ATLAS Run1 Constraints on the Electroweak Sector of SUSY

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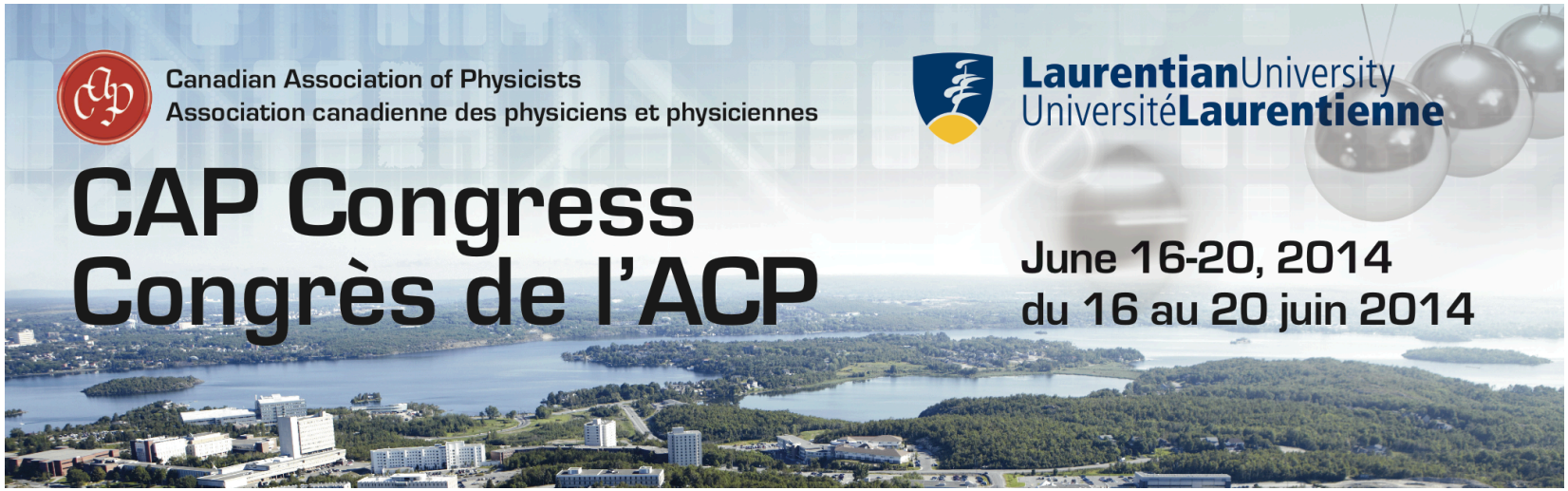
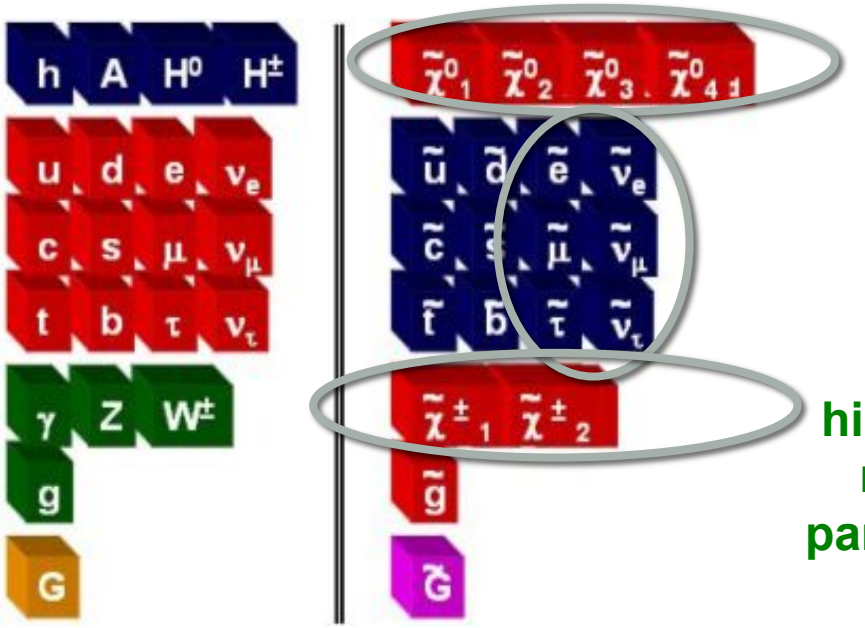


EWK Sector of the MSSM



tree-level:

$$-\frac{m_Z^2}{2} = |\mu^2| + m_{H_u}^2 + \mathcal{O}\left(\frac{1}{\tan^2\beta}\right)$$

- $|\mu^2|$: higgsino mass parameter
- $m_{H_u}^2$: weak scale soft SUSY breaking mass parameter in the higgs potential
- $\tan\beta$: ratio of the two vev of higgs in the theory

- The theory naturally yields the correct value of M_Z if the individual terms are comparable in magnitude
- If higgsinos are light ➔ charginos and neutralinos expected to be light

Parameterization of the EWK sector

- **The electroweakino sector is parameterized with only 4 parameters**
  - M1 (Bino); M2 (Wino); MU (Higgsinos); tanbeta

$$\begin{pmatrix} M_1 & 0 & -c_\beta s_W m_Z & s_\beta s_W m_Z \\ 0 & M_2 & c_\beta c_W m_Z & -s_\beta c_W m_Z \\ -c_\beta s_W m_Z & c_\beta c_W m_Z & 0 & -\mu \\ s_\beta s_W m_Z & -s_\beta c_W m_Z & -\mu & 0 \end{pmatrix} \qquad \begin{pmatrix} M_2 & \sqrt{2} s_\beta m_W \\ \sqrt{2} c_\beta m_W & \mu \end{pmatrix}$$

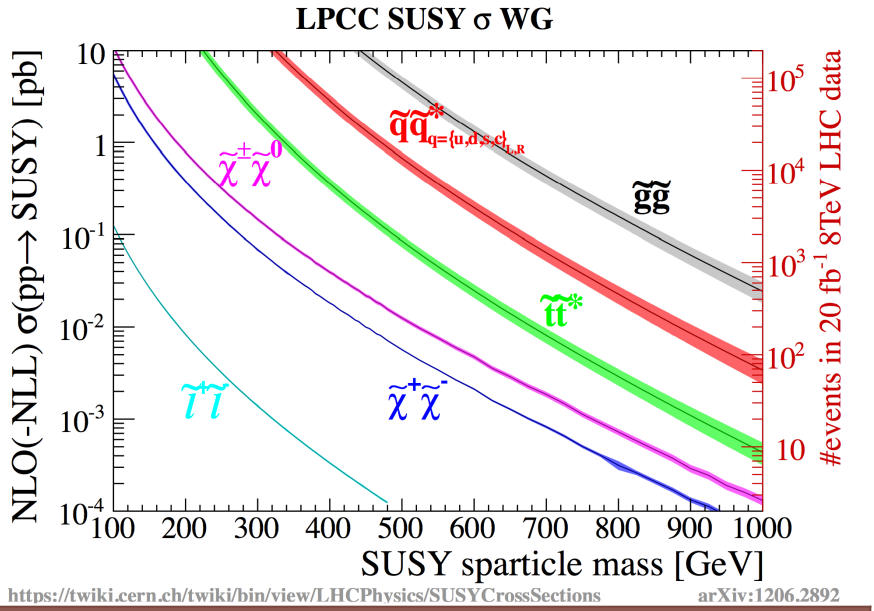
Neutralino Mass matrix **Chargino Mass matrix**

