Explaining multilepton excess with Gauge Mediation

Karen De Causmaecker

SUSY 2014 @ Manchester

Based on J. D'Hondt, K.D.C.,B. Fuks,
A. Mariotti, K.Mawatari.,C. Petersson, D. Redigolo
Phys.Lett. B731(2014) 7-12
[hep-ph, arXiv:1310.0018]

10.2 ± 2.4 events *expected*

vs.

22 events *observed*

10.2 ± 2.4 events *expected*

vs.

22 events *observed*

5 sigma
discovery of
SUSY?

In which search does this excess occur?

Can we explain it with SUSY?

Prospects

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Can we explain it with SUSY?

Prospects

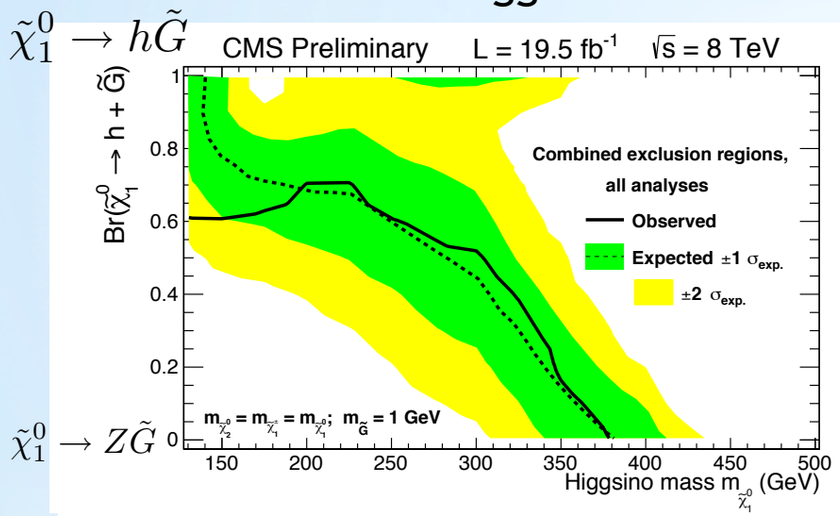
CMS searches for SUSY

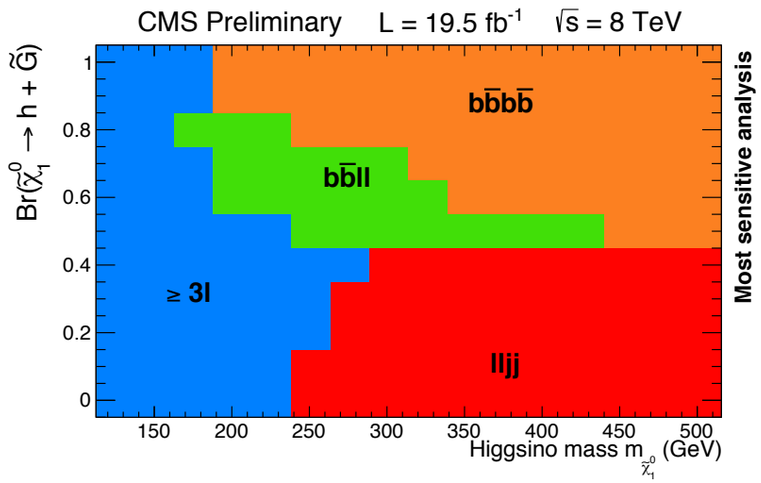
Slide from Henning Flaecher, plenary talk yesterday

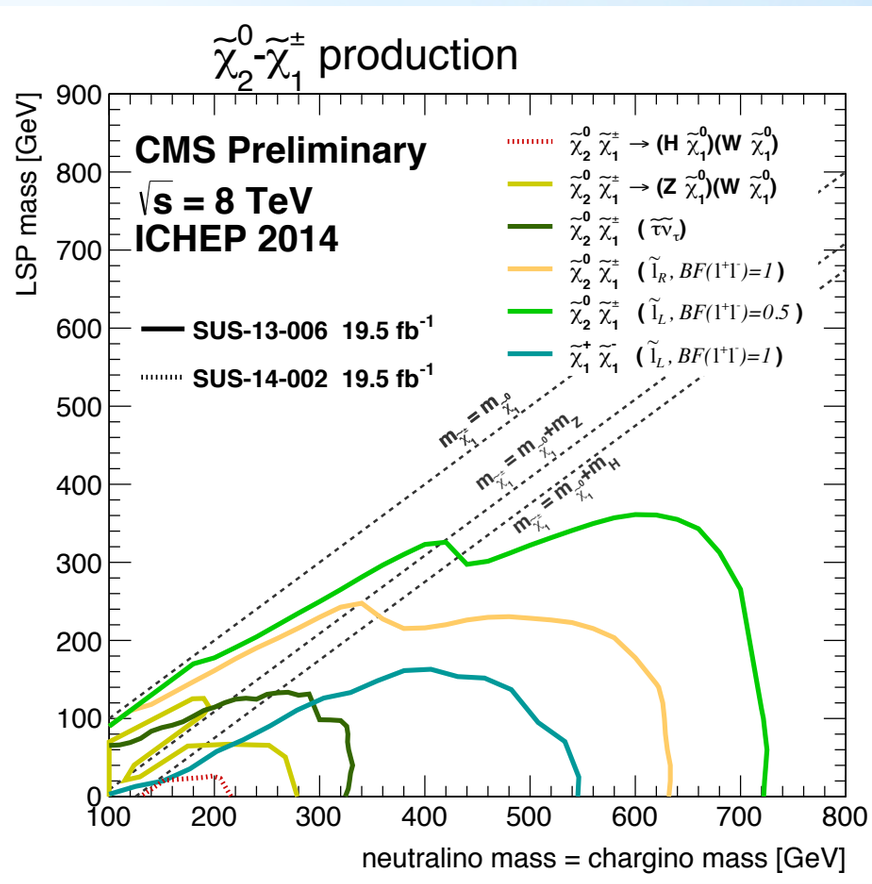
* Interpretations in Simplified models

SUS-14-002 & arXiv:1405.7570

GMSB Higgsino







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Caused by an excess

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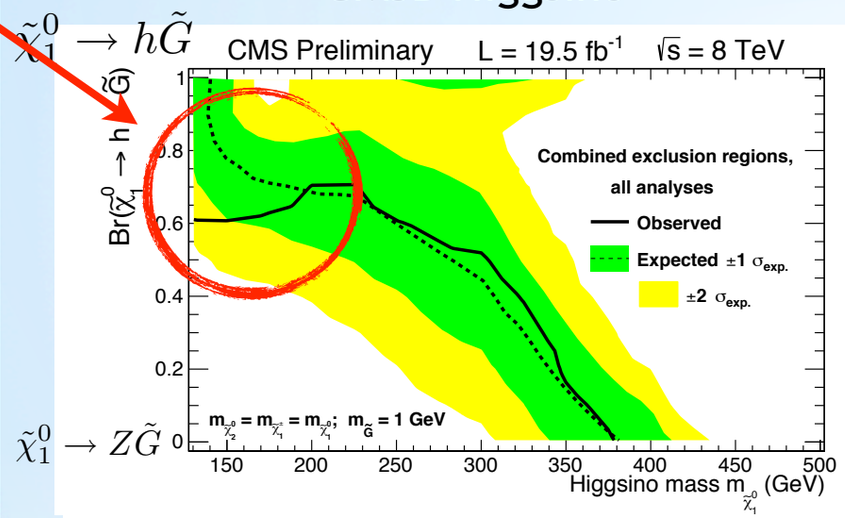
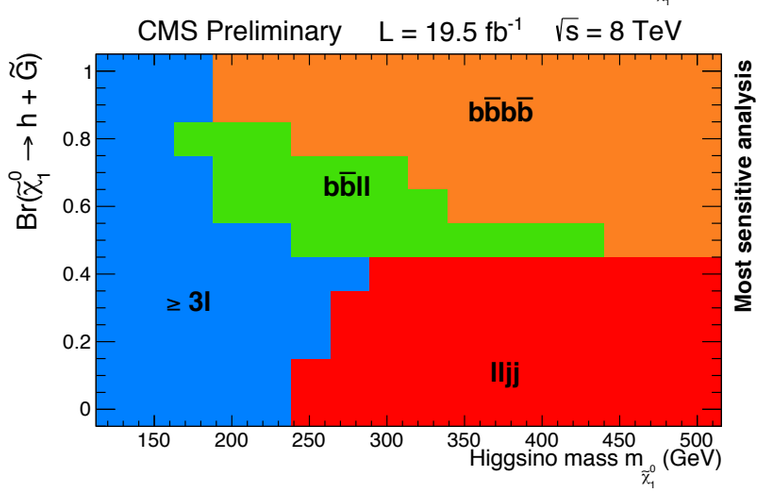
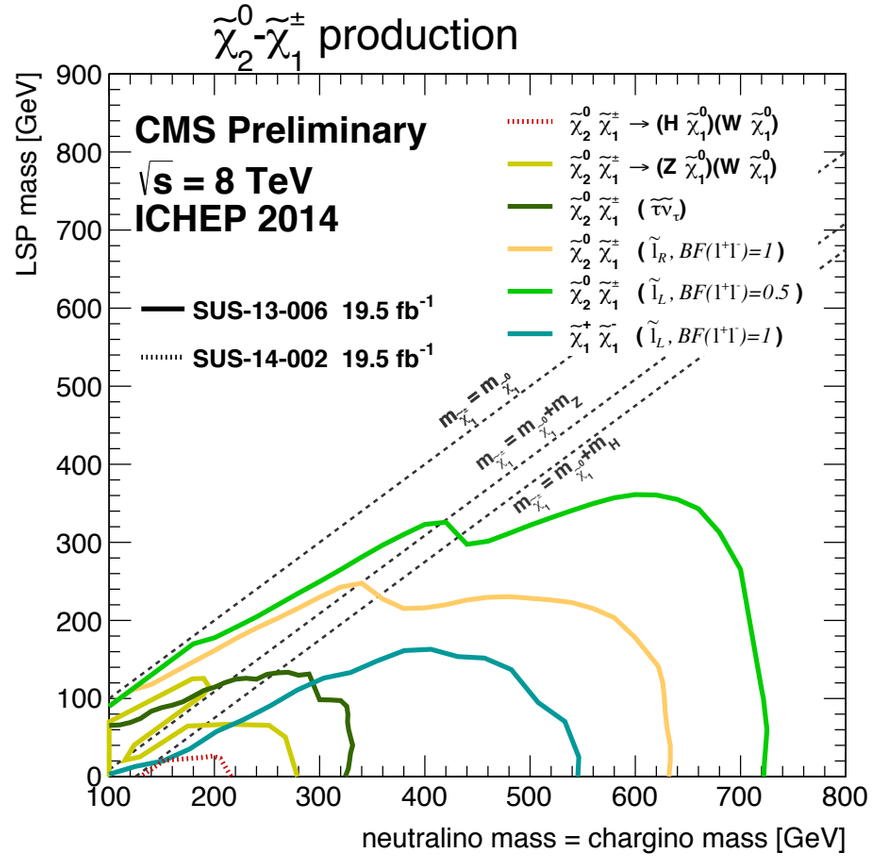






