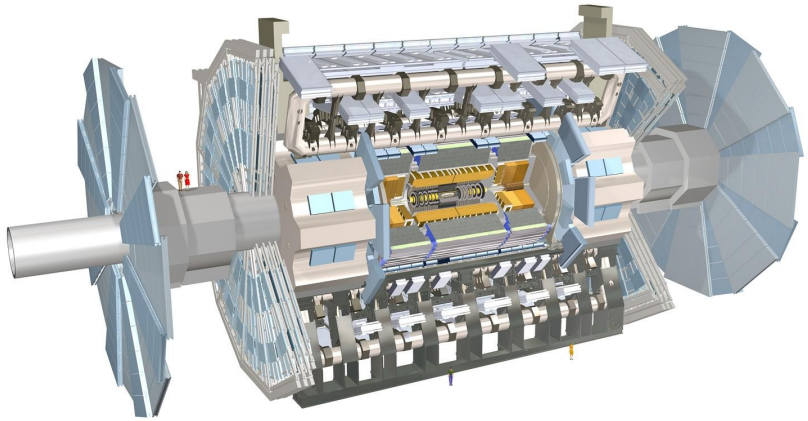


Searches for gauginos and sleptons in final states with leptons with the ATLAS detector

Tobias Kruker, Universität Bern

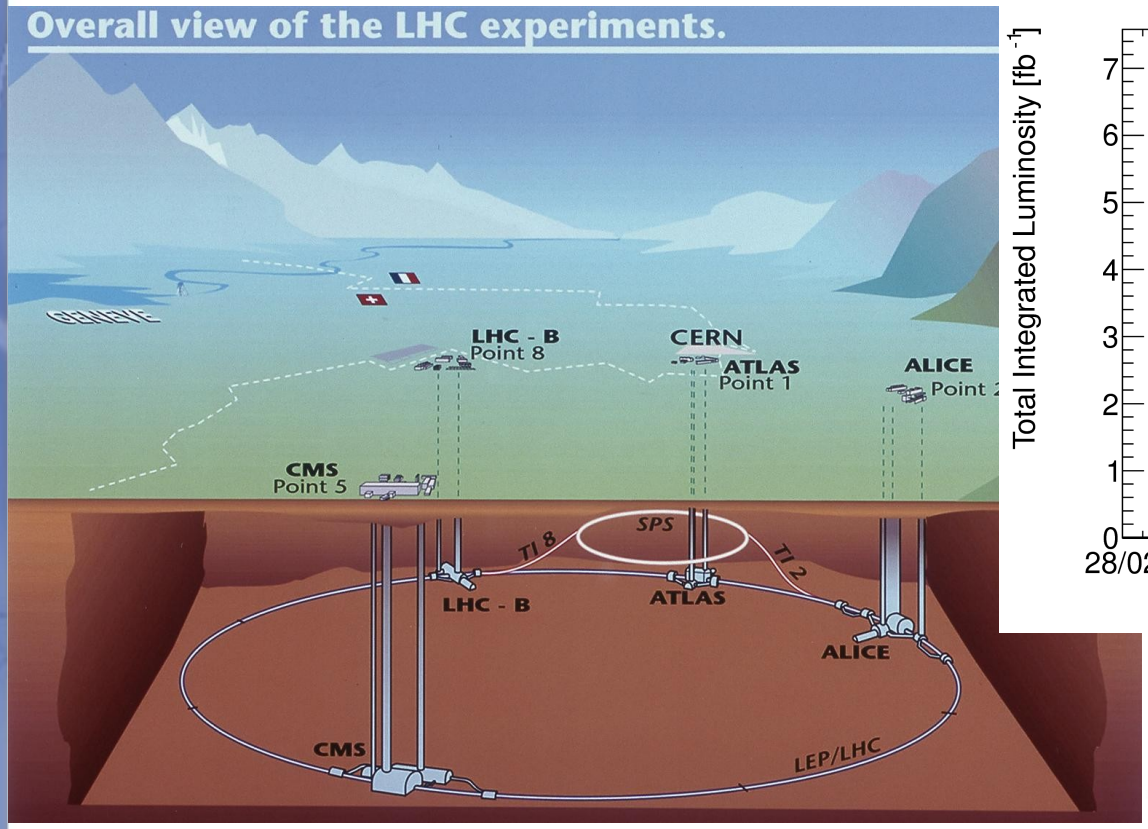
on behalf of the ATLAS Collaboration

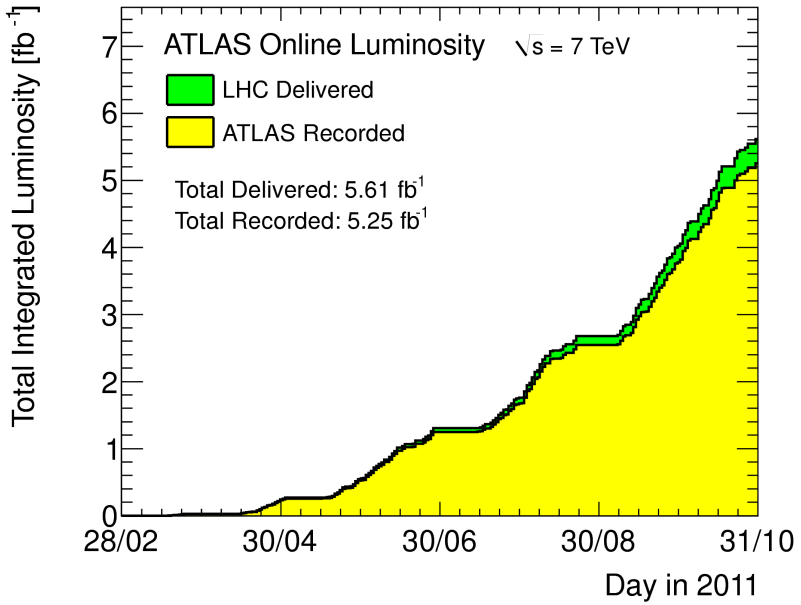
Outline

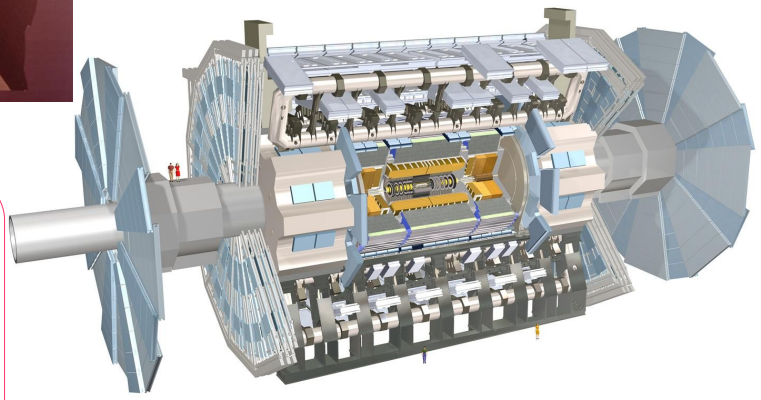
- LHC & ATLAS Detector
- Supersymmetry (SUSY)
- Searches:
  - Direct Gaugino Production in 2 and 3 Lepton Final States
  - Direct Slepton Production in 2 Lepton Final States
- Results
  - Data to Background Expectation Comparison
  - Limits on SUSY Models
- Summary

2011, $\sqrt{s}$ = 7 TeV
