



# Jet+MET Topology Group

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The Rockefeller University

LPC Jterm-III

January 16, 2009

## Conveners:

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## Meetings:

bi-weekly (alternate week dijet)

Tuesdays 13:00-15:00 (CST)

EVO/Round Table (WH11 SE)





**Wednesday 14 January 2009**  
from 10:30 to 15:30  
America/Chicago  
at LPC Fermilab West Wing WH10 NW

## Jet + MET Topology group meeting

**Description:** modification key jetmet

[Wednesday 14 January 2009](#) |

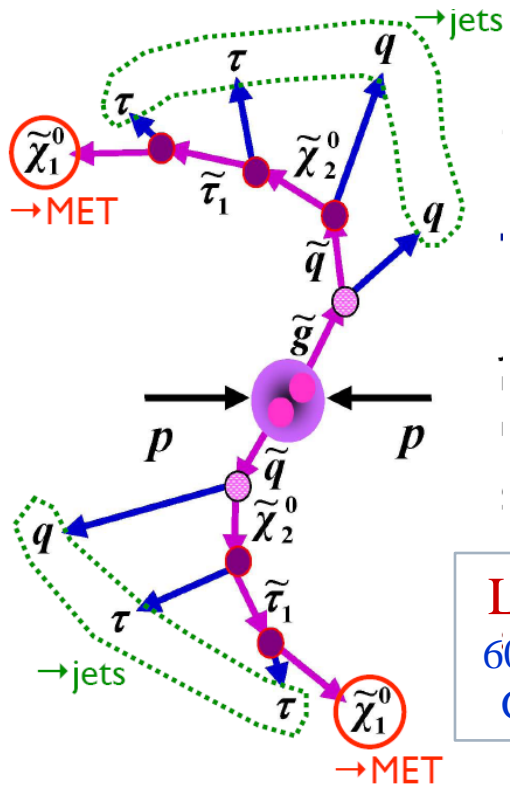
### Wednesday 14 January 2009

[top](#) ↑

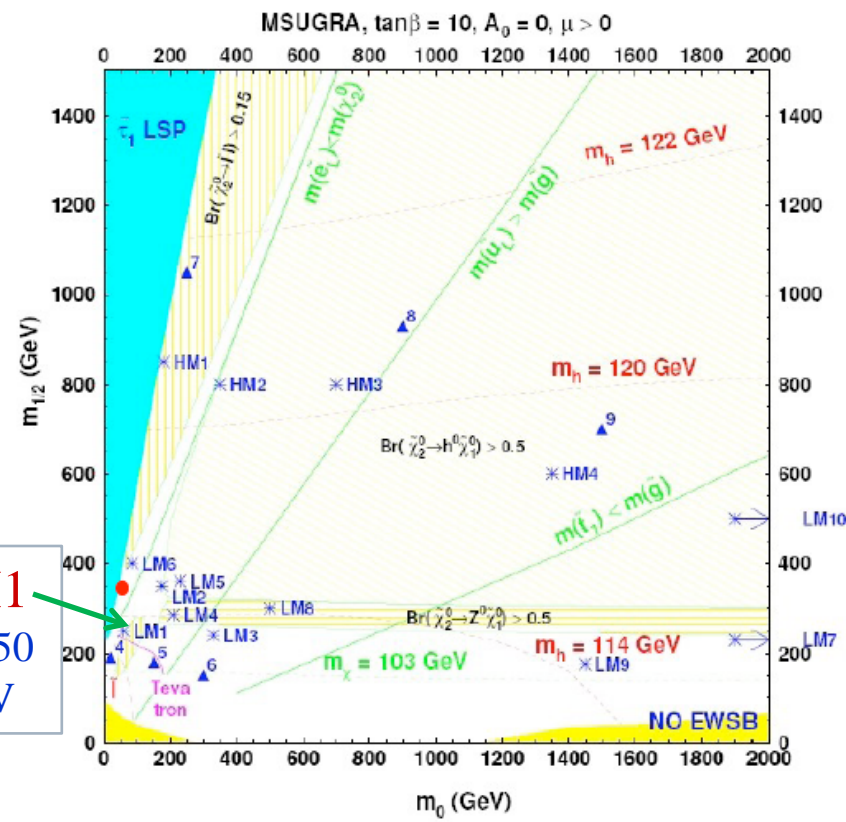
- |       |  |                                   |
|-------|--|-----------------------------------|
| 10:30 | News (10)  | Anwar/Teruki                      |
| 10:40 | Z--> TauTau Tool for Higgs and SUSY Searches (25')    ( Slides   )                                     | Alfredo Gurrola (Texas A&M)       |
| 11:05 | Generic SUSY Search: Invisible Z Background using W/Z/photon+jets (25')    ( Slides   )                | Sue Ann Koay (UCSB)               |
| 11:30 | Generic SUSY Search: Estimate of invisible Z Background using Z-->muon-muon+jets (20')    ( Slides   ) | Gheorghe Lungu (Rockefeller U.)   |
| 11:50 | Generic SUSY Search: Estimate of ttbar Background (20')    ( Slides   )                                | Duong Nguyen (Brown U.)           |
| 12:10 | Generic SUSY Search: Estimate of QCD Background Using Smearing Technique (20')    ( Slides   )         | Elif Albayrak (Iowa)              |
| 12:30 | break (1h00')  |                                   |
| 13:30 | SUSY Trigger Studies (20')   ( Slides  )   | Gheorghe Lungu (Rockefeller U.)   |
| 13:50 | Trigger Studies using Global Run data (25')    ( Slides   )  | Mehmet Deliomerglu (LPC/Cukurova) |
| 14:15 | Search for SUSY Higgs (25')    ( Slides   )  | Harold Nguyen (Riverside)         |
| 14:40 | Search for SUSY at High tan(beta) in Tau+jet+MET (25')    ( Slides   )                                 | Jonathan Asaadi (Texas A&M) (TBC) |



# Supersymmetry



**LM1**  
60,250  
GeV



Final state typically has multiple jets and large missing transverse energy. Cross sections depend on the SUSY parameters, specially masses of squarks and gluinos.



# Benchmark Point LM1

$m_0=60$  GeV,  $m_{1/2}=250$  GeV,  $\tan(\beta)=10, A_0=0, \text{sign}(\mu)>0$   
Gluino mass = 600 GeV, squark mass = 320 GeV

▶ Dominated by gluino and squark productions  
 $pp \rightarrow \tilde{g}\tilde{q}$  (47%),  $\tilde{q}\tilde{q}$  (27%),  $\tilde{g}\tilde{g}$  (9%),  $\tilde{q}\tilde{\chi}^{0(\pm)}$ ,  $\tilde{t}\tilde{t}$ ,  $\tilde{b}\tilde{b}$ , etc. (16%)

└─	$\tilde{g}\tilde{q}_L$ (22%)	└─	$\tilde{q}_L\tilde{q}_L$ (8%)
└─	$\tilde{g}\tilde{q}_R$ (25%)	└─	$\tilde{q}_L\tilde{q}_R$ (11%)
		└─	$\tilde{q}_R\tilde{q}_R$ (8%)

⇒  $\sigma_{LO} = 47$  pb

▶ Cascade decays lead to complex final states

$\tilde{g} \rightarrow \tilde{q}_L q$ (27%)	$\tilde{q}_L \rightarrow \tilde{\chi}_1^0 q + \nu l$ (34%), $\tau\nu$ (29%), $\tau\tau$ (15%), $\nu\nu$ (13%)
$\rightarrow \tilde{q}_R q$ (42%)	$\tilde{q}_R \rightarrow \tilde{\chi}_1^0 q$ (98%)

Final state contains  $\geq 2$  jets and 2 stable LSPs ( $\Rightarrow$  MET)



