

Search for exotics at LHCb

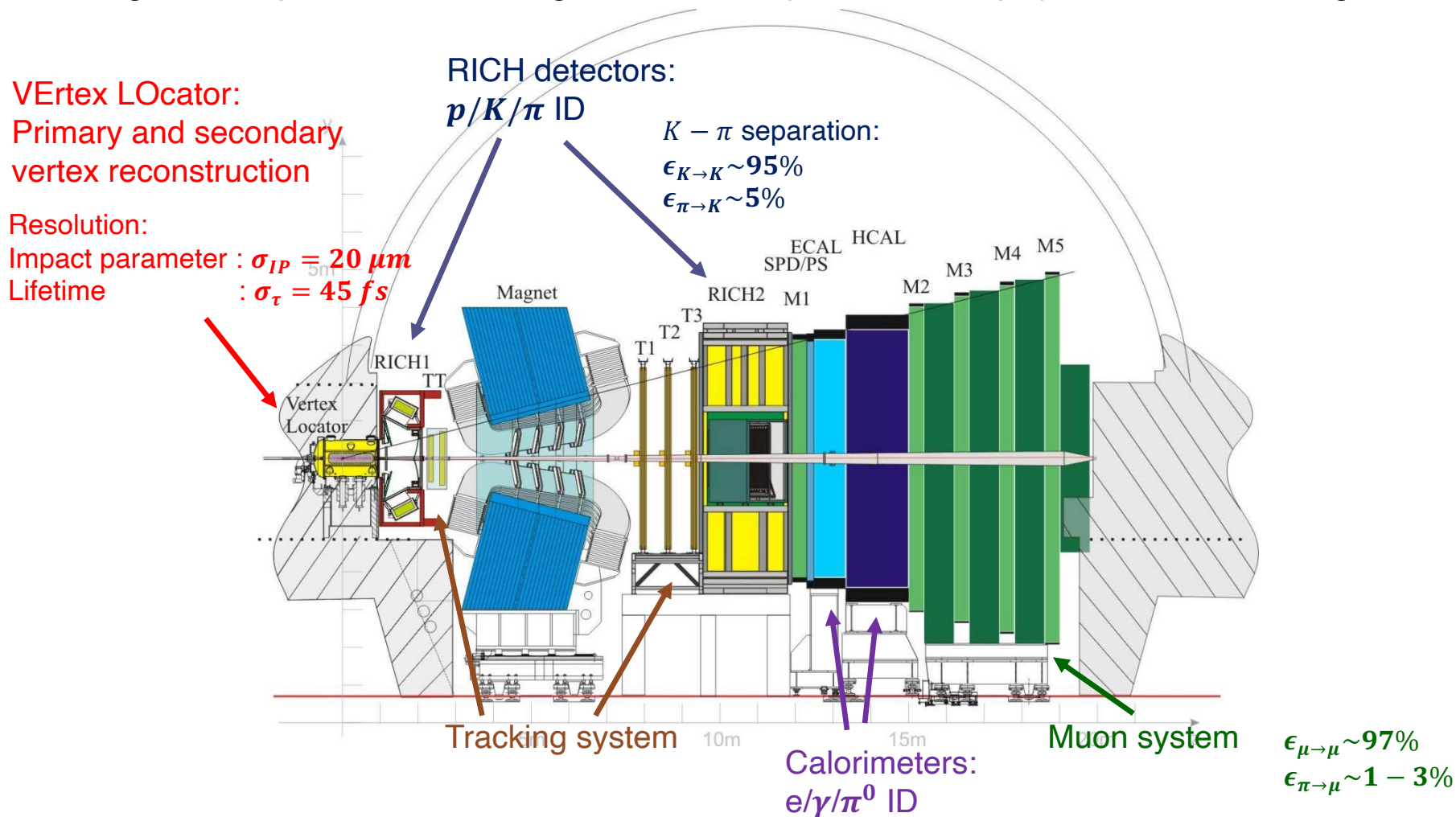
Andrii Usachov
Nikhef, Amsterdam

French-Ukrainian workshop, 2021

LHCb detector

IJMPA 30, 1530022
JINST 3, S08005

- Single-arm spectrometer designed for beauty and charm physics in forward region



- Precise vertex reconstruction with VELO
- Powerful charged hadrons ID by RICH detectors

