LHC constraints on monojet signatures from electroweakino DM and colored -superpartner decays

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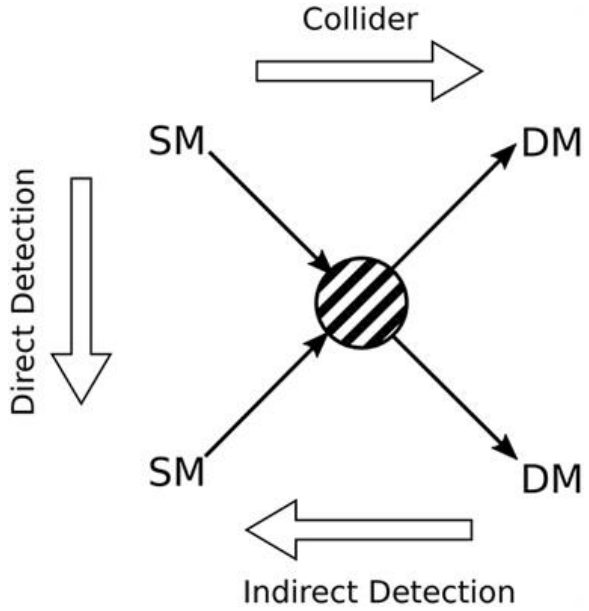
work in progress

in collaboration with Trygve Buanes , Rafał Maselek, Mihoko M. Nojiri and Kazuki Sakurai.

I. Electroweakino DM

- DM existence strongly suggested by cosmological data.
- Weakly interacting massive particle fits well the picture.
- No direct detection and/or collider signal thus far.
- Supersymmetric partners of gauge and Higgs bosons are strong candidates but remain elusive.



Quick summary of chargino-neutralino sector:

$$\mathcal{L}_{\tilde{\chi}} = \overline{\tilde{\chi}_i^-}(\not{p}\delta_{ij} - P_L(U^* X V^\dagger)_{ij} - P_R(V X^\dagger U^T)_{ij})\tilde{\chi}_j^- + \frac{1}{2}\overline{\tilde{\chi}_i^0}(\not{p}\delta_{ij} - P_L(N^* Y N^\dagger)_{ij} - P_R(N Y^\dagger N^T)_{ij})\tilde{\chi}_j^0$$

$$X = \begin{pmatrix} M_2 & \sqrt{2} M_W \sin\beta \\ \sqrt{2} M_W \cos\beta & \mu \end{pmatrix}$$

diagonalised via $\mathbf{M}_{\tilde{\chi}^+} = U^* X V^\dagger$

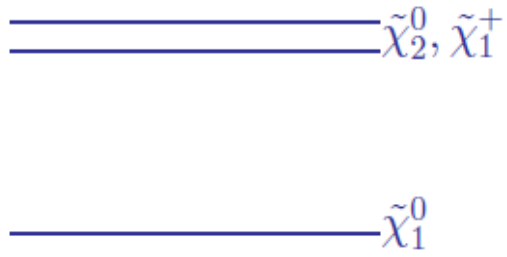
$$Y = \begin{pmatrix} M_1 & 0 & -M_Z c_\beta s_W & M_Z s_\beta s_W \\ 0 & M_2 & M_Z c_\beta c_W & -M_Z s_\beta c_W \\ -M_Z c_\beta s_W & M_Z c_\beta c_W & 0 & -\mu \\ M_Z s_\beta s_W & -M_Z s_\beta c_W & -\mu & 0 \end{pmatrix}$$

diagonalised via $\mathbf{M}_{\tilde{\chi}^0} = N^* Y N^\dagger$

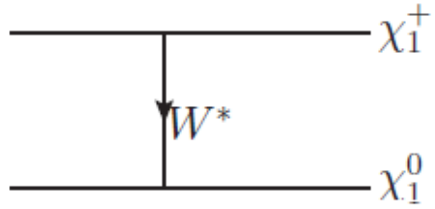
Small mixing expected if there is a hierarchy between M_1, M_2 and μ and/or particles much heavier than the EW scale.

We concentrate in three cases:

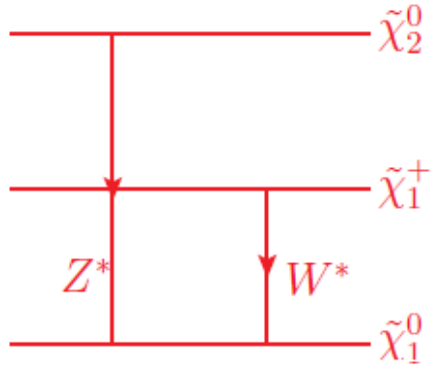
bino-wino: almost mass degenerate winos and bino LSP



