Searching for strongly produced SUSY with two like-charge or three leptons at ATLAS

IOP HEPP Meeting 2014

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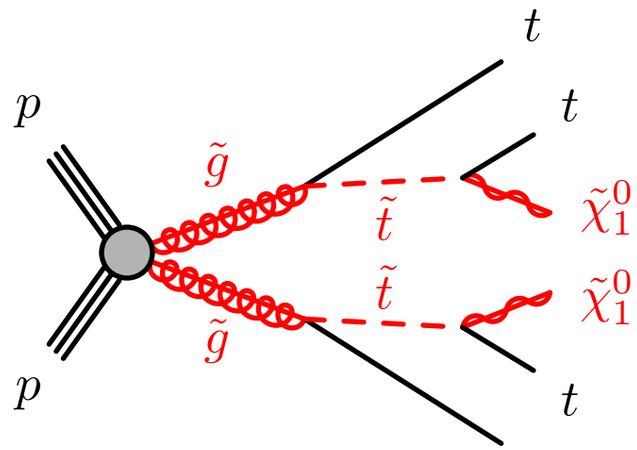
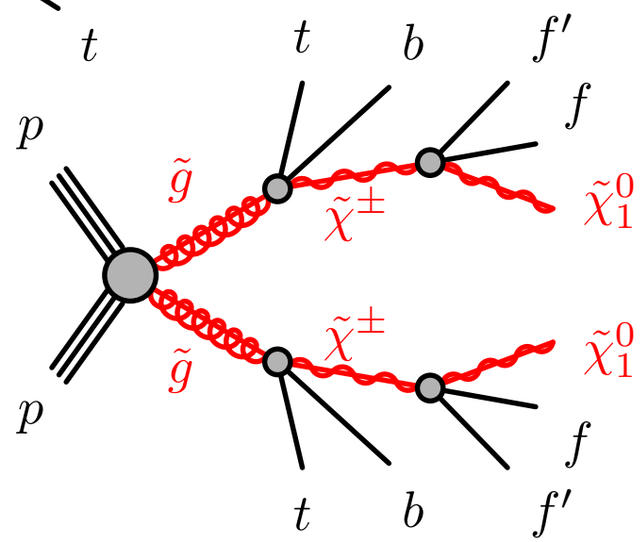
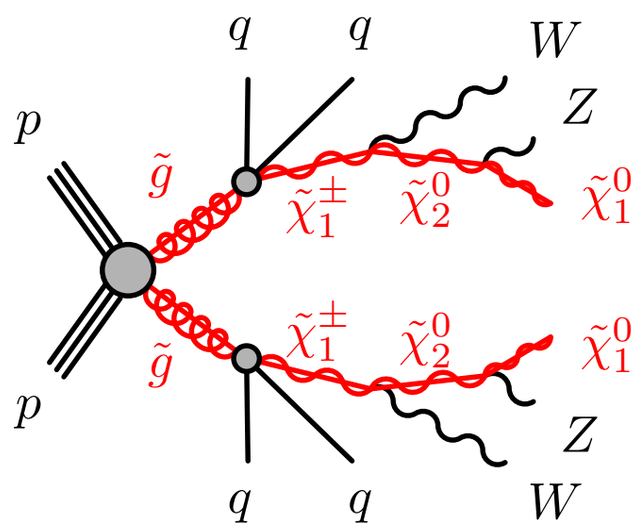
Typical features of events

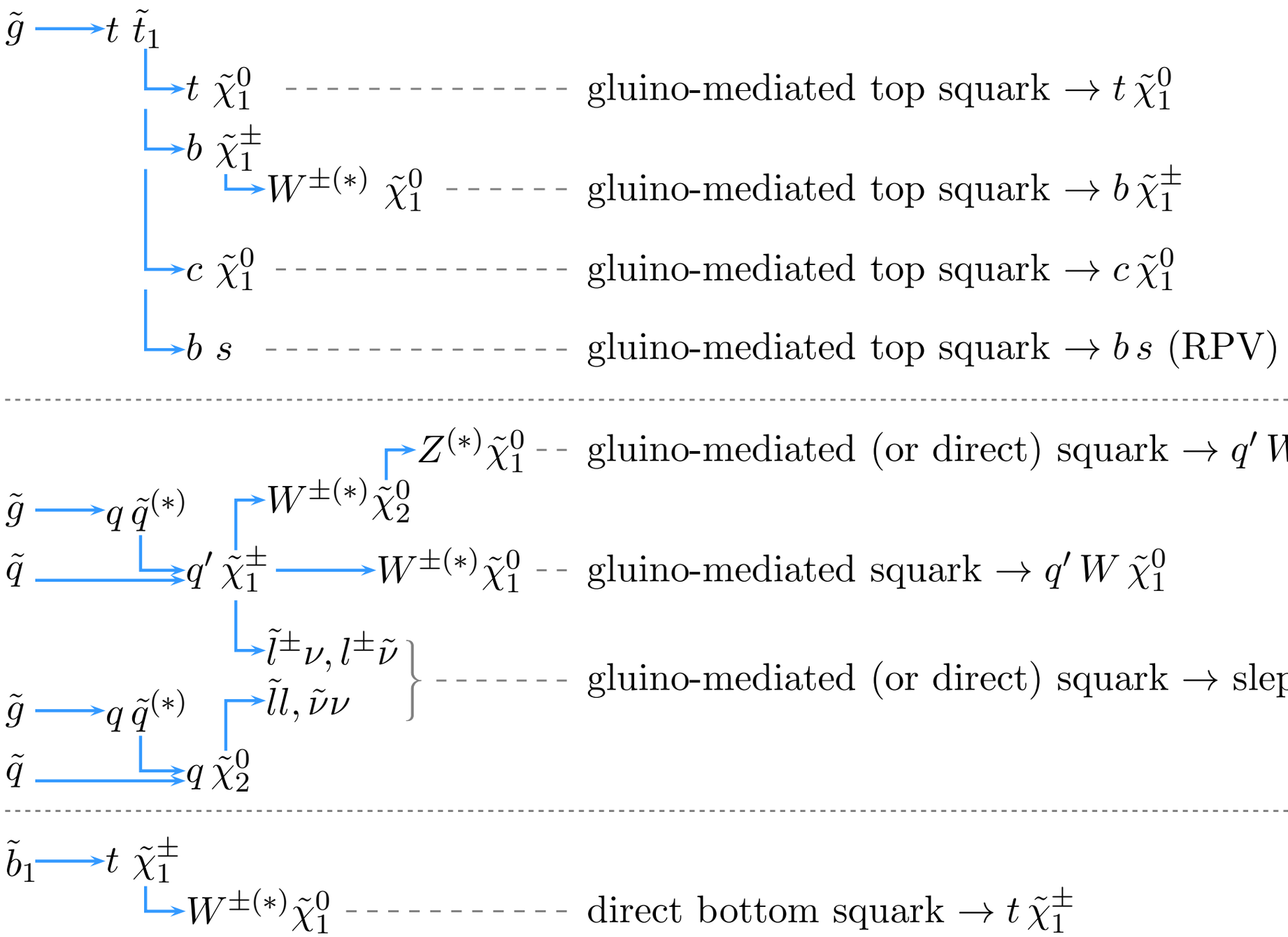
- **Many jets** — large effective mass
- ***b*-jets** (target 3rd generation squark models, favoured by naturalness)
- **MET** (in R-parity conserving models)
- Opportunities for forming **like-sign lepton pairs** (due to gluinos being Majorana fermions)
- **Three lepton** signatures from longer decay chains







