Search for Chargino Neutralino production at CMS

01. October 2013

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Outline

Public CMS PAS

- Introduction
- Signature
- Objects
- 3 lepton analysis
- Interpretation
- Projection to 3000 fb^{-1}

Available on the CERN CDS information server **CMS PAS SUS-13-006**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch 2013/07/19

Search for electroweak production of charginos, neutralinos, and sleptons using leptonic final states in pp collisions at $\sqrt{s} = 8$ TeV

Includes 5 Analysis form 8 different groups

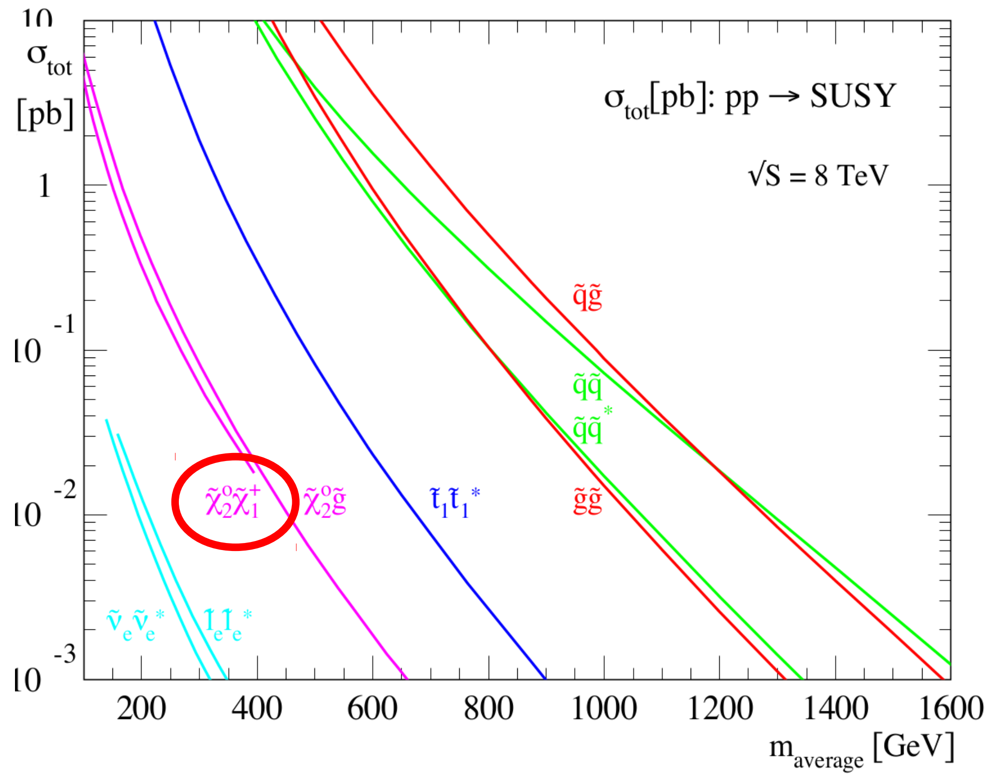
The CMS Collaboration

Abstract

Final states with exactly three leptons, four leptons, two same-sign leptons, two opposite-sign-same-flavor leptons plus two jets, and two opposite-sign leptons inconsistent with Z boson decay, are studied using a data sample consisting of an integrated luminosity of 19.5 fb^{-1} of proton-proton collision data collected in 2012 with the CMS detector at $\sqrt{s} = 8$ TeV. The observed event rates are in agreement with expectations from the standard model. The results are used to set limits on the direct production of charginos, neutralinos, and sleptons.

Introduction

- No SUSY found so far
- Most searches concentrate on colored particles
  - Strong limits on Squarks and Gluinos
- Chargino/Neutralino production has small cross section

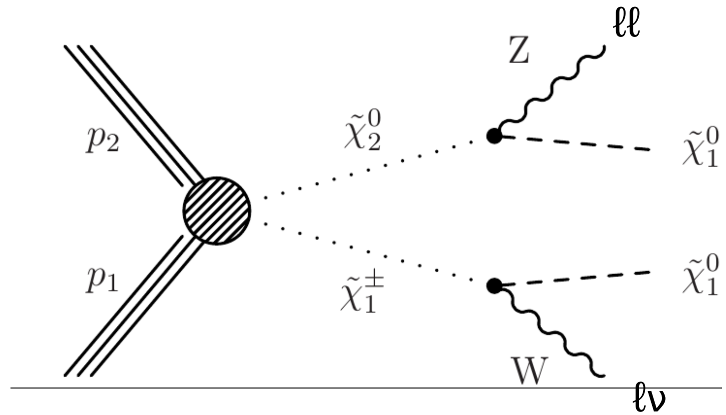


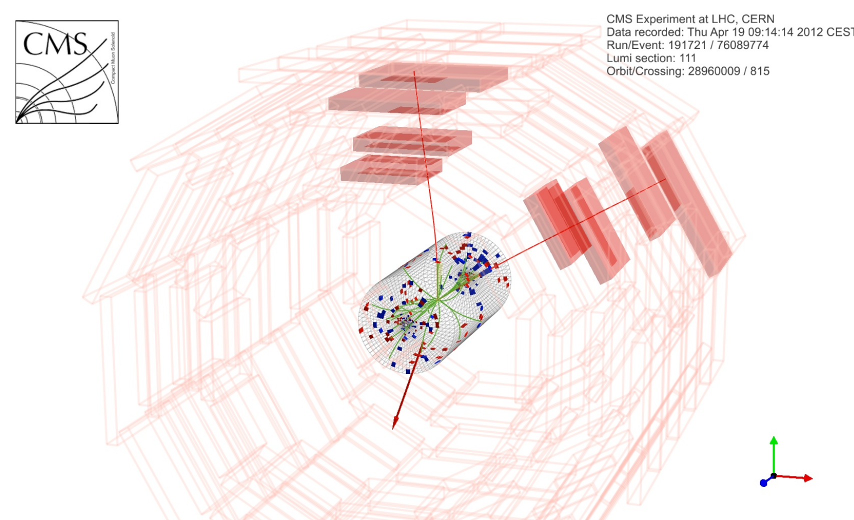
- Direct Chargino Neutralino production needs luminosity

Signature

Decay via W/Z Boson

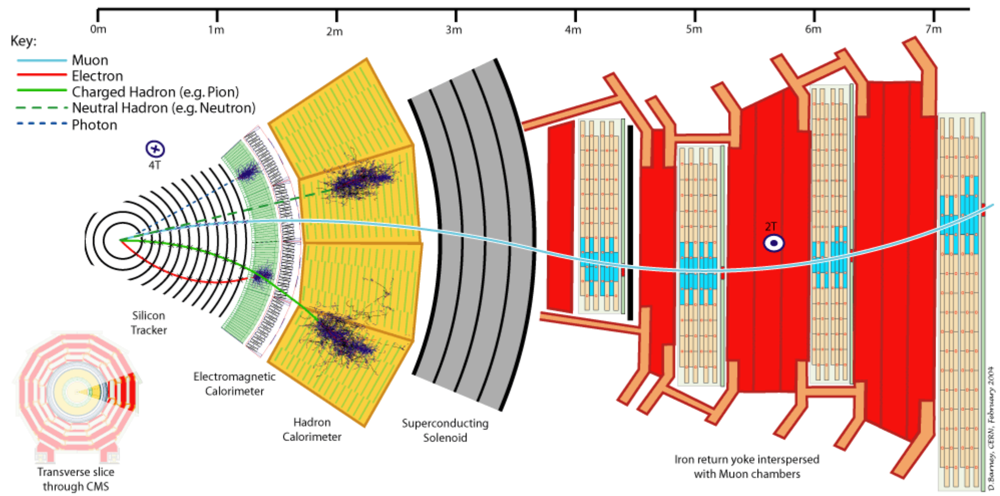
- Decay is motivated by many SUSY scenarios
- Exact branching ratio (Br) depends on many different parameters
  - Use simplified model approach, set Br to 100%
- Leptonic decay of Bosons lead to final states with 3 leptons
- Lightest Supersymmetric Particle (LSP) is stable and stays undetected → events with large missing transverse Energy (MET)





Objects

- Trigger:
  - Dilepton Trigger (ε ~ 90%)
    - First lepton p_T > 20 GeV
    - Second lepton p_T >10 GeV

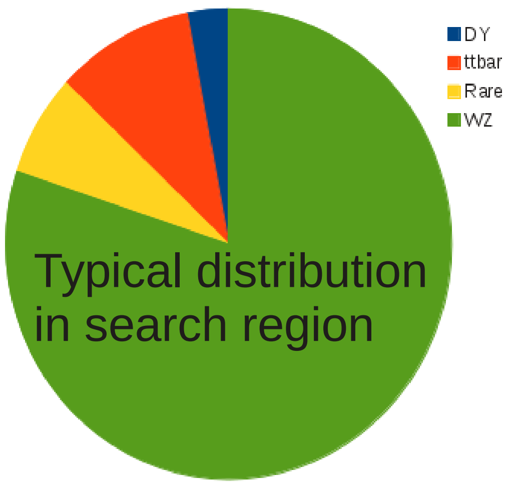


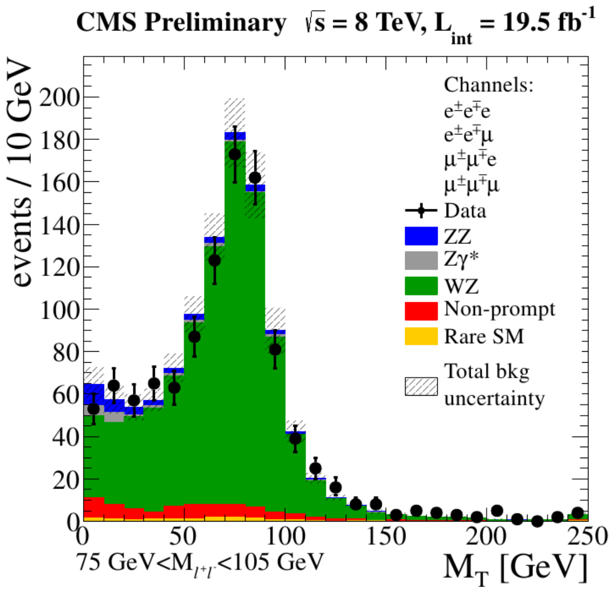
- Lepton ID's
  - Standard CMS Electrons (ε ~ 90%) and Muons (ε > 90%)
    - p_T > 10 GeV
    - |eta| < 2.4
    - (rel) Particle Flow isolation < 0.15
  - Hadronic Taus τ (ε ~ 50%) [arXiv:1109.6034]
    - P_T > 20 GeV
    - |eta| < 2.3