4.7 fb^{-1}
→ **new results** ←

LHC & ATLAS Detector



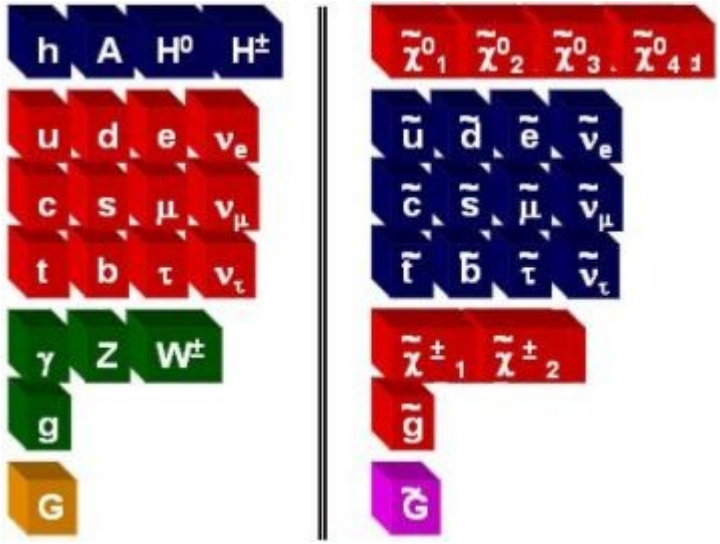




LHC 2011 Run, √s = 7 TeV
ATLAS collected 5.25 fb^{-1}
Results based on **4.7 fb^{-1}**
(after data quality and trigger requirements)

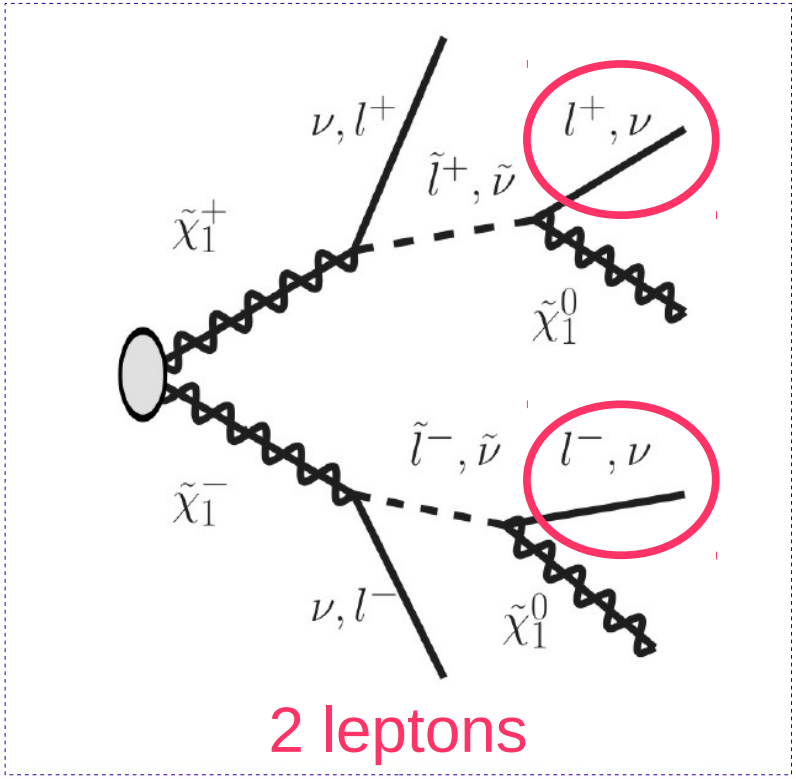
Supersymmetry (SUSY)

- Superpartners of SM electroweak gauge bosons and Higgs have spin ½ and are called Gauginos.
- *Charginos* $(\tilde{\chi}_j^{\pm}, i = 1,2)$
- *Neutralinos* $(\tilde{\chi}_i^0, j = 1,2,3,4)$
- Superpartners of fermions:
  - *sleptons* $\tilde{\ell}$
  - *squarks* $\tilde{q}$
- Superpartners of gluons:
  - *gluinos* $\tilde{g}$