Targeting simplified models

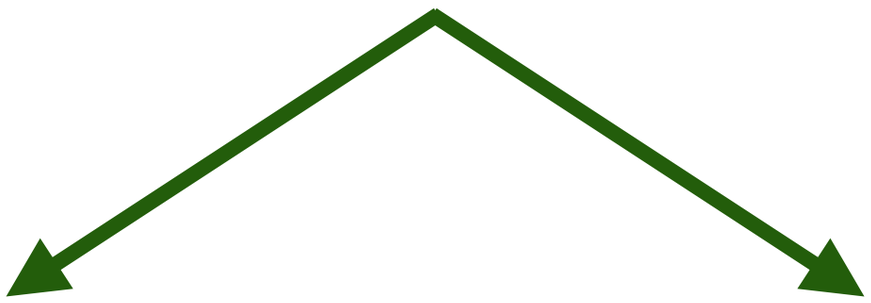


RPV = R-parity violating

Signal regions

SR0b	**SR1b**	**SR3b**	**SR3L$_{low}$**	**SR3L$_{high}$**
SS	SS	SS / ≥ 3 lep	≥ 3 leptons	≥ 3 leptons
$E_{\mathrm{T}}^{\mathrm{miss}} > 150\,\mathrm{GeV}$	$E_{\mathrm{T}}^{\mathrm{miss}} > 150\,\mathrm{GeV}$	–	$50 < E_{\mathrm{T}}^{\mathrm{miss}} < 150\,\mathrm{GeV}$	$E_{\mathrm{T}}^{\mathrm{miss}} > 150\,\mathrm{GeV}$
0 b-jets	≥ 1 b-jets	≥ 3 b-jets	–	–

Simultaneous maximum likelihood fit



Model-dependent limits in parameter space

Model-independent cross section limits

Signal regions

SR	Leptons	N_{b-jets}	Other variables	Additional requirement on m_{eff}
SR3b	SS or 3L	$\geq$3	$N_{jets} \geq 5$	m_{eff}>350 GeV
SR1b	SS	$\geq$1	$N_{jets} \geq 3$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, m_{T}>100 GeV, veto SR3b	m_{eff}>700 GeV
SR0b	SS	$= 0$	$N_{jets} \geq 3$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, m_{T}> 100 GeV, veto SR3b	m_{eff}>400 GeV
SR3Llow	3L	-	$N_{jets} \geq 4$, 50 < $E_{\text{T}}^{\text{miss}}$< 150 GeV, Z veto, veto SR3b	m_{eff}>400 GeV
SR3Lhigh	3L	-	$N_{jets} \geq 4$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, veto SR3b	m_{eff}>400 GeV

$$m_{\text{eff}} = E_{\text{T}}^{\text{miss}} + \sum p_{\text{T}}^{\ell} + \sum p_{\text{T}}^{\text{jet}}$$

Simultaneous maximum likelihood fit

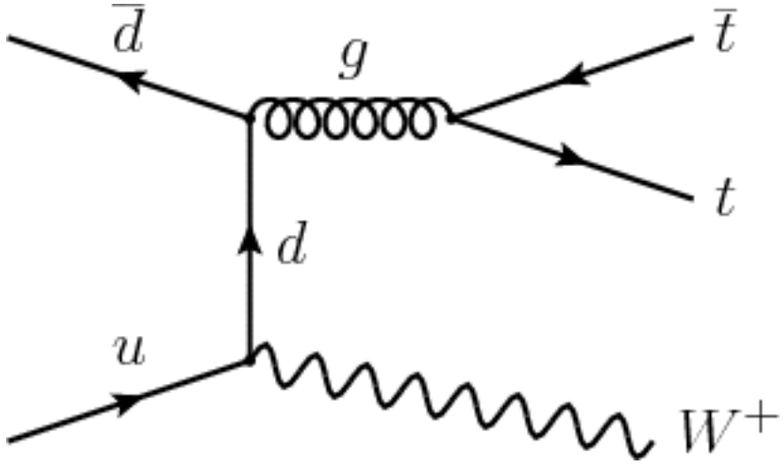
Shape fit in m_{eff}

Model-dependent limits in parameter space

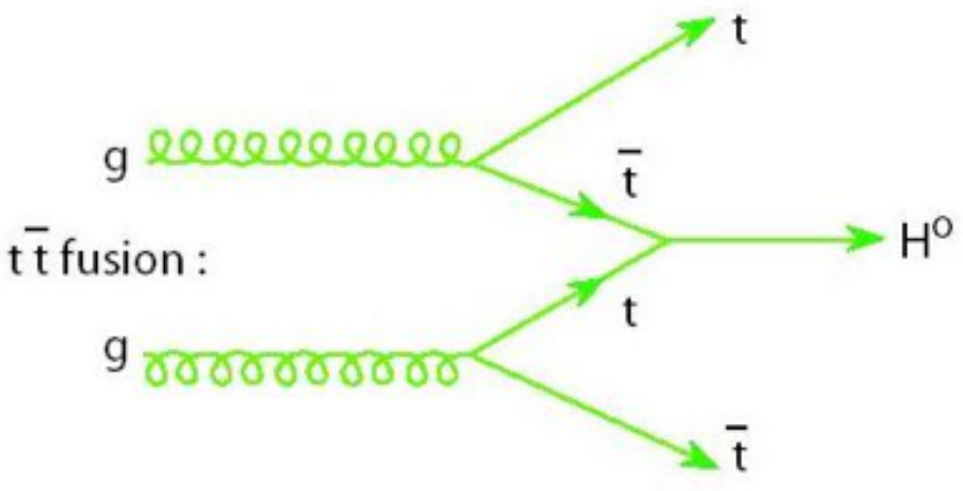
Model-independent cross section limits

Backgrounds to same-sign signature

Very low SM background — allows loose MET requirement, gaining sensitivity to compressed SUSY & RPV scenarios

