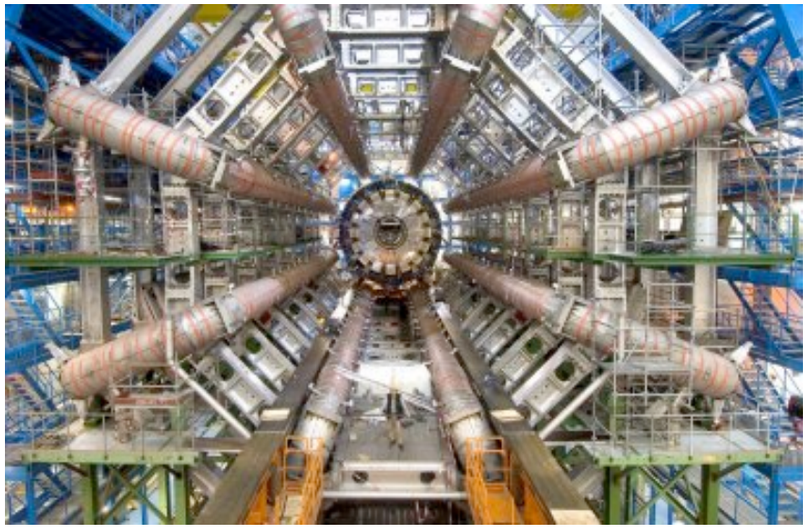
Searching for SUSY at ATLAS with Trilepton and Missing Transverse Momentum

SUSY08, Seoul

19/06/2008



- Importance of trilepton signature
- ATLAS' approach so far
- Discovery potential and plans for future

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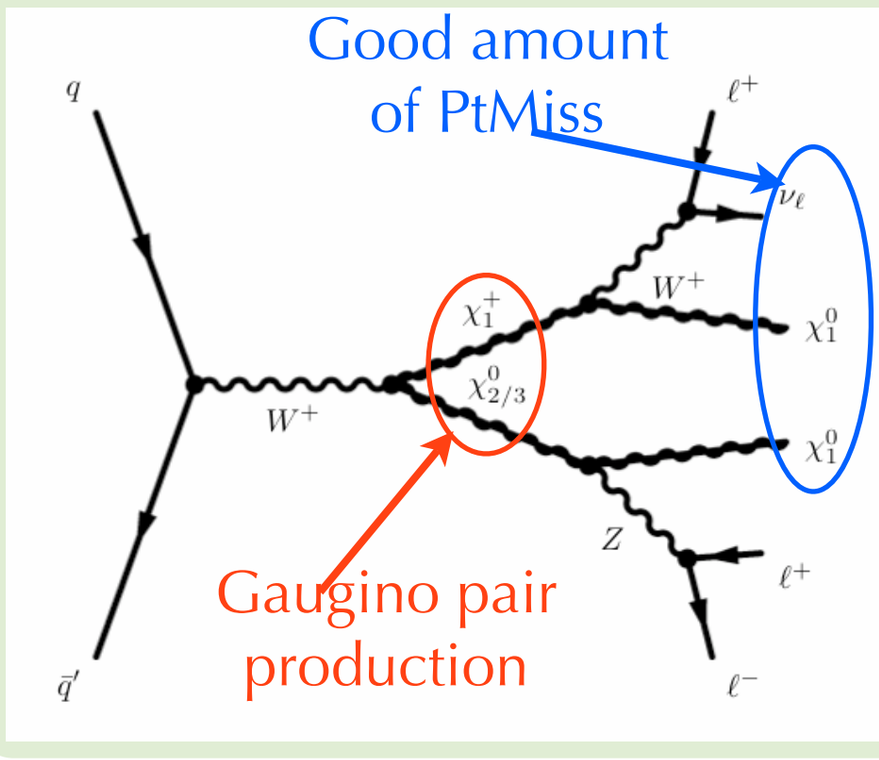
Introduction



✓Channels with multi-lepton and missing transverse momentum (PtMiss) has always been in the SUSY discovery pool at LHC

✓Here, we measure the discovery potential of three lepton and PtMiss with little jet activity in the final state

✓In SUSY R-parity conserved scenario leptonic final states are produced from the pairs of heavy gaugino decay through virtual W/Z decay or through sleptons

✓The analysis considered only the mSUGRA framework which is characterized by five parameters

✓In ATLAS, several benchmark points are studied within these parameter space

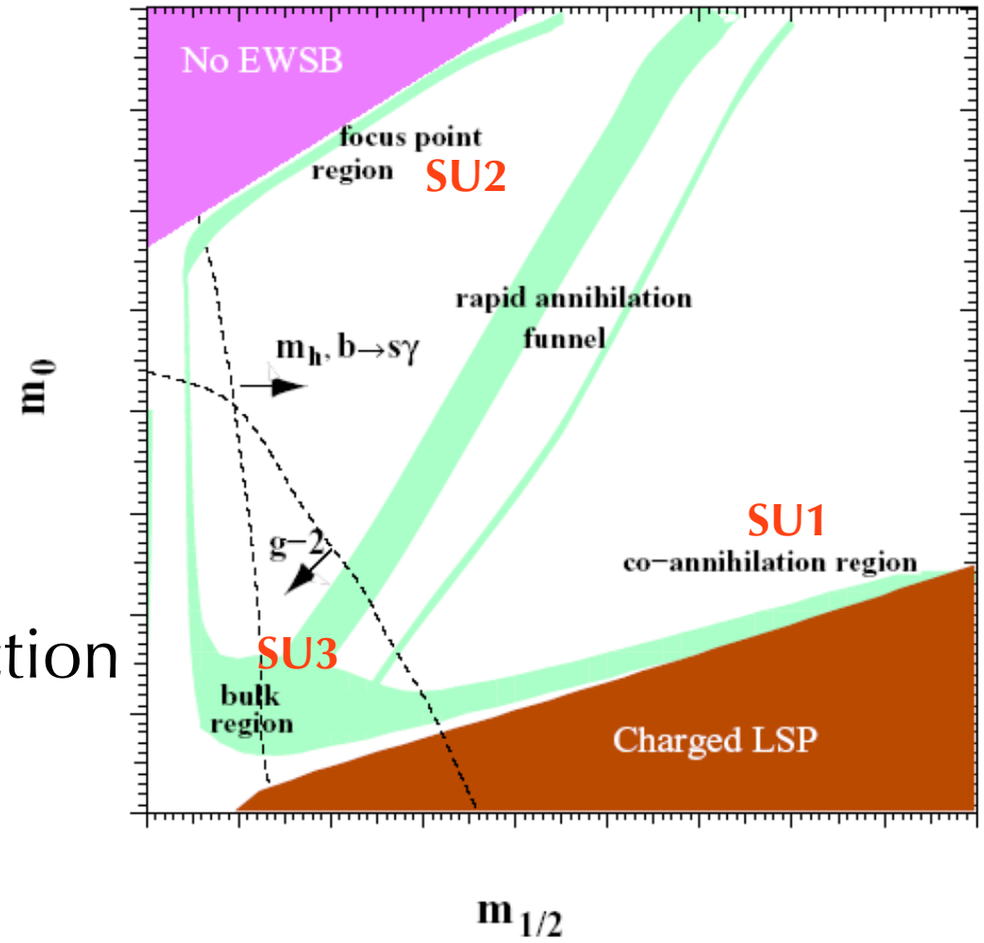
Parameter	SU1	SU2	SU3	SU4	SU8
m_0	70	3550	100	200	210
$m_{1/2}$	350	300	300	160	360
A_0	0	0	−300	−400	0
$\tan\beta$	10	10	6	10	40
signμ	+	+	+	+	+

