Search for Supersymmetry at CDF **using Trileptons**

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RUTGERS
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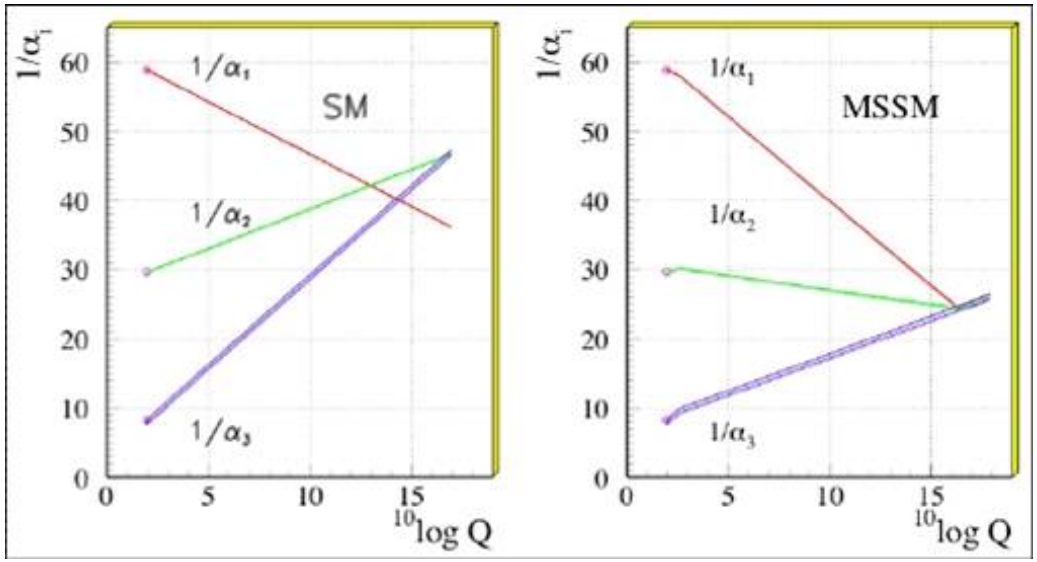
Supersymmetry

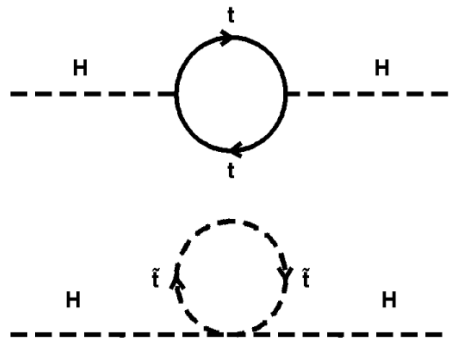
Proposes a new symmetry Fermions ↔ Bosons

Supersymmetry solves the hierarchy problem

Also provides an excellent dark matter candidate
(R_p conservation → LSP)

Gauge couplings are unified much better





27% down, 73% to go!!

mSUGRA

mSUGRA -- minimal SUper GRAvity grand unification

why? a) Widely used as a standard candle by Run I, LHC TDR's etc.

b) Manageable due to five parameters

Defined by five parameters

m_0 : common scalar mass at GUT scale

$m_{1/2}$: common gaugino mass at GUT scale

$M_1(GUT)=M_2(GUT)=M_3(GUT)= m_{1/2}$

$\tan(\beta)$: ratio of Higgs vacuum expectation values

A_0 : common trilinear scalar interaction at the GUT scale (Higgs-sfermionR-sfermionL)

$\text{sign}(\mu)$: μ is the Higgsino mass parameter ($|\mu^2|$ determined by EWSB)

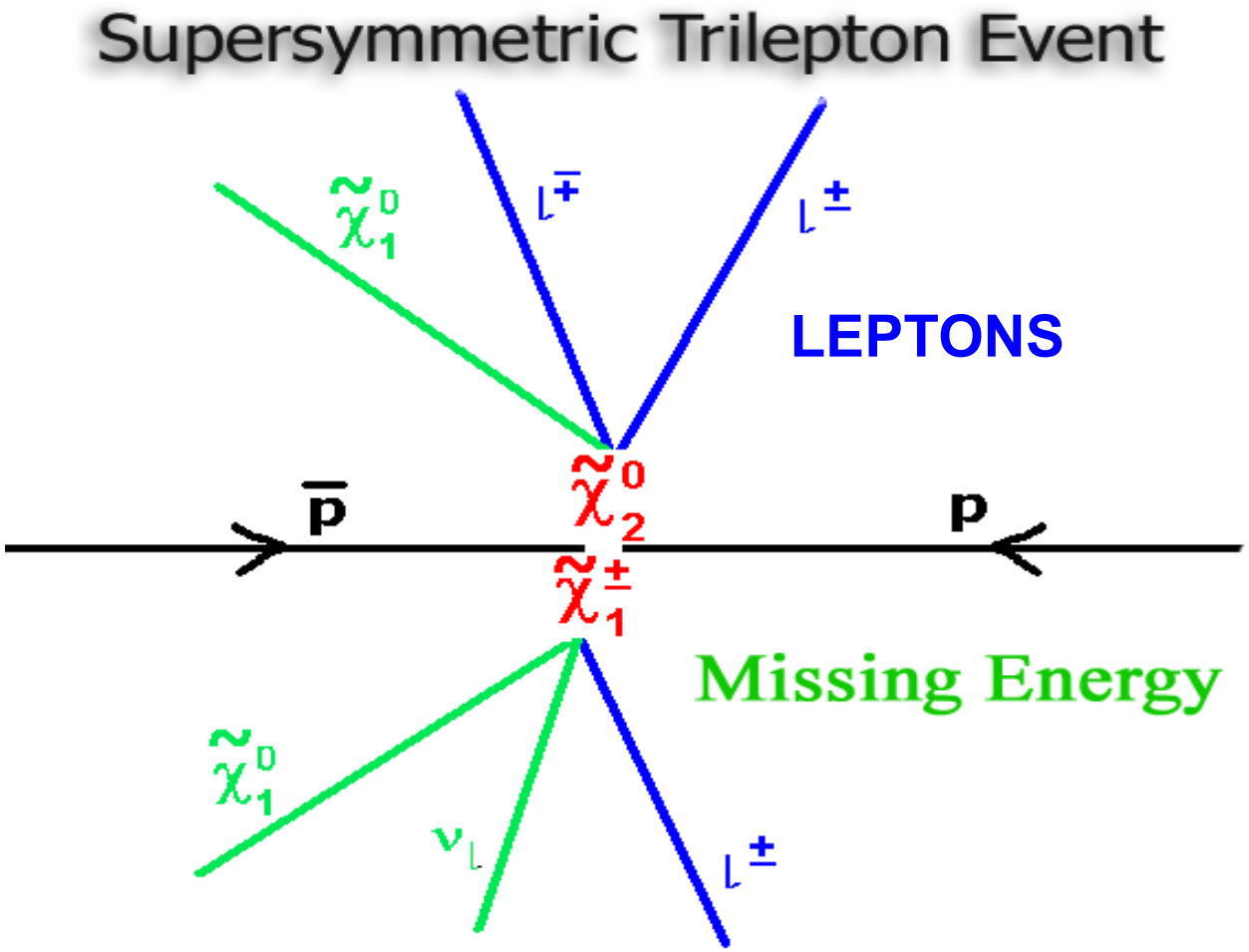
Signal Benchmark Point with parameters :
mSUGRA m_0=60 GeV, $m_{1/2}$=190 GeV,
$\tan(\beta)$=3, A_0=0, μ>0

Benchmark point
Mass Spectrum GeV

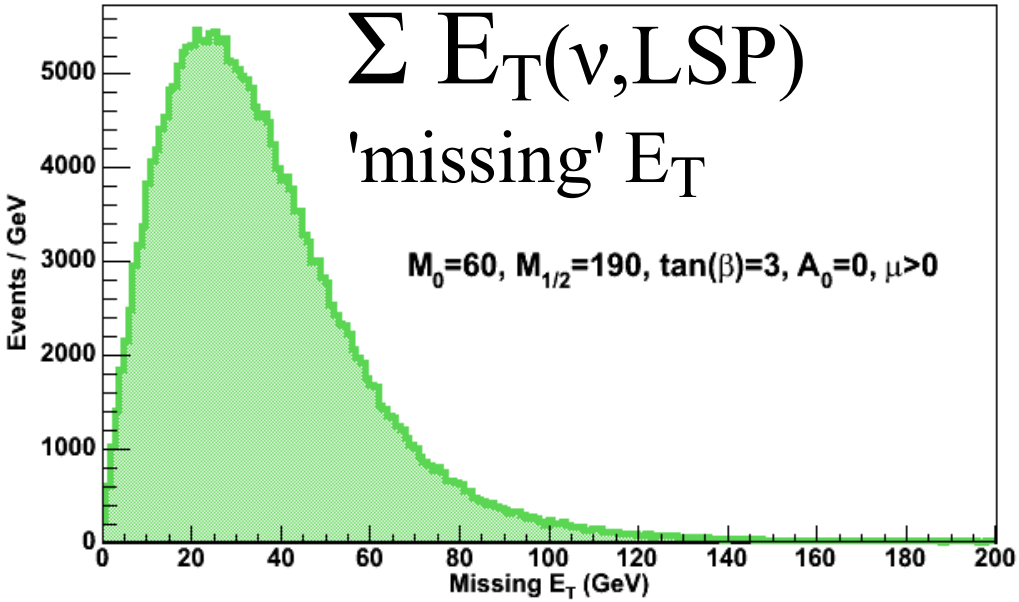
$\tilde{\chi}_2$	124
$\tilde{\chi}_1^{\pm}$	122
$\tilde{\chi}_1^0$	66
$\tilde{e}_L$	149
$\tilde{e}_R$	101
$\tilde{\tau}_1$	100
$\tilde{\tau}_2$	150
$\tilde{g}$	477
$\tilde{u}_R$	421
$\tilde{d}_L$	439