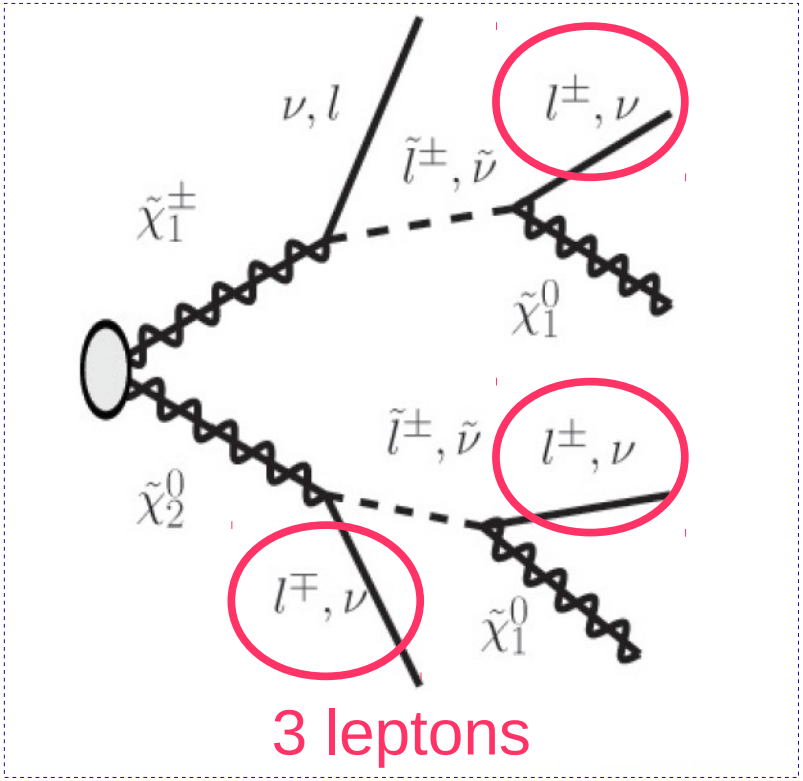


Direct Gauginos (DG)

- Gluinos and squarks are very massive: **Direct production of gauginos** may be dominant SUSY production process at LHC
- Signature of direct gauginos: multiple leptons



2 leptons

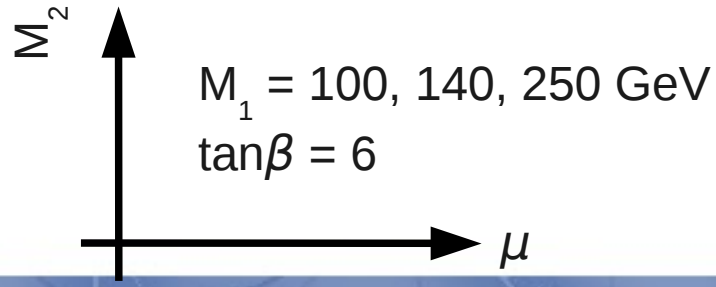


3 leptons

DG: pMSSM & Simplified Models

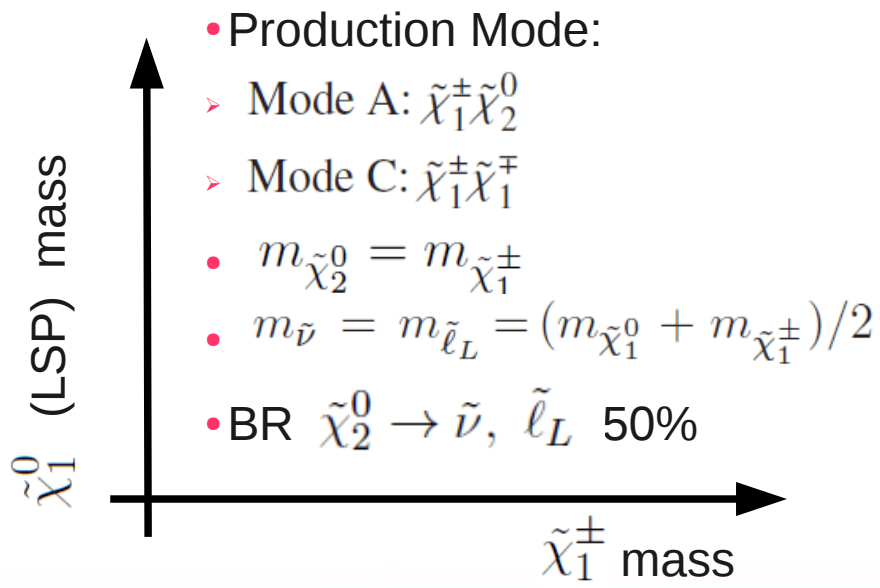
pMSSM (phenomenological MSSM)

- Gaugino x-sec governed by:
  → Gaugino masses M_1, M_2
  → Higgs mass para. μ; tanβ
- Masses of gluinos, squarks, left-handed sleptons > 2 TeV
- RH sleptons degenerate
  → $m_{\tilde{\ell}_R} = (m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0})/2$



Simplified Models

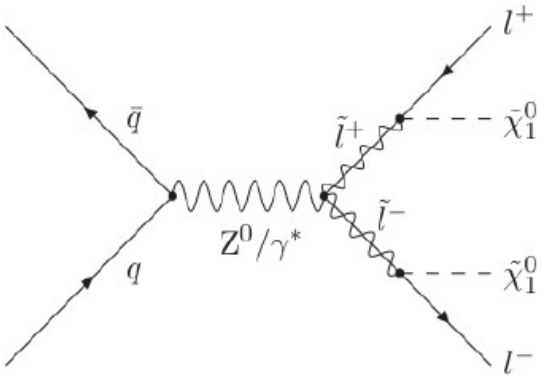
- Minimal particle content necessary to produce SUSY-like events
- Parametrized in SUSY-particle masses

