# Search for electroweak SUSY production at CMS

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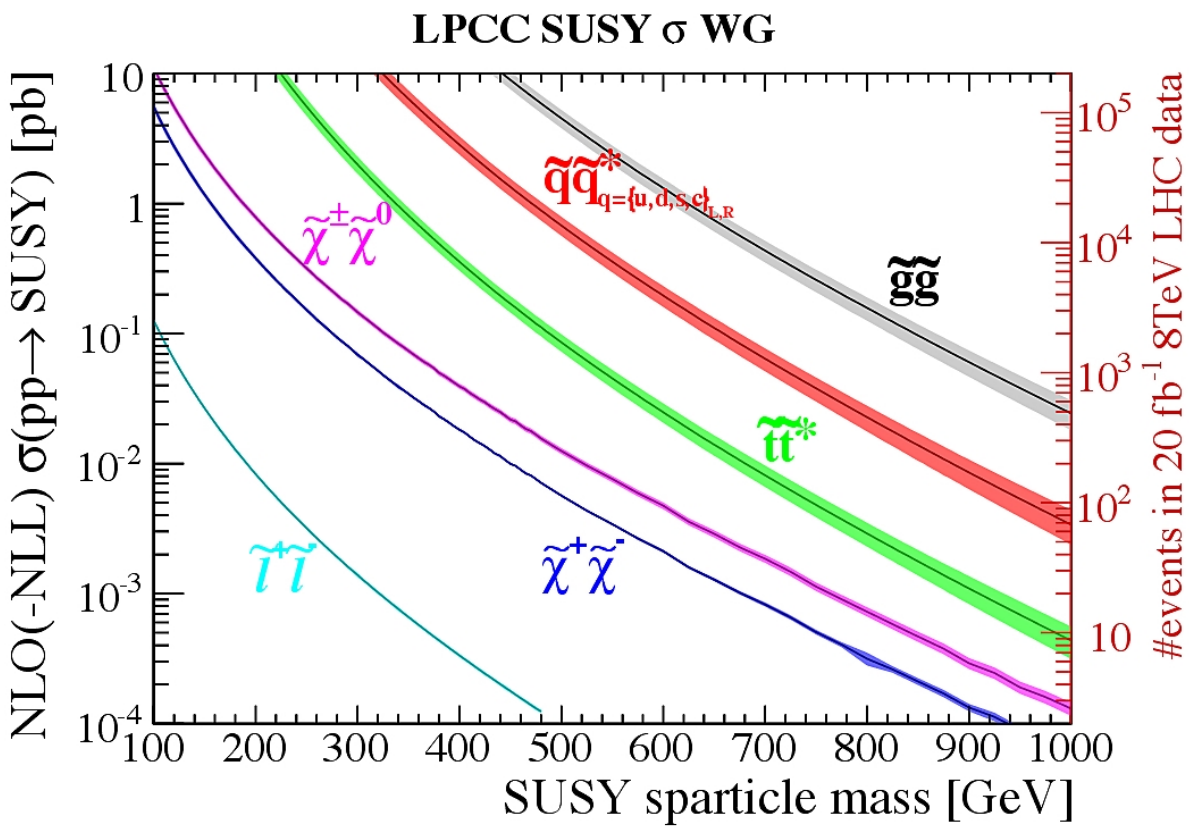
on behalf of the CMS collaboration

LHCP 2015
St. Petersburg, Russia

# What is this talk about




https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections arXiv:1206.2892

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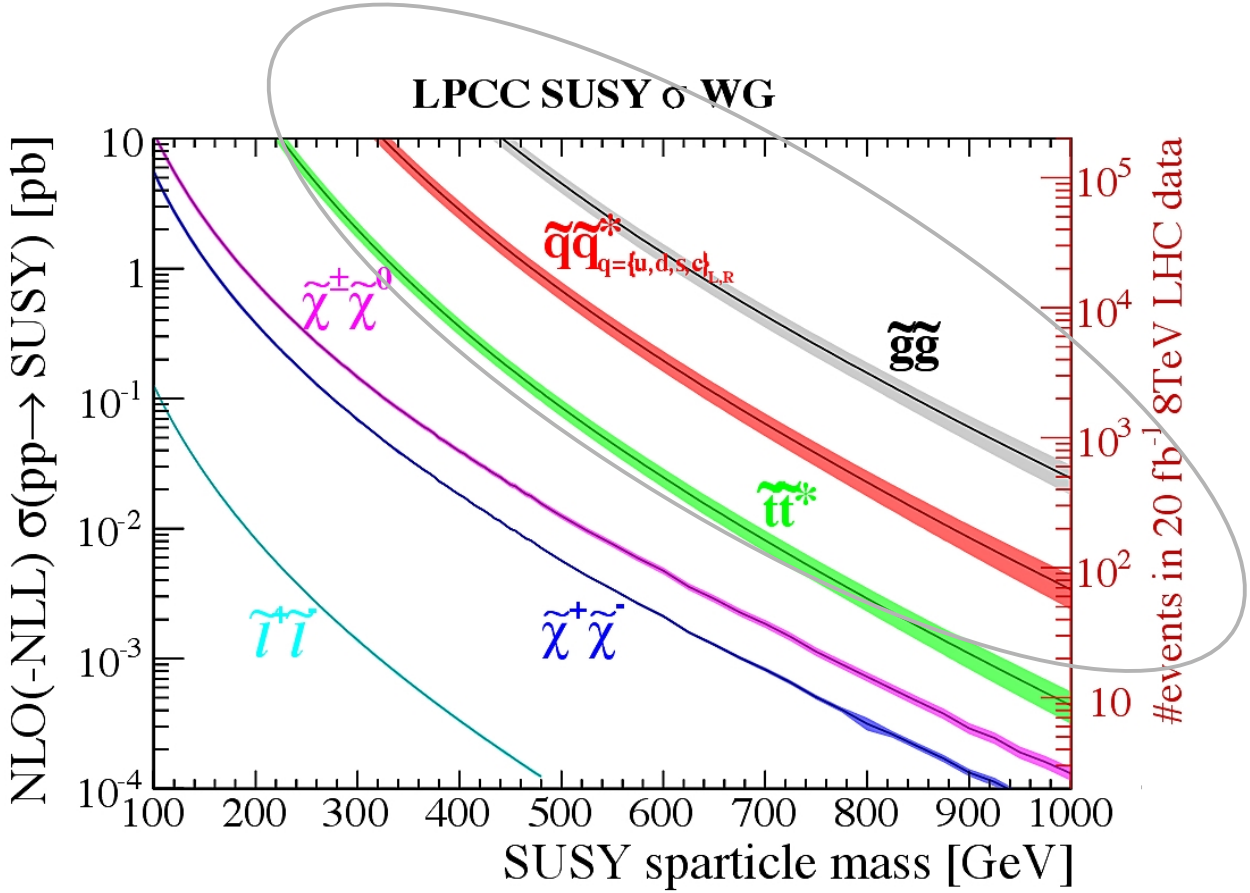


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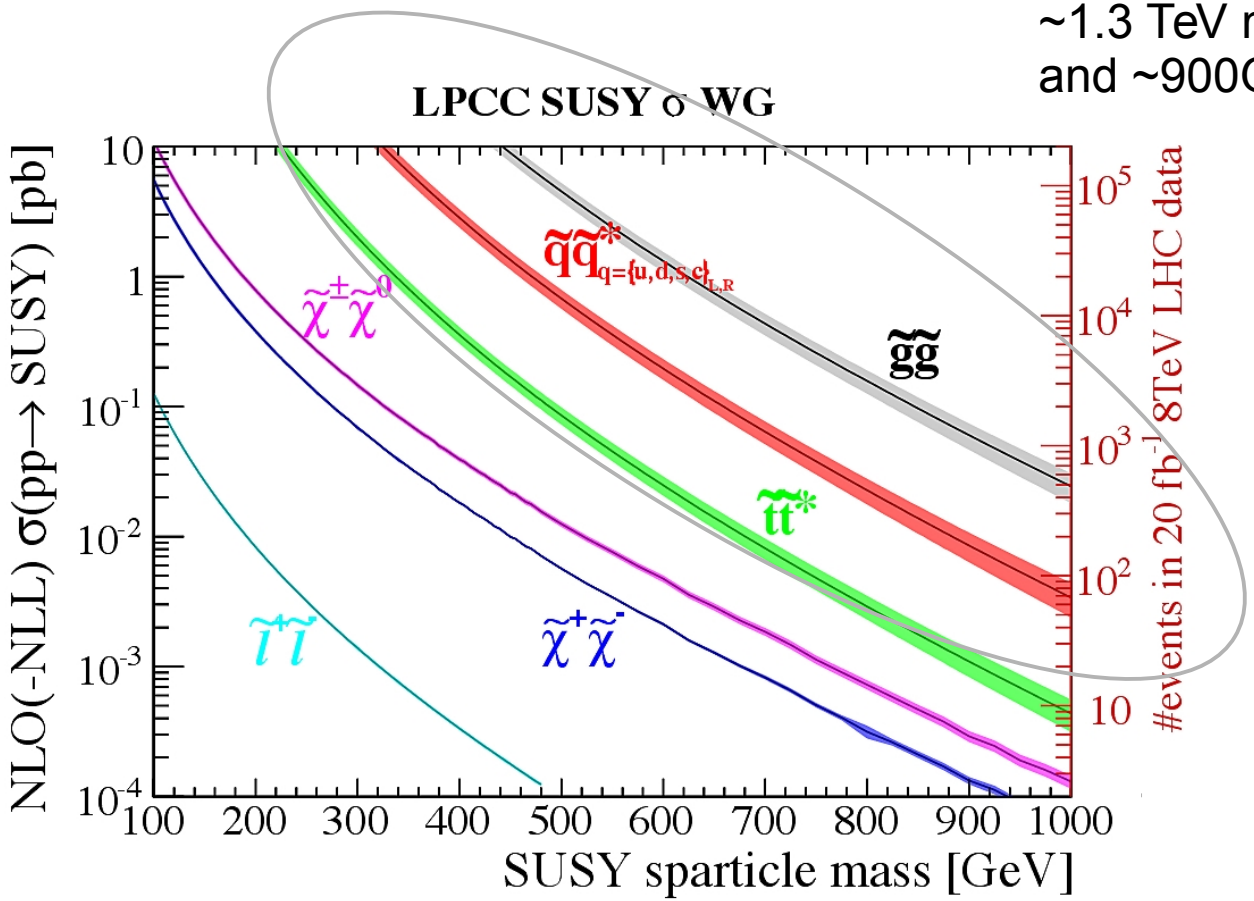
# What is this talk about

