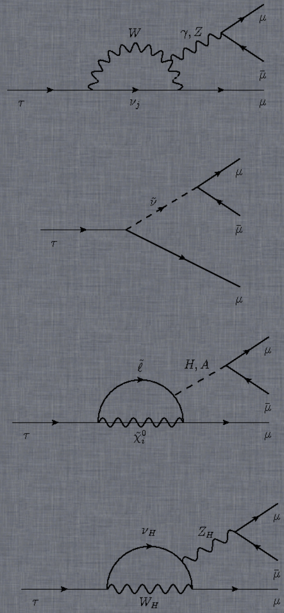
Search for LFV and LNV decays at LHCb

Marcin Chrząszcz

Institute of Nuclear Physics,
Polish Academy of Science,
on behalf of LHCb collaboration

25 września 2012



Introduction

Detector

Performance

Lepton Number Violation

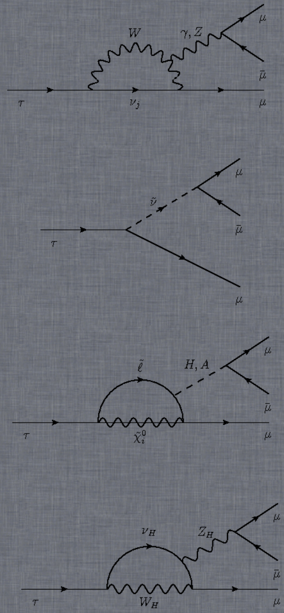
$B^- \to h^+ \ell^- \ell^-$

$B^- \to D^0 \pi^+ \mu^- \mu^-$

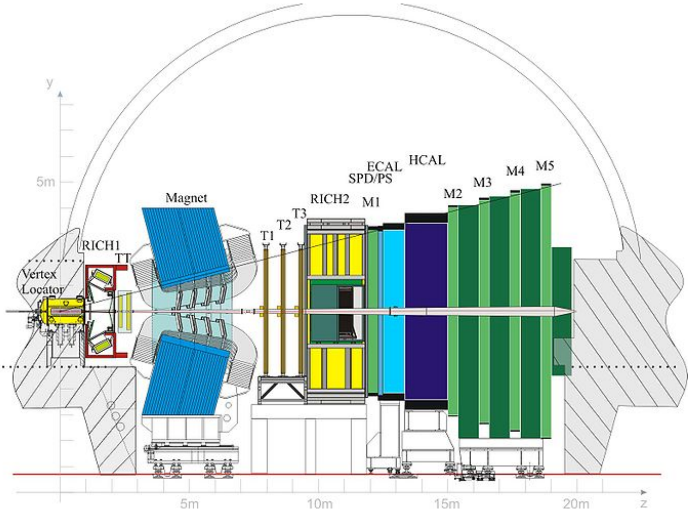
Lepton Flavour Violation

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

$\tau^- \to \bar{p} \mu^- \mu^+$

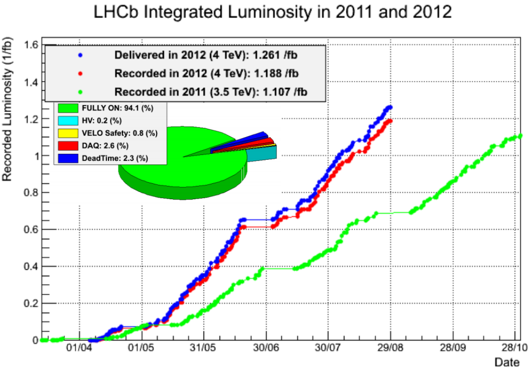


LHCb detector



M.Chrząszcz 2012

Luminosity



- Exelent detector performance.
- CM energy incresed to $8\,TeV \rightarrow \sim 15\%$ more $b\bar{b}$ events.
- Aiming to reach $3fb^{-1}$ in 2012.

