MULTI-LEPTON NEW PHYSICS SEARCHES

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Yang Institute for Theoretical Physics
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Based on:

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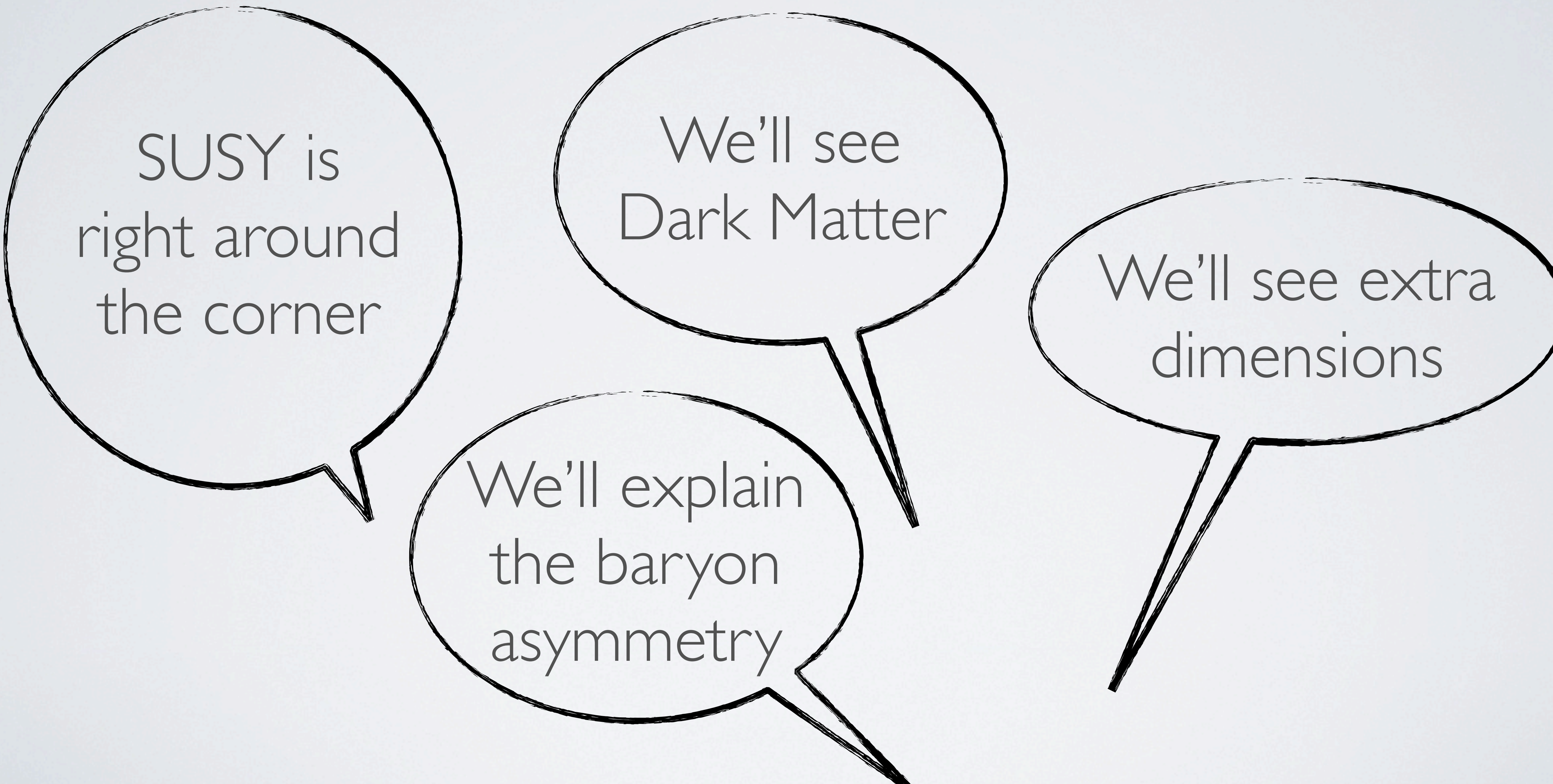
D. Curtin, P. Jaiswal, PM, P. Tien 1304.7011
+work in progress

WHY DO WE CARE ABOUT MULTILEPTONS?

- leptons are easier than jets!
- lower backgrounds
- objects are cleaner
- still tricky though depending on level of precision needed...

Where is the new physics!!!

WHAT THEORISTS WERE SAYING PRE LHC



POST 7 AND 8 TEV RUNS

Maybe SUSY is at 100 TeV

Maybe it's just the Higgs

Have we reached the end of particle physics?

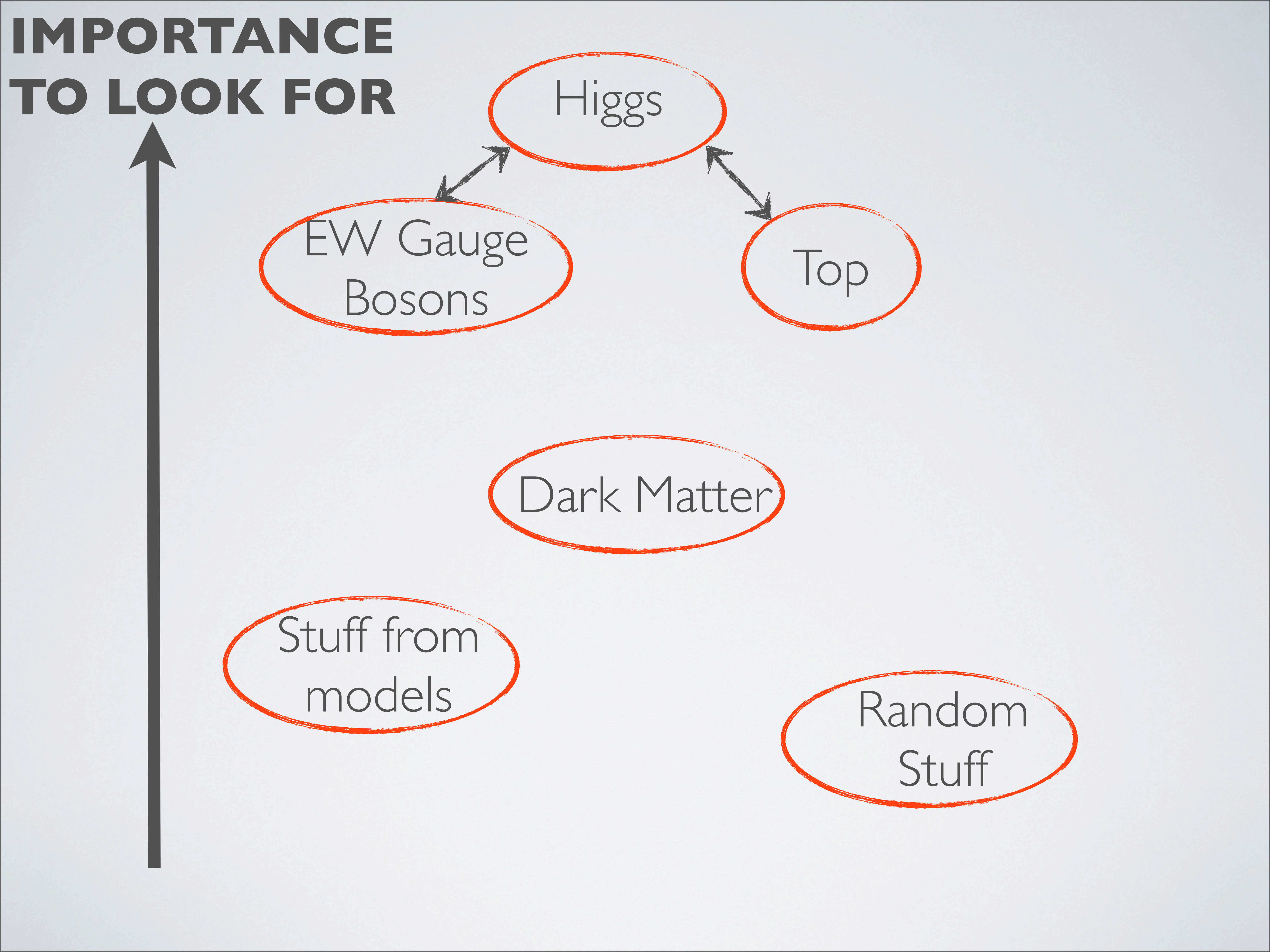
Maybe DM is an axion

WHIPLASH OF PREDICTIONS...

Are we better than financial analysts or weather forecasters at predictions?

Theorists come up with deep mechanisms for solving problems

WHERE CAN YOU EXPECT TO HUNT NEW PHYSICS?


IMPORTANCE
TO LOOK FOR
Higgs
EW Gauge Bosons
Top
Dark Matter
Stuff from models
Random Stuff

IMPORTANCE TO LOOK FOR
Higgs
SEARCHES WITH MULTILEPTONS
EW Gauge Bosons
Top
Dark Matter
Stuff from models
Random Stuff

WHERE TO FIND NEW PHYSICS?

TWiki > CMSPublic Web > PhysicsResults (29-May-2013, ChristopherHill)

Edit Attach PDF

CMS Physics Results

General Information

- All CMS public results can be found in CDS , and are categorized by subject (group) in this page.
- Publications and preprints on **collision data**, ordered by time, are available at this link.
- Publications on cosmic-ray data can be found here; the paper on muon charge ratio is available here .
- The complete list of publications is here.
- Preliminary results **on collision data at 0.9, 2.36, 7, and 8 TeV** are described in Physics Analysis Summaries; Monte Carlo studies can be found here.
- Public performance plots are shown in Detector Performance Summaries.
- For any questions, please contact the CMS Physics Coordinator, Greg.Landsberg@cernSPAMNOT.ch

Physics Analyses

Physics Analysis Group	Group page	Publications	Preliminary Results	Monte Carlo studies
Forward and Small-x QCD Physics	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
B Physics and Quarkonia	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Standard Model Physics (Vector Bosons & Jets)	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Top Physics	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Higgs Physics	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Supersymmetry	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Exotica	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Beyond 2 Generations	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries
Heavy-Ion Physics	Plots and Results	Papers	Physics Analysis Summaries	Physics Analysis Summaries

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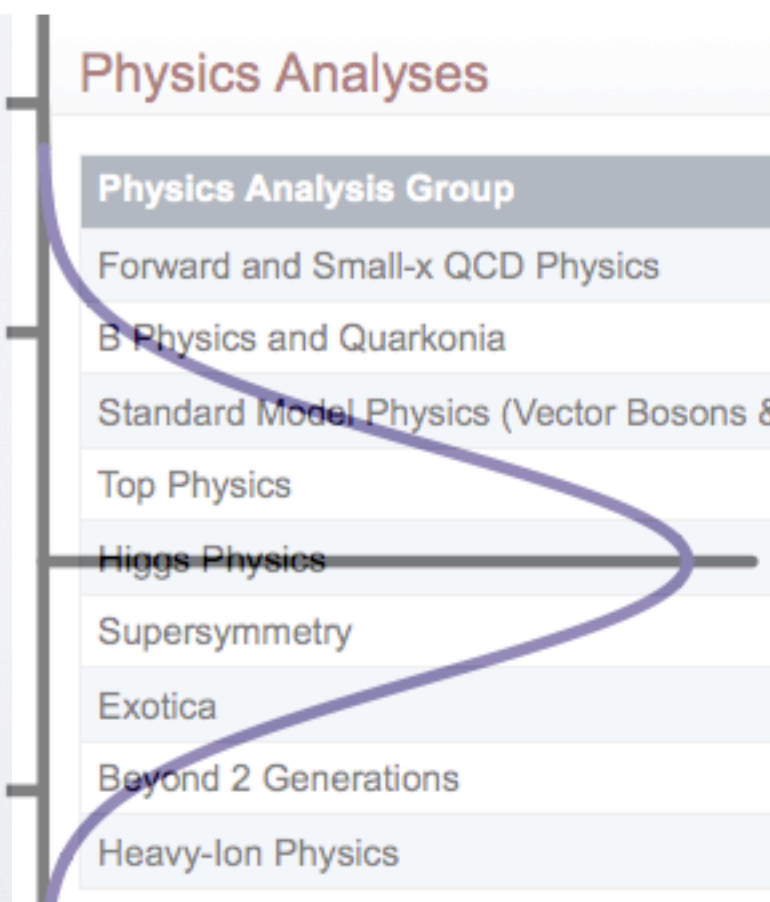
Interest from theory



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BOUNDS ON SUSY (MET) PRE LHC

300 GeV - colored
(Tevatron) sparticles

100 GeV
(LEP)
EW
States

BOUNDS ON SUSY (MET) EARLY LHC

1000 GeV - colored
(LHC) sparticles

100 GeV EW
(LEP) States

BOUNDS ON SUSY (MET) CURRENT LHC

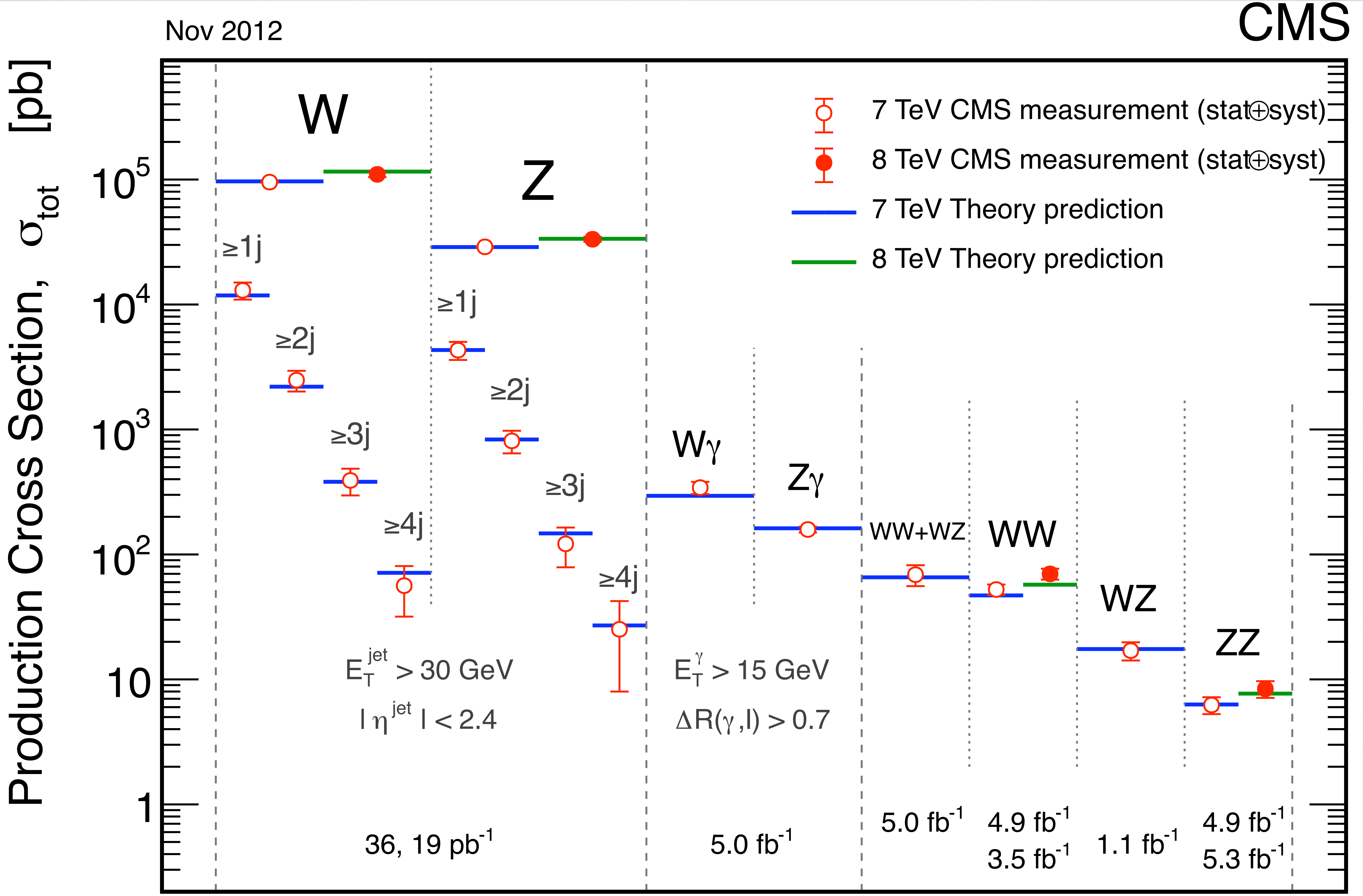
1000 GeV - colored sparticles
(LHC)

300 GeV
(LHC)
EW States

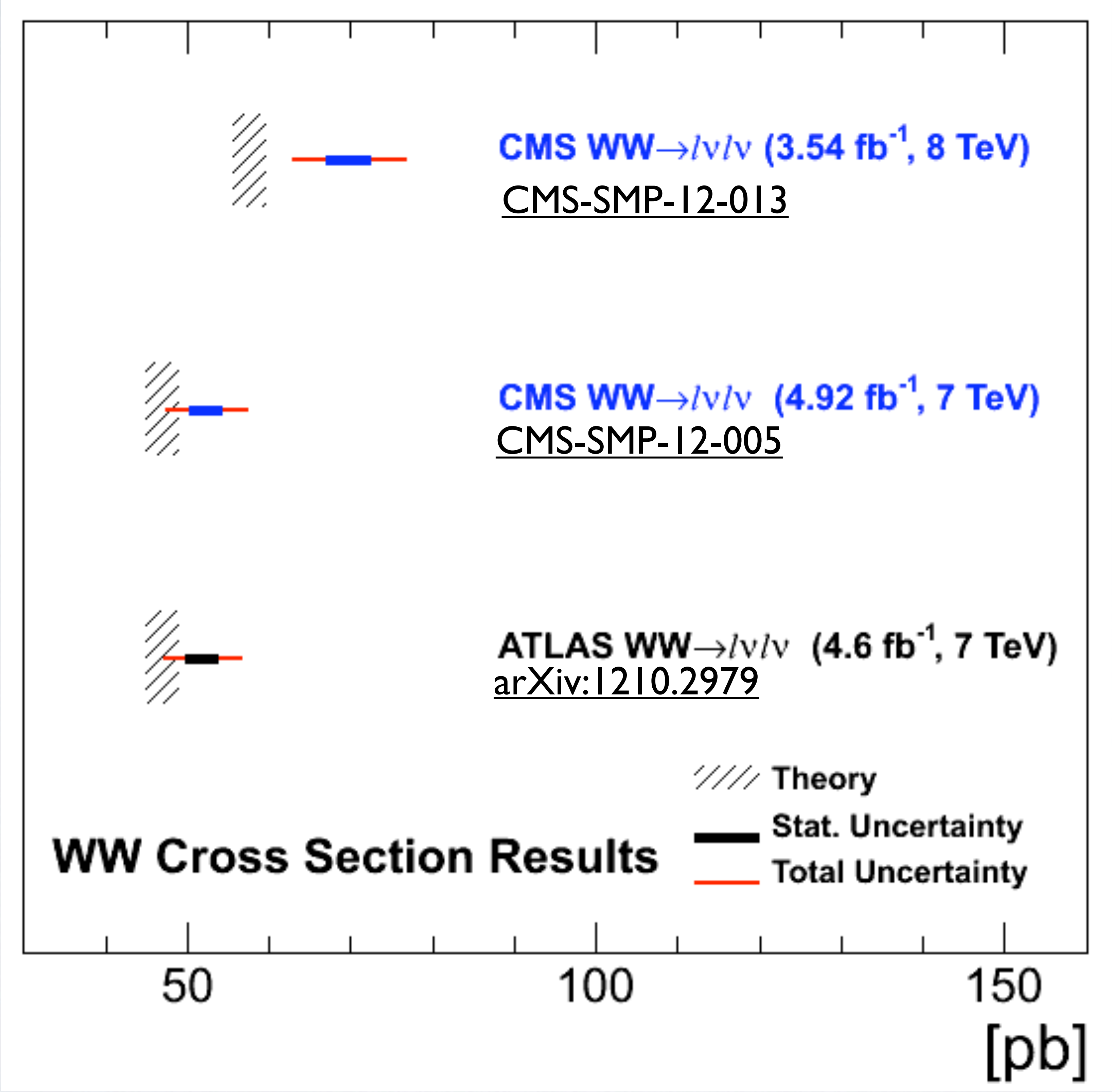
Caveats abound of course...

