The Quest for SUSY in Multijet events using 20.3 fb^{-1} of 8 TeV data

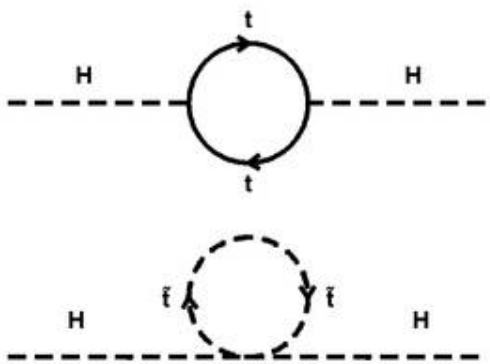
Mireia Crispin-Ortuzar

IOP HEPP Meeting 2014

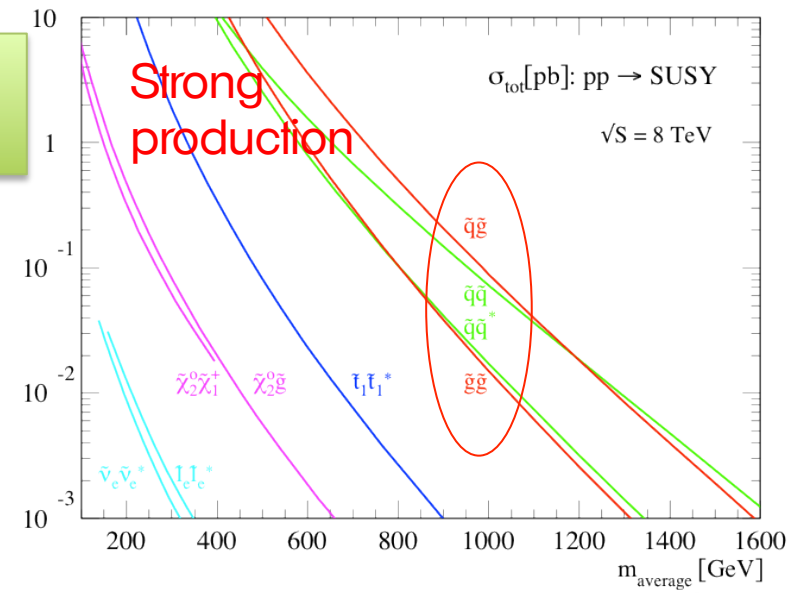
Motivation

UNIVERSITY OF OXFORD

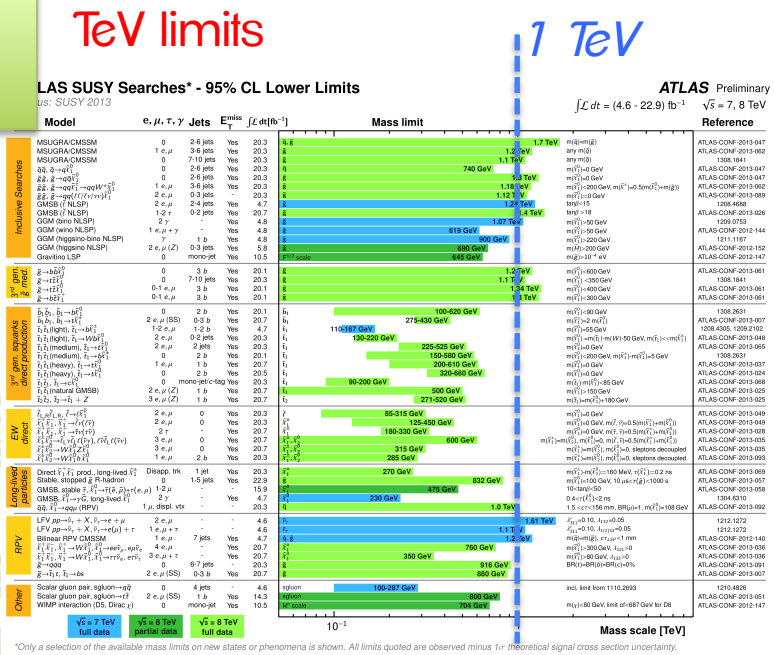
1 SUSY never dies



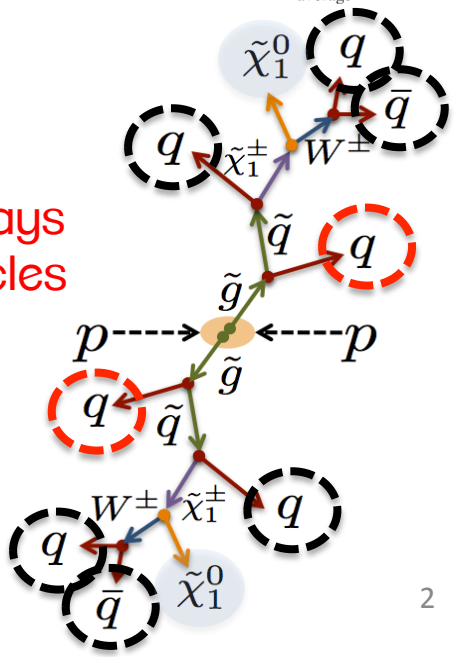
2 Strong production



3 TeV limits



4 Cascade decays of heavy particles



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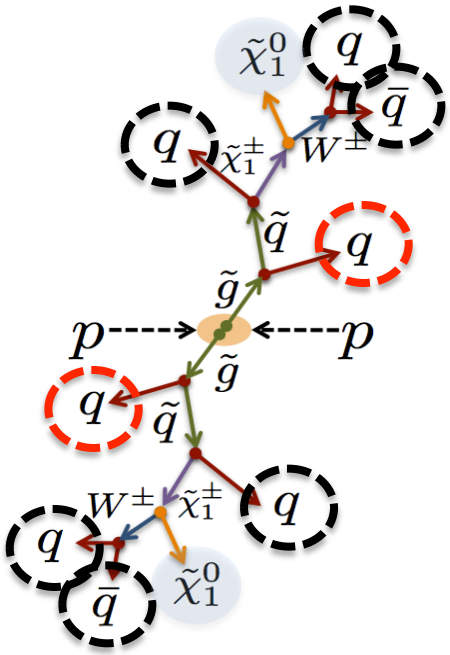


- We target **TeV—scale mass particles** that **decay rapidly to a large number of coloured particles** in association with weakly interacting particle(s) and no leptons
