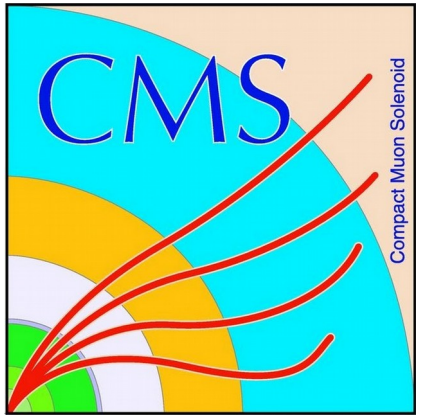
Search for supersymmetry with a compressed mass spectrum in the vector boson fusion topology with 1-lepton and 0-lepton final states in proton-proton collisions at √s = 13 TeV

3rd COMHEP

Jose Ruiz
on behalf of the CMS collaboration



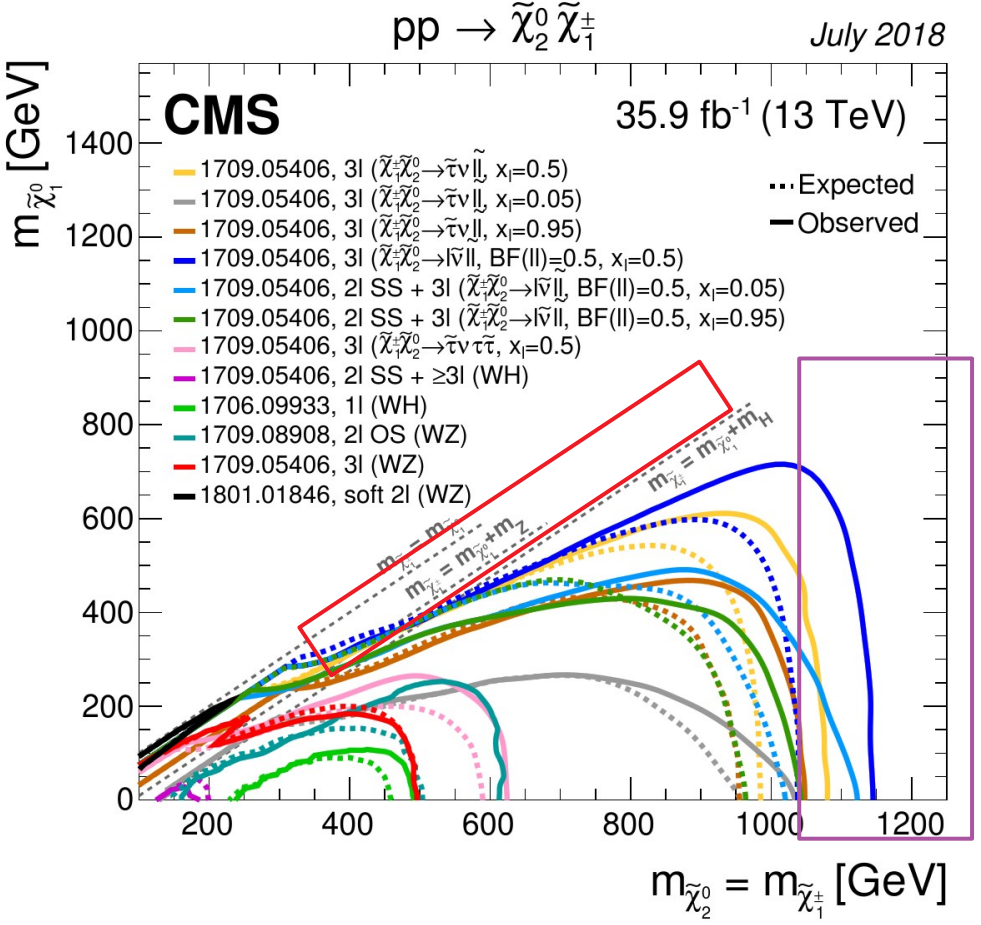
Chasing SUSY

Theory

Experiment

Parameter space

Motivation



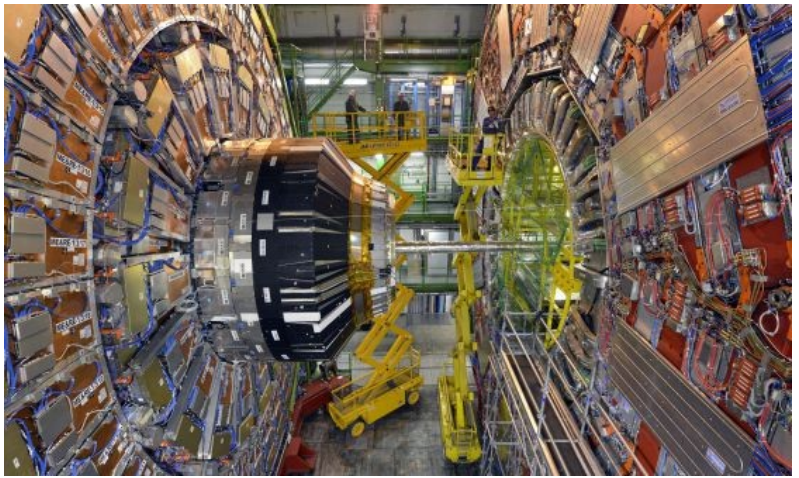
Compressed spectra:
Small mass differences →
Challenging with low-pT objects!

