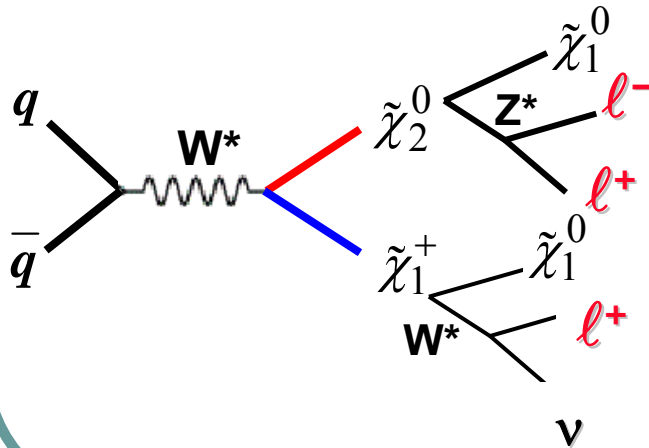




# Search for chargino and neutralino associated production with multileptons



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Representing CDF

Joint meeting of Pacific Regional Particle Physics Communities

October 26- November 3, 2006

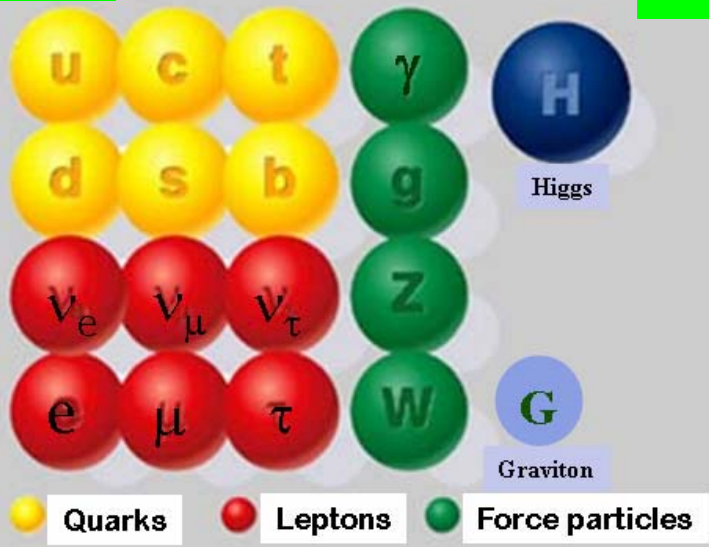
# SUSY



- **New symmetry between bosons and fermions**
  - Unifies gauge couplings
  - Includes quantum gravity
  - Solves “fine-tuning” problem (if  $M_{\text{SUSY}} < 1 \text{ TeV}$ )

$R_p = 1$

Standard particles



$R_p = (-1)^{B+L+2s}$

4 neutralinos

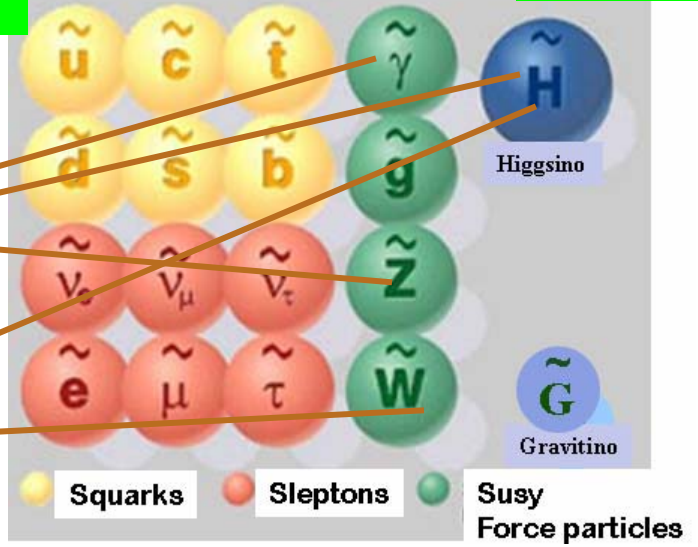
$$\tilde{\chi}_i^0$$

$$\tilde{\chi}_i^\pm$$

2 charginos

SUSY particles

$R_p = -1$

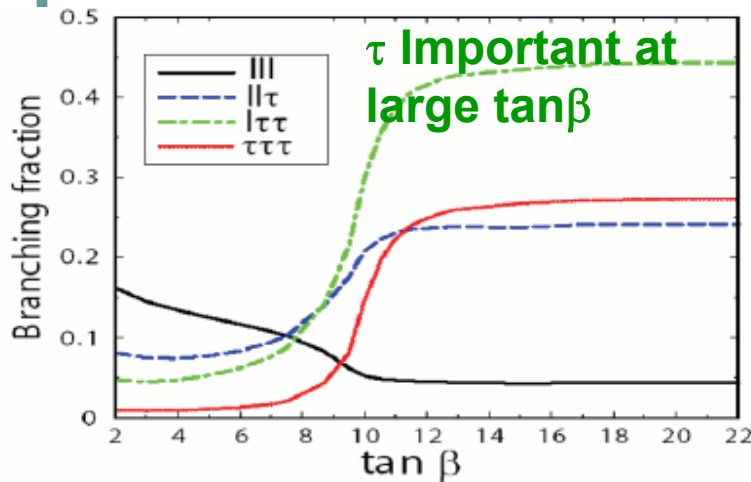
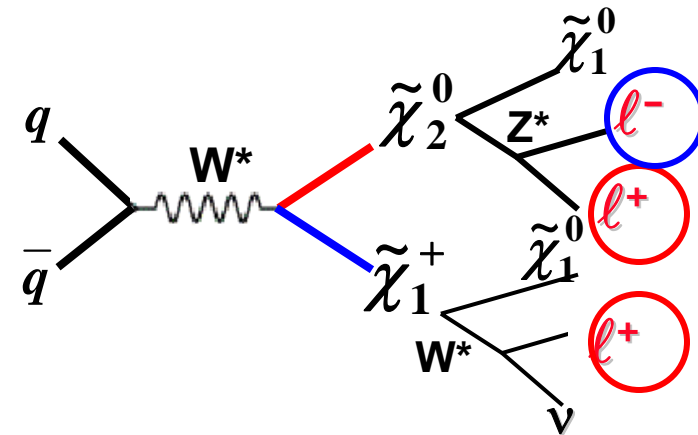


- In many models the lightest SUSY particles are the spartners of the EW bosons:  $\tilde{\chi}_i^0, \tilde{\chi}_i^\pm$
- $\tilde{\chi}_1^0$  is an excellent dark matter candidate

# Chargino and neutralino

## Chargino and neutralino associated production is a golden channel for SUSY:

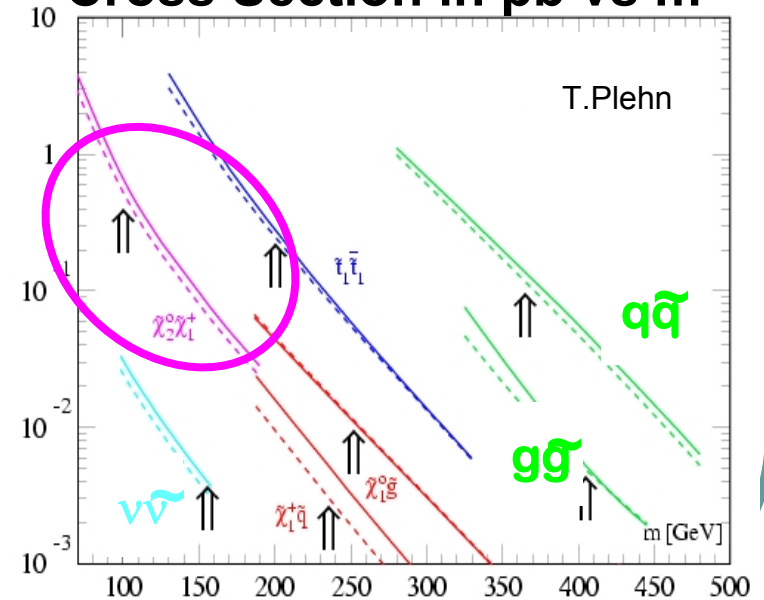
- Final state with leptons and missing  $E_T$
- Easy to trigger
- Final state depends on  $\tan \beta$



