SEARCH FOR SUPERSYMMETRY IN THE JETS + MET + TAUS FINAL STATE USING THE CMS DETECTOR AT THE LHC

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Outline

- Introduction
- Motivation
- Experimental Tools
- SM Backgrounds
- Trigger
- Event Selection
- Background Estimation
- Results
- Summary

Standard Model

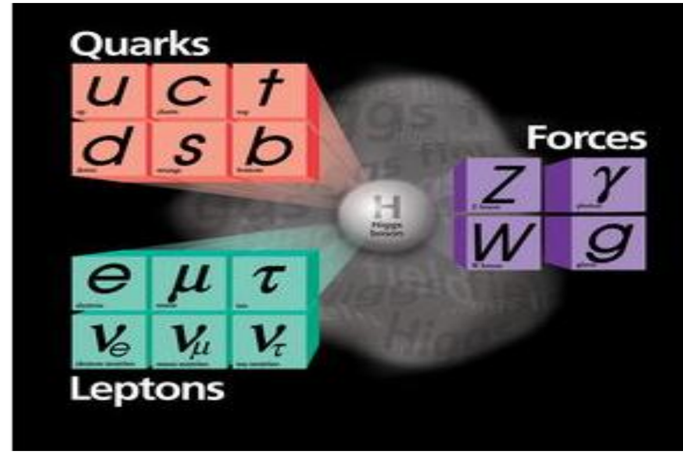
- Conceptually Simple.

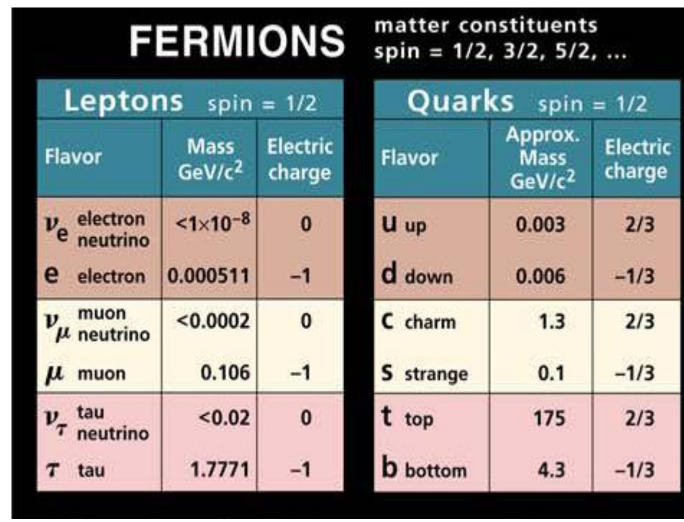
1. Matter is composed of fermions:
   -Spin ½ particles
   Leptons
   Quarks

2. Forces are the exchange of gauge bosons:
   -Integer spin particles
   γ – electromagnetic interactions
   Z/W – weak interactions
   Gluon (g) – strong interactions

3. All other particles are made up of these fundamental particles

4. Higgs boson: Needed to give mass to quarks and leptons as well as W and Z.



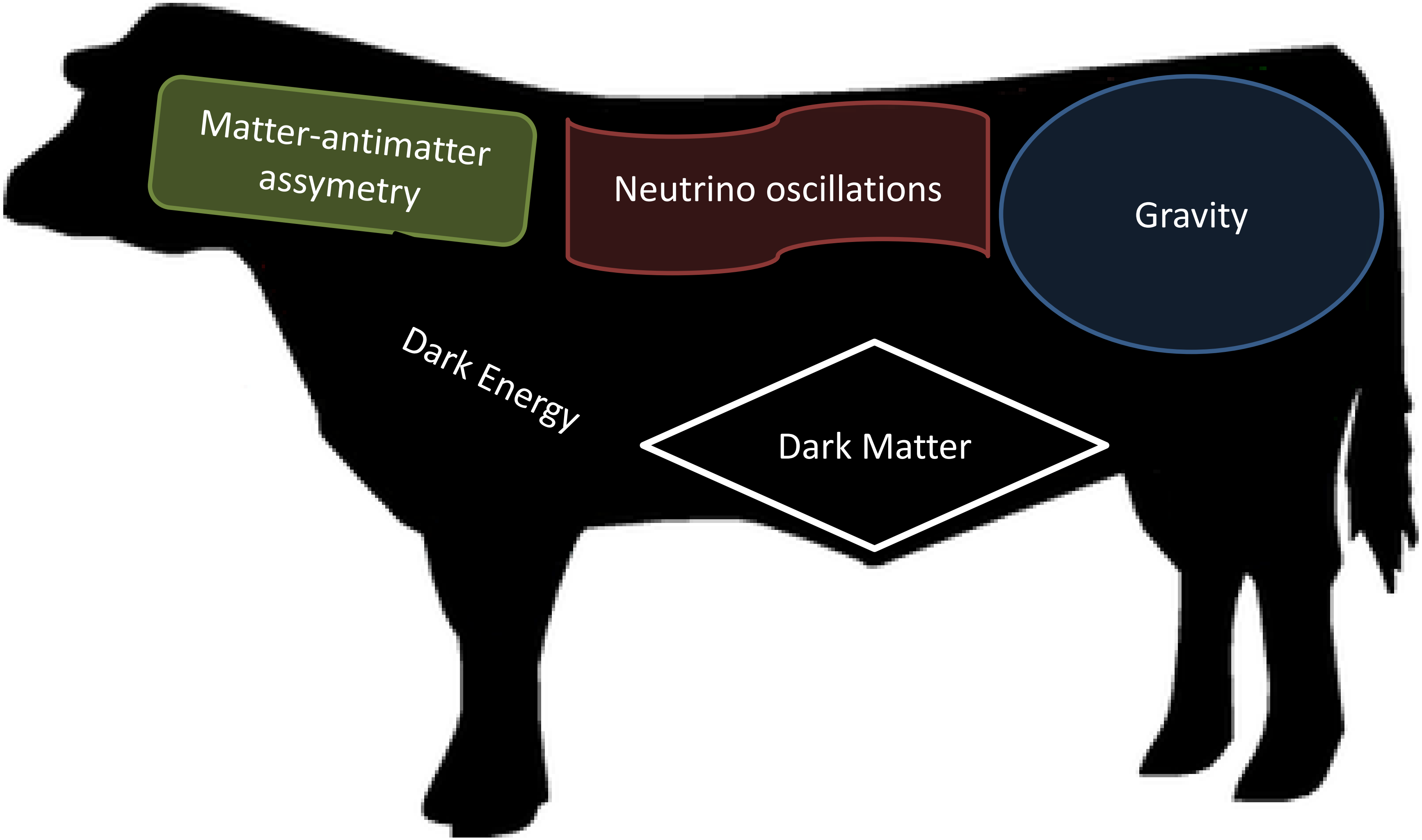


FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2		
Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

Quarks spin = 1/2		
Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

Our "Beef" with the Standard Model



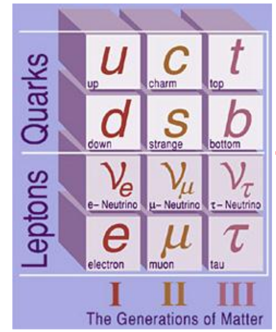
Supersymmetry (SUSY)

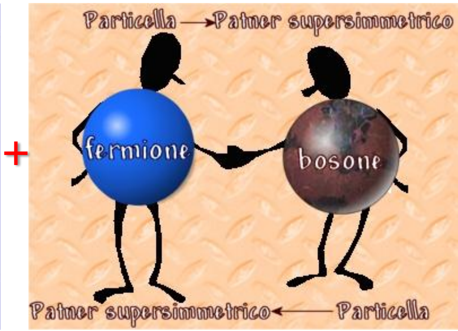
SUSY:

a) Symmetrized Standard Model (SM):

SM fermions ⇔ SUSY bosons

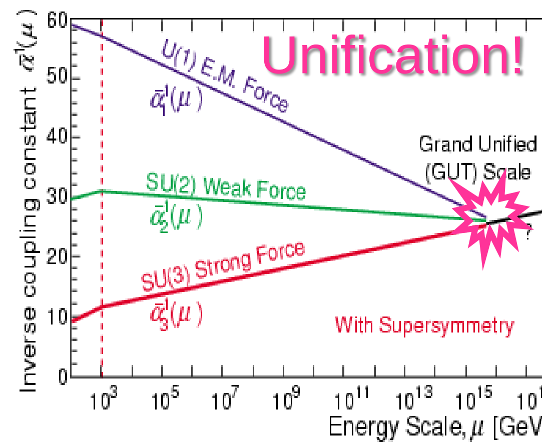
SM bosons ⇔ SUSY fermions





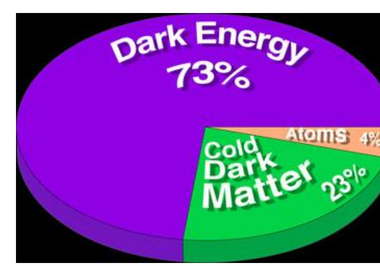
b) An elegant solution:

- Hierarchy Problem
- Connects SM with unification of gauge coupling constants
- R-parity SUSY consistent with a Dark Matter candidate → Stable neutralino



SUSY → $\tilde{\chi}_1^0$ ← Neutral

Particle type → $\tilde{\chi}_1^0$ ← Lightest



c) SUSY not yet observed so it must be a broken symmetry

SUSY Breaking

- SUSY has too many parameters (e.g. MSSM has 124 parameters)
- Making certain assumptions about SUSY breaking results in models with fewer parameters:
    - mSUGRA: SUSY breaking in hidden sector coupled to MSSM only through gravitational strength interactions.
        - LSP is the lightest neutralino.
        - 5 parameters:

          $m_{1/2}$ The gaugino mass

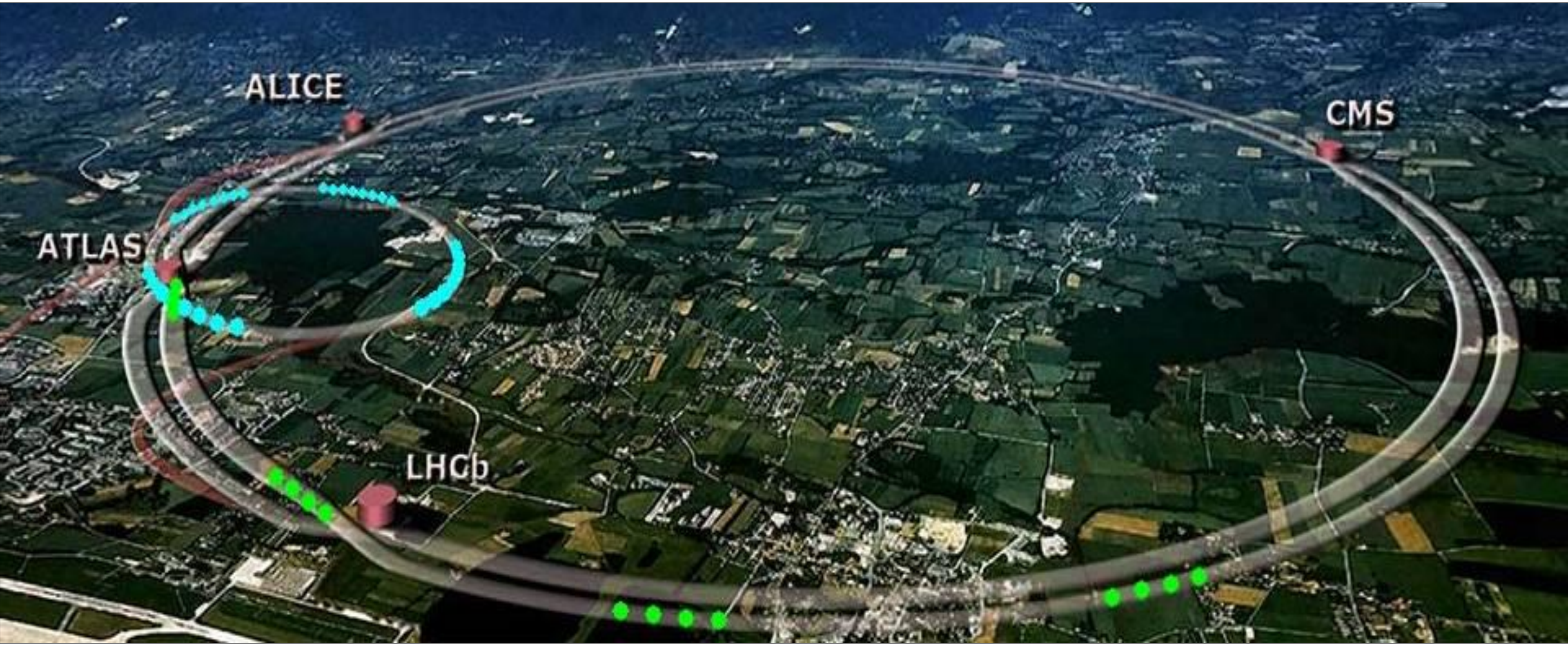
          m_0 The scalar masses

          A_0 Soft breaking trilinear coupling constant

          $\tan(\beta)$ The ratio of the VEVs of the two Higgs

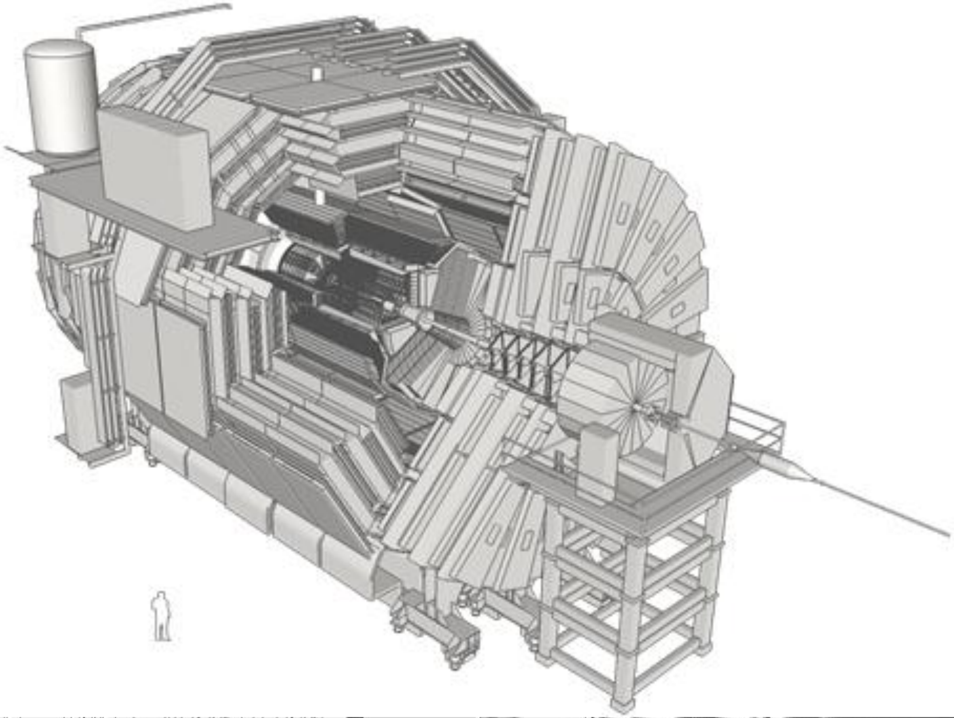
          $\text{sign}(\mu)$ The sign of the Higgsino mass parameter

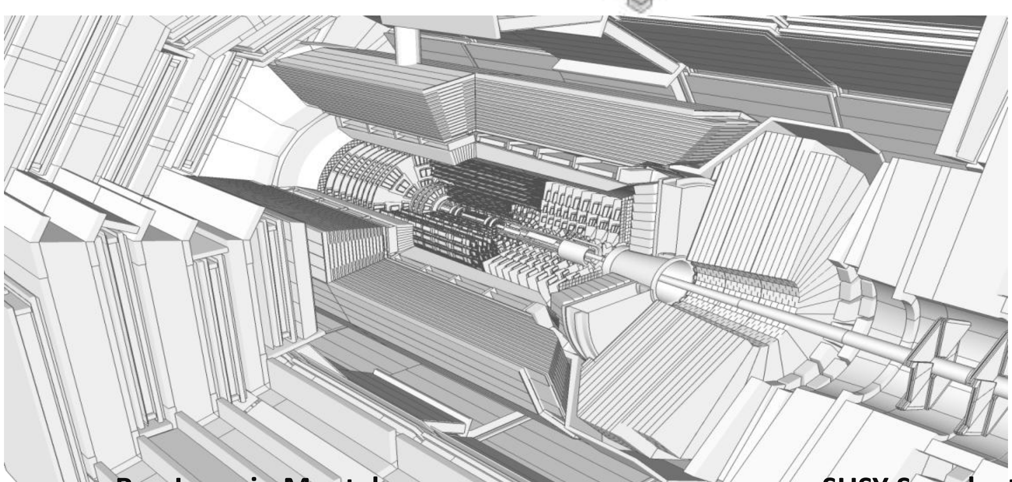
Large Hadron Collider



- 17 miles circumference, up to 574 feet deep.
- Designed to accelerate protons to 14TeV in center of mass energy.
- In 2011 CMS collected 5 fb^{-1} of data at 7TeV.

Compact Muon Solenoid





Inner Tracker System

- Pixel detector starts at ~ 4cm
- Outer silicon tracker ends at ~ 1m
- Tracks the trajectory of charged particles

Solenoid Magnet

- 3.8 T strength for the precise measurement of particle momentum

Electromagnetic Calorimeter (Ecal)

- Lead Tungstate crystals
- Designed to detect e's and γ's

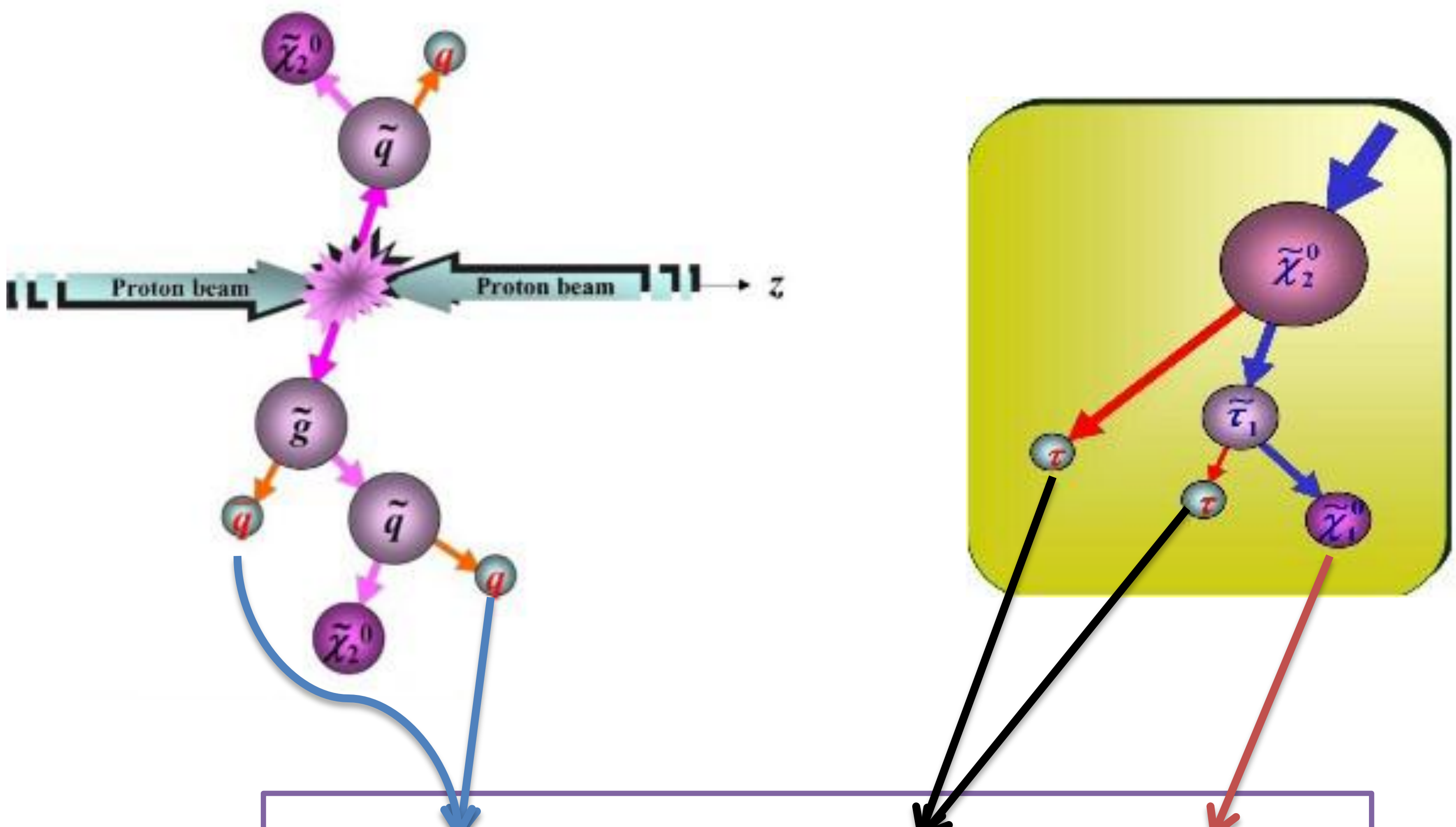
Hadron Calorimeter (Hcal)

- Brass and steel material sampled in with scintillators
- Designed to detect hadrons

Muon System

- Gas detectors

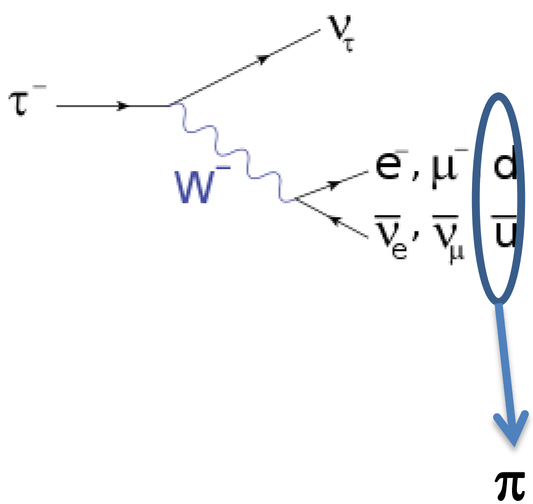
SUSY Signature



$\geq$2 Jets + $\geq$2 τ_h + MET

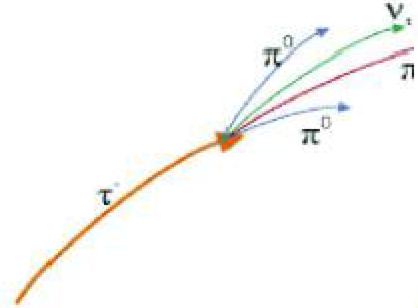
Tau Characteristics and τ_h ID at CMS

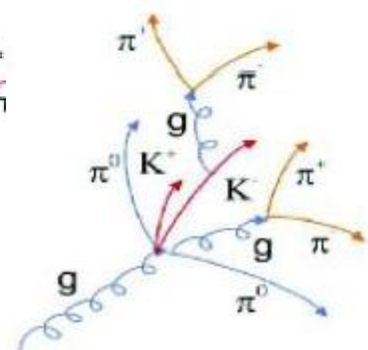
- m ~ 1.8 GeV
- ct = 87 μm
- Leptonic decays (~36%)
- Hadronic decays (τ_h ~64%)
  - Hadronic decays are collimated jet-like objects
  - Hadronic decays with 1 or 3 charged tracks (prongs)
  - τ_h direction given by leading pion.



The constituents of jets are analyzed using information from the entire detector (Particle Flow Algorithm) to identify a specific τ_h decay mode.

