Interpretations of SUSY Searches in ATLAS with Simplified Models

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on behalf of the ATLAS Collaboration

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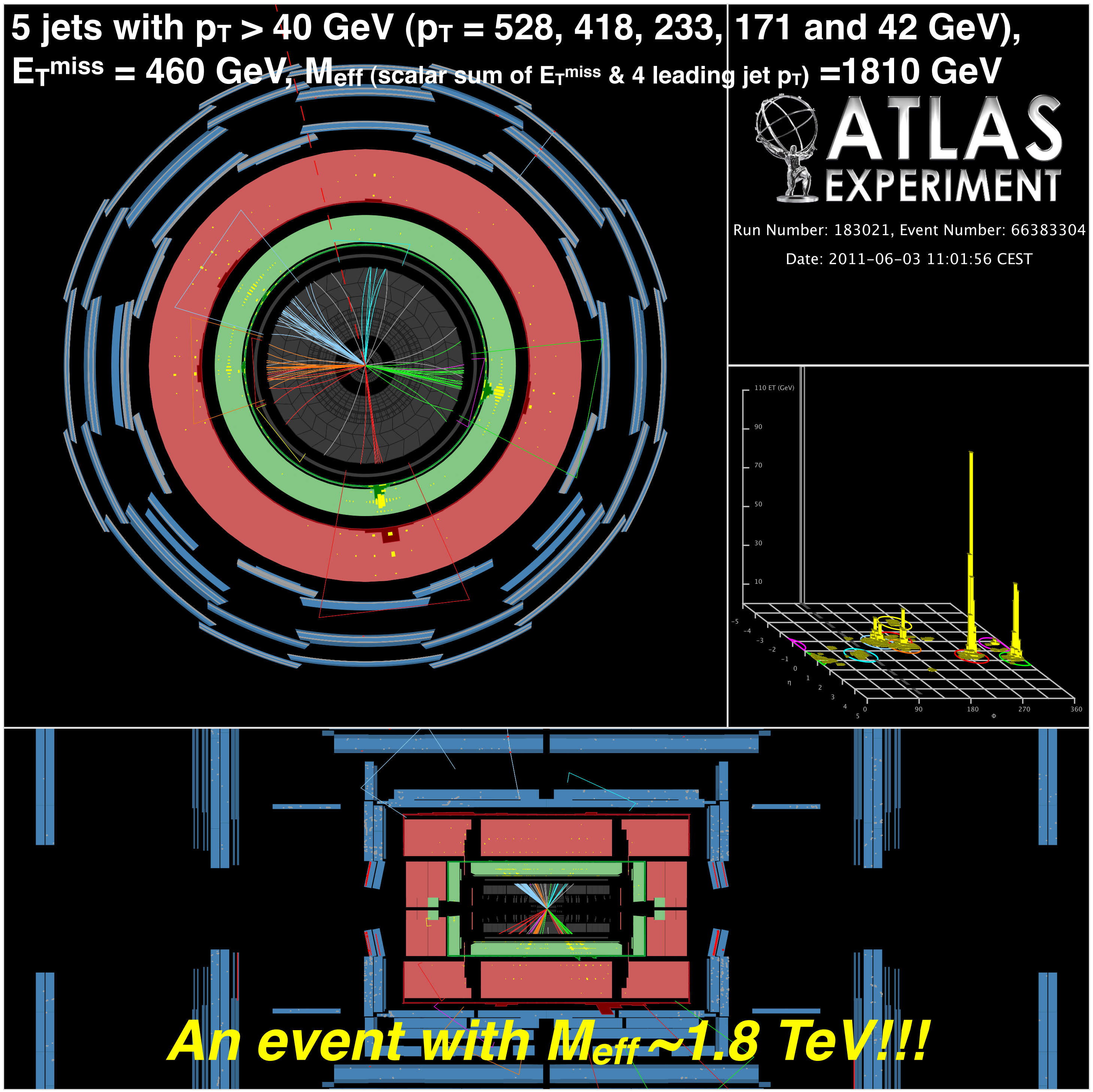
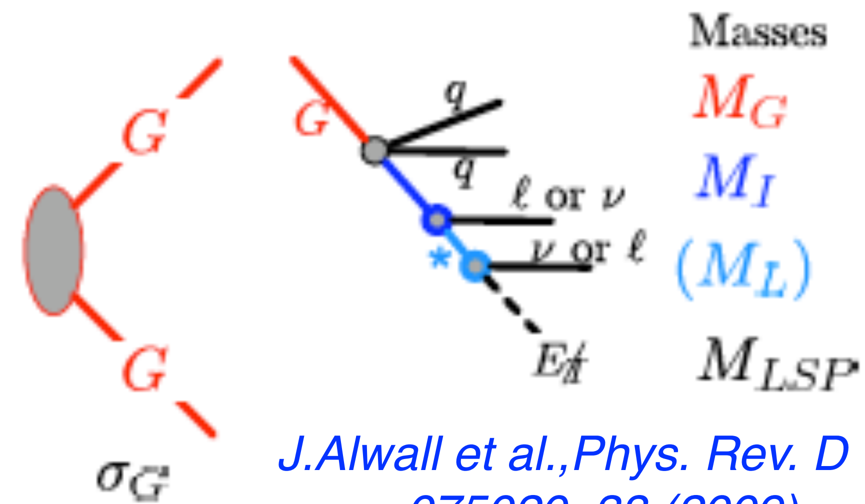
Where We Are



- ATLAS recorded ~2 fb^{-1} by early August (starting to have results with ~1 fb^{-1}).
- We are truly entering the TeV-scale
- We want to be model-independent not to miss signals being too driven by specific SUSY models
- Simplified model approach is one of the most promising (quasi-)model independent strategies for new physics searches
- Widely gaining interests in the experimental/theoretical community (lhcnewphysics.org)

Simplified Models

- **What are "Simplified Models"?**
    - **Effective models with minimal particle contents**
    - **Searches in the context of "particles"**

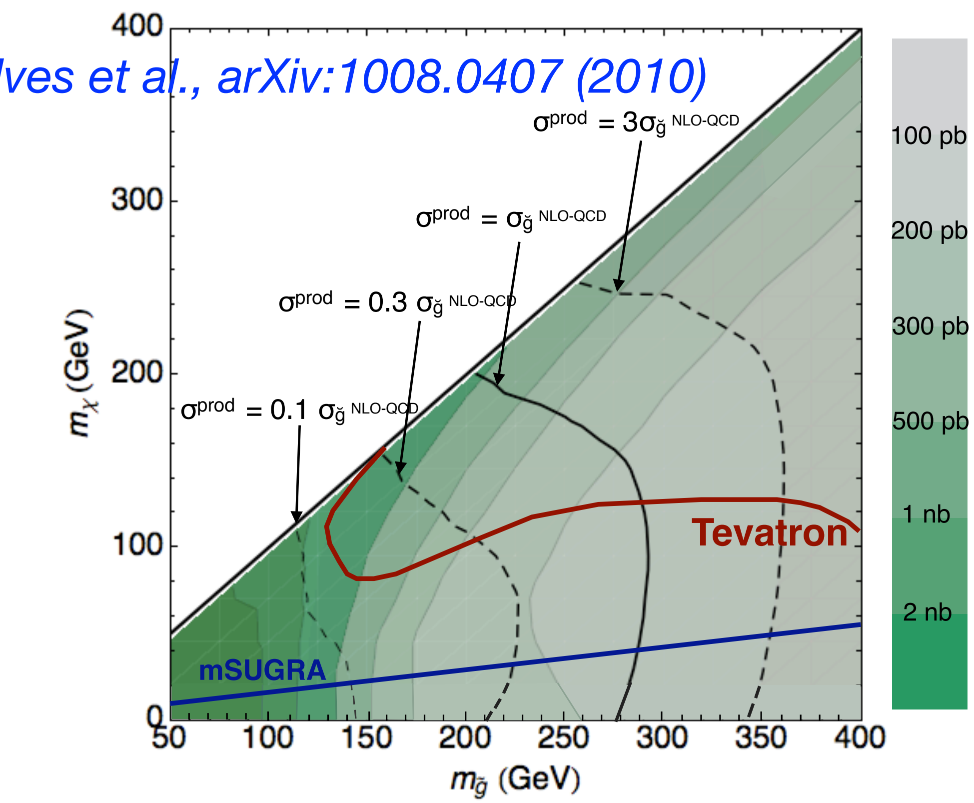


J.Alwall et al.,Phys. Rev. D 79, 075020, 38 (2009)

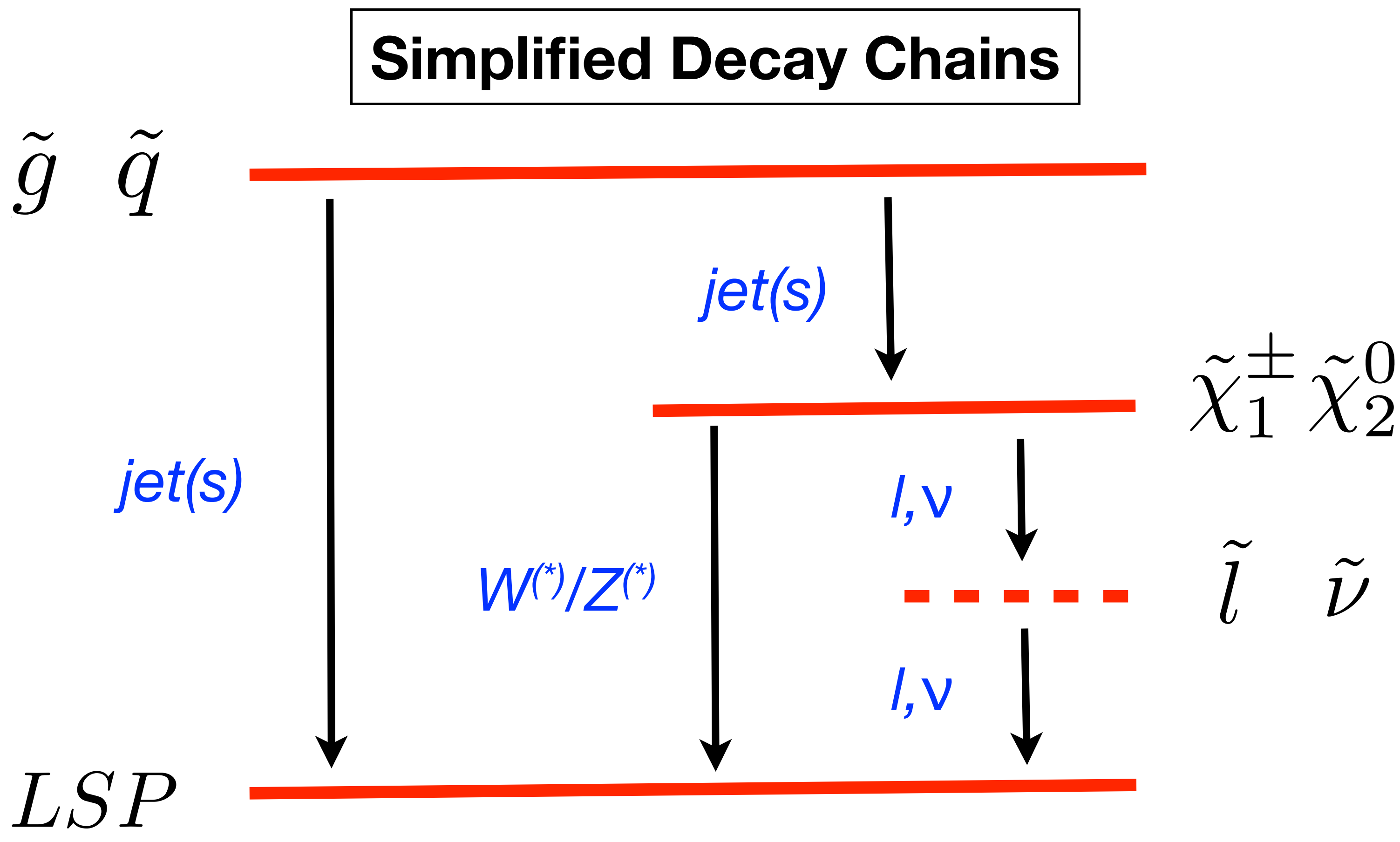
- **Model-independent results (upper limits on σ×BR) : Interface to specific models; can also be extended to non-SUSY models**

