Multilepton signatures of GMSB at the LHC

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GDR Terascale@Palaiseau, June 2-4 2014

Vrije
Universiteit
Brussel

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?

Supersymmetry (SUSY) still deserves to be studied

LHC mainly probed colored production
of SUSY particles

Study of the electroweak production can lead to
suggesting new searches at the LHC
and *improving stau mass bounds*

A multilepton CMS search
shows a possible excess

The CMS result

Can we explain this with SUSY?

Future studies

The CMS result

Can we explain this with SUSY?

Future studies

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 observes more events than expected

Selection 4 Lepton Results		E_T^{miss}	$N(\tau_h)=1, N_{b-jets}=0$ obs	 exp
OSSF1 $H_T < 200$	off-Z	$(100,\infty)$	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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One off-Z opposite sign same flavor pair

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One hadronic tau

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One off-Z opposite sign same flavor pair

Low hadronic activity

CMS observes more events than expected

No b-jets

One hadronic tau

4 leptons

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22 events observed

10.2 ± 2.4 events expected

Close to discovery?

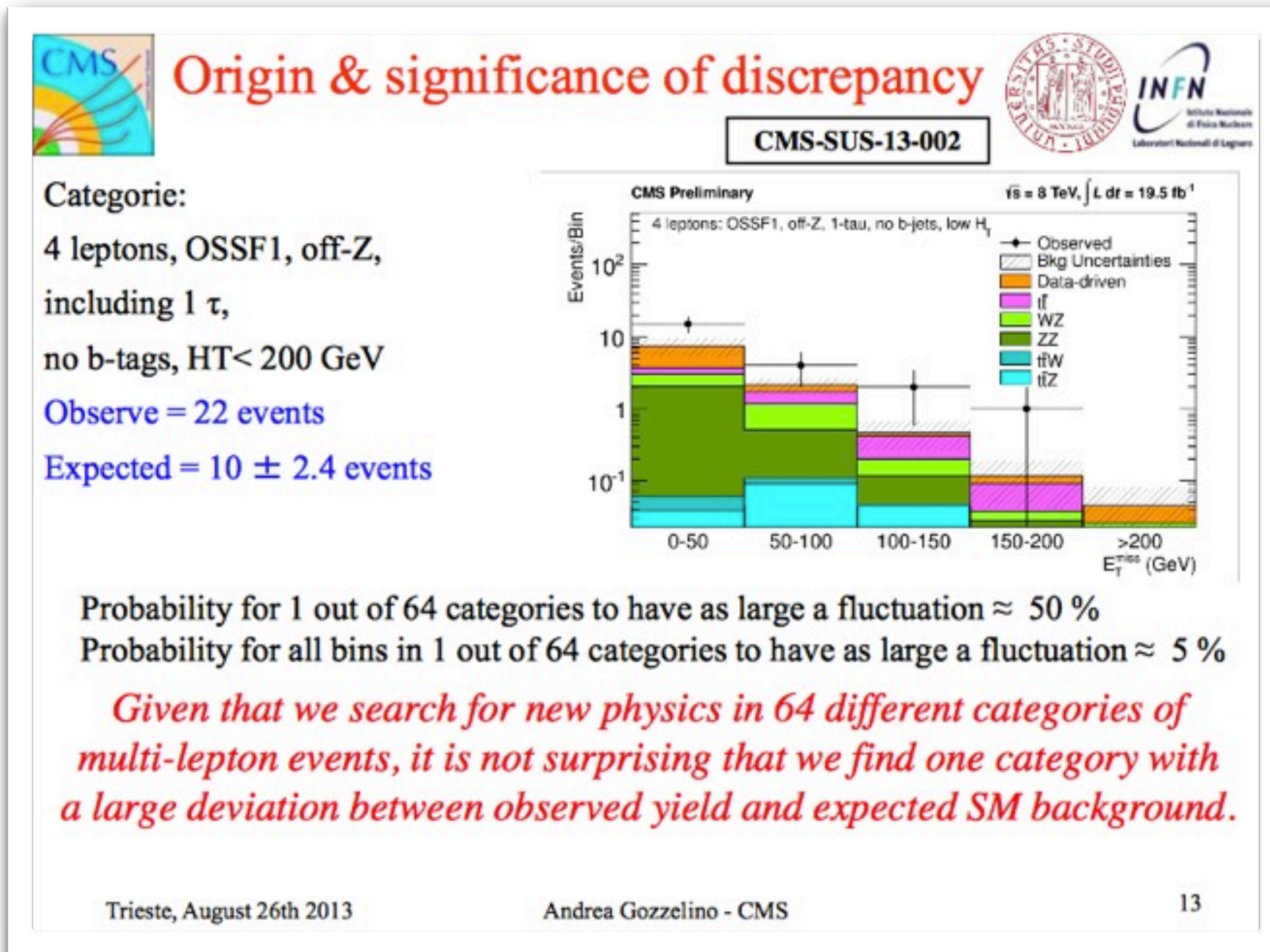
Excess in 3 out of 64 categories

Selection 4 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	exp	N(τ_h)=1, N_{b-jets}=0 obs	exp	N(τ_h)=0, N_{b-jets}≥1 obs	exp	N(τ_h)=1, N_{b-jets}≥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?

No real reason to be excited

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



Still a nice excercise...
Can this be explained in SUSY?

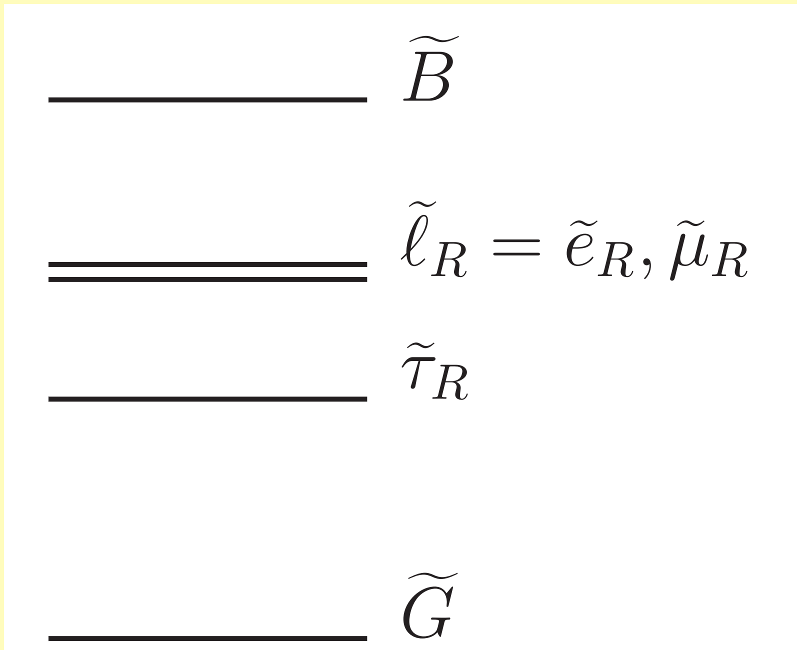
Excess in a category with
3 electrons/muons and 1 hadronic tau

