

Prompt dark photons searches at the LHC

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on behalf of



Dark Interactions
Brookhaven, Oct 2018

Overview

- What is a dark photon?
 - new $U(1)_{\text{Dark}}$ under which SM is not charged
 - classic extension of the SM gauge group and can connect to dark sector
 - γ_D or Z_D or A'

- How is it produced?

- **Vector portal:** kinetic mixing of ν_D with SM photon (ε)

$$\mathcal{L} \supset \frac{1}{2} \varepsilon F^{\mu\nu} F'_{\mu\nu}$$

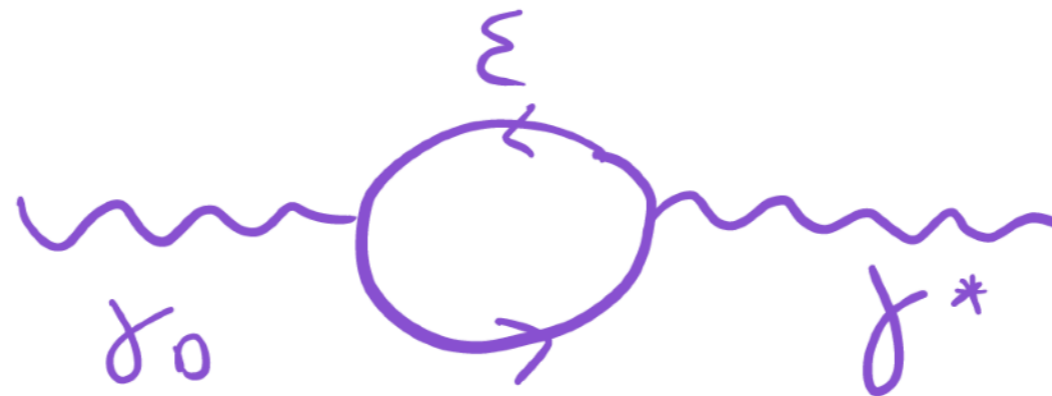
- **Higgs portal:** if massive γ_D , introduce a dark higgs (S) to break $U(1)_{\text{Dark}}$, mix H with S (κ),

$$\mathcal{L} \supset \kappa |S|^2 |H|^2$$

- more exotic portals: hidden valley sectors, neutrinos, **dark SUSY**....

Overview

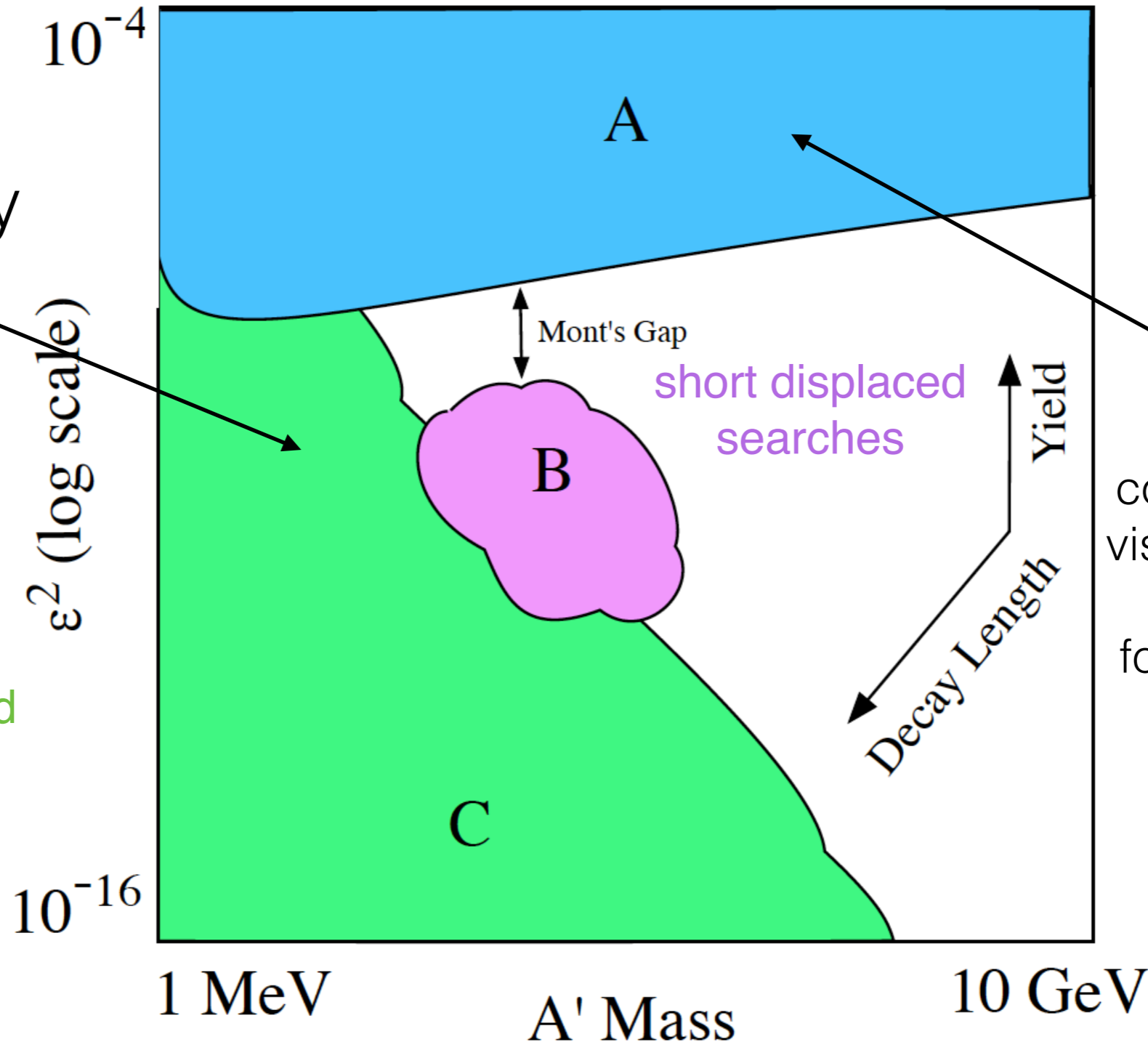
- How does it decay?
 - Visible: decays to SM particles
 - Invisible: decays can include dark matter particles
- Kinetic mixing
 - If generated by 1 loop corrections, $\epsilon \sim 10^{-3} - 10^{-1}$
 - If generated by 2 loop corrections, $\epsilon \sim 10^{-7} - 10^{-3}$



- Lifetime: $\tau(\gamma_0) \propto \frac{1}{m(\gamma_0)\epsilon^2}$

ϵ v. mass

Emma and
Adish's
talks
yesterday

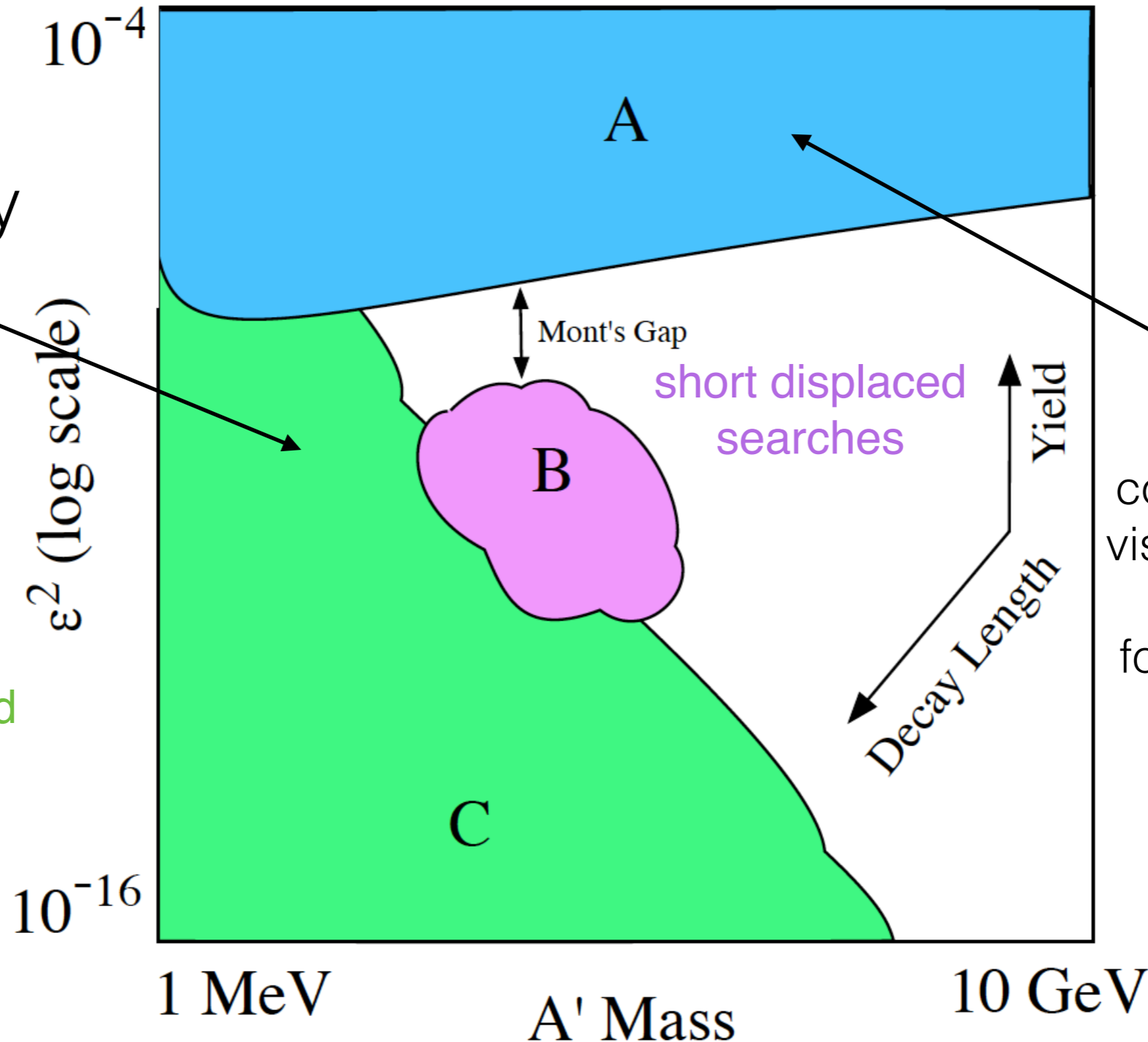


this talk
covers prompt and
visible signatures at
the LHC,
focusing on recent
(13 TeV) results

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← more collimated (lepton jets)

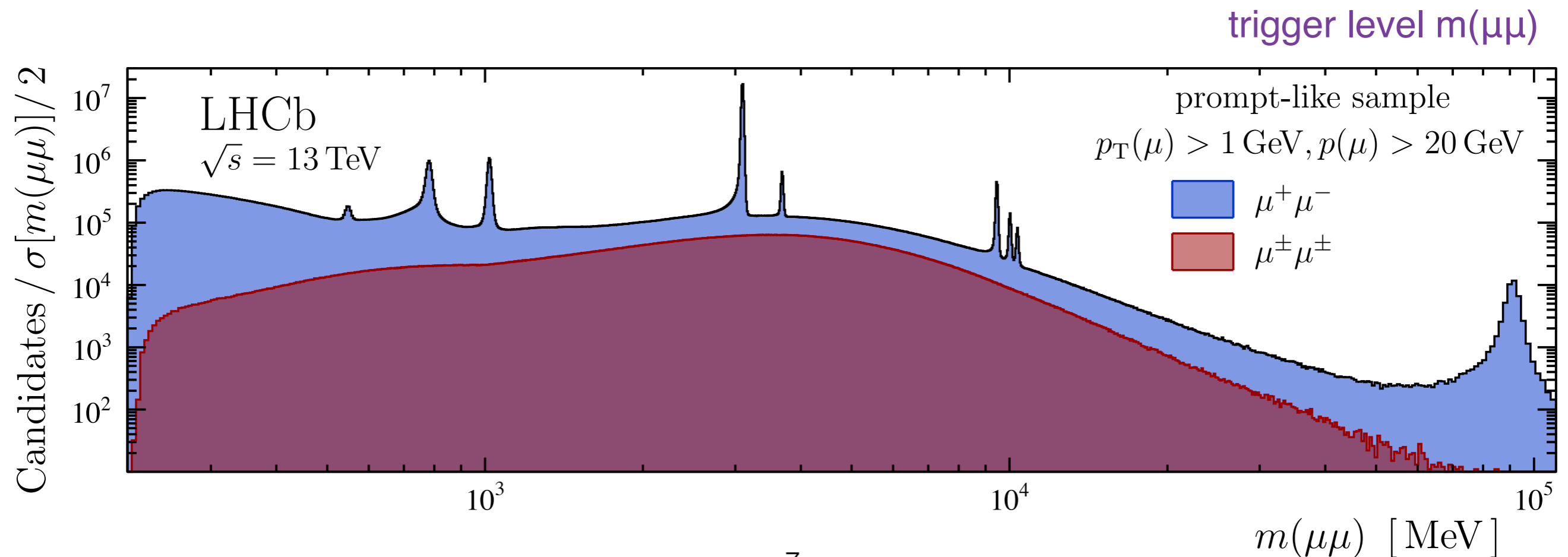


this talk covers prompt and visible signatures at the LHC, focusing on recent (13 TeV) results

