SUSY Physics

Multijet + Missing E_t final states

CMSDAS @ Taipei

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February 21, 2016

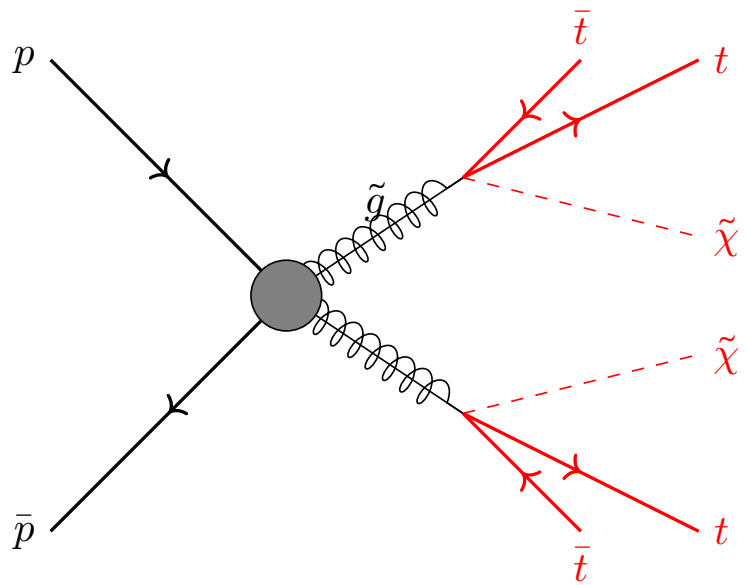
Motivation

SUSY:

- Hierarchy problem, dark matter candidate...

Channel: $\tilde{g} \to t\bar{t}\tilde{\chi}$

- $\tilde{\chi}$ No longer decays by R parity conservation.
- t decays give a lot of jets.



Analysis strategy and variables

Visible Transverse Energy:

$$H_T = \sum_{\text{jets}} |\vec{p}_{T,\text{jet}}| \quad (1)$$

Missing Transverse Energy:

$$\not{H}_T = \left| -\sum_{\text{jets}} \vec{p}_{T,\text{jet}} \right| \quad (2)$$

What we expect from our signal:

- Large H_T and $\not{H}_T$
- Large number of Jets and b-tagged jets.
- Jets Only! Select by $\vec{p}_{T,jet} - \not{H}_T \ \Delta\phi$

Sample	cross section(pb)	Total number of events
$W \to l\nu$ $H_T \in [100, 200)$	1627.45	10,152,718
$W \to l\nu$ $H_T \in [200, 400)$	435.24	5,221,599
$W \to l\nu$ $H_T \in [400, 600)$	59.18	1,745,914
$W \to l\nu$ $H_T \in [600, 800)$	14.58	4,041,997
$W \to l\nu$ $H_T \in [800, 1200)$	6.66	1,574,633
$W \to l\nu$ $H_T \in [1200, 2500)$	1.608	255,637
$W \to l\nu$ $H_T \in [2500, \infty)$	0.03891	253,036
$t\bar{t}$, $(t \to bl\nu)$	182.72	60,186,393
$t\bar{t}$, $(\bar{t} \to \bar{b}l\nu)$	182.72	59,816,364
$t\bar{t}$, Dileptonic	88.34	30,498,962
$Z \to \nu\bar{\nu}$ $H_T \in [100, 200)$	344.3	5,154,824
$Z \to \nu\bar{\nu}$ $H_T \in [200, 400)$	95.23	4,998,316
$Z \to \nu\bar{\nu}$ $H_T \in [400, 600)$	13.19	1,018,882
$Z \to \nu\bar{\nu}$ $H_T \in [600, \infty)$	5.063	1,008,333
QCD $H_T \in [300, 500)$	351300	19,826,197
QCD $H_T \in [500, 700)$	31630	19,664,159
QCD $H_T \in [700, 1000)$	6802	15,356,448
QCD $H_T \in [1000, 1500)$	1206	4,963,895
QCD $H_T \in [1500, 2000)$	120.4	3,868,886
QCD $H_T \in [2000, \infty)$	25.24	1,912,529
$M_{\tilde{g}} = 1300GeV$, $m_{\tilde{\chi}} = 100GeV$	0.0141903	103,140
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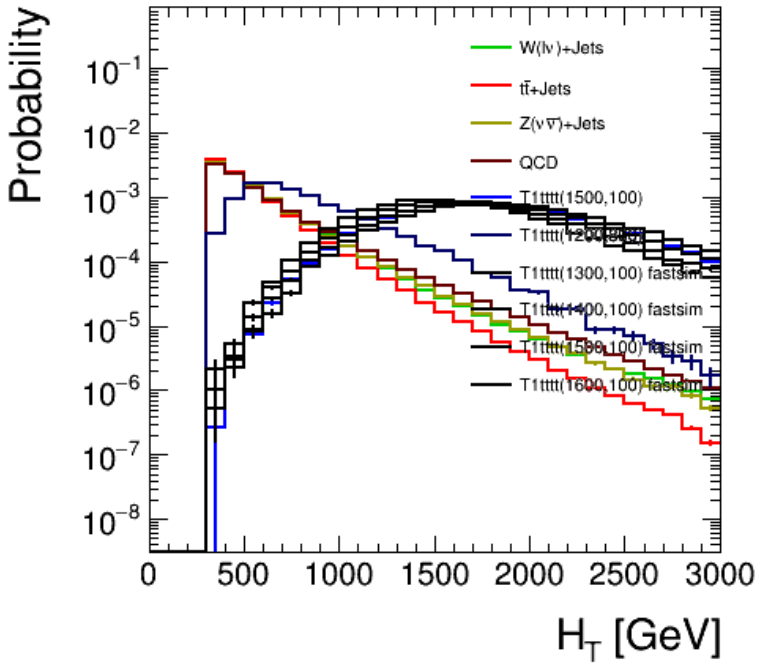
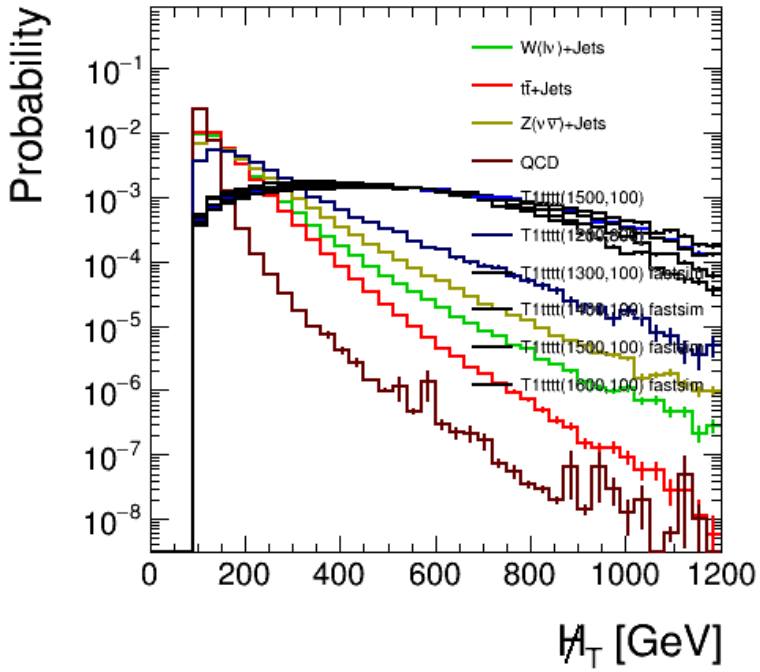
$M_{\tilde{g}} = 1500GeV$, $m_{\tilde{\chi}} = 100GeV$	0.0141903	103,140
$M_{\tilde{g}} = 1600GeV$, $m_{\tilde{\chi}} = 100GeV$	0.0141903	103,140


