Search for τ → 3μ decays with CMS experiment at LHC

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Motivation

Lepton Flavour Violation (LFV) is allowed in the standard model extended to include neutrino mass.

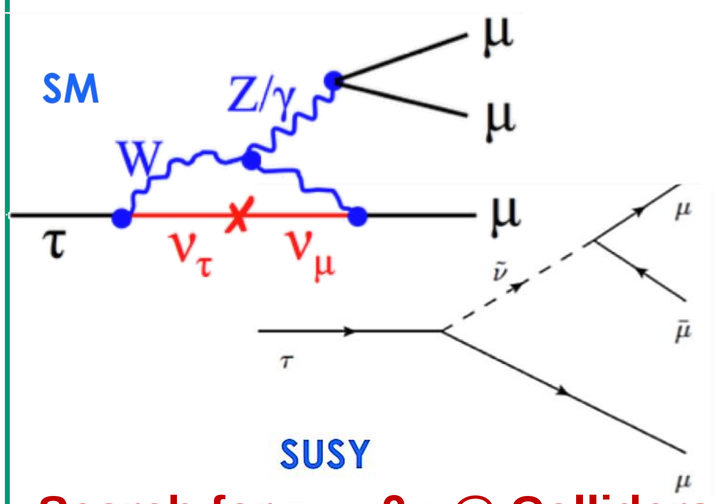
LFV has never been observed as of yet.

Suppressed n the Standard Model:
BranchingRatio

$\tau \rightarrow 3\mu$(SM) ~ $\mathcal{O}(10^{-54})$ [1]

Enhanced BR in SUSY, 2HDM:
BranchingRatio

$\tau \rightarrow 3\mu$(BSM) ~$\mathcal{O}(10^{-7} \div 10^{-9})$[2][3]



Search for τ → 3μ @ Colliders

YEAR	EXPERIMENT	EXP.[*]	OBS[*]	[*] X 10^{-8} @ 90% CL	
2010	Belle	-	2.1	ee → τ τ	[4]
2010	BaBar	4.0	3.2	ee → τ τ	[5]
2014	LHCb	5.0	4.6	HF channel – Run I	[6]
2016	ATLAS	39	38	W channel – Run I	[7]
2020	CMS	6.9	8.0	HF + W - 2016	[8]

Heavy Flavour (HF)

(D ⟶τν, B ⟶τν..., B ⟶D(τν)…)

Large cross section, low pT, high η, high bkg

Vector Boson (W)

Small cross section, high pT, low bkg

CMS IS EXPLORING BOTH

Perspectives

Run II, pp @ 13 TeV: Analysis at final stages
2017: 38 fb-1 **2018:** 59.7 fb-1

- Higher statistics → Higher sensitivity and larger statistics to train Multi-Variate discriminators

- CMS detector in 2017 and 2018: improved pixel detector → improved vertex reconstruction and track momentum resolution

Analysis Strategy

Search for a bump at nominal τ mass peak in the invariant mass of the 3μ system.

Heavy Flavour (HF)

Signal MC — Data

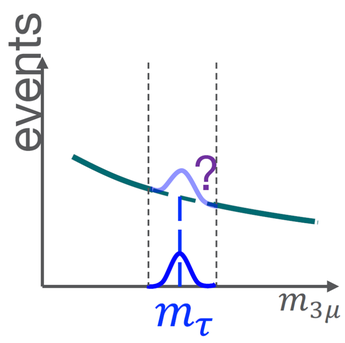
Online : Dedicated Trigger
Low pt μμ pairs + 1 track forming displaced common vertex

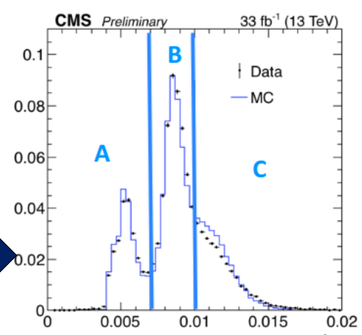
Offline Selections:
Reproduce HLT, Reconstruction of final-state muons

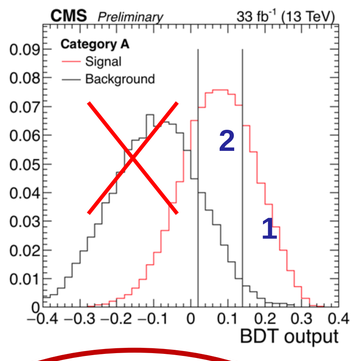
Event categories based on mass resolution m(3μ)

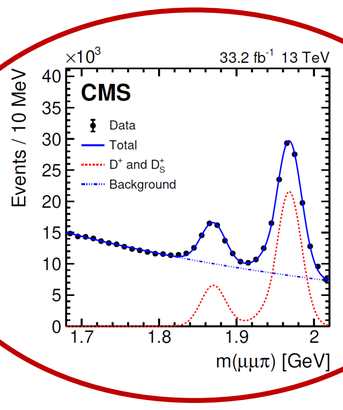
Train Boosted Decision Tree for signal-background seperation.
Signal: MC Bkg.: Data in mass sidebands

Limit on $\mathcal{B}(\tau \rightarrow 3\mu)$ from maximum likelihood fit on invariant mass shape.









$D_s \rightarrow \Phi(\mu\mu)\pi$ as **Control Channel** for the HF

W Channel

Signal MC — Data

Online : Dedicated Trigger
μμ pairs + 1 track forming isolated τ candidate

Efficiency corrections (trigger, μID) applied to MC

Event categorization:Barrel and endcap

Train Boosted Decision Tree for signal-background separation.
Signal: MC Bkg.: Data in mass sidebands

Limit on $\mathcal{B}(\tau \rightarrow 3\mu)$ from maximum likelihood fit on invariant mass shape.

