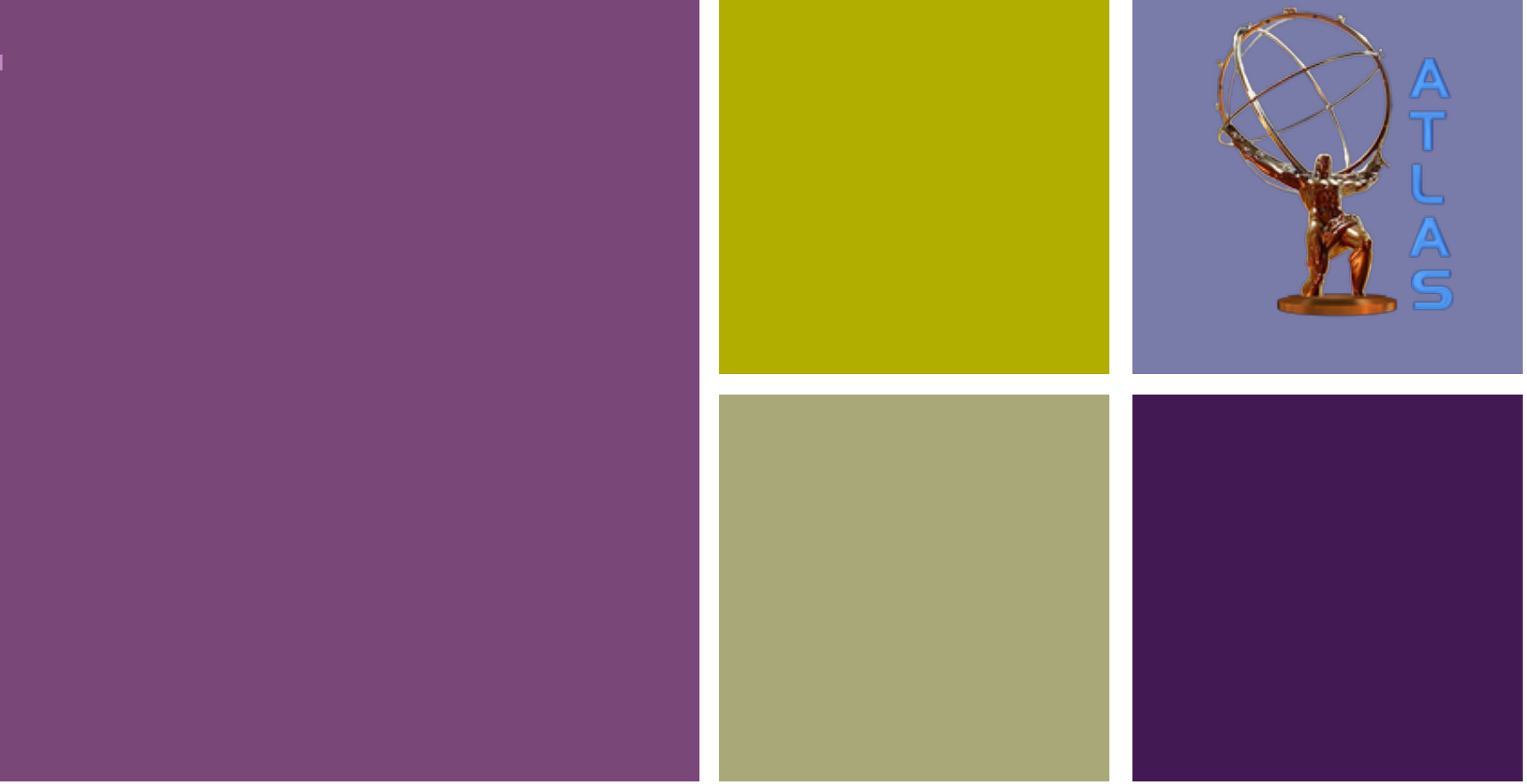


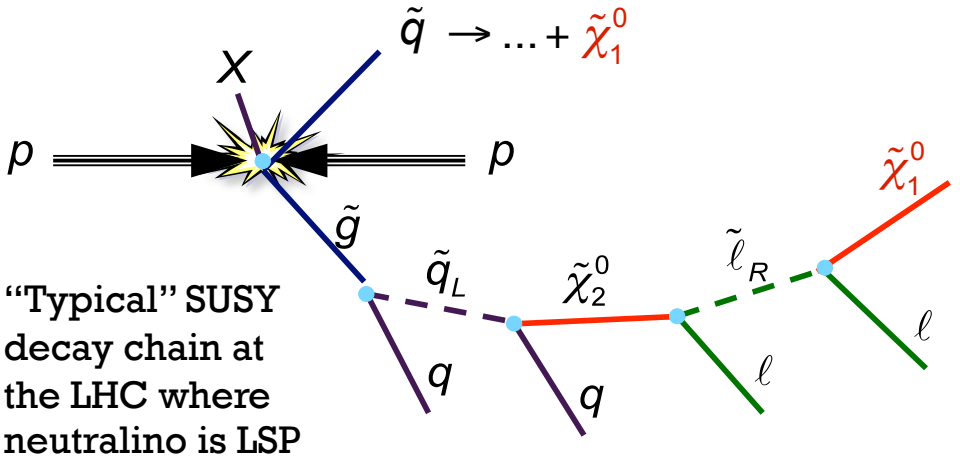
UNIVERSITY OF LIVERPOOL

Search for supersymmetry in lepton/photon(s)/b-jets and missing transverse momentum final states with the ATLAS detector

