Prospects for SUSY searches at the HL-LHC

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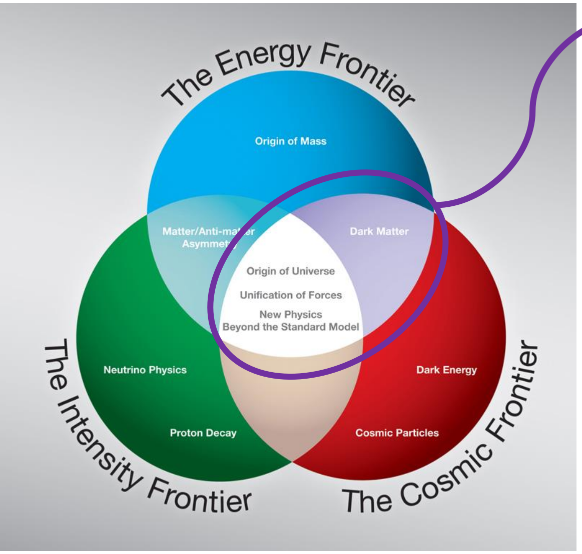
On behalf of ATLAS and CMS collaborations

SUSY searches so far



Colliders are a great instrument for looking at BSM physics: SUSY or DM

New physics BSM is out there and we have proofs (Dark Universe, neutrinos, baryogenesis)

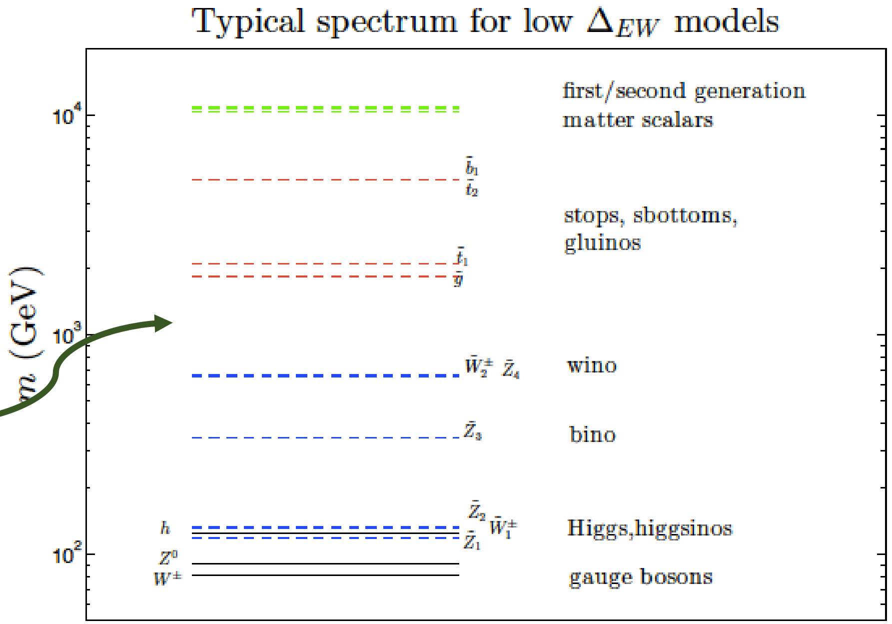
Where should we look for that? SUSY is a great candidate but we did not observe it yet

Limits m(g)>2TeV, m(stop)>1 TeV: are we at naturalness boundaries? Probably NOT

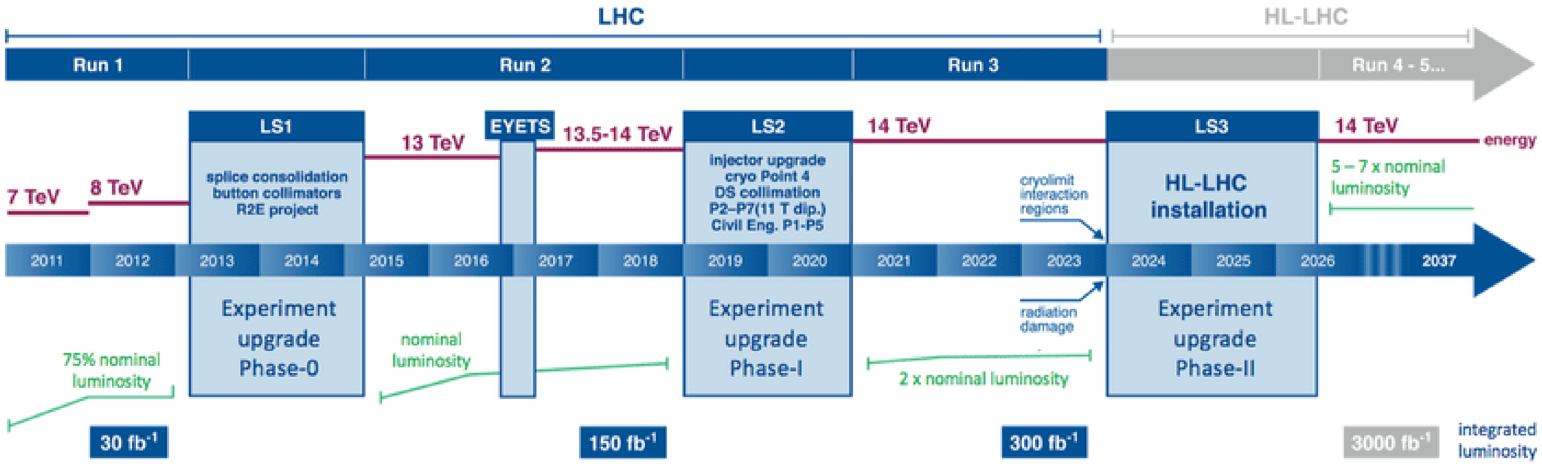
Is it over for SUSY? NO:
With EWK fine tuning (Δ_{EW}): m(g)<5-6 TeV, m(squarks)<20TeV)

Need low μ_H<100-300GeV

Candidate for DM: if R parity conserved, Higgsino is the LSP and it is stable



HL-LHC



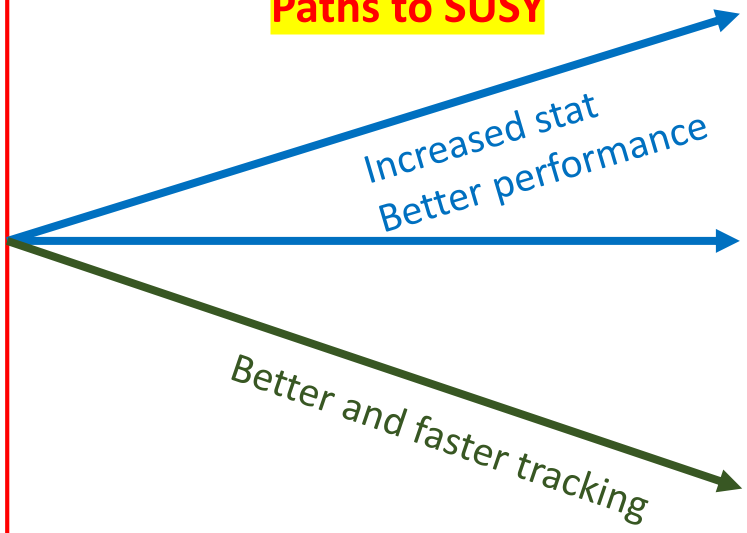
Integrated lumi: 3000 fb^{-1} @ 14 TeV

Pile up: from 60 events → up to 200

Increased fluencies.