Vector portal production of visible γ_D

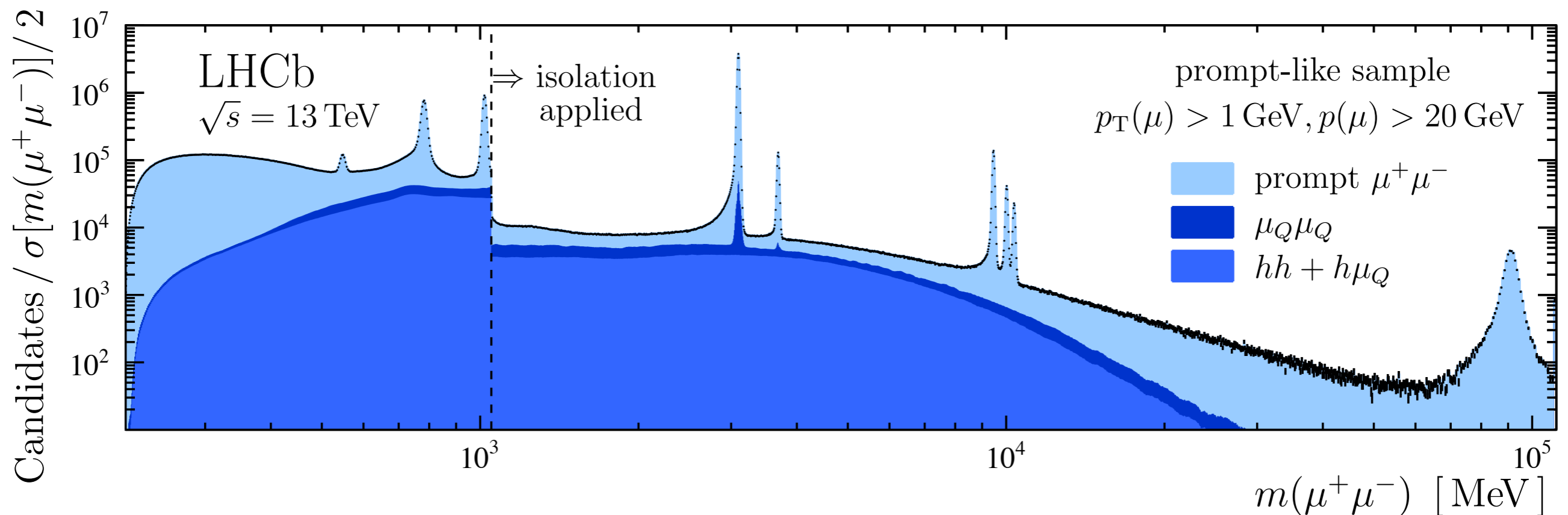
Dimuon search: LHCb

- Strategy
 - Look for low p_T , forward muons consistent with light, Drell-Yan production
 - Inclusive di-muon search in 1.6 fb^{-1}
 - Require $\mu^+\mu^-$ pairs consistent with primary vertex
 - To maximize sensitivity, work around trigger bandwidth limitations
 - hardware trigger: di-muon pair with $p_T > 1.8 \text{ GeV}$
 - reconstruct $\mu^+\mu^-$ pair in trigger sw, only save high level info



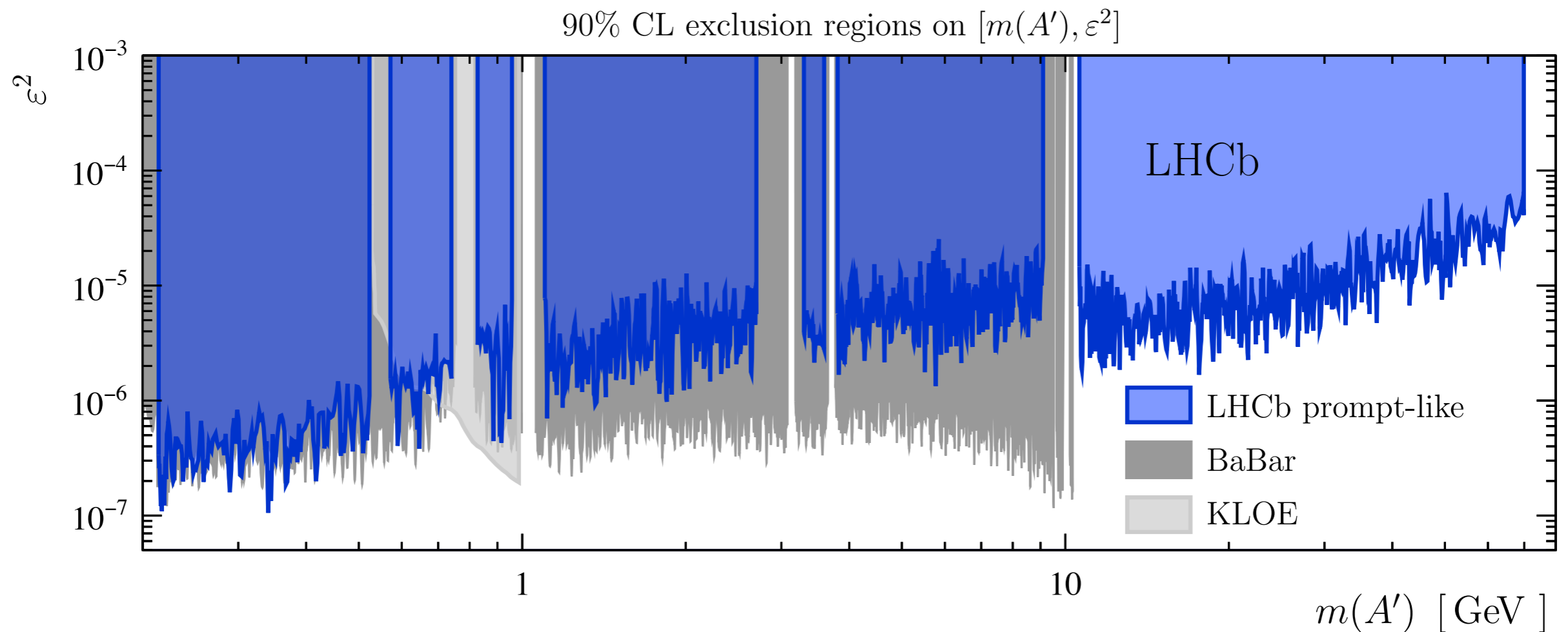
Dimuon search: LHCb

- Selection
 - No isolation applied where meson decay dominates (< 1 GeV)
- Background
 - prompt $\gamma^* \rightarrow \mu^+\mu^-$ (irreducible)
 - resonant (look around)
 - mis-ID of prompt hadrons (h) as μ or μ from heavy flavor decay (μ_Q)
- Signal extraction
 - Prompt $\mu^+\mu^-$ distinguished from background by fits to data-derived templates of vertex properties
 - Allow A' contribution to $\gamma^* \rightarrow \mu^+\mu^-$ extracted from extended maximum likelihood fit performed in bins of $m(\mu^+\mu^-)$ to extract limit on resonant contribution from dark photon



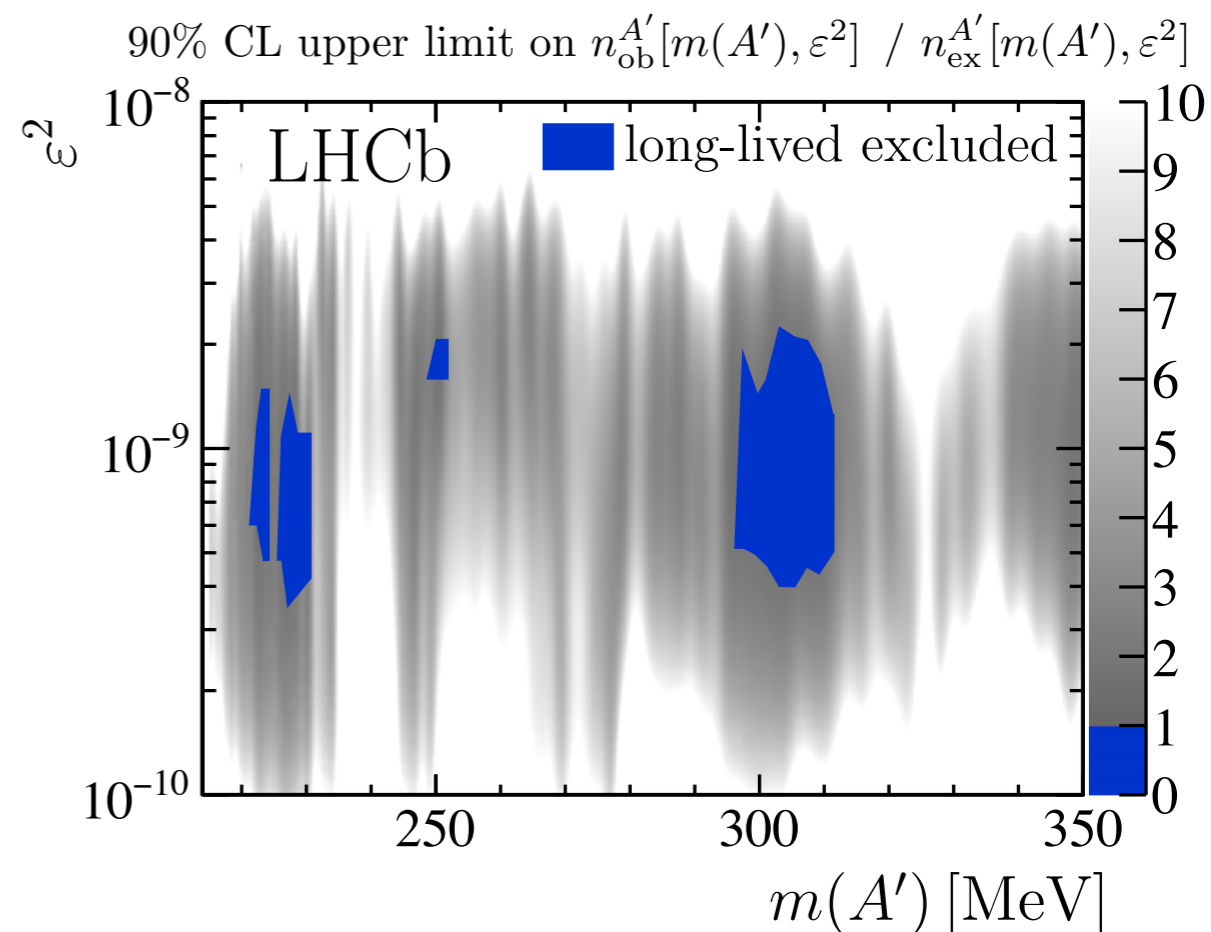
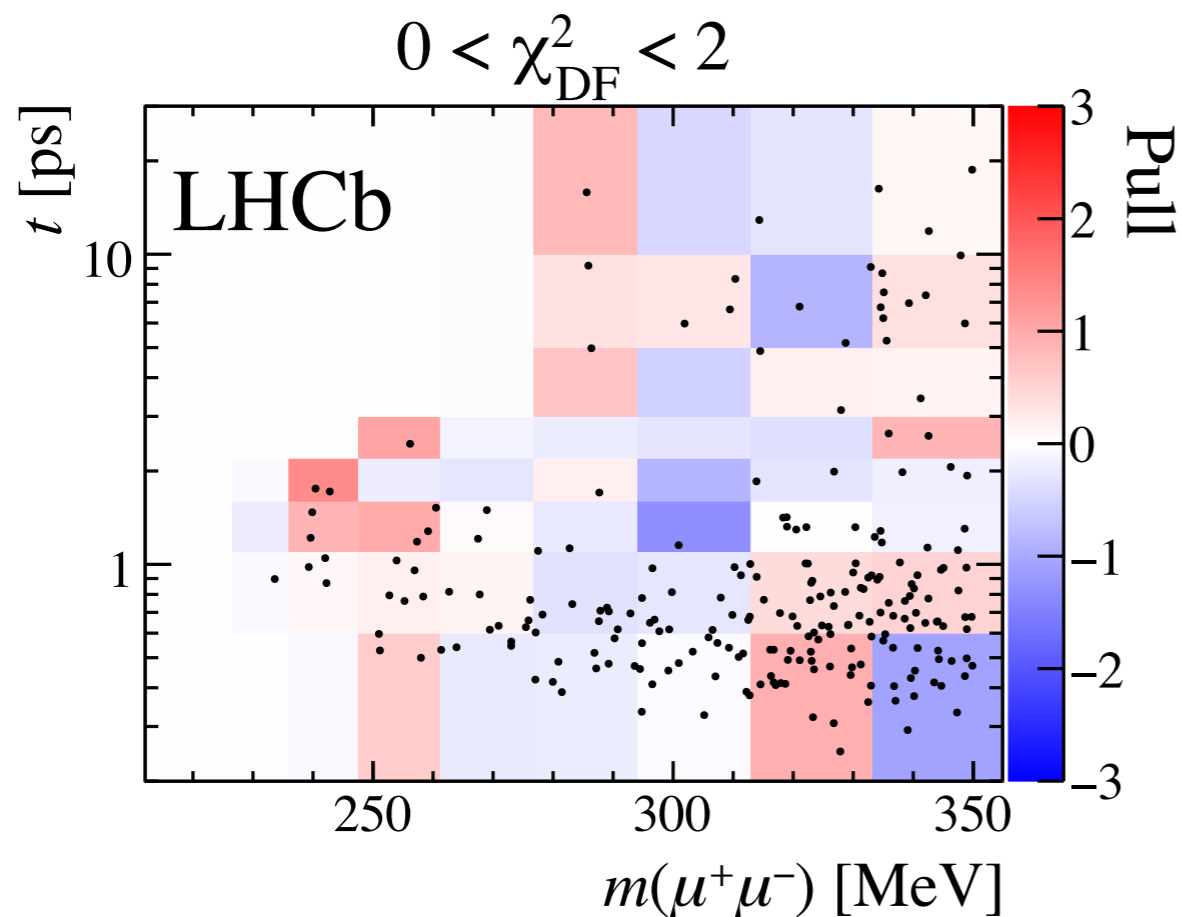
Dimuon search: LHCb

