SUSY SEARCHES AT THE HL-LHC

Marco Rimoldi
on behalf of the ATLAS and CMS Collaborations
Generic searches for SUSY
- Prospects for realistic SUSY models at the HL-/HE-LHC (S. Heinemeyer et al.)
- Probing SUSY at HL- and HE-LHC (T. Han et al.)
- Supersymmetry at a 28 TeV hadron collider: HE-LHC (A. Aboubrahim, P. Nath)

SUSY strong production
- SUSY strong - improved searches for squark and gluinos (ATLAS)
- Prospects for third generation squark production at the HL-LHC and HE-LHC (ATLAS)
- Same-sign di-lepton SUSY (CMS)
- Implications of a Stop Sector Signal at the LHC (A. Pierce et al.)

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHEWG3
WG3 Contributions

- **SUSY EWK production**
  - Prospects for C1N2 via WZ and Wh in multilepton at the HL-LHC and HE-LHC \((ATLAS)\)
  - Prospects for chargino pair production at HL- and HE-LHC \((ATLAS)\)
  - Search for chargino-neutralino in Wh channel using 1Lbb final states \((ATLAS)\)
  - Prospects for direct stau production at the HL-LHC \((ATLAS and CMS)\)
  - Compressed electroweakinos at HL- and HE-LHC \((ATLAS and CMS)\)
  - Prospects for radiative natural SUSY at HL- and HE-LHC \((H. Baer et al.)\)
  - Constraining slepton and chargino through compressed top squark search \((P. Konar et al.)\)

- **Long Lived particles signature in Carlos’s Talk**

[Link to Twiki page](https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHEWG3)
Introduction

Run 2 searches have set stringent limits on Simplified Model in both Strong (squark and gluino) and Electroweak (chargino, neutralino and slepton) productions.

✓ 1 TeV for Stop
✓ 1.5-2 TeV for Gluino, 1.5 TeV for Squark
✓ 600 GeV for C1N2

Marco Rimoldi - LHEP AEC, Universität Bern 18/06/18
In this talk, I will present the expected ATLAS and CMS contributions to the Yellow Report for the European Strategy for Particle Physics.

Different analysis approaches for HL-LHC have been used by the two collaborations.

- Based on truth-level events + smearing of the detector:
  - Reconstruct particles (e, \( \mu \), jets, MET) from truth + overlay and smear their energy and \( p_T \) using appropriate smearing functions based on full simulation of the detector
  - Jets from a pileup library
  - Cross checked with some of the ‘real’ data analyses

- Full simulation
- Analysis with parameterized detector performance: DELPHES with up-to-date phase-2 detector performance
- Projections using 13 TeV signal and background samples scaled at 14 TeV (foreseen to be mixed with the previous two)
Squark and Gluino

- Previous prospects show $5\sigma$ discovery reach at $\sim 2.5$ TeV ($\sim 1.3$ TeV) for $g$ ($q$) for massless neutralino simplified models.
- Discoverable squark pair production models are already excluded using the 36.1 $fb^{-1}$ Run 2 data. (ATLAS-CONF-2017-022, CMS-SUS-17-006).

**ATLAS might update the prospects in the multijet channel.**

**Theory studies are expected for the YR (cross section calculation)**

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**Summary of CMS SUSY Projections with SMS**

- Preliminary
- $5\sigma$ discovery: 14 TeV, 3000 fb$^{-1}$
- $5\sigma$ discovery: 14 TeV, 300 fb$^{-1}$
- 95% CL limits: 8 TeV

**Probe *up to* the quoted mass**

If discovered, HE-LHC will be needed to study in detail their properties.
Stop and Sbottom searches

1 TeV stops excluded in simplified models. Limits can get significantly worse in more complex scenarios.

The top diagonal was covered by 2L signature with previous results. ATLAS plan to update the result using 0L channel.

Prospect for high mass region was based on \( \sqrt{s} = 8 \) TeV analysis. Expect to improve.

Marco Rimoldi - LHEP AEC, Universität Bern
Electroweak SUSY: Chargino-Neutralino

- Targets WZ and Wh-mediated decay of Charginos and Neutralinos
- Different final state, $W(\ell\nu)Z(\ell\ell)$ or $W(\ell\nu)h(bb)$

Exclusion limit extends above 1 TeV for massless LSP. Current Run 2 analysis already better than 300 fb$^{-1}$ projection

Results to be updated for YR
**Electroweak SUSY: Chargino-Neutralino**

- Targets WZ and Wh-mediated decay of Charginos and Neutralinos
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**ATLAS Results to be updated for Summer with new detector parametrisation**

**CMS Expected improvement:**
- MET resolution using timing information
- Boosted tagger for $h(b\bar{b})$

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**Compressed Ewkinos**

In the limit of low-\(\mu\) the two lightest neutralino and lightest Chargino are Higgsino-like, and nearly mass degenerate.