wino LSP: $M_2 \ll M_1, \mu$, two quasi-degenerate states: χ_1^0, $\chi_1^\pm$

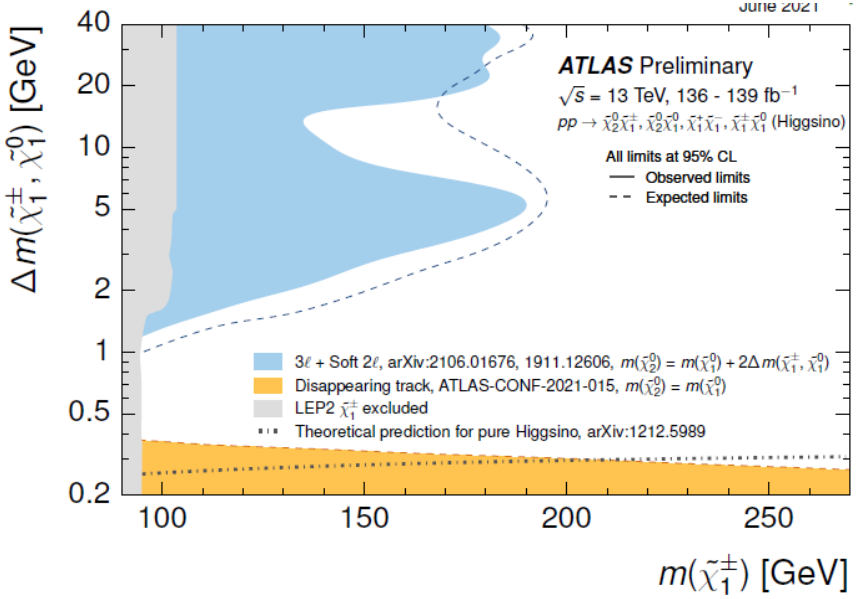


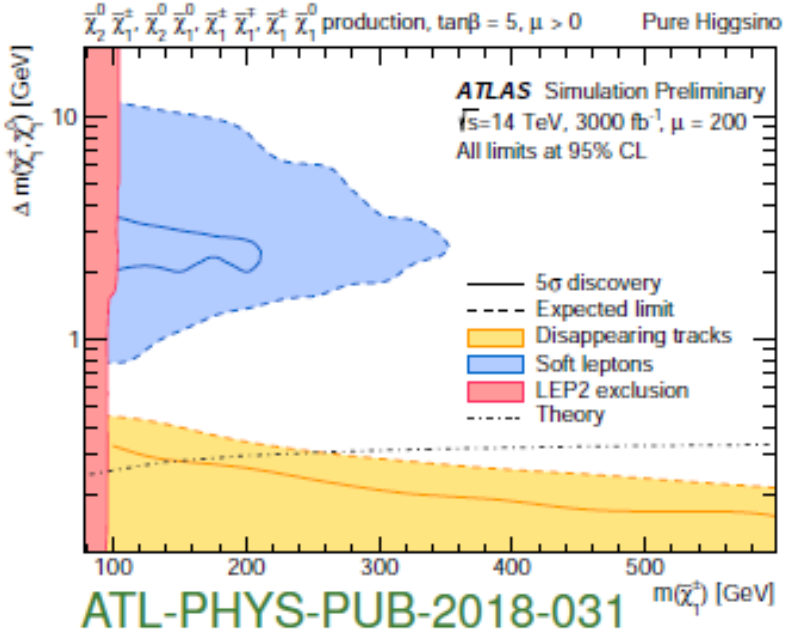
higgsino LSP, $\mu \ll M_1, M_2$, three quasi-degenerate states: $\tilde{\chi}_1^0$, $\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$



mass splittings of order 100–1000 MeV

At the LHC this scenarios has been constrained focusing on:





- Disappearing tracks: for sufficiently small mass gap, heavier states are long-lived.
- Soft leptons: For a mass difference $\gtrsim$1 GeV look for soft decay products.
- Long-standing limit at $\sim$ 100 GeV from LEP

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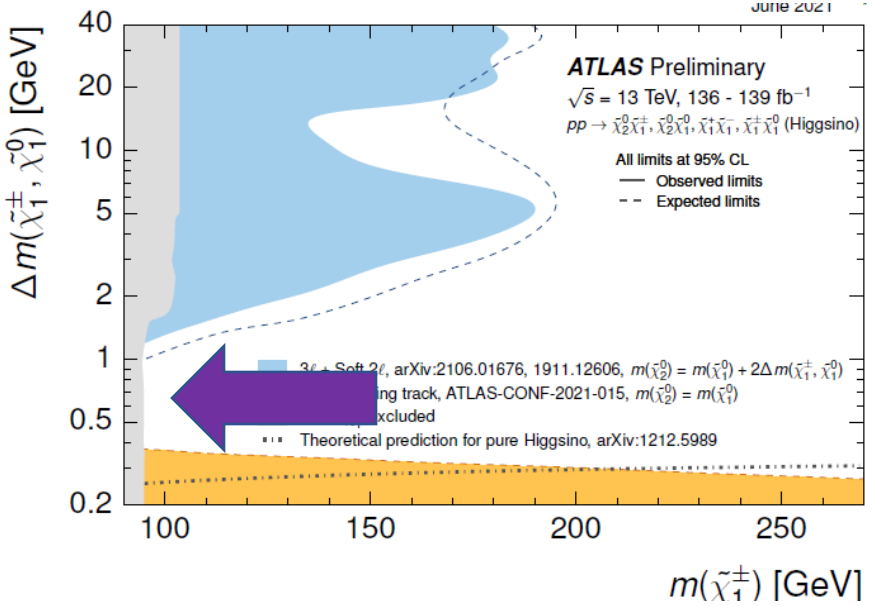

