Exotic Searches @ LHCb

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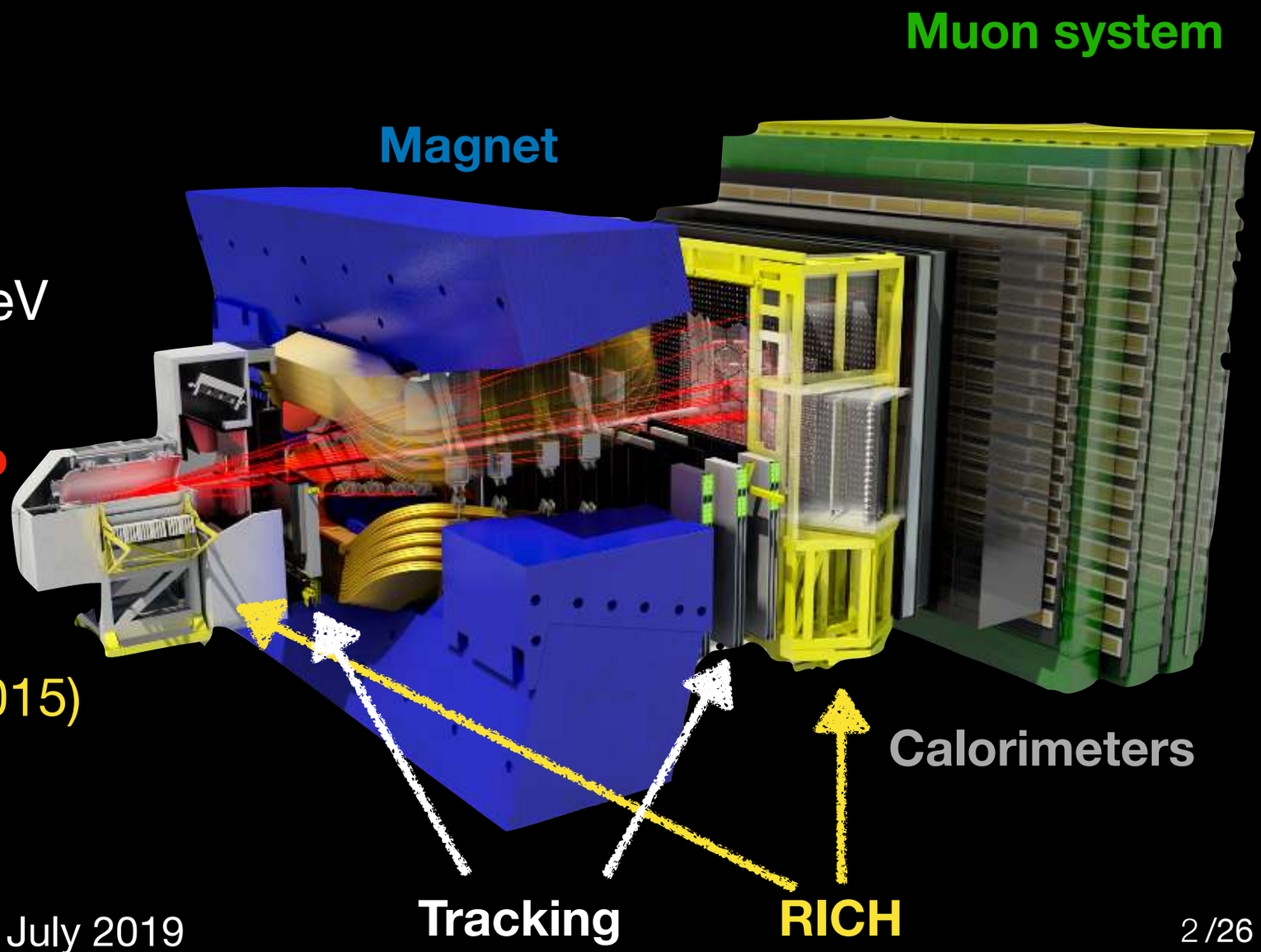
on behalf of LHCb Collaboration

LHCb Detector

- Good vertex resolution ~10 μm (transverse plane)
- Jet identification for a b(c) jet ~65%(25%) with misID of light-parton jet of 0.3%
- Muons identification efficiency ~90%
- Mass resolution 7 - 20 MeV
  in di-muon in Υ mass region
- Low p_T trigger, ex. $p_T > 1.5$ GeV

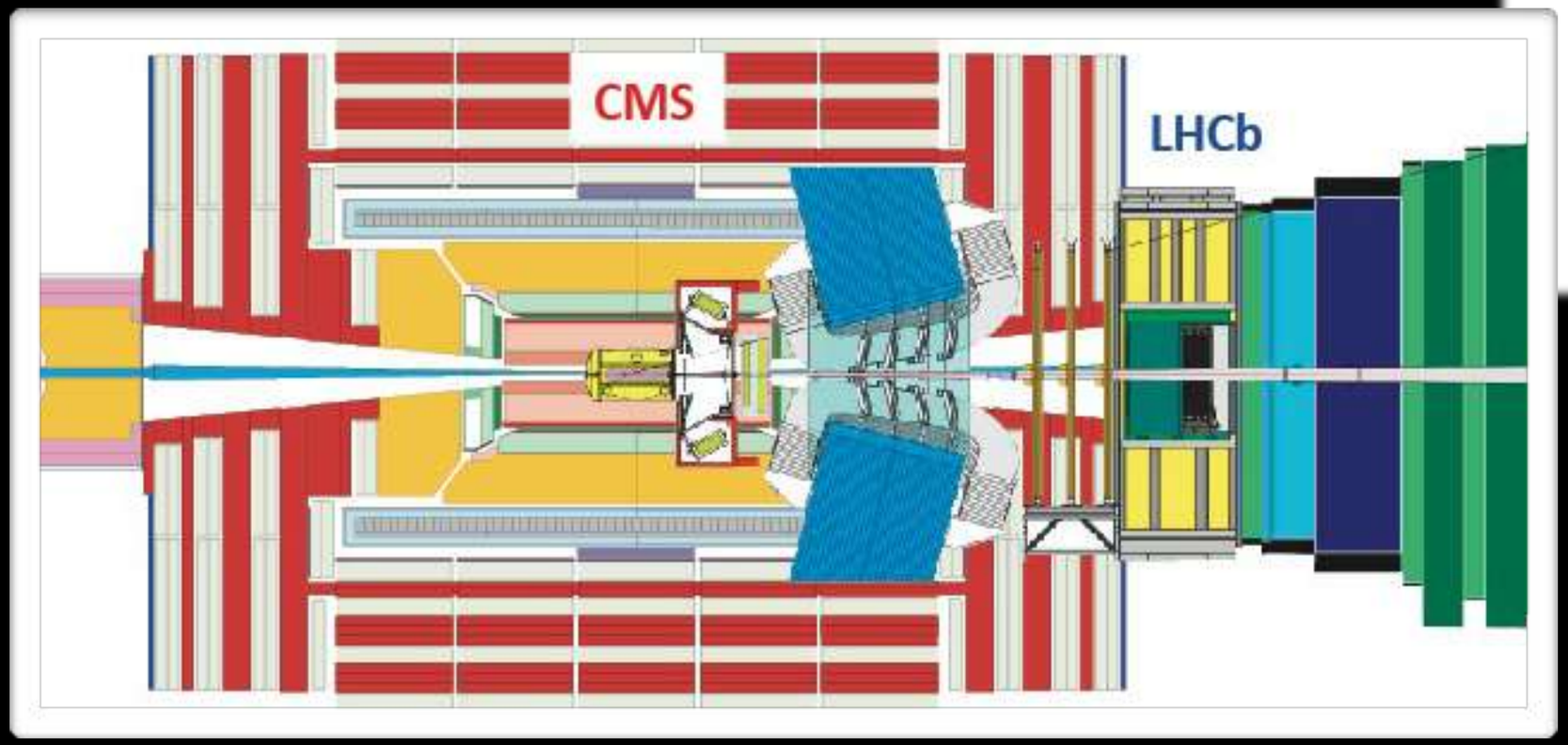


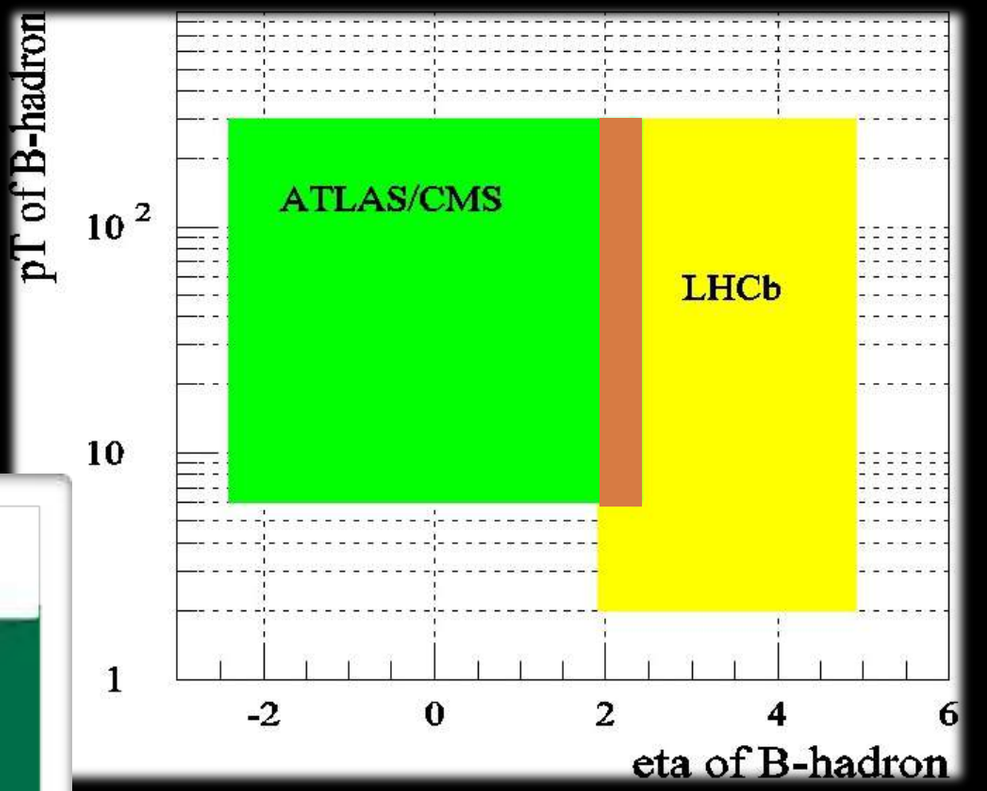
Int.J.Mod.Phys. A 30,1530022 (2015)

JINST 10 (2015) P06013

LHCb Complementarity

- Forward region ~1.9 < η < 4.9 (~1° - 15°)
- Precise flavour measurements
- Particle ID





Int.J.Mod.Phys. A 30,1530022 (2015)

