Search For New Physics with same-sign isolated dilepton events with jets and missing transverse energy at LHC

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Motivation

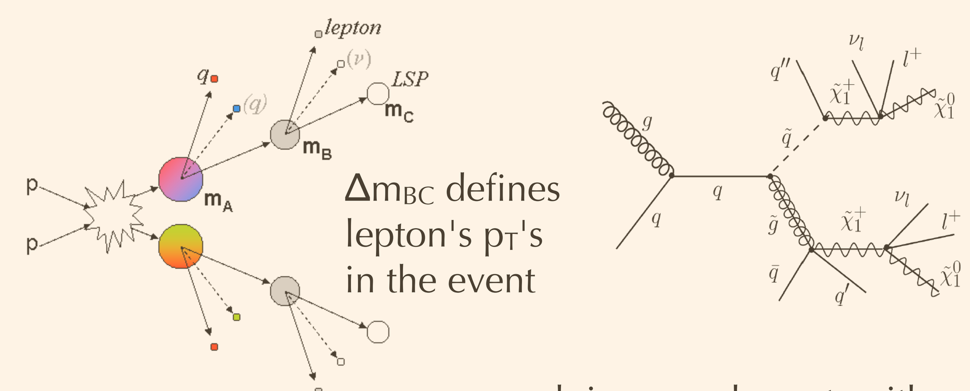
This search is motivated by the fact that events with **same-sign isolated lepton pairs** from hadron collisions are very rare in Standard Model but appear very naturally in many new physics scenarios.
Moreover the requirement of **Missing Transverse Energy (MET)** is suggested by the astrophysical evidence for the Dark Matter and **large hadronic activity** is expected for new physics signals with the largest cross sections.

- p_T spectrum of the leptons in the final state
- the amount of hadronic activity
- the yield of tau leptons

can depend on the specific model

In order for the search to be **as model independent as possible**, a large space phase has been investigated. It has been possible by using few **different strategies**

One example of New Physics scenarios is **Supersymmetry**:



Δm_{BC} defines lepton's p_T's in the event

Δm_{AB} defines the amount of hadronic activity in the event

gluino can decay to either positive or negative charge final state with the same probability

An integrated luminosity of
35 pb^{-1} collected at LHC in 2010
has been used in these searches

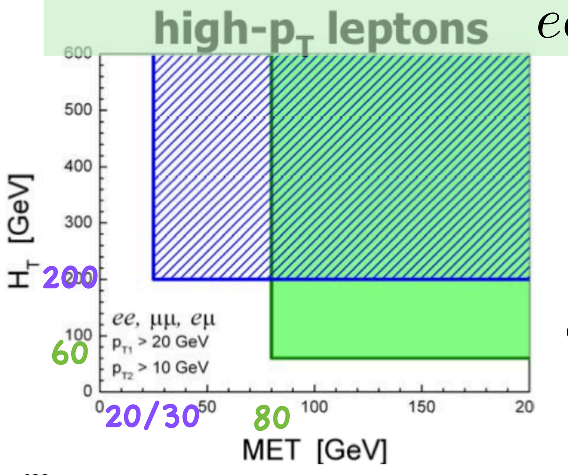
The variable H_T (defined as the sum of the transverse energy of jets with $p_T>30$ GeV) is used as an **indication of the hadronic activity**

fake leptons: defined as leptons coming neither from vector bosons, nor from new physics particles

CombIso: activity around the lepton candidate as measured by ECAL, HCAL and tracker system