- Important additional features
    - Can scan the whole sparticle mass plane (unlike mSUGRA)
    - Disentangle assumptions on various couplings & branching ratios (complementary to pMSSM approach)

D.Alves et al., arXiv:1008.0407 (2010)



Simplified Models in ATLAS



- **2 - 4 mass parameters :** subsets of gluino, squark, wino, slepton LSP masses
- Sparticles not relevant for the event topologies considered to be heavy (> a few TeV)
- Branching ratios can be free parameters, assume 1 or other realistic values

Simplified model interpretations in ATLAS

- **No-lepton channel (1.04 fb^{-1})**
- **SS 2-lepton channel (35 pb^{-1})**

} this presentation

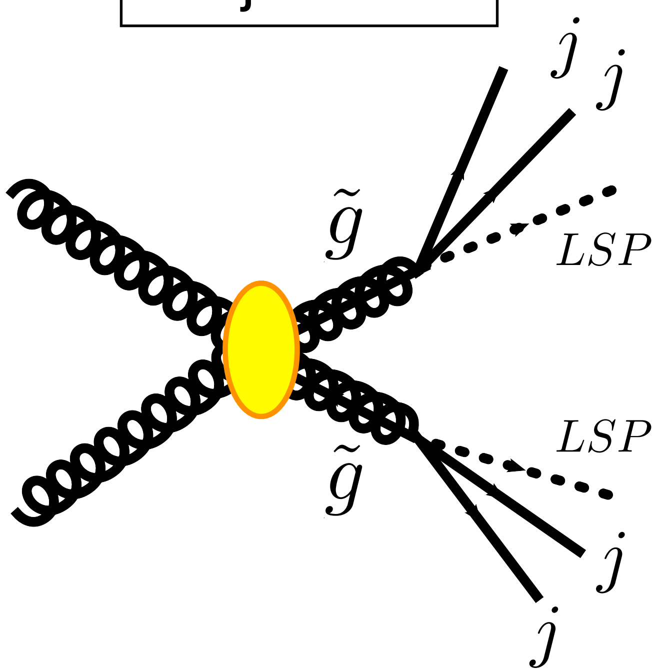
- b-jet + MET channel (0.83 fb^{-1}; see B. Butler's talk)

No-Lepton Search

- **Golden channel for SUSY search** → **Has the largest coverage over possible R-parity conserving pMSSM phase space**
  (J. Conley et al., Supersymmetry Without Prejudice at the 7 TeV LHC, arXiv:1103.1697 (2011))

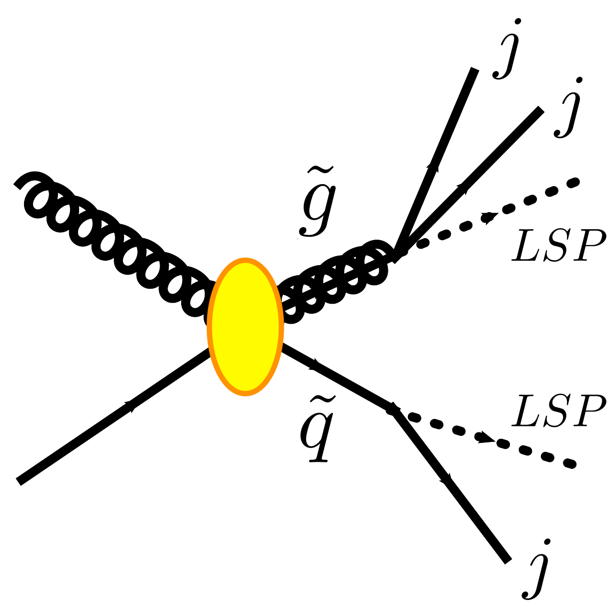
- Here, 3 diagrams considered, where gluinos/squarks directly decay down to the lightest supersymmetric particle (LSP)

4 jet-like



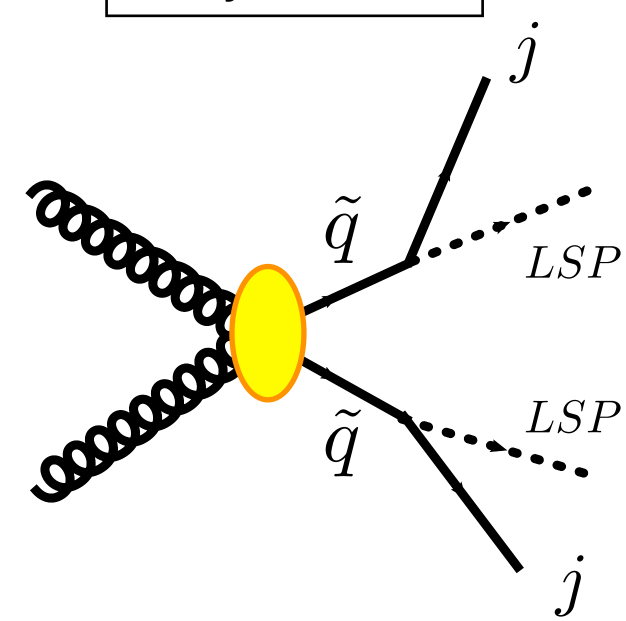
Dominant when
$m_{squark} >> m_{gluino}$

3 jet-like



Dominant when
$m_{squark} \sim m_{gluino}$

2 jet-like



Dominant when
$m_{gluino} >> m_{squark}$

No-Lepton Ev. Selections

- **Signature with large E_T^{miss} + multiple high-p_T jets**

- Using E_T^{miss}+jet trigger
  (E_T^{miss} 45 GeV, jet p_T 75 GeV at raw EM scale)
- 5 signal regions covering gluino/squark mass plane for various high-p_T jet multiplicities
- Additional cuts for QCD BG suppression

Signal Region	≥ 2 jets	≥ 3 jets	≥ 4 jets	High mass
E_T^{miss}	> 130	> 130	> 130	> 130
Leading jet p_T	> 130	> 130	> 130	> 130
Second jet p_T	> 40	> 40	> 40	> 80
Third jet p_T	–	> 40	> 40	> 80
Fourth jet p_T	–	–	> 40	> 80
$\Delta\phi(\text{jet}, E_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
E_T^{miss}/m_{eff}	> 0.3	> 0.25	> 0.25	> 0.2
m_{eff} [GeV]	> 1000	> 1000	> 500/1000	> 1100

$$m_{eff} = \sum_{i=1}^{n} |p_T^{jet(i)}| + E_T^{miss}$$

- **Main BG: W/Z+jets, top, QCD multijets.** Estimated with (quasi-)data-driven methods using various control regions (CR's)

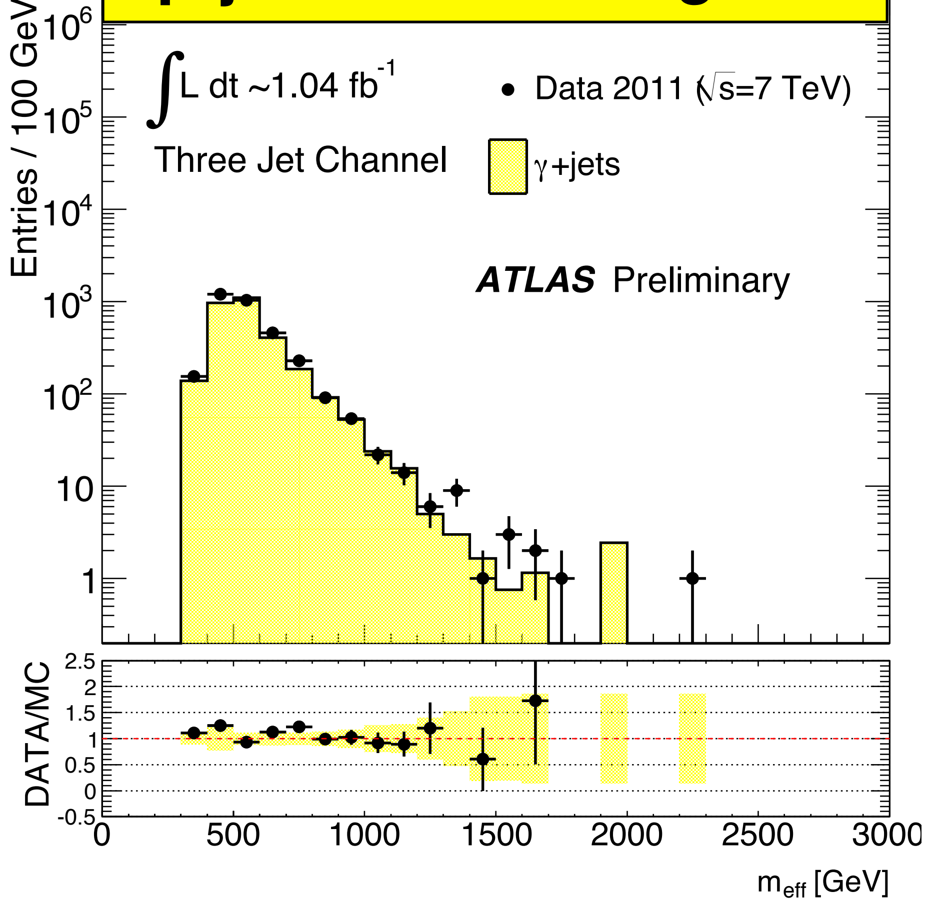
$$N(SR, est, proc) = N(CR, obs, proc) \times \frac{N(SR, raw, proc)}{N(CR, raw, proc)}$$

Common systematics
- JES/JER (~15% effect on transfer function)
- Pileup
- MC (generator, PDF, scale; ~25% effect)