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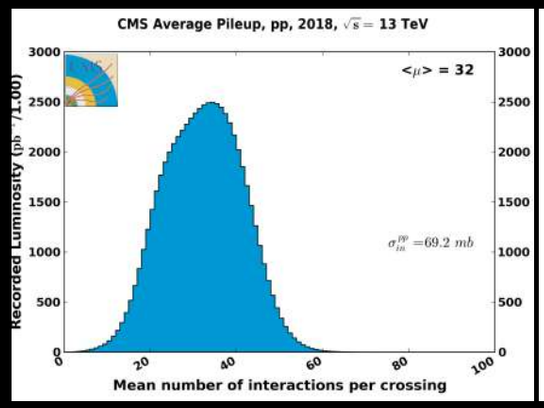
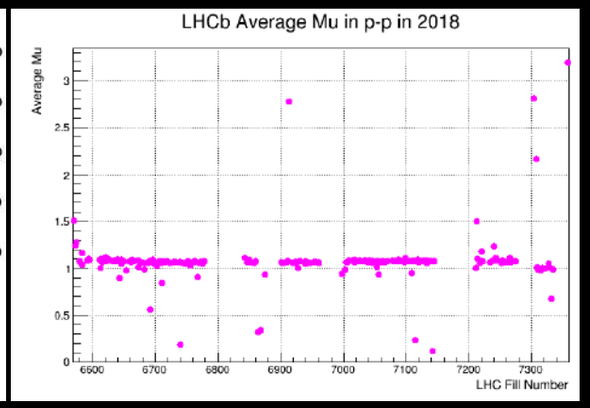
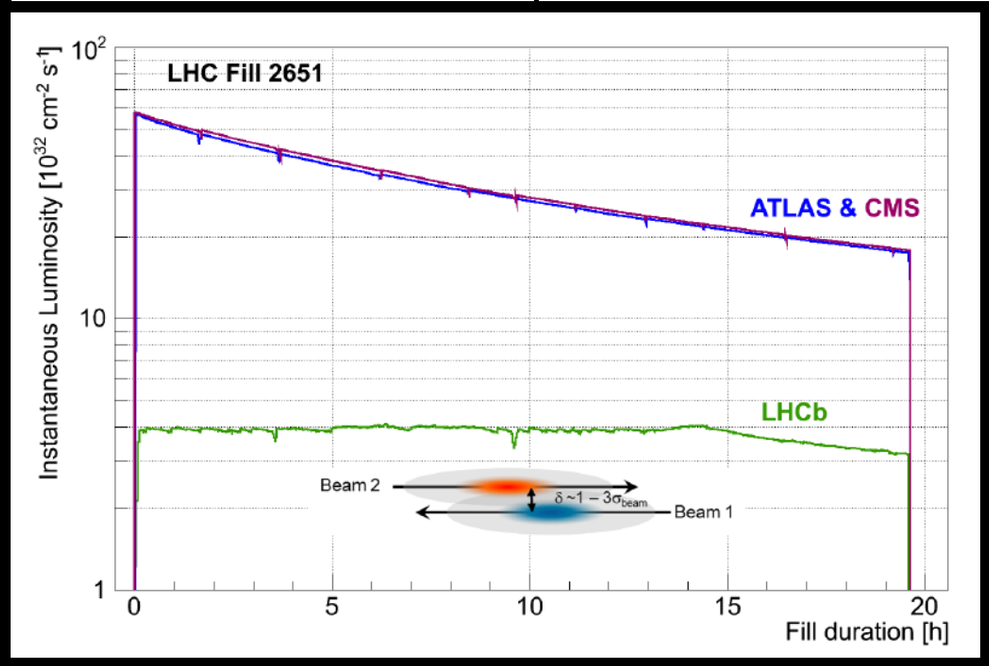
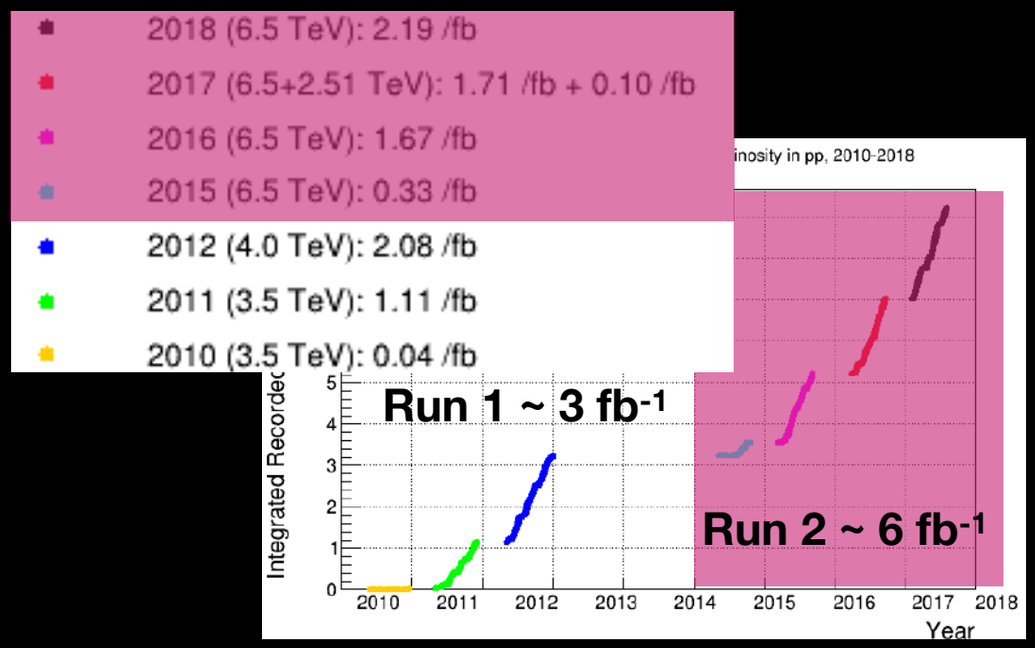
LHCb Operation









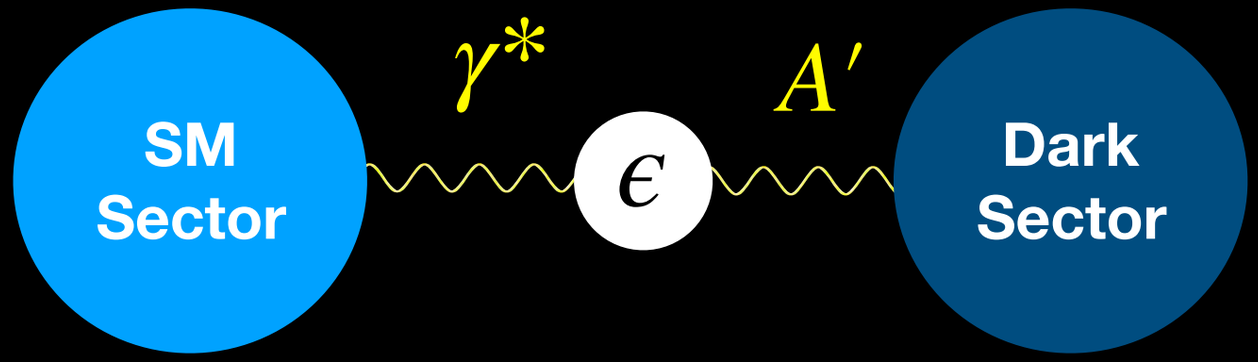
- Lower pile-up (lower luminosity)
  - LHCb <μ> ~1
  - CMS/ATLAS <μ> > 20
- Real time reconstruction - charged particles $p_T > 0.5$ GeV
- Full offline-like event selection
- 12.5 kHz (0.6 GB/s) to storage

Int.J.Mod.Phys. A 30,1530022 (2015)

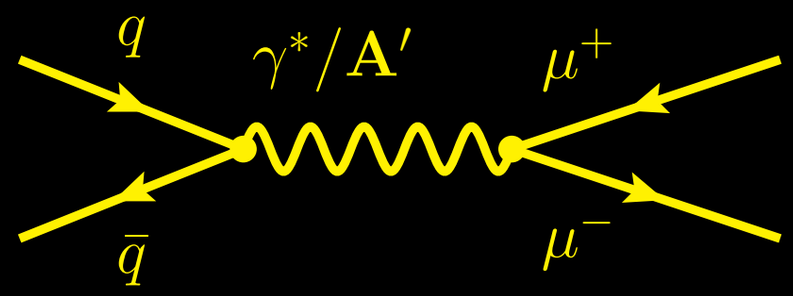
JINST 10 (2015) P06013

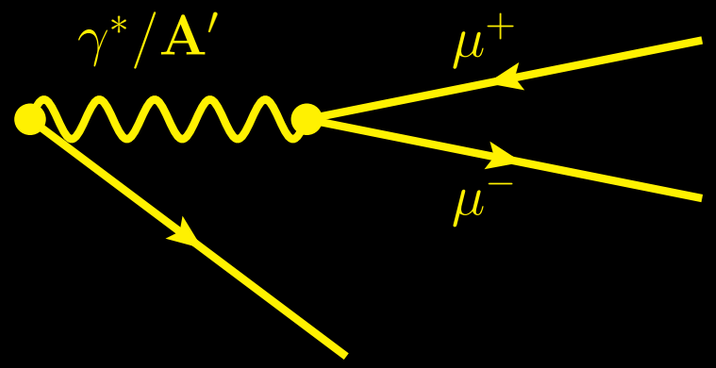
Run 1 and Run 2 results

Search for Dark Photons



- Dark sector vector portal
- Kinetic mixing of the dark photon with off-shell photon by a factor ϵ = < A' | γ^* >
  - ✦ A' inherits production mode from γ^*
  - ✦ A' → μ⁺μ⁻ can be normalised to γ^* → μ⁺μ⁻
  - ✦ Data-driven analysis
- If ϵ really small A' may be a long-lived particle
  - ✦ $\tau(A') \propto [m(A')\ \epsilon^2]^{-1}$
- 2016 LHCb data - 13 TeV - 1.6 fb^{-1}

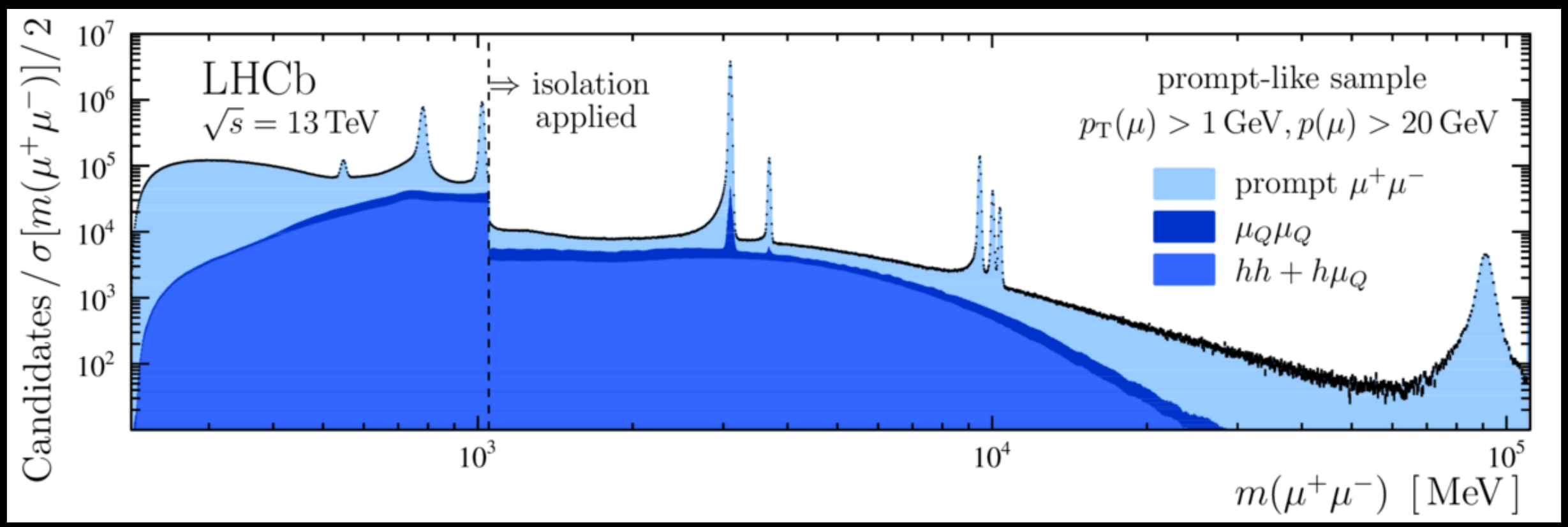




Phys. Rev. Lett. 120, 061801 (2018)