CMS searches for SUSY

Slide from Henning Flaecher, plenary talk yesterday

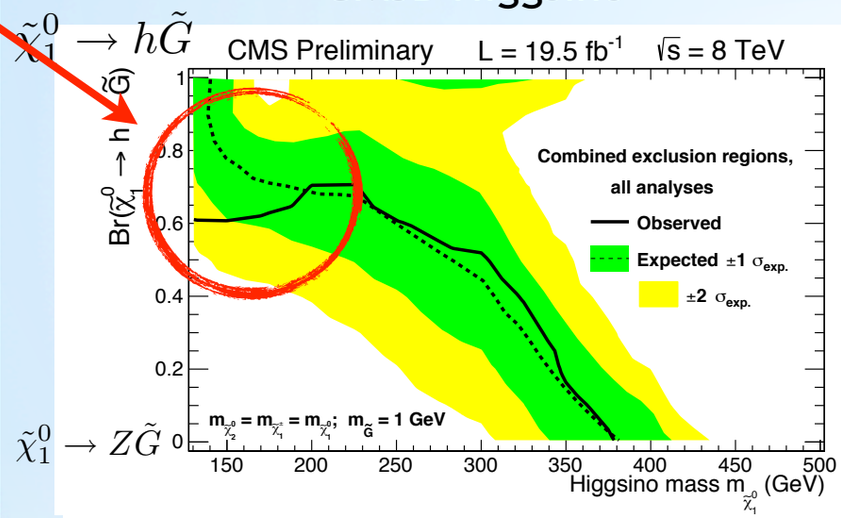
Caused by an excess

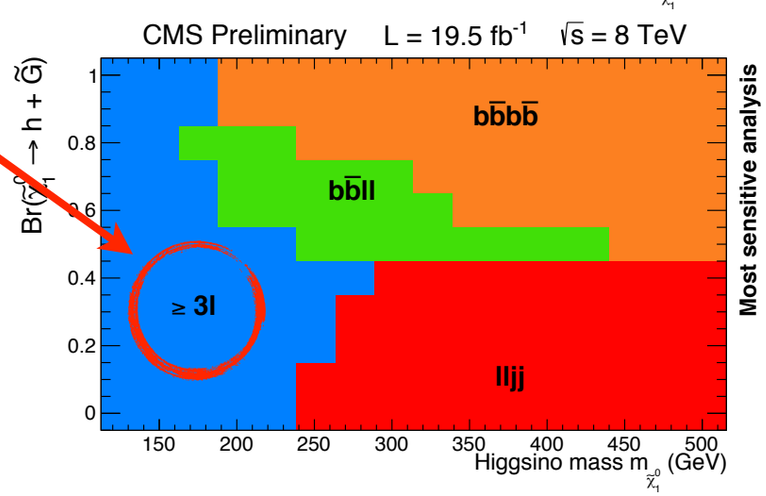
In the search for 3 or more leptons

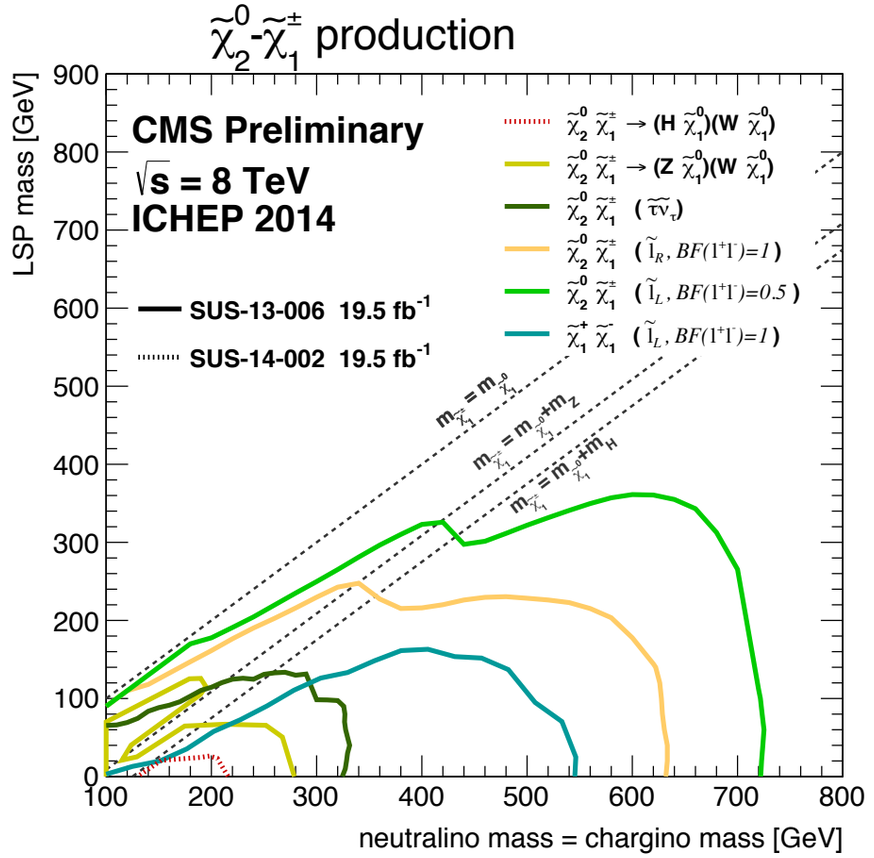
* Interpretations in Simplified models

SUS-14-002 & arXiv:1405.7570

GMSB Higgsino







CMS-SUS-13-002 searches for three or more leptons

In categories divided according to

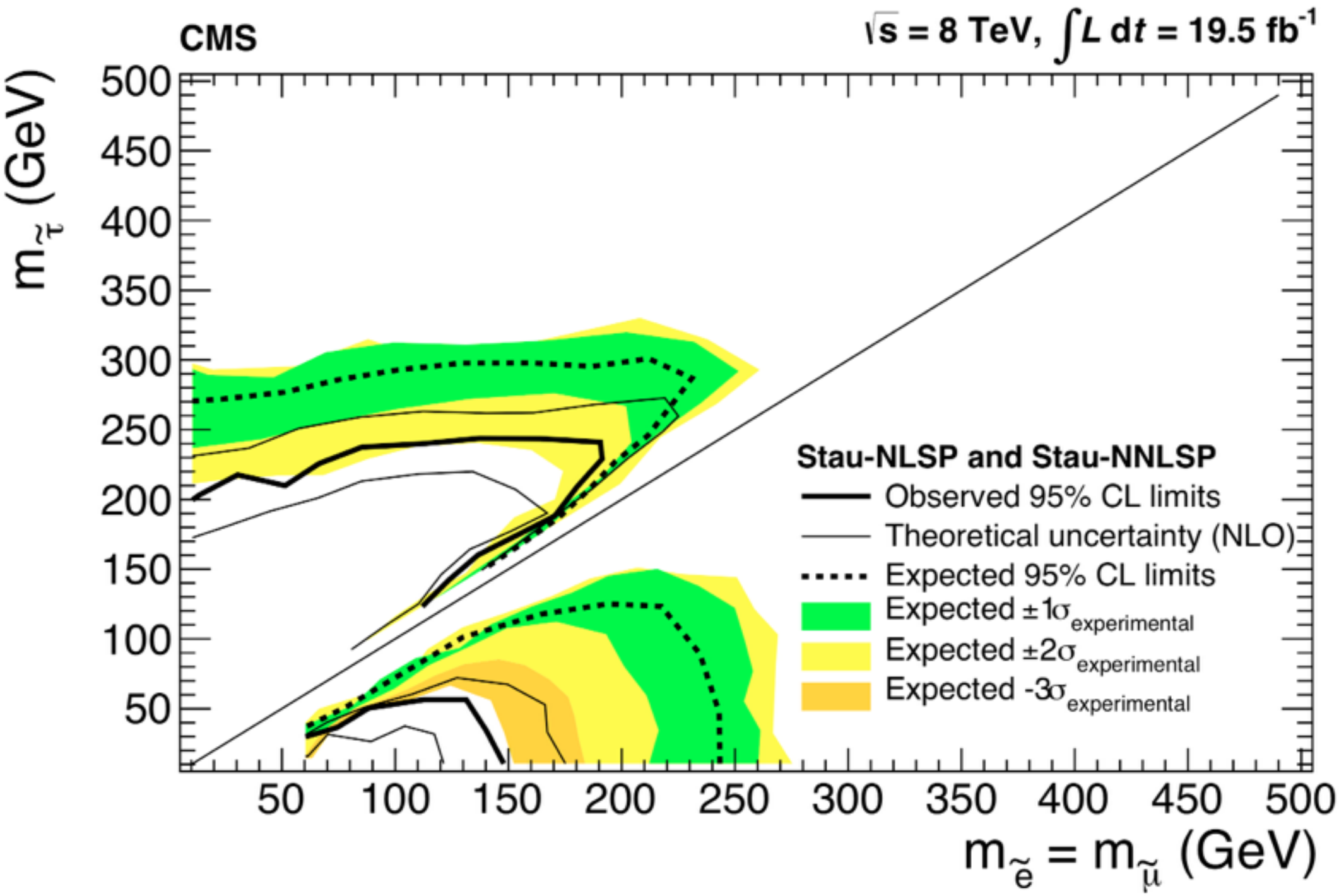
Number of leptons (= electrons or muons)

Opposite sign same flavor pairs (OSSF)

Number of hadronic taus

Hadronic activity (= H_T)

Number of b-jets



[CMS-SUS-13-002]

CMS observes more events than expected

4 leptons

Selection		E_T^{miss}	N(τ_h)=1, N_{b-jets}=0	
4 Lepton Results			obs	exp
OSSF1 $H_T < 200$	off-Z	(100,∞)	3	0.6 ± 0.24
OSSF1 $H_T < 200$	off-Z	(50,100)	4	2.1 ± 0.5
OSSF1 $H_T < 200$	off-Z	(0,50)	15	7.5 ± 2

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Low hadronic activity

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Close to discovery?

Excess in 1 out of 64 categories

Selection 4 Lepton Results		E_T^{miss}	$N(\tau_h)=0$, $N_{b-jets}=0$ obs	exp	$N(\tau_h)=1$, $N_{b-jets}=0$ obs	exp	$N(\tau_h)=0$, $N_{b-jets}\geq 1$ obs	exp	$N(\tau_h)=1$, $N_{b-jets}\geq 1$ obs	exp
OSSF0 $H_T < 200$	NA	(100,∞)	0	0.11 ± 0.08	0	0.17 ± 0.1	0	0.03 ± 0.04	0	0.04 ± 0.04
OSSF0 $H_T < 200$	NA	(50,100)	0	0.01 ± 0.03	2	0.7 ± 0.33	0	0 ± 0.02	0	0.28 ± 0.16
OSSF0 $H_T < 200$	NA	(0,50)	0	0.01 ± 0.02	1	0.7 ± 0.3	0	0.001 ± 0.02	0	0.13 ± 0.08
OSSF1 $H_T < 200$	off-Z	(100,∞)	0	0.06 ± 0.04	3	0.6 ± 0.24	0	0.02 ± 0.04	0	0.32 ± 0.2
OSSF1 $H_T < 200$	on-Z	(100,∞)	1	0.5 ± 0.18	2	2.5 ± 0.5	1	0.38 ± 0.2	0	0.21 ± 0.1
OSSF1 $H_T < 200$	off-Z	(50,100)	0	0.18 ± 0.06	4	2.1 ± 0.5	0	0.16 ± 0.08	1	0.45 ± 0.24
OSSF1 $H_T < 200$	on-Z	(50,100)	2	1.2 ± 0.34	9	9.6 ± 1.6	2	0.42 ± 0.23	0	0.5 ± 0.16
OSSF1 $H_T < 200$	off-Z	(0,50)	2	0.46 ± 0.18	15	7.5 ± 2	0	0.09 ± 0.06	0	0.7 ± 0.31
OSSF1 $H_T < 200$	on-Z	(0,50)	4	3 ± 0.8	41	40 ± 10	1	0.31 ± 0.15	2	1.5 ± 0.47
OSSF2 $H_T < 200$	off-Z	(100,∞)	0	0.04 ± 0.03	-	-	0	0.05 ± 0.04	-	-
OSSF2 $H_T < 200$	on-Z	(100,∞)	0	0.34 ± 0.15	-	-	0	0.46 ± 0.25	-	-
OSSF2 $H_T < 200$	off-Z	(50,100)	2	0.18 ± 0.13	-	-	0	0.02 ± 0.03	-	-
OSSF2 $H_T < 200$	on-Z	(50,100)	4	3.9 ± 2.5	-	-	0	0.5 ± 0.21	-	-
OSSF2 $H_T < 200$	off-Z	(0,50)	7	8.9 ± 2.4	-	-	1	0.23 ± 0.09	-	-
OSSF2 $H_T < 200$	on-Z	(0,50)	*156	159 ± 34	-	-	4	2.9 ± 0.8	-	-

... look elsewhere effect?

CMS: 'No real reason to be excited'

Slide from presentation by Andrea Gozzelino (CMS)
at the conference "SUSY 2013", August 26

Origin & significance of discrepancy

CMS-SUS-13-002

Categorie:

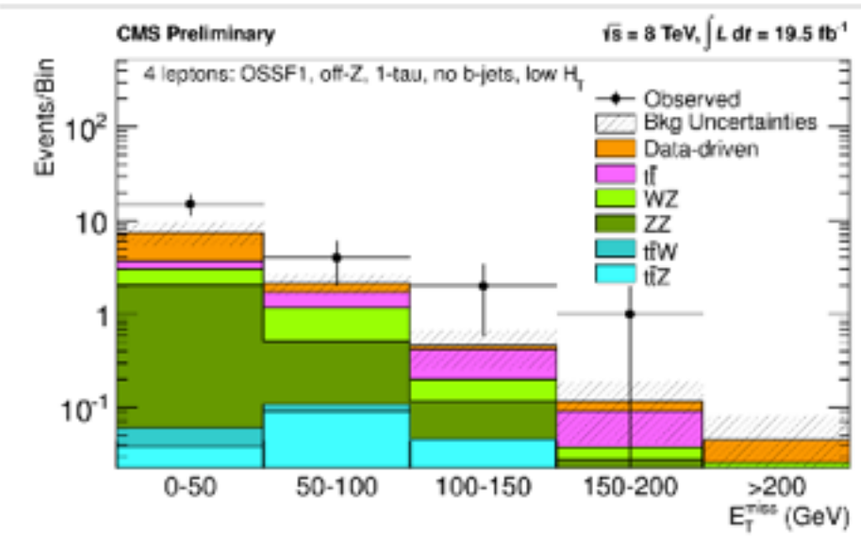
4 leptons, OSSF1, off-Z,

including 1 τ,

no b-tags, HT< 200 GeV

Observe = 22 events

Expected = 10 ± 2.4 events



Probability for 1 out of 64 categories to have as large a fluctuation ≈ 50 %
Probability for all bins in 1 out of 64 categories to have as large a fluctuation ≈ 5 %

Given that we search for new physics in 64 different categories of multi-lepton events, it is not surprising that we find one category with a large deviation between observed yield and expected SM background.

In which search does the excess occur?

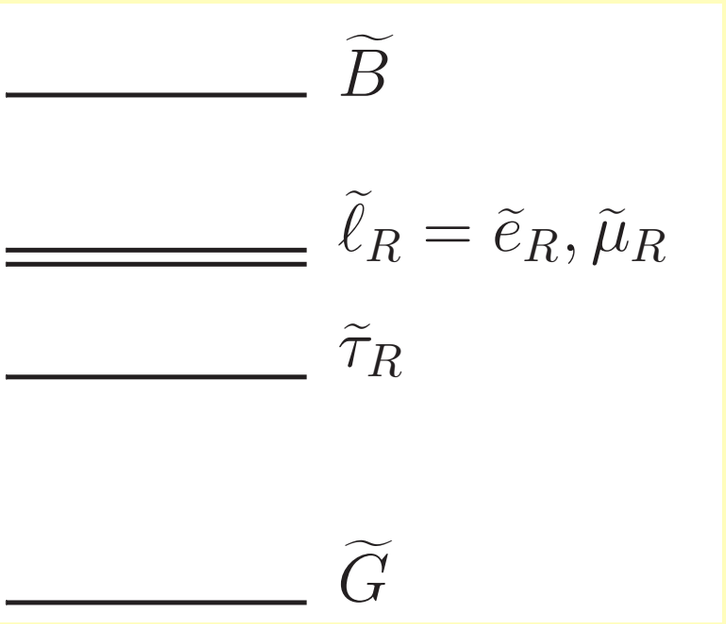
Can we explain it with SUSY?

