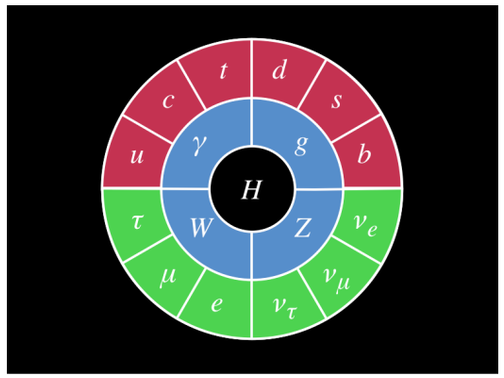
A New Probe for Dark Sector Dynamics at the LHC

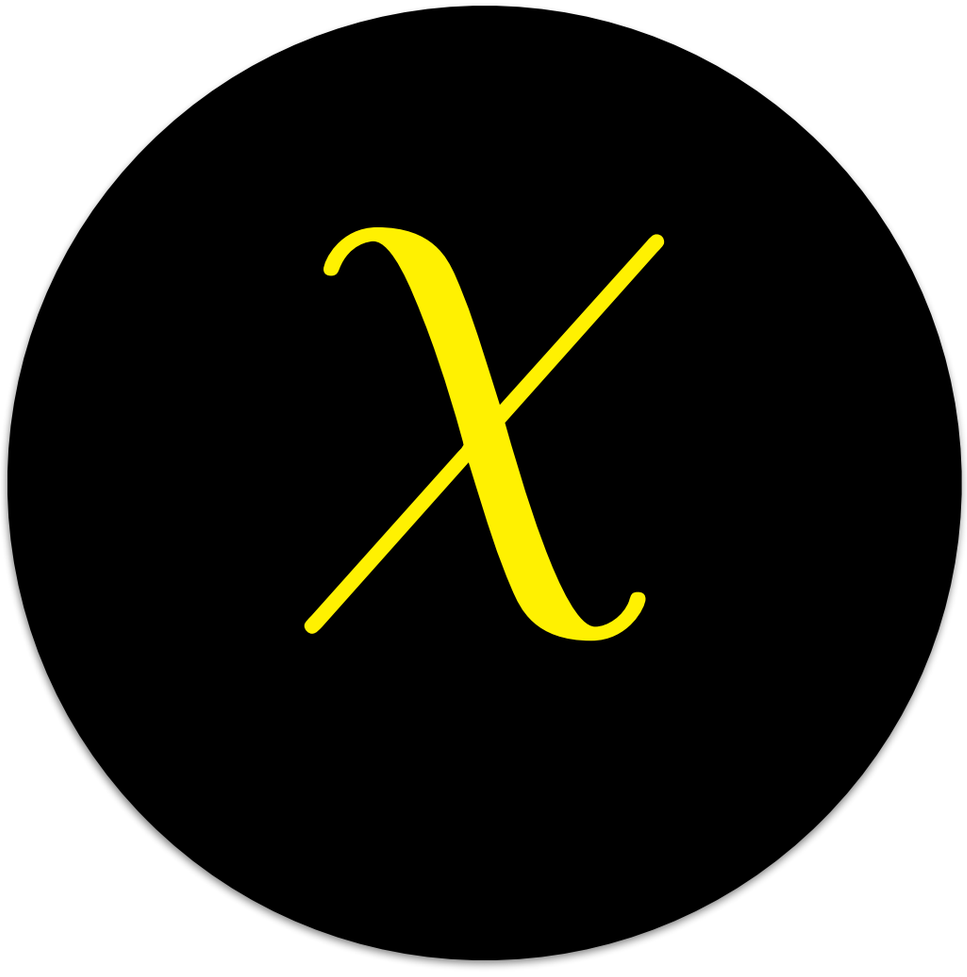
Reinard Primulando
with A. Gupta and P. Saraswat

A Tale of Two Sectors



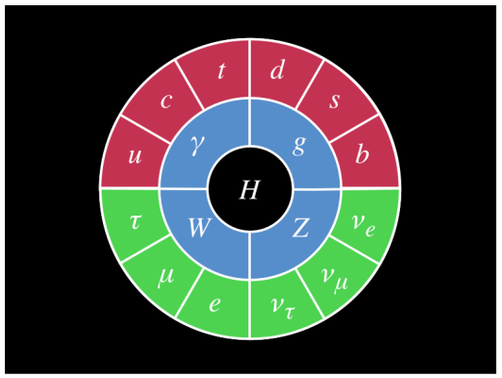
Our sector

Studying minimal dark sector is good for relating different DM search frontiers.



Minimal dark sector

A Tale of Two Sectors



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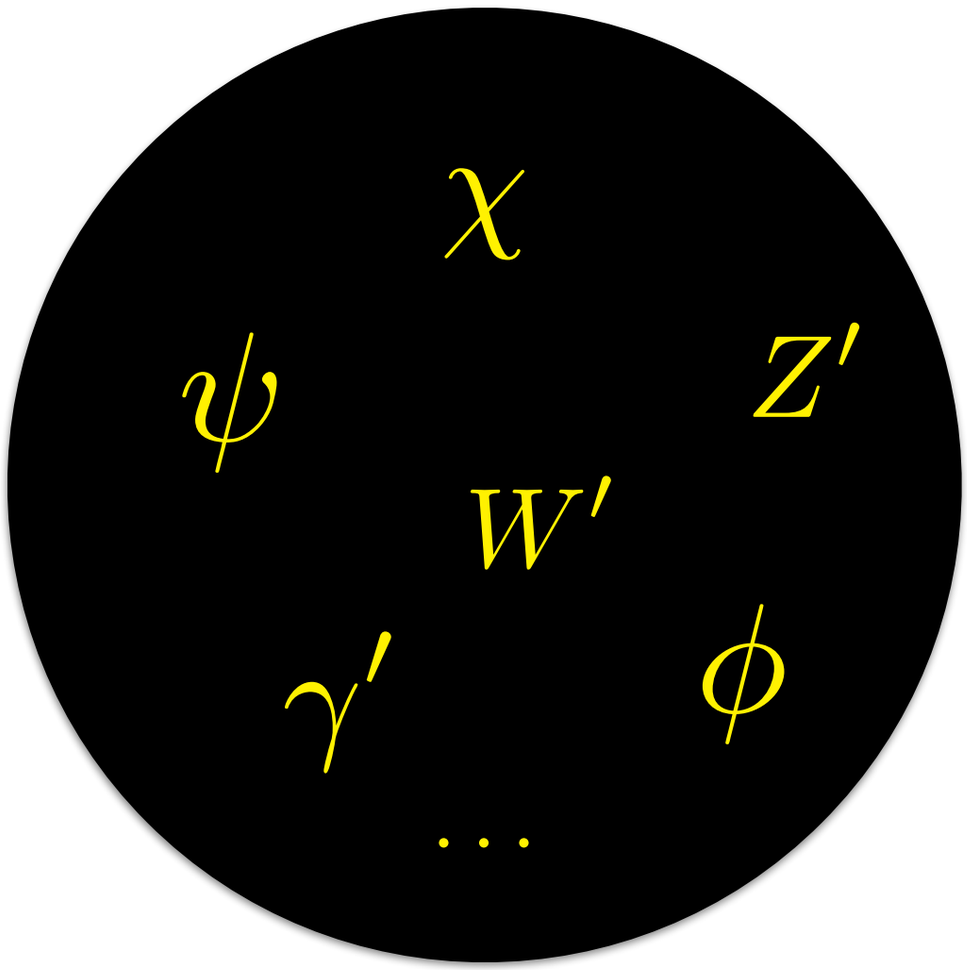


Non minimal dark sector

Collider Signatures of a Non-Minimal Dark Sector

- Assume the dark sector particles are neutral under SM charges.

- Lightest dark fermion is stable if B and L are conserved.

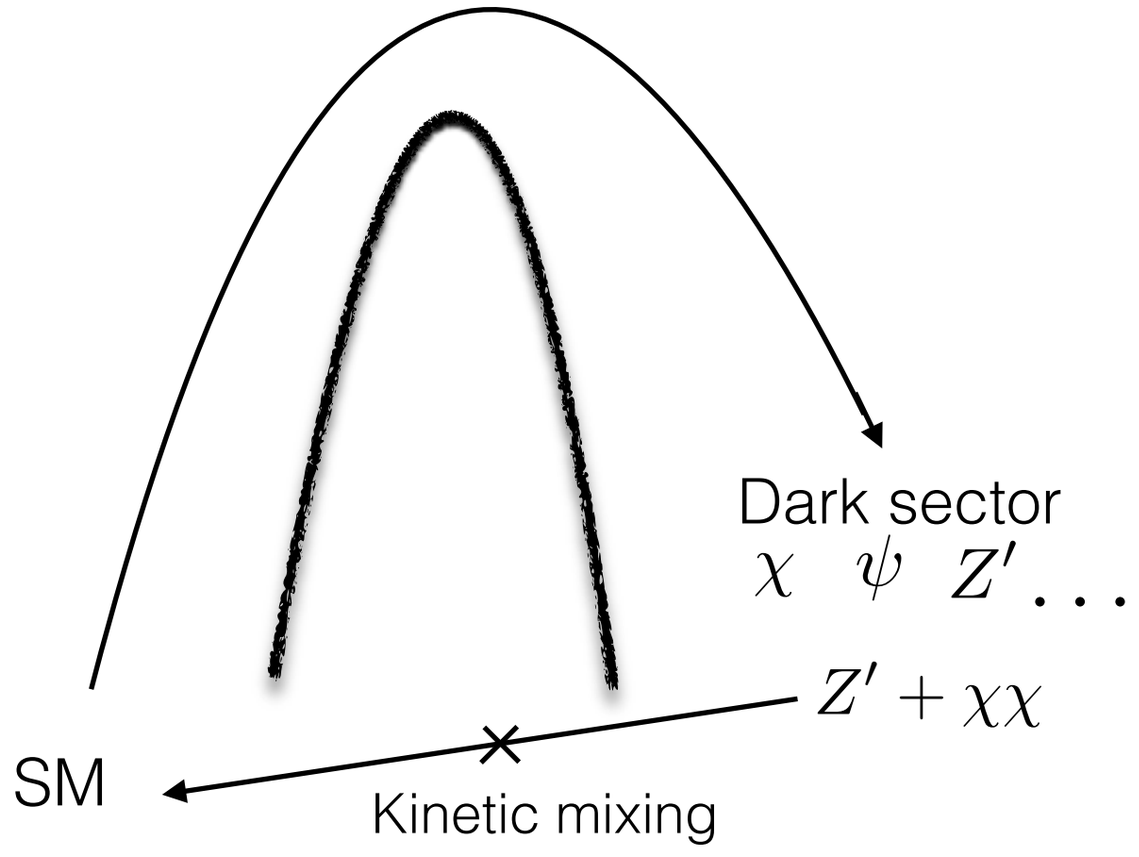
- Dark scalar can mix with the Higgs.

