Search for Chargino-Neutralino Associated Production in Dilepton Final States with Tau Leptons

DPF
Providence, Aug 10, 2011

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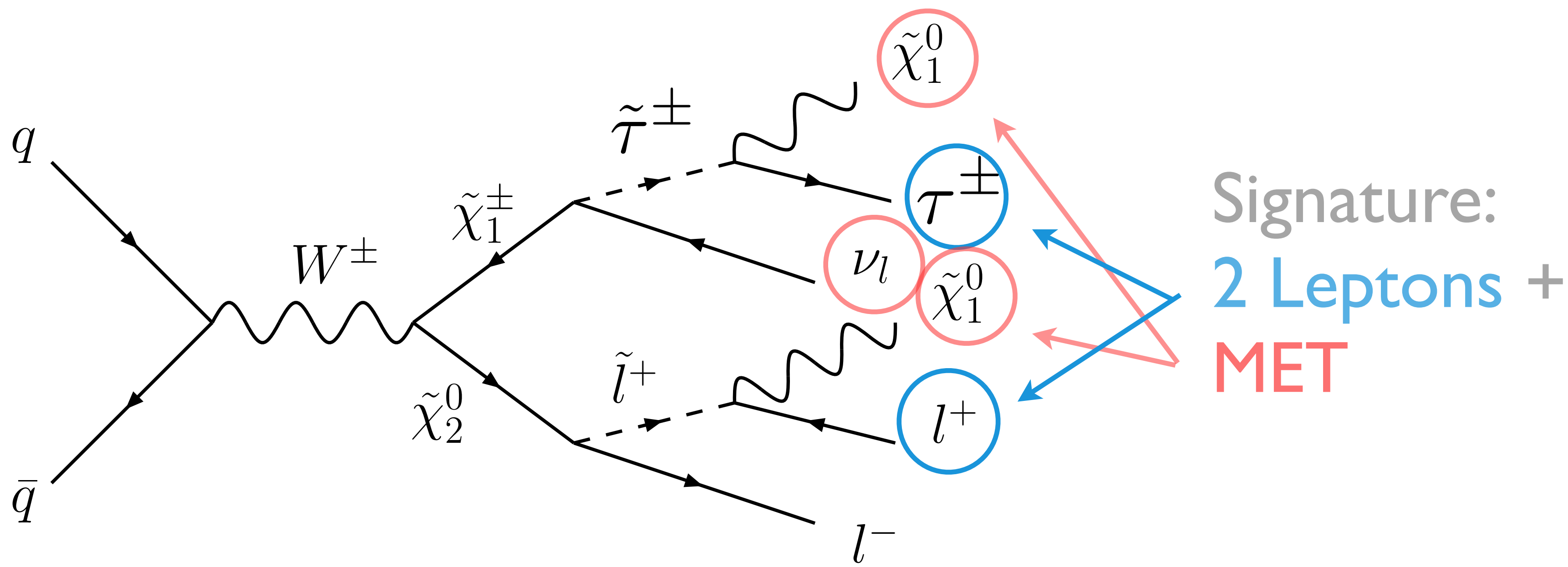
For the CDF collaboration

Same-Sign lepton and hadronic tau
(e/μ + τ)

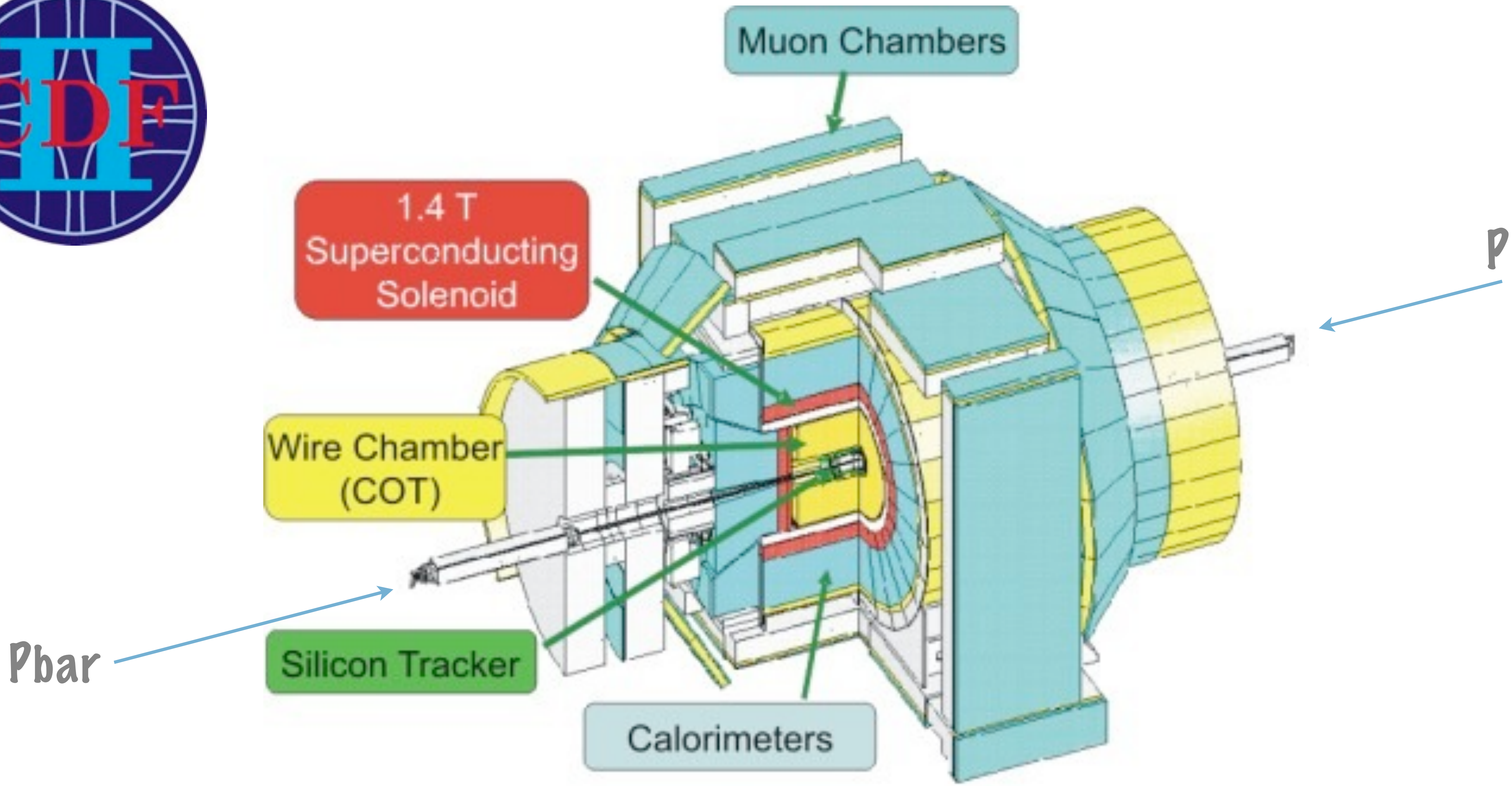


4 Channels

$e^+ \tau^+$
$e^- \tau^-$
$\mu^+ \tau^+$
$\mu^- \tau^-$

- Electroweak production of Charginos and Neutralinos
- Adding hadronic τ decays lends sensitivity to high tan β SUSY models.
- Dileptons increases acceptance relative to requiring trileptons.
- Same-Sign leptons reduces DY background.
- Complimentary to SS dilepton analysis with all es and μs.

Collider Detector at Fermilab (CDF)



Over 60 Institutions

~ 40 PhDs granted/year

Dilepton analysis strategy:

- Measure and validate Fake Rate Background
- Select OS dilepton events, compare expected BG to data.
  - OS Dileptons stage well understood, useful for validation.
- Make SUSY optimized event level MET cuts.
  - Use generic models, don't tune to mSUGRA.
- Open signal box and set limits (or discover!)

Data

Gathered through Feb '10

- 6.0 fb^{-1}

Triggers Used:

- 'Lepton + Track' triggers.

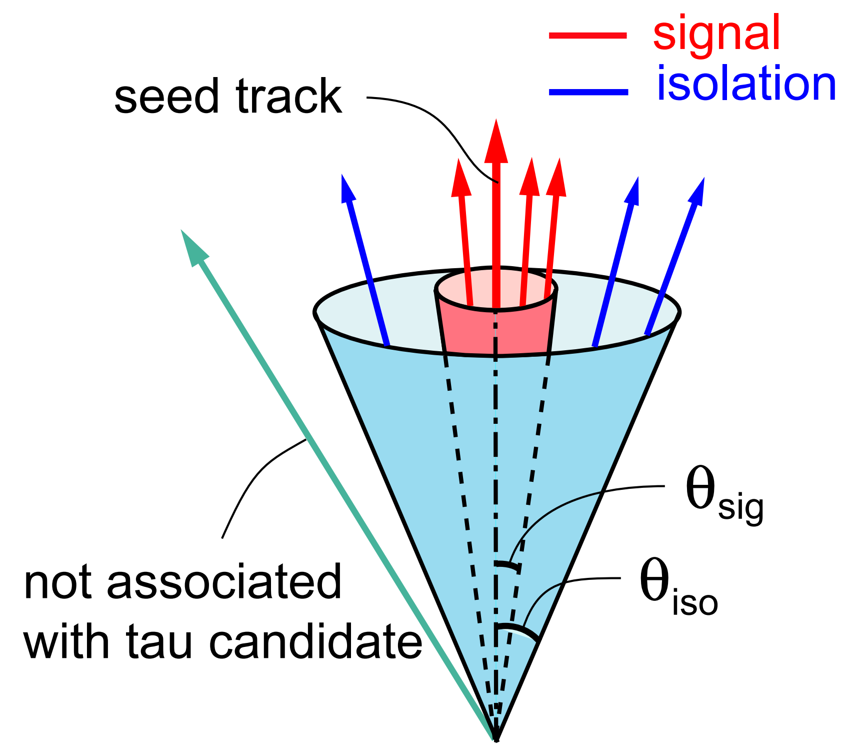


Figure 9: Tau isolation and signal cones.

- Lepton side standard e, μ
- τ side more complicated:
  - Requires τ-like signal and isolation cones
  - Much more efficient at τ finding than Jet triggers.

Lepton Selection

- Standard cuts for e/μ with $P_t > 20$ GeV/c
- Additional Isolation cuts for $P_t < 20$ GeV/c

Track and Calorimeter Isolation

$\Sigma P_T^{iso} < 2.0 \text{ GeV tracks in } \Delta R < 0.4$

$E_{rel}^{iso} < 0.1 \text{ GeV or } E^{iso} < 2.0 \text{ GeV}$

τ Selection

Have a 'tight' τ for Analysis and a 'loose' τ for Fake Rate

All τs have :

$P_T > 15.0 \text{ GeV/c for 1-pronged}$

$P_T > 20.0 \text{ GeV/c for 3-pronged}$

$P_T^{seedtrk} > 6.0 \text{ GeV/c}$

$P_T^{shtrk} > 1.0 \text{ GeV/c}$

$E_T^{\tau cl} > 9.0 \text{ GeV}$

$N_{sig}^{trk} = 1, 3$

$|\Sigma Q^{trk}| = 1$

'Tight' τs additionally have :

$\Sigma P_{T,trk}^{iso} < 2.0 \text{ GeV/c}$

$\Sigma E_{T,\pi^0}^{iso} < 1.0 \text{ GeV}$

$M(trks + \pi^0 s) < 1.8\ GeV/c^2$

$\frac{E_{tot}}{\Sigma|\ \vec{p}\ |}(0.95 - \frac{E_{EM}}{E_{tot}}) \equiv \xi' \ > 0.1$

Background Model

$Z \rightarrow ll,\ t\bar{t}$

Diboson

$W \rightarrow \tau\ \nu + \text{Jet}$

From Monte Carlo.
Well-modeled, small backgrounds.