Detector improvement needed: increase silicon tracking volume, enhance granularities, faster detector and readout

Paths to SUSY

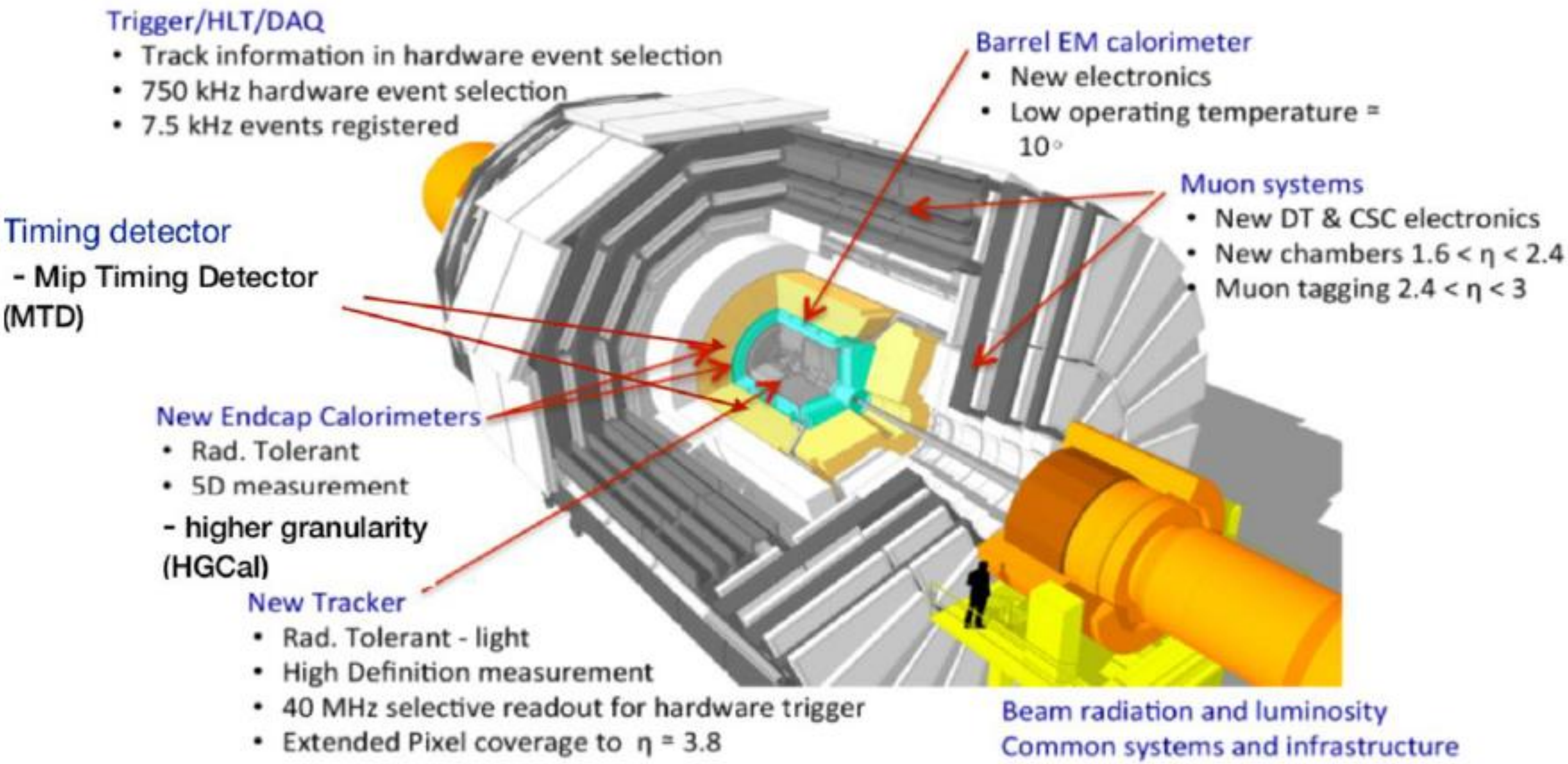


Checking naturalness limit: strongly interacting particles, Higgsinos

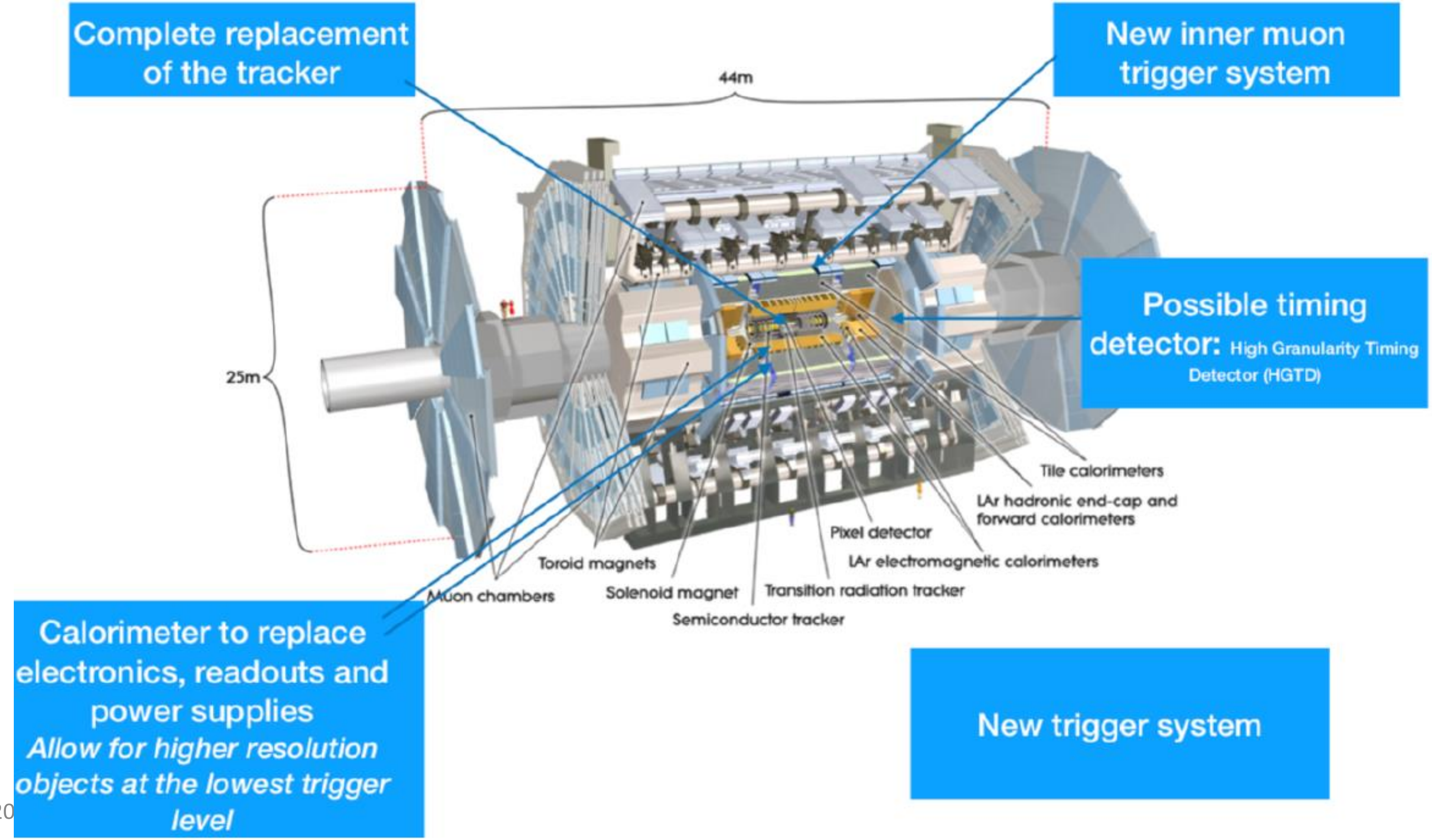
Search for accessible SUSY at TEV: Ewk interacting particles

Degeneracy, long lived particles: Disappearing tracks, displaced objects

CMS upgrade


Trigger/HLT/DAQ
• Track information in hardware event selection
• 750 kHz hardware event selection
• 7.5 kHz events registered
Barrel EM calorimeter
• New electronics
• Low operating temperature ≈ 10°
Muon systems
• New DT & CSC electronics
• New chambers 1.6 < η < 2.4
• Muon tagging 2.4 < η < 3
Timing detector
- Mip Timing Detector (MTD)
New Endcap Calorimeters
• Rad. Tolerant
• 5D measurement
- higher granularity (HGCal)
New Tracker
• Rad. Tolerant - light
• High Definition measurement
• 40 MHz selective readout for hardware trigger
• Extended Pixel coverage to η ≈ 3.8
Beam radiation and luminosity
Common systems and infrastructure

ATLAS upgrade



Analysis strategy

Experimental selection optimized for discovery

Different approaches used by different collaborations

Simulations based on truth level events:

Particles are reconstructed from truth and their energy and P_T are obtained from the MC truth value by applying resolution function from full detector simulation.