Higher masses →
Higher center of mass engery

Limited from the collider

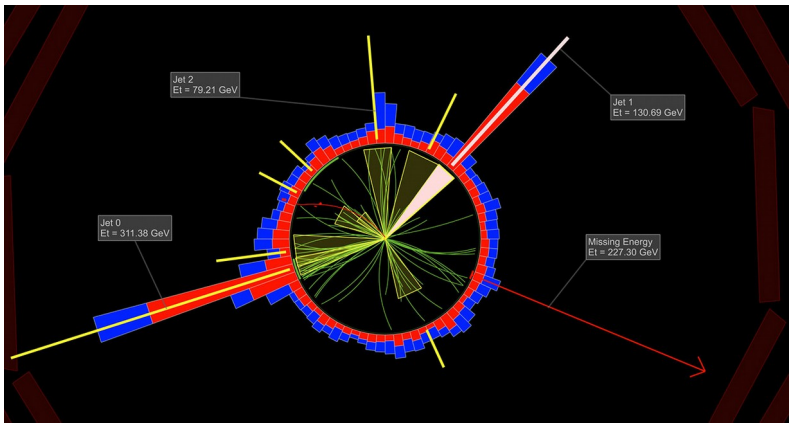
CMS experiment and LHC

LHC provides pp collisions



CMS records the products of LHC collisions

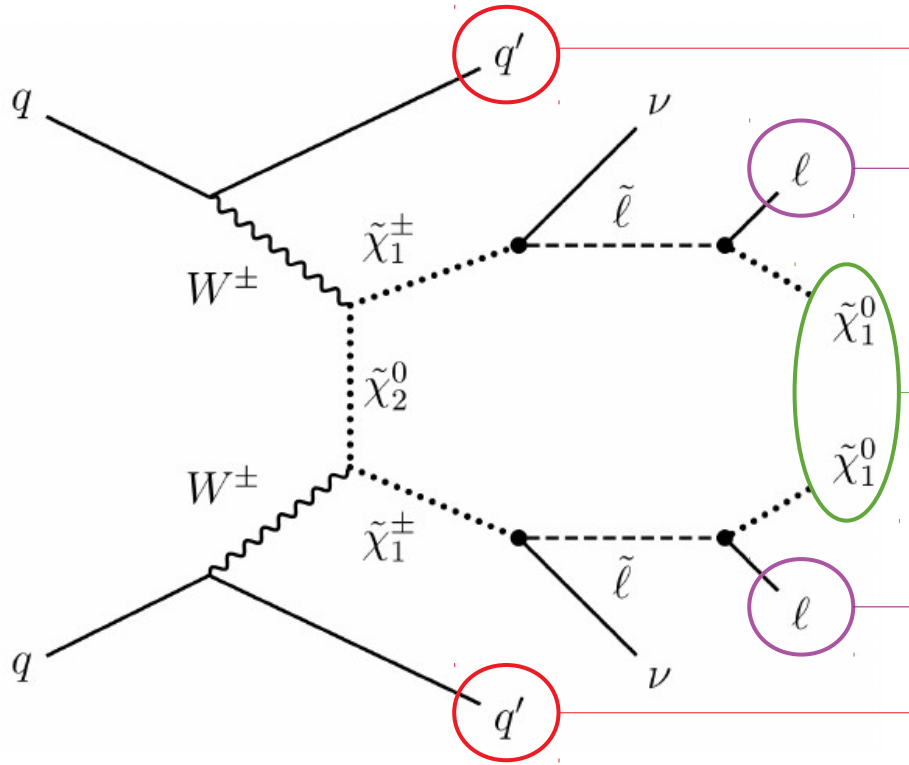
- **Muons**
- **Electrons**
- **Photons**
- **Jets**
  - **b-jets**
  - **taus**



Non-interacting particles cause momentum imbalance in the transverse plane of the beam

p_T,miss → "Missing energy"

Selection



Two VBF jets

1-lepton channel: 1 lepton lost
0-lepton channel: 2 leptons lost

Missing transverse momentum

Selection

Selection	e-channel	mu-channel	tau-channel	Inv. channel
p_T(e)	10-40 GeV	Veto > 10 GeV	Veto > 10 GeV	Veto > 10 GeV
p_T(mu)	Veto > 8 GeV	8-40 GeV	Veto > 8 GeV	Veto > 8 GeV
p_T(tau)	Veto > 20 GeV	Veto > 20 GeV	> 20 GeV	Veto > 20 GeV
m_T(l,p_T,miss)	> 110 GeV	> 110 GeV	> 110 GeV	---
pT,miss	> 250 GeV	> 250 GeV	> 250 GeV	> 250 GeV
b-jet	Veto	Veto	Veto	Veto
Jets	N(j)>1, p_T(j)>60 GeV	N(j)>1, p_T(j)>60 GeV	N(j)>1, p_T(j)>60 GeV	N(j)>1, p_T(j)>60 GeV
VBF	η(j1)xη(j2)<0	η(j1)xη(j2)<0	η(j1)xη(j2)<0	η(j1)xη(j2)<0
VBF	Δη(j1,j2)>3.8	Δη(j1,j2)>3.8	Δη(j1,j2)>3.8	Δη(j1,j2)>3.8
VBF	m(j1,j2)> 1 TeV	m(j1,j2)> 1 TeV	m(j1,j2)> 1 TeV	m(j1,j2)> 1 TeV
QCD rejec.	---	---	---	$\|\Delta\varphi_{min}(p_T,miss;j)\|>0.5$

