# SUSY Searches in Trilepton Final States at the LHC
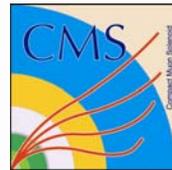
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for the ATLAS & CMS Collaborations

Outline

- Trilepton channel studied in ATLAS & CMS with full and fast detector simulations

Benchmark points for detailed analysis

	M0	M1/2	tanβ	A0	sign	σ [pb]	
SU2 (ATLAS)	3550	300	10	0	+1	4.5	Focus point
SU3 (ATLAS)	100	300	6	-300	+1	18.6	Bulk region
LM9 (CMS)	1450	175	50	0	+1	24.6	Light neutralino
SU4 (ATLAS)	200	160	10	-400	+1	262	Low mass SUSY

- **Exclusive Searches** with direct Gaugino production:
  Neutralino-Chargino (golden channel)
  $\chi_2^0 \chi_1^\pm \rightarrow$ 3l + no jets + MET
  SM equivalent : ZW → 3l +MET

- **Inclusive Search**: any decay originating from SUSY
  particles that gives 3l+Njets +MET

Motivation

- Total SUSY cross sections strong function of $m_{1/2}$

- Main channels: gluinos production

  squarks/sleptons production

  gauginos production

$$m(\tilde{g}) \sim 2.7 \cdot m_{1/2}$$

$$m(\chi_2^0) \sim m(\chi_1^\pm) \sim 0.8 \cdot m_{1/2}$$

- Gaugino production dominant at focus point region (large m_0)
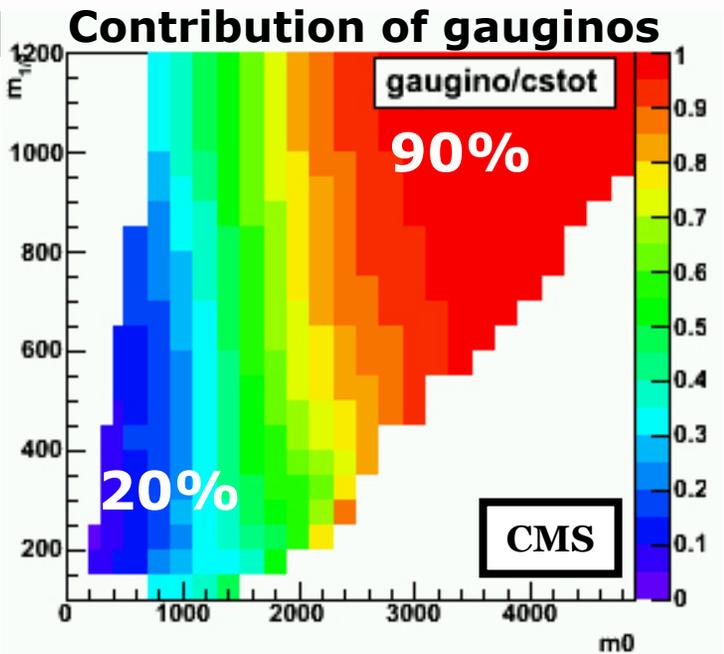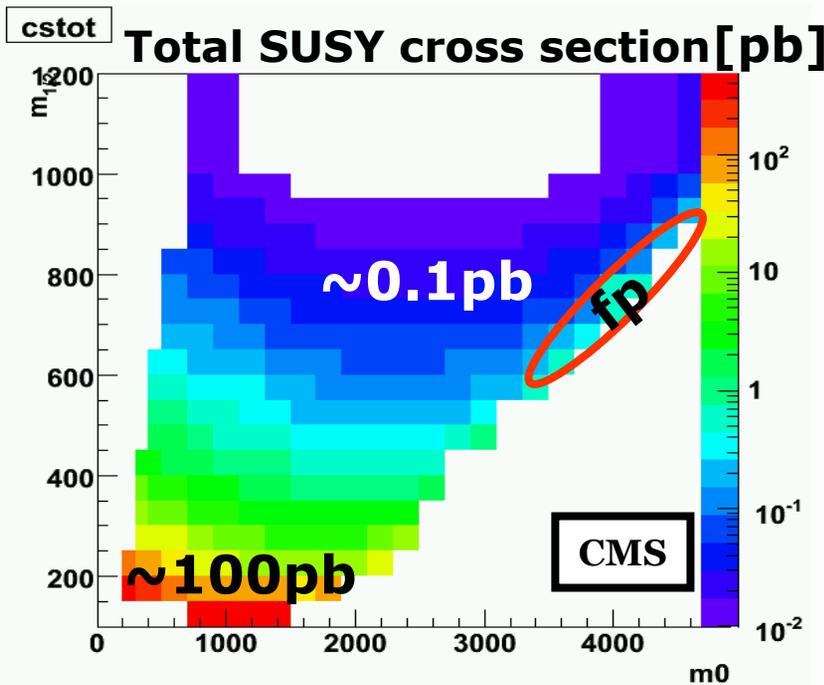
3 body:
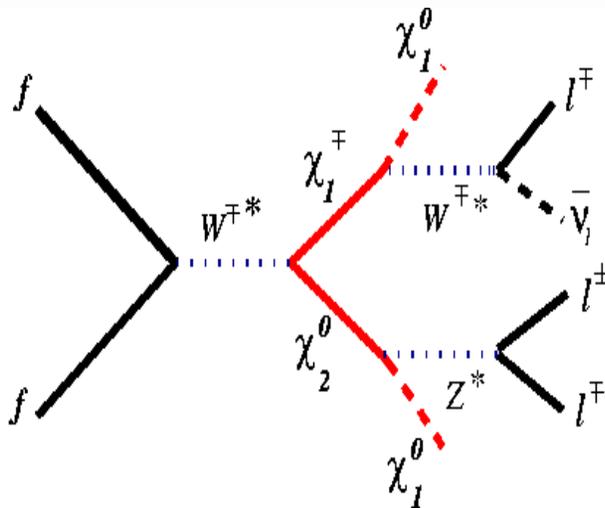
**Dilepton invariant mass**

$$M_{ll}^{max} = m_{\chi20} - m_{\chi10}$$

Fast sim.

