Sniffing out new physics with Standard Model Standard Candles

Pheno 2013 Symposium
Parallel Talk

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David Curtin
Yang Institute for Theoretical Physics
Stony Brook

Based on

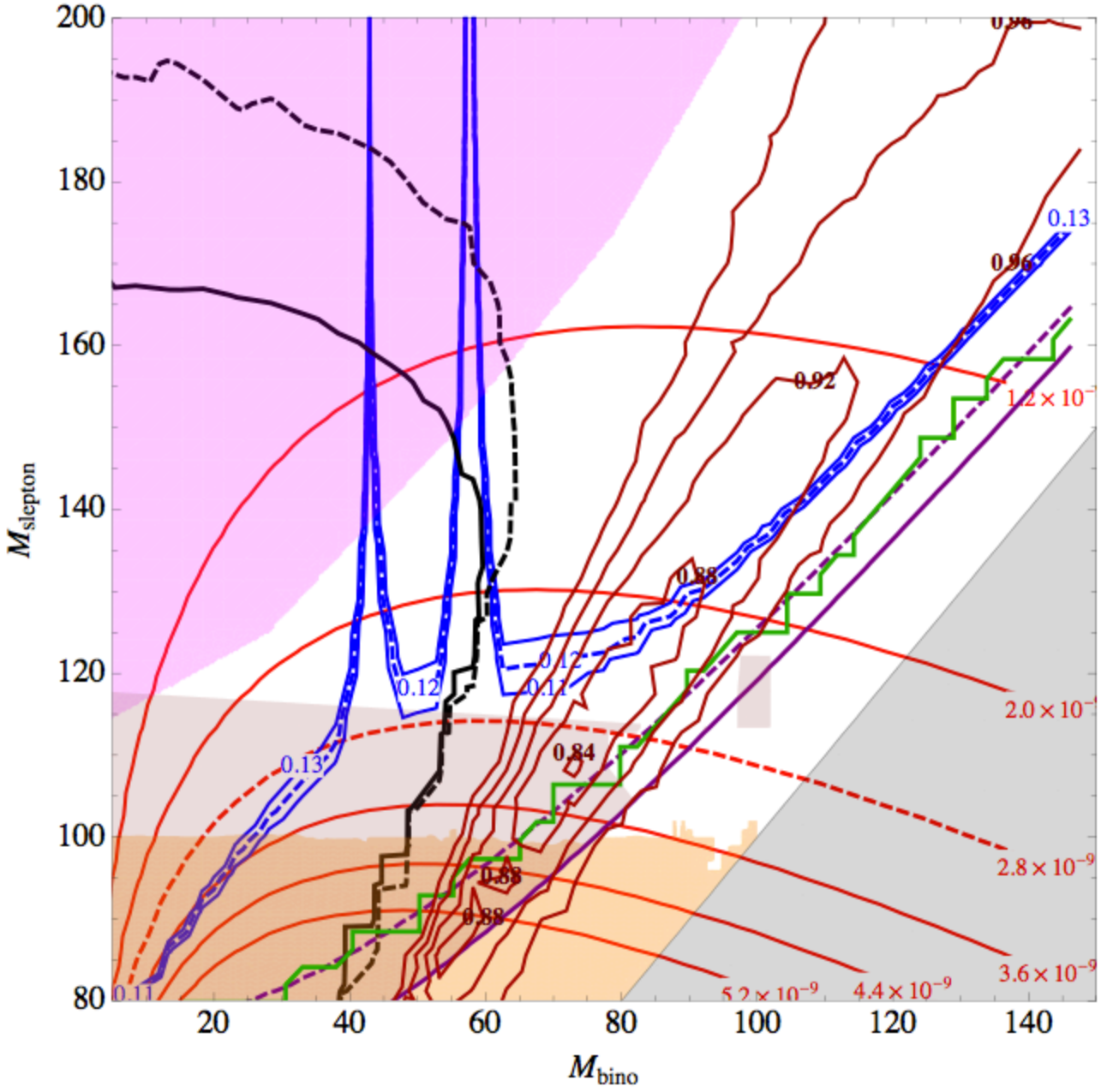
1206.6888 (DC, Prerit Jaiswal, Patrick Meade)
1304.7011 (DC, Prerit Jaiswal, Patrick Meade, Pin-Ju Tien)

Motivation / Summary

- New Physics in EW sector still relatively unconstrained by LHC
- There is a consistent excess in WW! What's going on?
- There are regions where WW actually **prefers** a BSM contribution.
  - Could be a fluke or SM explanation, but if so it's nothing obvious. (ZZ behaves as expected!)
  - It could be **charginos** at ~ 110 GeV → SS dileptons
  - It could be **sleptons** at ~ 110 GeV → WW excess only in ee, μμ
    - ✦ Naturally gives correct $(g\text{-}2)_\mu$, DM relic density.

- **WW cross section measurement is sensitive to new physics!**
  - We use it to set new slepton bounds that bridge the gap between LEP and LHC

Upshot: light sleptons fix WW, DM, (g-2)!



