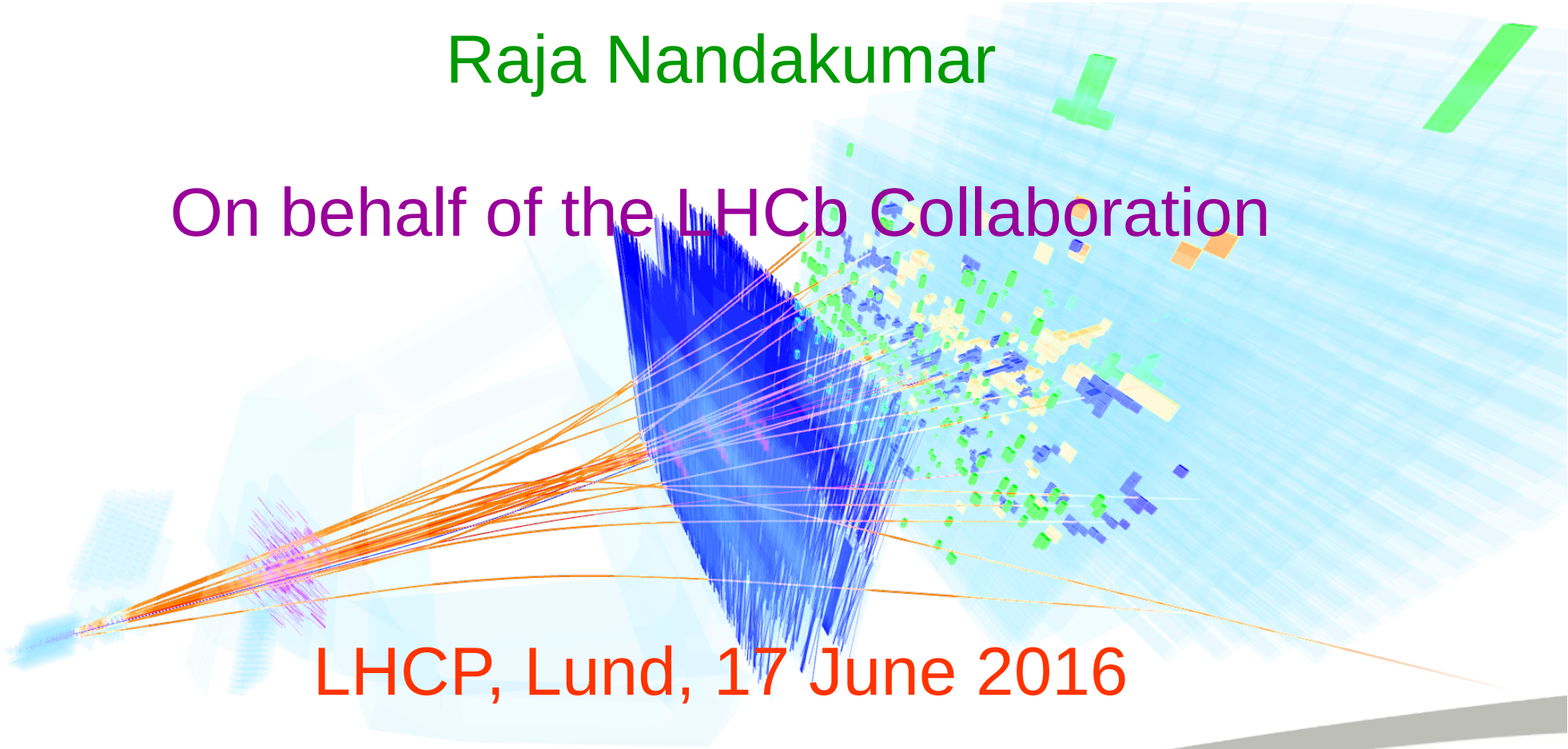
Searches for heavy neutrinos, LFV

Raja Nandakumar

On behalf of the LHCb Collaboration



LHCP, Lund, 17 June 2016

Science & Technology Facilities Council

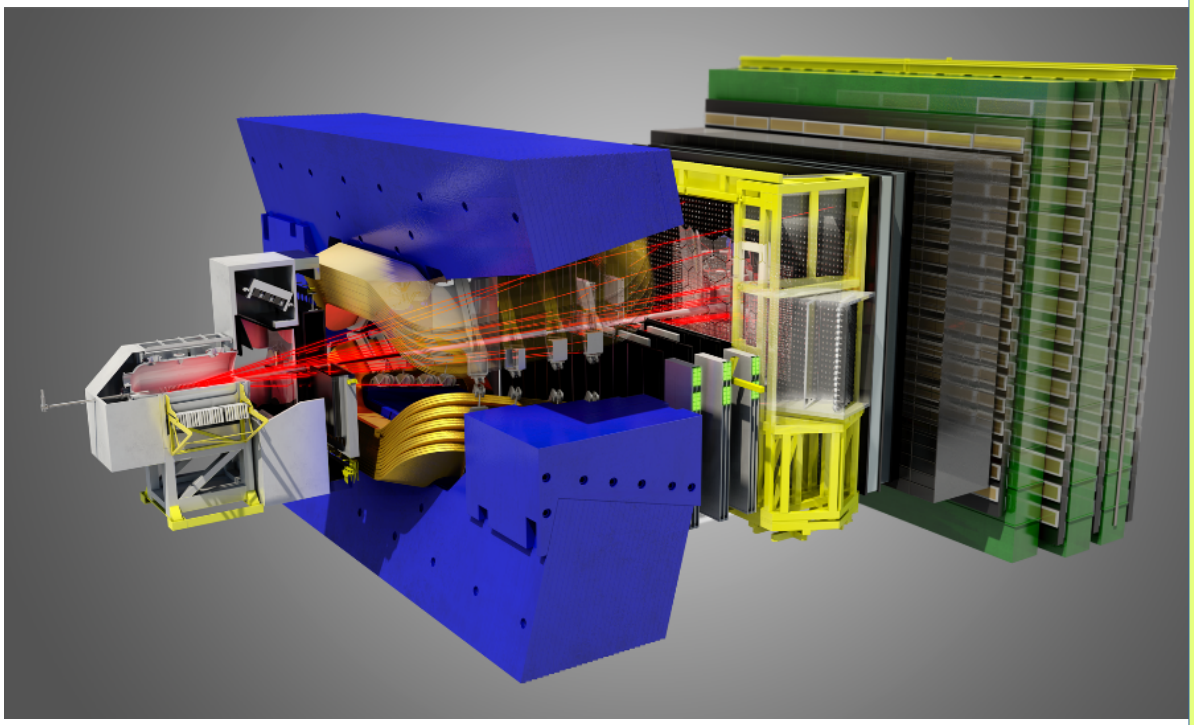
Introduction

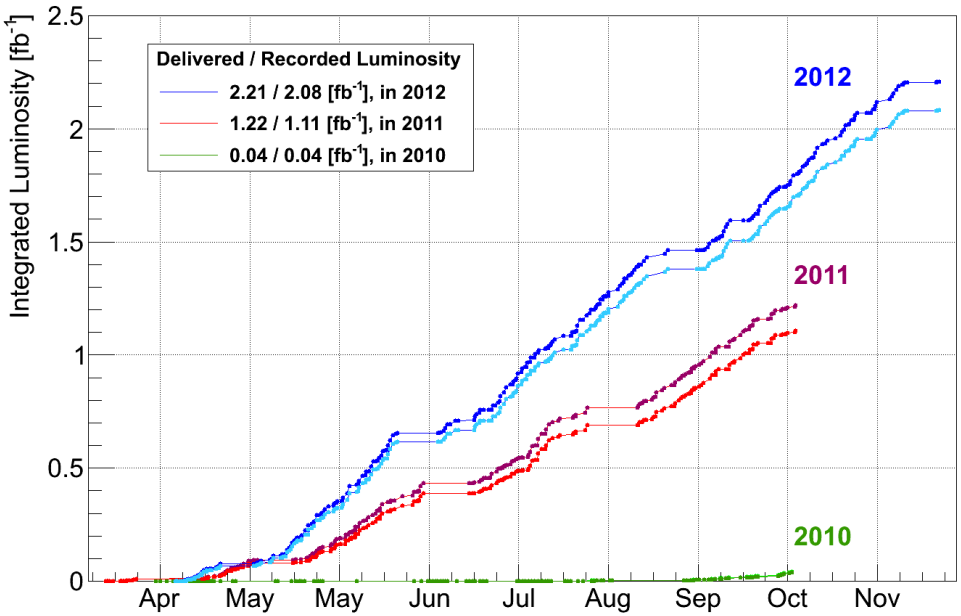
- LHCb for rare searches
- Search for LFV in $D^0 \to e^{\pm}\mu^{\mp}$
- Search for LFV in $\tau^- \to \mu^-\mu^+\mu^-$
- Search for Majorana neutrinos in $B^- \to \pi^+\mu^-\mu^-$
- Summary

LHCb detector

LHCb as flavour factory

- pp collisions at 7, 8 TeV
- Full spectrum of B hadrons
  - B^0, B_s^0, B^+, B_c, L_b^0, …
  - And c hadrons too
- $\mathcal{L} \sim 10^{32} – 10^{33}$ cm^{-2}s^{-1}
- $\int \mathcal{L} = 3.0$ fb^{-1} in Run I