- Results
 - Most significant excess has global p-value of 38% at $m = 5.8$ GeV
 - Tightest limits on ε in mass range from $10.6 < \text{mass dark photon} < 70$ GeV
 -



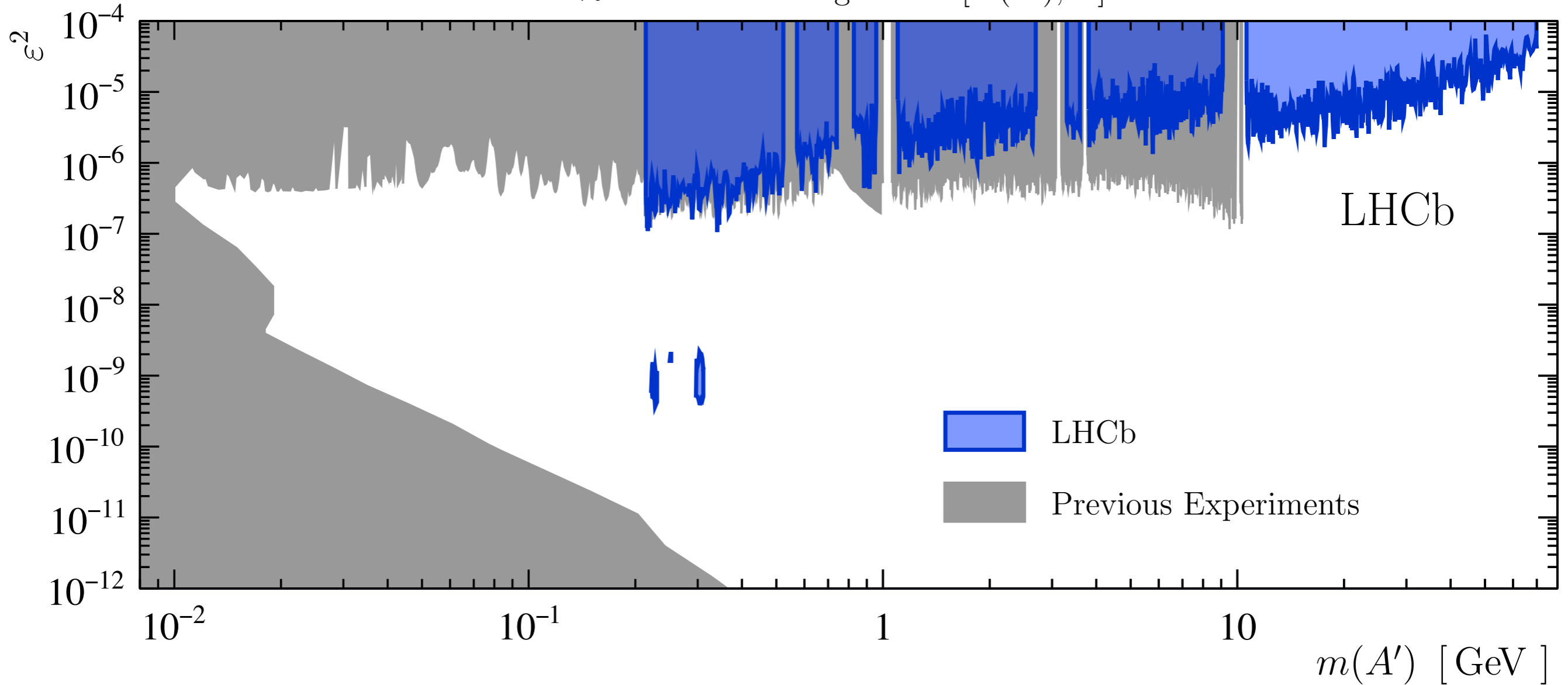
Displaced dimuons: LHCb

- Signature
 - Di-muon opposite sign pair with mass range 214 - 350 MeV, each muon inconsistent with coming from PV
 - Required to be consistent with coming from single, prompt, resonance
- Search strategy
 - BDT to reject muons from B-hadron decays based on looking for other displaced tracks
 - Detailed VELO map made to reject photon conversions to muons in material
- Results
 - Small regions of phase space ruled out, parameter space will become accessible with more data



Combined LHCb results

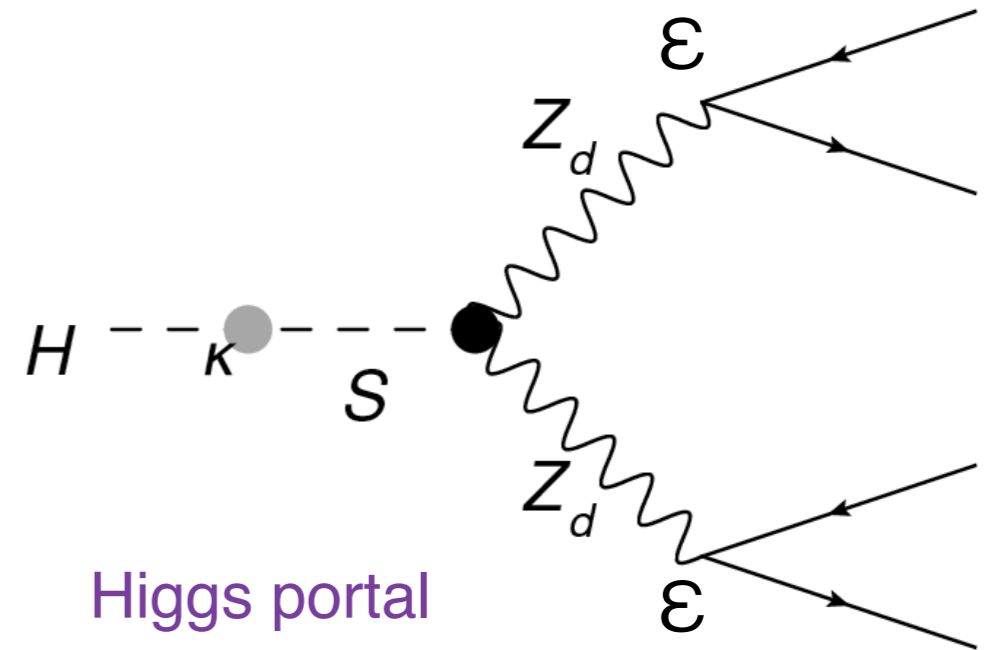
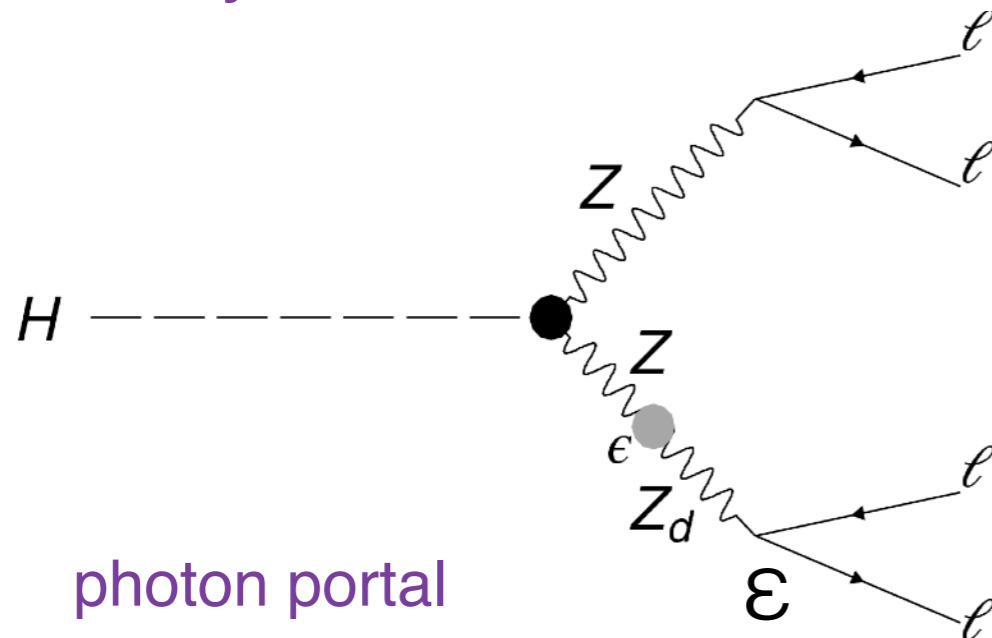
90% CL exclusion regions on $[m(A'), \varepsilon^2]$