$\chi_2^0 \to \chi_1^0 + ll$
$m_{1/2} = 250$
$m_0 = 1450$
$tan\beta = 50$
$m_{\chi_1^0} = 99\ GeV$
$m_{\chi_2^0} = 186.4\ GeV$

CMS

CMS

$$BR(\chi^{20}) \times 2l$$

$tan\beta = 50$

2 body:

$$Minv_{max} = \textbf{sqrt}((m^2_{\chi20} - m^2_{\sim l})(m^2_{\sim l} - m^2_{\chi10})/m^2_{\sim l})$$

Fast sim.

$\chi_2^0 \to \tilde{l}l \to \chi_1^0 + ll$
$m_{1/2} = 250$
$m_o = 60$
$tan\beta = 10$
$m_{\chi_1^0} = 94\ GeV$
$m_{\chi_2^0} = 180\ GeV$
$m_{\tilde{l}} = 119\ GeV$

CMS

CMS

$$BR(\chi^{20}) \times 2l$$

$\chi_2^0 \to \tilde{l}l \to \chi_1^0 + ll$
$tan\beta = 50$
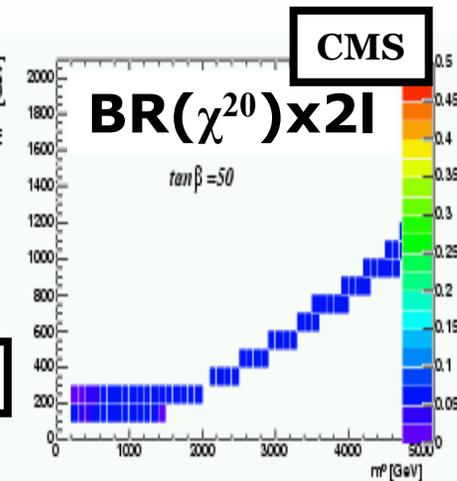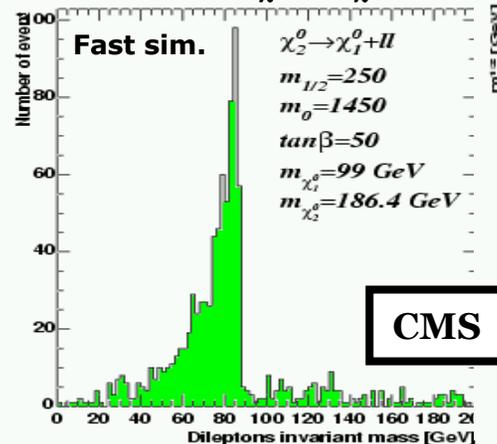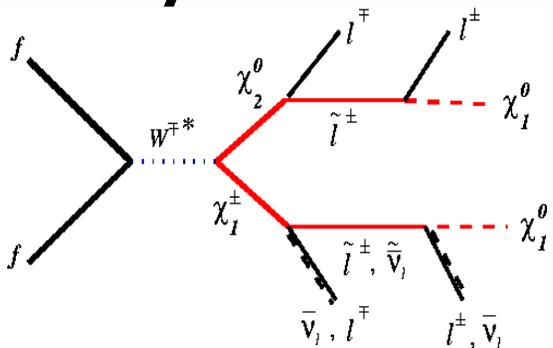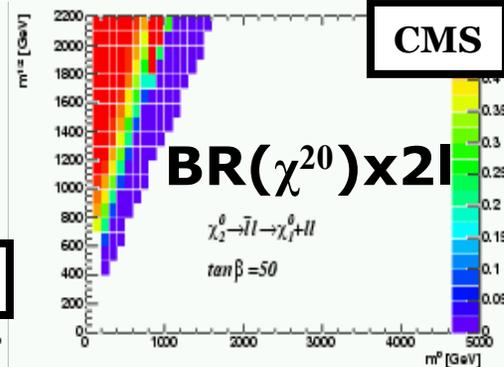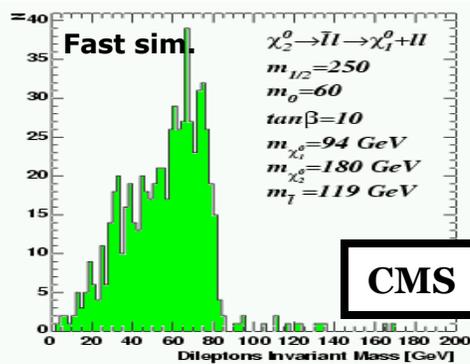
## Cross section of neutralino-chargino production x branching ratio to 3l
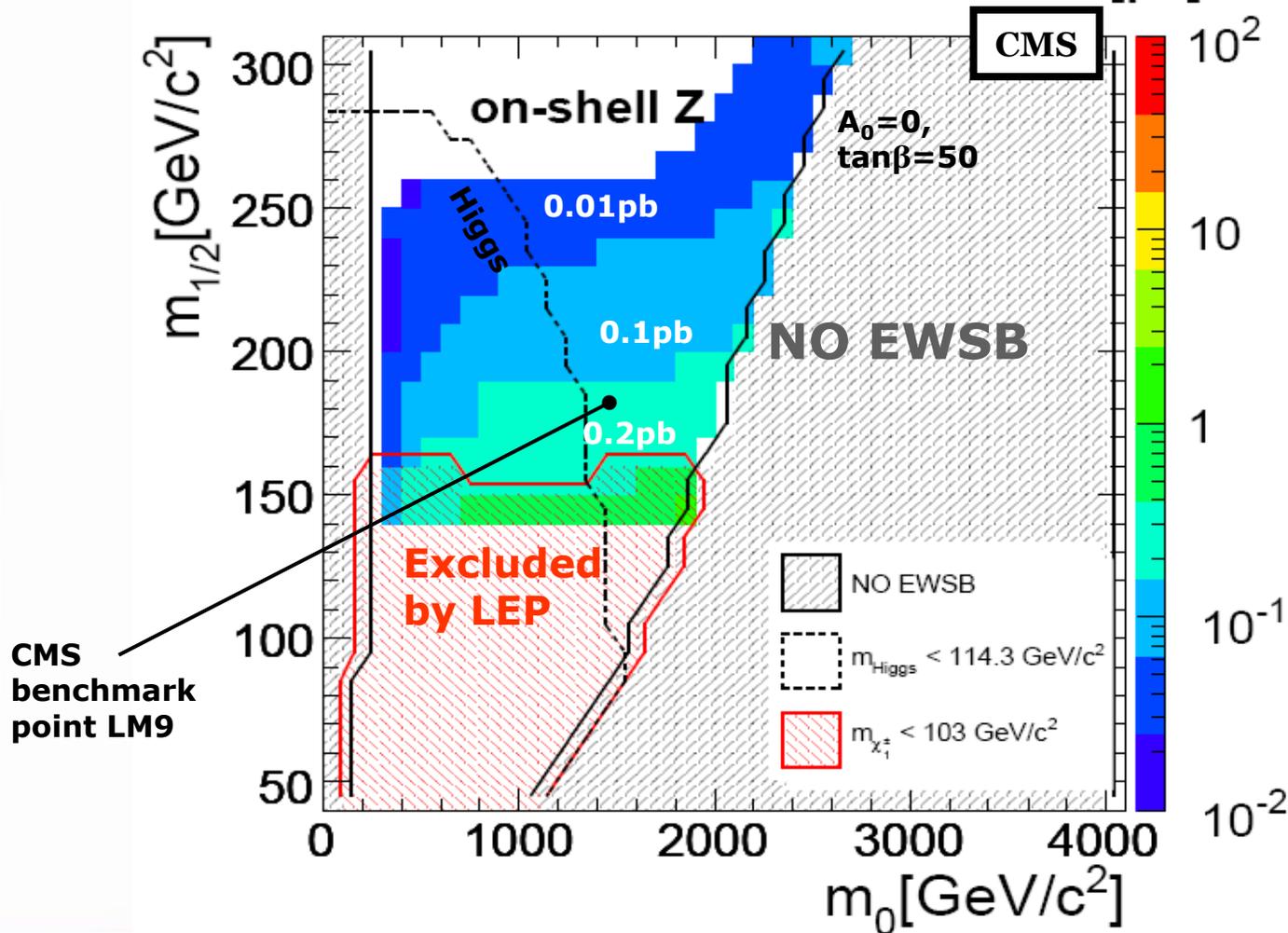
Trilepton Backgrounds

