Producing and detecting long-lived particles at different experiments at the LHC

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arXiv:2004.08820 [hep-ph]

Searching for long-lived particles

Long-lived particles generically exist in many extensions of SM.

Very hard to trigger the event or be distinguished from background.

Search strategies roughly fall into two categories:

- Adding new modules:

  FASER, MATHUSELA, CODEX-b, ANUBIS,
  MoEDAL with MAPP/MALL, MilliQan

- New search/trigger strategies:

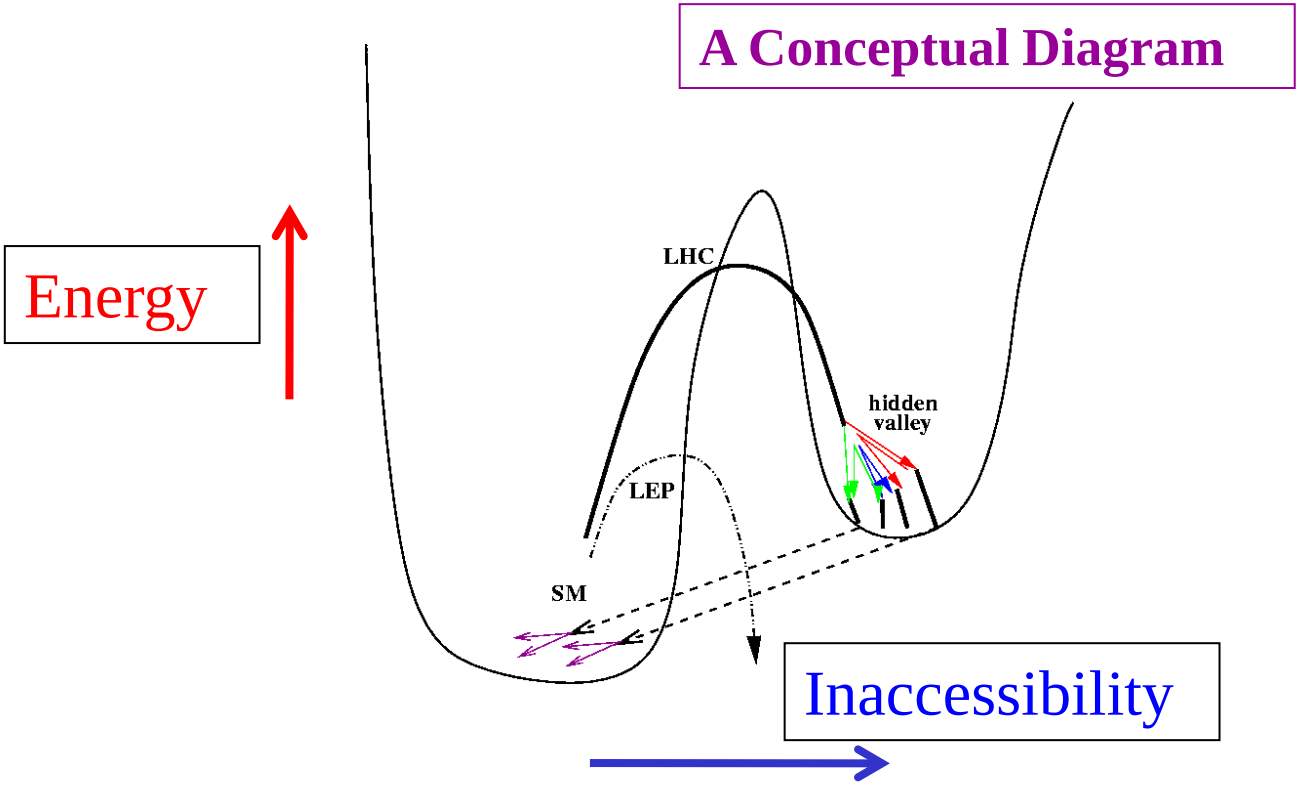
  LHCb with VELO/RICH, timing trigger
  Forward Spectrometer, CMS High Granularity Calorimeter