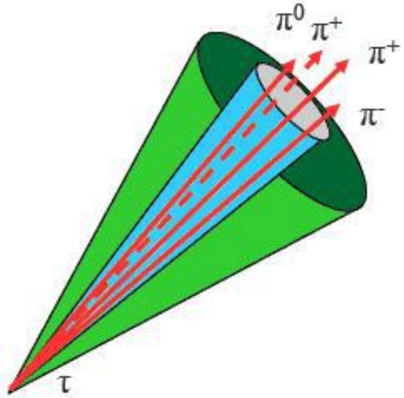
- Tau candidates have a narrow jet cone in the calorimeter.
- Combine PF electromagnetic particles in “strips”.
- Neutral objects combined with charged objects to reconstruct tau decay products (tau decay mode).
- After decay mode candidates are required to pass an isolation criteria (ΔR = 0.3)

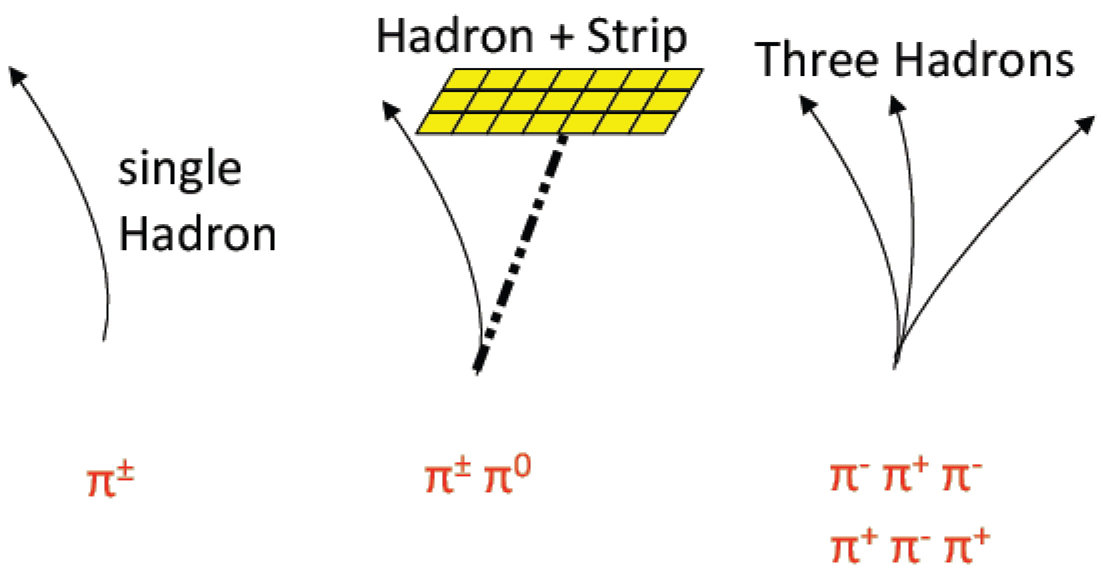




Tau ID at CMS Contd.

Decay Mode	Resonance	Mass (MeV/c^2)	Branching ratio(%)
$\tau^- \to h^- \nu_\tau$			11.6 %
$\tau^- \to h^- \pi^0 \nu_\tau$	ρ	770	26.0 %
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	a1	1200	10.8 %
$\tau^- \to h^- h^+ h^- \nu_\tau$	a1	1200	9.8 %
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$			4.8 %
Total			63.0%
Other hadronic modes			1.7%



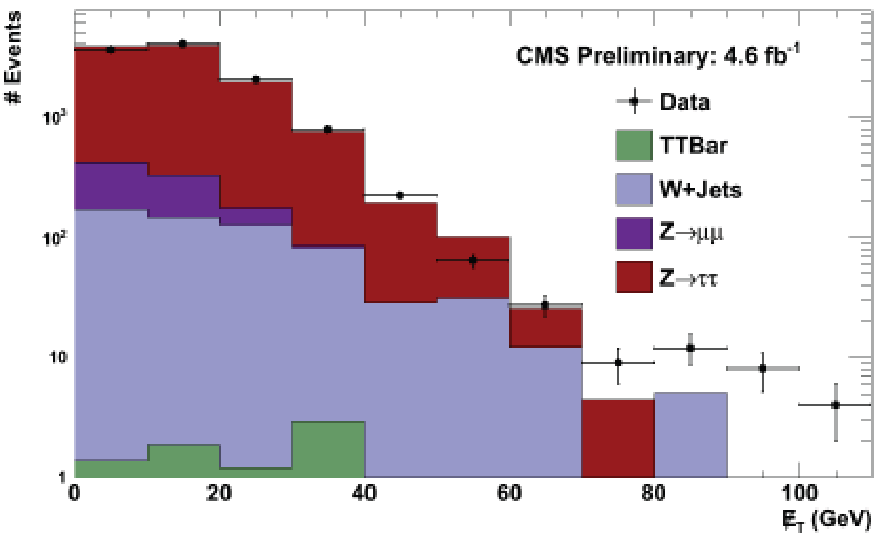


Tau ID Validation

- Use VLooseIsolation (no Charged candidates with $p_T > 1.5$ GeV and Gamma candidates $p_T > 2$ GeV, $\Delta R = 0.3$).

To validate τ identification we use a $Z \rightarrow \tau\tau$ sample in the $\mu\tau_h$ final state.

Consistency in shape



Consistent event rates

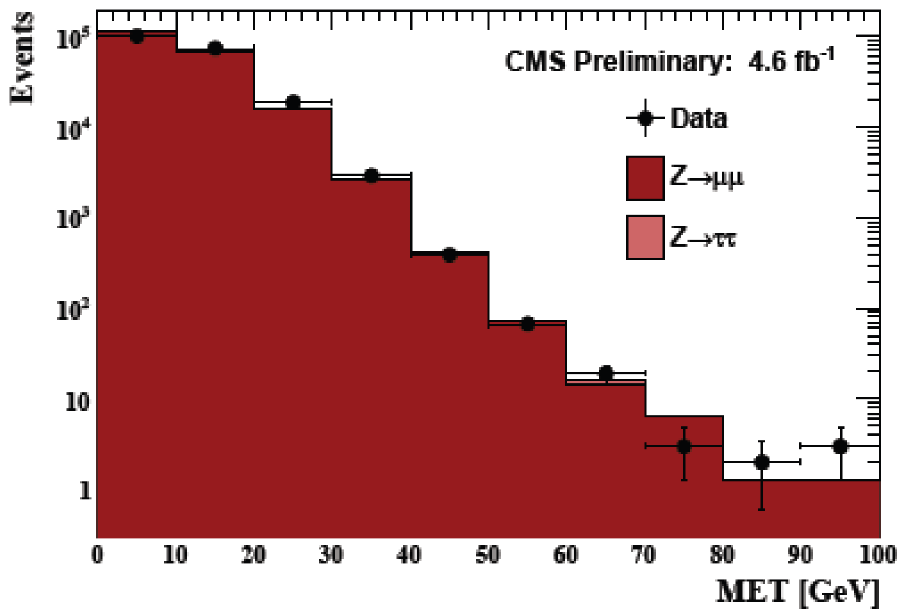
Sample	Events
Data	10725
QCD	—
$W + Jets$	$595.7 \pm 29.4_{stat} \pm 29.6_{syst}$
$t\bar{t}$	$13.22 \pm 1.5_{stat} \pm 2.0_{syst}$
$Z \rightarrow \tau\tau$	$9682.0 \pm 172.4_{stat} \pm 526.9_{syst}$
$Z \rightarrow \mu\mu$	$474.4 \pm 37.6_{stat} \pm 25.8_{syst}$

PU Reweighing

- MC samples have been reweighed according to:

$$W_{pu}(n) = P_{data}(n) \,/\, P_{MC}(n)$$

- In order to validate the PU correction method, a $Z \rightarrow \mu\mu$ control region is obtained and consistency in MET is required between data and MC.



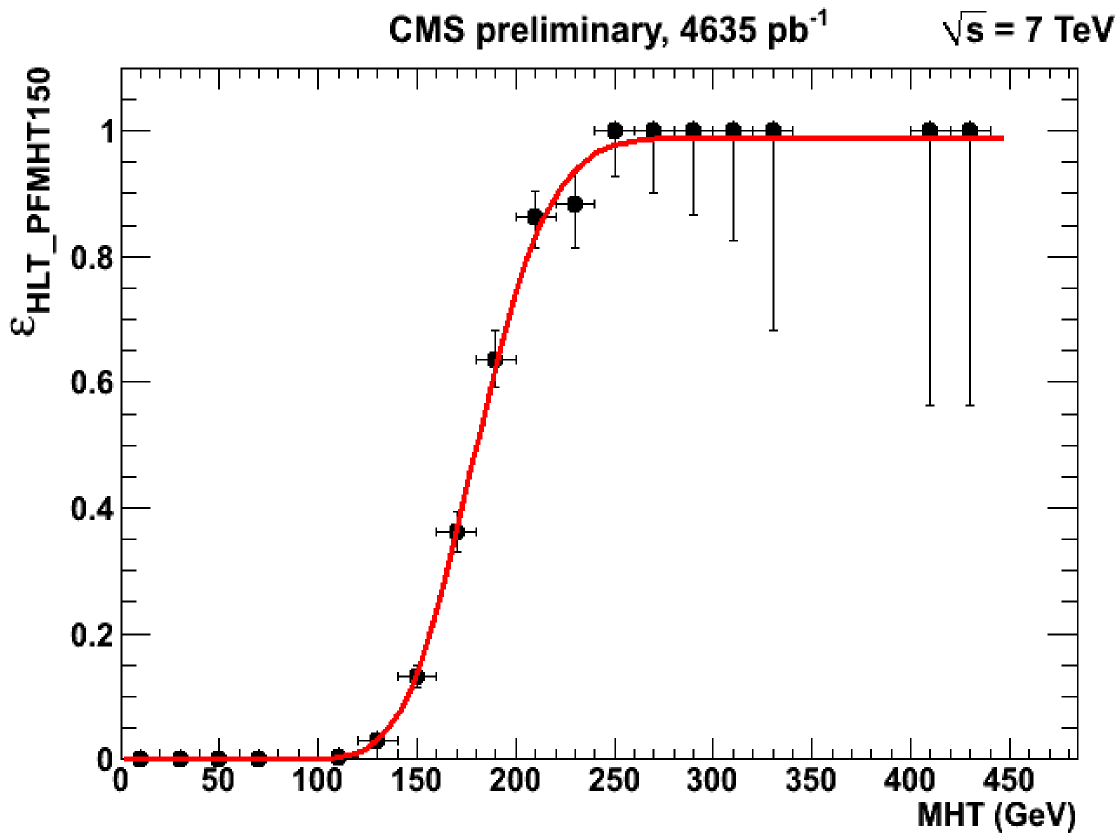
PU effect on MET dominates in $Z \rightarrow \mu\mu$

Trigger

- Validated using a ttbar CR extracted directly from data

Selections:

- At least 1 Global Muon or electron with p_T > 20 GeV and $|\eta|<2.1$
- At least 1 PFTau with p_T > 20 GeV, $|\eta|<2.1$
- At least 1 e/μ τ_h with $\Delta R > 0.7$
- e/μ and τ are of opposite charg
- MET > 30 GeV
- At least 1 b-jet

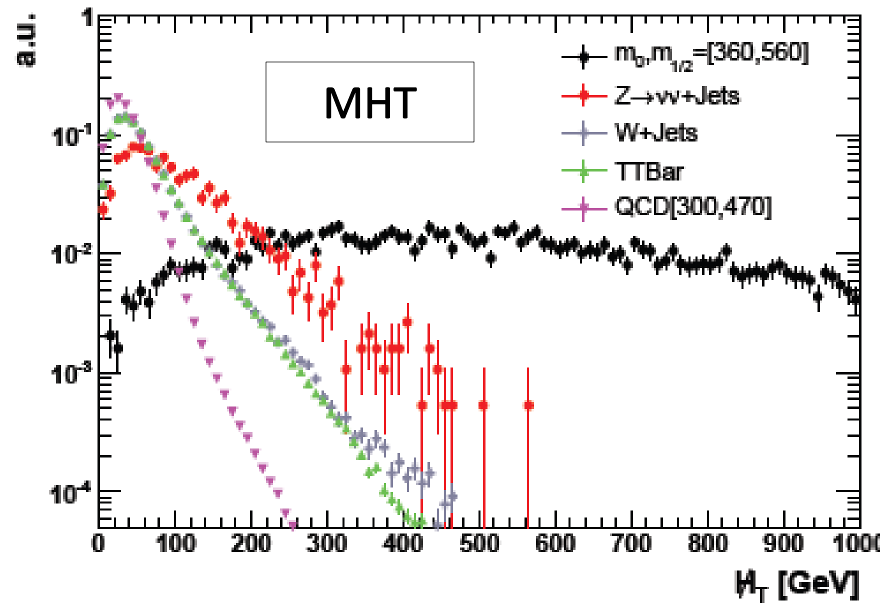


$$\varepsilon = \frac{\text{Number of Events Passing Selections AND HLT\_PFMHT150}}{\text{Number of Events Passing Selections}} = 98.9\ \%$$

Signal Selections

Baseline Selections: <u>2 Jets + MET</u>

- ≥1 Jet with pT > 30 GeV/c
- Highest Jet pT > 100 GeV/c and |η| < 3
- 2nd highest Jet pT > 100 GeV/c and |η| < 3
- MHT > 250 GeV



Observe a good balance between signal acceptance and background rejection!