$\tilde{e}, \tilde{\mu}, \tilde{\tau}$ universal
soft mass ~ 100 GeV

μ ~ 500 GeV
tan β ~ 5

CMS slepton

LEP

combined WW bounds

$(g\text{-}2)_\mu$

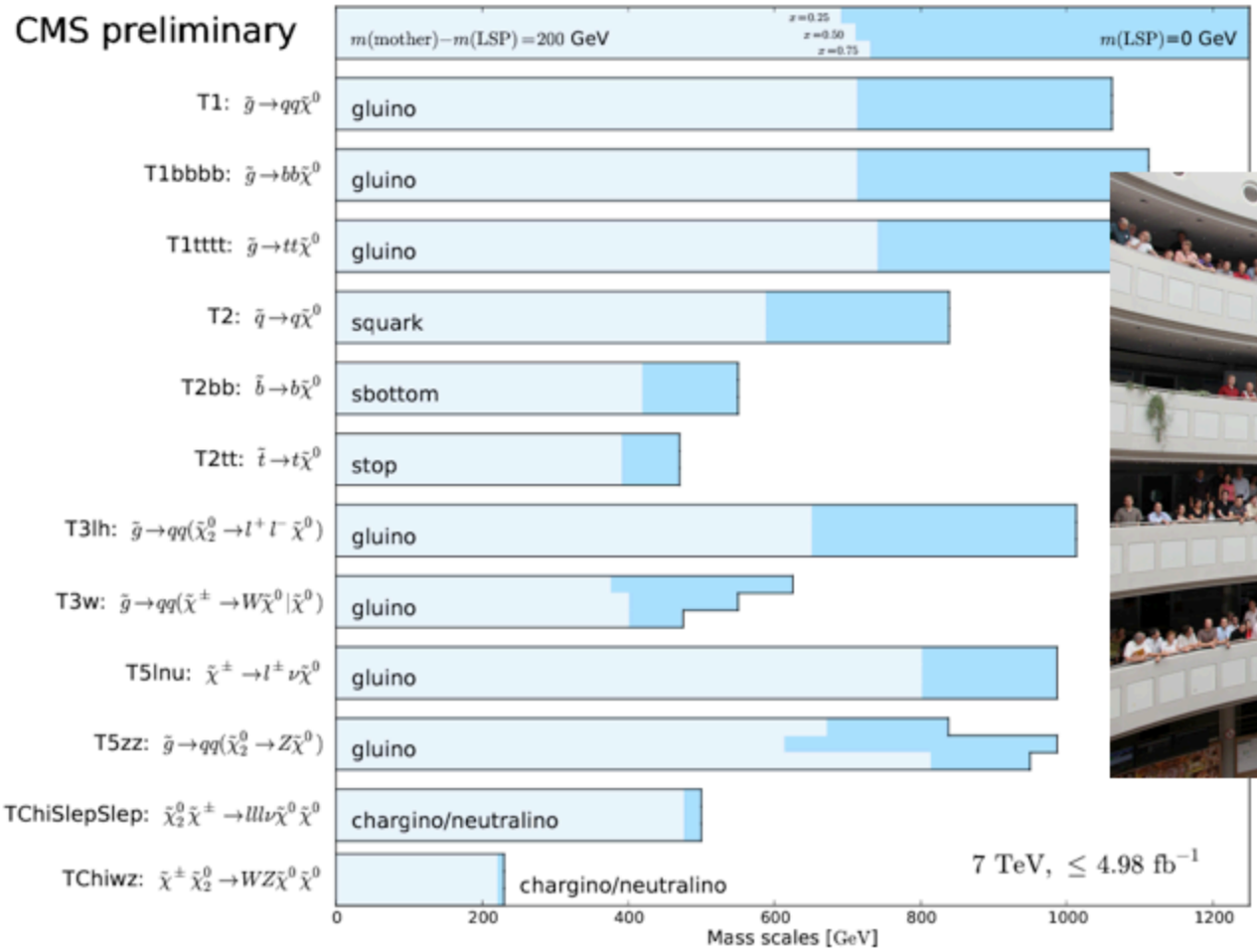
DM relic density

DM direct detection

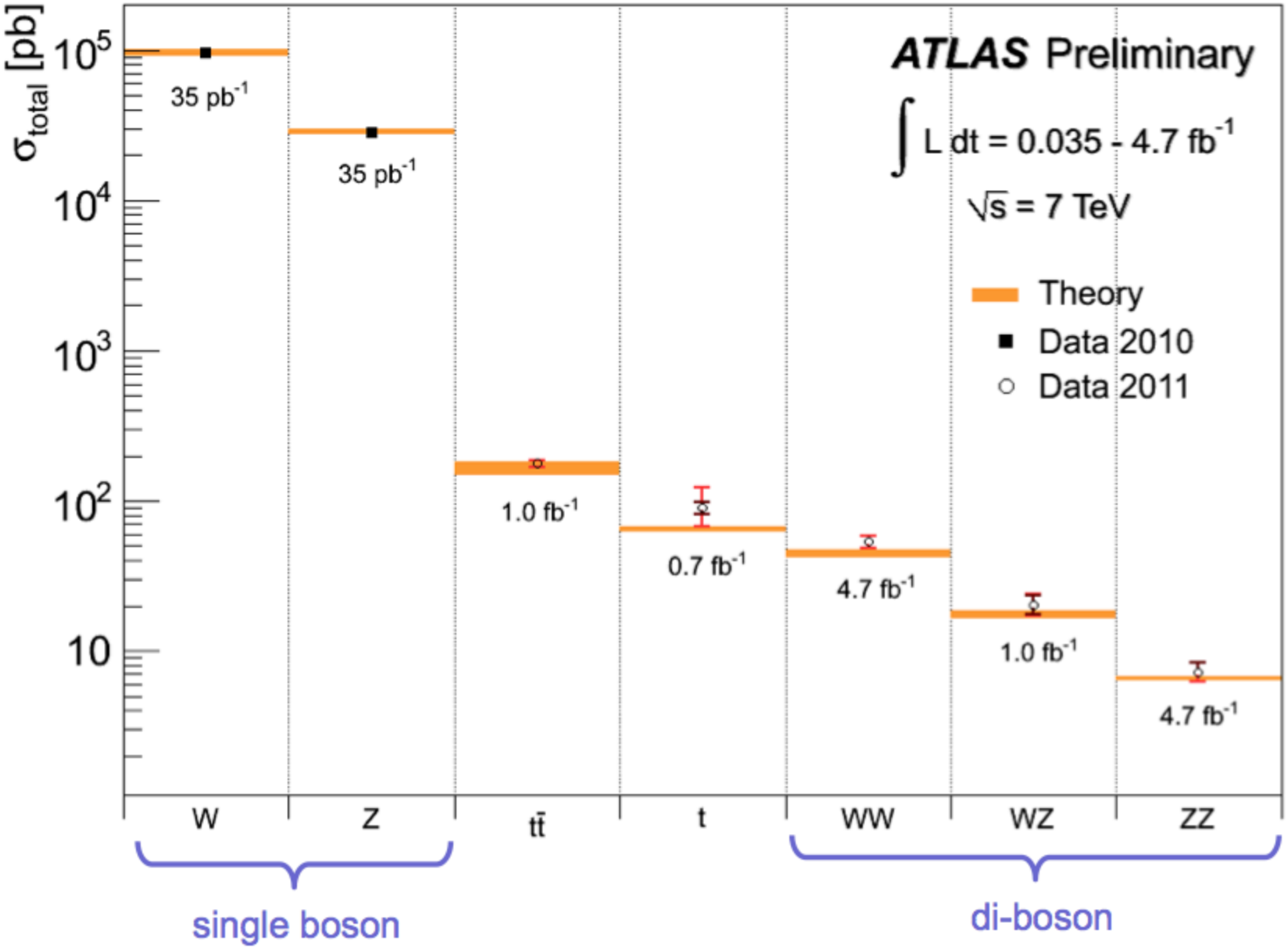
WW preferred region

We now return to our regularly scheduled programming.

Oh SUSY, where art thou?

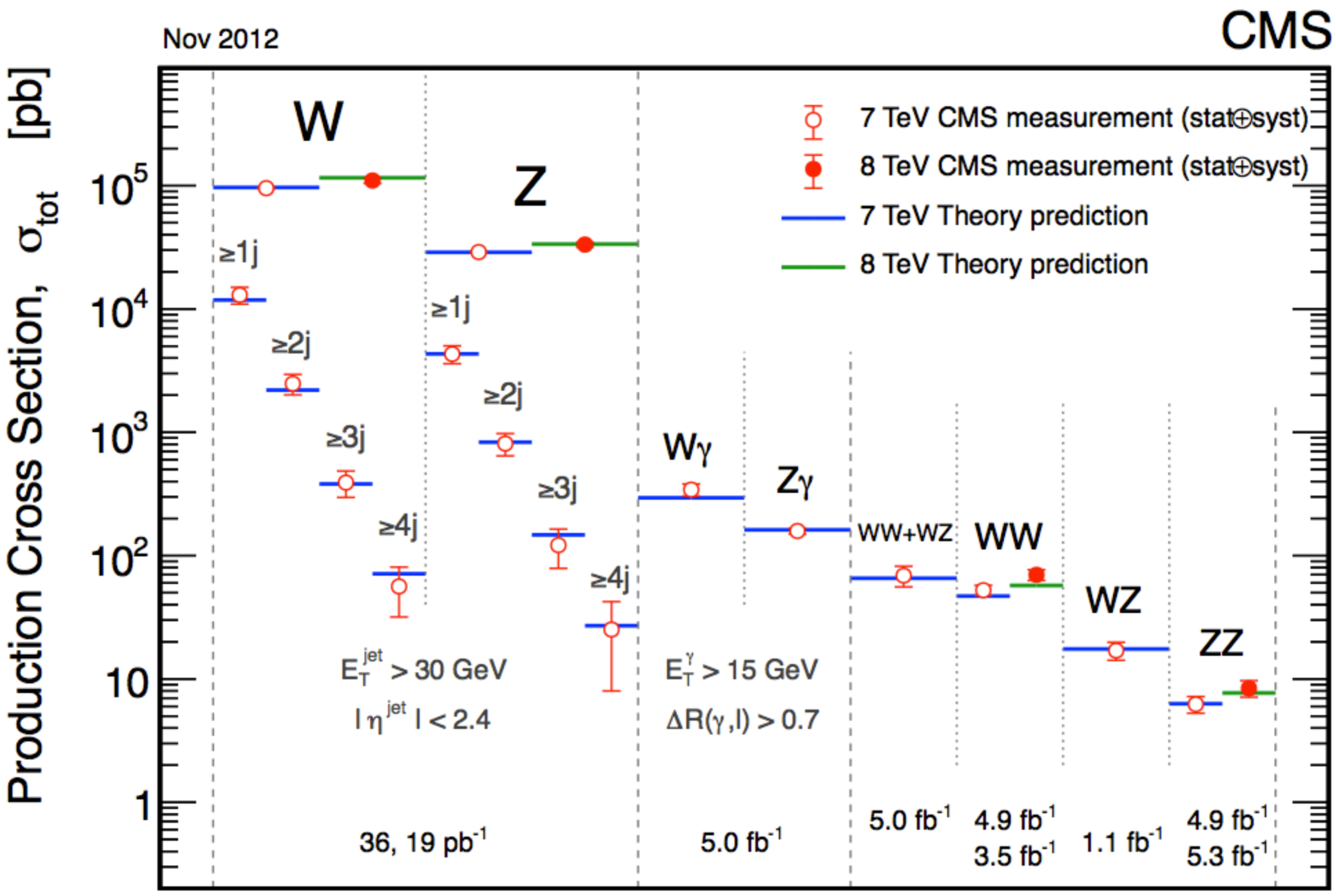


Let's use Standard Candles to look under the lamppost...

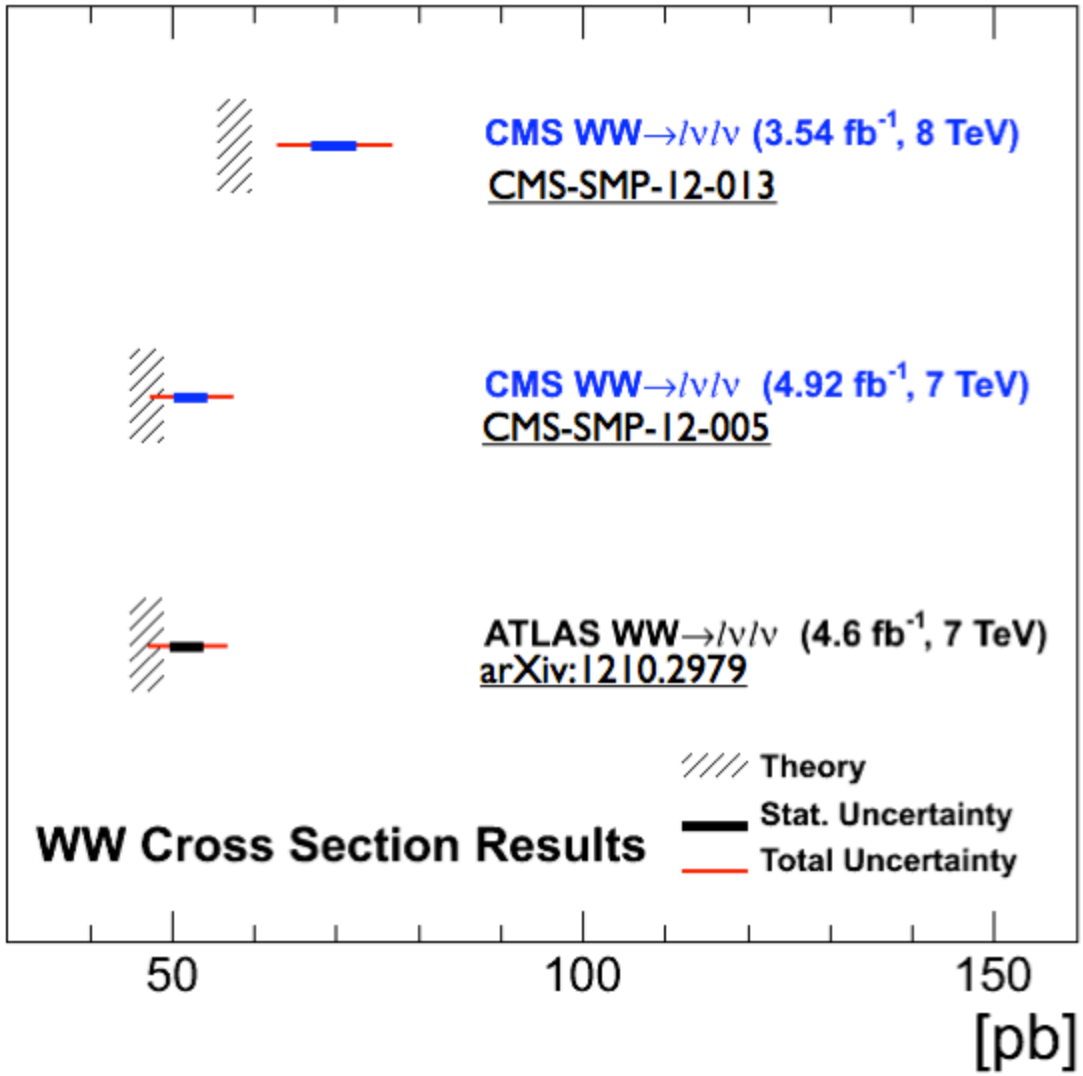


- Very similar agreement with (N)NLO predictions is observed by CMS

CMS EW HCP ZOOM IN



Some visual "evidence"



