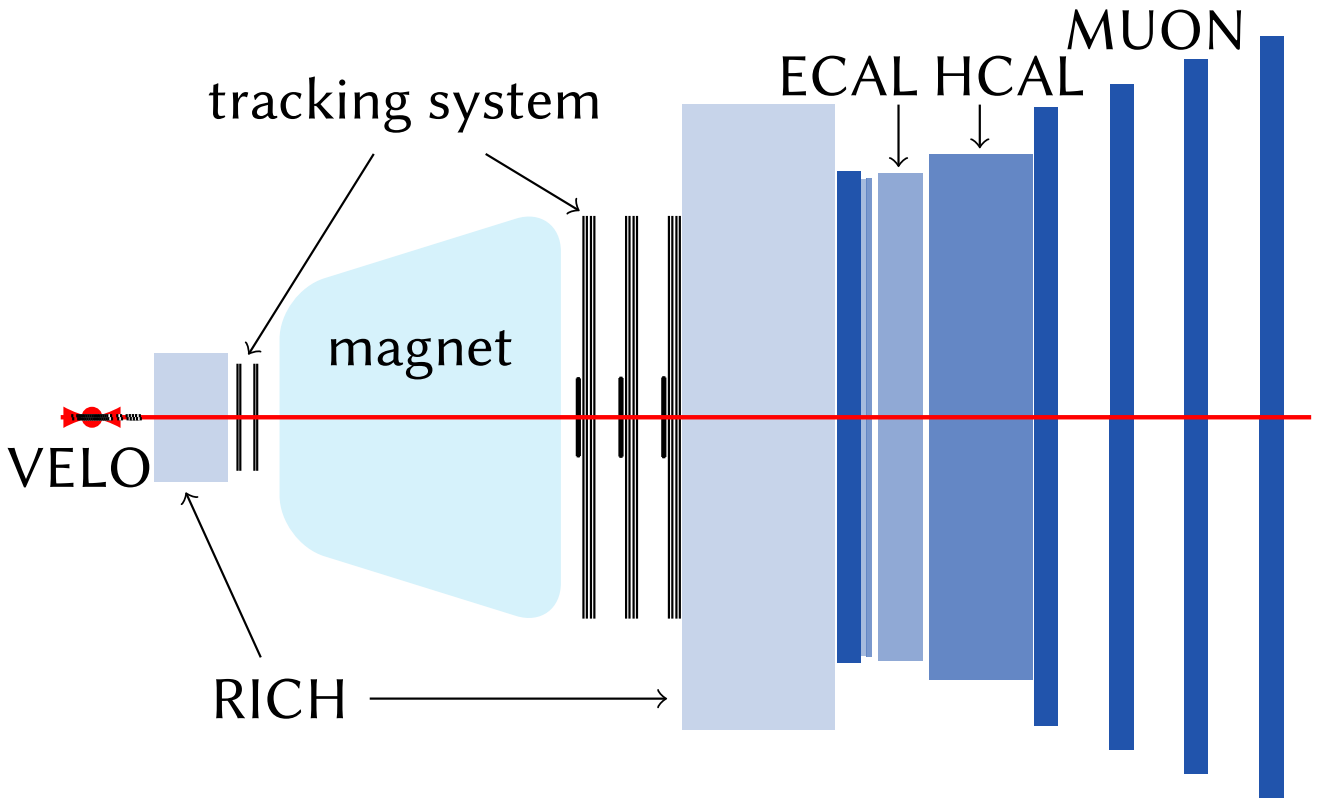
Electroweak-scale exotica with LHCb

Pieter David
on behalf of the LHCb collaboration

ICHEP 2016
3–10 August, Chicago

LHCb: a general-purpose detector in the forward direction

JINST**3**(2008)S08005;
IntJModPhys**A30**(2015)1530022



$2 < \eta < 5$

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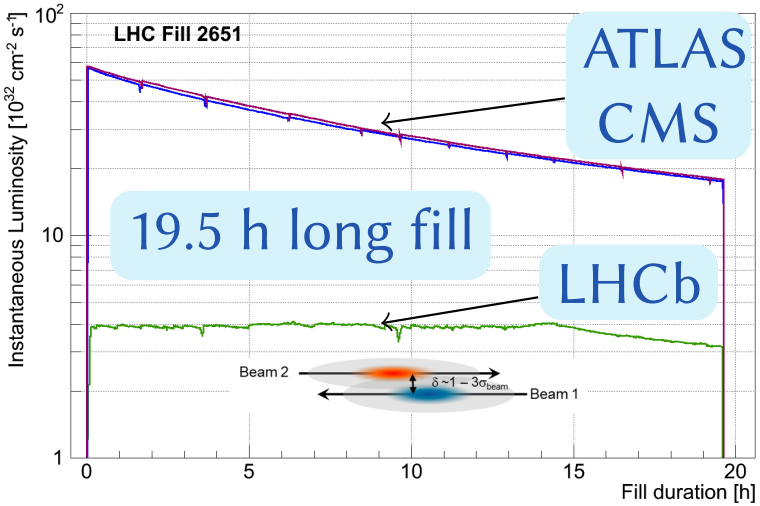

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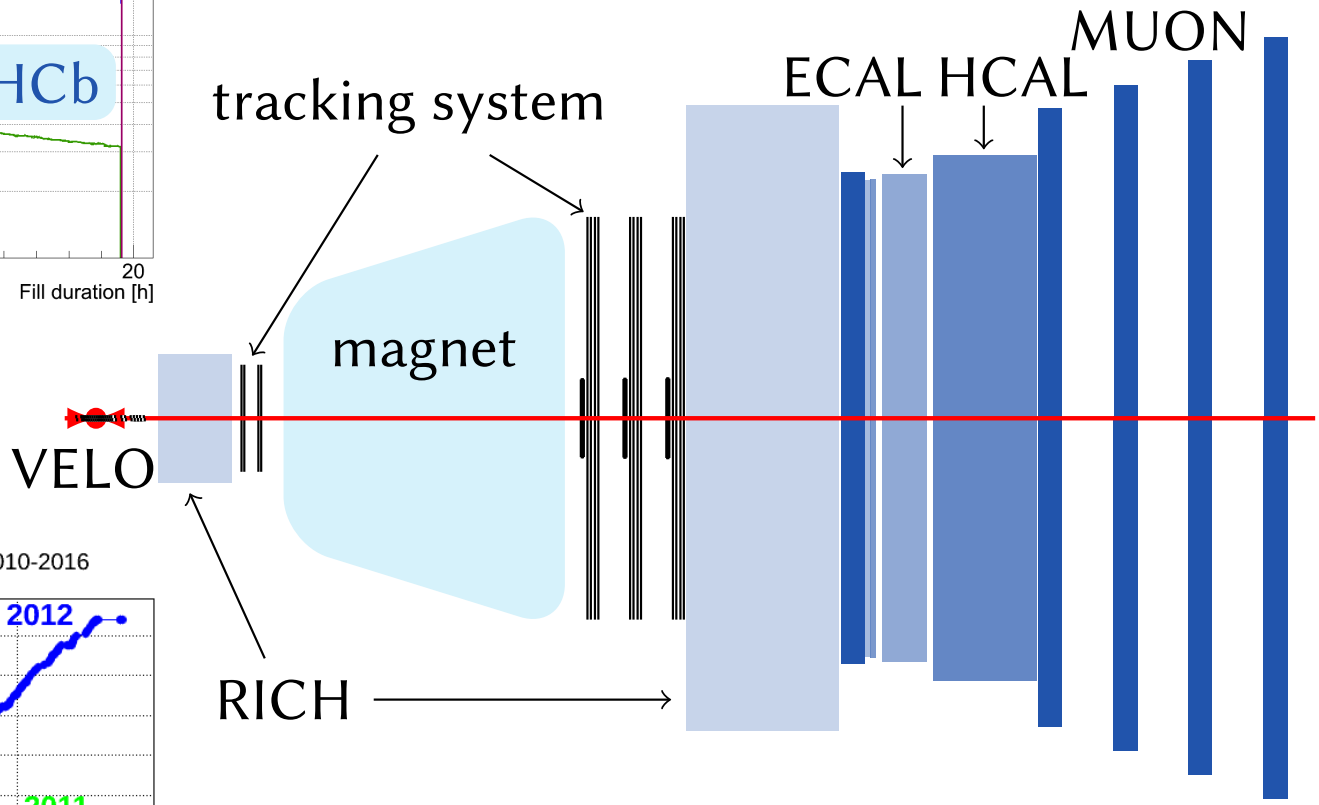