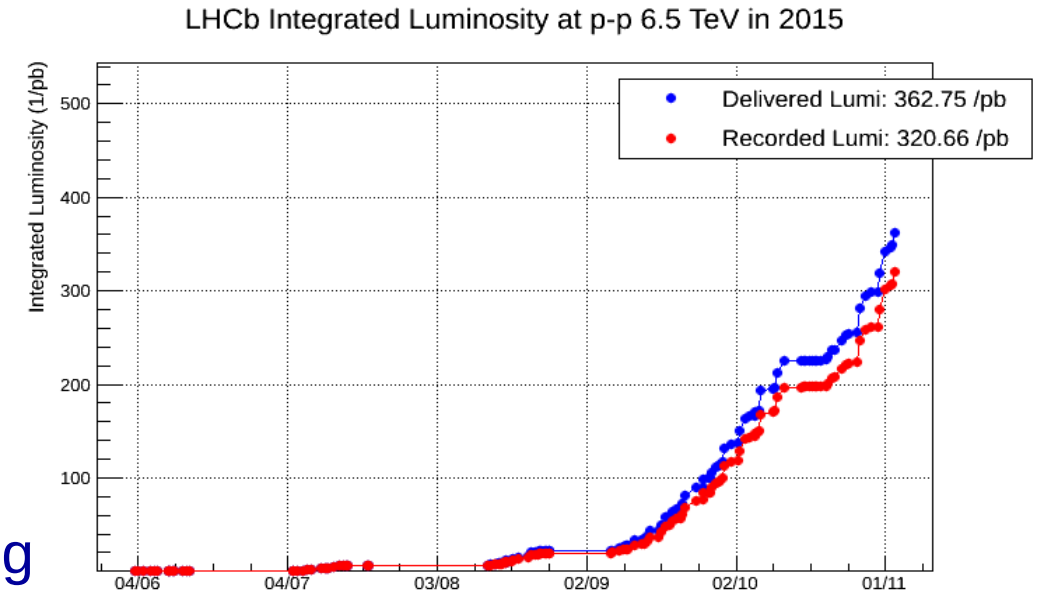
- Single arm forward spectrometer
- Acceptance $2 < \eta < 5$
- Momentum resolution :
  - $\delta p/p \sim 0.5 – 1\%$
- IP resolution ~ 20μm
  - Excellent pid, trigger, ...

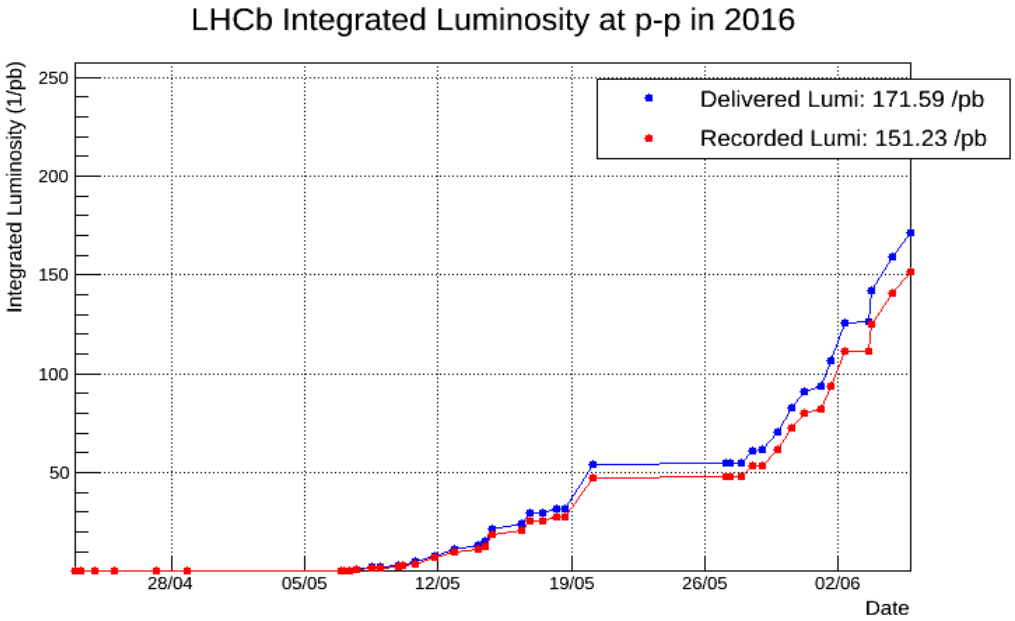
Int. J. Mod. Phys. A30 (2015) 1530022

Science & Technology Facilities Council

LHCb in Run II

- p-p collisions at 13 TeV
- $\mathcal{L} \sim 10^{32} - 10^{33}$ cm^{-2}s^{-1}
  - Luminosity levelling
  - Average Interactions / bunch crossing ~ 1
- Aim for 8 pb^{-1}
- Precision measurements using high statistics
- Redesigned trigger
  - Automatised calibration and alignment
  - Offline rate of ~12.5 Khz
    - 600 MB/s to storage
- Note - results presented today use only Run I data





Int. J. Mod. Phys. A30 (2015) 1530022

Motivation

- Neutrino oscillations
  - Only possible with massive neutrinos
    - Needs SM extensions
    - e.g. see-saw mechanism, with heavy neutrinos
- LFV
  - Suppressed in SM (BF $\lesssim 10^{-40}$)
  - Contributions from ν oscillations
- Interesting ground for studies
  - Difficult to detect ν directly
  - Test for properties indirectly using precision studies
  - Modifications in rates from SM extensions

