Are Charginos Hiding in Plain Sight?

David Curtin

in collaboration with Patrick Meade, Prerit Jaiswal

arXiv: next week

STONY BROOK UNIVERSITY

CERN BSM-TH Institute

June 21, 2012

PRELIMINARY **PRELIMINARY**

Where is the New Physics?

- The LHC is very good at producing strong particles.
  - $\Rightarrow$ limits rising to TeV & beyond on strong BSM physics.
  - $\Rightarrow$ maybe bad news for "natural" explanations of weak scale like SUSY (though not a killing blow yet).
- Limits on new electroweak physics much lower.
  - $\rightarrow$ could still expect to find new $\mathcal{O}(100\,\mathrm{GeV})$ particles!
- Many BSM signals are hard to see at the LHC because they look like SM background. (e.g. light stops).

This means that “boring” SM measurements could contain important BSM information.

Time for theorists to put their experimental hats on!

WW Cross Section Measurement

ATLAS and CMS [1] measured *WW* production cross section σ_{WW}^{tot} with $\approx 5\ \text{fb}^{-1}$ of data in the fully leptonic final state.

	measured (pb)	SM expectation
ATLAS	$53.4 \pm 2.1(\text{stat}) \pm 4.5(\text{syst}) \pm 2.1(\text{lumi})$	45.1 ± 2.8
CMS	$52.4 \pm 2.0(\text{stat}) \pm 4.5(\text{syst}) \pm 1.2(\text{lumi})$	47.0 ± 2.0

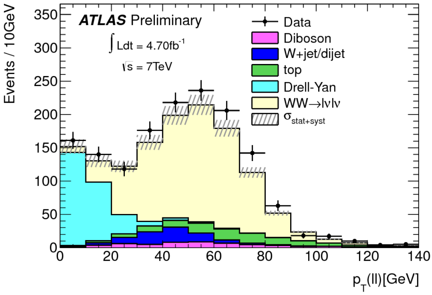
These measurements are extremely consistent with each other, and they are higher than SM prediction by $\sim 1.5\sigma$.

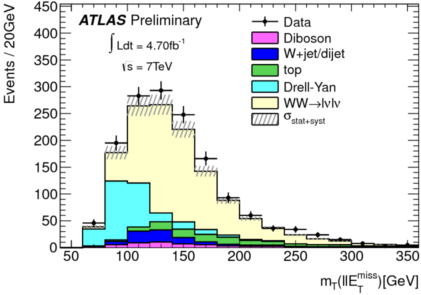
The shape of differential distributions seems slightly off as well.

[1] ATLAS-CONF-2012-025, CMS PAS SMP-12-005

WW Cross Section Measurement

ATLAS (CMS is similar):





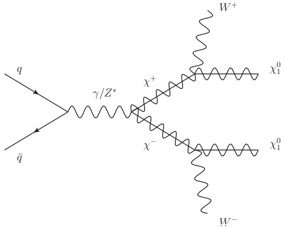
Most likely (conservative) explanation:
some issue with NLO BG calculation.

But it could be an early sign of new EW physics!
Indeed, something like this is expected in many scenarios

Wino-like Charginos?

- $\sigma(pp \to \tilde{\chi}_1^+ \chi_1^-)$ roughly right if $\tilde{\chi}_1^\pm$ is not much heavier than W.

- Decay & kinematics should be W-like since we do *not* want hard tails in the distributions, just some enhancement at moderate $\not{E}_T, p_T$.
  - $\rightarrow$ mass gap should be $\sim 100\,\mathrm{GeV}$.
  - $\rightarrow$ no sleptons with $m_{\tilde{\ell}} < m_{\tilde{\chi}_1^\pm}$



- Hence has to decay into something light: bino-like neutralino (gravity mediation) or gravitino (GMSB).

- This is obviously not a new idea. . .

Is this trivially excluded?

- Solid chargino mass bound from LEP: $m_{\tilde{\chi}_1^\pm} \gtrsim 100\,\mathrm{GeV}$. OK!
- ATLAS & CMS multi-lepton searches: possible constraints, but bounds still weak.
- What about the light particle $\tilde{\chi}_1^\pm$ decays to?

  $\rightarrow$ gravity mediation: even massless neutralinos are still **OK!** [Dreiner et. al '09]. Prior bounds assume gaugino mass unification.

