  - Invariant  $m_{eee} = m_\mu$  and  $\sum \vec{p}_e = \vec{0}$
  - Background from  $\mu^+ \rightarrow e^+ e^- e^+ \nu \bar{\nu}$  and accidental combinations
- Current limit by SINDRUM  
 $\mathcal{B}(\mu^+ \rightarrow e^+ e^- e^+) < 1.0 \times 10^{-12}$  at 90 % CL  
[Nucl.Phys.B 299 (1988) 1–6]
  - Upcoming Mu3e experiment with exp. sensitivity  
 $\mathcal{B}(\mu^+ \rightarrow e^+ e^- e^+) < 10^{-15}$  to  $10^{-16}$  at 90 % CL  
[NIM A 1014 (2021) 165679]

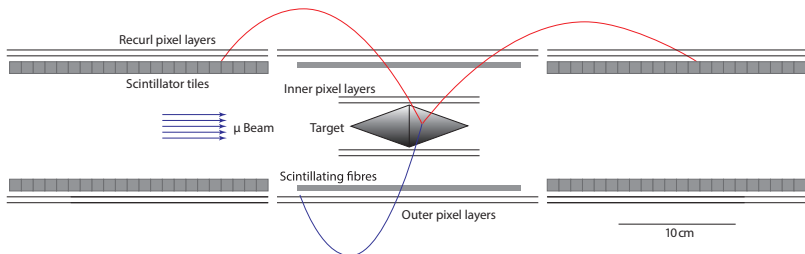




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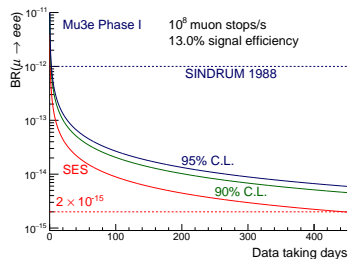
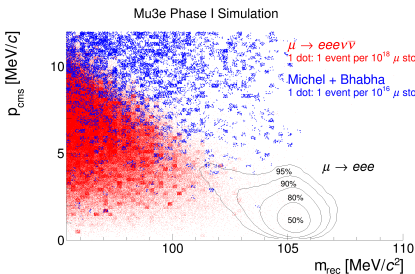


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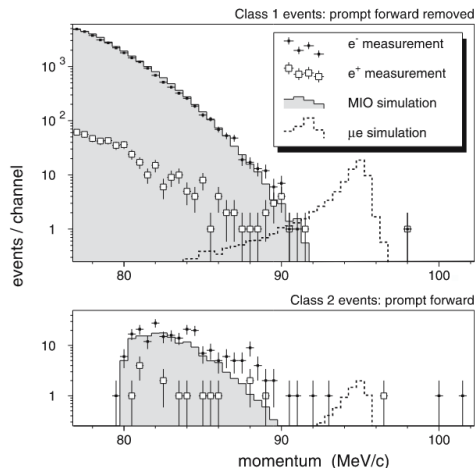
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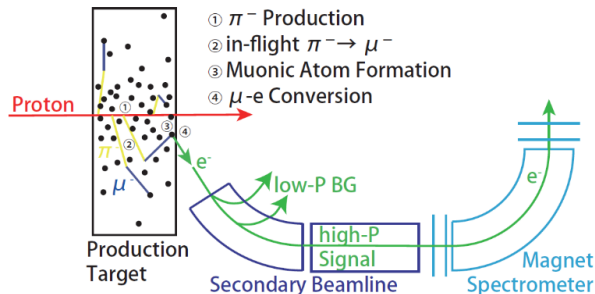
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- Mono-energetic  $e^-$
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[FERMILAB-TM-2594, Nucl.Phys.B Proc.Suppl. 248–250 (2014) 52–57, PTEP 2020 3 (2020) 033C01]



