Cornering electroweakinos at the LHC

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Susy at the near energy frontier workshop

Fermilab,
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Light Electroweakinos

- Naturalness wants Higgsino to be light.

  since the μ parameter enters the Higgs potential at tree level

- Natural for gauginos to be lighter than sfermions

  Split Susy, AMSB

- Light gauginos alone can preserve gauge unification

- EWKino masses get less renormalized than the gluino mass.

- LHC: much weaker bound for ewinos than for QCD charged particles

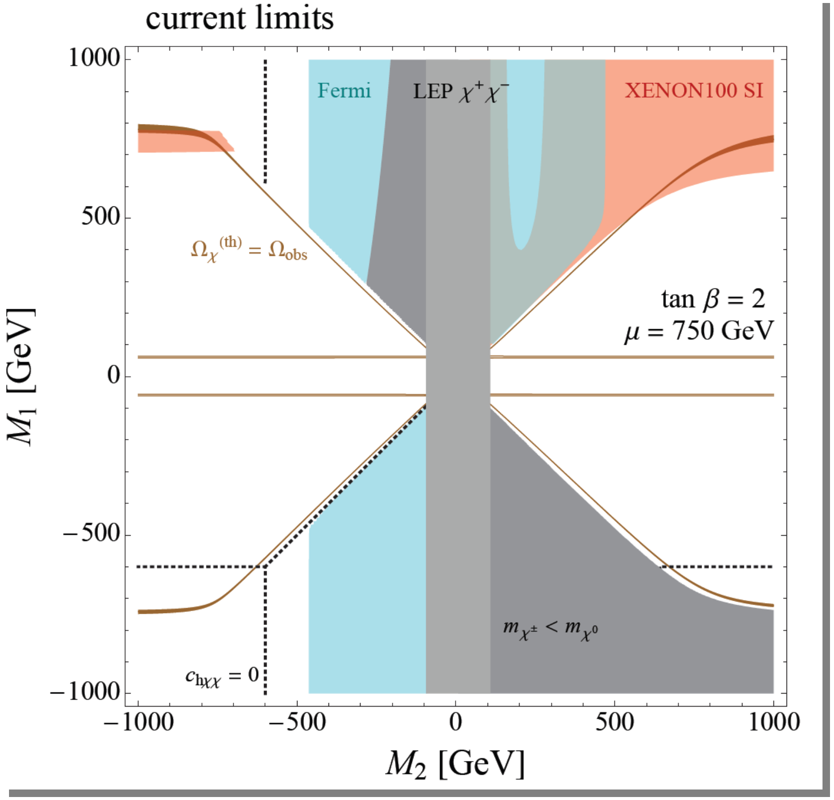
Compressed spectra

Some motivations for compression

