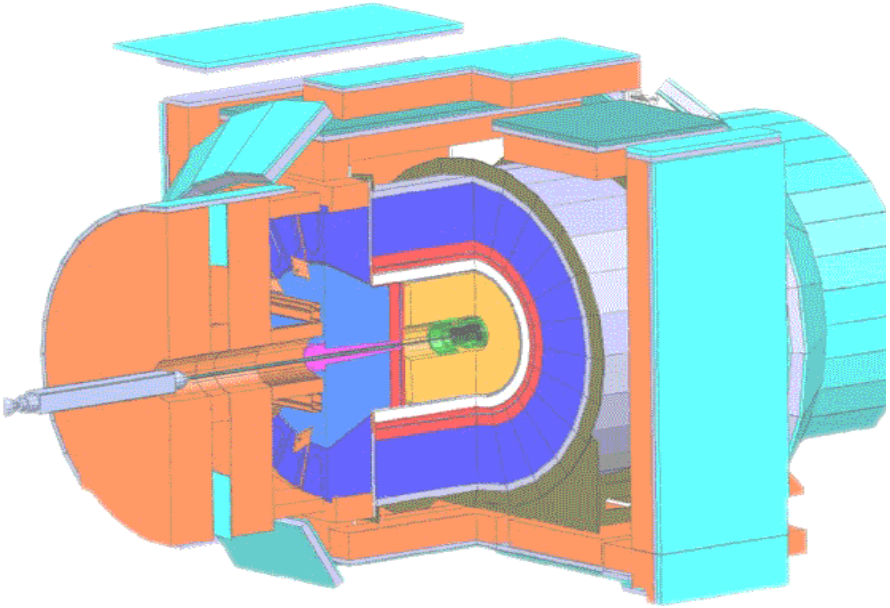
Search for Chargino-Neutralino Production using leptons at CDF, Fermilab

Sourabh Dube

Rutgers, The State University of New Jersey

New Perspectives 2006

June 2nd , Fermilab



The State University of New Jersey

Rutgers

Department of Physics and Astronomy

OUTLINE

- Supersymmetry and the Trilepton Signature
- CDF multilepton analyses
- Dielectron+track analysis in detail
- Summary of other channels
- Combined results
- Conclusions and Outlook

Why Supersymmetry ?

Standard Model has had great success in explaining Nature. Yet...

1) 'Hierarchy' problem:
   Higgs mass divergent
2) Electroweak symmetry breaking is ad hoc : Higgs mechanism
3) Gauge couplings don't unify.

Supersymmetry postulates

FERMIONS ↔ BOSONS

1) Solution to hierarchy problem
2) EWSB induced radiatively
3) MSSM leads to unification of gauge couplings

In addition...

(R_p) R parity is conservation of 'supersymmetric-*ness'*. If R_p is conserved, then lightest SUSY particle (LSP) will be stable. It is very weakly interacting and will escape the detector undetected. It is also an excellent dark matter candidate.

MSSM, Minimal SuperSymmetric extension of SM is constrained (to avoid large number of free parameters, too much additional CP-violation etc.) to obtain mSUGRA with 5 parameters: m_0 , $m_{1/2}$, $\tan(\beta)$, A_0 , $\mathrm{sign}(\mu)$

Our Signature of Supersymmetry

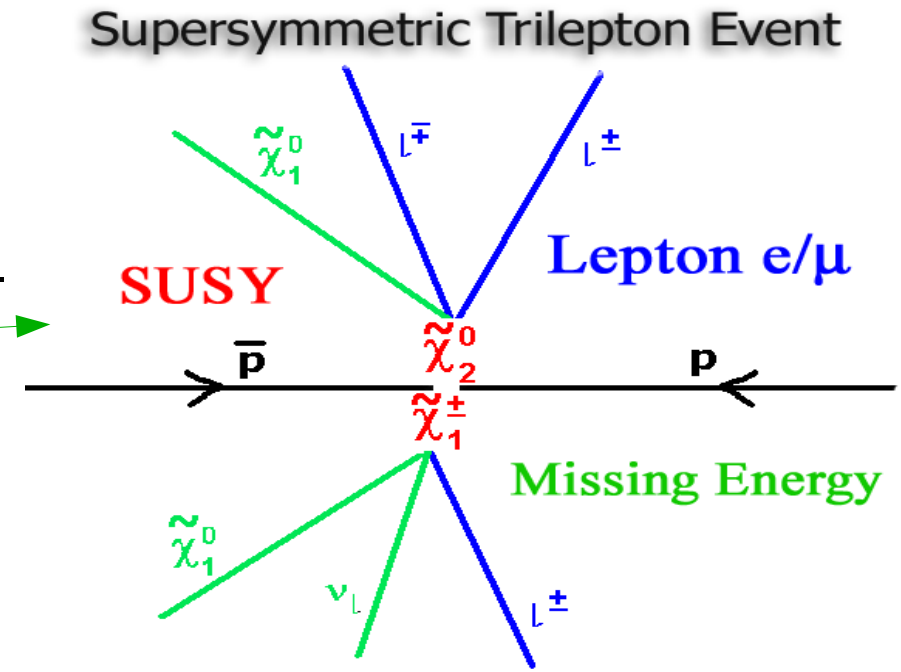
Charginos, Neutralinos (fermions) are the superpartners of the SM gauge bosons.

We take Rp to be conserved : Our signature - 3 leptons + energy imbalance

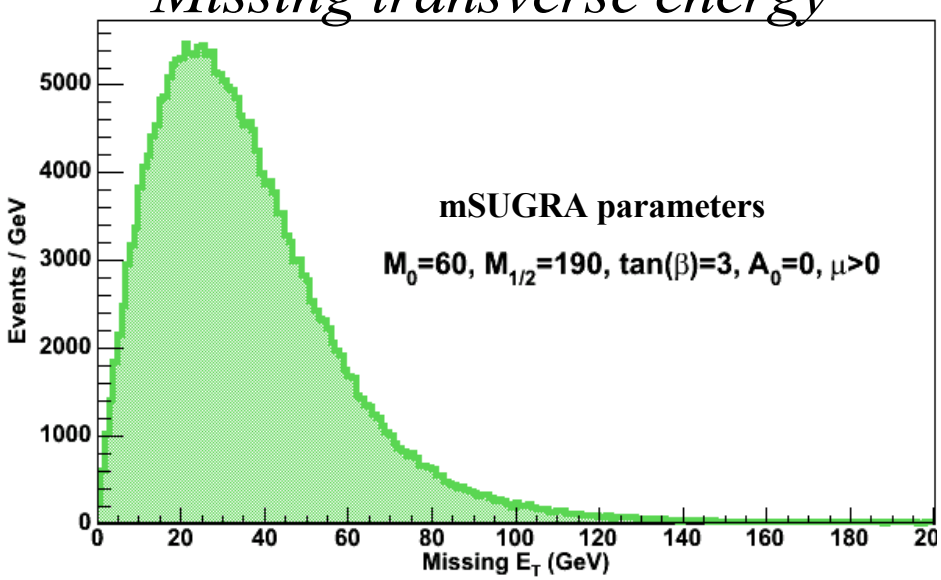
(missing E_T)

This signature is distinctive , and gives low SM backgrounds.

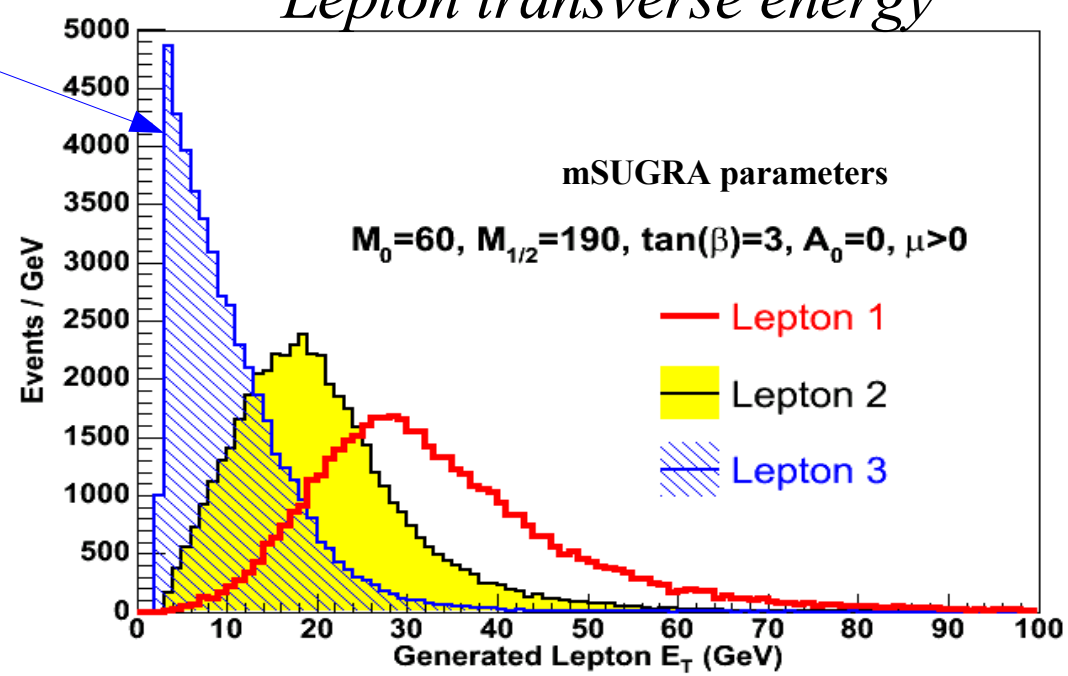
Identifying low energy leptons is essential