τs are Hard:

Jet→τ Fake Rate can be ~30%

QCD

$\gamma + Jet$

$W \rightarrow l\nu + \text{Jet}$

Jet→τ Fake Rate Method
Any event containing a fake tau.

$W \rightarrow l\nu + \text{Jet}$ will be the largest background

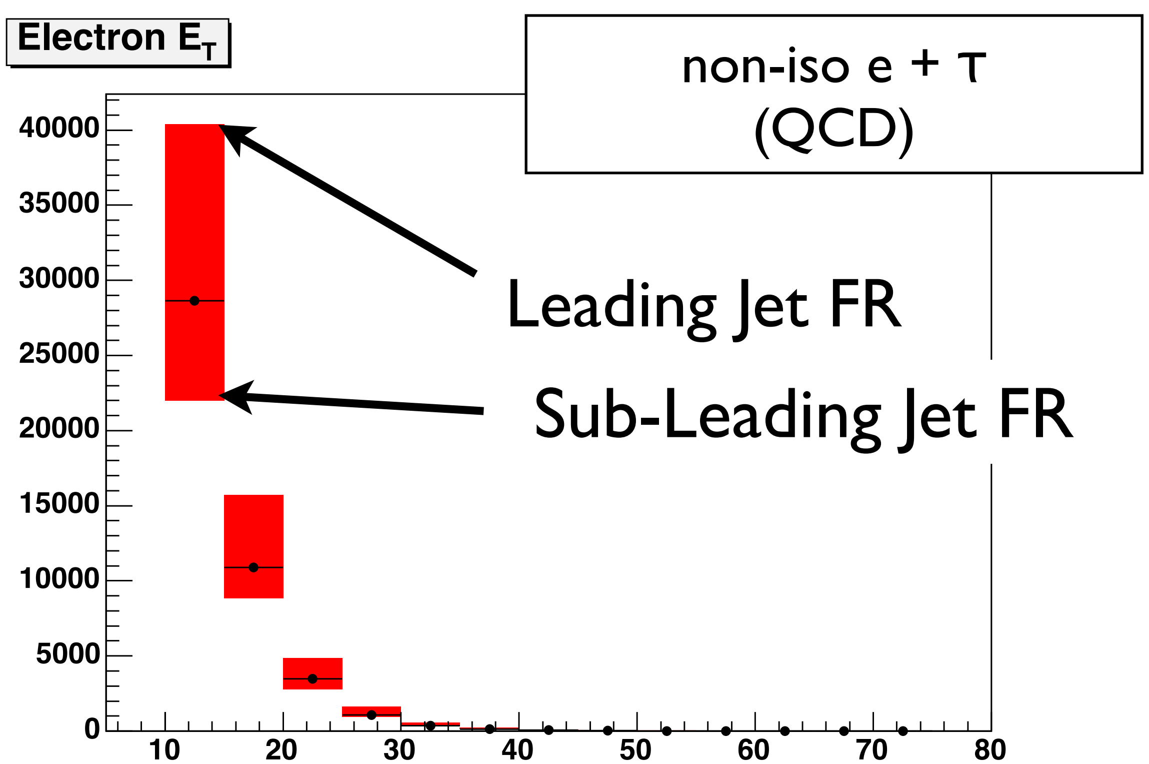
Measuring jet → τ Fake Rate

Measure **relative** FR from Jet data Tight/Loose τ's.
Denominator loose τs must be tighter than the trigger.
Trigger is actually quite rich in real τs.

jet → τ Fake Rate Validation

- Apply FR in orthogonal samples

Samples:
Tagged Conversions (γ + Jet)
Non-isolated e, μ (QCD)
W + Jets Enhanced region



Leading Jet and sub-leading jet determine systematic.

25% Systematic dominates result.

Tau Fake Rate Application

- Our signal sample 'contaminated' with many real τs
- Straight up fake rate application overestimates
- Subtraction procedure to correct for this.

Loose τ Weight: $w_i^{\overline{ID}} = \frac{f(\Omega_i)\epsilon(\Omega_i)}{\epsilon(\Omega_i) - f(\Omega_i)}$ Positive Fake Rate

Tight τ Weight: $w_i^{ID} = \frac{f(\Omega_i)(\epsilon(\Omega_i) - 1)}{\epsilon(\Omega_i) - f(\Omega_i)}$ Negative Correction

$\epsilon(\Omega_i)$ τ Finding Efficiency (From MC)

$f(\Omega_i)$ τ Measured Fake Rate

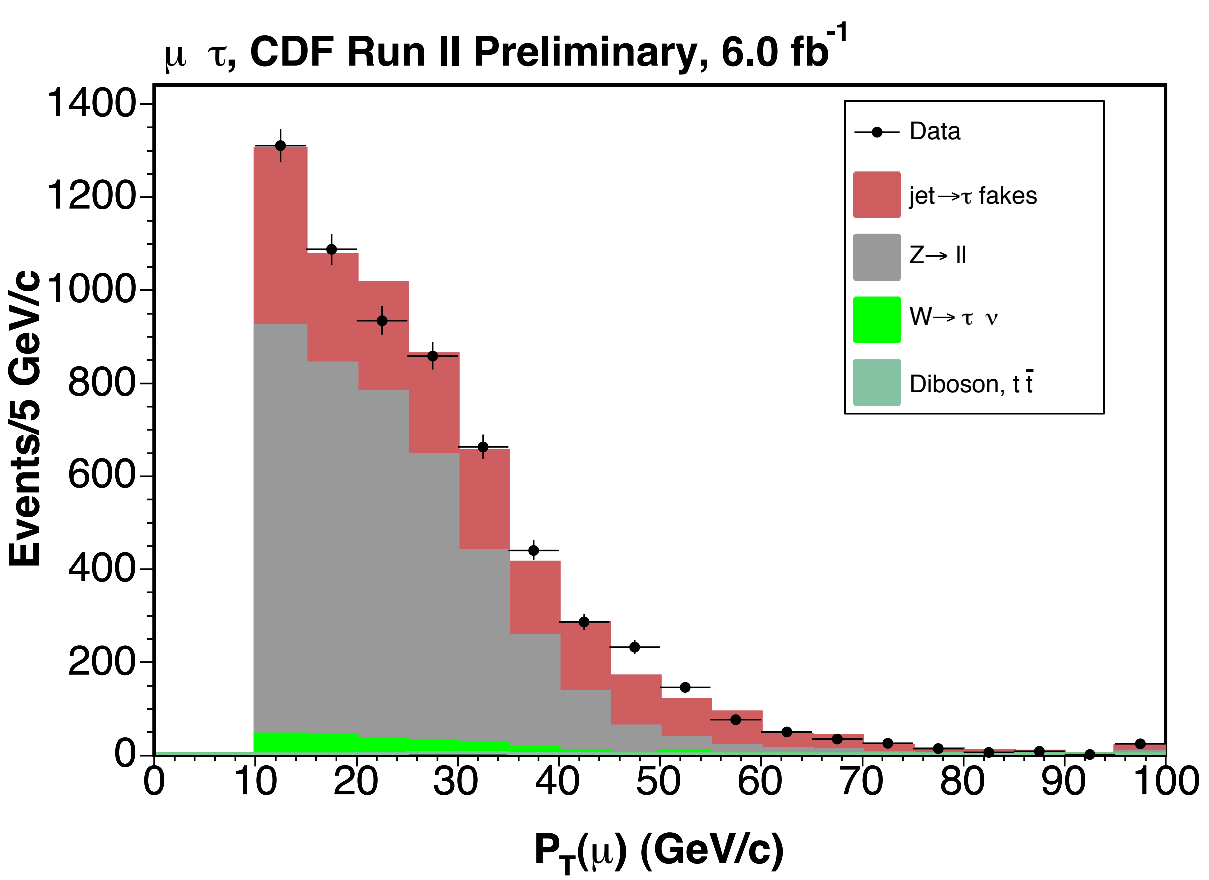
Additional corrections for γ+Jet process gluon composition

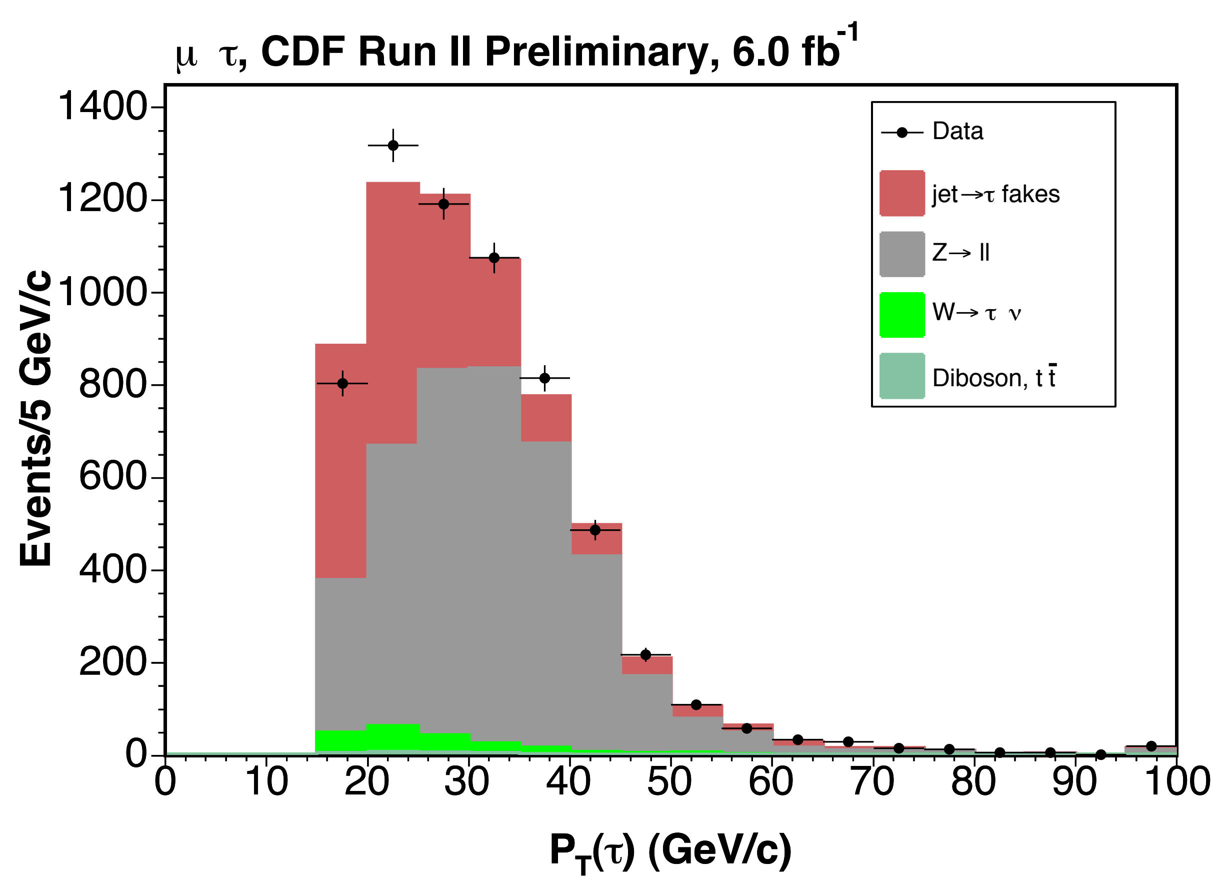
OS Control Region Plots - μ Channel

- Using OS control region as main validation.
- Basic Ht > 45 GeV cut for QCD Reduction