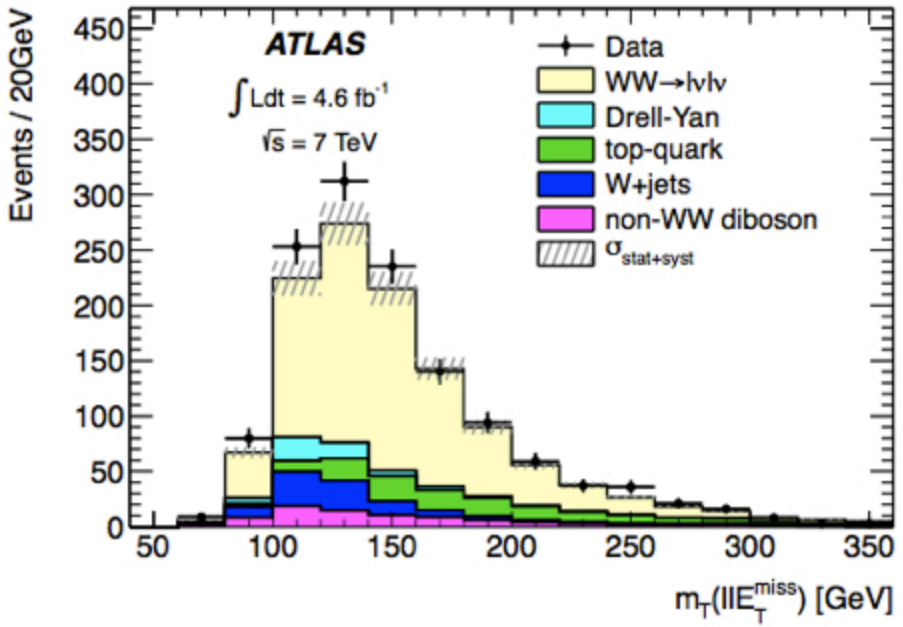
ATLAS7, 5/fb *(all in pb)*
measured:
51.9 ± 2.0 (stat) ± 3.9 (syst) ± 2.0 (lumi)
SM NLO (MC@NLO):
44.7 ± 2 **+1.4σ**

CMS 7, 5/fb
measured:
52.4 ± 2.0 (stat) ± 4.5 (syst) ± 1.2 (lumi)
SM NLO (MCFM):
47.0 ± 2 **+1.0σ**

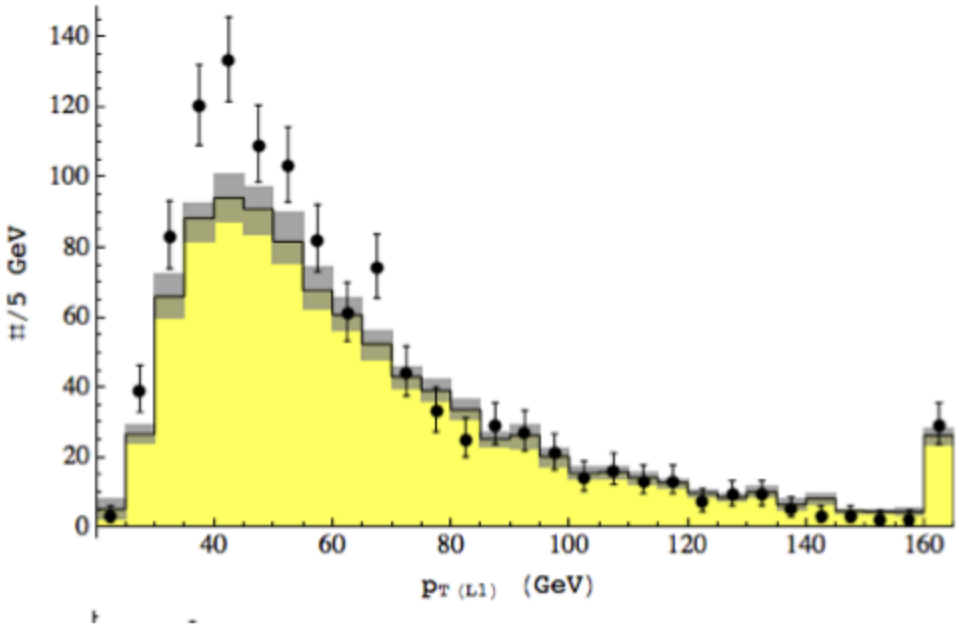
CMS 8, 3.5/fb
measured:
69.9 ± 2.8 (stat) ± 5.6 (syst) ± 3.1 (lumi)
SM NLO (MCFM):
57.25 + 2.35 - 1.60 **+1.7σ**

Naive Combination: almost 3σ

Not just normalization: shape disagrees as well!



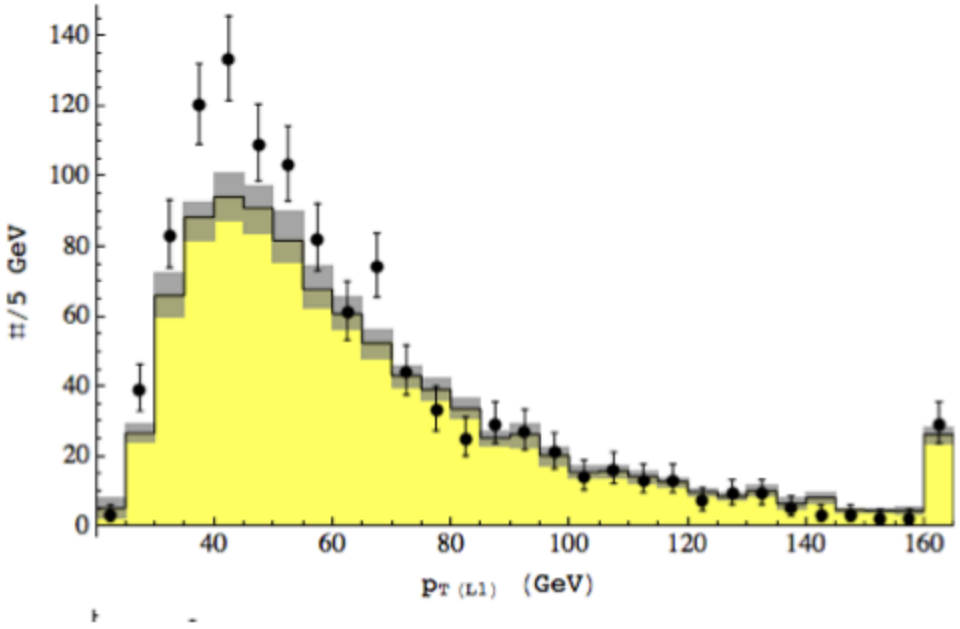
ATLAS7 WW



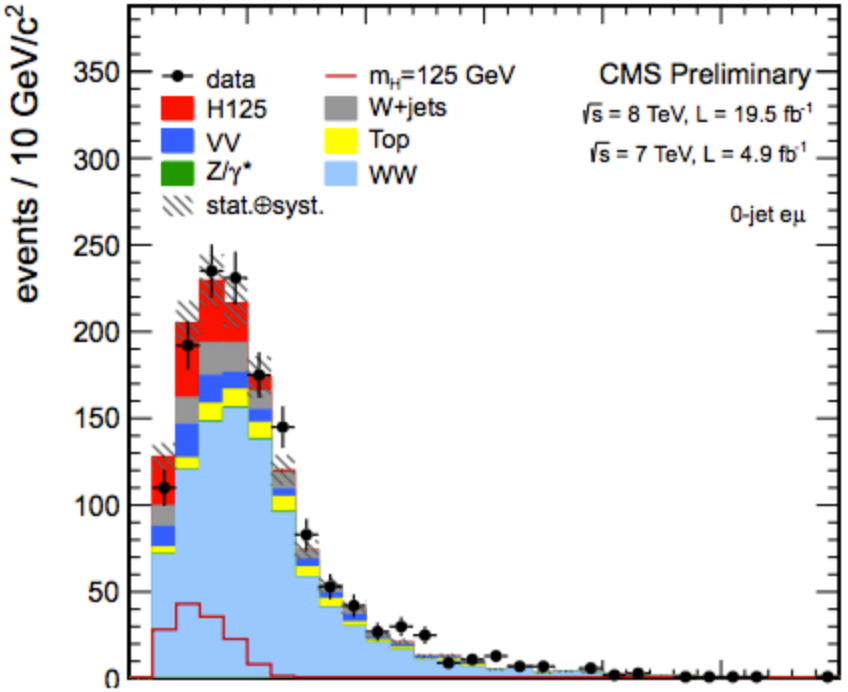
CMS8 WW

Not just normalization: shape disagrees as well!

This is serious business....



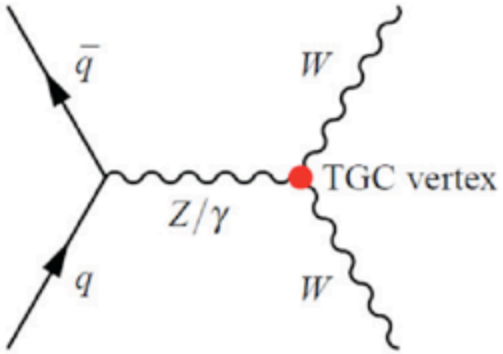
CMS8 WW

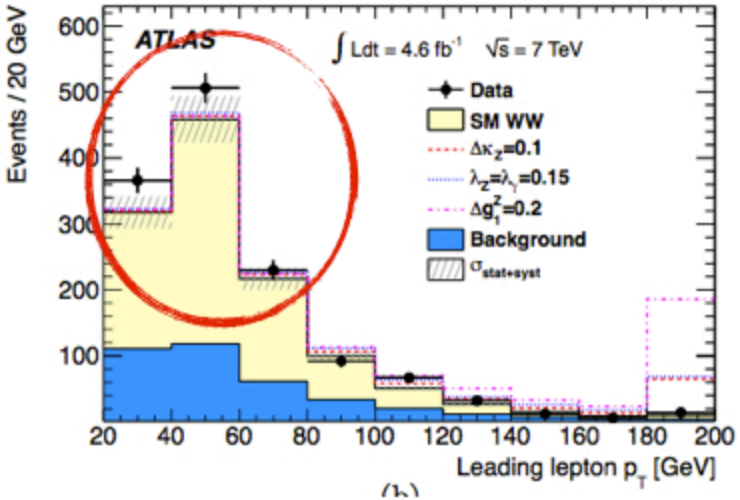


CMS8 H ⟶WW

Ingredients for a BSM explanation

- Need to produce dileptons + MET and NOTHING ELSE (jet veto)
- These new events do **not** have to contain real Ws (but that could help)
- The experimentalists do use WW to look for certain kinds of new physics...





.. but this modifies the TAILS of the distributions. We need to modify the BULK.

We need **a few pb** of WW-like events from BSM!

Ingredients for a BSM explanation

- It could be something decaying to WW + MET

  → **Charginos** or something like it.

- It could be something decaying directly to dileptons + MET

  → **Sleptons** or something like it

- Isn't SUSY dead?
  - NOPE.

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RPC SUSY pre-LHC:

———— ~300 GeV colored States (Tevatron limits)

———— ~100 GeV EW States (LEP limits)

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Hadron Colliders relatively insensitive to EW NP.

