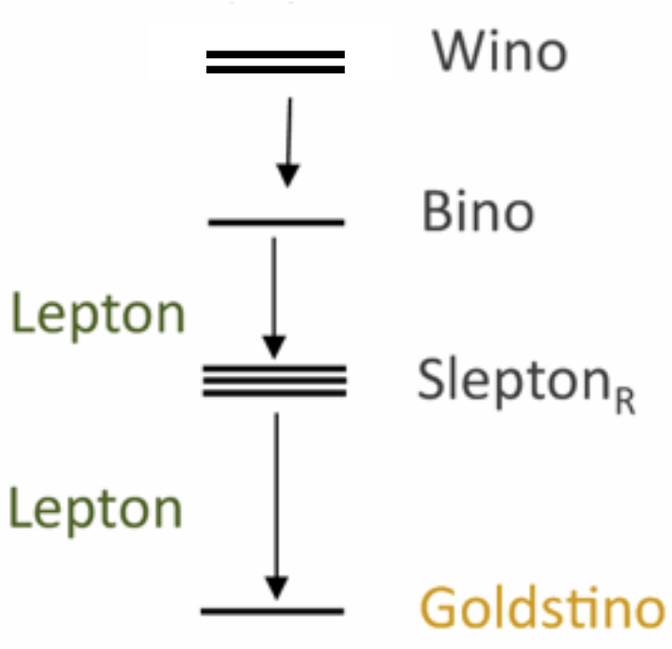
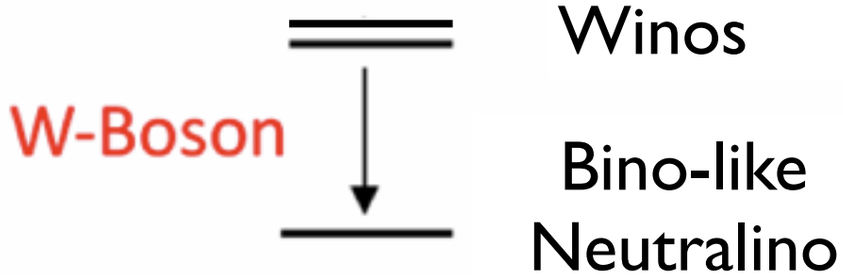
Search for electroweak SUSY production at CMS

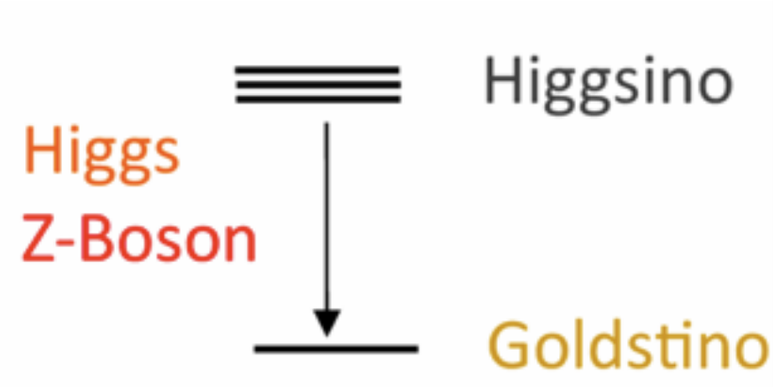
Anthony Barker

Pheno2014, May 5-7

Electroweak SUSY in a nutshell





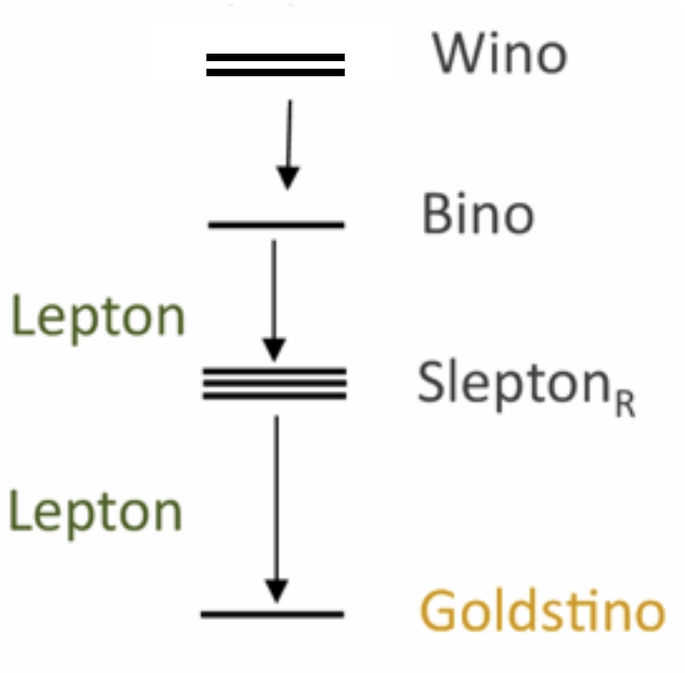


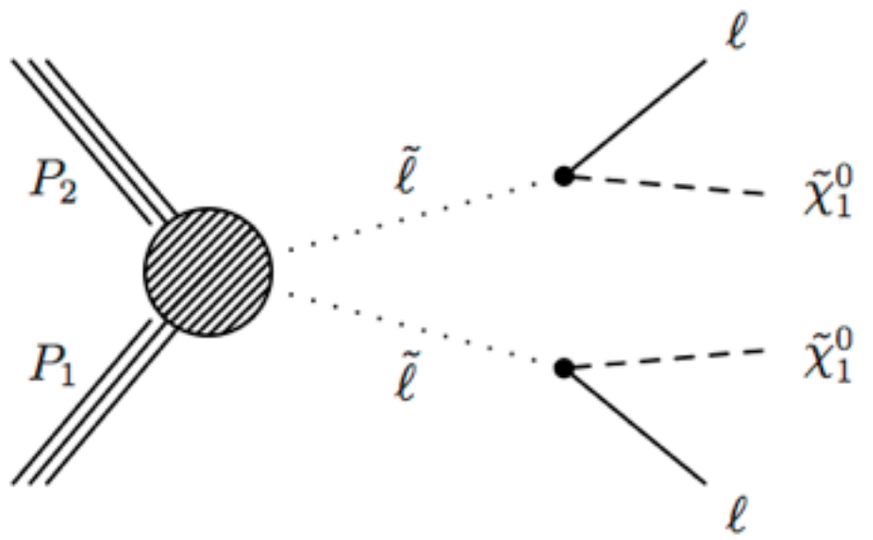
Cross sections tend to be smaller than strongly produced susy

Main Tools:

- Leptons!
- $\not{E}_T$
- b's
- Z
- Higgs (NEW!)

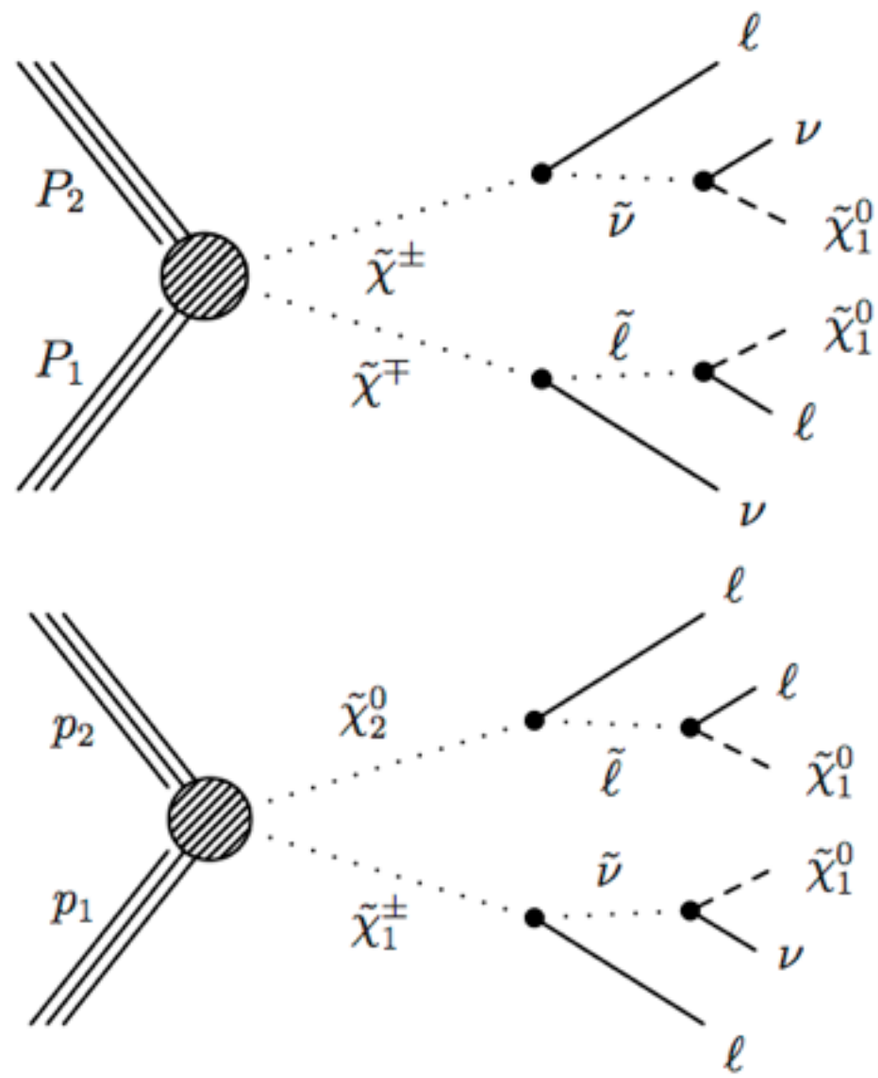
Sleptons





Highly binned multi-lepton search

- Channels:
  - 4+ leptons
  - **3 leptons**
  - 2 lep SS
  - OSSF+jj
  - 2 lep OS not Z
- Bin in:
  - MET
  - M_T
  - M_{ll}
  - N taus



Sleptons couple to chargino via higgsino component → likely tau-rich

Massively Binned Approach to Multi-leptons

3ℓ: SSτ

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 100$ GeV		$M_{\ell\ell} > 100$ GeV	
		total bkg	observed	total bkg	observed
>160	50 – 100	3.1±0.6	2	0.50±0.21	1
	100 – 150	2.3±0.5	1	0.40±0.17	1
	150 – 200	0.52±0.16	0	0.21±0.11	0
	200 – 250	0.41±0.12	2	0.06±0.05	0
120 – 160	50 – 100	5.5±1.0	6	0.35±0.13	1
	100 – 150	0.91±0.26	2	0.06±0.05	0
	150 – 200	0.15±0.10	0	0±0.008	0
	200 – 250	0.06±0.08	0		

3ℓ: OSOFτ

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 100$ GeV	
		total bkg	observe
>160	50 – 100	15±8	19
	100 – 150	14±9	14
	150 – 200	3.7±2.1	1
	200 – 250	1.5±1.0	2
120 – 160	50 – 100	42±16	41
	100 – 150	17±9	18
	150 – 200	2.0±1.2	2
	200 – 250	0.8±0.5	1
	50 – 100	259±93	290

