Summary of the second year work
Diphoton+E_T^{miss} search

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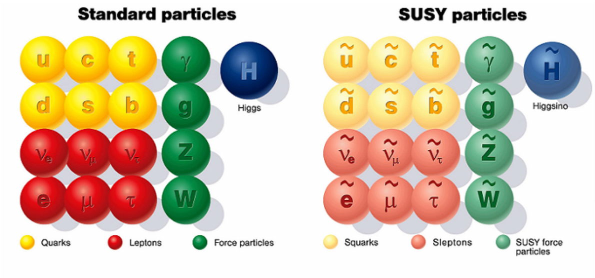
Introduction

- Supervisors: Dr. Leonardo Carminati and Dr. Giovanni Marchiori
- Co-tutorship with the Università degli studi di Milano
  - PhD started in October 2014 - Fall 2017 (expected)
  - In Paris from November 2015 to December 2016
- Major project: Search for supersymmetry in event with two photons and high E_T^{miss}
- First year (Milan):
  - qualification task: multivariate energy calibration for electrons and photons
  - Prepare the $\gamma\gamma$+MET analysis samples and tools:
    - Monte Carlo (MC) samples validation/request/production
    - data-analysis framework
    - statistical framework
- Second year (Paris):
  - Finalised the analysis:
    - Result
    - Paper, of which I am an editor
  - e/γ performace:
    - keep collaborating with calibration team
  - Diphoton resonance at high-mass: MC Sherpa NLO $\gamma\gamma$ validation
- Feb 2015-April 2016 co-supervision of the thesis of a master student in Milan



- Supersymmetry:
  - new bosonic field to each SM fermion.
  - new fermionic field to each SM gauge boson.

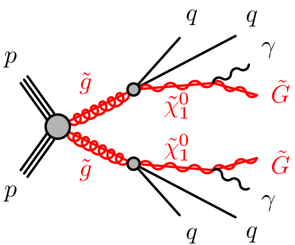
→ Solve the Higgs/hierarchy problem.

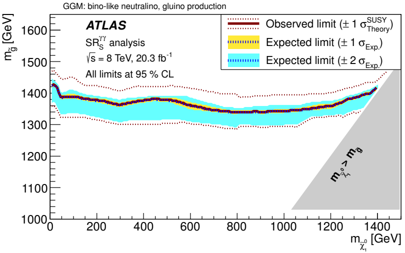
→ In Susy the unification of the coupling costants is far more precise than in Standard Model assumption.

→ Dark matter: Lightest Stable Particle (LSP) SUSY particle (with R-parity conservation).

Signal Processes

- Search for a signal from SUSY GGM models
  - Lightest Stable Particle (LSP): Gravitino ($\tilde{G}$).
  - Next to LSP: Neutralino ($\tilde{\chi}_1^0$).
- The neutralino is assumed to be purely bino-like (the SUSY partner of the SM U(1) gauge boson):
  - the final decay in each of the two cascades it would be predominantly: $\tilde{\chi}_1^0 \rightarrow \tilde{G} + \gamma$.
- Final state $\rightarrow \gamma\gamma + E_T^{miss}$.
- The mass of the neutralino is treated as a free parameter $m_{\tilde{\chi}_1^0} \in (0GeV, m_{\tilde{g}})$.
- Prompt decay $\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$ ($c\tau < 0.1$ mm).
- RUN1 analysis set a lower limit on $m_{\tilde{g}}$ at 1340 GeV (PhysRevD.92.072001).

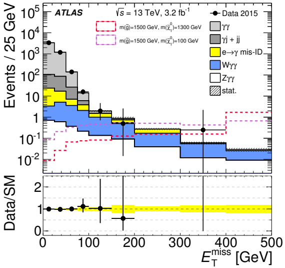


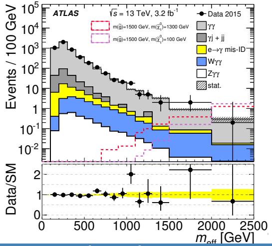


Backgrounds

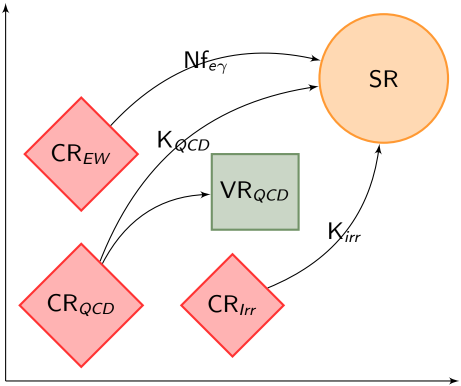
- QCD background (instrumental E_T^{miss} + 1 or 2 real photons):
  - SM $\gamma\gamma$, γ+jet
- Electroweak background (genuine E_T^{miss} + 1 real photon)
  - W+γ (W$\rightarrow$eν), Z+γ (Z$\rightarrow \tau^+\tau^-$), $t\bar{t}$+γ ($t \rightarrow$beν)
- Irreducible background (genuine E_T^{miss} + 2 real photons):
  - Final state identical to the searched signal
  - Z+$\gamma\gamma$ (Z$\rightarrow \nu\nu$)
  - W+$\gamma\gamma$ (W$\rightarrow e\nu$)
- Discriminant variables:
  - $p_T^{\gamma} > 75$ GeV.
  - $E_T^{miss} > 175$ GeV.
  - $\Delta\phi(jet, E_T^{miss}) > 0.5$, to reduce fake E_T^{miss} contribution.
  - $m_{eff} > 1500$ GeV, scalar sum of H_T(=total transverse energy of all visible objects) and E_T^{miss}.

