Sensitivity of prompt searches to long-lived particles

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on behalf of the ATLAS collaboration

Introduction

- Increasing interest in searches for long-lived particles, which are incredibly challenging analyses.
- Dealing with non-standard objects, have to provide their own calibration, systematics, data-driven method for instrumental backgrounds…
- All this leads to:

  ATLAS SUSY papers : 128, long-lived: 19
  ATLAS Exotics papers : 180, long-lived: 15

- Can we make use of the more numerous prompt searches to set limits on scenarios with long-lived particles?
- This is obviously sub-optimal in terms of sensitivity but allows to cover a wider model space without the need for dedicated year-long analyses

- Example RPV SUSY (18 papers), small couplings can easily lead to displaced decays but:

results. In all models, the RPV couplings and the SUSY particle masses are chosen to ensure prompt decays of the SUSY particles. Diagrams of the first three benchmark simplified models, which involve

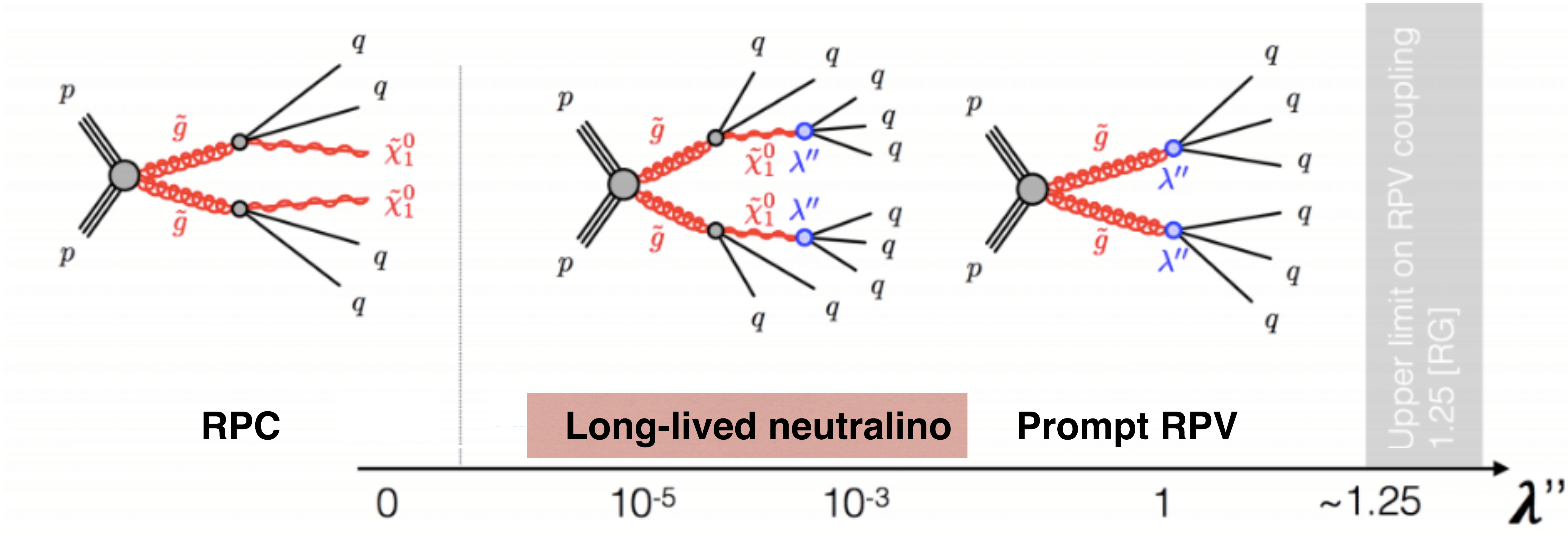
s section ranges from 175 ± 23 fb for a $\tilde{t}$ mass
The generated stops decay promptly through
r. When optimizing the signal event selection,

through baryon-number-violating RPV λ'' couplings, $\tilde{t} \rightarrow \bar{q}_j\bar{q}_k$. The couplings are assumed to be sufficiently large for the decays to be prompt, but small enough to neglect the single-top-squark resonant

missing transverse momentum, whose magnitude is referred to as $E_{\mathrm{T}}^{\mathrm{miss}}$. Only prompt decays of SUSY particles are considered. It is an extension of an earlier search performed by the ATLAS experiment [22]

RPC to RPV transition

- RPV SUSY provides a great model to test the sensitivity of prompt searches to long-lived decays:



- Is there a gap between RPC and prompt RPV SUSY? Are light gluinos or stops still allowed with small RPV couplings? **ATLAS-CONF-2018-003**
- Lifetime distribution is an exponential, everything that decays after the muon spectrometer is MET, looks exactly the same as RPC

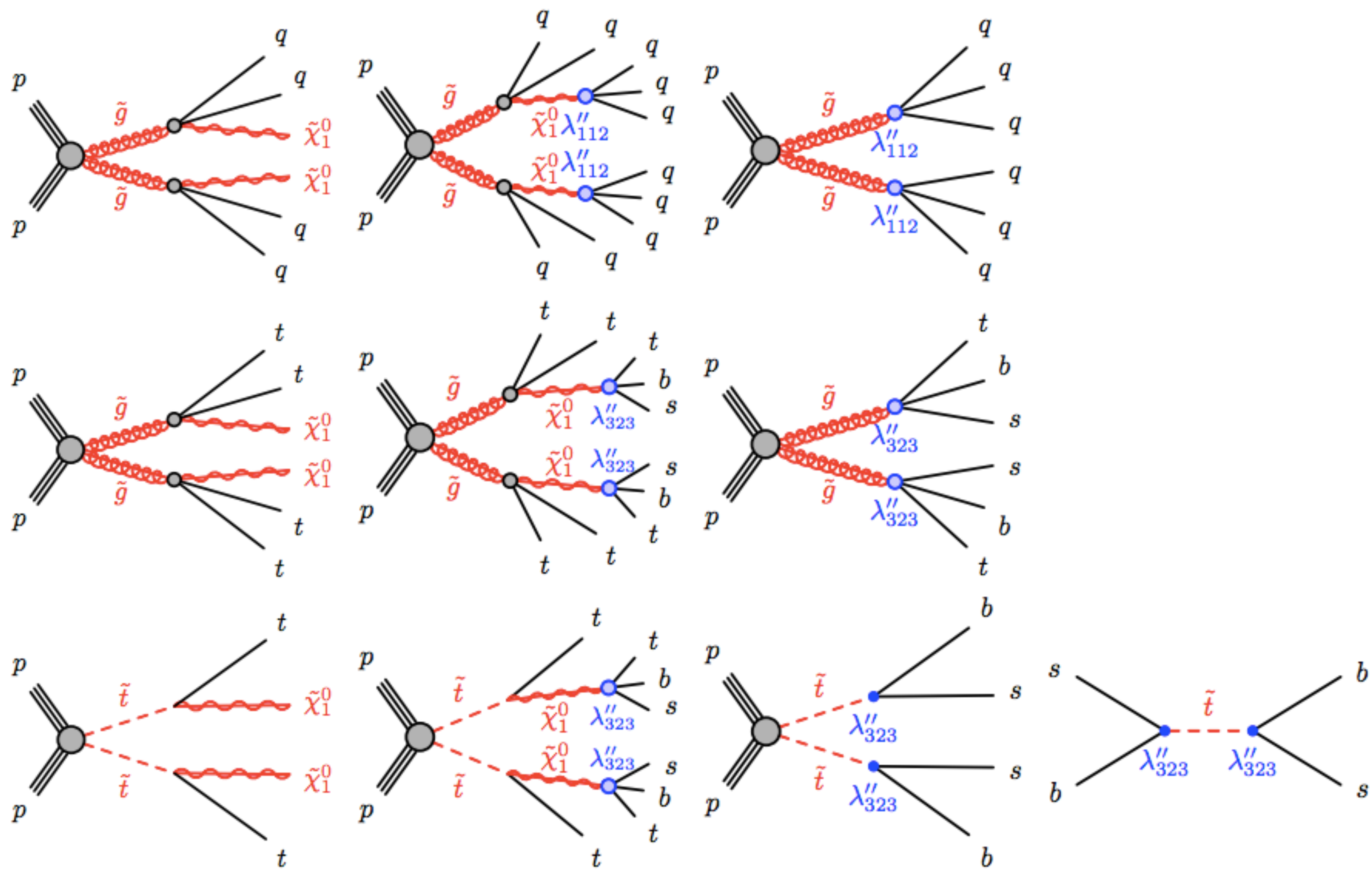
Signal models

- RPV SUSY, considering only baryon-number violating coupling UDD
- LSP is bino-like and m_{N1}=200 GeV (allow top quark in the decay)
- LSP lifetime depends on λ'' and choice of squark masses