- **The slepton sector is parameterized with only 5 parameters**
  - Mass of the LH/RH selectron and smuon
  - Mass of the LH/RH stau and the mixing

$$\mathbf{m}^{\mathbf{2}}_{\tilde{\tau}} = \begin{pmatrix} m^2_{L_3} + \Delta_{\tilde{e}_L} & v(a^*_\tau \cos\beta - \mu y_\tau \sin\beta) \\ v(a_\tau \cos\beta - \mu^* y_\tau \sin\beta) & m^2_{\tilde{e}_3} + \Delta_{\tilde{e}_R} \end{pmatrix}$$

Comprehensive Search for EWK SUSY

- **If gluinos and squarks are heavy, EWK SUSY can be the dominant SUSY production**
  - High discovery potential!
- **Complex search including variety of final states and ~100 signal regions**

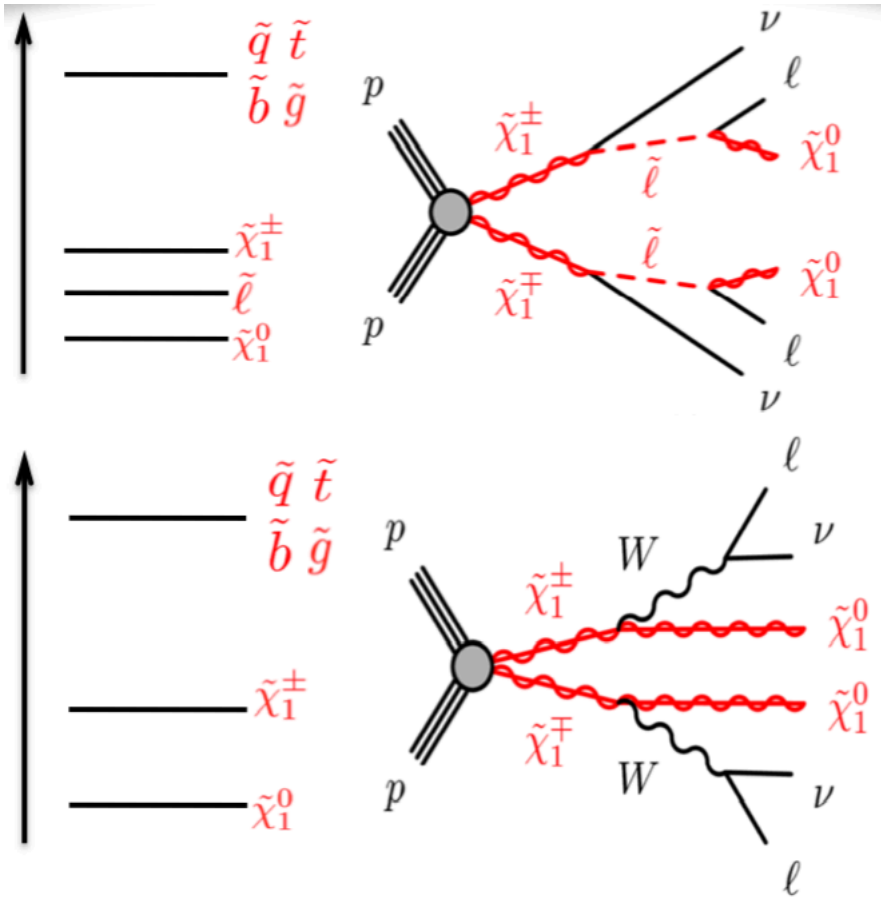


SUSY scenario	LSP
RPC production and decay	N1/Gravitino
RPC production and RPV decay	N1
RPC production and displaced decays	N1

SUSY Process	Signature
Sleptons and sneutrinos	Leptons (+ MET)
CiCi, CiNi, NiNj	Gauge, Higgs bosons + MET
	Leptons/taus (+ MET)
	Photon+MET
	'disappearing track'

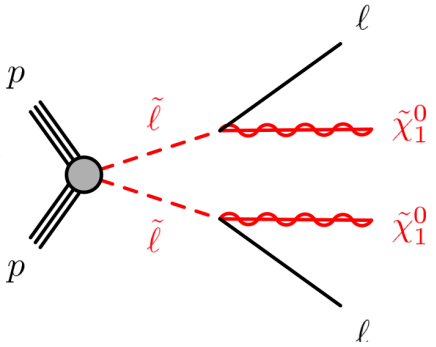
Simplified Models

- **Involve only a few new particles and interactions.**
- **Small number of parameters directly related to collider physics observables**
  - particle masses
  - production cross-sections
  - branching fractions



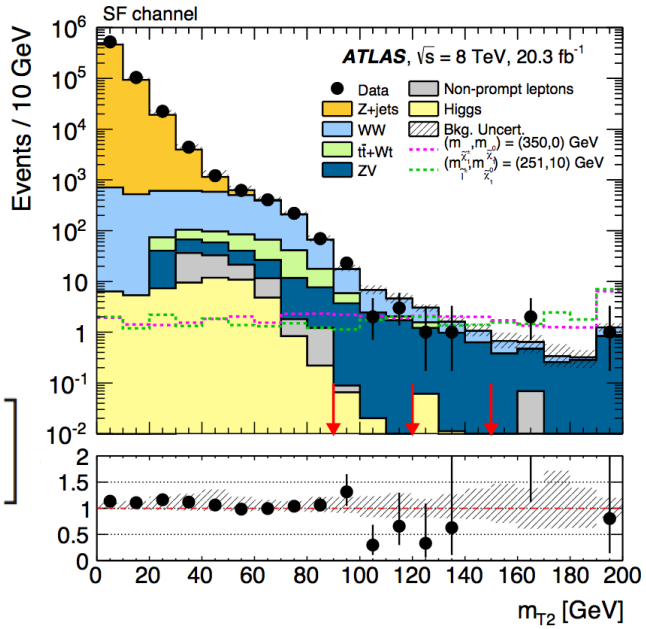
Results also interpreted in Phenomenological models (pMSSM, GGM, AMSB)