RPC SUSY post-LHC:

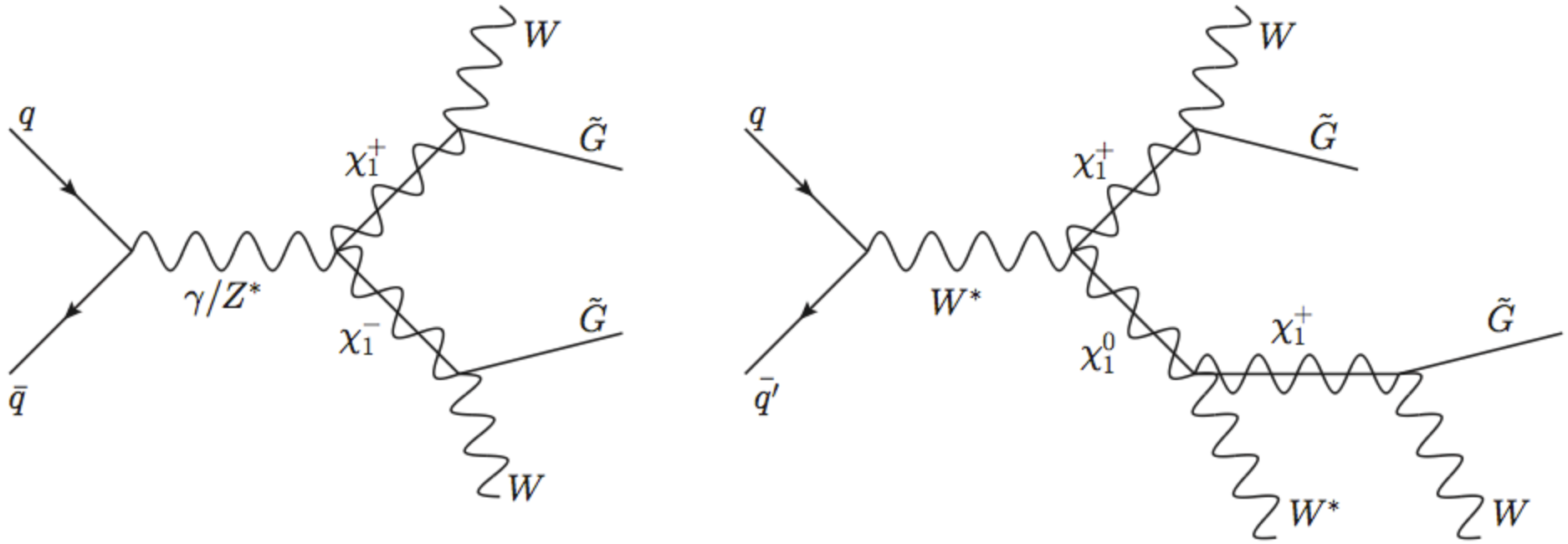
——— ~**1 TeV** colored States (LHC run1 limits)

——— ~**100 GeV** EW States (LEP limits)

EW NP game is just beginning!

Charginos: have to avoid WZ/Wh!

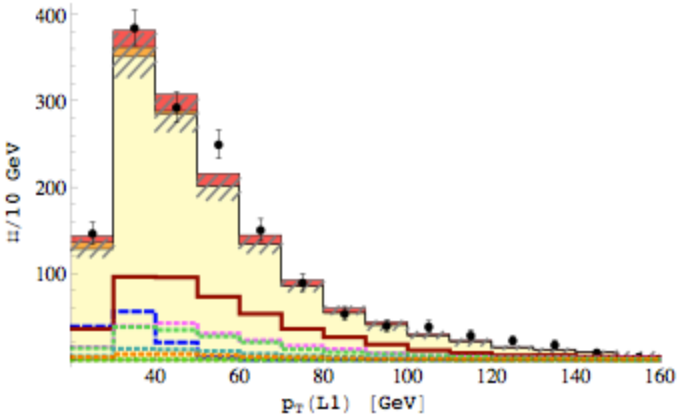
- Consider **Chargino-NLSP** in gauge-mediated SUSY breaking.
  - low tanβ, large Wino-Higgsino mixing

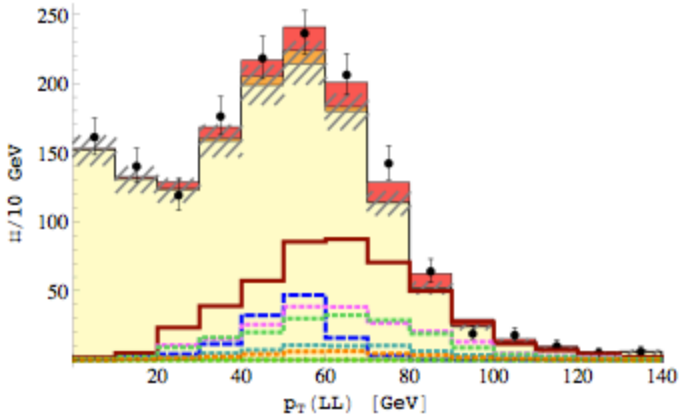


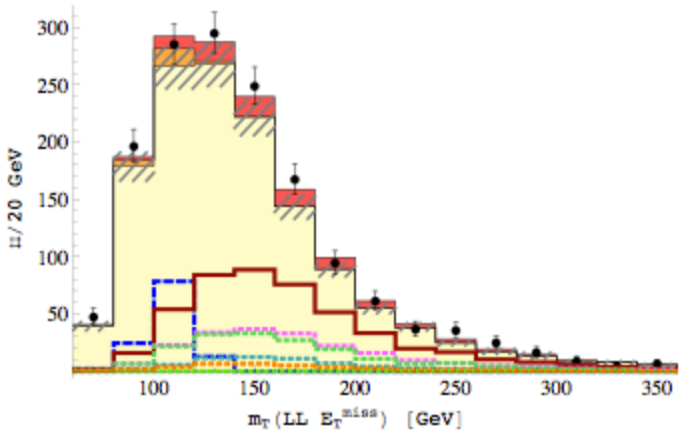
$$\boxed{m_{\chi_1^\pm} \approx 110\,\text{GeV}} \quad m_{\chi_2^0} \approx 130\,\text{GeV}$$
$$m_{\chi_1^0} \approx 113\,\text{GeV}$$

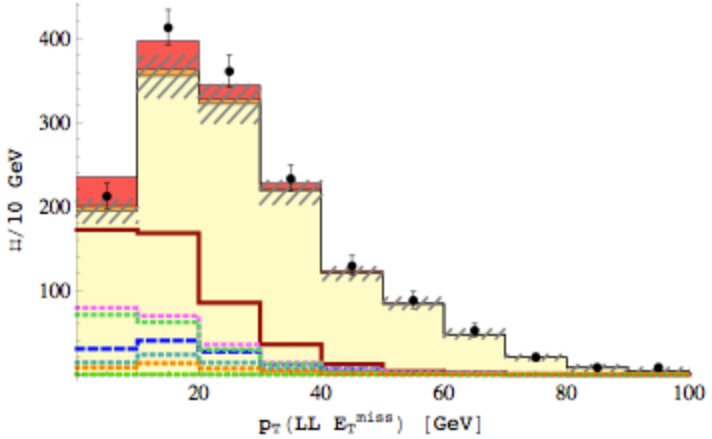
$$\boxed{\sigma_{NLO} \sim 4.3\,\text{pb}}$$