Higgs production of visible γ_D

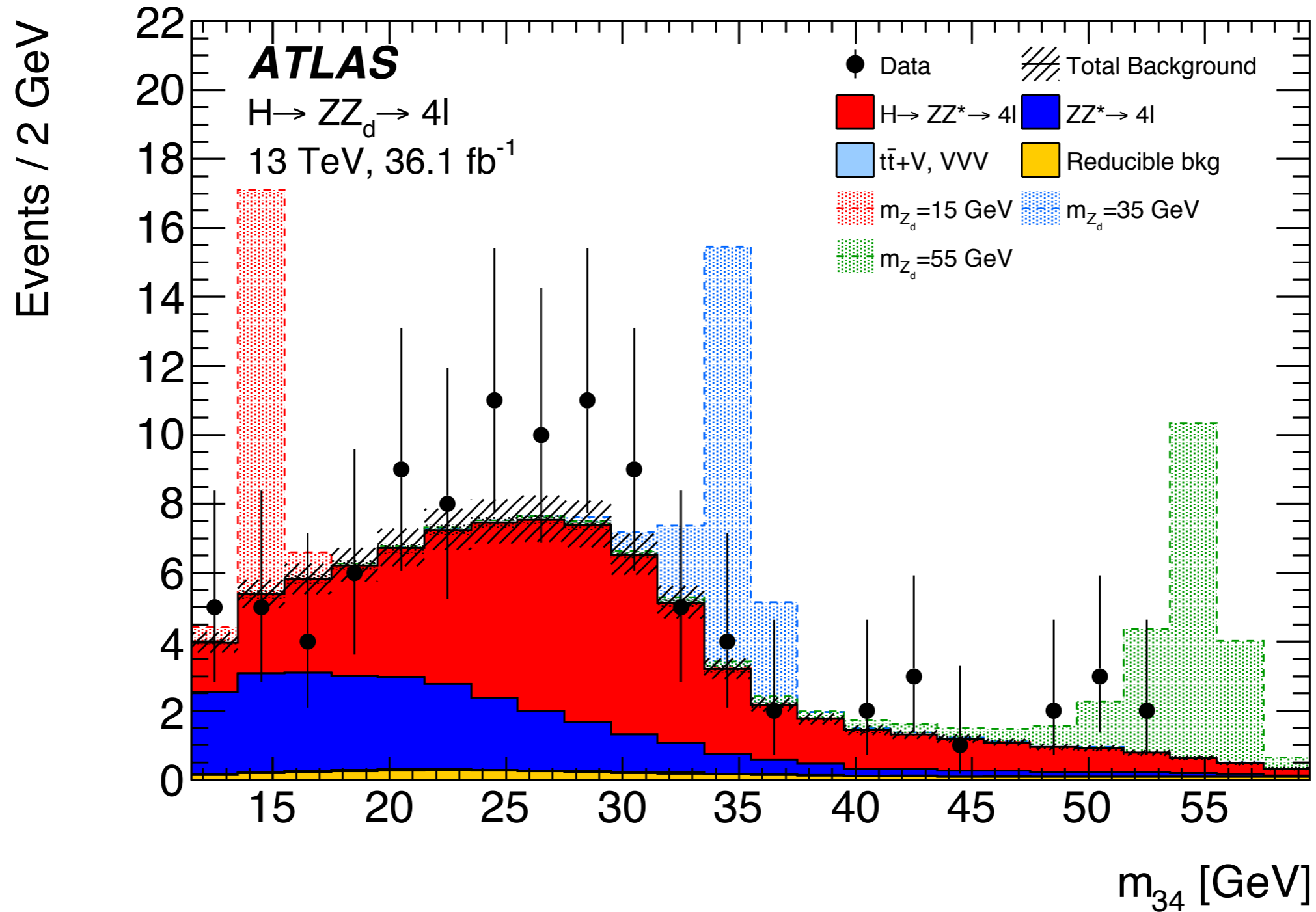
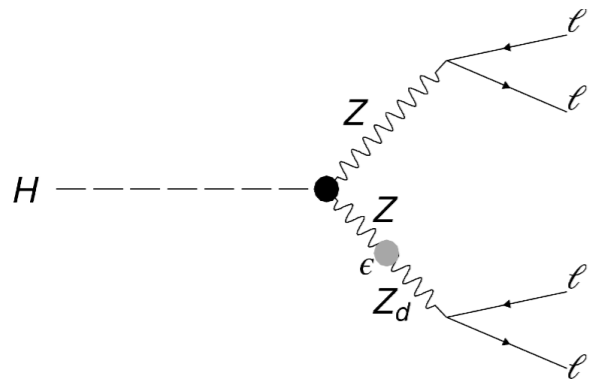
covered by
Diallo
yesterday

Higgs production: ATLAS



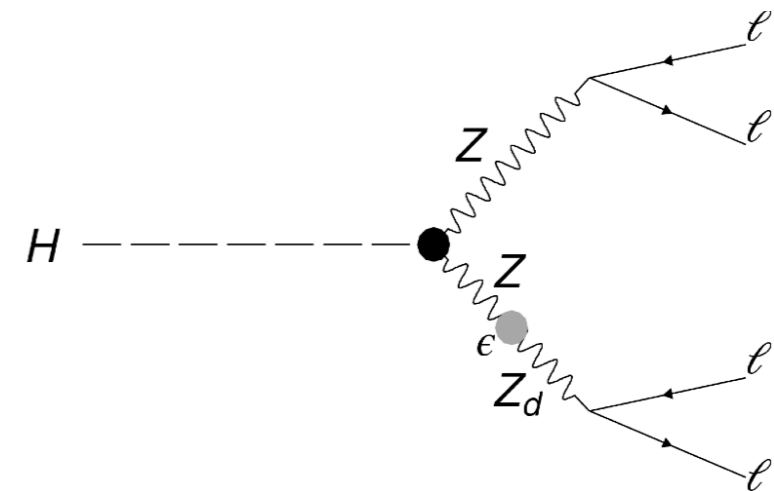
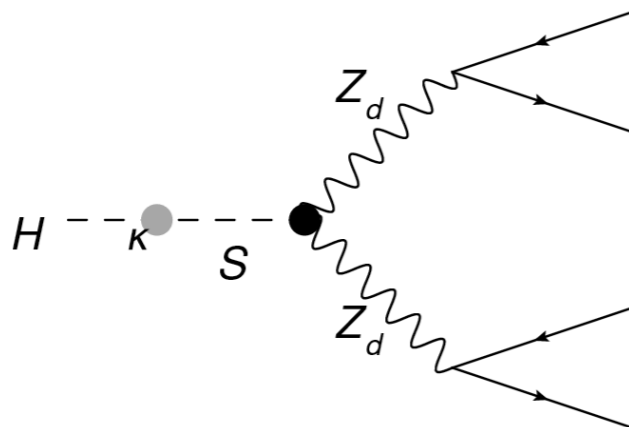
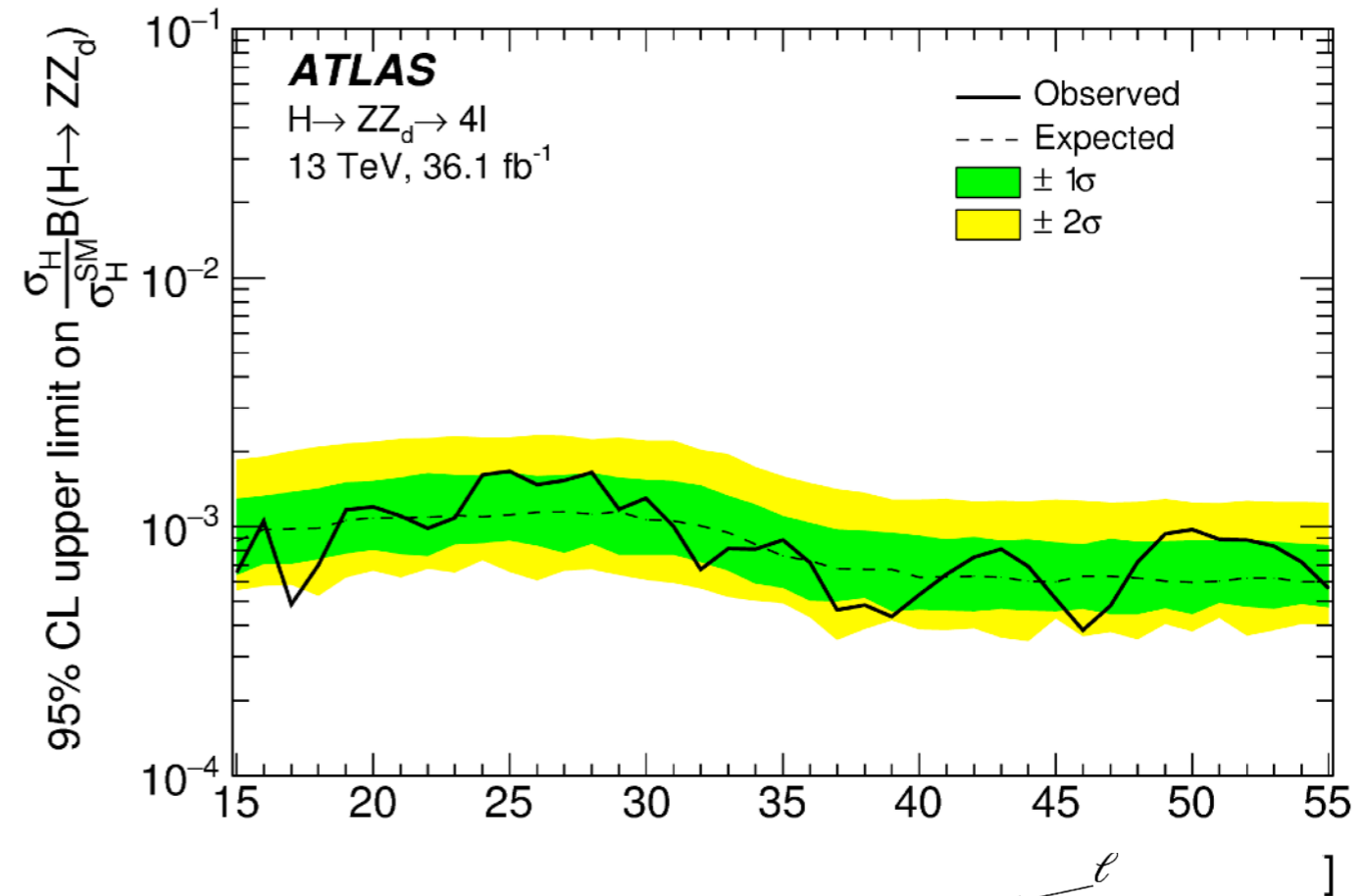
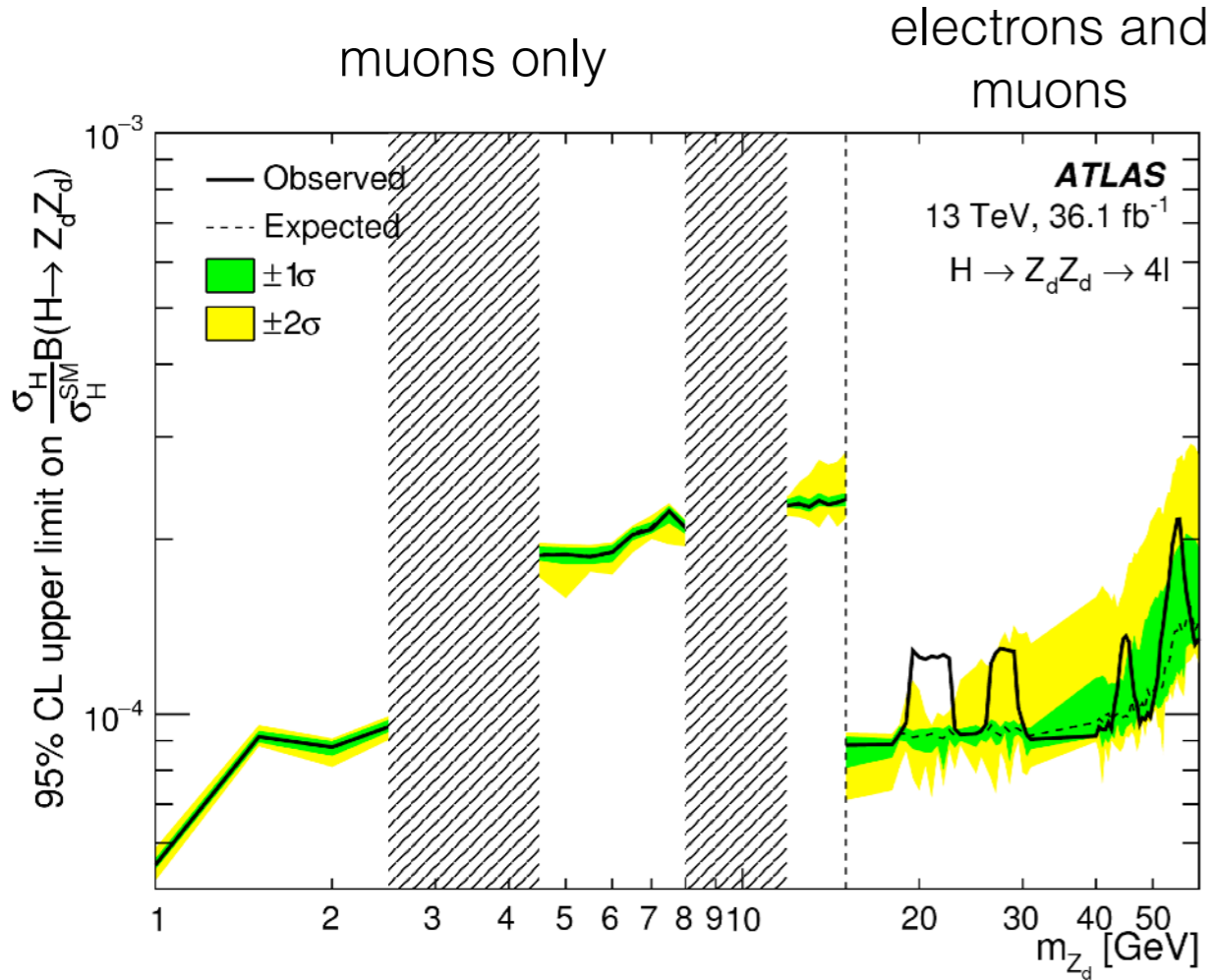
- Search strategy
 - Look for higgs production of dark photons
 - photon portal: Z mixing with γ_D (Z_D),
 - higgs portal: mixing of SM H with dark H (S) via mixing parameter κ
 - 4 lepton signature, require (m_{4L} consistent with 125 GeV)
 - photon portal: require m_{12} consistent with Z, look for di-lepton resonance above $H \rightarrow ZZ^*$ background
 - higgs portal: require consistent mass for two di-lepton pairs