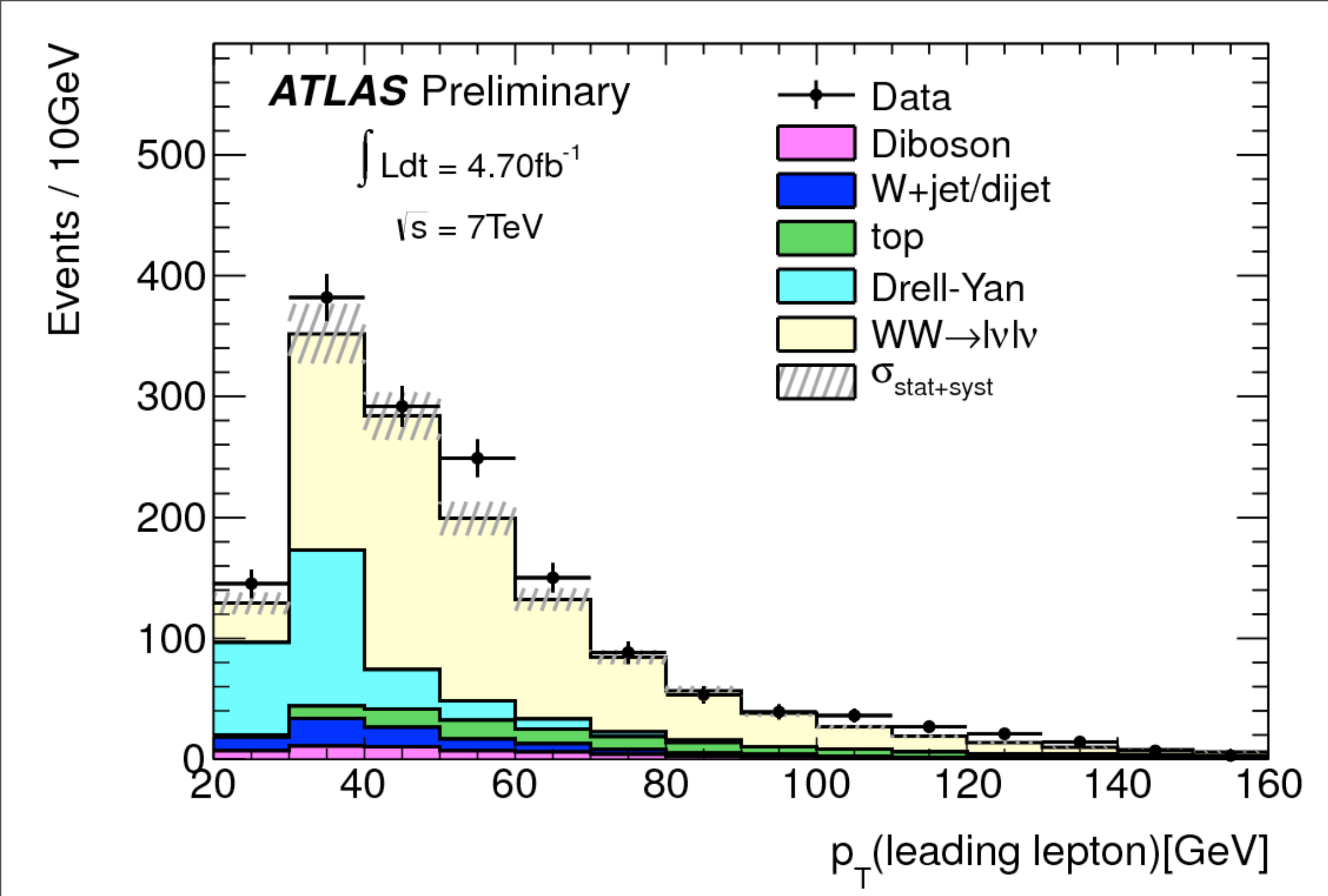
LET'S LOOK AT THE SM NOW FOR A MINUTE

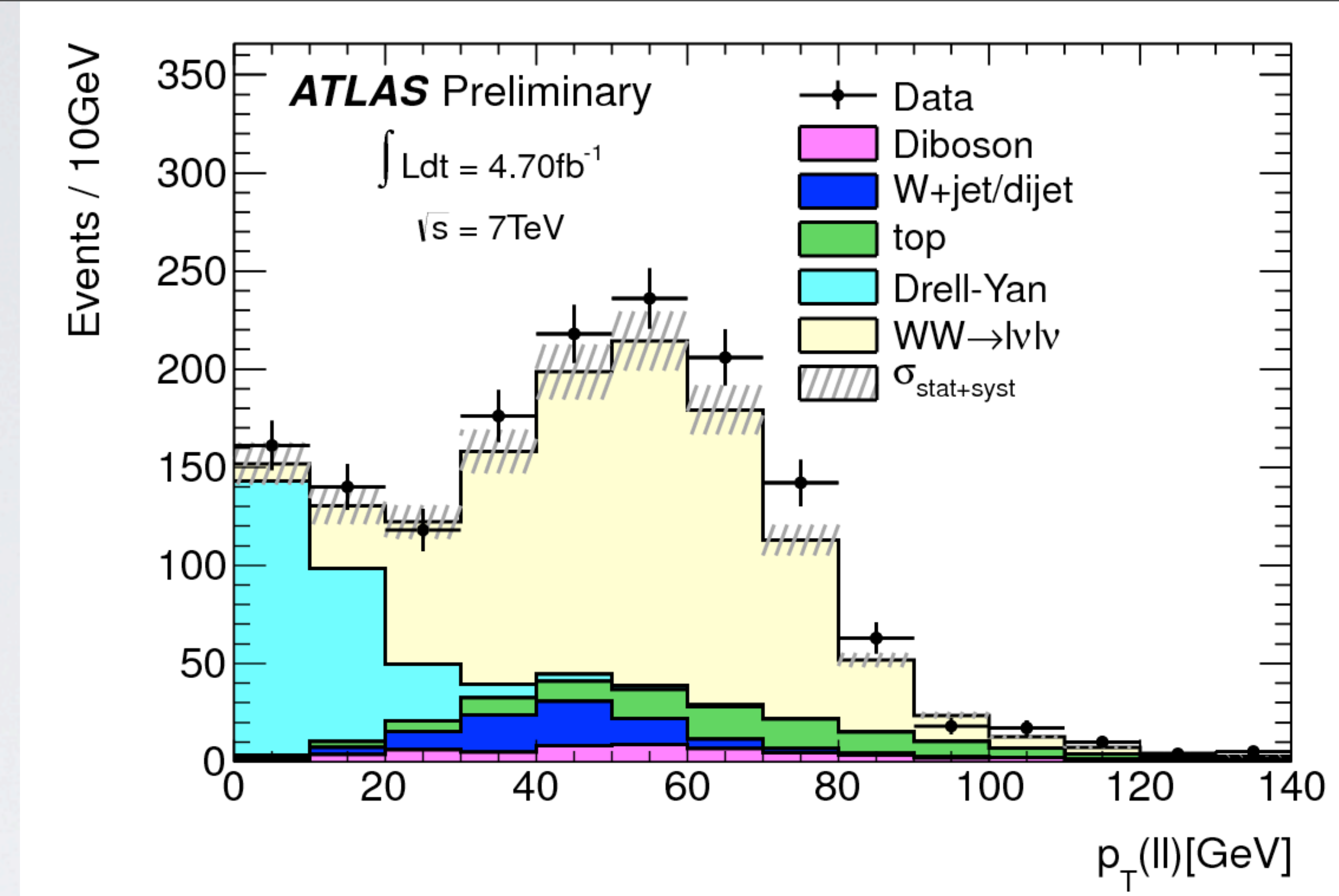
CMS EW HCP ZOOM IN



An example...


CMS WW→lνlν (3.54 fb^{-1}, 8 TeV)
CMS-SMP-12-013
CMS WW→lνlν (4.92 fb^{-1}, 7 TeV)
CMS-SMP-12-005
ATLAS WW→lνlν (4.6 fb^{-1}, 7 TeV)
arXiv:1210.2979
Theory
Stat. Uncertainty
Total Uncertainty
WW Cross Section Results
50
100
150
[pb]


ATLAS Preliminary
∫Ldt = 4.70fb⁻¹
√s = 7TeV
Data
Diboson
W+jet/dijet
top
Drell-Yan
WW→lνlν
σ stat+syst
Events / 10GeV
p_T(leading lepton)[GeV]
0
100
200
300
400
500
20
40
60
80
100
120
140
160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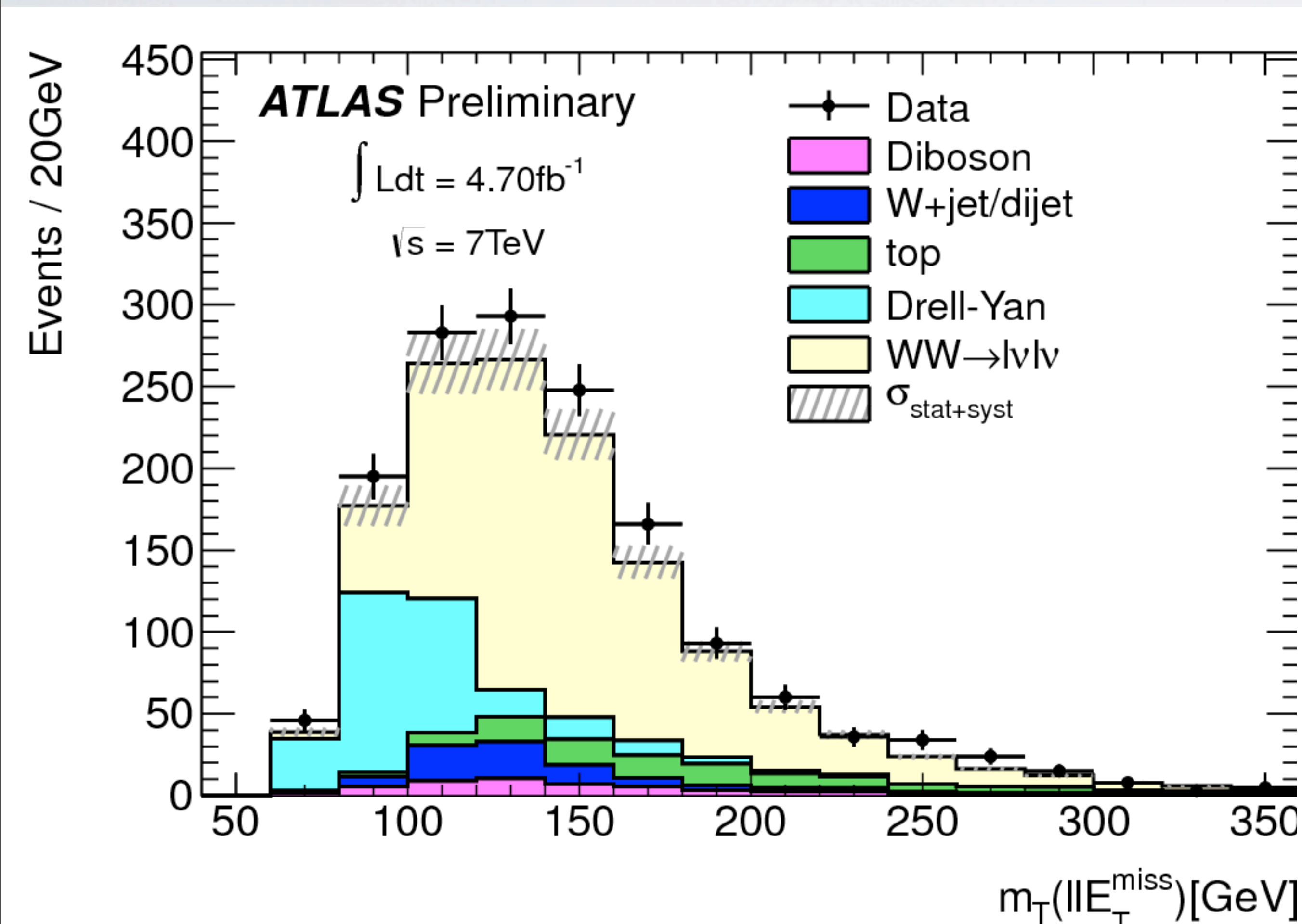
Data
Diboson
W+jet/dijet
top
Drell-Yan
WW→lνlν
σ stat+syst
Events / 10GeV
p_T(ll)[GeV]
0
50
100
150
200
250
300
350
0
20
40
60
80
100
120
140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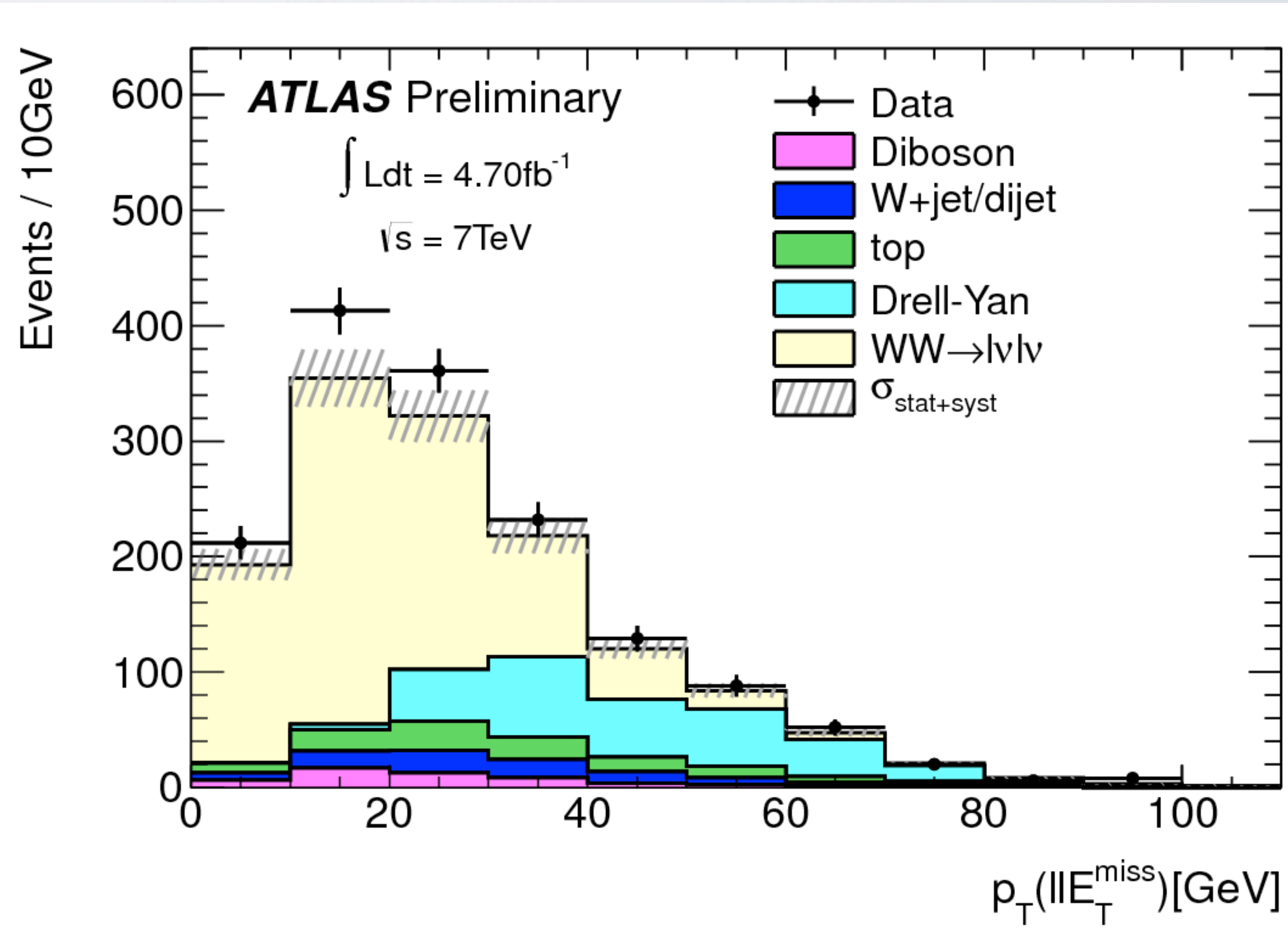
Data
Diboson
W+jet/dijet
top
Drell-Yan
WW→lνlν
σ stat+syst
Events / 20GeV
m_T(llE_T^miss)[GeV]
0
50
100
150
200
250
300
350
400
450
50
100
150
200
250
300
350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Data
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top
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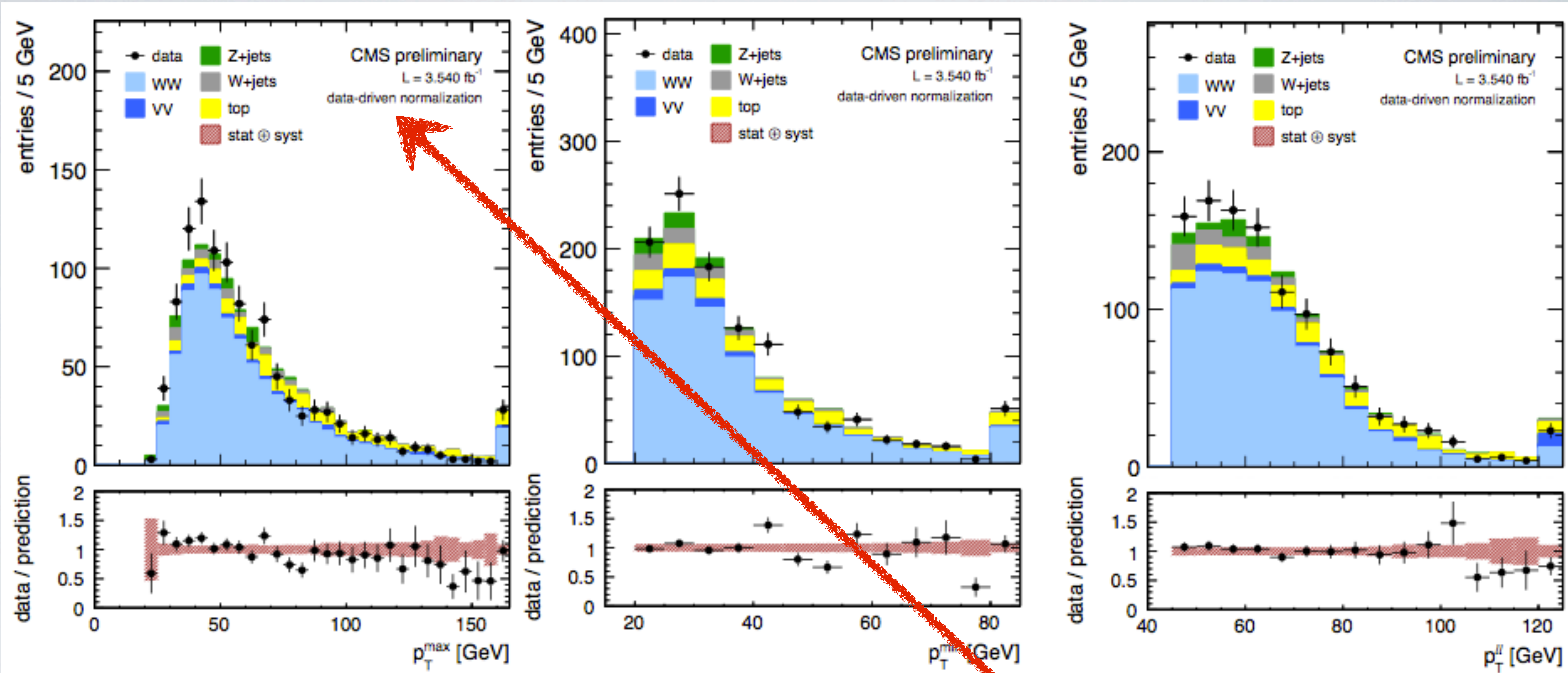
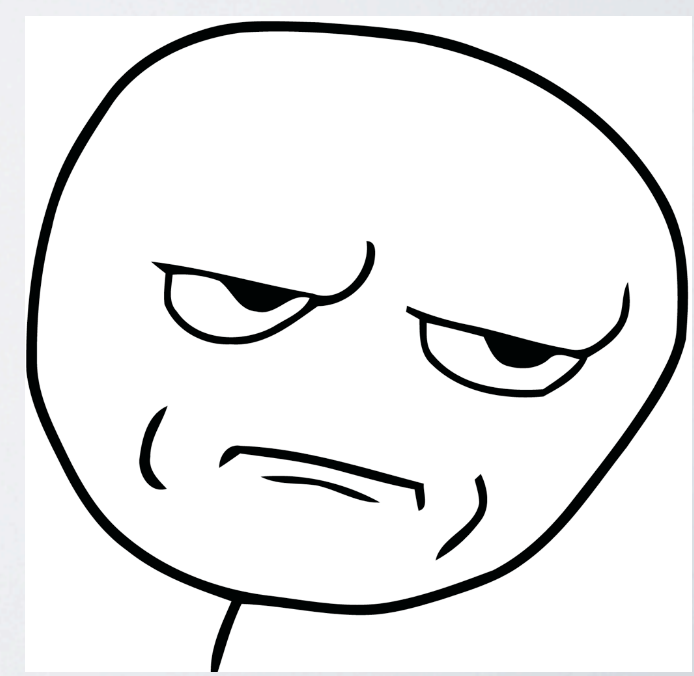
WW→lνlν
σ stat+syst
Events / 10GeV
p_T(llE_T^miss)[GeV]
0
100
200
300
400
500
600
0
20
40
60
80
100