M.Chrząszcz 2012

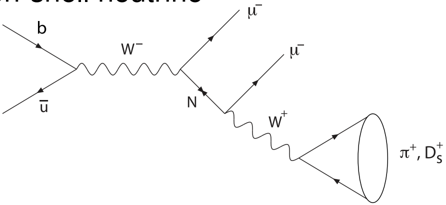
LNV in bottom decays

$\mathrm{B}^- \to h^+ \ell^- \ell^-$

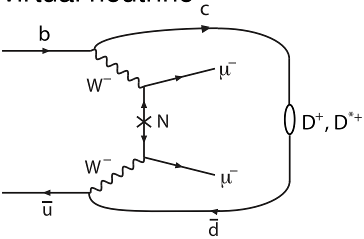
M.Chrząszcz 2012

LNV in bottom decays

on-shell neutrino



virtual neutrino



- resonant production in accessible mass range
- rates depend on Majorana neutrino–lepton coupling $|V_{\mu 4}|$ (e.g. arXiv:0901.3589)
- $m_4 = m_{\ell^-,\pi^+}$

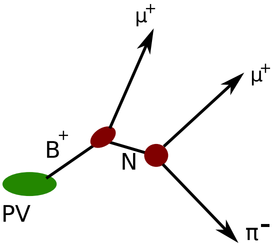
special for B decays

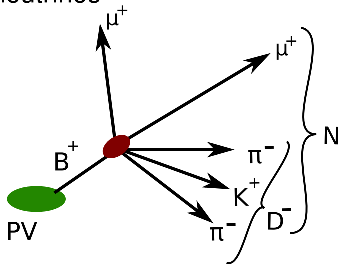
diagram without mass restriction
Cabbibo favoured for $\mathrm{B} \to \mathrm{D}$

M.Chrząszcz 2012

Search for Majorana neutrinos at LHCb

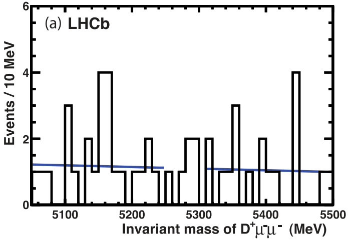
- LHCb: search for
  - $B^- \to \pi^+\mu^-\mu^-$
  - $B^- \to D^+\mu^-\mu^-$
  - $B^- \to {D_s}^+\mu^-\mu^-$
  - $B^- \to D^{*+}\mu^-\mu^-$
- consider topology in reconstruction
  - allow for flight distance for on-shell neutrinos
  - common vertex for virtual neutrinos



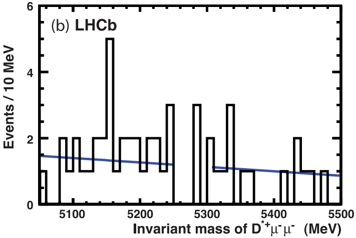


virtual Majorana neutrinos

$B^- \to D^+\mu^-\mu^-$



$B^- \to D^{*+}\mu^-\mu^-$



$\mathcal{B}(B^- \to D^+\mu^-\mu^-) < 6.9 \times 10^{-7}$ @ 95 % CL

$\mathcal{B}(B^- \to D^{*+}\mu^-\mu^-) < 2.4 \times 10^{-6}$ @ 95 % CL

$0.41\ \text{fb}^{-1}$

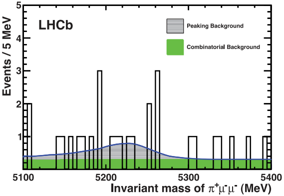
arXiv:1201.5600

M.Chrząszcz 2012

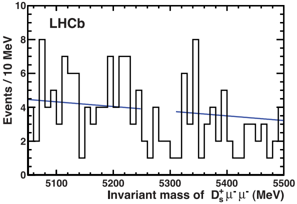
on-shell Majorana neutrinos

- mis-identification rates from data with mass shape from simulation

$B^- \to \pi^+\mu^-\mu^-$



$B^- \to D_s^+\mu^-\mu^-$



assuming B^- phase space decay:

$\mathcal{B}(B^- \to \pi^+\mu^-\mu^-) < 1.3 \times 10^{-8}$ @ 95 % CL

$\mathcal{B}(B^- \to D_s\mu^-\mu^-) < 5.8 \times 10^{-7}$ @ 95 % CL

0.41 fb^{-1}

arXiv:1201.5600

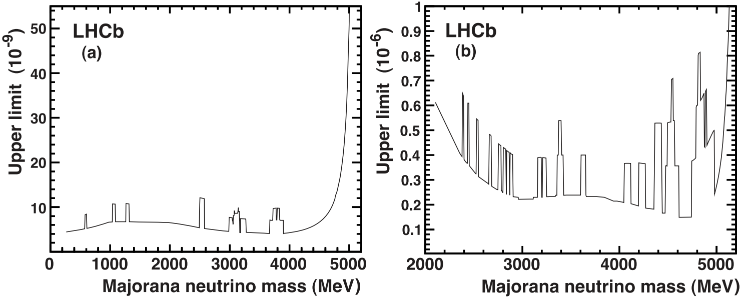
M.Chrząszcz 2012

implications on Majorana mass

mass extraction

Determine limit as function of $h^+\mu^-$ mass

$B^- \to \pi^+\mu^-\mu^-$ $\qquad$ $B^- \to D_s{}^+\mu^-\mu^-$

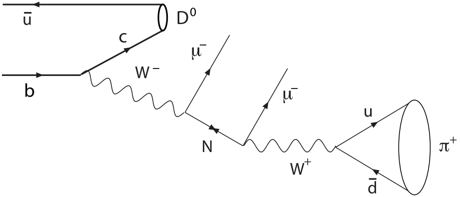


0.41 fb^{-1}

arXiv:1201.5600

M.Chrząszcz 2012

$B^- \to D^0 \pi^+ \mu^- \mu^-$



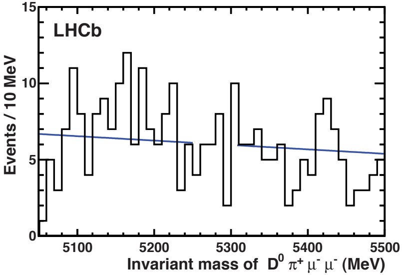
- Four body B decay complementary to three body decay (`arXiv:1108.6009`)
- $m_4 = m(\pi^+ \mu^-)$

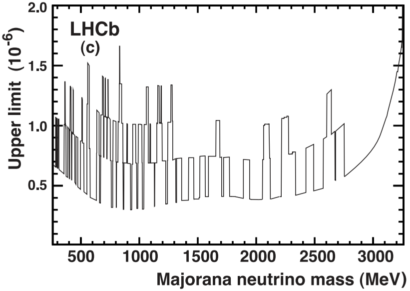
+ enhanced by W couplings
- smaller mass range accessible (260 MeV $< m_4 <$ 3.3 GeV)

- first performed at LHCb

M.Chrząszcz 2012

$B^- \to D^0\pi^+\mu^-\mu^-$





$\mathcal{B}(B^- \to D^0\pi^+\mu^-\mu^-) < 1.5 \times 10^{-6}$ @95 % CL [a]

Less restrictive than $B^- \to \pi^+\mu^-\mu^-$ on $|V_{\mu 4}|^2$

[a] LHCb, CERN-PH-EP-2012-006, arXiv:1201.5600

M.Chrząszcz 2012

Lepton Flavour Violation

1. $\tau^- \to \mu^-\mu^-\mu^+$
2. $\tau^- \to \overline{\mathrm{p}}\mu^-\mu^+$

M.Chrząszcz 2012

LFV in τ^- sector

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

M.Chrząszcz 2012

LFV in τ^- sector

1. In SM small $\mathcal{B}(\tau^- \to \mu^-\mu^-\mu^+) \sim 10^{-50}$
2. NP can enhance $\mathcal{B}$.
3. Nature still hides $\tau^- \to \mu^-\mu^-\mu^+$ from us.
4. Current limits:

Experiment	90% CL limit
BaBar	3.3×10^{-8}
Belle	2.1×10^{-8}

5. Can a hadron collider change the picture?

M.Chrząszcz 2012

Analysis aproach

$\mathcal{B}$ factories

1. Clean signal: $e^+e^- \to \tau^+\tau^-$
2. Claculate the trust axis
3. Semi tag the other tag

LHCb

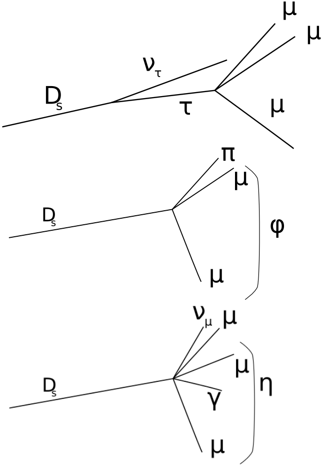
1. Inclusive τ cross section: 79.5 ± 8.3 µb.
2. $8 \times 10^{10} \tau$ produced.
3. Dominant contribution: $D_s \to \tau\nu_\tau$ (78%)
4. No tag possible.

