Searches for electroweak production of supersymmetric gauginos and sleptons with the ATLAS detector

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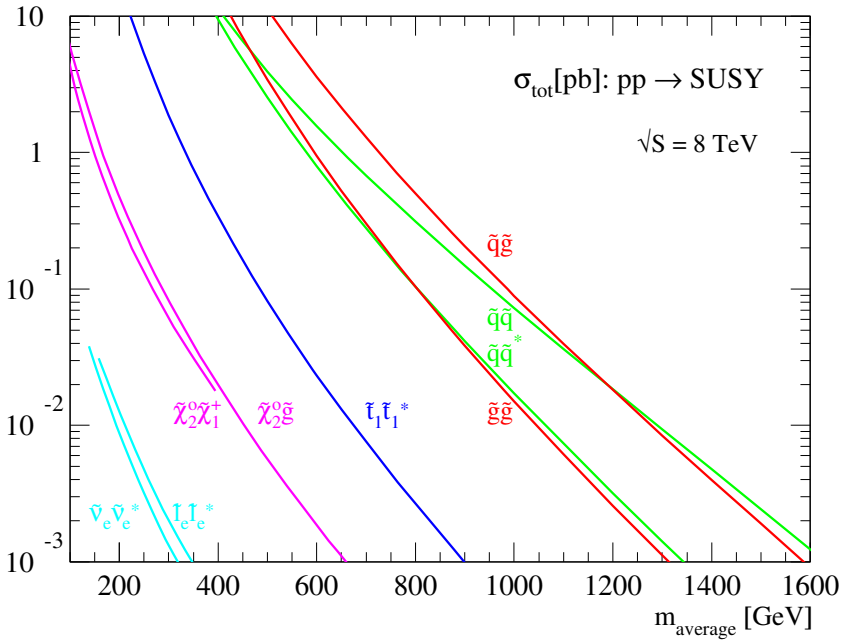
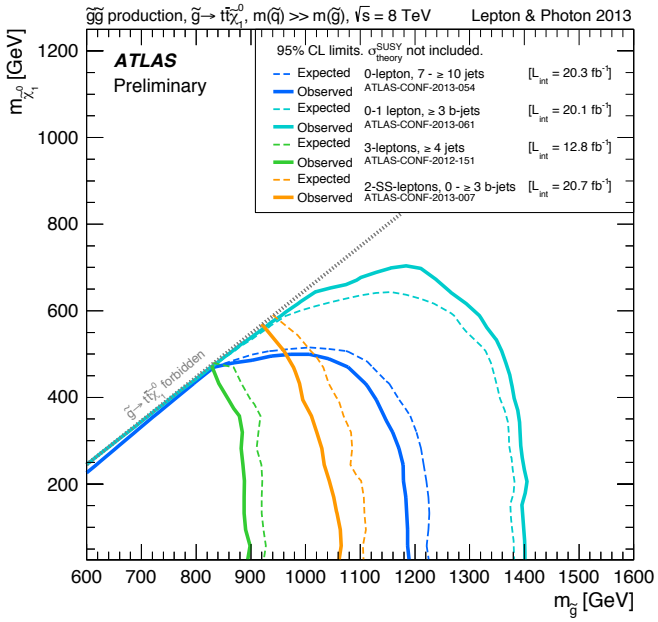
Supersymmetry

Weak-scale supersymmetry is an highly appealing BSM candidate:

- all Standard Model (SM) fields are associated to a partner with $\Delta s = \frac{1}{2}$
- can solve the electroweak hierarchy problem
- R-Parity Conservation (RPC) implies stability for the Lightest Supersymmetric Particule (LSP): natural dark matter candidate
- points to SM-gauges unification





- squark and gluino production thought to be dominant but now highly constrained [see O.Ducu's talk]
- we refer to EWK SUSY as the direct production of sleptons, neutralinos and charginos

EW SUSY phenomenology

EWK SUSY sector defined by 9 parameters (under some assumptions):

$$M_1, M_2, \mu, \tan\beta, m^2_{\tilde{e}_L}, m^2_{\tilde{e}_R}, m^2_{\tilde{\tau}_L}, m^2_{\tilde{\tau}_R}, \tilde{\theta}_{\tilde{\tau}}$$

Mass matrices for neutral and charged components:

$$\begin{pmatrix} M_1 & 0 & -c_\beta s_W m_Z & s_\beta s_W m_Z \\ 0 & M_2 & c_\beta c_W m_Z & -s_\beta c_W m_Z \\ -c_\beta s_W m_Z & c_\beta c_W m_Z & 0 & -\mu \\ s_\beta s_W m_Z & -s_\beta c_W m_Z & -\mu & 0 \end{pmatrix} \begin{array}{l} \longleftarrow \textbf{Bino} \\ \longleftarrow \textbf{Wino} \longrightarrow \\ \longleftarrow \textbf{Higgsino} \longrightarrow \\ \longleftarrow \textbf{Higgsino} \longrightarrow \end{array} \begin{pmatrix} M_2 & \sqrt{2} s_\beta m_W \\ \sqrt{2} c_\beta m_W & \mu \end{pmatrix}$$

Eigenstates=$\left(\tilde{\chi}^0_1, \tilde{\chi}^0_2, \tilde{\chi}^0_3, \tilde{\chi}^0_4\right)$ **Eigenstates=**$\left(\tilde{\chi}^\pm_1, \tilde{\chi}^\pm_2\right)$

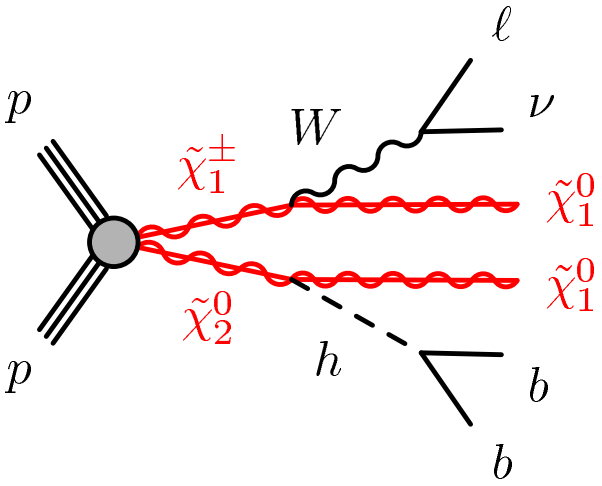
- Larger production cross-sections are for electroweakinos pair-produced
- dominant decays to: W, Z, h or, through sleptons (provided they're light enough)

