IPPP Hadron and Photon Analysis

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Introduction

- Search strategies priorities.
- Hadronic searches in CMS with focus on IC involvement.
- Main selection variables.
- Data driven background (example).

The content is "private" in the sense that plots are not CMS approved plots.

Search Strategies

Main Priorities:

- To be in a region of phase space where we can control our SM background:
  - ➔ SM reduction
  - ➔ Data-driven estimates of background (control sampels, regions)
- To be as model independent as possible.

However:

- We need to define signal regions where we have to control the SM background.
- We need some sort of SUSY-signal efficiency to define success of a search.

For both we need some sort of manageable SUSY MC, which might contradict the model independence to some extend.
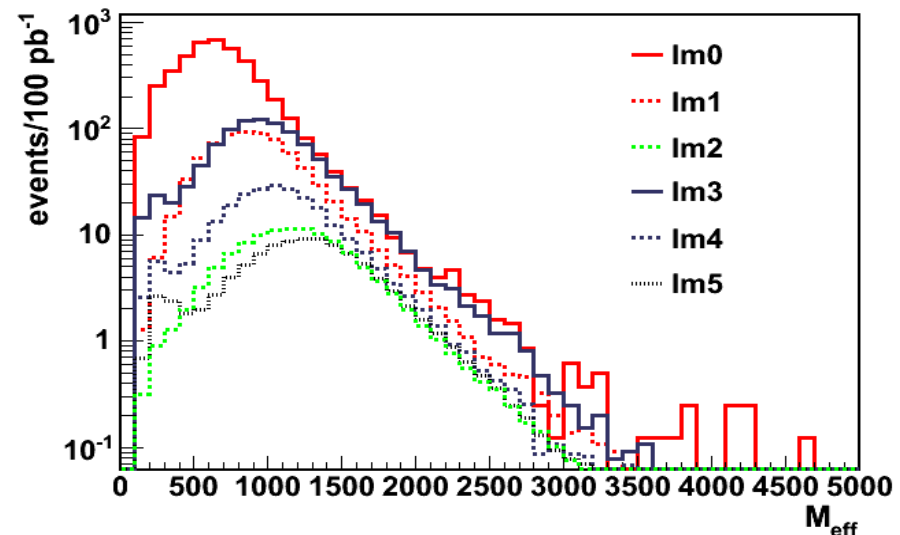
Sample	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0	$\tan\beta$	$\text{sign}(\mu)$	σ LO (pb)	lightest $\tilde{q}$ (GeV)	χ_1^0 (GeV)
LM0*	200	160	-400	10	+	110	207 ($\tilde{t}_1$)	60
LM1	60	250	0	10	+	16.1	410 ($\tilde{t}_1$)	97
LM2	185	350	0	35	+	2.4	582 ($\tilde{t}_1$)	141
LM3	330	240	0	20	+	11.8	446 ($\tilde{t}_1$)	94
LM4	210	285	0	10	+	6.7	483 ($\tilde{t}_1$)	112
LM5	230	360	0	10	+	1.9	603 ($\tilde{t}_1$)	145

*ATLAS BMP 4

$$HT = \Sigma P_T$$

$$MHT = |\Sigma \vec{p}_T|$$

$$M_{eff} = MHT+HT$$

Typically main characteristic used in searches. (large mass differences)

Hadronic Searches

Major IC involvement

- No electron, muons or photons.
- $|\eta|$ jets < 3 && $P_T > 50$ GeV.
- 2 or more jets.
- 2nd jet $P_T > 100$ GeV. (EW suppression)
- $|\eta|$ first jets < 2.
- HT $= \Sigma P_T > 350$ GeV.
- $\alpha_T > 0.55$ (QCD suppression: topological variable)

� Eventually more robust against QCD.
➙ Includes dijets (only dijet public so far)
➙ Uses topological variable
➙ α_T dependents on ratios (MHT/HT)
➙ Also applicible for photon+jet search.

Partial IC involement

- No electron, muons or photons.
- 1st jet $P_T > 180$ GeV; 2nd jet $P_T > 110$ GeV, 3rd Jet $P_T > 50$ GeV (EW suppression);
- 3 or more jets.
- MHT (MET) > 200 GeV
- $|\eta|$ first jets < 2.5
- angular cuts for QCD suppression: checks if met is aligned to a jet.