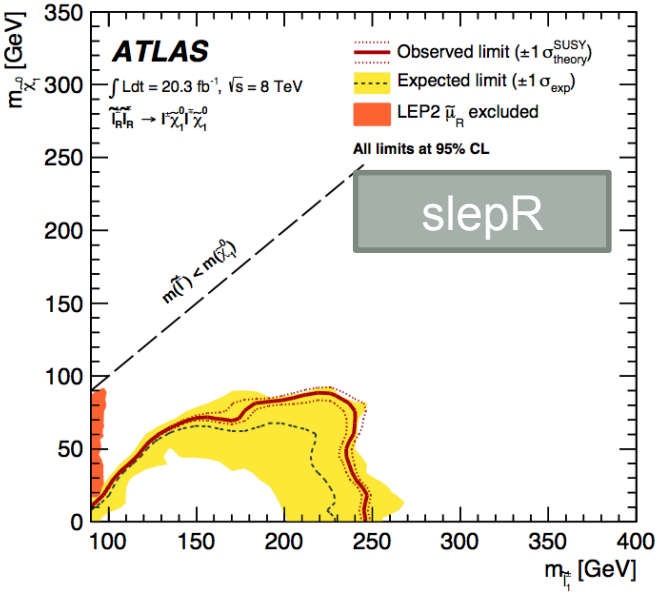
Searches for Slepton Pair-production

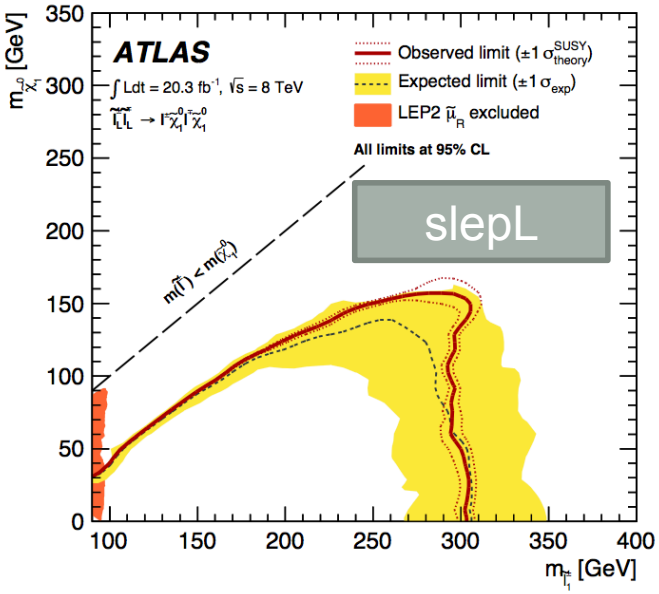


- **2 same flavor e/μ**
- **Signal and background discrimination based on $E_T^{miss,rel}$ and M_{T2}**

$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T) \right) \right]$$

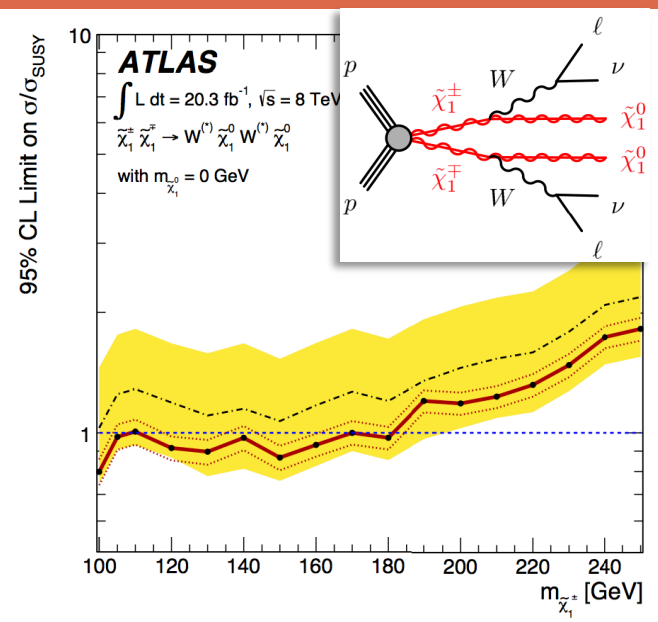


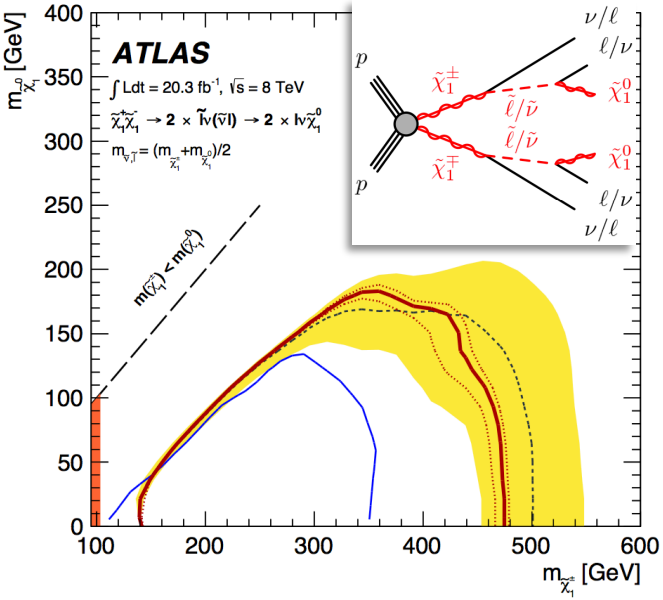




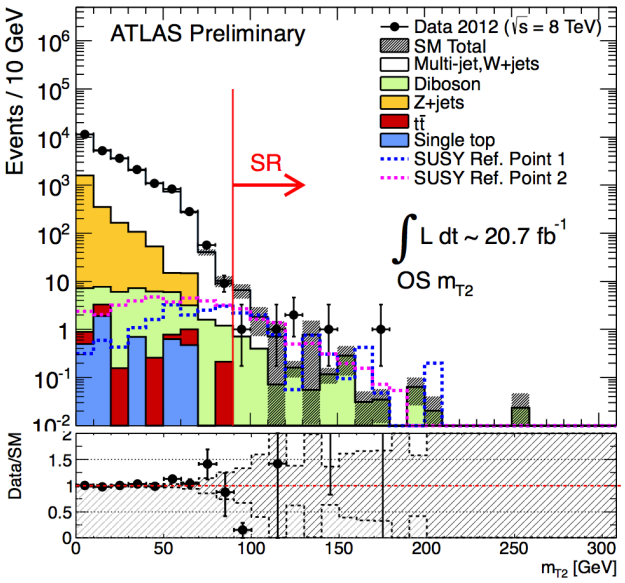
JHEP05 (2014) 071

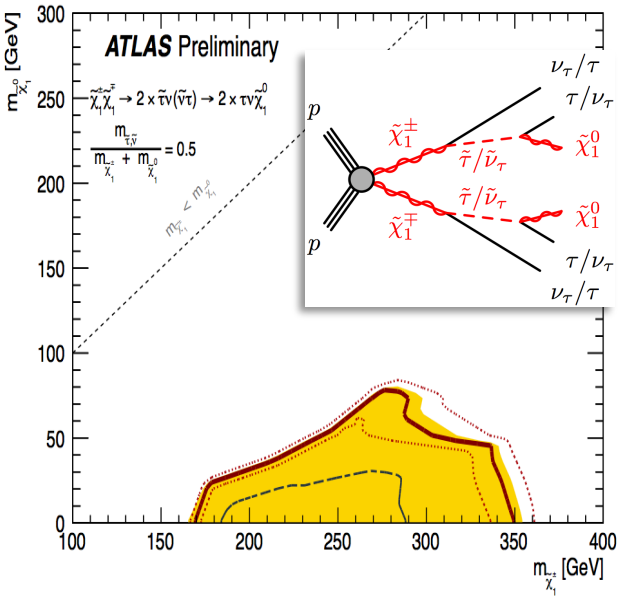
Searches for Chargino Pair-production





- **2 hadronically decaying taus**
- **Signal and background discrimination based on E_T^{miss}, M_{T2} and jet veto**

