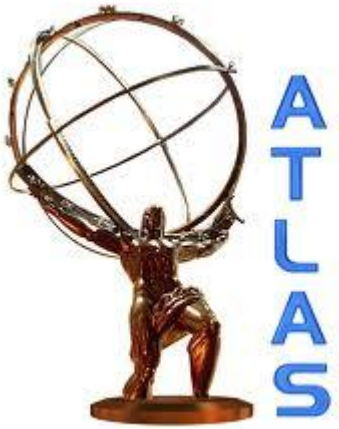
Sbottom Pair Production – What to do with 4.71fb-1?

UNIVERSITY OF LIVERPOOL



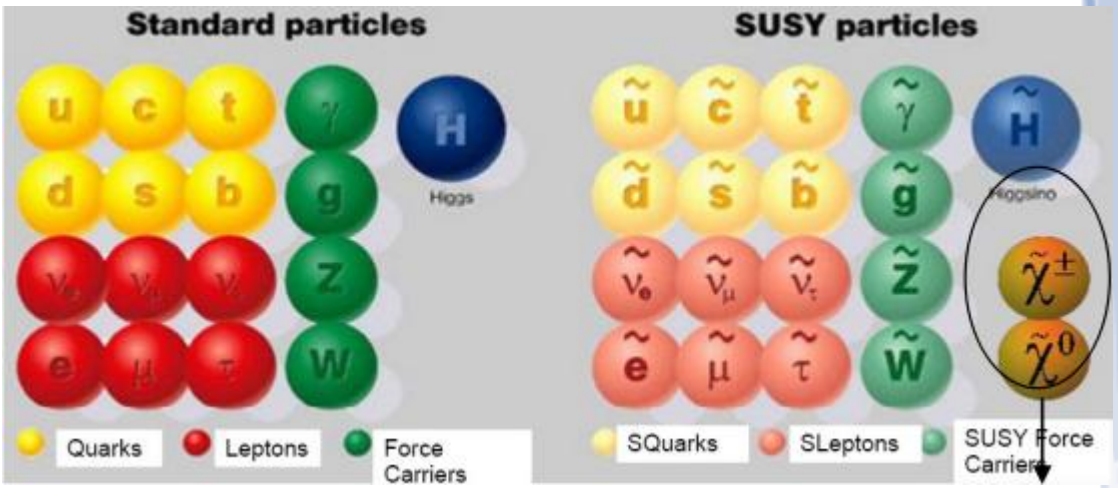
Sara Mahmoud

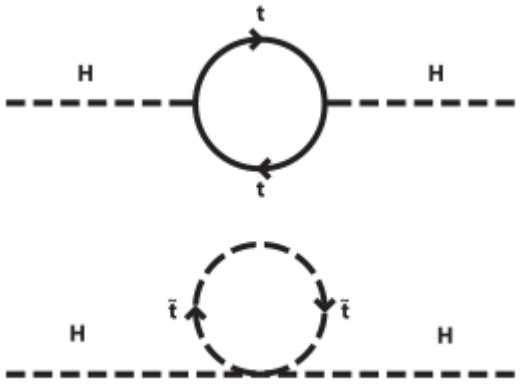
02/04/12

IOP meeting

SUperSYmmetry

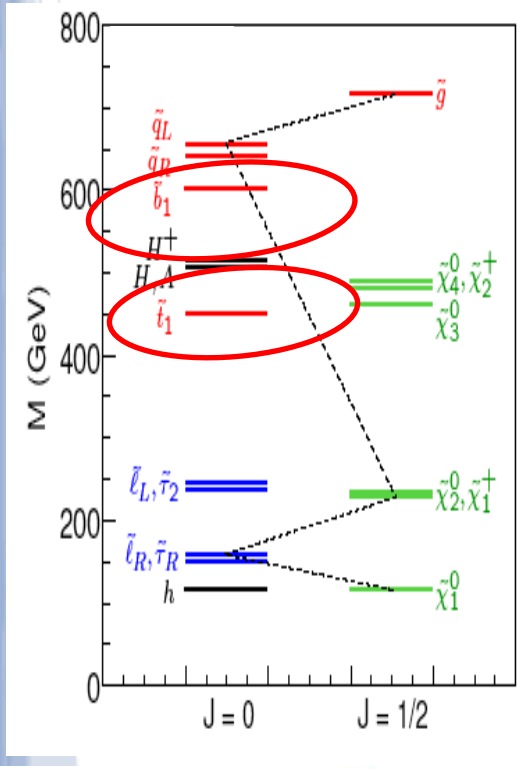
- Spin based theory relating fermions and bosons
  - All Standard Model bosons have a fermionic superpartner and vice verca
- Can help solve known theoretical issues and gaps in the Standard Model

