Searches for supersymmetric dark matter candidates and long-lived particles with the ATLAS experiment

Edoardo Farina

CERN & University of Pavia

on Behalf of the ATLAS Collaboration

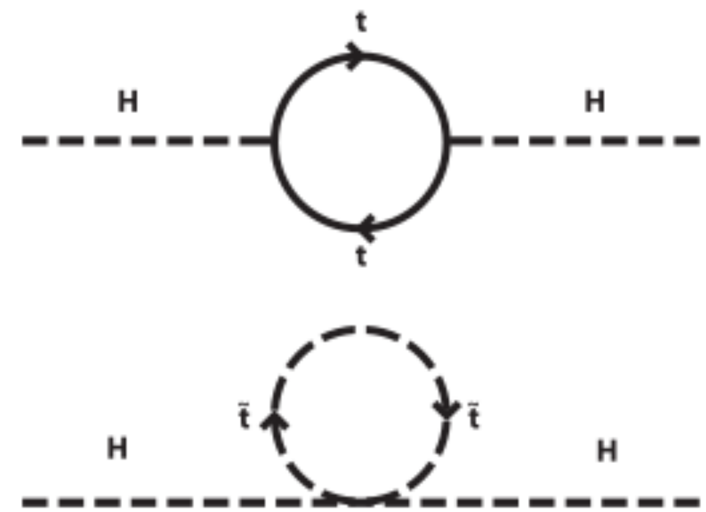
TeVPA 2017, Columbus, Ohio, USA **11 August 2017**

Supersymmetry as SM extension

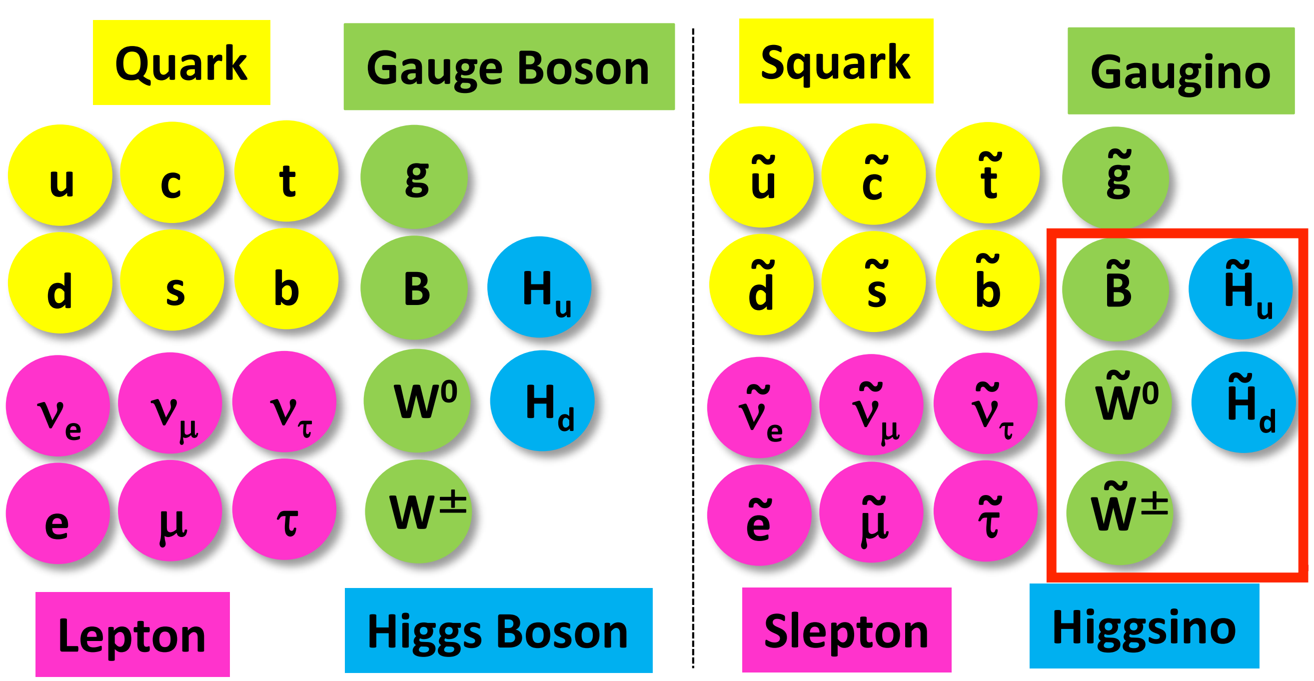
Possible SM extension based on a *broken Symmetry* between bosons and fermions: each SM particle has a supersymmetric partner differing by 1/2 spin

Could provide explanations to:

- Naturalness
- Gauge coupling unification
- Dark matter



Simplified models (reducing the number of free parameters) are studied at LHC

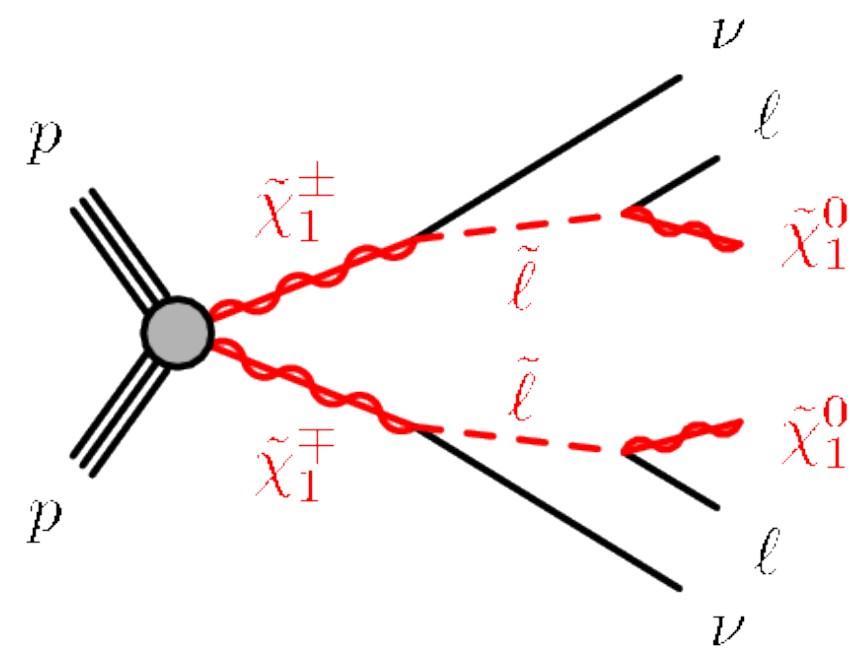


- 2 complex SM Higgs doublets are needed
- R-Parity conserved: sparticles cannot decay only into particles -> **LSP**
- Sparticle masses not fully defined by the theory
- Higgsinos and Gauginos define mass eigenstate $\tilde{\chi}^{\pm}_{1,2}$ and $\tilde{\chi}^{0}_{1,2,3,4}$

Looking for SUSY at ATLAS

Analyses are optimised for dedicated signal models based on assumptions:

- R-Parity conserved or violated
- Defined mass spectrum
- Restricting free parameters
- Specific final state



SM Background processes

MC normalized in background process enriched region

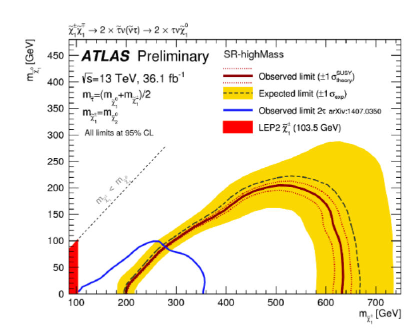
+

Pure MC estimation of non dominant background processes

Search optimisation

Based on cut and count regions, shape fit..

