Search for Supersymmetry at a 100 TeV (and 27 TeV) Future Circular Collider

Anadi Canepa

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Strategy

- **Targeted and significant effort to build a global vision for high energy particle physics**
- **Comprehensive documentation on proposed colliders submitted in preparation for the Granada Symposium**

Collider	$\sqrt{s}$ (TeV)	No. Det.	Pile Up	Luminosity (ab^{-1})	Start	Duration (years)
HE-LHC	27	2	800	15	~2050	20
FCC-hh	100	2	1000	30	~2060	25

Reach of HL-LHC in Cervelli's talk

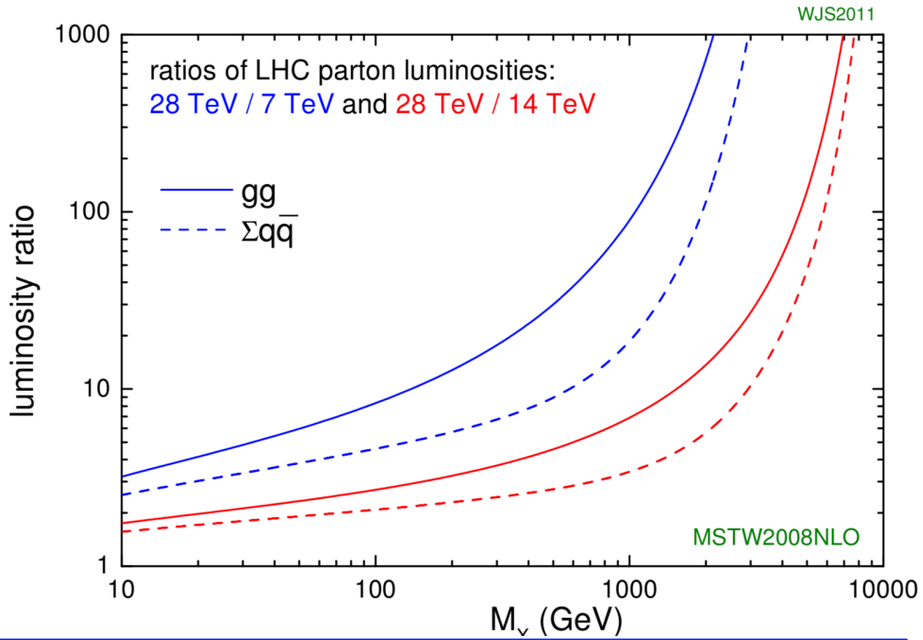
- **Searches carried out using different approaches (full analyses based on parameterized simulation, extrapolation of LHC and HL-LHC analyses, scaling of results using partonic distributions)**
  - **assumptions on background composition and yields driven by knowledge acquired in analyzing LHC data, but impact of pile up and rare process may require further investigation**
  - **at the same time, detector layout, reconstruction and selection algorithms expected to be optimized in the next decades ⇛ most likely, conservative projections presented today**

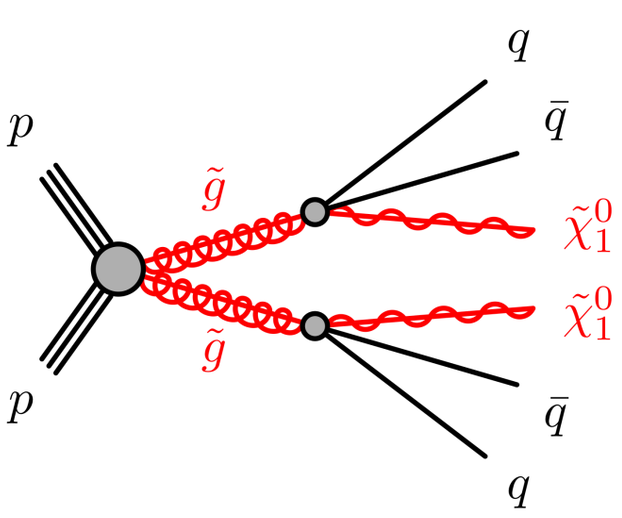
Outline

- Supersymmetry might manifest in different ways at hadron colliders
- Simplified models adopted in setting the search strategy and illustrating the reach for individual processes
- Focus on representative benchmark processes at pp machines
  - search for gluinos (RPC decays; compressed spectra)
  - search for scalar top quarks (RPC decays; co-annhilation scenarios)
  - search for electroweakinos (RPC decays, co-annihilation scenarios)
  - search for scalar tau leptons
- *Additional studies in references listed in back-up slides*

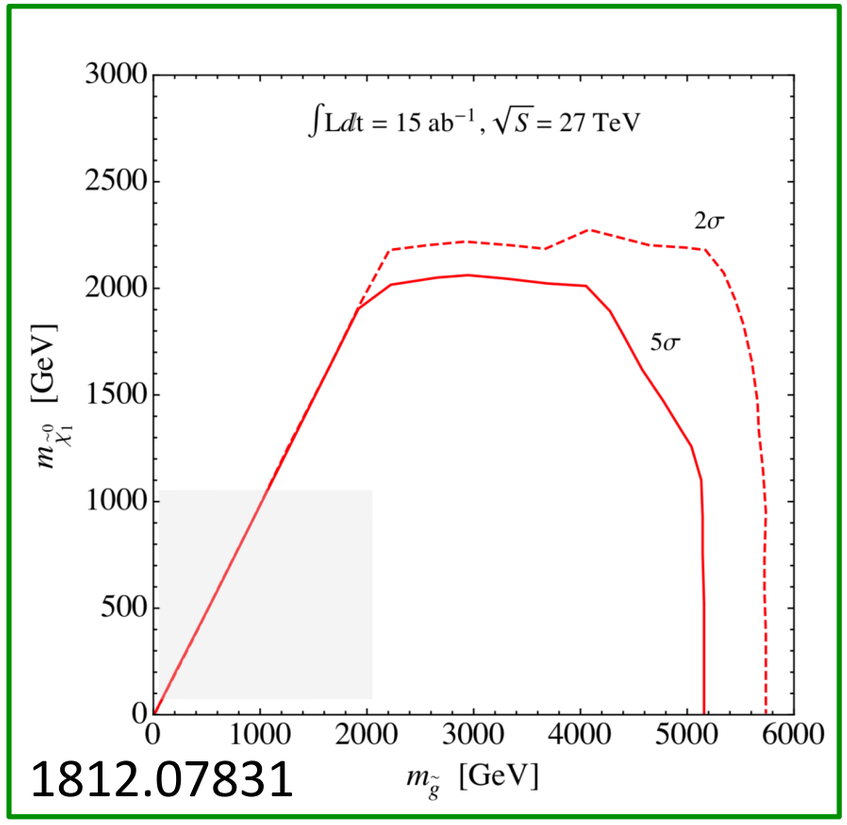
Searches for gluinos (1)

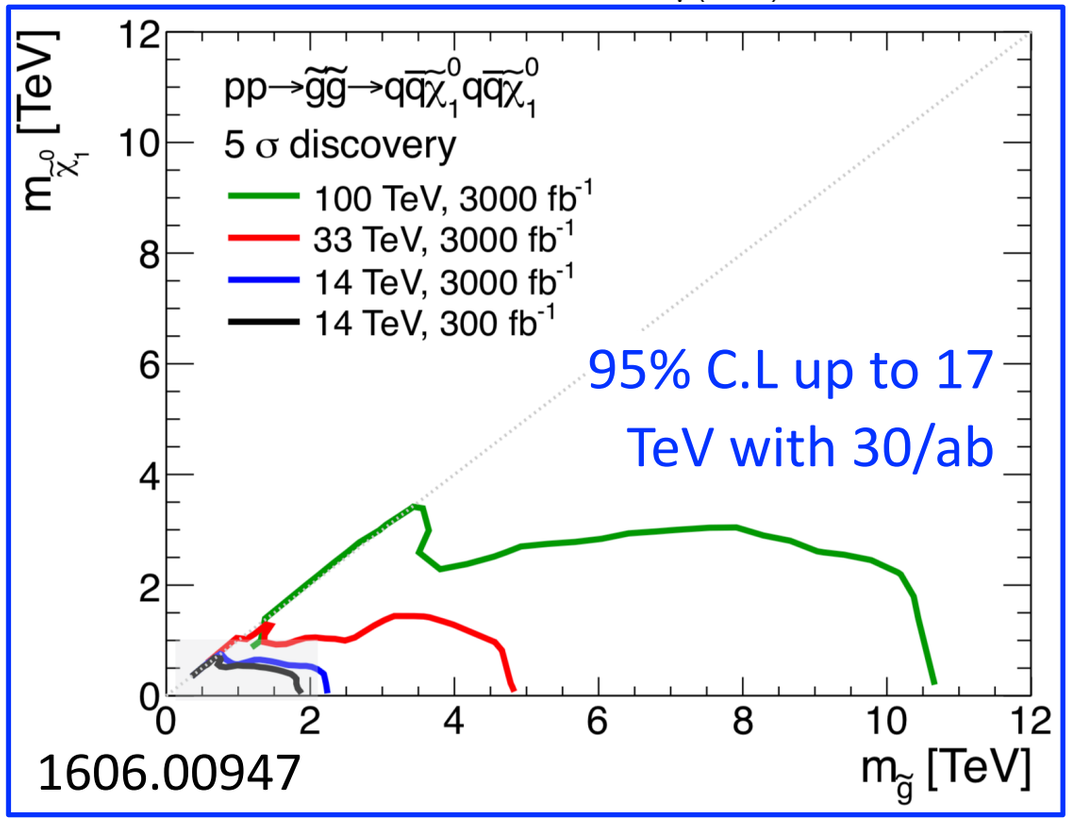
- Cross-sections for strongly produced (and ~heavy) SUSY particles expected to increase significantly with $\sqrt{s}$
  - At 2 TeV, σ(FCC-hh) ~ 4000 x σ(LHC)
    (LHC SUSY Cross Section Working Group, 1407.5066)
- Searches for un-compressed spectra benefitting greatly from presence of large ETmiss, HT, and highly boosted SM objects, especially at FCC-hh