Well tempered neutralino: Arkani-Hamed, Delgado, Giudice 0601041

Efficient annihilation → no significant mass splitting

Cheung, Hall, Pinner, Ruderman, 1211.4873



Squeezed spectra can also be „Blind spots" for DM direct searches

Difficulties: Electroweakino direct production cross sections are small

Soft visible particles and no sizable MET

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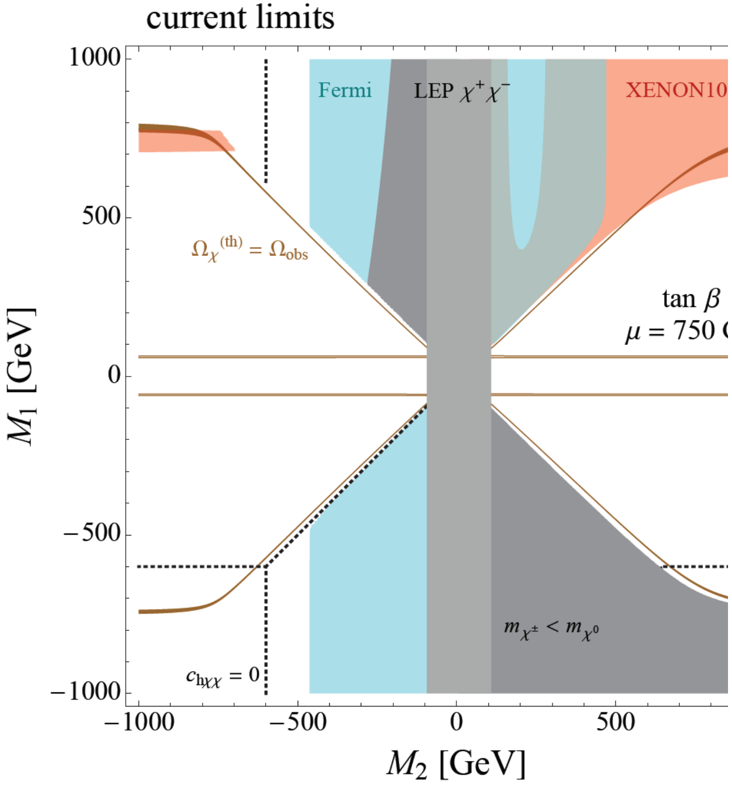
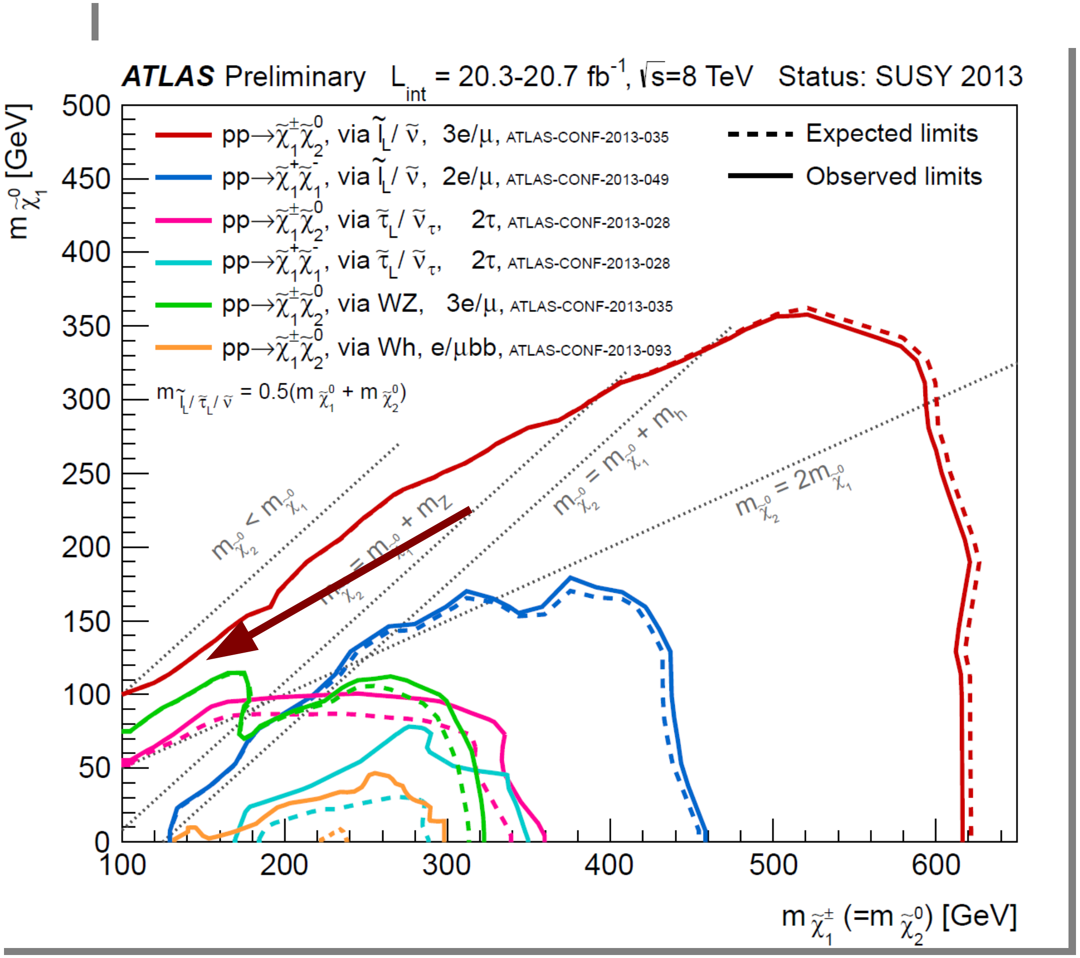
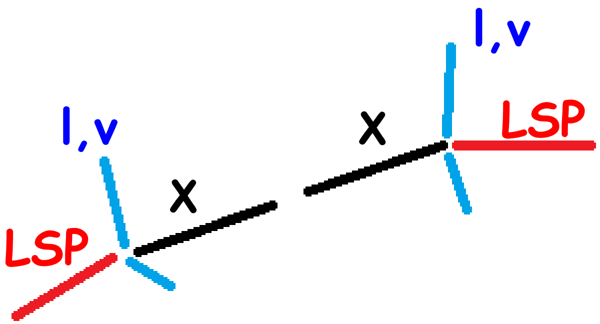


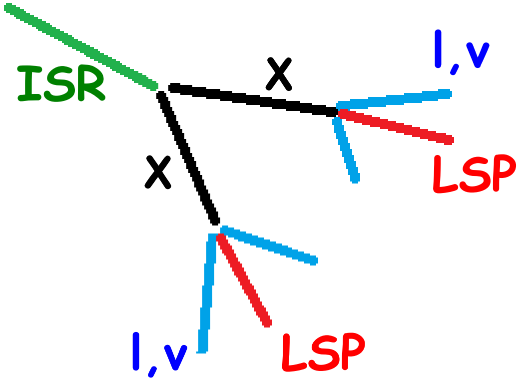


Difficulties: Electroweakino direc

Soft visible particle

Use of a ISR jet





Giudice, Han, Wang, Wang, 1004.4902

- Very squeezed.

