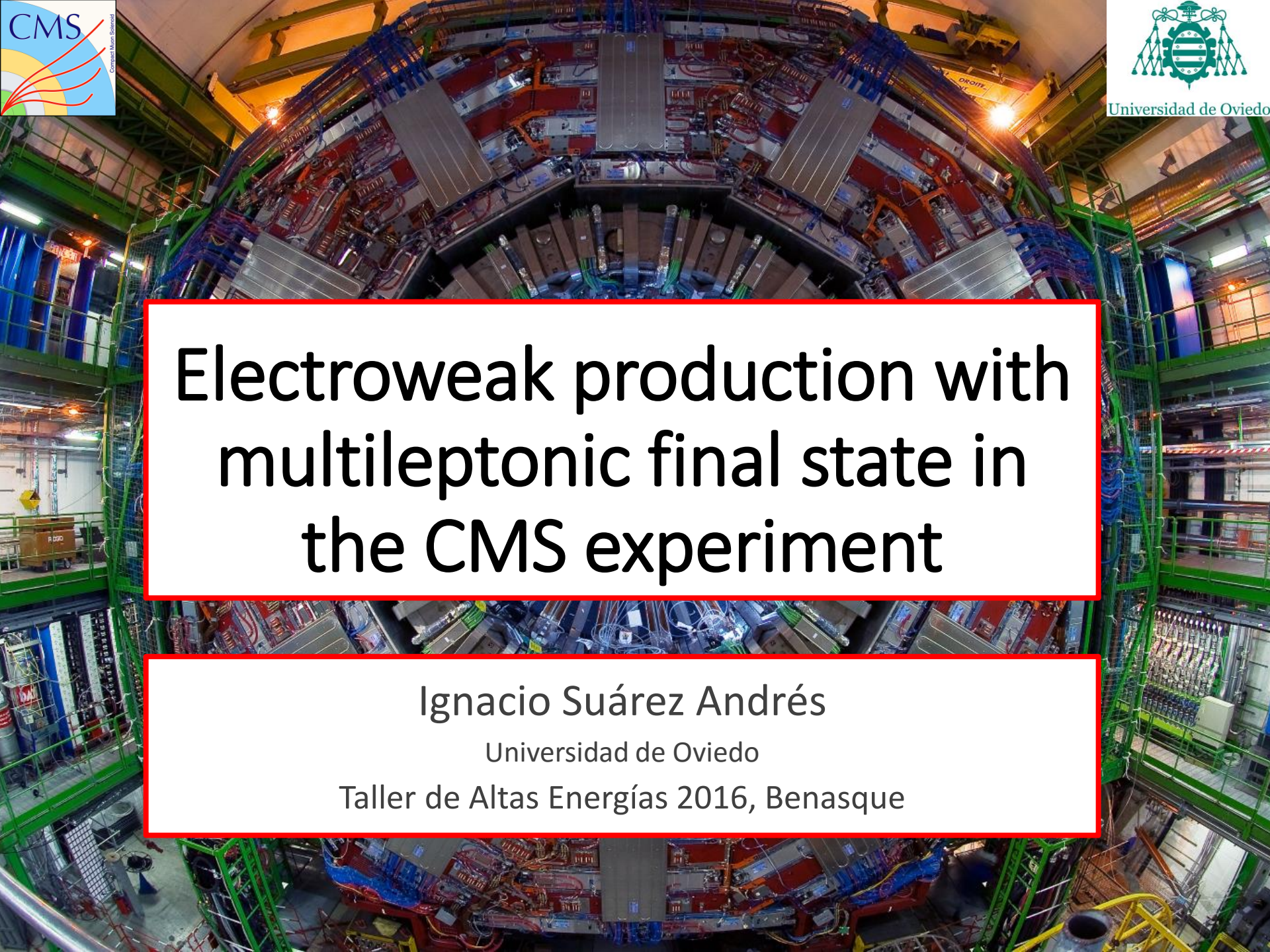

Electroweak production with multileptonic final state in the CMS experiment

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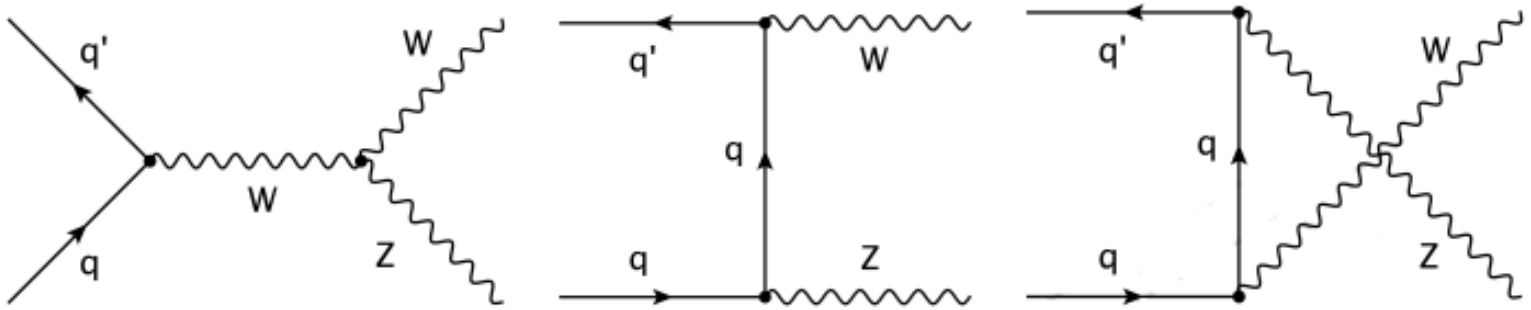
Taller de Altas Energías 2016, Benasque

List of contents

- WZ cross section measurement
  - CMS-SMP-16-002, submitted to *Phys. Lett. B*
- Search for electroweak SUSY production
  - CMS-PAS-SUS-16-024, presented in ICHEP2016

WZ cross section measurement

Motivation



- First measurement of WZ cross section at 13 TeV.
- Very important background source in multileptonic BSM searches.
- Potential tests for anomalous triple gauge couplings (aTGC).

Main background: *fake* leptons

Prompt lepton: lepton coming from the main interaction vertex, such as from a vector boson or some BSM process.
Non-prompt (*fake*) lepton: lepton contained in a jet, jet misidentified as a lepton, etc.