Channel	$[N_{Events}/fb^{-1}]$	
$\chi^{20}\chi^{1\pm} \rightarrow$ **3l** (M0=1450,M1/2=175,tanβ=50)	130	NLO
ZW→3l+ν (irred.)	1680	NLO
ZZ →4l	160	NLO
Z/γ*+jets→2l+jets	$12 \cdot 10^6$	NLO
ttbar →2l+jets	88000	NLO
Wt+jets →2l+jets	10000	NLO
WW+jets →2l+jets	20000	LO
Susy-background	13100	NLO
W+jets →1l+jets	$1.8 \cdot 10^7$	LO
QCD	$2.4 \cdot 10^{10}$	LO

Reconstruction of Leptons

Lepton has to be isolated from jets

Isolation by tracks: $\Sigma P_t < 1.5\ GeV$ in $\Delta R < 0.3$

Isolation by calo (muons): $\Sigma E_t < 5\ GeV$ in $\Delta R < 0.3$

Electron id by likelihood: E/P , H/E , E_{3x3}/E_{5x5}, $\Delta\eta$, $\sigma_{\eta\eta}$

P_t of first muon

CMS

Z/γ^*jets ttbar 3l

P_t of third muon

CMS

muons
— LM9 3l
— bkg: ZW
— bkg: ttbar
— bkg: Z/γ*jets

ZW
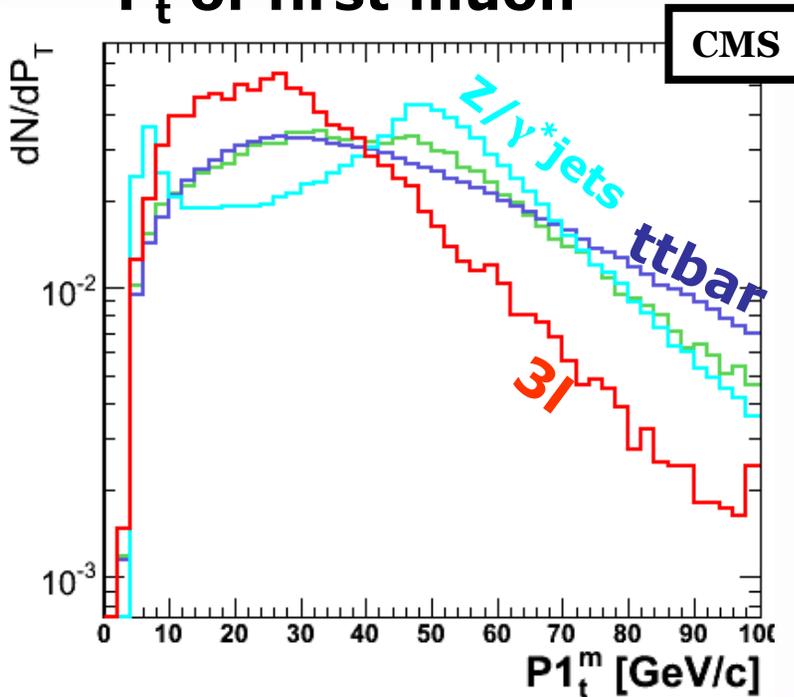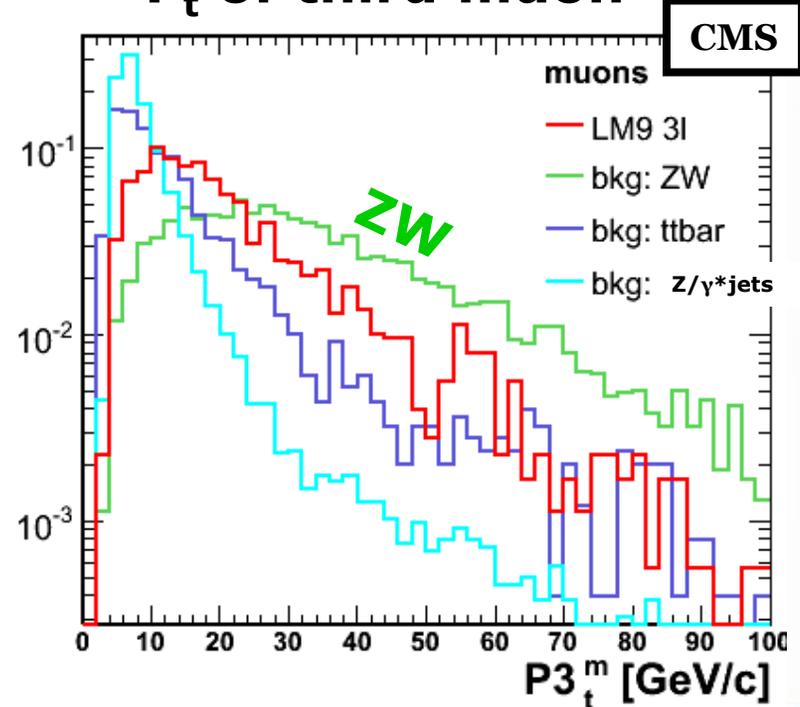
Jet multiplicity shapes
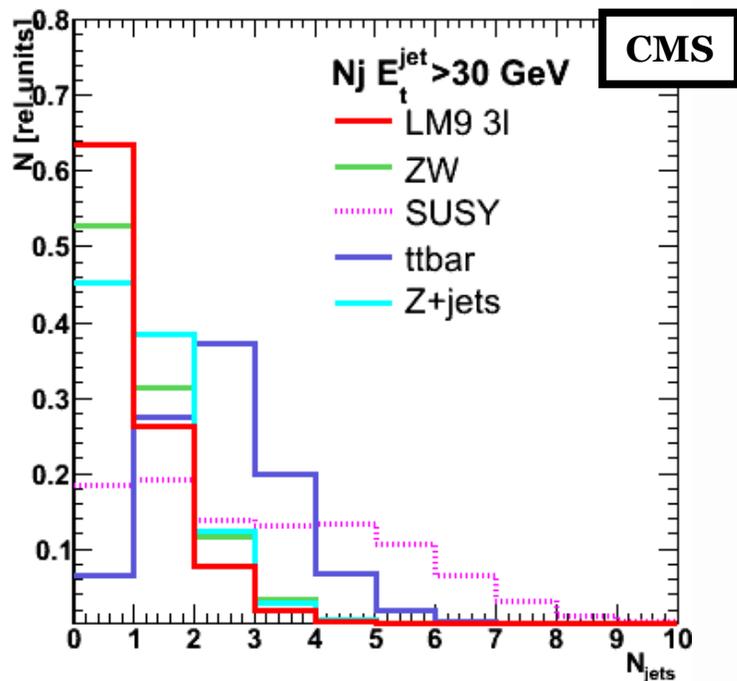
Signal has small MET
due to light LSP and small mass difference $\Delta m(\chi_{20}-\chi_{10})$

Missing ET
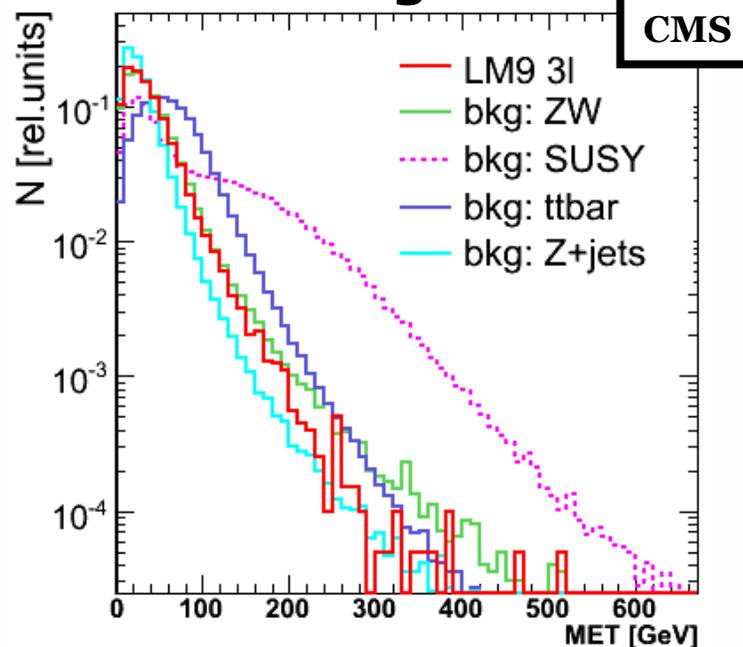
• 1/3 of signal evts have ISR