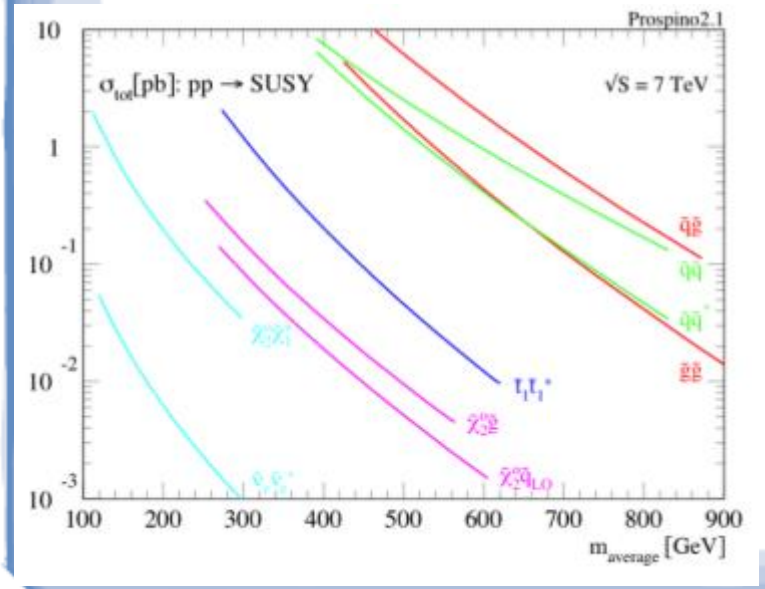




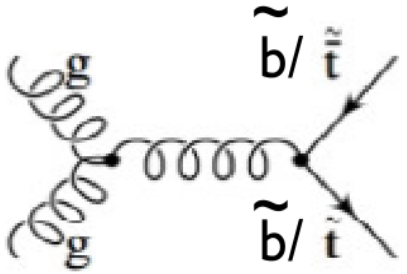
- Mass hierarchy problem
  - Higgs mass corrections proportional to scale of new physics, taken to be the Planck Mass
  - SUSY introduces scalars that add a positive correction to the Higgs mass that cancels out the negative corrections from Standard Model fermions
- Dark Matter
  - 23% of matter in the Universe cold dark matter
  - Lightest Supersymmetric Particle (LSP) could be a candidate

Third generation squarks





- Third generation squarks might be lighter than 1st, 2nd generation squarks, possibly high cross sections:
  - More dedicated search natural extension to inclusive searches in terms of sensitivity
  - Especially relevant considering the approaching TeV limits on light squarks and the gluino
- Consider sbottom pair production:

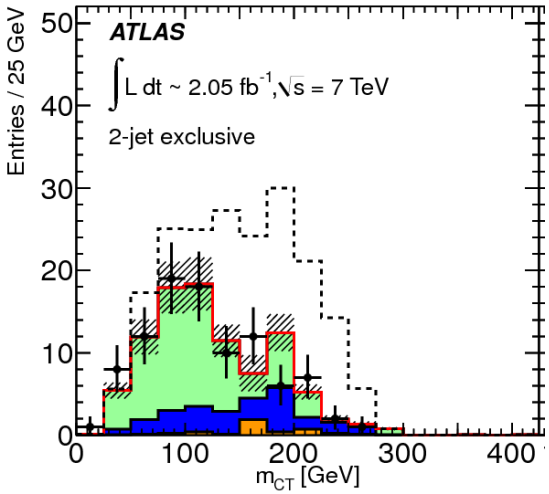


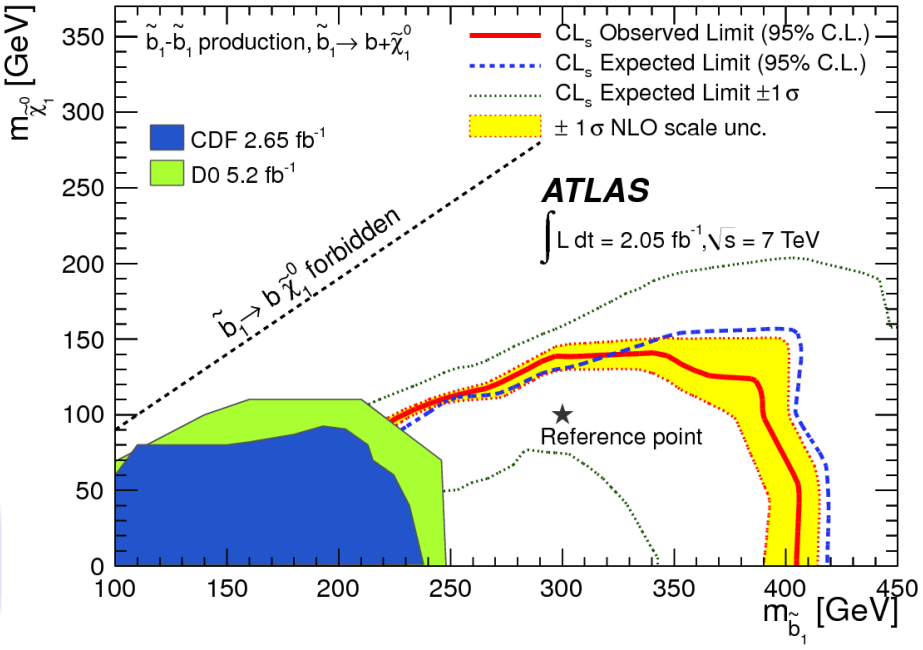
- Phenomenology depends on the SUSY particle mass hierarchy

Sbottom Pair Production with 4.71 fb-1

m_{CT} GeV	top, W+hf TF-e (MC)	Z+hf TF-e (MC)	Others MC+DD	Total SM	Data
0	67 ± 10 (60 ± 23)	23 ± 8 (16 ± 9)	3.6 ± 1.5	94 ± 16 (80 ± 35)	96
100	36 ± 10 (34 ± 16)	23 ± 9 (12 ± 7)	3.1 ± 1.6	62 ± 13 (49 ± 25)	56
150	12 ± 5 (13 ± 8)	12 ± 6 (8.3 ± 4.7)	2.7 ± 0.9	27 ± 8 (24 ± 13)	28
200	3.2 ± 1.6 (4.1 ± 3.4)	3.9 ± 3.2 (2.8 ± 1.5)	1.0 ± 0.9	8.1 ± 3.5 (8.0 ± 4.9)	10