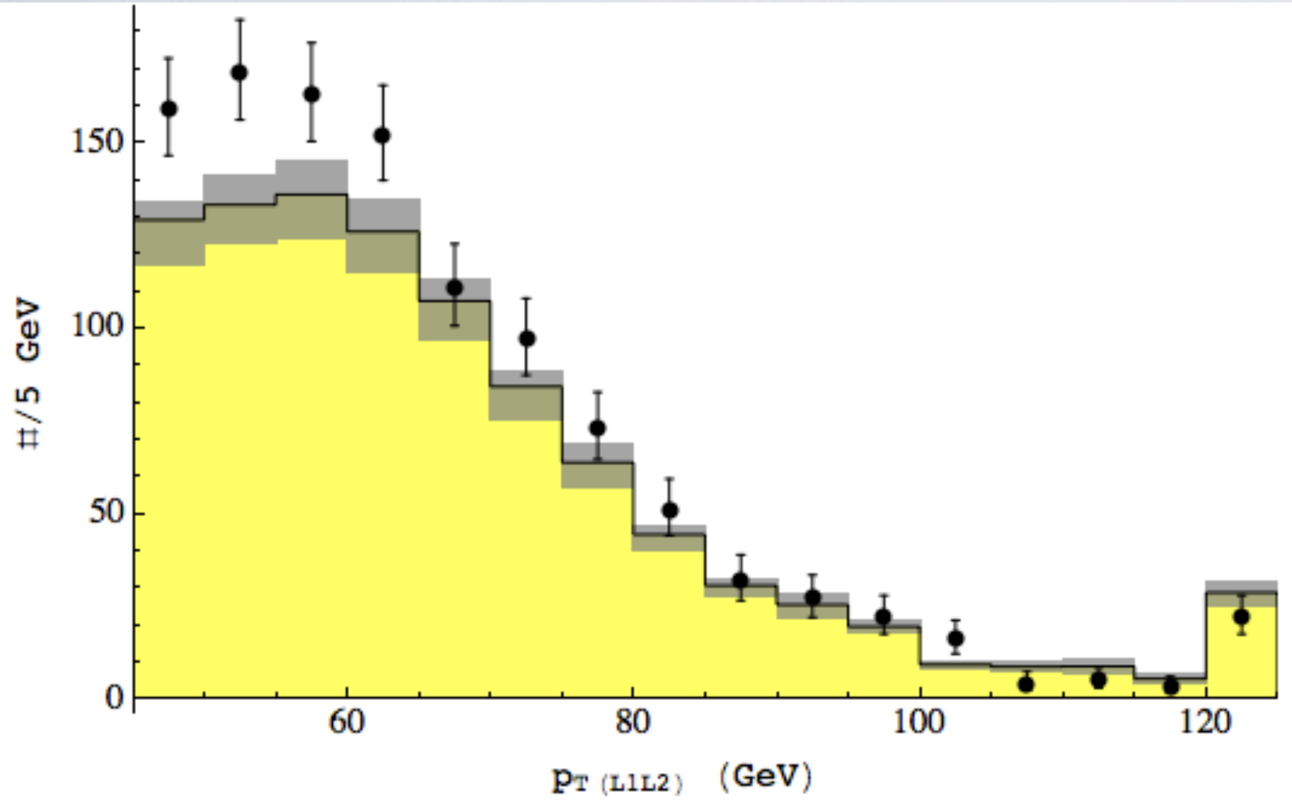
CMS8

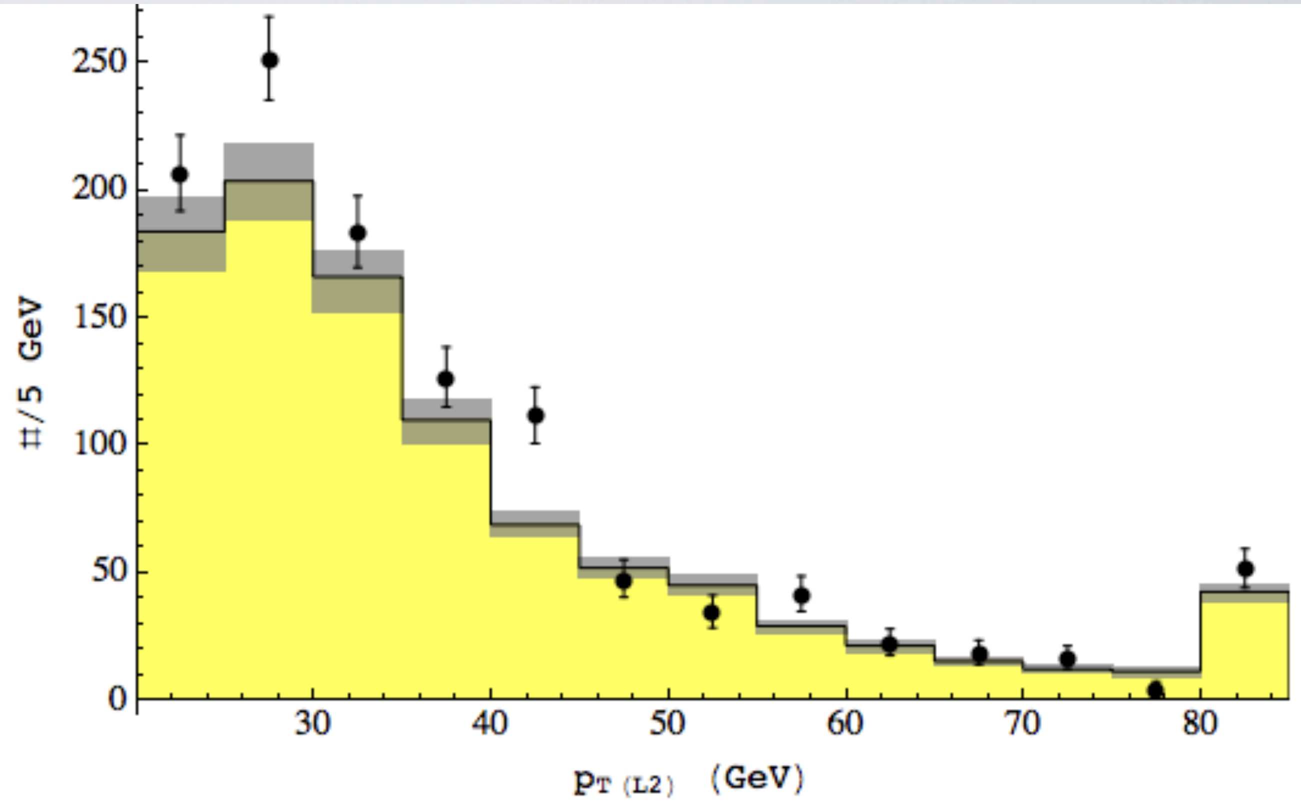


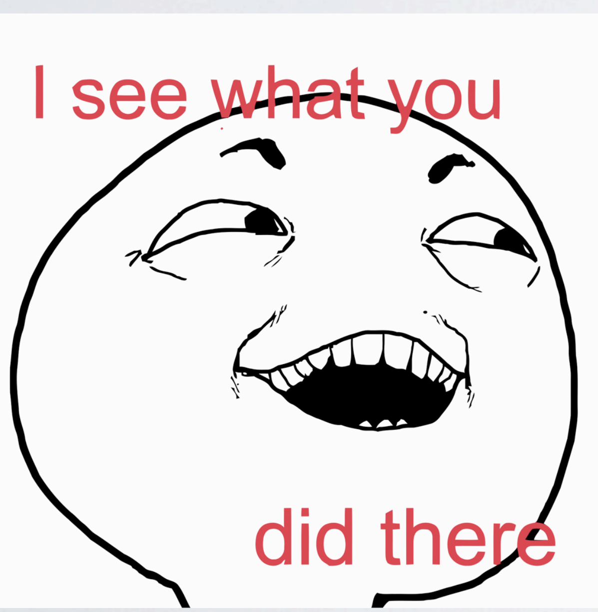
Looks pretty good...

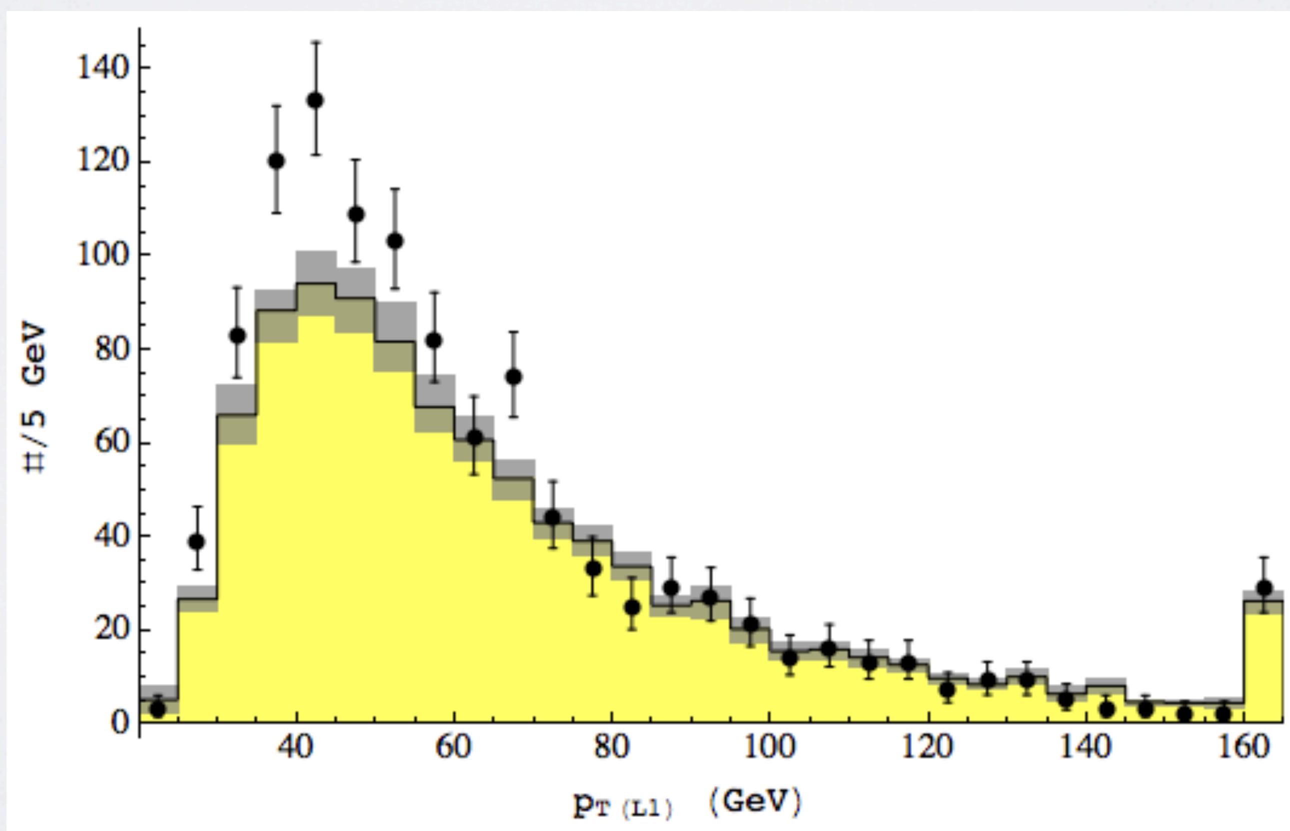


NO EXTRA NORMALIZATION...









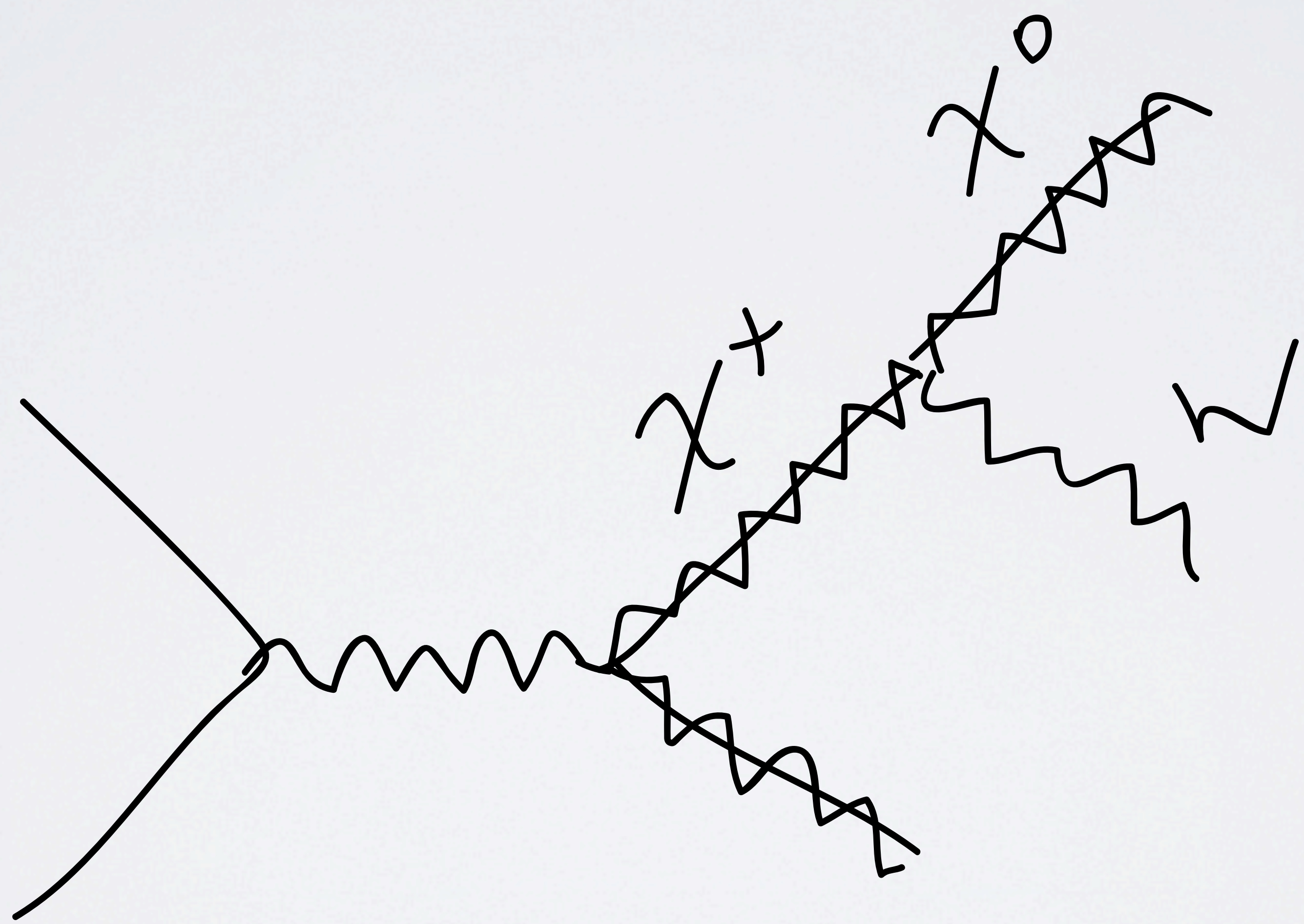
INGREDIENTS FOR BSM EXPLANATION

- ATLAS and CMS both measure OS dileptons + MET **with** a jet VETO
- Final state needs to be OS leptons+MET with *nothing* else essentially
- Does ***NOT*** imply there have to be ***REAL W's***