The main background contributions are due to fake leptons and are estimated with data driven methods

high-p_T leptons $ee, e\mu, \mu\mu$ — Leptonic Trigger



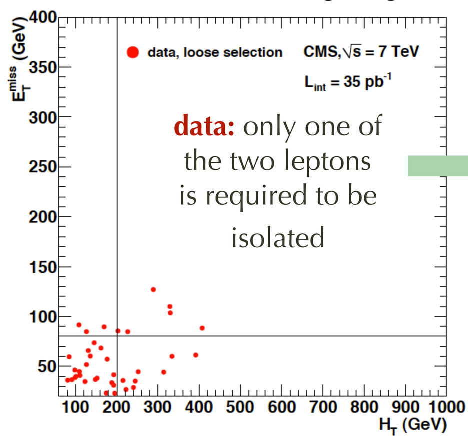
for all the leptons $|\eta| < 2.4$

$p_T(l_1), p_T(l_2) > 20, 10$ GeV

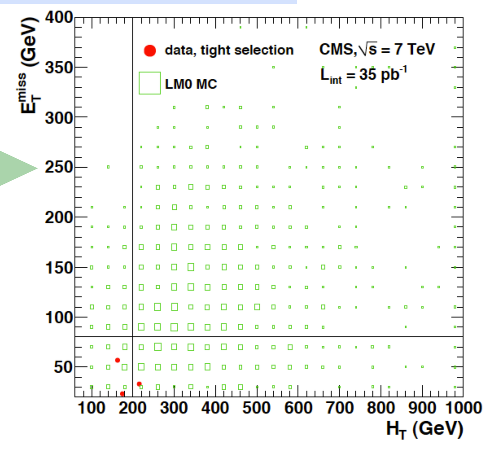
$\frac{CombIso}{p_T} < 0.1$ for $p_T > 20$ GeV

$CombIso < 2$ GeV for $p_T < 20$GeV

see [1] for further event selection details



requiring both the leptons to be isolated the bkg is reduced of a factor 10



Data driven method for the estimation of Background contributions from fake leptons: the Tight-Loose (TL) method

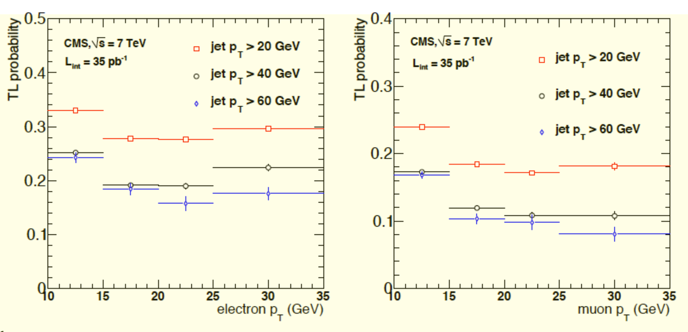
A **loose lepton selection** is defined: **isolation, impact parameter, muon fit relaxed**

The probability ϵ_{TL} for a lepton passing the loose selection to pass also the tight one is measured in QCD multi-jet events as a function of the lepton p_T and pseudo-rapidity

1 fake lepton | **2 fake leptons**

consistent results obtained with the two methods in the overlap region

Main systematics:
It has been observed
* a dependence on the pt of the jet from which the lepton originate
Systematic uncertainty of 50 % assigned



* No dependence on the jet flavor

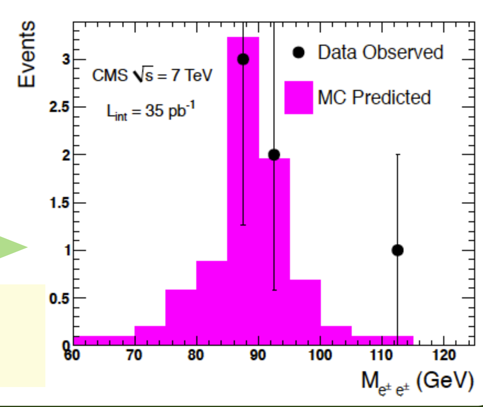
Background from mis-measurement of the electron charge

