Search for SUSY using Dilepton Events

3rd Annual Workshop of the Helmholtz Alliance "Physics at the Terascale"

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Contents

Inclusive SUSY search using

- **same-sign di-lepton* events**
  (D. Sprenger, work in progress)

- **opposite-sign di-lepton* events**
  (N. Mohr)

*) selecting electrons and muons

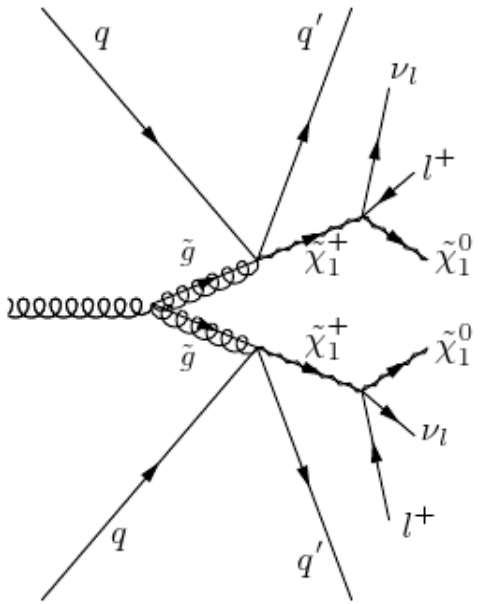
Same-sign Lepton Analysis

Same-sign lepton analysis

- SUSY discovery analysis
- Benchmark point LM0 (MSSM, mSUGRA parametrization)
- Look for events with at least 2 same-sign leptons in final state
- Pure counting experiment
- Low SM background

LM0 parameters

$m_0 = 200$ GeV
$m_{1/2} = 160$ GeV
$A_0 = -400$ GeV
$\tan\beta = 10$
$\text{sign}(\mu) = +1$
$\sigma_{LO} = 110.0$ pb / $\sigma_{NLO} = 151.8$ pb



Example:
gluino pair production

Used Cuts

Select events with at least

- 2 same-sign leptons (e or μ) with $p_T > 10$ GeV
- 3 jets ($p_T > 50$ GeV)
- 100 GeV of missing transverse energy $\not{E}_T$

$\sqrt{s} = 10$ TeV
("Summer08" datasets)

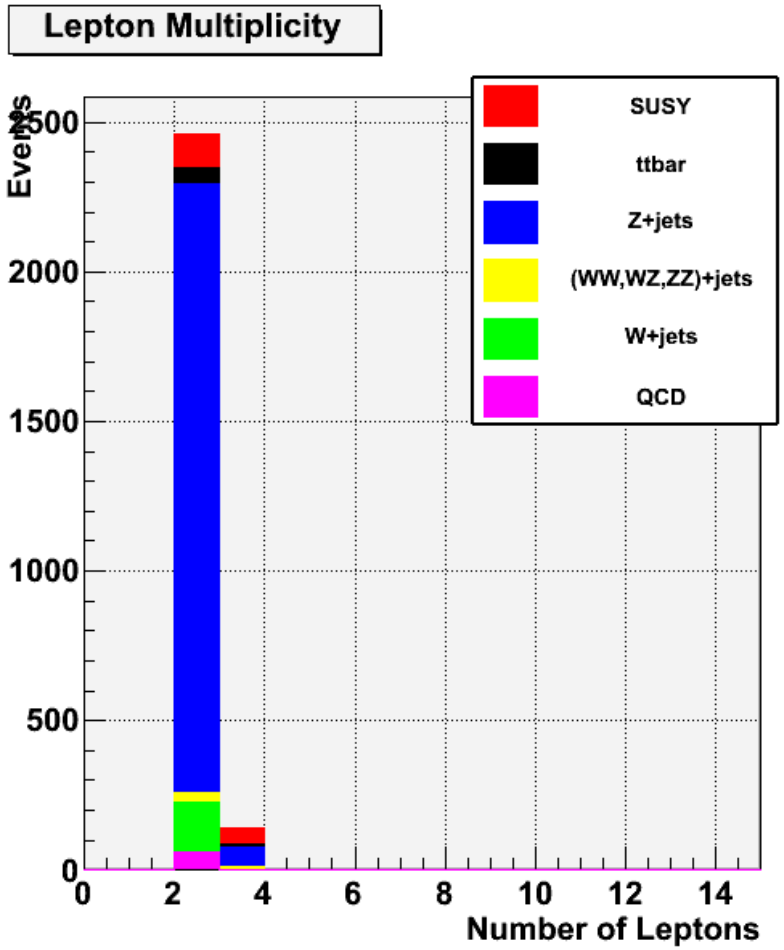
Quality cuts

Muon p_T	$>$	10 GeV
η	$<$	2.1
χ^2/n_{dof}	$<$	10
d_0	$<$	0.2 cm
n_{Hits}	$\geq$	11
Iso	$<$	0.2
HCAL Iso	$<$	6.0
ECAL Iso	$<$	4.0
Electron ID	$=$	"eidTight"
p_T	$>$	10 GeV
η	$<$	2.5
d_0	$<$	0.2 cm
Iso	$<$	0.4
Jet p_T	$>$	30 GeV
η	$<$	2.4
EMF	$>$	0.1

Step 1: Demand 2 same-sign Leptons

- **At least 2 same-sign leptons (e or μ, $p_T > 10$ GeV)**
- 100 GeV of MET
- 3 jets ($p_T > 50$ GeV)

