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Direct stop searches at ATLAS

04/04/2012

Josh McFayden

Outline

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- Introduction
  - Motivation for stop searches
  - Stop signatures

- Analysis
  - Basic selection
  - Background estimation
  - Optimisation

Motivation & Backgrounds

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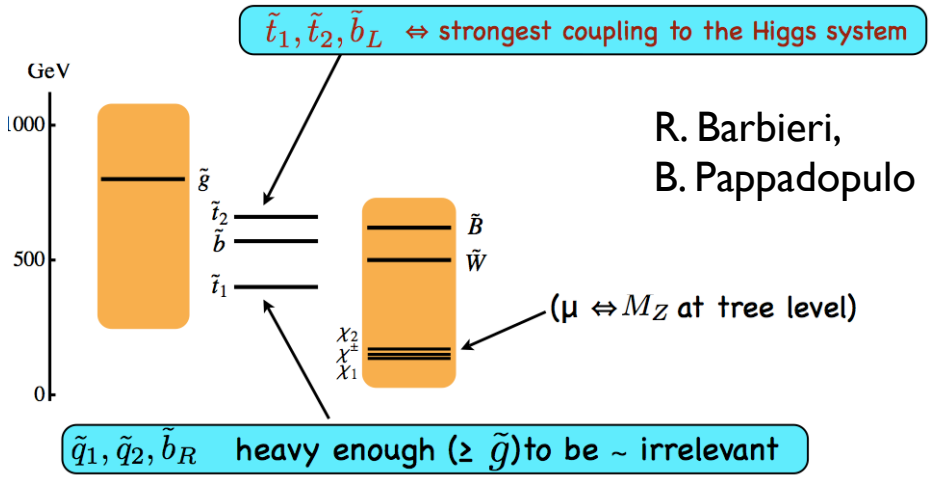
- Stop quark searches are a **natural extension** to inclusive SUSY searches at the LHC.
  - Additional requirement of **b-jets** can give better sensitivity to these signatures than the inclusive SUSY selection.

- The stop quark can be the lightest of the squarks
  - Can even be lighter than the top quark

- 3rd generation squark searches are now also even more strongly **motivated by early LHC results**
  - ~TeV scale exclusion of light squarks and gluinos narrows down phase space for "natural SUSY"



Stop production at the LHC

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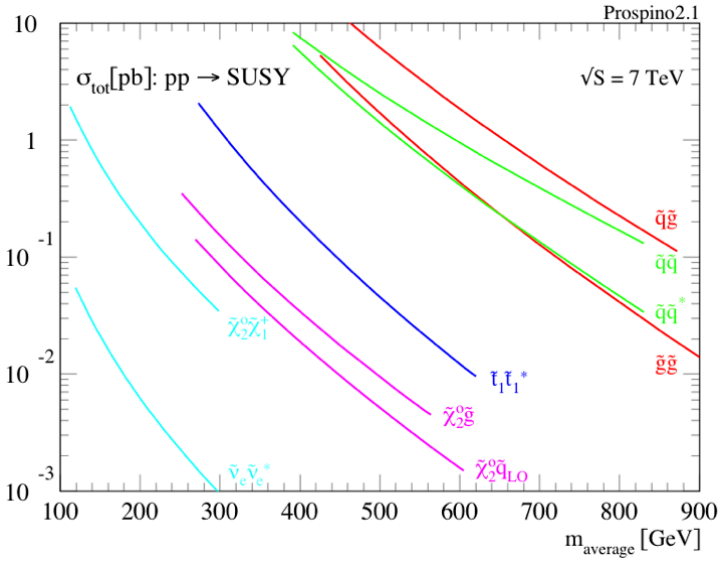
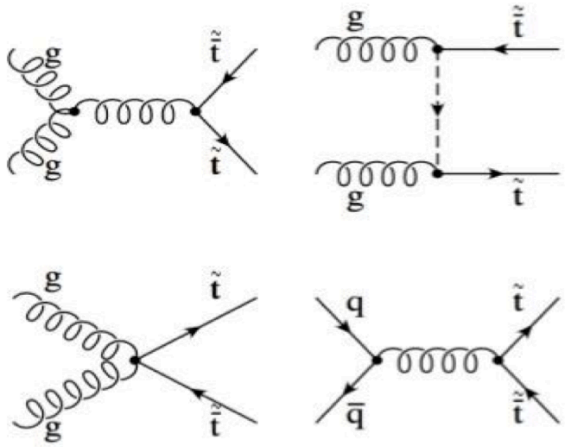
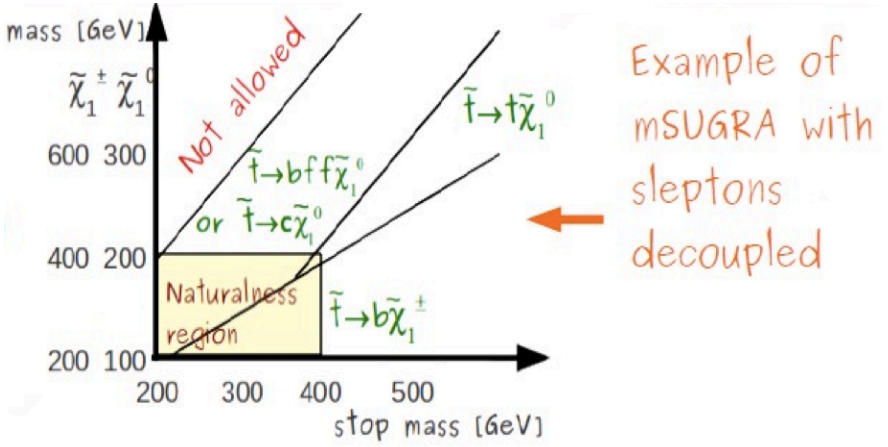
- The following production modes are currently studied in ATLAS SUSY analyses:
  - **Gluino mediated** stop production
    - Larger cross section - more suitable for first data
  - If TeV gluinos are excluded stop pair production a more interesting search
  - Stop **pair production**
    - **The focus of this talk**