# Inclusive Jet+MET Analysis



## Standard Model Processes

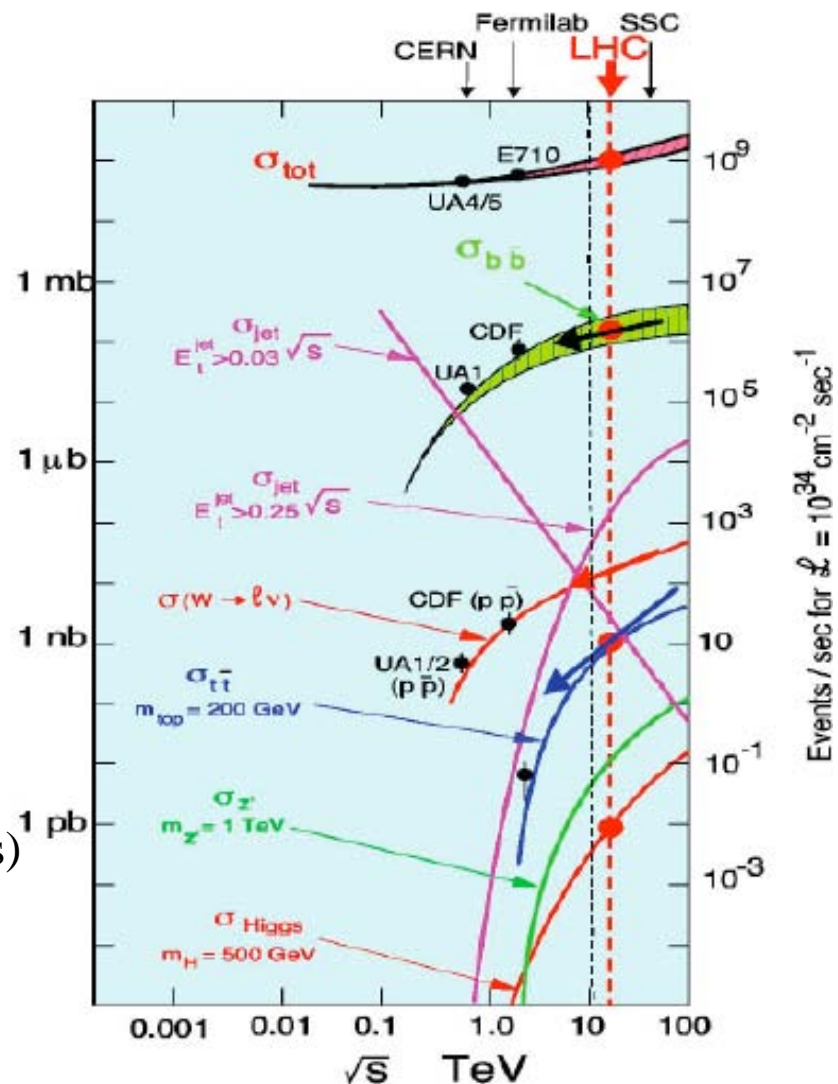
QCD	$10^{10}$ pb
W+jet (leptons)	$7 \times 10^4$ pb
Z+jets (leptons)	$7 \times 10^3$ pb
$t\bar{t}$	800 pb

## SUSY LM1 $\sim 50$ pb

- Require large MET and multi-jets to suppress the SM backgrounds.
- Use data-driven techniques to estimate backgrounds.

## Event Selection: (PTDR2)

- Cleanup
- No leptons (no e,  $\mu$ , isolated tracks, EM rich jets)
- Three leading jets with  $P_t > 180, 110, 30$  GeV
- $HT = P_t \text{Jet2} + P_t \text{Jet3} + P_t \text{Jet4} + \text{MET} > 500$  GeV
- $\text{MET} > 200$  GeV

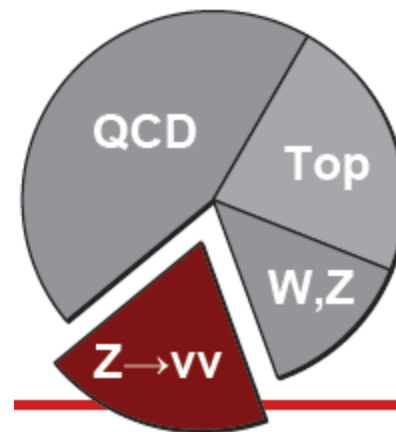




# Significant Backgrounds



QCD                    mis-measured jet, b/c quarks  
 Top                    semi-leptonic  $\tau$ -lepton or lost lepton  
 W,Z diboson         $\tau$ -leptons, lost leptons  
 $Z \rightarrow \nu\nu$         irreducible



Estimated based on Monte Carlo PTDR-II ( $fb^{-1}$  @ 14 TeV)

Signal	QCD	Top pair	Z( $\nu\nu$ )	W/Z	Single top
6319	107	54	48	33	3

Major effort over last year has been to develop methods to extract these background from data.

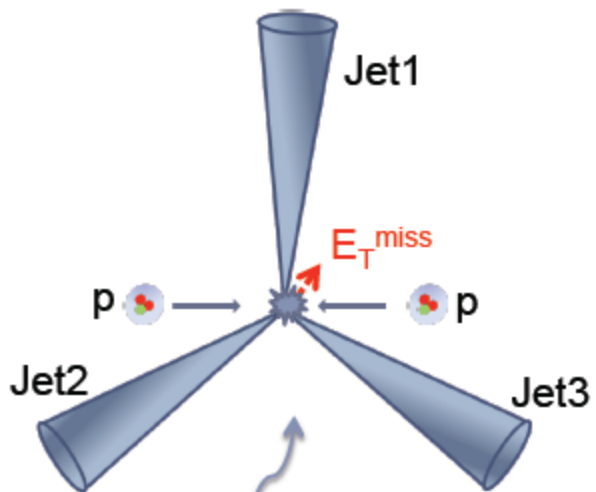




# QCD background Elif Albayrak (Iowa)

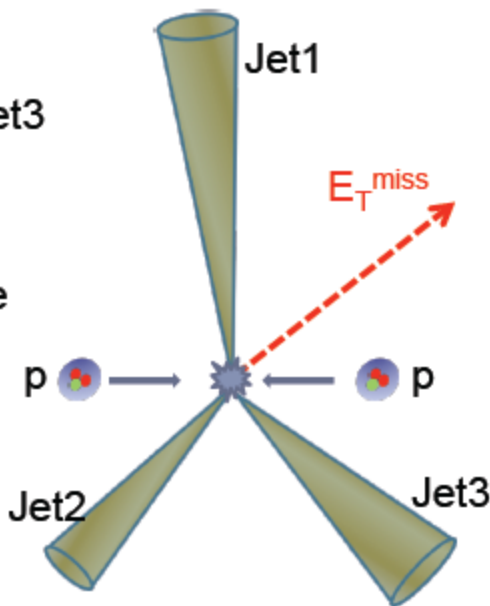


Low  $E_T^{\text{miss}}$  Event

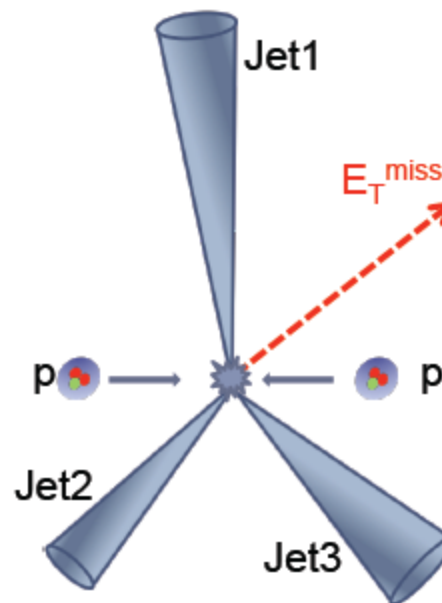


Introduce artificial imbalance by smearing  $p_T$  of the jets.

Smeared High  $E_T^{\text{miss}}$  Event



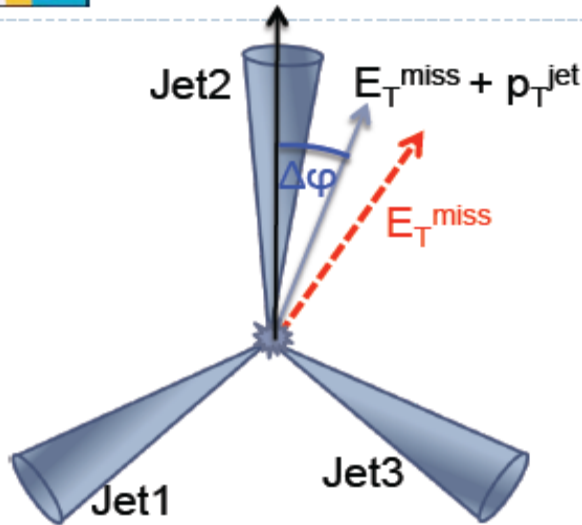
High  $E_T^{\text{miss}}$  Event



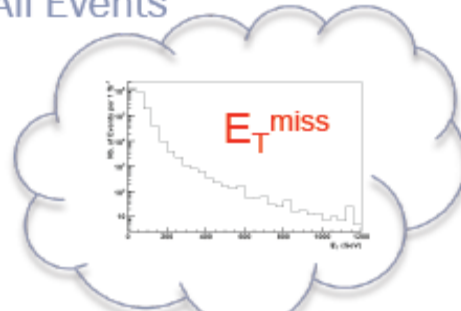
Other Efforts at CMS:  
C. Auterman et al (Hamburg)  
ABCD Method  
Jess Reidel (UCSB)  
Smearing Technique