MHT ≡ Missing Transverse Momentum of Jets above threshold.
(Jet pT > 30 GeV)

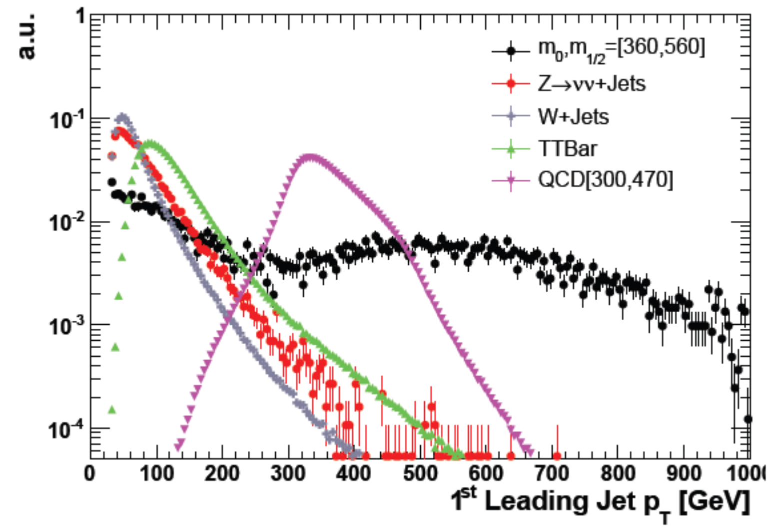
Signal Selections contd.

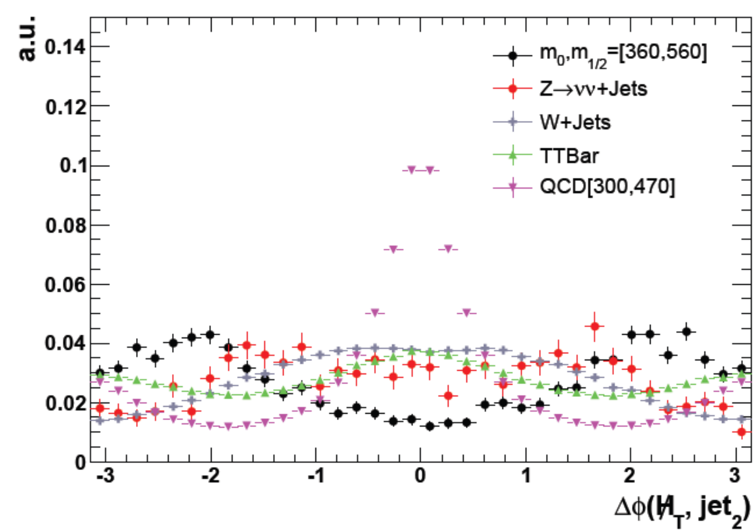
Tau Selections: $\geq \underline{2\tau_h}$

- pT > 15 GeV/c and $|\eta| < 2.1$
- pass the μ veto
- pass the e veto
- pass the decay mode
- pass isolation

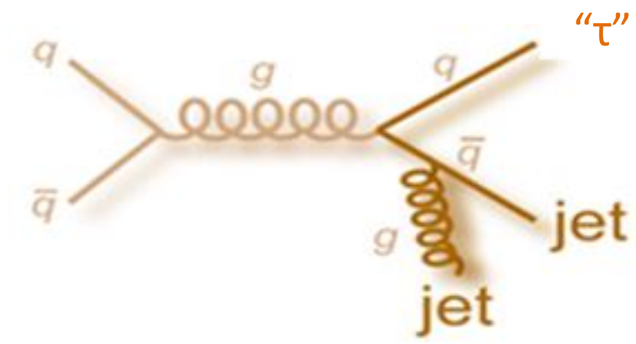
Topological Selections:

- Highest pT Jet separated from τ_h ($\Delta R(j_1, \tau_h) > 0.3$)
- 2nd Highest pT Jet separated from τ_h ($\Delta R(j_2, \tau) > 0.3$)
- At least one t_h, t_h pair with $\Delta R(\tau_{h,1}, \tau_{h,2}) > 0.3$
- $\Delta\phi(j_2, \mathrm{MHT}) > 0.5$





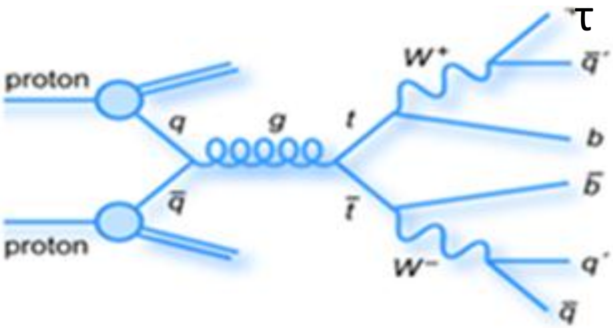
SM Backgrounds: QCD



- QCD events could become a background if one of the jets is largely mismeasured and additional jets provide fake tau pairs.
  - Fake rate $j \rightarrow \tau_h$ is small (~ 0.2%).

- QCD background is small because of the large MET required in this analysis.

SM Backgrounds: Top Pair

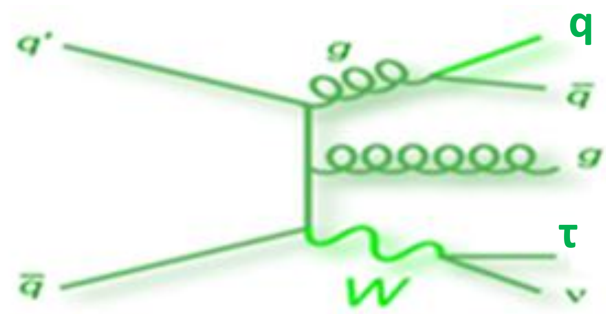


"τ"

The contribution comes from the decay of one of the W bosons:

- Will produce real taus
- Fake taus from jets.

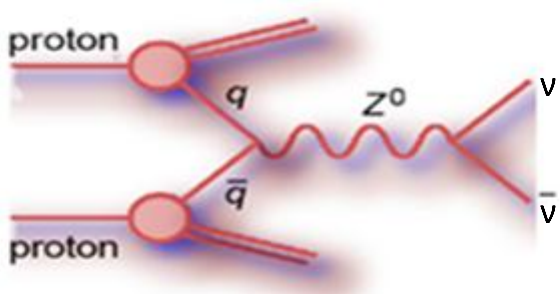
SM Backgrounds: W + Jets



Along with Top-pairs this is one of the major backgrounds:

- W decay creates a very clean tau.
- Also quark and gluon jets could fake a tau.

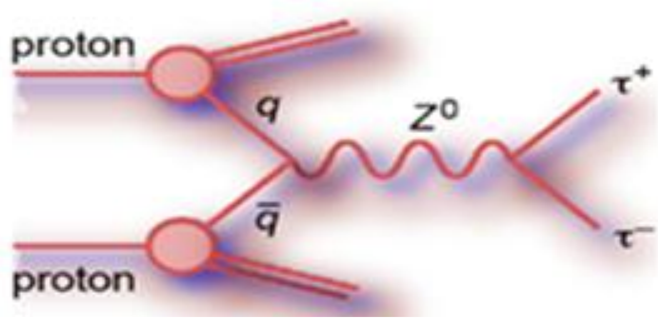
SM Backgrounds: Z(→νν)+Jets



Expected to be negligible:

- Has a large missing energy but low jets multiplicity.

SM Backgrounds: Z(→ττ)+Jets

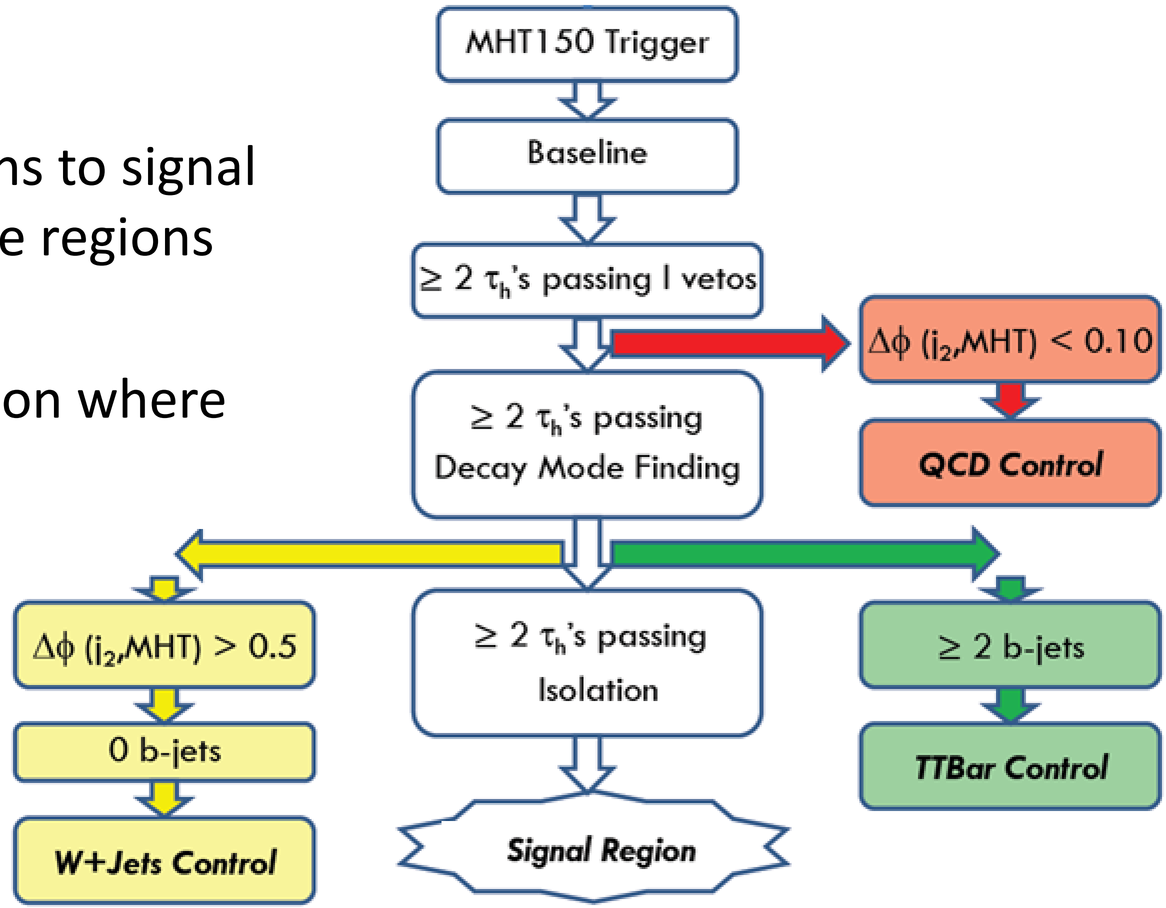


- Both taus could pass the tau requirements + two jets could pass the selection criteria.
- One of the tau passes selections and a jet fakes a tau + two other jets pass jet cuts.

Background Estimation

Strategy:

- Data-driven
  - Minor modifications to signal selections to create regions of high purity.
  - Extrapolate to region where signal is expected.