Non-Abelian Dark Sector

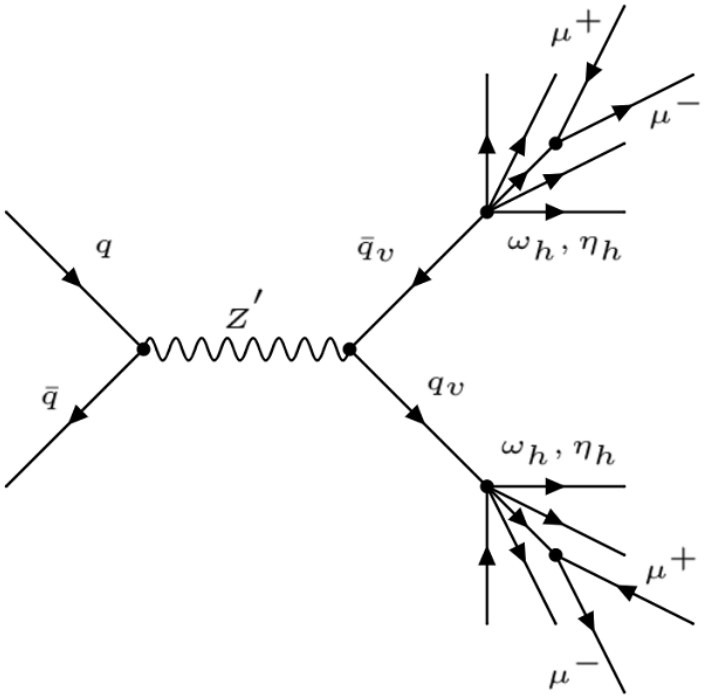
Dark Sector remains largely unknown.

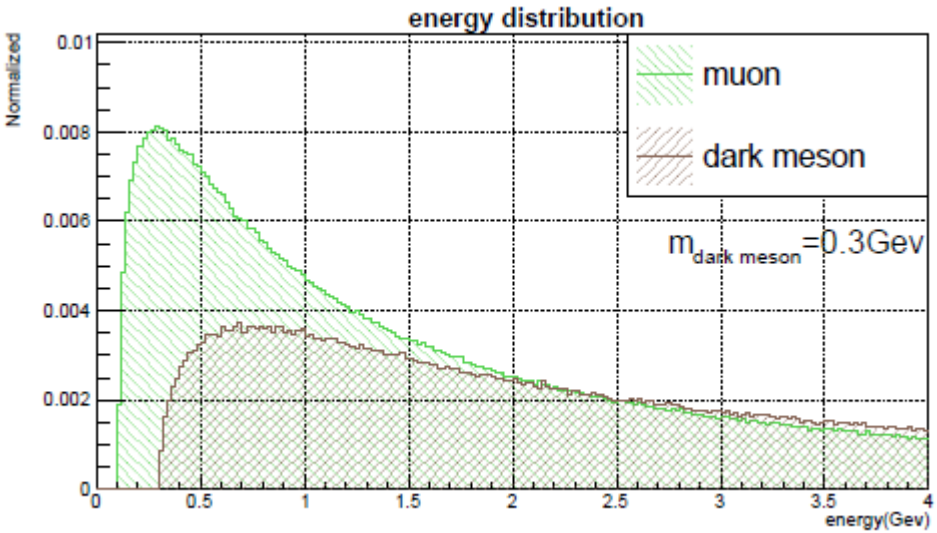
Non-abelian choice on Dark Sector remains to be further studies!

- Generically classified as Hidden Valley models.



