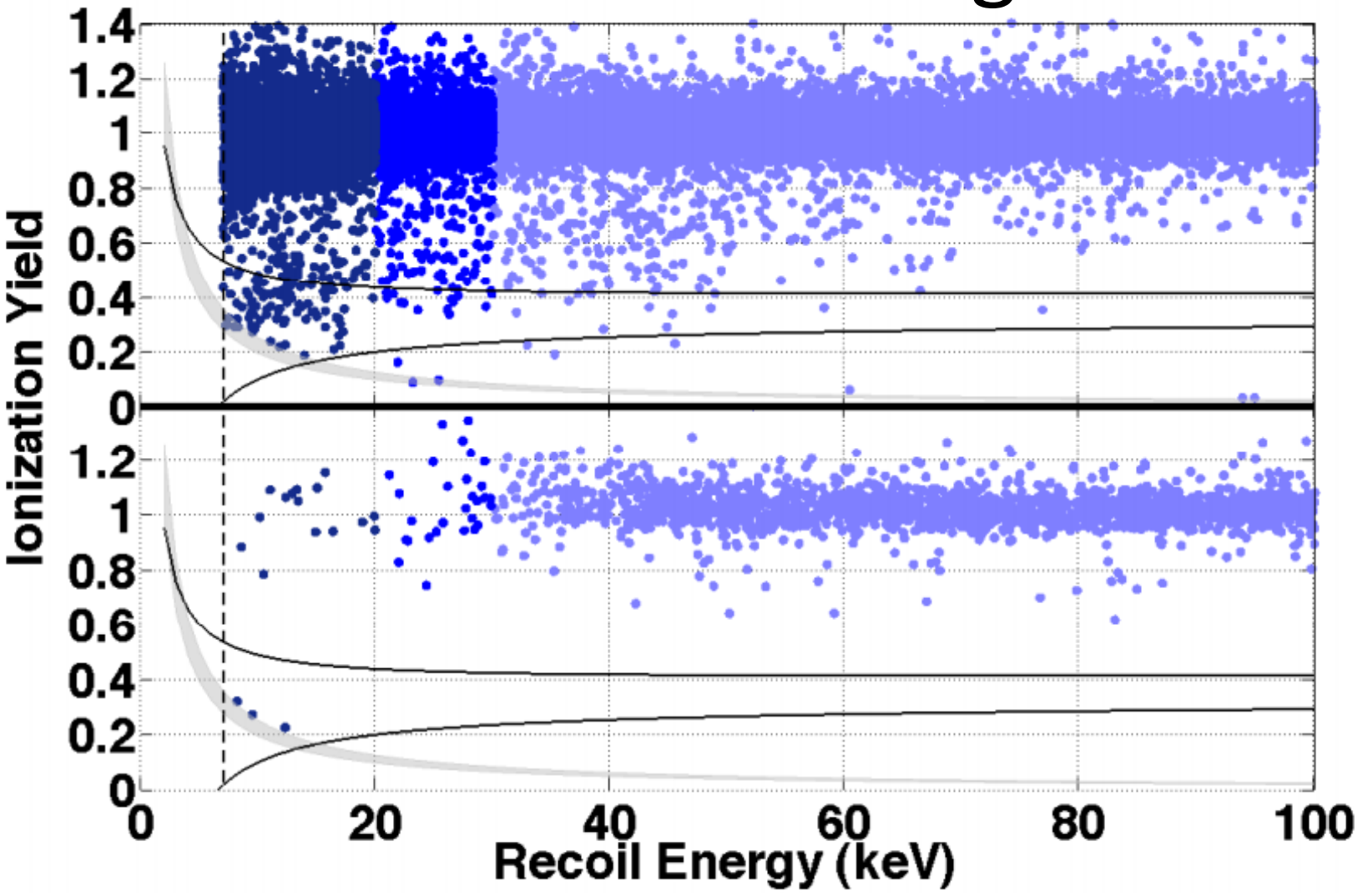
Particle Physics Implications and Constraints on Dark Matter Interpretations of the CDMS Signal

Alexander M. Wijangco

UC Irvine

R. C. Cotta, A. Rajaraman, T. M.P. Tait

What is the CDMS Signal?



