Search for new physics with same-sign isolated dilepton events in CMS

Aniello Spiezia
University of Perugia

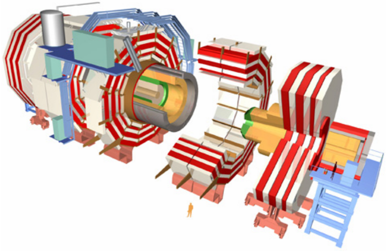
Summer School and Workshop on the Standard Model and Beyond

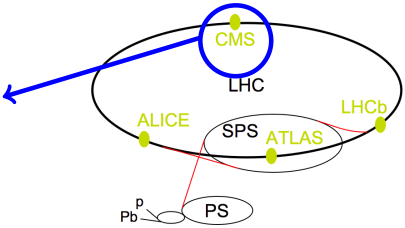
September 8 - 17, 2012

Outline

- **CMS experiment**
- **Supersymmetry**
- **Same Sign DiLepton topology**
- **TriLepton topology**
- **Analysis strategy**
- **Interpretation of the results**

CMS Experiment @ LHC



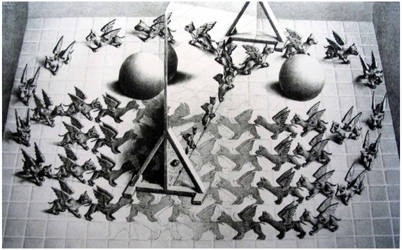


CMS = Compact Muon Solenoid

- General-purpose particle physics detector built at the Large Hadron Collider (LHC)
- Overall diameter 15 m and length 22 m
- Five layers:
  1. tracker
  2. electromagnetic calorimeter
  3. hadronic calorimeter
  4. magnet
  5. muon chambers

SuperSimmetry

The Standard Model is a *success*, but many questions are still open



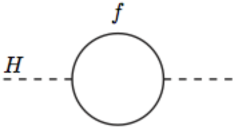
- Why Higgs Boson has a finite mass?
- Does an energy scale at which the interaction coupling constants assume the same value exist?
- What is the 96% of the Universe?

SuperSymmetry helps to solve several problems of the SM...

...and introduces many new particles and many parameters that could be measured!

SuperSymmetry

- SM gives great quantum corrections to the Higgs mass

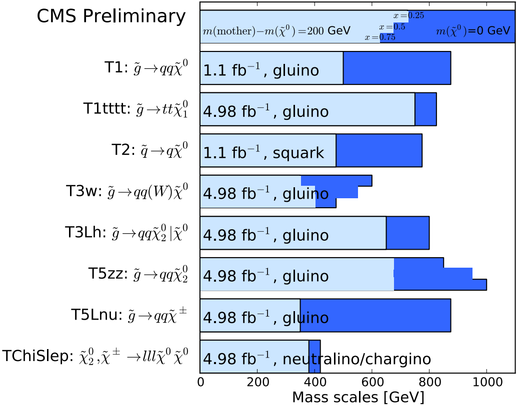


$$\Delta m_H^2 = -\frac{|\lambda_f|^2}{8\pi^2}\Lambda_{UV}^2$$

- **Hierarchy problem**:
  - Higgs mass is finite
  - m_H^2 has a quadratic divergence due to Λ_{UV}
- Introduction of a new symmetry to solve the problem
  - Introduces *superpartners* to each SM particle $\rightarrow$ called *superparticles* or *sparticles*
  - Introduces a new quantum number: **R-parity** $\rightarrow$ conservation of it gives dark matter candidate

SuSy search at CMS

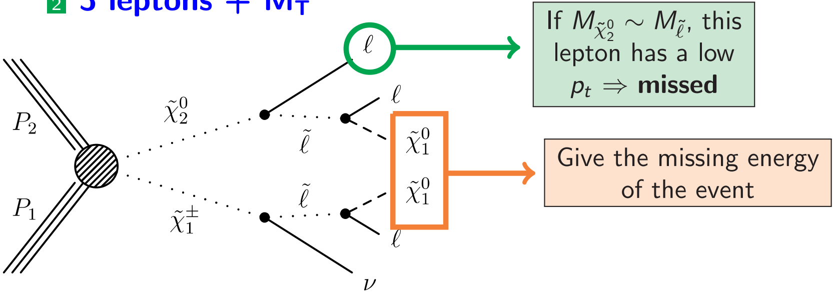
- Many searches at CMS have focused on the study of models with new heavy strongly interacting particles
- Strongly interacting particles can be produced with large cross sections and hence could be *easily* seen with early LHC data



Limits on these models probe masses up to $\sim$ TeV

Chargino-Neutralino pair production

- **Electroweak** production of *sparticles* does not yield to large hadronic activity
- Models with electroweak production of *sparticles* could have **eluded detection in early searches**
- We decide to study a *simplified model*: the **chargino-neutralino pair production** (Phys. Rev. D79 (2009) 075020, arXiv:0810.3921)
- This model has been investigated in two complementary ways:
  1. **2 same sign leptons + MET***
  2. **3 leptons + $\mathbf{M_T}$***



