Searches for strong production of SUSY with ATLAS

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On behalf of the ATLAS Collaboration

University of Illinois Urbana-Champaign

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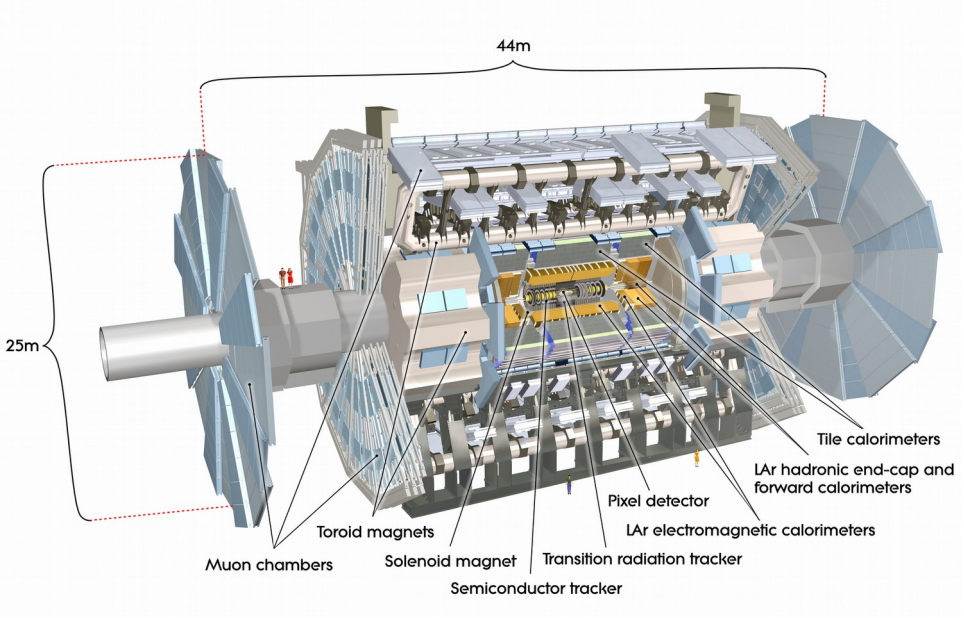
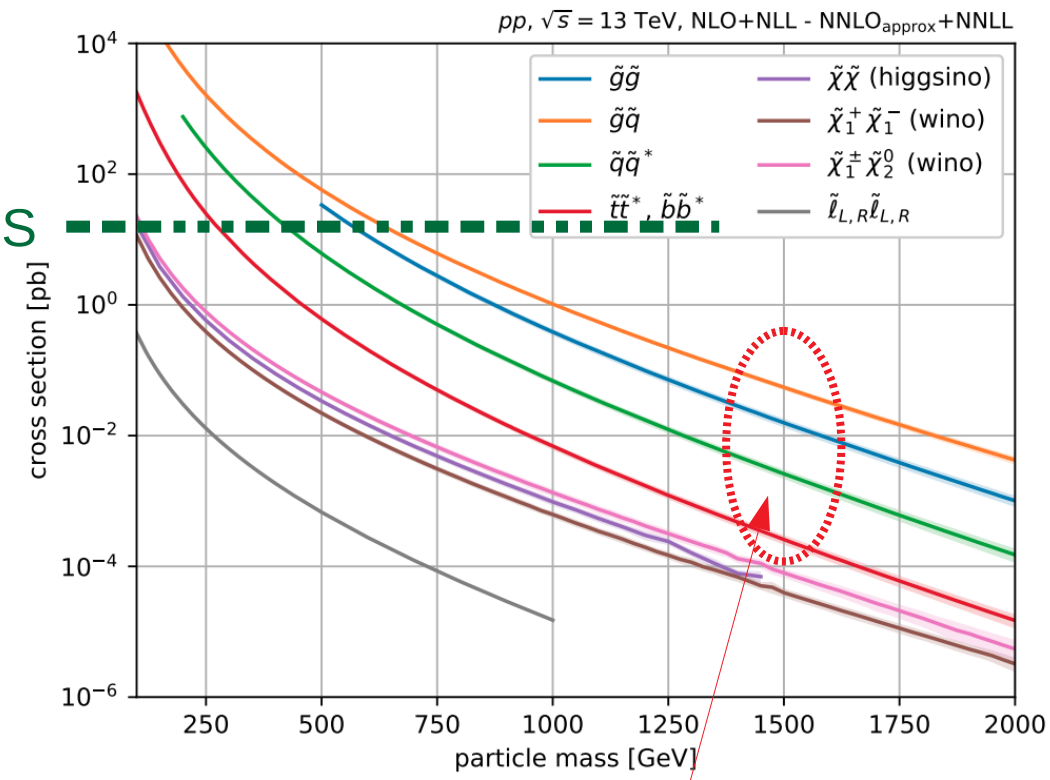
LLWI 2020