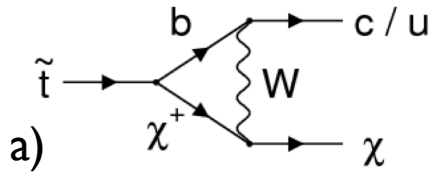


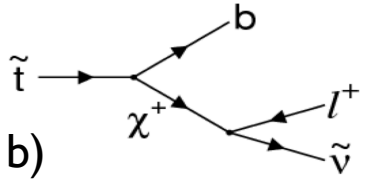


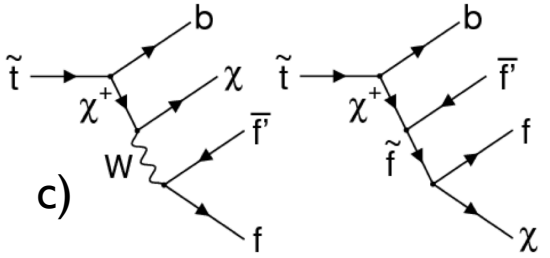
Stop pair production

- A huge variety of possible final states, constrained kinematically
  - a) 2-body
    - stop → c χ^0
  - b) 3-body
    - stop → b $\chi^\pm$ → b $W^\pm$ χ^0
    - stop → b l ν
  - c) 4-body
    - stop → b f f' χ^0
  - d) stop → t χ^0









- I will cover **stop → t + χ^0** (0-lepton channel) in this talk.

Analysis Overview

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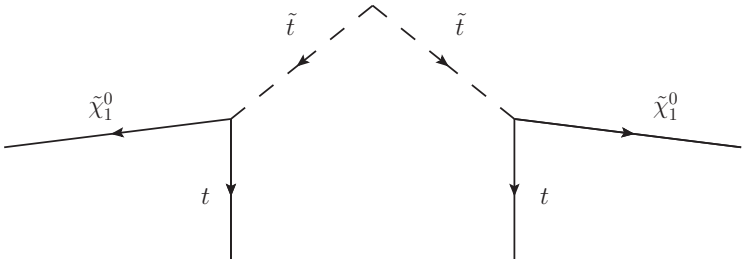
- **Signature stop → top + LSP in 0-lepton channel:**



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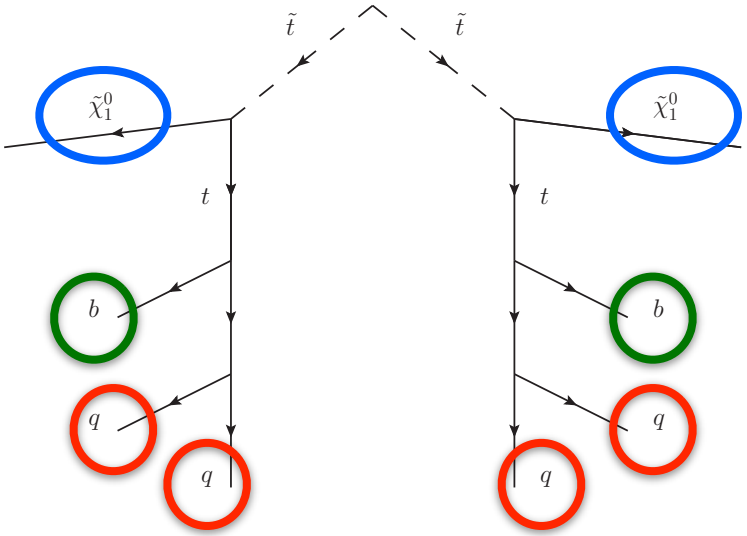

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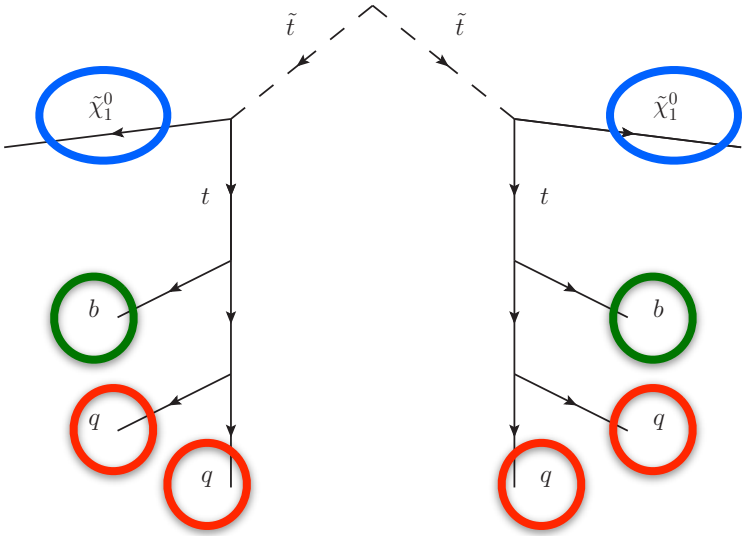

- **Analysis cuts:**
  - jet + E_T^{miss} trigger
  - veto events with loose leptons
  - ≥ **6 jets** p_T > 130,30,...,30 GeV
  - ≥ **2 b-jets** p_T > 30 GeV
  - **E_T^{miss}** > 150 GeV
  - $\Delta\phi(6j, E_T^{miss}) > 0.2$

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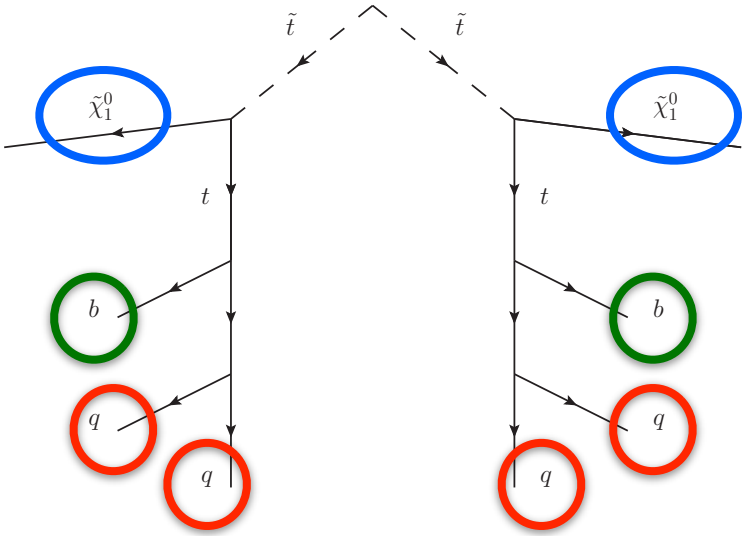