Inspired by GMSB, we constructed
simplified models contributing
to this excess

Simplified model 1

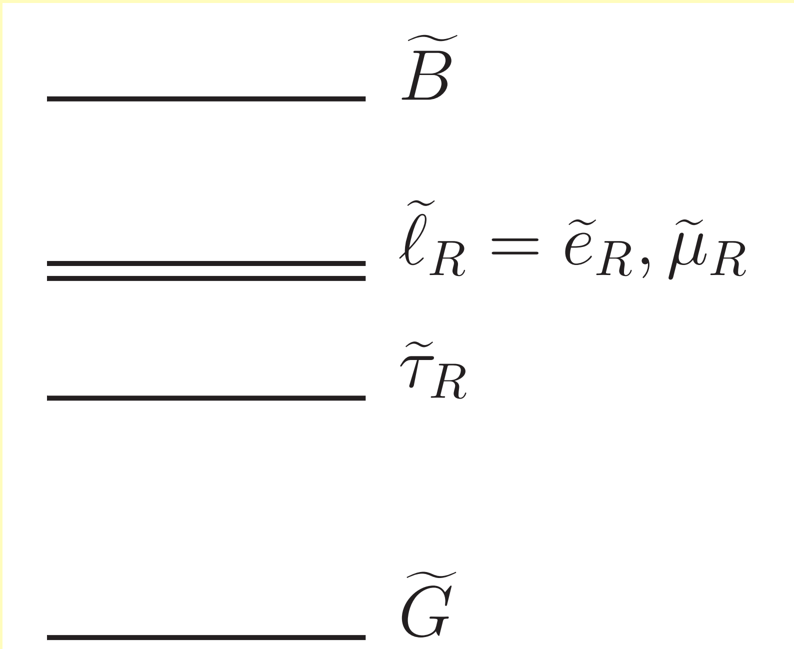
Simplified model 2

Simplified model 1

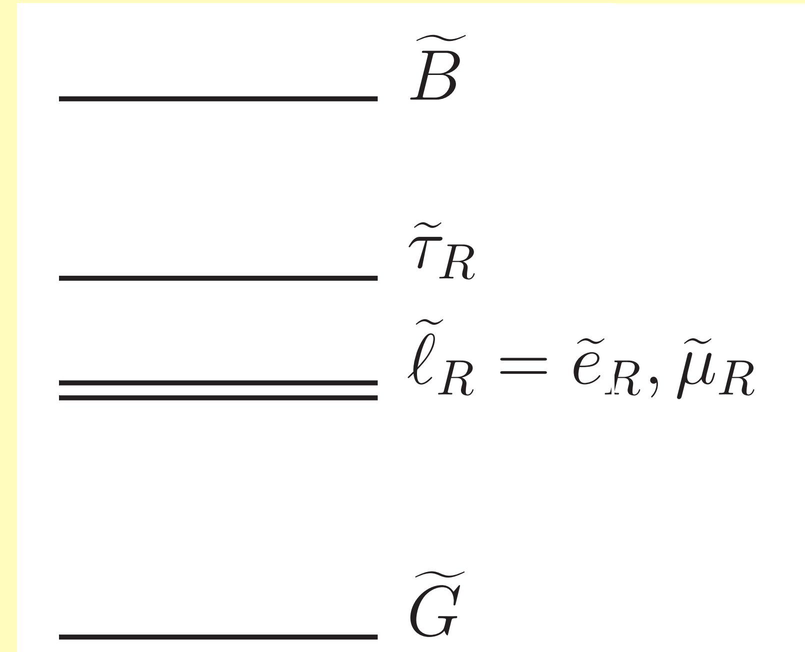


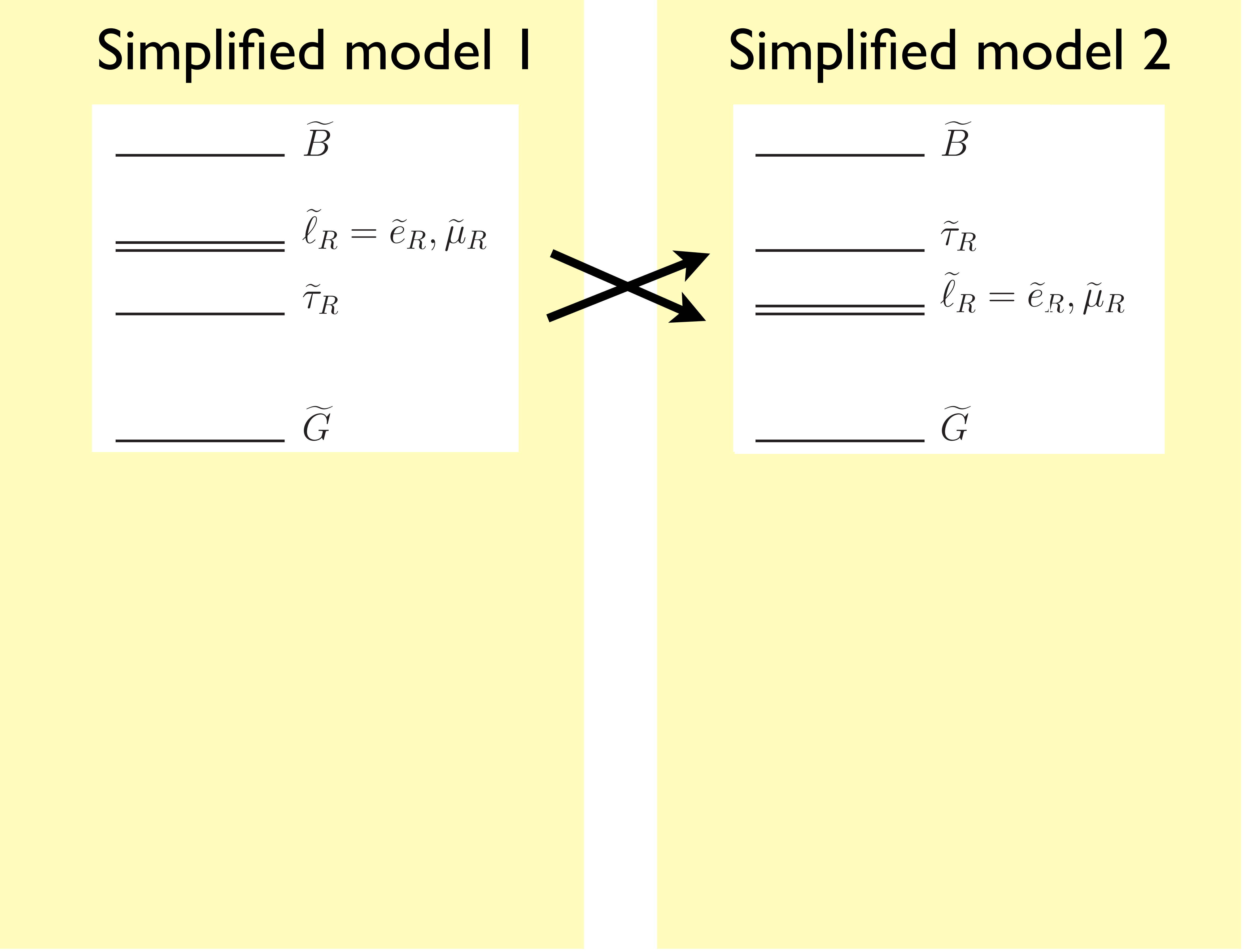
Simplified model 2

Simplified model 1



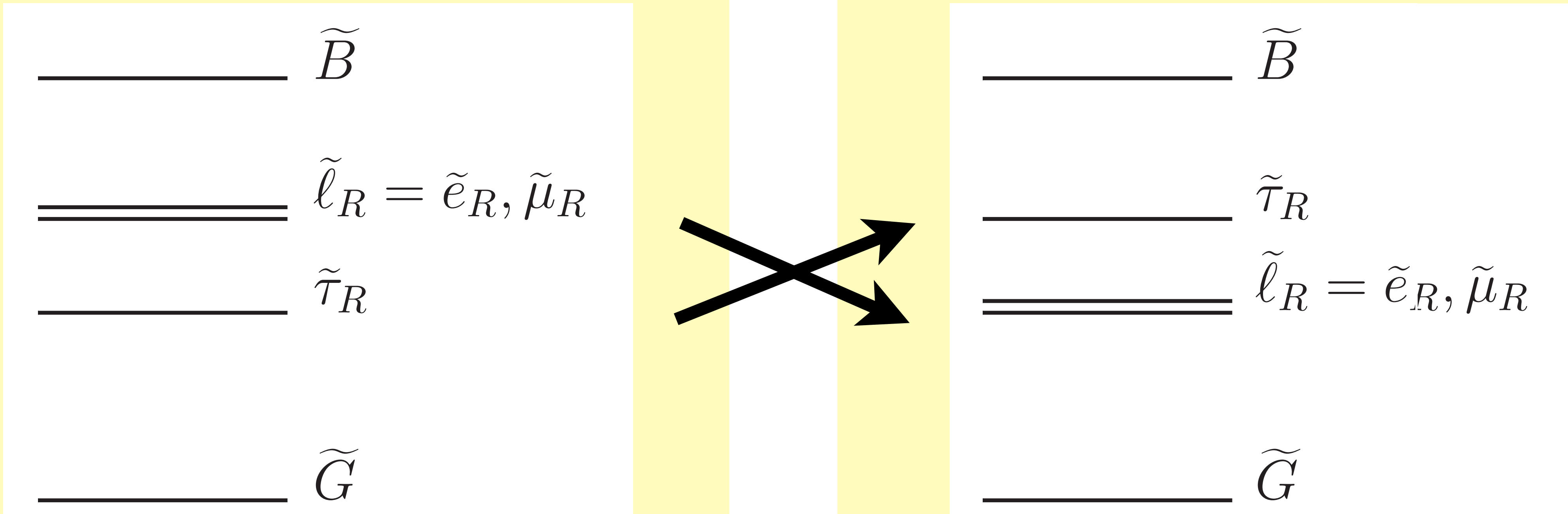
Simplified model 2




Simplified model 1
$\widetilde{B}$
$\tilde{\ell}_R = \tilde{e}_R, \tilde{\mu}_R$
$\tilde{\tau}_R$
$\widetilde{G}$
Simplified model 2
$\widetilde{B}$
$\tilde{\tau}_R$
$\tilde{\ell}_R = \tilde{e}_R, \tilde{\mu}_R$
$\widetilde{G}$

Simplified model 1

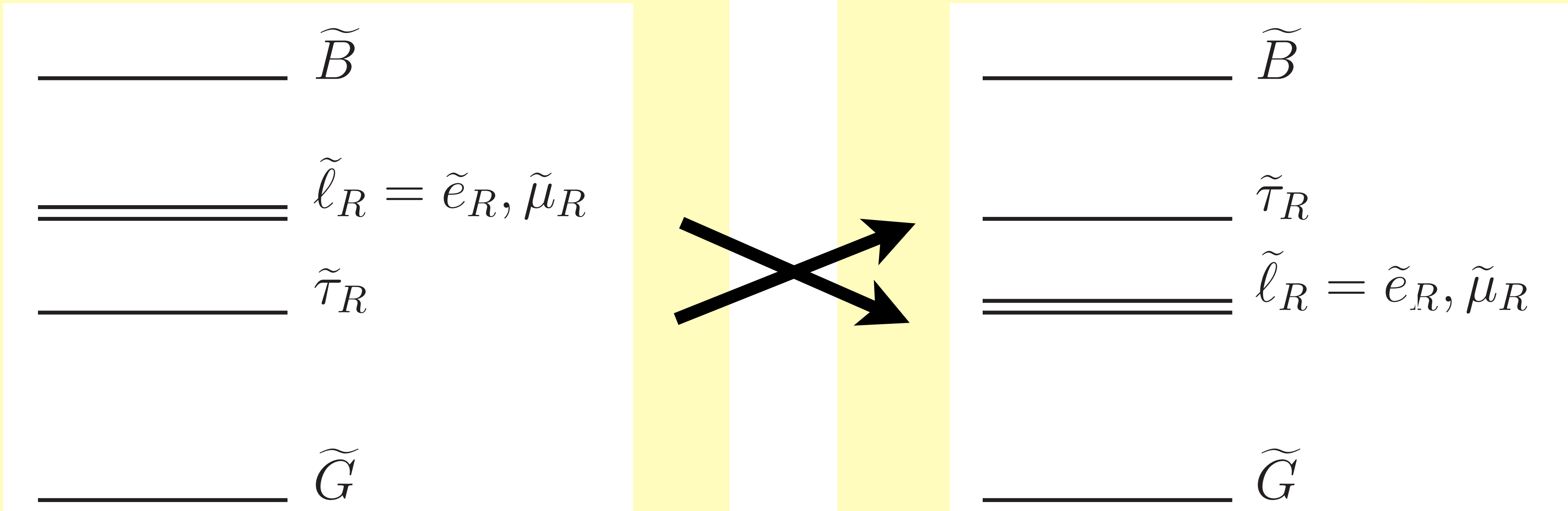
Simplified model 2



Common in GMSB

Simplified model 1

Simplified model 2



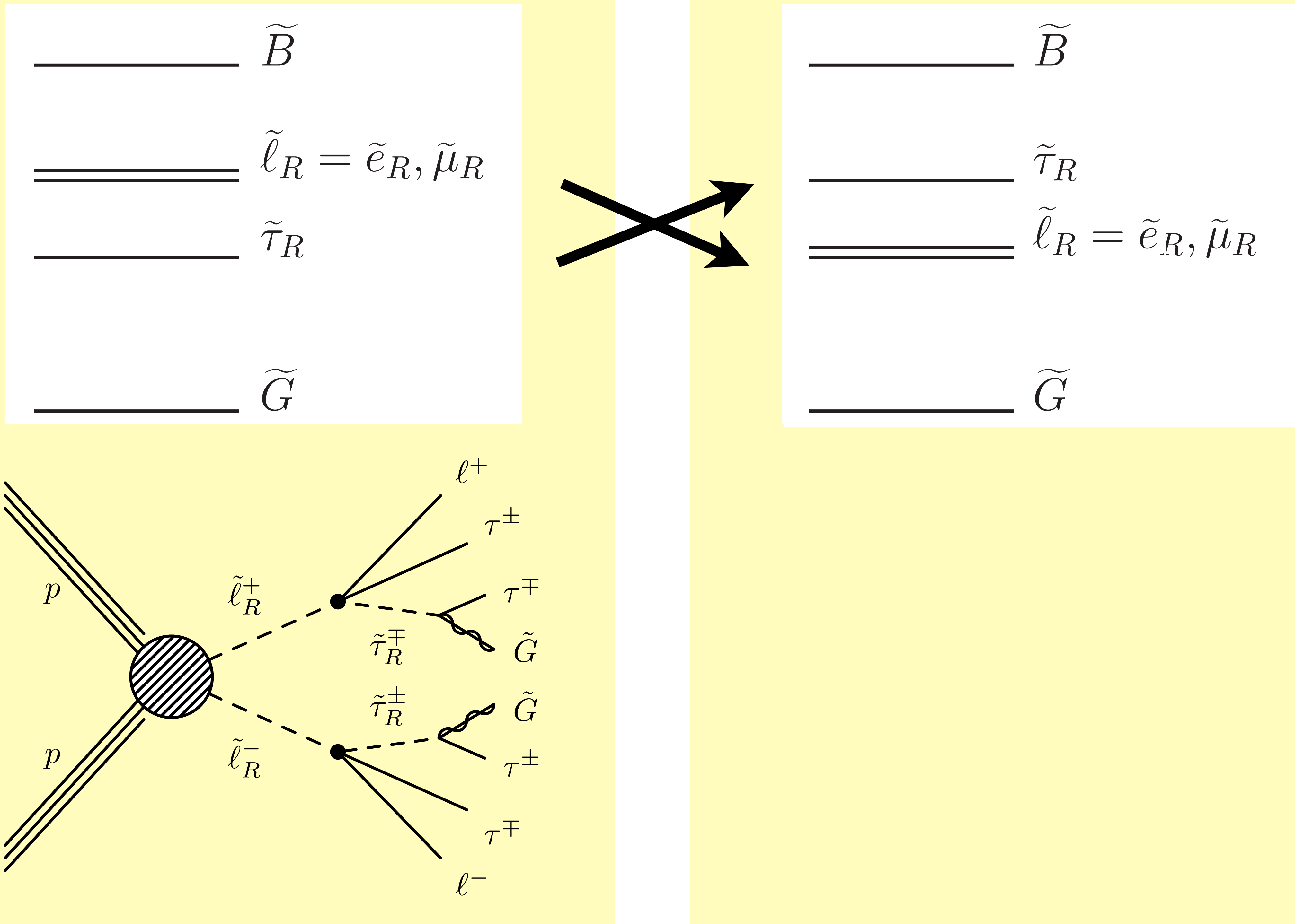
Common in GMSB

Can be realized when the soft masses for both Higgs fields are allowed to receive extra, non-gauge mediated, contributions