opposite sign leptons

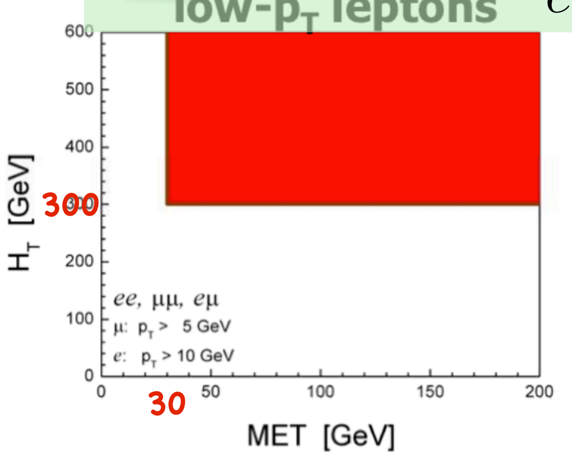
The e charge can be mistaken due to converted photon from e bremstrahlung.

The probability for this is taken into account and demonstrated to be under control

50% of systematic uncertainty due to limited statistics to validate the method



low-p_T leptons $ee, e\mu, \mu\mu$ — Hadronic Trigger



for all the leptons $|\eta| < 2.4$

$p_T(e) > 10$ GeV
$p_T(\mu) > 5$ GeV

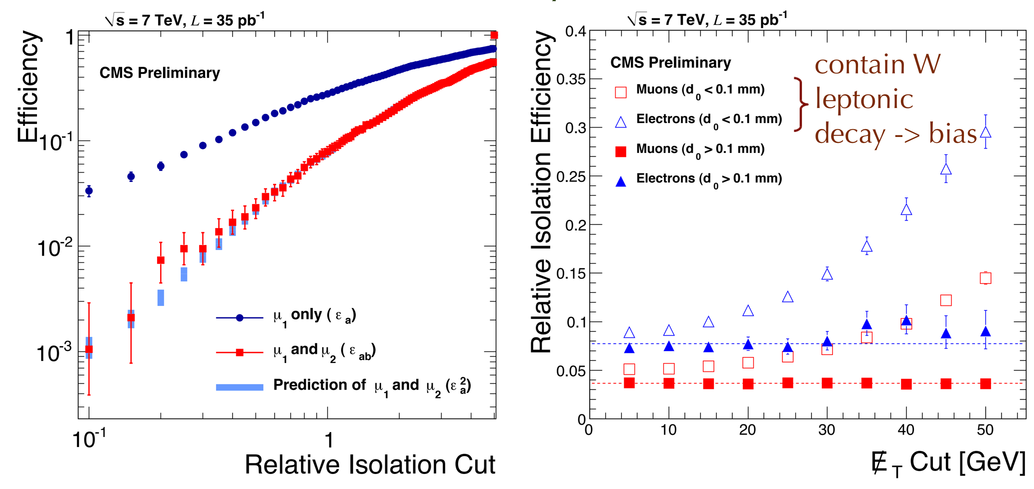
$\frac{CombIso}{p_T} < 0.15$

see [1] for further event selection details

Data driven methods for the estimation of Background contribution

2 fake leptons factorization: $n = N_{preselected} \cdot \varepsilon_{\ell_1}^{Iso} \cdot \varepsilon_{\ell_2}^{Iso} \cdot \varepsilon^{MET}$