Helen Hayward

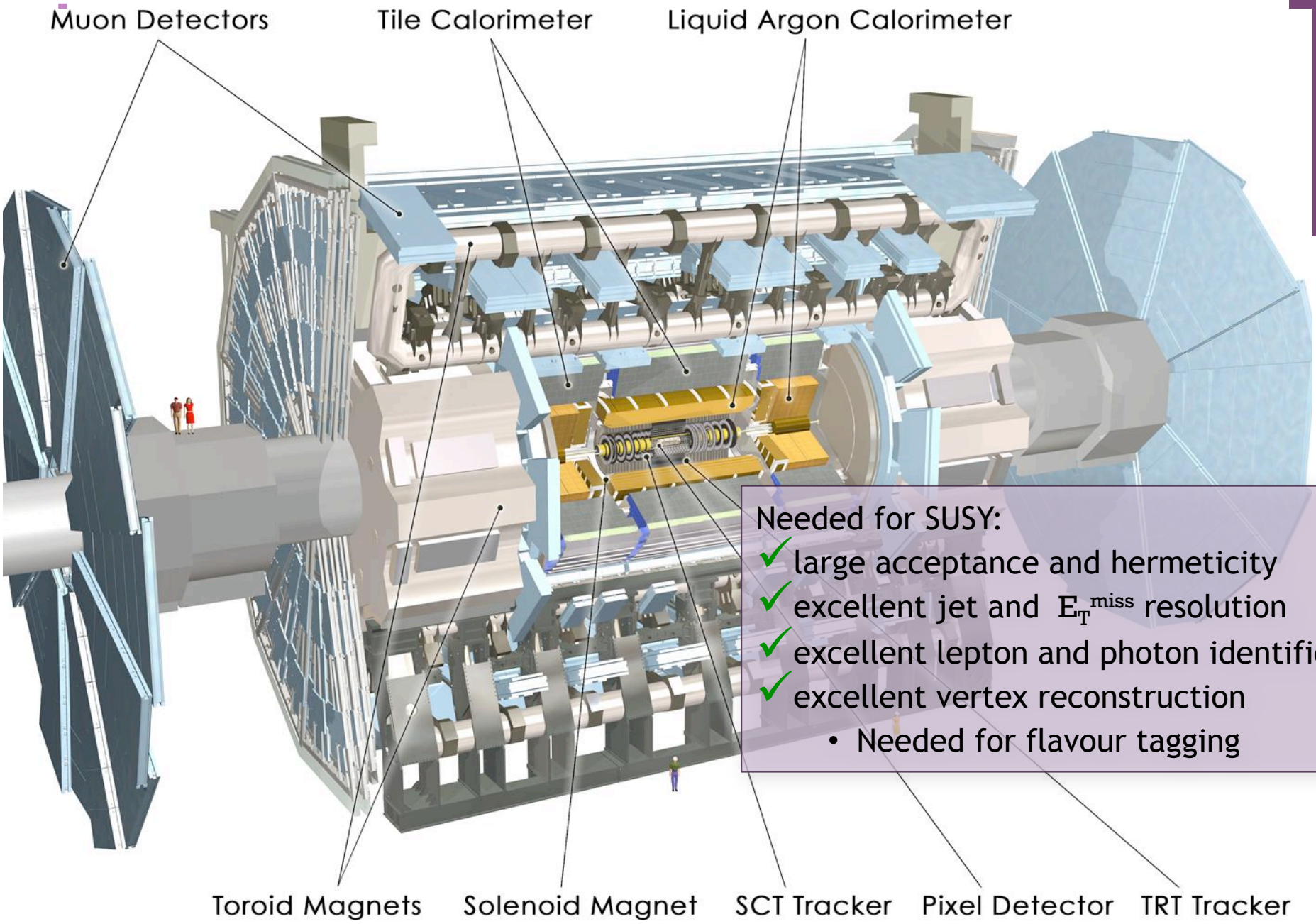
Characteristic SUSY Decay Cascades

- Assume R-parity requires,
  - Pair production of SUSY particles
  - stable lightest SUSY particle (LSP):
    - if neutral, candidate for Dark Matter
    - typical LSP:
      - lightest neutralino (mSUGRA-like/CMSSM models)
      - gravitino (gauge-mediated models)



"Typical" SUSY decay chain at the LHC where neutralino is LSP

- LSP Escapes detection
  - Missing Transverse Momentum (E_T^{miss})
- SUSY cascades produce high-pT jets + leptons + E_T^{miss}
  - If lightest squark is stop or sbottom
    - -> bjets
  - If NLSP is neutralino -> photon
    - (LSP is gravitino)



Needed for SUSY:

- ✓ large acceptance and hermeticity
- ✓ excellent jet and E_T^{miss} resolution
- ✓ excellent lepton and photon identification
- ✓ excellent vertex reconstruction
  - Needed for flavour tagging

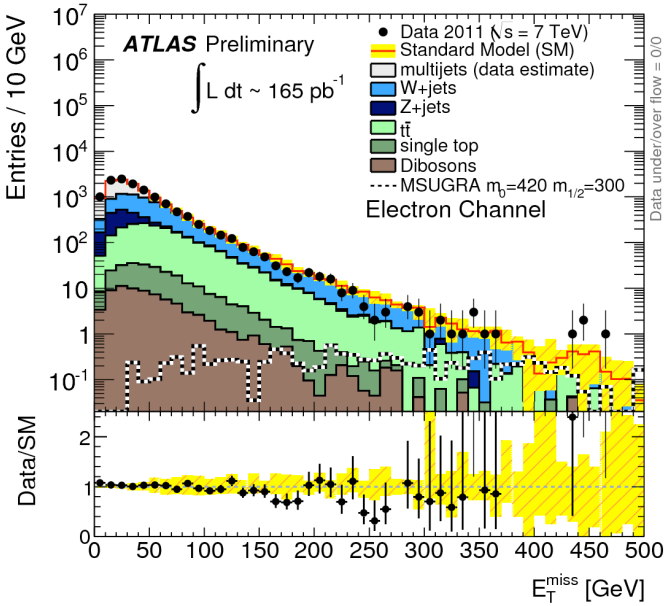
SUSY with Photons, Leptons, B-jets

- Advantages:
  - efficient triggers and clean signal
  - Typically low backgrounds which can be be modeled using data-driven control samples
- Other distinguishing event measurements used for analyses presented here
  - Missing Transverse Momentum from two LSPs escaping detection (E_T^{miss})
  - Generally a lot of activity in the event from the two susy decay chains:
    - Effective mass M_{eff} is the scalar sum of the p_T of the N leading jets, the p_T of the lepton, and E_T^{miss} . (N=3 for analyses presented here).
  - Transverse mass formed by E_T^{miss} and p_T of the lepton (l)
    - $$m_T = \sqrt{2 \cdot p_T^l \cdot E_T^{miss} \cdot (1 - \cos(\Delta\phi(\vec{l}, \vec{E}_T^{miss})))}$$