Nothing else to see. Mono-jet type signals.

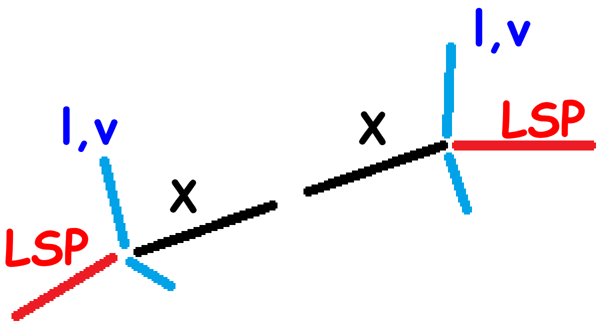
- Pretty squeezed.

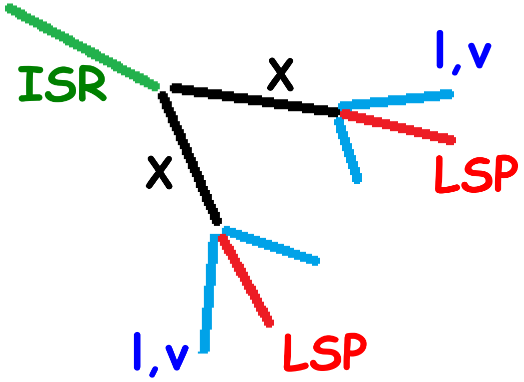
„traditional" method possible, but suffers from low efficiency.

ISR jet + soft leptons + some MET signature

More challenging signal, could be the reason that we have not discovered them yet?

Use of a ISR jet





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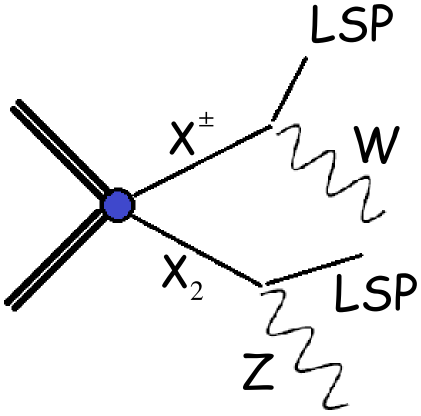
⇨ ISR jet + soft leptons + some MET signature

More challenging signal, could be the reason that we have not discovered them yet?

3l+MET+ISR jet

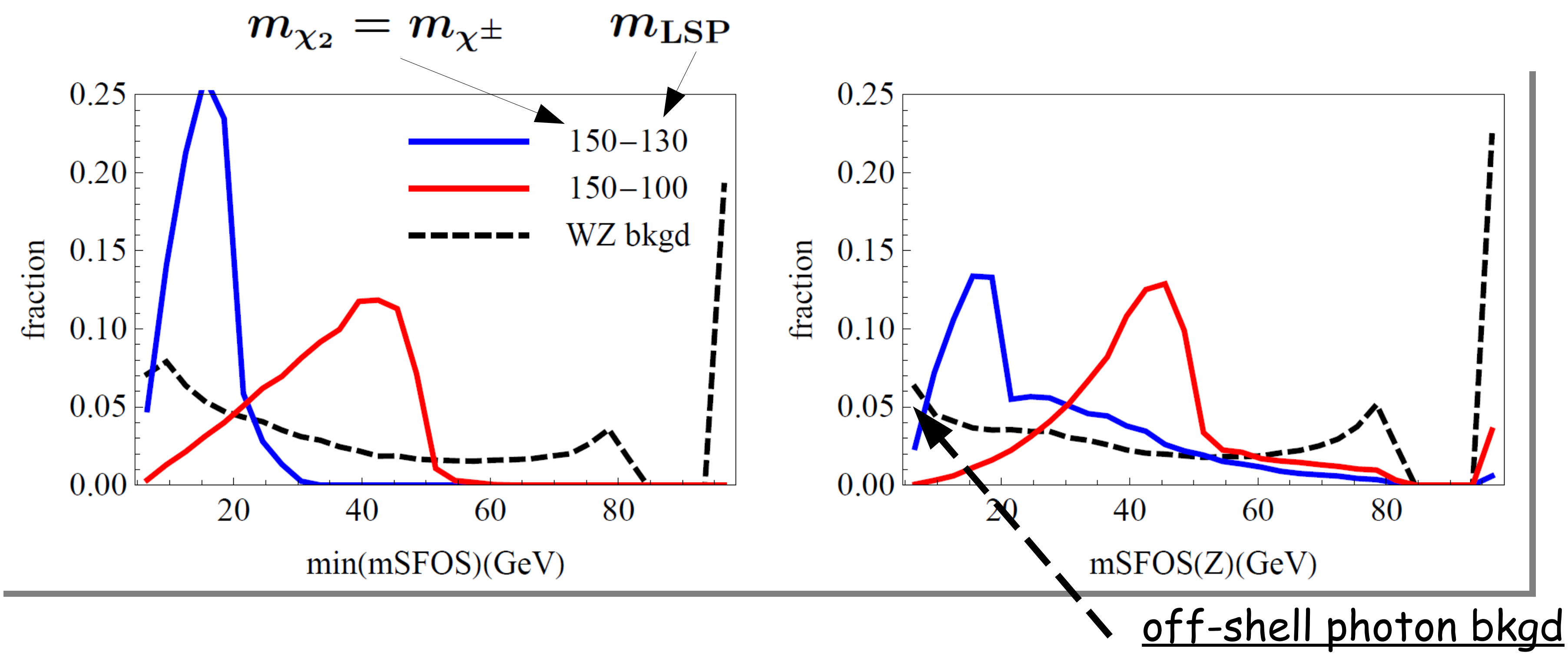
For this talk:

1. Main background: W Z/γ
2. Subleading backgrounds: ZZ, Tri-boson, fake backgrounds



Based on S.G., S.Jung, L-T.Wang, 1307.5952

Lepton invariant masses

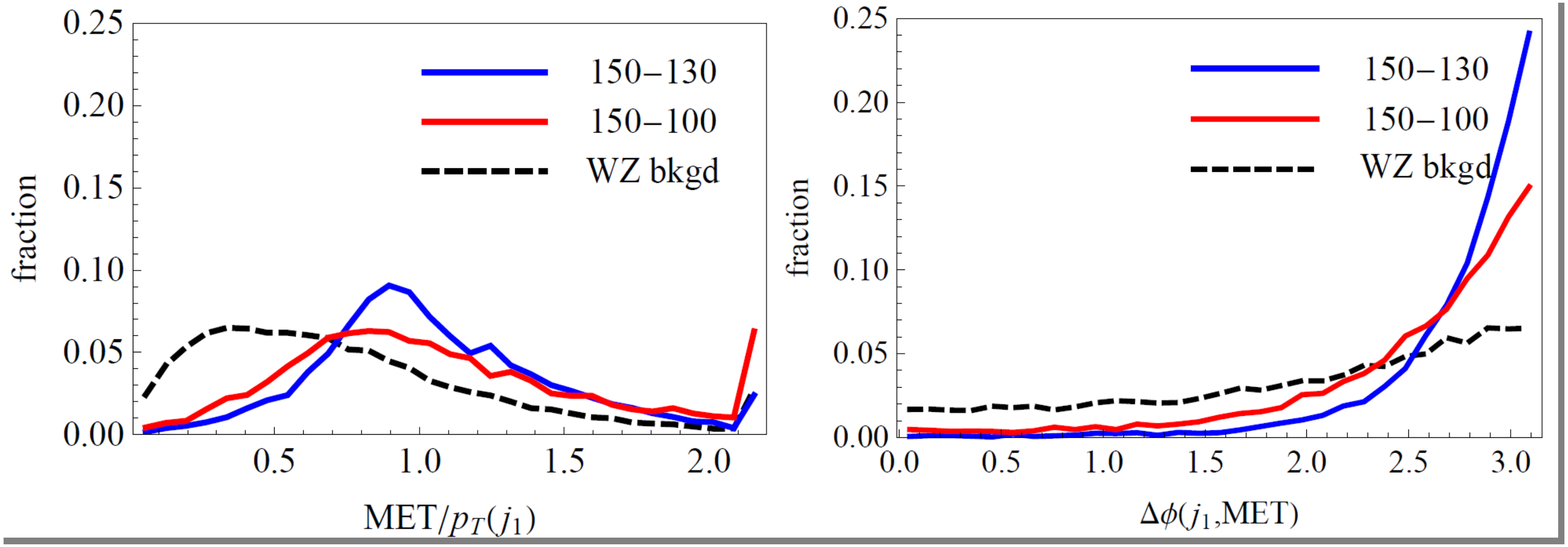


off-shell photon bkgd
mSFOS>12GeV
(low mass QCD resonances)

- Edge at mSFOS~$\Delta \equiv m_{\chi_2} - m_{LSP}$
- Experimental collaborations use mSFOS(Z), however, the minimum of all possible SFOS invariant masses min(mSFOS) has a clearer edge

➡ Lower and upper bounds on the values of mSFOS

ISR and correlation variables



$$-\vec{E}_T^{\text{miss}} = \vec{p}_T(j_1) + \sum \vec{p}_T(\ell), \qquad |\vec{p}_T(\ell)| \sim \gamma E_\ell^0$$