Jets are obtained from pileup library

Results are validated by using existing analyses

Full Detector simulation used for MC production

CMS: uses DELPHES as parametrized detector response

Analysis made on MC reconstructed objects with parametrized detector performance with up to date phase-2 expectations

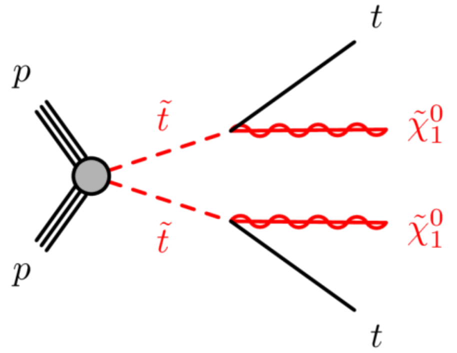
Background and signal projections are made by scaling backgrounds and signal from 13 to 14 TeV

Search for stops

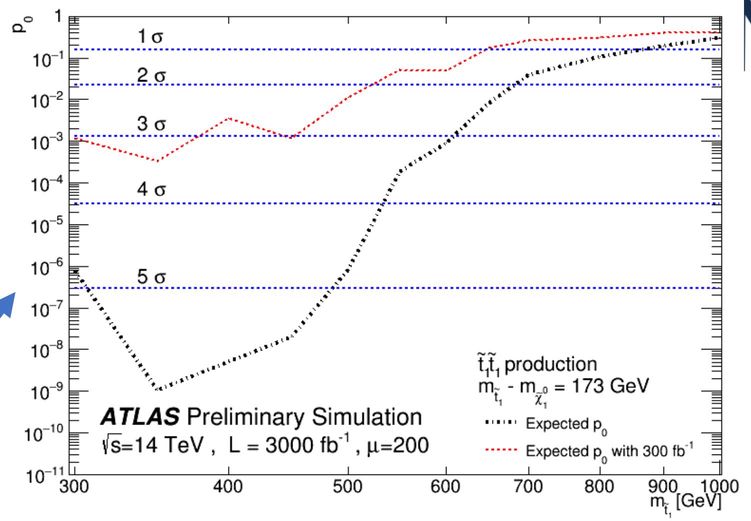
High Cross section: can push limits to high masses: is it enough to reject naturalness?

With HL-LHC opportunity to increase limits by several hundred GeVs

Statistics will allow to explore compressed spectra suffering from low statistics and high systematics today