- Some models have a fixed number of b-jets: gain sensitivity by adding signal regions **exclusive in the** number of *b*-jets.
- Heavy, highly boosted particles are expected to form large-radius jets with large masses, so we cut on the total mass of all the large-R jets in the event (see slide 6).

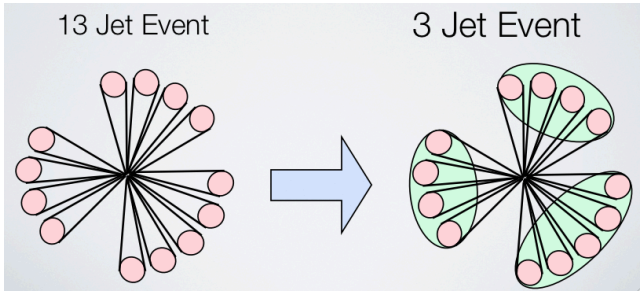
Lots of jets + E_T^{miss}

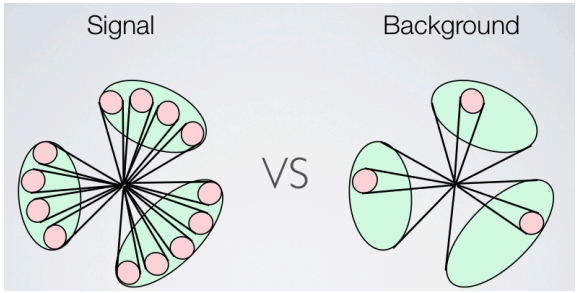
+

b-jets

or

Large mass



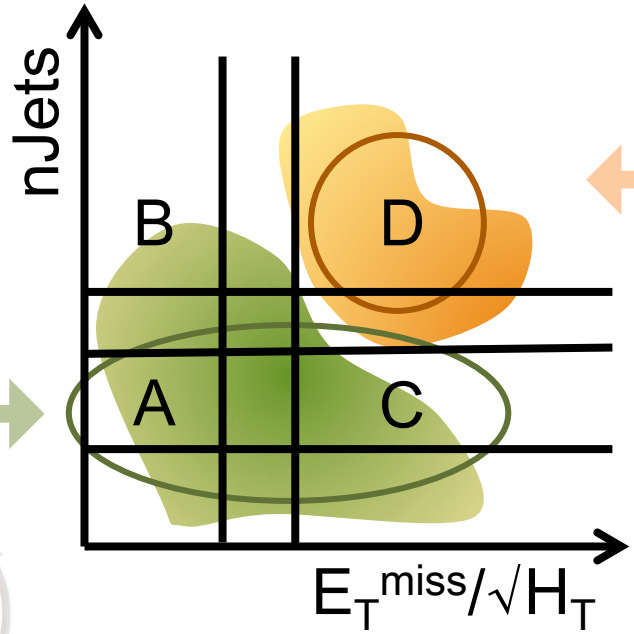


Jay Wacker, SLAC

Basics

- Rely heavily on the multijet background determination, obtained via an ABCD method between the jet multiplicity and the variable MET/$\sqrt{H_T}$.

