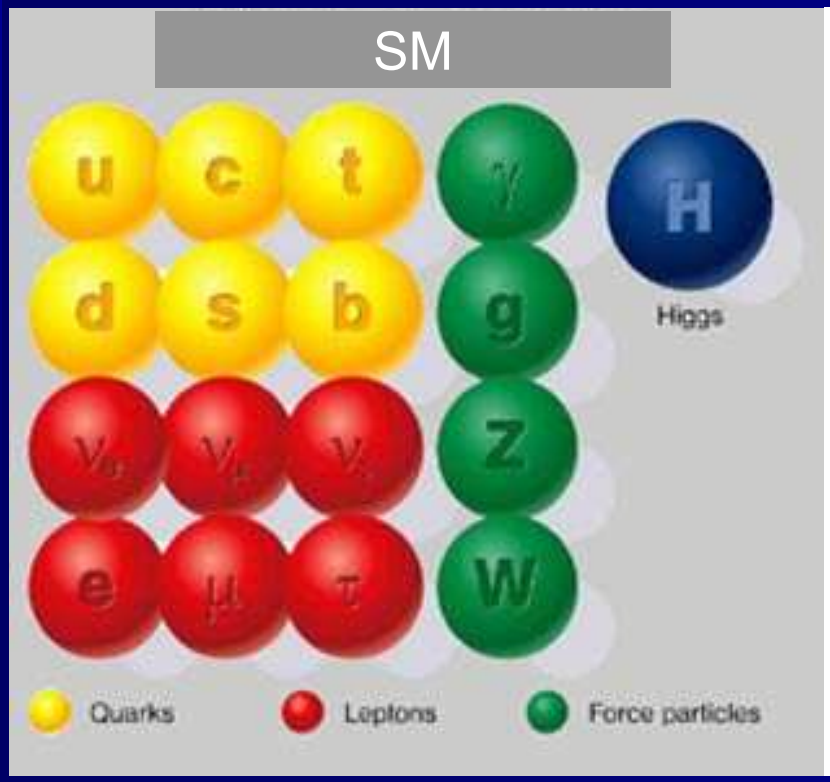
Search for SUSY in the Golden Mode

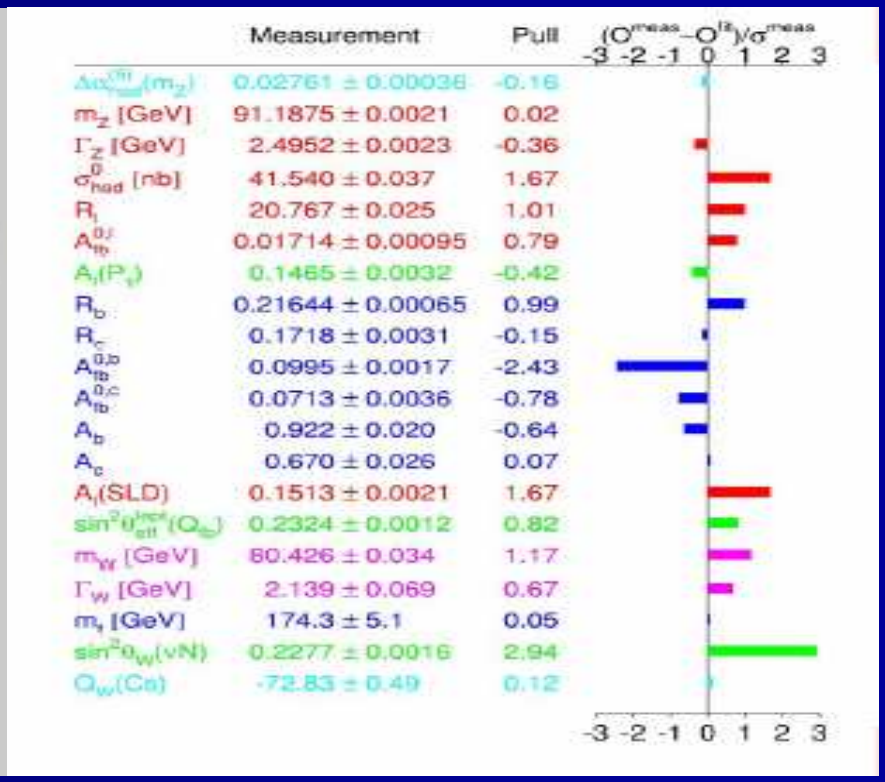
Anadi Canepa

What do we know ?

The Standard Model
has been extremely successful

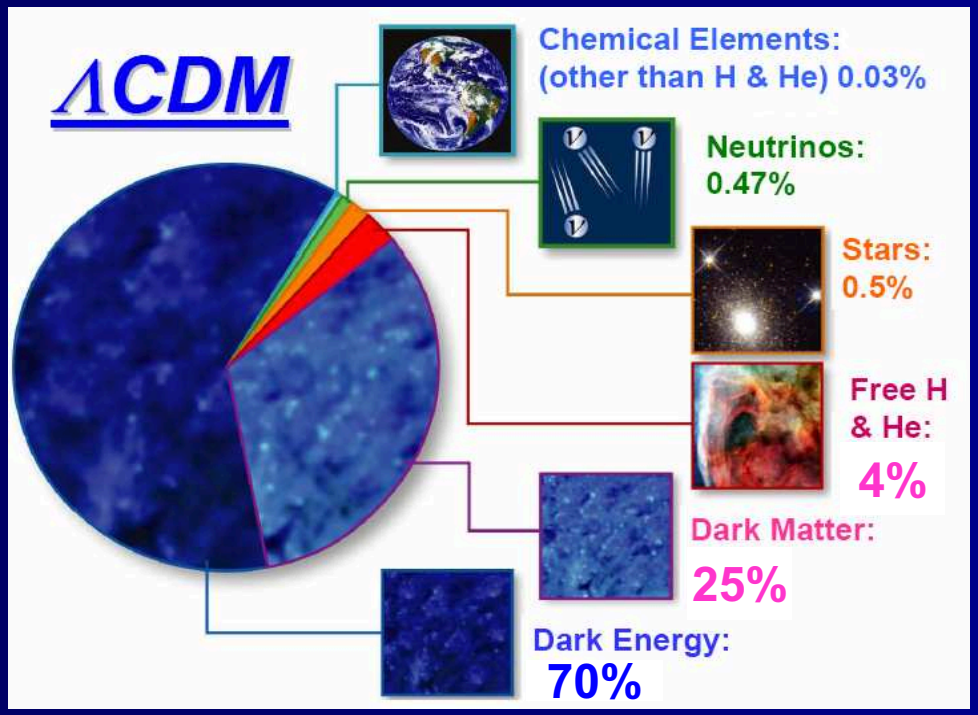
Precision EWK measurements

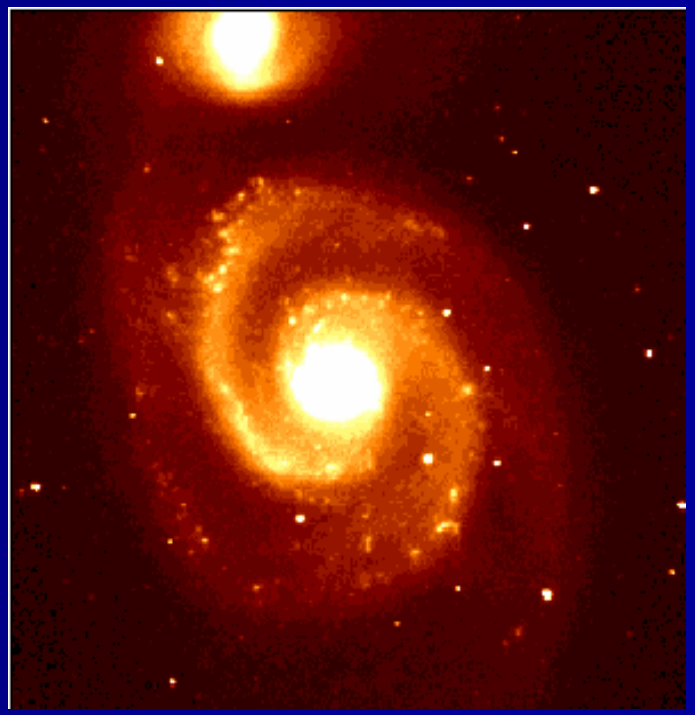




Yet to discover

What is the Universe made of ?

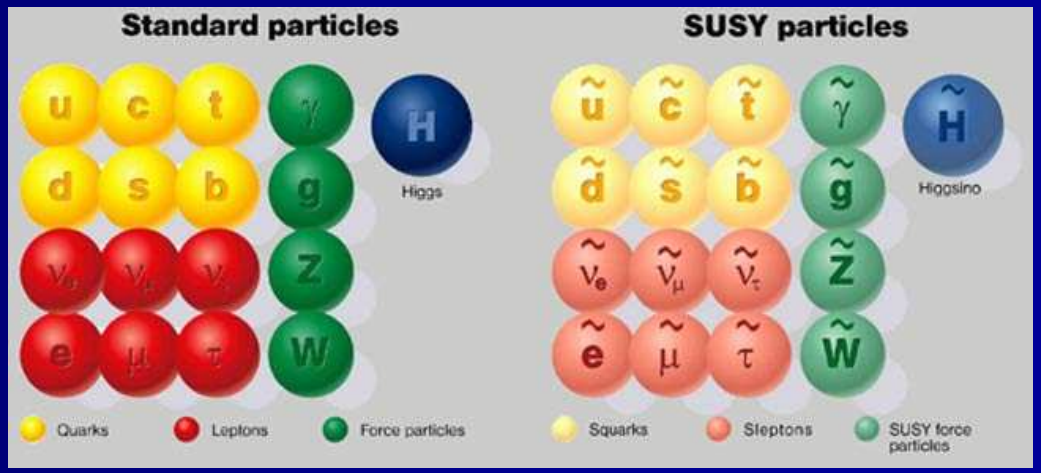


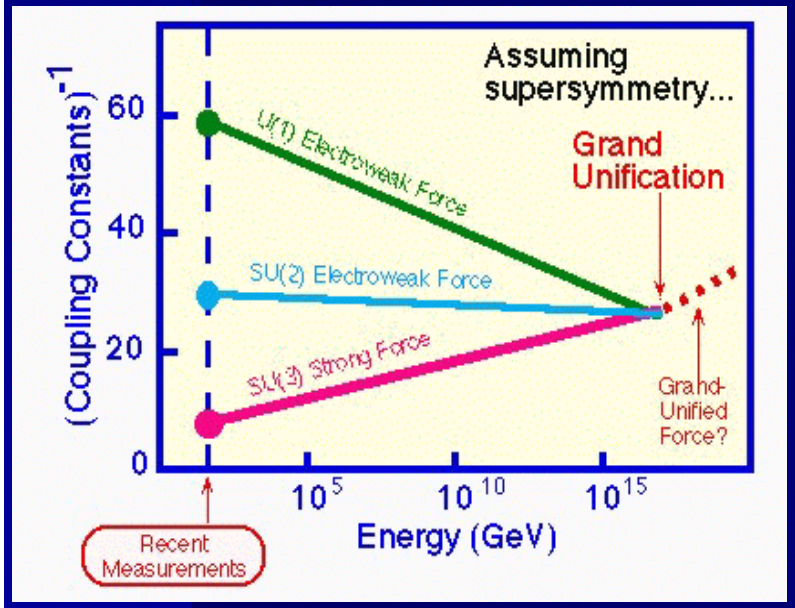


SUSY can explain it

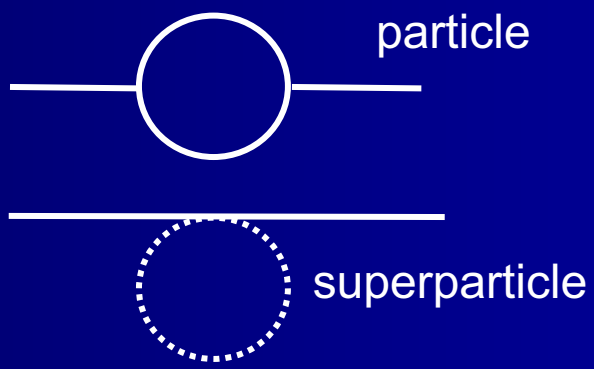
New proposed symmetry of Nature

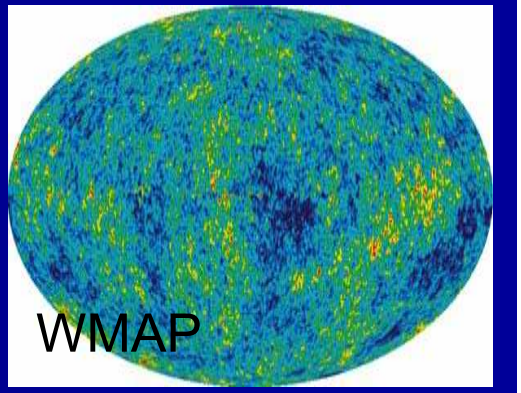
- SM boson ↔ MSSM fermion
- SM fermion ↔ MSSM boson