Search for Prompt-like Dark Photons

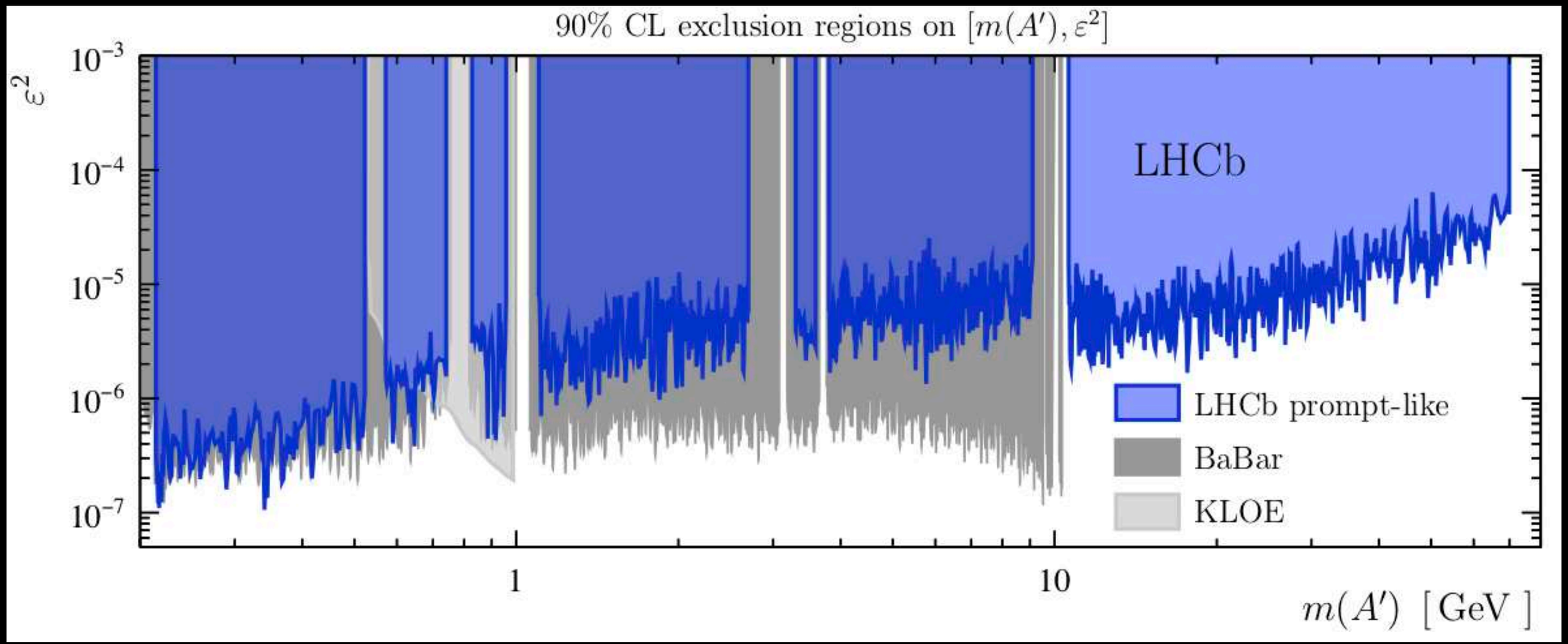
- Prompt search - m(A') < 70 GeV/c^2
  - ✦ All online-reconstructed stored with reduced information (saving space)
  - ✦ All dimuon candidates saved without mass constraints
  - ✦ Requirement: good quality vertex and muon identification
  - ✦ Background 1: mis-reconstruction,



Phys. Rev. Lett. 120, 061801 (2018)

Search for Prompt-like Dark Photons

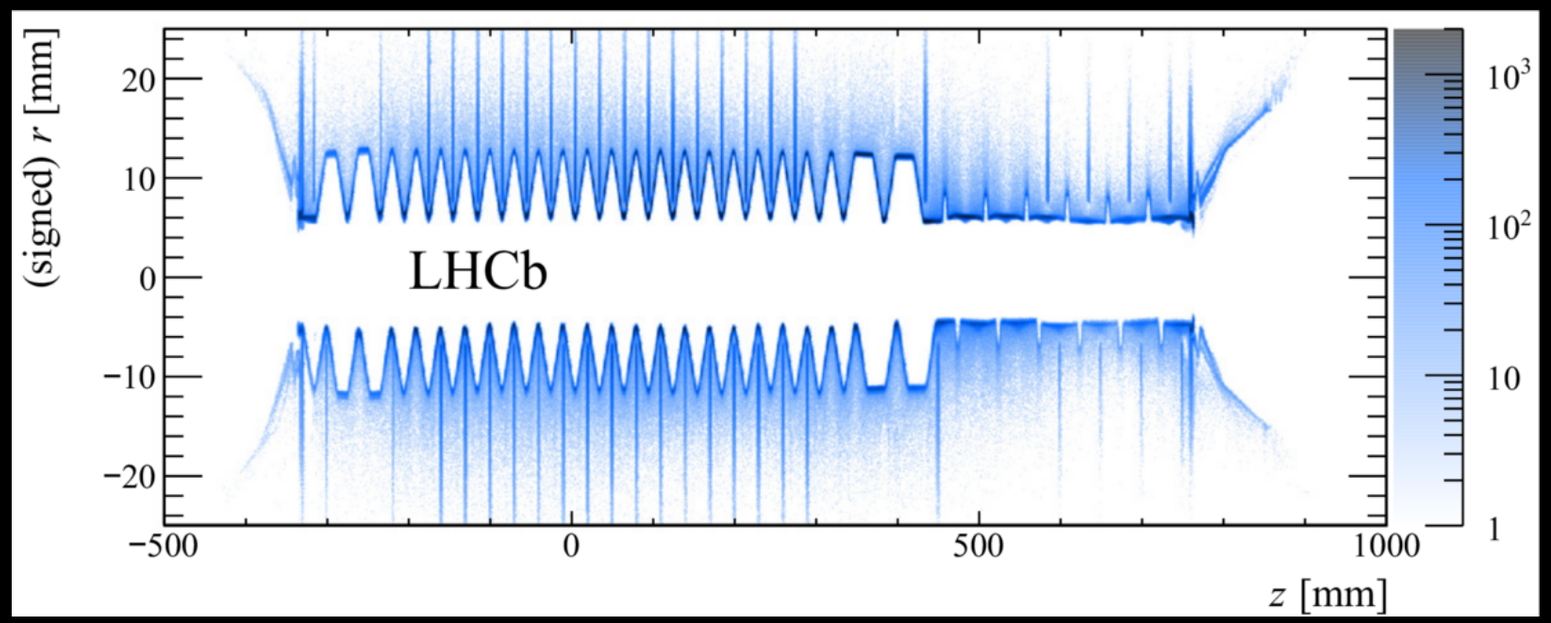
- Background 2: Resonant decays do $\mu^+\mu^-$ mass regions are excluded
- No excess observed



Phys. Rev. Lett. 120, 061801 (2018)

Search for Long-lived Dark Photons

- Long-lived search - 214 MeV/c^2 < m(A') < 350 GeV/c^2
  - ✦ Background
    - Photo conversions
      - 3D High precision Material map

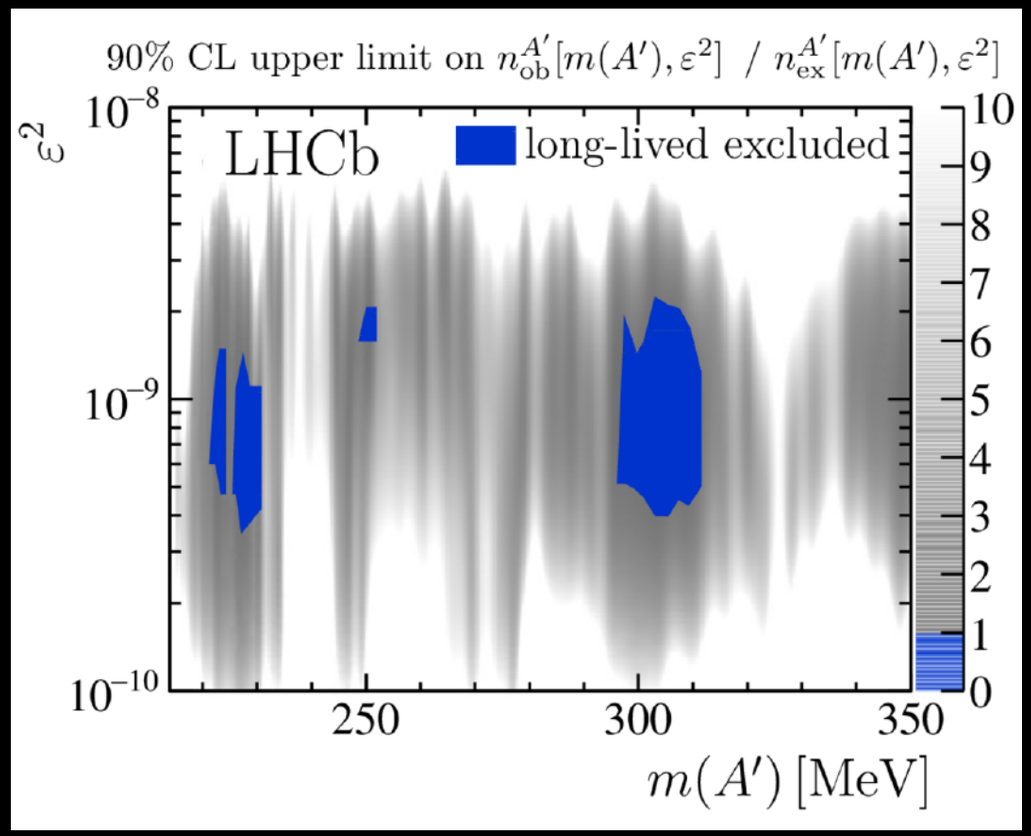


JINST 13, P06008 (2018)

Search for Long-lived Dark Photons

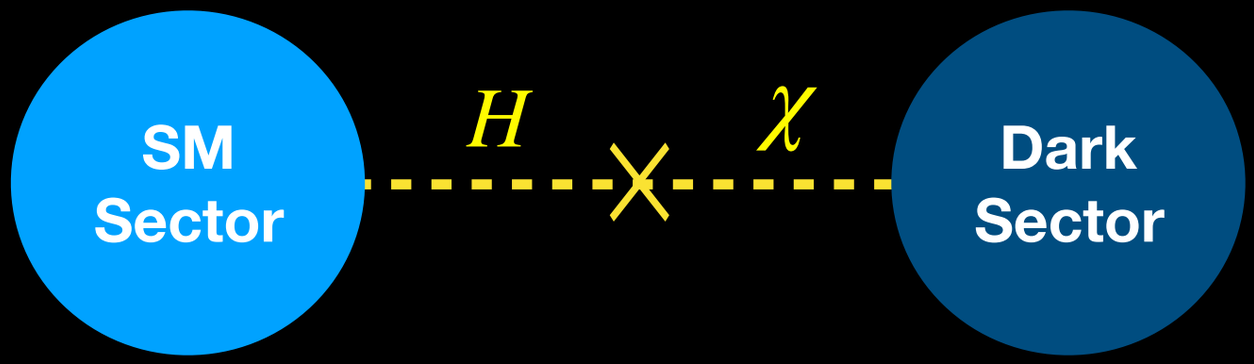
- Long-lived search - 214 < m(A') < 350 GeV/c^2
  - ✦ Background
    - b-hadron decays with 2 μ
    - Misindentified pions from low mass tail of $K_s \to \pi^+\pi^-$

      Isolation decision tree from $B_s \to \mu^+\mu^-$
  - ✦ Looser requirements than for prompt like
  - ✦ No significant excess
  - ✦ First limit ever not from beam dump
- ◉ ~25% of Run2 data