- Take background shape from A+C (reweight to B/A)
- QCD-dominated: missing E_T = mismeasured jet energy
- Subtract electro-weak contributions
- 5- or 6-jet template



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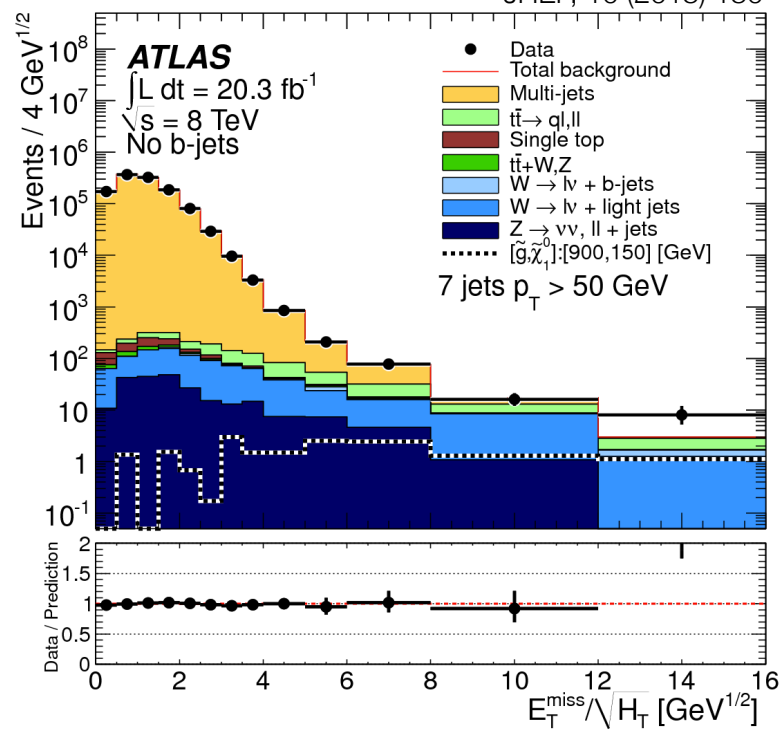

- Signal has large missing E_T from weakly interacting SUSY particles
- Different background templates derived for each value of b-jet multiplicity and fat jet mass.

Analysis regions

- We look at different regions of phase space to, in summary:
  - ensure a good background description
  - enhance signal sensitivity

SIGNAL

- Regions where we look for new physics signals, defined to have high sensitivity
- Tight cuts in jet multiplicity and $E_T^{miss}/\sqrt{H_T}$

CONTROL

- Electroweak: *Constrain* the backgrounds in a phase space close to the signal regions.
- Hadronic: Validate the data-driven multijet background and derive systematic.

VALIDATION

- Rough validation of the Monte Carlo description of electroweak backgrounds.
- Loose cuts in jet multiplicity, number of leptons and E_T^{miss}.

CONFIRMATION

- Used to be signal regions in the past (lower jet multiplicity than the ones we use now), now used to check background description at high jet multiplicities.