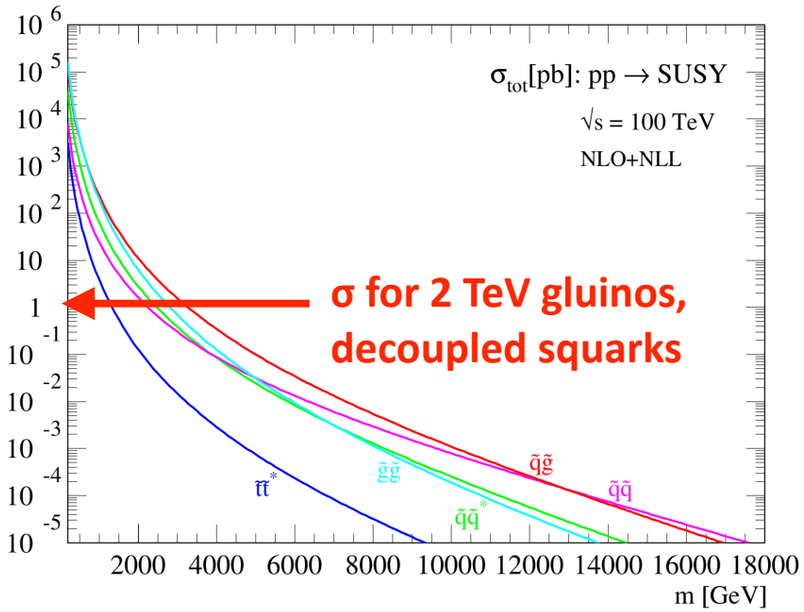
- *Similar sensitivity to scenarios when gluinos decays via scalar top quarks*

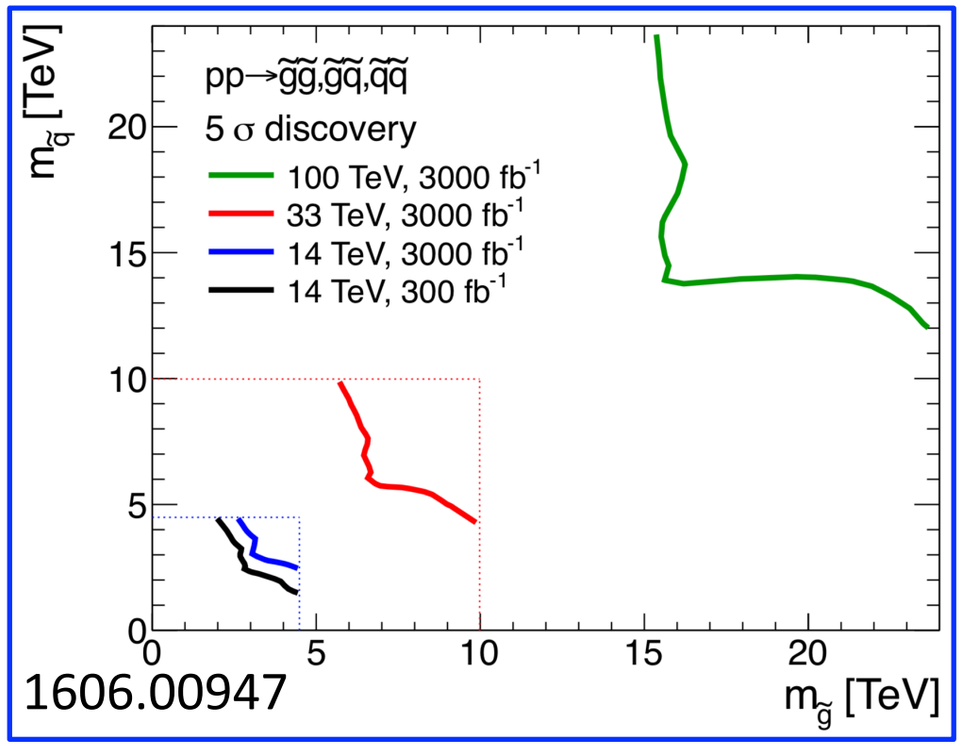




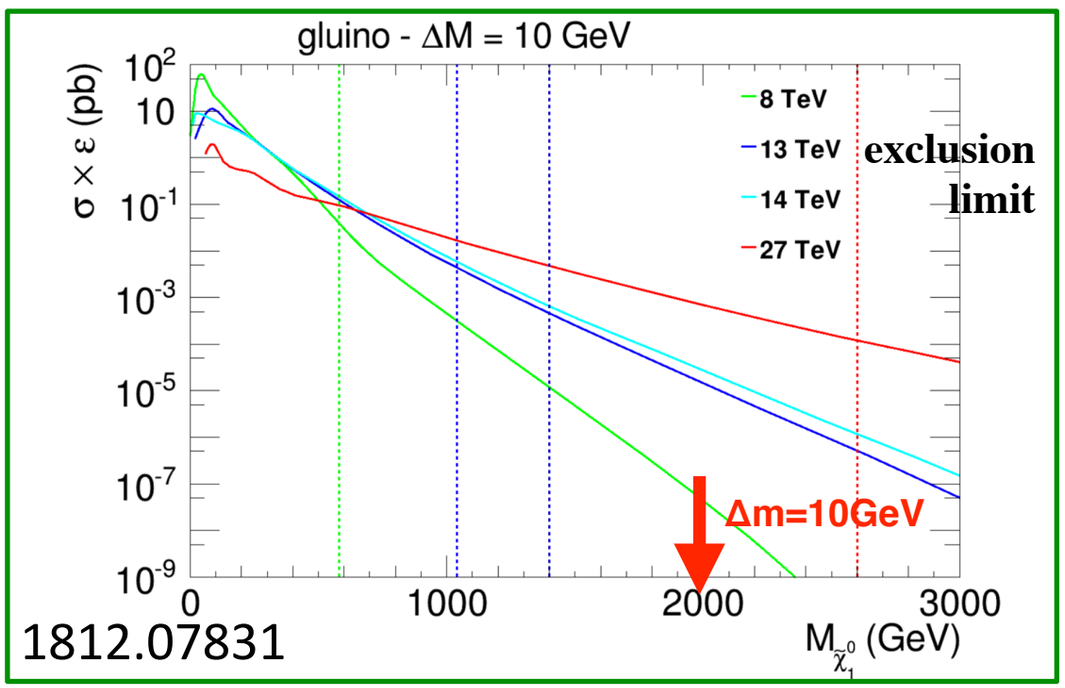
Searches for gluinos (2)

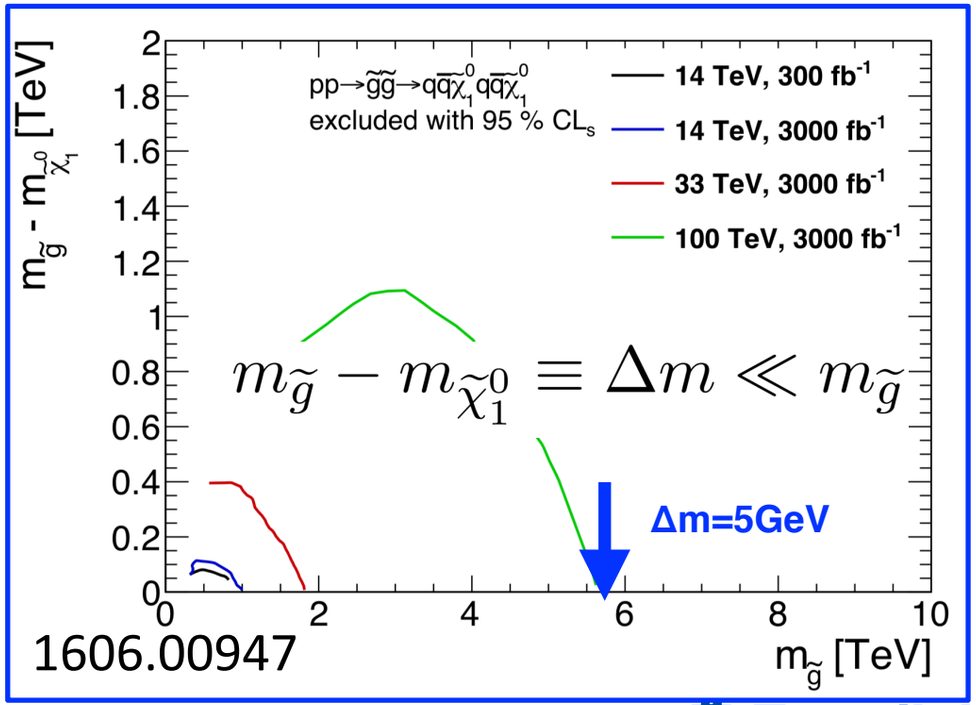
- **Further extension of sensitivity achieved for scenarios with non-decoupled squarks**
  - **constructive interference**



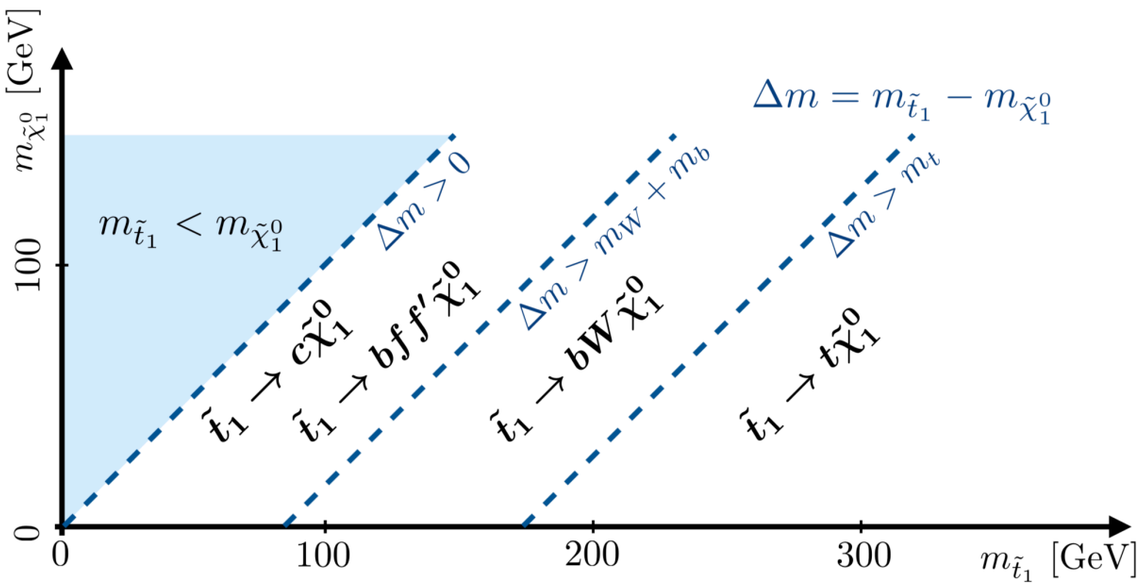


- **Monojet-like searches, powerful probes for scenarios with compressed spectra**