- Jets and MET:
  - Particle Flow Jets:
    - P_T > 30 GeV
    - Use CSV b-tag [arXiv:1211.4462]
  - Particle Flow MET

3l Search Overview

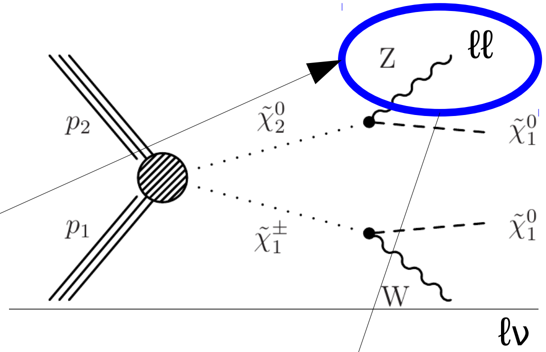
- Backgrounds
  - WZ: dominant, contains 3 prompt leptons + MET
  - Non-prompt (fakes+ leptons escaping Jets)
    - ttbar: MET
    - DY (Z-Boson)+Jets: no MET
  - Rare (very low cross section) taken from MC:
    - VVV/ttV/H/VH/ZZ
- Select 3 leptons (electrons and muons)
  - Find lepton pair which matches best to a Z
    - Invariant mass (mll) closest to 91 GeV
  - Remaining lepton used for M_T calculation
    - $M_T=(2*p_T*MET*[1-\cos(\Delta\varphi[p_T,MET])])^{1/2}$
  - Veto on events with b-tagged jets
  - Veto on events with hadroinic τ

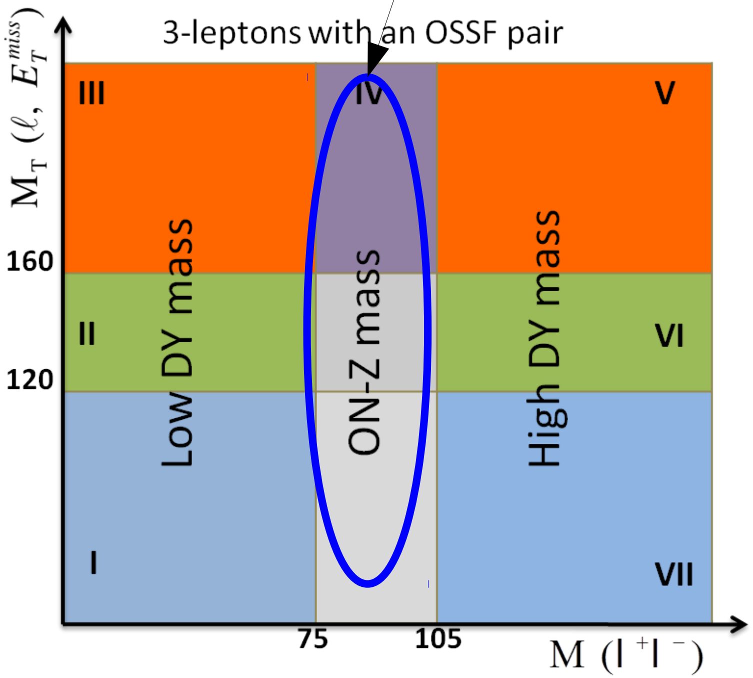




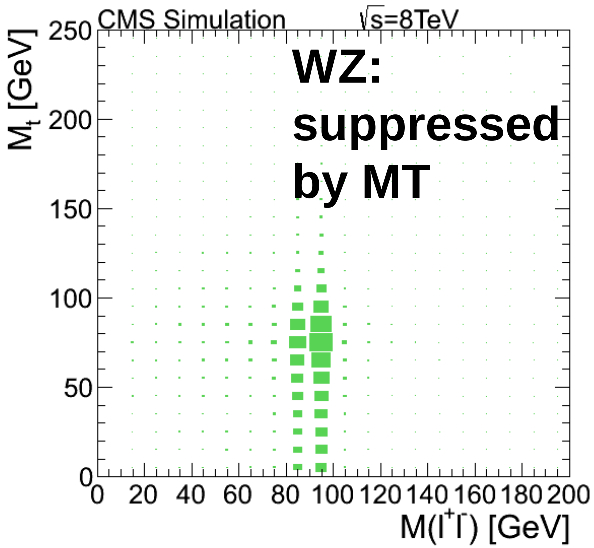
3 Lepton Search Region

- Use 3D binning to optimize separation between signal and background: MET, M_T and dilepton mass (mll)
  - Three mll channels:
    - LowZ mll < 75
    - OnZ: 75 < mll < 105
    - HighZ: 105 < mll
  - Three M_T channels:
    - [0 ,120],[120,160],[160,∞]
  - Four MET channels:
    - [50,100],[100,150],[150,200],[200,∞]
    - MET<50 GeV used for background methods



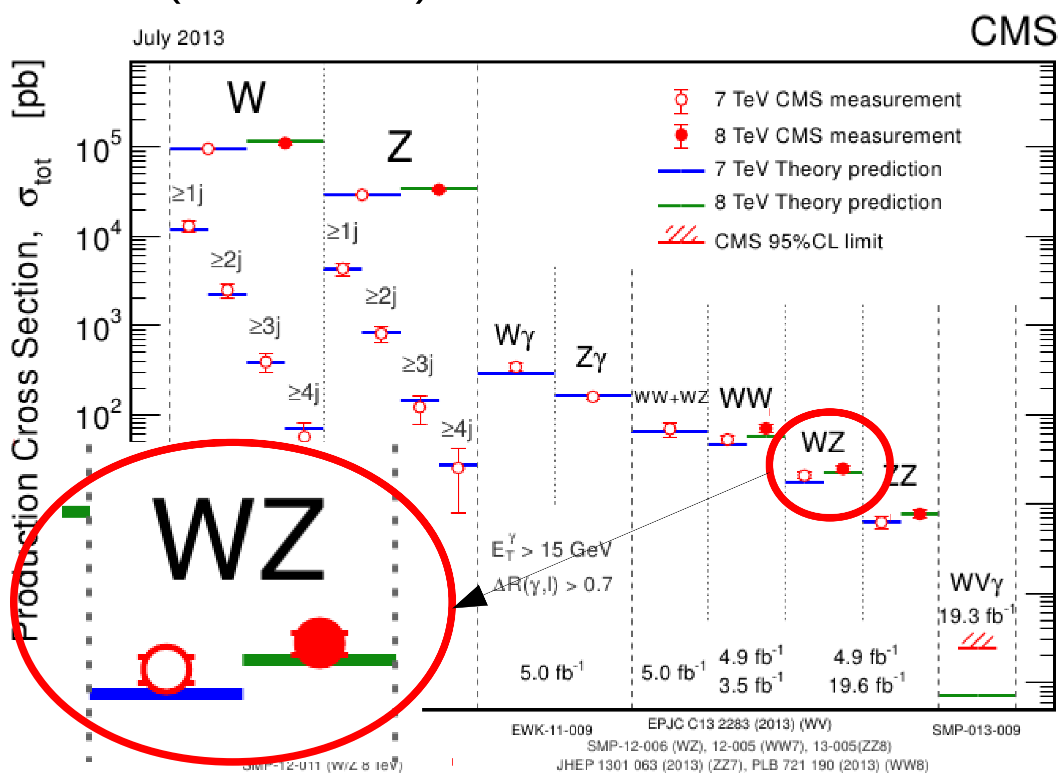


WZ Backgrounds



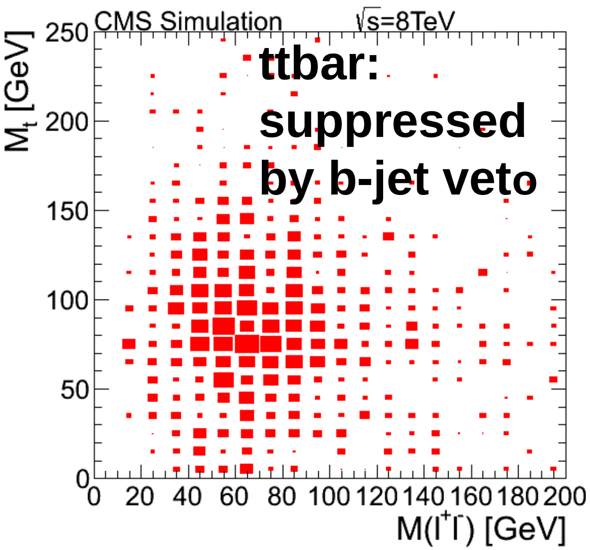
- WZ:
  - SM WZ cross section measurement shows an ~20% excess compared to the theory prediction
  - We using MC → take theory cross section, apply uncert of ~20% (dominating uncertainty)

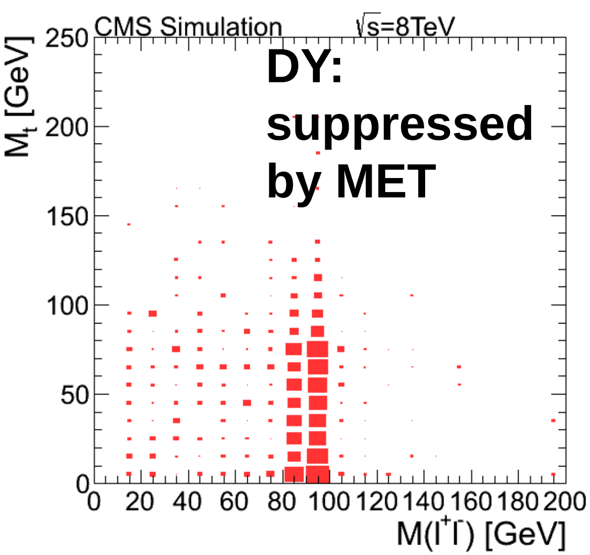
- WZ:
  - Use MC and validate it in control region
  - Measure the Detector response for MET (in Z events) and correct the MC