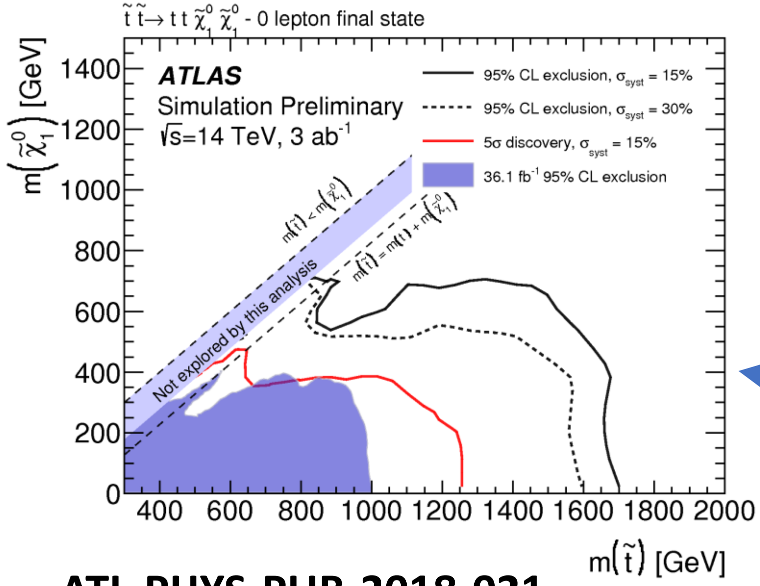


ATL-PHYS-PUB-2016-022

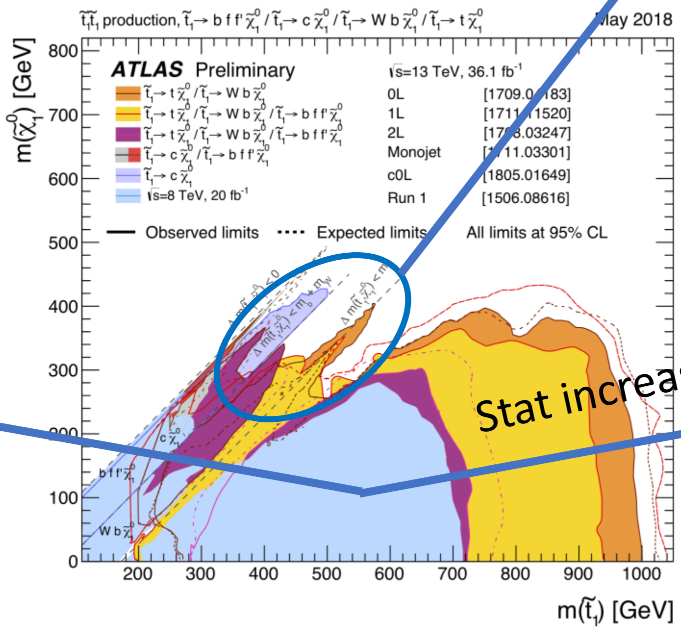


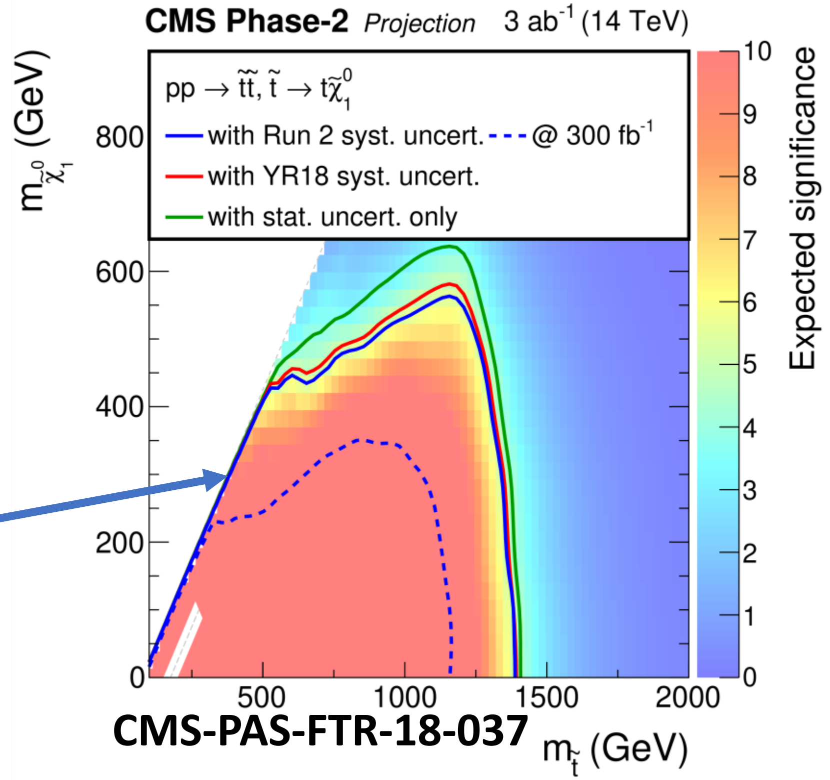
Compressed spectra

Stat increase



ATL-PHYS-PUB-2018-021

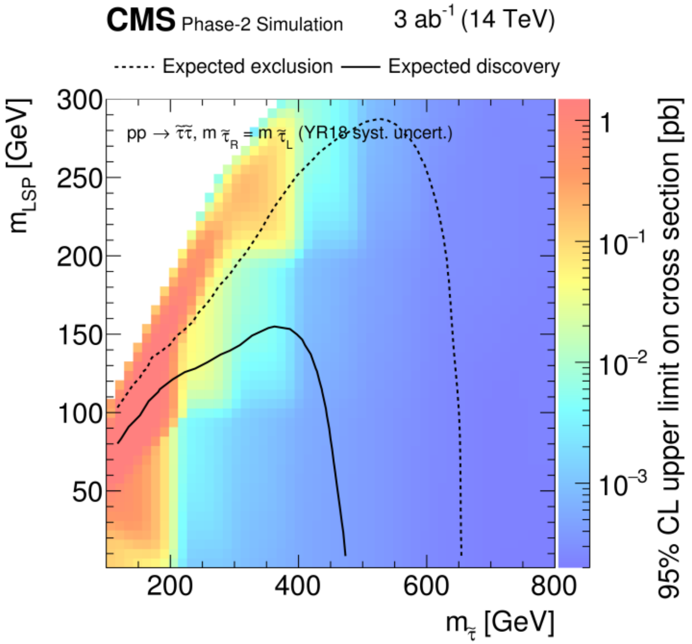


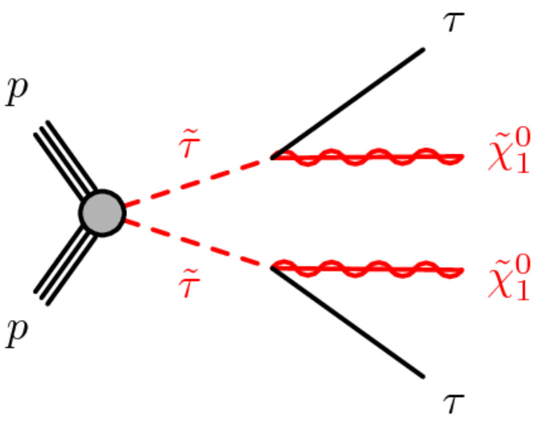


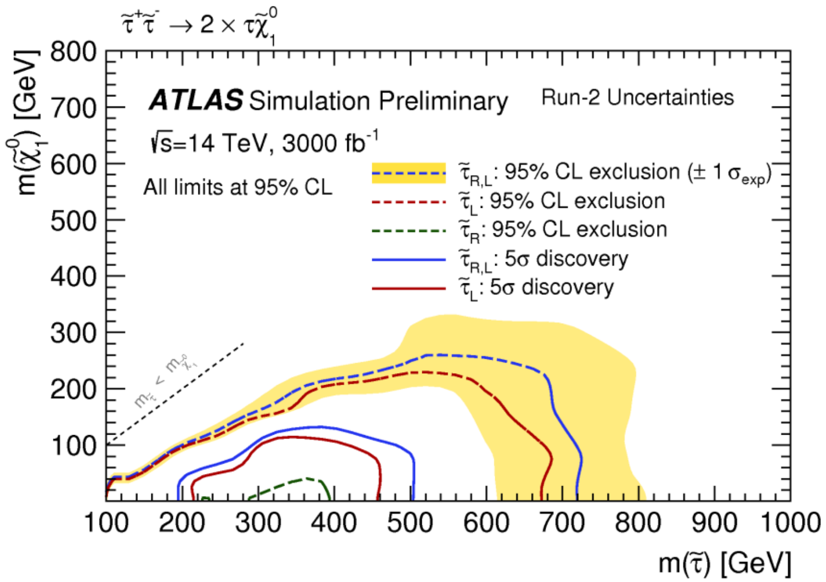
CMS-PAS-FTR-18-037

EWK searches: Staus

LHC sensitivity to slepton low: small x-section, low acceptance → challenging scenario
Slepton production dominant if charginos and NLSP are heavy







Targets both reconstruction of both $\tau_{had}\tau_{had}$ and $\tau_{had}\tau_{lep}$ final states
Improvement in tau ID thanks to new ID and timing detector

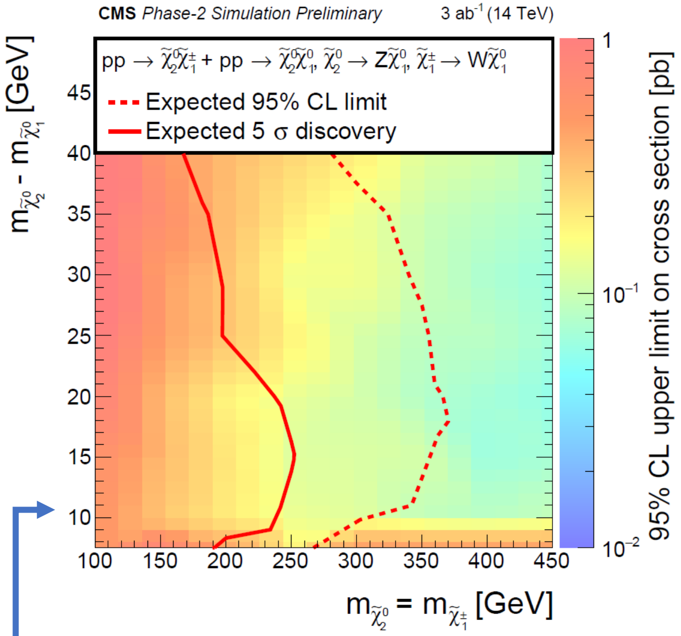
Staus currently excluded up to 109 GeV

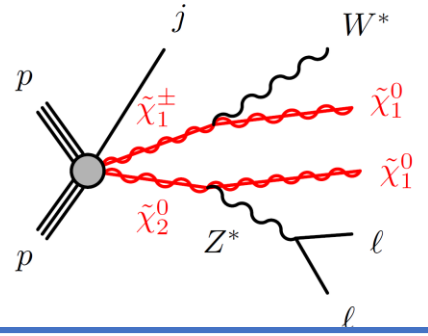
Expected exclusion increasing up to 700 GeV
Sensitive also to $\tilde{\tau}_R$