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Driven by trigger thresholds

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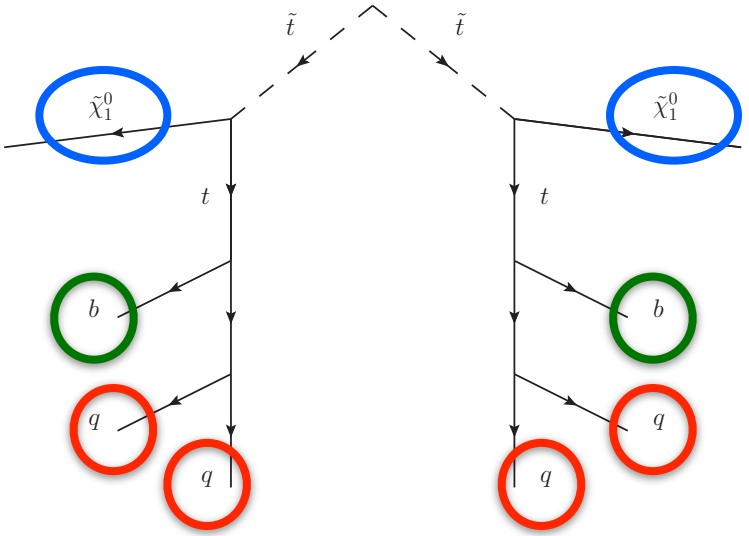

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Driven by trigger thresholds

QCD background rejection

Analysis Overview

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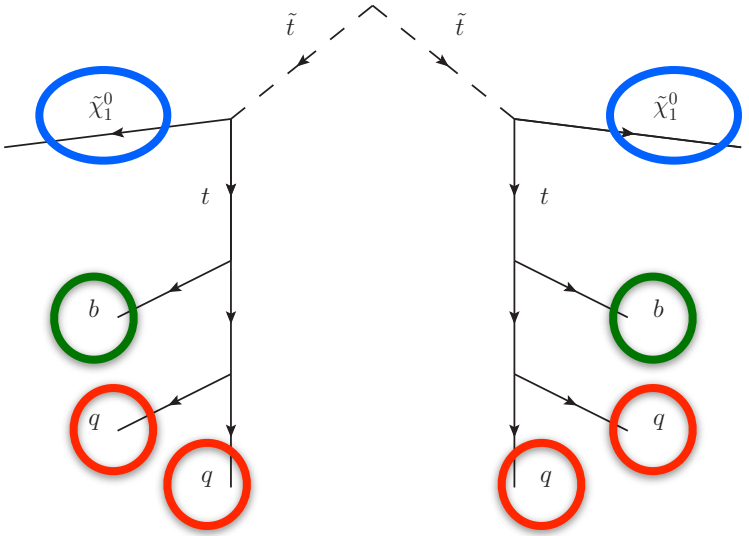

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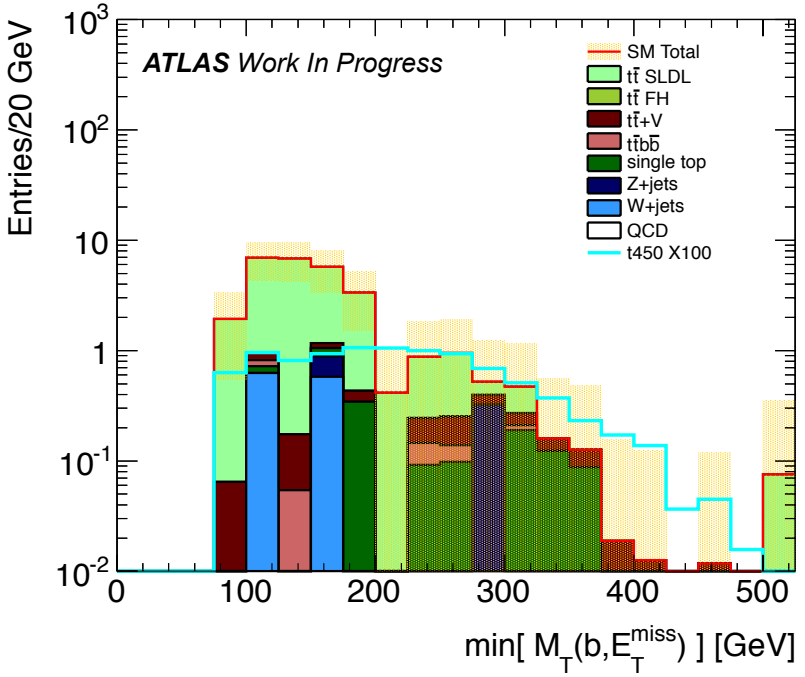
Driven by trigger thresholds

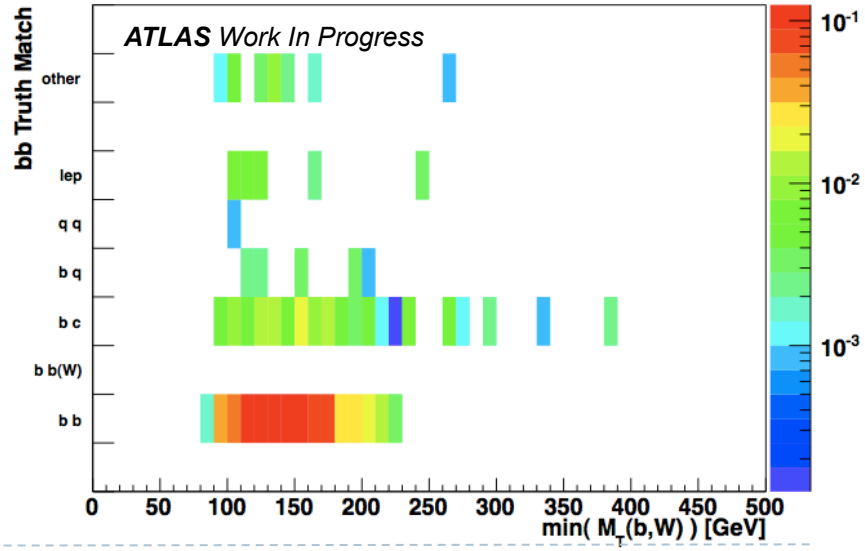
QCD background rejection

- Cut and count
- Semi-data driven background estimation
- Full 5 fb^{-1} 2011 dataset used