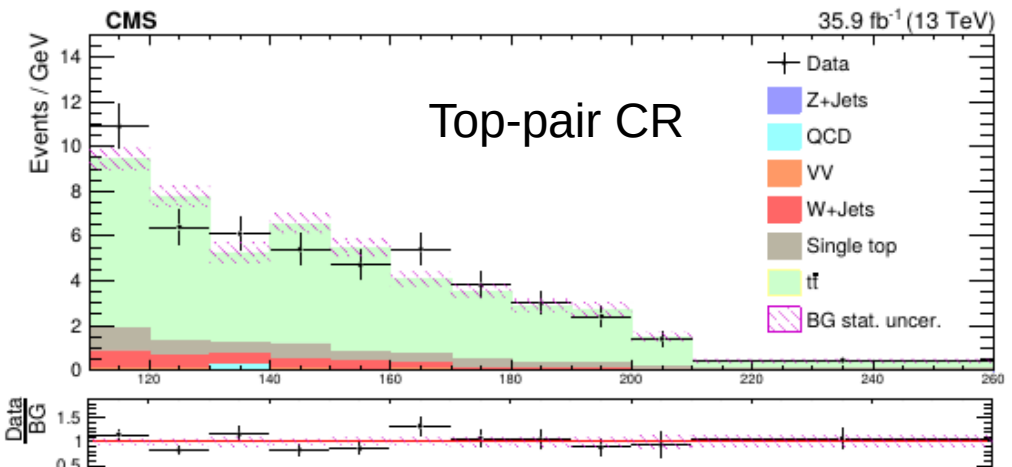
Background estimation

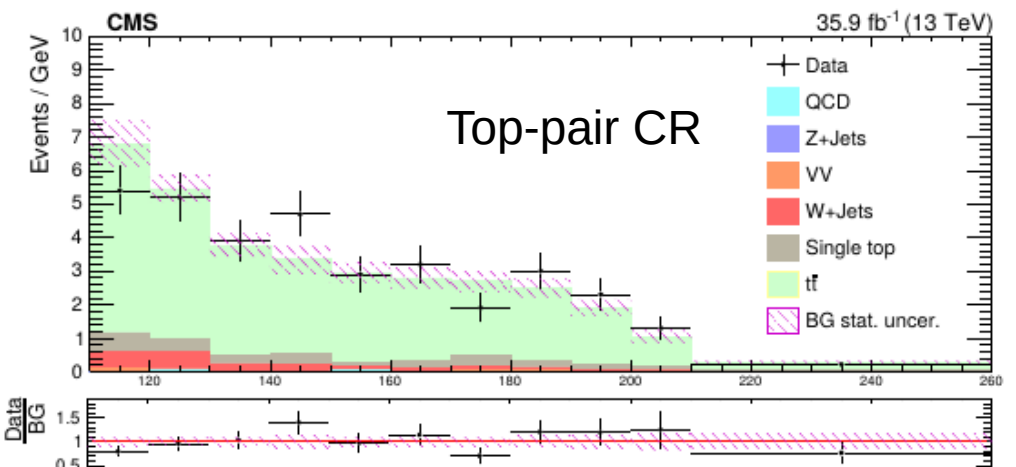
- Main backgrounds:
  - Estimated using data-driven techniques
  - Background enriched Control Region (CR) build by applying orthogonal selection to the Signal Region (SR)
  - Enriched stats by requiring VBF inverted criteria
  - Shapes derived from data (m_T for lepton channels and mjj for inv. channel)
- Sub-dominant backgrounds:
  - Estimated from MC

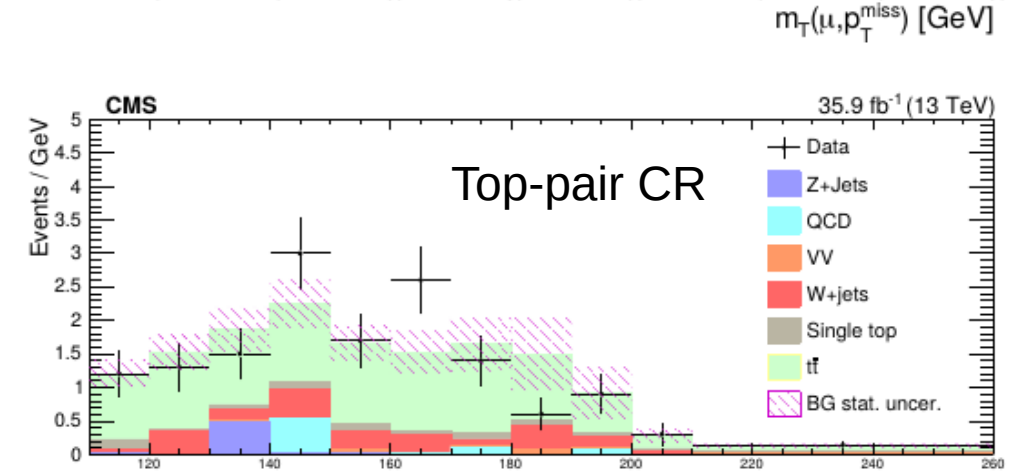
Background estimation

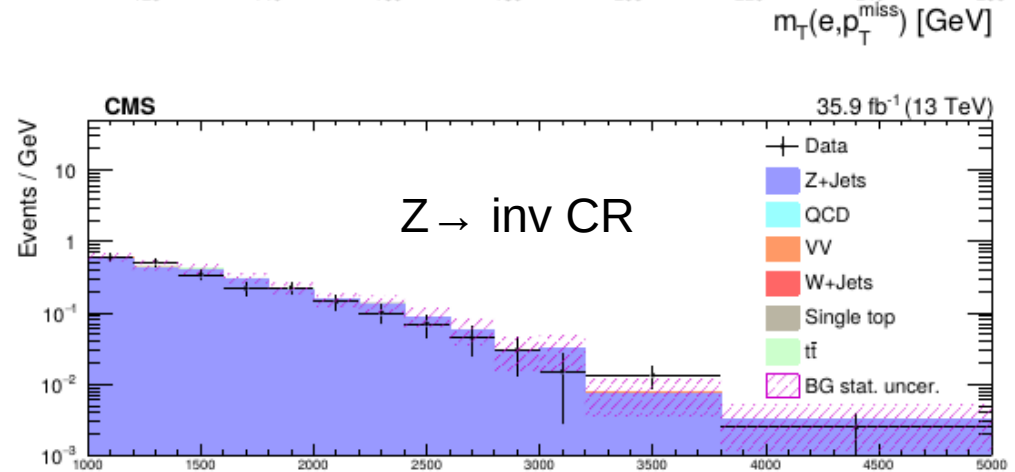
Technique	Top-pair	W(→l,nu)	Z → nu, nu	DY+jets	QCD	Other
Invisible	MC	1-mu CR	2-mu CR	MC	$\Delta\varphi_{min}$ inv CR	MC
e	1-b jet CR	m_T inv CR	---	MC	---	MC
mu	1-b jet CR	m_T inv CR	---	MC	---	MC
tau	1-b jet CR	m_T inv CR	---	MC	Iso inv CR	MC