Prospects

Simplified model 1

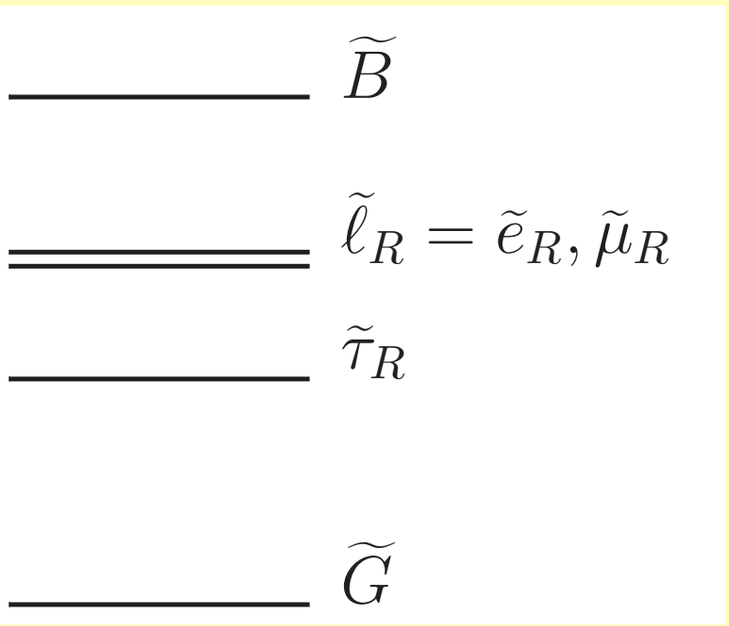
Simplified model 2

Simplified model 1

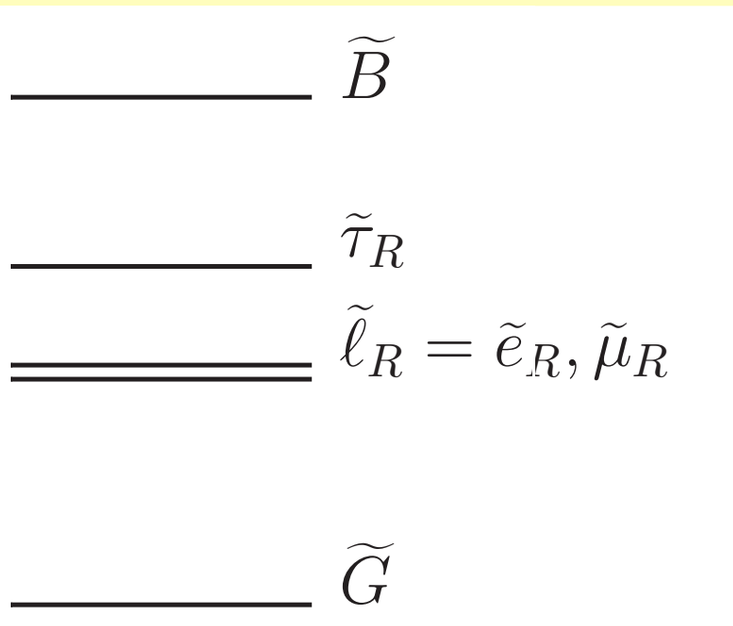


Simplified model 2

Simplified model 1



Simplified model 2



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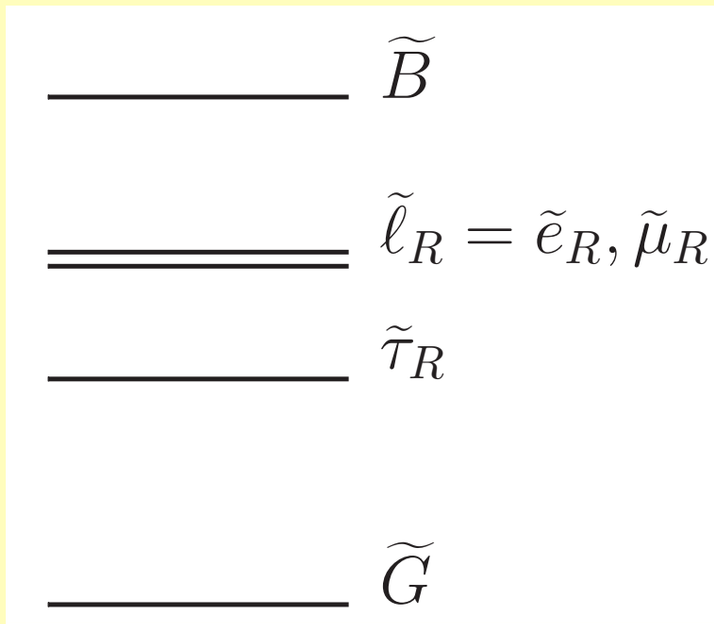
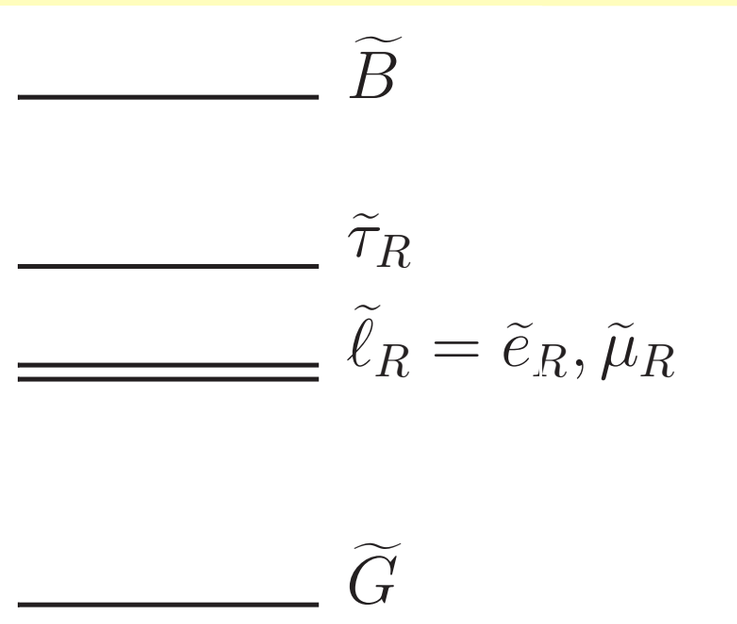


Simplified model 2



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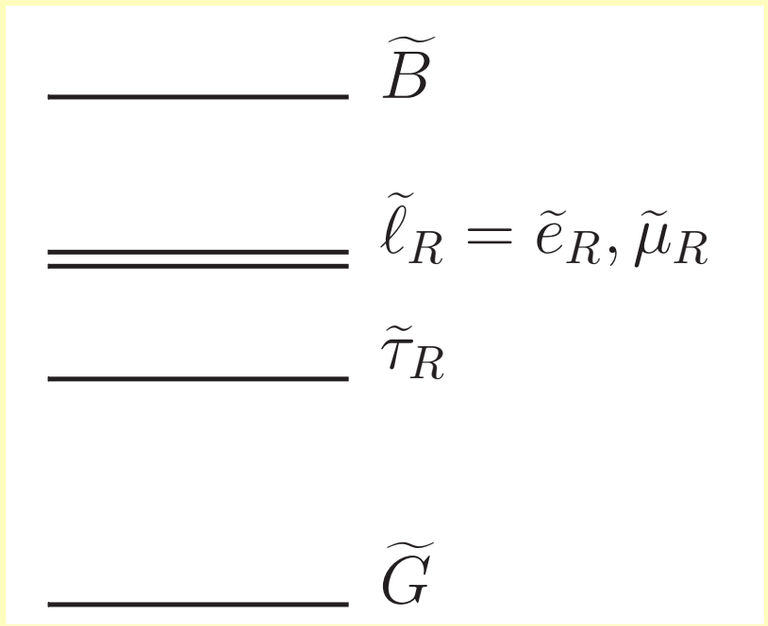
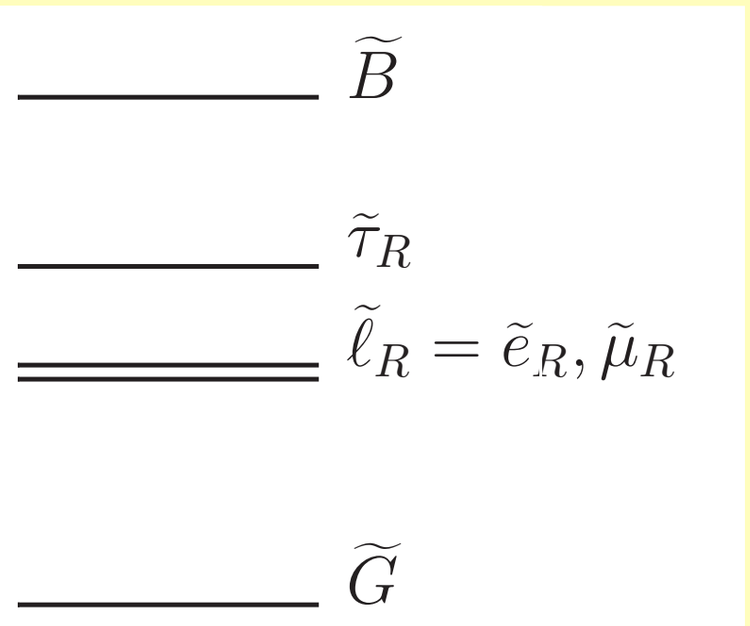


Common in GMSB

Simplified model 2



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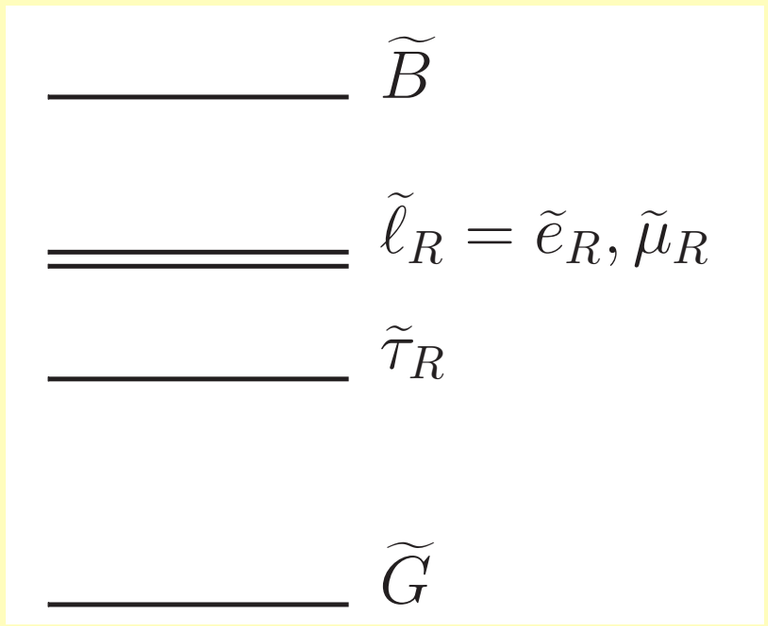

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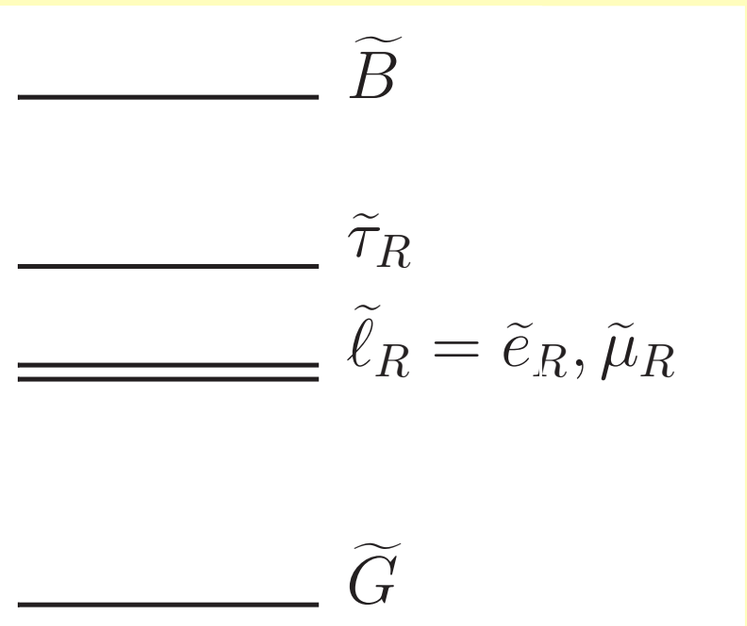

Realized when the soft masses for both Higgs fields receive extra, non-gauge mediated, contributions

[Evans, Morrisey, Wells, Phys. Rev. D75, 055017 (2007)
Grajek, Mariotti, Redigolo, JHEP 1307 (2013) 109]

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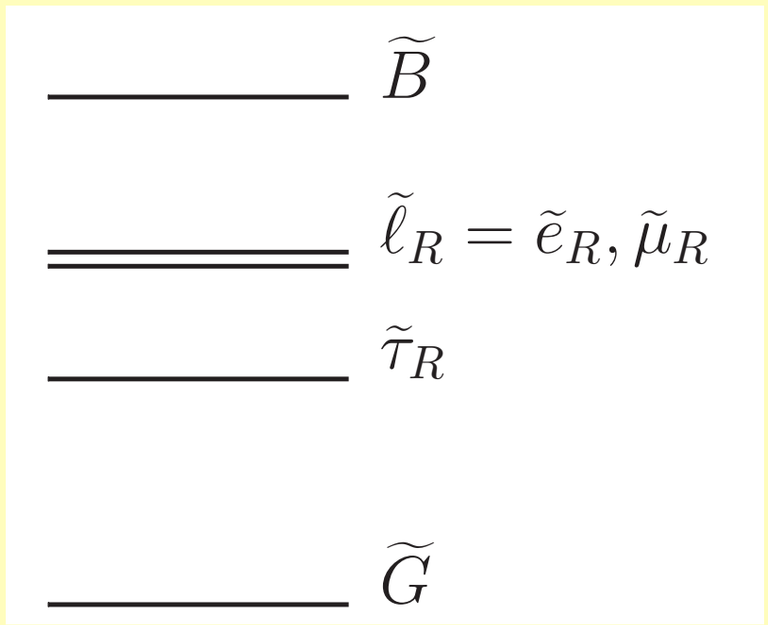

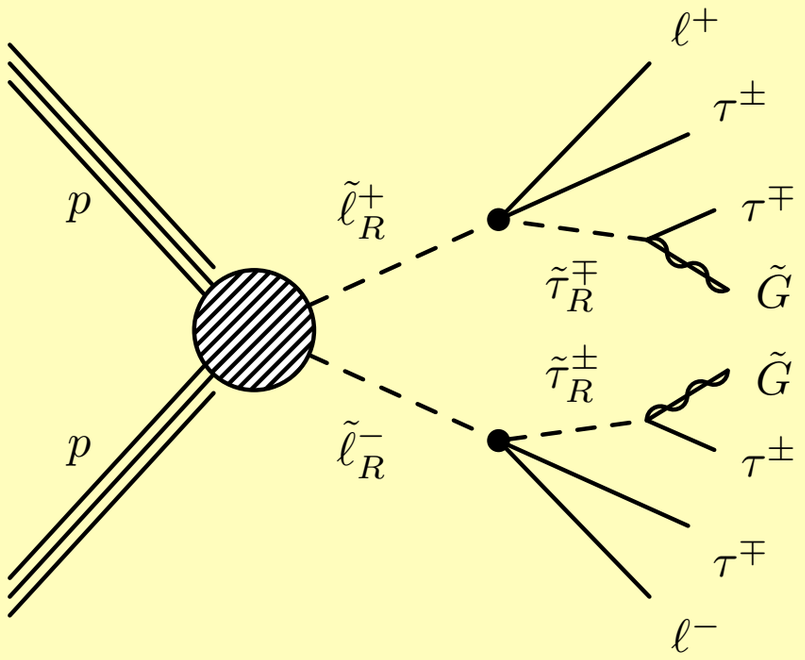

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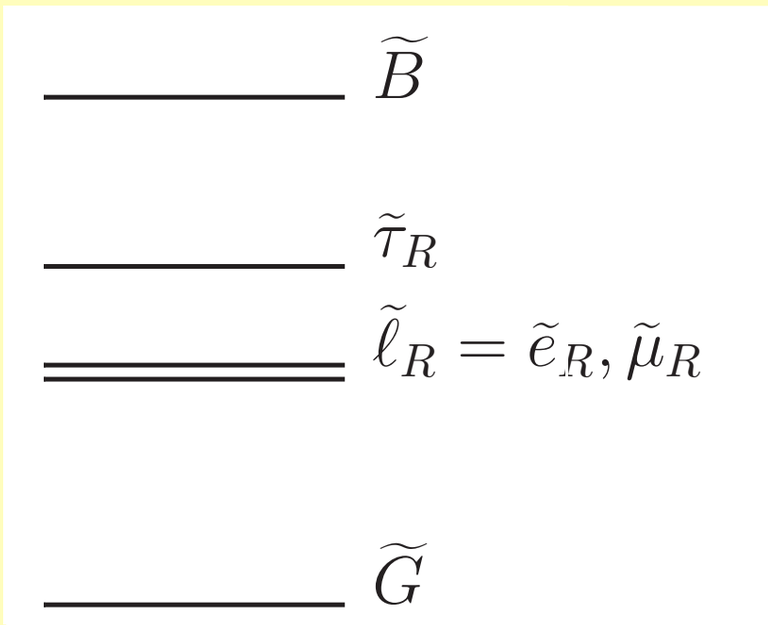