* = **missing energy of the events due to the lightest superparticle**

SSDL with τ

Focalize on the **τ-enriched scenario**:

✔ *chargino* decays **exclusively** to τ leptons
✔ *neutralino* decays **democratically**

We will search for two same sign dilepton (SSDL) of which one is a τ decaying hadronically:

- if one of the three leptons is missed $\rightarrow$ SSDL
- *chargino* has an *higgsino* component $\rightarrow$ its decay to *slepton* could favor the τ lepton

To be considered:
Request for the SSDL signature permits to suppress the SM background

Look for final state:
$$\mathbf{pp \rightarrow e^{\pm}\tau^{\pm}, \mu^{\pm}\tau^{\pm}, \tau^{\pm}\tau^{\pm} + MET}$$

Background evaluation

Fake(s) τ: **data-driven study**

- Events with one *real* lepton and **hadronic activity** that mimics the τ ($ttbar$, $W + jets$, QCD)
- This is the **dominant** contribution

Mis-reconstructed charge: **data-driven study**

- An **opposite sign event** can pass the selection if one lepton is reconstructed with the **wrong charge**
- We evaluate this **only** for τ: charge mis-id $\sim 10^{-2}$
- **Electron** and **muon** have charge misidentification rate of the order of $\sim 10^{-3}$ and $\sim 10^{-5}$

Prompt leptons from SM **from MC study**

- Production of two *prompt* same sign lepton from *SM processes*
- The main contribution is from the **production of two gauge bosons** that decay leptonically that is $q\bar{q} \to WZ,\ ZZ$
- Predicted from **MC studies**

Background evaluation

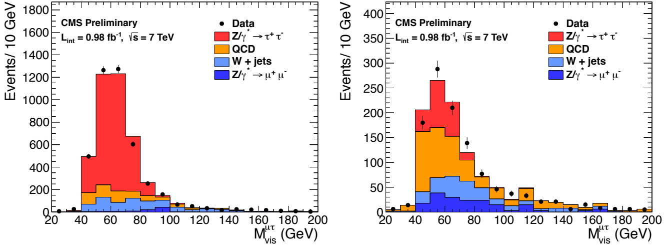
Fake(s) τ:

- Prediction using the *fake-ratio method*
- Choose a data sample **reach of QCD** events and **poor of real τ**
- Measure the **probability** that a *fake* τ passes the signal selection
- Use this probability to evaluate the contribution to the background of the *fake* τ events

Mis-reconstructed charge:

- Estimate the **probability to mis-reconstruct the τ charge** from $Z \to \tau\tau \to \mu\tau$

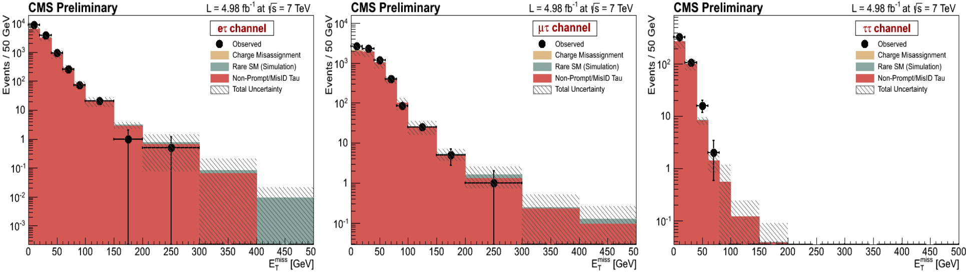
$M^{\mu\tau}$ **invariant mass for *opposite-sign* and *same-sign* $\mu\tau$**



Validation of the background evaluation methods

- The signal region is defined requesting for high *transverse missing energy*, i.e. **MET $>$ 200 GeV**
- Validation of the background evaluation methods is done in bins of *MET*
- The agreement is good in each bin

MET distribution in the $e\tau$, $\mu\tau$ and $\tau\tau$ channels

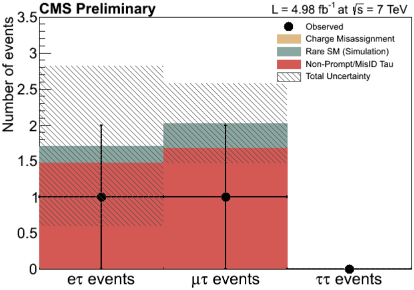


Results for SSDL

Definition of **Signal Region**:

- Two same sign leptons
  (of which one is a hadronically decaying τ)
- *Transverse missing energy* greater than 200 GeV
- No requirement on hadronic activity