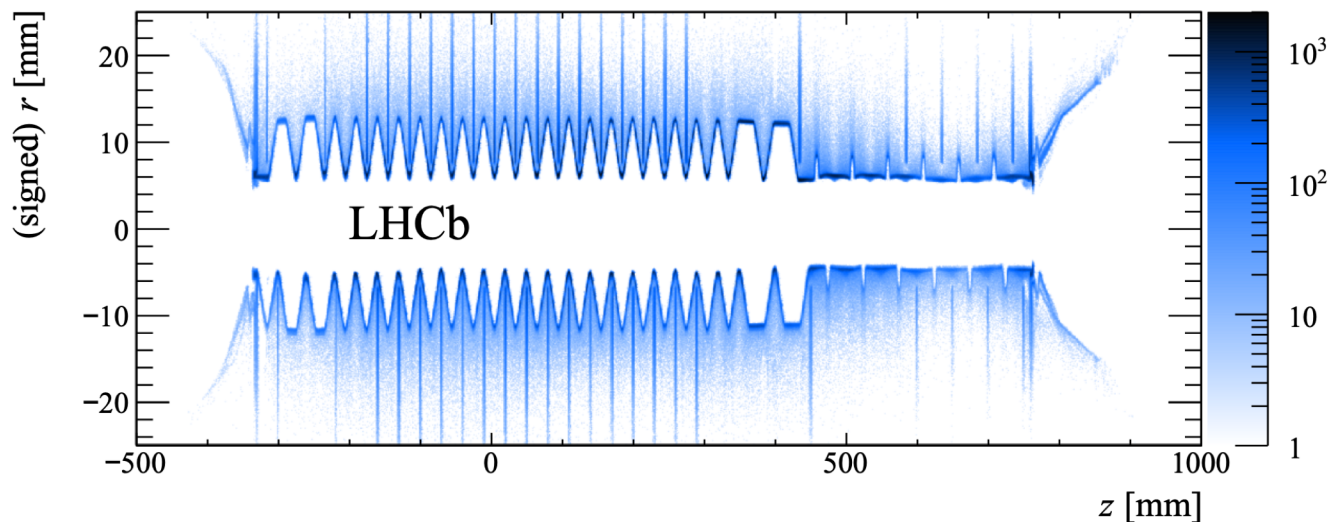
IJMPA 30, 1530022
JINST 3, S08005



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Exotica searches at LHCb

- So far only within VELO

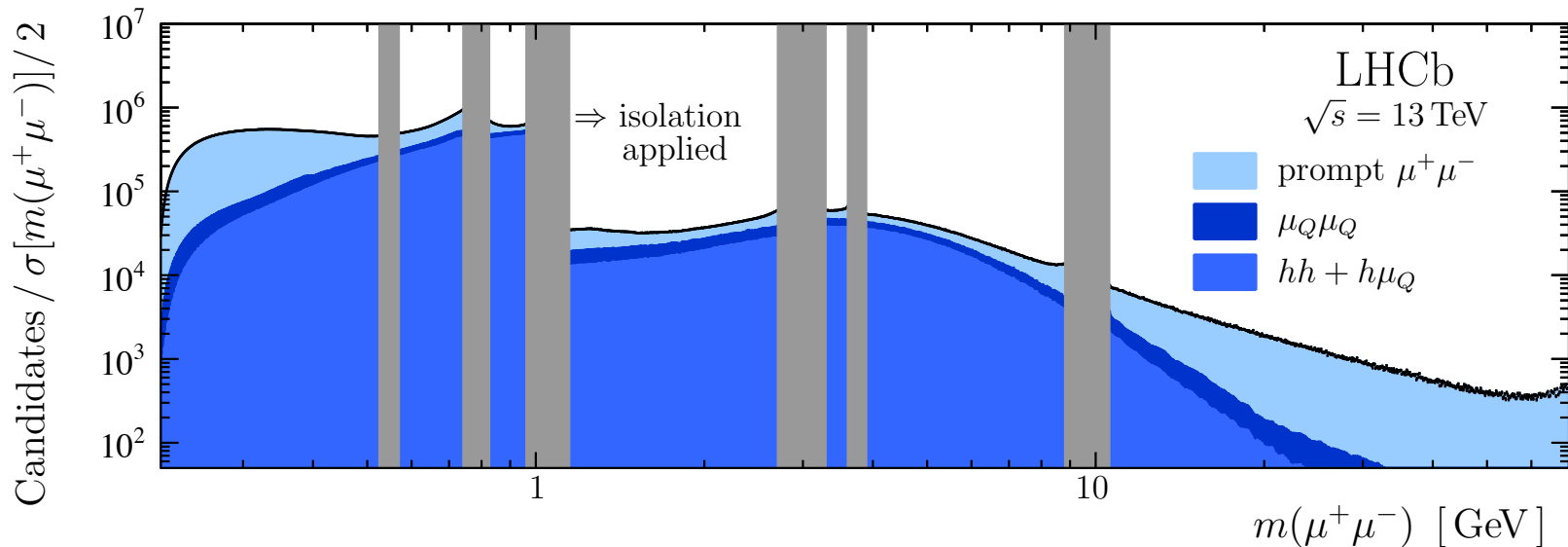


- Displacement up to 20 cm [JINST 13 \(2018\) 06, P06008](#)
 - *decays of B -mesons with $\tau = 1.5 \text{ ps}$ correspond to displacement of $0(\text{mm})$
- Thin VELO envelope (RF foil) - background dominated by
 - heavy flavour decays at $< 5 \text{ mm}$