Probability
W(lν)+Jets
tt̄+Jets
Z(νν̄)+Jets
QCD
T1tttt(1500,100)
T1tttt(1200,800)
T1tttt(1300,100) fastsim
T1tttt(1400,100) fastsim
T1tttt(1500,100) fastsim
T1tttt(1600,100) fastsim
H_T [GeV]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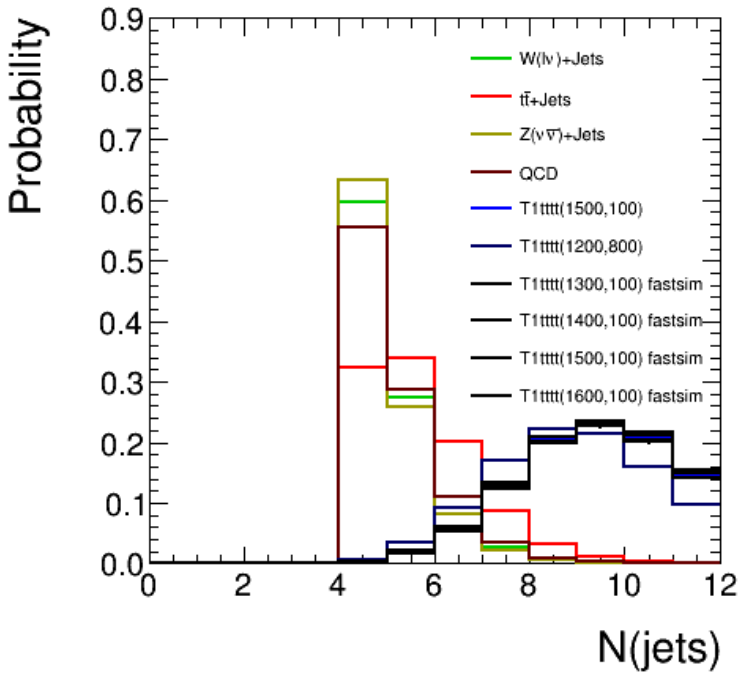
T1tttt(1600,100) fastsim
H_T [GeV]


Probability
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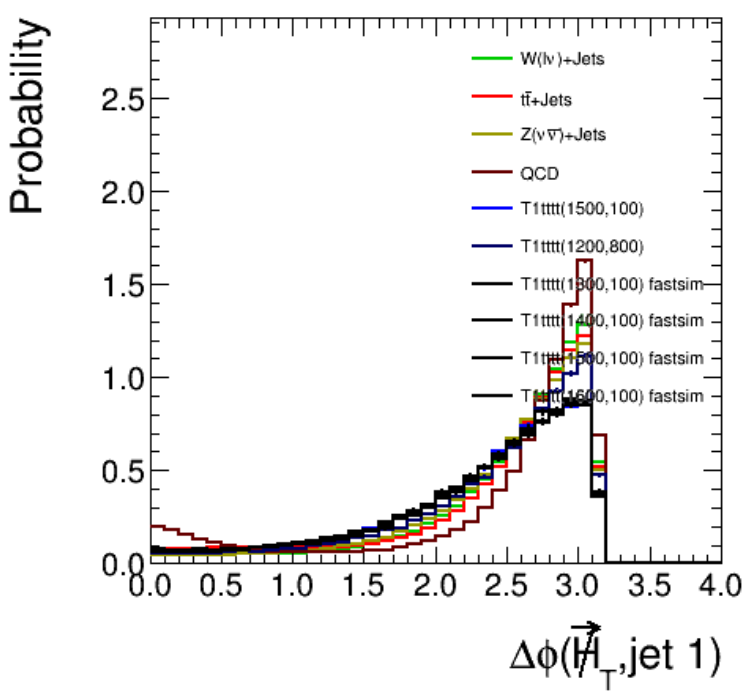
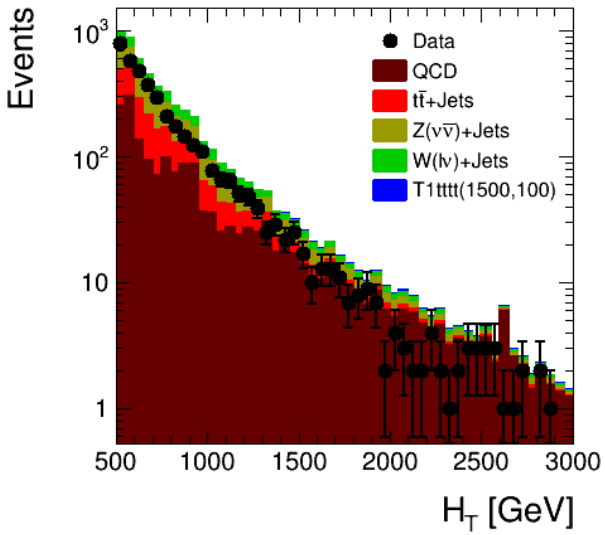
T1tttt(1500,100)
T1tttt(1200,800)
T1tttt(1300,100) fastsim
T1tttt(1400,100) fastsim
T1tttt(1500,100) fastsim
T1tttt(1600,100) fastsim
N(jets)