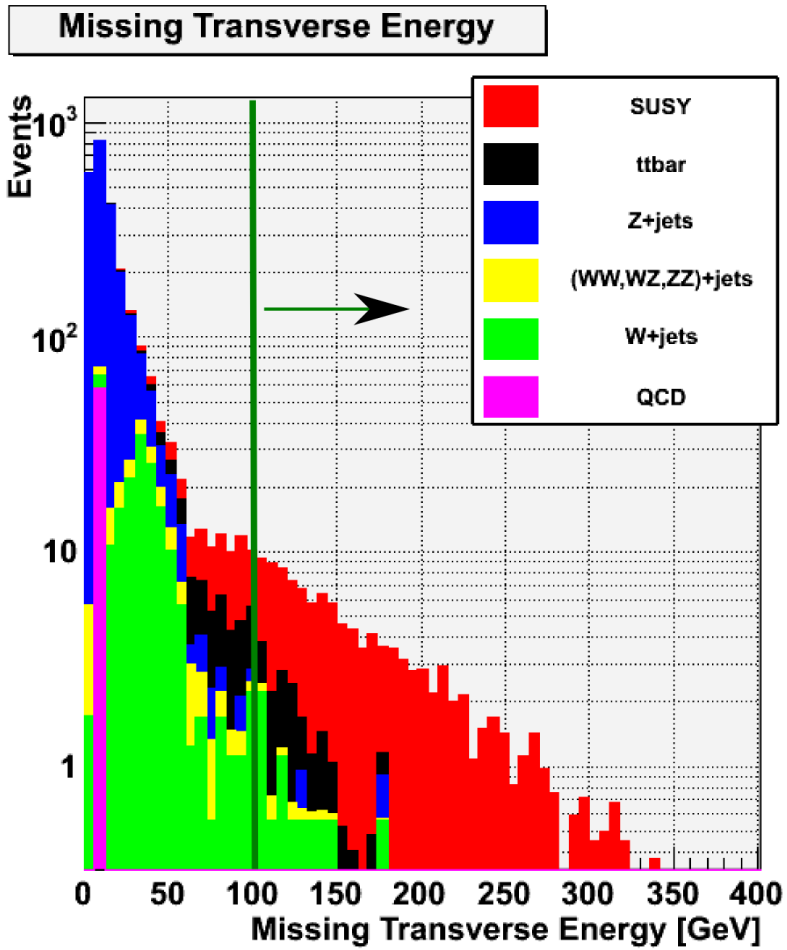
Events	$\geq$ 2 SSL	MET	Jets
LM0 dataset	2260	1349	830
$L = 100$ pb^{-1}	168.72	100.71	61.96
BG datasets	9229	331	48
$L = 100$ pb^{-1}	2436.57	22.11	2.30



Step 2: MET Cut

- At least 2 same-sign leptons (e or μ, $p_T > 10$ GeV)
- **100 GeV of MET**
- 3 jets ($p_T > 50$ GeV)

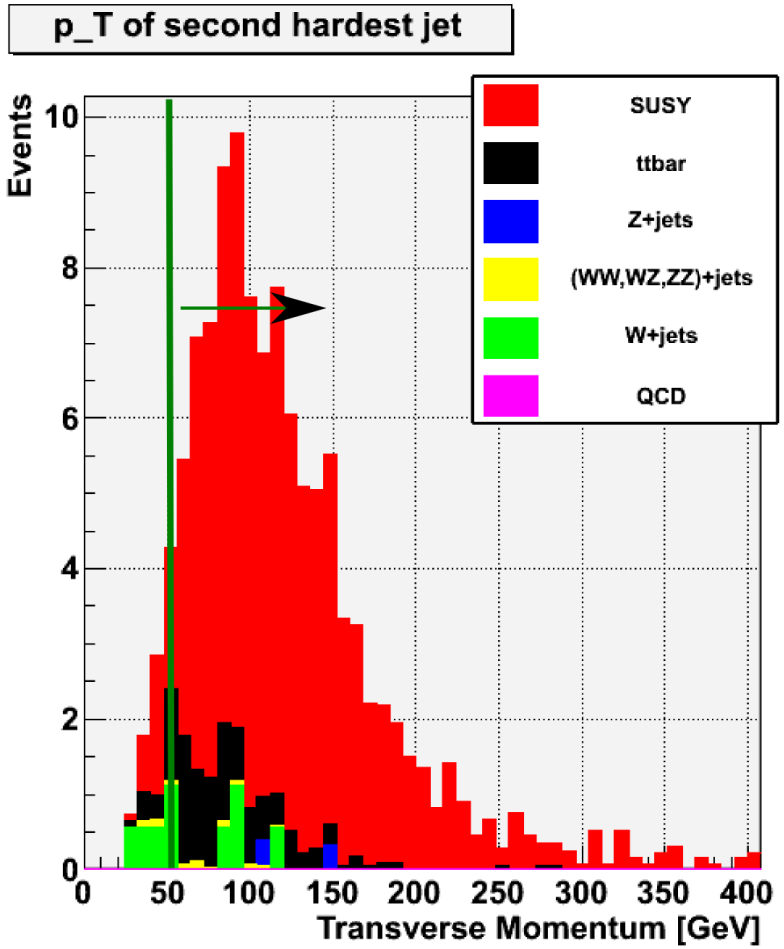
Events	$\geq$ 2 SSL	MET	Jets
LM0 dataset	2260	1349	830
$L = 100$ pb $^{-1}$	168.72	100.71	61.96
BG datasets	9229	331	48
$L = 100$ pb $^{-1}$	2436.57	22.11	2.30



Step 3: Jet Cuts

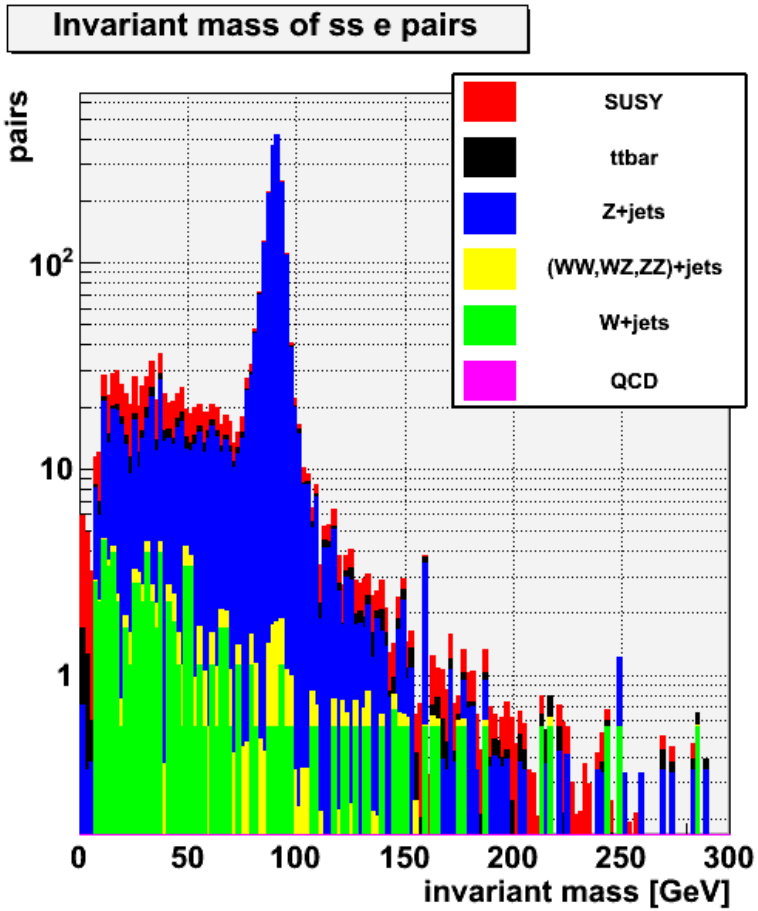
- At least 2 same-sign leptons (e or μ, $p_T > 10$ GeV)
- 100 GeV of MET
- **3 jets ($p_T > 50$ GeV)**