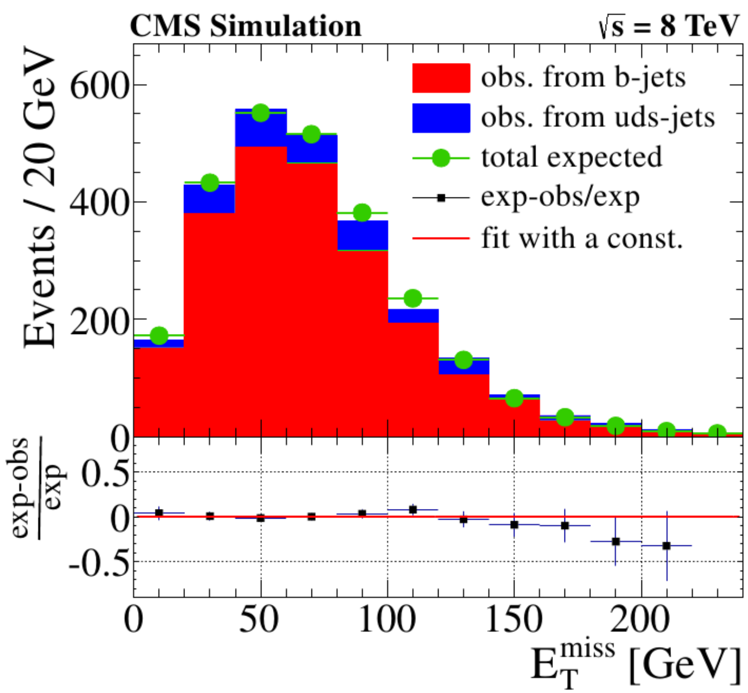
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP

Non-prompt Backgrounds

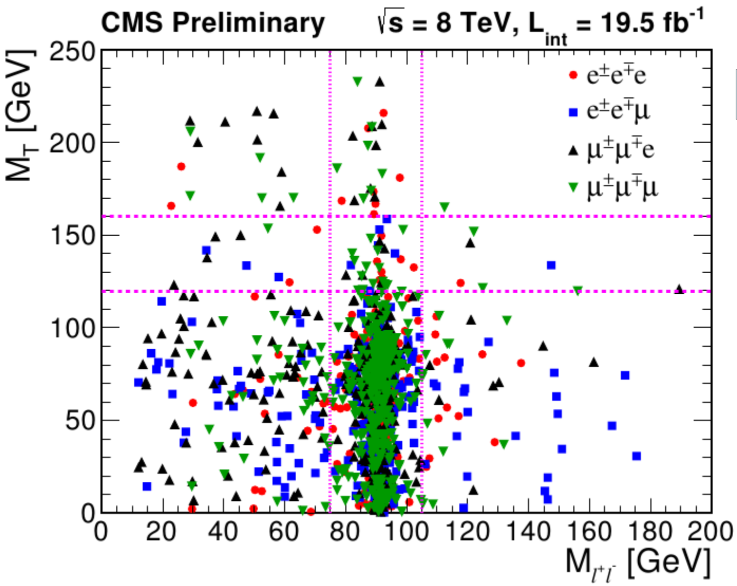




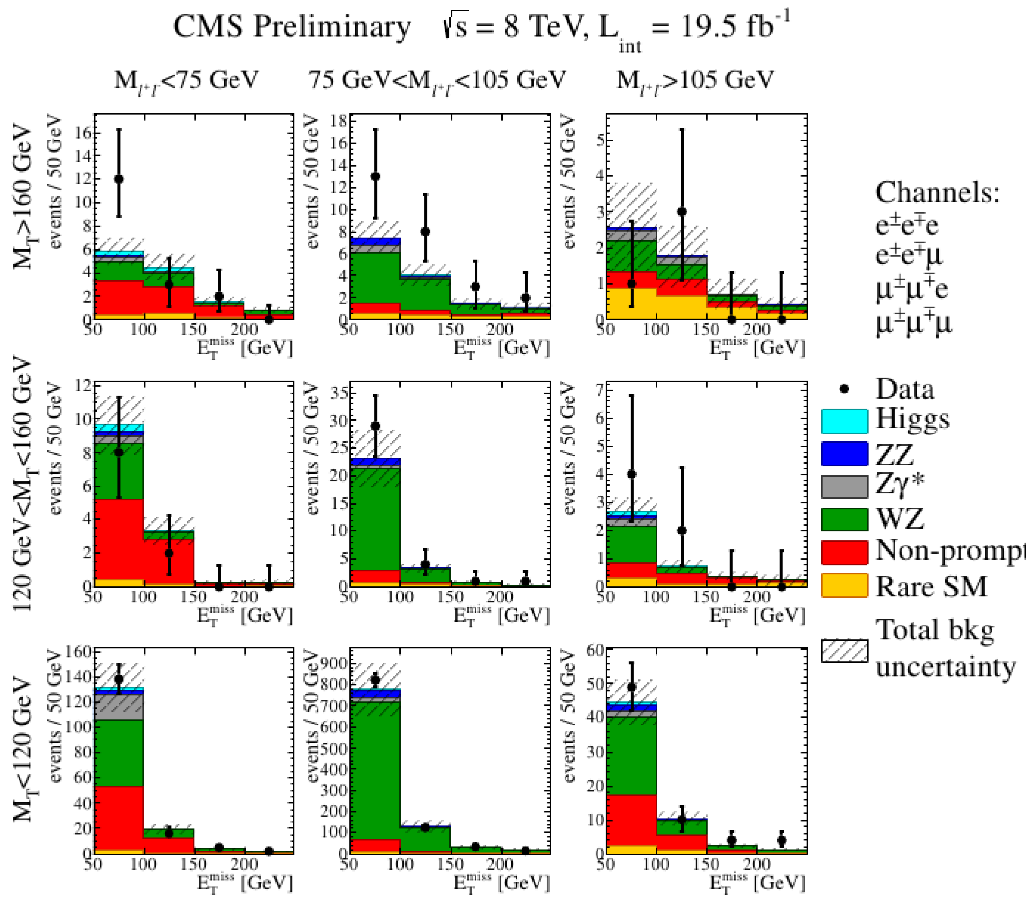
- Non prompt:
  - We have 3 independent prediction methods, for example: select events with 2 leptons+ isolated track
  - Measure the fake rate as function of isolation and impact parameter in pure QCD
  - Apply the fake rate to the 2l+isolated track selection:
  - Plot shows the measured fake rates applied on ttbar MC
  - Prediction works well and gives same results as two other different methods



Result

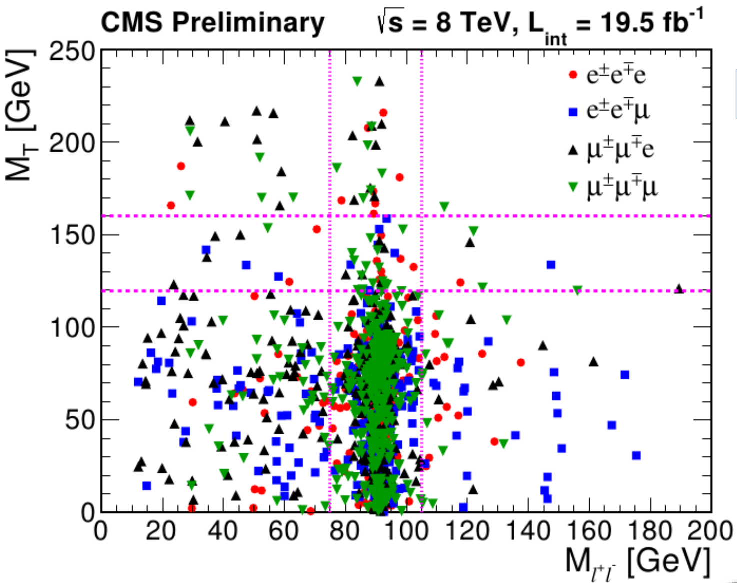


Fill into the MET bins

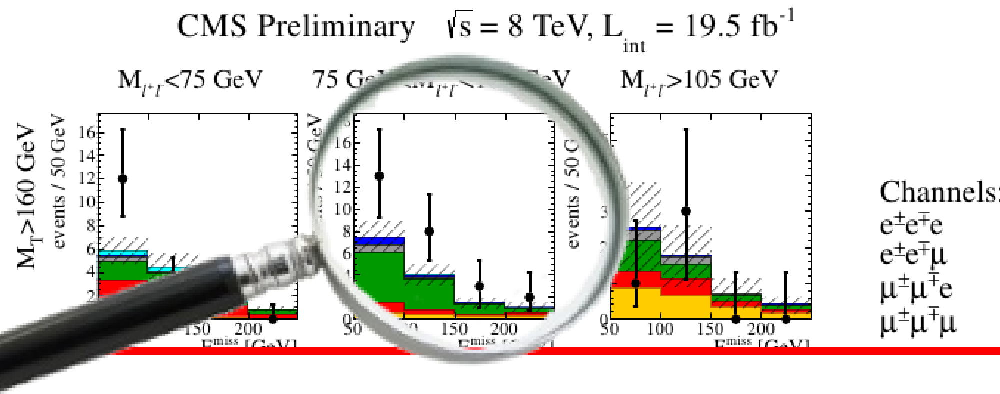


- Most events are from WZ
- No significant excess can be observed
- Each of this MET bin are used for limit settings
  - Important are the onZ channels

Result



Fill into the MET bins

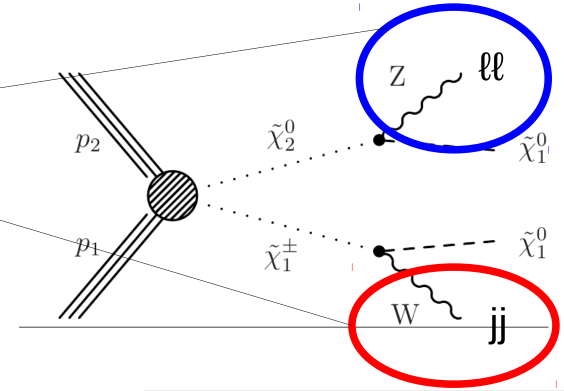


- Most events are
- ~~No significant ex~~ be observed
- Each of this MET used for limit set
  - Important for search are th channels