$$\phi^\dagger \phi H^\dagger H$$

- Dark vector boson can mix with the SM vector bosons. $\epsilon X_{\mu\nu} B^{\mu\nu}$

A Non-Minimal Dark Sector at the LHC

- The signal we consider is a lepton pair resonance+ MET.
- Z' boost determines the MET of the system.
- For highly boosted Z', the SM background is practically zero.



Other Proposed LHC Searches for Kinetically Mixed Z'

- Drell-Yan productions of Z'.

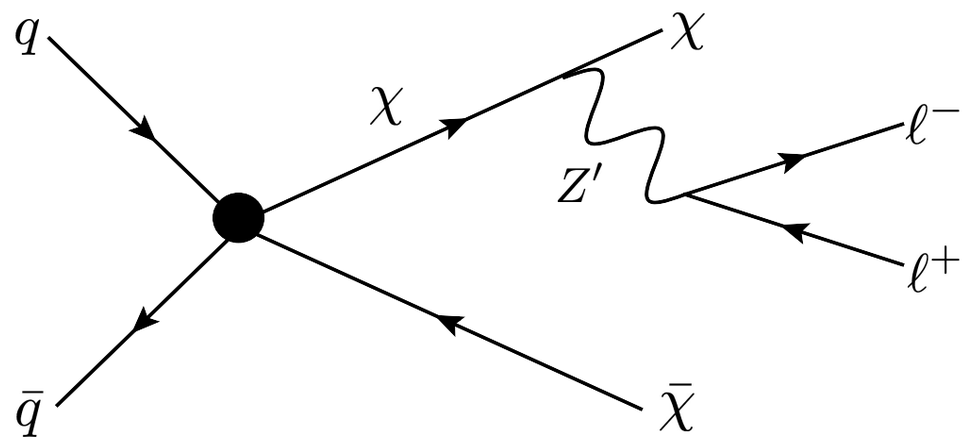
- Higgs decays to Z'+X (e.g. Davoudiasl,et.al.: 1203.2947, Davoudiasl,et.al.: 1401.2164).

- Top decays to Z'+bW (Kong,et.al: 1401.5020).

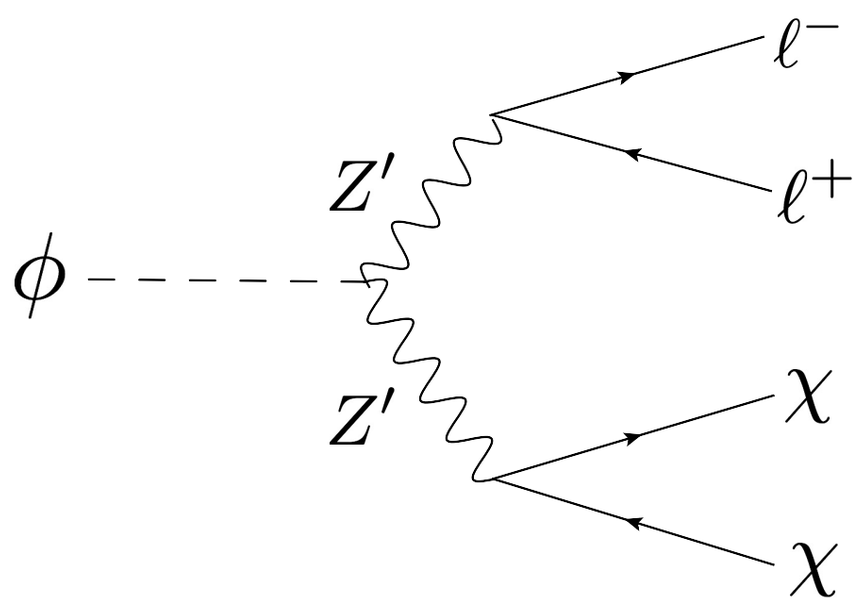
- None of these searches involve MET, which is the expected signature for dark sector production.

Simplified Models

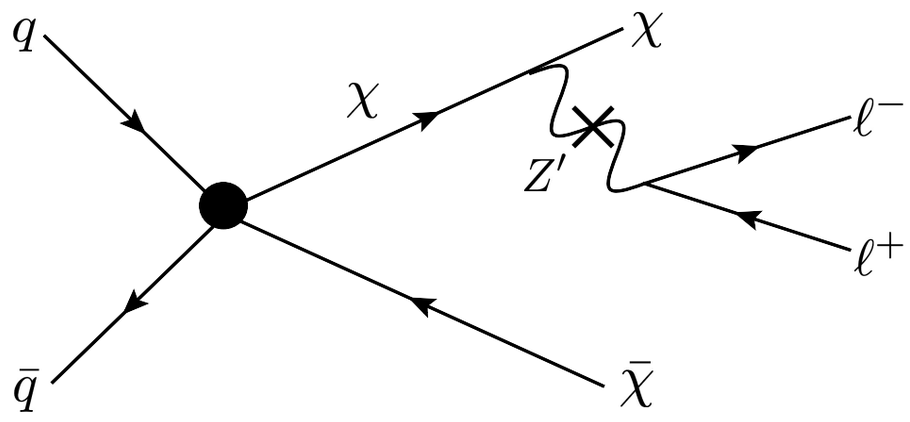
- Darkstrahlung



- Dark Higgs



Darkstrahlung



- The dark sector production Lagrangian is assumed to be

$$\mathcal{L} \supset \frac{\bar{q}\gamma^{\mu}\gamma^{5}q\,\bar{\chi}\gamma_{\mu}\gamma^{5}\chi}{\Lambda^{2}}$$

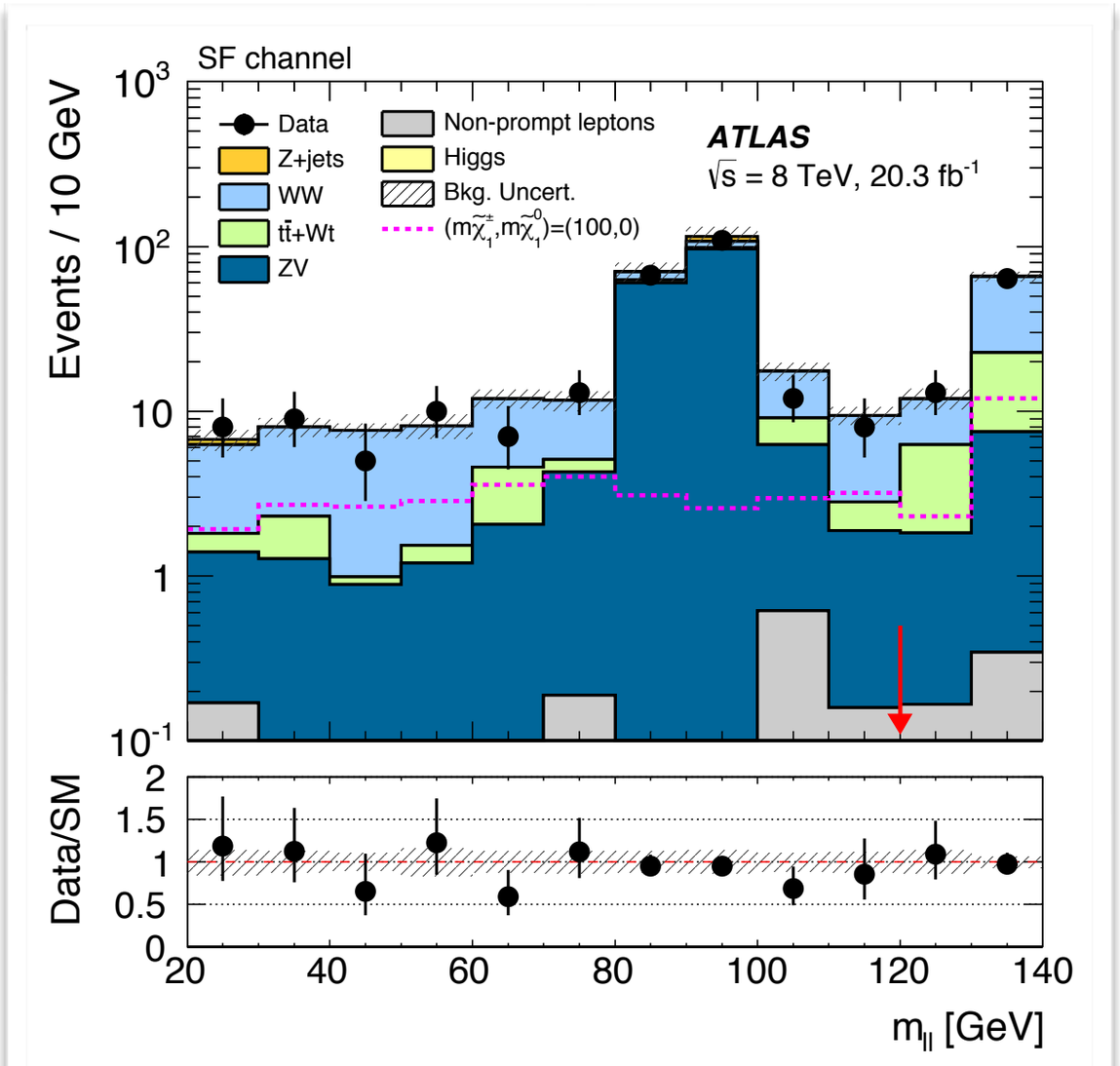
- Z' is usually highly boosted.