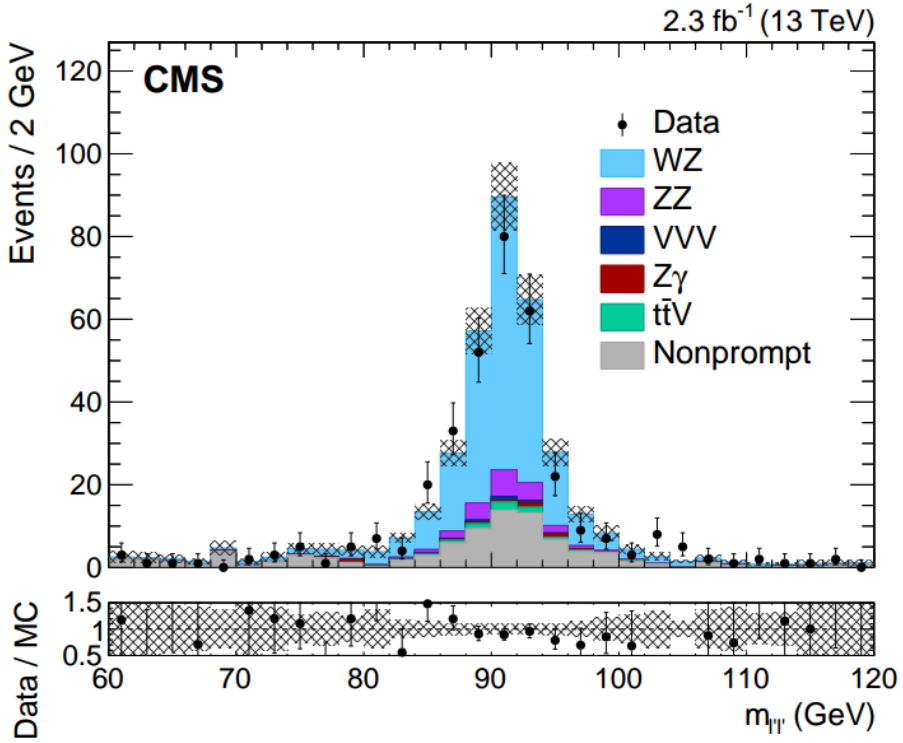
Data-driven approach: *tight-to-loose* method.
Efficiency of preselected (*loose*) prompt and non-prompt leptons passing the final selection (*tight*) is estimated from data in dedicated control regions.
Data events failing to pass lepton requirements enter the analysis region with a weight based on these probabilities.

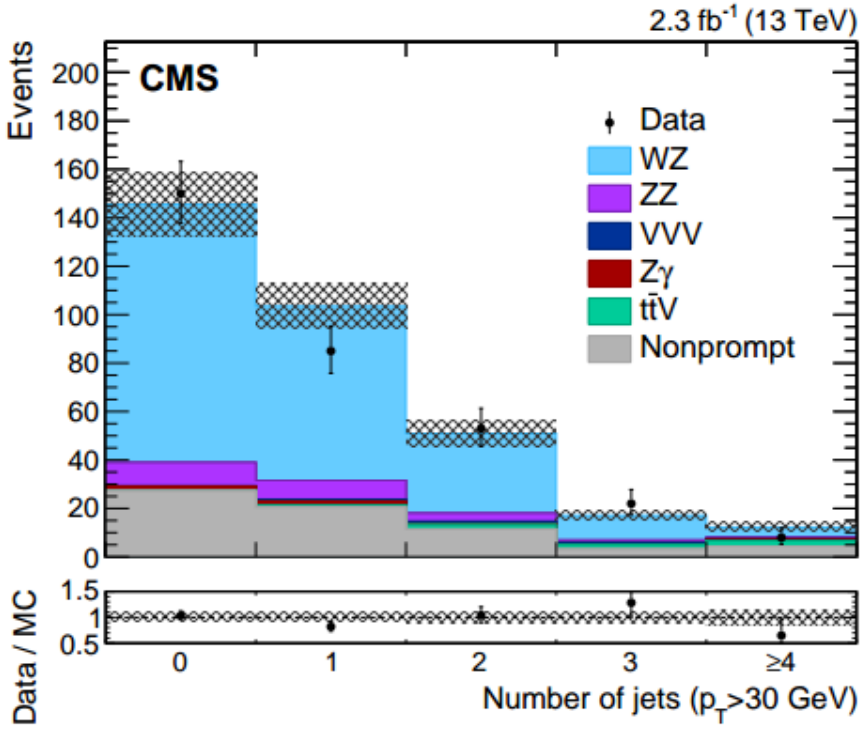
Cut

$$N^{\text{loose}} = N^{\text{loose}}_{\text{real}} + N^{\text{loose}}_{\text{fake}}$$

$$N^{\text{tight}} = \epsilon_{\text{real}} N^{\text{loose}}_{\text{real}} + \epsilon_{\text{fake}} N^{\text{loose}}_{\text{fake}}$$

Selection





Fiducial region (selected at generator level):

- $p_{\mathrm{T}}^{\ell \mathrm{Z1}}$ > 20 GeV, $p_{T}^{\ell \mathrm{Z2}}$ > 10 GeV.
- $p_{\mathrm{T}}^{\ell \mathrm{W}}$ > 20 GeV.
- All leptons $|\eta|$ < 2.5.
- 60 < m_{Z} < 120 GeV.

Final event selection:

- Exactly 3 isolated leptons.
- 76 < m_{Z} < 106 GeV.
- $m_{\ell\ell}$ > 4 GeV (all $\ell\ell$ combinations).
- $E_{\mathrm{T}}^{\mathrm{miss}}$ > 30 GeV.
- $m_{3\ell}$ > 100 GeV.
- Veto on events with b-tagged jets.

Results

Fiducial region:

- $60 < m_Z < 120$ GeV
- $p_T^{\ell\,Z1} > 20$ GeV
- $p_T^{\ell\,Z2} > 10$ GeV
- $p_T^{\ell\,W} > 20$ GeV
- $\left|\eta^{\ell\,Z1/Z2/W}\right| < 2.5$

Theoretical predictions	Fiducial	Total (in $60 < m_Z < 120$ GeV range)
NLO (MCFM with NNPDF3.0 PDFs, dynamic QCD scales)	$274\ ^{+11}_{-8}$(scale) ± 4 (PDF) fb	$42.3\ ^{+1.4}_{-1.1}$(scale) ± 0.6 (PDF) pb
NNLO (MATRIX with NNPDF3.0 PDFs, fixed QCD scales)	–	$50.0\ ^{+1.1}_{-1.0}$(scale) pb
NNLO (MCFM with NNPDF3.0 PDFs, fixed QCD scales)	$291\ ^{+16}_{-13}$(scale) ± 4 (PDF) fb	$44.9\ ^{+2.2}_{-1.8}$(scale) ± 0.7 (PDF) pb

Measurement

Fiducial:

$$\sigma_{\text{fid}}\left(pp \to WZ \to \ell\nu\ell'\ell'\right) = 258 \pm 21\ (\text{stat})\ ^{+19}_{-20}\ (\text{syst}) \pm 8\ (\text{lumi})\ \text{fb}$$

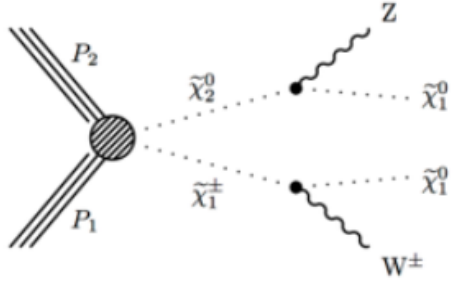
Total (in $60 < m_{\ell^+\ell^-} < 120$ GeV range):

$$\sigma\ (pp \to WZ) = 39.9 \pm 3.2\ (\text{stat})\ ^{+2.9}_{-3.1}\ (\text{syst}) \pm 0.4\ (\text{theo}) \pm 1.3\ (\text{lumi})\ \text{pb}$$