$75\ \text{GeV} < M_{\ell\ell} < 105\ \text{GeV}$	
total bkg	observed
7.5±1.4	13
4.0±1.0	8
1.5±0.5	3
1.1±0.4	2

- Yeah we have an small overshoot on data
- Okay its only about 2 sigma
- **If it is SUSY we should see it in other Analysis**

Z + 2 Jets

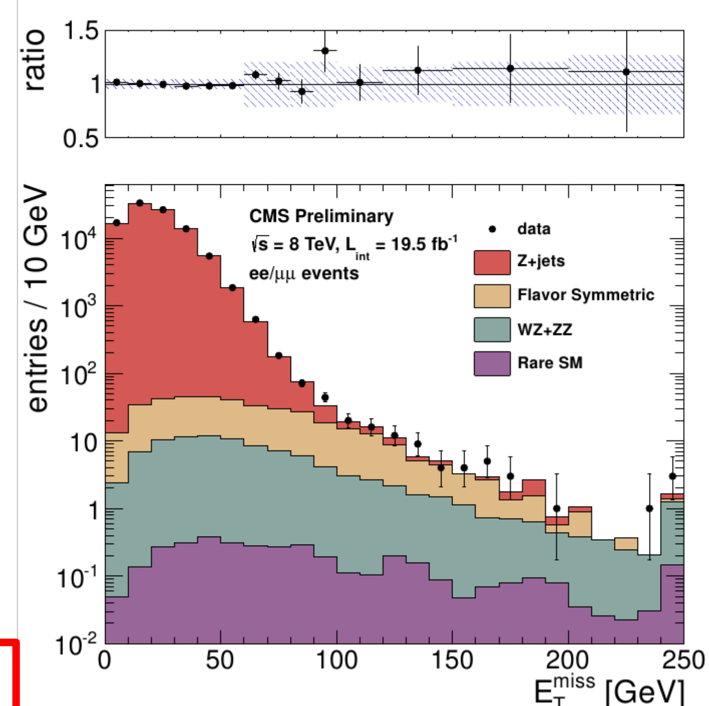


- Select: 2 leptons OSSF + at least 2 Jets
- Major Background ttbar, DY+jets, WZ+ZZ:
  - ttbar ->use flavor symmetry (e mu sample)
  - DY+jets use gamma+jets for the MET shape
  - WZ+ZZ validated MC

Data driven background predictions

- Search region:
  - Veto on events without Z-Candidate (75 GeV < invM(ll) < 105 GeV) (suppress ttbar)
  - Veto on events with b-jets (suppress ttbar)
  - Invariant JetJet Mass has to be in W range (70 GeV < invM(jj) < 111 GeV)
  - Result binned in MET [0-30-60-80-100-120-150-200-inf] where low MET bins are control regions

Result

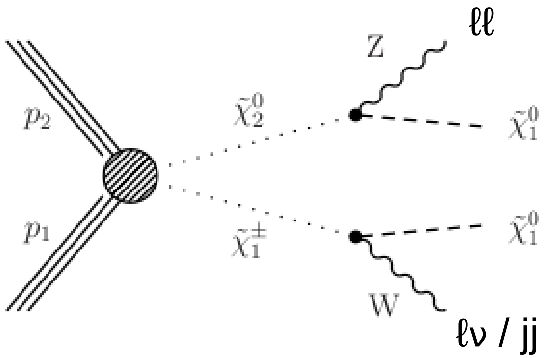


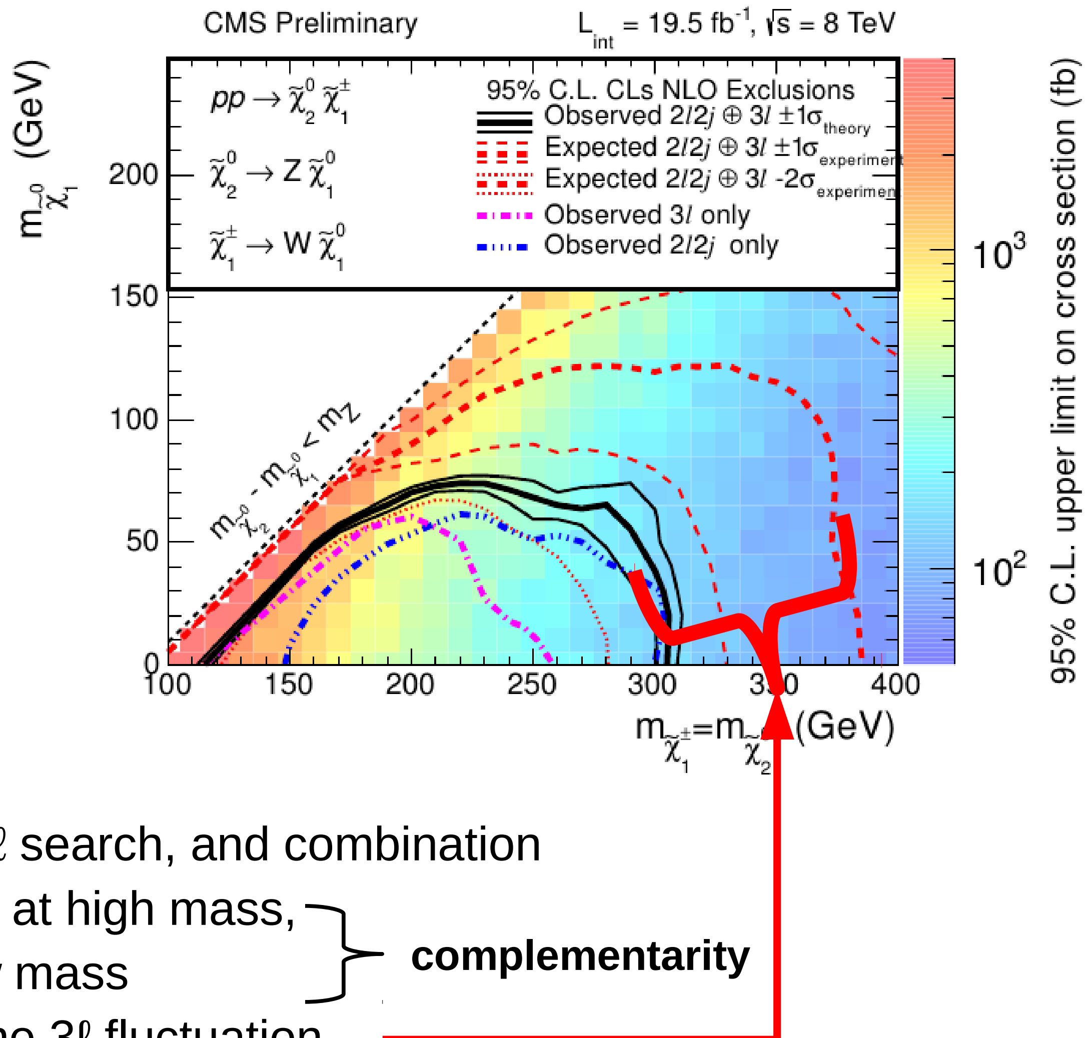
No excess here !

SMS Interpretations into TChiWZ

- Used Channels:
  - 108 channels 3 lepton
  - 8 channels 2 lepton+2 jet

One simplified model (SMS):
TChiWZ





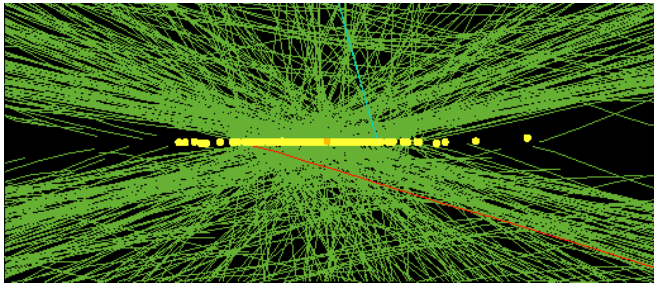
- Results for Z(ℓℓ)V(jj) search, 3ℓ search, and combination
- Z(ℓℓ)W(jj) has better sensitivity at high mass,
- 3ℓ has better sensitivity at low mass

} **complementarity**

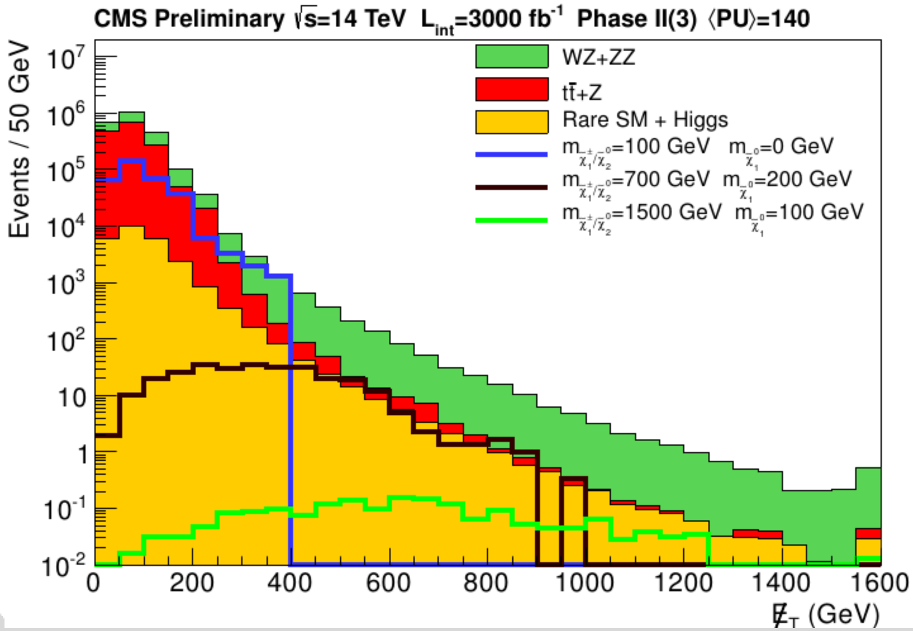
- Small discrepancy driven by the 3ℓ fluctuation