 - material interactions at $> 5 \text{ mm}$
- Precise material veto thanks to beam-gas imaging
- Can be extended to downstream region
 - Displacement up to 200 cm
 - Much worse momentum resolution

Dark photons in di-muon spectrum

- Light dark photon can appear in a mixing with off-shell photon
 - large fraction in forward region, low p_T
- Normalized to off-shell photons
 - No need for efficiencies (for prompt search)

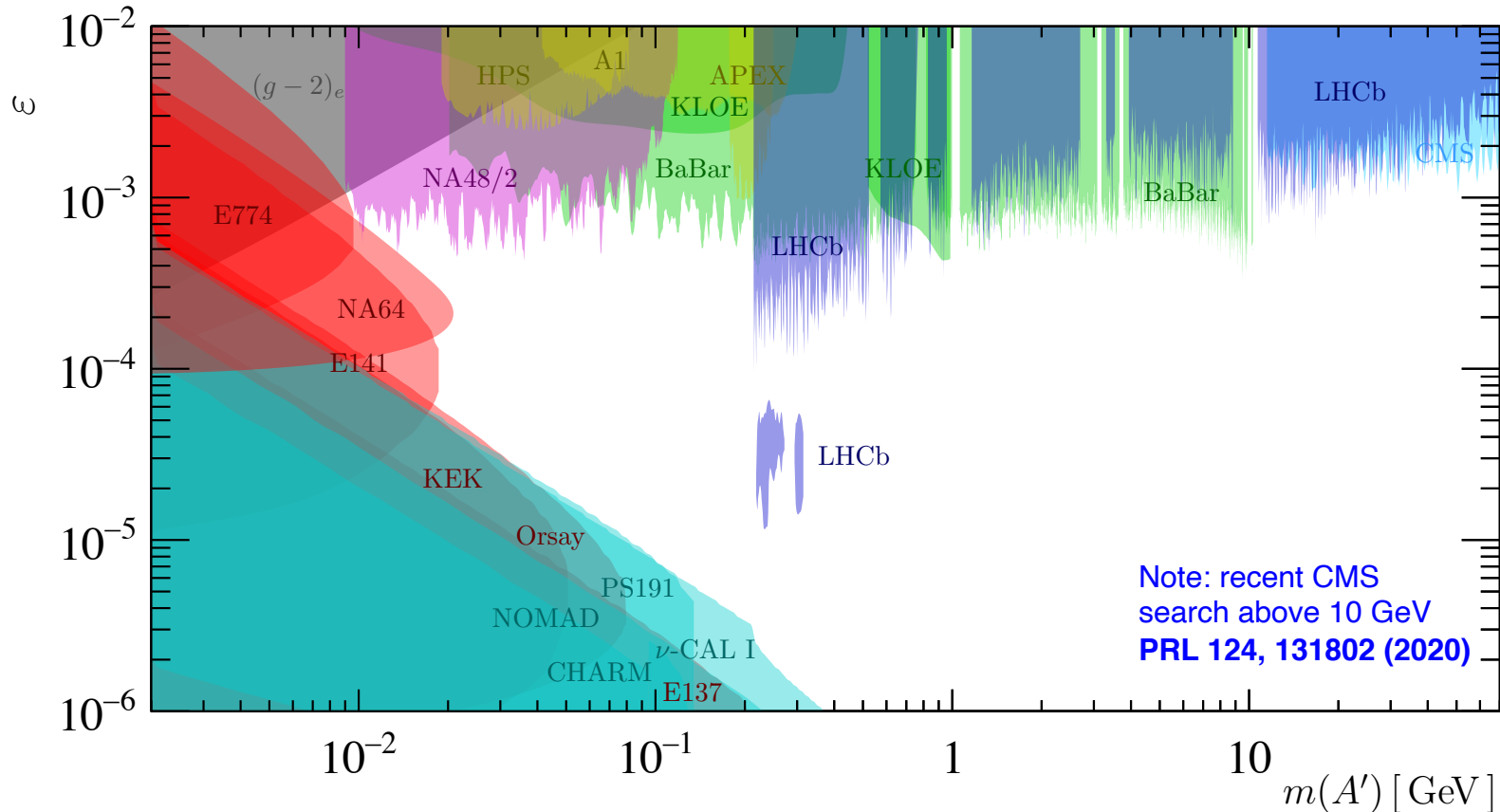
[PRL 124 \(2020\) 041801](#)