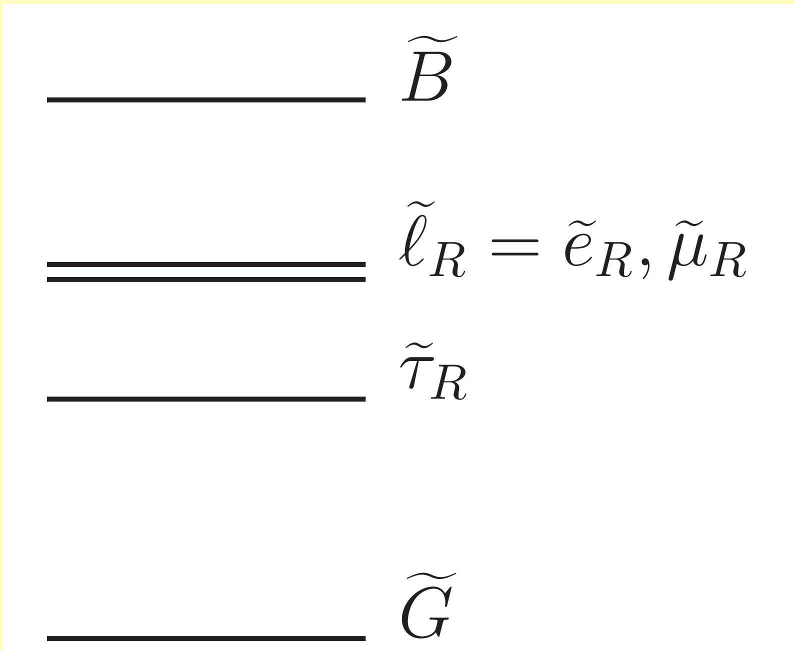
[P.Grajek, A.Mariotti, D.Redigolo, JHEP 1307 (2013) 109]