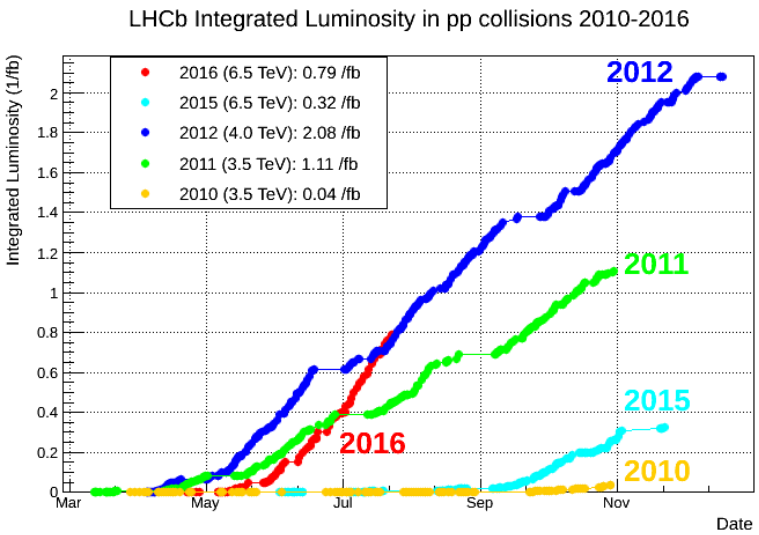

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Outline

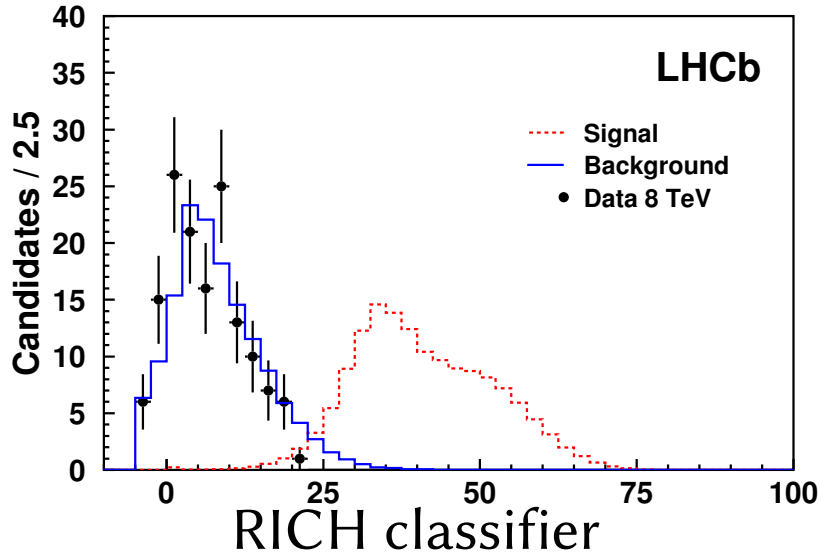
1. Search for long-lived heavy charged particles using a ring imaging Cherenkov technique at LHCb
2. Search for Higgs-like bosons decaying into long-lived exotic particles NEW
3. Search for long-lived particles decaying to jet pairs
4. Prospects for run 2 and the LHCb upgrade
5. Short-lived physics at the electroweak scale

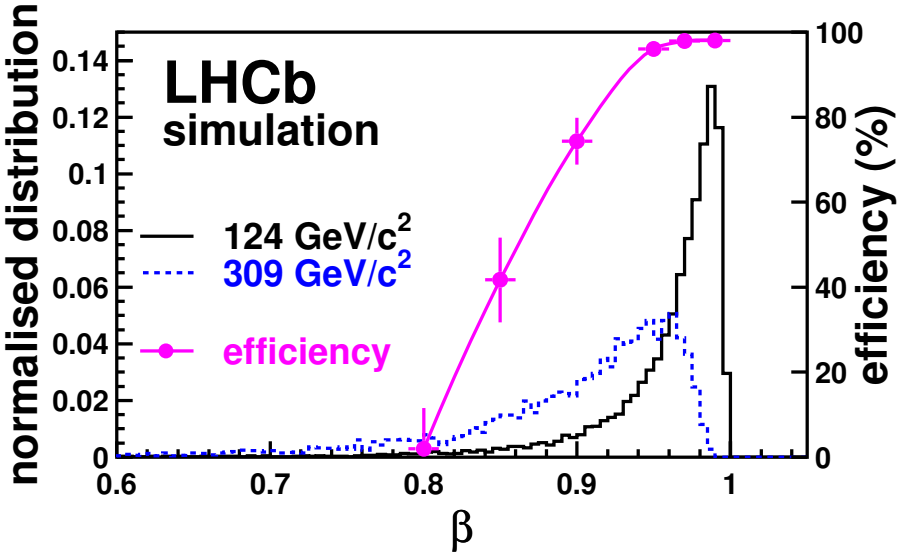
→ talk by Xabier Cid Vidal and poster by Donatella Lucchesi

Search for pairs of detector-stable charged particles

EurPhysJC75(2015)595

- Long-lived $\tilde{\tau}$ NLSP in mGMSB (for large tan β) NuclPhys**B488**(1997)39; PhysRept**322**(1999)419; arχiv:hep-ph/9709356
- Drell-Yan production assumed
- Discriminated from $\mu^{\pm}$ using
  - Energy loss in the Velo
  - *RICH below threshold*
  - ECAL and HCAL deposits
- ANN classifier with PID variables, product of the two responses is used for final selection
- Selection calibrated on $Z \to \mu^{+}\mu^{-}$