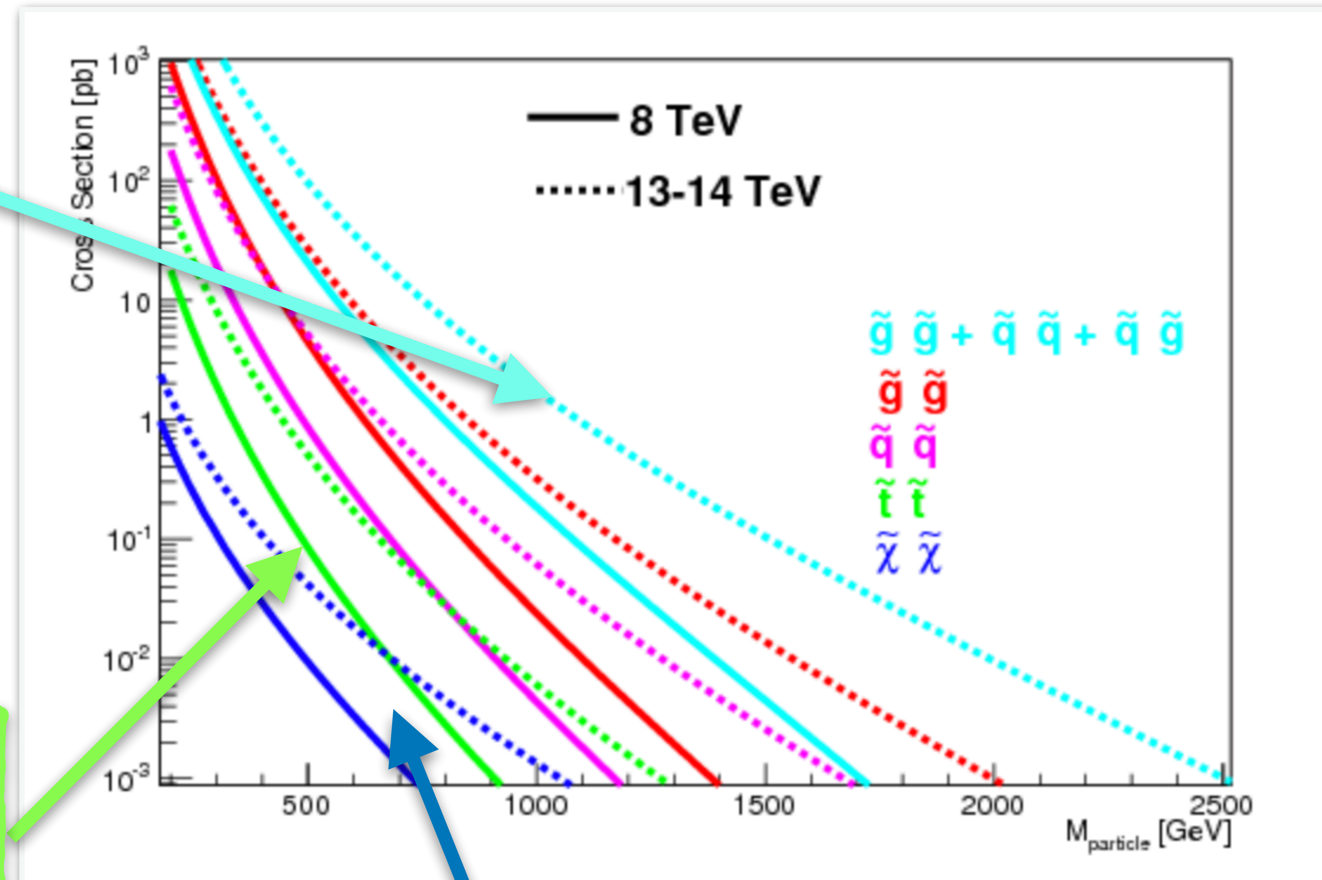
if nothing found…



Looking for SUSY at ATLAS: latest results

Strong production (Inclusive searches):
0L 2-6Jets ATLAS-CONF-2017-022
0L 7-11 Jets ATLAS-CONF-2017-033
multi b-jets ATLAS-CONF-2017-021
SS/3L + jets arXiv:1706.03731

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections



3rd Generation
stop 0L ATLAS-CONF-2017-020
stop 1L with DM+HF ATLAS-CONF-2017-037
Stop 2L ATLAS-CONF-2017-034
2b+MET ATLAS-CONF-2017-038
Stop in Z/h arXiv:1706.03986

EWK production
EWK 2/3L ATLAS-CONF-2017-039
EWK di-tau ATLAS-CONF-2017-035

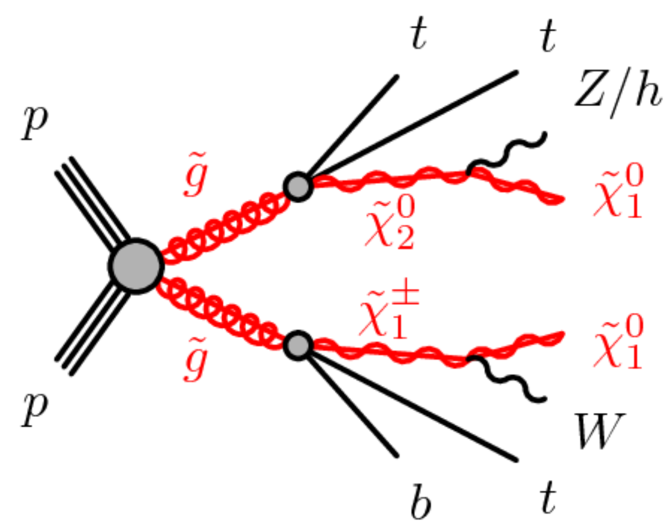
+

Many R-Parity violating analyses

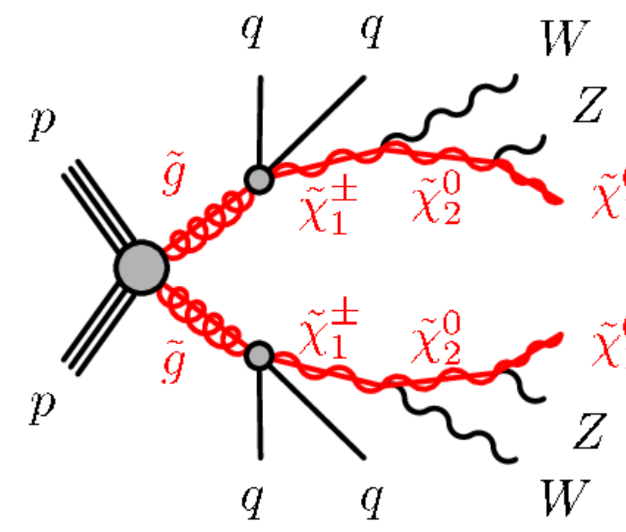
Inclusive search: multijets analysis

Target:
High multiplicity jet events originating from gluinos decay

Main discriminating variables:
- Missing transverse energy
- Jet and b-tagged jet multiplicity
- Scalar sum of jet momenta
- Mass of “fat" jets