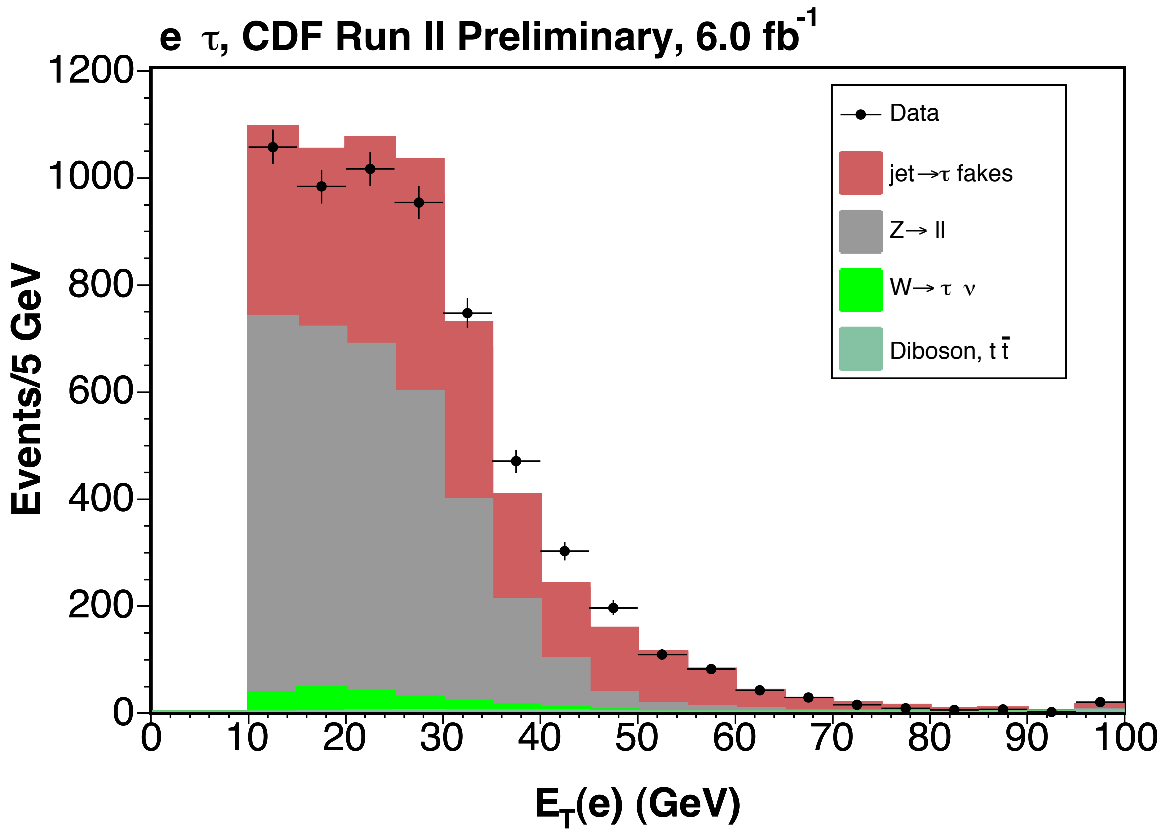
$$H_T = |P_T^l| + |P_T^\tau| + \not{E}_T$$

CDF Run II Preliminary 6.0 fb^{-1} OS $\mu - \tau$	
Process	Events ± stat ± syst
Z→ $\tau\tau$	$3708.8 \pm 41.1 \pm 296.7$
Jet→ τ	$1956.2 \pm 16.5 \pm 489.8$
Z→ $\mu\mu$	$262.0 \pm 20.1 \pm 21.0$
Z→ ee	$0.0 \pm 0.0 \pm 0.0$
W→ $\tau\nu$	$189.5 \pm 8.9 \pm 18.6$
$t\bar{t}$	$18.5 \pm 0.2 \pm 2.6$
Diboson	$31.0 \pm 0.7 \pm 3.0$
Total	$6166.1 \pm 49.4 \pm 573.4$
Data	6210

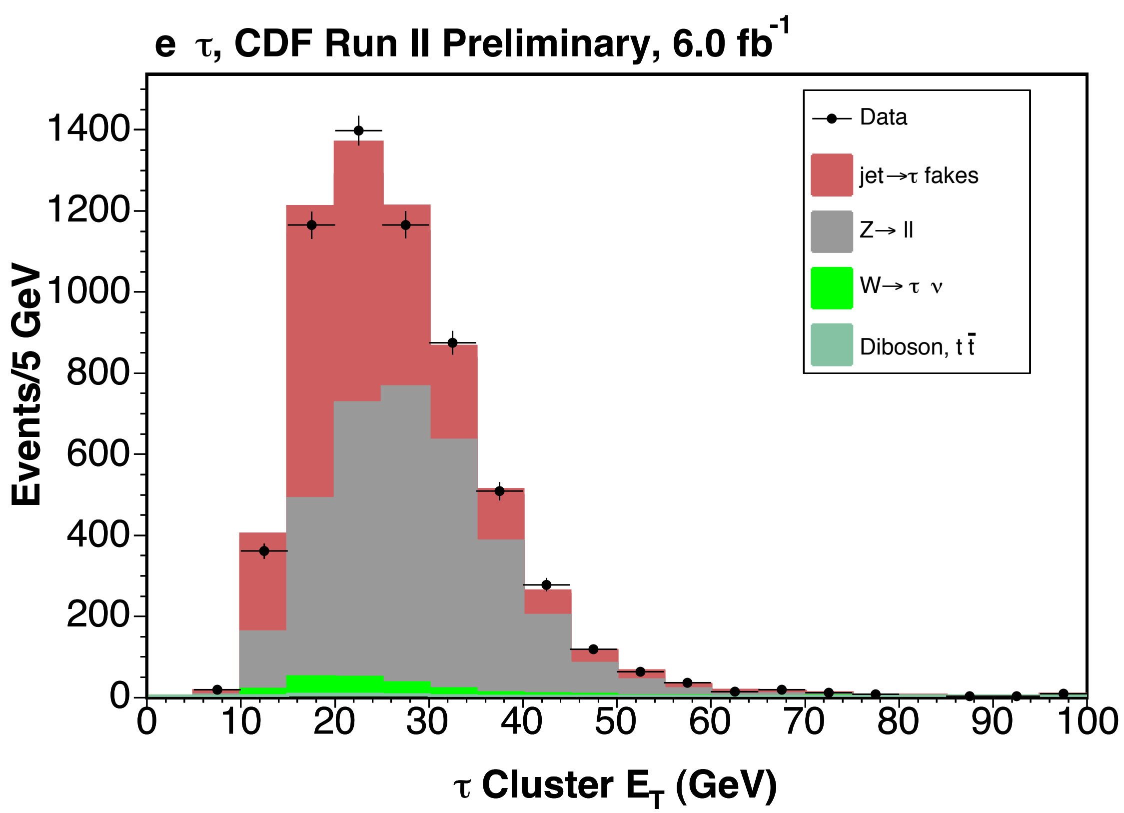




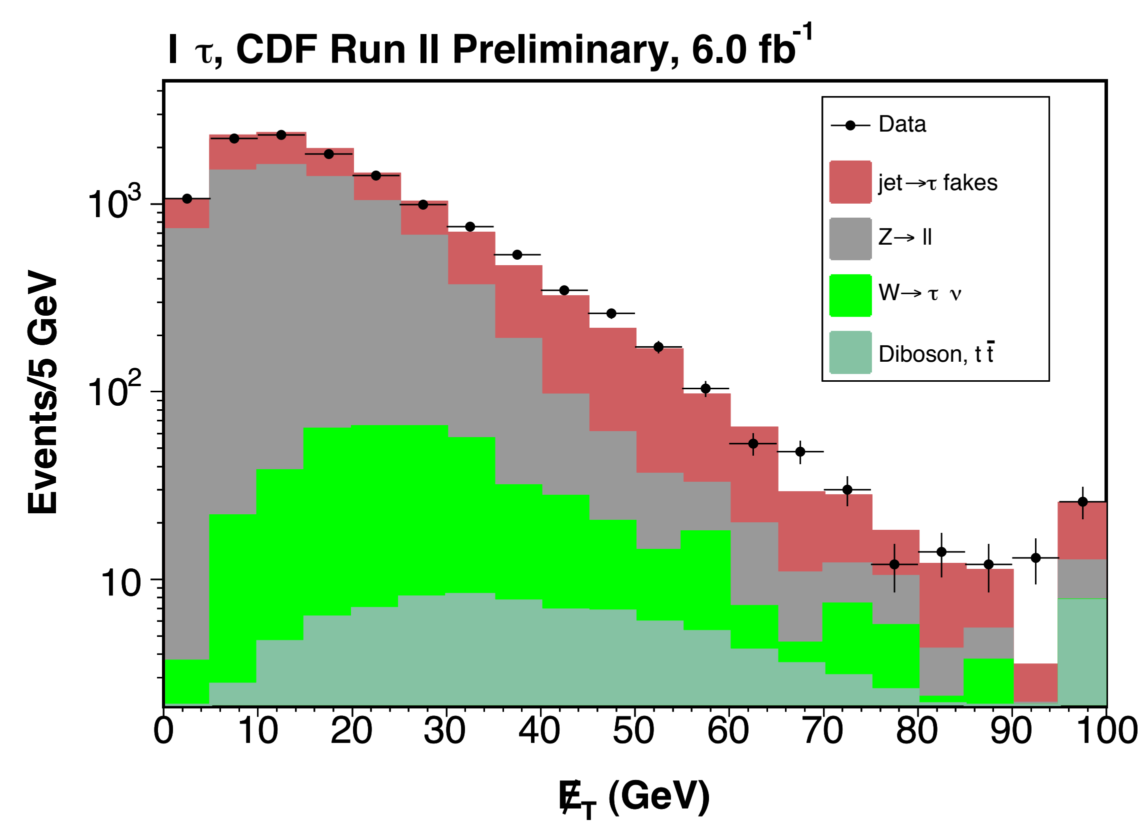
OS Control Region Plots - e Channel



CDF Run II Preliminary 6.0 fb^{-1} OS $e-\tau$	
Process	Events $\pm$ stat $\pm$ syst
Z$\to\tau\tau$	$3258.5 \pm 38.5 \pm 260.7$
Jet$\to\tau$	$2570.2 \pm 21.1 \pm 577.6$
Z$\to\mu\mu$	$0.5 \pm 0.9 \pm 0.0$
Z$\to ee$	$82.5 \pm 8.6 \pm 6.6$
W$\to\tau\nu$	$182.0 \pm 8.7 \pm 17.8$
$t\bar{t}$	$17.8 \pm 0.2 \pm 2.5$
Diboson	$30.3 \pm 0.7 \pm 3.0$
Total	$6141.9 \pm 45.6 \pm 634.0$
Data	6058

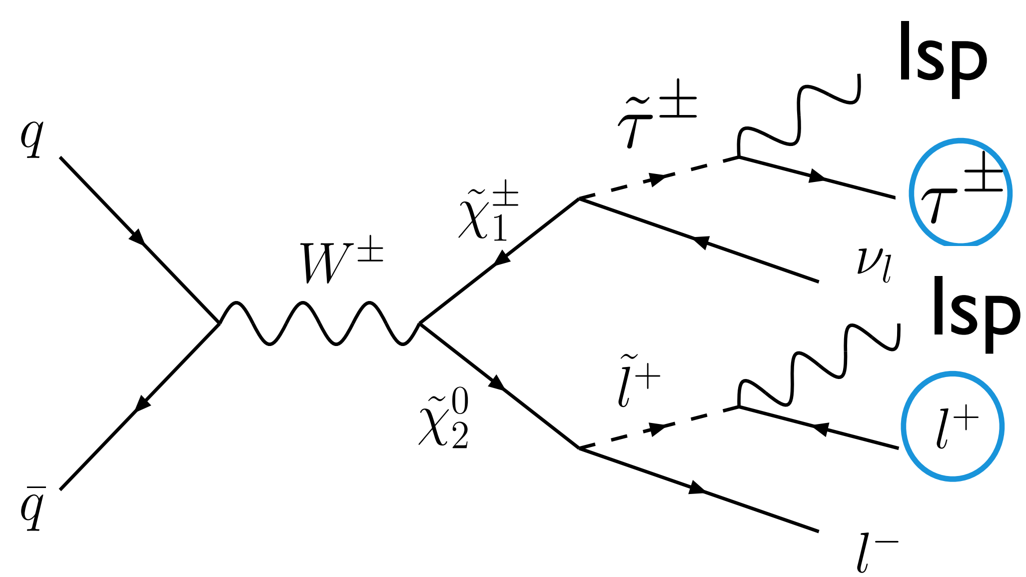


Both Channels:



Simplified Signal Models

- Mass spectrum of Charginos, Neutralinos, sTau, LSP determine kinematics of final state particles.
- Simplified models enable direct manipulation of MSSM masses, independent of mSugra constraints.