Gqq model

Gtt model

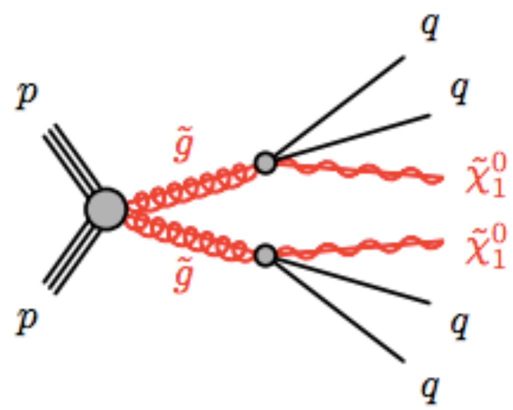
Stop model



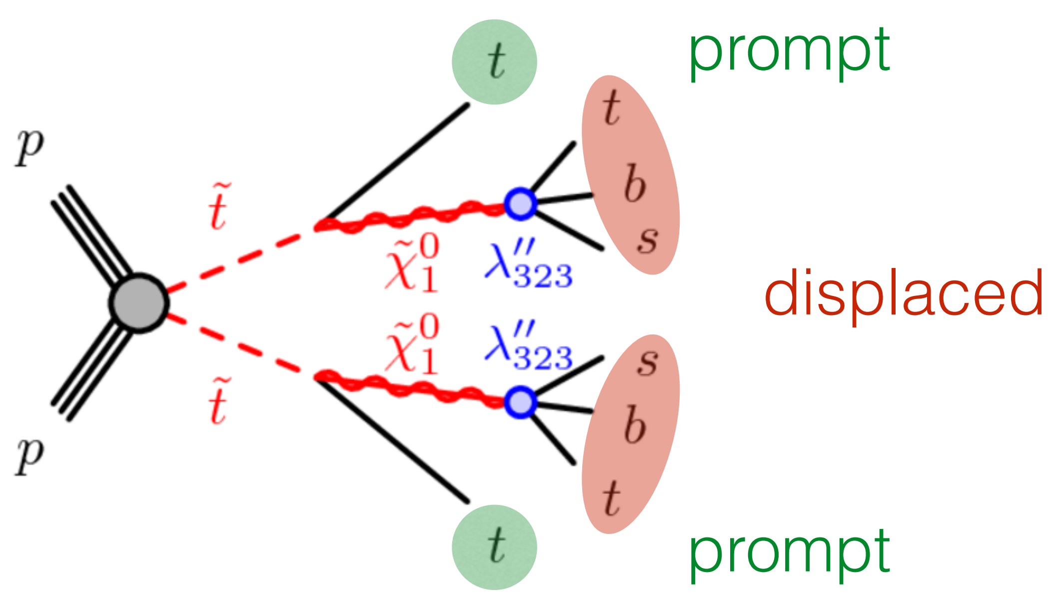
Signal models

- Additional R-hadron model inspired by split-SUSY
- In this model the gluino is long-lived and the neutralino stable, in previous slide the neutralino is long-lived

R-hadron model



- RPV SUSY models with small couplings feature both prompt and displaced decay products



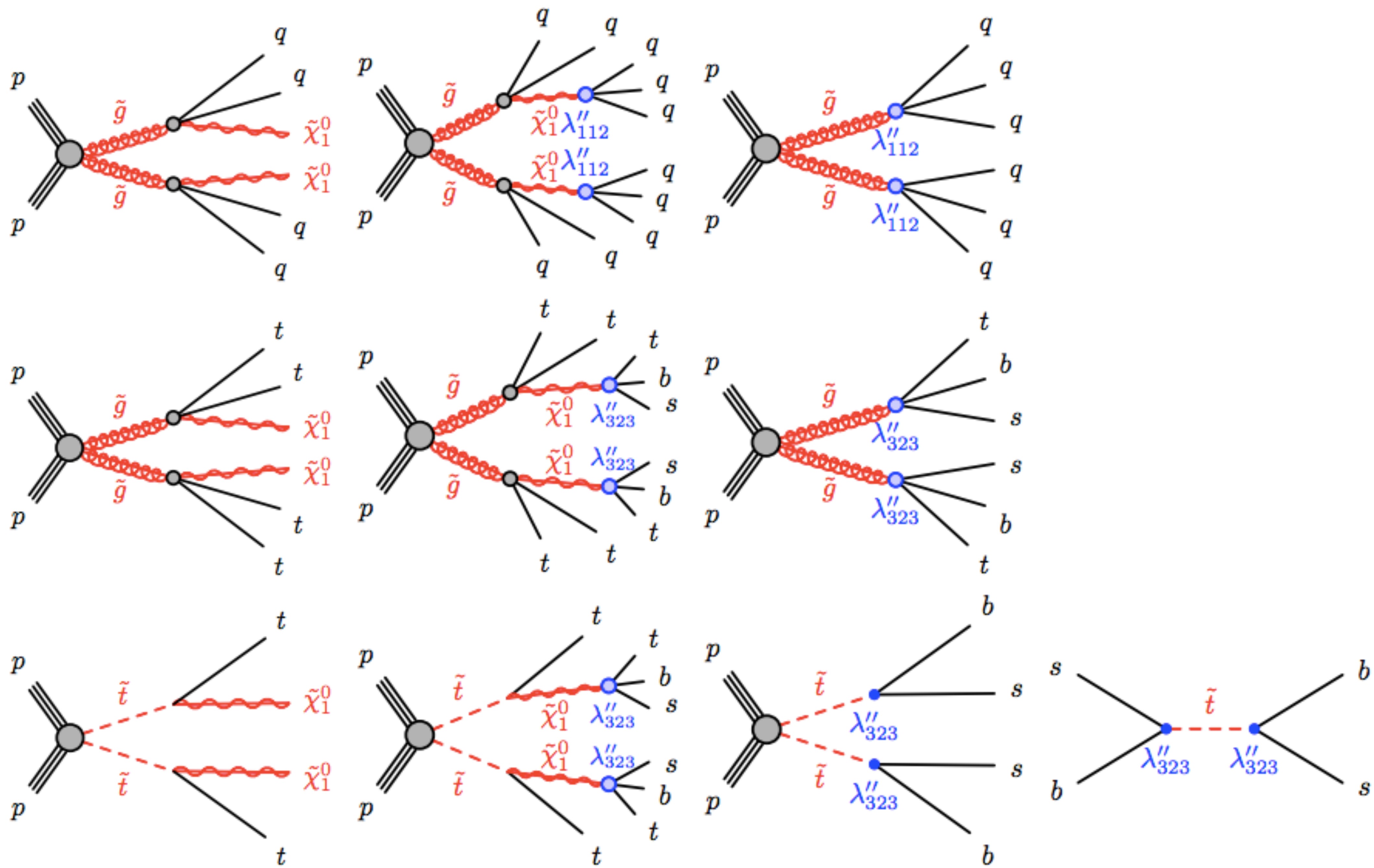
Suite of analyses

- All the RPC and prompt models are covered except for prompt Gqq (RPV 0L not ready on time)
- No dedicated analysis for the long-lived intermediate regime