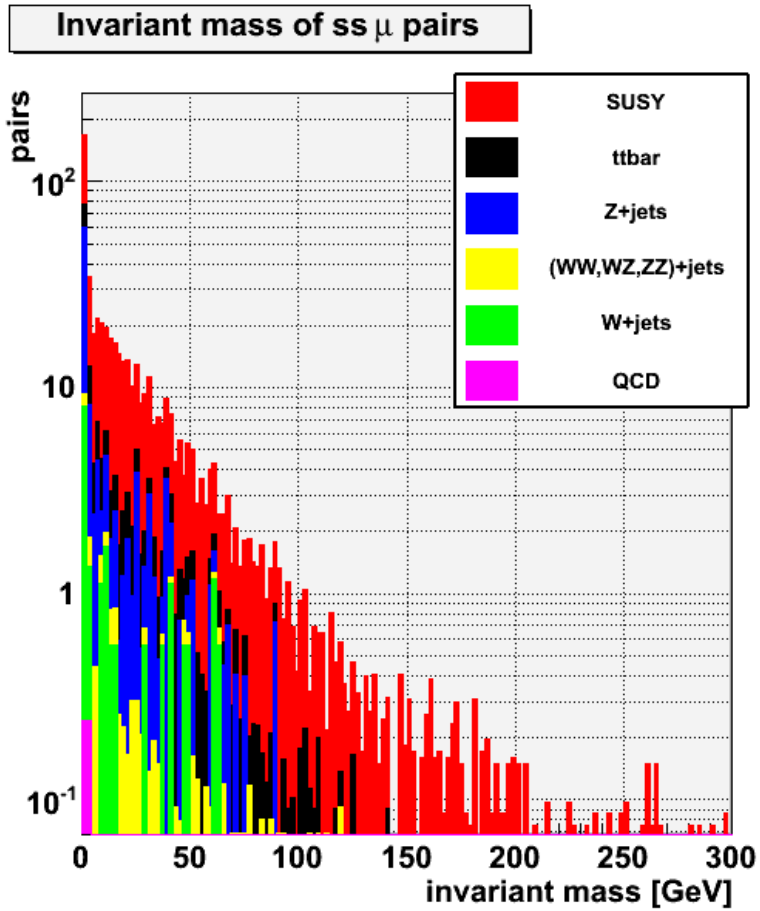
Events	**$\geq$ 2 SSL**	**MET**	**Jets**
LM0 dataset	2260	1349	830
$L = 100$ pb^{-1}	168.72	100.71	61.96
BG datasets	9229	331	48
$L = 100$ pb^{-1}	2436.57	22.11	2.30



Charge misidentification (I)

Invariant mass distribution of same-sign lepton pairs

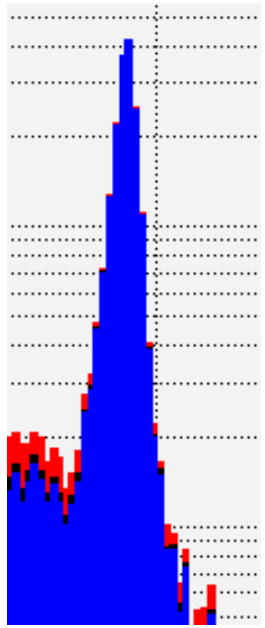




SUSY LM0 + Background, at least 2 same-sign leptons

Charge misidentification (II)

- Invariant mass distribution of same-sign electron pairs shows clear Z-peak
  - Z cannot decay into same-sign electrons
    $\Rightarrow$ Misidentification of charge of one electron
  - Charge misidentification is important factor for estimation of SM background
    $\Rightarrow$ Need to determine charge misidentification rate
    $\Rightarrow$ Try to reduce charge misidentification rate



- Muon charge seems to be determined quite reliably

Significance

Events	$\geq$ **2 SSL**	**MET**	**Jets**
LM0 dataset	2260	1349	830
$L = 100$ pb^{-1}	168.72	100.71	61.96
BG datasets	9229	331	48
$L = 100$ pb^{-1}	2436.57	22.11	2.30

Using the significance estimator

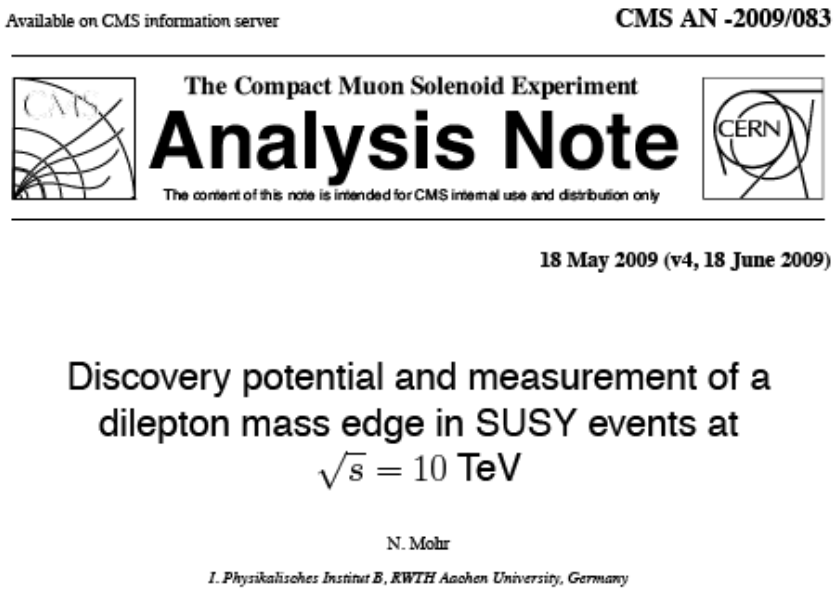
$$S_{cL} = \sqrt{2((s+b)\ln(1+\frac{s}{b}) - s)}$$

61.96 signal events over 2.30 background events lead to a significance of $S_{cL} = 19.13$.