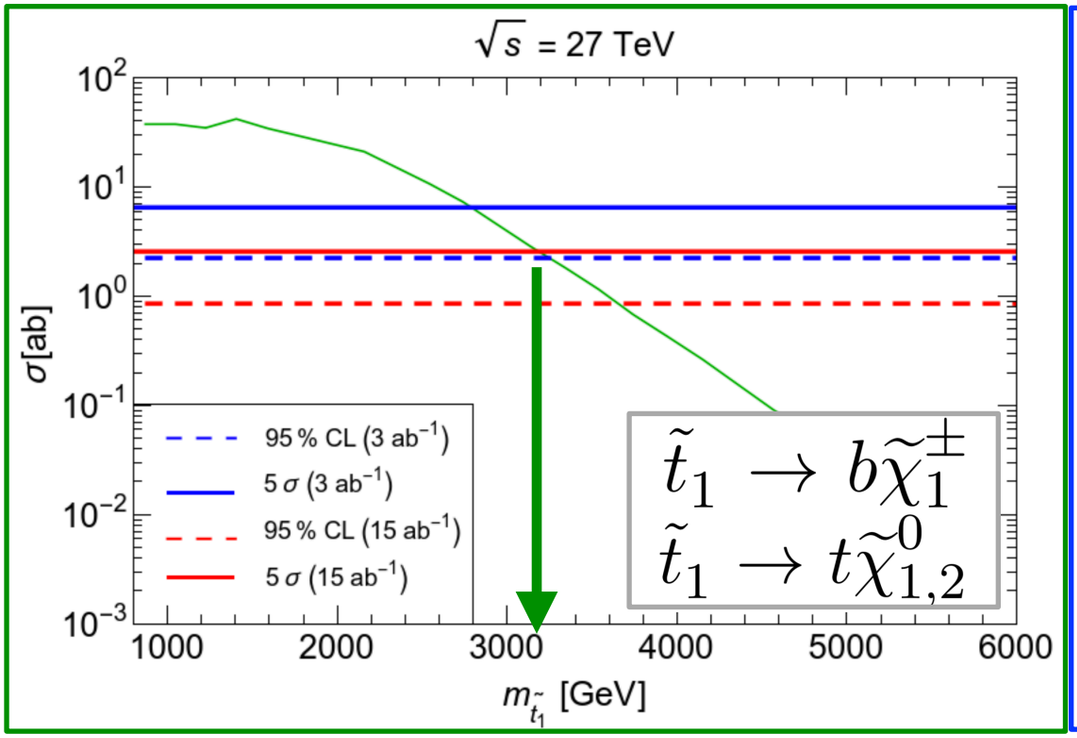




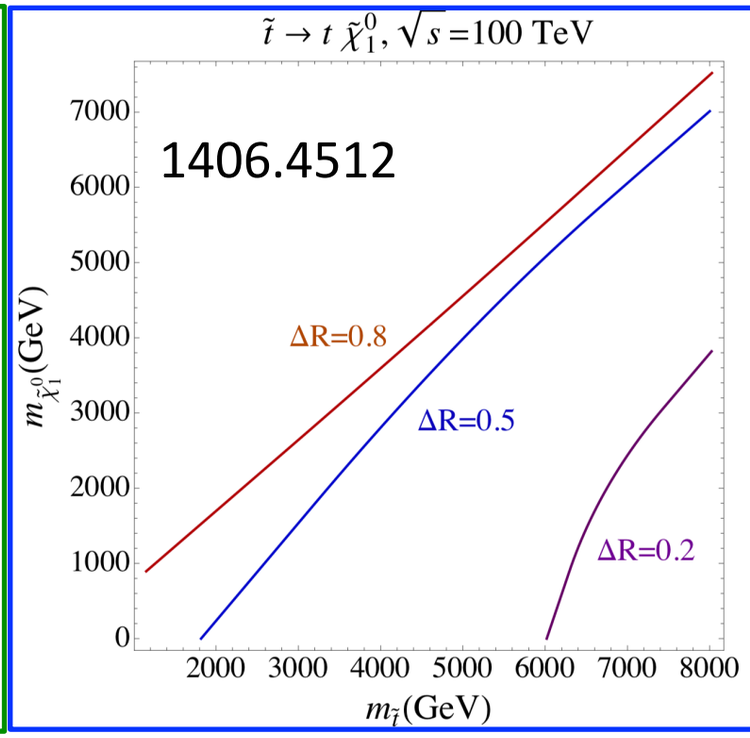
Searches for scalar top quarks



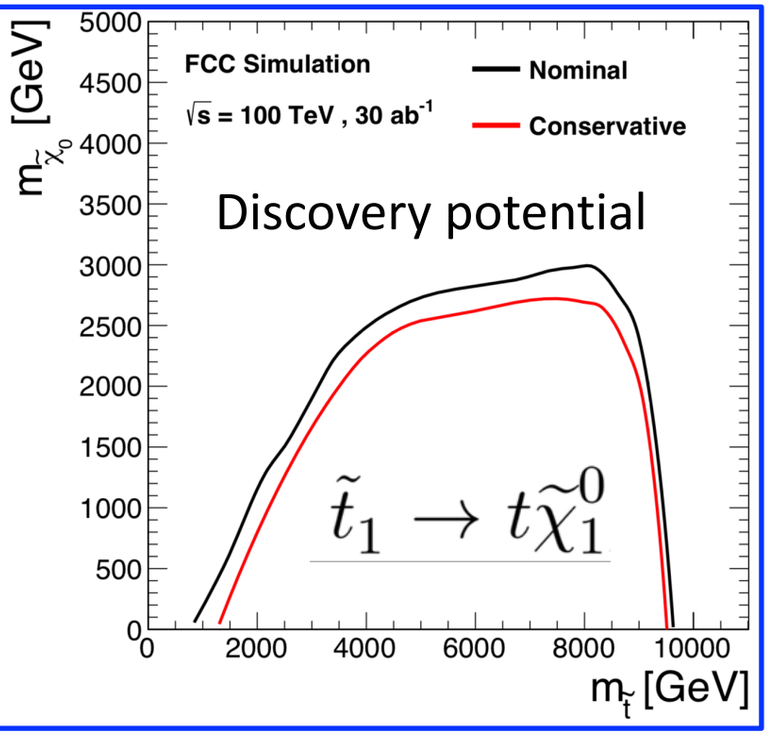
- Smaller increase of cross-section with respect to gluinos pair production
  - At 1 TeV, σ(FCC-hh) ~ 20 x σ(LHC) / 200 x σ(LHC)
- Complex search where the sensitivity is highly dependent on the mass splitting, scale of the SUSY EWK sector, stop helicity