SR com.	Top-pair	W(→l,nu)	Z → nu, nu	DY+jets	QCD	Other
Invisible	7%	37%	46%	---	7%	2%
e	58%	32%	---	<1%	0%	9%
mu	43%	43%	---	<1%	0%	13%
tau	14%	19%	---	<1%	63%	4%


CMS
35.9 fb-1 (13 TeV)
Top-pair CR
Data
Z+Jets
QCD
VV
W+Jets
Single top
tt̄
BG stat. uncer.
Events / GeV
Data/BG
mT(μ,pTmiss) [GeV]


CMS
35.9 fb-1 (13 TeV)
Top-pair CR
Data
QCD
Z+Jets
VV
W+Jets
Single top
tt̄
BG stat. uncer.
Events / GeV
Data/BG
mT(e,pTmiss) [GeV]

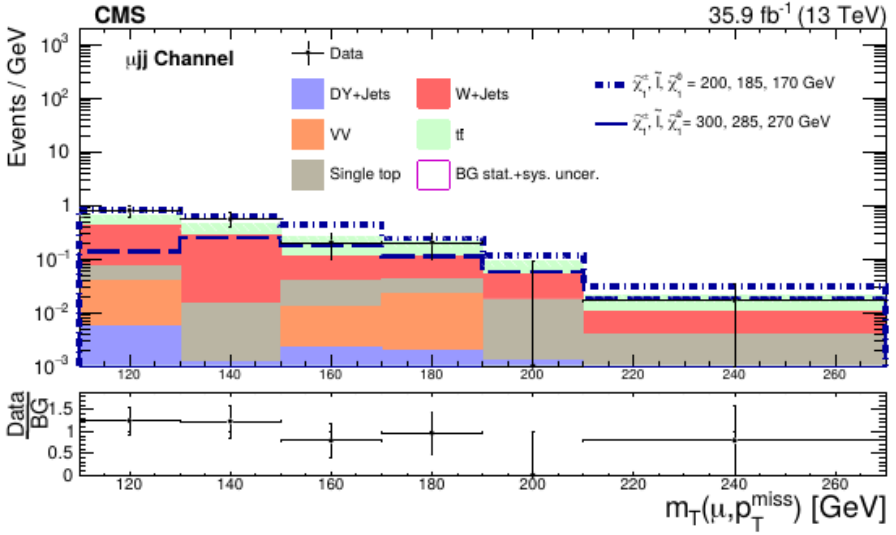

CMS
35.9 fb-1 (13 TeV)
Top-pair CR
Data
Z+Jets
QCD
VV
W+jets
Single top
tt̄
BG stat. uncer.
Events / GeV
Data/BG
mT(τh,pTmiss) [GeV]

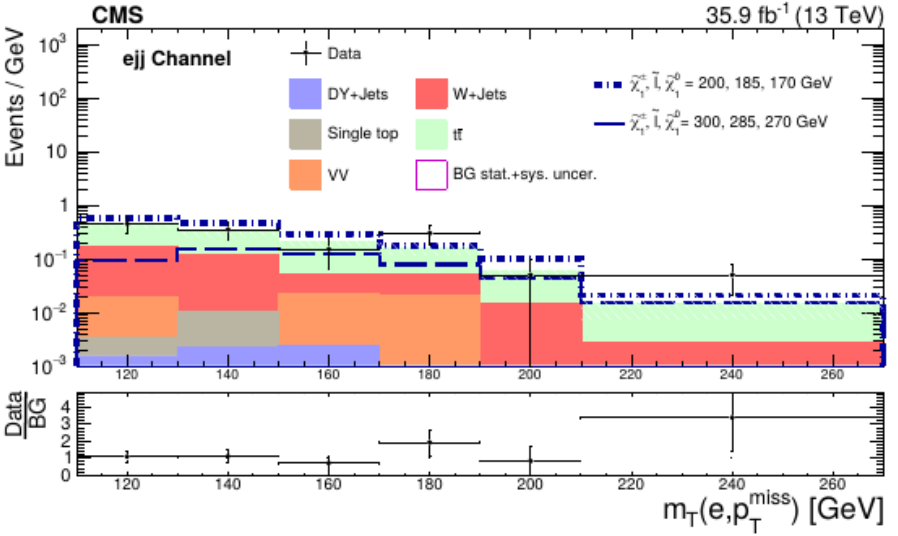

CMS
35.9 fb-1 (13 TeV)
Z→ inv CR
Data
Z+Jets
QCD
VV
W+Jets
Single top
tt̄
BG stat. uncer.
Events / GeV
Data/BG
mjj [GeV]

