Lepton Flavour Violation searches in B decays at LPNHE

TOMMASO FULGHESU Biennale LPNHE - 05/2024

Introduction to LFV

- According to the Standard Model (SM), **lepton flavour and lepton quantum numbers are conserved in electroweak processes**;
- Extending the SM with massive neutrinos, **flavour changing neutral currents (FCNC) are allowed via neutrino oscillations** (highly suppressed);
- No LFV or LNV process for charged lepton has been observed yet!
- Observation of charged LFV and LNV would constitute a **clear sign of New Physics (NP)**[1].

Interest on studying different b→sll' transitions

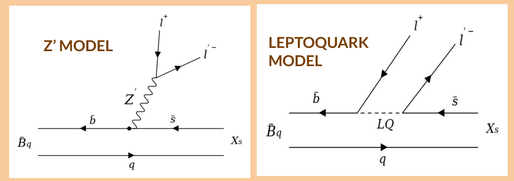
NEUTRINO OSCILLATIONS

Predicted BR up to $O(10^{50})$

NEW PHYSICS MODELS

Predicted BR up to $O(10^{-6}\text{-}10^{-10})$

NP models could depend on **fermion interaction strengths**



Decay	Limit (90% C.L.)	Integrated luminosity
$B^0 \to e\mu$	$1.0 \cdot 10^{-9}$	3 fb^{-1}
$B_s \to e\mu$	$5.4 \cdot 10^{-9}$	3 fb^{-1}
$B^+ \to K^+e^+\mu^-$	$7.0 \cdot 10^{-9}$	3 fb^{-1}
$B^+ \to K^+e^-\mu^+$	$6.4 \cdot 10^{-9}$	3 fb^{-1}
$B^0 \to K^{*0}e^\mp\mu^\pm$	$9.9 \cdot 10^{-9}$	9 fb^{-1}
$B^0 \to K^{*0}e^+\mu^-$	$6.7 \cdot 10^{-9}$	9 fb^{-1}
$B^0 \to K^{*0}e^-\mu^+$	$5.7 \cdot 10^{-9}$	9 fb^{-1}
$B_s \to \phi e^\mp\mu^\pm$	$1.6 \cdot 10^{-8}$	9 fb^{-1}
$B^0 \to \tau\mu$	$1.2 \cdot 10^{-5}$	3 fb^{-1}
$B_s \to \tau\mu$	$3.4 \cdot 10^{-5}$	3 fb^{-1}
$B^+ \to K^+\tau e\mu$	$3.9 \cdot 10^{-5}$	9 fb^{-1}
$B^0 \to K^{*0}\tau^+\mu^-$	$1.0 \cdot 10^{-5}$	9 fb^{-1}
$B^0 \to K^{*0}\tau^-\mu^+$	$8.2 \cdot 10^{-6}$	9 fb^{-1}

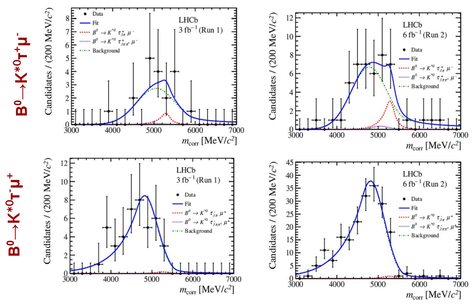
Searches @ LHCb for τμ and μe in the final state

RECENT RESULTS @ LHCb

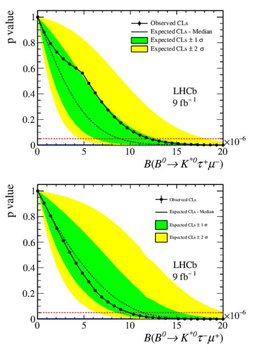
Search for $B^0 \to K^{*0}\tau^\mp\mu^\pm$ [2]

LPNHE group conducted the analysis with the full Run 1+2 dataset (9 fb^{-1}) and results were published last year, setting the **most stringent limit**, sensible to $O(10^{-6})$.