Higgs



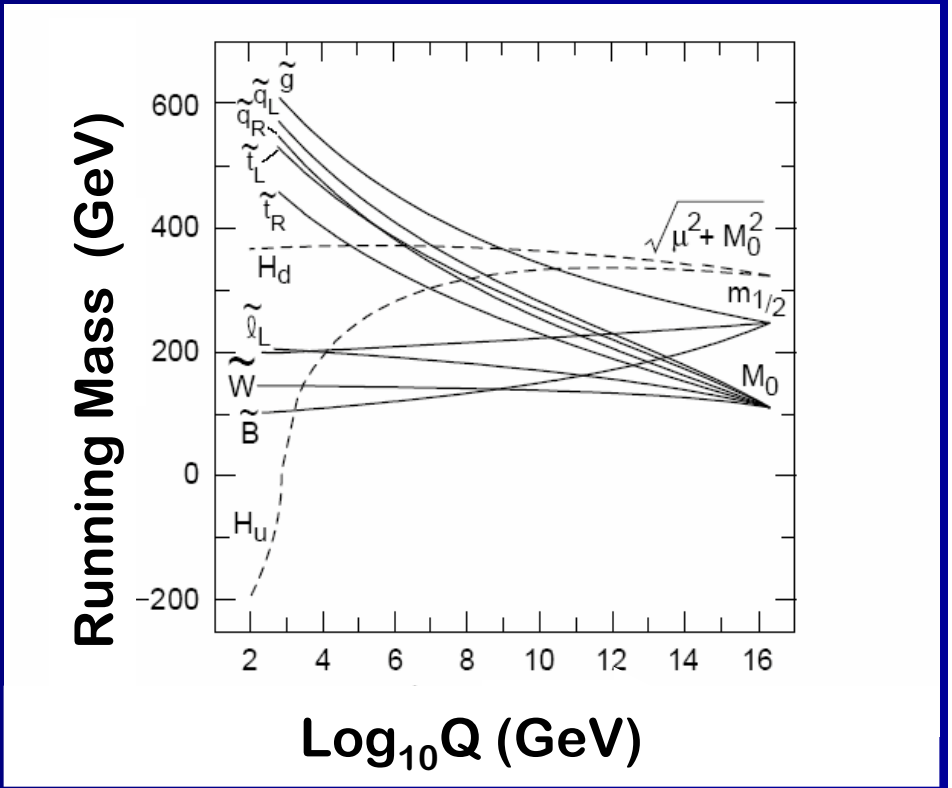


mSUGRA breaking scenario

SUSY is a broken symmetry

- Gravity breaks SUSY
- Model with 5 parameters
  - Masses $m_{1/2}$, m_0
  - Coupling A_0
  - Higgs sector:

    sgn(μ), tanβ
- New parity R_p is conserved
  - R_p = +1 for SM particle
  - R_p = -1 for SUSY particle



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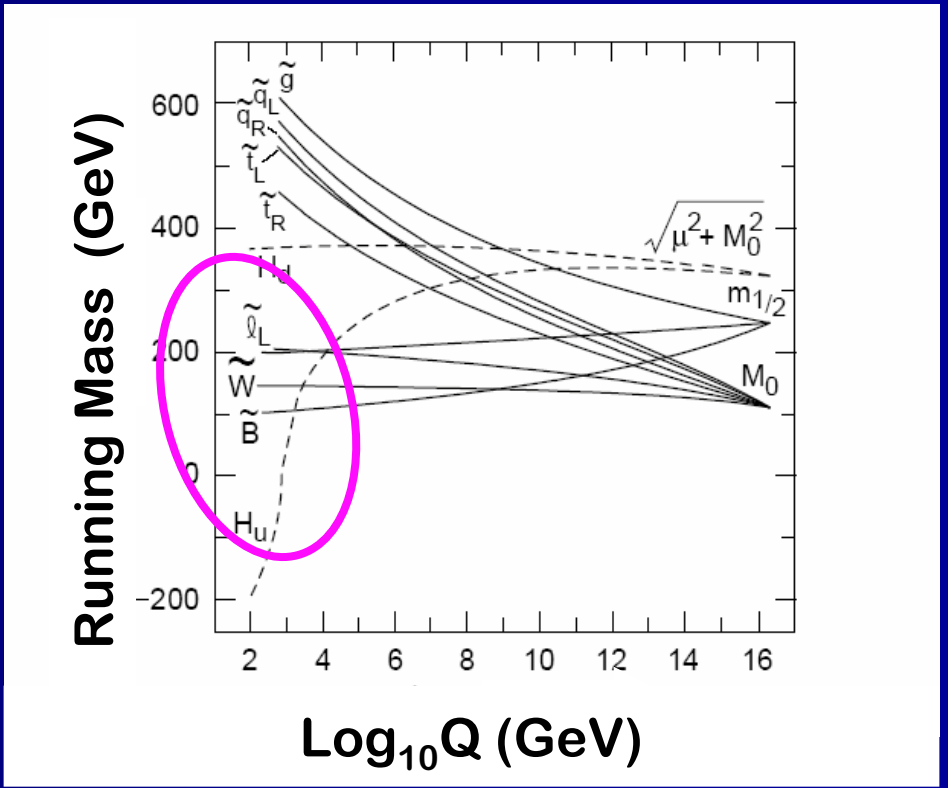


Charginos and Neutralinos

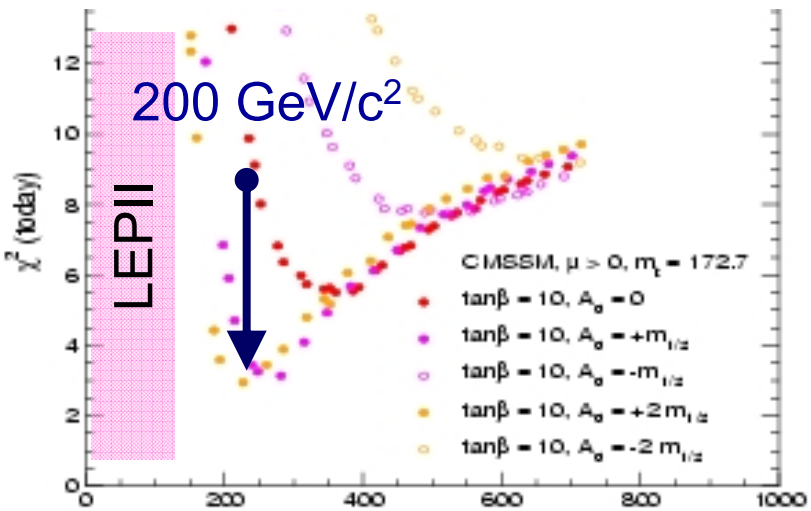
$\tilde{W}, \tilde{H}, \tilde{B}$ mix into charginos and neutralinos ($\tilde{\chi}$)

- $\tilde{\chi}_1^0$ is the LSP
- R_p conserved $\Rightarrow$ LSP stable

  $\rightarrow$ dark matter candidate

  $\rightarrow$ *key for our search*

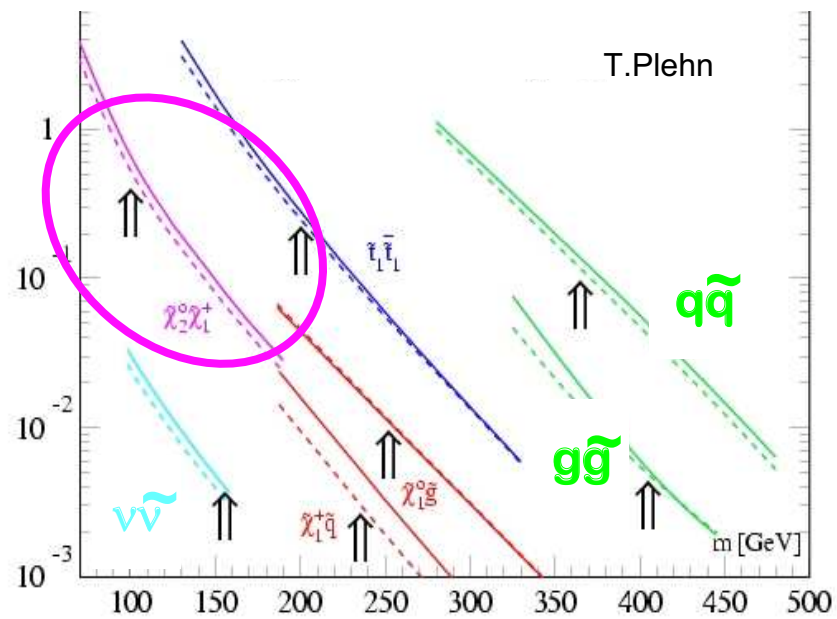
Range of Chargino m (GeV/c^2)



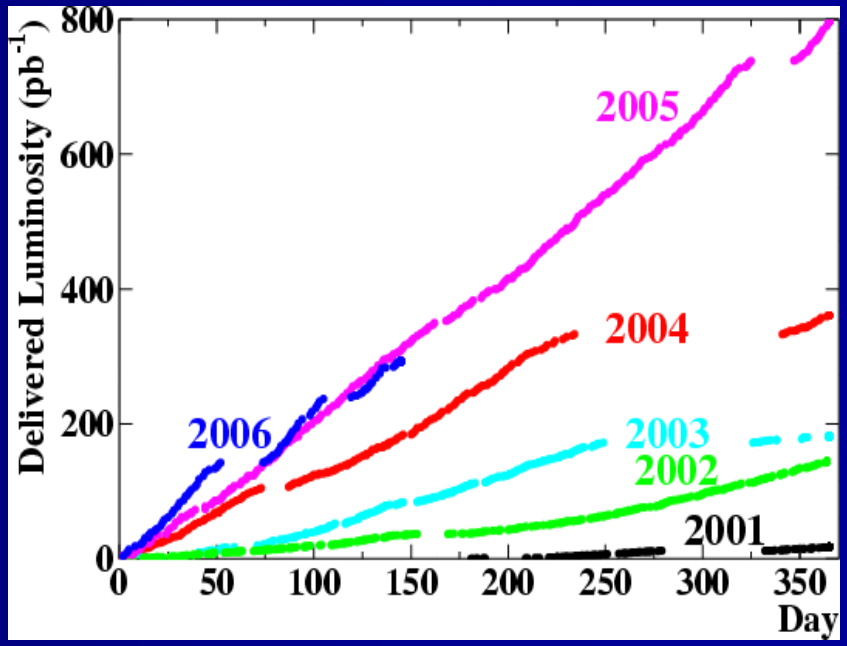
χ^2 of M_w, $\sin^2\theta_{eff}$, $(g-2)_\mu$, $BR(b\rightarrow s\gamma)$, m_h

Hep-ph/0600220

Cross Section vs m (pb)



