Supersimmetry part II

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What is in this lesson

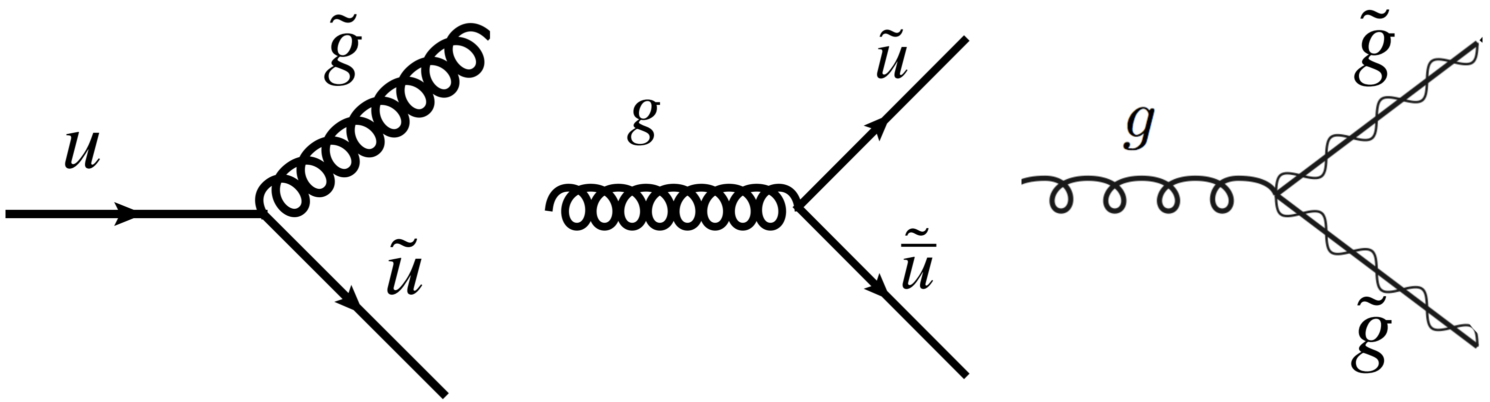
- Yesterday you have learned what Supersimmetry is – the motivations, how to build the Lagrangian, the particle content etc.
- The theory predicts the existence of at least 35 new particles which (4 other Higgs bosons, 12 scalar leptons, 12 scalar quarks, 6 neutralinos e charginos, the gluino)
- Today I will tell you about the searches of these particles at LHC

- Production of SUSY particles in *pp* collisions
- Decays of SUSY particles
- What the detector measure
- How to separate signal from backgrounds
- Something different: long-lived (s)particles, R-parity violation
- Prospects for LHC run 2

Names	Spin	P_R	Gauge Eigenstates	Mass Eigenstates
Higgs bosons	0	+1	$H_u^0\ H_d^0\ H_u^+\ H_d^-$	$h^0\ H^0\ A^0\ H^\pm$
squarks	0	−1	$\widetilde{u}_L\ \widetilde{u}_R\ \widetilde{d}_L\ \widetilde{d}_R$	(same)
			$\widetilde{s}_L\ \widetilde{s}_R\ \widetilde{c}_L\ \widetilde{c}_R$	(same)
			$\widetilde{t}_L\ \widetilde{t}_R\ \widetilde{b}_L\ \widetilde{b}_R$	$\widetilde{t}_1\ \widetilde{t}_2\ \widetilde{b}_1\ \widetilde{b}_2$
sleptons	0	−1	$\widetilde{e}_L\ \widetilde{e}_R\ \widetilde{\nu}_e$	(same)
			$\widetilde{\mu}_L\ \widetilde{\mu}_R\ \widetilde{\nu}_\mu$	(same)
			$\widetilde{\tau}_L\ \widetilde{\tau}_R\ \widetilde{\nu}_\tau$	$\widetilde{\tau}_1\ \widetilde{\tau}_2\ \widetilde{\nu}_\tau$
neutralinos	1/2	−1	$\widetilde{B}^0\ \widetilde{W}^0\ \widetilde{H}_u^0\ \widetilde{H}_d^0$	$\widetilde{N}_1\ \widetilde{N}_2\ \widetilde{N}_3\ \widetilde{N}_4$
charginos	1/2	−1	$\widetilde{W}^\pm\ \widetilde{H}_u^+\ \widetilde{H}_d^-$	$\widetilde{C}_1^\pm\ \widetilde{C}_2^\pm$
gluino	1/2	−1	$\widetilde{g}$	(same)
goldstino (gravitino)	1/2 (3/2)	−1	$\widetilde{G}$	(same)

Production of SUSY particles

- We start from gluons and quarks
- The strong interaction is, well, strong… reactions which occur trough the strong interaction will be more frequent than those which proceed trough the electromagentic or weak couplings
- Because of the symmetry, SUSY diagrams are obtained from SM ones adding tilde on two of the particles
  - Two for R-parity conserving processes

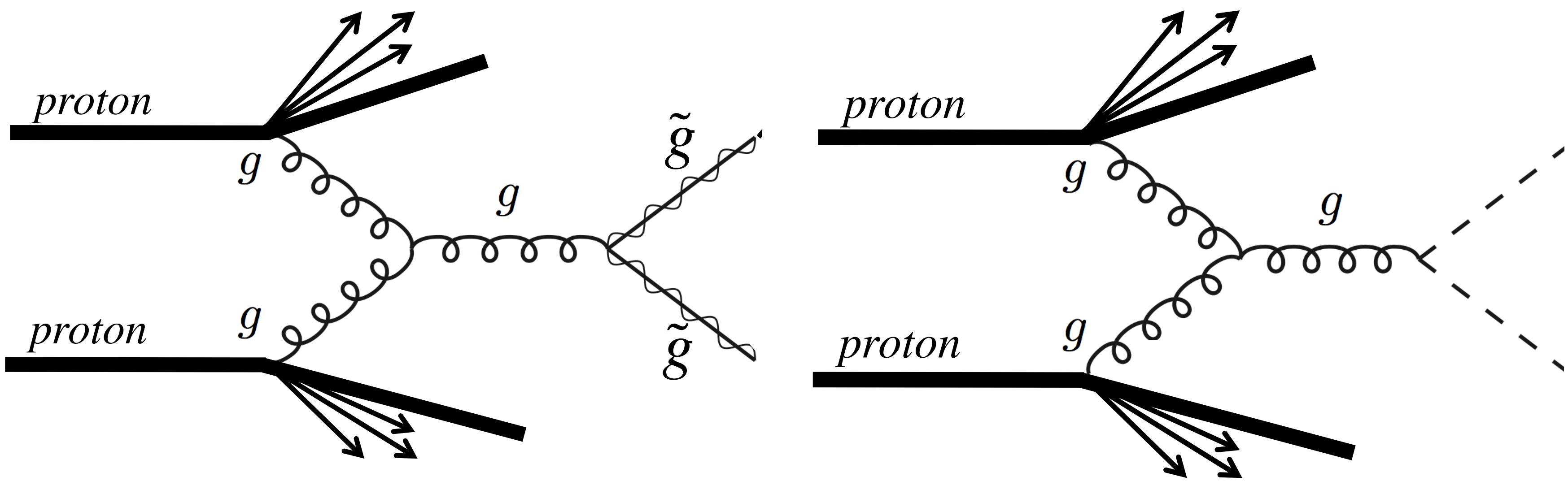


R-parity = (-1)$^{3(B-L)+2S}$ = +1 for SM particles; -1 for SUSY particles

- Guarantees proton is stable
- Provides DM candidate

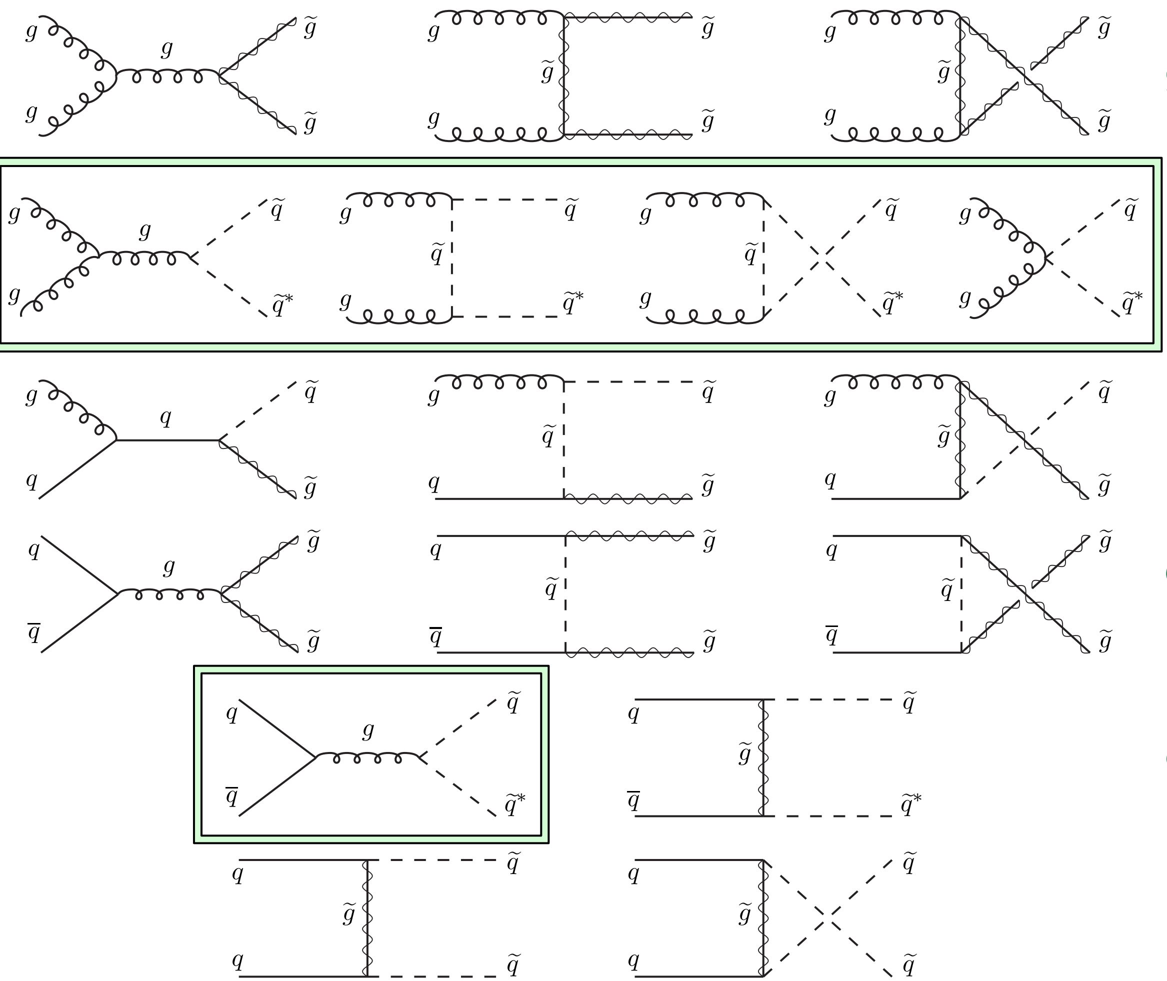
Scalar quark and gluon interactions

SUSY and SM interactions are the same: you can take a SM diagram and add tilde on two particles (two because of R-parity)



- Here we take a gluon as the colliding constituent of each proton
- The merge into a third virtual gluon (this is called an s-channel process) to produce a pair of gluinos (left) or a pair of squarks (right)

Scalar quark and gluino production



gluon-gluon ⇨ gluino pair

gluon-gluon ⇨ squark antisquark

gluon-quark ⇨ squark gluino

quark-antiquark ⇨ gluino pair

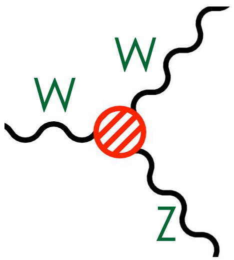
quark-antiquark ⇨ squark antisquark

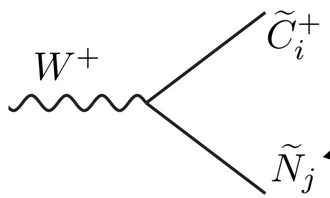
quark-quark ⇨ squark pair

There are few bottom and no top quarks in the proton, because of their mass. Thus, third generation scalar quarks are only produced by boxed diagrams

Neutralino and chargino diagrams

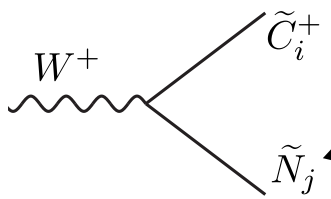
- Remember these particles are in general mixtures of Winos, Binos, Higgsinos
- Their diagrams can also be obtained from the SM ones adding two tilde
- Examples:



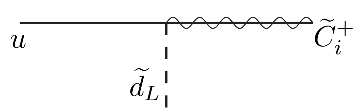


$$\begin{pmatrix} \tilde{N}_1 \\ \tilde{N}_2 \\ \tilde{N}_3 \\ \tilde{N}_4 \end{pmatrix} = M_{\tilde{N}} \begin{pmatrix} \tilde{B}^0 \\ \tilde{W}^0 \\ \tilde{H}_d^0 \\ \tilde{H}_u^0 \end{pmatrix} \qquad \begin{pmatrix} C_1^+ \\ C_2^+ \end{pmatrix} = M_{\tilde{C}} \begin{pmatrix} \tilde{H}_u^+ \\ \tilde{W}^+ \end{pmatrix}$$