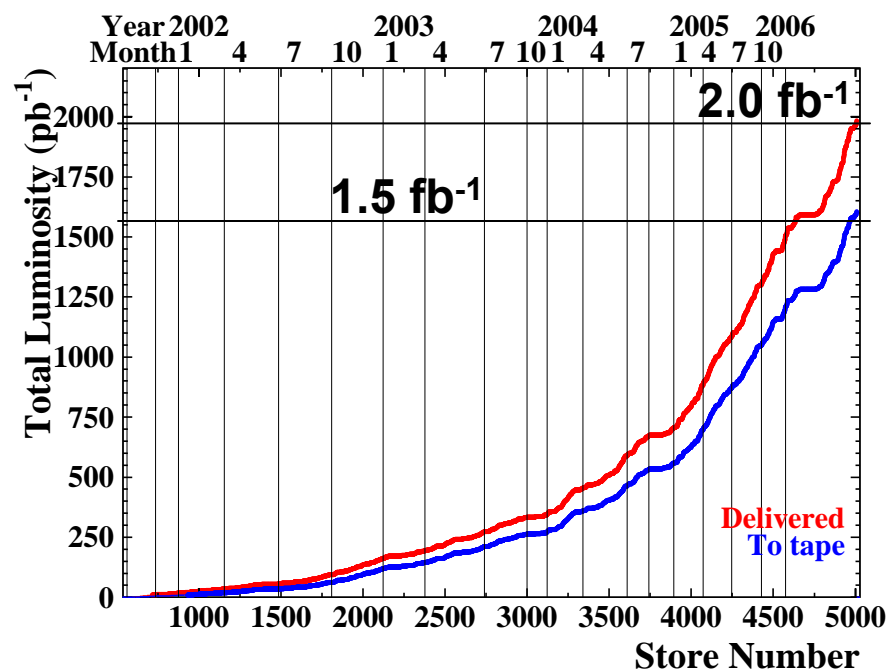
- Low cross section
- Must reduce SM backgrounds

$\tan \beta =$  ratio of the higgs vev's

## Cross Section in pb vs m



# The Tevatron at Fermilab



**Run II: about 2 fb<sup>-1</sup> delivered to the experiments**

**Analysis presented are based on  $\leq 1\text{fb}^{-1}$**

# Overview



## UNBIASED SEARCHES

CHANNEL	L (fb <sup>-1</sup> )	TRIGGER PATH
<b>LS: e<sup>±</sup>e<sup>±</sup>, e<sup>±</sup>μ<sup>±</sup>, μ<sup>±</sup>μ<sup>±</sup></b> <b>P<sub>T</sub>&gt;20, 10 GeV</b>	<b>1</b>	<b>High p<sub>T</sub> Single Lepton</b>
<b>μℓ + e/μ</b> <b>P<sub>T</sub>&gt;20, 5, 5 GeV</b>	<b>0.75</b>	<b>High p<sub>T</sub> Single Lepton</b>
<b>eℓ + e/μ</b> <b>P<sub>T</sub>&gt;20, 8, 5 GeV</b>	<b>1</b>	<b>High p<sub>T</sub> Single Lepton</b>
<b>μμ + e/μ</b> <b>P<sub>T</sub>&gt;5, 5, 5</b>	<b>1</b>	<b>Low p<sub>T</sub> Dilepton</b>
<b>ee + track</b> <b>P<sub>T</sub>&gt;15, 5, 4</b>	<b>1</b>	<b>Low p<sub>T</sub> Dilepton</b>

Like-sign dilepton:  
larger acceptance  
at low chargino  
mass mass

Use e/mu only  
Very small  
backgrounds

Dielectron + track:  
Sensitive to τ as 3<sup>rd</sup>  
lepton ⇒ larger  
acceptance at  
large tanβ

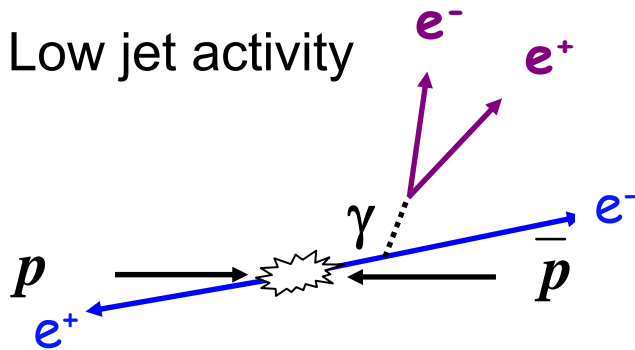
ℓ=e or μ

# Backgrounds



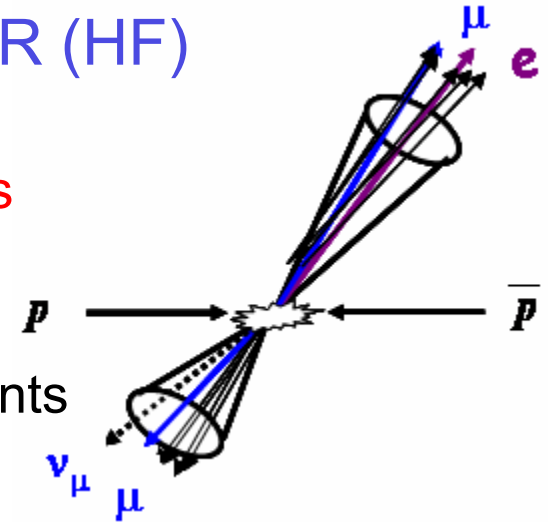
## ■ DRELL YAN (DY)

- Mainly high  $p_T$  leptons
- **Small MET**
- Low jet activity



## ■ HEAVY FLAVOUR (HF)

- **Lower  $P_T$  non isolated leptons**
- MET due to neutrinos or jet mis-measurements



## ■ DIBOSON

- Leptons have high  $p_T$
- Leptons are isolated
- MET due to neutrinos

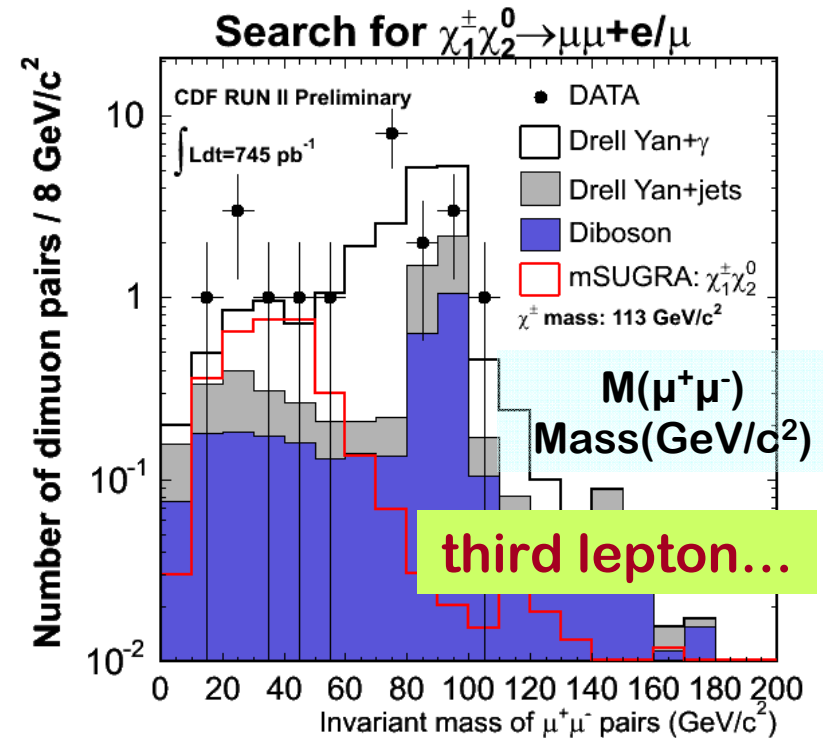
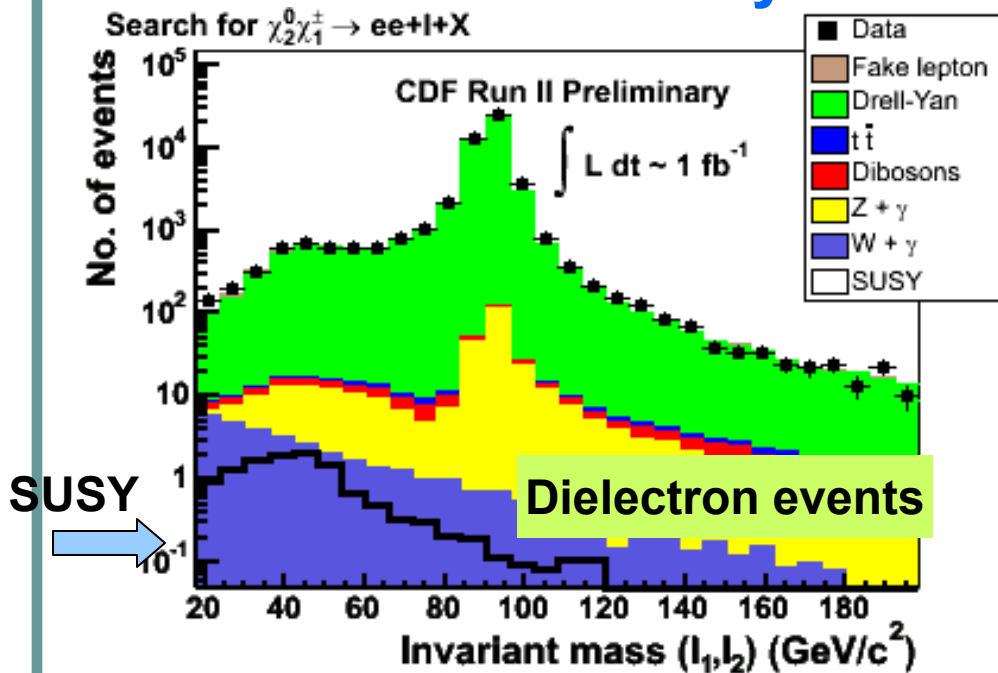
***irreducible background***