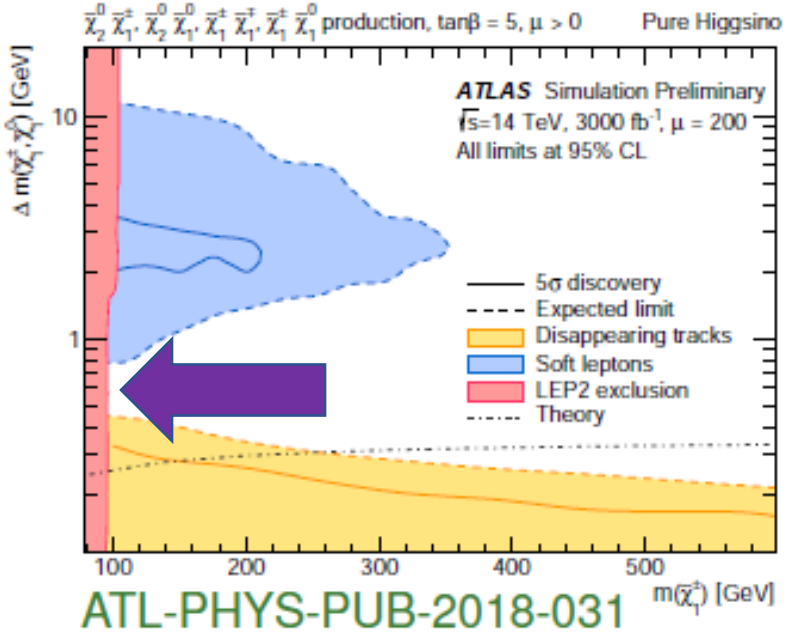

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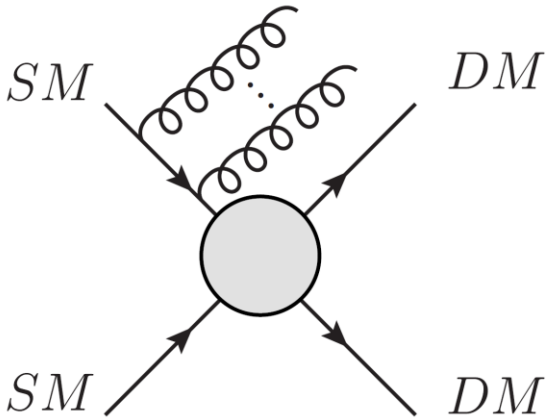
GAP between the two LHC searches. Use Mono/few-jets searches on this region.

Monojet searches from ATLAS and CMS are not sensitive (yet) to *electroweakino* DM. More than one jet emitted is possible, thus *more-than-one-jet* searches may be used also.

- We recast with CheckMATE a general search for squarks and gluinos, arXiv:2010.14293, in total 70 signal regions.
- Basic (preselection) signal requirements:
  - no electrons or muons.
  - 2–6 jets
  - large missing energy > 300 GeV
  - hard leading jet p_T > 200 GeV
  - large effective mass > 800 GeV



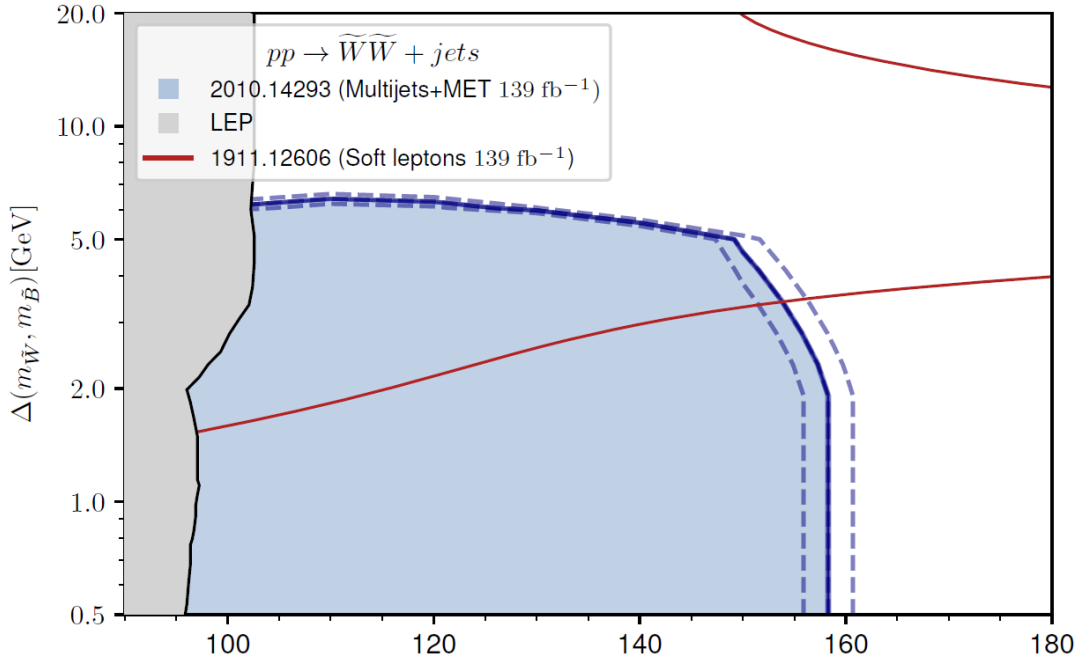
- Some overlap of the final states with “mono”-jet.
- We focus on bins with the largest sensitivity (originally intended for squark pair production):

2–3 jets, $p_{\mathrm{T}}^{\mathrm{jet1}}, p_{\mathrm{T}}^{\mathrm{jet2}} > 250$ GeV
effective mass > 1600 GeV
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}} > 16\sqrt{\mathrm{GeV}}$