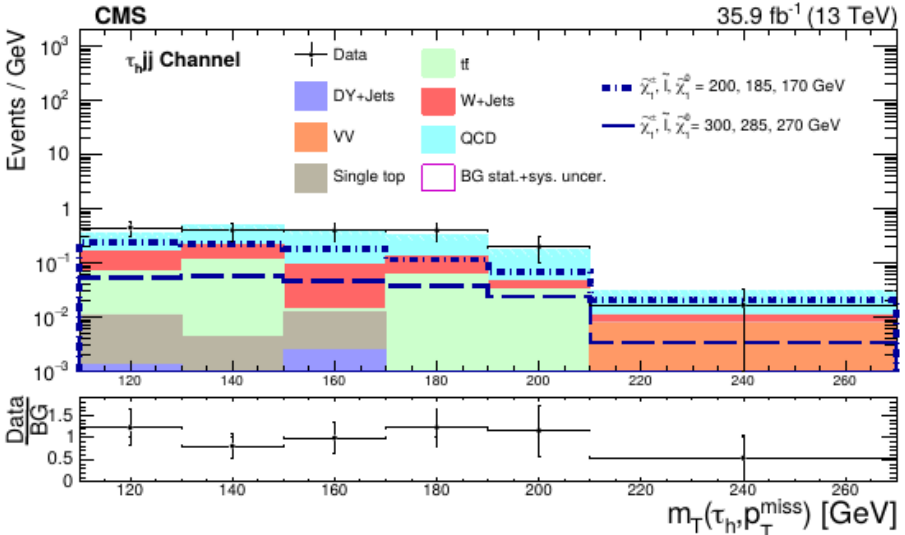
Systematic uncertainties

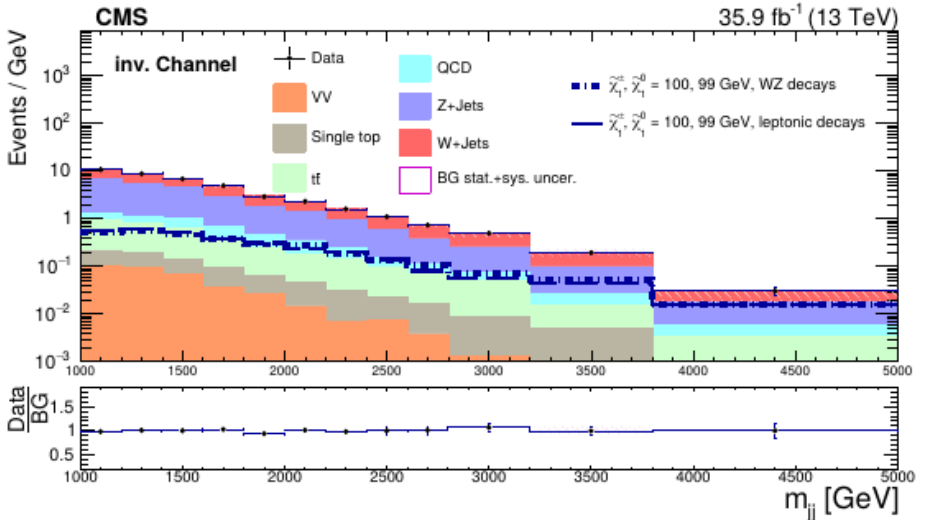
- Luminosity = 2.5%
- mu-e ID ~1-2 %
- tau-ID ~ 1-9%
- Trigger = 3%
- b-jets ID ~ 1-7%
- PDF ~ 4-7%
- CRs ~ 8-42%
- Shape systematics

Results

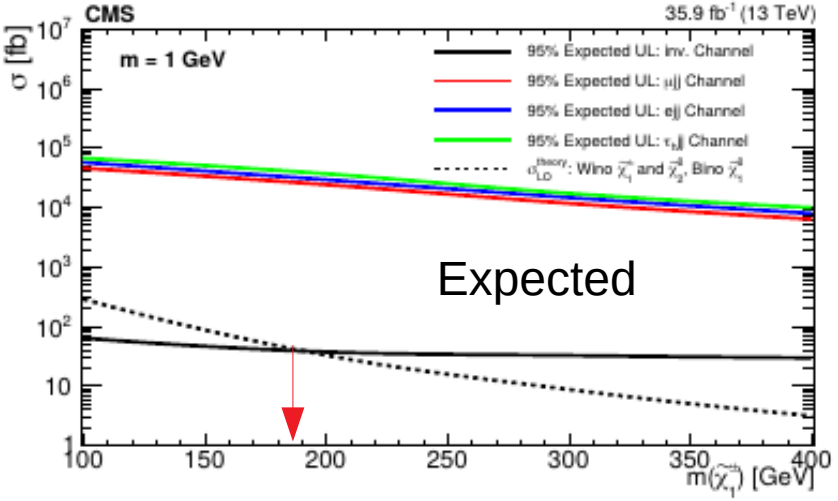

CMS
35.9 fb-1 (13 TeV)
μjj Channel
Data
DY+Jets
W+Jets
VV
tt
Single top
BG stat.+sys. uncer.
= 200, 185, 170 GeV
= 300, 285, 270 GeV
Events / GeV
Data/BG
mT(μ,pTmiss) [GeV]

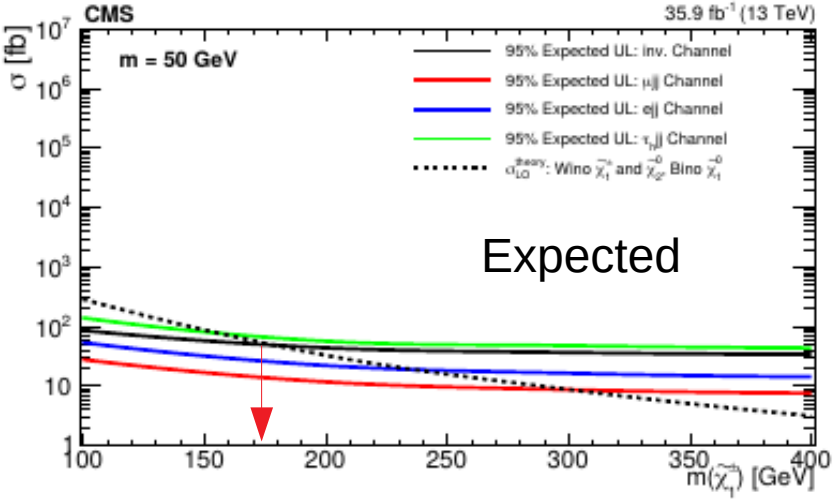

CMS
35.9 fb-1 (13 TeV)
ejj Channel
Data
DY+Jets
W+Jets
Single top
tt
VV
BG stat.+sys. uncer.
= 200, 185, 170 GeV
= 300, 285, 270 GeV
Events / GeV
Data/BG
mT(e,pTmiss) [GeV]