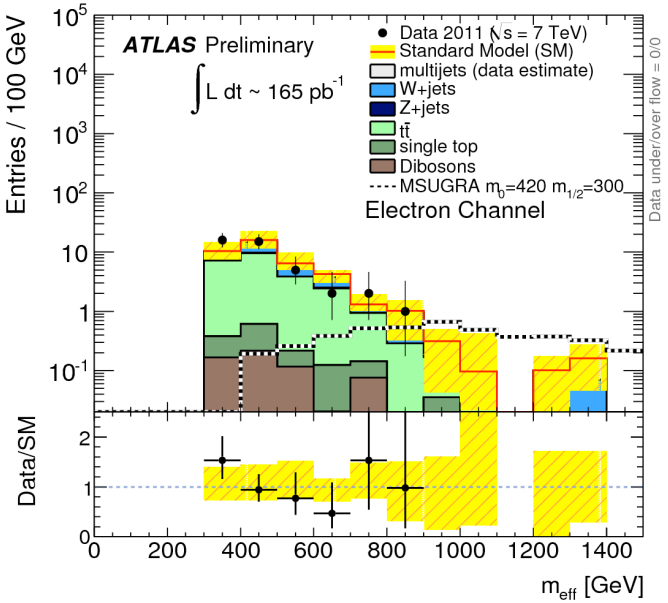
One lepton channel – 165pb^{-1}

- Selection
  - 1 lepton,
    - Electron p_T>25GeV
    - Or Muon p_T>20GeV
      - (difference due to trigger threshold)
  - Veto second lepton if
    - Electron p_T>20GeV
    - Muon p_T>10GeV
      - ATLAS has dedicated analyses for multi lepton channels
  - 3 Jets (60,25,25GeV)
  - $\Delta\phi$ (jet , E_T^{miss}) >0.2 for all jets
  - E_T^{miss}> 125GeV, E_T^{miss}>0.25×M_{eff}
  - M_{eff}>500GeV: m_T>100GeV
- Main BG : Top production and W+jets

Before E_T^{miss}, Meff, Mt cuts



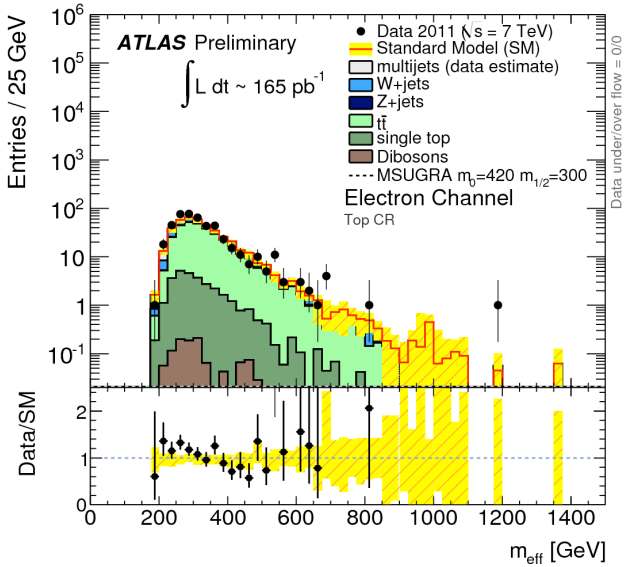
After all cuts except Meff cut.



One lepton channel – 165pb^{-1}

Top CR

- background estimated using control samples at intermediate E_T^{miss} (30-80 GeV) and M_T (40-80 GeV):
  - W+jets CR: no jets tagged as b-jets
  - top CR: at least 1 b-tagged jets



Each Sample is normalised using MC

$$N^{SR}_{predicted} = N^{CR}_{data} \times \frac{N^{SR}_{MC}}{N^{CR}_{MC}}$$

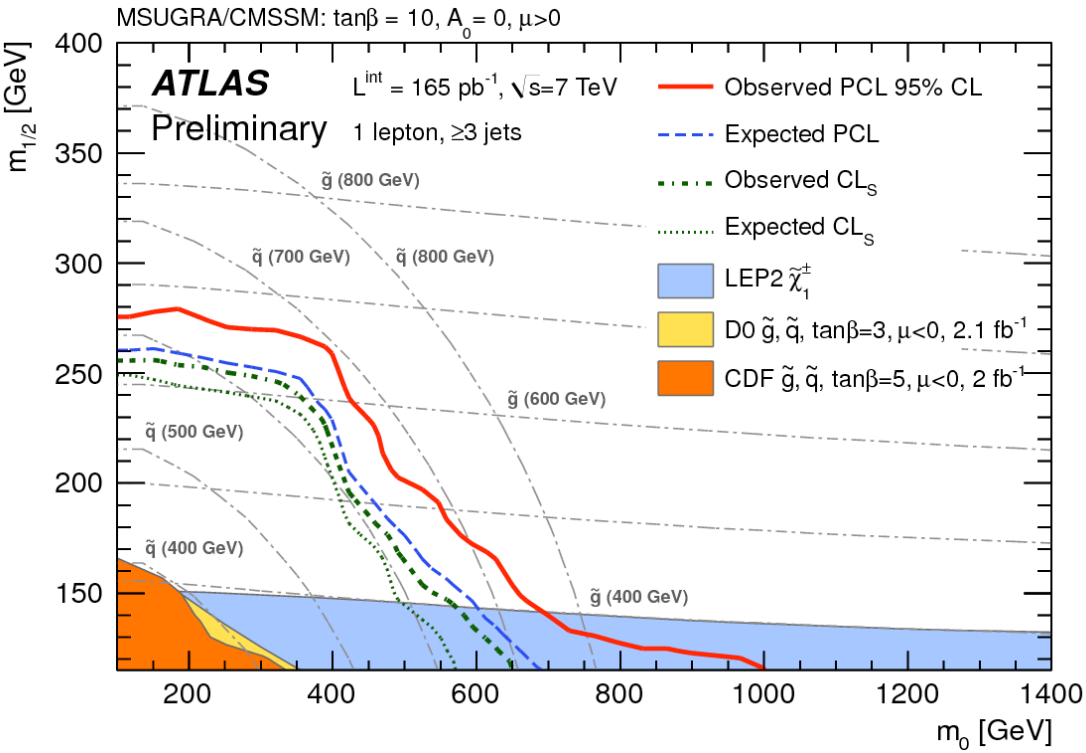
Electron channel	Signal region	Top region	*W* region
Observed events	10	465	1719
Fitted top events	$8.7 \pm 3.6\ (7.7)$	$373 \pm 28\ (329)$	$223 \pm 17\ (196)$
Fitted *W*/*Z* events	$4.6 \pm 2.8\ (4.9)$	$64 \pm 16\ (69)$	$1206 \pm 91\ (1283)$
Fitted QCD events	$1.12^{+0.70}_{-0.40}$	27.7 ± 8.5	290 ± 81
Fitted sum of background events	14.5 ± 5.2	465 ± 22	1719 ± 41