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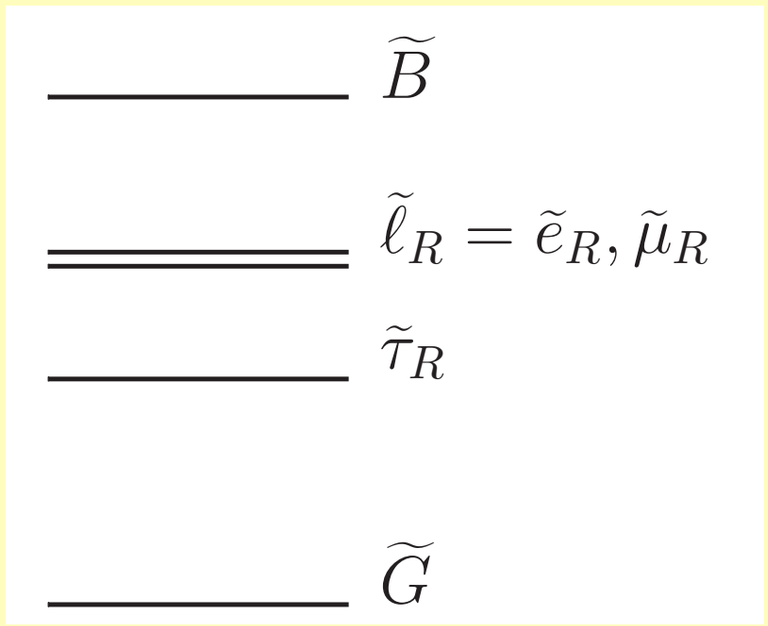
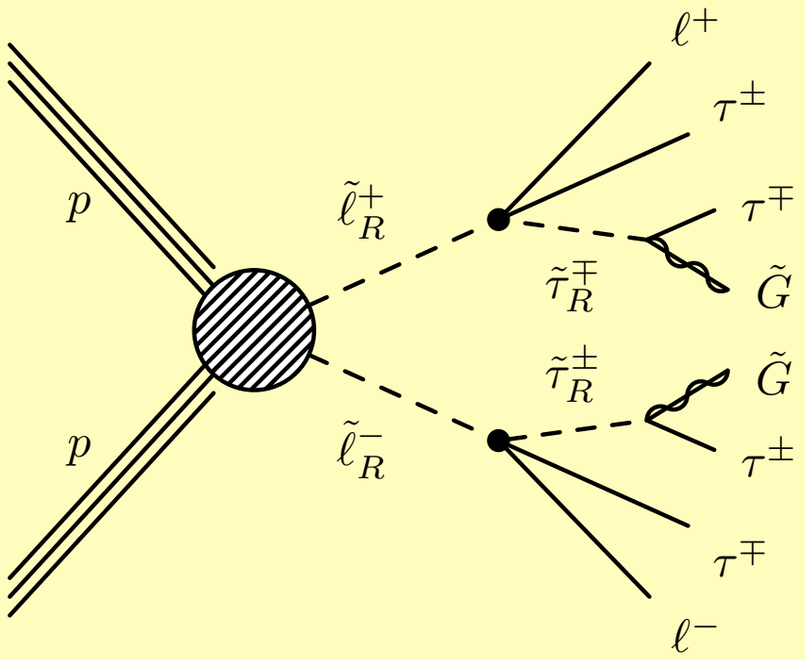
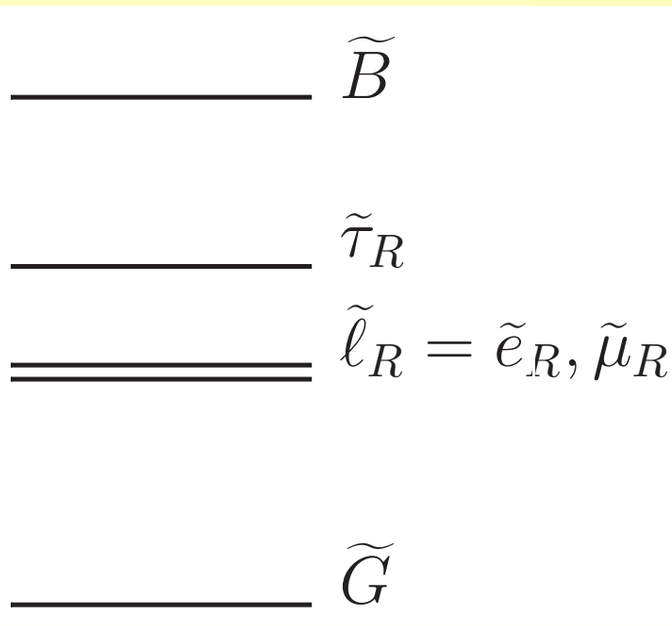




$2\ell + 4\tau + \text{MET}$

Simplified model 2



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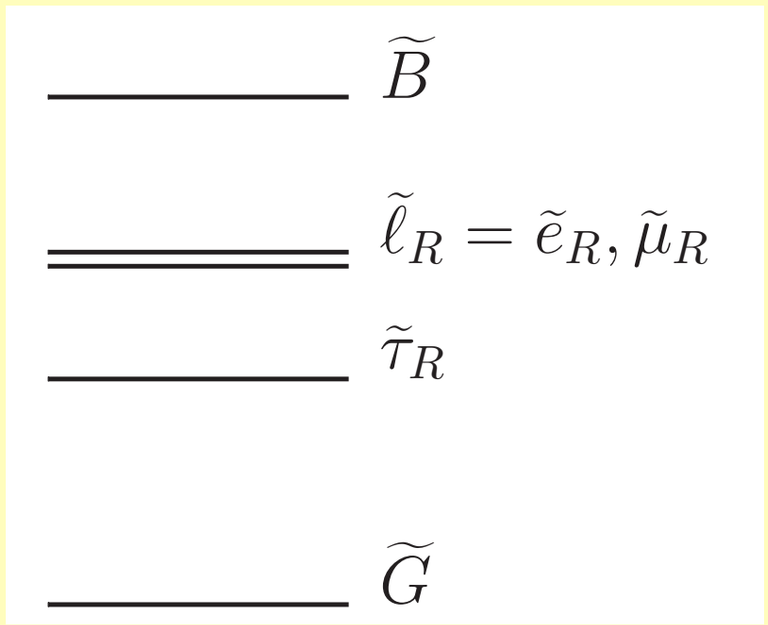

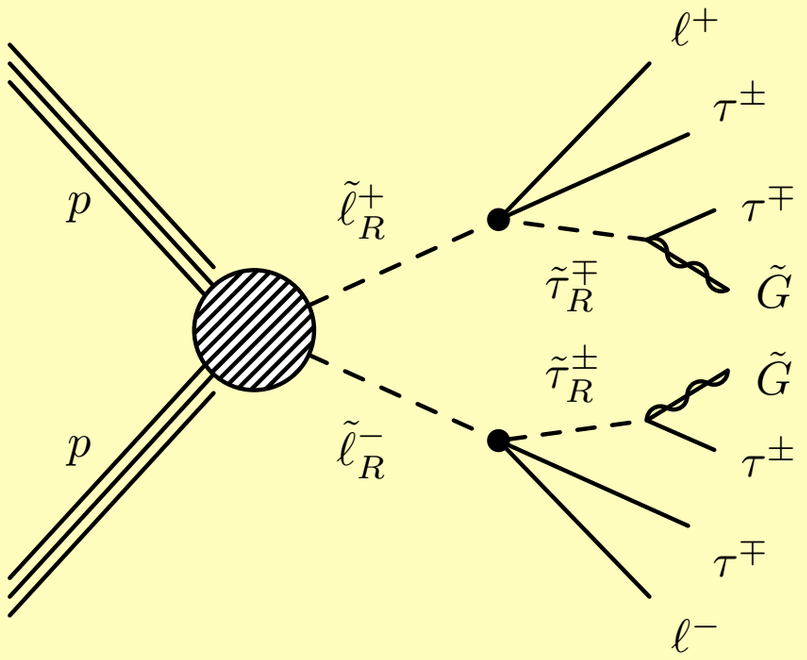

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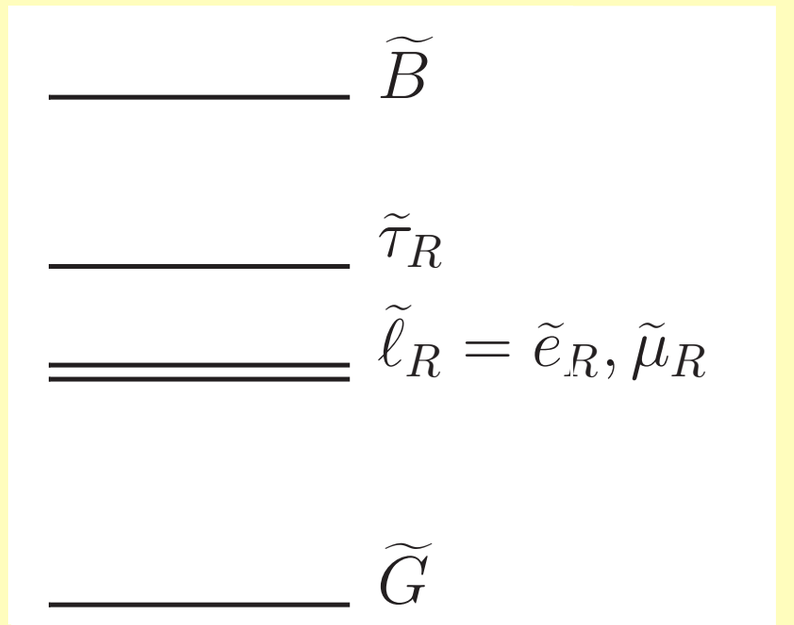

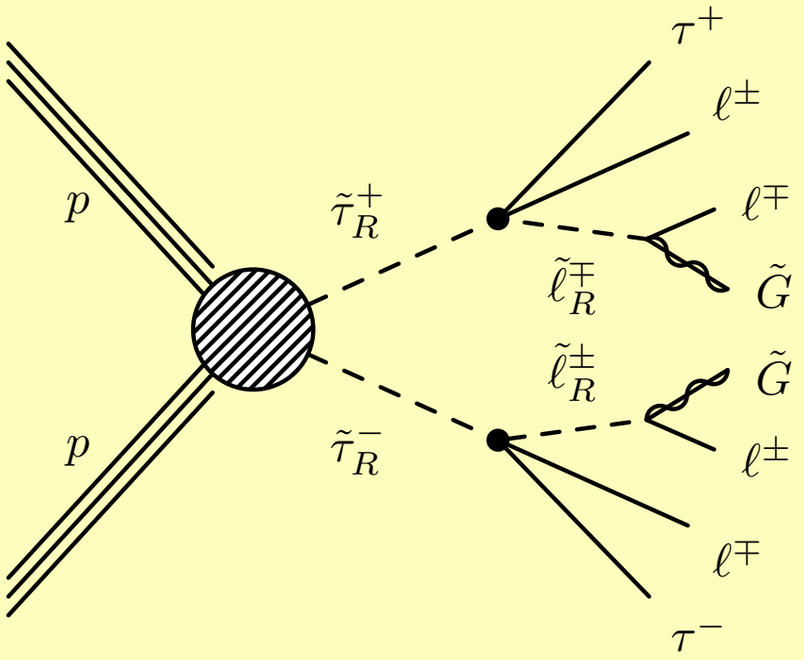

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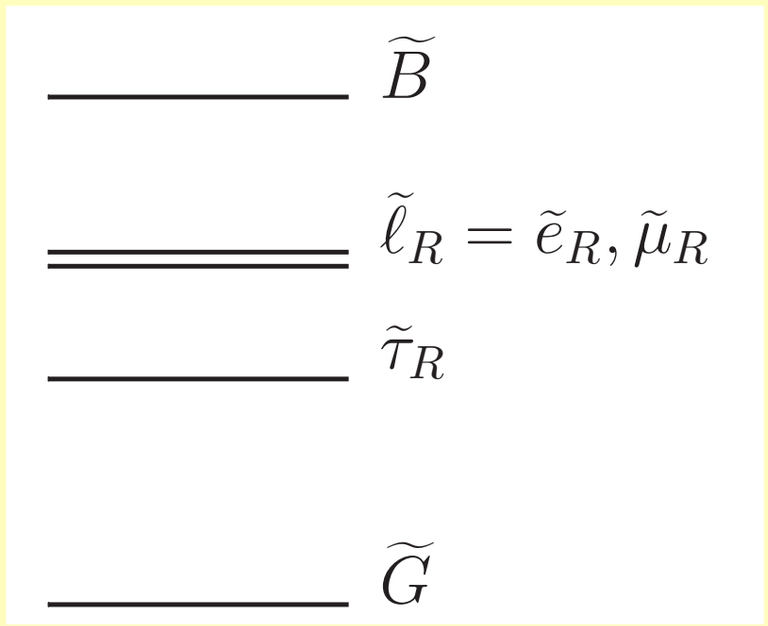
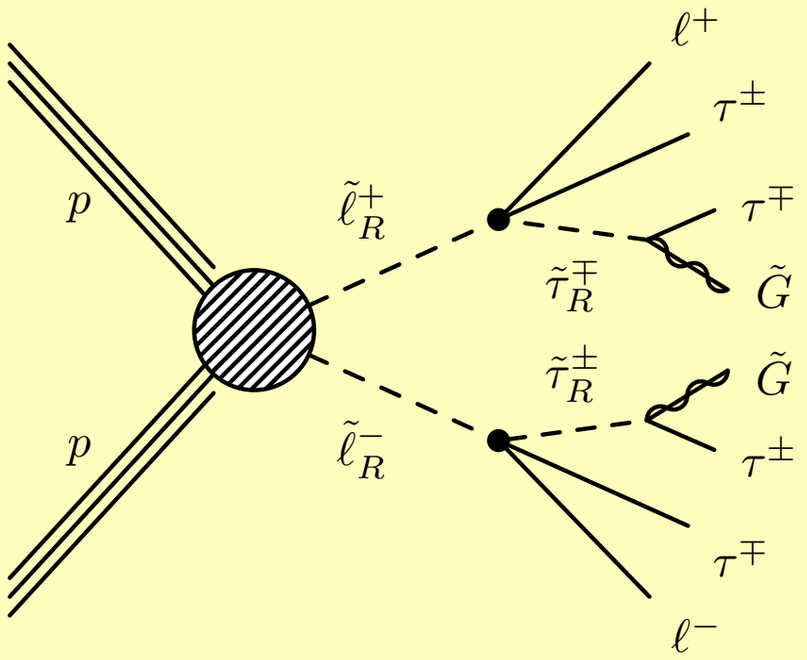
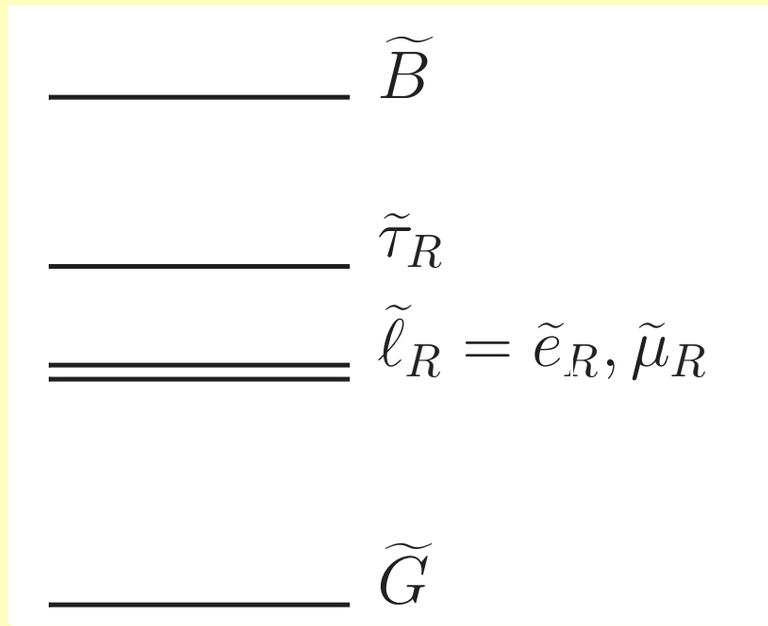
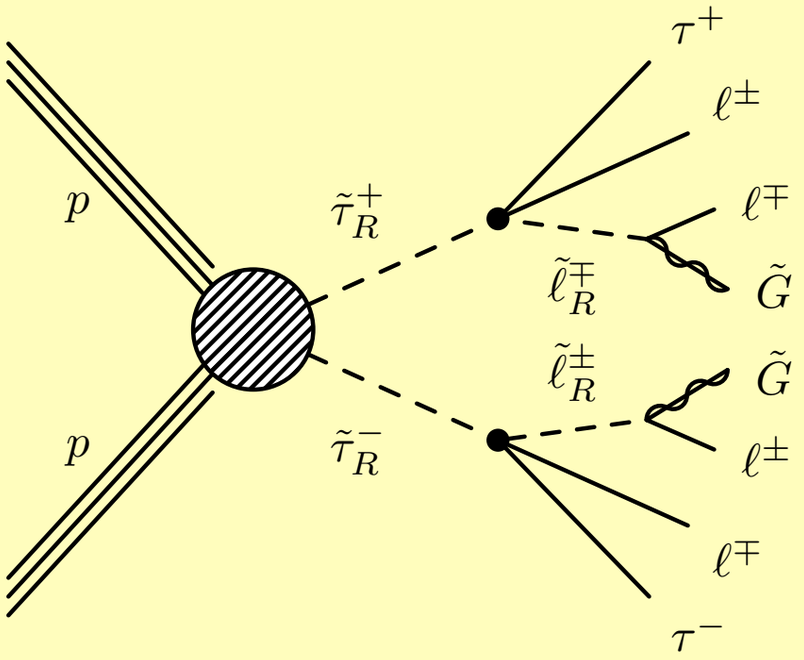