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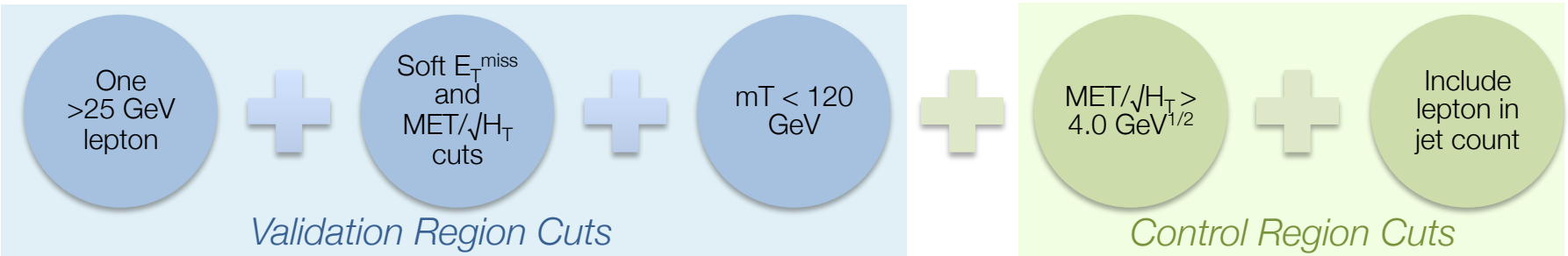
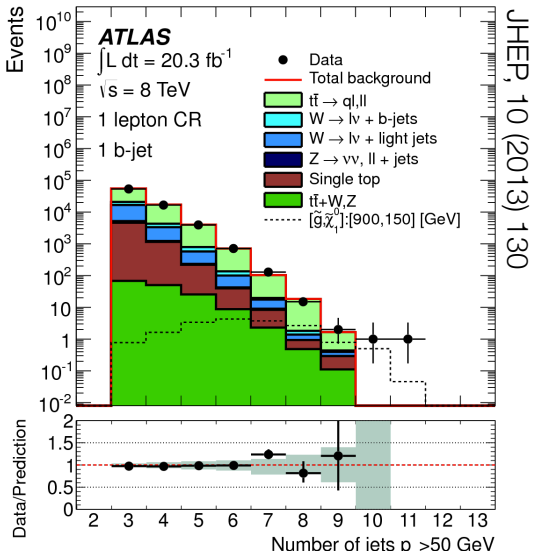
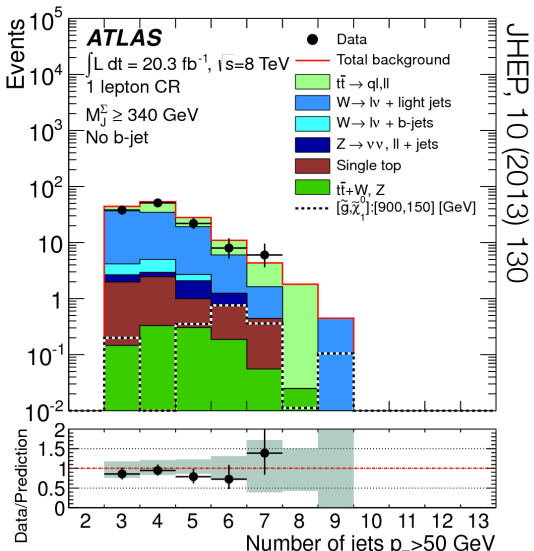
Control regions

- **Control regions** are defined to resemble the phase space of the signal regions.
- They are used to constrain the non-QCD SM backgrounds (Monte Carlo), and evaluate the accuracy of the QCD multijet background (data-driven).
- **QCD control regions:** see next slide.
- **Non-QCD control regions:** Built on top of validation regions. 1-lepton requirement. Same jet and *b*-jet multiplicity or M_J^{Σ} cuts as signal regions.