Overview of ATLAS EWK SUSY searches

Final State	Reference	Interpretation
$1l + \overline{b}b + E_T^{\mathbf{miss}}$	**ATLAS-CONF-2013-093**	**Simp.Model**
$2l + E_T^{\mathbf{miss}}(+jj)$	**1403.5294v1**	**Simp. Model, pMSSM**
$3l + E_T^{\mathbf{miss}}$	**1402.7029v2**	**Simp. Model, pMSSM**
$4l + E_T^{\mathrm{miss}}$	ATLAS-CONF-2013-036	Simp. Model, RPV, GGM
$2\gamma + E_T^{\mathrm{miss}}$	ATLAS-CONF-2014-001	GGM
$\simeq 2\tau^{\mathrm{had}} + E_T^{\mathrm{miss}}$	ATLAS-CONF-2013-028	Simp. Model, pMSSM

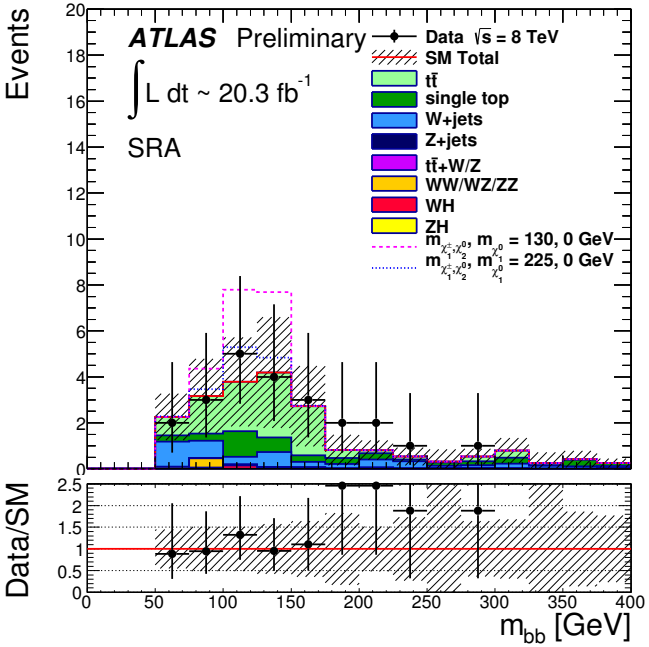
- Simplified models
  - pure states: *ie* no mixing of wino, bino and higgsinos, usually: $\tilde{\chi}_1^0 \equiv \tilde{B}, (\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0) \equiv \left(\tilde{W}^{\pm}, \tilde{W}^0\right)$
  - $\mathrm{BR}(\tilde{\chi}_i \to V + \tilde{\chi}_1^0) = 1$, $\mathrm{BR}\left(\tilde{l} \to l + \tilde{\chi}_1^0\right) = 1$
  - for slepton mediated decays: $m_{\tilde{l}} = 0.5\left(m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_{2,1}^{0,\pm}}\right)$
  - gluino and squarks masses set above the TeV scale
  - heavy higgses decoupled. Lightest higgs have a mass of 125 GeV and SM couplings
- pMSSM interpretation on grids with 125 GeV higgs
- R-Parity Violating SUSY covered by A.Kenneth Lehan's talk