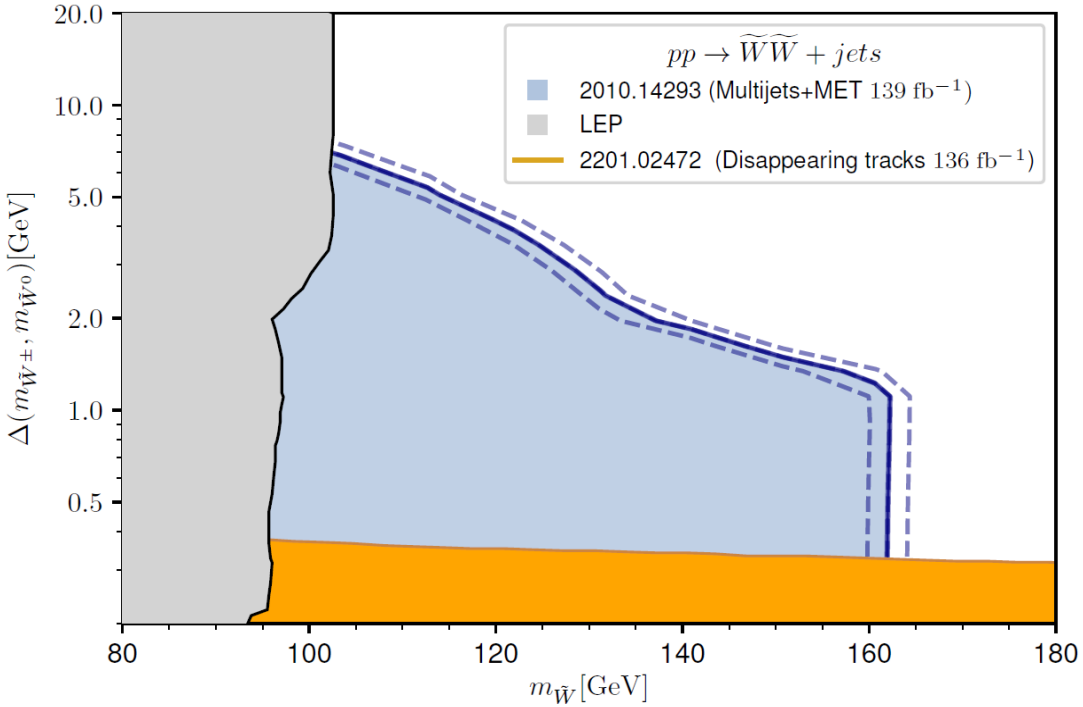
- Multi-bin fit using Histfitter.

Limits over Wino

- bino-wino model
- $\widetilde{W}^{\pm} \to \widetilde{B}^0 W^*, \widetilde{W}^0 \to \widetilde{B}^0 Z^*$
- comparison with ATLAS exclusion (red line)

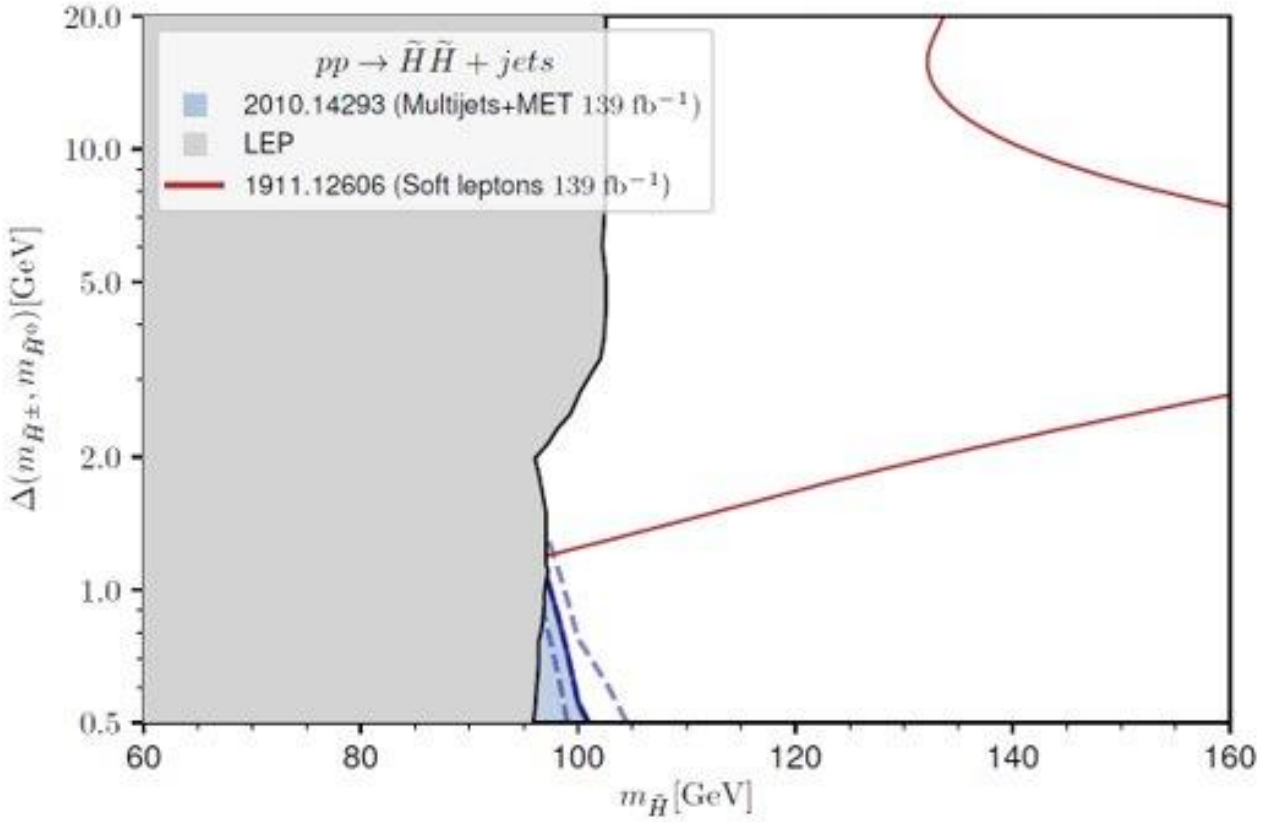


- wino model
- $\widetilde{W}^{\pm} \to \widetilde{W}^0 W^*$
- the new exclusion on top of LEP and long-lived charged wino limits