  We are more interested in this scenario as a simplified model.

  $\rightarrow$ GMSB: Have to be careful to avoid photon constraints.

What are the allowed GMSB scenarios?

In gauge mediation, the NLSP decays to its superpartner and a (practically massless) graviton.

- **Bino NLSP:** $\tilde{\chi}_1^0 \to \gamma \tilde{G}$ gives striking photon signals.

  CMS $\gamma\gamma$ + MET + jet search rules out chargino pair production* and decay to neutralinos for $m_{\tilde{\chi}_1^\pm} \lesssim 450\,\mathrm{GeV}$. **NOPE!**

- **Wino co-NLSP:** for $M_1 > M_2 > m_{\tilde{G}}$, the chargino $\tilde{\chi}_1^\pm$ decays directly to $W + \tilde{G}$, since an accidental cancellation makes the mass gap to χ_0^1 very small.

  The Wino NLSP $\tilde{\chi}_1^0$ decays to $Z/\gamma + \tilde{G}$, so $\chi_1^0 \chi_1^\pm$ associated production yields at most one photon.

  Tevatron $\gamma + \ell + \not{E}_T$ search rules* out $m_{\tilde{\chi}_1^\pm} < 135\,\mathrm{GeV}$. **OK!**

- **Chargino NLSP†:** narrow region of parameter space where charged higgsino is NLSP, and Higgsino-rich $\tilde{\chi}_1^0$ decays to $\chi_1^\pm$ via off-shell $W^\pm$, so $\chi_1^0 \chi_1^\pm$ production yields no photons: **No additional $m_{\tilde{\chi}_1^\pm}$ constraints.**

*Kats, Meade, Reece, Shih ’11 †Kribs, Martin, Roy ’09

Example Scenario

- Simplified model from pMSSM (gravity mediation):
  - $m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0} \approx 115\,\mathrm{GeV}$
  - $m_{\tilde{\chi}_1^0} \approx 20\,\mathrm{GeV}$.
  - $m_{\tilde{f}},\ \mu > 1\,\mathrm{TeV}$

- **MC Info:**
  - Calculate spectrum & NLO production cross section in `SuSpect` & `Prospino`.
  - Generate & shower $pp \to \tilde{\chi}_1^+ \chi_1^- \to W^+ W^- \tilde{\chi}_1^0 \tilde{\chi}_1^0 \to \ell\ell + \mathrm{MET}$ events in Pythia 8, interfaced with Pythia 6.4 for hard process.
  - Perform toy-version of ATLAS & CMS *WW*-analyses in `FastJet`-based program with simple detector simulation.

Add chargino contribution to ATLAS & CMS background predictions and see whether agreement with data improves.

$m_{\tilde{\chi}_1^\pm} = 115\,\text{GeV} \qquad m_{\tilde{\chi}_1^0} = 20\,\text{GeV}$

$\sigma(pp \to \chi_1^+\chi_1^- \to \chi_1^0\chi_1^0\ W^+W^-) = 2430.$ fb,
$\sigma \times \text{Br}(W \to e/\mu/\tau + \nu)^2 = 257.776$ fb (K-factor = 1.29255).
With 4.7 fb^{-1} of data we expect ~1212 events.

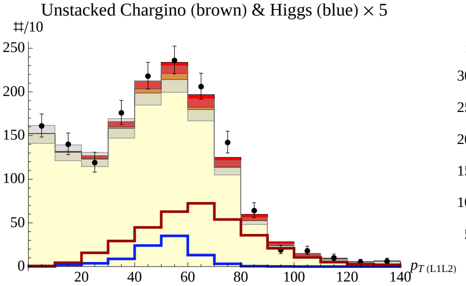
Cut Efficiencies (ATLAS_WW_5ifb)