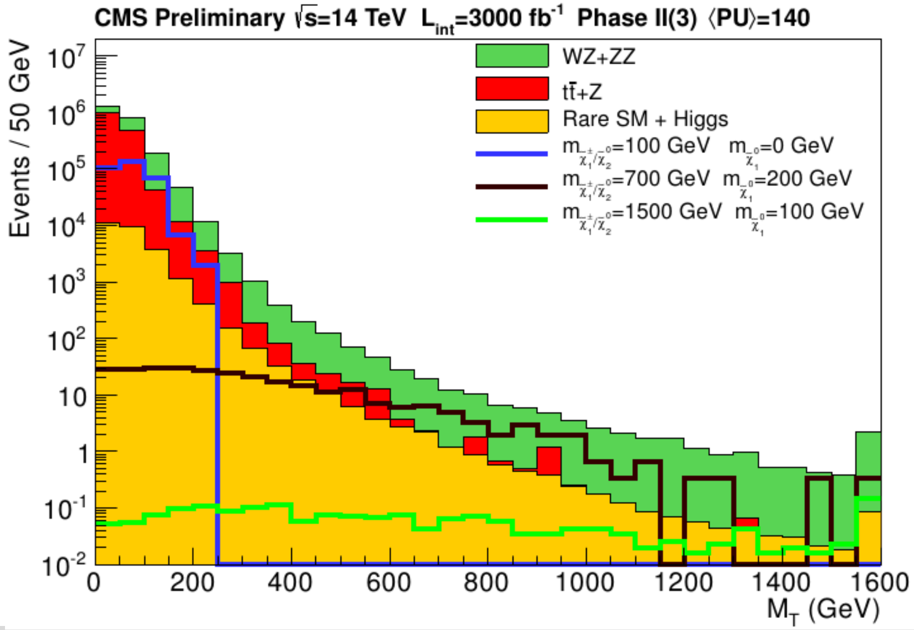
Projection to HL-LHC (2023-2030)

- Have to struggle with multiple interaction per bunch crossing, so called Pile Up (PU)
- Projection of the 3l analysis to 3000 fb^{-1}
  - Use Delphes for detector simulation: “easy” to simulate <PU> = 140
  - Simulate one possible Phase II upgraded CMS Detector
  - Extended search regions in M_T and MET

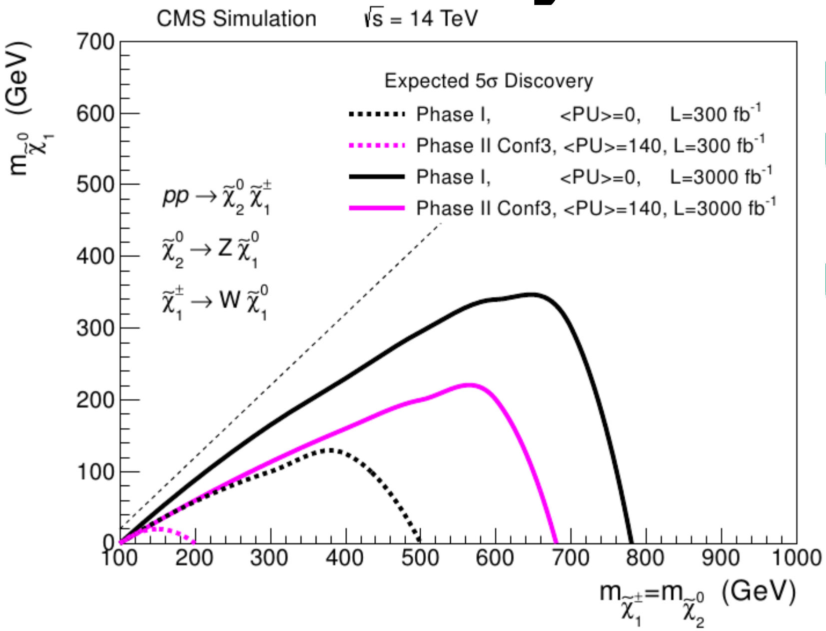


One real event with 78 reconstructed vertices!



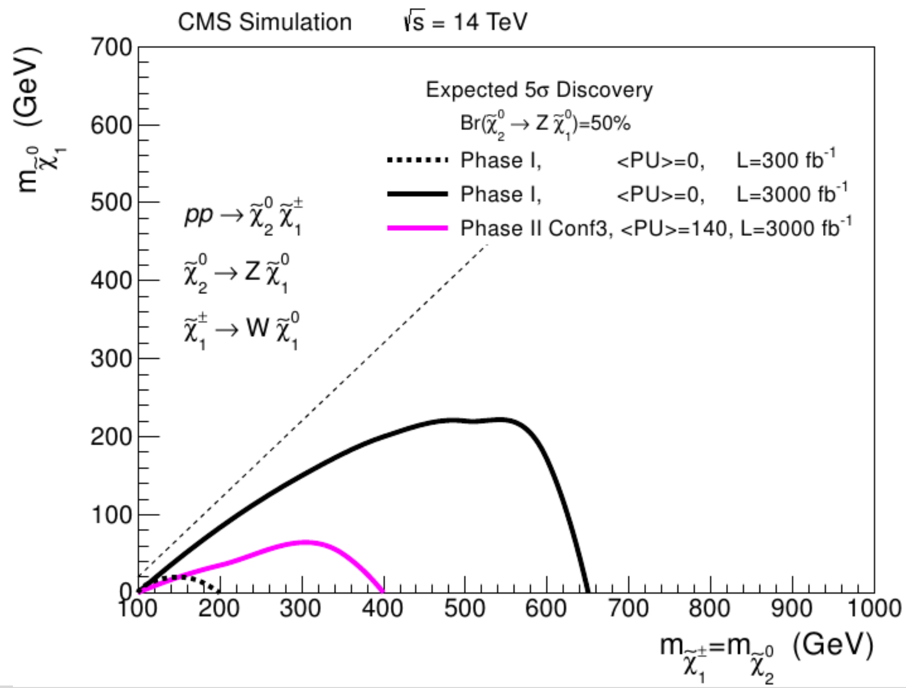


5σ Discovery reach with HL-LHC



- Probe Chargino masses up to 800 GeV
- Going from 300 fb^{-1} to 3000 fb^{-1} gives about 300 GeV in Chargino mass
- <PU> = 140 cost about 100 GeV in mass reach

- More realistic 50% Branching Ratio
- Here <PU> = 140 cost over 200 GeV in mass reach
  - Non-prompts play a important role → Analysis not optimized for this region



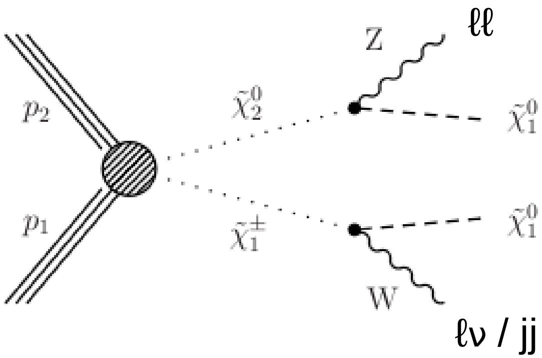
Conclusion

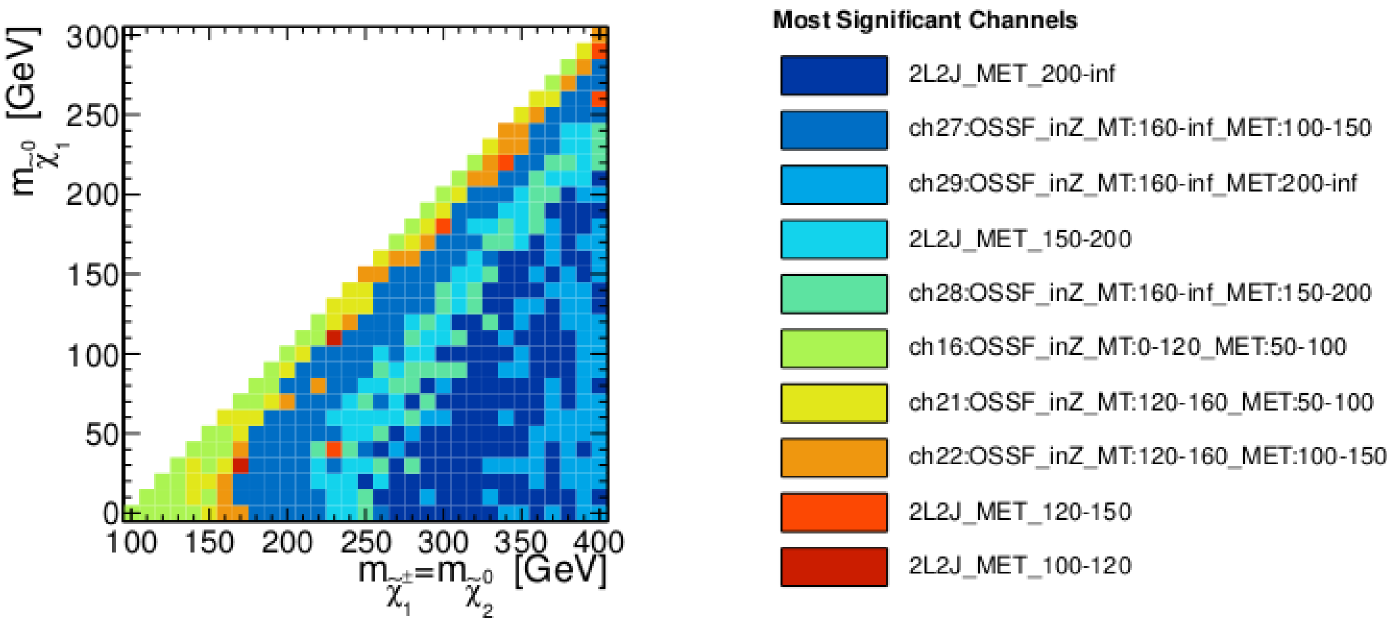
- CMS is an excellent detector for searching in channels with leptons
- No significant deviation from Background prediction can be observed
- Probe Chargino masses up to 300 GeV
- Results published in
  - CMS-PAS-SUS-13-006
- Paper by the end of this year
- Projection to 3000 fb^{-1} increase discovery reach up to 800 GeV
  - Result will be shown today on EFCA-Workshop 1-3 Oct. 2013
  - CMS PAS-FTR-13-014