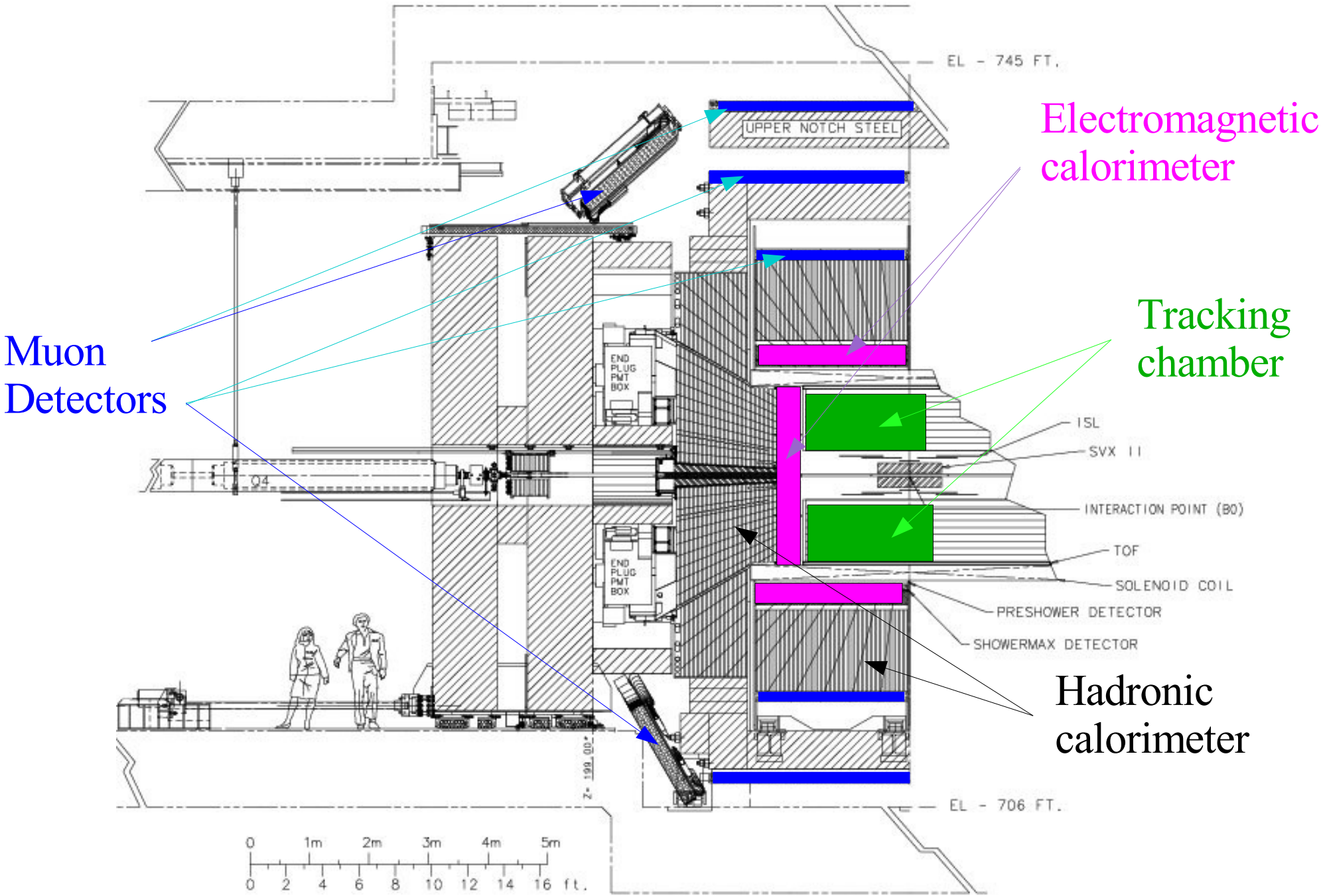
Missing transverse energy



Lepton transverse energy

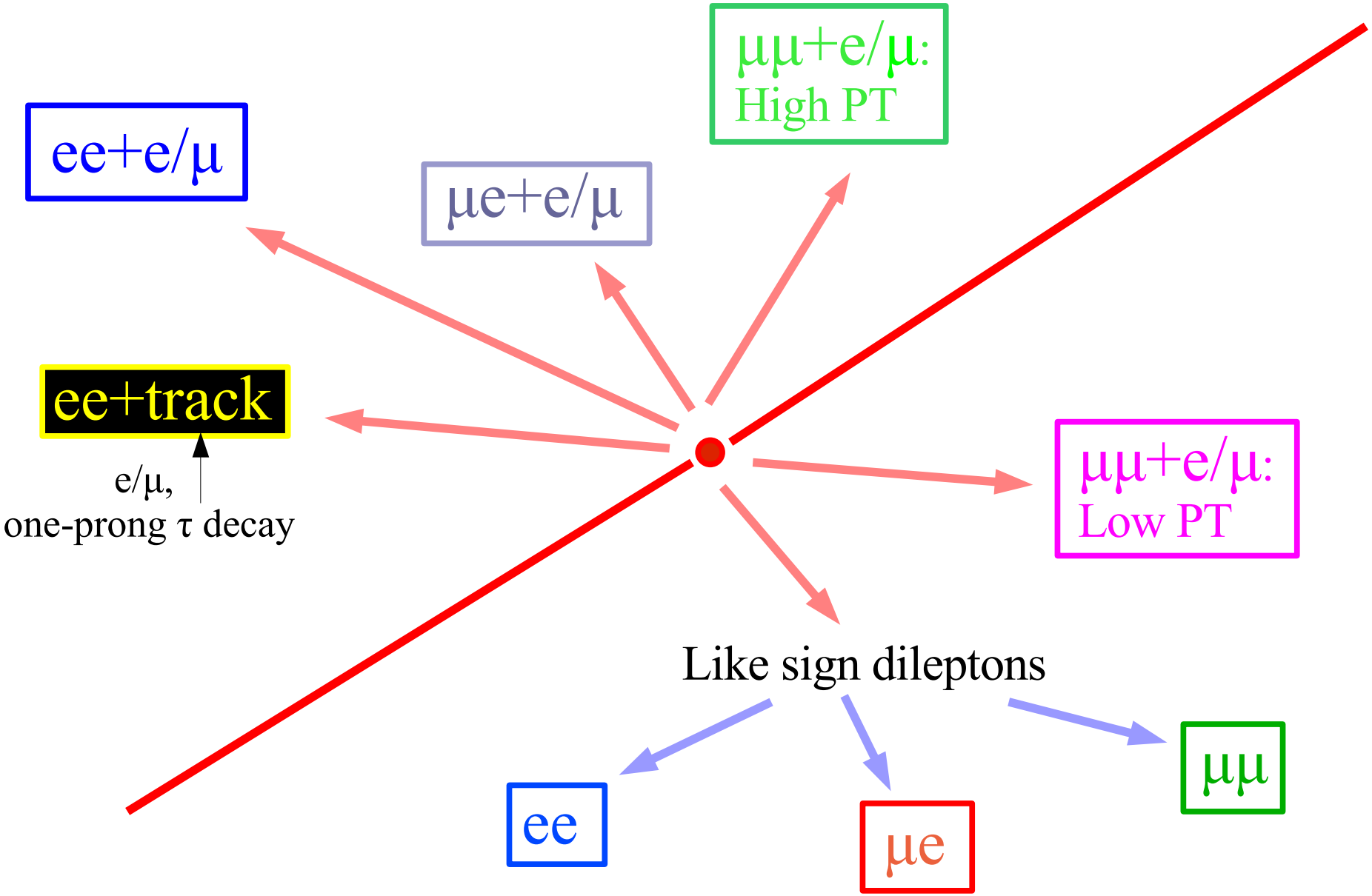


The CDF Detector



CDF Multilepton Zoo

16 people
7 institutes



Common Analysis Strategy

Unbiased analysis method

Perform counting experiment :

- Compare Expected *background* and *signal* events in signal region with Observed events in data.

- Estimate backgrounds using data as much as possible and Monte Carlo simulations..

- Test predictions of background events in 'background-dominated' ***control regions***.

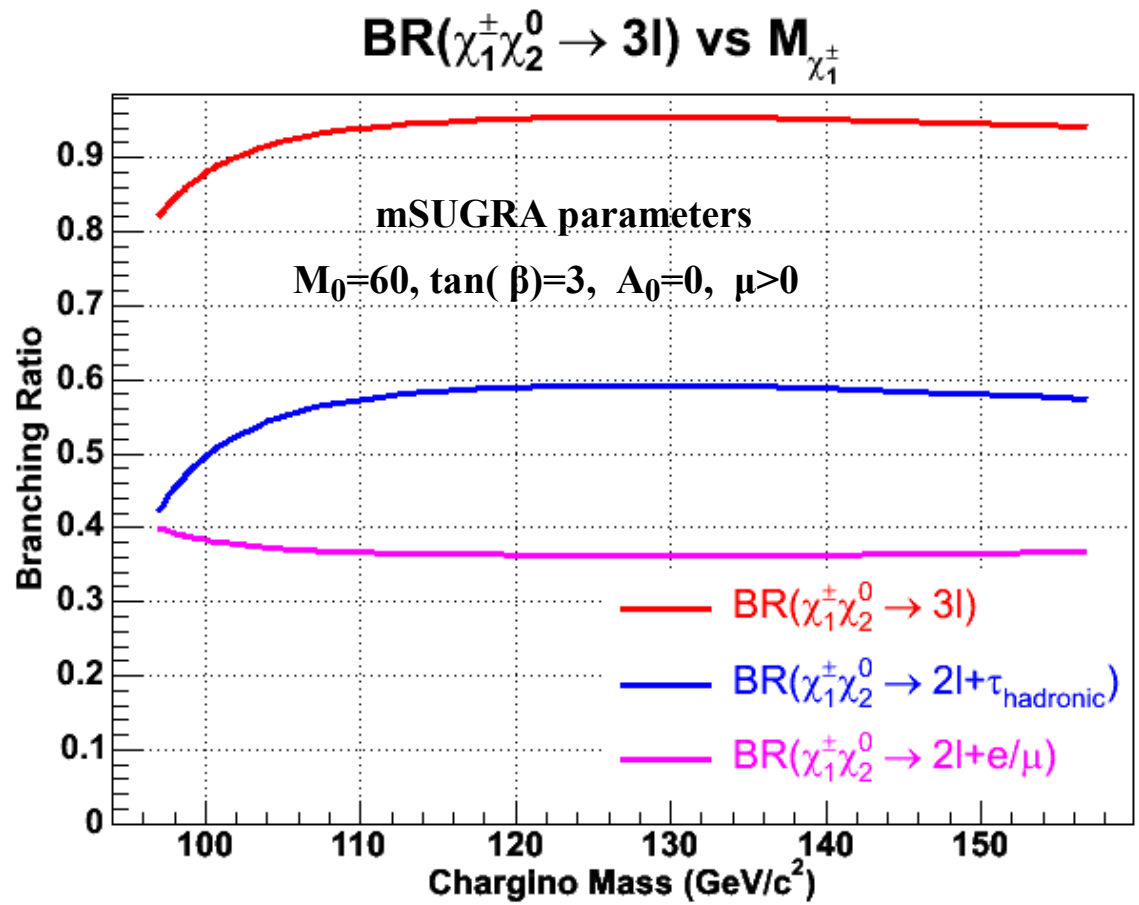
- Only after control-region studies are validated, predict events in signal region and look at data.

Dielectron+Track

An Analysis in Detail

Outline

- Event Selection and Backgrounds
- Control Region Studies
- Optimization
- Result



Event Selection and Backgrounds

for ee+trk

DATA: 607 pb^{-1}

Data collected using dielectron trigger with 4 GeV threshold.

Selection:

'tight'

- Two isolated electrons which pass restrictive identification with transverse energies (E_T) > 15,5 GeV
- One isolated track in our tracking chamber with transverse momentum (P_T) > 4 GeV
- Require significant missing E_T (15 GeV to start with) in the detector.
- Require electrons, track to be physically separated in detector – from each other and from any hadronic activity (jets) in the event.

Sources of Background:

Drell-Yan + track

(2 real electrons + 1 'fake' track)

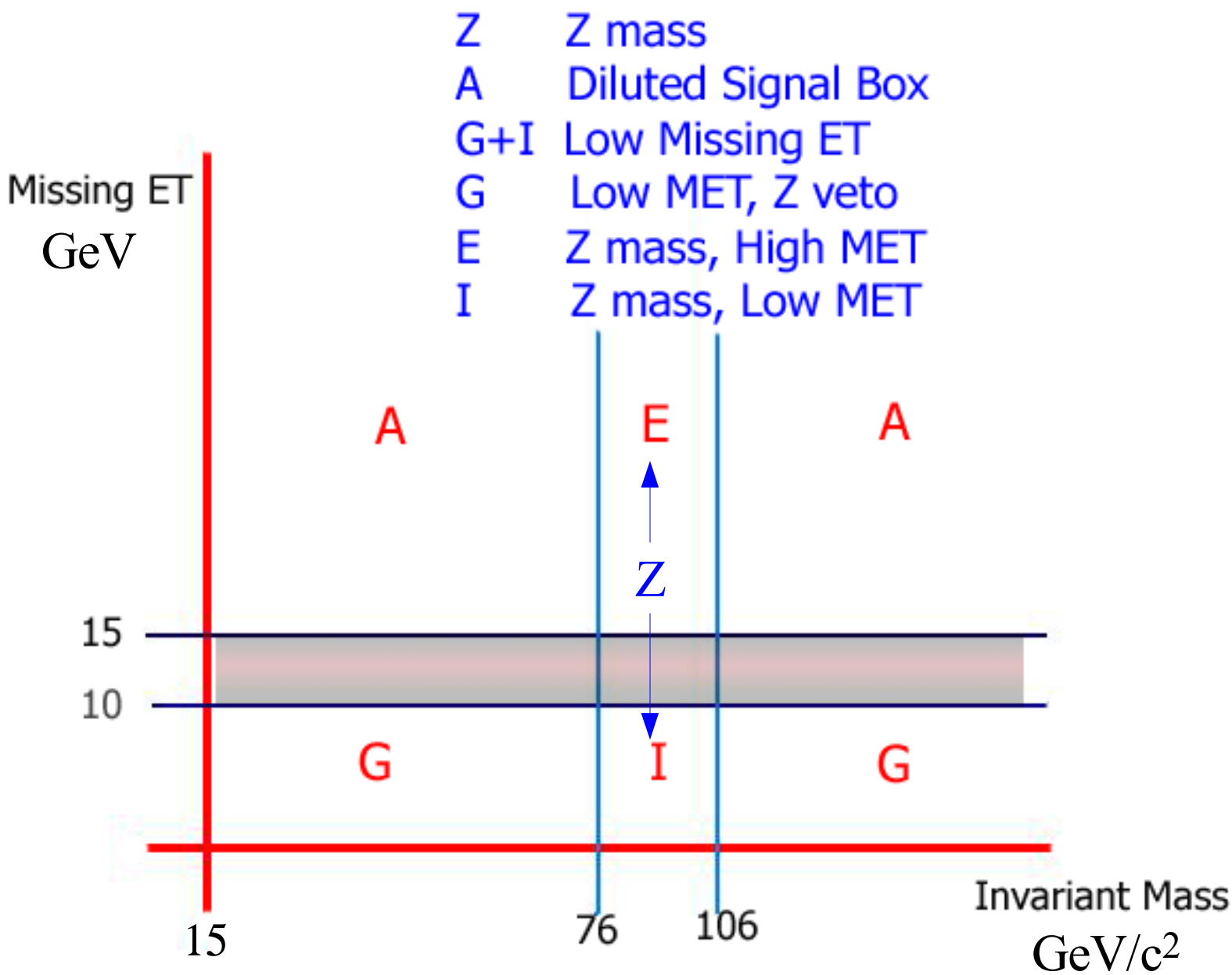
DiBoson (+track):

