Large Scattering Cross Sections in the MSSM

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May 11 / PHENO

- Recent dark matter experiment – CoGent

$$7 \text{ GeV} \lesssim m_{DM} \lesssim 11 \text{ GeV}$$
$$3 \times 10^{-41} \text{ cm}^2 \lesssim \sigma \lesssim 1 \times 10^{-40} \text{ cm}^2$$

- Similar region indicated by DAMA.
- Will be tested soon by Xenon100.
- Try our most favorite model – MSSM.

- Recent dark matter experiment – CoGent

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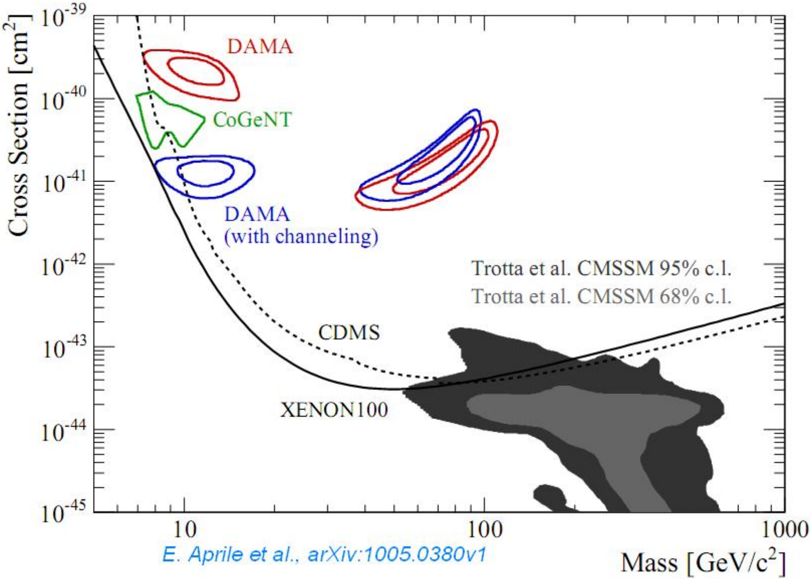
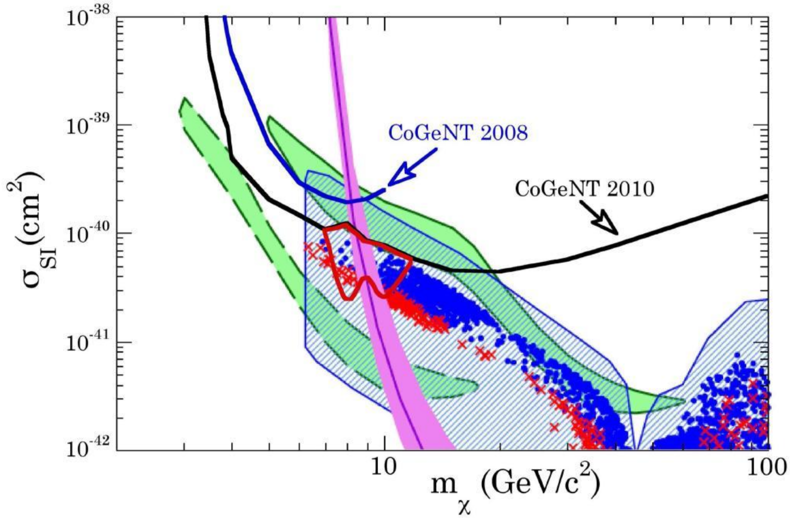


E. Aprile et al., arXiv:1005.0380v1

Motivation - CoGent/DAMA



Bottino, Donato, Formengo, Scopel

CoGeNT Collaboration, C. E. Aalseth *et al.*, *Results from a Search for Light-Mass Dark Matter with a P- type Point Contact Germanium Detector*, 1002.4703.

What are we doing differently?

- Understand what is being constrained. No scans
  Many constraints can be set to zero by fixing parameters. ($B \to \mu^+\mu^-$,$b \to s\gamma$)
- Push the limits with loop corrections.
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Z-width

How can we get a light LSP

- Check the invisible Z-width.

$$\chi = \tilde{z}_B \tilde{B} + \tilde{z}_W \tilde{W} + \tilde{z}_d \tilde{H}_d + \tilde{z}_u \tilde{H}_u$$

- Should be mostly Bino, since a pure Bino does not couple to the Z.
  But with largest possible Higgsino component consistent with the invisible Z-width
- $\Gamma(Z \to \chi^0 \chi^0) = \frac{g^2}{4\pi} \frac{(\tilde{z}_d^2 - \tilde{z}_u^2)^2}{24 c_w^2} M_Z$
- Higgsino Component: $\tilde{z}_d \sim s_W m_Z / \mu$ – constraint on μ
- At 2σ, $\Gamma(Z \to \chi^0 \chi^0) < 3$ MeV.
- $\mu \geq 108$ GeV – similar to Chargino limits at LEP.