Discriminating variable - min[$m_T(b,E_T^{miss})$]

- Dominant background is leptonic top pair production
  - Extra suppression needed for sensitivity!
- Construct pseudo transverse mass (m_T) of top quark:
  - Assume $\mathbf{p_T(W) = E_T^{miss}}$
    → construct min[$m_T(b, E_T^{miss})$]
  - **Endpoint at ~m_{top}**





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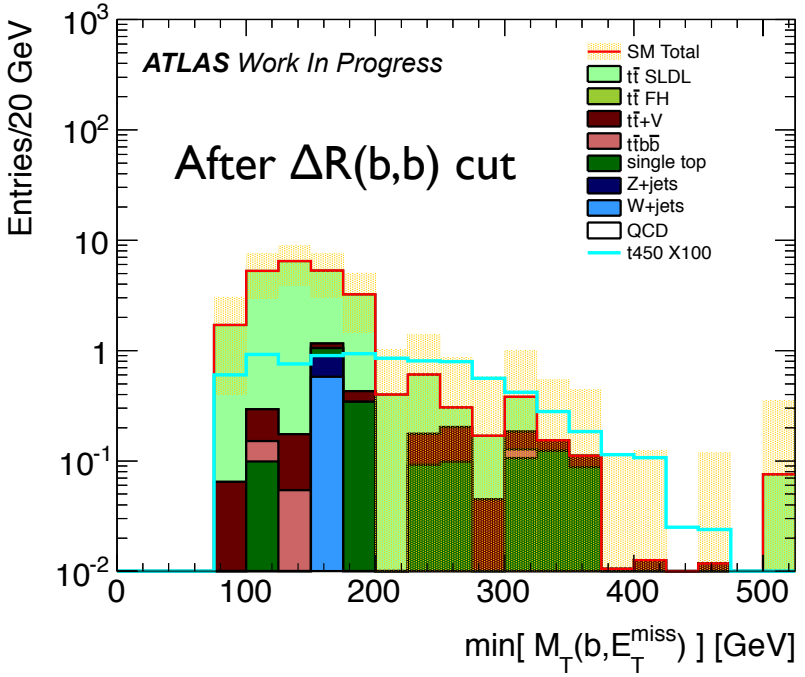
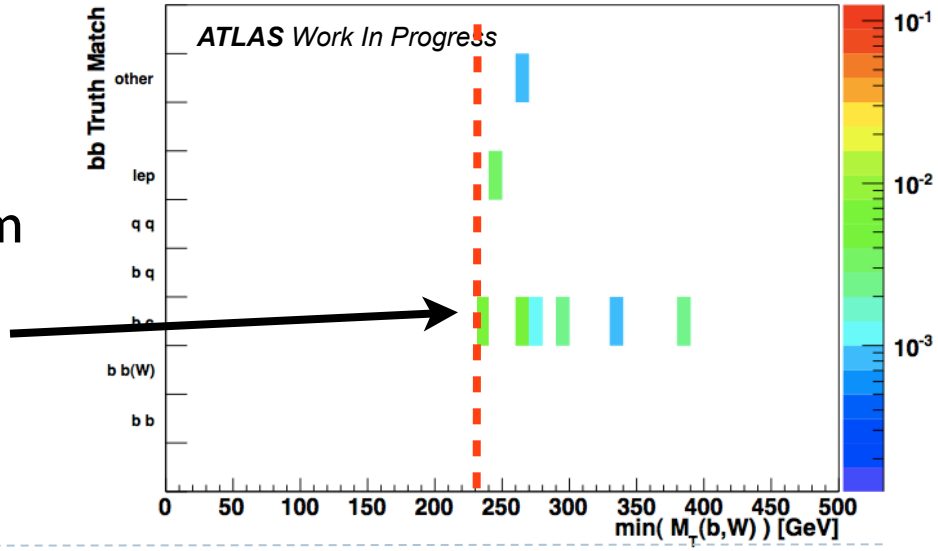
    → construct min[$m_T(b, E_T^{miss})$]
  - **Endpoint at ~m_{top}**
- Tail dominated by b-jets coming from heavy flavour W decay
  - Reduce by requiring b-jets are **well separated** ($\Delta R(b,b) > 1.0$)