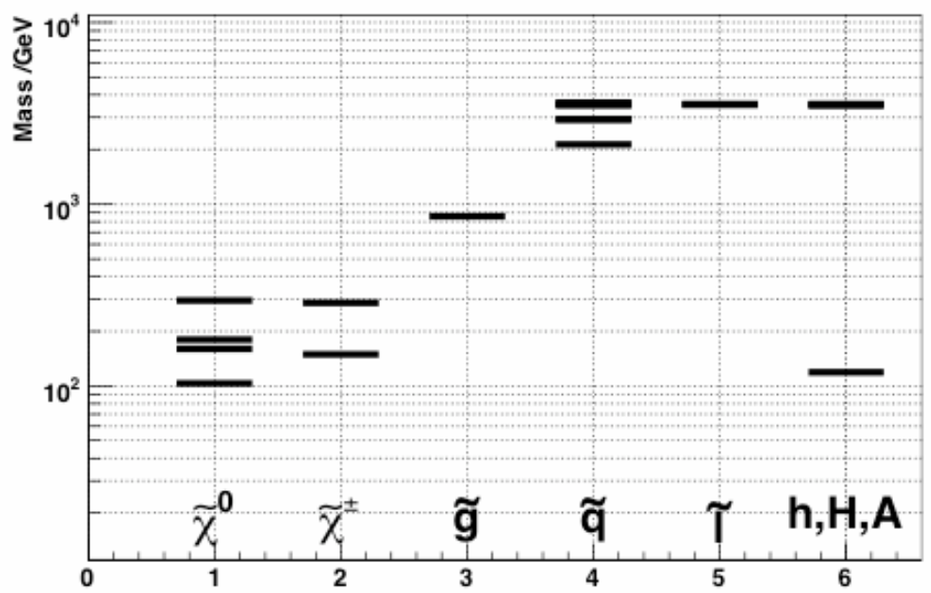
Benchmark point

✓For the trilepton analysis we considered SU2 as the important benchmark point

✓It lies within the focus point region of m_0, $m_{1/2}$ plane

✓This is the only region of mSUGRA parameter space where there is a larger cross-section for direct gaugino pair production than any other considered points





[sparticle mass spectrum in SU2]

✓Squarks and sleptons are very heavy in this region and make the cross-section smaller for discovery with jets and PtMiss at LHC

✓Still, abundant gluino and gaugino production keeps it's potential for discovery in multi-lepton final state

Gaugino pair production in benchmark point SU2

✓Exclusive trilepton signal for SU2 is dominated by the pair production of lighter chargino ($\tilde{\chi}_1^{\pm}$) and 2nd lightest neutralino ($\tilde{\chi}_2^0$)

✓Where, $\tilde{\chi}_1^{\pm} \to \tilde{\chi}^0 l^{\pm} \nu$

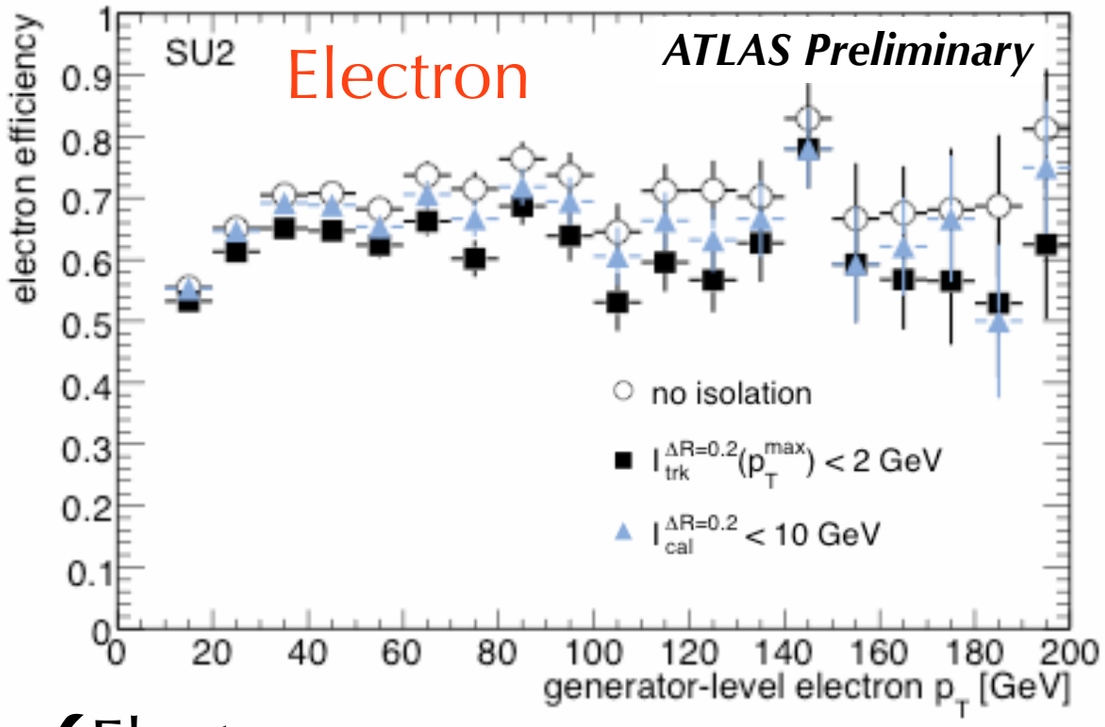
$\tilde{\chi}_2^0 \to \tilde{\chi}^0 l^+ l^-$