Table and plots taken from *Search for scalar bottom pair production with the ATLAS detector in pp Collisions at sqrt{s} = 7 TeV*, ATLAS Collaboration, Dec 2011 http://arxiv.org/abs/1112.3832



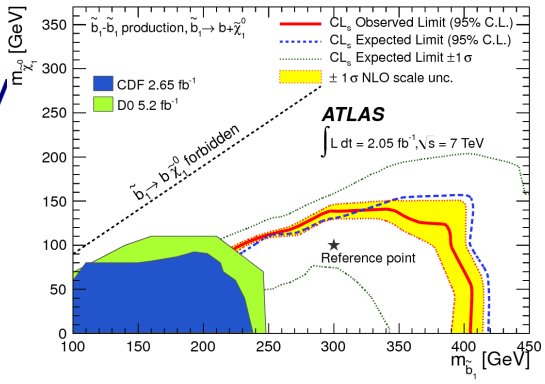


- Three main avenues to extend limit
  - Can extend in sbottom mass for low neutralino masses with an additional high mct region
  - Reduce uncertainties; boson+jets limited by statistics in the control region
  - Use lower pt jets to acess the lower Δm region
    - This might also be useful to reduce the uncertainties due to CR used for bkg estimate using TF techniques (see A.Tua slides)

Extending in Sbottom Mass

- Can use previous analysis selection
  - Two jet exclusive selection: (130,50, veto 50) GeV
  - MET > 130 GeV
  - Require two leading jets be b-tagged
- Discriminating variable is Mct

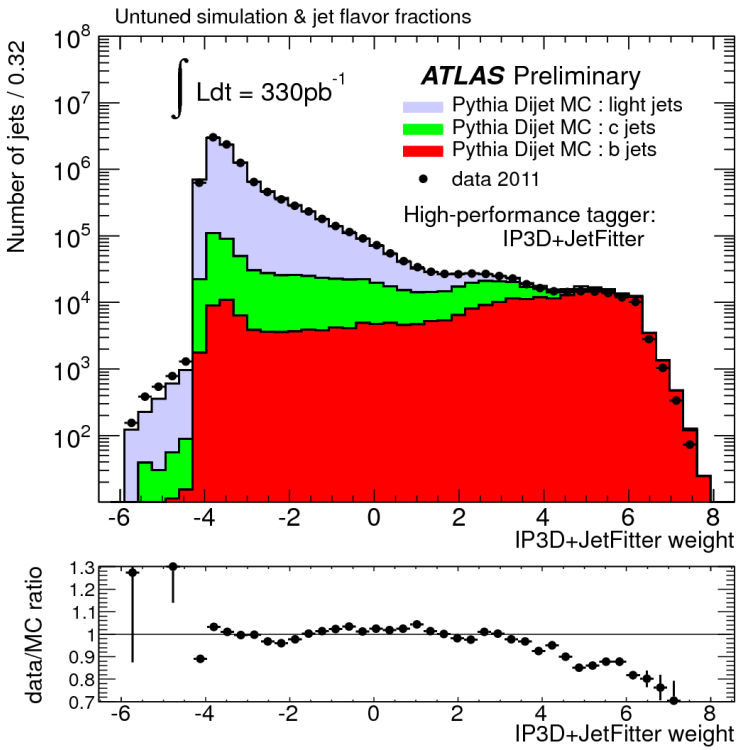
$$m_{CT}^2(v_1,v_2) = [E_T(v_1)+E_T(v_2)]^2 - [\mathbf{p_T}(v_1)-\mathbf{p_T}(v_2)]^2$$



(600,1)

Dan Tovey, http://arxiv.org/abs/0910.0174

- End point = Δ(m(sb)^2-m(neut)^2)/m(sb); most powerful for Δm >> 200 GeV



- Check statistics for some signal points and semi-leptonic top for possible new signal regions
- Look at taking advantage of new and improved MV1 tagger
  - Looked at numbers/plots for old COMBNN 60% efficiency point, MV1 60% efficiency point and MV1 70% efficiency point

Commissioning of the ATLAS high-performance b-tagging algorithms in the 7 TeV collision data, ATLAS-CONF-2011-102, Atlas Collaboration

Tagger Compare – (130,50) Jet Selection

- Check advantage from moving from COMBNN to recommended MV1 60% efficiency point
  - Increase in acceptance for both signal and top
  - Main advantage comes from lowered systematic uncertainties (at least 20%)

COMBNN

***ATLAS** Work in Progress*

Sample	Mct > 0	Mct > 100	Mct > 150	Mct > 200	Mct > 250	Mct > 300
Sb 400 n 1	79.38	74.54	66.87	47.50	31.46	13.51
Sb 600 n 100	4.35	4.18	3.91	3.45	2.92	2.17
Top	143.54	61.28	14.91	4.97	2.76	1.10
Significance (600,1)	0.36	0.53	1.01	1.55	1.76	2.07

MV1 60%

***ATLAS** Work in Progress*

Sample	Mct > 0	Mct > 100	Mct > 150	Mct > 200	Mct > 250	Mct > 300
Sb 400 n 1	85.84	80.09	71.51	51.04	33.59	14.93
Sb 600 n 100	4.76	4.59	4.33	3.83	3.34	2.48
Top	152.38	65.15	17.67	6.07	3.31	1.66
Significance (600,1)	0.39	0.57	1.03	1.55	1.84	1.92

Tagger Compare – (130,50) Jet Selection (2)

