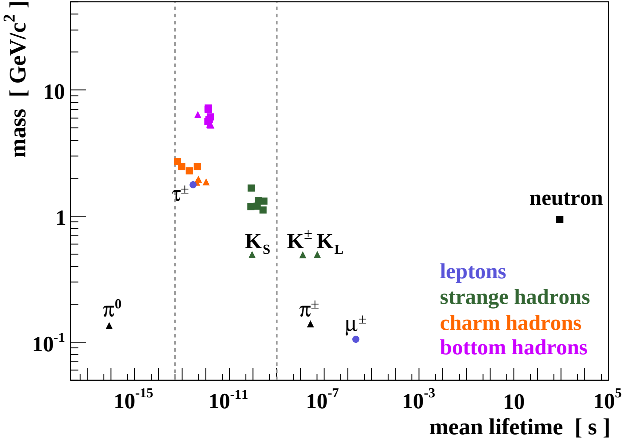
Searches for exotic long-lived particles at LHCb

Pieter David

Nikhef Jamboree 2014

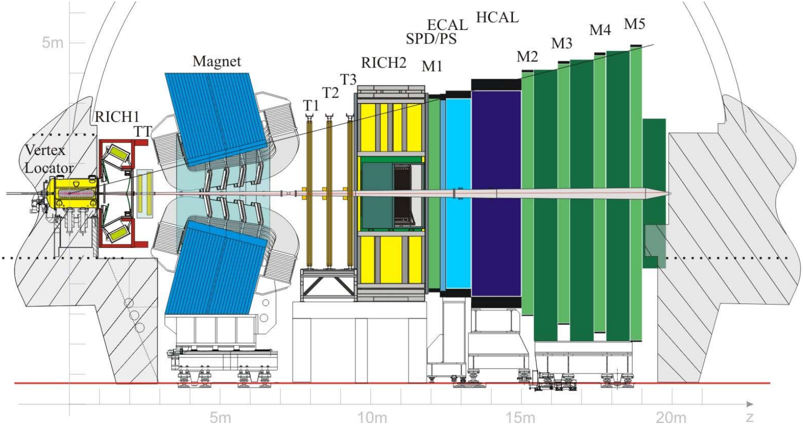
New Physics and long-lived particles



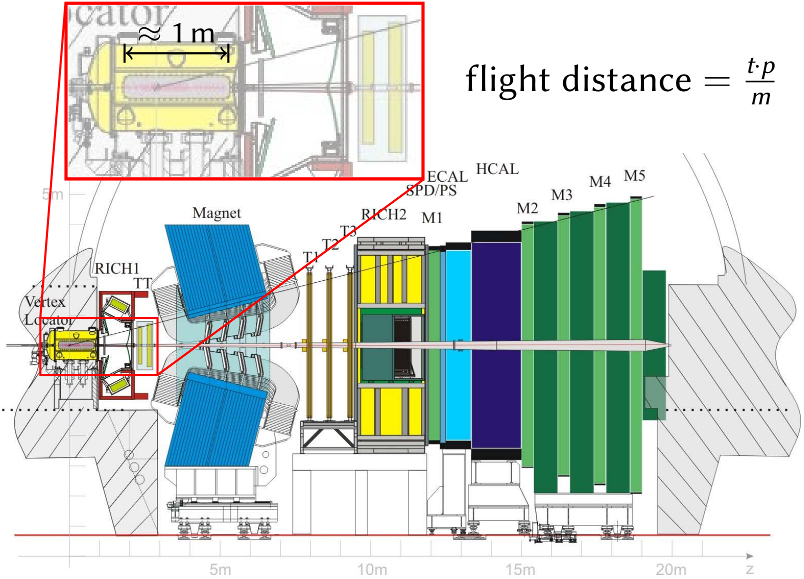
In BSM theories:

- *R*-parity violating LSP decays
- suppressed NLSP decays
- decays of exotic hidden sector particles into SM particles
- …

LHCb: a detector for long-lived particles


5m
Magnet
RICH1
TT
Vertex Locator
T1
T2
T3
RICH2
SPD/PS
ECAL
M1
HCAL
M2
M3
M4
M5
5m
10m
15m
20m
z