- Sizable MET in the signal arises only from a hard ISR (the two LSPs are not anymore back to back)

$$(E_\ell^0)_{\text{sig}} \sim \Delta,$$

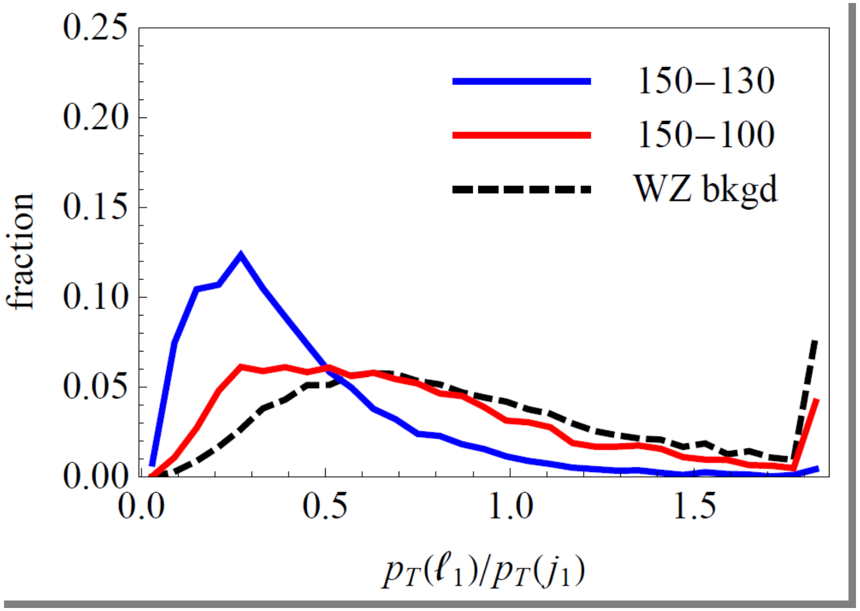
$$\Delta \equiv m_{\chi_2} - m_{\text{LSP}} \ll m_{\chi_2}$$

$$(E_\ell^0)_{\text{bkgd}} \sim m_{W,Z}/2$$

Correlations are more and more pronounced going to more and more squeezed spectra

ISR and correlation variables

Weaker correlation between the pT of the leptons and the pT of the ISR jet



$p_T(j_1) > 30\,\mathrm{GeV}$

$$-\vec{E}_T^{\mathrm{miss}} = \vec{p}_T(j_1) + \sum \vec{p}_T(\ell), \qquad |\vec{p}_T(\ell)| \sim \gamma E_\ell^0$$

$$(E_\ell^0)_{\mathrm{sig}} \sim \Delta,\ \Delta \equiv m_{\chi_2} - m_{\mathrm{LSP}} \ll m_{\chi_2}$$

$$(E_\ell^0)_{\mathrm{bkgd}} \sim m_{W,Z}/2$$

$$\gamma \sim \frac{\sqrt{p_T^2(j_1)/4 + M^2}}{M}$$

$$M_{\mathrm{sig}} \sim m(\chi_2),\ M_{\mathrm{bkgd}} = m_{\mathrm{W,Z}}$$

Stronger correlation going to harder ISR jets

It can be a more useful variable at the 14 TeV LHC with high luminosity

Example of optimization of the cuts

$(150-120)$	cuts	S	$\frac{S}{B}$	$\frac{S}{\sqrt{B}}$	$\frac{S}{\sqrt{B+(0.15\cdot B)^2}}$
Tight-p_T baseline	$p_T(\ell)>10$ GeV, $p_T(j)>30$ GeV, min(mSFOS) $>$ 18 GeV, mSFOS(Z) $<$81 GeV	18	0.17	1.8	0.97
Tight-p_T cuts	min(mSFOS) $< \Delta=30$ GeV	17	0.47	2.8	2.1
	$\Delta\phi(j_1, \mathrm{E_T^{miss}}) > 2.4$	14	0.91	3.5	3.1
	$\mathrm{E_T^{miss}}/p_T(j_1) > 0.64$	12	1.4	4.1	3.7
	$\mathrm{E_T^{miss}} > 20\,\mathrm{GeV},\ p_T(\ell_1) < 50\,\mathrm{GeV}$ $p_T(\ell_1)/p_T(j_1) < 1.21$	11	1.7	4.3	4.0
ATLAS-CONF-2013-035	SRnoZa	17	0.32	2.3	1.6

Note: imposing $\mathrm{E_T^{miss}} > 50\,\mathrm{GeV}$ would change the significance by only ~10%