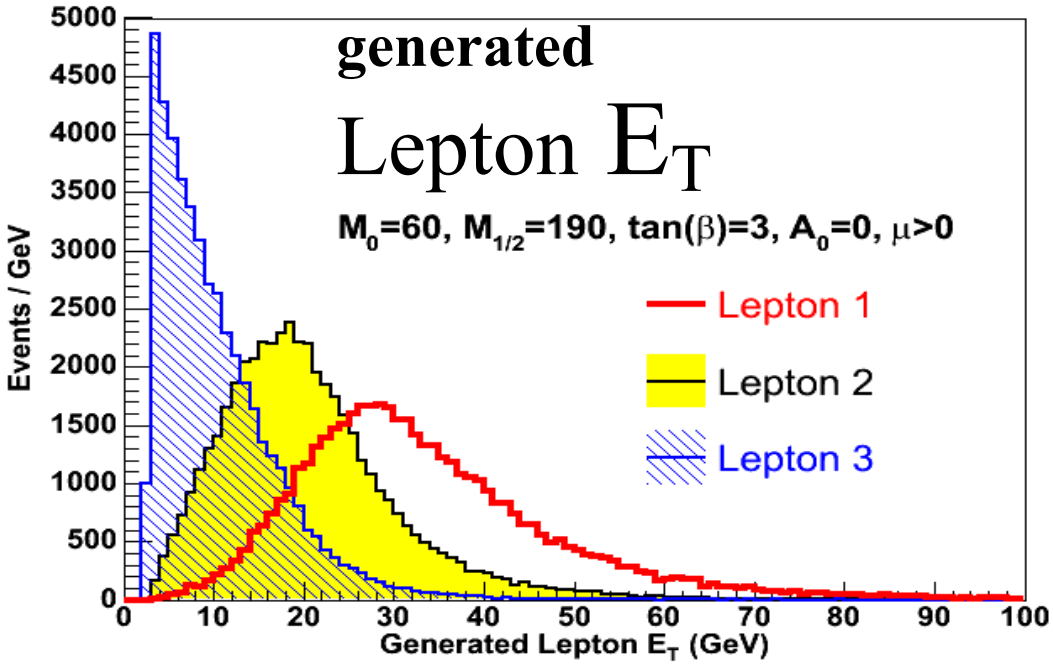
Chargino/Neutralino Trilepton Decay

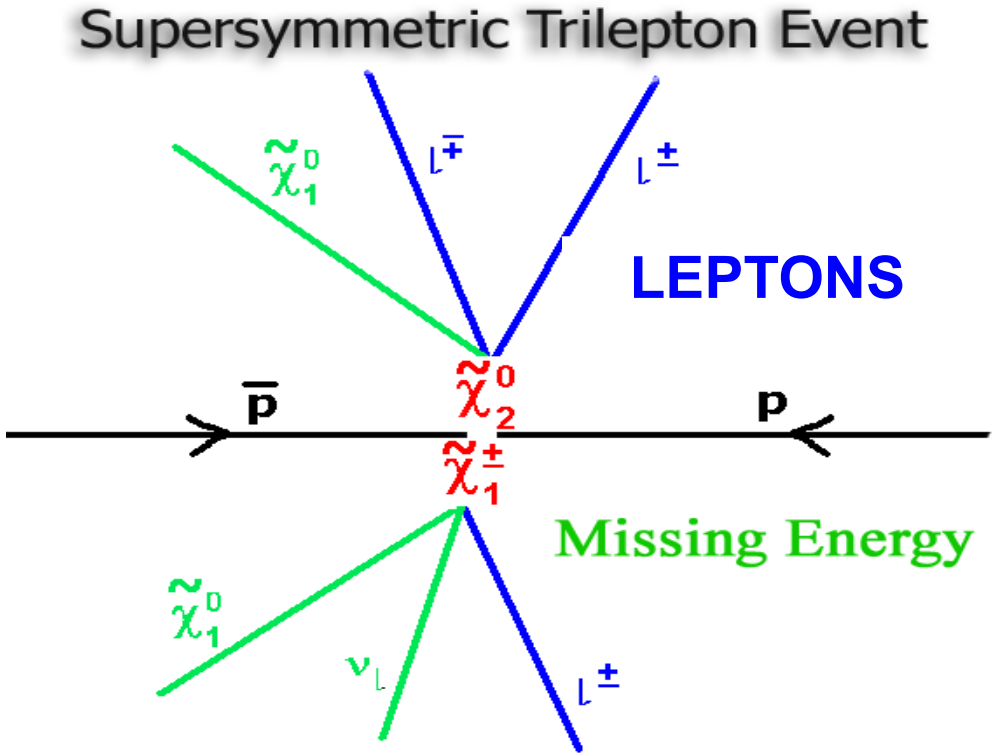
Charginos/Neutralinos decay via virtual W,Z or sleptons. Observe three leptons + missing energy(MET) from decays of lightest Chargino $\tilde{\chi}_1^{\pm}$ and next-to-lightest Neutralino $\tilde{\chi}_2^0$



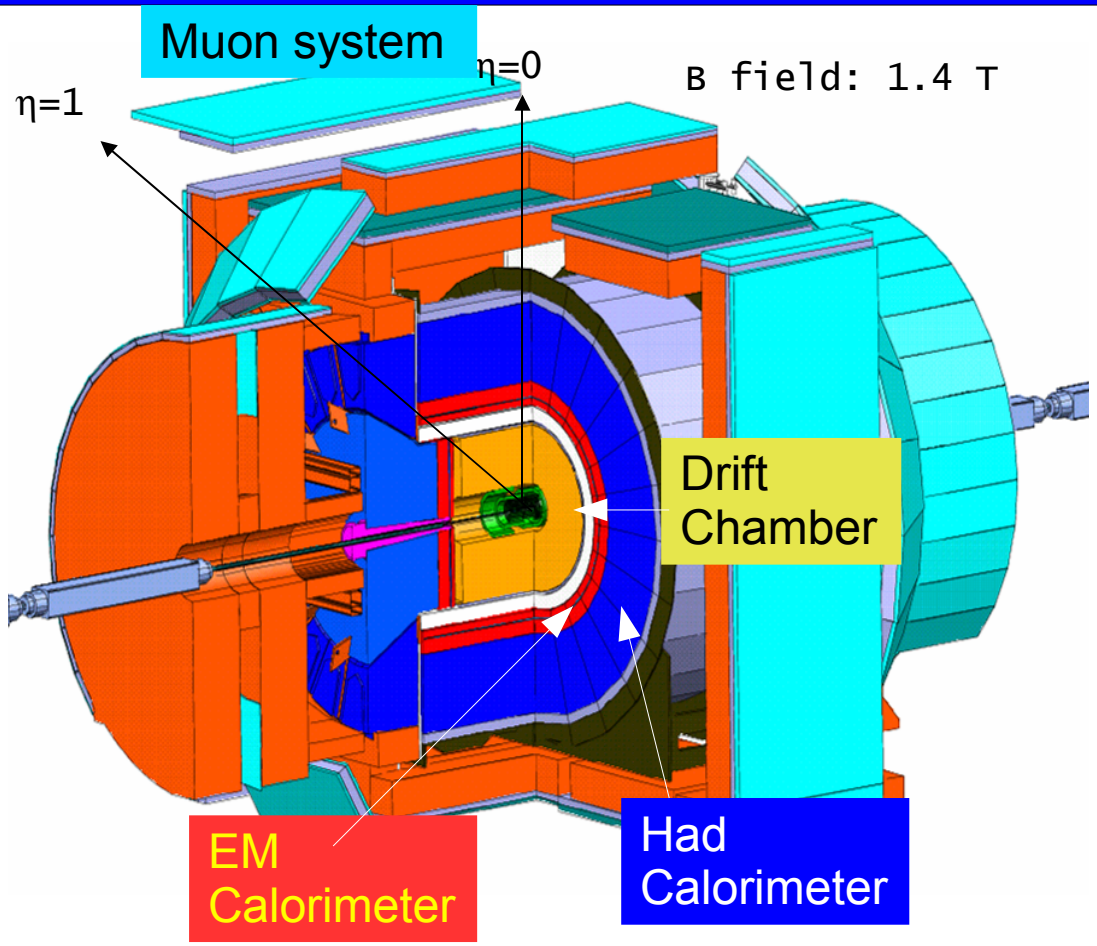
Signature of Interest

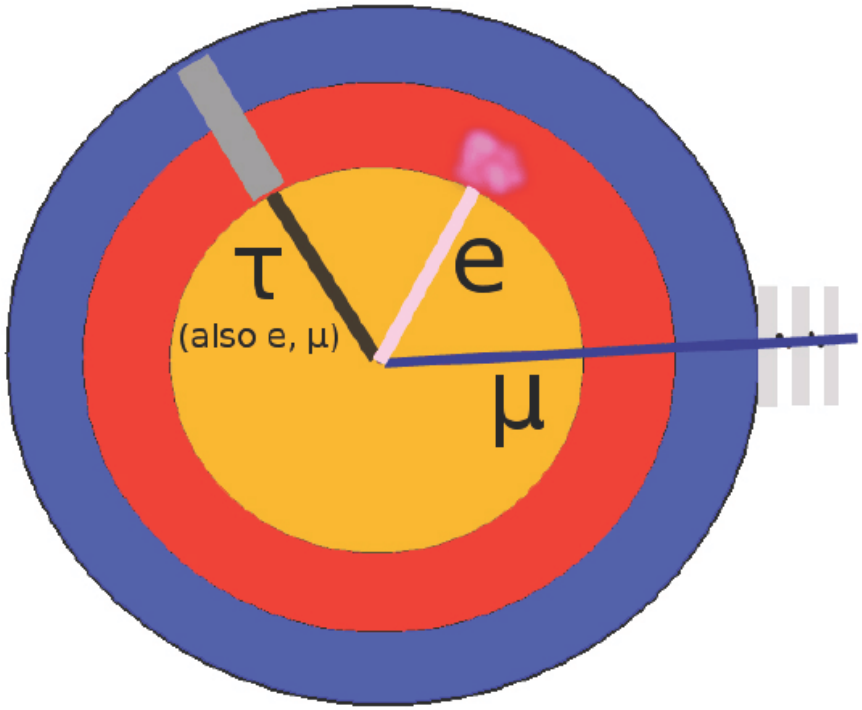






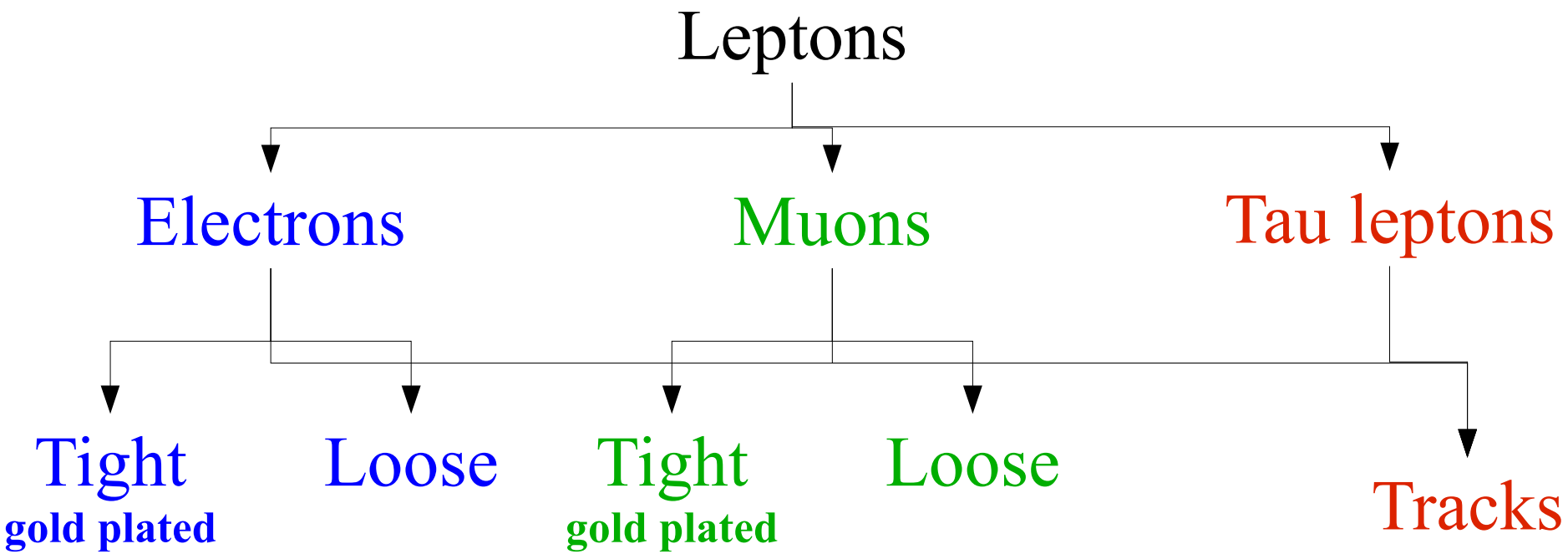
CDF Detector





Total Integrated Luminosity for this result is 2.0 fb^{-1}

Three Leptons : Types



For example, Loose Electron has E/p < 2 and HadE/EmE < 5%
Tight Electron has additional requirements based on shower shape of electron in calorimeter, pointing of track to calorimeter shower etc.

