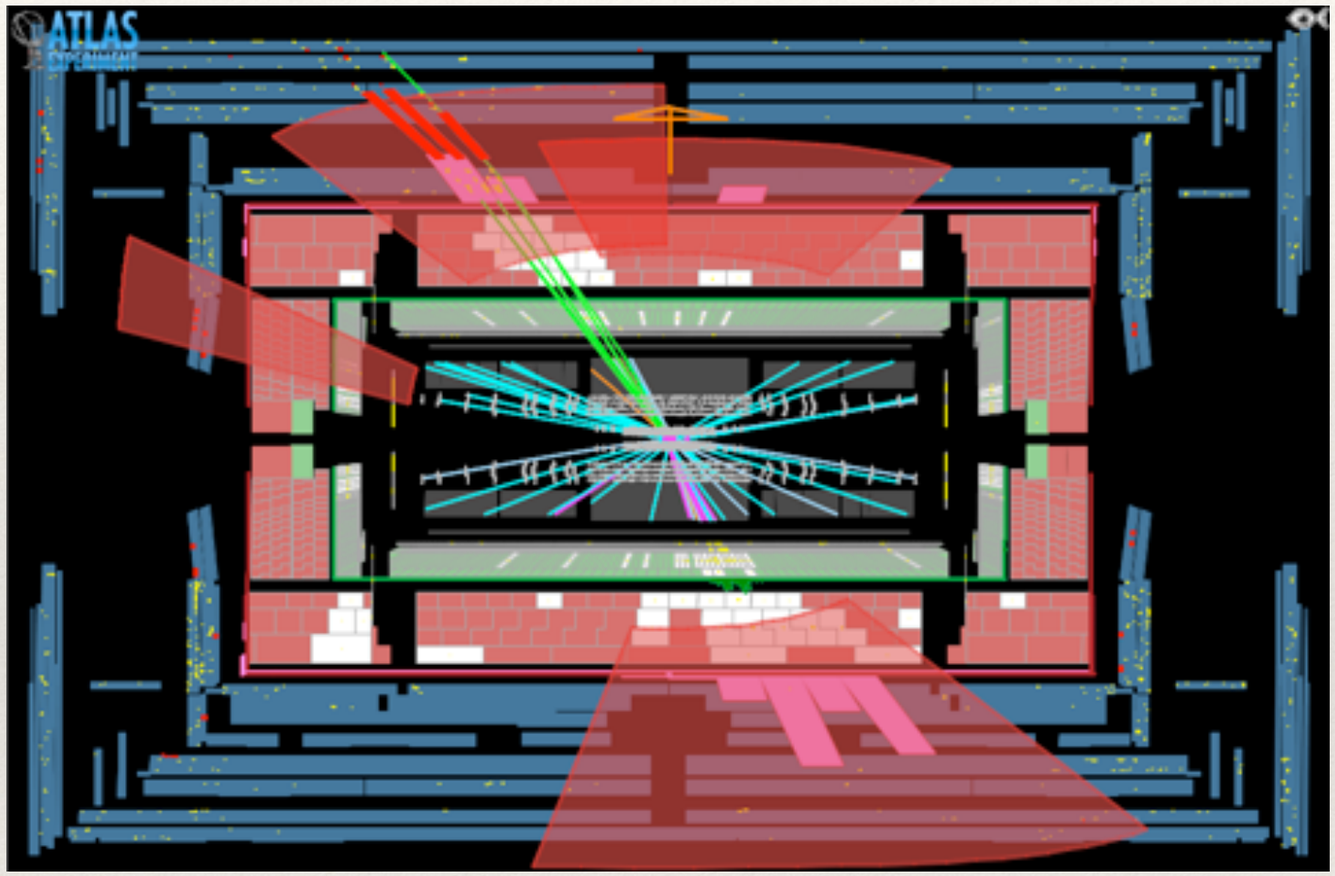
PROBING HIDDEN SECTORS AT THE LHC

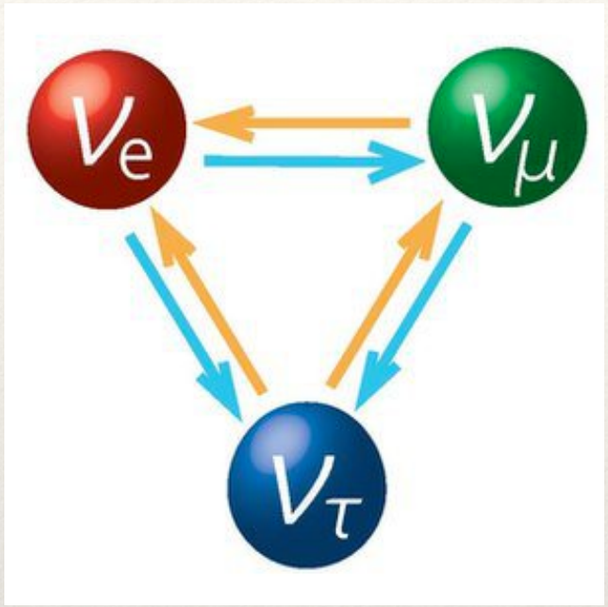


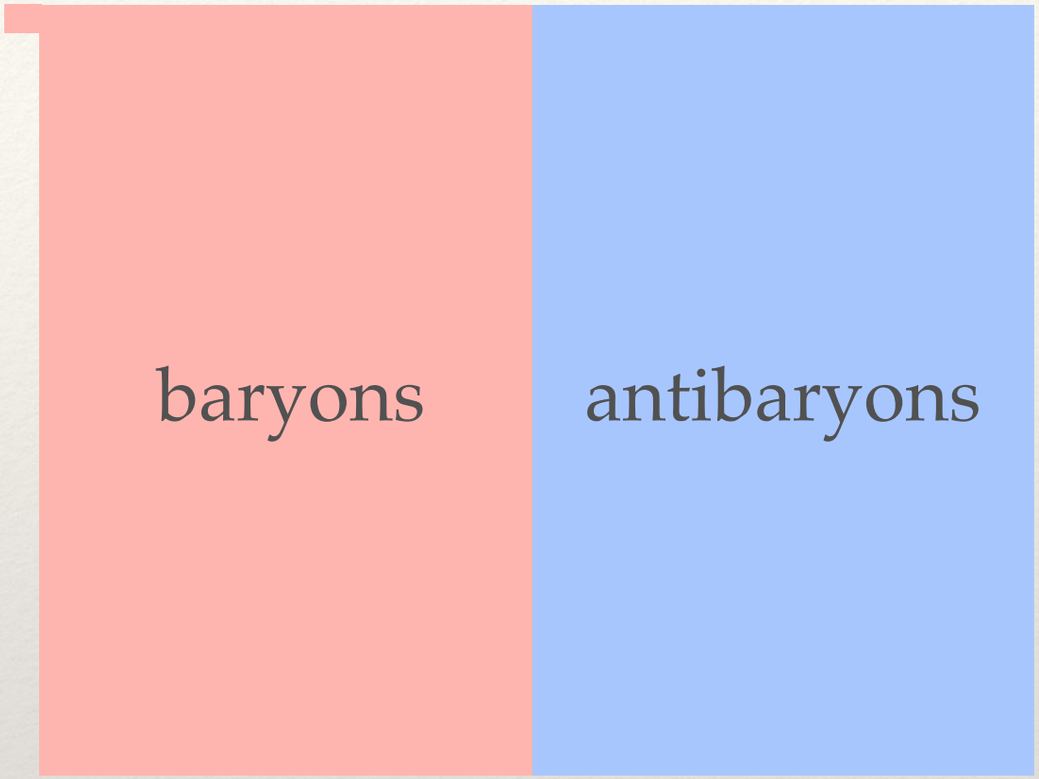
Brian Shuve

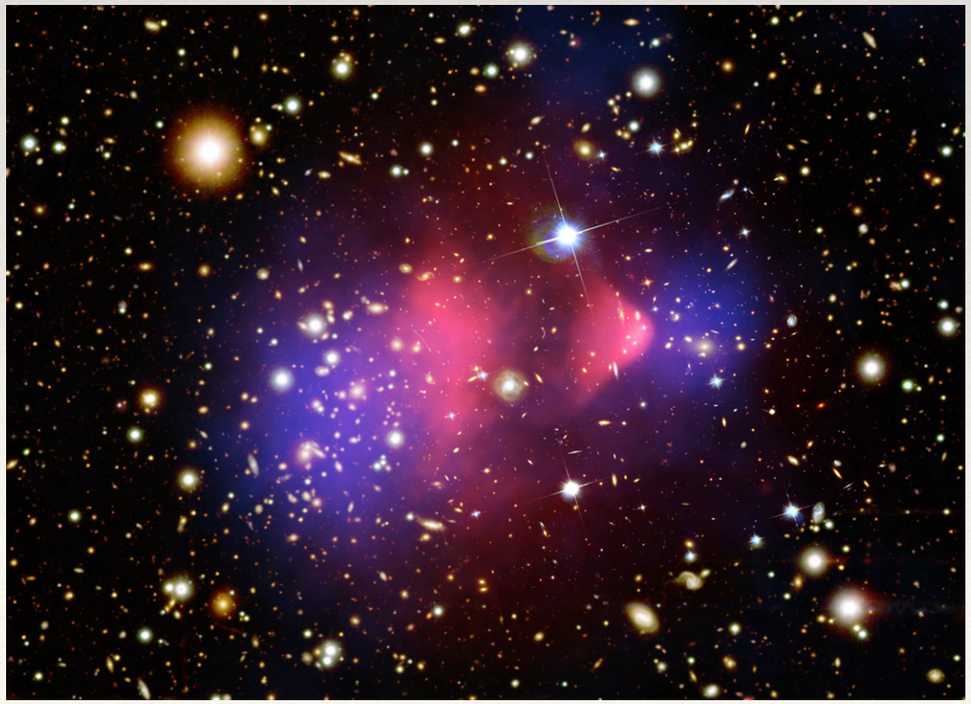
CIPANP 2018

HARVEY MUDD COLLEGE

EVIDENCE FOR HIDDEN SECTORS



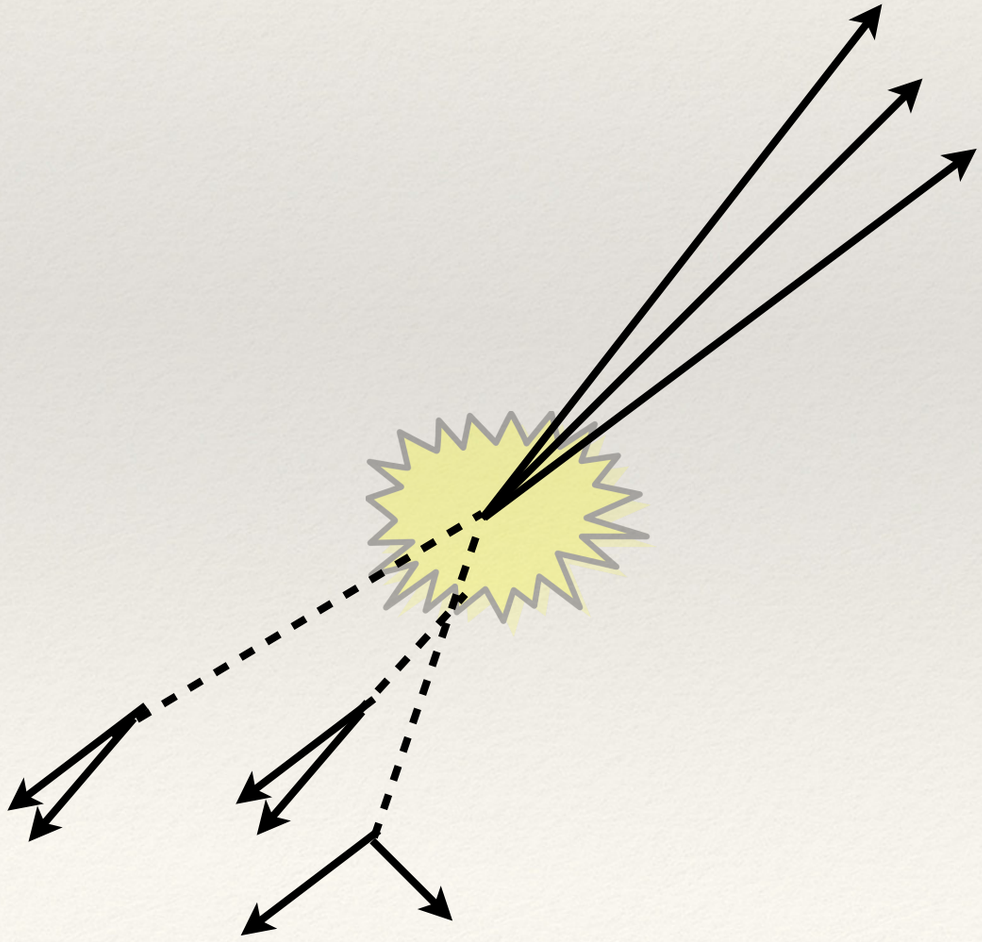




- In many well-motivated models, have new particles in **GeV** range
- No **definitive** mass scale for new physics