- 'Simplified Gravity' and 'Simplified Gauge' Models. Set limits on SUSY σ.

Simplified Gravity Model

- Can vary M(Chargino), M(slepton), M(LSP).
- Also vary slepton coupling to e, μ, τ.

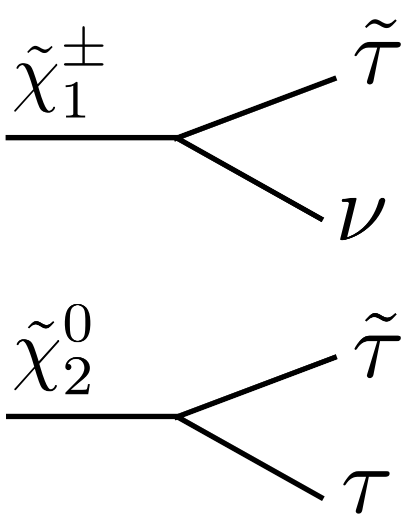
Constraints:
-M(Chargino) = M(Neutralino)
-Masses chosen so as not to decay through W,Z,H
-M(gluino, squark) is high.

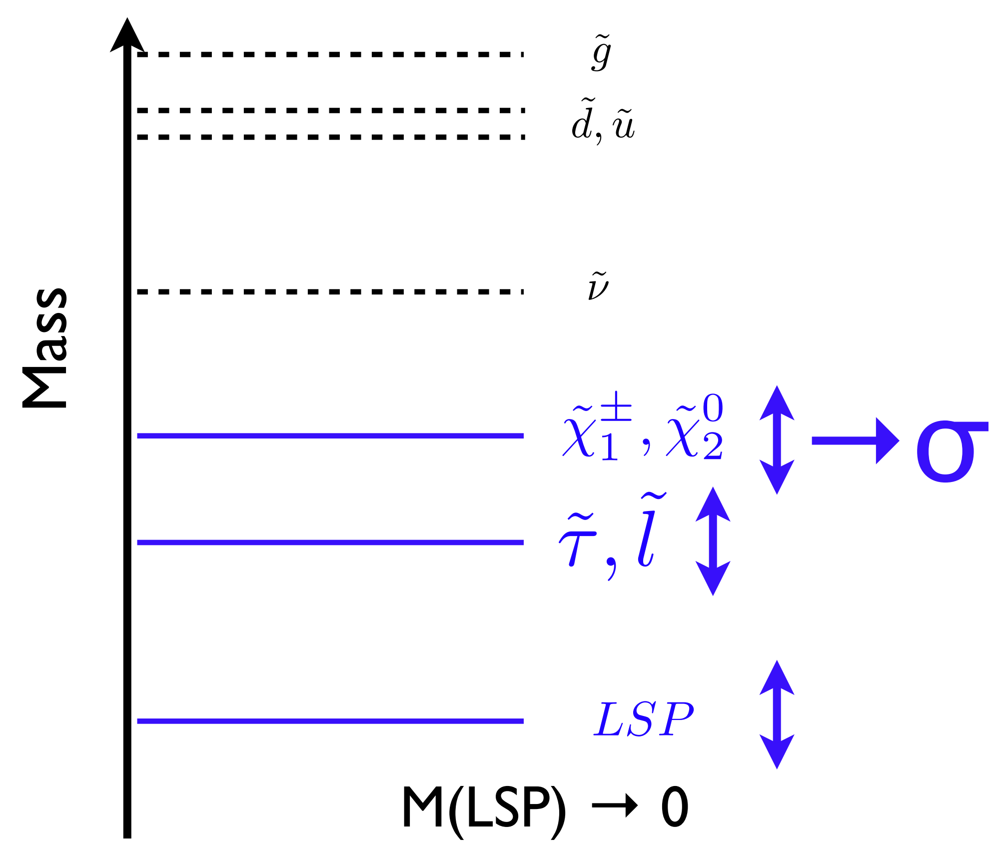
Simplified Gauge Model

- GMSB Generally predicts light (sub-KeV) gravitino (MET).
- NLSP decays to gravitino plus SM partner
- We identify simple parameter space with **slepton** NLSPs

No intermediate decays through W, Z, H

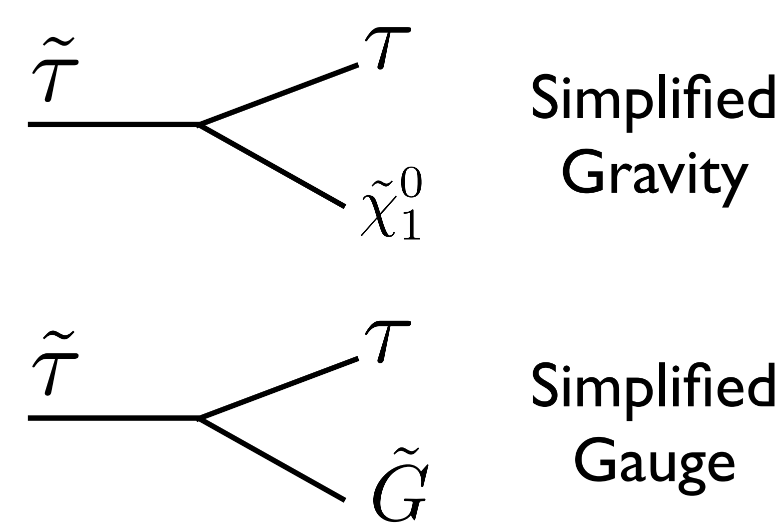
Chargino, Neutralino Decays:



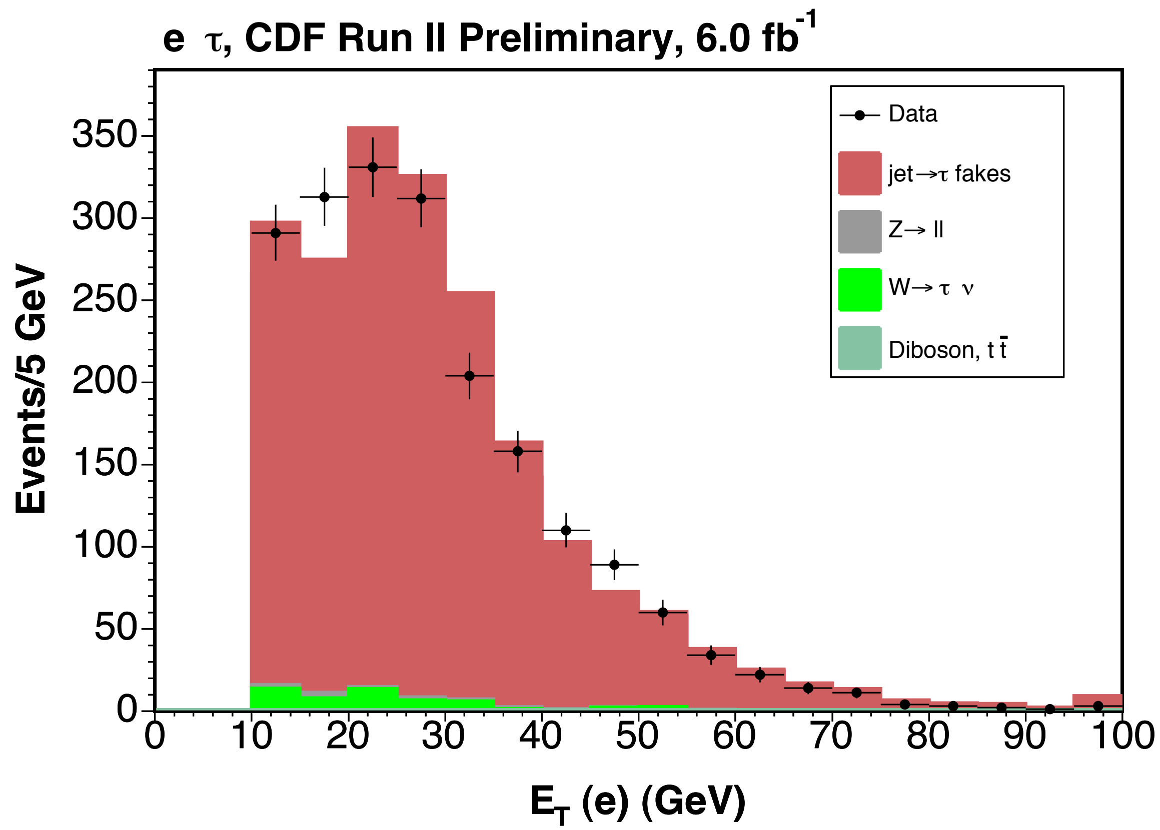


M(LSP) → 0
for Gauge

sTau Decays:



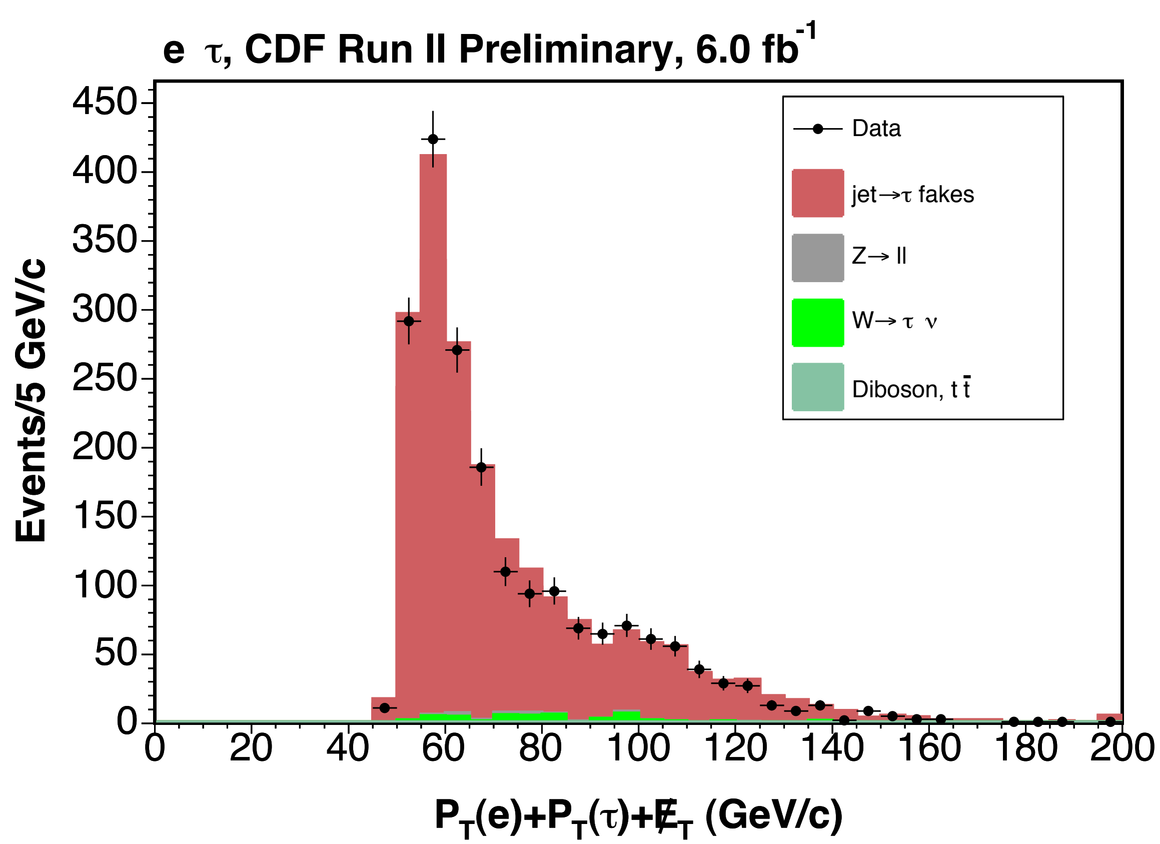
SS Control Region Plots - e Channel

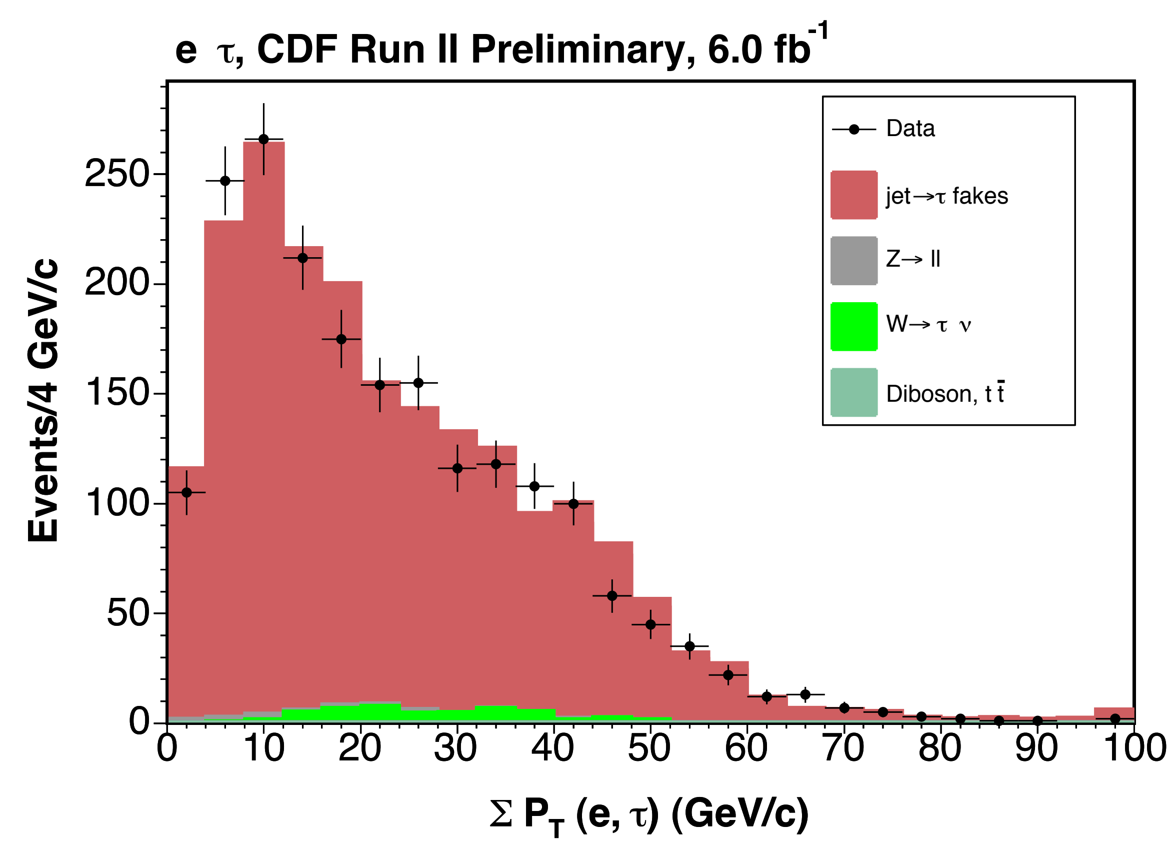


CDF Run II Preliminary 6.0 fb^{-1}
SS $e - \tau$

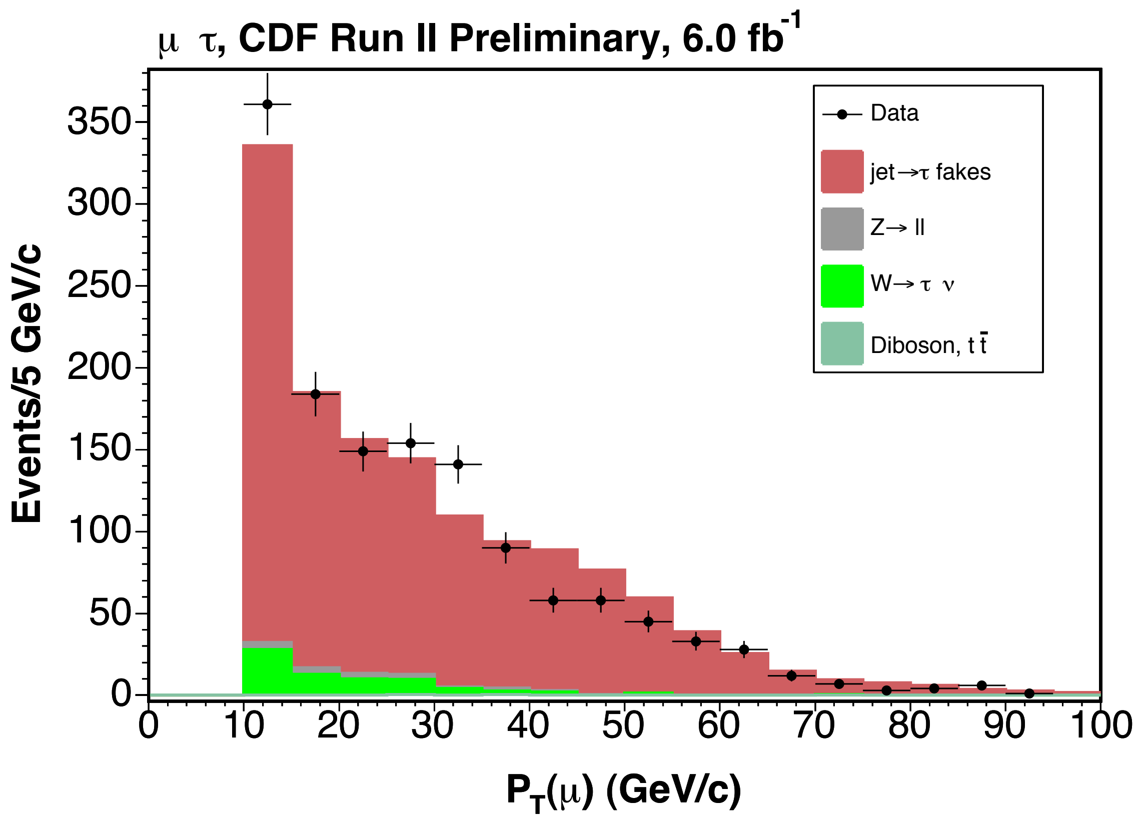
Process	Events ± stat ± syst
$Z \to \tau\tau$	$5.0 \pm 1.5 \pm 0.4$
$Jet \to \tau$	$537.0 \pm 10.4 \pm 129.0$
$Z \to \mu\mu$	$0.0 \pm 0.0 \pm 0.0$
$Z \to ee$	$0.0 \pm 0.0 \pm 0.0$
$W \to \tau\nu$	$43.2 \pm 4.2 \pm 4.2$
$t\bar{t}$	$0.4 \pm 0.0 \pm 0.0$
Diboson	$2.1 \pm 0.2 \pm 0.2$
Total	$587.7 \pm 11.3 \pm 129.1$
Data	518