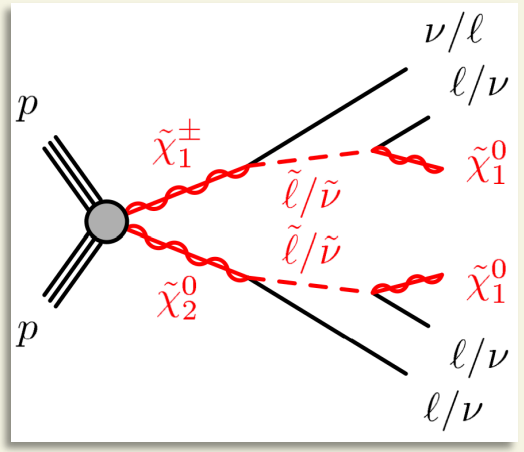




JHEP05 (2014) 071, ATLAS-CONF-2013-028

Searches for Chargino-Neutralino Production

- **Search in the trilepton final states**
  - Search for decays via gauge and higgs boson, light sleptons and staus
  - Dedicated talk by Matthew Gignac



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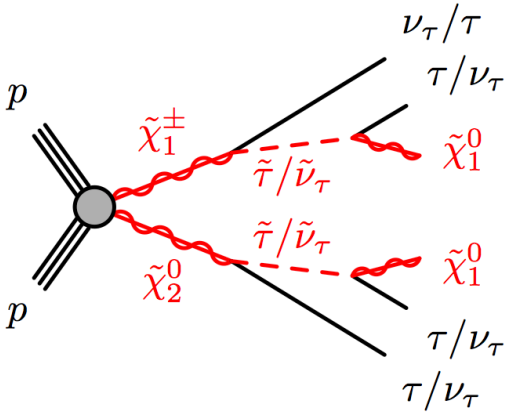

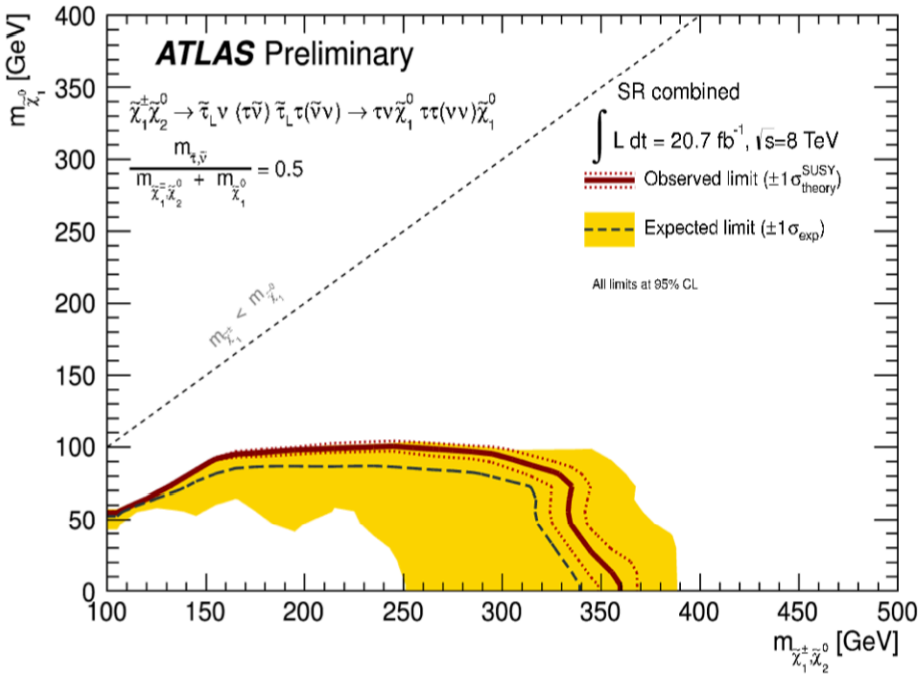

ATLAS-CONF-2013-028, JHEP04 (2014) 169

Searches for Chargino-Neutralino Production

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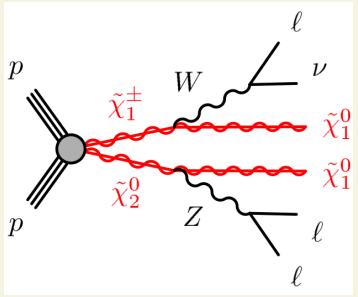
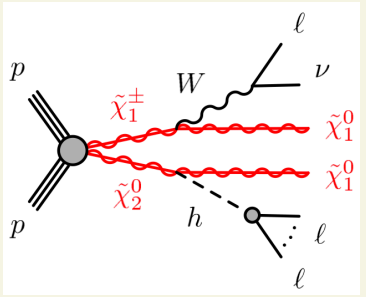
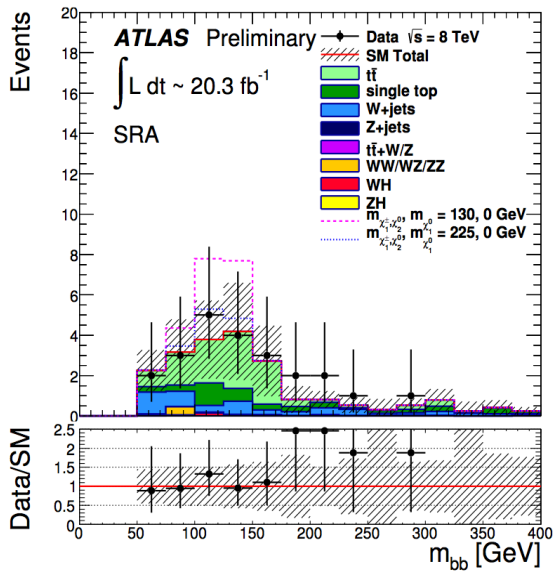
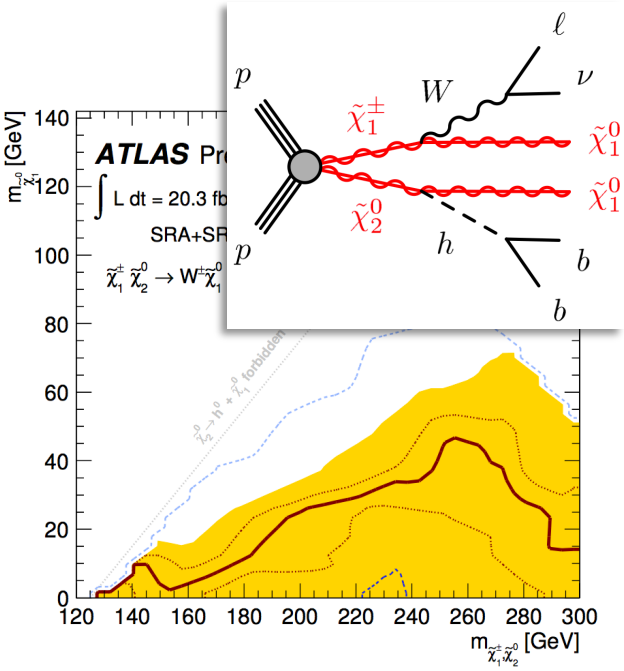




- **Search in events with one lepton and 2 b-jets**
  - Background discrimination based on Etmiss, MT, and MCT

$$m_{\mathrm{CT}}^2 = \left(E_{\mathrm{T}}^{b_1} + E_{\mathrm{T}}^{b_2}\right)^2 - \left|\mathbf{p}_{\mathrm{T}}^{b_1} - \mathbf{p}_{\mathrm{T}}^{b_2}\right|^2$$