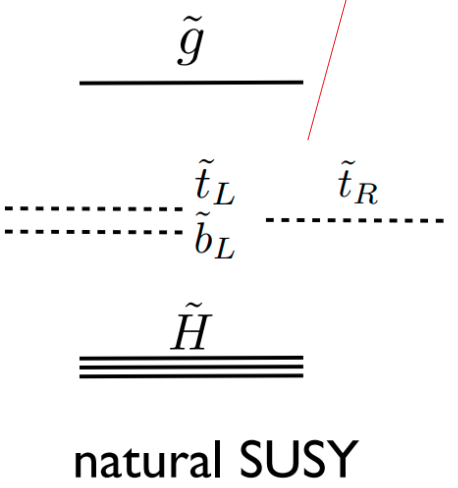
Strong SUSY at the LHC



SUSYCrossSections



Higgs boson XS

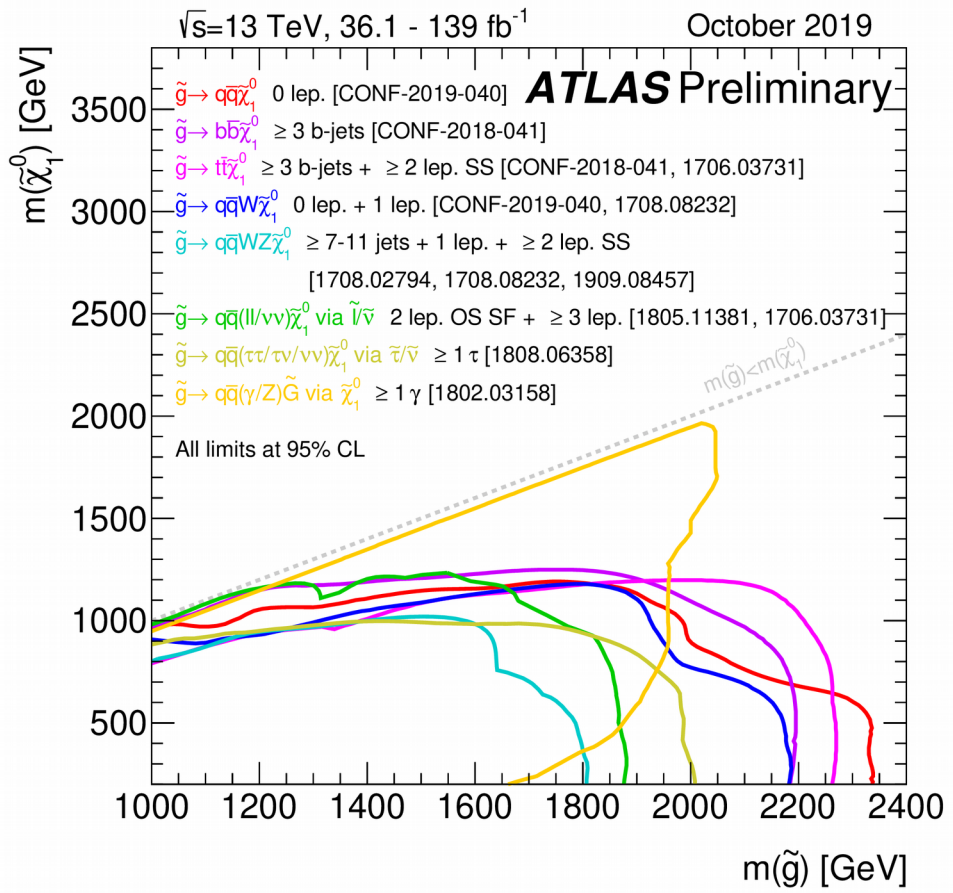


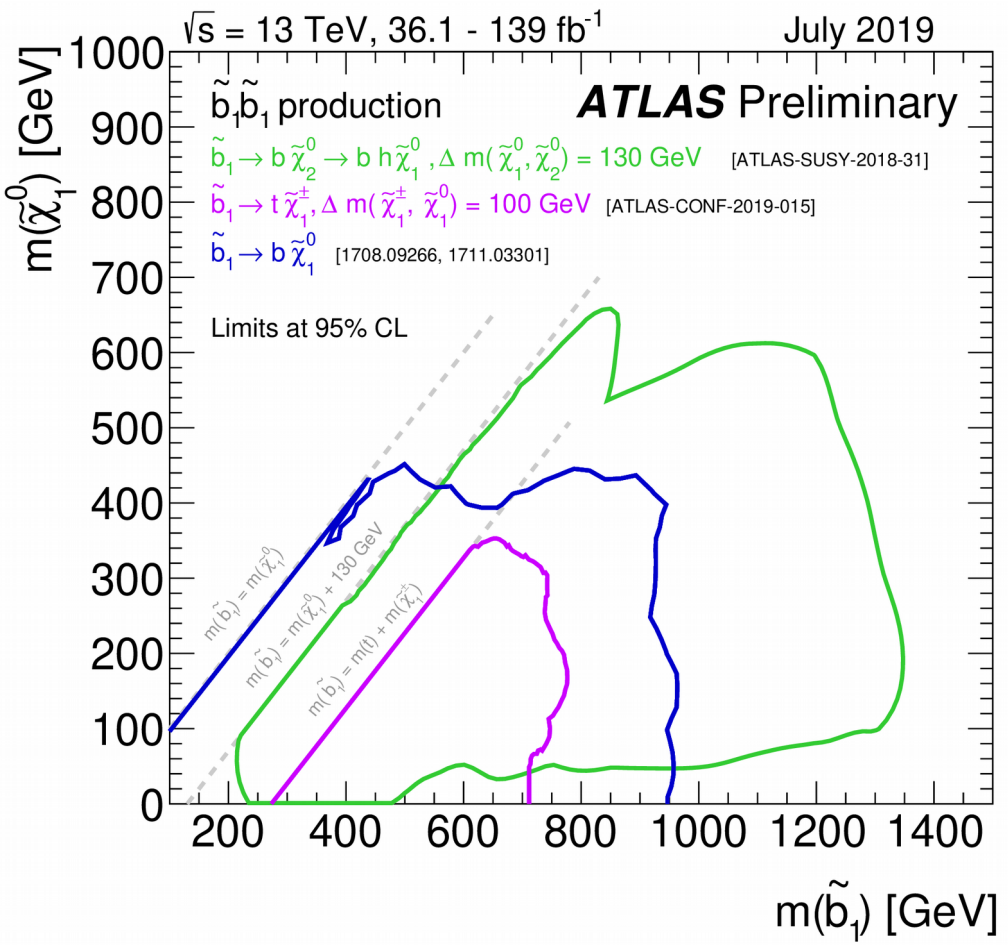
natural SUSY

Generally searching for events with jets, missing momentum (MET), and sometimes other high momentum objects.

Limits on prompt, strongly-produced SUSY

ATLAS SUSY Public Results

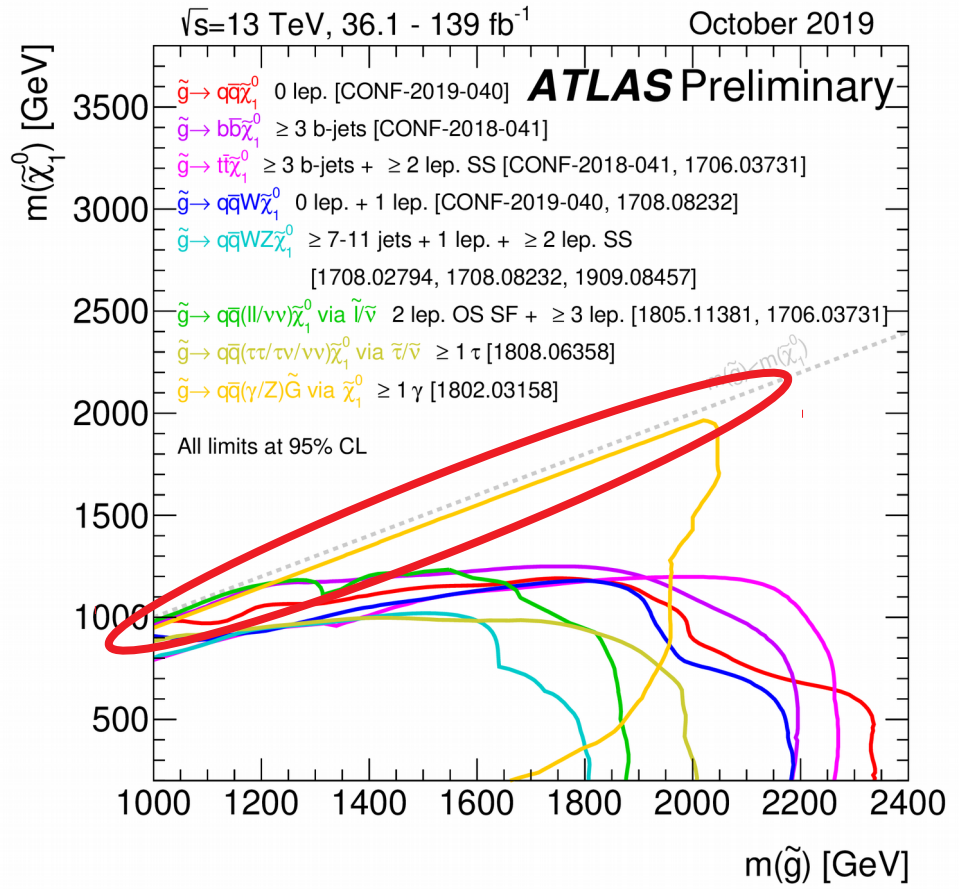




Where to focus...

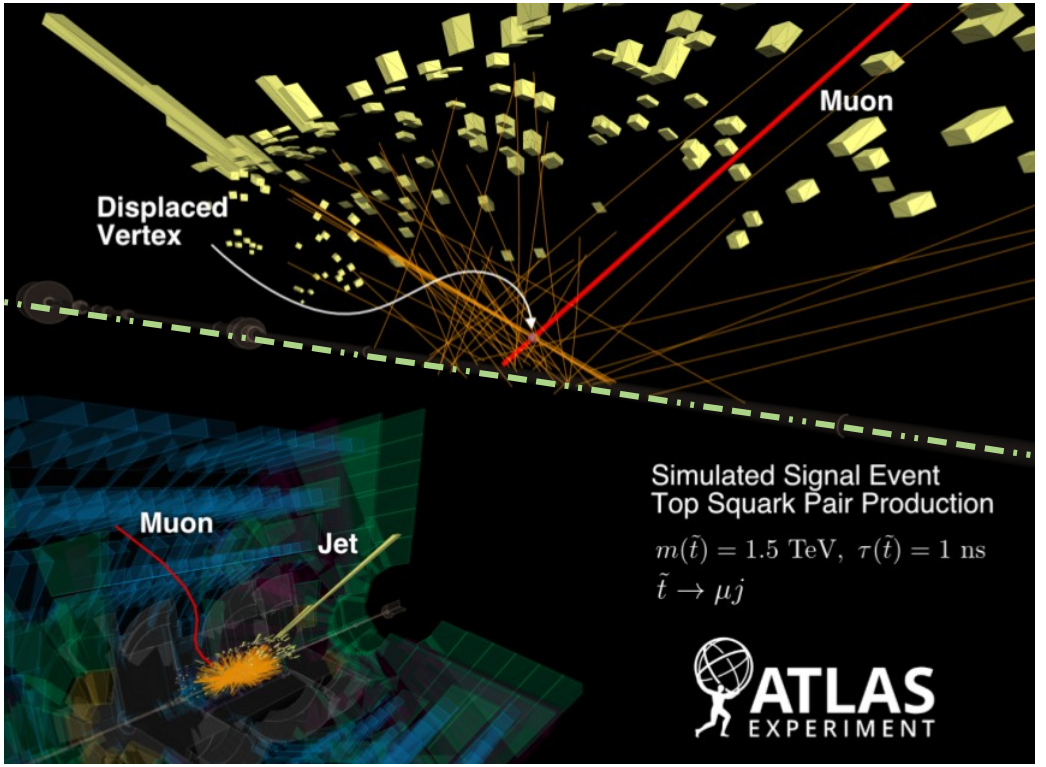
Challenging phase space at the LHC

‘Compressed spectra’ or small mass splittings



Particles with significant lifetimes

See C. Hill and C. Dallapiccola’s talks



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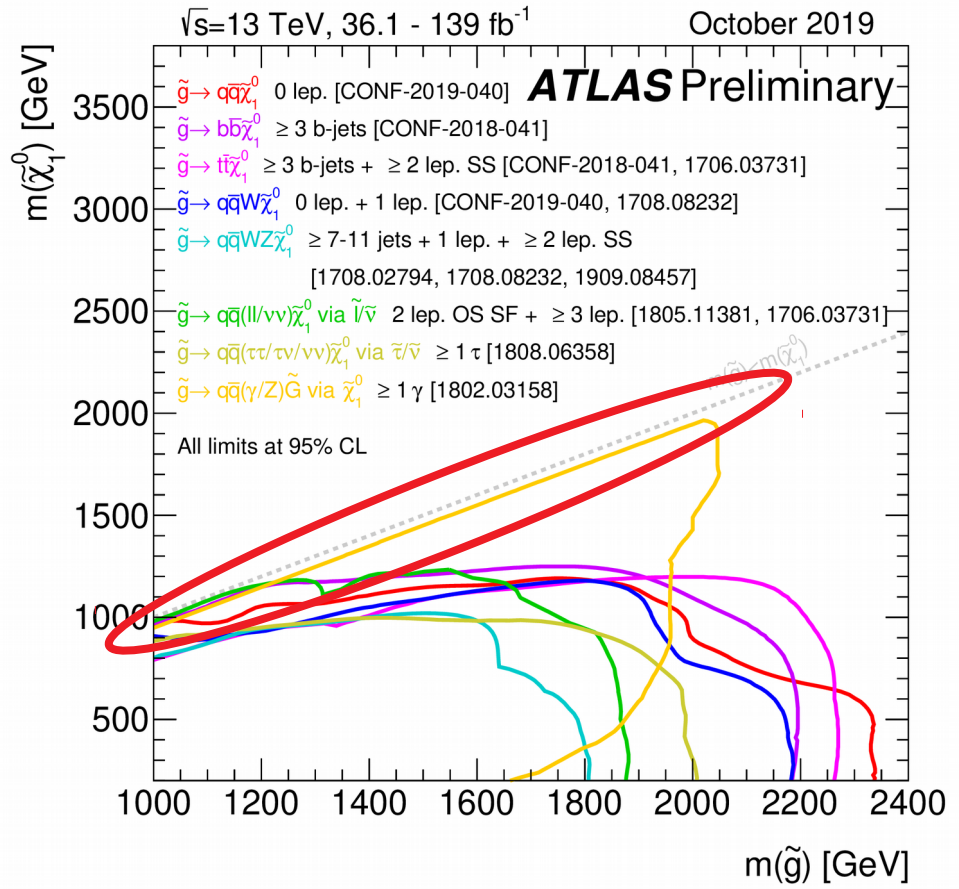