Non-Abelian Dark Sector





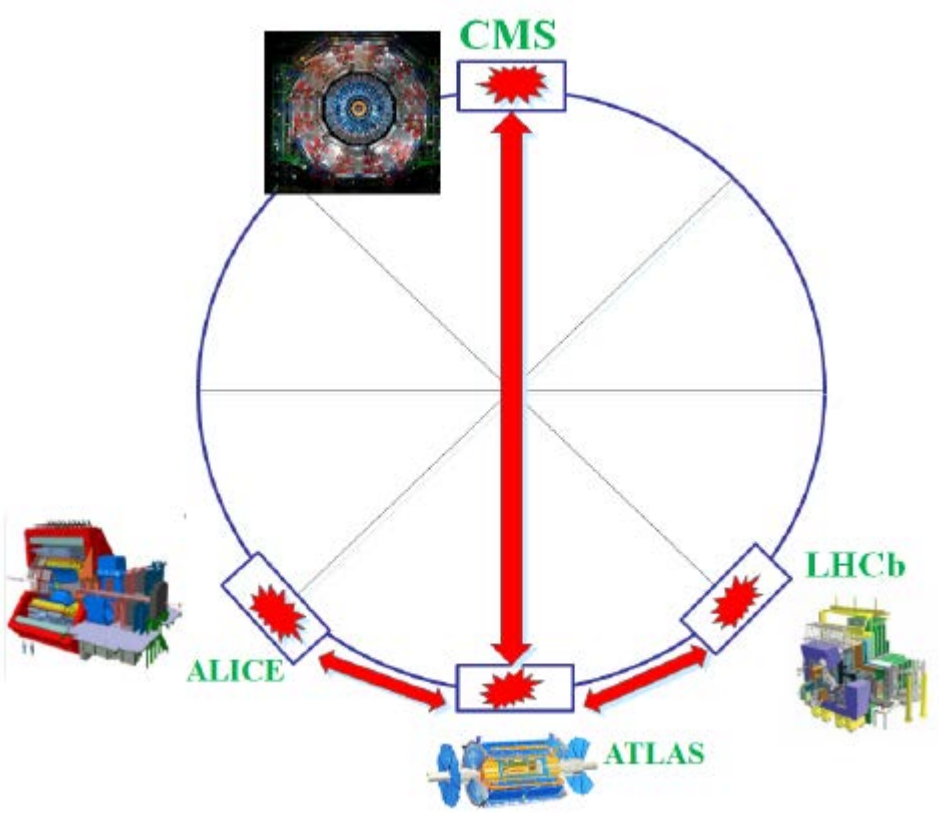
Z' mass: 200 GeV
HV meson: 0.3 GeV
< N >: 40

Showering and hadronization in the hidden sector distribute energy to many soft HV mesons.

Not easy to trigger in a conventional LHC search.

General picture

Rather than building new modules,
one may use existing facilities as far detectors.



Produce	Detect	Distance(m)
ALICE/LHCb	ATLAS	1676
ALICE/LHCb	CMS	8429
ATLAS	CMS	8594
ALICE	LHCb	3289

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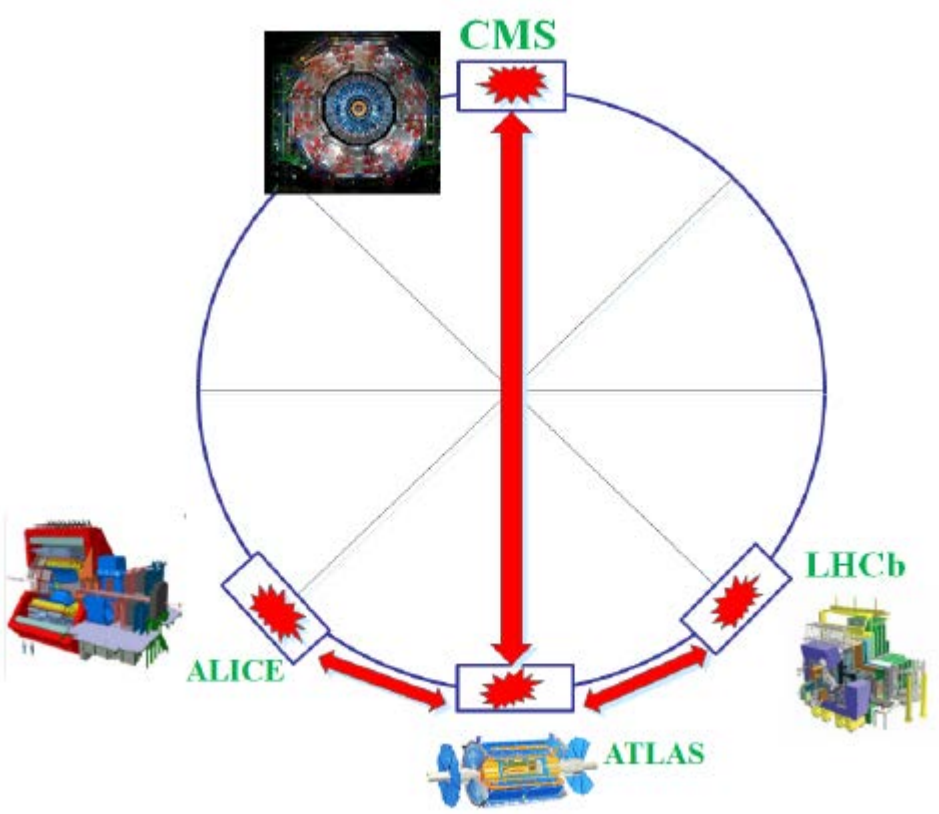