• Large jet multiplicity for ttbar and Z+jets reduce background

Invariant Mass Reconstruction

CMS full simulation
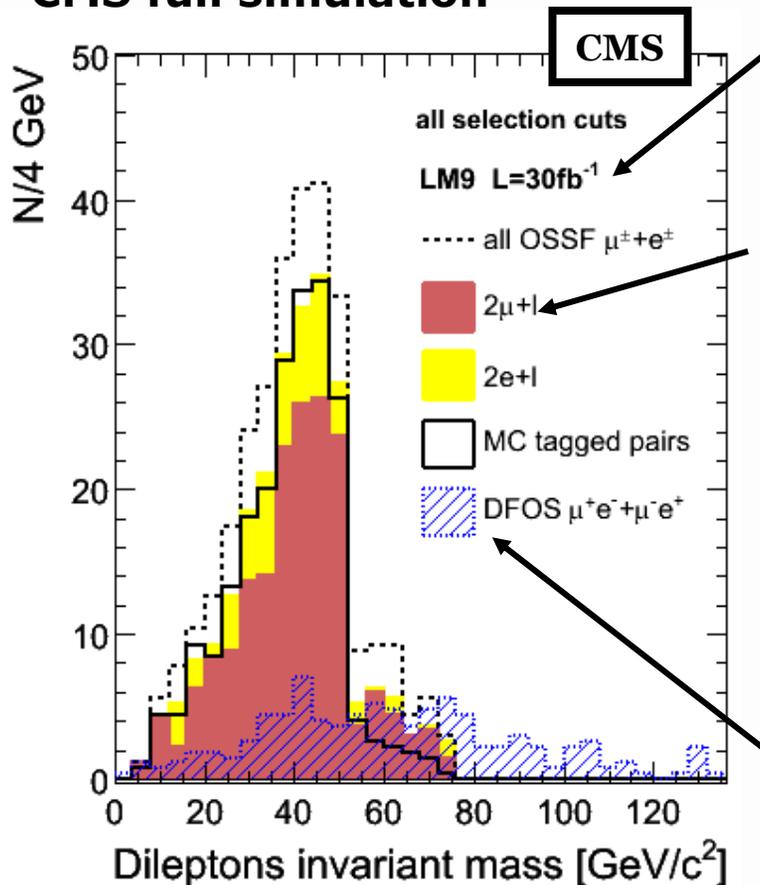
Different possibilities:

All OSSF combinations-> largest significance

high Pt pairs.
good efficiency to the MC tagged pairs.

low Pt pairs
difficult – moves Z peak to the signal region

DFOS related to the combinatorial bkg., useless here

Selection Cuts

<u>Trigger selection (LV1):</u> (Trileptons **M0=1450,M1/2=175,tanβ=50)**)
        dimuon stream   ($P_t >$ 3 *GeV*) : ~75%
        dielectron stream   ($P_t >$ 17 *GeV*): ~25%

<u>Offline Selection:</u>

- No central Jets with $E_t >$ 30 *GeV*, $\eta <$ 2.4

- Two isolated opposite sign same flavour (OSSF) leptons in $\eta <$ 2.4 with: P_t of muons   > 10 *GeV*
                                              P_t of electrons > 17 *GeV*

- Invariant mass of leptons below Z-Peak Mll < 75 *GeV*

- Third isolated lepton Pt > 10 *GeV*, $\eta <$ 2.4

Mll result plots for LM9 (30fb⁻¹)

CMS fast sim.

2e+l
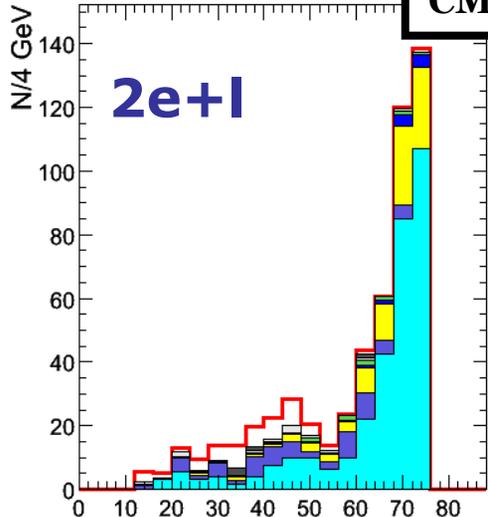
final state	Nev signal	Nev bkg	s/sqrt(s+b)
2e+l	51	501	2.3
2µ+l	179	1016	5.6
All OSSF	297	1517	6.6
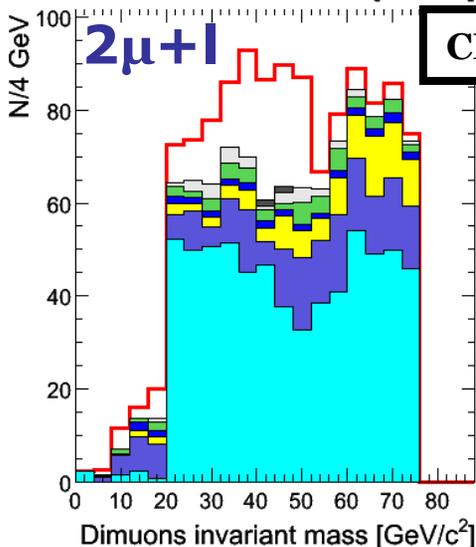
All OSSF leptons (e,µ)