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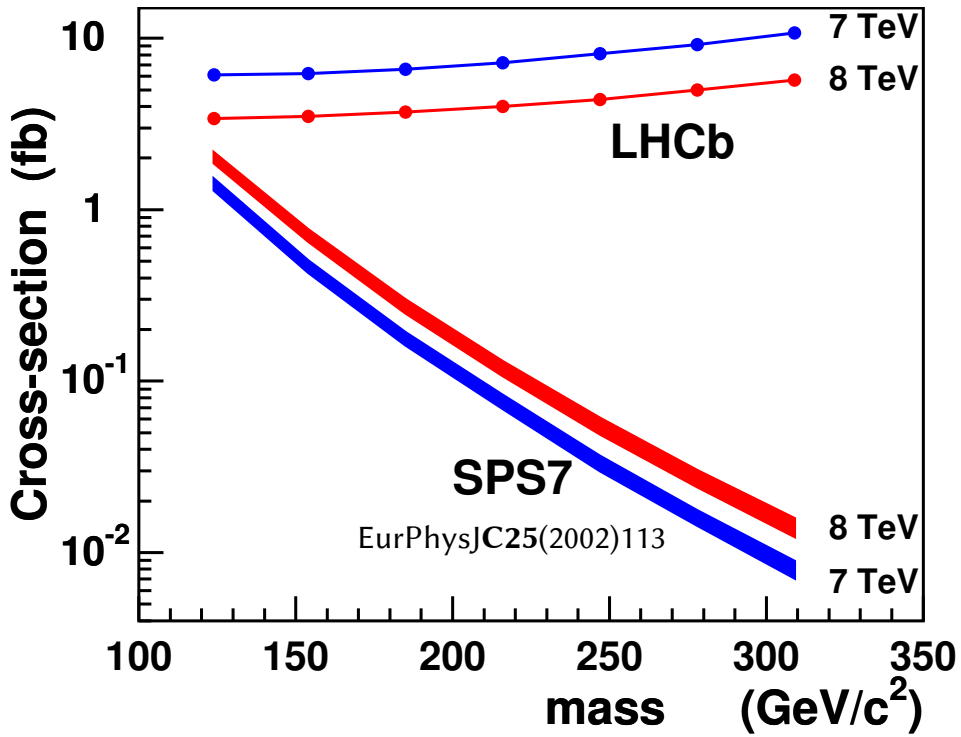
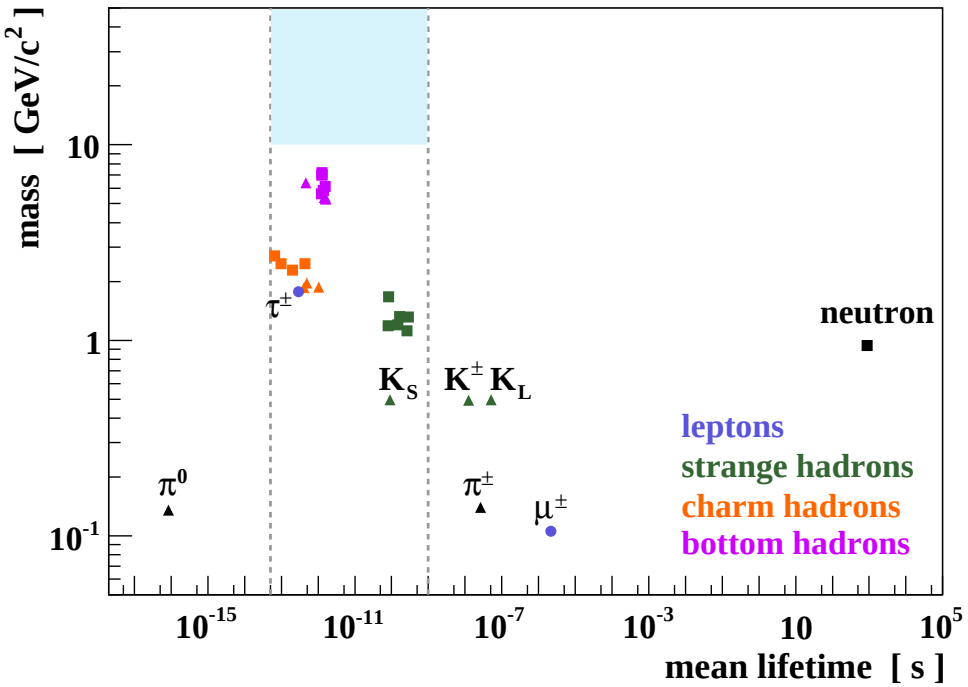


Exotic particles decaying in the detector volume

- particles with mass 25–55 GeV/c^2, lifetime 1–100 ps ($\gamma\beta c\tau \lesssim 20$ cm)
- predicted by Hidden Valley models, GMSB, SUSY models with baryon number violation trilinear couplings

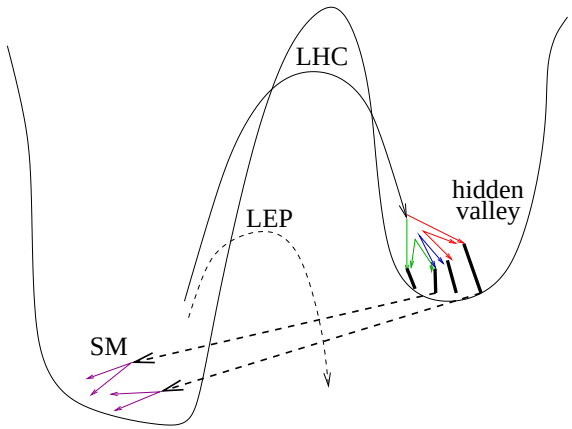
  PhysLett**B661**(2008)263; PhysRevLett**103**(2009)241803;

  PhysRevLett**99**(2007)211801
- benchmark signals:
  $H \to \pi_v \pi_v$, $\pi_v \to b\bar{b}$ (HV) and
  $H \to \tilde{\chi}_1^0 \tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \to$ 3jets (BV)



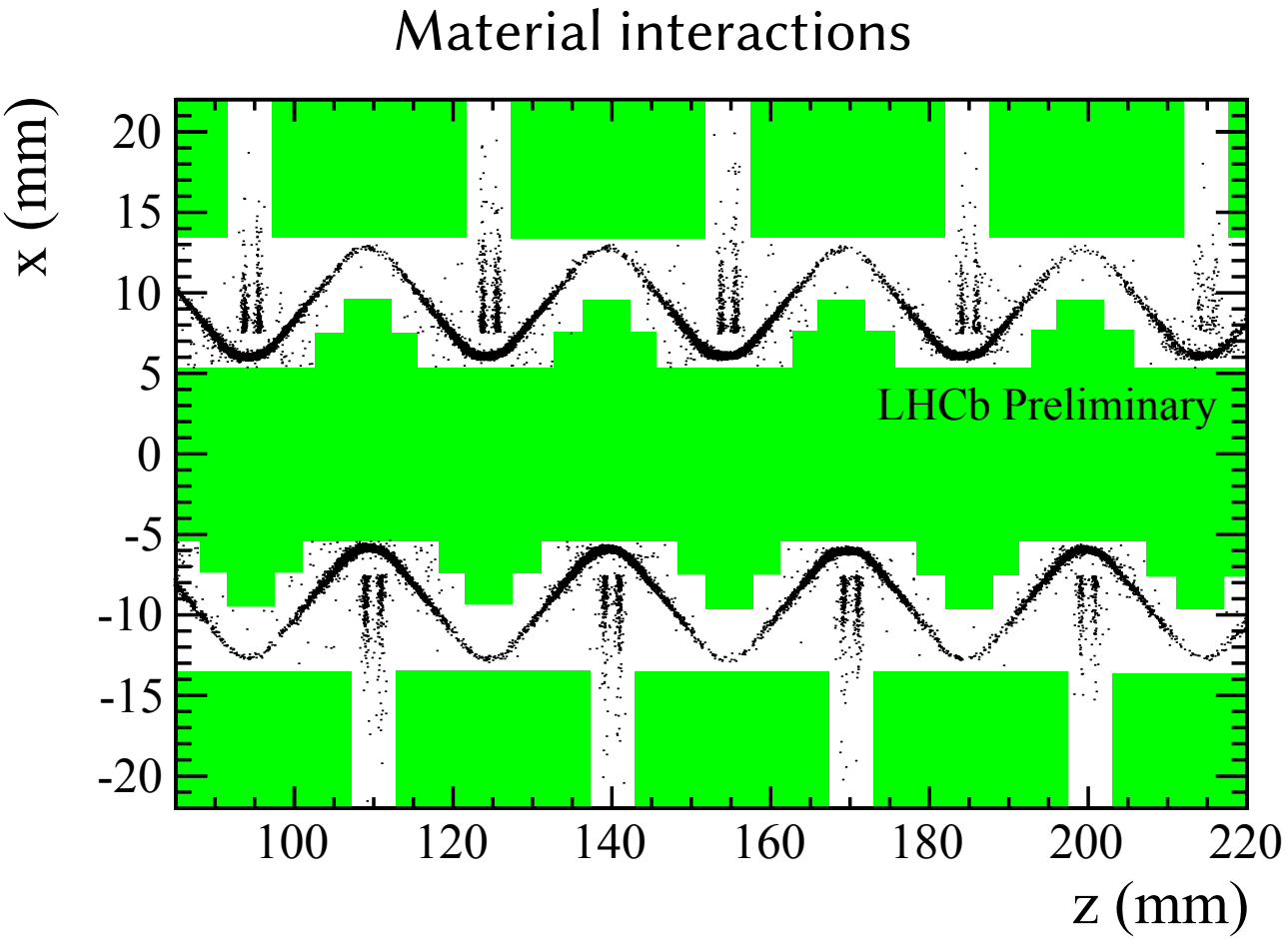
Complementary analysis strategies:
vertex finding in software trigger, and

- two candidates coming from a resonance
- a single candidate with particle flow jets



Inclusive displaced vertex reconstruction in Hlt2

- Starting from all reconstructed VELO tracks, like a PV search
- Selections on track multiplicity (≥ 4), radial displacement ($R_{xy} \geq 0.4$ mm), track invariant mass *etc.*, in different R_{xy} categories
- Loose selection for two-candidate events