CDMS Collaboration, R. Agnese et. al., Dark Matter Search Results Using the Silicon Detectors of CDMS II, Phys.Rev.Lett. (2013) [arXiv:1304.4279].

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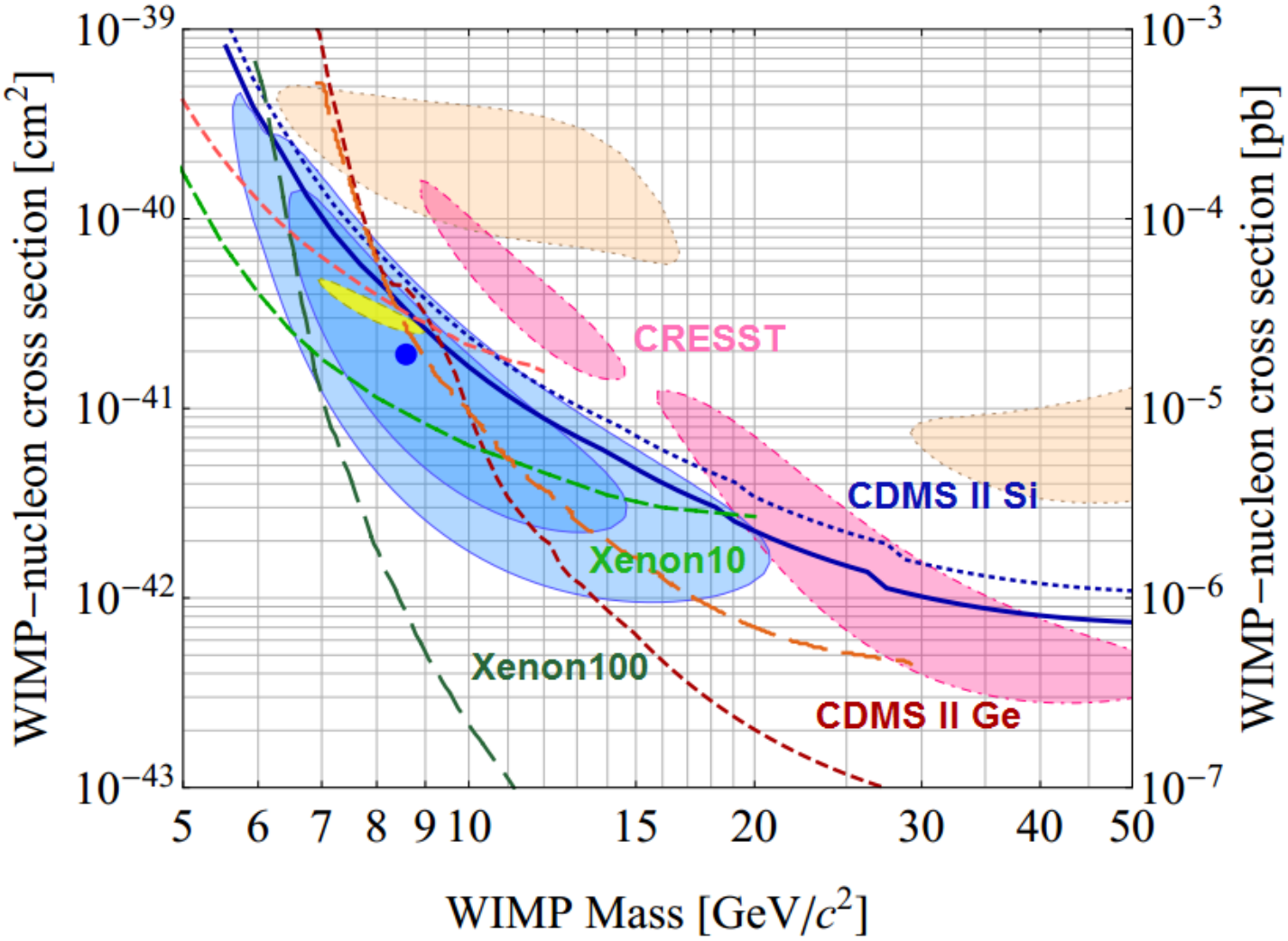