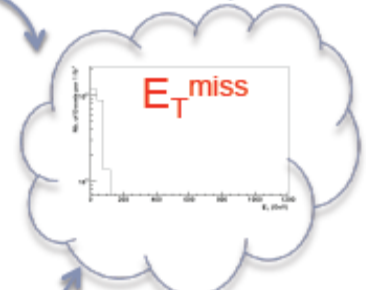
# Smearing Function



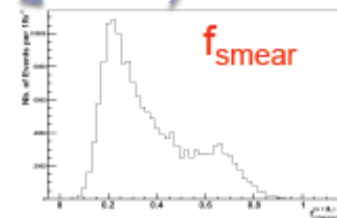
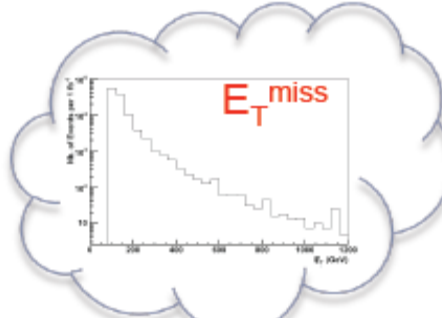
All Events



Events  $E_T^{\text{miss}} < X$



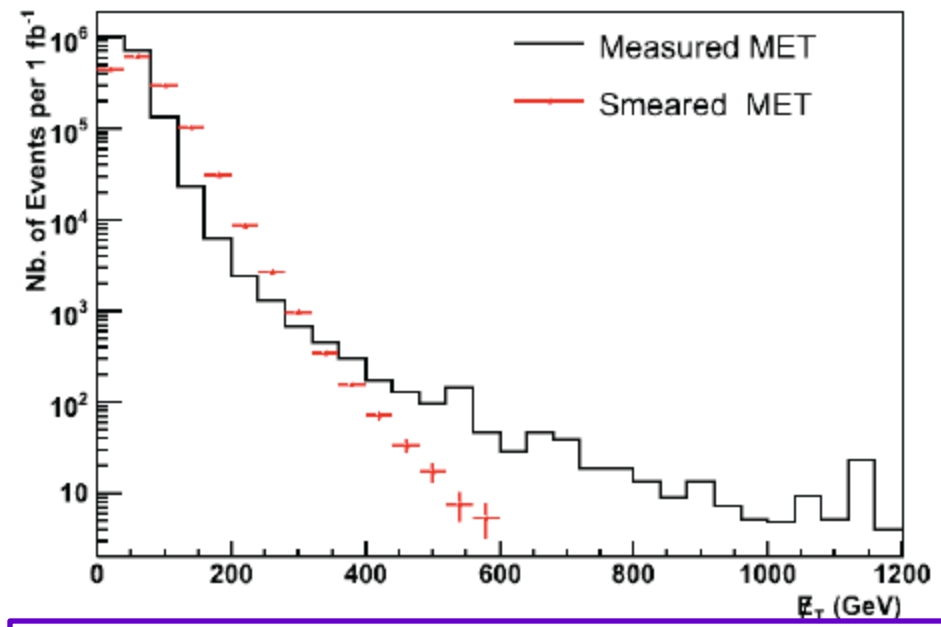
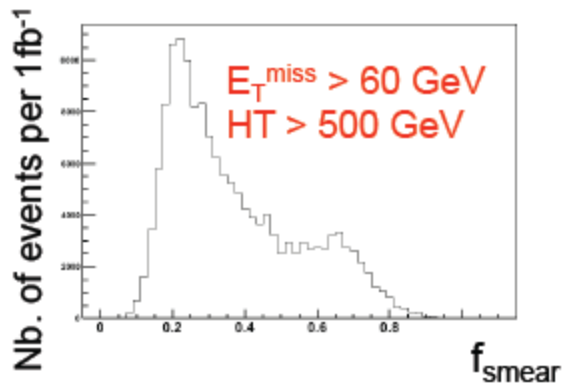
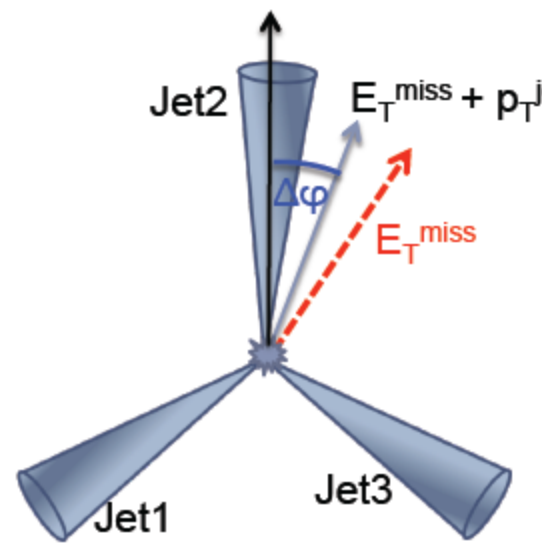
Events with  $E_T^{\text{miss}} > X$



$$f_{\text{smear}}^{(\vec{E}_T^{\text{miss}} > X)} = 1 - \frac{p_T^{\text{Jet}} \cos(\Delta\phi)}{|\vec{p}_T^{\text{Jet}} + \vec{E}_T^{\text{miss}}|}$$

$$f = 1 - \frac{\vec{M} \cdot \vec{E}}{|\vec{E}|^2} \quad (\text{or simplified})$$





This method over (under) estimated the low (high)  $E_T^{\text{miss}}$  region. **Under study.**

**Need to understand the tails in the response function.**

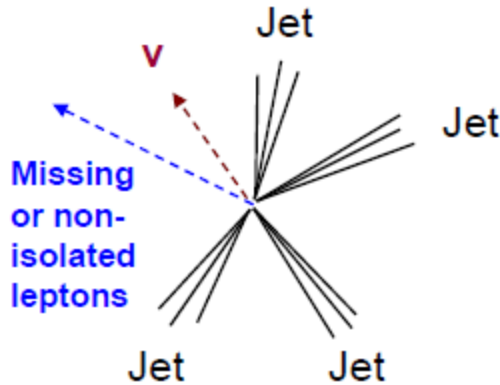


# $t\bar{t}$ background

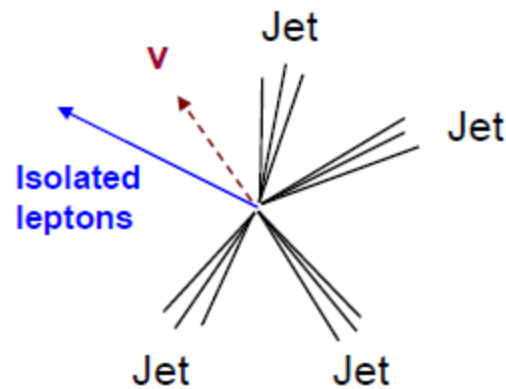
Duong Nguyen (Brown)



## Method



*$Tt\bar{t}$  background in data selected by Susy selections requiring no isolated leptons*



*$Tt\bar{t}$  in control sample selected by Susy selections requiring isolated leptons*

- Control sample: selected by susy selections (no MET cut) requiring at least 1 isolated leptons.
- Data: selected by susy selections (no MET cut) requiring no isolated leptons



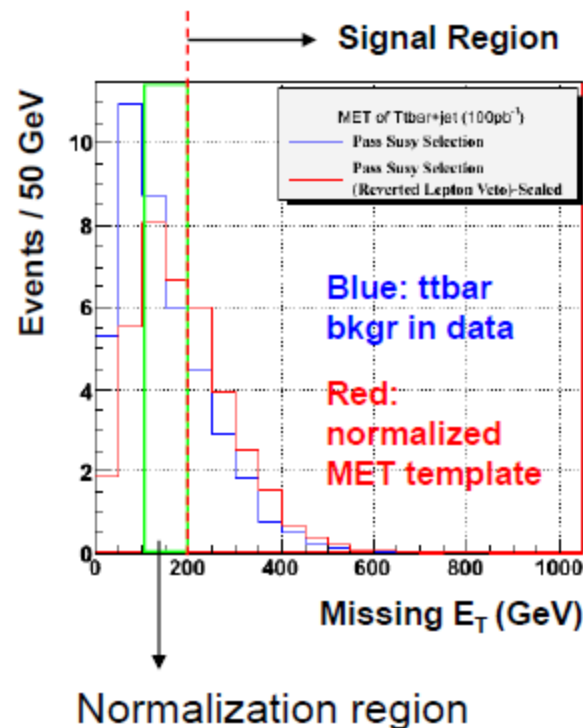
# $t\bar{t}$ background



## Method (Cont.)



- Control sample is selected by the same susy selections except lepton  $\rightarrow$  MET shape is used as template for  $T\bar{t}$  MET in data.
- Normalize that template to data MET distribution at low MET regions
- Normalized MET template distribution at signal region (above MET cuts)  $\rightarrow$   $T\bar{t}$ +jet background