LFV decay $D^0 \to e^{\pm}\mu^{\mp}$

- Forbidden in SM
  - 2.6×10^{-7} (90%CL) from Belle
    - PRD 81 (2010) 091102
- Possible for various SM extensions
  - BR ~ 10^{-6} for R-parity violating SUSY models

    ~ 10^{-8} for some leptoquark models

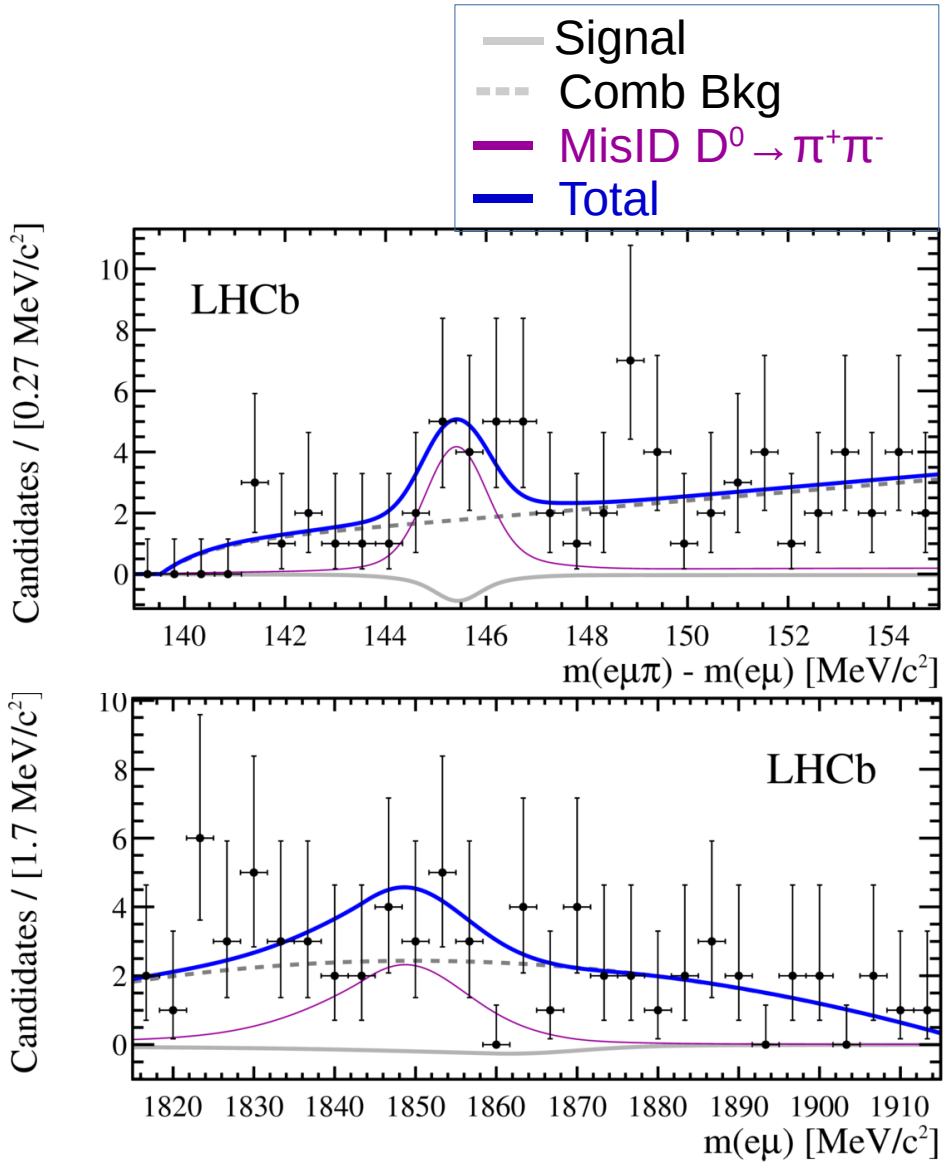
    ~ 10^{-14} for SM with extra fermions