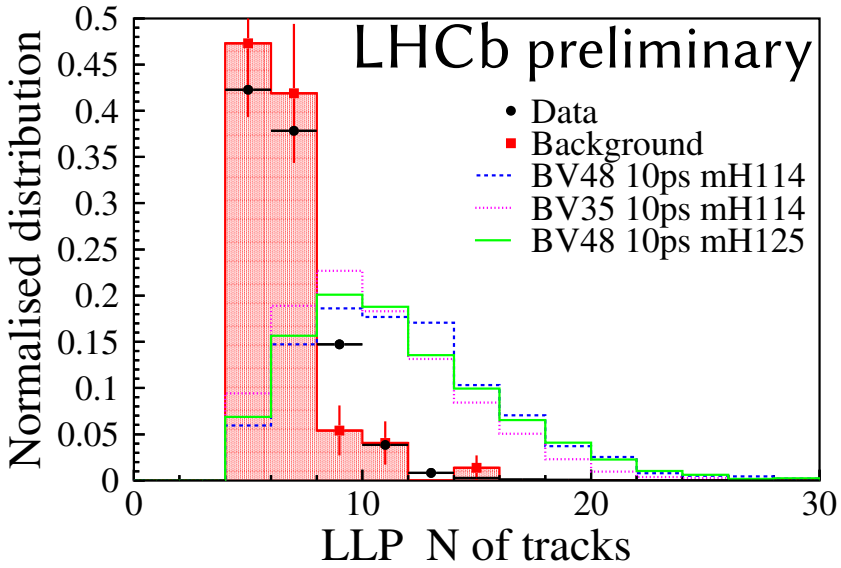


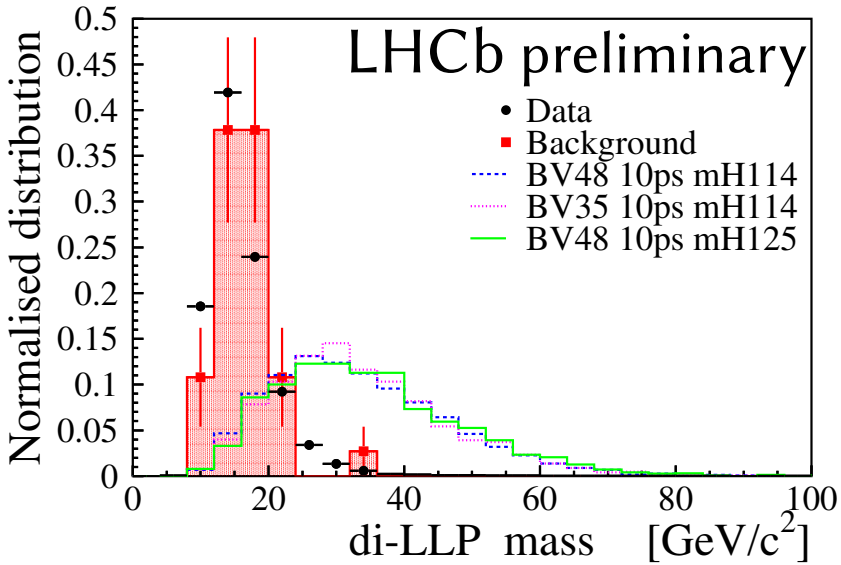
Additional veto for other instrumental backgrounds

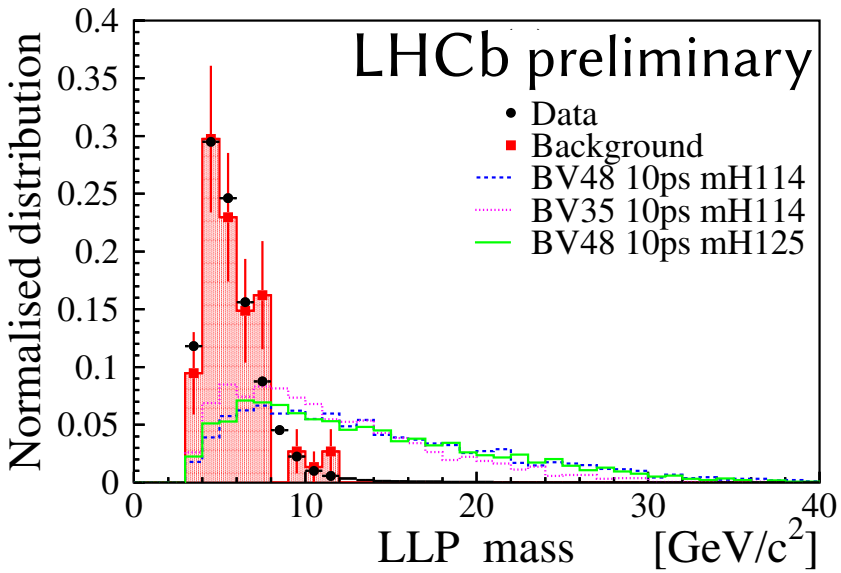
Higgs-like bosons decaying to pairs of long-lived particles

LHCb-PAPER-2016-014 in preparation

- $0.62\,\text{fb}^{-1}$ of pp collisions at 7 TeV
- Baseline selection: $N_{trk} > 6$, $m_{trk} > 6\,\text{GeV}/c^2$, small vertex position uncertainty
- Good compatibility of remaining data with shapes from $b\bar{b}$ simulation