SRnoZa

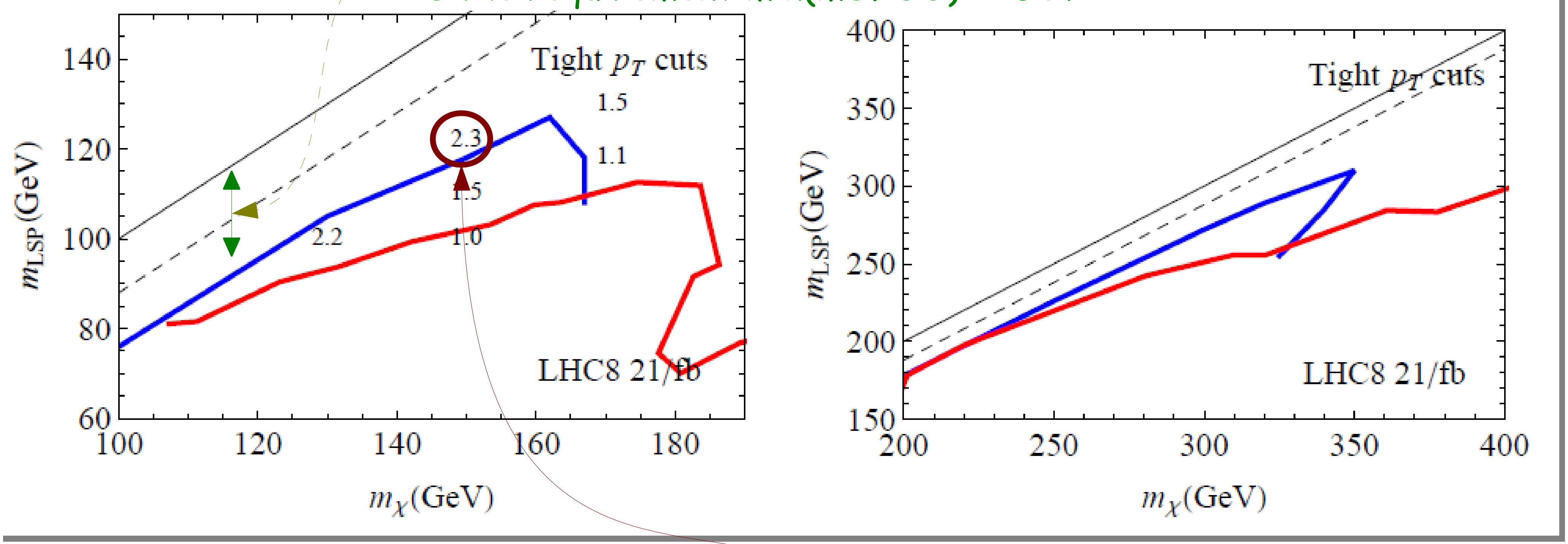
$$\mathrm{mSFOS} < 60\,\mathrm{GeV},\ \mathrm{min(mSFOS)} > 12\,\mathrm{GeV},\ \mathrm{E_T^{miss}} > 50\,\mathrm{GeV}\ \text{and}$$

$$\text{either}\ \ \mathrm{E_T^{miss}} < 75\,\mathrm{GeV}\ \text{or}\ \ m_T(W) < 110\,\mathrm{GeV}\ \text{or}\ \ p_T(\ell_3) < 30\,\mathrm{GeV}$$

Potential improvements

Assuming wino-like NLSP
and branching ratios = 1
(see next talk by Tao Han)

Main issue in this region
is the requirement min(mSFOS)>12GeV



$$\chi_1^\pm \to W^{(*)}\chi_1^0 \to \ell\nu\chi_1^0,$$
$$\chi_2^0 \to Z^{(*)}\chi_1^0 \to \ell\ell\chi_1^0$$

$$\chi_1^\pm \to \tilde{\ell}\nu,\ \tilde{\nu}\ell \to \ell\nu\chi_1^0,$$
$$\chi_2^0 \to \tilde{\ell}\ell \to \ell\ell\chi_1^0$$

(light sleptons in the spectrum)