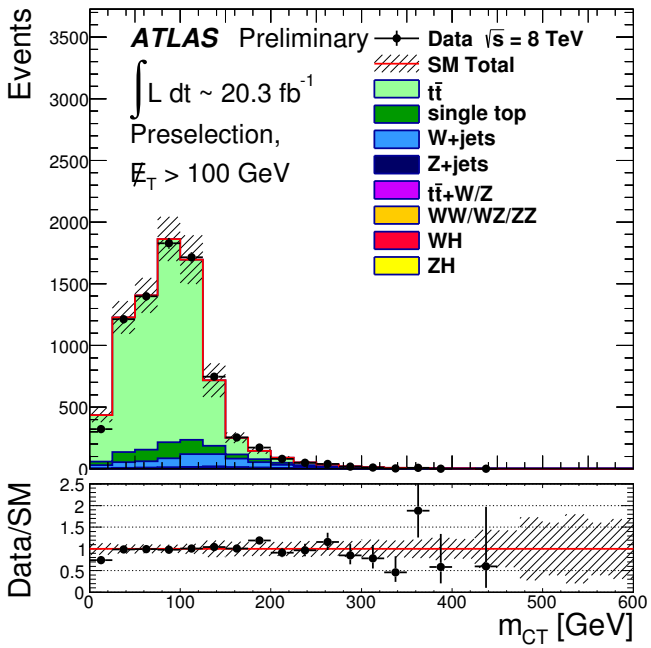
$1l + \bar{b}b + E_T^{\text{miss}}$



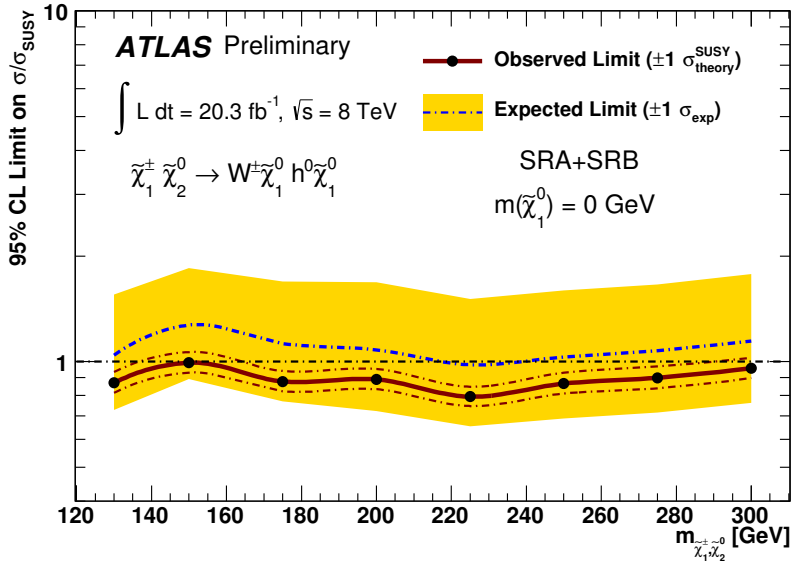
SUSY-dressed WH production

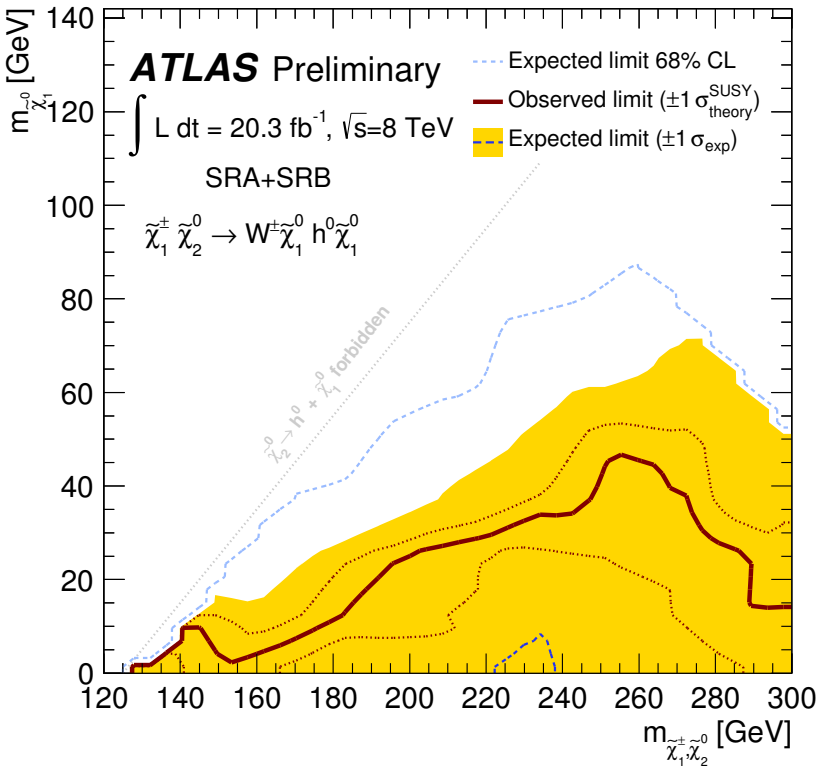
- analysis optimized to exploit $h^0 \to \bar{b}b$ resonnance
- main backgrounds are $t\bar{t}$, single-top and W+jets
- $t\bar{t}$ $m_{CT}^{see\ def}$ distributions have an endpoint at ~135 GeV
- two exclusive signal regions targeting at different $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$ (separated using $m_T^{see\ def}$)





$1l + \bar{b}b + E_T^{\text{miss}}$





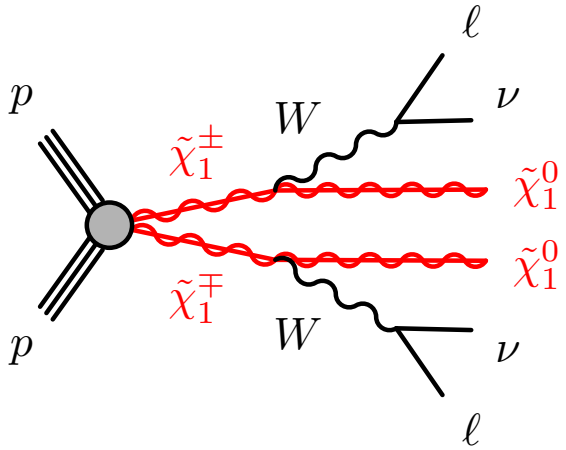
For a massless LSP, masse ranges:

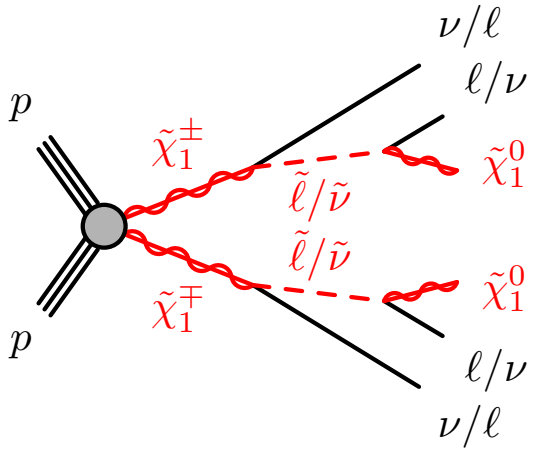
- 125< $m_{\tilde{\chi}_2^0,\tilde{\chi}_1^\pm}$ <141 GeV
- 166< $m_{\tilde{\chi}_2^0,\tilde{\chi}_1^\pm}$ <287 GeV