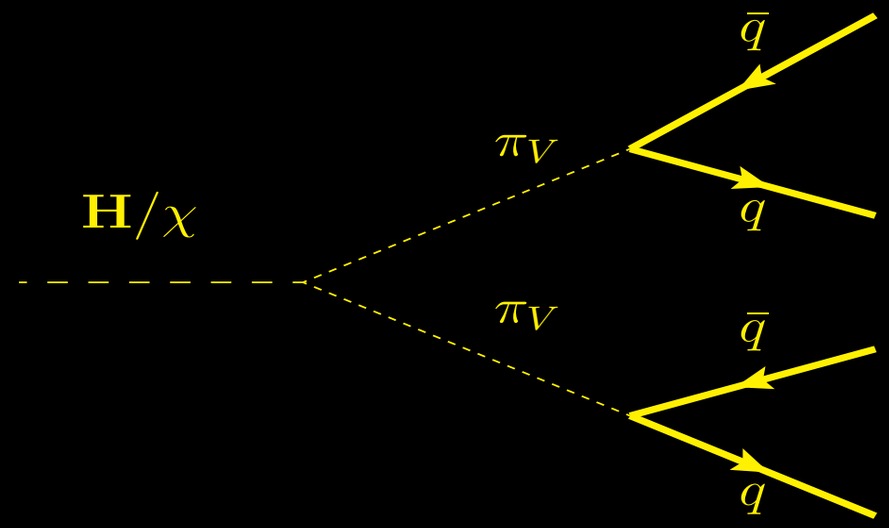


Phys. Rev. Lett. 120, 061801 (2018)

Search for Massive Long-Lived Particles



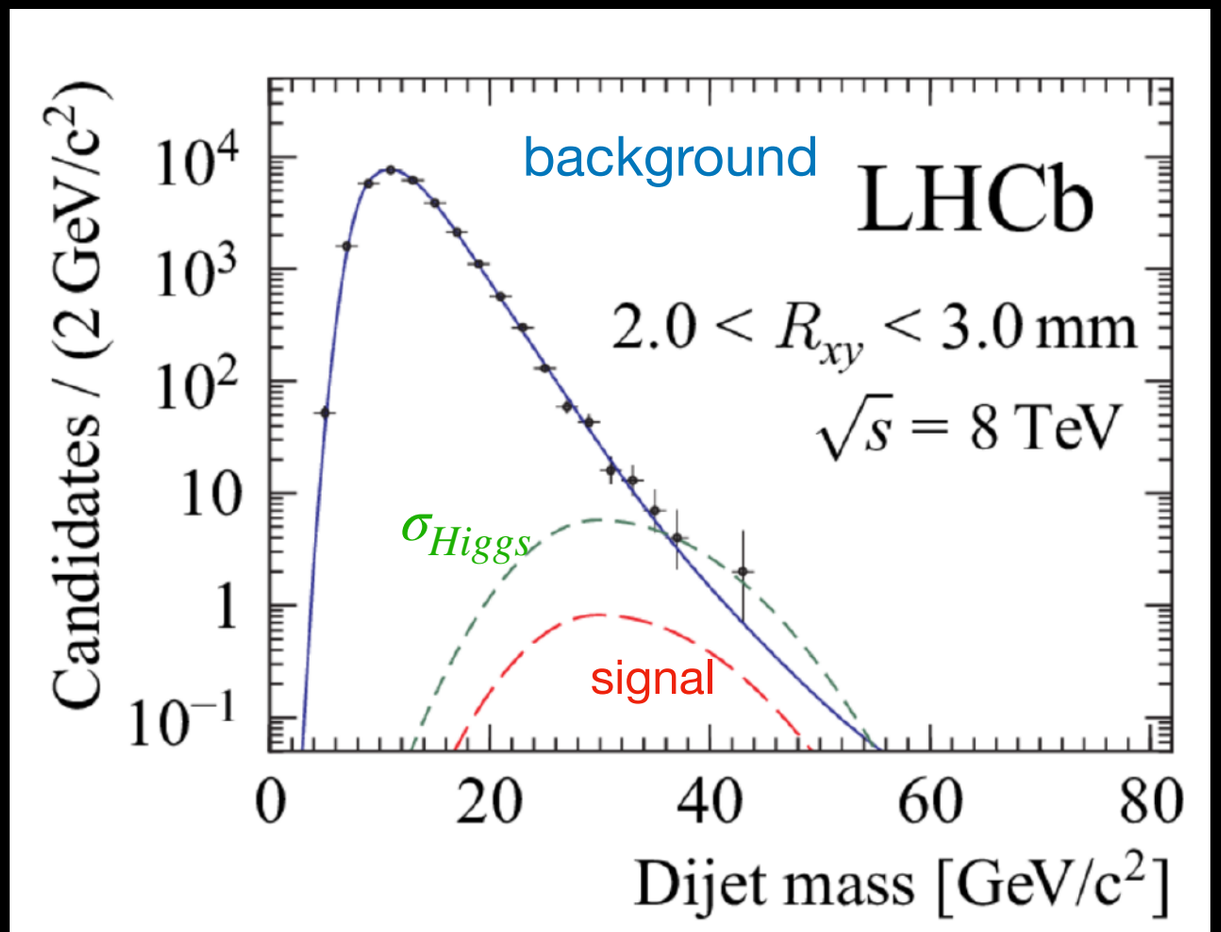
- Dark sector Higgs portal
  - Hidden-valley pion - π_V
- Decaying to jet pairs
- LHCb Run1 data
  - 7 and 8 TeV - 3 fb^{-1}
  - Single vertex with two jets
  - Material veto

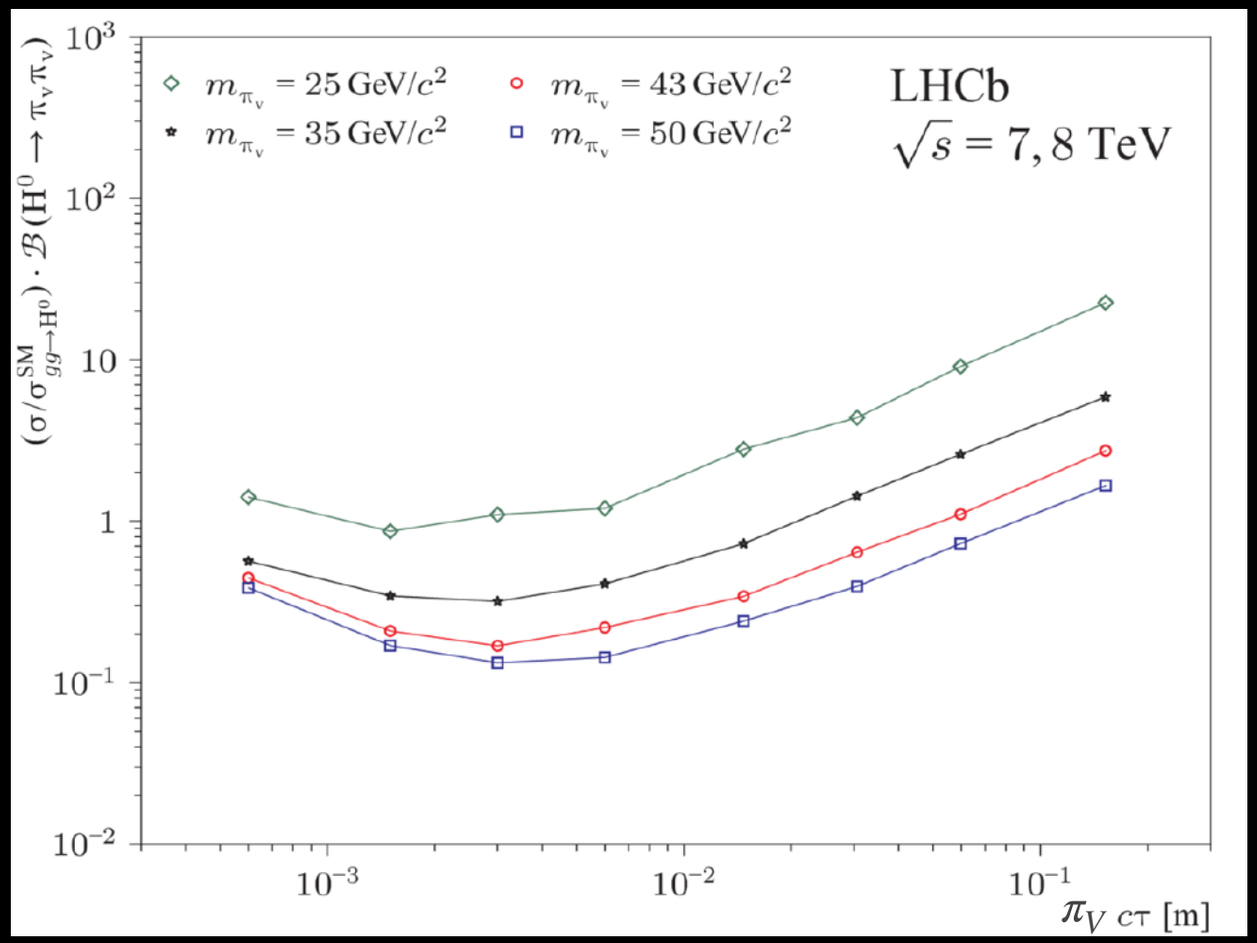


Eur. Phys. J. C77 (2017) 812

Search for Massive Long-Lived Particles

- No significant excess
- Limits on $\dfrac{\sigma}{\sigma^{SM}_{gg\to H}} BR(H \to \pi_V \pi_V)$

