Complex Singlet Extended SM and CoGeNT (and Xenon100)

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Outline

- Motivation
- Intro to the complex singlet extended SM (csxSM)
- Constraints
- Results
  - Spin independent scattering cross section
  - Higgs signatures
- The debate: CoGeNT vs. Xenon100
- Conclusions

Motivation

- Recent results from the CoGeNT collaboration favor a light DM scenario: arXiv:1002.4703
  - $M_{DM} \sim 7 - 11\ GeV$
  - $\sigma_{SI} \sim 10^{-41} - 10^{-40}\ cm^2$
- In the context of the complex singlet extened SM (csxSM): arXiv:0811.0393
  - Satisfy CoGeNT, WMAP, LEP constraints.
  - Study Higgs phenomenology

The csxSM

$$V_{\rm csxSM} = \frac{m^2}{2} H^\dagger H + \frac{\lambda}{4}(H^\dagger H)^2 + \frac{\delta_2}{2} H^\dagger H |\mathcal{S}|^2 + \frac{b_2}{2}|\mathcal{S}|^2 + \frac{d_2}{4}|\mathcal{S}|^4 + \left(\frac{|b_1|}{4} e^{i\phi_{b_1}} \mathcal{S}^2 + |a_1| e^{i\phi_{a_1}} \mathcal{S} + c.c.\right)$$

$$\mathcal{S} = S + iA$$

- Real component, S, obtains a vacuum expectation value v_s
- Complex component, A, is stable (DM particle)
- For viable phenomenology we set $\varphi_{b1} = \pi$ and $\varphi_{a1} = 0$

Particle Content

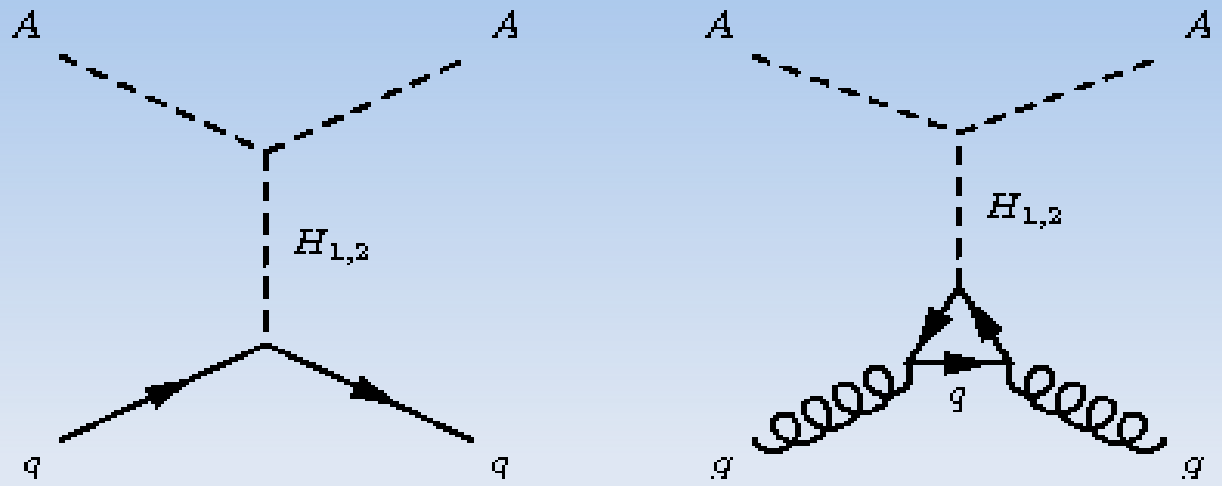
$$M^2_{H_{1,2}} = \frac{1}{4}\left(\lambda v^2 + d_2 v_S^2 - \frac{2\sqrt{2}a_1}{v_S} \mp \sqrt{\left(\lambda v^2 - d_2 v_S^2 + \frac{2\sqrt{2}a_1}{v_S}\right)^2 + 4\delta_2^2 v^2 v_S^2}\right)$$

$$M_A^2 = b_1 - \frac{\sqrt{2}a_1}{v_S}$$

$$\tan 2\phi = \frac{2\delta_2 v v_S}{\lambda v^2 - d_2 v_S^2 + \frac{2\sqrt{2}a_1}{v_S}}$$

- H_1 and H_2 couplings to SM particles are reduced by cos(φ) and -sin(φ) respectively.