Muon channel	Signal region	Top region	*W* region
Observed events	12	504	1650
Fitted top events	$7.2 \pm 2.7\ (5.7)$	$416 \pm 29\ (327)$	$247 \pm 17\ (195)$
Fitted *W*/*Z* events	$5.0 \pm 2.6\ (5.0)$	$66 \pm 16\ (66)$	$1335 \pm 48\ (1336)$
Fitted QCD events	$0.00^{+0.50}_{-0.00}$	22.8 ± 6.1	68 ± 16
Fitted sum of background events	12.2 ± 3.8	504 ± 22	1650 ± 41

A combined fit is performed

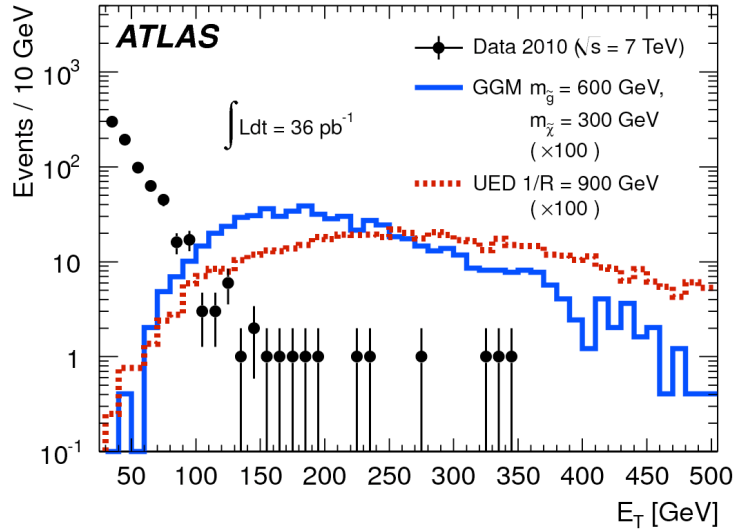
One lepton channel– 165pb^{-1}

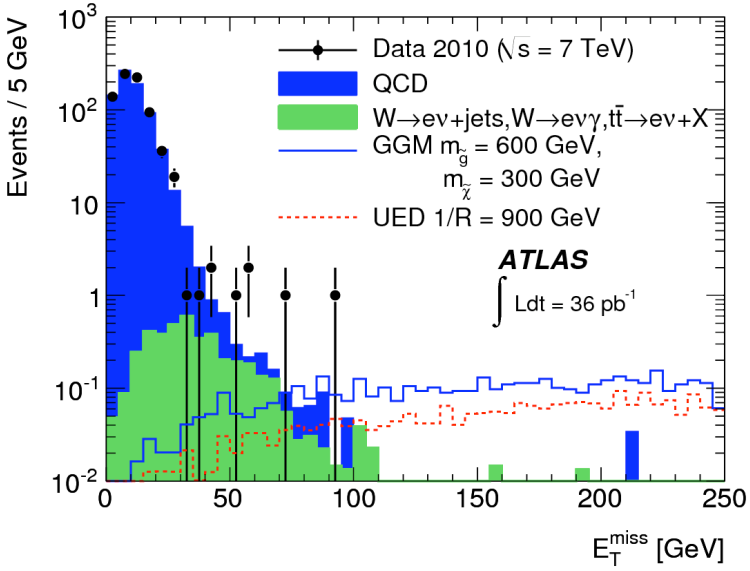
- No excess observed
- Data used for exclusion limits
  - MSUGRA/CMSSM framework
- 95% CL upper limit on the observed number of signal events
  - Electron : 6.8
  - Muon: 8.8
- **ATLAS-CONF-2011-090**



Di-photon +MET– 36pb^{-1}

- If LSP is Gravitino $\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$
- Expect 2 photons+ E_T^{miss}+X
- Selection:
  - 2 photons (p_T>30,20GeV)
  - E_T^{miss} > 125 GeV
- Background estimated from two control samples:
  - QCD:
    - reversing one or more requirements for photon ID
  - Electrons misidentified as photons
    - Control sample containing 1 electron, 1 photon
      - Scale by the electron-photon fake rate
- Also interpreted in term of UED
  - Please see talk by T. Hryn'Ova for details