ATLAS7



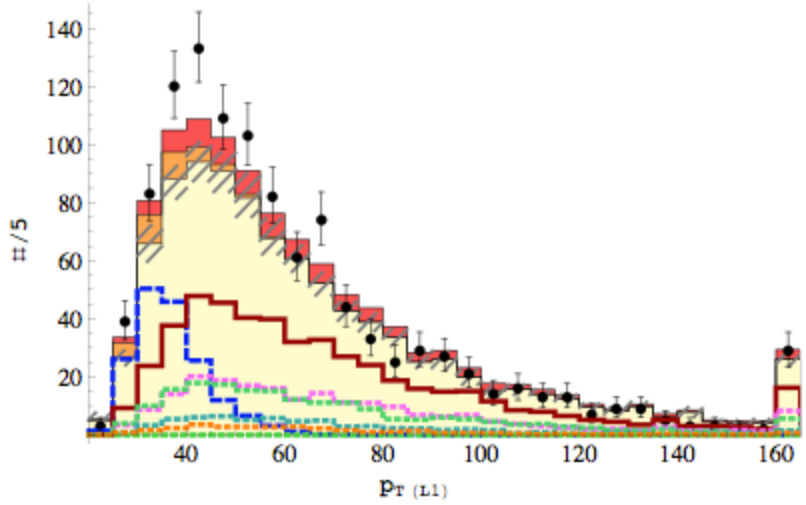


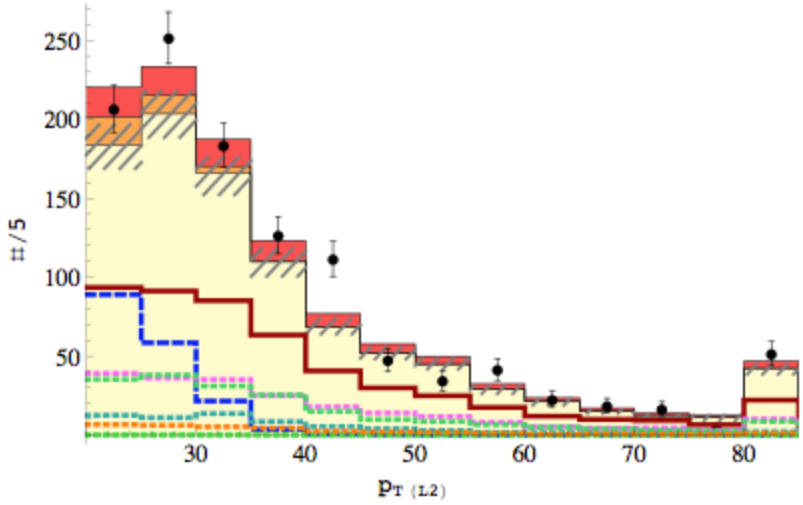


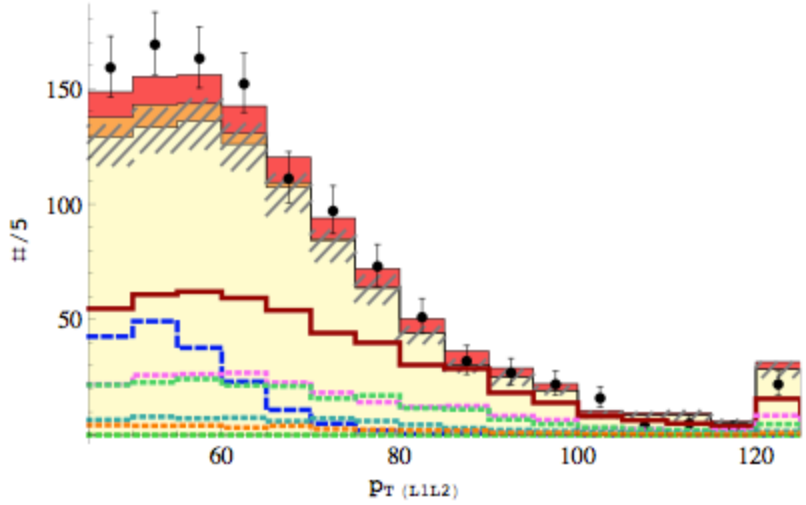


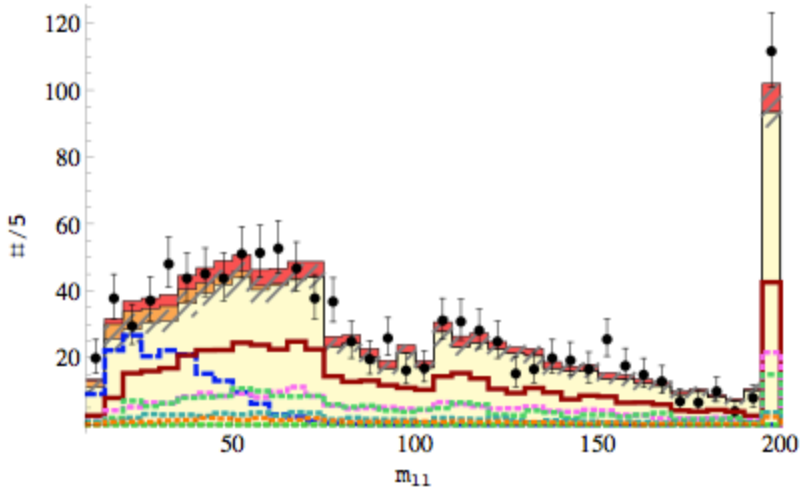
χ^2 cut in half compared to SM

CMS8









SM p-value 0.001

SM+charginos 0.3

SM+h 0.1

SM+h+charginos 0.75

Other consequences of this Scenario

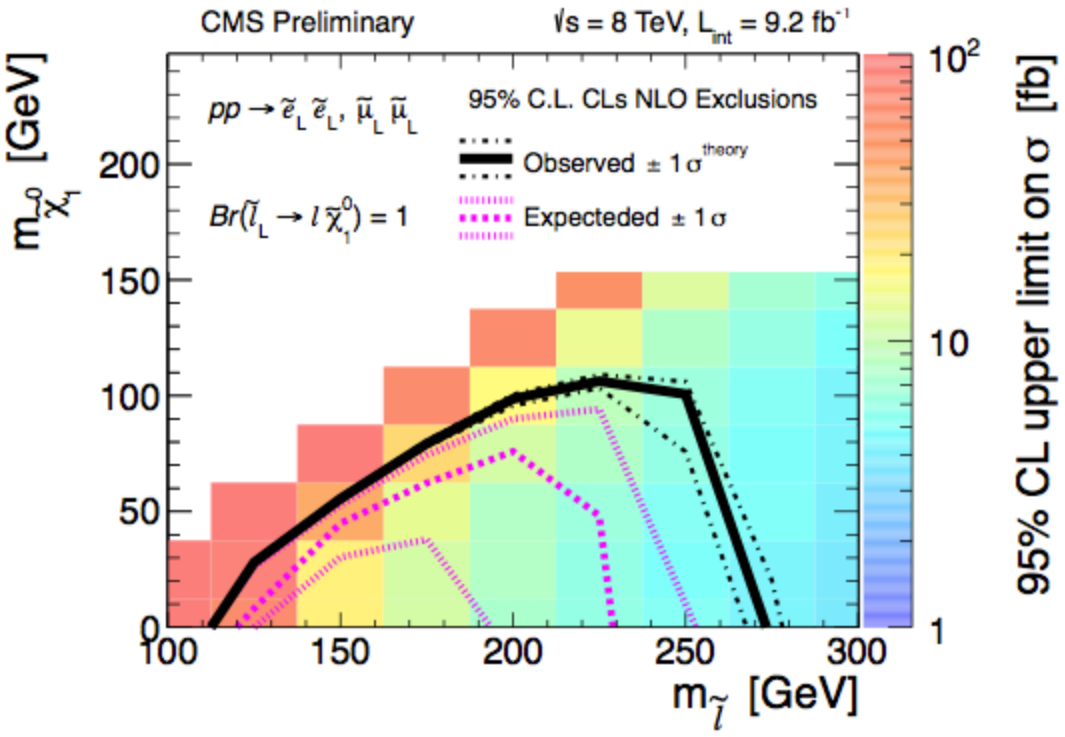
- Smoking Gun: **SS Dileptons**, some OS dileptons
  - **Everything still OK, but new bounds will rule this out or discover this!**
- Does not affect h → WW sensitivity (distributed proportional to WW in signal and control region)
- Amusingly, this is the only scenario in which charginos can increase h →γγ , by about 15%

Another possibility: charginos from squeezed stops (1303.5696). Avoids SS dileptons.

What about Sleptons?

Standard Candles have BSM Sensitivity!

- We learned from examining the Chargino and Slepton scenarios that the WW measurement can be the harbinger of new physics!
- We should exploit that sensitivity not just for **discoveries** but also for **setting bounds**.
- These bounds will be **entirely complementary** to LHC bounds (heavy states with lots of MET) and LEP bounds (light states below 100 GeV)



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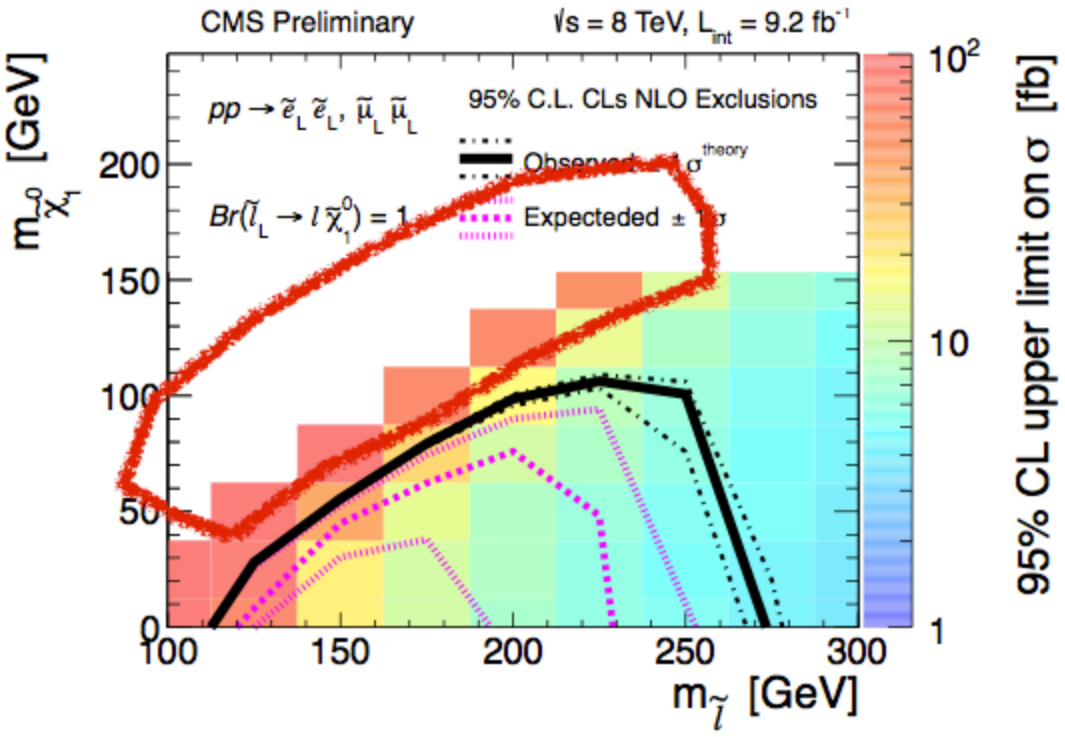
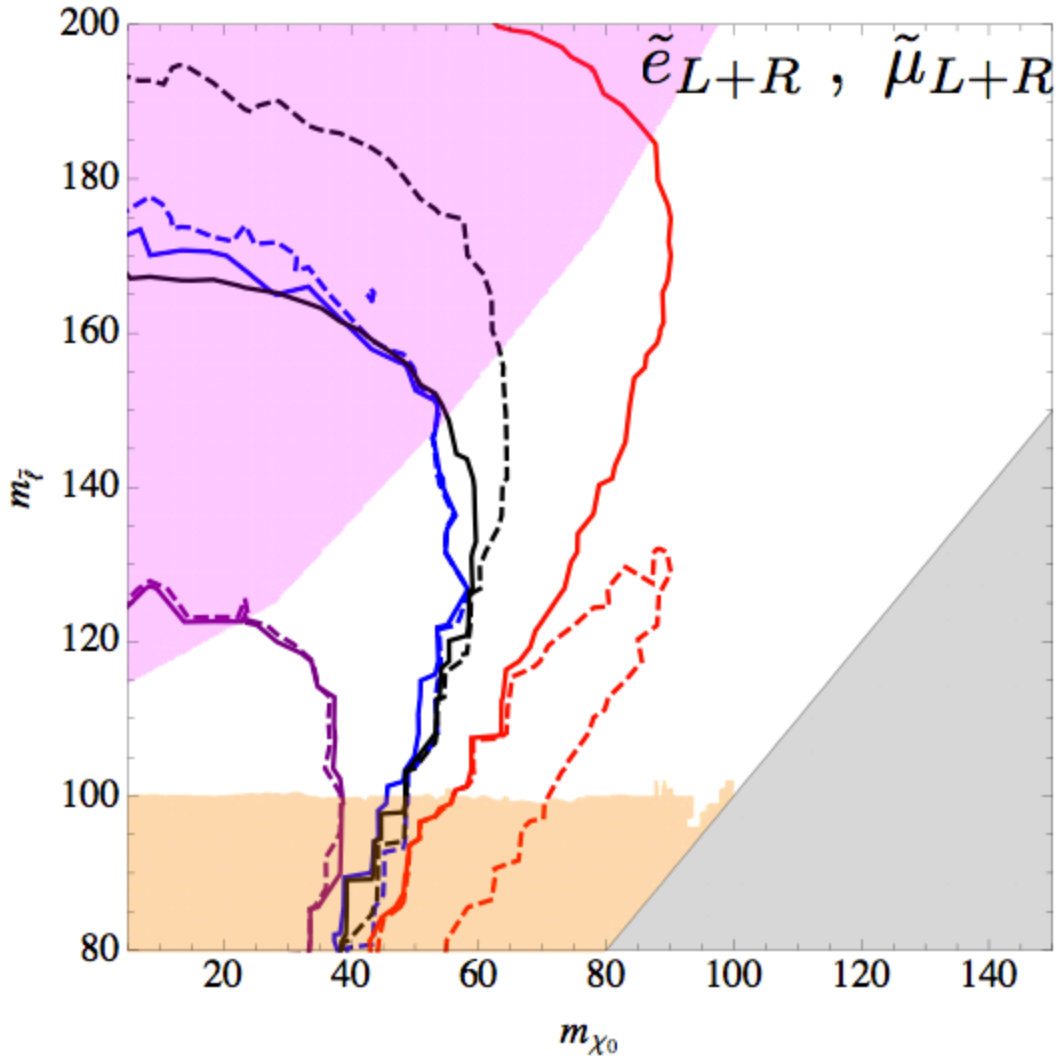
→ Exclude New Physics along the "WW-like Funnel"