- Bump hunt analysis
- Regions of SM resonances removed
- Search for **both prompt and displaced** signatures using Run 2 data

Dark photons in di-muon spectrum

[PRL 124 \(2020\) 041801](#)



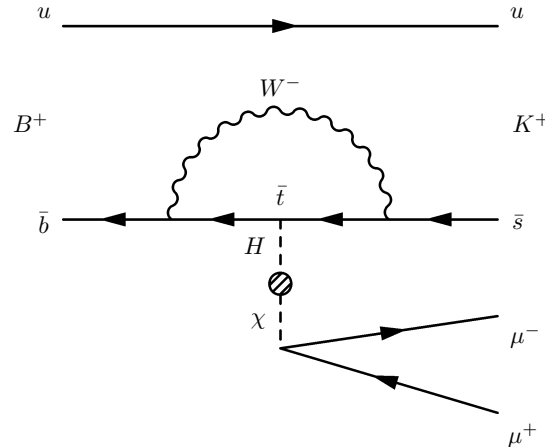
- World's best upper limits for inv. mass range of $\sim 200\text{-}700$ MeV (prompt)
- First displaced search not from beam-dump experiments
 - *explored invariant mass range: 214-350 MeV*
- *Can be extended with di-electron search at very low masses in $D^* \rightarrow Dee$*
[PRD92 \(2015\) 115017](#)

Light boson from $b \rightarrow s$ decays

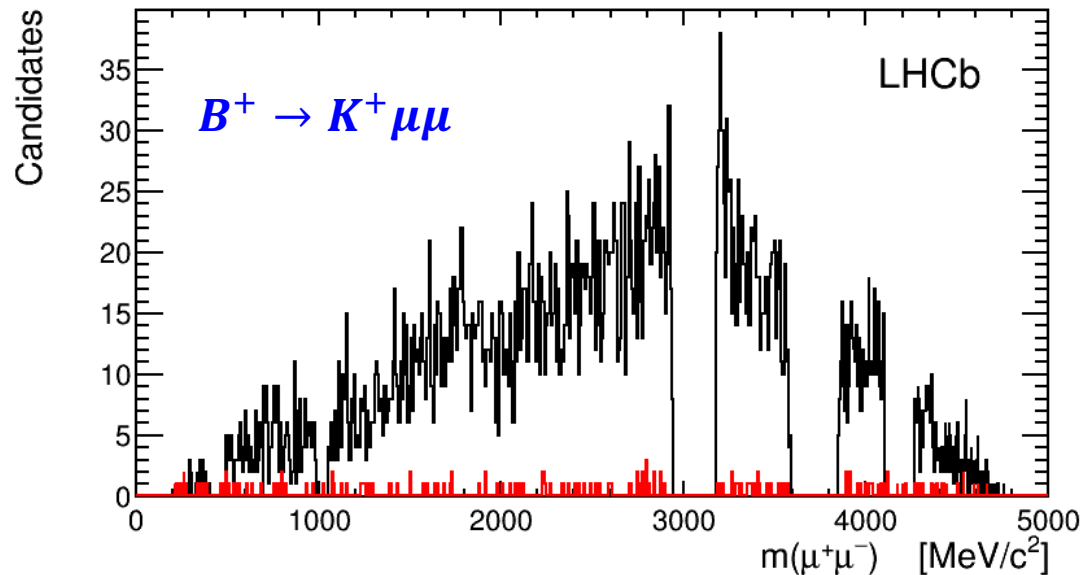
- Light boson can contribute to $b \rightarrow s\mu\mu$ penguin decays

[PRL 115 \(2015\)161802](#)

[PRD 95 \(2017\) 071101](#)



- LHCb has world's largest sample of $b \rightarrow s\mu\mu$ decays
- Study of di-muon spectrum