2 step decay

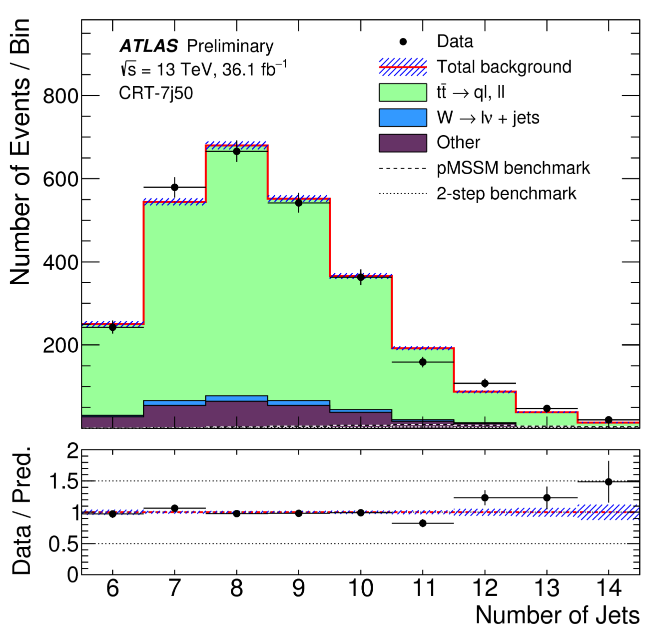


pMSSM

Background estimates

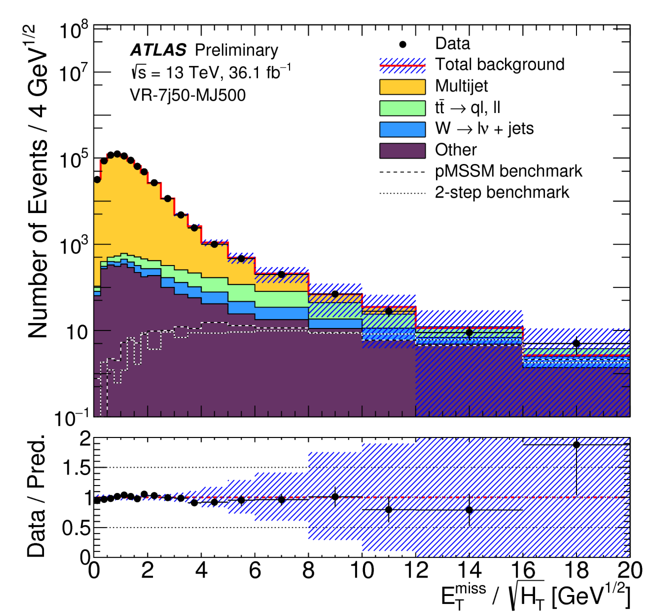
W+jets/ttbar enriched 1 lepton CR

1 lepton, same SR selection lower jet multiplicity



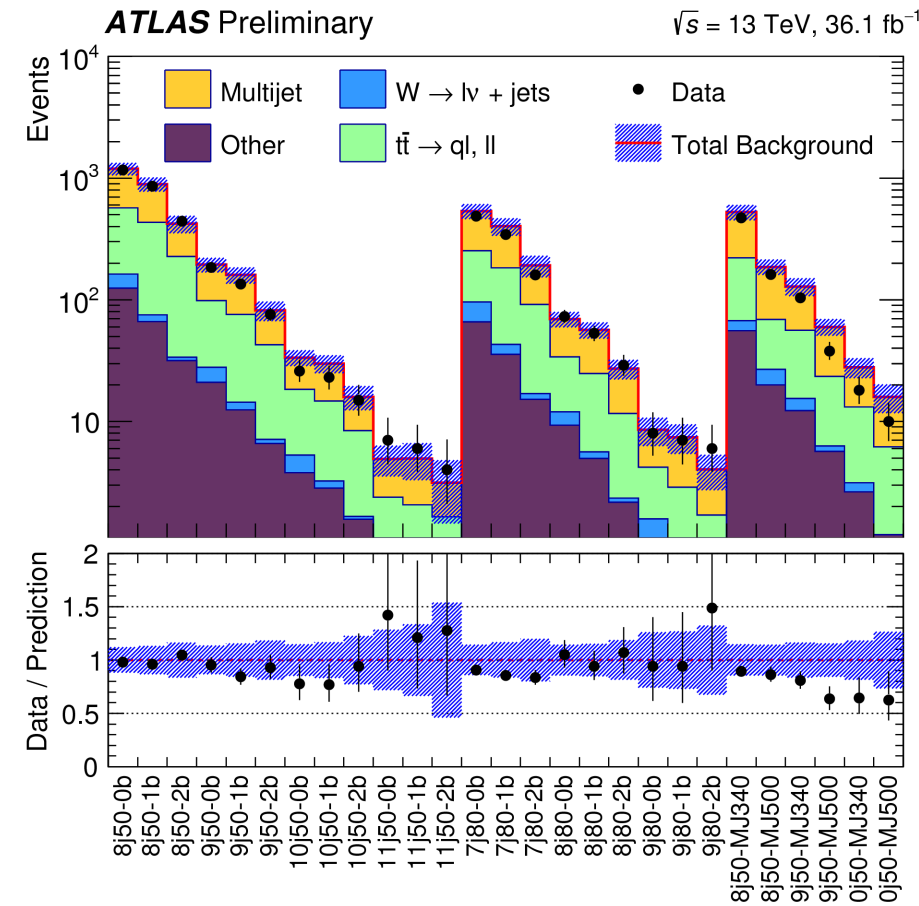
QCD Multijet background

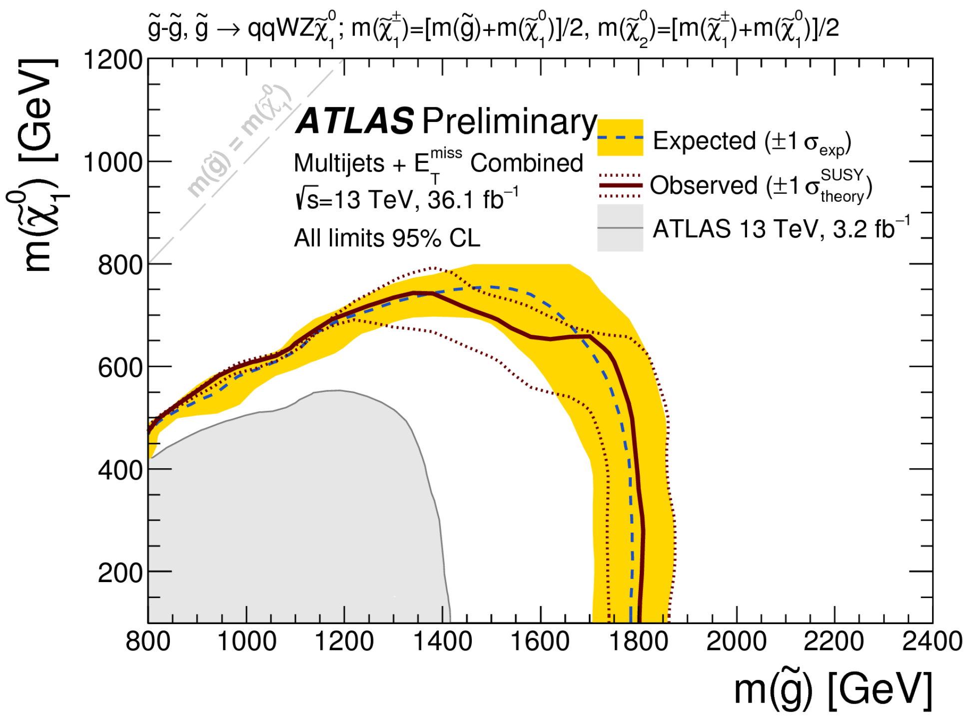
Template based on MET/$\sqrt{H_T}$ at lower jet multiplicity

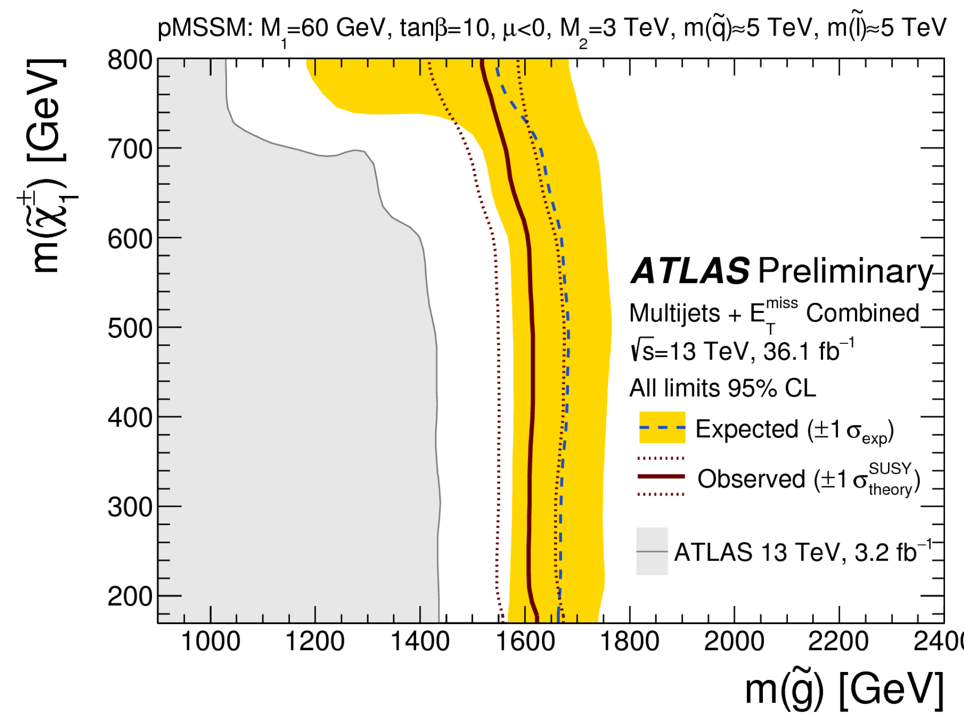


Inclusive search: multijets analysis

- 27 SRs based on jet/b-jet multiplicity and sum of reclustered jet masses
- No significant excess found
- Limits on gluino masses obtained:
  - In two steps decay gluino is excluded up to 1.8 TeV for light LSP
  - In pMSSM for chargino mass below 600 GeV gluino excluded up to 1.6 TeV