Thank You

Backup

SMS interpretations

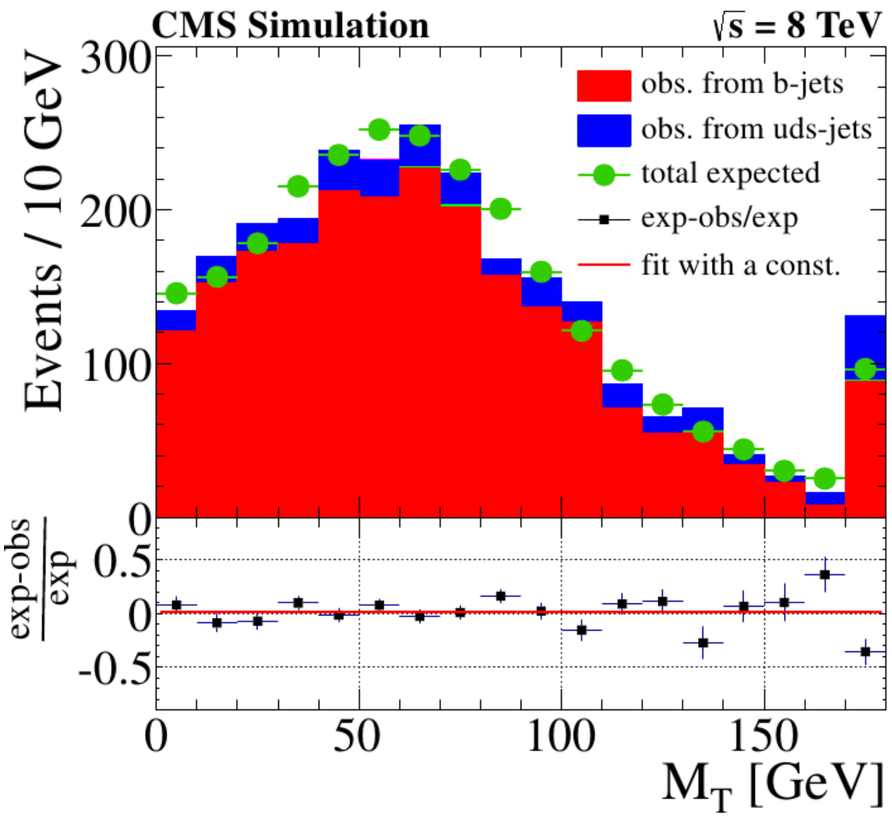


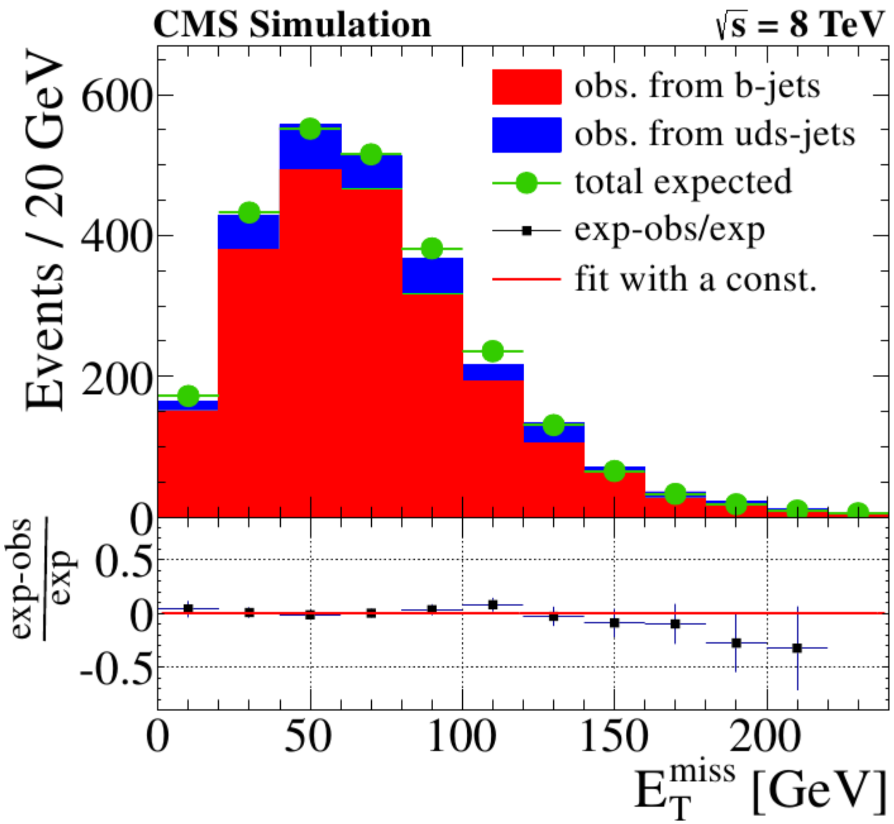


Fake prediction

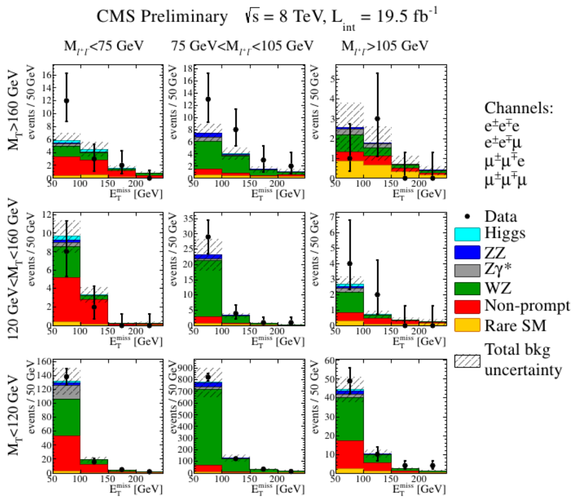
Red is mostly from ttbar

Blue most contribution from Dy+Jets





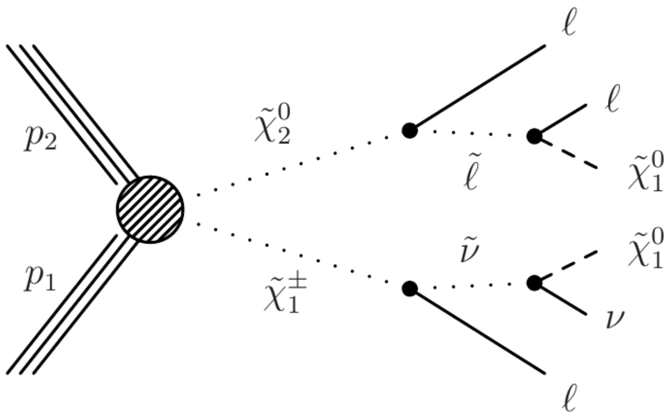
3 leptons Results



3ℓ: OSSF

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV		$75 \text{ GeV} < M_{\ell\ell} < 105$ GeV		$M_{\ell\ell} > 105$ GeV	
		total bkg	observed	total bkg	observed	total bkg	observed
>160	50 – 100	5.8±1.1	12	7.5±1.4	13	2.6±1.2	1
	100 – 150	4.5±1.1	3	4.0±1.0	8	1.8±0.9	3
	150 – 200	1.5±0.4	2	1.5±0.5	3	0.7±0.4	0
	200 – 250	0.81±0.21	0	1.1±0.4	2	0.40±0.24	0
120 – 160	50 – 100	9.6±1.7	8	23±5	29	2.7±0.5	4
	100 – 150	3.3±0.8	2	3.4±0.7	4	0.71±0.22	2
	150 – 200	0.26±0.10	0	0.72±0.19	1	0.38±0.14	0
	200 – 250	0.29±0.11	0	0.36±0.12	1	0.24±0.20	0
0 – 120	50 – 100	132±19	138	776±125	821	45±7	49
	100 – 150	20±4	16	131±30	123	10.0±1.9	10
	150 – 200	4.0±0.8	5	34±8	34	2.5±0.5	4
	200 – 250	1.9±0.4	2	21±7	14	1.2±0.3	4

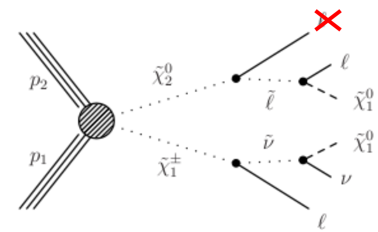
Slep Snu Signature



Decay via Sleptons:

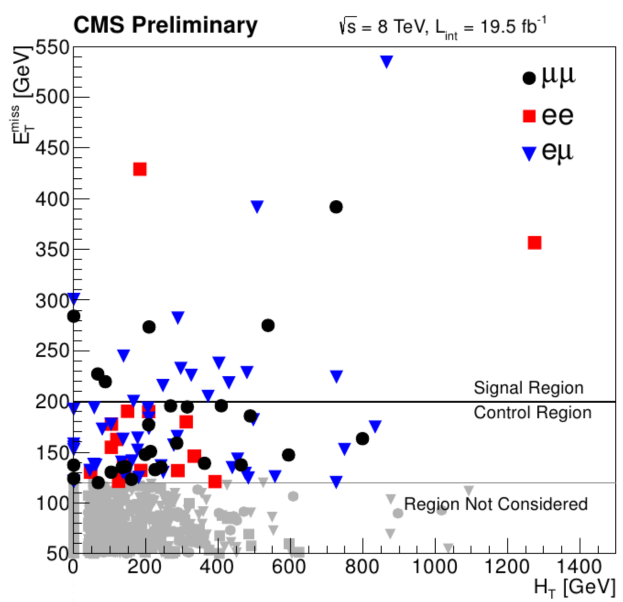
- Final state with 3l and MET from LSP
- Different lepton flavor composition possible
- Wide range of possible final states (like enhanced taus, ...)