Nothing observed up to ~1.3 TeV masses for gluino and ~900GeV for squarks




https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections arXiv:1206.2892

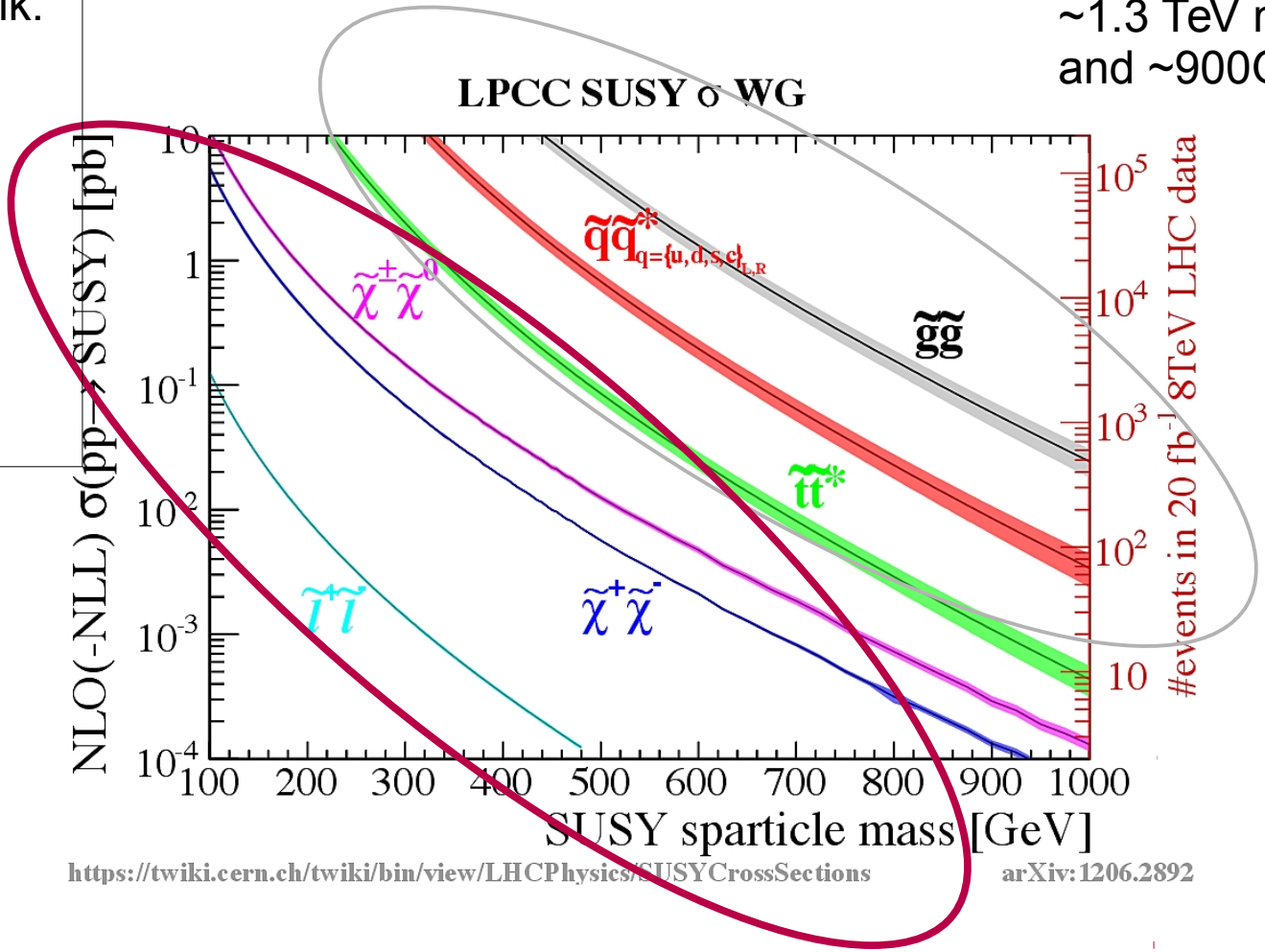
# What is this talk about

Subject of this talk:

[very] Low cross sections

Clear Signatures

Nothing observed up to ~1.3 TeV masses for gluino and ~900GeV for squarks



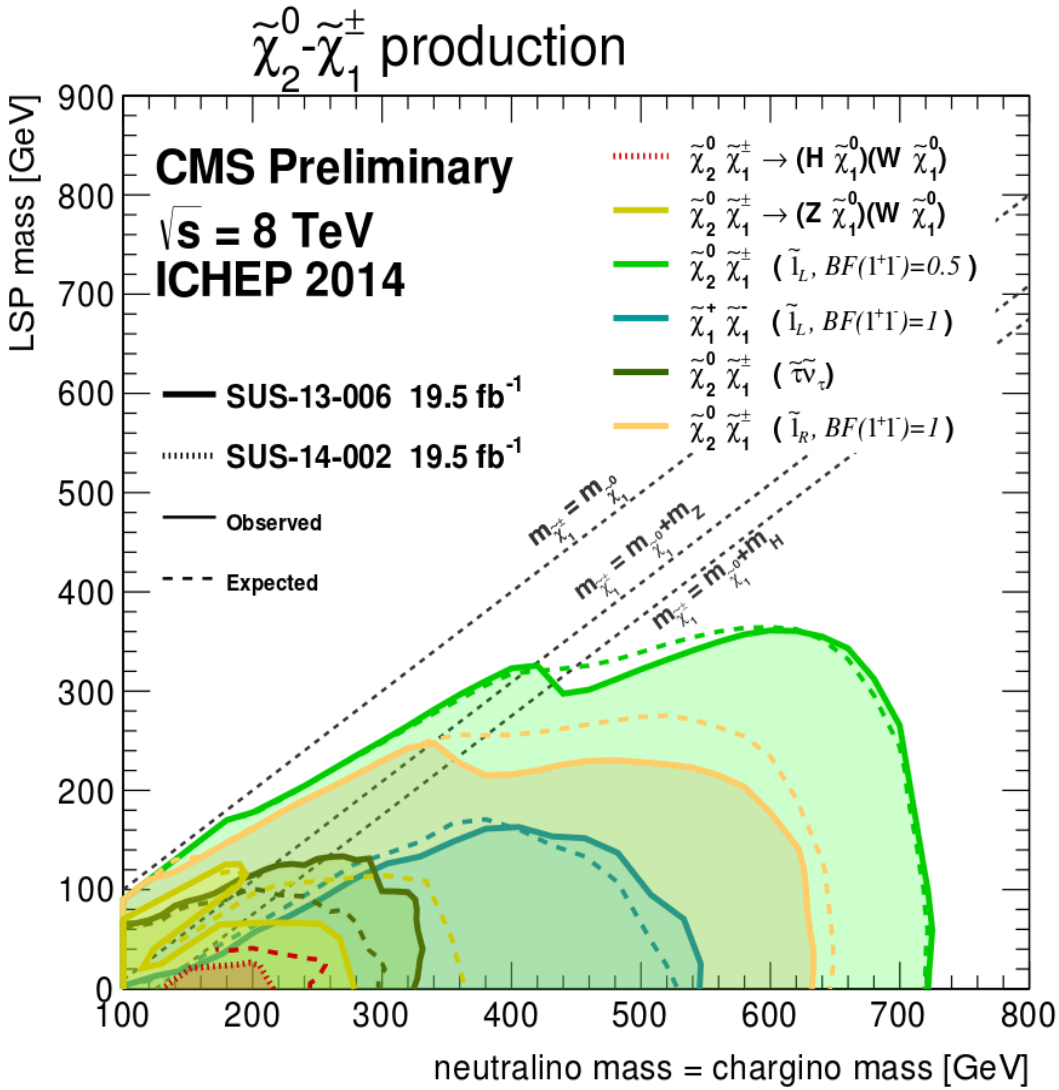
# Bibliography

- **Eur. Phys. J. C 74 (2014) 3036** : Searches for electroweak production of charginos, neutralinos, and sleptons decaying to leptons and W, Z, and Higgs bosons in pp collisions at 8 TeV
- **Phys. Rev. D 90 (2014) 092007** : Searches for electroweak neutralino and chargino production in channels with Higgs, Z, and W bosons in pp collisions at 8 TeV
- **CMS-SUS-14-005** : Search for electroweak SUSY production in VBF production