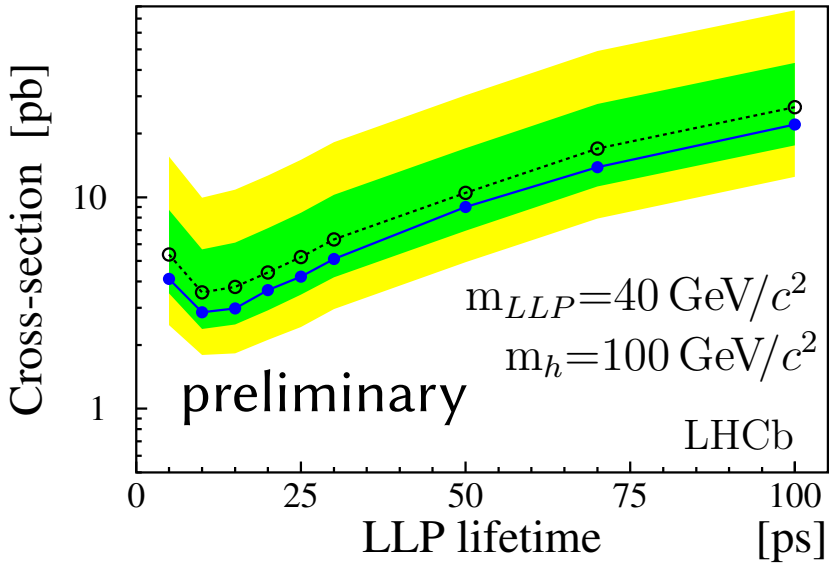


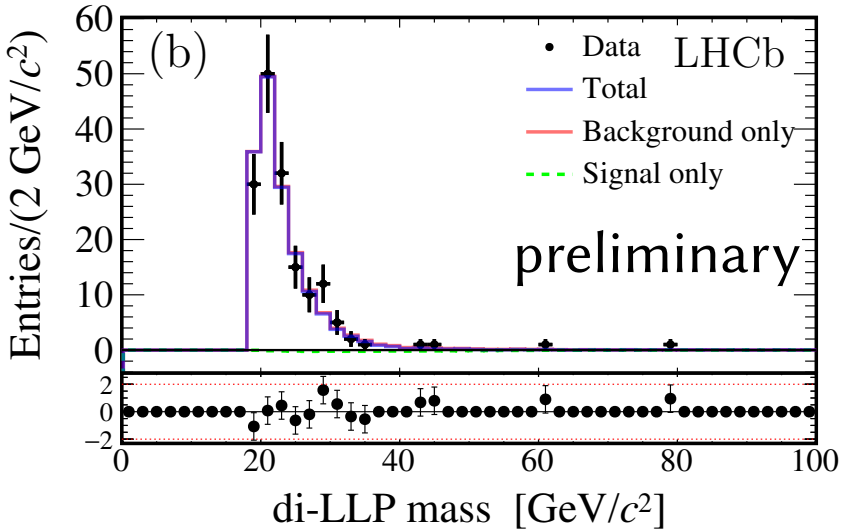


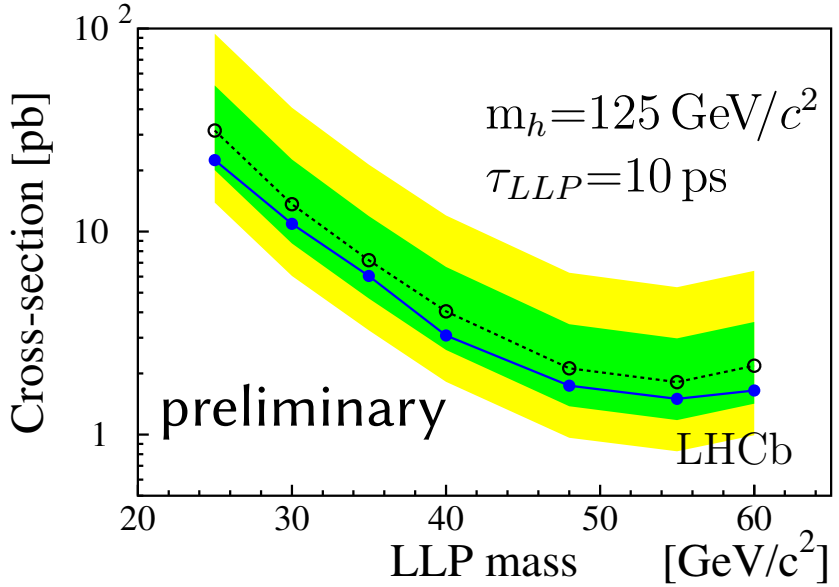
Higgs-like bosons decaying to pairs of long-lived particles

LHCb-PAPER-2016-014 in preparation

- Template fit to di-LLP (long-lived particle) invariant mass distribution
- Background shapes from data control regions (different methods as cross-check)
- No excess observed







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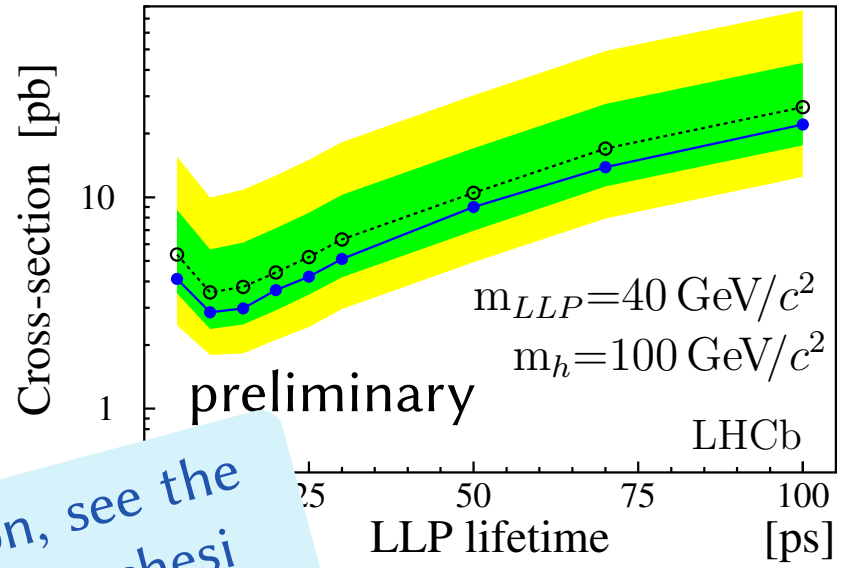
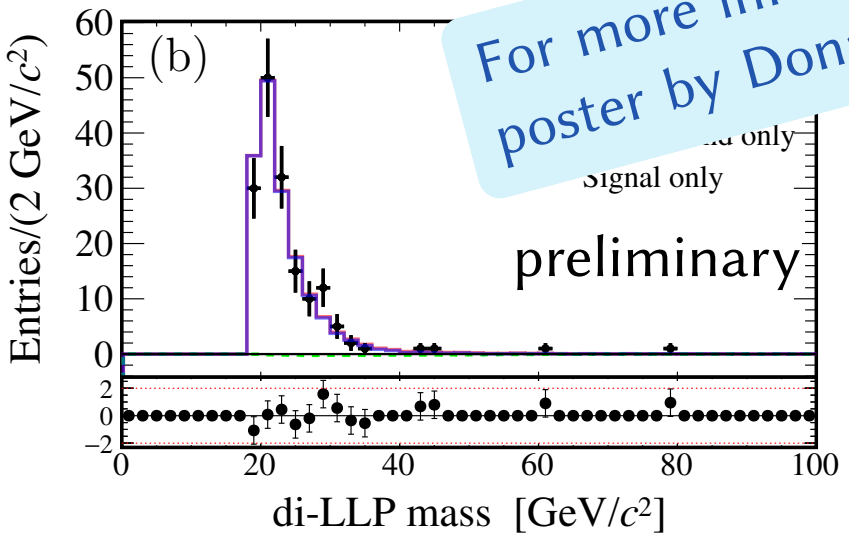
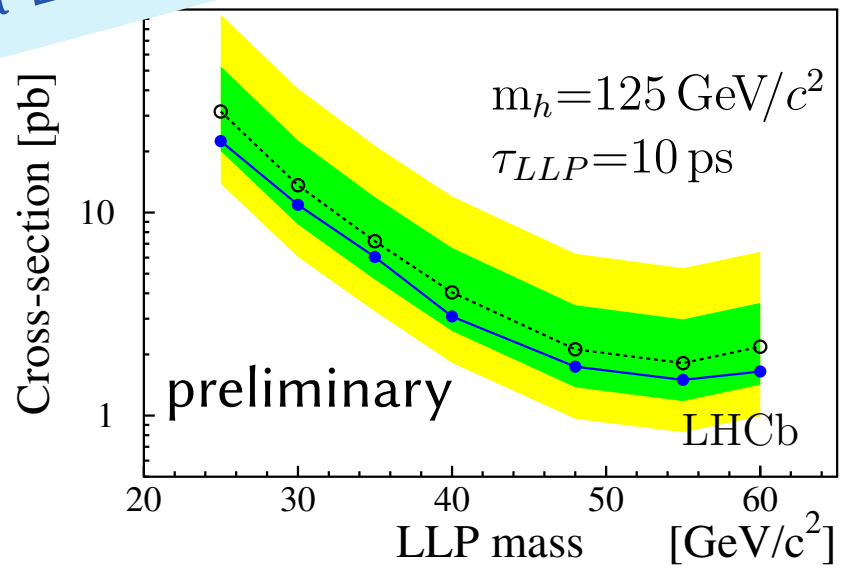