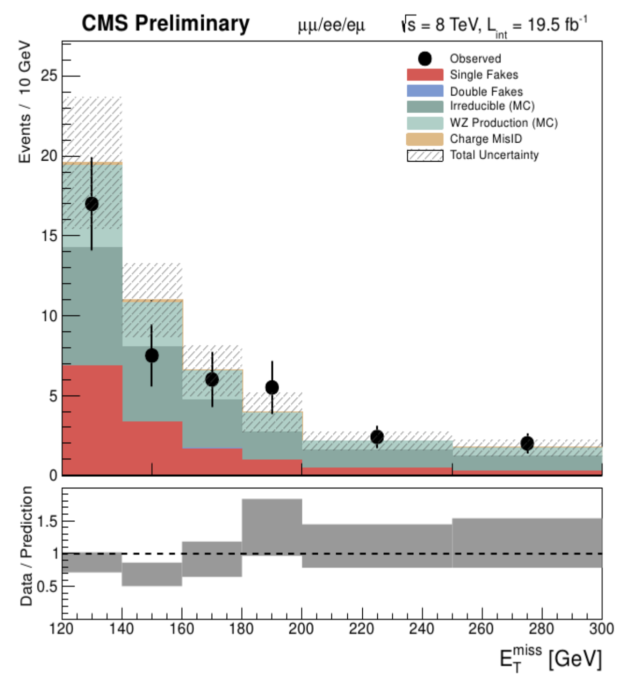
2 leptons same sign (SS)



- Major Background WZ, fakes, misidentified sign:
  - WZ validate MC in control region (inverted Z-veto)
  - Fakes determine fake rate in side-band
  - Misidentified sign (electrons), determine in Z-> ee and apply on 2l OS sample
- Search region:
  - Require Z-veto
  - 3 lepton veto
  - MET >200

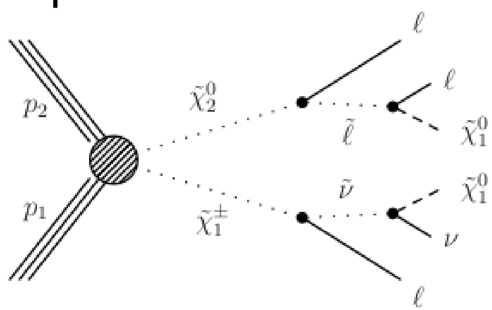
Data and prediction agrees well → Set limits on SMS

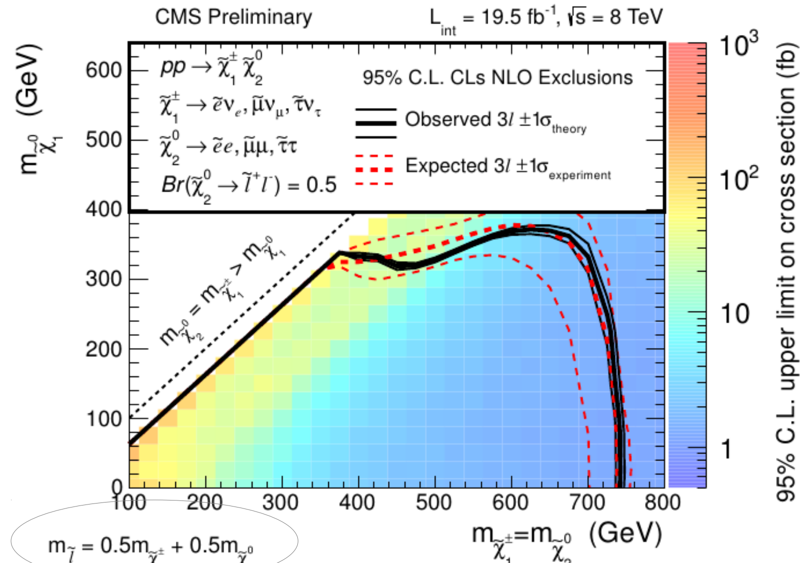




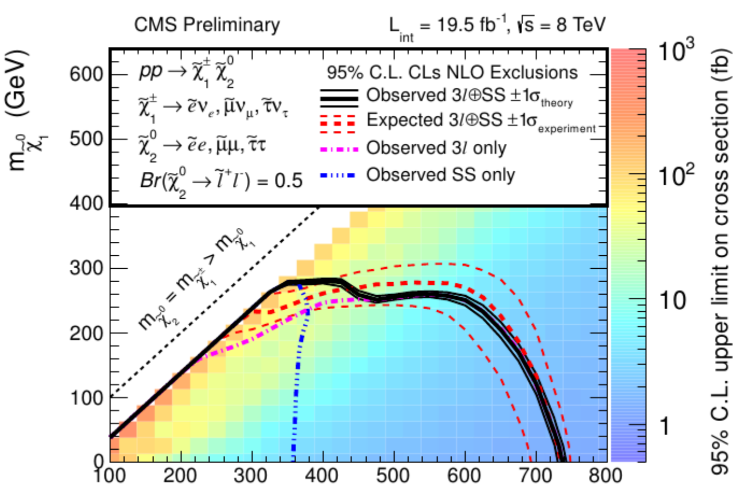
Other Interpretations

- There are many SMS under discussion.
- On this slide interpretation into TChiSlepSnu is shown
- Result depends on slepton mass

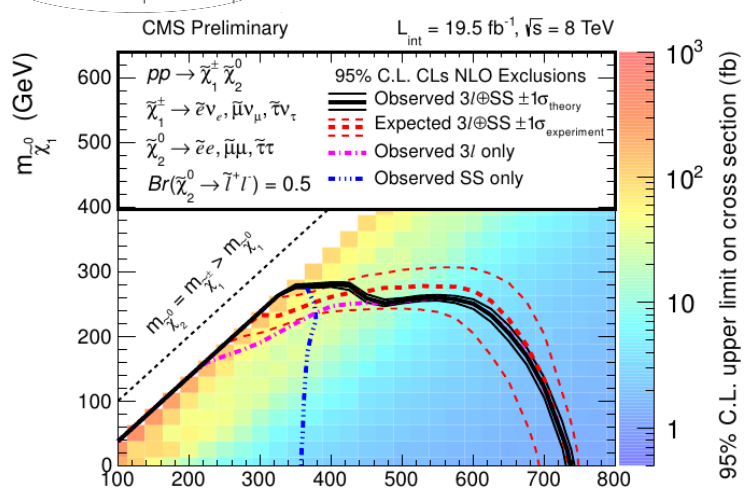




$m_{\tilde{l}} = 0.5 m_{\tilde{\chi}_1^\pm} + 0.5 m_{\tilde{\chi}_1^0}$



$m_{\tilde{l}} = 0.05 m_{\tilde{\chi}_1^\pm} + 0.95 m_{\tilde{\chi}_1^0}$



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Other Interpretations

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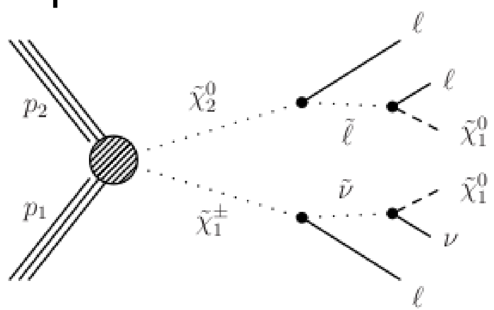