2 More SM Processes:
Z→ νν + Jets
Z→ττ + Jets

Data Driven Background Estimation

$$N^{SR}_{Background} = N^{CR}_{Background}[\alpha_{\tau\tau}\mathcal{P}(0) + \alpha_{\tau j}\mathcal{P}(1) + \alpha_{jj}\mathcal{P}(2)]$$

Correction factor of events with two real τ's to signal region

Correction factor of events with one real τ and one fake τ to signal region

Correction factor of events with two fake τ's to signal region

Probability of **more than** (0,1,2) jets faking taus

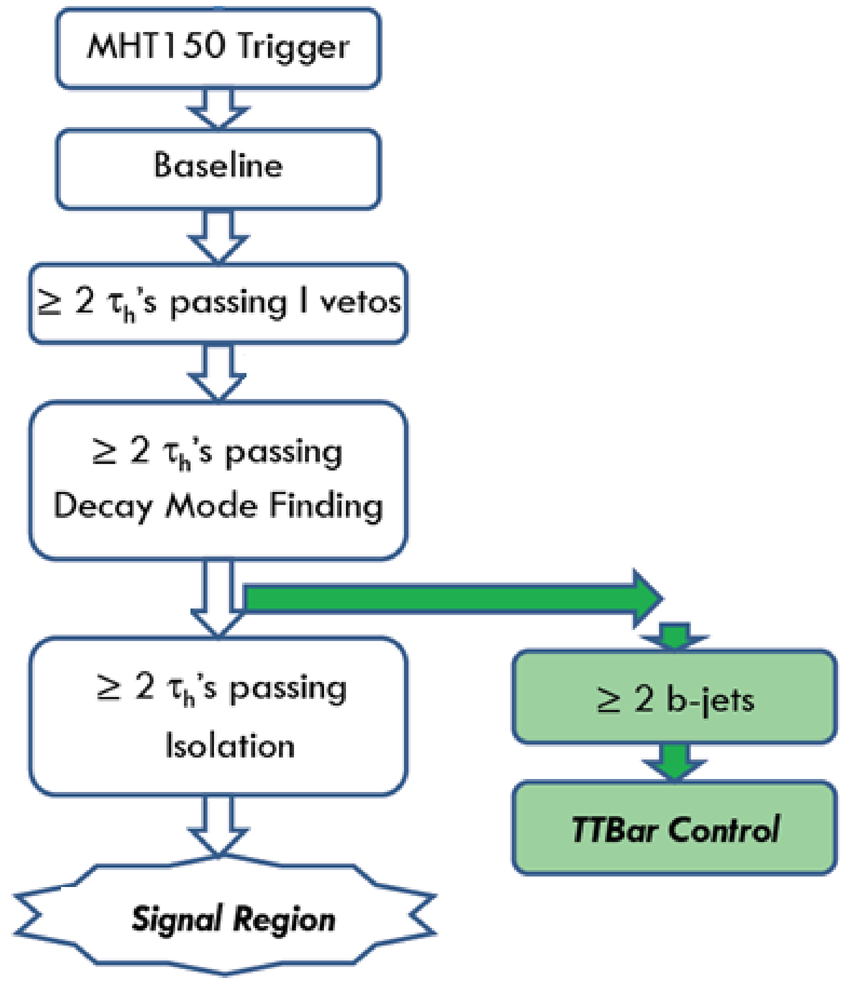
$$\mathcal{P}(m) = \sum_{N=m}^{\infty} P(N) \sum_{n=m}^{N} C(N,n) f^n (1-f)^{N-n}$$

Probability of N_{jets} "N choose n" Jet fake rate

Top Pair Control Region

To obtain a TTbar enhanced region we modify our standard selection criteria as follows:

- Remove τ isolation requirement.
- Require ≥ 2 jets tagged as b-jets.



Top Pair Background

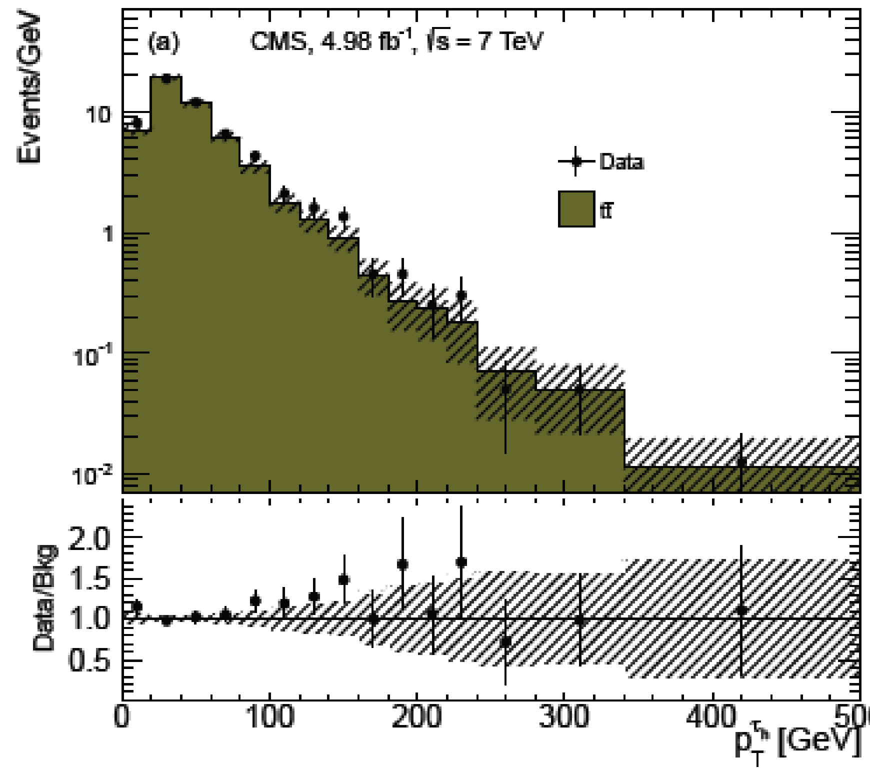
$$N_{t\bar{t}}^{\mathrm{SR}} = \frac{N_{t\bar{t}}^{\mathrm{CR}}}{P(2\,b\,jets)}[A_{\tau j}\varepsilon^{\tau\ iso}\mathcal{P}(1) + A_{jj}\mathcal{P}(2)]$$

Two types of events in TTbar control region:

1. 1 real τ_h + 1 jet faking a τ
2. 2 jets faking 2 τ.

To calculate the final number we use the follwing variables:

- $A_{\tau+j}$ = fraction of t-tbar events with 1 real τ_h and 1 jet.
- A_{j+j} = fraction of t-tbar events with 2 jets.
- P(1) & P(2) are the probabilities to have 1 or 2 jets that can fake the τ in category (1) and (2).
- P(2b) = Probability of tagging 2-b-jets.
- ε_τ^{iso} =Tau isolation efficiency.



$$N_{t\bar{t}}^{\mathrm{SR}} = 2.03 \pm 0.36$$

Z(→νν)+Jets Control Region

- Small contribution due to Z→ νν + Jets
- Don’t have a method to obtain a clean sample:
  - To determine contribution we use Z→ μμ + Jets, then treat μ’s as neutrinos.

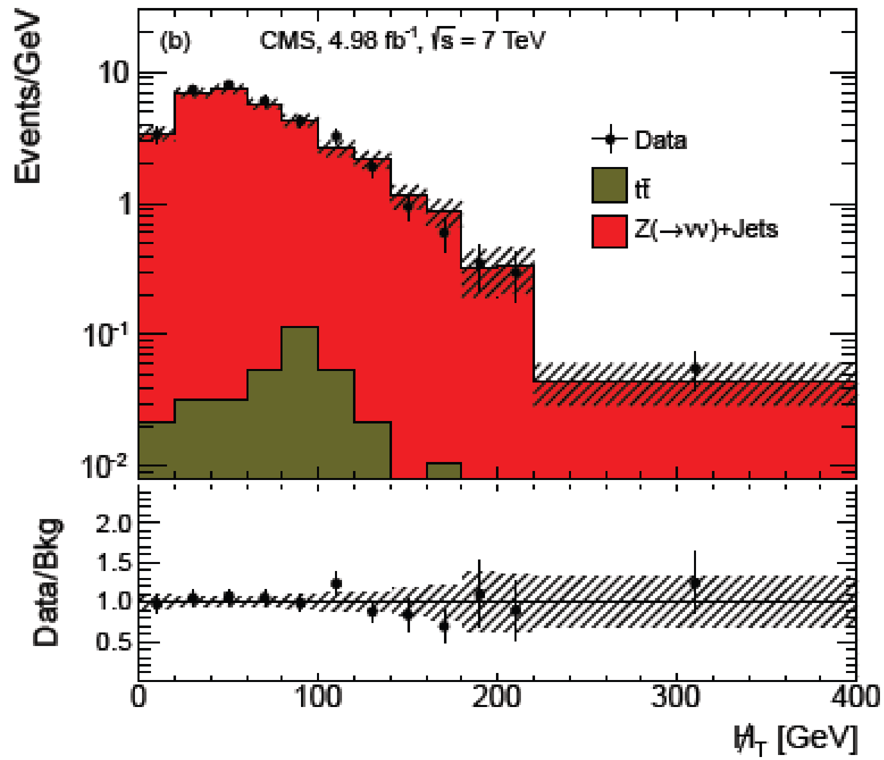
To obtain a clean Z→ μμ + Jets control sample we modify our standard selection as follows:

- Remove MHT and use μ trigger.
- Remove τ isolation requirement.
- Require 2 clean μ

Z(→νν)+Jets Background

$$N^{SR}_{Z\to\nu\bar{\nu}+jets} = \frac{N^{CR}_{Z\to\mu\bar{\mu}+jets}}{A^2_\mu \epsilon^2_\mu} \frac{B(Z\to\nu\bar{\nu})}{B(Z\to\mu\bar{\mu})} \frac{\epsilon^{Trigger}_{\not{H}_T}}{\epsilon^{Trigger}_{\mu\tau}} \epsilon^{\not{H}_T} \mathcal{P}(2)$$

- A_μ = μ acceptance efficiency.
- ε_μ = μ ID efficiency.
- B(Z→ νν) = branching ratio for Z→ νν
- B(Z→μμ) = branching ratio for Z → μμ
- $\varepsilon^{Trigger}_{MHT}$ = efficiency of HLT_PFMHT150 (plateau)
- $\varepsilon^{Trigger}_{\mu\tau}$ = efficiency of μτ cross-trigger.
- ε^{MHT} = efficiency of MHT (>250)
- P(2) is the probability to have 2 jets that can fake the τ.

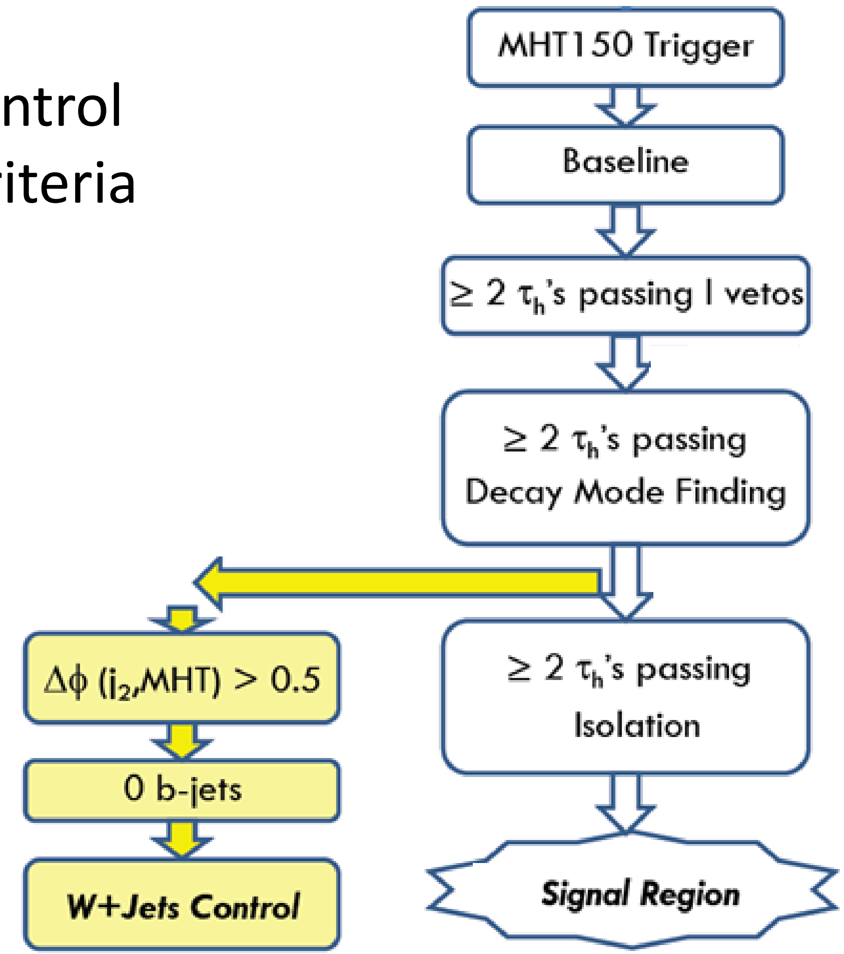


$$N^{SR}_{Z\to\nu\bar{\nu}+jets} = 0.03 \pm 0.02$$

W + Jets Control Region

To obtain an enhanced W+Jets control region we modify our selection criteria as follows:

- Remove τ isolation.
- Require 0 jets tagged as b-jets
- Subtract off contamination sources .