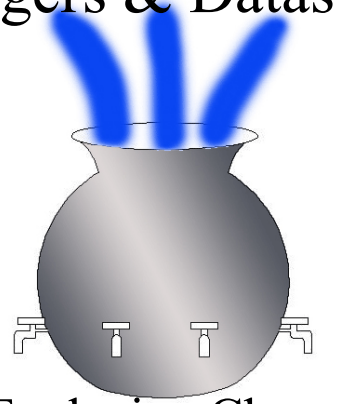
Setting up the Analysis

Challenge : Overlapping datasets with multiple trigger paths.

Channels in this analysis are

A) Mutually **exclusive** and,
B) Ordered in terms of purity (S/B).

Triggers & Datasets



Exclusive Channels

Setting up the Analysis

Challenge : Overlapping datasets with multiple trigger paths.

Channels in this analysis are

A) Mutually **exclusive** and,
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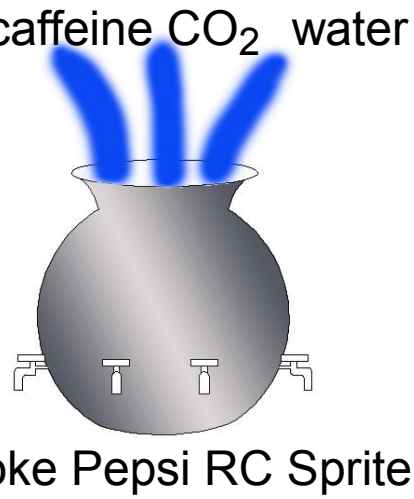


S/B

Find three tight leptons

Else, two tight leptons and a loose lepton.

Else, one tight and two loose leptons.

Else, two tight leptons and one isolated track.

Else, one tight, one loose lepton and one isolated track.

SM Backgrounds

Our signature is three leptons + missing energy –
What SM processes also look like this?

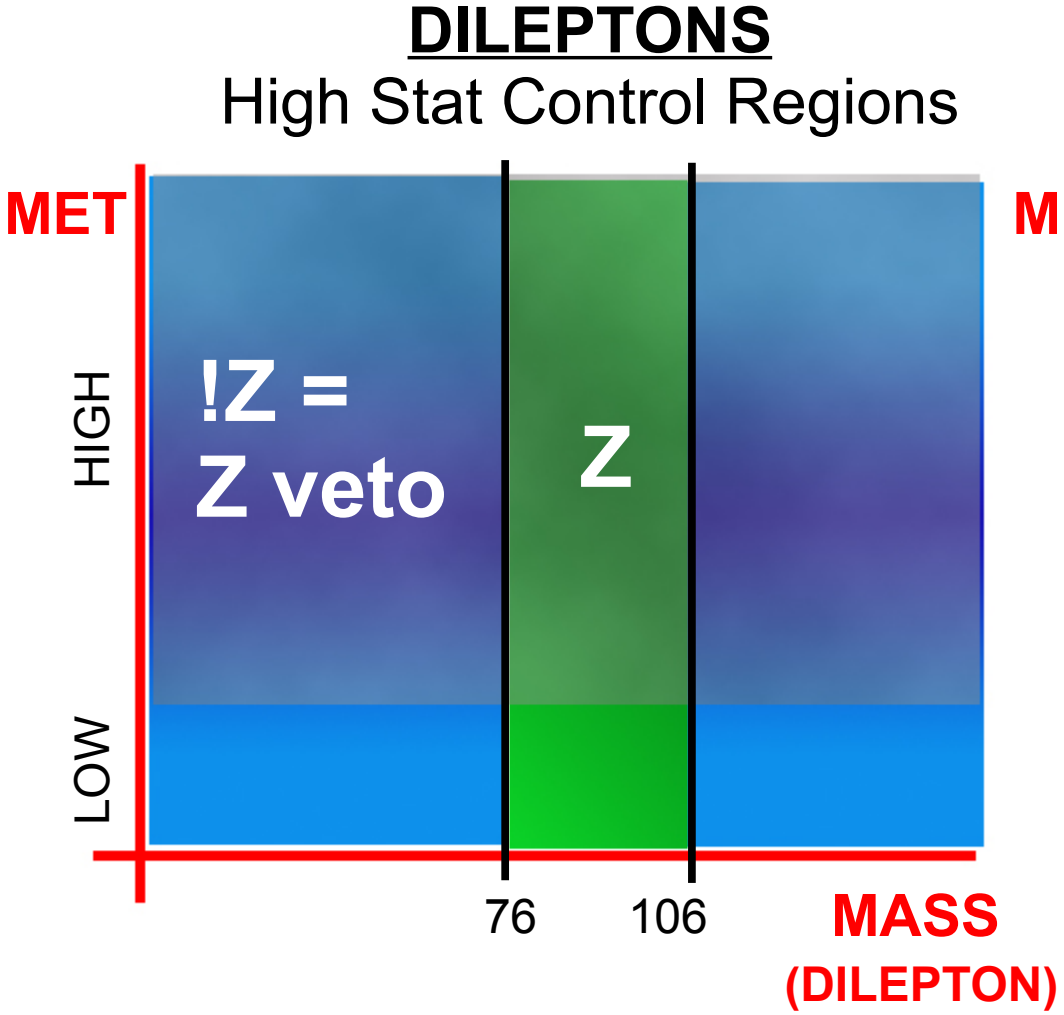
Process	
WZ	3 leptons + missing E_T
ZZ	4 leptons
DY	2 leptons
WW	2 leptons + missing E_T
top-pair	2 leptons + missing E_T
	a) + γ conversion
	b) + track from underlying event
	c) + hadron misidentified as lepton
W+jets	1 lepton + missing E_T
	a) + track from jets
	b) + hadron misidentified as lepton

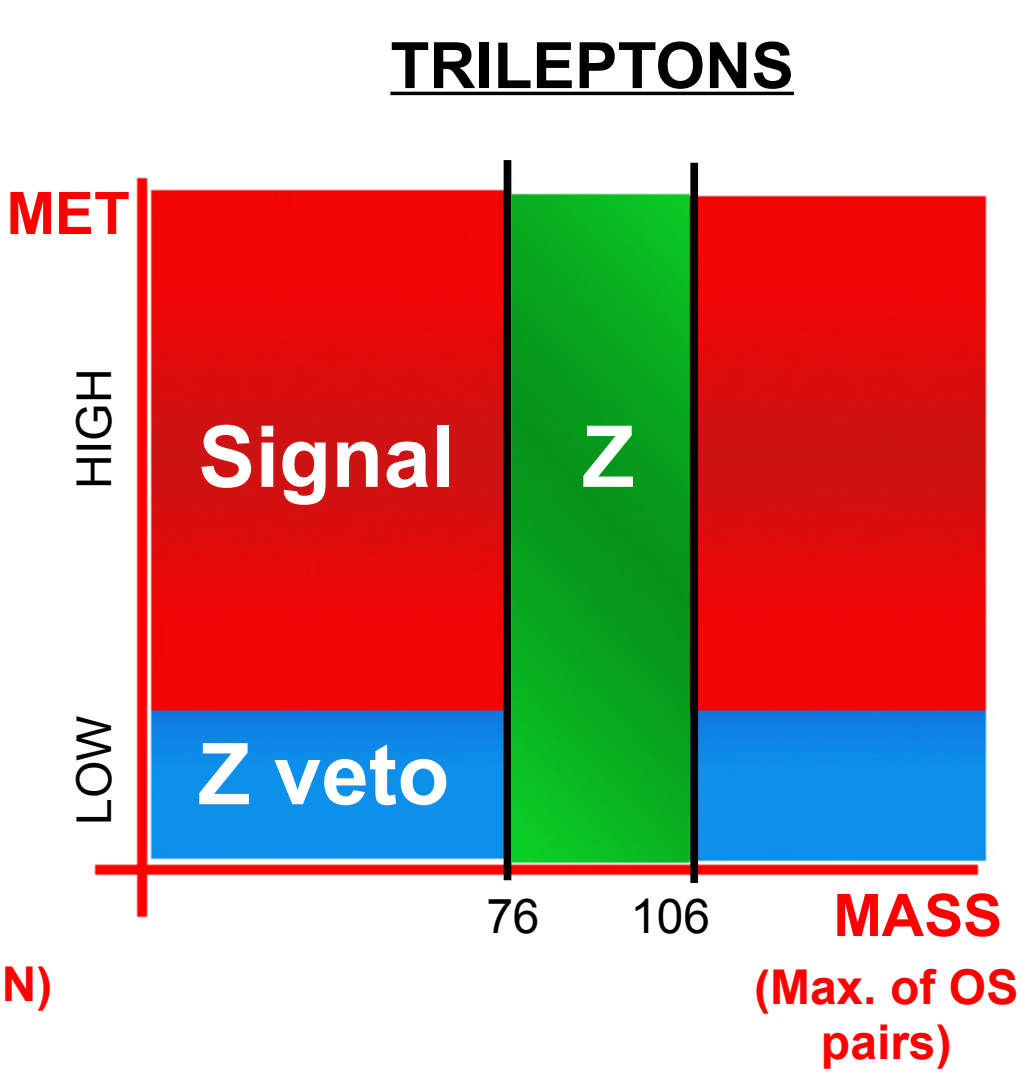
Three Real Leptons

Two Leptons + 'Fake'