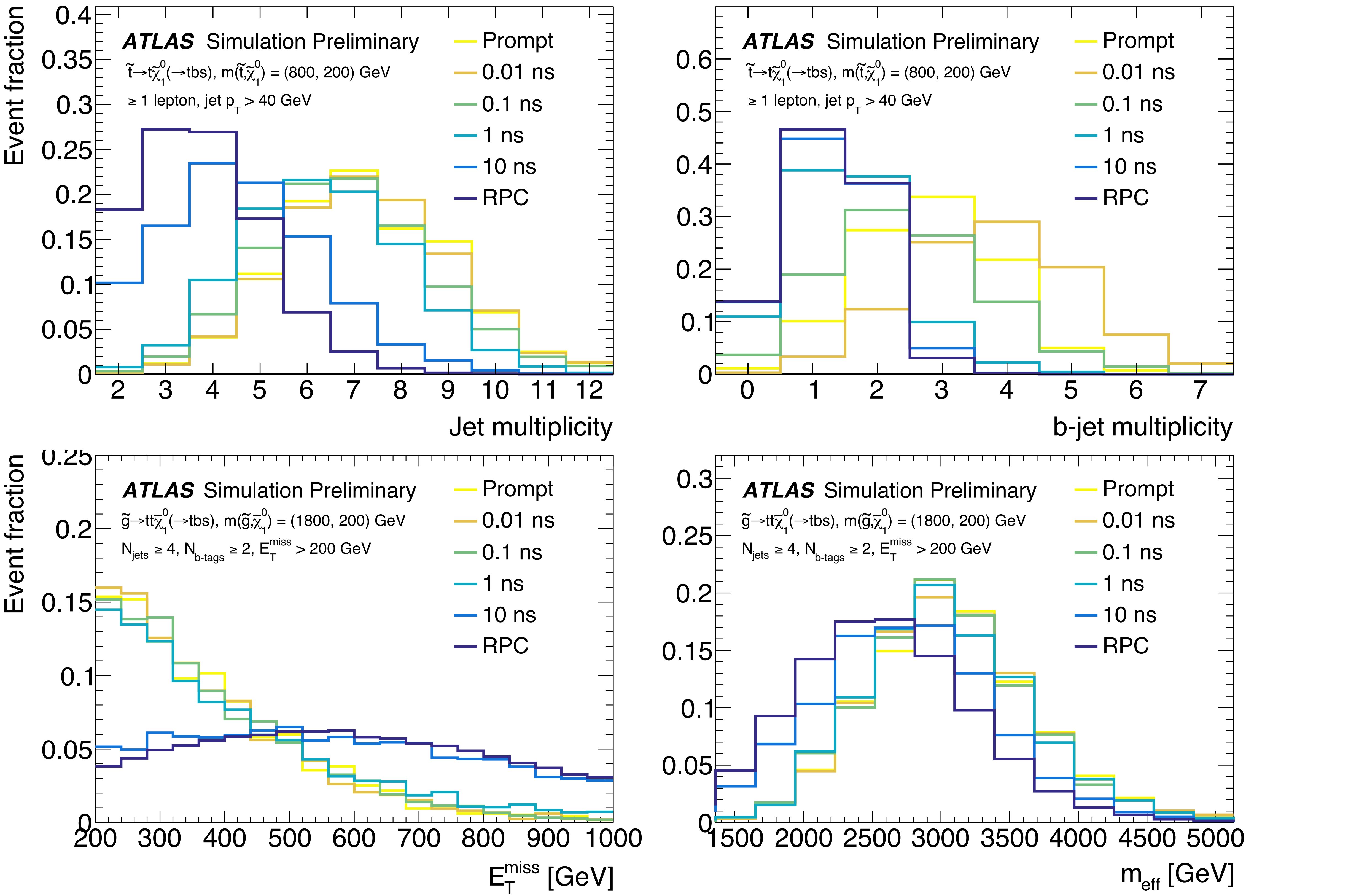
RPC 0L 2-6 jets
RPC 0L 7-11 jets
~~**RPV 0L**~~

RPC multi-b
RPC+RPV SS/3L
RPV 1L

RPC stop 0L
RPC stop 1L
RPV 1L
RPV paired dijet
Dijet ____



Lifetime comparisons



Systematics on displaced objects

- Displaced jet energy scale
  - Studied jet response in MC as a function of radial decay length
  - Almost no variation in response up to ~1m in radial decay length
  - Response increases linearly up to 30% above the nominal value at 1.6 m
  - Assign deviation as uncertainty, conservative as data might follow the same trend

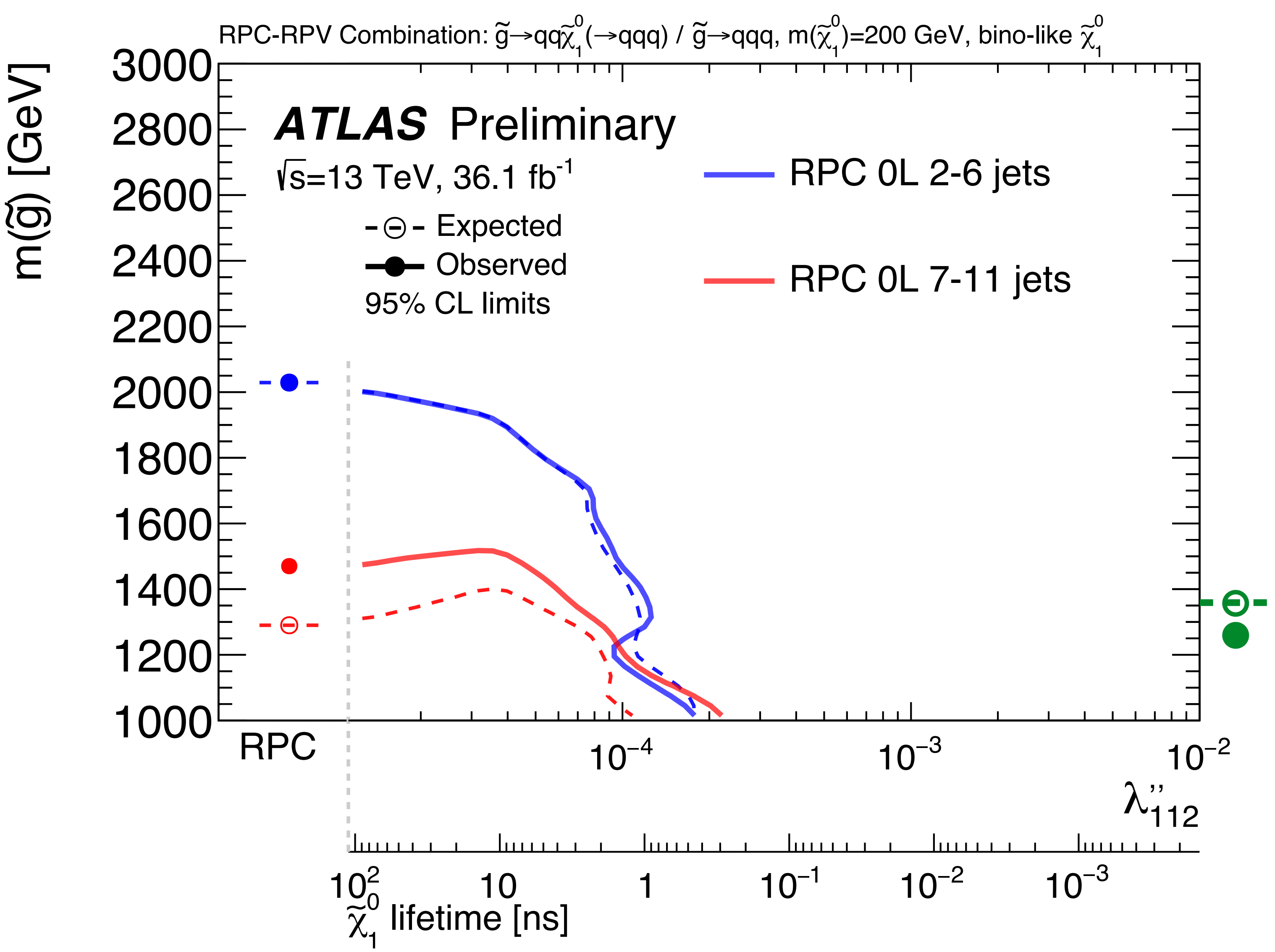
- Displaced jet b-tagging
  - Run tracking variations on signal MC, assign deviation from nominal as systematic
  - Variation of 20% on SRs with ≥ 4 b-tags, and a signal with 1 ns lifetime

- Displaced lepton systematics
  - No systematic, leptons require impact parameter cuts (z_0 and d_0 significance) no acceptance of displaced leptons

- Missing energy uncertainties
  - Hard object systematics are propagated to MET
  - No uncertainty on soft term, tracks required to originate from primary vertex
  - No uncertainty on MET trigger, no variation seen on trigger efficiency turn-on