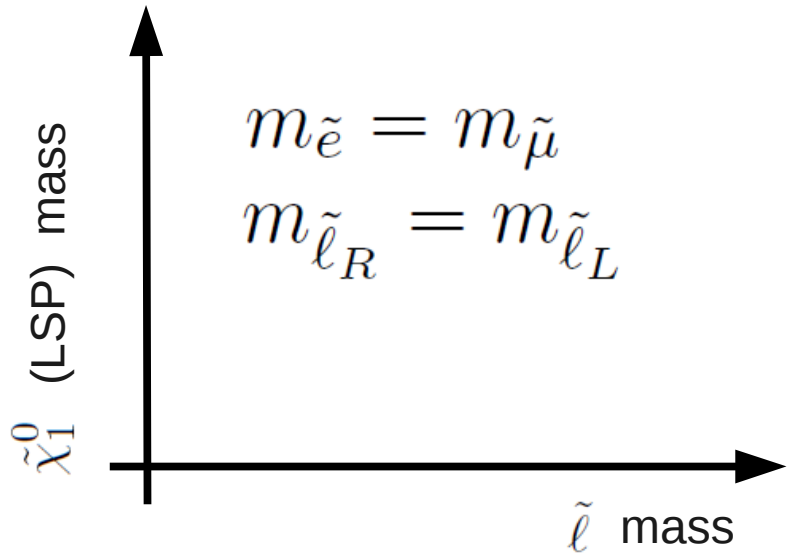


Direct Slepton (DS) Model

based on pMSSM

- Direct production of sleptons
- Masses gauginos (except $\tilde{\chi}_1^0$): 2.5 TeV



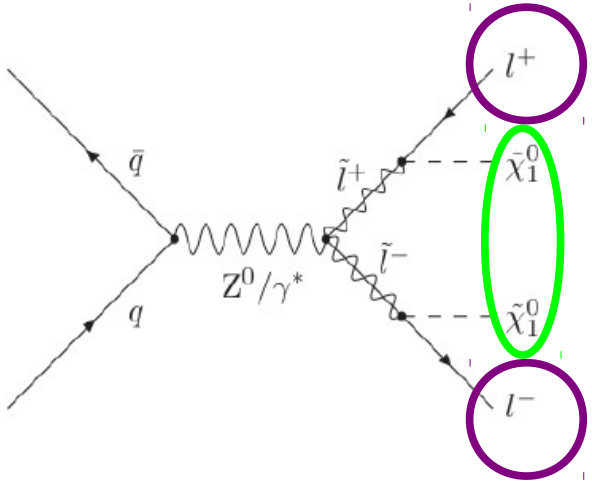


2&3 Lepton Signatures / Analyses

- Gaugino / slepton decay: multiple leptons.
  - Leptons: electrons and muons
- Two separate analyses for the 2 and 3 lepton final states.
  - Both optimized separately
  - Complement each other in final states but also in sensitivity for different models
- Both use a cut & count approach.

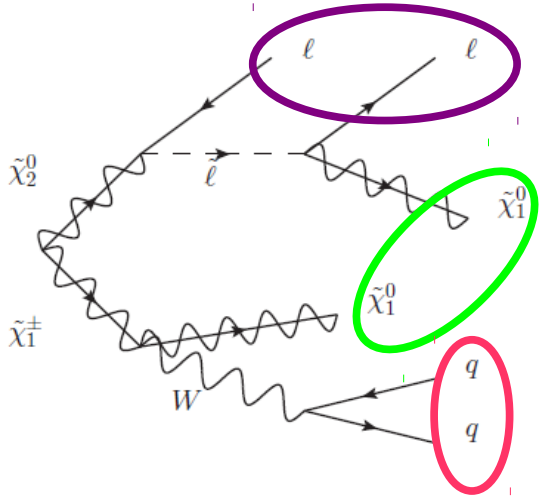
2 Lepton Analysis Signal Regions

- Four SR optimized for direct slepton production and different Chargino/Neutralino decay modes.
  - All require exactly 2 leptons and **missing transverse energy**



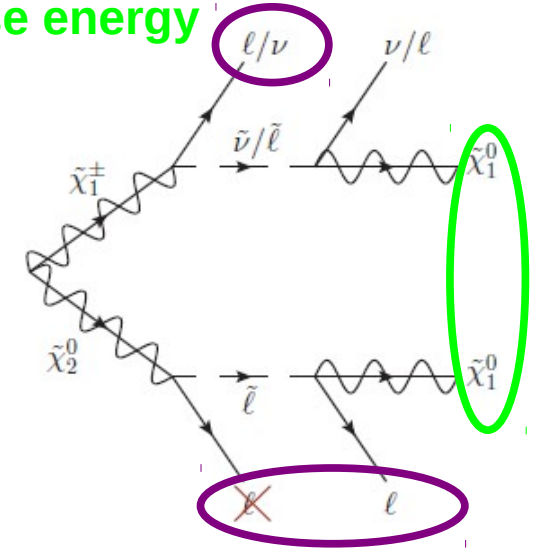
2 Lepton Final State
- Opposite charge
- BG reduction through **stransverse mass m_{T2}** cut

SR-m_{T2}



2 Lepton Final State
- Opposite charge
- 2 jets

SR-2jets



3 Lepton Final State
- Lepton not reconstructed / out of acceptance
- Opposite **or** same charge
- No jets

SR-OSjveto
SR-SSjveto

Full definitions of SR in backup.

2 Lepton Analysis: Backgrounds

Main **backgrounds** in the SR

opposite sign SR
SR - mT2, OSjveto, 2jets

top-antitop pairs, Z/γ+jets, WW:

Retrieved from data in dedicated phase-space regions (normalization regions).

- Extrapolation to SR based on MC derived transfer factors.
- [WW: determined using MC simulation in SR-mT2 and SR-2jets]

same sign SR
SR-SSjveto

Fake background from multijets / W+jets:

Matrix Method:
Categorize events according to lepton identification quality.
Use efficiency / fake rate to obtain fake contribution in SR.

3 Lepton Analysis: Signal Regions

- SR1a: sparticle decay via sleptons, off-shell bosons (Z-candidate veto) $\tilde{\chi}_2^0 \to \tilde{\ell}\bar{\ell} \to \ell\bar{\ell}\tilde{\chi}_1^0$
- SR1b: tighter version of SR1a to enhance sensitivity to large mass splittings (i.a. $p_T^{lep1,2,3} > 30$ GeV)
- SR2: sparticle decays via on-shell bosons (Z-candidate requirement) $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0 \to \ell\bar{\ell}\tilde{\chi}_1^0$
- Common: 3 leptons, $E_T^{miss} > 75$ GeV

Full definitions of SR in backup.