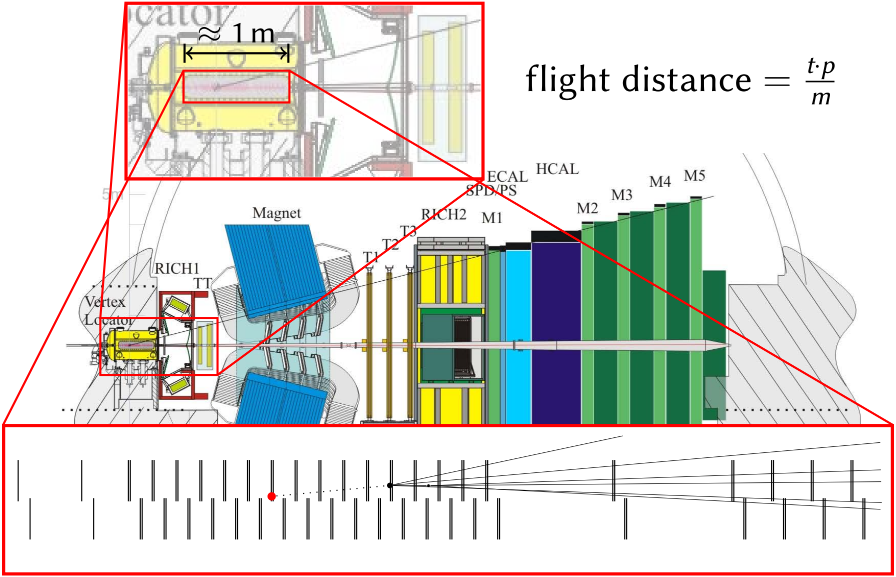
LHCb: a detector for long-lived particles


≈ 1 m
Vertex Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
ECAL
SPD/PS
HCAL
M1
M2
M3
M4
M5
5m
5m
10m
15m
20m
z

$$\text{flight distance} = \frac{t \cdot p}{m}$$

LHCb: a detector for long-lived particles

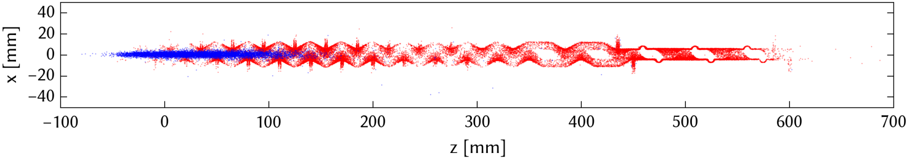
$$\text{flight distance} = \frac{t \cdot p}{m}$$



≈ 1 m
5m
Magnet
RICH1
TT
Vertex Locator
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5