- We assume that Z' decays only to SM particles.

- The total cross section is independent of the value of ε.

Bounds from Released LHC Data

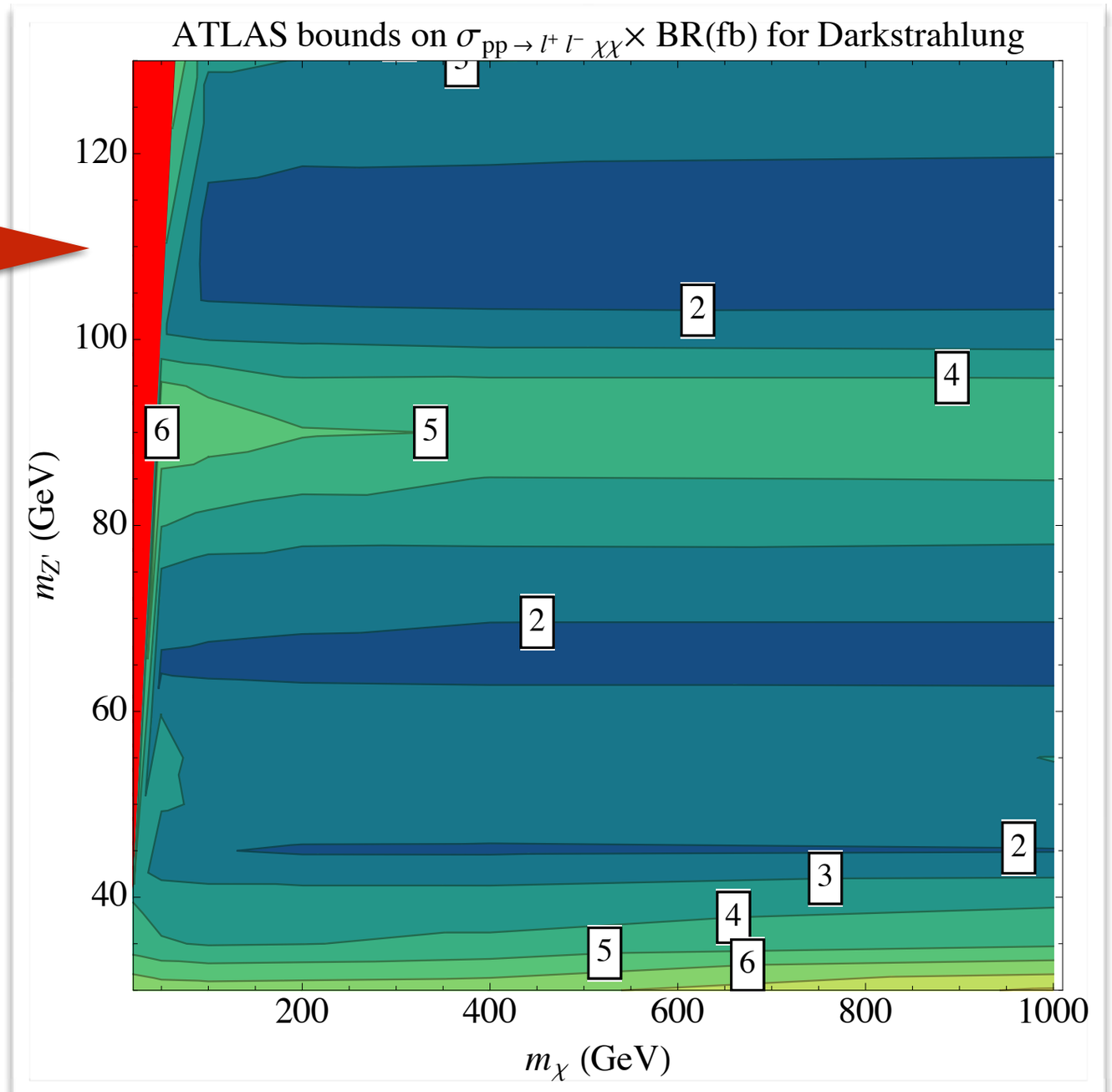
- ATLAS electroweakino search (arXiv:1403.5294).



	ATLAS SR WWa
$p_{T,e}$	> 10 GeV
$\lvert\eta_e\rvert$	< 2.47
$p_{T,\mu}$	> 10 GeV
$\lvert\eta_\mu\rvert$	< 2.4
$p_{T,\text{leading lepton}}$	> 35 GeV
$p_{T,\text{second lepton}}$	> 20 GeV
$m_{\ell\ell'}$	> 20 GeV
$\lvert m_{\ell\ell'} - m_Z \rvert$	> 10 GeV
$p_{T,\ell\ell'}$	> 80 GeV
$\not{E}_{T\,rel}$	> 80 GeV
jet veto	events with $p_j^T > 30$ GeV and $\lvert\eta_j\rvert < 2.4$
	events with $p_j^T > 30$ GeV and $2.4 < \lvert\eta_j\rvert < 4.5$

Bounds from Released LHC Data

$m_{Z'} > 2m_\chi$



An Optimized Search

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- Smaller invariant mass window search.

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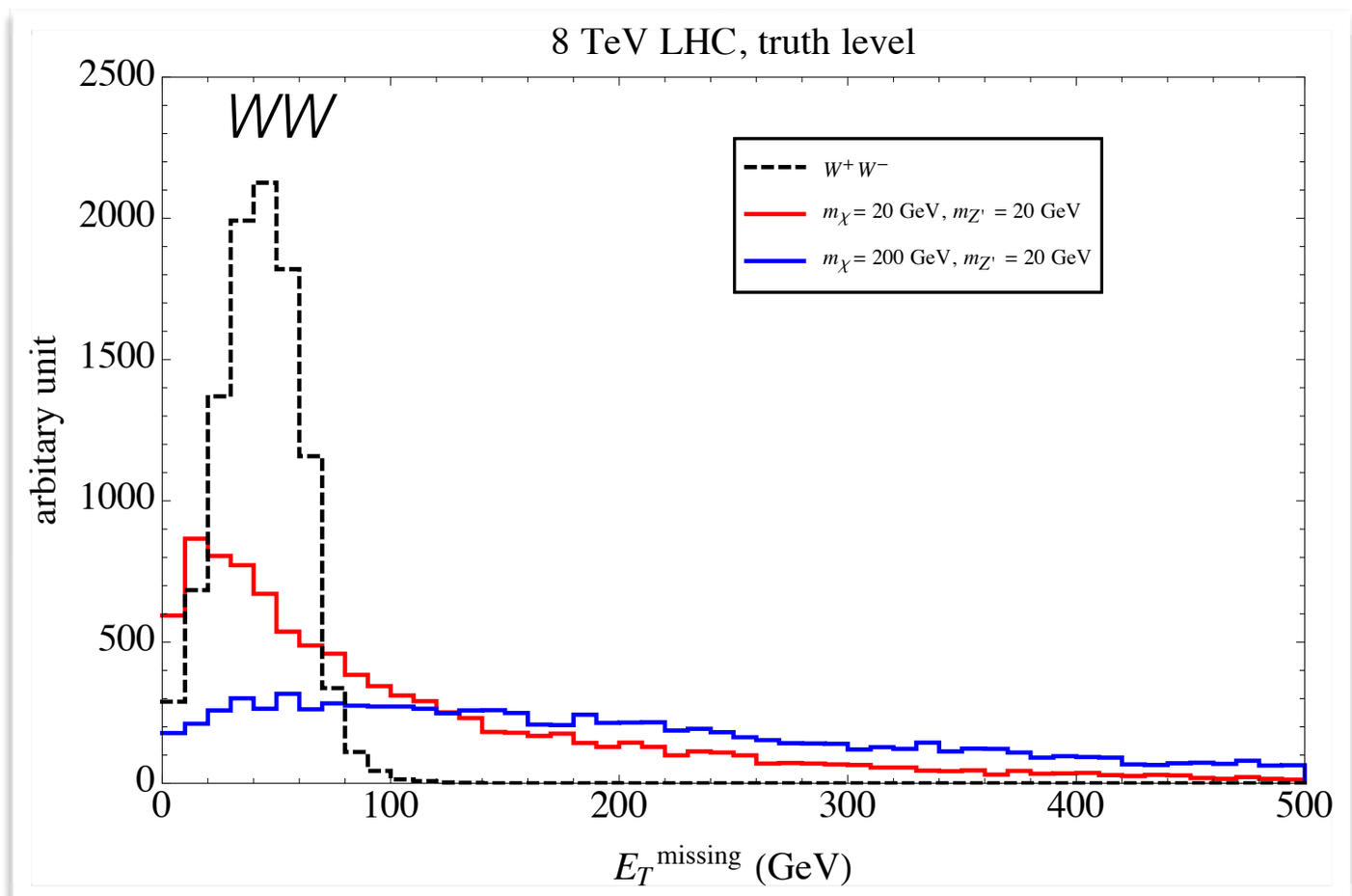
- Larger MET cut.