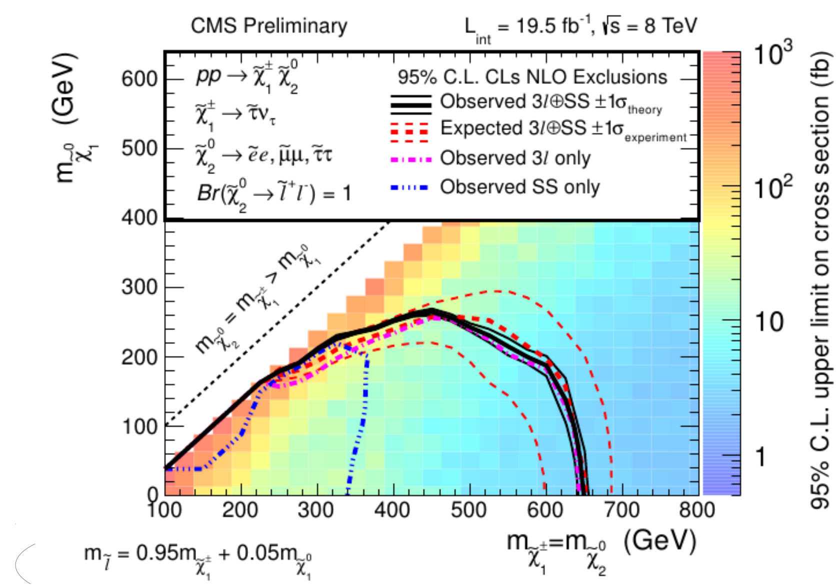

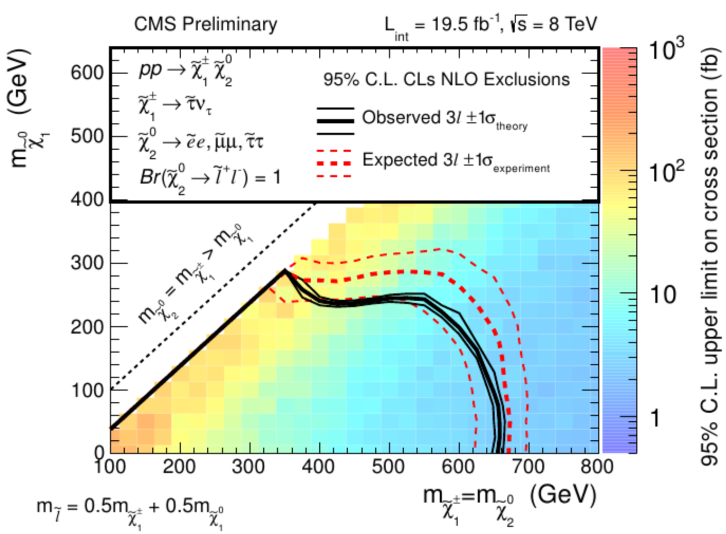

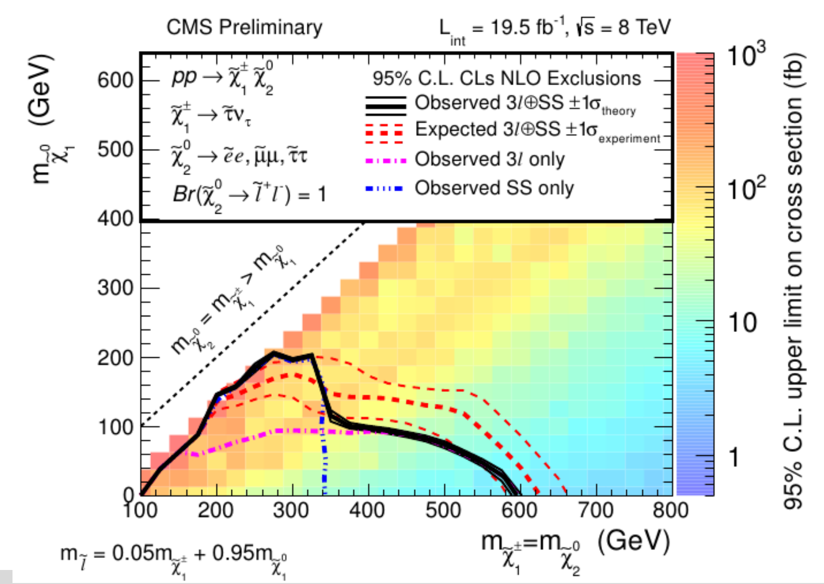

Other Interpretations

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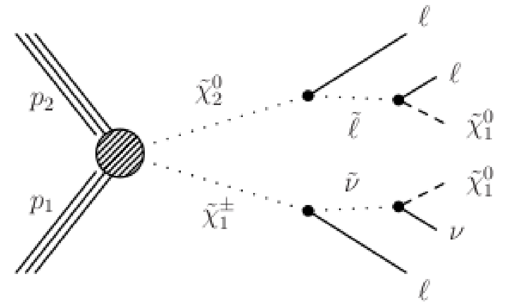
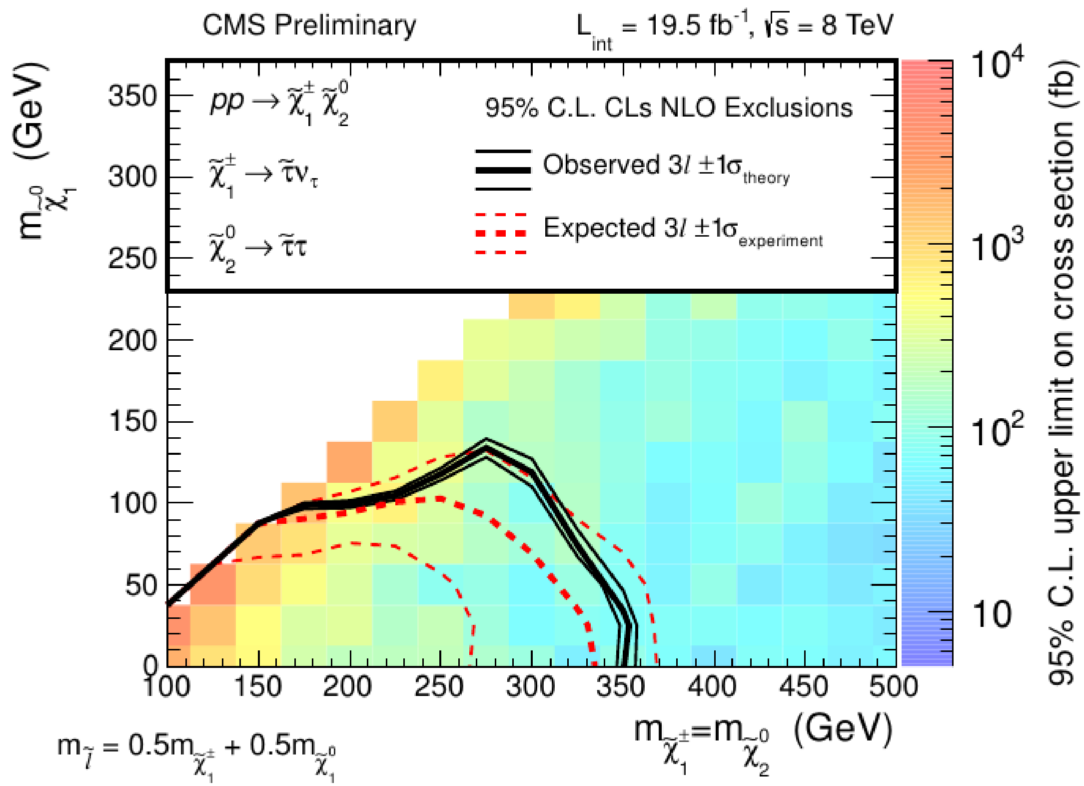
- Result depends on slepton mass





Phase II upgrade search region

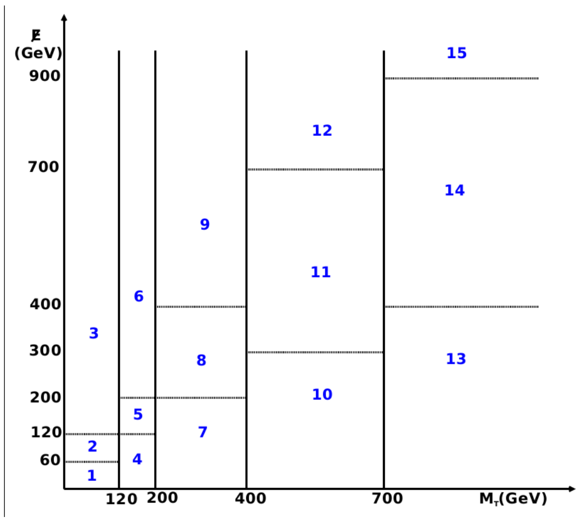


Table 2: Standard model prediction for the different scenarios

Selection in GeV		PhaseI $<PU>=0$ yield $\pm$ uncert.	PhaseI $<PU>=140$ yield $\pm$ uncert.	PhaseII Conf3 $<PU>=140$ yield $\pm$ uncert.
$0 < M_T < 120$	$0 < \not{E}_T < 60$	$7.3\times10^5 \pm 7.1\times10^4$	$8.0\times10^5 \pm 1.2\times10^5$	$9.3\times10^5 \pm 1.2\times10^5$
$0 < M_T < 120$	$60 < \not{E}_T < 120$	$1.8\times10^5 \pm 1.8\times10^4$	$8.4\times10^5 \pm 1.2\times10^5$	$9.3\times10^5 \pm 1.1\times10^5$
$0 < M_T < 120$	$120 < \not{E}_T < \infty$	$5.6\times10^4 \pm 7.7\times10^3$	$3.3\times10^5 \pm 7.4\times10^4$	$3.3\times10^5 \pm 7.3\times10^4$
$120 < M_T < 200$	$0 < \not{E}_T < 120$	$7.9\times10^3 \pm 796$	$7.7\times10^4 \pm 7.0\times10^3$	$8.2\times10^4 \pm 7.4\times10^3$
$120 < M_T < 200$	$120 < \not{E}_T < 200$	$1.2\times10^3 \pm 213$	$4.0\times10^4 \pm 7.1\times10^3$	$4.3\times10^4 \pm 7.4\times10^3$
$120 < M_T < 200$	$200 < \not{E}_T < \infty$	359 ± 84	$5.7\times10^3 \pm 2.3\times10^3$	$4.8\times10^3 \pm 2.1\times10^3$
$200 < M_T < 400$	$0 < \not{E}_T < 200$	$2.3\times10^3 \pm 239$	$1.5\times10^4 \pm 1.9\times10^3$	$1.5\times10^4 \pm 2.0\times10^3$
$200 < M_T < 400$	$200 < \not{E}_T < 400$	303 ± 52	$1.6\times10^3 \pm 489$	$1.4\times10^3 \pm 471$
$200 < M_T < 400$	$400 < \not{E}_T < \infty$	24 ± 4.1	69 ± 35	39 ± 12
$400 < M_T < 700$	$0 < \not{E}_T < 300$	249 ± 24	395 ± 58	390 ± 42
$400 < M_T < 700$	$300 < \not{E}_T < 700$	67 ± 13	95 ± 19	100 ± 24
$400 < M_T < 700$	$700 < \not{E}_T < \infty$	1.1 ± 0.4	1.3 ± 0.5	1.4 ± 0.4
$700 < M_T < \infty$	$0 < \not{E}_T < 400$	30 ± 3.0	27 ± 3	27 ± 2.8
$700 < M_T < \infty$	$400 < \not{E}_T < 900$	32 ± 5.3	31 ± 5	30 ± 4.9
$700 < M_T < \infty$	$900 < \not{E}_T < \infty$	1.4 ± 0.4	1.5 ± 0.47	1.2 ± 0.37

Delphes Simulation

- Delphes is a very fast tool for running a detector simulation
- It is used by several other groups and compared to results obtained with fullsim
  - $\rightarrow$ good agreement has been observed
- Four different scenarios are studied for EFCA
  - CF1PU0: the PhaseI detector with 0 PileUp events
  - CF1PU140: the PhaseI detector with 140 PileUp events
  - CF3PU140: possible PhaseII detector with 140 PileUp events
    - Replacement of EE and retrofitting of HE
    - Use of EE shashlik resolution and transverse size
    - Increase of phi segmentation for HE by factor of four
    - Use of the Phase II tracker in barrel and endcap;
    - Extension of μ system to full coverage from $1.6 < |\eta| < 2.4$
  - CF4PU140: possible PhaseII detector with 140 PileUp events
    - like CF3PU140
    - tracker cover $|\eta| < 4$

LHC roadmap

Period [approx.]	Energy [TeV]	Lumi [/fb]	<PU>
2012	8	~25	~20
2015 – 2017	13-14	~100	~25
2020 – 2022	14	~300	~50
2023 – …	14	~3000	~140

→ Phase0 (2015 – 2017)
→ PhaseI, conf0 (2020 – 2022)
→ PhaseII (2023 – …) → Conf3, Conf4

- **PhaseII, conf3:**
  - Use PhaseII tracker in Barrel & Endcap
  - Replace EE & retrofitting of HE
  - Increase φ segmentation in HE
  - Full muon coverage from $1.6<|\eta|<2.4$
- **PhaseII, conf4 [in add. to Conf3]:**
  - TRK+Calo+MC extended up to $|\eta|=4$
  - Complete replacement of endcap