3 Lepton Analysis: Backgrounds

Main **backgrounds** in the SR

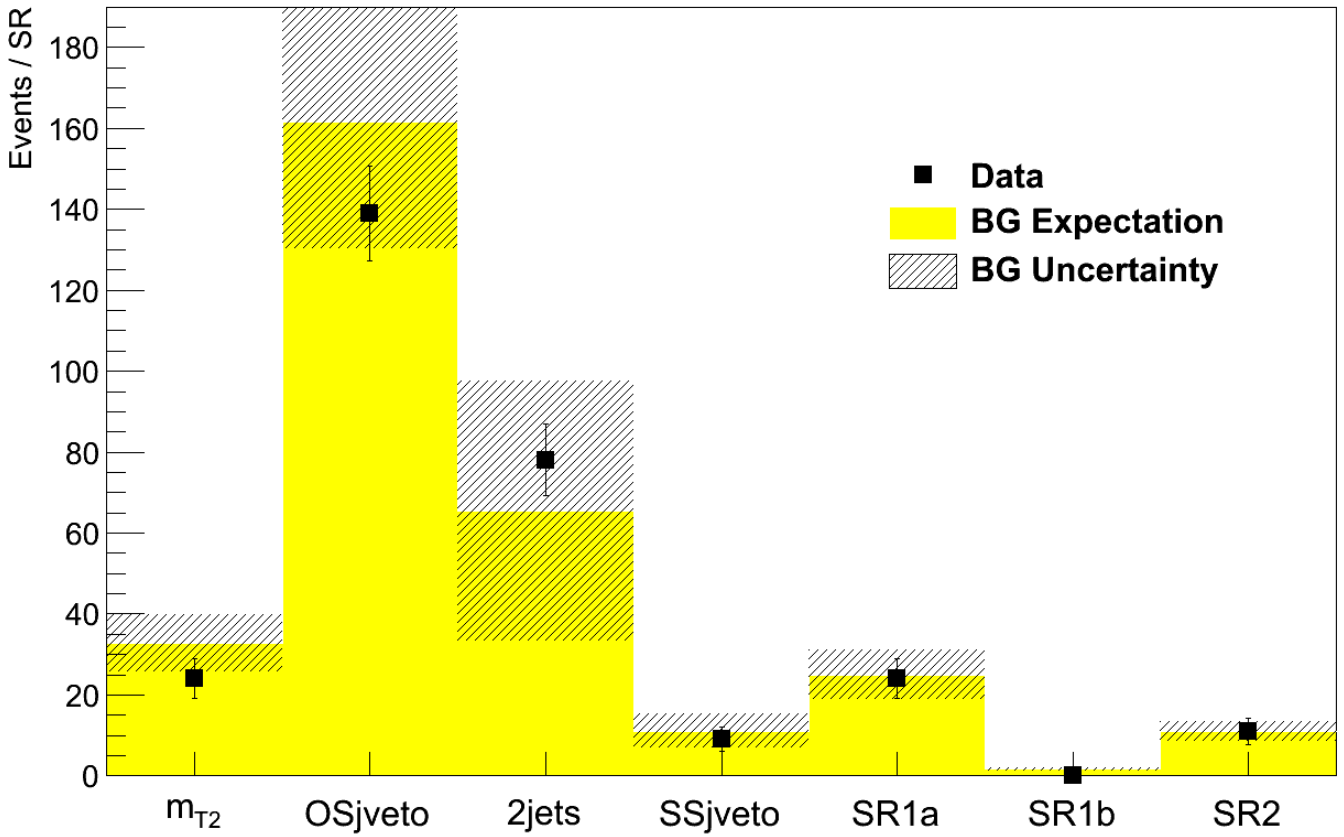
Reducible (fake) BG
at least one fake lepton
dominant: top-antitop pair production

Matrix Method

WZ/γ BG
three real, prompt leptons

Simultaneous fit:
Fit for signal and WZ/γ in SR and a dedicated WZ/γ-enhanced normalization region.