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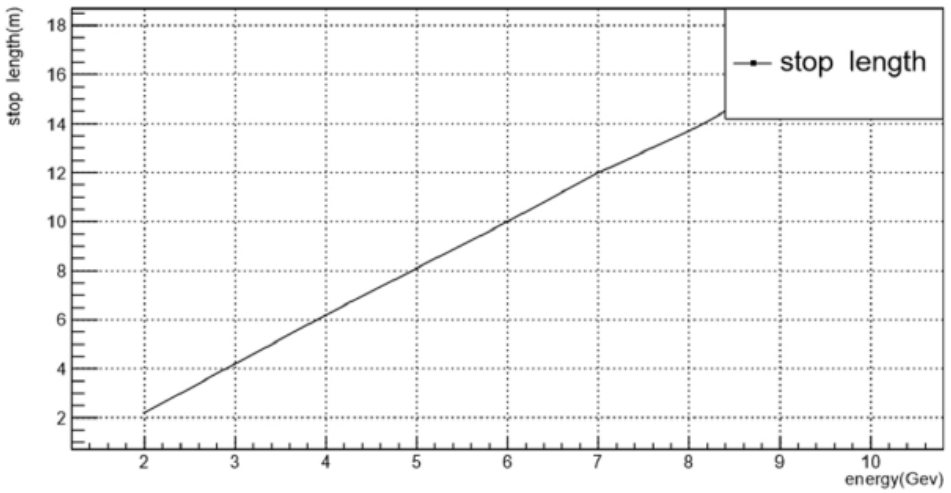
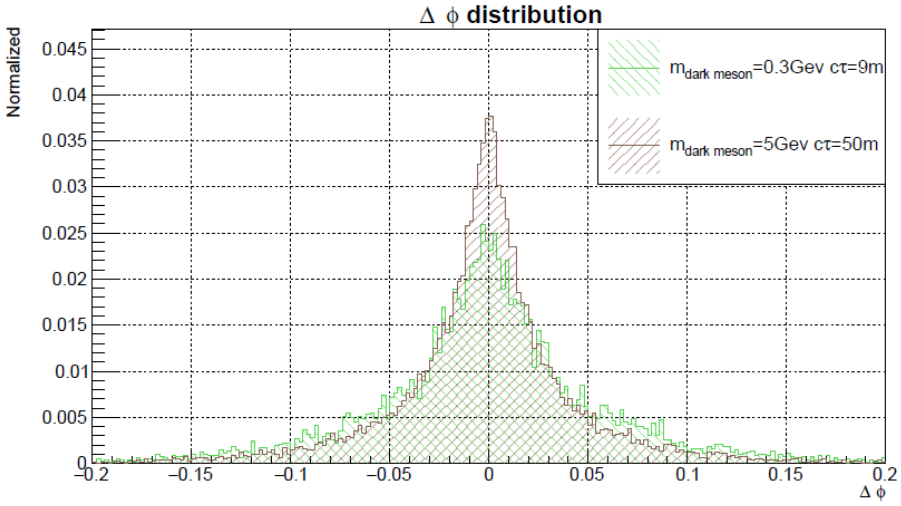
- smallest distance
- along forward direction

Muon channel:

Focus on muon channel, result scales linearly with muon decay BR.