Results Gqq model

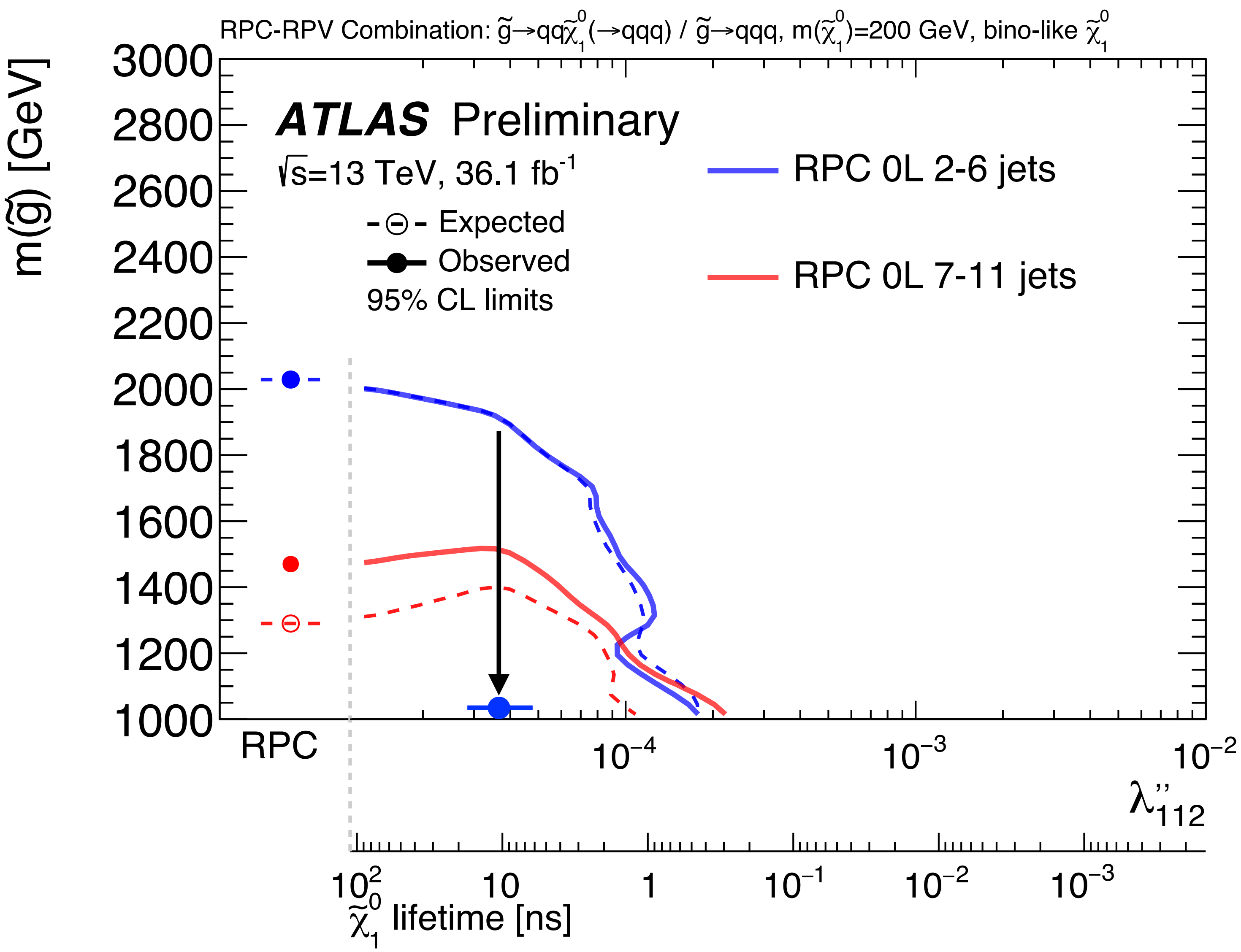
- RPC 0L 2-6 jets provides strong limits until the signal produces no MET
- Gluino mass limits drop 2 TeV ➞ 1 TeV with a neutralino lifetime of 1 ns
- Missing RPV 0L to cover the high side of the spectrum



<u>SUSY-2016-22</u>
Preliminary RPV 0L result but signal model not exactly identical

Results Gqq model

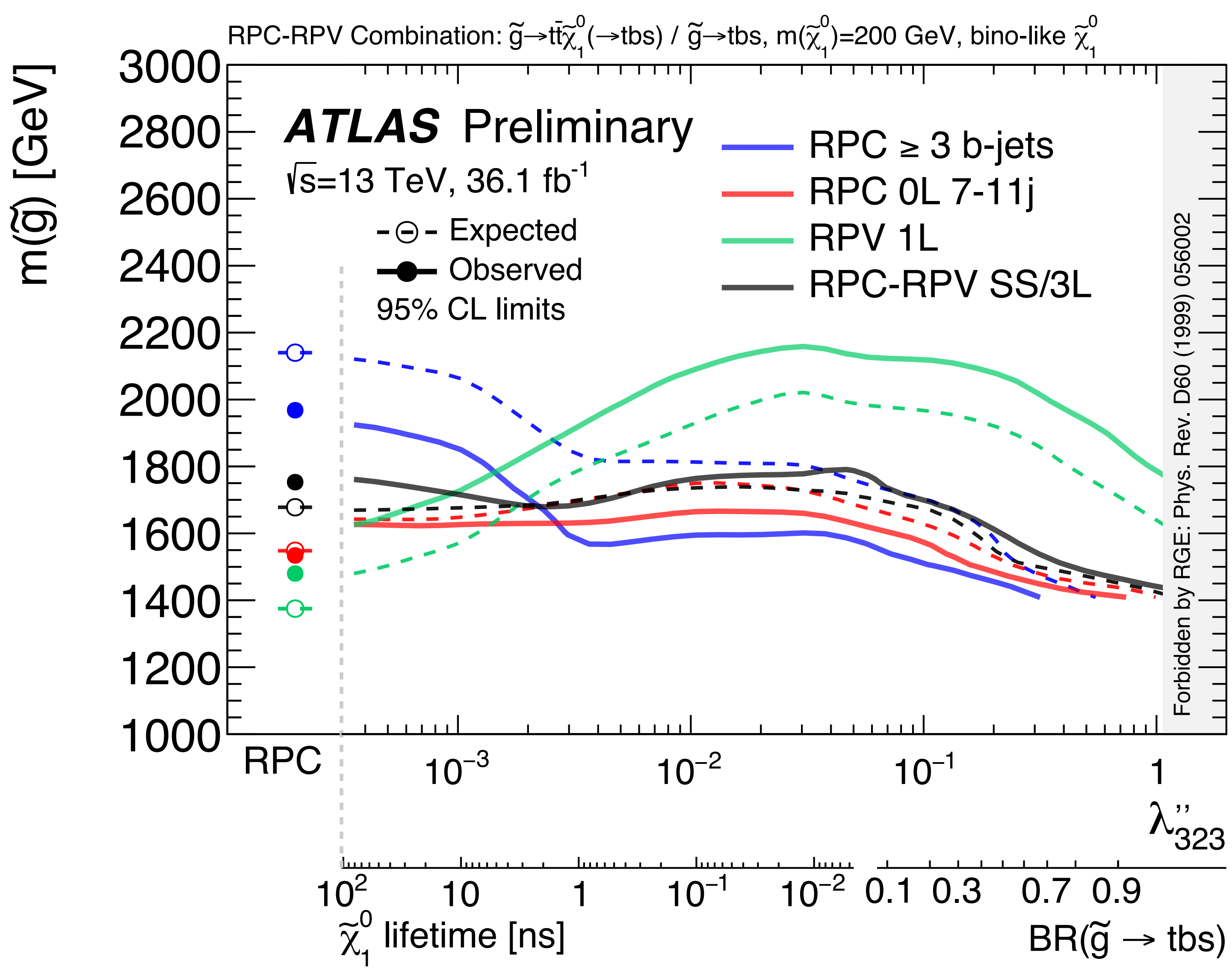
- RPC 0L 2-6 jets provides strong limits until the signal produces no MET
- Gluino mass limits drop 2 TeV → 1 TeV with a neutralino lifetime of 1 ns
- Missing RPV 0L to cover the high side of the spectrum



- RPC 0L 2-6 jets was the only analysis modified to retain efficiency to long-lived signals
- Jet cleaning cut was based on track requirements, switched to energy fractions on calorimeter layers
- With the original cleaning, limit dropped 2 TeV → 1 TeV at 10 ns lifetime