For splitting larger than a GeV, soft leptons can be reconstructed

- Low-\(p_T\) lepton reconstruction is crucial
- Analysis fit on low value \(m_{\ell\ell}\) and MET
- Potential improvement from adding 3L final state and VBF production.
- Expected results for YR by CMS and ATLAS

For very low mass splitting, Charginos can give **disappearing track** signature

March 2018

ATLAS Preliminary

\(\sqrt{s} = 13\ TeV, 36.1\ fb^{-1}\)

\(pp \rightarrow \tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm, \tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_1^\pm (\text{Higgsino})\)

All limits at 95% CL

- Observed limits
- Expected limits

**ATLAS**

\[ \Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_2^0) [\text{GeV}] \]

\[ m(\tilde{\chi}_1^\pm) [\text{GeV}] \]

**CMS**

33.2-35.9 fb\(^{-1}\) (13 TeV)

Higgsino-like: \(pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_2^0 + pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0 + \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \)

\(m_{\chi_2^0} = m_{\chi_1^\pm} + m_{\chi_1^\pm} + m_{\chi_1^\pm} (\text{BR}=1), m_{\chi_2^0} = (m_{\chi_1^\pm} + m_{\chi_1^\pm})/2\)

- Observed \(\pm 1\ \sigma_{\text{theory}}\)
- Expected \(\pm 1\ \sigma_{\text{experiment}}\)

95% CL upper limit on cross section [pb]

\[ \Delta \chi^2 [\text{GeV}] \]

\[ m_{\chi_2^0} [\text{GeV}] \]

Expected results for YR by CMS and ATLAS

- ATLAS Preliminary

- Analysis fit on low value \(m_{\ell\ell}\) and MET

- Potential improvement from adding 3L final state and VBF production.

- Expected results for YR by CMS and ATLAS
Compressed Ewkinos

Discussion between the ATLAS and CMS collaborations:

- Check the cross section for C1N2 Higgsino like (i.e. compare Resummino input, pdf sets etc.)
- Add 30% uncertainties on signal (due to ISR modelling)
- Add 30% uncertainties data driven fakes
- Fake leptons estimation will be compared between the ATLAS and CMS. Different approach are used.
C2N4: Same sign leptons signature

- RNS Model -> Naturalness oriented model -> Higgsino LSP
- C1-N1-N2 are compressed, Unique signature in C2N4 decay:
  - **Largest visible cross-section**
  - 25% BR into Same Sign $W$.
  - Powerful probe complementing direct searches for higgsinos

Expected results for the YR
**Electroweak SUSY:**

**chargino-chargino to WW**

Challenging signature with low sensitivity during Run 1 analysis.
Very interesting channel for HL-LHC

- Analysis based on $E_T^{\text{miss}}$ and $m_{T^2}$ with jet veto
- Sensitivity also in function of the different WW background assumption.
  - **Update results for the Yellow report.**
Direct stau production

- Direct stau production become dominant if charginos and NLSP neutralinos are heavy.
- Very challenging search due to low cross-section for producing stau pair and low acceptance

- Both $\tau_{\text{had}}\tau_{\text{had}}$ and $\tau_{\text{had}}\tau_{\text{lep}}$ will be targeted.
- Information from timing detector expected to significantly impact tau ID performance
- Expect sensitivity up to 500-600 GeV for current assumption on Phase2 detector.

- Current Run 1 limits excludes $\tau_R$ only up to 109 GeV.
- Discovery sensitivity 400 GeV for $\tau_L$
- No discovery sensitivity for pure $\tau_R$
- Update with improved tau performance parameterisation

Both results planned for YR

![Graph showing CMS Preliminary results with events/50 GeV and mass distributions for $\tilde{\tau}$ and $\tilde{\chi}^0$ production](image)
Conclusion

■ The current plan for the Yellow Report mostly focused on EW SUSY due to low expected low cross-section. High statistic is needed.

■ Discussion on common items between ATLAS and CMS (e.g. Higgsino). Working also on having common plots to give a LHC wide view.

■ Particular attention needed for coherent cross-sections and uncertainties assessment.
WG3 Contribution

- **Long Lived particles**
  - Prospects for disappearing track analysis at HL-LHC (*J. Anders et al. ATLAS*)
  - Prospects for disappearing track analysis at HE-LHC (*M. Saito et al.*)
  - displaced vertex
    - Prospects for LLP->DV+MET (*L. Jeanty et al. ATLAS*)
    - displaced muons (*CMS*)
    - Prospects for LLP->mu+jets at the HL-LHC (*X. Cid Vidal et al. LHCb*)
    - Prospects for LLP->dijets at the HL-LHC (*X. Cid Vidal et al. LHCb*)
  - heavy stable charged particles (dE/dx and TOF) (*CMS*)
  - fast timing signatures for long-lived particles (*CMS*)
  - various interpretations
    - Searching for Confining Hidden Valleys at the LHCb and ATLAS/CMS (*A. Pierce et al.*)

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