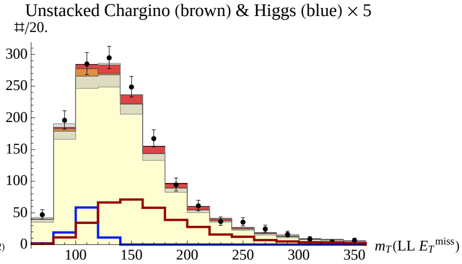
Cut Description	N_{SIM}	%	N_{exp}
before any cuts	60 000	100.	1211.55
PASSING ANY OF THE LEPTON TRIGGERS	39 494	65.8233	797.479
exactly two leptons	13 309	22.1817	268.741
pass jet veto	9010	15.0167	181.934
opposite sign leptons	9010	15.0167	181.934
pass pT_LL > 25, 20 cut	6877	11.4617	138.863
pass mLL cut (mLL > 15 && |mLL - mZ| > 15 for ee/mumu, mLL > 10 for emu)	5990	9.98333	120.953
pass ETmissREL > 50 GeV cut (25 for emu)	3622	6.03667	73.1369

- $\sigma_{\tilde{\chi}_1^+\tilde{\chi}_1^-} = 2.4$ pb.
- About 6% of leptonic decays ($\sim$ 70 events) pass cuts of the ATLAS /CMS *WW* cross section measurement analyses.

$m_{\tilde{\chi}_1^\pm} = 115\,\mathrm{GeV}$ $m_{\tilde{\chi}_1^0} = 20\,\mathrm{GeV}$

Using ATLAS analysis (CMS is similar):



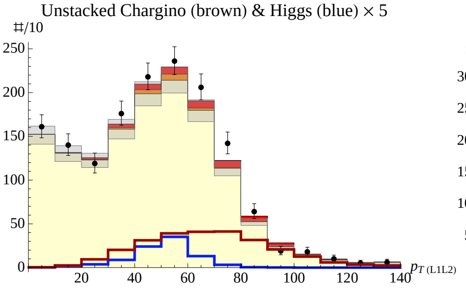


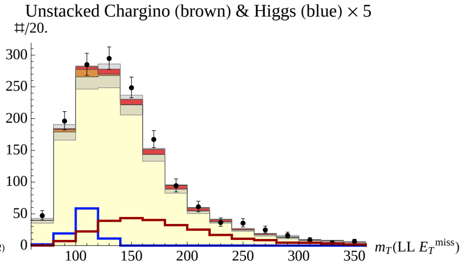
- In all 6 kinematic distributions, $\chi^2/N_{dof} \approx 1$ for SM alone and $\chi^2/N_{dof} \approx 0.5$ for SM + charginos.
- By eye we can see that bins that were deficient are preferentially filled by the chargino contribution, while bins that worked well aren't changed much.

$m_{\tilde{\chi}_1^\pm} = 130\,\text{GeV}$ $m_{\tilde{\chi}_1^0} = 1\,\text{GeV}$

Cut efficiencies & production cross section about the same.

Using ATLAS analysis (CMS is similar):





- Works about equally well.
- Kinematically similar to GMSB Wino co-NLSP scenario.

  (Chargino NLSP scenario would get even more contributions, under investigation.)

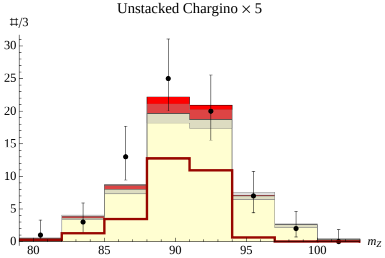
Would this signal appear elsewhere?

- *WZ* cross section measurement.
- $h \to WW$ searches use data-driven *WW* BG estimation. Charginos could contaminate both signal and control regions, with different results. [see Feigl, Rzehak, Zeppenfeld '12]
- ATLAS/CMS multi-lepton searches

We have to understand the effect on each channel, and make sure our scenario is not already excluded.

WZ Cross Section Measurement

- Done by ATLAS and CMS for 1 fb^{-1} datasets.
- New contributions can help here as well, but there is not enough statistics for it to really matter yet.
- Example using ATLAS analysis:



- GMSB scenarios would have smaller contributions in this channel than the gravity-mediated example shown here.

$h \to WW$ Searches

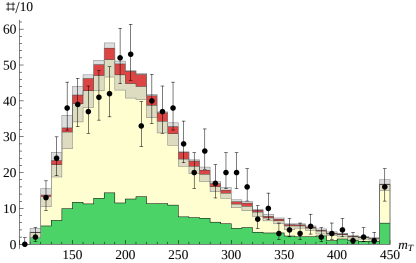
- It is known that Charginos can show up in Higgs searches. For example:
  - Lisanti, Weiner ('11) explored the ability of such searches to find charginos in their signal region.
  - Feigl, Rzehak, Zeppenfeld ('11, '12) demonstrate that these searches might miss a higgs in the signal region if charginos contaminate the *WW* control region.
- We examined the effects of our scenario in detail using the ATLAS $h \to WW$ analysis.