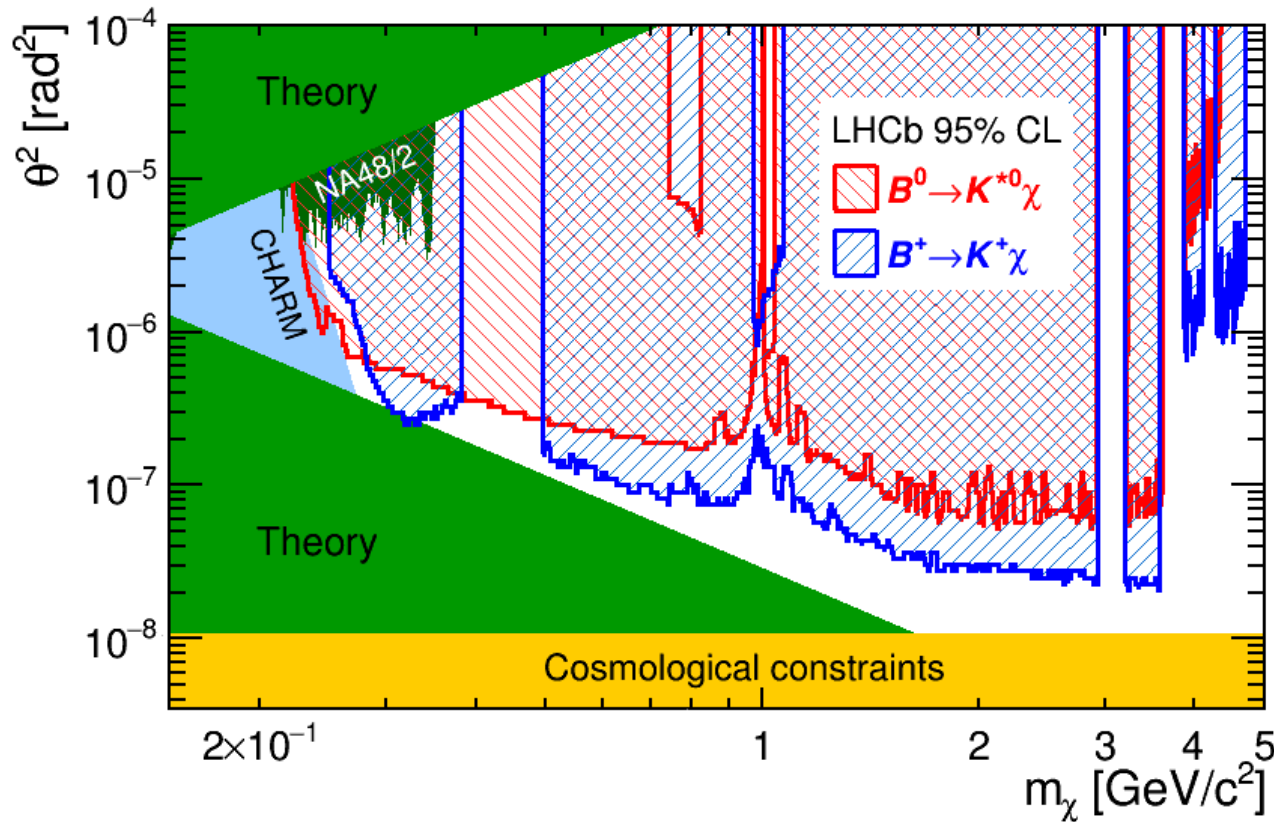


Light boson from $b \rightarrow s$ decays

- Search for a narrow di-muon peak
- Displacement of muon pair is considered
- Upper limits on mixing with SM Higgs

[PRL 115 \(2015\)161802](#)

[PRD 95 \(2017\) 071101](#)