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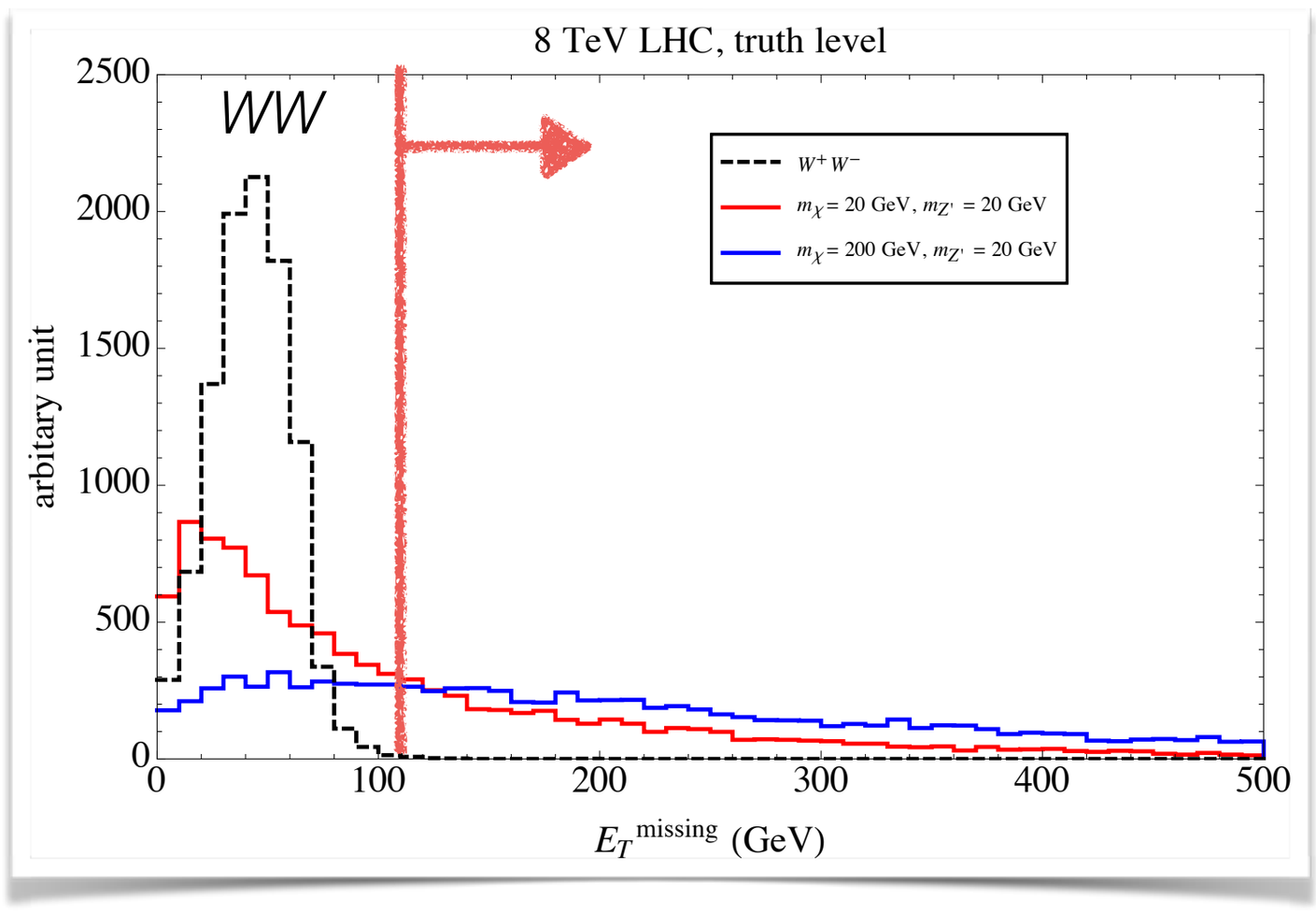
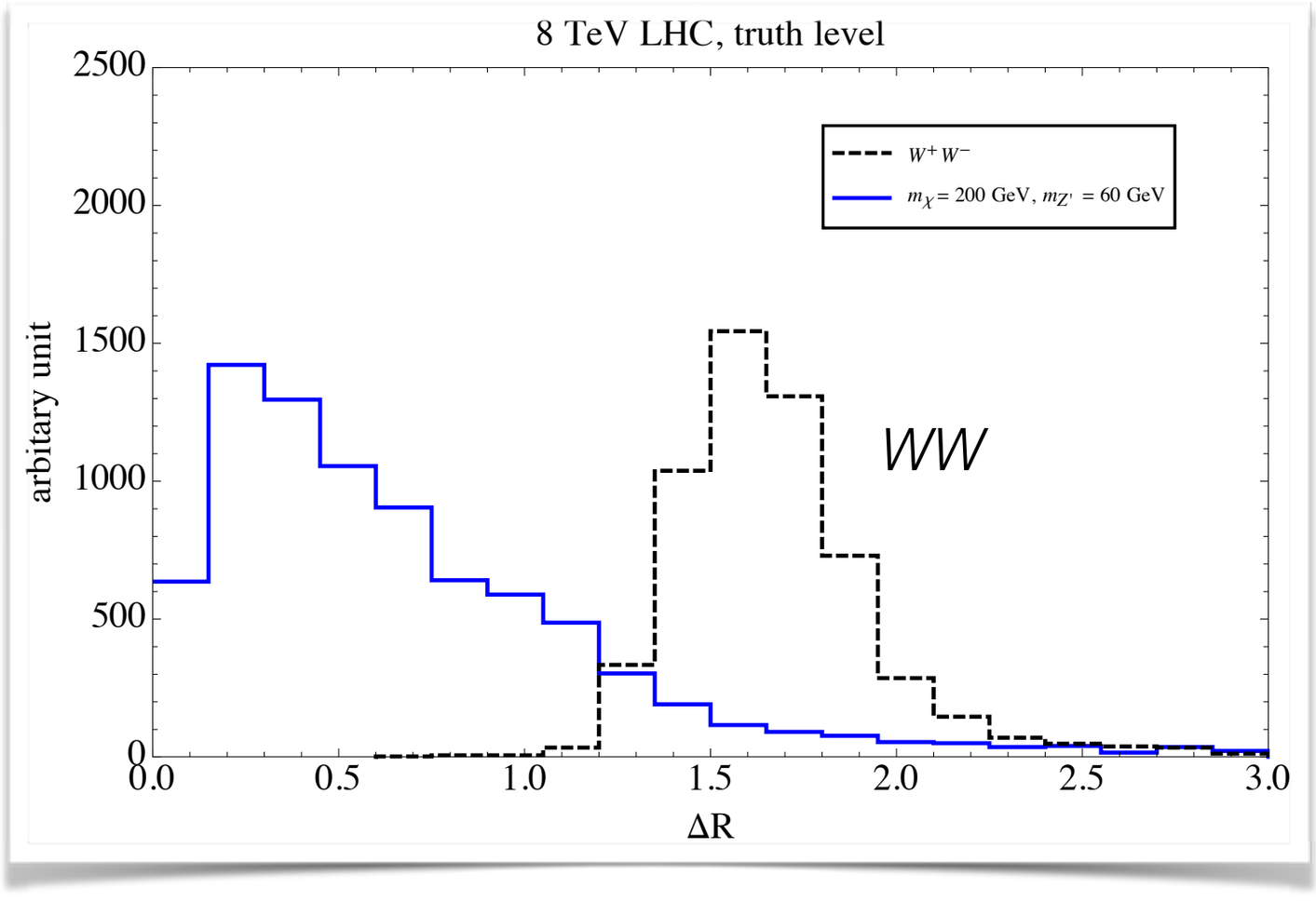


An Optimized Search

- Smaller invariant mass window search.
- Larger MET cut.
- Cut on Δ R.