CDMS Collaboration, R. Agnese *et. al.*, Dark Matter Search Results Using the Silicon Detectors of CDMS II, Phys.Rev.Lett. (2013) [arXiv:1304.4279].
XENON10 line moves due to M.T. Frandsen *et al.*, 1304.6066

How can we explain this signal?

- Tension with XENON
  - Isospin Violation
- Could be a contact operator
  - Tension with colliders
- Light Mediator
  - Vector or Scalar
  - Vectors outside of a U(1) tend to have equal coupling

Related Work

- Contact Operators:
  - K. Cheung *et al.*, 1308.0067; M. Buckley, 1308.4146
- Vector Mediators
  - R. Foot, 1209.5602; S, Andreas *et al.*, 1306.1168
- Other
  - D. Hooper, 1306.1790; K-Y Choi *et al.*, 1305.4322; Y. Zhang *et al.*, 1307.6178; Y. Bai *et al.*, 1308.0612; L. Bian *et al.*, 1308.3851; N. Okada *et al.*, 1304.6791, S. Socpel *et al.*, 1304.5353

Particle Framework

- The Dark Matter: χ
  - χ is a WIMP
  - χ is a Dirac fermion
  - The mass of χ is assumed to be about 8.6 GeV, the CDMS best fit value.
- Dark Matter Interactions:
  - Interactions are mediated by a scalar particle, φ
  - Scalar interactions follow the MFV framework and thus proportional to the SM Higgs Yukawas.

Light Scalar and Light DM

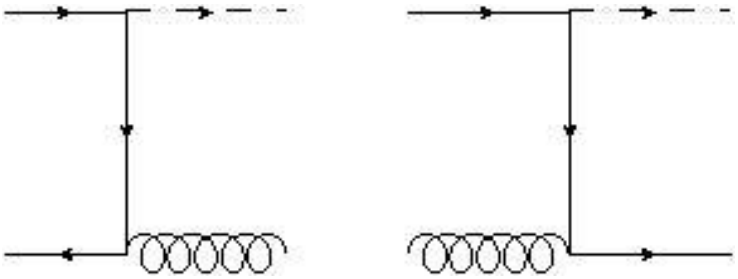
- The interaction Lagrangian:

$$\mathcal{L}_{int} = g_\chi \phi \bar{\chi} \chi + \sum_i g_d \lambda_i^d \phi \bar{d}_i d_i + \sum_i g_u \lambda_i^u \phi \bar{u}_i u_i$$

- There are three couplings: g_χ, g_d, g_u
  - Changing the ratio of g_d to g_u determines whether one is in the isospin preserving or isospin violating case

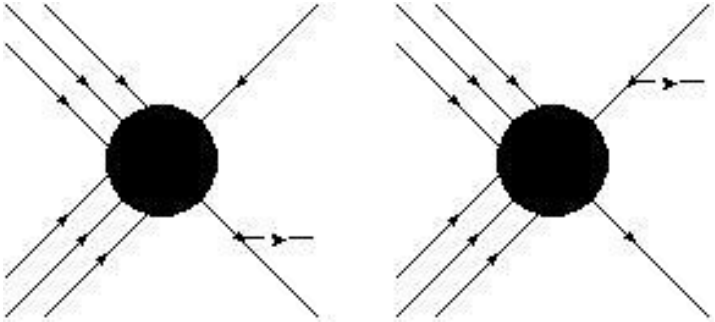
Collider Bounds

- Monojet Searches:



  - Function of g_χ, g_d, and g_u
  - Requires off shell production of mediator to pass MET cuts

- Top pair + MET:

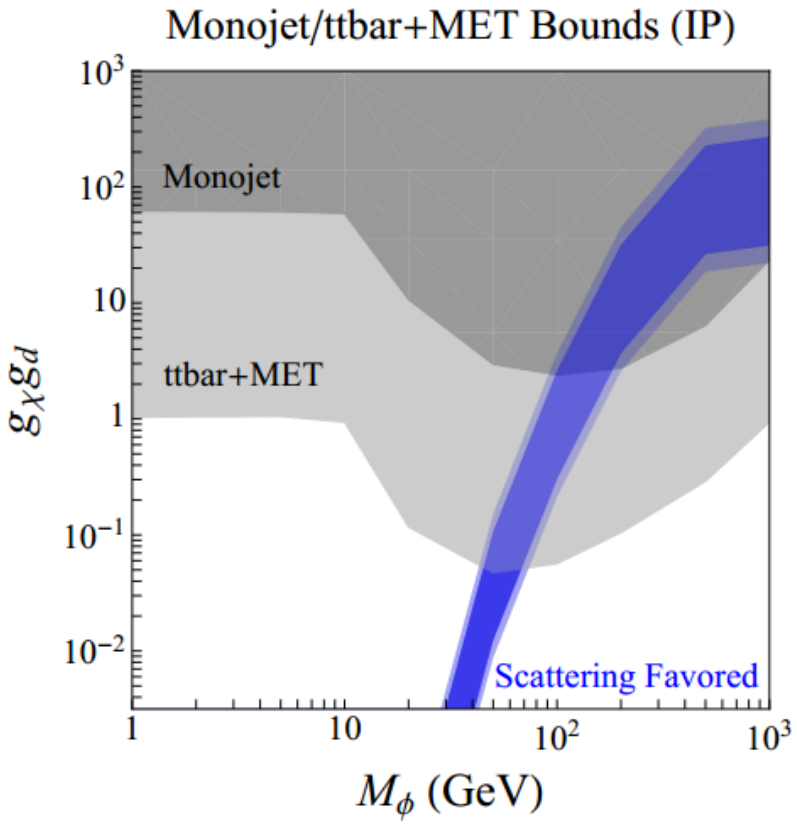


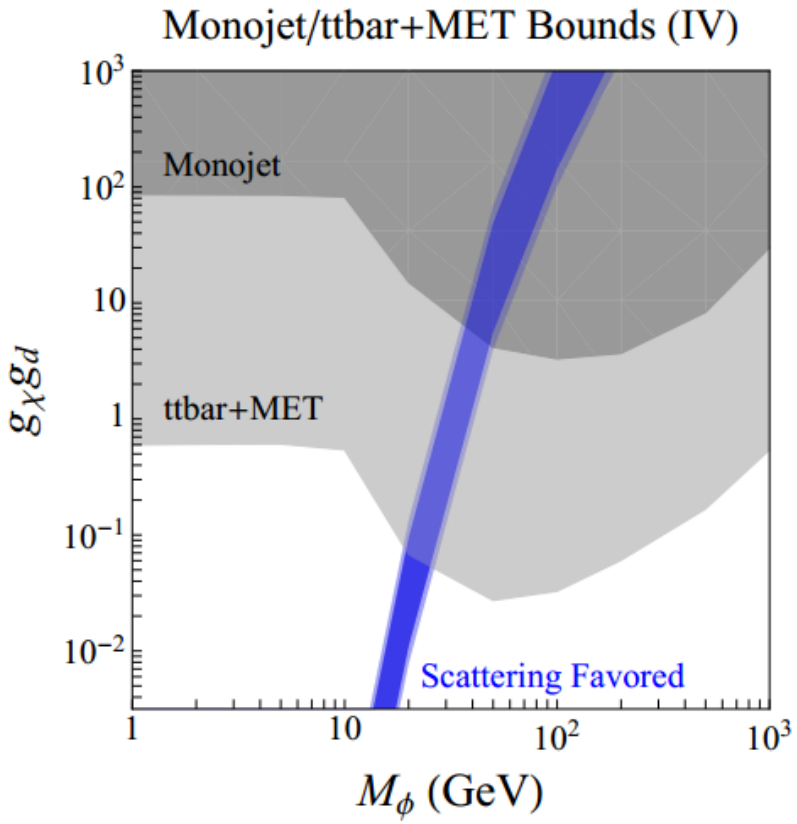
  - Function of g_χ and g_u
  - Requires top pair tag
- Top pair + HF
  - Not yet comparable