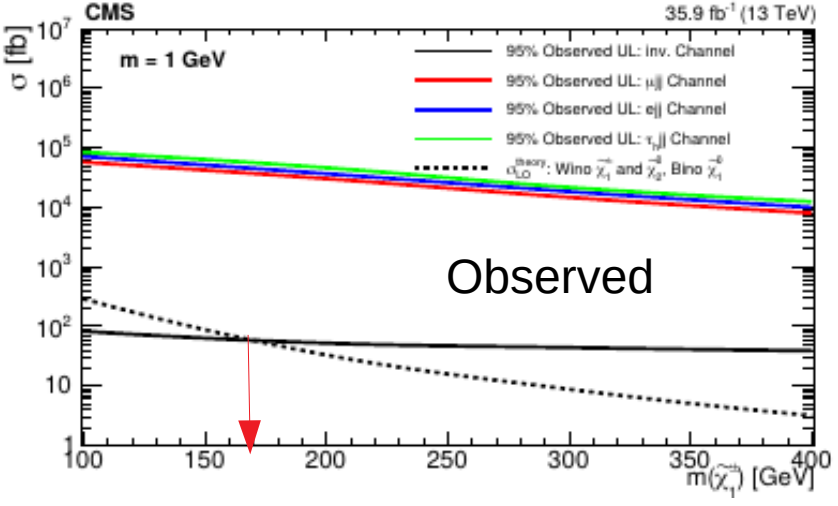

CMS
35.9 fb-1 (13 TeV)
τhjj Channel
Data
DY+Jets
VV
Single top
tt
W+Jets
QCD
BG stat.+sys. uncer.
= 200, 185, 170 GeV
= 300, 285, 270 GeV
Events / GeV
Data/BG
mT(τh,pTmiss) [GeV]

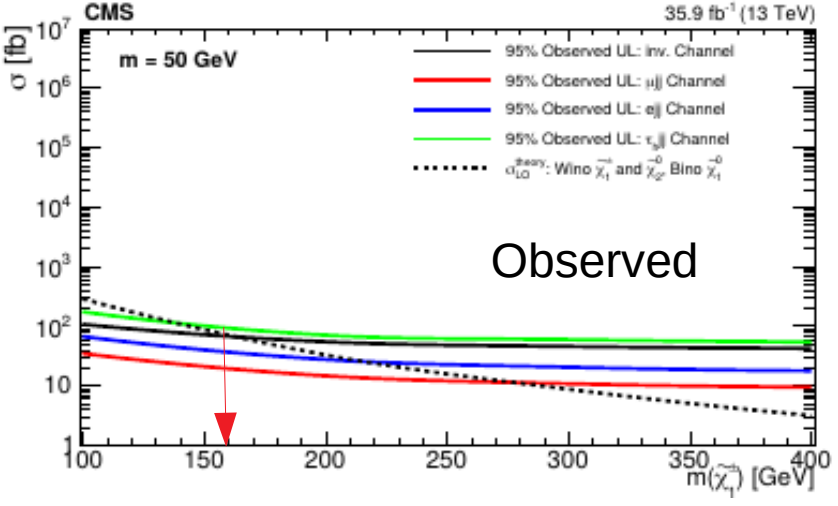

CMS
35.9 fb-1 (13 TeV)
inv. Channel
Data
VV
Single top
tt
QCD
Z+Jets
W+Jets
BG stat.+sys. uncer.
= 100, 99 GeV, WZ decays
= 100, 99 GeV, leptonic decays
Events / GeV
Data/BG
mjj [GeV]