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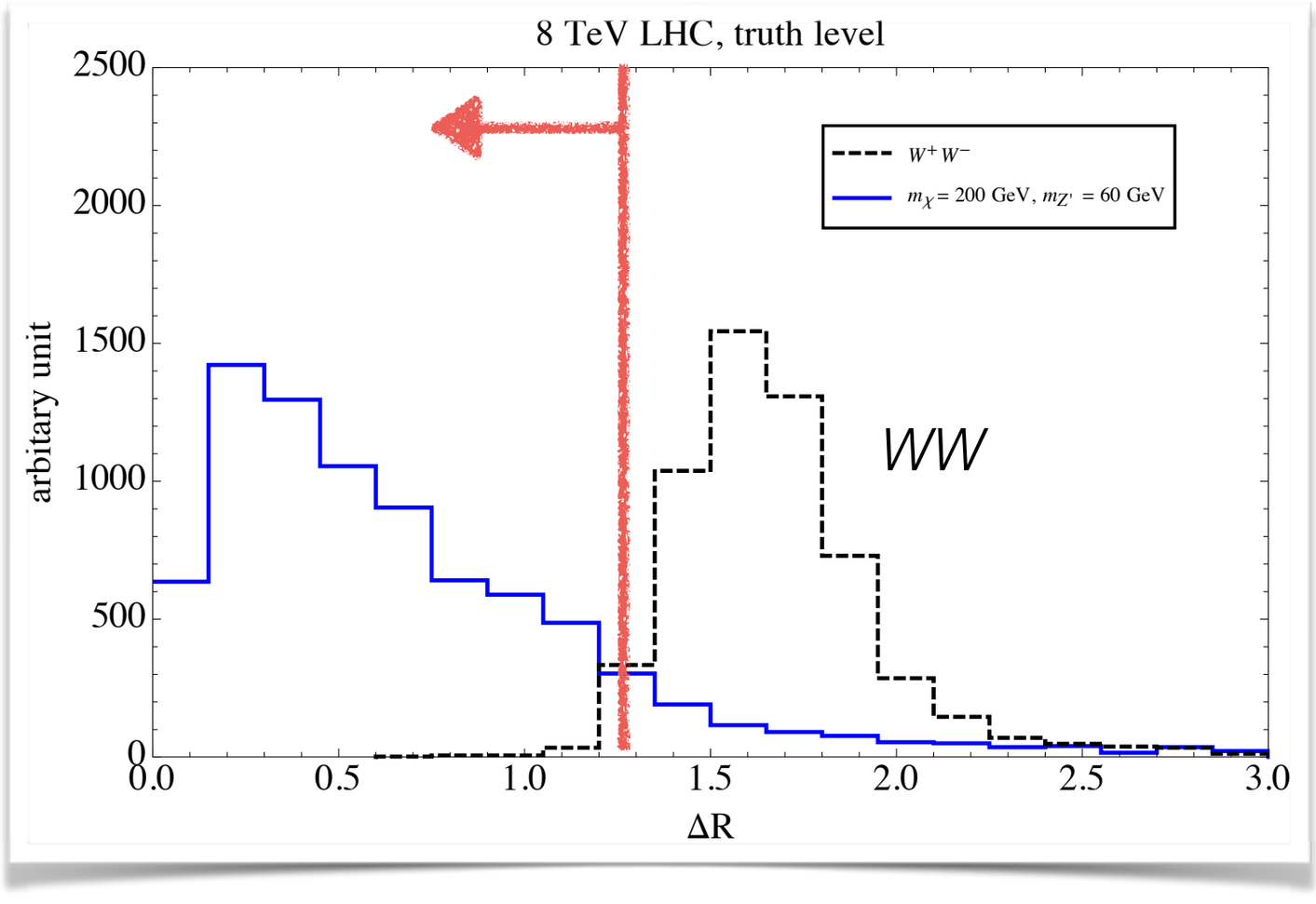
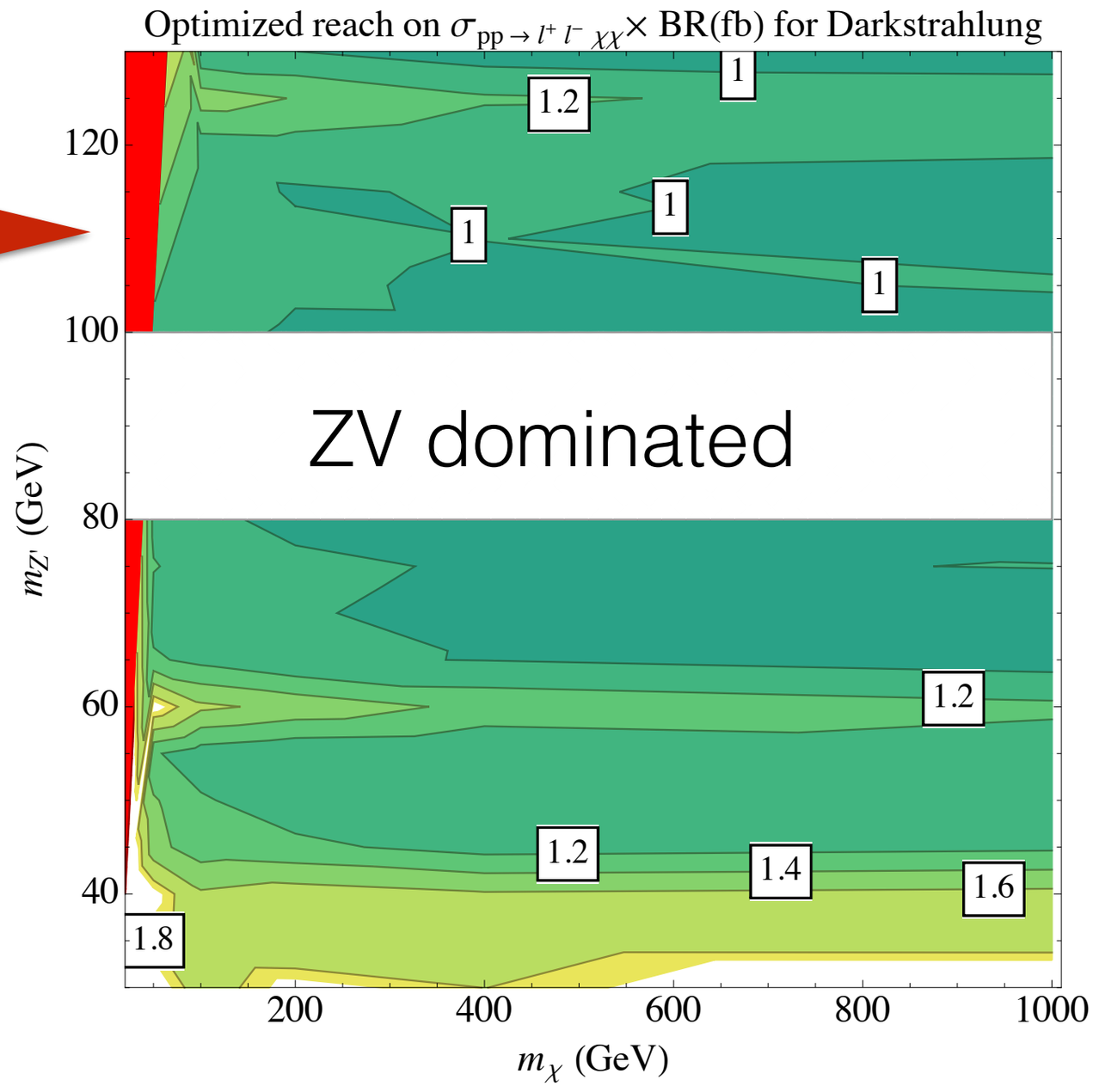
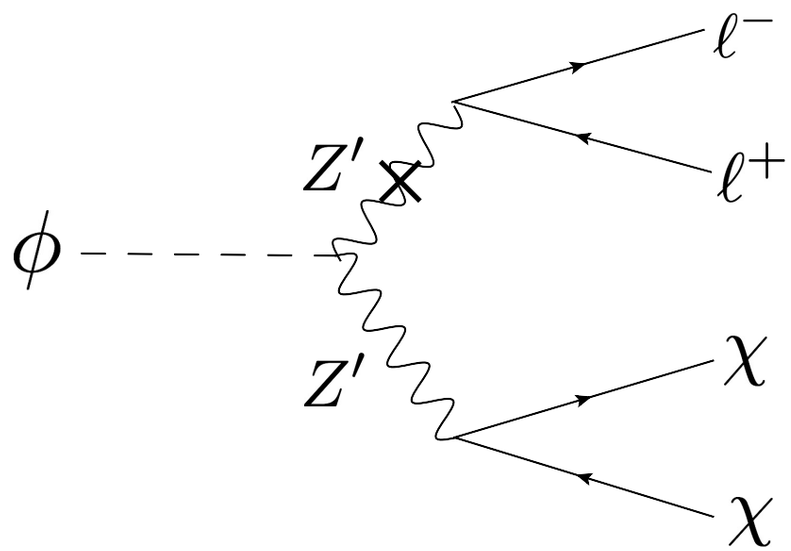