3ℓ: no OSSF

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 100$ GeV		$M_{\ell\ell} > 100$ GeV	
		total bkg	observed	total bkg	obse
>160	50 – 100	3.2±0.8	2	0.44±0.33	
	100 – 150	2.1±0.7	3	0.42±0.19	
	150 – 200	0.59±0.18	0	0.10±0.06	
	200 – 250	0.37±0.13	1	0.16±0.14	
120 – 160	50 – 100	5.5±1.2	3	0.25±0.07	
	100 – 150	1.9±0.5	1	0.19±0.10	
	150 – 200	0.46±0.18	1	0.03±0.03	
	200 – 250	0.10±0.05	0	0.008±0.010	
0 – 120	50 – 100	32±7	29	1.7±0.4	
	100 – 150	7.3±1.7	5	0.30±0.11	
	150 – 200	1.0±0.3	1	0.14±0.09	

3ℓ: OSSF

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV		75 GeV $< M_{\ell\ell} <$ 105 GeV		$M_{\ell\ell} > 105$ GeV	
		total bkg	observed	total bkg	observed	total bkg	obser
>160	50 – 100	5.8±1.1	12	7.5±1.4	13	2.6±1.2	1
	100 – 150	4.5±1.1	3	4.0±1.0	8	1.8±0.9	3
	150 – 200	1.5±0.4	2	1.5±0.5	3	0.7±0.4	0
	200 – 250	0.81±0.21	0	1.1±0.4	2	0.40±0.24	0
120 – 160	50 – 100	9.6±1.7	8	23±5	29	2.7±0.5	4
	100 – 150	3.3±0.8	2	3.4±0.7	4	0.71±0.22	2
	150 – 200	0.26±0.10	0	0.72±0.19	1	0.38±0.14	0
	200 – 250	0.29±0.11	0	0.36±0.12	1	0.24±0.20	0
	50 – 100	132±19	138	776±125	821	45±7	49

4 leptons

E_T^{miss} (GeV)	Observed	Total Bkg
1 OSSF, 0 τ		
0–30	1	2.3 ± 0.6
30–50	3	1.2 ± 0.3
50–100	2	1.5 ± 0.4
> 100	2	0.8 ± 0.3
1 OSSF, 1 τ		
0–30	33	25 ± 12
30–50	11	11 ± 3.1
50–100	9	9.3 ± 1.9
> 100	2	2.9 ± 0.6
2 OSSF, 0 τ		
0–30	142	149 ± 46
30–50	25	28 ± 11
50–100	4	4.5 ± 2.7
> 100	1	0.8 ± 0.3

	E_T^{miss} 0–30 GeV	E_T^{miss} 30–60 GeV	E_T^{miss} 60–80 GeV	E_T^{miss}
s bkg	75839 ± 3042	21234 ± 859	690 ± 154	6
g	69.9 ± 11.9	96.7 ± 16.3	48.3 ± 8.3	3
kg	16.1 ± 8.1	27.1 ± 13.5	11.8 ± 5.9	
g	2.9 ± 1.4	6.0 ± 3.0	3.3 ± 1.7	
SM bkg	0.5 ± 0.2	1.0 ± 0.5	0.6 ± 0.3	
bkg	75929 ± 3042	21364 ± 859	754 ± 154	
	76302	20991	809	

	E_T^{miss} 100–120 GeV	E_T^{miss} 120–150 GeV	E_T^{miss} 150–200 GeV	E_T^{miss}
s bkg	7.8 ± 3.1	3.7 ± 1.6	2.0 ± 1.0	
g	21.9 ± 4.0	13.2 ± 2.5	5.7 ± 1.6	
kg	3.7 ± 1.9	2.9 ± 1.5	1.9 ± 0.9	
g	1.8 ± 0.9	1.9 ± 0.9	1.4 ± 0.7	
SM bkg	0.2 ± 0.1	0.4 ± 0.2	0.4 ± 0.2	
bkg	35.4 ± 5.5	22.2 ± 3.5	11.3 ± 2.2	

Backgrounds	Opposite Flavor		Same Flavor	
	$10 < M_{CT\perp} < 120$ GeV	$M_{CT\perp} > 120$ GeV	$10 < M_{CT\perp} < 120$ GeV	$M_{CT\perp}$
Top	3561 ± 152	< 0.4	2704 ± 184	0.
Diboson and Rare SM	1678 ± 120	1.6 ± 0.7	1528 ± 140	7.
Z/γ^*	67^{+136}_{-67}	< 0.01	601 ± 345	0.
Non-Prompt	< 272	< 0.01	555 ± 417	
Total	5307 ± 73	1.6 ± 0.8	5389 ± 73	8.
Data	5309	5	5388	

	$120 < E_T^{miss} < 200$ GeV, $N_{jets} \leq 2$, $N_{bjets} = 0$	$E_T^{miss} > 200$ GeV	$120 < E_T^{miss} < 200$ GeV, $N_{jets} = 0$	$120 < E_T^{miss} < 200$ GeV, $N_{jets} \leq 2$, $N_{bjets} = 0$, 3rd lepton veto	$E_T^{miss} > 200$ GeV, 3rd lepton veto	120<
Fakes	15.1 ± 7.7	3.4 ± 1.9	4.1 ± 2.2	12.3 ± 6.3	3.1 ± 1.7	
Charge MisID	0.36 ± 0.02	0.09 ± 0.01	0.08 ± 0.01	0.34 ± 0.02	0.09 ± 0.01	
Rare SM	15.0 ± 7.8	10.5 ± 5.7	2.4 ± 2.4	11.9 ± 6.3	8.6 ± 4.8	
WZ	19.4 ± 2.9	5.3 ± 0.8	5.0 ± 0.8	14.3 ± 2.2	3.9 ± 0.6	
Total Bkg	49.9 ± 11.4	19.4 ± 6.0	11.5 ± 3.3	38.8 ± 9.2	15.6 ± 5.1	

Massively Binned Approach to Multi-leptons

3ℓ: SSτ

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 100$ GeV		$M_{\ell\ell} > 100$ GeV	
		total bkg	observed	total bkg	observed
>160	50 – 100	3.1±0.6	2	0.50±0.21	1
	100 – 150	2.3±0.5	1	[illegible]±0.17	1
	150 – 200	0.52±0.16	0	[illegible]11	0
	200 – [illegible]	[illegible]	[illegible]	[illegible]05	0
120 – 160	50 – 100				
	100 – 150	0.9[illegible]	2	[illegible]	
	150 – 200				
	200 – 25[illegible]				

3ℓ: OSSF

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV		75 GeV $< M_{\ell\ell} <$ 105 GeV		$M_{\ell\ell} > 105$ GeV	
		total bkg	observed	total bkg	observed	total bkg	obser
>160	50 – 100	5.8±1.1	12	7.5±1.4	13	2.6±1.2	1
	100 – 150	4.5±1.1	3	4.0±1.0	8	1.8±0.9	3
	150 – 200	1.5±0.4	2	1.5±0.5	3	0.7±0.4	0
	200 – 250	0.81±0.21	0	[illegible]±0.4	2	0.40±0.24	0
120 – 160	50 – 100	9.6±1.7	8	[illegible]±5	29	2.7±0.5	4
	100 – 15[illegible]	3.3±0.8	2	[illegible]±0.7	4	0.71±0.22	2
	150 – [illegible]	[illegible]±0.10	0	[illegible]±0.19	1	0.38±0.14	0
	2[illegible]	[illegible]11	0	[illegible]±0.12	1	0.24±0.20	0
	50 – 1[illegible]	[illegible]38			821	45±7	49

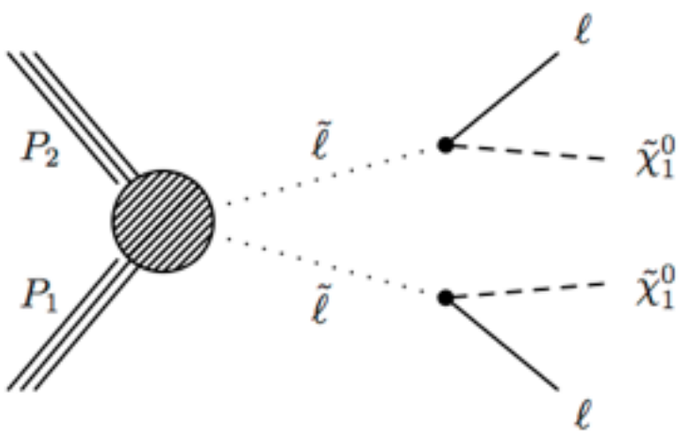
M_T (GeV)	E_T^{miss} (GeV)				
>160	50 – 100	3.2±0.8			
	100 – 150	2.1±0.7			
	150 – 200	0.59±0.18		0.[illegible]	
	200 – 250	0.37±0.1[illegible]		0.16±[illegible]	
120 – 160	50 – 100	5.5±1.2		0.25±0.[illegible]	
	100 – 150	1.9±0.5		0.19±0.10	
	150 – 200	0.46±0.18		0.03±0.03	
	200 – 250	0.10±0.05		[illegible].008±0.010	
0 – 120	50 – 100	32±7	2[illegible]		
	100 – 150				
	150 – [illegible]				

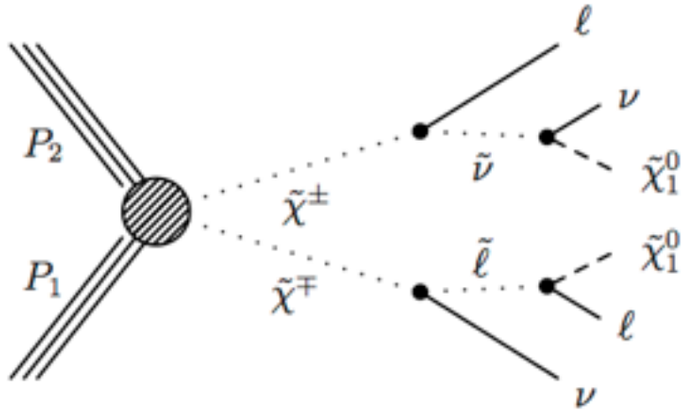
	E_T^{miss} 0–[illegible]	E_T^{miss} 60–80 GeV	E_T^{miss}
s bkg	[illegible]304[illegible]	[illegible] 859	690 ± 154	6
g	[illegible]	[illegible] ± 16.2	48.3 ± 8.3	3
kg	[illegible]1 ± 8		11.8 ± 5.9	
g	2.8 ± [illegible]		3.3 ± 1.7	
SM bkg	[illegible].0 ± [illegible]		0.6 ± 0.3	
bkg	[illegible]	[illegible] 855	754 ± 154	1
			8[illegible]	

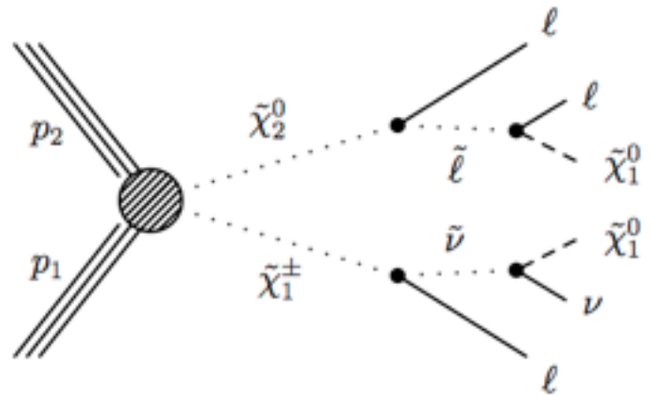
	E_T^{miss}	120	E_T^{miss} 150–200 GeV	E_T^{miss}
s b[illegible]		[illegible] ± 1.6	2.0 ± [illegible].0	
g		[illegible]2.5	5.7 ± [illegible]	
kg		[illegible].5	1.9 ± 0.9	
g	[illegible]		1.4 ± 0.7	
SM bkg			0.4 ± 0.2	
bkg	[illegible] ± 5.[illegible]		11.3 ± 2.[illegible]	

	Opposite [illegible]		
	10 < $M_{CT\perp}$ < 120 GeV	$M_{CT\perp}$ > [illegible] GeV	$M_{CT\perp}$
SM	3561 ± 152	[illegible]	0.
	1678 ± 120	[illegible]	7.
	67^{+136}	[illegible]	0.
	[illegible]	[illegible]	8.