$2\ell + 4\tau + \text{MET}$

Simplified model 2

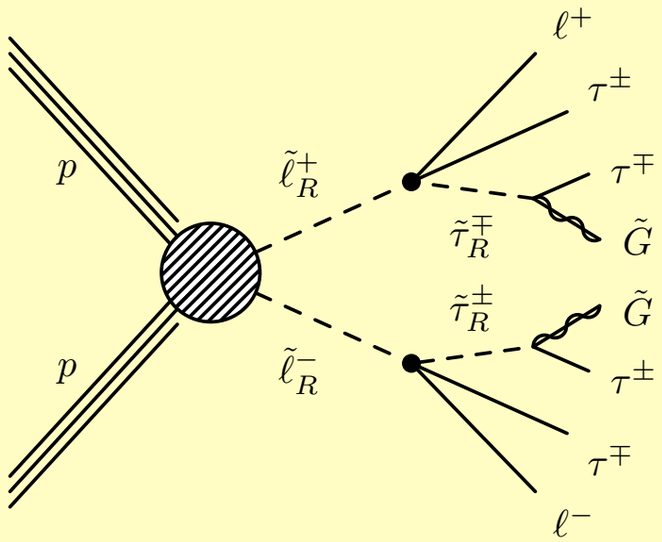




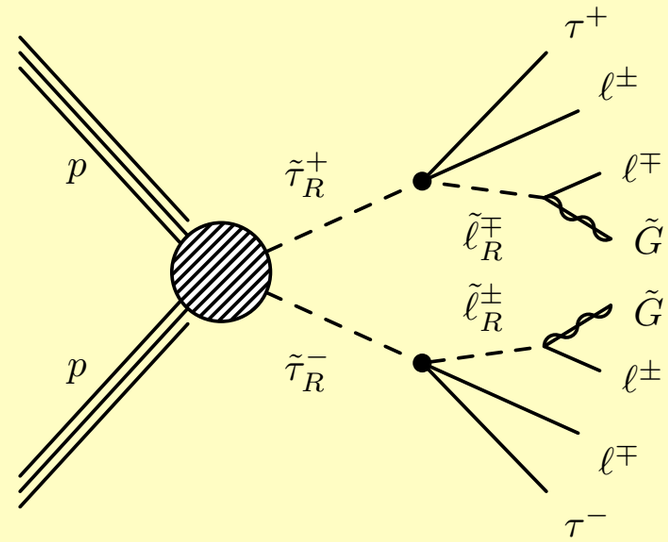
$2\tau + 4\ell + \text{MET}$

Compare with the CMS results

Simulate the two processes at LHC 8 TeV



$2\ell + 4\tau + \mathrm{MET}$



$2\tau + 4\ell + \mathrm{MET}$

FeynRules [Alloul,Christensen,Degrande,Duhr,Fuks]

MG5_aMC [Alwall et all.]

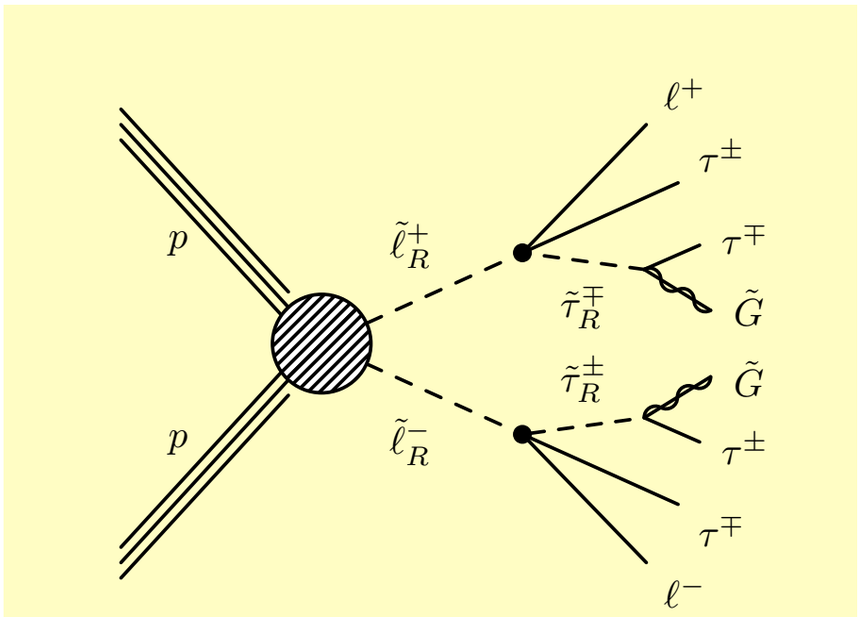
Pythia [Sjöstrand,Mrenna,Skands]

Tauola [Jadach,Was,Decker,Kuhn]

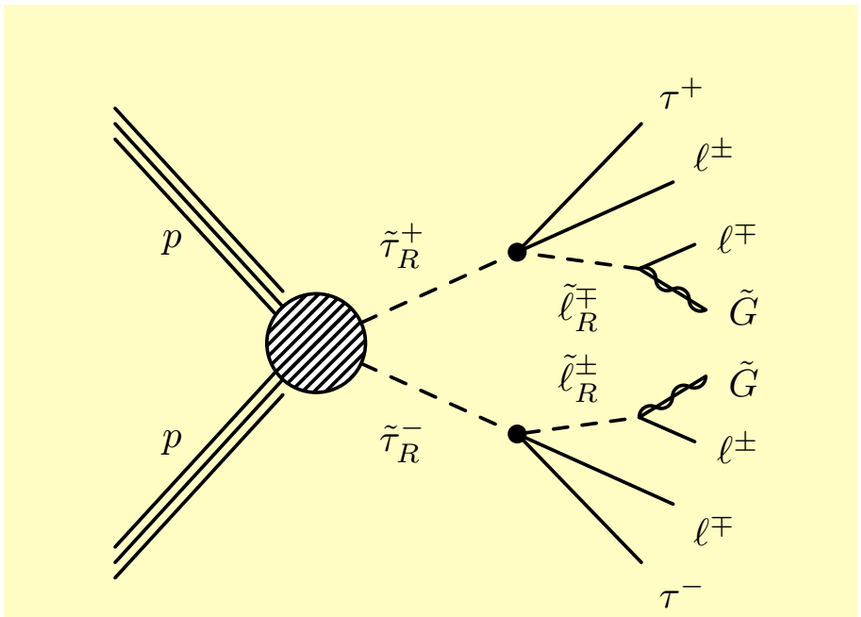
Delphes 2 [Ovyn,Rouby,Lemaitre]

MadAnalysis 5 [Conte,Fuks,Serret]

Choose the mass ranges



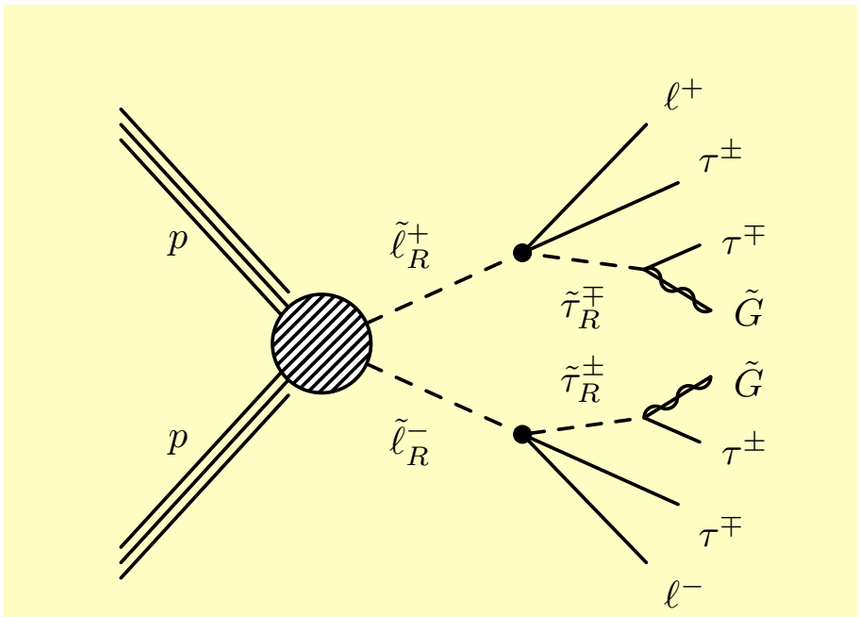
$2\ell + 4\tau + \mathrm{MET}$



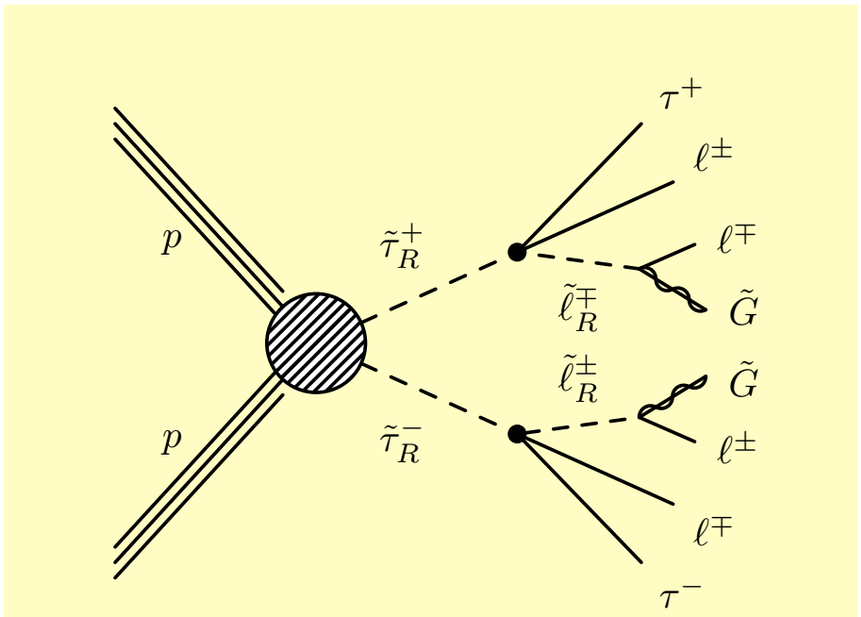
$2\tau + 4\ell + \mathrm{MET}$

Mass

Choose the mass ranges

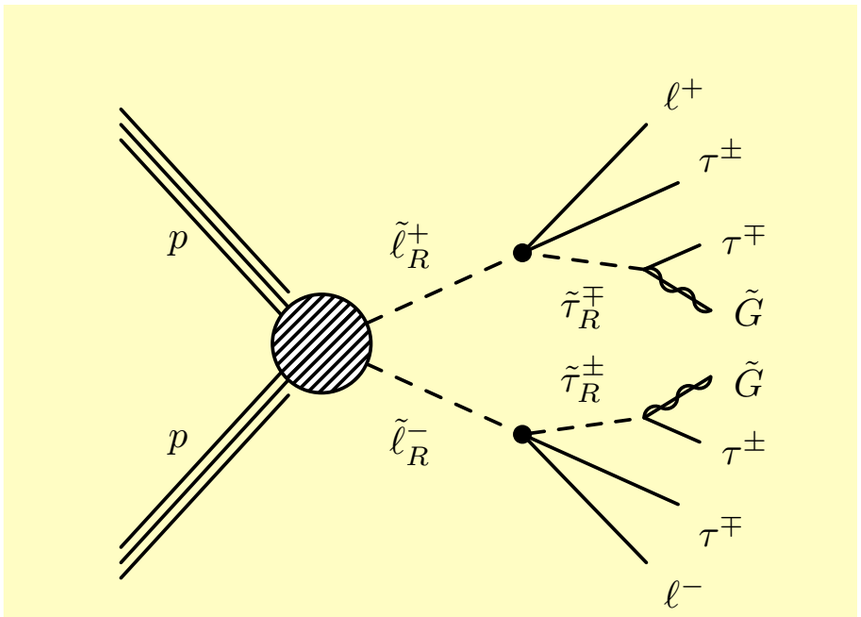


$2\ell + 4\tau + \mathrm{MET}$



$2\tau + 4\ell + \mathrm{MET}$

Choose the mass ranges



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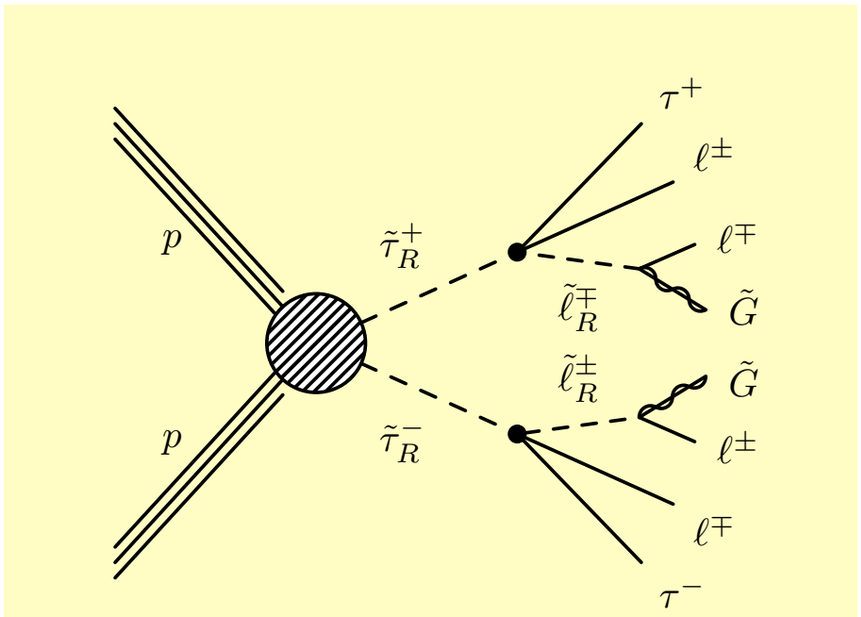
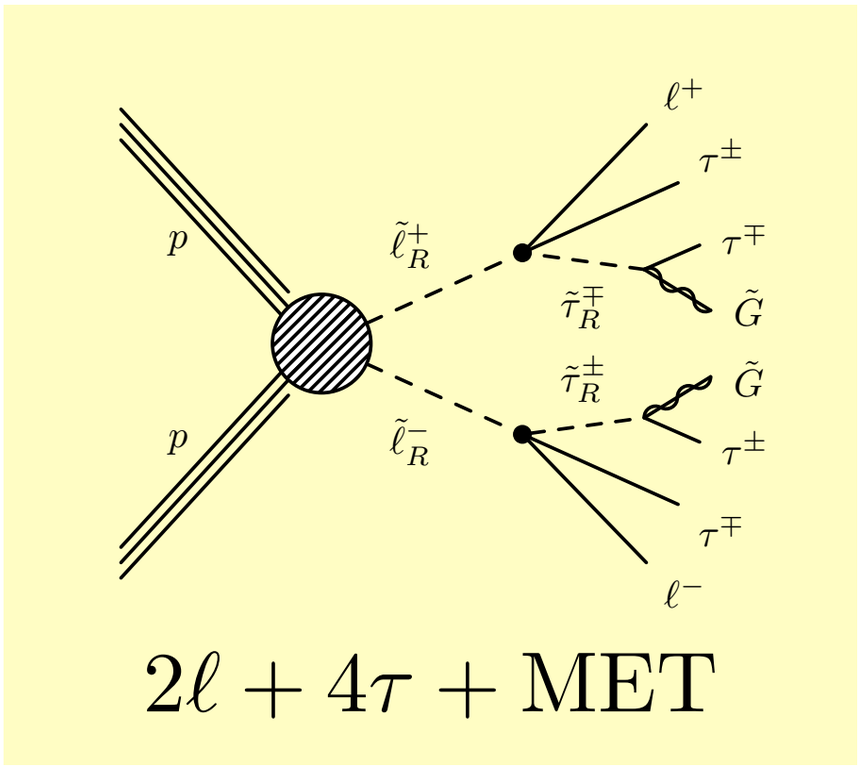
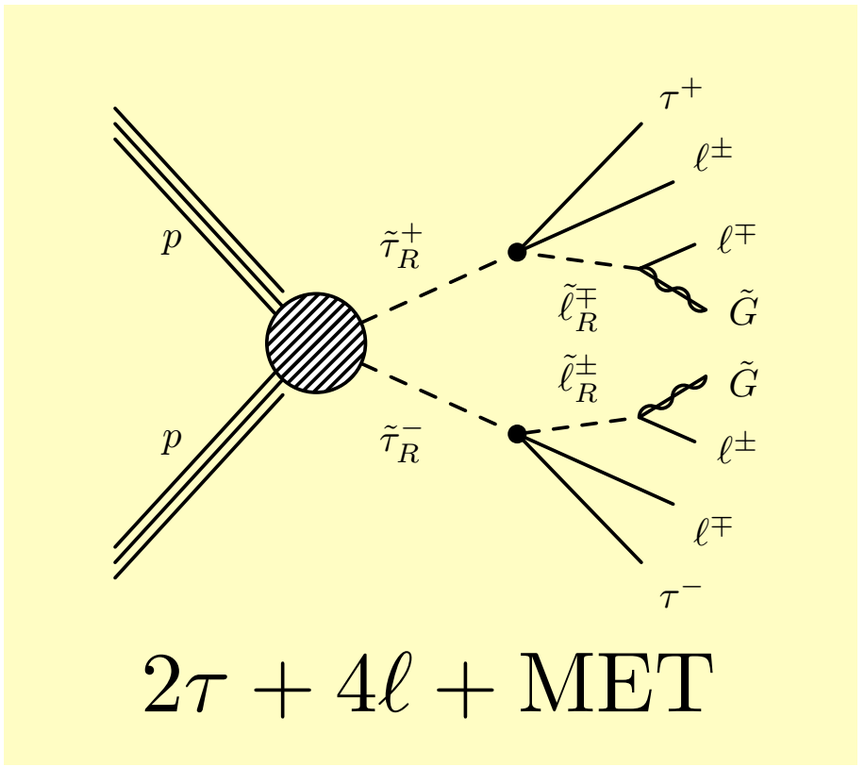