Slepton Exclusions from WW Measurement



LEP

CMS 9/fb LHC8 slepton search

ATLAS7

CMS7

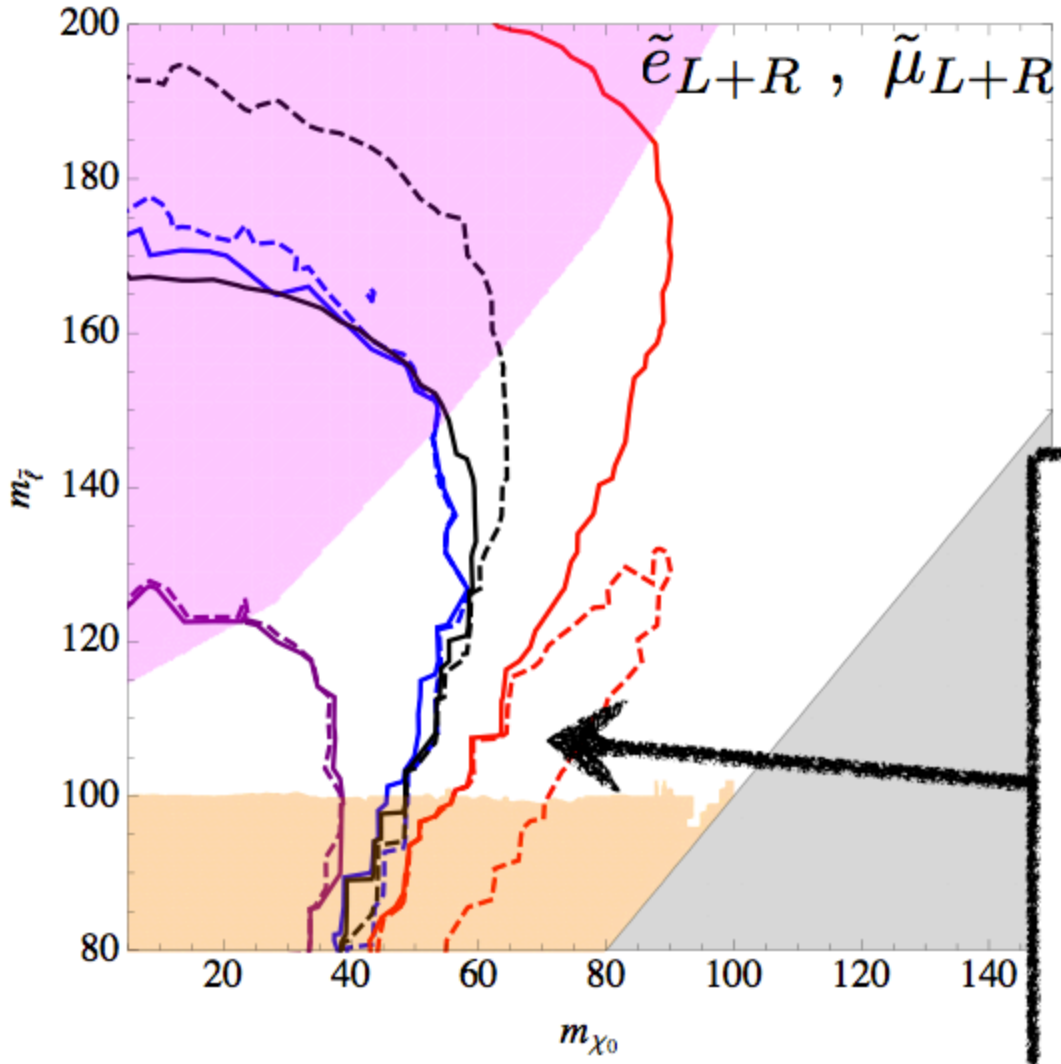
CMS8

combined

——— shape only

- - - - - - - - shape + normalization

Slepton Exclusions from WW Measurement



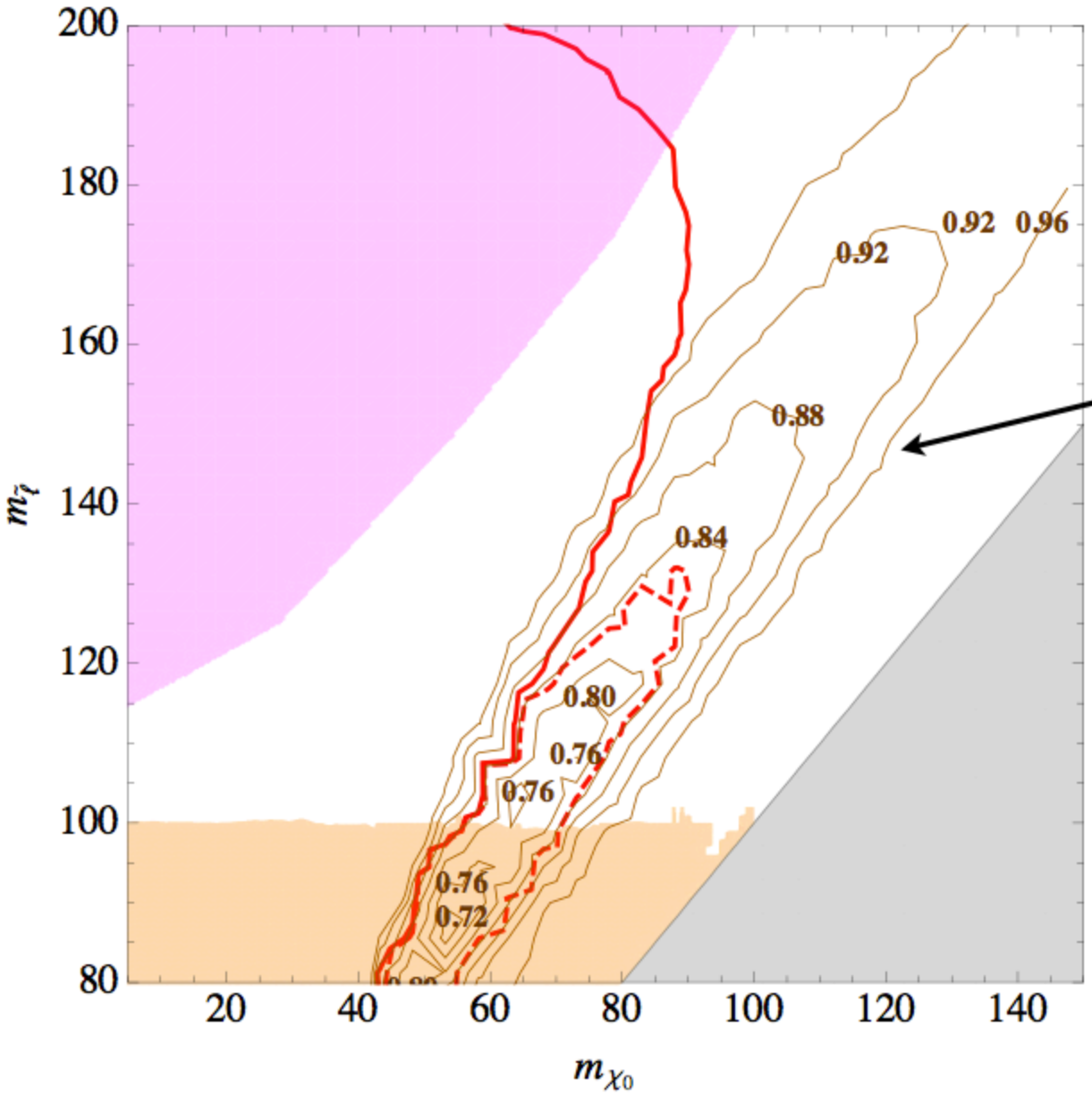
LEP

CMS 9/fb LHC8 slepton search

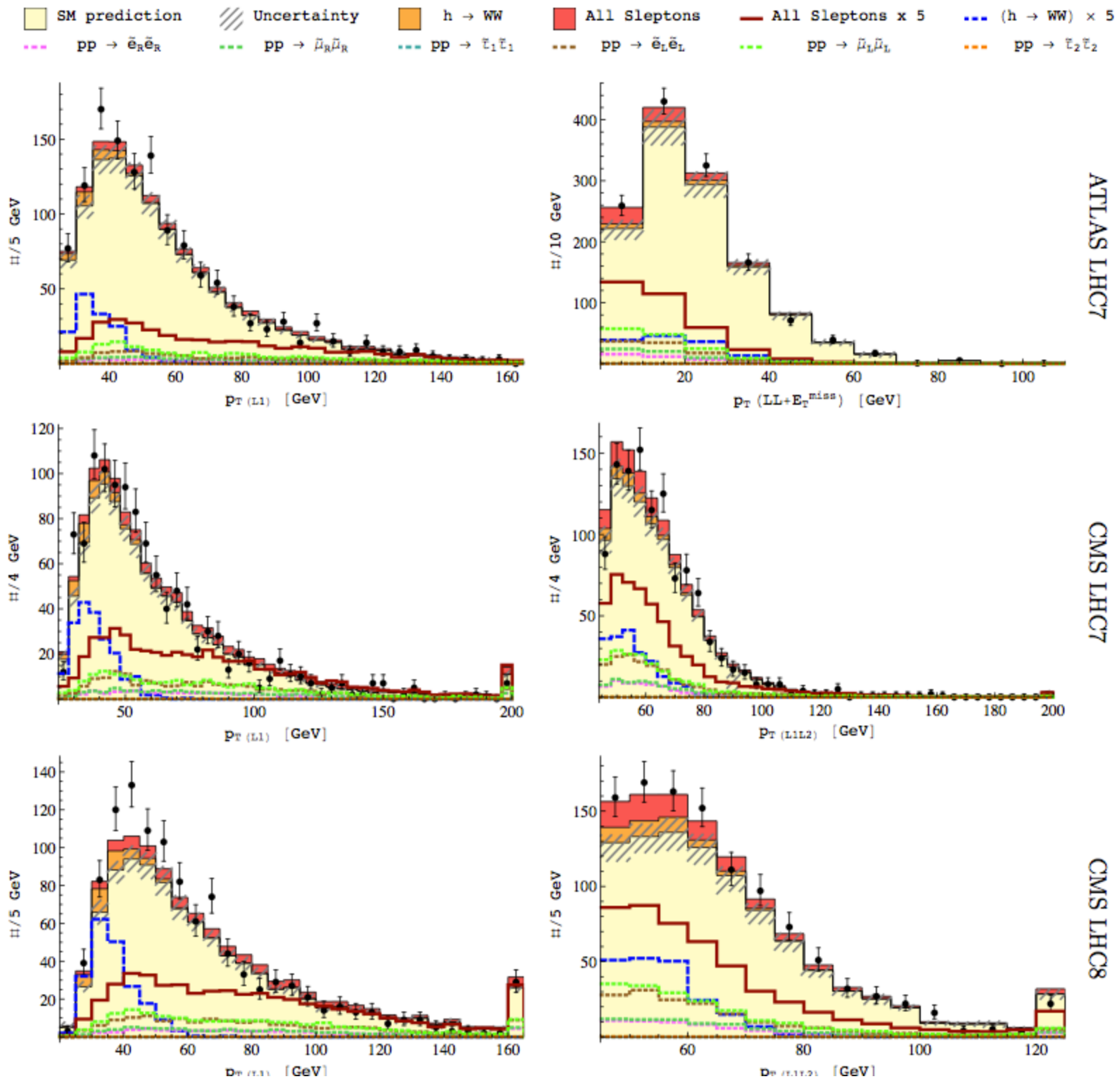
ATLAS7

CMS8:
Amusing "SM Exclusion" everywhere except here
~ 115 GeV Sleptons
~ 75 GeV Binos

Sleptons can improve WW fit



$$r_{\chi^2} = \chi^2_{\mathrm{SM+sleptons}} / \chi^2_{SM}$$


SM prediction
Uncertainty
h → WW
All Sleptons
All Sleptons x 5
(h → WW) × 5
pp → $\tilde{e}_R\tilde{e}_R$
pp → $\tilde{\mu}_R\tilde{\mu}_R$