Results I: Background vs. Data



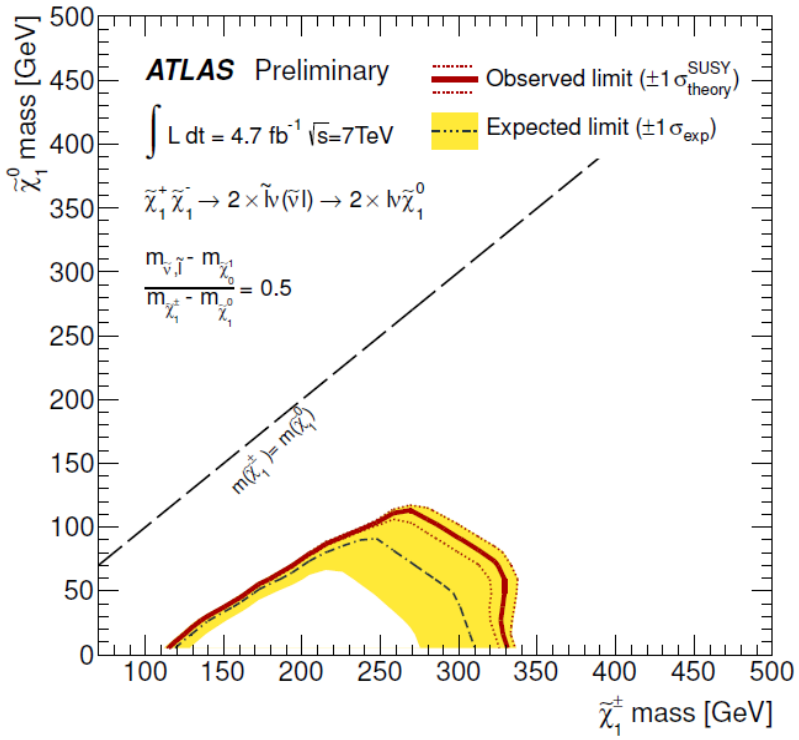
Results II: Simplified Models

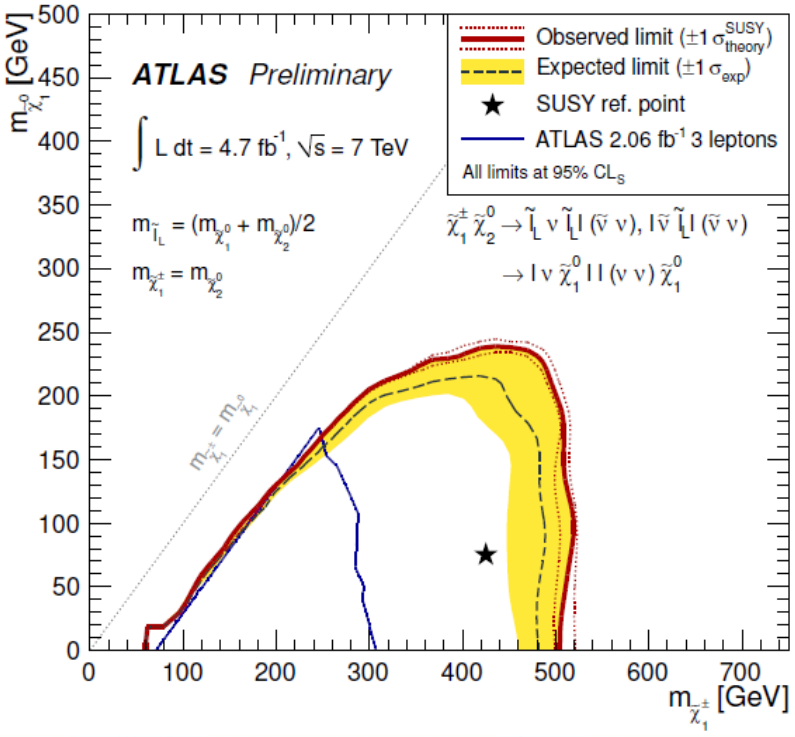
2011, $\sqrt{s}$ = 7 TeV, 4.7 fb^{-1}

2 Lepton Analysis – $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ Production

→ *1st ATLAS limits* ←

ATLAS-CONF-2012-076





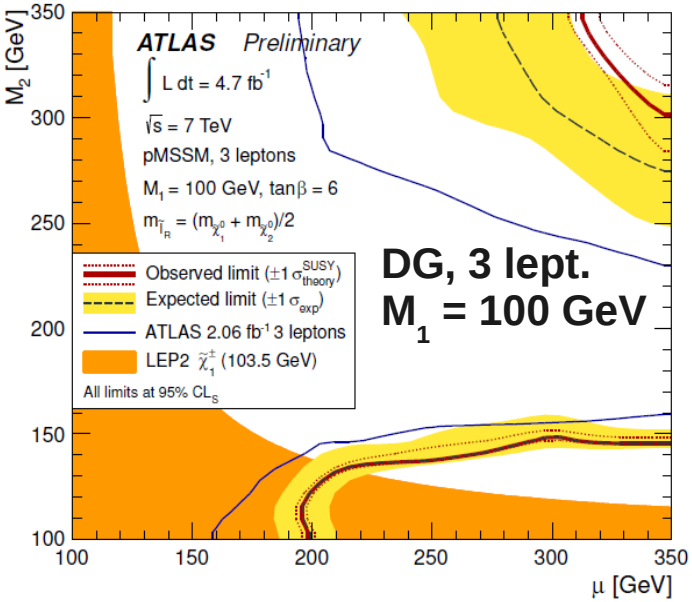
3 Lepton Analysis – $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}$ Production