demonstration of the validity of the factorization

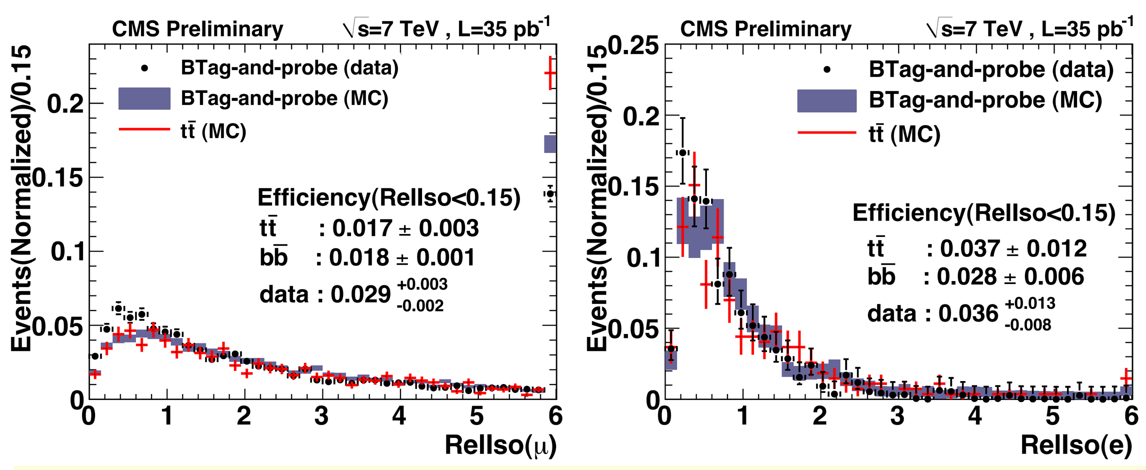


1 fake lepton the main contribution is from **semileptonic** $t\bar{t}$ (fake lepton from Heavy Flavor)

Btag-probe method

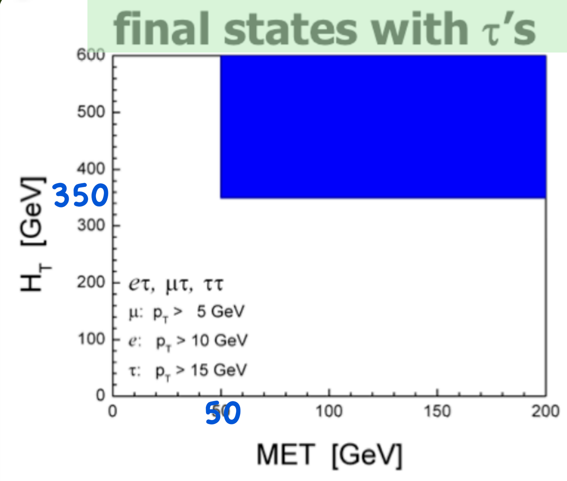
In QCD events, BTag one jet (to select b bbar events) and look for a lepton far from it. Take such lepton to measure the isolation efficiency as a function of lepton eta and p_T

Re-weight to the distribution of b-jets in MC ttbar



Main systematics are due to limited statistics available to validate the methods and bias in measuring the efficiency for the presence of prompt leptons in data

final states with τ's $e\tau, \mu\tau, \tau\tau$ — Hadronic Trigger



for all the leptons $|\eta| < 2.4$

$p_T(e) > 10$ GeV
$p_T(\mu) > 5$ GeV
$p_T(\tau) > 15$ GeV

$\frac{CombIso}{p_T} < 0.15$

see [1] for further event selection details

hadronically decaying taus reconstructed in two steps:
- pre-identification
- 5 Neural Networks (NN) which try to reconstruct the intermediate resonances decaying to pions

Data driven method for the estimation of Background contributions from fake Tau leptons: the Tight-Loose (TL) method

A **loose Tau lepton selection** is defined : **No NN identification** applied

The probability for a Tau lepton passing the loose selection to pass also the tight one is measured in data selected as QCD multi-jet events as a function of the tau p_T and pseudo-rapidity.