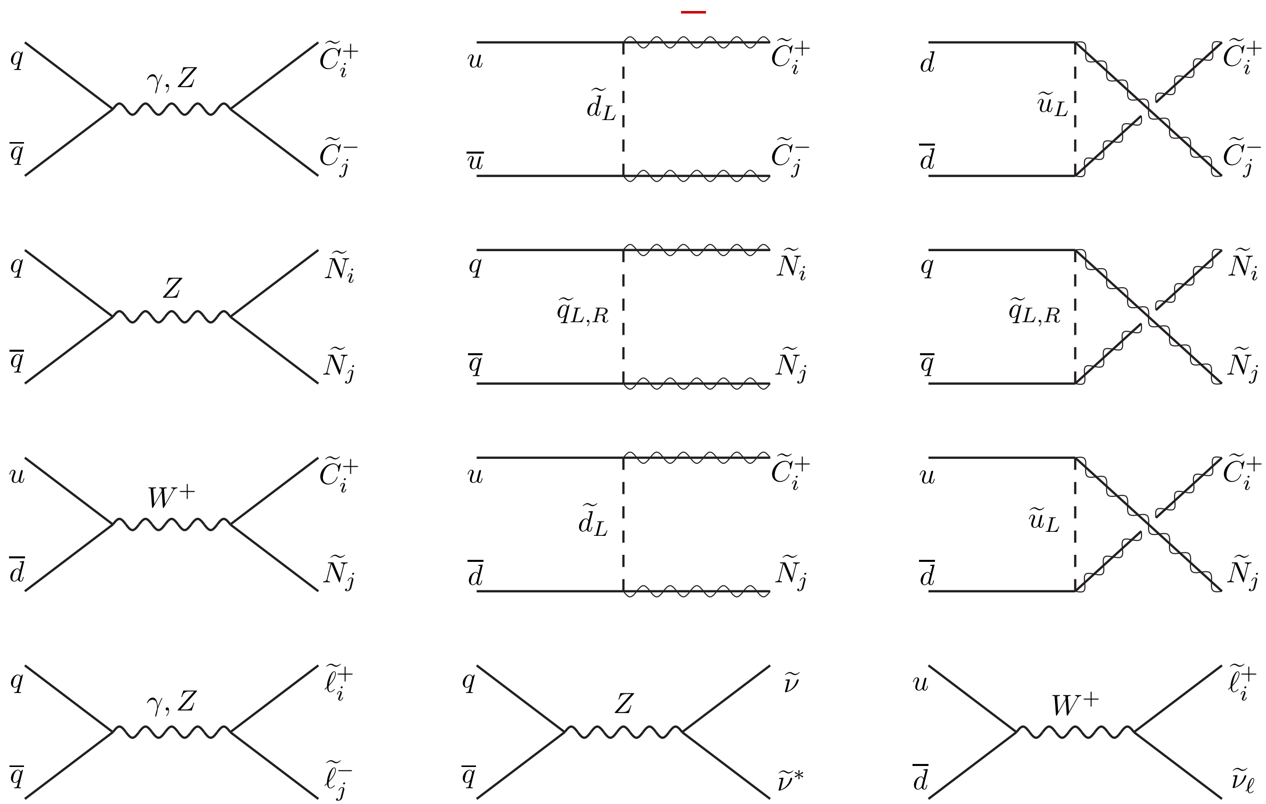
<u>H => WW</u>



<u>W => qq'</u>



Electroweak production



Pairs of charginos

Pairs of neutralinos

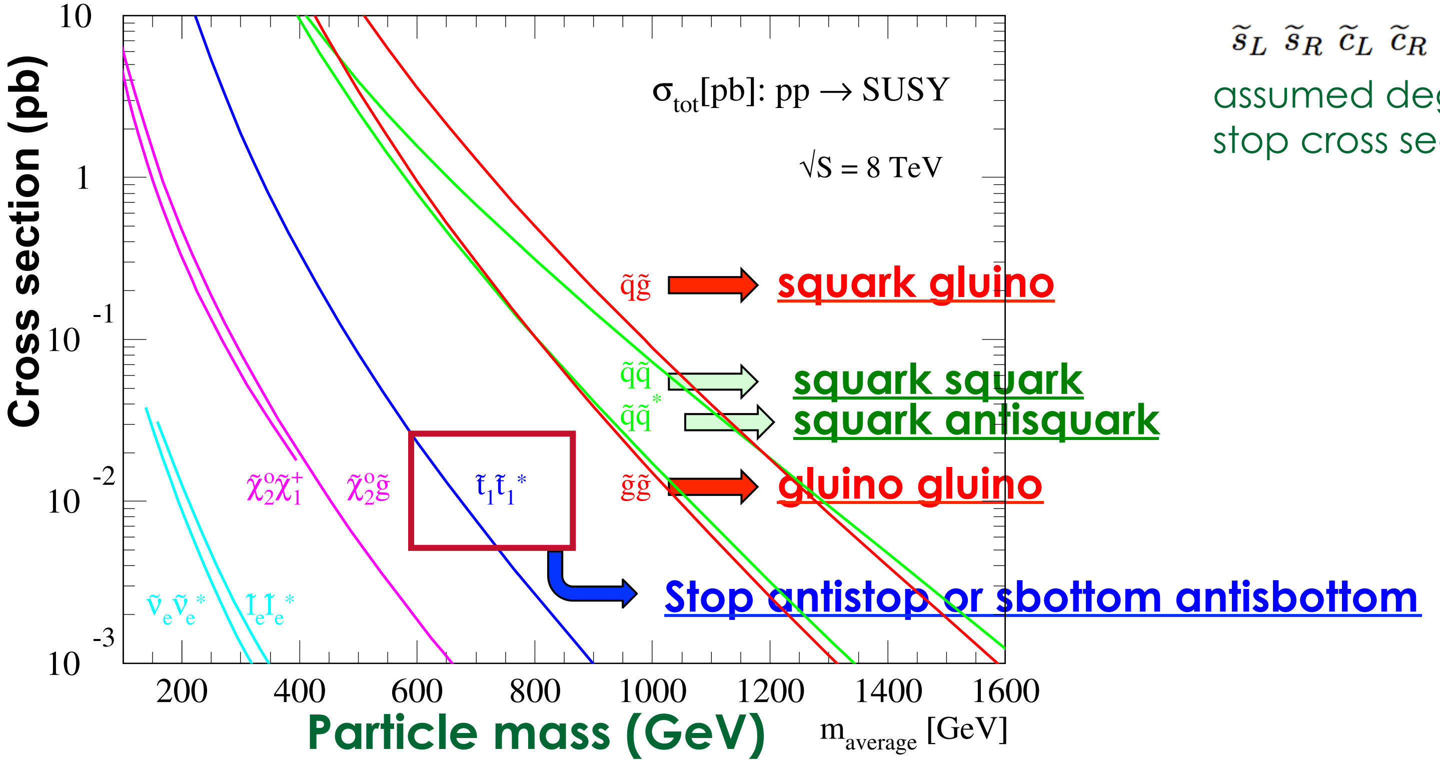
Chargino neutralino

Slepton pairs
Sneutrino pairs
Sneutrino-slepton

These production processes are suppressed compared to those of slide 5

- Only quarks in the initial state
- At least two vertices involving the electromagnetic or weak coupling…

Cross sections



Squark cross section is the sum over

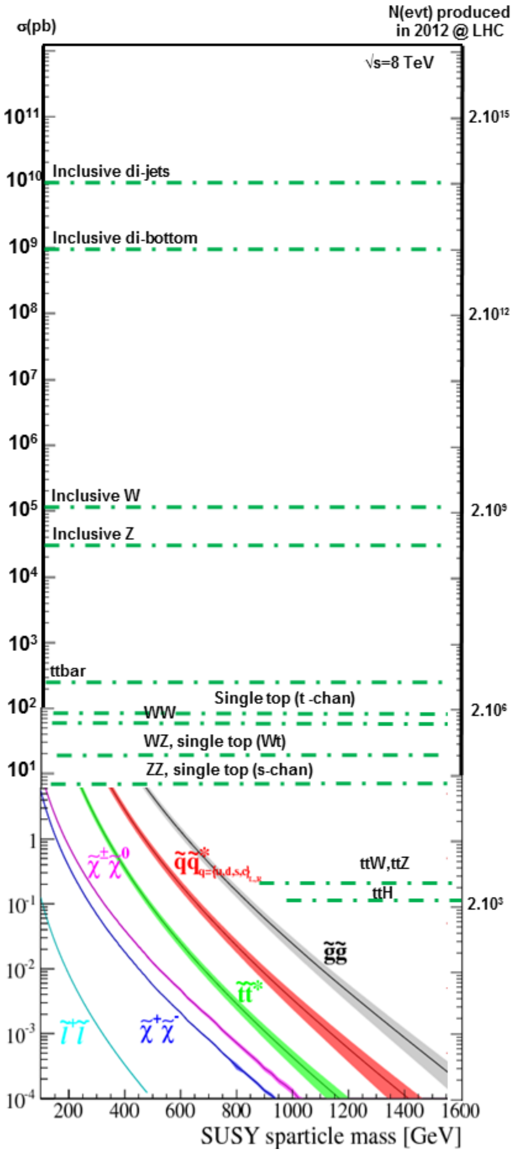
$\tilde{u}_L\ \tilde{u}_R\ \tilde{d}_L\ \tilde{d}_R$

$\tilde{s}_L\ \tilde{s}_R\ \tilde{c}_L\ \tilde{c}_R$

assumed degenerate in mass. The stop cross section is only one state.

- For the same mass, cross section is **much larger** for particles produced trough strong interaction (squark and gluinos)
- It's also larger for first generation squarks (more production diagrams)

Other cross sections

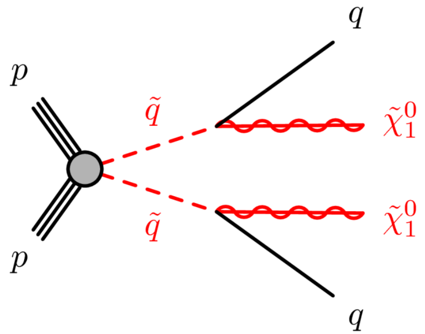


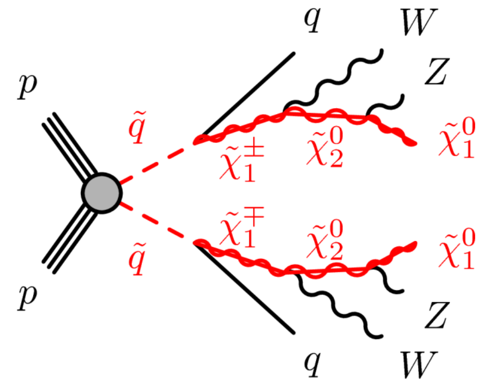
Even the SUSY processes with "high" cross are a tiny fraction of the total collisions.
Out of 1 bilion collisions per second, less than one will produce SUSY particles.

Disk and CPU constraints imply only one collision in 100,00 can be registered – the first selection of signal candidates is done by the data acquisition software *(trigger)*

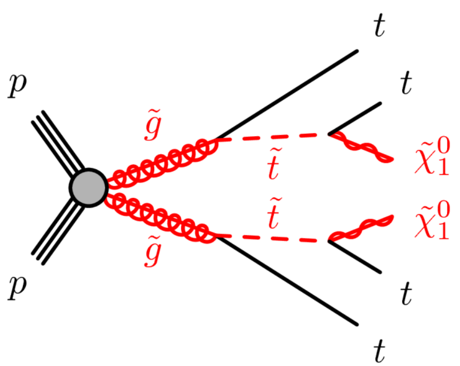
Squark and gluino decays

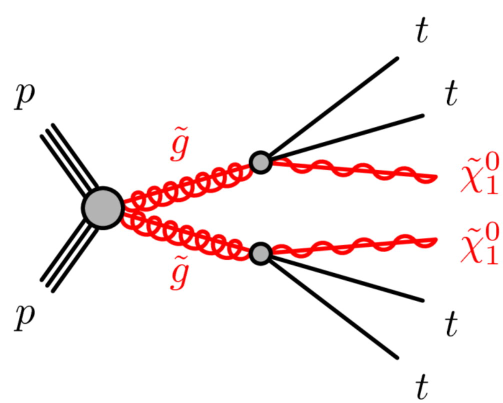
- If $m(\tilde{q}) > m(\tilde{g})$, $\tilde{q} \to \tilde{g}q$ via strong interaction
- Otherwise, $\tilde{q} \to q\tilde{\chi}^0$ and $q\tilde{\chi}^{\pm}$ via EW interaction





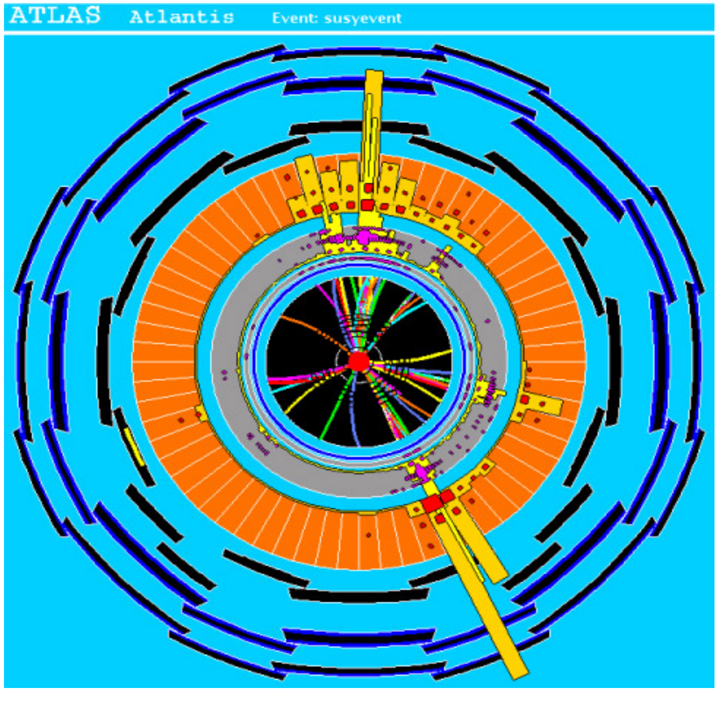
- The gluino only interacts via strong interaction, so the decay is to squark-quark. If m($\tilde{g}$)<m($\tilde{q}$), then the squark will be virtual and you'll have a 3-body decay:





Observable final state: jets

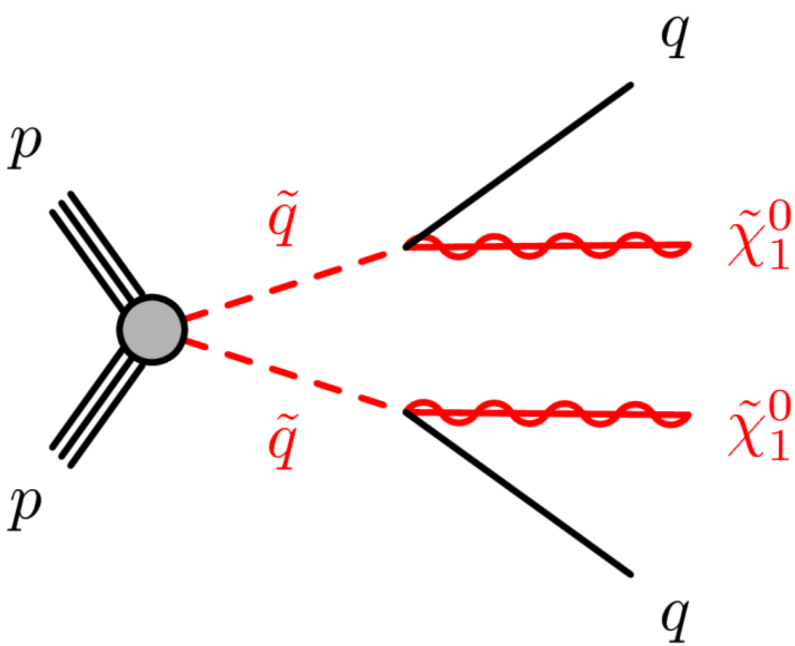
- The top decays to bW before forming hadrons
- All other quarks will be observed as a jet of collimated hadronic particles

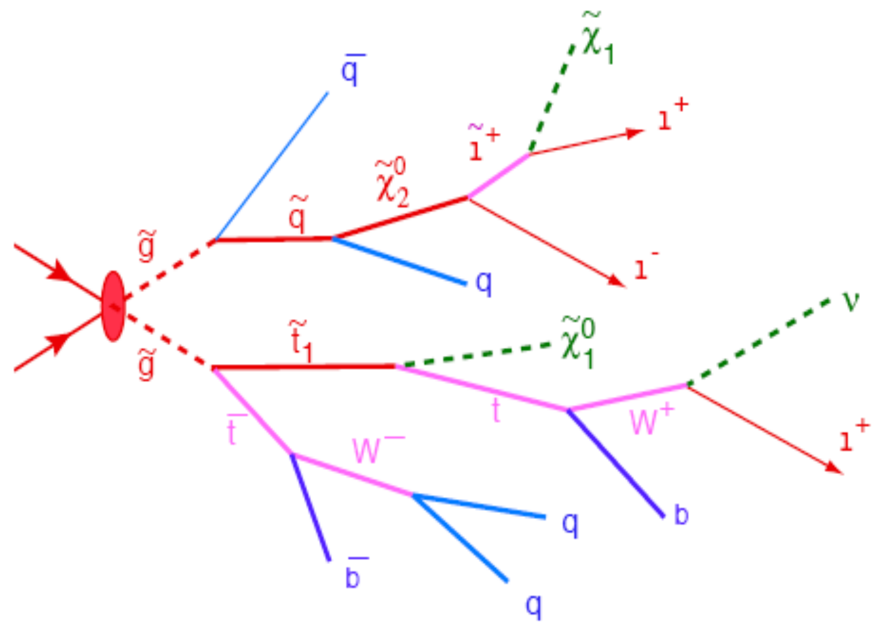


A proton proton collision with three jets

An other type of jet

Possible SUSY events



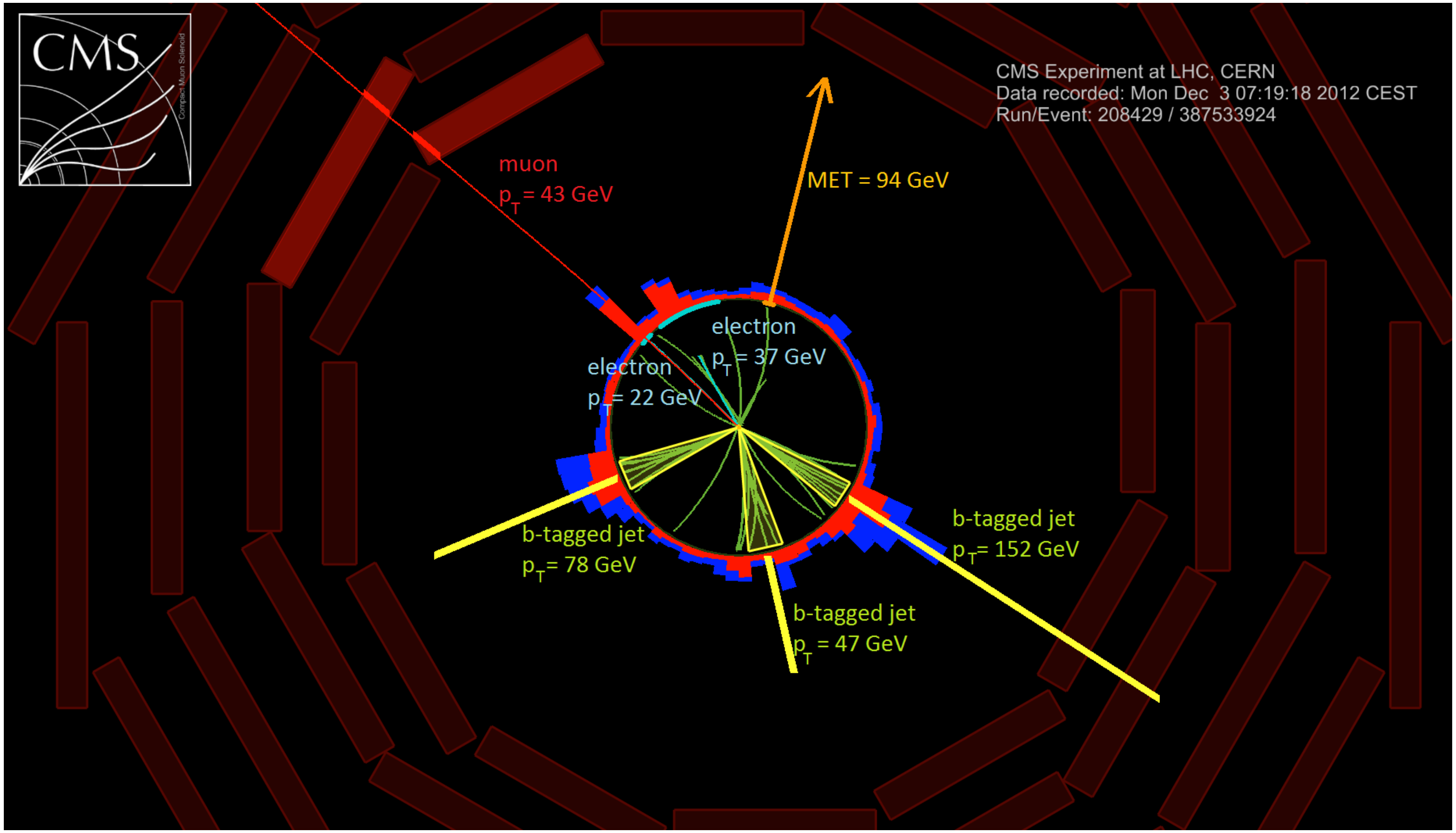


➔Two hadronic jets (from the quarks) and missing momentum (from the two weakly interacting particles)

➔ Six jets, three leptons, and missing momentum

- R-parity conservation and squark and gluinos lighter than about 1 TeV means events with **jets and missing momentum**
- The *number* of jets, and wether leptons or photons are also produced, depends on the (unknown) details of mass spectrum and decay chains.

A signal event ?



Maybe… but while pretty rare, an handful of events like this is expected from SM processes.

Search strategies

In R-parity conserving scenarios

- SUSY particles are produced in pairs
- The lightest one one is stable and weakly interacting.

Since there are two unmeasured particle in the final state it is not possible to measure all decay products of a SUSY particle and reconstruct invariant mass.

The simplest SUSY search proceed as follows:

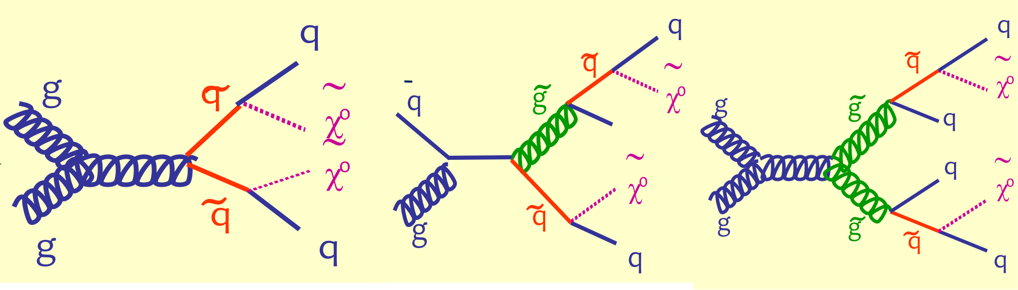
- Count the number of collisions satisfying a given selection (say "six jets with p_T > 60 GeV and missing transverse momentum larger than 150 GeV")
- Compute the number of background events expected to pass the selection
- Compare the observed number of events with the expected background rate. An excess of the former indicates the presence of a signal.

The key difficulties are:

- How we determine the selection criteria, since we do not know the masses and decays of SUSY particles ?
- How do we compute the expected background rate in such a reliable way that we can attribute an higher observed rate to a non-Standard Model process ?

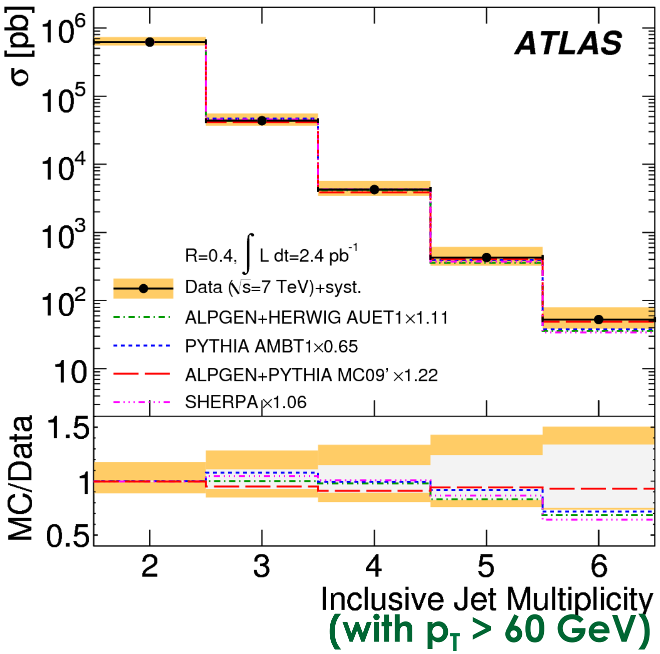
Choice of selection criteria

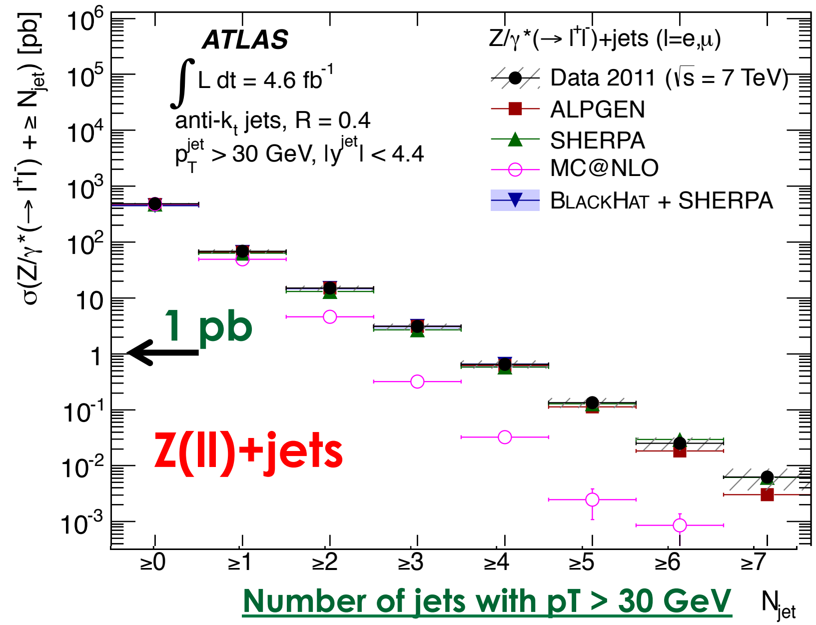
- Typically, we choose the signal to be targeted. Each choice defines an analysis and the set of all analysis is supposed to target all possible signal processes.
- Say we target squark or gluinos decaying to the LSP plus jets:



- We still do not know masses and decay chains
  - Gluinos give more jets and squark production
  - Long decay chains give more jets than decays directly to the LSP
  - If the mass difference ΔM between the produced particle and the LSP is small, the jet momenta and missing momentum will be smaller
- The selection criteria need to accommodate all scenarios
  - One can define a set of criteria for each scenario: 2,3,4,5,6,…9 jet selections, for each number of jets have a set of cuts for large ΔM and one for low ΔM, etc.
  - In alternative, we can use the shape of 2-3 key distributions (say, number of jets and missing transverse momentum) and compare the data with the expected background in all bins.