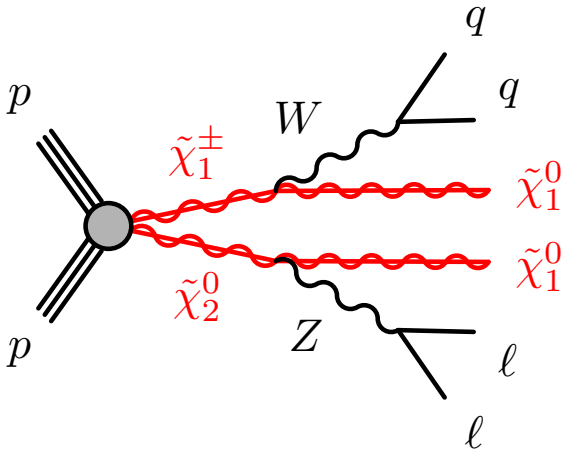
are excluded

- first ATLAS analysis using higgs as a direct probe for SUSY

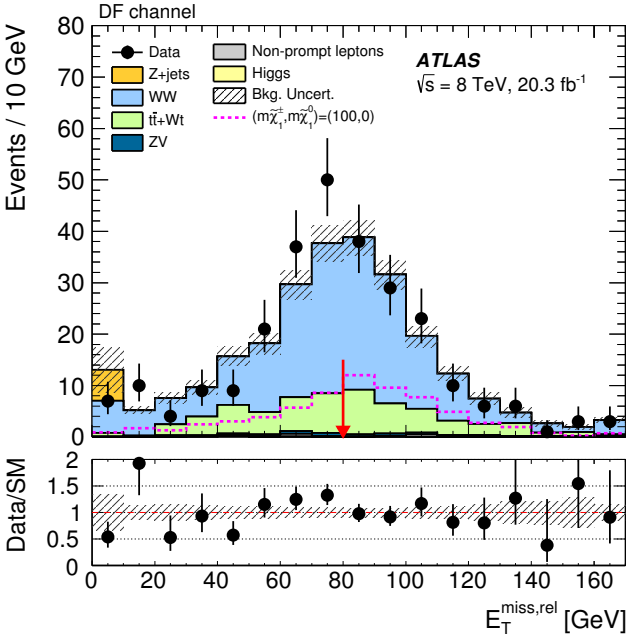
$2l + E_T^{\text{miss}}(+jj)$



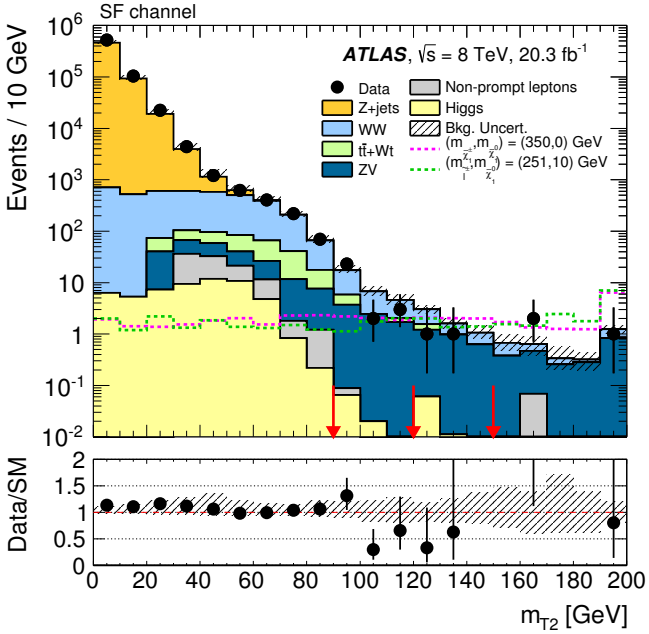




SR-WW

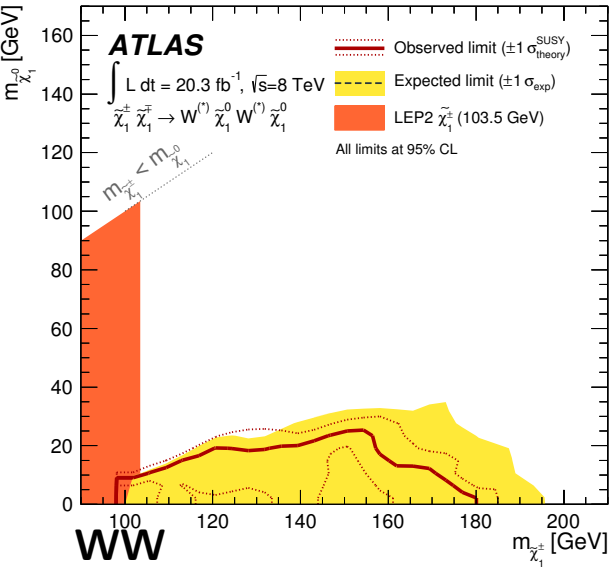


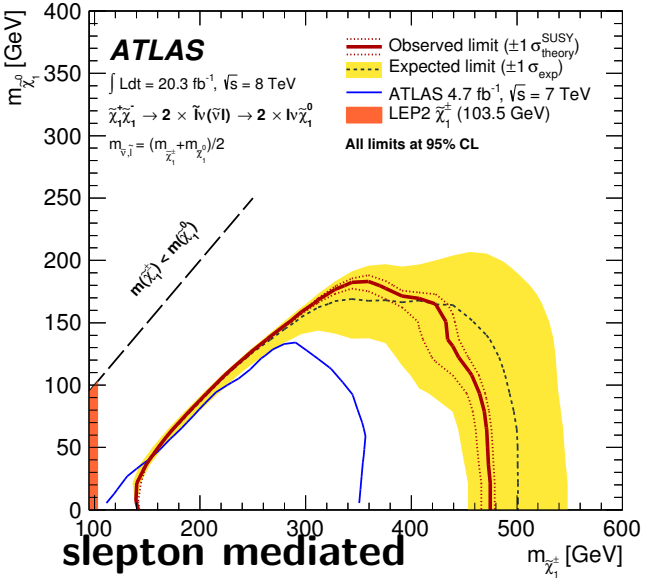
SR-m_{T2}

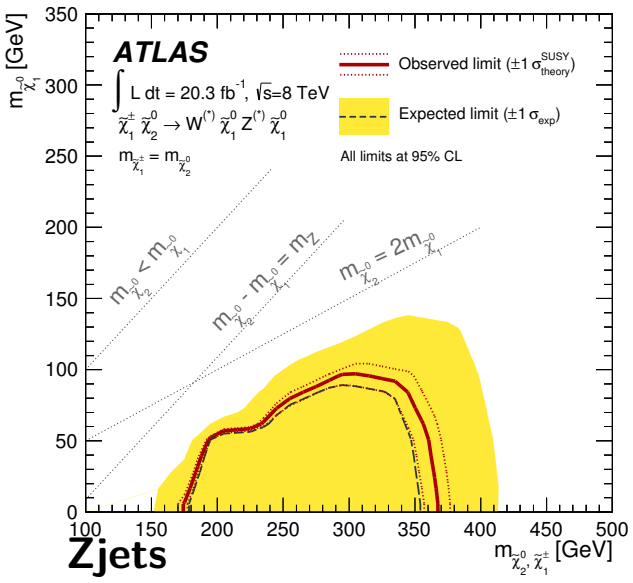


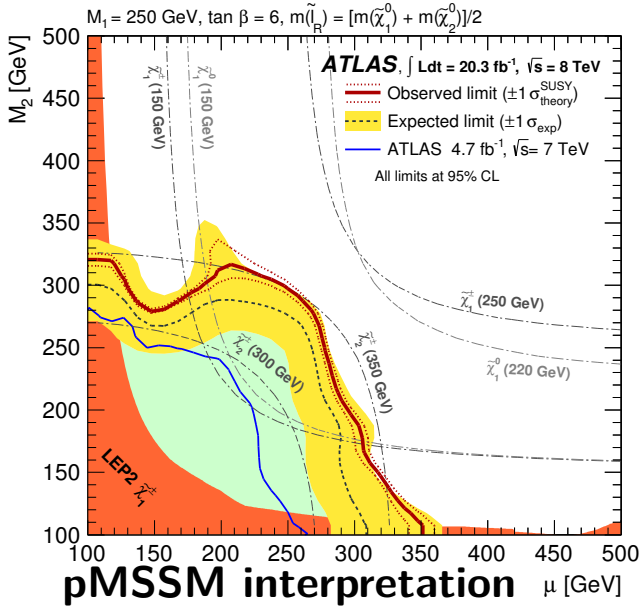
- main backgrounds are $t\bar{t}$, Wt and diboson.
- $t\bar{t}$ and WW m_{T2} *see def* distribution has an upper point at m_W
- 3 main signal regions targeting at slepton-mediated, W-mediated and "Z+jets" decays