Sparticle	Decay Mode	B.R.
$\tilde{\chi}_2^0$	$\tilde{\chi}_1^0 \ell^+ \ell^-$	7%
$\tilde{\chi}_3^0$	$\tilde{\chi}_1^0 \ell^+ \ell^-$	7%
$\tilde{\chi}_4^0$	$\tilde{\chi}_1^{\pm} W^{\mp}$	81%
	$\tilde{\chi}_3^0 Z$	12%
$\tilde{\chi}_1^{\pm}$	$\tilde{\chi}_1^0 l^{\pm} \nu$	22%
$\tilde{\chi}_2^{\pm}$	$\tilde{\chi}_2^0 W^{\pm}$	38%
	$\tilde{\chi}_3^0 W^{\pm}$	18%
	$\tilde{\chi}_1^{\pm} Z$	30%

Production	σ [fb]	Trilepton events /10 fb^{-1}
$\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0$	1138.0	175
$\tilde{\chi}_1^{\pm} \tilde{\chi}_3^0$	679.3	105
$\tilde{\chi}_1^{\pm} \tilde{\chi}_4^0$	51.4	6
$\tilde{\chi}_2^{\pm} \tilde{\chi}_2^0$	58.5	7
$\tilde{\chi}_2^{\pm} \tilde{\chi}_3^0$	61.6	7
$\tilde{\chi}_2^{\pm} \tilde{\chi}_4^0$	310.3	26
TOTAL		326

[Leading Order cross-sections are mentioned here]

Lepton ID, Efficiency



✓Electron :

- Pt>10 GeV, |eta|<2.5
- Events that fall into the barrel-endcap transition region were rejected
- Require energy < 10 GeV in a cone of radius DR($\sqrt{\Delta\eta^2 + \Delta\phi^2}$) < 0.2 around the electron

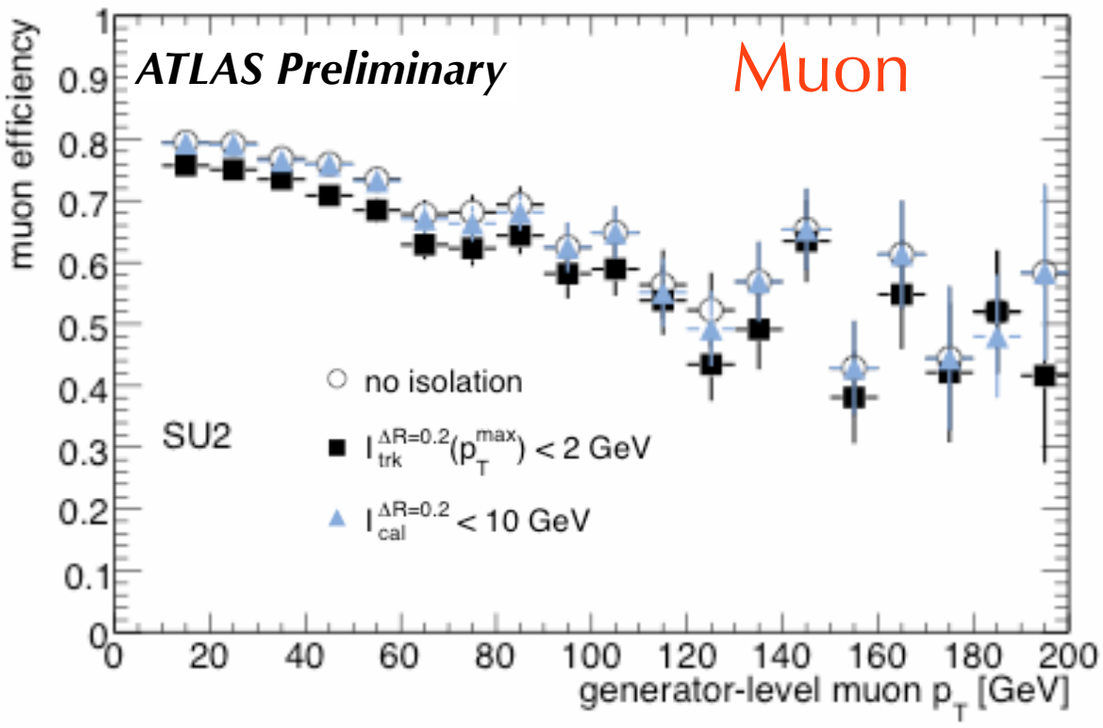
✓Muon :

- Pt>10 GeV, |eta|<2.5
- Find the best match with the inner detector track
- Track segment match Chi2 is required to be < 100
- An isolation energy in the calorimeter surrounding muon within a cone of DR<0.2 is applied to be < 10 GeV

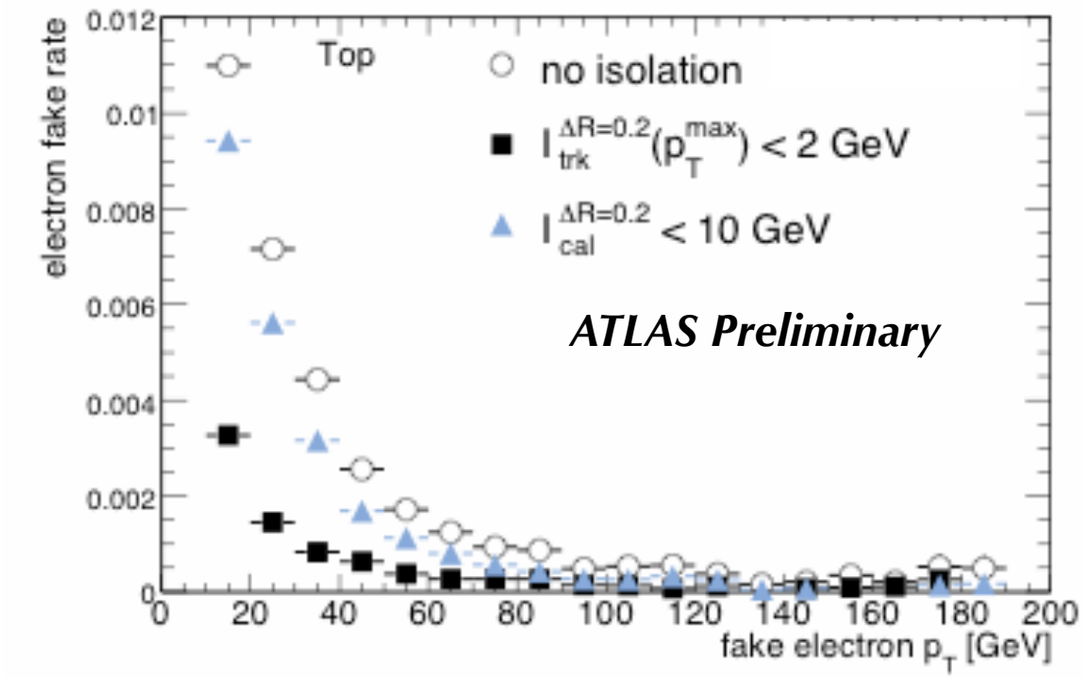
✓Good lepton selection criteria is crucial for measurements like this