Higgs portal: ATLAS



Higgs portal: ATLAS

- Results presented in terms of BR of Higgs to new states, assuming SM production of H

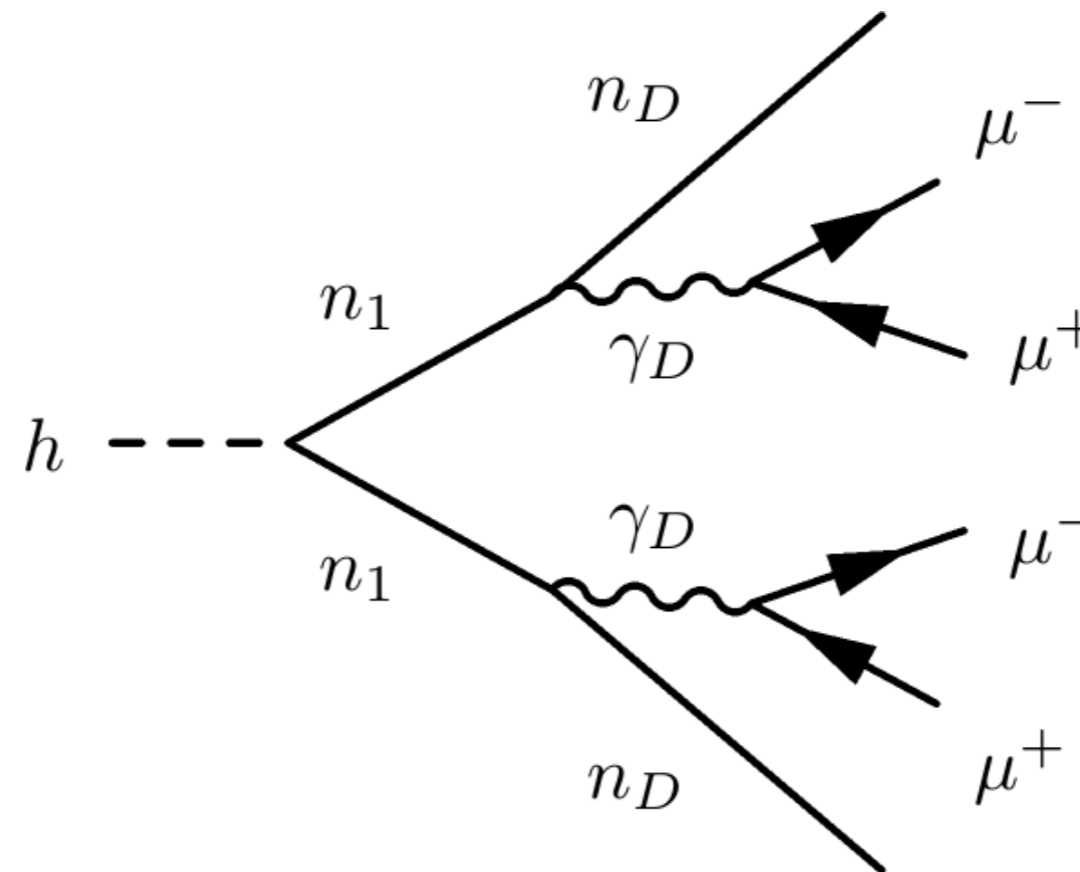


Higgs production, with SUSY

covered by Adish
yesterday

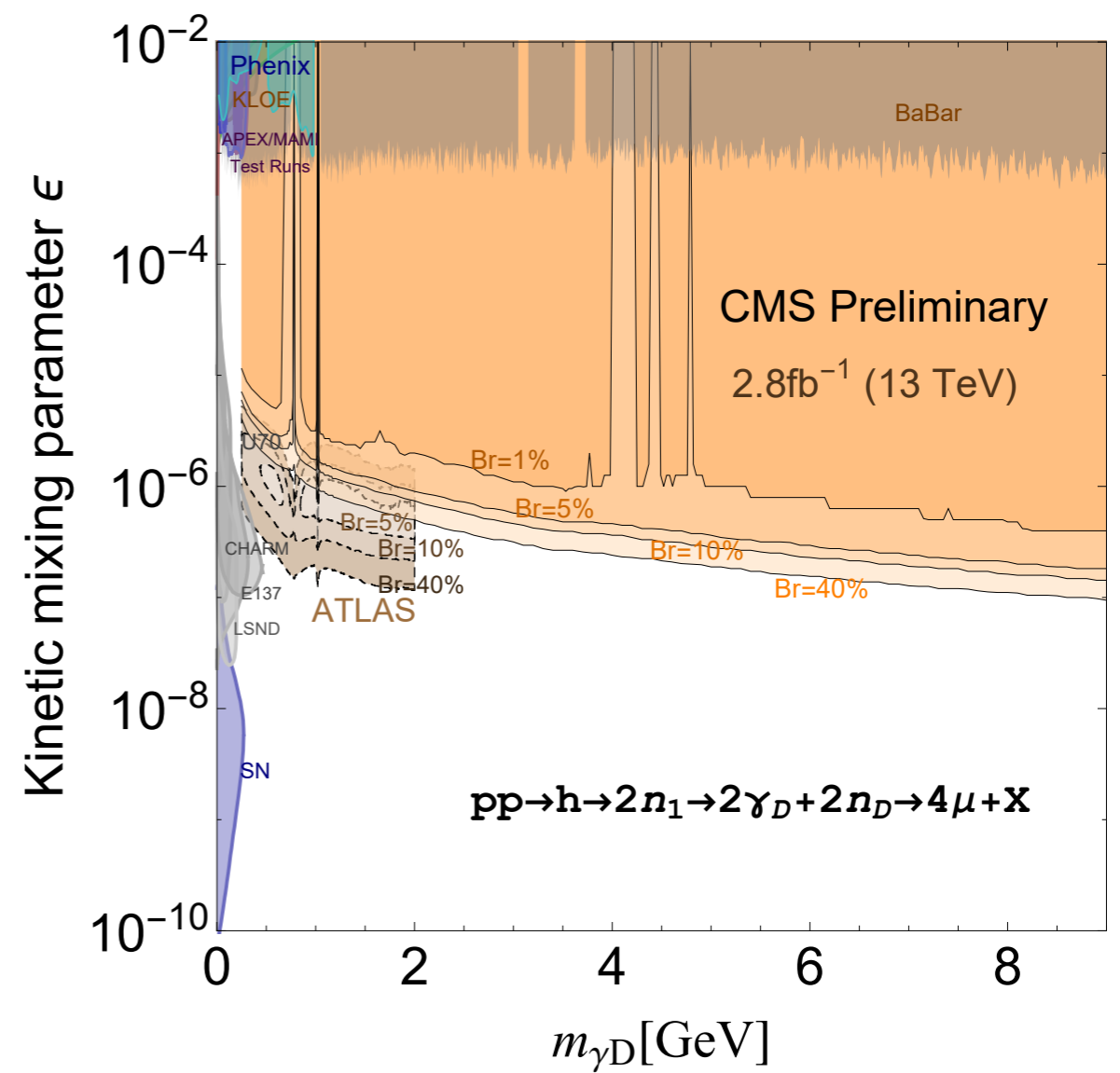
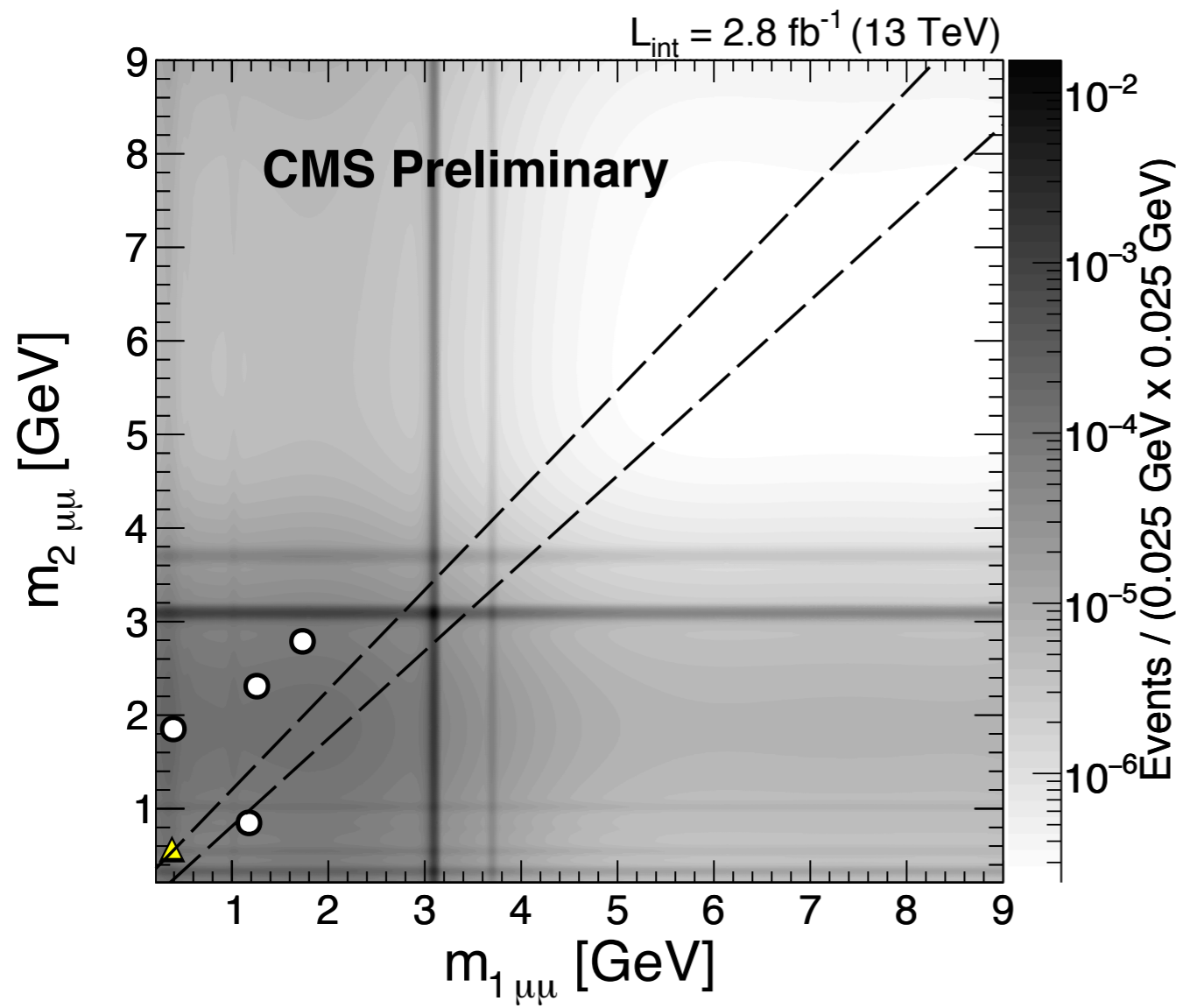
Dark SUSY: CMS

- Supersymmetry with an additional dark sector



- Signature
 - 2 pairs of $\mu^+\mu^-$ ($m(\mu^+\mu^-) < 9$ GeV) in an event, with comparable masses
 - requires $m_h > 2 m_{n_1}$
 - muon $p_T > 8$ GeV, each pair is isolated