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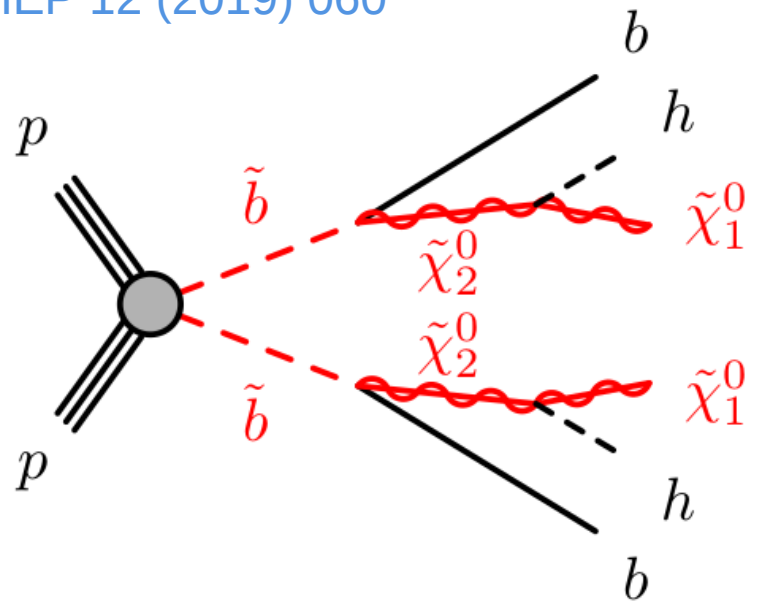
Sbottom with multiple b-jets

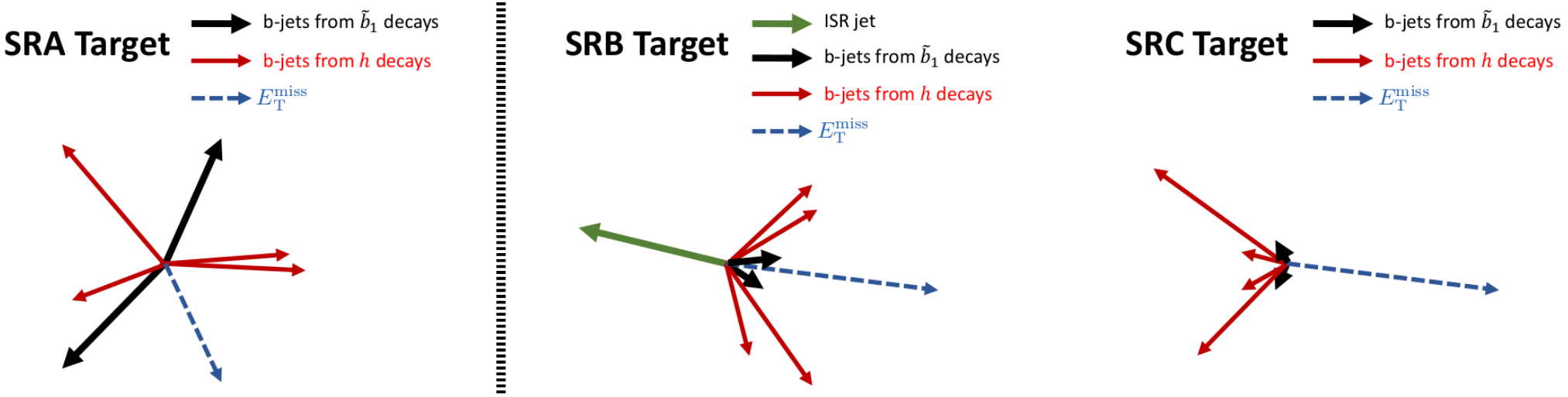
JHEP 12 (2019) 060



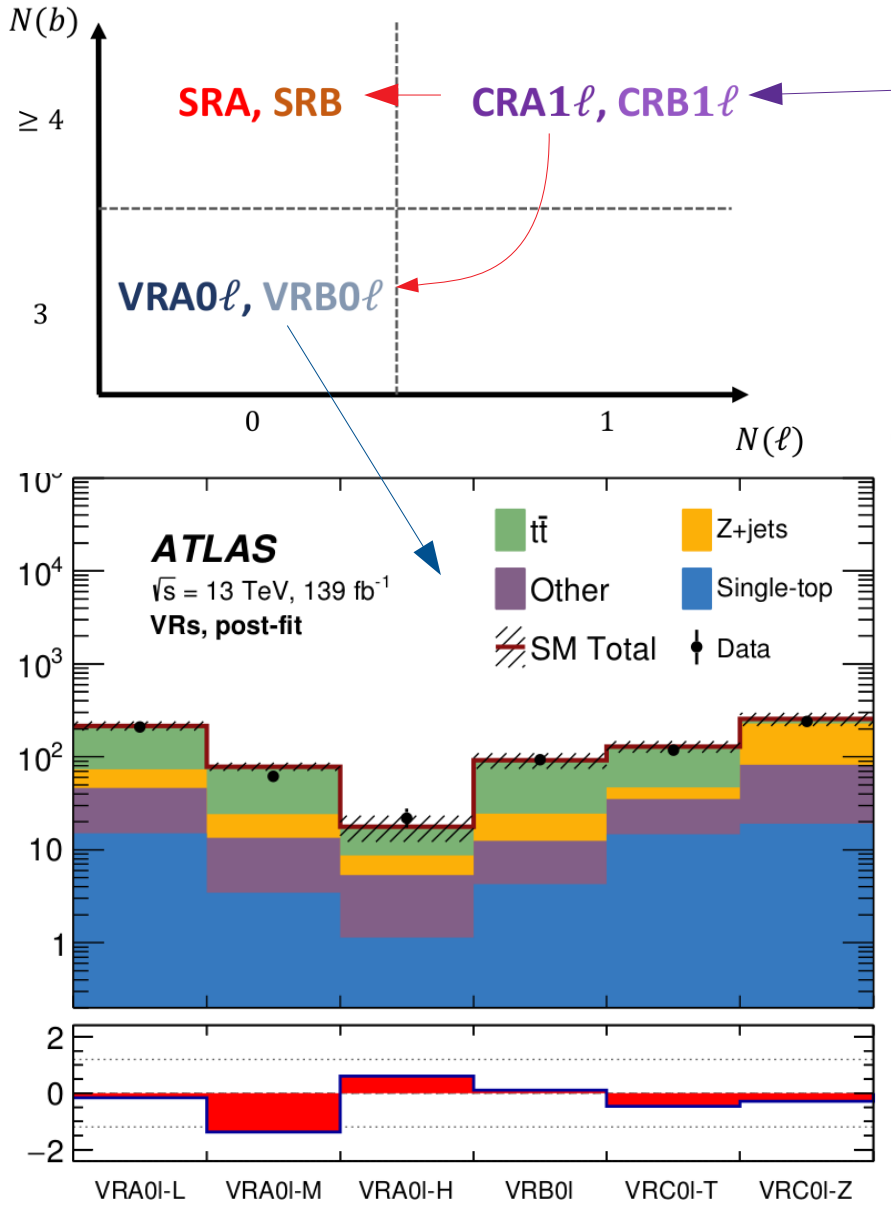
- Up to 6 b-jets in final state
  - Try to associate to sbottom or Higgs decays via angular variables
- Reject events with jets pointing towards MET and with low object-based MET significance
- Have soft b-jets in compressed regions