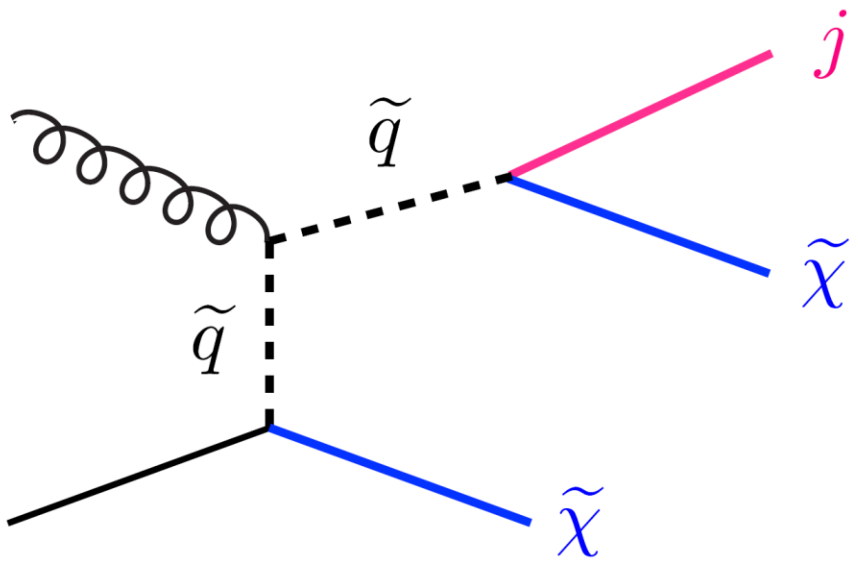
Limits over Higgsino

- higgsino model
- $pp \to \widetilde{H}^{\pm}\widetilde{H}^{0}_{1,2}, \widetilde{H}^{+}\widetilde{H}^{-}, \widetilde{H}^{0}_{1}\widetilde{H}^{0}_{2}$
- $\widetilde{H}^{\pm} \to \widetilde{H}^{0}_{1}W^{*}, \widetilde{H}^{0}_{2} \to \widetilde{H}^{0}_{1}Z^{*}$



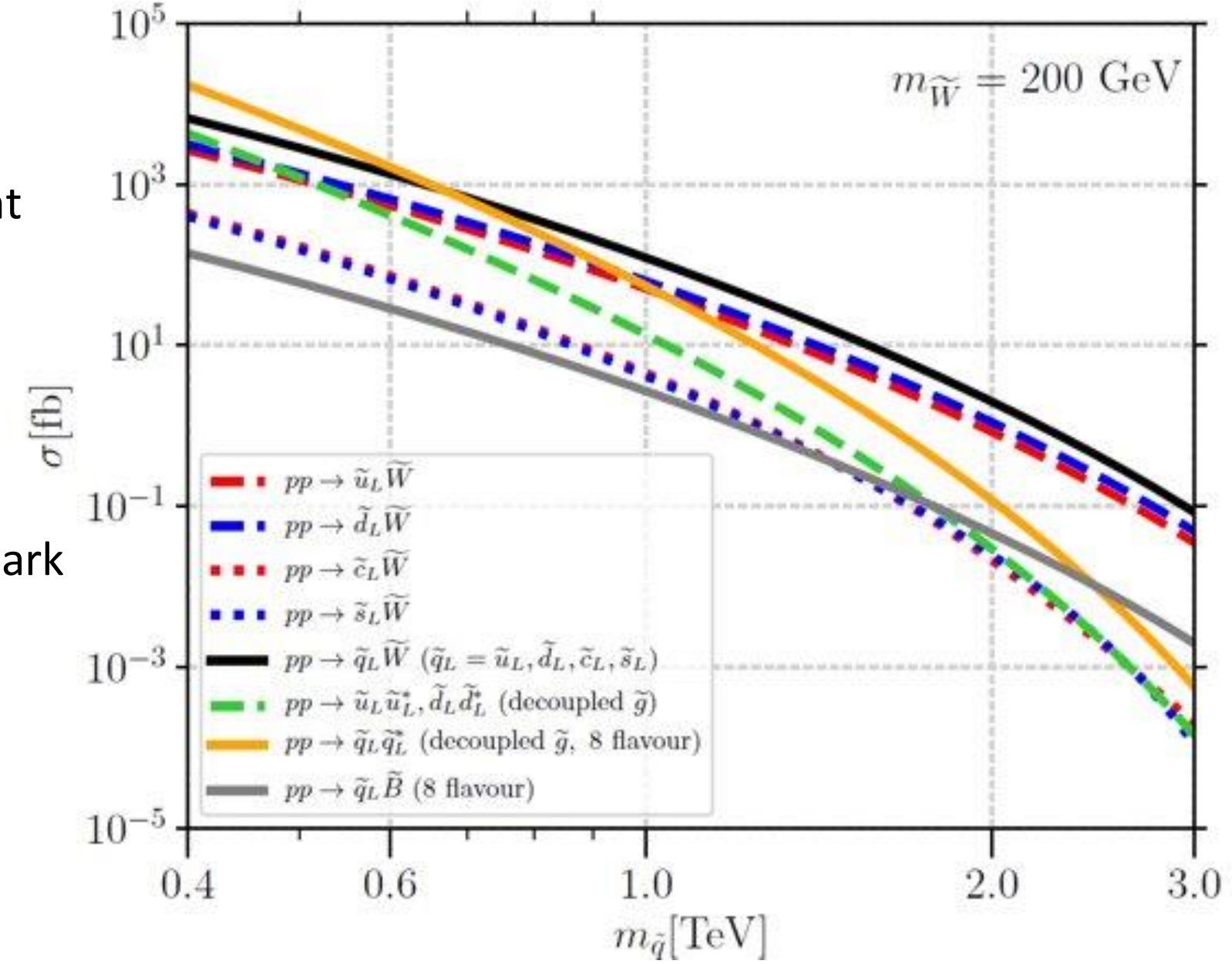
II. Mono-jets from colored particles

- An isolated energetic jet could result from the associated production of squarks together with electroweakinos.
- Specifically sensitive to 1st generation of squarks.
- Not relevant for higgsino-like electroweakinos.