- **Lepton  $P_T$  to reject HF**
- **Veto resonances ( $J/\Psi$ ,  $\Upsilon$ ,  $Z$ )**
- **Large MET to reject DY, HF**
- **Low jet activity to reject  $t\bar{t}$ ,  $W$ +jets,  $Z$ +jets**
- **More kinematic selection for low  $P_T$  analysis**

# Background reduction



■ SM background  $Z/\gamma^*$ ,  $W+\gamma$ , diboson,  $Z/\gamma^* \rightarrow \tau\tau$ ,  $t\bar{t}$  overwhelms New Physics

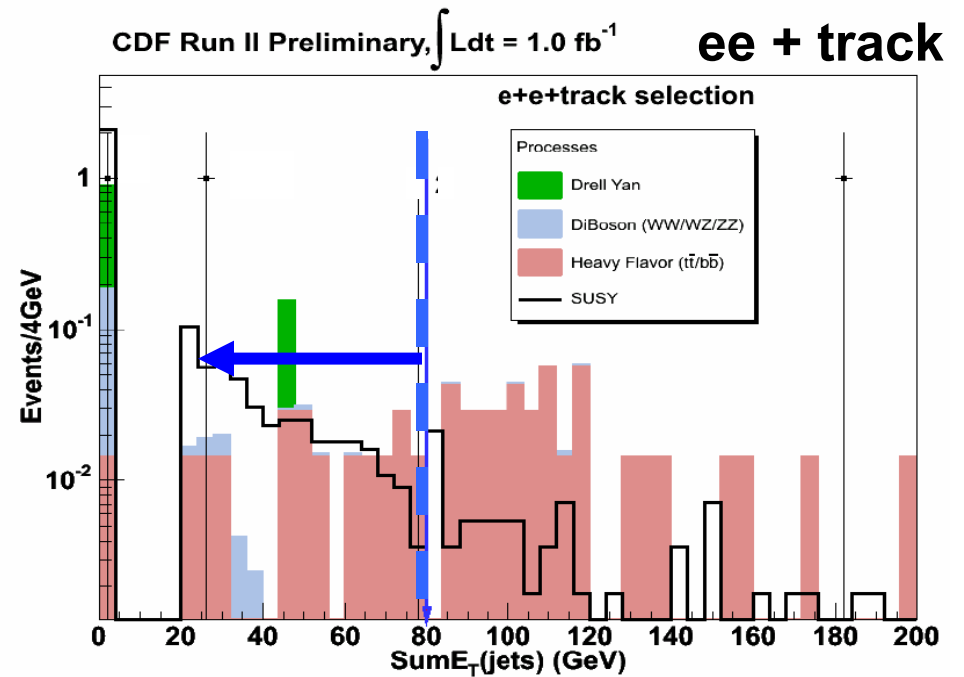
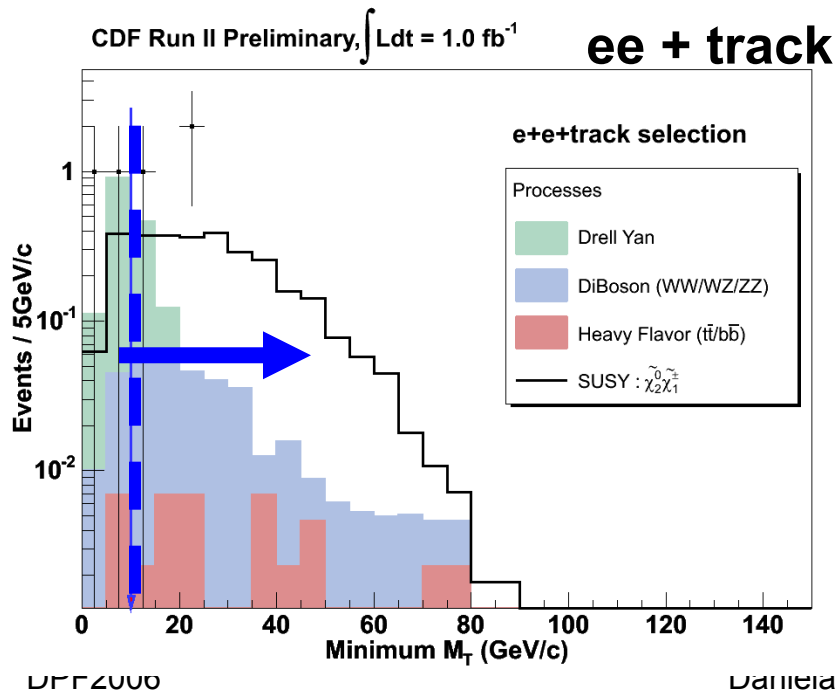
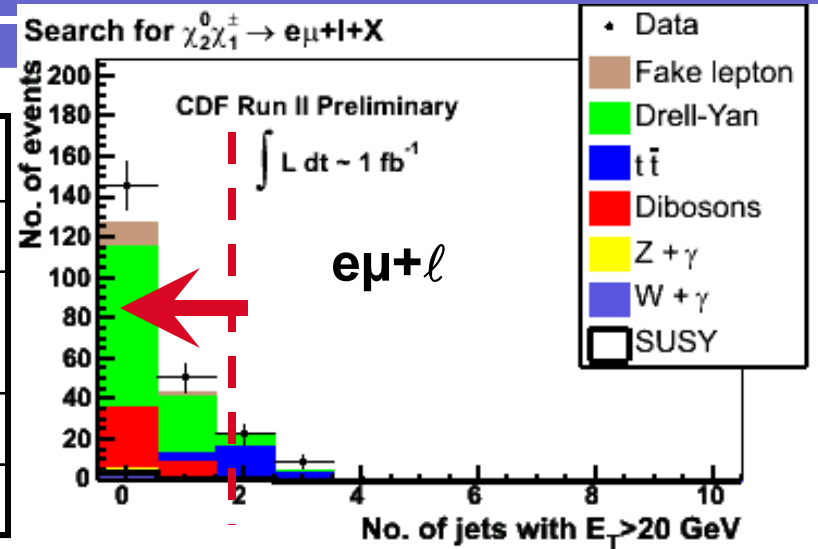


Rejection  
of  $J/\Psi$ ,  
 $\Upsilon$  and  $Z$

- $M_{\ell\ell} < 76 \text{ GeV}$  &  $M_{\ell\ell} > 106 \text{ GeV}$
- $M_{\ell\ell} > 15 \text{ GeV}$  (20 for dielectron + track, 25 for LS)
- $\min M_{\ell\ell} < 60 \text{ GeV}$  (dielectron+track)

# Other selections

Analysis	Kinematic Selections
Trilepton	n. Jets( $E_T > 20$ GeV) < 2
Dielectron + track	$H_T = \sum \text{jet} E_{Tj} < 80$ GeV
Dielectron+ track	$\Delta\phi(\ell\ell) < 2.8$ rad
Dielectron+ track	Min $MT(\ell, MET) > 10$ GEV/c <sup>2</sup>