HIDDEN SECTORS AT THE LHC

- It can be challenging to trigger on low-mass hidden sectors & fight large backgrounds from SM processes
- Need to exploit characteristics of hidden sector signals



- High multiplicities of soft particles from decay of hidden-sector particles

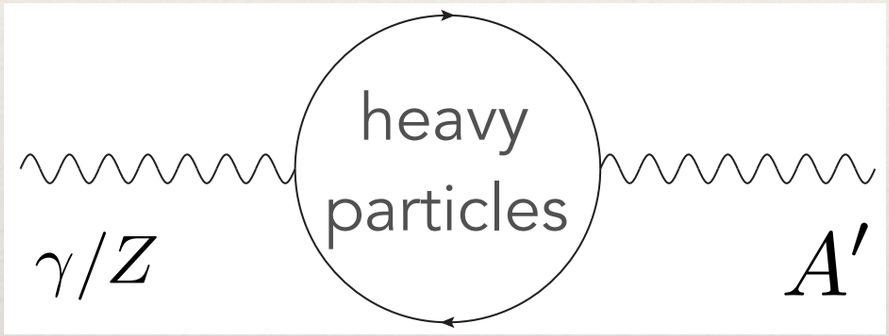
and/or

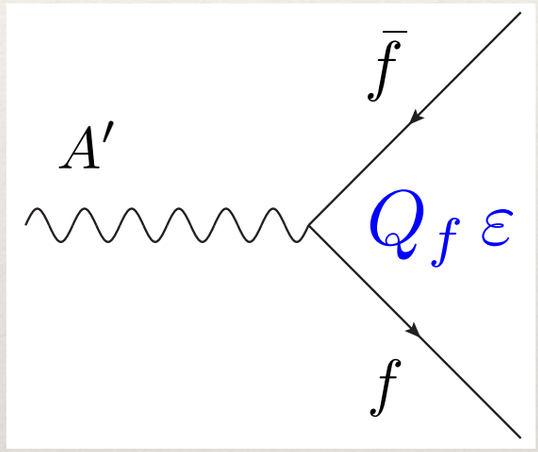
- Associated production of prompt, SM objects