- Can also try a looser MV1 point with 70% efficiency
  - Some gain in significance for Mct > 300 GeV region
  - Higher efficiency -> lower purity
    - Need to check for boson + jets background as wrong combinatorics can distort mct distributions

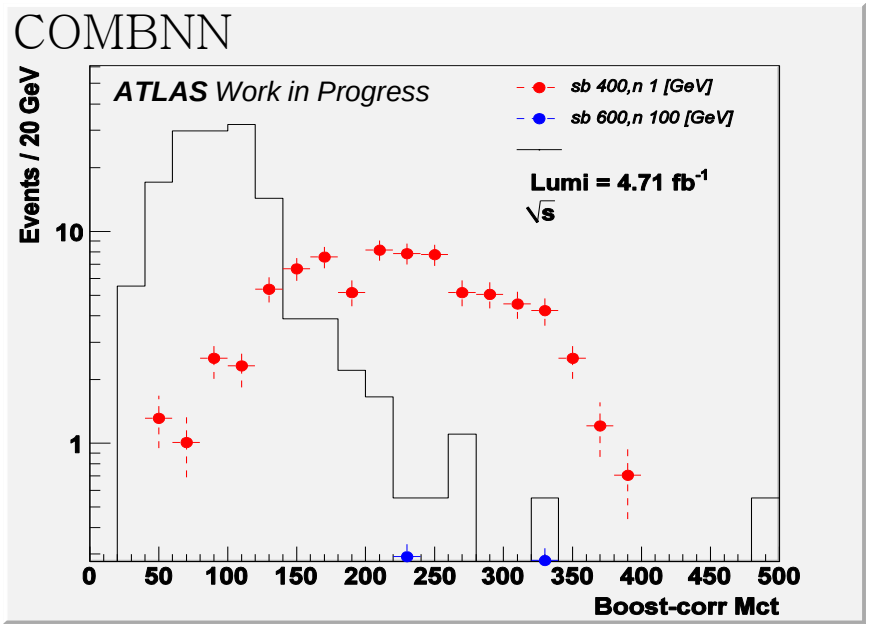
MV1 70%

***ATLAS** Work in Progress*

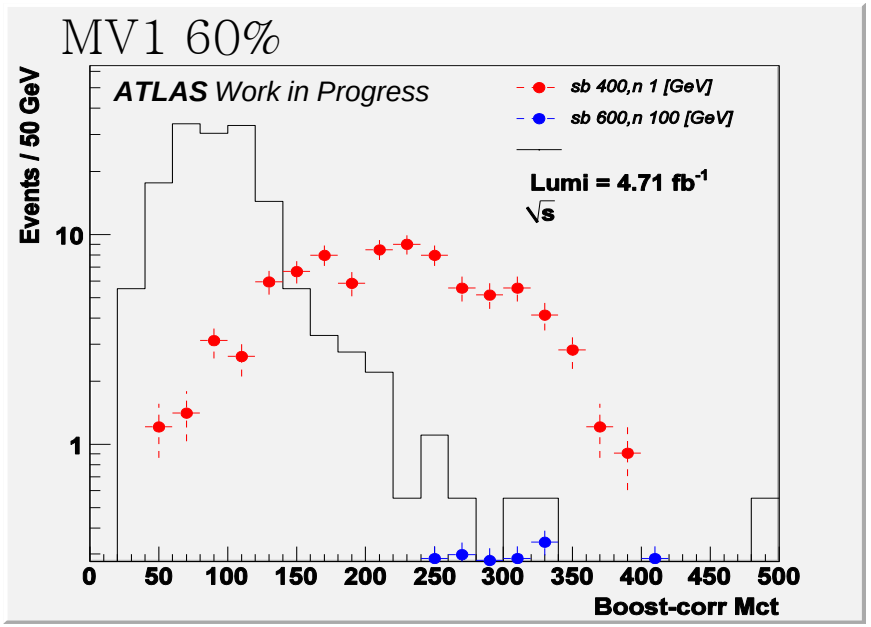
Sample	Mct > 0	Mct > 100	Mct > 150	Mct > 200	Mct > 250	Mct > 300
Sb 400 n 1	122.65	114.99	102.58	74.03	50.53	22.39
Sb 600 n 100	7.31	7.01	6.63	5.81	5.04	3.83
Top	228.56	104.34	35.89	8.83	3.86	1.66
Significance	0.48	0.69	1.11	1.96	2.57	2.97

Mct Tagger Compare – (130,50)