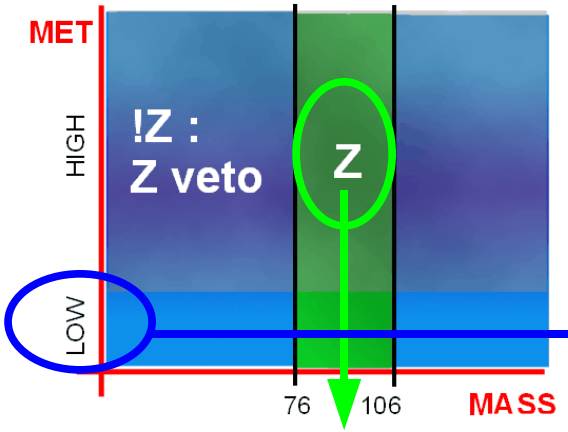
One Lepton + 'Fake' + Track

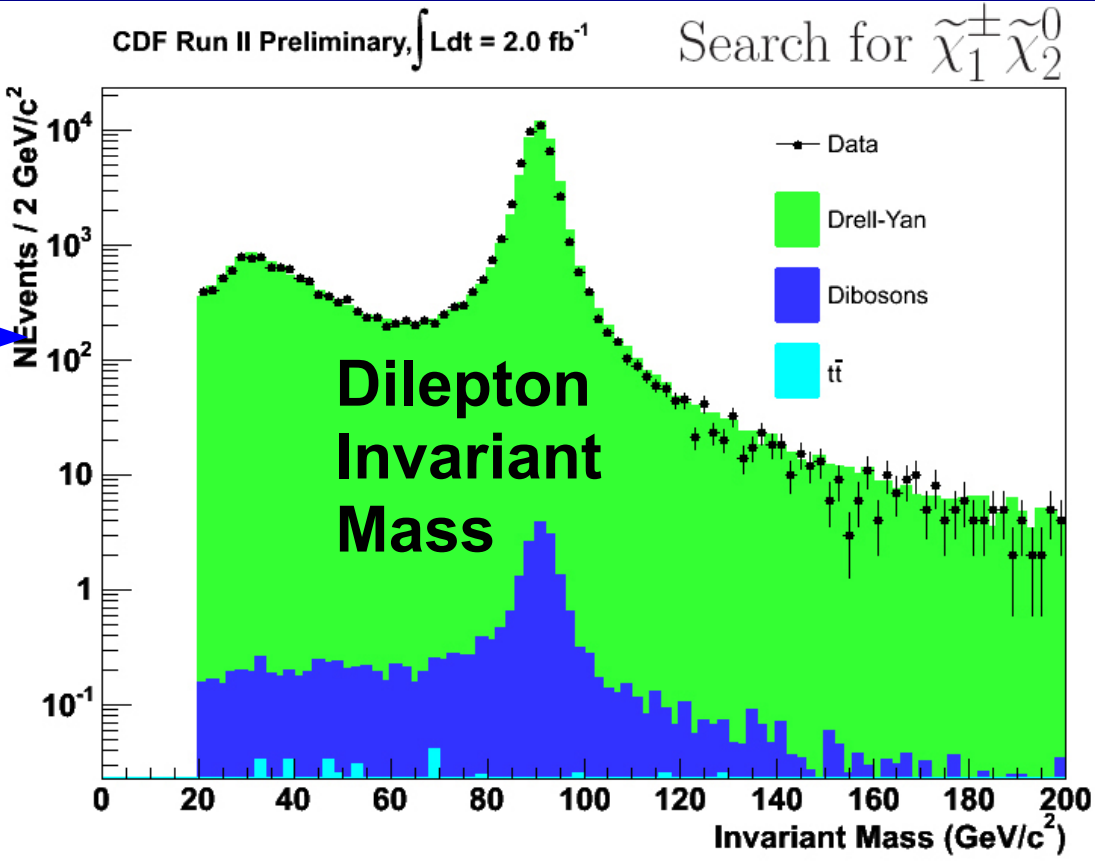
Testing Background Predictions

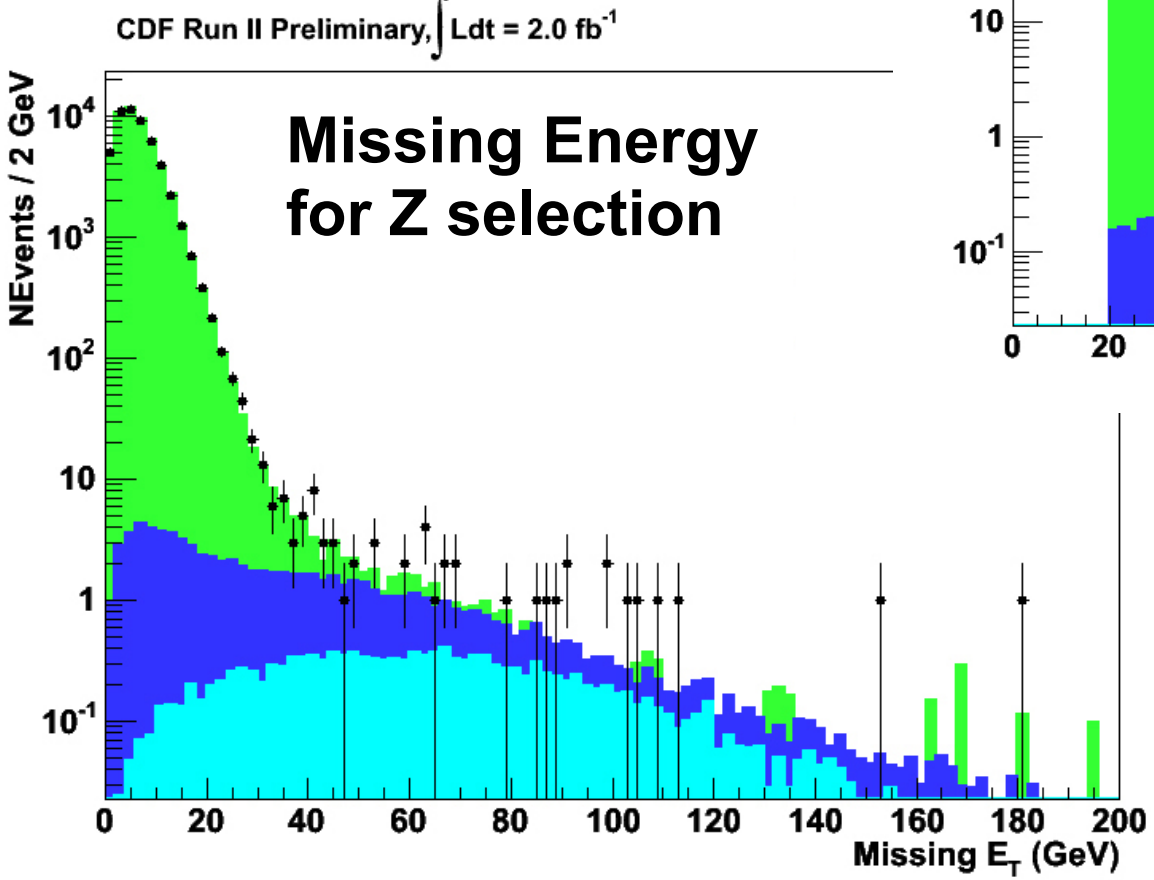




Control Regions : Dileptons

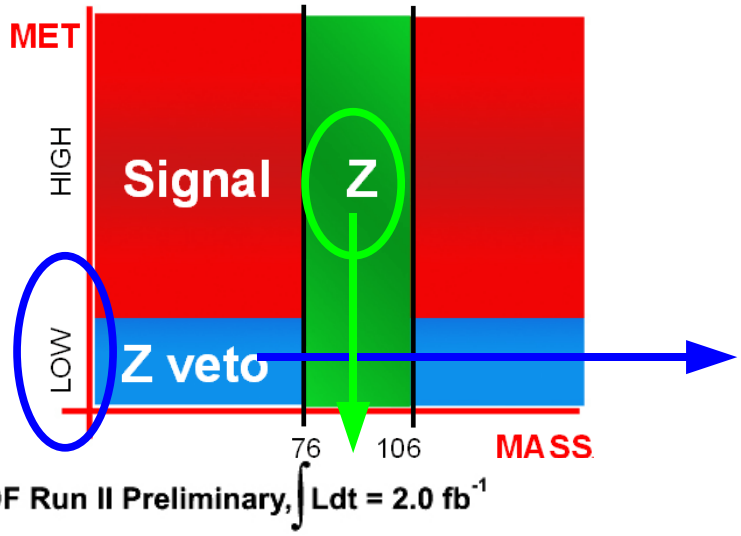


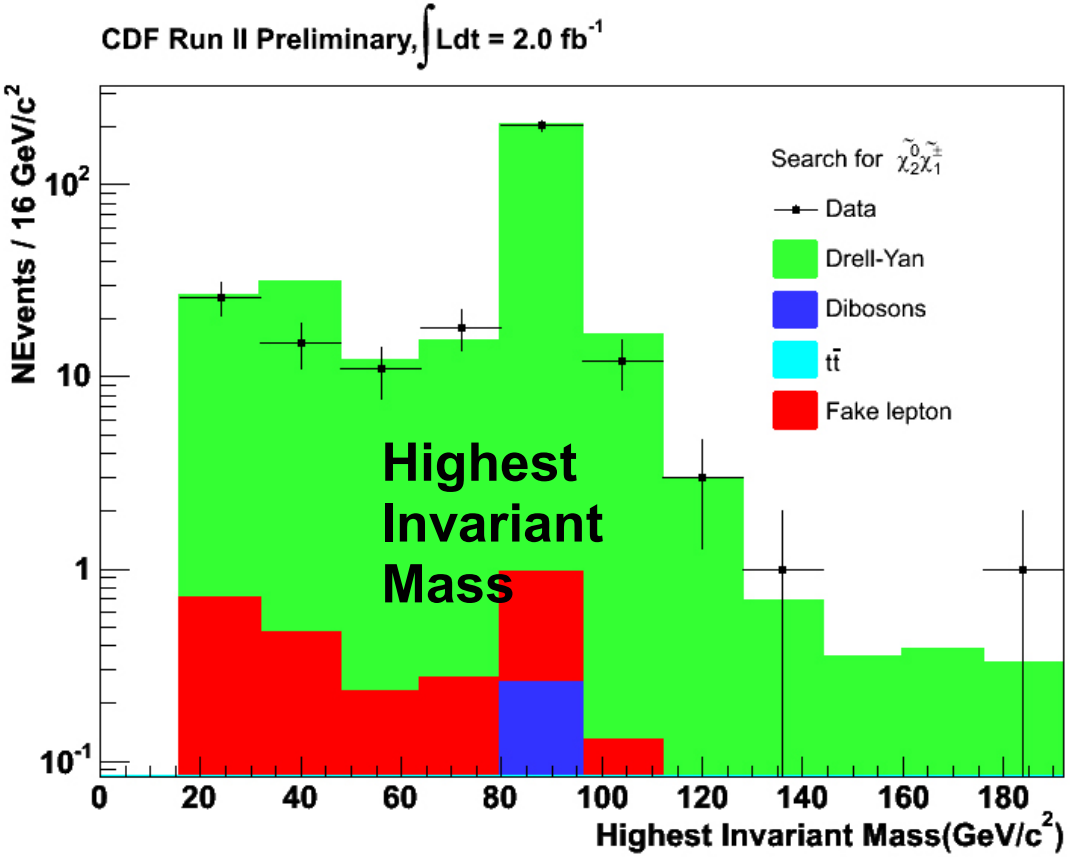


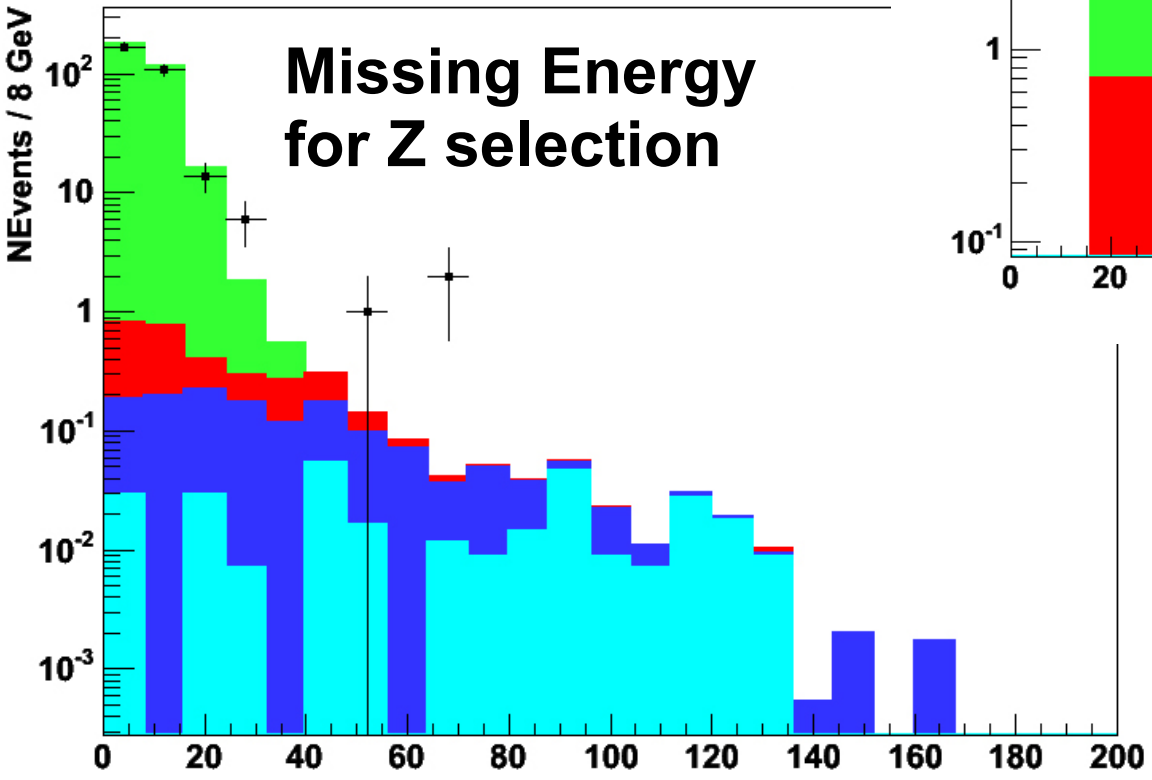


Selection :
2 tight leptons

Control Regions : Trileptons







Selection :
2 tight leptons + 1 Track

Reducing Backgrounds

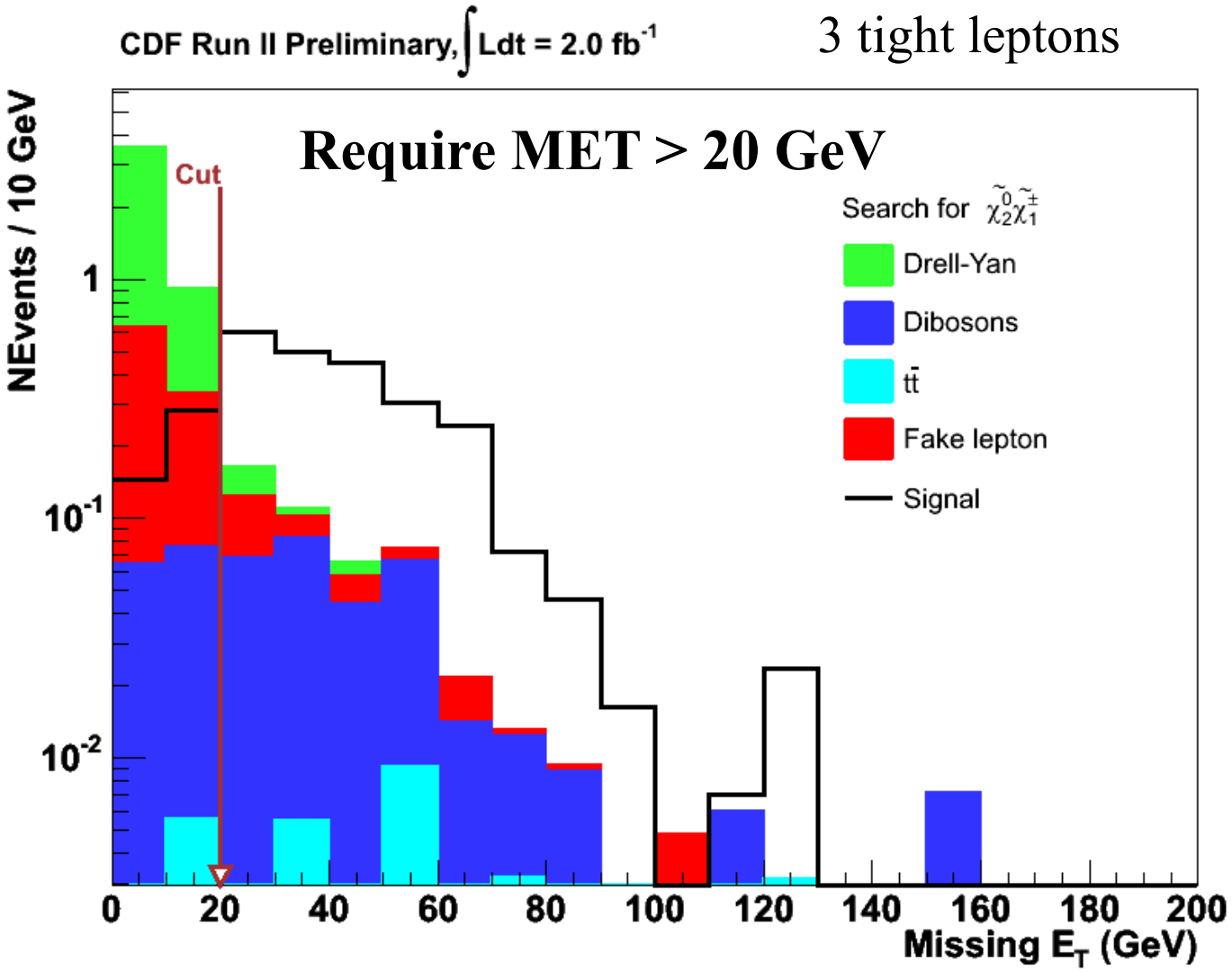
Process		How to reduce?
Drell-Yan + γ Drell-Yan + track	low MET	make MET cut
top-pair production hadrons faking leptons	has jets	require no more than 1 jet

Dibosons : WZ,ZZ — on-shell contribution of Z can be removed by a invariant mass cut for the Z.

off-shell contribution for ZZ → make MET cut