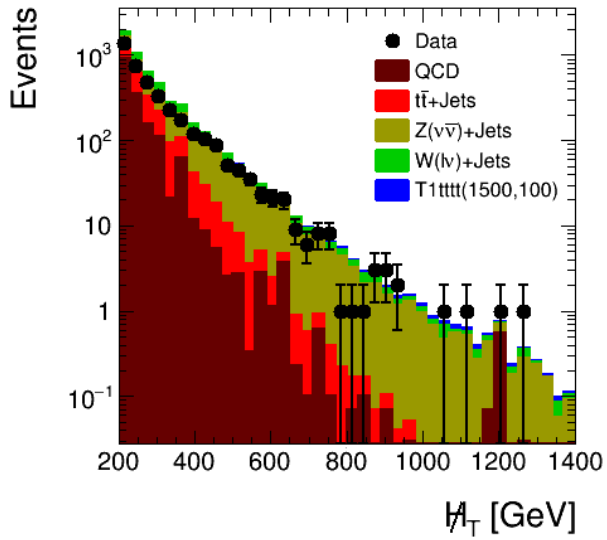

Probability
W(lν)+Jets
tt̄+Jets
Z(νν̄)+Jets
QCD
T1tttt(1500,100)
T1tttt(1200,800)
T1tttt(1300,100) fastsim
T1tttt(1400,100) fastsim
T1tttt(1500,100) fastsim
T1tttt(1600,100) fastsim
Δφ(H_T, jet 1)

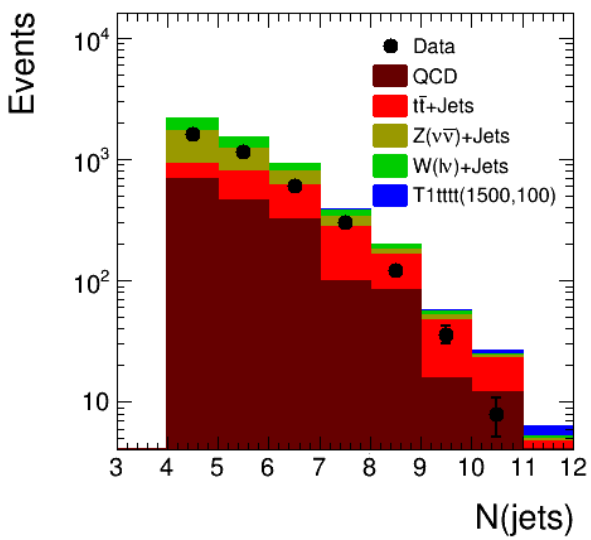
Baseline Selections

- Detector perfomance:
  - ECal discharge filters
  - Beam Halo Filters
  - One primary vertex
  - No noise jets
- Jets: $p_T > 30\text{GeV/c}$, $|\eta| < 2.4$
- At least 4 selected jets.
- $\Delta\phi_{1,2} > 0.5$, $\Delta\phi_{3,4} > 0.3$
- $H_T (= \sum_{\text{selc. jets}} |p_T|) > 500\text{GeV/c}$
- $\not{H}_T = \left| -\sum_{\text{selc. jet}} \vec{p}_T \right| > 200\text{GeV/c}$
- Other object vetos:
  - No isolated lepton with $p_T > 10\text{GeV}$ and $|\eta| < 2.4$
  - No isolated lepton-like tracks with $p_T > 5\text{GeV}$ and $|\eta| < 2.4$
  - No isolated π-like track with $p_T > 10\text{GeV}$ and $|\eta| < 2.4$