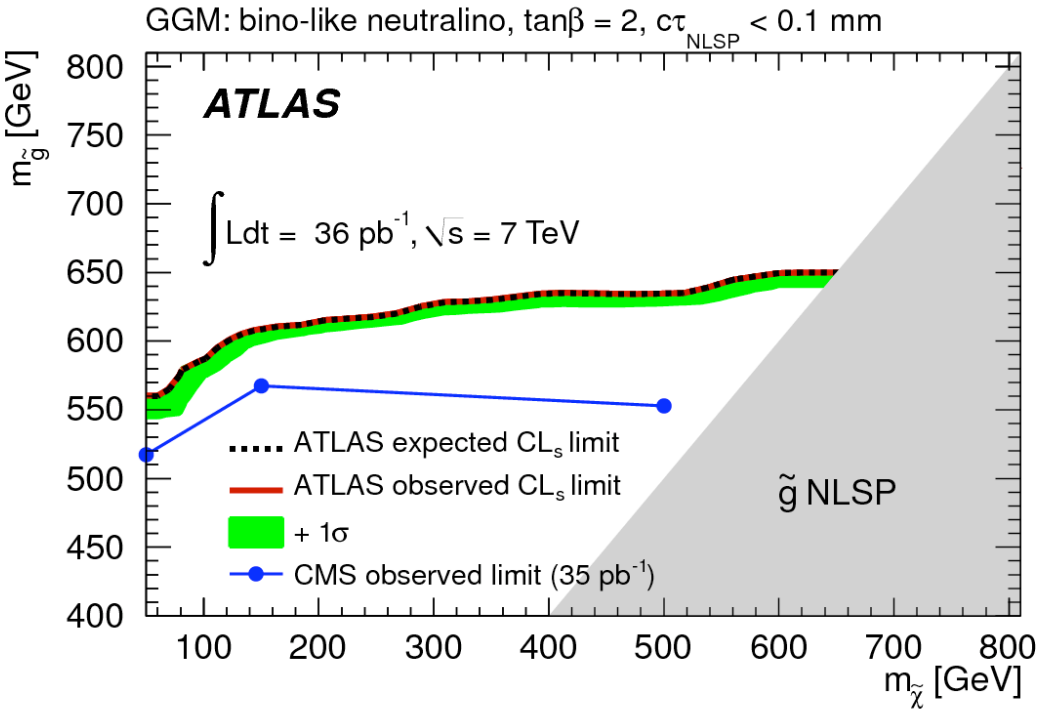




Di-photon +MET– 36pb^{-1}

- Interpret using a generalised model of gauge mediated supersymmetry breaking (GGM) with a bino-like lightest neutralino
  - upper limit is set on the cross section for new physics of
    - σ <0.38 –0.65pb.
  - Mass (gluinos)>560 [GeV]
- Submitted to EPJCL
  - http://arxiv.org/abs/1107.0561

- N_{signal}=0
- $N_{background}$=0.10 ±0.04(stat) ±0.05(syst)



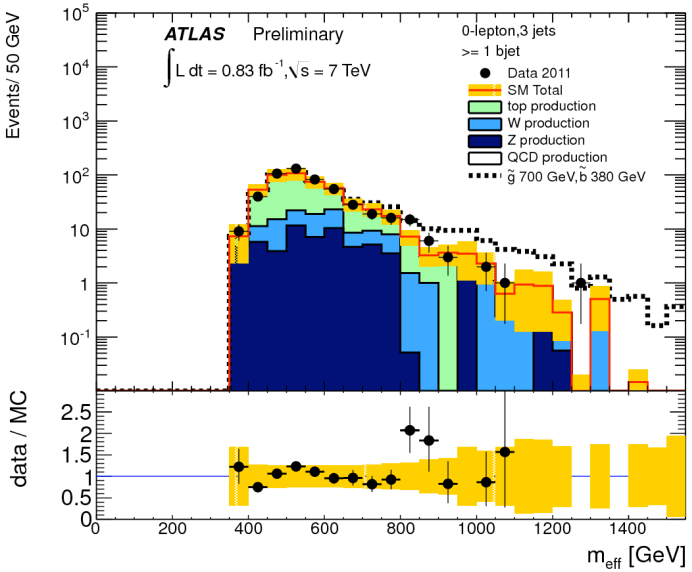
MET+bjet(s) analysis– 833pb^{-1}

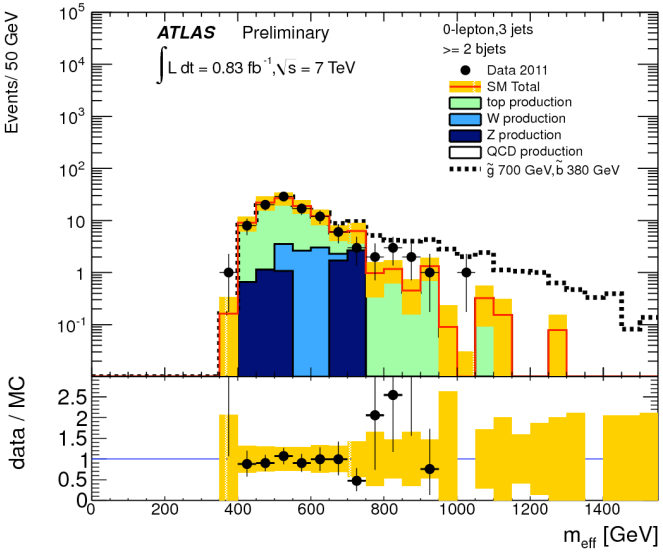
- Sbottom is the NLSP

$$\tilde{g}\tilde{g}(production)$$
$$\tilde{g} \rightarrow b\tilde{b}_1$$
$$\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$$

- We expect
  - >=2 bjets +E_T^{miss} +X
- Selection:
  - Lepton veto
  - E_T^{miss} >130 GeV
    - (trigger plateau)
  - 3 jets
    - p_T>130,50,50 GeV
    - η <2.5
  - $\Delta\phi$ (jet , E_T^{miss}) >0.4
  - E_T^{miss}>0.25×M_{eff}
- Main BG:
  - Top production

- 4 signal regions considered:
  - >= 1 b-tag, M_{eff} > 500 GeV
  - >= 1 b-tag, M_{eff} > 700 GeV
  - >= 2 b-tags, M_{eff} > 500 GeV
  - >= 2 b-tags, M_{eff} > 700 GeV

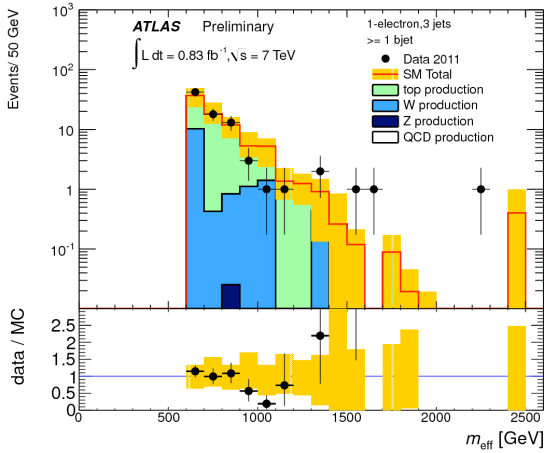




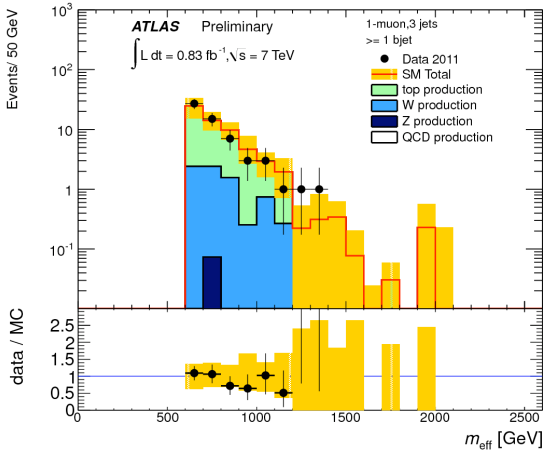
MET+bjet(s) analysis– 833pb^{-1}

- top background is done using MC and validated with a data-driven method
  - same kinematic as signal reg:
    - 1 electron(muon)
      - p_T > 25(20) GeV
    - m_{eff} > 600 GeV
    - 40 GeV< m_T <100 GeV
    - At least 1 b-jet.