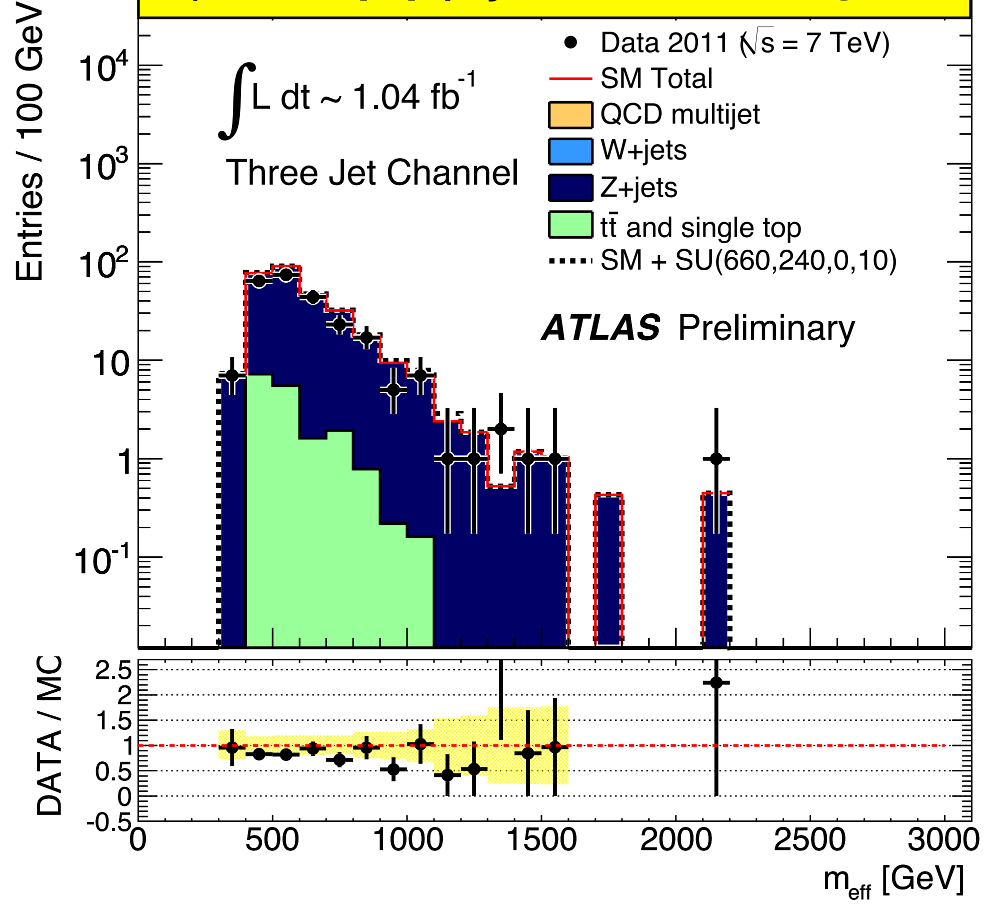
Z+jets BG

- $Z(\rightarrow \nu\bar{\nu})$+jets is the dominant component in Z+jets BG
- 2 CR's: γ+jets & $Z(\rightarrow e^+e^-, \mu^+\mu^-)$+jets from single photon or lepton triggered events; bosons are replaced with E_T^{miss}
- Transfer functions: p_T-dependent cross section ratio between Z/γ etc. for γ+jets; acceptance effects, etc. for $Z(\rightarrow e^+e^-, \mu^+\mu^-)$+jets

γ+jets Control Regions



$Z(\rightarrow e^+e^-, \mu^+\mu^-)$+jets Control Regions



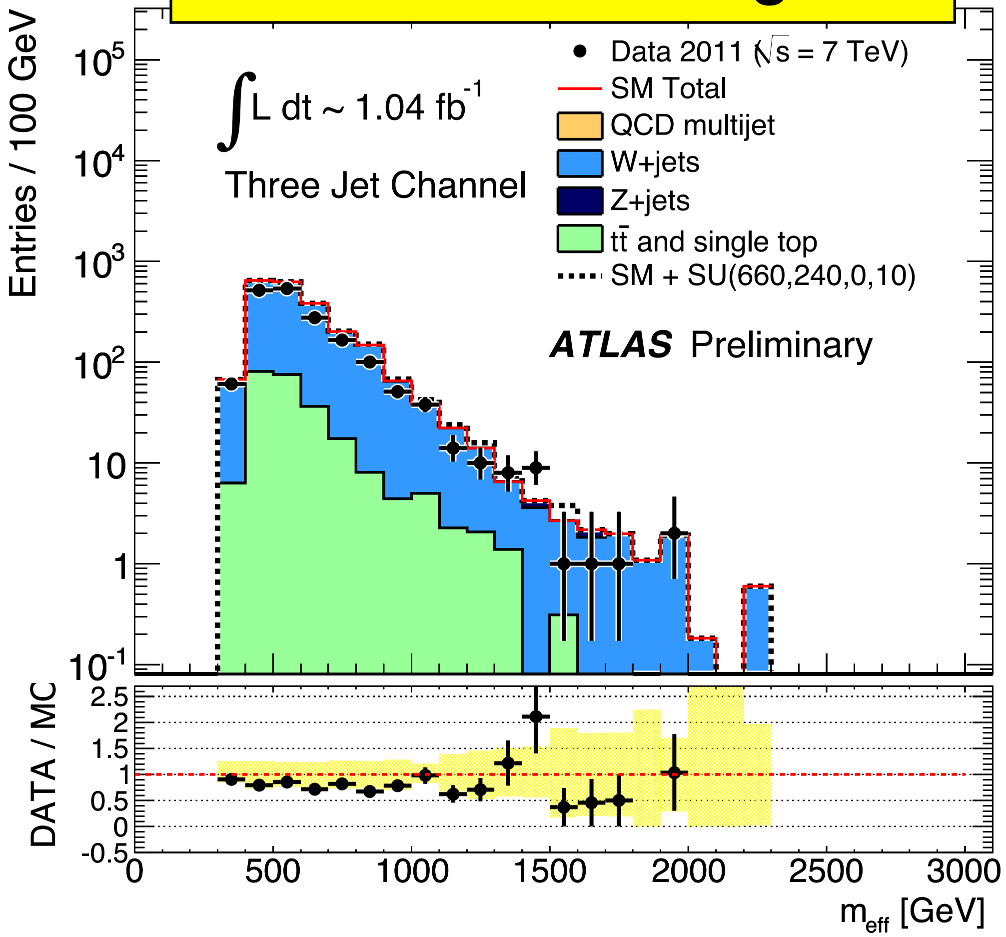
CR-specific systematics

- Photon/lepton trigger efficiency, reconstruction efficiency, energy scale and resolution
- Photon acceptance & BG
- MC statistics

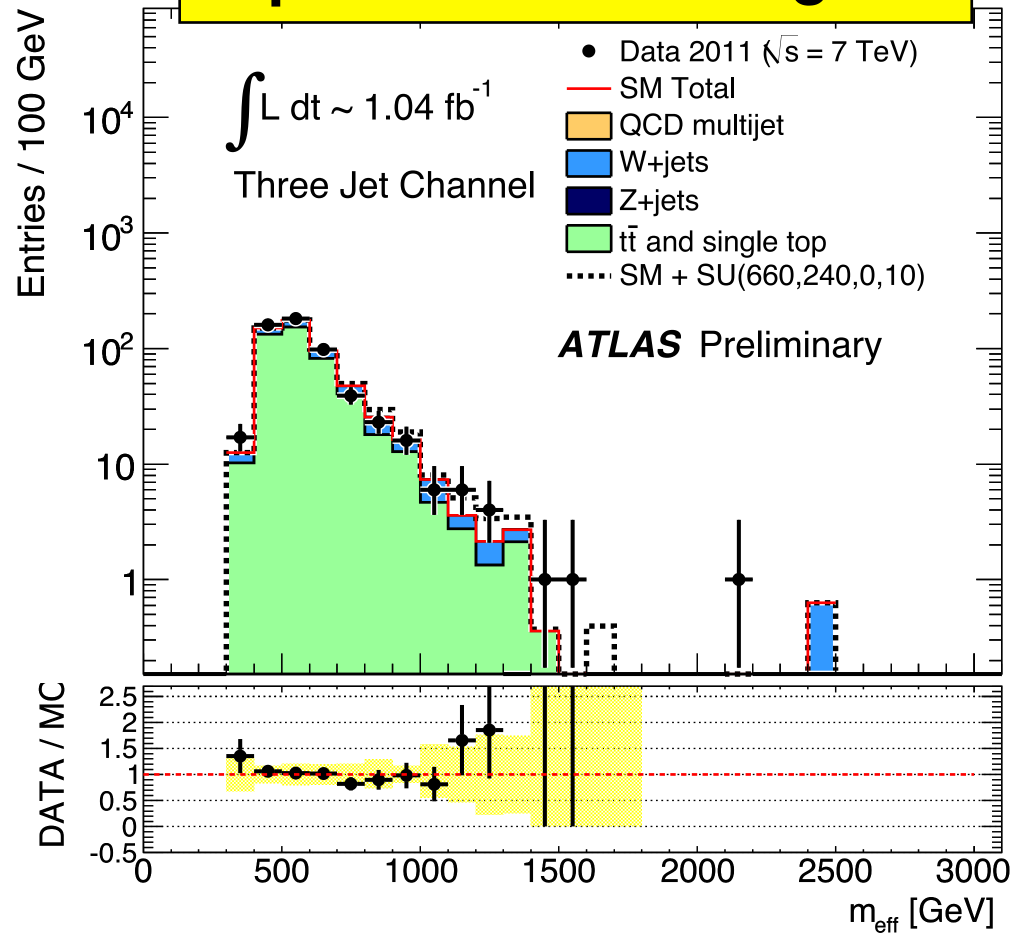
W+jets & Top BG

- 1 lepton + E_T^{miss} + jets CR's with $30<M_T<100$ GeV are used for W+jets/Top
- CR's were further separated to W+jets & Top-dominant regions using b-tagging
- Lepton is replaced as "jet," since no-lepton BG dominantly comes from hadronic τ's