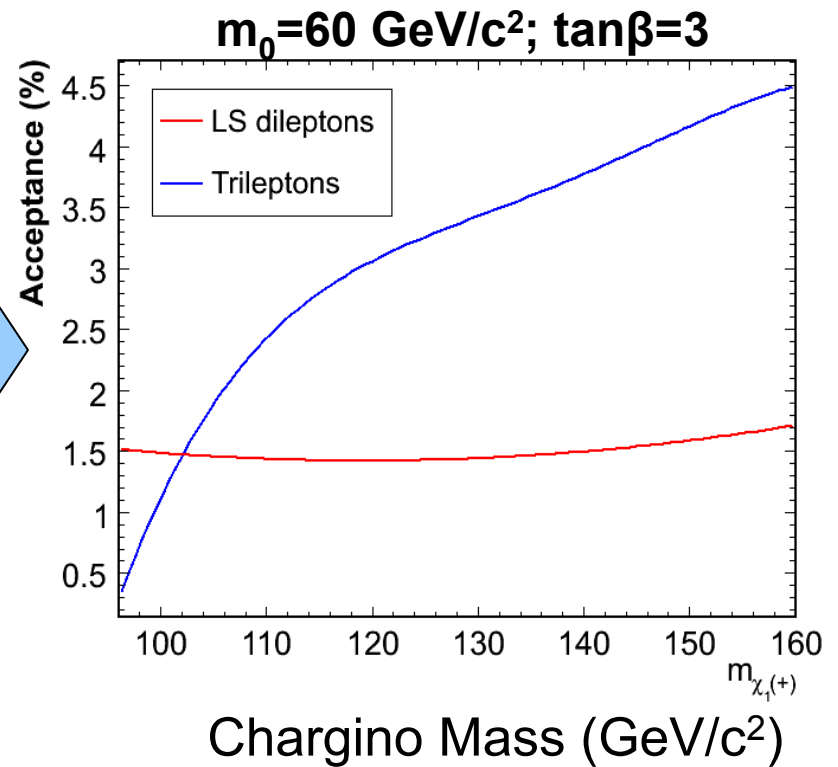
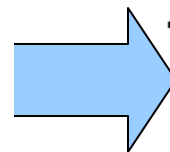
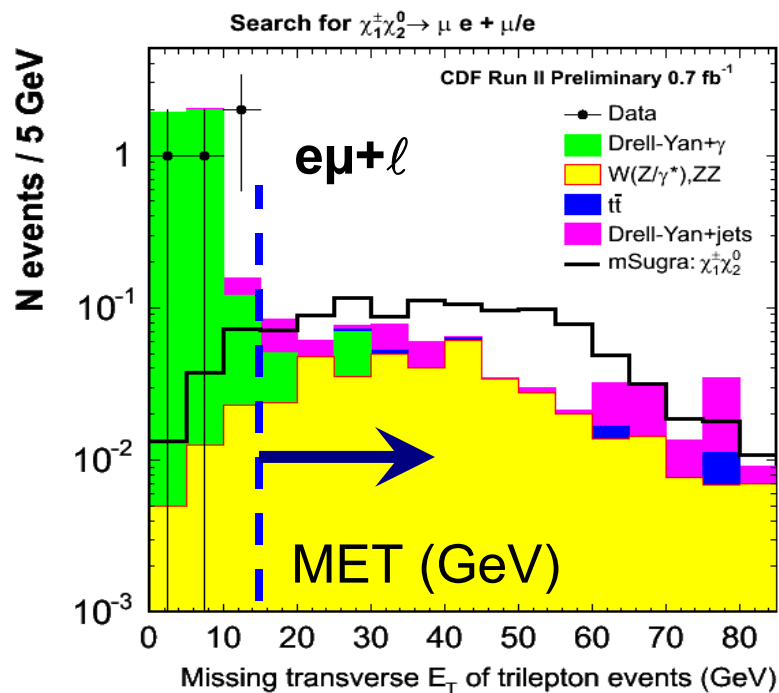




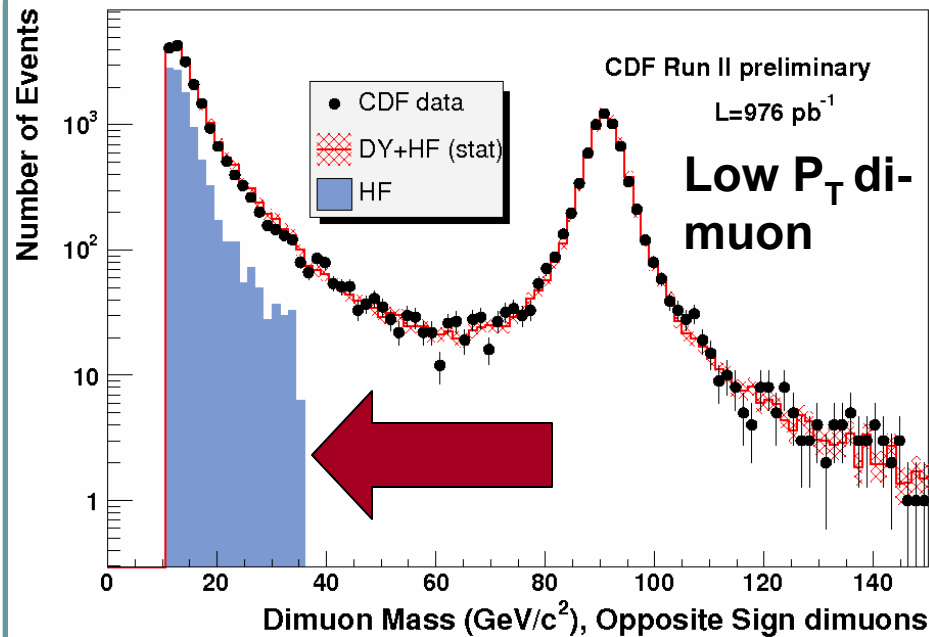
# MET selection



Further reducing DY by asking  $MET > 15 \text{ GeV}$   
 ( $MET > 20 \text{ GeV}$  for di-electron + track)

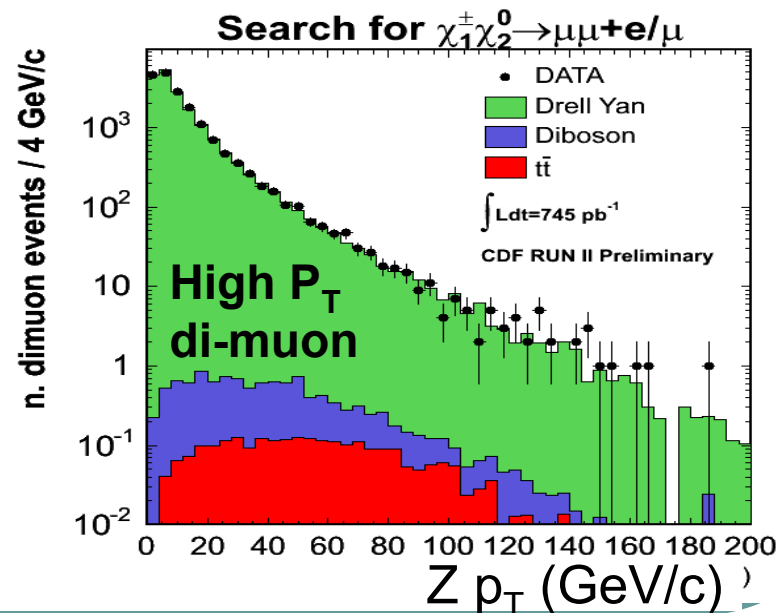


# Understanding the SM

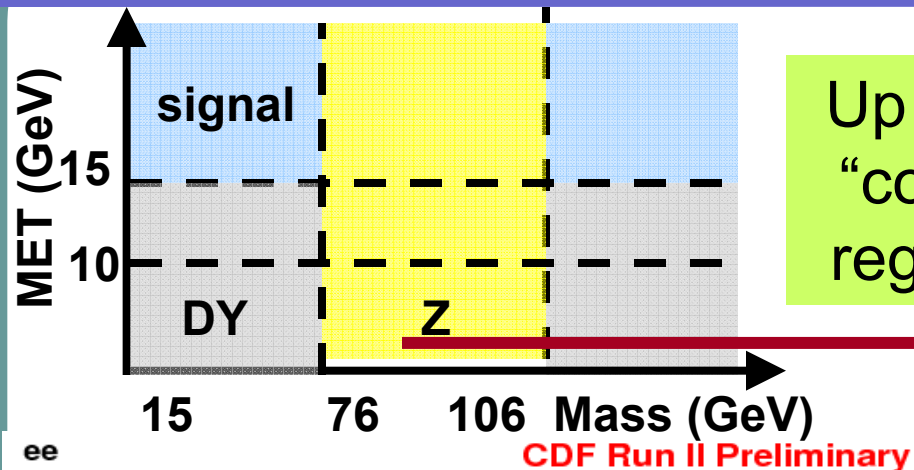


- HF estimated from data using with large impact parameter muons  $|d_0| > 0.2$  cm (no) or  $|d_0| > 0.02$  cm (with silicon hits)

- Major effort to investigate SM in control regions:
  - Dilepton
  - Tri-lepton (low statistic)
  - Combination of data (misidentified leptons, HF) and MC (PYTHIA, etc.)