M.Chrząszcz 2012

Strategy

- Loose cut based selection
- Classification in 3D space:
  - invariant mass
  - decay topology (multivariate)
  - particle identification (multivariate)
- Classifier trained on simulation
- Calibration with control channel
- Normalisation with D_s
- CLs method to extract the result

Signal & Calibration & Background channel



M.Chrząszcz 2012

signal likelihoods

particle identification

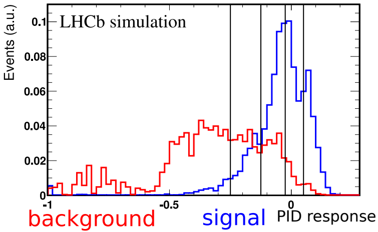
- hits in muon chambers
- energy in calorimeters
  - compatible with MIP
- RICH response

3 body decay likelihood

- vertex properties
  - vertex fit, pointing
- track quality
- isolation

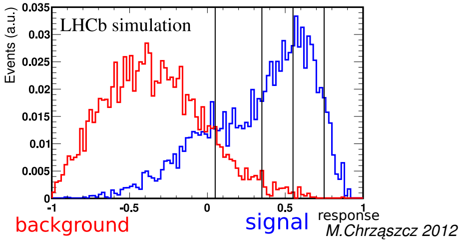
Calibration

$J/\psi \to \mu^+\mu^-$



Calibration

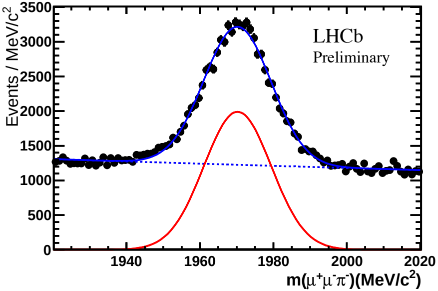
$D_s \to \phi\pi$



Normalisation channel $D_s^+ \to \phi(\mu^+\mu^-)\pi^+$

Produced τ leptons

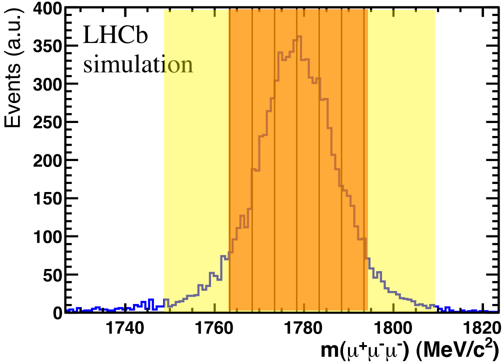
$$\mathcal{B}(\tau \to \mu\mu\mu) = \frac{\sigma(pp \to D_s \to \tau)}{\sigma(pp \to \tau)} \frac{\mathcal{B}(D_s \to \phi(\mu\mu)\pi)}{\mathcal{B}(D_s \to \tau\nu_\tau)} \frac{\varepsilon_{norm}}{\varepsilon_{sig}} \frac{N_{\tau \to \mu\mu\mu}}{N_{D_s \to \phi(\mu\mu)\pi}}$$



M.Chrząszcz 2012

Invariant mass

- background estimation in sidebands
- different signal likelihood inside signal region