Selection Results - Baseline



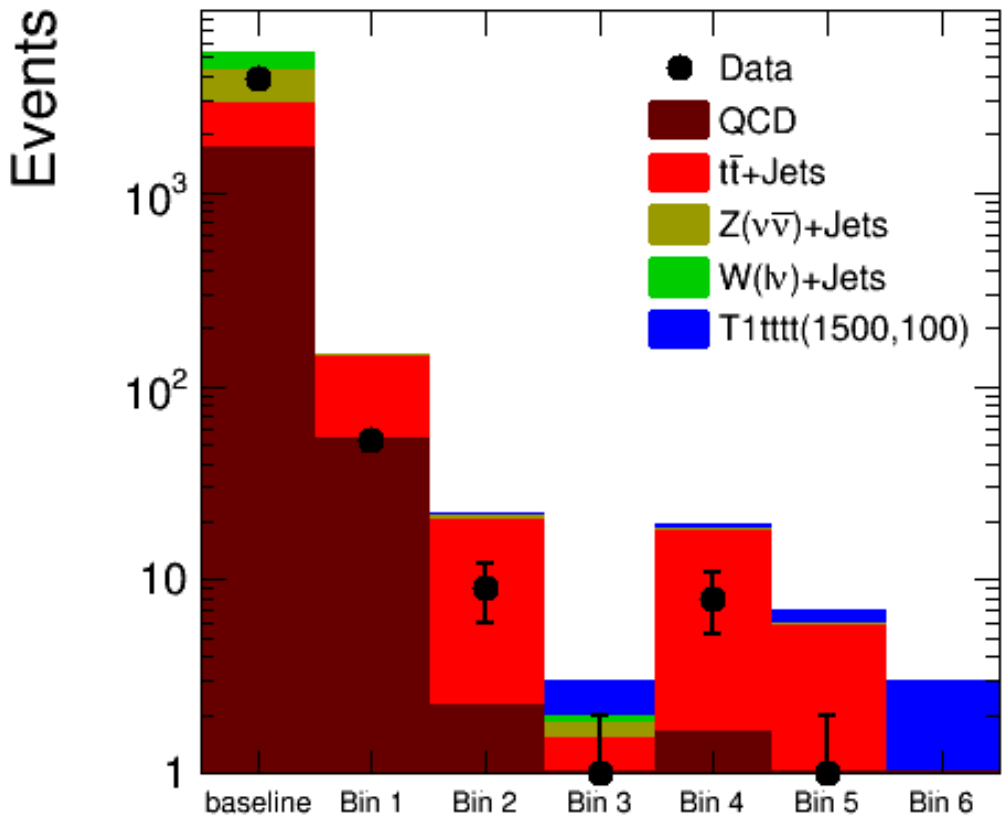




Selection - Extended binning

Bin	Num. of. Jets	$\not{H}_T$GeV/c	H_TGeV/c	Num. of b tagged Jets
1	7 or 8	(200,500)	>500	2
2	7 or 8	(200,500)	>500	≥3
3	7 or 8	>500	>500	≥2
4	≥9	(200,500)	>500	2
5	≥9	(200,500)	>500	3
6	≥9	>500	>500	≥2

Simple Results - with Signal



Data Driven Methods for Background

Merits of estimating data background from other sections data:

- Reduces impact of artificial artefacts in MC.
- Improves statistics of background estimation.
- Avoids theoretical uncertainties of process yields.

Here we are going to operate two method:

- Leptonic backgrounds but lepton was lost in reconstruction. ($W \to l\nu$, t decay)
- $Z \to \nu\bar{\nu}$

Lost Lepton methods- W Jets and $t\bar{t}$

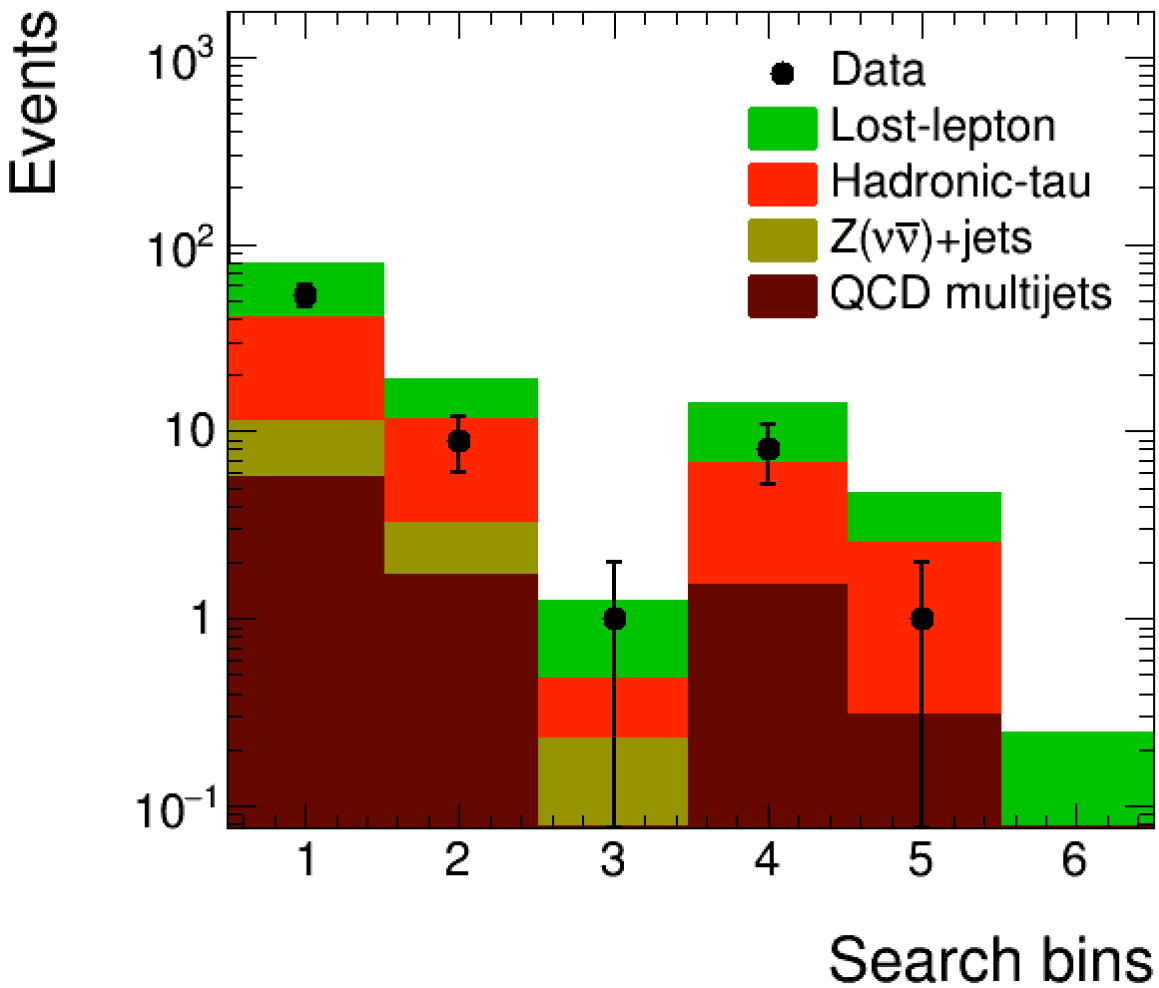
Consider our base selection cut:

No isolated lepton

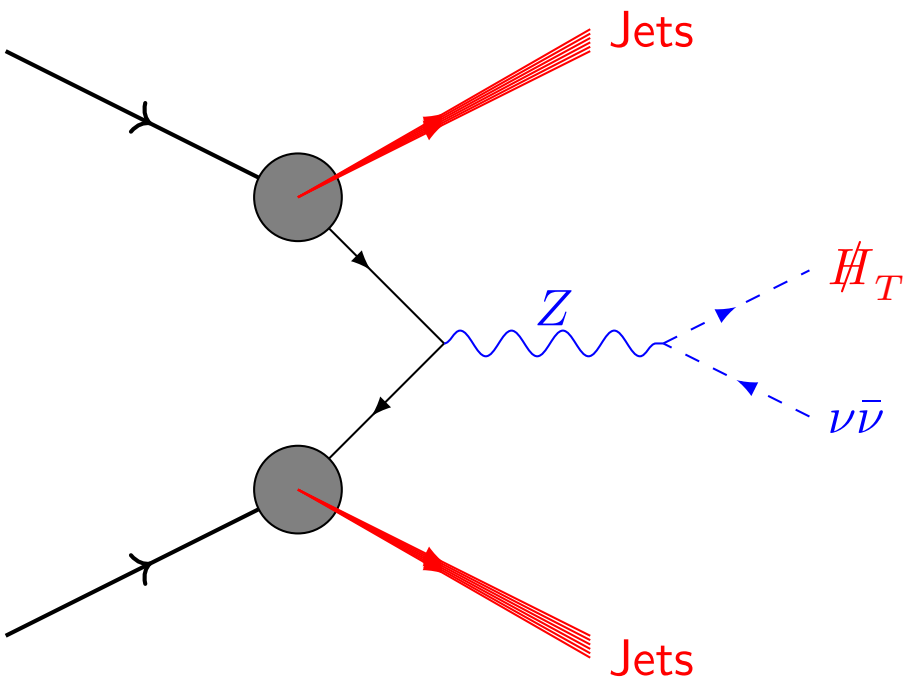
This only effect the leptonic background process, no effect on signal!

- Study lepton selection factor in"no signal" control regions ($\not{H}_T < 100$GeV)
- Reproduce effect in "signal region" ($\not{H}_T > 500$GeV)

Lost Lepton methods results

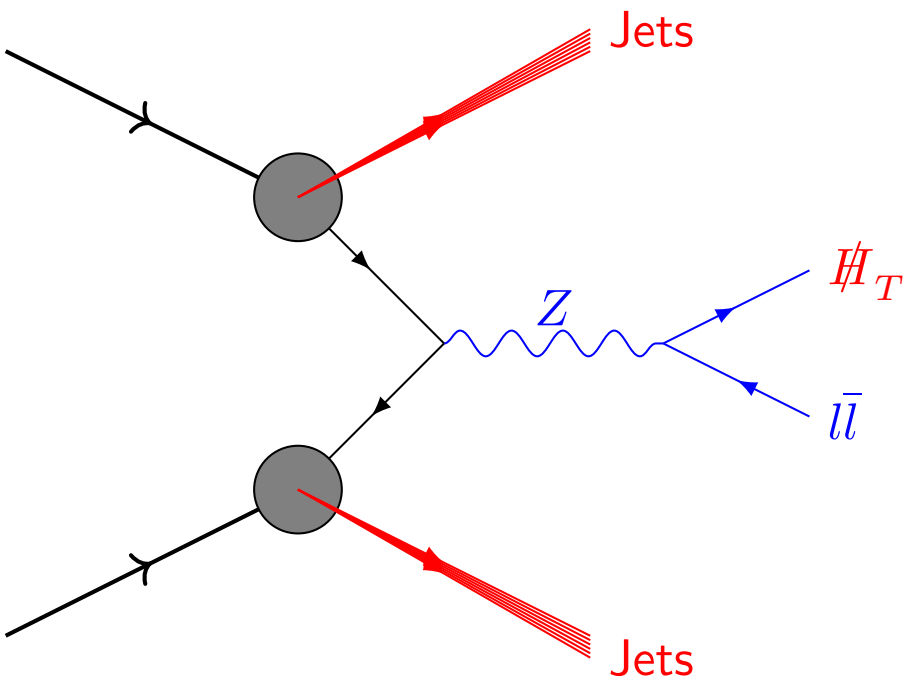


Photons methods - $Z \to \nu\bar{\nu}$



$$\sqrt{s} \gg M_z \gg M_l, M_\nu,$$

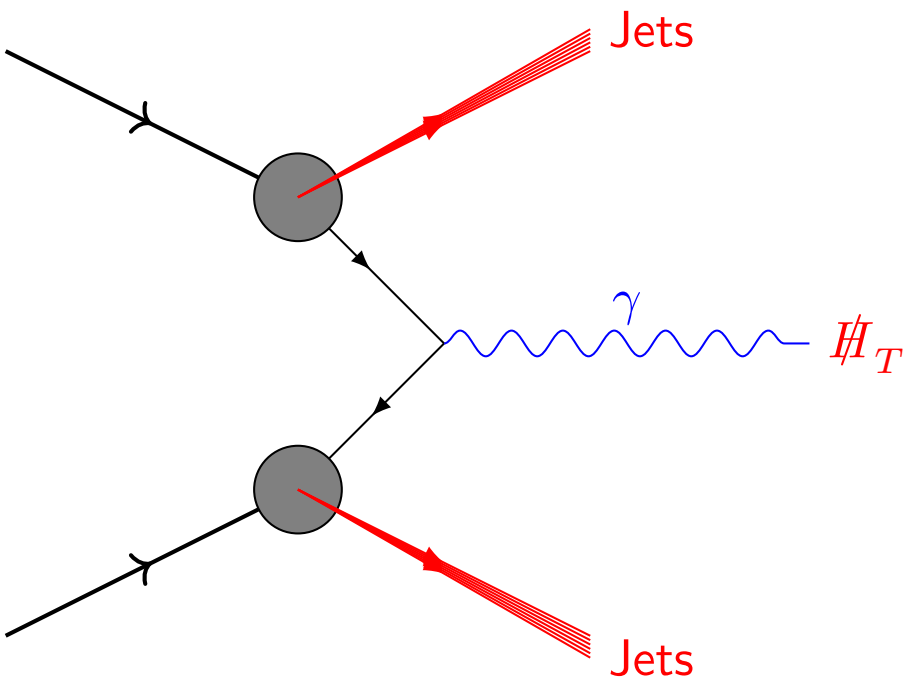
Photons methods - $Z \to \nu\bar{\nu}$



$$\sqrt{s} \gg M_z \gg M_l, M_\nu,$$

- $\frac{N^{\text{Data}}_{Z\to\nu\bar{\nu}}}{N^{\text{MC}}_{Z_\to\nu\bar{\nu}}} = \frac{N^{\text{Data}}_{Z\to l\bar{l}}}{N^{\text{MC}}_{Z\to l\bar{l}}}$
  This has statistical problems...