pp → $\tilde{\tau}_1\tilde{\tau}_1$
pp → $\tilde{e}_L\tilde{e}_L$
pp → $\tilde{\mu}_L\tilde{\mu}_L$
pp → $\tilde{\tau}_2\tilde{\tau}_2$
ATLAS LHC7
CMS LHC7
CMS LHC8
/ 5 GeV
/ 10 GeV
/ 4 GeV
$p_{T\,(L1)}$ [GeV]
$p_{T\,(LL+E_T^{miss})}$ [GeV]
$p_{T\,(L1L2)}$ [GeV]

Are there any dangerous processes?

No!

However, WW excess should be concentrated in Same-Flavor channels.

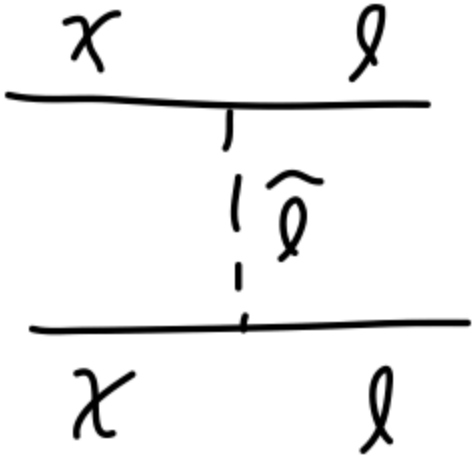
→ **That's our smoking gun!**

We sure would love to see more flavor-resolved kinematic distributions for WW.

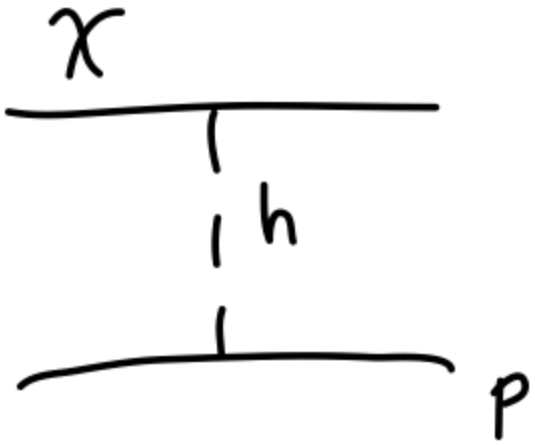
Also, 20/fb?

Can light sleptons do anything else for you?

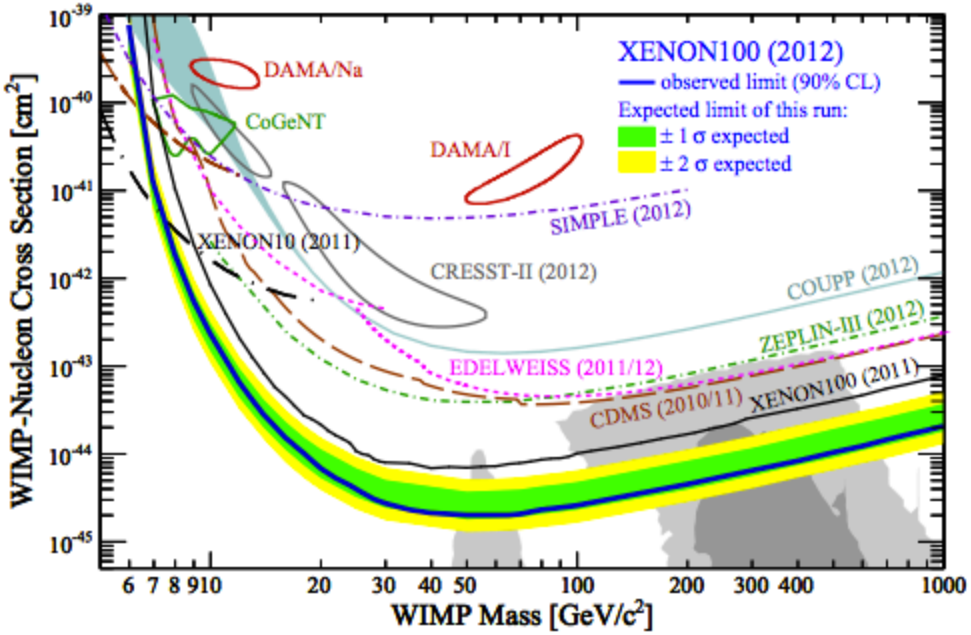
BINO DM!