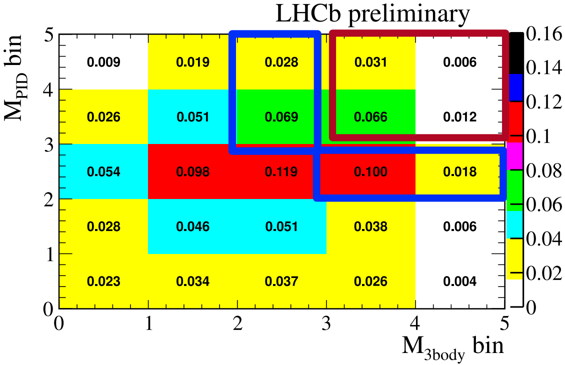


- mass resolution and mass scale calibrated on data

Signal likelihoods

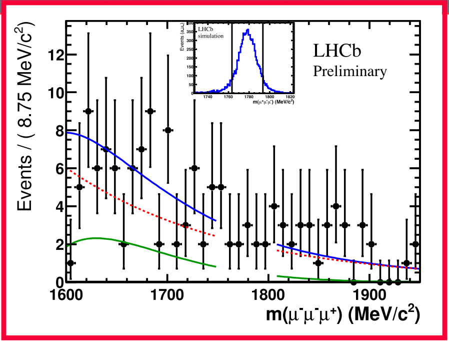
combined signal distribution

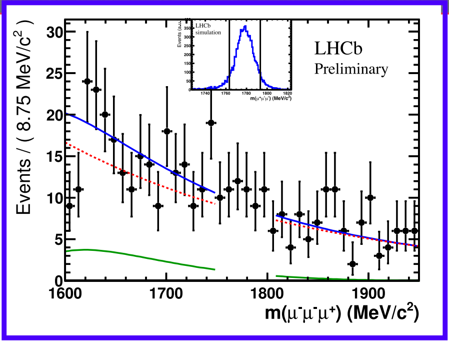
- events distributed over 25 likelihood bins
- background estimate from mass sidebands



- 11 % signal efficiency
- 21 % signal efficiency
- for illustration: high likelihood range shown

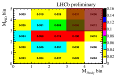
Observed events





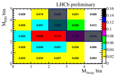
11 % of the signal

0.03 % of the background



21 % of the signal

0.14 % of the background



red dashed combinatorial background

green $D_s^+ \to \eta(\mu^-\mu^+\gamma)\mu^+\nu_\mu$

blue combined background

1 fb^{-1}

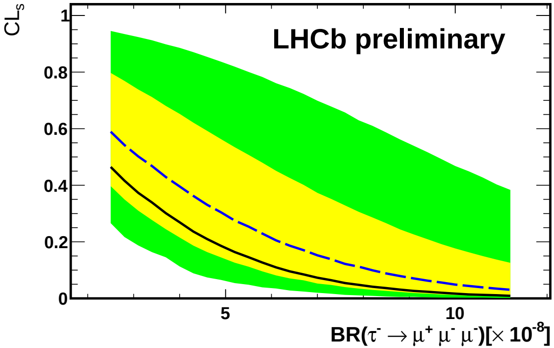
LHCb-CONF-2012-015

Extracted limit

$1\ fb^{-1}$

LHCb-CONF-2012-015

	observed	expected
$\mathcal{B}(\tau \to \mu\mu\mu) <$	6.3×10^{-8}	8.2×10^{-8}
	7.8×10^{-8}	9.9×10^{-8}



M.Chrząszcz 2012

LFV in τ^- sector

$$\tau^- \to \overline{\mathrm{p}}\mu^-\mu^+$$

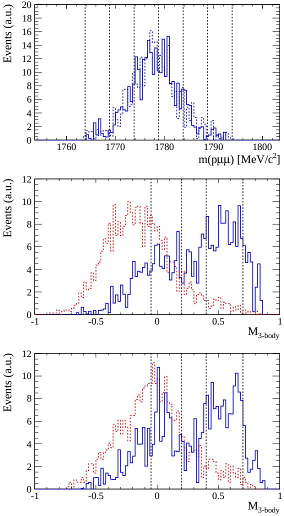
LFV in τ^- sector

1. Search for baryon number violation processes so far unsuccessful, but must have occurred in the early universe
2. Decay fall into $|B - L| = 0$ category, which is predicted by many NP models.
3. Similar decays $\tau^- \to \tilde{}\ell$, previous studied in $\mathcal{B}$ factories.
4. Two possible decay and new physics modes: $\tau^- \to \bar{\mathrm{p}}\mu^-\mu^+$, $\tau^- \to \mathrm{p}\mu^-\mu^+$.
5. Analysis adopted from $\tau^- \to \mu^-\mu^-\mu^+$