1812.07831, 1708.09054



$\Delta R \sim 1/\gamma_t \sim m_t/p_T^t$



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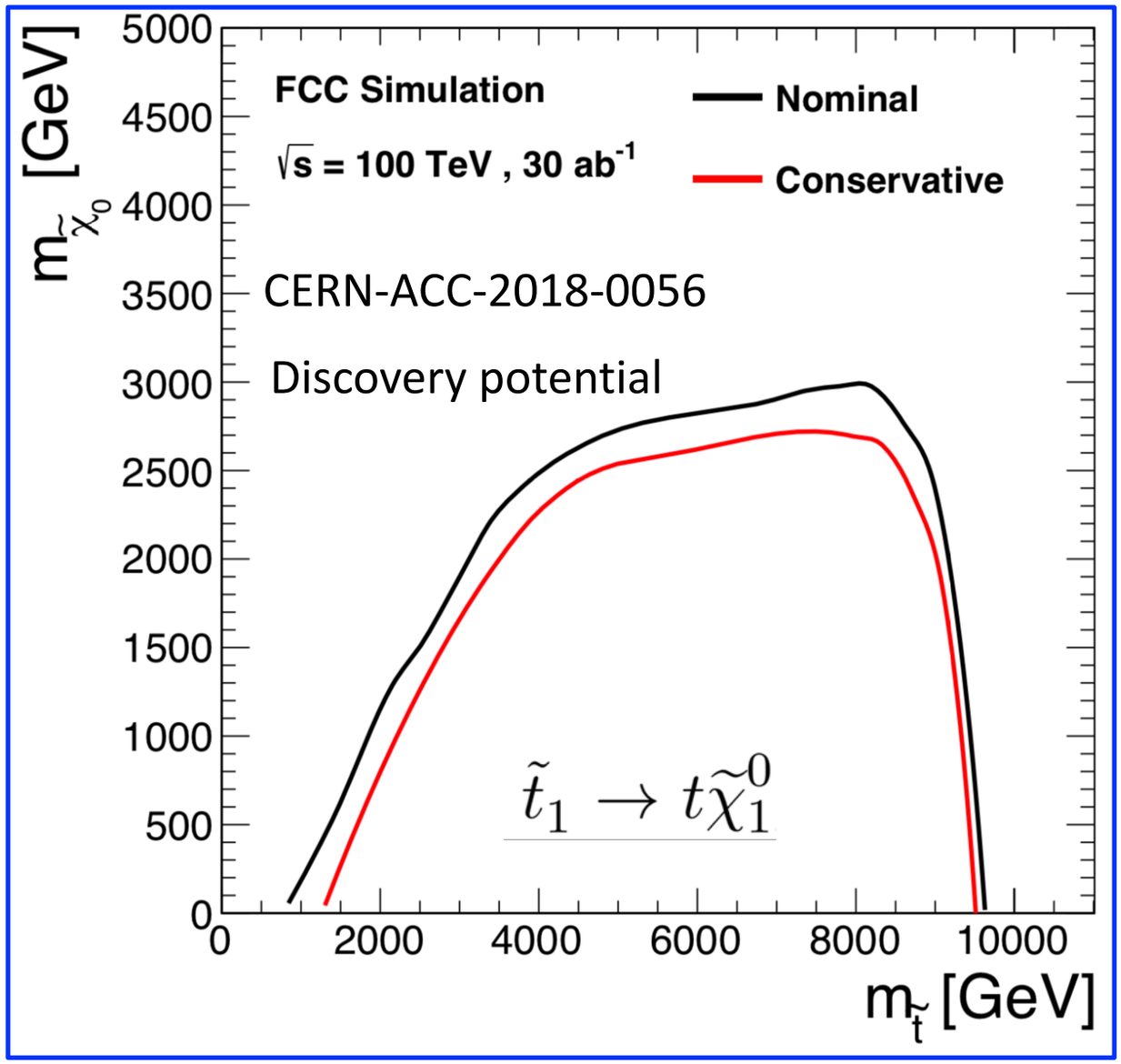
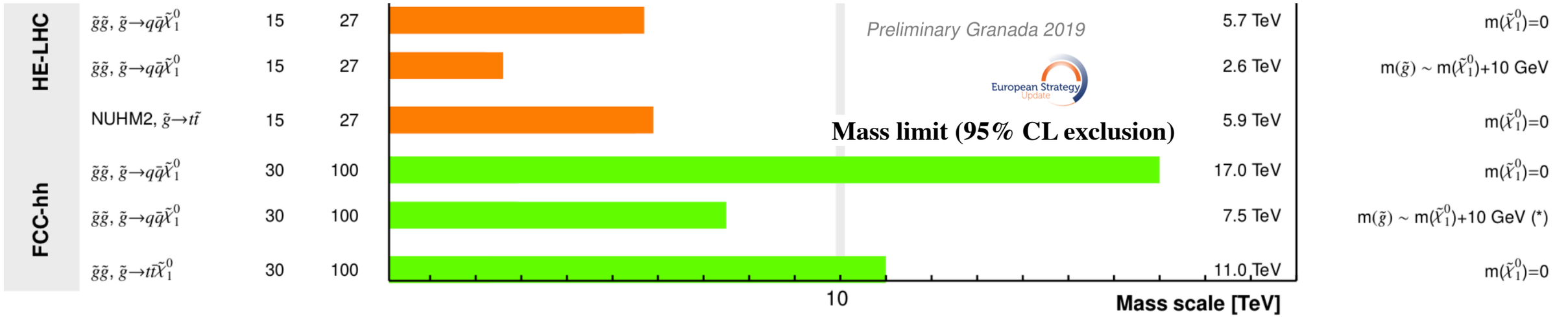
Searches for scalar top quarks

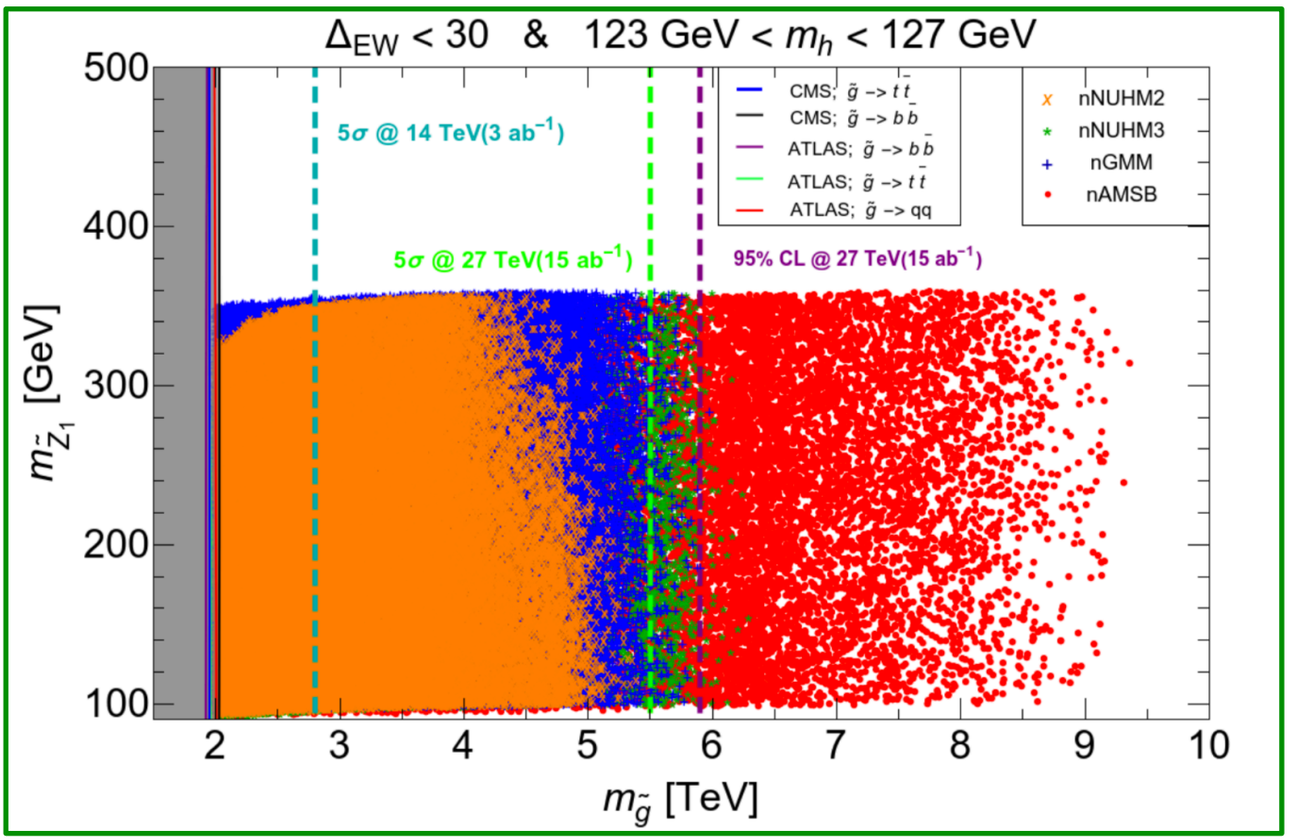
- ***Compressed region probed with mono-jet and low pT momentum analyses***
- ***Extrapolations of Run-2 searches using 'ColliderReachTool'***
  - ***HE-LHC, 3 TeV***
  - ***FCC-hh, 7.5 TeV***

for Δm=2-10 GeV



Confronting Natural SUSY (1)





$$\frac{m_Z^2}{2} = \frac{m_{H_d}^2 + \Sigma_d^d - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2 \simeq -m_{H_u}^2 - \Sigma_u^u(\tilde{t}_{1,2}) - \mu^2 \qquad \Delta_{EW} \equiv max_i \left|C_i\right| / (m_Z^2/2)$$