Tevatron Performance



Already delivered 1.6 fb^{-1}

Exploring up to 0.7 fb^{-1}

Peak instantaneous luminosity $1.82 \cdot 10^{32}$ $cm^{-2}s^{-1}$

CDF @ Tevatron

Muon system

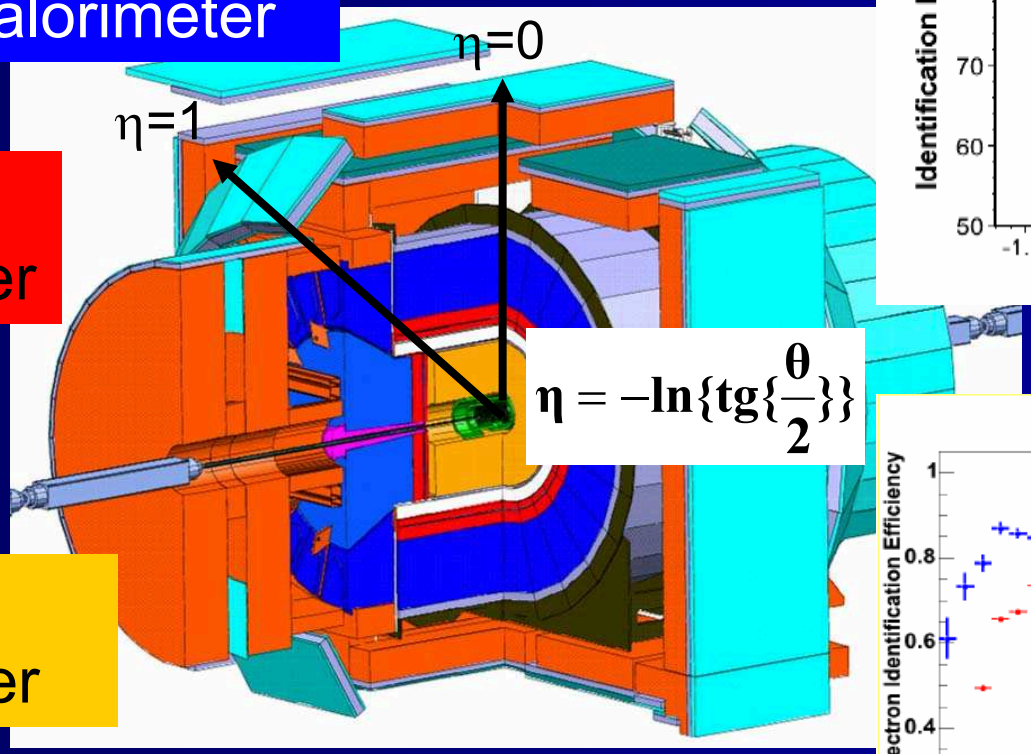
Had Calorimeter

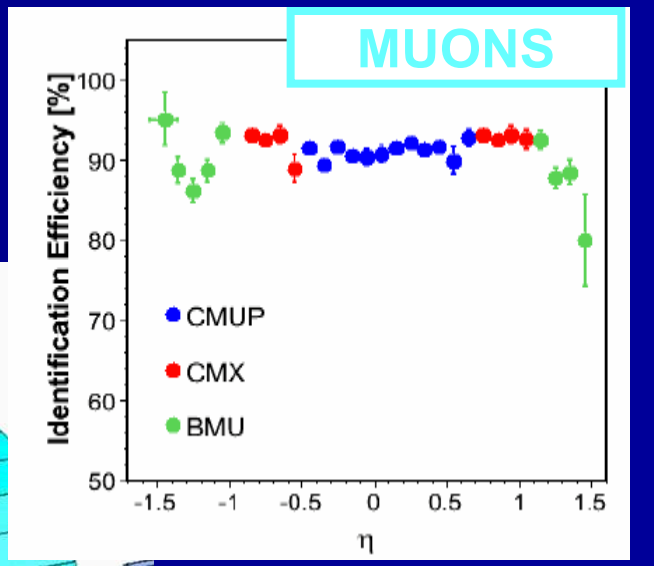
Em Calorimeter

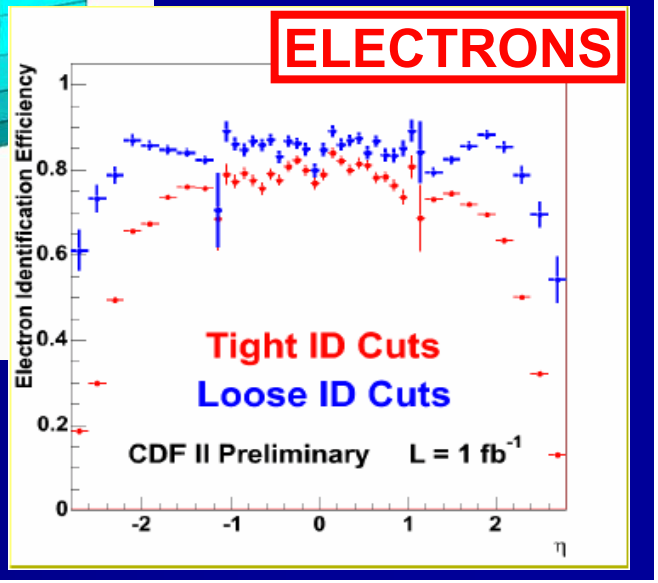
B field: 1.4 T

Drift chamber

Inner tracker (Si)

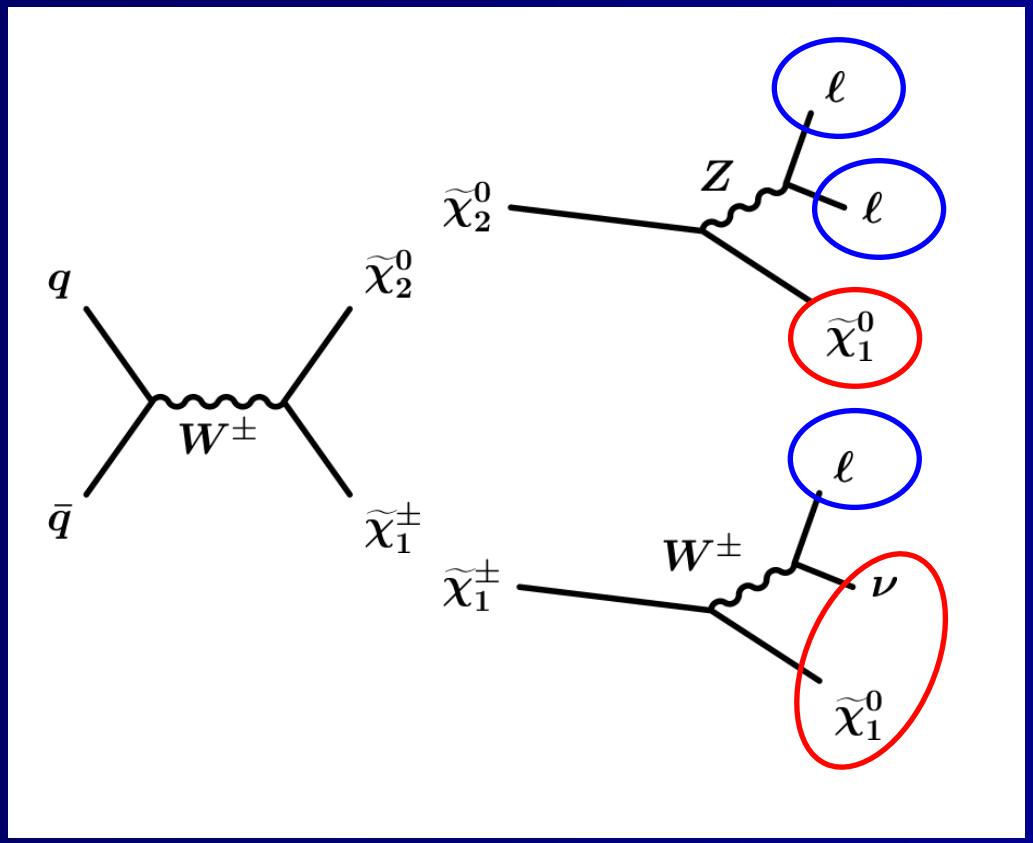


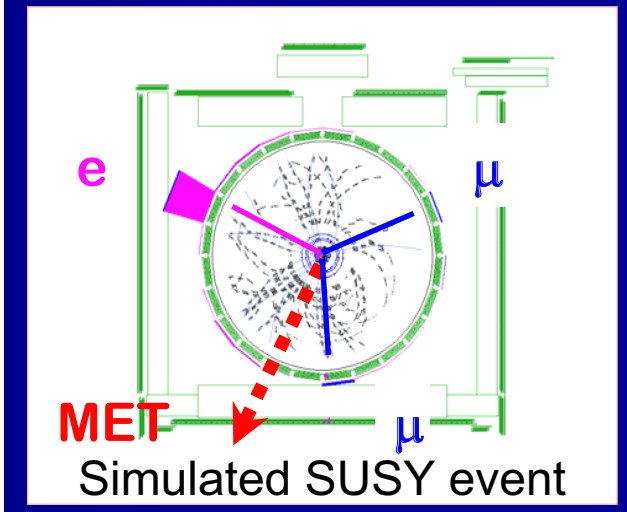




The Golden Mode

Three leptons and Missing Energy in the Transverse plane



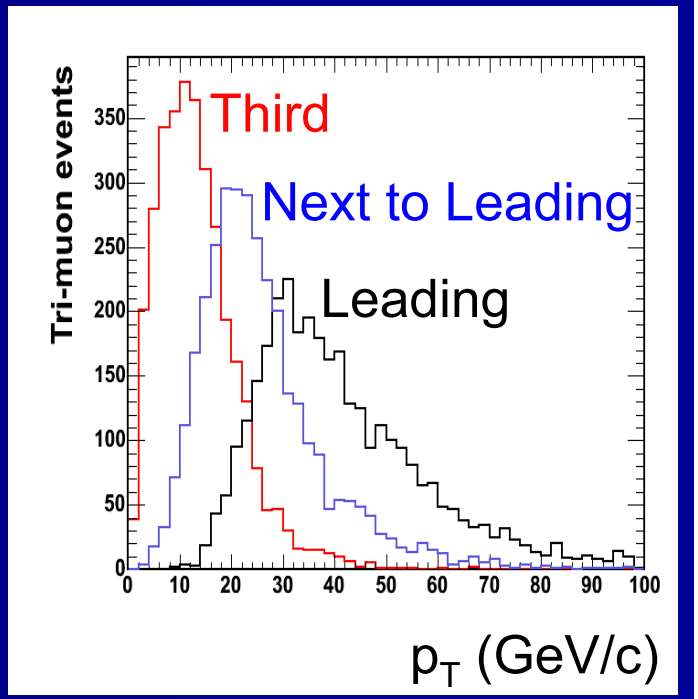


The Search

$\sigma \cdot BR \sim 0.2$ pb

- Need good **acceptance**
  - achieved using different trigger paths

CHANNEL	p/E_T's (GeV/c)
$\mu\mu$	20, 5, 5
μe	20, 5, 5
ee	20, 5,5
$\mu\mu$	5, 5, 5
ee	15, 5, 4
LS $\mu^{\pm}\mu^{\pm}$, $e^{\pm}e^{\pm}$, $\mu^{\pm}e^{\pm}$	20,10



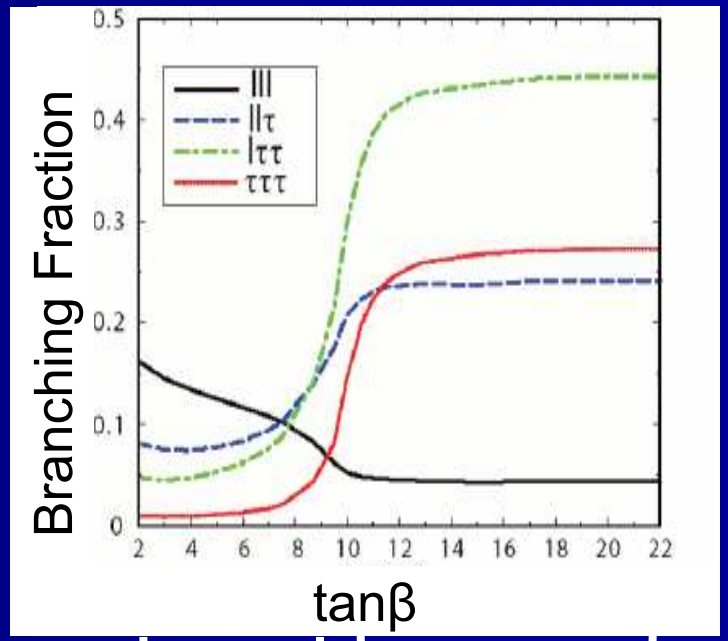
Wide p_T range

The Search

$\sigma \cdot$BR ~ 0.2 pb

- Need good **mSUGRA parameter space coverage**
  - achieved using different requirements for the 3rd lepton