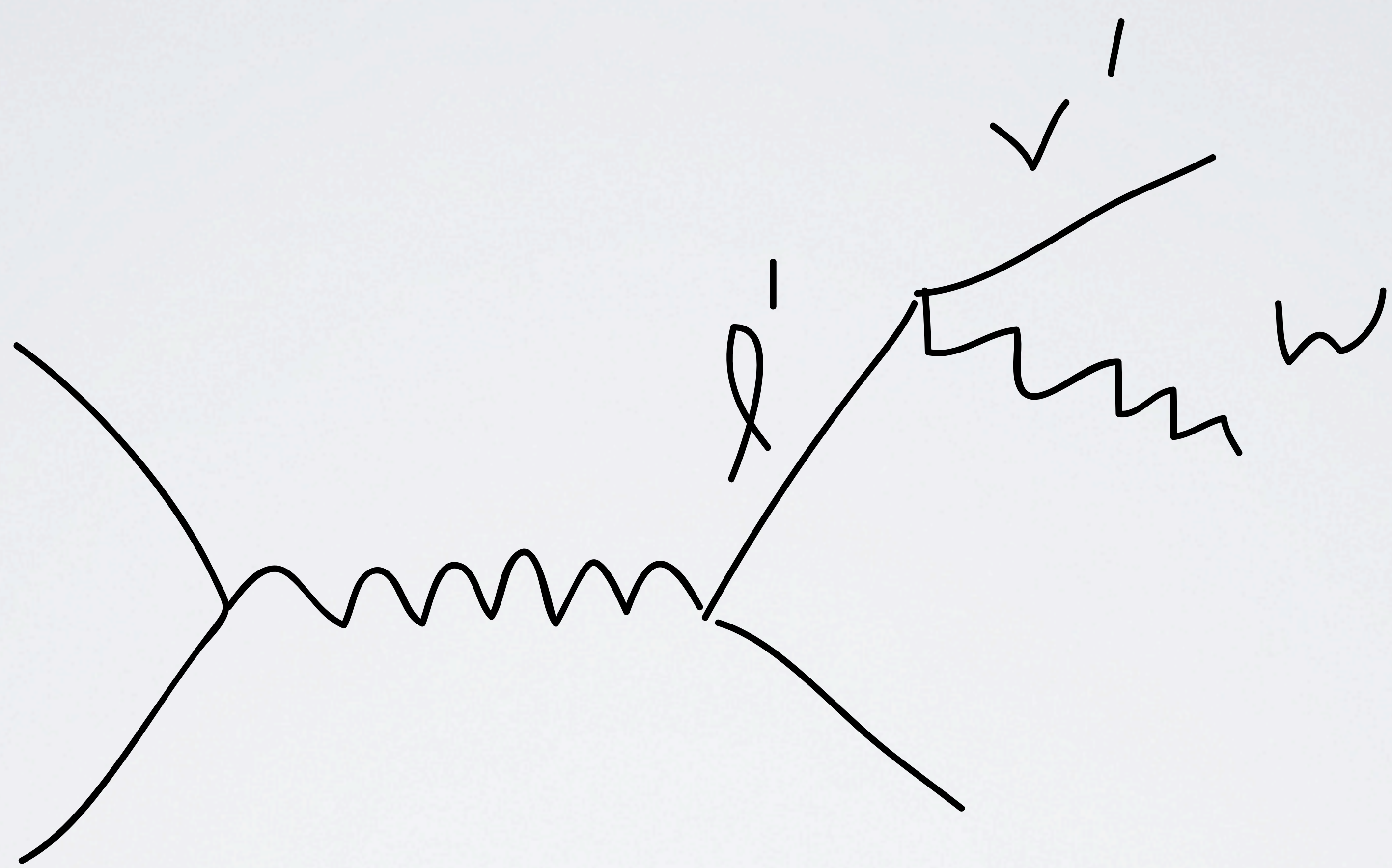
Zoom through 3 explanations:

Charginos, Stops, Sleptons

EXAMPLE TOPOLOGIES FOR WW+MET

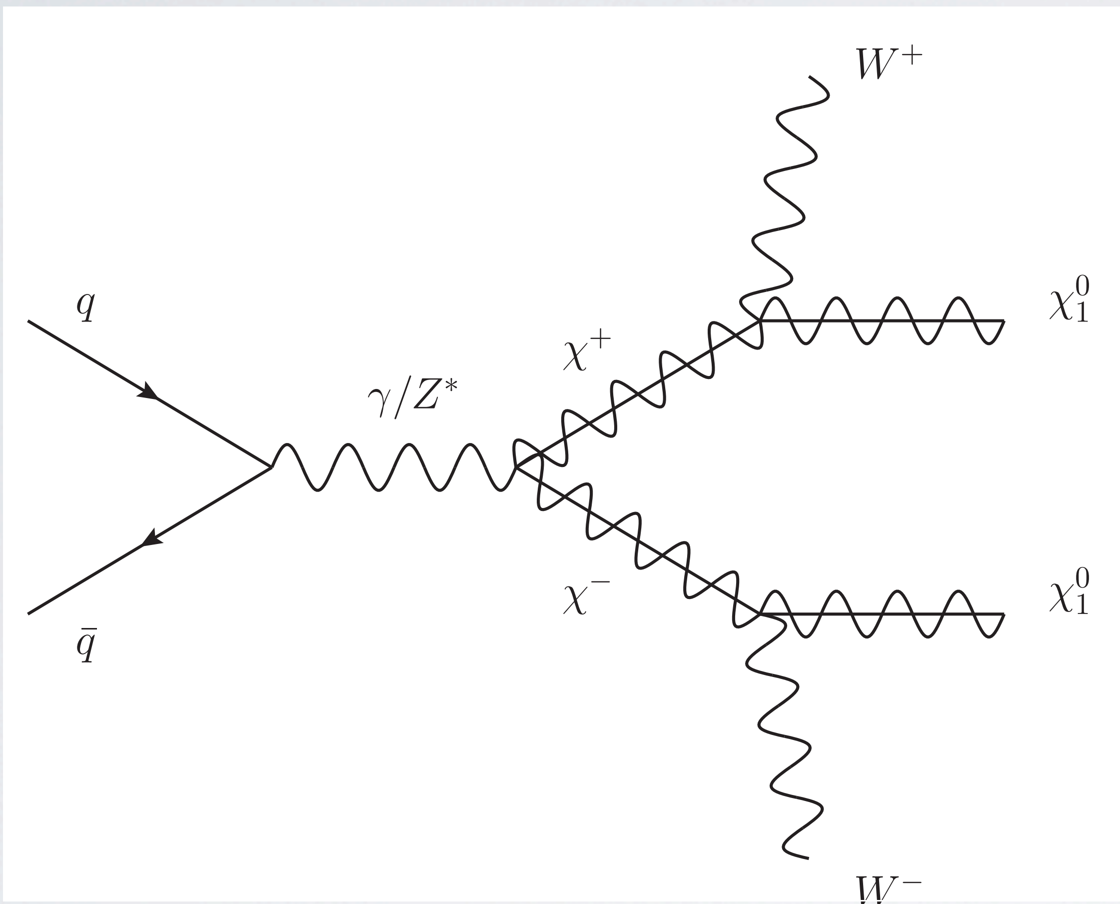


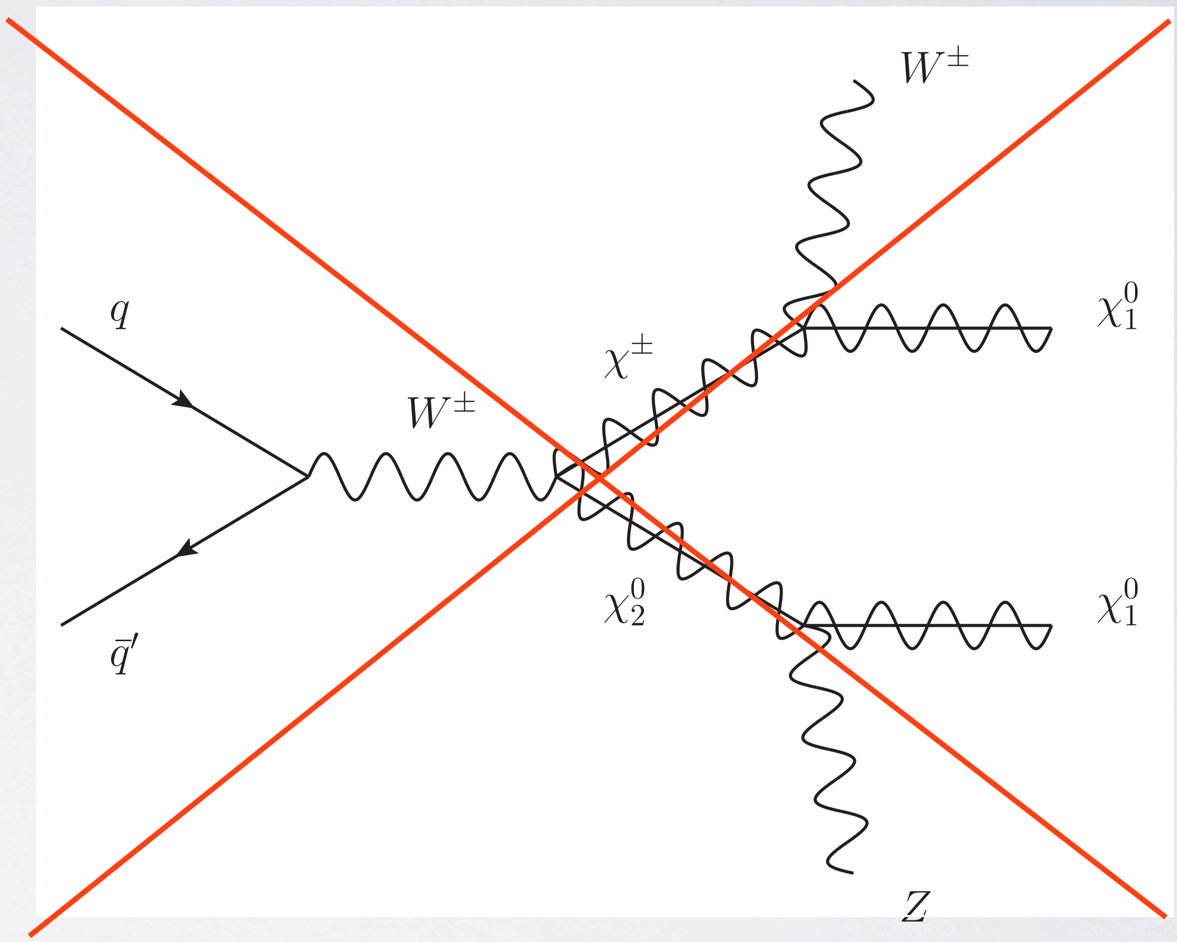
DON'T LIKE SUSY??



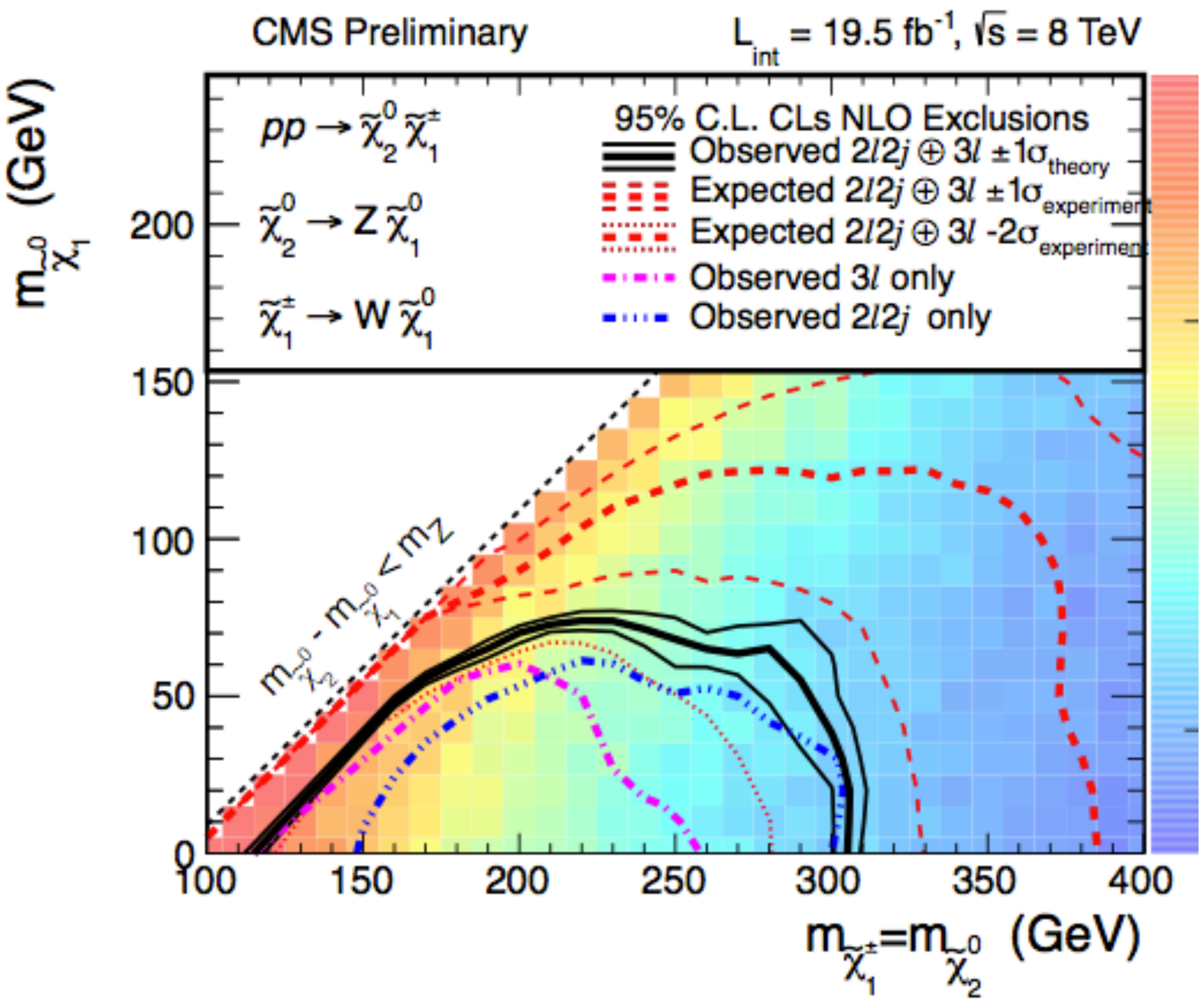
"Heavy Lepton"

EXAMPLE TOPOLOGIES

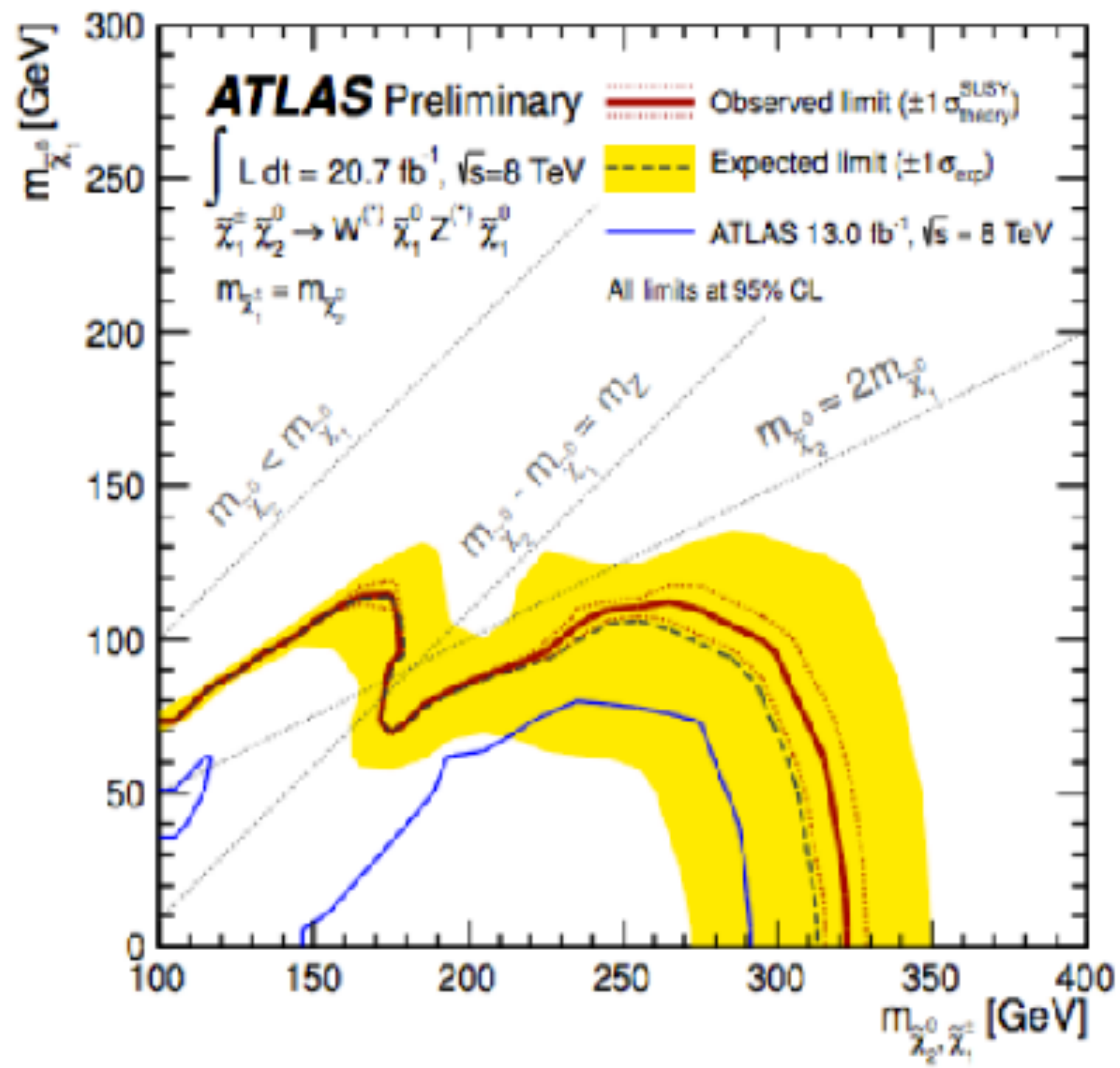




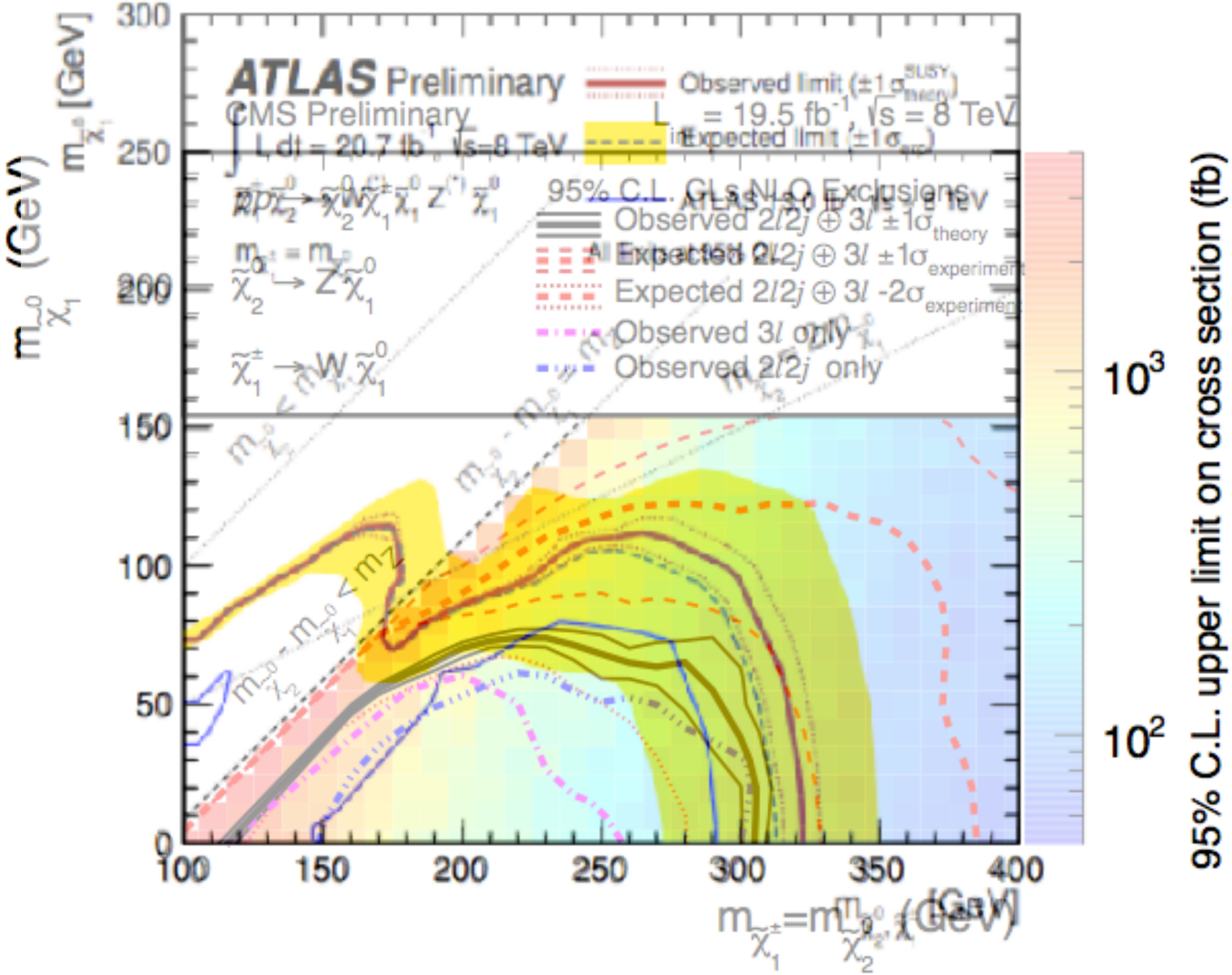
Trileptons harder
to get away with
depending on your experiment...