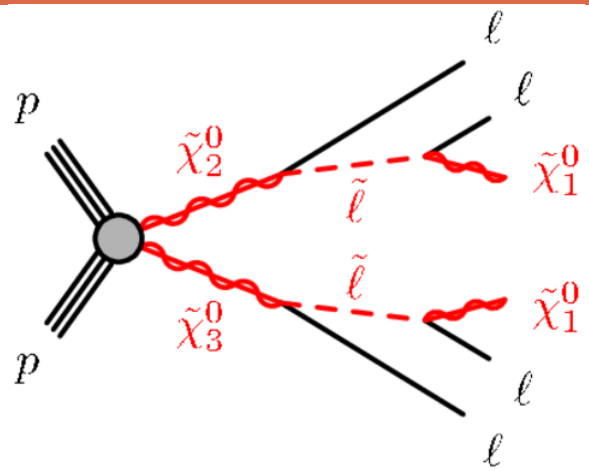


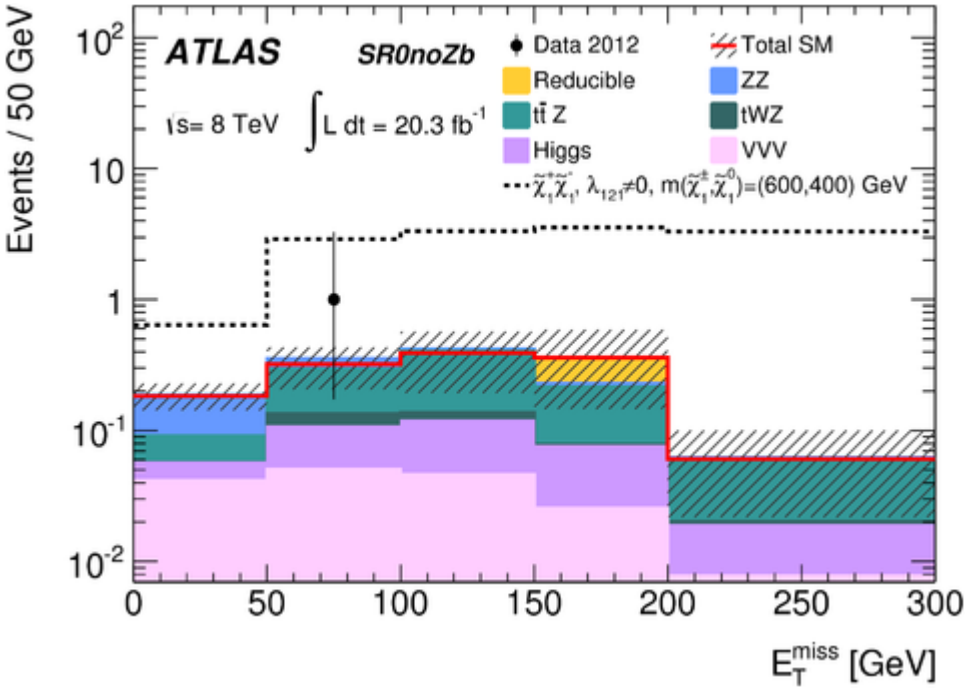


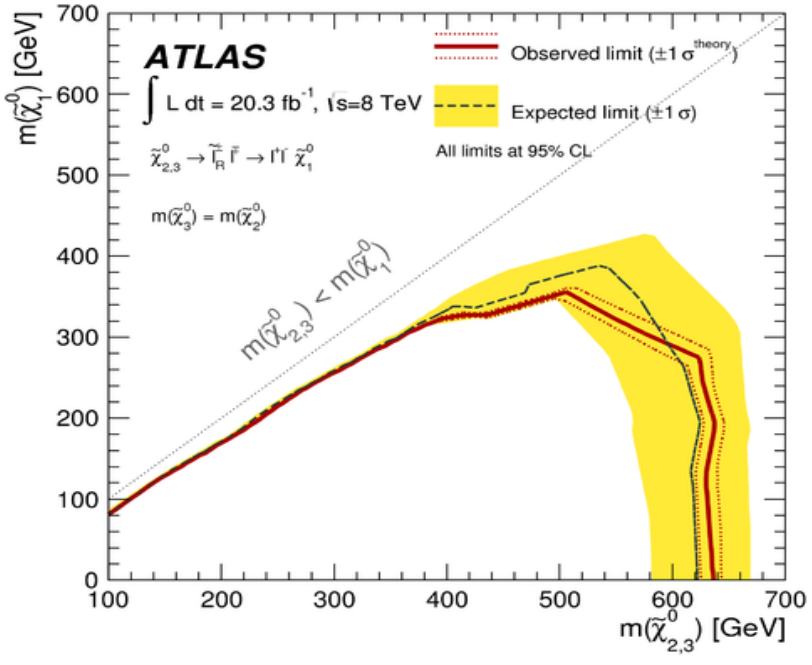
ATLAS-CONF-2013-093, JHEP04 (2014) 169

Searches for Neutralino Pair-production

- **N2N3 production compelling if higgsino like**
- **Final states with 4 leptons (including hadronically decaying taus) used in the search**
  - Signal vs background discrimination based on MET and Z-boson veto