Spin-independent scattering cross section



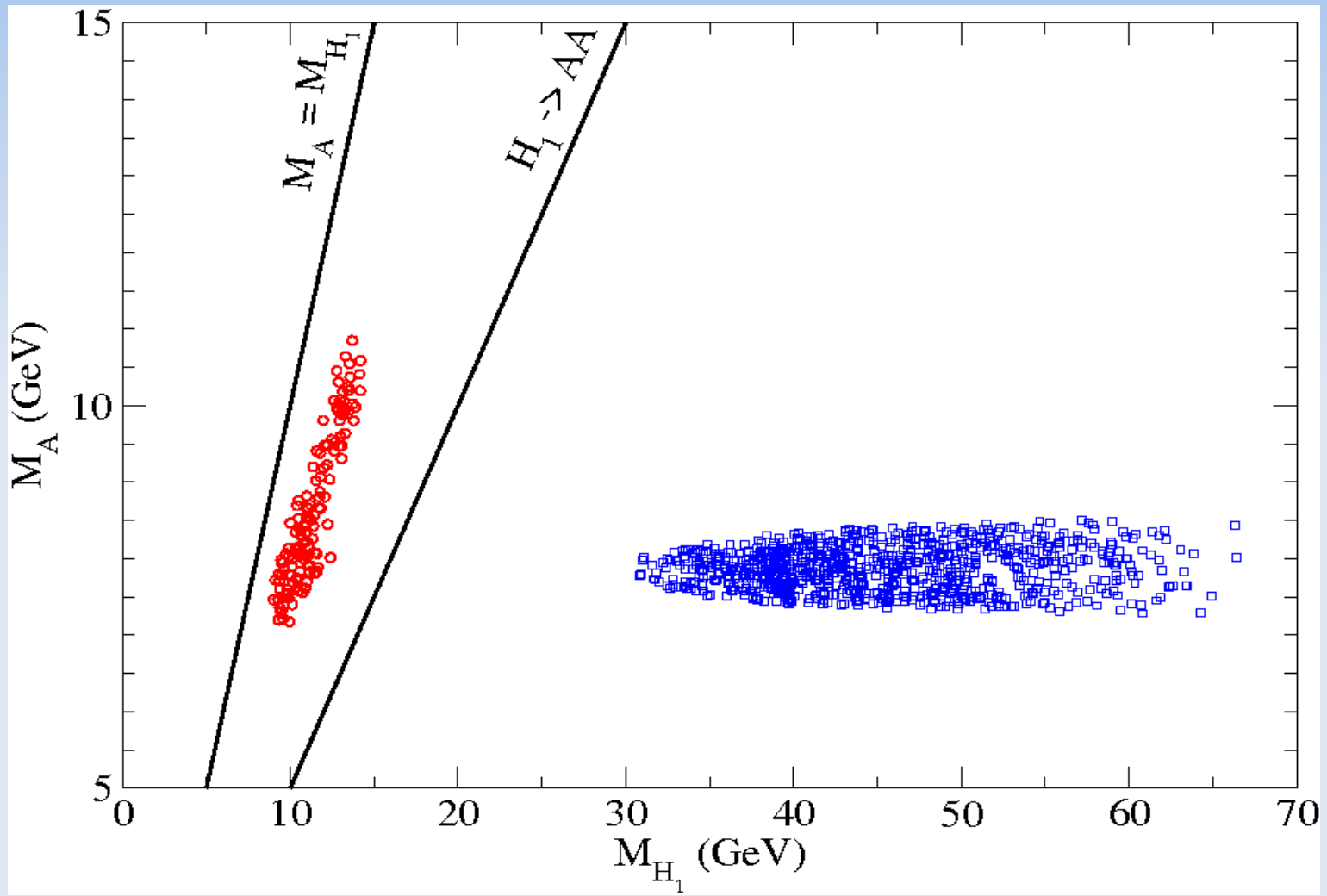
$$\sigma_{SI} = \frac{m_p^4}{2\pi v^2 (m_p + M_A)^2} \left(\frac{g_{AAH_1} \cos\phi}{M_{H_1}^2} - \frac{g_{AAH_2} \sin\phi}{M_{H_2}^2} \right)^2 \left(f_{pu} + f_{pd} + f_{ps} + \frac{2}{27}(3 f_G) \right)^2$$

- Barger, Keung, Shaughnessy. arXiv:0806.1962
- Spin-independent cross sections agree with those calculated by micrOmegas.