- This signal is generally disregarded in front of strong production of squarks.

- For wino-like neutralino/chargino and squark mass ~ 1 TeV, the cross section is competitive with squark pair production (m_W = 200 GeV)



Improvement of the limit based on the combination of the signals:

- Squark pair production.

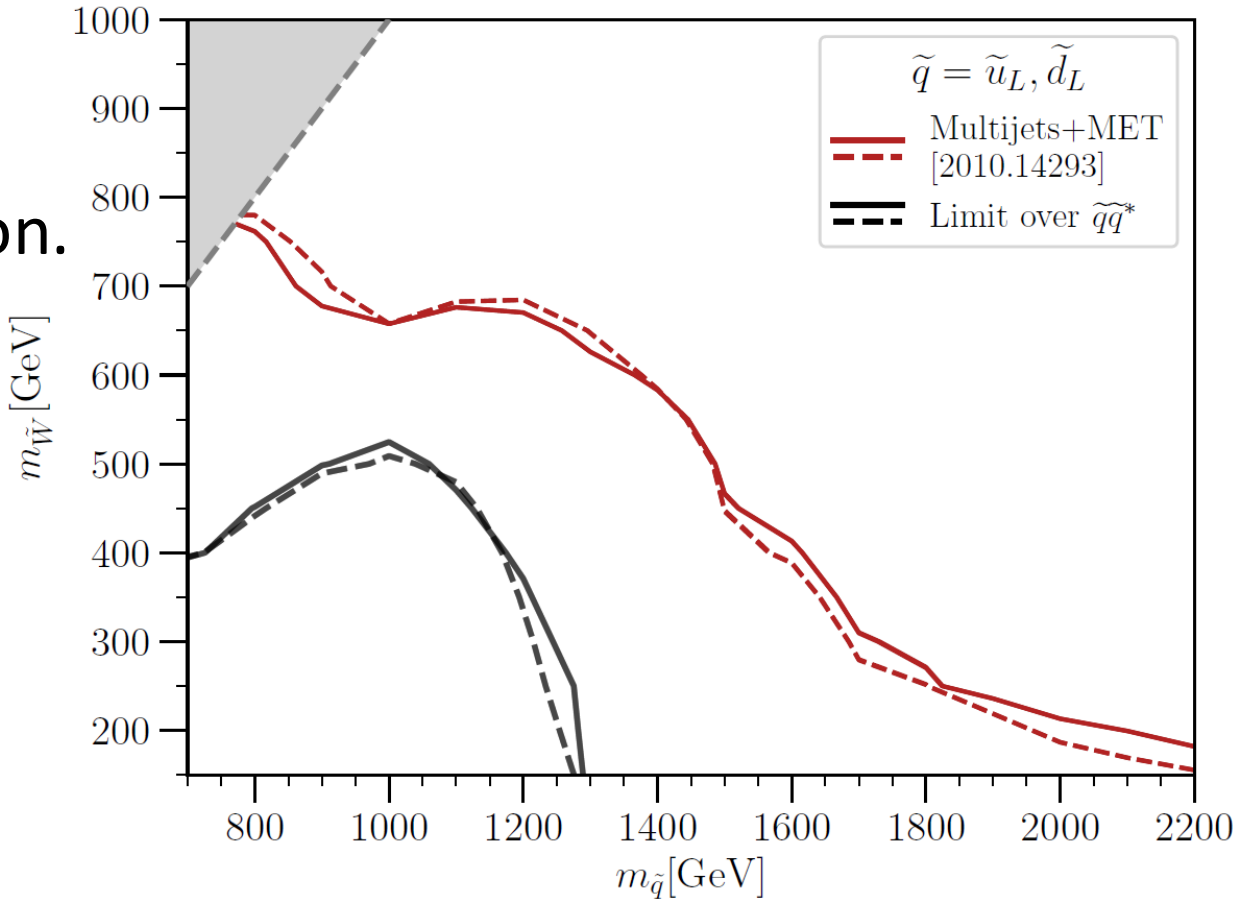
$$pp \rightarrow \widetilde{q}\widetilde{q}$$

- Squark-wino associated production.

$$pp \rightarrow \widetilde{q}_L \widetilde{W}$$

- Wino pair production + ISR jets.