Reach for the Optimized Search

$m_{Z'} > 2m_{\chi}$



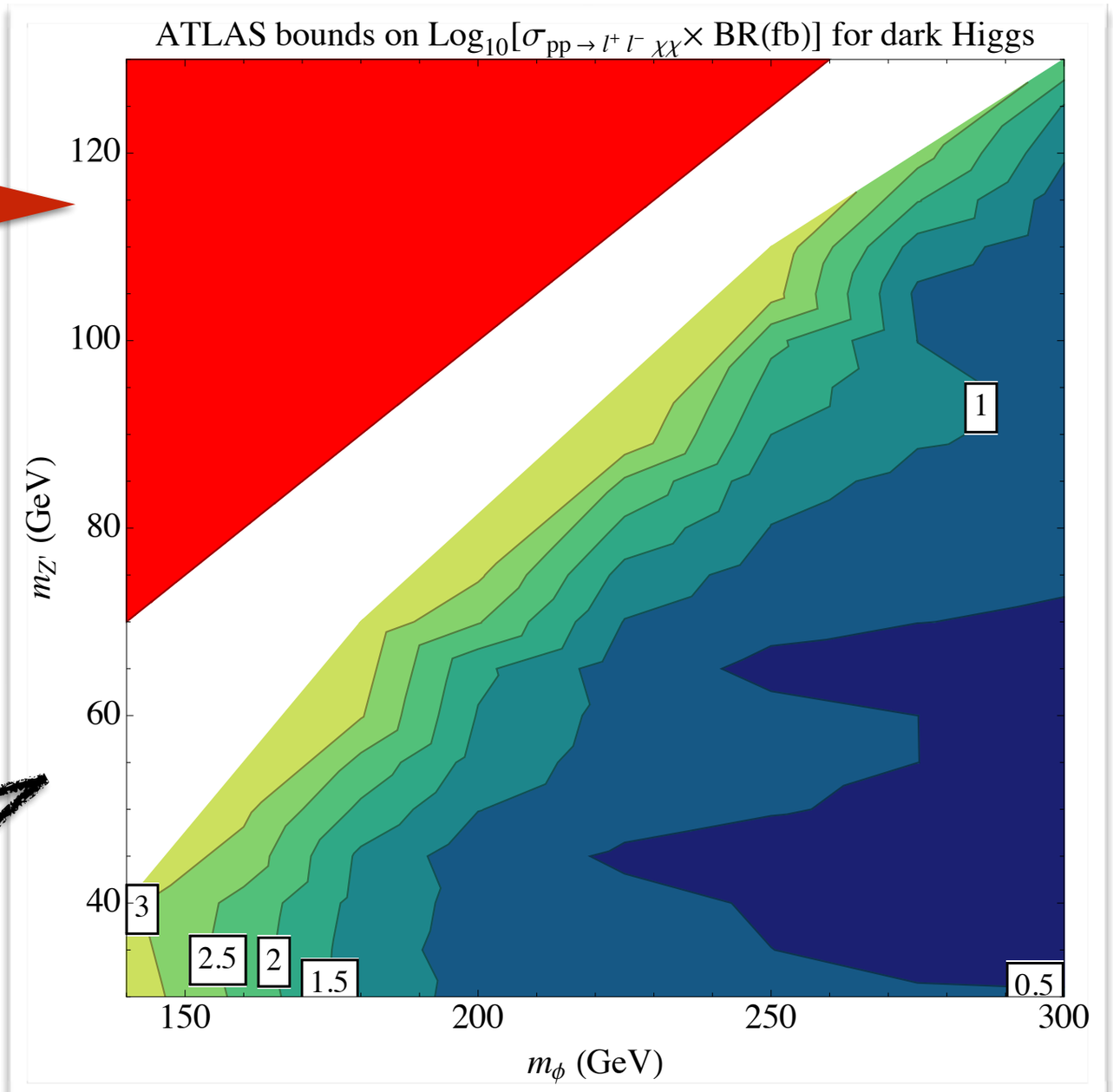
Discovering the Dark Higgs



- The dark Higgs mixes with the SM Higgs; It is produced via standard Higgs production channels.
- Small $m_\phi - 2m_{Z'}$ captures the case which Z' is less boosted.
- In this model we assume that Z' can also decay to dark sector particles.
- A possible signature of the Twin Higgs model.

Current Bounds on Dark Higgs

$m_{h_D} > 2m_{Z'}$



Small mass splitting

$\sigma > 10$ pb

Optimized Search for Dark Higgs

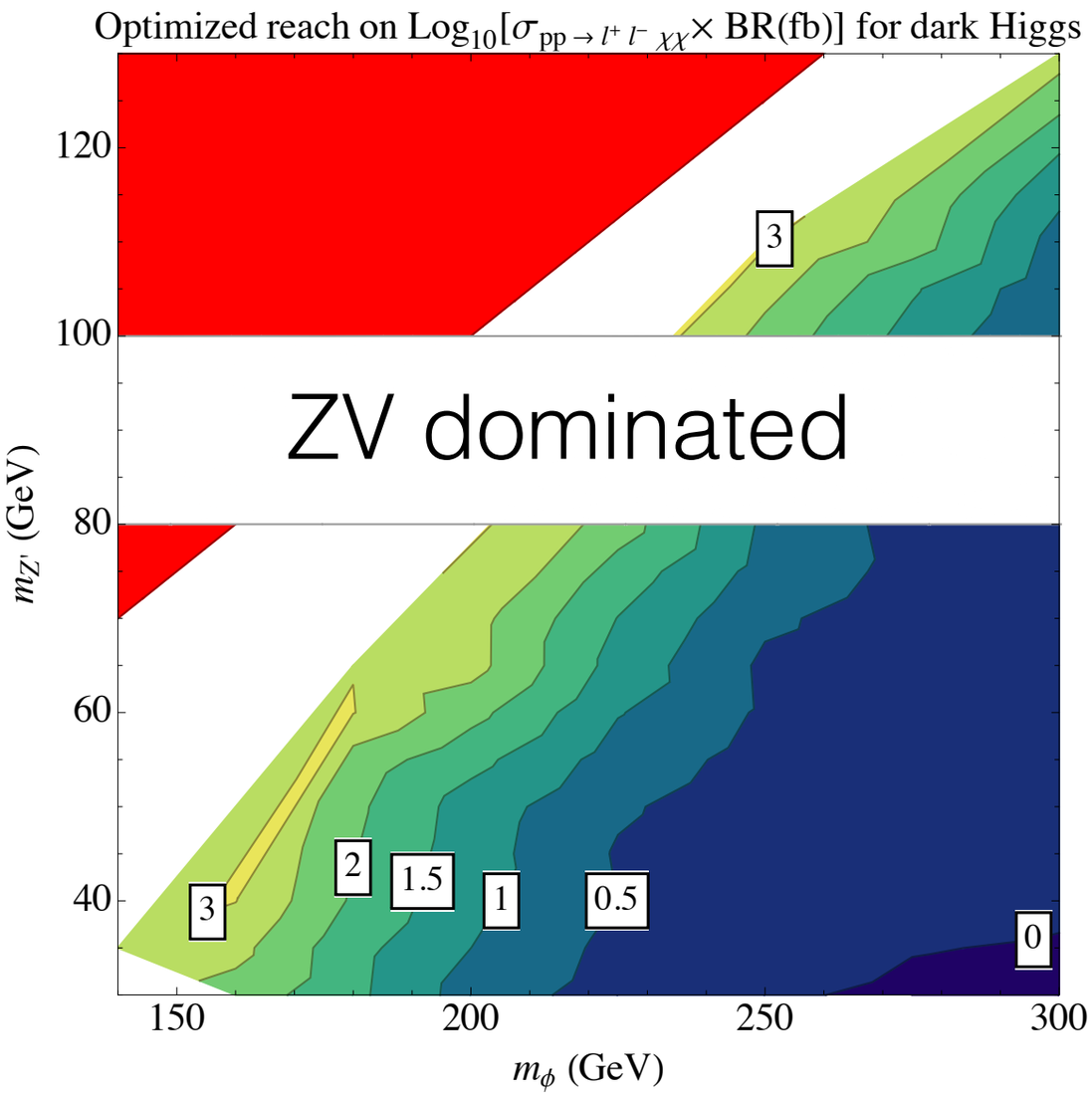
- Search with a smaller mass window can still be applied.

- For a large mass splitting, a high MET cut is more desirable.

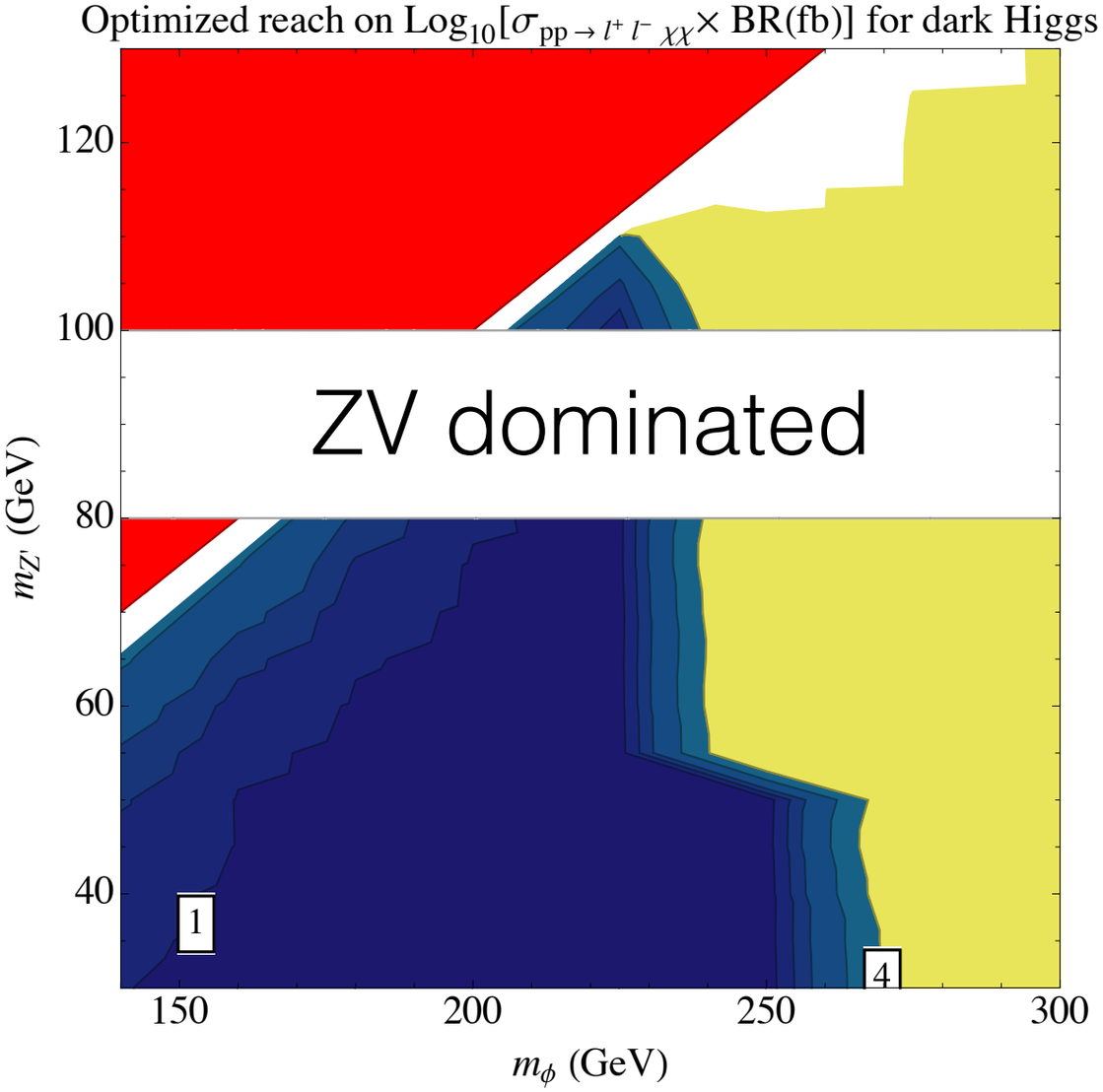
- In the case of small mass splitting, the MET cut has to be lowered to probe the less boosted Z'.