Constraints

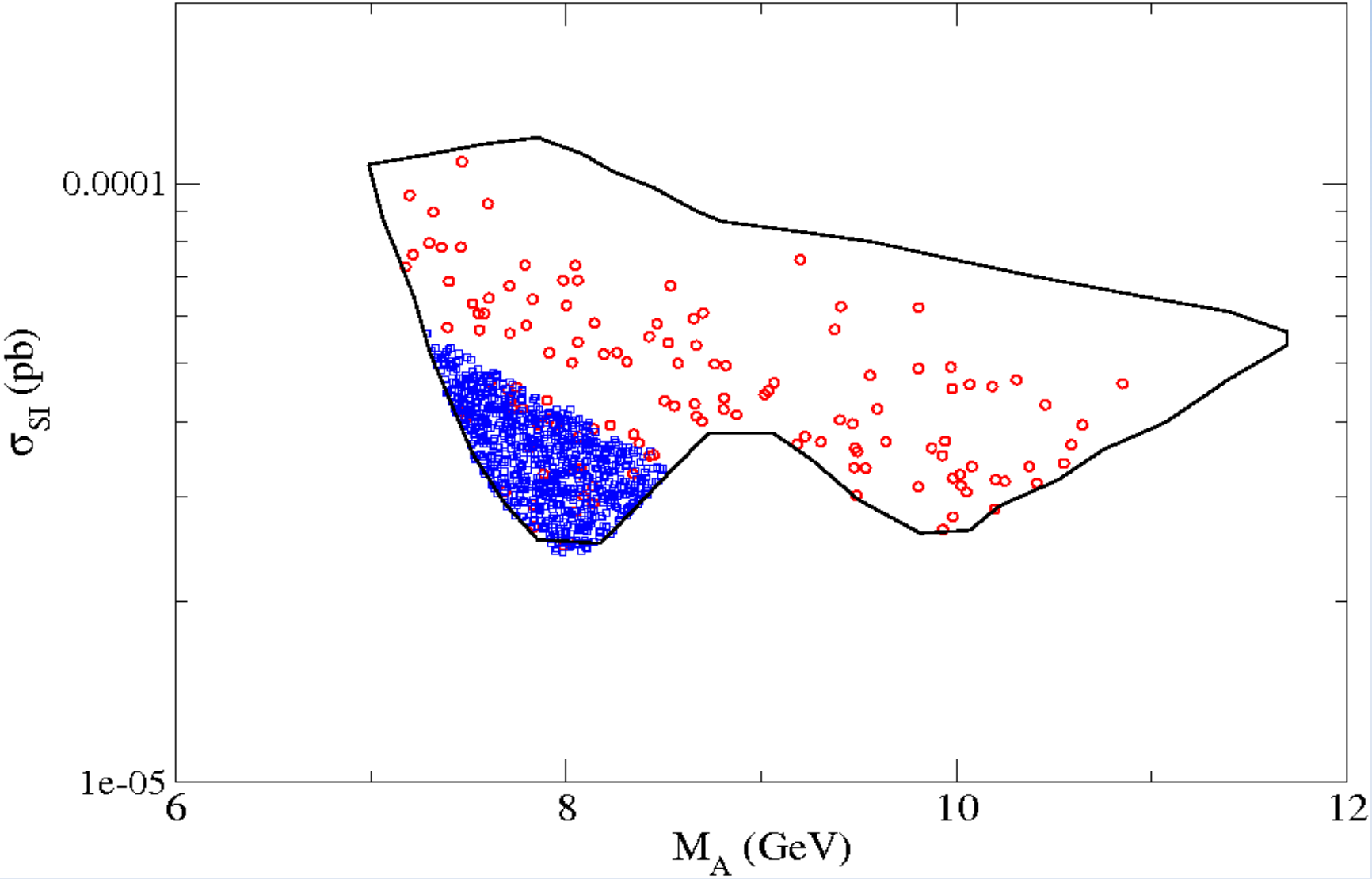
- WMAP constraints on the relic density
  - $0.099 < \Omega h^2 < 0.122$
  - Calculated using micrOmegas
- LEP constraints (OPAL and DELPHI)
  - Higgs decay to SM and invisible modes
  - ZZh coupling
- Cascade decays
  - $H_2 \rightarrow$ 4 b, 2b 2tau, 4 tau
- EWPO
  - $H_2 < 180$ GeV