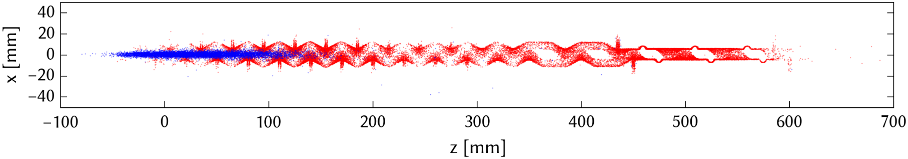
Vertex backgrounds

Material interactions: veto region around detector parts

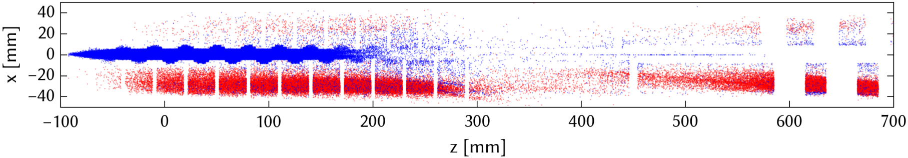


Vertex backgrounds

Material interactions: veto region around detector parts

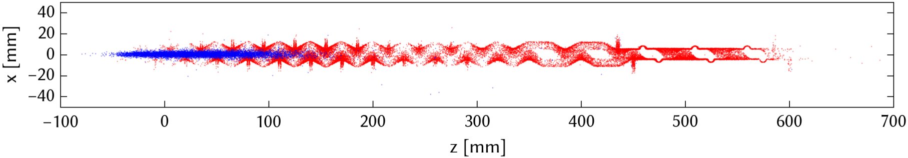


Fake vertices from beam-induced ghost tracks

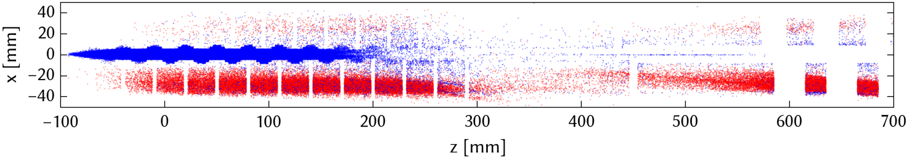


Vertex backgrounds

Material interactions: veto region around detector parts

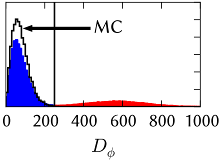


Fake vertices from beam-induced ghost tracks



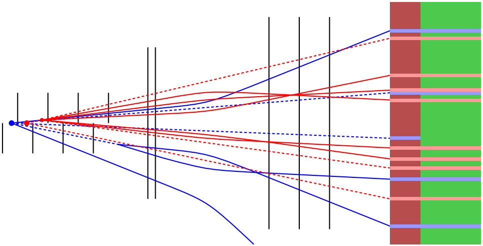
Velo hit ϕ distribution strongly peaked

$$D_\phi = \sqrt{\left(\sum_{\text{Velo hits}} \cos\phi_i\right)^2 + \left(\sum_{\text{Velo hits}} \sin\phi_i\right)^2}$$

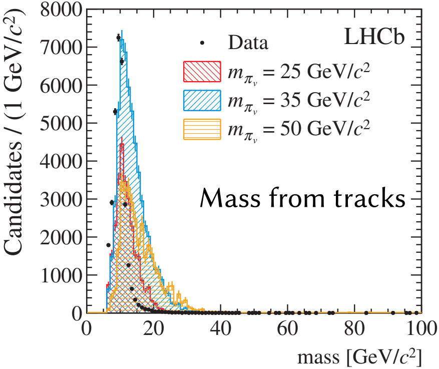


Improved mass reconstruction with jets

Particle Flow: tracks used to improve neutral resolution and suppress pile-up and underlying event



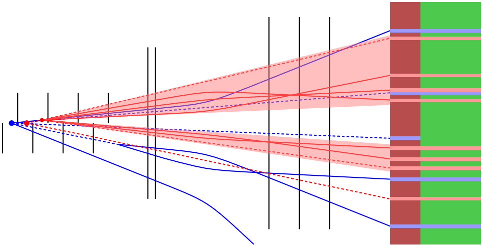
cfr. LHCb Z+jet measurement
JHEP 01 (2014) 033

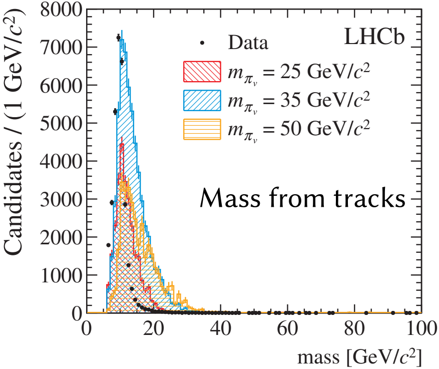


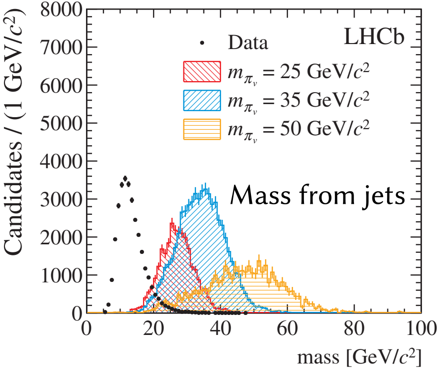
Improved mass reconstruction with jets

Particle Flow: tracks used to improve neutral resolution and suppress pile-up and underlying event

cfr. LHCb Z+jet measurement
JHEP 01 (2014) 033



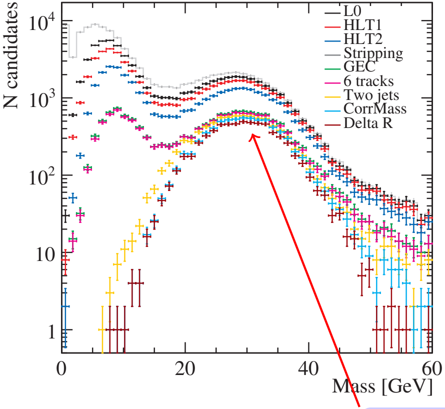

Candidates / (1 GeV/c^2)
8000
7000
6000
5000
4000
3000
2000
1000
0
Data
LHCb
m_{π_v} = 25 GeV/c^2
m_{π_v} = 35 GeV/c^2
m_{π_v} = 50 GeV/c^2
Mass from tracks
0
20
40
60
80
100
mass [GeV/c^2]