The isolation is included in the loose selection, so the bias due to different physics environment is expected to be reduced

two closure tests:
- full selection applied to MC background
- relaxed selection applied to data

Channel	Simulation Only SM BKG: Observed	Simulation Only SM BKG: Predicted	Data Relaxed selection: Observed	Data Relaxed selection: Predicted	
$\tau\tau$	0.08±0.03	0.15±0.15	14	14.0±4.3±2.6	2 fake leptons
$e\tau$	0.35±0.12	0.30±0.11	1	0.8±0.4±0.1	1 fake lepton
$\mu\tau$	0.47±0.15	0.49±0.20	2	2.9±0.6 ±0.4	

Main systematics are due to limited simulated event statistics needed to validate the method and correlation between the TL efficiency and H_T

Background from SM with same sign leptons in the final state

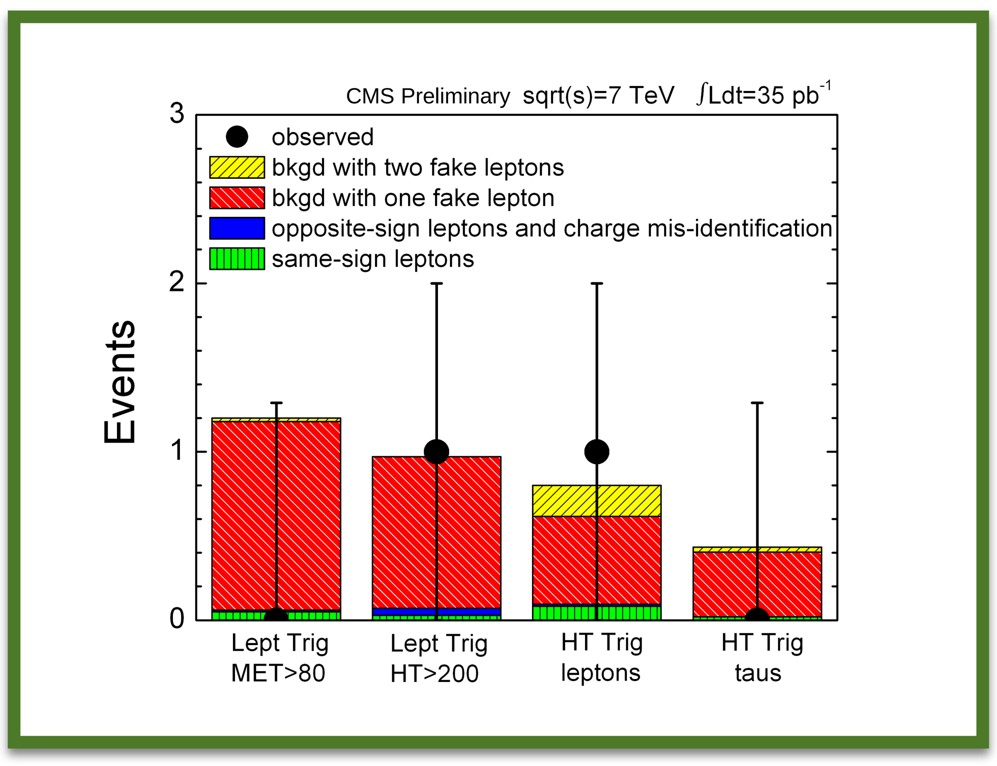
$q\bar{q} \to WZ, ZZ$
$qq \to q'q'W^{\pm}W^{\pm}$
$t\bar{t}W \quad WWW$
Double Parton Scattering: $2 \times (q\bar{q} \to W^{\pm})$

same sign leptons

they constitute only few percent for each channel.