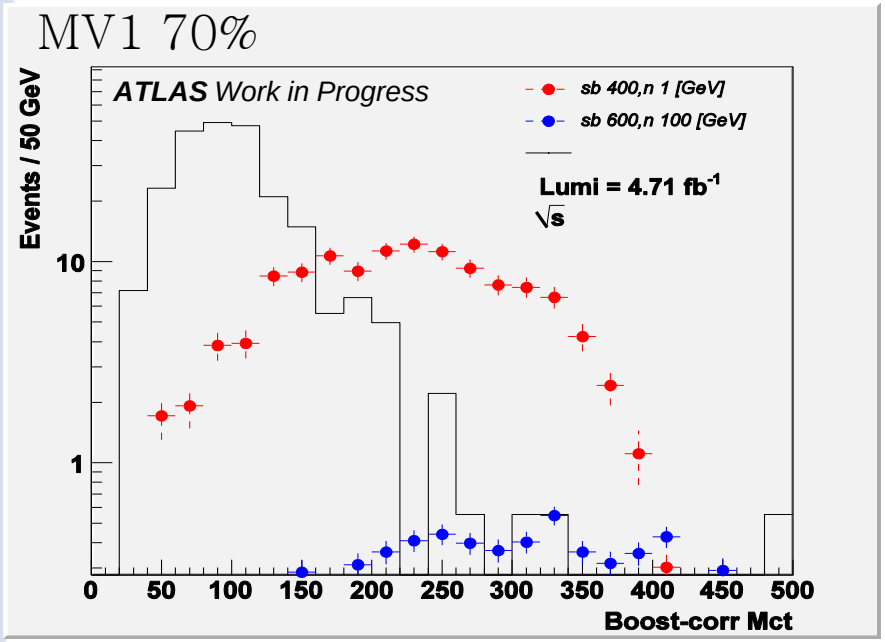
COMBNN

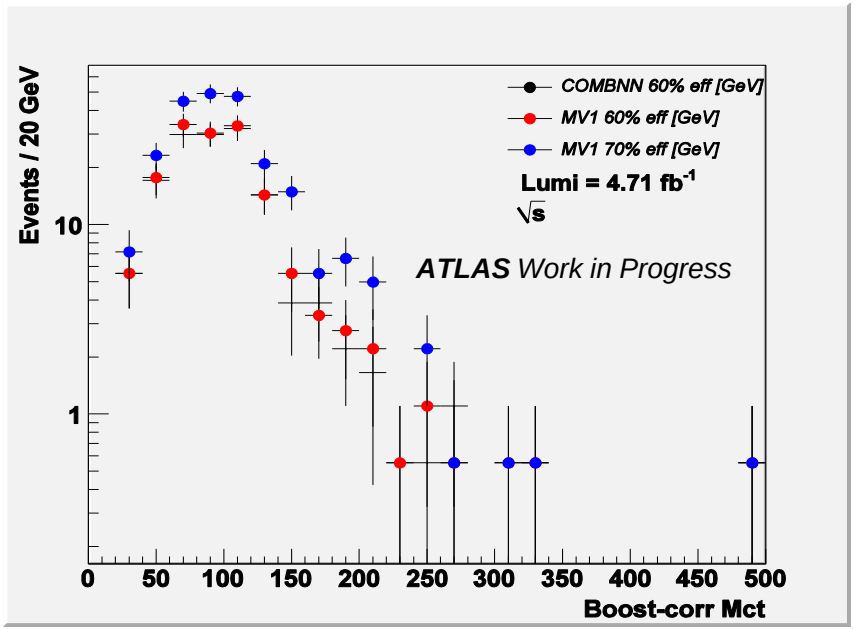


MV1 60%

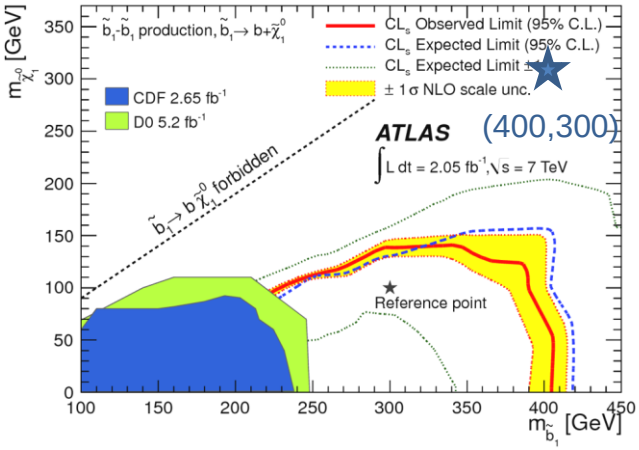


MV1 70%





Sbottom Pair Production – Compressed Scenarios

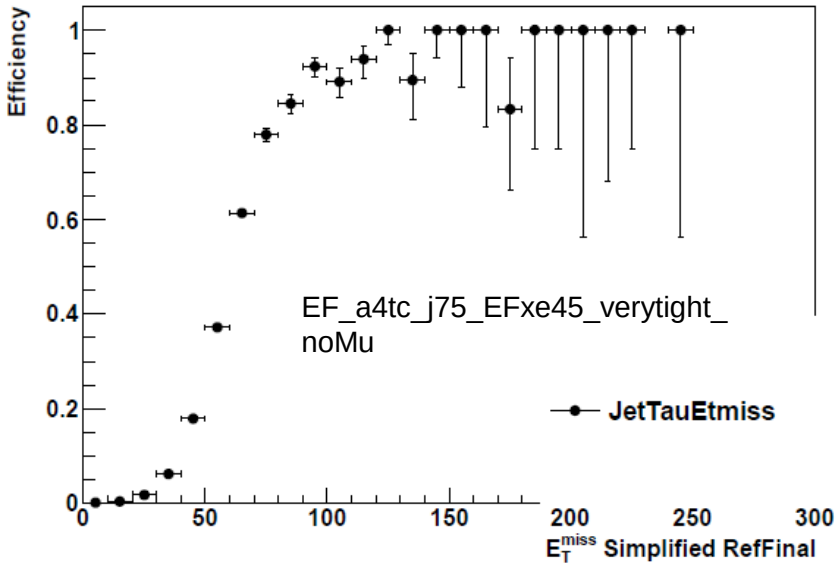


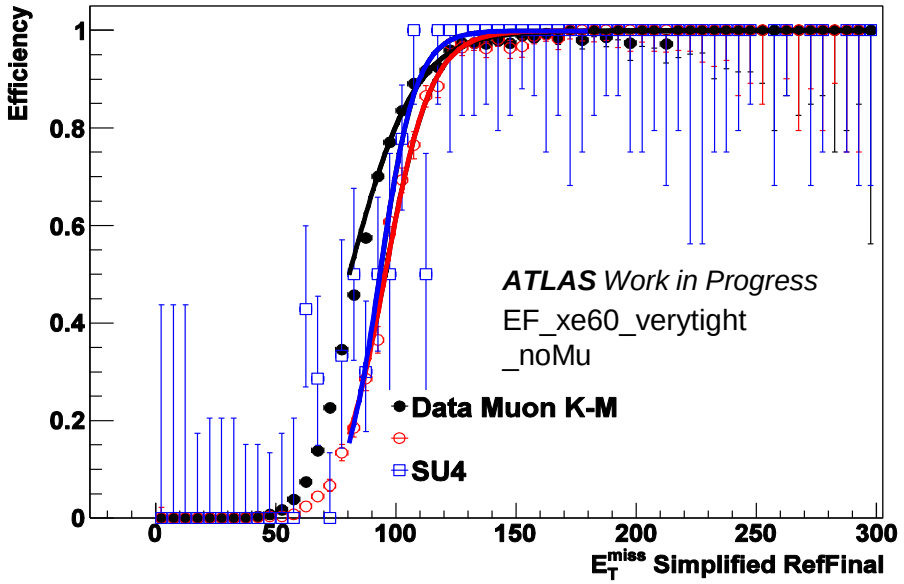
- Use of new tagger and higher mct signal region still do not help for more compressed scenarios
- Old cuts kill signal acceptance – e.g m(sb) = 400 GeV, m(n) = 300GeV
  - Need softer cuts on MET and jet pt

Cut	Trigger	Cleaning cuts (jet cleaning, Lar hole veto, P.V., cosmic muon veto)	Electron veto	Muon veto	Two jet exclusive (130, 50, veto pt>50)	MET > 130	MET/Meff > 0.25	Δφ(MET, j1 or j2) > 0.4	1 b-tag (MV1 60% eff)	2 leading b-tagged
20000	8939	8920	8825	8781	1820	1312	1286	1145	878	190

Scaled is 9.58 events

Compressed Scenarios (2)