MET > 20 GeV



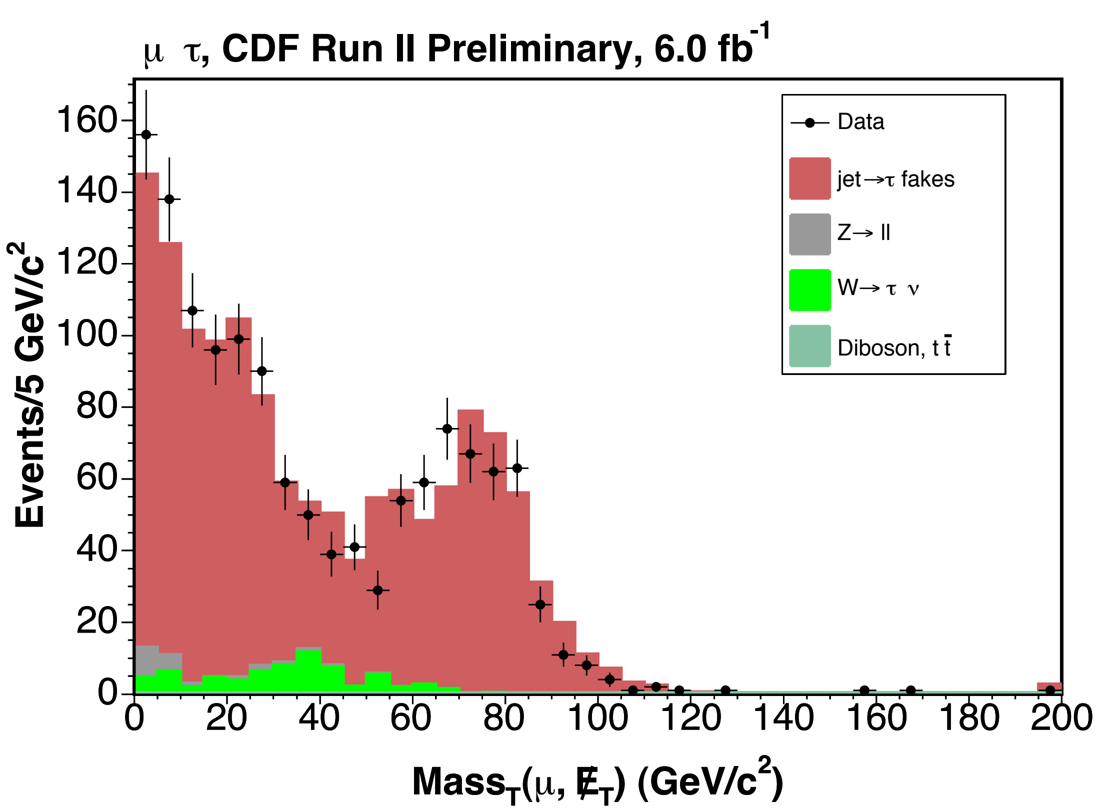


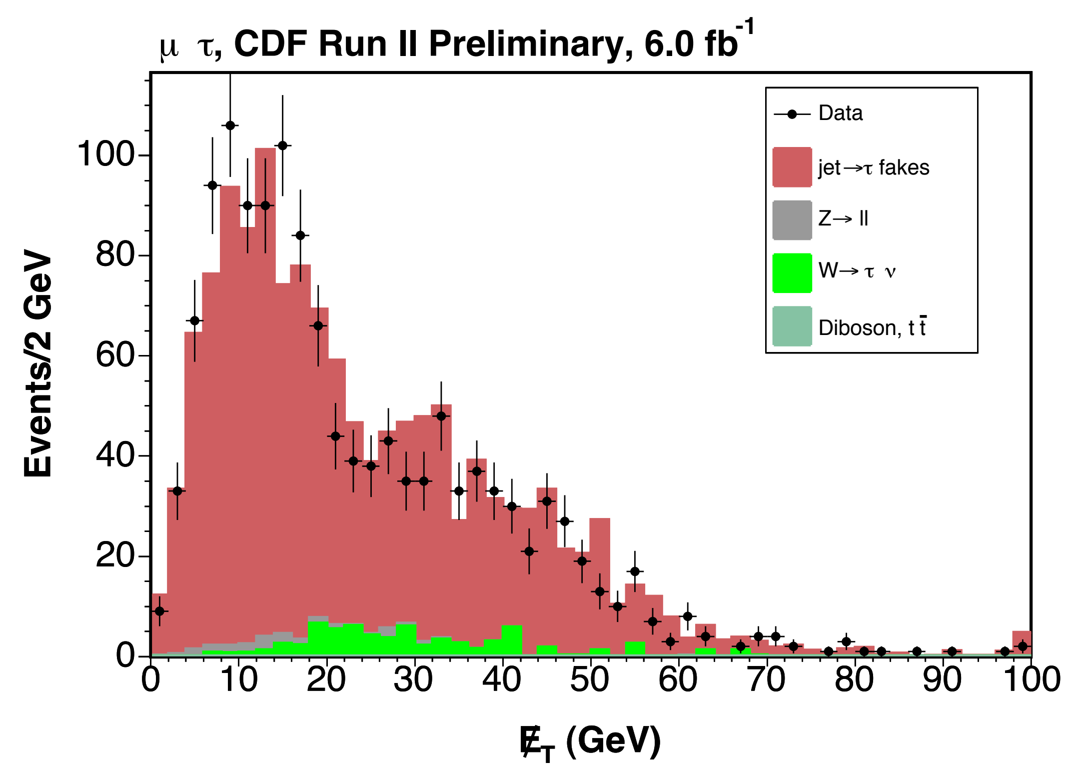
SS Control Region Plots - μ Channel



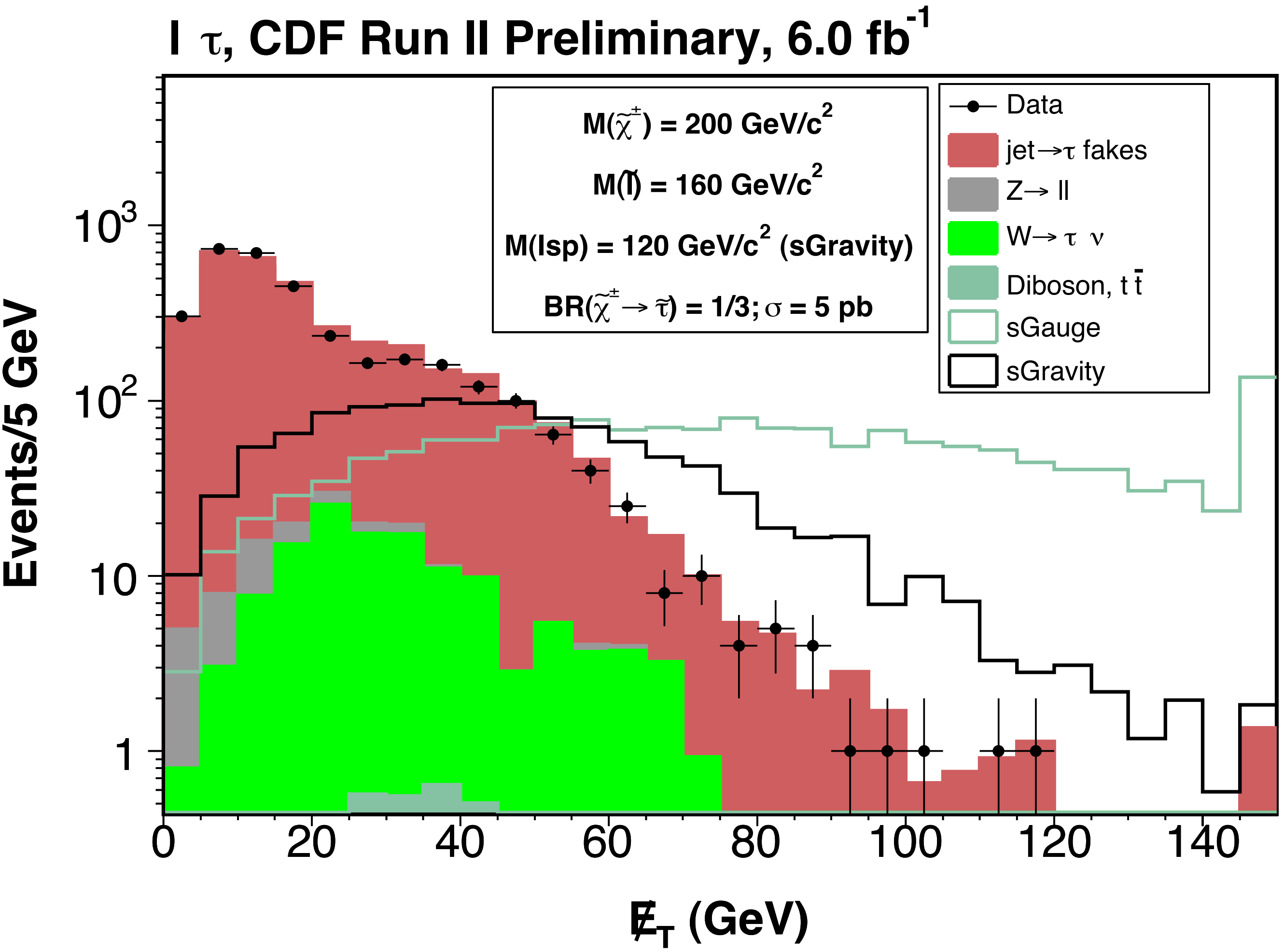
CDF Run II Preliminary 6.0 fb^{-1} SS $\mu - \tau$	
Process	Events $\pm$ stat $\pm$ syst
Z$\rightarrow \tau\tau$	$5.1 \pm 1.5 \pm 0.4$
Jet$\rightarrow \tau$	$615.7 \pm 11.2 \pm 154.2$
Z$\rightarrow \mu\mu$	$0.0 \pm 0.0 \pm 0.0$
Z$\rightarrow ee$	$0.0 \pm 0.0 \pm 0.0$
W$\rightarrow \tau\nu$	$53.7 \pm 4.7 \pm 5.3$
$\text{t}\bar{\text{t}}$	$0.4 \pm 0.0 \pm 0.0$
Diboson	$2.3 \pm 0.2 \pm 0.2$
Total	$677.1 \pm 12.2 \pm 154.3$
Data	598