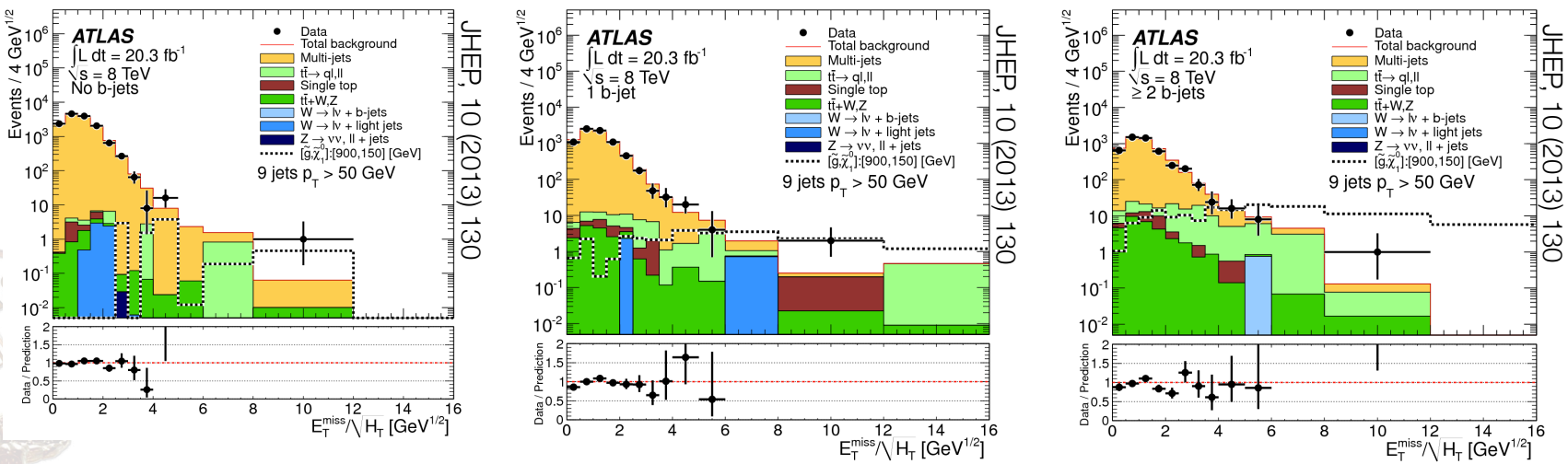




b-jet signal regions

Jet multiplicity	Jet p_T	B-jet multiplicity	METSig	
==6	50 GeV	0, 1, 2+	inclusive	
==7		0, 1, 2+	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$
==8		0, 1, 2+	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$
==9		0, 1, 2+	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$
>=10		inclusive	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$
==5	80 GeV	0, 1, 2+	inclusive	
==6		0, 1, 2+	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$
==7		0, 1, 2+	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$
>=8		0, 1, 2+	< 3.5 $GeV^{1/2}$	> 4.0 $GeV^{1/2}$

Legend: control regions, confirmation regions, signal regions

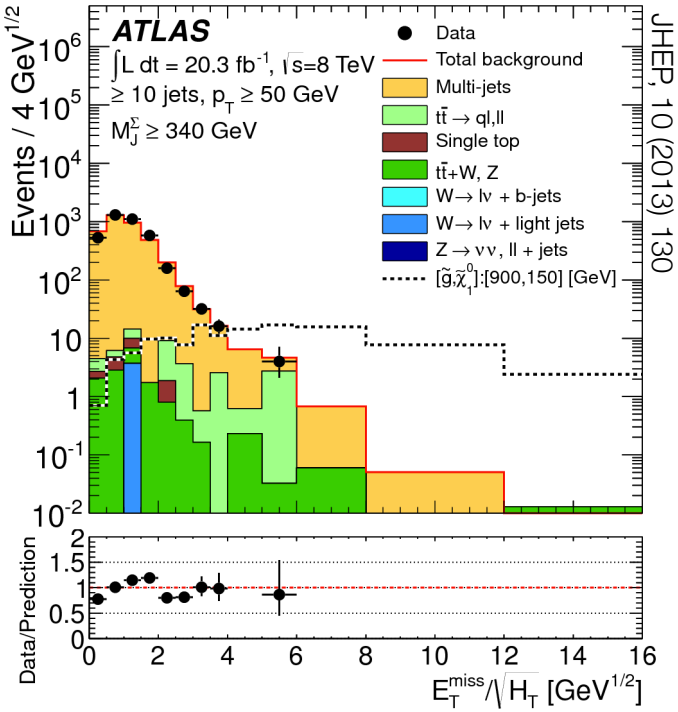


M_J^{Σ} signal regions

- M_J^{Σ} is defined as $M_J^{\Sigma} = \sum_{\substack{p_T^{R=1.0} > 100\,\mathrm{GeV} \\ |\eta^{R=1.0}| \leq 1.5}} m_{\mathrm{jet}}^{R=1.0}$.

- It acts both as an **event-level** variable to describe the multijet topology and as a measure of the **mass of the large-R jets** originating from boosted, heavy particles.

- The R=1.0 'composite' jets are built by reclustering standard R=0.4 jets with p_T>20 GeV and $|\eta|$<2.8.



Jet multiplicity	Jet p_T	M_J^{Σ} cut [GeV]	METSig	
==6	50 GeV	>340, >420	inclusive	
==7			< 3.5 GeV$^{1/2}$	> 4.0 GeV$^{1/2}$
>=8			< 3.5 GeV$^{1/2}$	> 4.0 GeV$^{1/2}$
>=9			< 3.5 GeV$^{1/2}$	> 4.0 GeV$^{1/2}$
>=10			< 3.5 GeV$^{1/2}$	> 4.0 GeV$^{1/2}$