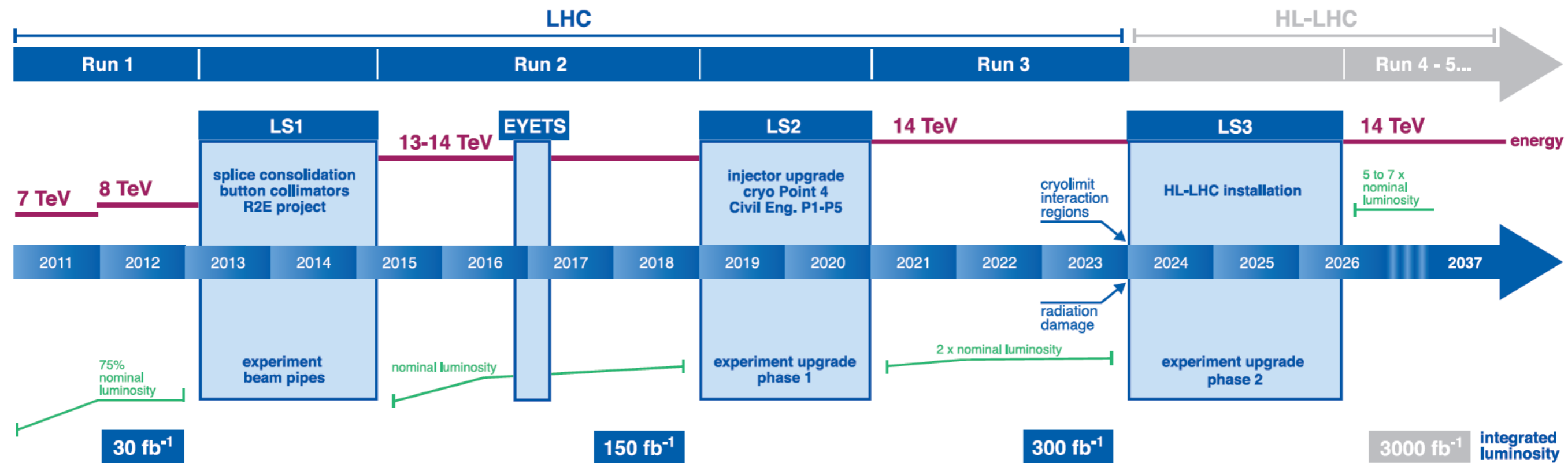
Dark SUSY: CMS

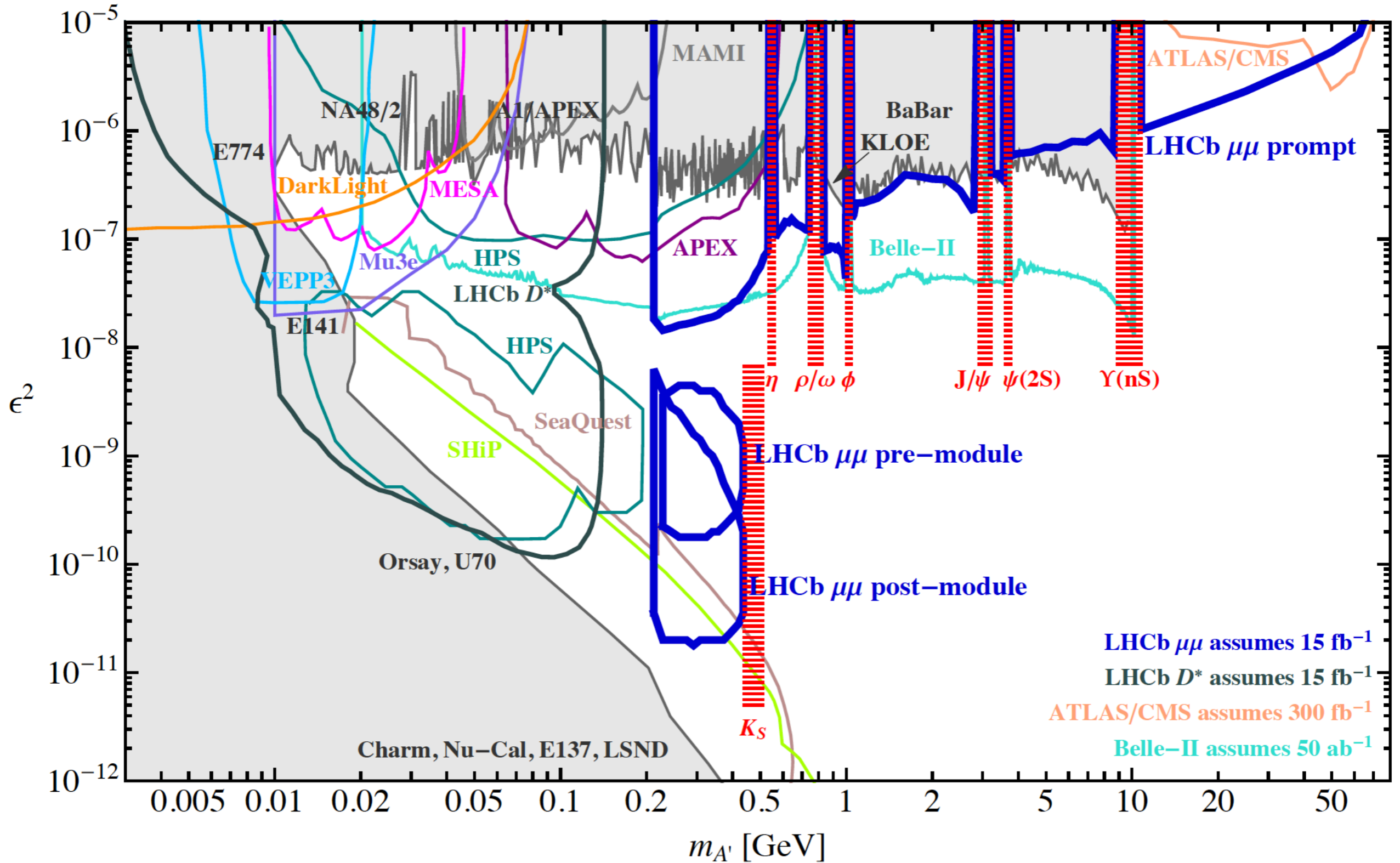


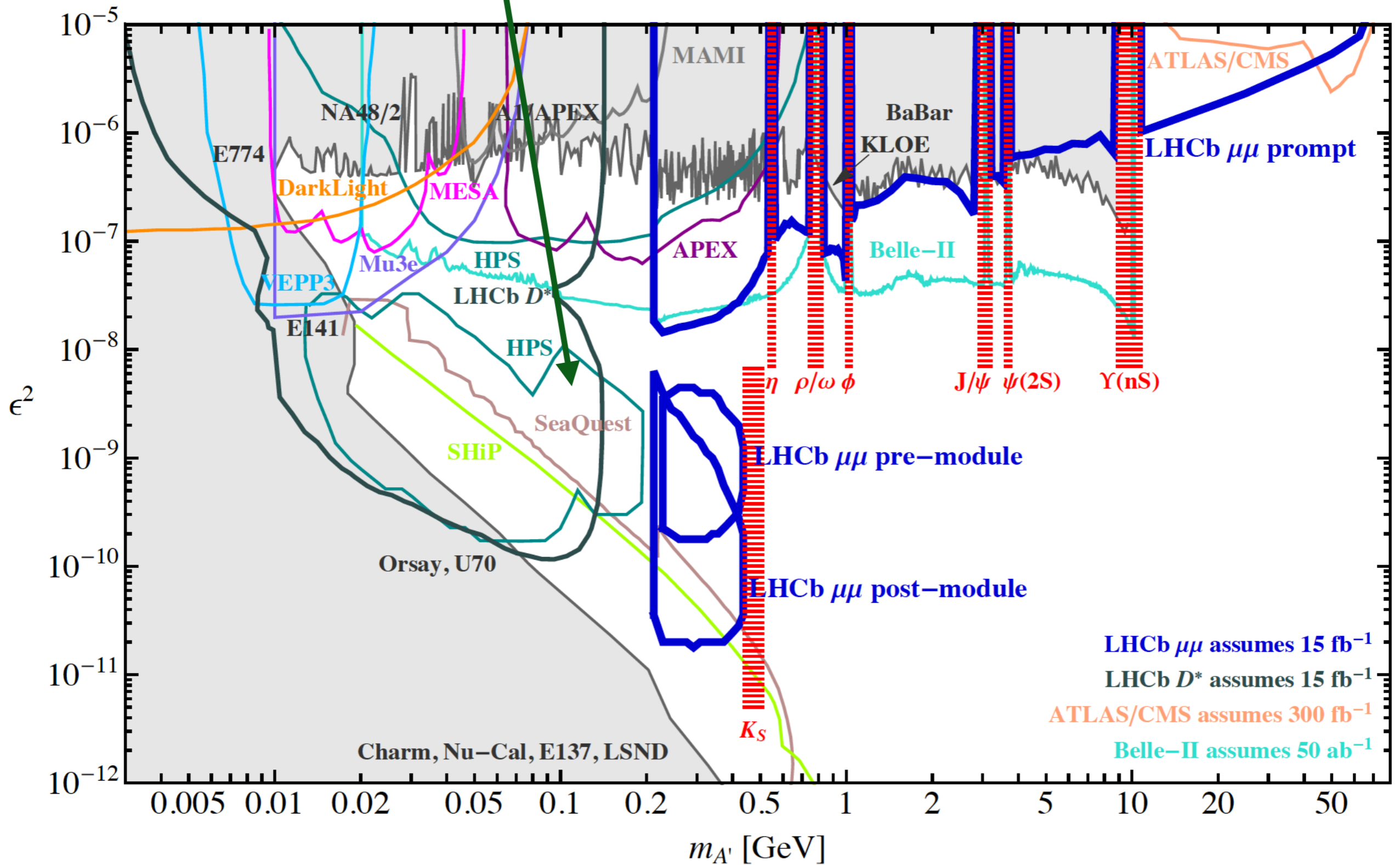
Summary and Outlook

Lots of data to come!