G. Aad *et al.* [ATLAS Collaboration], "Search for dark matter candidates and large extra dimensions in events with a jet and missing transverse momentum with the ATLAS detector," JHEP **1304**, 075 (2013) [arXiv:1210.4491 [hep-ex]].

[ATLAS Collaboration], "Search for a supersymmetric top-quark partner in final states with two leptons in sqrt(s) = 8 TeV pp collisions using 13 ifb of ATLAS data," ATLAS-CONF-2012-167.

Collider Bounds





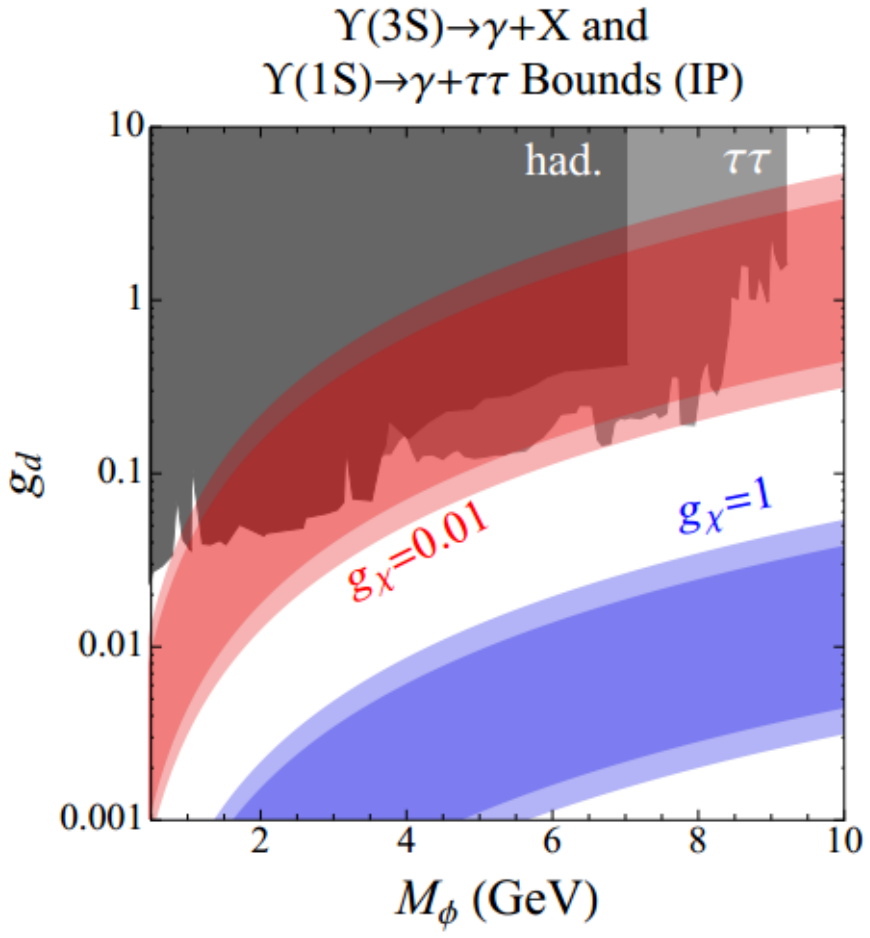
Upsilon Decay Bounds

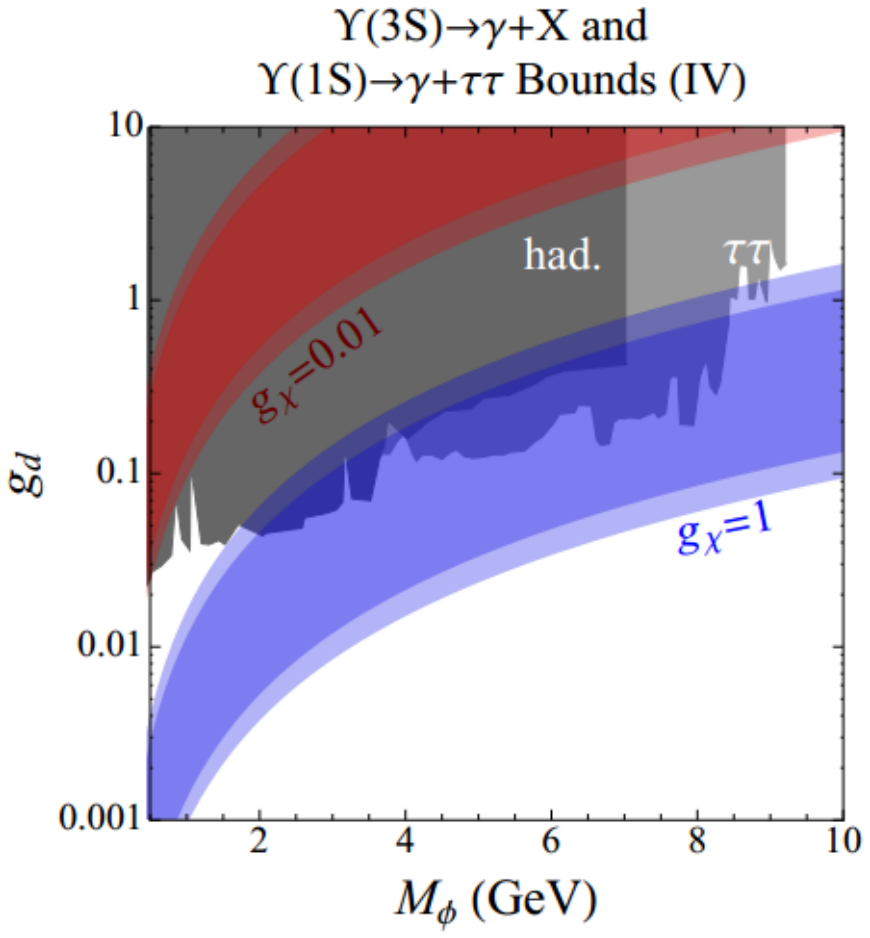
- Photon + Hadronic and Photon + Tau Pair
  - Consider $\Upsilon \rightarrow \gamma + \varphi$ and φ decays either hadronically or to a pair of taus.
  - Search for resonance in on-shell production of φ
  - For tau channel, we make the additional assumption that the coupling to the tau is proportional to the $\lambda_\tau \times g_d$