Photons methods - $Z \to \nu\bar{\nu}$



$\sqrt{s} \gg M_z \gg M_l, M_\nu,$

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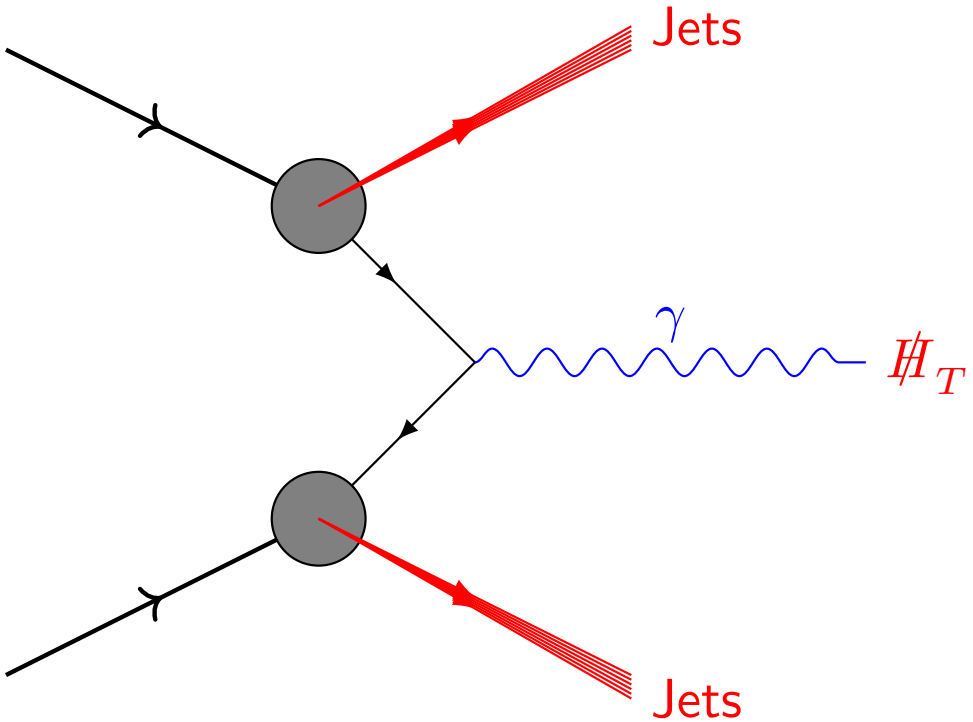
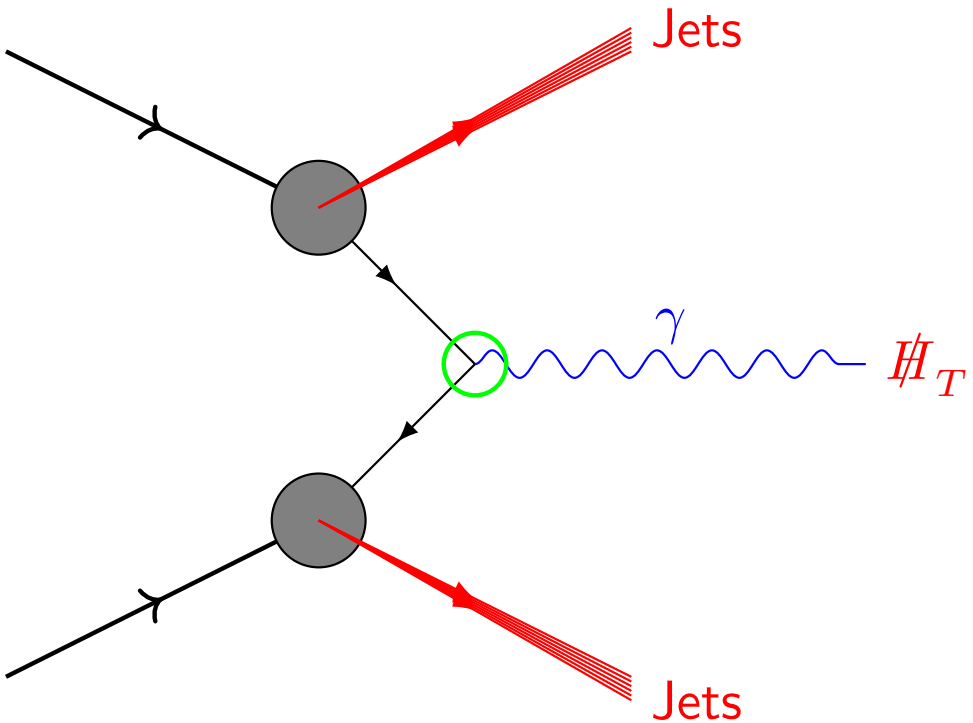
  This has statistical problems...
- $\frac{N^{\text{Data}}_{Z\to\nu\bar{\nu}}}{N^{\text{MC}}_{Z_\to\nu\bar{\nu}}} = \frac{N^{\text{Data}}_{\gamma}}{N^{\text{MC}}_{\gamma}}$
- How do we correct for our over-optimistic assumptions?