Bulk Region

Compressed Regions

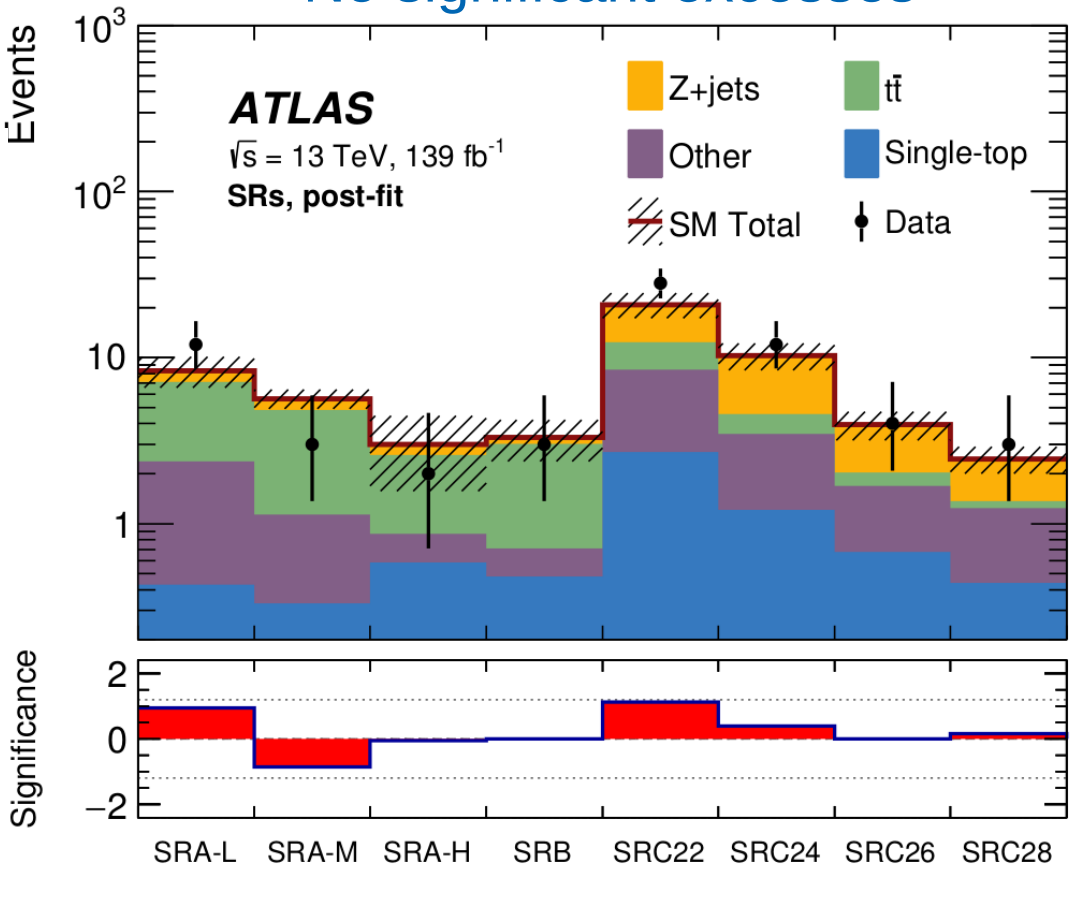


Sbottom with multiple b-jets

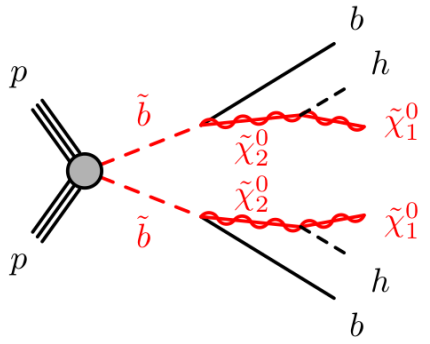


Normalize major backgrounds (ttbar and Z+jets) in Control Regions with 1 or 2 leptons

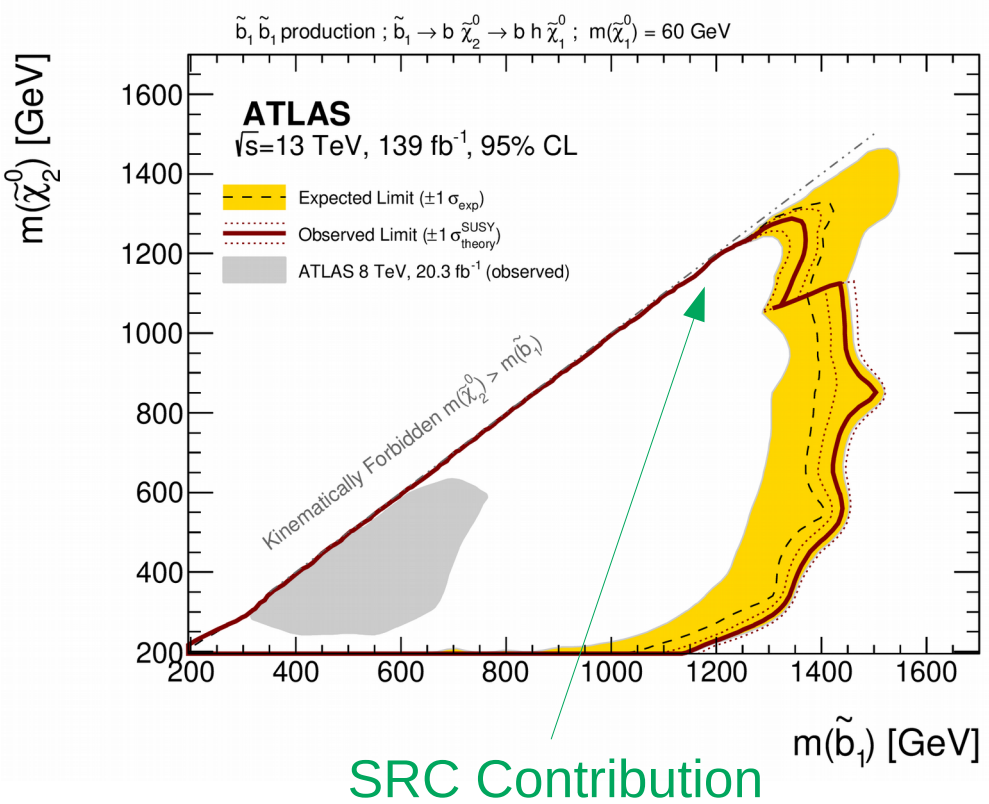
No significant excesses



Sbottom Exclusion Limits

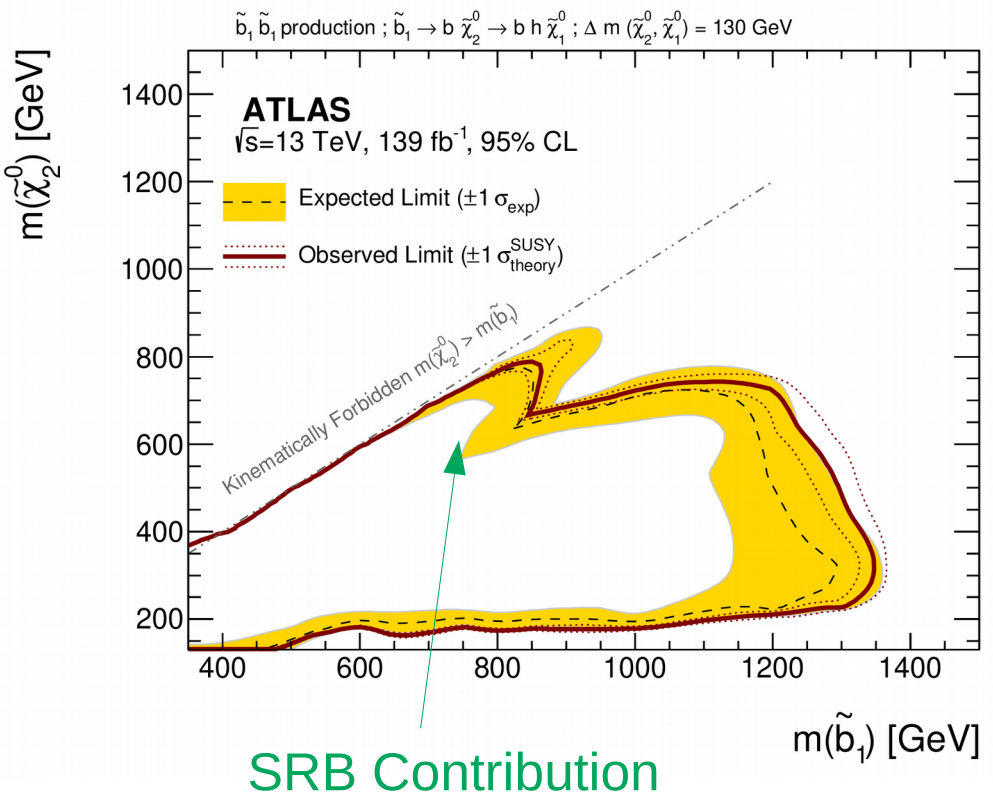


m_LSP = 60 GeV



SRC Contribution

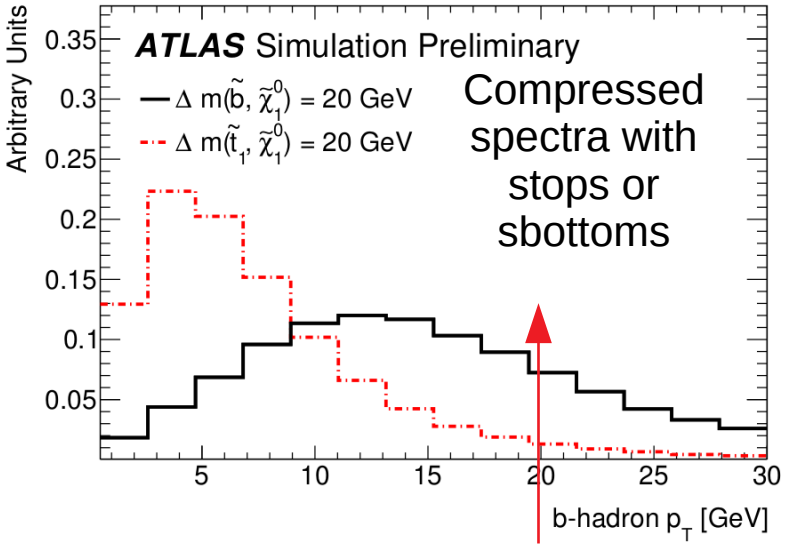
Δm(NLSP-LSP) = 130 GeV



SRB Contribution

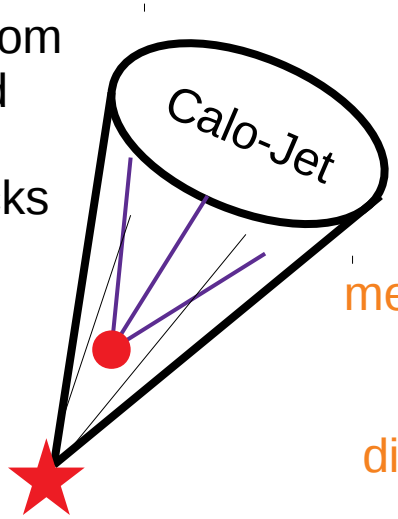
Dedicated signal regions needed to cover compressed phase-space