CMS Preliminary
L_{int} = 19.5 fb^{-1}, √s = 8 TeV
$pp \to \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$
$\tilde{\chi}_2^0 \to Z \tilde{\chi}_1^0$
$\tilde{\chi}_1^\pm \to W \tilde{\chi}_1^0$
95% C.L. CLs NLO Exclusions
Observed 2l2j ⊕ 3l ±1σ$_{theory}$
Expected 2l2j ⊕ 3l ±1σ$_{experiment}$
Expected 2l2j ⊕ 3l -2σ$_{experiment}$
Observed 3l only
Observed 2l2j only
$m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} < m_Z$
$m_{\tilde{\chi}_1^0}$ (GeV)
$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$ (GeV)



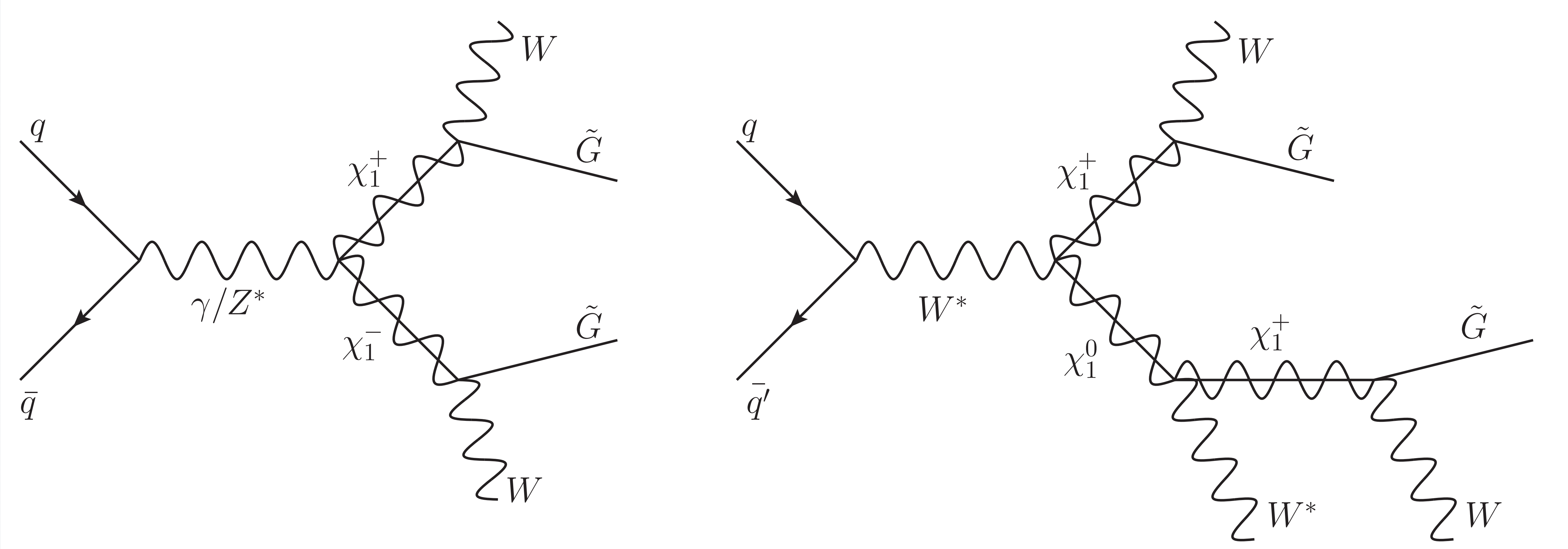
ATLAS Preliminary
∫ L dt = 20.7 fb^{-1}, √s=8 TeV
$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to W^{(*)} \tilde{\chi}_1^0 Z^{(*)} \tilde{\chi}_1^0$
$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$
Observed limit (±1 σ$^{SUSY}_{theory}$)
Expected limit (±1 σ$_{exp}$)
ATLAS 13.0 fb^{-1}, √s = 8 TeV
All limits at 95% CL
$m_{\tilde{\chi}_2^0} < m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = m_Z$
$m_{\tilde{\chi}_2^0} = 2m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{\chi}_2^0, \tilde{\chi}_1^\pm}$ [GeV]



ATLAS Preliminary
CMS Preliminary
Observed limit (±1 σ^SUSY_theory)
Expected limit (±1 σ_exp)
L = 19.5 fb⁻¹, √s = 8 TeV
∫ L dt = 20.7 fb⁻¹, √s=8 TeV
95% C.L. CLs NLO Exclusions
Observed 2l2j ⊕ 3l ±1σ_theory
Expected 2l2j ⊕ 3l ±1σ_experiment
Expected 2l2j ⊕ 3l -2σ_experiment
Observed 3l only
Observed 2l2j only
95% C.L. upper limit on cross section (fb)
m_χ̃₁⁰ (GeV)
m_χ̃₁± = m_χ̃₂⁰ (GeV)

ARE THERE WAYS OUT? WW WITHOUT WH AND WZ??

- Chargino NLSP in Gauge Mediated SUSY breaking
  - low tan beta, large Wino-Higgsino mixing



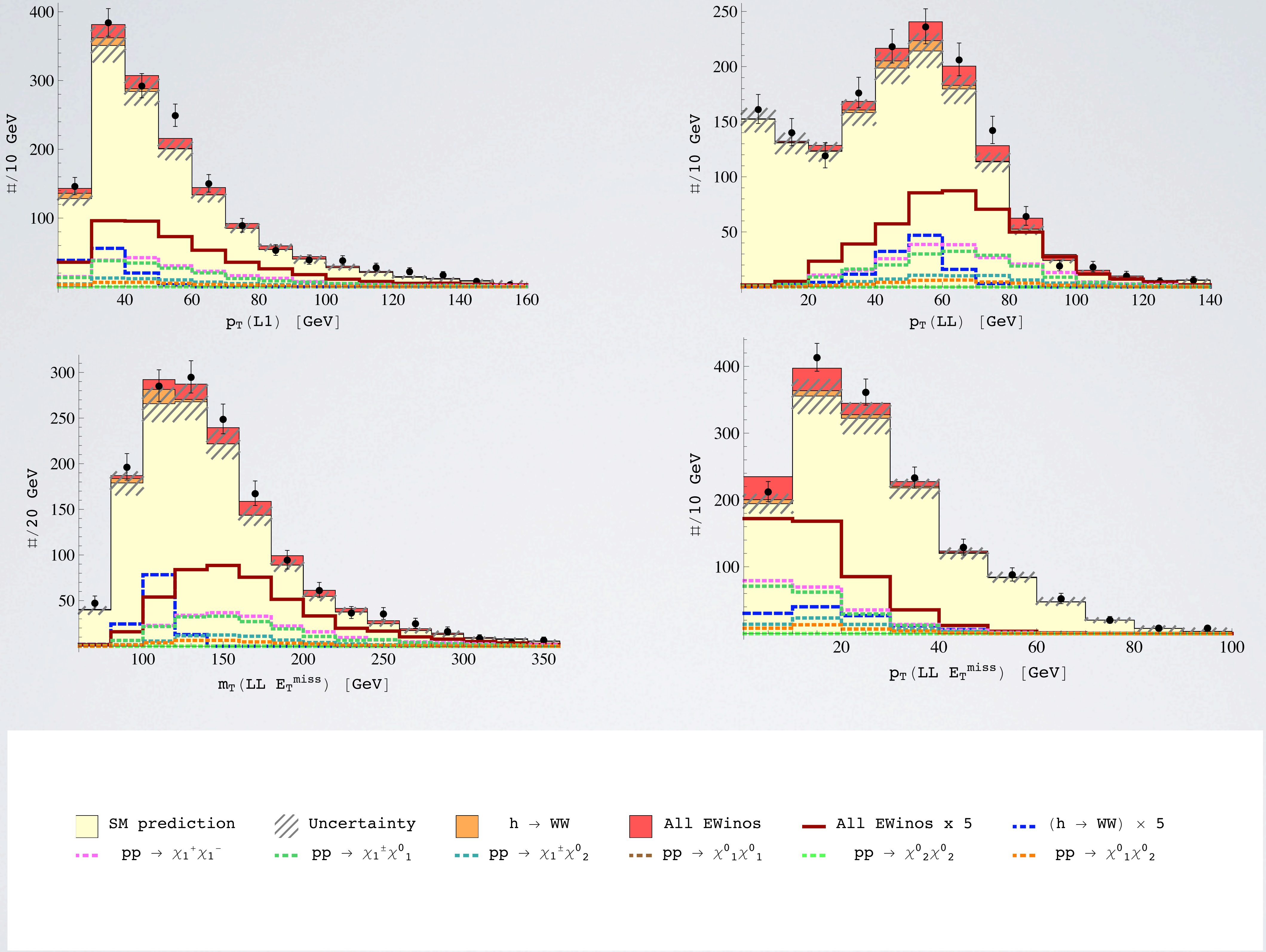
$m_{\chi_1^\pm} \approx 110\,\mathrm{GeV}$

$m_{\chi_1^0} \approx 113\,\mathrm{GeV}$

$m_{\chi_2^0} \approx 130\,\mathrm{GeV}$

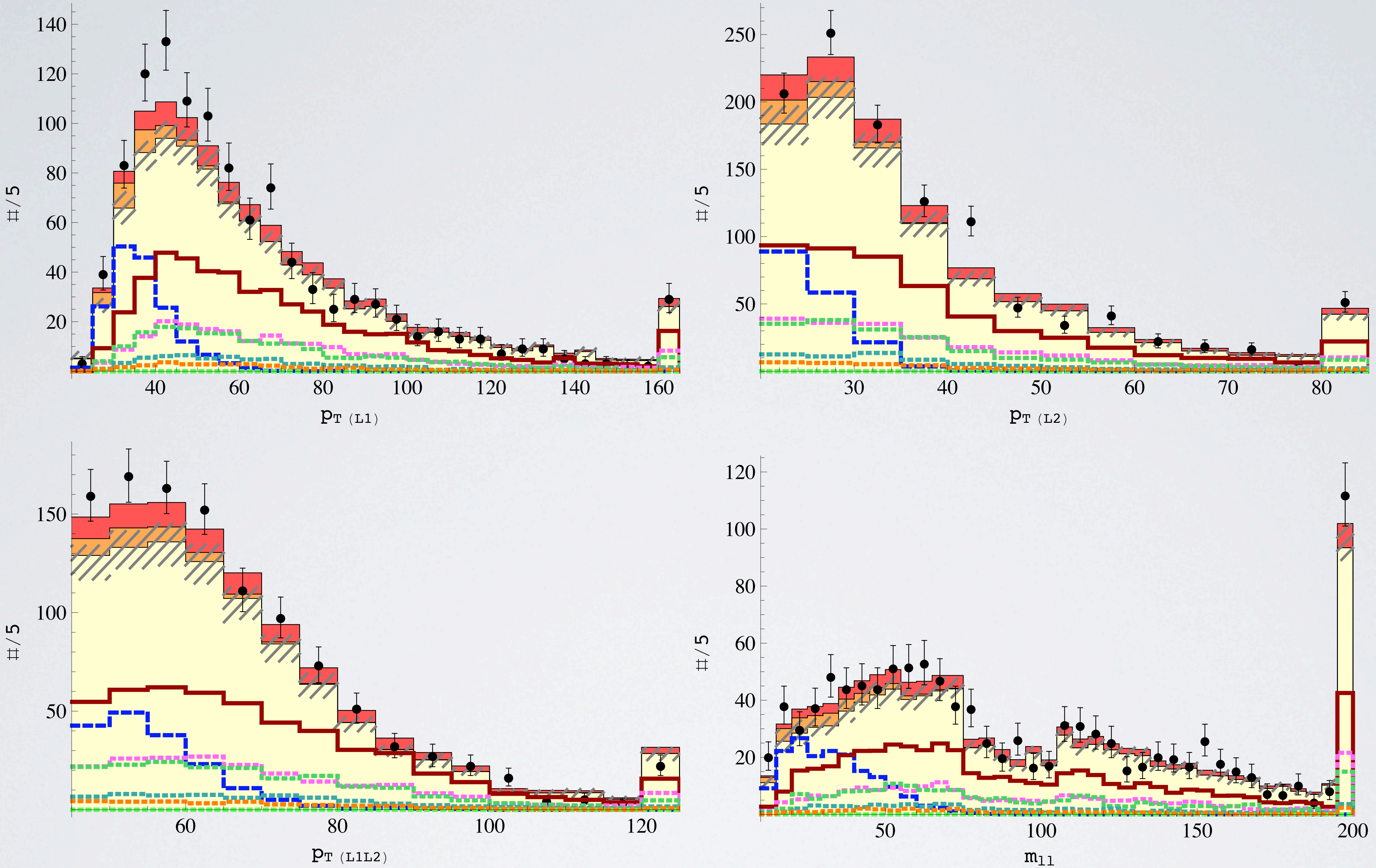
$\sigma_{NLO} \sim 4.3\,\mathrm{pb}$

ATLAS 7



χ^2 cut in **half** compared to SM

CMS 8

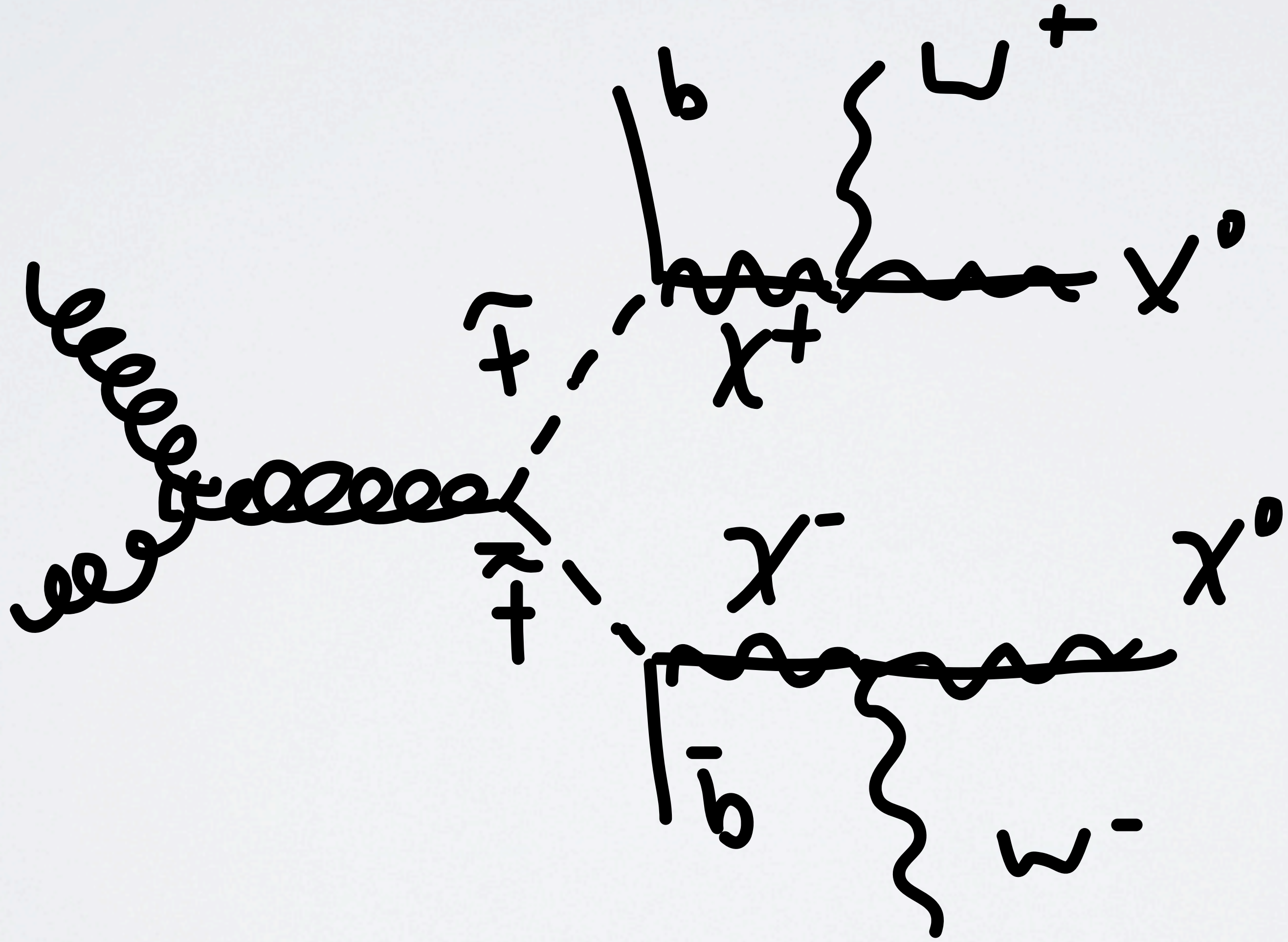


SM p-value .001 SM+charginos .3

SM+h .1 SM+h+charginos .75

CHARGINOS FROM STRONG PRODUCTION?

$$\tilde{t}_1 \rightarrow \tilde{\chi}_1^{\pm}\, b \rightarrow \tilde{\chi}_1^0\, W^{(*)}\, b \rightarrow \tilde{\chi}_1^0\, \ell\, \nu\, b$$