Need to develop background estimation technique

(No systematic uncertainties included, yet)

Opposite-sign lepton analysis



Available on CMS information server CMS AN -2009/083

The Compact Muon Solenoid Experiment

Analysis Note

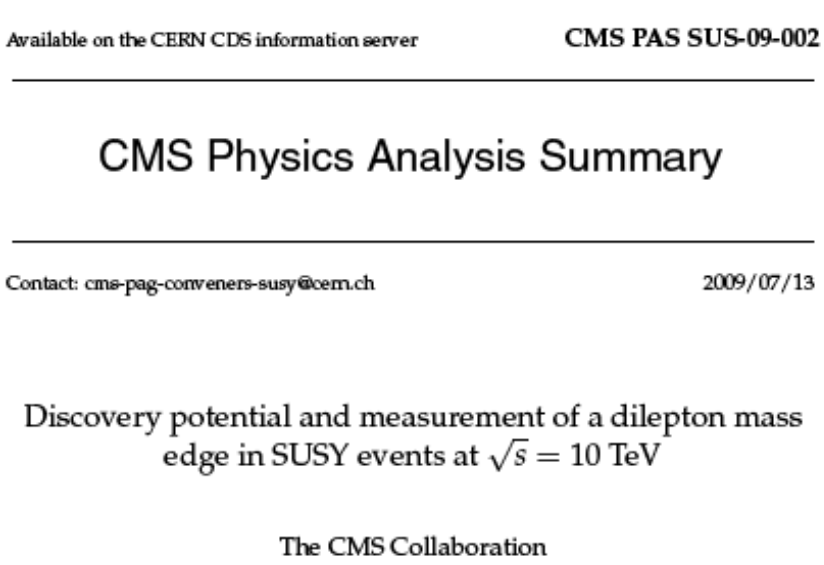
The content of this note is intended for CMS internal use and distribution only

18 May 2009 (v4, 18 June 2009)

Discovery potential and measurement of a dilepton mass edge in SUSY events at $\sqrt{s} = 10$ TeV

N. Mohr

I. Physikalisches Institut B, RWTH Aachen University, Germany



Available on the CERN CDS information server CMS PAS SUS-09-002

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch 2009/07/13

Discovery potential and measurement of a dilepton mass edge in SUSY events at $\sqrt{s} = 10$ TeV

The CMS Collaboration

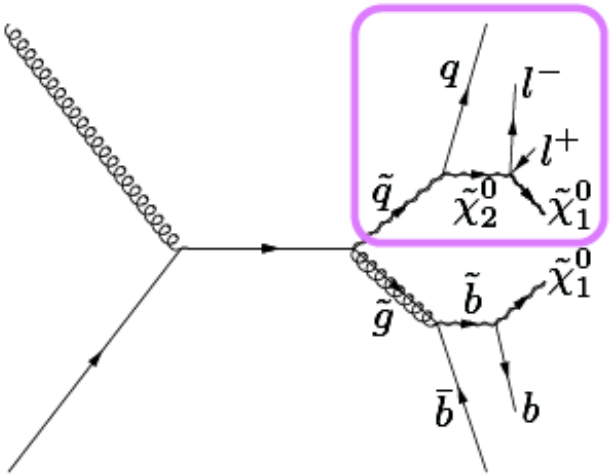
http://cms-physics.web.cern.ch/cms-physics/public/SUS-09-002-pas.pdf

Analysis

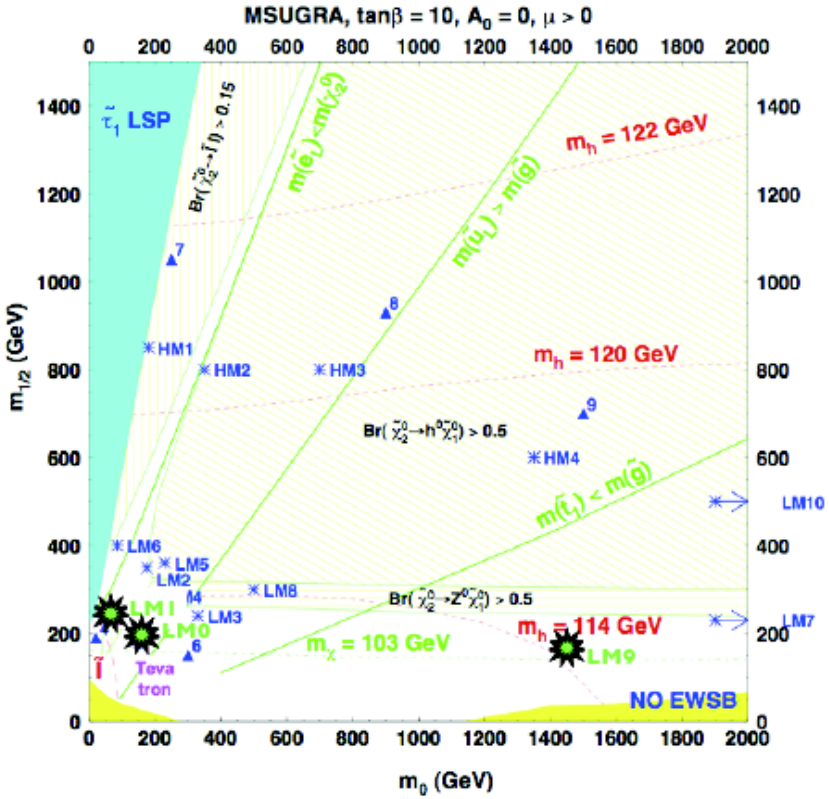
Looking for decay mode

$$\tilde{q} \rightarrow q + \tilde{\chi}_2 \rightarrow q + \tilde{\chi}_1 + l^+ l^-$$