# *Chargino-Neutralino production*

# Early Summary

- **Eur. Phys. J. C 74 (2014) 3036**




Chargino-Neutralino production has the largest cross section

Limits on chargino mass up to ~700 GeV

# Early Summary

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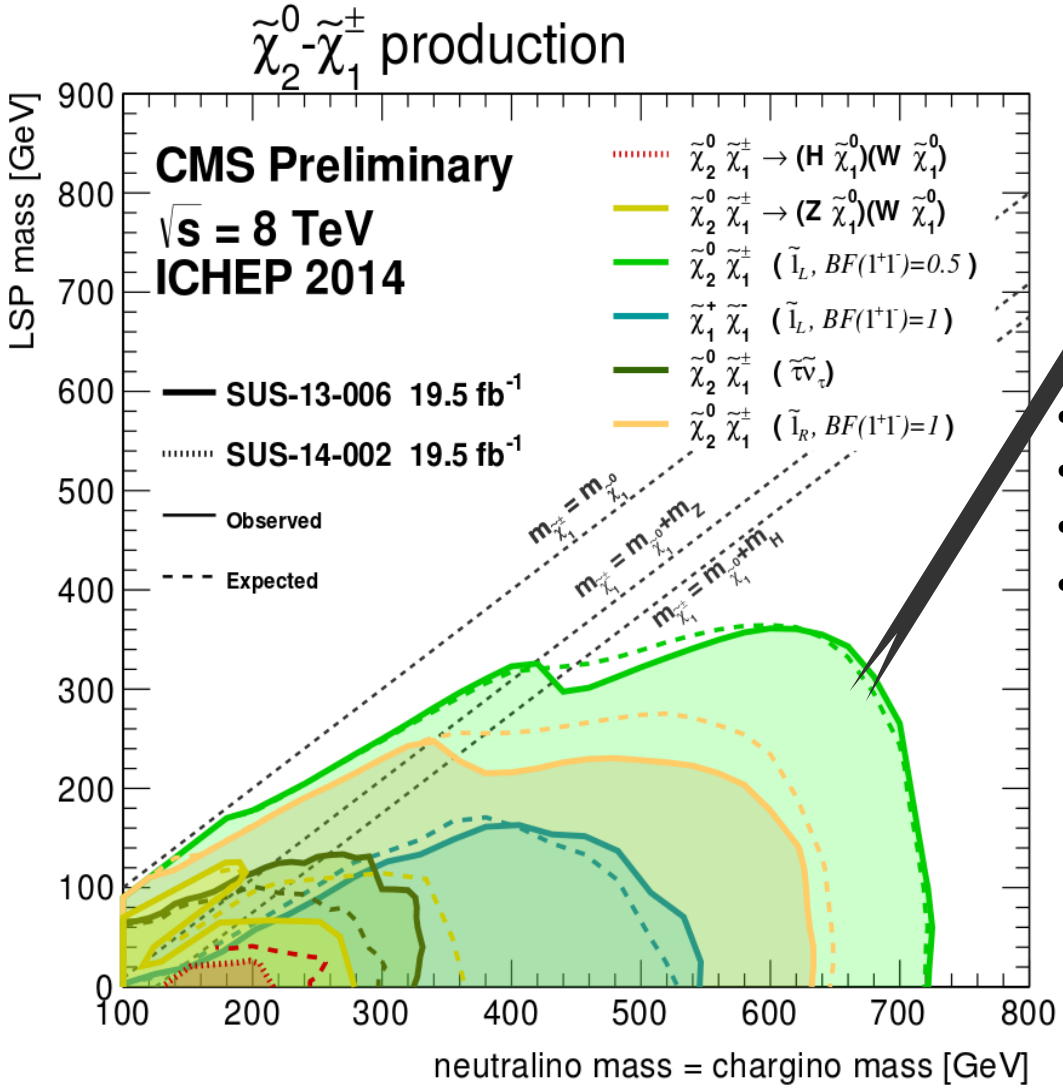
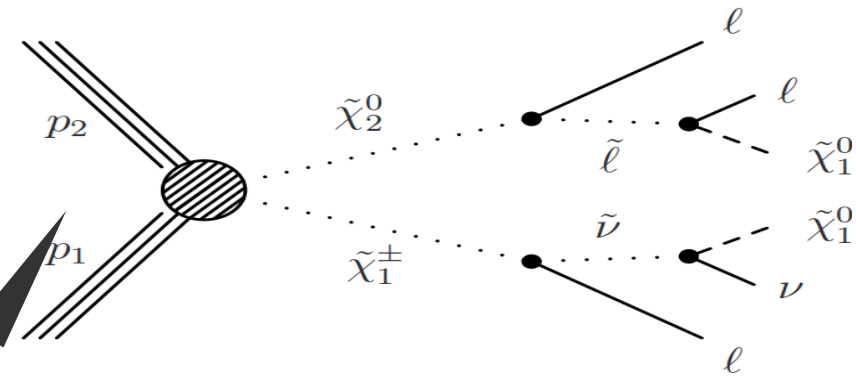
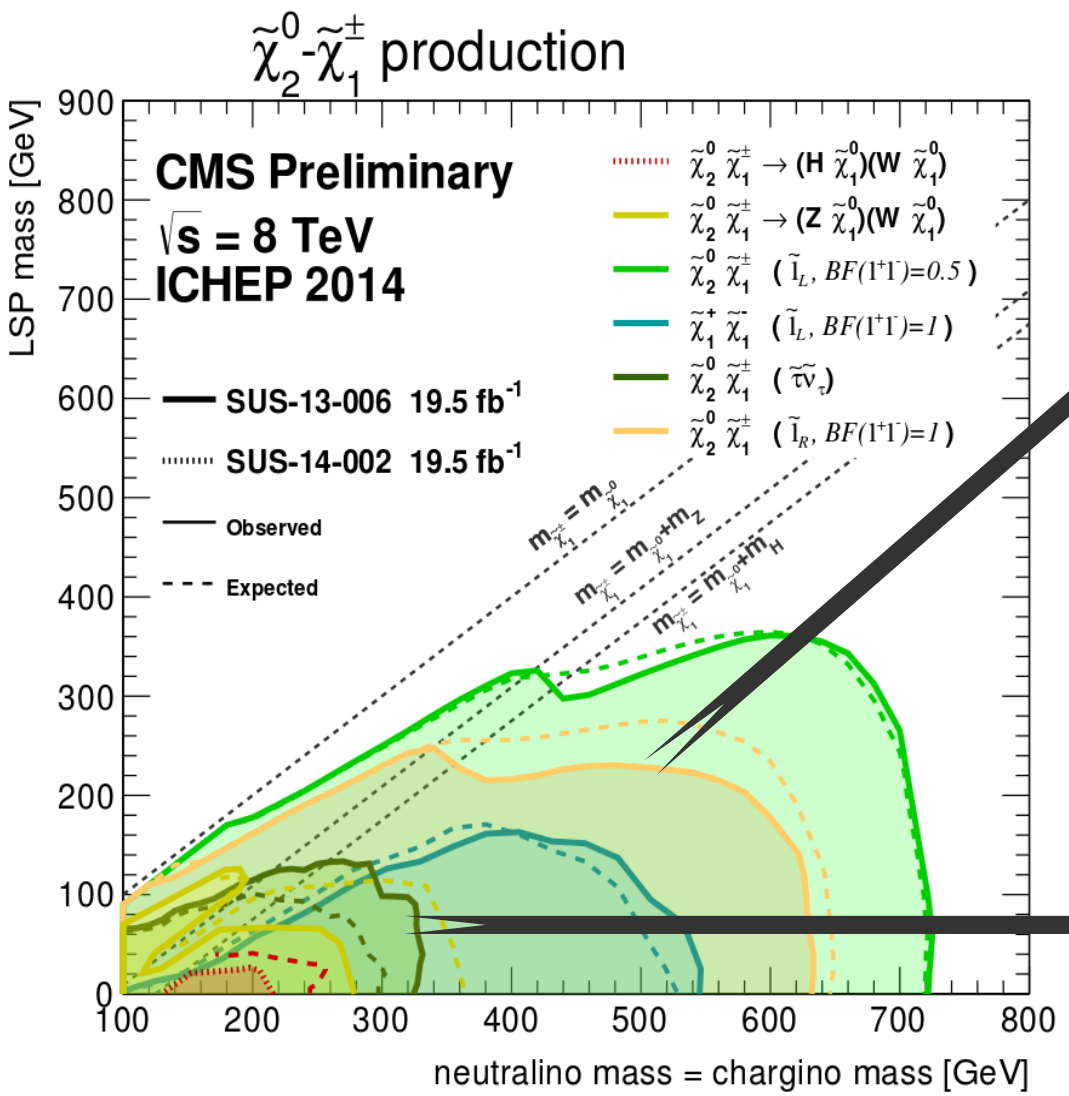