Discriminating variables





- Most common process: multi-jet production
- Many jets, but no missing momentum, unless a jet momentum is mismeasured or a particle in the jet decays producing neutrinos (B ➔D l ν)

But then missing momentum is aligned with a jet, which is not the case for signal

- Once we get rid of multi-jets, we are left with Z+jets, W+jets, top pairs
- Z(νν)+jets is an irreducible background (it looks like the signal) but the cross section decreases rapidly with the number (and momentum) of jets

Selections, one example

Requirement	Channel									
	A (2-jets)		B (3-jets)		C (4-jets)		D (5-jets)	E (6-jets)		
	L	M	M	T	M	T	–	L	M	T
E_T^{miss}[GeV] >	160									
$p_T(j_1)$ [GeV] >	130									
$p_T(j_2)$ [GeV] >	60									
$p_T(j_3)$ [GeV] >	–		60		60		60	60		
$p_T(j_4)$ [GeV] >	–		–		60		60	60		
$p_T(j_5)$ [GeV] >	–		–		–		60	60		
$p_T(j_6)$ [GeV] >	–		–		–		–	60		
$\Delta\phi(\text{jet}_i, \mathbf{E}_T^{miss})_{min}$ >	0.4 ($i = \{1, 2, (3 \text{ if } p_T(j_3) > 40 \text{ GeV})\}$)				0.4 ($i = \{1, 2, 3\}$), 0.2 ($p_T > 40$ GeV jets)					
$E_T^{miss}/m_{eff}(Nj)$ >	0.2	–[a]	0.3	0.4	0.25	0.25	0.2	0.15	0.2	0.25
m_{eff}(incl.) [GeV] >	1000	1600	1800	2200	1200	2200	1600	1000	1200	1500

• $m_{eff} = E_T^{miss} + H_T \sim 1.8(M_{SUSY}^2 - M_{LSP}^2)/M_{SUSY}$ [hep-ph/0006276]

Alternative selections, from 2 to 6 jets

One jet with p_T > 160 GeV, missing momentum > 130 GeV*

Further jets

These kills most of the multi-jets

"effective mass", scalar sum of transverse momenta of jets and missing transverse momentum.

It peaks at a value correlated with the mass of produced particles (hence the name)

• $m_{eff} = E_T^{miss} + H_T \sim 1.8(M_{SUSY}^2 - M_{LSP}^2)/M_{SUSY}$ [hep-ph/0006276]

Loose/medium/tight cuts. Overall, 10 alternative selections

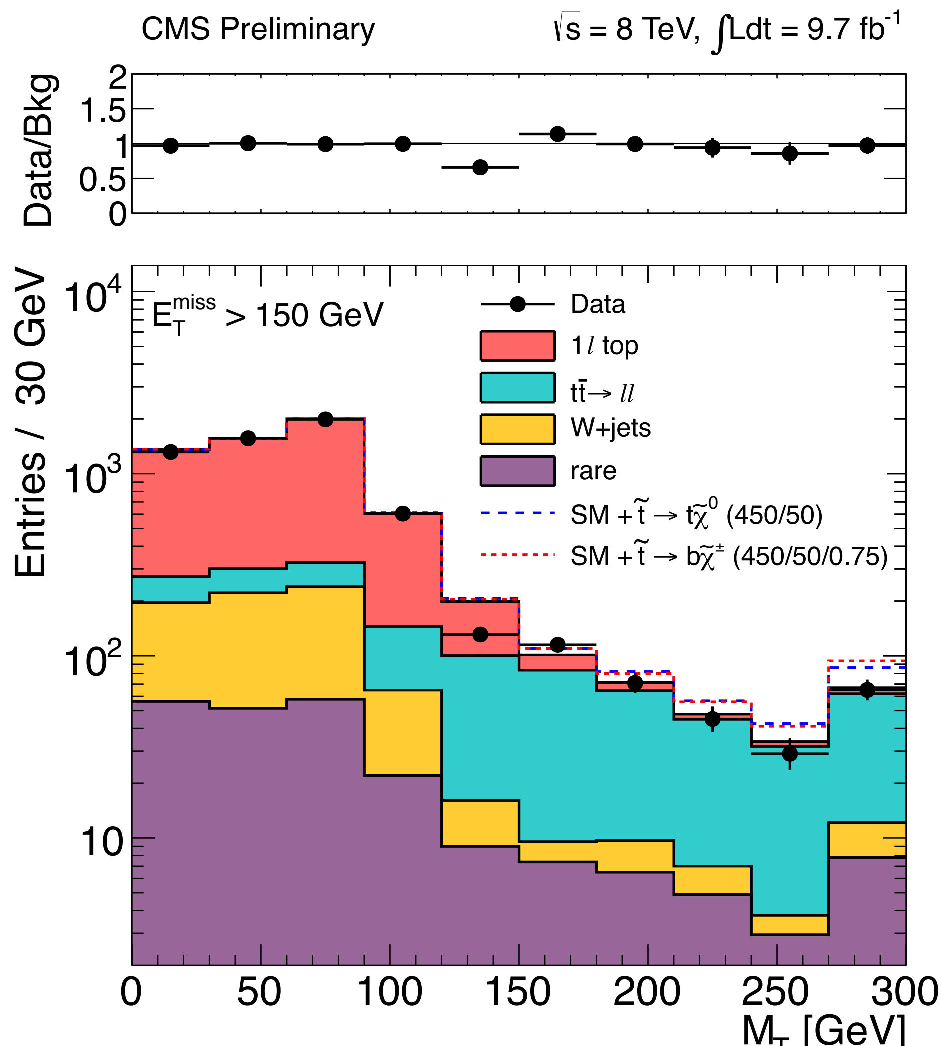
S/B separation, an other example

For search channels with one lepton:

$$M_T(l,\nu) = \sqrt{2p_T(l)p_T(\nu)\left[1-\cos(\phi_l-\phi_\nu)\right]}$$

- In Background the invariant mass of the lepton and missing momentum (the neutrino) is the W mass, and the transverse mass is lower than that.
- Signal has two extra invisible particles and some signal events will have $M_T > M_W$

In fact, top antitop **both** decaying to blν is the main background at large M_T.



Step 2: estimate of backgrounds

Background rates can be estimated using MonteCarlo simulation, but is the physics and detector description in the simulation reliable ?

Remember: any excess in data compared to expectation must be confidently attributed to non-Standard Model processes, we need to be super-confident about our background estimate !

Control selection for background (CR)

Measure the rate in data here

Extrapolate using MC or some scaling law

Validation selection

Signal selection (SR)

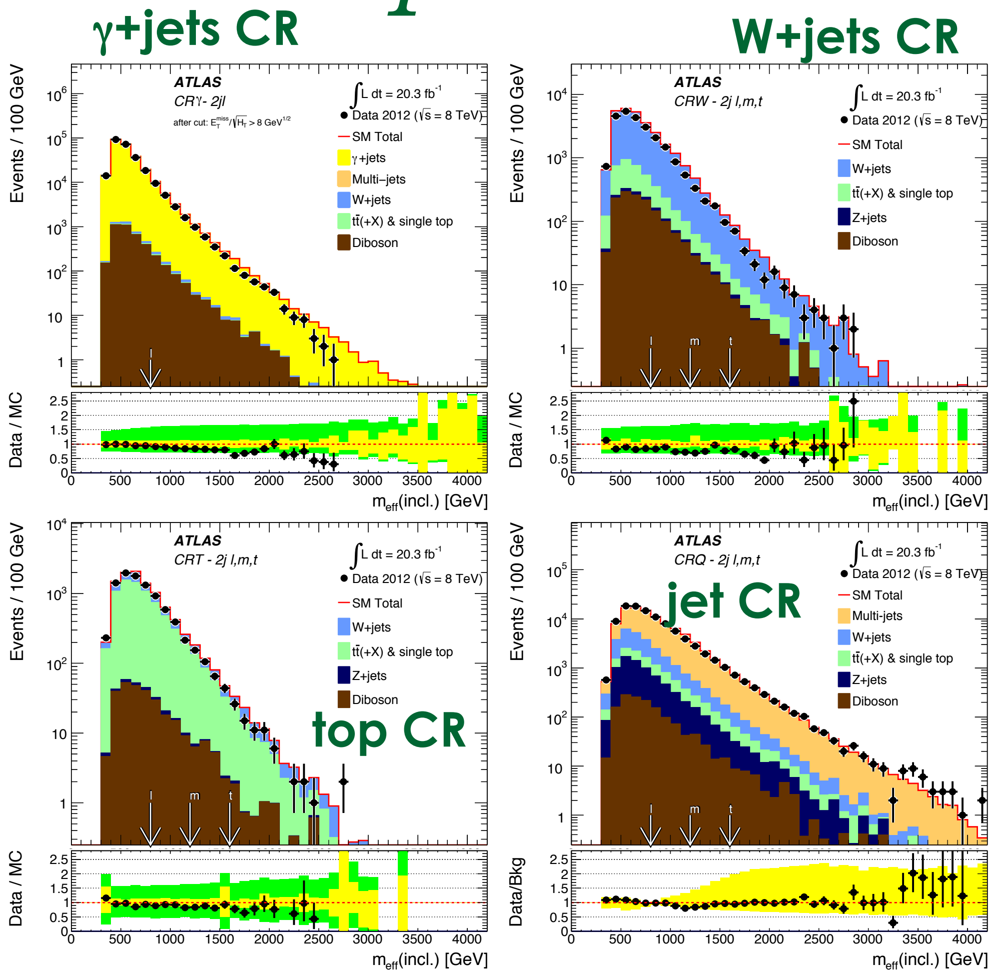
Typically, we measure the rate in a set of control selections

- One control selection for each major background
- CS (and VS) are designed so that the target signal is negligible there
- All selections which are difficult to model are common for the CR and the SR

Example

- Use γ+jets as a control process for $Z(\nu\nu)$+jets
  - The kinematics of the two processes is similar for large boson momenta (>> m_Z)
  - The cross section of γ+jets is larger than Z+jets (good statistics in the control sample)
  - Asking a photon and veto large missing transverse momentum ensure negligible contribution of the targeted signals in the control sample
- Procedure:
  - Ask a photon, and add the photon transverse momentum to measured missing transverse momentum (=> pretend the observed photon was an invisible decaying Z)
  - Apply the full signal selection (using the new missing momentum)
  - The $Z(\nu\nu)$ background estimate is the observed rate, corrected for the difference in γ+jets and Z+jets cross sections, photon identification efficiency, and any difference between γ+jets and Z+jets
  - The last piece comes from theory/MonteCarlo but it is a relatively well known and small correction

Control plots



- ➢ Effective mass distributions in some control selections
- ➢ The agreement between ata and MC (the histograms) is shown, but only the data counts contribute to the background estimate

CR	SR background	CR process	CR selection
CRγ	$Z(\rightarrow \nu\nu)$+jets	γ+jets	Isolated photon
CRQ	Multi-jets	Multi-jets	SR with reversed requirements on (i) $\Delta\phi(\text{jet}, \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ and (ii) $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(N_{\mathrm{j}})$ or $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$
CRW	$W(\rightarrow \ell\nu)$+jets	$W(\rightarrow \ell\nu)$+jets	30 GeV $< m_{\mathrm{T}}(\ell, E_{\mathrm{T}}^{\mathrm{miss}}) <$ 100 GeV, b-veto
CRT	$t\bar{t}$ and single-t	$t\bar{t} \rightarrow b\bar{b}qq'\ell\nu$	30 GeV $< m_{\mathrm{T}}(\ell, E_{\mathrm{T}}^{\mathrm{miss}}) <$ 100 GeV, b-tag

Opening the box

- The decision of the selections, the estimation of the background, and all the cross-checks are done with the signal candidates “blinded”, without having access to them in data
- Once one has the final estimate of expected background and uncertainty, the signal candidates are “unblinded”
- So far, the rate in data has always been in agreement with the Standard Model expectation

Signal Region	**4jl-**	**4jl**	**4jm**	**4jt**
		MC expected events		
Diboson	175	70	7.2	0.34
Z/γ^*+jets	885	333	30	2.9
W+jets	832	284	16	1.2
$t\bar{t}$(+EW) + single top	764	167	4.0	0.62
		Fitted background events		
Diboson	180 ± 90	70 ± 34	7 ± 4	0.34 ± 0.17
Z/γ^*+jets	660 ± 60	238 ± 28	16 ± 4	$0.65^{+0.78}_{-0.65}$
W+jets	560 ± 80	151 ± 28	10 ± 4	0.9 ± 0.4
$t\bar{t}$(+EW) + single top	730 ± 50	167 ± 18	3.8 ± 1.9	0.6 ± 0.6
Multi-jets	$1.7^{+3.9}_{-1.7}$	$0.73^{+1.57}_{-0.73}$	–	–
Total bkg	2120 ± 110	630 ± 50	37 ± 6	2.5 ± 1.0
Observed	2169	608	24	0
$\langle\epsilon\sigma\rangle^{95}_{\rm obs}$ [fb]	13	4.5	0.52	0.15
$\langle\epsilon\sigma\rangle^{95}_{\rm obs}$ [fb] (asymptotic)	13	4.3	0.45	0.12
$S^{95}_{\rm obs}$	273	91	10	3.1
$S^{95}_{\rm obs}$ (asymptotic)	268	87	9.2	2.5
$S^{95}_{\rm exp}$	244^{+91}_{-66}	103^{+34}_{-29}	16^{+6}_{-4}	$4.0^{+1.8}_{-0.9}$
$S^{95}_{\rm exp}$ (asymptotic)	242^{+87}_{-65}	97^{+35}_{-25}	15^{+6}_{-4}	$4.0^{+2.4}_{-1.4}$
p_0 (Z)	0.35 (0.4)	0.50 (0.0)	0.50 (0.0)	0.50 (0.0)

MC prediction of background

Actual background prediction (using CR observations)

