Search for New Physics at CMS with Jets and Missing Momentum

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on behalf of the CMS Collaboration

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New Physics Search with Jets and MHT

A search for New Physics in the CMS 2010 pp data [1] is based on:
- at least **three jets** accompanied by
- large **missing transverse momentum**.

This analysis is **inclusive**: the search is not optimized for any (SUSY) model or specific event kinematics. The strategy and methodology are appropriate for an **early search** in the 2010 pp data:
- **counting experiment**;
- **data-driven background** estimations.

The **three main backgrounds** are QCD, vector bosons and $t\bar{t}$ with lost leptons or hadronic τ, and Z decaying to neutrinos.

Transverse Momentum and **Missing Transverse Momentum**

$$H_T = \sum_{i \in \text{jets}} |\mathbf{p}_T^i| \qquad \not{H}_T = \left| -\sum_{i \in \text{jets}} \mathbf{p}_T^i \right|$$

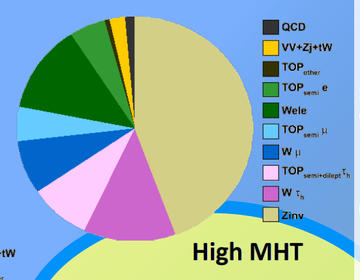
are the main discriminating variables.

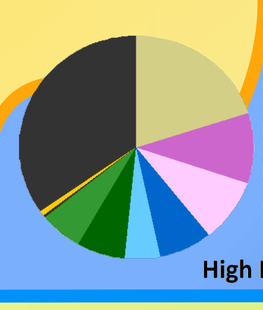
[1] The CMS Collaboration, "Inclusive search for new physics at CMS with the jets and missing momentum signature", CMS PAS SUS-10-005 (2011).

Search Strategy & Event Selection

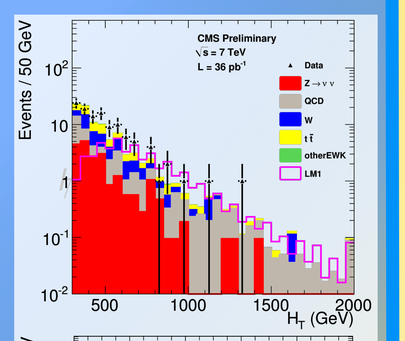
Baseline Selection:
- At least 3 jets ($p_T > 50\,\text{GeV}/c$, $|\eta| < 2.5$ jets)
- $H_T > 300\,\text{GeV}/c$ ($p_T > 50\,\text{GeV}/c$, $|\eta| < 2.5$ jets)
- $\Delta\varphi(\not{H}_T, J_{[1,2,3]}) > [0.5, 0.5, 0.3]$
- $\not{H}_T > 150\,\text{GeV}/c$ ($p_T > 30\,\text{GeV}/c$ jets)
- Isolated Lepton Veto

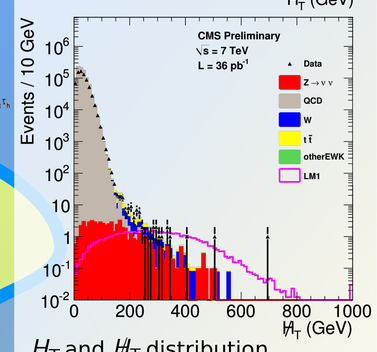
High-MHT Search
- Baseline
- $\not{H}_T > 250\,\text{GeV}/c$