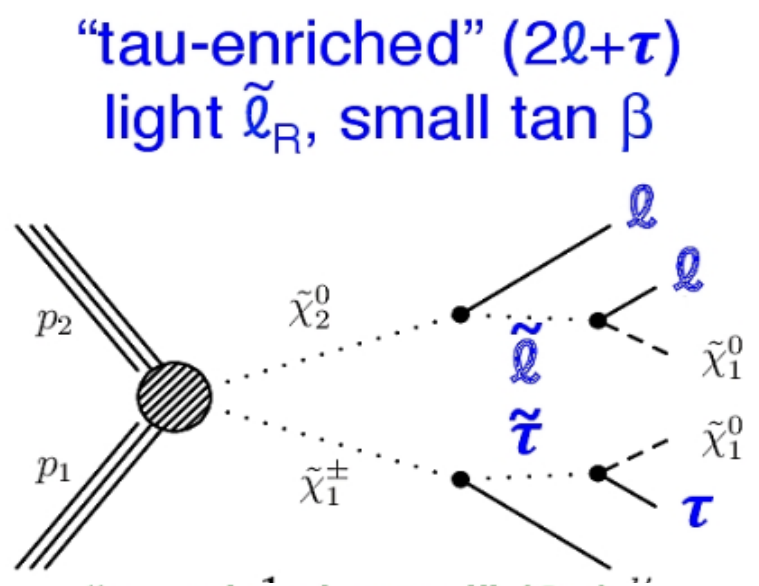



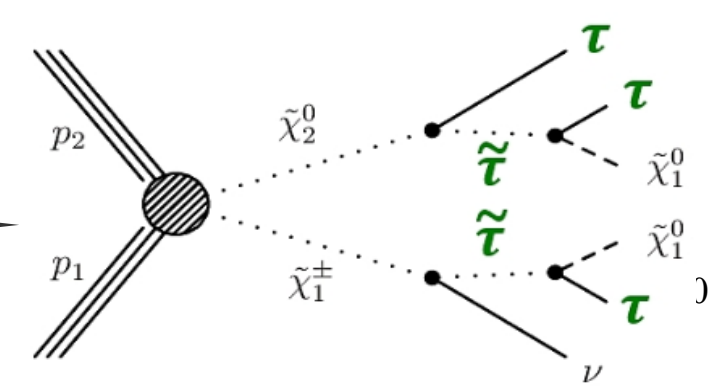

- 3leptons + MET
- Flavor democratic decay of SUSY parents
- b-veto (Suppress ttbar)
- Main Backgrounds
  - WZ : MC (with data-driven MET correction)
  - ttbar+fake : data-driven fake rate method

# Early Summary

- **Eur. Phys. J. C 74 (2014) 3036**



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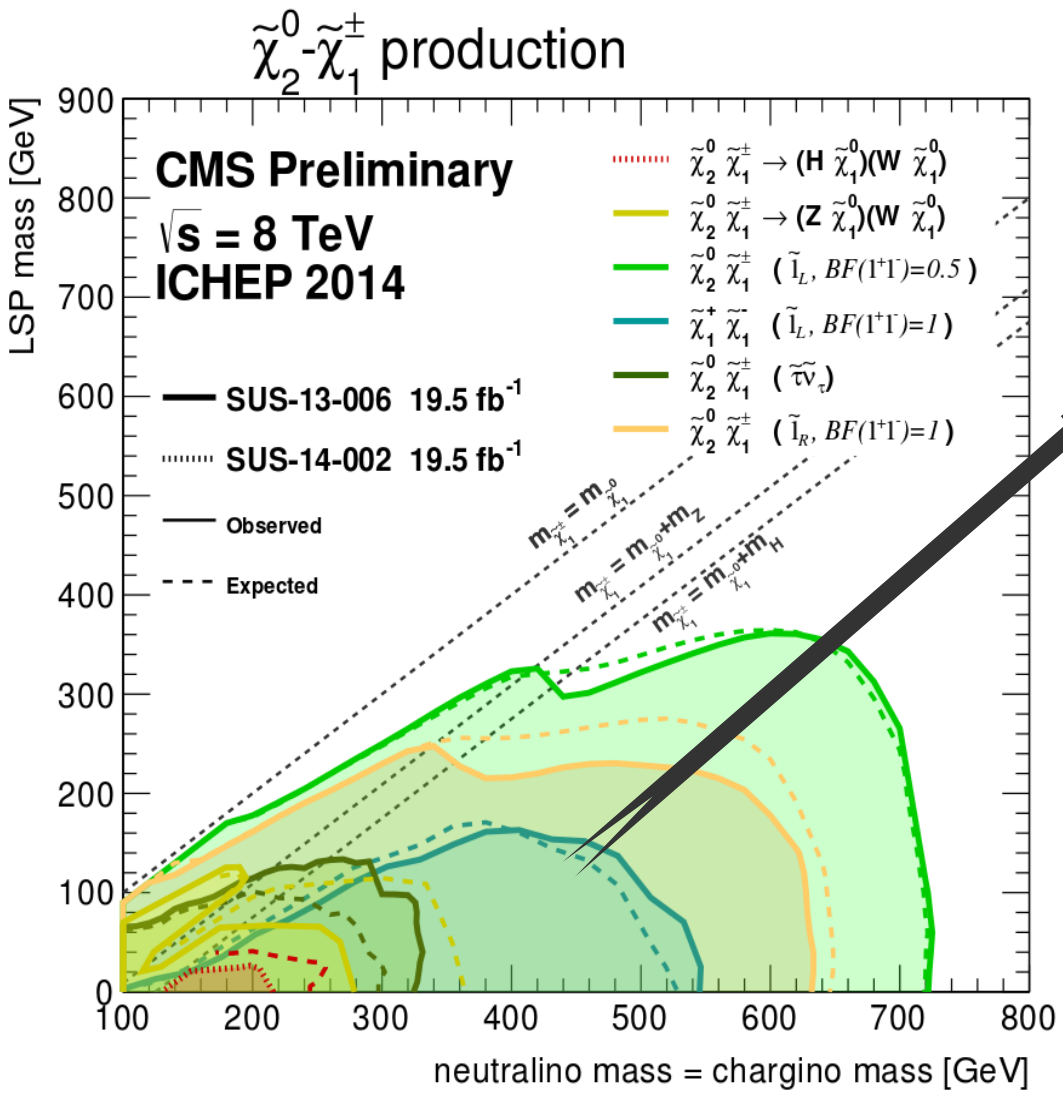
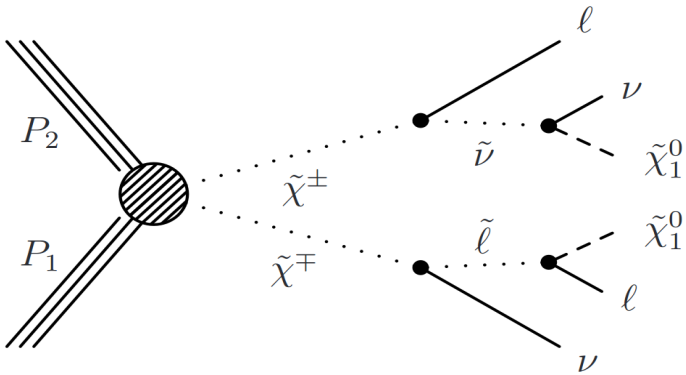
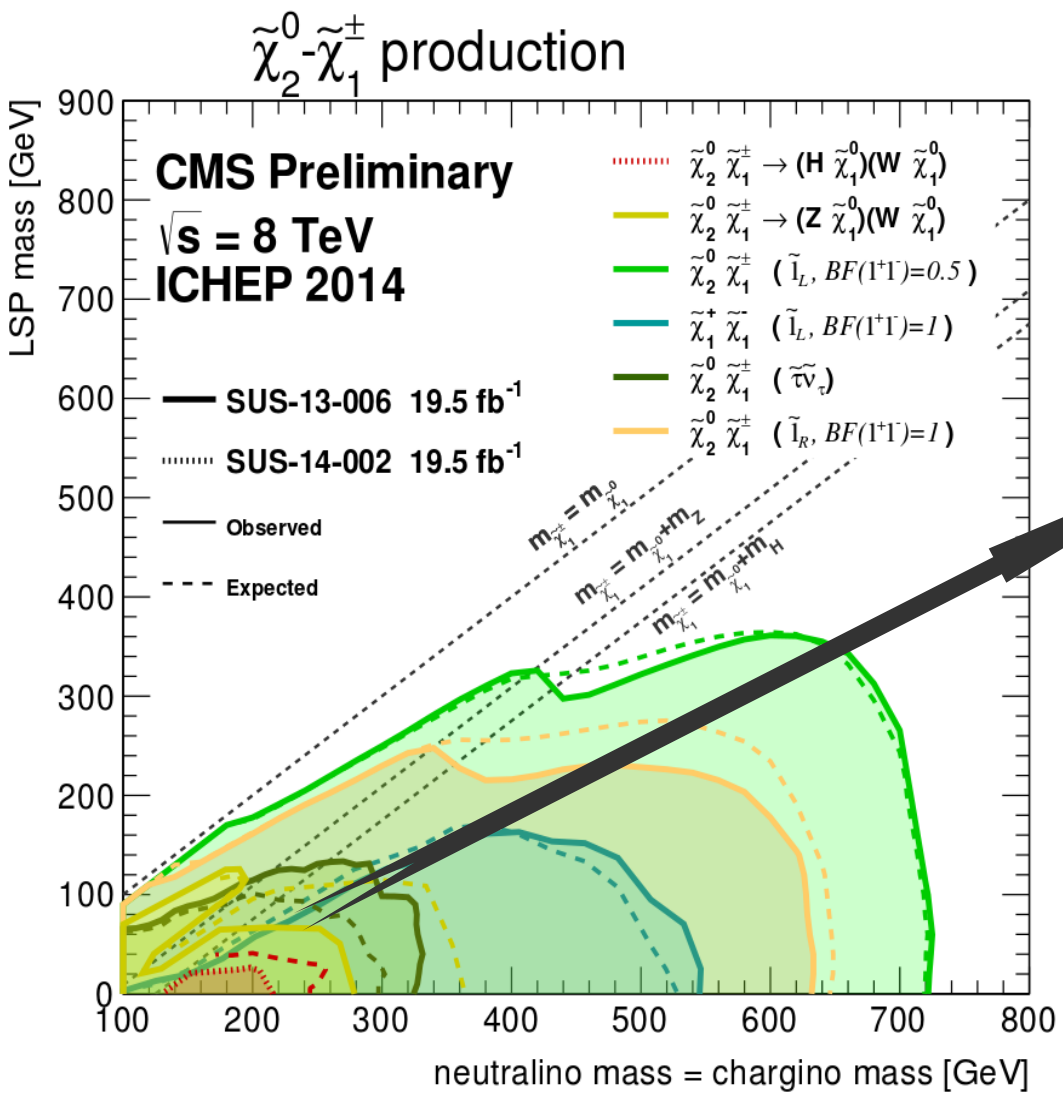