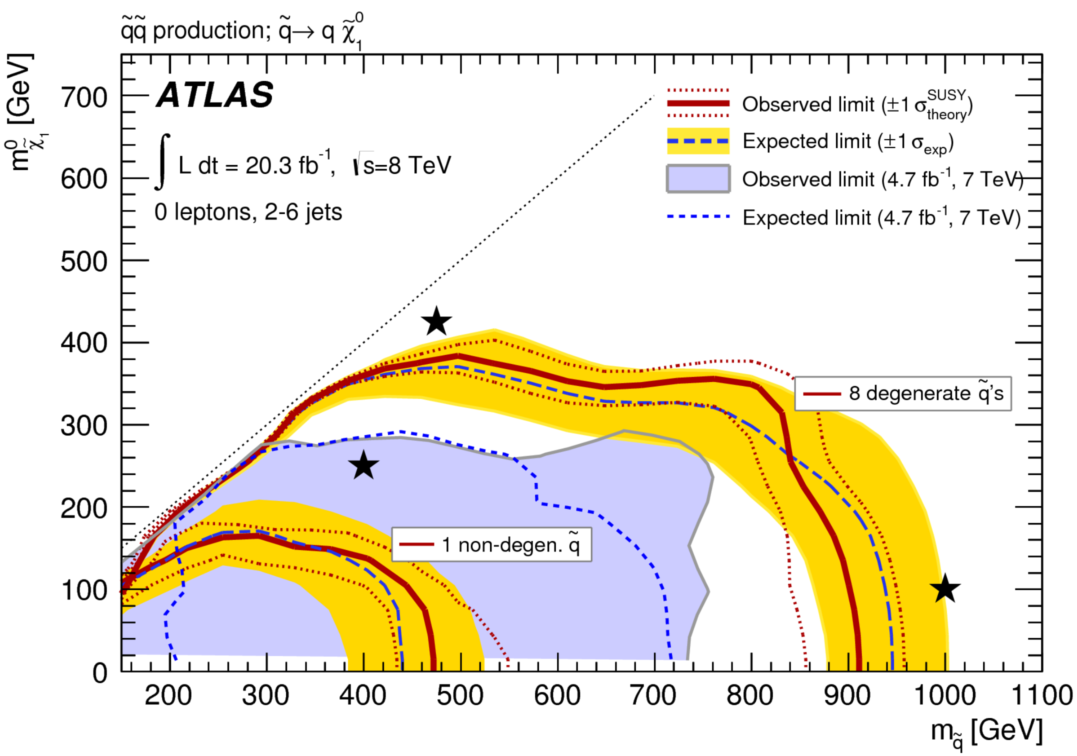
Observed event counts

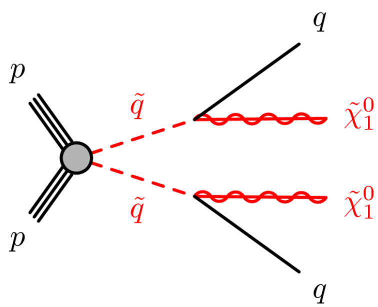
Limit on signal rates: for average signal rate larger than this, the probability of having as few (or fewer) events as observed is < 5%

Compatibility with Standard Model

Limits on SUSY models

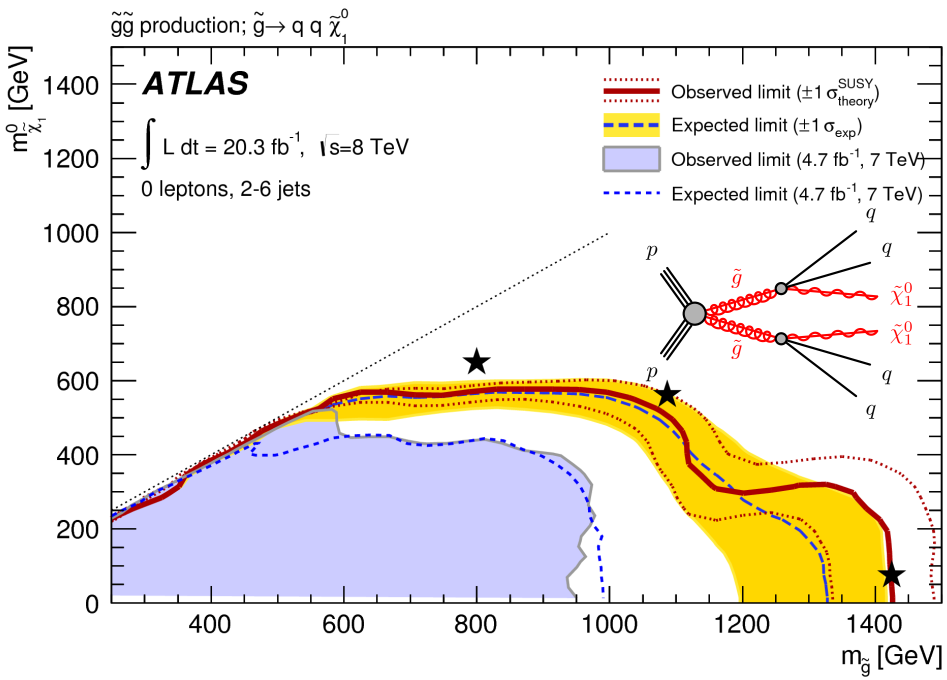
Given a negative result, the theory parameter space incompatible with the observation is derived.
Problem: SUSY has O(100) free parameters (at least) but we can made only 2D plots and simulate pp-collisions for a few thousands of different signal hypothesis at best.
Solution: for each production process and decay chain produce a 2D limit plot.

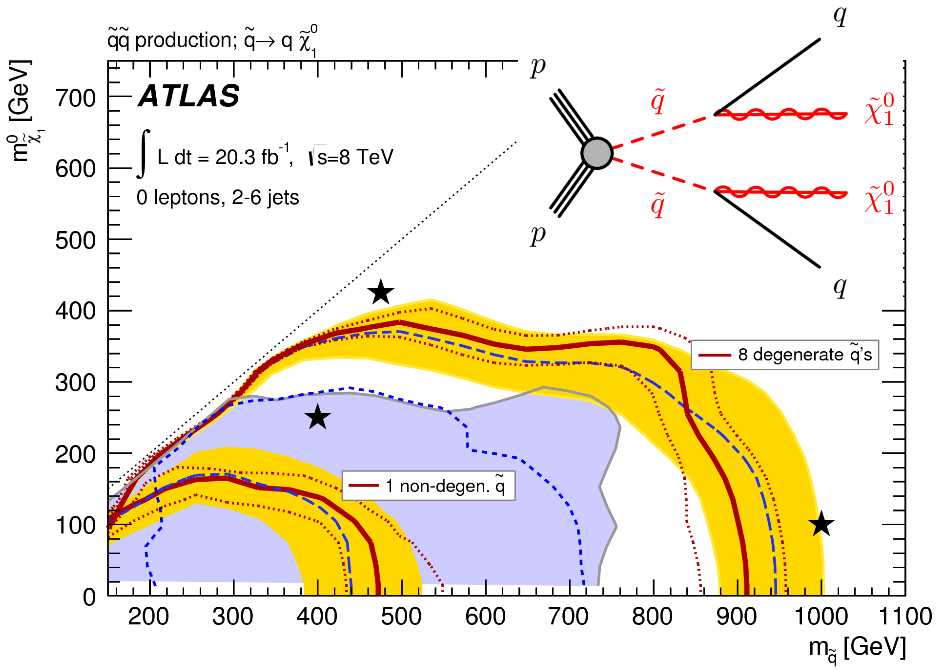




Limit on squark and neutralino mass, assuming all squark are degenerate in mass and the branching ratio of the decay in the diagram is 100%

Status of squark and gluino limits

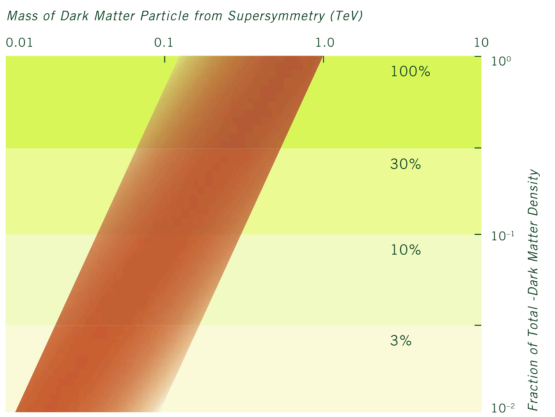


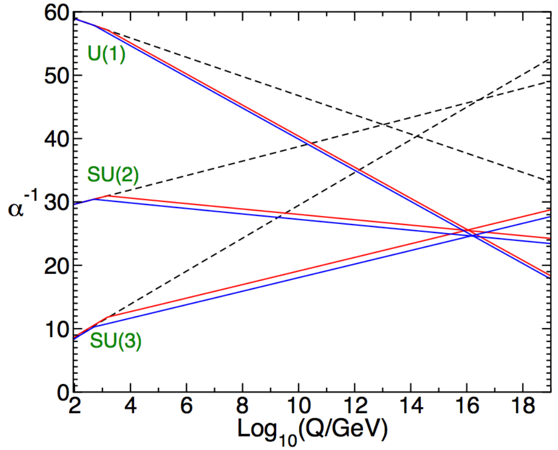


- Depending on the mass of the lightest SUSY particle and on the decay chain, lower limits of 400-900 GeV (600-1400 GeV) are placed on the masses of squarks of the first two generations (gluinos).
- A single squark eigenstate (say c_L) might be lighter
- **But is this a problem for the Supersymmetric theory ?**

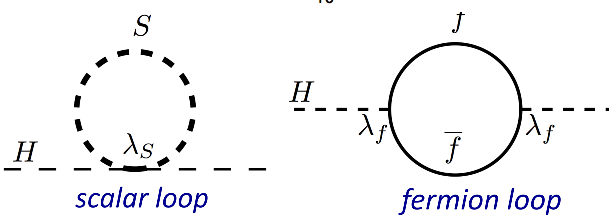
Why should SUSY particles be light ?

- The "right" amount of Dark Matter is obtained for a weakly interacting particle with (roughly) 100-1000 GeV of mass
- A good convergence of the coupling constants is obtained inserting SUSY particles at the (roughly)100-1000 GeV energy scale
- The Higgs mass is natural only if SUSY particles have a mass of the same order of magnitude of the Higgs mass





The latter argument is more powerful, because it also tells us **which SUSY particles** should be light (if we want to have a natural 125 GeV Higgs)



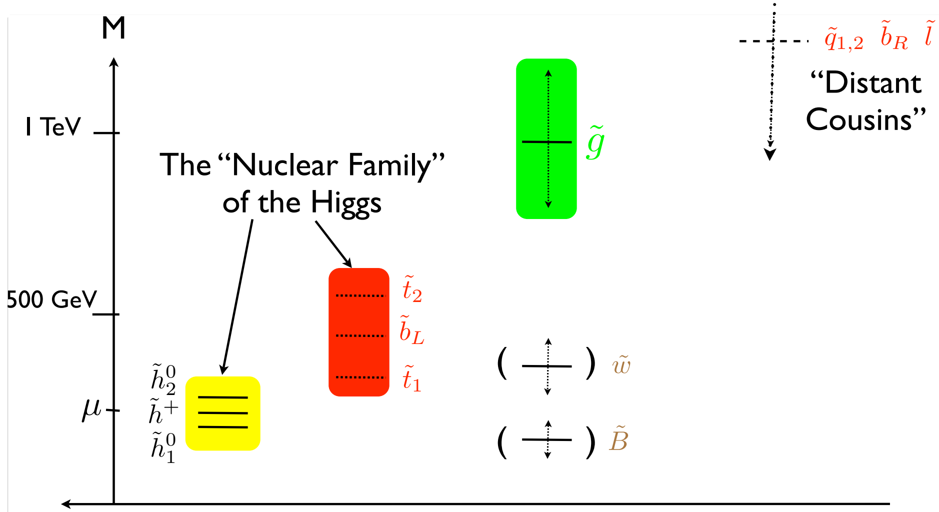
The Higgs mass in SUSY

$$\frac{m_H^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$$

$$\delta m_H^2\Big|_{stop} \cong -\frac{3y_t^2}{8\pi^2}\left(m_{Q_3}^2 + m_{U_3}^2 + |A_t|^2\right)\ln\left(\frac{\Lambda}{TeV}\right)$$

$$\delta m_H^2\Big|_{gluino} \cong -\frac{2y_t^2}{\pi^2}\left(\frac{\alpha_s}{\pi}\right)|M_3|^2 \ln^2\left(\frac{\Lambda}{TeV}\right)$$

- The tree level Higgs (and Higgsinos) mass should be O(100 GeV) in a natural theory.
- The stop mass terms dominates the 1-loop corrections, because it's the stop which cancels the top quark loop, the biggest SM contribution to the Higgs mass
- There is a gluino correction at 2-loop (M_3 is the gluino mass term)



- The scalar top, the lightest neutralino, and the lightest chargino should be well below 1 TeV mass.
- Other particles might be light or heavy.