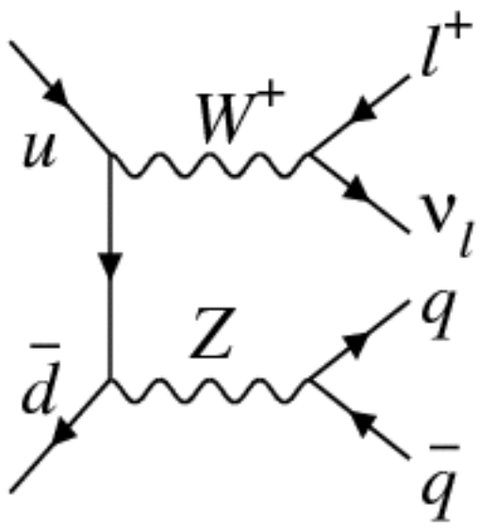


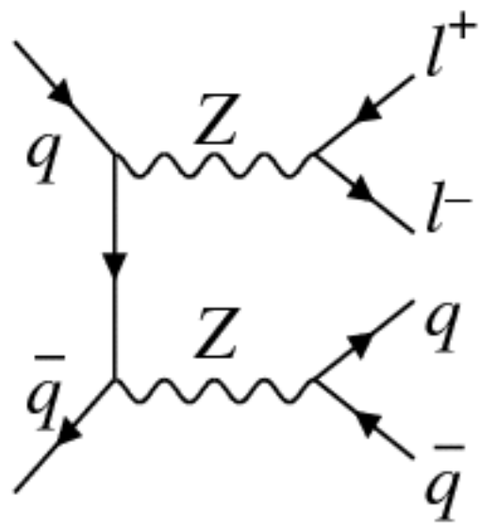
$t\bar{t} + V$



$t\bar{t} + H$

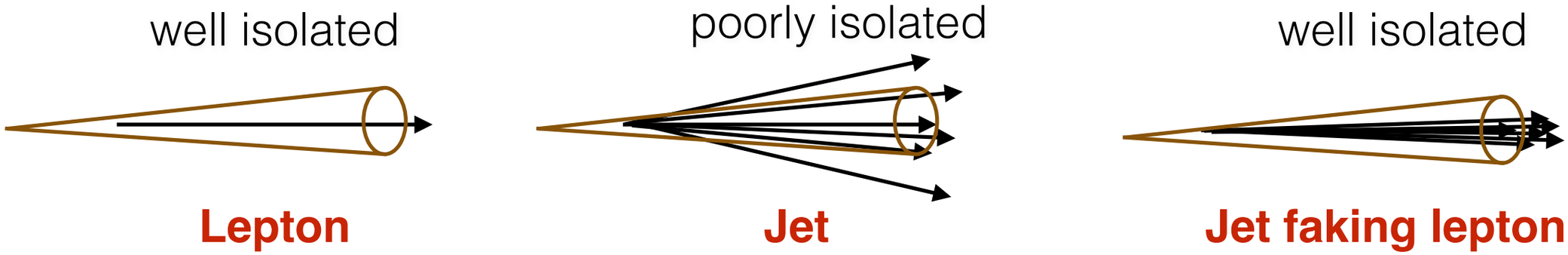
WZ, ZZ

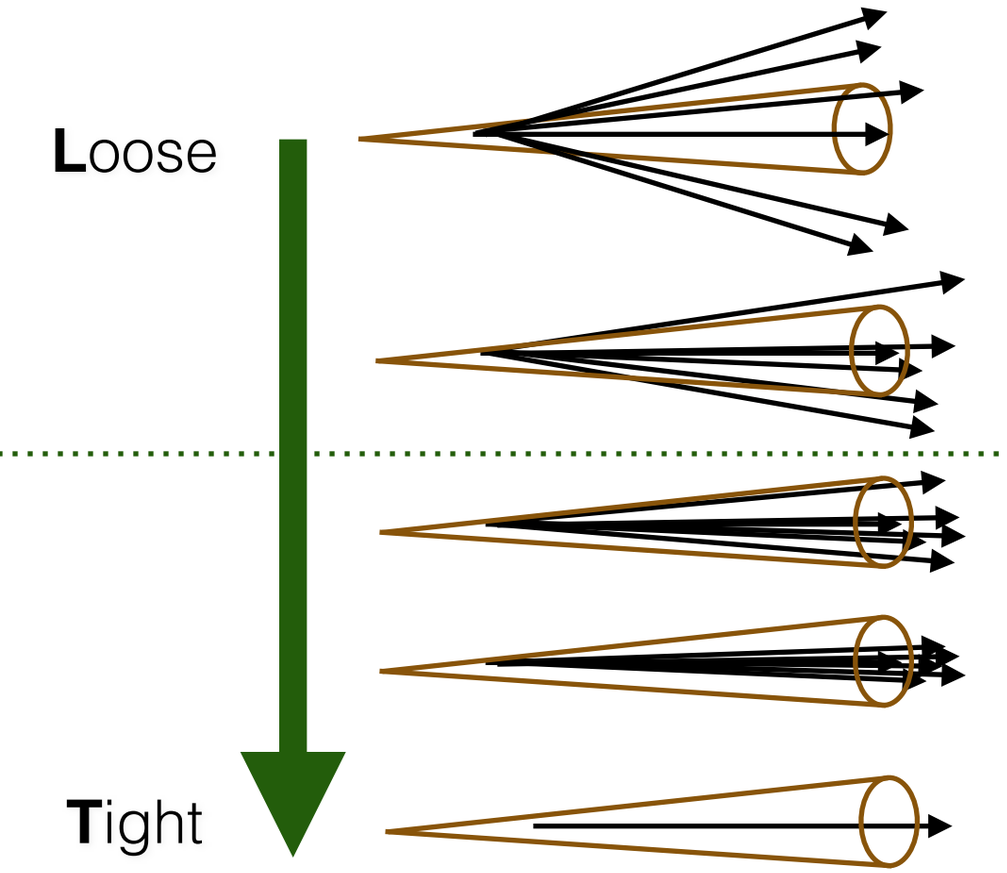




… and reducible components with fake or charge-flipped leptons

Fake leptons: ‘matrix method’ estimation





Isolation of **R**eal leptons is better than **F**akes

$$P(T|R) = \epsilon_r$$
$$P(T|F) = \epsilon_f$$
$$P(L|R) = 1 - \epsilon_r$$
$$P(L|F) = 1 - \epsilon_f$$