PLB 754 (2016) 167 - 175

LFV decay $D^0 \to e^{\pm}\mu^{\mp}$

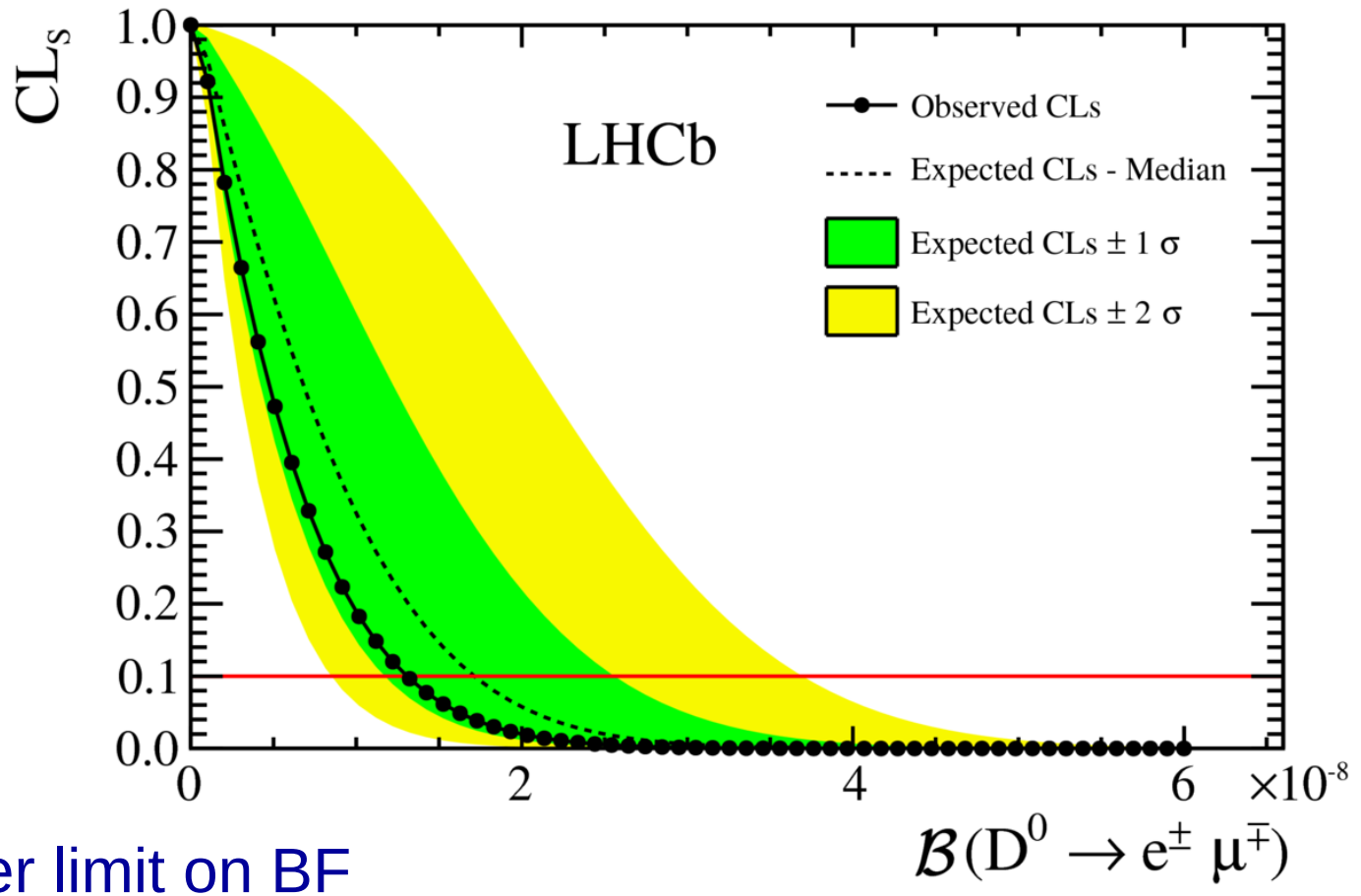
- Analysis using Run I data
  - 3 fb^{-1}, $\sqrt{s}$ = 7–8 TeV
  - Use D^0 from $D^{*+} \to D^0\pi^+$
  - Normalisation channel :

    $D^0 \to K^-\pi^+$
- Standard LHCb blind analysis
  - Pre-selection + MVA
  - Evaluate backgrounds
    - $\pi^+\pi^-$, $\pi^-e^+\nu_e$, $\pi^-\mu^+\nu_\mu$
  - Understand systematics
  - Unblind and extract fit values
    - Fit 3 bins of BDT output
    - 2D fit for Δm, m
  - Plot : Most signal-like BDT bin