Sleptons





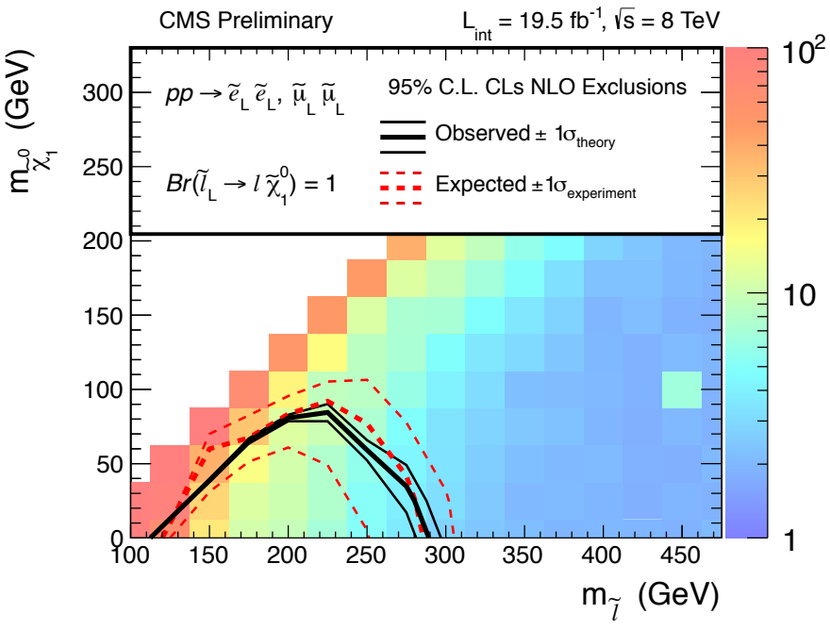


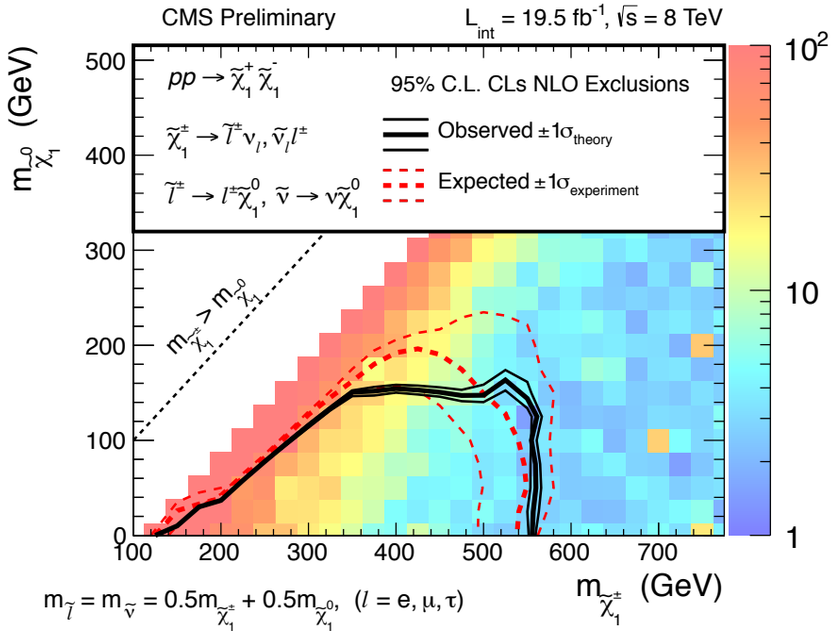
Handles:

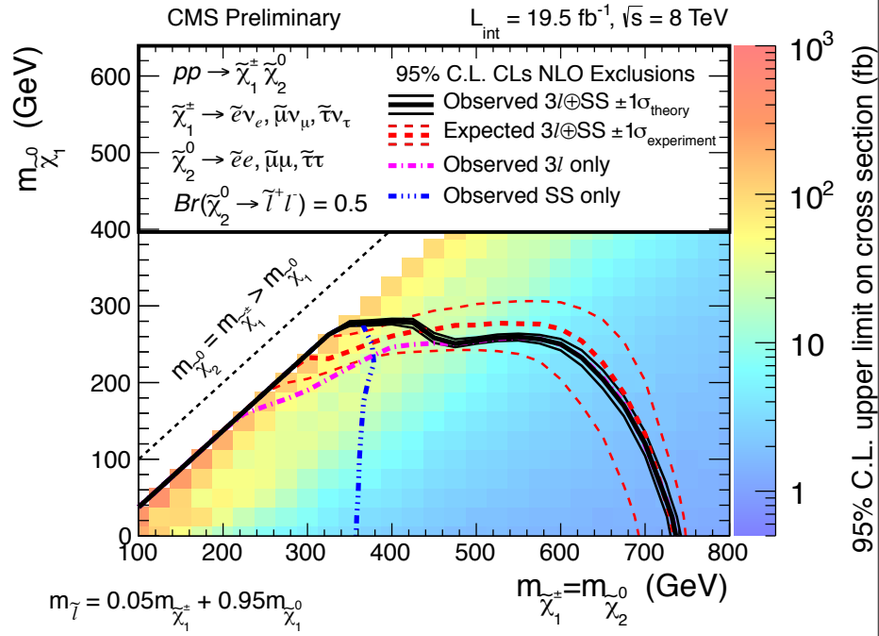
OSSF di-leptons, not on mZ

OSSF, OSOF di-leptons, not on mZ

Tri-leptons and SS 2 lep

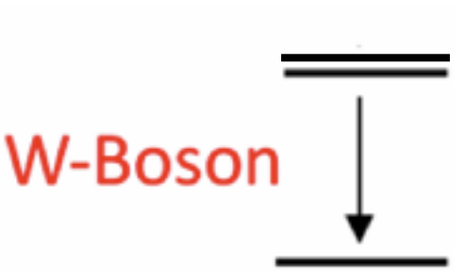






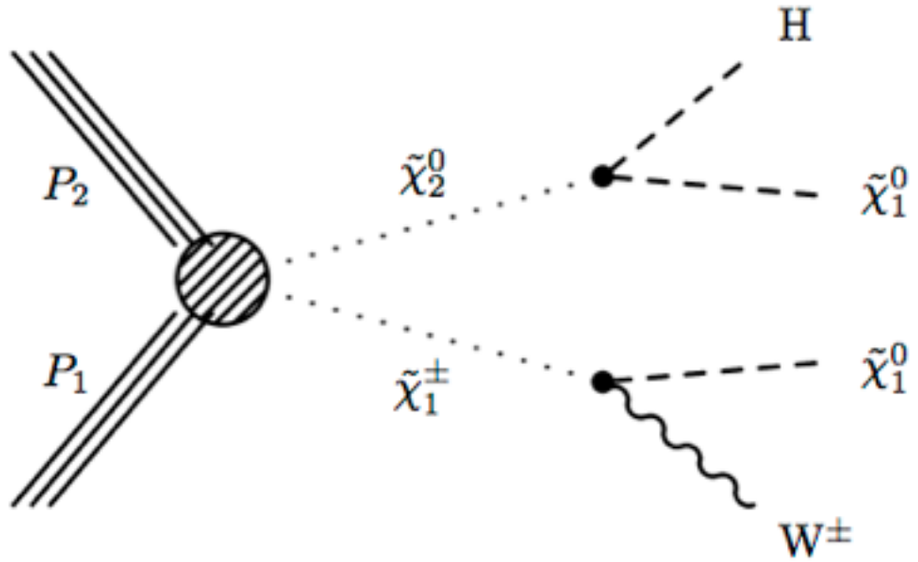
Simplified Model Spectrum Scenario

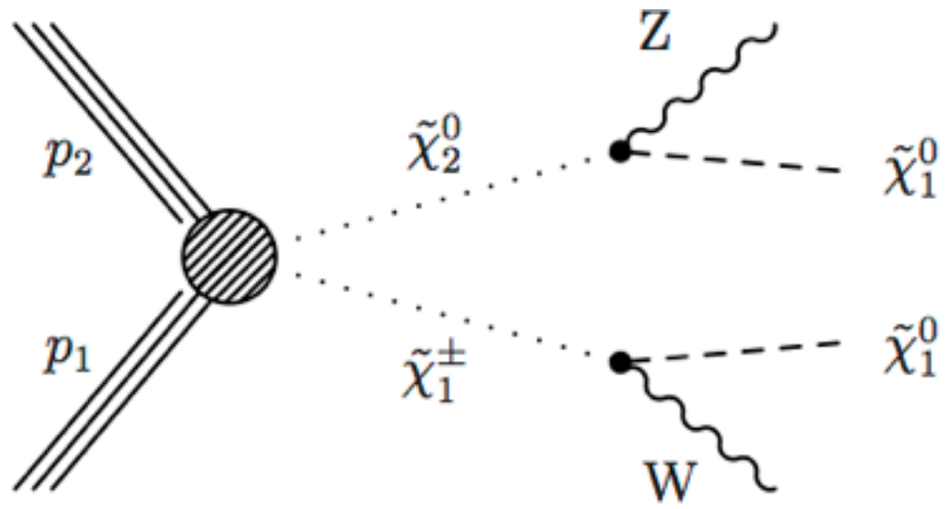
- Wino-like Chargino
- Bino-like LSP neutralino
- $\tilde{\chi}_2^0$ is allowed to decay through Z and h.