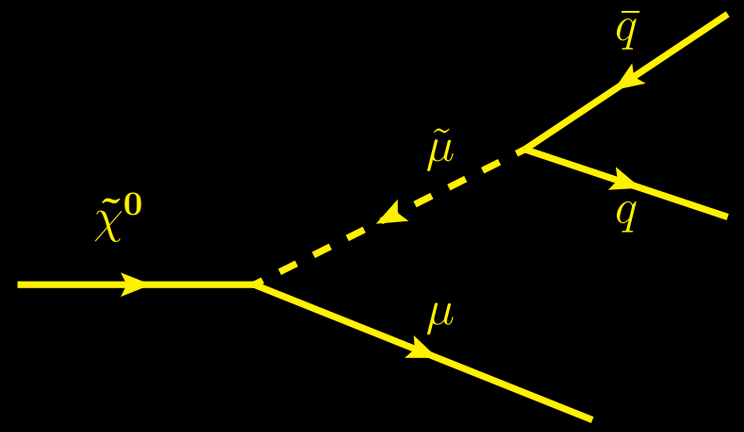


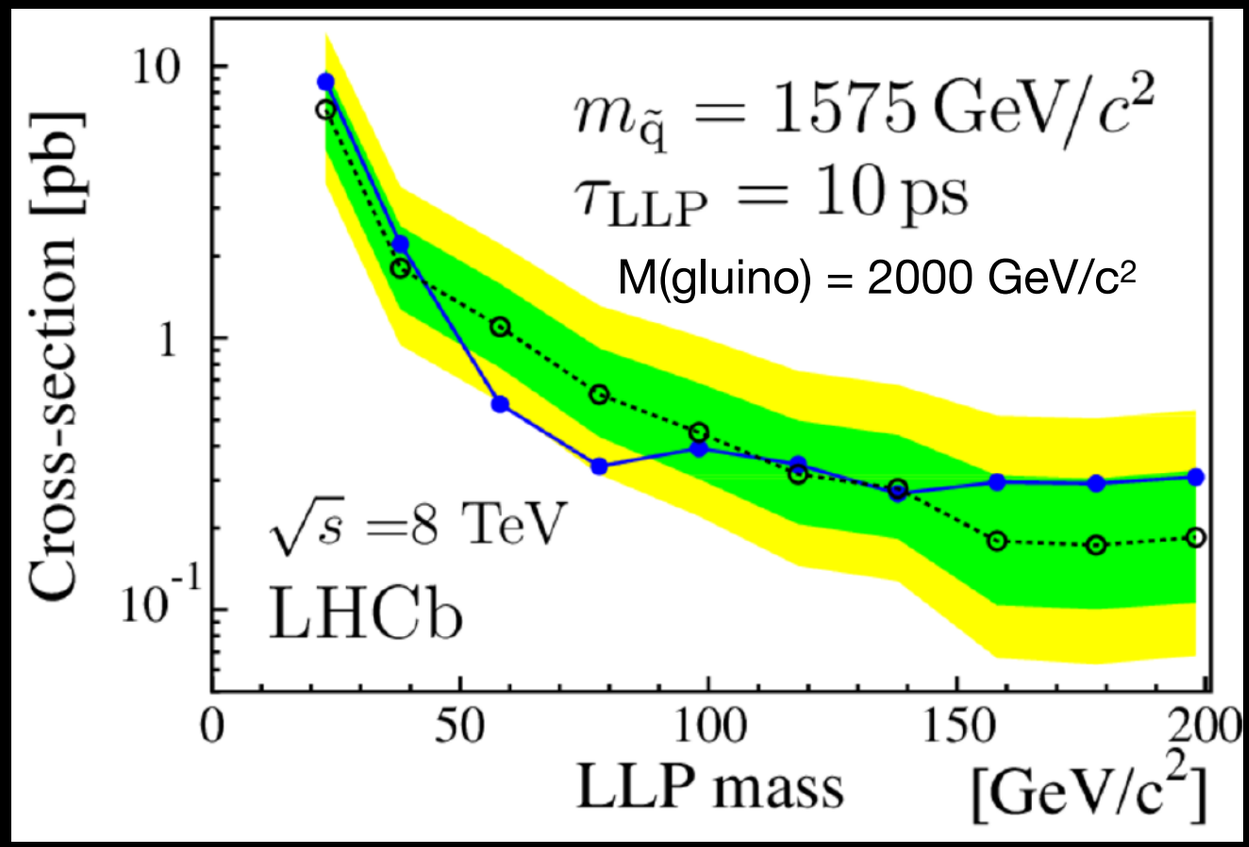


Eur. Phys. J. C77 (2017) 812

Search for Massive Long-Lived Particles

- Several neutralino production modes
- mSUGRA realisation of MSSM with RPV
- Semi-leptonic decay in a high p_T muon and jet
- LHCb Run1 data
  - 7 and 8 TeV - 3 fb^{-1}
  - Displaced vertex with one high-p_T muon
  - Material veto
- Sensitivity range
  - Mass range 20-80 GeV/c^2
  - Lifetime range 5-100 ps
- No excess is observed





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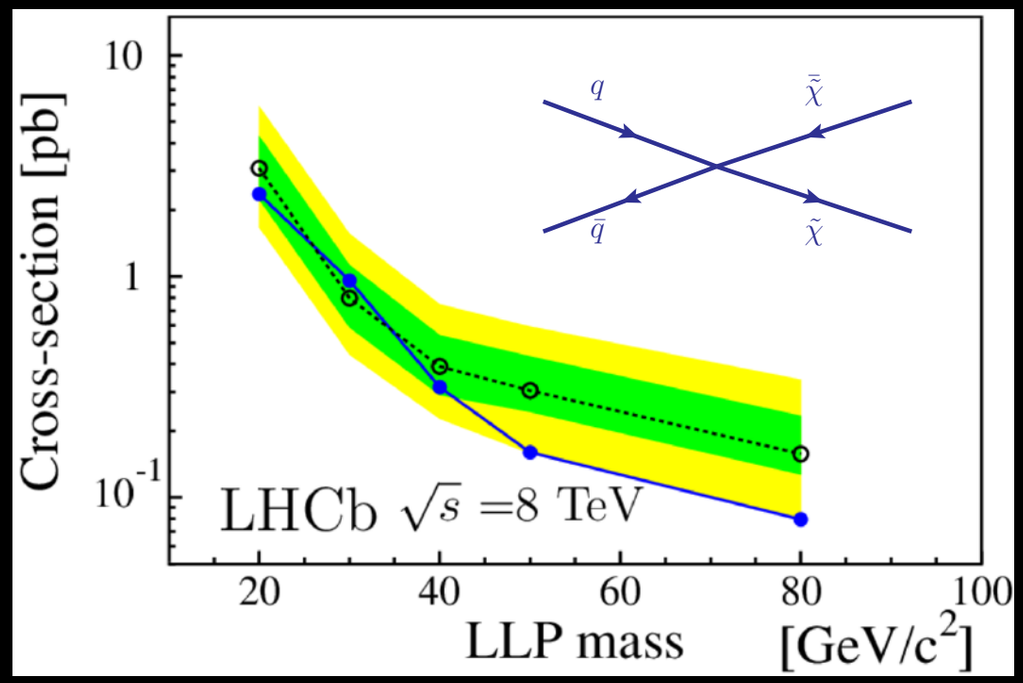
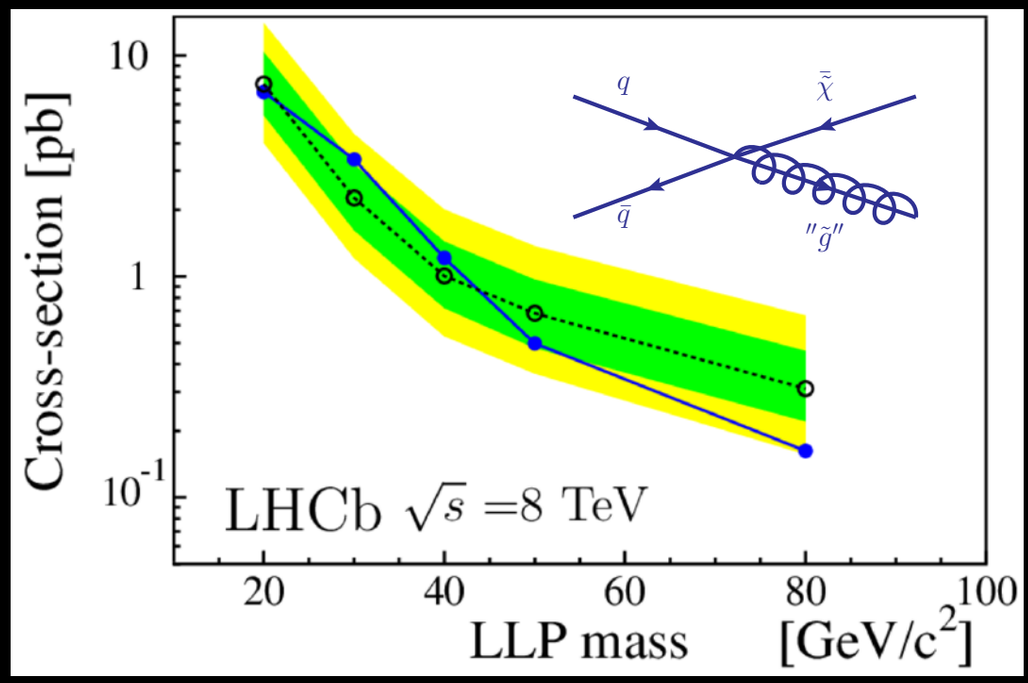
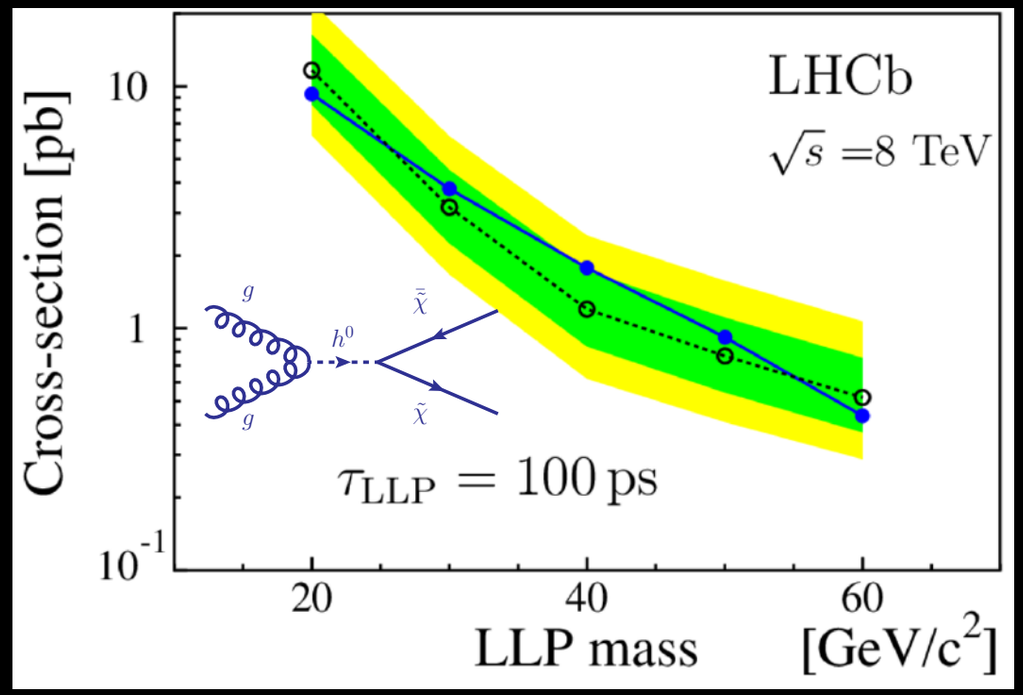
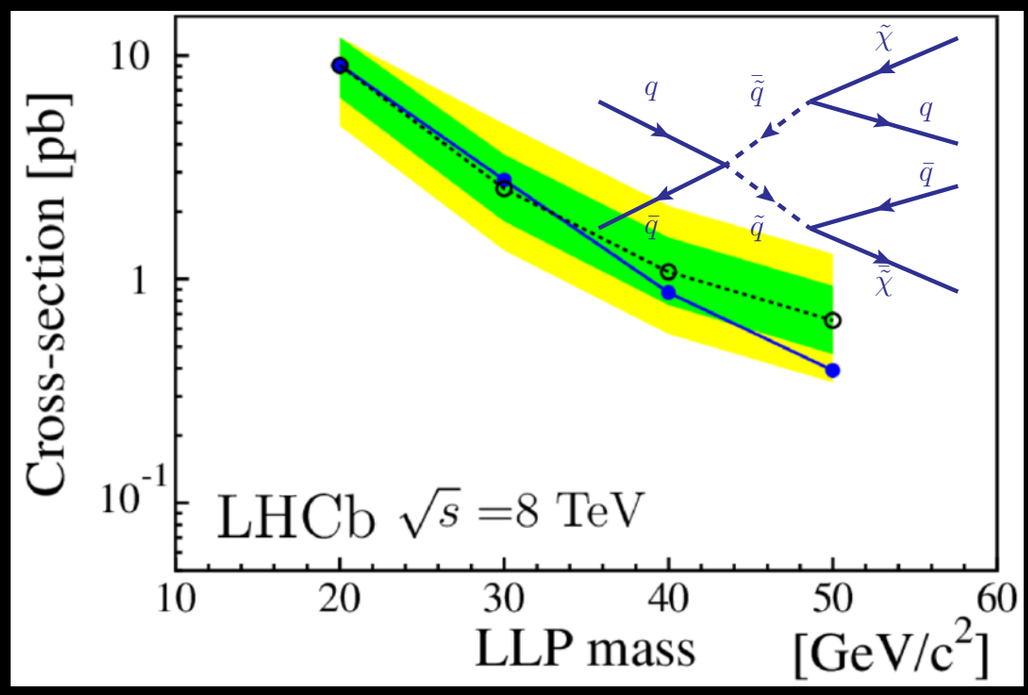
Search for Massive Long-Lived Particles