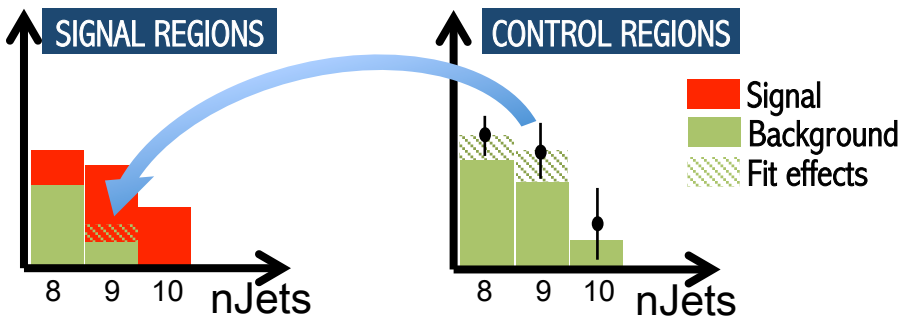
Legend: control regions, confirmation regions, signal regions

Main uncertainties

- The **dominant uncertainties in the QCD multijet background** are the heavy flavour (HF) systematic for the *b*-jet stream and the closure systematic for the M_J^{Σ} stream.
  - The **HF systematic** in the *b*-jet stream evaluates the accuracy of the QCD extrapolation in a fully hadronic ttbar Monte Carlo sample, in the $MET/\sqrt{H_T}>4.0$ $GeV^{1/2}$ region.
  - The **closure systematic** evaluates the agreement of data with the background prediction in the QCD control regions (i.e. low high jet multiplicity or low $MET/\sqrt{H_T}$)
- The dominant uncertainties in the **non-QCD background** are:

1. **Jet Energy Scale** uncertainty
2. **Monte Carlo statistics**
3. Theory: Additional parton splittings (for ttbar)

Results



- **Profile likelihood fit**: all the b-jet signal and control regions
- Constrain background shapes (all regions are orthogonal) and normalisations
- Reduce uncertainties
- MJ regions are fitted one by one
- Combine using **best expected SR**

Model-independent limits: (background-only fits)

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B-jet regions

Signal region	8j50			9j50			10j50
b-jets	0	1	≥ 2	0	1	≥ 2	—
Observed events	40	44	44	5	8	7	3
Total events after fit	35 ± 4	40 ± 10	50 ± 10	3.3 ± 0.7	6.1 ± 1.7	8.0 ± 2.7	1.37 ± 0.35

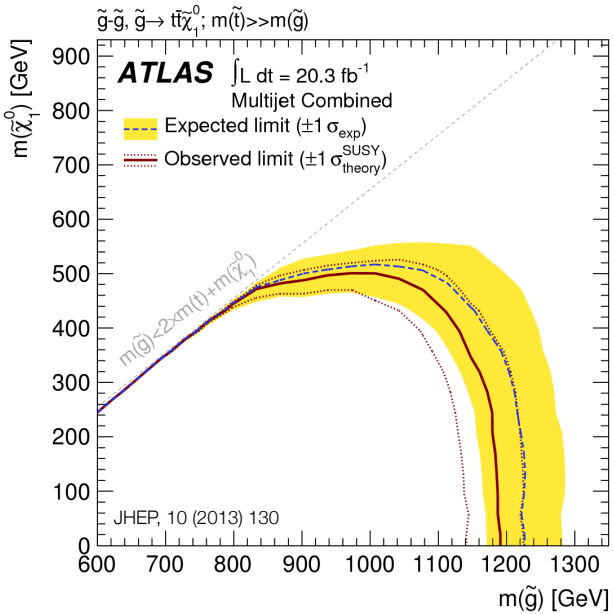
Signal region	7j80			8j80		
b-jets	0	1	≥ 2	0	1	≥ 2
Observed events	12	17	13	2	1	3
Total fitted events	11.0 ± 2.2	17 ± 6	25 ± 10	0.9 ± 0.6	1.5 ± 0.9	3.3 ± 2.2