estimated from MC. A systematic uncertainty of 50 % is assigned

No excess over SM prediction



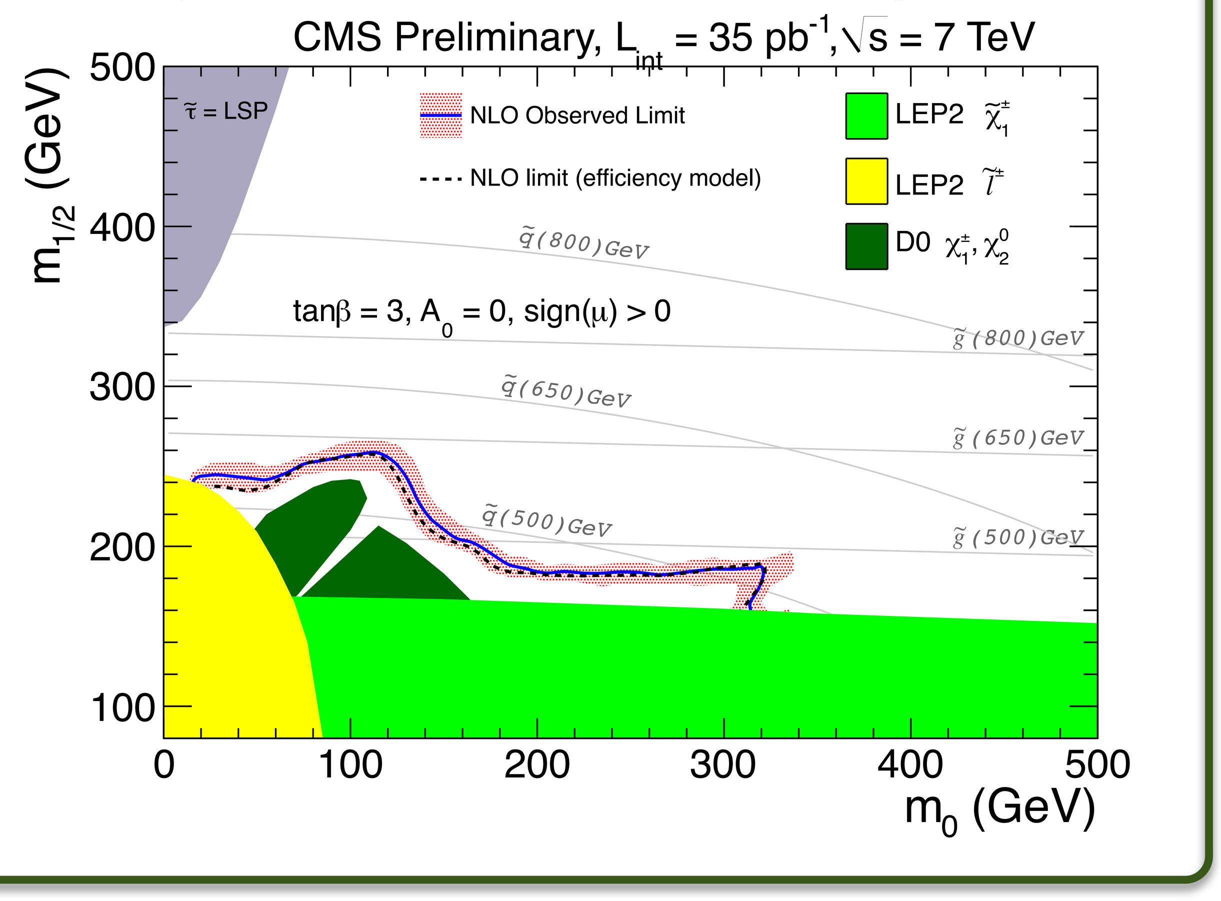
Set Upper Limit to the event number

Search Region	ee	$\mu\mu$	$e\mu$	total	95% CL UL Yield
Lepton Trigger					
$E_T^{miss} > 80$ GeV MC	0.05	0.07	0.23	0.35	
predicted BG	$0.23^{+0.35}_{-0.23}$	$0.23^{+0.26}_{-0.23}$	0.74 ± 0.55	1.2 ± 0.8	
observed	0	0	0	0	3.1
$H_T > 200$ GeV MC	0.04	0.10	0.17	0.32	
predicted BG	0.71 ± 0.58	$0.01^{+0.24}_{-0.01}$	$0.25^{+0.27}_{-0.25}$	0.97 ± 0.74	
observed	0	0	1	1	4.3
H_T Trigger					
Low-p_T MC	0.05	0.16	0.21	0.41	
predicted BG	0.10 ± 0.07	0.30 ± 0.13	0.40 ± 0.18	0.80 ± 0.31	
observed	1	0	0	1	4.4
	$e\tau_h$	$\mu\tau_h$	$\tau_h\tau_h$	total	95% CL UL Yield
τ_h enriched MC	0.36	0.47	0.08	0.91	
predicted BG	0.10 ± 0.10	0.17 ± 0.14	0.02 ± 0.01	0.29 ± 0.17	
observed	0	0	0	0	3.4