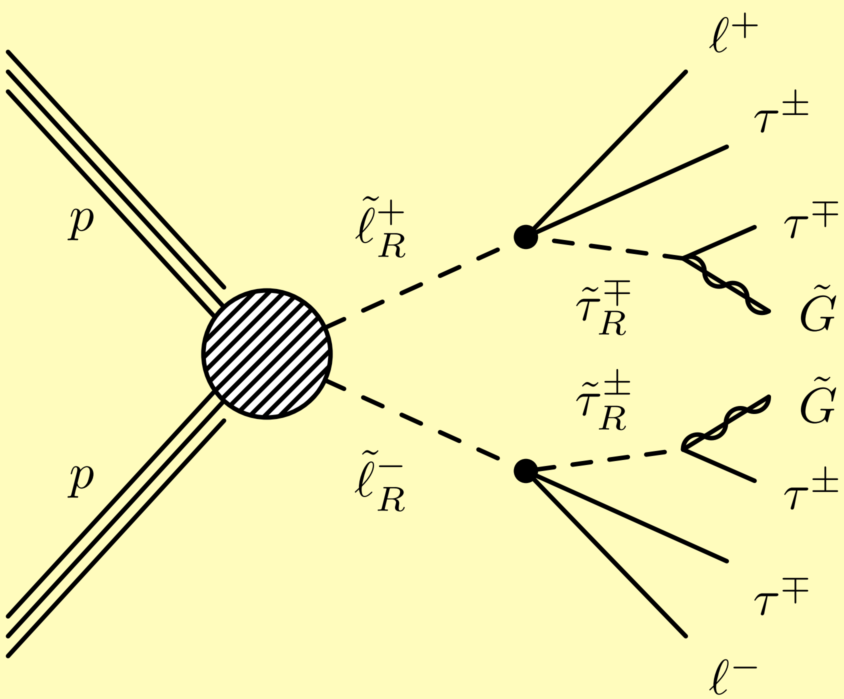
Simplified model 1

Simplified model 2



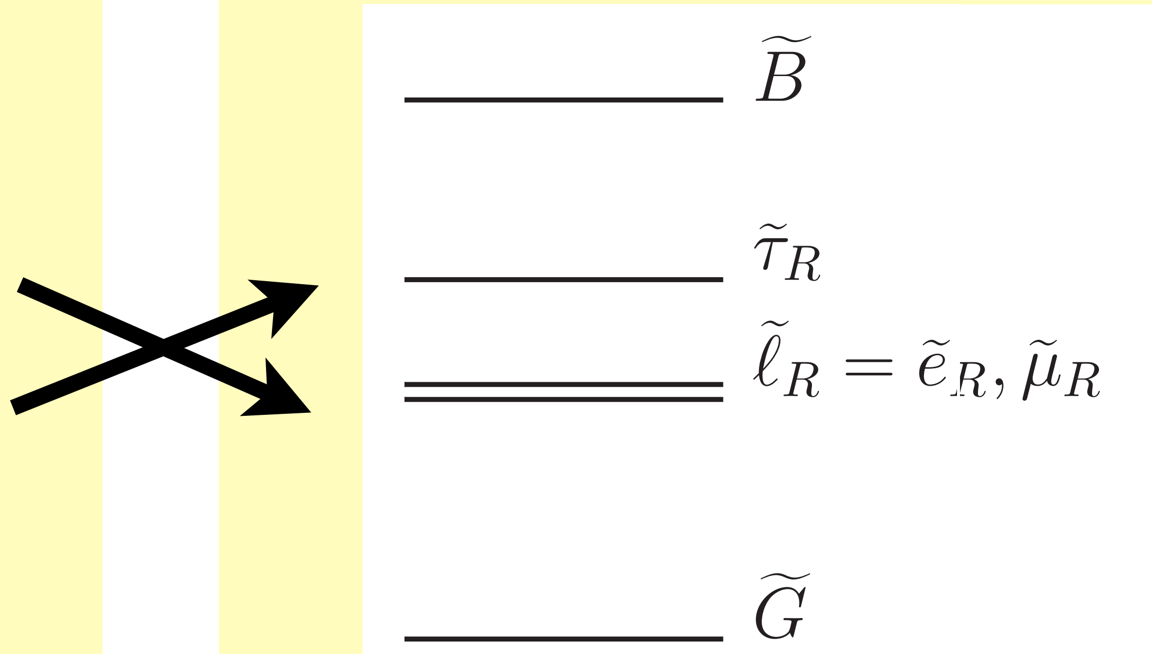
Simplified model 1

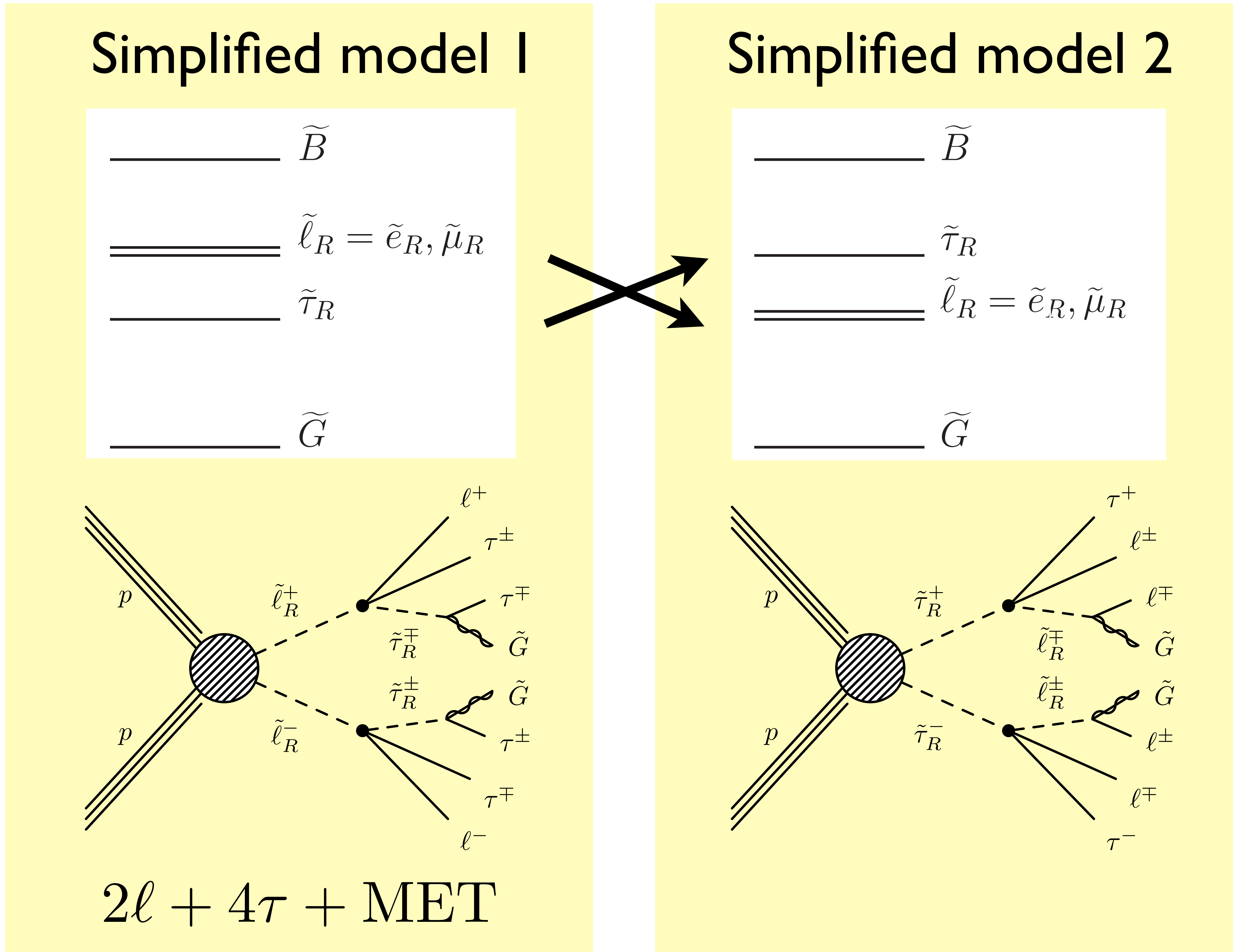




$$2\ell + 4\tau + \text{MET}$$

Simplified model 2

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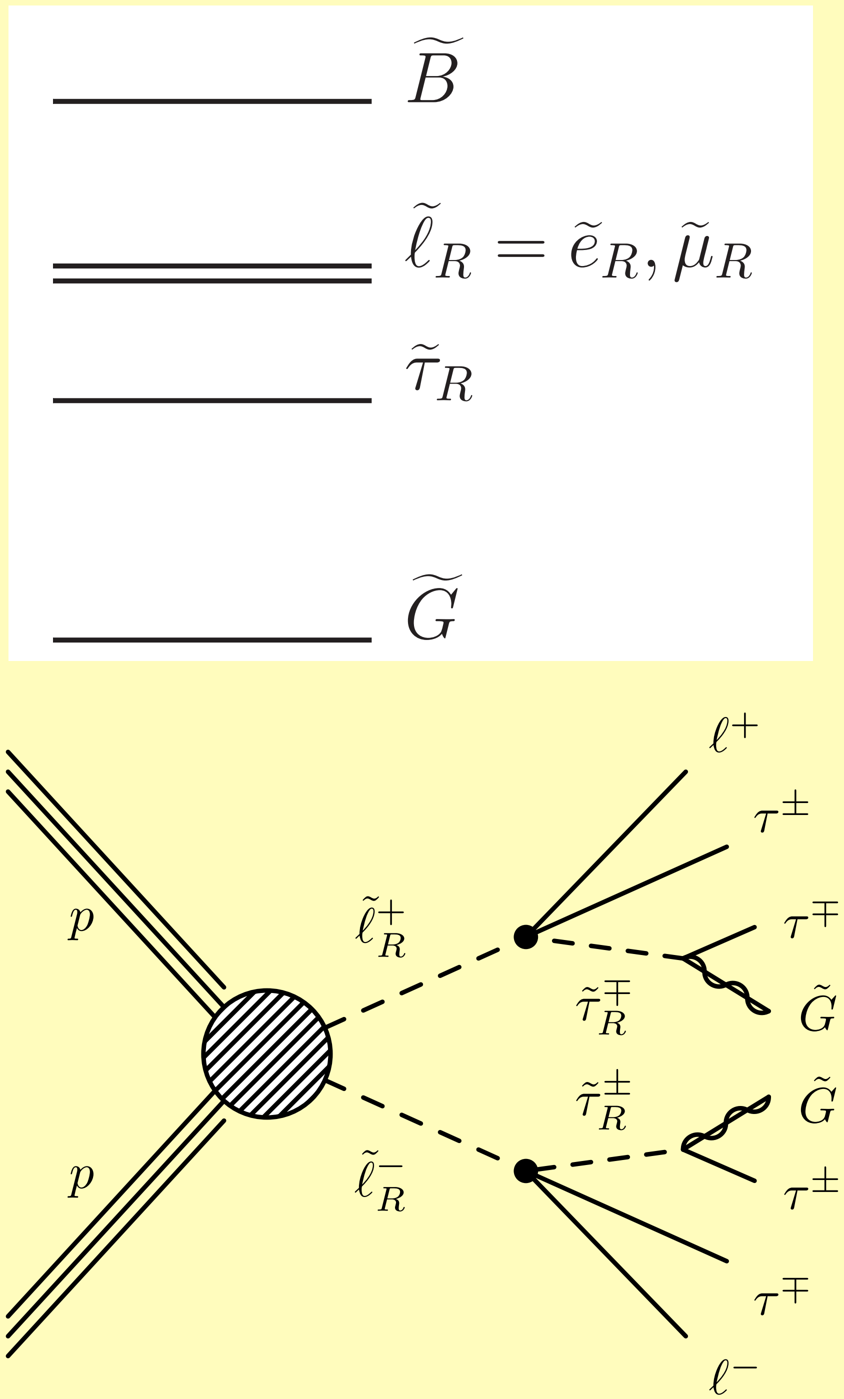
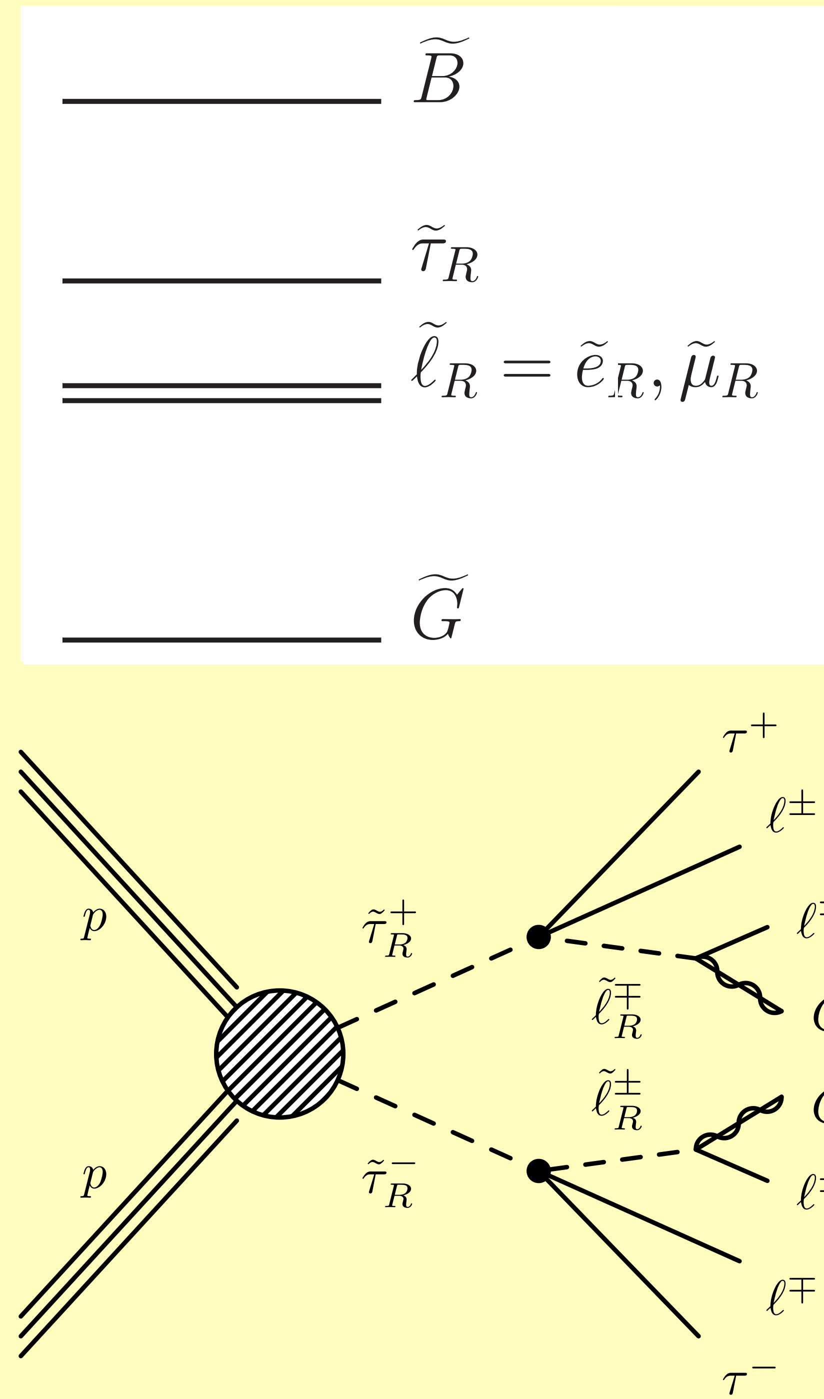
$\widetilde{B}$
$\tilde{\ell}_R = \tilde{e}_R, \tilde{\mu}_R$
$\tilde{\tau}_R$
$\widetilde{G}$
p
p
$\tilde{\ell}_R^+$
$\tilde{\ell}_R^-$
$\tilde{\tau}_R^\mp$
$\tilde{\tau}_R^\pm$
ℓ^+
$\tau^\pm$
$\tau^\mp$
$\tilde{G}$
$\tilde{G}$
$\tau^\pm$
$\tau^\mp$
ℓ^-
$2\ell + 4\tau + \mathrm{MET}$
Simplified model 2
$\widetilde{B}$
$\tilde{\tau}_R$
$\tilde{\ell}_R = \tilde{e}_R, \tilde{\mu}_R$
$\widetilde{G}$
p
p
$\tilde{\tau}_R^+$
$\tilde{\tau}_R^-$
$\tilde{\ell}_R^\mp$
$\tilde{\ell}_R^\pm$
τ^+
$\ell^\pm$
$\ell^\mp$
$\tilde{G}$
$\tilde{G}$
$\ell^\pm$
$\ell^\mp$
τ^-