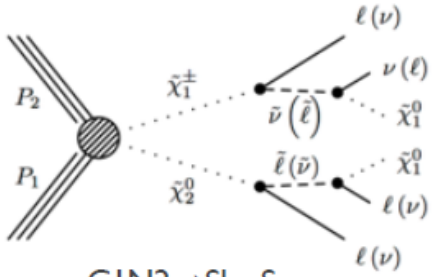
Search for electroweak SUSY production

Guiding models

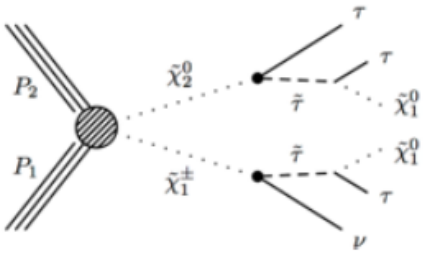
leading models: aim to improve sensitivity



C1N2→WZ

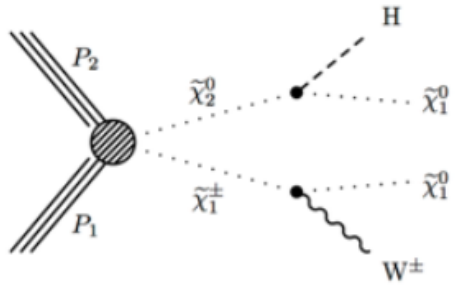


C1N2→SlepSneu
(flavor-democratic decay)

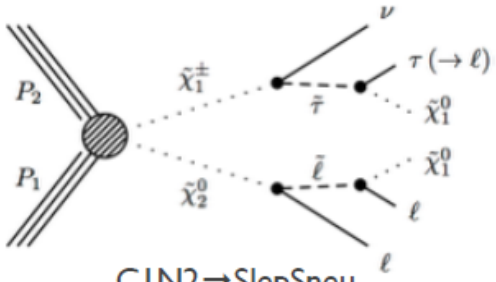


C1N2→SlepSneu
(tau-dominated decay)

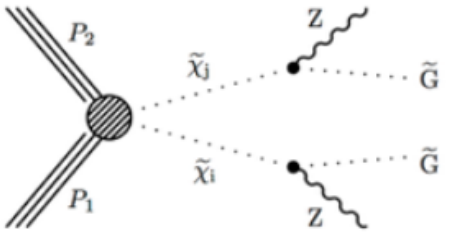
subleading models: no or little sensitivity expected (or signal is not ready)



C1N2→WH

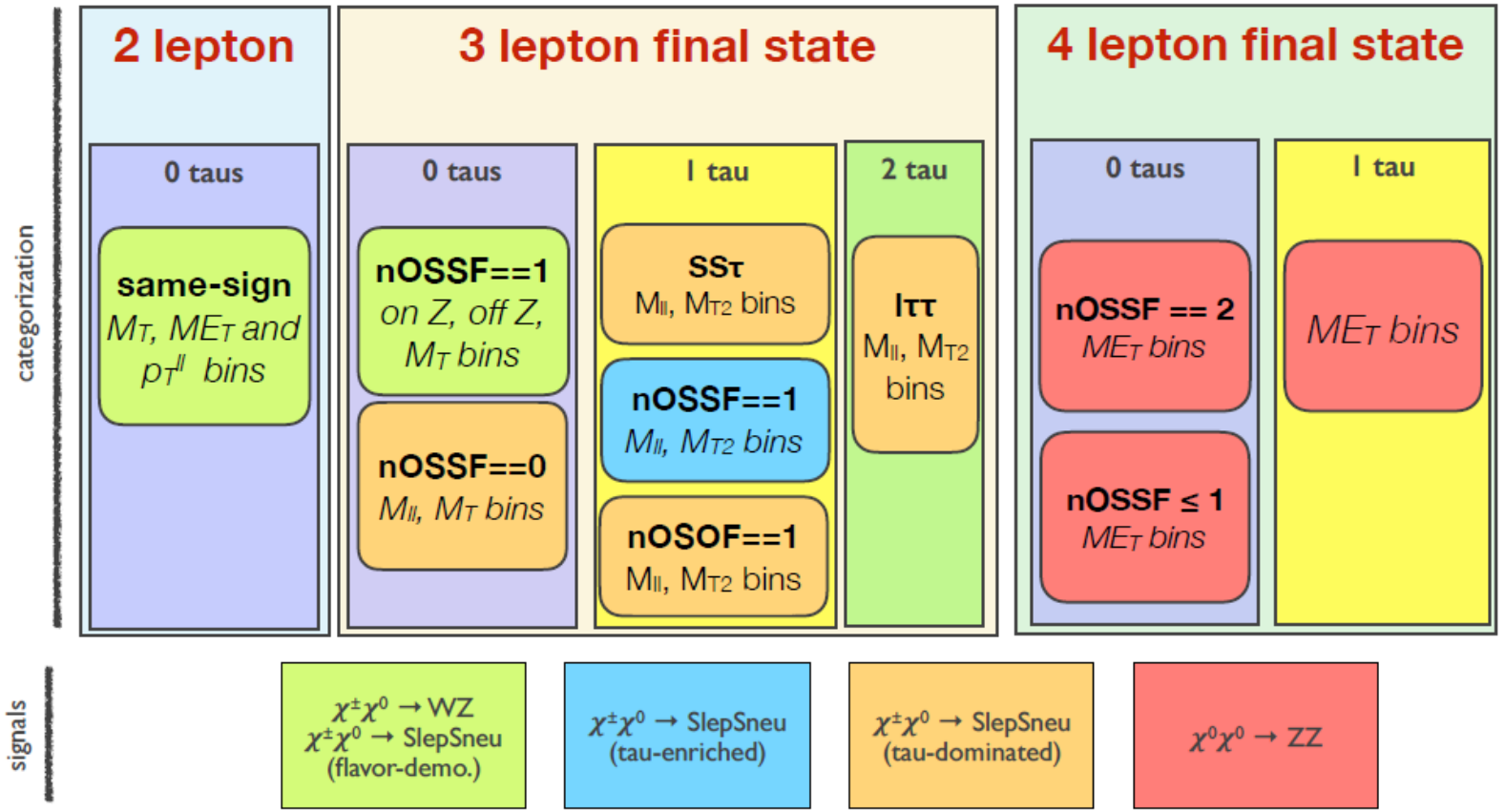


C1N2→SlepSneu
(tau-enriched decay)



N2N3→ZZ

Final state channels



nOSSF = number of OSSF pairs (ee, μμ, ττ)
nOSOF = number of OS different flavour pairs (ee, μμ, eμ)

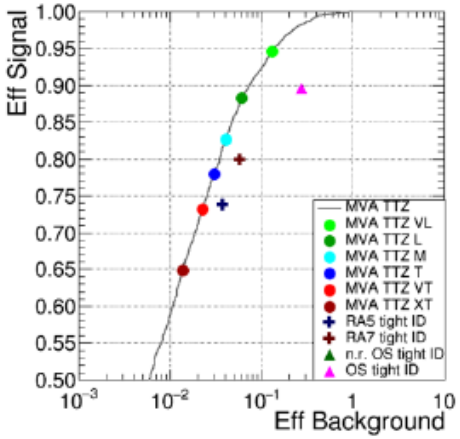
Lepton MVA

New MVA lepton identifier developed.