HIDDEN U(1) MODEL

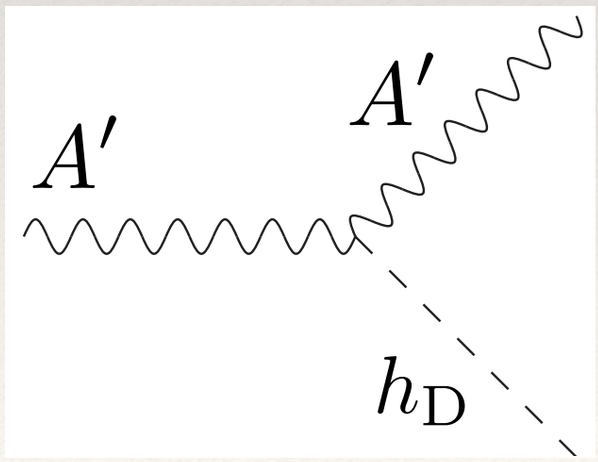
- A simple example of a hidden sector has a dark Higgsed gauge interaction

Holdom, Phys.Lett. 166B (1986) 196-198



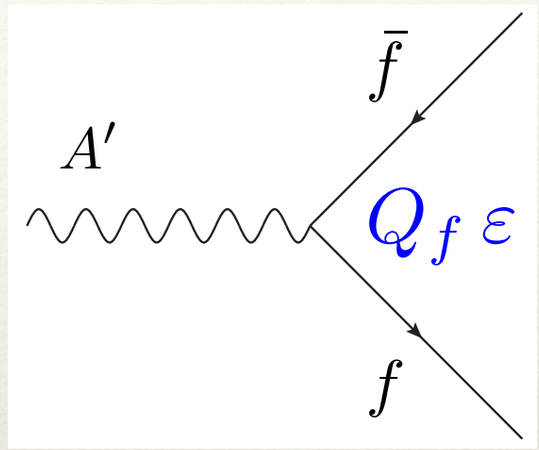


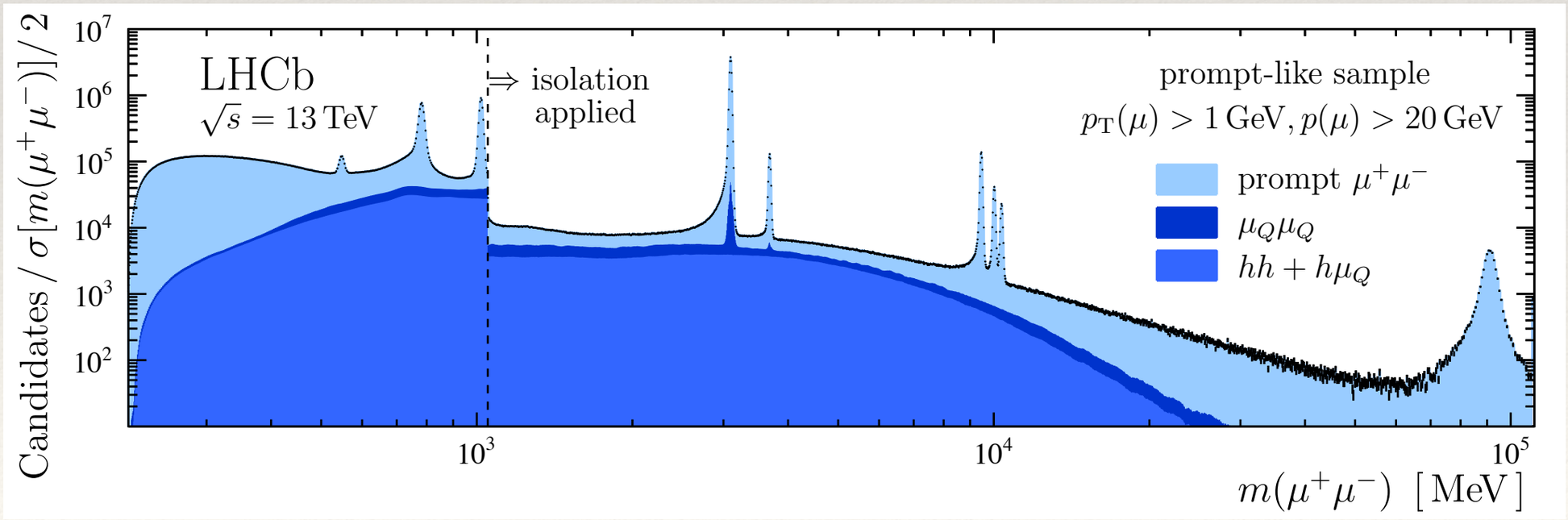
- The presence of a dark mass generation mechanism also give rise to interactions