Results – 2016 Data

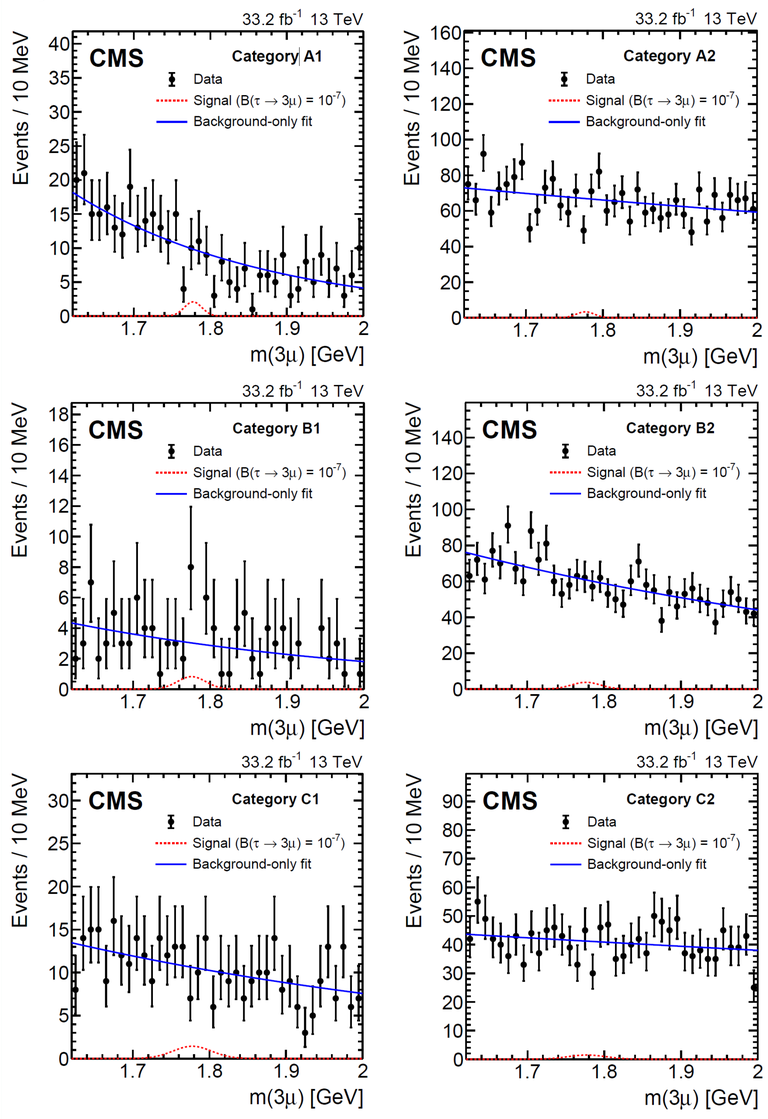
Heavy Flavour (HF)

Signal extracted from a maximum likelihood fit in each category.

MC → Crystal Ball

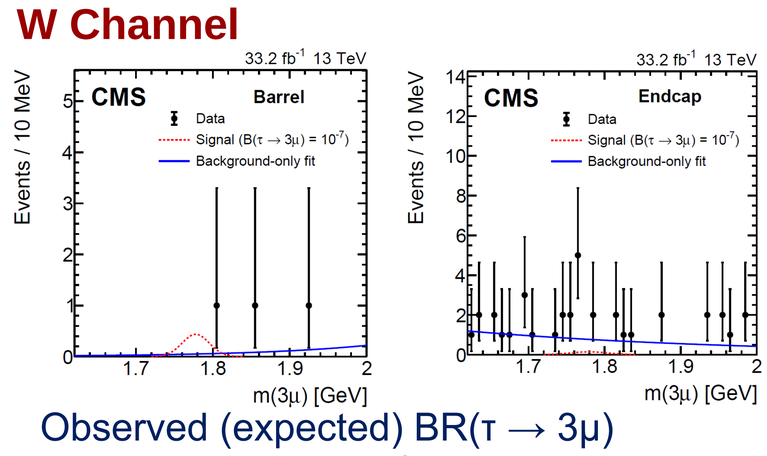
Background → Exponential + Polynomial

Systematics → Nuisance Parameters



Observed (expected) BR(τ → 3μ)
= **9.2 (10.0)10^{-8} at 90% C.L.**

W Channel



Observed (expected) BR(τ → 3μ)
= **19.5 (12.9)10^{-8} at 90% C.L.**

Combined

Observed (expected) BR(τ → 3μ)
= **8.0 (6.9)10^{-8} at 90% C.L.**

Dedicated trigger path in place:

- Goal: lowering the pT threshold to enhance the signal acceptance while keeping similar rates as 2018.

New tools in Run 3:

- Level-1 trigger: implementation of a 3-μ invariant mass object
- CSC-GEM segment (1.6 < |eta|< 2.1) (Not yet completed)
  - improved momentum resolution at L1 trigger
  - Extended eta coverage

Bibliography:
[1] Eur. Phys. J. C 79, 84 (2019)
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Acknowledgments:
State Ministry of Skills Development, Vocational Education, Research & Innovation, Government of Sri Lanka

Posters@LHCC: 29 Nov 2022,
CERN, Geneva (Switzerland)

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