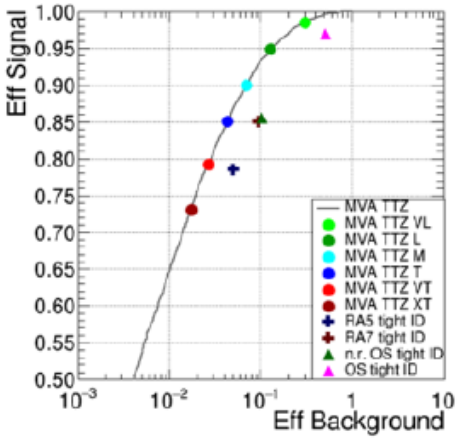
Improved signal efficiency and background rejection wrt ID used in similar previous analyses.

Boosted Decision Tree:
Leptons from ttZ vs semileptonic tt

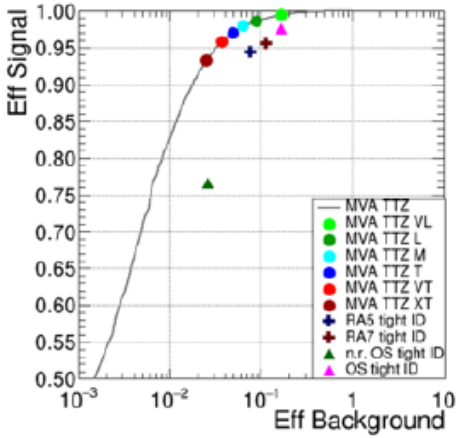
category	input variables
kinematics	p_T η
isolation	PF miniRelIso, charged had. (R=0.3) PF miniRelIso, neutral had. & photon (R=0.3, scaled EA)
impact parameters	3D IP significance (SIP3D) 2D IP|dxy| and |dz|
lepton's closest jet (lepAware JEC applied)	pTratio (= pT(lep)/pT(jet)) lepton's pTrel w.r.t. jet jet CSVv2 b-tag #charged tracks in jet
identification	segment compatibility (for muons) POG electron ID non-trig. MVA (for electrons)



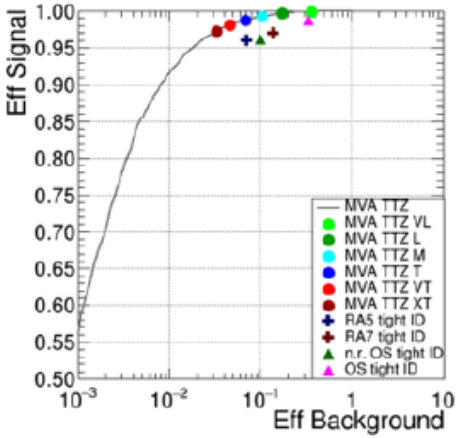
electrons, 10 < pT < 25



muons, 10 < pT < 25



electrons, pT > 25



muons, pT > 25

https://indico.cern.ch/event/526363/contributions/2163510/attachments/1273352/1894663/leptonMVA_summary_forTwiki.pdf

Baseline selection

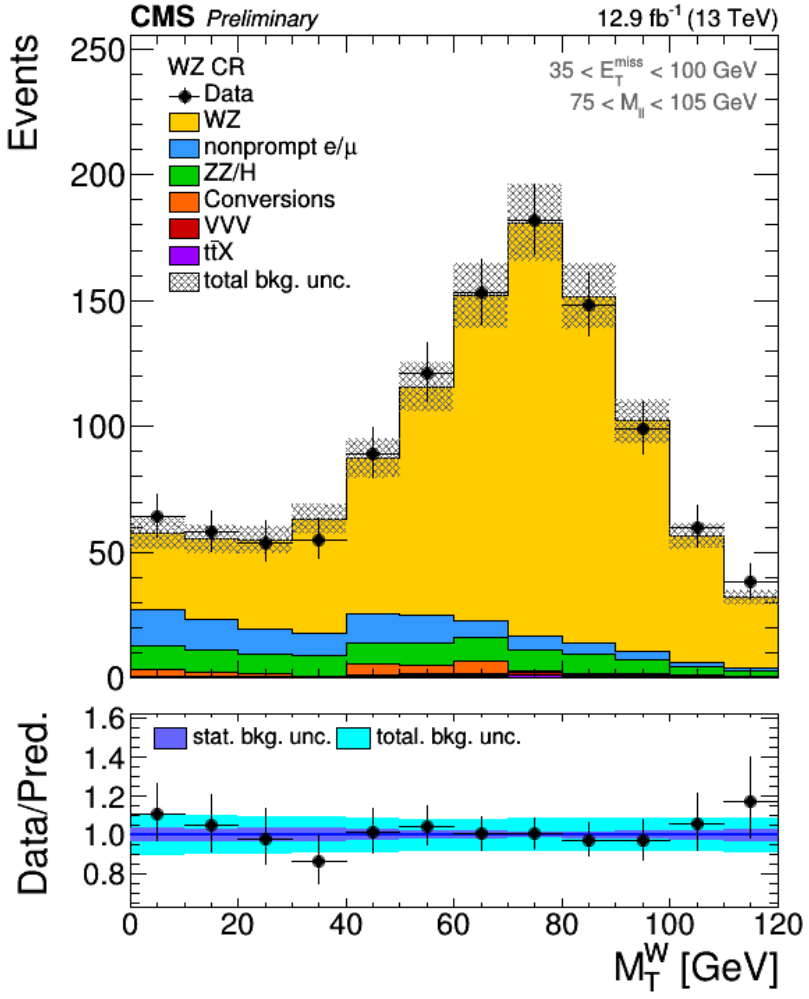
selection	same-sign dilepton channel	trilepton channel	4-lepton channel
#leptons	2, same charge	3	> 3
lepton p_T for e(μ)	25(20)/15(10)	25(20)/15(10)/10	25(20)/15(10)/10/10
#taus	0	0, 1, 2	≥ 0
lepton p_T for τ_h(e/μ)	-	20(30/25)	20
#jets	0, 1	≥ 0	≥ 0
veto events with OSSF pair Mll<12	✅	✅	✅
veto events with on-Z M3L	❌	✅ (in certain categories)	❌
veto events with >0 b-tagged jet	✅	✅	✅
MET	> 60	> 50	> 0
overlap removal	no third lepton	no fourth lepton	❌