Results: Mass spectrum



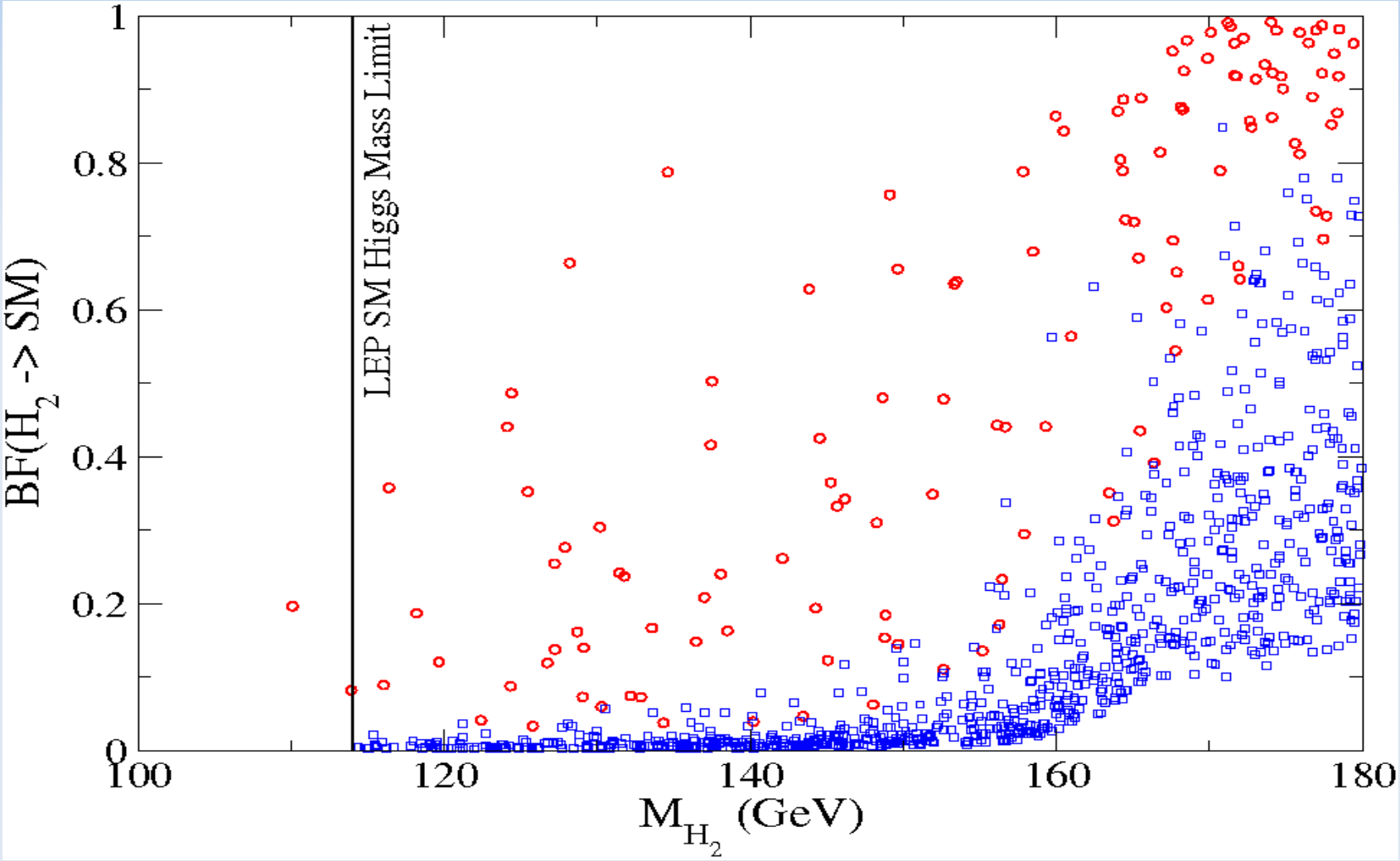
- 110 GeV < MH_2 < 180 GeV

Results: σ_{SI}

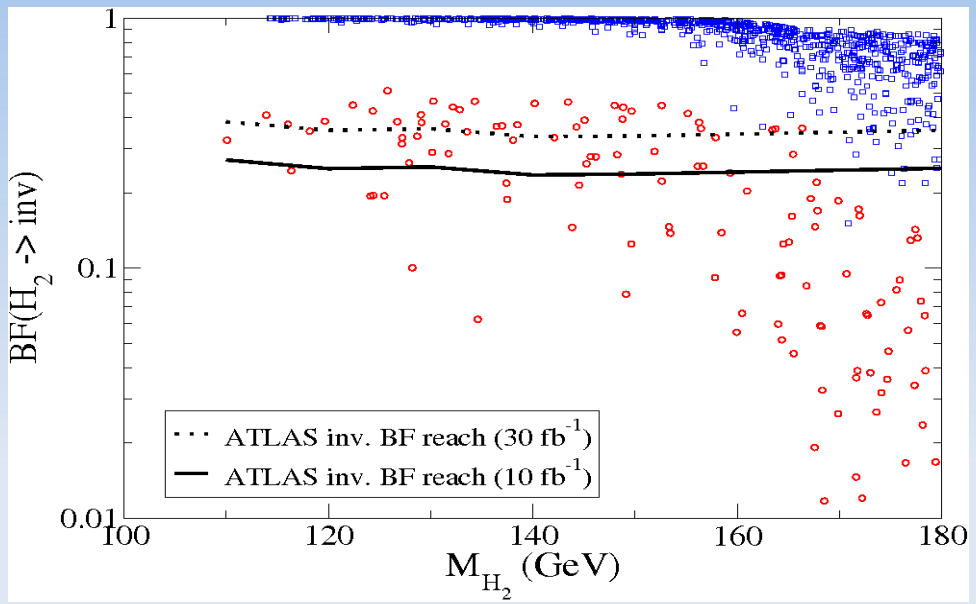