CERN-LPCC-2019-01

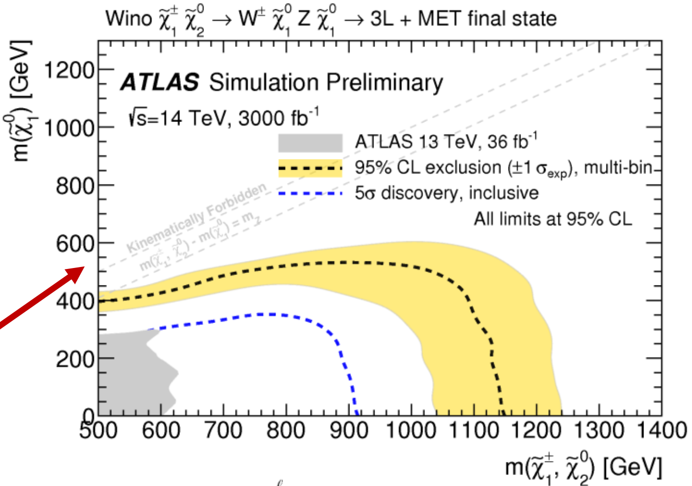
EWKinos searches

CMS-PAS-FTR-18-001





ATL-PHYS-PUB-2018-048

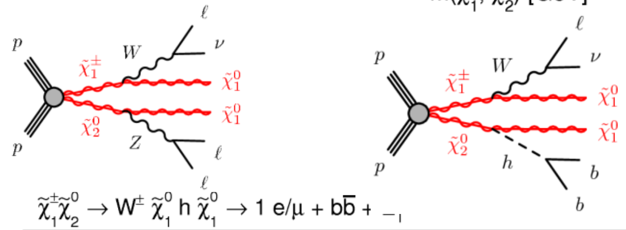


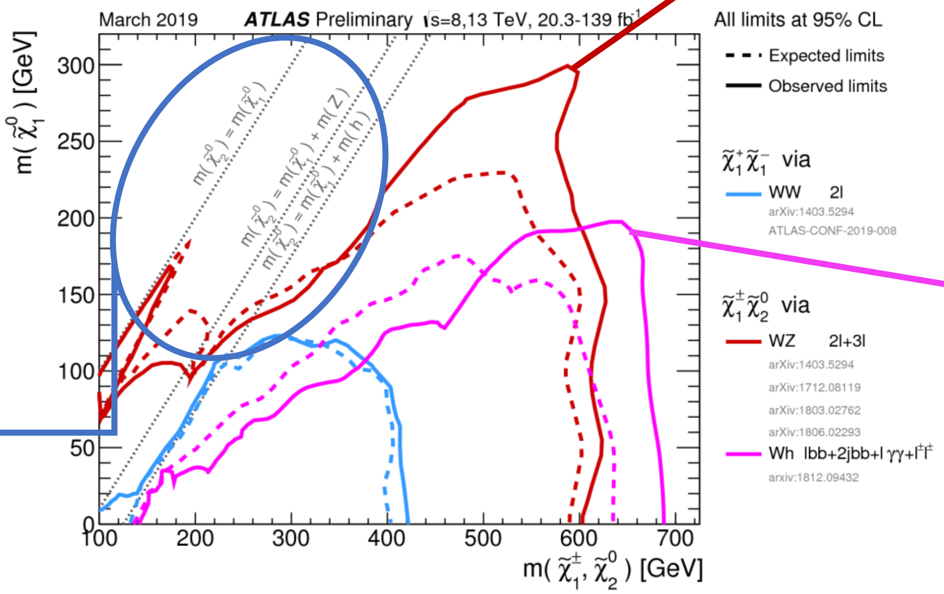
EWK Searches fundamental for DM

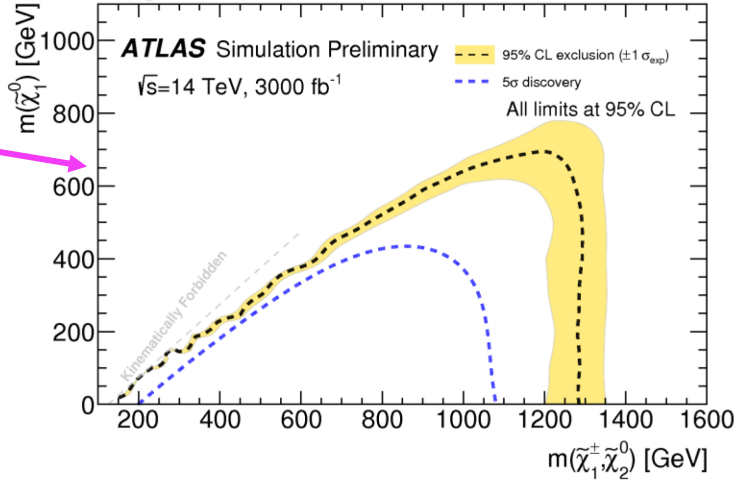
Sensitivity is strongly dependent on the composition of electroweakinos

Cross section decreases with gaugino masses

Challenging final states with Higgs



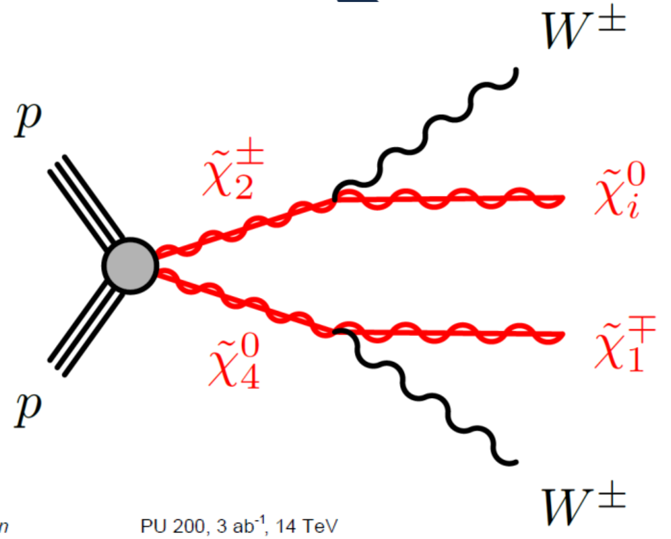




Compressed spectra: offshell W/Z and use of an ISR jet for triggering

EWKinos searches

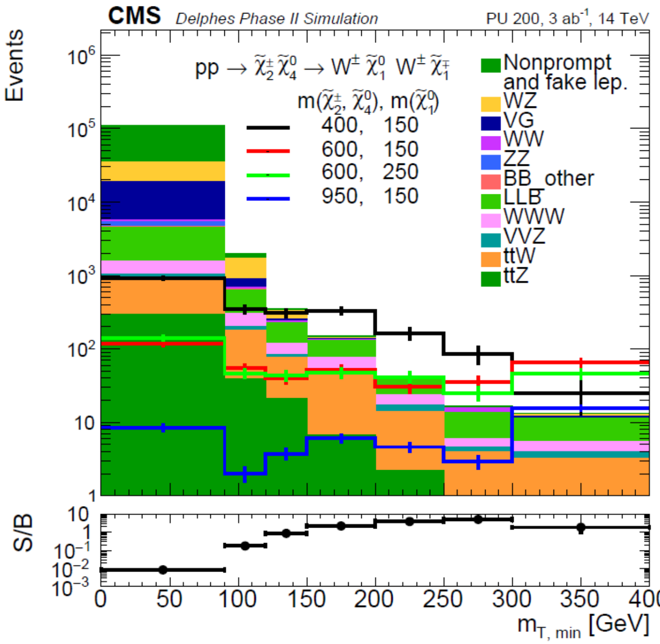
In models characterized by low mass $\chi^0_{1,2}$ and $\chi^{\pm}_1$ higgsinos, and heavier bino-like χ^0_3, and mass degenerate χ^0_4 and $\chi^{\pm}_2$ winos



Clear signature with two same charge leptons in final state from W decays

$$M_T(min) = \min\left[M_T\left(E^T_{Miss}, p_T^{lep1}\right), M_T\left(E^T_{Miss}, p_T^{lep12}\right)\right]$$

further suppress SM background



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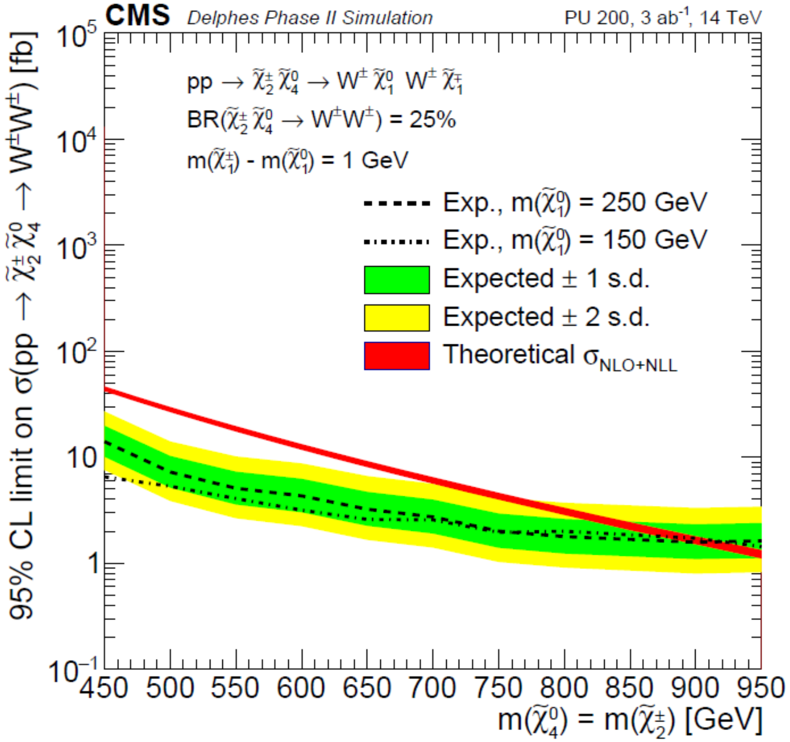