W-rich Control Regions



Top-rich Control Regions

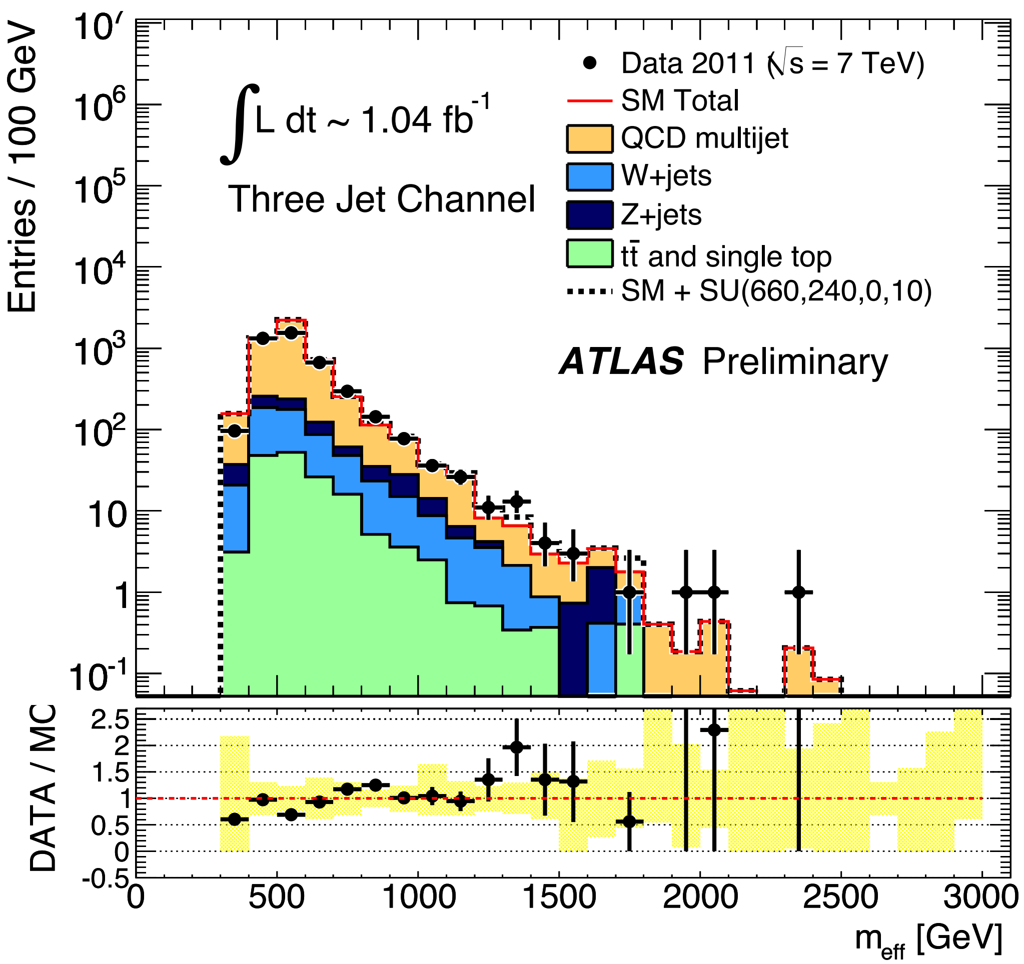


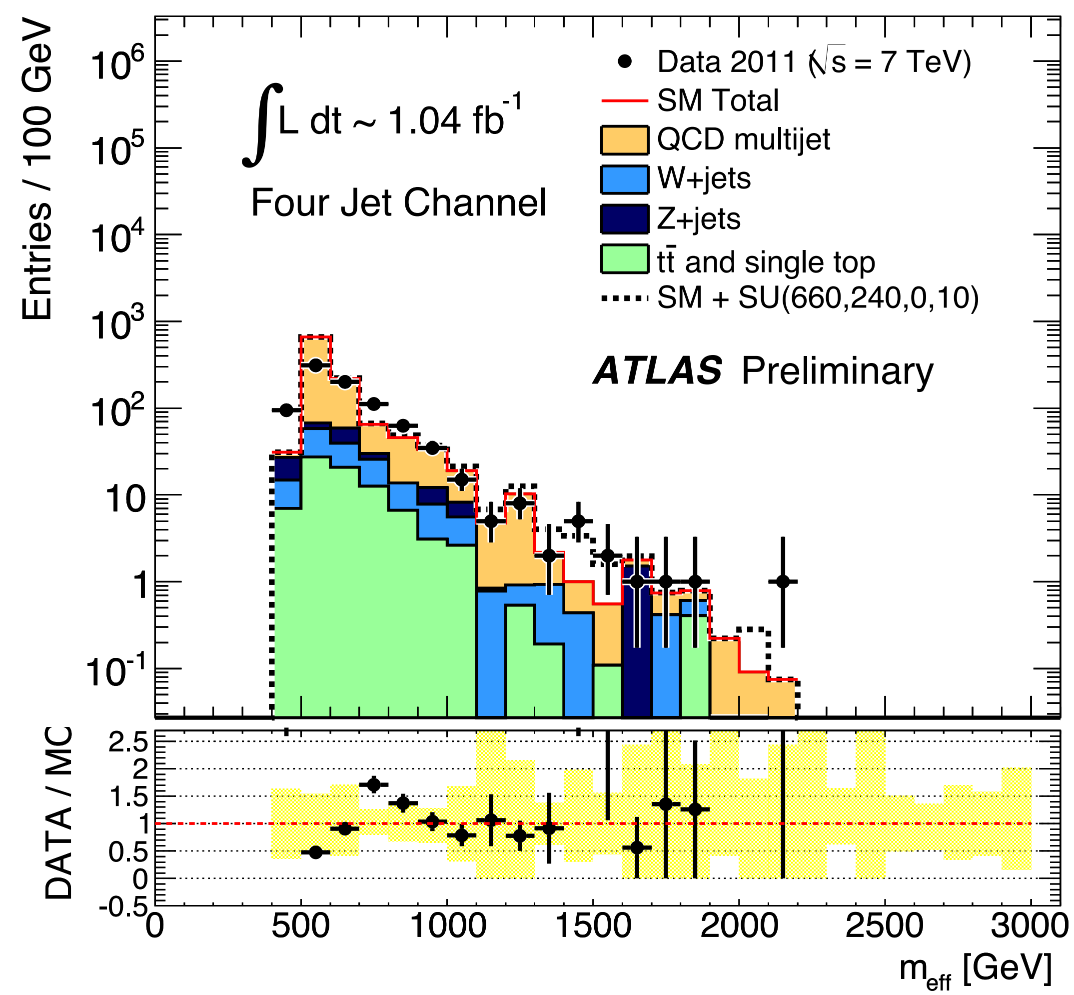
CR systematics

- Lepton trigger eff., reconstruction eff., energy scale and resolution
- b-tag/veto eff.
- MC statistics