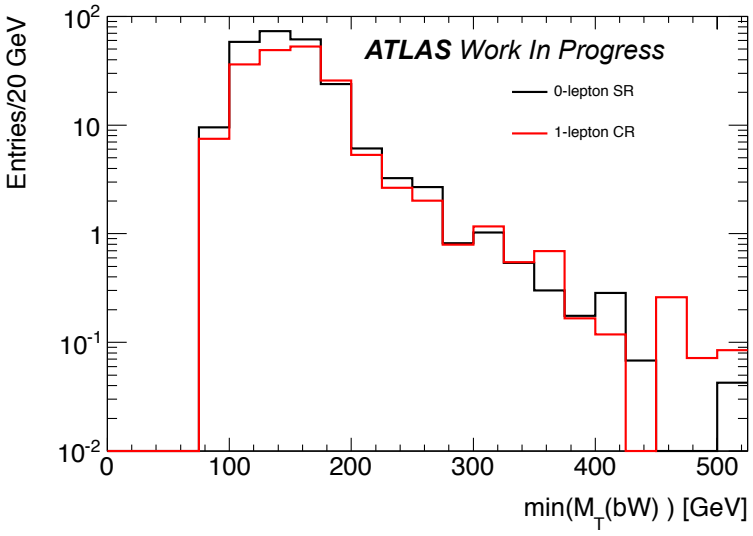


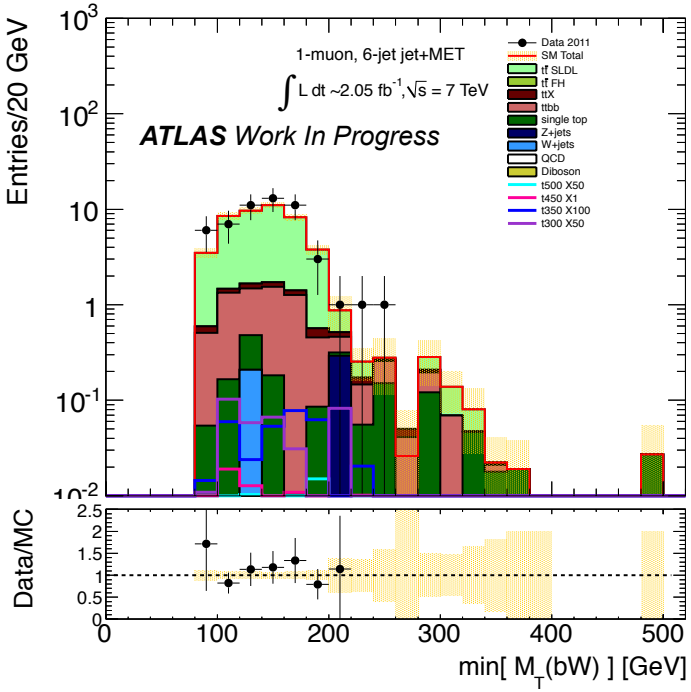
Leptonic top background estimation

- Semi-data driven technique using leptonic control region (CR).

$$N_{top,signal} = N_{t\bar{t},control} \frac{MC_{t\bar{t},signal}}{MC_{t\bar{t},control}}$$

- The ratio provides a **transfer factor** (TF) to extrapolate from CR to SR.
- TF derived from MC but validated in data by the CRs.
- Some **systematic uncertainties cancel** in the TF.

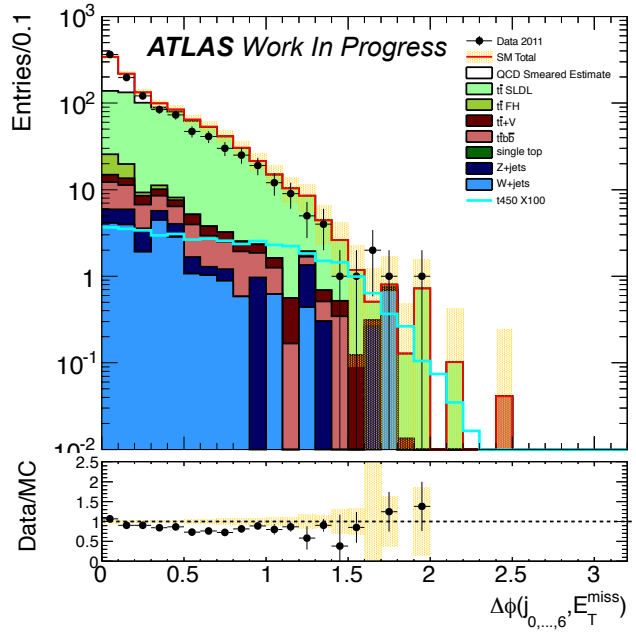


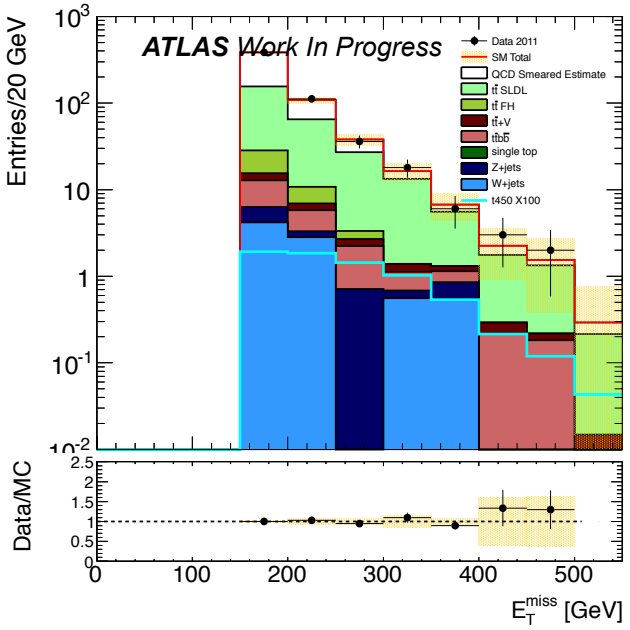


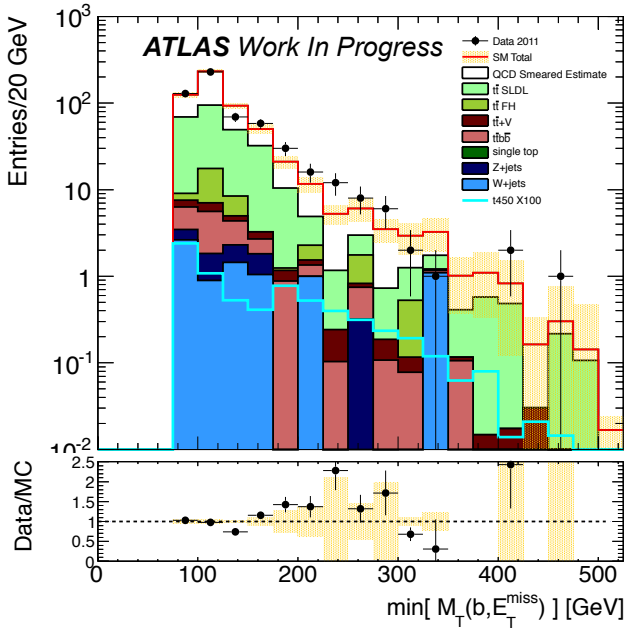
QCD background estimation

- QCD background is expected to be very small in the signal regions.
  - But Monte Carlo is not sufficient to estimate this contribution.

- We employ a data-driven estimation - **Jet Smearing** method
  - Smear jets in well reconstructed seed events to simulate detector mismeasurement and generate pseudo data for QCD estimation.
  - Normalise in reverse $\Delta\phi(6j, E_T^{miss})$ control region.