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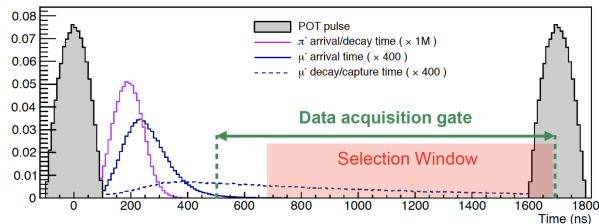
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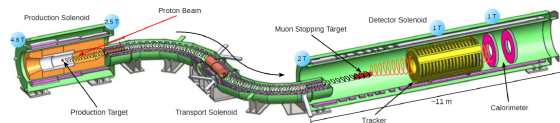
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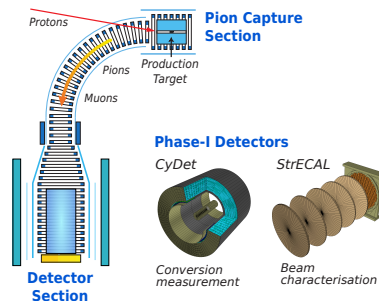
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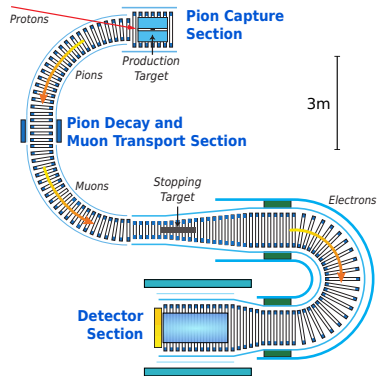
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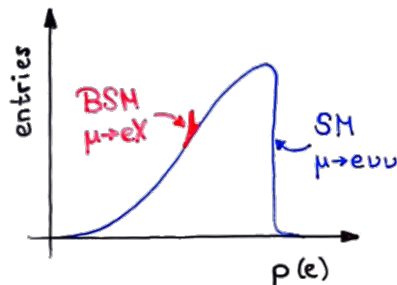
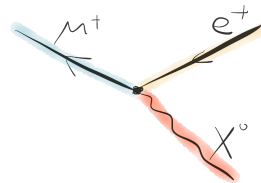




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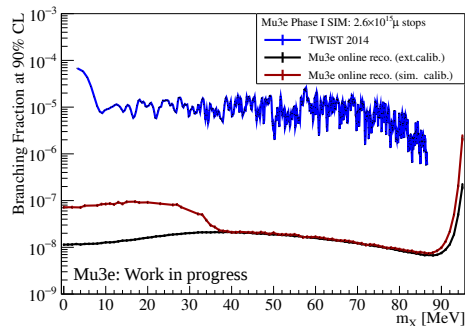
- Mu3e search for  $\mu^+ \rightarrow e^+ X \Rightarrow$  mono-energetic  $e^+$
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- Online histogramming
  
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Jodidio et al.[Phys.Rev.D 34 (1986) 1967]
- $\mathcal{B}(\mu^+ \rightarrow e^+ X) < 9 \times 10^{-6}$  at 90 % CL on average for  
 $13 \text{ MeV} < m_X < 80 \text{ MeV}$   
TWIST [Phys.Rev.D 91 (2015) 052020]
- Mu3e phase I sensitivity at around  $10^{-8}$
  
- Ideas for  $\mu \rightarrow eX$  searches also at MEG II, muon conversion experiments and  $\text{Mu}\chi\text{e}$



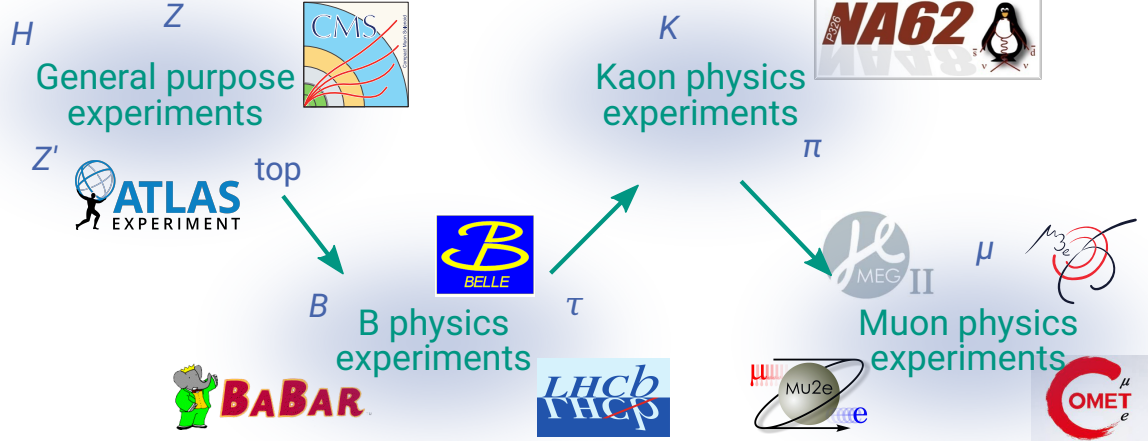
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# Summary



# Summary

- Many channels to search for cLFV
- No observation (yet?)