- **Final states**: $K^{*0}(\to K^+\pi^-)$ $\tau^\mp(\to\pi^\mp\pi^\mp\pi^\pm(\pi^0))$ $\mu^\pm$
- Fit performed separately for Run 1 and Run 2 and for Kμ charge combination



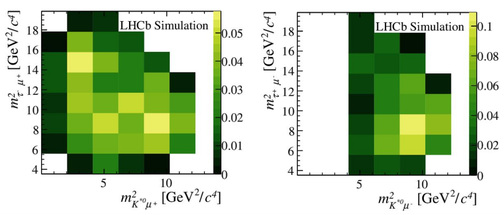
NORMALIZATION SAMPLE: $B^0 \to DsD$



- **No signal observation**
- **Limits to BR** set at 90(95)% CL[3]

$$B(B^0 \to K^{*0}\tau^+\mu^-) < 1.0(1.2) \times 10^{-5}$$
$$B(B^0 \to K^{*0}\tau^-\mu^+) < 8.2(9.8) \times 10^{-6}$$

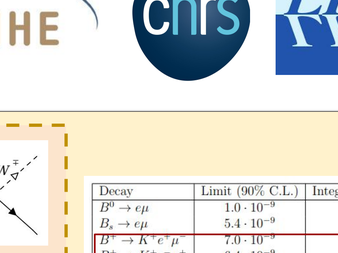
Efficiency maps on dilepton phase-space to allows **reweight on different model**[4]



Search for $B^0 \to K^{*0}\tau^\mp e^\pm$

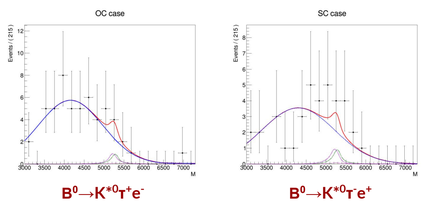
Under the supervision of **Francesco Polci and Pascal Vincent,** we are conducting **the first search at LHCb with τe** (missing energies from both leptons)**.** The analysis is planned to be done with 2016, 2017, 2018 data with **5.6 fb^{-1}** (now ongoing using 2016 data)

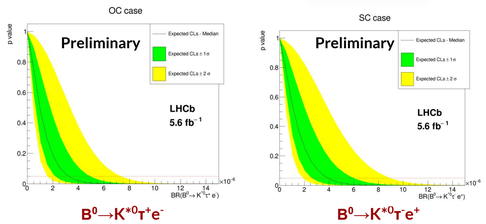
- **Final states**: $K^{*0}(\to K^+\pi^-)$ $\tau^\mp(\to\pi^\mp\pi^\mp\pi^\pm(\pi^0))$ $e^\pm$
- Electrons reconstruction is complicated by the emission of photons by bremsstrahlung
- Less efficient trigger compared to μ
- Improvement in reconstruction with missing particle



Strategy to improve B mass resolution: **reconstruction refitting the kinematics with mass and vertex constraints**

NORMALIZATION SAMPLE: $B^0 \to DsD$





- **Toy MC fit**, separately for charge combination
- **Estimated limits to BR**
- **Finalizing systematics, plan towards unblinding**

DISCLAIMER: not all the systematics are included in the estimated limits

Searches for τe in Belle and BaBar

Decay	Limit (90% C.L.)	Integrated luminosity	Experiment
$B^0 \to e^\pm\tau^\mp$	$1.6 \cdot 10^{-5}$	772M BB (711 fb^{-1})	Belle
$B^+ \to K^+e^\pm\tau^\mp$	$3.0 \cdot 10^{-5}$	472M BB (426 fb^{-1})	BaBar
$B^+ \to K^+e^+\tau^-$	$4.3 \cdot 10^{-5}$	472M BB (426 fb^{-1})	BaBar
$B^+ \to K^+e^-\tau^+$	$1.5 \cdot 10^{-5}$	472M BB (426 fb^{-1})	BaBar
$B^+ \to \pi^+e^\pm\tau^\mp$	$7.5 \cdot 10^{-5}$	472M BB (426 fb^{-1})	BaBar
$B^+ \to \pi^+e^+\tau^-$	$7.4 \cdot 10^{-5}$	472M BB (426 fb^{-1})	BaBar
$B^+ \to \pi^+e^-\tau^+$	$2.0 \cdot 10^{-5}$	472M BB (426 fb^{-1})	BaBar
$B^0 \to K^{*0}e^+\tau^-$	?	$5.6\ fb^{-1}$	LHCb
$B^0 \to K^{*0}e^-\tau^+$	?		LHCb

1. D. Guadagnoli and P. Koppenburg, Lepton-flavor violation and lepton-flavor-universality violation in b and c decays, 2022.76 doi: arXiv.2207.01851.
2. LHCb collaboration, R. Aaij et al., Search for the lepton flavour violating decay $B^0 \to K^{*0}\tau^\mp\mu^\pm$, arXiv:2209.09846, to appear in JHEP.
3. A. L. Read, Presentation of search results: The CLs technique, J. Phys. G28 (2002) 2693.D. M. Straub, flavio: a python package for flavour and precision phenomenology in the standard model and beyond, 2018.
4. D. Becirevi´c, O. Sumensari, and R. Z. Funchal, Lepton flavor violation in exclusive b → s decays, The European Physica Journal C 76 (2016) .