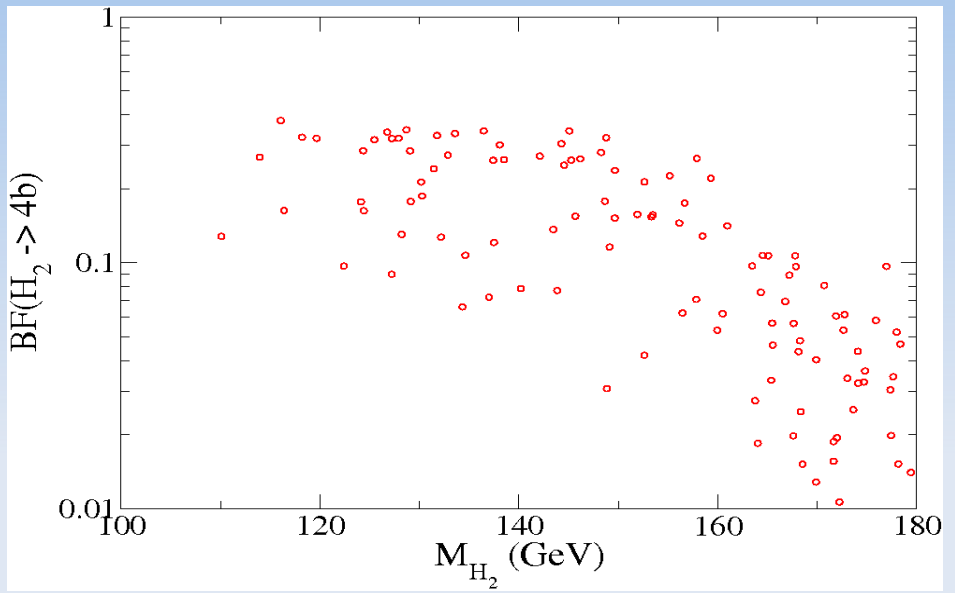
Higgs signatures

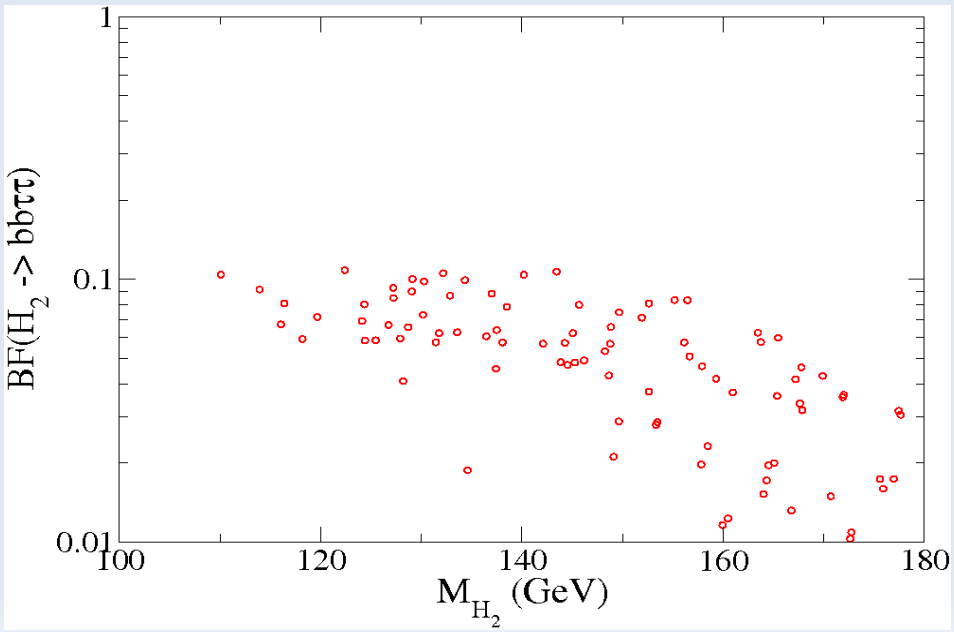
- H_1 decays either to DM (blue) or SM (red)