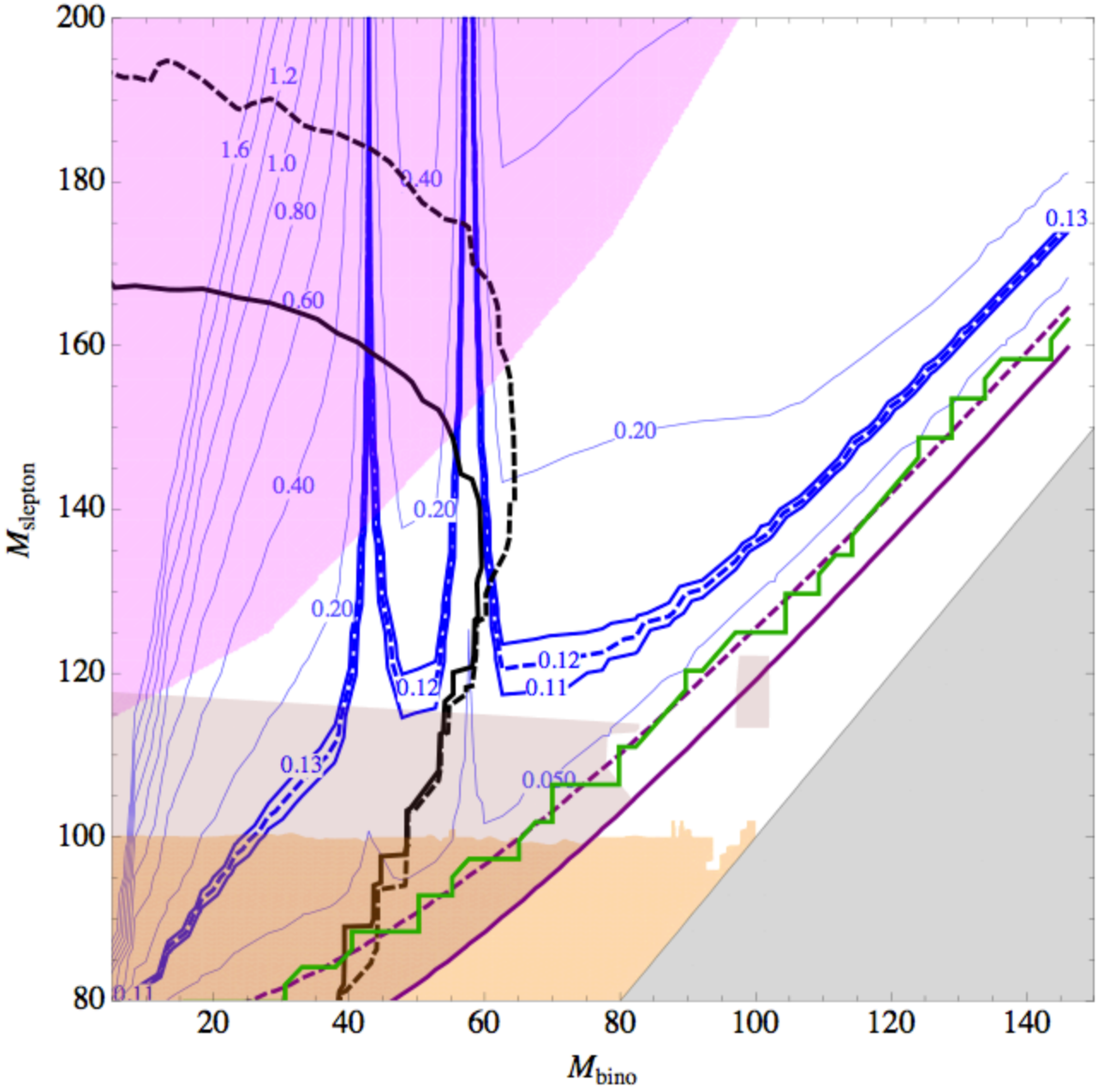
Can get right relic density



Direct Detection sails right through and is interesting for **XenonIT!**



DM and light sleptons



$\tilde{e}, \tilde{\mu}, \tilde{\tau}$ universal
soft mass ~ 100 GeV

μ = 400 GeV
tan β = 6

CMS slepton

LEP

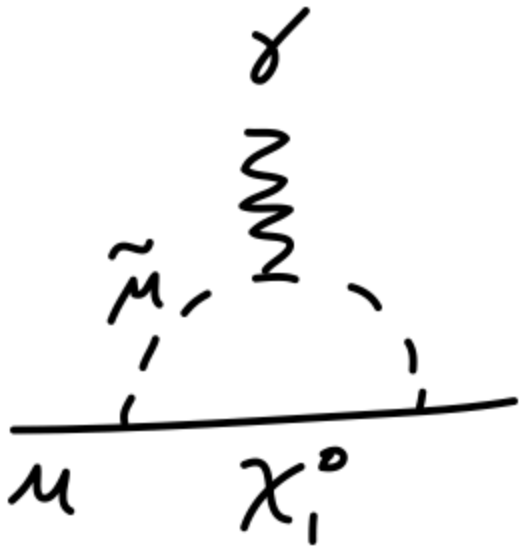
combined WW bounds

DM relic density

DM direct detection

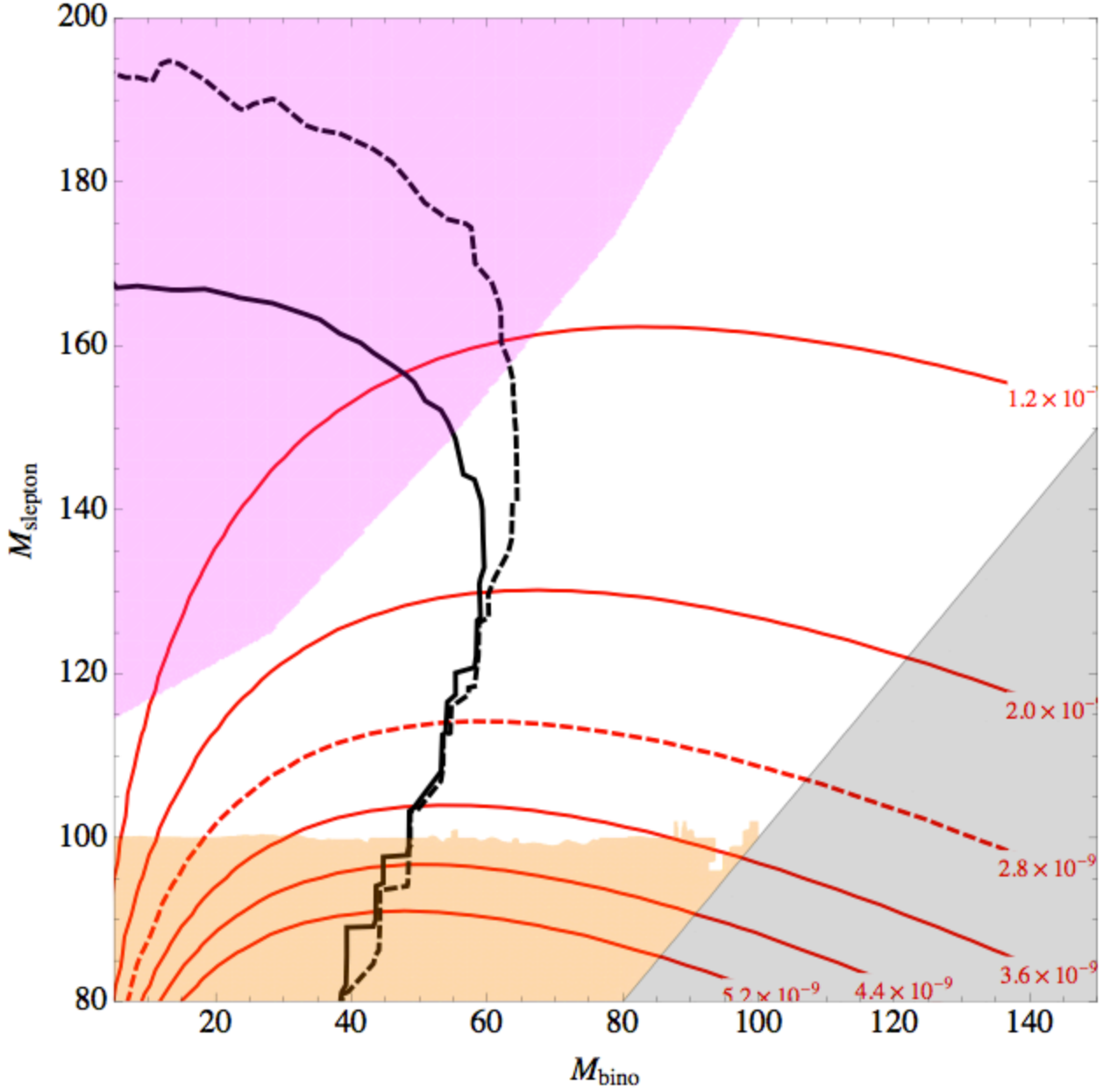
Can light sleptons do anything else for you?

Muon (g-2) !



$$\delta a_\mu = a_\mu^{\rm exp} - a_\mu^{\rm SM} = (2.8 \pm 0.8) \times 10^{-9}$$

g-2 and light sleptons



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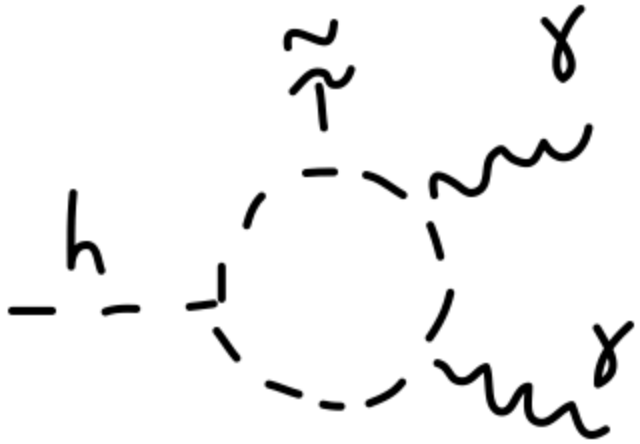
combined WW bounds

g-2

Can light sleptons do anything else for you?

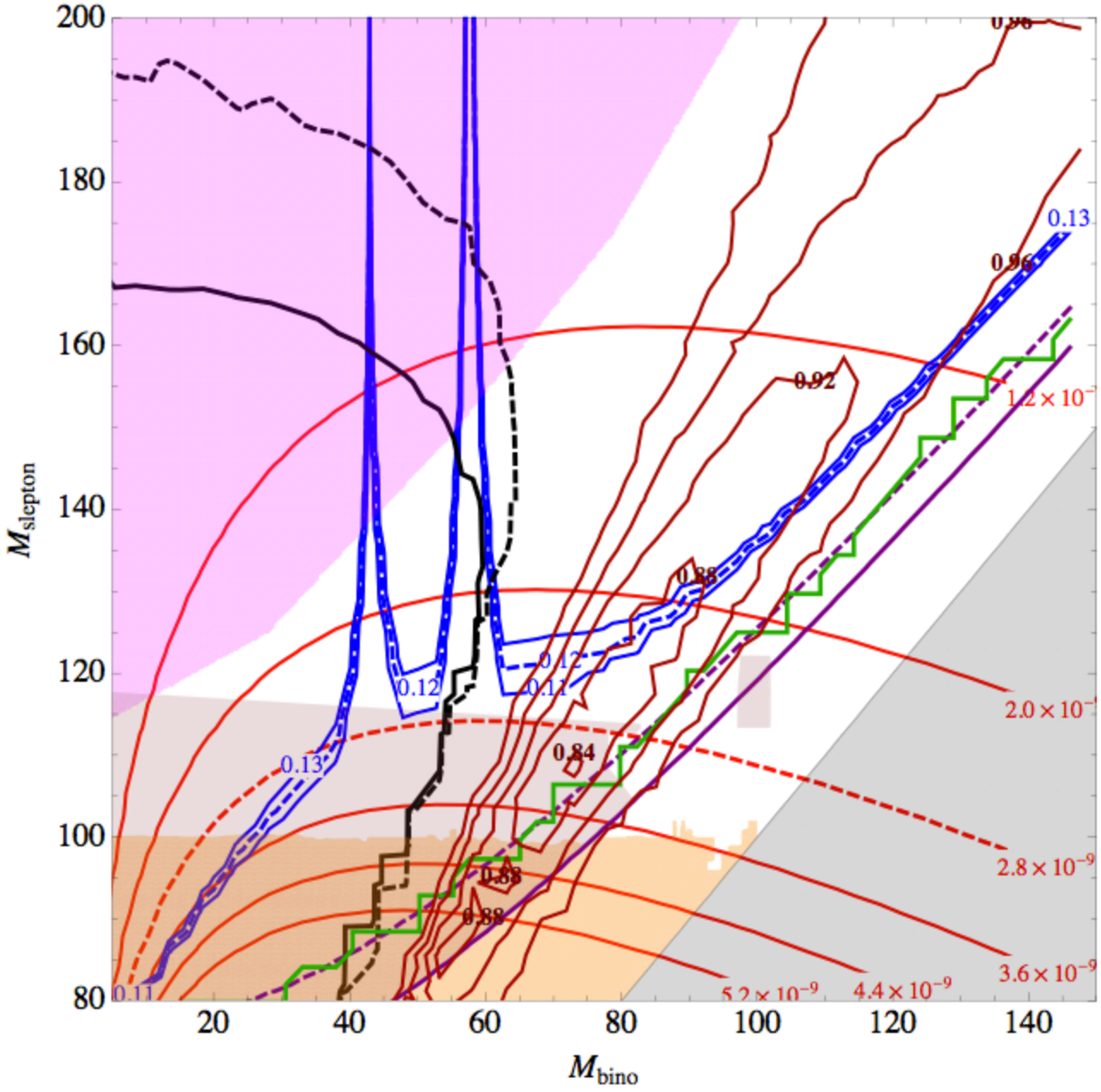
$h \to \gamma\gamma$?



Some enhancement (15%) possible
without diluting DM relic density....

Some slepton soft mass non-universality
→ FLV bounds OK!

DM, WW, g-2 all work simultaneously!



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CMS slepton

LEP

combined WW bounds

g-2

DM relic density

DM direct detection

WW preferred region

Conclusions

- WW discrepancy is consistent enough to be interesting to theorists.
- **WW can set bounds on EW physics that is invisible to other searches!**
- New Physics can fit WW measurements better than SM:
  - **Chargino explanation** (real Ws) → tested soon with SS dileptons!
  - **Slepton explanation** (not Ws) → Can explain more phenomena, harder to see.

    → Want flavor-resolved WW measurement!
- SM calculations should be improved to NNLO+N^(n)LL