Optimisation & Sensitivity

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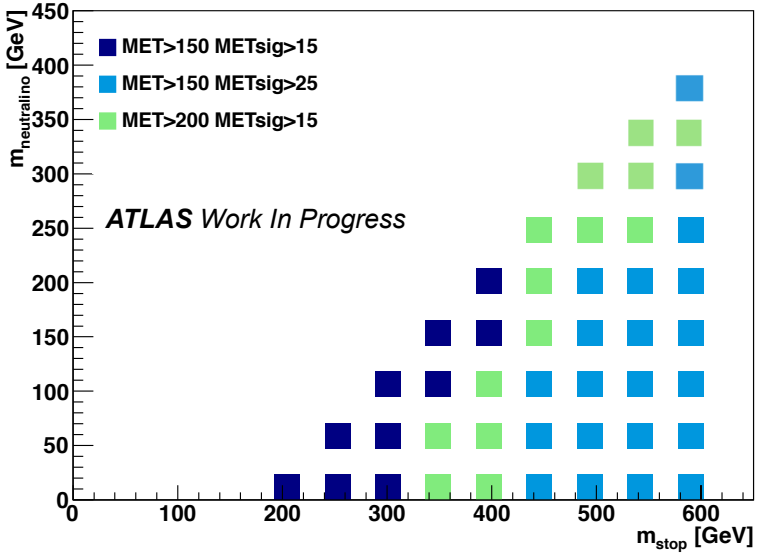
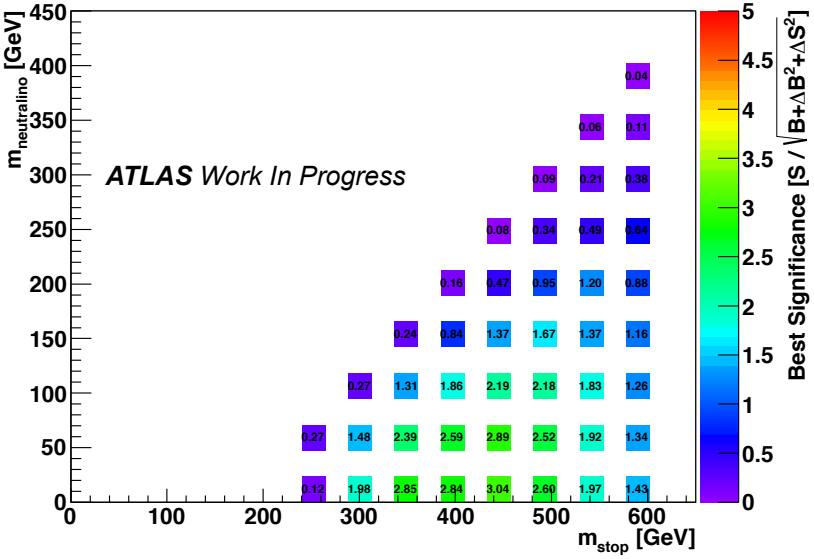
- Optimisation over the following variables performed
  - E_T^{miss}
  - E_T^{miss} significance (METsig) $= E_T^{miss}/0.5\sqrt{H_T}$
  - $\min[m_T(b, E_T^{miss})]$

- Based on Significance:

$$\frac{S}{\sqrt{B + \Delta B^2 + \Delta S^2}}$$

S = Signal
B = Background
$\Delta B, \Delta S$ = Systematic Uncertainty

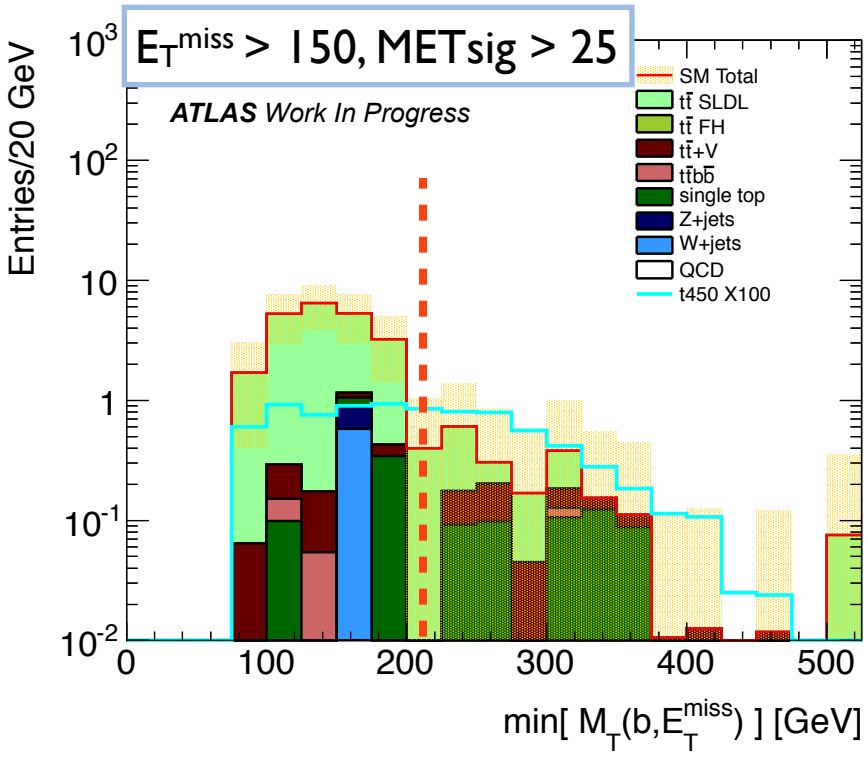


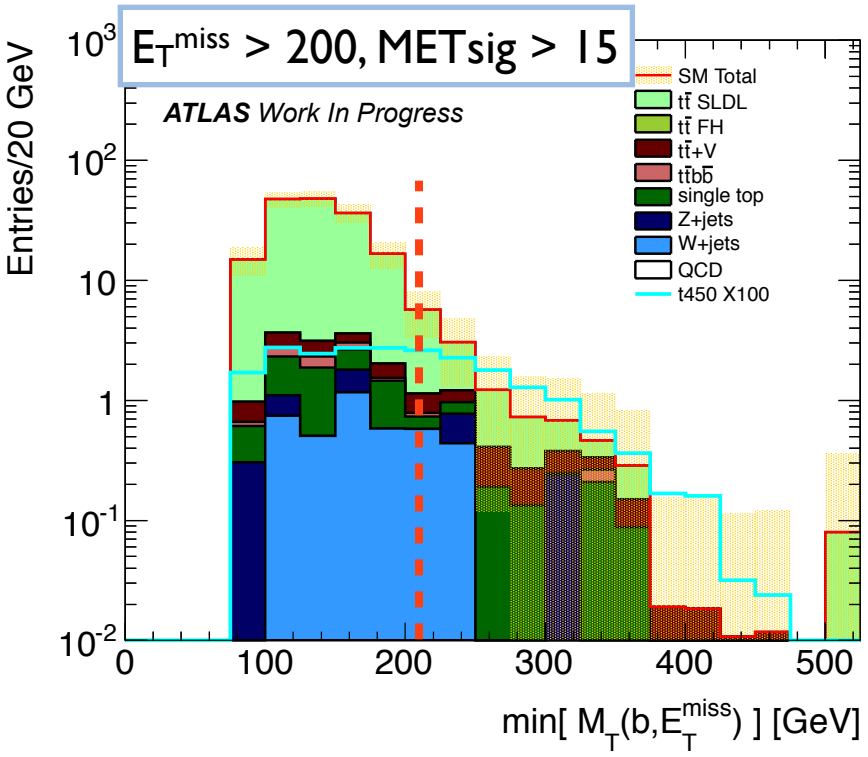


- Three signal regions obtained:
  - E_T^{miss} > **150** GeV, METsig > **15** $\sqrt{GeV}$
  - E_T^{miss} > **150** GeV, METsig > **25** $\sqrt{GeV}$
  - E_T^{miss} > **200** GeV, METsig > **15** $\sqrt{GeV}$
  - $\min[m_T(b, E_T^{miss})]$ > **210** GeV

Signal Region

- E_T^{miss} and METsig cuts enhance discriminating power of $\min[m_T(b, E_T^{miss})]$
- After all cuts the dominant backgrounds are
  - leptonic top pair
  - single top
  - top pair + X (X = W, Z, bb)





Summary

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- There is currently significant focus on stop searches at the LHC from a theoretical perspective.
  - Results have wider consequences for SUSY.
- Good sensitivity can be obtained with 2011 data in a very challenging search.
- Results expected soon!

Finally…

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Back-ups

ATLAS gluino mediated stop limits

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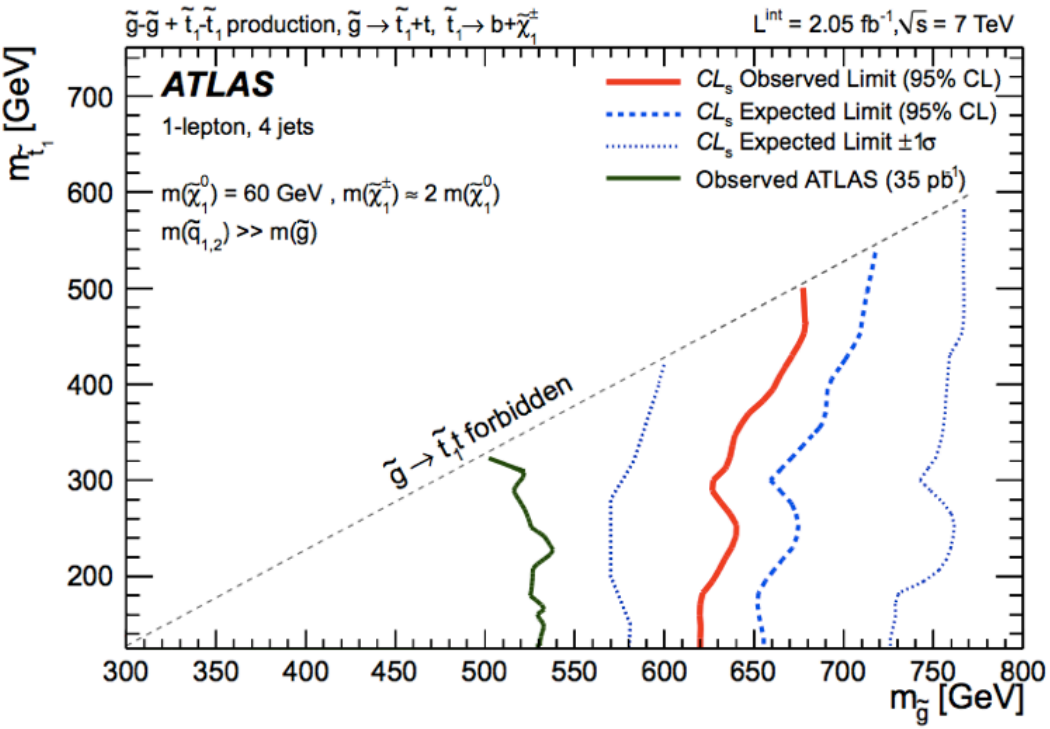