Top CR: electron



Top CR: muon

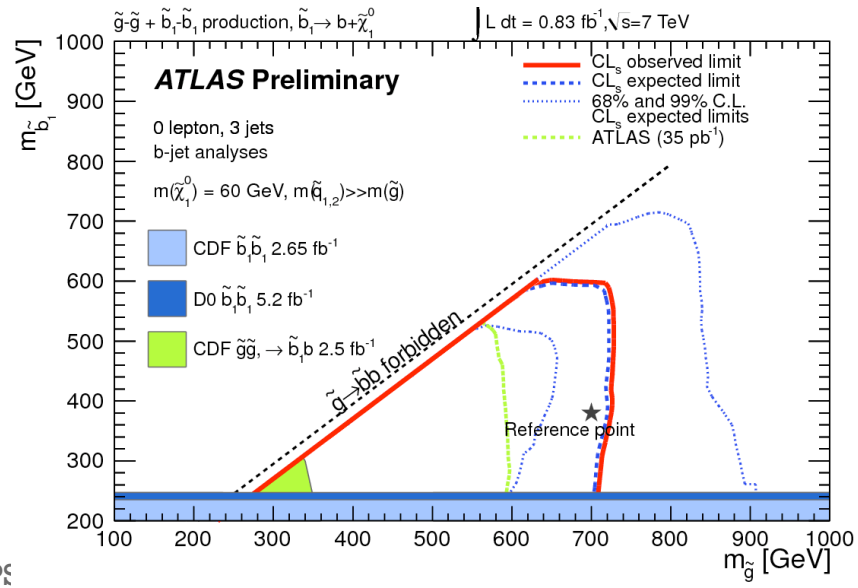


- QCD data driven method:
  - Jet Smearing method
  - See I. Vivarelli's talk for details

Sig. Reg.	Data (833pb^{-1})	Top	W/Z	QCD	Total
3JA (1 btag m_{eff} >500 GeV)	361	221^{+82}_{-68}	121 ± 61	15 ± 7	356^{+103}_{-92}
3JB (1 btag m_{eff} >700 GeV)	63	37^{+15}_{-12}	31 ± 19	1.9 ± 0.9	70^{+24}_{-22}
3JC (2 btag m_{eff} >500 GeV)	76	55^{+25}_{-22}	20 ± 12	3.6 ± 1.8	79^{+28}_{-25}
3JD (2 btag m_{eff} >700 GeV)	12	$7.8^{+3.5}_{-2.9}$	5 ± 4	0.5 ± 0.3	$13.0^{+5.6}_{-5.2}$

MET+bjet(s) analysis– 833pb^{-1}

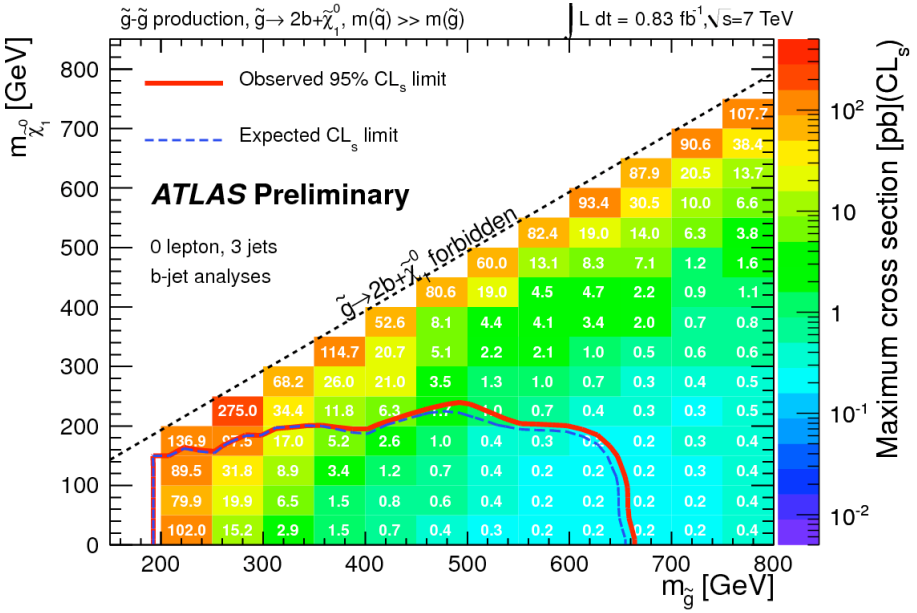
- Interpretation of results in gluino-sbottom scenarios:
  - $\tilde{g} \rightarrow b\tilde{b}_1 (BR = 1)$
    $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0 (BR = 1)$
- Gluino masses< 720 GeV excluded for m(sbottom) < 600 GeV