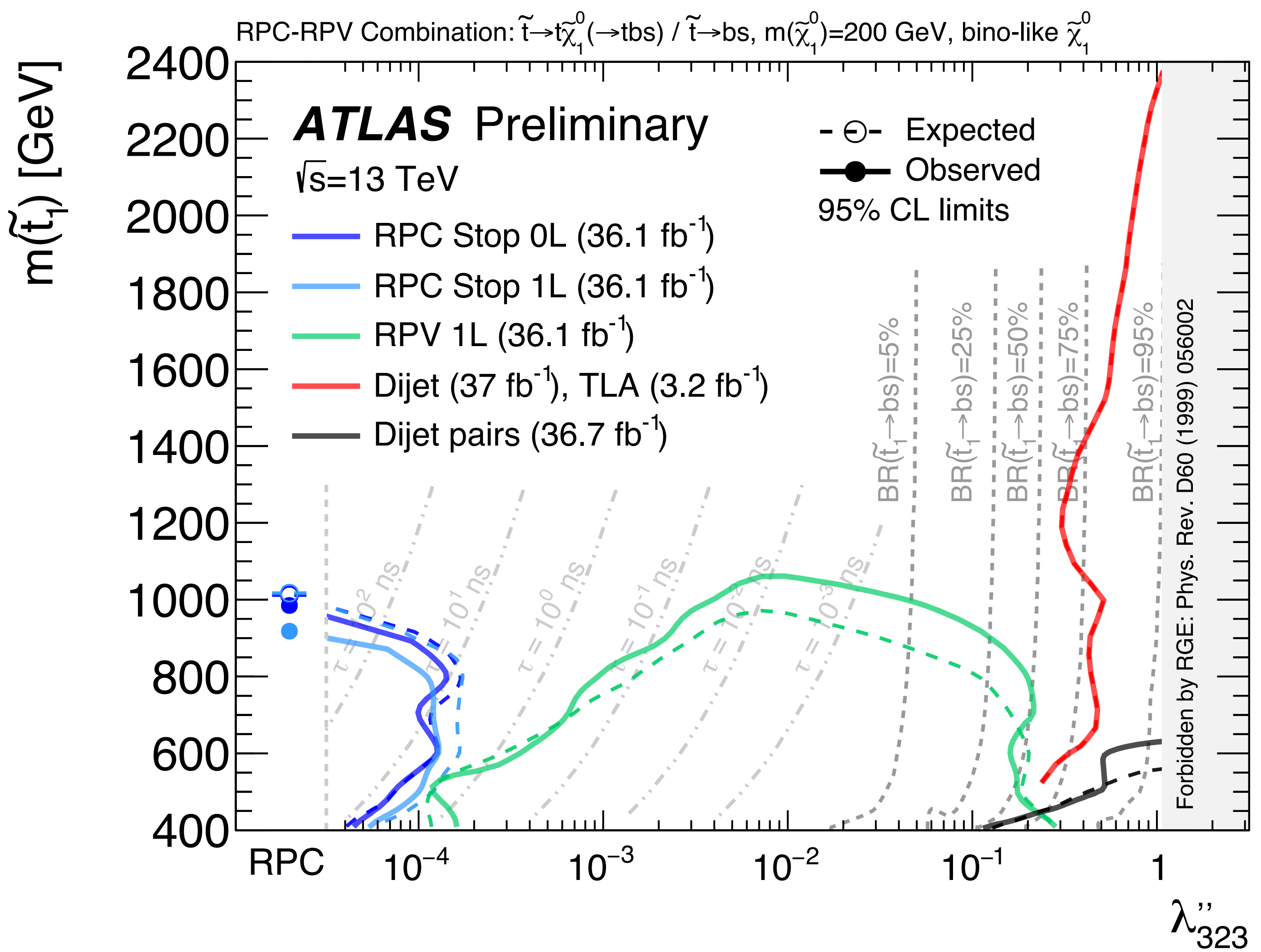
Results Gtt model

- RPC multi-b and RPV 1L cover the full spectrum
- No gluino decaying to tops below 1.8 TeV !
- At high coupling values the decay is prompt and transitions from g→ttχ_1(→tbs) to g→tbs



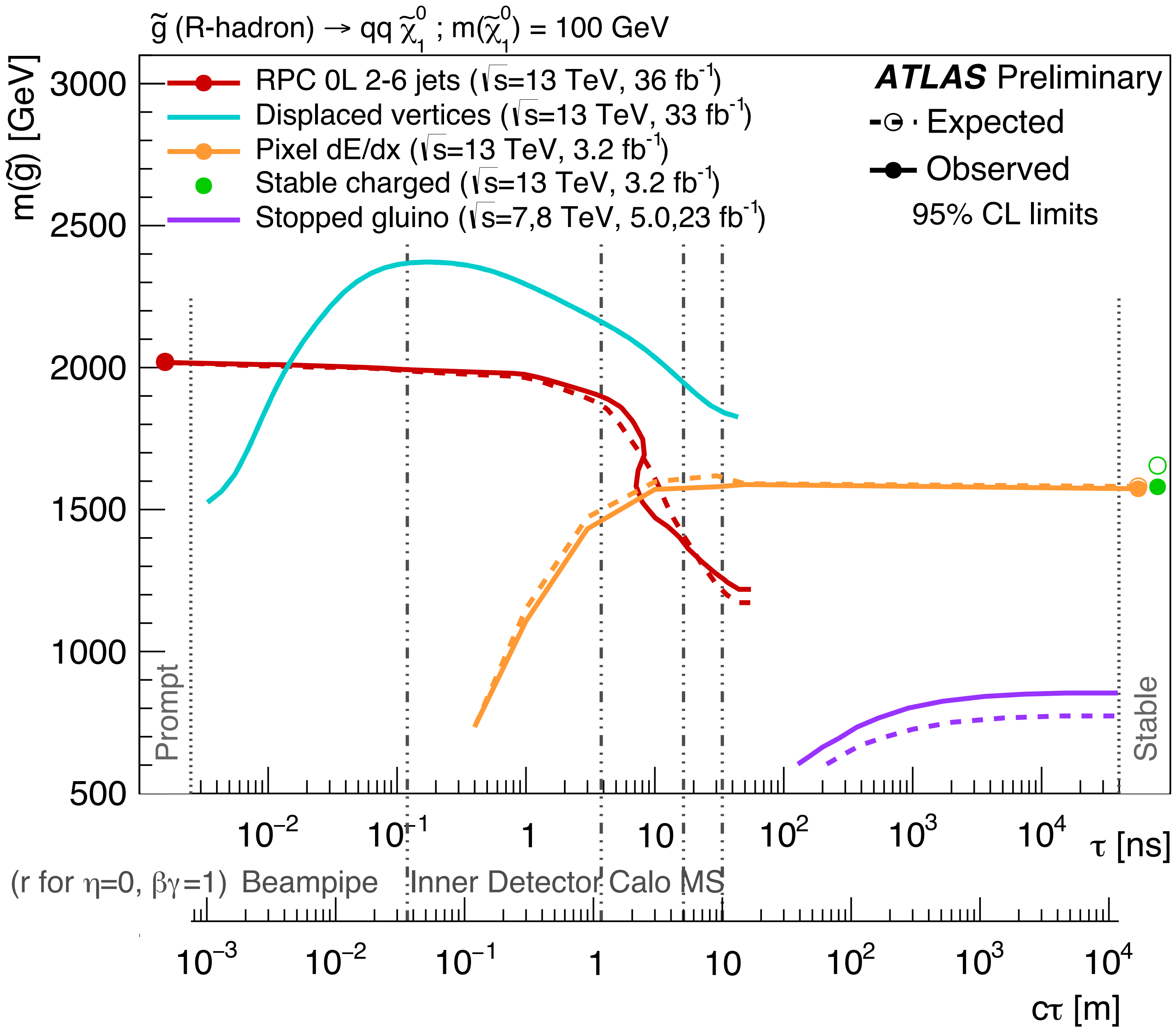
Results stop model

- Neutralino lifetime and stop branching ratio depends on the stop mass, no second x-axis but contours
- Gap in sensitivity between RPC and prompt RPV regimes, no exclusion for neutralino lifetime of 1 ns. Equivalent to λ'' ~10^{-4} which is actually the prediction of MFV SUSY, very good motivation for new analyses
- At very high coupling, dijet sets very stringent limit on resonant stop production



Results R-hadron model

- RPC 0L 2-6 jets closes the gap at low gluino masses (red line)
- R-hadrons from gluinos below 1.5 TeV (and as high as 2.5 TeV) are excluded



Reinterpretation

- Could we have done this with public data and without running the ATLAS simulation?
  - No, two main ingredients missing, efficiencies and systematics for displaced objects and b-tagging
- Could we provide enough information after this result for others to run such a reinterpretation?
  - Jet response and jet reconstruction efficiency as a function of radial decay length, including impact from JVT
  - B-tagging efficiency as a function of p_T and decay length
  - Jet energy scale and b-tagging uncertainties

- Which of the previous ingredients are model-dependent? E.g. 2-prong vs 3-prong decays in R-hadron vs RPV signals.
- Up to here it seems feasible, but there are caveats (next slide)