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Higgs sector in the MSSM

- 5 Higgses $h, H, A, H^{\pm}$
- At tree level

$$
\begin{aligned}
m^2_{h,H} &= \frac{1}{2}\left(m^2_A + m^2_Z \mp \sqrt{(m^2_A - m^2_Z)^2 + 4m^2_Z m^2_A \sin^2 2\beta}\right) \\
m^2_{H^\pm} &= m^2_A + m^2_W.
\end{aligned}
$$

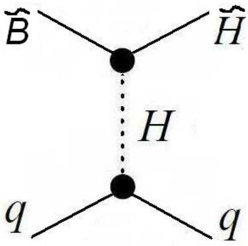
- For small m_A and large $\tan\beta$

$$m_H = m_A$$

- H, A has large ($\tan\beta$ enhanced) couplings to down-type quarks
- H, A searches at Tevatron:

$$H, A \to \tau\tau, t \to bH^{\pm}$$

Largest scattering cross sections occur for large $\tan\beta$ and small Higgs mass m_A

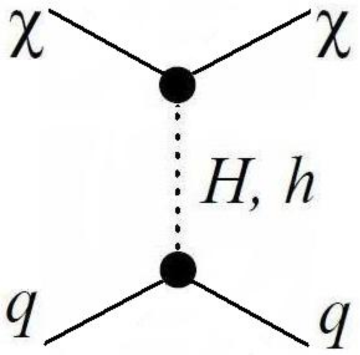


$$\sigma_n \approx 2.3 \times 10^{-41}\,\text{cm}^2 \left(\frac{\tilde{z}_d}{0.4}\right)^2 \left(\frac{\tan\beta}{50}\right)^2 \left(\frac{100\,\text{GeV}}{m_H}\right)^4 \times \frac{1}{(1+\Delta m_b)^2}, \quad (1)$$

- Maximized for small m_H, large $\tan\beta$, and large Higgsino fraction

Direct Detection Scattering

- Higgsino/Bino Components
- Parameter: $\tan\beta$, μ, m_χ
- Z-Width, Chargino Limits
- Yukawa couplings, Higgs masses
- Parameter: $\tan\beta$, m_H, m_A, $m_{H^\pm}$, Δm_b
- Collider Searches, $H, A \to \tau^+\tau^-$ $t \to H^\pm b$
- B-Physics: $B \to \mu^+\mu^-$, $B^\pm \to \tau^\pm\nu$, $b \to s\gamma$



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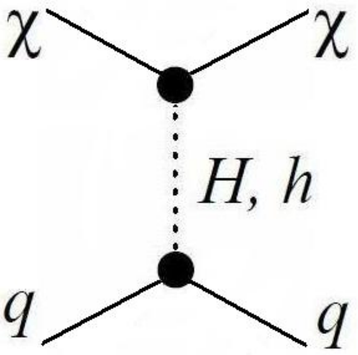
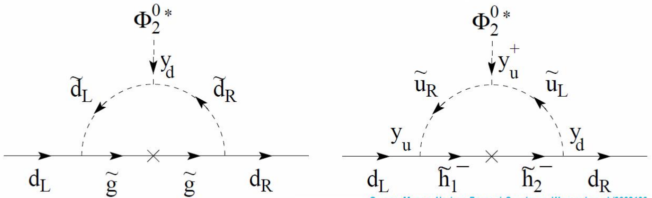


Δm_b - Hall, Kostelecky and Raby

- Corrections to the b-mass



Carena, Menon, Noriega-Papaqui, Szynkman, Wagner hep-ph/0603106

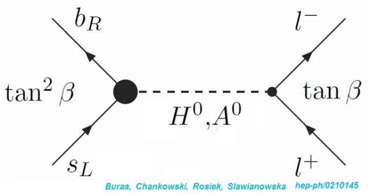
$$\Delta m_b = (\epsilon_0 + y_t^2 \epsilon_Y) \tan\beta$$

$$\epsilon_0 \sim \frac{2\alpha_s}{3\pi} M_3 \mu \qquad \epsilon_Y \sim \frac{1}{16\pi^2} A_t \mu$$