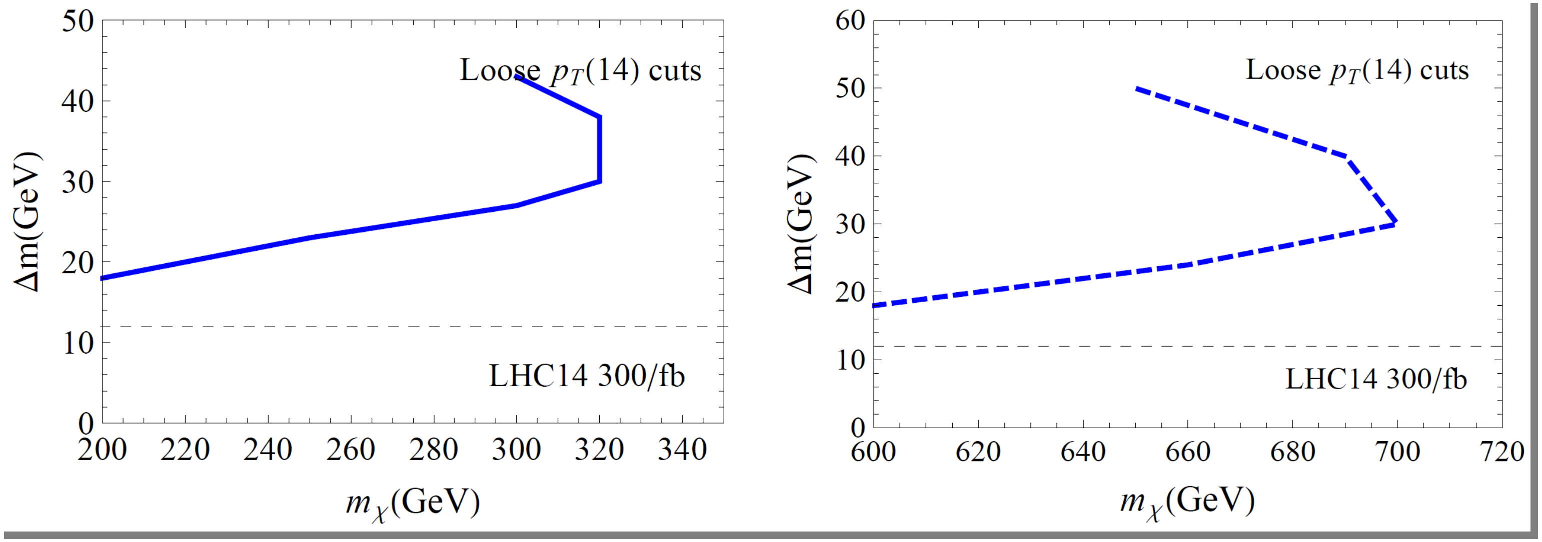
$$m_{\tilde{\ell}} = (m_{\chi_2} + m_{\rm LSP})/2$$

Improvement on $S/\sqrt{B + (0.15 \cdot B)^2}$
in comparison with SRnoZa

Prospects for the 14TeV LHC

With 300 fb^{-1} data

$300 - 280$	cuts	S	$\frac{S}{B}$	$\frac{S}{\sqrt{B}}$	$\frac{S}{\sqrt{B+(0.15\cdot B)^2}}$
Loose-p_T baseline	$p_T(\ell) > 7$ GeV, $p_T(j) > 30$ GeV, min(mSFOS) > 12 GeV, mSFOS(Z) < 81 GeV	56	0.018	1.0	0.12
Loose-p_T (14) cuts	min(mSFOS) $< \Delta = 20$ GeV	50	0.049	1.6	0.32
	$E_T^{\rm miss} > 60$ GeV $p_T(\ell_1) < 50$ GeV	32	0.21	2.6	0.78
	$p_T(\ell_1)/p_T(j_1) < 0.2$	17	0.64	3.3	2.59
	$E_T^{\rm miss}/p_T(j_1) > 0.9$	13	1.2	3.9	3.44



Heavy sleptons

Light sleptons

Conclusions and outlook

- Squeezed and light electroweak spectra are an interesting theoretical possibility
- Experimental searches are known to be more difficult

To exploit the presence of a relatively boosted ISR jet

Possible improvements for the 3leptons+MET+ISR jet signature

- Weaker lower bound on min(mSFOS)
- Lower thresholds for leptons. Requiring 1-2 muons might help