High-HT Search
- Baseline
- $H_T > 500\,\text{GeV}/c$



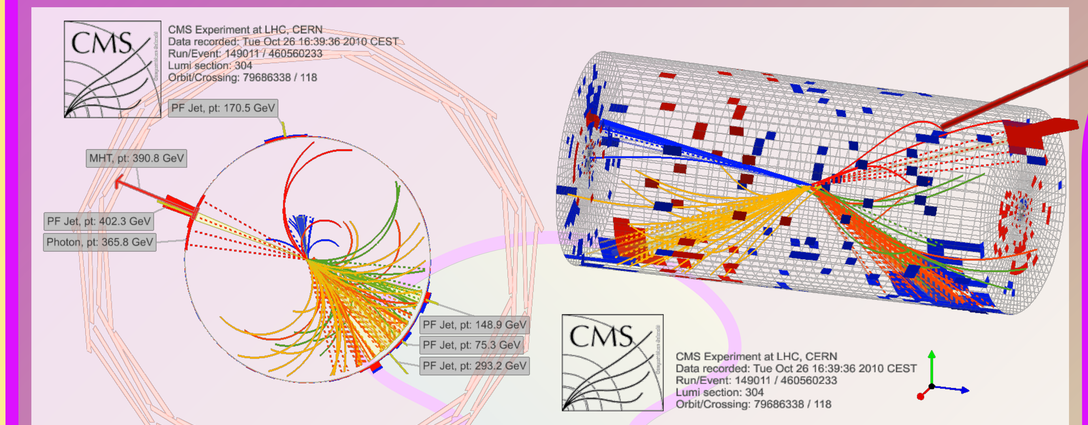


H_T and $\not{H}_T$ distribution, SM MC is shown for comparison

Predicting Invisible Z background

Z decaying to neutrinos constitutes an **irreducible background**. Photons and Z bosons exhibit similar characteristics at high energy, **Photons are used to estimate the Z background from data**. Removing the Photon from the events mimicks the invisible Z decay. Differences between Photon + jets and Z + jets events are due to:
- the mass of the Z;
- the Z boson coupling also to the weak force , while the photon couples only to the electromagnetic force.

An indirect cut on the p_T^γ was implemented by the $\not{H}_T$-requirement, which is not high enough to remove the Z-mass effect. A **correction factor** between Photon and Z events was obtained from MC.

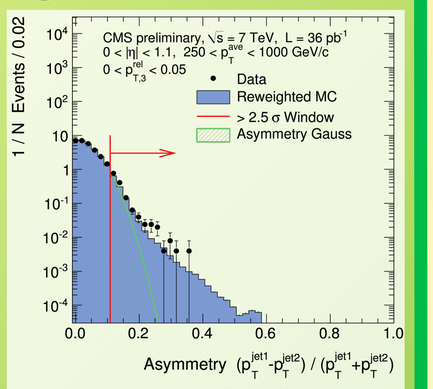


Display of an event with a 366 GeV/c Photon. After removal of the Photon jet, $\not{H}_T$ was computed to be 390 GeV/c, while H_T equals 688 GeV/c.

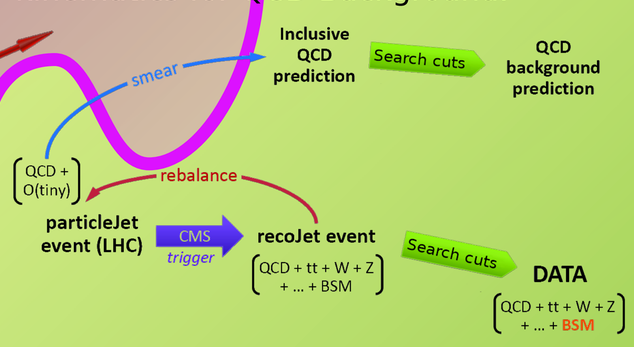
QCD Multi-Jet Backgrounds

The **Rebalance and Smear** (R&S). method relies on the in-depth knowledge of **Jet Energy Resolutions**.

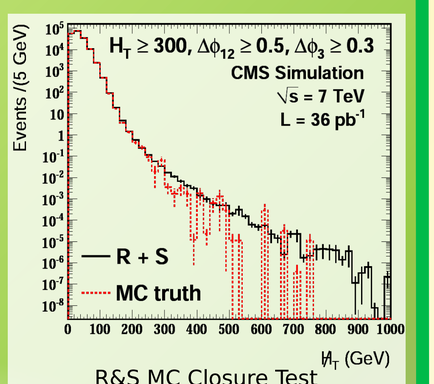
- An H_T Trigger selects QCD Events.
- QCD Multi-Jet events are unfolded within measurement uncertainties to be well balanced "particleJet " events.
- These "seed" events are smeared using the Jet Energy Resolutions.
- This method predicts full event kinematics for QCD Background.



Di-Jet asymmetry for adjusted MC and data



Second method: **The Factorization Method:** A modified ABCD method based on two correlated variables $\not{H}_T$ and $\Delta\varphi_{\min}$ are connected by a functional form.



R&S MC Closure Test

Background from W and $t\bar{t}$

- Lepton Veto removes Events with ν's
- Lepton not **identified** or not **isolated:**
  - Predicted yields from a $\mu + \text{jets}$ control sample (CS):

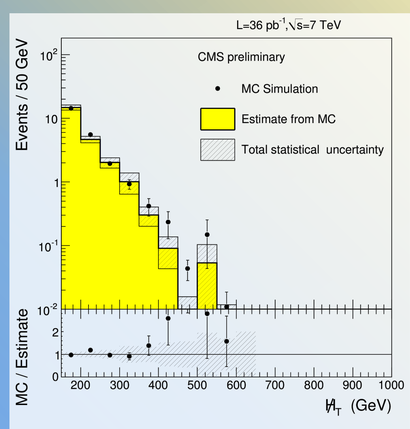
$$!\text{ISO}^{e,\mu} = \text{CS} \cdot \frac{\epsilon_{\text{ID}}^{e,\mu}}{\epsilon_{\text{ID}}^{\mu}} \cdot \frac{1-\epsilon_{\text{ISO}}^{e,\mu}}{\epsilon_{\text{ISO}}^{\mu}}$$

$$!\text{ID}^{e,\mu} = \text{CS} \cdot \frac{1}{\epsilon_{\text{ISO}}^{\mu}} \cdot \frac{1-\epsilon_{\text{ID}}^{e,\mu}}{\epsilon_{\text{ID}}^{\mu}}$$