➙ Higher signal (LMX) efficiency
➙ Details in PTDR.

CMS-PAS SUS08-003 and Phys. Rev. Lett vol. 101, p. 221803 2008,

Two pseudo jets are formed which balance each other as good as possible in the "pseudo-jet" $H_T = \Sigma E_T$, where the E_T are from the jets of the pseudo jet. This way of construction the pseudo dijet system showed to have similar properties like a real dijet system.

$$M_T(j_1, \ldots, j_i, \ldots, j_n) = \sqrt{\left[\sum_{i=1}^{n} E_T(j_i)\right]^2 - \left[\sum_{i=1}^{n} p_x(j_i)\right]^2 - \left[\sum_{i=1}^{n} p_y(j_i)\right]^2}$$

$$\alpha_T = 0.5 \frac{H_T - \Delta H_T}{M_T}$$,where $\Delta H_T = H_{T.1} - H_{T.2}$

$$\alpha_T = 0.5 \frac{1 - \Delta H_T/H_T}{\sqrt{1 - MHT^2/H_T^2}}$$, MHT and ΔH_T occur relative to H_T

Selection Variables: α_T

after all cuts but α_T:

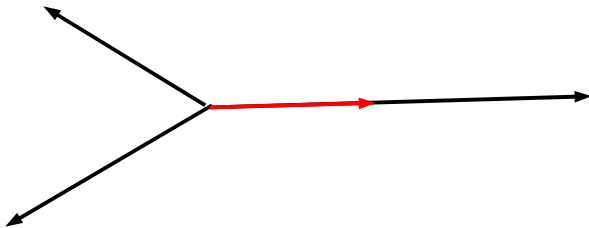HT > 350 GeV   350 GeV > HT >250 GeV
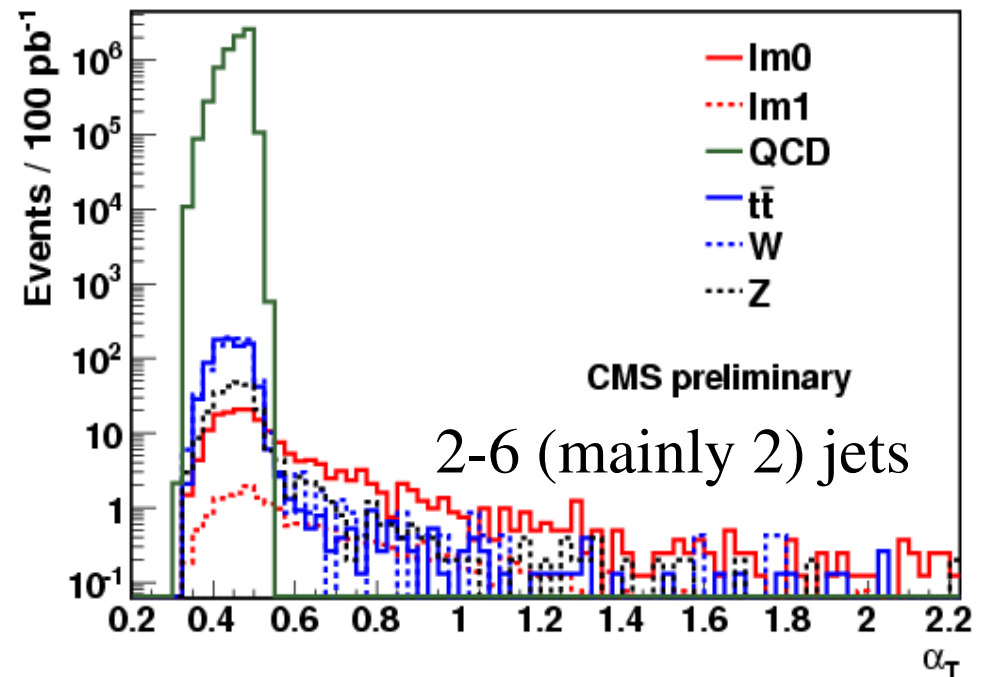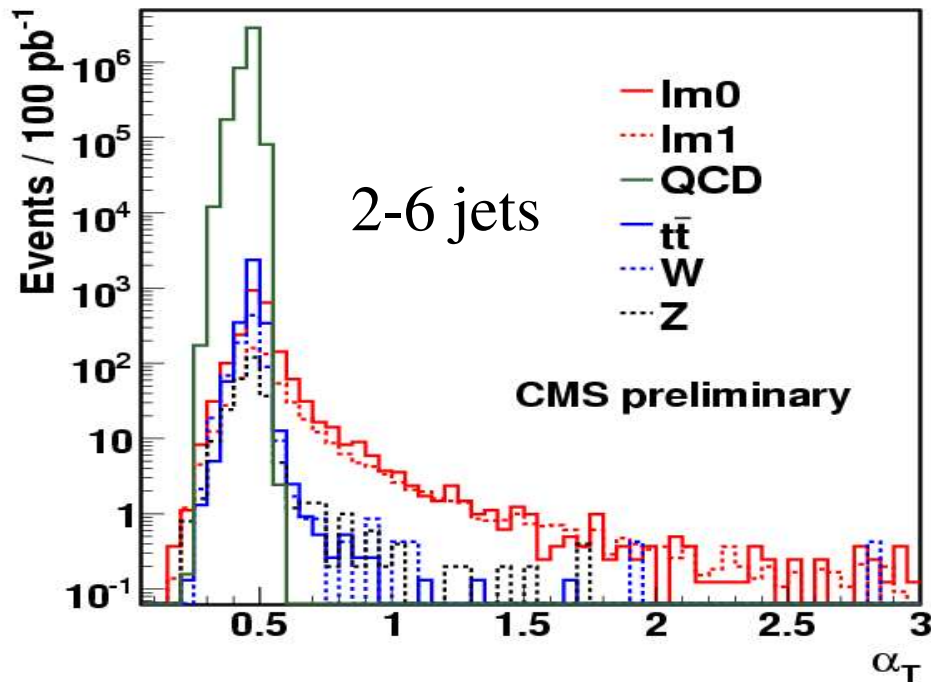
- Cut values at 0.55.
- The tails are literally QCD empty.
- Is "250 GeV < HT < 350 GeV" potential signal or background region?
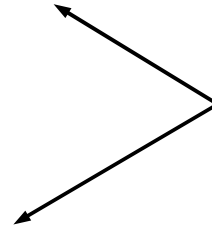
Other Variables (for Control)