$\to$ Contamination is not as big an issue for us, but it might reduce signal sensitivity. Under Investigation.

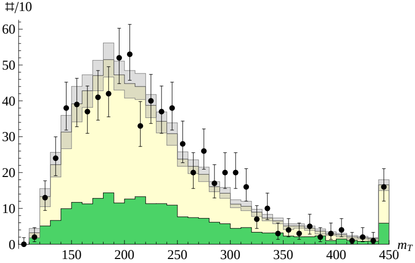
  - charginos decay via *W*'s, no sleptons to boost leptonic decay fraction. $\to$ smaller contamination.
  - Both signal and control regions get roughly equal contributions that are $\sim 10\%$ of and similar in shape to the *WW* contribution.

Example: ATLAS $h \to WW$ 0j channel

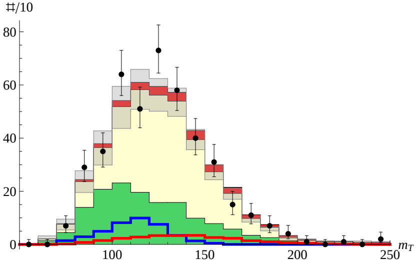
Control Region with Charginos



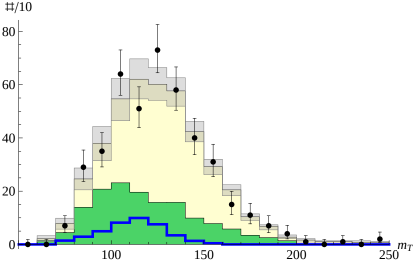
Control Region without Charginos



Signal Region with Charginos



Signal Region without Charginos:



Trilepton Searches

- The most constraining LHC bound on charginos comes from CMS 5 fb^{-1} multi-lepton search[2] which is sensitive to $pp \to \tilde{\chi}_2^0 \tilde{\chi}_1^\pm \to 3\ell + \text{MET}$
- They define many signal regions differentiated by $\not{E}_T$, H_T and character of the lepton triplet (no OSSF, OSSF w/o Z, OSSF Z).

For $m_{\tilde{\chi}_1^\pm} = 115\,\text{GeV}$, $m_{\tilde{\chi}_1^0} = 20\,\text{GeV}$ Scenario:

Signal Region	$N_{\chi_2^0 \chi_1^\pm}$	N_{data}	N_{BG}
$\not{E}_T > 50, H_T > 200, \quad Z$	1.4	20	18.9 ± 6.4
$\not{E}_T > 50, H_T < 200, \text{ no } Z$	**5.3**	**30**	**27.0 ± 7.6**
$\not{E}_T > 50, H_T < 200, \quad Z$	**44**	**141**	**134 ± 50**
$\not{E}_T < 50, H_T < 200, \text{ no } Z$	5.4	123	144 ± 36
$\not{E}_T < 50, H_T < 200, \quad Z$	52.	657	764 ± 183

Not excluded, but might be visible soon!

[2] arXiv:1204.5341

How to find these Charginos?

PRELIMINARY

- *W*-like decay kinematics make these charginos harder to detect, but trilepton searches are already approaching the necessary sensitivity
- An update of the *WZ* cross section analysis would be helpful.
- The chargino NLSP scenario might be harder to find.
- Improvements in higher-order *WW* calculations are needed.
  - Either show that this “excess" is just SM, OR
  - conclusively allow BSM physics to be detected in *WW* cross section measurement.
- There are also some kinematic differences between the chargino contributions and *WW* or *H* contributions. Under Investigation.

Conclusion

- With bounds on strongly produced BSM physics approaching TeV, New Physics might show up in EW sector first.
- *“You look but you do not see."*
  $\mathcal{O}(100\,\mathrm{GeV})$ Charginos might be right under our noses.
- Could be a background issue! Needs to be clarified.
- If the “excesses" in *WW* analyses are BSM physics, they should show up in other searches soon!
- Updated *WZ* measurement?