Long Lived Particles

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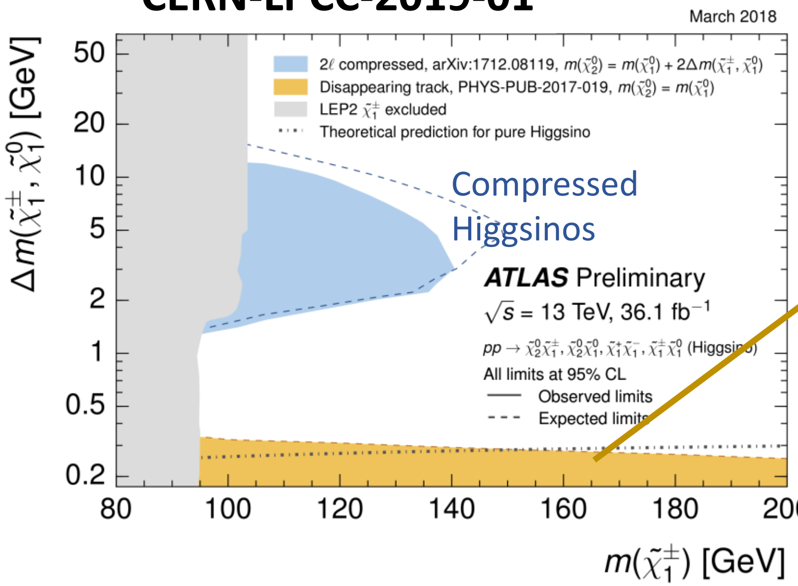
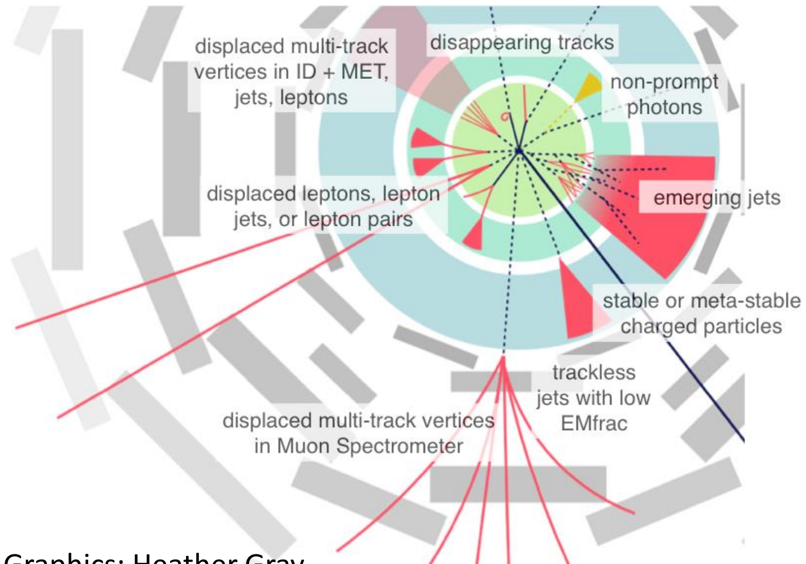




Graphics: Heather Gray

Long lived particles are complementary to compressed searches

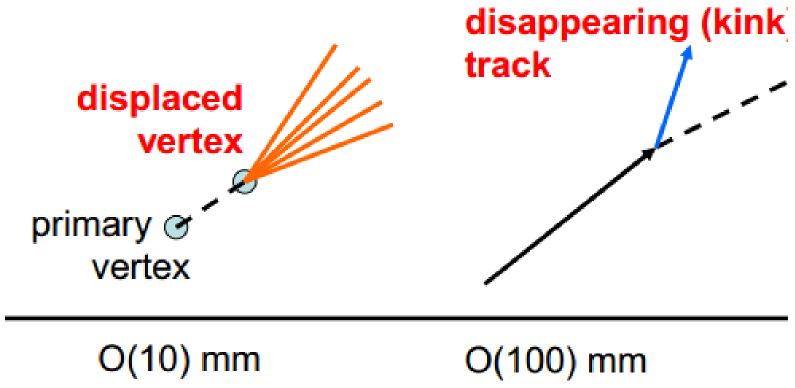
Great Discovery potential! Predicted by many different SUSY models:

- Small couplings → RPV decays
- Small mass splittings → quasi-degenerate spectra
- Many more (split SUSY…)

Challenging final states, strongly dependent on detector performance and knowledge

Different Layouts mean different acceptances so different detectors may be complimentary in terms of mass and lifetimes:

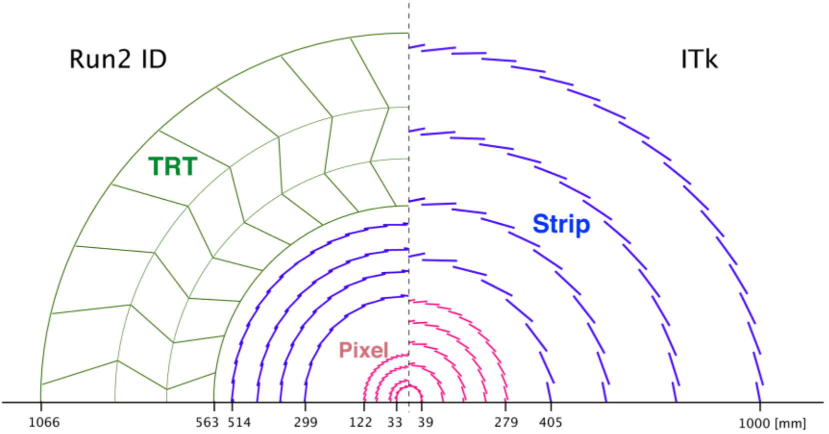
Focus on:

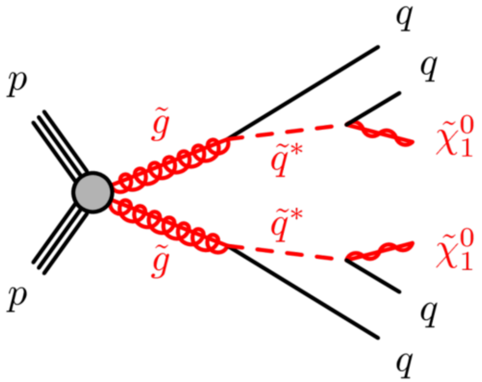


Alberto Cervelli

Graphics: Nora Patterson

Displaced Vertex

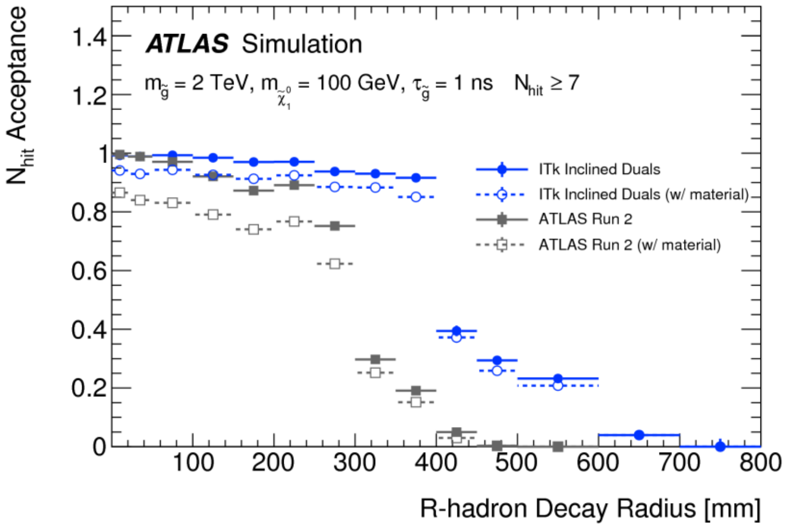




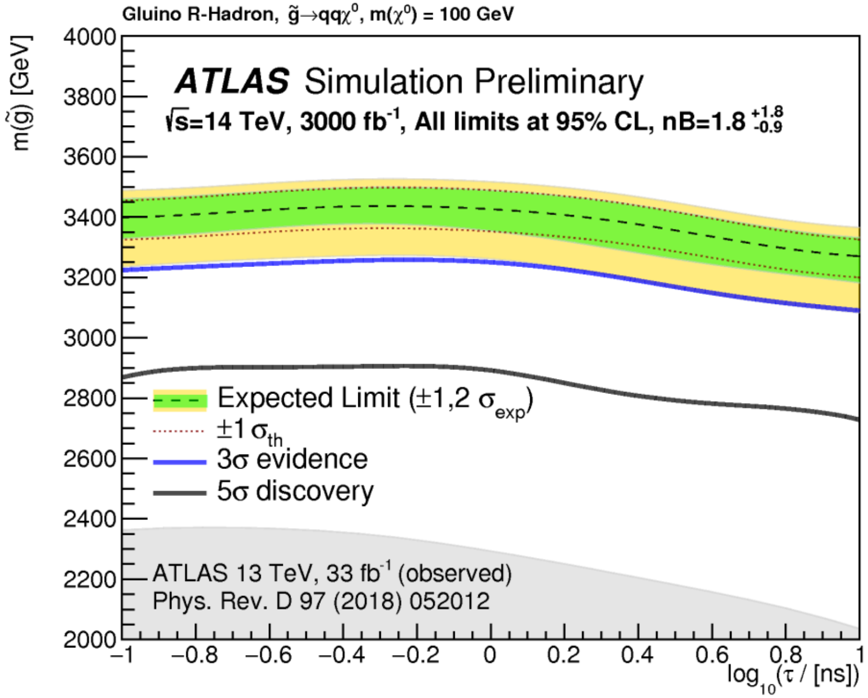
Signature from displaced vertex between a track from gluino decay and the decay of a R-particle

Main challenge is vertexing in high track density environment

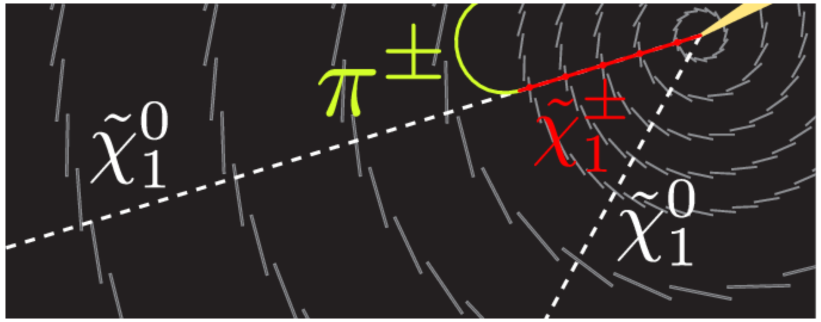
New ITK will provide better performances thanks to increased number of pixel layers increasing the sensitivity to DV from 300 to 400 mm

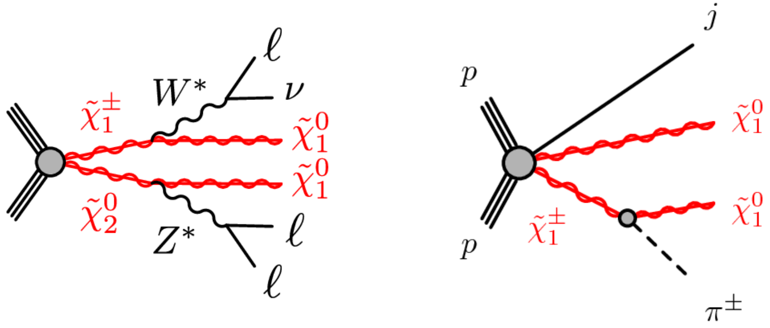


CERN-LPCC-2019-01



Disappearing Tracks





Two models tested:

2 soft leptons, MET, disappearing track

ISR jet, MET, disappearing track

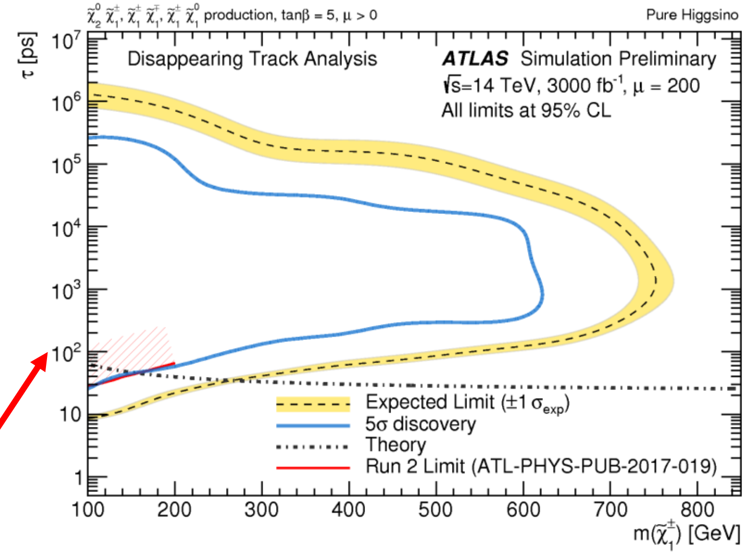
The product of $\widetilde{\chi_1^{\pm}}$ are not reconstructed

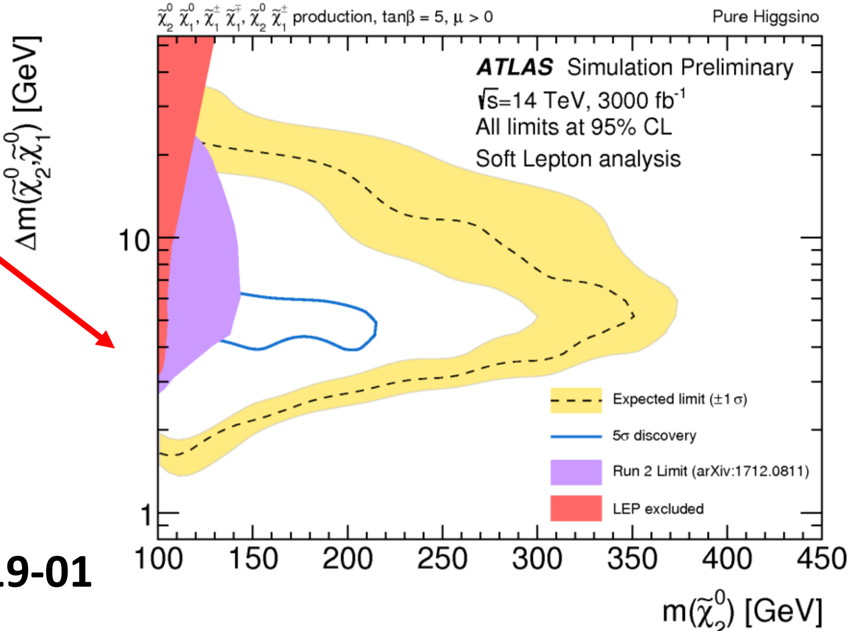
Better fake rejection thanks to new ID, worse sensitivity to short tracks due to larger ID radii