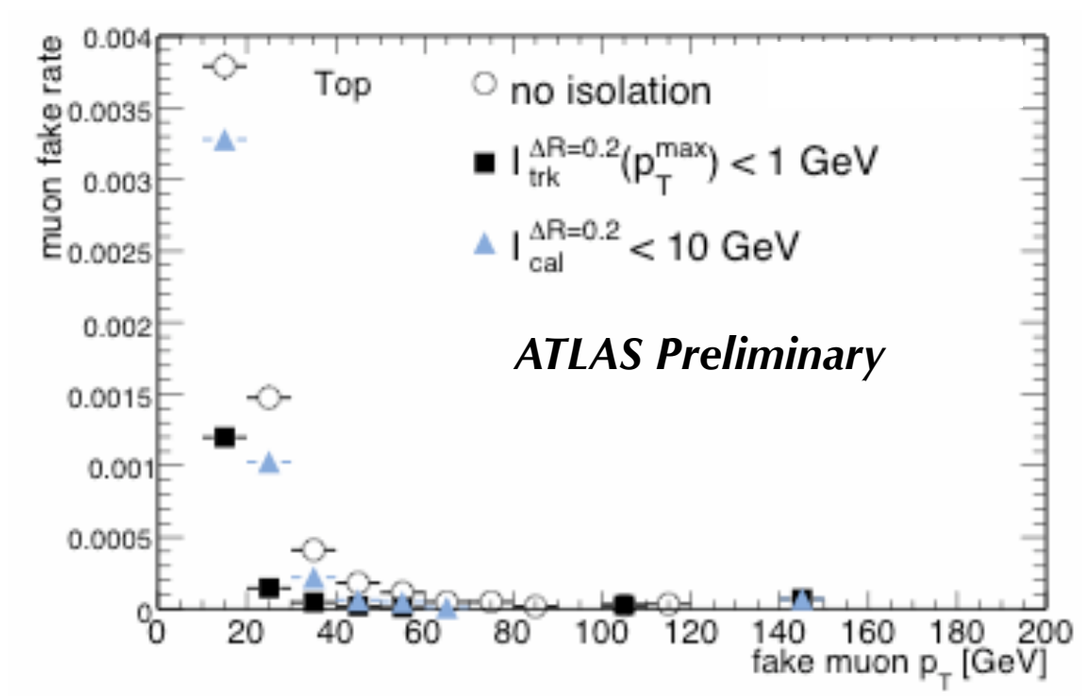
✓ Electron and Muon identification are done based on official ATLAS criteria

✓In this analysis a lower Pt threshold of 10 GeV is used in an attempt to improve the trilepton event rate



Fake Lepton Rate





✓Jets :

- Pt > 10 GeV, |eta|<2.5
- Reconstructed based on calorimeter tower signals with a seeded cone algorithm of size 0.4
- Those overlap with an electron/muon within a DR(lep,jet) < 0.2 are not considered

✓Veto Electrons and Muons if DR(lep, jet) < 0.4 (referred as no isolation in the plots)

✓This reduces the efficiency (few %) but acts as very good discriminant already in reducing the fake background from top sample

✓Using the overlap removal criteria

fake rate = 4.1±0.1 x 10-3 (electrons)

= 1.1±0.1 x 10-3 (muons)

✓The isolation criteria provides relative suppression of fake rate :

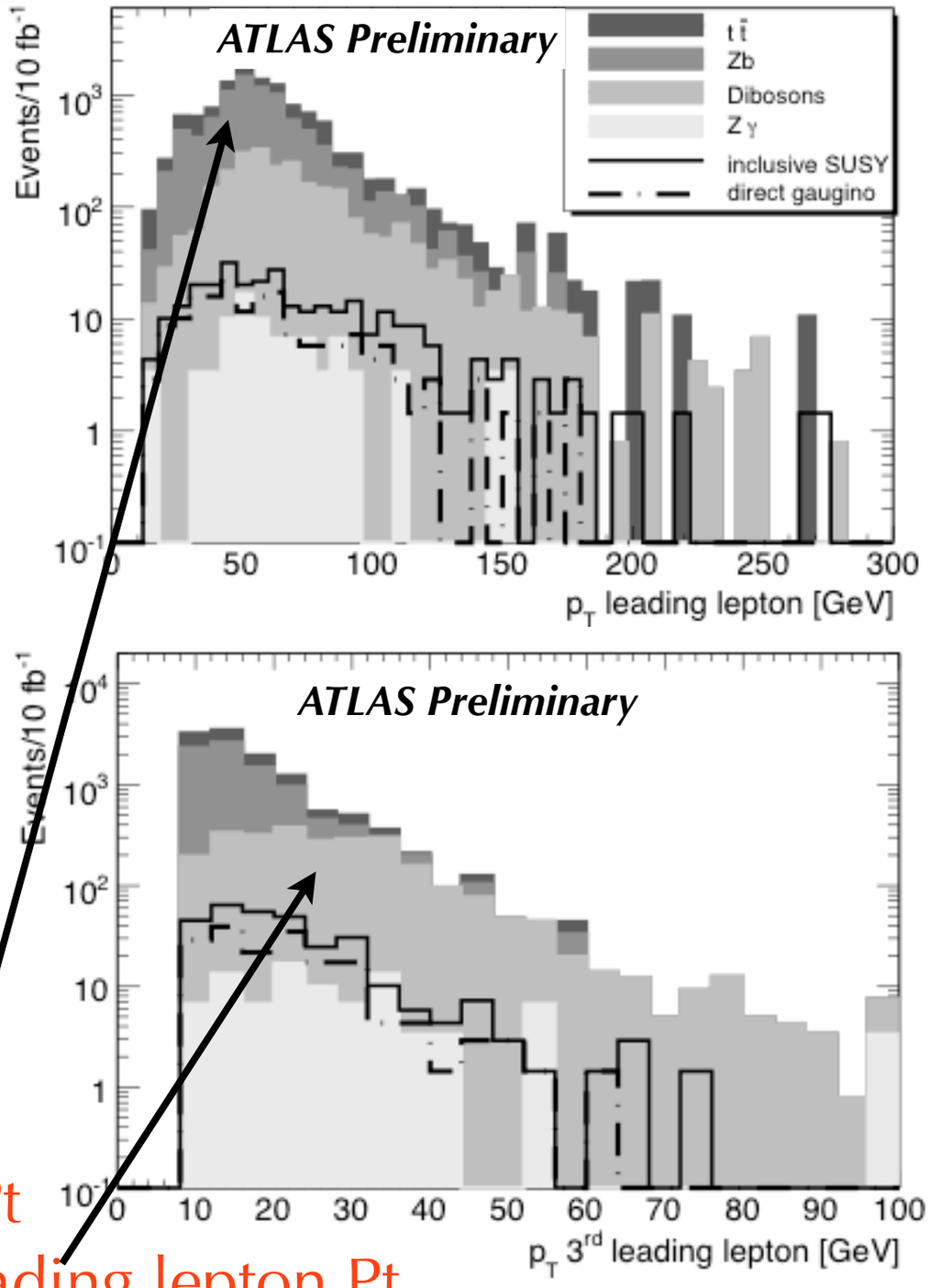
20% (calorimeter isolation< 10 GeV)