WW, WZ/γ*, ZZ/γ*γ*

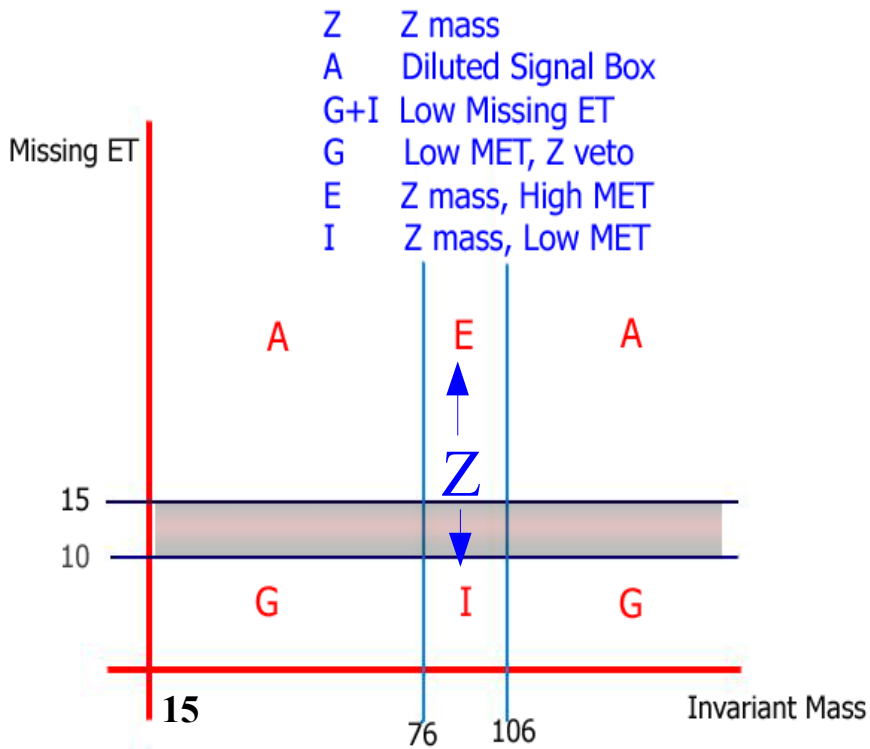
WW+'fake track', real 3 objs for WZ,ZZ

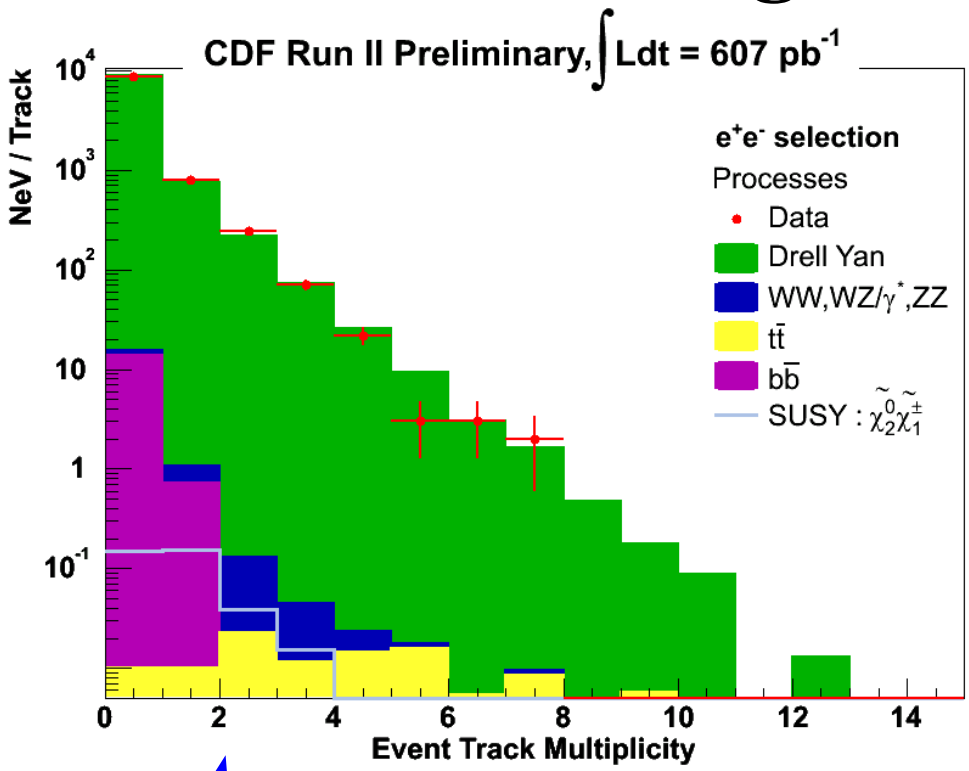
Top pair production

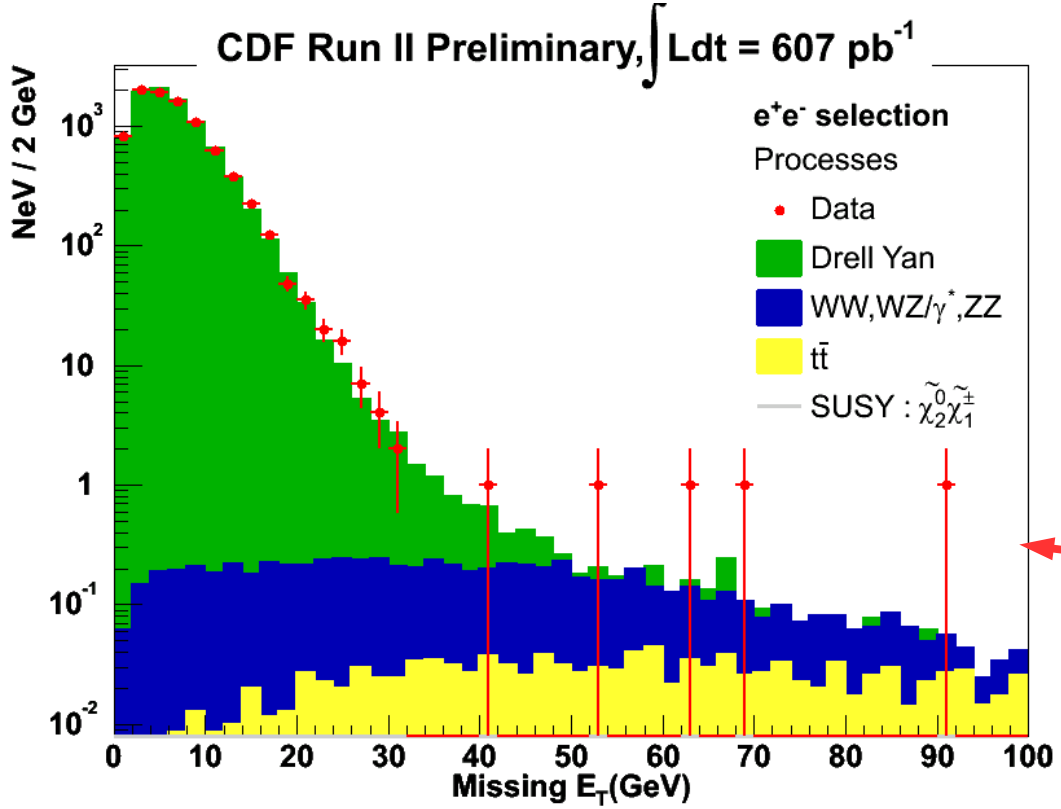
Control Regions: Dilepton level



Dielectron Control Regions





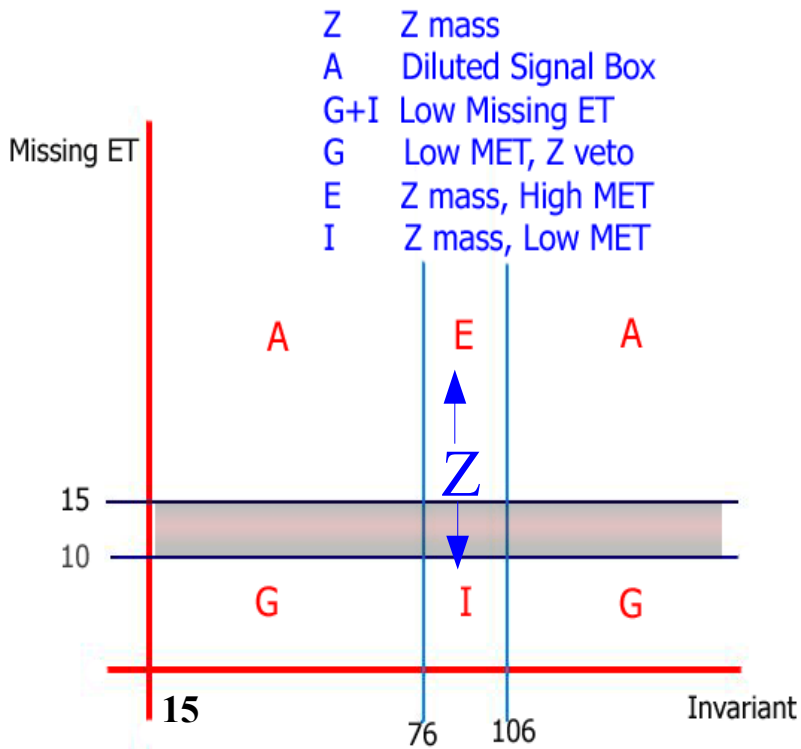


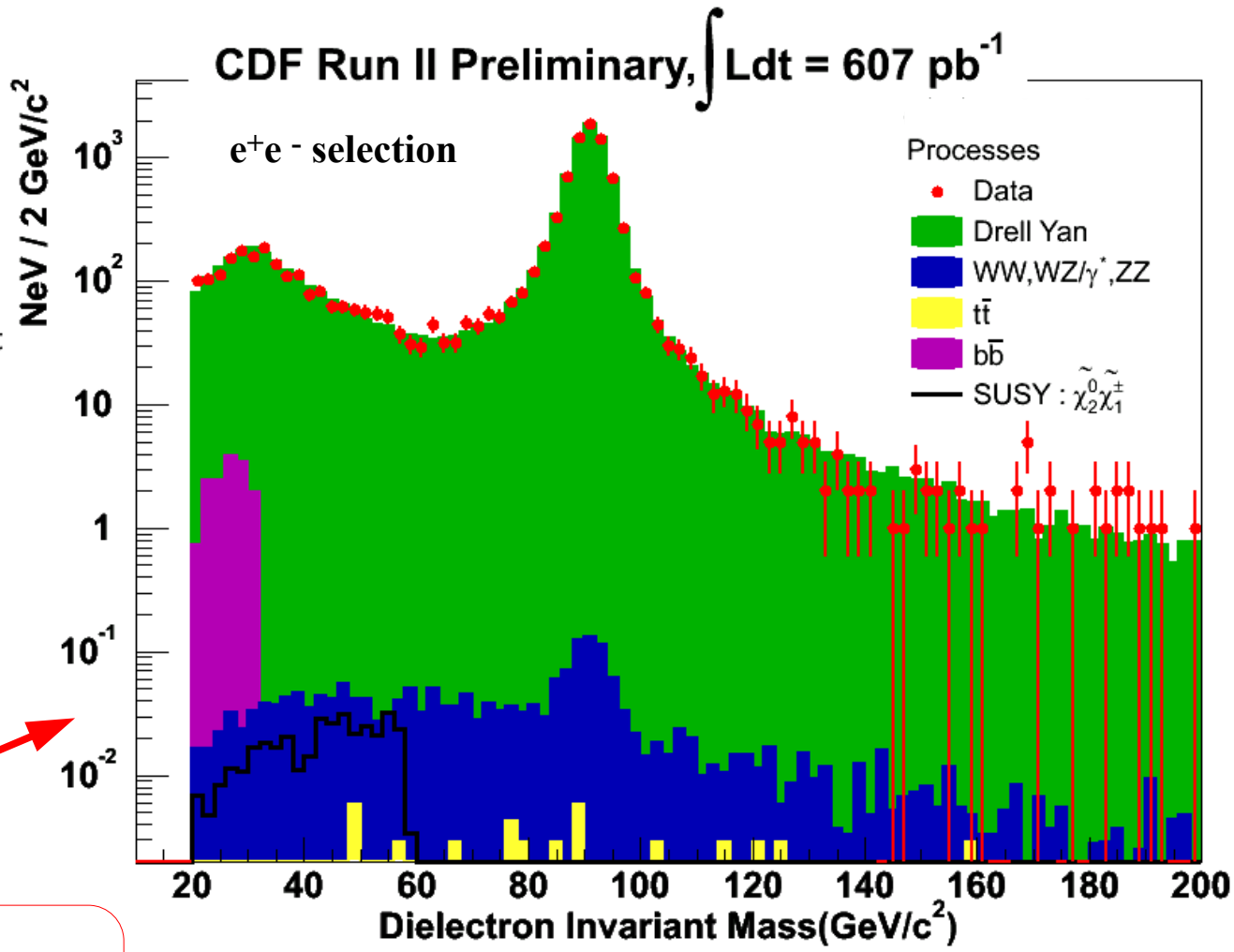
G+I: dielectron
Exp:6169±230 , Obs:6185 events