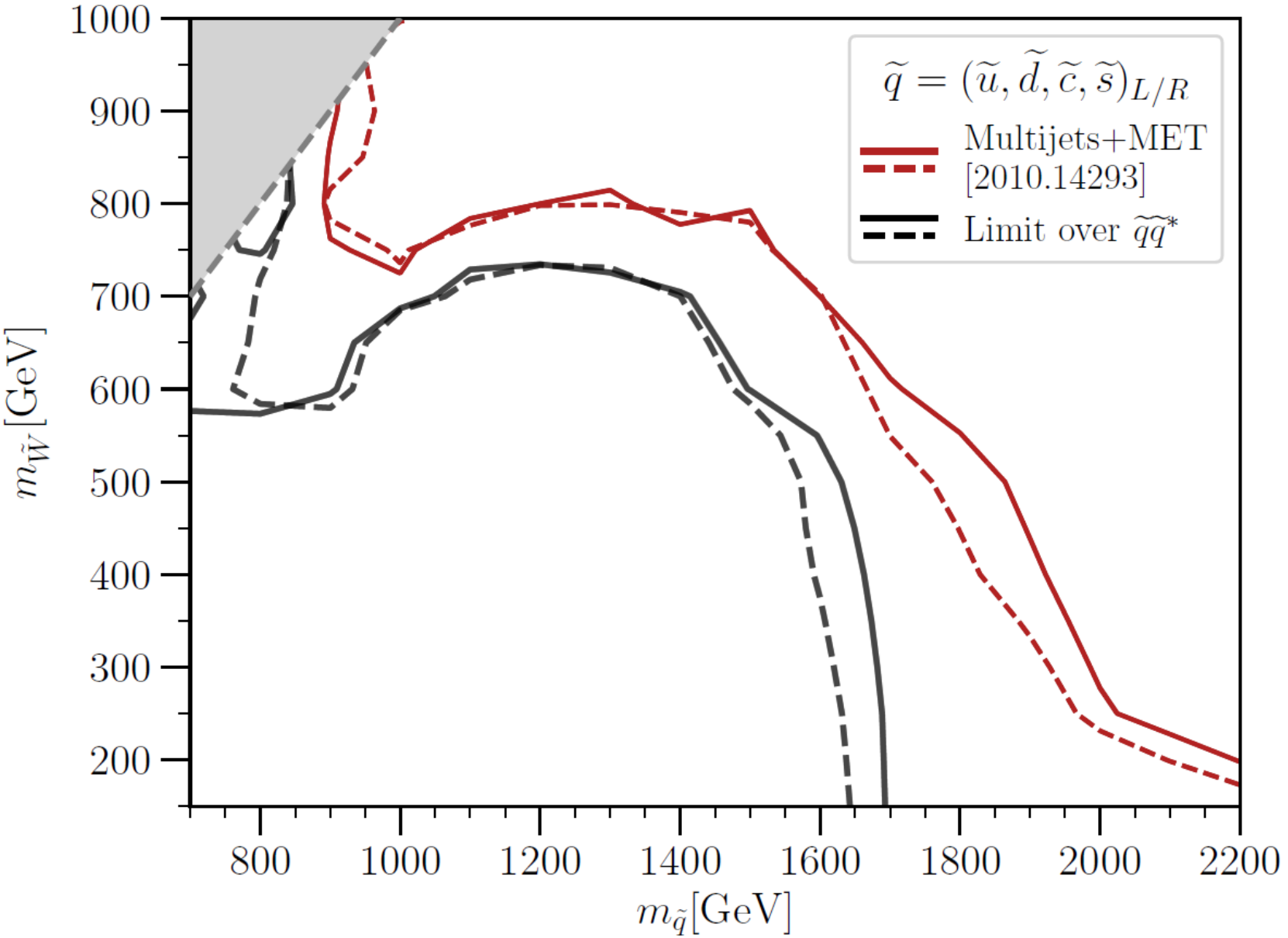
$$pp \rightarrow \widetilde{W}\widetilde{W} + jets$$



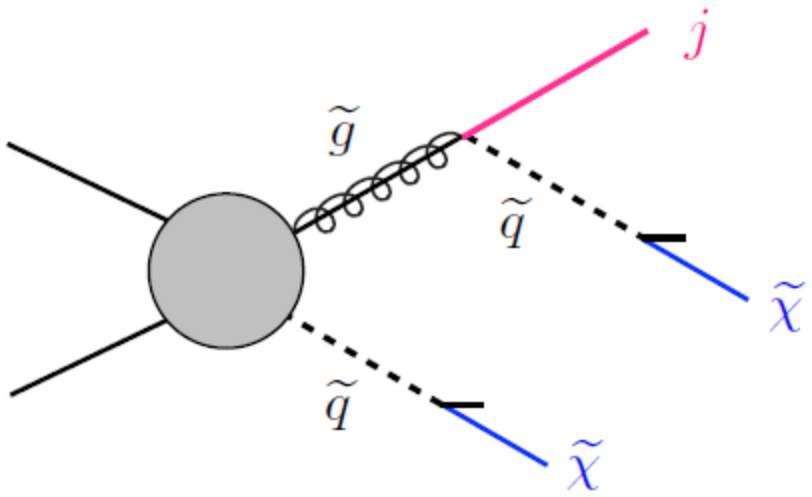
Same analysis as for the electroweakinos.

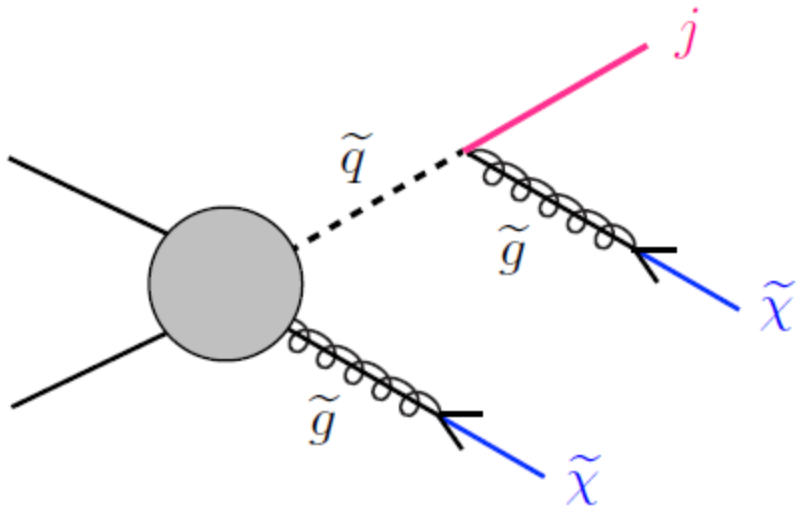
Only 1st generation left squarks light.