For more information, see the poster by Donatella Lucchesi

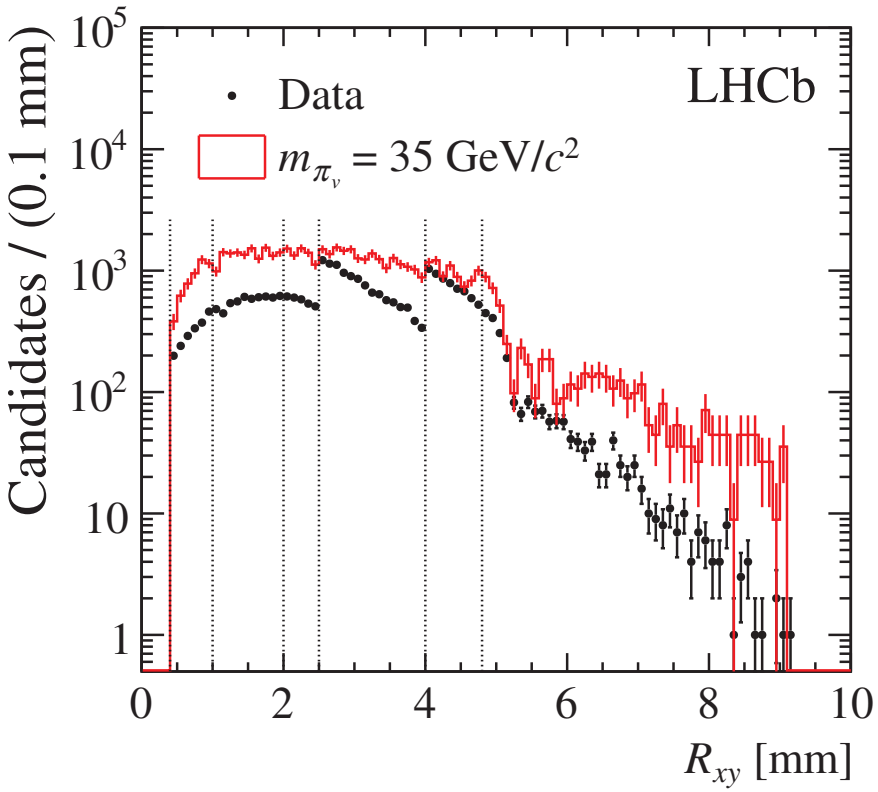


Search for long-lived particles decaying to jet pairs

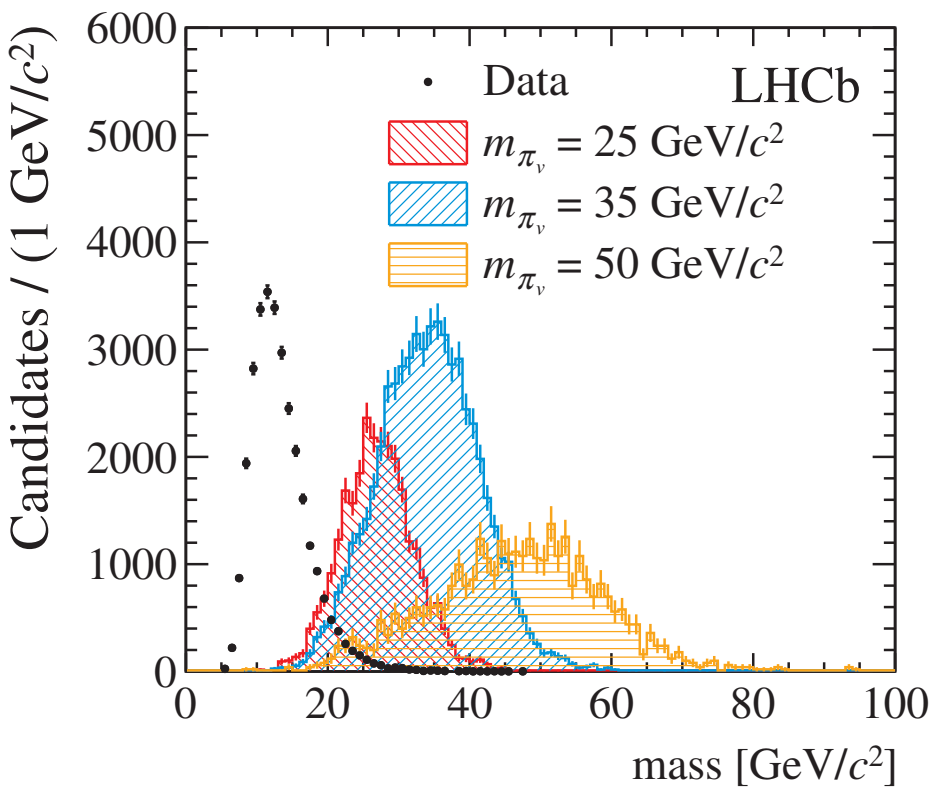
EurPhysJC75(2014)152

Alternative analysis on the same dataset, based on the presence of a single candidate vertex (larger acceptance), with two jets attached (HV model).

Vertex reconstruction



Particle Flow jets



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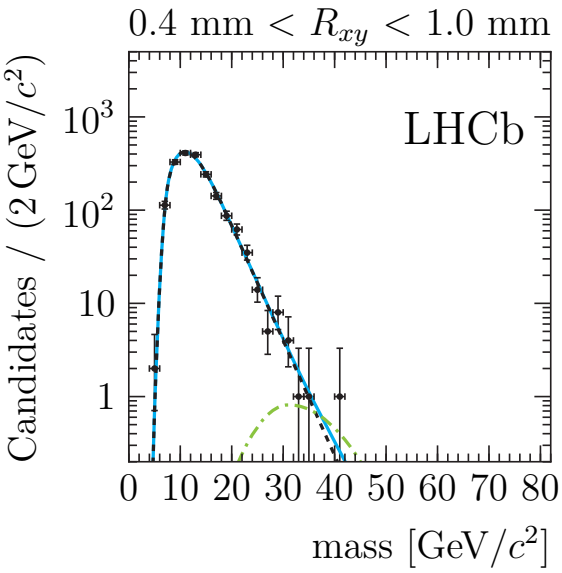