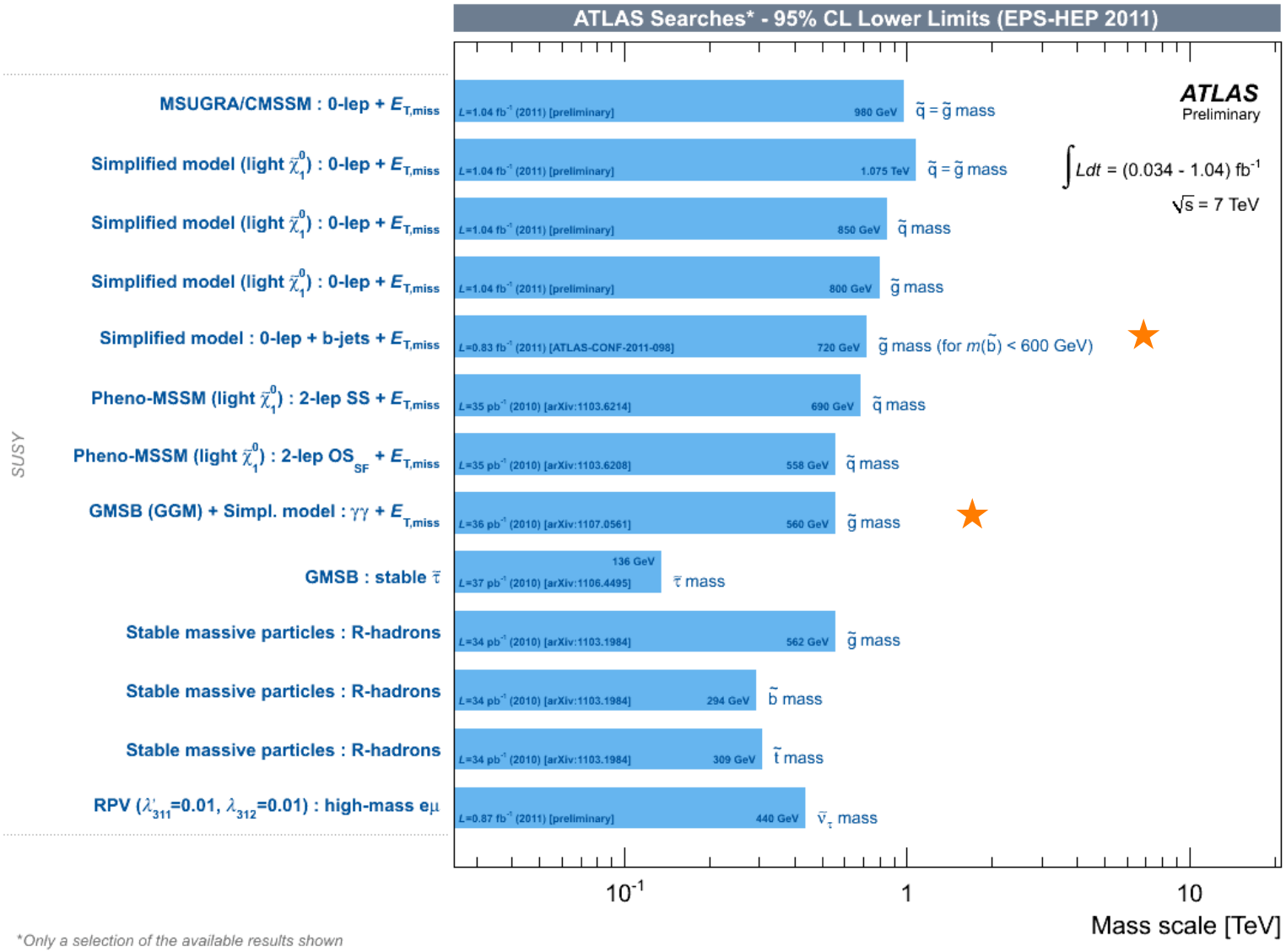
- Interpretation of results in gluino-gluino production, where:

$$\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0 (BR = 1)$$

- gluino masses< 660 GeV excluded up to LSP masses of 200-250 GeV
- **ATLAS-CONF-2011-098**



Summary of ATLAS SUSY so far….

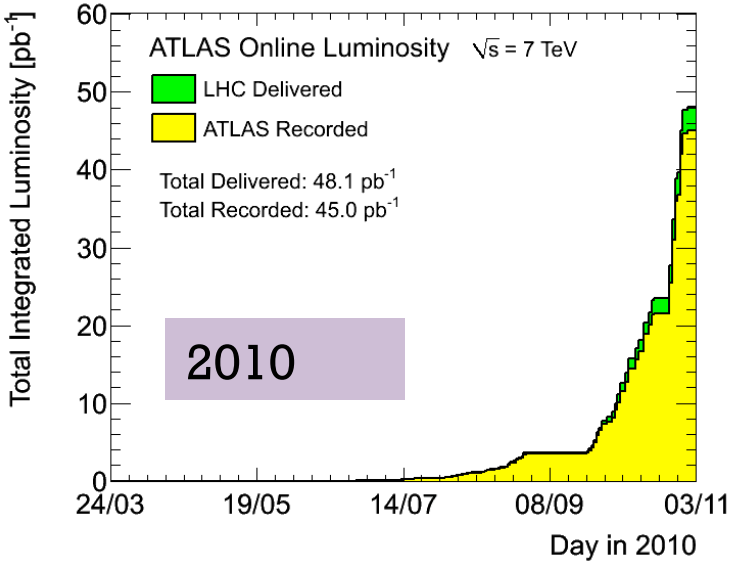


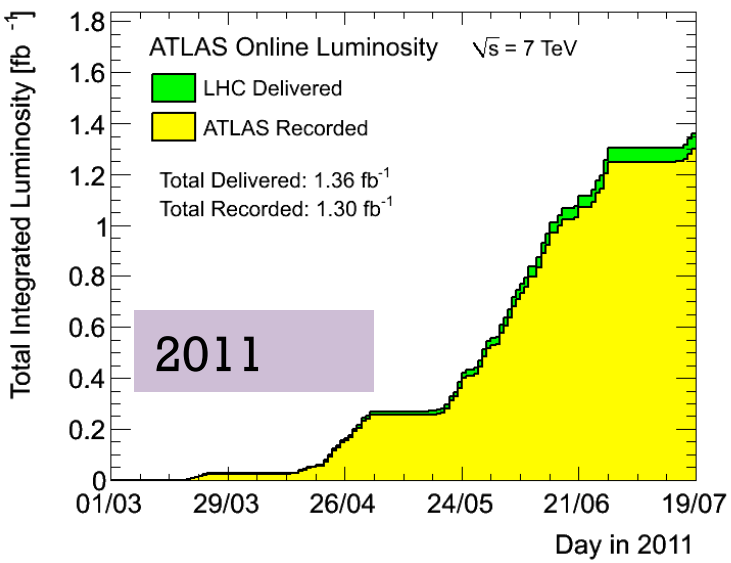
*Only a selection of the available results shown

★limits presented here

Conclusions

- No excess over SM predictions observed -> No evidence of SUSY yet ☹
  - But we still have plenty of parameter space to go
- Limits in various channels, excluding ever more parameter space
- Interpreting signatures for different models
- We are already exceeding the Tevatron reach
  - Further to go when full 2011 data is analysed!