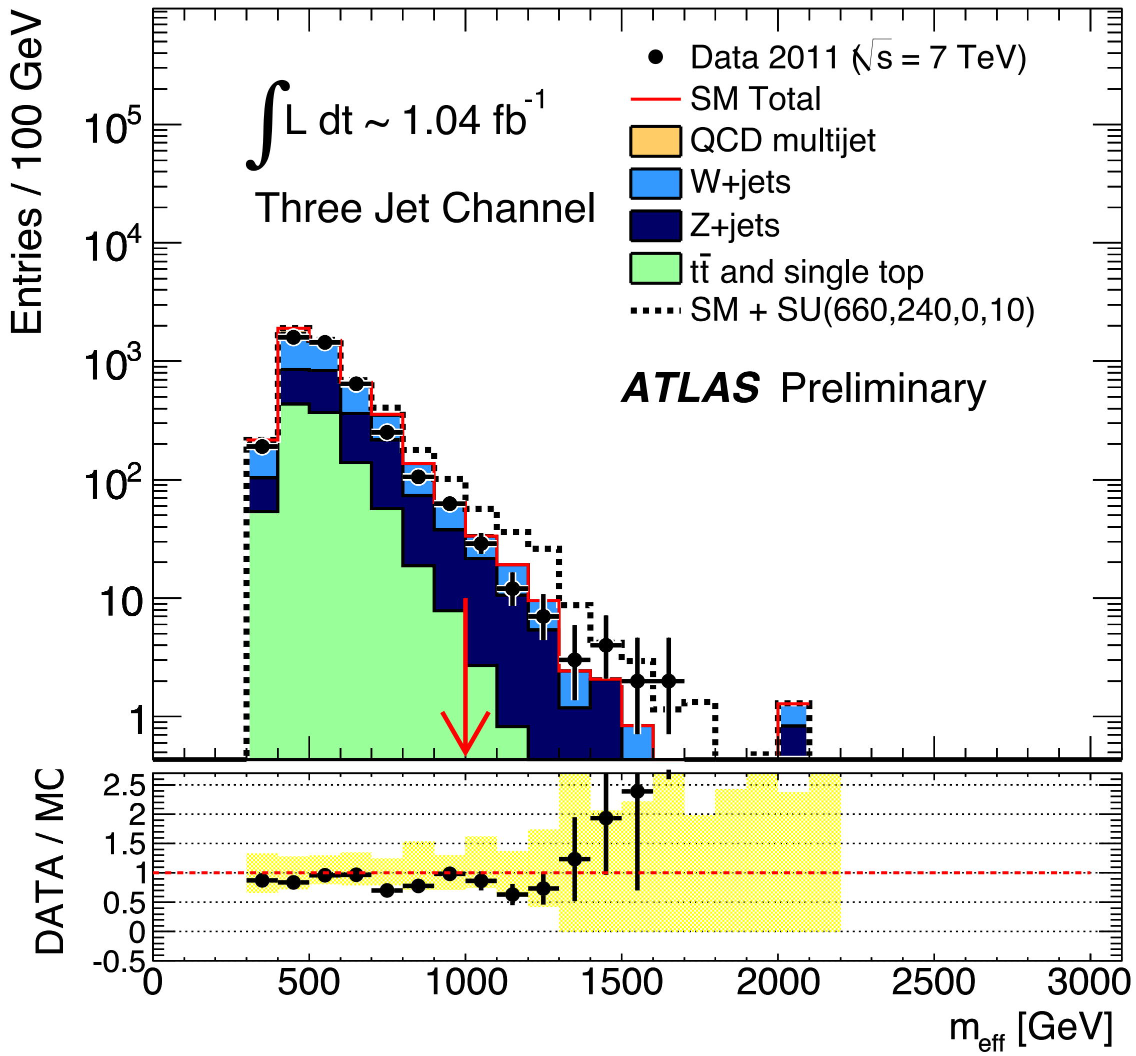
QCD BG

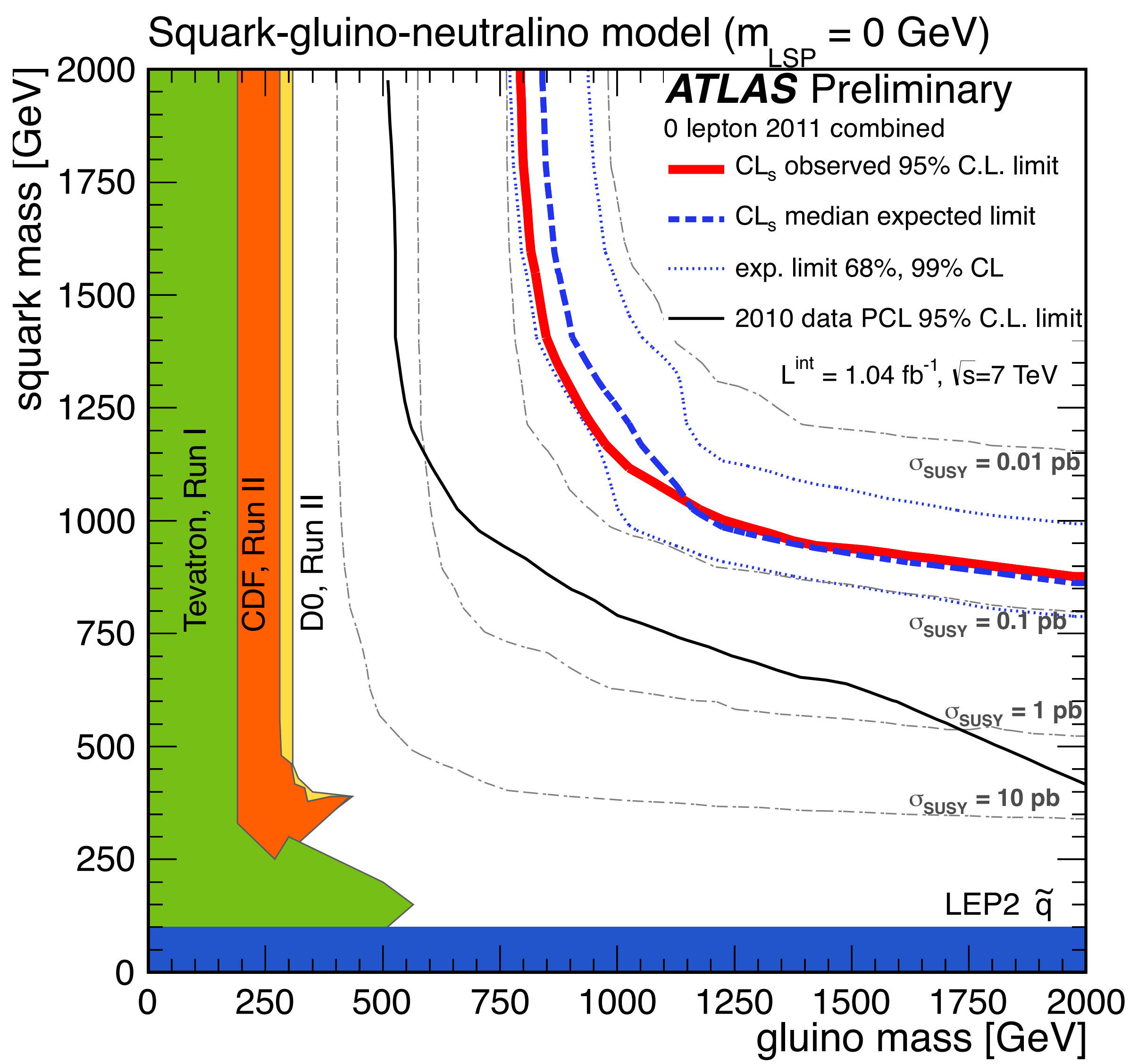
- Fake E_T^{miss} originates in multijet events from jet mismeasurement and heavy flavors
- Low E_T^{miss} region used for CR. Jets are smeared using response function measured from data (systematics arise from modeling of non-Gaussian tail)





No-Lepton Channel Limits





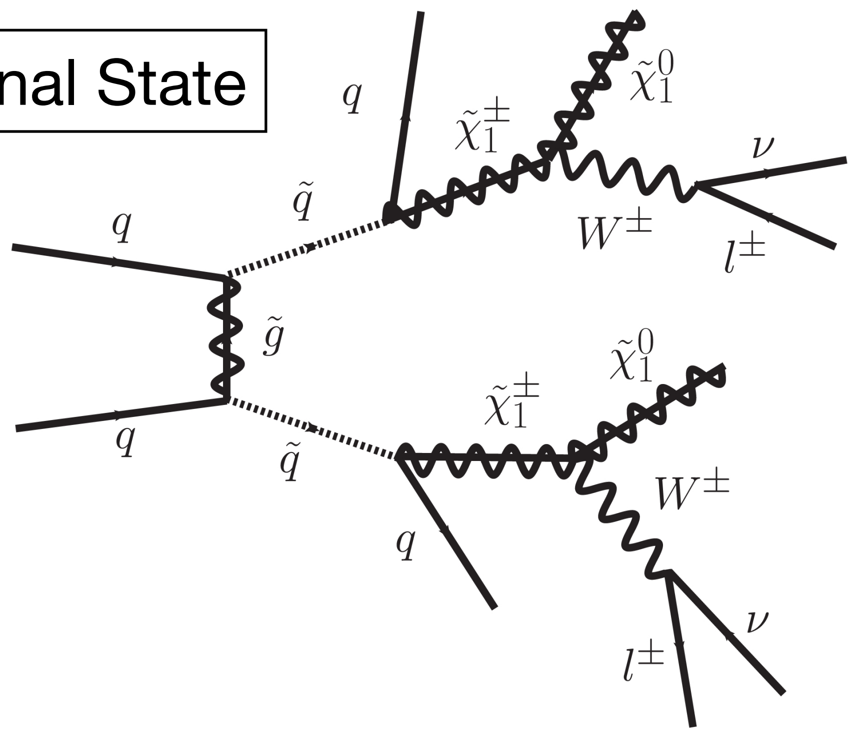
- Limits on the simplified models with LSP mass at 0. Combined from 5 channels
- m ≤ 1.075 TeV excluded when $m_{gluino} = m_{squark}$ at 95% confidence level
  $m_{gluino} \leq$ 800GeV, $m_{squark} \leq$ 850GeV are excluded respectively
- Exclusion limit is not sensitive to the LSP mass up to ~ 200 GeV

SS 2-Lepton Search

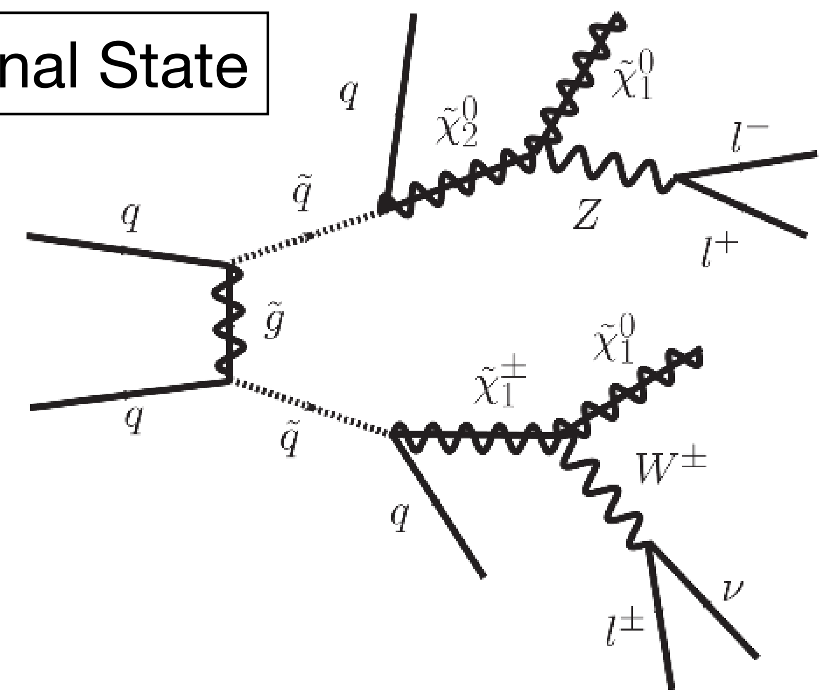
- **Very small Standard Model BG → clear channel for SUSY search**
  (M. Barnett et al., Phys. Lett. B 315, 349)

- Simplified models with same-sign same-flavor squark production considered in particular *(H.Okawa, presentation at Characterization of new physics at the LHC II, Nov. 2011; ATLAS Collaboration, ATLAS Note, ATLAS-CONF-2011-091)*

2-lep Final State



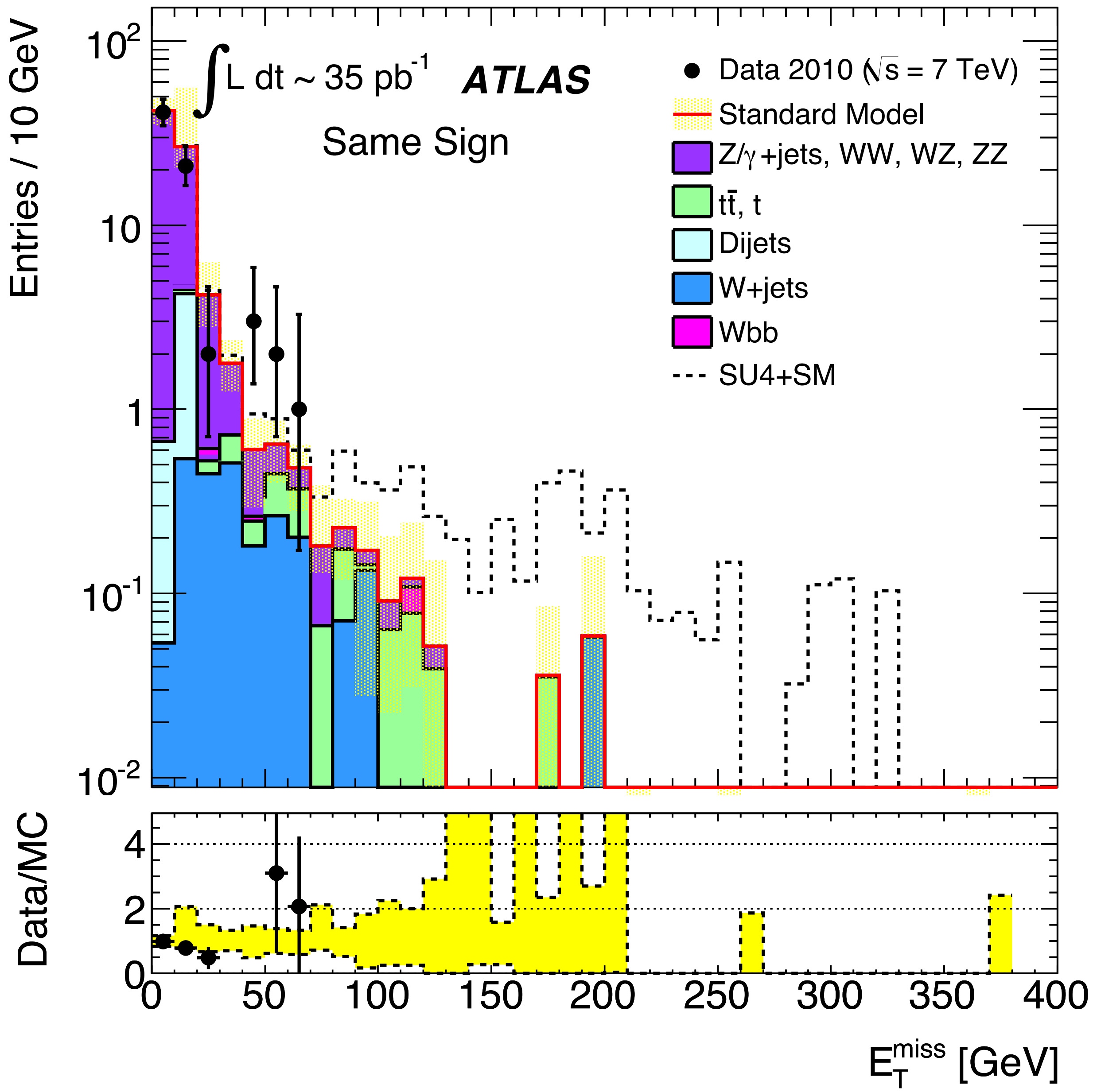
3-lep Final State



Masses (3 parameters): squark, $\chi_1^\pm/\chi_2^0$, LSP ($m_{\chi 1\pm} = m_{\chi 20}$ assumed)