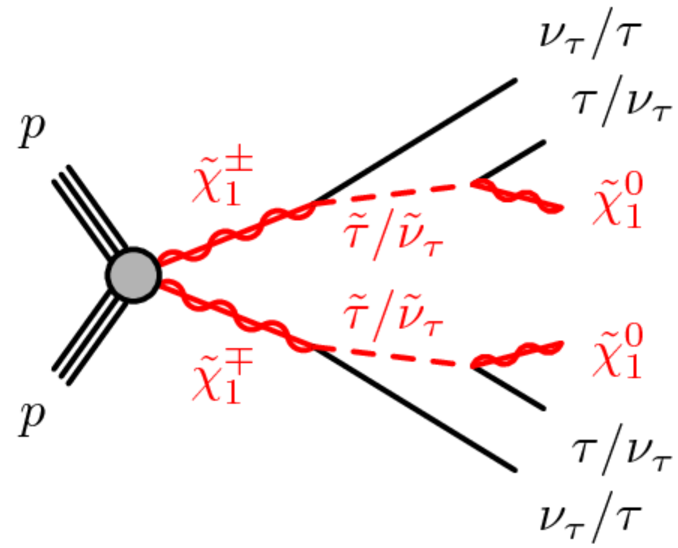


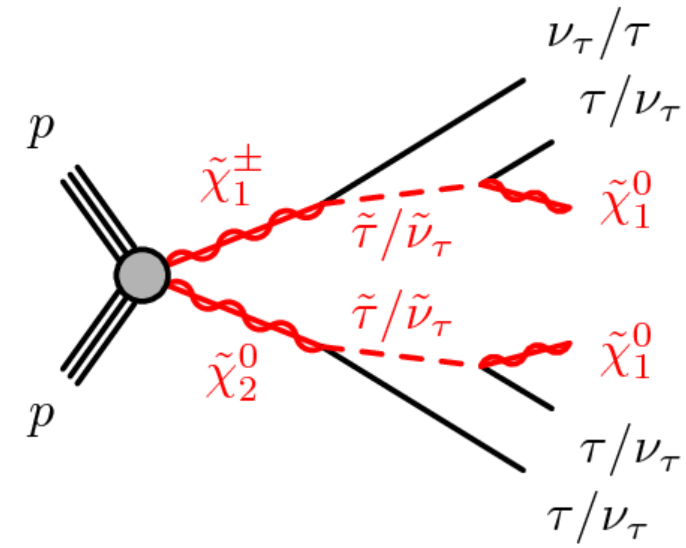




Electroweak production: 2 τ final state

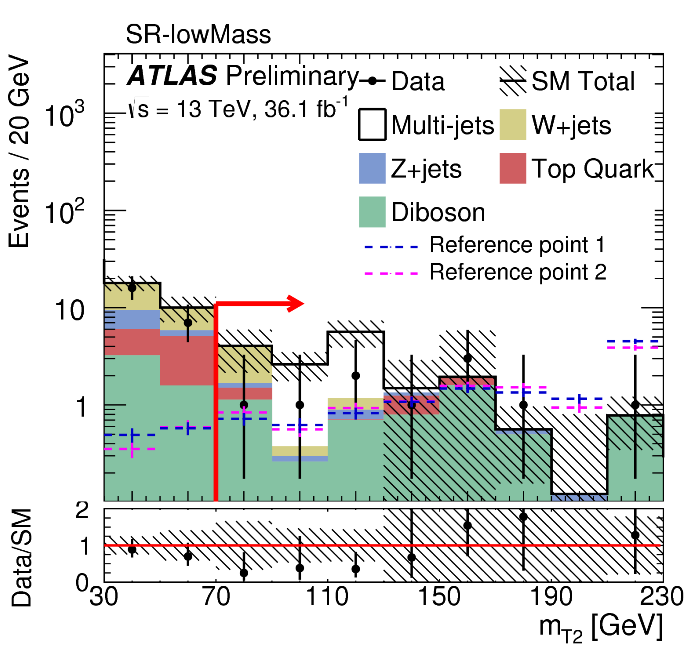
Target:
Neutralino/Chargino production having tau leptons in final state





Models with stau can lead to dark matter relic density compatible with observation

Main discriminating variables:
- Missing transverse energy
- Stranverse mass (m_{T2})



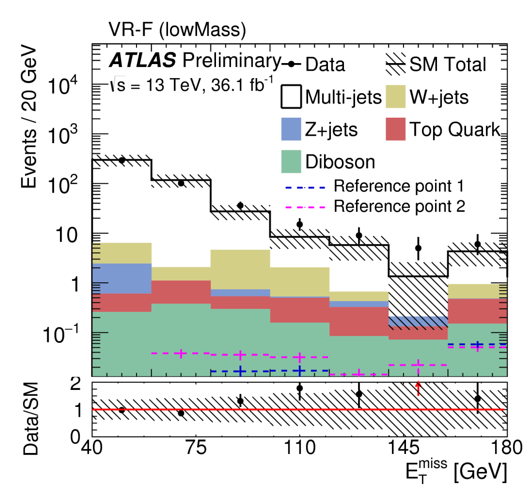
Background estimates

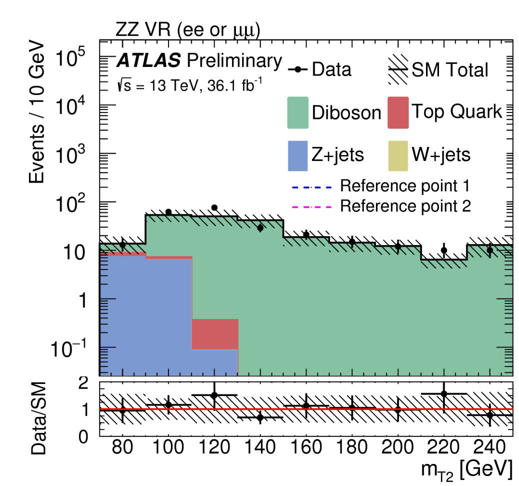
Multijets (mis. taus): Estimated from data

W+jets (mis. taus): Estimated from MC and data

Irreducible background (ttbar, single top, WW, ZZ): Estimated from MC

VRs are defined to validate each background estimation:

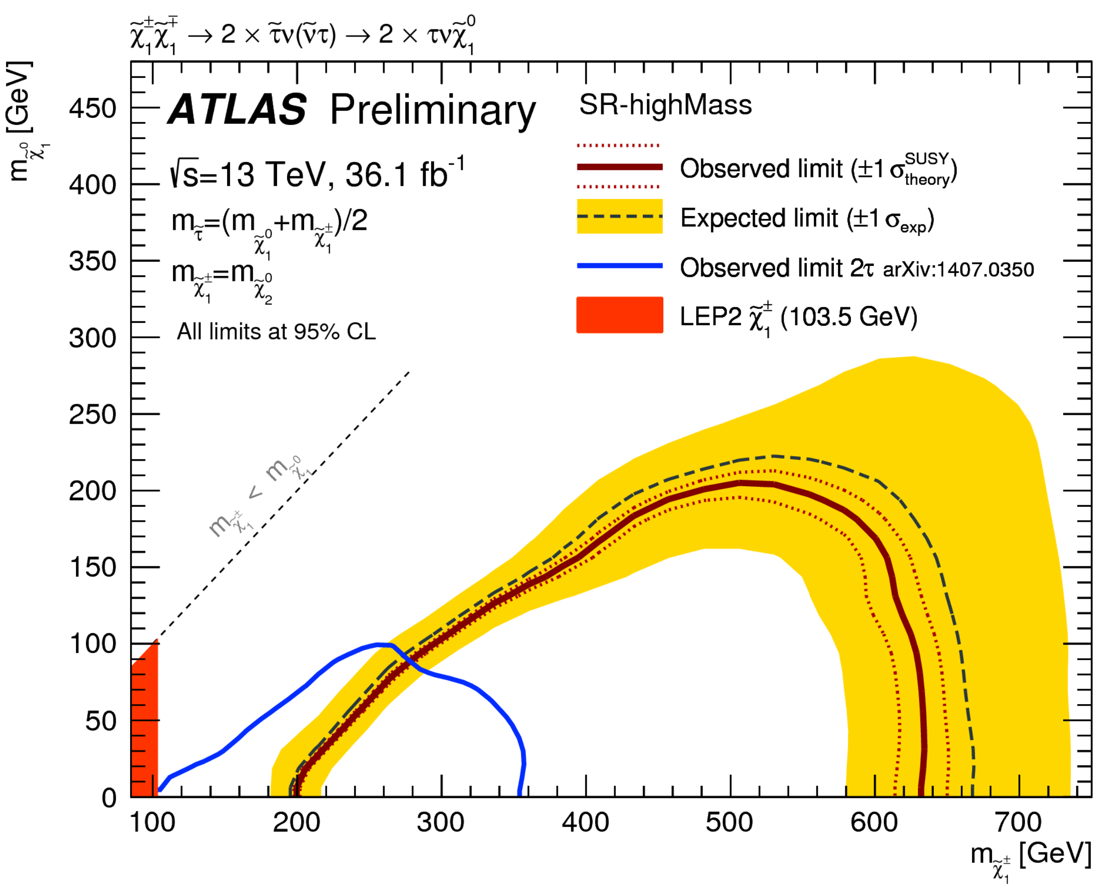


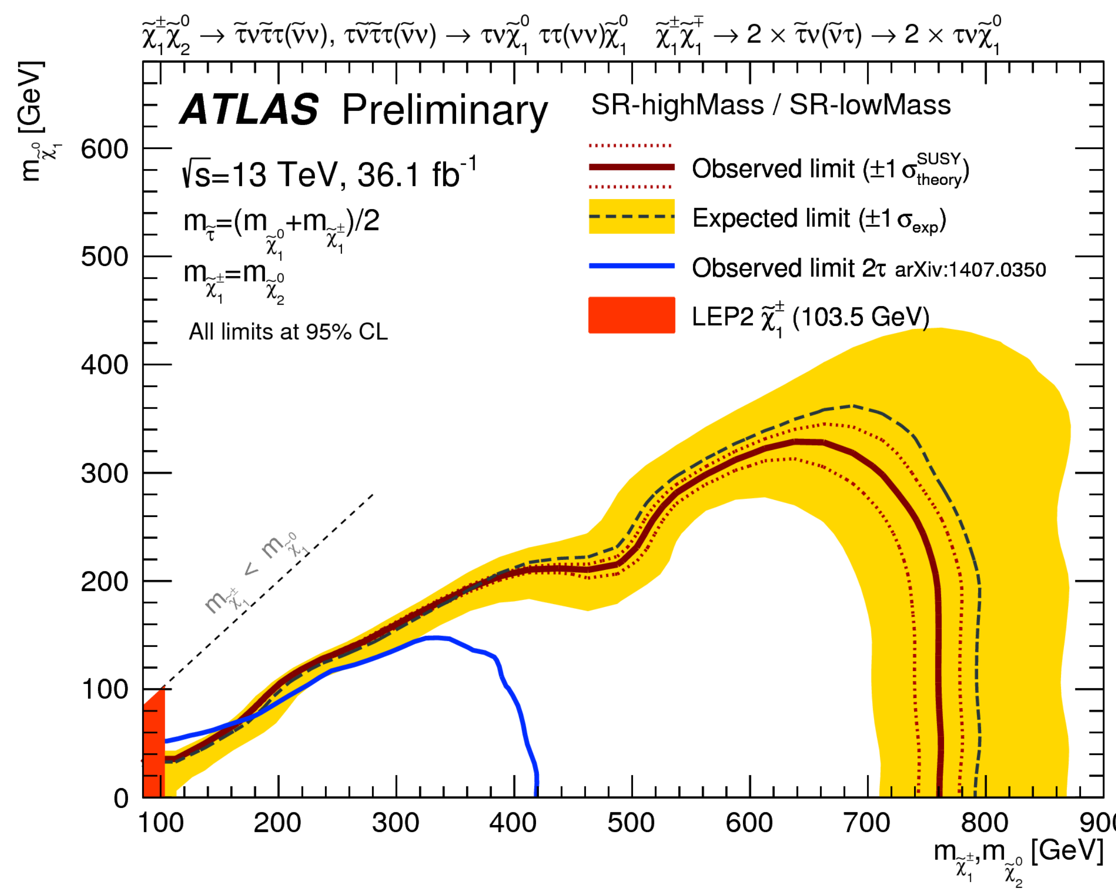


Electroweak production: 2 τ final state

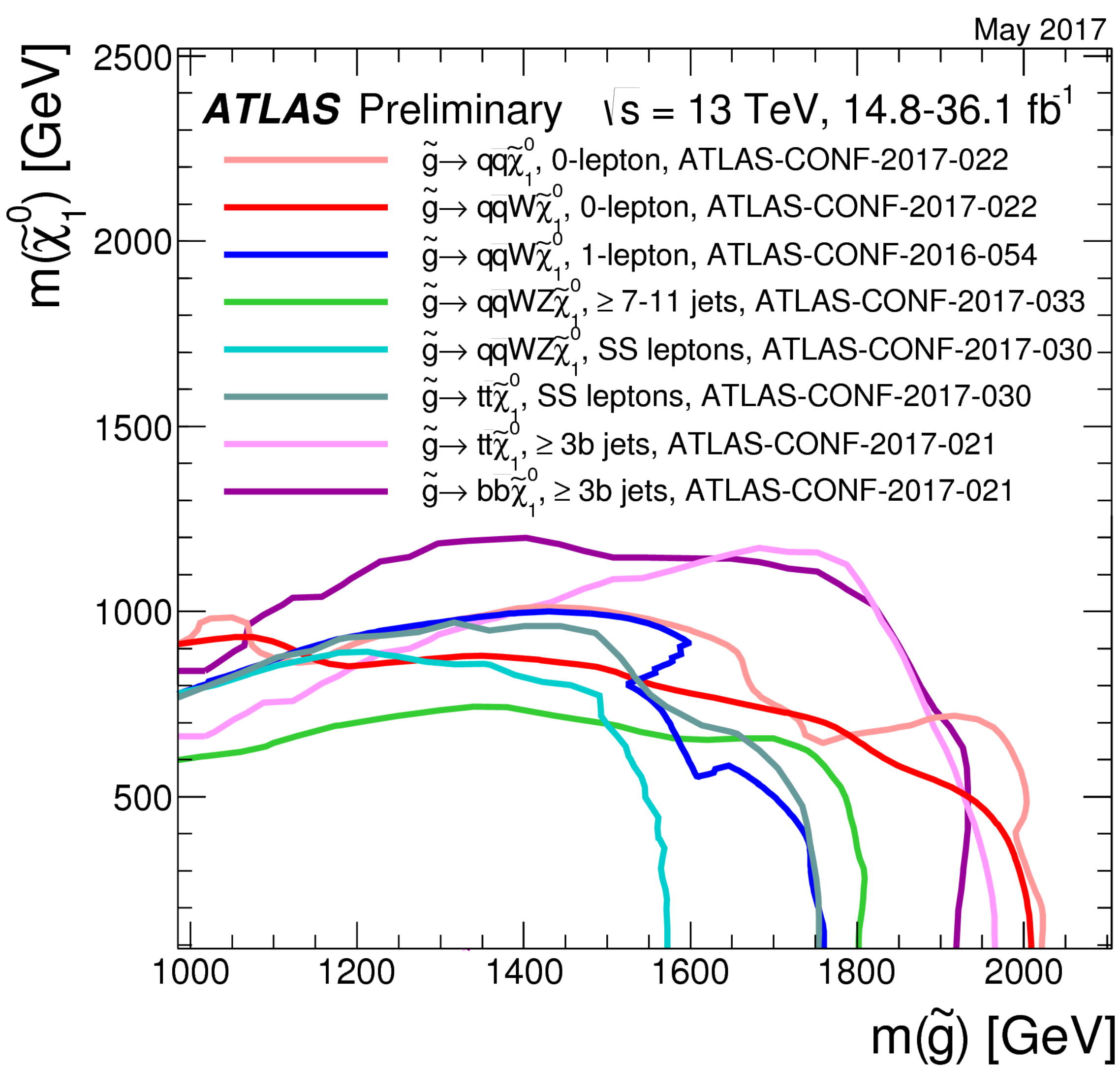
- **2 Signal regions defined** targeting signal model with mass difference between chargino and neutralino smaller or larger than 200 GeV
- No significant excess found
- Chargino/next-to-lightest Neutralino masses up to 630 GeV and 760 are excluded for massless neutralino in the two scenarios

SM process	SR-lowMass	SR-highMass
diboson	5.9 ± 2.2	1.0 ± 0.8
W+jets	1.8 ± 1.1	0.7 ± 0.5
Top quark	1.2 ± 1.0	$0.03^{+0.26}_{-0.03}$
Z+jets	$0.6^{+0.7}_{-0.6}$	0.6 ± 0.5
multi-jet	4.3 ± 4.0	1.3 ± 1.1
SM total	14 ± 6	3.7 ± 1.4
Observed	10	5
Reference point 1	11.6 ± 2.6	11.8 ± 2.8
Reference point 2	10.0 ± 2.1	11.4 ± 2.6
p_0	0.5	0.3
Expected $\sigma^{95}_{\rm vis}$ [fb]	$0.31^{+0.12}_{-0.08}$	$0.17^{+0.08}_{-0.05}$
Observed $\sigma^{95}_{\rm vis}$ [fb]	0.26	0.20

