Rare dileptonic $B^0_{(s)}$ decays at LHCb

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Personal informations

Born in Catania (Italy) 9/06/1987

First level degree in Physics in Catania (2006-2009)

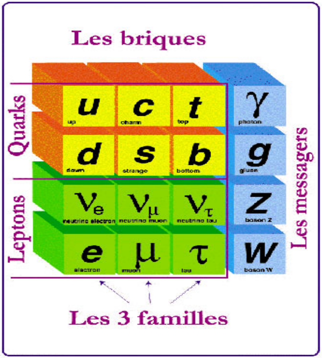
Second level degree in Theoretical Physics in Pisa (2009-2012):

- Master thesis title: "Study of a model of chiral effective Lagrangian with two light flavours above the chiral transition"
- Subject: Effective theories of QCD at finite Temperature
- Advisor: Prof. Enrico Meggiolaro

The thesis project: "Rare dileptonic B^0 decays"
Thesis advisors: Giampiero Mancinelli (CPPM), Jerome Charles (CPT)

Goal: use the results obtained analyzing the data collected by the LHCb collaboration to get a deeper knowledge of the Standard Model and Beyond Standard Model (BSM) fundamental couplings.

The Standard Model



Standard Model describes particles and their interactions

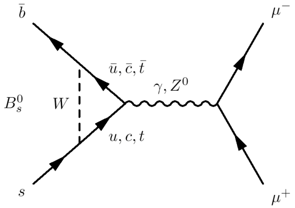
- interactions among particles are required by symmetries between particles
- It has been verified at a high precision level and in a lot of prediction
- But it doesn't answer to several questions:
  - origin and hierarchies of particle masses
  - matter-antimatter asymmetry
  - strong CP-violation
  - gravity
  - ...

$\Rightarrow$ We look for New Physics (NP) beyond the Standard Model

How to look for New Physics?

- **Direct** searches: production of new on-shell high-mass particles (CMS, ATLAS...)

- **Indirect** searches: observe in low-energy fenomena (like decays) the effects of new particles and/or interactions in the quantum loop (LHCb, Babar, Belle..)
  - **precision measurements**: BR(rare decays) & CP violation

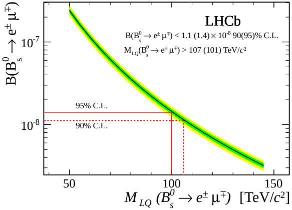


<u>What we need</u>: very **precise theoretical predictions** to be compared with as **precise experimental measurements**

  - **SM-forbidden processes** (*e.g.* Lepton Flavour Violation)

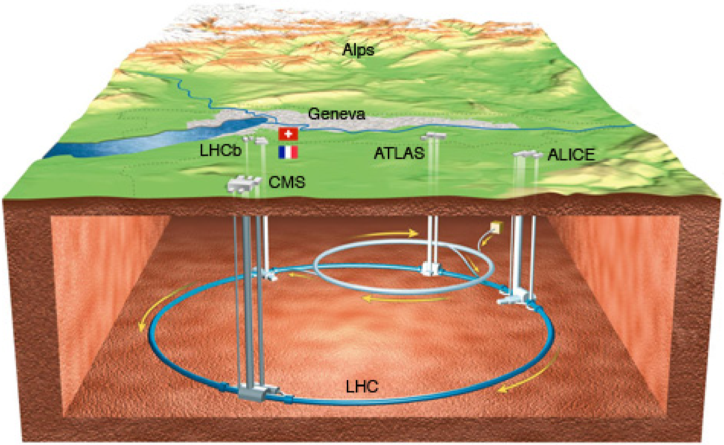
$B^0_{(s)} \to e^{\pm}\mu^{\mp}$:

  - forbidden by SM (LFV mode)
  - allowed in NP models thanks to Leptoquark particles (*e.g.* Pati-Salam model)
  - upper-limit on BR $\Rightarrow$ lower bound on Leptoquark mass $> \sim 100$ TeV!



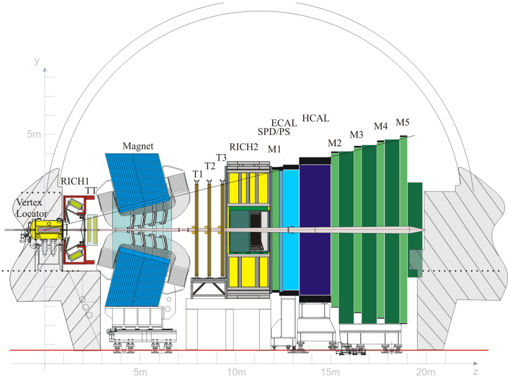
The LHC accelerator & the LHCb detector

Large Hadron Collider (LHC) has been built to test the SM and look for New Physics. It has been designed to work at an energy of 14 TeV in the center of mass frame LHCb is one of the 4 big experiments (and collaborations) of LHC: ALICE, ATLAS, CMS et LHCb.



LHCb detector

A dedicated detector for the study of B decays
It is a **one arm spectrometer with a forward geometry**:
mainly a **track detector** together with a very good **Particle IDentification (PID)** system.