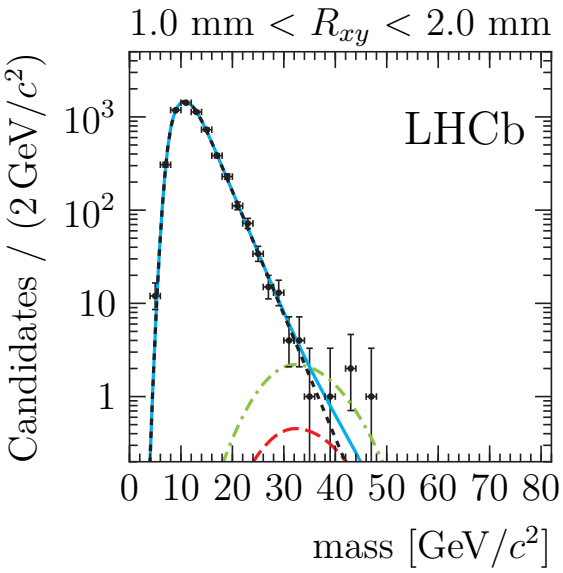

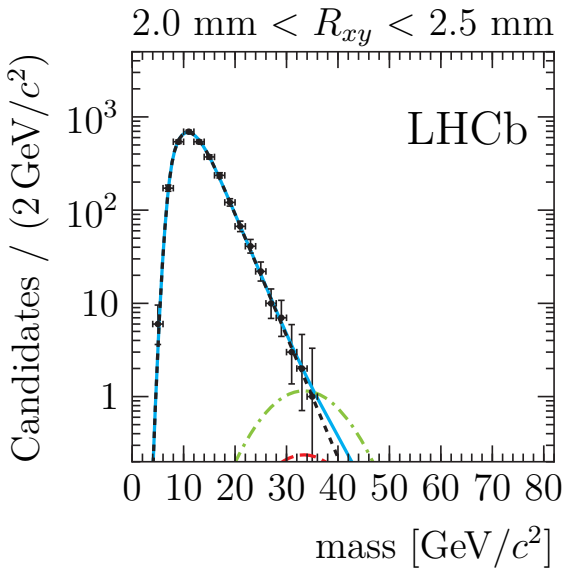

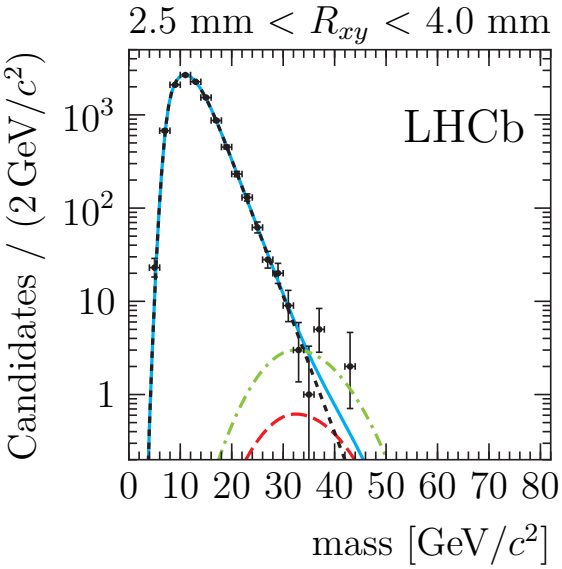

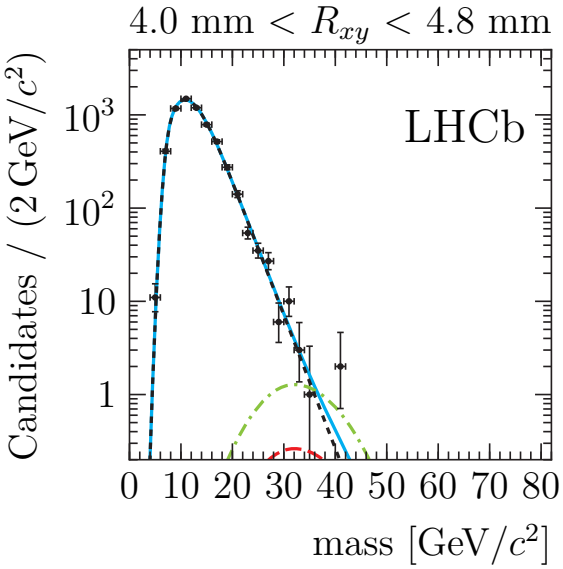

Red long-dashed: best fit signal
Green dash-dotted: signal for SM Higgs cross-section, 100 % BR

arχiv:1307.1347

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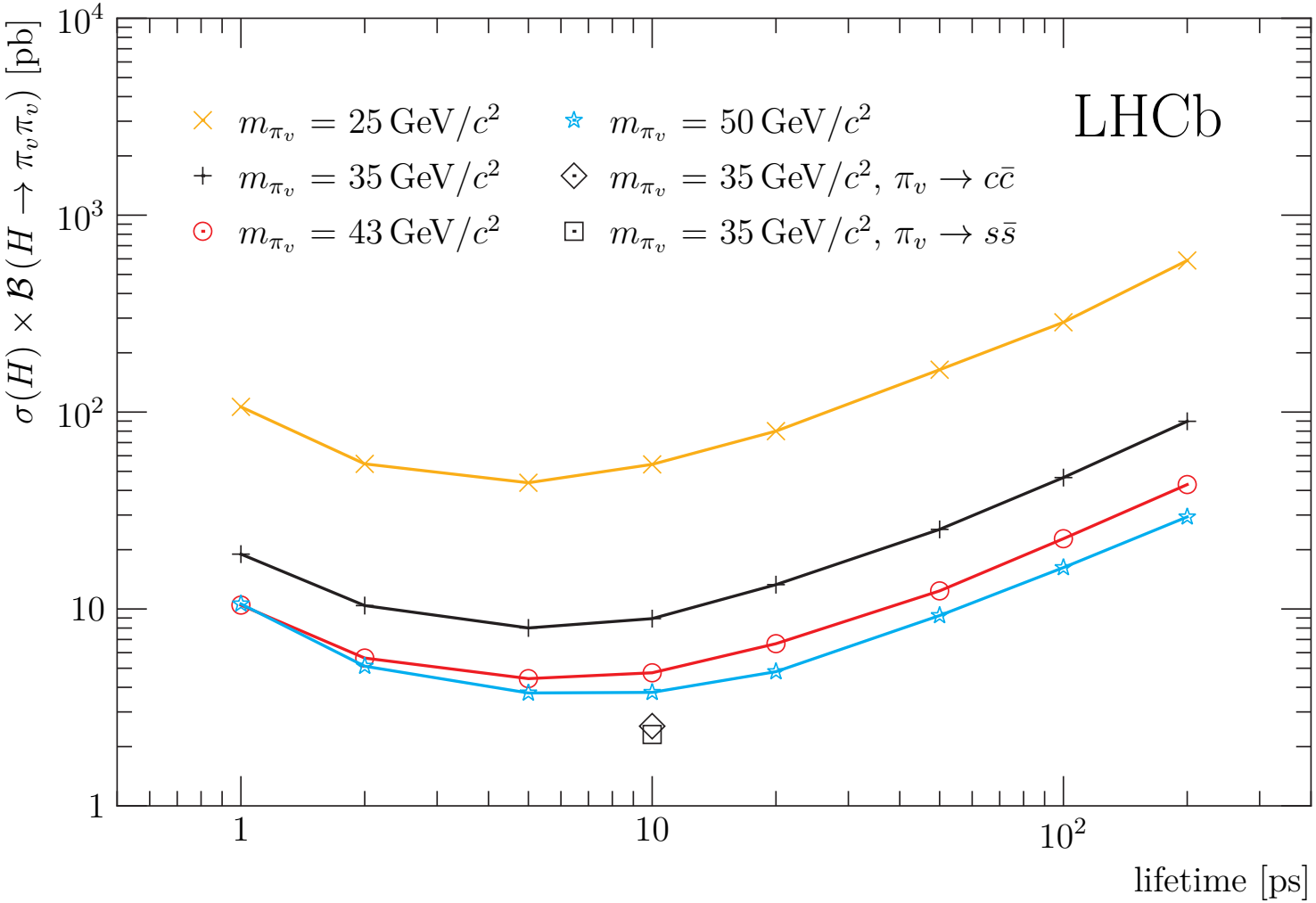
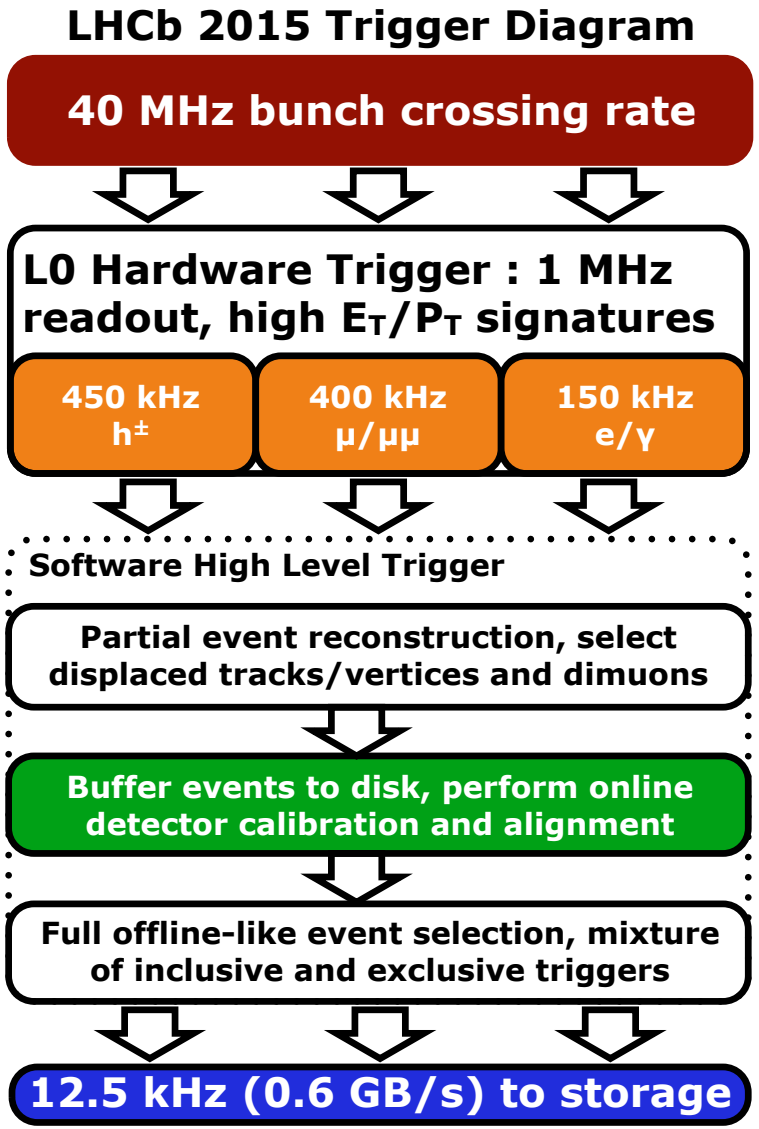