Main background: WZ

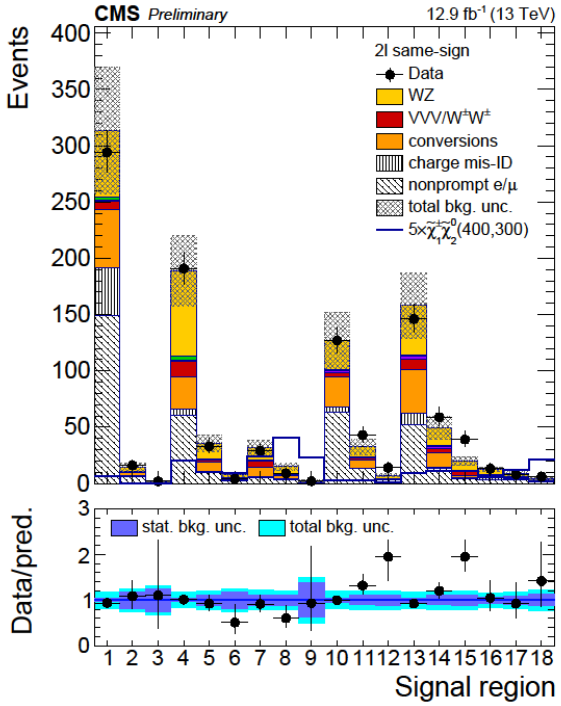
- Exactly 3 light leptons (lepton MVA VT)
- 0 or 1 jet
- 0 b-tagged jets

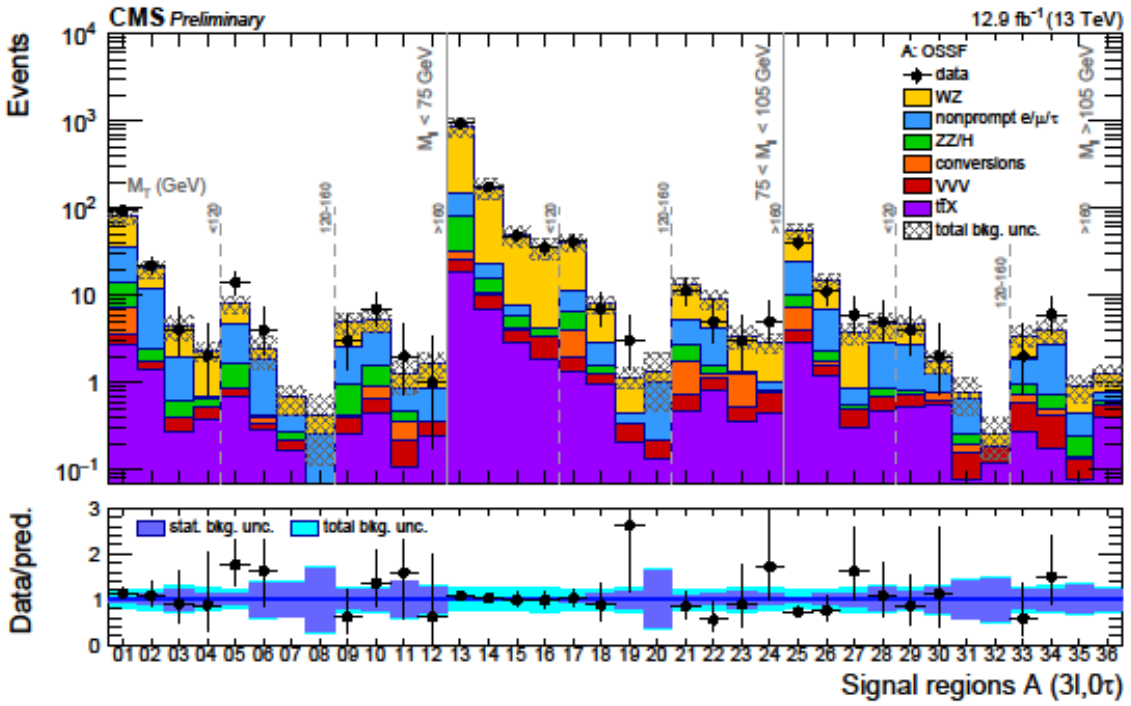
- OSSF pair with 75 < $M_{\ell^+\ell^-}$ < 105 GeV
- 35 < $E_{\mathrm{T}}^{\mathrm{miss}}$ < 100 GeV
- $M_{\mathrm{T}}^{\mathrm{W}}$ < 120 GeV

CR used to constrain WZ background. Negligible signal contamination, except for $\tilde{\chi}^{\pm}\tilde{\chi}^{0} \rightarrow$ WZ models with $\Delta M \sim M_{\mathrm{Z}}$ (WZ-like kinematics). Additional uncertainty. Overlap with SRA13 → substituted in the interpretation.



Most relevant signal regions





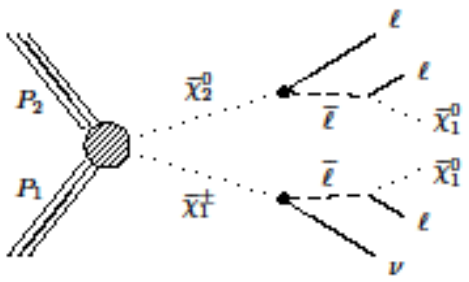
Categorization based on:

- p_{T}^{ll}
- M_{T}
- $E_{\mathrm{T}}^{\mathrm{miss}}$

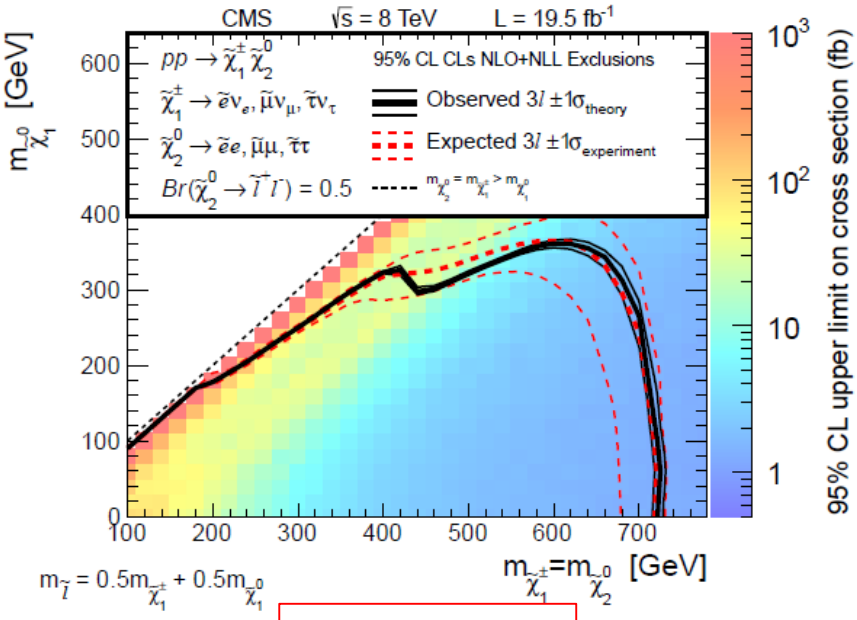
Categorization based on:

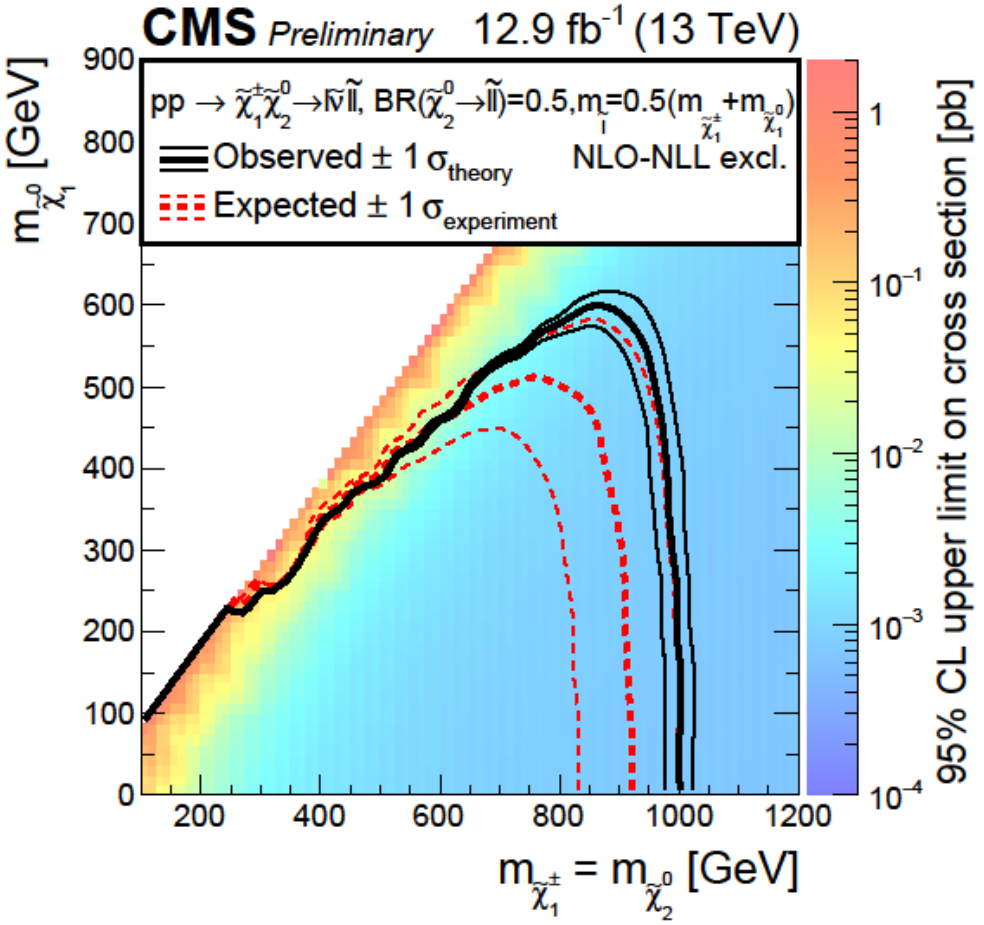
- $M_{\ell^+\ell^-}$
- M_{T}
- $E_{\mathrm{T}}^{\mathrm{miss}}$

Flavor-democratic SlepSneu



x=0.5





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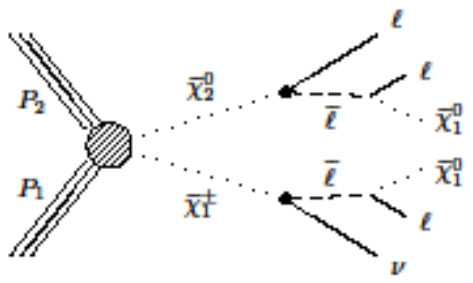
Flavor-democratic SlepSneu



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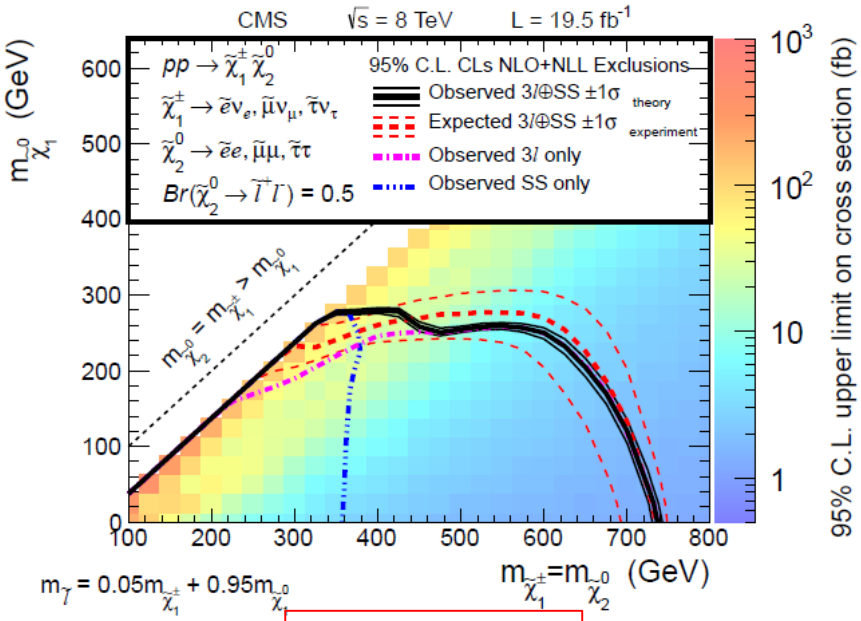

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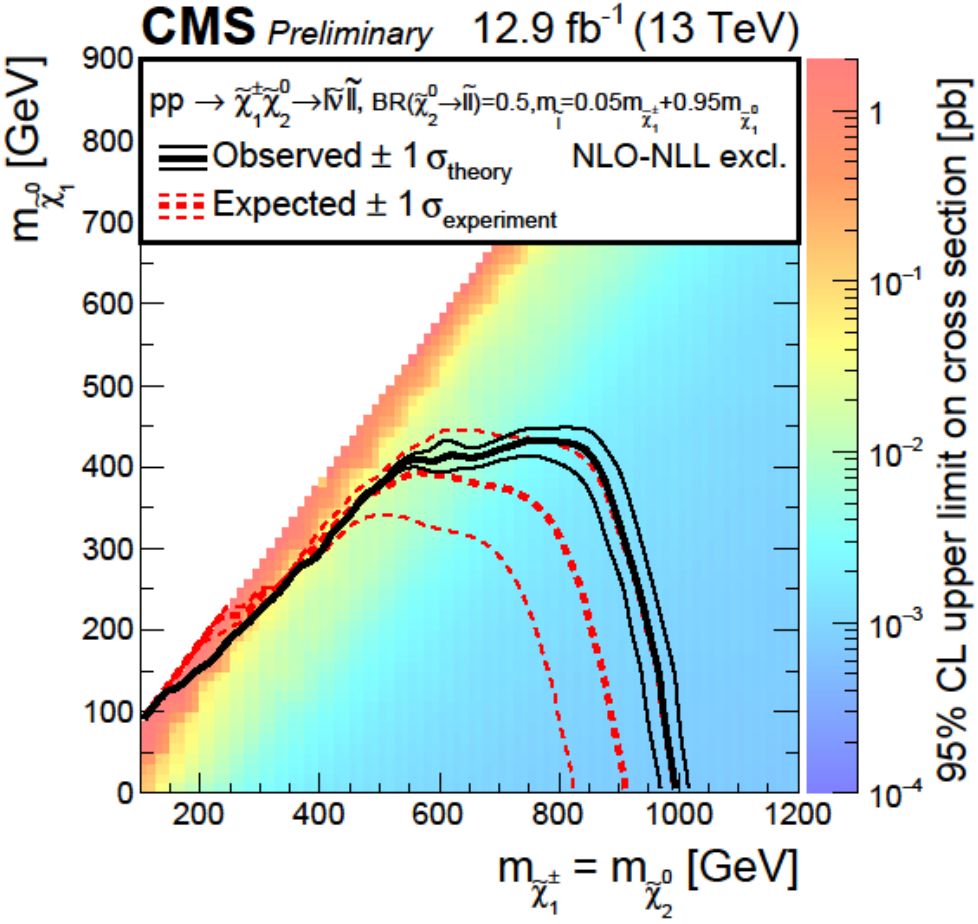
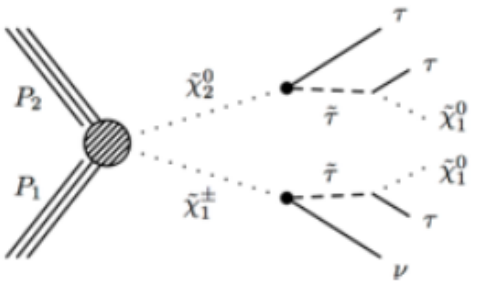