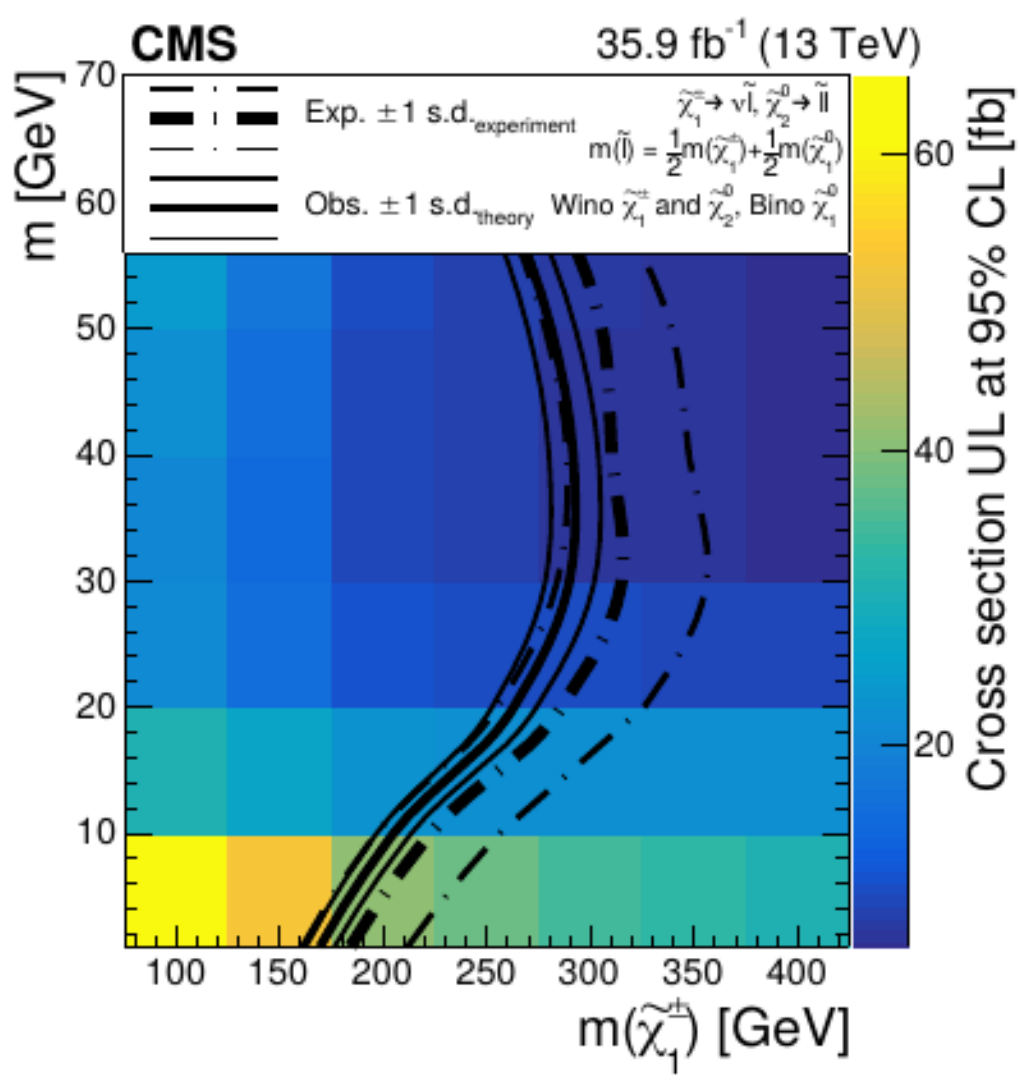
Interpretation

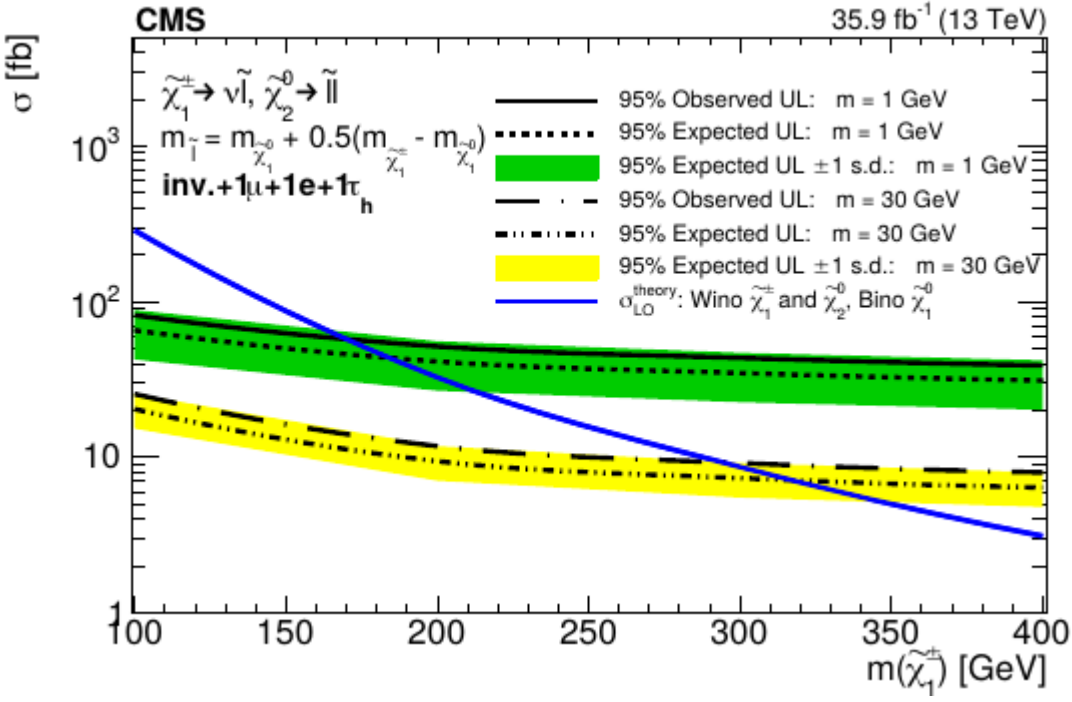


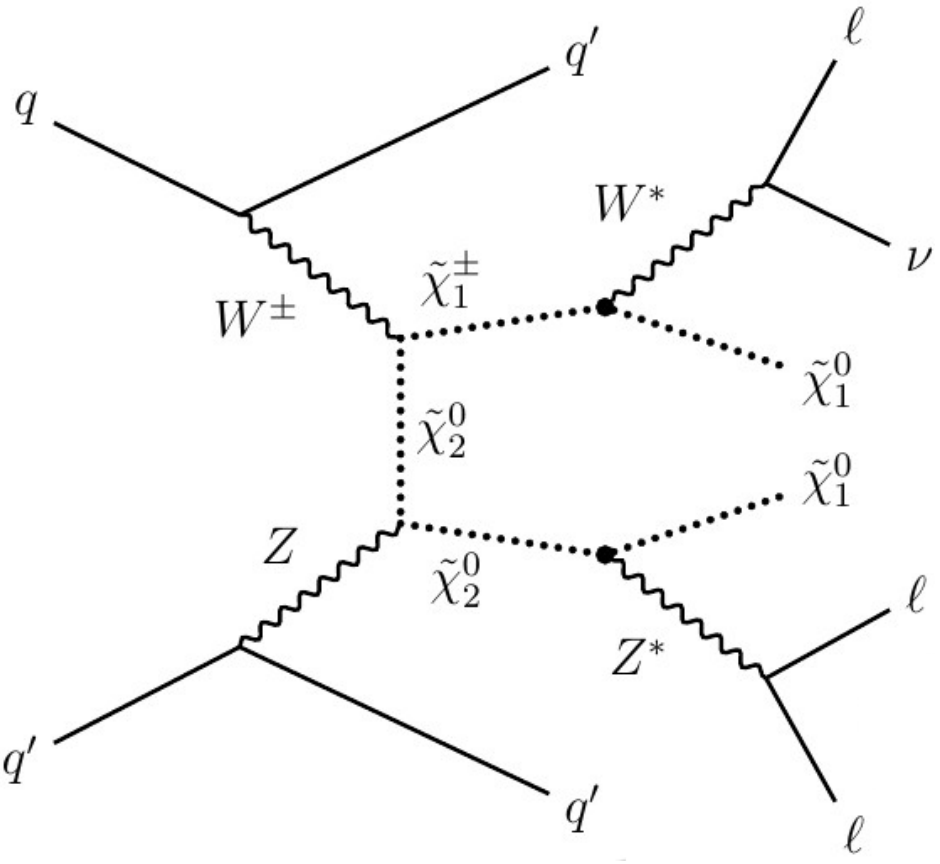


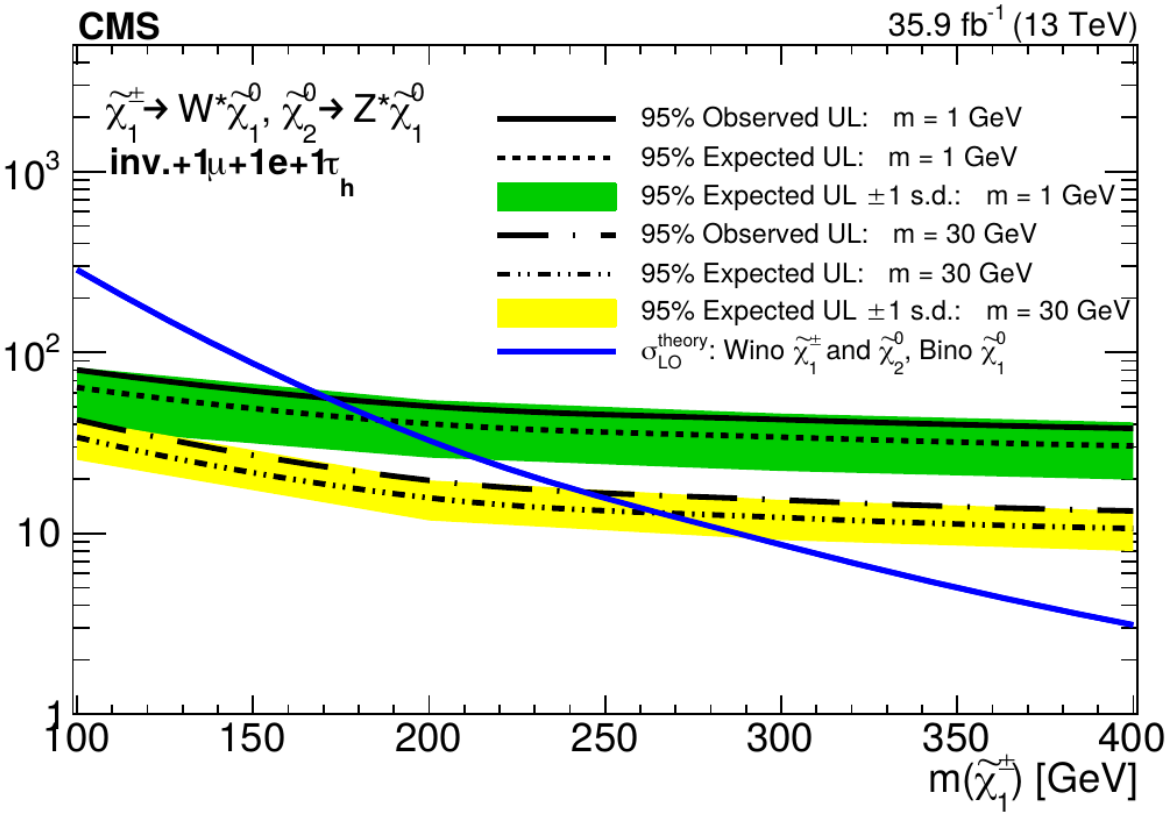





CMS
35.9 fb-1 (13 TeV)
Exp. ±1 s.d.experiment
Obs. ±1 s.d.theory
Wino and , Bino
m [GeV]
m(χ̃±1) [GeV]
Cross section UL at 95% CL [fb]


CMS
35.9 fb-1 (13 TeV)
inv.+1μ+1e+1τh
95% Observed UL: m = 1 GeV
95% Expected UL: m = 1 GeV
95% Expected UL ±1 s.d.: m = 1 GeV
95% Observed UL: m = 30 GeV
95% Expected UL: m = 30 GeV
95% Expected UL ±1 s.d.: m = 30 GeV
σ [fb]
m(χ̃±1) [GeV]


q
q'
$W^{\pm}$
$\tilde{\chi}_1^{\pm}$
W^*
ℓ
ν
$\tilde{\chi}_1^0$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^0$
Z
$\tilde{\chi}_2^0$
Z^*
ℓ
q'
q'
ℓ


CMS
35.9 fb^{-1} (13 TeV)
$\tilde{\chi}_1^{\pm} \rightarrow W^* \tilde{\chi}_1^0$, $\tilde{\chi}_2^0 \rightarrow Z^* \tilde{\chi}_1^0$
inv.+1μ+1e+1τ$_h$
95% Observed UL: m = 1 GeV
95% Expected UL: m = 1 GeV
95% Expected UL ±1 s.d.: m = 1 GeV
95% Observed UL: m = 30 GeV
95% Expected UL: m = 30 GeV
95% Expected UL ±1 s.d.: m = 30 GeV
σ_{LO}^{theory}: Wino $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$, Bino $\tilde{\chi}_1^0$
10^3
10^2
10
1
100
150
200
250
300
350
400
m($\tilde{\chi}_1^{\pm}$) [GeV]

Summary and conclusions

- A new search for SUSY signals has been performed using 35.9 fb^{-1} integrated luminosity of data collected by CMS experiment from pp collisions from the LHC
- Results show no deviation from the SM expectations
- This new results have closed one of the possible windows for SUSY in the compressed spectra regime
- 2-leptons and 3-leptons final states possible → For the future!
- Keep tuned! Keep looking!