Comparison between observation and background prediction



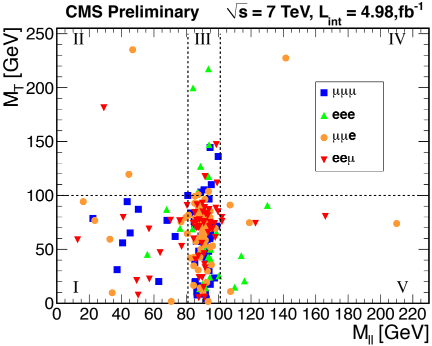
Channel	Prediction	Observation
$e\tau$	$1.6 \pm 0.3(stat) \pm 1.1(syst)$	**1**
$\mu\tau$	$1.9 \pm 0.3(stat) \pm 1.0(syst)$	**1**
$\tau\tau$	$0.0 \pm 0.0(stat) \pm 0.0(syst)$	**0**
Total	**3.5 ± 0.5(stat) ± 1.5(syst)**	**2**

3 Leptons + M_T (I)

Definition of **Signal Region**:

- Three leptons with at least one OSSF (*Opposite Sign Same Flavor*) pair
- *Transverse missing energy* greater than 50 GeV
- Veto on the events with b-jet

Six signal regions defined in a plane of *transverse mass*, M_T, and the *invariant mass*, $M_{\ell\ell}$, between the OSSF, are studied.



Background sources:

1. **Events with two prompt leptons and one fake lepton**
   - *fake-ratio method* is used

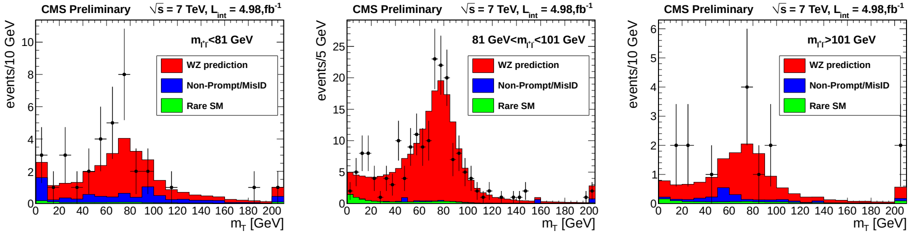
2. **Events with three prompt leptons**
   - MC studies are used

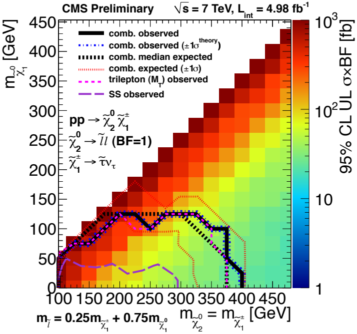
3 Leptons + M_T (II)

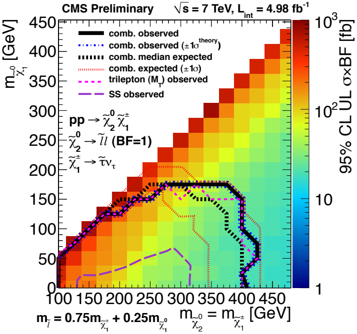
- No excess of events has been observed with respect to the background prediction
- Within the errors there is agreement between prediction and observation

Region	WZ	Non-prompt	Rare SM	Total background	Data
I	16.2 ± 2.9	4.7 ± 2.4	2.1 ± 1.5	23.0 ± 5.1	31
II	3.6 ± 0.8	1.94 ± 1.02	0.4 ± 0.2	6.0 ± 1.3	3
III	15.6 ± 5.7	0.2 ± 0.1	0.8 ± 0.4	16.6 ± 5.7	17
IV	1.6 ± 0.4	0.2 ± 0.1	0.4 ± 0.2	2.2 ± 0.5	2
V	8.7 ± 1.7	1.4 ± 0.8	0.9 ± 0.4	11.0 ± 1.9	12
VI	150.6 ± 25.7	2.6 ± 1.4	11.7 ± 5.8	164.90 ± 26.4	173

Transverse mass distribution







- Results are interpreted in the contest of the τ-enriched *chargino – neutralino* **pair production**
- Two are the parameters of the model, while two choices for intermediate slepton mass are done

Results probe charginos/neutralinos up to ∼400 GeV

Conclusions

- **Supersymmetry** is one of the **favored extension of the SM** at higher energy
- **Early** search at CMS focused on the search of **strongly interacting particles** that can be produced with large cross sections
- Models with **electroweak production of** *sparticles* could have **eluded detection in early searches**
- We studied the process known as **chargino-neutralino pair production**
- **Two complementary searches** have been performed:
  - 3 leptons + $\mathbf{M_T}$
  - 2 same sign leptons + **MET**
- **No excess of events** has been observed with respect to the prediction
- We put **limits** on the charginos/neutralinos masses up to $\sim$ **400 GeV**

THANK YOU