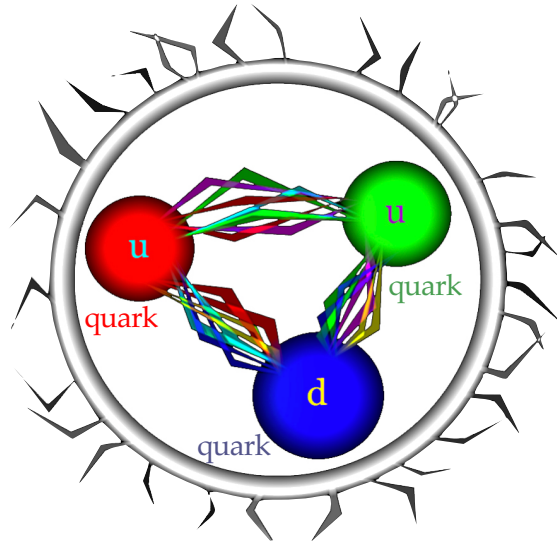


- **World's best upper limits below $2m_\tau$**

Search for dark hadrons

Building blocks of matter

Ordinary matter

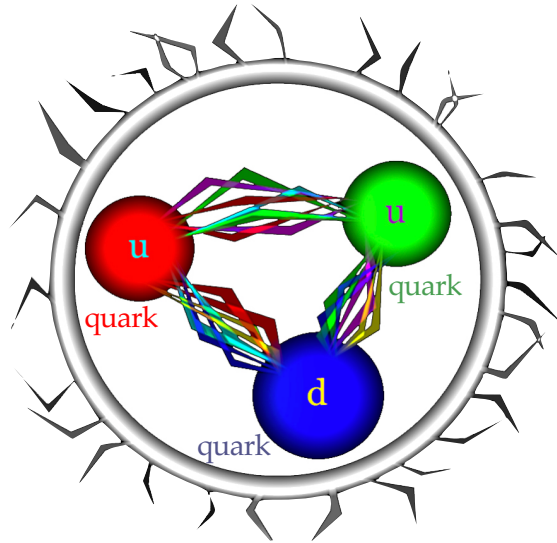


stable hadron: proton

other 100+ hadrons decay

Building blocks of matter

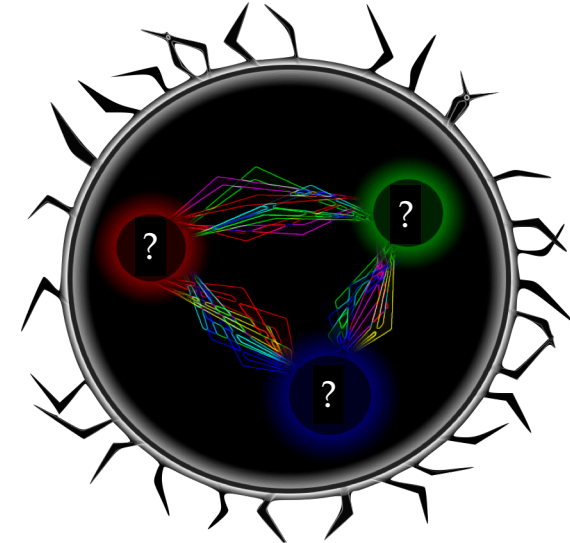
Ordinary matter



stable hadron: proton

other 100+ hadrons decay

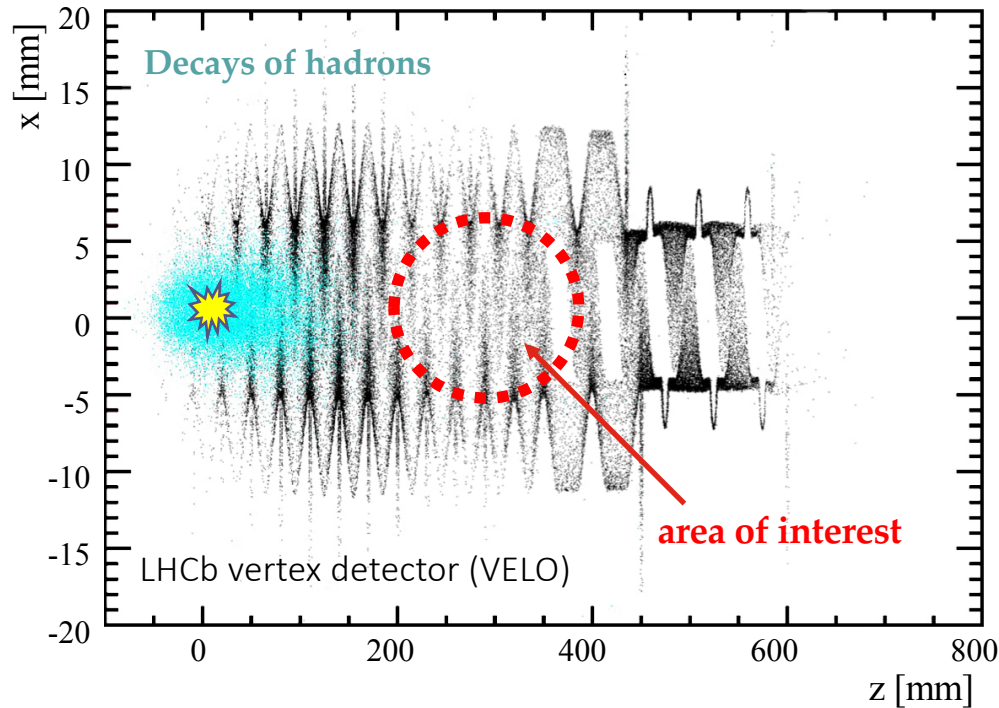
Dark matter



stable dark hadron

other dark hadrons may decay
to ordinary hadrons

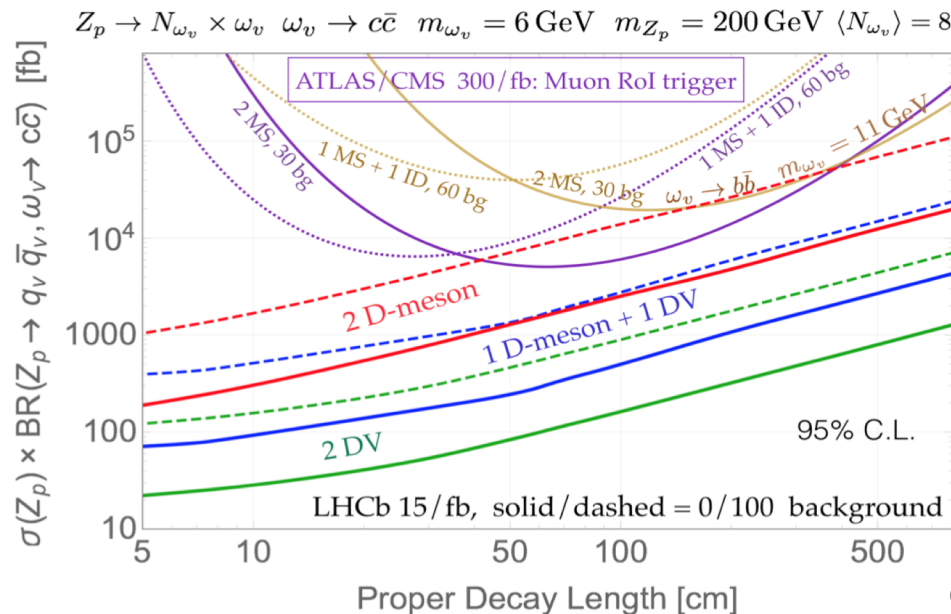
LHCb sensitivity



- LHCb is built to study hadrons
- dark hadrons can be found similarly
- as displaced decay vertices