1808.04844

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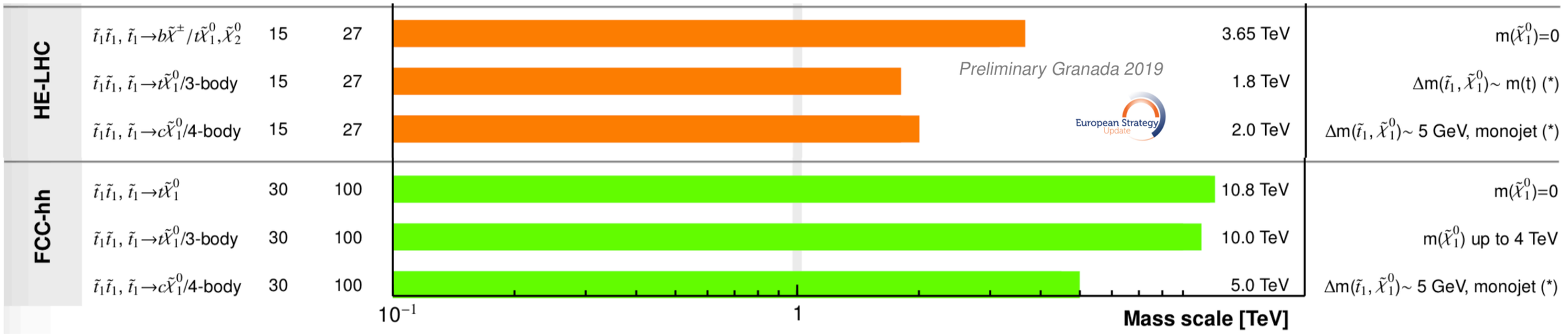
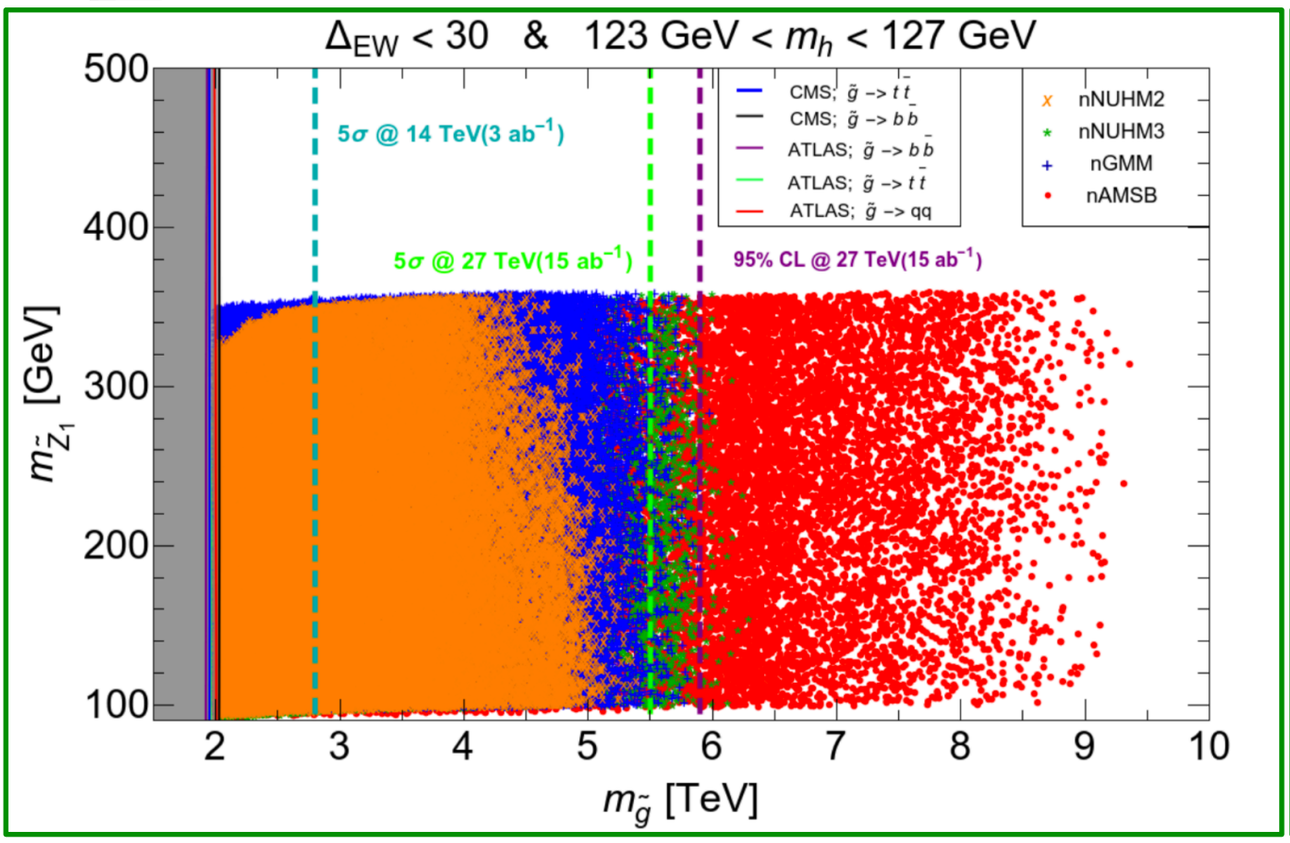
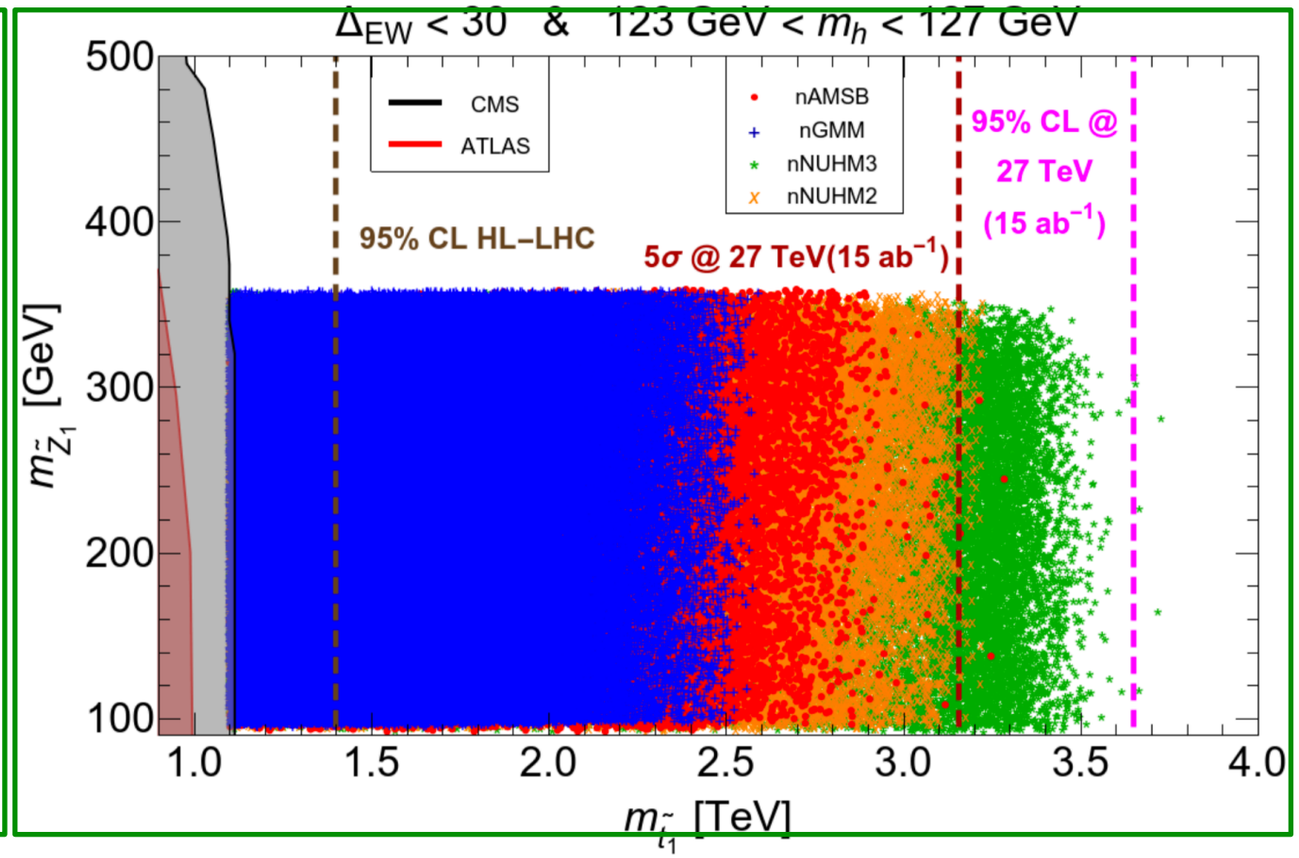
Confronting Natural SUSY (2)







$$\frac{m_Z^2}{2} = \frac{m_{H_d}^2 + \Sigma_d^d - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2 \simeq -m_{H_u}^2 - \Sigma_u^u(\tilde{t}_{1,2}) - \mu^2 \qquad \Delta_{EW} \equiv max_i \left|C_i\right| / (m_Z^2/2)$$

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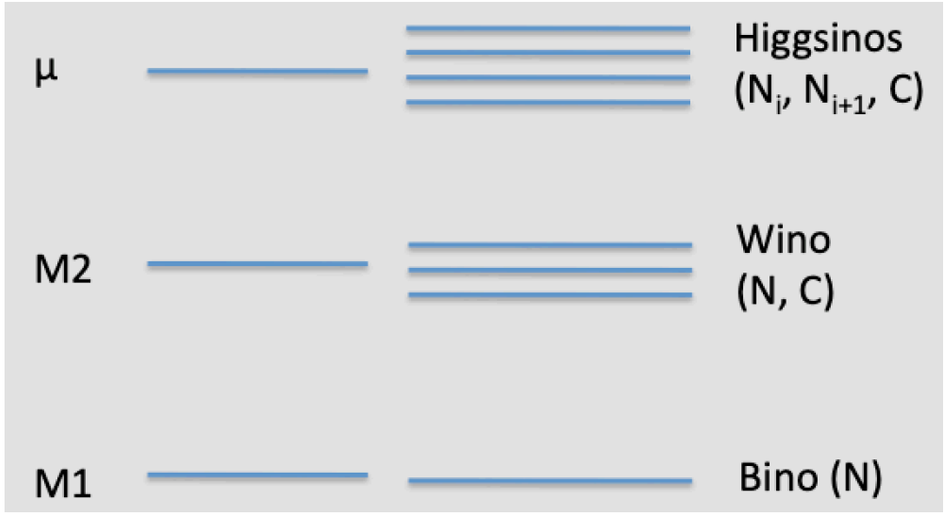
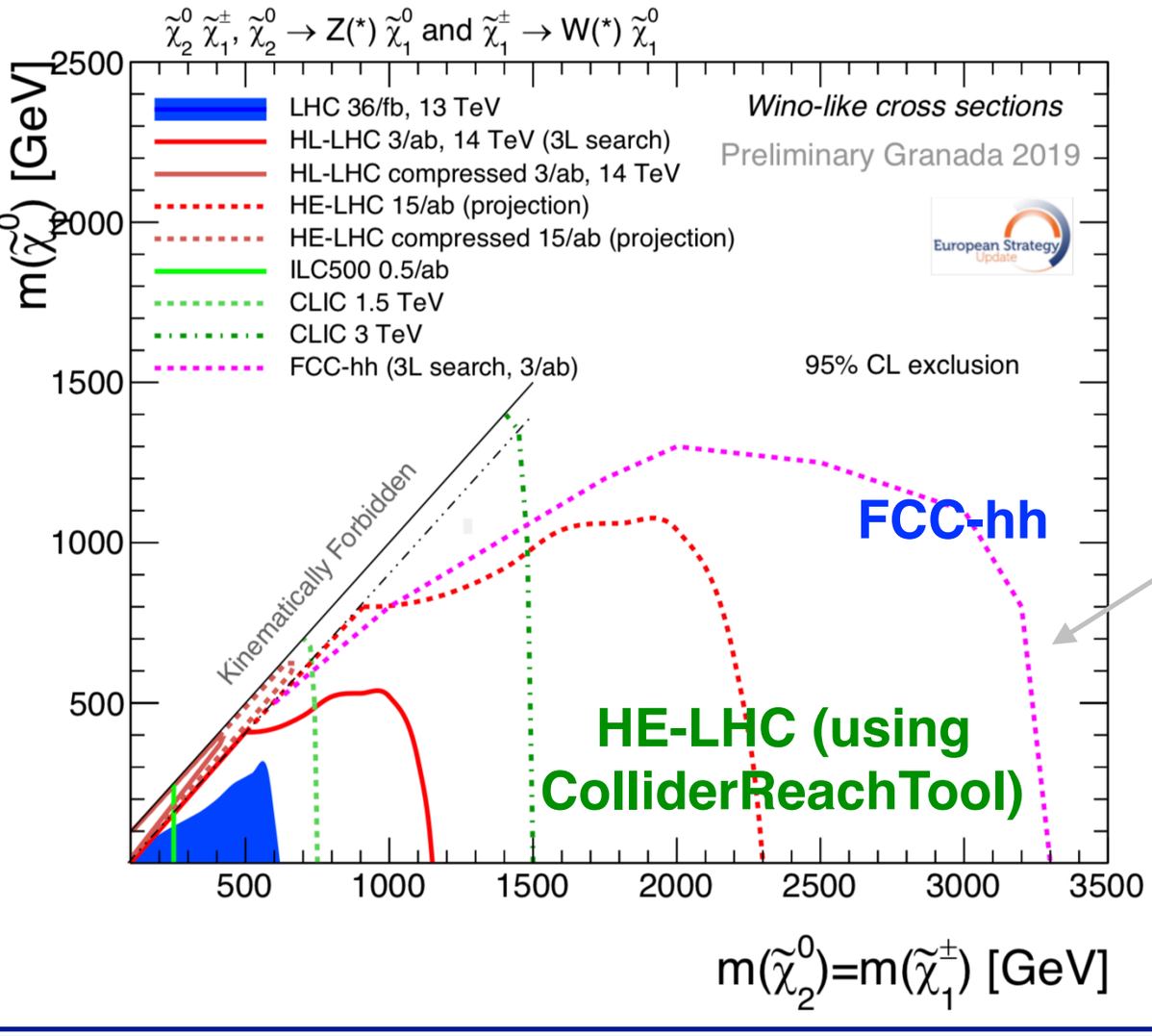
Search for EWK-inos