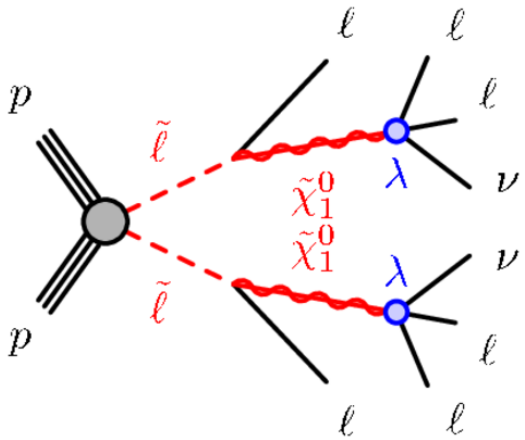


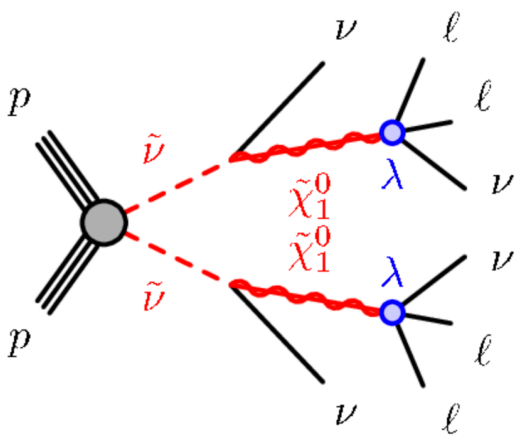


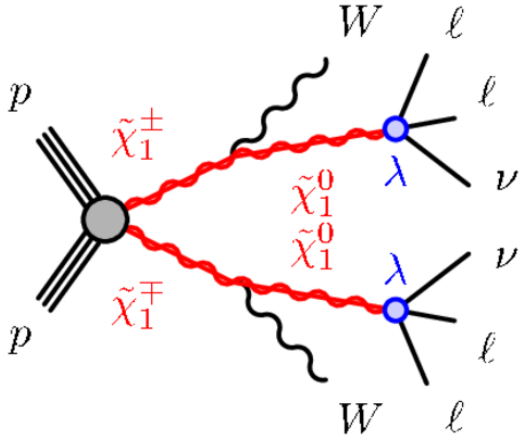
arXiv:1405.5086

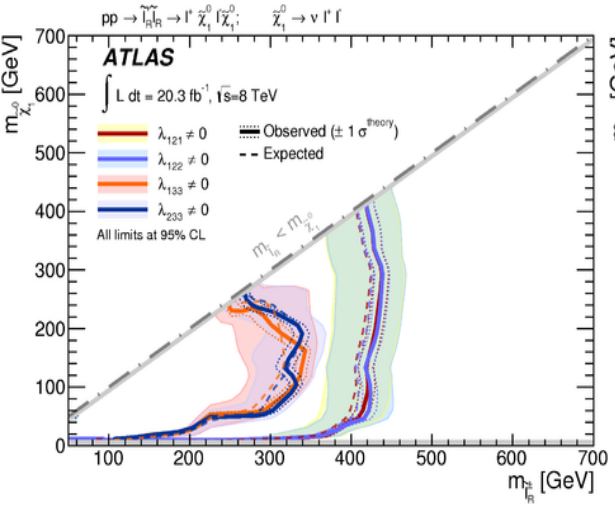
EWK SUSY with RPV Decays

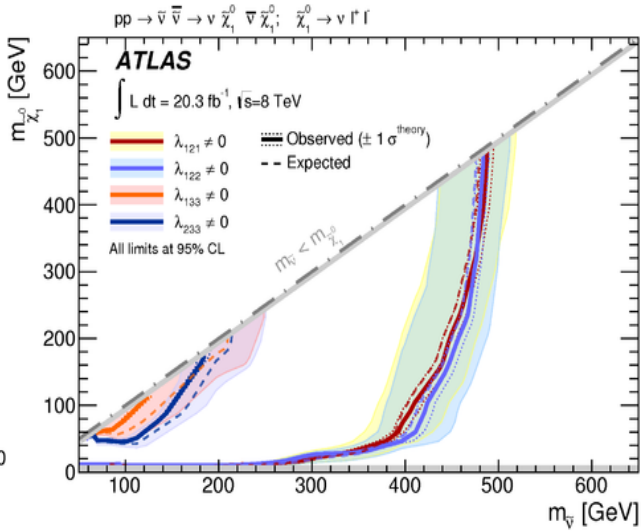
- **4L sensitive probe for RPV decays of LSP**
  - Z-veto and Etmiss from neutrinos