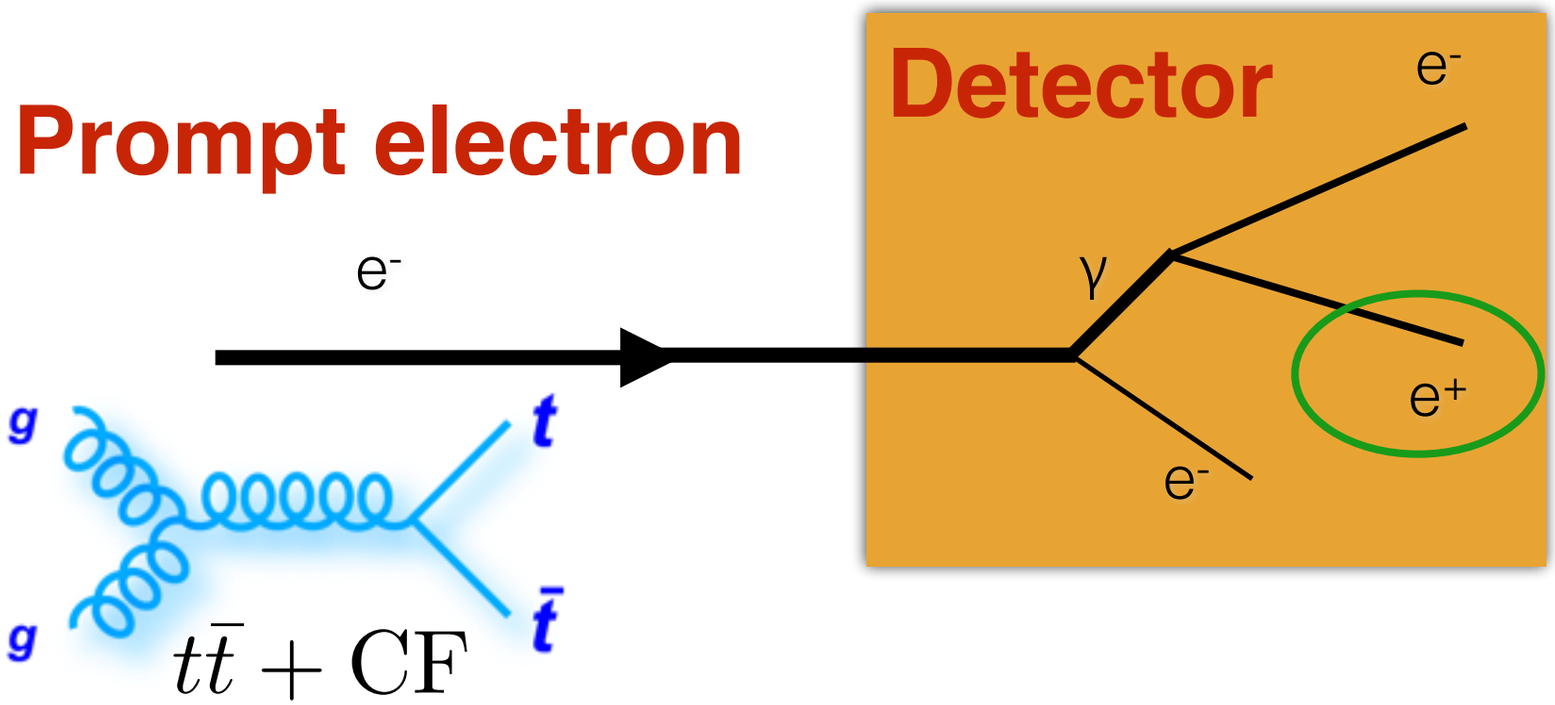
$$\begin{pmatrix} n_T \\ n_L \end{pmatrix} = \begin{pmatrix} \epsilon_r & \epsilon_f \\ 1-\epsilon_r & 1-\epsilon_f \end{pmatrix} \begin{pmatrix} n_R \\ n_F \end{pmatrix}$$

extend to more leptons by taking outer product of these matrices

Input **Output**

$$e^+e^-\mu^+, TLL \longrightarrow \begin{cases} LLL & w_{LLL} & e_L^+e_L^-\mu_L^+ & \text{Fails cuts} \\ \cdots & \cdots & & \\ TTL & w_{TTL} & e_T^+e_T^-\mu_L^+ & \text{Fails cuts} \\ TLT & w_{TLT} & e_T^+e_L^-\mu_T^+ & \text{2 lepton SS} \\ LTT & w_{LTT} & e_L^+e_T^-\mu_T^+ & \text{Fails cuts} \\ TTT & w_{TTT} & e_T^+e_T^-\mu_T^+ & > \text{2 lepton} \end{cases}$$