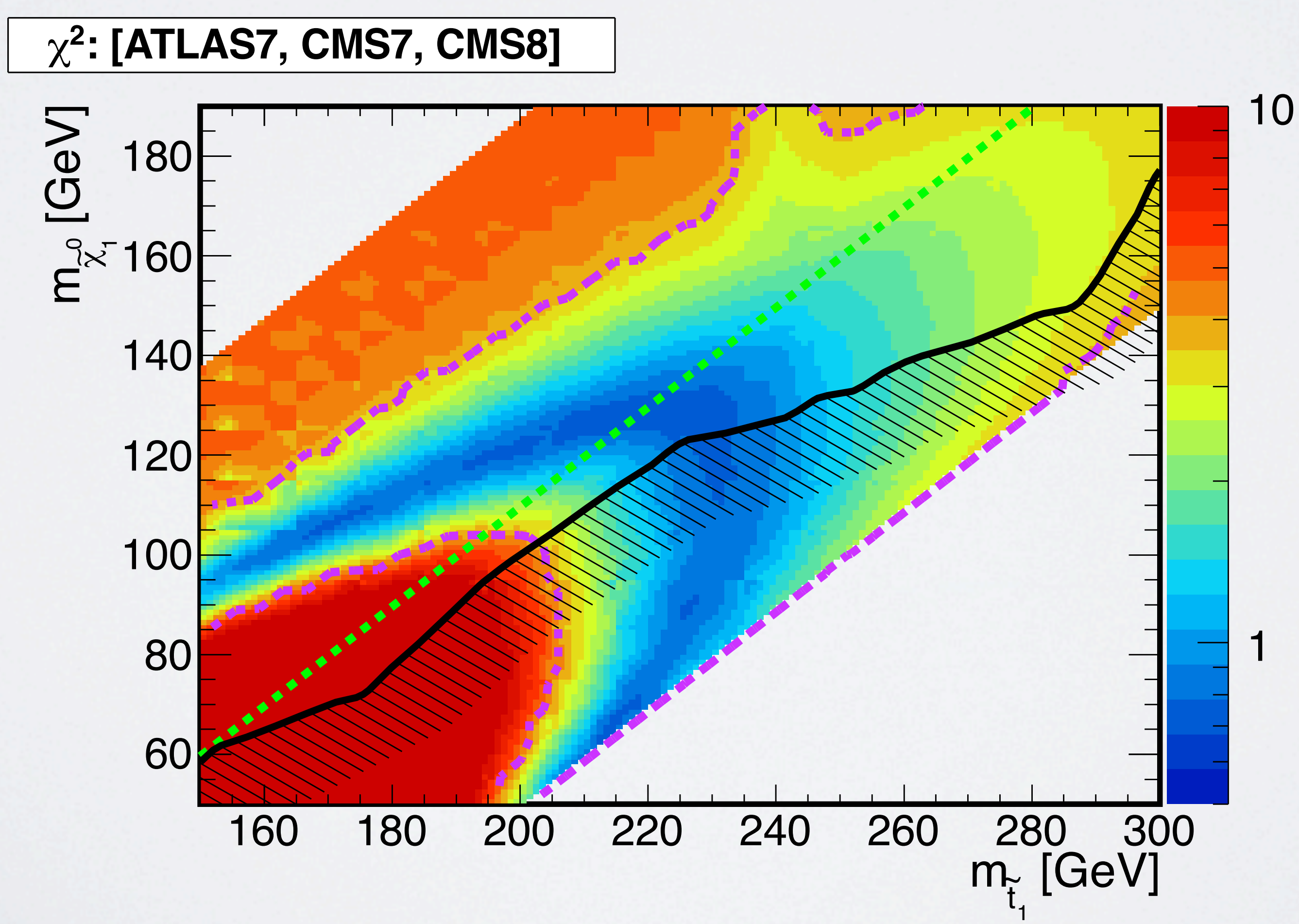


CHARGINOS FROM STRONG PRODUCTION?

$$\tilde{t}_1 \to \tilde{\chi}_1^{\pm}\, b \to \tilde{\chi}_1^0\, W^{(*)}\, b \to \tilde{\chi}_1^0\, \ell\, \nu\, b$$

Squeeze the b's and you get WW production

Rolbiecki and Sakurai 1303.5696



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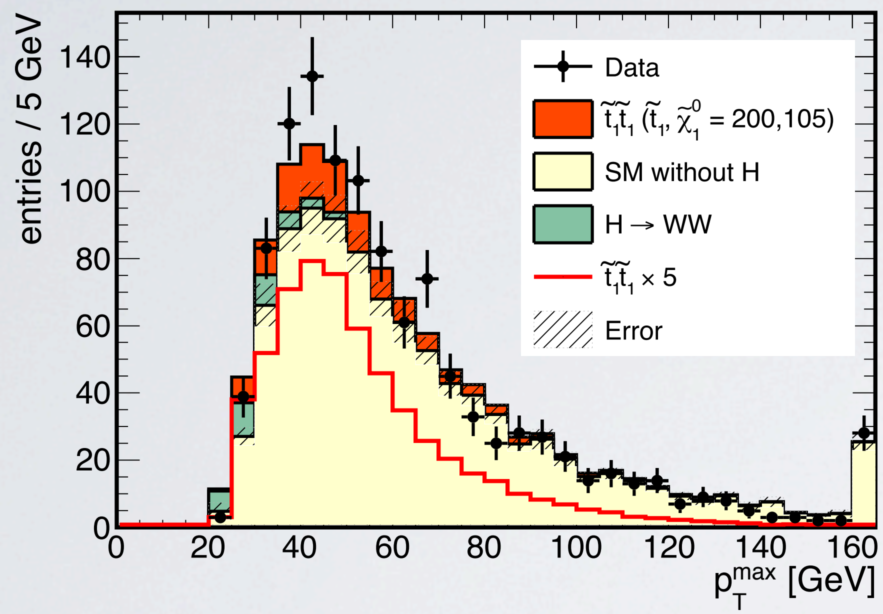
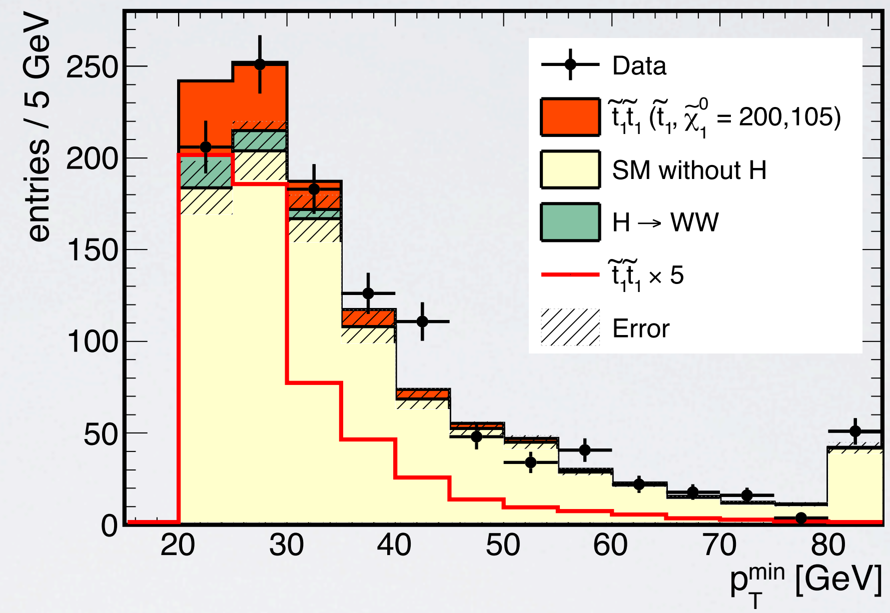
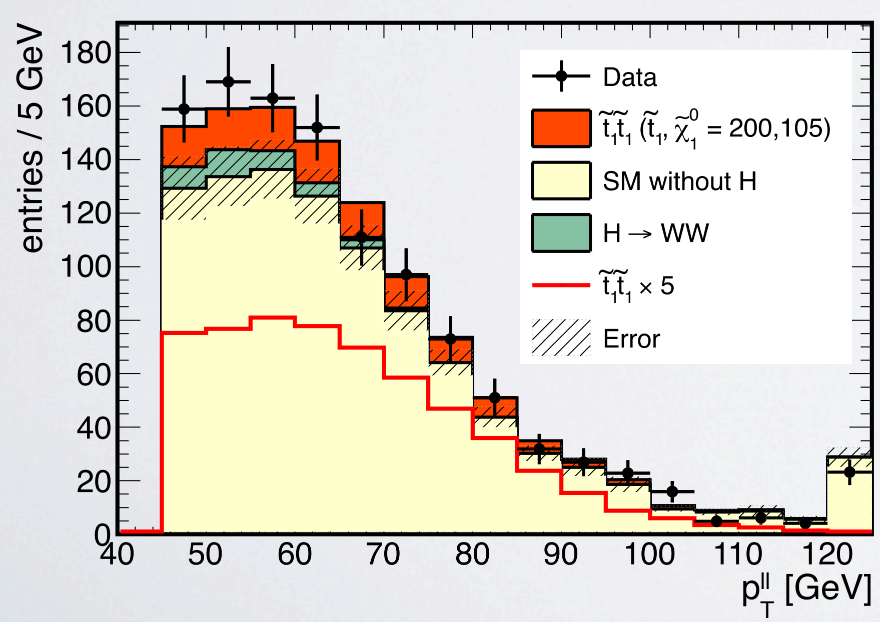


(a)

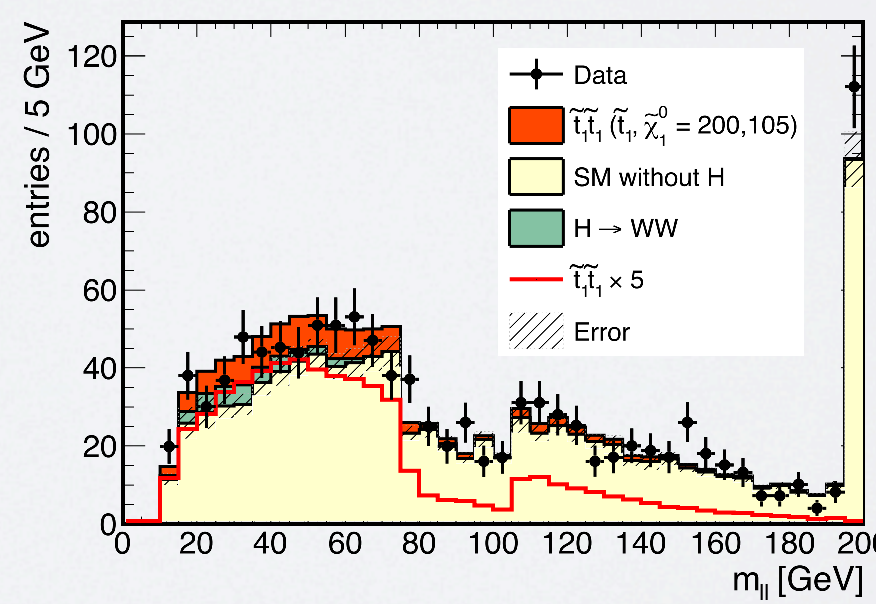


(b)

Rolbiecki and Sakurai
1303.5696

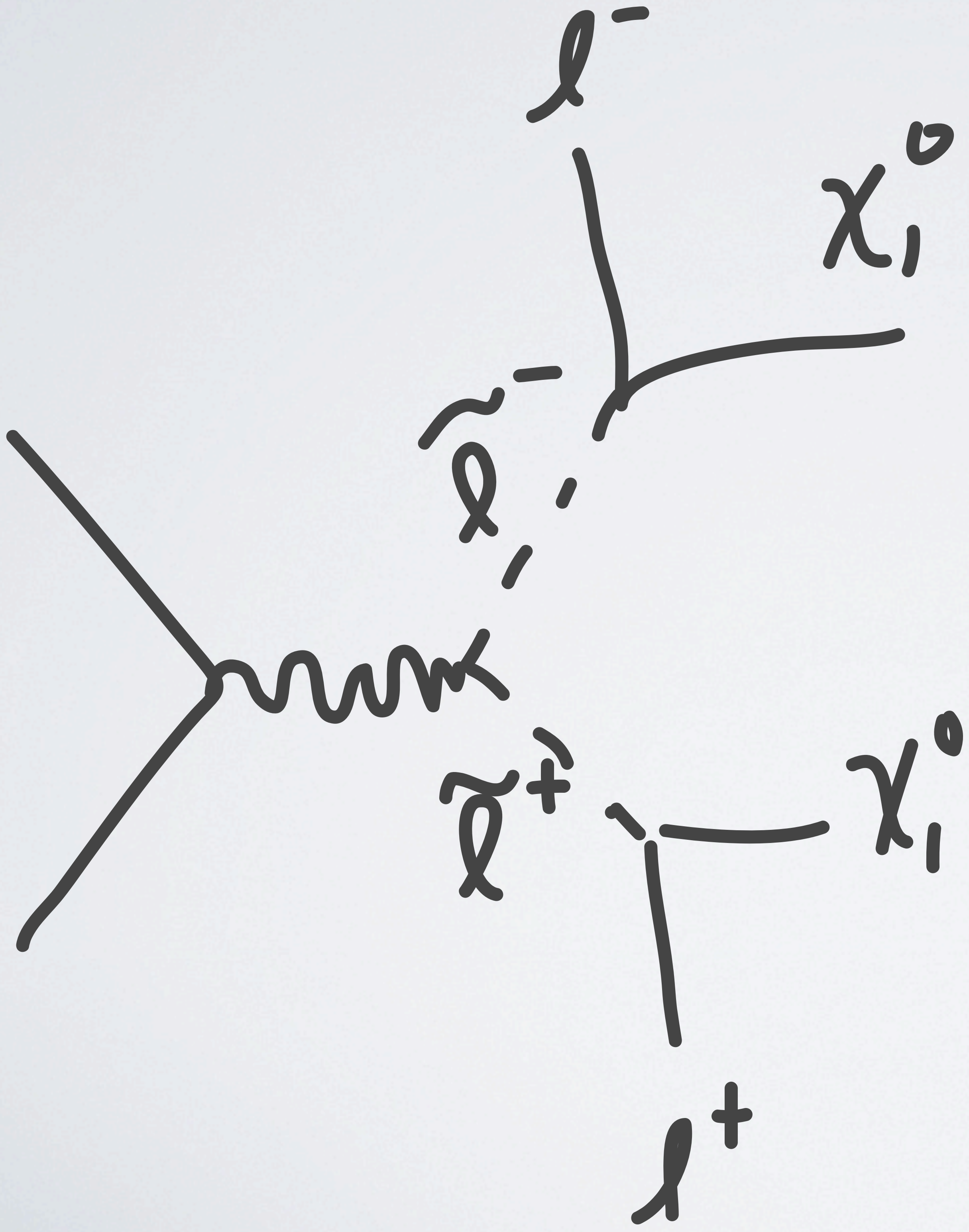


(c)

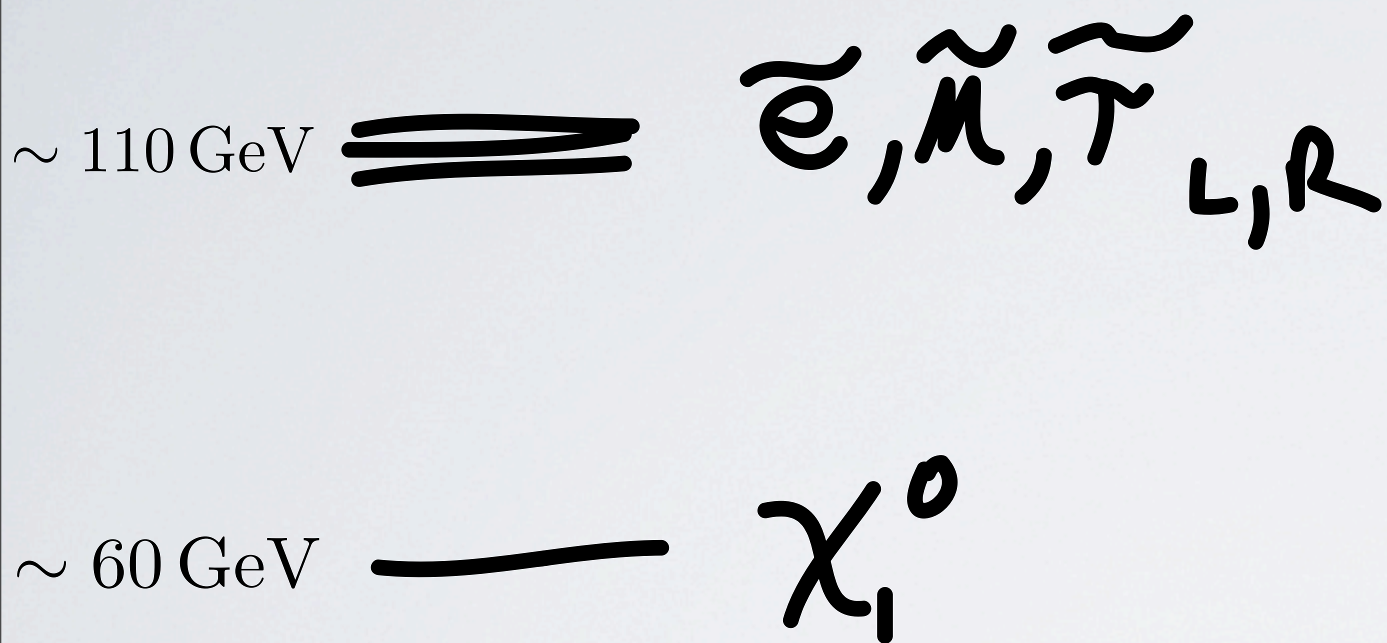


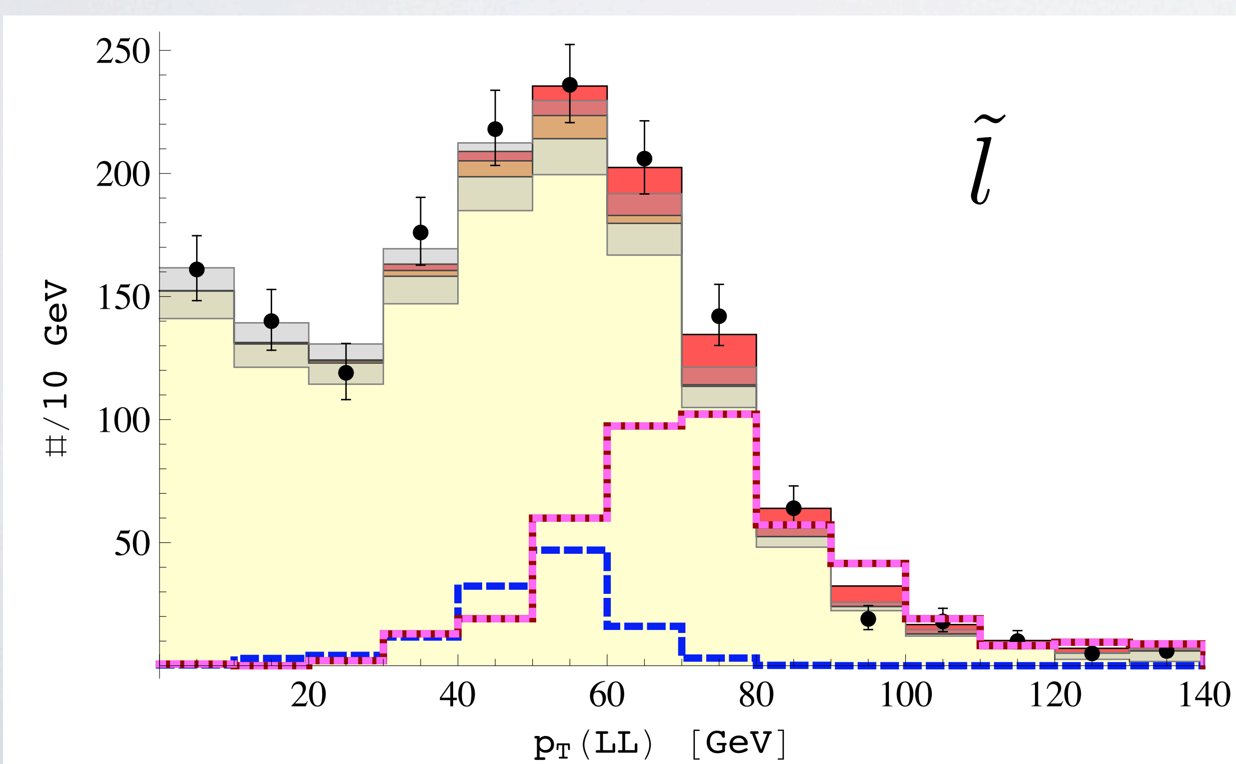
(d)

