LAKE LOUISE WINTER INSTITUTE

Wednesday 22nd February 2017

Search for Supersymmetry in scenarios with electroweakly produced particles, R-parity violating signatures, or long-lived states

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on behalf of the ATLAS Collaboration

University of Sussex

ATLAS EXPERIMENT

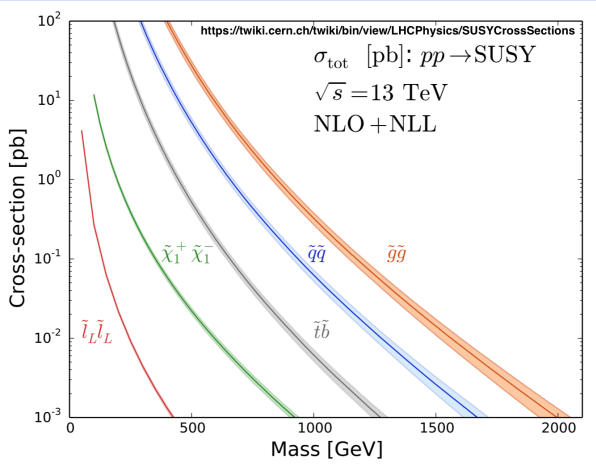
Electroweak, RPV and long lived SUSY in ATLAS

- ATLAS has a program of searches for SUSY models that covers a broad variety of experimental signatures. I will focus on **13 TeV** results.

ELECTROWEAK SUSY

Direct production of neutralinos or charginos.

Dominant if other particles are heavier.



RPV SUSY

No R-parity conservation:

$$R = (-1)^{3(B-L)+2S}$$

Lightest Supersymmetric Particle (LSP) can be charged or unstable.

Sparticles can decay into SM quarks or leptons.

The final states can have no missing transverse momentum (E_T^{miss}).

LONG LIVED SUSY

Drop the assumption that BSM particles have a short lifetime.

Long lived particles travel a finite distance before decaying.

Dedicated analysis strategies are required.

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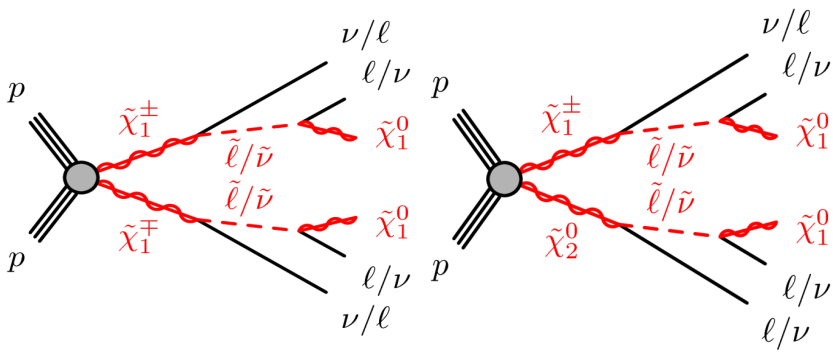
Electroweak SUSY: RPC 2-3 leptons

ATLAS-CONF-2016-096

- Pair production of charginos, or chargino and next-to-lightest neutralino.



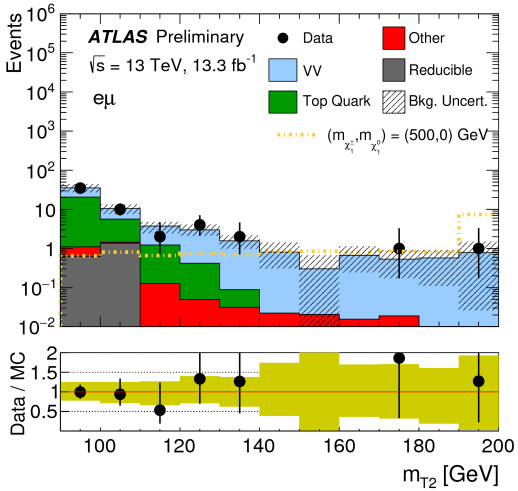
- **2 lepton channel**: Signal Regions (SRs) with 3 m_{T2} thresholds.
- **3 lepton channel:** 2 SRs for intermediate and high masses.
- Dominant background from dibosons.

THE STRANSVERSE MASS (m_{T2})

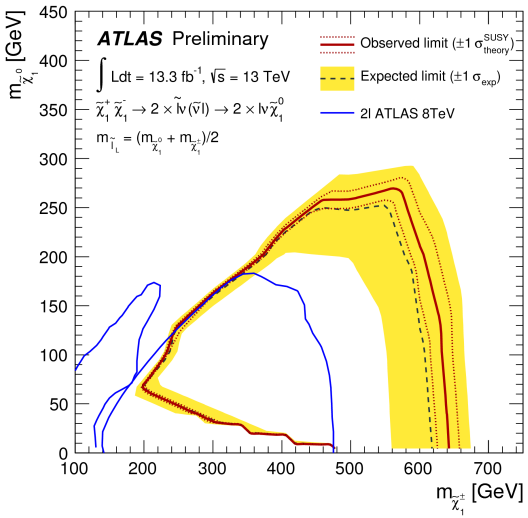
$$m_{T2}^2(p_1, p_2, E_{miss}^T) = \min\left\{\max\left[m_T^2(p_1, v_1), m_T^2(p_2, v_2)\right]\right\}$$

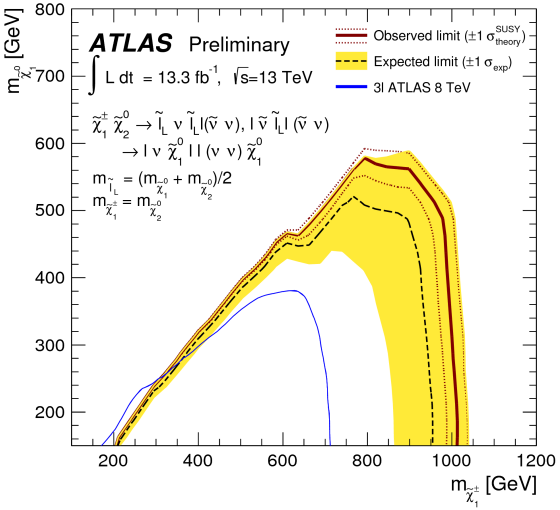
Minimize among decompositions of E_t^{miss} in v_1 and v_2.