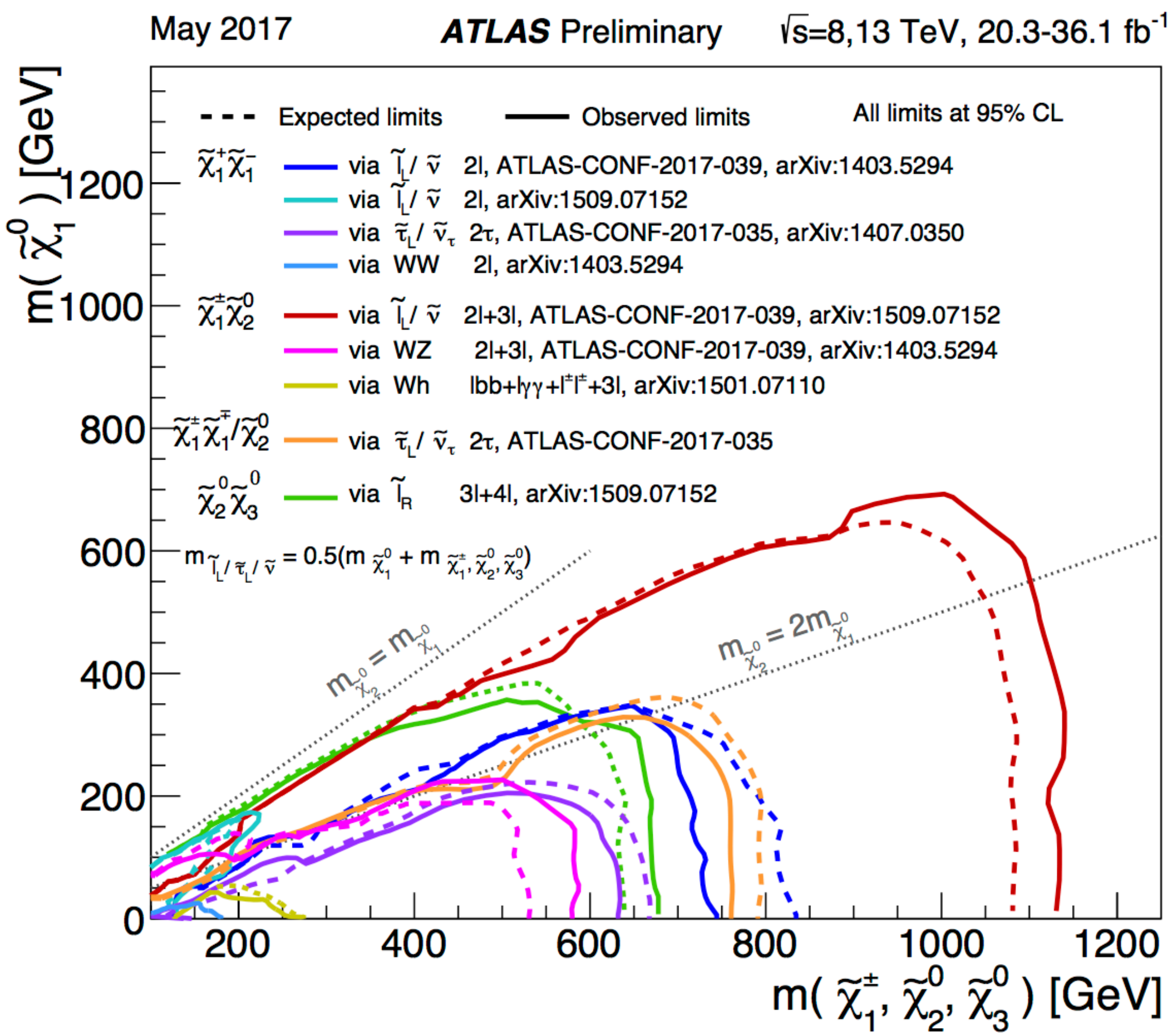




Summary of strong and electroweak production



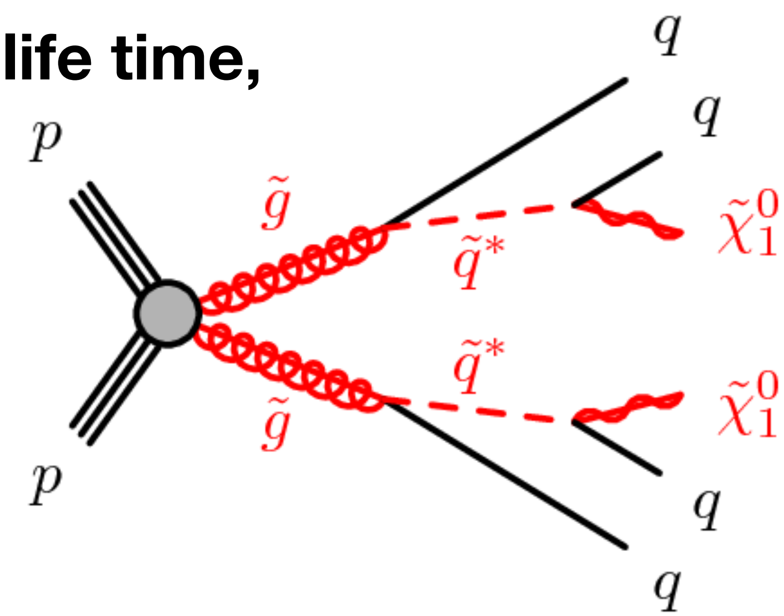
Strong



Electroweak

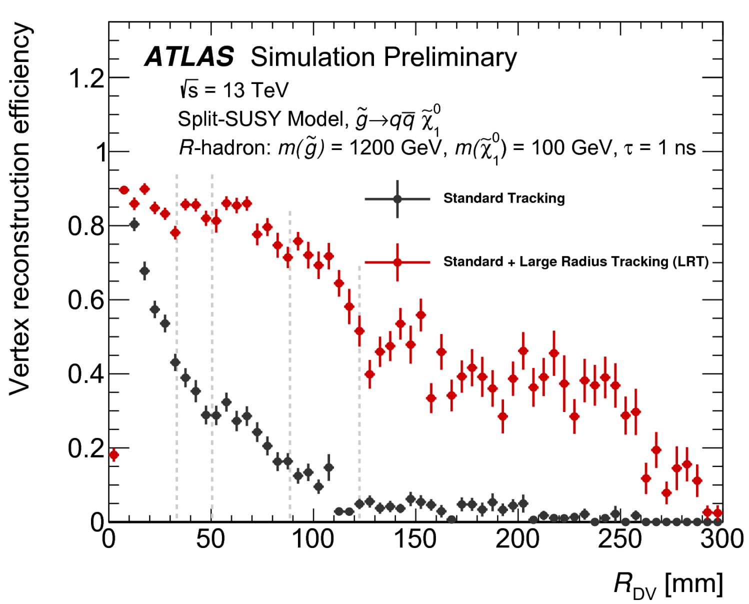
Search for long lived particles: displaced vertices

Several SUSY models foresee sparticles having long life time,
leading to **displaced** vertices

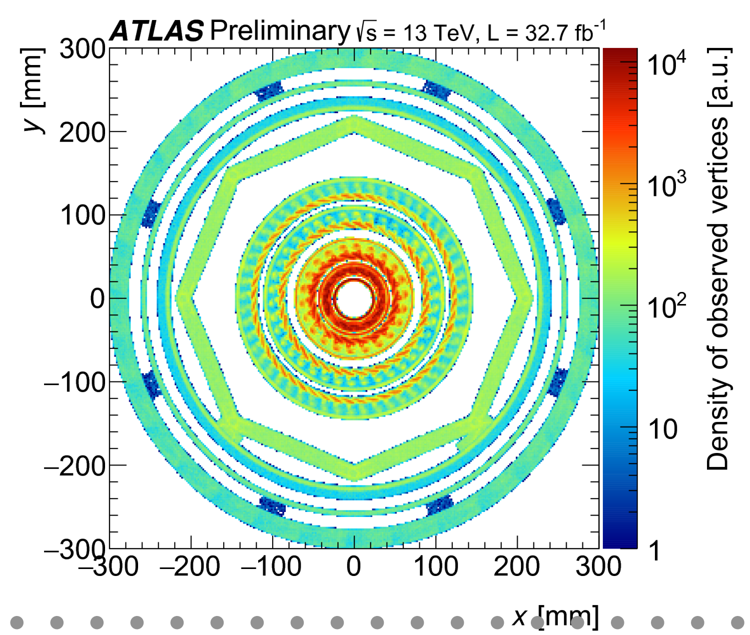


Target:
Gluino production decaying into virtual heavy squark (suppressed decay)

Analysis strategy:
Reconstruction of displaced vertices, accepting tracks up to $|d_0|<300$ mm and $|z_0|<1500$ mm. Minimum invariant mass of selected vertices and missing transverse energy are also required.



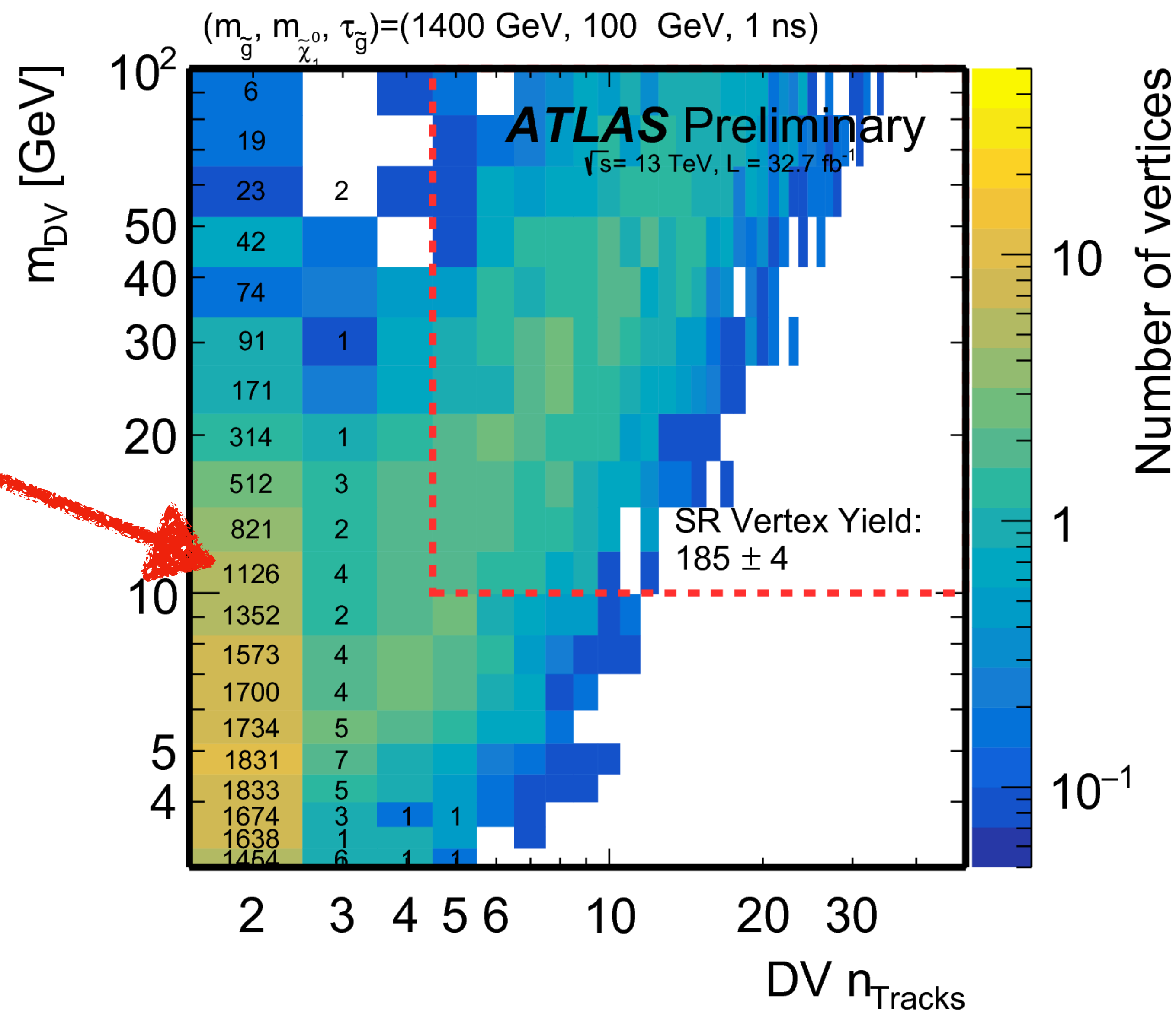
Background:
- Hadronic interactions in the material
- Merged vertices
- Accidental tracks crossing vertices