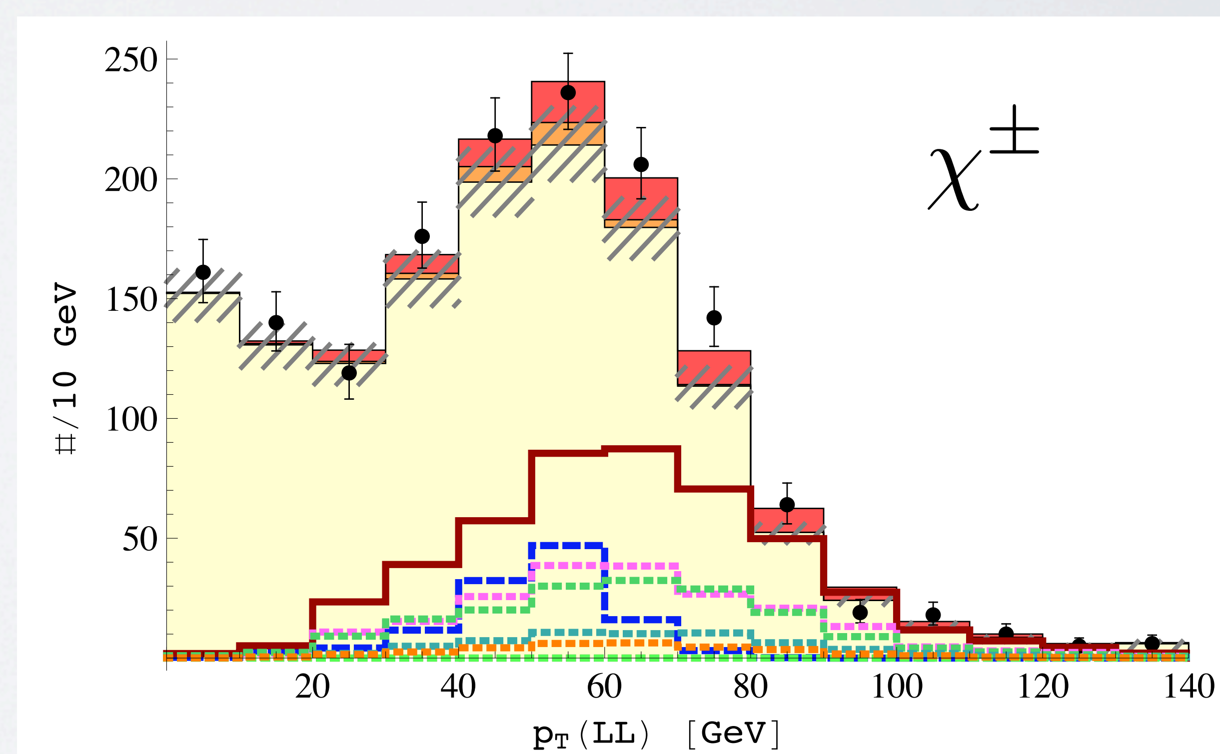
NO ONE SAID THERE HAD TO BE REAL W BOSONS!



TURNS OUT IT FITS JUST AS WELL...





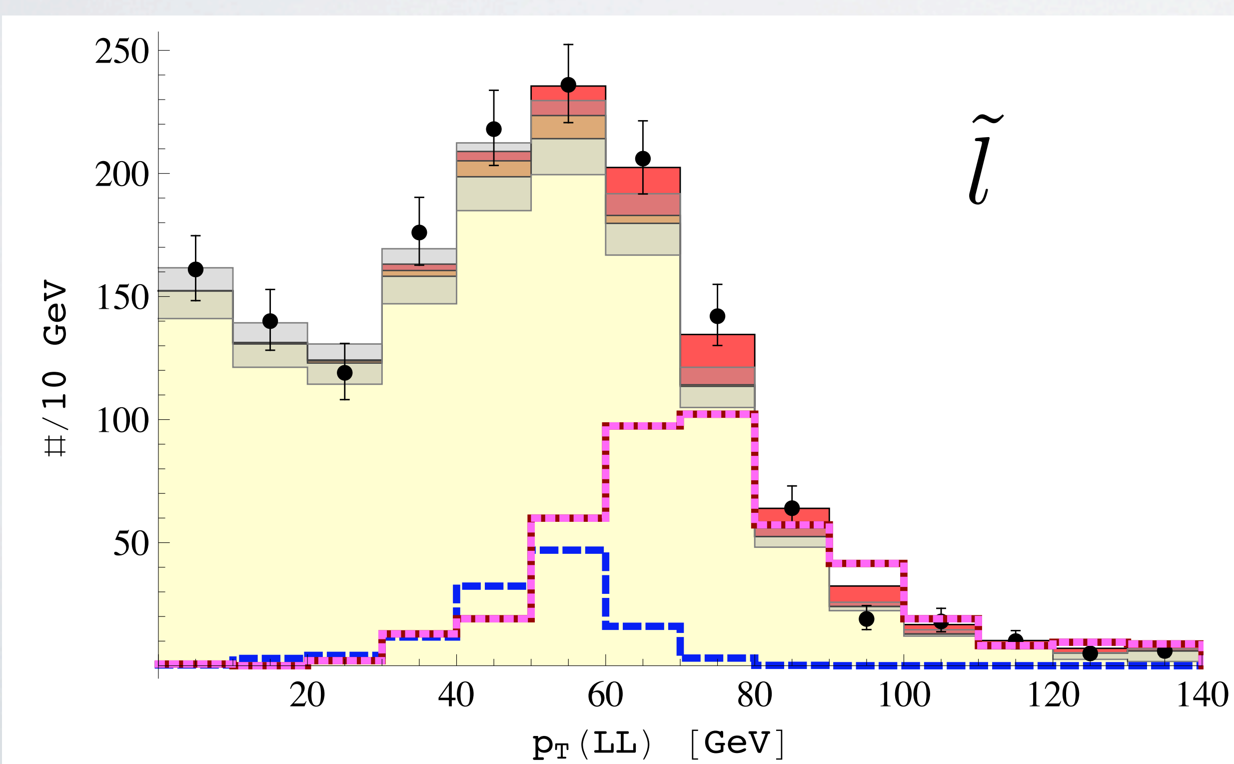


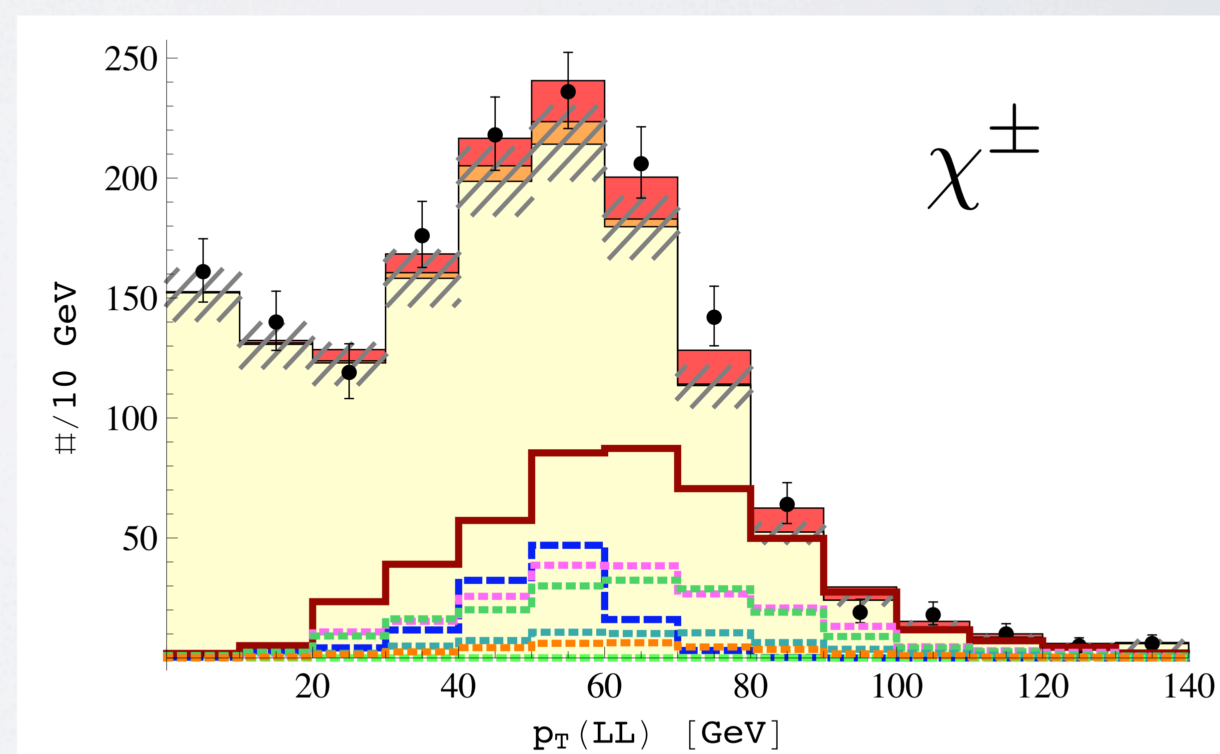
TURNS OUT IT FITS JUST AS WELL...

$\sim 110\,\mathrm{GeV}$ — $\tilde{e}, \tilde{\mu}, \tilde{\tau}_{L,R}$

Can also do this just with LH sleptons

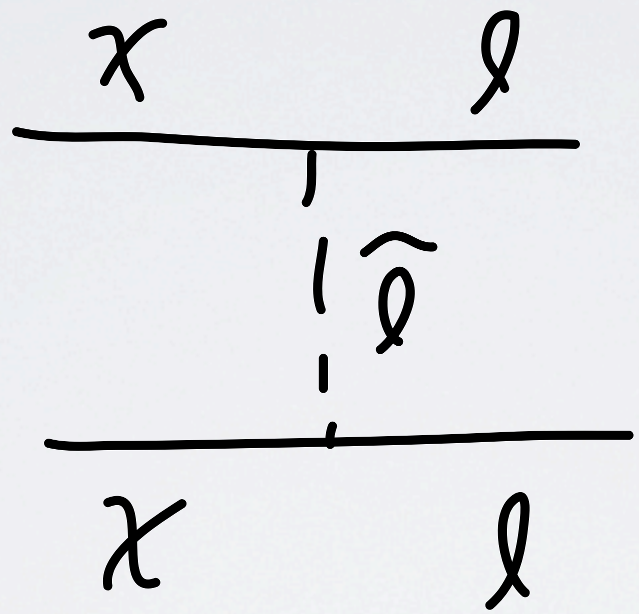
$\sim 60\,\mathrm{GeV}$ — χ_1^0



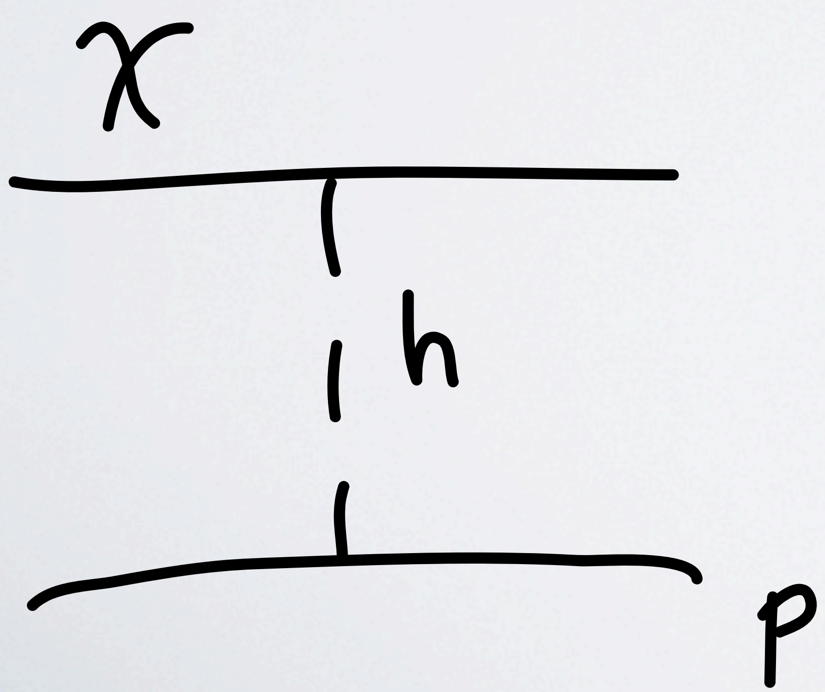


WHAT ELSE ARE SLEPTONS GOOD FOR?

BINO DM!



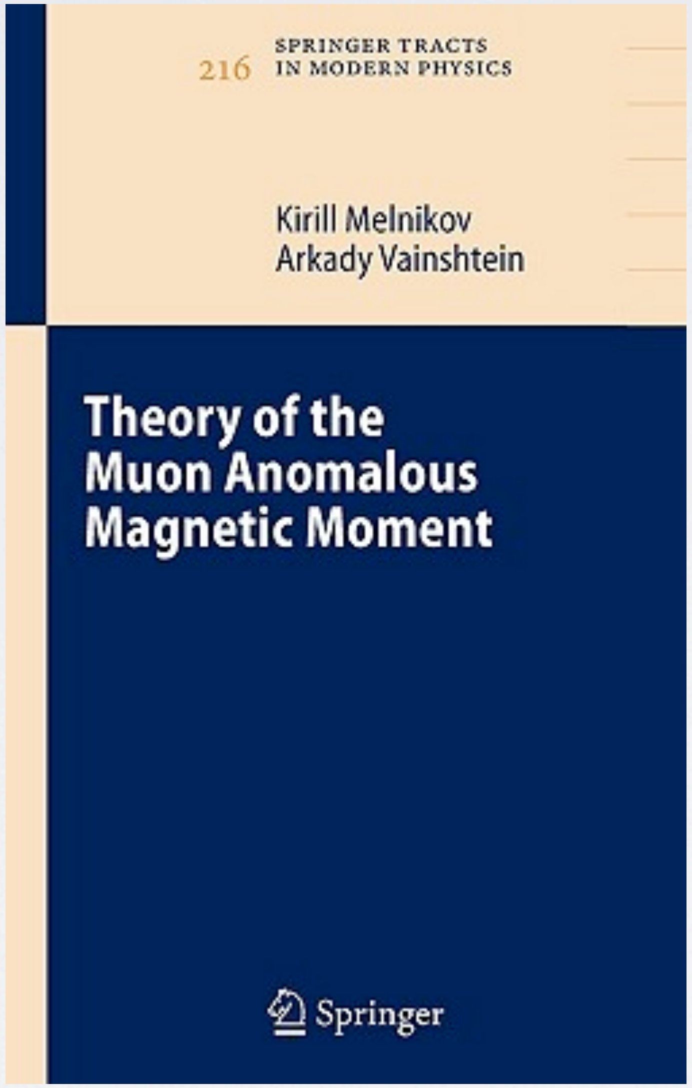
Can get right relic density



Direct Detection sails right through and is interesting for future exp!

OTHER BENEFITS OF LIGHT SLEPTONS?

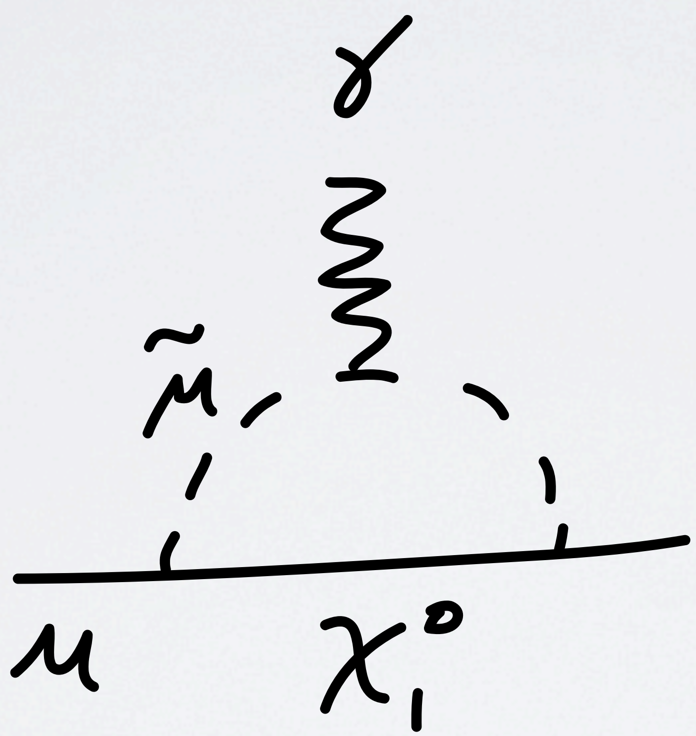
$$(g-2)_\mu$$



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

OTHER BENEFITS OF LIGHT SLEPTONS?