PLB 754 (2016) 167 - 175

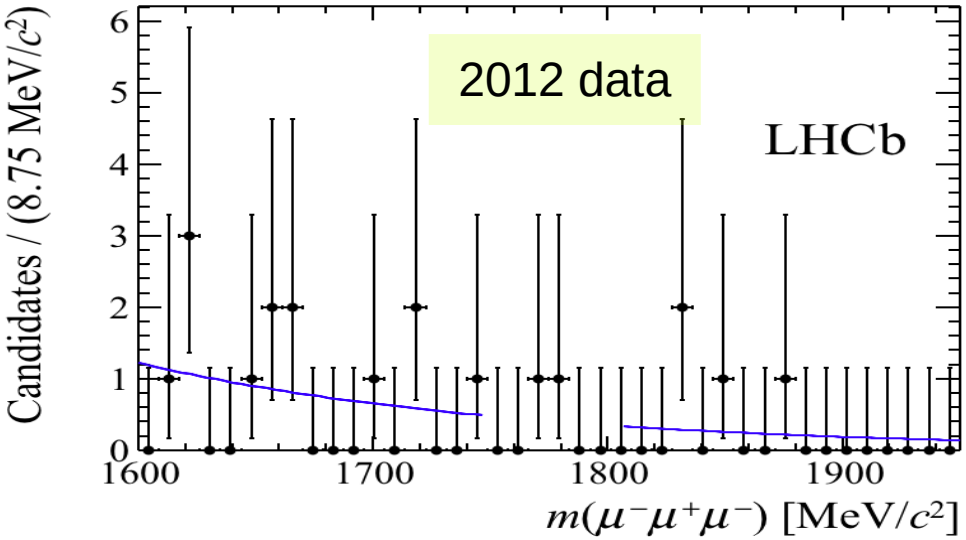
LFV decay $D^0 \to e^{\pm}\mu^{\mp}$

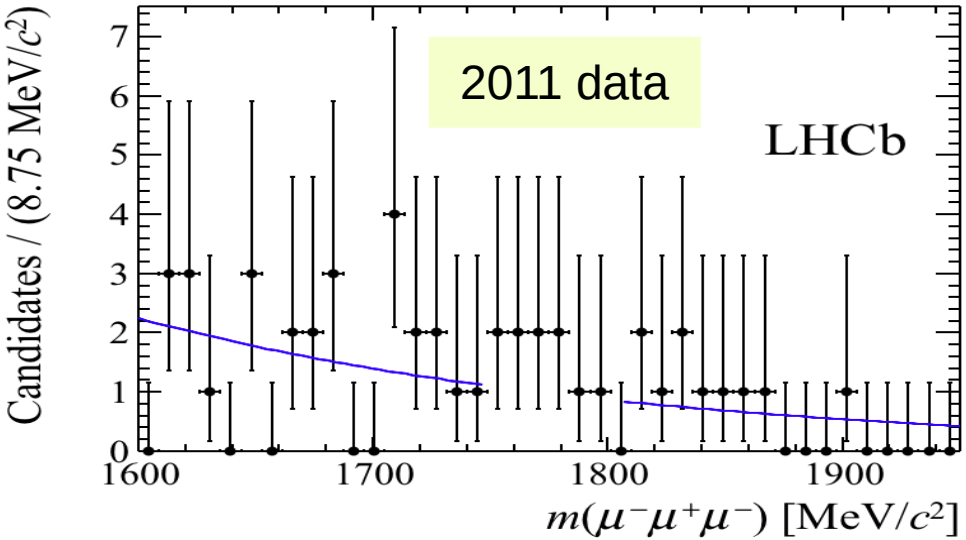


- Upper limit on BF
  - 1.3 x 10^{-8} (90%)
  - 1.6 x 10^{-8} (95%)
  - Dominated by statistics

PLB 754 (2016) 167 - 175

LFV decay $\tau^- \to \mu^-\mu^+\mu^-$





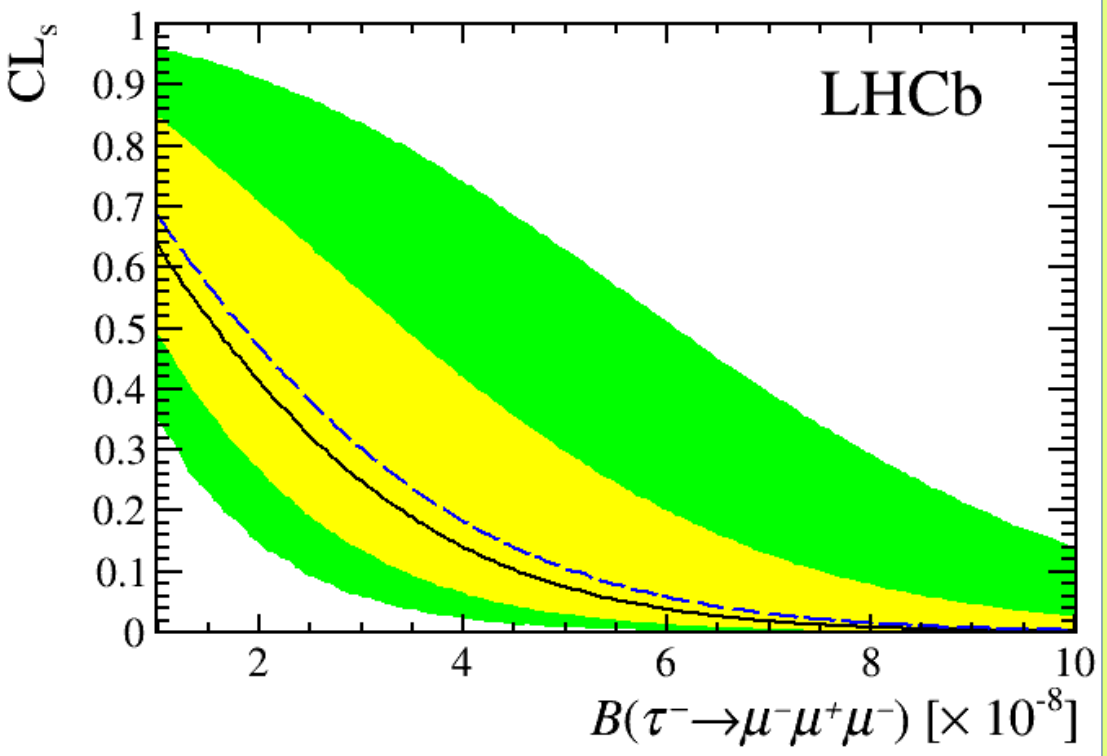
MVA response bin with highest signal prob.