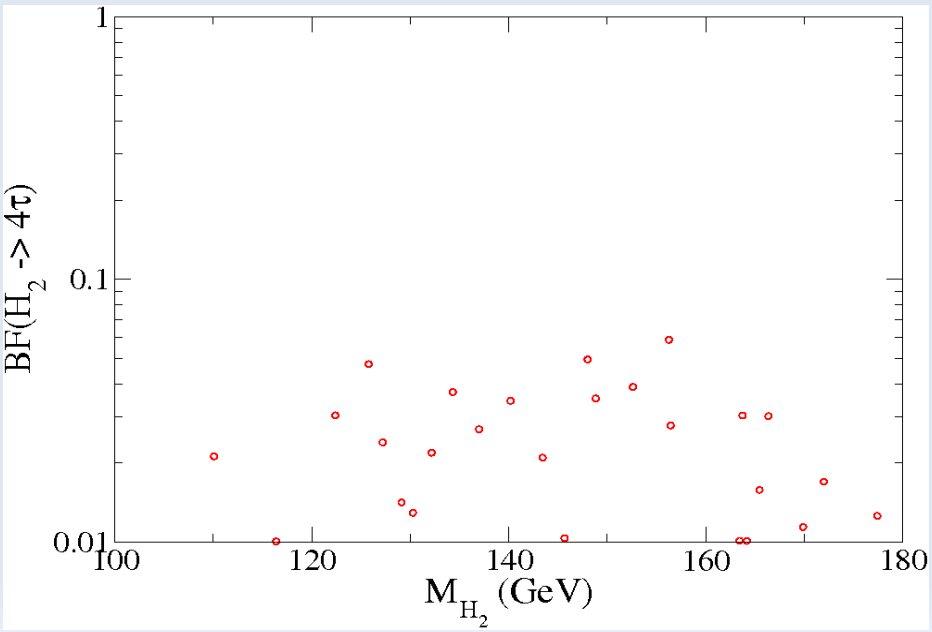


Cascade Decays









The Debate: Part 1

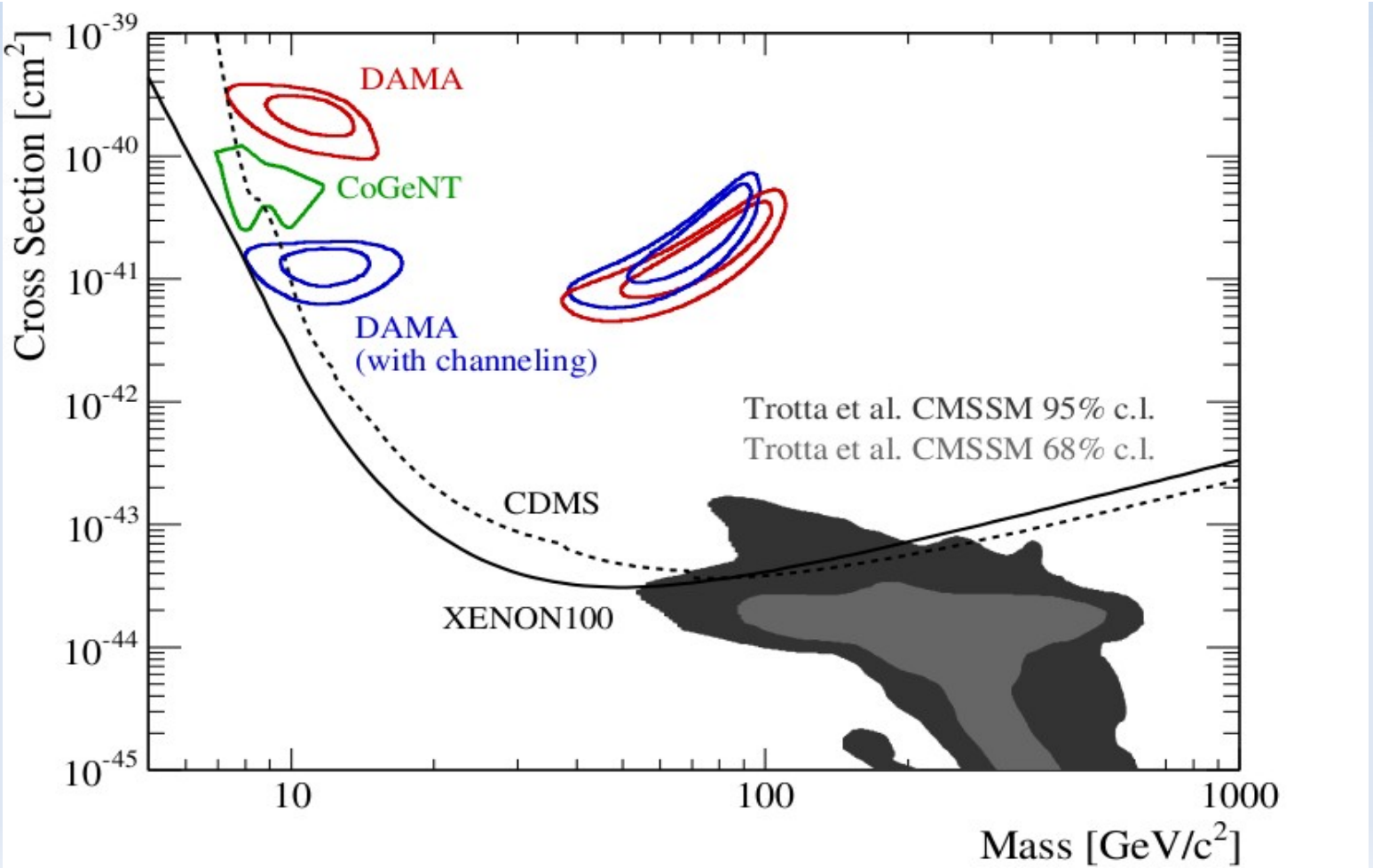
arXiv:1005.0380 [pdf, other]

First Dark Matter Results from the XENON100 Experiment

E. Aprile, K. Arisaka, F. Arneodo, A. Askin, L. Baudis, A. Behrens, E. Brown, J. M. R. Cardoso, B. Choi, D. B. Cline, S. Fattori, A. D. Ferella, K.-L. Giboni, K. Hugenberg, A. Kish, C. W. Lam, J. Lamblin, R. F. Lang, K. E. Lim, J. A. M. Lopes, T. Marrodán Undagoitia, Y. Mei, A. J. Melgarejo Fernandez, K. Ni, U. Oberlack, S. E. A. Orrigo, E. Pantic, G. Plante, A. C. C. Ribeiro, R. Santorelli, J. M. F. dos Santos, M. Schumann, P. Shagin, A. Teymourian, D. Thers, E. Tziaferi, H. Wang, C. Weinheimer (XENON100 Collaboration)

Comments: 4 pages, 5 figures.

Subjects: **Cosmology and Extragalactic Astrophysics (astro-ph.CO)**



The Debate: Part 2

arXiv:1005.0380 [pdf, other]

First Dark Matter Results from the XENON100 Experiment

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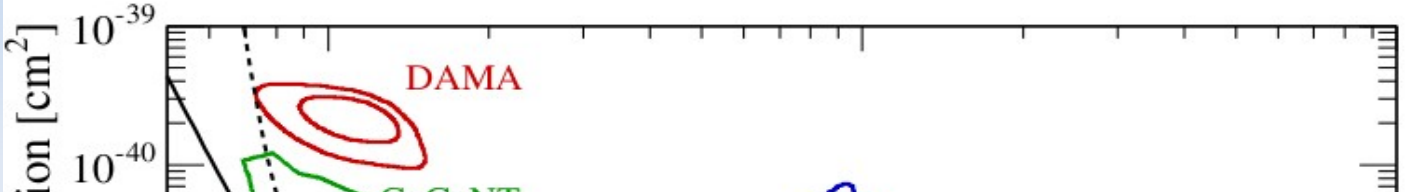