$$(g-2)_\mu$$



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

3 ANOMALIES AUTOMATICALLY ISN'T BAD...

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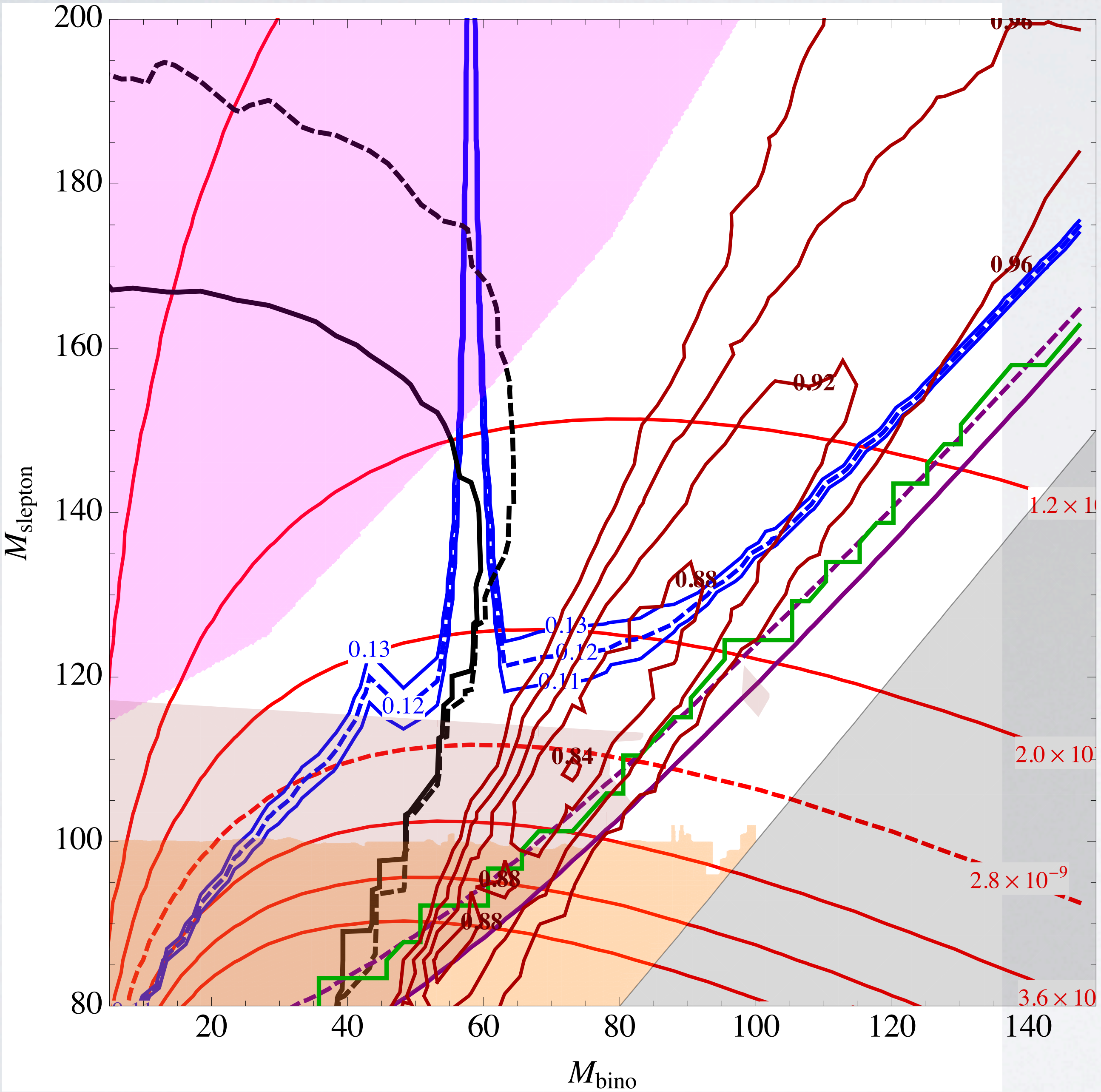
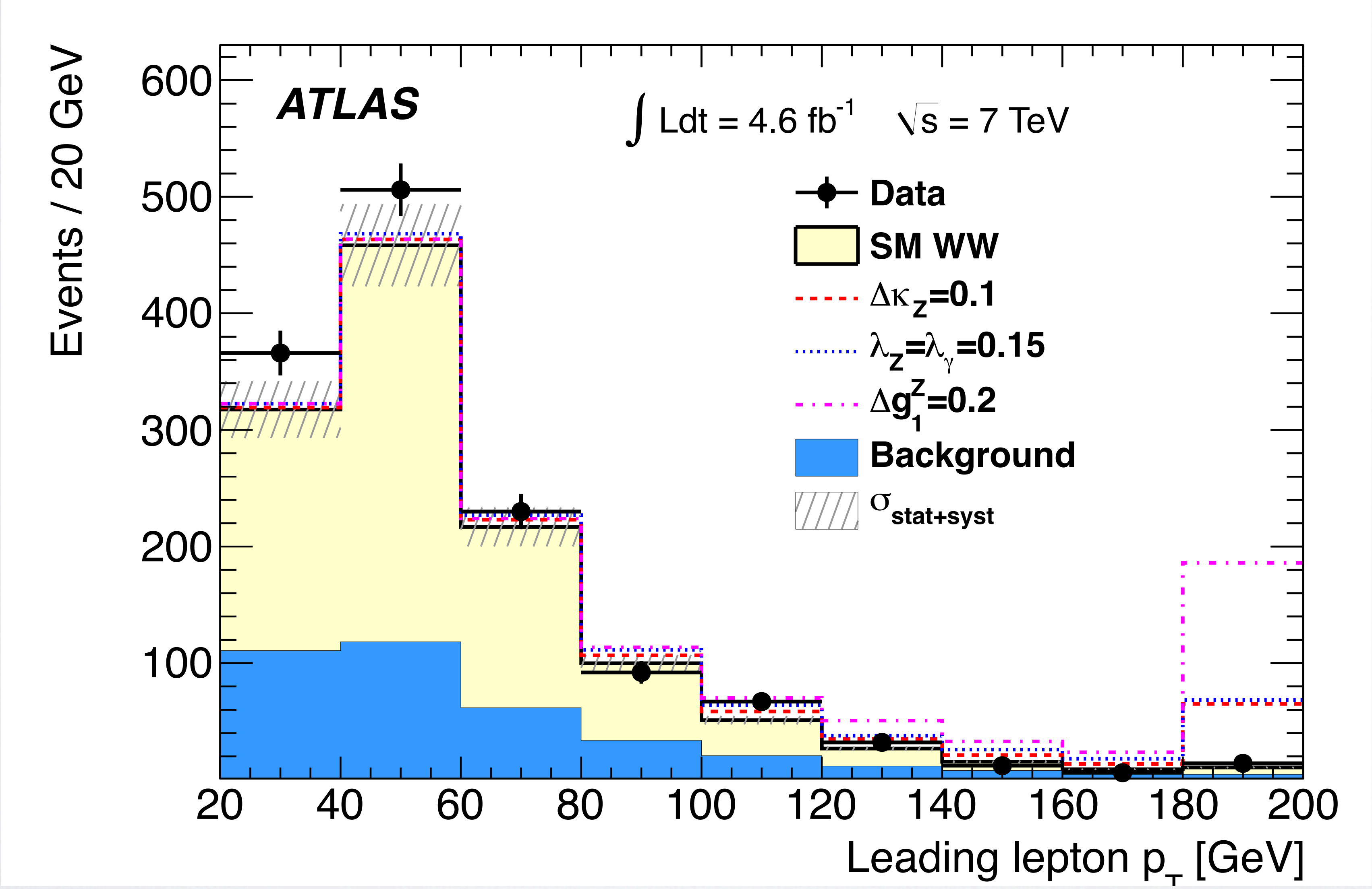


(b) $\tan\beta = 4, \mu = 600\,\text{GeV}$

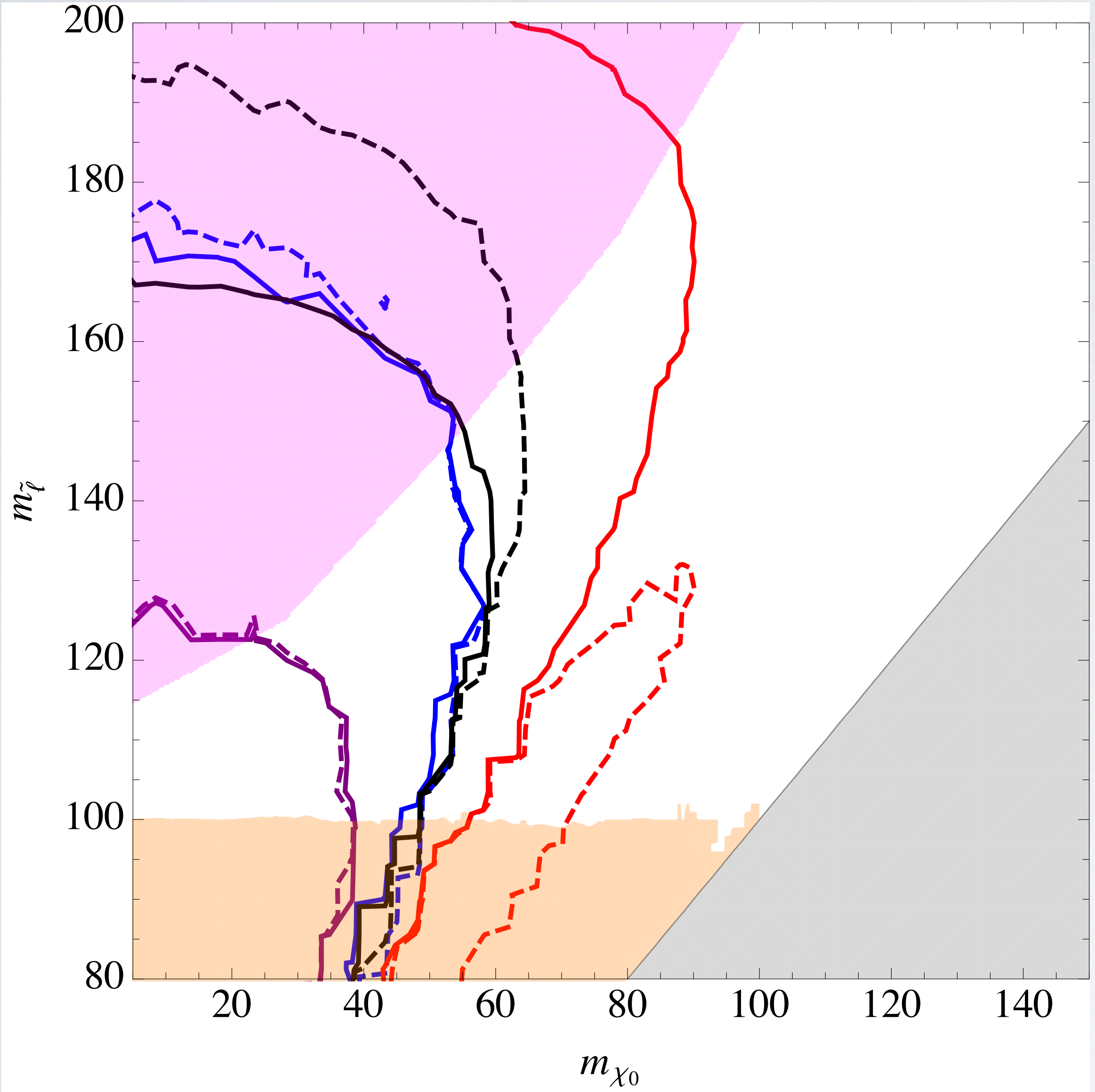
This model ALSO changes the interpretation of the Higgs!!

DO YOU ONLY CARE ABOUT SM MEASUREMENTS FOR ANOMALIES???



Bounds on TGC

CAN ALSO **BOUND** NEW EW PHYSICS WITH SM MEASUREMENTS



LH + RH $\tilde{e}/\tilde{\mu} \rightarrow \ell + \tilde{\chi}_1^0$

Figure 1: 95% Exclusions in the neutralino-slepton mass plane for degenerate $\tilde{e}, \tilde{\mu}$ decaying to $e/\mu + \tilde{\chi}_1^0$. Magenta regions are excluded by the CMS 9fb^{-1} LHC8 slepton search [2] (see text footnote). Orange regions are excluded by LEP [5]. The regions below the Purple (ATLAS LHC7 [9], Blue (CMS LHC7 [10]), Red (CMS LHC8 [11]) and Black (combined) lines are new exclusions we obtained from the respective W^+W^- measurements. Solid (dashed) lines represent limits obtained by (not) renormalizing the SM expectation in all kinematic distributions to match the SM + BSM normalization to data. The CMS8 W^+W^- measurement was so high that only the region *inside* the red dashed line is not 'excluded' when normalization is taken into account.

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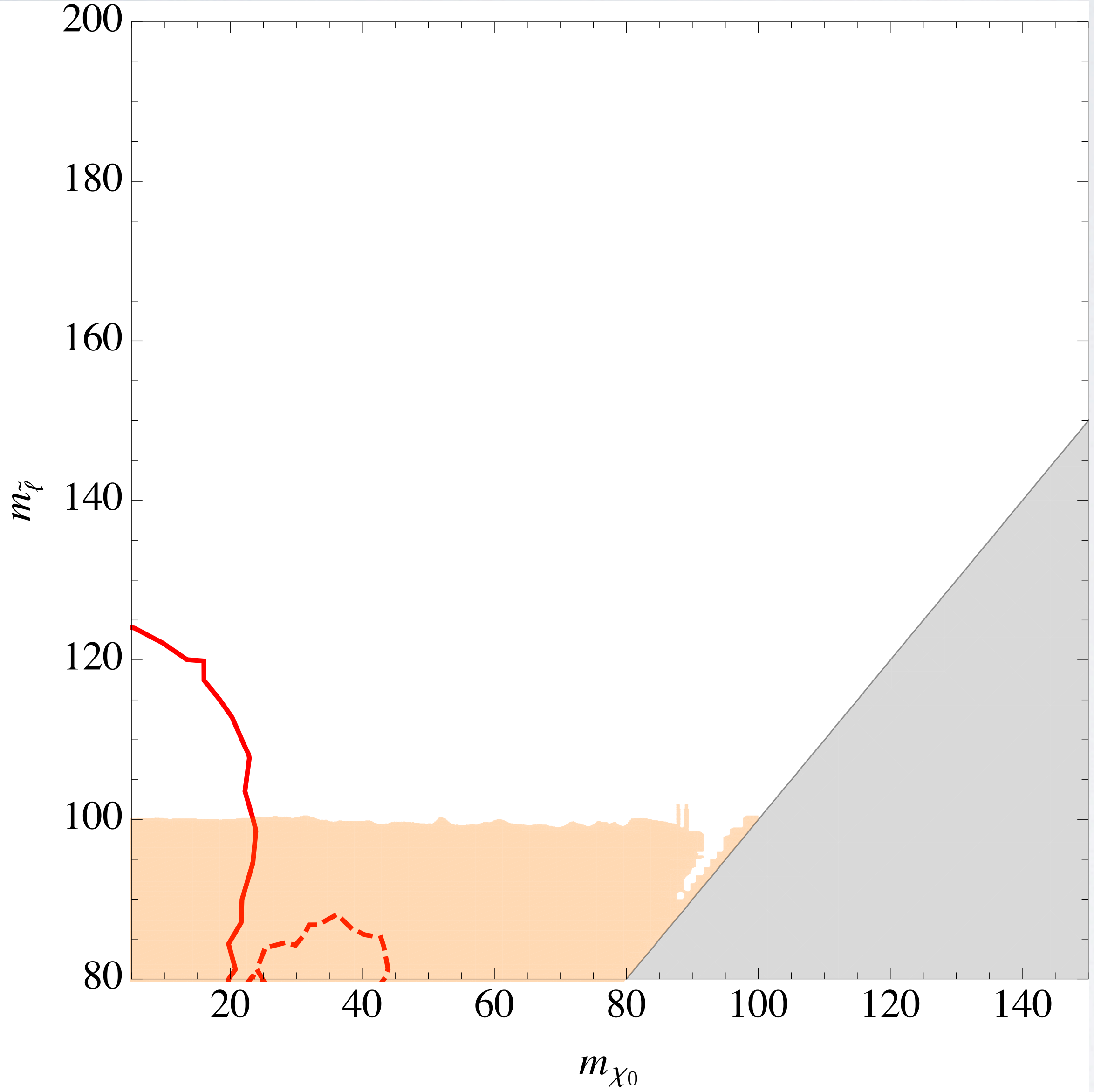

RH $\tilde{e}/\tilde{\mu} \to \ell + \tilde{\chi}_1^0$

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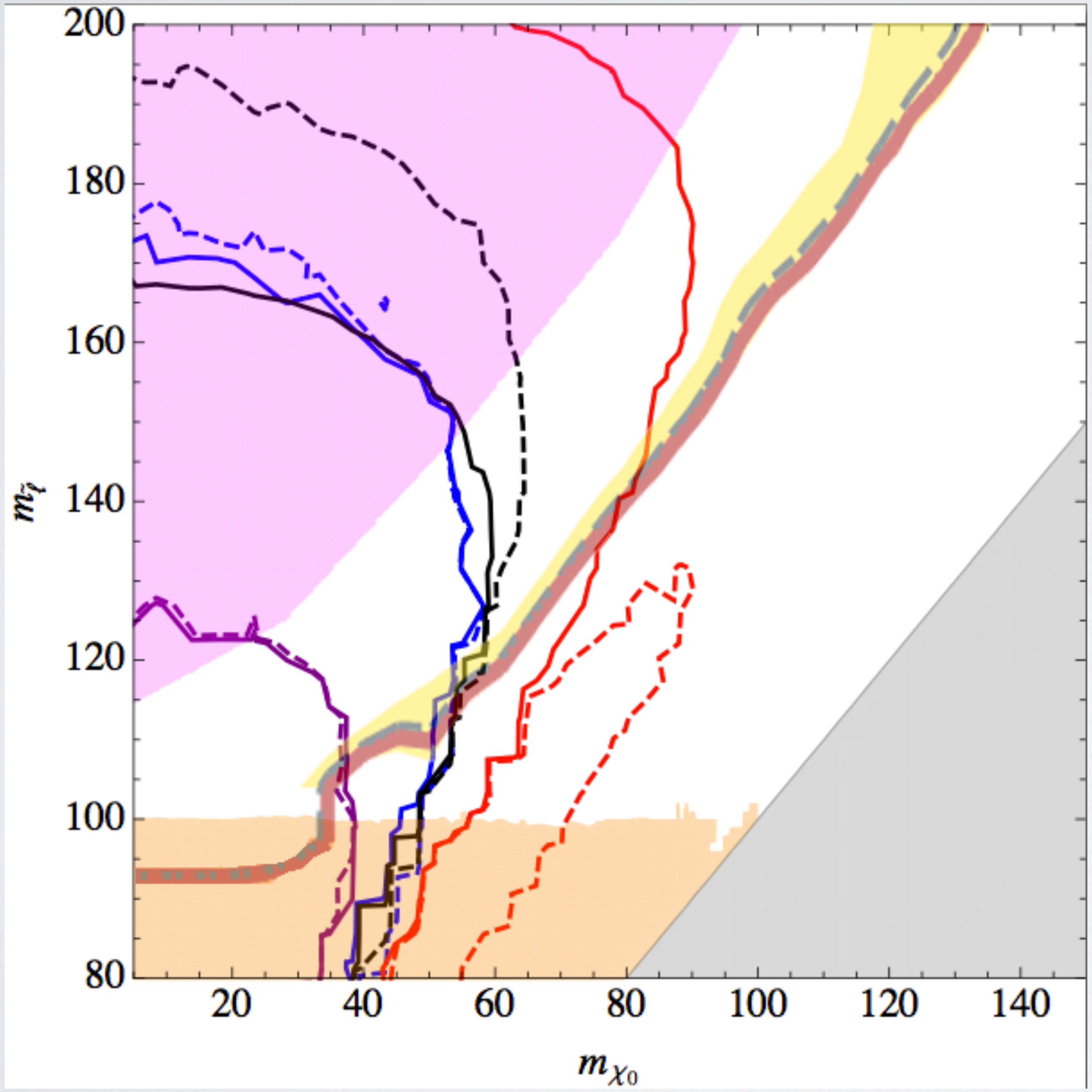
NEW ATLAS DIRECT SLEPTON SEARCH



LH+RH sleptons

Full dataset from ATLAS versus 3.5/fb CMS WW

CONCLUSIONS

NEW PHYSICS CAN BE RIGHT AROUND THE CORNER OR IN YOUR DATA!

The EW sector is the only one we know that "new" physics is occurring

These signals aren't invisible you just have to do things differently

Big Ramification: Data Driven Backgrounds can easily be invalidated by NP