Photons methods - $Z \to \nu\bar{\nu}$



$$N^{\text{Data}}_{Z\to\nu\bar{\nu}} = N^{\text{Data}}_{\gamma} \times \frac{N^{\text{MC}}_{Z\to\nu\bar{\nu}}}{N^{MC}_{\gamma}}$$

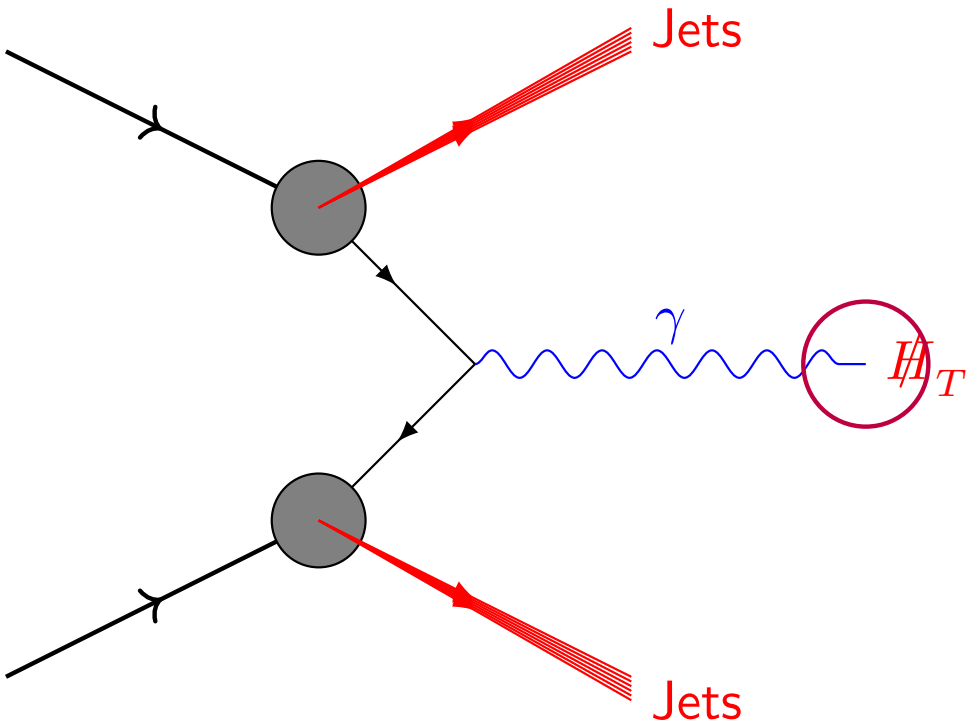
Photons methods - $Z \to \nu\bar{\nu}$



Correcting for vertex coupling

$$N^{\text{Data}}_{Z\to\nu\bar{\nu}} = N^{\text{Data}}_{\gamma} \times \frac{N^{\text{MC}}_{Z\to\nu\bar{\nu}}}{N^{MC}_{\gamma}} \times \left(\frac{N^{\text{Data}}_{Z\to l\bar{l}}}{N^{Data}_{\gamma}} \Big/ \frac{N^{\text{MC}}_{Z\to l\bar{l}}}{N^{MC}_{\gamma}} \right)$$

Photons methods - $Z \to \nu\bar{\nu}$



Correcting for detector response difference

$$N^{\text{Data}}_{Z\to\nu\bar{\nu}} = N^{\text{Data}}_{\gamma} \times \frac{N^{\text{MC}}_{Z\to\nu\bar{\nu}}}{N^{MC}_{\gamma}} \times \left(\frac{N^{\text{Data}}_{Z\to l\bar{l}}}{N^{Data}_{\gamma}} \Big/ \frac{N^{\text{MC}}_{Z\to l\bar{l}}}{N^{MC}_{\gamma}} \right) \times \left(\frac{N_{\text{prompt}}}{N_{\text{prompt}} + N_{\text{non-prompt}}} \right)$$

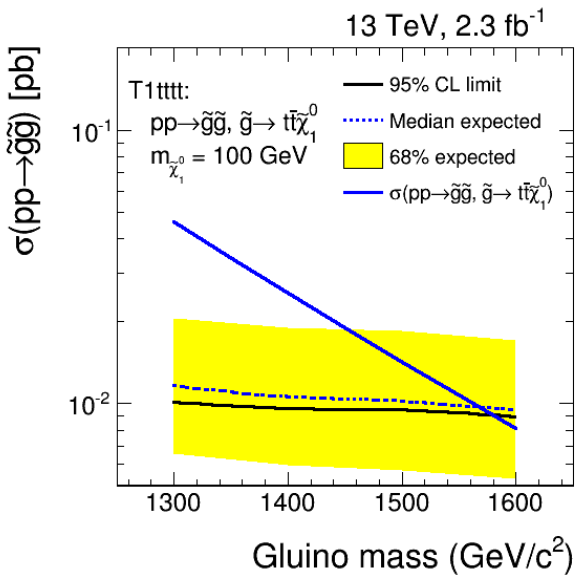
Data Driven Methods - Putting it all together

Bin	Lost-Lepton	$Z \to \nu\nu$	QCD†	Hadronic †	Total Exp. bkg.	Dat
1	38.6	$5.414^{+1.313+1.209}_{-1.313-1.060}$	$5.6^{+0.8+2.1}_{-0.6-2.0}$	$28.6^{+2.7+1.5}_{-2.6-1.5}$	78.2	53
2	7.35	$1.511^{+1.068+0.657}_{-1.068-0.631}$	$1.7^{+0.7+1.0}_{-0.4-0.8}$	$8.1^{+1.6+0.7}_{-1.4-0.7}$	18.65	9
3	0.75	$0.155^{+0.155+0.081}_{-0.155-0.067}$	$0.07^{+0.23+0.09}_{-0.04-0.01}$	$0.25^{+1.13+0.08}_{-0.15-0.01}$	1.225	1
4	7.18	$0.000^{+0.376+0.104}_{-0.000-0.091}$	$1.5^{+0.5+0.9}_{-0.3-0.9}$	$5.1^{+1.5+0.3}_{-1.2-0.3}$	13.7	8
5	2.05	$0.000^{+0.317+0.052}_{-0.000-0.048}$	$0.3^{+0.3+0.2}_{-0.1-0.1}$	$2.2^{+1.1+0.2}_{-0.8-0.2}$	4.55	1
6	0.23	$0.000^{+0.259+0.034}_{-0.000-0.030}$	$0.00^{+0.20+0.05}_{-0.00-0.00}$	$0.01^{+1.13+0.00}_{-0.01-0.00}$	0.24	0

† Given in SUSY-015-002

Result Summary

$$p\bar{p} \to \tilde{g}\tilde{g}\,; \quad g \to t\bar{t}\tilde{\chi}$$
$$M_{\tilde{g}} = 1300GeV - 1600GeV\,; \quad M_{\tilde{\chi}} = 100GeV$$



[1] Computed with HiggCombine package

Thanks for your attention!