Simplified model 1



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

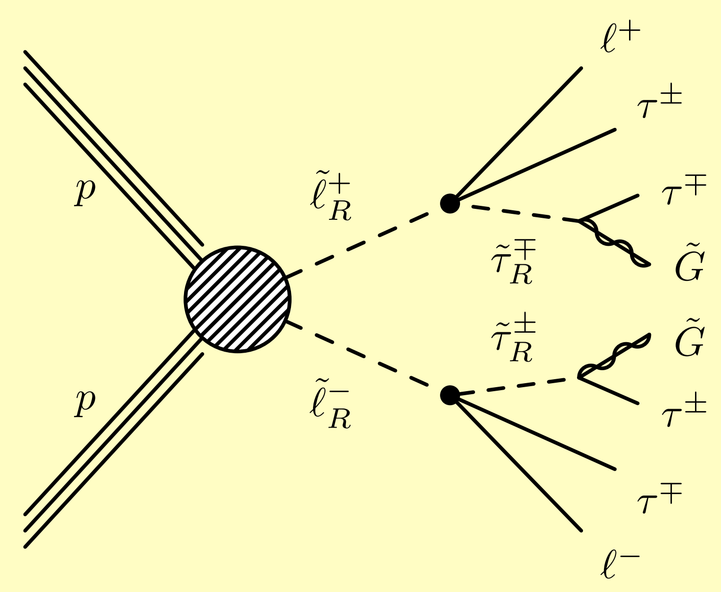
Simplified model 2



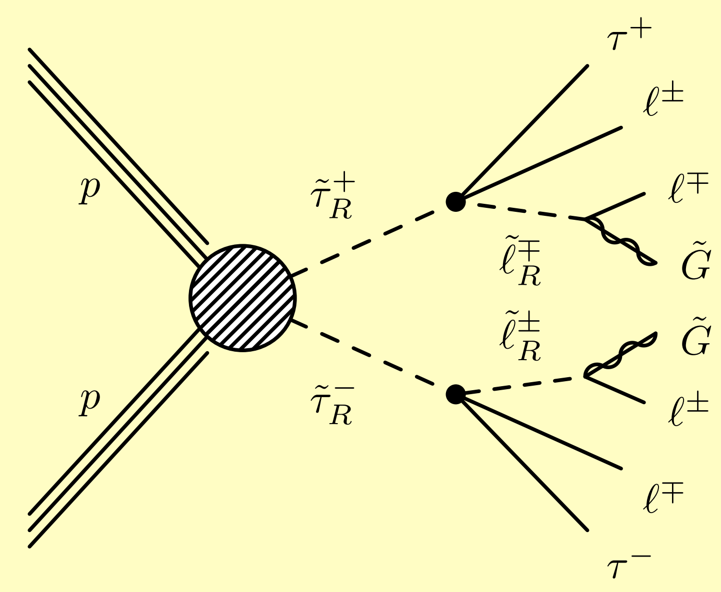
$$2\tau + 4\ell + \mathrm{MET}$$

Compare with the CMS results

Simulate the two processes at LHC 8 TeV



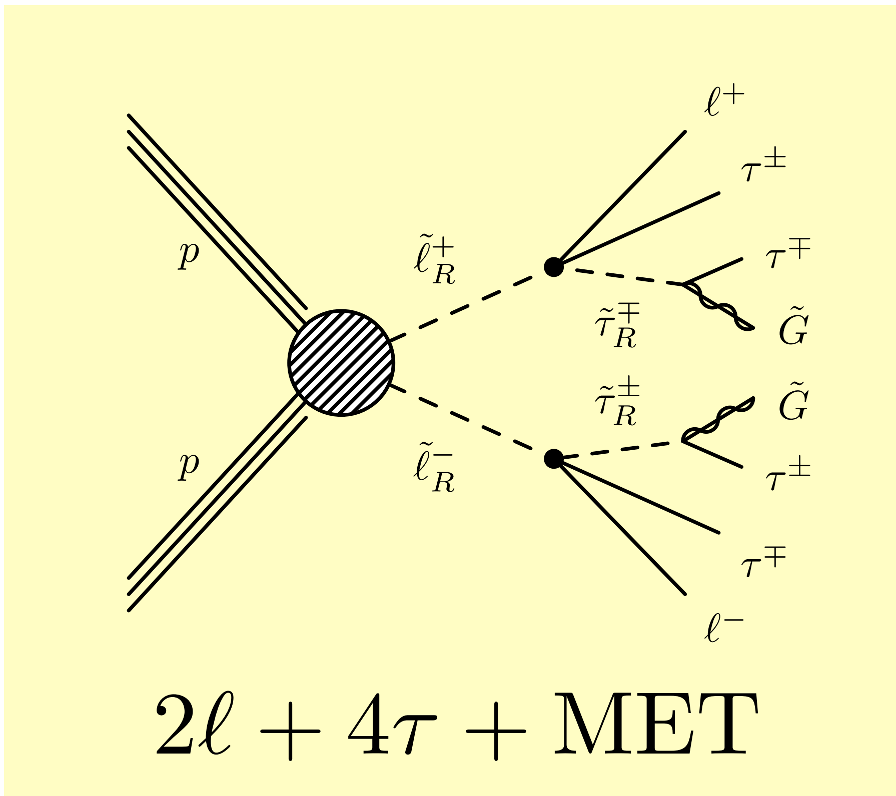
$2\ell + 4\tau + \mathrm{MET}$

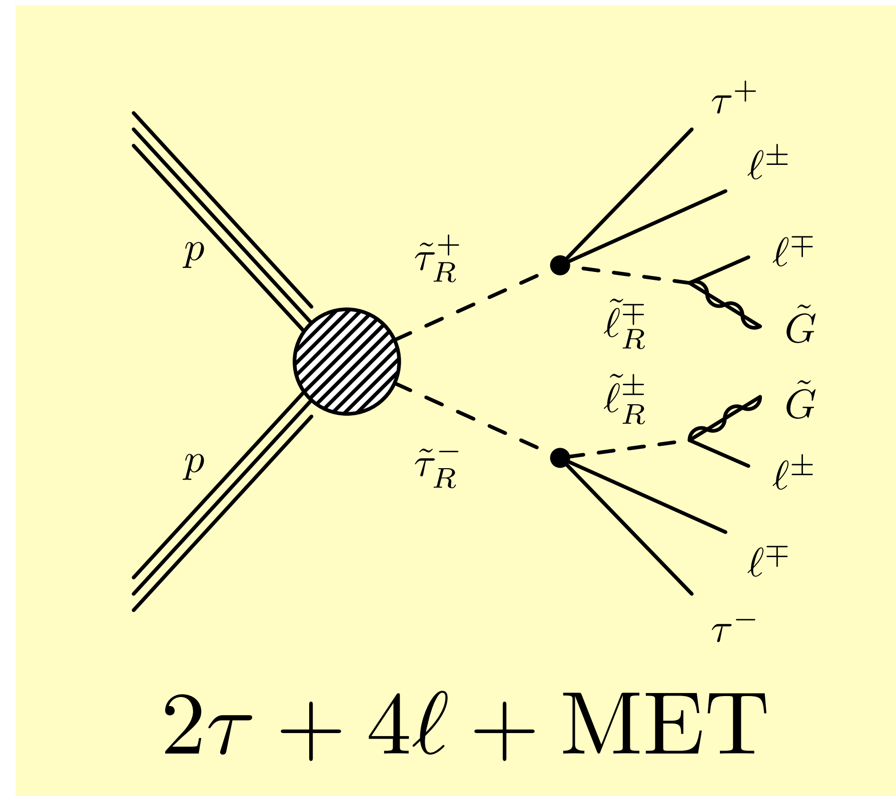


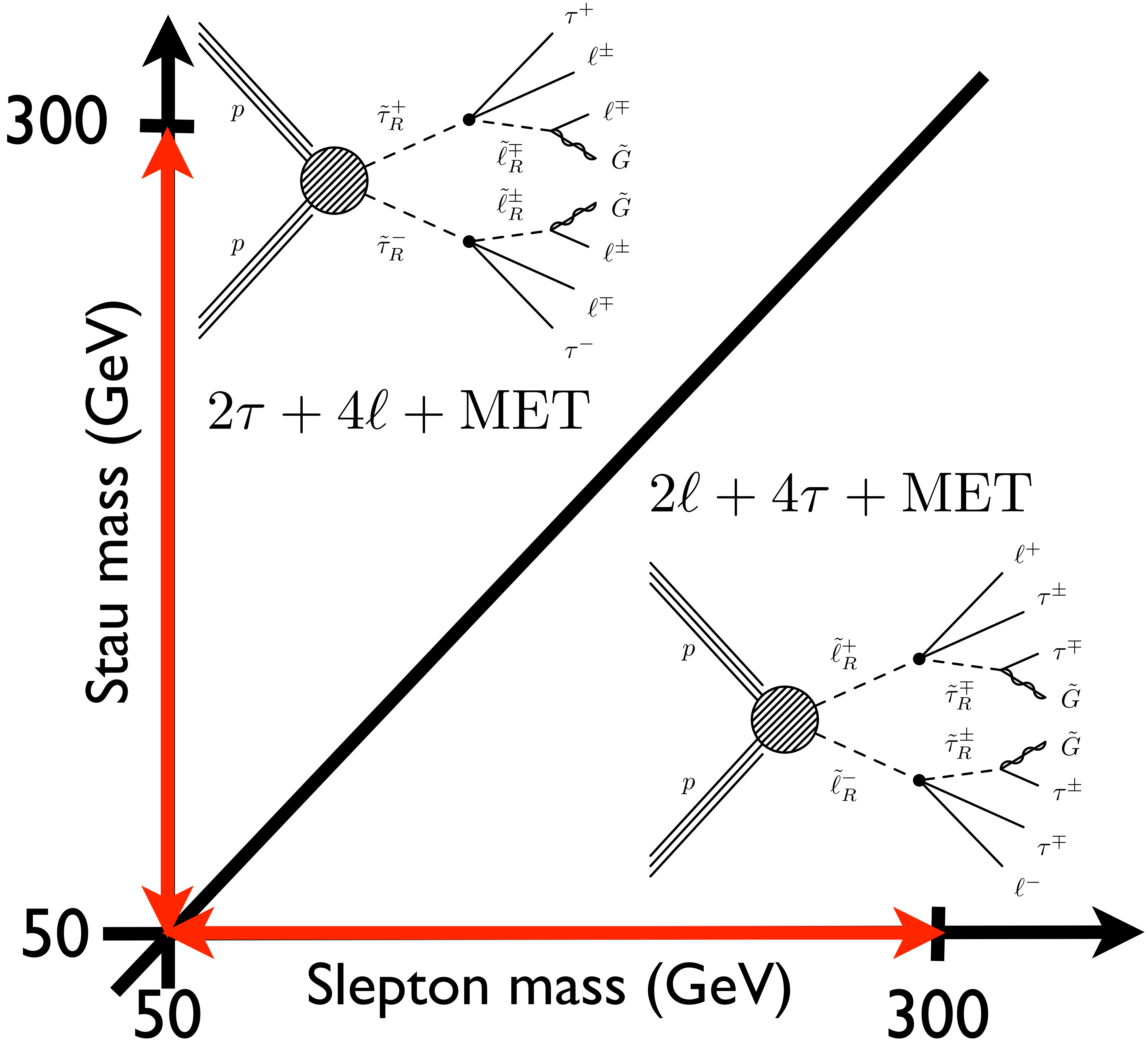
$2\tau + 4\ell + \mathrm{MET}$

FeynRules	[Christensen,Duhr,Fuks]
MadGraph 5	[Alwall,Herquet,Maltoni,Mattelaer,Stelzer]
Pythia	[Sjöstrand,Mrenna,Skands]
Tauola	[Jadach,Was,Decker,Kuhn]
Delphes	[Ovyn,Rouby,Lemaitre]
MadAnalysis 5	[Conte,Fuks,Serret]