CHANNEL	3rd lepton
$\mu\mu$	**μ/e**
μe	**μ/e**
ee	**μ/e**
$\mu\mu$	**μ/e**
ee	**Track**
LS $\mu^\pm\mu^\pm$, $e^\pm e^\pm$, $\mu^\pm e^\pm$	



e/μ τ

SM Backgrounds

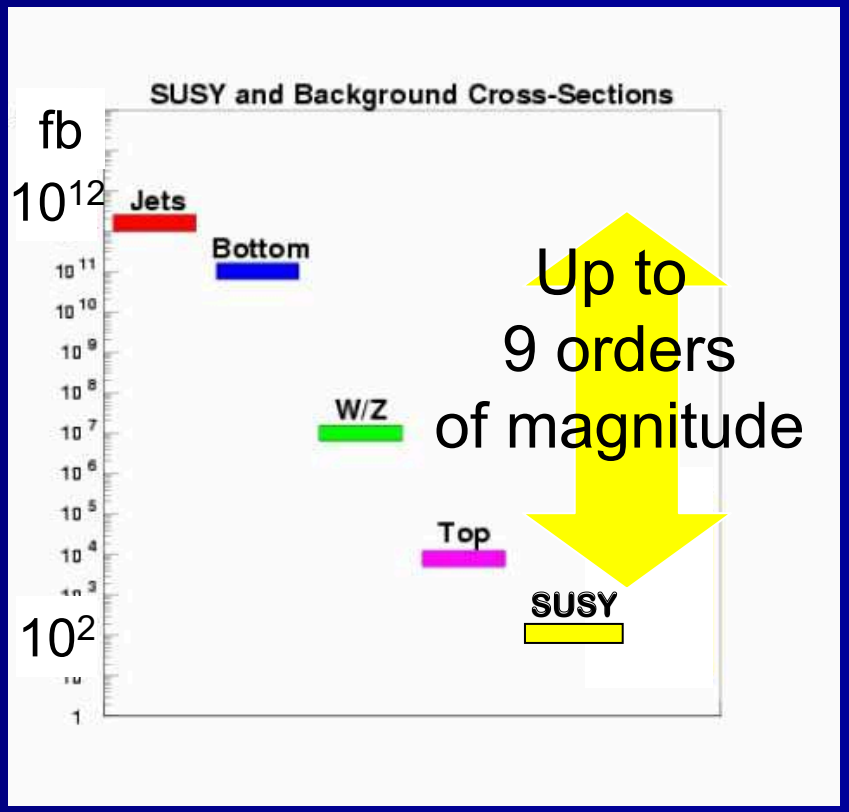
Small contributions from

- Diboson WZ, ZZ
- Top pair production
  - jet activity
- QCD
  - Low MET
  - Non isolated leptons

DOMINANT contributions from

- Hadrons or $\gamma(\rightarrow e^+e^-)$
  - Low MET
  - Back to back leptons
- Diboson $W\gamma(\rightarrow e^+e^-)$

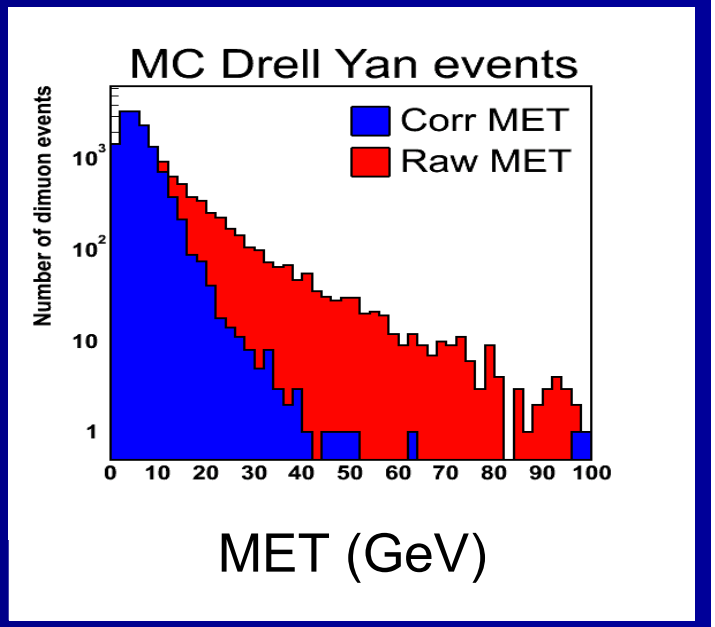
SUSY and SM Cross Sections



What are the challenges?

- In depth understanding of the material to simulate photon conversions
- Data driven measurement of the leptons misidentification rate
- Data based heavy flavor estimate

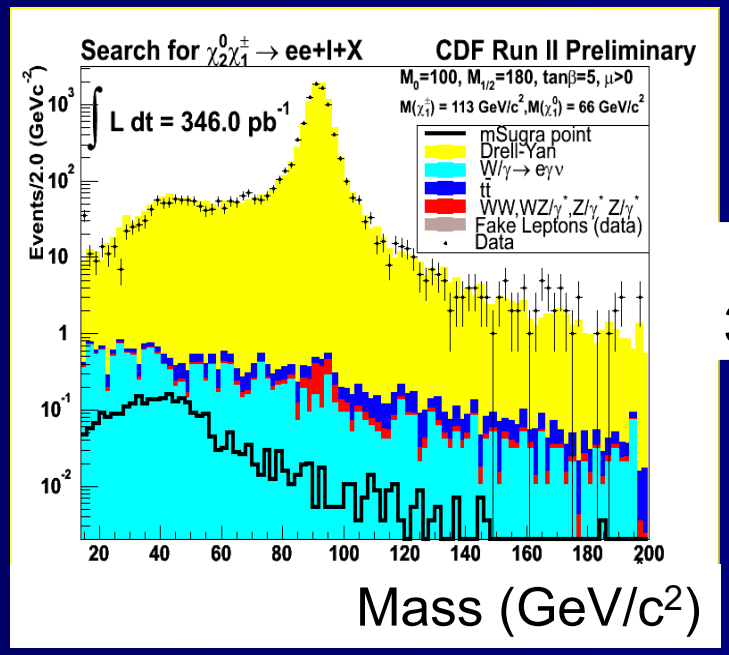
- MET correction sensitive to
  - quality of track reconstruction
  - knowledge of the calorimeter geometry
  - simulation of extra interactions



Reducing the background

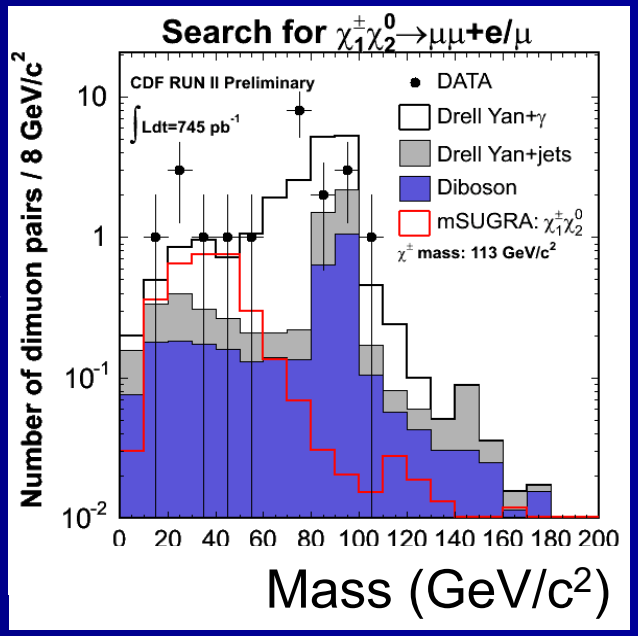
Veto resonances (J/Ψ, Upsilon, Z)

Dilepton Events
~ 10^3



Require
3rd lepton

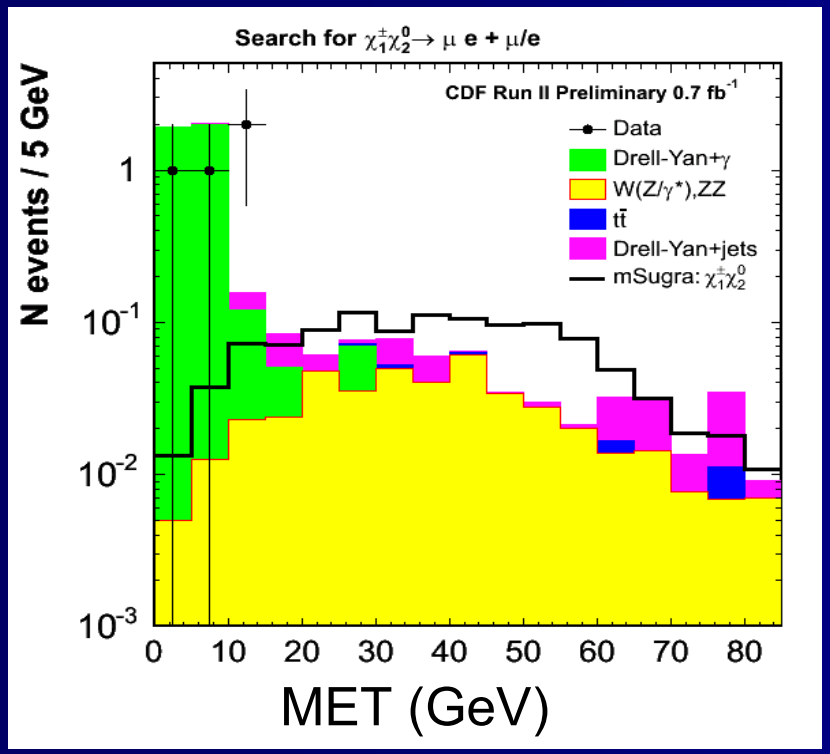
Trilepton Events
~ 10

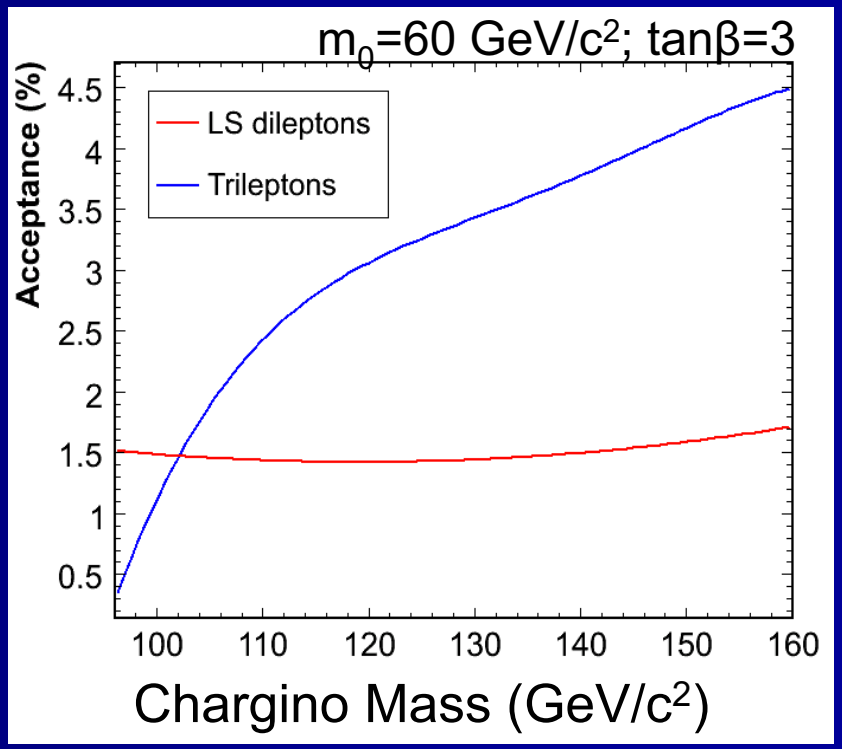


Veto events with jet activity

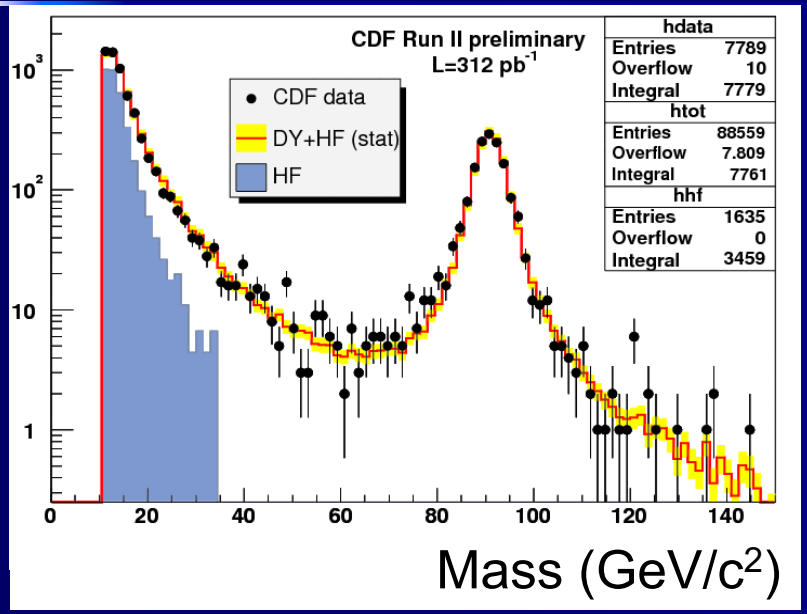
Total acceptance

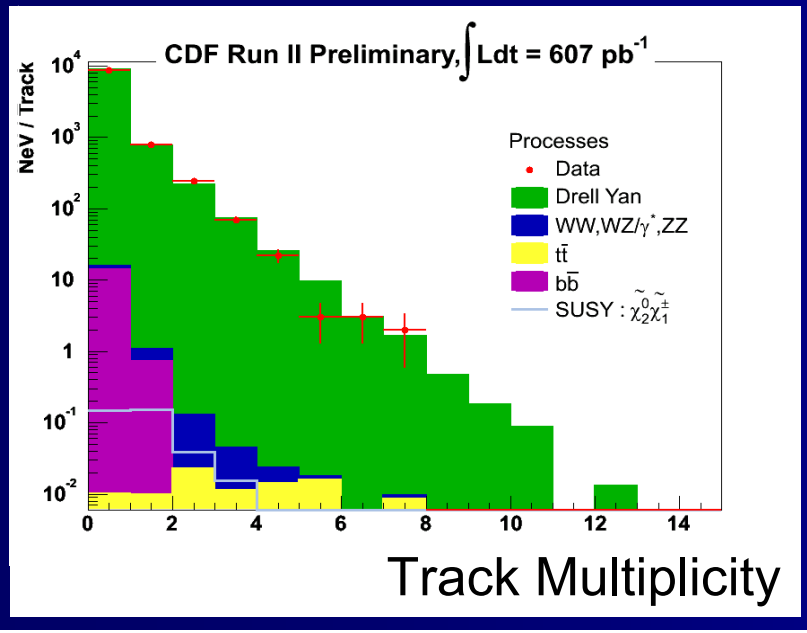
Acceptance after 3rd lepton requirement
and MET > 15 GeV