Kinematic endpoint in pair produced backgrounds.



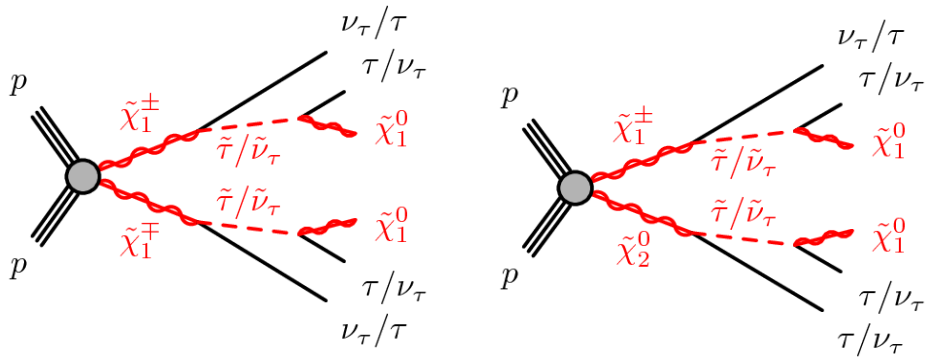
arXiv:hep-ph/0304226v1

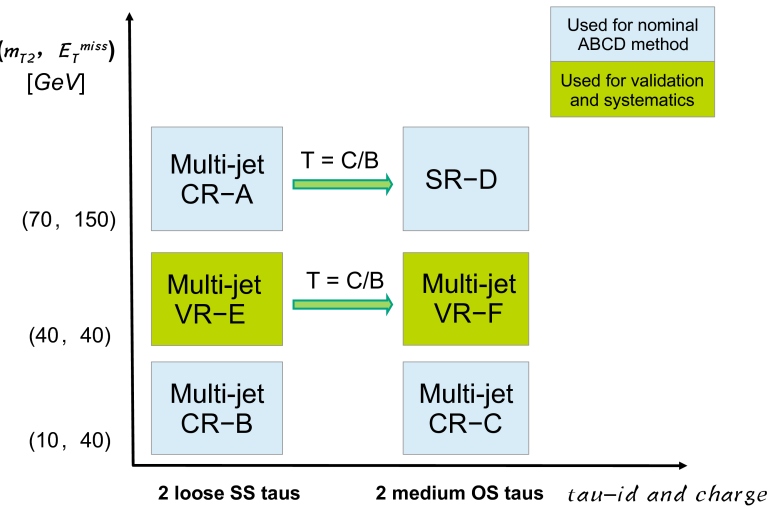




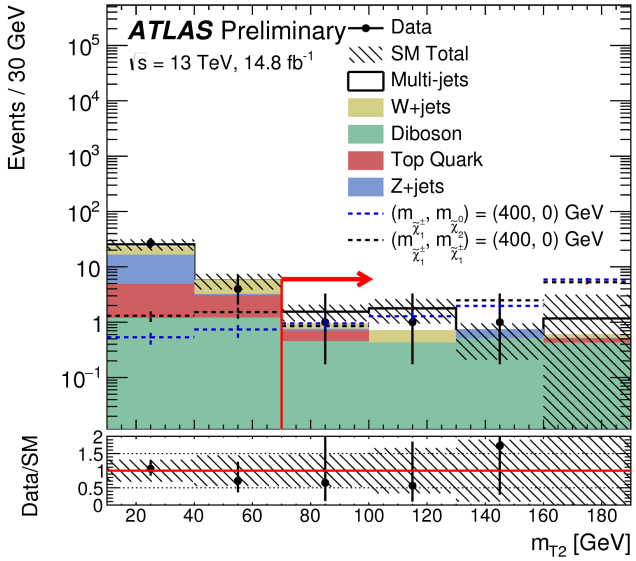
Electroweak SUSY: RPC τ decays

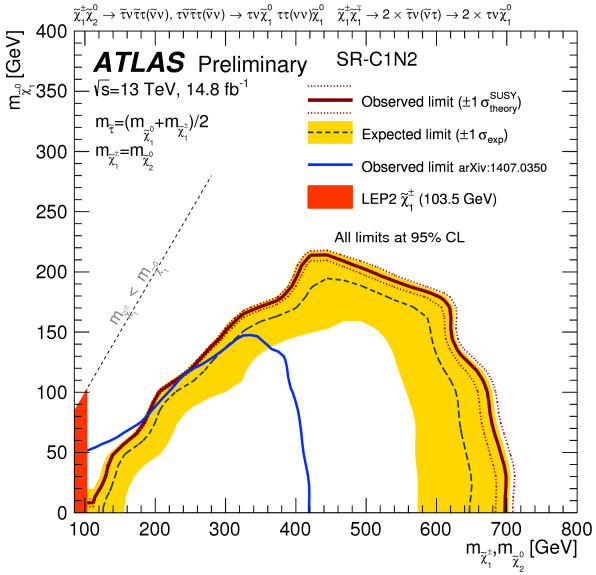
ATLAS-CONF-2016-093





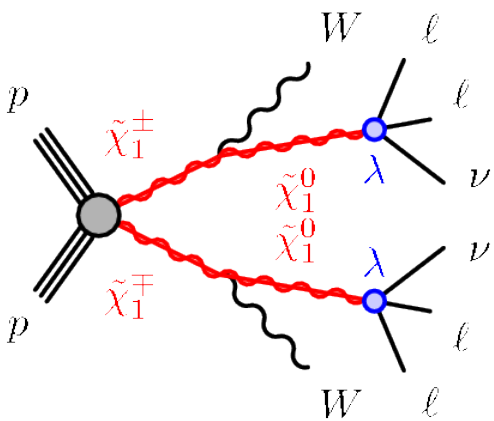
- SRs with ≥2 hadronic τ, E_t^{miss} and m_{T2}.
- Data driven estimate of fake taus from multijets.
- m_{T2} rejects the top pair background.
- Chargino and next-to-lightest neutralino excluded up to 700 GeV.