Measure mass edge

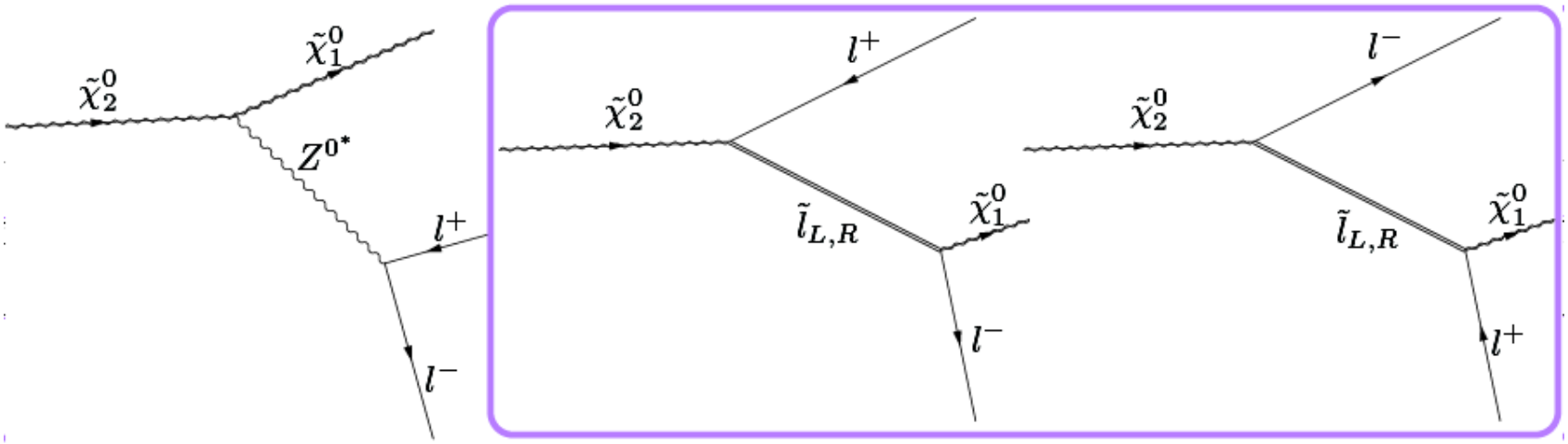


$BR \approx 1\%$



	m_0 [GeV]	$m_{1/2}$ [GeV]	A_0 [GeV]	$\tan\beta$	sign μ	σ_{LO} [pb]	σ_{NLO} [pb]	$m_{ll,max}$ [GeV]
LM0	200	160	-400	10	+1	110.0	151.8	52,7
LM1	60	250	0	10	+1	16.1	21.7	78,2
LM9	1450	175	0	50	+1	11.1	18.2	62,9

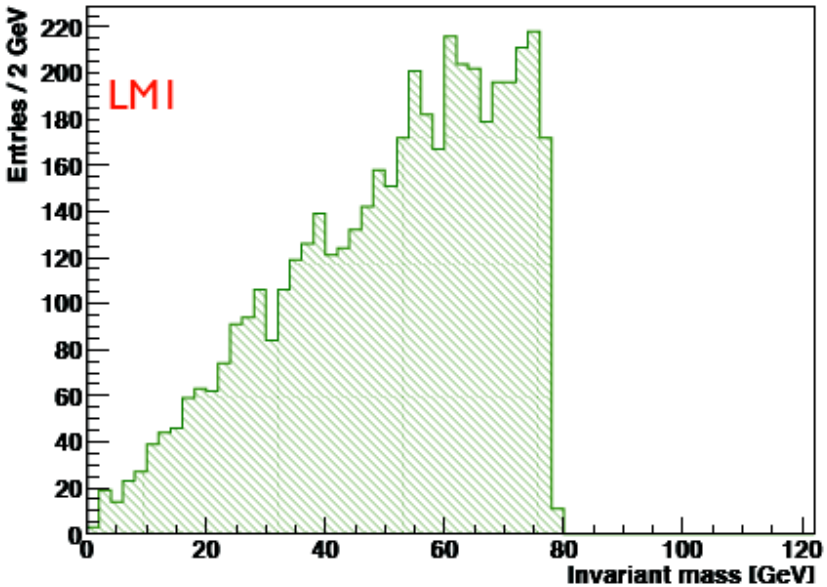
Shape Dependence (I)