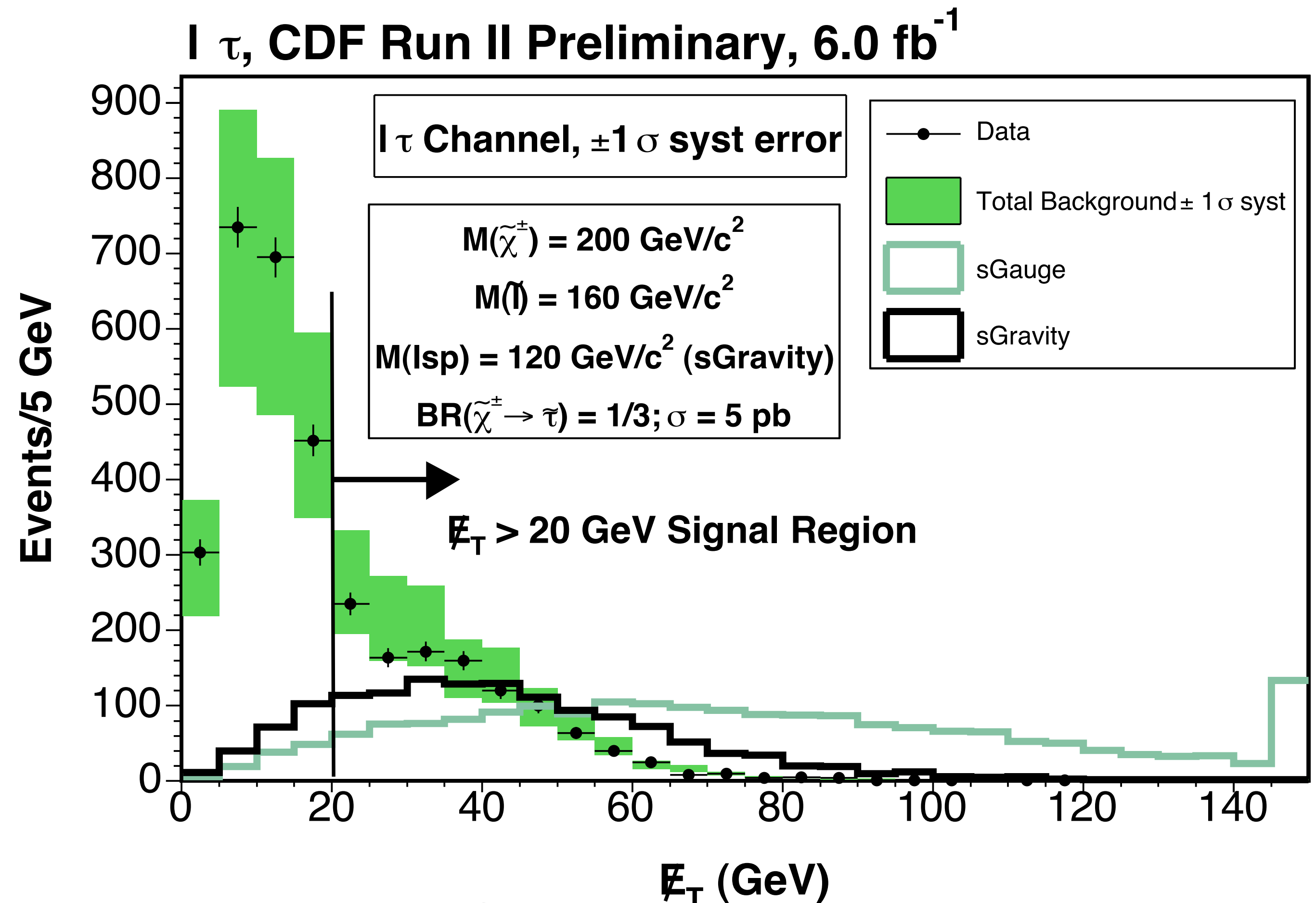
MET > 20 GeV





SS Control Region Plots - MET Both Channels



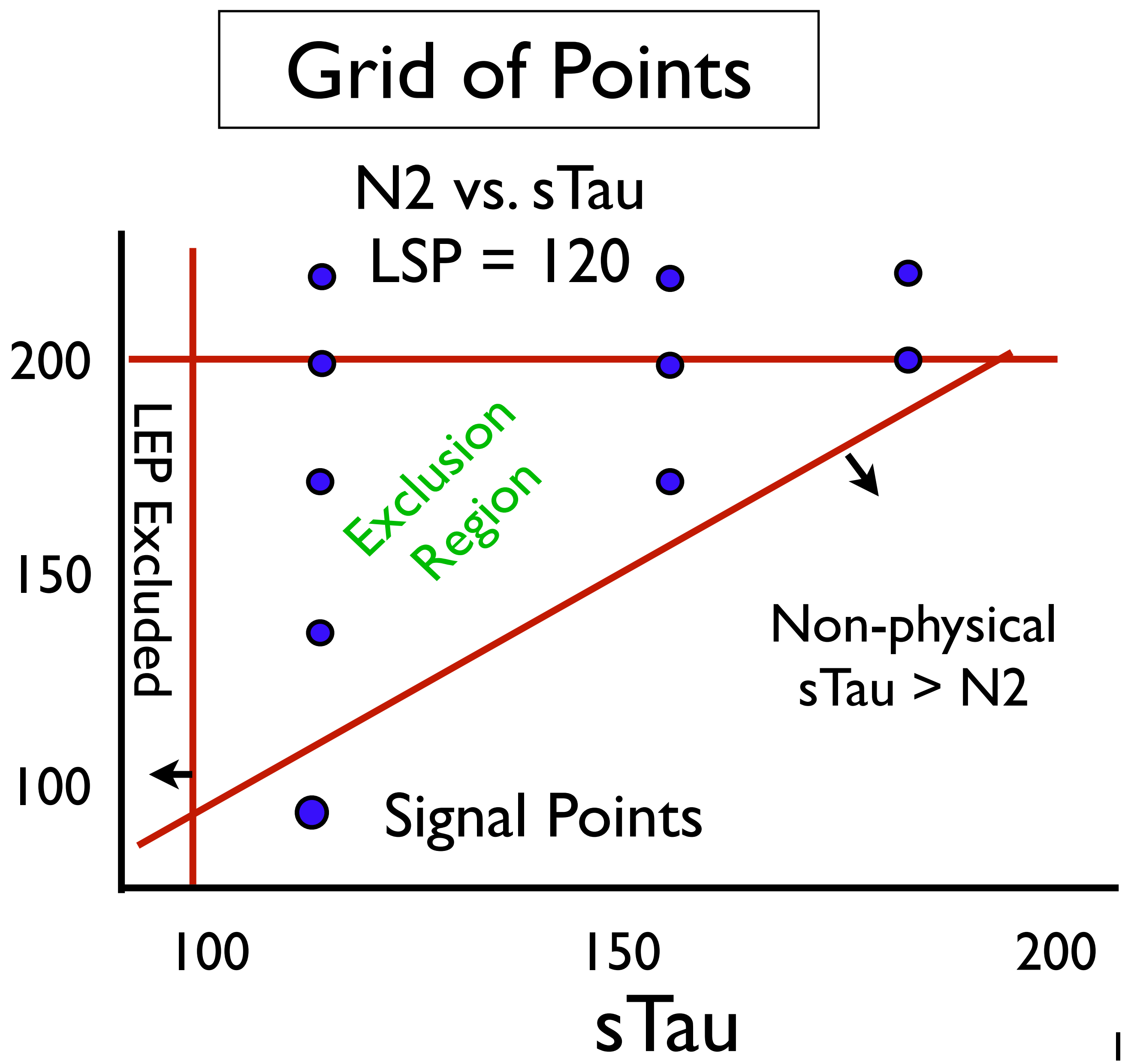


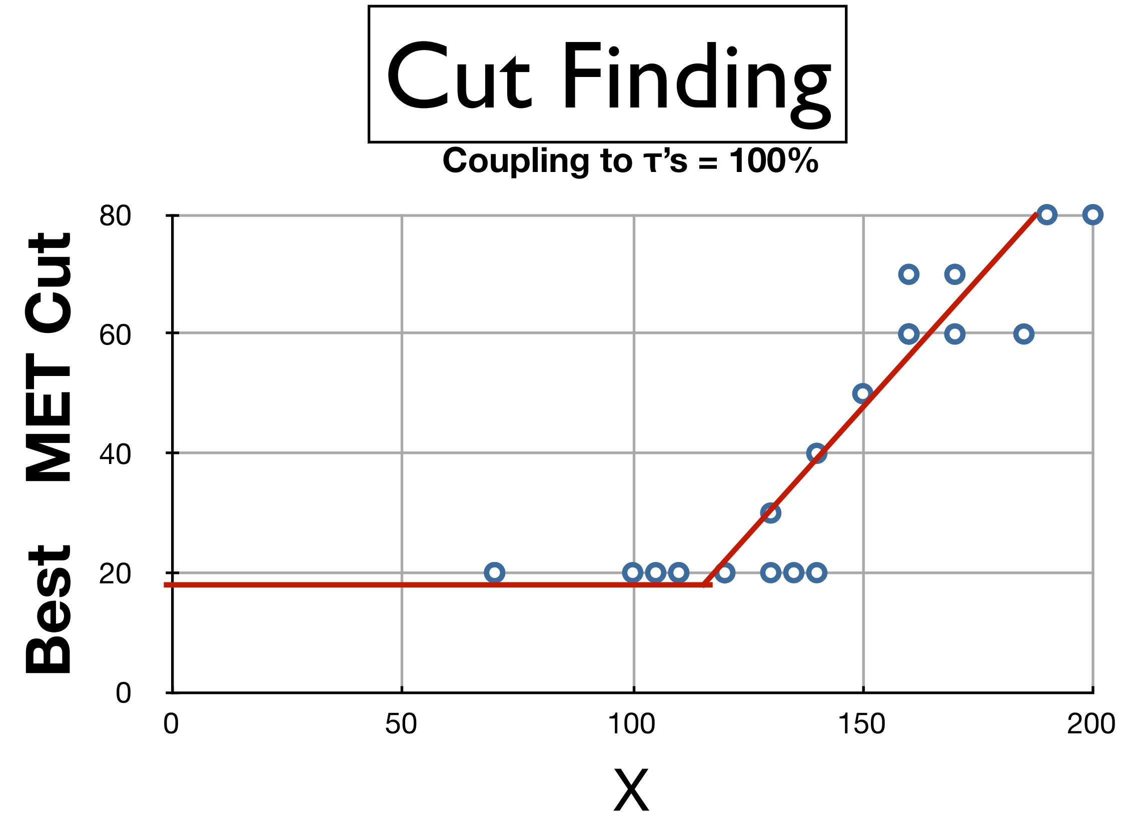
Total Systematic Errors

- Signal shown here for two models.
- MET is our final, tuned event level cut.
- Final exclusions will be SUSY σ limits (arbitrary here)

2-D Exclusion Contours

- Create grid of signal points for many LSP values (GeV): 45, 120, 220 or LSP = 0 (for Simplified Gauge)
- Find best MET cut ($s/\sqrt{b}$) at each point.
- Create simple analytical expression for MET cut value.