- Large inclusive τ cross–section
  - From decays of c, b hadrons
  - ~ 85μb at 7 TeV
- Analysis based on Run I data
  - 3 fb^{-1}, $\sqrt{s}$ = 7–8 TeV
- Typical LHCb selection
  - Three μ tracks which make up a τ
  - Multiple MVAs
    - Separate optimizations for 2011 and 2012 data
- Normalised to
  - $D_s^- \to \varphi(\mu^+\mu^-)\pi^-$

JHEP 02 (2015) 121

LFV decay $\tau^- \to \mu^-\mu^+\mu^-$

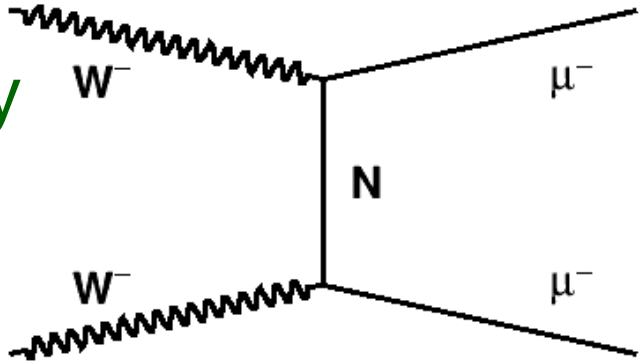
- No significant excess over background found
- Measured
  - BF ($\tau^- \to \mu^-\mu^+\mu^-$)
    $< 4.6\ (5.6) \times 10^{-8}$
  - 90 (95) % CL
- Expected
  - BF ($\tau^- \to \mu^-\mu^+\mu^-$)
    $< 5.0\ (6.1) \times 10^{-8}$



JHEP 02 (2015) 121

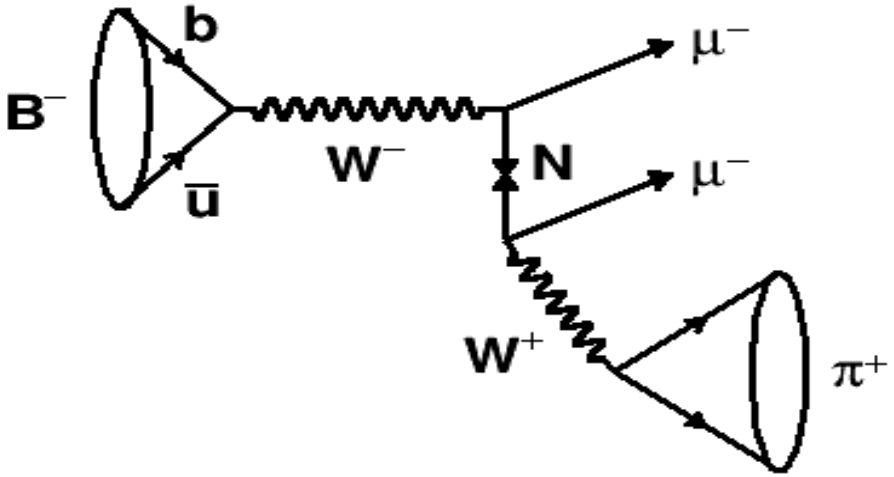
Majorana neutrinos in LHCb

- Neutrino masses from see-saw mechanism
  - Likely mass has Majorana component
  - Heavy ($m \gg eV$), unstable
- Majorana neutrinos
  - Neutrino-less double beta decay
    - Can be probed in LHC
  - Pairs of identical leptons
    - LFV, LNV