off-shell contribution is irreducible for WZ

Example : Reducing Drell-Yan, ZZ



After all other selections are made

Signal : mSUGRA m_0=60, $m_{1/2}$=190, tan(β)=3, A_0=0, μ>0, M($\chi_1^\pm$)=120 GeV/c^2

Final Predictions & Observations

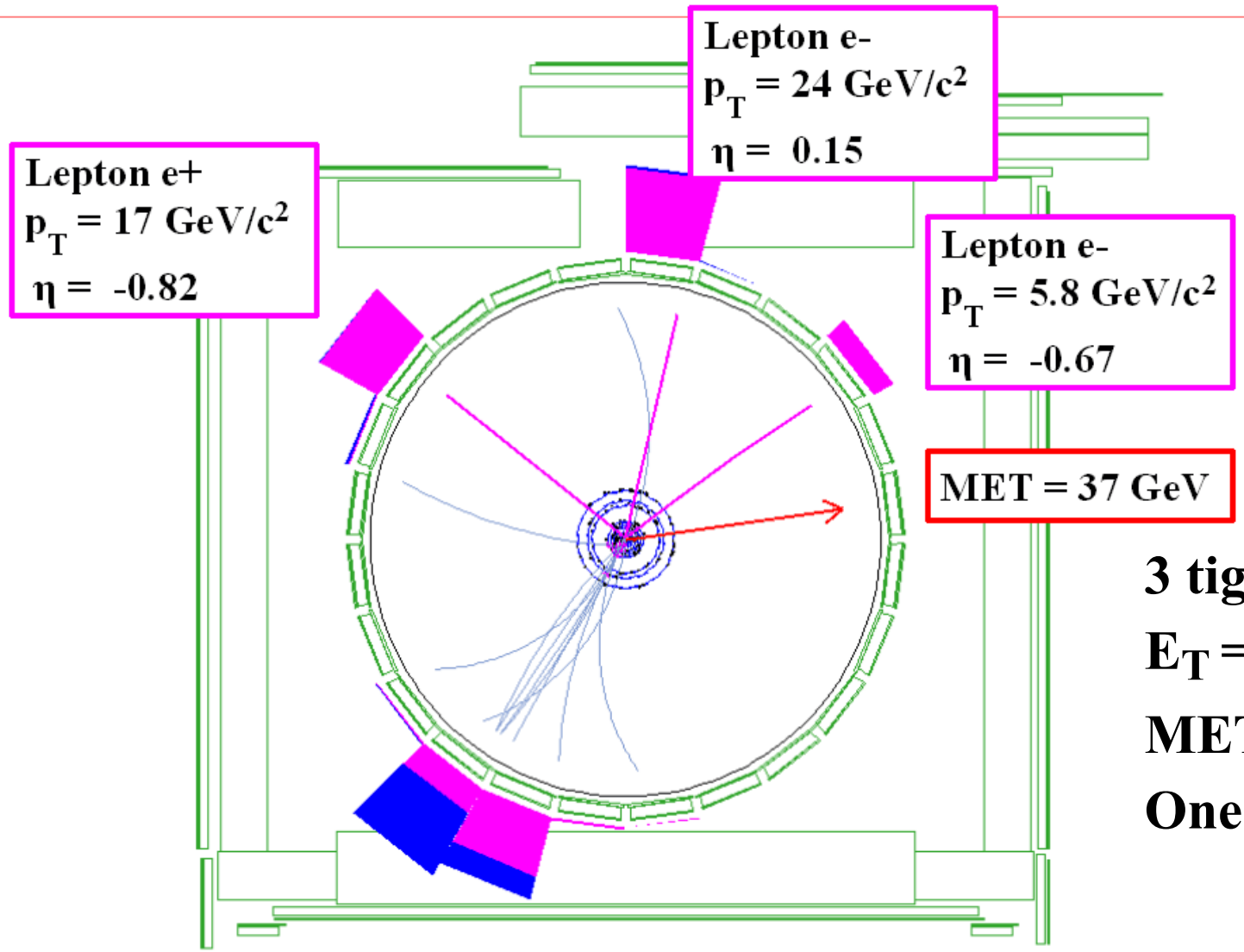
$CDF\ Run\ II\ Preliminary \int \mathcal{L}dt = 2.0 fb^{-1}$

Channel	Expected Signal	Background	Observed
3tight	2.3±0.1±0.3	0.5±0.04±0.1	1
2tight,1loose	1.6±0.1±0.2	0.3±0.03±0.03	0
1tight,2loose	0.7±0.1±0.1	0.1±0.02±0.02	0
Total trilepton	4.6±0.2±0.6	0.9±0.1±0.2	1
2tight,1Track	4.4±0.2±0.6	3.2±0.5±0.5	4
1tight,1loose,1Track	2.4±0.1±0.3	2.3±0.5±0.4	2
Total dilepton+track	6.8±0.2±0.9	5.5±0.7±0.9	6

Total Expected Signal = 11.4 events

Signal : mSUGRA m_0=60, $m_{1/2}$=190, tan(β)=3, A_0=0, μ>0, $M(\chi_1^{\pm})$=120 GeV/c^2