Soft b-tagging ATLAS-CONF-2019-027

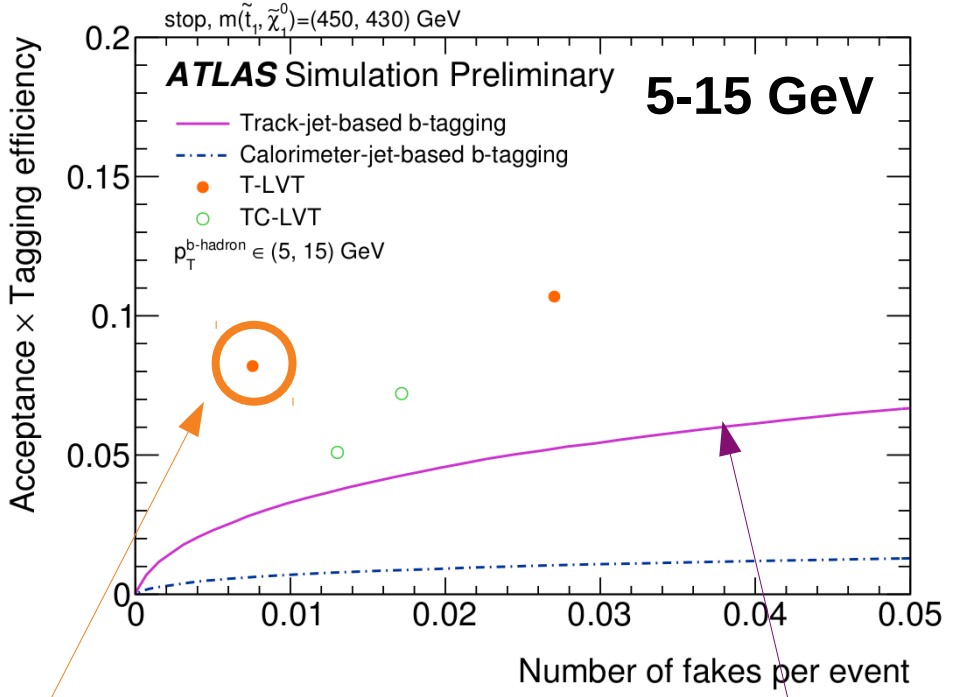


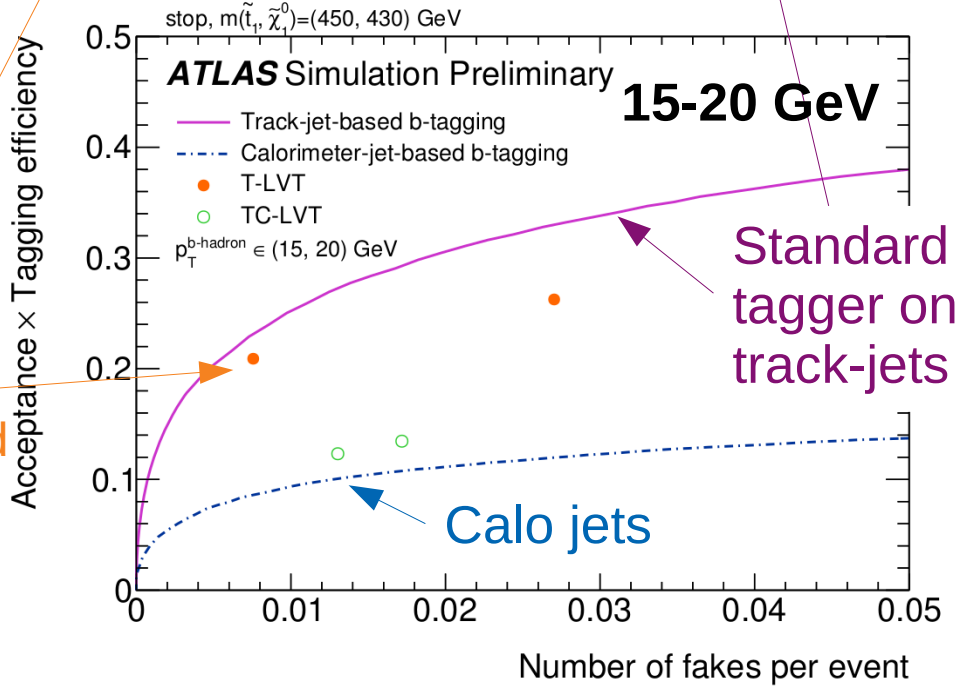
ATLAS b-tagging p_T threshold

Standard b-tagging starts from a calo-jet and looks at associated tracks



New tagging methods developed focusing on searching for displaced vertices





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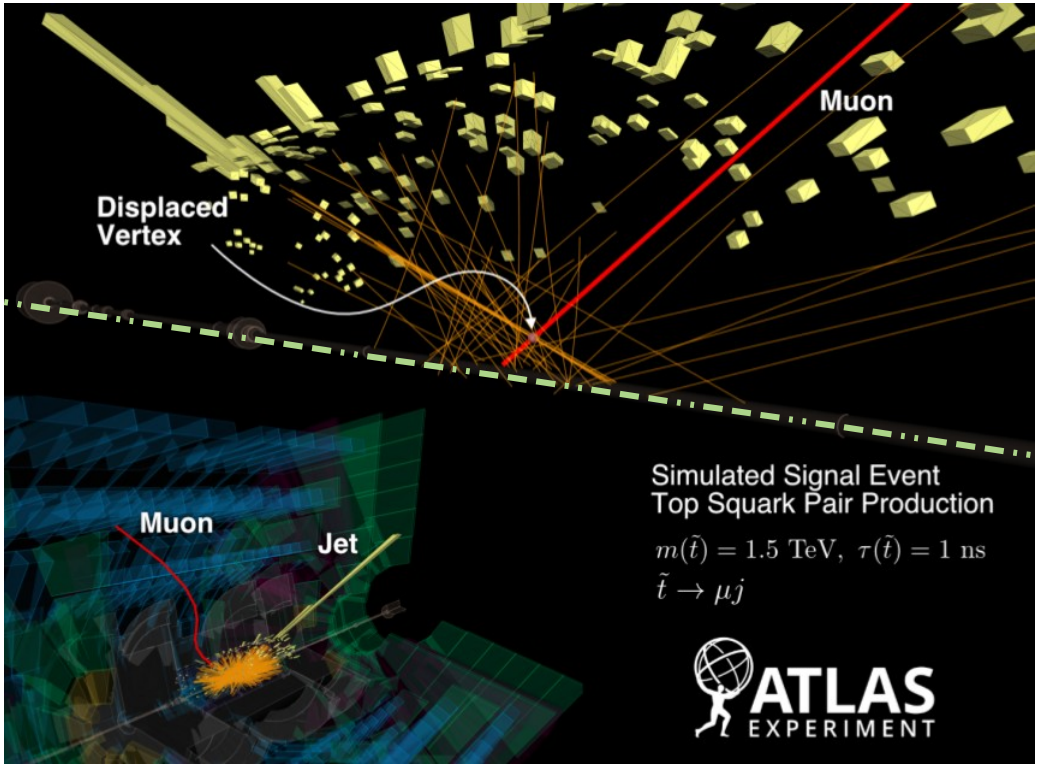
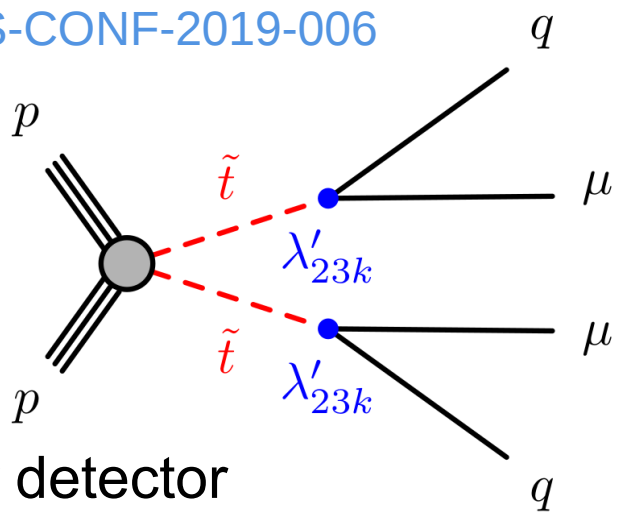