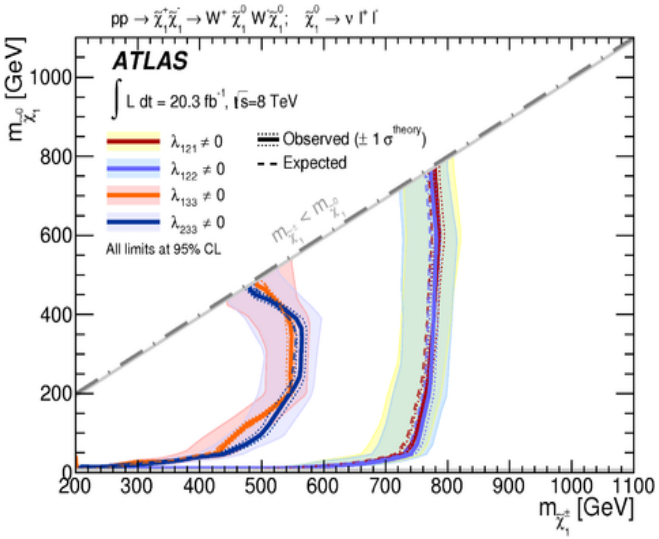










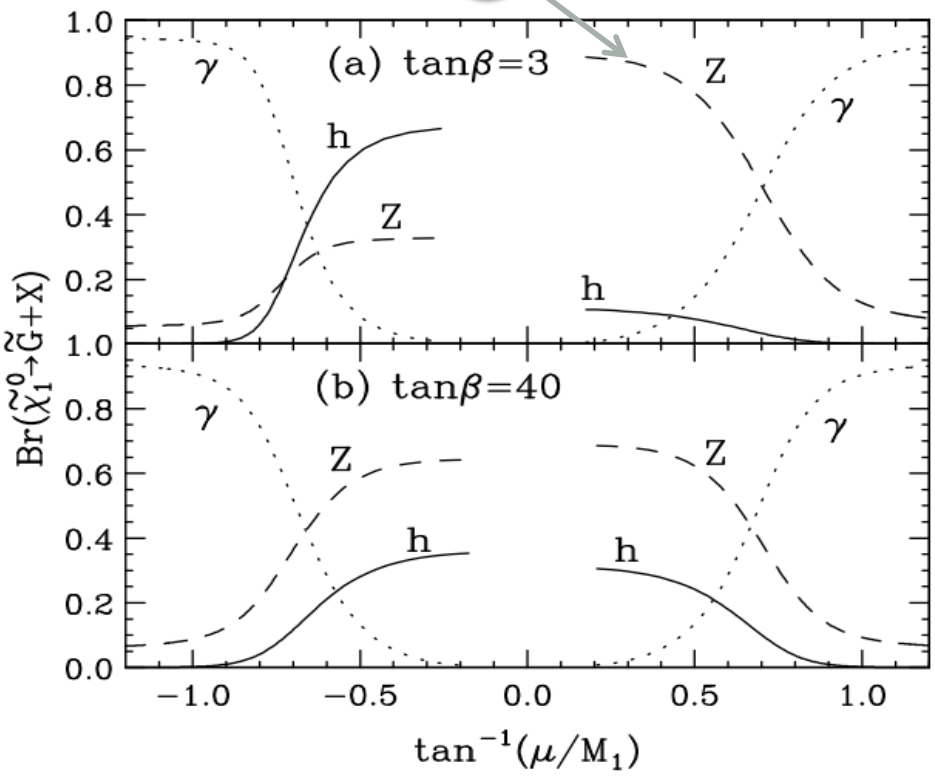


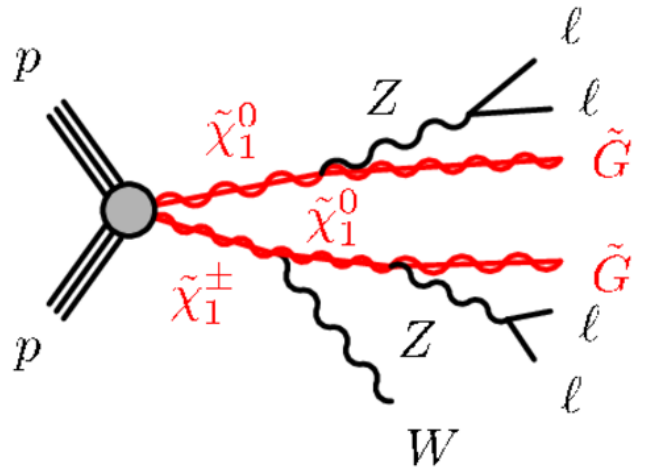
arXiv:1405.5086

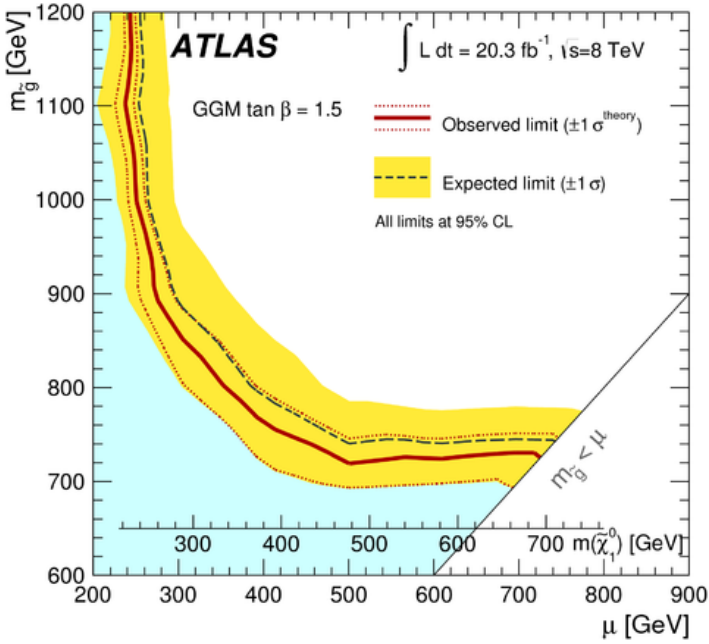
EWK SUSY with Gravitino LSP (I)

- **4L events with Z boson candidates probing for GGM scenarios (with Gravitino LSP)**

$$\chi_1^0 \rightarrow (\gamma , Z , h) + \tilde{G}$$







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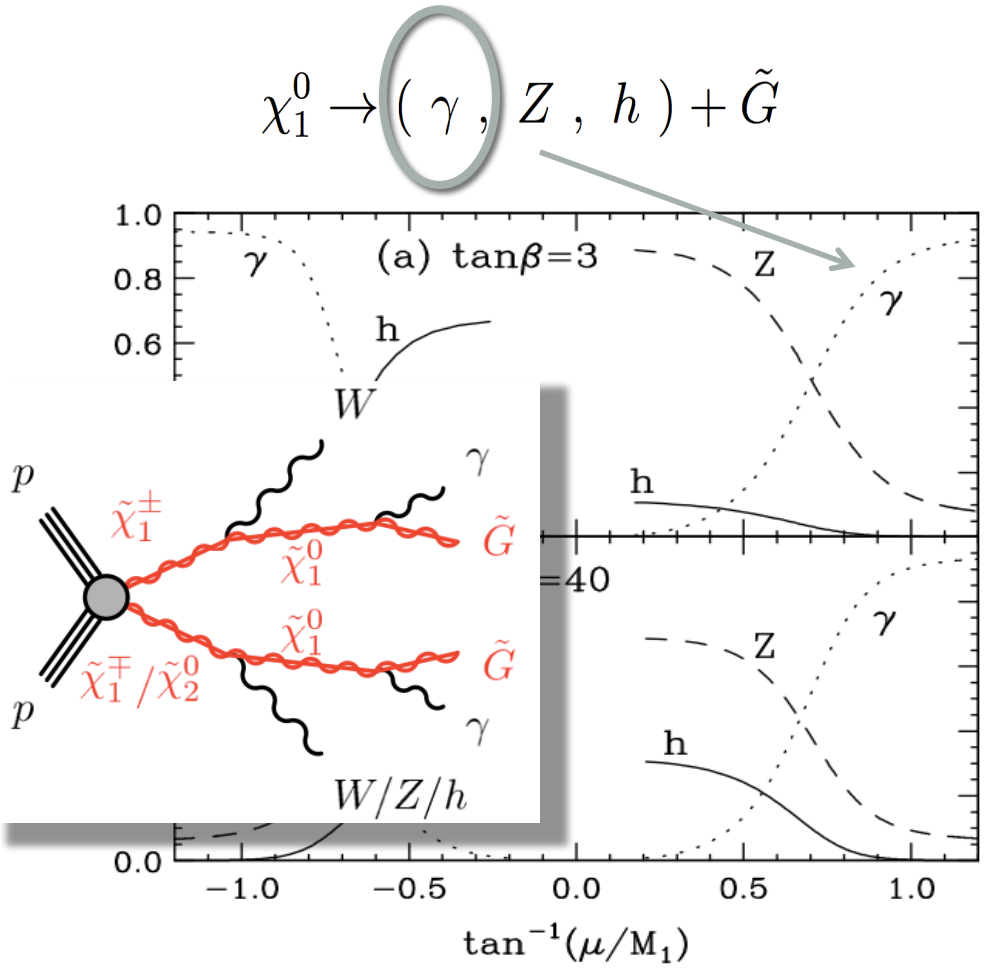
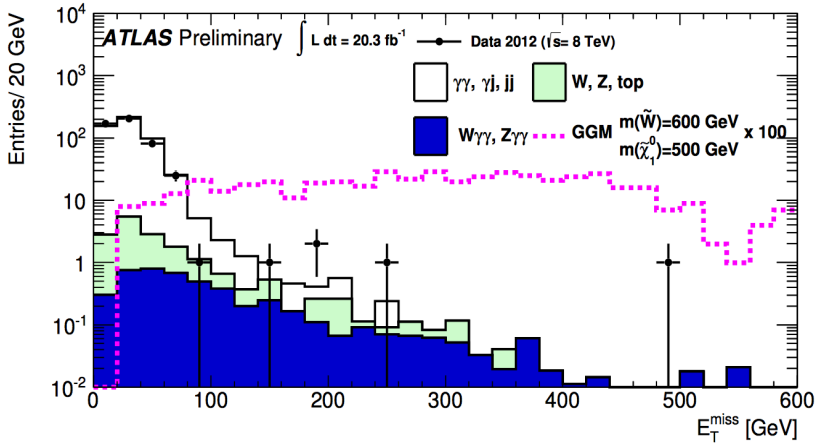
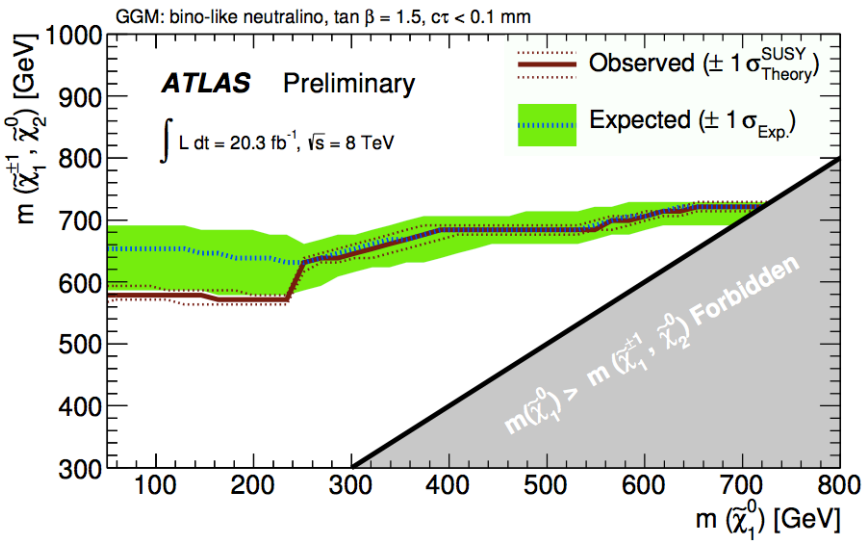
EWK SUSY with Gravitino LSP (II)