  - Efficiencies are measured with a $Z(\ell\ell) + \text{jets}$ sample:

$$\epsilon_{\text{ISO}} = f(p_T, \eta) \qquad \epsilon_{\text{ID}} = f(p_T, \Delta R(\ell, J))$$

- Lepton out of acceptance:
  - Acceptance correction determined with MC.
- τ Lepton decaying hadronically:
  - μ substituted for τ-jet in CS, smearing p_T^μ according to a MC template describing the Visible Energy Fraction.



Lost Lepton MC Closure test

Summary of Data-driven Backgrounds

Method	Baseline		High-$\not{H}_T$ ($\not{H}_T > 250$ GeV/c)		High-H_T ($H_T > 500$ GeV/c)	
$Z \to \nu\bar{\nu}$ from γ+jets	26.3	±4.8	7.1	±2.2	8.4	±2.3
$t\bar{t}/W \to e, \mu$+X lost-lepton method	33.0	±8.1	4.8	±1.9	10.9	±3.4
$t\bar{t}/W \to \tau_{\text{hadr}}$+X method	22.3	±4.6	6.7	±2.1	8.5	±2.5
QCD Rebalance+Smear method	29.7	±15.2	0.16	±0.10	16.0	±7.9
QCD factorization method	25.2	±13.4	0.4	±0.3	17.3	±9.4
Total data-driven background	111.3	±18.5	18.8	±3.5	43.8	±9.2
Observed in 36 pb^{-1} of data	111		15		40	
95% CL limit on signal events	40.4		9.6		19.6	

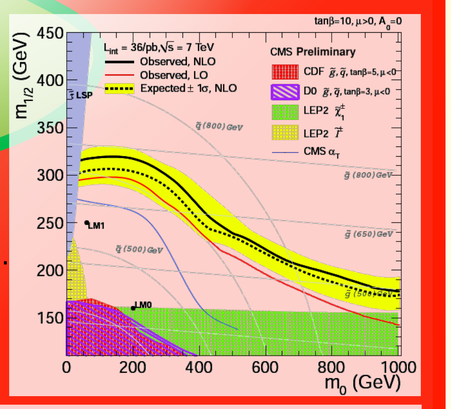
Methods predict full event kinematics & are limited by statistical uncertainties

Results

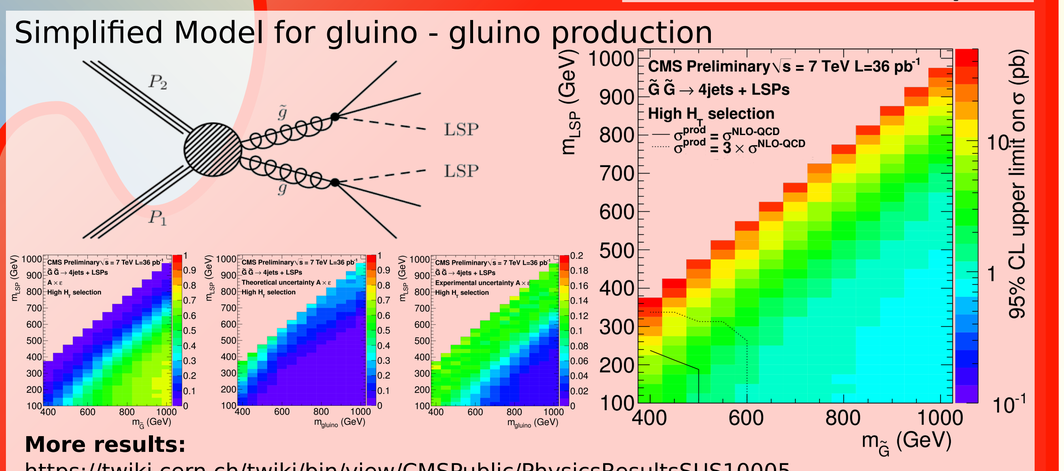
Results are presented in Simplified Models [2] and in the Constrained MSSM (CMSSM) [3].

Simplified models aim to characterize New Physics in a way that allows comparison to any model:
- Few parameters: M, BR, σ.
- Easy to reinterpret results for Model Builders.

In this analysis, limits are set for di-squark and di-gluino production for both search regions.



Simplified Model for gluino - gluino production



More results:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS10005

[2] Simplified Models for LHC New Physics Searches [hep-ph/1105.2838]
[3] Study of Constrained Minimal Supersymmetry, Phys. Rev. D 49 (1994) 6173 - 6210