Wino-like
Chargino & Neutralino

Bino-like Neutralino



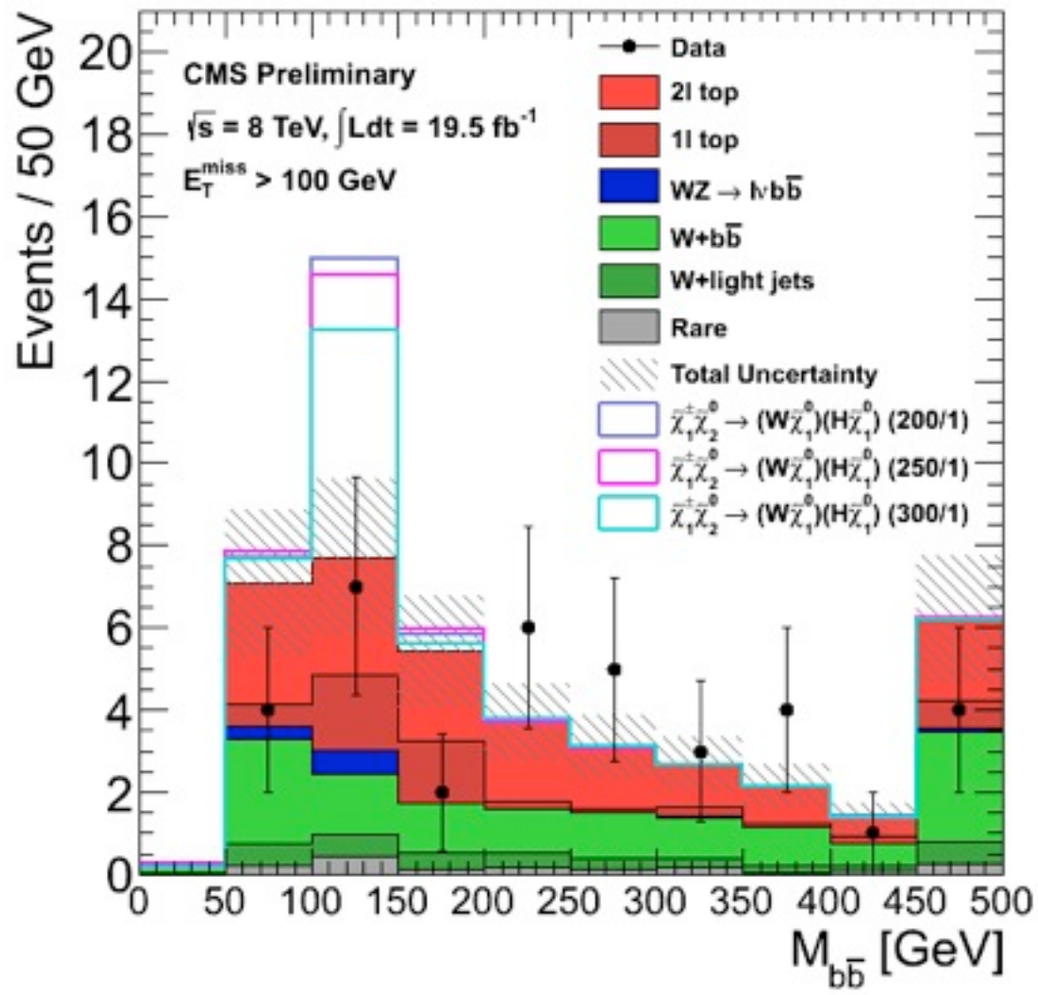


hW

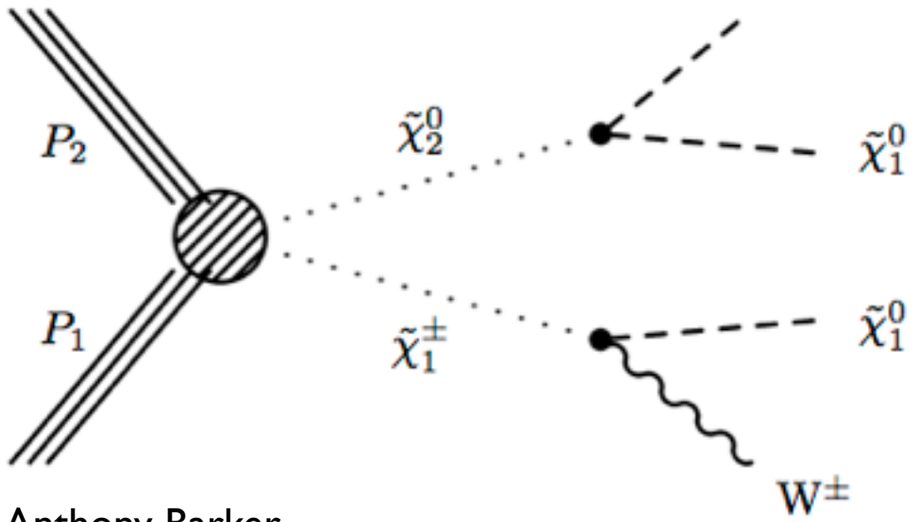
Wino-like
Chargino & Neutralino

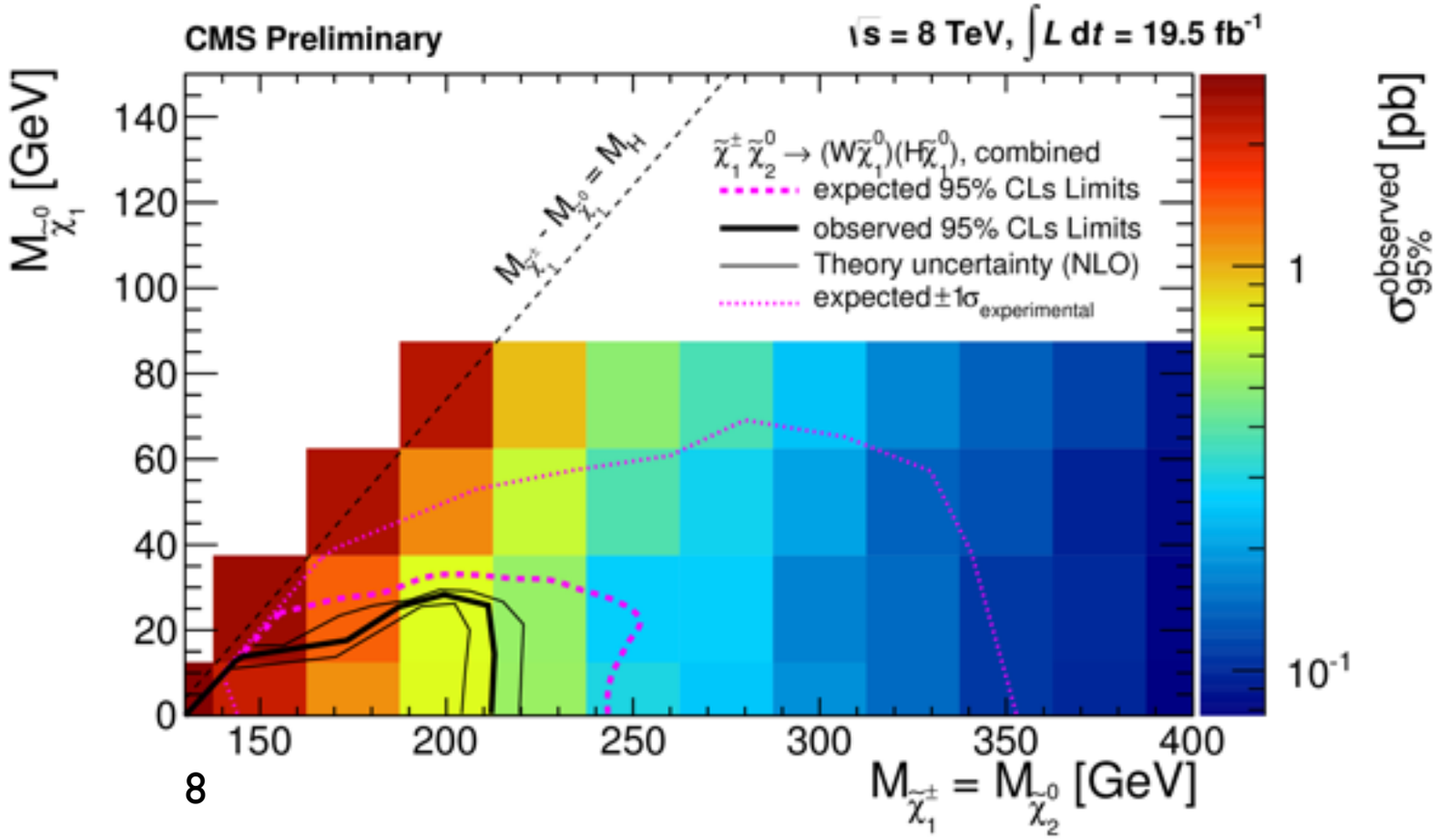
Bino-like Neutralino

- Look for 1, 2, and ≥ 3 leptons
  - Strongest channel:
    leptonic W + h(bb)