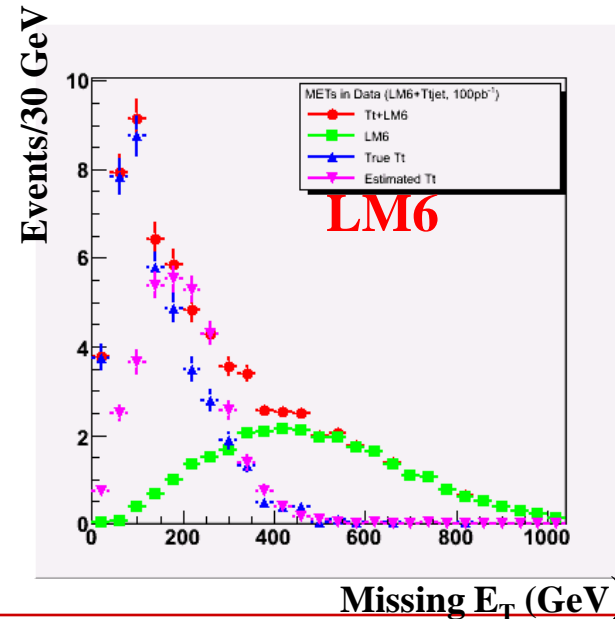
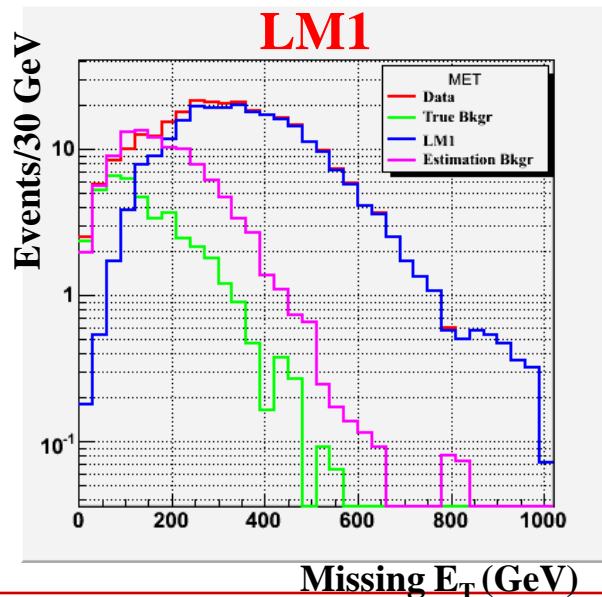


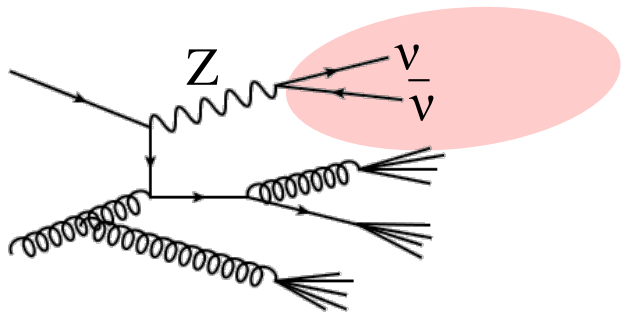


# $t\bar{t}$ background



- The procedure works reasonable well in absence of SUSY.
- SUSY contaminates (template , data) → over estimate
- Investigating various techniques to separate  $t\bar{t}$  and SUSY.
  - $MT$  = mass of lepton and missing transverse energy
  - $\Delta\phi$  between the hemisphere containing lepton and MET
  - Top and W mass constraints

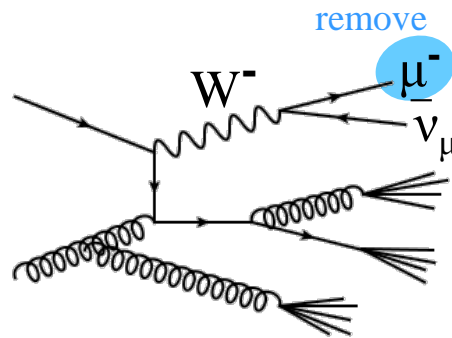
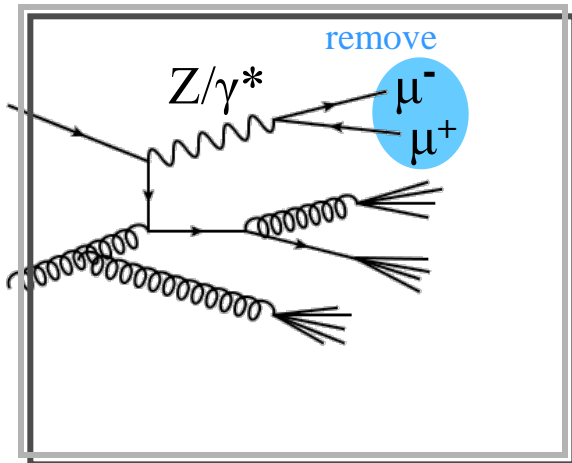




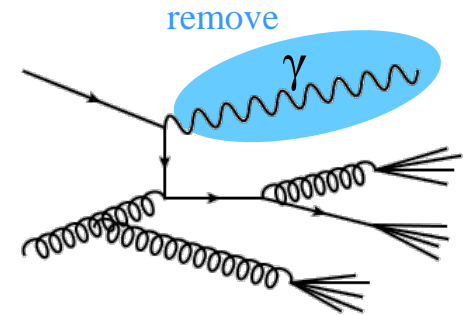
$$p_T^Z > 200 \text{ GeV} \Rightarrow \text{MET} > 200 \text{ GeV}$$

$$\sigma(Z \rightarrow \nu\nu) = 20\% \times \sigma(Z)$$

What processes are similar?



- Lower statistics  
(than  $\gamma$ , a bit  $> Z \rightarrow \nu\nu$ )
- Simpler theory corrections



- Higher statistics  
(no branching ratio)
- More theory corrections

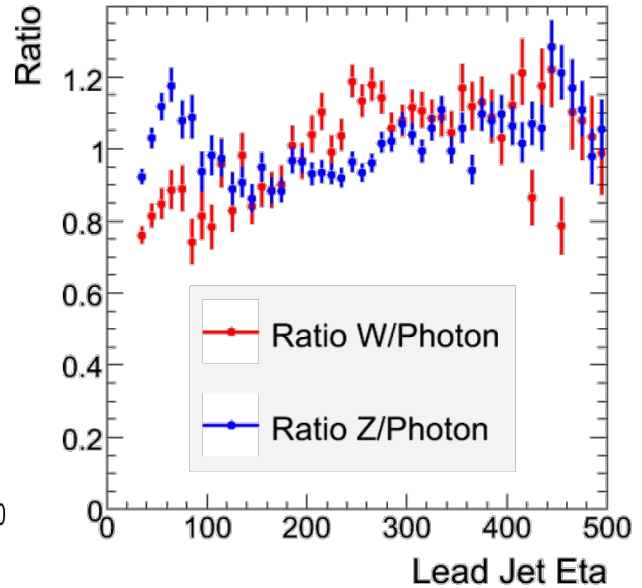
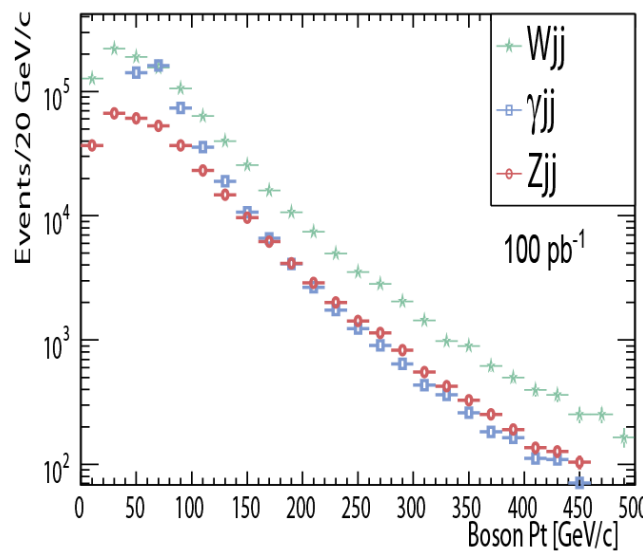
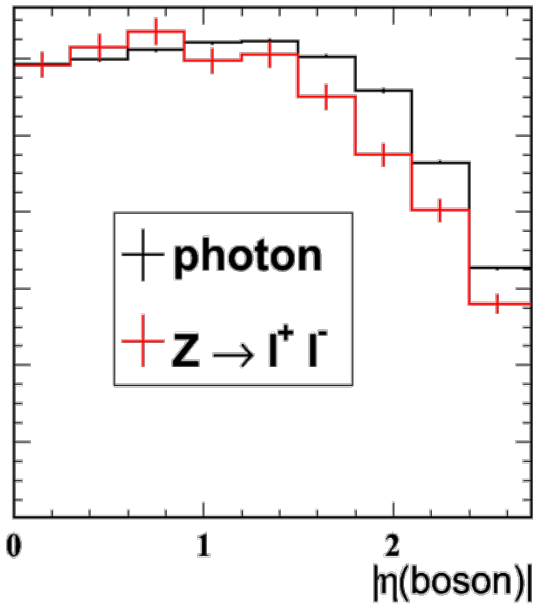


# Photon+jets

# Sue Ann Koay (UCSB)



- For large  $p_T > 200$  GeV, Pt and  $\eta$  spectrum are similar.
- Hadronic activity within 20%.
- Detailed studies to determine fake rate, photon efficiency from data