$2l + E_T^{miss}(+ii)$



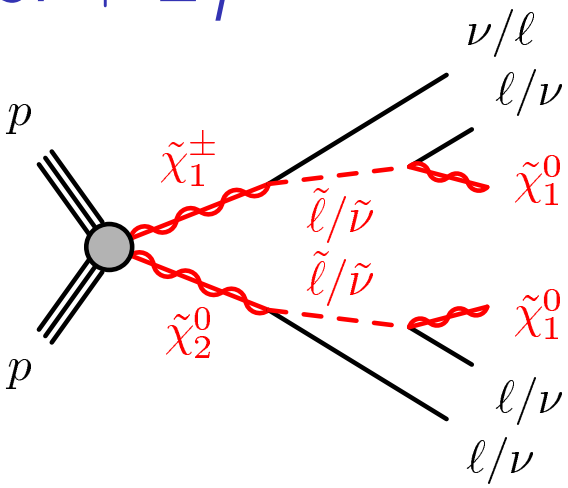


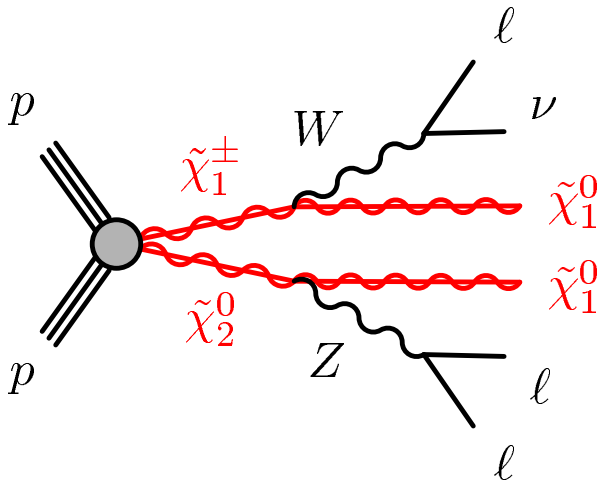


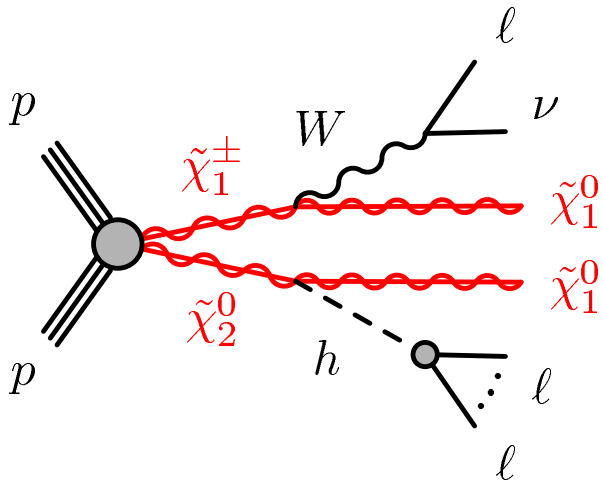


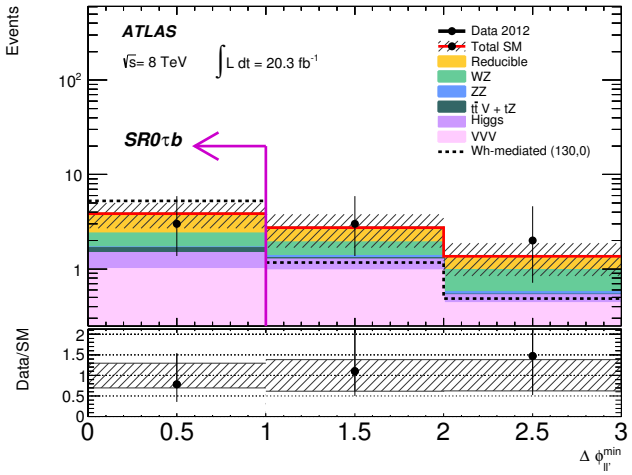
- for a massless LSP:
  - if $\tilde{\chi}_1^+\tilde{\chi}_1^-$ decay via Ws, **[First exclusion]**
    $100 < m_{\tilde{\chi}_1^\pm} < 105$ GeV, $120 < m_{\tilde{\chi}_1^\pm} < 135$ GeV,
    $145 < m_{\tilde{\chi}_1^\pm} < 160$ GeV, ranges are excluded
  - if $\tilde{\chi}_1^+\tilde{\chi}_1^-$ decay via sleptons,
    $140 < m_{\tilde{\chi}_1^\pm} < 465$ GeV range is excluded