- **Strategy of EWK-inos search driven by the mass scales, in turn governing the mass splitting and decay modes**
- **Classical searches for non compressed spectra based on final states with multi-leptons, one lepton & jets (WZ mode), or one lepton & b-jets (Wh mode)**



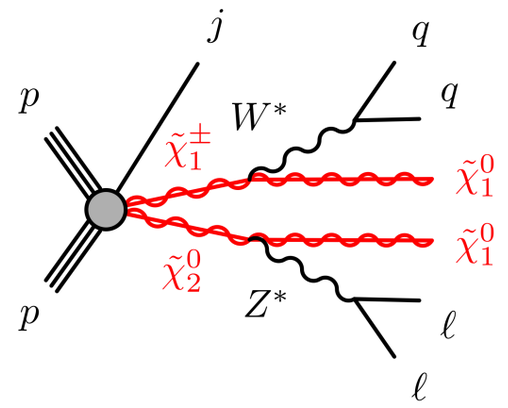


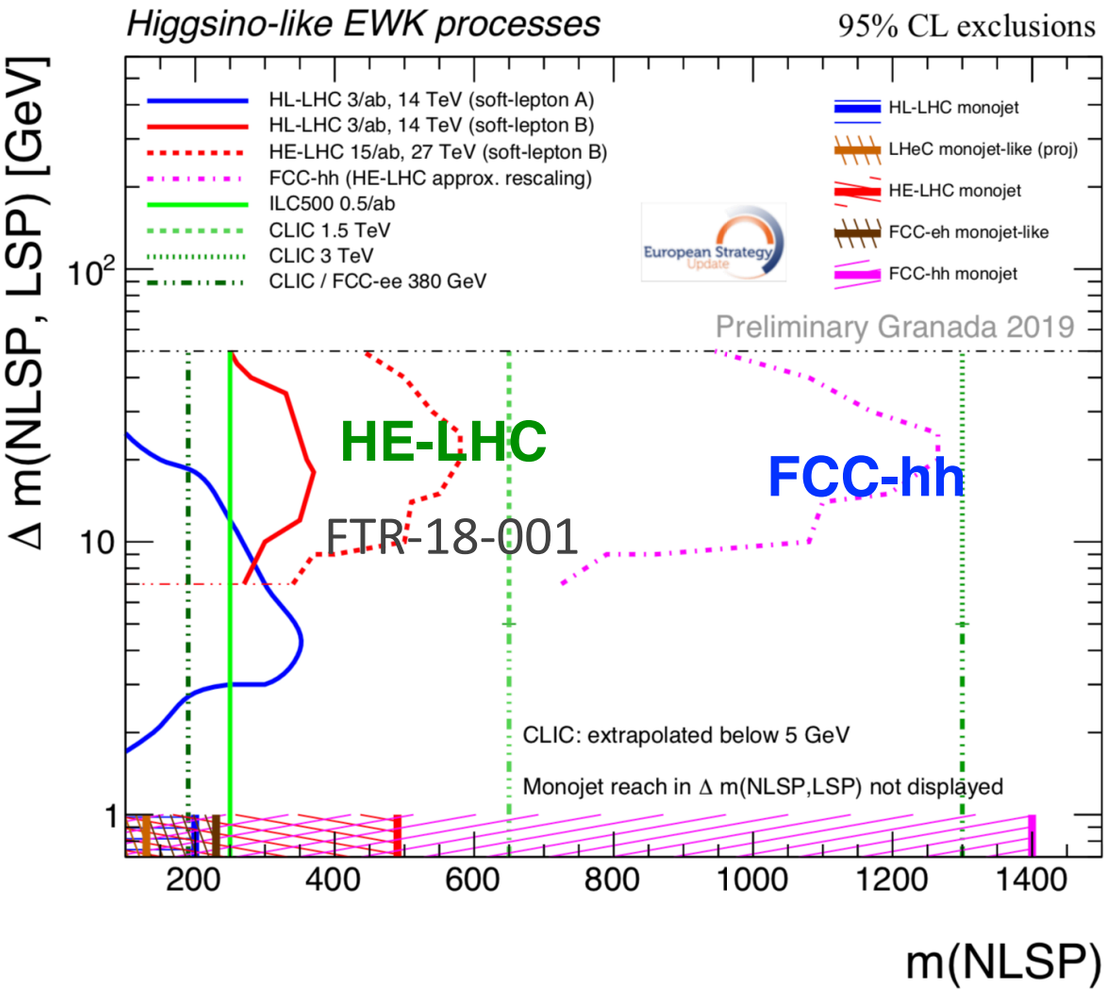
1410.6287 (full models, using multi-lep signatures only

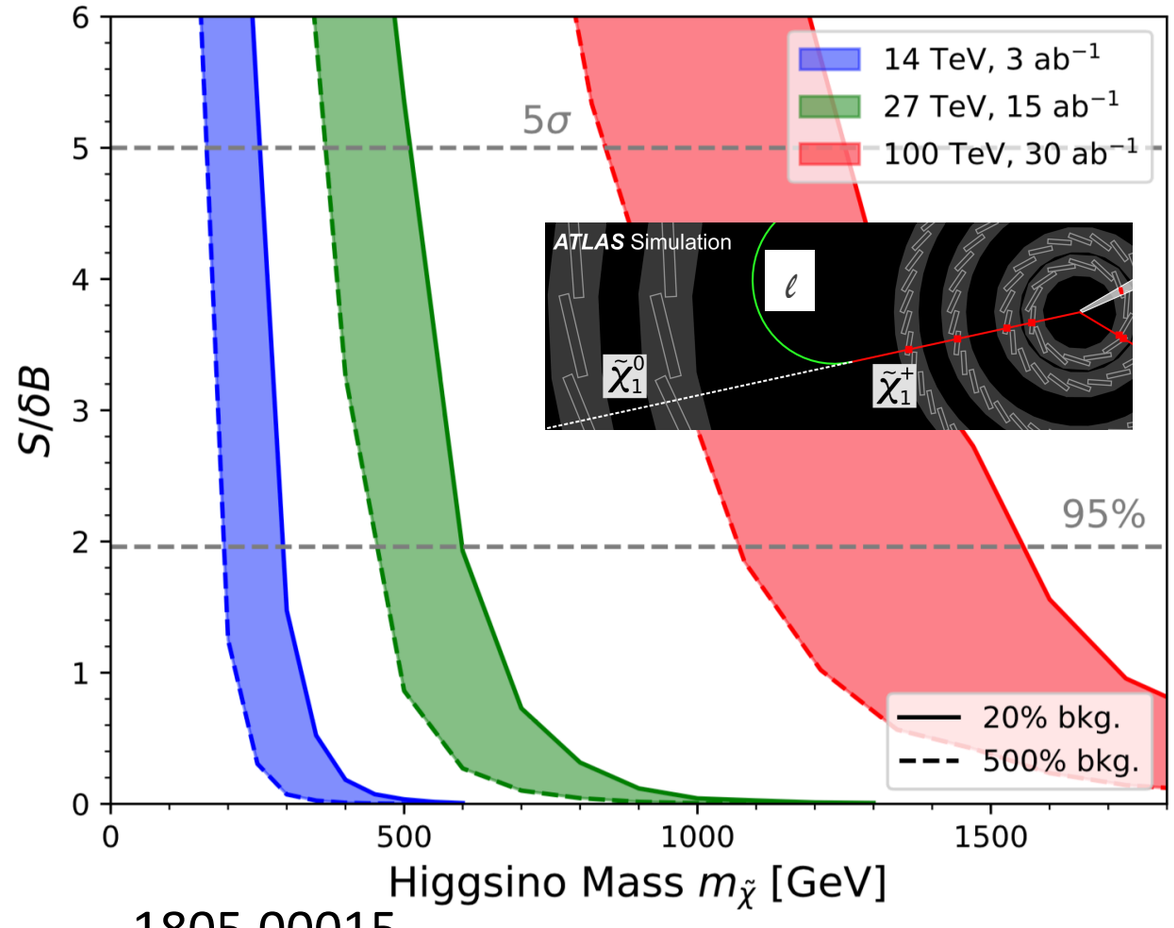
(NLSP, LSP)	5σ discovery	95% CL exclusion
$(\tilde{W}, \tilde{H})$	(2.2, 0.8) TeV	(3.3, 1.3) TeV
$(\tilde{H}, \tilde{W})$	(1.5, 0.6) TeV	(2.6, 1.0) TeV
$(\tilde{H}, \tilde{B})$	(1.8, 0.7) TeV	(2.9, 1.1) TeV
$(\tilde{W}, \tilde{B})$	(3.2, 1.4) TeV	(4.2, 2.2) TeV