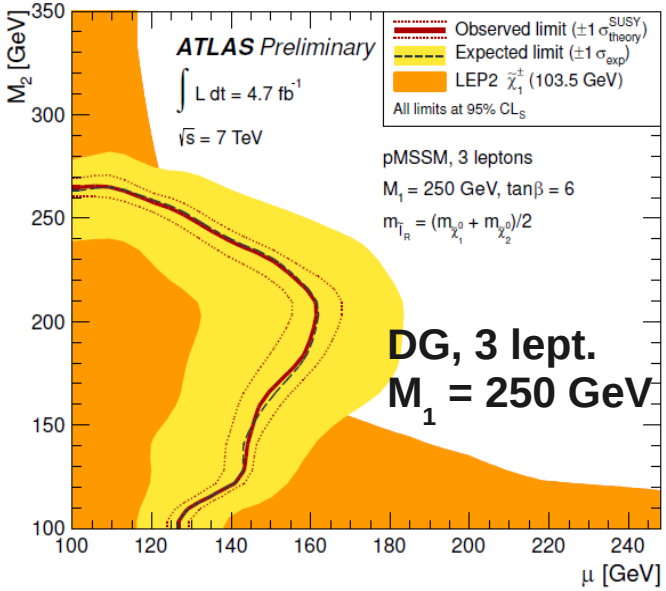
→ *extended limits* ←

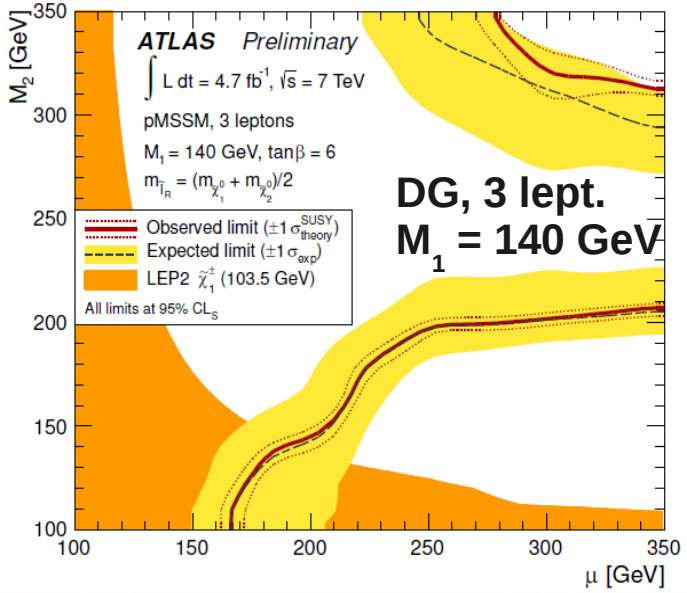
ATLAS-CONF-2012-077

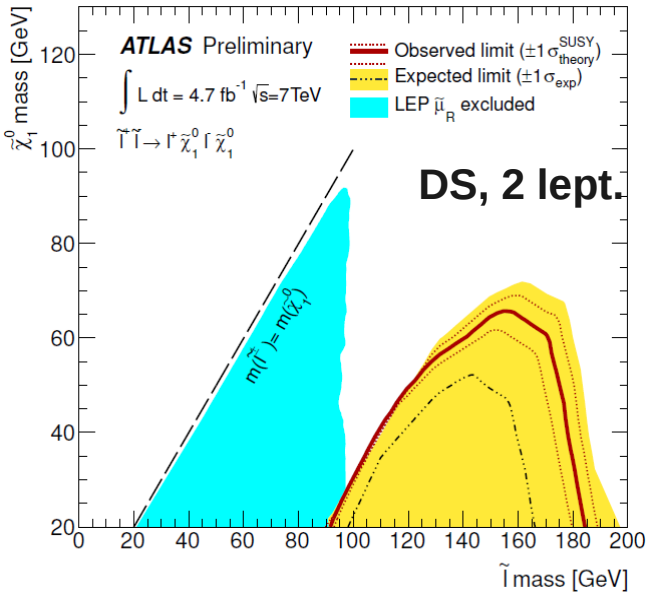
Results III: pMSSM

2011, $\sqrt{s}$ = 7 TeV, 4.7 fb^{-1}









Direct Gaugino
3 lepton analysis

ATLAS-CONF-2012-077

Direct Slepton
2 lepton analysis
→ 1st ATLAS limits ←

ATLAS-CONF-2012-076

Summary

- Dedicated and optimized direct gaugino/slepton searches with ATLAS in 2 and 3 leptons final states
- Significantly probe electroweak SUSY production
- No significant excesses observed in the full 2011 $\sqrt{s}$ = 7 TeV dataset (4.7 fb^{-1})
- First ATLAS limits on direct slepton / chargino production
- Interpretation of results in pMSSM and Simplified Models

  - 2 Lepton Analysis: ATLAS-CONF-2012-076
  - 3 Lepton Analysis: ATLAS-CONF-2012-077
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

2 Lepton Signal Regions Details I

- Exactly 2 leptons +

SR-	m_{T2}	OSjveto	SSjveto	2jets
charge	OS	OS	SS	OS
flavour	any	any		SF
m_{ll}	Z-veto	Z-veto	-	Z-veto
signal jets	$= 0$	$= 0$		≥ 2
signal b-jets	-	-		$= 0$
$E_{\mathrm{T}}^{\mathrm{miss,rel.}}$	> 40	> 100		> 50
other	$m_{T2} > 90$	-		m_{CT}-veto

- Syst. uncert. in %

SR-	m_{T2}	OSjveto	2jets	SSjveto
Total statistical	9	4	6	13
Total systematic	19	19	49	35
Jet systematics	9	8	5	3
Lepton systematics	14	1	5	1
b-tagging efficiency	1	1	14	0
MC modelling	7	17	45	4
Fake leptons	5	5	4	35

2 Leptons: Signal Region Details II

SR-m_{T2}					
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all	SF
Z+X	$3.2 \pm 1.1 \pm 1.7$	$0.3 \pm 0.1 \pm 0.2$	$3.6 \pm 1.3 \pm 1.7$	$7.1 \pm 1.7 \pm 2.1$	$6.8 \pm 1.7 \pm 2.1$
WW	$2.3 \pm 0.3 \pm 0.4$	$4.8 \pm 0.4 \pm 0.7$	$3.5 \pm 0.3 \pm 0.5$	$10.6 \pm 0.6 \pm 1.5$	$5.8 \pm 0.4 \pm 0.9$
$t\bar{t}$, single top	$2.6 \pm 1.2 \pm 1.3$	$6.2 \pm 1.6 \pm 2.9$	$4.1 \pm 1.3 \pm 1.6$	$12.9 \pm 2.4 \pm 4.6$	$6.8 \pm 1.8 \pm 2.3$
Fake leptons	$1.0 \pm 0.6 \pm 0.6$	$1.1 \pm 0.6 \pm 0.8$	$-0.02 \pm 0.01 \pm 0.05$	$2.2 \pm 0.9 \pm 1.4$	$1.0 \pm 0.6 \pm 0.6$
Total	$9.2 \pm 1.8 \pm 2.5$	$12.4 \pm 1.7 \pm 3.1$	$11.2 \pm 1.9 \pm 3.0$	$32.8 \pm 3.2 \pm 6.3$	$20.4 \pm 2.6 \pm 3.9$
Data	7	9	8	24	15
$\sigma_{vis}^{obs(exp)}$ (fb)	1.6 (1.9)	1.7 (2.2)	1.7 (2.1)	2.6 (3.8)	2.0 (2.7)