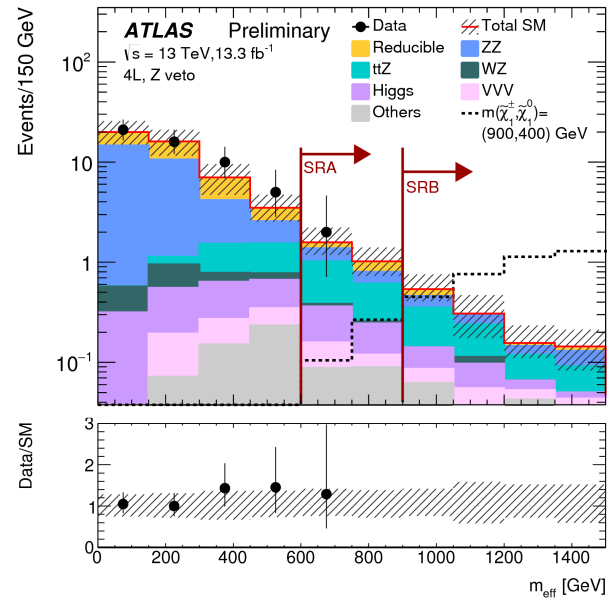


Electroweak SUSY: RPV 4 leptons

ATLAS-CONF-2016-075



- RPV decay of the neutralino into leptons.
- SRs with ≥4 leptons (e/μ).
- Background from top pairs plus 2 fake leptons.

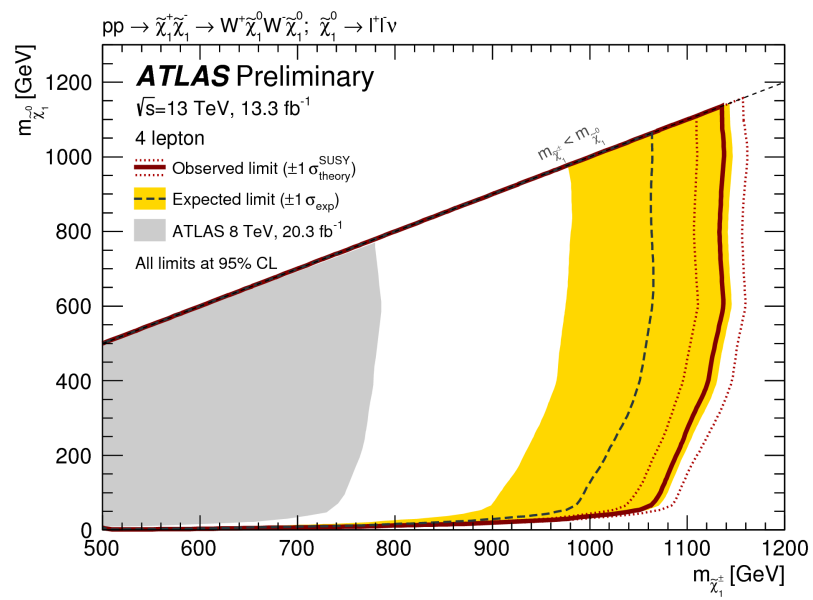


FAKE FACTOR METHOD

- Use fake-dominated Control Region defined as SR with loose lepton quality.

$$N_{red}^{SR} = \left[N_{data}^{CR} - N_{irr.1\,fake}^{CR} \right] \times F_{w,1} \times F_{w,2}, \quad F = f_S / f_L$$

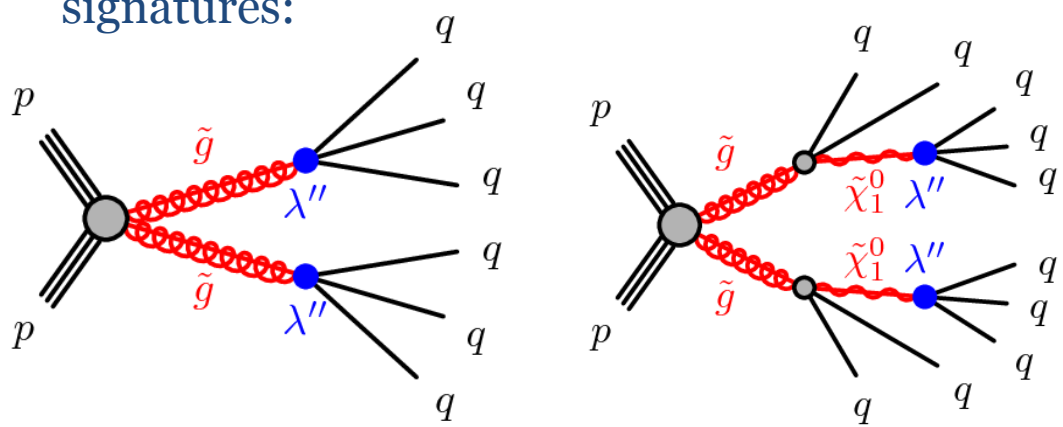
$F_{w,1}$ and $F_{w,2}$ are fake factors: ratios of the probabilities that a reconstructed object is misidentified as a signal or loose lepton.