### Z→ $\nu\nu$ background estimate (100 pb<sup>-1</sup>)

MC-truth	35
From $\gamma$ +jet	29 $\pm$ 3(stat) $\pm$ 5(sys)

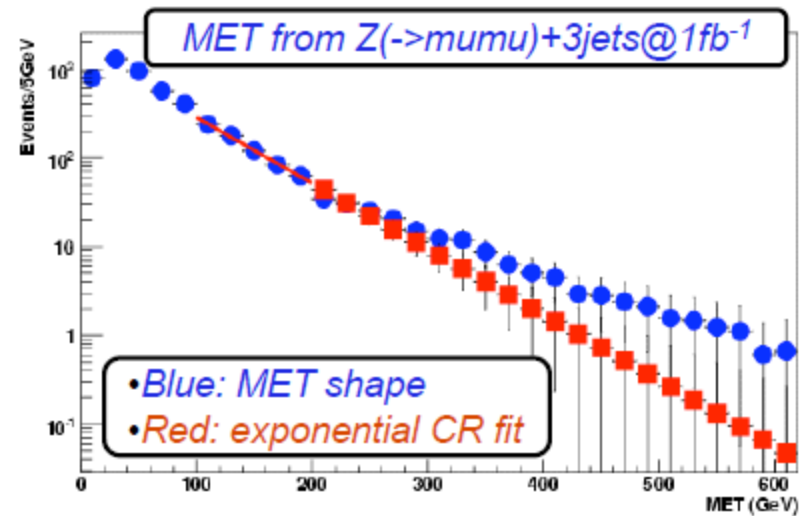




# Invisible Z background from $Z \rightarrow \mu\mu$

- Similar production mode but
$$\sigma(Z \rightarrow \mu\mu) = \sigma(Z \rightarrow \nu\nu)/6$$
- Statistically limited .  
→ Loosen the cuts and extrapolate.
- Signal Region MET > 200 GeV
- Control Region 100-200 GeV
  - Fit exponential
- Events @ 100  $pb^{-1}$ 
  - Fit 15, true 19.4
- Features of the method
  - \_relies minimally on Monte Carlo
  - biased by shape of function
- At high luminosity (> 600  $pb^{-1}$ )
  - Enough statistics to direct measurement.
  - 116 events with MET > 200 in  $Z \rightarrow \mu\mu + 3jets$

Gheorghe Lungu (Rockefeller)





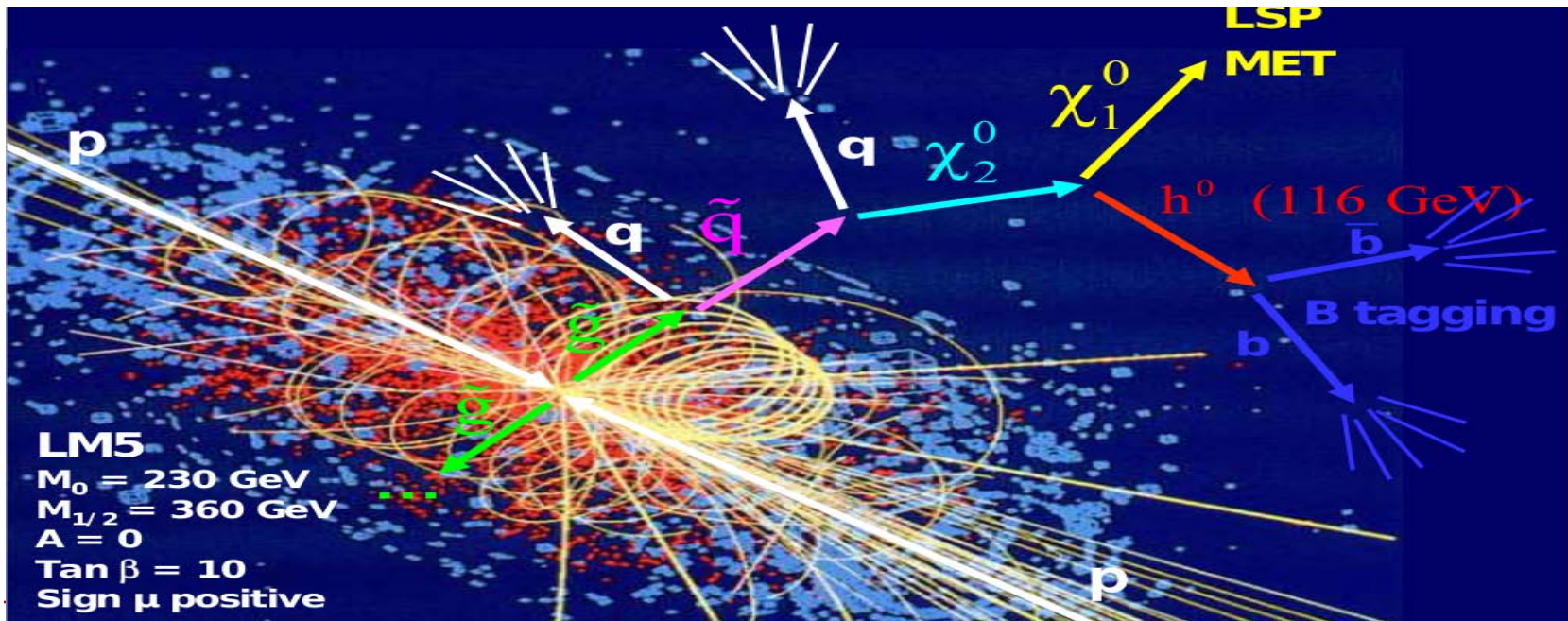
# Working Point LM5

Table 1: Some sparticle masses at LM5.

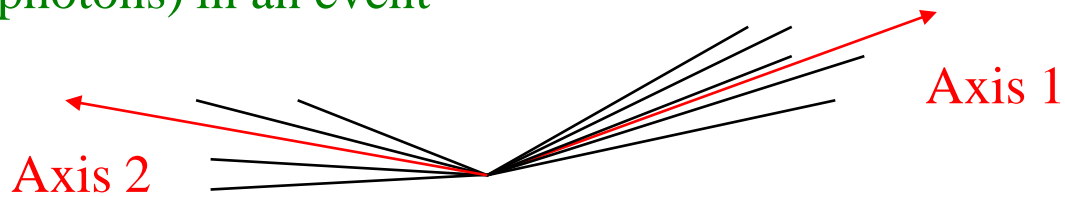
Sparticle	Mass ( GeV/c <sup>2</sup> )
$\tilde{g}$	860
$\tilde{q}$	800
$\tilde{\chi}_2^0$	273
$\tilde{\chi}_1^0$	142
$h^0$	116

Table 2: Interesting branching ratios at LM5.

Decay	Branching ratio in %
$\tilde{g} \rightarrow \tilde{q} + q$	100
$\tilde{q} \rightarrow \tilde{\chi}_2^0 + q$	35
$\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + h^0$	85
$h^0 \rightarrow b\bar{b}$	72
$\tilde{q} \rightarrow \tilde{\chi}_2^0 + q$ and $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + h^0 \rightarrow \tilde{\chi}_1^0 + b\bar{b}$	21

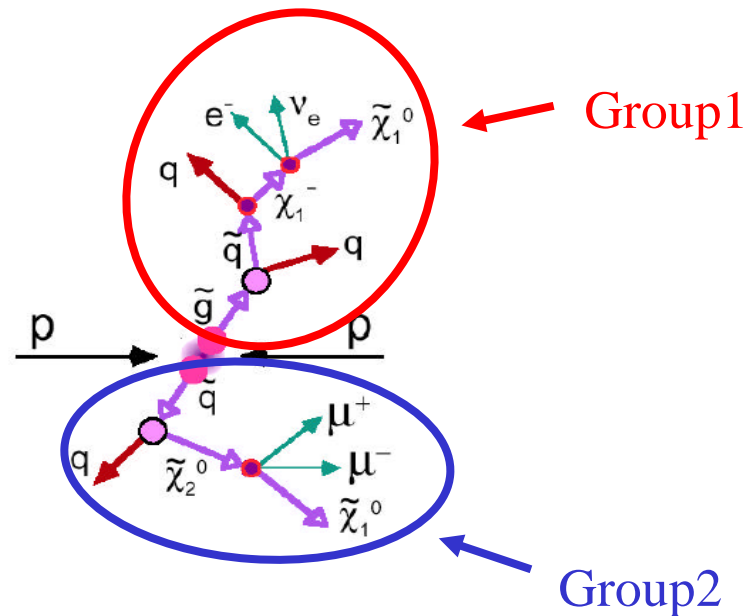


- Determine two axes that approximate the direction of primary partons by using all objects (jets, leptons, photons) in an event



Axes are computed by:

- Starting with two initial seeds –
  - two objects which form the highest object-object invariant mass
- Objects are then associated to the nearest hemisphere axis based on relative transverse momentum.
- Sum connected momenta → new axes
- Keep iterating until no objects switch