2µ+l

LM9 ($m_{1/2}$=175 m_0=1450 tanβ=50)

$\chi_2^0 + \chi_1^\pm \rightarrow 3l\nu\,\chi_1^0$

L=30fb⁻¹

— all $\mu^\pm + e^\pm$
▭ LM9 3l
▪ bkg: WWj
▫ bkg:SUSY
▪ bkg: Wtjets
▪ bkg: ZZ
▪ bkg: ZW
▪ bkg: ttbar
▪ bkg: Z+jets
······ all $\mu^+e^- + \mu^-e^+$

all selection cuts

CMS fast simulation

mSUGRA $A_0=0$ $\tan\beta=10$

mSUGRA $A_0=0$ $\tan\beta=50$
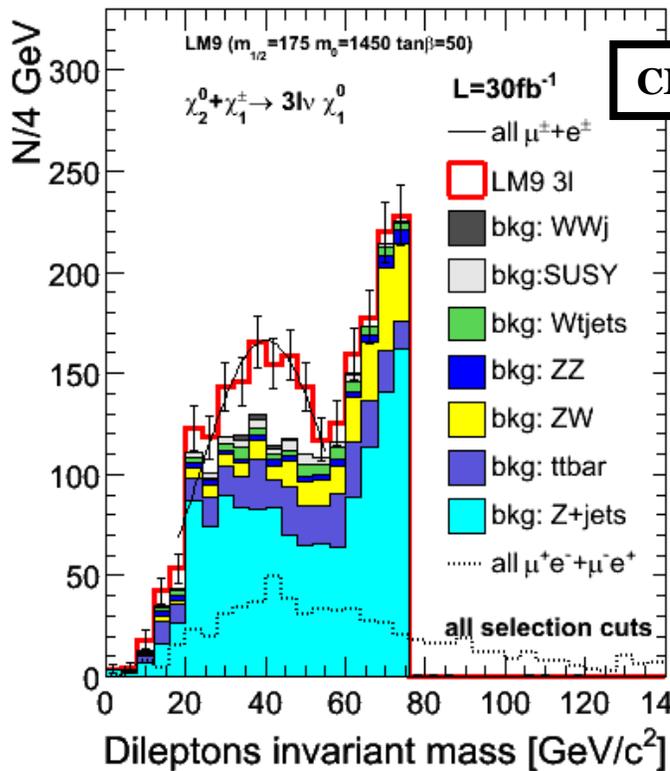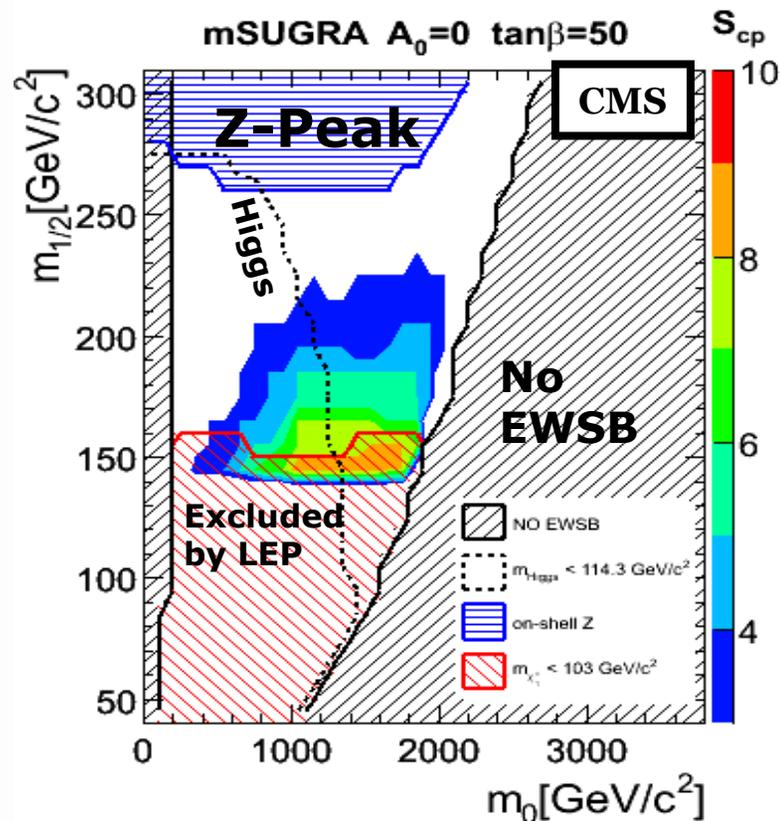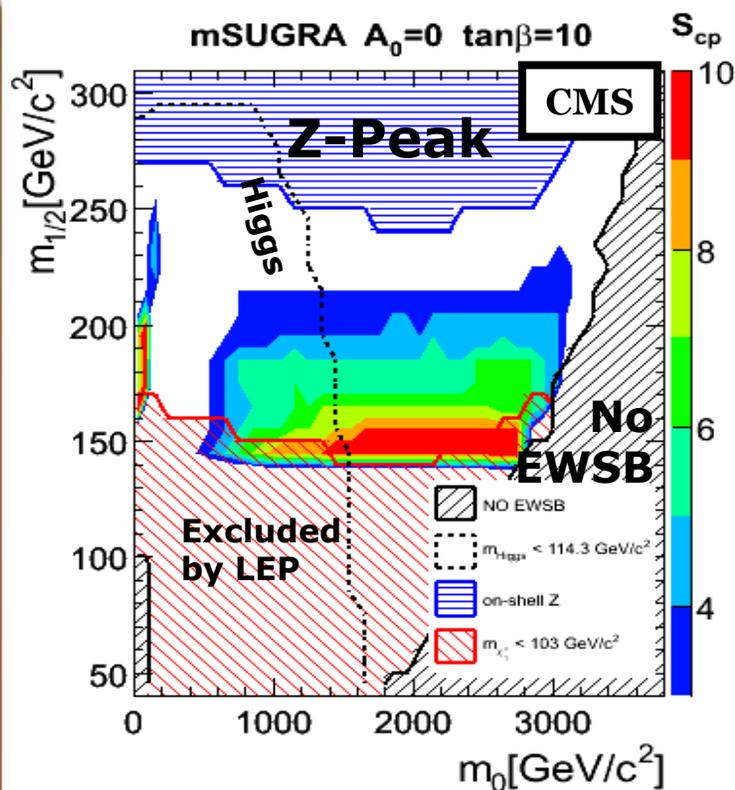
LM9 [CMS] **: O(30fb⁻¹)   Focus Point** [ATLAS] **: O(100 fb⁻¹)**