- Muon can travel for a long distance in earth.
- Its direction is barely changed during its propagation.





Muon channel:

- Muon chamber is usually the largest component in a detector with much less busy environment.

ATLAS: diameter 25m; length 44 m → largest

CMS: diameter 15m; length 28.7 m

LHCb: diameter 4.5m; length 4 m

ALICE: no muon chamber → should only be treated as a production site

- Established trigger scheme at CMS:

Barrel Muon Track Finder (L1 tracking algorithm) for HL-LHC based on Kalman Filter algorithm.

The ideal combination

LHCb/ALICE for production, ATLAS for detection.

- Short distance
- Forward direction

→ CMS is less attractive.

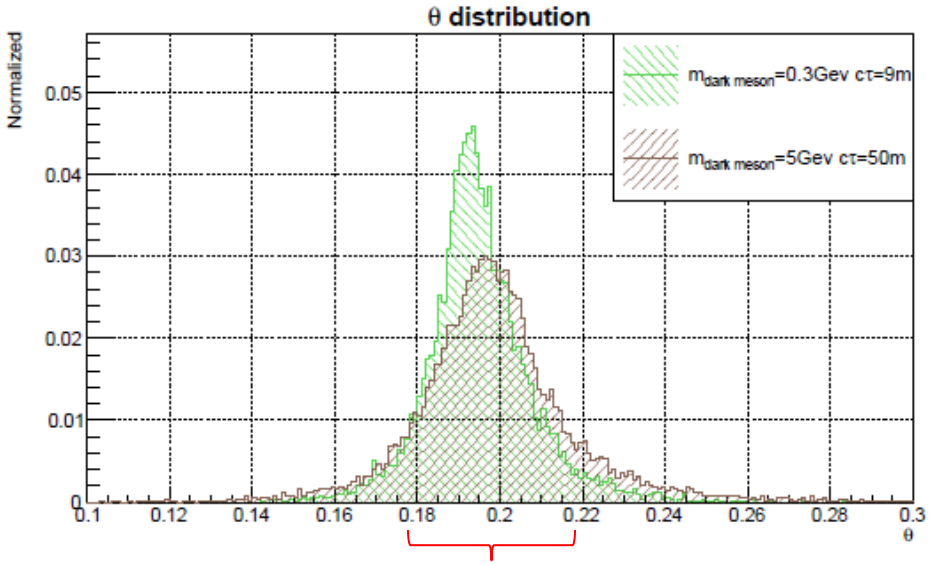
- Large Muon chamber
- Luminosity: LHCb is ~10 times lower than that of ATLAS.
  The pp luminosity at ALICE is not clear.

Competing factors for the choice of production vs detection.

Combining LHCb and ALICE, we assume 600 fb^-1 total luminosity.

Event selection

- Muons from LLP decays have a preferred incidence angle.