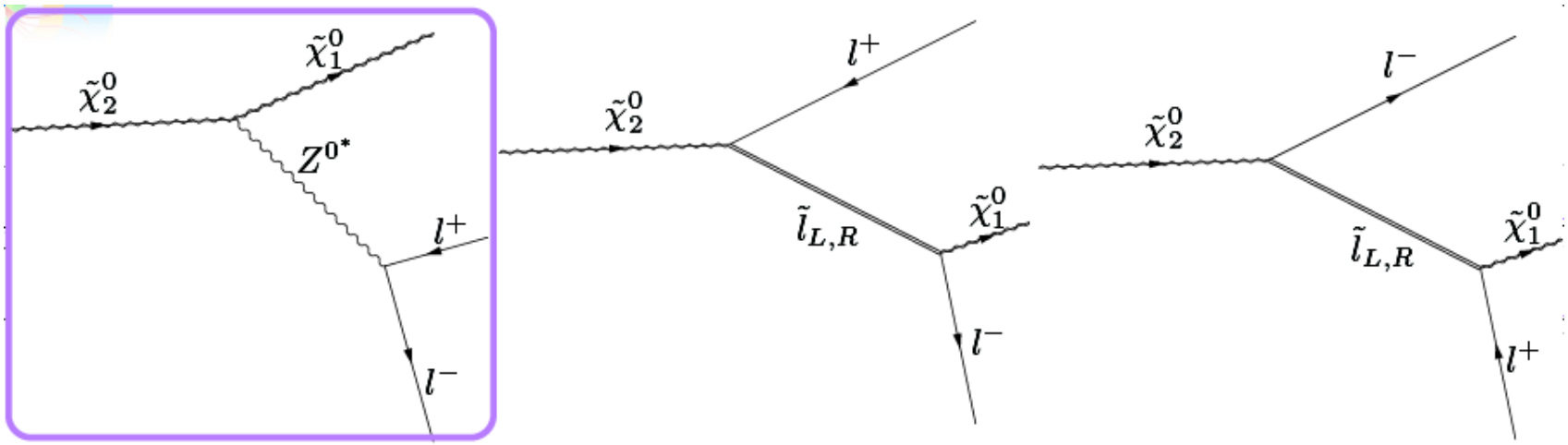
LM1

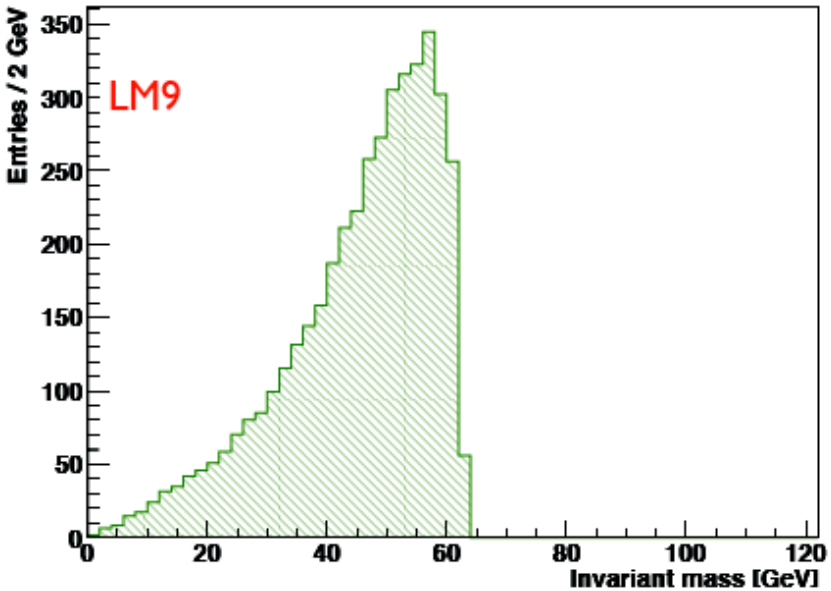
- Subsequent two-body decays via on-shell slepton
- Mass edge triangular

$$(m_{ll}^{max})^2 = \frac{(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}})(m^2_{\tilde{l}} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{l}}}$$



Shape Dependence (II)





LM9

- Three-body decay via off-shell Z boson or slepton
- Shape of mass edge parameter dependent

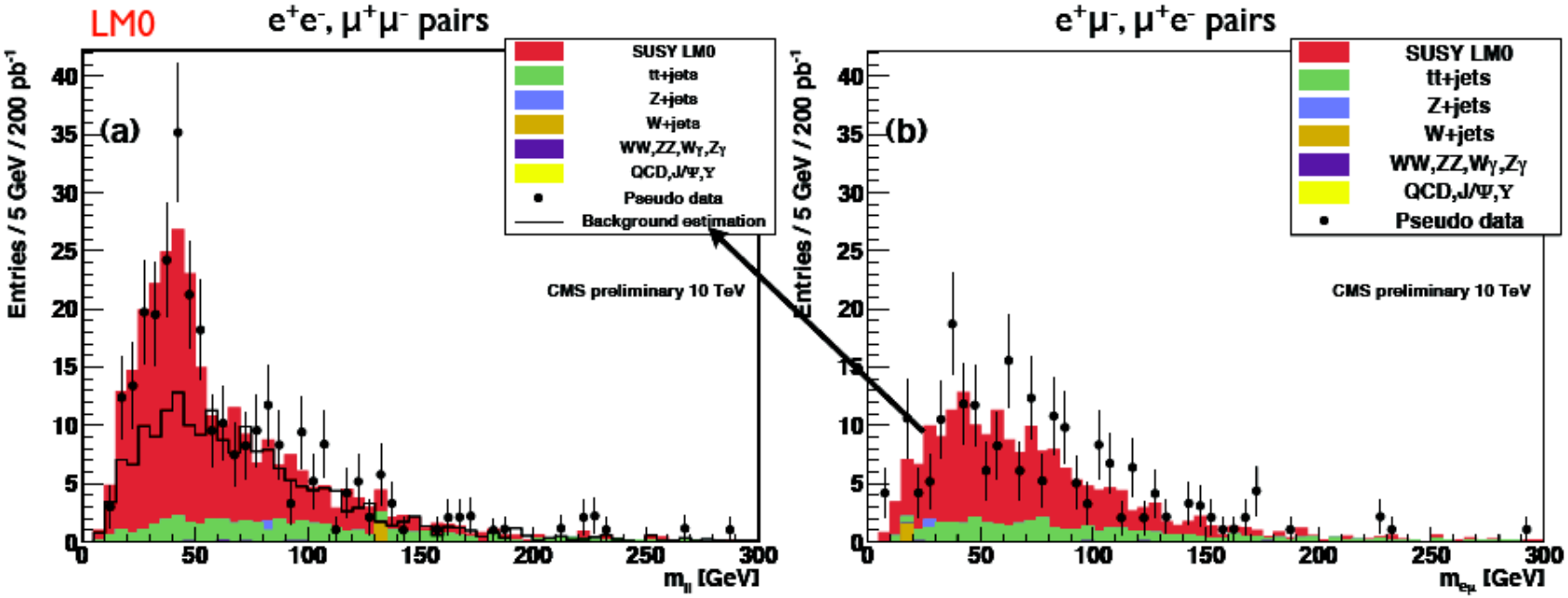
$$m_{ll}^{max} = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$$

Final Event Selection

- Background mostly SUSY and $t\bar{t}$
- Can be measured from data by looking at opposite-flavour lepton pairs