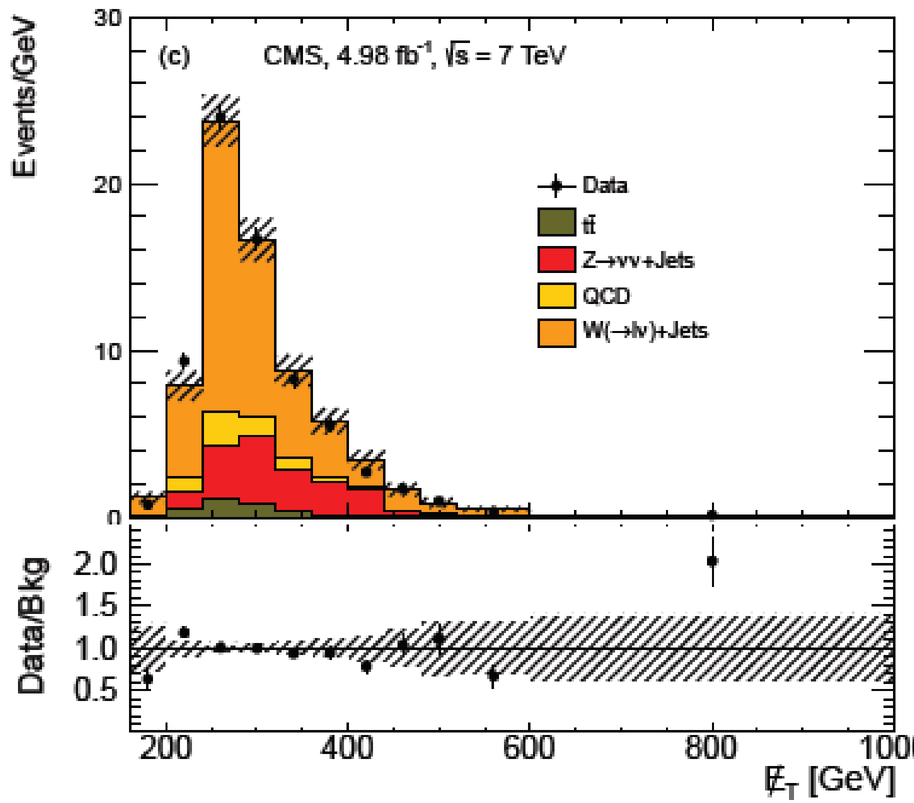


W + Jets Background

$$N^{SR}_{W+jets} = \frac{N^{After\ subtraction}_{W+jets}}{P(0\ b\ jets)}[A_{\tau j}\varepsilon^{\tau\ iso}\mathcal{P}(1) + A_{jj}\mathcal{P}(2)]$$

Two types of events:

1. 1 real τ_h + 1 jet faking a τ.
2. 2 jets faking 2 taus.



Variables:

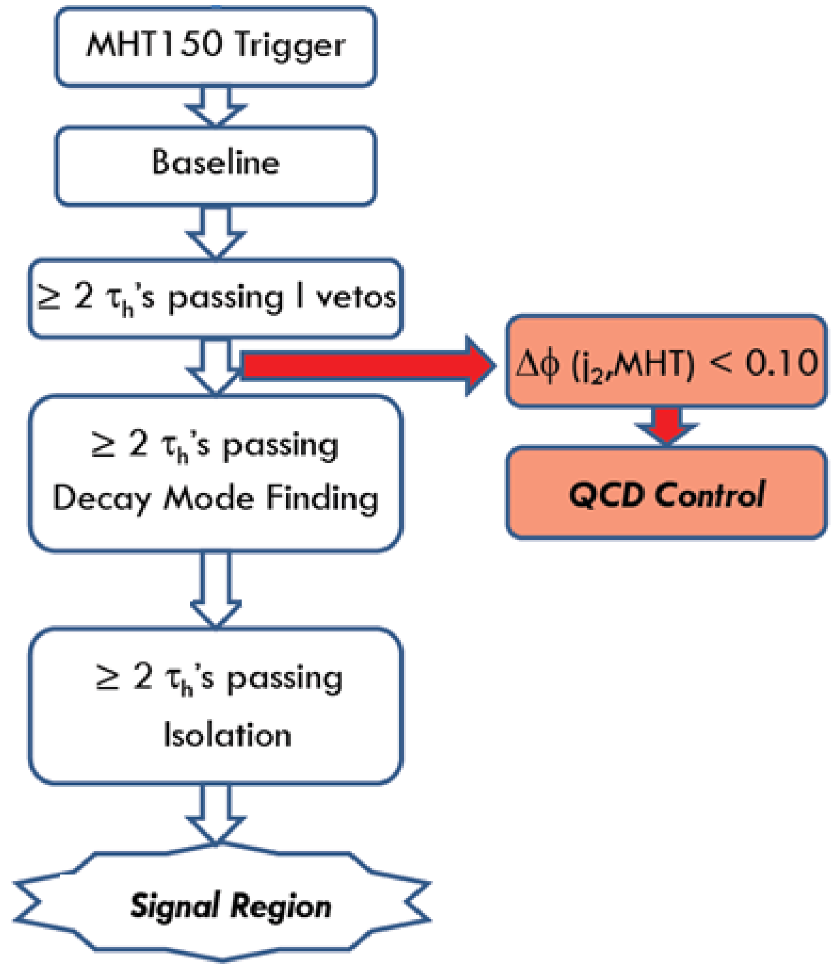
- $A_{\tau+j}$ = fraction of Wjet events with 1 real τ_h and 1 jet faking τ
- A_{j+j} = fraction of Wjet events with 2 jets faking τ's
- P(N) & P(M) are the probabilities to have N (M) jets that can fake the τ in category (1) and (2).
- f = "fake rate"
- P(0b) = Probability of tagging zero jets as b-jets.
- ε_τ^{iso} =Tau isolation efficiency.
- C(N,n) = N choose n.

$$N^{SR}_{W+jets} = 5.20 \pm 0.63$$

QCD Control Region

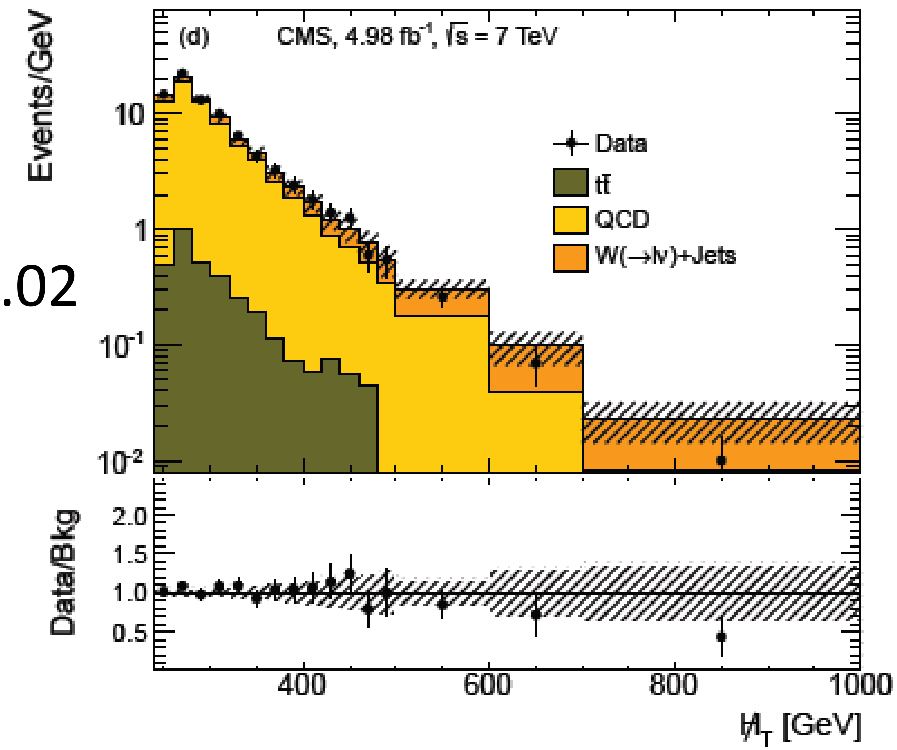
QCD contribution comes from jets faking taus. Tau-id takes care of most QCD background.
To obtain our QCD control region we modify our standard selection:

- Remove the τ isolation requirement.
- Require $|\Delta\phi(j_2,\mathrm{MHT})| < 0.10$.



QCD Background

To estimate the QCD contribution we obtain a data-MC scale factor (SF_{QCD}).



$$SF_{QCD} = \frac{N^{control}_{Data}}{N^{control}_{Simulation}}$$ =0.74 ± 0.02

$$N^{Signal}_{QCD} = SF_{QCD} \times N^{MC}_{QCD}$$

$$N^{Signal}_{QCD} =$$ 0.02 ± 0.02

Z→ττ+Jets Control Region

- Don’t have a method to obtain a clean sample:
  - To determine contribution we use Z→ μμ + Jets, then treat μ’s as τ’s.

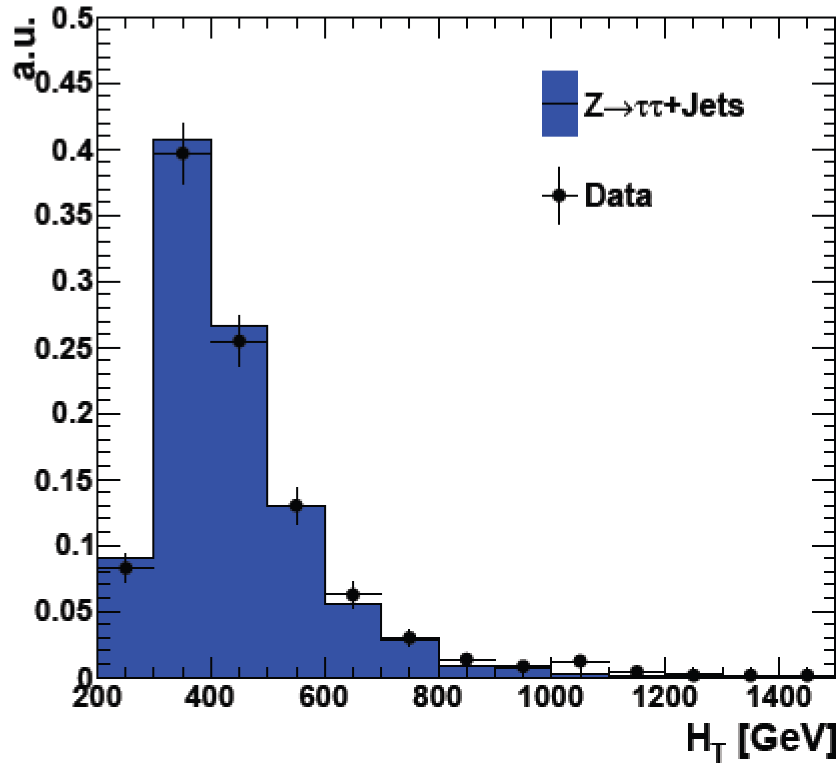
To obtain a clean Z→ μμ + Jets control sample we modify our standard selection as follows:

- Remove MHT and use μ trigger.
- Remove τ isolation requirement.
- Require 2 clean μ

Z(→ττ)+Jets Background

$$N^{SR}_{Z\to\tau\bar\tau} = N^{CR}_{Z\to\mu\bar\mu} R\left[\frac{A_\tau^2\varepsilon_\tau^2}{A_\mu^2\varepsilon_\mu^2} + \frac{2A_\tau^2\varepsilon_\tau(1-\varepsilon_\tau)}{A_\mu^2\varepsilon_\mu^2}\mathcal{P}(1) + \frac{2A_\tau(1-A_\tau)\varepsilon_\tau}{A_\mu^2\varepsilon_\mu^2}\mathcal{P}(1) + \frac{(1-A_\tau)^2}{A_\mu^2\varepsilon_\mu^2}\mathcal{P}(2)\right]$$

- $R=[B(Z\to\tau\tau)B^2(\tau\to\tau_h)/B(Z\to\mu\mu)]$ x $[\varepsilon^{Trig}_{MHT}$ x $\varepsilon^{MHT} / \varepsilon^{Trig}_{\mu\tau}]$.
- A_μ = μ acceptance efficiency.
- A_τ = τ acceptance efficiency.
- ε_μ = μ ID efficiency.
- $B(Z\to \nu\nu)$ = branching ratio for $Z\to \nu\nu$
- $B(Z\to\mu\mu)$ = branching ratio for $Z \to \mu\mu$
- ε^{Trig}_{MHT} = efficiency of HLT_PFMHT150 (plateau)
- $\varepsilon^{Trig}_{\mu\tau}$ = efficiency of μτ cross-trigger.
- ε^{MHT} = efficiency of MHT (>250)
- P(2) is the probability to have 2 jets that can fake the τ.



$N^{SR}_{Z\to\tau\bar\tau} = 0.21 \pm 0.13$

Summary of Background Estimation

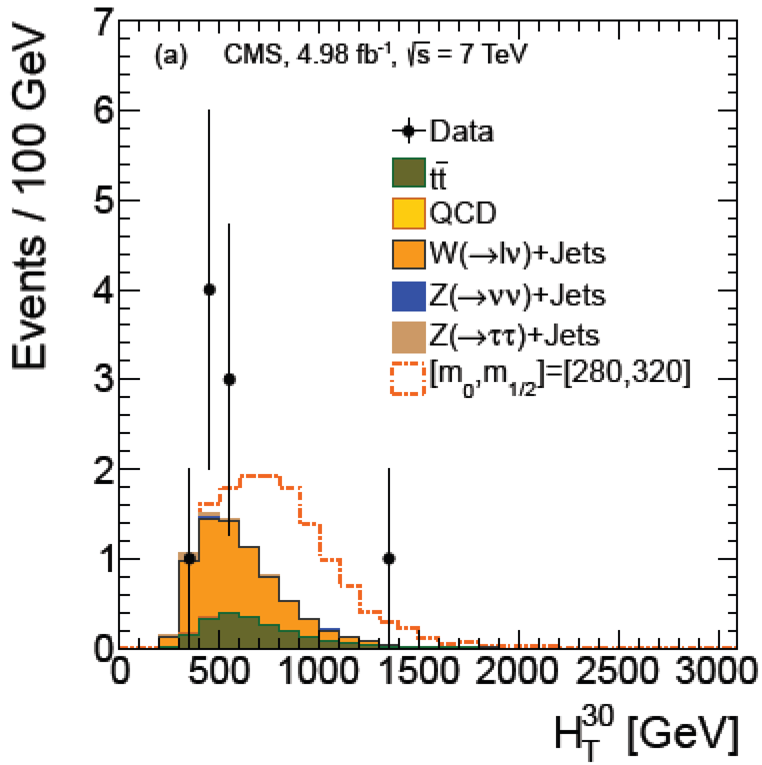
Process	Signal Region
QCD events	0.02 ± 0.02
W + Jets events	5.20 ± 0.63
Top pair events	2.03 ± 0.36
Z ($\rightarrow\tau\tau$) + Jets events	0.21 ± 0.13
Z ($\rightarrow\nu\nu$) + Jets events	0.03 ± 0.02
Estimated Total	7.49 ± 0.74

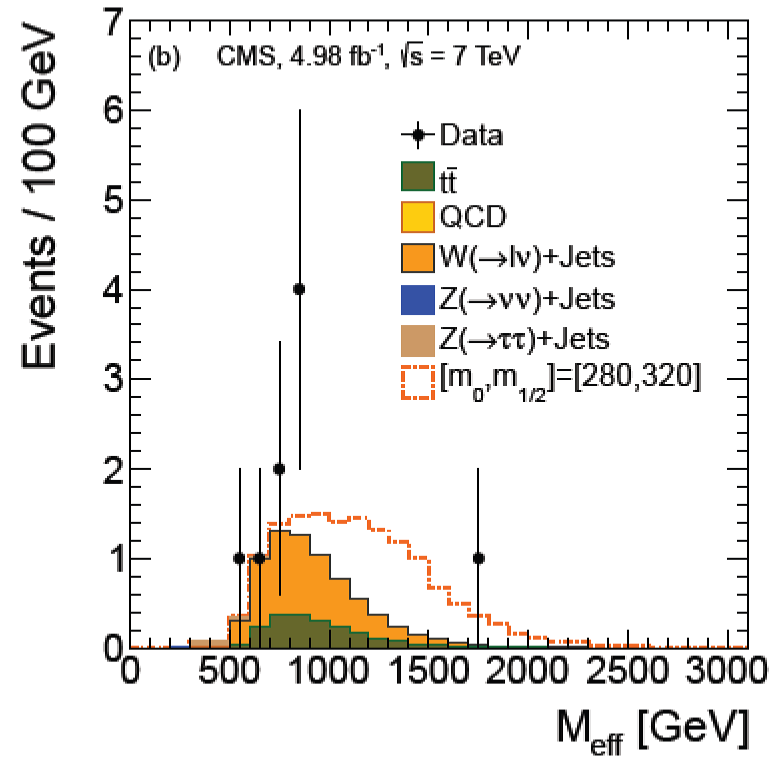
Results

Number of observed data events and estimated background rates is consistent with SM processes.

Process	Signal Region
multijet events	$0.02 \pm 0.02_{stat} \pm 0.17_{syst}$
W+jets	$5.20 \pm 0.63_{stat} \pm 0.62_{syst}$
$\mathrm{t\bar{t}}$	$2.03 \pm 0.36_{stat} \pm 0.34_{syst}$
$\mathrm{Z} \rightarrow \tau\bar{\tau}+$ jets	$0.21 \pm 0.13_{stat} \pm 0.17_{syst}$
$\mathrm{Z} \rightarrow \nu\bar{\nu}+$ jets	$0.03 \pm 0.02_{stat} \pm 0.50_{syst}$
Estimated $\sum SM$	$7.49 \pm 0.74_{stat} \pm 0.90_{syst}$
Observed $Data$	9
$[m_0, m_{1/2}] = [280, 320]$	$7.1 \pm 1.2_{stat}$

Results



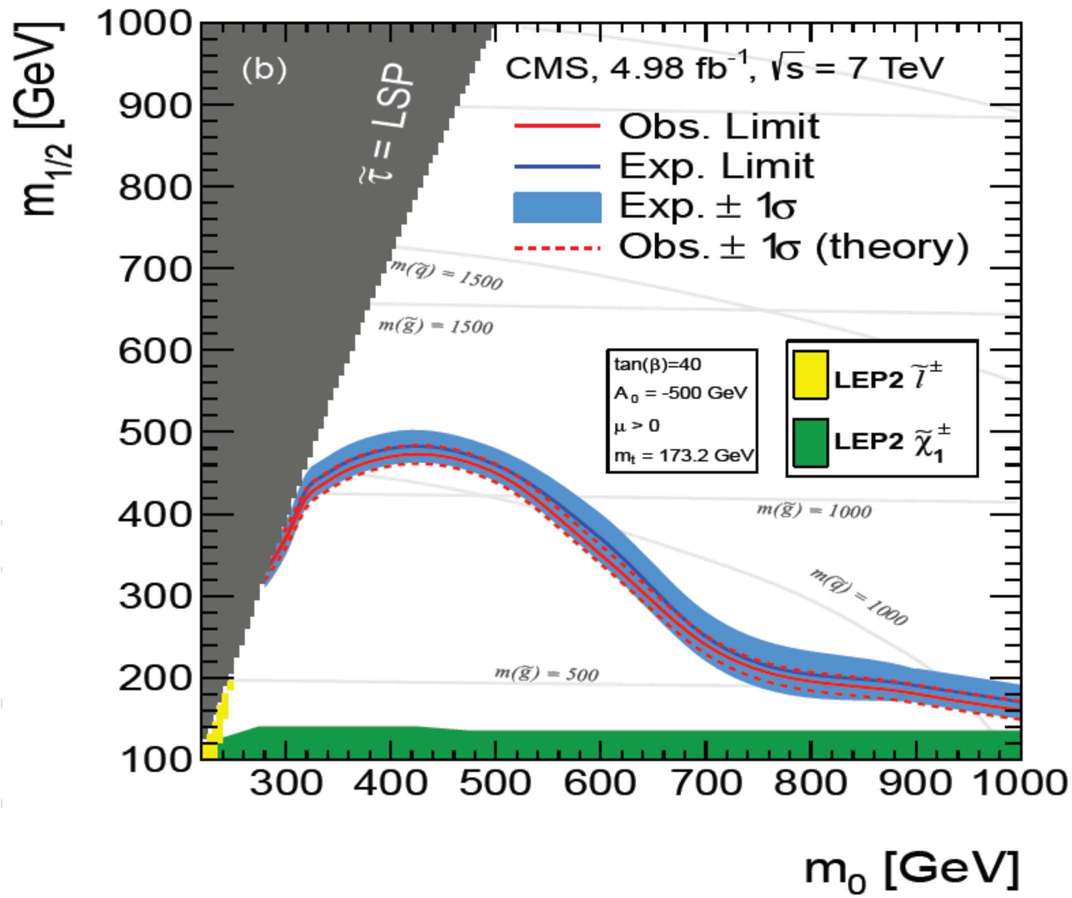


H_T^{30} distribution in the signal region

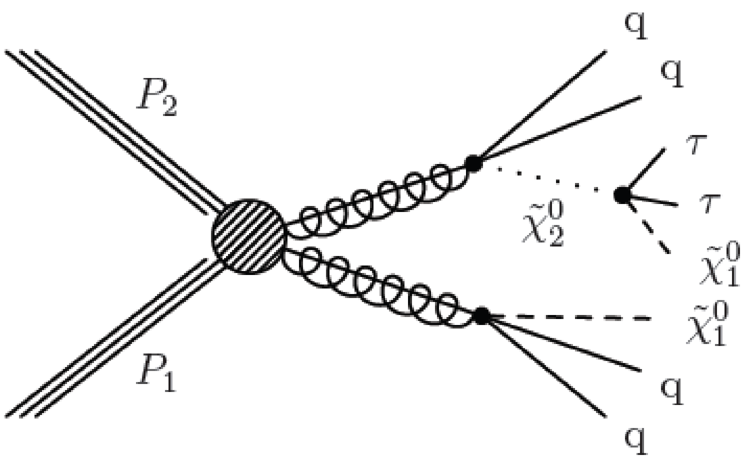
H_T^{30}+ MH_T distribution in the signal region

Interpretation: CMSSM

- Fixed tanβ = 40, A_o = 500 GeV, μ > 0, M_{top} = 173.8 GeV
- Limits set using cut and count method.
- Gaugino mass of < 510 GeV is excluded at 95% CL
- Gluino with mass < 1.15 TeV is excluded at 95% CL