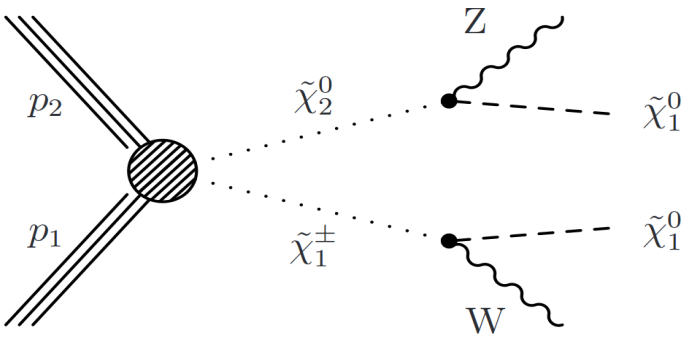




- Event Selection
  - 2 high Pt OS e/mu leptons with Z-veto
  - b-veto, moderate MET cut
- $M_{CT\perp}$:Kinematic Reconstruction
  - Separate WW backgrounds
  - Fitted using data driven templates and MC
  - Data agrees well with prediction

# Early Summary

- **Eur. Phys. J. C 74 (2014) 3036**

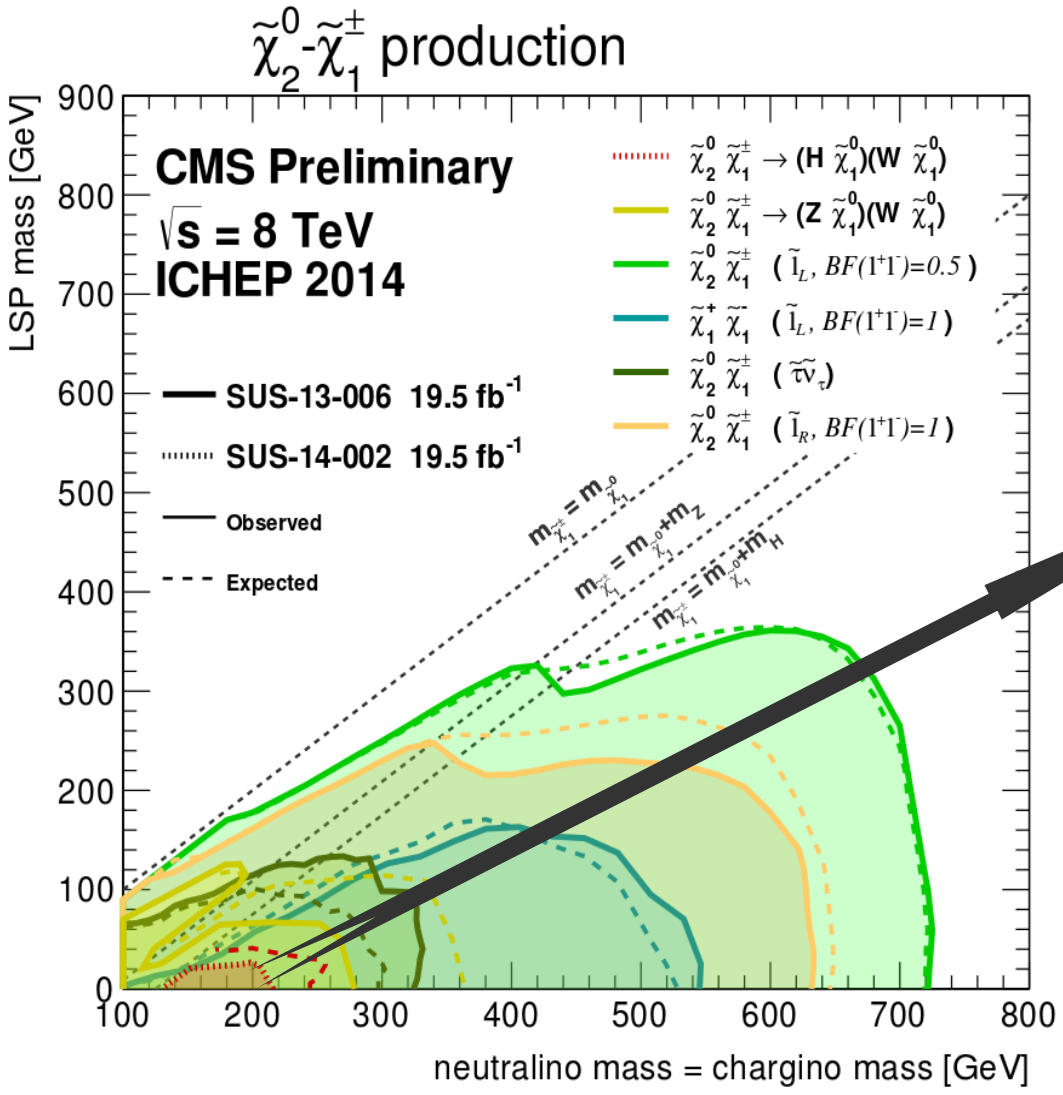


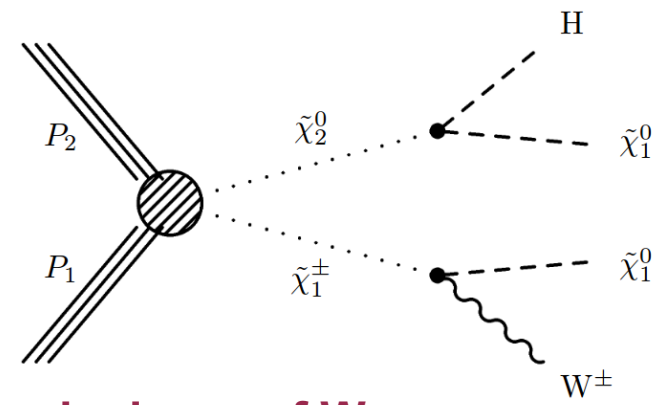




- Event Selection
  - Z → ll candidate
  - MET > 80 GeV
  - 2Jets with Mjj ~ W/Z mass
  - b-veto (to supress ttbar)
- Backgrounds
  - Z+Jets : Fake MET is modeled using photon+jets events
  - ttbar : estimated using e/mu control sample
- Categorizing events based on the ll inv.mass , MET and transverse mass