Reinterpretation

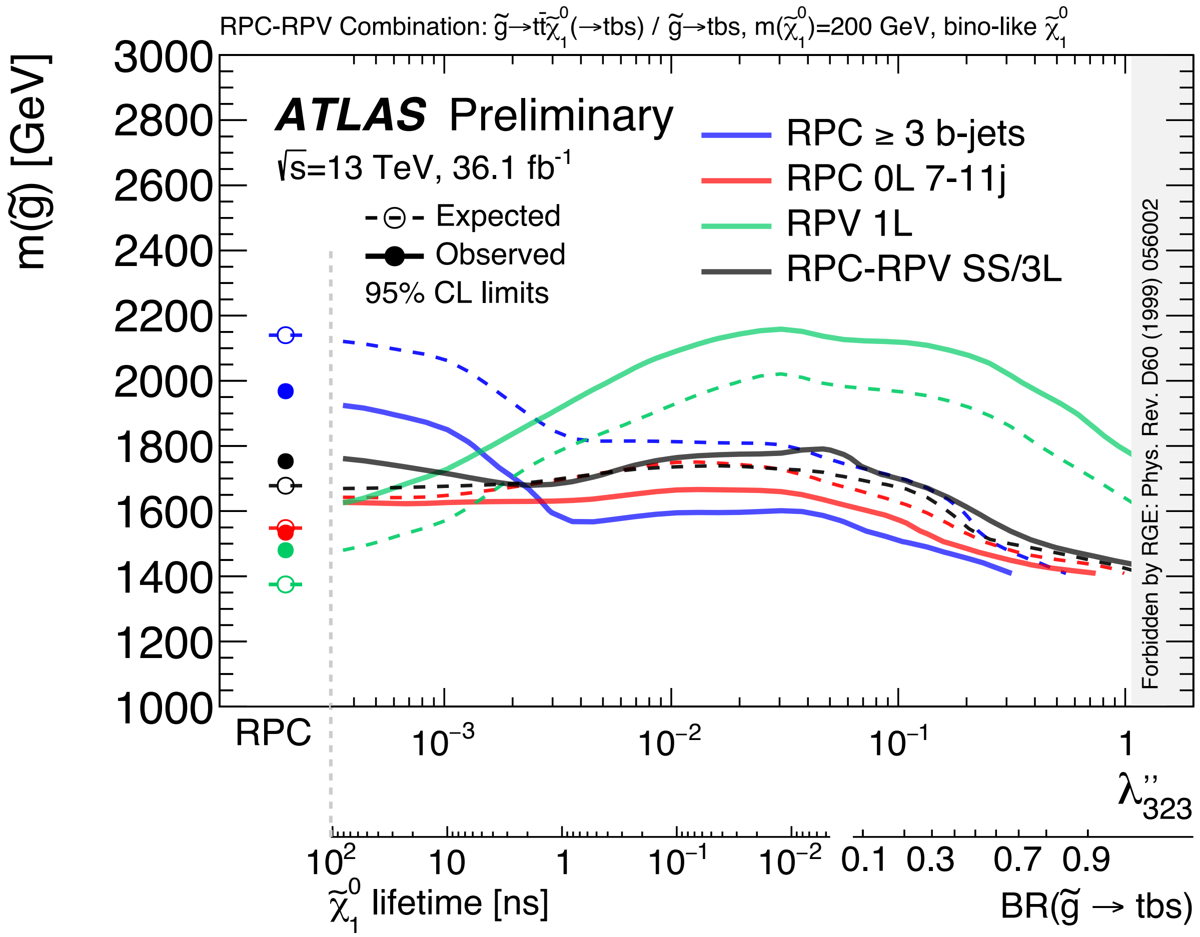
- Several cuts that are usually ~100% efficient have to be taken seriously when working with displaced signals, not easy to provide efficiencies for these
  - Analyses requiring/vetoing leptons, how to cut on displaced lepton d_0 significance?
  - Angle between MET and track-MET ?
  - Cosmic muon veto?
  - Jet/MET cleaning? Original cleaning was ~0% efficient for RPC 0L 2-6 jets analysis
- Very easy to accumulate two or three 25-30% inefficiencies, overestimate of the signal by a factor two if not accounted properly

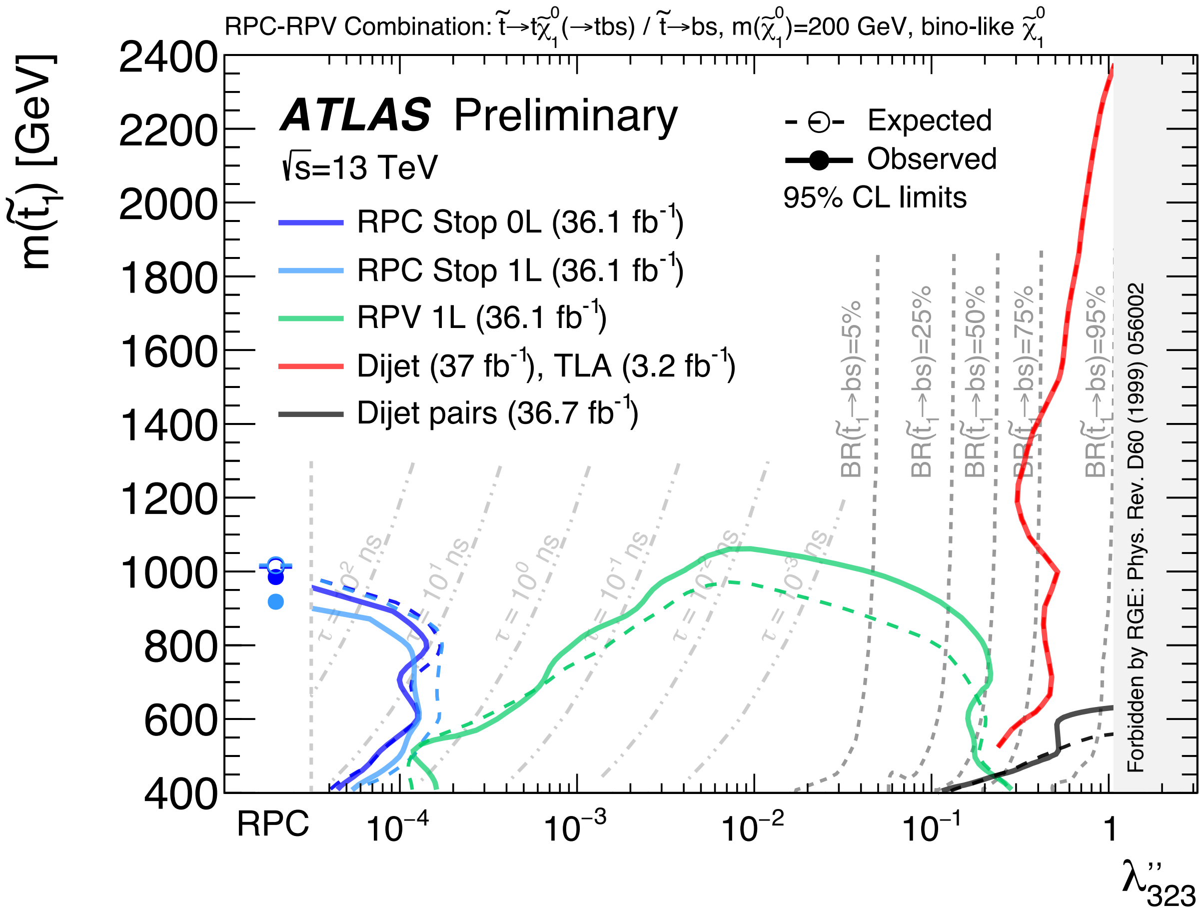
Selection GeV	RPC	$\tau = 100$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns	$\tau = 0.01$ ns
DxAOD skimming	94.0	82.0	86.0	75.0	77.0	78.0
Jet/$E_{\mathrm{T}}^{\mathrm{miss}}$ cleaning	98.9	93.9	76.7	96.0	100.0	100.0
Cosmic muon cut	98.9	98.7	97.0	93.1	77.9	78.2
Lepton veto	58.7	53.9	54.7	47.8	43.3	39.3
$N_{\mathrm{jets}} \geq 4$	98.1	97.6	97.1	100.0	100.0	100.0
$\mathbf{p}_{\mathrm{T}}^{\mathrm{miss,track}} > 30$ GeV	71.7	75.0	85.3	90.6	88.5	87.5
$N_{b-\mathrm{jet}} \geq 1$	92.1	90.0	93.1	89.7	100.0	100.0
$E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV	60.0	59.3	44.4	15.4	12.6	10.5
$\left\|\Delta\phi\left(\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss,track}}\right)\right\| < 1/3\pi$	95.2	93.8	91.7	72.5	72.4	63.6
$\left\|\Delta\phi\left(\mathrm{jet}^{0,1,2}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}\right)\right\| > 0.4$	95.0	93.3	85.5	65.5	71.4	71.4
$m_{\mathrm{jet},R=1.2}^{0} > 120$ GeV	73.7	78.6	75.5	78.9	86.7	90.0

Cutflow for the stop 0L analysis. The numbers given are the relative efficiency of each cut in per-cent.

Conclusions

- Presented a reinterpretation of prompt searches to long-lived SUSY signals.
- Prompt searches have some sensitivity to displaced signals. Clearly suboptimal but allows to set limits on uncovered models or parameter-space.
- Difficult to provide material for externals to perform such reinterpretations, specially for cuts designed to remove noise, cosmics or instrumental background
- Should keep in mind all these caveats when designing an analysis, can very easily lose acceptance to long-lived signals





Backup

RPC 0L 2-6 jets jet cleaning

- Modified cleaning criteria led to much better sensitivity at moderate lifetimes
- R-hadron mass limit with 10 ns lifetime: 1 TeV → 2 TeV !

analysis rejects events from detector noise and non-collision background, if at least one of the two leading jets with $p_T > 100$ GeV fails to satisfy the 'Tight' quality criteria, as described in Ref. [54]. This requirement places a cut on the jet charged particle fraction, defined as the ratio of the scalar sum of the p_T of the tracks associated with the jet to the jet p_T. This requirement introduces a high inefficiency for long-lived signals where displaced jets have no associated tracks, and is modified with respect to the original result. The modified requirement is based on the longitudinal calorimeter-sampling profile of these jets, and has been used in ATLAS searches for long-lived particles [15]. The two leading jets are required to have less than 96% of their energy in the electromagnetic calorimeter and less than 80% of their energy in a single calorimeter layer.