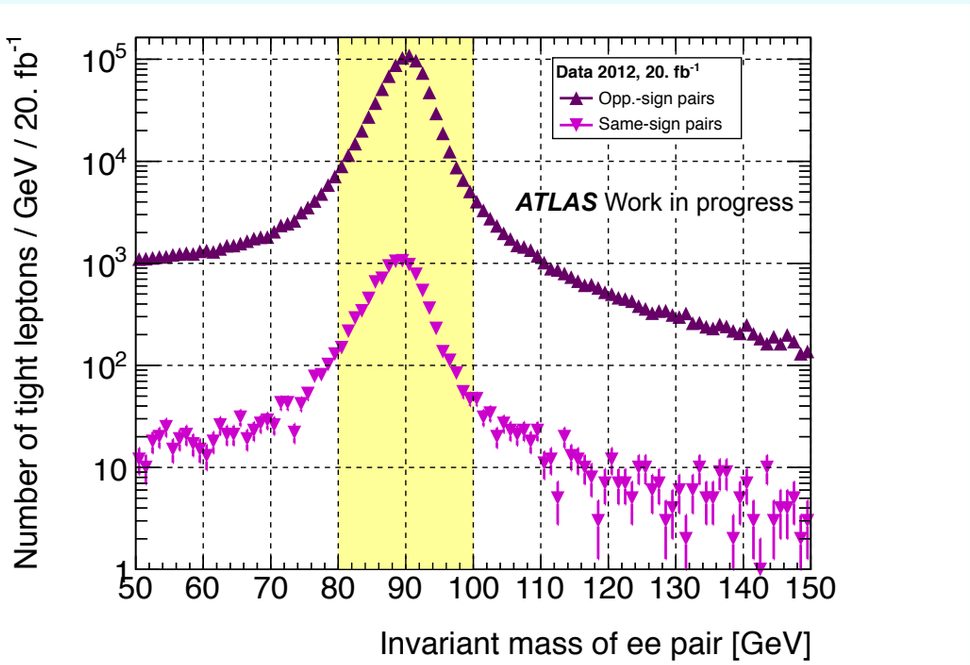
Charge-flipped electrons



Sometimes we observe an electron of the opposite charge

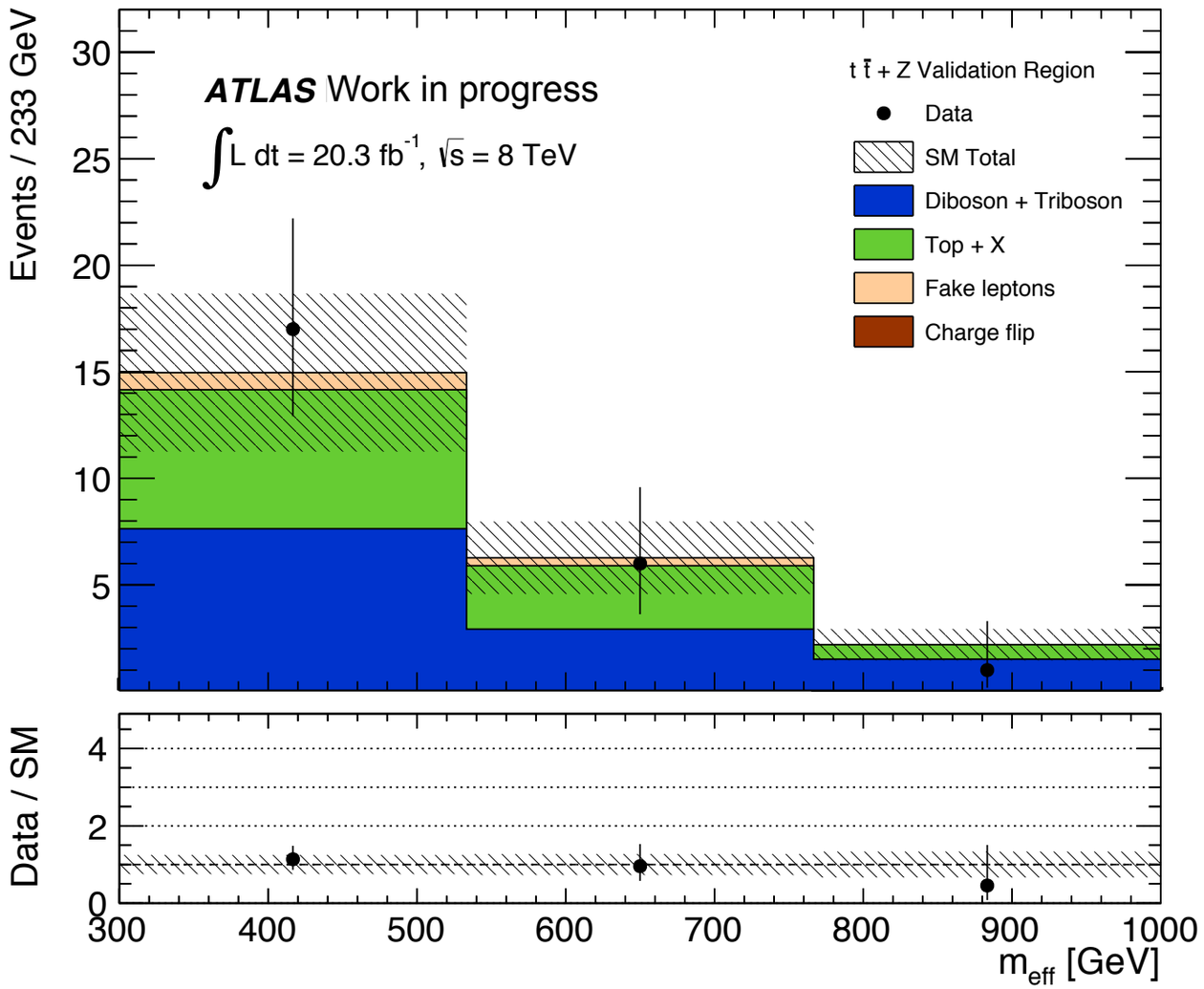
- Measure flip rate in data CR (Z peak) with likelihood fit
- Reduced uncertainties cf. tag-and-probe
- Estimate formed by reweighting OS data