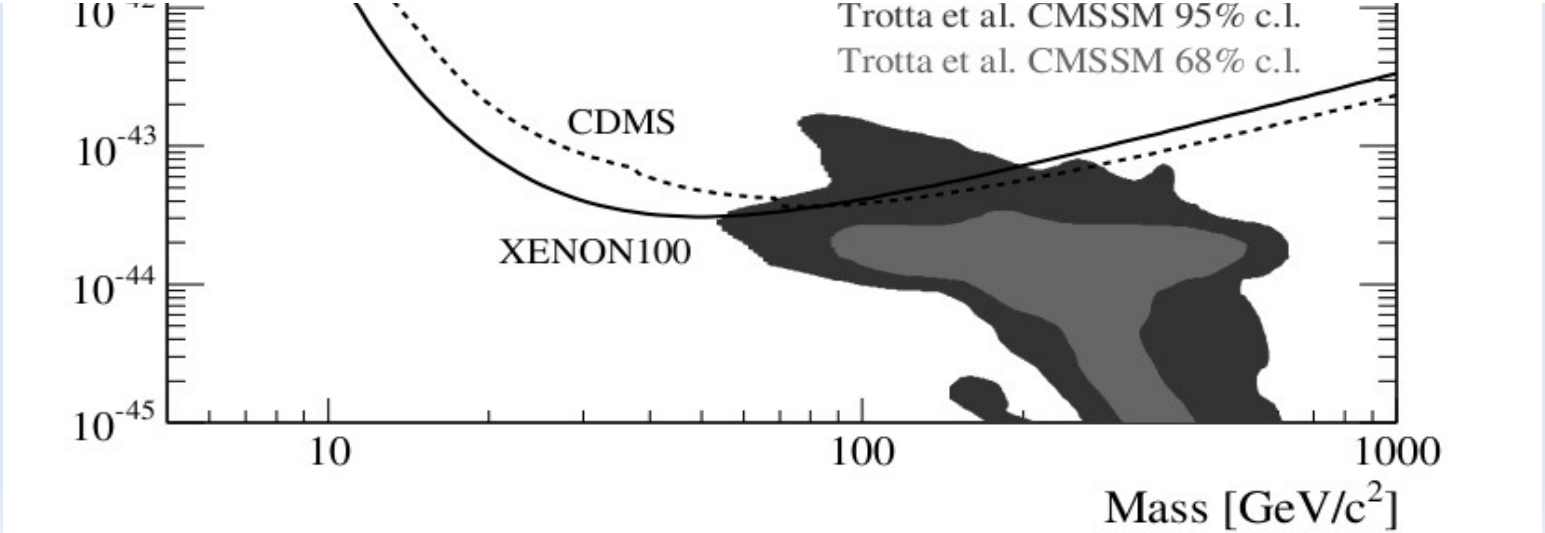
arXiv:1005.0838 [pdf, ps, other]

Comments on "First Dark Matter Results from the XENON100 Experiment"