- unique sensitivity by LHCb
- just like a search for long-lived hadron !

LLP decays to light hadrons

- Access to low masses $O(\text{GeV})$
- Use charged hadron ID from RICH
- Complicated mixture of heavy flavor background
- Several searches suggested:
 - Model-independent search for $H \rightarrow SS, S \rightarrow K^+ K^-$
LHCb projections: JHEP 01 (2020) 115
 - ALPs
 - Dark hadrons via decays to D -mesons / displaced vertices
LHCb projections: PRD 97 (2018) 9, 095033



credit: Y. Tsai

Searches of LLPs decaying to jets

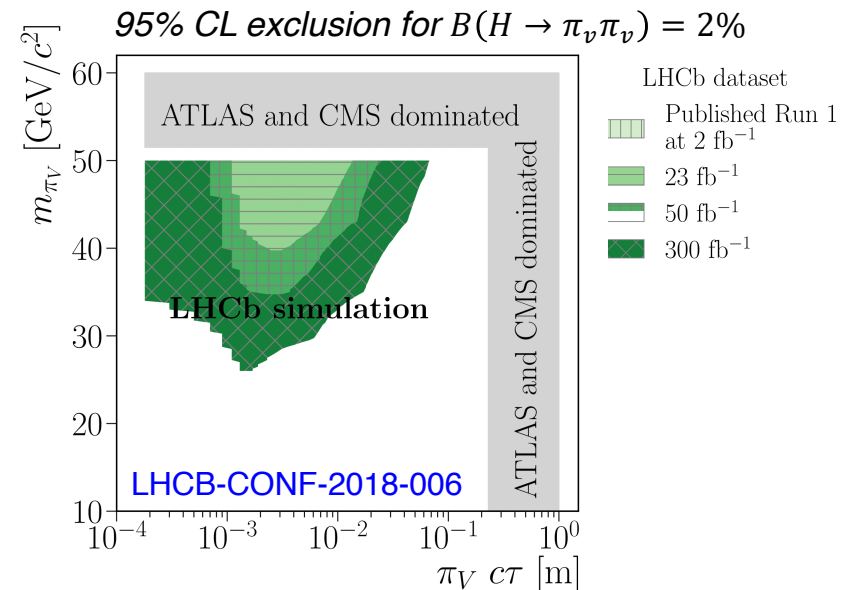
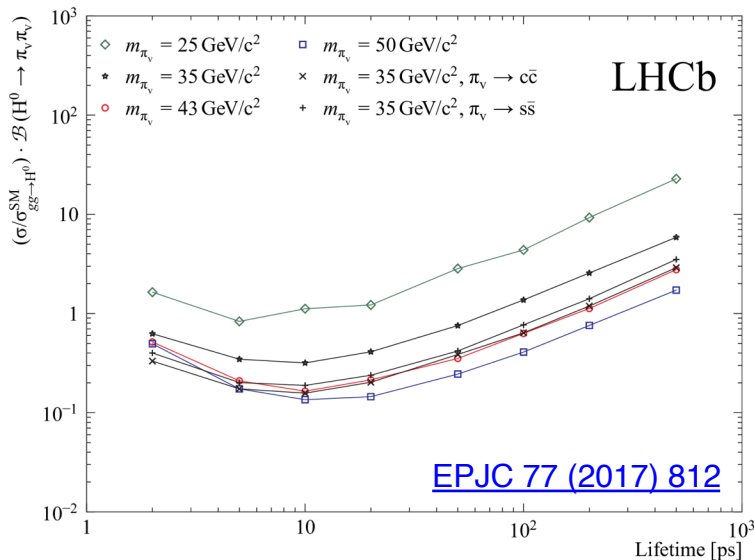
Signature: single displaced vertex with two (b-) jets