HIDDEN U(1) MODEL

- Can search directly for dark photon as a dilepton resonance



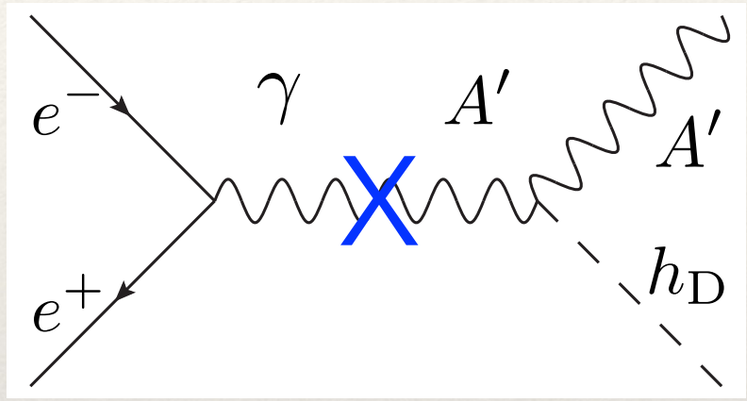


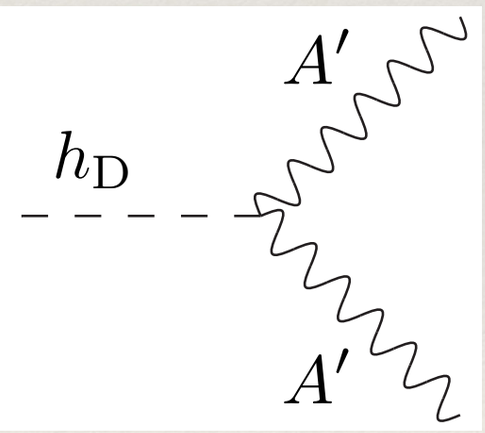
LHCb, arXiv:1710.02867

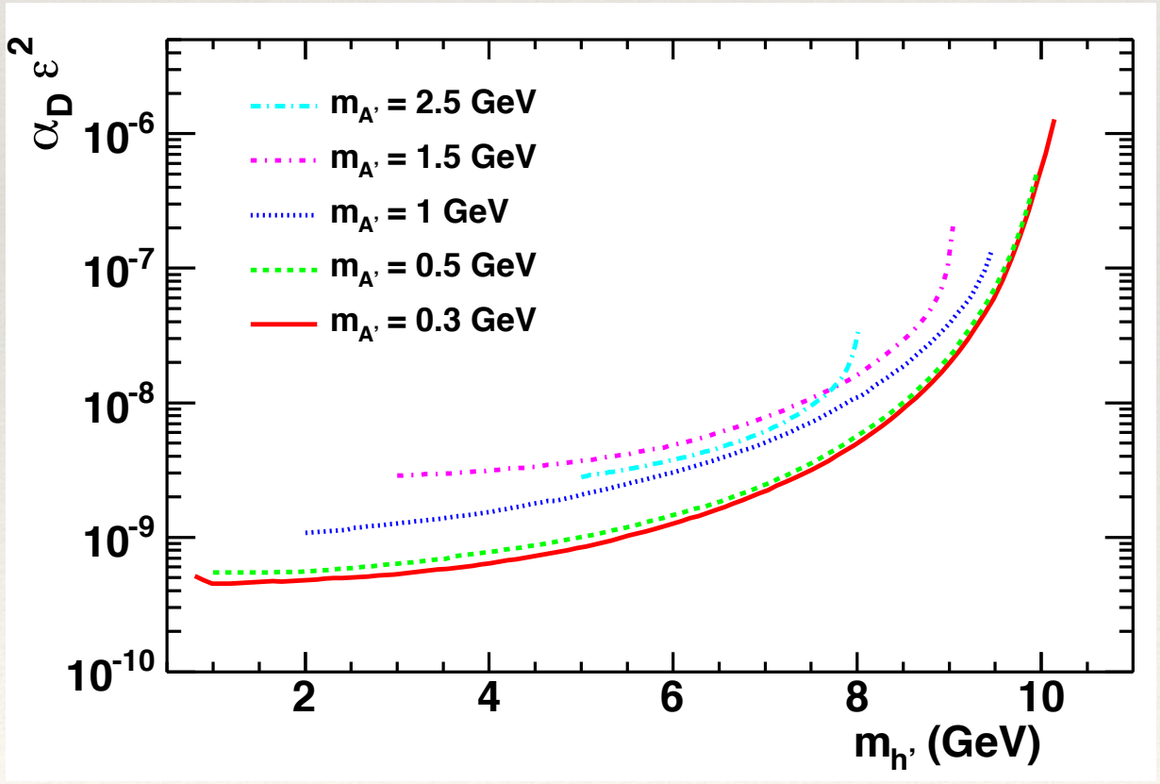
Batell, Pospelov, Ritz, arXiv:0903.0363

HIDDEN U(1) MODEL

- However, we can also look for the dark Higgs via dark Higgs-strahlung
- Can provide best sensitivity to model!







BABAR, arXiv:1202.1313

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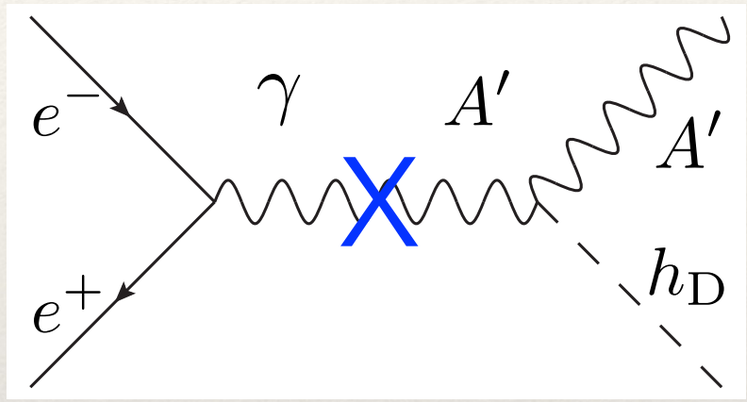
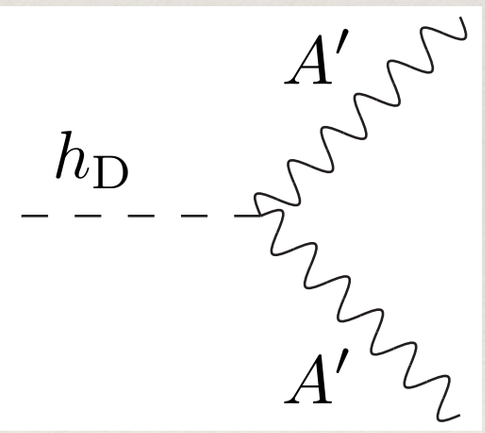
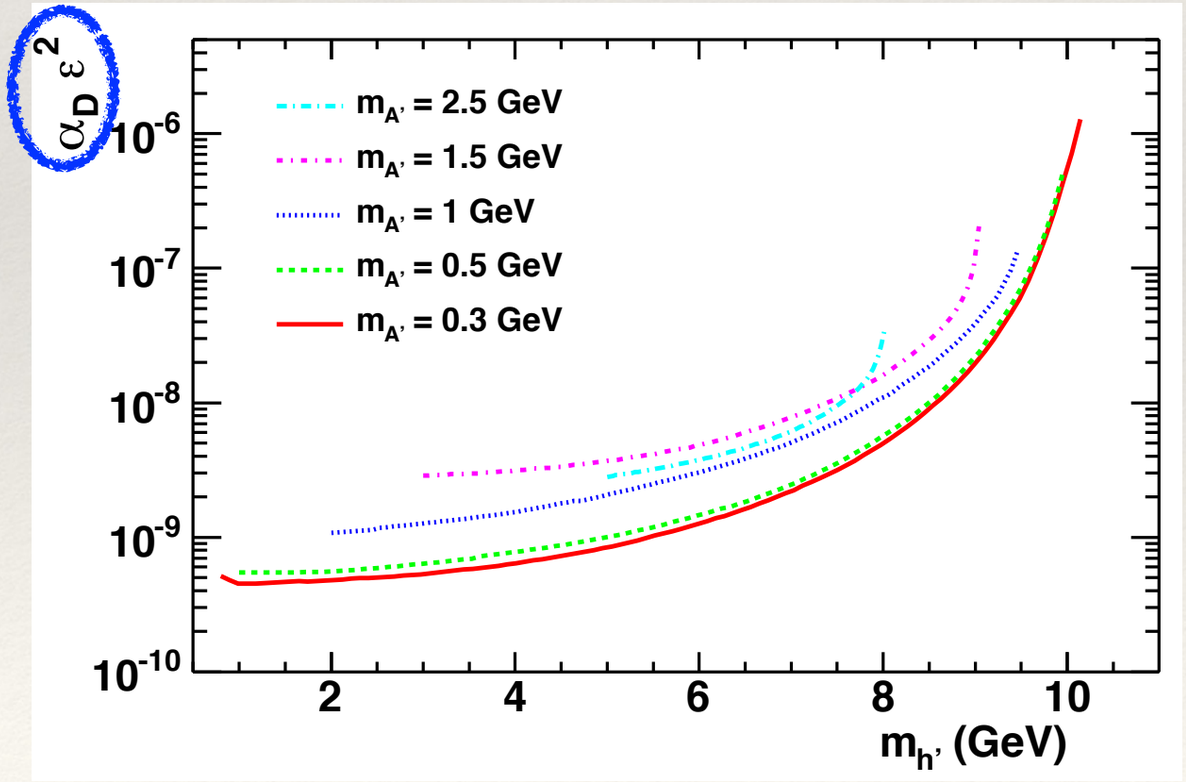