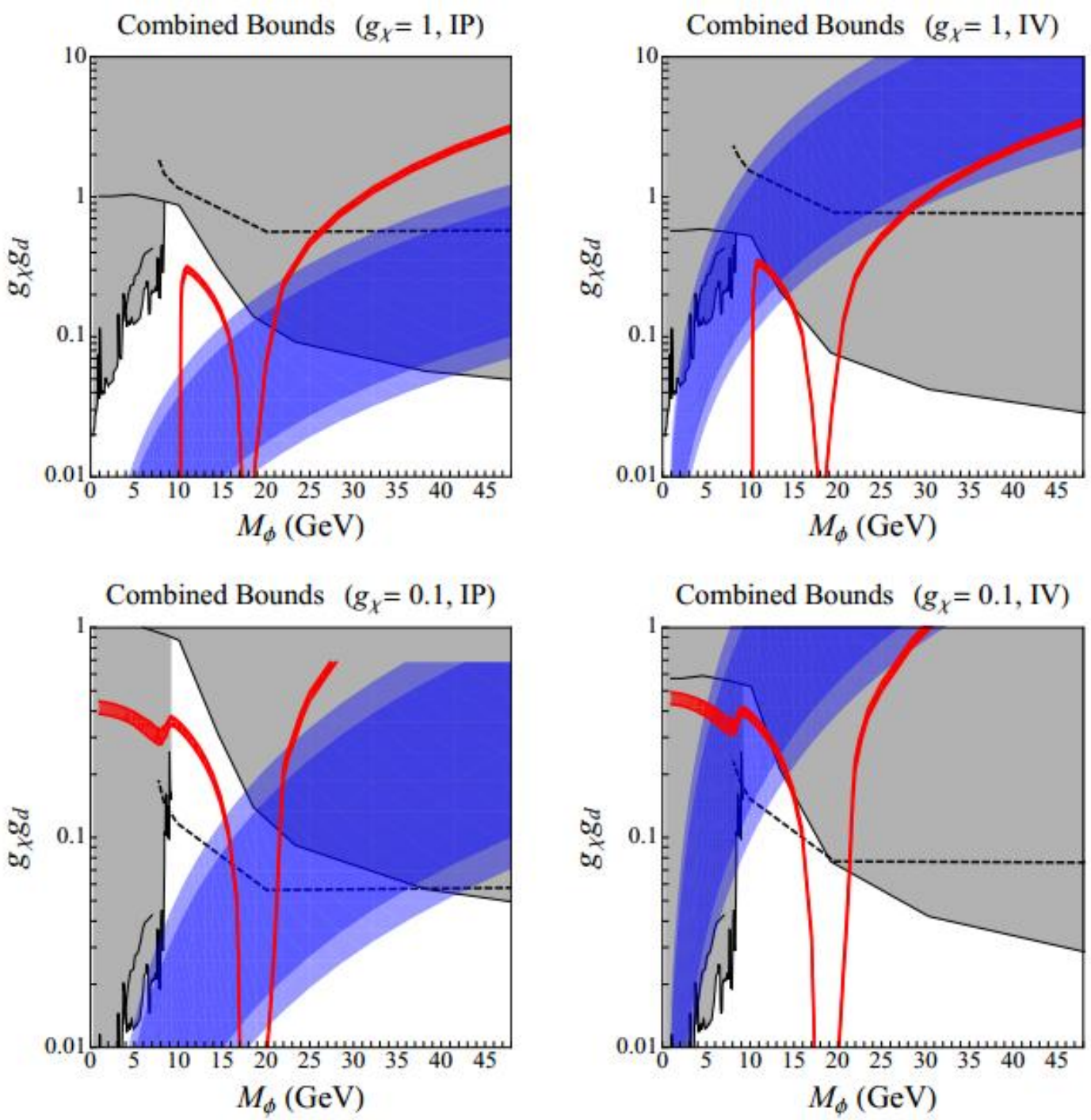
J. P. Lees *et al.* [BaBar Collaboration], "Search for a Low-Mass Scalar Higgs Boson Decaying to a Tau Pair in Single-Photon Decays of Upsilon(1S)," arXiv:1210.5669 [hep-ex].

J. P. Lees *et al.* [BaBar Collaboration], "Search for hadronic decays of a light Higgs boson in the radiative decay Upsilon to gamma A^0," Phys. Rev. Lett. **107**, 221803 (2011) [arXiv:1108.3549 [hep-ex]].

Upsilon Decay Bounds






Combined Bounds (g_χ= 1, IP)
Combined Bounds (g_χ= 1, IV)
Combined Bounds (g_χ= 0.1, IP)
Combined Bounds (g_χ= 0.1, IV)
$g_\chi g_d$
M_ϕ (GeV)
10
1
0.1
0.01
0 5 10 15 20 25 30 35 40 45

Window for 10 GeV Scale Physics

- There exists a window for new physics on the order of 10 GeV
- This simplified model is not UV complete
  - NMSSM
  - Dark Light Higgs
- This window may be probed in the future by:
  - Improved direct detection bounds
  - Anomalous heavy flavor LHC searches
  - Higgs sector measurements