Z: dielectron
Exp:5698±190, Obs:5757

...we understand missing E_T well

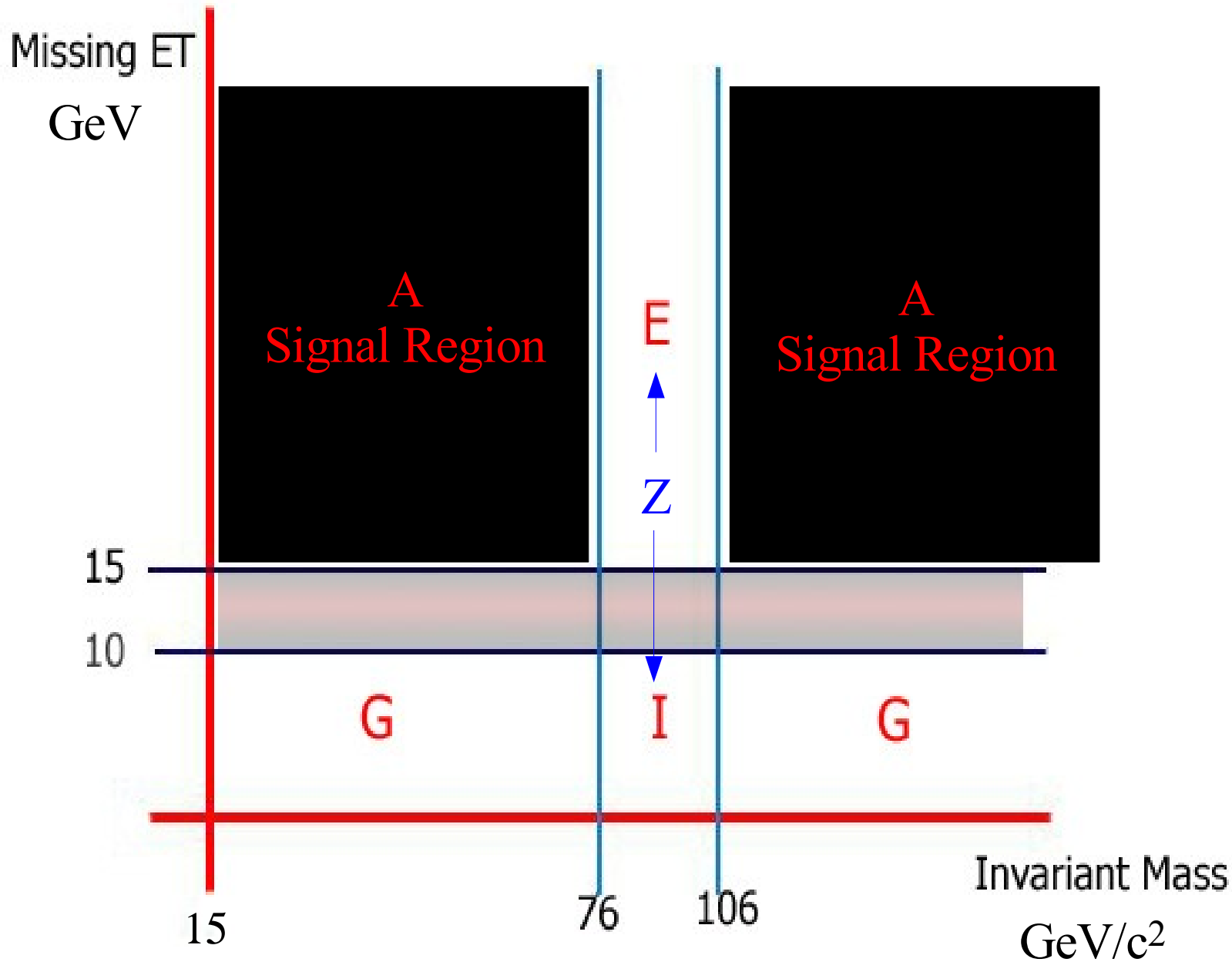
Dielectron Control Regions



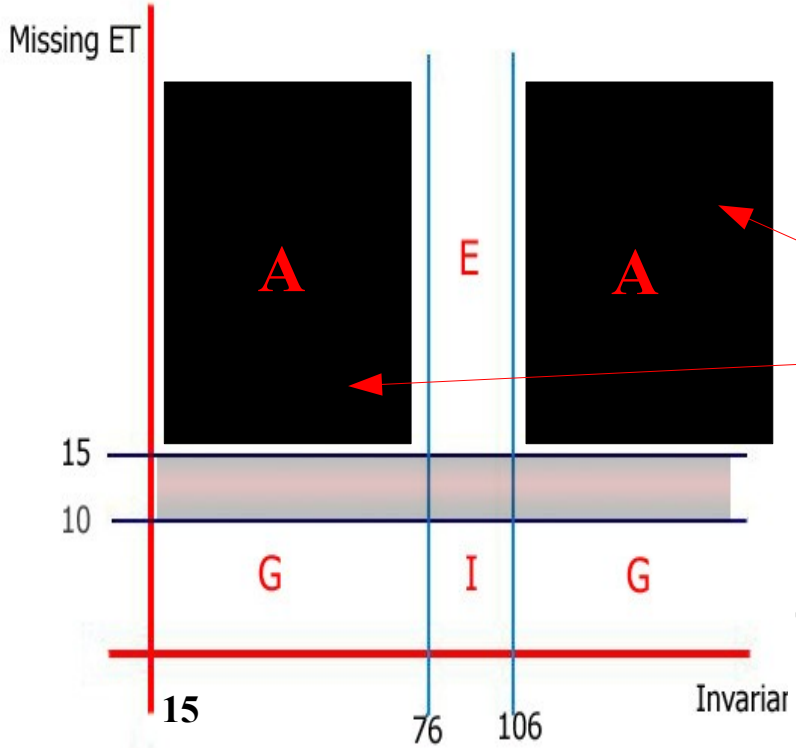


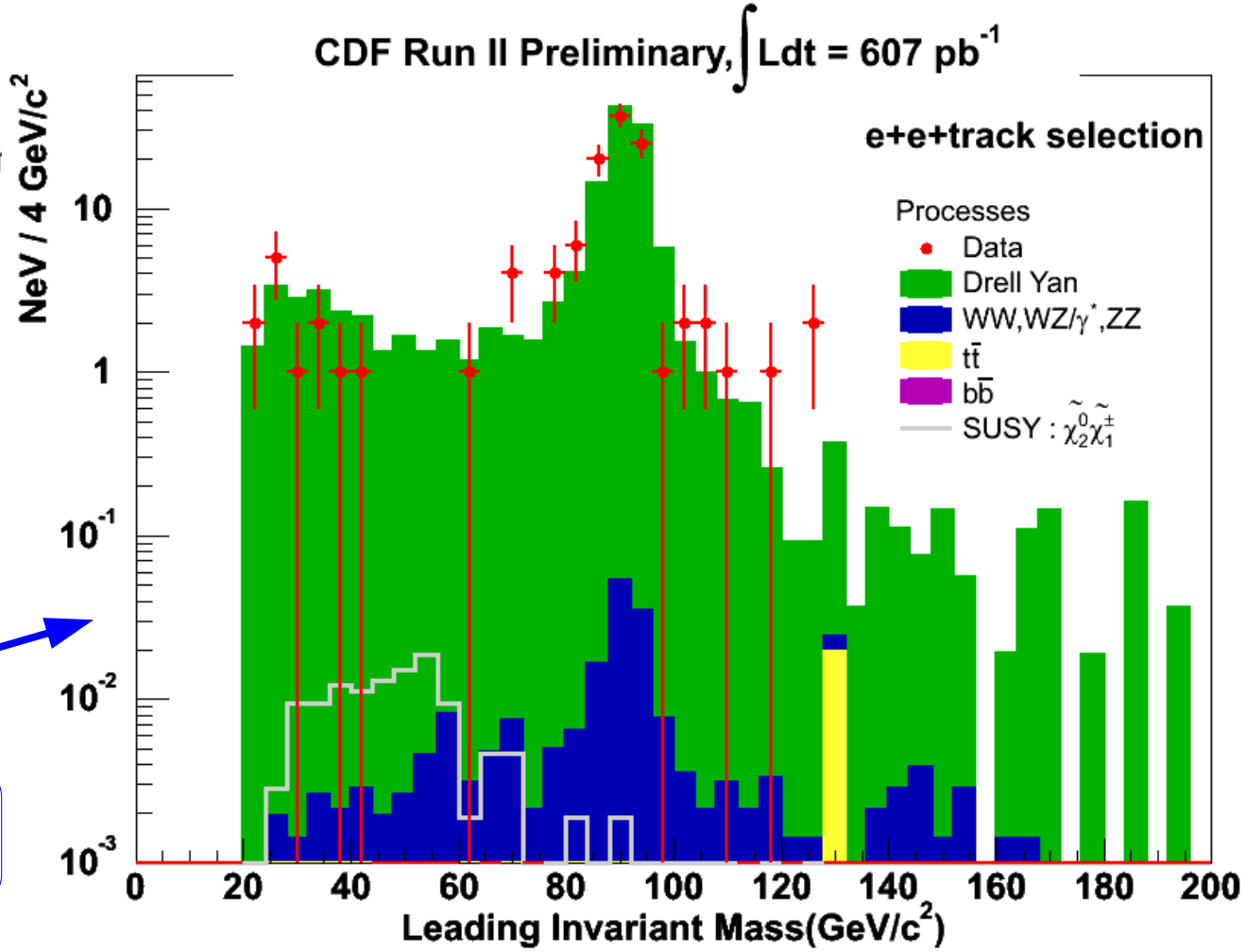
G+I: dielectron
Exp:6169±230 , Obs:6185 events

Control Regions: Dilepton+Track level



Dielectron+Track Control Region



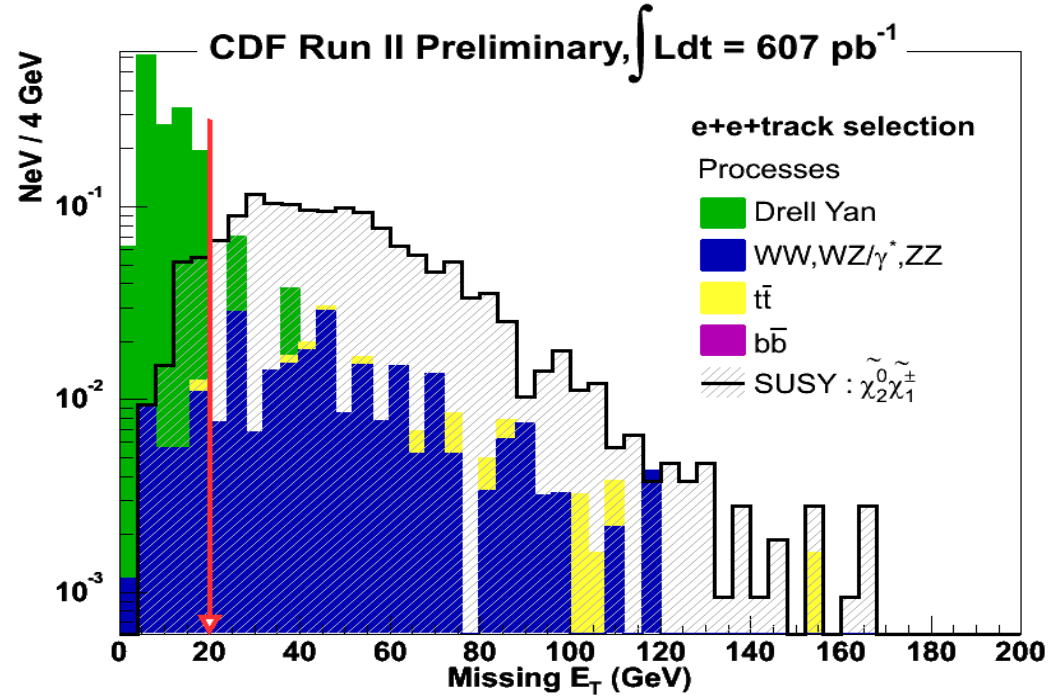


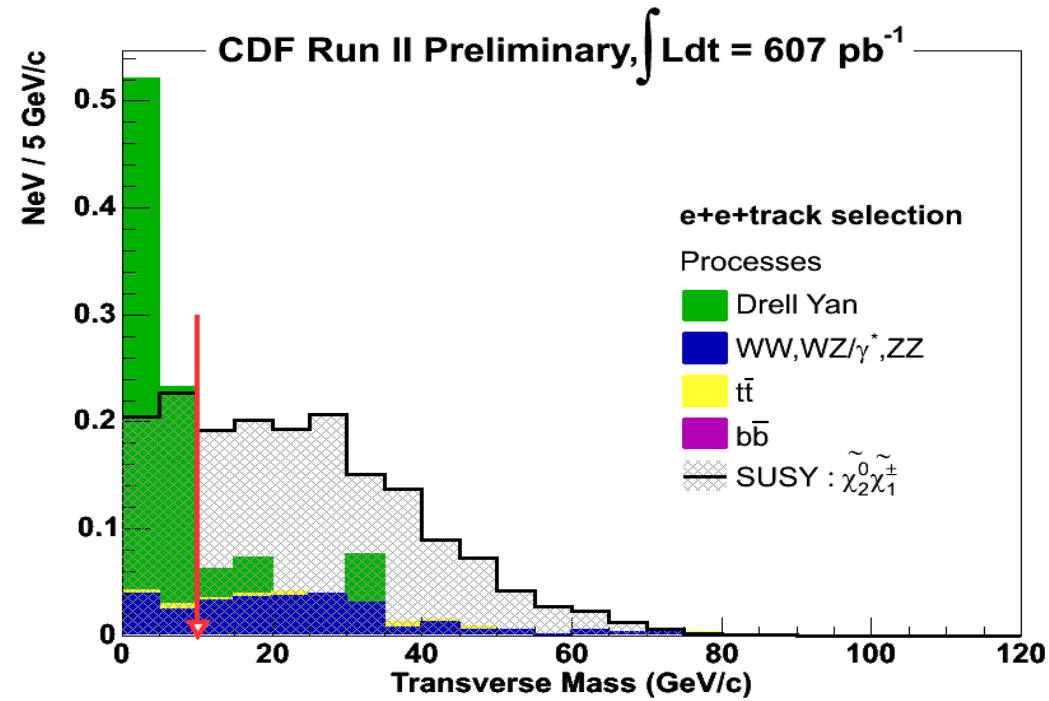
G+I: dielectron+trk
Exp:90±14 , Obs:80 events

Final selections to reduce backgrounds

for ee+trk

Variable	Selection
Missing E_T	> 20 GeV
Leading Mass (Z veto)	$20<M_1<76$, or $M_1>106$ GeV
Next Mass	$20<M_2<60$ GeV
$\Sigma E_T^{(jets)}$	< 80 GeV
$\Delta\varphi(ee)$	< 2.8 rad
min M_T (transverse mass)	> 10 GeV





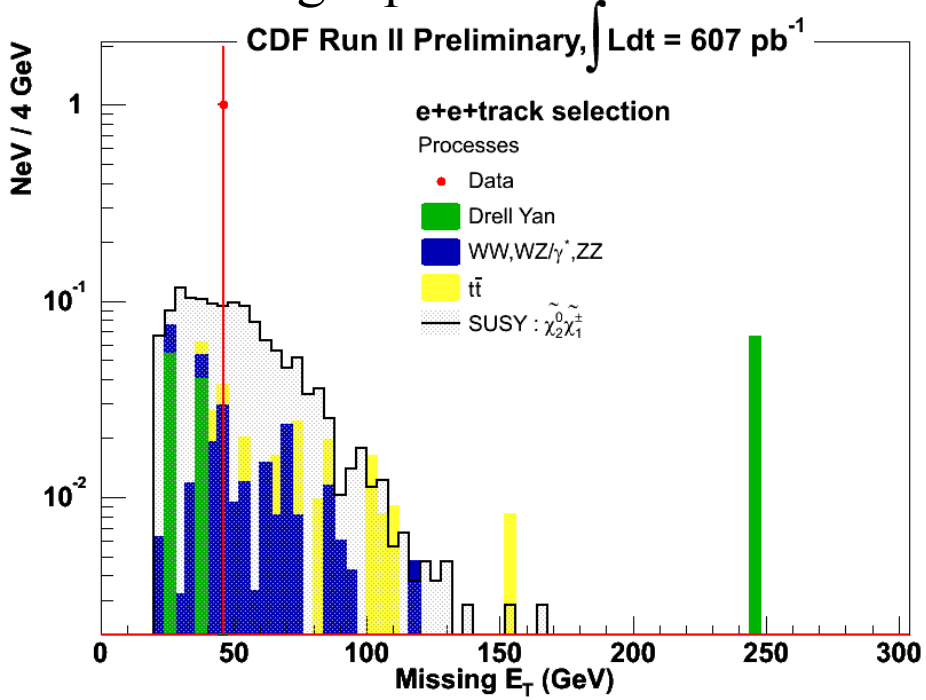
Results

CDF Run II Preliminary, $\int Ldt = 607\ pb^{-1}$
Expected Signal,Background and Observed events.

from ***dielectron+track*** search

Sample	Expected events
Drell Yan	0.16 ± 0.12
WW+ZZ	0.17 ± 0.04
WZ/γ*	0.05 ± 0.01
tt	0.11 ± 0.07
Total Bkgd	0.49 ± 0.14
Signal A	1.1 ± 0.1
Observed	1