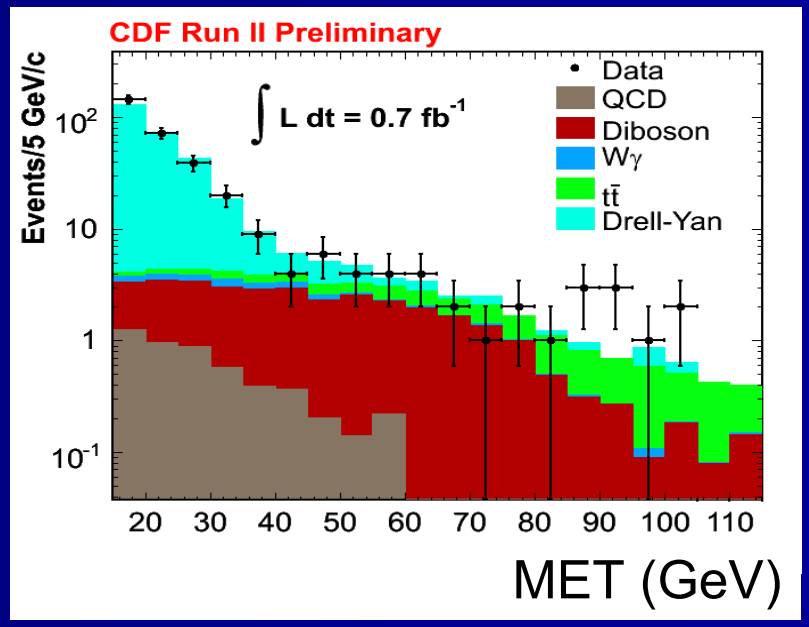


Do we understand the SM?



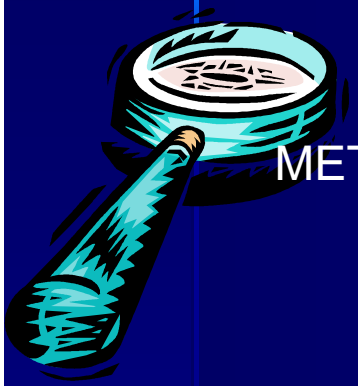


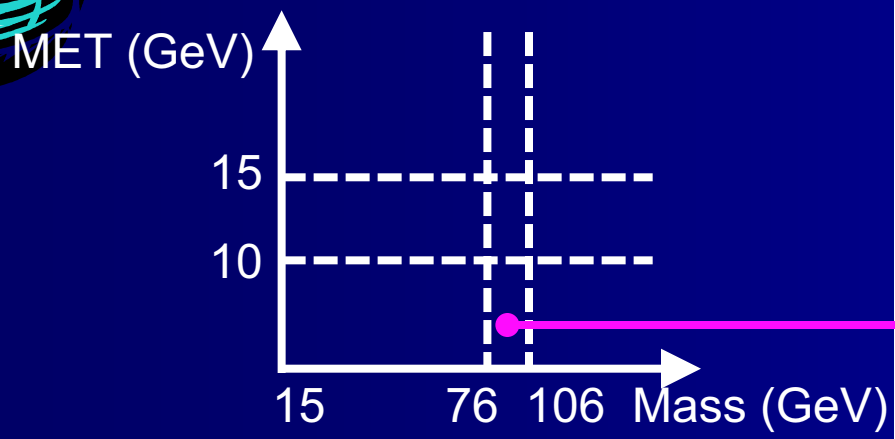
Inclusive investigation of observables in dilepton events

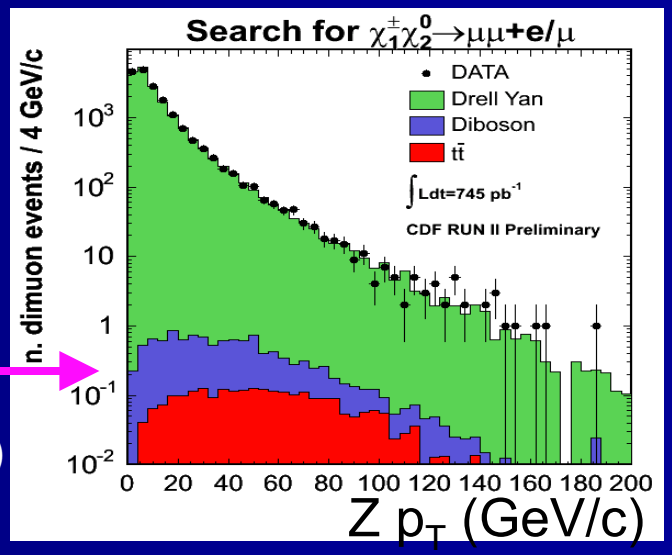


More detailed investigation

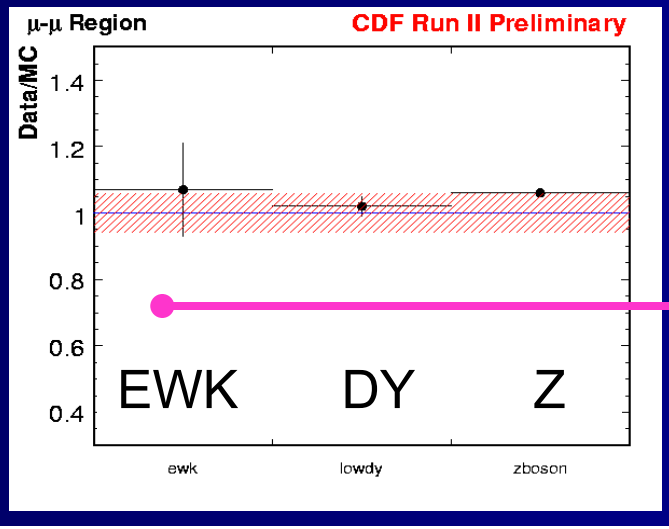
Up to 19 inclusive "control regions"

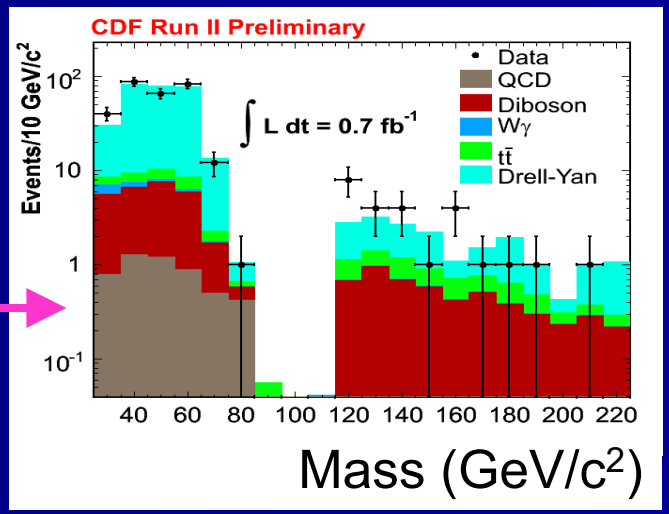




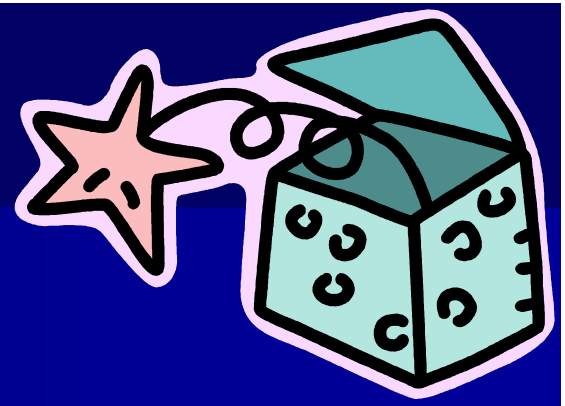


Ratio Data/MC





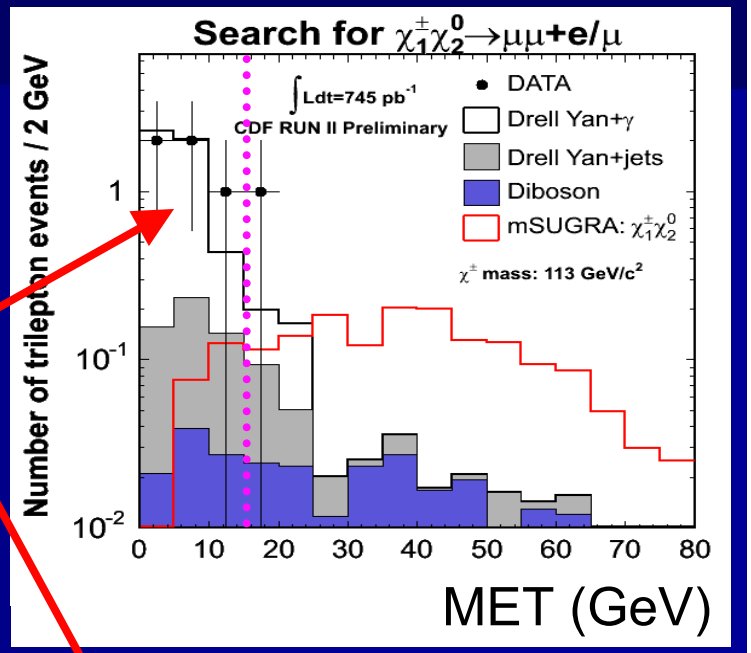
The “signal box”

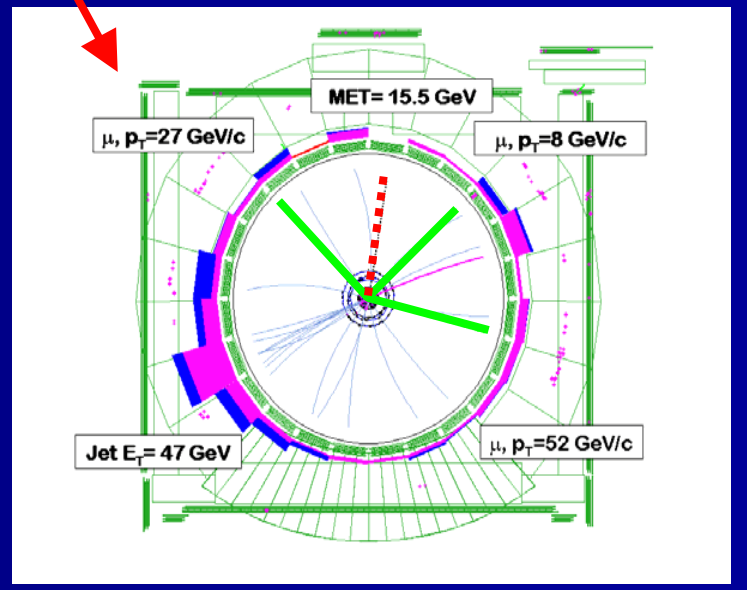


Channel	SM	SUSY benchmark	S/√B
μμ + l	**0.6** ± 0.1 ± 0.1	**1.6** ± 0.1 ± 0.2	2
μe + l	**0.8** ± 0.1 ± 0.2	**1.0** ± 0.1 ± 0.1	1.1
ee + l	**0.17** ± 0.03 ± 0.04	**0.5** ± 0.1 ± 0.1	1.2
μμ + l	**0.13** ± 0.03 ± 0.03	**0.17** ± 0.01 ± 0.03	0.5
ee + track	**0.5** ± 0.1 ± 0.1	**0.72** ± 0.04 ± 0.05	1.0
LS	**6.8** ± 0.5 ± 1.0	**3.2** ± 0.1 ± 0.5	1.2

Results !!!