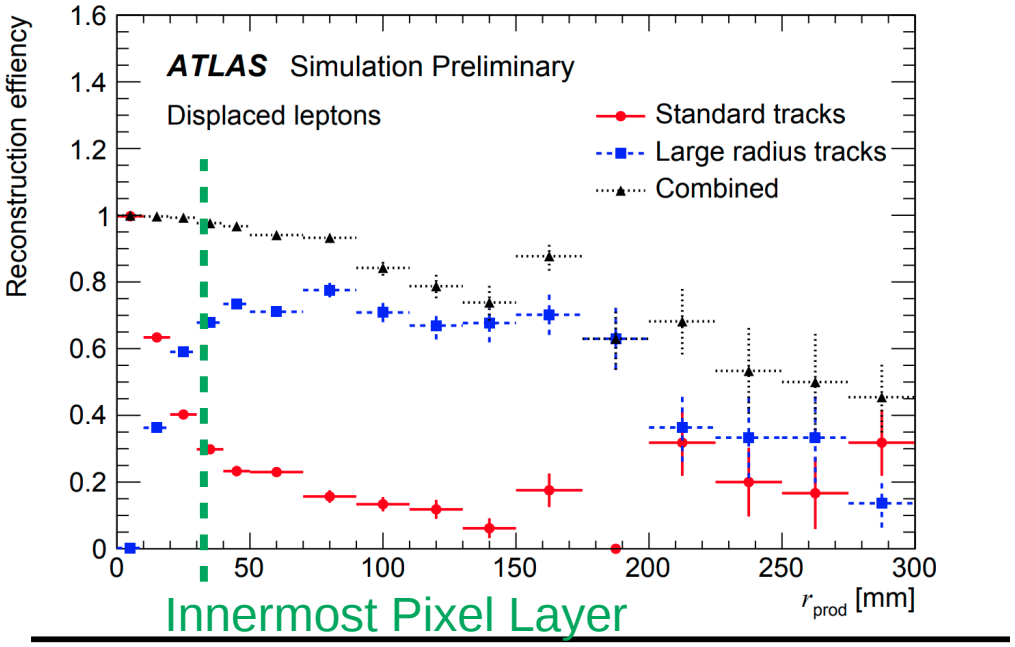
Displaced Vertex + Muon

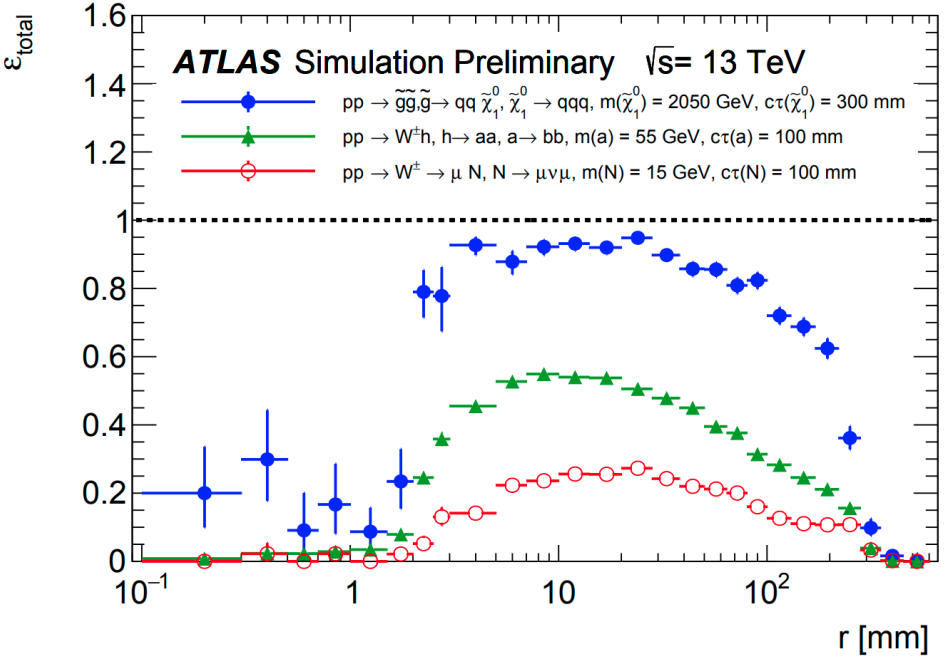
ATLAS-CONF-2019-006

- Model: Small λ' R-parity violating coupling
  - LSP is unstable
  - Stop is long-lived R-hadron



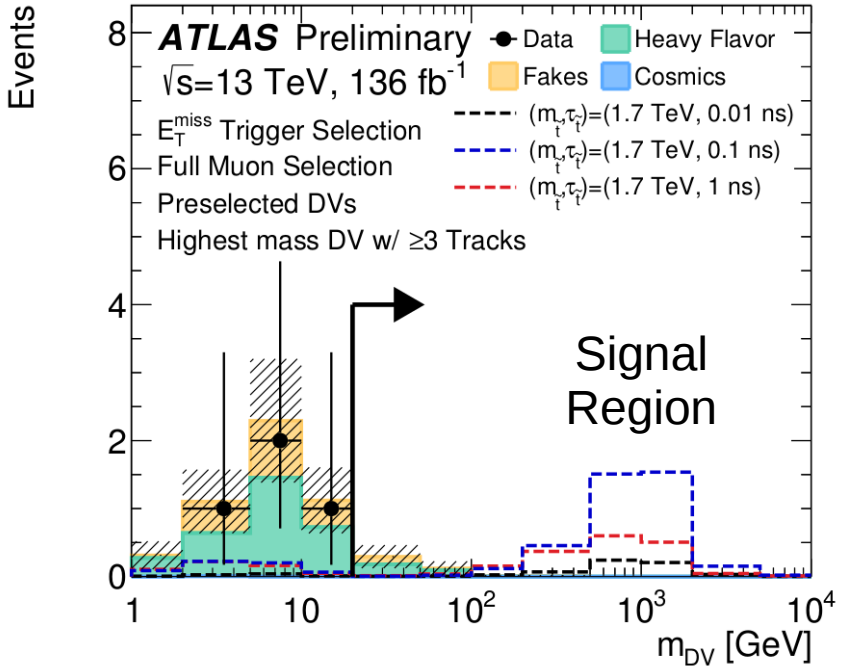
- Special reconstruction to target decays in inner detector
  - Dedicated 'Large-Radius Tracking' to reconstruct displaced tracks
  - Dedicated secondary-vertex finding for long-lived particles

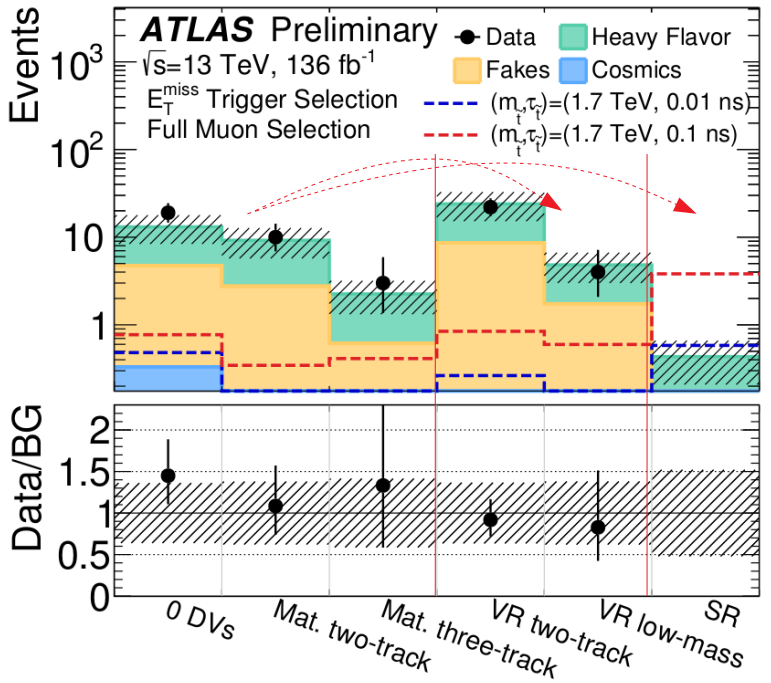




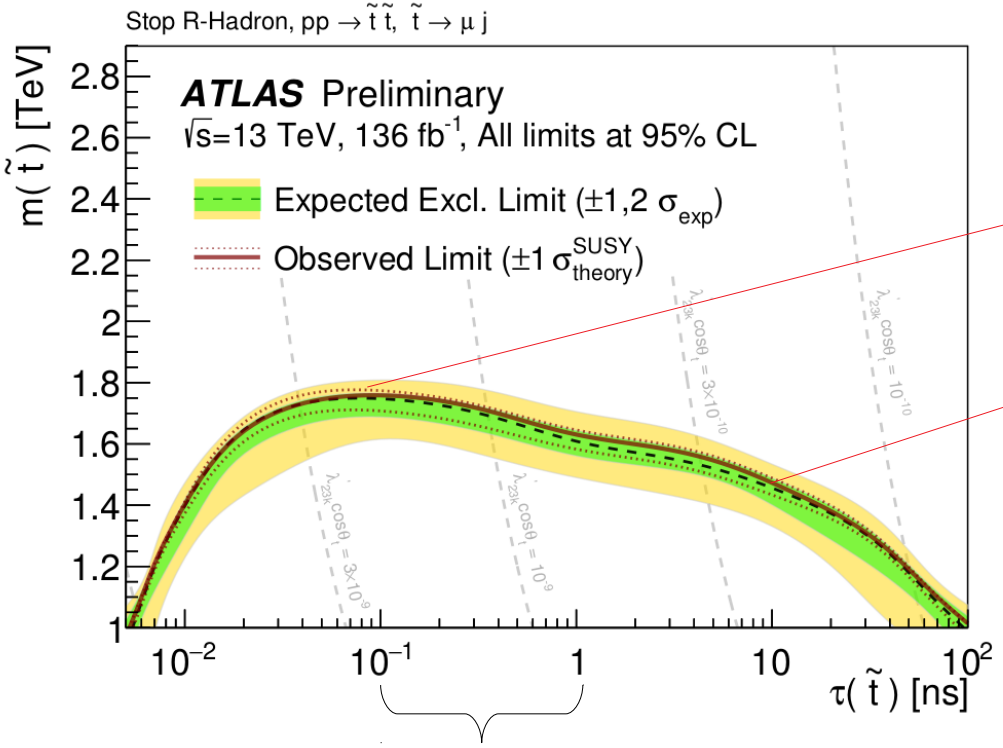
Displaced Vertex + Muon

- Estimate backgrounds using CRs with inverted selections
  - **Displaced vertices** – material map veto, vertex mass, and n_track req.
  - **Cosmic rays** – reject events with Muon Spectrometer activity opposite the muon (or lack of MS coverage)
  - **Fake displaced-muons** – muon quality requirements (MS segments and track χ^2)
  - **Heavy flavor hadron decays** – muons must be isolated