- $\Delta m_b < 0$ implies a larger bottom Yukawa coupling to H
- $\Delta m_b > 0$ implies a smaller bottom Yukawa coupling to H

$\Delta m_b, B_s \to \mu^+\mu^-$ Buras, Chankowski, Rosiek, Slawianowska

- Need an allowed range for Δm_b
- $B_s \to \mu^+\mu^-$



$$BR(B_s \to \mu\mu) \sim \tan^6\beta \left(\frac{m_t}{M_A}\right)^4 \frac{(16\pi^2\epsilon_Y)^2}{(1+\Delta m_b)^2(1+\epsilon_0\tan\beta)^2}.$$

- This requires $\epsilon_y \sim 0$. Can always take $A_t = 0$.
- Taking sbottom masses near the Tevatron bound $m_{\tilde{b}} = 250$ GeV and $\mu = \pm 110$ GeV.

$$|\epsilon_0| < \epsilon_{max} = 6 \times 10^{-3}$$

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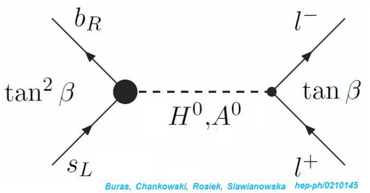

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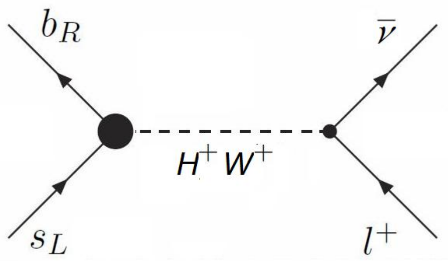
$B \to \tau\nu$



$$R_{B\tau\nu} = \frac{Br(B \to \tau\nu)_{MSSM}}{Br(B \to \tau\nu)_{SM}} = \left[1 - \left(\frac{m_B^2}{m_{H^\pm}^2}\right) \frac{\tan^2\beta}{1 + \epsilon_0 \tan\beta}\right]^2$$

- Babar and Belle give 4σ combined significance away from 0.

$$0.85 < R_{B\tau\nu} < 2.43$$

- Can suppress SM contribution, but for large $\tan\beta$ and small $m_{H^\pm}$ the MSSM can dominate.

$B \to D\tau\nu$

Kamenik, Mescia, 0802.3790; Bona, et al, 0908.3470

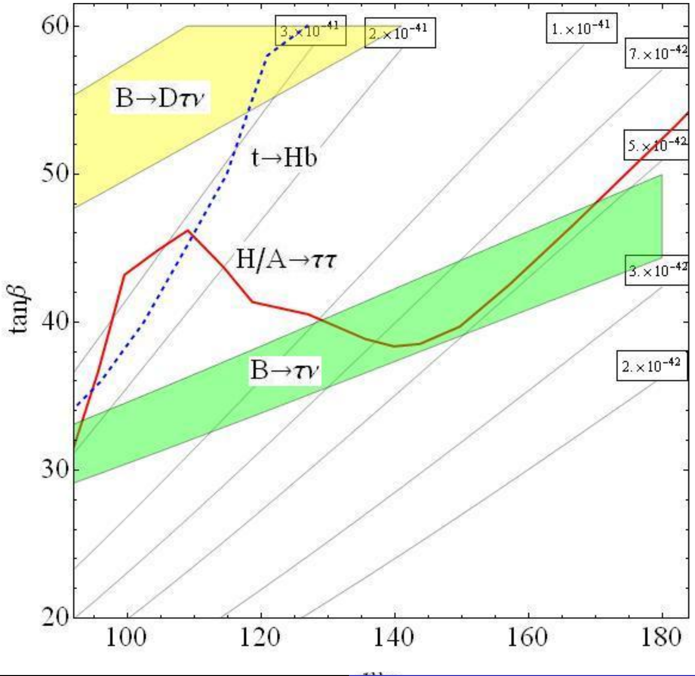
$$\frac{Br(B \to D\tau\nu)}{Br(B \to De\nu)} = (0.28) \times \left[1 + 1.38 Re(C^{\tau}_{NP}) + 0.88|C^{\tau}_{NP}|^2\right]$$

where

$$C^{\tau}_{NP} = -\frac{m_b m_\tau}{m^2_{H^+}} \frac{\tan^2\beta}{1 + \epsilon_0 \tan\beta}$$

$$\frac{Br(B \to D\tau\nu)}{Br(B \to De\nu)}_{EXP} = .49 \pm .10$$

- Can overwhelm SM contribution for large $\tan\beta$ and small $m_{H^\pm}$.