(M0=1450,M1/2=175,tanβ=50)   (M0=3550,M1/2=300,tanβ=10)

$N_{trilepton}$/fb⁻¹: 130 $N_{trilepton}$/fb⁻¹: 30

Inclusive Search in Trileptons

Inclusive = any decay originating from SUSY particles that gives three leptons (+jets) in the final state


Backgrounds:

ttbar, ZW, ZZ, Zb, Zγ, WW
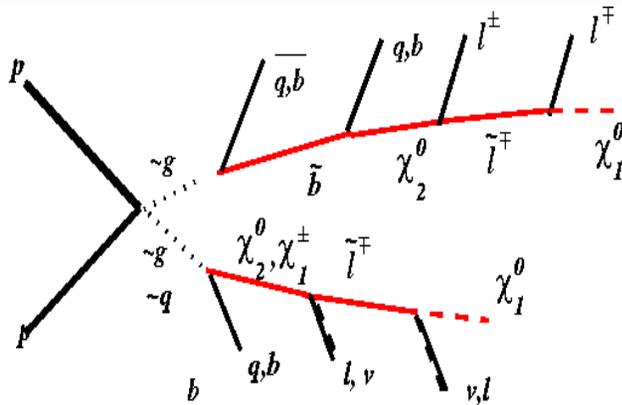
5σ-Discovery reach: [ATLAS]

O(10-15fb^{-1})
[SU2]:(M0=3550,M1/2=300,tb=10)

O(1-2fb^{-1})
[SU3]:(M0=100,M1/2=300,tb=6)

O(100-150pb^{-1})
[SU4]:(M0=200,M1/2=160,tb=10)

ATLAS Preliminary

SU3

Signal only

ATLAS preliminary

theoretical endpoint at ~ 100 GeV

Events/10 fb^{-1}

OSSF Dilepton Edge (GeV)

Outlook
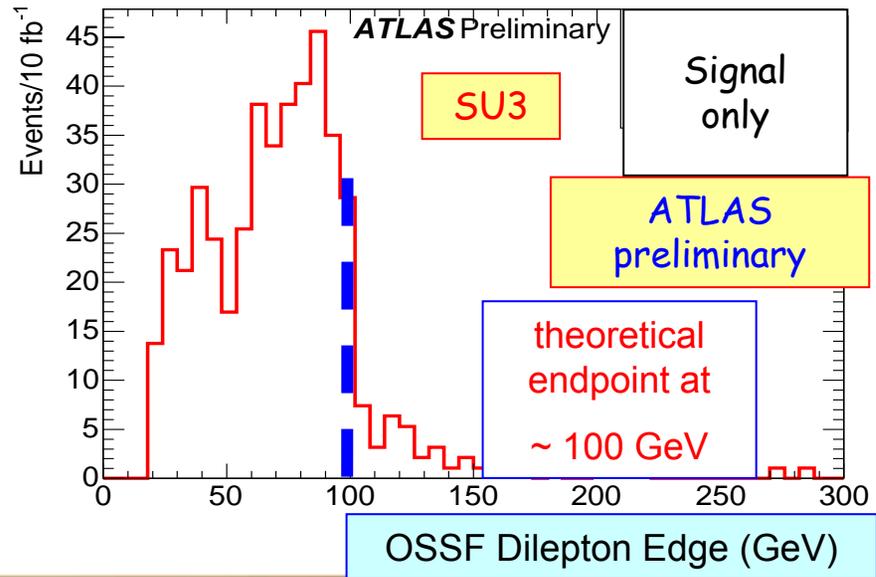
- **The 5σ trilepton signal from direct neutralino chargino production can be observed for $m_{1/2}$<200 GeV, m_0>1000 GeV in mSUGRA mass plane**

- **The discovery reach is limited by isolation efficiency of leptons and low missing ET for the signal**

- **Observation of trilepton signal from gauginos production is complimentary to gluino (squarks) cascade decays and allows to identify region in mSUGRA parameter space**