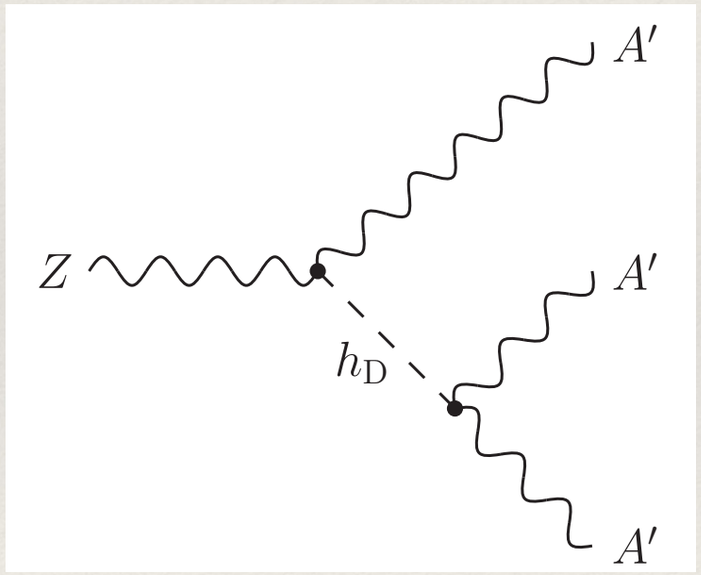


BABAR, arXiv:1202.1313

Blinov, Izaguirre, Shuve, arXiv:1710.07635

HIDDEN U(1) AT THE LHC

- Could the same thing work at the LHC?
- Most interested in masses > 10 GeV where *B*-factories cannot reach



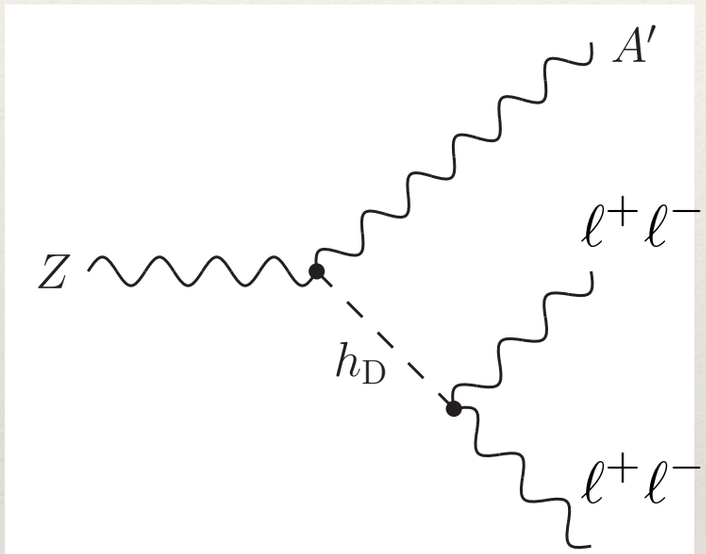
$$\Gamma(Z \to A' h_{\rm D}) \approx \frac{1}{12} \alpha_{\rm D}\, \varepsilon^2\, \tan^2\theta_{\rm W}\, m_Z$$

$$(m_{A'},\, m_{h_{\rm D}} \ll m_Z)$$

- Get up to 6 leptons with many resonances, but they are soft!

HIDDEN U(1) AT THE LHC

- To improve signal efficiency, we look at leptonic decays of dark Higgs, inclusive decays of other dark photon



- 4 muons, $p_{\rm T} > 7$ GeV *or* 4 leptons with $p_{\rm T} > 15,\ 8,\ 7,\ 5$ GeV
- Leptons must be isolated
- Veto events with dilepton reconstructing Z or any $m_{4\ell} > 95$ GeV

- Dominant background is $pp \to 4\ell + X$

CMS, arXiv:1709.05406

- Can perform resonance search in 4-lepton mass

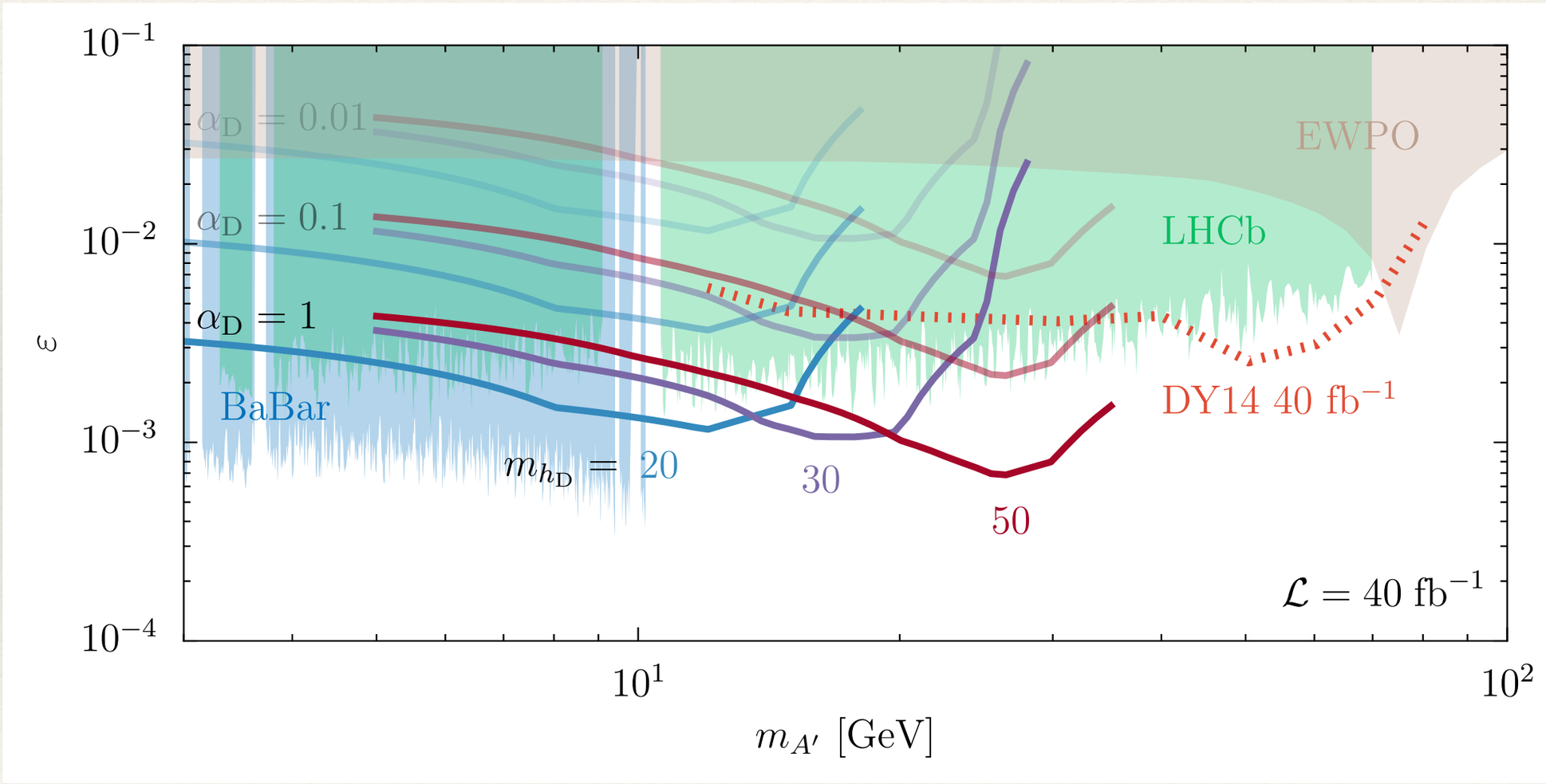
$$\Delta m_{4\ell} = 0.13\ \text{GeV} + 0.065 m_{4\ell}$$