Searches for natural SUSY

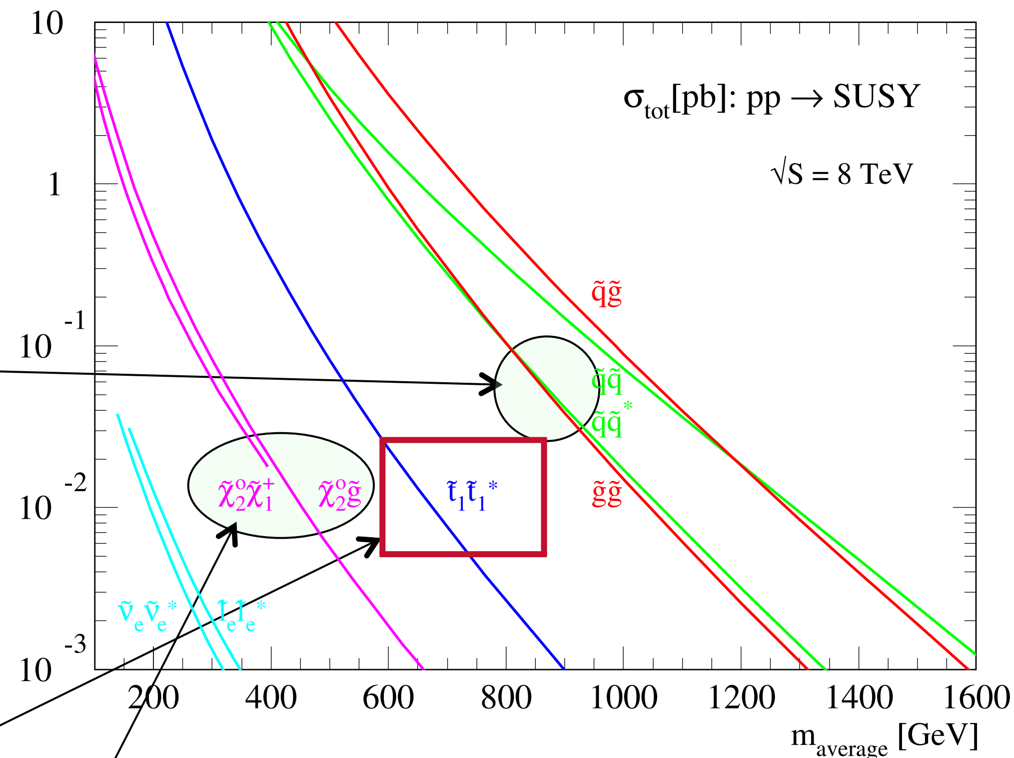
Given the natural mass spectrum, priority searches are

- Gluino pairs decaying into third generation squarks

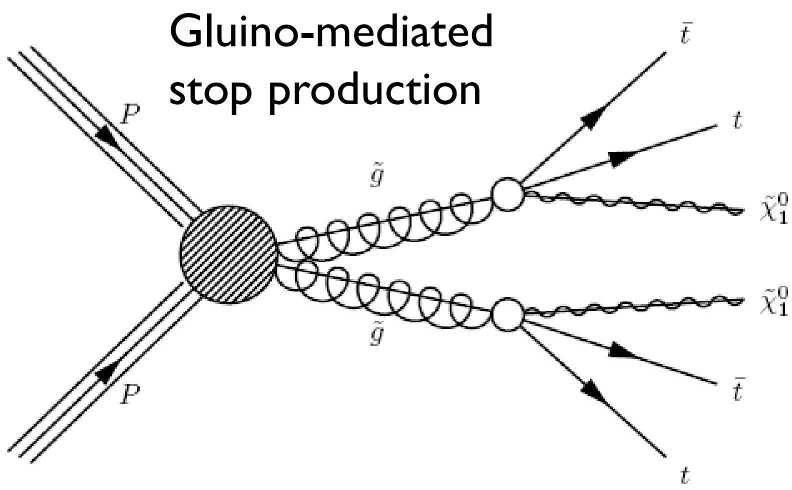
$$\tilde{g}\tilde{g} \rightarrow t\tilde{t}t\tilde{t} \rightarrow t\bar{t}\,\chi^0 t\bar{t}\,\chi^0$$

- Direct production of scalar top and bottom quarks

- Direct production of neutralinos and charginos

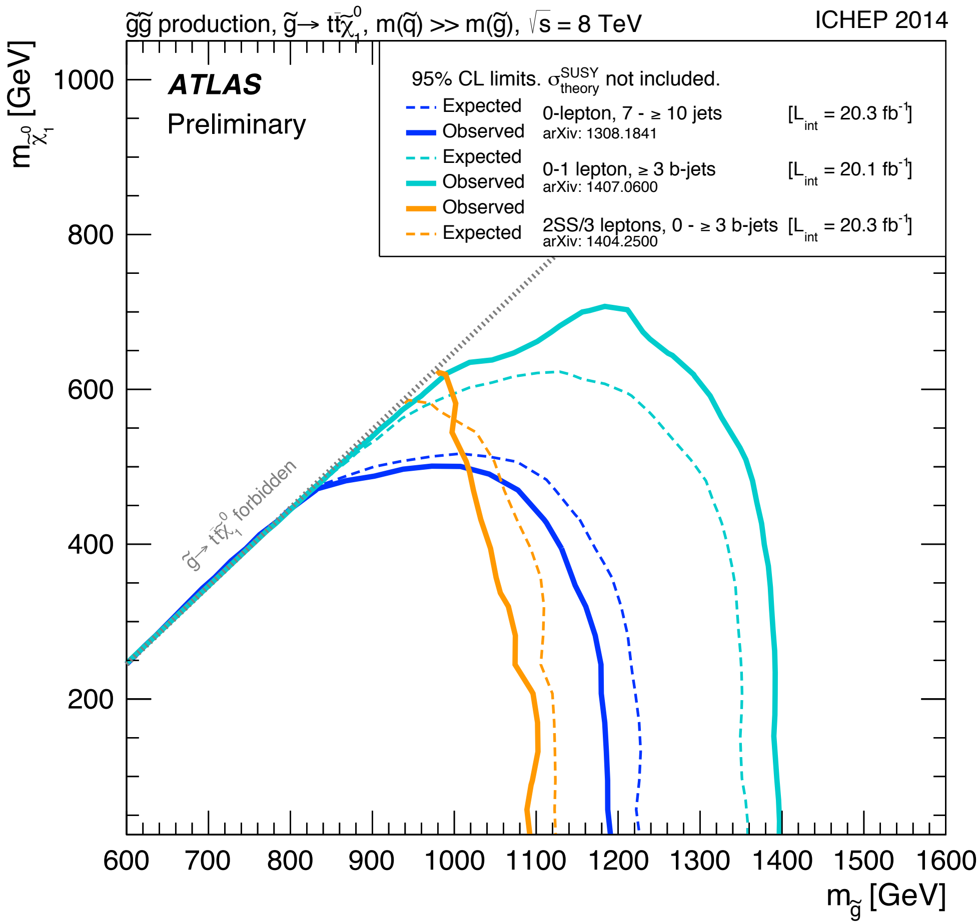


Gluino to top stop



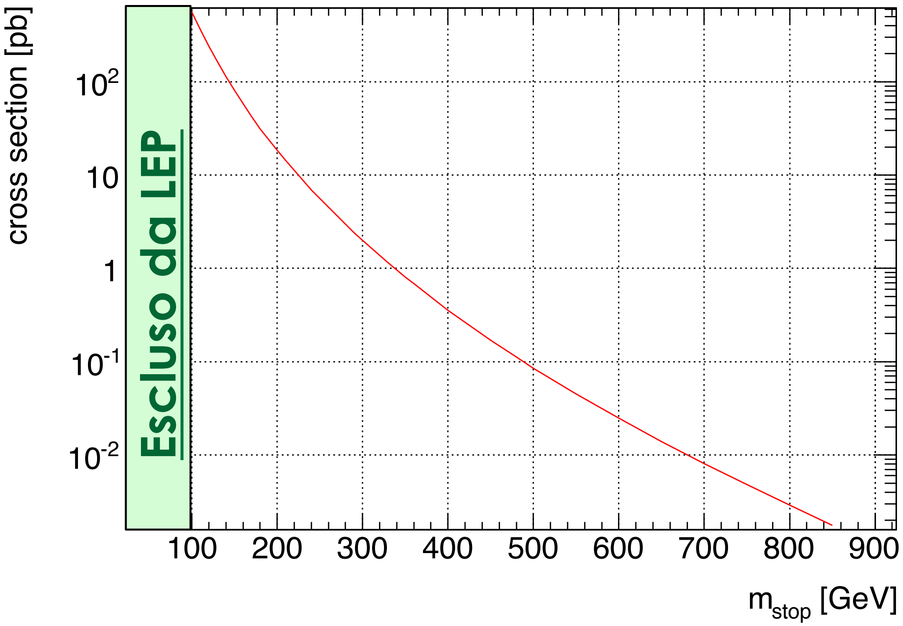
Four W boson and four b-jets !

Gluino excluded up to 1000-1400 GeV depending on the neutralino mass

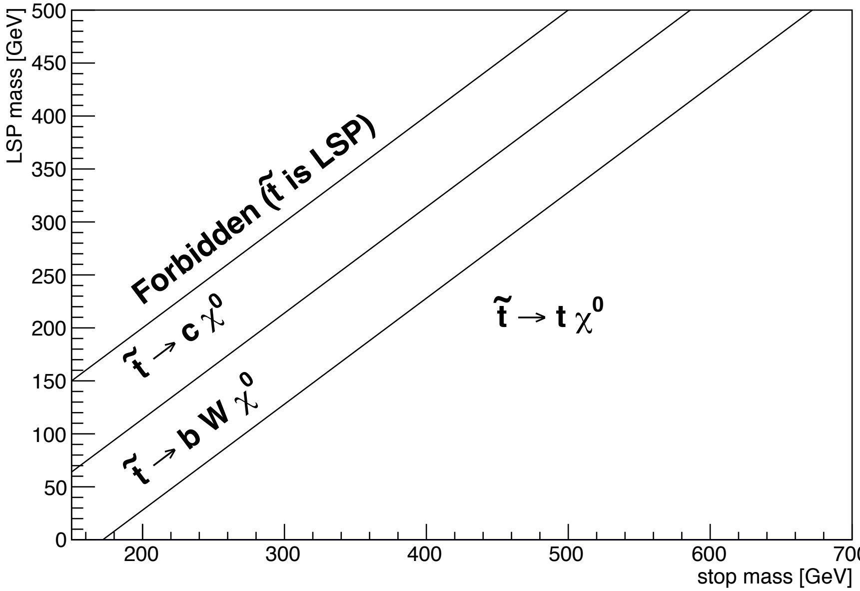


Here each curve is a different search (final state), everything on the left of *any* curve is excluded

Stop quark pair production



Decays if charginos are heavier than the stop



At low mass the cross section is relatively large – but it's more difficult to tell the signal from the background

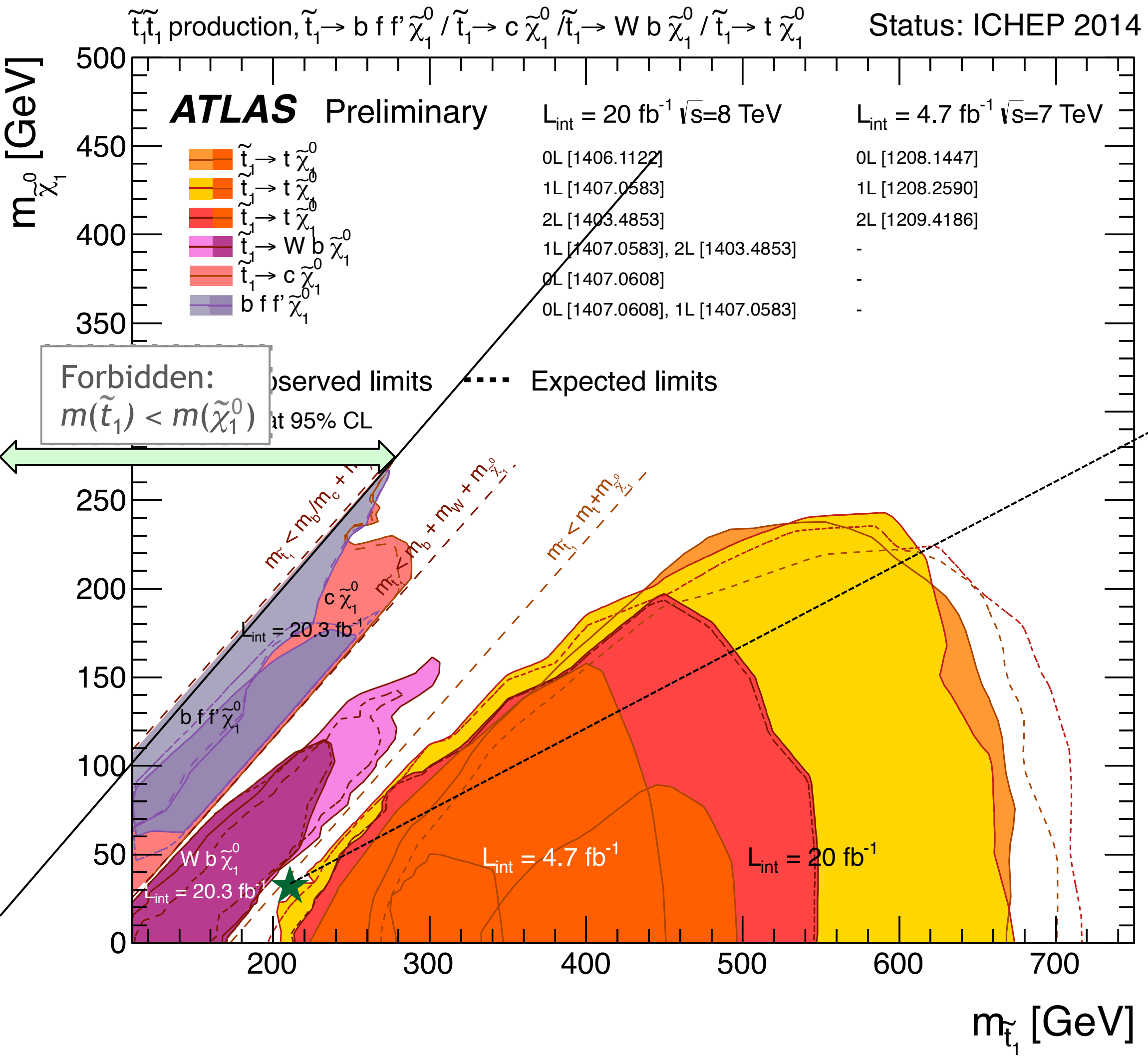
Decays depend on the masses of other SUSY particles. They often give one b-jet, one W boson, and an invisible particle in the final state, the same detectable particles as in the top quark decay:

$$\tilde{t} \to t\chi^0 \to Wb\chi^0$$

$\tilde{t} \to Wb\chi^0$ (direct 3-body)

$$\tilde{t} \to b\chi^{\pm} \to bW\chi^0$$

Scalar top limits



- The plot refer to the case of the stop decaying directly to the lightest neutralino.