$$\epsilon = \frac{N_{SS}}{N_{SS} + N_{OS}}$$



Validation region distributions

$t\bar{t} + Z$



≥ 3 leptons

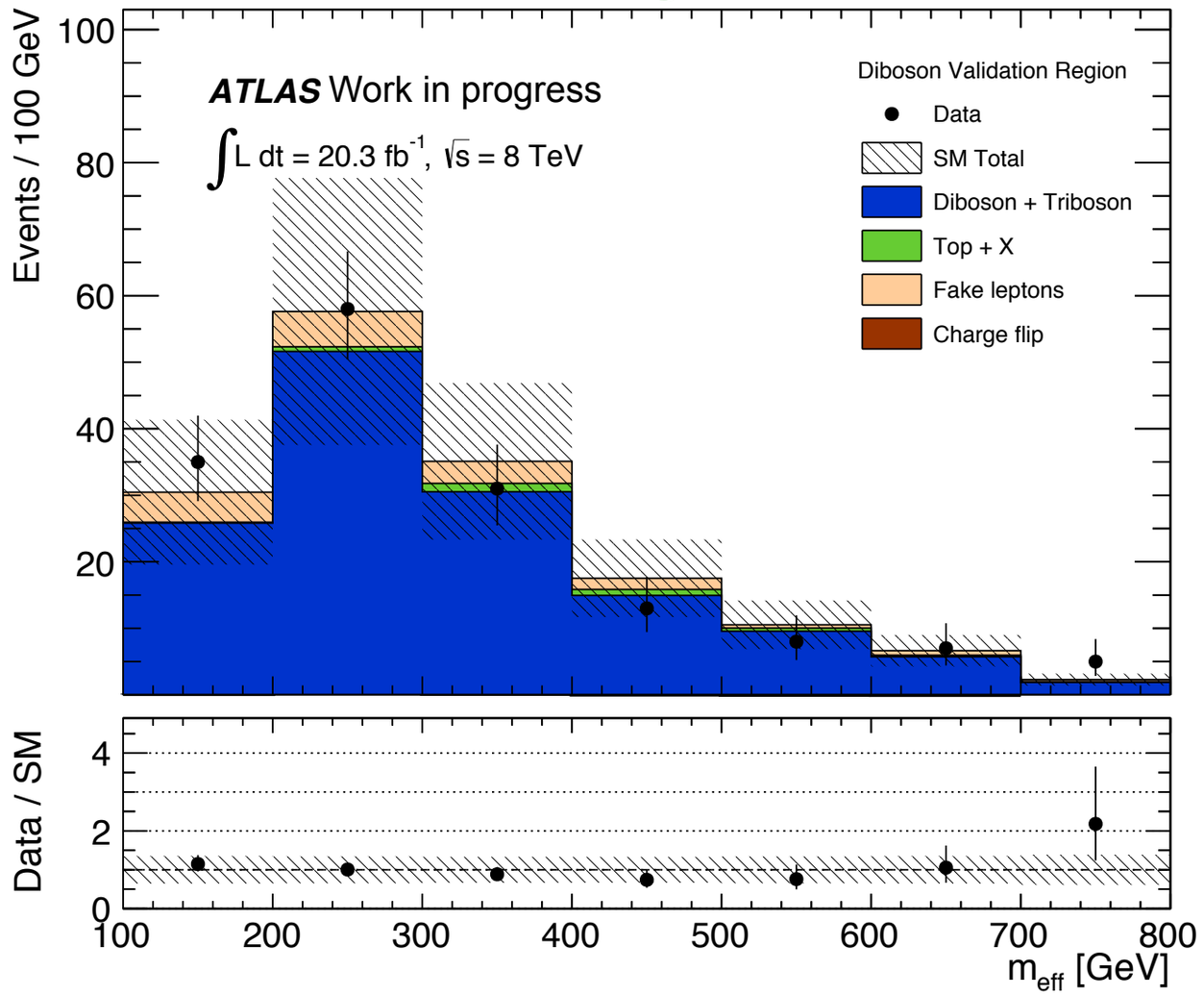
$1, 2$ b-jets

$20 < E_{\mathrm{T}}^{\mathrm{miss}} < 120\,\mathrm{GeV}$

$m_{\mathrm{eff}} > 300\,\mathrm{GeV}$

Z window

WZ + jets



2 SS μ

b-jet veto

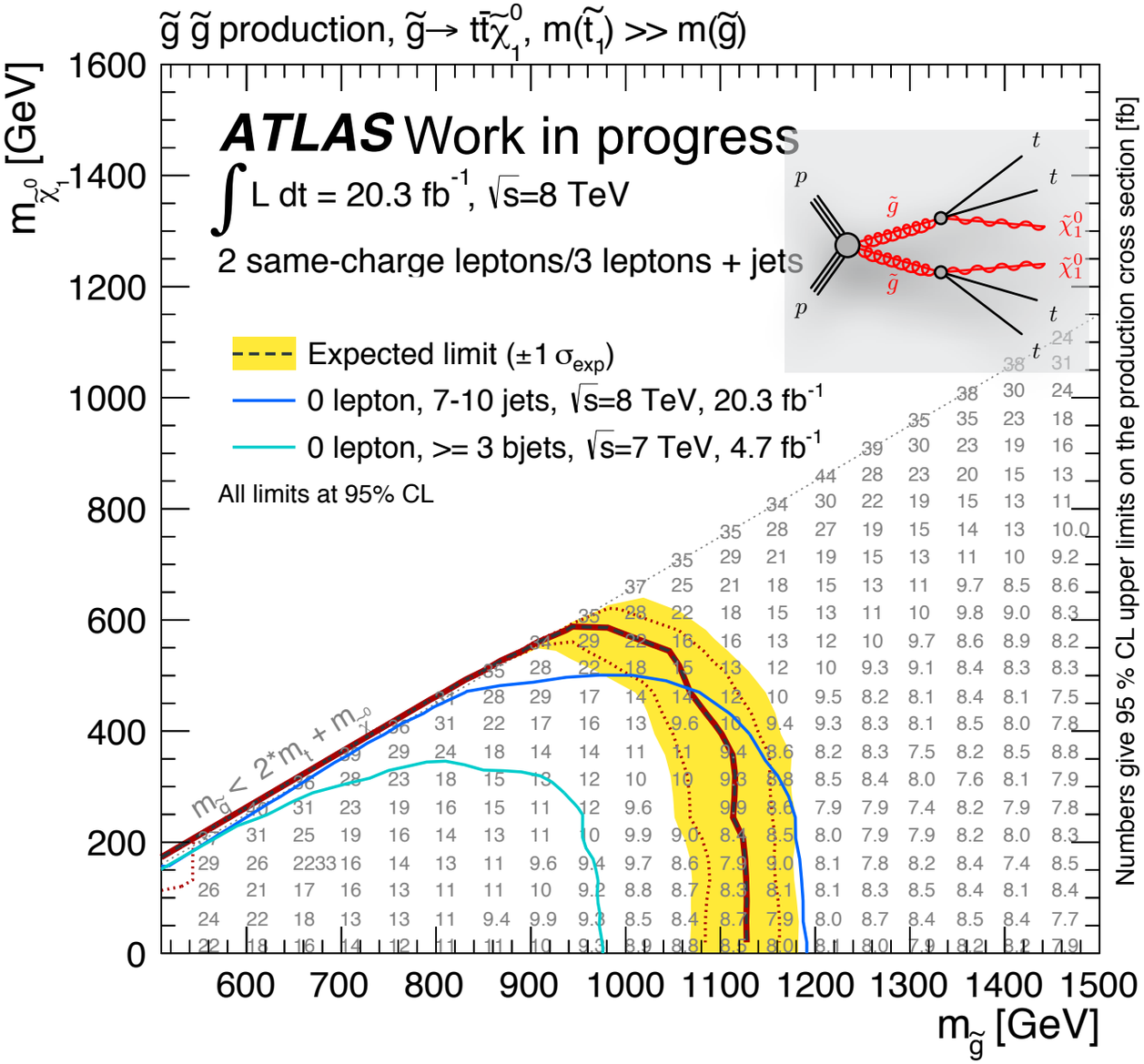
$20 < E_{\mathrm{T}}^{\mathrm{miss}} < 120\,\mathrm{GeV}$