$$\text{``biased''}\,\Delta\phi = min_k\left(\Delta\phi\left(\left(\sum_{i=0}^{n}-\vec{j}_i\right)+\vec{j}_k;\vec{j}_k\right)\right)$$

For QCD:

For true MET:

Checks if there would be a jet that, if rescaled, balances the event.

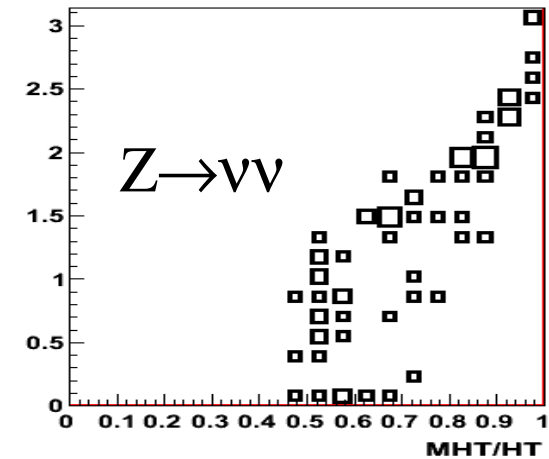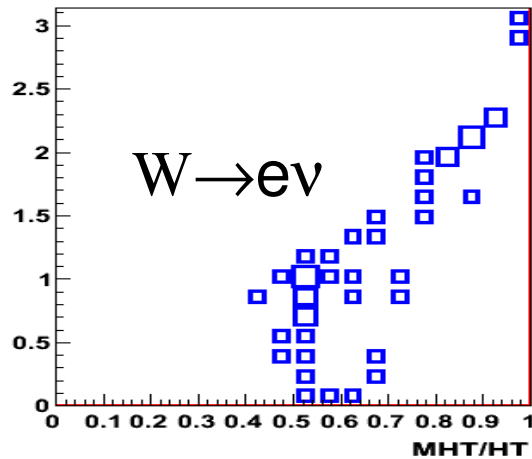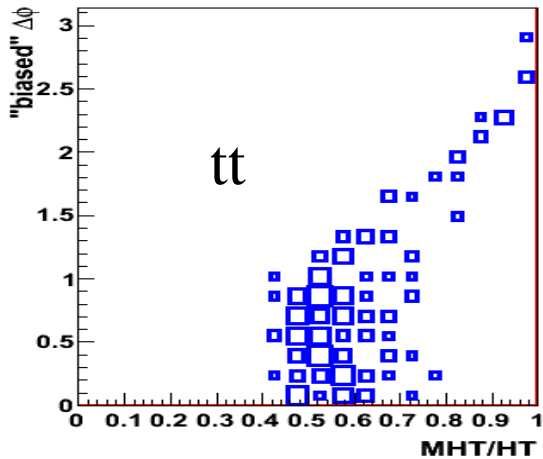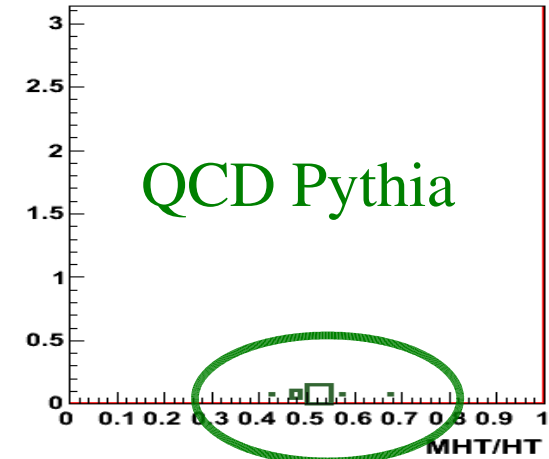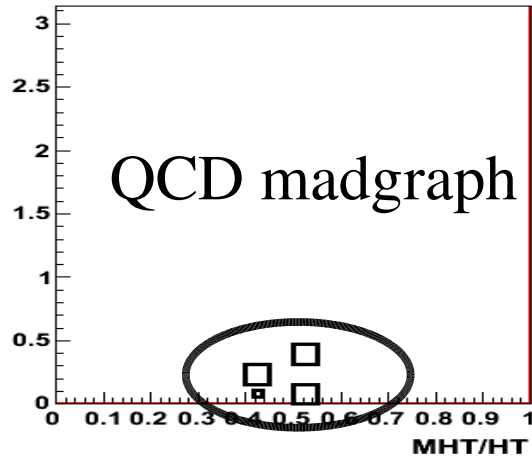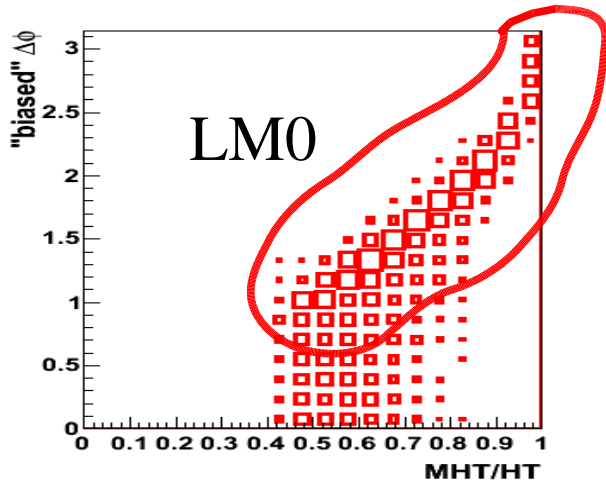If $\Delta\phi$ is large, then the jet are close in ϕ and MHT/HT is large.