# Background and systematics



## Systematic errors, example $e\ell\ell$ :

### Backgrounds:

- Jet energy scale 5%
- Fake rate 10%
- MC stat 13%

### Signal

- Conversion scale factor 6%
- Lepton ID 4%
- Theor. cross section 7%

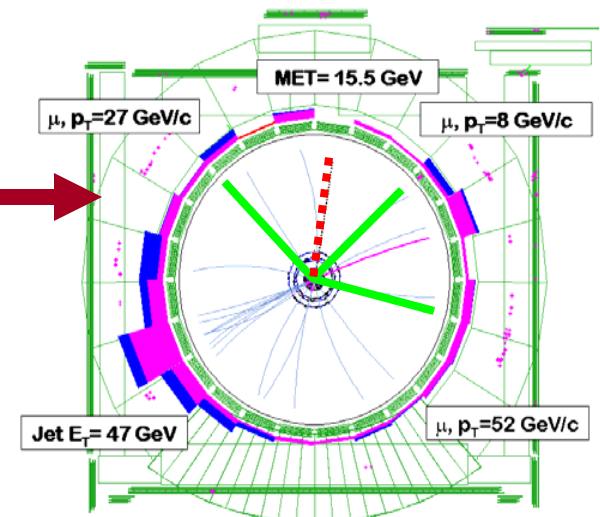
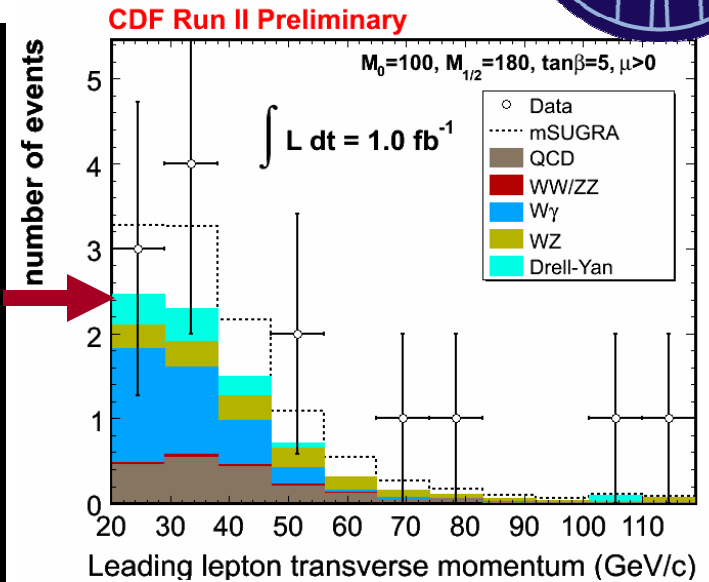
### Luminosity 6%

# Results



Analysis	L (fb <sup>-1</sup> )	Total predicted background	Observed data	L in limit
$e^{\pm}e^{\pm}, e^{\pm}\mu^{\pm}, \mu^{\pm}\mu^{\pm}$	1	$7.5 \pm 0.3$	13	0.71 (9)
$\mu\mu + e/\mu$ (low- $p_T$ )	1	$0.4 \pm 0.1$	1	0.31 (0)
ee+track	1	$0.97 \pm 0.28$	3	0.61 (1)
$e\ell + e/\mu$	1	$0.73 \pm 0.09$	0	0.35 (0)
$\mu\mu + e/\mu$	0.75	$0.64 \pm 0.18$	1	0.75 (1)
$\mu e + e/\mu$	0.75	$0.78 \pm 0.15$	0	0.75 (0)

Combination is not yet available for the entire luminosity



# Limit



- Combine all analyses to obtain a **limit** on the mass of the chargino in a mSugra-like scenario :

- Equal slepton masses
- Observed limit:

$$M(\chi^{\pm}_1) \sim 127 \text{ GeV}/c^2$$

$$\sigma \times \text{BR} \sim 0.25 \text{ pb}$$

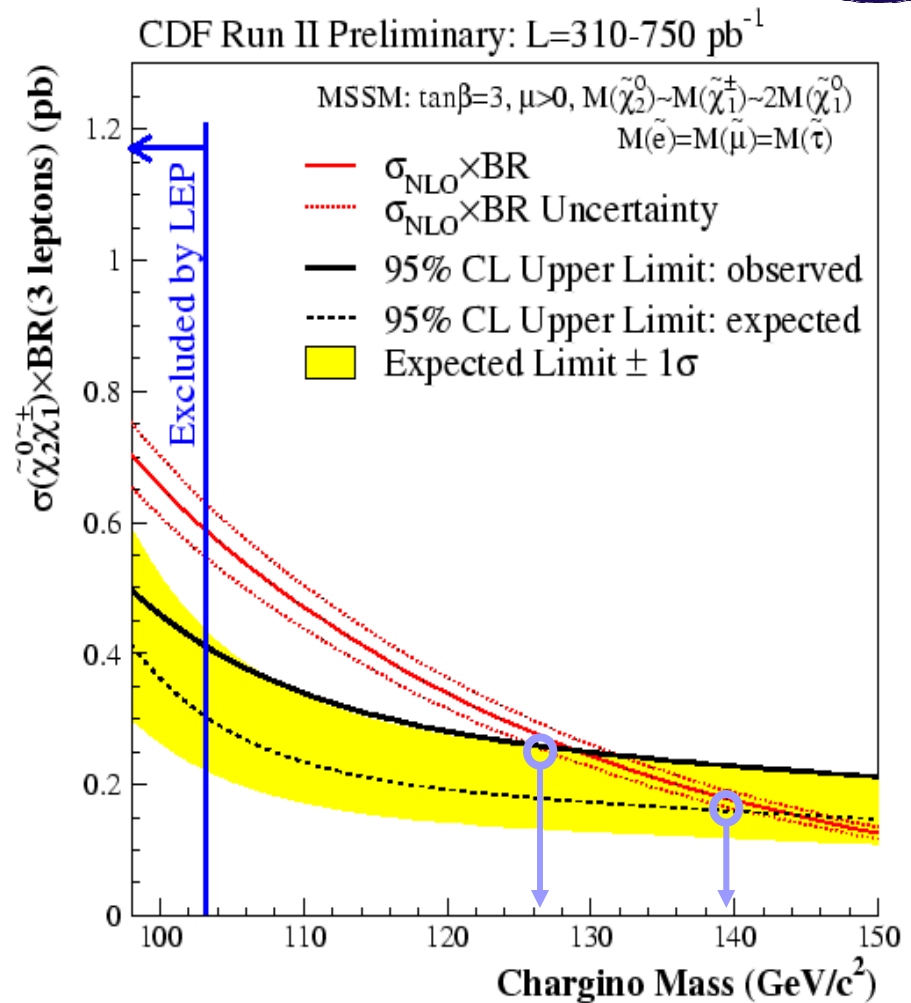
- Sensitive up to masses

$$M(\chi^{\pm}_1) \sim 140 \text{ GeV}/c^2$$

$$\sigma \times \text{BR} \sim 0.2 \text{ pb}$$

D0 limit in similar scenario:

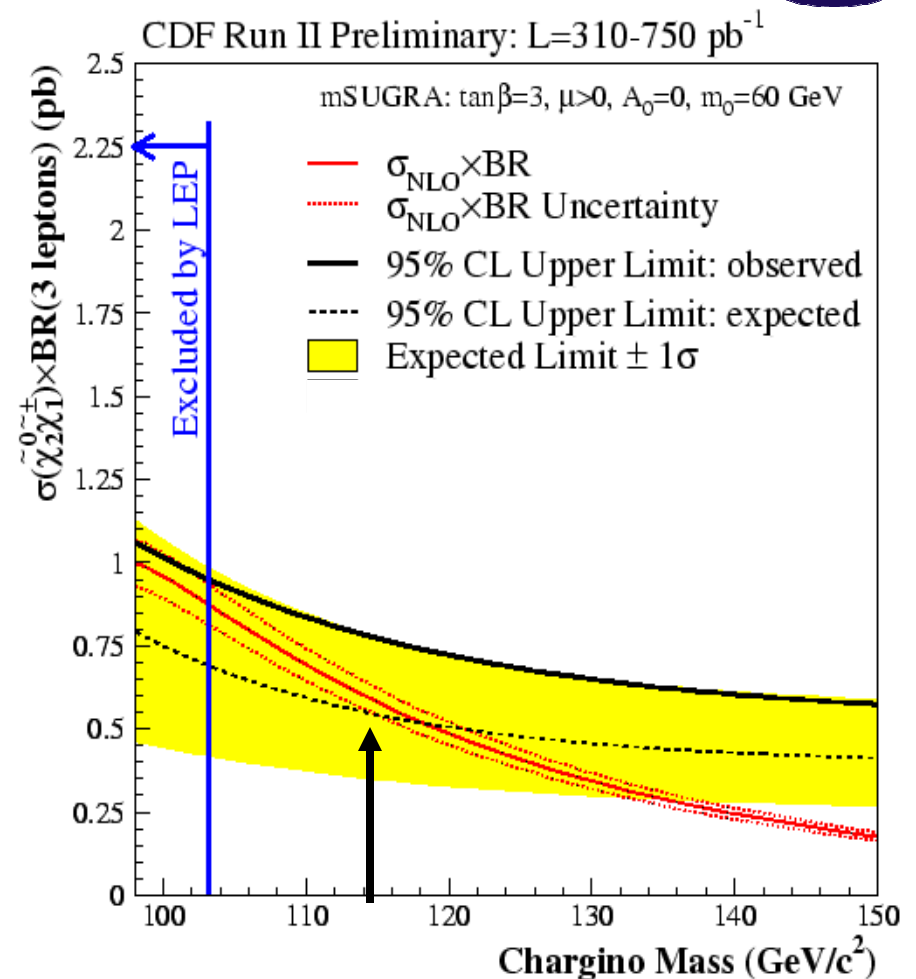
$$M(\chi^{\pm}_1) > 140 \text{ GeV}/c^2$$



# Limit in msugra



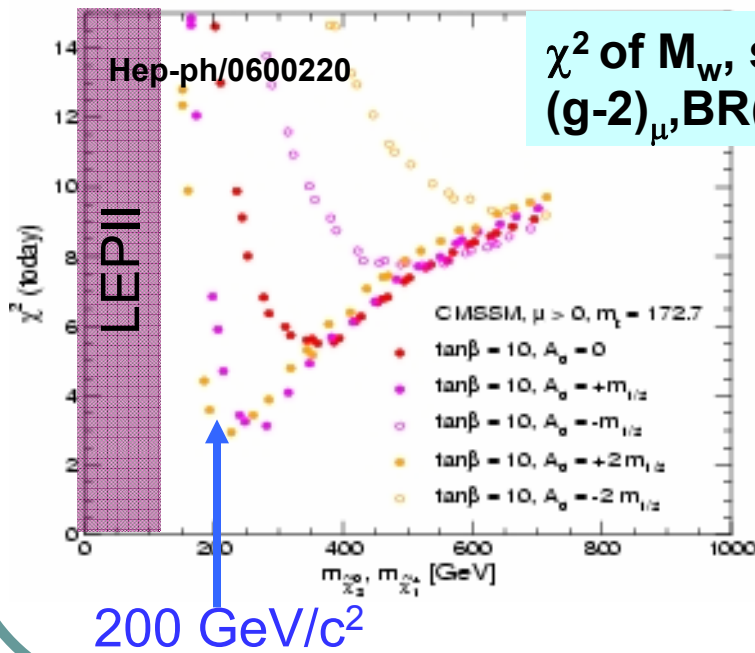
- **mSugra :**
  1.  $M_0$ =scalar mass at GUT scale=60 GeV/c<sup>2</sup>
  2.  $M_{1/2}$ =Gaugino mass at GUT scale=160-200 GeV/c<sup>2</sup>
  3.  $\tan\beta$ =ratio of Higgs vev's=3
  4.  $A_0$ =trilinear coupling term=0
  5.  $\text{sign } \mu$ = sign of Higgs mixing parameter>0
- Sensitive to chargino masses of  $\sim 116$  GeV/c<sup>2</sup>
- Unable to exclude this region of parameter space with the current data
- **In Standard mSugra the BR into taus is larger and the acceptance is lower**



# Conclusions



- Tevatron is starting to probe the region above LEP limit.
- Updated CDF combined limit almost ready
- Expect to probe chargino masses up to  $\sim 250 \text{ GeV}/c^2$  with  $\sim 8\text{fb}^{-1}$  of data
- Tevatron will provide direction to the LHC searches

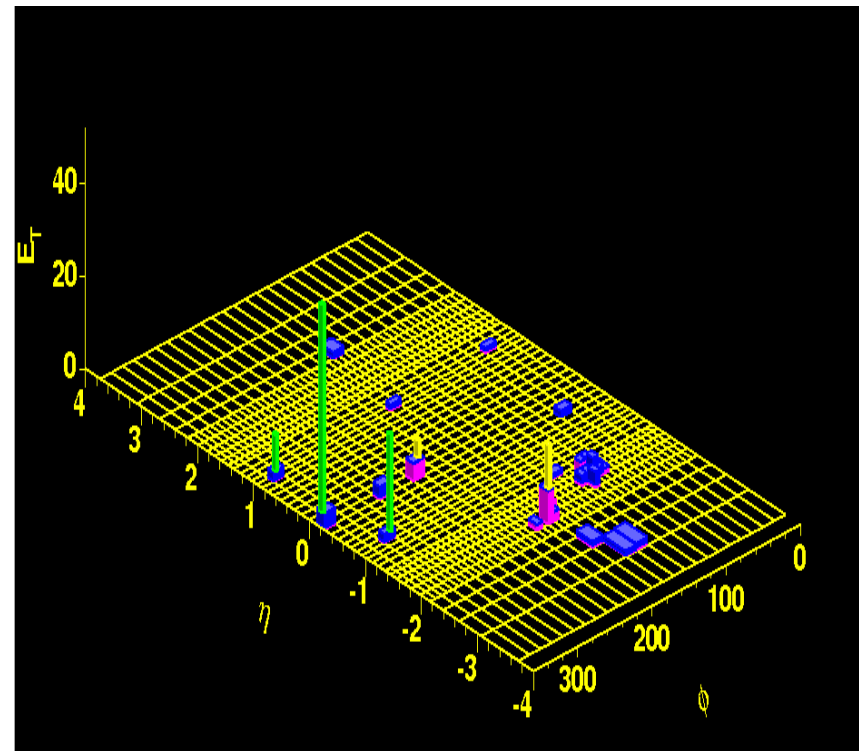
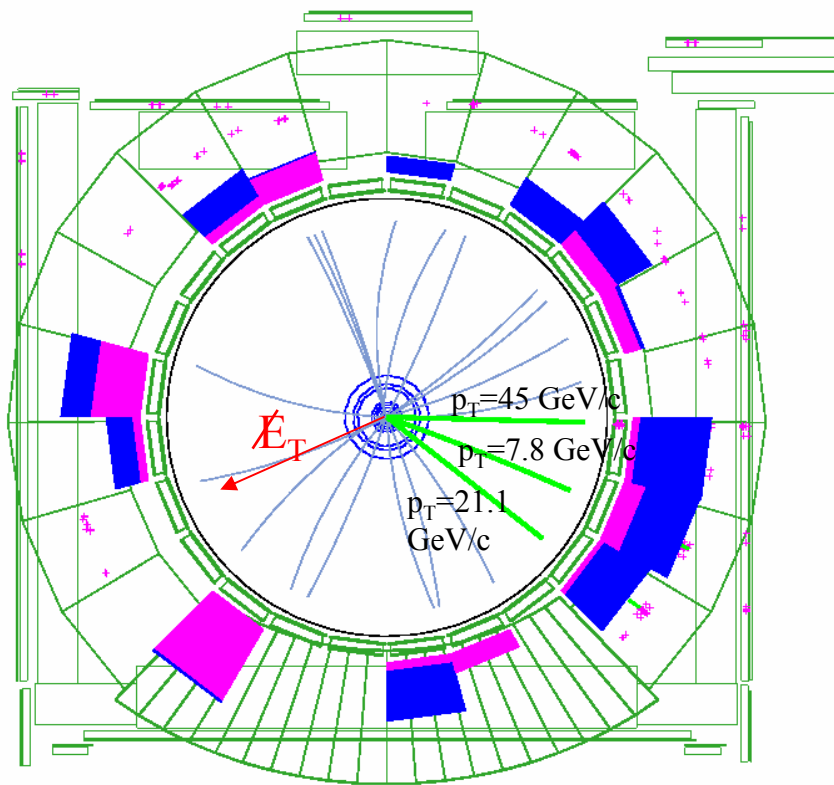