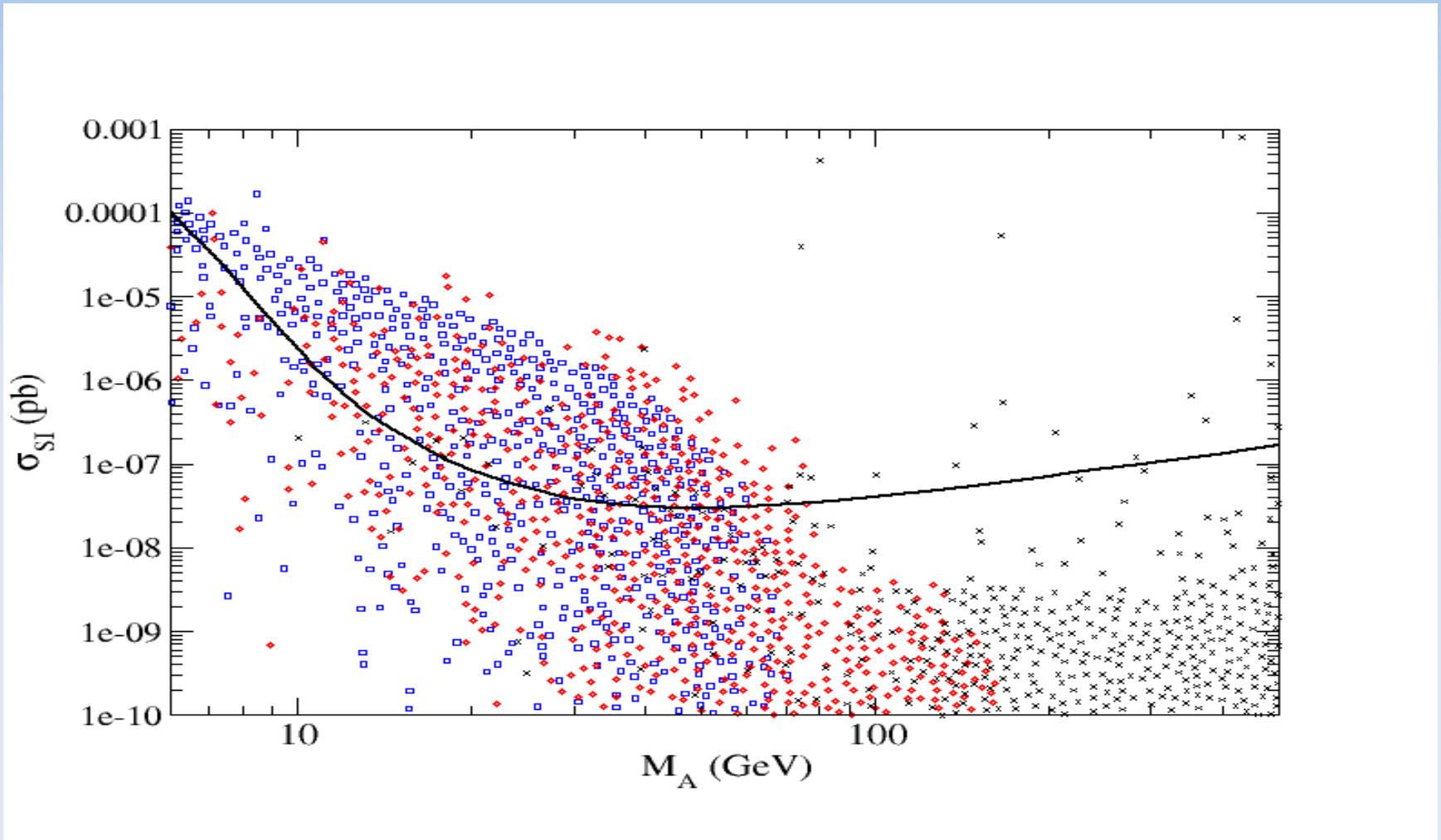
J.I. Collar, D.N. McKinsey

Comments: Important information added to a footnote. Figures enlarged, references fixed.

Subjects: **Cosmology and Extragalactic Astrophysics (astro-ph.CO)**; High Energy Physics - Experiment (hep-ex); Instrumentation and Detectors (physics.ins-det)



Preliminary Results with Xenon100



- Need to analyze the Higgs phenomenology (work in progress)

Conclusions

- CoGeNT
  - Spin-independent scattering cross section consistent with CoGeNT
  - Light singlet-like Higgs mostly decays to DM
  - Heavy SM-like Higgs can be probed at the LHC (both SM decays and non-SM decays)
- Xenon100
  - The csxSM can also be consistent with Xenon100
- Either way we still have some very interesting Higgs phenomenology that can potentially be seen at the LHC!

The End

Thank you!

References

- CoGeNT (C. E. Aalseth et al., (2010), arXiv:1002.4703)
- Hadronic matrix elements (J. R. Ellis, A. Ferstl, and K. A. Olive, Phys. Lett. B481, 304 (2000))
- micrOmegas (G. Belanger et al., (2010), arXiv:1004.1092.)
- WMAP (D. Larson et al., (2010), arXiv:1001.4635)
- LEP (A. Sopczak, (2005), arXiv:hep-ph/0502002)
- OPAL Collaboration, G. Abbiendi et al., Eur. Phys. J. C27, 311 (2003)
- DELPHI, J. Abdallah et al., Eur. Phys. J. C32, 475 (2004), arXiv:hep-ex/0401022
- Cascade decays: R. Dermisek and J. F. Gunion, Phys. Rev. D73, 111701 (2006)
- V. Barger, P. Langacker, and G. Shaughnessy, Phys. Rev. D75, 055013 (2007)
- M. Carena, T. Han, G.-Y. Huang, and C. E. M. Wagner, JHEP 04, 092 (2008)
- EWPO (C. Amsler et al., Physics Letters B 667, 1 (2008), Review of Particle Physics)
- ATLAS inv. BF: O. J. P. Eboli and D. Zeppenfeld, Phys. Lett. B495, 147 (2000)

Backup slides

Parameter scan

$$
\begin{aligned}
7\ GeV\ &< \sqrt{b_1} <\ 100\ GeV, & \left(14\ GeV\ < \sqrt{b_1} <\ 100\ GeV\right)\\
7\ GeV\ &< M_A <\ 12\ GeV, & (7\ GeV\ < M_A <\ 12\ GeV)\\
0\ &< \lambda <\ 2, & (0.4\ < \lambda <\ 1.1)\\
-2\ &< \delta_2 <\ 2, & (0.01\ < |\delta_2| <\ 1.1)\\
0\ &< d_2 <\ 4, & (0\ < d_2 <\ 4)\\
10\ GeV\ &< v_S <\ 1000\ GeV, & (10\ GeV\ < v_S <\ 400\ GeV)
\end{aligned}
$$

Couplings

$$g_{AAH_1} = \left(\delta_2 v \cos\phi + d_2 v_S \sin\phi\right)/2$$
$$g_{AAH_2} = \left(d_2 v_S \cos\phi - \delta_2 v \sin\phi\right)/2$$

- Hadronic matrix elements (J. R. Ellis, A. Ferstl, and K. A. Olive, Phys. Lett. B481, 304 (2000))

$$f_{pu} = 0.02, \qquad f_{pd} = 0.026, \qquad f_{ps} = 0.118, \qquad f_G = 0.836$$