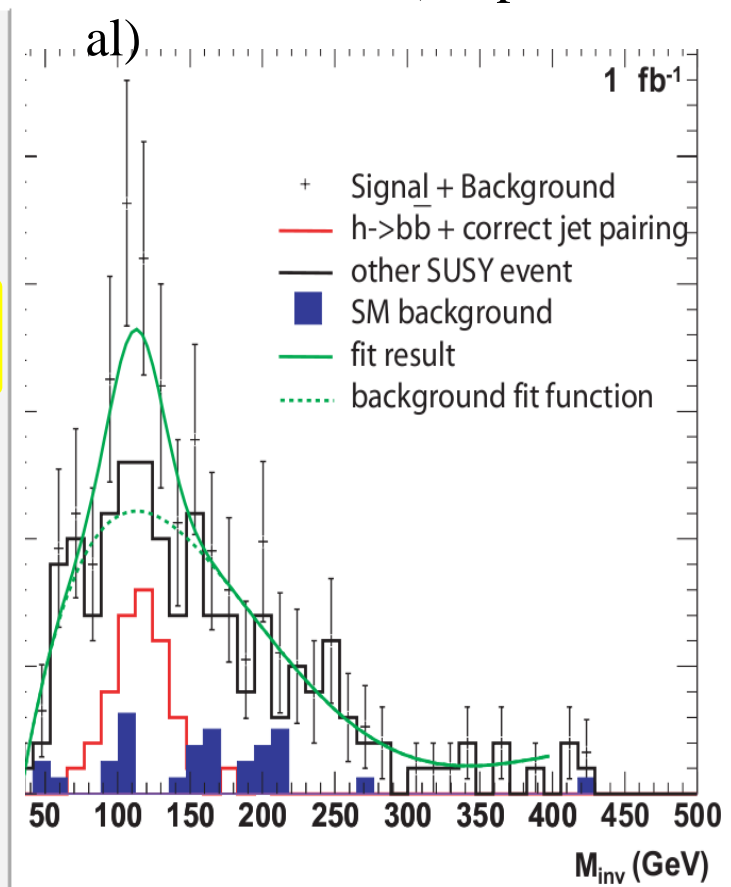
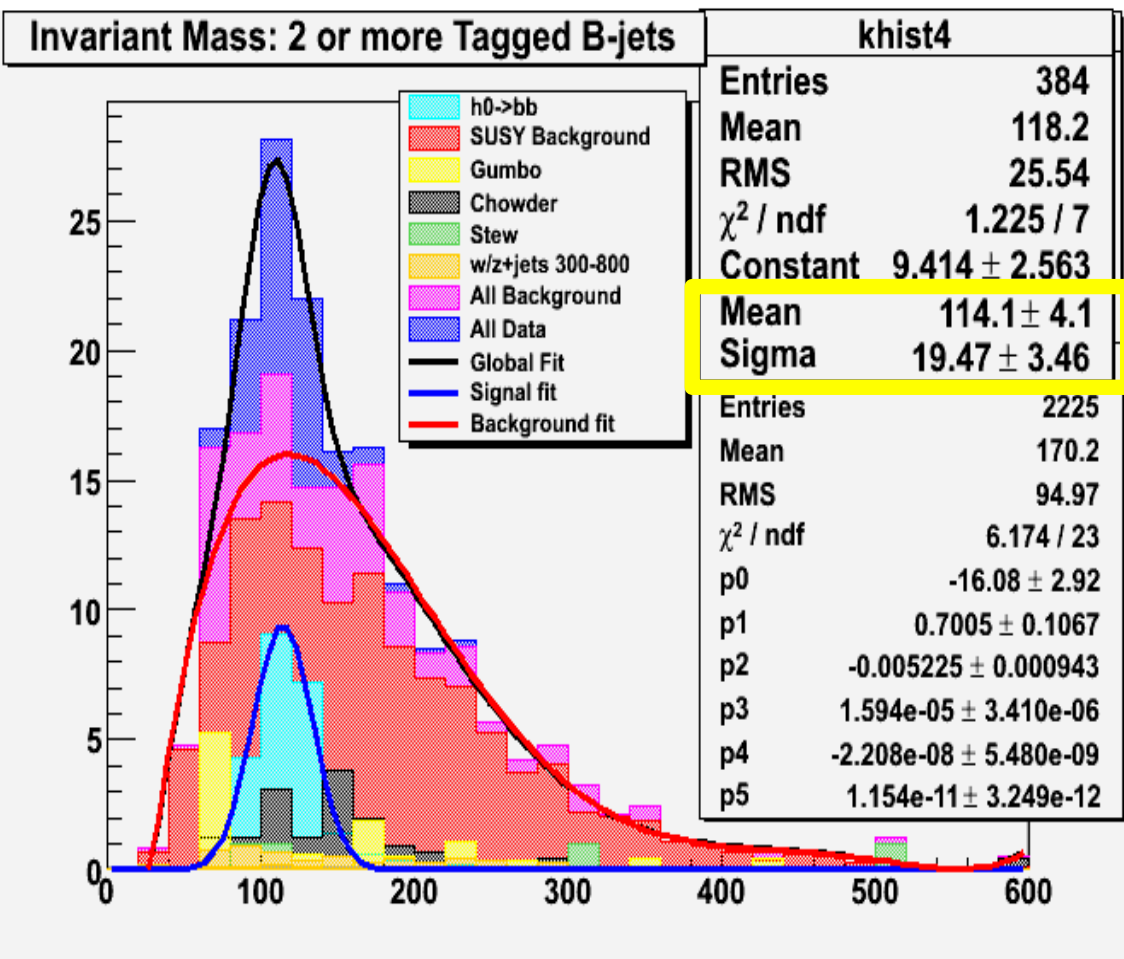


Reduce QCD background by  
 $\Delta\phi(h1,h2) > 2.7$  (rejection of ~5)



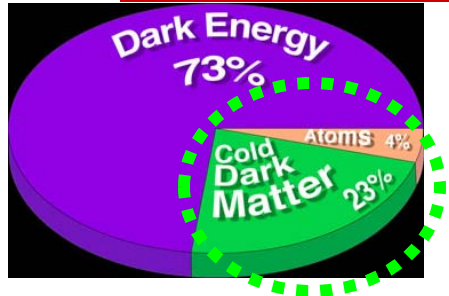
## All events with number of b-jets

## PTDR Results (Filip et. al)

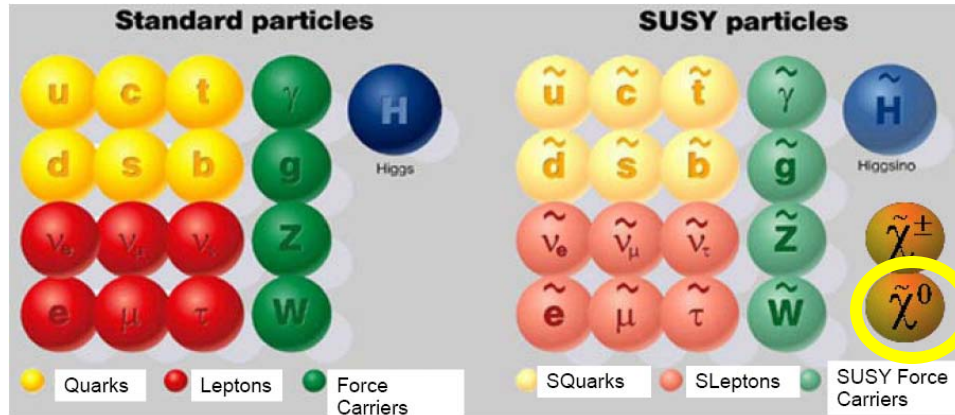


● Similar shape to PTDR





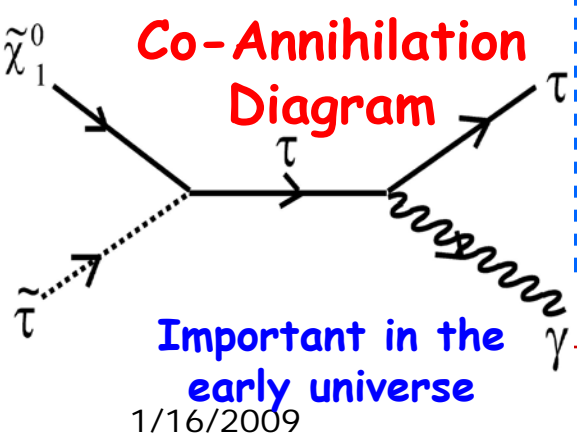
Astronomical observation indicates that we live in a universe that is made of a type of heavy weakly interacting matter that we call Dark Matter



Supersymmetry models with R-Parity Conservation give rise to a dark matter candidate particle

## Co-Annihilation Region

Minimal Super Gravity (mSUGRA) type models with a near mass degeneracy between the stau and the lightest neutralino give rise to dark matter density predictions that agree with observation