τ-dominated SlepSneu



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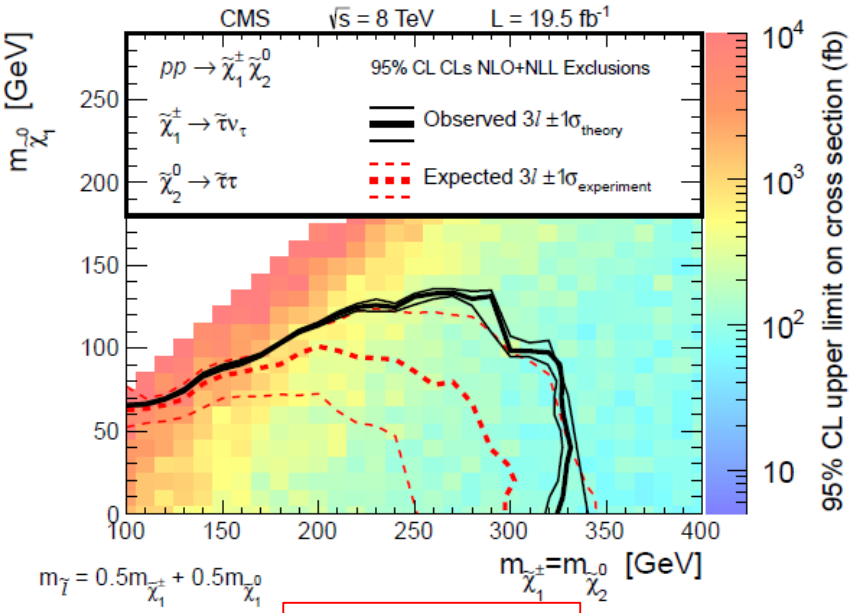