More information about CDF analyses  
can be found at:  
<http://www-cdf.fnal.gov/physics/exotic/exotic.html>

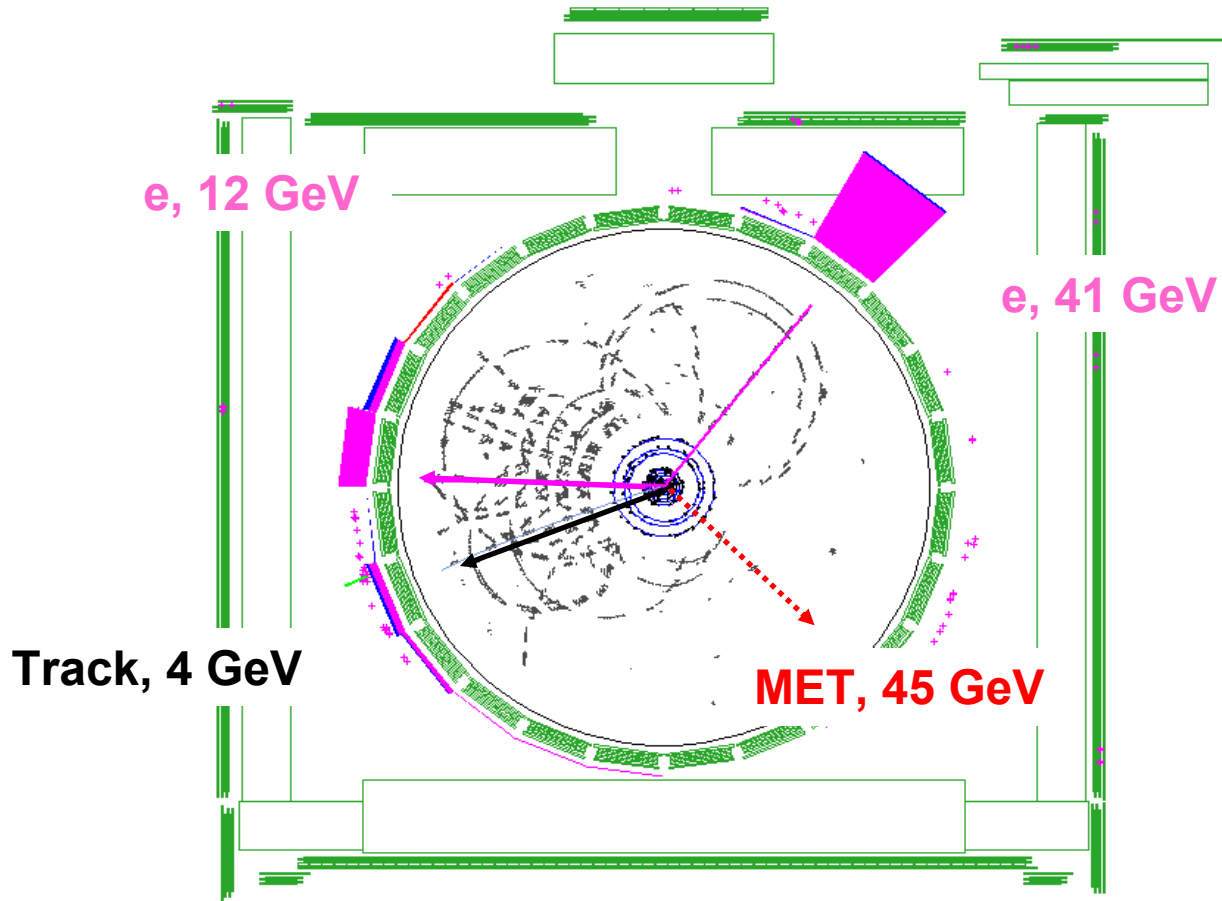
# BACKUP



# Low $P_T$ tri-muon

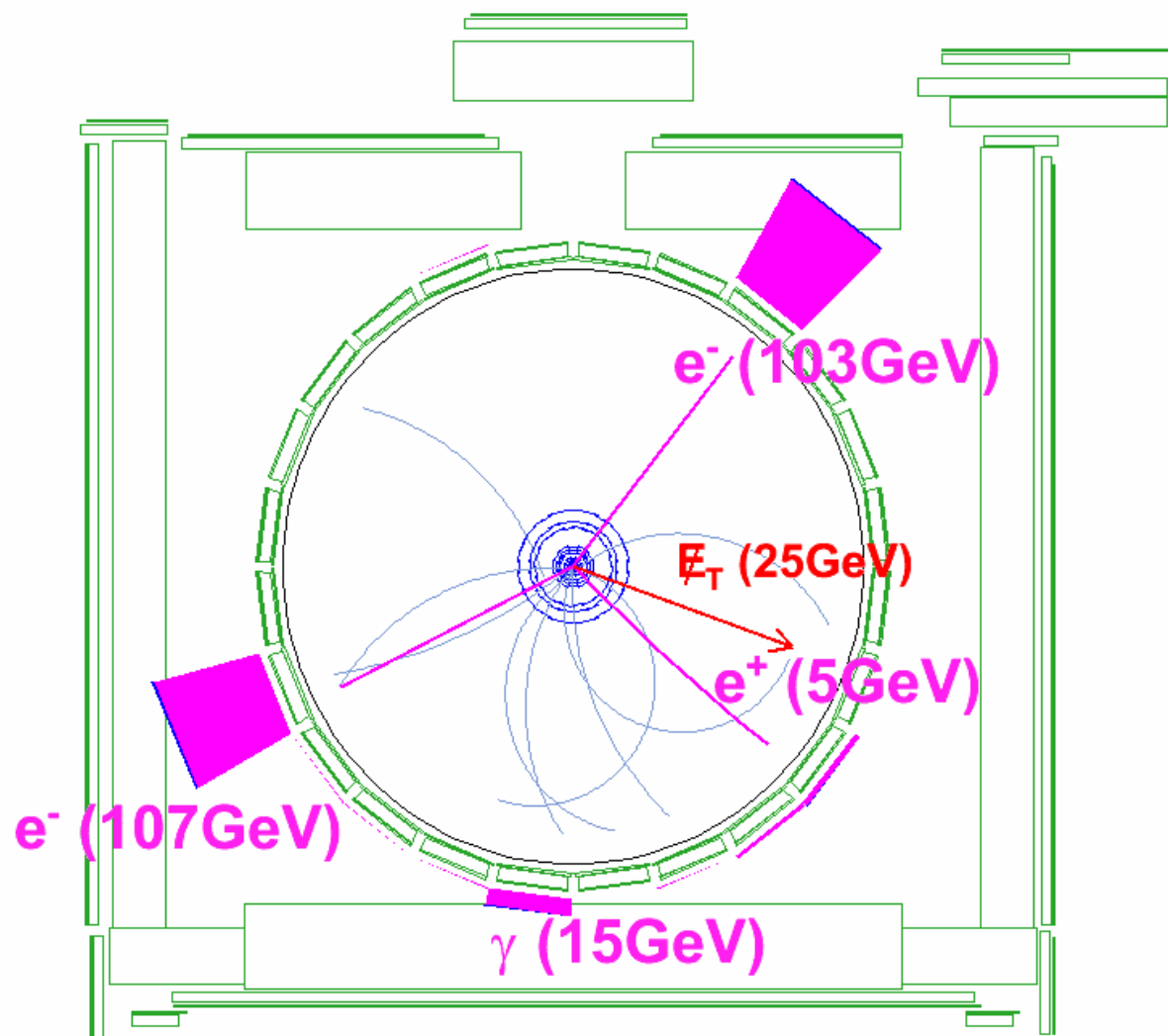


# Di-lepton + track

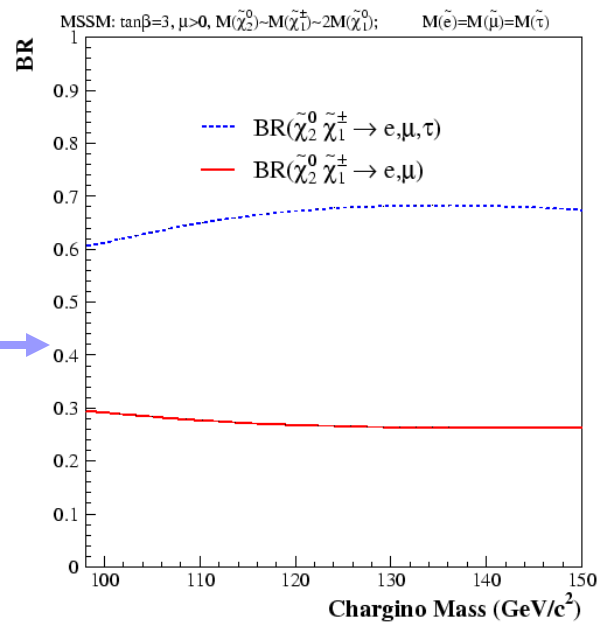
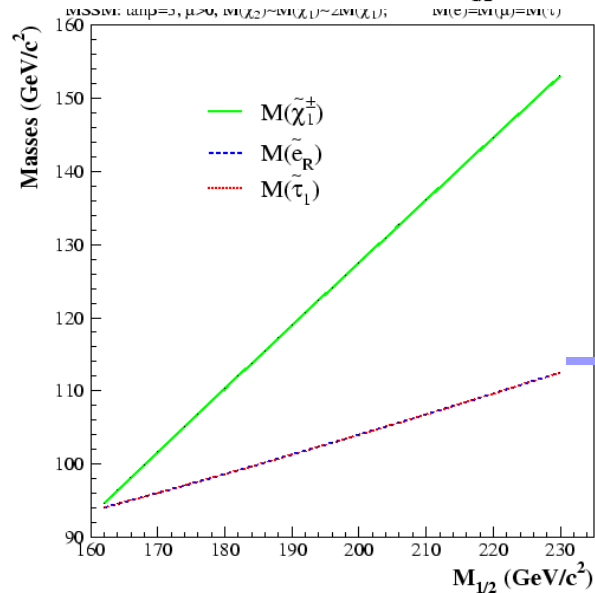
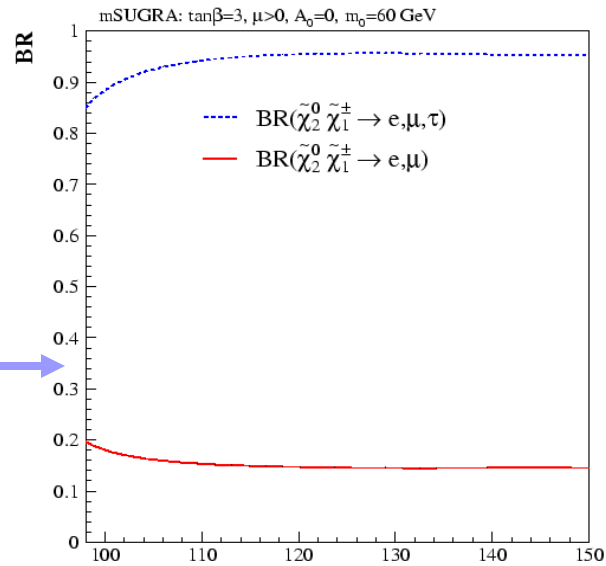