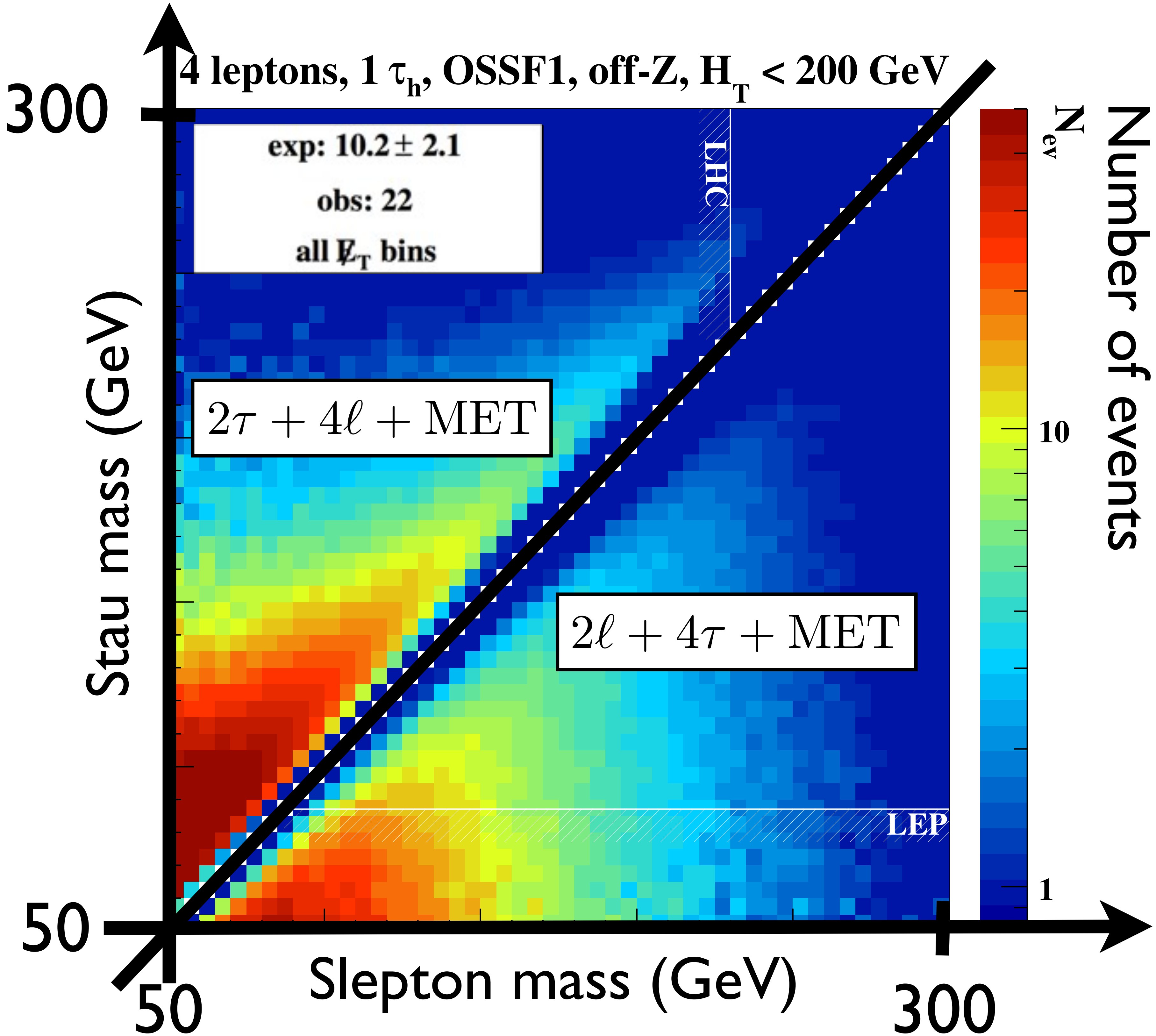
Choose the mass ranges



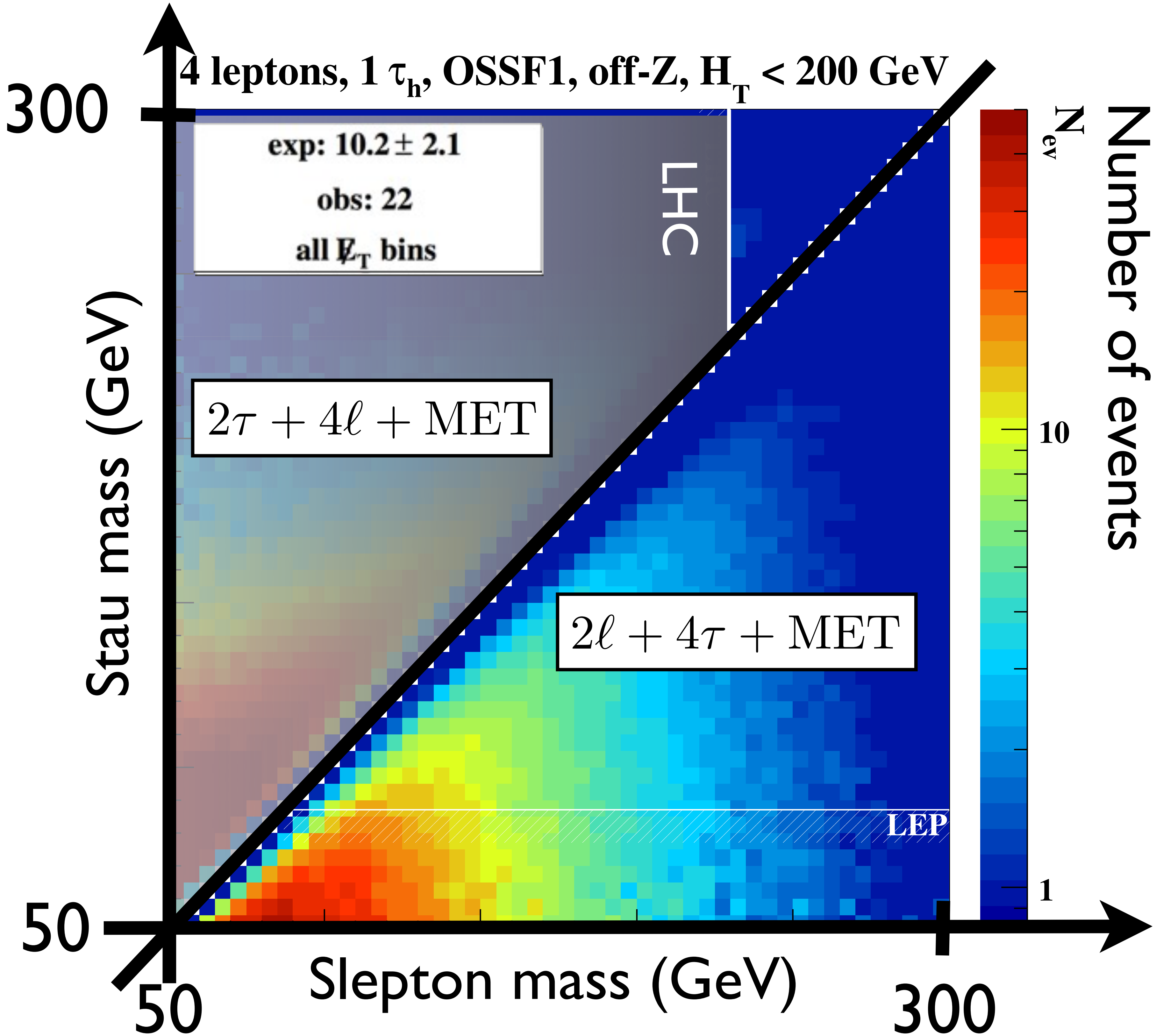



300
50
Stau mass (GeV)
Slepton mass (GeV)
50
300
$2\tau + 4\ell + \mathrm{MET}$
$2\ell + 4\tau + \mathrm{MET}$
p
p
$\tilde{\tau}_R^+$
$\tilde{\tau}_R^-$
$\tilde{\ell}_R^\mp$
$\tilde{\ell}_R^\pm$
τ^+
$\ell^\pm$
$\ell^\mp$
$\tilde{G}$
$\tilde{G}$
$\ell^\pm$
$\ell^\mp$
τ^-
$\tilde{\ell}_R^+$
$\tilde{\ell}_R^-$
$\tilde{\tau}_R^\mp$
$\tilde{\tau}_R^\pm$
ℓ^+
$\tau^\pm$
$\tau^\mp$
$\tilde{G}$
$\tilde{G}$
$\tau^\pm$
$\tau^\mp$
ℓ^-

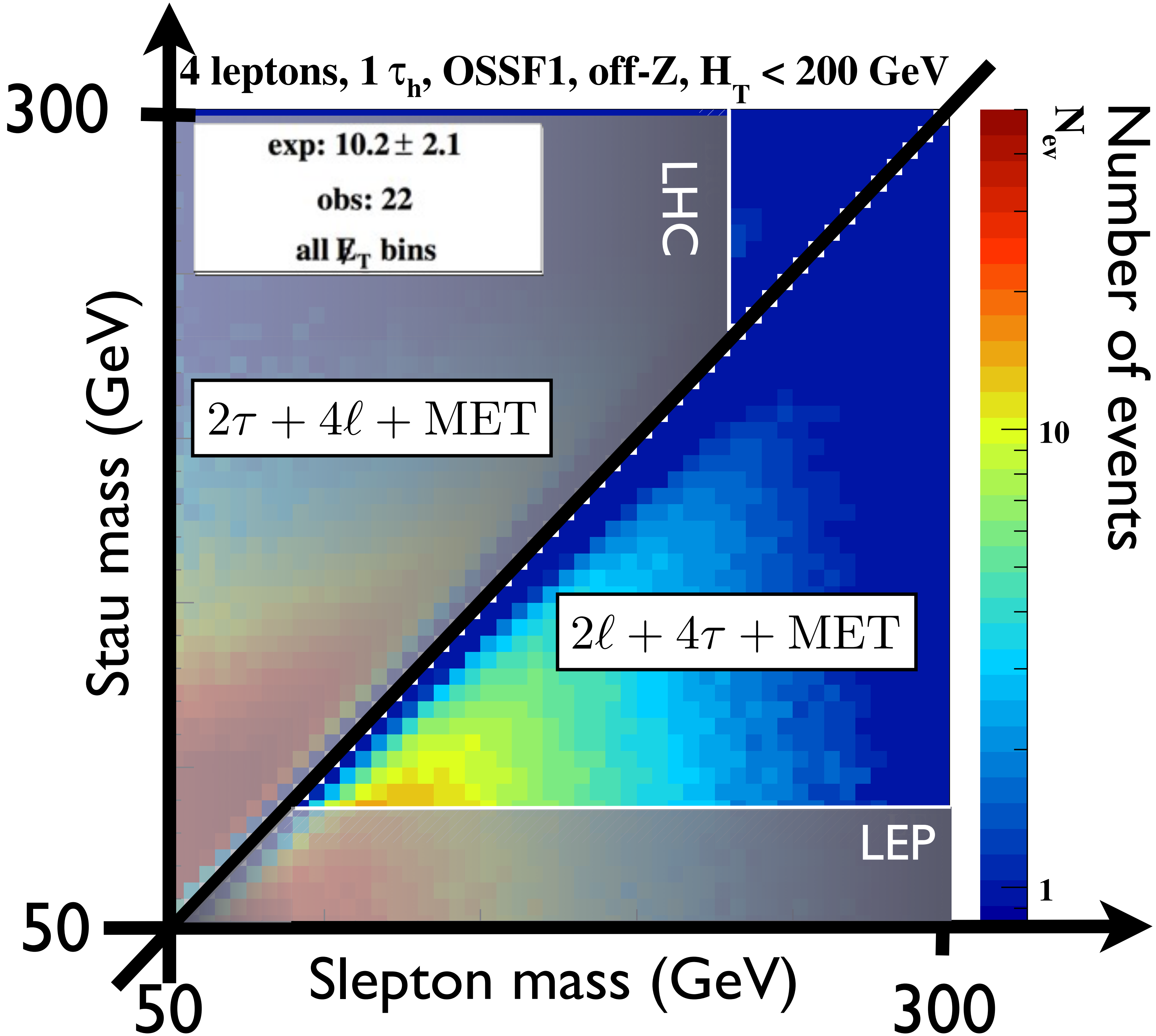
Obtain the numer of events



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

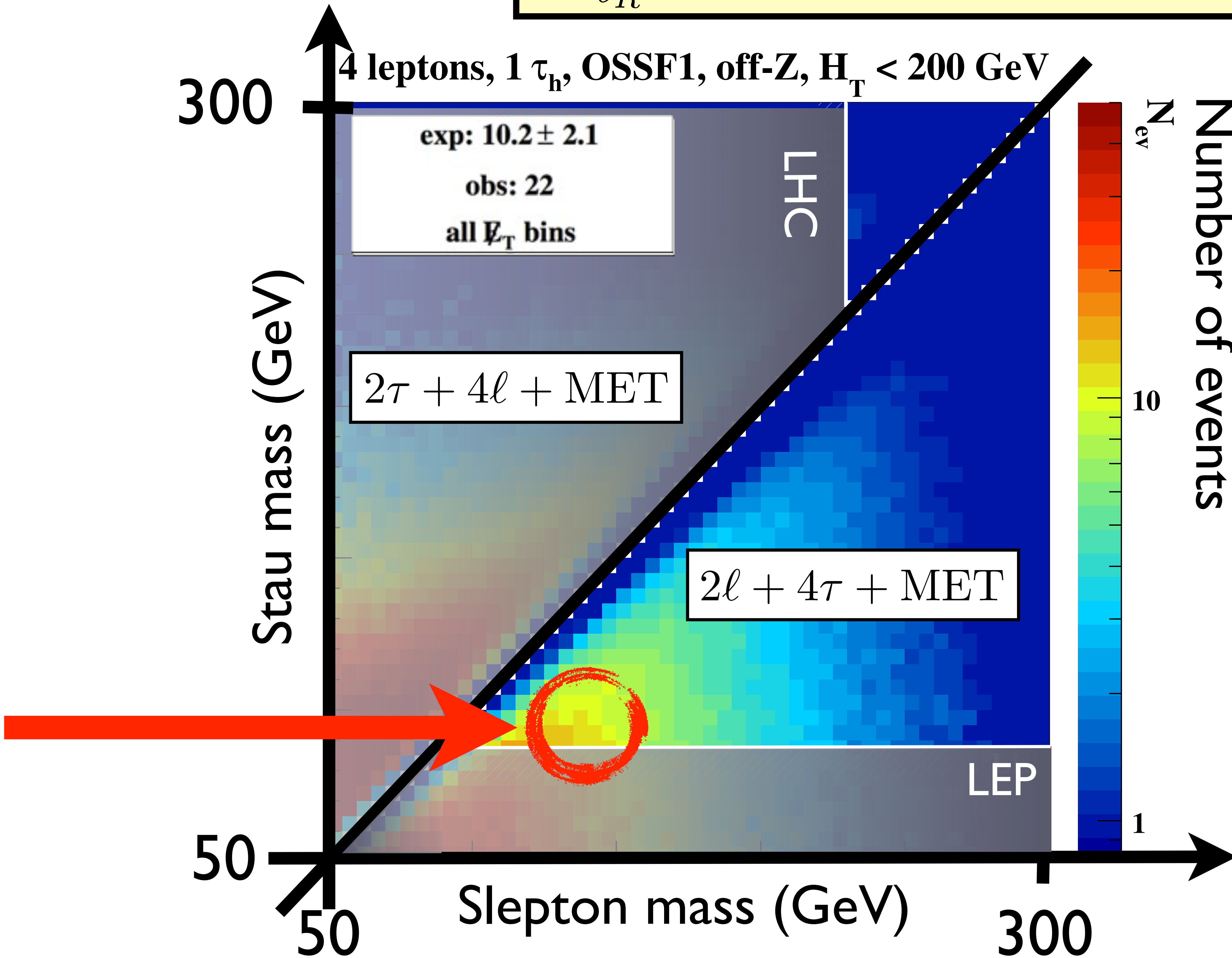


$m_{\tilde{\tau}_R} > 87\,\mathrm{GeV}$ [LEP]



Preferred region:

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

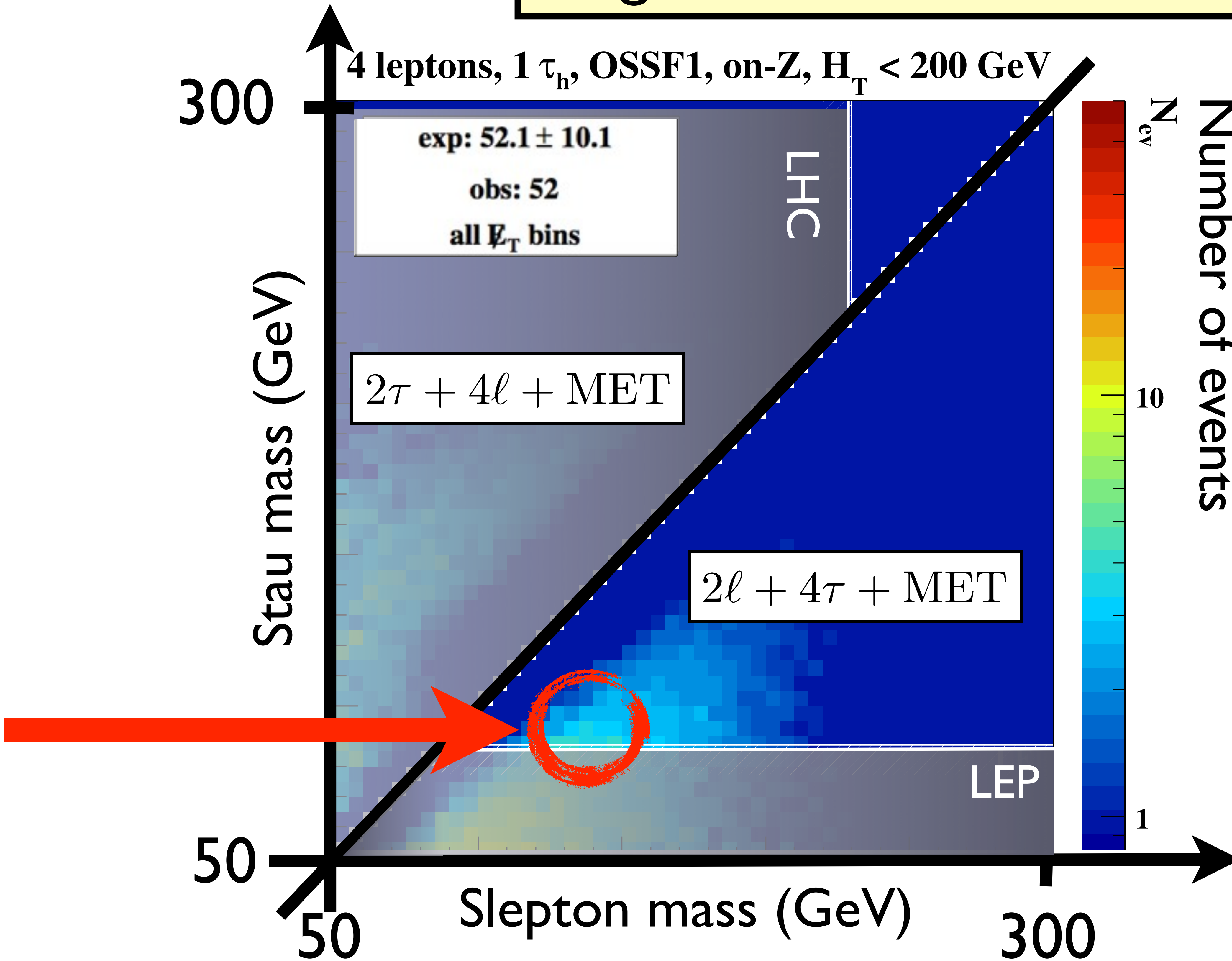


What about the other categories?

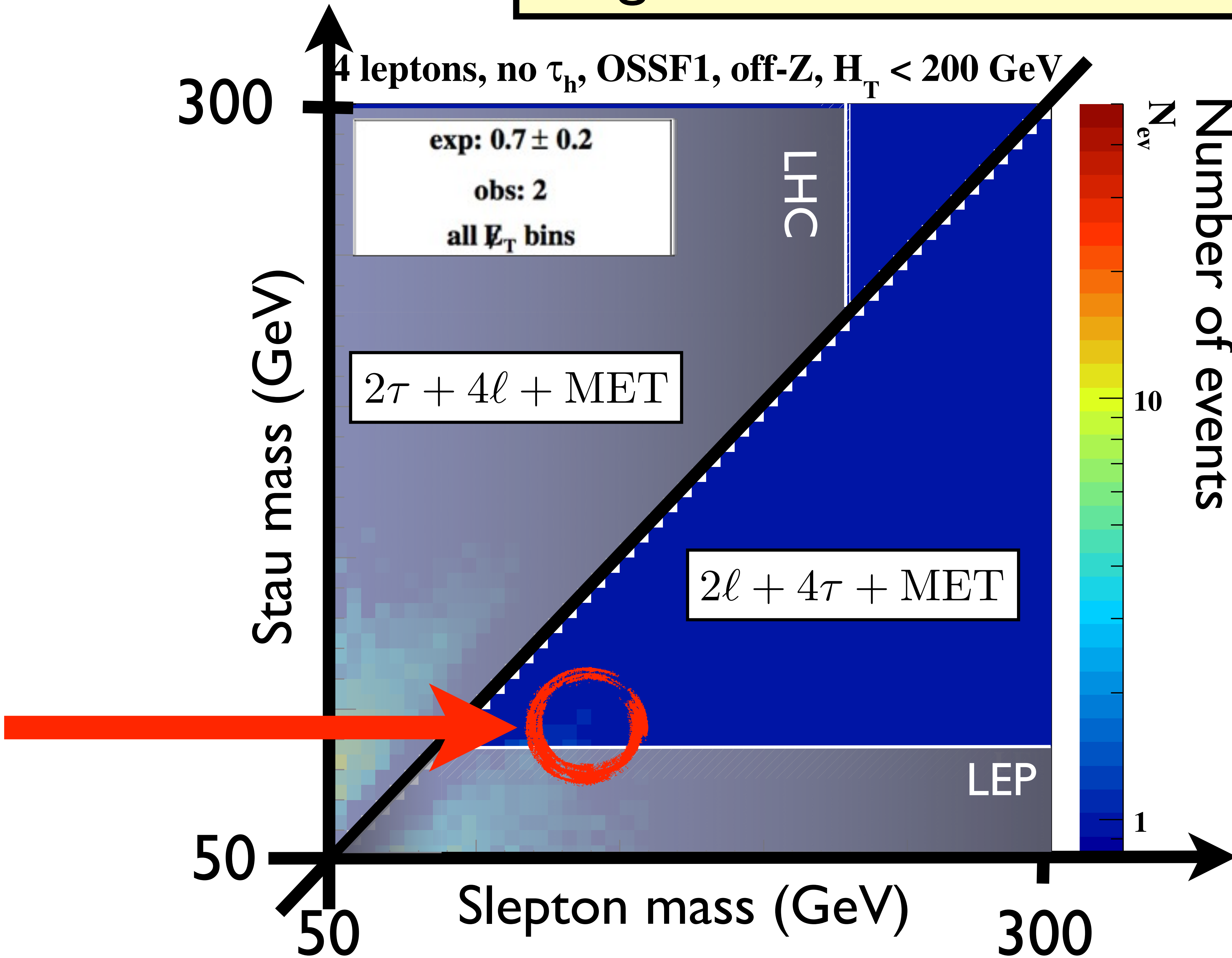
Categories with 3 leptons are irrelevant since the background is too high

And the others...

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



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

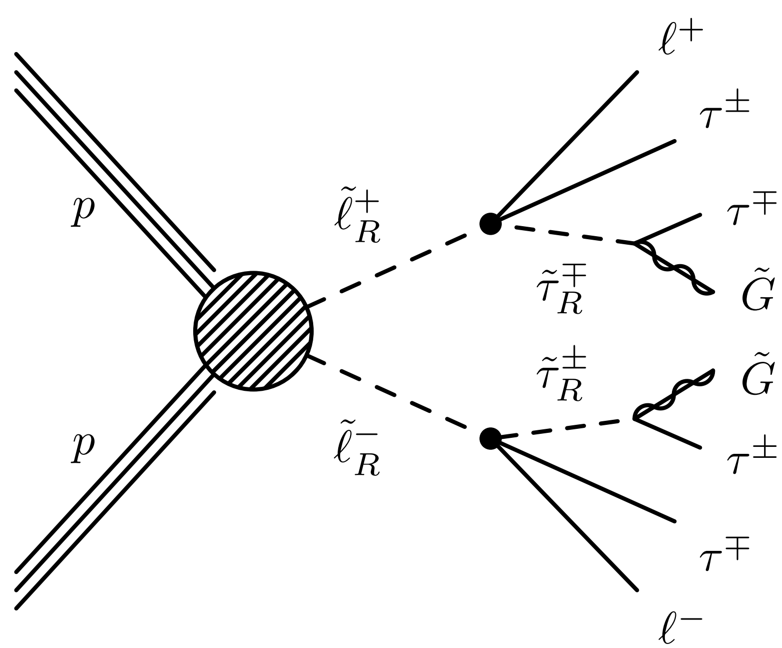


Other searches don't exclude our scenario

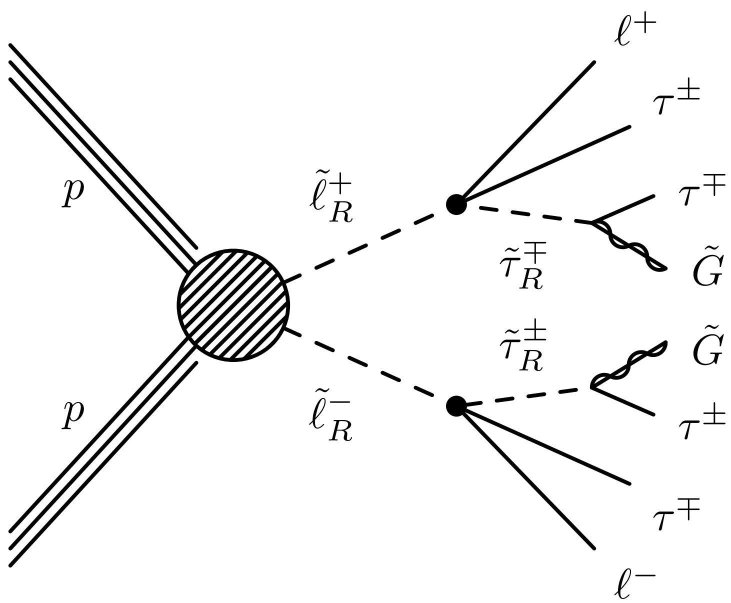
CMS multi-lepton search CMS SUS-13-010 (requires 4 electrons or muons)

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

ATLAS di-tau+MET search (lepton veto)



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



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

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

$N(\ell)$	$N(\tau_h)$	$N_{\mathrm{events}}(8\ \mathrm{TeV})$ $19.5\,\mathrm{fb}^{-1}$	$N_{\mathrm{events}}(13\ \mathrm{TeV})$ $100\,\mathrm{fb}^{-1}$
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

The CMS result

Can we explain this with SUSY?