open angle ~ 0.02

position resolution ~ 40 m at LHCb/ALICE

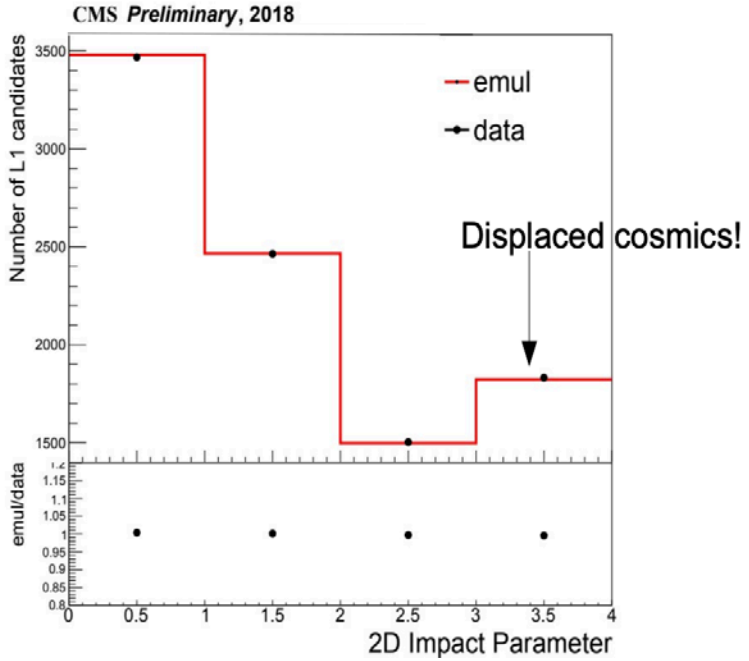
comparable to the experiments

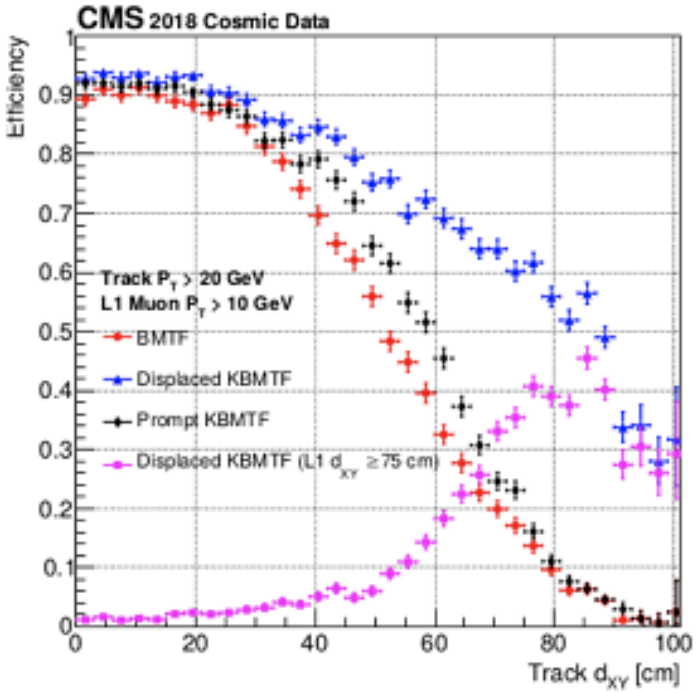
- Large impact parameter: O(10) m
- Muon Pt > 1GeV to ensure multiple hits in muon chamber.
- The timing sequence is reversed to that of a muon from ATLAS collisions.

Trigger

- Track from outside to inside use Kalman-Filter @ L1
- Deployed in L1 FPGA, mainly use the DSP(25%)
- Algorithm has been tested at CMS and is ready for Run III
- More details: PoS TWEPP2018(2019) 139.
- Subtlety: The LLP signal is not synchronized with LHC clock,

  ⇨ One has to carefully define "event" after triggering.