  - if $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ decay via WZ,
    $180 < m_{\tilde{\chi}_1^\pm,\tilde{\chi}_2^0} < 355$ GeV range is excluded
  - pMSSM interpretation excludes $m_{\tilde{\chi}_2^\pm} < 300$ GeV

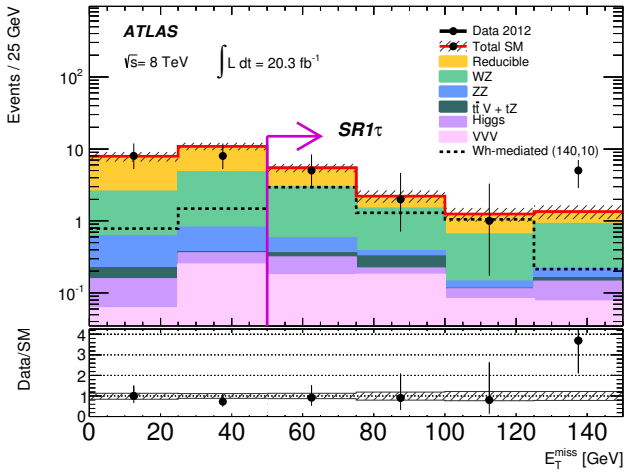
$3l + E_T^{miss}$

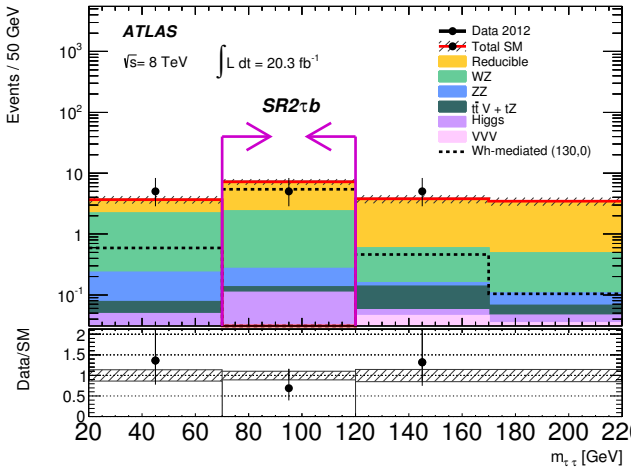








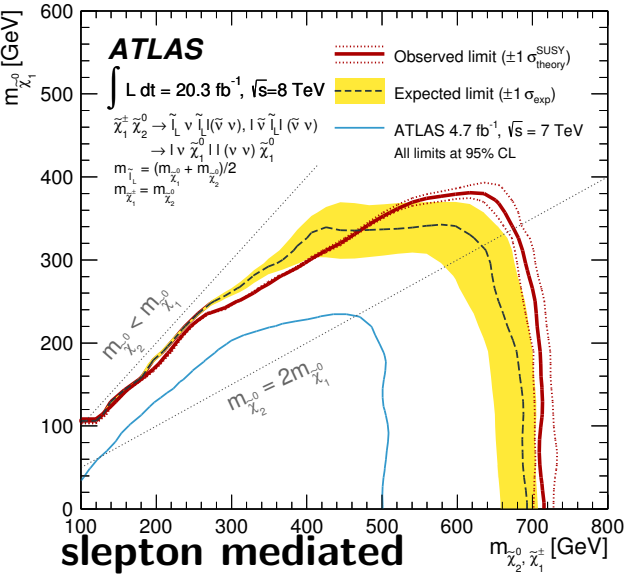


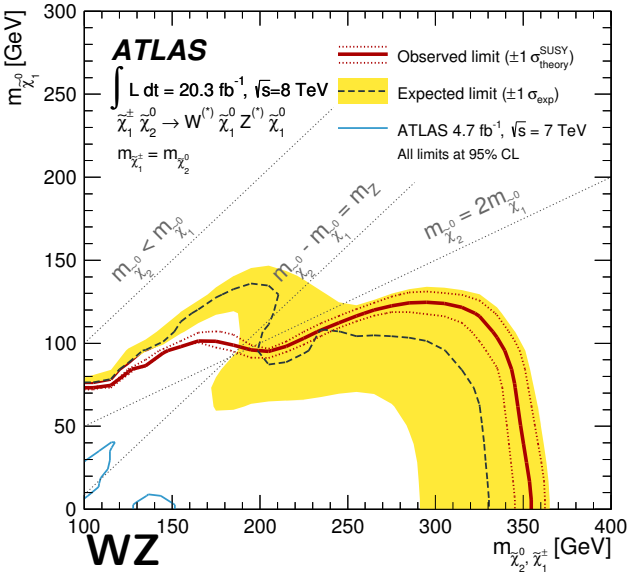


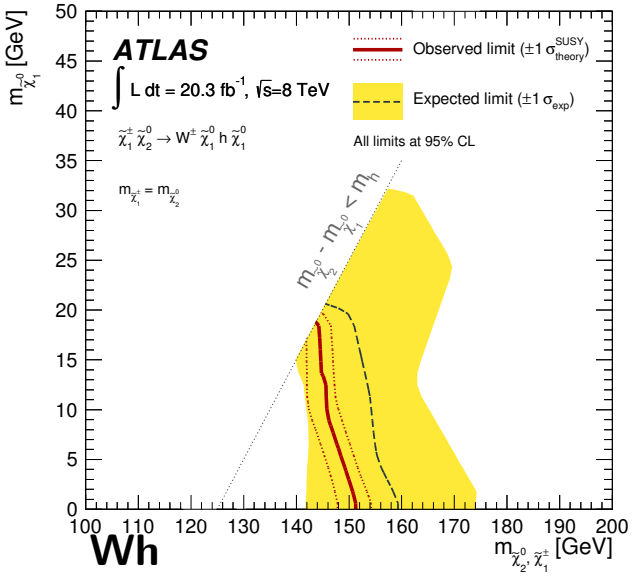
- analysis includes up to 2 hadronic taus
- 5 SRs are defined according to the flavor and charge of the leptons