LHC / HL-LHC Plan

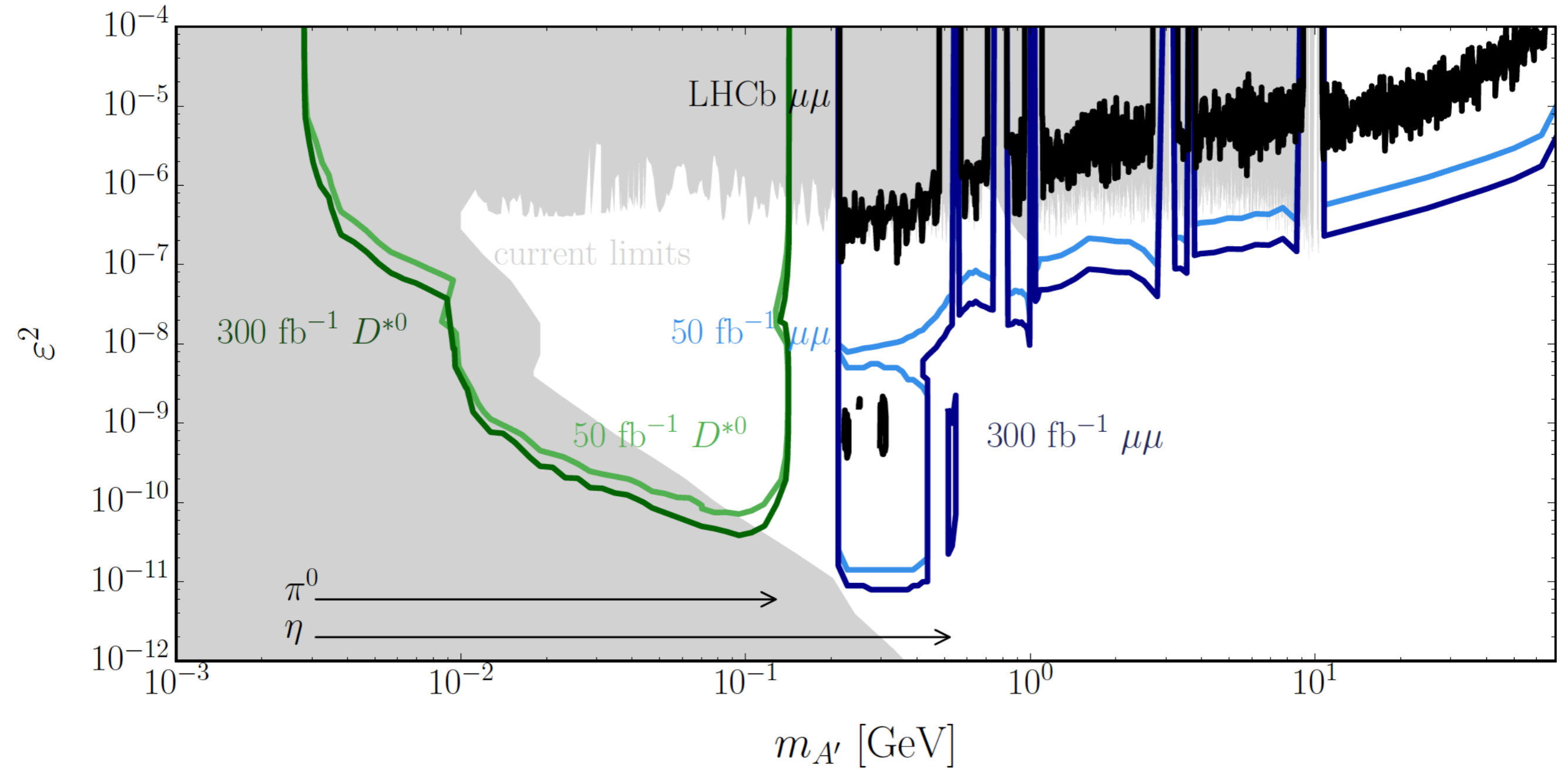






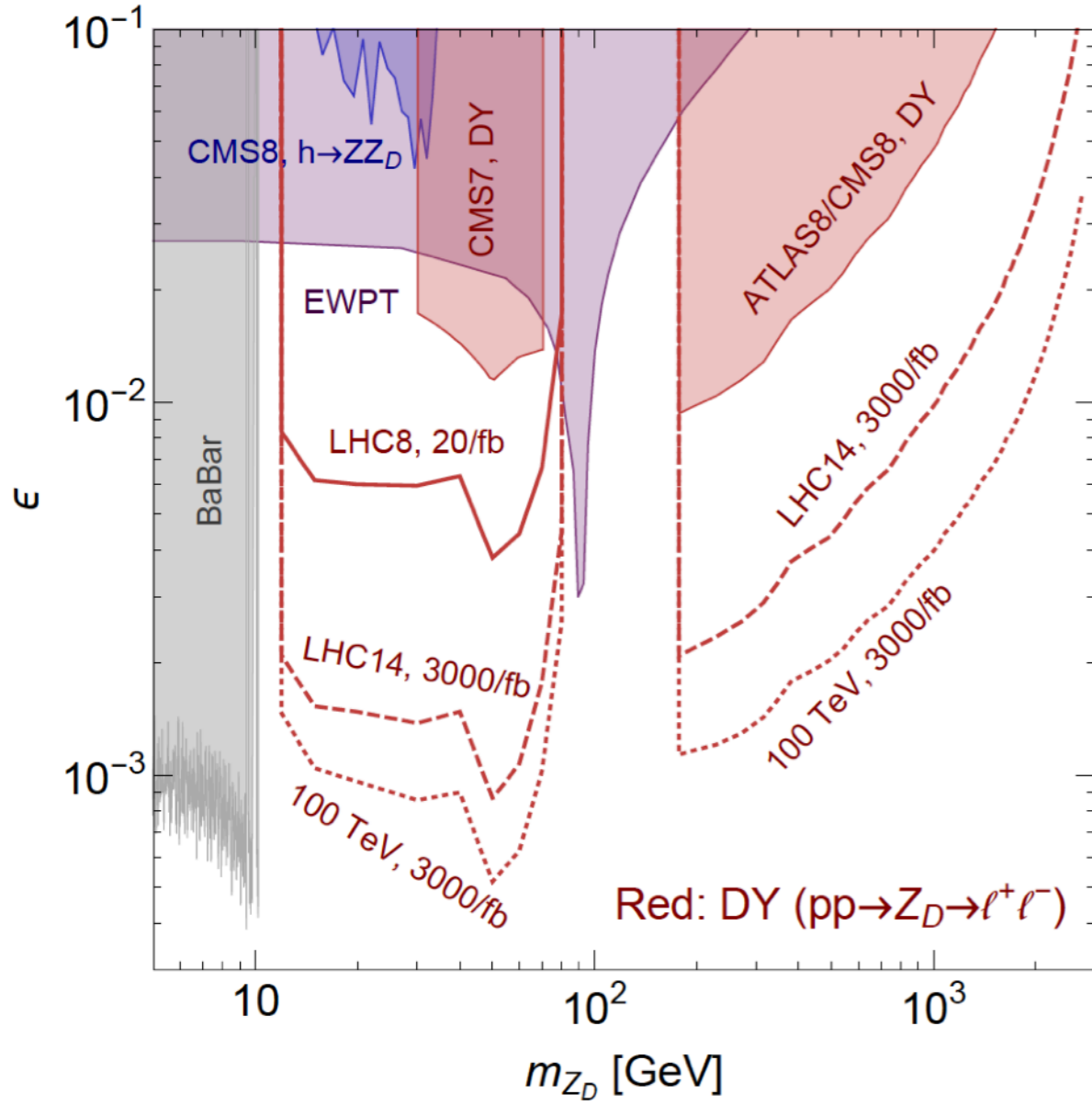
LHCb Upgrade II

- Possible upgrade beyond 2030



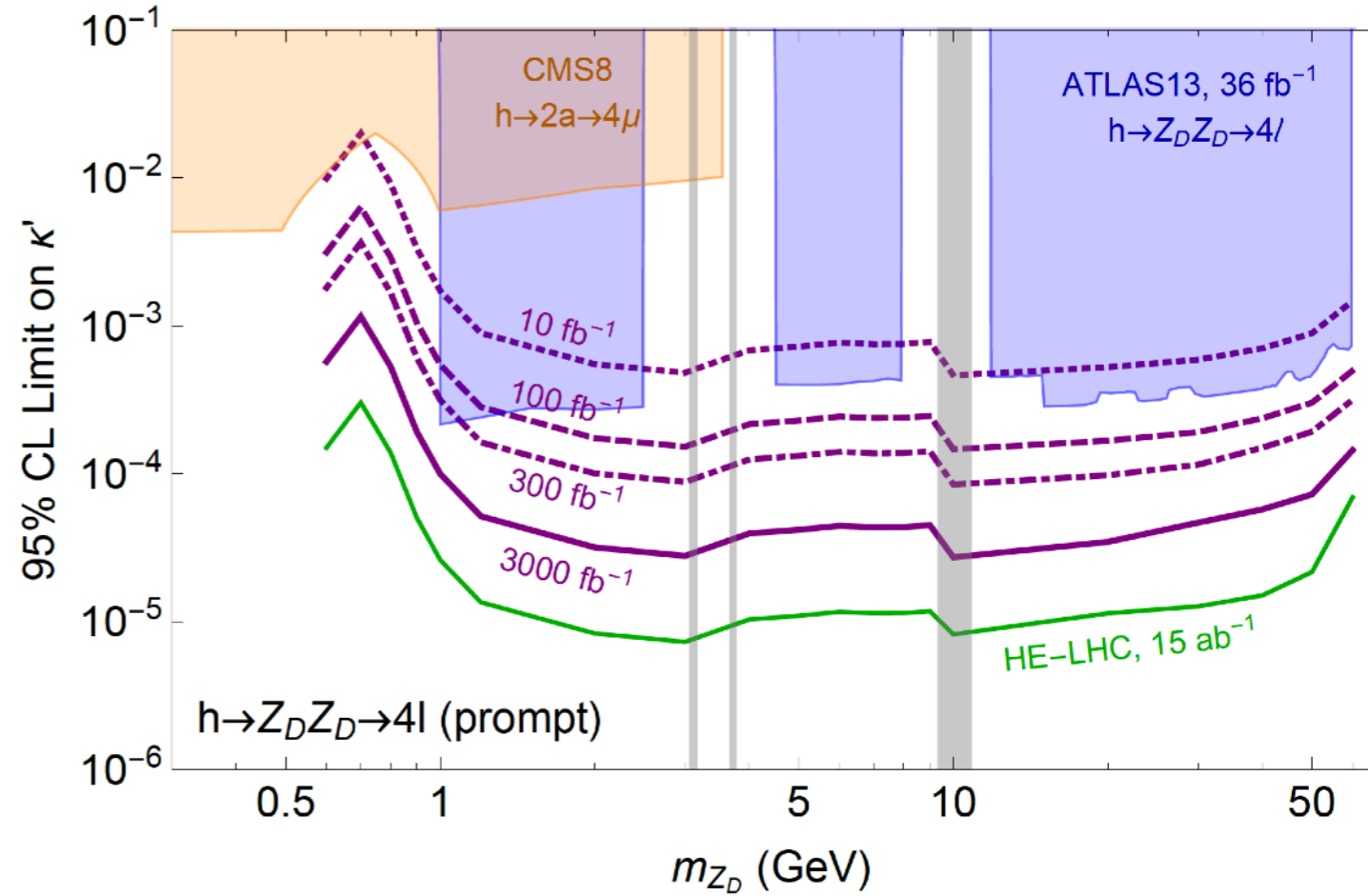
HL-LHC

Heavy dark photons



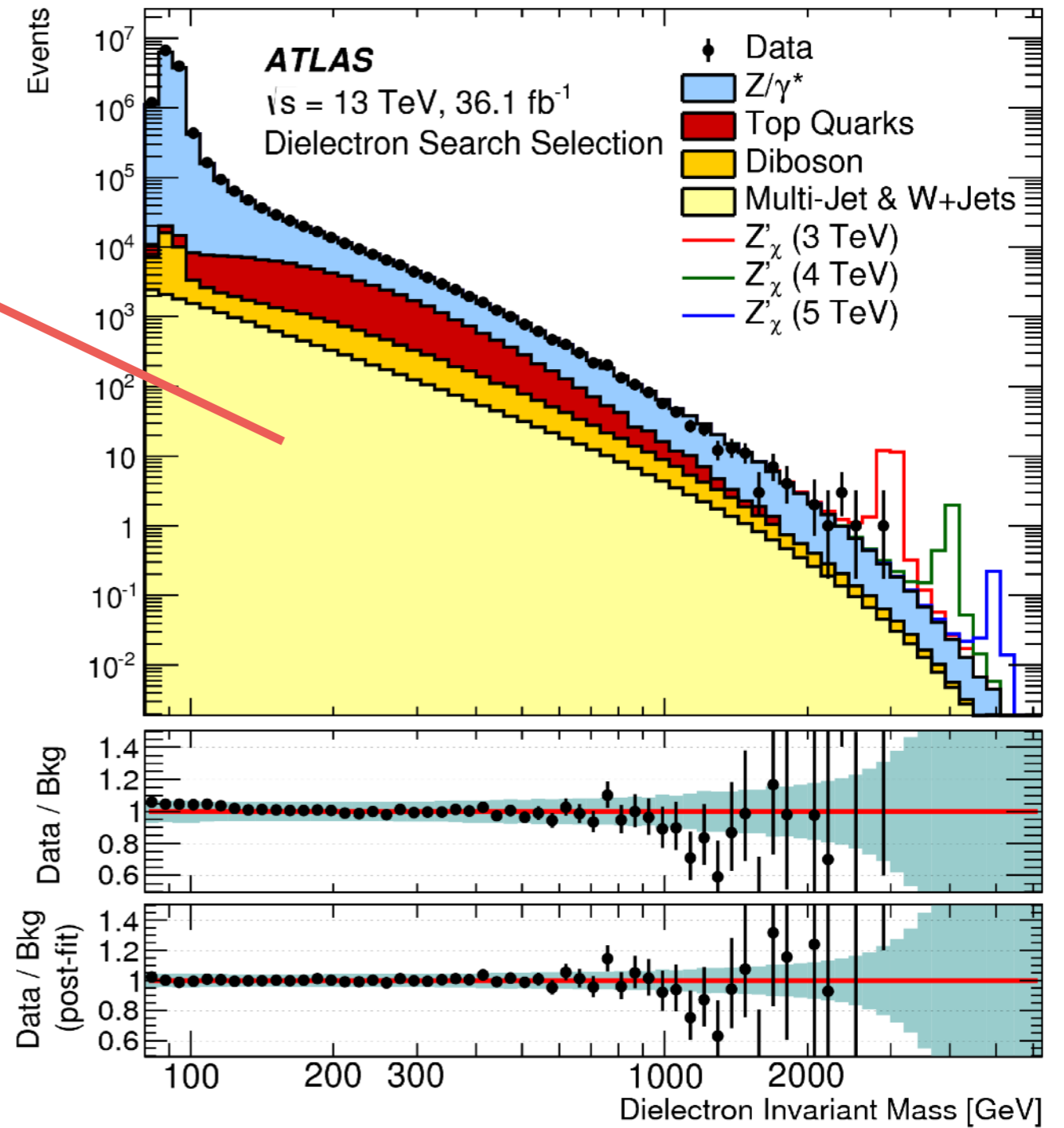
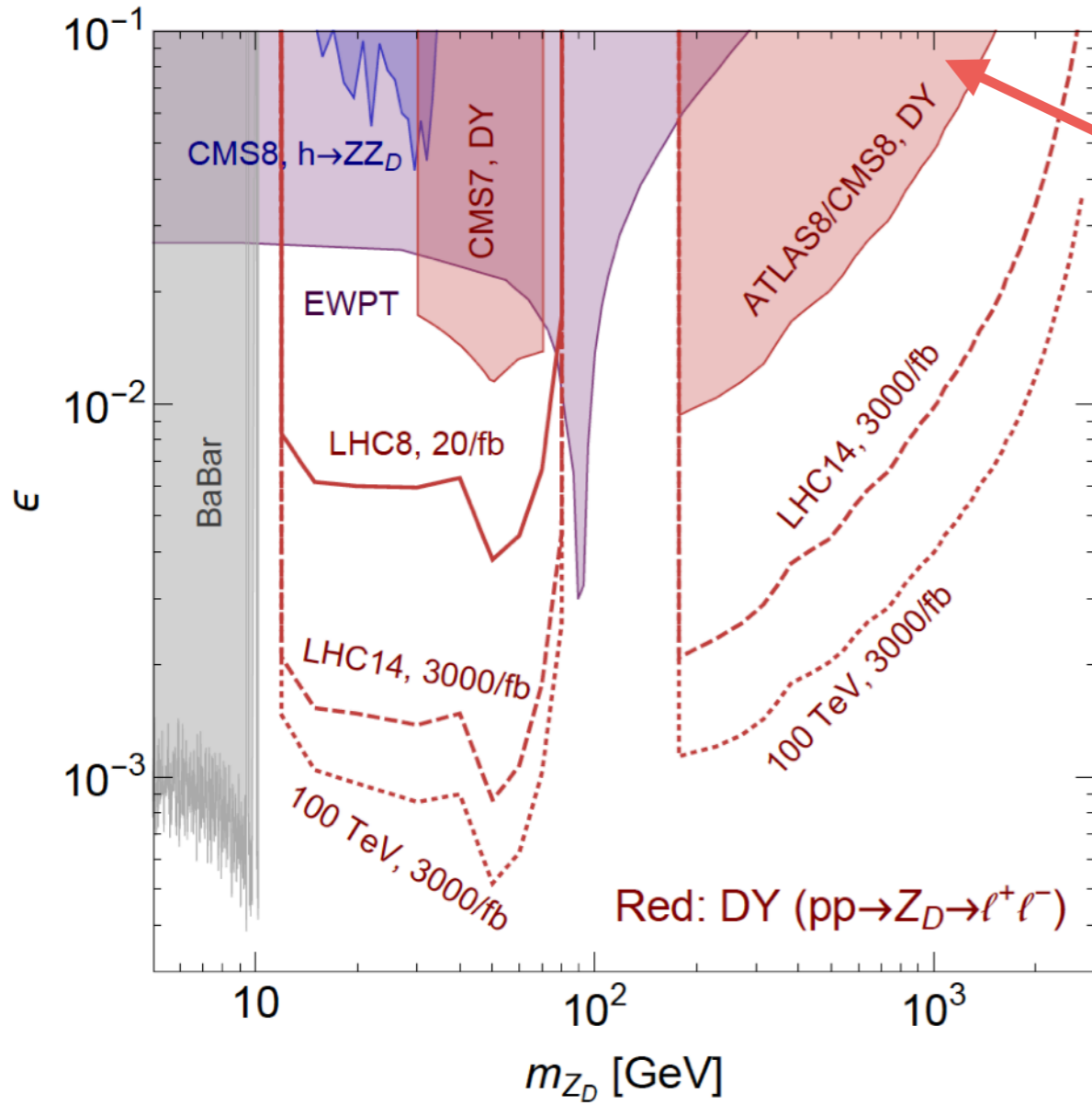
1412.0018

Higgs portal