74% (track isolation < 2/1 GeV, e/mu)

Event Selection-i

✓**Signal events are divided into two categories**

- Inclusive SUSY particle pair production
  - A general case where we obtain signal from different benchmark points
  - Here, the three leptons are produced in the cascade decays of heavier sparticles, typically squarks and gluinos
- Direct production of chargino and neutralino only
  - This is for harder case at LHC where the final state is obtained from gaugino pair production and the coloured sparticles are very heavy to be contained with high jet activity
  - This scenario is sensitive to SUSY while the other signatures (requiring jets) will have more difficulties making a discovery

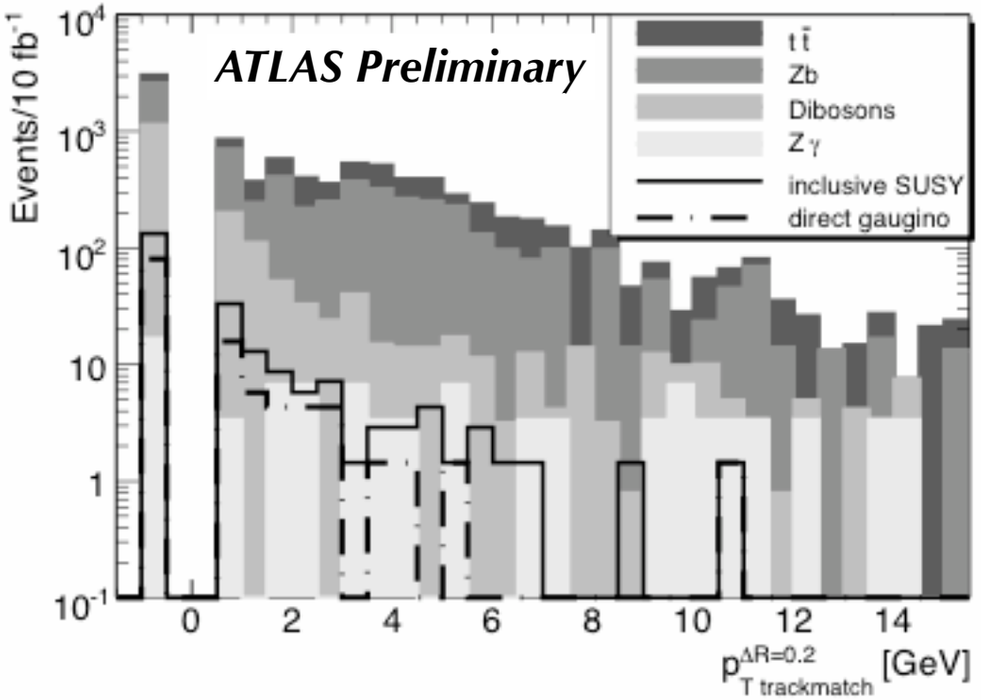


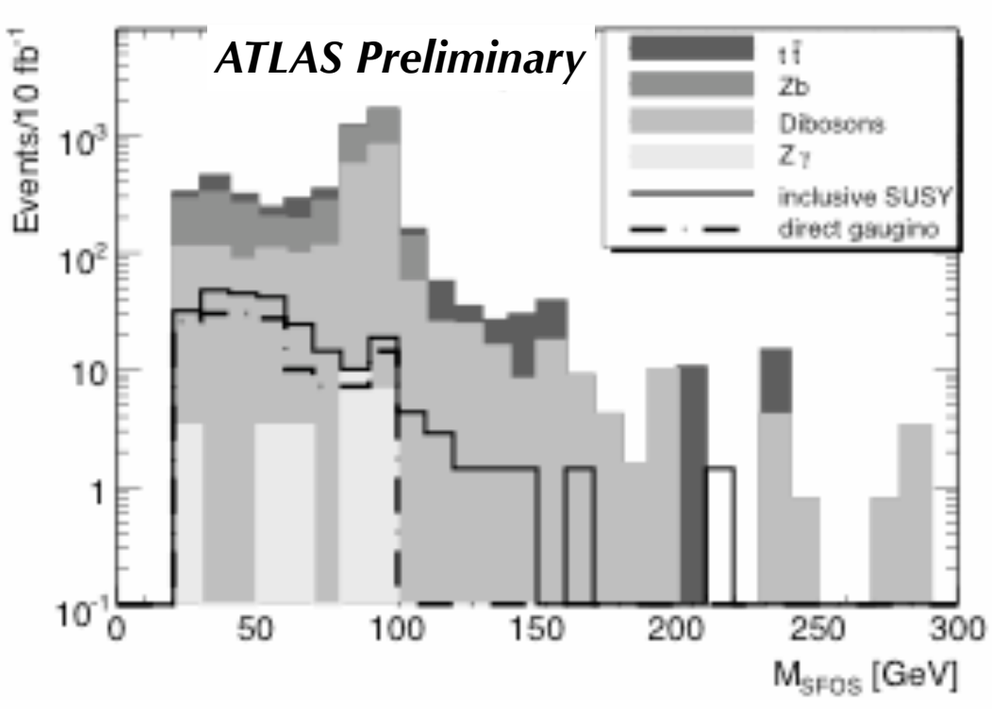
✓After a 3 lepton requirement,
ttbar and Zb : dominant background in low Pt
Diboson : in the entire phase space of 3rd leading lepton Pt

Event Selection-ii

✓Use more stringent track isolation cut on the leptons $P_{T(trk,max)}^{\Delta R=0.2}$: Maximum Pt of the tracks inside a cone of DR<0.2 is applied to be < 1 GeV

✓The cut reduces 23% (tt), 37% (Zb) background events. Keep 82% (incl. SUSY), 86% (direct gaugino) signal events for SU2 benchmark point