Branching ratios: BR(sq→q$\chi_1^\pm$), BR(sq→qχ_2^0), BR($\chi_1^\pm$→l$\nu\chi_1^0$), BR(χ_2^0→$l^+l^-\chi_1^0$)

BG in SS 2-Lepton

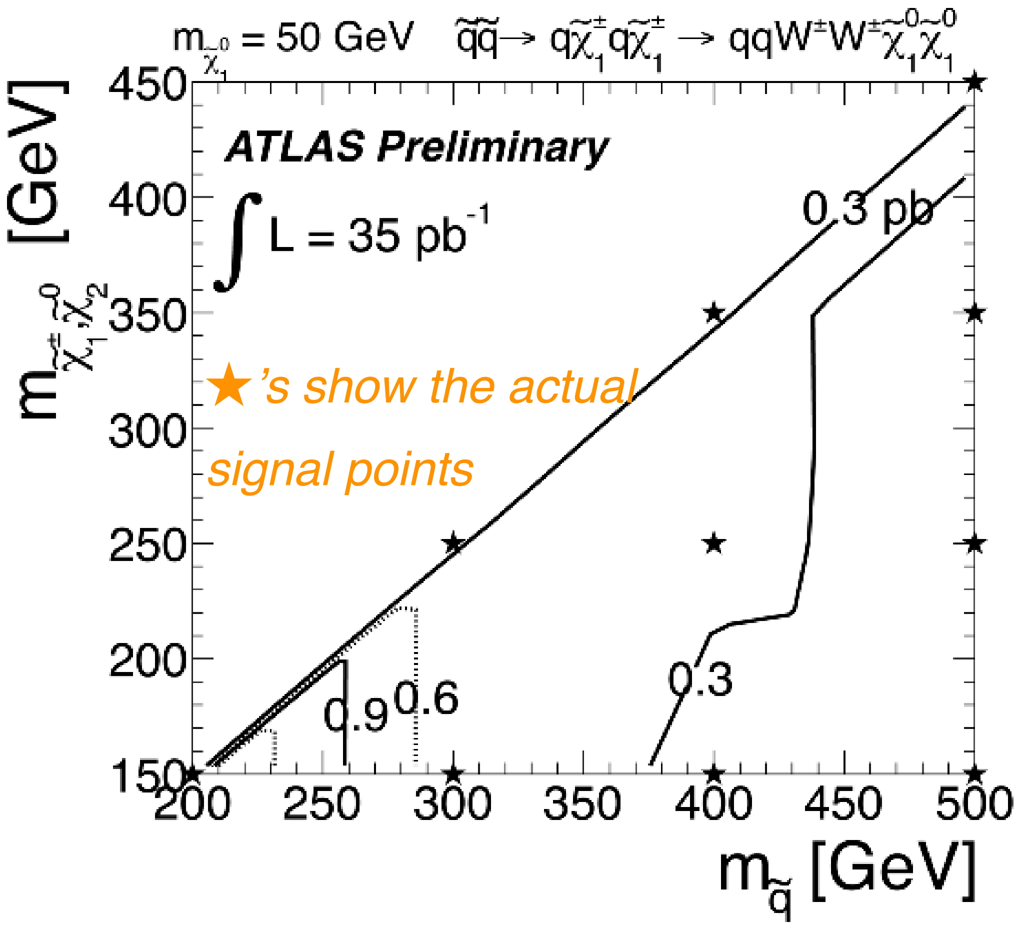


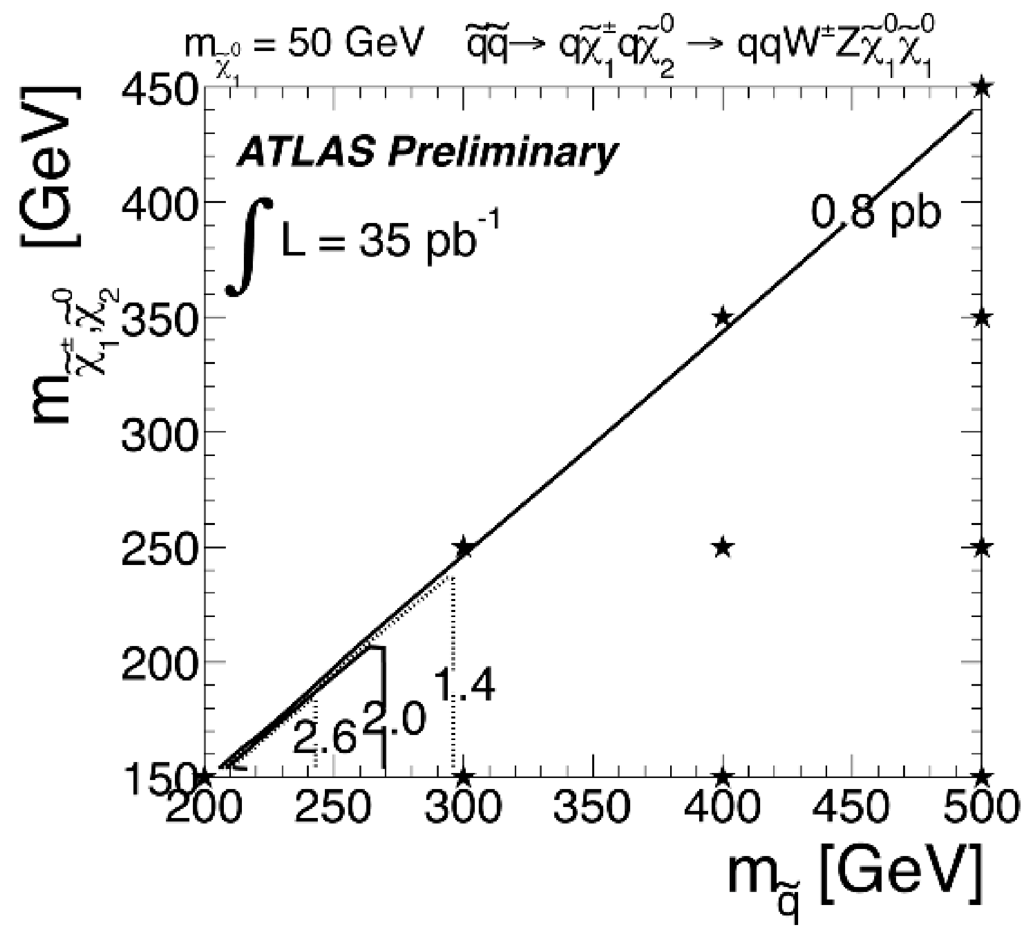
Also see T. Sarangi's talk

	Same Sign, $E_T^{miss} > 100$ GeV		
	$e^\pm e^\pm$	$e^\pm \mu^\pm$	$\mu^\pm \mu^\pm$
Data	0	0	0
Fakes	0.12 ± 0.13	0.030 ± 0.026	0.014 ± 0.010
Di-bosons	0.015 ± 0.005	0.035 ± 0.012	0.021 ± 0.009
Charge-flip	0.019 ± 0.008	0.026 ± 0.011	-
Cosmics	-	$0^{+1.17}_{-0}$	-
Total	0.15 ± 0.13	$0.09^{+1.17}_{-0.03}$	0.04 ± 0.01

- Fake BG: 2 fake leptons from $b\bar{b}$, $c\bar{c}$, multijet. 1 real + 1 fake lepton from W/Z+jets & Top. Estimated from data-driven method using loose & tight lepton selection.
- Diboson : WW, WZ, ZZ. Estimated purely from MC.
- Charge flip : electron undergoing brems/pair creation ("trident events") & reconstructed with wrong sign (other softer electrons are not identified). Mostly $t\bar{t}$.
- Cosmic BG : muons from cosmics

σ×BR Upper Limits





$$Br(\tilde{q}\tilde{q} \to qql\nu l\nu\tilde{\chi}_1^0\tilde{\chi}_1^0) = \left[Br(\tilde{q} \to q\tilde{\chi}_1^{\pm})Br(\tilde{\chi}_1^{\pm} \to l\nu\tilde{\chi}_1^0)\right]^2$$

$$Br(\tilde{q}\tilde{q} \to qql\nu l^+l^-\tilde{\chi}_1^0\tilde{\chi}_1^0) =$$
$$2Br(\tilde{q} \to q\tilde{\chi}_1^{\pm})Br(\tilde{q} \to q\tilde{\chi}_2^0)Br(\tilde{\chi}_1^{\pm} \to l\nu\tilde{\chi}_1^0)Br(\tilde{\chi}_2^0 \to l^+l^-\tilde{\chi}_1^0)$$