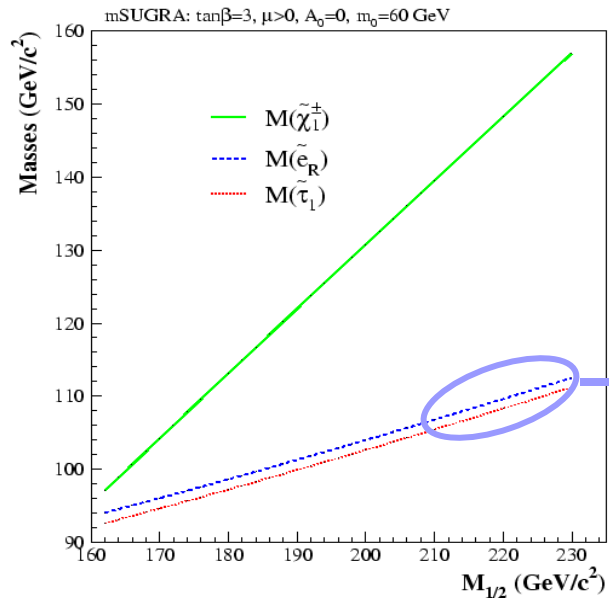


Mass OS1	41.6 GeV
Mass OS2	27.0 GeV

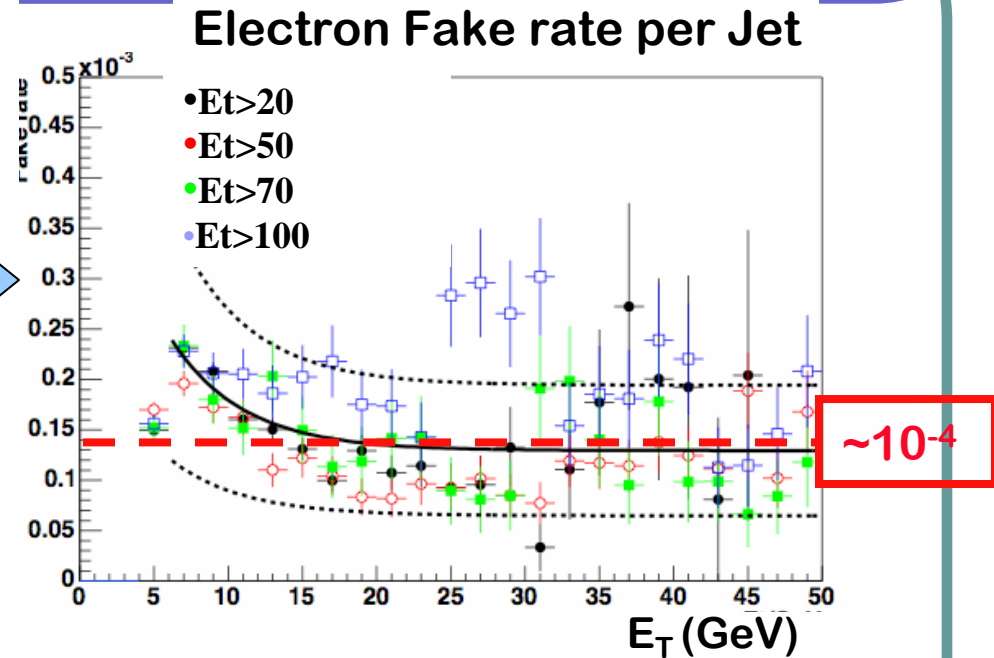
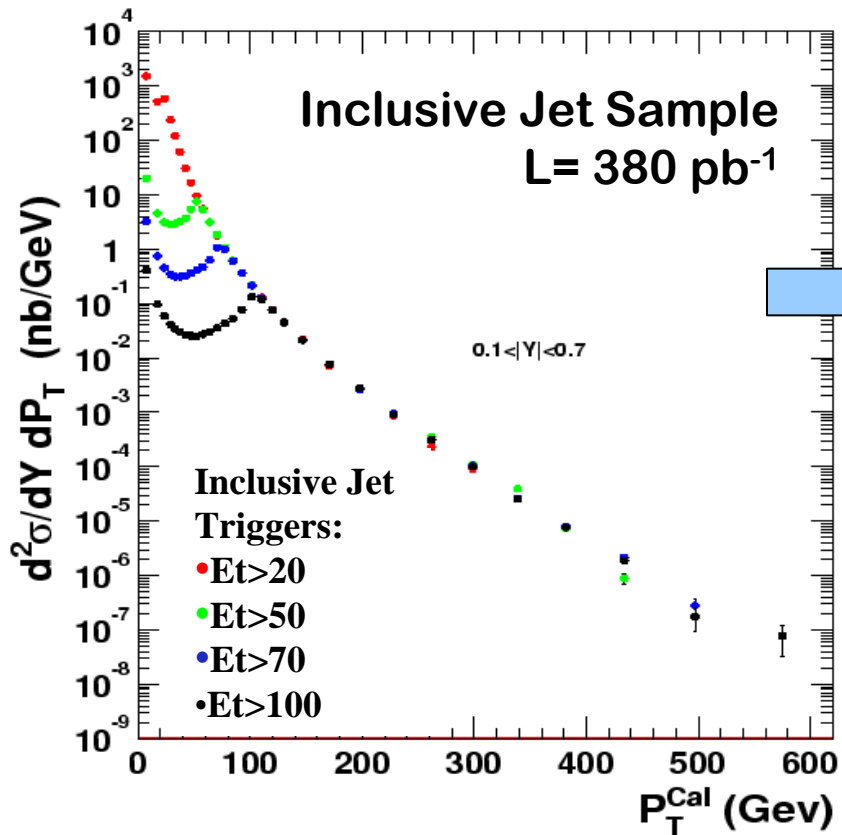
# LS dilepton event



# The differences in the models



# Jets Faking Leptons



**Inclusive Jet Sample with different trigger thresholds used to extract Fake rates and test Jet Energy Scale**