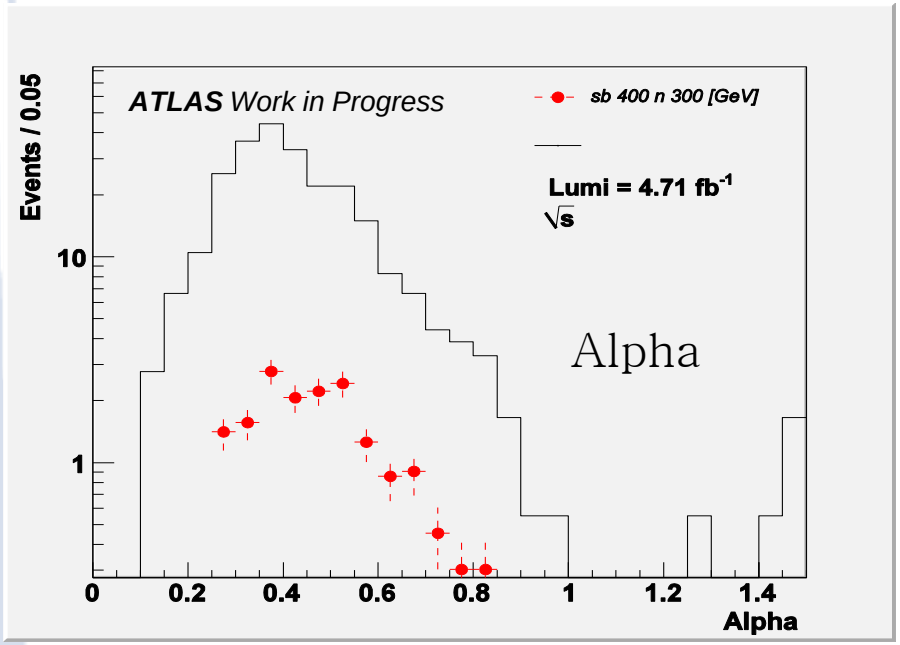


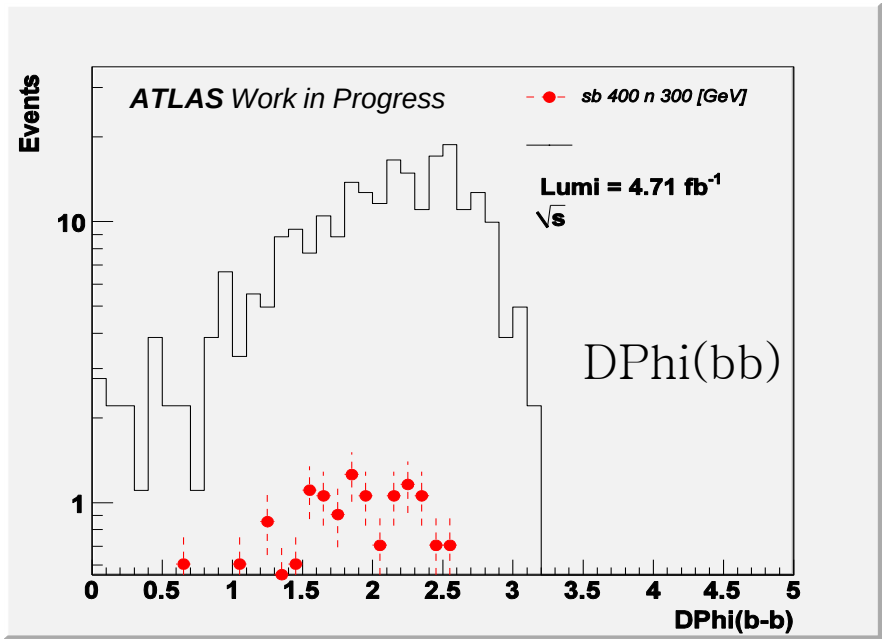


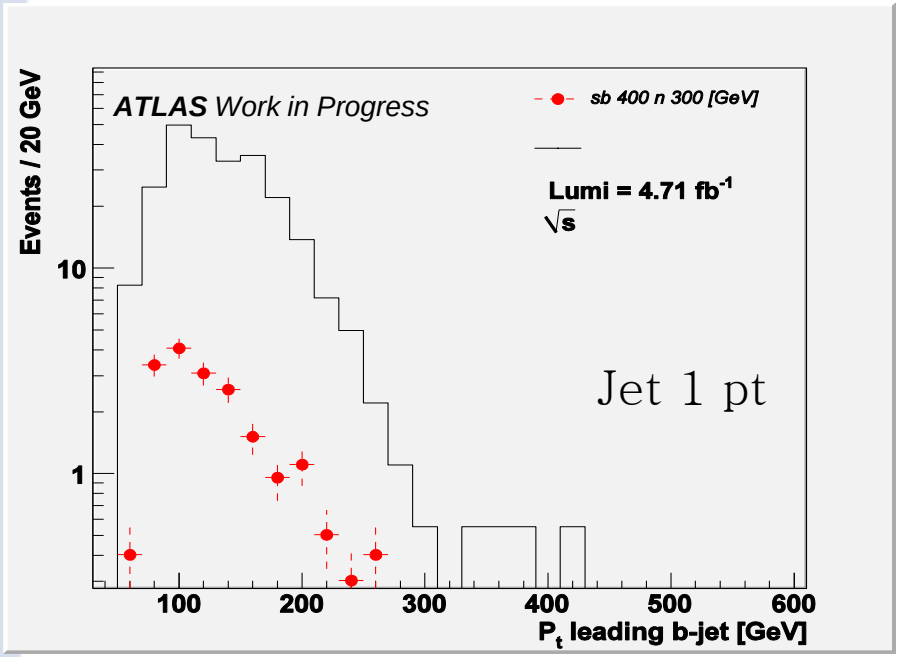
MV1 60%	Sb400 n300	Top	S/Sqrt(B)
Met > 130, jet (130,50)	9.58	152.4	0.8
Met > 120, jet (60,60)	18.0	219.7	1.2

- Two trigger options – jet+MET trigger (EF_aftc_j75_EFxe55_noMu) or MET only trigger (EF_xe60_verytight_noMu
- MET only trigger allows for the reduction of jet pt cuts
- Some gains in terms of significance
- Mct not useful for small mass splittings as endpoint proportional to mass splitting