Strong RPV SUSY: multijets

ATLAS-CONF-2016-057

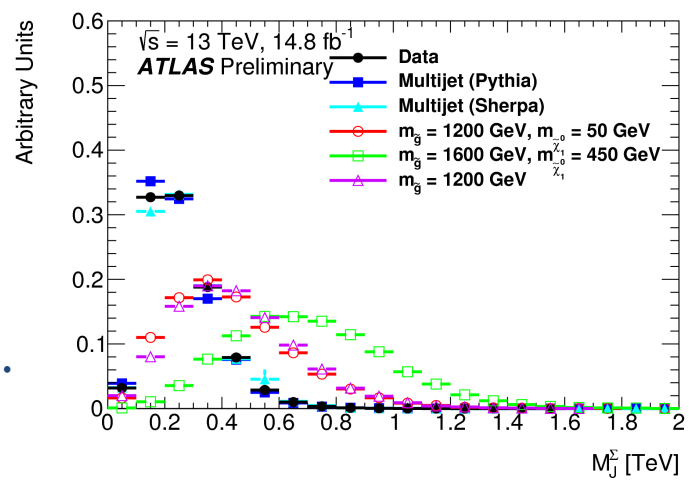
- RPV decays into quarks yielding multijet signatures:



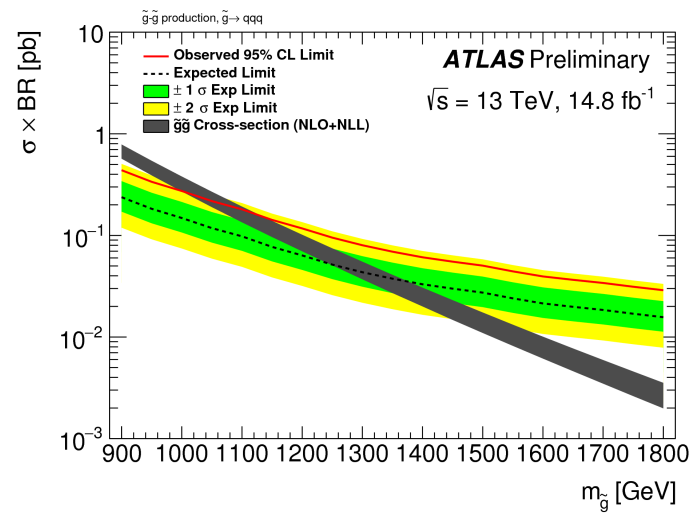
- Reconstruct at least 3 jets with large radius. The sum of their masses is used as discriminant:

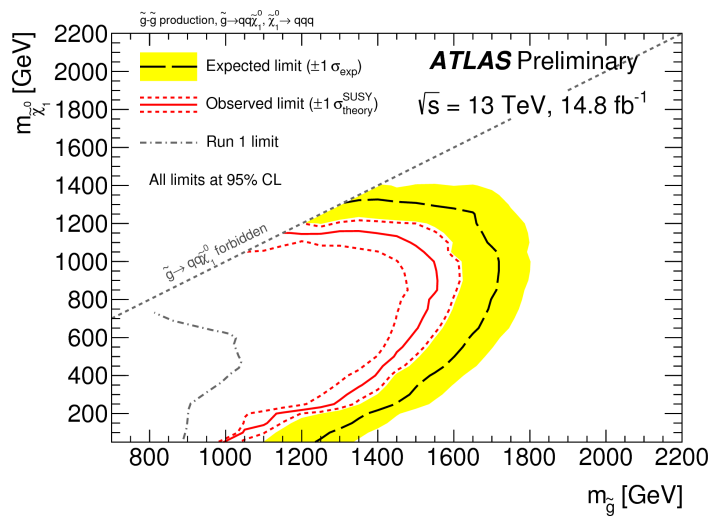
$$M_J^{\Sigma} = \sum_{p_T > 200\,GeV}^{4} m_{jet}$$

- Data driven jet mass templates applied in the SRs.



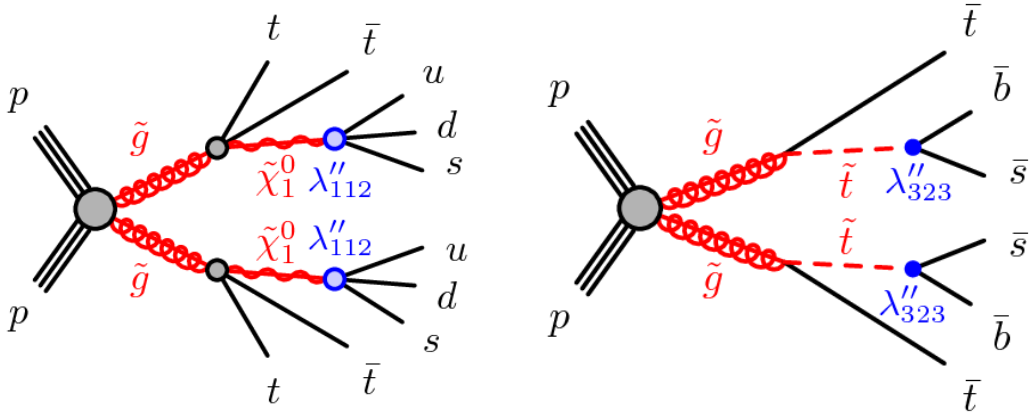
- Strong limits due to large gluino cross section:





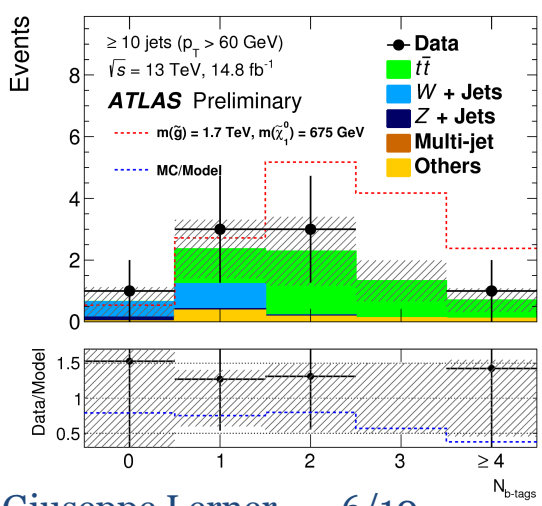
Strong RPV SUSY: multijets 1-lepton

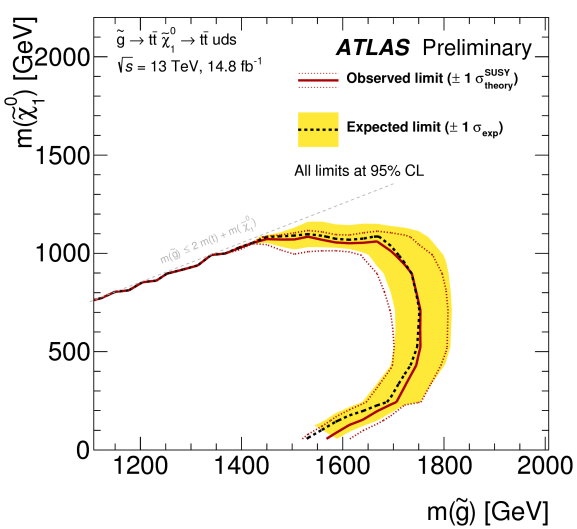
ATLAS-CONF-2016-094

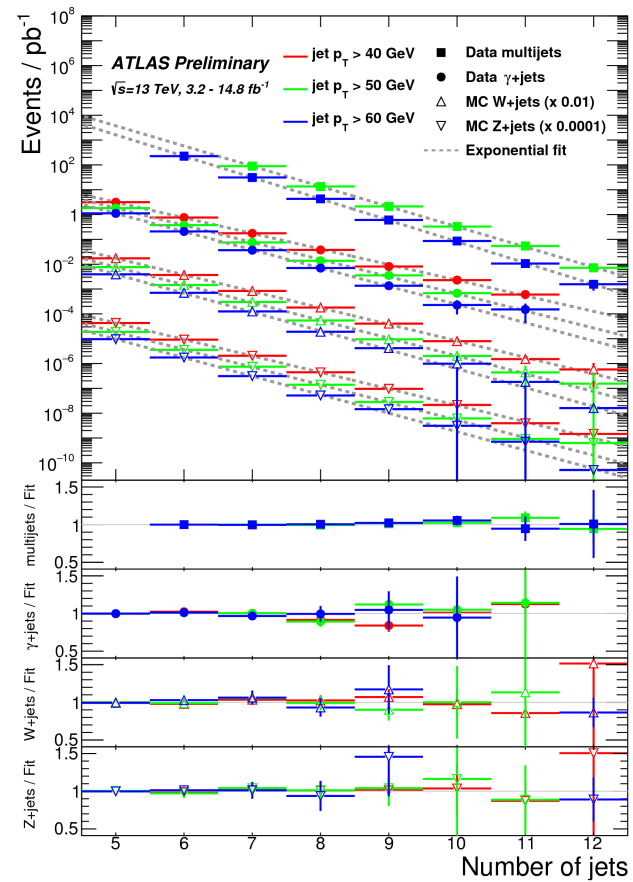


Templates of b-tag distributions extrapolated from 5-6 jet bins using a parametrization of N_{jets}.

- Final states with many jets and b-quarks.
- 1-lepton SRs binned in number of jets and b-tags: dominant backgrounds from top and W+jets.



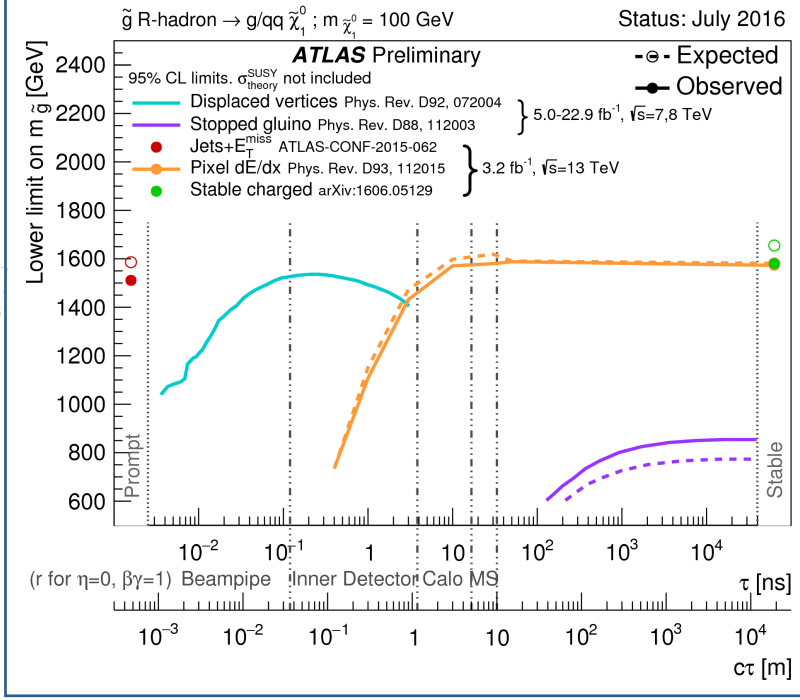




Long Lived Particles (LLPs)

SUSY particles with non negligible lifetime compose R-hadrons that travel before decaying.

Limits on gluino mass and lifetime.