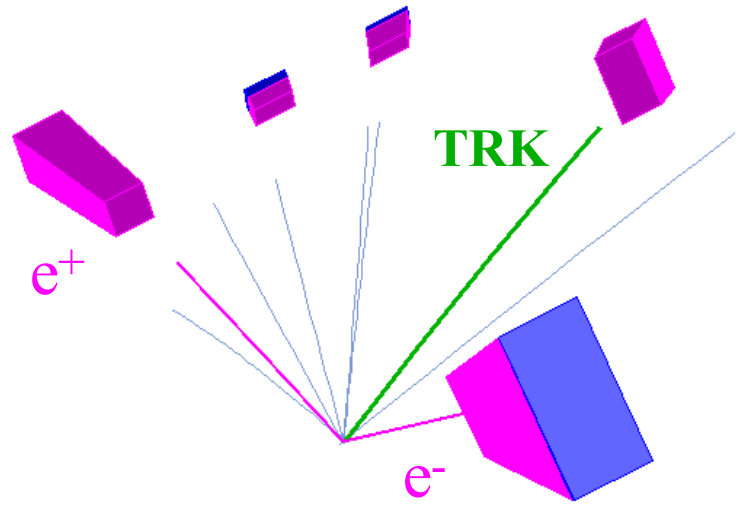
Missing E_T after all selections

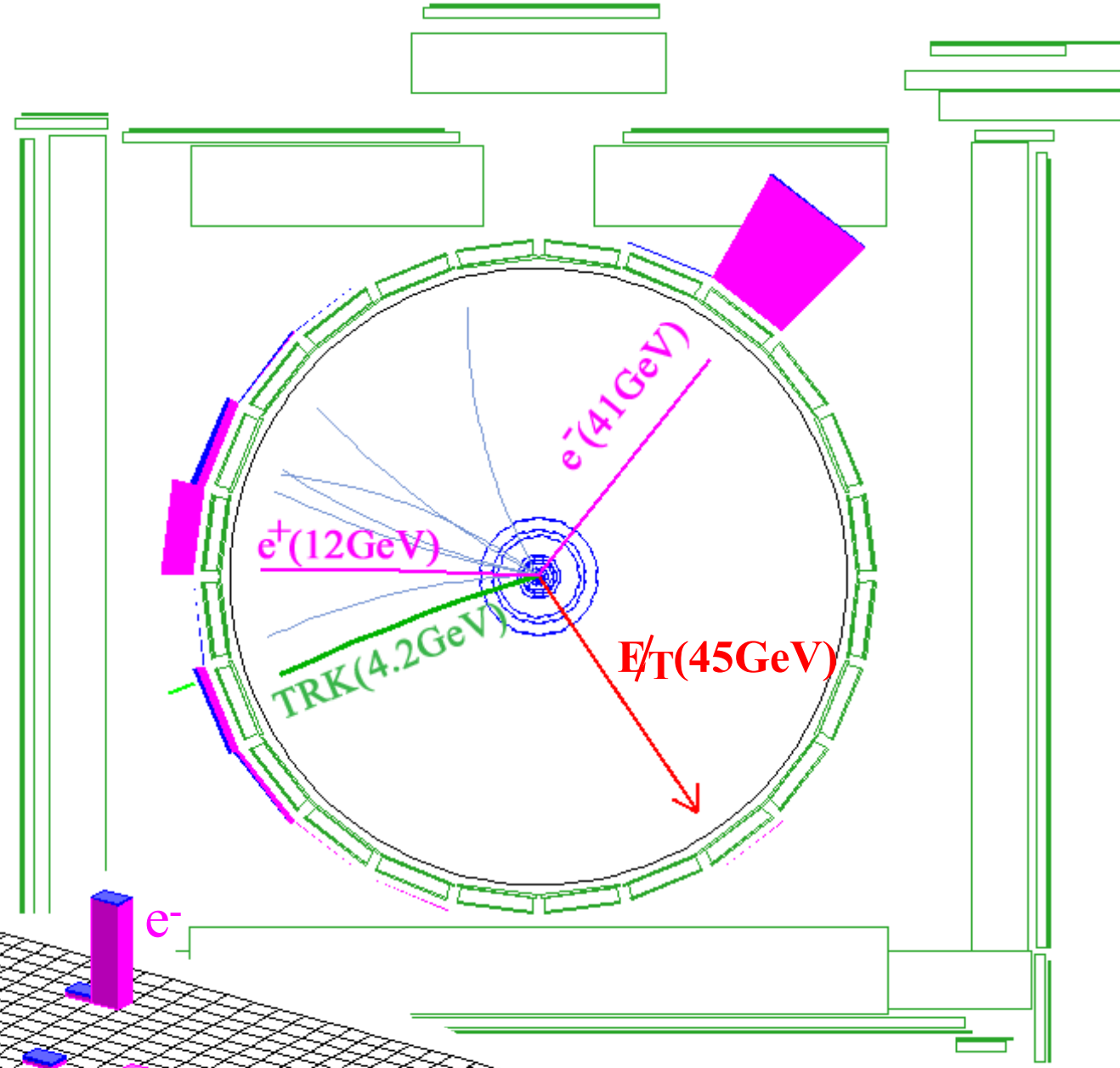


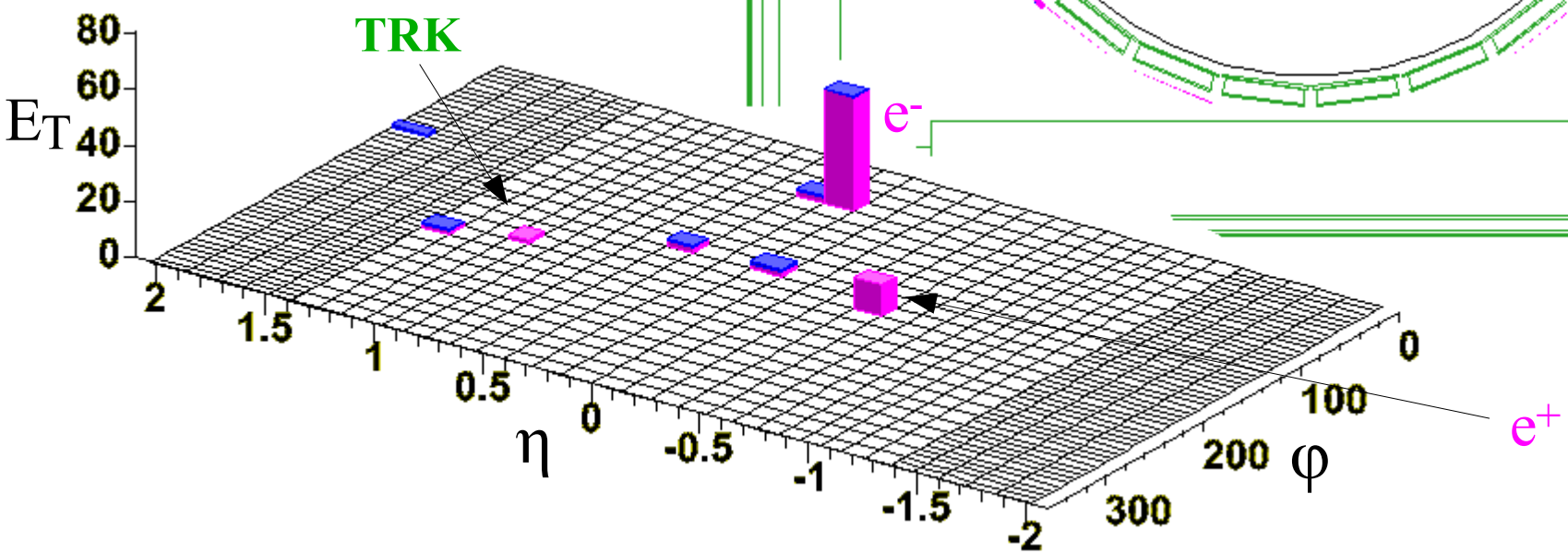
Signal A has the following mSUGRA prameters:
M_0=100 $M_{1/2}$=180 tan(β)=5 A_0=0 μ>0

Chargino mass = 113 GeV

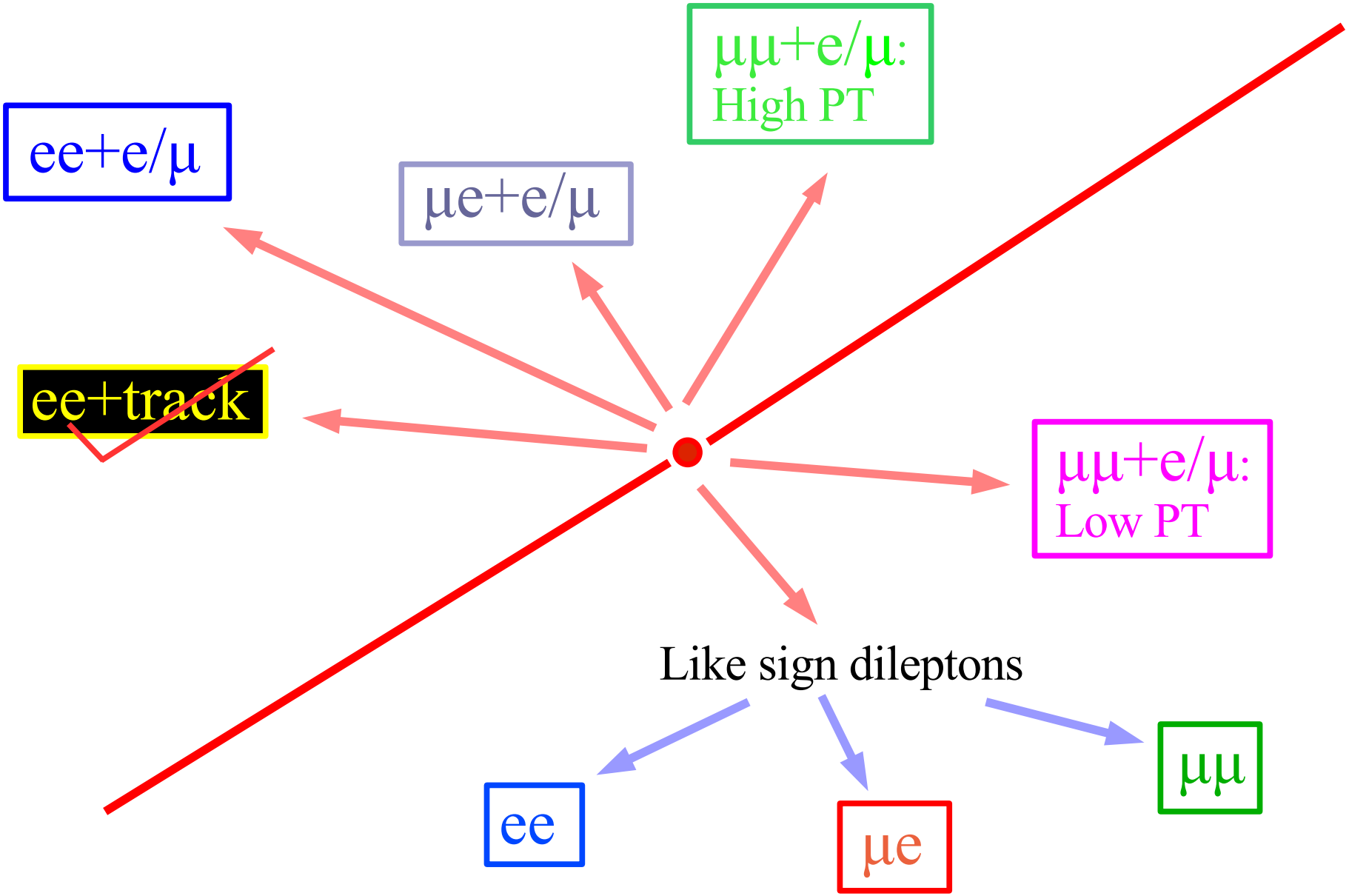
The Event


TRK
e+
e-


e-(41GeV)
e+(12GeV)
TRK(4.2GeV)
E/T(45GeV)


TRK
e-
e+
ET
80
60
40
20
0
η
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
φ
0
100
200
300

CDF Multilepton Zoo



ee+e/μ

20 GeV electron trigger
tight-loose-loose selection

μe+e/μ

20 GeV muon trigger
tight-tight-loose selection

μμ+e/μ:
High PT

20 GeV muon trigger
tight-loose-loose selection

Differences in analyses:

Trigger paths used to collect data

Kinematic differences in selection

Aim to cover different regions of parameter space

ee+track

4 GeV dielectron trigger
tight-tight-track selection

μμ+e/μ:
Low PT

4 GeV dimuon trigger
tight-tight-tight selection

20 GeV electron/muon trigger
tight-tight same-sign selection

Like sign dileptons

ee

μe

μμ

Dielectron + Lepton Analysis

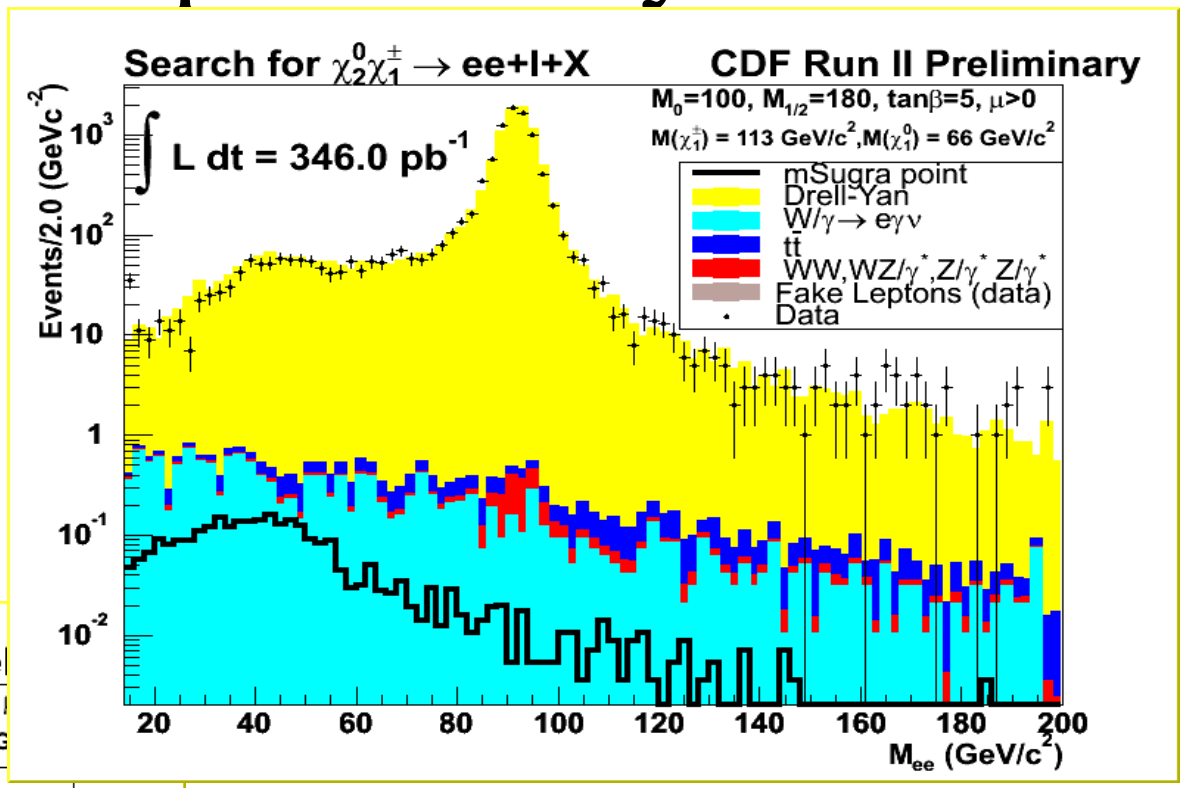
$\int Ldt = 346\ pb^{-1}$

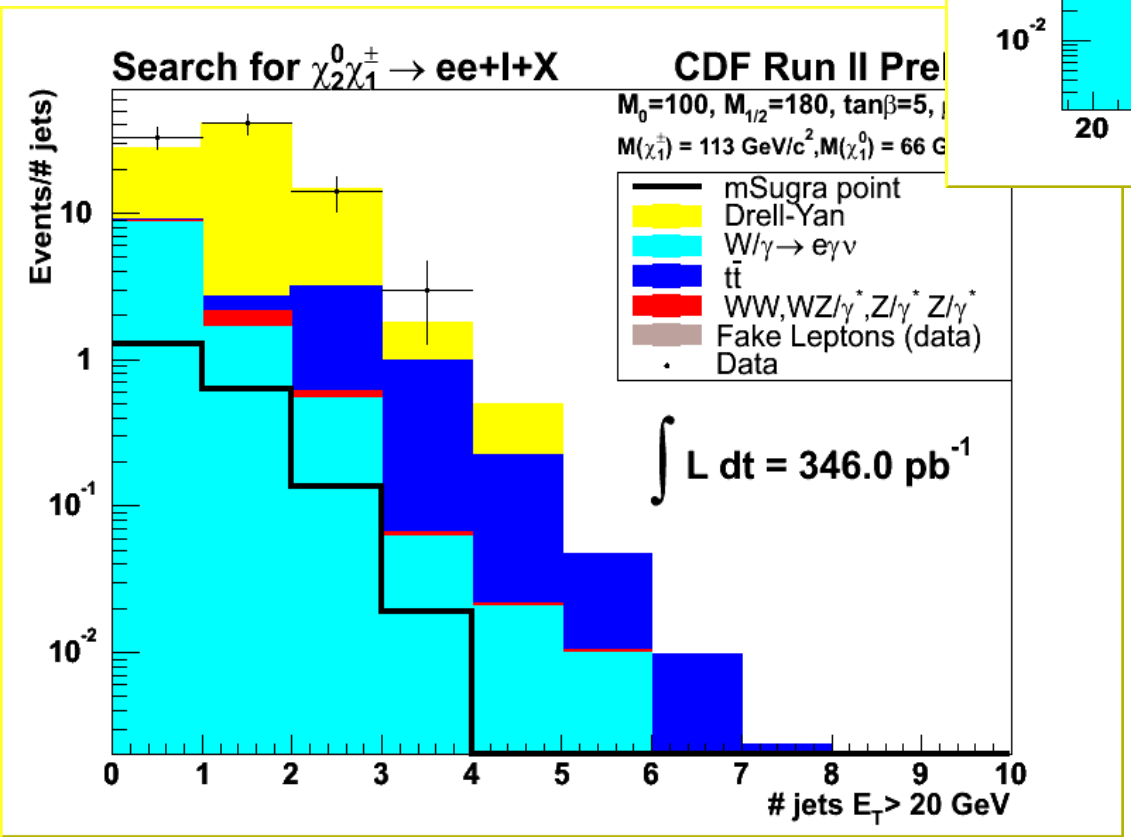
Single 20 GeV electron trigger

Expected SM : 0.17 ± 0.05

Signal point A : 0.49 ± 0.05

Observed : 0





Selection:

One 'tight' electron with $E_T > 20$ GeV

+ 'loose' ele + e/μ with $E_T/P_T > 8{,}4$ GeV

missing $E_T > 15$ GeV

$\Delta\Phi(ee) < 160$ deg

Njets < 2

High P_T Dimuon + Lepton Analysis

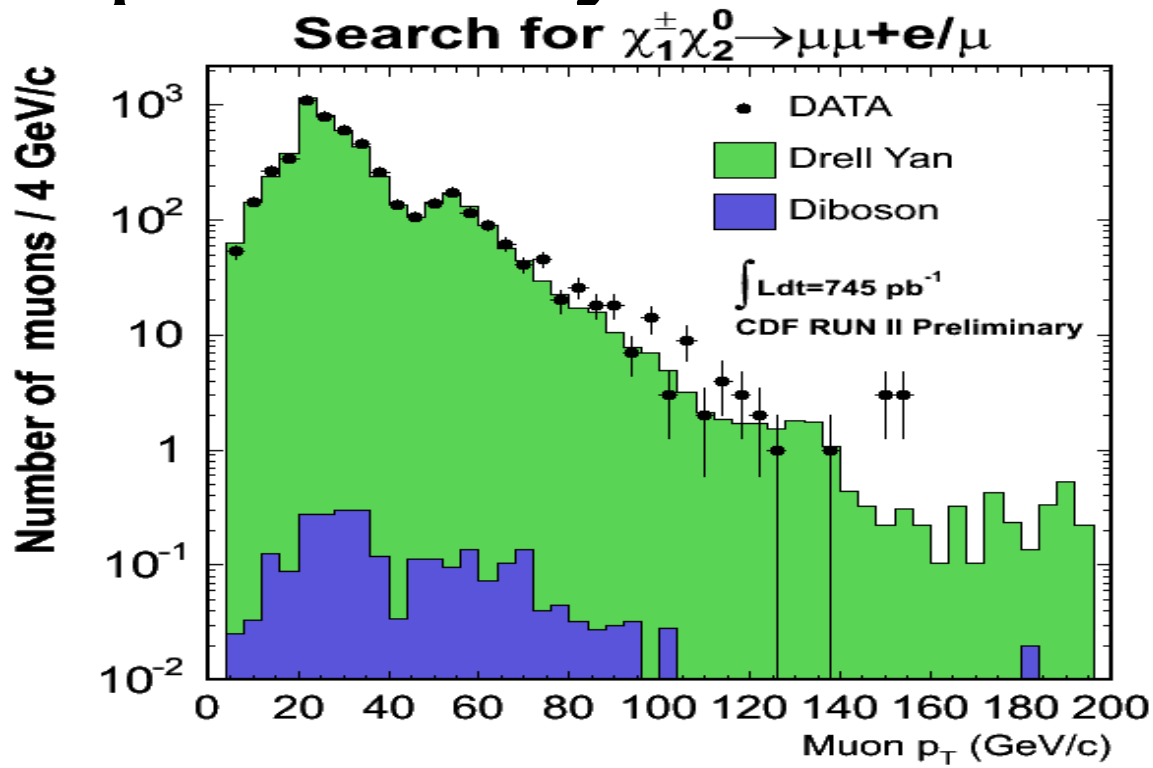
$\int Ldt = 745\ pb^{-1}$

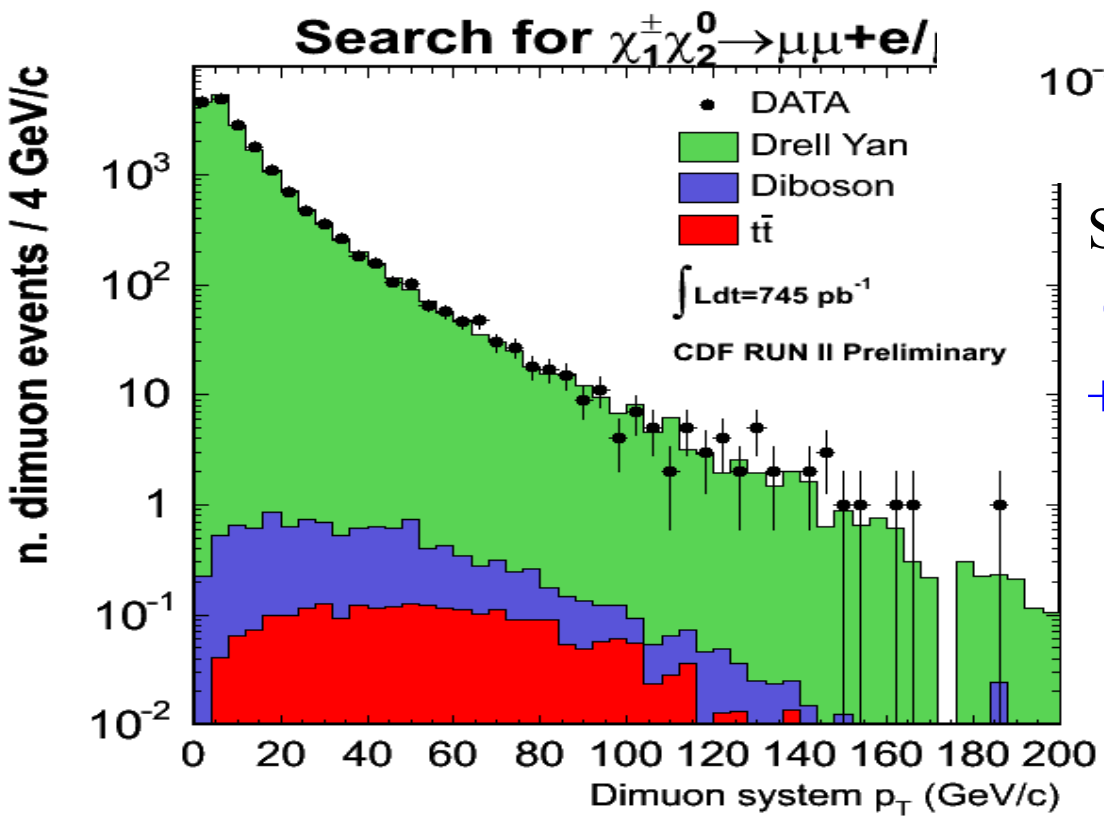
Single 20 GeV muon trigger

Expected bkgd : 0.64 ± 0.18

Signal point A : 1.6 ± 0.22

Observed : 1





Selection:

One 'tight' muon with $P_T > 20$ GeV

+ 'loose' muon + μ/e with $P_T/E_T > 5{,}5$ GeV

missing $E_T > 15$ GeV

Njets < 2

Additional selections to remove residual cosmics

μe + Lepton Analysis

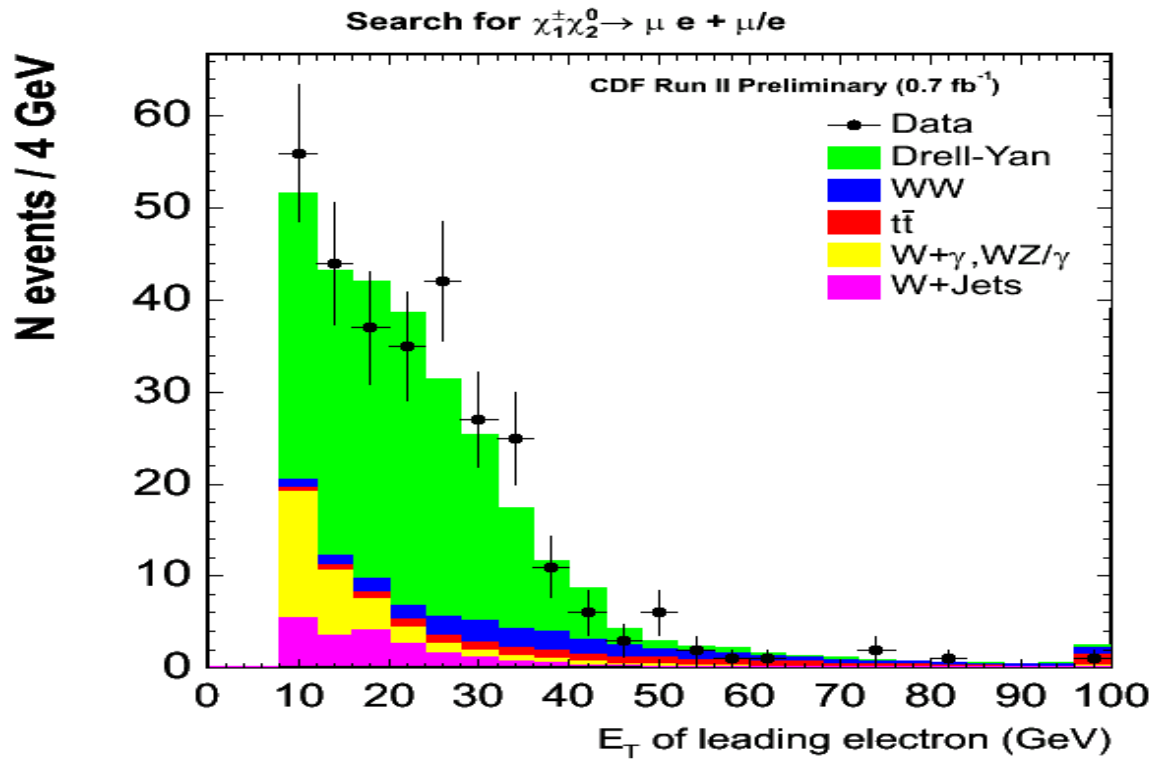
$\int Ldt = 680/745\ pb^{-1}$

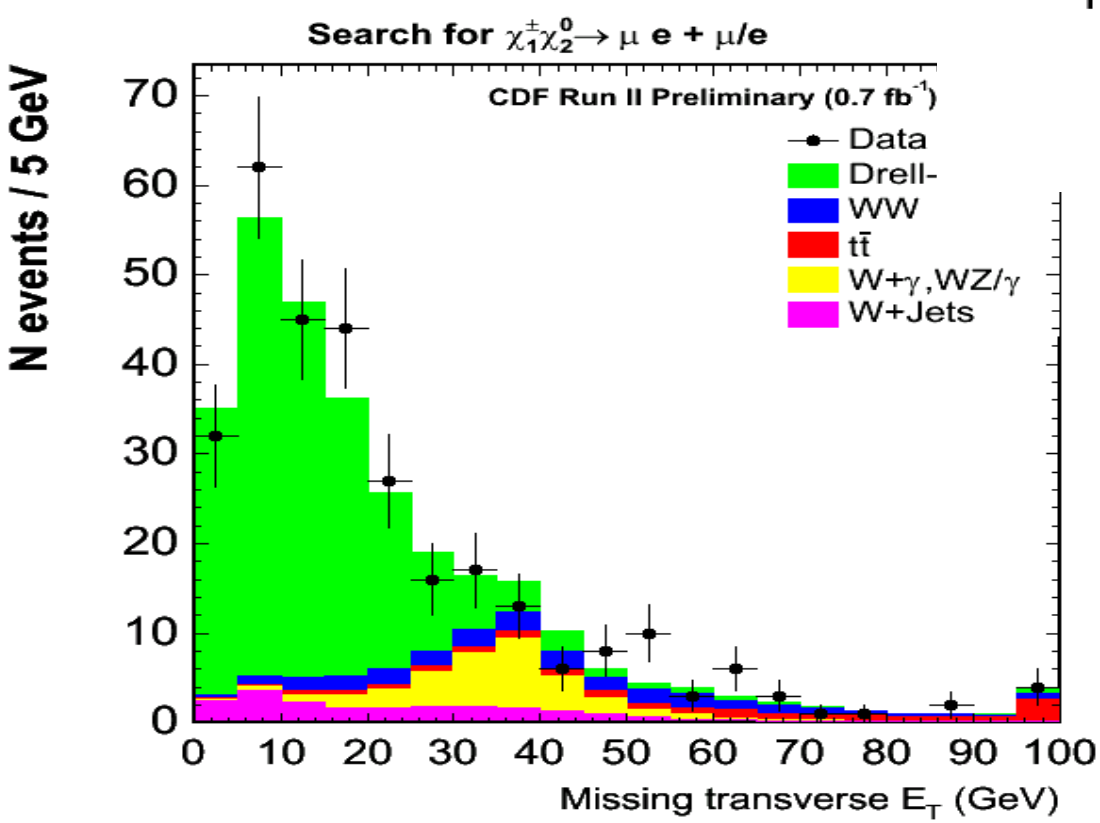
Single 20 GeV muon trigger

Expected bkgd : 0.78 ± 0.13

Signal point A : 1.03 ± 0.12

Observed : 0





Selection:

One 'tight' muon with $P_T > 20$ GeV

+ 'tight' ele + μ/e with $P_T/E_T > 8{,}5$ GeV

missing $E_T > 15$ GeV

Njets < 2

Low P_T Dimuon + Lepton Analysis

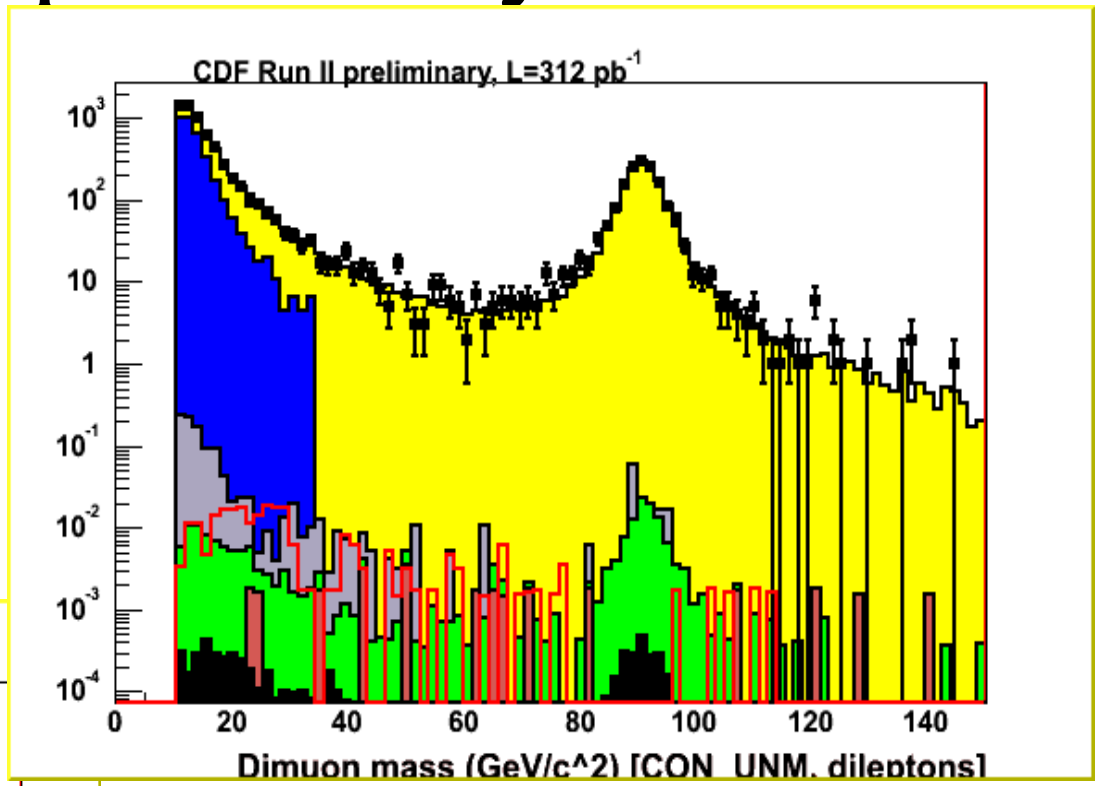
$\int Ldt = 312\ pb^{-1}$

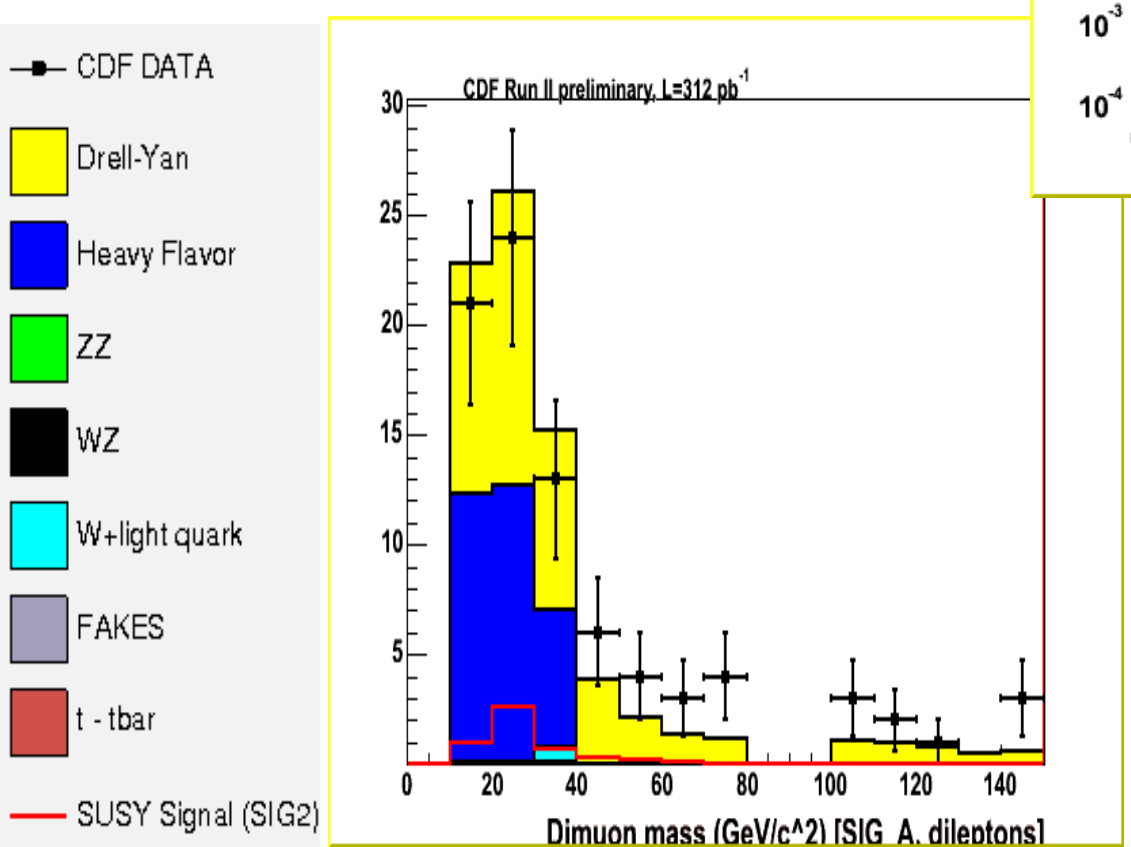
Dimuon trigger : 4 GeV each

Expected bkgd : 0.13 ± 0.04

Signal point A : 0.17 ± 0.03

Observed : 0





Selection:

Two 'tight' muons with $P_T > 5$ GeV

+ μ/e with $P_T/E_T > 5$ GeV

missing $E_T > 15$ GeV

Like sign dileptons ee,eμ,μμ

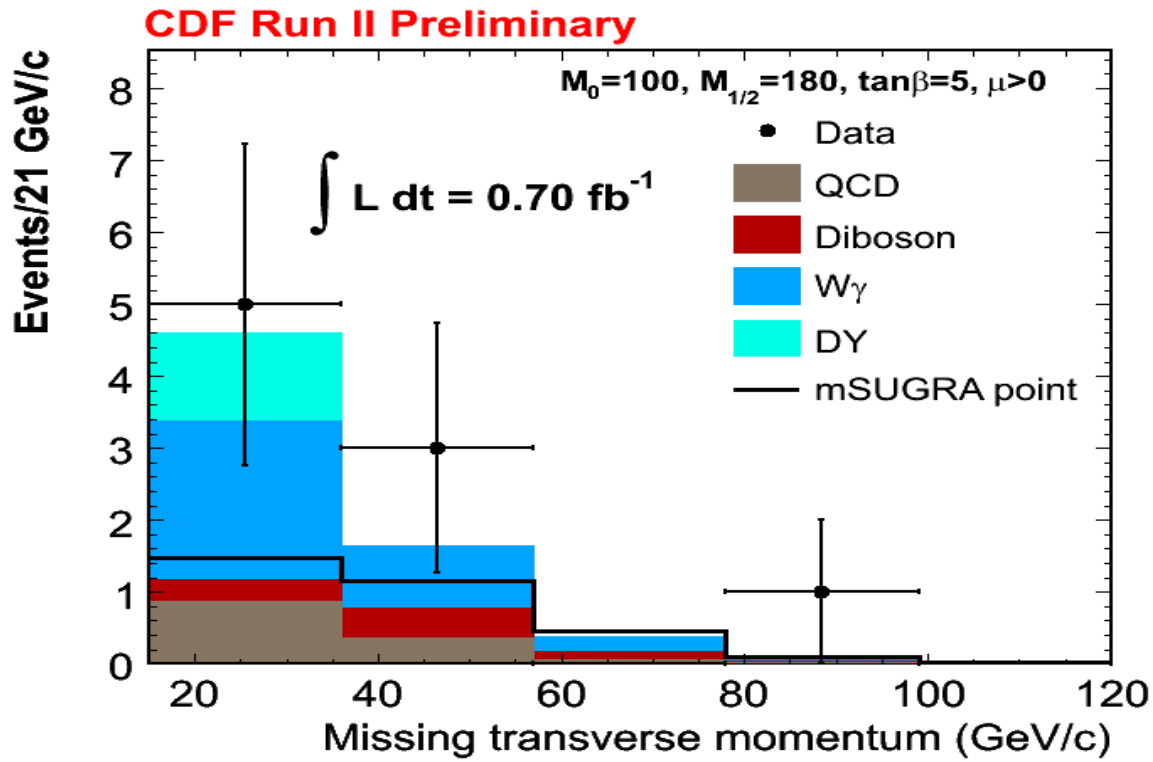
$\int Ldt = 704\ pb^{-1}$

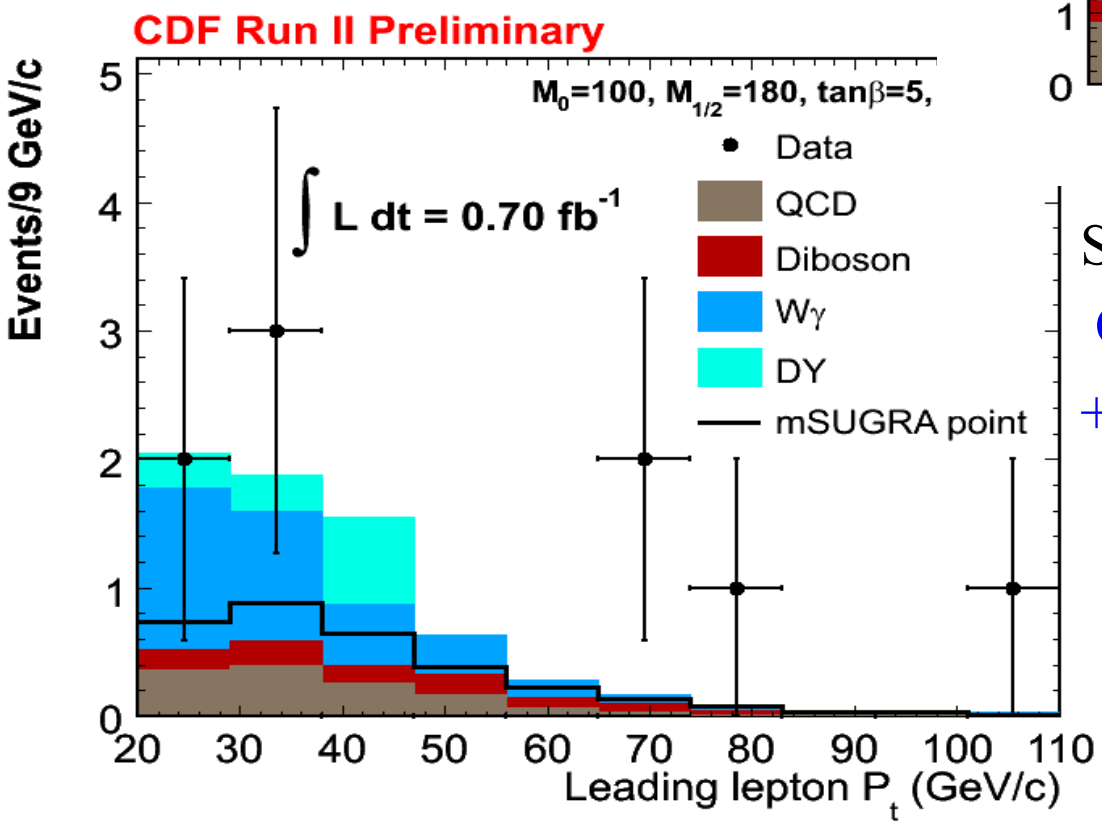
Single 20 GeV e/μ trigger

Expected bkgd : 6.8 ± 1.0

Signal point A : 3.2 ± 0.5

Observed : 9





Selection:

One 'tight' e/μ with E_T > 20 GeV

+ same sign tight e/μ with P_T/E_T > 10 GeV

missing E_T > 15 GeV

Signal A mSUGRA prameters:

M_0=100 $M_{1/2}$=180 tan(β)=5 A_0=0 μ>0

Combining the Analyses

Our observations are consistent with the standard model predictions.

We use a frequentist approach and set limits on (chargino-neutralino production) cross-section X branching ratio (chargino-neutralino to 3 leptons) as a function of chargino mass.

The analyses are combined as independent channels after all correlations between them in signal events and with background events has been taken care of.