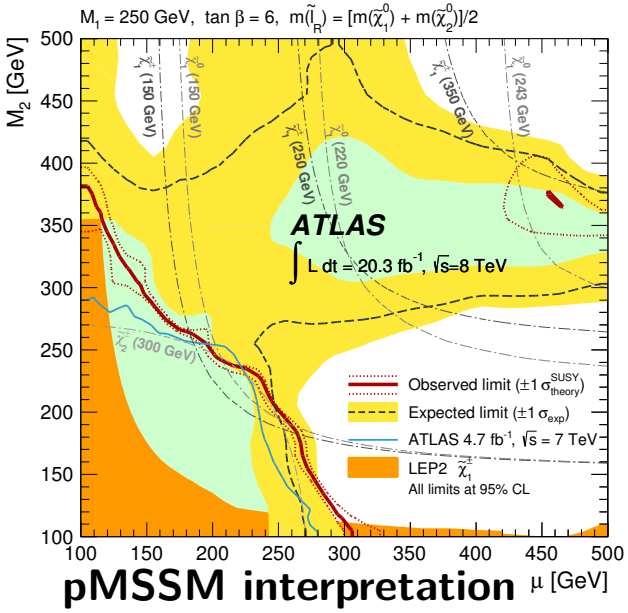
- main backgrounds are diboson, triboson, $t\bar{t}V$, tZ and VH
- SR0τ mainly targeting at slepton mediated and WZ decays
- SR1τ and SR2τ mainly optimized for Wh

$3l + E_T^{miss}$









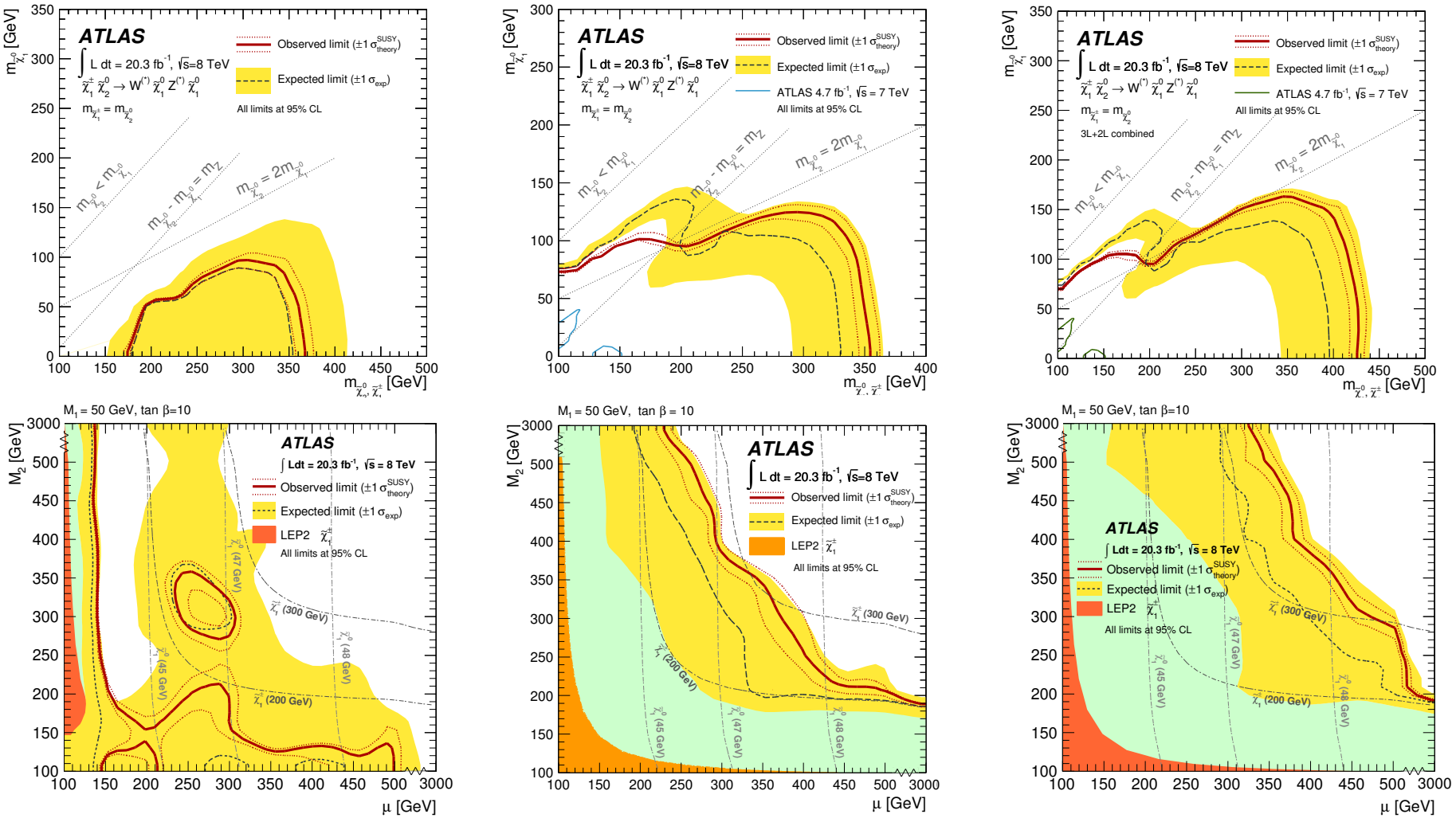
- for a massless LSP:
  - if $\tilde{\chi}_1^+\tilde{\chi}_1^-$ decay via sleptons, $m_{\tilde{\chi}_1^\pm} < 700$ GeV is excluded
  - if $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ decay via WZ, $m_{\tilde{\chi}_1^\pm,\tilde{\chi}_2^0} < 345$ GeV is excluded
  - if $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ decay via Wh, $m_{\tilde{\chi}_1^\pm,\tilde{\chi}_2^0} < 148$ GeV is excluded
  - pMSSM interpretation excludes $m_{\tilde{\chi}_2^\pm} < 300$ GeV