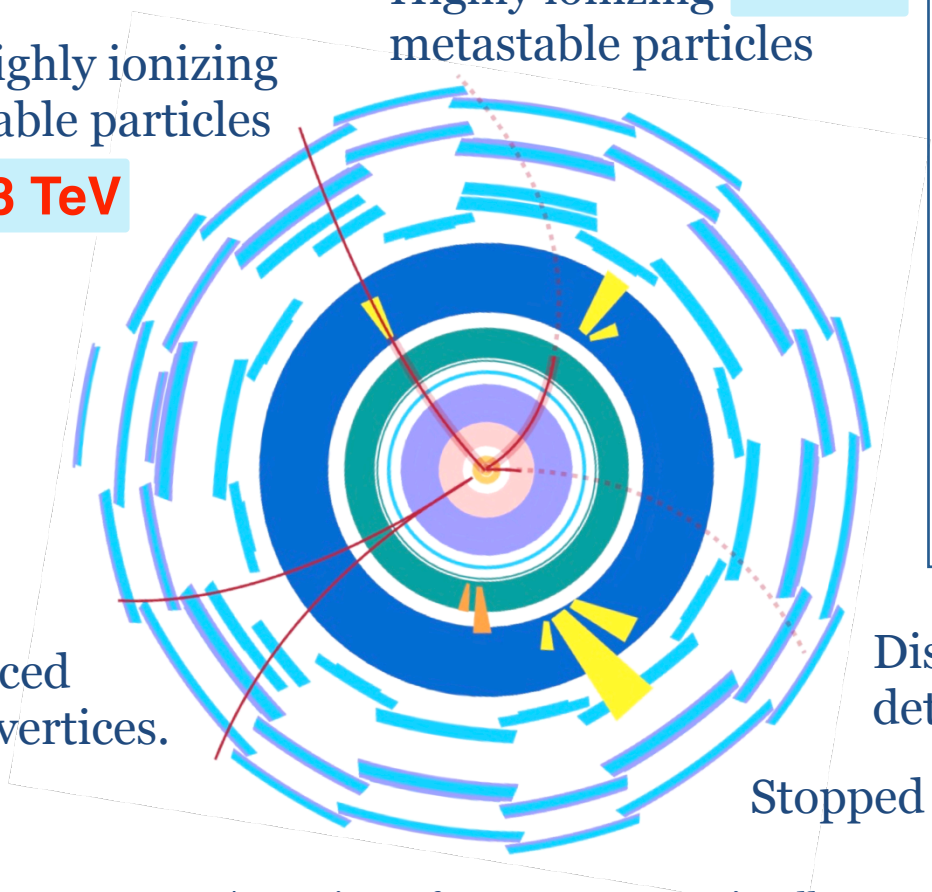


Highly ionizing metastable particles

13 TeV

Highly ionizing stable particles

13 TeV



Displaced decay vertices.

Disappearing tracks in the inner detector

Stopped particles in the calorimeters

 Figure from Laura Jeanty's talk at ICHEP 2016

Metastable particles: pixel dE/dx

Phys. Rev. D 93, 112015

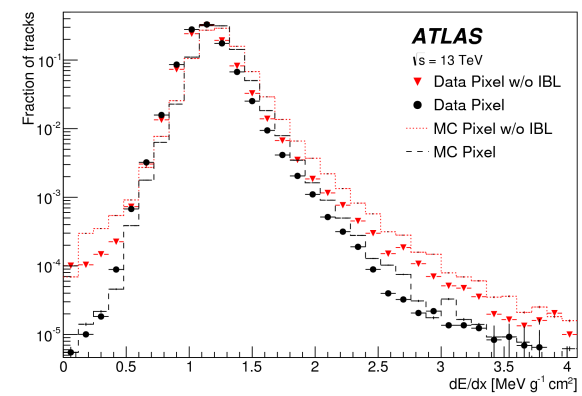
Signal: $\tilde{g} \rightarrow qq\tilde{X}_1^0$ with lifetime range 0.5-50 ns.

Measure **track dE/dx** from ionization in ID pixels.

Extract the **R-hadron mass** from dE/dx and track p_T using a calibrated Bethe-Bloch:

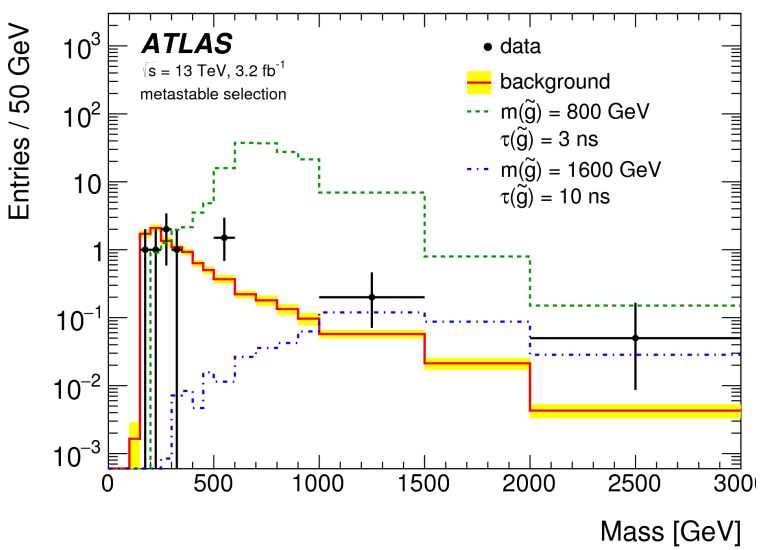
$$(dE/dx)_{MPV} = \frac{p_1}{\beta^{p_3}} \ln\left[1 + (p_2\beta\gamma)^{p_5}\right] - p_4 \qquad m = p/\beta\gamma$$

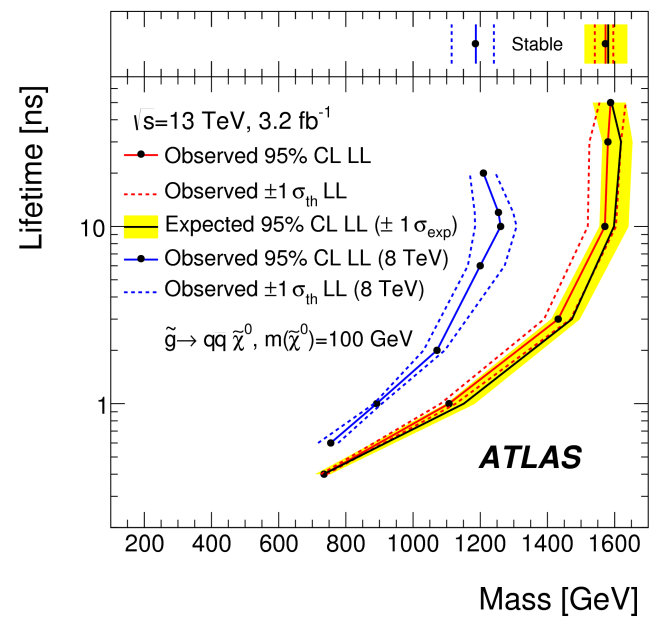
Reduced dE/dx tails in Run 2 thanks to the IBL.



2 SRs with E_t^{miss} trigger, no excess observed.

Background from merged clusters of multiple tracks.