Also if squarks 8-fold degenerated.



If Squark/gluino is degenerate with chargino/neutralino (coannihilation!) we have monojets from squark-gluino associated production.





Best limit from Mono-jet search.

Case $m_{\tilde{g}} > m_{\tilde{q}}$:

$pp \to \tilde{g}\tilde{q},\ \ \tilde{g} \to q\tilde{q}$

$pp \to \tilde{g}\tilde{g},\ \ \tilde{g}\tilde{g} \to (q\tilde{q})(q\tilde{q})$

$pp \to \tilde{q}\tilde{q} + \text{jets}$

Case $m_{\tilde{q}} > m_{\tilde{g}}$:

$pp \to \tilde{g}\tilde{q},\ \ \tilde{q} \to q\tilde{g}$

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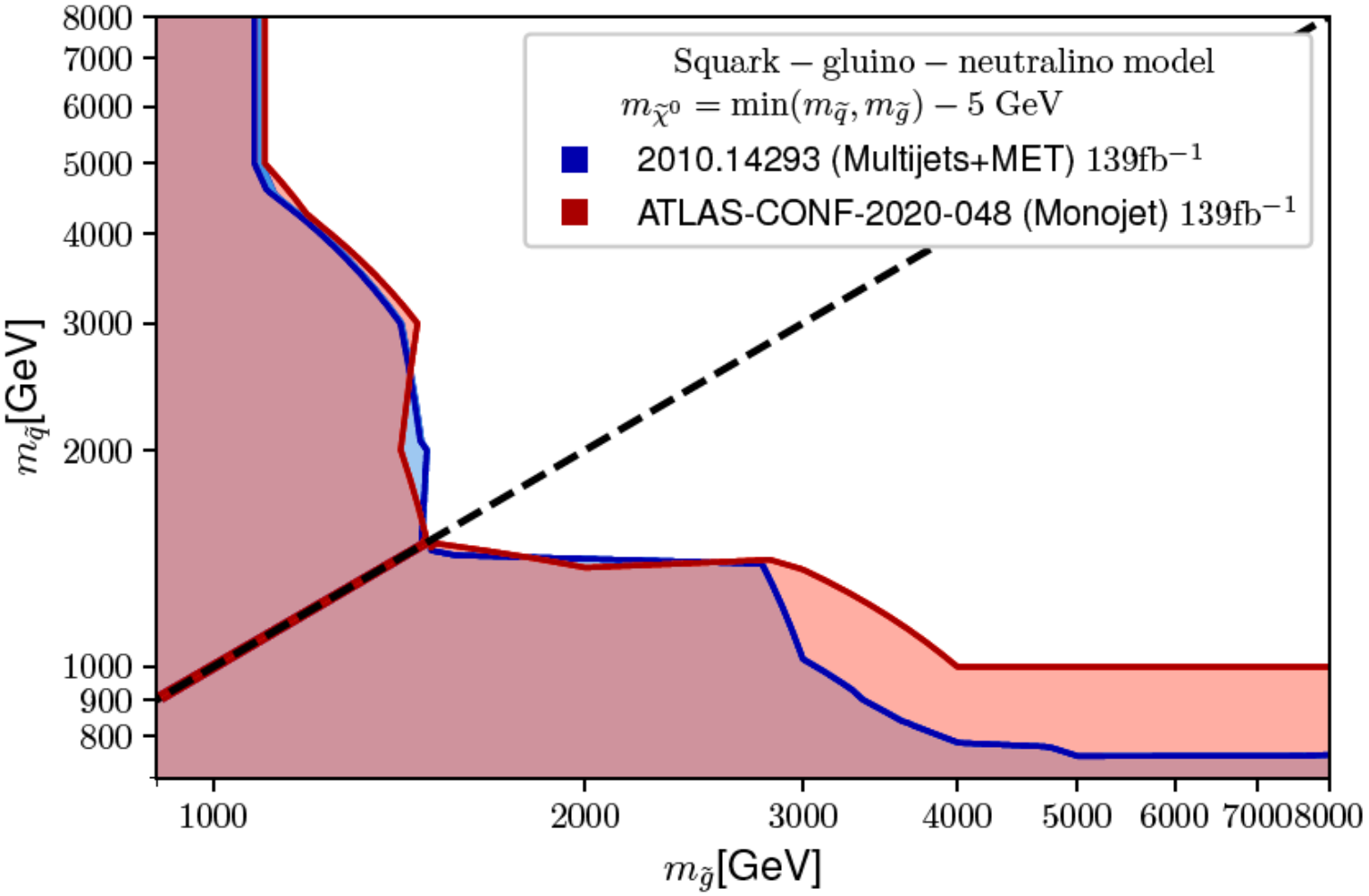
$pp \to \tilde{g}\tilde{g} + \text{jets}$



Summary

- Initial state radiation can give a handle on challenging bits of LSP parameter space.
- Multijet+MET search designed for squarks outperforms Monojet search for direct production of electroweakinos.
- The new constraints close the gap for (model independent) constraints over wino production.
- Monojet signatures originated form the decay of colored heavy particles are competitive with usual squark searches at current excluded masses.
- Wino-squark associated production is important for model dependent exclusion of squarks.
- Bino-squark associated production could be important for higher squark masses.