Signal models

- Signals simulated with aMC@NLO_MG5+Pythia8 and run through full ATLAS simulation

Model name	Gqq	Gtt	Stop	R-hadron
Coupling	λ''_{112}	λ''_{323}	λ''_{323}	–
Decay	$\tilde{g} \to qq\tilde{\chi}_1^0$ $\tilde{g} \to qq\tilde{\chi}_1^0(\to qqq)$ $\tilde{g} \to qqq$	$\tilde{g} \to tt\tilde{\chi}_1^0$ $\tilde{g} \to tt\tilde{\chi}_1^0(\to tbs)$ $\tilde{g} \to tbs$	$\tilde{t}_1 \to t\tilde{\chi}_1^0$ $\tilde{t}_1 \to t\tilde{\chi}_1^0(\to tbs)$ $\tilde{t}_1 \to bs$	$\tilde{g} \to qq\tilde{\chi}_1^0$
Other colored sparticle masses	$m(\tilde{q}) = 3$ TeV $m(\tilde{t}, \tilde{b}) = 5$ TeV	$m(\tilde{q}) = 5$ TeV $m(\tilde{t}, \tilde{b}) = 2.4$ TeV	$m(\tilde{q}, \tilde{g}) = 3$ TeV $m(\tilde{t}_2, \tilde{b}) = 3$ TeV	$m(\tilde{q}, \tilde{t}, \tilde{b}) \approx$ PeV
LSP	The LSP is bino-like, $m(\tilde{\chi}_1^0) = 200$ GeV			$m(\tilde{\chi}_1^0) = 100$ GeV

Summary of signal models. First and second generation squark masses are assumed to be degenerate (q̃ = ũ, d̃, s̃, c̃). Left- and right-handed superpartner masses are also assumed to be degenerate (q̃= q̃1, q̃2), except for the stop model where the right-handed top quark partner is assumed to be lighter.

Suite of analyses

Analysis name	Leptons	Jets / b-tags	E_T^{miss} requirement	Representative cuts	Model targeted
RPC 0-lepton, 2-6 jets [53]	0	≥ 4 / –	$E_T^{miss}/m_{eff} > 0.2$	$m_{eff} > 3000$ GeV	Gqq, R-hadron
RPC 0-lepton, 7-11 jets [55]	0	≥ 7 / – ≥ 11 / ≥ 2	$E_T^{miss}/\sqrt{H_T} > 5$ GeV$^{1/2}$	–	Gqq Gtt
RPC multi-b [56]	0 1	≥ 7 / ≥ 3 ≥ 5 / ≥ 3	$E_T^{miss} > 350$ GeV $E_T^{miss} > 500$ GeV	$m_{eff} > 2600$ GeV $m_{eff} > 2200$ GeV	Gtt
RPV 1-lepton [57]	1	≥ 10 / ≥ 4	–	–	Gtt, stop
RPC Stop 0-lepton [58]	0	≥ 4 / ≥ 2	$E_T^{miss} > 400$ GeV	$m_{jet,R=1.2} > 120$ GeV	stop
RPC Stop 1-lepton [59]	1	≥ 4 / ≥ 1	$E_T^{miss} > 250$ GeV	$m_T > 160$ GeV	stop
RPC and RPV same-sign and three leptons [60]	2 SS or 3	≥ 6 / ≥ 2 ≥ 6 / ≥ 2	E_T^{miss}/m_{eff}¿0.15 –	$m_{eff} > 1800$ GeV $m_{eff} > 2000$ GeV	Gtt, stop
RPV stop dijet pairs [61]	–	≥ 4 / ≥ 2	–	$\mathcal{A} < 0.05$	stop
Dijet and TLA [62,63]	–	≥ 2 / –	–	$\|y^*\| < 0.6$	stop

Main characteristics of the most sensitive signal region per analysis. Only an illustrative subset of the cuts that define each signal region are included here. A dash (–) is used to indicate that the variable is not used in the analysis selection. The requirement of two same-sign leptons is denoted as SS. The variables used to illustrate the signal region selections are defined in the text.

Cutflow RPC 0L 2-6 jets

Selection	RPC	$\tau = 100$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns
Pre-selection, $E_{\mathrm{T}}^{\mathrm{miss}}$¿250 GeV, p_{T}(jet1)¿200 GeV, $m_{\mathrm{eff}} > 800$ GeV	88.5	82.0	70.5	8.4	1.6
jet multiplicity ≥ 2	100.0	100.0	100.0	100.0	100.0
Cleaning Cuts	97.6	94.9	79.4	70.6	98.7
jet multiplicity ≥ 4	95.5	95.2	97.1	99.7	100.0
$\Delta\Phi(\mathrm{jet}_{1,2,(3)}, E_{\mathrm{T}}^{\mathrm{miss}})$¿0.4	81.4	82.1	80.7	69.5	24.8
$\Delta\Phi(\mathrm{jet}_{i>3}, E_{\mathrm{T}}^{\mathrm{miss}})$¿0.4	75.9	75.8	70.9	60.1	15.8
$p_{\mathrm{T}}(\mathrm{jet}_3)$ ¿150 GeV	71.3	72.4	75.5	90.7	100.0
$\lvert\eta(\mathrm{j}_{1,2,3,4}\rvert$¡2.0	92.5	92.9	92.7	96.4	100.0
Aplanarity ¿0.04	73.1	75.0	77.7	70.8	83.3
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(4\mathrm{j})$¿0.2	76.4	74.3	71.3	87.6	0.0
$m_{\mathrm{eff}}(\mathrm{incl.})$¿3000 GeV	50.7	52.8	61.2	83.6	–

Cutflow for the 0-lepton Meff4j-3000 signal region, considering a signal in the Gqq model with m(g̃,χ̃10) = (1800,200) GeV, and different neutralino lifetimes. The numbers given are the relative efficiency of each cut in per-cent.

- Updated cleaning cut has ~70% efficiency for 1 ns lifetime, original cleaning cut had ~0% efficiency

Cutflow RPV 1L

Selection	RPC	$\tau = 100$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns	$\tau = 0.01$ ns	BR=0%	BR=25%	BR=50%	BR=75%	BR=100%
All Events	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
$\geq$ 1 baseline lepton and trigger	40.6	39.7	39.5	40.2	45.7	48.8	53.9	46.2	38.1	29.6	20.7
$\geq$ 1 signal lepton	84.9	84.8	84.9	82.0	74.1	68.2	82.0	81.6	81.2	80.5	79.3
$\geq$ 5 jets	91.7	92.4	94.4	99.2	99.6	99.8	100.0	99.8	99.6	99.2	98.6
$\geq$ 10 jets	8.2	9.6	15.6	38.5	47.5	54.3	55.0	48.0	40.3	31.1	18.0
$\geq$ 4 b-jet	32.7	36.1	33.4	32.8	59.9	91.4	70.3	65.9	59.9	50.4	24.6

Cutflow for the RPV 1L analysis, considering a signal in the Gtt model with m(g̃,χ̃10) = (1800, 200) GeV, and different lifetimes and branching fractions. The BR in the column headers refer to BR(g̃ → tbs). The numbers given are the relative efficiency of each cut in per-cent.

Selection	RPC	$\tau = 100$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns	$\tau = 0.01$ ns	BR=0%	BR=25%	BR=50%	BR=75%	BR=100%
All Events	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
$\geq$ 1 baseline lepton and trigger	24.2	23.1	21.3	26.5	32.1	37.4	39.9	31.1	21.5	11.2	0.2
$\geq$ 1 signal lepton	87.3	88.2	45.1	81.2	66.8	59.8	82.7	83.0	83.1	82.8	0.0
$\geq$ 5 jets	23.6	27.9	1.2	83.2	88.3	92.0	93.9	90.4	87.2	84.2	–
$\geq$ 10 jets	0.3	0.4	0.0	3.2	6.2	7.7	8.2	6.8	5.4	4.0	–
$\geq$ 4 b-jet	0.0	0.0	–	9.4	34.7	87.2	43.2	40.8	37.1	30.8	–

Cutflow for the RPV 1L analysis, considering a signal in the stop model with m(t̃1,χ̃10) = (800, 200) GeV, and different lifetimes and branching fractions. The BR in the column headers refer to BR(t̃1 → bs). The numbers given are the relative efficiency of each cut in per-cent.