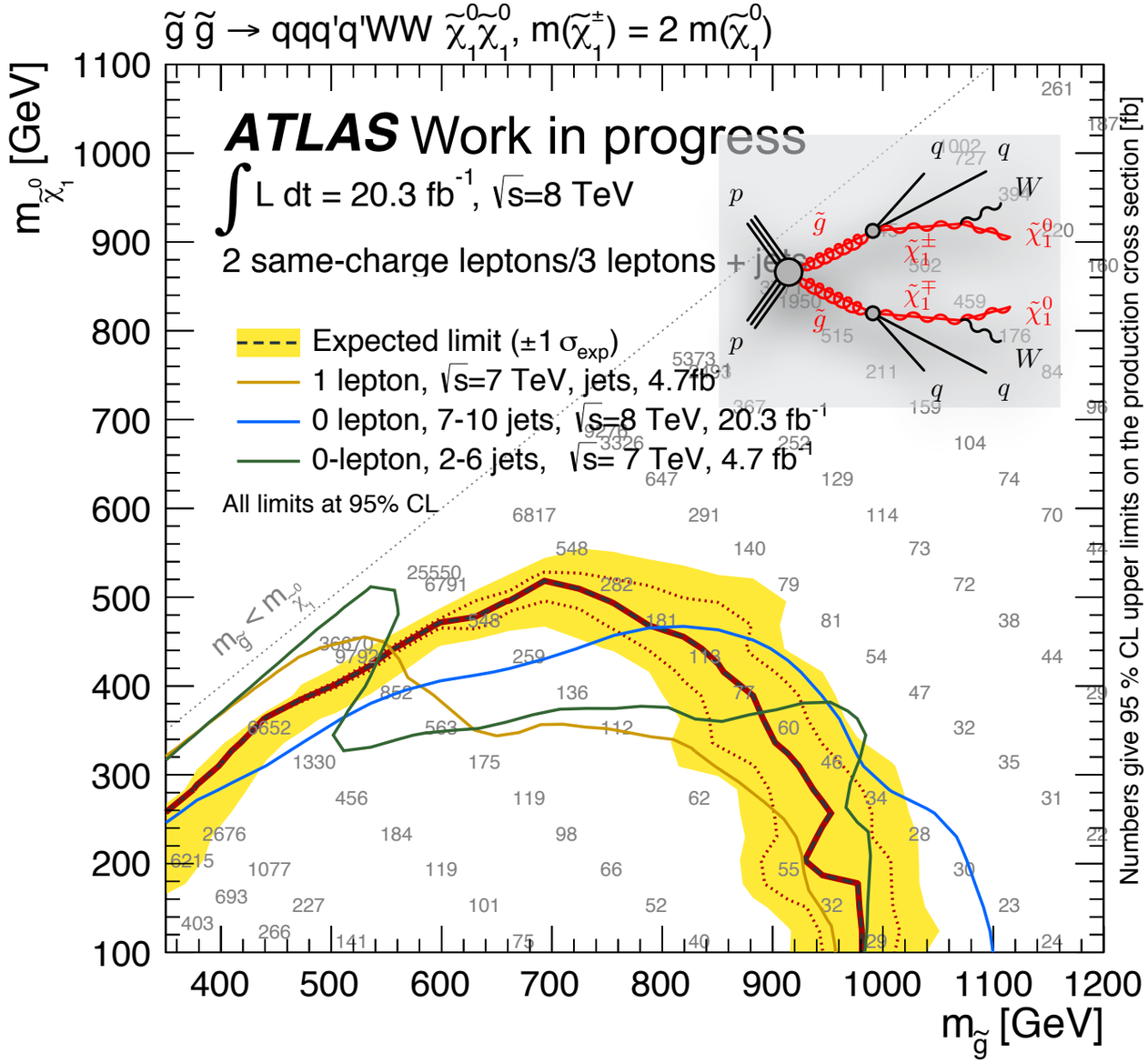
$m_{\mathrm{T}} > 100\,\mathrm{GeV}$

Expected exclusion reach

Gluino-stop, off-shell (Gtt)