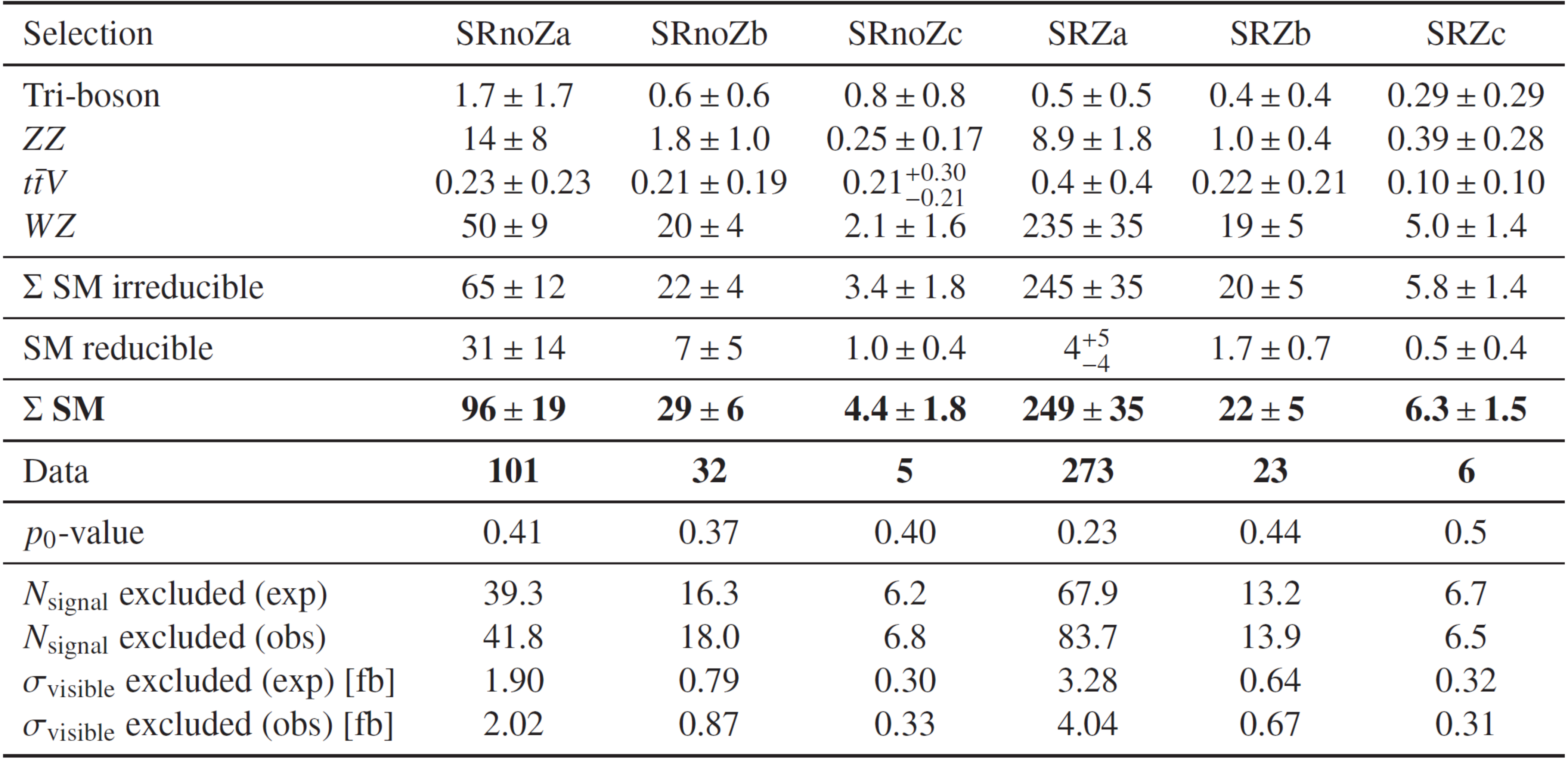
Some work for experimentalists

Complementary signatures:

- SS leptons+MET+ISR jet (ask Graham!)
- Mono-jet

ATLAS 3l search

ATLAS-CONF-2013-035



Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
Tri-boson	1.7 ± 1.7	0.6 ± 0.6	0.8 ± 0.8	0.5 ± 0.5	0.4 ± 0.4	0.29 ± 0.29
ZZ	14 ± 8	1.8 ± 1.0	0.25 ± 0.17	8.9 ± 1.8	1.0 ± 0.4	0.39 ± 0.28
$t\bar{t}V$	0.23 ± 0.23	0.21 ± 0.19	$0.21^{+0.30}_{-0.21}$	0.4 ± 0.4	0.22 ± 0.21	0.10 ± 0.10
WZ	50 ± 9	20 ± 4	2.1 ± 1.6	235 ± 35	19 ± 5	5.0 ± 1.4
Σ SM irreducible	65 ± 12	22 ± 4	3.4 ± 1.8	245 ± 35	20 ± 5	5.8 ± 1.4
SM reducible	31 ± 14	7 ± 5	1.0 ± 0.4	4^{+5}_{-4}	1.7 ± 0.7	0.5 ± 0.4
Σ SM	**96 ± 19**	**29 ± 6**	**4.4 ± 1.8**	**249 ± 35**	**22 ± 5**	**6.3 ± 1.5**
Data	**101**	**32**	**5**	**273**	**23**	**6**
p_0-value	0.41	0.37	0.40	0.23	0.44	0.5
N_{signal} excluded (exp)	39.3	16.3	6.2	67.9	13.2	6.7
N_{signal} excluded (obs)	41.8	18.0	6.8	83.7	13.9	6.5
σ_{visible} excluded (exp) [fb]	1.90	0.79	0.30	3.28	0.64	0.32
σ_{visible} excluded (obs) [fb]	2.02	0.87	0.33	4.04	0.67	0.31

SRnoZa

$\mathrm{mSFOS} < 60\,\mathrm{GeV}$, $\min(\mathrm{mSFOS}) > 12\,\mathrm{GeV}$, $\mathrm{E_T^{miss}} > 50\,\mathrm{GeV}$ and

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