What's happening here ?

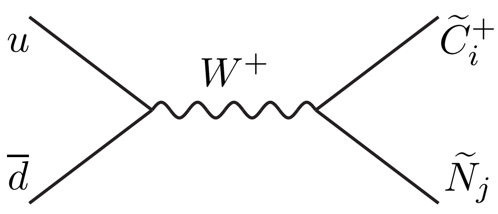
- The stop decays to top N1.
- mstop-mtop-mN1 is ≈ 0, hence top and N1 are at rest in the stop reference frame
- The final state is ttbar plus two very low-pt invisible particle, so it's basically like SM ttbar production (with 10 times less cross section)

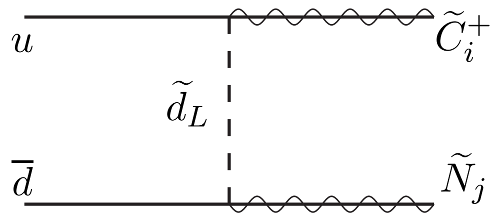
Coloured areas are excluded

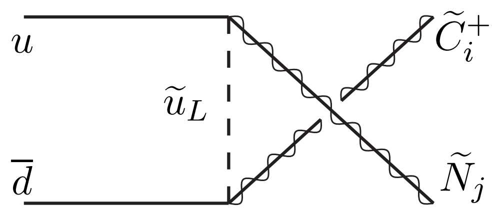
Direct pair production of gauginos

- The production cross section is quite small, as it doesn't occur via strong interaction
- Similar Standard Model processes: WW, WZ, ZZ, WH, ZH production (only the first three have been observed so far)
- If the charginos and neutralinos decay hadronically, the (strong interaction produced) background is just too large
- If there are leptons in the decay, the dominant backgrounds are vector boson production and this can be handled.

- Let's focus on just the example of N_2C_1 production

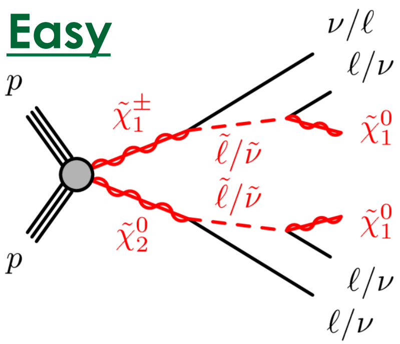






N_2C_1 final states

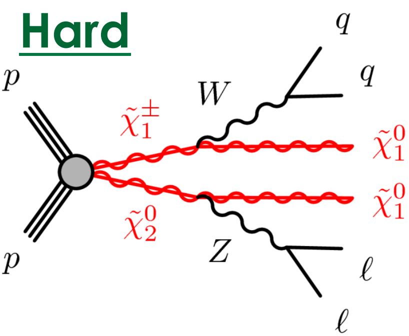
Easy



- This is the same coupling of W,Z to fermions
- If it can, the gauginos will decay to sfermion fermion. In practice only sleptons can be lighter than gauginos because of squark direct production limits.
- This is the easy case – three leptons in 100% of the events

Signature : three leptons, missing energy, no jets

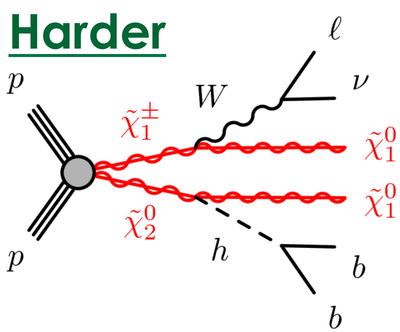
Hard



- If sleptons are heavy, things get more difficult.
- Only 3.3% of the events have three leptons because BR($Z \rightarrow l^+l^-$) = 3 x 3.3% BR($W \rightarrow l^+\nu$) =1/3

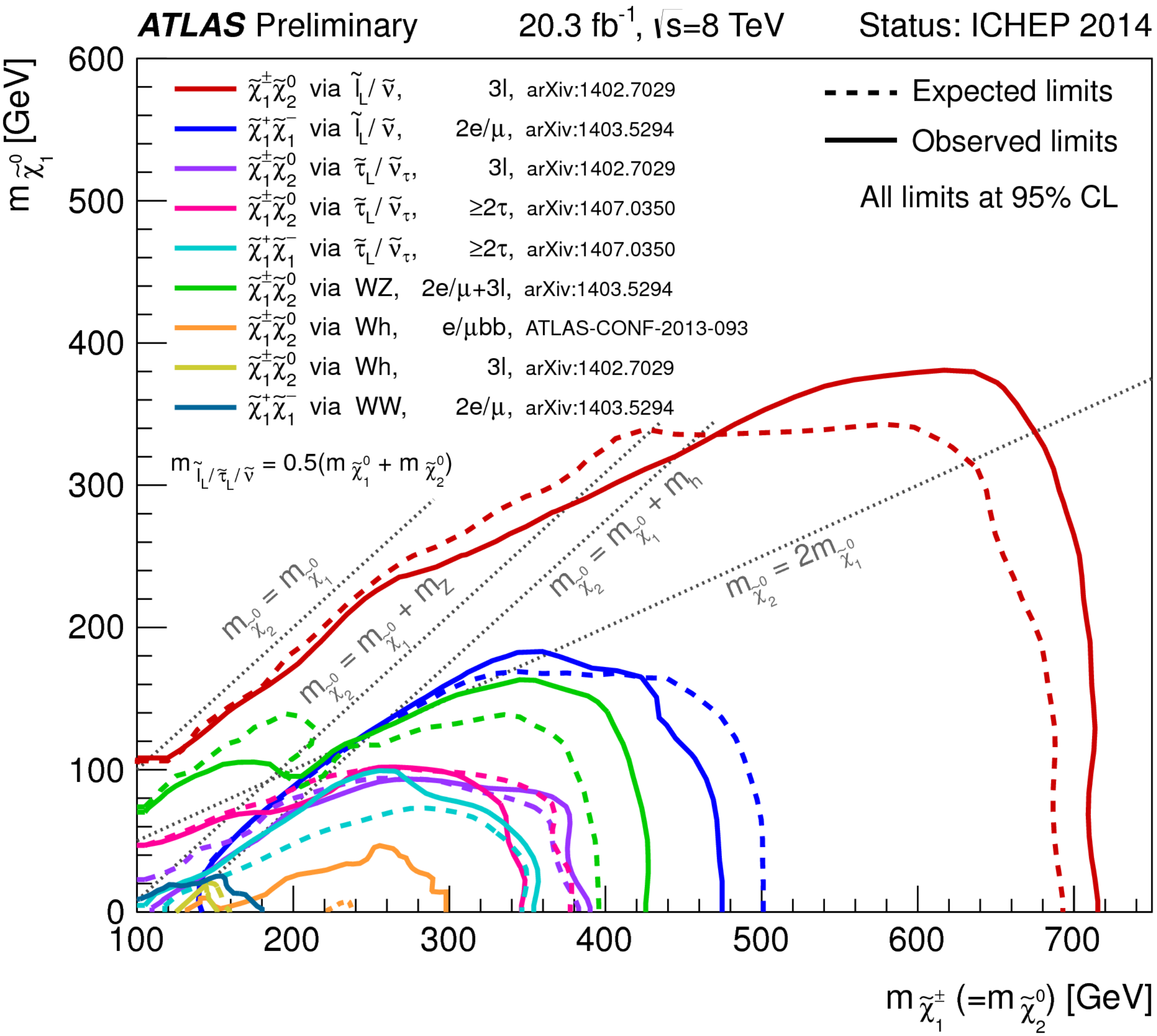
Signature : three leptons, missing energy, no jets

Harder



- If $m(N_2)-m(N_1) > m(h)$, and depending on the neutralino mixing, the Higgs decay might be dominant.
- Similar to (still unobserved) WH production, with comparable cross section at best, and with two extra undetected particles

Direct gaugino limits



- Charginos cannot be lighter than 100 GeV, they would have been seen at LEP

- Red curve: intermediate sleptons
- Green curve: decays to WZ
- Orange: decays to WH

No limits if sleptons heavy and ΔM(C1,N1) < 30 GeV

R-parity violating SUSY

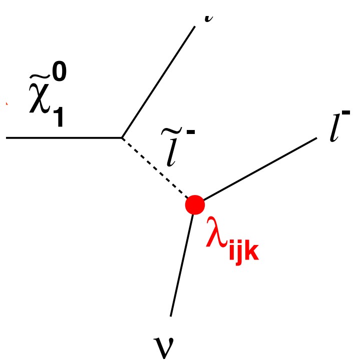
- No Dark Matter candidate
- The LSP is not stable : less missing momentum, higher particle multiplicity in the final state
- Several possible R-parity violating terms in the Lagrangian, giving many different experimental signatures:

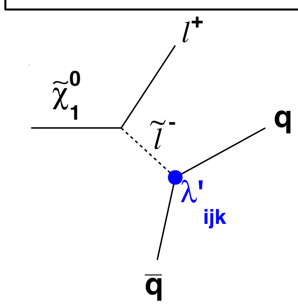
$$W_{RPV} = \underbrace{\boxed{\lambda_{ijk} L_i L_j \bar{E}_k} + \boxed{\lambda'_{ijk} L_i Q_j \bar{D}_k}}_{\text{Lepton Violating}} + k_i L_i H_2 + \underbrace{\boxed{\lambda''_{ijk} \bar{D}_i \bar{D}_j \bar{D}_k}}_{\text{Baryon Violating}}$$

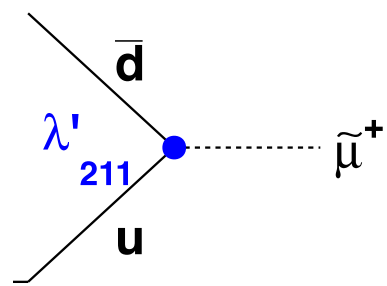
- Multi-jet resonances
- Many jets but with little ETMiss

High lepton multiplicity, from LSP decays like:

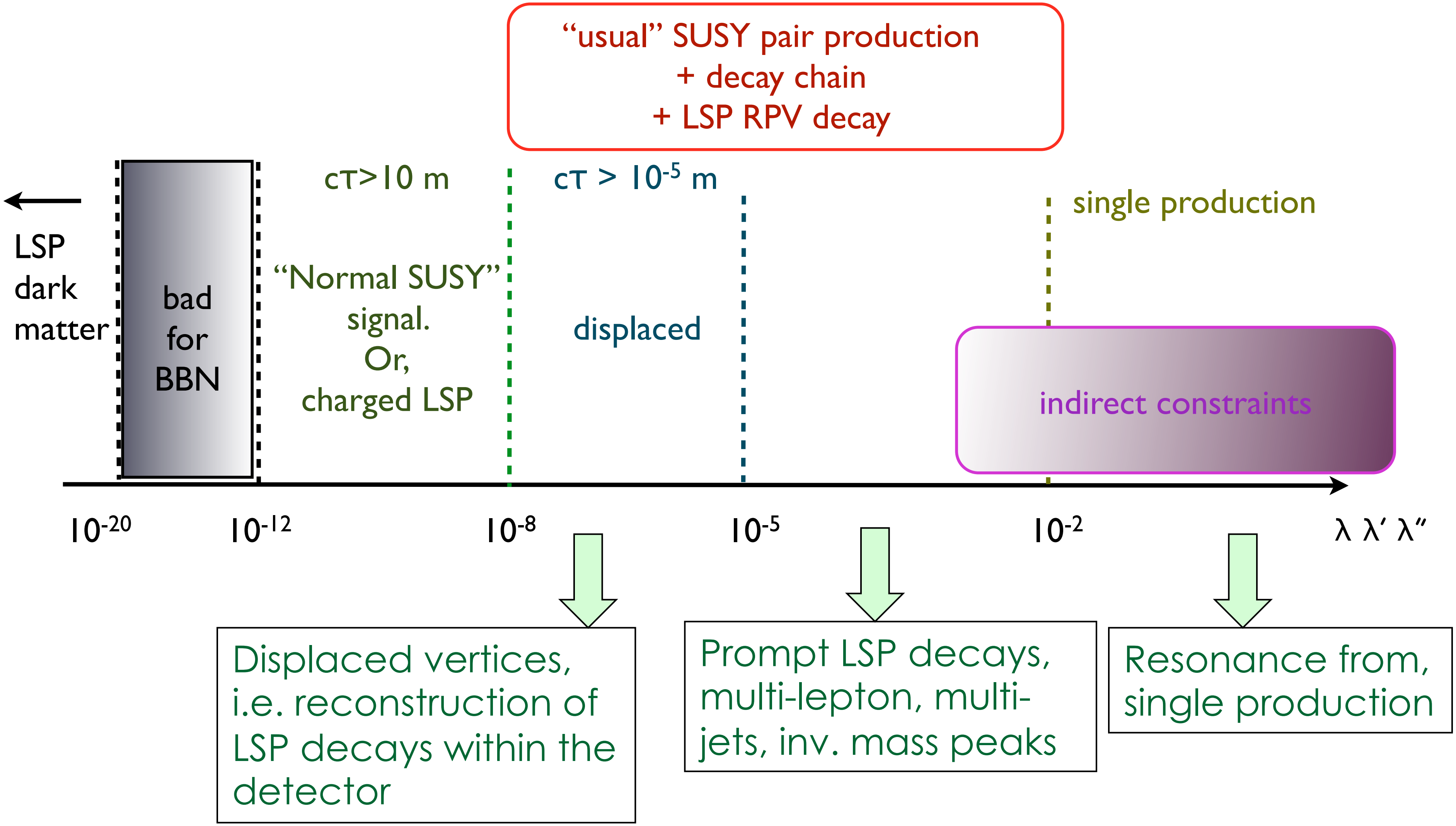
- Additional leptons and jets from LSP decay
- Single production of sleptons?