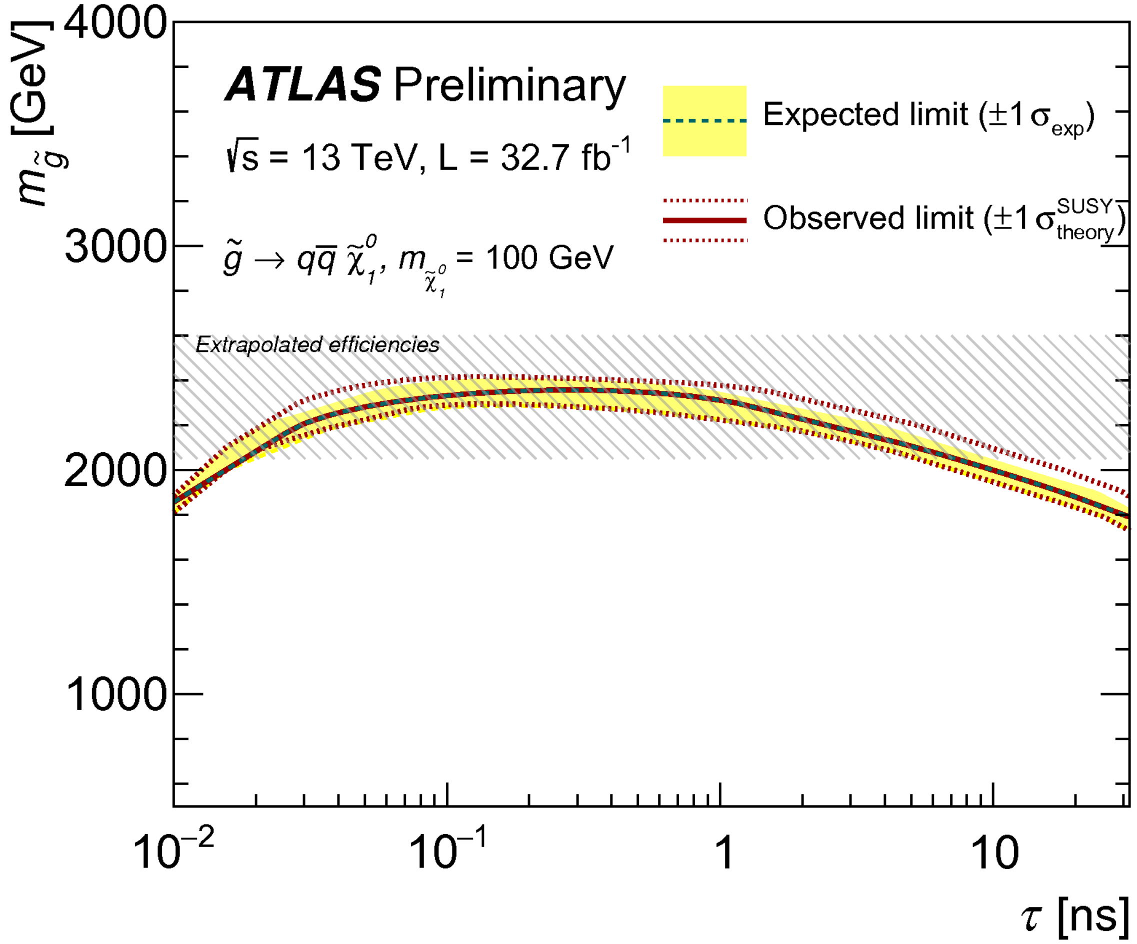


Search for long lived particles: displaced vertices

No events observed,
exclusion limits are derived

Numbers refer to events observed from data, colors refer to the benchmark signal

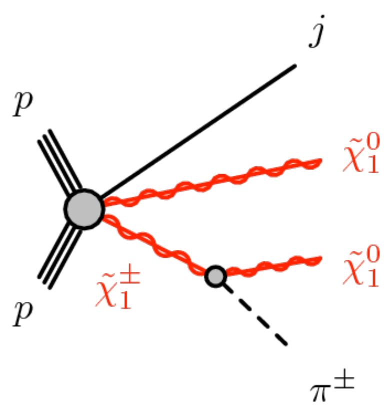


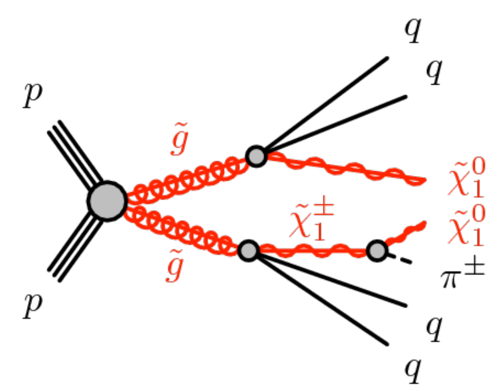


Gluino masses up to 2300 GeV are excluded for LSP mass of 100 GeV and lifetime between 0.02 and 10 ns

Search for long lived particles: disappearing tracks

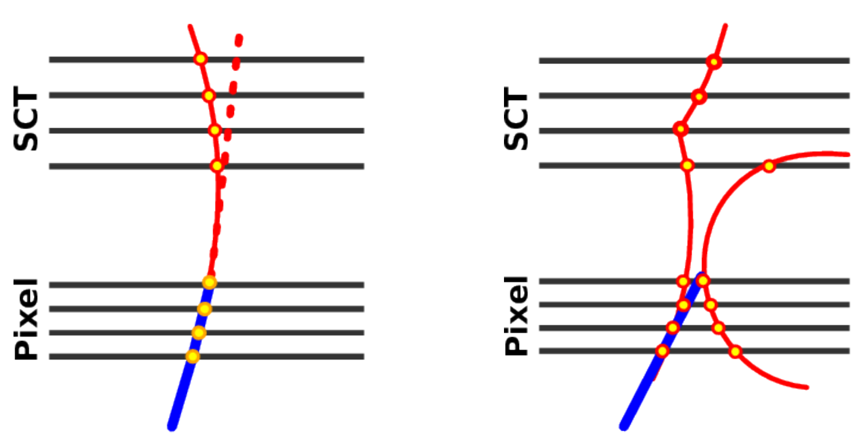
Target:
Long living chargino decaying into pion (not reconstructed) and neutralino