- More data / new experiments will explore uncharted territory:
  - 300 fb<sup>-1</sup> to 3000 fb<sup>-1</sup> in Run 3 of LHC and HL-LHC
  - 50 ab<sup>-1</sup>  $\hat{=}$   $4.5 \times 10^{10} \tau\bar{\tau}$  at Belle II
  - 10<sup>8</sup>  $\mu/s$  to 10<sup>10</sup>  $\mu/s$  at the upcoming muon cLFV experiments



$H$   $Z$   
General purpose experiments



top

$B$

B physics experiments



$\tau$



$K$   
Kaon physics experiments

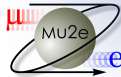


$\pi$



$\mu$

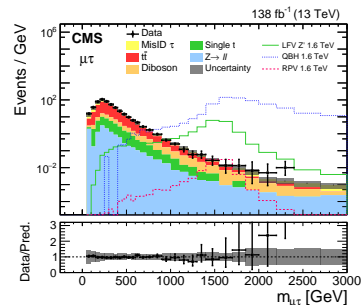
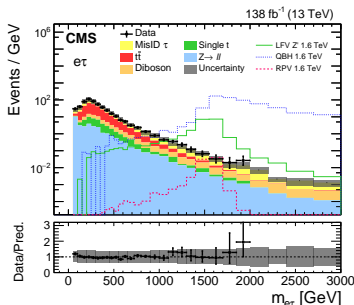
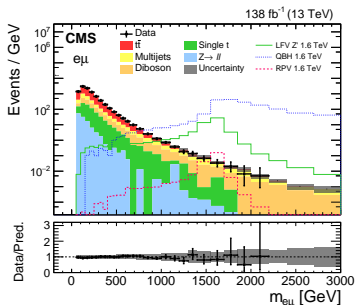
Muon physics experiments



# cLFV Searches at the LHC

## Heavy $ll'$ Resonances

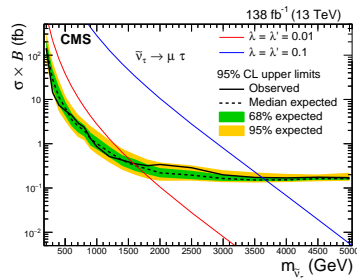
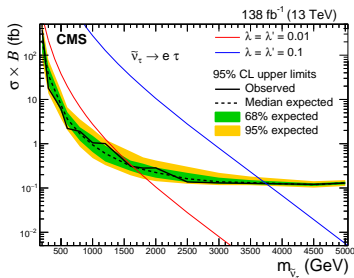
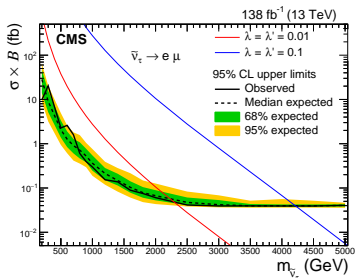
CMS search for heavy  $e\mu$ ,  $eT_{\text{had}}$  and  $\mu T_{\text{had}}$  resonances [arXiv:2205.06709]



# cLFV Searches at the LHC

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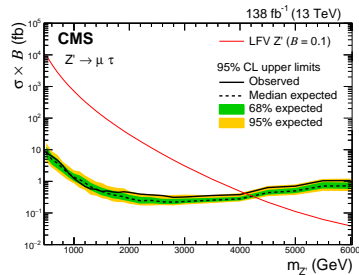
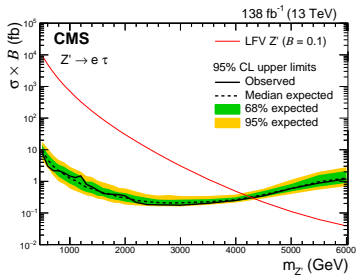
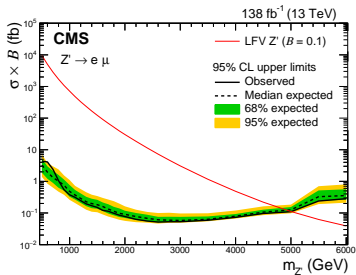
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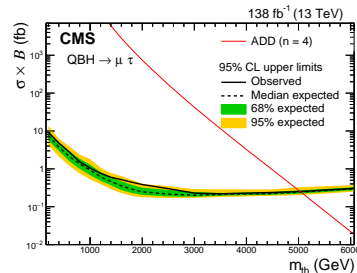
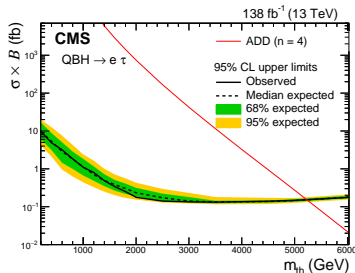
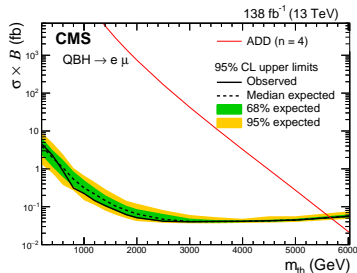