# Early Summary

- **Eur. Phys. J. C 74 (2014) 3036**



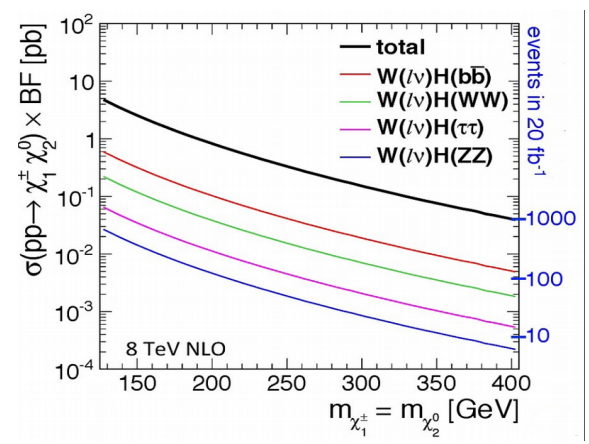




**Leptonic decay of W**
**Higgs decay :**

- **bb, W(lnu)W(jj), WW/tautau/ZZ**

**Decay to Gamma is studied in (Phys. Rev. D 90 (2014) 092007)**

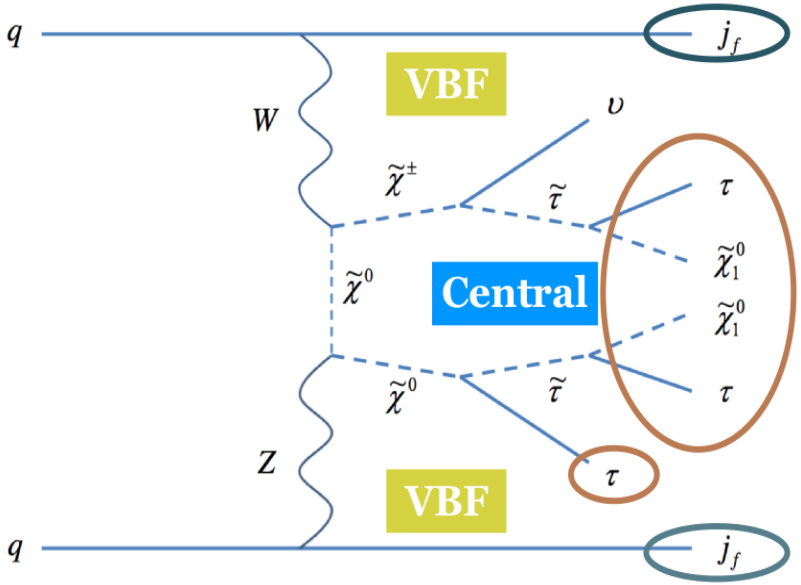
**1Lepton, SS Leptons, > 2 leptons**



# *Vector Boson Fusion production*

*Will be published soon (CMS-SUS-14-005)*

# Searches via VBF process with ≥ 2 leptons




8 channels are studied:
eμjj, μμjj, μ$\tau_h$jj , $\tau_h\tau_h$ jj
(opposite sign and same sign leptons).

Vector Boson Fusion Selection :

- ≥ 2 jets with p T > 30 GeV "Loose" ( or 50 GeV "Tight") with |η| < 5.0
- |Δη(j,j)| > 4.2 , η1*η2 < 0
- m(jj) > 250 GeV (shape based analysis)

**Helps a lot in reducing SM backgrounds (1%-0.01%)**

Central Selection :
Single Muon trigger and di-tau triggers are used

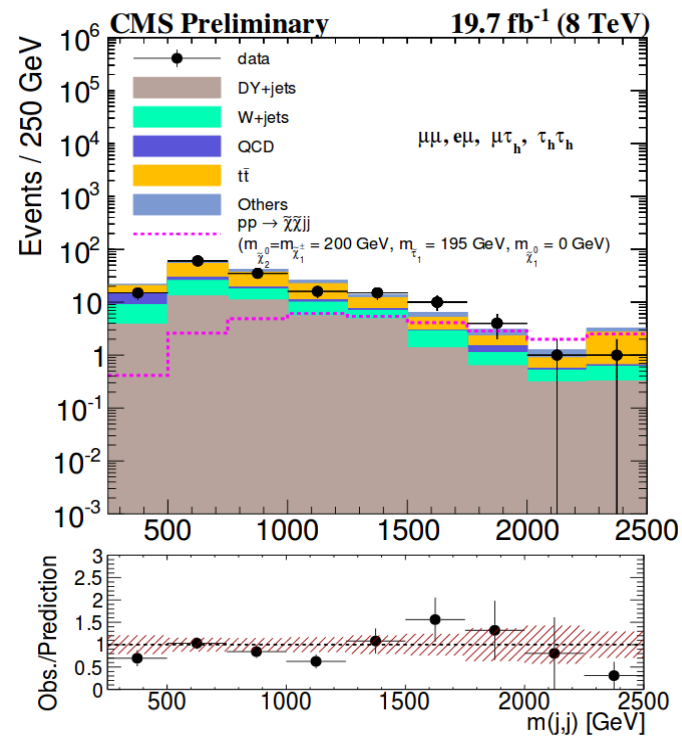
- 2 isolated leptons with |η| < 2.1, dR(l1,l2) > 0.3
- MET > 75 GeV ( > 30 for di hadronic tau channel)
- No b-jets

# Searches via VBF process with ≥ 2 leptons

Event yields in **OS** and **SS** selections

| Process | $\mu^\pm\mu^\mp jj$ | $e^\pm\mu^\mp jj$ | $\mu^\pm\tau_h^\mp jj$ | $\tau_h^\pm\tau_h^\mp jj$ |
|---|---|---|---|---|
| DY + jets | $4.3 \pm 1.7$ | $3.7\pm^{2.1}_{1.9}$ | $19.9 \pm 2.9$ | $12.3 \pm 4.4$ |
| W + jets | $< 0.01$ | $4.2\pm^{3.3}_{2.5}$ | $17.3 \pm 3.0$ | $2.0 \pm 1.7$ |
| VV | $2.8 \pm 0.5$ | $3.1 \pm 0.7$ | $2.9 \pm 0.5$ | $0.5 \pm 0.2$ |
| $t\bar{t}$ | $24.0 \pm 1.7$ | $19.0\pm^{2.3}_{2.4}$ | $11.7 \pm 2.8$ | – |
| QCD | – | – | – | $6.3 \pm 1.8$ |
| Higgs | $1.0 \pm 0.1$ | $1.1 \pm 0.5$ | – | $1.1 \pm 0.1$ |
| VBF Z | – | – | – | $0.7 \pm 0.2$ |
| Total | $32.2 \pm 2.4$ | $31.1\pm^{4.6}_{4.1}$ | $51.8 \pm 5.1$ | $22.9 \pm 5.1$ |
| Observed | 31 | 22 | 41 | 31 |

| Process | $\mu^\pm\mu^\pm jj$ | $e^\pm\mu^\pm jj$ | $\mu^\pm\tau_h^\pm jj$ | $\tau_h^\pm\tau_h^\pm jj$ |
|---|---|---|---|---|
| DY + jets | $< 0.01$ | $0\pm^{1.7}_{0}$ | $0.5 \pm 0.2$ | $< 0.01$ |
| W + jets | $0.1 \pm 8.2 \times 10^{-4}$ | $0\pm^{3.0}_{0}$ | $9.3 \pm 2.3$ | $0.5 \pm 0.1$ |
| VV | $2.1 \pm 0.3$ | $1.9\pm^{0.4}_{0.2}$ | $1.1 \pm 0.2$ | $0.1 \pm 6.5 \times 10^{-2}$ |
| $t\bar{t}$ | $3.1 \pm 0.1$ | $3.5\pm^{0.7}_{0.9}$ | $6.7 \pm 2.8$ | $0.1 \pm 1.2 \times 10^{-2}$ |
| Single top | – | – | – | $< 0.1$ |
| QCD | – | – | – | $7.6 \pm 0.9$ |
| Higgs | – | – | – | $< 0.01$ |
| Total | $5.4 \pm 0.3$ | $5.4\pm^{3.5}_{0.9}$ | $17.6 \pm 3.8$ | $8.4 \pm 0.9$ |
| Observed | 4 | 5 | 14 | 9 |



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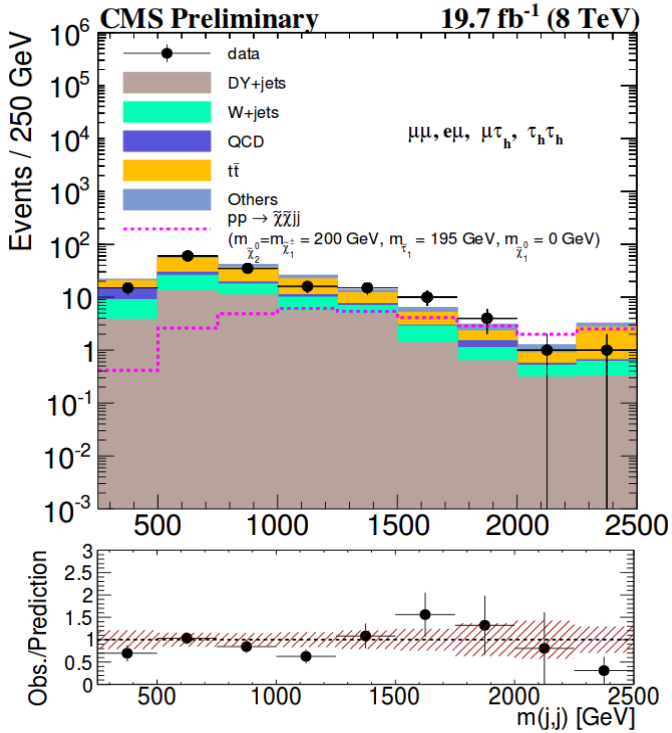
Backgrounds are :
ttbar , V+jets, QCD multijets and VV

BG in Signal Region are estimated from data using :

$$N_{BG}^{Data} = N_{BG}^{MC}(\text{central}) \cdot SF_{\text{central}}^{CR1} \cdot \epsilon_{VBF}^{CR2}(m_{jj})$$