SR-OSjveto				
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Z+X	$4.5 \pm 1.2 \pm 1.2$	$3.0 \pm 0.9 \pm 0.5$	$4.7 \pm 1.1 \pm 1.2$	$12.2 \pm 1.8 \pm 1.8$
WW	$8.8 \pm 1.8 \pm 4.4$	$20.9 \pm 2.6 \pm 6.2$	$13.3 \pm 1.9 \pm 3.5$	$43.0 \pm 3.7 \pm 12.2$
$t\bar{t}$, single top	$21.1 \pm 2.3 \pm 4.2$	$47.7 \pm 3.4 \pm 20.5$	$27.5 \pm 2.5 \pm 9.0$	$96.2 \pm 4.8 \pm 29.5$
Fake leptons	$2.9 \pm 1.2 \pm 1.2$	$6.9 \pm 1.8 \pm 2.6$	$0.4 \pm 0.6 \pm 0.3$	$10.3 \pm 2.2 \pm 4.1$
Total	$37.2 \pm 3.3 \pm 6.4$	$78.5 \pm 4.7 \pm 20.9$	$45.9 \pm 3.4 \pm 9.4$	$161.7 \pm 6.7 \pm 30.8$
Data	33	66	40	139
$\sigma_{vis}^{obs(exp)}$ (fb)	3.5 (4.0)	8.1 (9.6)	4.3 (5.1)	11.4 (14.1)

SR-2jets				
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	SF
Z+X	$3.8 \pm 1.3 \pm 2.7$	—	$5.8 \pm 1.6 \pm 3.9$	$9.6 \pm 2.0 \pm 5.1$
WW	$6.4 \pm 0.5 \pm 4.3$	—	$8.4 \pm 0.6 \pm 5.7$	$14.8 \pm 0.7 \pm 9.9$
$t\bar{t}$, single top	$14.8 \pm 1.9 \pm 9.2$	—	$22.1 \pm 2.1 \pm 20.7$	$36.9 \pm 2.9 \pm 29.6$
Fake leptons	$2.5 \pm 1.2 \pm 1.5$	—	$1.7 \pm 1.3 \pm 0.8$	$4.2 \pm 1.8 \pm 2.3$
Total	$27.5 \pm 2.6 \pm 10.6$	—	$37.9 \pm 3.0 \pm 21.0$	$65.5 \pm 4.0 \pm 31.8$
Data	39	—	39	78
$\sigma_{vis}^{obs(exp)}$ (fb)	7.1 (5.1)	—	9.7 (9.6)	15.6 (13.9)

SR-SSjveto				
	e^+e^-	$e^\pm\mu^\pm$	$\mu^+\mu^-$	all
Charge flip	$0.49 \pm 0.03 \pm 0.17$	$0.34 \pm 0.02 \pm 0.11$	—	$0.83 \pm 0.04 \pm 0.18$
Dibosons	$0.62 \pm 0.13 \pm 0.18$	$1.93 \pm 0.23 \pm 0.36$	$0.94 \pm 0.16 \pm 0.26$	$3.50 \pm 0.31 \pm 0.54$
Fake leptons	$3.2 \pm 0.9 \pm 1.7$	$2.9 \pm 0.9 \pm 1.9$	$0.6 \pm 0.6 \pm 0.3$	$6.6 \pm 1.4 \pm 3.8$
Total	$4.3 \pm 0.9 \pm 1.7$	$5.1 \pm 1.0 \pm 1.9$	$1.5 \pm 0.6 \pm 0.4$	$11.0 \pm 1.5 \pm 3.9$
Data	1	5	3	9
$\sigma_{vis}^{obs(exp)}$ (fb)	0.8 (1.2)	1.5 (1.5)	1.3 (0.8)	2.0 (2.3)

3 Lepton Signal Regions Details I

Selection	SR1a	SR1b	SR2
Targeted Intermediate Decay	$\tilde{l}^{(*)}$ or Z^*		on-shell Z
N leptons (e, μ)	Exactly 3		
Lepton charge, flavour	At least one SFOS pair with $m_{\ell\ell} > 20$ GeV		
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 75 GeV		
m_{SFOS}	Z-veto	Z-veto	Z request
N b-jets	0	0	any
m_{T}	any	> 90 GeV	> 90 GeV
p_{T} ℓ_3	> 10 GeV	> 30 GeV	> 10 GeV

3 Lepton Signal Regions Details II

Selection	SR1a	SR1b	SR2
SUSY ref. point	8.0±0.8	6.5±0.6	0.46±0.05
$t\bar{t}Z$	0.06±0.05	0.025±0.023	0.6±0.5
$t\bar{t}W$	0.36±0.29	0.10±0.08	0.09±0.08
$t\bar{t}WW$	0.010±0.008	0.0023±0.0019	0.004±0.004
ZZ	0.67±0.21	0.09±0.08	0.34±0.17
WZ	13.5±3.2	1.1±0.28	9.3±2.2
Reducible Bkg.	10±5	0.35±0.34	$0.5^{+1.0}_{-0.5}$
Total Bkg.	25±6	1.6±0.5	10.9±2.4
Data	24	0	11
Visible σ (exp)	< 3.0 fb	< 0.8 fb	< 2.0 fb
Visible σ (obs)	< 3.0 fb	< 0.7 fb	< 2.0 fb

"SUSY ref. point", $(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_L}, m_{\tilde{\chi}_1^0} = 425,\ 425,\ 250,\ 75\,\text{GeV})$

Dominating systematic uncertainties

- WZ: MC generator
- Fake: Limited number of data events with three tagged leptons

Abbreviations

- MSSM: minimal supersymmetric standard model
- SFOS: same flavor opposite sign pair (e.g. electron positron pair)
- E_T^{miss}: missing energy in the transverse (i.e. perpendicular to beam axis) plain.
- M_T: transverse mass. Invariant mass in the transverse plain formed by E_T^{miss} and the lepton that does not belong to the SFOS pair that forms the best Z-candidate (mass)
- tanβ: ratio of vacuum expectation values of the two Higgs doublets
- μ: Higgs mass parameter
- m_{T2}: related to transverse mass. End-point of WW expected at 90 GeV. *J.Phys. G29 (2003) 2343-2363, Phys.Lett. B463 (1999) 99-103*
- m_{CT}: top-tagging, calc. from selected jets and leptons:

$$m_{\mathrm{CT}}^2(v_1, v_2) = [E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\mathbf{p}_{\mathrm{T}}(v_1) - \mathbf{p}_{\mathrm{T}}(v_2)]^2,$$

- $$E_{\mathrm{T}}^{\mathrm{miss,rel.}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$