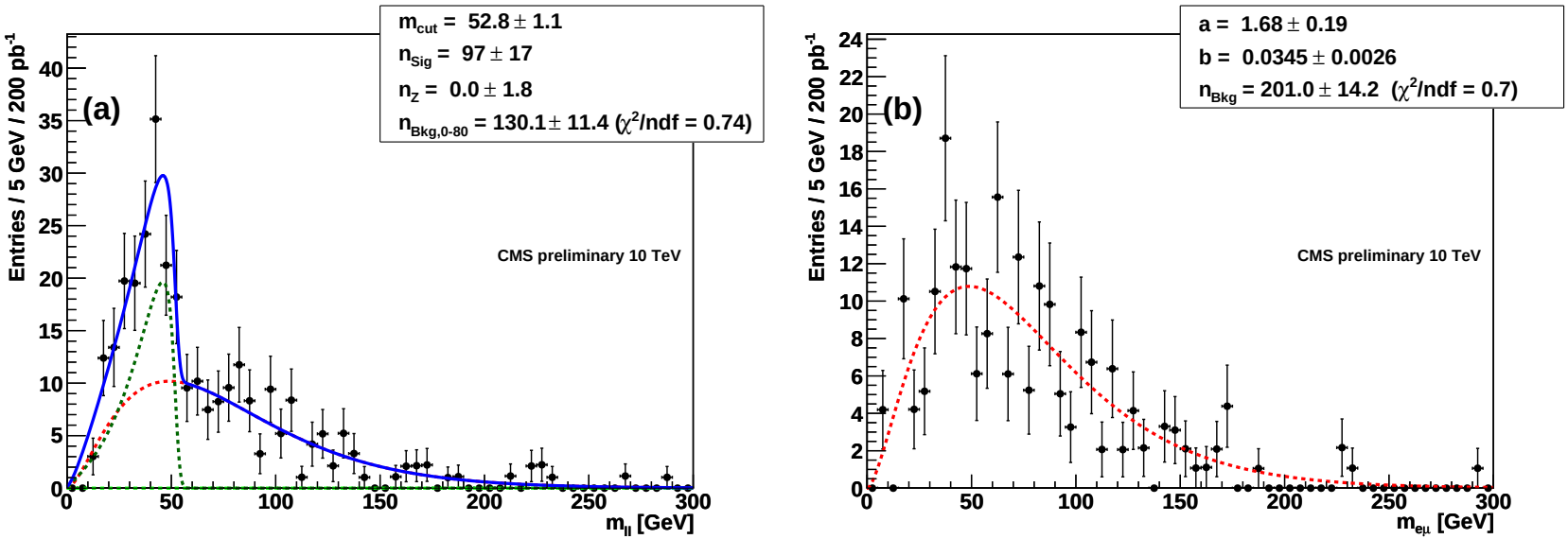
Selection

- 2 isolated opposite sign leptons
- 3 jets, $p_T > (100, 50, 50)$ GeV
- Missing transverse energy > 100 GeV



Fit Model / Results

LM0



- Decay chain discoverable within first 200 pb^{-1} at LM0, 250 pb^{-1} at LM1, 350 pb^{-1} at LM9
- Endpoint can be reconstructed with 200 pb^{-1} at LM0
  Combined fit ($m_{theo} = 52.7$ GeV):

$$m_{ll,max} = (51.3 \pm 1.5_{stat} \pm 0.9_{sys})\ \text{GeV}$$

Conclusion

Summary

- Set up SUSY search using same-sign lepton events
- SUSY analysis using opposite-sign lepton events approved by CMS

Outlook

- Improve same-sign analysis: Systematic uncertainties, background estimation, charge misidentification rate, ...
- Extend same-sign analysis to τ channels: $e\tau$, $\mu\tau$, $\tau\tau$ (M. Edelhoff)

... waiting for data ... \(^_^)/

Backup

Backup Same-sign: Summer08 Datasets

SUSY LM0:
/SUSY_LM0-sftsht/Summer08_IDEAL_V11_v1/GEN-SIM-RECO

ttbar:
/TTJets-madgraph/Fall08_IDEAL_V9_v1/GEN-SIM-RECO

ZJets:
/ZJets-madgraph/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
/AstarJets-madgraph/Fall08_IDEAL_V9_v2/GEN-SIM-RECO

WJets:
/WJets-madgraph/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO

Diboson:
/VVJets-madgraph/Fall08_IDEAL_V9_v2/GEN-SIM-RECO
/Zgamma/Summer08_IDEAL_V9_v1/GEN-SIM-RECO
/Wgamma/Summer08_IDEAL_V9_v1/GEN-SIM-RECO

QCD:
/JPsi/Summer08_IDEAL_V9_v1/GEN-SIM-RECO
/Upsilon2S/Summer08_IDEAL_V9_v10/GEN-SIM-RECO
/Upsilon1S/Summer08_IDEAL_V9_v10/GEN-SIM-RECO
/QCDpt80/Summer08_IDEAL_V9_v2/GEN-SIM-RECO
/QCDpt170/Summer08_IDEAL_V9_v2/GEN-SIM-RECO
/QCDpt300/Summer08_IDEAL_V9_v2/GEN-SIM-RECO
/QCDpt470/Summer08_IDEAL_V9_v2/GEN-SIM-RECO
/QCDpt800/Summer08_IDEAL_V9_v2/GEN-SIM-RECO

Backup Same-sign: PATLayer1 Datasets

SUSY LM0:
/SUSY_LM0-sftsht/Summer08_IDEAL_V11_v1/GEN-SIM-RECO

ttbar:
/TTJets-madgraph/Fall08_IDEAL_V11_redigi_v10/GEN-SIM-RECO

ZJets:
/ZJets-madgraph/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO

WJets:
/WJets-madgraph/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO

QCD:
/QCD100to250-madgraph/Fall08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
/QCD250to500-madgraph/Fall08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
/QCD500to1000-madgraph/Fall08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
/QCD1000toInf-madgraph/Fall08_IDEAL_V11_redigi_v1/GEN-SIM-RECO

Backup Opposite-sign: Event selection

	σ_{LO} [pb]	k-factor	HLT	≥2 leptons	≥3 jets	MET
SUSY LM0 signal	1	1,38	362	226	128	86
SUSY LM0	110	1,38	8167	1007	543	362
$t\bar{t}$+jets	319	1,3	25655	2411	238	80
Z+jets	3700	1,14	541013	199773	510	1
W+jets	40000	1,14	3108397	298	5	2
VV, Wγ, Zγ	12,37,11	1,0	5444	885	2	0
QCD (p_T > 15), J/Ψ, Υ	-	1,0	28010134	560	4	0

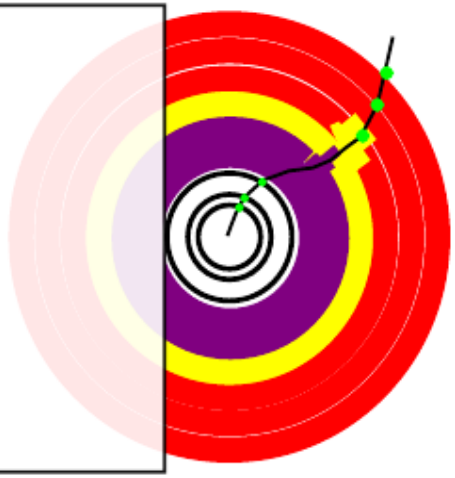
- Single muon (11 GeV) and single electron (15 GeV) trigger
  - 97% efficient
- First lepton p_T > 16 GeV
- SingleJet (110 GeV)
  - 97,4% efficient

- 2 isolated opposite sign leptons
- 3 jets > (100,50,50) GeV
- Missing transverse energy >100 GeV

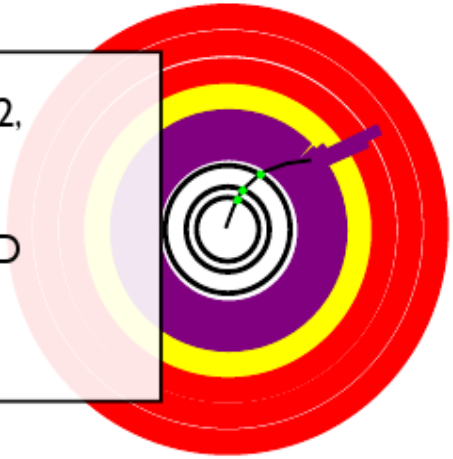
Efficiency of 24% for signal decays

Backup Opposite-sign: Objects

- Muons $|\eta| < 2$, $p_T > 10$ GeV
- $\chi^2/ndf < 10$
- Number of valid hits ≥ 11
- $|d0| < 2$ mm