[EPJC 77 \(2017\) 812](#)

Model: Hidden Valley dark pions through Higgs portal

Data set: Run 1

- Analysis in bins of R_{xy} - radial distance to the beam axis
- Invariant mass range explored: 25-50 GeV
- No excess found, upper limit for lifetimes range 2-500 ps
- Complementary limits to ATLAS and CMS



- Can be pushed to lower masses in Run 3 using jet substructure
- [LHCb-CONF-2018-006](#)

Unleashing the full power of LHCb to probe Stealth New Physics

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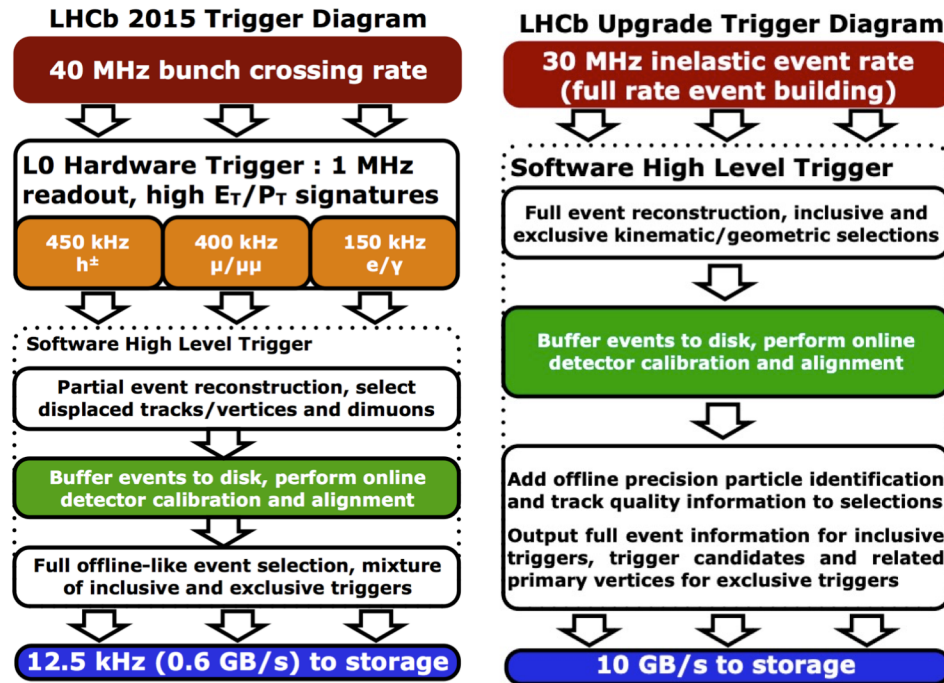
Abstract

In this paper we describe the past, present and future potential of LHCb to find Stealth physics. This refers to Beyond the Standard Model signatures with excellent theory motivation and not falling in the category of “flavor physics”. Examples of these signatures include Long-Lived particles, light resonances or hadronic final states where particle identification can play an important role. We will describe why LHCb is very well equipped to discover this kind of physics at the Large Hadron Collider, and provide good examples of well motivated theoretical models that can be probed with great detail at the experiment.

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Towards Run 3



- x5 luminosity compared to Run 2
 - fully-software trigger, 30 MHz event reconstruction
 - GPU-based first trigger stage (HLT1) [Comput.Softw.Big Sci. 4 \(2020\) 1, 7](#)
- convenient to trigger exotic signatures

Summary

LHCb provides unique capabilities for

- detecting **low-mass** particles and **soft** signatures
- studies in ***b*-** and/or ***c*- decays**
- complementing searches at ATLAS and CMS

Available searches for

- di-muon resonances
- HNLs
- semi-leptonic and hadronic LLP decays

Inspiring prospects for Run 3 with

- x5 larger luminosity
- fully-software trigger, convenient for exotica searches