bb, WW, ZZ, $\tau\tau$



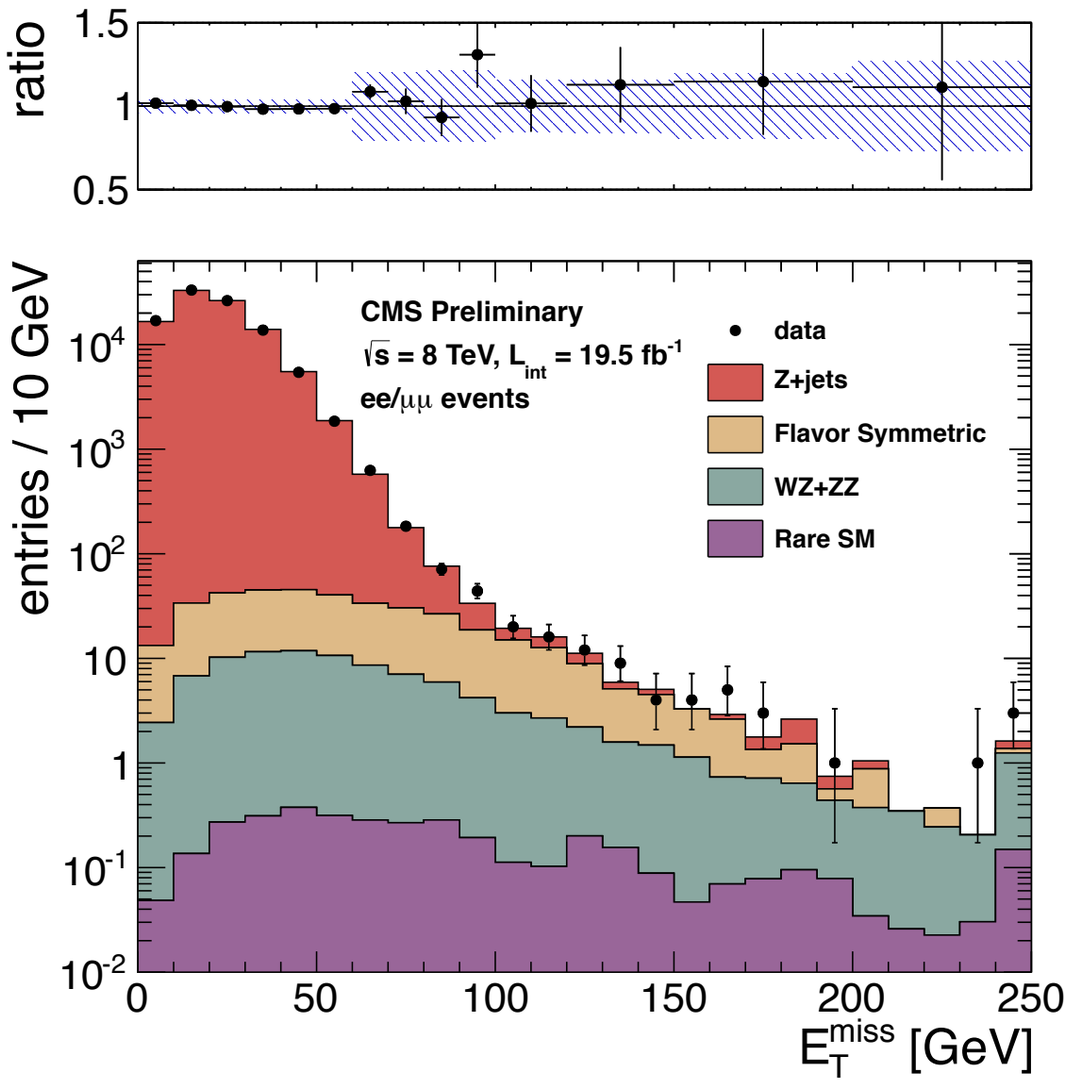


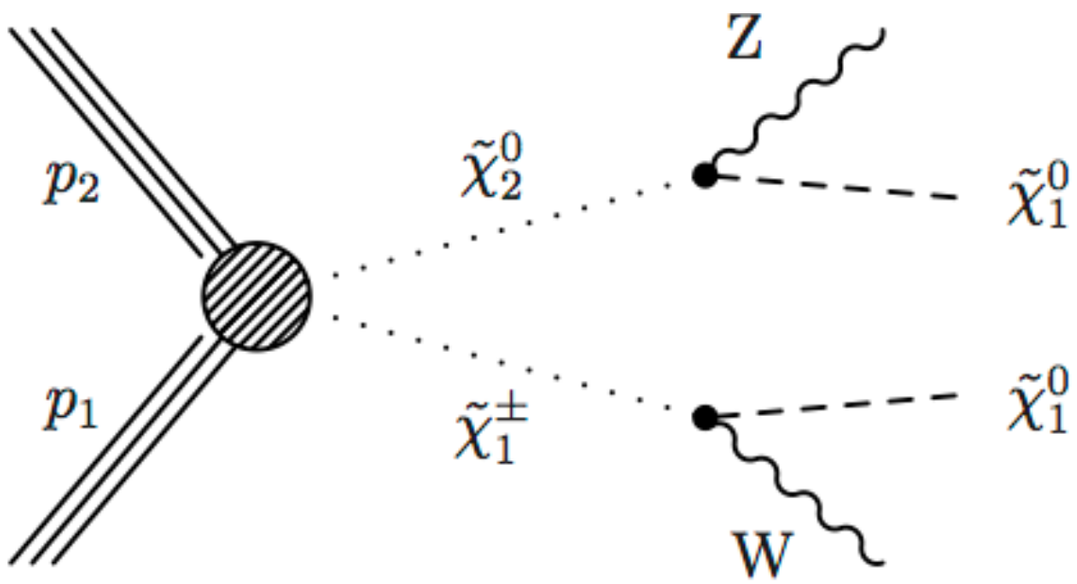
$Z(\ell\ell)W(jj)$

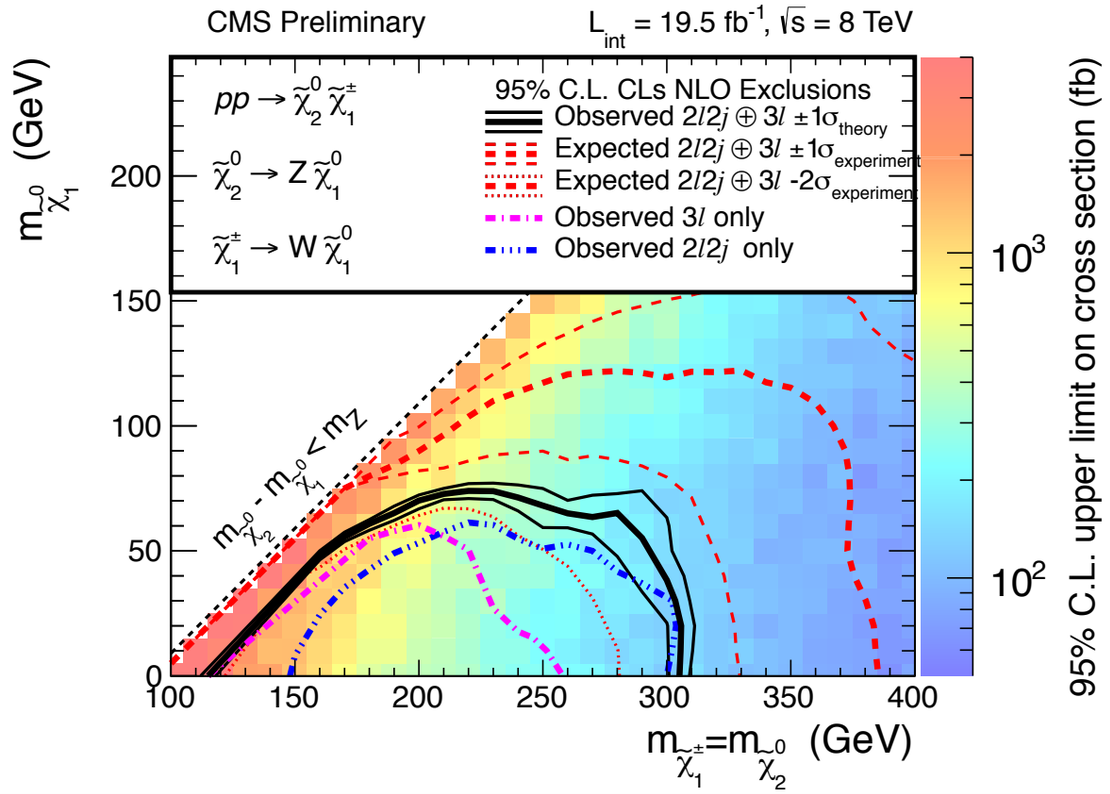
Wino-like
Chargino & Neutralino

Bino-like Neutralino

- Reuse ZZ search



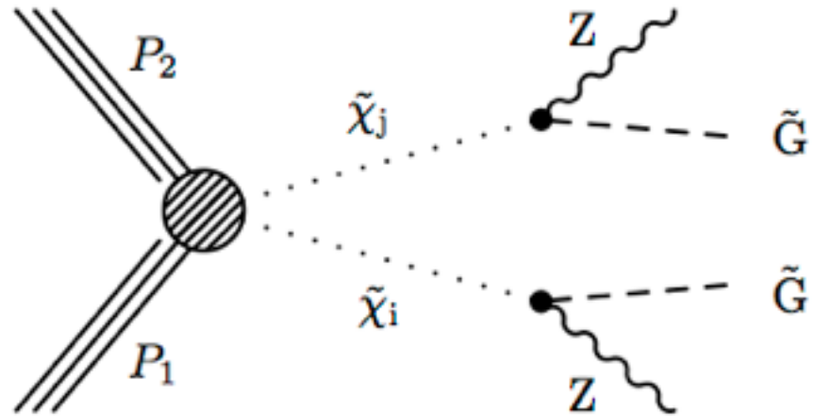




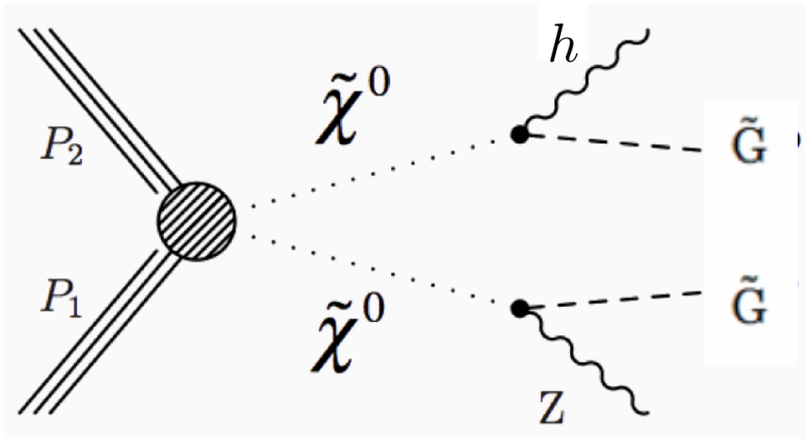
Higgsino Signatures

- Natural SUSY model
- hh, hZ, and ZZ signatures are possible
- Wide variety of observable final states