Channel	SM	Data
$\mu\mu$ + l	**0.6** ± 0.1 ± 0.1	**1**
μe + l	**0.8** ± 0.1 ± 0.2	**0**
ee + l	**0.17** ± 0.03 ± 0.04	**0**
$\mu\mu$ + l	**0.13** ± 0.03 ± 0.03	**0**
ee + track	**0.72** ± 0.04 ± 0.05	**1**
LS	**6.8** ± 0.5 ± 1.0	**9**





Results !!!

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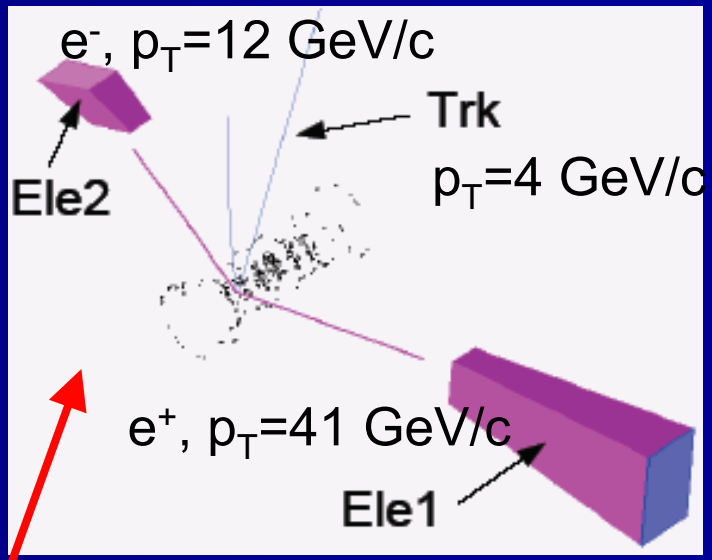
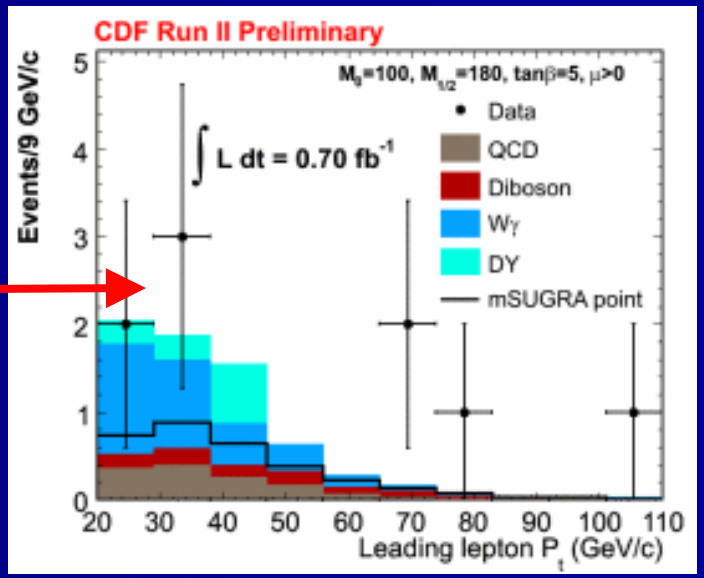
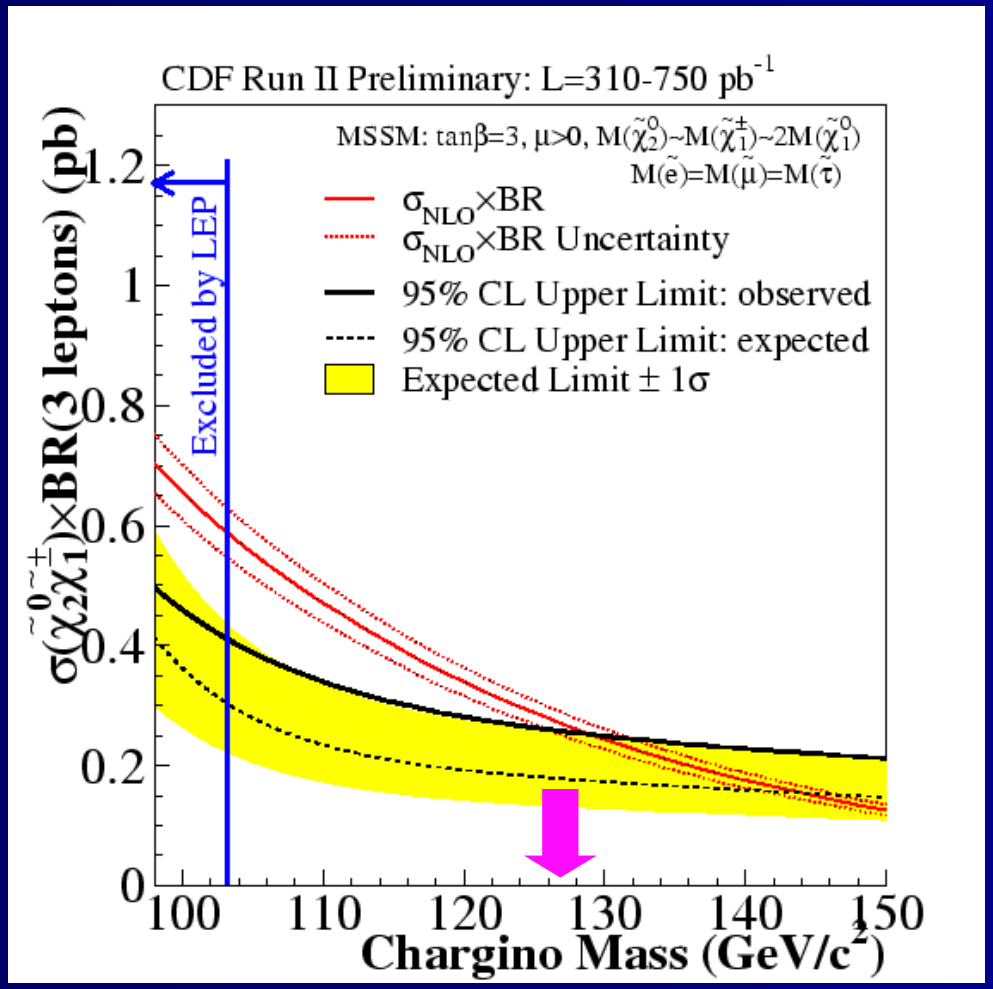




CDF Run II Limit

Analyses are combined exclusively and a frequentist based limit is calculated



EXCLUSION LIMIT

m ~ 127 GeV/c^2

$\sigma\cdot$BR ~ 0.25 pb

SENSITIVITY

m ~ 140 GeV/c^2

$\sigma\cdot$BR ~ 0.2 pb

D0 Limit m ~ 117 GeV/c^2 in similar scenario

Systematic uncertainties have negligible impact

Need more statistics!

Outlook

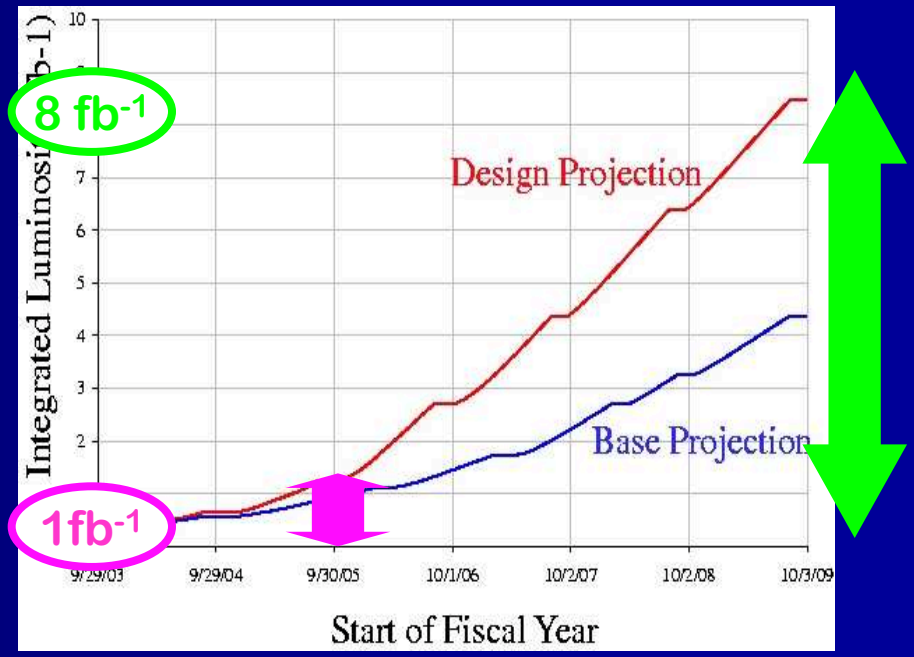
Searching for New Physics is exciting

Trileptons are an excellent signature for SUSY!

No evidence for SUSY production in ~ $1fb^{-1}$

Set limit on Chargino mass ~ 127 GeV/c^2

With ~ 8 fb^{-1}, sensitive up to Chargino mass ~ 240 GeV/c^2



this is just the beginning !!!

Back up

Data

Channel	Data (pb^{-1})
$\mu\mu$ + l	745
μe + l	745 (680)
ee + l	346
$\mu\mu$ + l	312
ee + track	607
LS	704

Channel	Trigger Eff.
$\mu\mu$ + l	Cmup=90-92% Cmx=96-97%
μe + l	same
ee + l	CEM=96%
$\mu\mu$ + l	Cmup=89% Cmx=91%
ee + track	CEM = 92%
LS	Cmup=90-92% Cmx=96-97% CEM = 96-98%

Systematic uncertainties LS

luminosity	5%
fakes	4%
ID + trigger	1%
conversions	11%
Theory predictions	5%
Statistical uncert.	7%
TOTAL	15%

Systematic uncertainties ee+track

luminosity	6%
fakes	13%
Theory predictions	7%
JET Energy scale	17%
PDF	2%
ISR	9%
FSR	6%
TOTAL	31%

Systematic uncertainties
$\mu\mu$ low pt

Luminosity	1%
fakes	21%
Theory predictions	7%
Muon ID	1%
Muon isolation	2%
Heavy Flavor	6%
TOTAL	22%

Systematic uncertainties $\mu\mu$ high pt

Luminosity	4%
fakes	16%
Theory predictions	5%
Muon ID	4%
Jet Energy scale	6%
Conversion	10%
ISR	4%
PDF	2%
TOTAL	22%

Systematic uncertainties
μe (CEM-plug)

Luminosity	4% - 5 %
fakes	13% - 8%
Theory predictions	5%
Muon ID	4% - 4%
Jet Energy scale	7% - 2%
Electron ID	4% - 14%
Conversion	7%
ISR	4%
PDF	2%
TOTAL	19%