One Such Model

Jonathan ASa

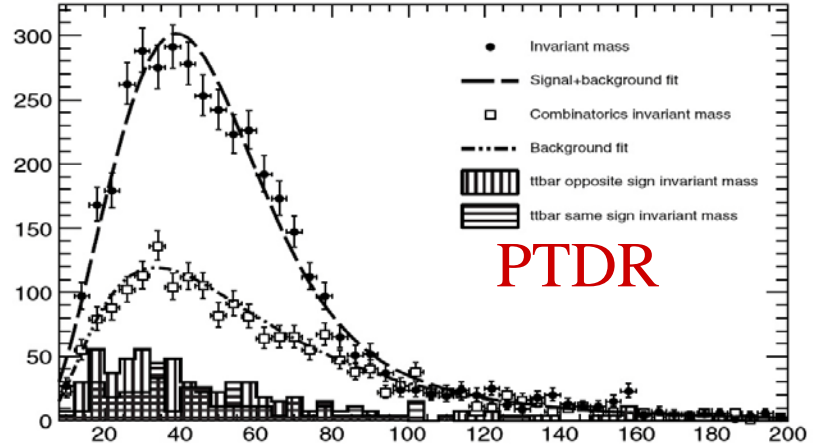
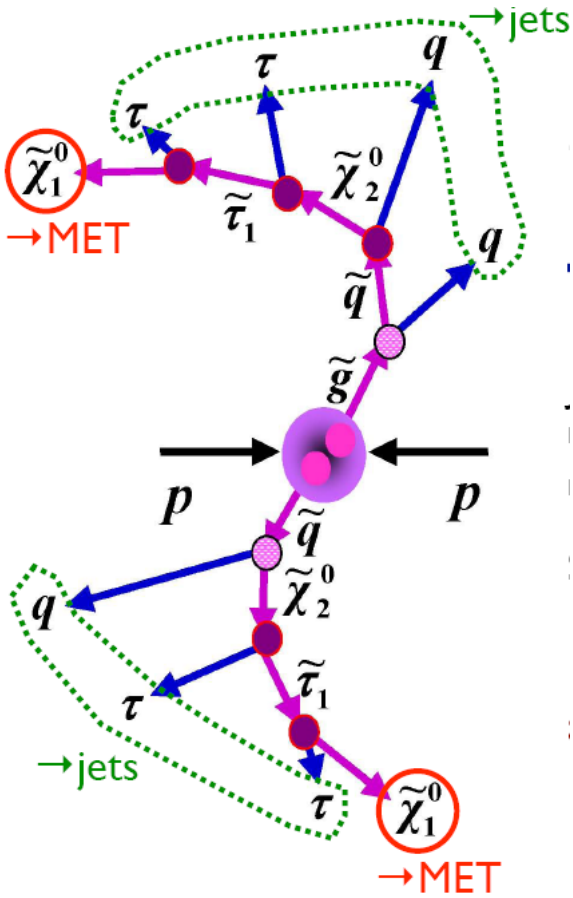
SUSY Low Mass Point 2					
$m_0$	$m_{1/2}$	$\tan\beta$	$\text{sgn}(\mu)$	$A_0$	
185 GeV	350 GeV	35	+	0.0	



$m_0$	$m_{1/2}$	$\tan\beta$	$\text{sgn}(\mu)$	$A_0$
185 GeV	350 GeV	35	+	0.0

$$\tilde{q} \rightarrow q\tilde{\chi}_2^0 \rightarrow q\tau\tilde{\tau} \rightarrow q\tau\tau\tilde{\chi}_1^0$$

Large  $\tan\beta \rightarrow$  large number of  $\tau$ s  
 Branching ratio  $\sim 95\%$  at LM2



- Using PF-Taus, a lot of technical issues
- Optimizing selection cuts
- Plan to move to 2\_2\_x



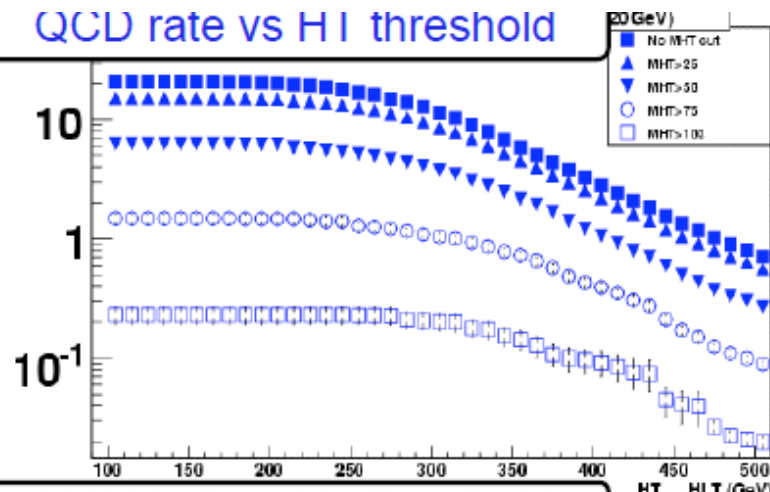


# Trigger Studies HT+MHT Trigger Jim Lungu

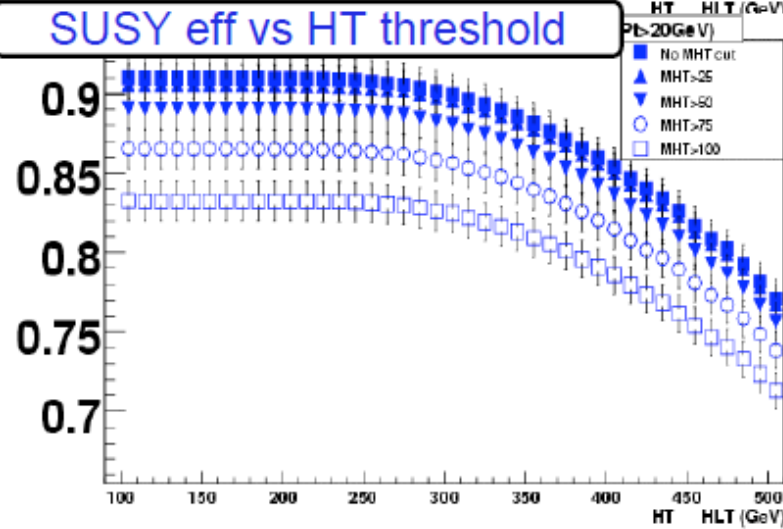


- Our proposal for 1E31 menu:
  - L1:  $HT > 200$  GeV ( $jetPt > 5$  GeV)
  - HLT:  $HT > 300$  GeV,  $MHT > 100$  GeV, ( $jetPt > 20$  GeV)
    - QCD rate is  $\sim 0.2$  Hz
    - SUSY LM1 efficiency  $\sim 82\%$
    - corresponds to lowest curve
- Overlap with HLT\_Jet180 = 90%
- Noise rate from GlobalRun data
  - CRAFT run 68288, HLT\_jet30
  - for  $HT > 100$  GeV  $\sim 6$  Hz
  - for  $HT > 200$  GeV  $\sim 2$  Hz

### QCD rate vs H1 threshold



### SUSY eff vs HT threshold



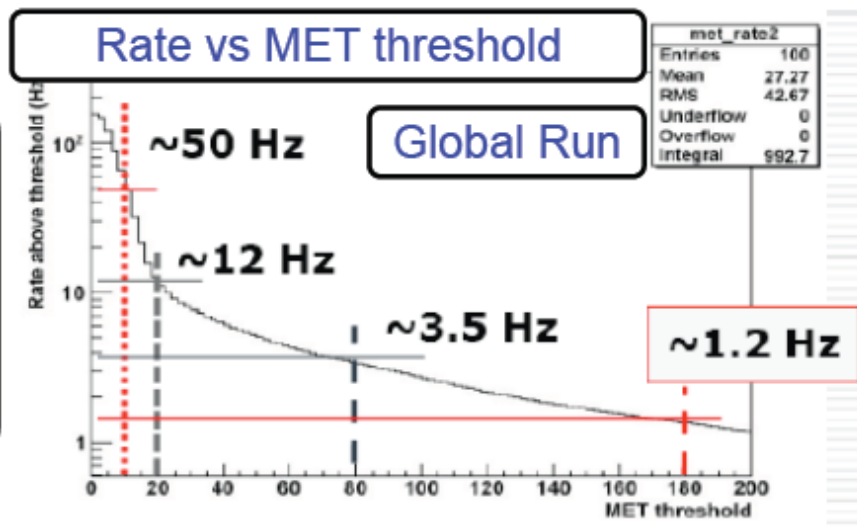


# Missing Et Rates

Gheorge Lungu



- Noise rate from GlobalRun data
  - for MET > 80 GeV ~ 3.5Hz
  - for MET > 180 GeV ~ 1.2Hz
- For noise study to be added:
  - L1ETM80 & HLT\_MET100



Plot based on study by A.Gurola



# $Z \rightarrow \tau\tau$ , tool for SUSY/Higgs Search

- $Z \rightarrow \tau\tau$  is good place to study  $\tau$  identification.