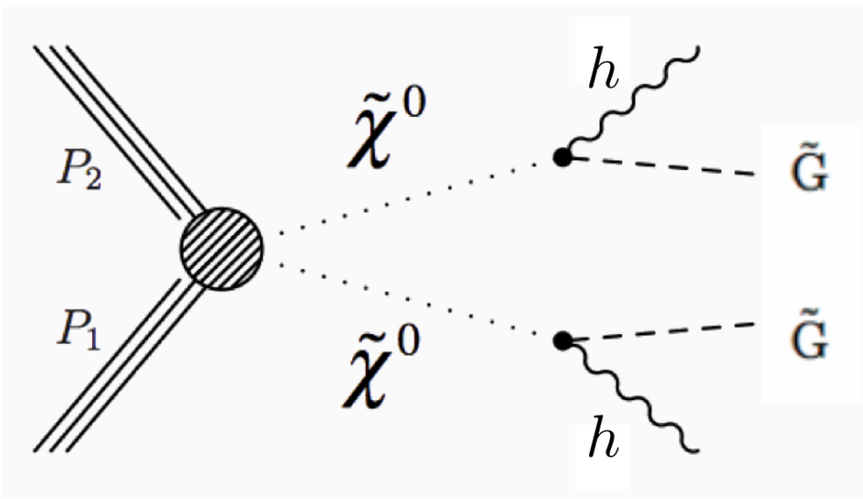
ZZ



hZ



hh



Other super-partners
Heavy and decoupled

Compressed Spectrum

Higgs
Z-Boson

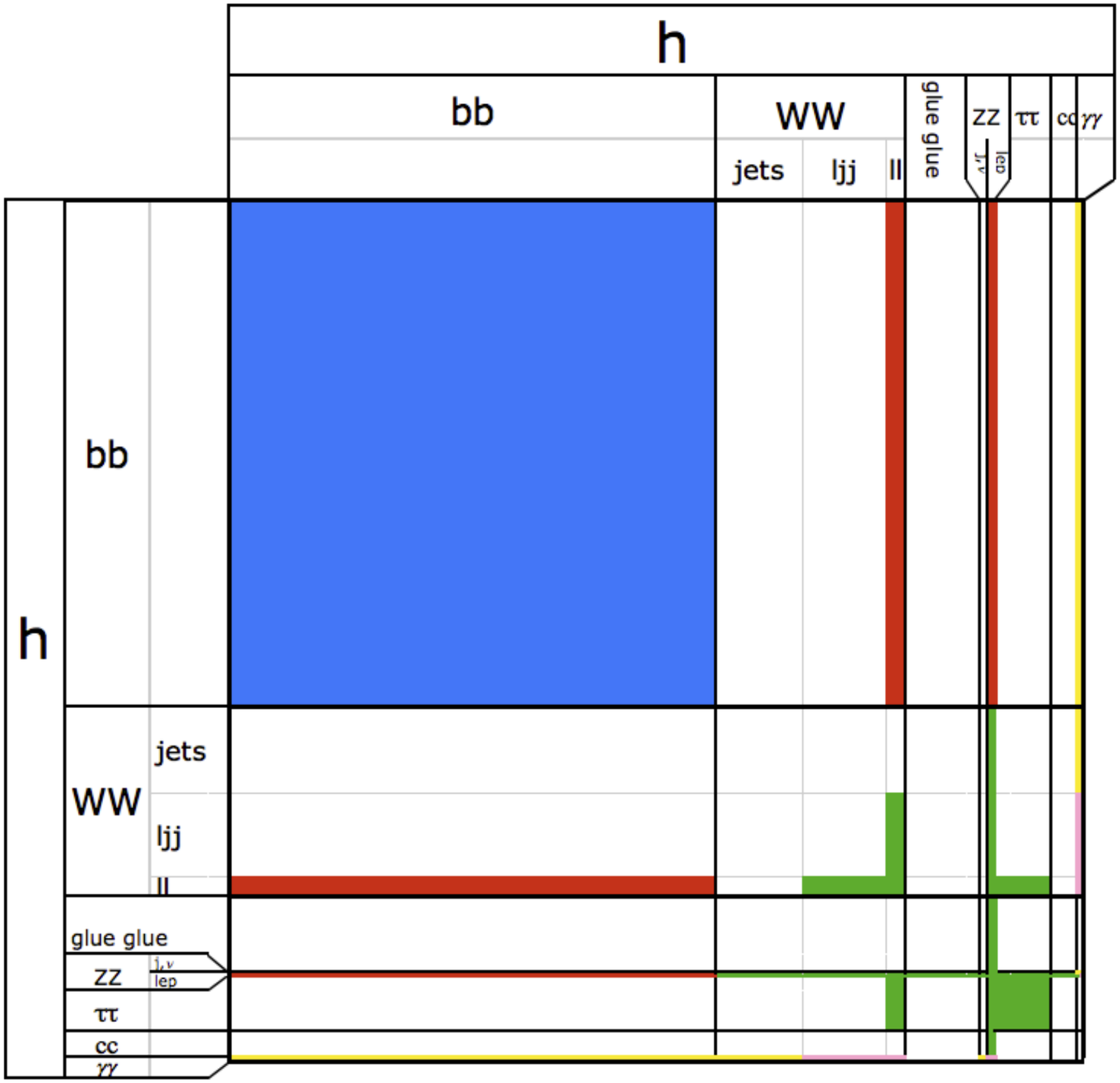
Assume
1 GeV LSP

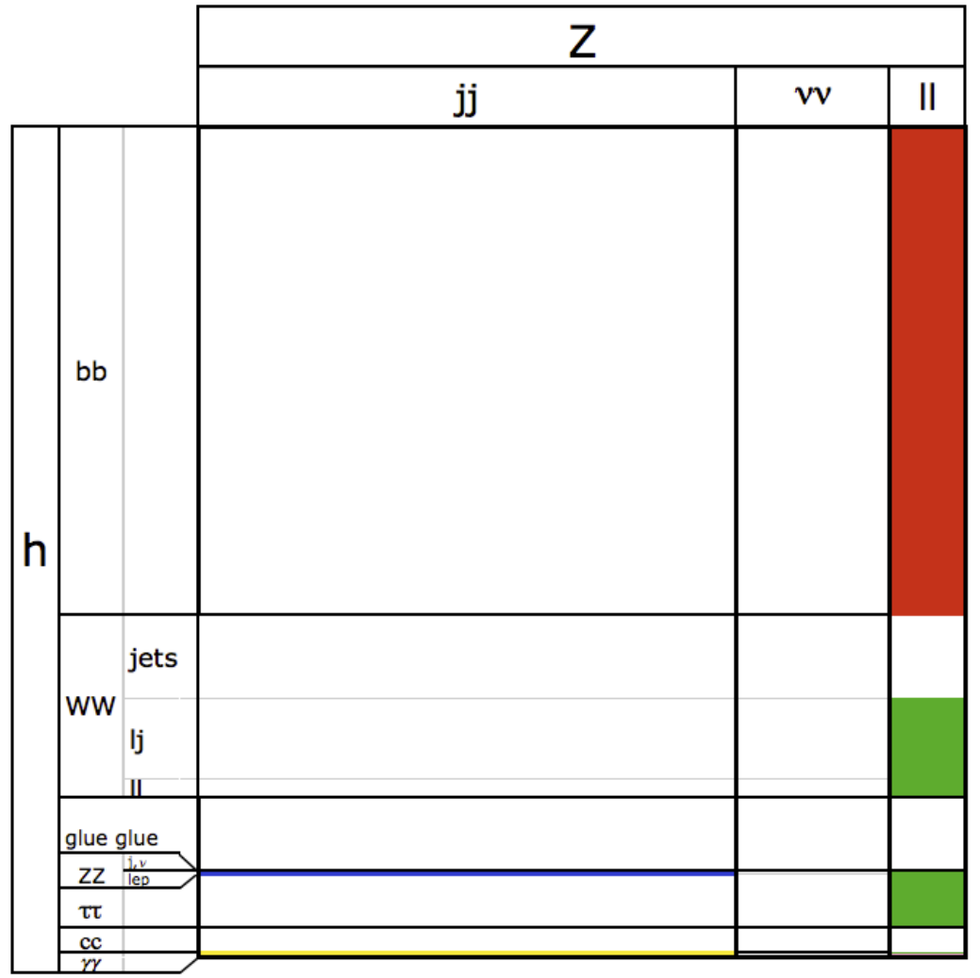
The Higgsino Hydra

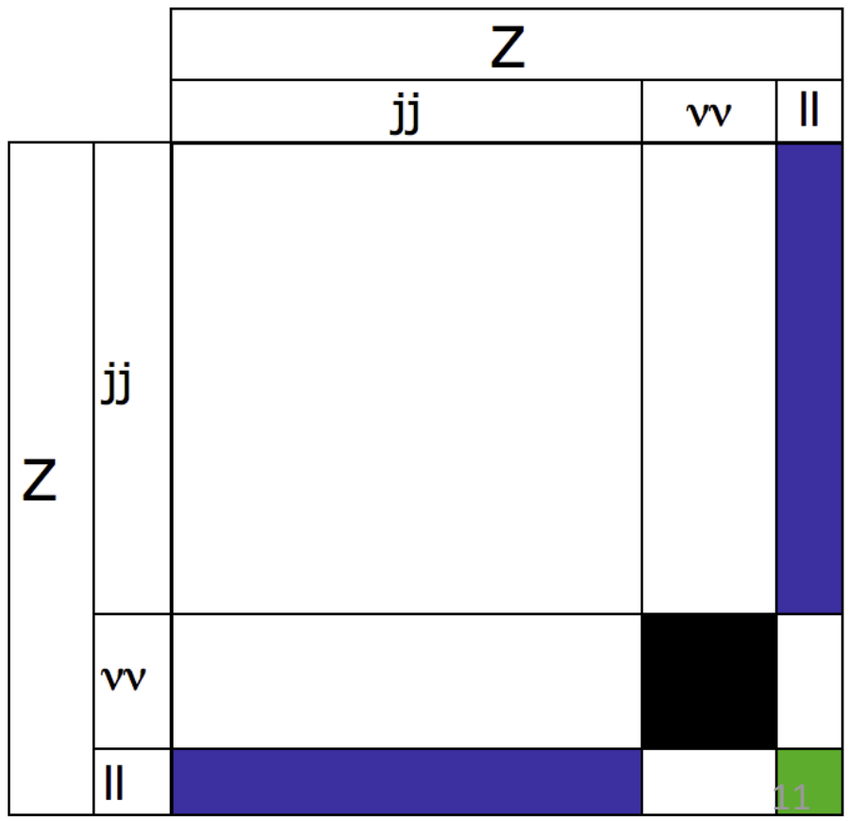
(Mondrian Style)