Search for higgsinos-like EWK-inos

- Scenarios with higgsinos only at low mass scale (μ≪M1, M2) characterized by small mass splitting between light states (approx. 0.5 GeV)
  - Δm ~ GeV probed with ISR & soft lepton signatures
  - MeV < Δm < GeV probed with mono-jet and 'disappearing track' signature







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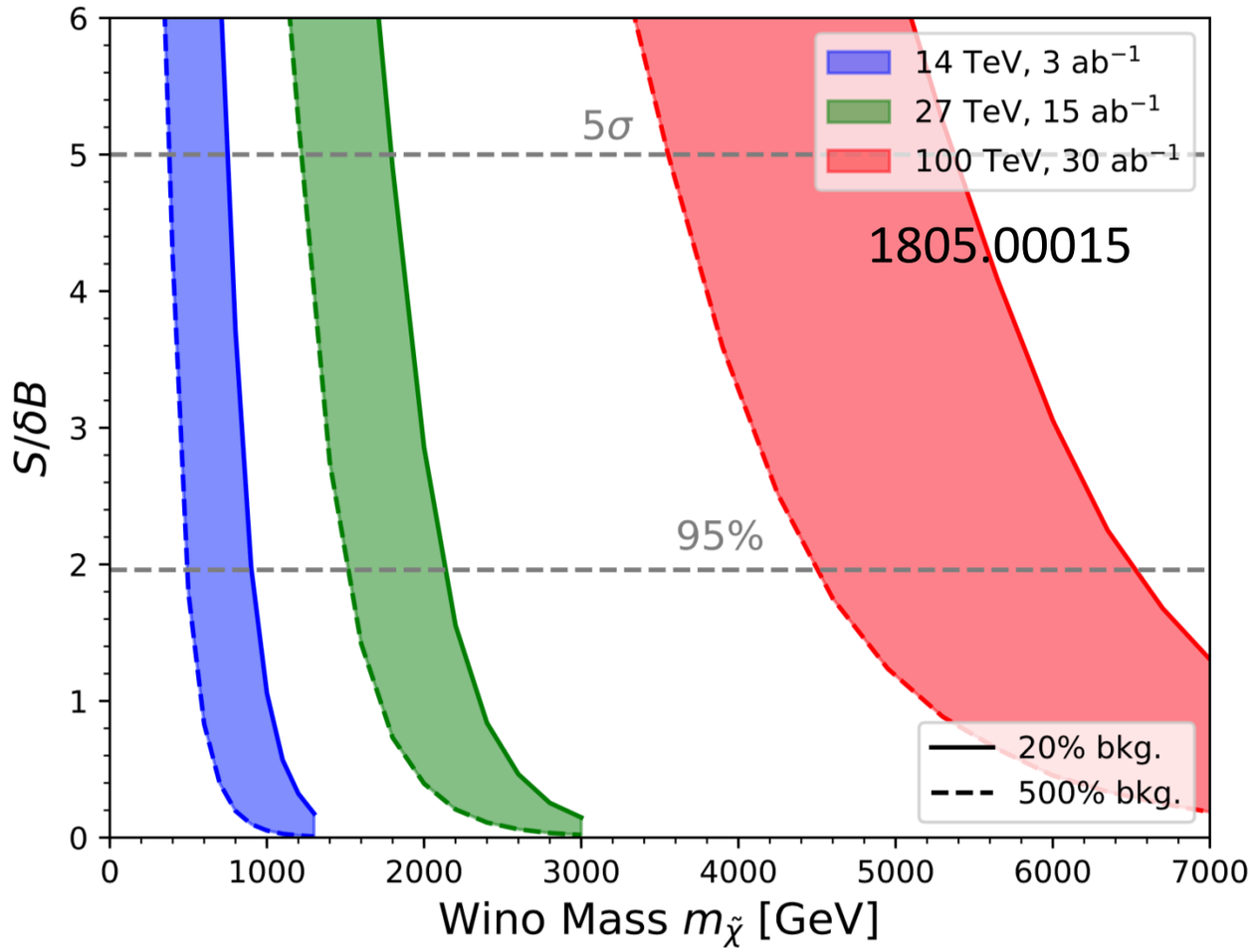
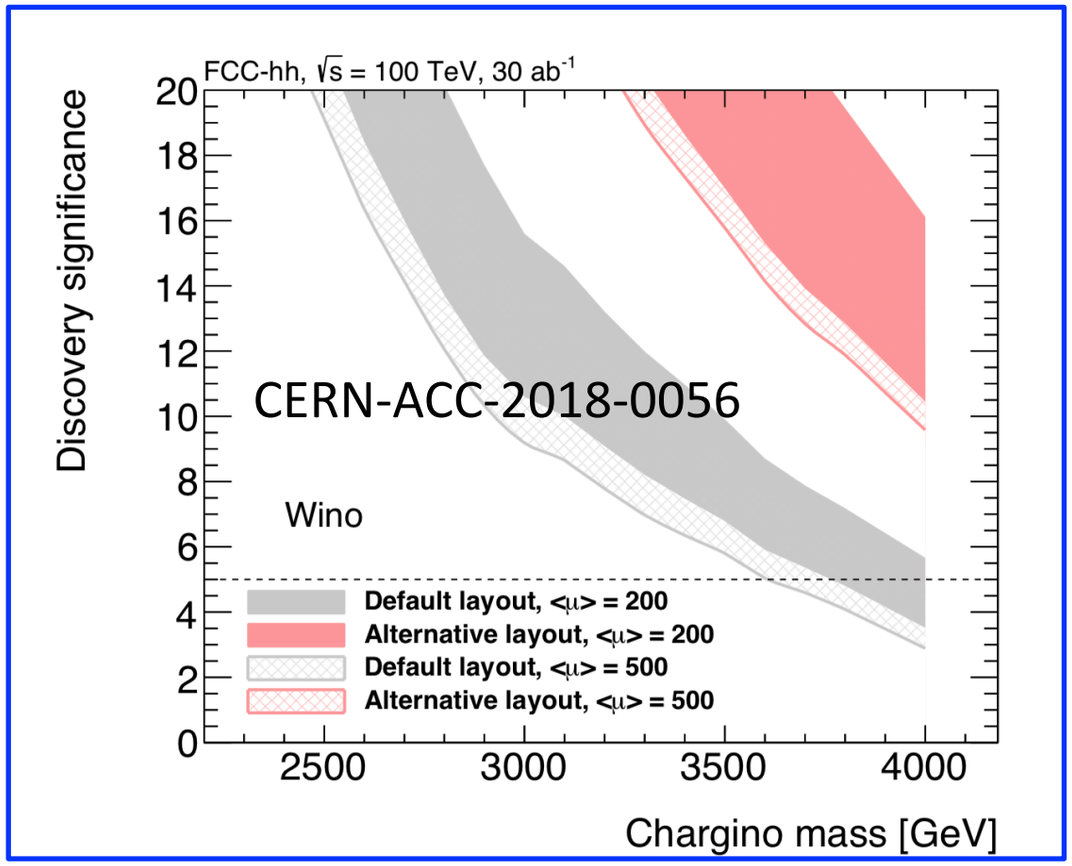
Search for wino-like EWK-inos

- **Wino-like EWK-inos characterized by even smaller mass splitting between the chargino and the LSP (approx. 0.2 GeV)**
  - **can be probed using disappearing track (and some sensitivity from mono-jet/photon signatures)**