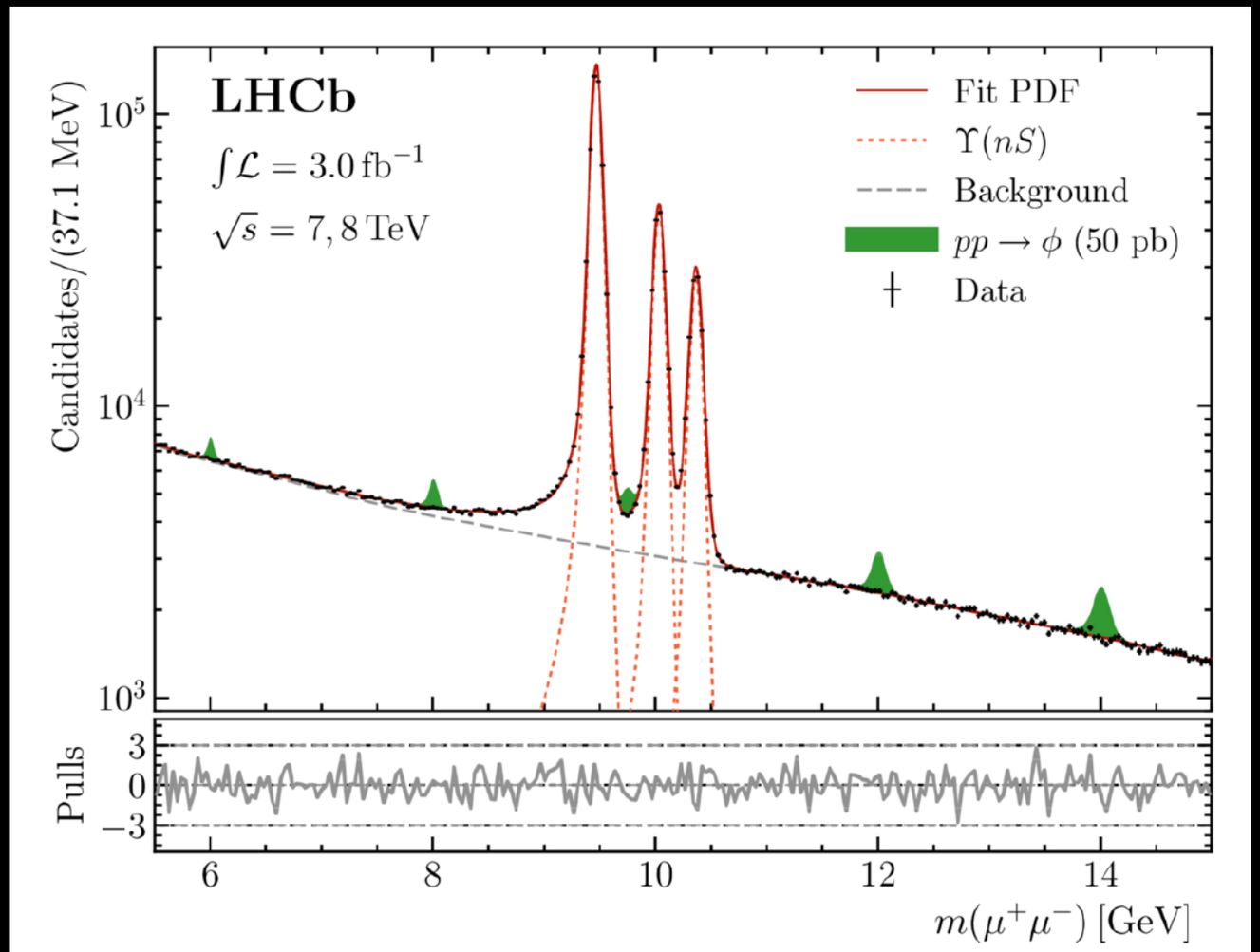




Eur. Phys. J. C77 (2017) 224

Search for a New Boson in the Υ mass region

- There are many proposals of an additional spin-0 boson: NMSSM, Little Higgs, two-Higgs doublet, Dark sector scalar portal
- LHCb has good sensitivity for light spin-0 particle
- Mass range - 5.5 to 15 GeV
- LHCb Run1 data - 3 fb^{-1}
- Decay channel $\phi \to \mu^+\mu^-$



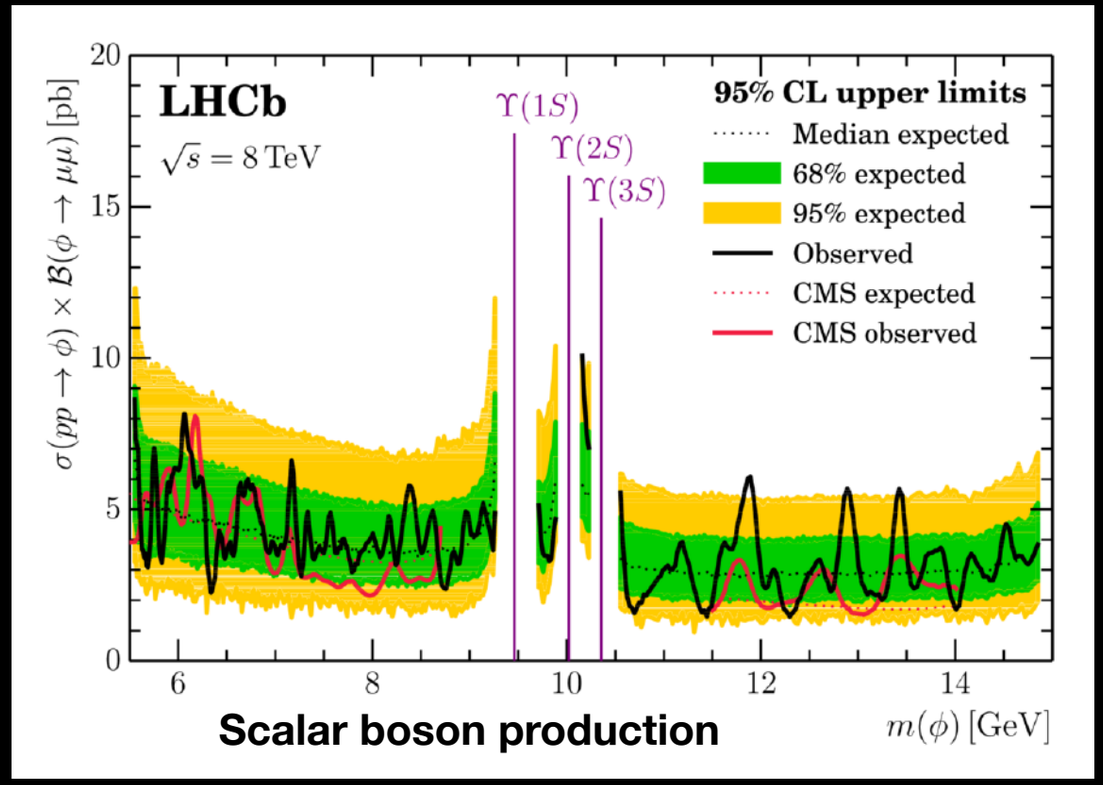
JHEP 09 (2018) 147

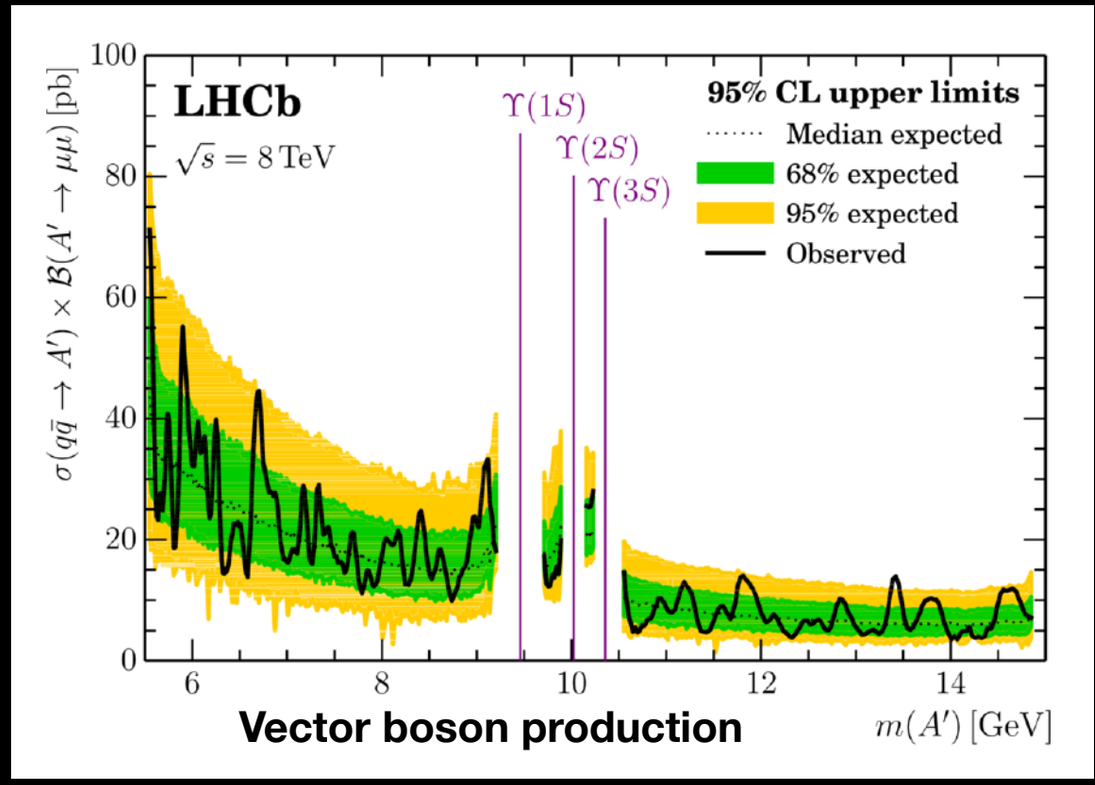
Search for a New Boson in the Υ mass region

At least one boson decaying to μμ

Scalar boson **Vector boson produced via Drell-Yan**

No excess found





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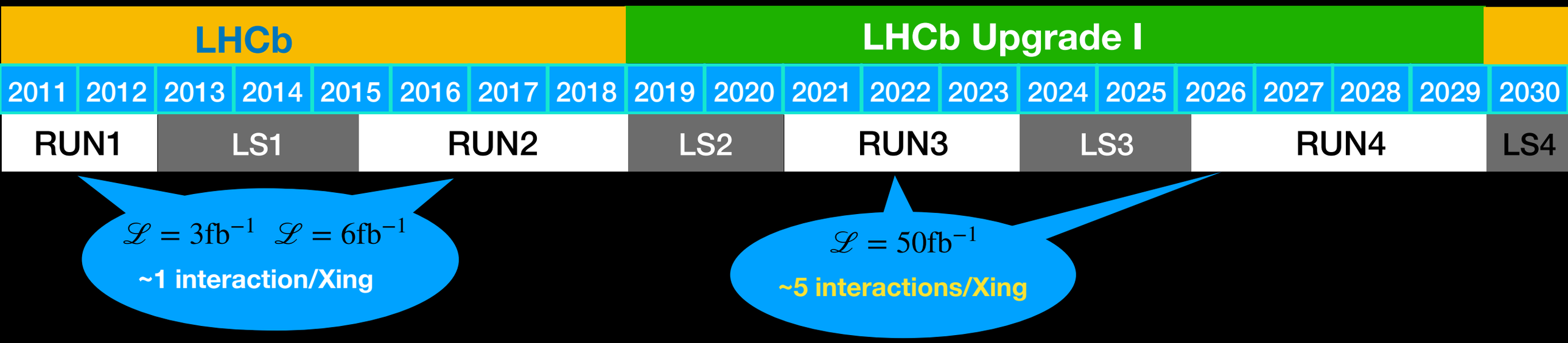
LHCb Upgrade

LHCb Upgrade



New detector needs to cope with

- Increase of pile up
- High occupancy
- Higher radiation

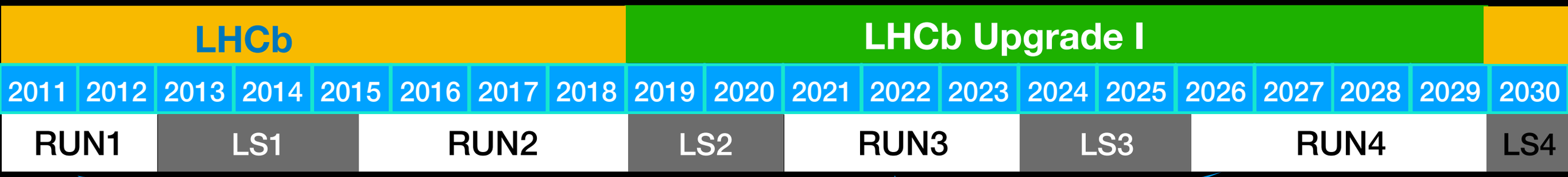
Upgrade I

- Tracking system
  - New VeLo
    Strips → Pixels
  - New Tracking Stations
    Straw tubes → Fibers
- RICH
  HPD → Multi-anode PM
- New DAQ
- New Trigger