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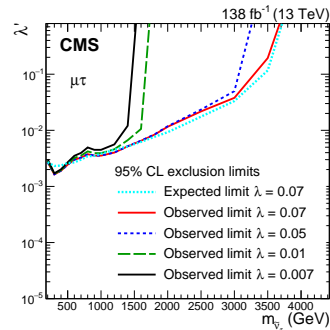
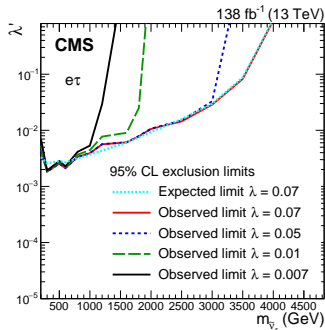
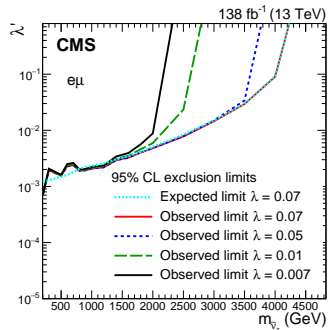
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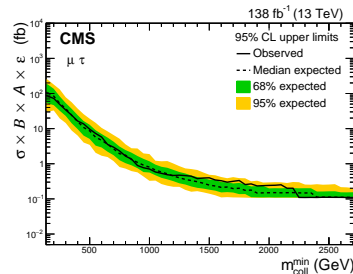
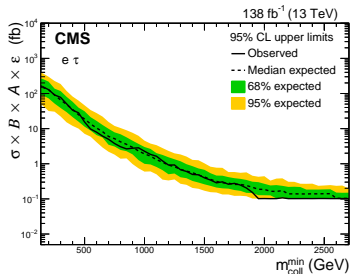
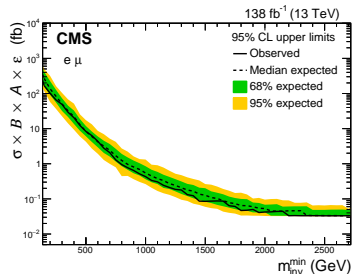
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CMS search for heavy  $e\mu$ ,  $e\tau_{\text{had}}$  and  $\mu\tau_{\text{had}}$  resonances [arXiv:2205.06709]

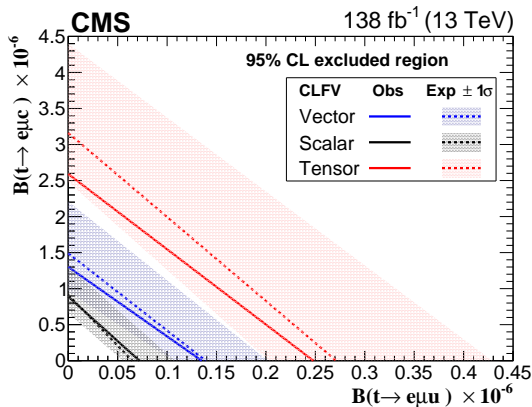
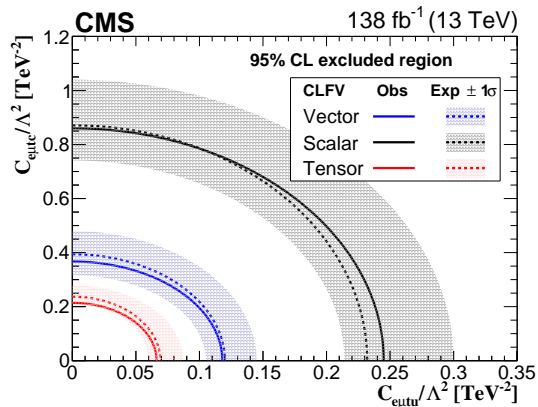