- Studies complementary to those from ATLAS / CMS

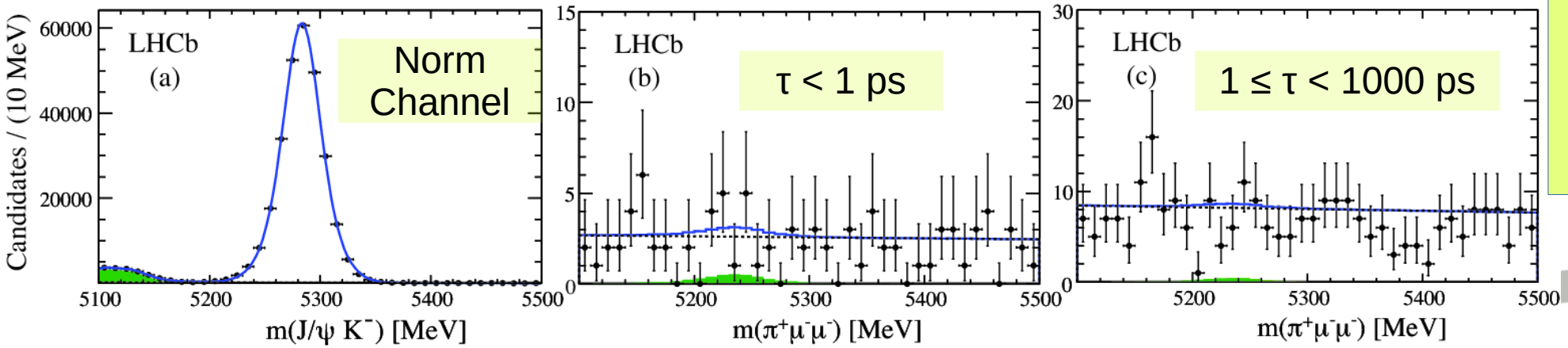
Majorana neutrinos in $B^- \to \pi^+ \mu^- \mu^-$



- Search for neutrinos with
  - 250 MeV < $\mathcal{M}$ < 5000 MeV
  - Two samples :
    - $\tau < 1$ ps
    - $1 \leq \tau < 1000$ ps
- Normalise to

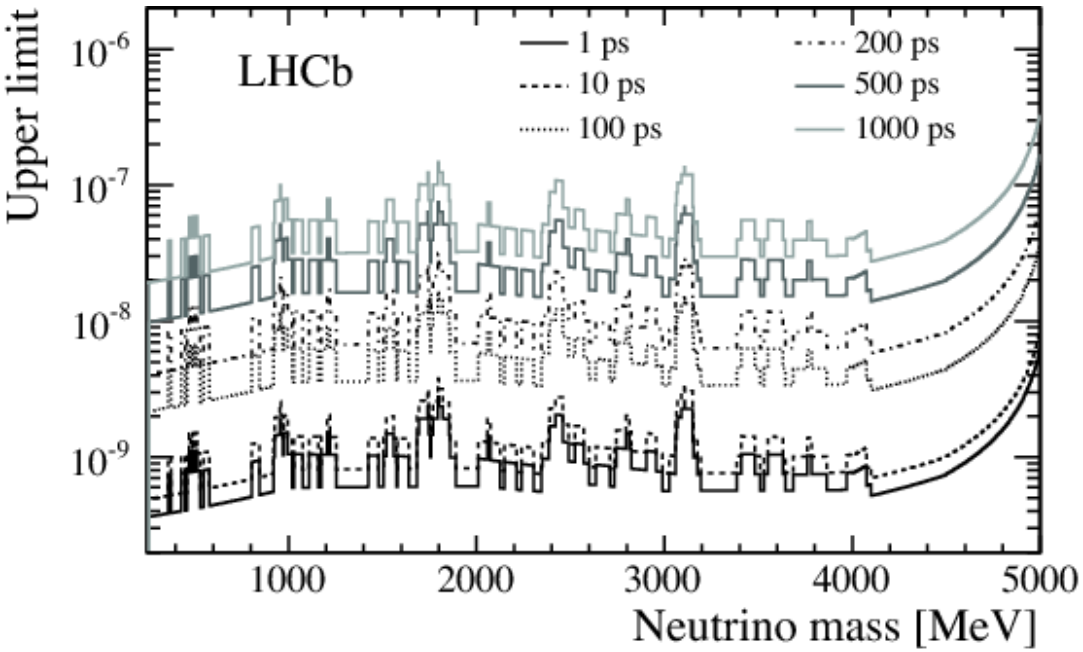
  $B^- \to J/\psi\, K^-$ where $J/\psi \to \mu^+\mu^-$
- Analysis using Run I data
  - 3 fb^{-1}, $\sqrt{s}$ = 7–8 TeV

PRL 112, 131802 (2014)



Majorana neutrinos in $B^- \to \pi^+ \mu^- \mu^-$

95% CL



- No signal found
- BF($B^- \to \pi^+ \mu^- \mu^-$)

  $< 4 \times 10^{-9}$

  - Also quote limits on coupling of 4th generation majorana neutrino to muons

PRL 112, 131802 (2014)

Summary

- LHCb is an excellent b and c factory
- Various searches for very rare decays performed
  - No signal so far
  - Various limits improved by ~x10
    - Starting to constrain some models
  - Still far from systematic wall
  - J. Prisciandaro talk on LU/LFV tests
- Run II ongoing
  - Improved trigger system
    - L. Grillo talk on LHCb trigger and alignment
  - Larger data set than proportional to $\mathcal{L}$
- Look forward to exciting times
  - A. Cardini talk on LHCb Upgrade
  - More analyses in future from LHCb for LFV / LNV tests