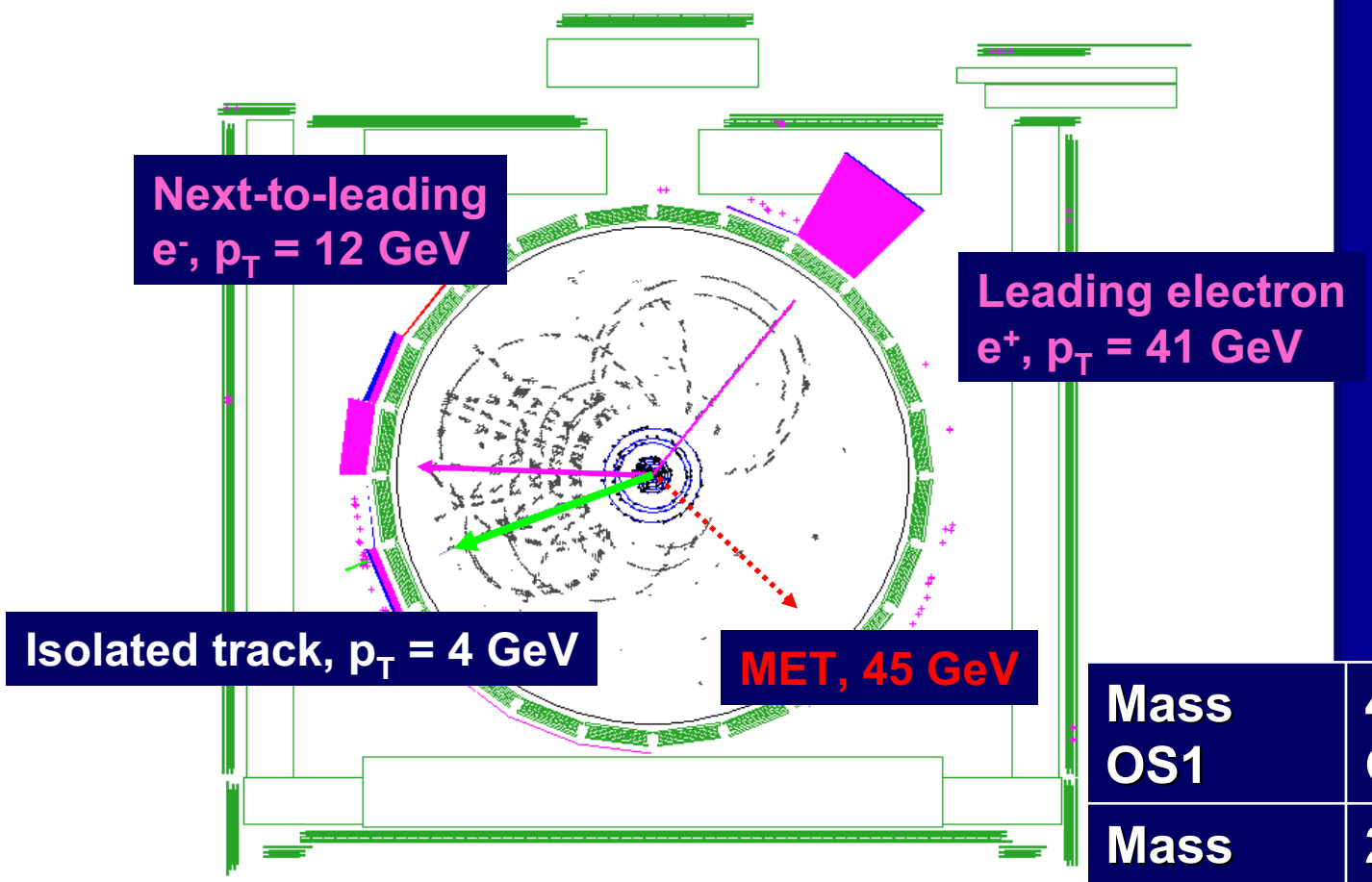
Systematic uncertainties ee

Luminosity	6%
fakes	13%
Theory predictions	7%
Electron E scale	3%
Jet Energy scale	4%
Electron ID	7%
Conversion	11%
ISR	4%
PDF	2%
TOTAL	22%

Heavy Flavor estimate low pt muons analysis

- Select HF rich – invert d0
- Fit DY + HF to data in OS and LS
- Get a scale factor for OS and one for LS
- Run the analysis on the HF rich sample but scaling up if needed the contribution

ee track

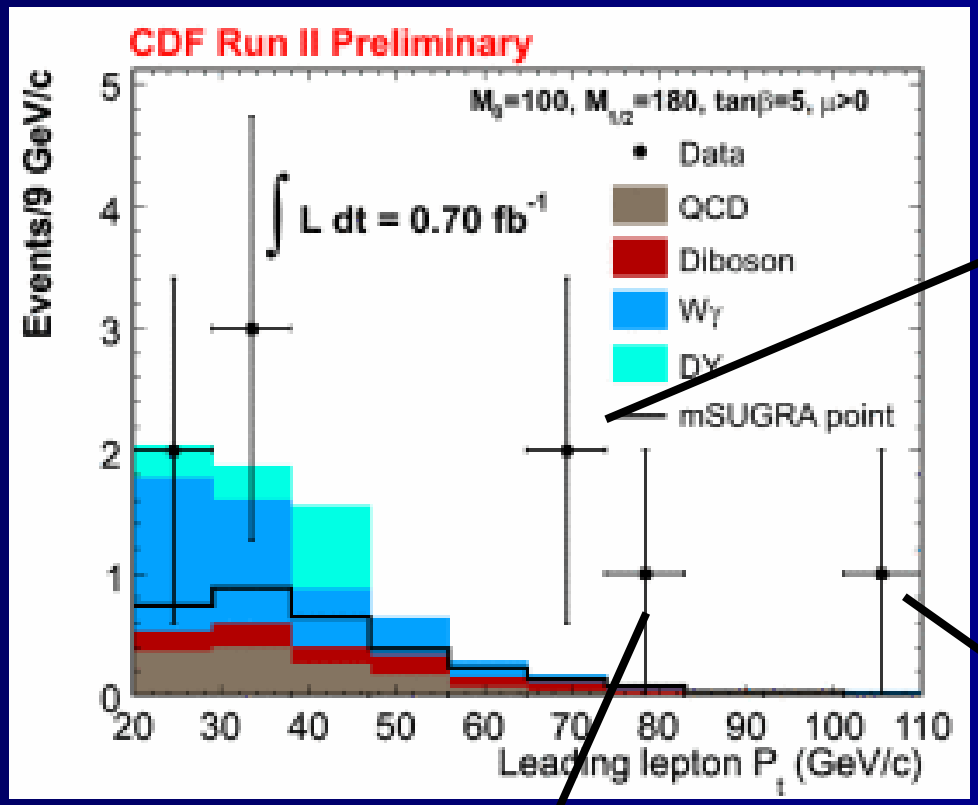


Mass OS1	41.6 GeV
Mass OS2	27.0 GeV

Track fake rate

- Fake rate per event in Z data
- Checked as a function of # tracks and Ht
- Applied to MC if no third genp track
  - DY WW W/Z ZZ

LS events



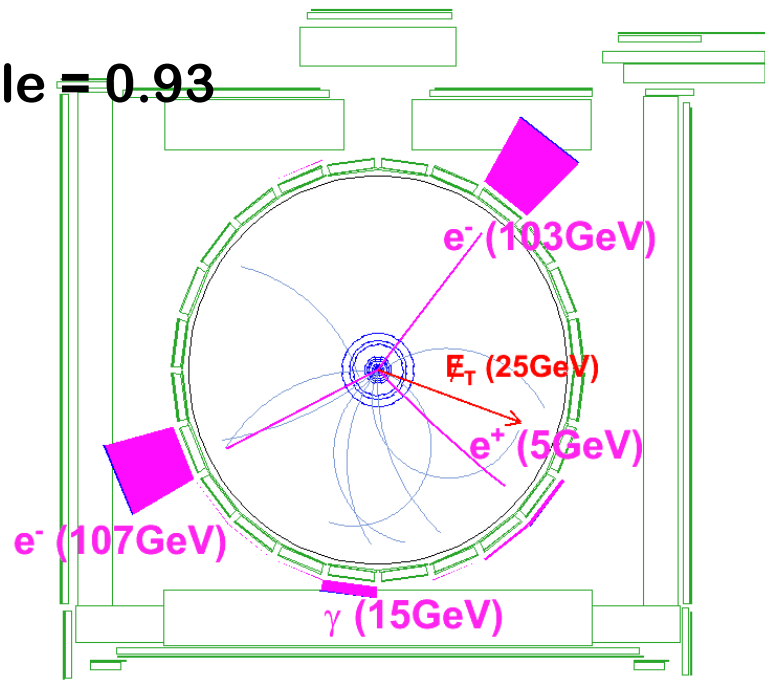
* e=73 GeV
e=41 GeV
met 96 GeV,
pile up
3rd ele from different vertex