CMS, arXiv:1210.7619

Blinov, Izaguirre, Shuve, arXiv:1710.07635

PROJECTIONS: 4 LEPTON

- Projected 95% CL sensitivity with 40/fb luminosity, 13 TeV



Blinov, Izaguirre, Shuve, arXiv:1710.07635

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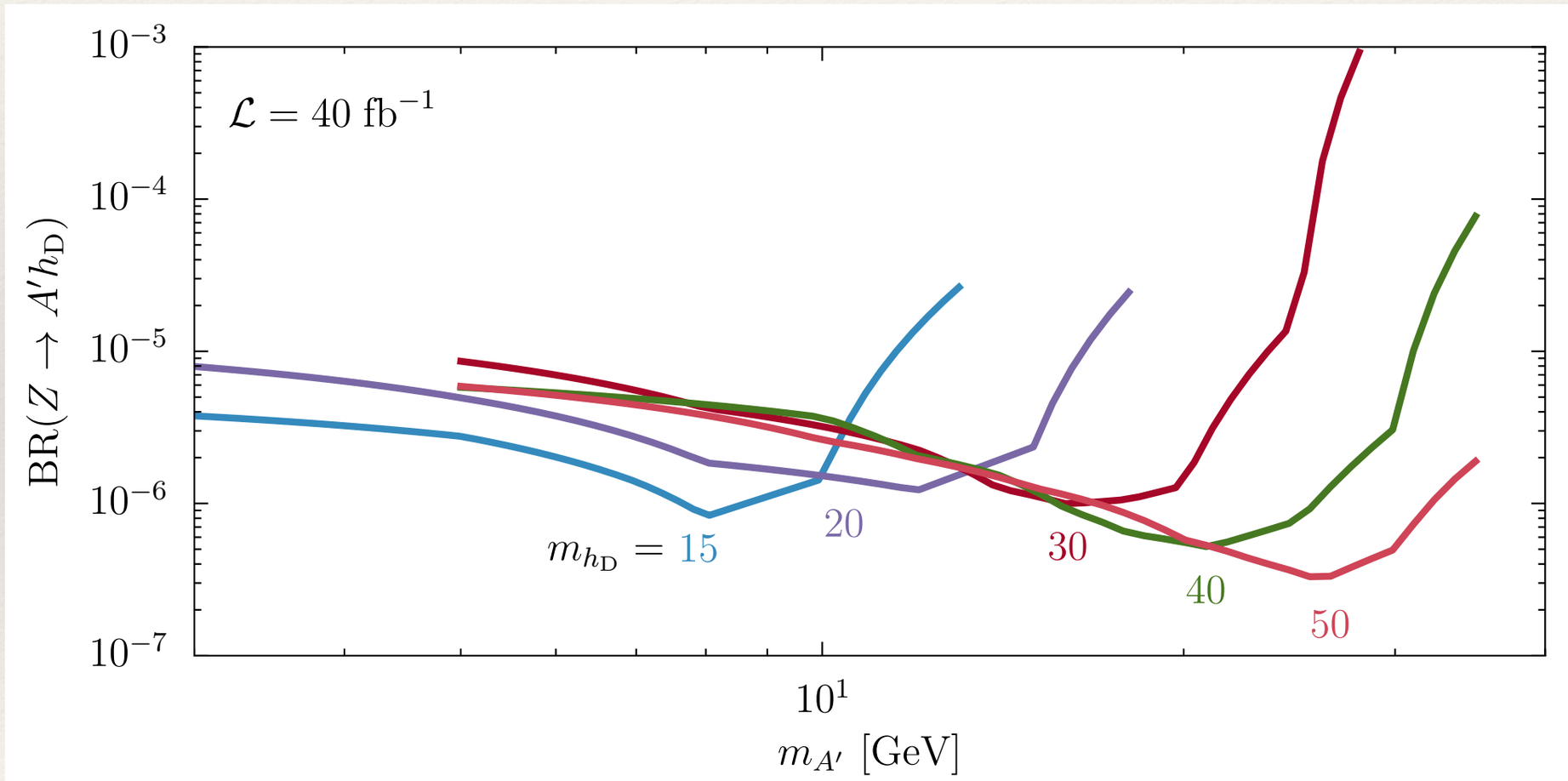
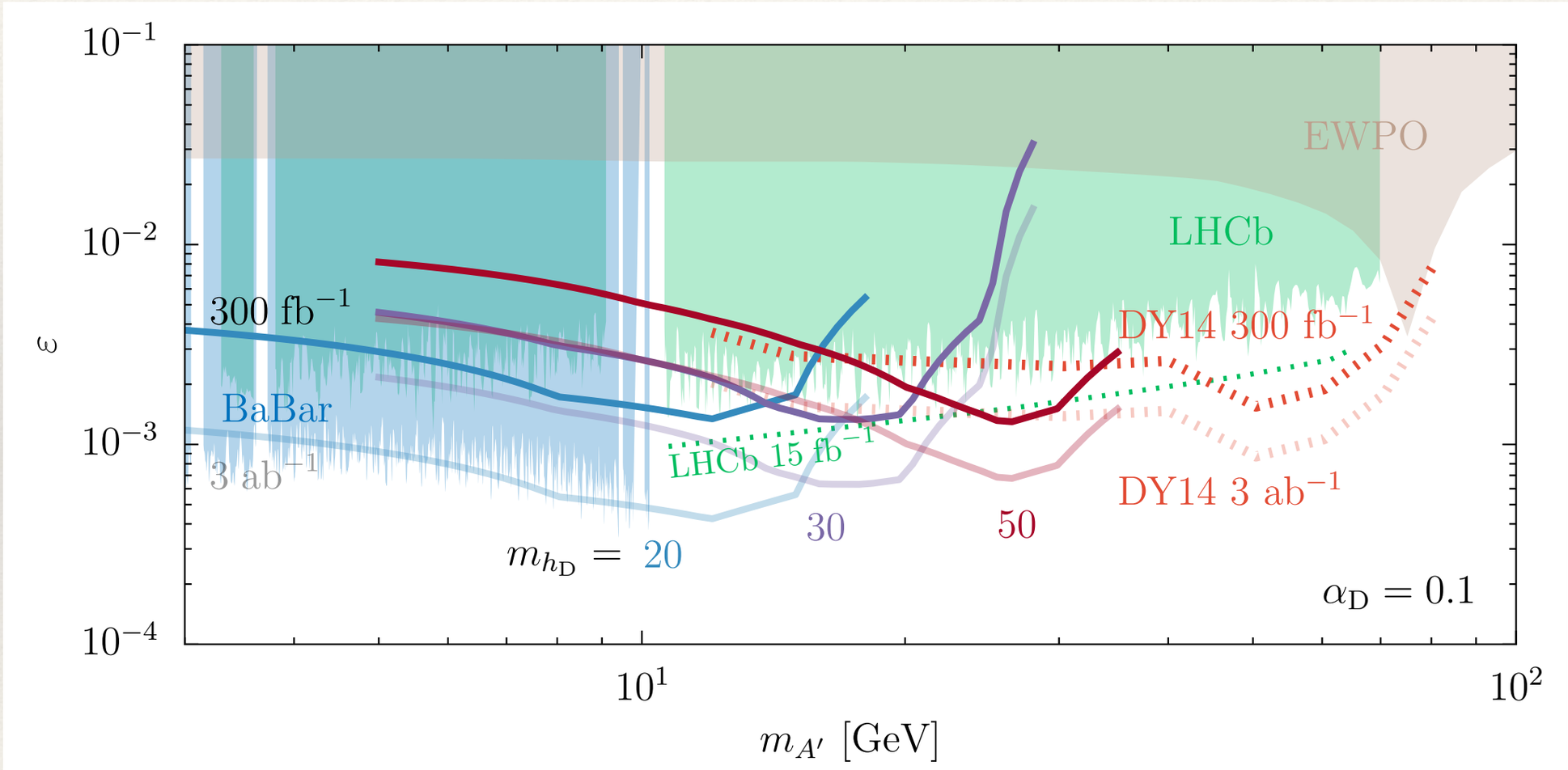