Backup

Data selection

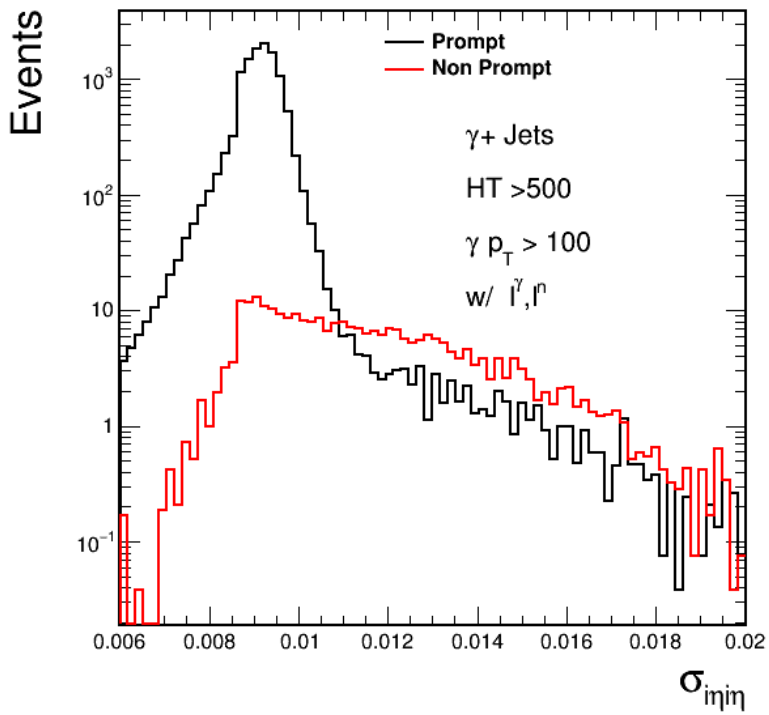
Signal region:

- `HLT PFHT350 PFMET100 NoiseCleaned v*`
- `HLT PFHT350 PFMET100 JetIDCleaned v*`

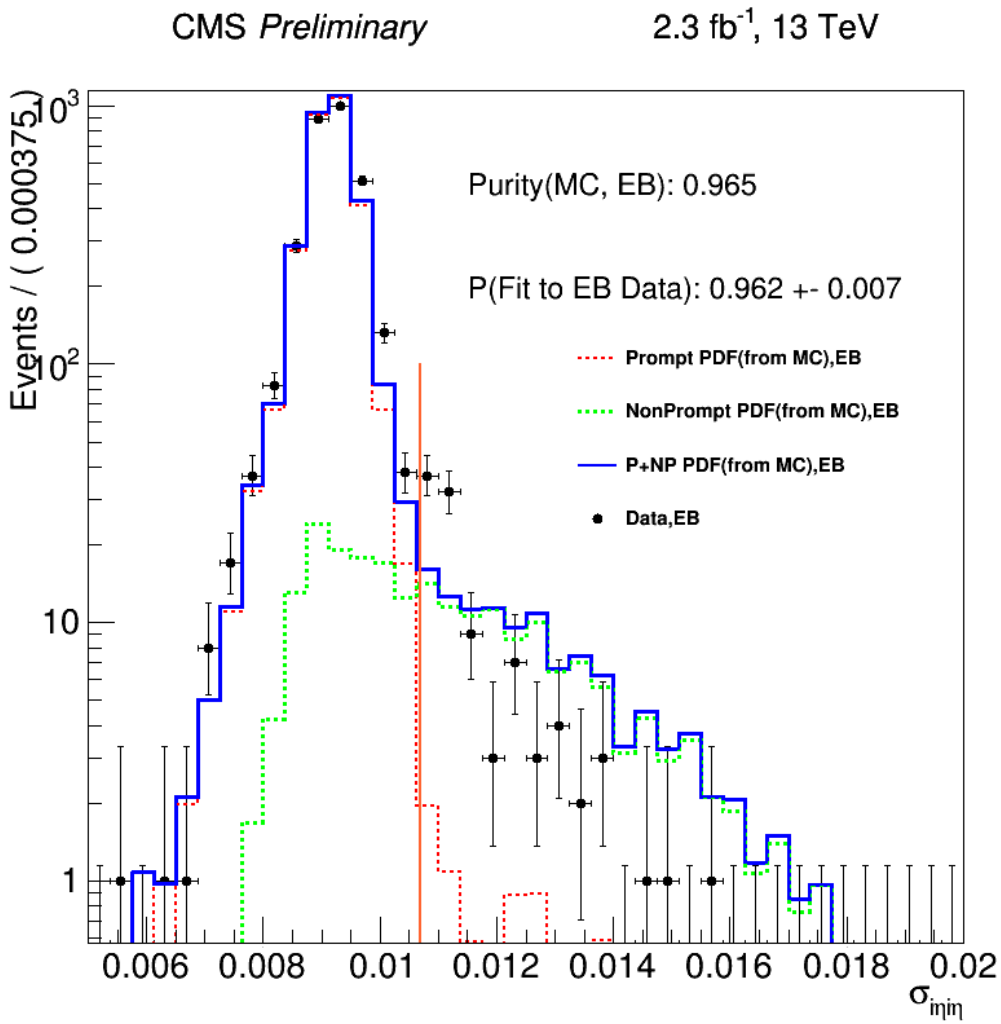
Photon Method - Photon Purity

$$\text{Purity} \equiv \frac{N_{\text{prompt}}}{N_{\text{prompt}} + N_{\text{non-prompt}}} \tag{3}$$

- MC: Use generator truth.
- Data: Use template fit of $\sigma_{i\eta i\eta}$ of photon



Photon Method - Photon Purity of Data



Photon Method - Summary