$$Area \propto BR$$

Colors are regions covered by various analyses



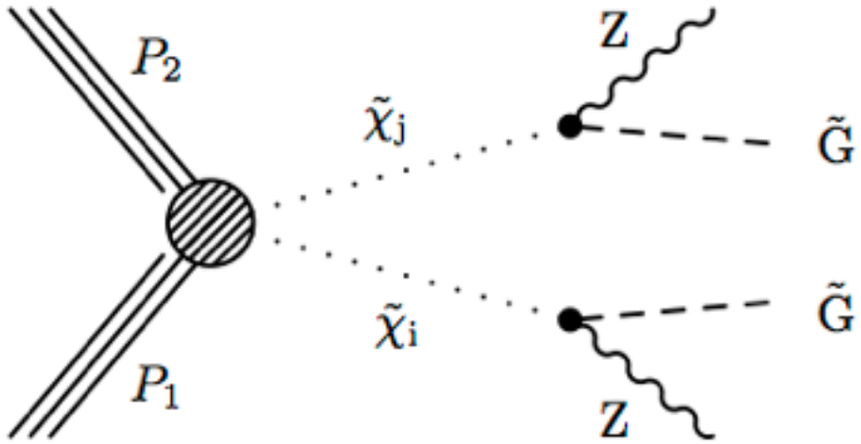


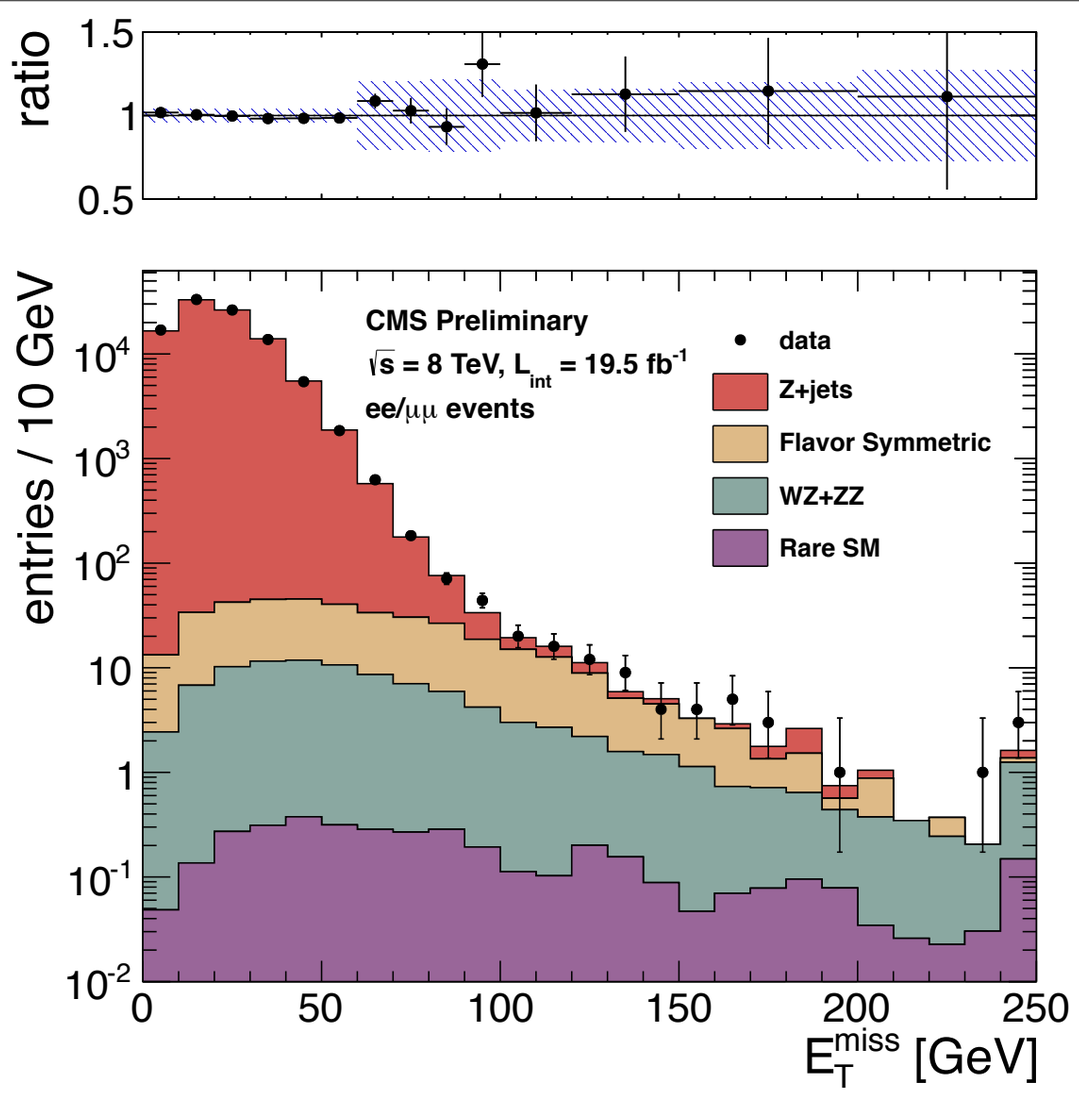


Anthony Barker

$Z(\ell\ell)Z(jj)$

- Select events with a $Z \rightarrow \ell\ell$ candidate and two jets consistent with W/Z decay, then search for excess at high MET.





Signal Regions:

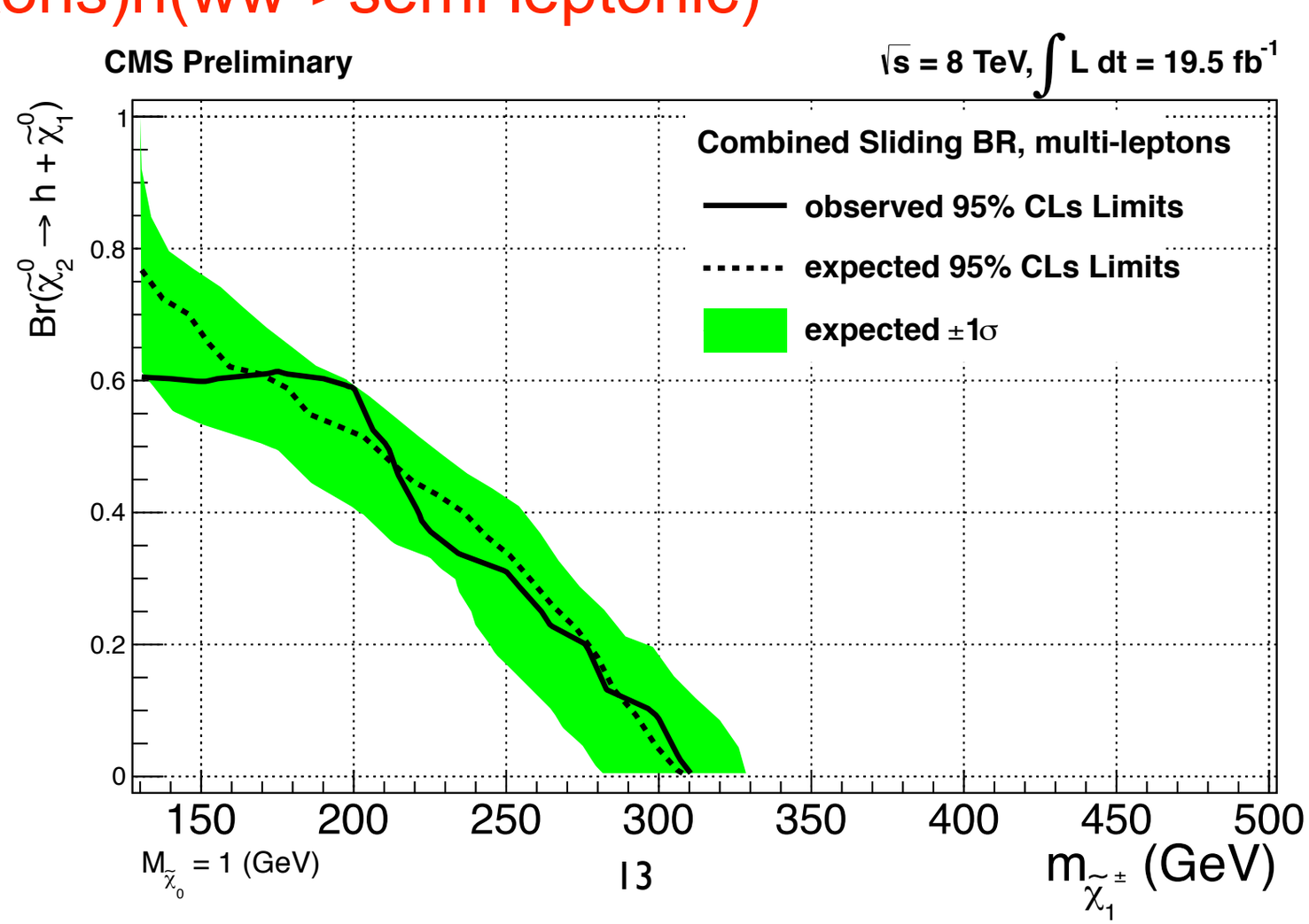
	E_T^{miss} 0–30 GeV	E_T^{miss} 30–60 GeV	E_T^{miss} 60–80 GeV	E_T^{miss} 80–100 GeV
Z+jets bkg	75839 ± 3042	21234 ± 859	690 ± 154	64.5 ± 22.2
FS bkg	69.9 ± 11.9	96.7 ± 16.3	48.3 ± 8.3	35.2 ± 6.2
WZ bkg	16.1 ± 8.1	27.1 ± 13.5	11.8 ± 5.9	6.8 ± 3.4
ZZ bkg	2.9 ± 1.4	6.0 ± 3.0	3.3 ± 1.7	2.8 ± 1.4
Rare SM bkg	0.5 ± 0.2	1.0 ± 0.5	0.6 ± 0.3	0.5 ± 0.2
Total bkg	75929 ± 3042	21364 ± 859	754 ± 154	110 ± 23
Data	76302	20991	809	115
	E_T^{miss} 100–120 GeV	E_T^{miss} 120–150 GeV	E_T^{miss} 150–200 GeV	E_T^{miss} > 200 GeV
Z+jets bkg	7.8 ± 3.1	3.7 ± 1.6	2.0 ± 1.0	0.4 ± 0.3
FS bkg	21.9 ± 4.0	13.2 ± 2.5	5.7 ± 1.6	0.8 ± 0.4
WZ bkg	3.7 ± 1.9	2.9 ± 1.5	1.9 ± 0.9	0.9 ± 0.4
ZZ bkg	1.8 ± 0.9	1.9 ± 0.9	1.4 ± 0.7	1.3 ± 0.7
Rare SM bkg	0.2 ± 0.1	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.1
Total bkg	35.4 ± 5.5	22.2 ± 3.5	11.3 ± 2.2	3.6 ± 1.0
Data	36	25	13	4

Multi-leptons

- Reinterpretation of the Slepton search
- Sensitive decay modes:
  - hh topology: hh → 4W, 4Z, 4τ, 2W2Z, 2W2τ, 2Z2τ, and 2Z2b.
  - hZ topology: hZ → WWZ, ZZZ, ττZ
  - ZZ topology: ZZ → 4 leptons

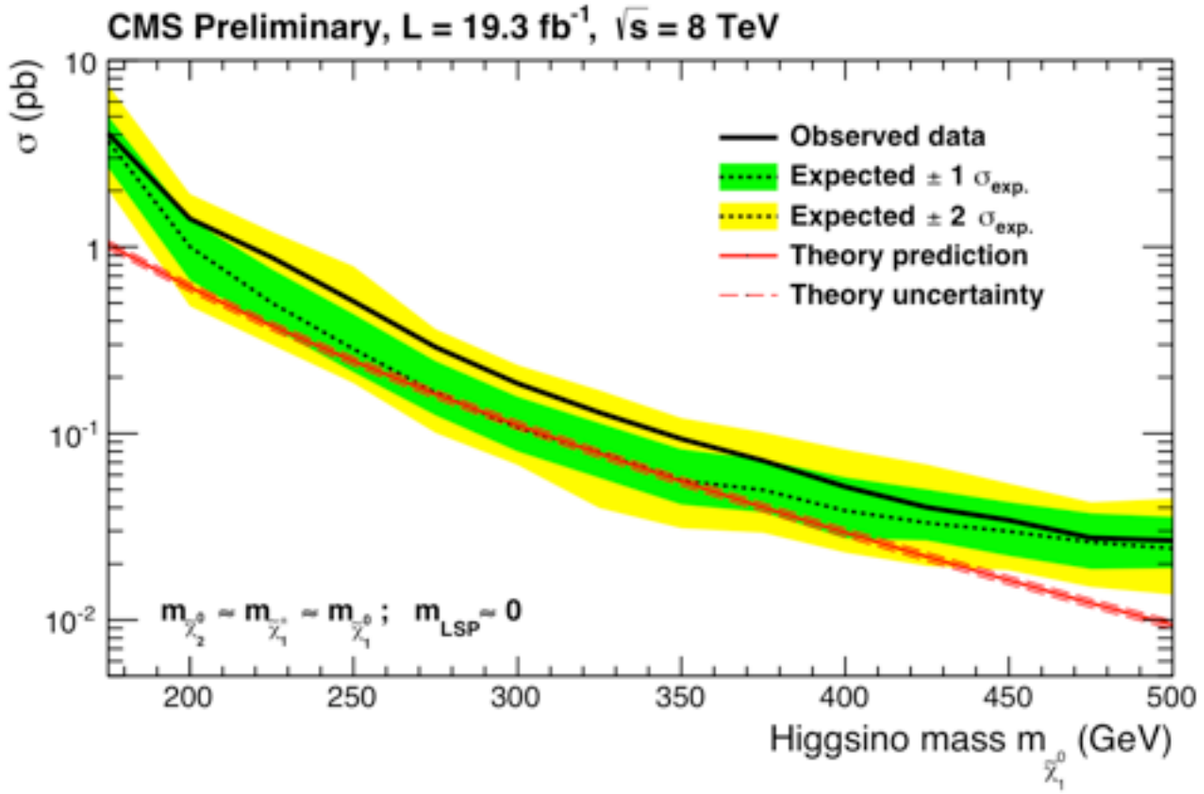
Most important bin: 3 leptons, no b-jets, and low HT