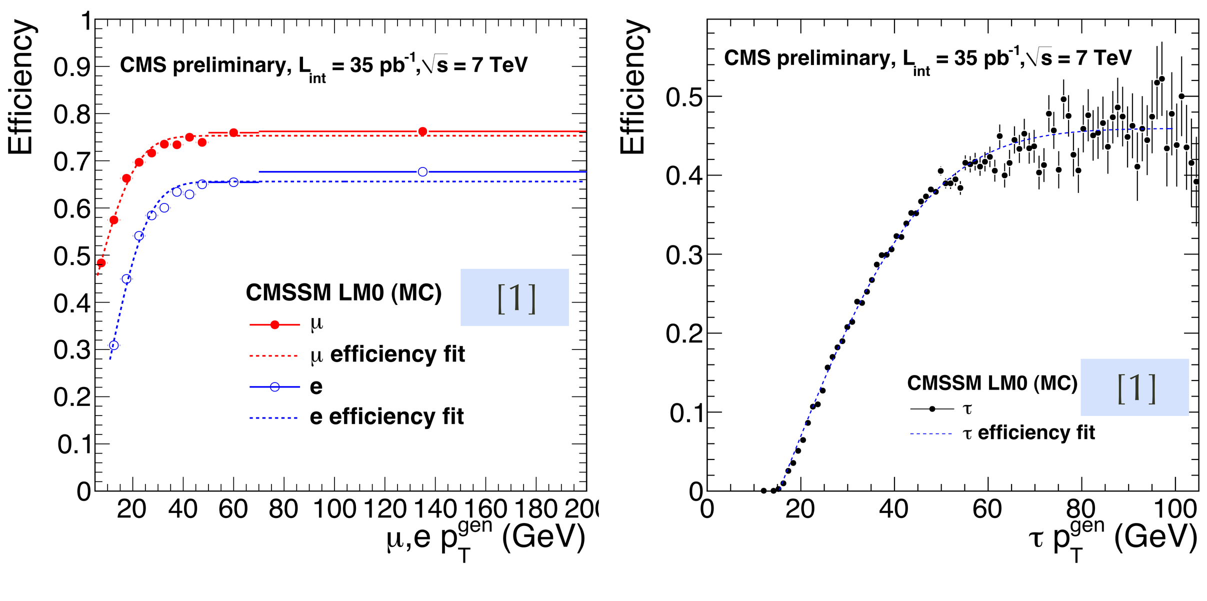
see [1] for the statistical method used

Lepton reconstruction efficiencies and MET, H_T resolutions are provided so that any model can be tested with these results

Upper Limit to one specific model
(of CMSSM [1] in Supersymmetry scenario)
Validation of the efficiency model



Efficiency model



efficiency(p_T) = $\epsilon_{max} + A\times$ (erf(($p_T - P_{Tcut}$)$/B$) -1)

$p_{Tcut}(e, \mu, \tau) = 10, 5, 15$ GeV

	(A, B, ϵ_{max})
e	(0.40, 18, 0.66)
μ	(0.32, 18, 0.75)
τ	(0.45, 31, 0.45)

- MET resolution measured in data
- H_T resolution taken from simulation of a specific model

see [1] for values

Reference

[1] The CMS Collaboration
- CMS PAS SUS-10-004 http://cdsweb.cern.ch/record/1345080?ln=no
- arXiv:1104.3168 (submitted to JHEP)