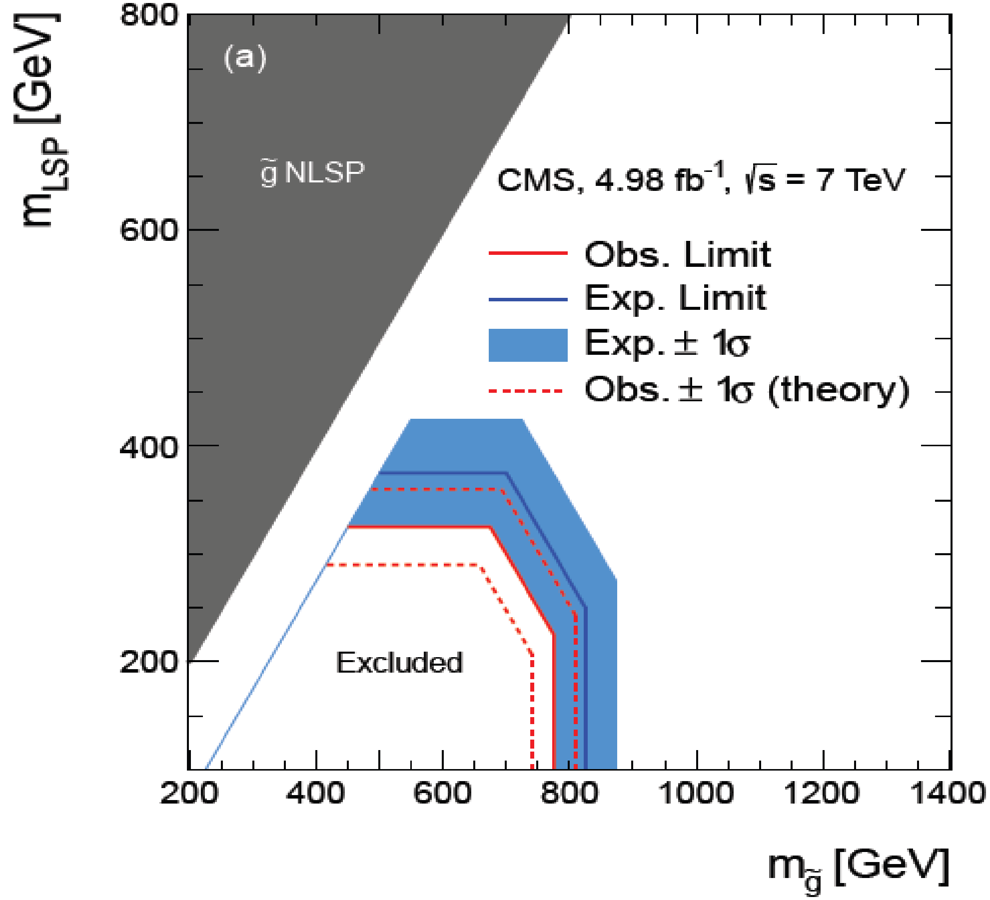


Interpretation: SMS (T3Tauh Model)



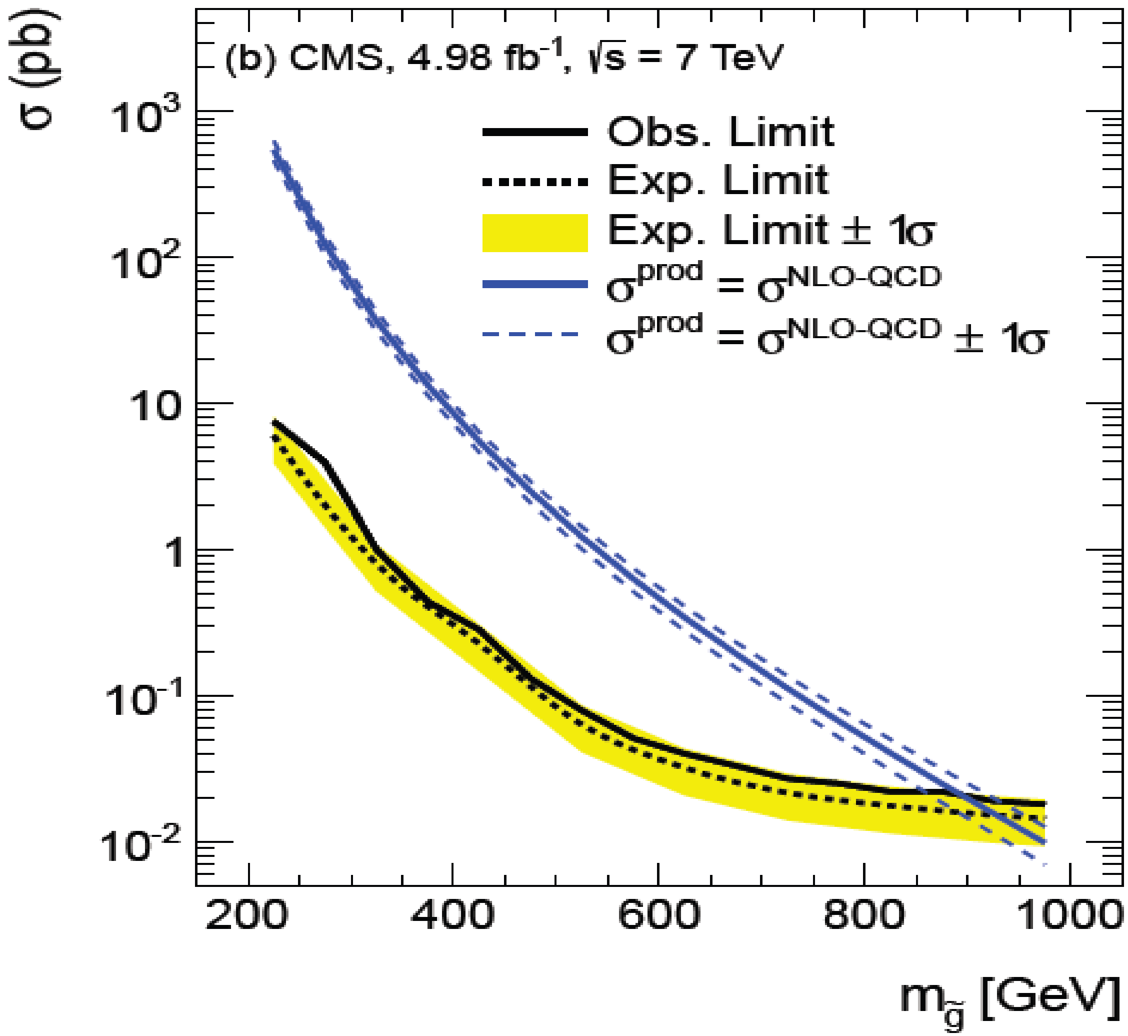
- Results interpreted in simplified model scenario.

- Gluino mass of < 775 GeV excluded at 95% CL for LSP masses up to 325 GeV.



Interpretation: Simplified GMSB

- A gluino mass < 900 is excluded at 95% CL.
- Figure shows exclusion limits as a function of gluino mass.



Summary

- A search for SUSY in the Jets + MET + τ's Final state
- Estimations for SM backgrounds based on collision data.
- Results are consistent with SM processes
- Results interpreted in BSM scenarios
- ~20 fb^{-1} of data at 8 TeV already collected in 2012! … Gig'em!

Backup

Top pair Background

Sample	Events
Data	394
QCD	—
$W + Jets$	—
$t\bar{t}$	$357.5 \pm (55.4)_{syst} \pm (9.8)_{stat}$
$Z \to \nu\nu$ + Jets	—

Cut	Data
$A_{\tau+j}$	$0.166 \pm 0.011(stat) \pm 0.005(syst)$
A_{j+j}	$0.834 \pm 0.025(stat) \pm 0.005(syst)$
ε^{τ} iso	$0.55 \pm 0.006(stat) \pm 0.04(syst)$
f	$0.022 \pm 0.003(stat) \pm 0.002(syst)$
$\varepsilon^{b-Tagging}$(TCHEM) [15]	$0.684 \pm 0.021(stat + syst)$
Probability to tag $\geq 2\ b - jets$ (TCHEM)	$0.468 \pm 0.02(stat + syst)$
Expected Number of Events	2.03 ± 0.46

Z(→νν)+Jets Background

Sample	Events
Data	738
QCD	—
$W + Jets$	—
$t\bar{t}$	$6.81 \pm 1.20_{stat} \pm 1.06_{syst}$
$Z \to \mu\mu$ + Jets	$709.5 \pm 15.43_{stat} \pm 38.61_{syst}$

Cut	Data
$N^{pure}_{Z\to\mu\mu+Jets}$	738
$B(Z \to \nu\nu)$	0.20 ± 0.0006
$B(Z \to \mu\mu)$	0.03366 ± 0.00007
$\varepsilon^{Trigger}_{\mu\tau}$	$0.87 \pm 0.04(stat + syst)$
$\varepsilon^{Trigger}_{\not{H}_T}$	$0.989 \pm 0.025(stat + syst)$
$\varepsilon^{\not{H}_T}$	$0.0081 \pm 0.0033(stat) \pm 0.004(syst)$
A_μ	$0.7007 \pm 0.004(stat) \pm 0.029(syst)$
ε_μ	$0.8678 \pm 0.0014(stat + syst)$
f	$0.0164 \pm 0.00193(stat) \pm 0.001(syst)$
Expected Number of Events	0.03 ± 0.03

Z(→ττ)+Jets Background

Cut	Data
$N^{pure}_{Z\to\mu\mu+Jets}$	738
$B(Z\to\tau\tau)$	0.03367 ± 0.0008
$B(\tau\to\tau_h)$	0.6479 ± 0.0008
$B(Z\to\mu\mu)$	0.03366 ± 0.00007
$\varepsilon^{Trigger}_{\mu\tau}$	$0.87\pm0.04(stat+syst)$
$\varepsilon^{Trigger}_{\not{H}_T}$	$0.989\pm0.025(stat+syst)$
$\varepsilon^{\not{H}_T}$	$0.00271\pm0.00192(stat)$
A_τ	$0.503\pm0.001(stat)\pm0.014(syst)$
ε_τ	$0.649\pm0.007(stat)\pm0.045(syst)$
A_μ	$0.7007\pm0.004(stat)\pm0.029(syst)$
ε_μ	$0.8678\pm0.0014(stat+syst)$
f	$0.0164\pm0.00193(stat)\pm0.001(syst)$
Expected Number of Events	0.21 ± 0.20

W + Jets Background

Sample	Events
Data	2874
QCD	$194.3 \pm 32.1_{stat} \pm 30.1_{syst}$
$W + Jets$	$1734.3 \pm 87.8_{stat} \pm 86.3_{syst}$
$t\bar{t}$	$116.2 \pm 7.2_{stat} \pm 18.0_{syst}$
$Z \rightarrow \nu\nu$ + Jets	$549.9 \pm 73.8_{stat} \pm 29.9_{syst}$

Cut	Data
$A_{\tau+j}$	$0.149 \pm 0.016(stat) \pm 0.004(syst)$
A_{j+j}	$0.851 \pm 0.038(stat) \pm 0.004(syst)$
ε^{τ} iso	$0.649 \pm 0.007(stat) \pm 0.045(syst)$
f	$0.019 \pm 0.001(stat) \pm 0.001(syst)$
Probability to tag 0 $b - jets$	$0.83 \pm 0.08(stat + syst)$
Expected Number of Events	5.20 ± 0.89

QCD Background

Sample	Events
Data	1678
QCD	$1847.5 \pm 37.6_{stat} \pm 286.22_{syst}$
$W \to l\nu$ + Jets	$242.0 \pm 19.7_{stat} \pm 12.04_{syst}$
$t\bar{t}$	$66.2 \pm 3.6_{stat} \pm 10.26_{syst}$
$Z \to \nu\nu$ + Jets	—

Summary of Systematic Uncertainties

Source of Systematic	Systematic Uncertainty
Luminosity	2.2%
$\not{H}_{\mathrm{T}}$ Trigger	2.5%
Tau ID	6.8%
Parton Distribution Functions	11.0%
Initial State Radiation	*Negligible*
Final State Radiation	*Negligible*
Tau Energy Scale (3.0%)	2.3%
Jet Energy Corrections (2-5%)	4.6%
Pile-up	*Negligible*
Background Estimation	15.6%