M.Chrząszcz 2012

Differences

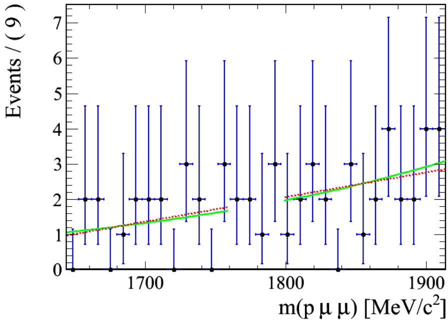
- Use the same $\mathcal{M}_{3body}$ BDT as for $\tau^- \to \mu^-\mu^-\mu^+$
- Insead of PID BDT use hard PID cut optimised on MC and Data.
- Worse normalization factor, due to hard PID cuts.
- Only combinatorical background expected.

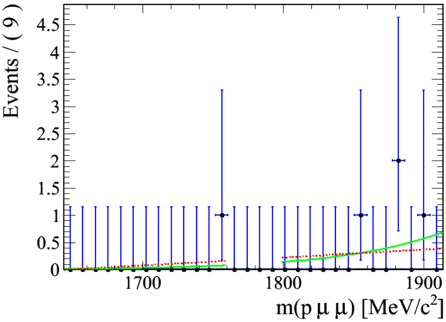


M.Chrząszcz 2012

Backorund Fits

$$\tau^- \to \overline{p}\mu^-\mu^-$$

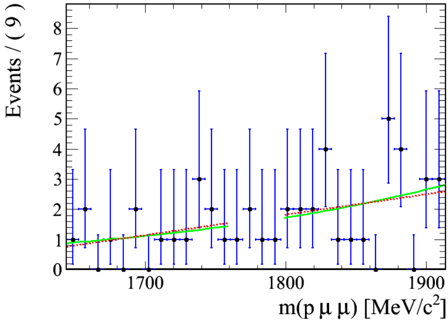


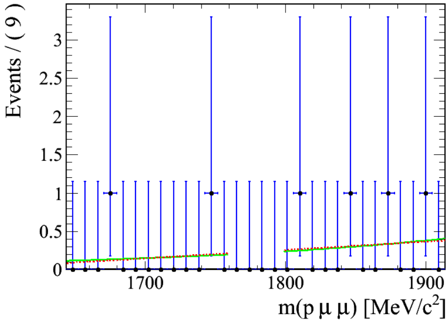


M.Chrząszcz 2012

Backorund Fits

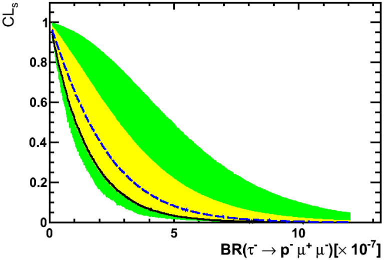
$\tau^- \to p\mu^-\mu^+$

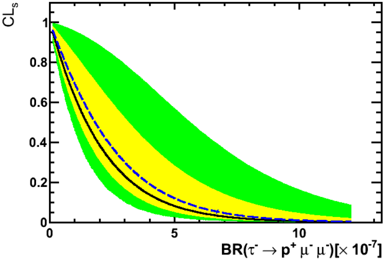




M.Chrząszcz 2012

Limits on $\tau^- \to \bar{p}\mu^-\mu^+$ and $\tau^- \to p\mu^-\mu^-$





CLs	Observed	expected
90%	4.7×10^{-7} 5.4^{-7}	4.7^{-7} 5.4^{-7}
95%	5.9×10^{-7} 6.9^{-7}	4.5^{-7} 6.0^{-7}

First time measured!!

M.Chrząszcz 2012

Summary

1. LNV, LFV and BNV still hides before us.
2. First measurements on τ physics on hadron coliders.
3. LHCb caughting up $\mathcal{B}$ factories.
4. $\mathcal{B}(\tau \rightarrow \mathrm{p}\mu\mu)$ first time measured.

Thank you for your attention.

M.Chrząszcz 2012