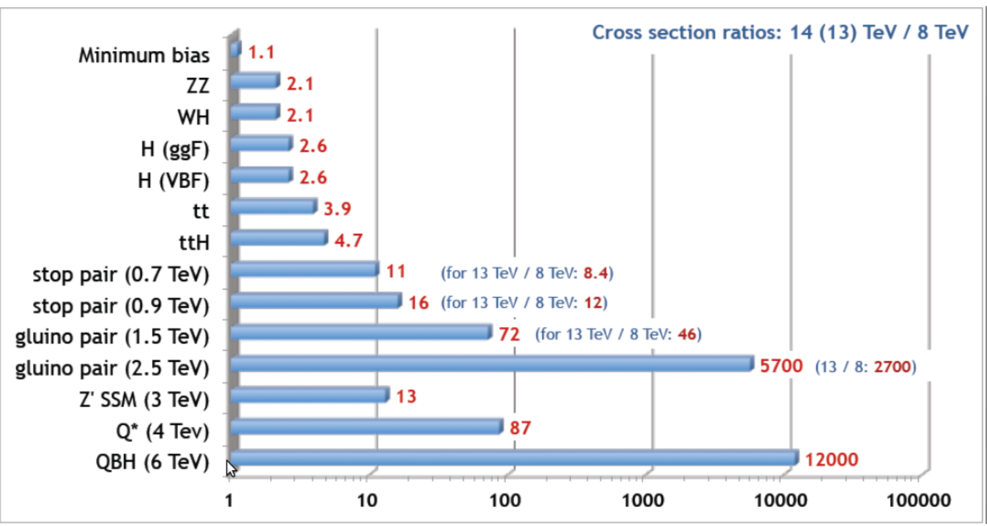


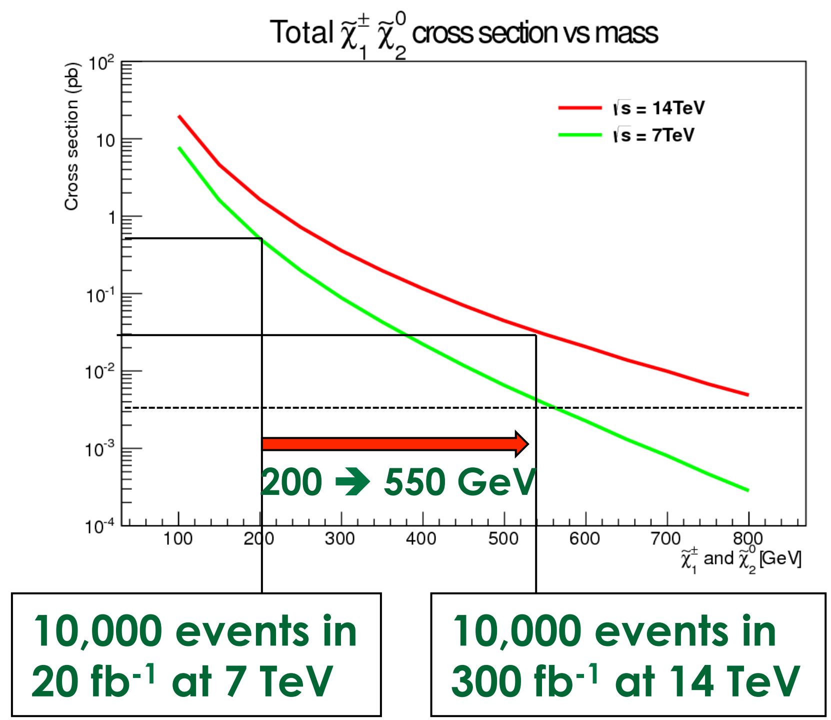
Size of R-parity violating couplings



Outlook

- LHC Run 1 analysis are being completed
- LHC is set to resume operations in april 2015 at 13 TeV collision energy
- Luminosity will also be increased, with ~300 fb^{-1} foreseen by 2021
- Proposal to further increase luminosity and collect 3000 fb^{-1} afterwards

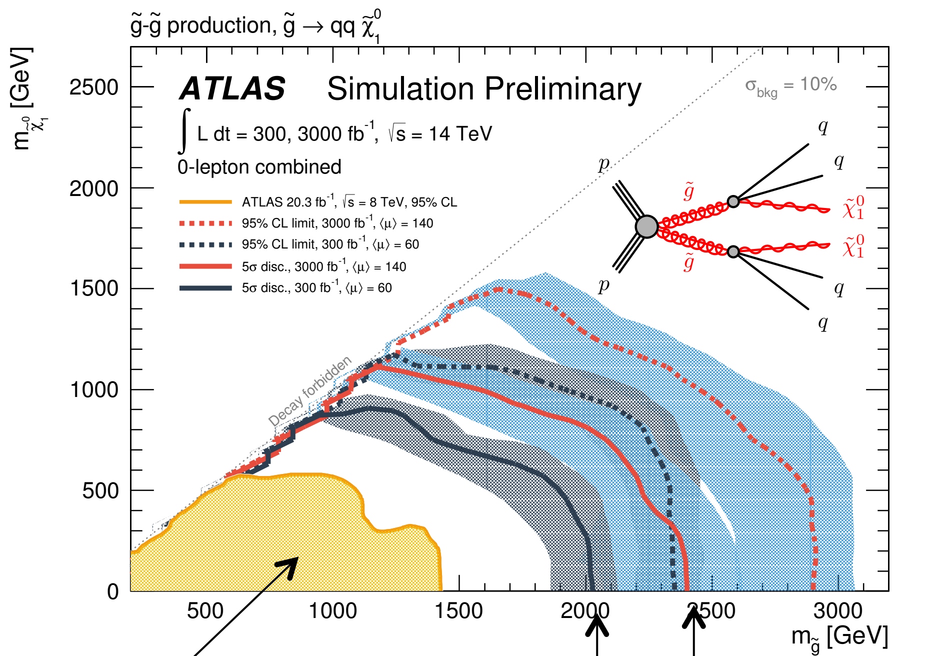


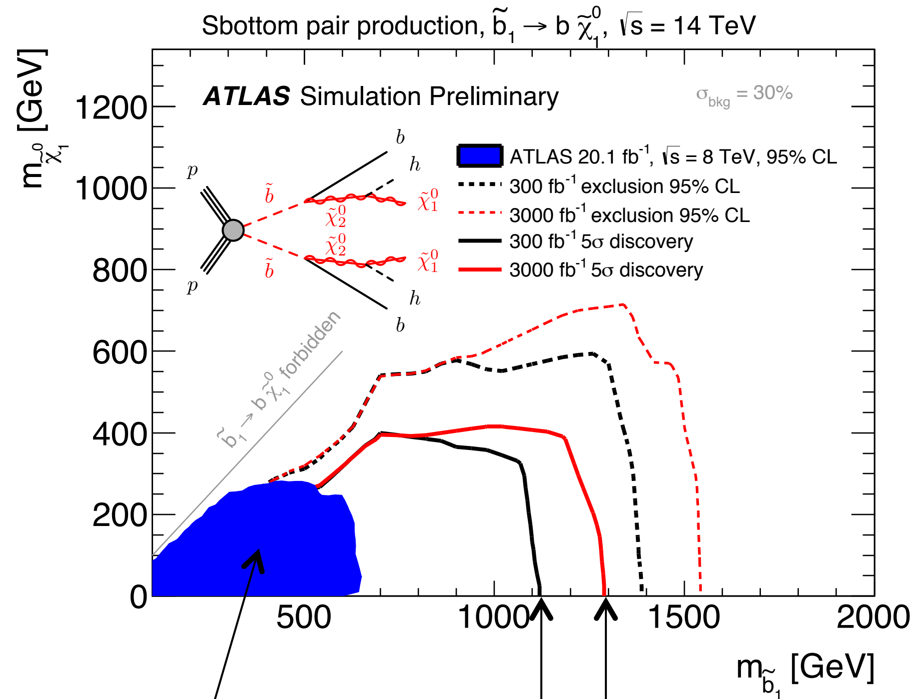


- Strong production of heavy particles benefit of the largest cross section increases : might produce 100 times more gluinos in 2015 than in 2012
- Of course backgrounds increase too, but less than that

Electroweak production benefits from increased luminosity (and energy)

Outlook: strong production





Current limits

5σ (discovery) sensitivity for 300/3000 fb^{-1}

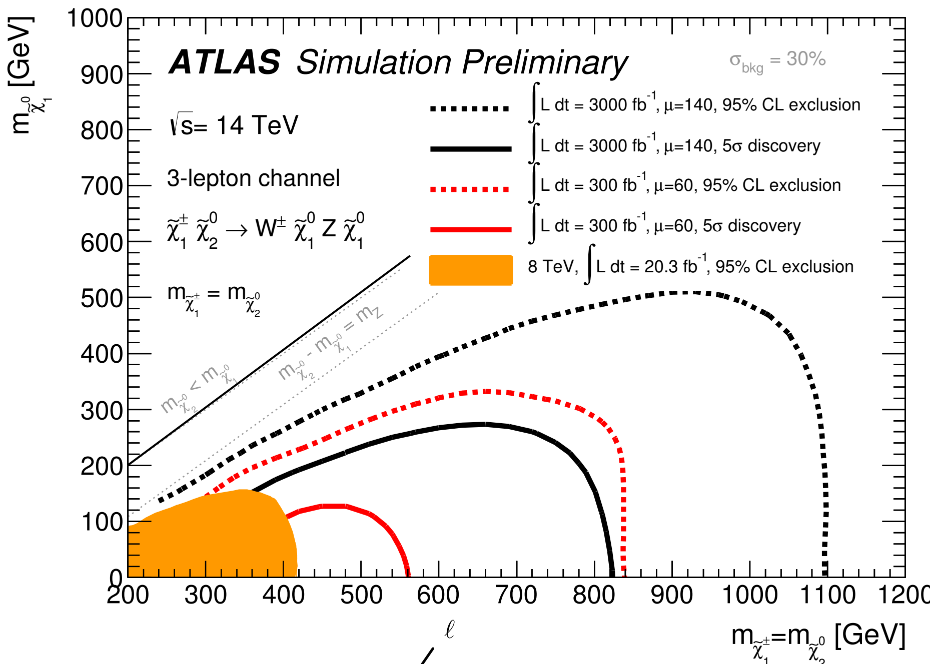
Current limits

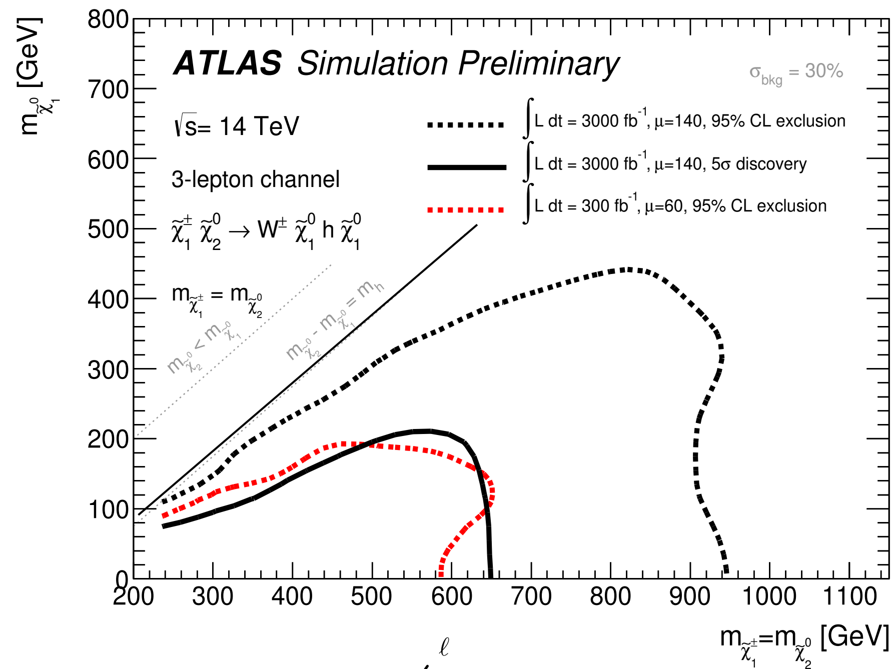
5σ (discovery) sensitivity for 300/3000 fb^{-1}

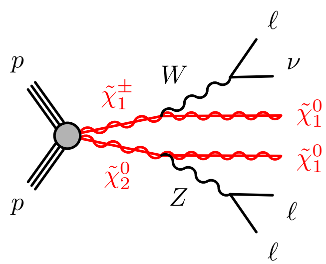
Gluino pair production

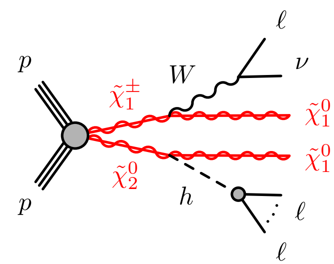
sbottom pair production

Outlook: electroweak production









- Possibility to discover heavy EWK-inos decaying in the lightest one up to 6-800 GeV
- Uncovered: mass difference between EWK-inos smaller than 30 GeV (μ small, M_1 and M_2 > 800 GeV), or only the LSP (M_1 small, μ and M_2 > 800 GeV)

Conclusions

- I hope I gave you the feeling that searches for new particles at colliders are interesting…
- Supersymmetry has been considered for some decades one of the most promising extensions of the Standard Model (which we know ***must*** be extended)
- The negative results from the first three years of LHC data put **new strong constraints** on the supersimmetric particle masses
- Obviously what we would like is to find some signal… looking forward for the 14 TeV collision data and hoping for the best