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| Single top | – | – | – | $< 0.1$ |
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Backgrounds are :
ttbar , V+jets, QCD multijets and VV

BG in Signal Region are estimated from data using :

$$N_{BG}^{Data} = N_{BG}^{MC}(\text{central}) \cdot SF_{\text{central}}^{CR1} \cdot \epsilon_{VBF}^{CR2}(m_{jj})$$

**N : Predicted rate in simulation without VBF selection**

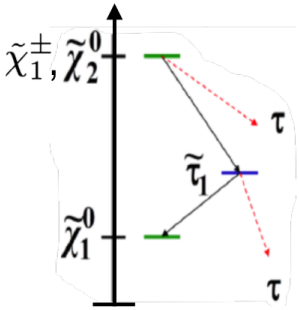
**SF : data to simulation corrections**

**E : VBF efficiency as a function of mjj, from data**

# VBF Result interpretation

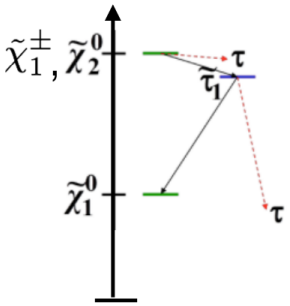
*Scenario 1*

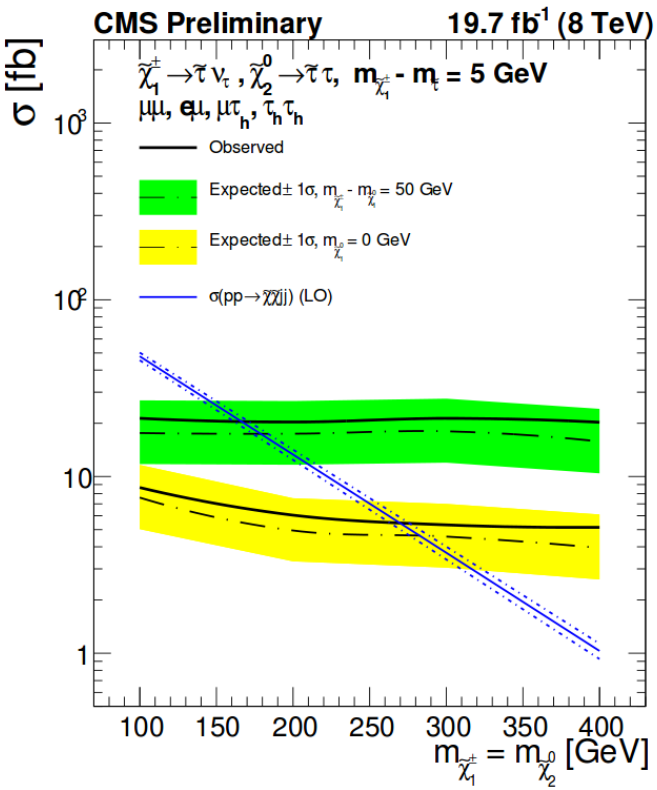
$$m(\tilde{l}) = \frac{1}{2}m(\tilde{\chi}_1^0) + \frac{1}{2}m(\tilde{\chi}_1^\pm)$$