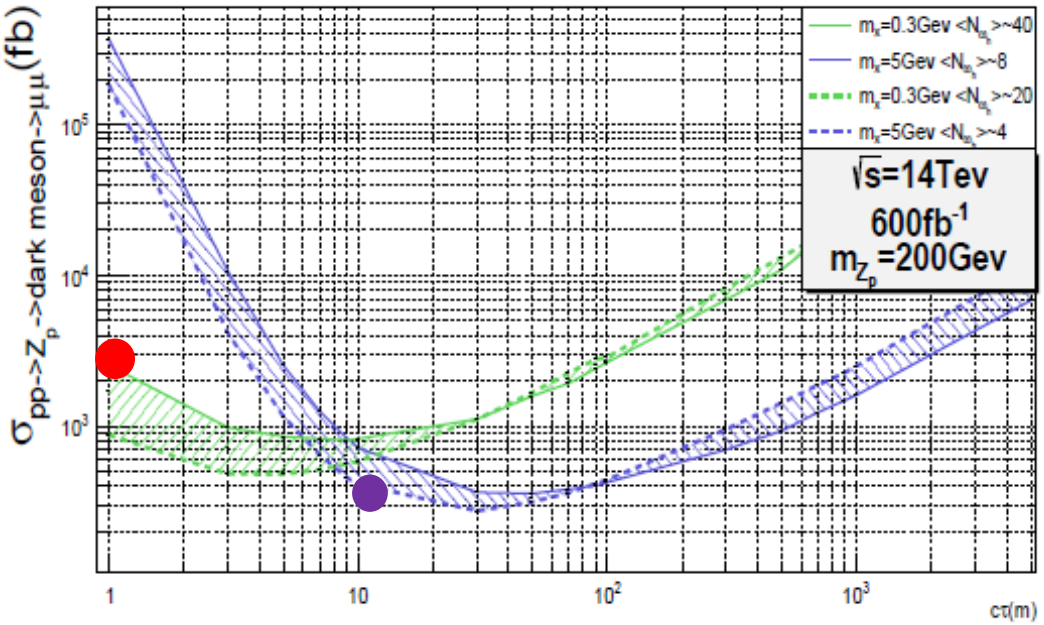
Background

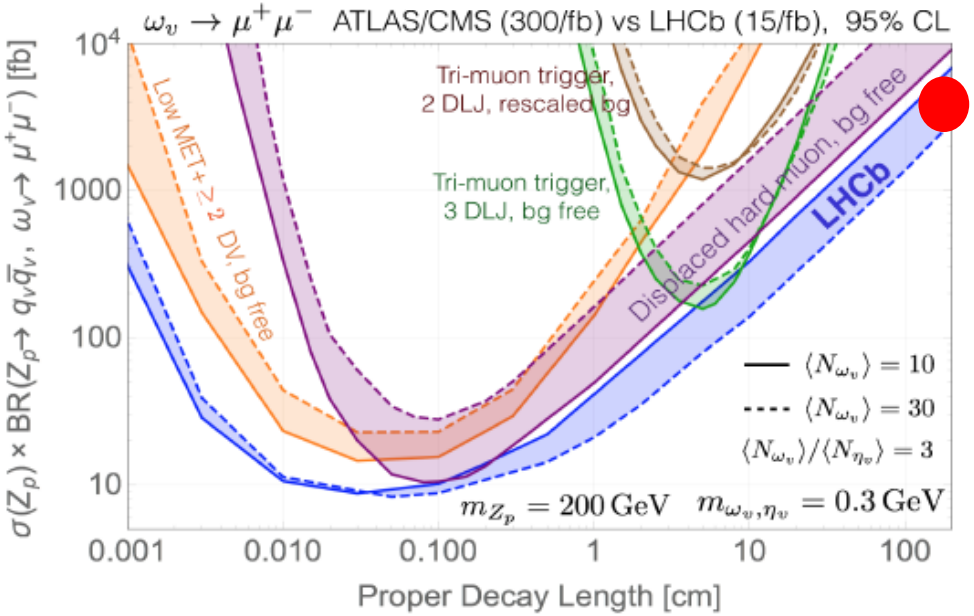
- Cosmic muons can be removed by horizontal direction
  (~36km rocks)