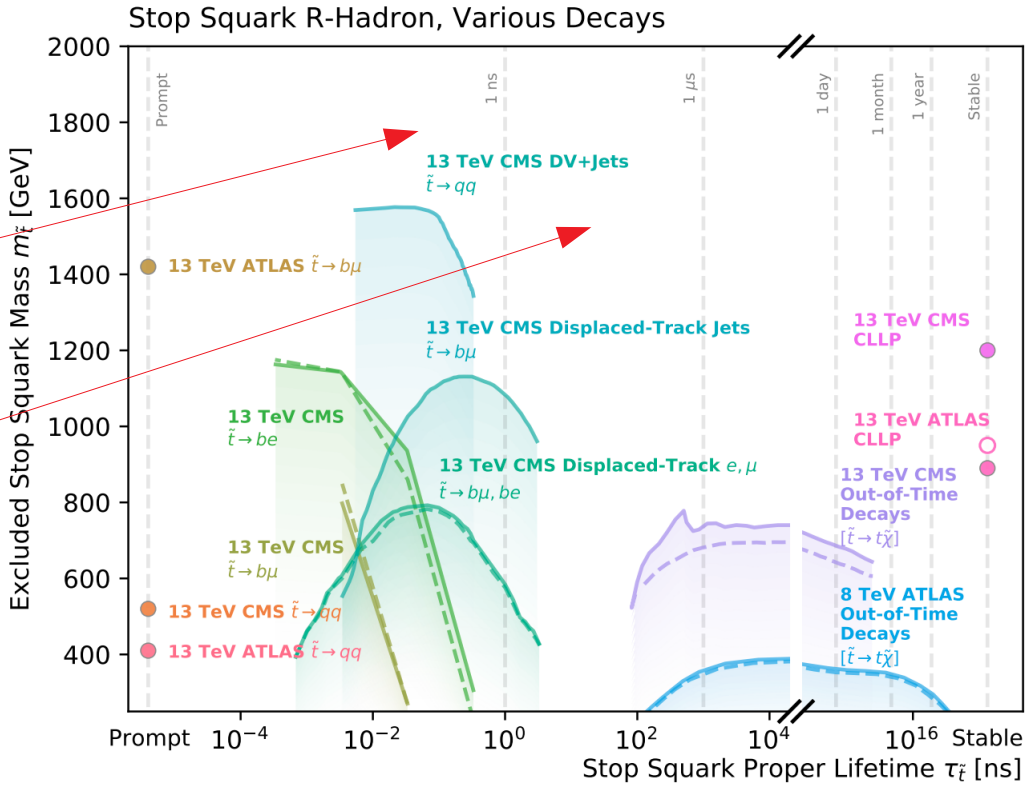


Displaced Vertex + Muon



Roughly the Pixel Detector

1810.12602 (Lee, Ohm, Soffer, Yu)



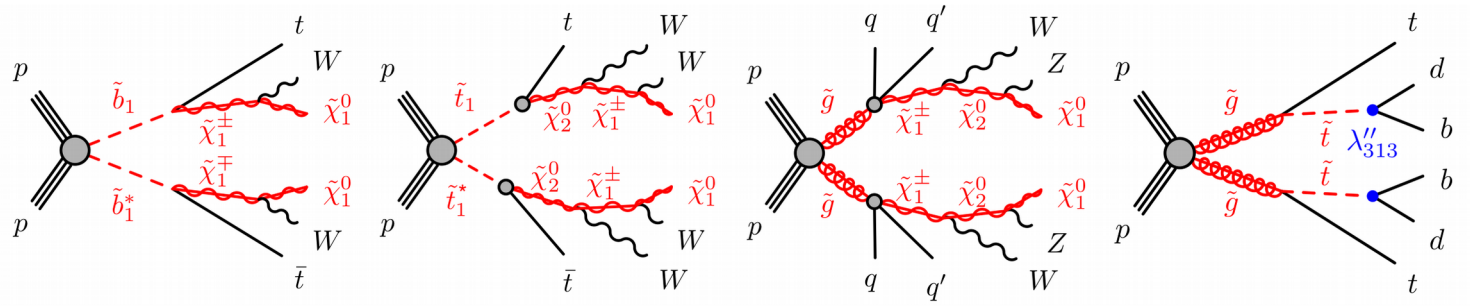
Conclusion

- No SUSY discovery yet
- Many Strong SUSY searches that were not covered here
  - See ATLAS SUSY Public Results for everything
- Object performance and reconstruction work are opening up new avenues to probe BSM physics with unique signatures

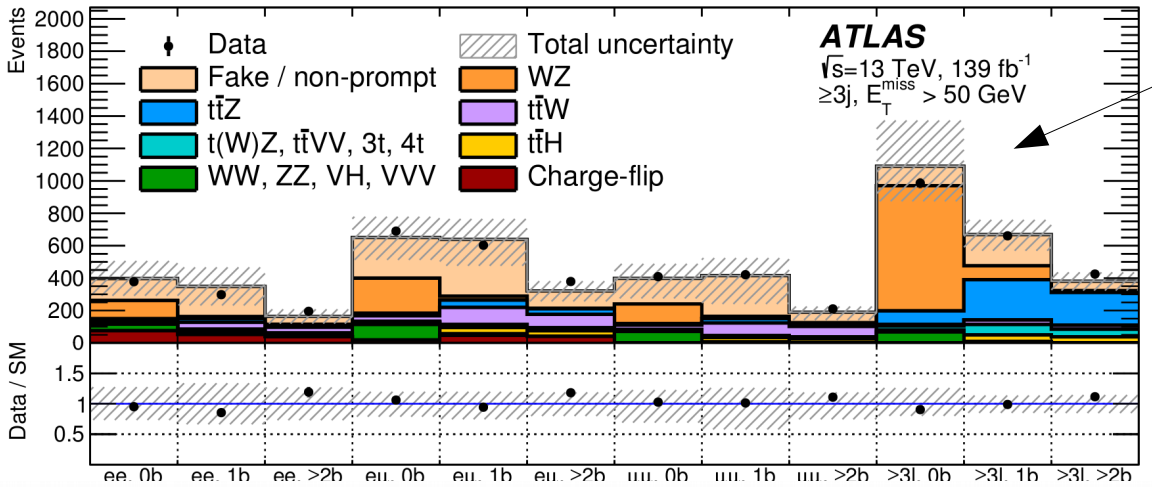
Backup

Same-Sign/3L

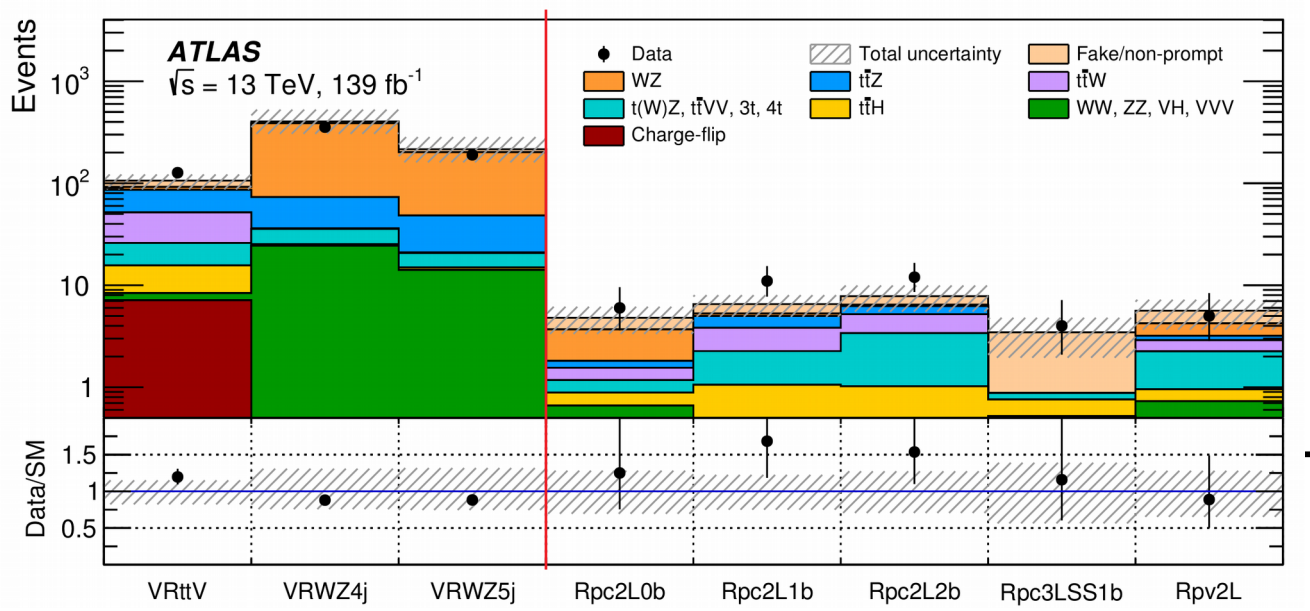
1909.08457



- 5 Signal regions, including one for RPV
- Charge-flip and fake-leptons estimated from data