Prospects for run 2 and the LHCb upgrade

- 13 TeV
  - higher cross-sections
  - better geometrical acceptance
- Run 2
  - more integrated luminosity
  - better reconstruction in the trigger
  - opportunities with “turbo” processing
- Upgrade
  - pixel vertex detector: lower ghost rate
  - improved tracker
  - full software trigger



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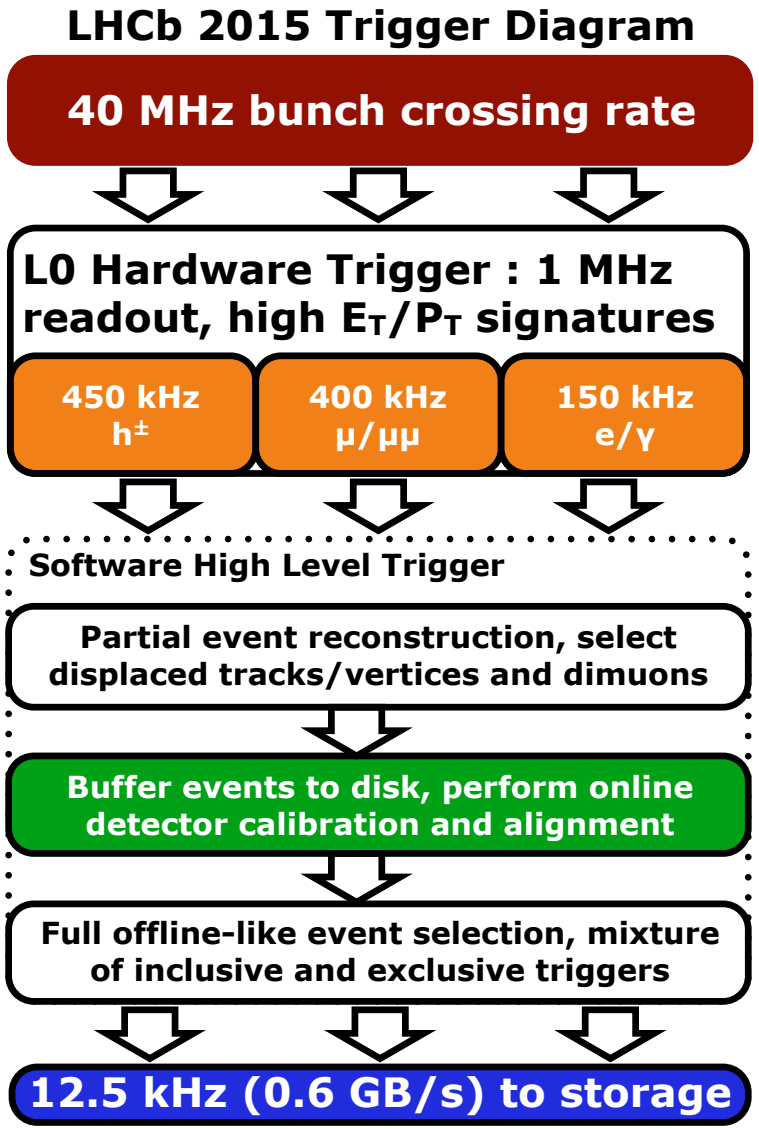
For more information, see the talk by Stefano De Capua and the posters by Marina Artuso and Renato Quagliani



Conclusions

- LHCb offers unique opportunities to search for exotic long-lived particles
  - Precise vertex detector and flexible software trigger allow to cover the low-mass low-lifetime region
  - fully instrumented in the forward region, can use RICH detectors to identify heavy stable charged particles

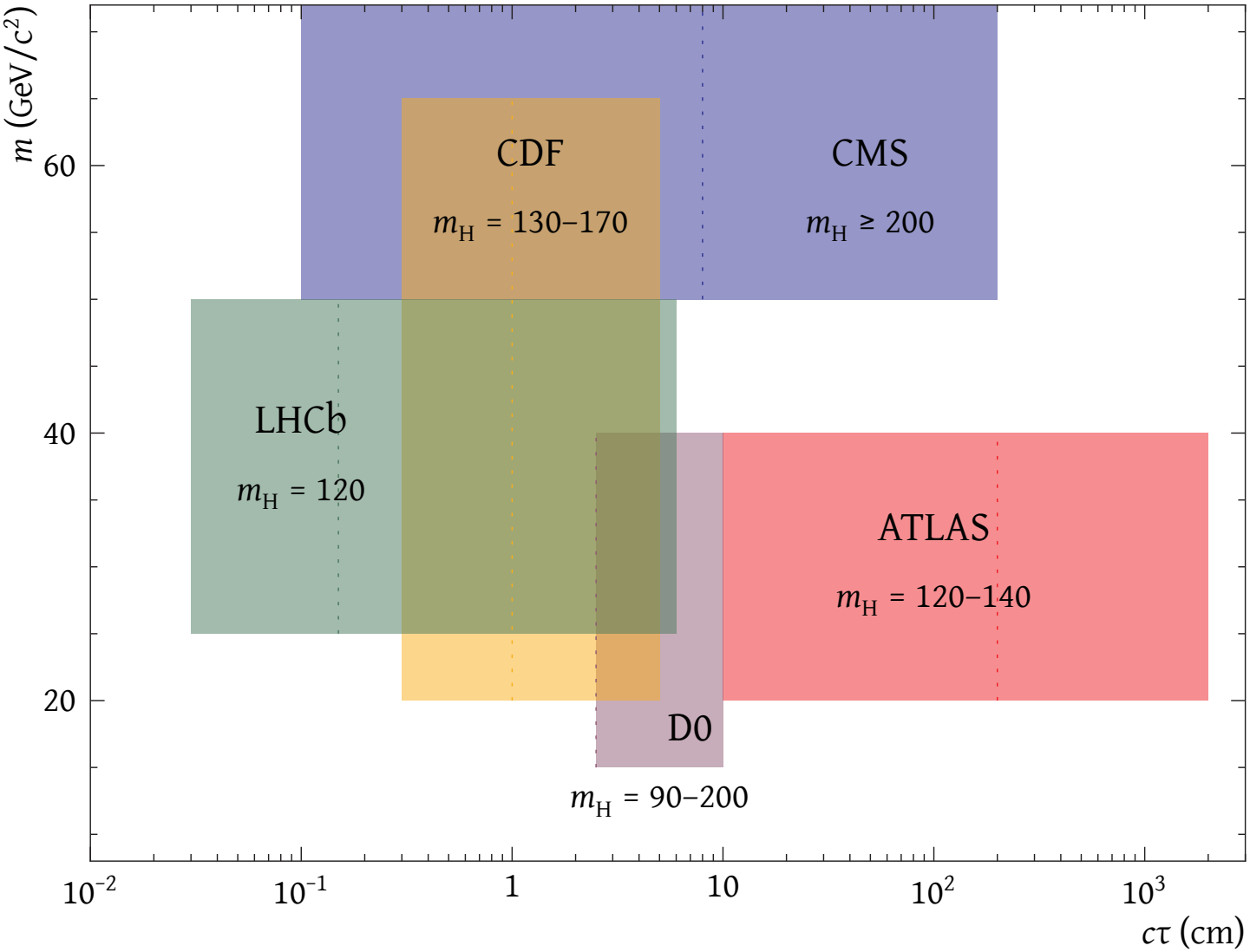
- Presented bounds on the production of heavy stable charged particle pairs, pairs of long-lived particle pairs decaying to high-multiplicity final states, and long-lived particles decaying to jet pairs

- More results in preparation — and more exotic ideas are always welcome

Additional material

Search for long-lived particles decaying to jet pairs

EurPhysJC75(2014)152



Results

- LHCb collaboration, Search for long-lived heavy charged particles using a ring imaging Cherenkov technique at LHCb, Eur. Phys. J. **C75** (2015) 595, arχiv:1506.09173.
- LHCb collaboration, Search for Higgs-like boson decaying into pair of long-lived particles, LHCb-PAPER-2016-014, in preparation.
- LHCb collaboration, Search for long-lived particles decaying to jet pairs, Eur. Phys. J. **C75** (2014) 152, arχiv:1412.3021.

References I

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References II

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