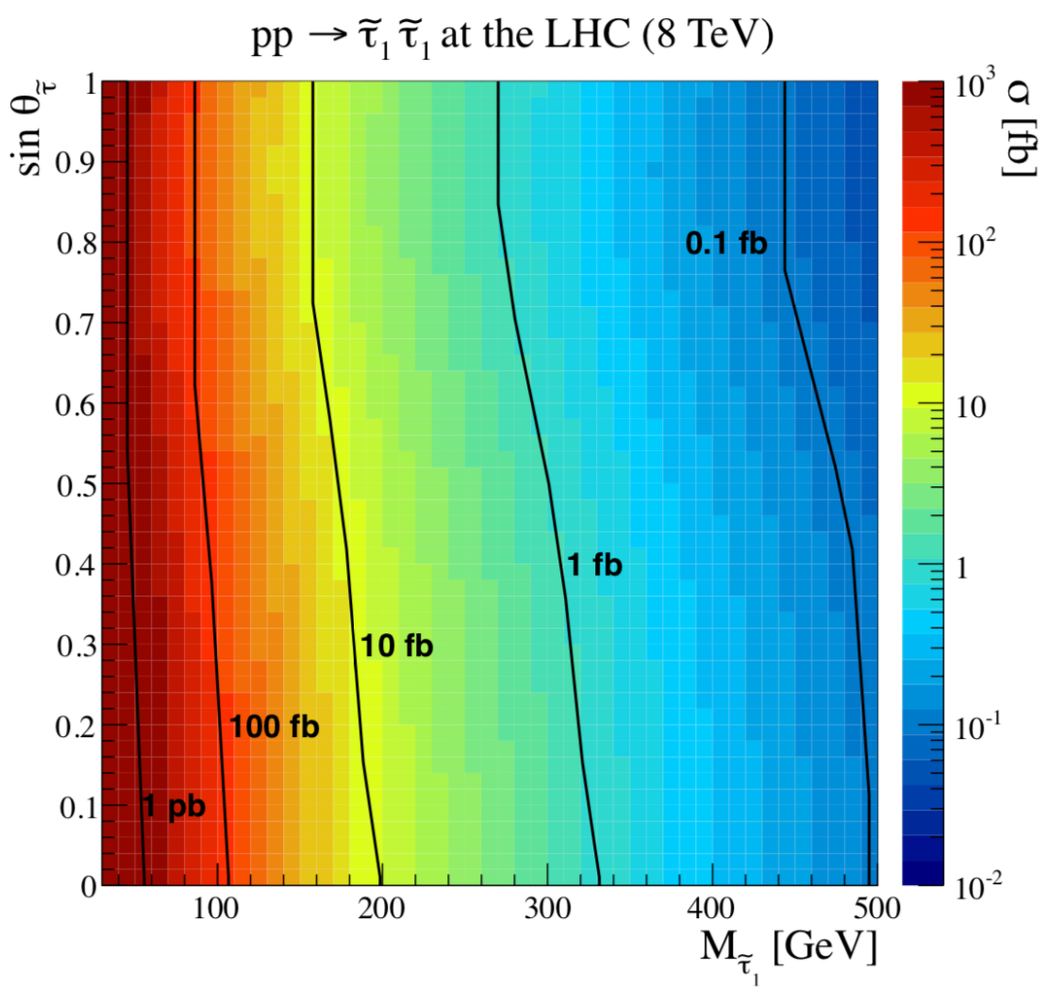


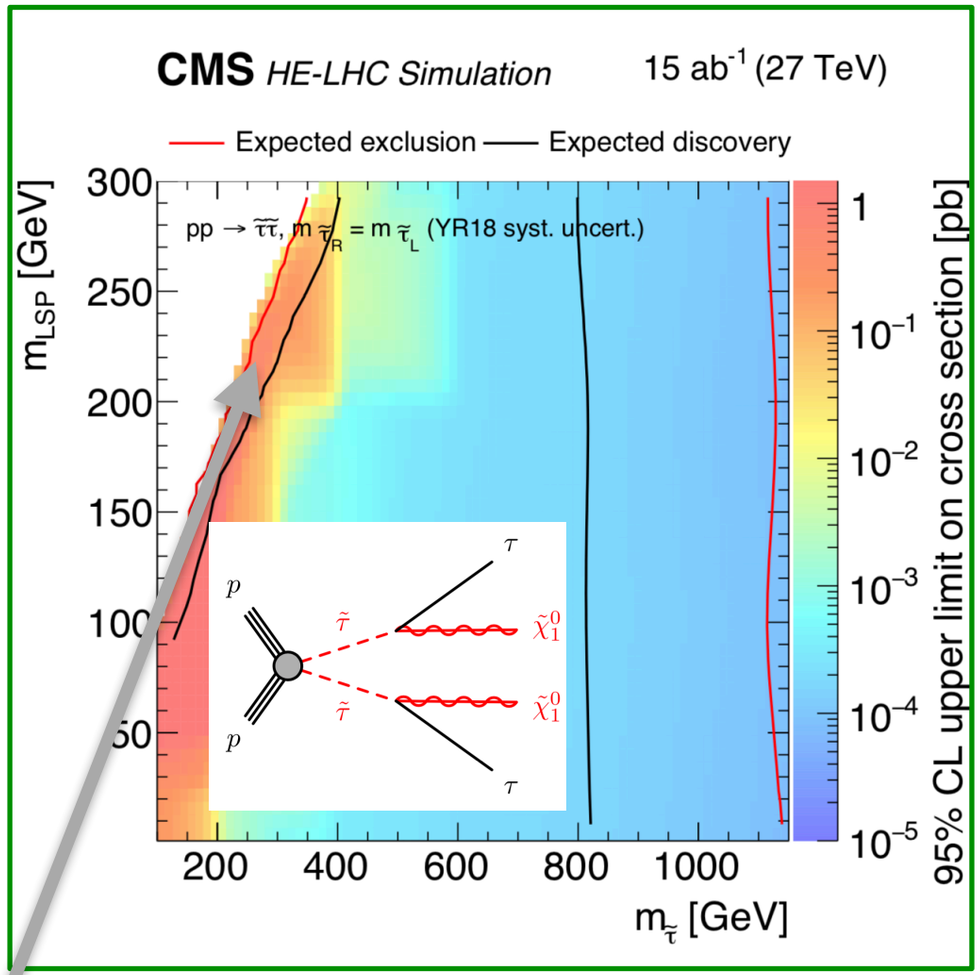


Monojet: 5σ at 200 GeV, HE-LHC; 5σ at 600 GeV, FCC-hh in conservative scenario

Search for scalar tau leptons

- **Tau sleptons expected to be light, exhibiting however low and helicity dependent cross-section ($\sigma_{\tau L \tau L} \sim 3 \times \sigma_{\tau R \tau R}$)**





Potential extension of sensitivity in co-annihilation corridor using ISR signatures

FCC-hh, extension of sensitivity up to 3-4TeV based on partonic extrapolation

1310.2621

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Conclusions

- **Future pp colliders exhibit an unprecedented potential for discovery of of strongly and weakly produced supersymmetry**

Sparticle	HE-LHC	FCC-hh
gluinos	5 TeV (5σ)	10 TeV (5σ, 3/ab)
stops	3 TeV (95% C.L)	10 TeV (5σ, 30/ab)
higgsinos	0.5 TeV (5σ)	0.8 TeV (5σ)
winos	1.5 TeV (5σ)	4.0 TeV (5σ)
staus	0.8 TeV (5σ)	3-4 TeV (5σ extrap.)

Conservative scenarios

- **Current analysis techniques have already allowed to explore challenging regions of parameter and phase space (*e.g.* low cross-section processes and compressed spectra)**
  - **further improvements to be expected when innovative object reconstruction and event selection algorithms are refined and will exploit information from new sub-detectors (*e.g.* advanced triggers, timing information, etc.)**

Nice readings

1406.4512
1804.08642
CERN-ACC-2019-0006
1406.4512
1808.04844
1407.7058
1810.11263
FTR-18-013
1410.6287
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1505.04702
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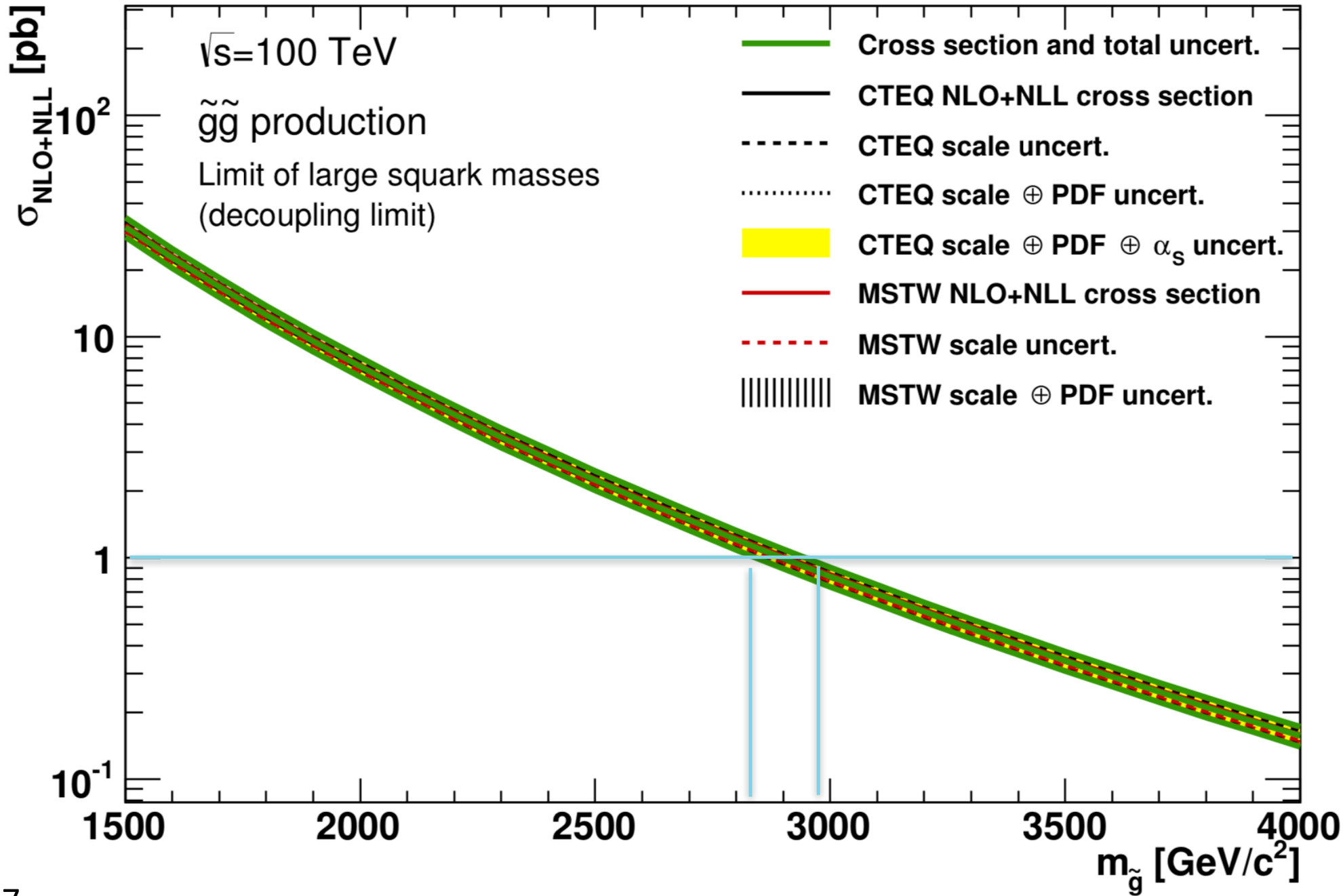
1612.03978

CERN-ACC-2018-0044
1702.06588
CERN-ACC-2018-0056
1708.09054
CERN-ACC-2018-0059
1712.02729.pdf
CERN-ACC-2019-0005

PDF Uncertainties on gluinos pair production



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