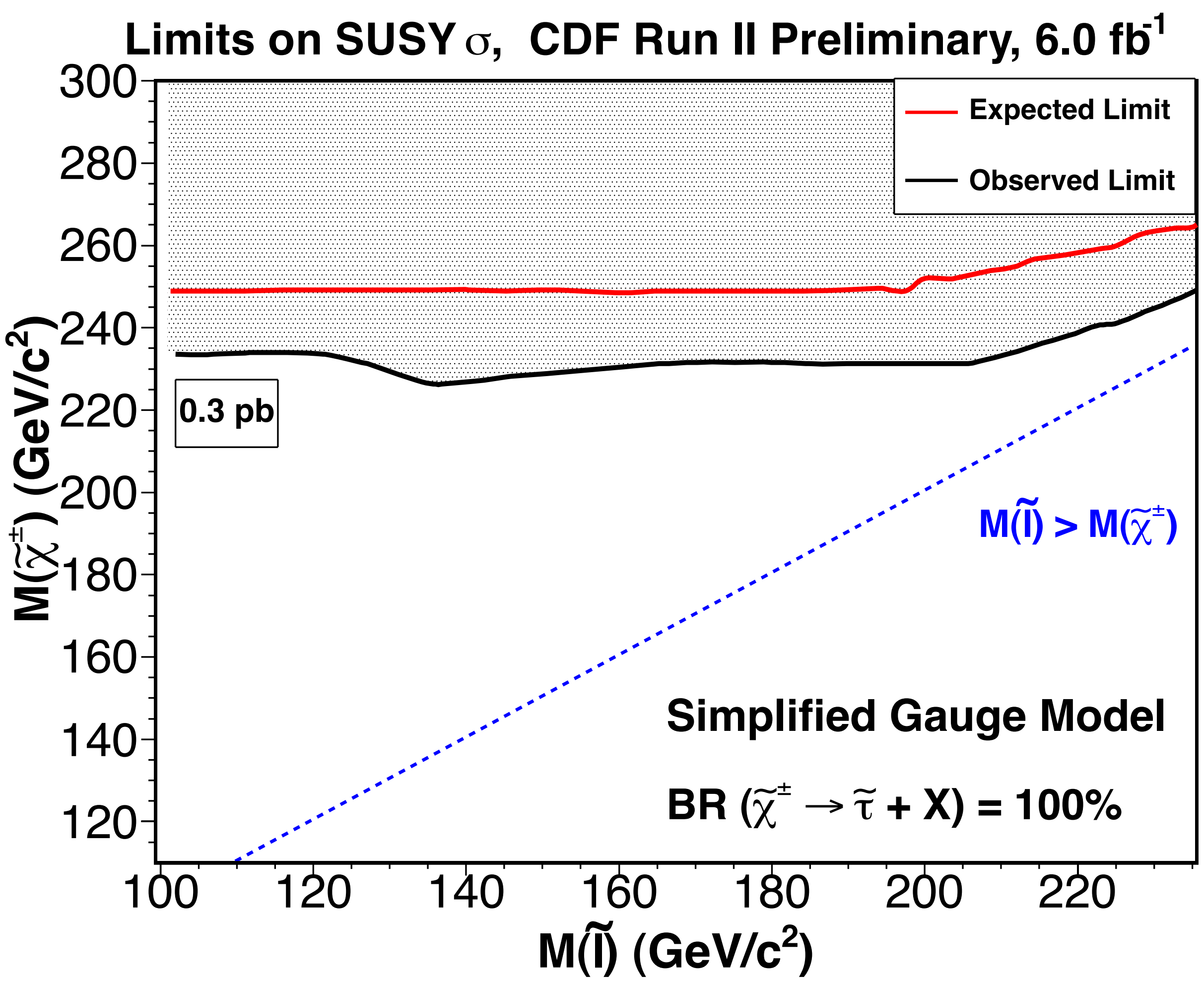


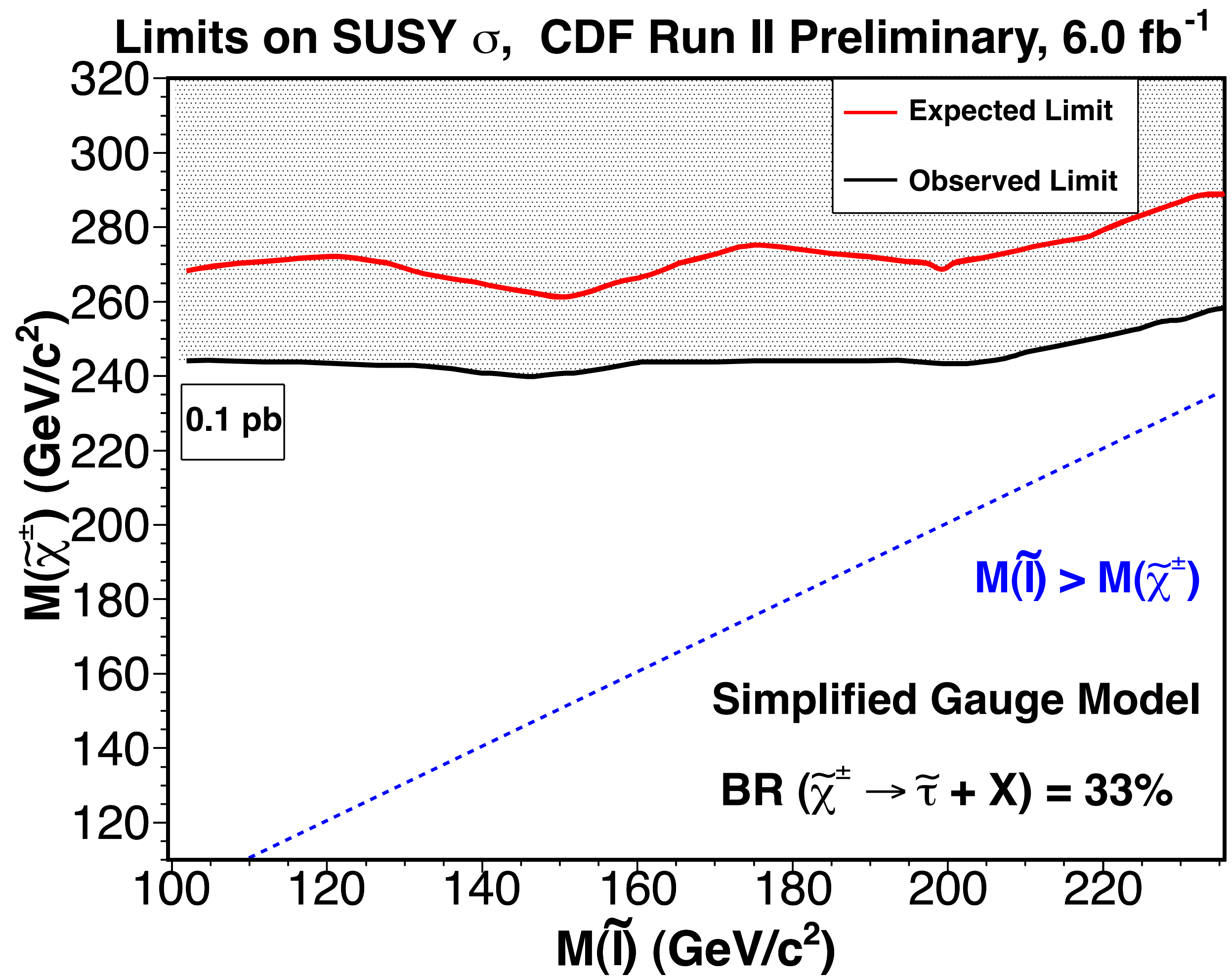


X = Quantity correlated with MET as a function of model parameters

Red Line
MET=Max(20, .85*X -83)

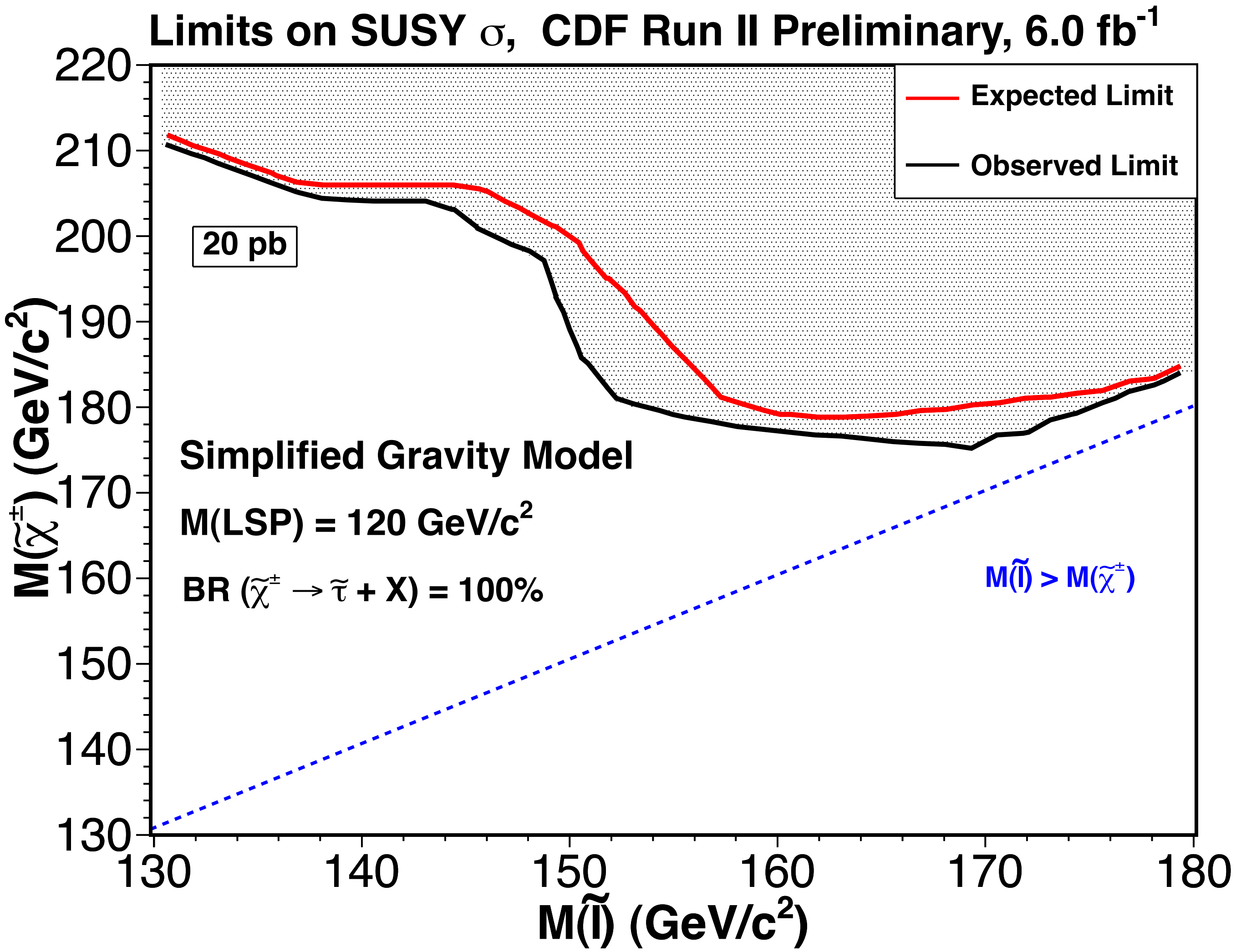
Results
Simplified Gauge Model



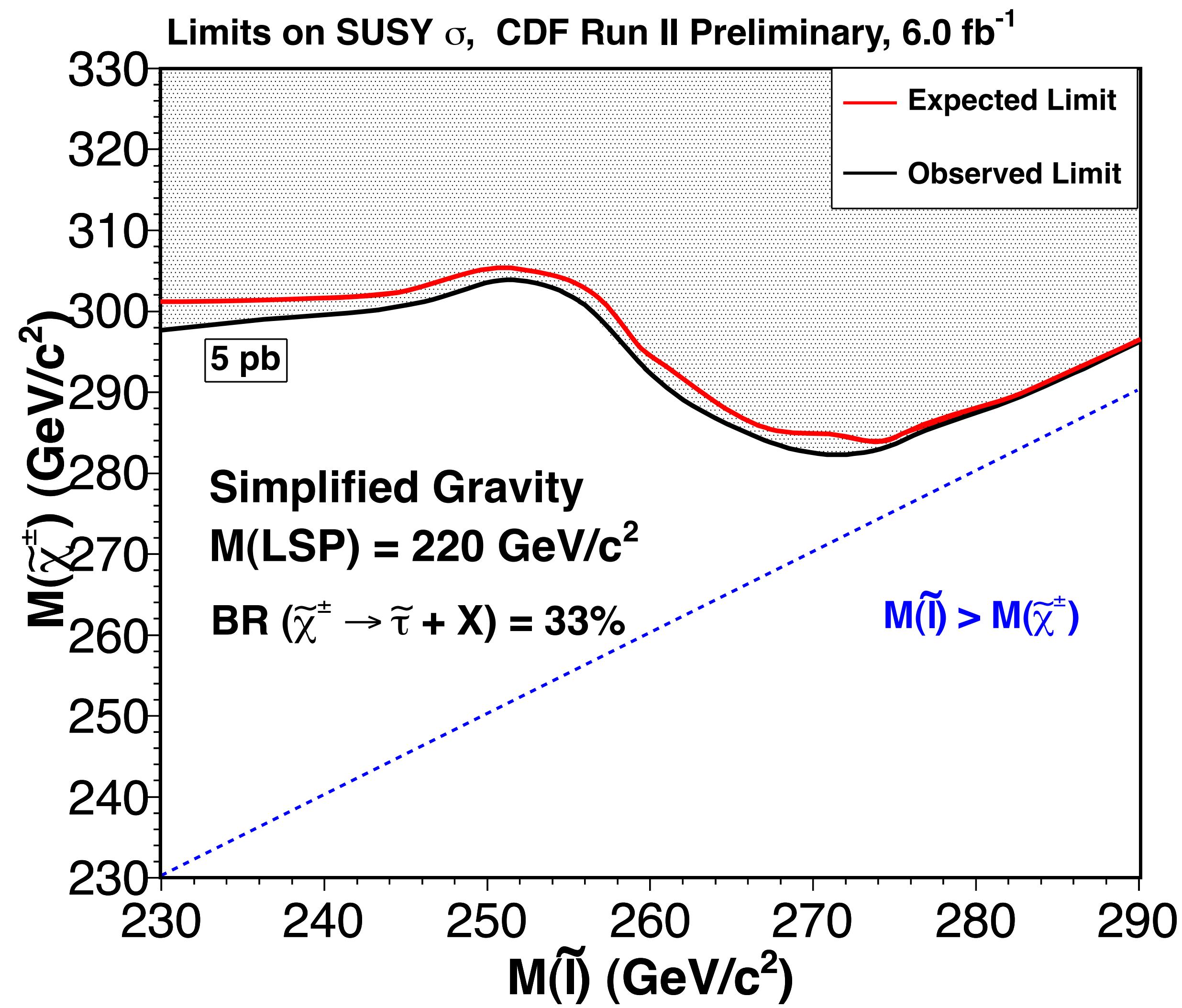


- Plot contours of iso-σ.
- Excluding SUSY process σ, lower value is better.

Results
Simplified Gravity Model



LSP = 120 GeV



LSP = 220 GeV

- Simplified Gravity models suffer from massive LSP

Conclusions

- Including a hadronic τ while being as inclusive as possible, should have unique sensitivity to unexplored high tan β SUSY space.
- Final selection background almost totally data driven.
- Generic models free us from dependence on specific model constraints, increasing utility to theorists.

Analysis Webpage:

http://www-cdf.fnal.gov/~rforrest/dilepton/