# cLFV Searches at the LHC

## LFV top Decays

CMS search for  $q \rightarrow e^\pm \mu^\mp t$  production and  $t \rightarrow e^\pm \mu^\mp q$  decay ( $q = u, c$ )

[JHEP 06 (2022) 082]

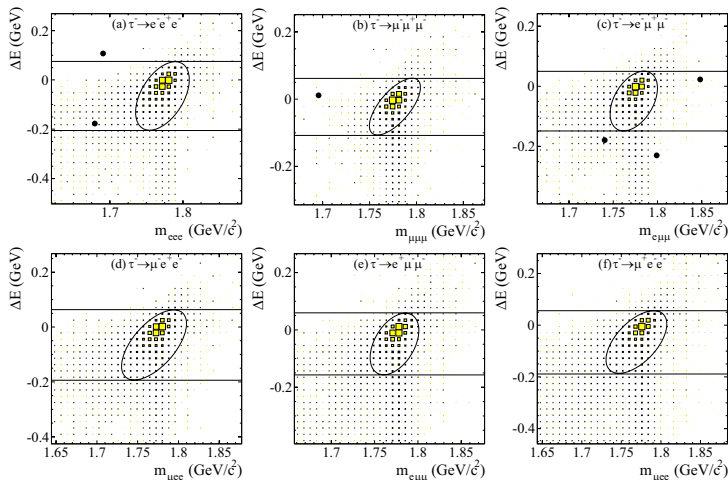


# cLFV Searches at $B$ -Physics Experiments

## LFV $\tau$ Decays

Belle search for  $\tau^- \rightarrow l^- l^+ l^-$

[Phys.Lett.B 687 (2010) 139–143]

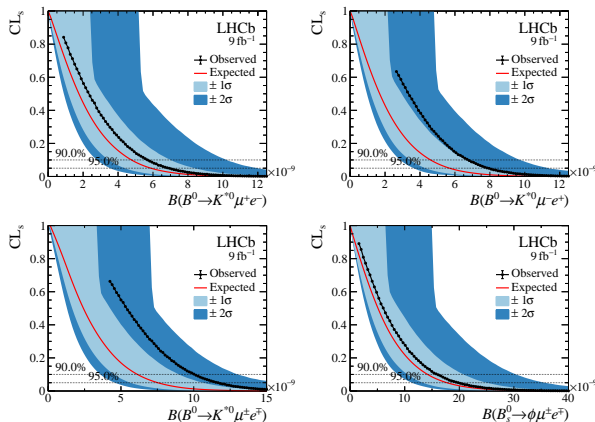


# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

LHCb search for  $B^0 \rightarrow K^{*0} e^\pm \mu^\mp$  and  $B_s^0 \rightarrow \phi e^\pm \mu^\mp$

[arXiv:2207.04005]

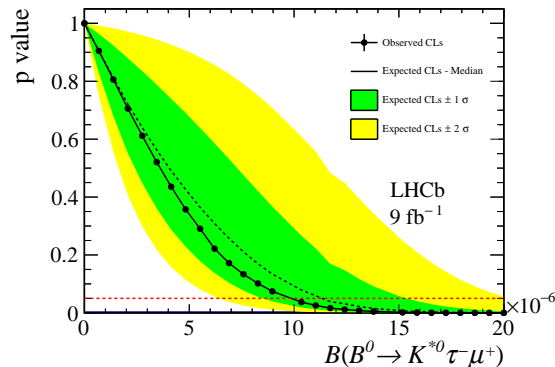
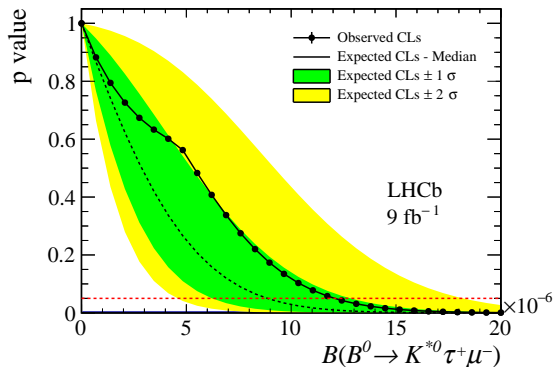


# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

LHCb search for  $B^0 \rightarrow K^{*0} \mu^\pm \tau^\mp$

[arXiv:2209.09846]



# cLFV Searches at $B$ -Physics Experiments

## LFV $B$ Decays

LHCb search for  $B_{(s)}^0 \rightarrow p\mu^-$

[arXiv:2210.10412]