High $B_{(d,s)}$ statistics: large cross section ($pp \to b\bar{b}X$), acceptance of $b\bar{b}$ pair & trigger efficiency for μ

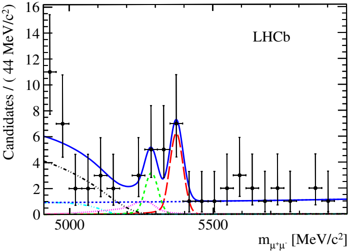
$B^0_{(s)} \rightarrow \mu^+\mu^-$

Theory predictions [Bobeth *et al.*, arXiv:1311.0903v1]:

$$BR_{SM}(B^0_s \rightarrow \mu^+\mu^-) = (3.65 \pm 0.23) \times 10^{-9}$$
$$BR_{SM}(B^0_d \rightarrow \mu^+\mu^-) = (1.06 \pm 0.09) \times 10^{-10}$$

Experimental status: after **30 years** of searches

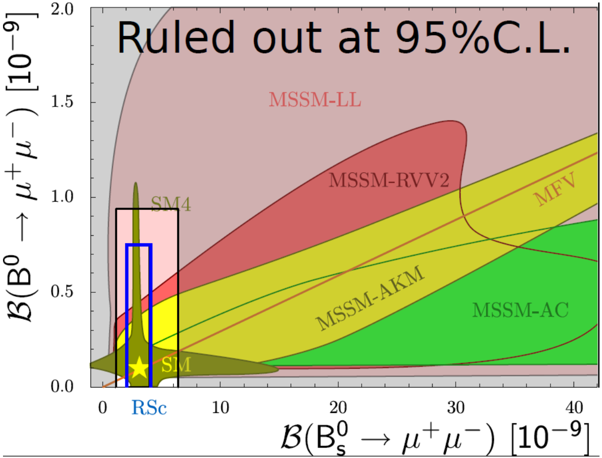
- November '12: first evidence for $B^0_s \rightarrow \mu^+\mu^-$ (@ 3.5 σ - 2.1 fb^{-1}) [LHCb, PhysRevLett.110.021801]
- July '13: update of the analysis (3.1 fb^{-1}) [LHCb,PhysRevLett.110.101805]:
  - $BR(B^0_s \rightarrow \mu^+\mu^-) = 2.9^{+1.1}_{-1.0} \times 10^{-9}$ @ 4σ
  - $BR(B^0_d \rightarrow \mu^+\mu^-) = 3.7^{+2.4}_{-2.1} \times 10^{-10}$ @ 2σ



Implications of measurements

Measured values of $BR(B^0_{(s)} \to \mu\mu)$ are consistent with SM predictions.

Updated from [Straub, ArXiv:1205.6094]



Indicative only: LHCb $2.1 fb^{-1}$, $3.1 fb^{-1}$

$B_s^0 \to \tau^+\tau^-$

- In SM we have [Bobeth *et al.*, arXiv:1311.0903v1] :

$$BR_{SM}(B_s^0 \to \tau^+\tau^-) = (7.73 \pm 0.49) \times 10^{-7}$$
$$BR_{SM}(B_d^0 \to \tau^+\tau^-) = (2.22 \pm 0.04) \times 10^{-8}$$

- $B_s^0 \to \tau^+\tau^-$ a good candidate where do look for NP effects even if these are absents in other $B_{(s)}^0$ decays [Dighe *et al*, arXiv:1207.1324v2]:
  - respecting all the constraints on other B_s^0 decays it could be as large as 15%
  - in models with a flavour depending Z' coupling it could be up to 5%
  - in models with scalar Leptoquark it could be up to 0.3%

- Current status:
  - $BR(B_d^0 \to \tau^+\tau^-) < 4 \cdot 10^{-4}$ @ 90% CL by BaBar
  - $BR(B_s^0 \to \tau^+\tau^-)$ has **not yet been constrained**

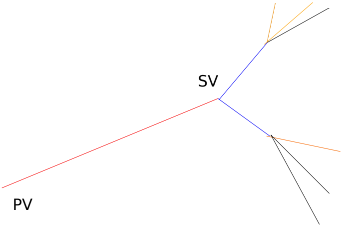
Challenging issues

τ particles have a very short lifetime $\Longrightarrow$ we must reconstruct them from their daughter particles

But...

- at least a neutrino for each τ decay (1 for semileptonic or 2 for leptonic channels) $\Rightarrow$ at least **2 unreconstructable neutrinos** (due to the detector geometry) and so...
- we cannot completely reconstruct the two τ momenta & invariant mass (not easy τ identification)
- we can rely only on a **partial mass reconstruction**

B_s
τ
ν
visible tracks (μ or π)



The "best" τ decays to look for this channel are

- $\tau \rightarrow 3\pi + \nu(+\pi^0)$
- $\tau \rightarrow \mu + \nu + \nu$ which has a higher trigger efficiency, but no reconstructable vertex

Merci pour votre attention !