Blinov, Izaguirre, Shuve, arXiv:1710.07635

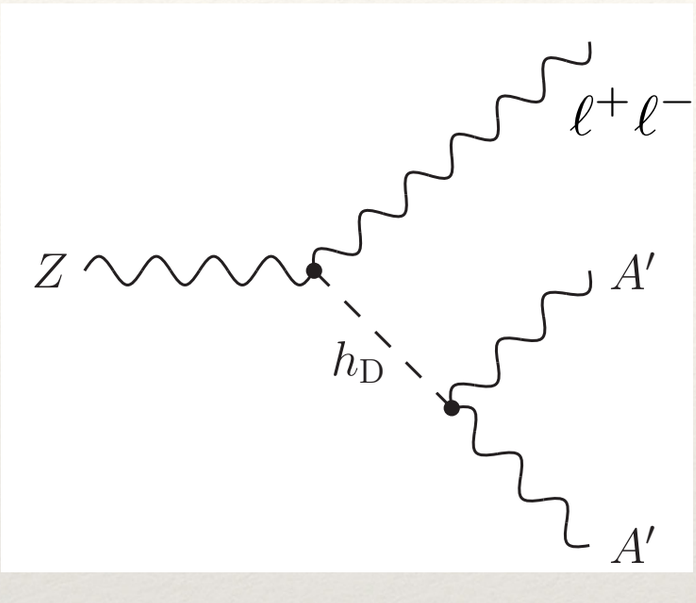
PROJECTIONS: 4 LEPTON

- For the future…



- But the sensitivity degrades significantly if thresholds increase

HIDDEN U(1) AT THE LHC



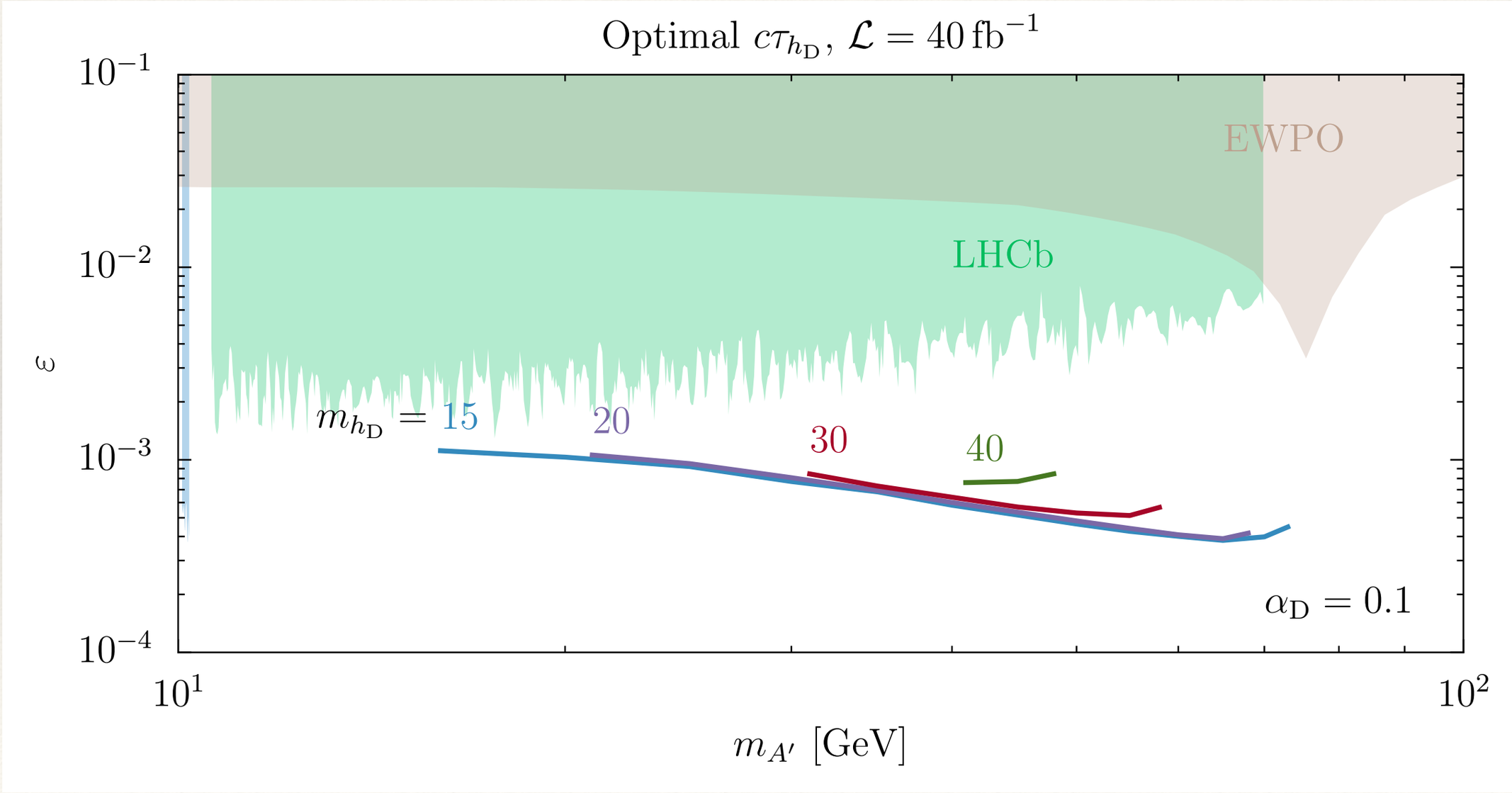
- If dark Higgs cannot decay on-shell to dark photon, it can be long lived!
- Signature: **prompt** dilepton resonance + displaced vertex!

- We apply a dilepton trigger, assume a 50% vertex reconstruction efficiency
- Challenging for us to evaluate backgrounds (should be easy experimentally because of dilepton bump hunt)
- Plot sensitivity for **ten signal events**