3.×10^-41
2.×10^-41
1.×10^-41
7.×10^-42
5.×10^-42
3.×10^-42
2.×10^-42
B→Dτν
t→Hb
H/A→ττ
B→τν
tanβ
60
50
40
30
20
100
120
140
160
180

- The light Higgs mass and large $\tan\beta$ region is ruled out.
- Look at the region where the MSSM contribution to *B*-decays is small.

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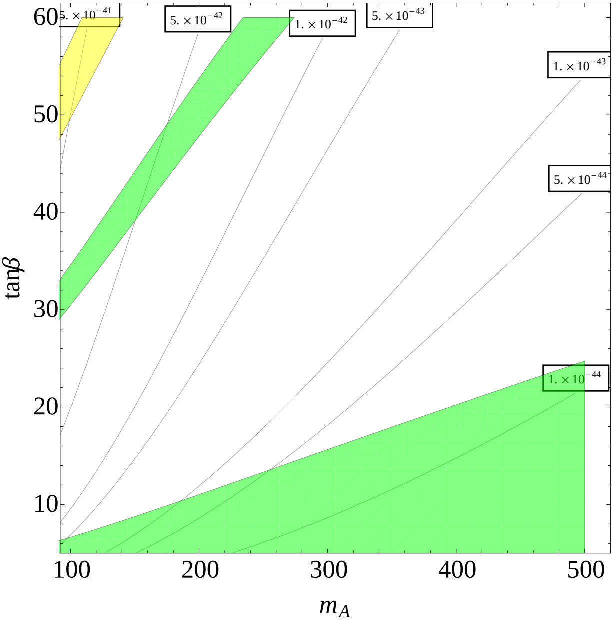
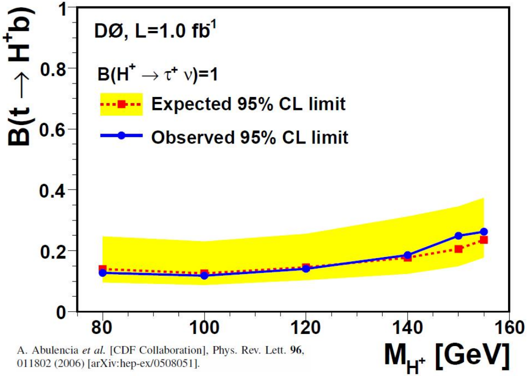

5. × 10^−41
5. × 10^−42
1. × 10^−42
5. × 10^−43
1. × 10^−43
5. × 10^−44
1. × 10^−44
60
50
40
30
20
10
100
200
300
400
500
tanβ
m_A

Conclusions

- B decays are the most constraining.
- Maximum Cross Sections $\sigma_n \lesssim 10^{-42}$ cm^2
- Too small for CoGent and DAMA.
- This region will be tested by XENON100
- Need to understand the low/mid tan β region.