Other variables:

- $\Delta\phi$ between hemispheres seeded by transverse thrust axis.
- $\Delta\phi$ transverse thrust axis to MHT.
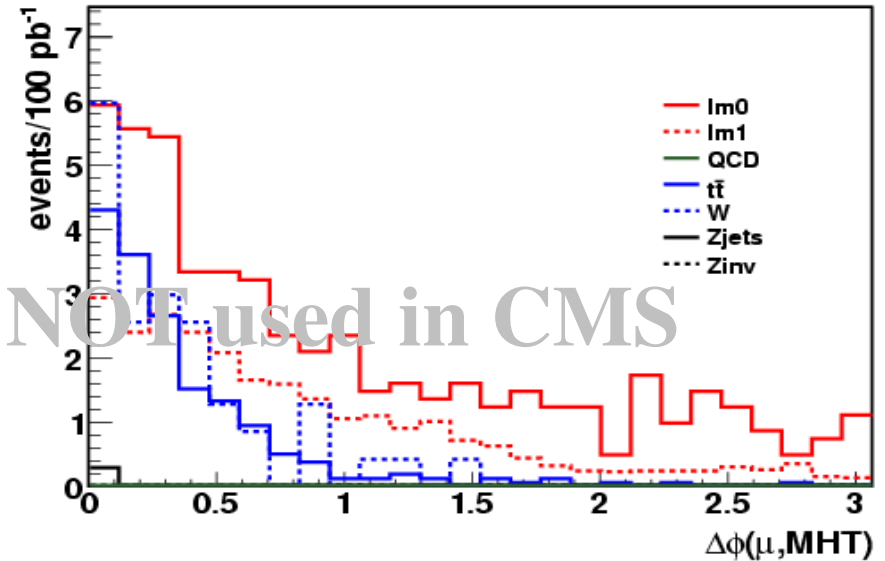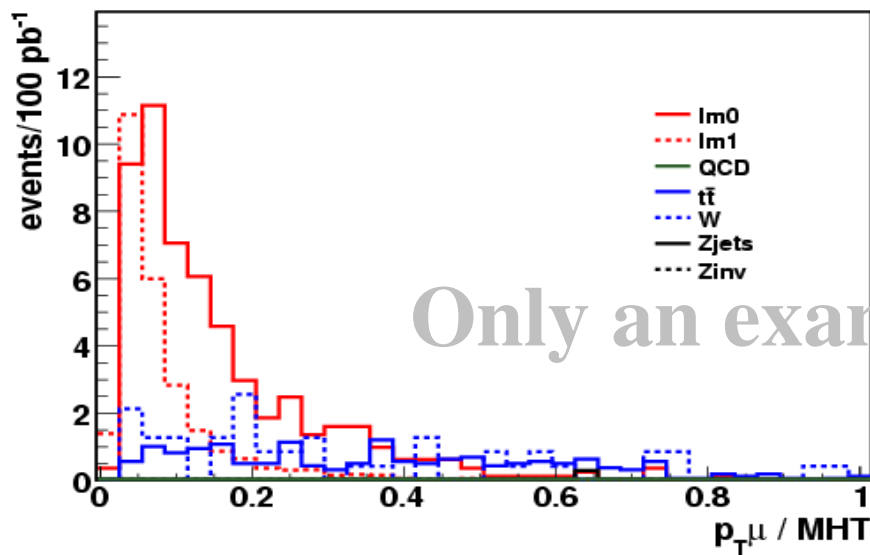
Control Plots

after final selection

QCD events are in "typical" region.

SUSY "contamination" in Control Samples

Applying all cuts and require for a single isolated muon would be a nice control sample:

- Dominantly semi-leptonic tt, W+jets remain from SM.
- Only SM with W of few 100 GeV (~ MHT) remain.
- Muon momentum stems dominatly from W boost.

Only an example, NOT used in CMS

- Clear shape expectation for SM.
- SUSY amplitude and shape very model dependent.
- Adds complexity to the model dependence.

2-6 jet cut flow:

Selection cut	QCD	Z nunu	W lnu	tt	Z+jets	LM1	LM0
pre-selection	2.2×10^7	690	2479	3547	265	630	3011
HT > 350 GeV	5.2×10^6	305	960	2660	100	605	2757
$\alpha_T > 0.55$	10.9	12.8	15.4	10.3	0.3	169	335
$MHT_{ratio} < 1.25$	2.4	12.8	15.4	9.1	0.3	168	321

Most important : **There is discovery potential.**

Would be nice to design searches such, that such statements are not too model dependent.

- Presented typical variables used in hadronic searches.
- Are there more general variables, which should decrease the model dependence derived from theoretical principles?
- A question valid for all variables from 2nd jet P_T to α_T...
- Model dependence also effects data-driven background estimation methods.

We have potential to discover SUSY in the hadronic channel with few 100 pb^{-1}.