$2l + E_T^{miss}(+jj)$ and $3l + E_T^{miss}$ combined

$2l$ | $3l$ | $2l + 3l$

WZ mediated

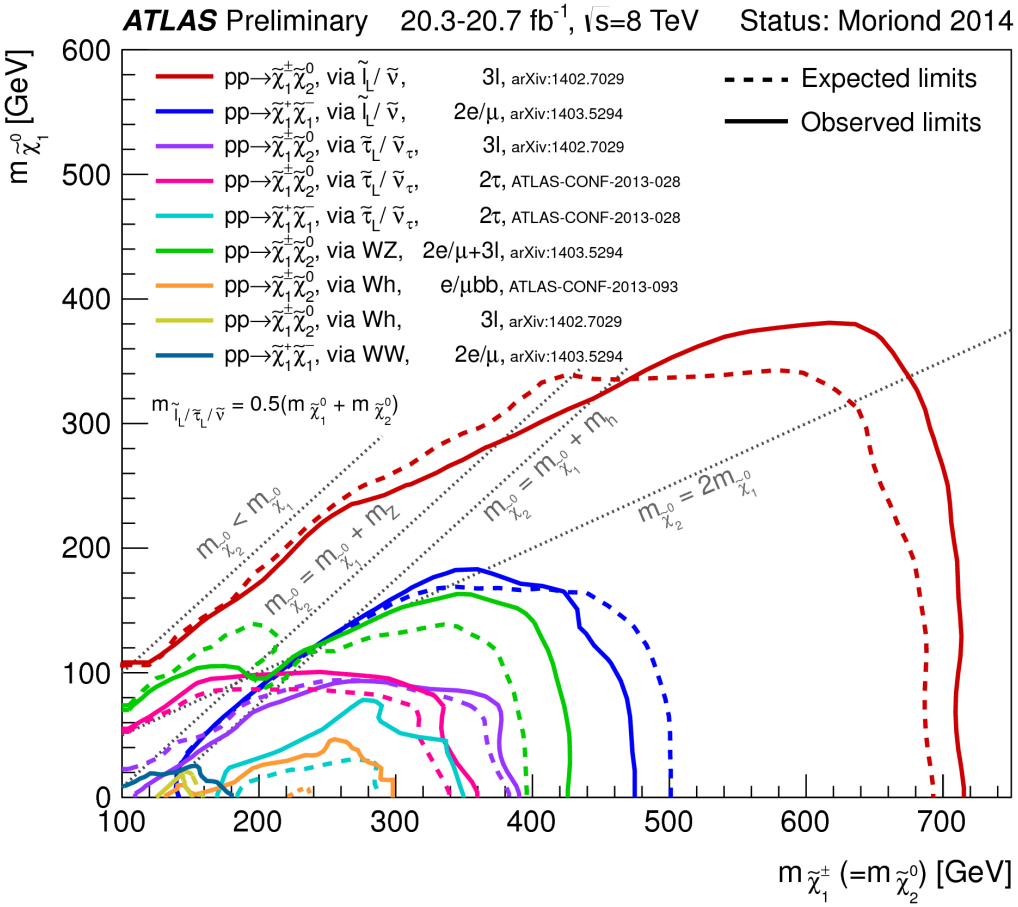
no slepton



- combination significantly improves the exclusion regions
- complementarity between 2L and 3L searches

Conclusion

- ATLAS analyzed 20.3fb^{-1} of 8TeV *pp* collisions recorded in 2012
- No significant excess above the Standard Model has been measured



- Significant limits are set in simplified model as well as pMSSM scenarios
- Complementary exclusion power between analyses

Extras

m_{CT}

m_{CT} without boost-correction:

$$m_{\mathrm{CT}}^2(v_1, v_2) = [E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\mathbf{p}_{\mathrm{T}}(v_1) - \mathbf{p}_{\mathrm{T}}(v_2)]^2 ,$$

where v_1 and v_2 denote the visible particles or particle aggregates. with:

- b_1 and b_2 as aggregates
- lepton (e or μ) is the downstream vector combined with $E_{\mathrm{T}}^{\mathrm{miss}}$ for boost-correction

In $1l + \overline{b}b + E_T^{\mathrm{miss}}$ analysis, m_{CT} is designed to build an endpoint in ttbar:

$$m_{\mathrm{CT}}^{\mathrm{max}} \approx \frac{m_t^2 - m_W^2}{m_t} \approx 135 \ GeV$$

m_{T2}, m_T and $E_T^{\text{miss,rel}}$

m_{T2}, stransverse mass:

$$m_{T2} = \min\left[\max\left(m_T\left(\mathbf{p_T^{l1}}, \mathbf{q_T}\right), m_T\left(\mathbf{p_T^{l2}}, \mathbf{p_T^{miss}} - \mathbf{q_T}\right)\right)\right]$$

where m_T:

$$m_T\left(\mathbf{p_T}, \mathbf{q_T}\right) = \sqrt{2(p_T q_T - \mathbf{p_T} \cdot \mathbf{q_T})}$$

$E_T^{\text{miss,rel}}$:

$$E_{\mathrm{T}}^{\mathrm{miss,rel}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$