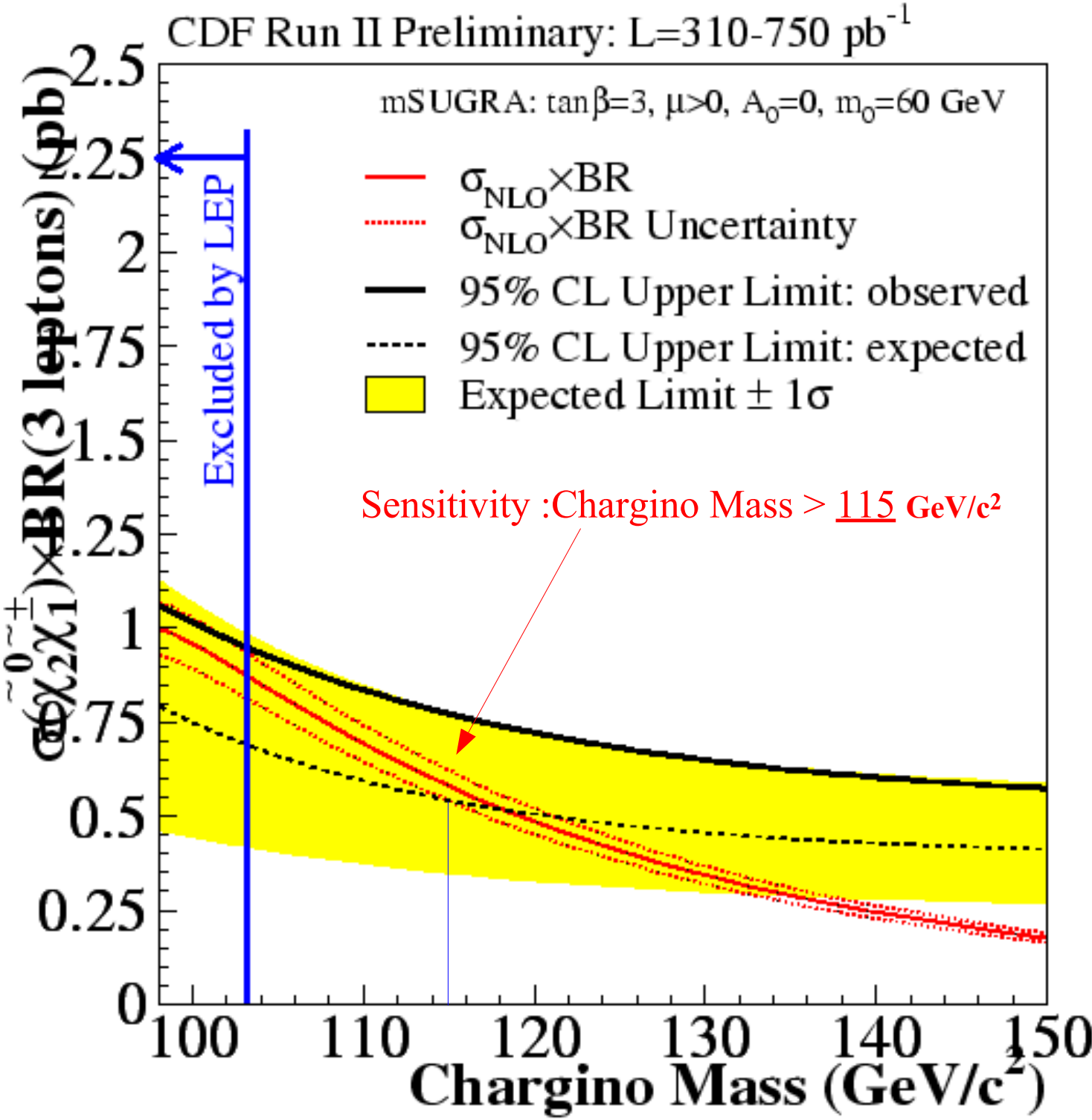
Care is taken to not over/under count signal acceptance, which is the single most important effect on the final limits.

We set such limits in two scenarios :

Limits

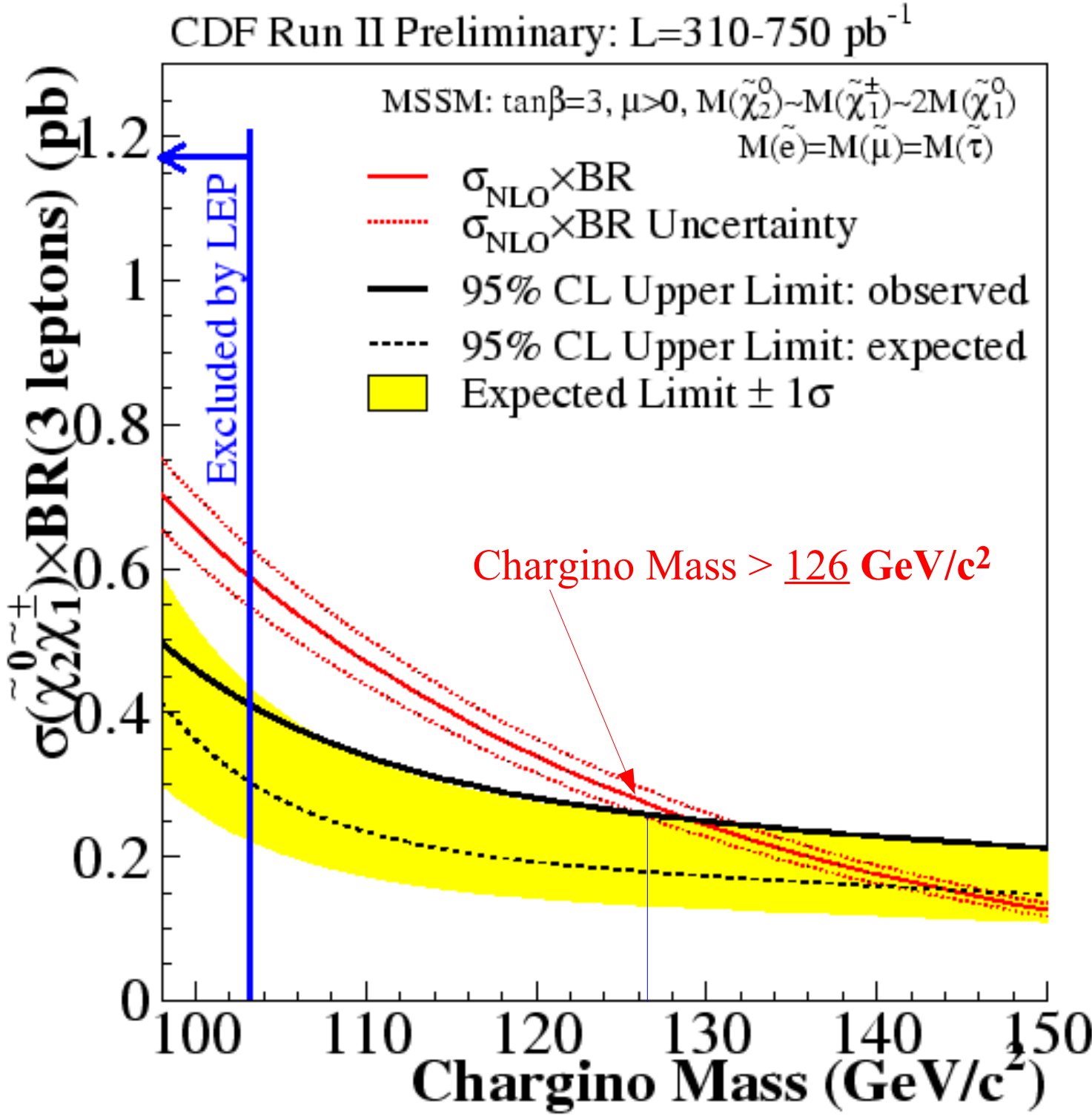
A) mSUGRA

no new exclusions



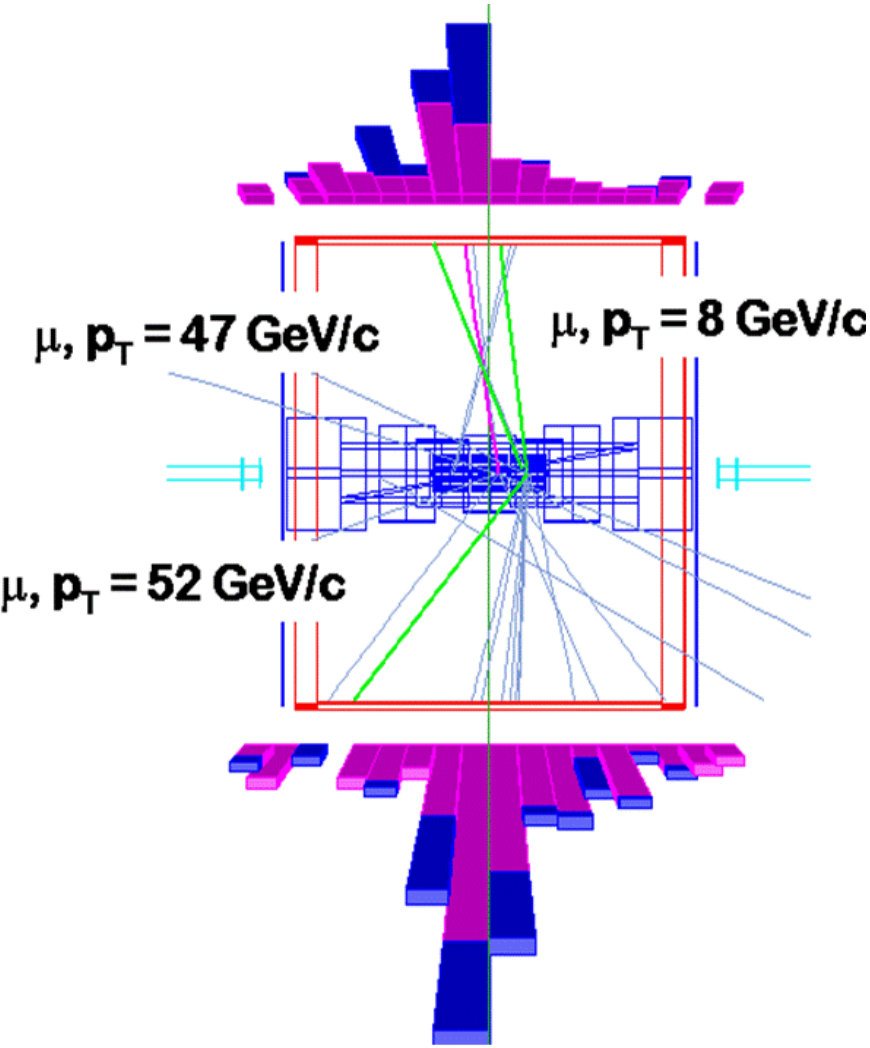
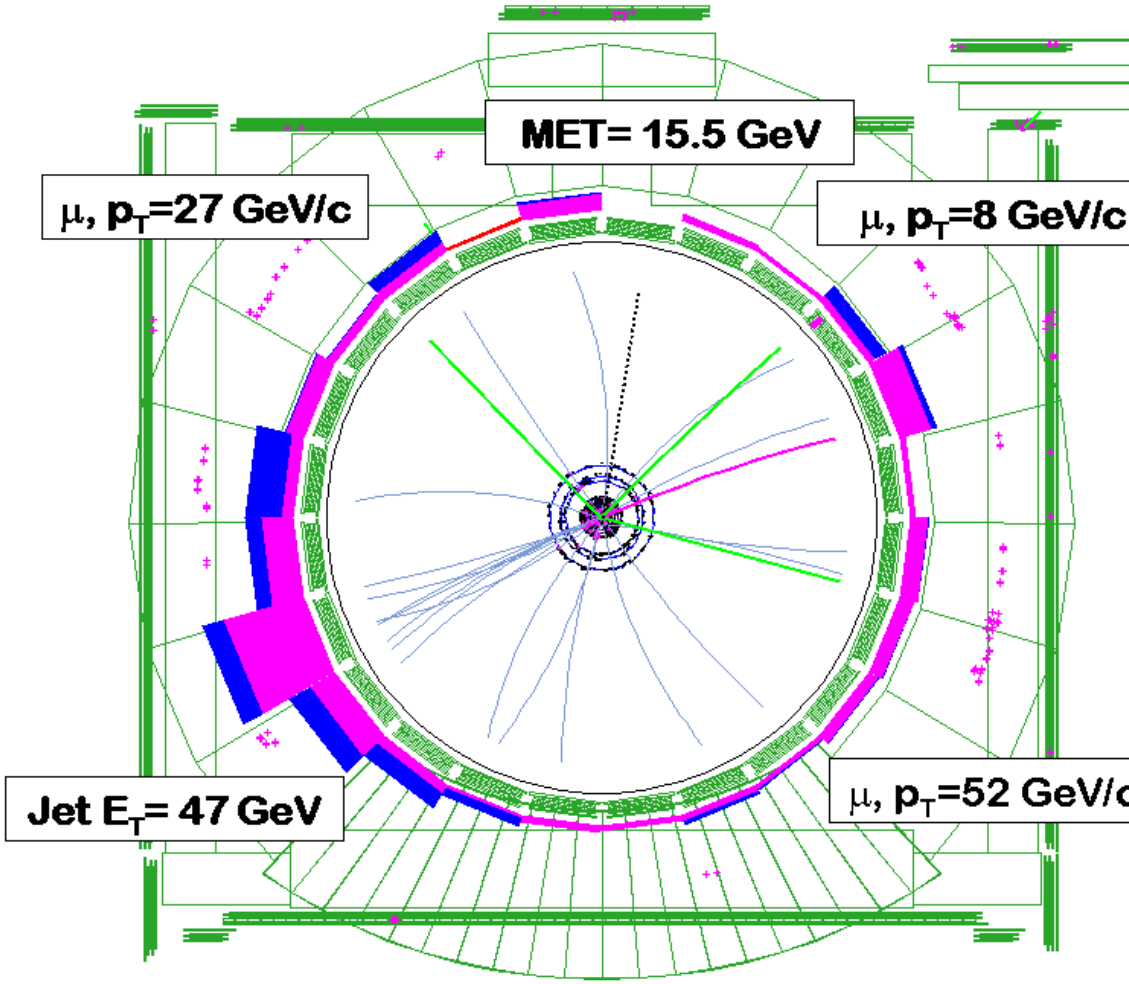
Limits

B) no slepton-mixing



Conclusion and Outlook

- CDF has searched for supersymmetry in the associated production of chargino-neutralino in various final states with luminosity upto 745 pb^{-1}.
- With our current analyses we can exclude chargino masses below 126 GeV at 95% C.L. assuming 'no slepton-mixing' occurs.
- We plan to extend each analysis channel to 1 inverse femtobarn shortly.
- Other models/final states are being investigated.
- Stay tuned for new developments from the Tevatron as we reach 2,4,6 fb^{-1}.

BACKUP

Event for Dimuon+e/μ analysis