Loose preselection



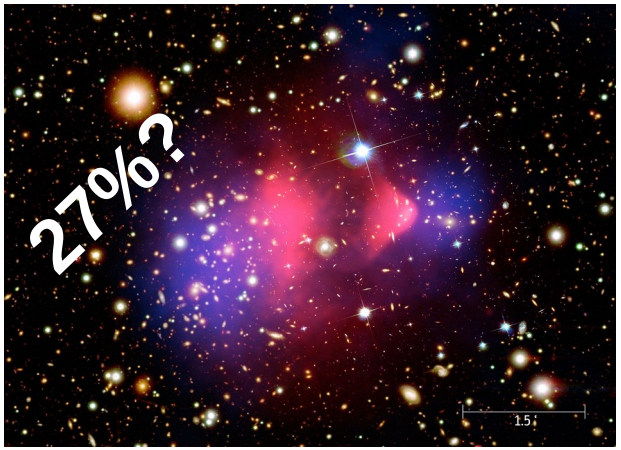
Short Title	Journal Reference	Date	√s (TeV)	L	Links
Stop pair, sbottom pair, gluino pair; two same-sign leptons or three leptons	Submitted to JHEP	18-SEP-19	13	139 fb^{-1}	Documents | 1909.08457 | Inspire Internal
Sbottom; b-jets	JHEP 12 (2019) 060	08-AUG-19	13	139 fb^{-1}	Documents | 1908.03122 | Inspire HepData | Internal
Gluino pair, squark pair; displaced lepton pairs	Phys. Lett. B 801 (2020) 135114	23-JUL-19	13	33 fb^{-1}	Documents | 1907.10037 | Inspire HepData | Internal
Gluino pair, squark pair, stop pair, R-hadron; pixel ionisation, calorimeter and muon timing	Phys. Rev. D 99 (2019) 092007	05-FEB-19	13	36.1 fb^{-1}	Documents | 1902.01636 | Inspire HepData | Internal
Gluino pair, squark pair; taus	Phys. Rev. D 99 (2019) 012009	20-AUG-18	13	36 fb^{-1}	Documents | 1808.06358 | Inspire HepData | Internal
Gluino pair, squark pair, stop pair, long-lived; pixel ionisation	Phys. Lett. B 788 (2019) 96	13-AUG-18	13	36 fb^{-1}	Documents | 1808.04095 | Inspire HepData | Internal
Gluino pair, squark pair; 2 leptons, Z boson, edge	Eur. Phys. J. C 78 (2018) 625	29-MAY-18	13	36 fb^{-1}	Documents | 1805.11381 | Inspire HepData | Briefing | Internal
Stop pair; charm tagging	JHEP 09 (2018) 050	04-MAY-18	13	36 fb^{-1}	Documents | 1805.01649 | Inspire HepData | Briefing | Internal
Gluino pair; squark pair; gluino-squark; 0-lepton	ATLAS-CONF-2019-040	05-AUG-19	13	139 fb^{-1}	Documents | Internal
Soft b-hadron tagging for compressed SUSY scenarios	ATLAS-CONF-2019-027	11-JUL-19	13	139 fb^{-1}	Documents | Internal
Stop pair; 1-lepton	ATLAS-CONF-2019-017	19-MAY-19	13	139 fb^{-1}	Documents | Internal
Stop pair; Z boson	ATLAS-CONF-2019-016	17-MAY-19	13	139 fb^{-1}	Documents | Internal
Stop pair, long-lived; displaced vertex and displaced muon	ATLAS-CONF-2019-006	18-MAR-19	13	136 fb^{-1}	Documents | Internal
Gluino pair; 0-1 leptons, many b-jets	ATLAS-CONF-2018-041	23-JUL-18	13	80 fb^{-1}	Documents | Internal
Sbottom; b-jets	ATLAS-CONF-2018-040	23-JUL-18	13	80 fb^{-1}	Documents | Internal
Gluino pair, stop pair; reinterpretation in long-lived scenarios	ATLAS-CONF-2018-003	12-MAR-18	13	36 fb^{-1}	Documents | Internal

ATLAS SUSY Public Results

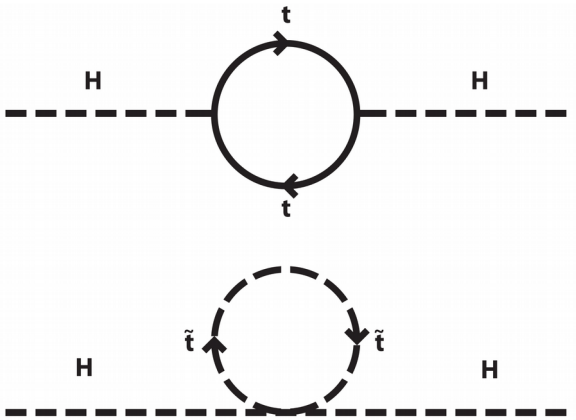
Supersymmetry

- Additional symmetry on top of standard model which relates Boson ↔ Fermion
  - Implies (super)partner particles to the SM differing in spin by ½
  - Must be broken, haven't seen 2nd set of particles with the same masses
- Framework for producing models with many free parameters
  - Naturalness arguments promote relatively light **higgsinos**, stops, and **gluinos** (Papucci et al)
- Many advantageous properties, e.g.

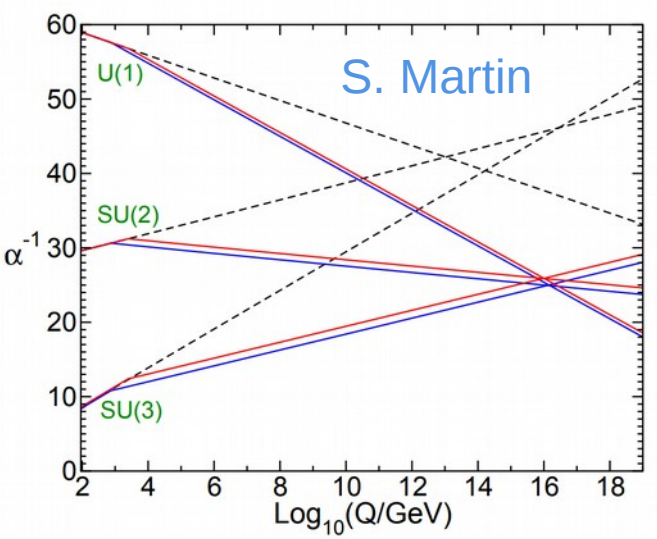
R-parity conserving SUSY implies a stable lightest particle (LSP), a dark matter candidate



Cancellation of divergences in Higgs mass

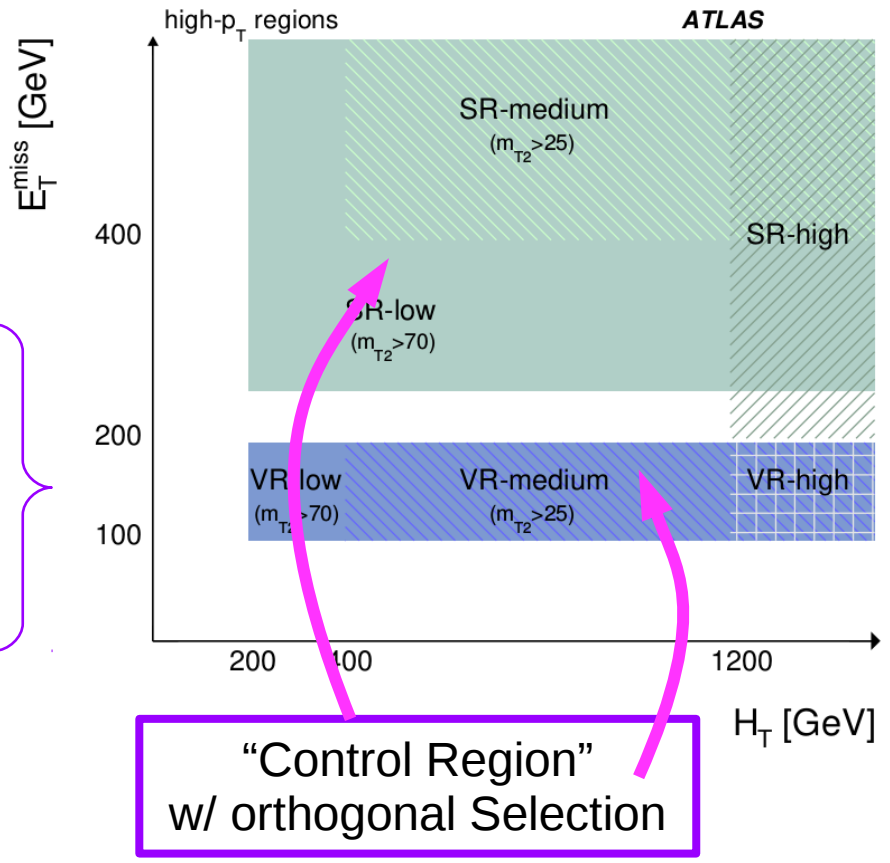


Gauge coupling unification



General Strategy

- Use variables like mass scale, MET, event kinematics, RJR,...
- Use control regions where possible to estimate backgrounds
  - Validate in region near SR



- Interpret with simplified models
  - Shape-fits or multi-bin fits can improve sensitivity
- Model-independent tests based on a single-bin SR
  - Assumes no signal contamination in any CR
  - Meant for p-value evaluation for excesses and reinterpretation

Using MET triggers to find SUSY events

- Lepton trigger rates linear with inst. lumi, but we don't have infinite resources to record every event (moderate pT requirements)
  - Lower threshold lepton-triggers are prescaled
- B-jet triggers require vertexing online, which is very cpu-expensive
  - Seeded by high-pT jet triggers
- RPC SUSY models generally have MET from the LSP