$2\tau + 4\ell + \mathrm{MET}$

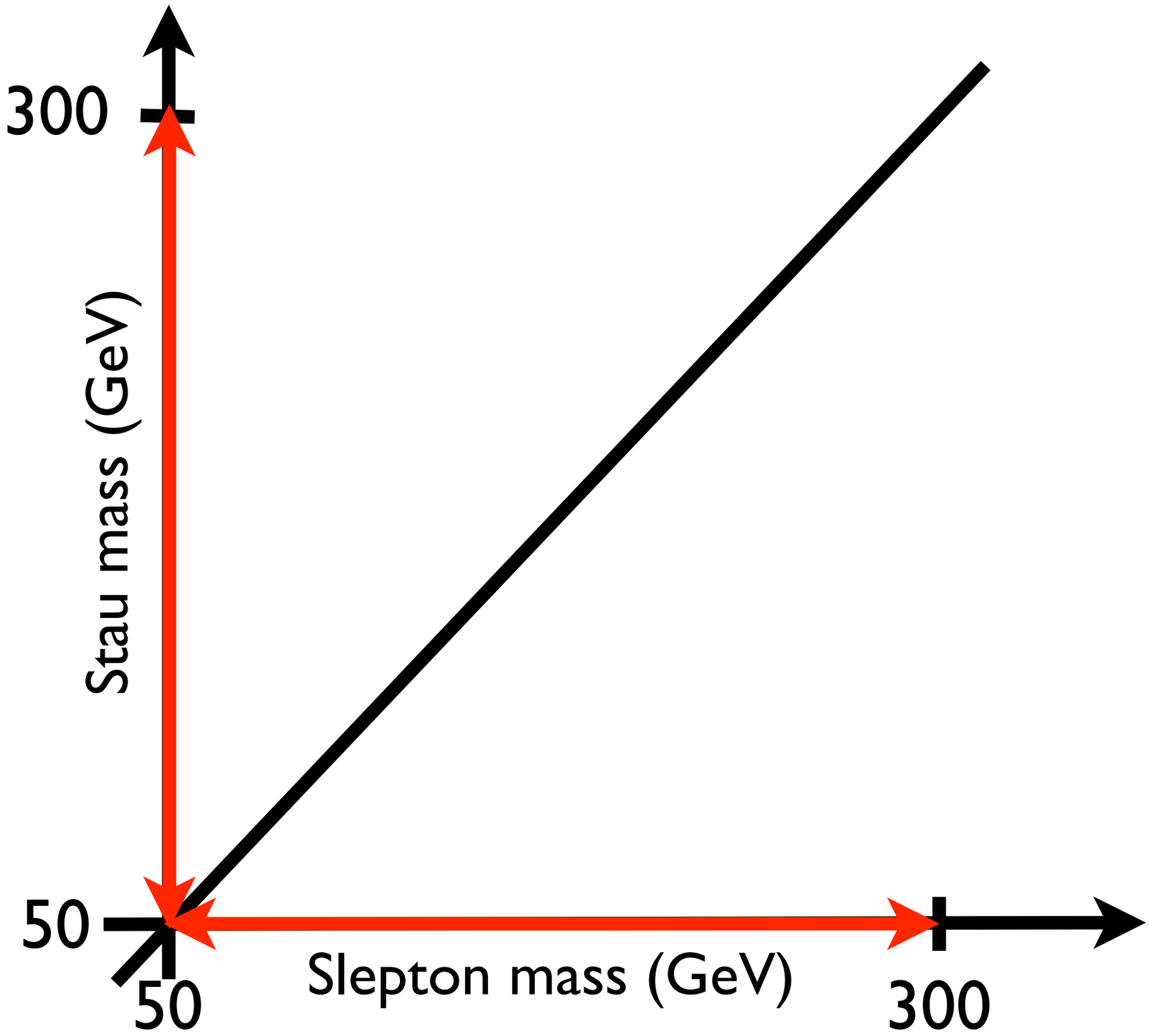
Choose the mass ranges



$2\ell + 4\tau + \mathrm{MET}$

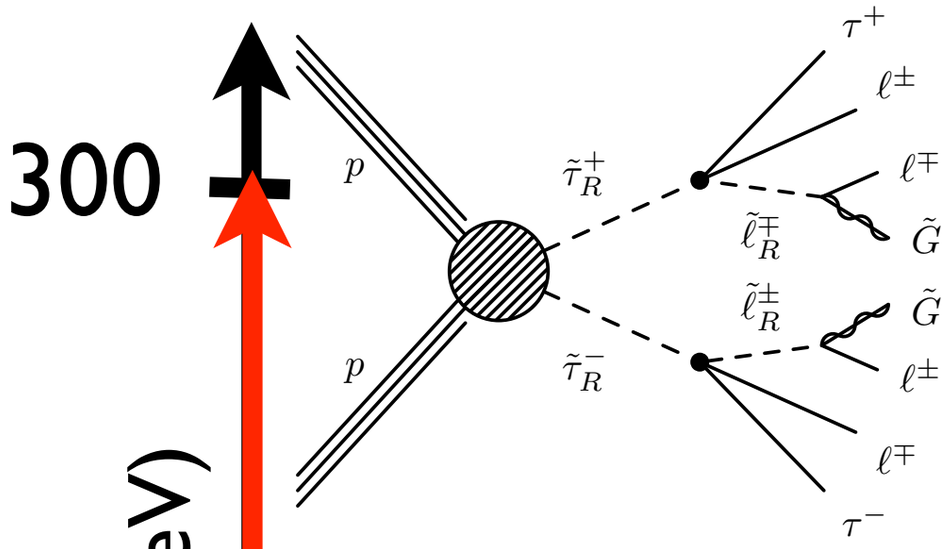


$2\tau + 4\ell + \mathrm{MET}$


300
Stau mass (GeV)
50
50
Slepton mass (GeV)
300

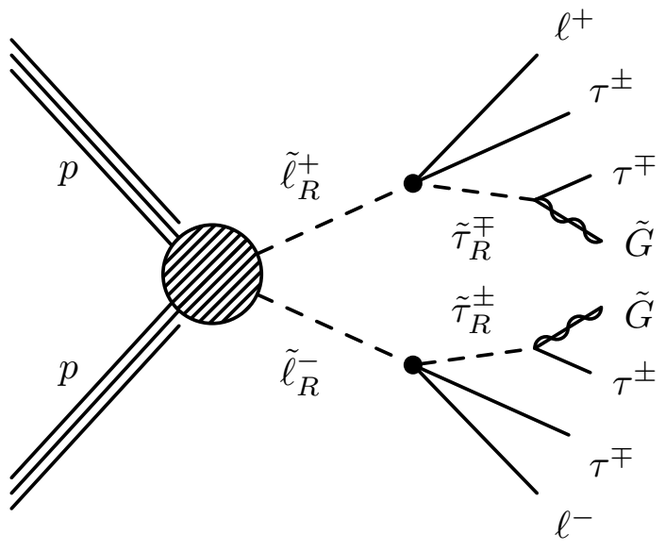
300

Stau mass (GeV)



$2\tau + 4\ell + \mathrm{MET}$

$2\ell + 4\tau + \mathrm{MET}$



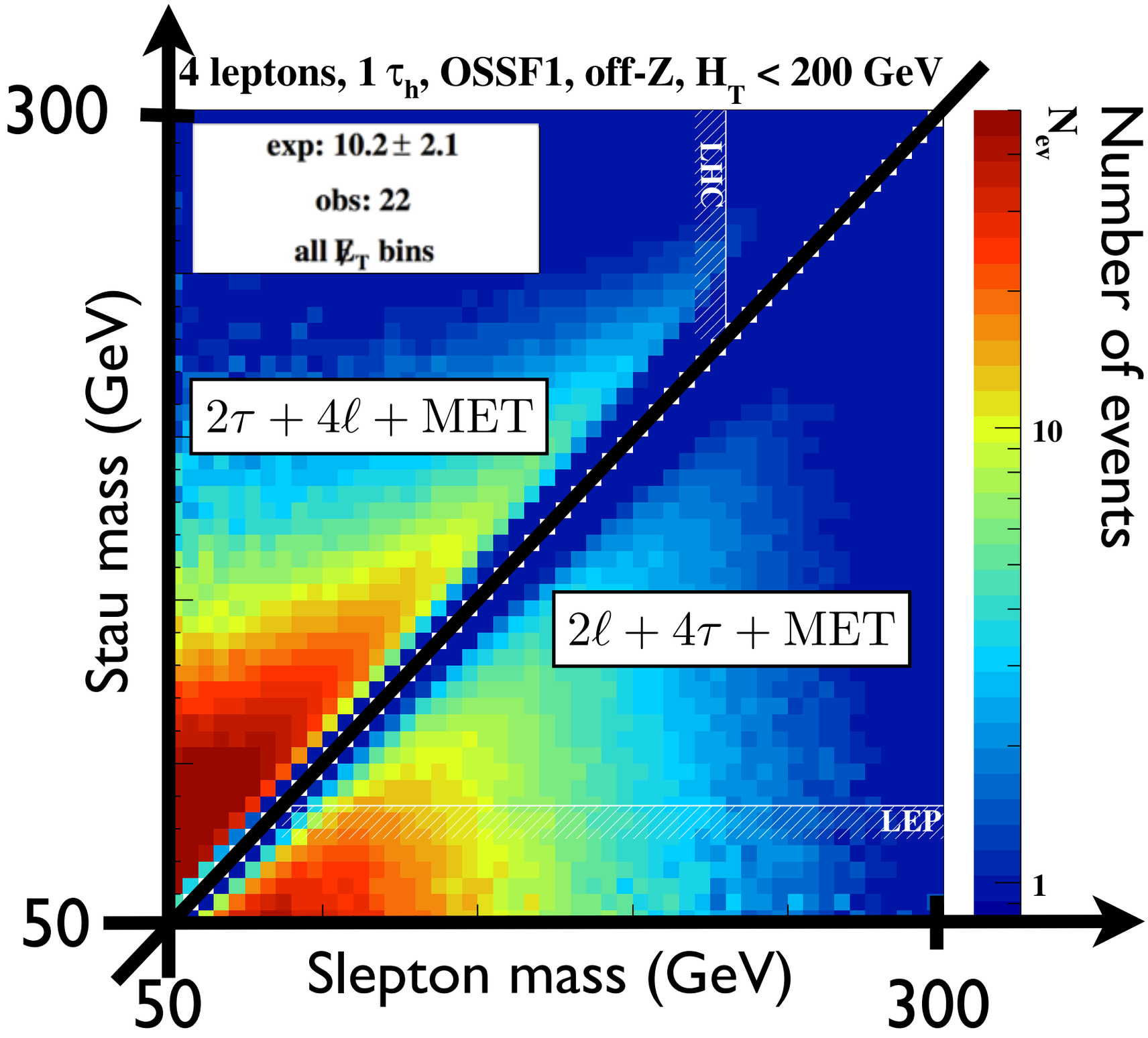
50

50

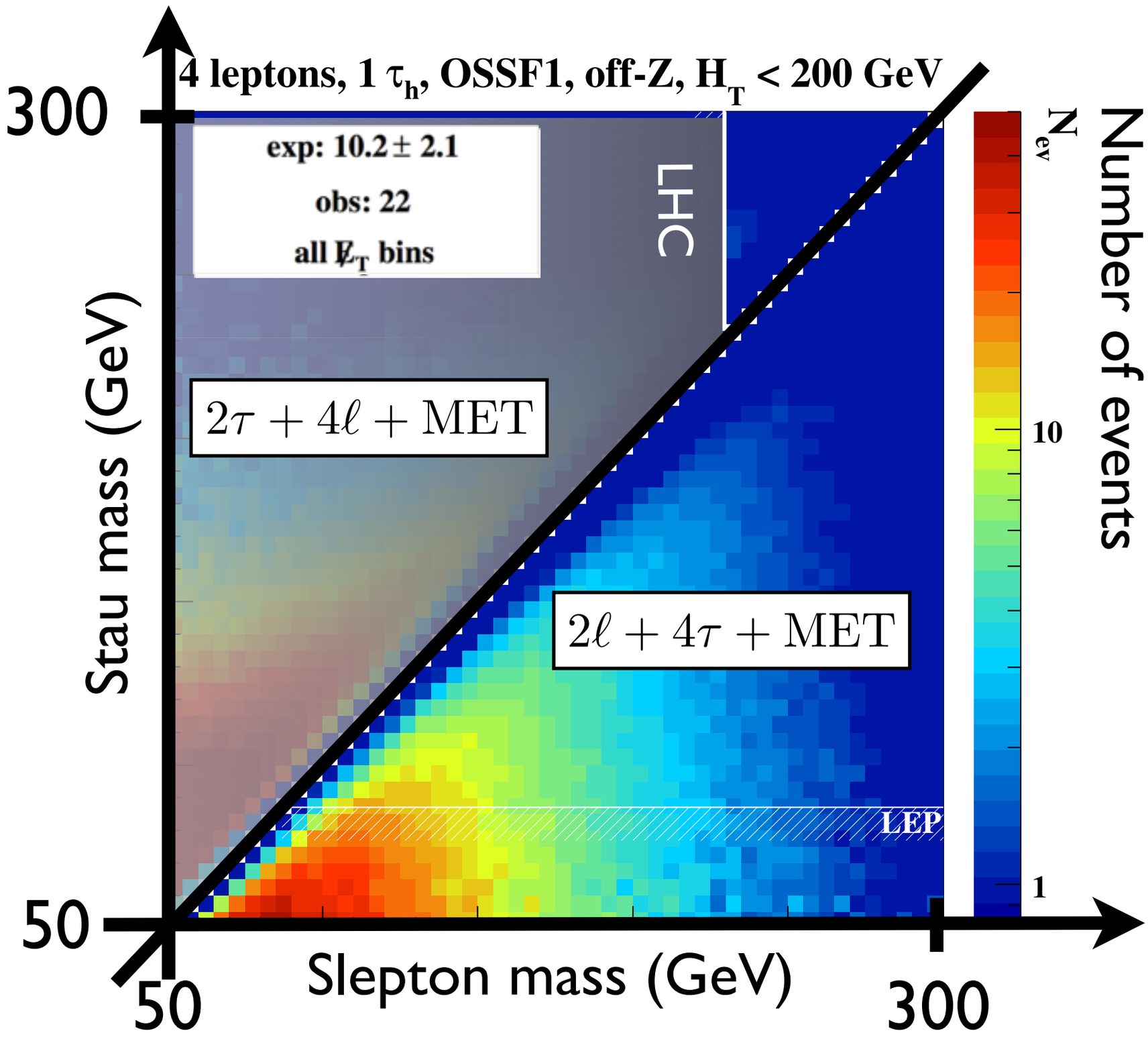
Slepton mass (GeV)