- Solution: define two search regions. One with high MET cut (zero background), other with low MET cut $p_T > 50$ GeV.

Reach for Dark Higgs Search



High MET cut search



Low MET cut search

Conclusion

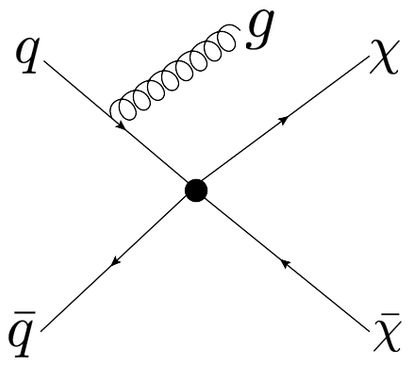
- Dilepton resonance + MET is a generic and powerful signature to probe a non minimal dark sector.

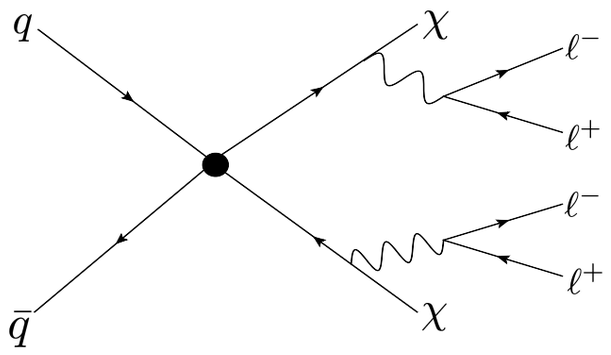
- Using the data from the current ATLAS electroweakino search we can place a bound as tight as few fb.

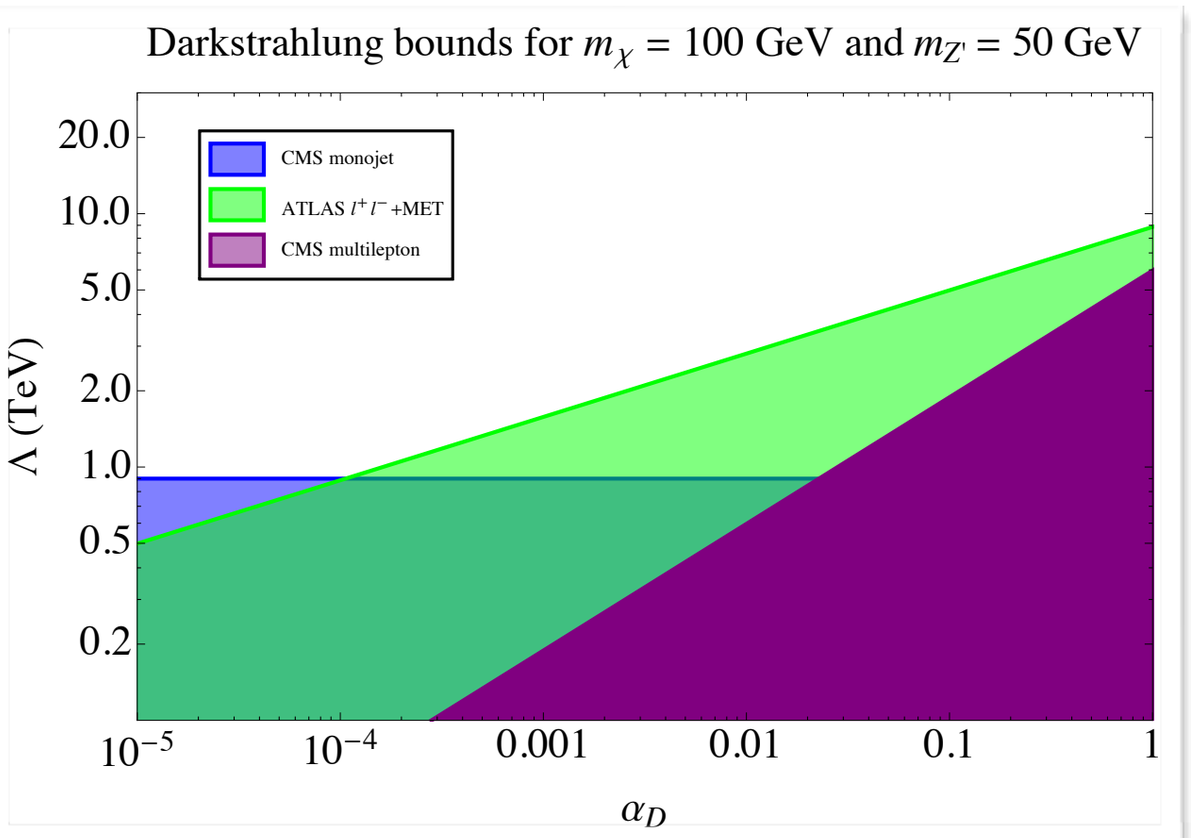
- An optimized search can improve the bounds by a factor of 3-4 times better in the case of Darkstrahlung, and some orders of magnitude better in the case of a dark Higgs.