Compressed Scenarios (3)



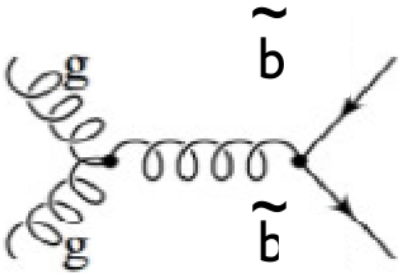


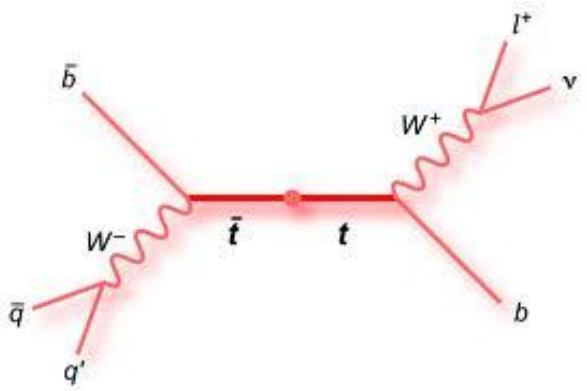


- Try to find new discriminating variables, possibly could help with a multi-variant technique, e.g.
  - alpha= Pt(2nd jet)/Mass1st jet + 2nd jet)
  - Dphi(b,b)
- Need to increase acceptance and decrease background
- Stick with 2-jet exclusive analysis for now

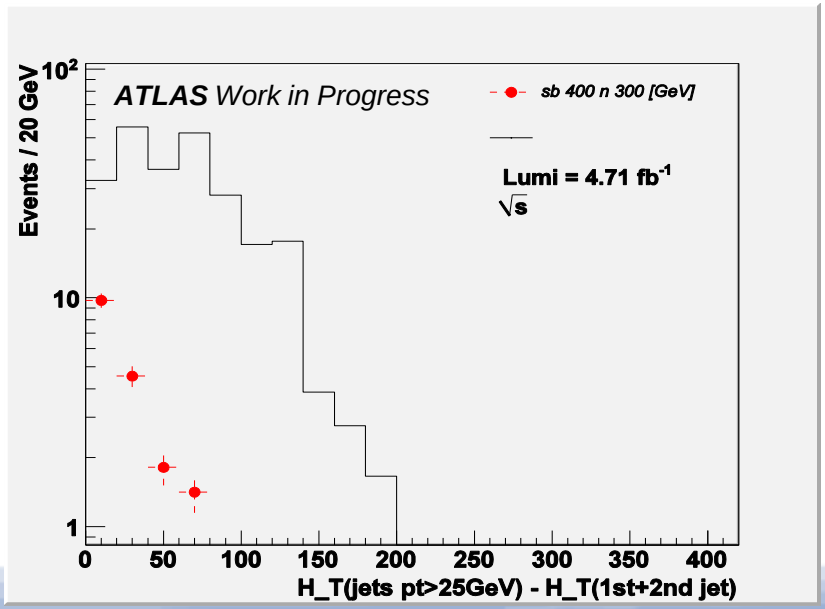
Compressed Scenarios – Background reduction