300

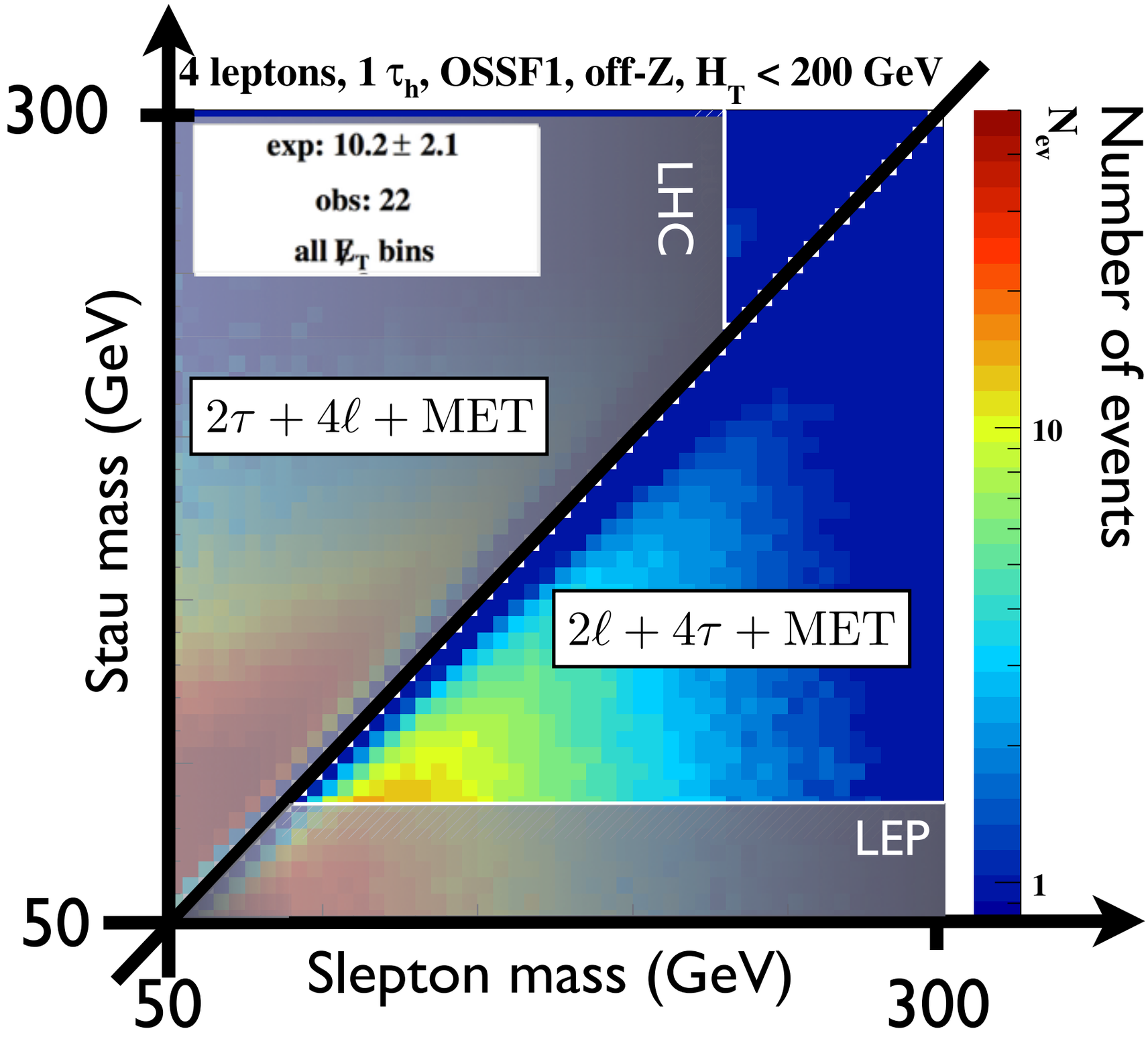
Obtain the expected number of events



$$m_{\tilde{\ell}_R} > 230\,\text{GeV}$$ [ATLAS-CONF-2013-049] [CMS-PAS-SUS-13-006]

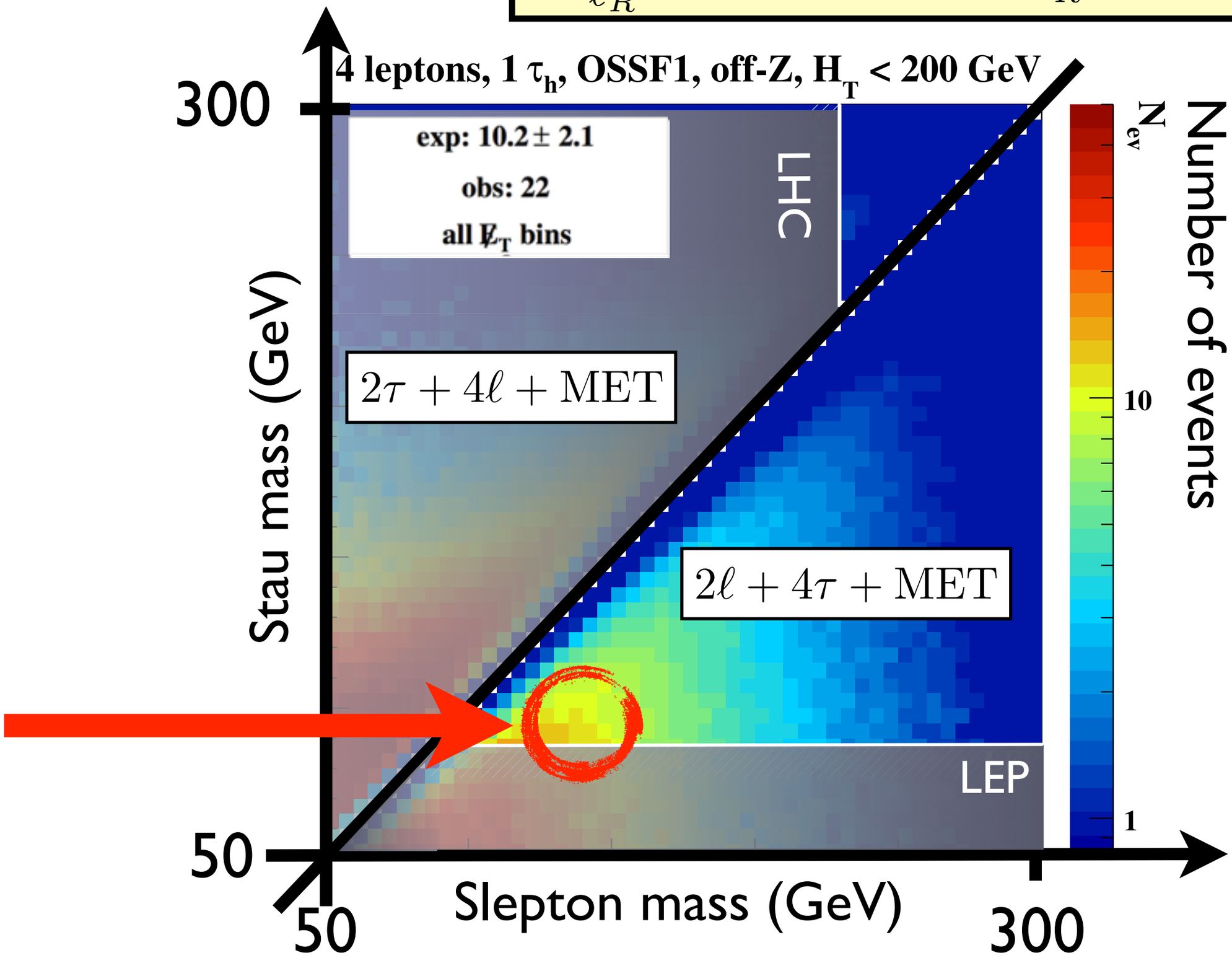


$$m_{\tilde{\tau}_R} > 87\,\mathrm{GeV}$$ [LEP]



Preferred region:

$m_{\tilde{\ell}_R} \sim 145\,\mathrm{GeV}\ ,\ m_{\tilde{\tau}_R} \sim 90\,\mathrm{GeV}$

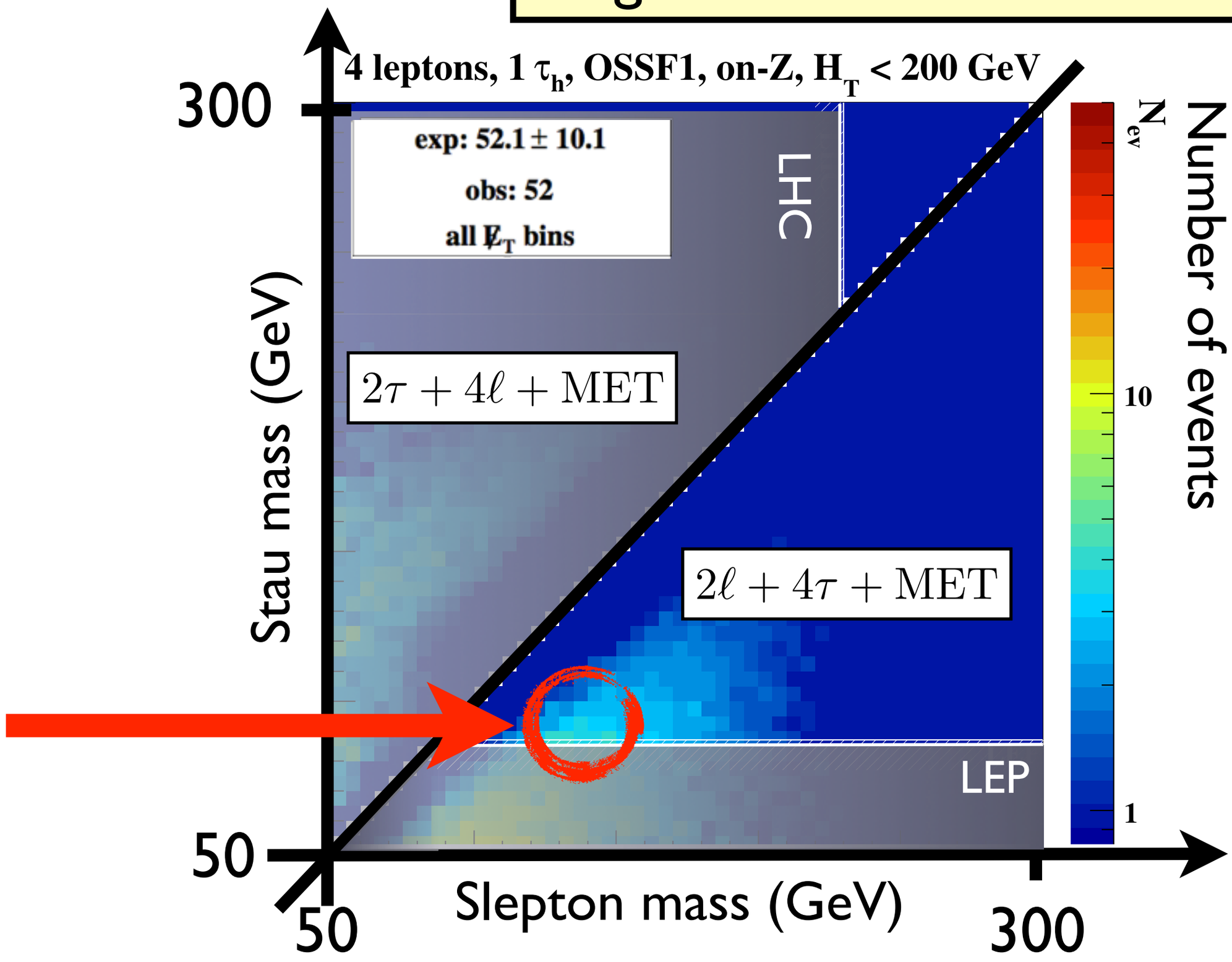


What about the other categories?

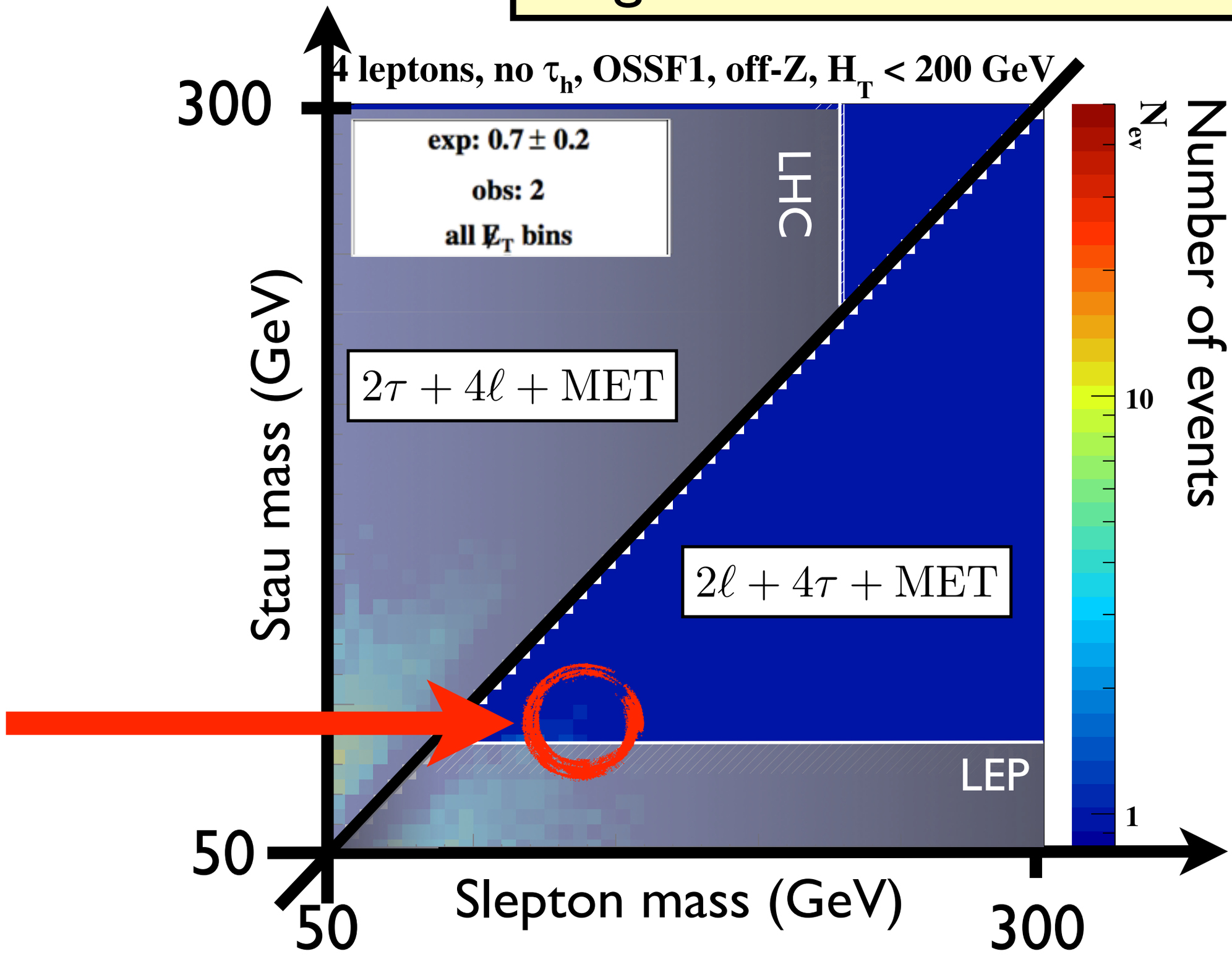
Categories with 3 leptons are irrelevant since the background is too high

And the others...