D. Curtin, preliminary, to appear in HXSWG

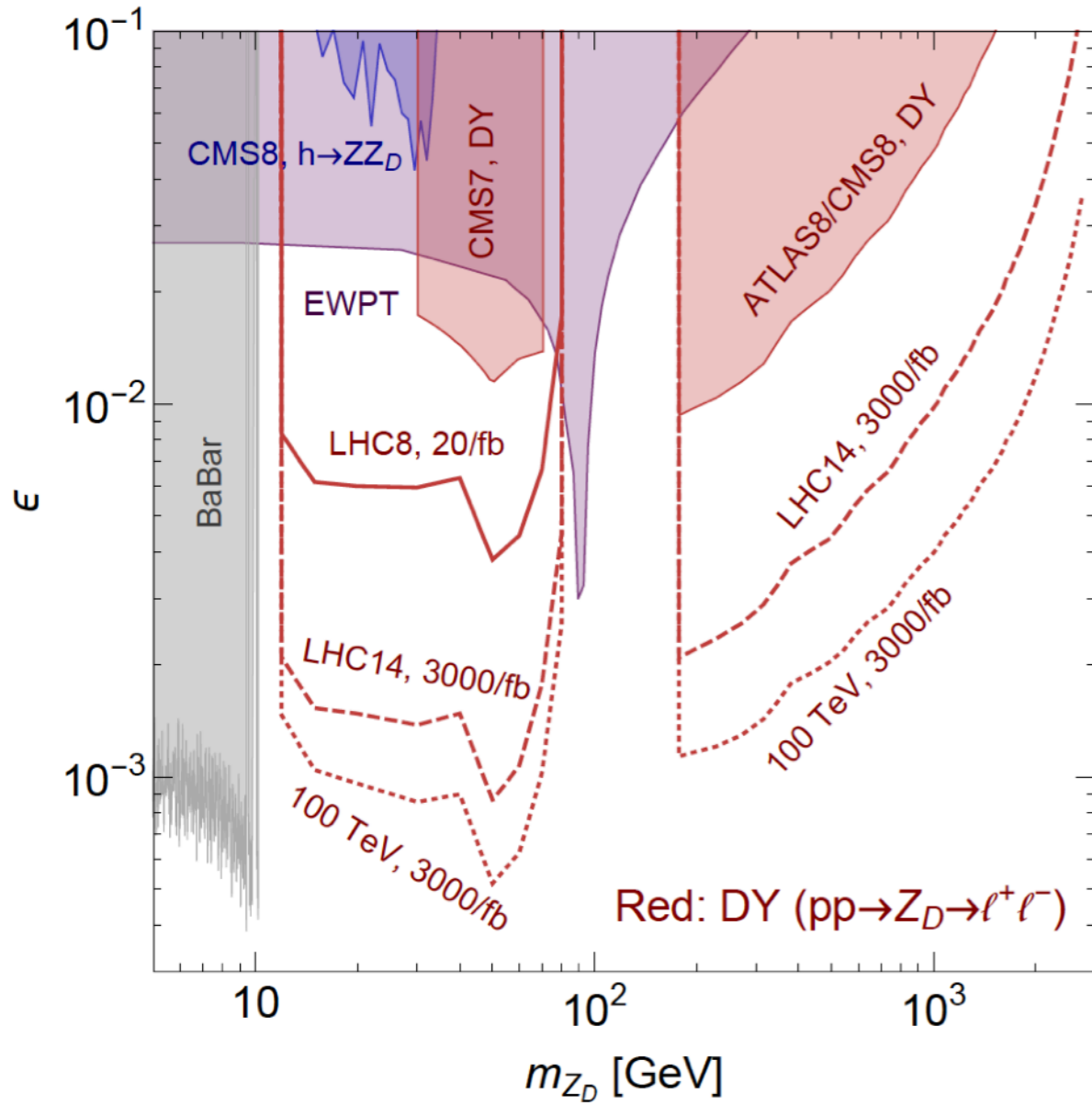
Heavy dark photons



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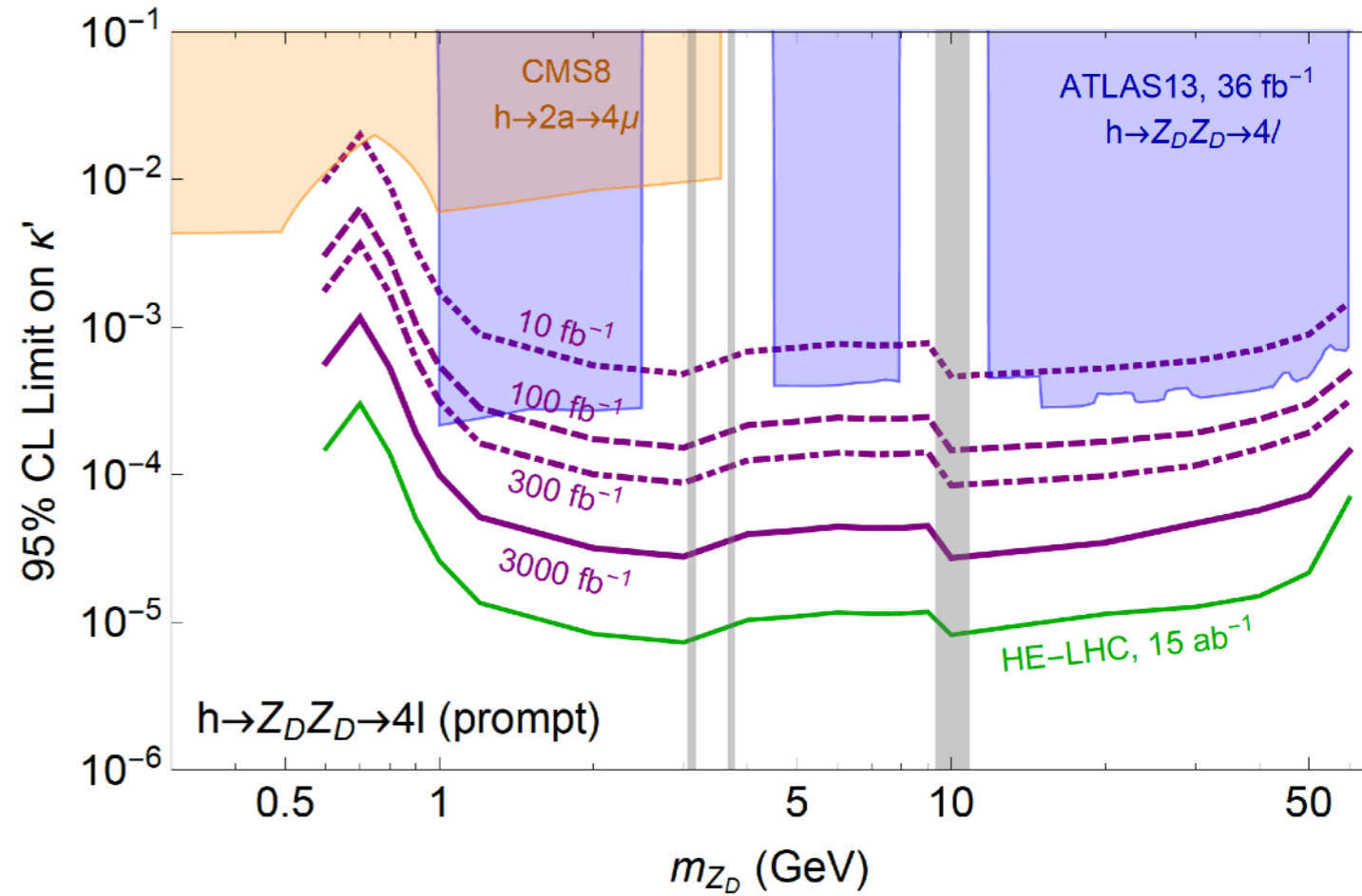
HL-LHC

Heavy dark photons



1412.0018

Higgs portal



D. Curtin, preliminary, to appear in HXSWG

extras

Prompt LJs with ATLAS (8 TeV)