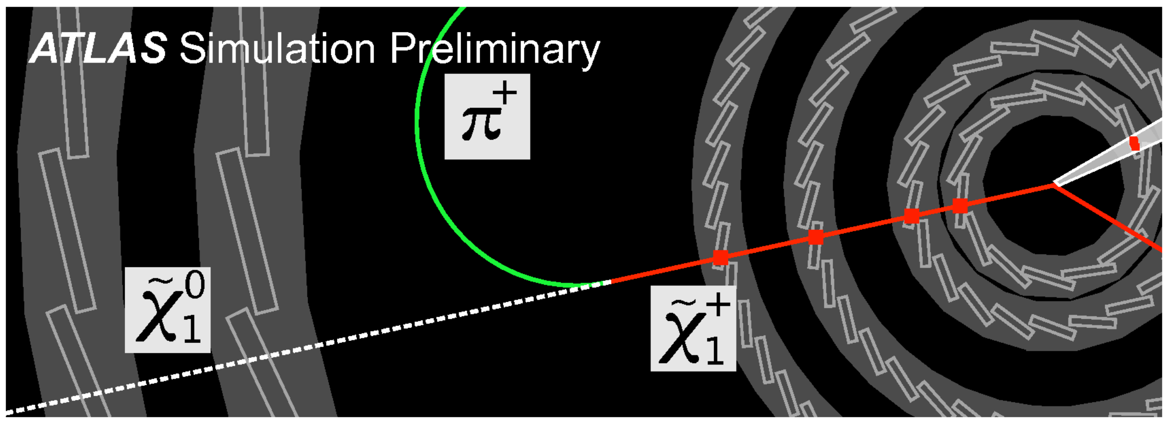




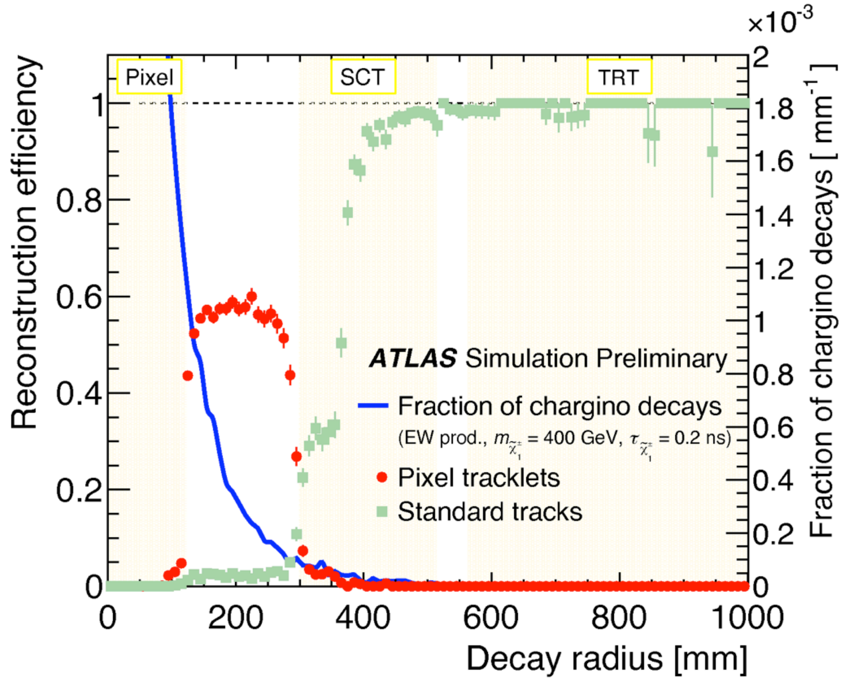
Background:
Interaction in the detector material

- Lepton emitting hard photon radiation
- Random combination of hits

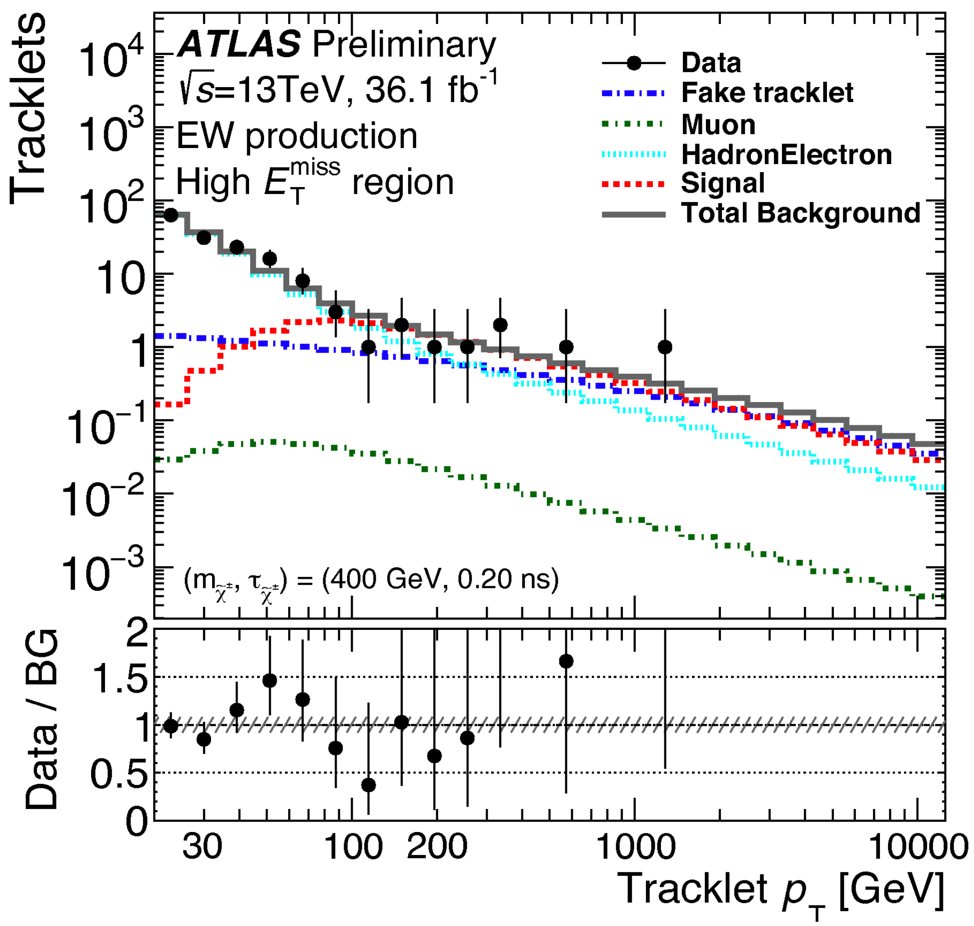




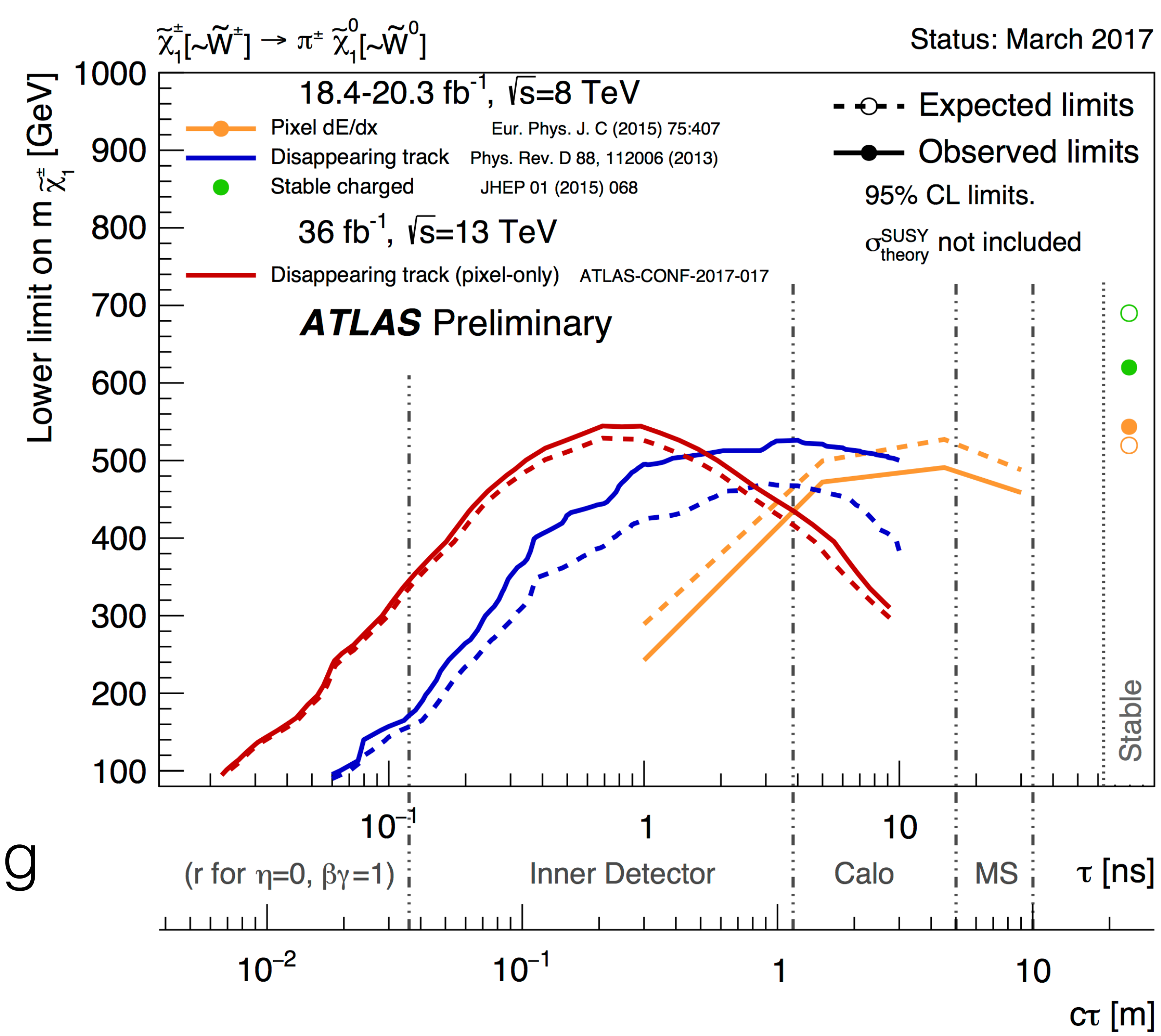
Analysis strategy:
Reconstruction of tracklets based on pixel hits only. To reject background, jet activity and missing transverse energy also required



Search for long lived particles: disappearing tracks



No excess observed,
exclusion limits are derived



Chargino masses up to 430 GeV are excluded for lifetime of 0.2 ns, corresponding to a mass splitting of 160 MeV

Summary and conclusions

- **Many SUSY searches foresee LSP dark matter candidates as final state**
- **Only few analyses have been discussed, much wider panorama (see next slide)**
- **No significant excess found so far, but:**
  - **Full Run 2 dataset will provide more insight in many unexplored SUSY scenarios**
  - **More complex tools and analysis strategies are being implemented**

Summary and conclusion