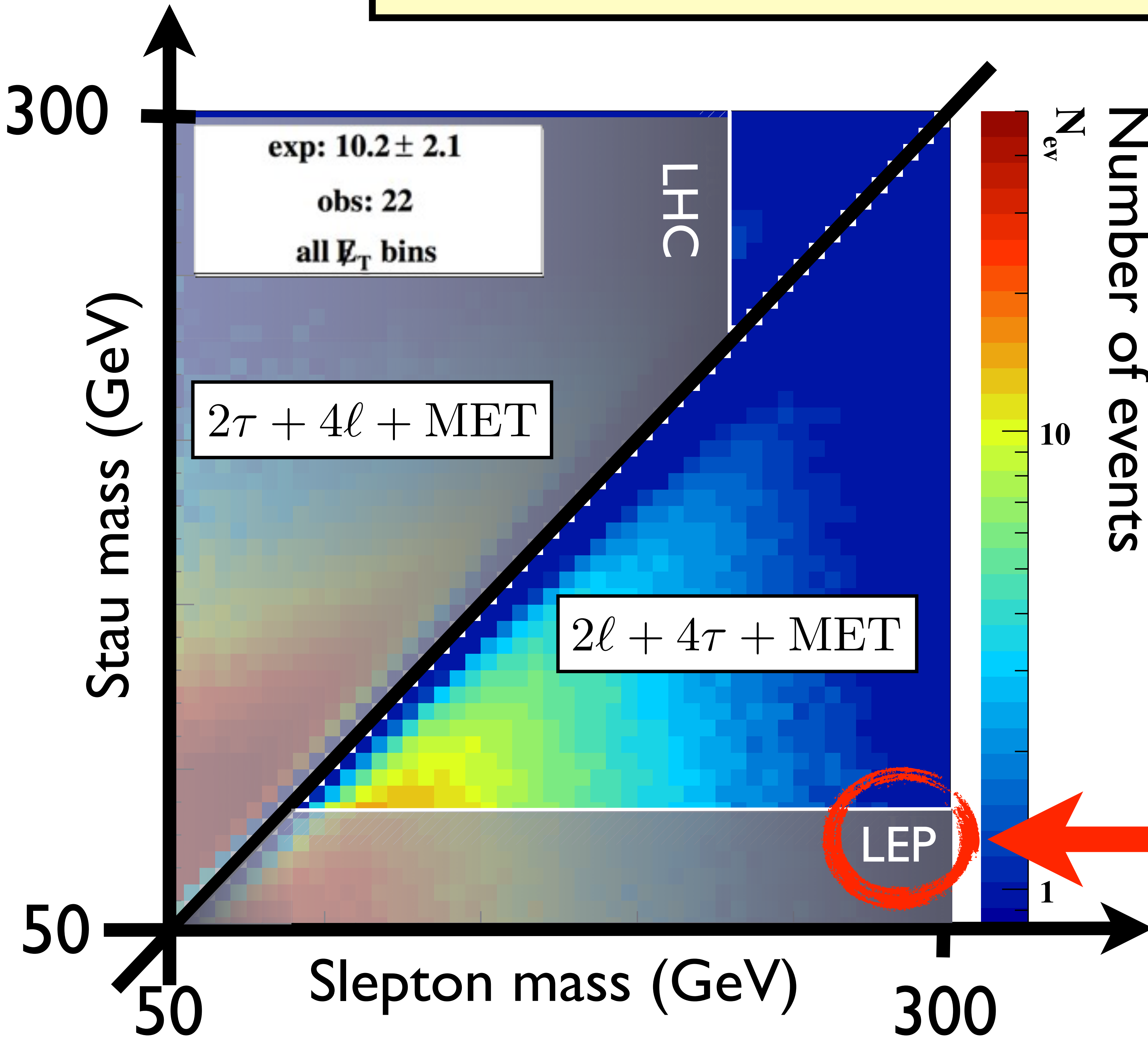
Future studies

A more complete study is in progress

Implement and validate all relevant analyses in MadAnalysis 5:

CMS SUS-13-002 [arxiv:1404.5801]: 3 leptons or more
CMS SUS-13-010: 4 leptons
CMS SUS-13-006 [arxiv:1405.7570]: 2 leptons
ATLAS-CONF 13-036 [arxiv:1405.5086]: 4 leptons or more
ATLAS-CONF 13-049 [arxiv:1403.5294]: 2 opposite sign leptons
ATLAS-CONF 13-028: 2 leptons with hadronic taus
ATLAS [arxiv:1402.7029]: 3 leptons

The bound on the stau mass is still the limit from LEP!



Try to improve the bound on the stau mass

ATLAS search for at least 2 hadronic taus and MET is not sensitive enough

We will try to reinterpret the dilepton (electron, muon) searches in terms of stau mass bounds

The CMS result

Can we explain this with SUSY?

Future studies

The CMS result

CMS observes an excess in a multilepton search

Can we explain this with SUSY?

Future studies

The CMS result

CMS observes an excess in a multilepton search

Can we explain this with SUSY?

Yes we can!

Future studies

The CMS result

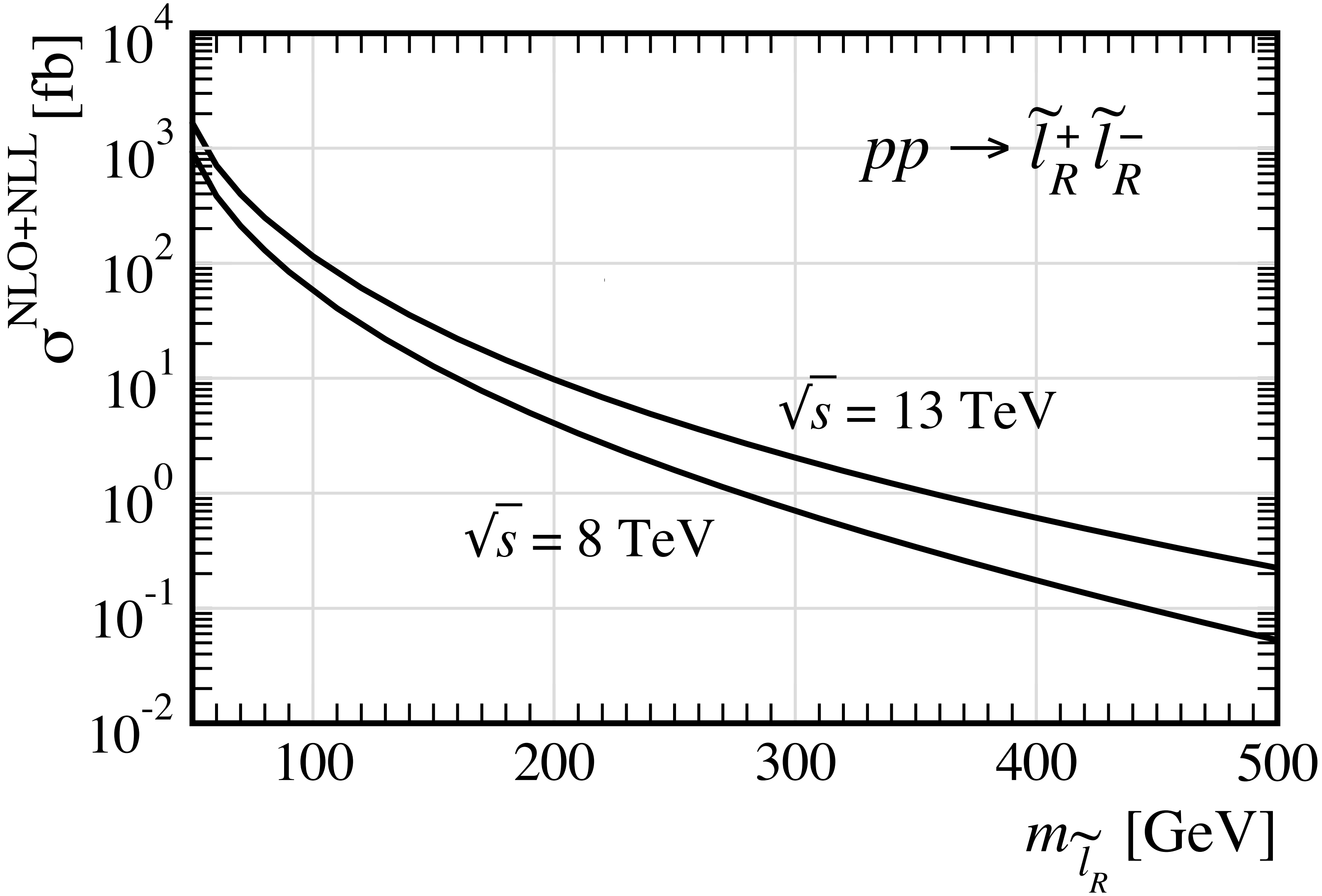
CMS observes an excess in a multilepton search

Can we explain this with SUSY?

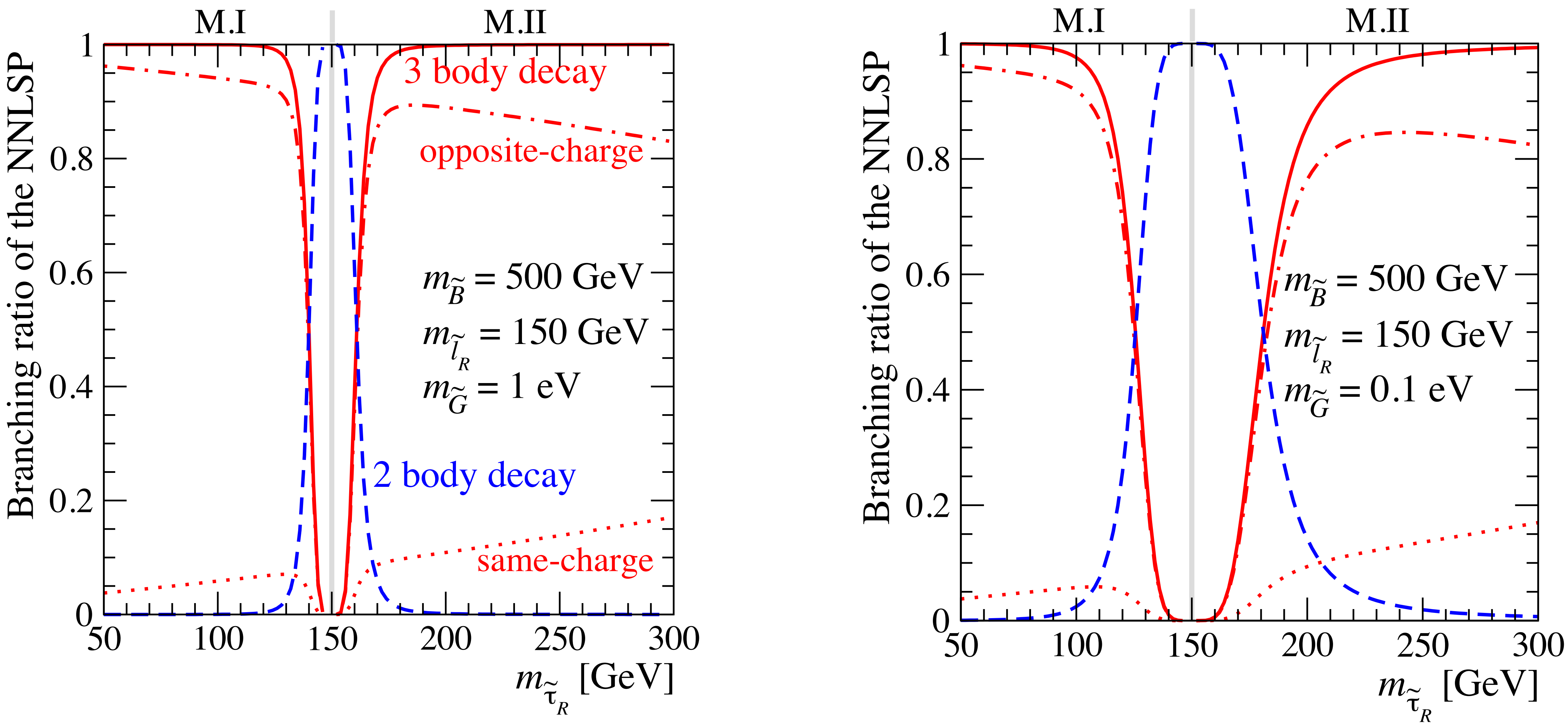
Yes we can!

Future studies

Implement all lepton analyses in MA5 and improve the stau mass bound



$\sigma^{\mathrm{NLO+NLL}}$ [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]


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