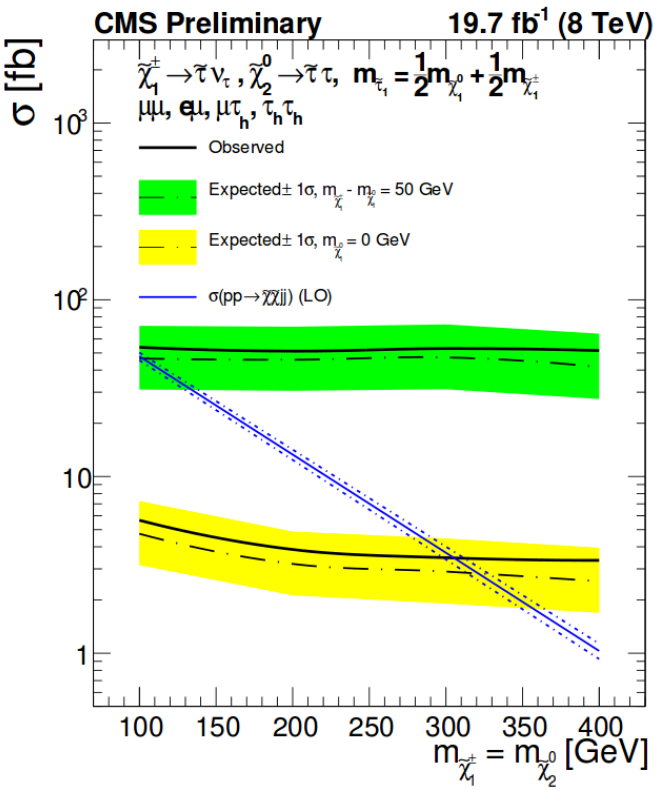



*Scenario 2*

$$m(\tilde{\chi}_1^\pm) - m(\tilde{l}) = 5GeV$$



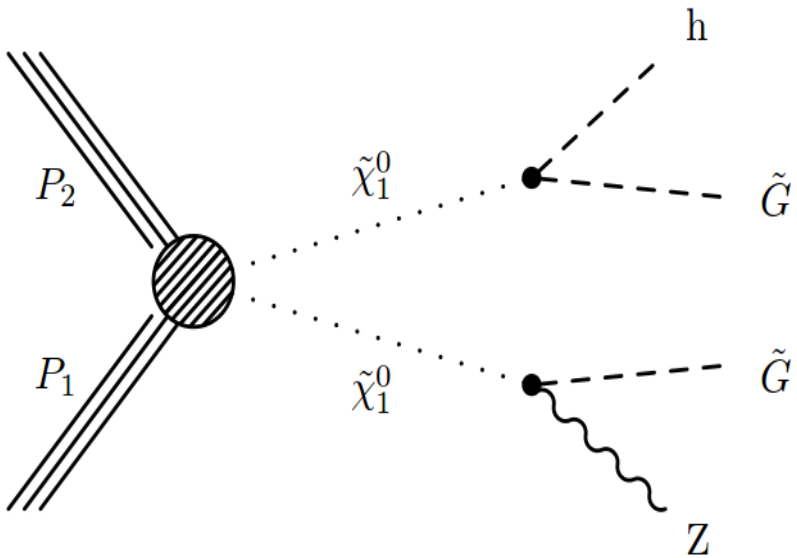



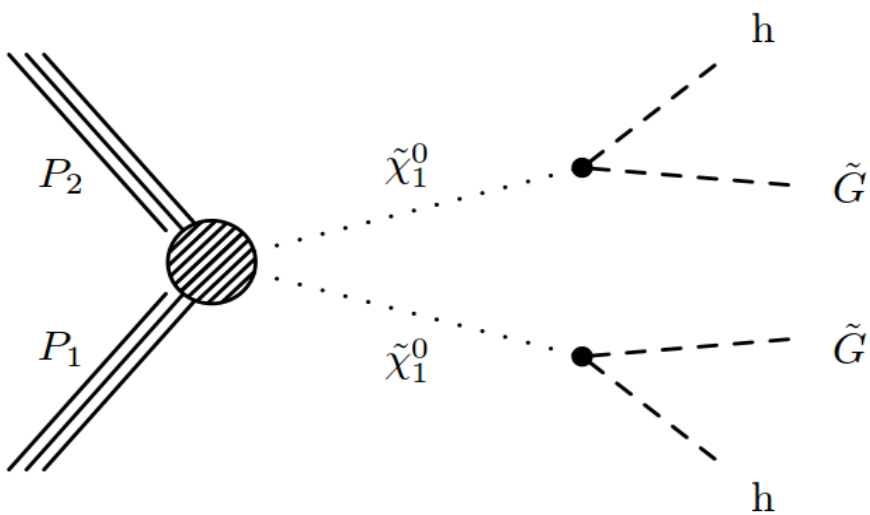
# Neutralino-Neutralino

*Phys. Rev. D 90 (2014) 092007*

# Neutralino-Neutralino decay modes



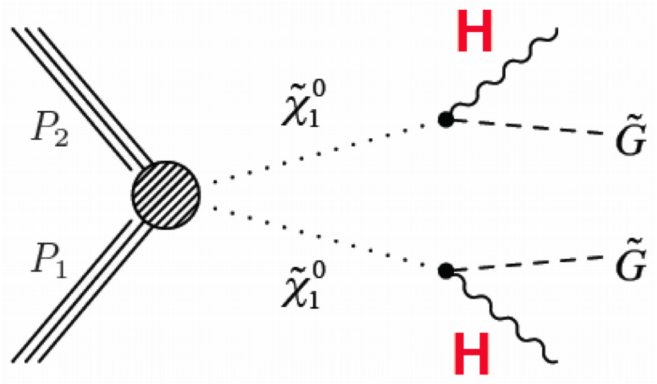

- Gamma-gamma, jj
- Gamma-gamma, ll
- b-bbar + leptons

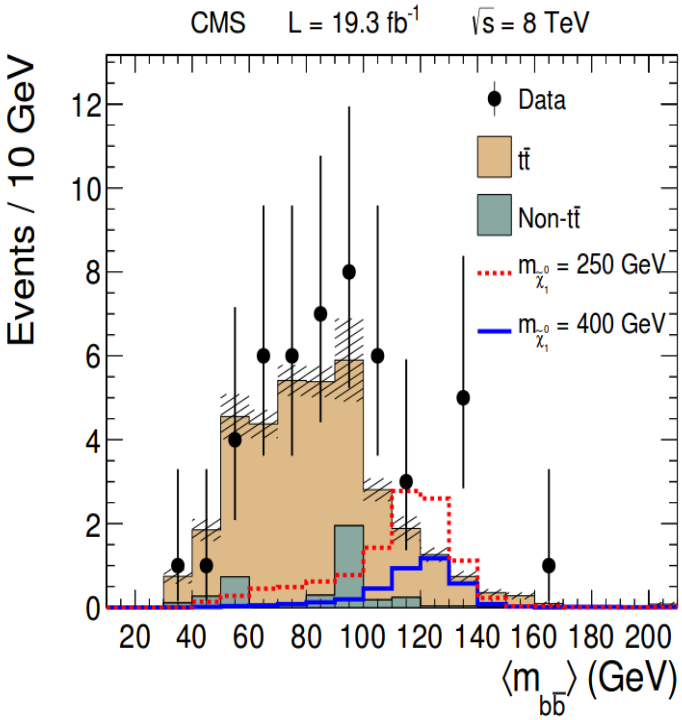



- 4 b-jets
- Gamma-gamma, bb
- Gamma-gamma + at least one lepton

# Neutralino-Neutralino

# H+H+MET (4b)

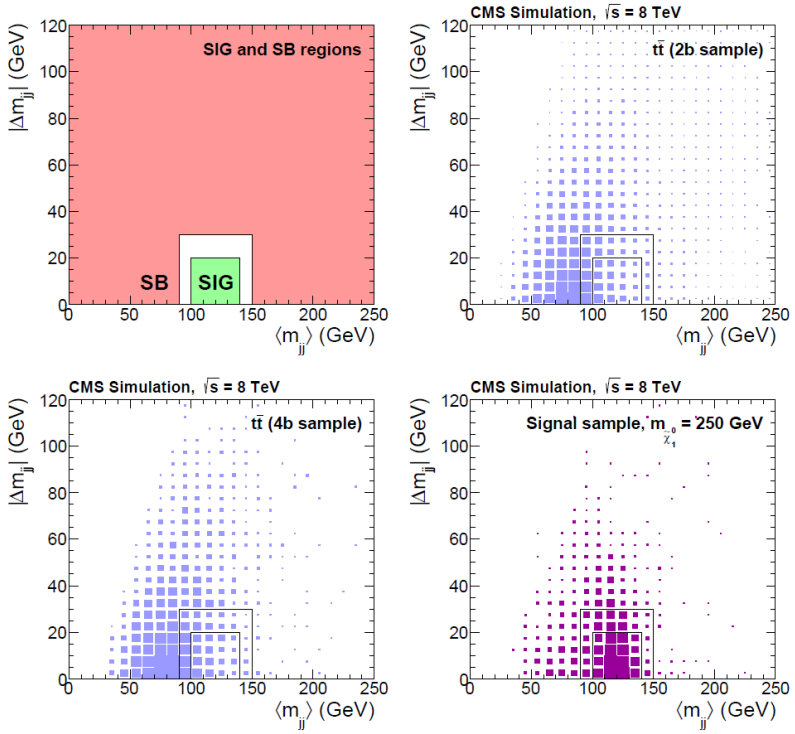


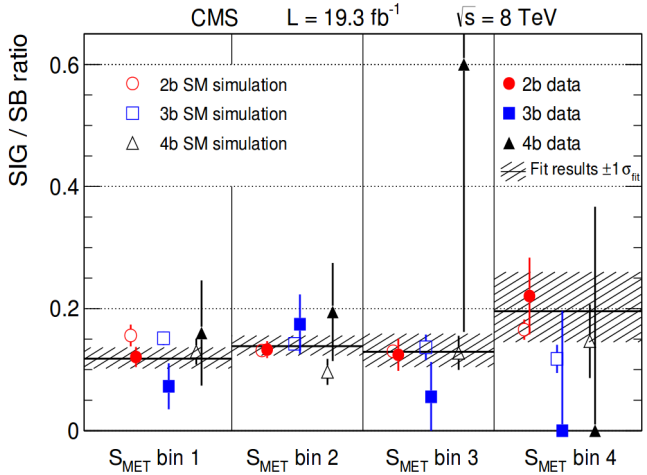




- Event Selection
  - 4/5 Jets, at least 3 b's
  - Moderate MET cut
  - Cut on Dphi of MET and Jets to eliminate QCD and ttbar
- HH Reconstruction
  - $|\Delta m_{jj}| \equiv |m_{jj,1} - m_{jj,2}|$ is minimized
  - $|\Delta m_{jj}| < 20\,\mathrm{GeV}$
  - $100 < \langle m_{jj} \rangle < 140\,\mathrm{GeV}$

# Neutralino-Neutralino
# H+H+MET (4b)

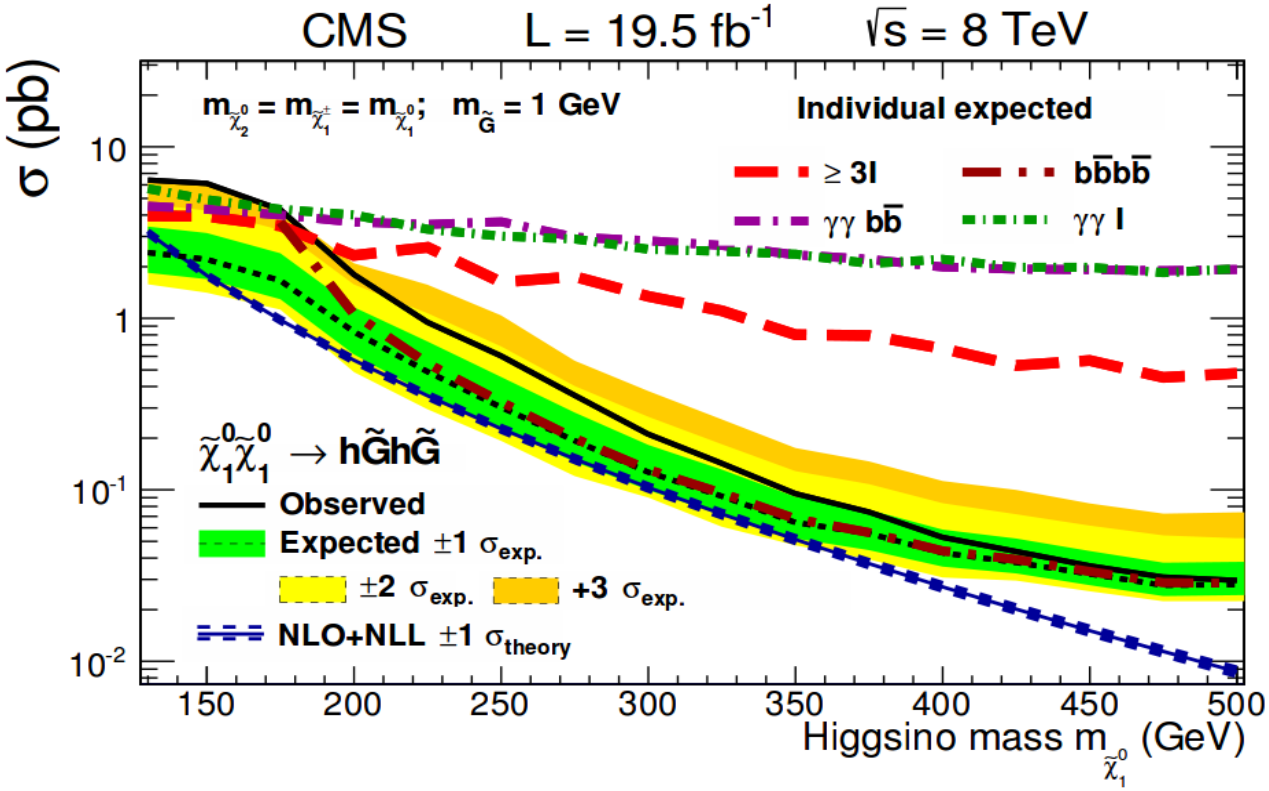
- Background estimation
  - $\langle m_{jj} \rangle$ and $|\Delta m_{jj}|$ are used to define signal and background regions
  - #Signal and background for different #b's are illustrated
  - #background can be estimated using an ABCD method
- Results
  - Binning vs. MET
  - No sign of new physics is observed



# Neutralino-Neutralino

# H+H+MET (4b)




- Because of a slight excess in the observed number of events compared to the estimated background, we are unable to exclude the signal model for any value of higgsino mass.

# Summary and Conclusion

- A wide range of searches for electroweak SUSY production is performed with full 8 TeV dataset
- Different decay scenarios are considered :
  - 1,2,3,4 leptons
  - 2leptons + 2jets
  - 4b
  - VBF
- The results are interpreted in various simplified models spectra
- No sign of new physics is observed