✓The 2nd lightest neutralino produces two OSSF (Opposite Sign Same Flavor) leptons

✓In Zb and diboson background events, these are mostly from Z decays which results a peak around Z mass

✓Apply a cut on M_{OSSF} (invariant mass of OSSF lepton pair) window

81.2 GeV < M_{OSSF} < 101.2 GeV

Summary of Event Selection

✓Minimum 1 OSSF lepton pair (e+e-, mu+mu-)

✓number of lepton >= 3

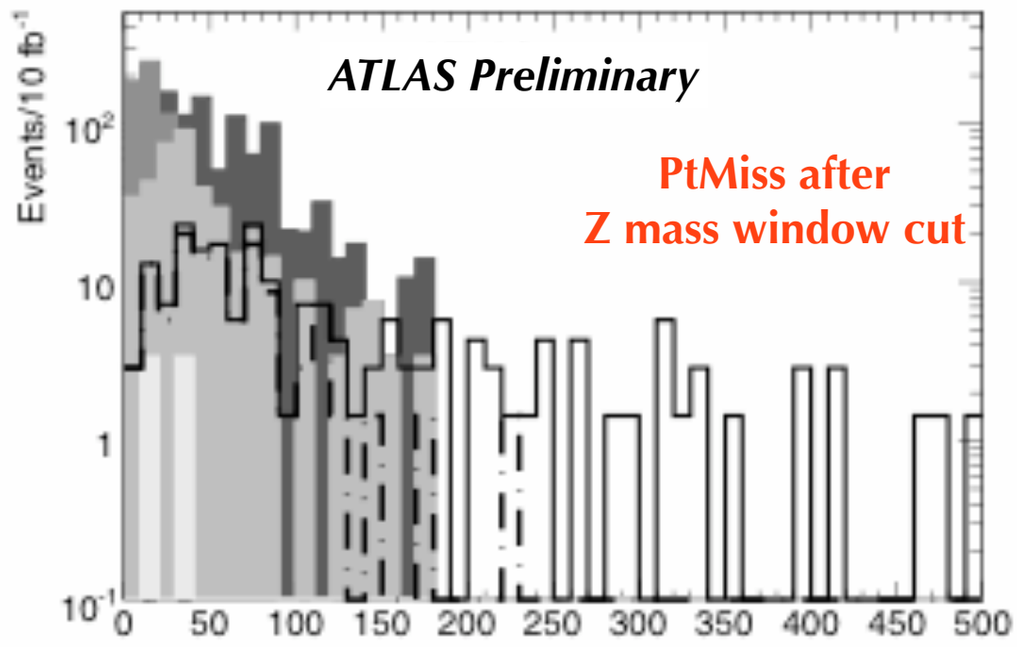
✓ $P_{T(trk,max)}^{\Delta R=0.2}$ < 2 GeV (electrons)
< 1 GeV (muons)

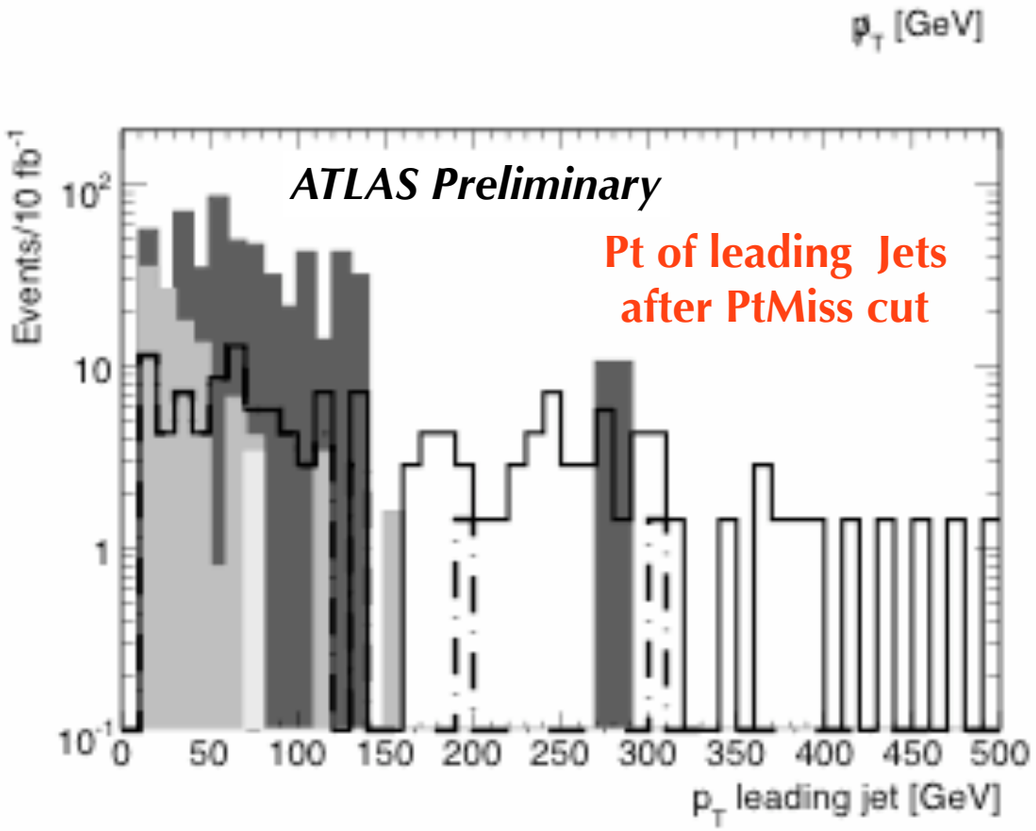
✓Veto events which which falls within 81.2 GeV < M_{OSSF} < 102.2 GeV

✓PtMiss > 30 GeV

✓Optional jet veto cut :

- Reject events containing jets with Pt > 20 GeV
- Useful where the direct gaugino production dominates in the event rate
- ttbar background is suppressed with this cut





Discovery potential

Statistical signal significance, $\mathcal{S} = \frac{S}{\sqrt{S + B}}$

Event Selection	Luminosity needed for 5 sigma discovery (SU2)	Luminosity needed for 5 sigma discovery (SU3)
Inlusive SUSY + direct gaugino production	**7.1 fb^{-1}**	**0.8 fb^{-1}**
only with direct gaugino production	**22.4 fb^{-1}**	**92.9 fb^{-1}**
only with direct gaugino production with a jet veto	**66.9 fb^{-1}**	**119.3 fb^{-1}**

✓The Inclusive SUSY gives us a potential discovery with a several fb^{-1} analysis for the two considered points

✓Benchmark point SU2 (focus point region) gives promising result for measuring direct gaugino production while more difficult for SU3 (bulk region)