3 Tight Lepton Event



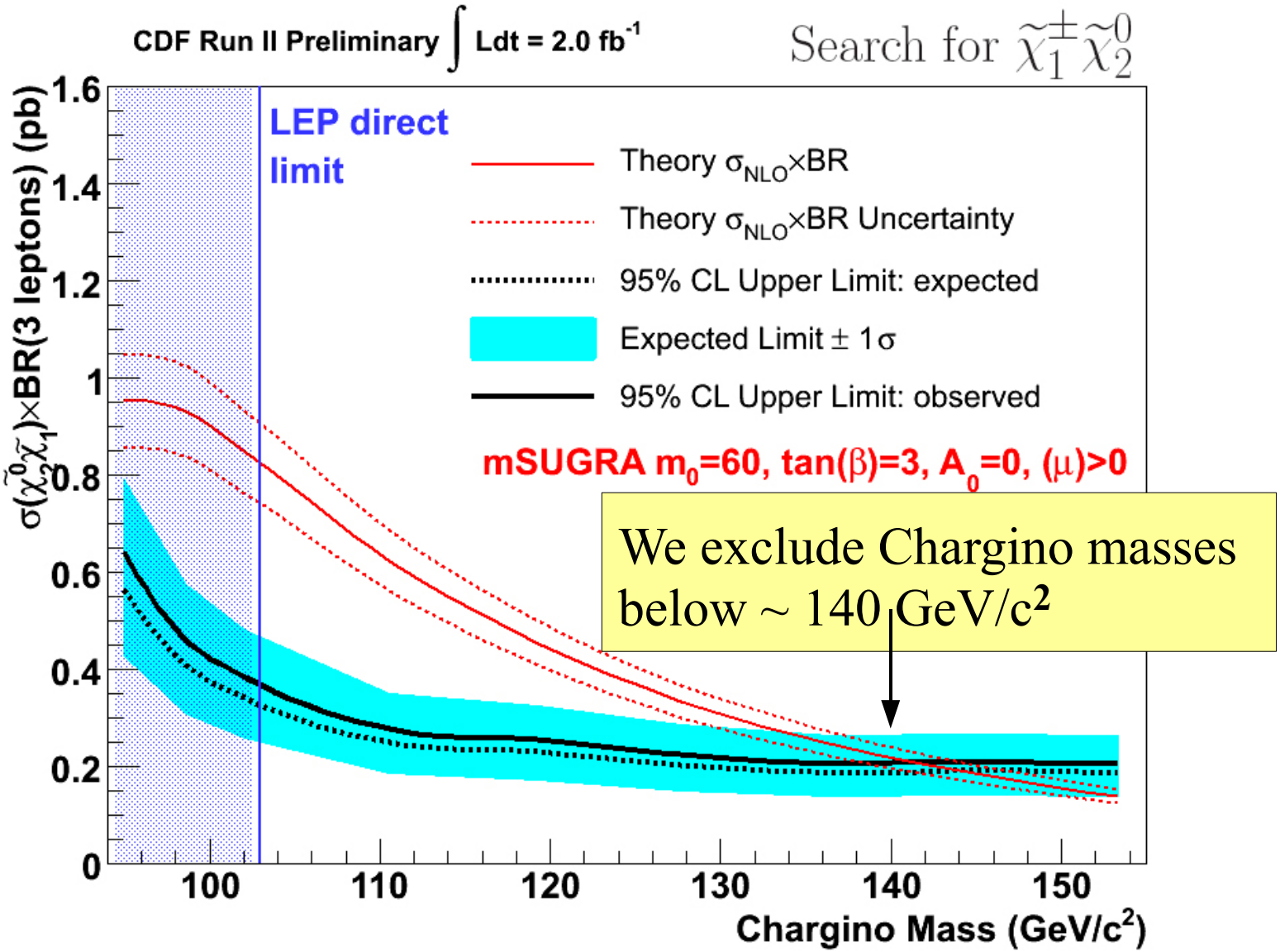
3 tight electron event

E_T = 24 , 17 , 6 GeV

MET = 37 GeV

One jet, Jet E_T = 60 GeV

mSUGRA Limits



Summary and Outlook

- We analyzed 2 fb^{-1} of 1.96 TeV p-pbar collisions at CDF. For benchmark mSUGRA parameters, we expected ~12 SUSY events.
- Our observation of 7 events is consistent with the standard model expectation of 6.4 events.

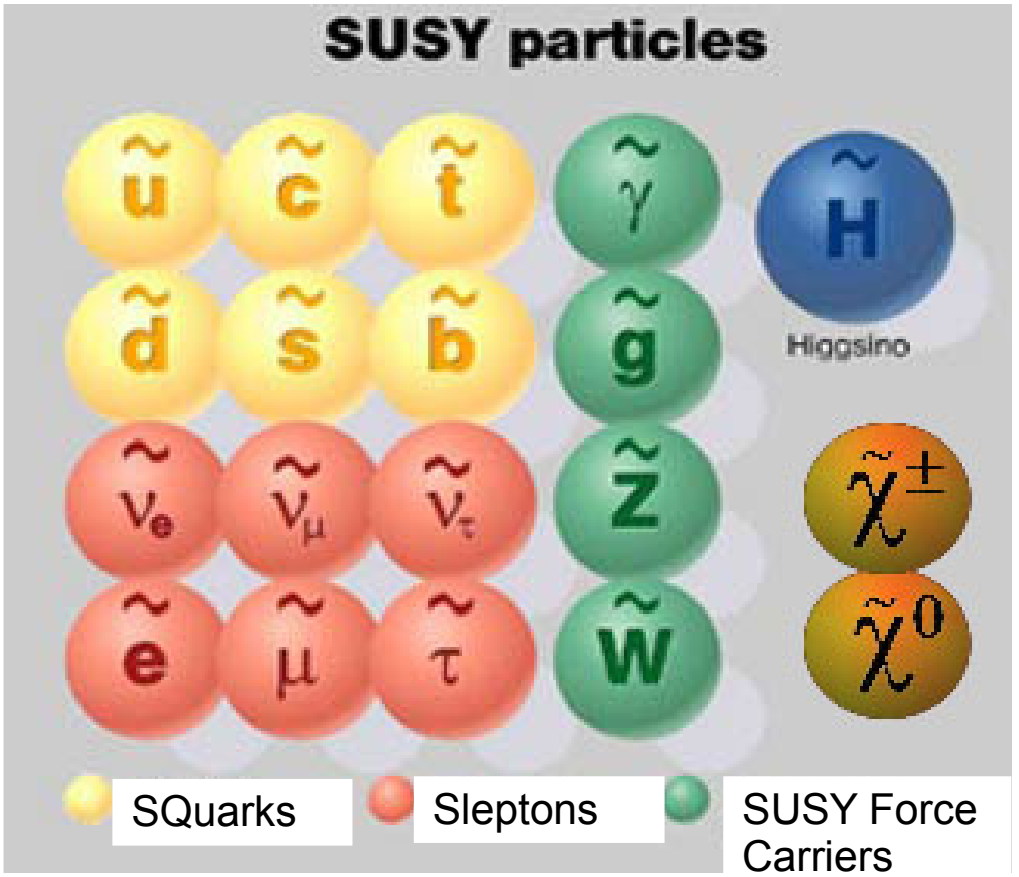
- We set limits on mSUGRA Chargino mass well beyond LEP for the first time.
- More data and more channels at the Tevatron will allow us to probe other regions in mSUGRA, and other models – we hope that SUSY is found there!

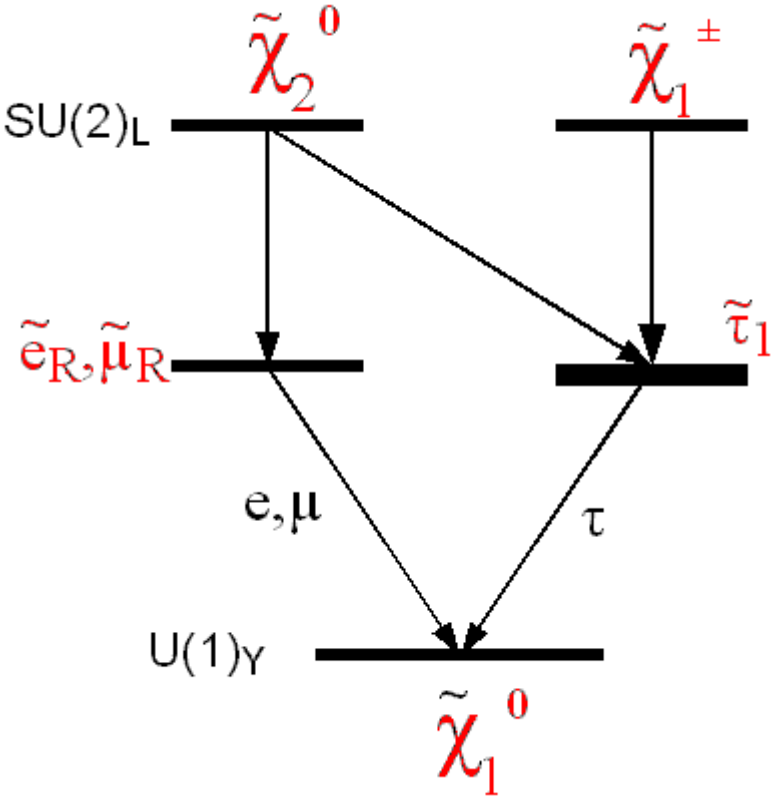
- If not, there is always the LHC.

Backup

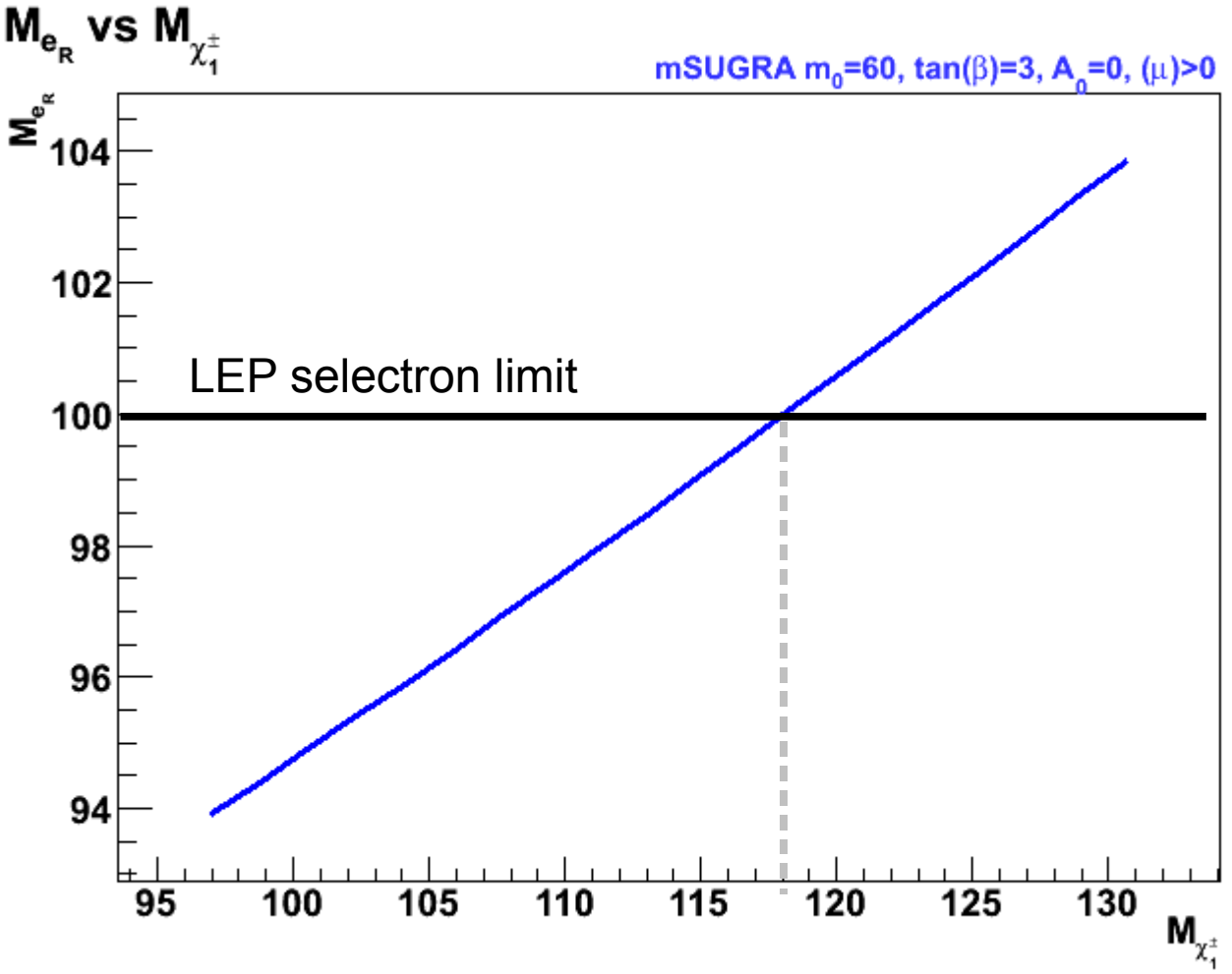
Charginos and Neutralinos

- W's and Z's of Supersymmetry
- Charginos($\chi^{\pm}$) & Neutralinos (χ^0) are mixtures of the higgsino, binos and winos.
- There are four neutralinos and two charginos.