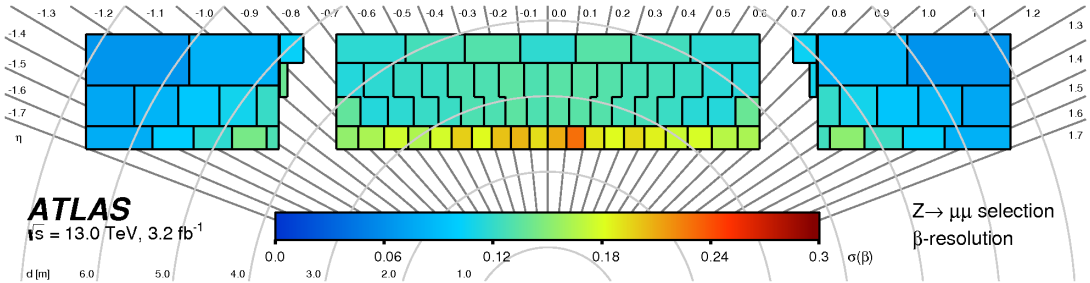


Stable particles: dE/dx and time measurement

Physics Letters B 760 (2016), pp. 647-665

Similar to the dE/dx analysis.

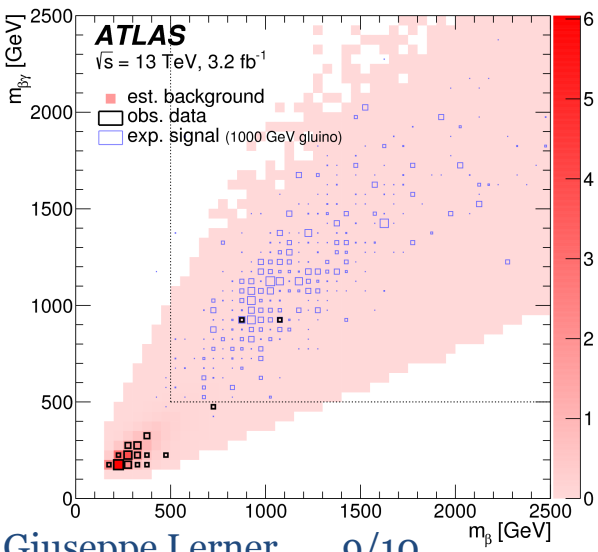
Expect β <1 for heavy stable particles.

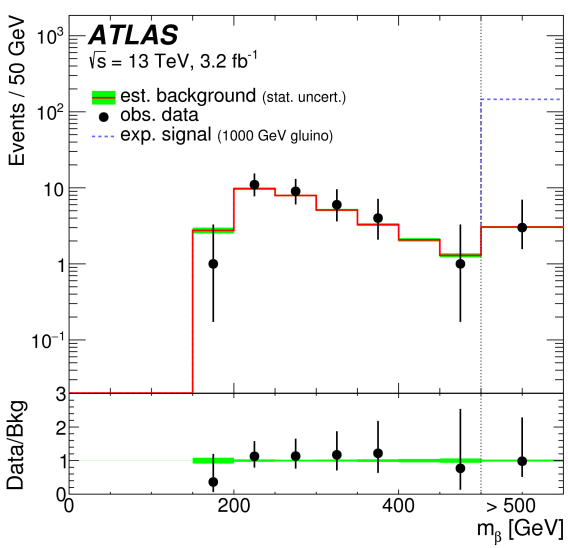


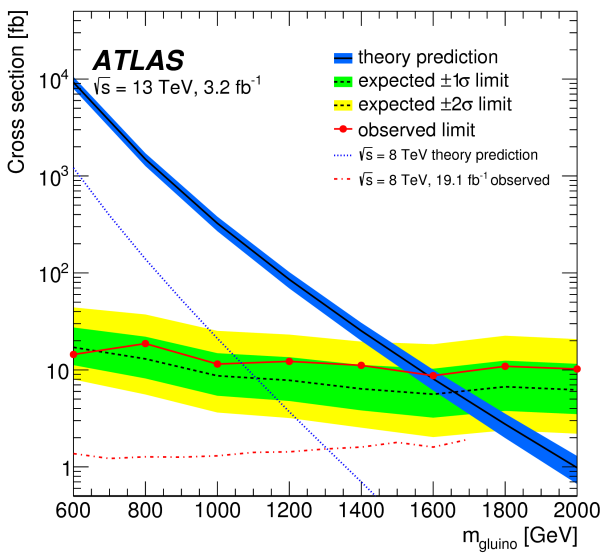
Measure β using the time of flight from the interaction point to the tile calorimeter.

2 mass estimates used to define SRs: from dE/dx ($m_{\gamma\beta}$) and from β (m_β).

Strong limits on stable gluino, stop and sbottom benchmark models.