$\tilde{g} \to qqW\chi_1^0$ (via squark), x=½



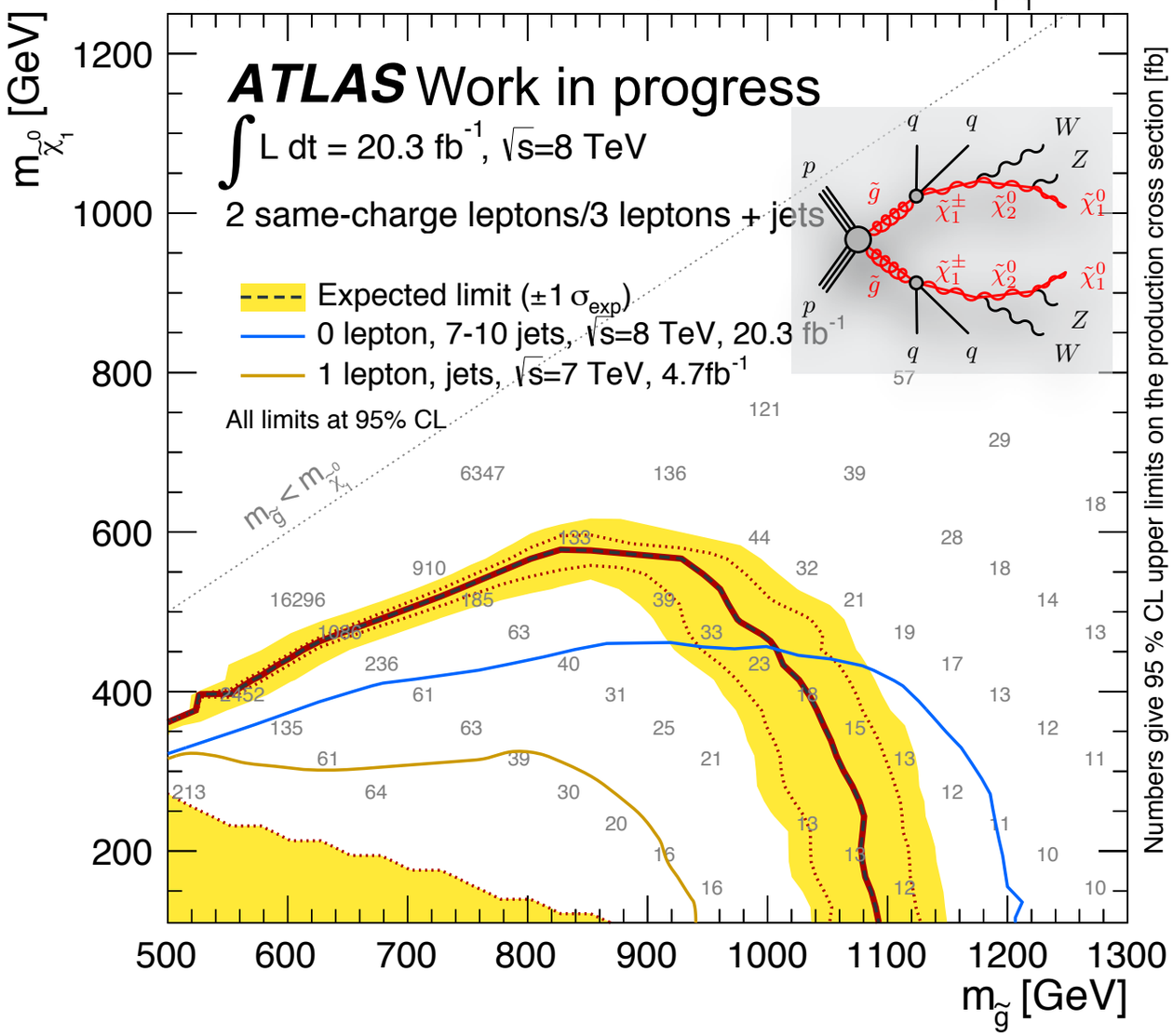


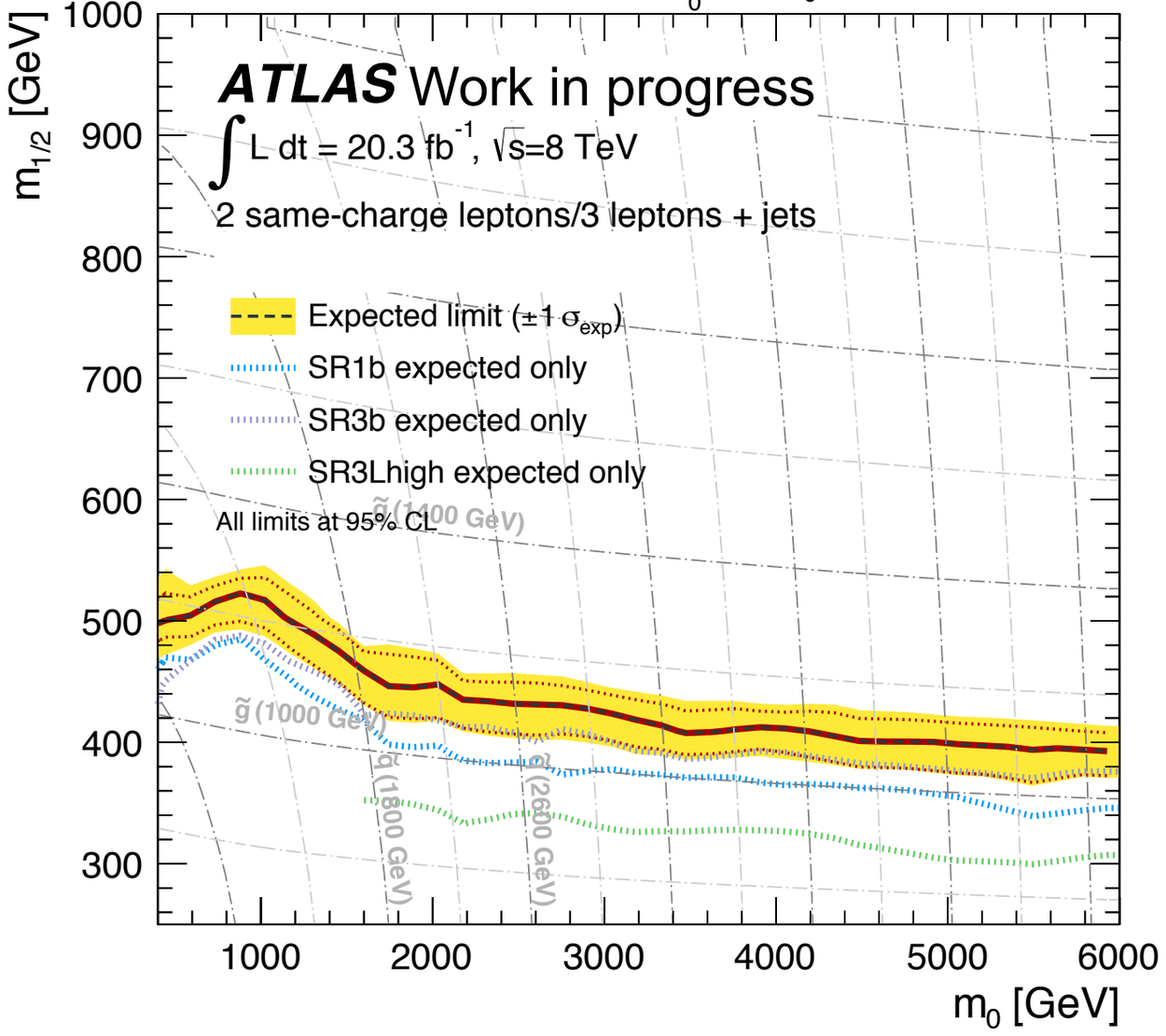
Expected exclusion reach

$\tilde{g} \to qqWZ\chi_1^0$

(via squark)

mSUGRA/CMSSM





How can we keep SUSY?

- Heavier LSP: compressed spectra => reduced effective mass, MET
- Stealth SUSY: light LSP, near degenerate fermion/boson pairs => low MET
- RPV signals: no LSP => low MET

Conclusions

- Except in compressed scenarios, rule out gluinos to ~1 TeV
- Assumptions of “simple” SUSY or naturalness under strain
- We hope to see significant increase in reach in Run 2!