Selection

Simulated signal

$m_{\pi_v} = 35\,\mathrm{GeV}/c^2,\ \tau_{\pi_v} = 10\,\mathrm{ps}$

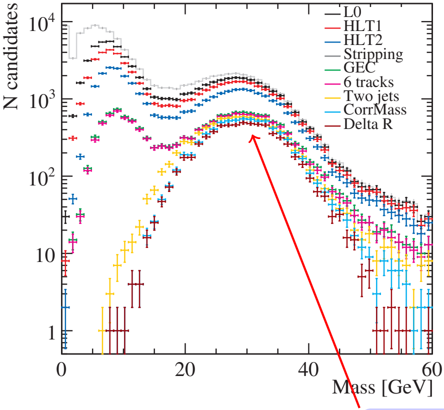


Final selection

Selection

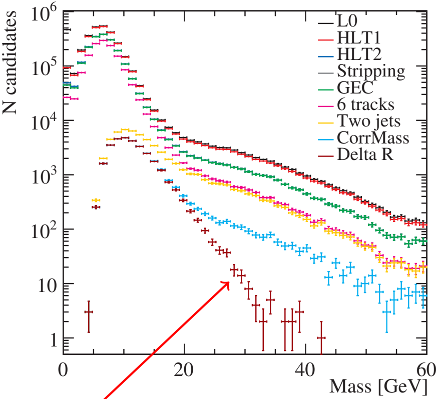
Simulated signal

$m_{\pi_v} = 35\,\mathrm{GeV}/c^2,\ \tau_{\pi_v} = 10\,\mathrm{ps}$



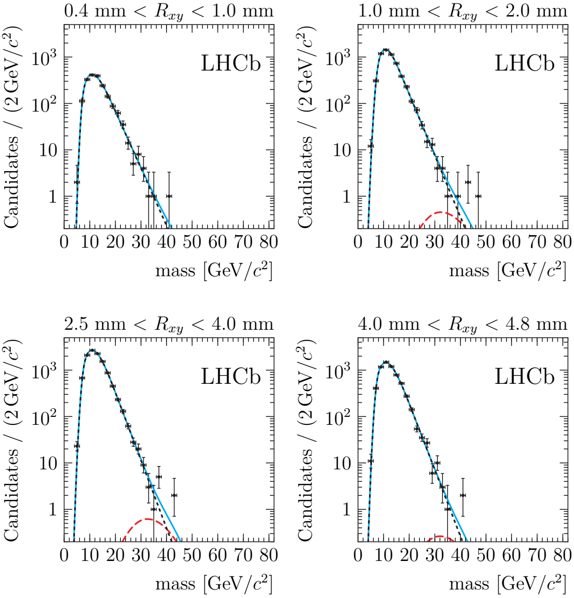
Data

$\sqrt{s} = 7\,\mathrm{TeV},\ \mathcal{L} = 0.62\,\mathrm{fb}^{-1}$



Final selection

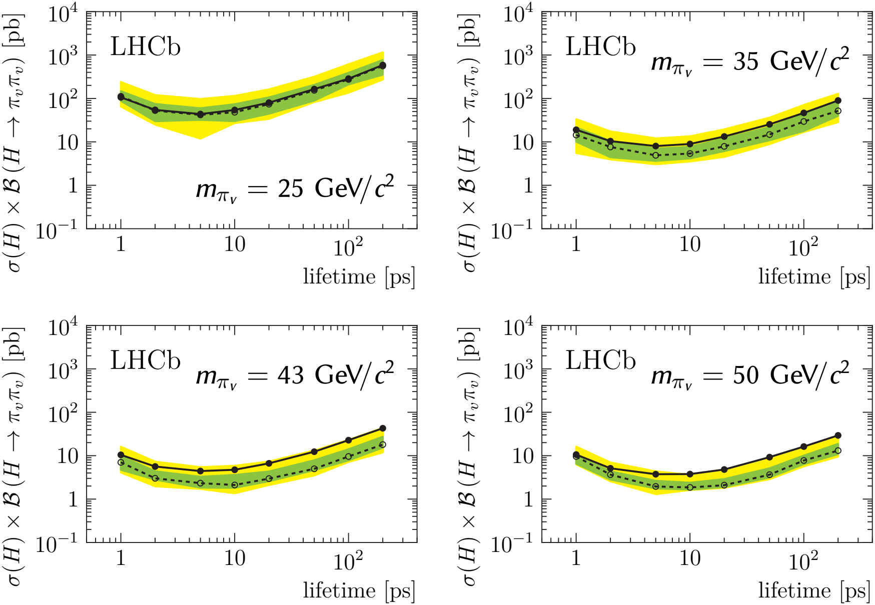
Signal+background fit to data



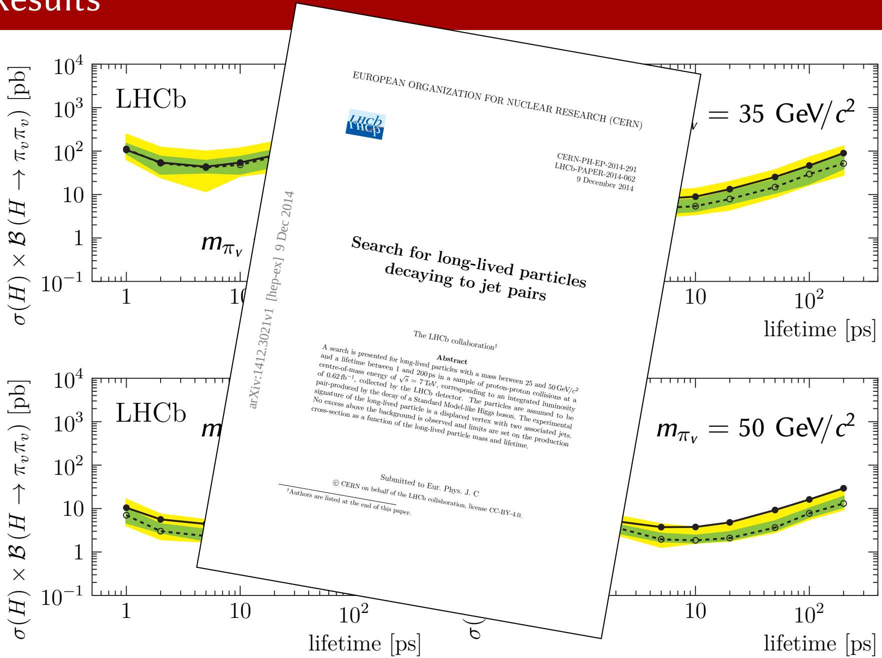
R_{xy} intervals aligned with trigger and preselection categories

Simultaneous fit with RooFit and limit with RooStats

Results


LHCb
$m_{\pi_v} = 25$ GeV$/c^2$
LHCb
$m_{\pi_v} = 35$ GeV$/c^2$
LHCb
$m_{\pi_v} = 43$ GeV$/c^2$
LHCb
$m_{\pi_v} = 50$ GeV$/c^2$
$\sigma(H) \times \mathcal{B}(H \to \pi_v \pi_v)$ [pb]
10^{-1}
1
10
10^2
10^3
10^4
1
10
10^2
lifetime [ps]

Results



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP-2014-291
LHCb-PAPER-2014-062
9 December 2014

arXiv:1412.3021v1 [hep-ex] 9 Dec 2014

Search for long-lived particles decaying to jet pairs

The LHCb collaboration†

Abstract

A search is presented for long-lived particles with a mass between 25 and 50 GeV/c^2 and a lifetime between 1 and 200 ps in a sample of proton-proton collisions at a centre-of-mass energy of $\sqrt{s} = 7$ TeV, corresponding to an integrated luminosity of 0.62 fb^{-1}, collected by the LHCb detector. The particles are assumed to be pair-produced by the decay of a Standard Model-like Higgs boson. The experimental signature of the long-lived particle is a displaced vertex with two associated jets. No excess above the background is observed and limits are set on the production cross-section as a function of the long-lived particle mass and lifetime.