BACKUP SLIDES

Cut Flow Table

| channel	N_{ev}	L1	HLT	NoJets	$N^l_{rec} > 2$	$N_{isolated} > 2$ $M_{ll} < 75$GeV
LM1	2640	1795 (68%)	1544 (89%)	864 (56%)	337 (39%)	70 (21%)
LM7	1540	1360 (88%)	1250 (92%)	738 (59%)	310 (42%)	91 (29%)
LM9	3700	3182 (86%)	2896 (91%)	1740 (60%)	851 (49%)	231 (27%)
ZW	$5 10^4$	39000 (79%)	36000 (92%)	$1.9 10^4$ (53%)	4900 (26%)	173 (3.5%)
ZZ	4800	3860 (80%)	3530 (91.5%)	1681 (48%)	818 (49%)	38 (4.6%)
$t\bar{t}$	$2.6 10^6$	$2.1 10^6$ (81%)	$1.8 10^6$ (86%)	$1.3 10^5$ (7%)	$1.2 10^4$ (9%)	239 (2%)
Zjets(3l)	$6.4 10^5$	$5.1 10^5$ (80%)	$4.5 10^5$ (89%)	$2 10^5$ (44%)	$11 10^4$ (57%)	970 (0.9%)
Wtj	$3. 10^5$	$2.7 10^5$ (90%)	$2.1 10^5$ (78%)	$3.9 10^4$ (18.5%)	4910 (13%)	52 (1%)
WWj	$6. 10^5$	$4.5 10^5$ (75%)	$3.8 10^5$ (84%)	$1.9 10^4$ (50%)	$1.3 10^4$ (68%)	7 (0.05%)
SUSY	$4 10^5$	$3.4 10^5$ (85%)	$2.5 10^5$ (74%)	$1.8 10^4$ (7%)	$1.4 10^4$ (78%)	34 (0.24%)
Wjets(3l)	$4.87 \cdot 10^5$		$1.16 \cdot 10^5$	$9.28 \cdot 10^4$	$1.5 \cdot 10^3$	94
QCD(3l)	$7.37 \cdot 10^7$		$7.37 \cdot 10^4$	$2.22 \cdot 10^3$	$3.01 \cdot 10^2$	<4.9

MET resolution

$$\sigma_{MET}{}^2 = (3.8)^2 + (0.97 \ \sqrt{\Sigma E_T})^2 + (0.012\Sigma E_T)^2$$
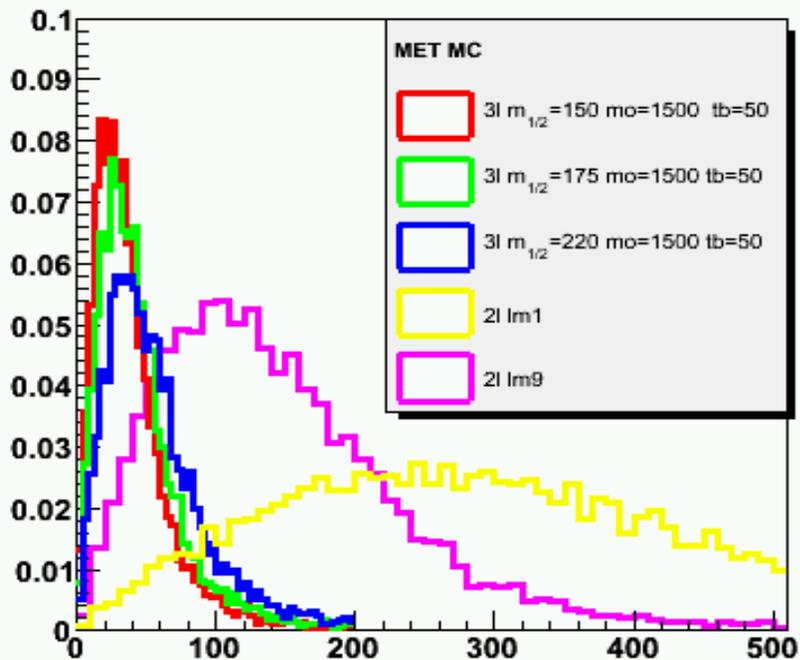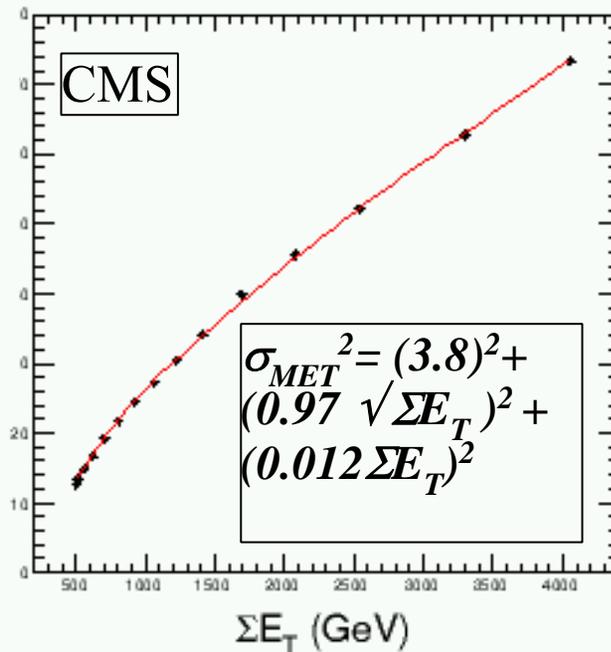
Backup: TEVATRON

Dataset	LHC [pb]	Tev [pb]
Trilepton	6.3	0.56
Zjets(mll>10)	~70000	~6600
WZ	16.7	1.27