Detector with higher granularity, increase DAQ and data acquisition performance

LHCb-TDR-012/013/014/015/016

LHCb Upgrade



$\mathscr{L} = 3\text{fb}^{-1}$ $\mathscr{L} = 6\text{fb}^{-1}$

~1 interaction/Xing

$\mathscr{L} = 50\text{fb}^{-1}$

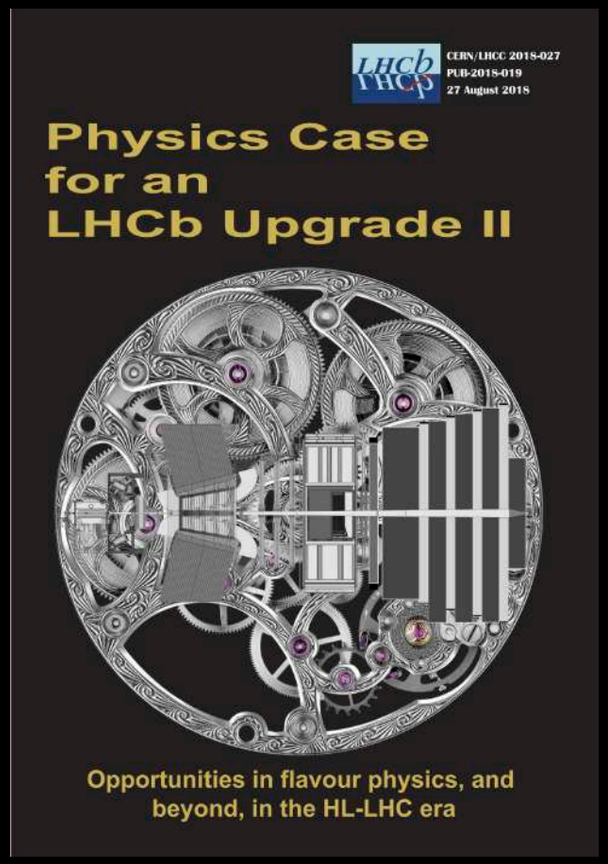
~5 interactions/Xing

LHCb Upgrade II

$\mathscr{L} = 300\text{fb}^{-1}$

~50 interactions/Xing

LHCb upgrade I is in progress but we are already designing a detector that can fully exploit HL-LHC



Upgrade II

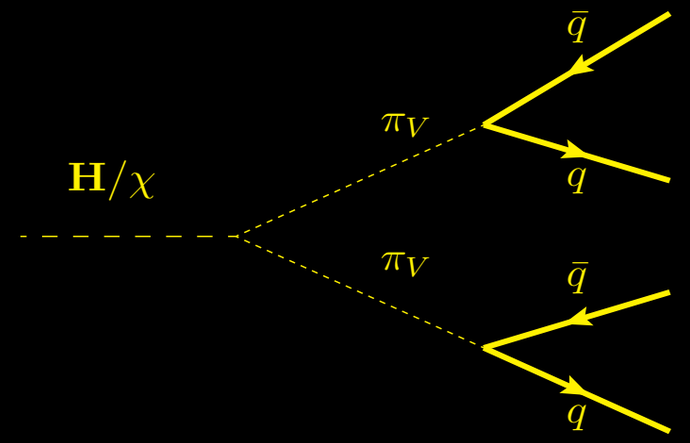
- Improve tracking system
  - Detectors
  - Magnet stations
- TORCH
- New Calorimeter
- Improve muon system

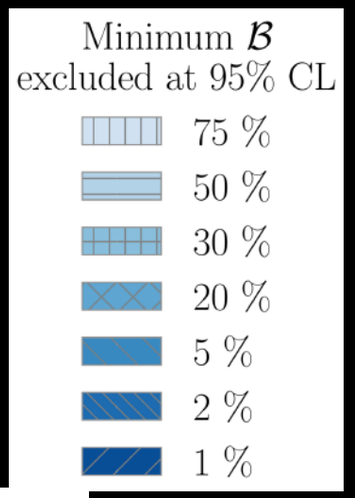
CERN-LHCC-2017-003/2018-0027

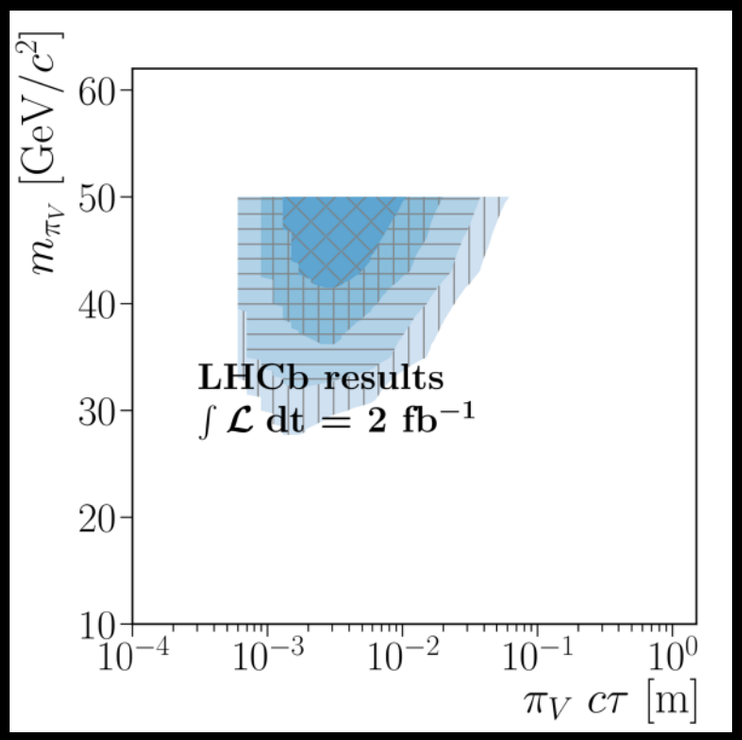
Prospects of Long Lived Particle Searches

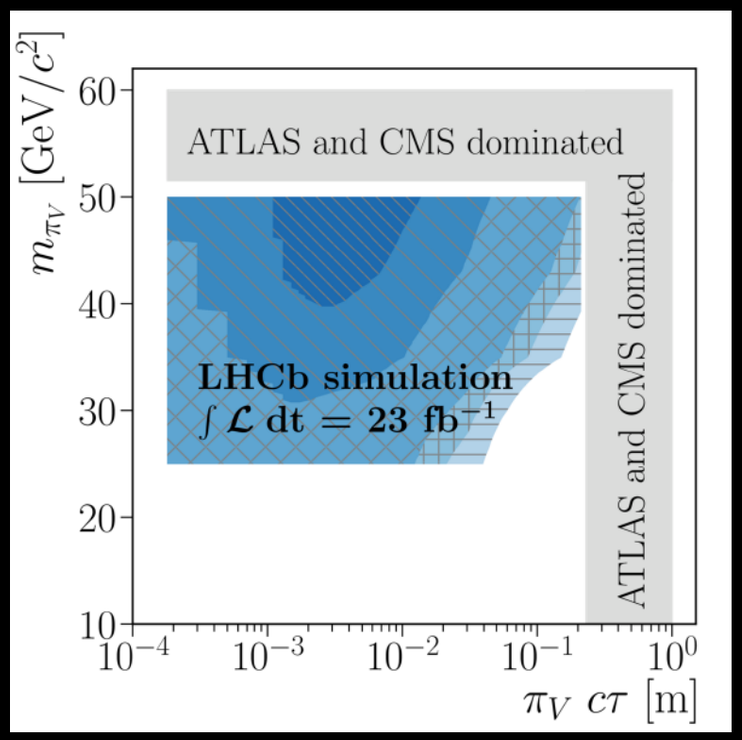
Long-Lived Particle decaying to jets

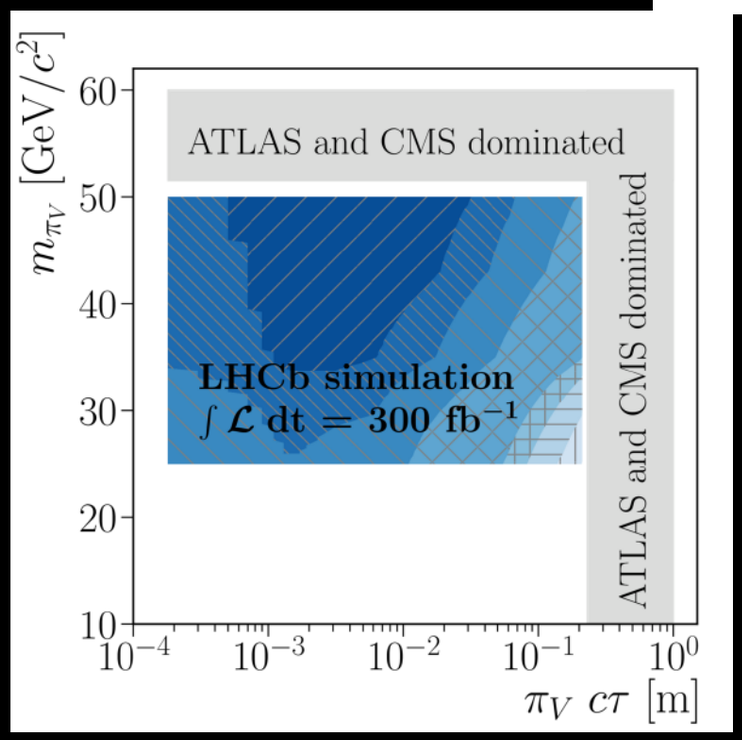
- Hidden valley V-pion - jets final state