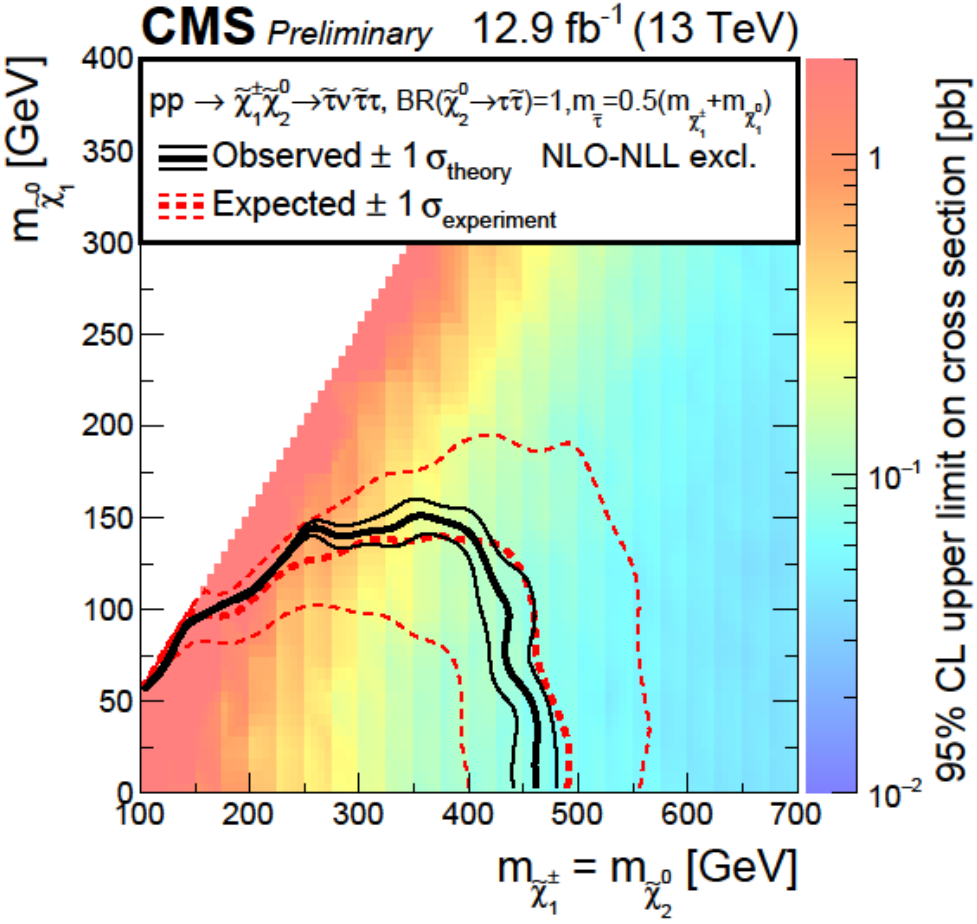

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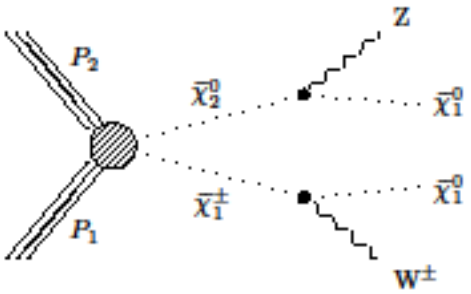
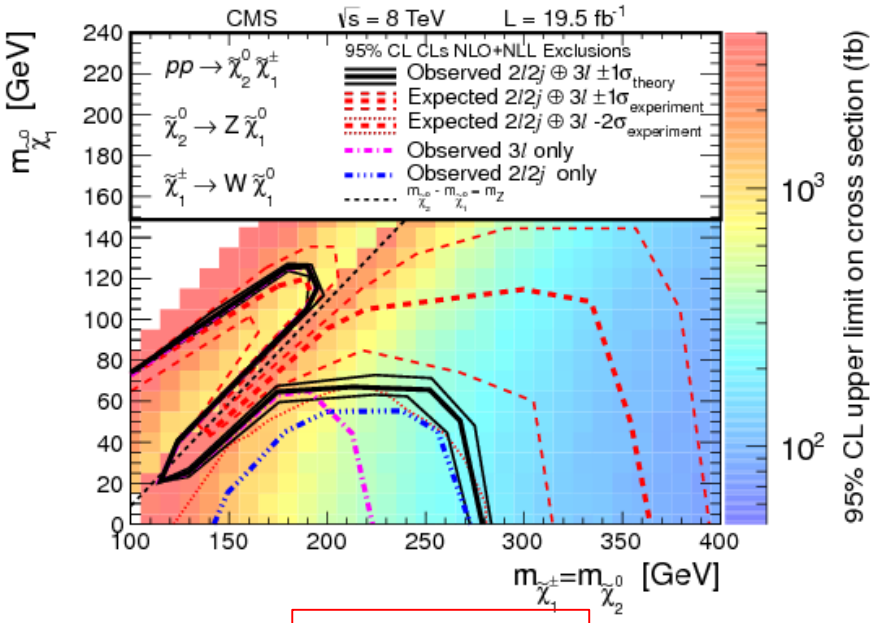
WZ





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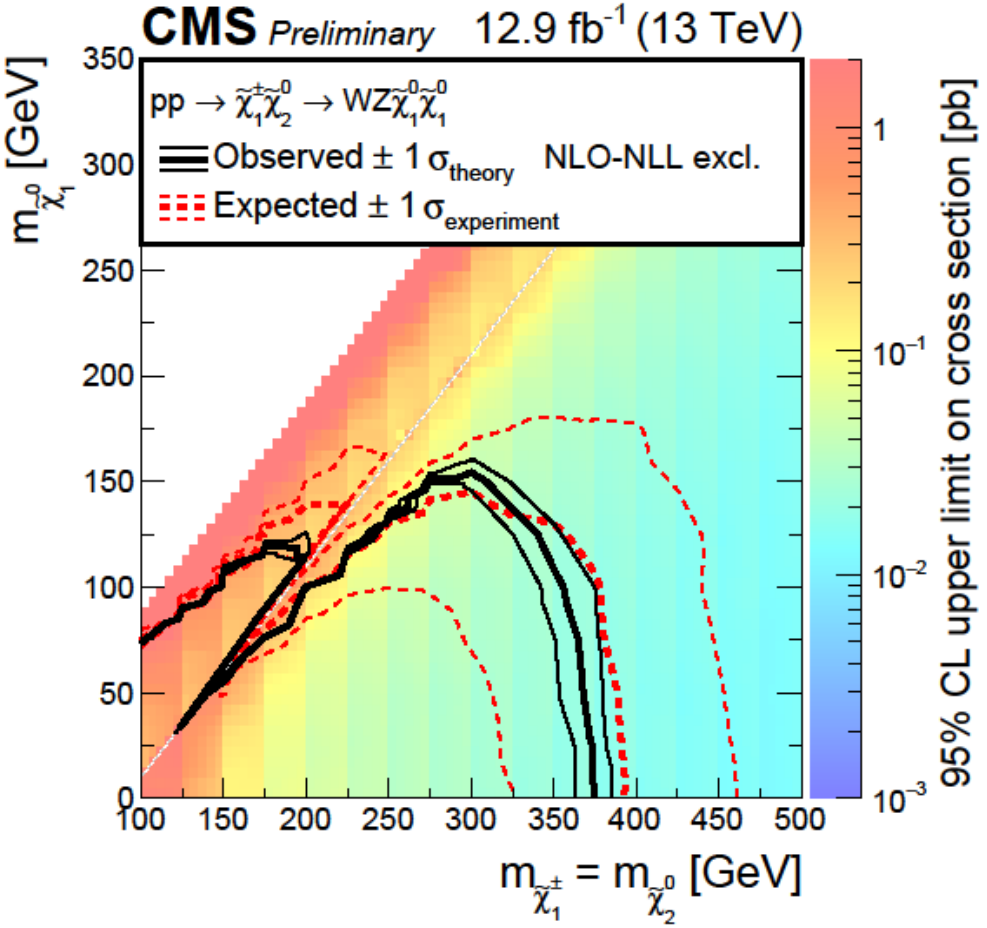


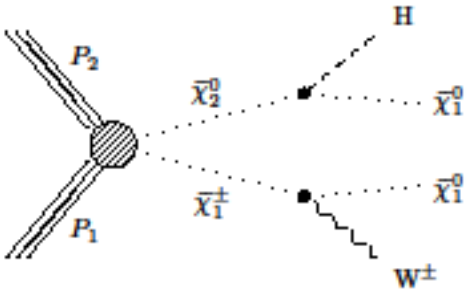
Conclusions

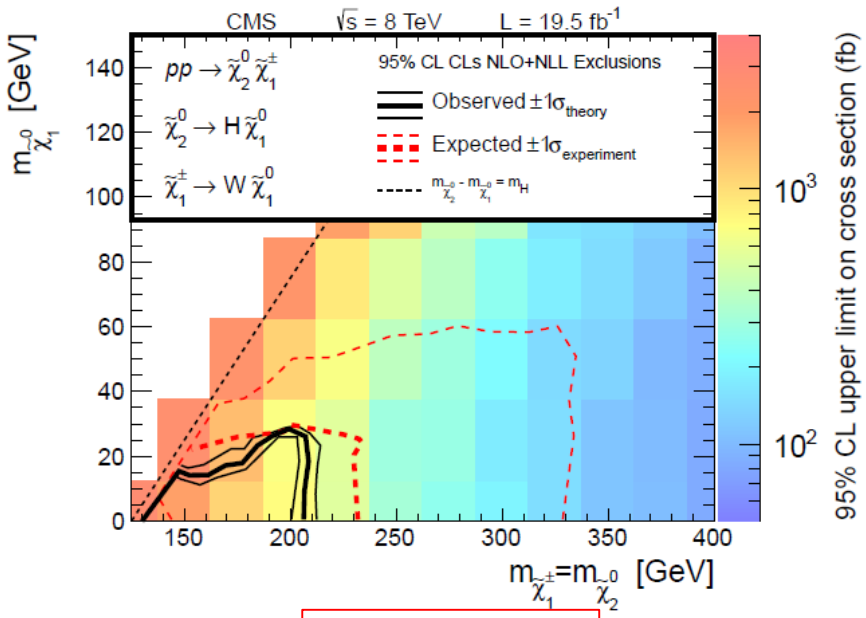
- WZ cross section measurement with 13 TeV data (2015, 2.3 fb^{-1})
  - Measured value noticeably lower than NNLO prediction: future measurements should shed some light on this.

- Electroweak SUSY production (2016, 12.9 fb^{-1})
  - Expanded exclusion upper limits on several models with combination of same-sign dilepton and multileptons.
  - No SUSY found (otherwise you would probably know already).

Thank you for your attention!

WH





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