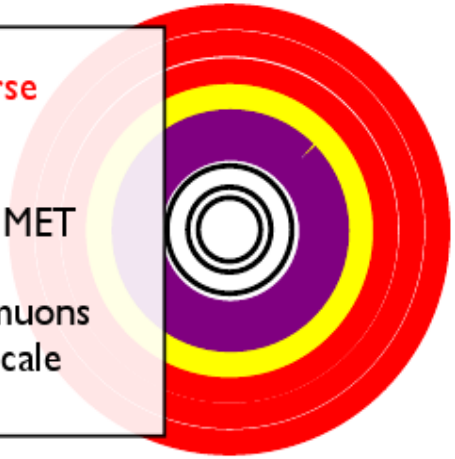


- Electrons $|\eta| < 2$, $p_T > 10$ GeV
- Tight electron ID
- $|d0| < 2$ mm

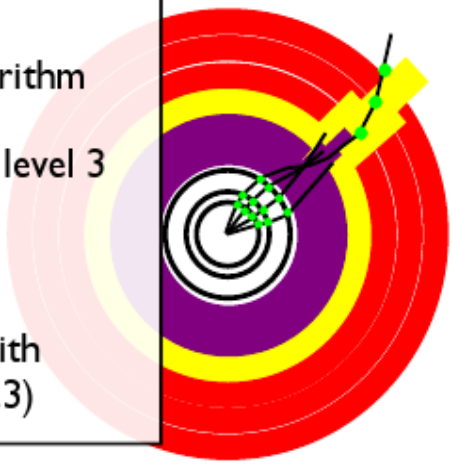


https://twiki.cern.ch/twiki/bin/view/CMS/VplusJets

- Missing transverse energy
  - Calorimetric MET
- Corrected for muons and jet energy scale

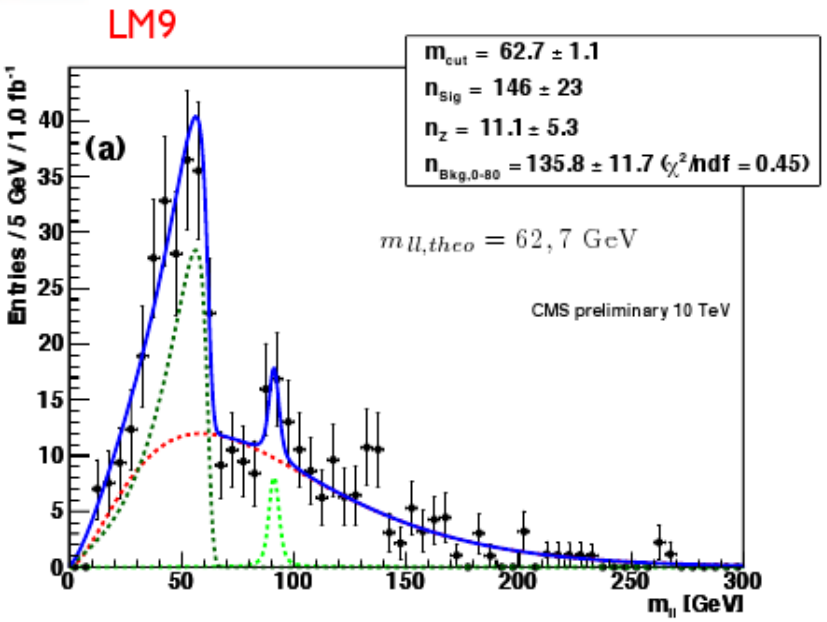


- Jets $|\eta| < 2.5$, $p_T > 50$ GeV
- SIScone5 jet algorithm
- Corrected up to level 3 using jet energy corrections
- Check overlap with electrons ($\Delta R<0.3$)

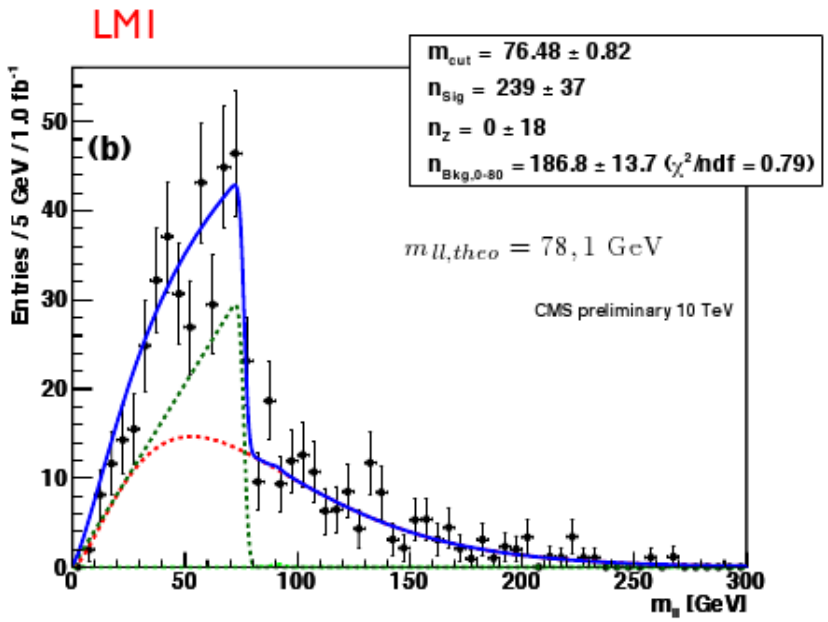


Backup Opposite-sign: Different Benchmark Points

LM9



LM1



$m_{ll,max} = (62.8 \pm 1.4_{stat.} \pm 0.8_{syst.})$ GeV

$m_{ll,max} = (77.3 \pm 0.9_{stat.} \pm 0.9_{syst.})$ GeV

- Fit at different benchmark point using 1 fb^{-1}
- Reproduce at all LM points the theoretical endpoint in the invariant mass
- Statistical and systematic error are evaluated in the same way
- With 1 fb^{-1} we can distinguish between 2- and 3-body decay based on goodness of fit