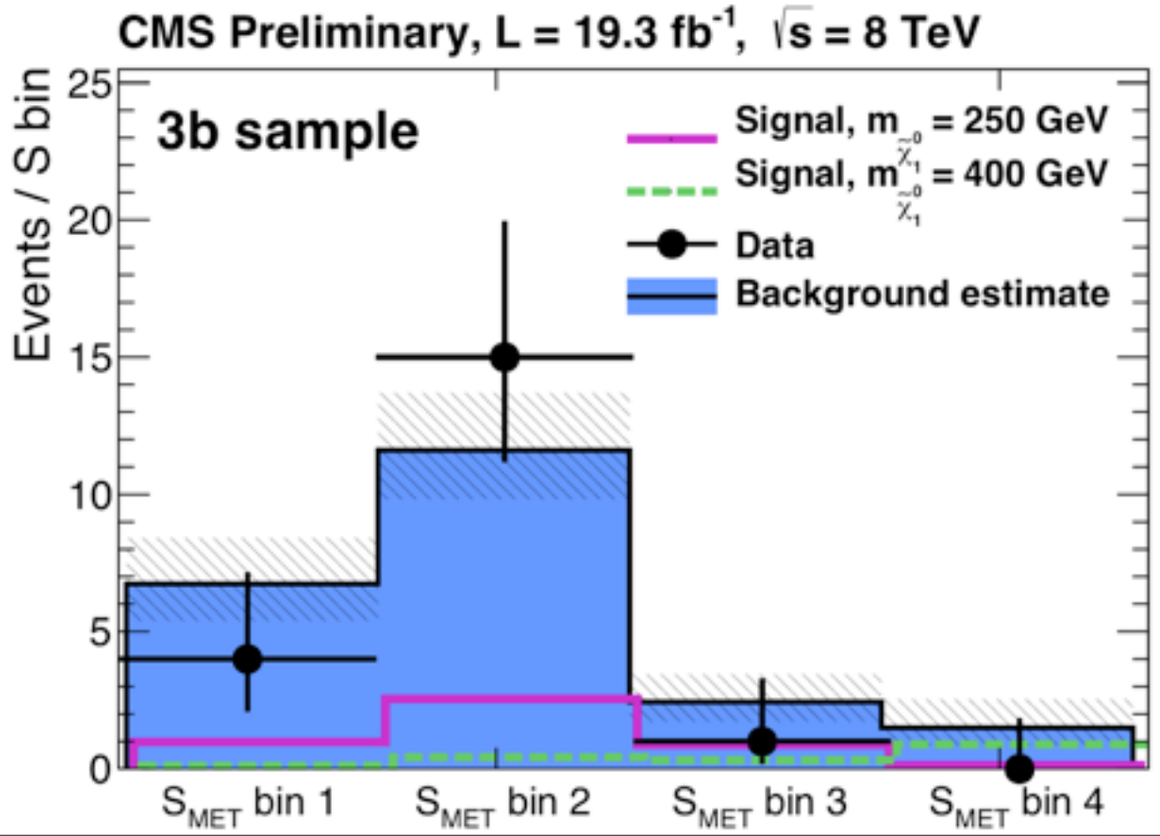
h(ww->leptons)h(ww->semi leptonic)

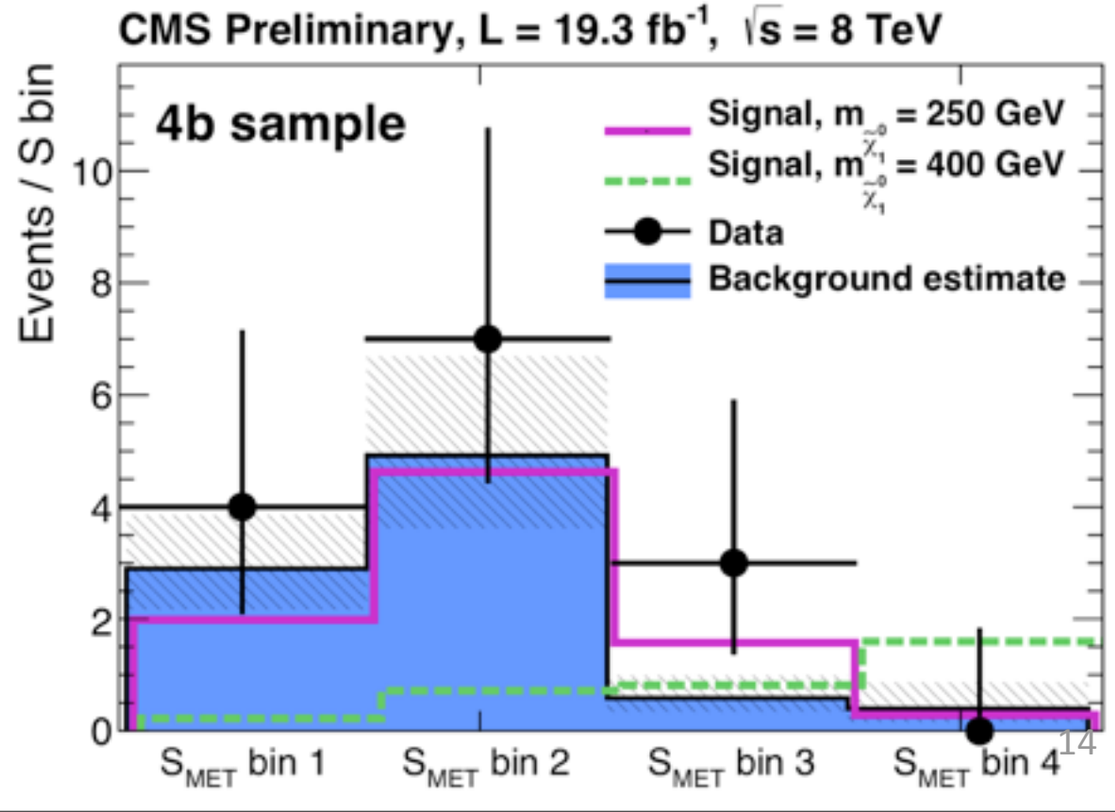


h(bb)h(bb)+MET

- Exploits double Higgs resonance
  - Pair 4 jets into 2 higgs candidates
  - Cut on invariant masses of both candidates
- Data-driven background
  - ABCD method using higgs mass sidebands and number of b-tags







Conclusions

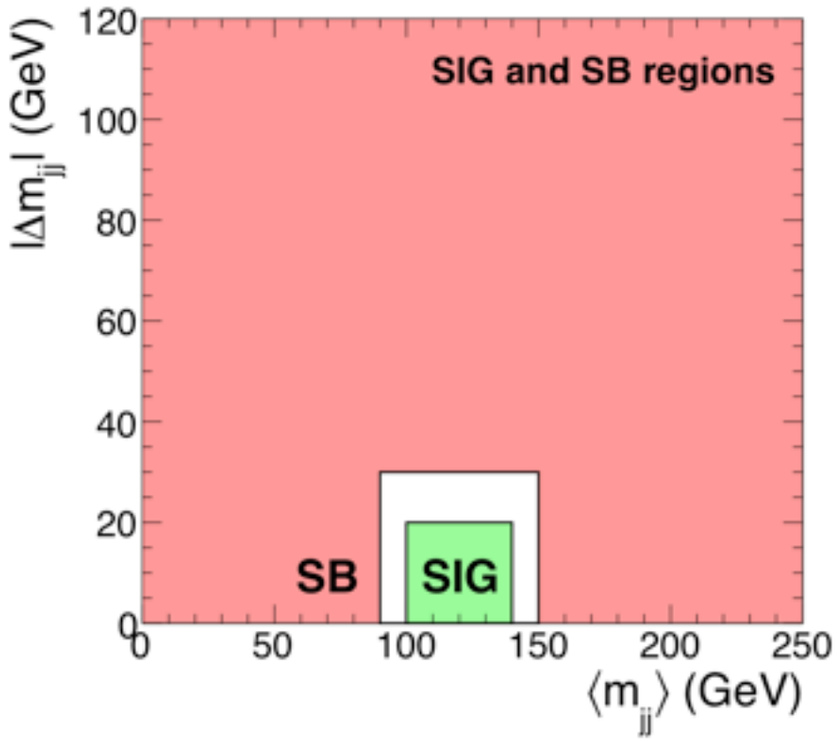
- Lots of models, final states, channels.
- Fortunately they can be reinterpreted to constrain multiple models.
- Need to combine results from multiple analyses for better sensitivity. (Work in progress)
- No strong signs of susy yet.

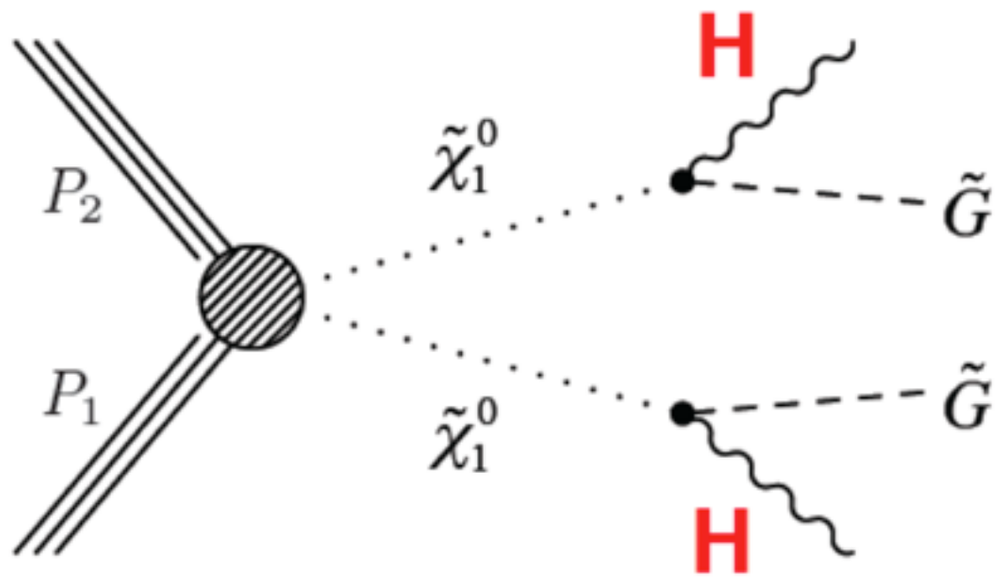
Back-up

References

- "A search for anomalous production of events with three or more leptons using 19.5fb^{-1} of $\sqrt{s}$ = 8 TeV LHC data". CMS-2013/002 arXiv Twiki PAS
- "Search for electroweak production of charginos, neutralinos, and sleptons using leptonic final states in pp collisions at $\sqrt{s}$ = 8 TeV". CMS-2013/006 Twiki PAS
- "Search for electroweak production of charginos and neutralinos in final states with a Higgs boson in pp collisions at $\sqrt{s}$ = 8 TeV". CMS-2013/017 Twiki PAS
- "Search for electroweak production of higgsinos in channels with two Higgs bosons decaying to b quarks in pp collisions at 8 TeV". CMS-2013/022 Twiki PAS

h(bb)h(bb)+MET





$\mathcal{S}_{\mathrm{MET}}$ bin 1	$30 < \mathcal{S}_{\mathrm{MET}} < 50$
$\mathcal{S}_{\mathrm{MET}}$ bin 2	$50 < \mathcal{S}_{\mathrm{MET}} < 100$
$\mathcal{S}_{\mathrm{MET}}$ bin 3	$100 < \mathcal{S}_{\mathrm{MET}} < 150$
$\mathcal{S}_{\mathrm{MET}}$ bin 4	$\mathcal{S}_{\mathrm{MET}} > 150$