- Low signal acceptance for compressed, 'quiet' scenarios, as expected
- Possible variable to consider is
  - Sum(pt all jets with pt>25GeV) – Sum(pt two leading jets)





- For an exclusive selection, should be lower for signal and higher for semi-leptonic top background
  - Working on optimising upper cut on this variable



Compressed Scenarios – Signal Acceptance

- Check which cut is killing acceptance

Cut	Trigger	Cleaning cuts (jet cleaning, Lar hole veto, P.V., cosmic muon veto)	Electron veto	Muon veto	Two jet exclusive (60, 60, veto pt>50)	MET > 120	MET/Meff > 0.25	Δφ(MET, j1 or j2) > 0.4	1 b-tag (MV1 60% eff)	2 leading b-tagged
20000	8939	8868	8825	8781	2751	1976	1950	1818	1429	356

- Can lower MET cut
  - Need to understand and parmetrise turn-on curve further
- Two b-tag also reduces acceptance
  - Can possibly reduce number of b-tags
  - Need to work hard to estimate background in this case

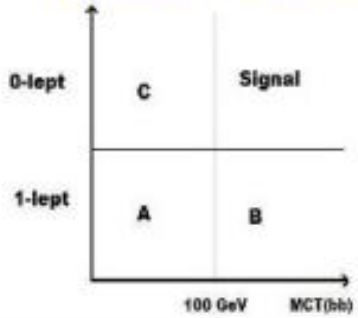
Conclusions and Outlook

- Extension for high sbottom mass low neutralino mass more straight forward
  - Can repeat previous analysis (MET>130 GeV, jets (130,50)GeV) and extend up to ~600GeV in sbottom mass for neutralino masses < 100 GeV
- More compressed scenarios contain much softer jets and pose much more of a challenge
  - Ongoing optimisation and study

BACK UP

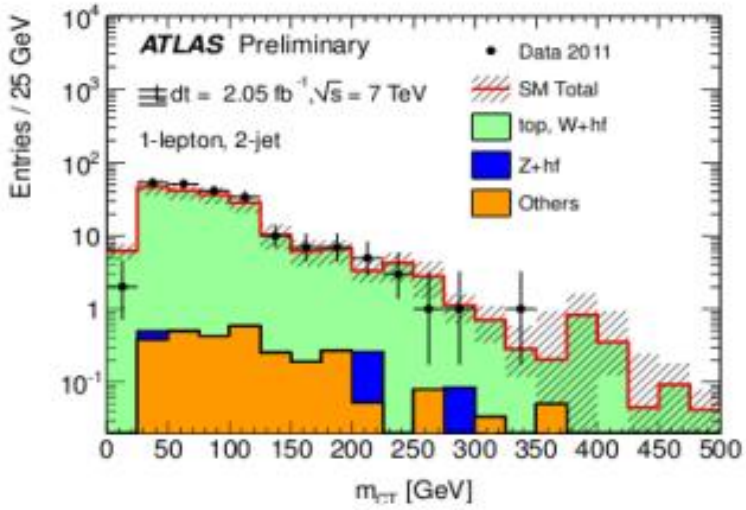
Sbottom Pair Background Estimation

- QCD estimated via adapted data-driven method used in 3-jet analysis
- Boson+jets +top estimated via semi data-driven method that utilises 1 lepton CR. Transfer function between signal and control region measure in MC

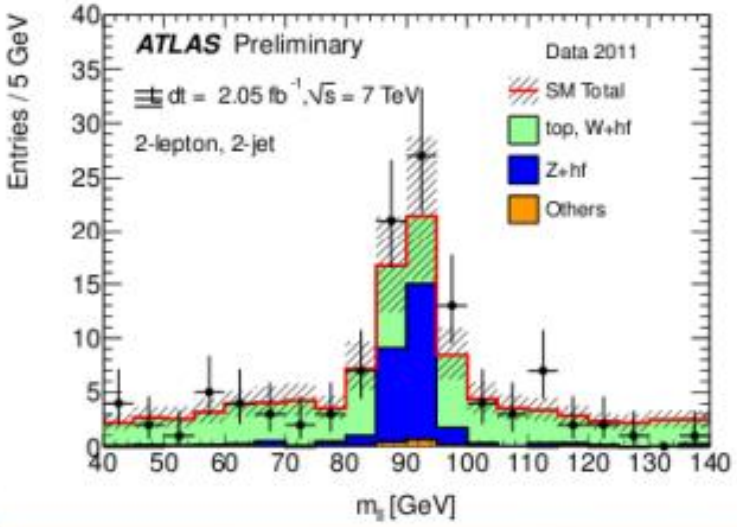


$$N_D^{top+(W+HF)} = \left(\frac{N_D}{N_B}\right)_{MC}^{top+(W+HF)} \times [N_B^{data} - N_B^{Z,MC} - N_B^{others,MC} - N_B^{QCD}]$$

Mct in 1 lepton control regions A and B



- Znunu+jets estimated via di-lepton CR with 81 < M(l,l) < 101 GeV
- Top contribution to Znunu+jets in this CR estimated using side bands



Invariant mass of di-leptons after requiring 1 b-tag and no Mct cut