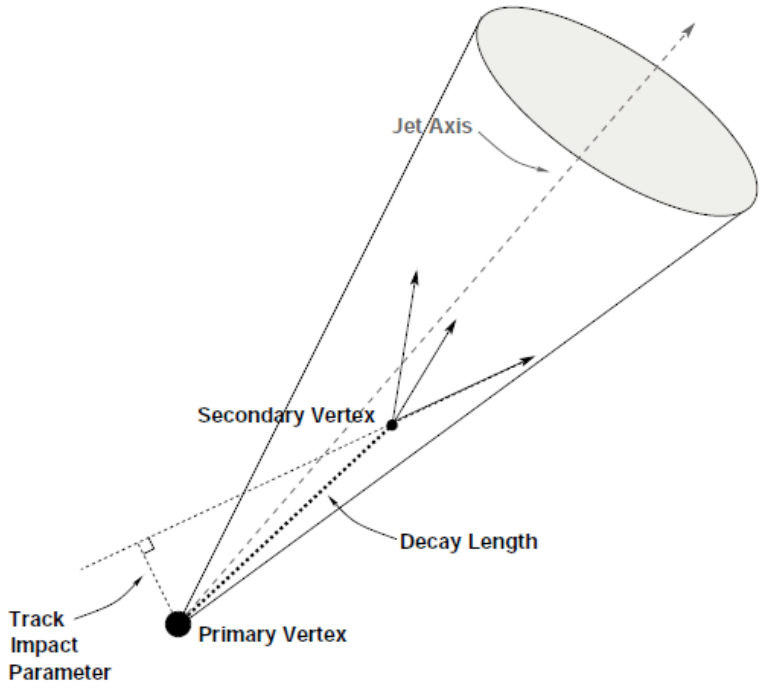


To be continued…

Backup

Flavour tagging

- B-jets are "tagged" by searching for a Secondary Vertex



Data driven control method for QCD for 1 lepton analysis

- Background from misidentified or non-isolated leptons in QCD mulitjet events
- BG is estimated from the data in the signal and W and Top control regions by matrix method.
- Define QCD enhanced samples by loosening quality cuts and dropping isolation criteria of leptons.
- $N_{pass}(N_{fail})$ = number of events in loose sample passing(failing) final lepton selection
- $N_{pass}(N_{fail})$ = number of events in loose sample passing(failing) final lepton selection
- $N_{real}(N_{fake})$ = number of real(fake) leptons
- ε_{real}= identification efficiency for real leptons
- ε_{fake}= mis-identification efficiency for fake leptons

$$N_{pass} = \epsilon_{real} N_{real} + \epsilon_{fake} N_{fake}$$

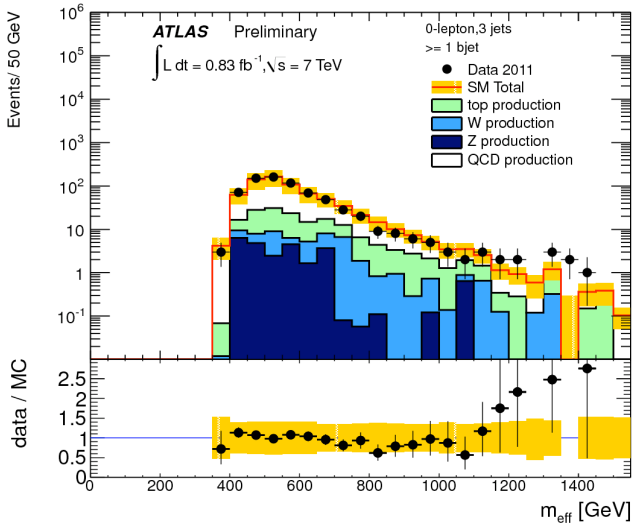
$$N_{fail} = (1 - \epsilon_{real}) N_{real} + (1 - \epsilon_{fake}) N_{fake}$$

$$N_{fake}^{pass} = \epsilon_{fake} N_{fake} = \frac{N_{fail} - (1/\epsilon_{real} - 1) N_{pass}}{1/\epsilon_{fake} - 1/\epsilon_{real}}$$

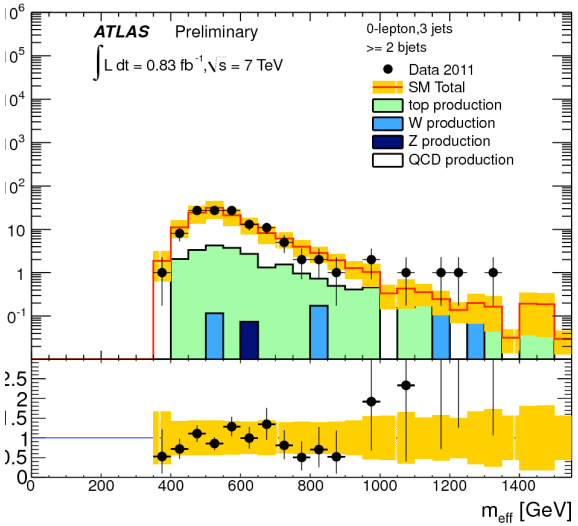
Data driven control method for QCD for B-jet analysis

- To create QCD prediction:
  - Take clean data events with low E_t^{miss} ,
  - smear the momentum of the jets to generate "pseudo-events" with possibly large E_t^{miss}.
  - Validate by comparing to QCD enriched control regions by reverting cut on $\Delta\phi_{min}$

One btag jet



Two btag jets



0 lepton, 3 jets– 833pb-1

(At least one of which is tagged as a B-jet)

- Third interpretation done in grand unification SO10 model.
  - DR3: the $\tilde{g} \rightarrow \bar{b} b \tilde{\chi}_1^0$ dominates up to gluino masses of about 550 GeV.
  - HS: the $\tilde{g} \rightarrow \bar{b} b \tilde{\chi}_2^0$ becomes more relevant at large gluino masses, resulting in a loss of acceptance.
  - Limits at 570 GeV (450 GeV) in the DR3 (HS) case.