Systematic uncertainties

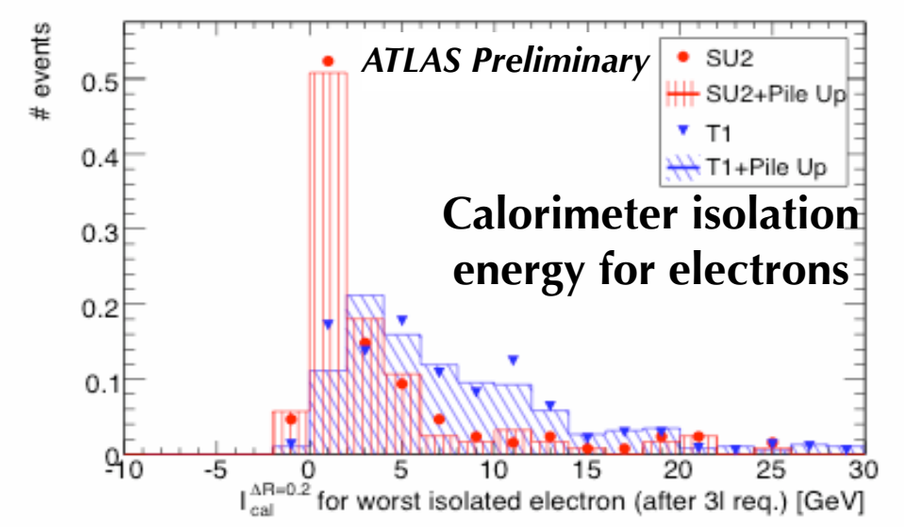
Source	Uncertainty	
	No jet veto	With jet veto
Background production rates	0.8 %	1.9 %
Lepton Efficiency	2.3 %	2.3 %
Fakes ($R_{b\to\ell}$)	4.0 %	1.2 %
Hadronic energy scale	–	1.8 %
Missing energy scale	1.5 %	1.0 %
Total systematic	4.9 %	3.8 %
Statistical	3.7 %	6.9 %
Statistical + Systematic	6.2 %	7.9%

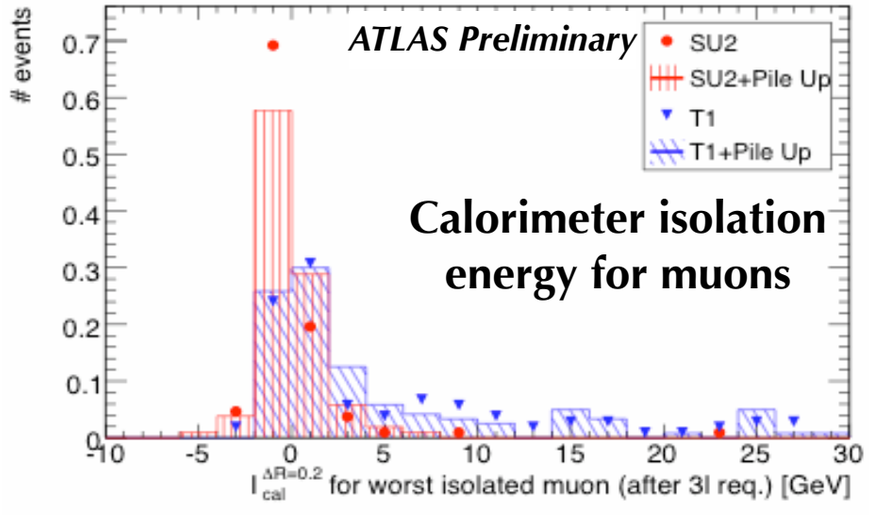
- Statistical uncertainty of BG. cross section
- Lepton trigger and reconstruction efficiency with tag&probe method using Z mass peak
- Mostly from ttbar background where the 3rd lepton comes from a b-decay. Uncertainty in the rate is given as,
- By varying jet energy scale by ±5% and recalculating the missing transverse momentum

Trigger Efficiency, Events with Pile-up

Selection stage	SU2χ L2_e22i	SU2χ L2_mu20	SU2χ $\cup$	SU3χ L2_e22i	SU3χ L2_mu20	SU3χ $\cup$	SU3 incl. L2_e22i	SU3 incl. L2_mu20	SU3 incl. $\cup$
OSSF pair	41%	54%	89%	42%	54%	92%	51%	51%	94%
OSSF+3$^{rd}\ell$	58%	67%	93%	59%	63%	95%	66%	68%	98%
after all cuts	57%	66%	92%	58%	57%	94%	66%	64%	97%

[after the event selection cuts, lepton triggers yields a very high efficiency]





Isolation	e eff. (%)	μ eff. (%)
no isolation	64.0 ± 0.7 (-1.3)	74.1 ± 0.6 (-1.1)
$E_{\text{cal}}^{\Delta R=0.2} < 10\,\text{GeV}$	61.9 ± 0.5 (-1.7)	74.0 ± 0.4 (-0.8)
$p_{T\,\text{track,max}}^{\Delta R=0.2}(\ell) < 2/1\,\text{GeV}$ for e/μ	57.6 ± 0.5 (-2.6)	67.0 ± 0.5 (-3.5)

✓Loss of signal efficiency because of pile-up events in SU2 is ~1% for calorimeter isolation and ~3% for track isolation in LHC running at 10^{-33} cm^{-2} s^{-1} luminosity

Summary

✓As, LHC is getting closer to begin data taking, ATLAS is preparing and exploring all aspects of SUSY for a discovery

✓Here, we presented the discovery potential of three lepton signature, missing transverse momentum and with a little jet activity in the final state

✓We consider several benchmark points within the mSUGRA parameter space, where as, focused our search to SU2 point. This point is specially chosen because of the heavy masses of the coloured sparticles which makes direct chargino, neutralino pair production to be the dominant process

✓Here, we found a discovery is possible in several fb^{-1} of LHC data for an inclusive signature without a jet veto, whereas, we need several tens of fb^{-1} data to do a discovery with a jet veto analysis