- E_T^{miss} and m_{eff} distributions after p_T^{γ} and $\Delta\phi$ requests

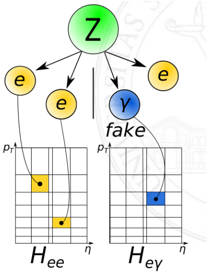




- RUN2 2015 data: $\sqrt{s} = 13$ TeV and $L = 3.2$ fb^{-1}
- Cut and count analysis:
  - Signal Region optimisation
  - Background evaluation:
    - SM contribution
    - Evaluation in Control Region (orthogonal to SR) with data-driven/MC methods
    - Validation Region
  - Statistical comparison of Expected (bkg) events vs. Observed



- EW background accounts for SM contributions mainly from W(W→eν)γ, $t\bar{t}\gamma$, Z(W→ee/$\tau\tau$)γ.
- Evaluated rescaling the number of events in a control region defined as SR but which requests to have exactly one photon and at least one electron with $p_T^{\gamma} > 75$ GeV

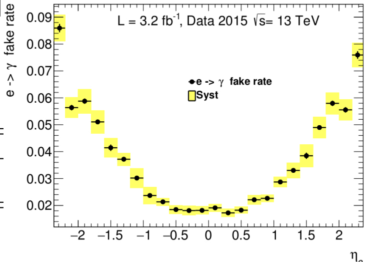


$$N_{e\to\gamma}(p_{\rm T},\eta,x) = F_{e\to\gamma}(p_{\rm T},\eta) \times N_{e\gamma}(p_{\rm T},\eta,x)$$

where $F_{e\to\gamma}(p_{\rm T},\eta)$ is measured starting from a Z→ee data sample as the ratio of the number of the selected ee and eγ couples (see next slide).

- The contribution to SR is 0.03 ± 0.02

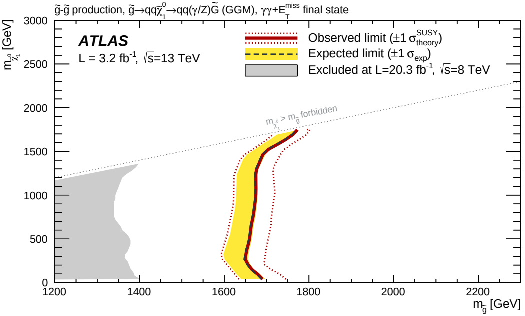
$p_T(e)$	$\eta(e)$	$p_T(\gamma)$	$\eta(\gamma)$	H_T	E_T^{miss}	$F_{e\to\gamma}$
113	-0.606	88	-1.849	1606	186	0.019
166	0.581	105	-1.273	1033	586	0.012



Result and Limit setting

- Good agreement between background prediction and observed data.
- Model-independent 95% CL upper limit of 3.0 events (0.93 fb) on the number of beyond SM events (visible cross section).
- 95% CL lower limit are set on $m_{\tilde{g}}$ at 1650 GeV (1340 at 8 TeV).

Source	Contribution [Events]
QCD ($\gamma\gamma$, γj, jj)	$0.05^{+0.20}_{-0.05}$
$e \to \gamma$ fakes	0.03 ± 0.02
$W\gamma\gamma$	0.17 ± 0.08
$Z\gamma\gamma$	0.02 ± 0.02
Sum	$0.27^{+0.22}_{-0.10}$
$(m_{\tilde{g}}, m_{\tilde{\chi}^0_1}) = (1500, 100)$	7.0
$(m_{\tilde{g}}, m_{\tilde{\chi}^0_1}) = (1500, 1300)$	8.0
Data	0



Conclusion and future plan

- The diphoton+E_T^{miss} result using 3.2 fb^{-1} have been published (paper accepted by EPJC, link arXiv).

$\rightarrow$ Update the analysis with 2016 data
  - expand the search for other different production of the $\gamma\gamma + E_T^{miss}$ final state.
- Precise measurement of the SM Higgs mass.
  - Performance: energy calibration of e/γ.

Look for new physics everywhere!