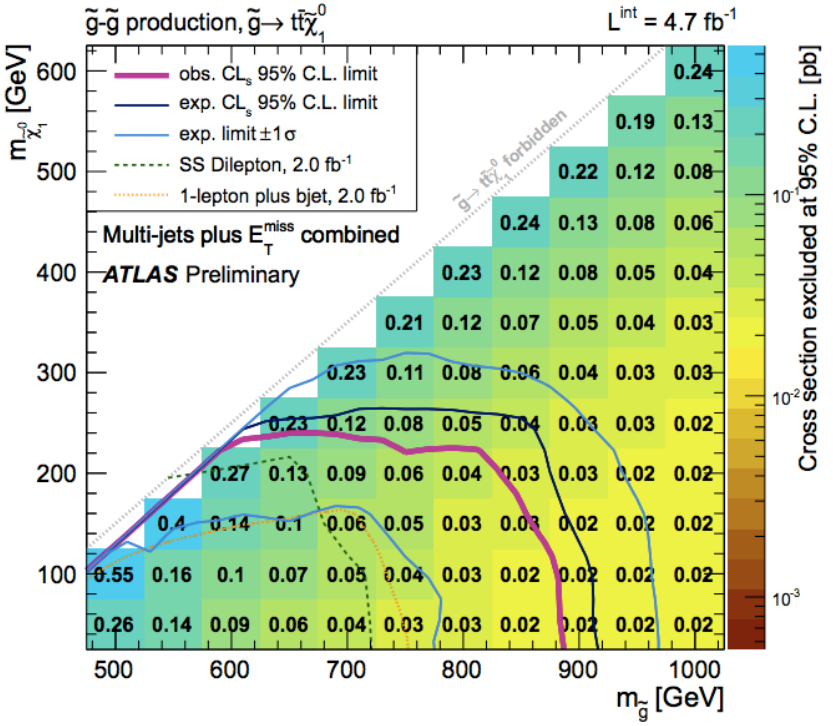

SR MC - Breakdown

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	$\min[m_T(b,MET)] > 210$			
	MET > 150 METsig > 25		MET > 200 METsig > 15	
	Scaled	Raw	Scaled	Raw
ttbar MC@NLO	**0.509167**	**1**	**3.83503**	**11**
ttbar Alpgen	**1.10031**	**13**	**5.96082**	**71**
ttbar fullHad	0	0	0	0
ttW	0.0854538	16	0.238711	45
ttZ	0.347074	82	0.905239	213
ttbb	0.0216077	1	0.130595	3
singletop	0.50644	5	0.887495	12
QCD	0	0	0.000891234	1
Zjets	0	0	0.333302	1
Zbb	0	0	0.241242	1
Wjets	0	0	0.578164	1
Wbb	0	0	0.439396	1
Wcc	0	0	0	0

SR MC-only Systematics

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- The dominant systematic uncertainties are the JES and b-tagging

	Nominal		JES [%]	b [%]	c [%]	light [%]
MET > 150 METsig > 15	9.405	UP	26.28	6.93	2.65	4.65
		DOWN	-22.25	-8.23	-2.53	-4.73
MET > 150 METsig > 25	1.47	UP	2.73	12.52	-1.62	10.96
		DOWN	-12.76	-11.97	1.71	-11.2
MET > 200 METsig > 15	7.59	UP	21.94	7.01	3.4	3.72
		DOWN	-26.49	-8.48	-3.24	-3.8

Jet Smearing method

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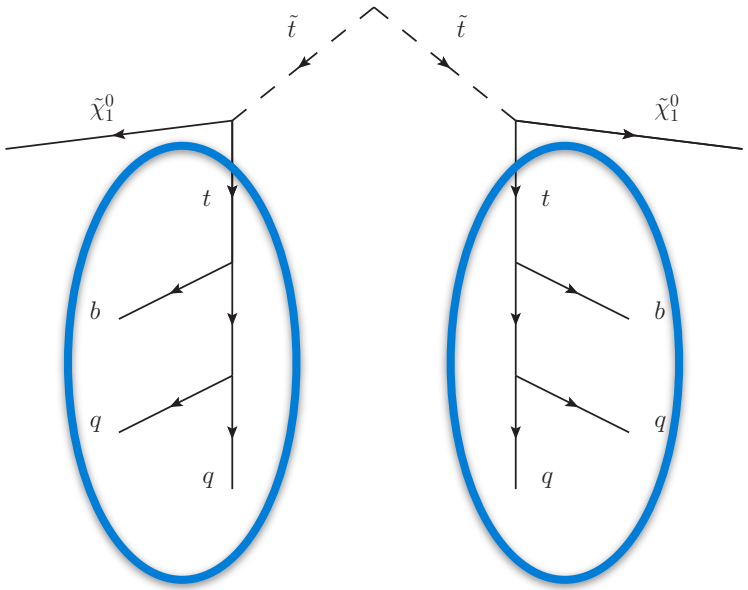
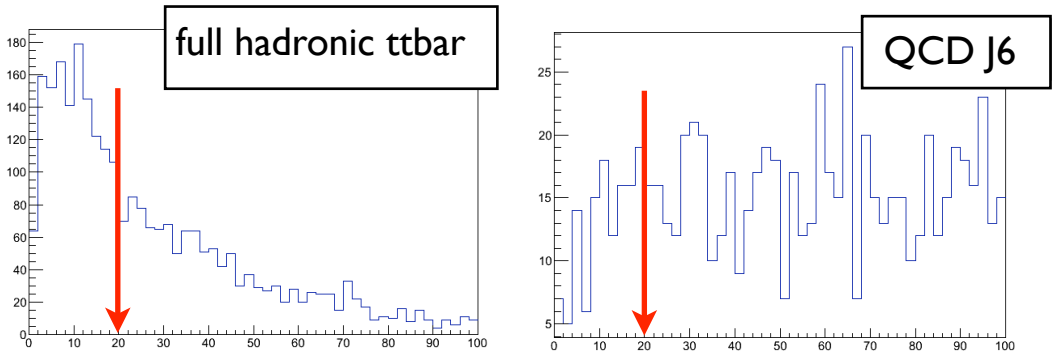
- Select low MET significance seed events with same no. of jets
- Construct smearing function using a sample of simulated jet events.
- Smear the momentum of jets in seed events selected in (1) using the smearing function defined in (2).
  - Repeat Nsmear=500 times per seed event to randomly generate configurations where MET comes from multiple fluctuating jets.
- Once a large sample of pseudo-events is generated, these are passed through the same analysis cuts as the data and the non-QCD MC to give the QCD distribution of any variable of interest. Distributions are normalised within a QCD enriched control region:
- Reverse the $\Delta\Phi$ cut
- Drop the MET/$\sqrt{\Sigma ET}$ and $\Delta R(bb)$ cuts
- Then subtracting the non-QCD component using the Monte Carlo.

Top reconstruction

- Combine **2 b-jets** and **4 other jets** - Attempt to **reconstruct 2 tops**



- Use χ^2 **kinematic fit** to determine "best combination" and reject backgrounds



- Contransverse mass of reconstructed top pairs - $M_{CT}(t,t)$

$$M_{CT}{}^2 = (E_{T_1} + E_{T_2})^2 - (\mathbf{p_{T_1}} - \mathbf{p_{T_2}})^2$$

  - $M_{CT}(t,t)$ will be **small for SM ttbar** reconstructed top pairs (if well reconstructed they should be back-to-back)
  - But **large with an endpoint for signal**