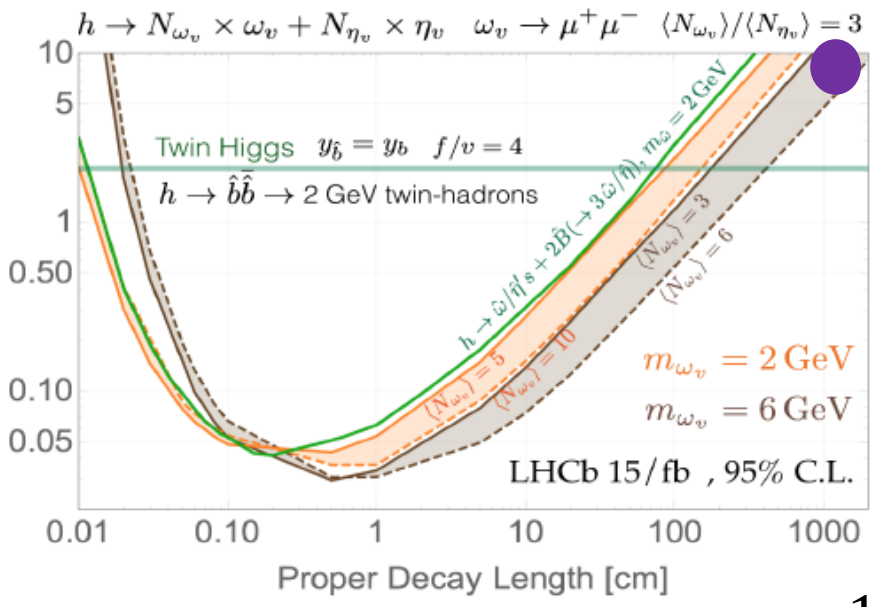
- Background from radioactive environment can be reomved by muon Pt (> 1GeV) requirement.

- Background from ATLAS are removed by:
  - Pointing back to production site (LHCb/ALICE)
  - Large impact parameter
  - Out-in track (inverse timing) coincides with in-out track.

Expected sensitivity





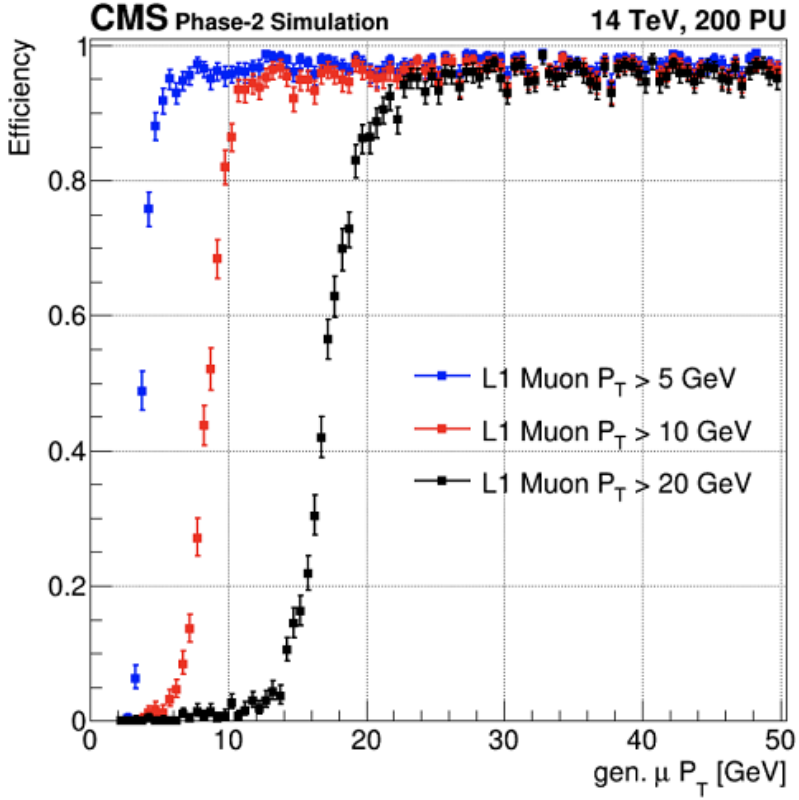


(arXiv:1708.05389)

Conclusion

- Low cost and can carve into interesting unexplored parameter space.
- Sensitivity comparable to other proposed search, such as the LHCb LLP search. (arXiv:1708.05389)
- Serve as an independent cross check.

Backup



Efficiency as a function of P_T with an L1 threshold of 5, 10, and 20 GeV respectively for the Phase II Kalman Barrel Muon Track Finder