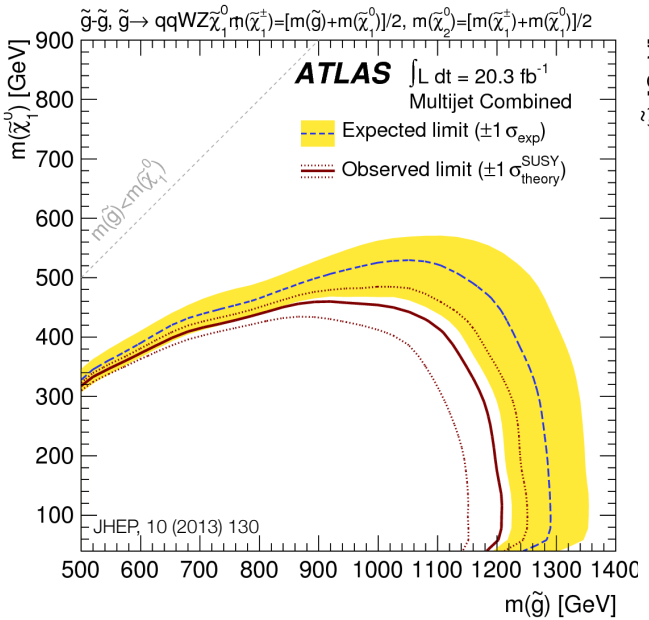
m_J regions

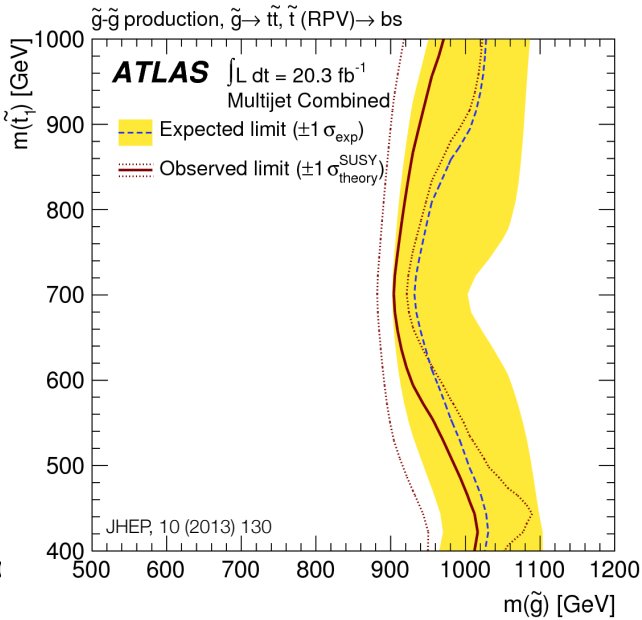
Signal region	8j50		9j50		10j50	
M_J^{Σ} [GeV]	340	420	340	420	340	420
Observed events	69	37	13	9	1	1
Total events after fit	75 ± 19	45 ± 14	17 ± 7	11 ± 5	$3.2^{+3.7}_{-3.2}$	2.2 ± 2.0

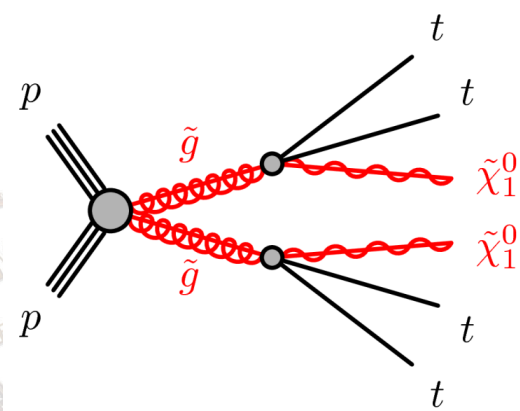
Results

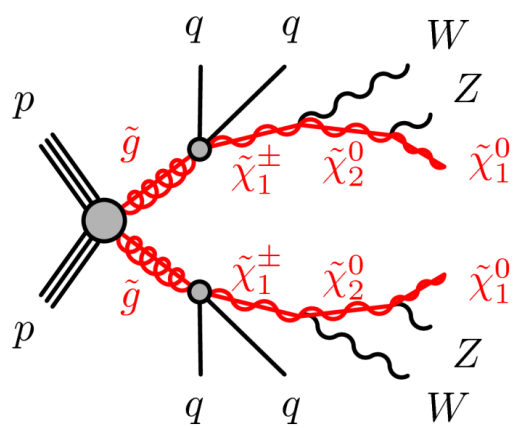
Model-dependent limits:

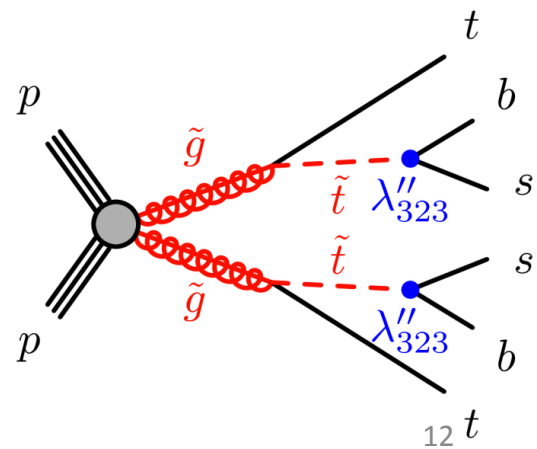






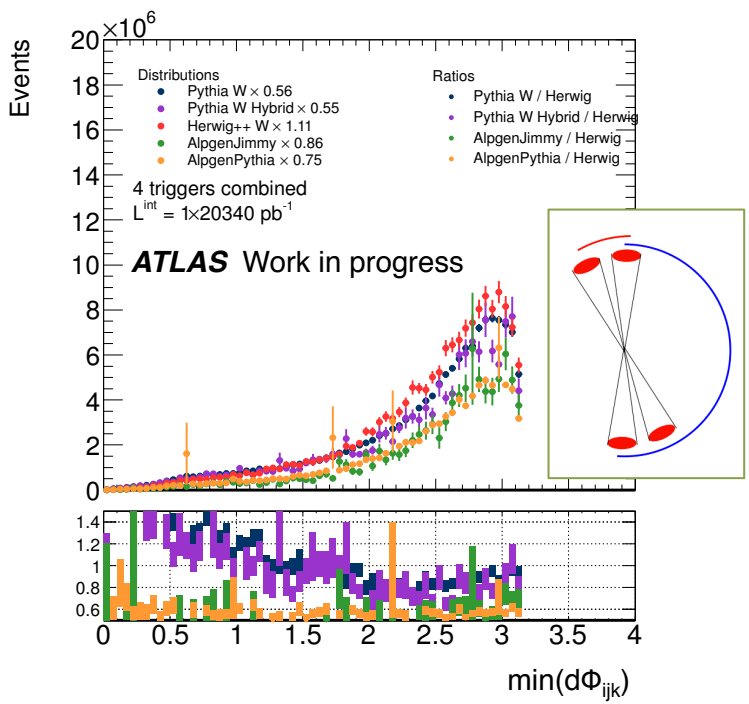


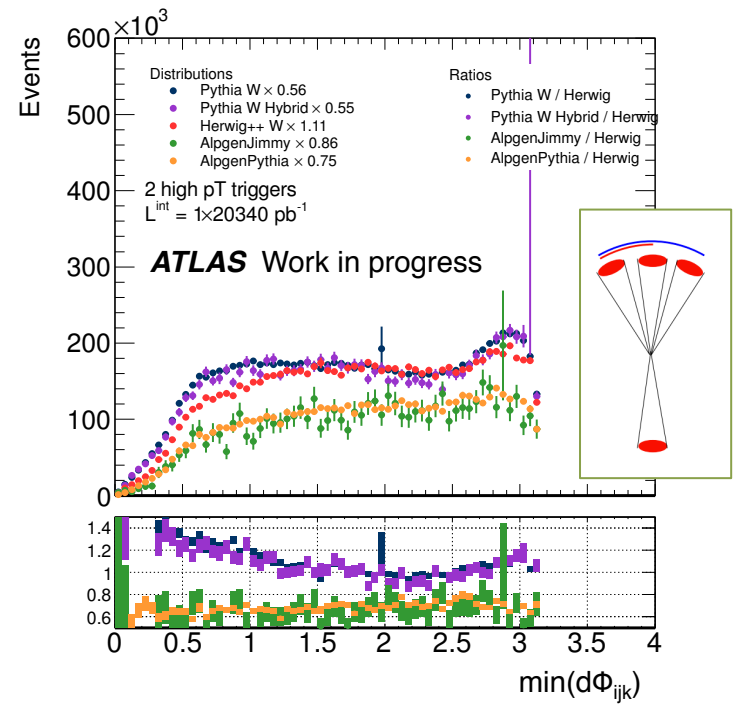




Cross section measurement

- Measurement of cross section of multijet events will improve the description of our backgrounds in Monte Carlo.
- Future: 5+ jets, and jet multiplicity ratios.
- Currently: 4-jet events (inclusive).
- Measuring the cross section differentially in variables sensitive to properties of the event: kinematics, topology (1-3 vs 2-2…), perturbative regime (NLO effects?), etc.
- Plots show the shape of the minimum separation in **Φ** of the closest 3 jets in the event.





Conclusions

- Sensitive search for multi-jet + MET final states
- Current version considerably more sophisticated than its predecessors
- Paper published in JHEP (JHEP, 10 (2013) 130)
- Ideas exist for future extensions. Currently working on a multijet cross section measurement.
- No hints of SUSY yet …