Results interpreted as:

Function of $m(\chi_1^{\pm})$ and lifetime of chargino

Function of $m(\chi_2^0) - m(\chi_1^{\pm})$ and $m(\chi_2^0)$ in 2 soft lepton scenario





LHCC-P-009

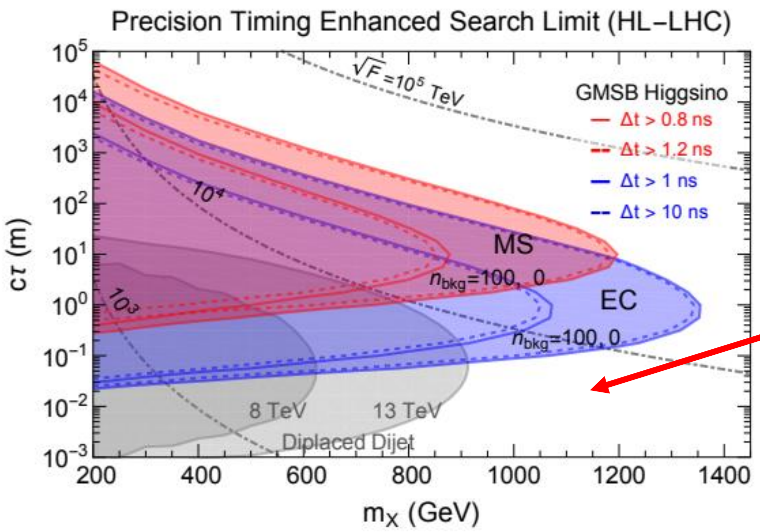
CMS MIP Detector

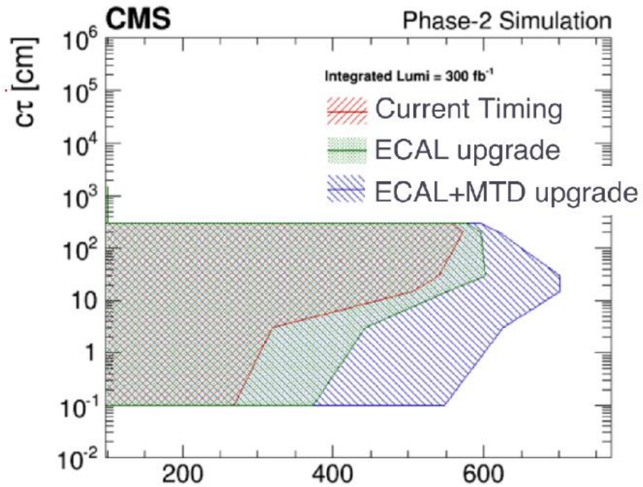
New timing detector in CMS: increase spurious track rejection to PV three fold

Vertex timing increase sensitivity to LLP searches

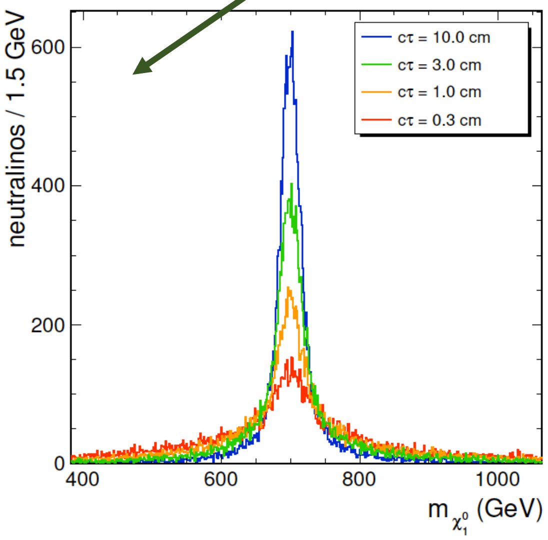
Use of ISR to reconstruct vertex timing: improvement on m and τ sensitivity

Possible to reconstruct mass of the LLP from secondary vertexes

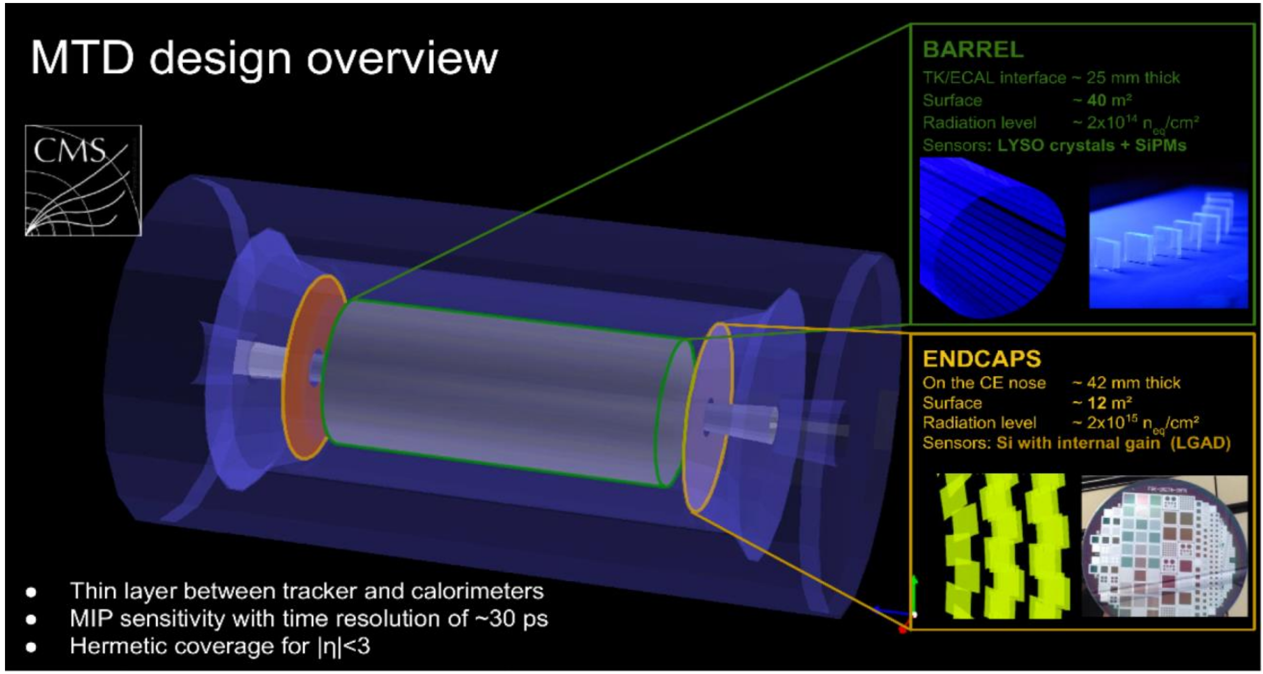




(a) $\chi_1^0 \to G + \gamma$ Limits



(b) $\chi_1^0 \to G + Z$ Peaking Variable



Conclusion

- We did not discover SUSY yet: is it over? NO
- Well we pushed limits over 1 TeV, is naturalness over? No(t yet)

- HL-LHC will provide statistics and the ATLAS and CMS collaborations will improve their detectors.
- We can tackle down SUSY in complimentary ways:
  - Push limits to higher masses for strongly produced particles and maybe exclude naturalness
  - We can look for SUSY in more complex topologies, like compressed electroewakinos, or we can push our limits also for EWK produced particles
  - More advanced detectors will make us more sensitive to long lived particles and more exotic signatures

- HL-LHC is going to shed light on what is now still dark in the SUSY sector, allowing for more and more sensitive searches