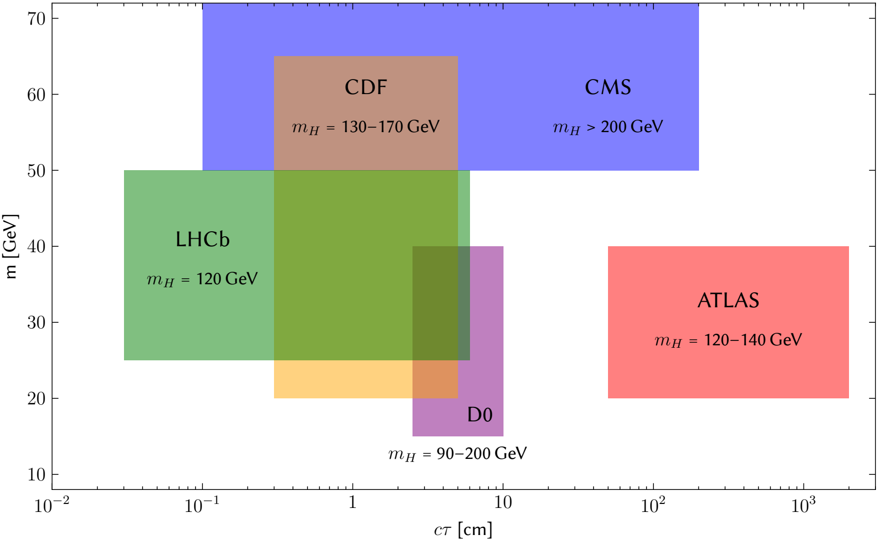
Submitted to Eur. Phys. J. C

© CERN on behalf of the LHCb collaboration, license CC-BY-4.0.

---

† Authors are listed at the end of this paper.

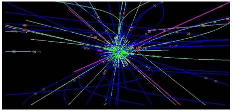
Sensitivity of other experiments



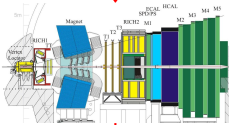
Improvements for the next iteration

LHCb jargon

Data



↓


5m
Vertex Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5

↓

Hardware trigger
hadron or muon p_T

↓

HLT1 inclusive 1-track
HLT2 dedicated + topo

→

Reconstruction

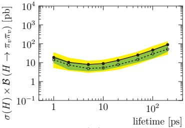
↑

Stripping

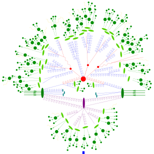
↑

Analysis

↑



Simulation



↓

Detector simulation

↓

Digitisation

↓

Trigger (emulated)

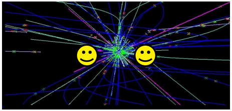
→ Reconstruction

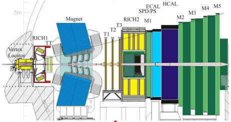
online | offline

Improvements for the next iteration

LHCb jargon

Data

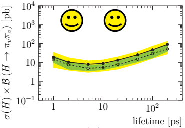



5m
Vertex Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5

Hardware trigger
hadron or muon p_T

HLT1 inclusive 1-track
HLT2 dedicated + topo

online | offline

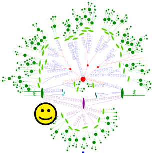


Analysis

Stripping

Reconstruction

Simulation



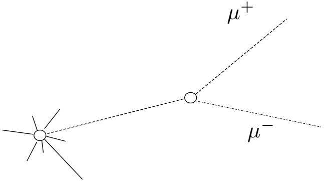
Detector simulation

Digitisation

Trigger (emulated)

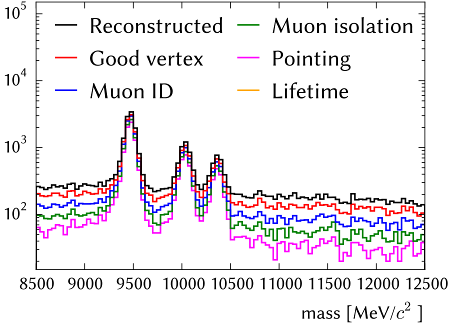
Another final state: $X \to \mu^+\mu^-$

Search in the range $m \gtrsim 7.5\,\mathrm{GeV}/c^2$, $c\tau \lesssim 100\,\mathrm{mm}$



Advantages of LHCb:

- Good muon identification
- Excellent mass and vertex resolution
- Efficient inclusive trigger
- Large $\Upsilon(1S)$ and Z^0 control samples

$\Rightarrow$ high efficiency and little background, even for small lifetimes