Same category but on-Z region
... agrees with our best fit



Category without hadronic tau
... agrees with our best fit



Other searches do not exclude our scenario

CMS multi-lepton search CMS SUS-13-010
(requires 4 electrons or muons)

ATLAS multi-lepton search ATLAS-CONF-2013-036
(requires MET>100 GeV)

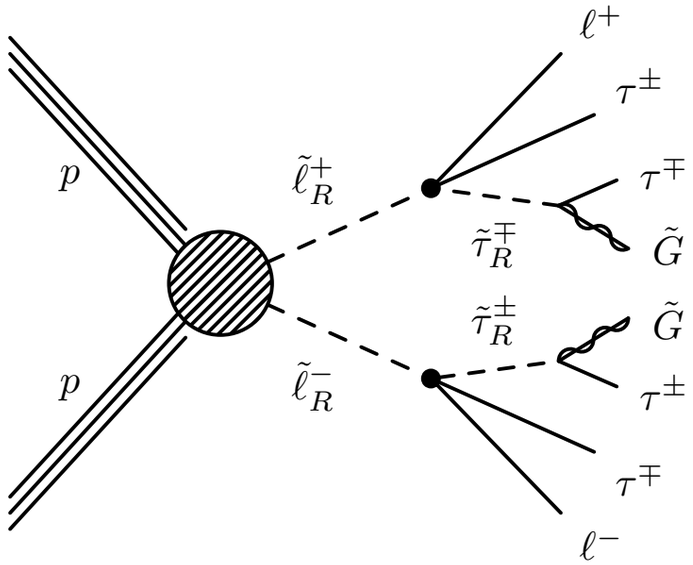
ATLAS di-tau+MET search [arxiv:1407.0350]
(lepton veto)

In which search does the excess occur?

Can we explain it with SUSY?

Prospects

We suggest to look for 2 hadronic taus + 2/3 leptons



$$m_{\tilde{\ell}_R} = 145\,\text{GeV}$$

$$m_{\tilde{\tau}_R} = 90\,\text{GeV}$$

		$19.5\,\text{fb}^{-1}$	$100\,\text{fb}^{-1}$
$N(\ell)$	$N(\tau_h)$	$N_{\text{events}}(8\text{ TeV})$	$N_{\text{events}}(13\text{ TeV})$
4	2	22.5	223
5	0	0.074	0.79
5	1	1.7	14.7
5	2	7.4	76.1
6	0	0	0
6	1	0.075	0.66
6	2	1.0	7.89
>6	0	0.038	13.9

In which search does the excess occur?

Can we explain it with SUSY?

Prospects

In which search does the excess occur?

CMS search for three or more leptons

Can we explain it with SUSY?

Prospects

In which search does the excess occur?

CMS search for three or more leptons

Can we explain it with SUSY?

Yes we can! In Gauge Mediation

Prospects

In which search does the excess occur?

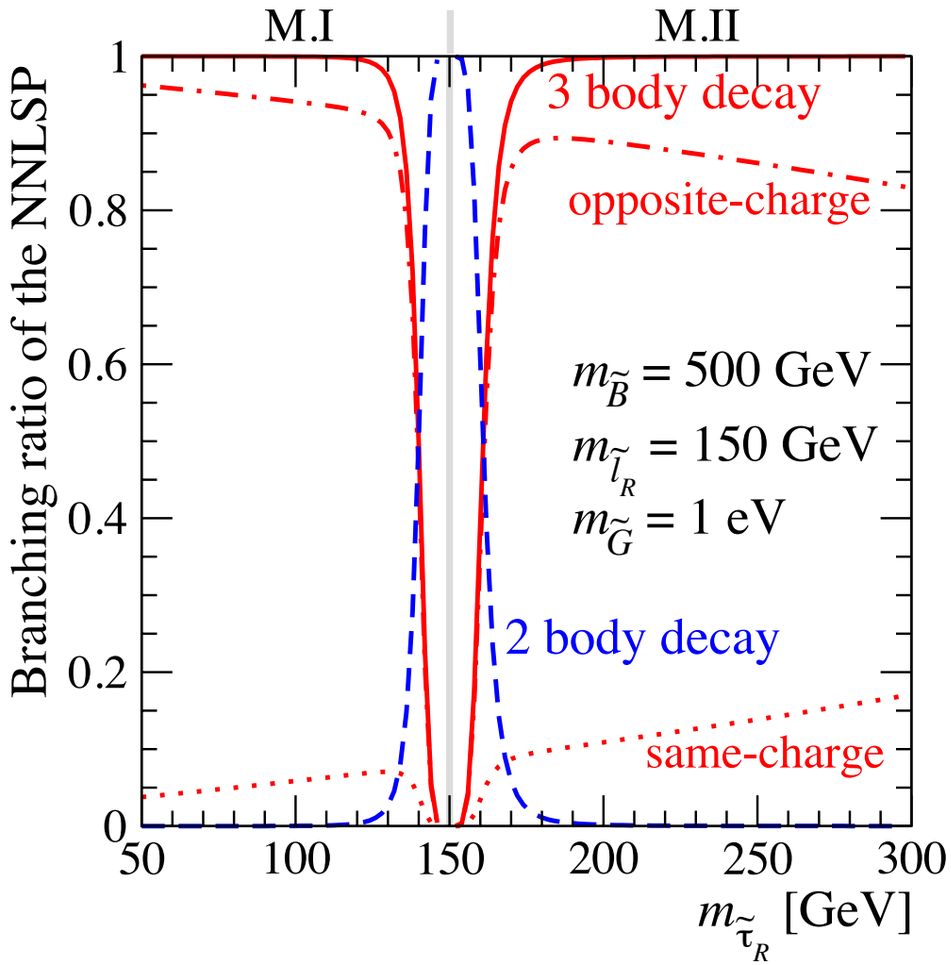
CMS search for three or more leptons

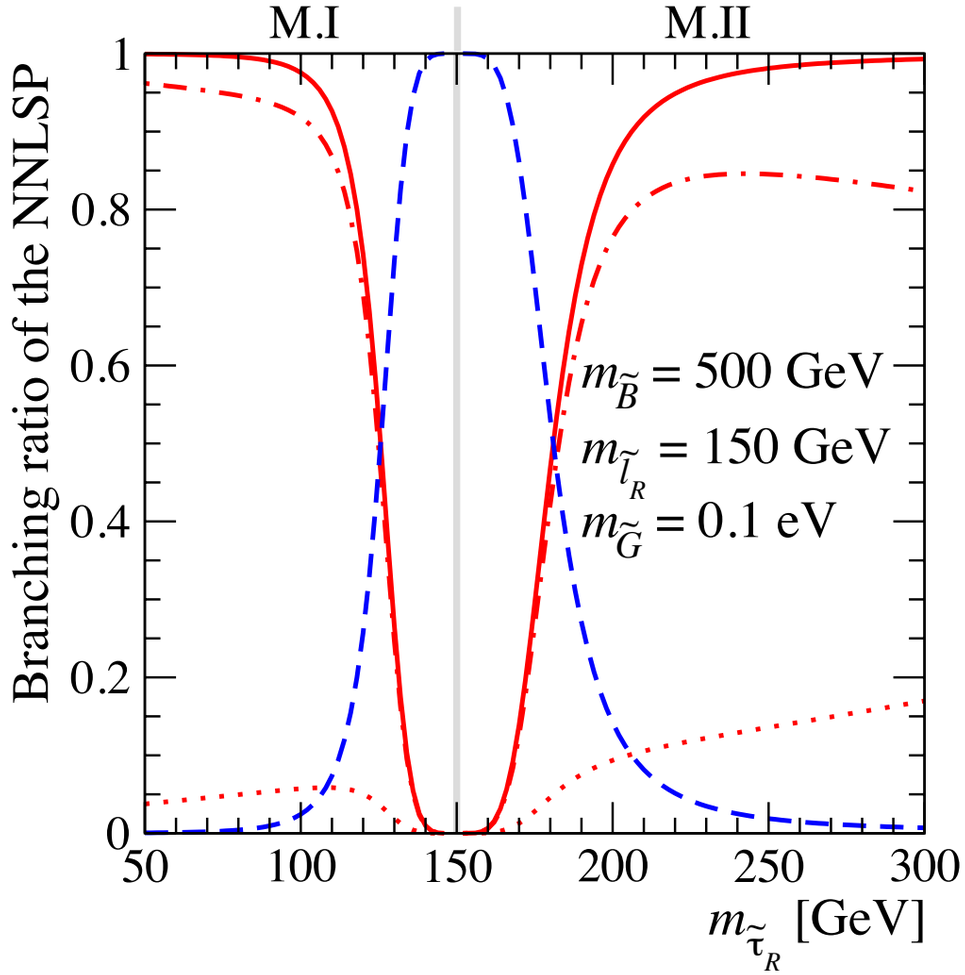
Can we explain it with SUSY?

Yes we can! In Gauge Mediation

Prospects

Ongoing update with respect to new results


M.I
M.II
Branching ratio of the NNLSP
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
300
$m_{\tilde{\tau}_R}$ [GeV]
3 body decay
opposite-charge
$m_{\tilde{B}}$ = 500 GeV
$m_{\tilde{l}_R}$ = 150 GeV
$m_{\tilde{G}}$ = 1 eV
2 body decay
same-charge


M.I
M.II
Branching ratio of the NNLSP
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
300
$m_{\tilde{\tau}_R}$ [GeV]
$m_{\tilde{B}}$ = 500 GeV
$m_{\tilde{l}_R}$ = 150 GeV
$m_{\tilde{G}}$ = 0.1 eV

Requirements on the gravitino mass

Not too high

the NLSP decay should be prompt

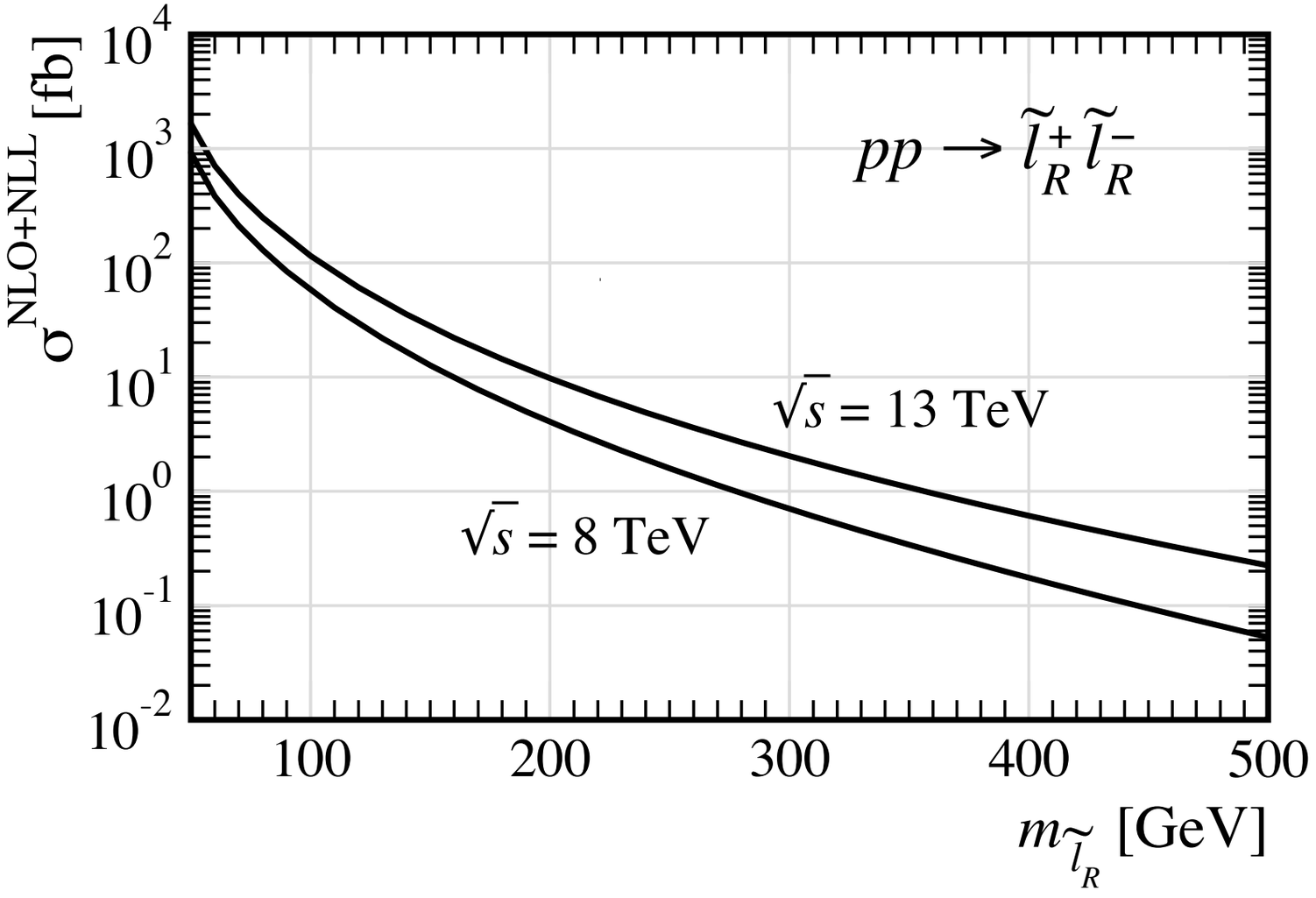
m32 < 10 eV

Not too low

3 body decay NNLSP has to be dominant

m_bino/mslep = 1.1? m32 > 0.03 eV

m_bino/mslep = 2? m32 > 0.50 eV


$\sigma^{\mathrm{NLO+NLL}}$ [fb]
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$pp \to \tilde{l}_R^+ \tilde{l}_R^-$
$\sqrt{s}$ = 13 TeV
$\sqrt{s}$ = 8 TeV
100
200
300
400
500
$m_{\tilde{l}_R}$ [GeV]