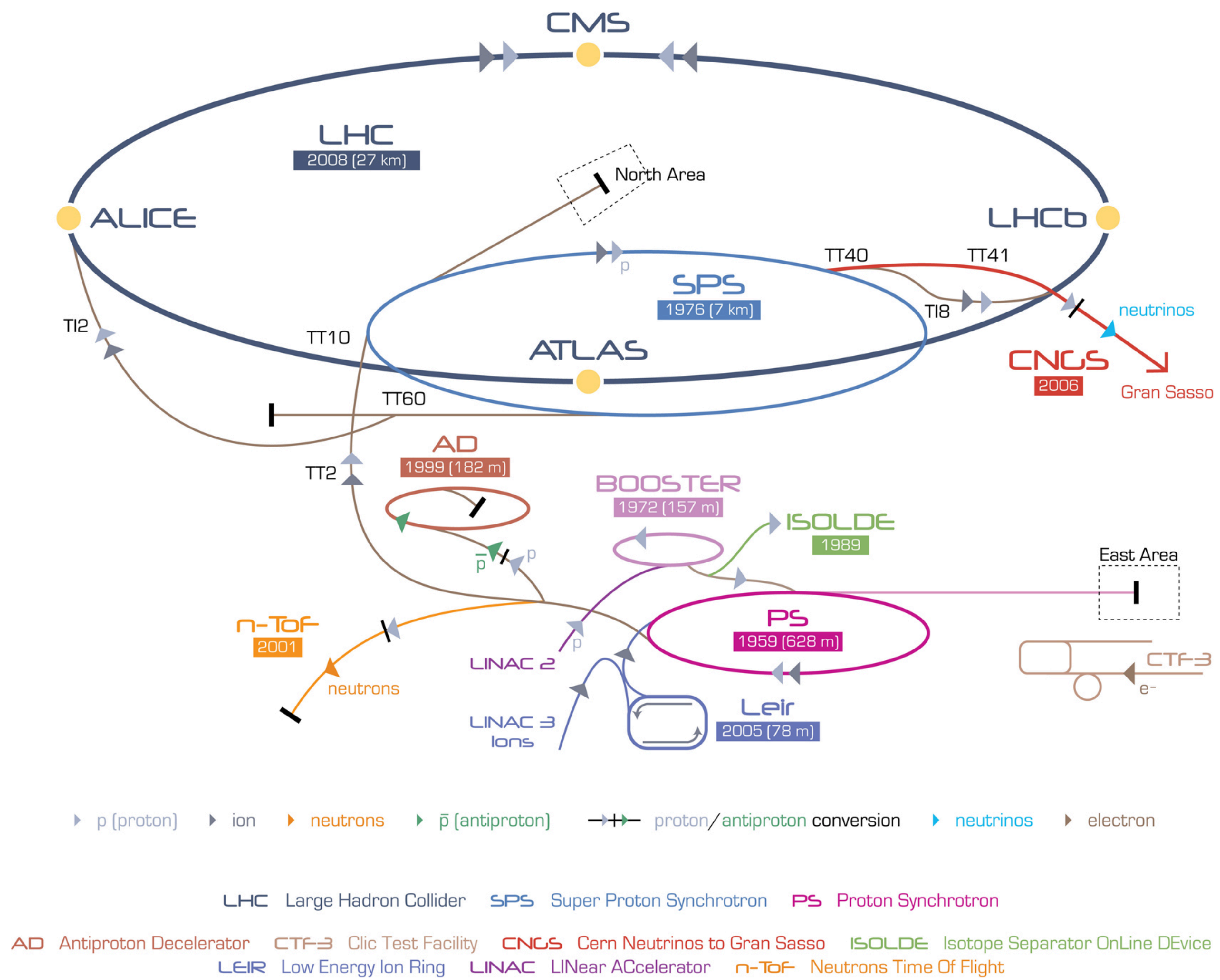
- Observed upper limits (95% CL) on σ×Br as a function of squark, weakino, and LSP masses
- Tighter upper limits for 2-lepton final state due to the acceptance
- These results can also be considered for other BSM models contributing to the same event topologies

Summary

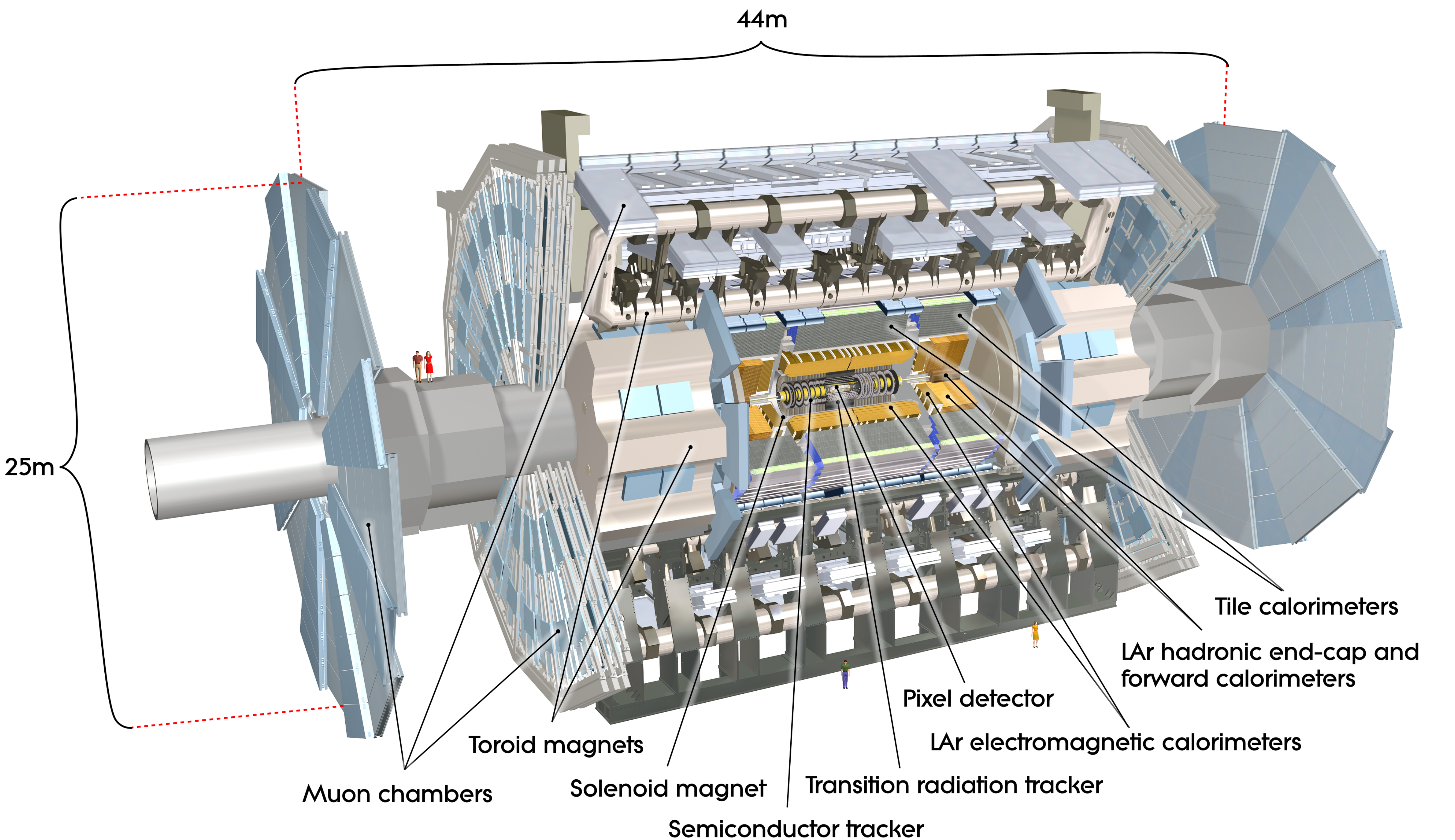
- No excess was found in no-lepton & SS 2-lepton searches
- The results were interpreted with simplified models
- Provides interface to map the results to specific models
- Also provides information about which phase space of sparticle masses are currently covered.
- Interplay between different search channels is becoming more important & currently under way.
- More simplified model results are coming for wider range of channels with larger dataset! Stay tuned!

BACKUPS

LHC


CMS
LHC
2008 (27 km)
North Area
ALICE
LHCb
TT40
TT41
p
SPS
1976 (7 km)
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
2006
Gran Sasso
TT60
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1989
p̄
p
East Area
n-ToF
2001
PS
1959 (628 m)
LINAC 2
p
CTF3
e–
neutrons
LINAC 3
Ions
LEIR
2005 (78 m)
p (proton)
ion
neutrons
p̄ (antiproton)
proton/antiproton conversion
neutrinos
electron
LHC Large Hadron Collider
SPS Super Proton Synchrotron
PS Proton Synchrotron
AD Antiproton Decelerator
CTF3 Clic Test Facility
CNGS Cern Neutrinos to Gran Sasso
ISOLDE Isotope Separator OnLine DEvice
LEIR Low Energy Ion Ring
LINAC LINear ACcelerator
n-ToF Neutrons Time Of Flight