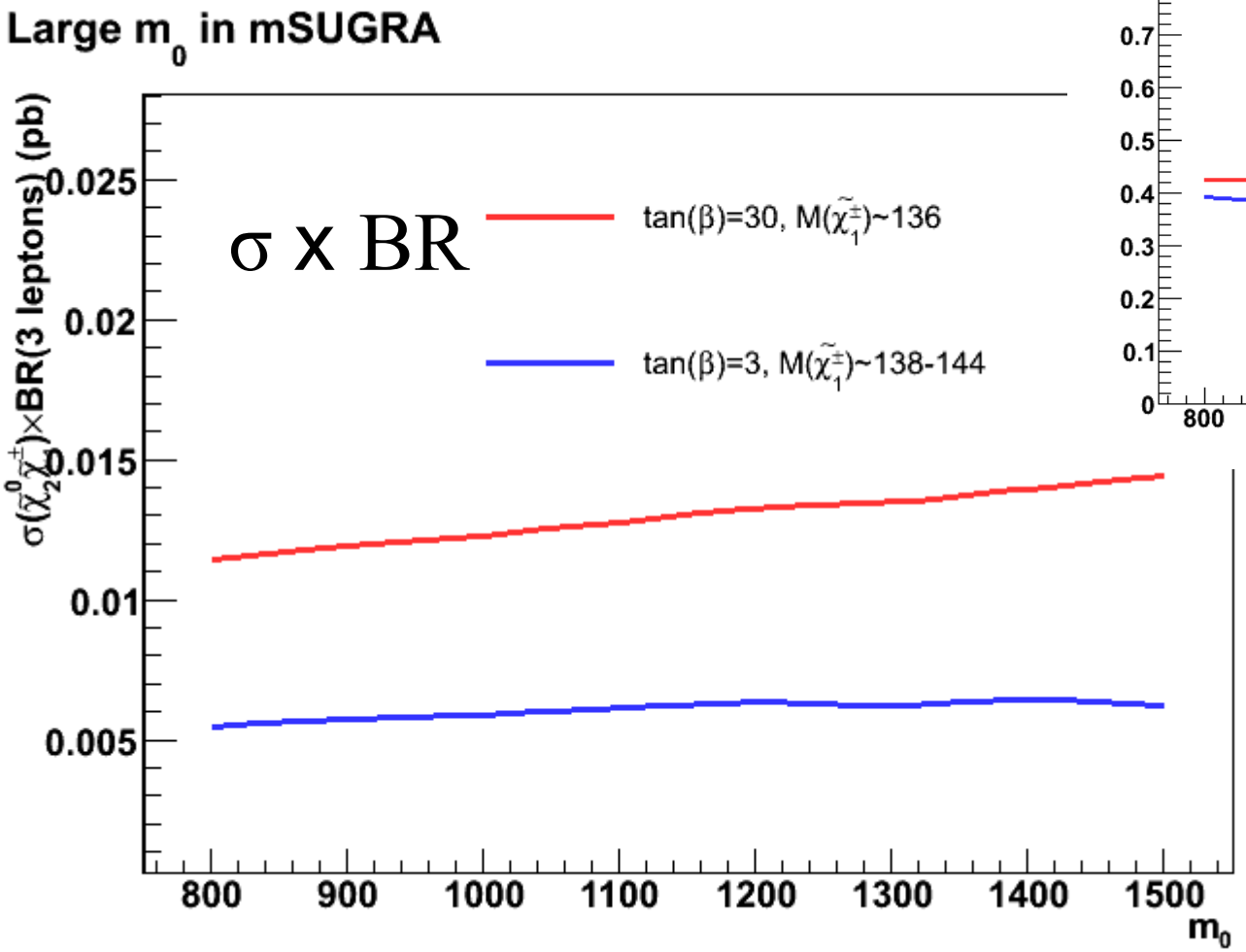


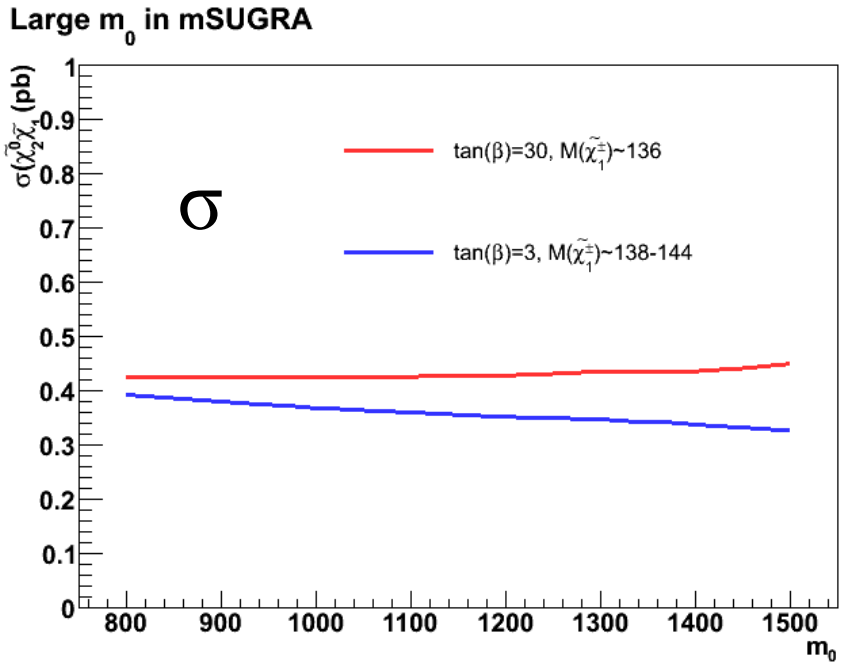


Signal Plots
M(selector) vs M(chargino)



Signal Plots : Large m_0



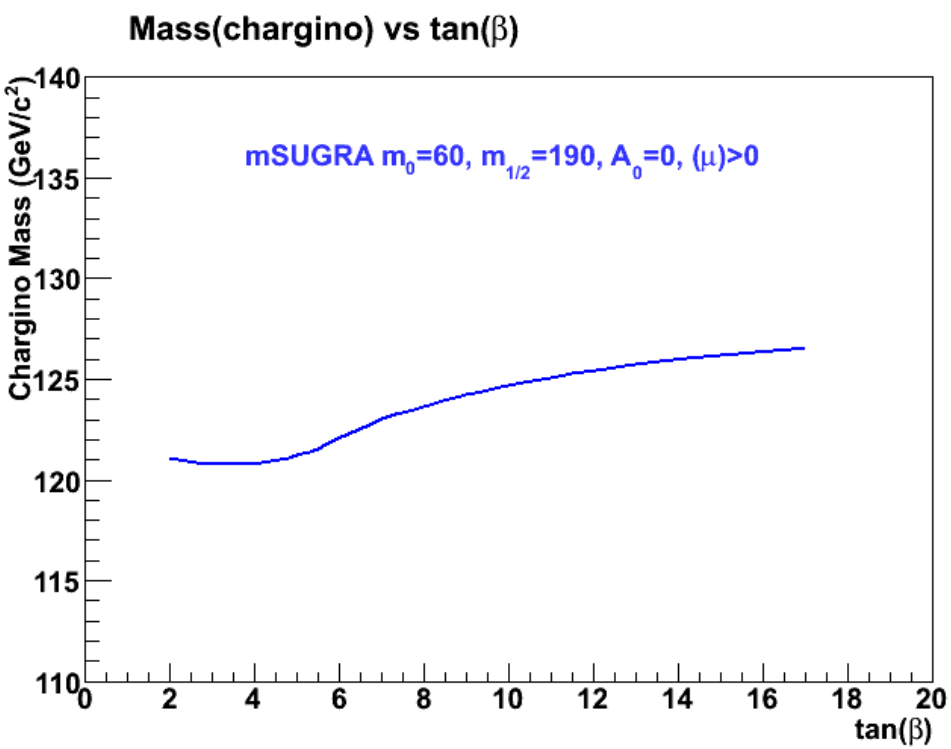


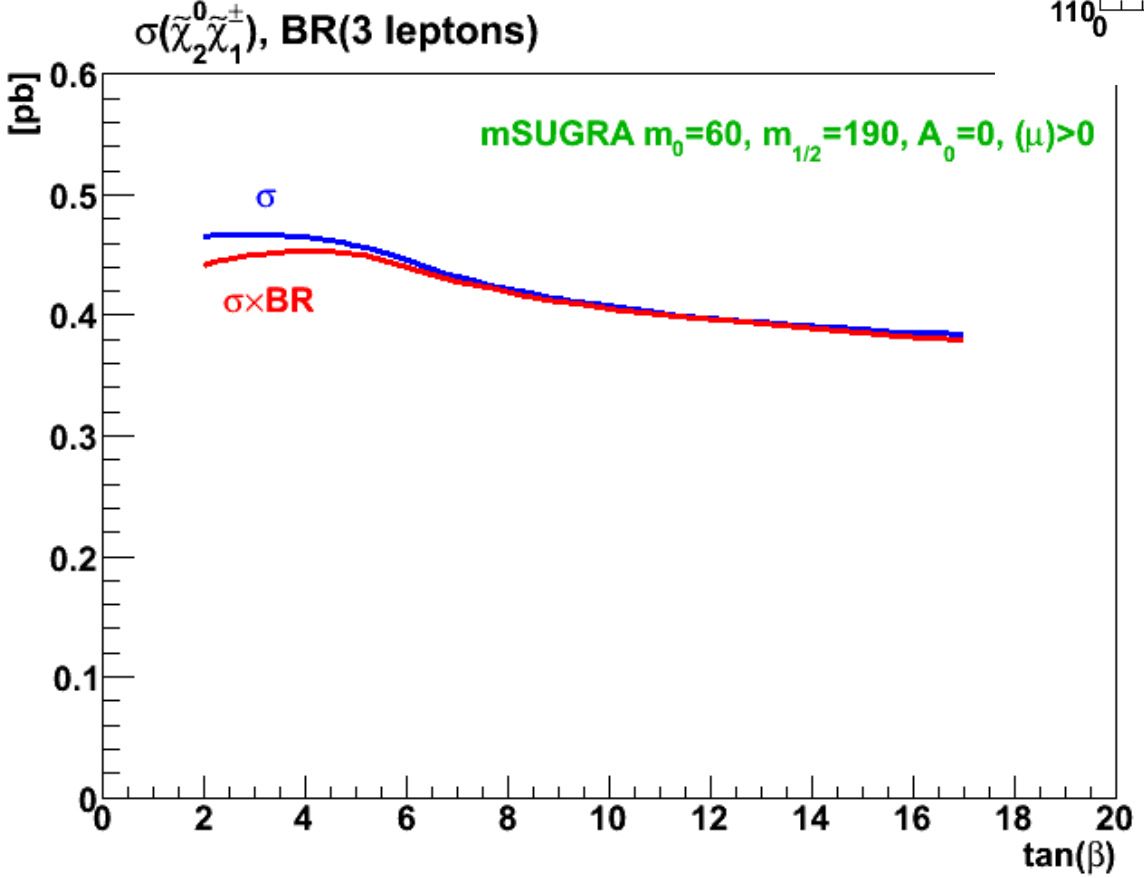
tan(β) = 30

tan(β) = 3

$m_{1/2}$ =190, A_0=0, μ>0

Signal Plots tan(β) variation





E_T/p_T Cuts

The five exclusive channels :

Channel	E_T (P_T) GeV
3 tight leptons OR 2 tight leptons + 1 loose electron	**15, 5, 5**
2 tight leptons + 1 loose muon	**15, 5, 10**
1 tight lepton + 2 loose leptons	**20, 8, 5 (10 if loose muon)**
2 tight leptons + 1 Track	**15, 5, 5**
1 tight lepton, 1loose lepton, 1 Track	**20, 8(10 if loose muon), 5**

The five exclusive channels constitute five independent experiments within CDF

Systematic Uncertainties

Backgrounds

hadrons faking leptons
underlying event → tracks ~ 10%

Lepton identification ~ 2%
Jet energy scale ~ 2 to 5 %
Process Cross-section ~ 5%