Blinov, Izaguirre, Shuve, arXiv:1710.07635

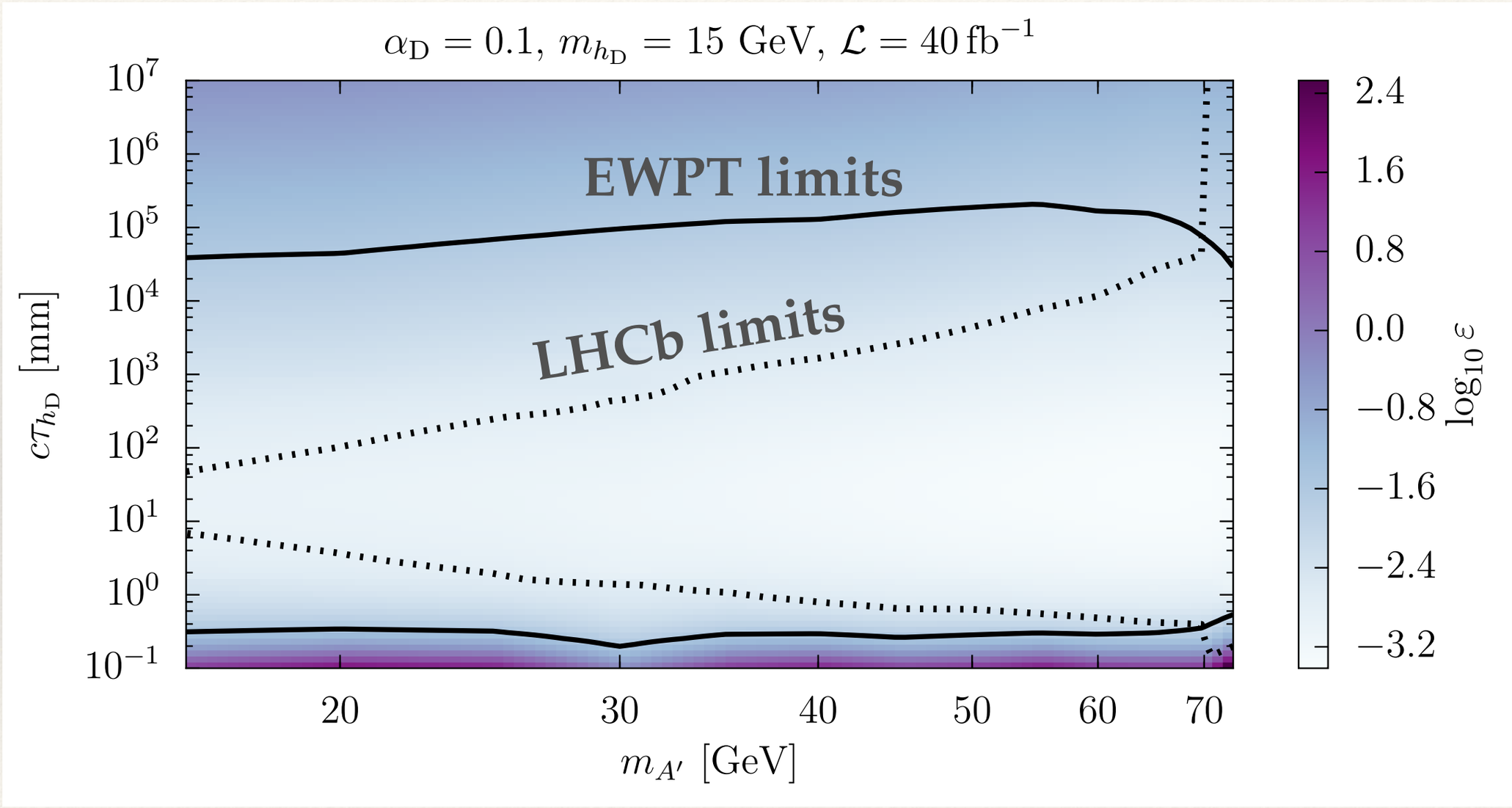
PROJECTIONS: DISPLACED

- Set lifetime to value with maximum acceptance:



Blinov, Izaguirre, Shuve, arXiv:1710.07635

PROJECTIONS: DISPLACED

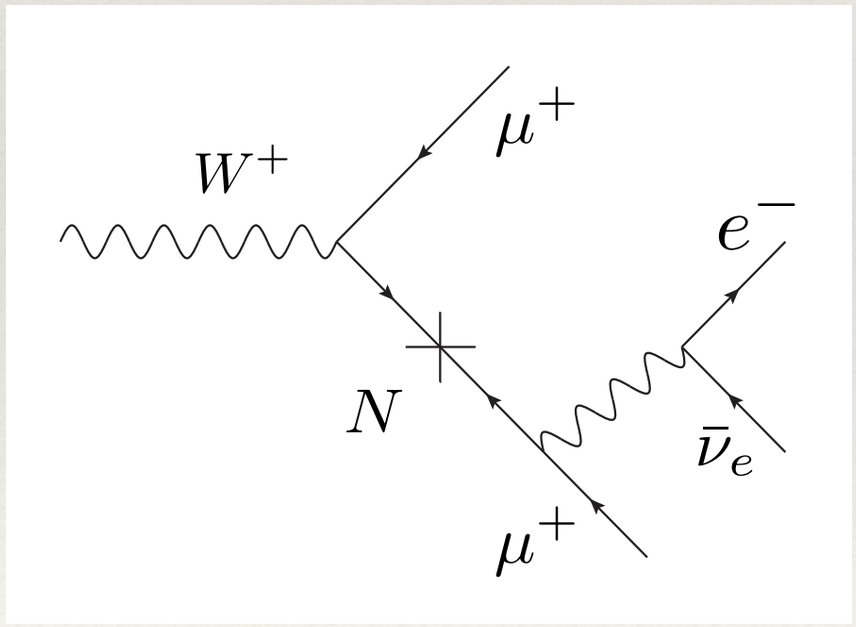


Izaguirre, Shuve, arXiv:1504.02470

OTHER EXAMPLES

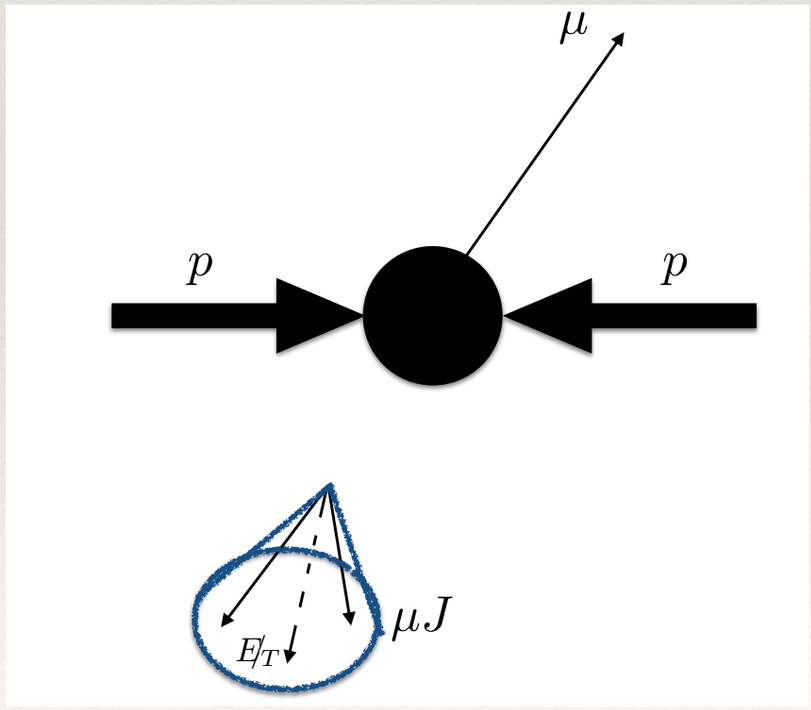
- Majorana neutrinos: can get striking signatures in rare decays of W/Z/h/Z' bosons, but need to keep thresholds low!

lepton number violation



CMS now beats LEP!
arXiv:1802.02965

soft displaced vertices



SUMMARY

- LHC is excellent place to look for hidden sectors, can provide best constraints on hidden-sector decays of EW bosons

- Need to exploit associated objects or high multiplicities from hidden-sector decays — keep thresholds as low as possible!

- This is just one example of how searches for high multiplicities of soft leptons can cover new ground
    - Hidden valleys
    - Exotic Higgs decays
    - …