$t \to bH^{\pm}$

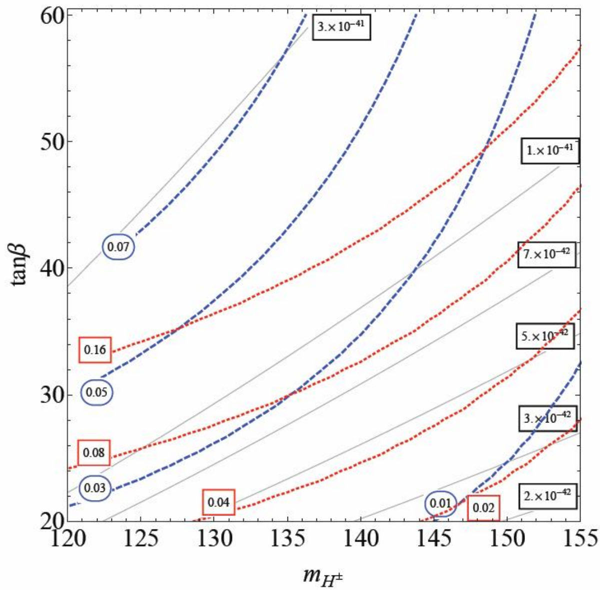
- Tevatron Constraints



A. Abulencia *et al.* [CDF Collaboration], Phys. Rev. Lett. **96**, 011802 (2006) [arXiv:hep-ex/0508051].

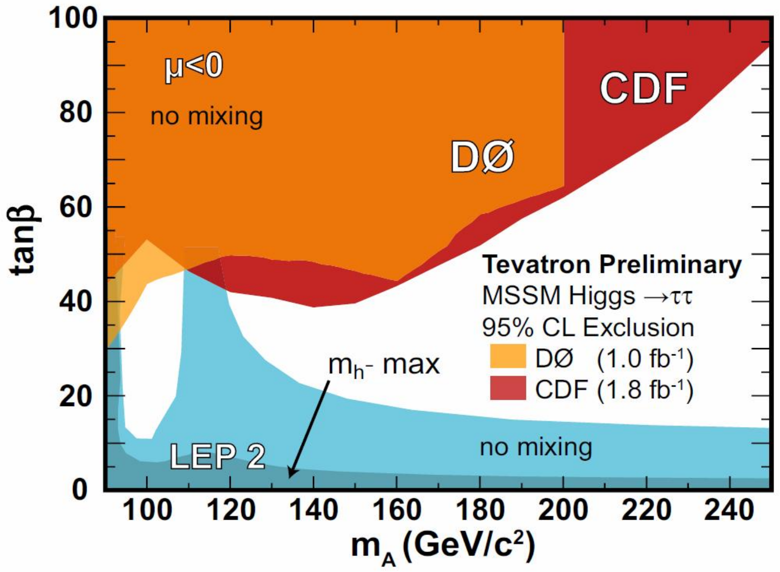
$$\Gamma(t \to bH^{+}) = \frac{1}{(1+\Delta m_b)^2} \frac{g^2 m_t}{64\pi M_W^2} \left(1 - \frac{m_b^2}{m_t^2}\right)^2 m_b^2 \tan^2\beta$$

$t \to bH^{\pm}$



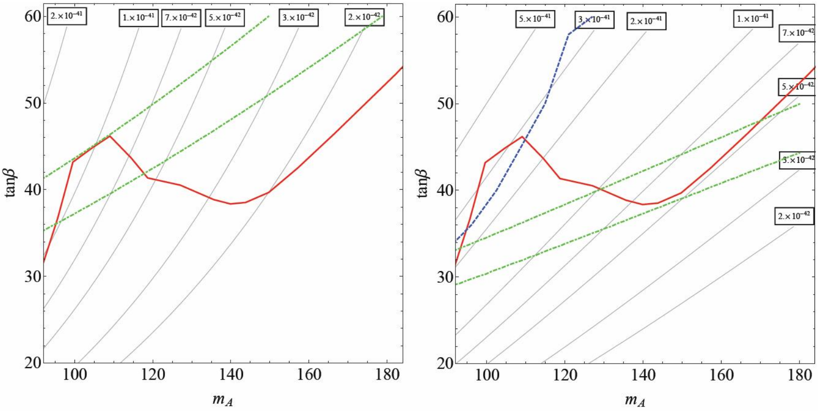
60
50
40
30
20
tanβ
120
125
130
135
140
145
150
155
$m_{H^{\pm}}$
3.×10^-41
1.×10^-41
7.×10^-42
5.×10^-42
3.×10^-42
2.×10^-42
0.07
0.16
0.05
0.08
0.03
0.04
0.01
0.02

$H, A \to \tau^+\tau^-$



μ<0
no mixing
CDF
DØ
Tevatron Preliminary
MSSM Higgs →ττ
95% CL Exclusion
DØ (1.0 fb-1)
CDF (1.8 fb-1)
mh- max
LEP 2
no mixing
tanβ
100
80
60
40
20
0
100
120
140
160
180
200
220
240
mA (GeV/c2)

Summary



2.×10^-41
1.×10^-41
7.×10^-42
5.×10^-42
3.×10^-42
2.×10^-42
tanβ
m_A
5.×10^-41
3.×10^-41
2.×10^-41
1.×10^-41
7.×10^-42
5.×10^-42
3.×10^-42
2.×10^-42
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m_A