Alfredo Gurrola (TAMU)

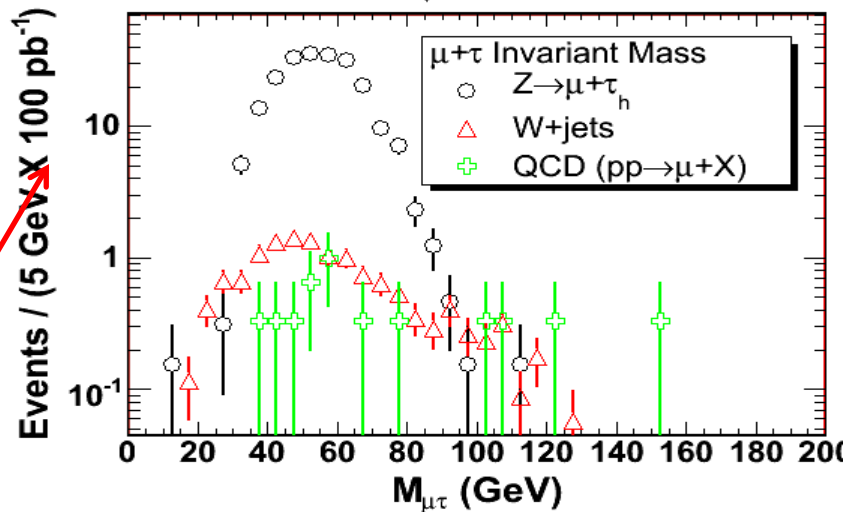
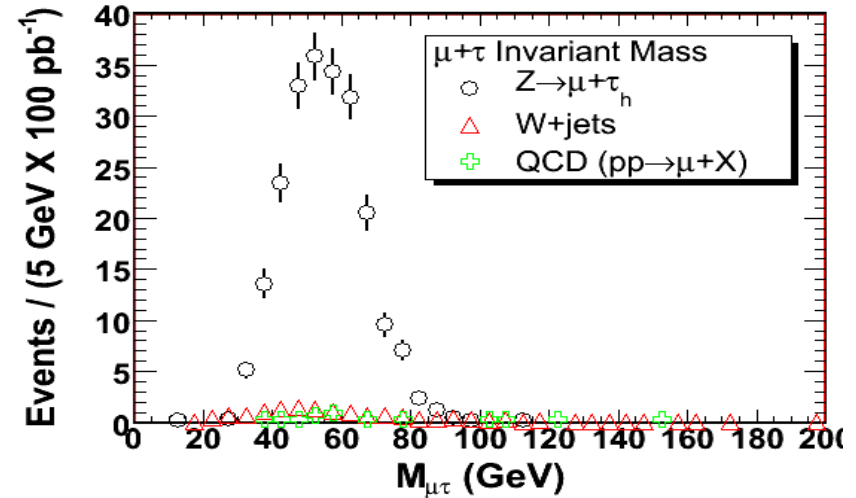
- Detailed study tau reconstruction and isolation variables
- Background
  - $W + \text{jet}$
  - QCD
- Data driven techniques to determine BG
- QCD BG:
  - ABCD method using using muon and tau isolation variables
- $W + \text{jet}$ 
  - $\tau$  isolation and  $\Delta\phi(\mu, \tau)$



# Estimated # of Events at 100 pb<sup>-1</sup> Alfredo G.



- Define all the selections:
  - $\geq 1$  global muon w/  $P_T > 20$  and  $|\eta| < 2.1$
  - $\geq 1$  jet with  $P_T > 10$  GeV and  $|\eta| < 2.5$
  - Seed track ( $\Delta R < 0.2$  from jet axis) with  $P_T > 6$
  - Exactly 1 jet with  $P_T > 10$  GeV (jet veto)
  - Muon-Jet separation cut :  $\Delta R_{\mu\text{-jet}} \geq 0.7$
  - Muon  $P_T < 50$
  - Muon Isolation  $< 1$  (both tracks & gammas)
  - Muon IP  $< 0.01$  cm
  - $\cos \Delta\phi(\mu-\tau) < -0.95$
  - $\mu$  track &  $\tau$  seed track opposite charge
  - $\tau$  isolation (both tracks & gammas)
- # of events at 100 pb<sup>-1</sup>
  - $Z \rightarrow \mu\tau$  :  $218.86 \pm 9.82$
  - W+jets :  $13.40 \pm 2.76$
  - QCD ( $pp \rightarrow \mu+X$ ) :  $4.60 \pm 2.30$





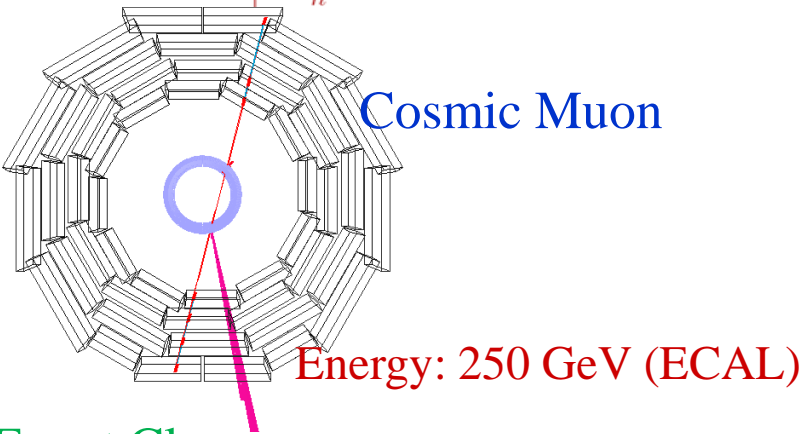
# Other Studies



- Extension of  $\alpha_T$  to three jets (Taylan Yektin, Mehmet Vergili)
  - So far main effort by CERN, Imperial College Groups.
- Global run analysis
  - Missing Et clean-up (Ming Yan, Alfredo Gurola)
  - Jet trigger Studies (Mehmet Deliomeroglu LPC/Bogazici)

# Missing Transverse Energy

$$E_T^{\text{miss}} = |\mathbf{p}_T| = \left| - \sum_n \left( E_n \sin \theta_n \cos \phi_n \hat{\mathbf{i}} + E_n \sin \theta_n \sin \phi_n \hat{\mathbf{j}} \right) \right|$$



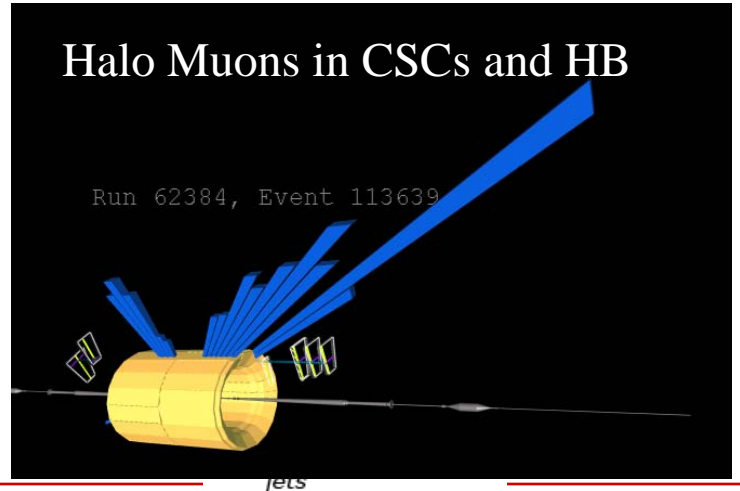
## Event Cleanup

- $\geq 1$  primary vertex
- Activity in Ecal, Hcal and tracker

$$EEMF = \frac{\sum_{jet} p_T(jet) \times EMF(jet)}{\sum_{jets} p_T(jet)} > 0.175$$

$$ECHF = \frac{1}{N_{jet}} \sum_{jets} \frac{\sum_{tracks} p_T(track)}{p_T(jet)} > 0.1$$

Not a big issue as long as such events do not overlap with real pp collision.







- Studies of CRAFT and CRUZET data shows that the rate of very high missing Et rate (from detector (HCAL) and cosmic rays) is a few Hertz. The overlap rate is expected to be small.
- We will be able to understand MET quickly (months!!) to make a statement about SUSY at LM1 i.e. exclude/discover.
  - 600 events for  $100 \text{ pb}^{-1}$  @14 TeV.

Come and join us to be part of the excitement.



- Trigger
  - HT/MHT trigger studies
  - Studies of Jet trigger in CRAFT
- Missing transverse Energy
  - Analysis of CRUZET and CRAFT data
  - Clean-up and filters
- Hadronic SUSY analysis
  - QCD background
  - Top background
  - Invisible Z boson background
  - $h \rightarrow b\bar{b}$
  - $\tau$ -lepton final states
  - $\alpha_T$  analysis