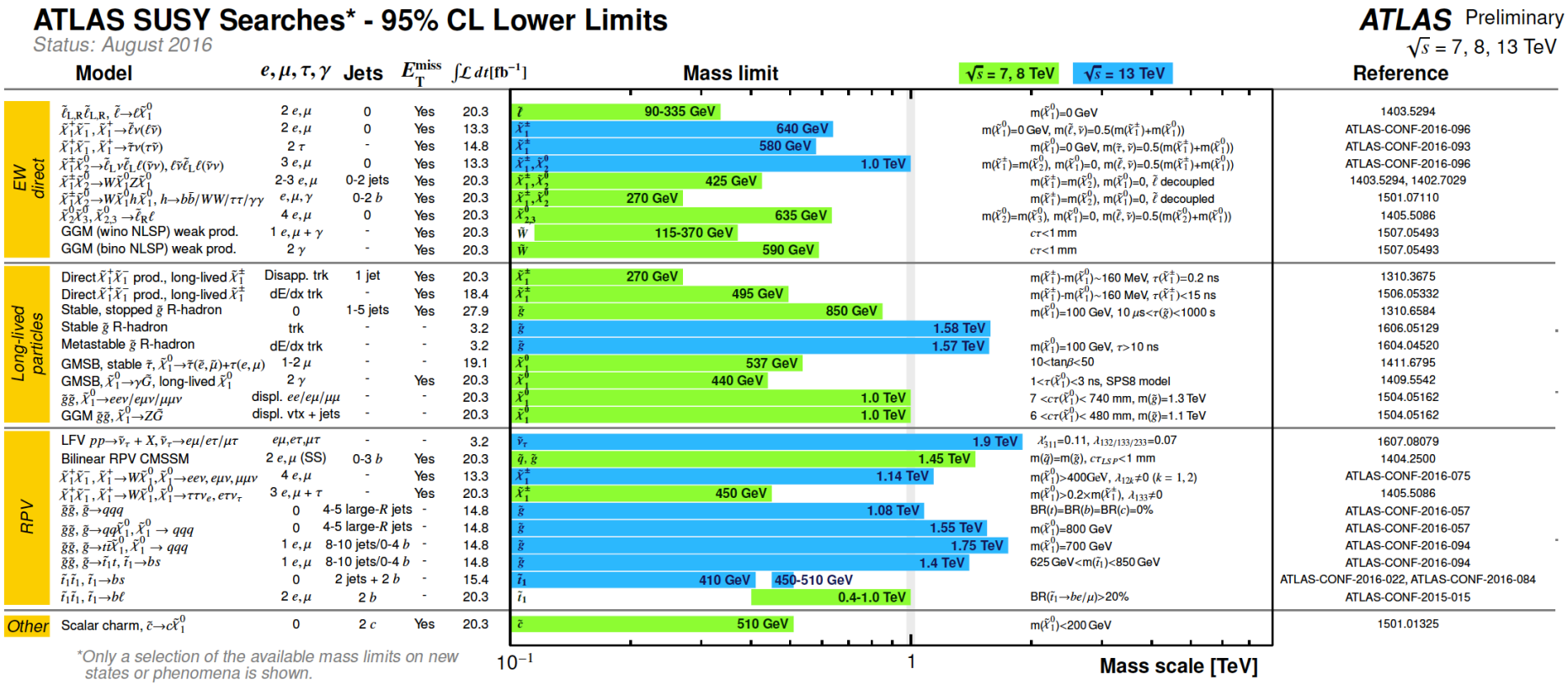






Summary

- No significant excess in the first results at √s=13 TeV.
- Uncovered: RPV stop in 4-jet final state, ATLAS-CONF-2016-084 (in Merve Sahinsoy's talk).
- Ongoing studies to target different scenarios: more results will appear soon.



BACKUP

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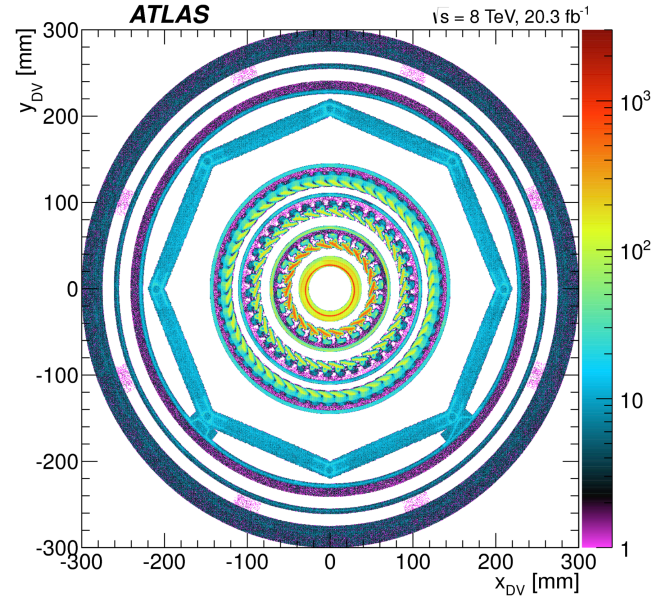
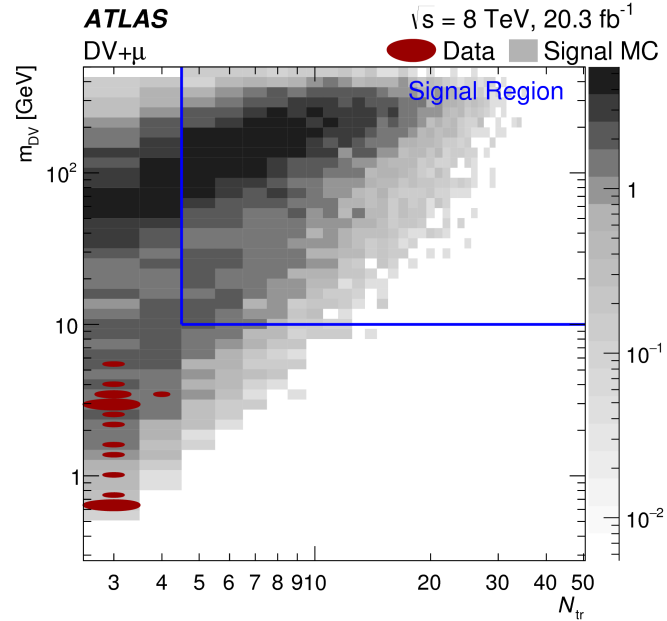
Displaced vertices analysis (Run 1)

Phys. Rev. D 92, 072004 (2015)

- Target lifetimes of the order of the ns.
- Reconstruct a Displaced Vertex (DV) in the ID, excluding volumes occupied by material.
- Run dedicated tracking algorithms to increase signal efficiency by adding extra tracks.
- **2 vertex types:** multitrack (>4 charged tracks) or dilepton.
- **4 analysis channels:** DVs with decays into photons, leptons (e/μ) and jets.
- Main backgrounds: low-m_{DV} vertices accidentally crossed by a track, merged vertices, accidental lepton crossings.





Strong RPV SUSY: 3rd generation stop 2x2

ATLAS-CONF-2016-084

- Pair production of stop quarks or colorons decaying into two jets. Signature with 4 high-P_T jets: dominant multijet background estimated with an data driven method.
- Pairing algorithm to identify jets from the same leg based on their angular distance.
- SR with small mass asymmetry between the two reconstructed jet pairs, $A = |m_1 - m_2|/(m_1 + m_2)$
- The signal appears as a peak in $m_{avg} = (m_1 + m_2)/2$.