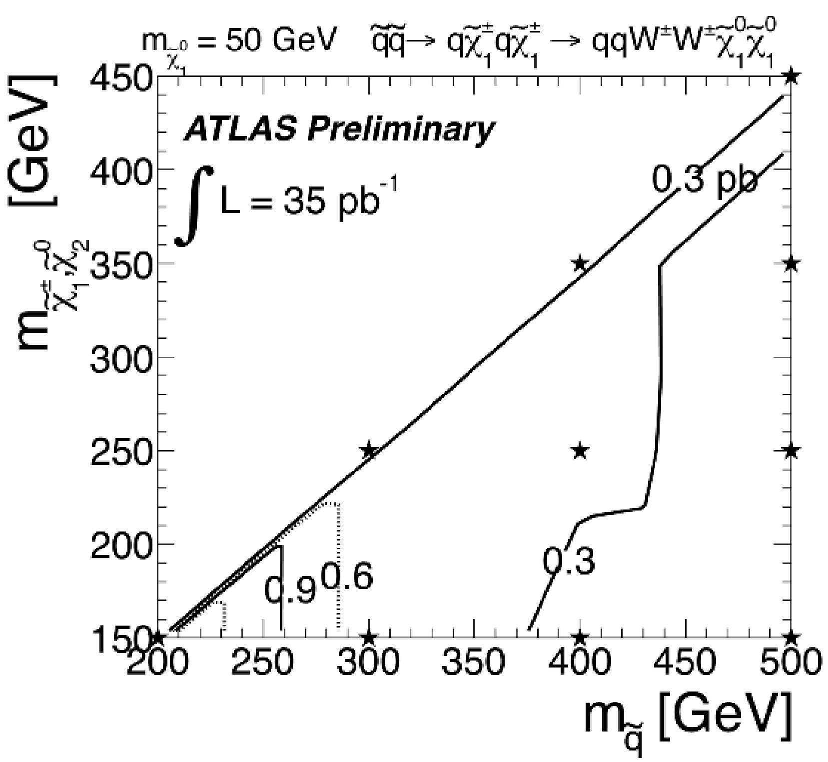
ATLAS Detector

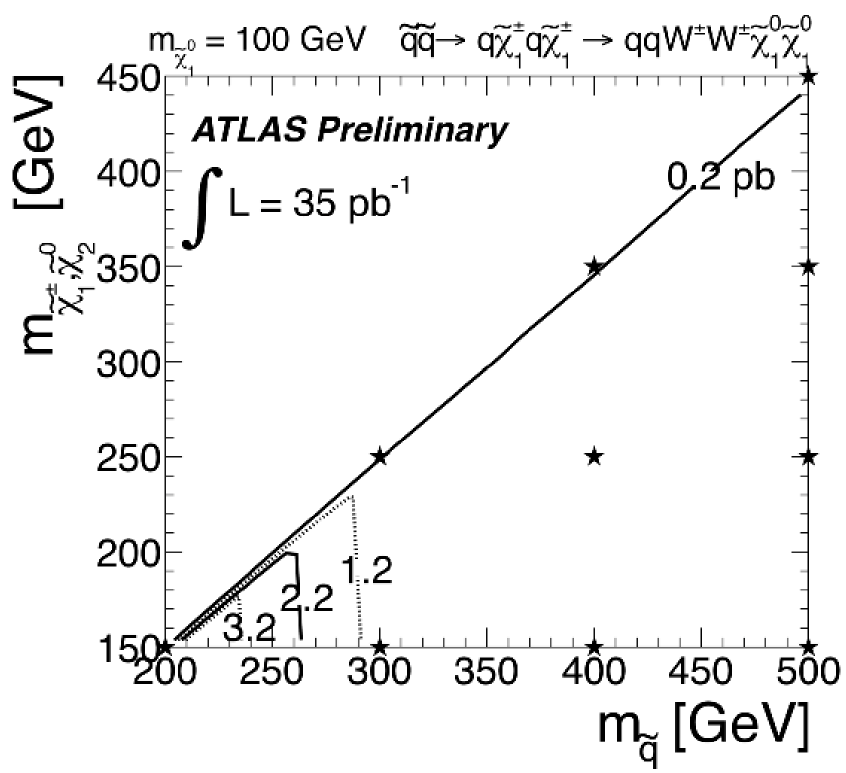


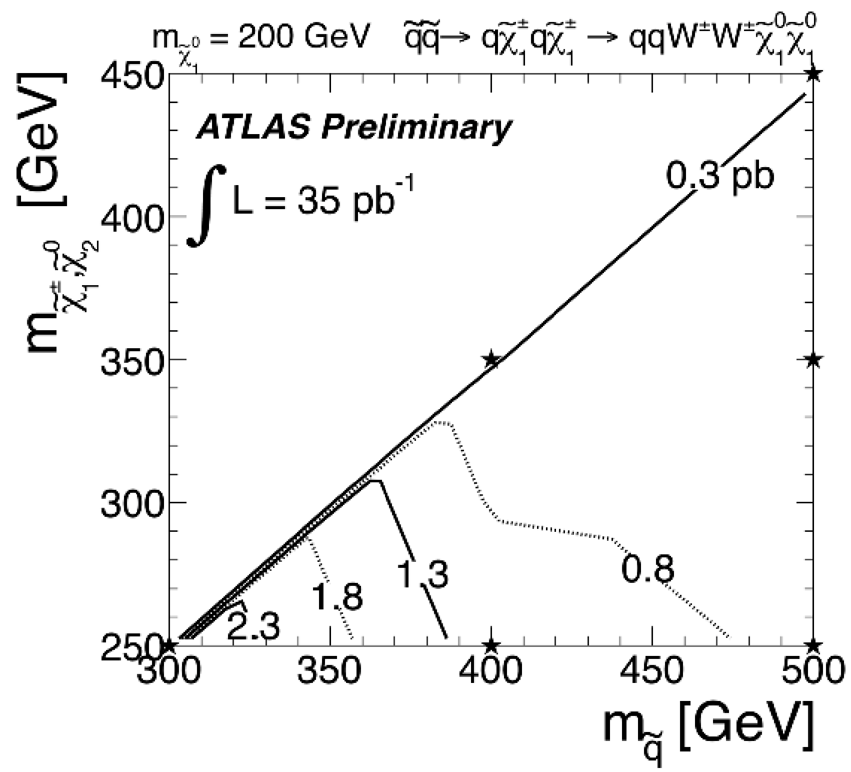
No-Lepton Search

Process	Signal Region				
	$\geq$ 2-jet	$\geq$ 3-jet	$\geq$ 4-jet, $m_{\mathrm{eff}} > 500$ GeV	$\geq$ 4-jet, $m_{\mathrm{eff}} > 1000$ GeV	High mass
Z/γ+jets	32.5 ± 2.6 ± 6.8	25.8 ± 2.6 ± 4.9	208 ± 9 ± 37	16.2 ± 2.1 ± 3.6	3.3 ± 1.0 ± 1.3
W+jets	26.2 ± 3.9 ± 6.7	22.7 ± 3.5 ± 5.8	367 ± 30 ± 126	12.7 ± 2.1 ± 4.7	2.2 ± 0.9 ± 1.2
$t\bar{t}$+ Single Top	3.4 ± 1.5 ± 1.6	5.6 ± 2.0 ± 2.2	375 ± 37 ± 74	3.7 ± 1.2 ± 2.0	5.6 ± 1.7 ± 2.1
QCD jets	0.22 ± 0.06 ± 0.24	0.92 ± 0.12 ± 0.46	34 ± 2 ± 29	0.74 ± 0.14 ± 0.51	2.10 ± 0.37 ± 0.83
Total	62.3 ± 4.3 ± 9.2	55 ± 3.8 ± 7.3	984 ± 39 ± 145	33.4 ± 2.9 ± 6.3	13.2 ± 1.9 ± 2.6
Data	58	59	1118	40	18

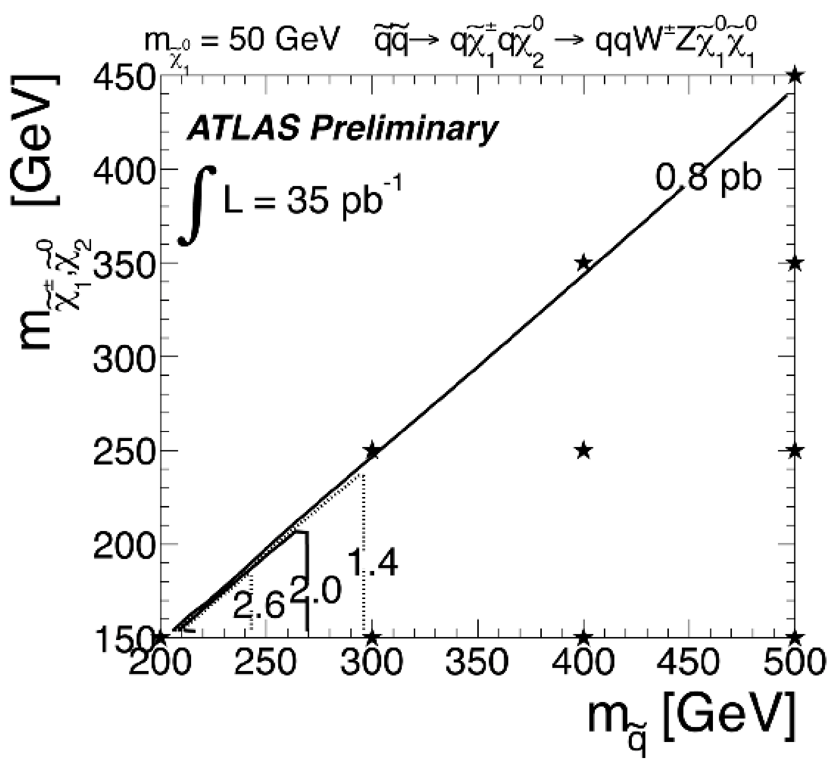
SS 2-lepton Limits

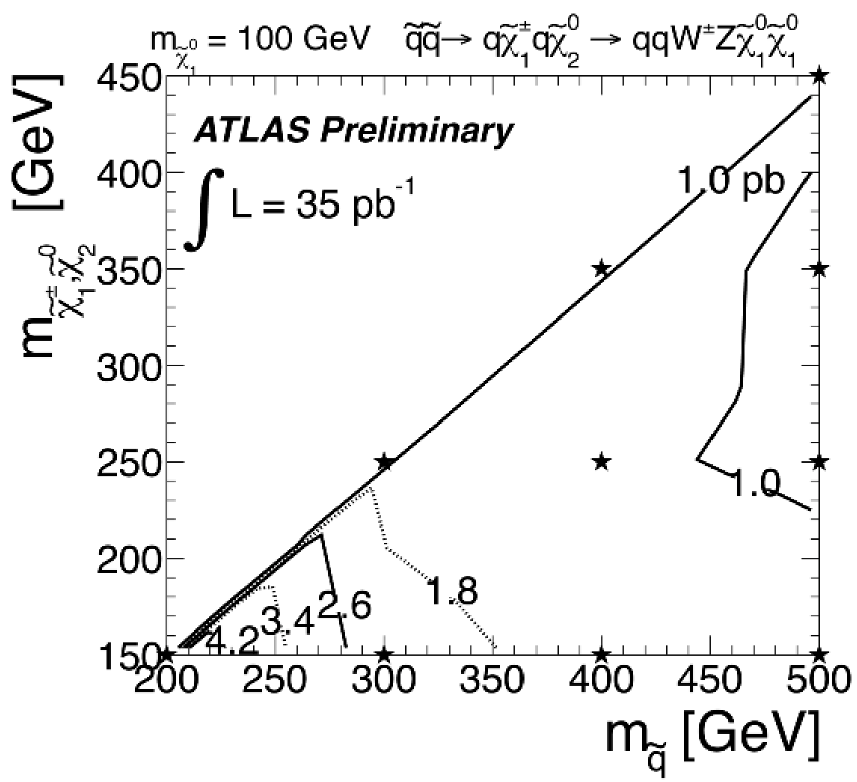


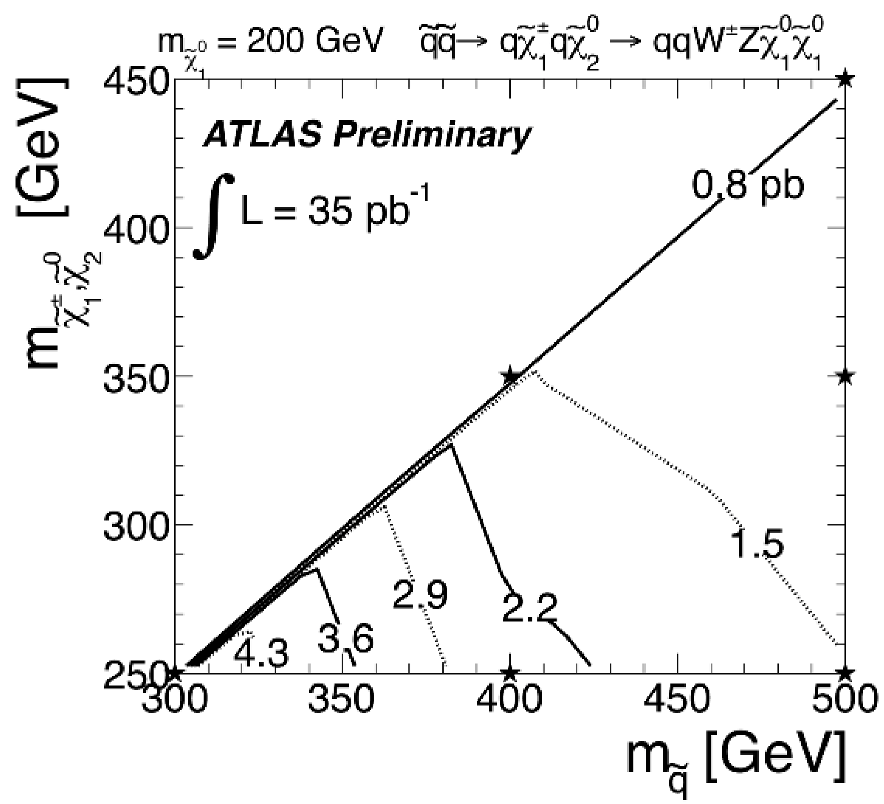




SS 2-lepton Limits







SS 2-lepton Limits