Run 1

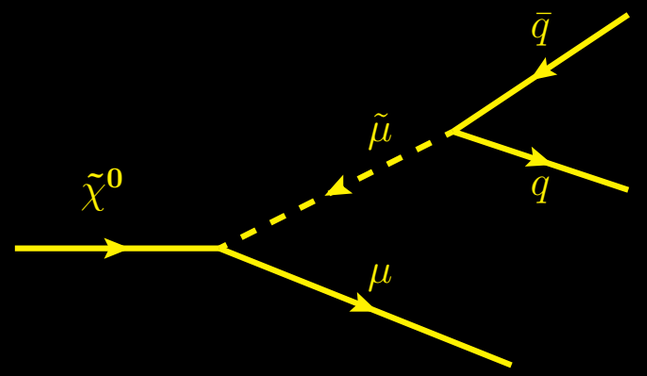
Prospects for run 3

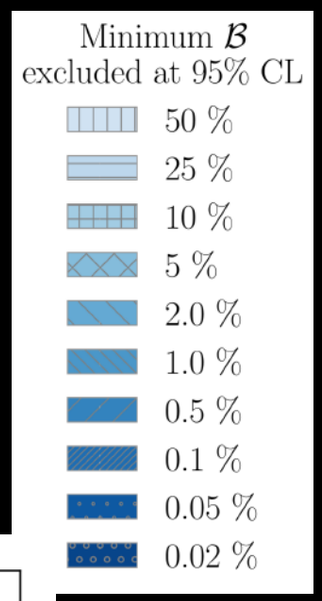
Prospects for run 5

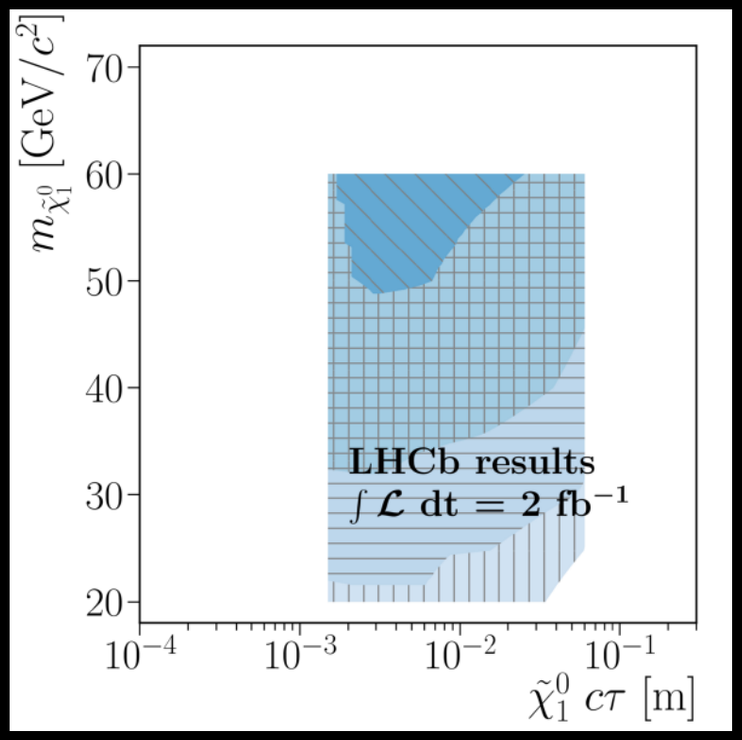
LHCb-CONF-2018-006

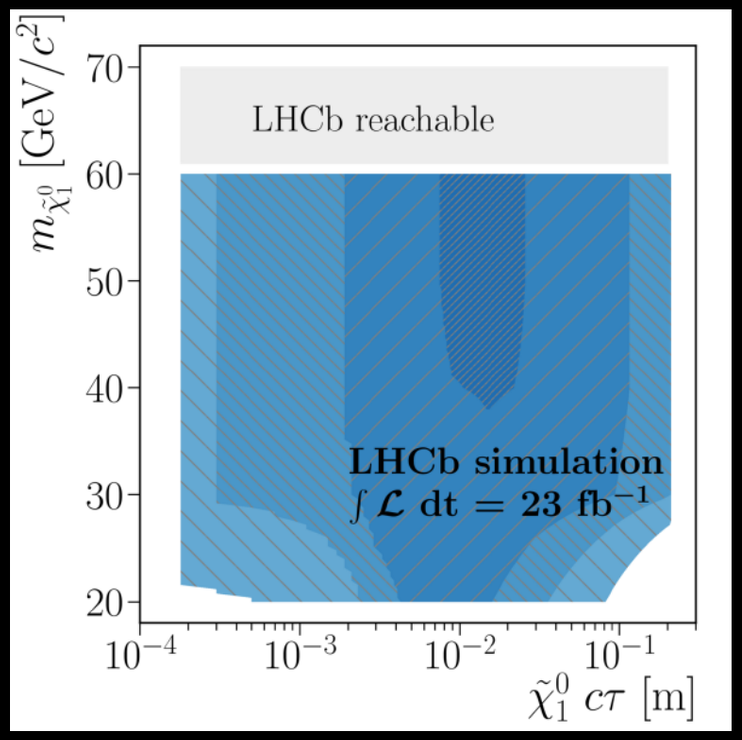
Long-Lived Particle with Semi-Leptonic Decay

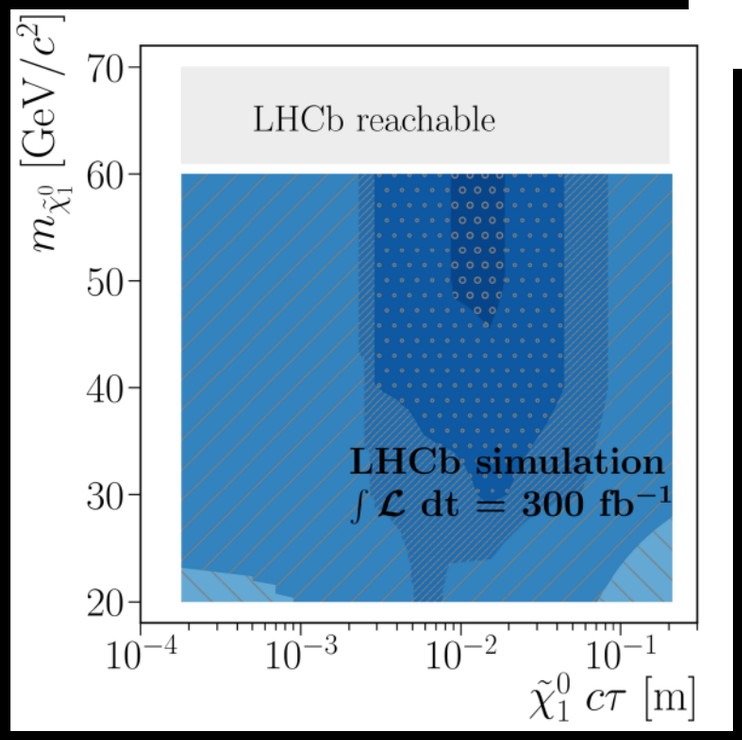
- mSUGRA neutralino - 2 jets + muon











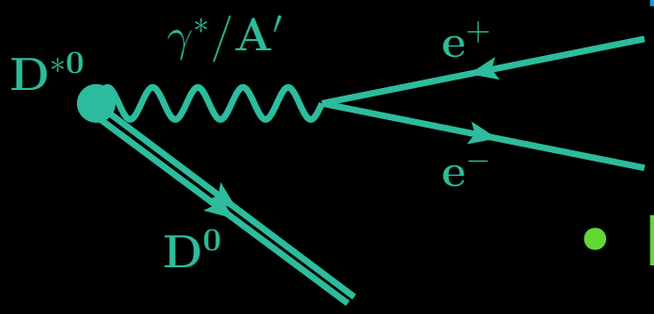
Run 1

Prospects for run 3

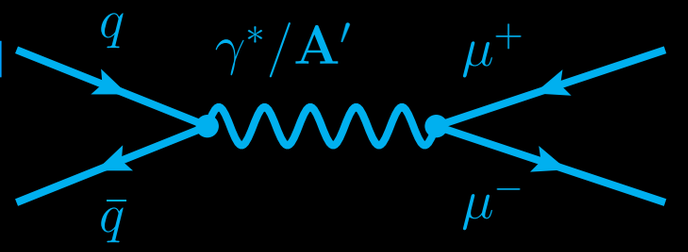
Prospects for run 5

LHCb-CONF-2018-006

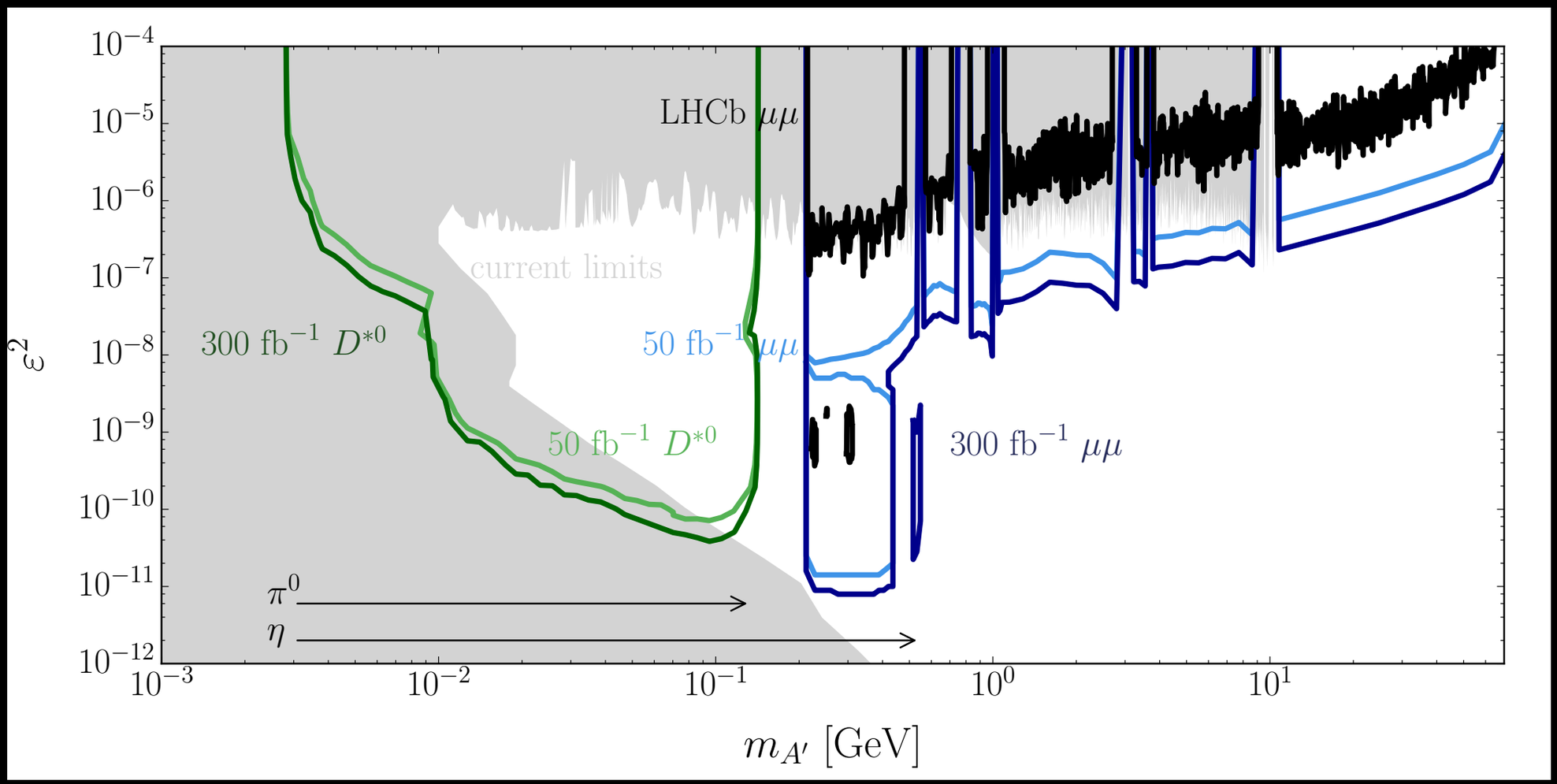
Search for Dark Photons



- Prompt or long-lived decaying to μ μ



- $D^*(2007)^0 \rightarrow D^0 A'$ with $A' \rightarrow e^+e^-$



Phys. Rev. D92, 115017 (2015) - LHCb-PUB-2018-006

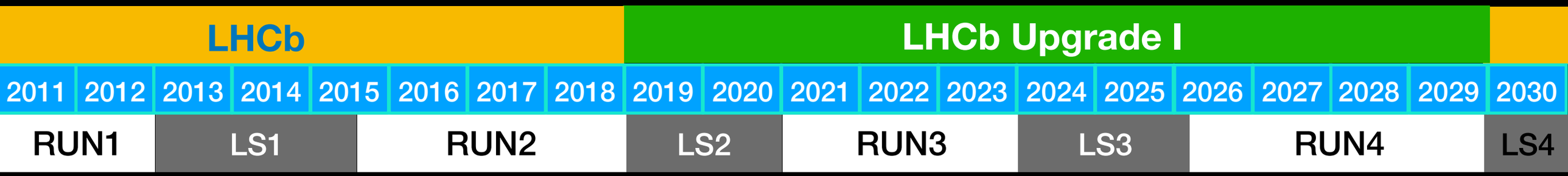
Conclusions

LHCb Results

- LHCb has an active program of searches beyond Flavour Physics
  - Run 1 data - 3 fb^{-1}
    - Long-lived particles decaying
      - semileptonically - mSUGRA neutralino with RPV
      - jets - Hidden Valley V-pion
      - Light new boson (Υ mass region)
  - Run 2 data - 25% of 6 fb^{-1} recorded data
    - Dark photon - prompt and long-lived
- New limits in space parameters

LHCb Prospects

- Run 2 analysis ongoing
- LHCb Upgrade I: sub-detectors, trigger and DAQ being installed
  - Operation in 2021-23 and 26-29 - Large potential with 5x luminosity
- LHCb Upgrade II: proposal in preparation
  - Starting ~2032: Exploit HL-LHC
- Long-lived and Dark Photons are exciting searches and LHCb is on the game



Cảm ơn