Backup Slides

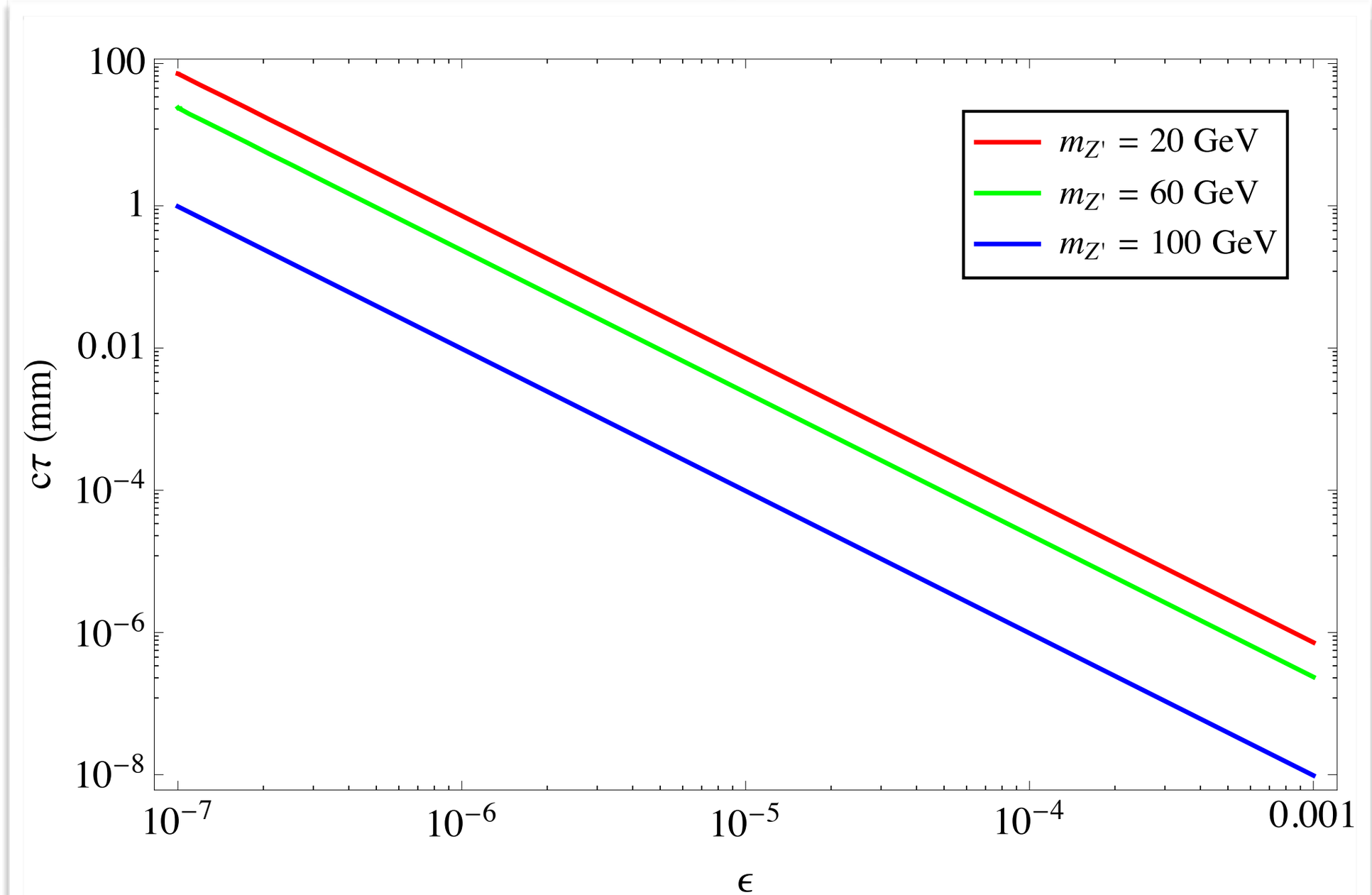
Other Final States for Darkstrahlung





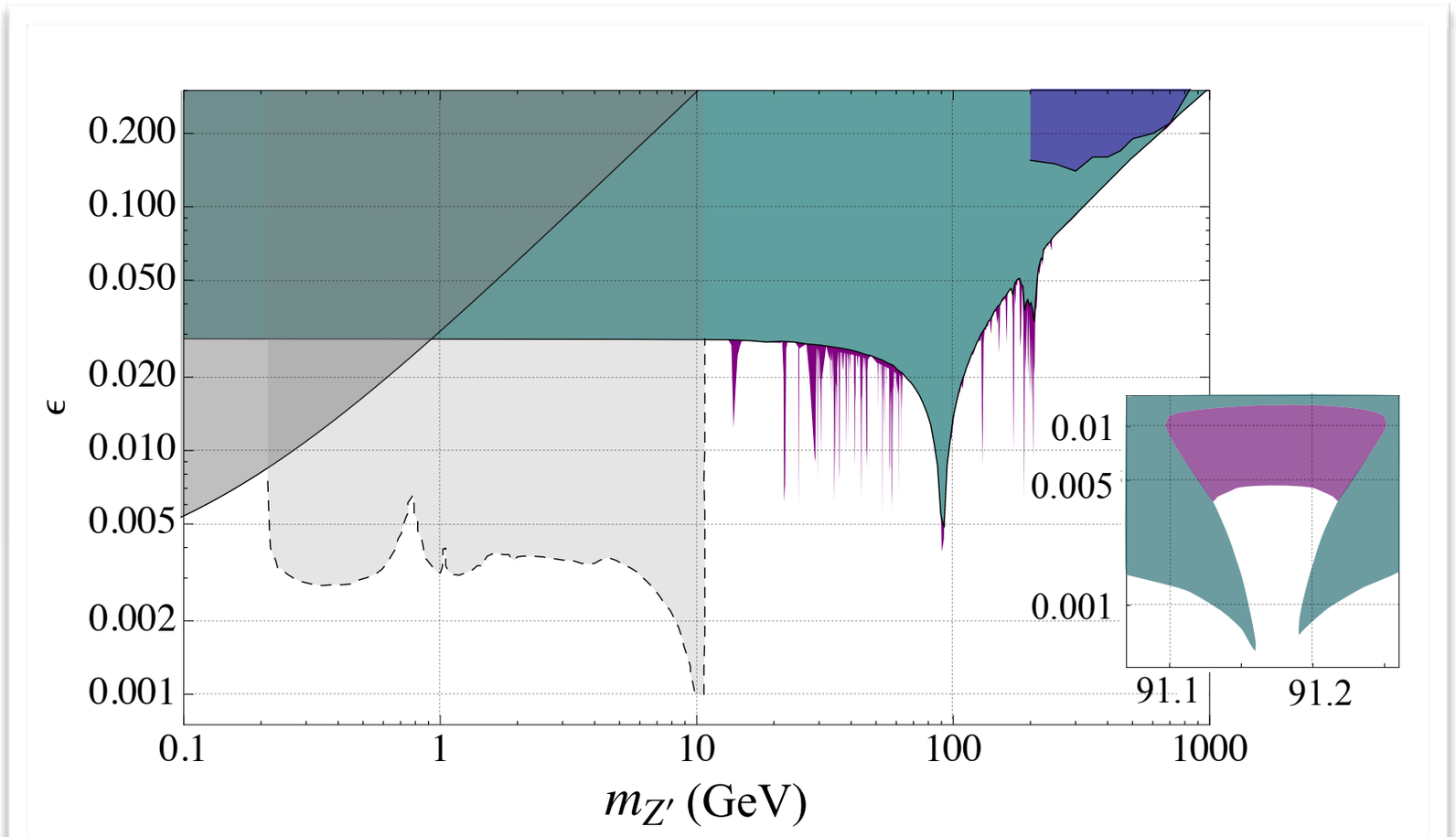


Decay Length



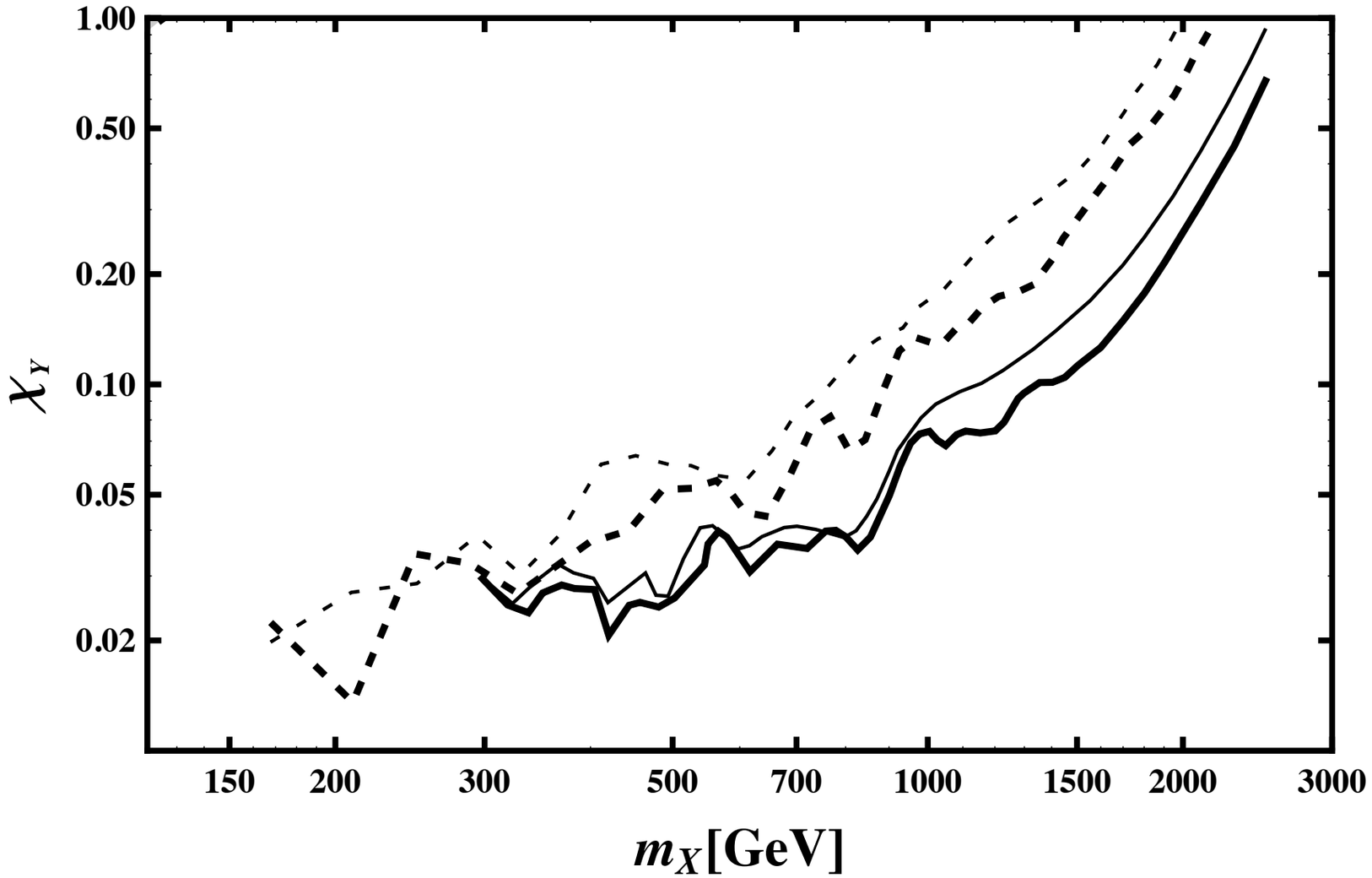
Bounds on Kinetic Mixing

Precision EW Bounds



A. Hook, E. Izaguirre, J.G. Wacker: arXiv:1006.0973

LHC Bounds on Z’



J. Jaeckel, M. Jankowiak, M. Spannowsky: arXiv:1212.3620

Assume no Z’ decay to dark sector