✓Methods to obtain background events using real data is underway

✓More work on lepton efficiencies and fake rate estimation

✓These will improve the overall performance of the analysis

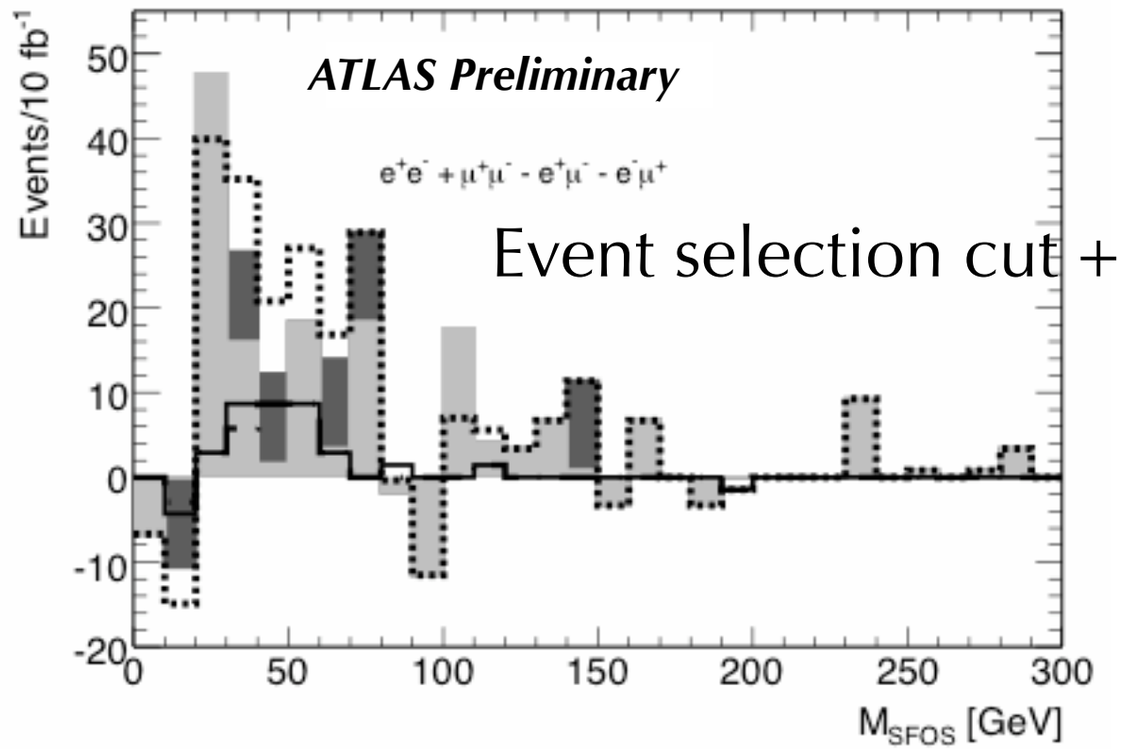
BACKUP

Discovery potential in SU2 Vs other points

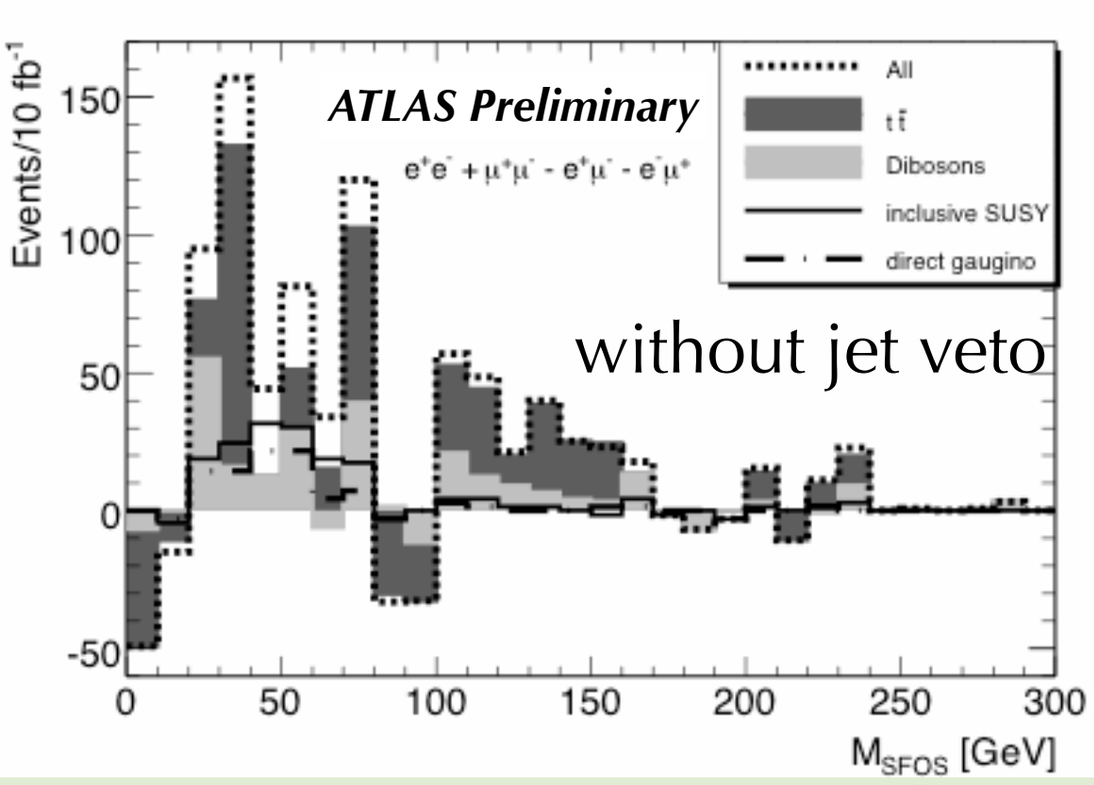
Kinematic Cut	No Cuts	$N_L >= 2$	OSSF	$N_L >= 3$	TrackIsol	$m_{\ell\ell}$	$\not\!\!E_T$	JetVeto
Sample								
SU2 gauginos	64037	1647	1108	178	153	120	95	29
SU2 other	7081	776	353	127	95	85	82	0
$t\bar{t}$	4406579	234656	104187	2812	634	507	476	42
ZZ	38202	10413	9984	580	476	57	13	6
ZW	156720	17224	14476	1910	1682	322	218	154
WW	400217	22708	10687	25	8	8	8	8
$Z\gamma$	32832	7184	6970	91	27	7	3	0
Zb	1591157	573601	559237	6523	2409	386	0	0
inclusive SUSY $\mathscr{S}$		2.60	1.74	2.76	3.36	5.31	**5.94**	**1.87**
direct gaugino $\mathscr{S}$		1.77	1.32	1.61	2.09	3.20	**3.34**	**1.87**

	SU1	SU2	SU3	SU4	SU8	SU2	SU3	SU2+JV	SU3+JV
$\mathscr{S}$, 10 fb^{-1}	7.7	5.9	17.2	69.3	1.9	3.3	1.6	1.9	1.4
$\int dt\,\mathscr{L}$ for 5#	4.2	7.1	0.8	0.1	70.5	22.4	92.9	66.9	119.3

Flavor subtracted Invariant mass



Event selection cut + jet veto



without jet veto

LHC and ATLAS