Signal

Signal cross section~ 10%

Lepton identification ~ 4%
Initial/Final State radiation ~ 4%

Common to both

Luminosity ~ 6%
PDF ~ 2%

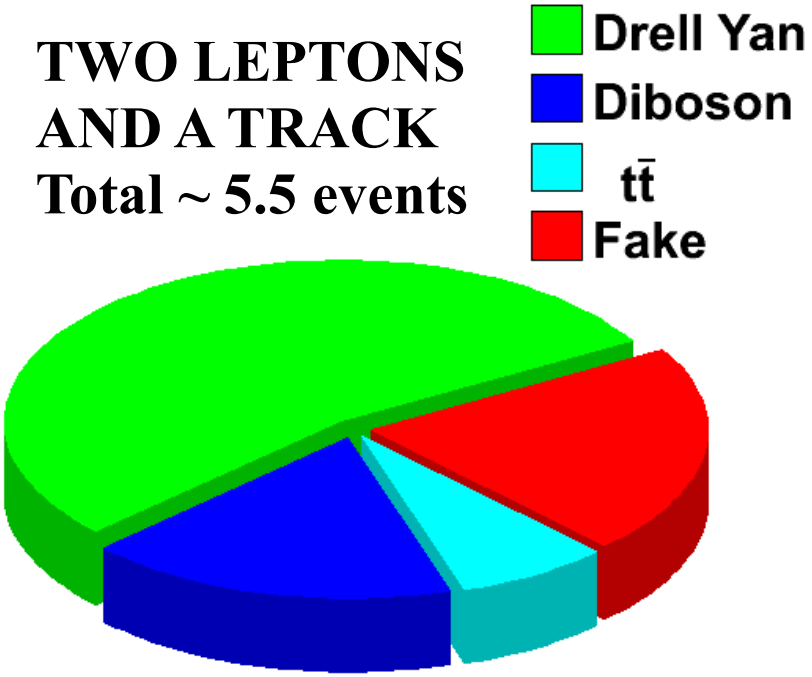
FINAL PREDICTIONS

Breakdown of Backgrounds

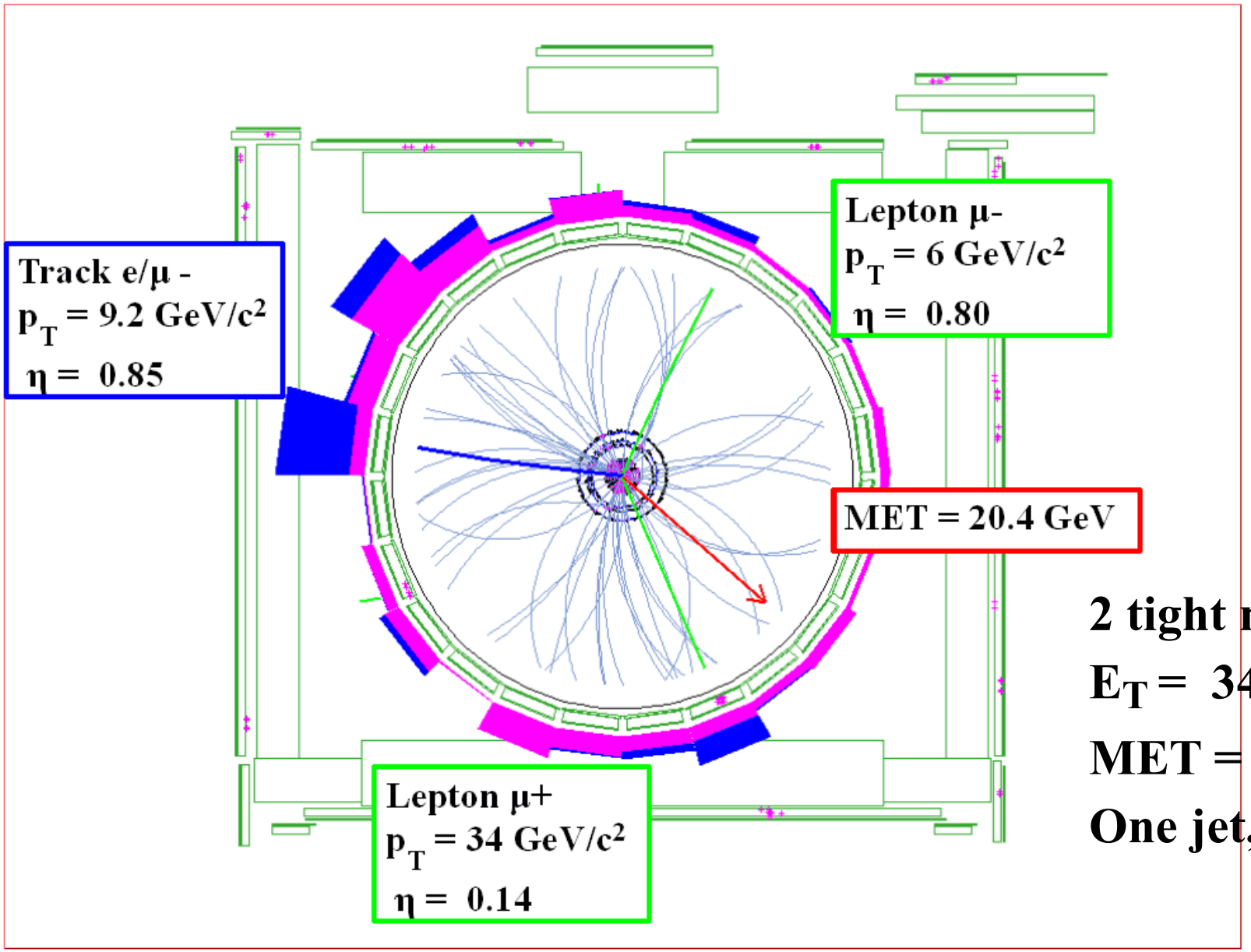
CDF Run II Preliminary, $\int Ldt = 2.0\ fb^{-1}$

ALL THREE LEPTONS
Total ~ 1 event

TWO LEPTONS AND A TRACK
Total ~ 5.5 events



EVENTS



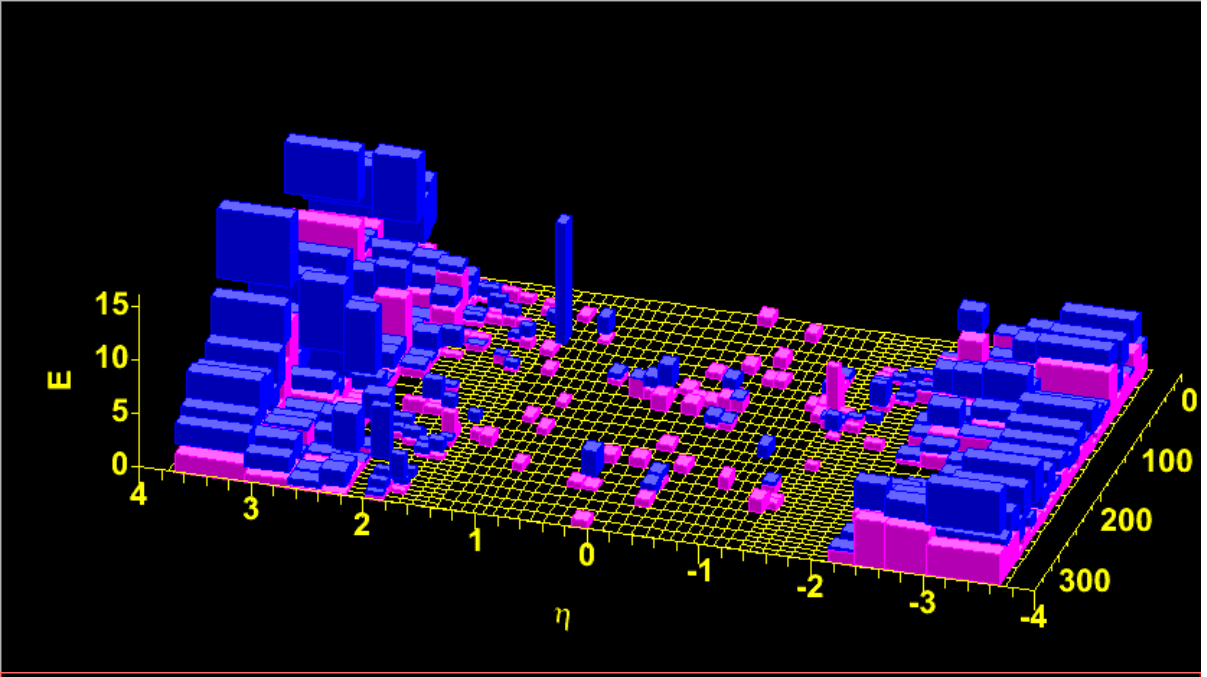
2 tight muons + 1 Track

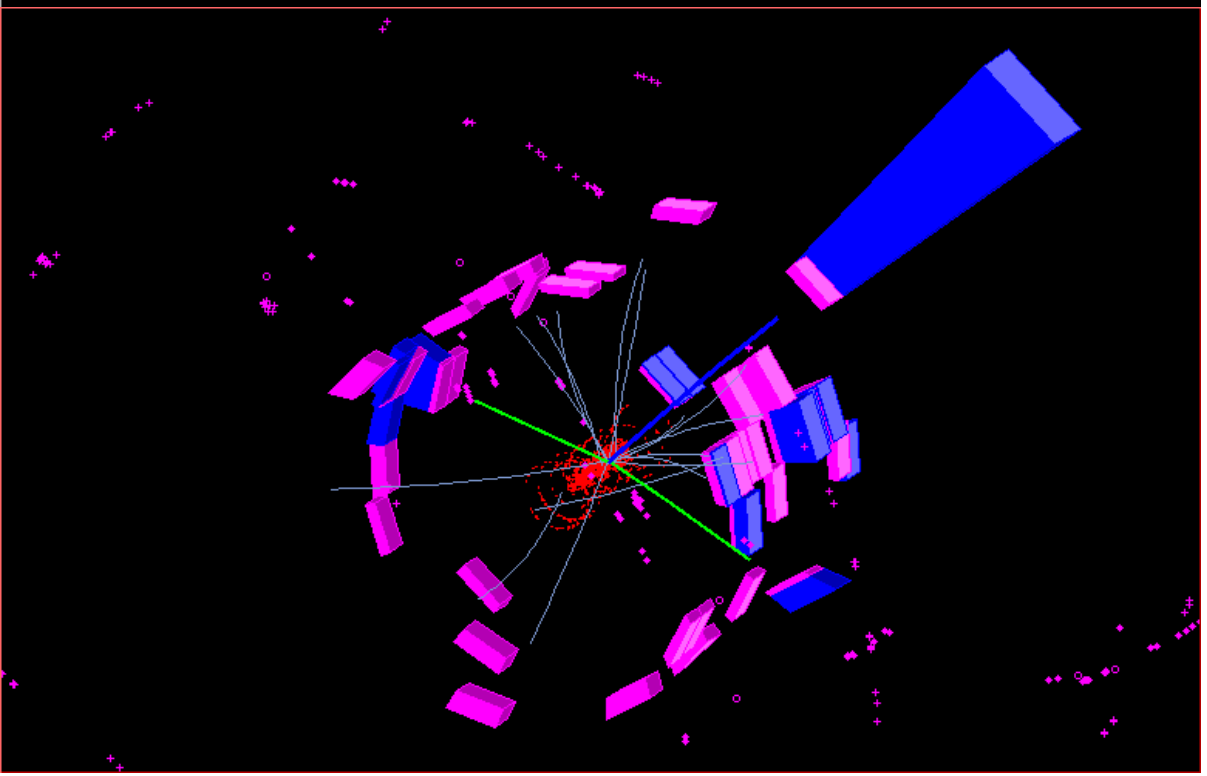
E_T = 34 , 6 , 9 GeV

MET = 20.4 GeV

One jet, Jet E_T = 22 GeV

EVENTS





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Cross Sections : Tevatron & LHC

T. Plehn, PROSPINO