Cutflow RPC stop 0L

Selection GeV	RPC	$\tau = 100$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns	$\tau = 0.01$ ns
DxAOD skimming	94.0	82.0	86.0	75.0	77.0	78.0
Jet/$E_{\mathrm{T}}^{\mathrm{miss}}$ cleaning	98.9	93.9	76.7	96.0	100.0	100.0
Cosmic muon cut	98.9	98.7	97.0	93.1	77.9	78.2
Lepton veto	58.7	53.9	54.7	47.8	43.3	39.3
$N_{\mathrm{jets}} \geq 4$	98.1	97.6	97.1	100.0	100.0	100.0
$\mathbf{p}_{\mathrm{T}}^{\mathrm{miss,track}} > 30$ GeV	71.7	75.0	85.3	90.6	88.5	87.5
$N_{b-\mathrm{jet}} \geq 1$	92.1	90.0	93.1	89.7	100.0	100.0
$E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV	60.0	59.3	44.4	15.4	12.6	10.5
$\left\lvert\Delta\phi\left(\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss,track}}\right)\right\rvert < 1/3\pi$	95.2	93.8	91.7	72.5	72.4	63.6
$\left\lvert\Delta\phi\left(\mathrm{jet}^{0,1,2}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}\right)\right\rvert > 0.4$	95.0	93.3	85.5	65.5	71.4	71.4
$m_{\mathrm{jet},R=1.2}^{0} > 120$ GeV	73.7	78.6	75.5	78.9	86.7	90.0
SRB-TT						
$m_{\mathrm{jet},R=1.2}^{1} > 120$ GeV	18.6	19.1	28.2	31.3	46.9	50.0
$\Delta R\,(b,b) > 1.2$	84.6	85.7	80.0	78.7	82.0	75.6
$m_{\mathrm{T}}^{b,\mathrm{max}} > 200$ GeV	90.9	94.4	87.5	81.1	88.0	88.2
$m_{\mathrm{T}}^{b,\mathrm{min}} > 200$ GeV	70.0	76.5	69.3	60.0	36.4	18.0
Tau Veto	85.7	84.6	75.3	47.2	42.5	20.4
$N_{b-\mathrm{jet}} \geq 2$	58.3	61.8	61.6	29.4	52.9	100.0
SRB-TW						
$m_{\mathrm{jet},R=1.2}^{1} < 120$ GeV	78.6	77.3	71.8	73.3	50.0	51.1
$m_{\mathrm{jet},R=1.2}^{1} > 60$ GeV	35.5	35.3	41.2	51.8	50.8	54.3
$\Delta R\,(b,b) > 1.2$	79.5	76.7	81.0	77.2	81.8	80.0
$m_{\mathrm{T}}^{b,\mathrm{max}} > 200$ GeV	87.1	87.0	82.4	86.4	77.8	95.0
$m_{\mathrm{T}}^{b,\mathrm{min}} > 200$ GeV	70.4	65.0	70.0	57.9	45.2	24.7
Tau Veto	84.2	76.9	72.4	40.9	43.2	72.3
$N_{b-\mathrm{jet}} \geq 2$	58.8	51.0	53.5	37.8	75.6	64.7
SRB-T0						
$m_{\mathrm{jet},R=1.2}^{1} < 60$ GeV	51.4	50.0	43.7	33.3	23.8	23.3
$m_{\mathrm{T}}^{b,\mathrm{min}} > 200$ GeV	69.4	69.1	67.7	54.0	41.9	20.5
$\Delta R\,(b,b) > 1.2$	66.0	65.8	66.7	74.1	60.0	74.4
$m_{\mathrm{T}}^{b,\mathrm{max}} > 200$ GeV	97.0	100.0	92.9	100.0	100.0	100.0
Tau Veto	84.4	84.0	76.9	48.0	46.2	65.6
$N_{b-\mathrm{jet}} \geq 2$	51.9	52.4	53.0	52.1	55.6	52.4

Cutflow for the stop 0L analysis, considering a signal in the stop model with m(t̃1,χ̃10) = (600, 200) GeV, and different lifetimes. The numbers given are the relative efficiency of each cut in per-cent. The DxAOD skimming step requires at least one of the following four criteria to be fullfilled: HT > 150 GeV; at least one loose electron with pT > 100 GeV or at least two loose electrons with pT > 20 GeV; at least one muon with pT > 100 GeV or at least two muons with pT > 20 GeV; or at least one photon with pT > 100 GeV or at least two photons with pT > 50 GeV.

Cutflow RPC stop 1L

Selection	RPC	$\tau = 100$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns
Total	100.0	100.0	100.0	100.0	100.0
DxAOD skimming	73.8	70.4	75.9	72.9	79.7
Jet/MET cleaning	98.8	94.1	75.1	94.3	99.7
Bad muon veto	99.8	99.1	98.9	99.1	98.9
≥ 1 baseline lepton	60.7	60.8	59.4	63.8	72.2
≥ 1 signal lepton	68.5	70.2	68.6	64.8	52.8
$==1$ signal lepton	90.8	90.6	90.2	89.8	90.4
$==1$ baseline lepton	84.1	83.2	83.1	78.1	58.1
XE trigger, ≥ 4 jets, $E_{\mathrm{T}}^{\mathrm{miss}} > 230$ GeV	50.2	50.6	49.1	21.7	18.8
$\lvert\Delta\phi(j_1, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\rvert > 0.4$	99.4	99.2	98.9	97.6	96.4
$\lvert\Delta\phi(j_2, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\rvert > 0.4$	95.8	94.6	94.3	85.2	84.5
$m_{\mathrm{T2}}^{\tau} > 80$ GeV	98.2	99.0	99.0	97.2	93.7
First jet $p_{\mathrm{T}} > 60$ GeV	99.7	100.0	100.0	100.0	100.0
Second jet $p_{\mathrm{T}} > 50$ GeV	98.6	98.8	99.8	100.0	100.0
Third jet $p_{\mathrm{T}} > 40$ GeV	94.7	95.2	97.8	99.7	100.0
Fourth jet $p_{\mathrm{T}} > 40$ GeV	75.8	81.2	85.7	96.9	98.7
$E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV	92.4	93.6	92.4	81.1	83.5
$E_{\mathrm{T},\perp}^{\mathrm{miss}} > 230$ GeV	66.8	65.4	61.7	47.2	47.4
$H_{\mathrm{T,sig}}^{\mathrm{miss}} > 14$	86.6	85.1	76.4	41.4	46.2
$m_{\mathrm{T}} > 160$ GeV	85.4	85.7	82.1	51.2	27.7
$am_{\mathrm{T2}} > 175$ GeV	88.7	87.3	84.5	82.1	82.8
≥ 1 b-jet	93.9	94.3	92.9	80.8	100.0
$\Delta R(b,\ell)<2.0$	94.3	96.0	89.3	100.0	100.0
$m_{\mathrm{top}}^{\mathrm{recl}} > 150$ GeV	75.0	79.0	75.9	60.5	87.5

Cutflow for the stop 1L analysis, considering a signal in the stop model with m(t̃1,χ̃10) = (700, 200) GeV, and different lifetimes. The numbers given are the relative efficiency of each cut in per-cent. The DxAOD skimming step requires at least one of the following criteria to be fullfilled: one of the ETmiss triggers has fired and there is at least one loose muon (electron) with pT > 3.5 (4.5) GeV; or one of the ETmiss or lepton triggers has fired and there is at least one loose lepton with pT > 25 GeV.

Cutflow RPC 0L 2-6 jets, R-hadron

Selection	$\tau = 50$ ns	$\tau = 10$ ns	$\tau = 1$ ns	$\tau = 0.1$ ns	$\tau = 0.01$ ns	$\tau = 0$ ns
Pre-selection, $E_{\mathrm{T}}^{\mathrm{miss}}$¿250 GeV, p_{T}(jet1)¿200 GeV, $m_{\mathrm{eff}} > 800$ GeV	43.8	79.5	85.3	83.9	86.5	88.5
jet multiplicity ≥ 2	91.7	98.1	100.0	100.0	100.0	100.0
Cleaning Cuts	74.3	76.1	98.8	98.8	99.0	97.6
jet multiplicity ≥ 4	46.3	82.2	95.0	95.4	95.6	95.5
$\Delta\Phi(\mathrm{jet}_{1,2,(3)}, E_{\mathrm{T}}^{\mathrm{miss}})$¿0.4	81.9	78.9	80.9	81.2	81.2	81.4
$\Delta\Phi(\mathrm{jet}_{i>3}, E_{\mathrm{T}}^{\mathrm{miss}})$¿0.4	82.4	77.5	76.4	75.9	75.8	75.9
$p_{\mathrm{T}}(\mathrm{jet}_3)$ ¿150 GeV	30.3	55.0	69.7	70.4	70.3	71.3
$\lvert\eta(\mathrm{j}_{1,2,3,4}\rvert$¡2.0	85.1	90.8	92.7	93.2	93.1	92.5
Aplanarity ¿0.04	67.9	69.9	72.6	73.4	72.2	73.1
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(4\mathrm{j})$¿0.2	77.3	70.2	71.1	73.6	74.2	76.4
m_{eff}(incl.)¿3000 GeV	18.3	27.3	41.2	45.8	46.8	50.7

Cutflow for the 0-lepton Meff4j-3000 signal region, considering a signal in the R-hadron model with m(g̃,χ̃10) = (1800,100) GeV, and different R-hadron lifetimes. The numbers given are the relative efficiency of each cut in per-cent.