- **Search in events with 2 photons and large ETmiss**

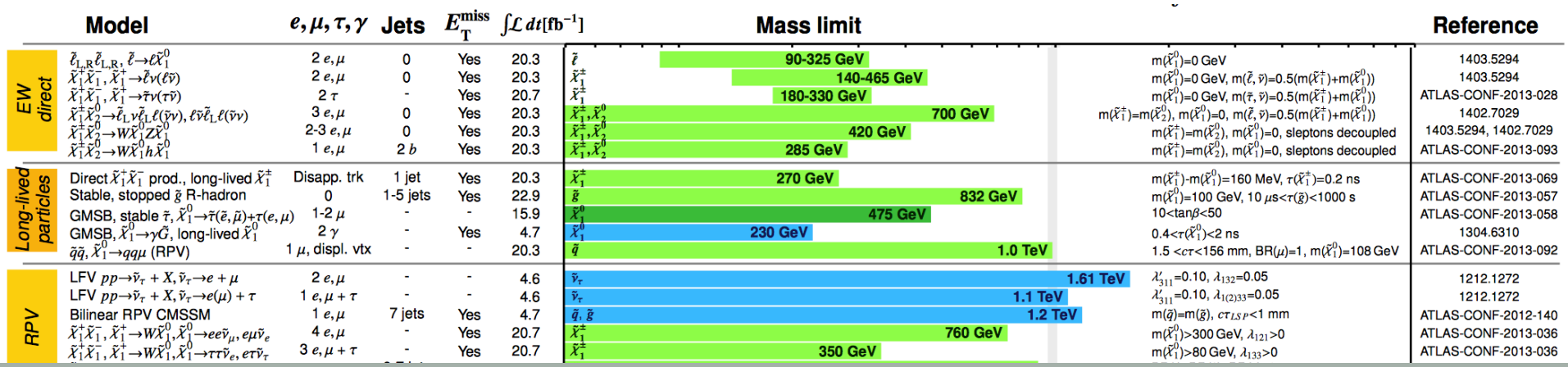






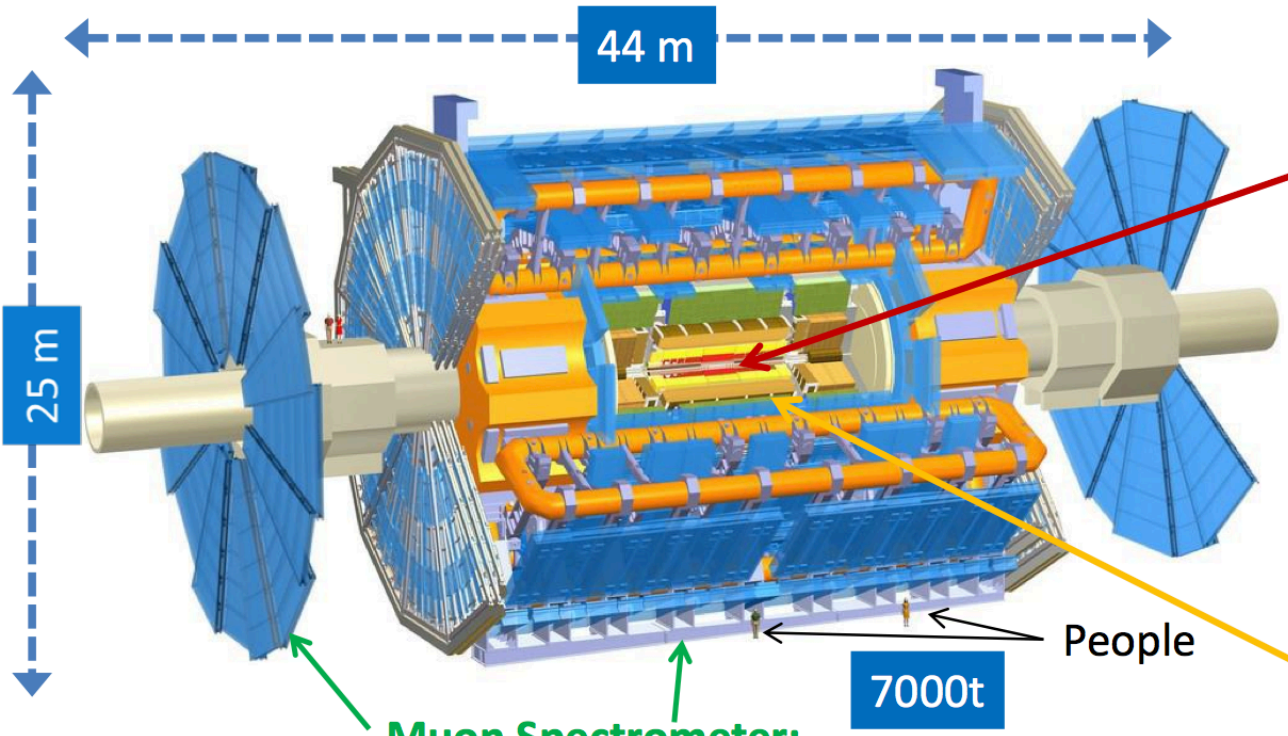
Summary and Outlook

- **EWK SUSY can be the dominant SUSY production at the LHC**
- **Comprehensive search for EWK SUSY carried out in Run 1 data collected by ATLAS at 8 TeV under the assumptions of neutralino1 or gravitino LSP**
- **No significant excess is seen**
  - Stringent limits set in simplified and phenomenological models
- **New regions of parameter phase space will be explored in the ~14 TeV data to be collected starting in 2015**



Additional Slides

The ATLAS Detector



JINST 3 (2008) S08003

Inner Detector:

- 2T solenoid
- Silicon pixel & strip detectors
- Transition radiation tracker
- Interaction vertex
- $|\eta| < 2.5$
- Several hundred tracks per collision

Muon Spectrometer:

- 0.5-1T torroidal magnetic field
- Resistive Plate Chambers & Thin Gap Chambers for trigger
- Monitored Drift Tubes & Cathode Strip Chambers measure sagitta
- $\Delta p/p$ 3% @ 100 GeV rising to 10% at 1TeV
- $|\eta| < 2.7$

Calorimeters:

- Liquid argon electromagnetic calorimeter
- Tile hadronic calorimeter
- $|\eta| < 4.9$
- 9.7 interaction lengths at $\eta=0$

Gravitino as LSP

- **GMSB breaks SUSY via intermediate-scale messenger interactions**
  - Naturally protects SM flavor symmetry
  - Gravitino is always the LSP
    - very light and non-interacting→harder spectrum (w.r.t. N1 LSP case)
    - NLSP can be N1, taus, sleptons
      - decays always to *G*ravitino + SM
      - Its nature determines the signatures
      - Can be long-lived (focus on prompt in this talk)
- **General Gauge Mediation (GGM) :**
  - No specific SUSY mass hierarchy for (un)colored states
  - neutralino's nature depends on: M1, M2, μ, tan(β)