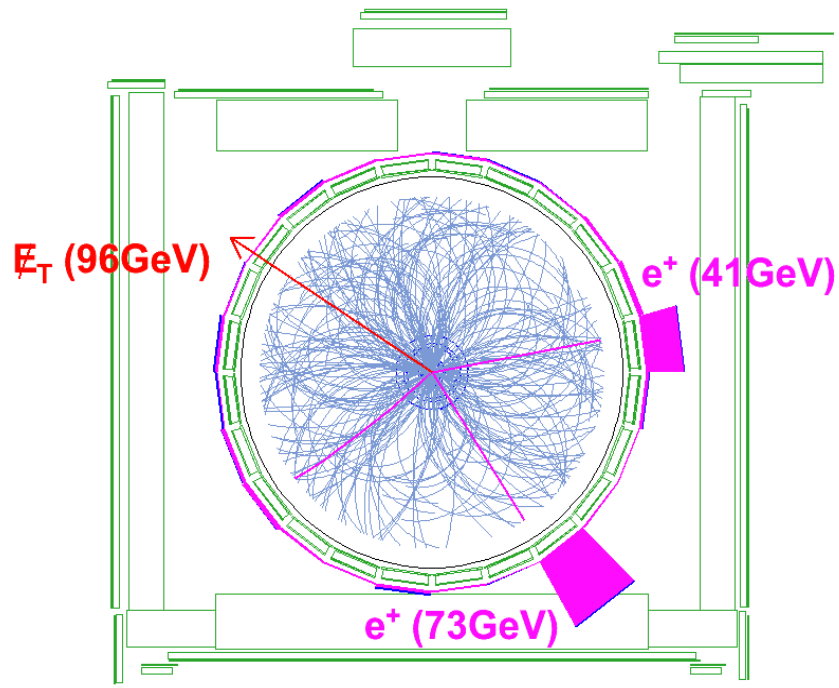
*eμ μ CMX=66 GeV,
e= 10 GeV, MET=37 GeV

* e=107 GeV
e=103 GeV
e=5 GeV non iso
Gamma
Met=25 GeV

eμ e= 74 GeV μ CMX=15 GeV
MET = 31 GeV

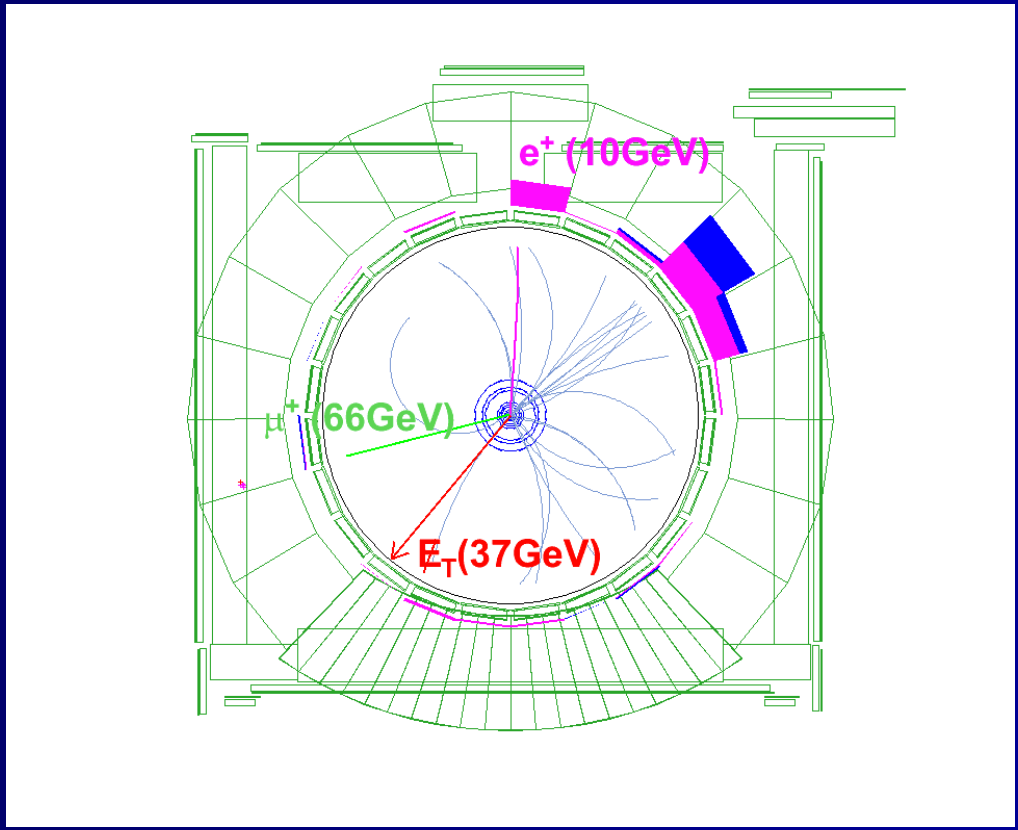
E/p ele = 0.93



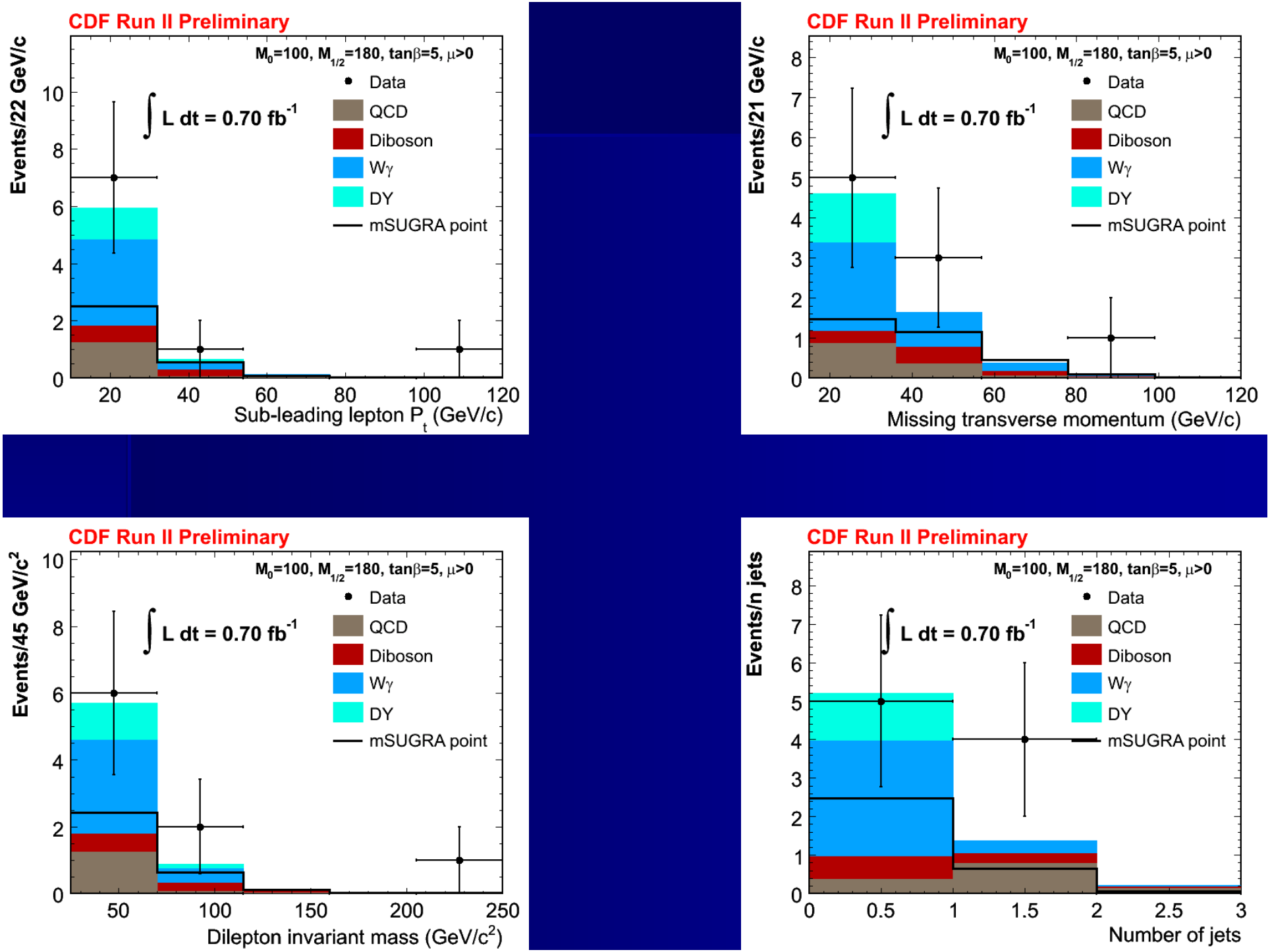


Two electrons above 100 GeV each. In the same event we have a photon of 15GeV, Met of 25GeV and a third electron of 5GeV that does not pass the calorimeter isolation

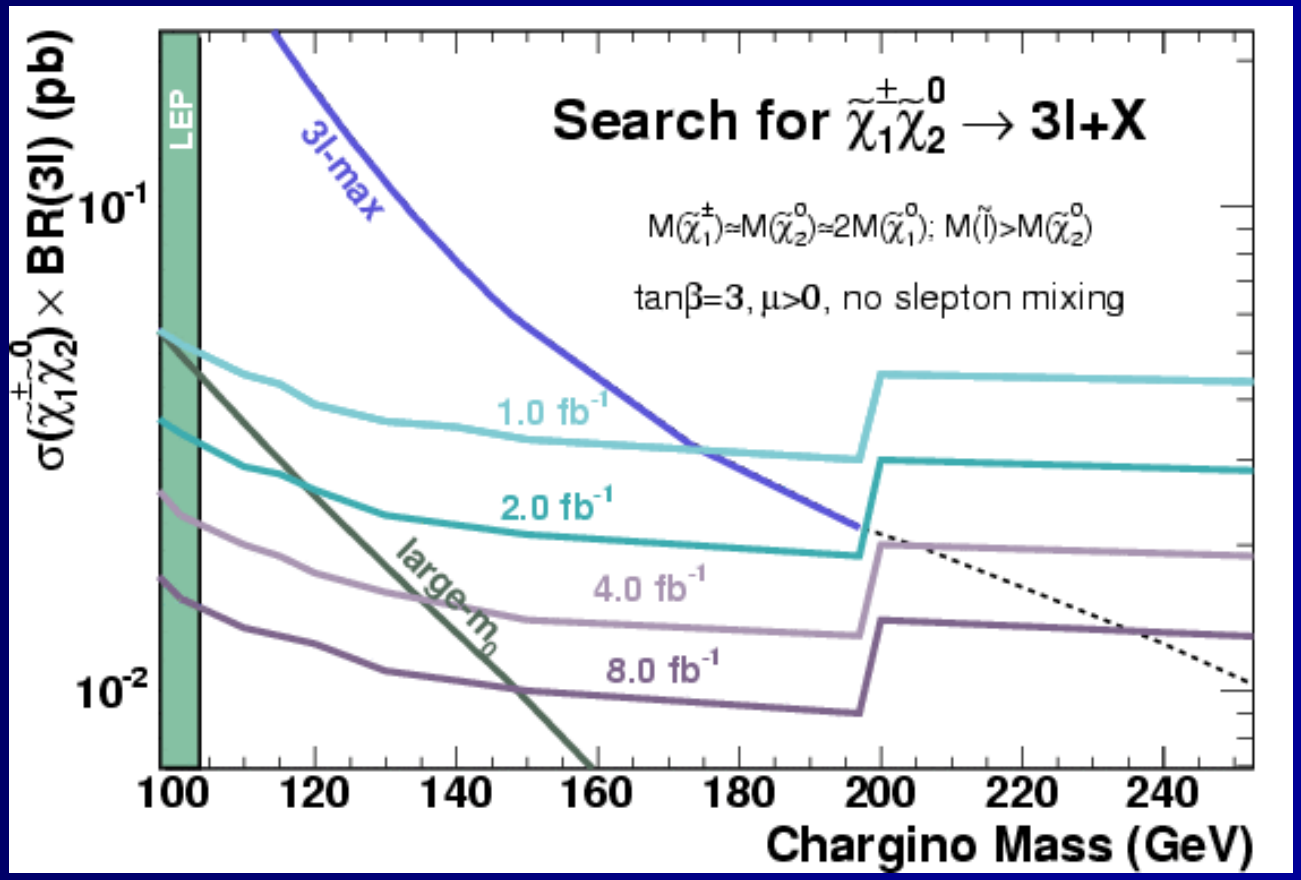
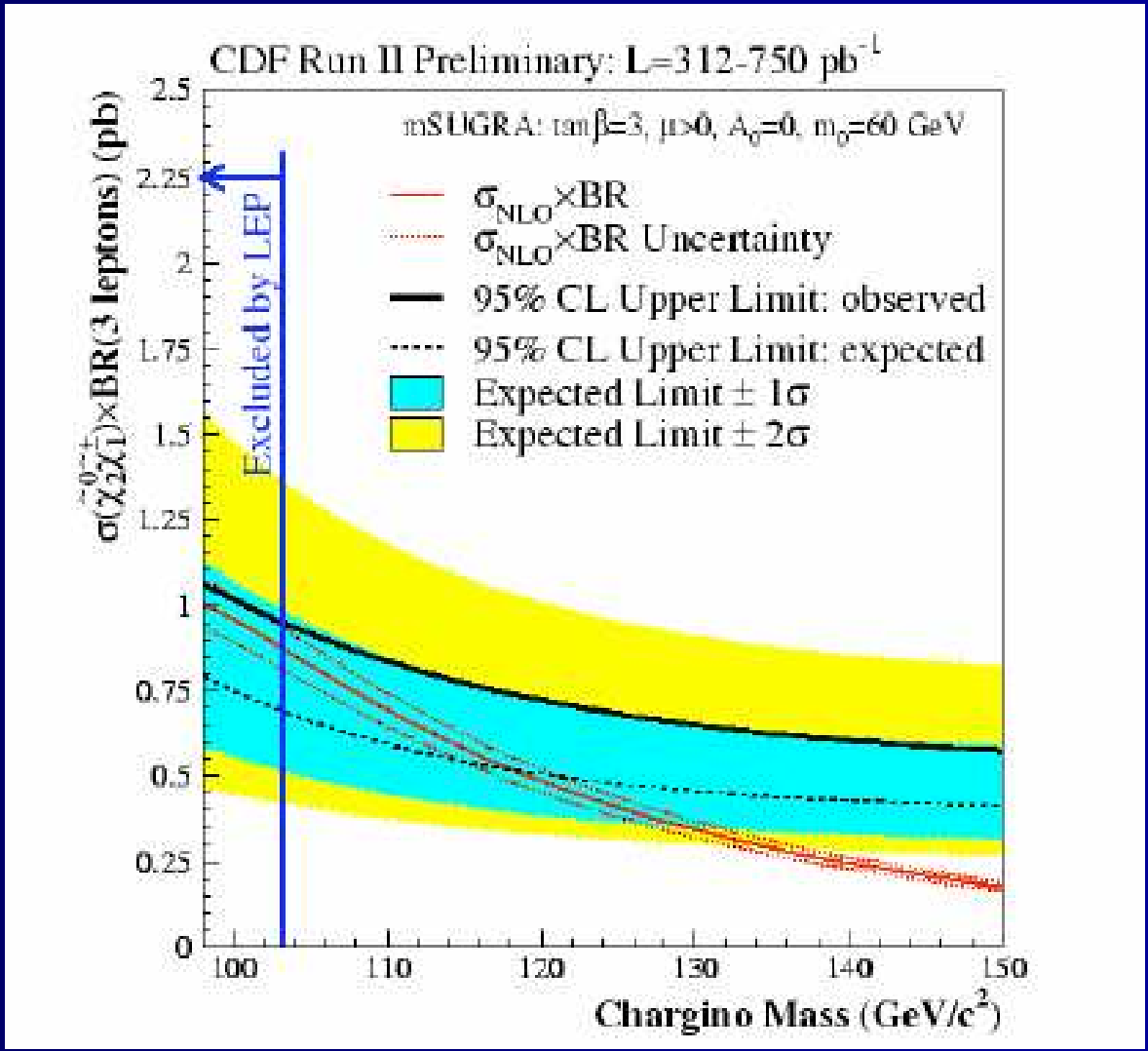
This event has more than 100GeV Met. There are lots of piled-up interactions. the third electron does not come from the same interaction vertex



Probability of the observed spectrum is 25%
Hypothesis = SM is null


CDF Run II Preliminary
M_0=100, $M_{1/2}$=180, tanβ=5, μ>0
∫ L dt = 0.70 fb^{-1}
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/22 GeV/c
Sub-leading lepton P_t (GeV/c)
CDF Run II Preliminary
M_0=100, $M_{1/2}$=180, tanβ=5, μ>0
∫ L dt = 0.70 fb^{-1}
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/21 GeV/c
Missing transverse momentum (GeV/c)
CDF Run II Preliminary
M_0=100, $M_{1/2}$=180, tanβ=5, μ>0
∫ L dt = 0.70 fb^{-1}
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/45 GeV/c^2
Dilepton invariant mass (GeV/c^2)
CDF Run II Preliminary
M_0=100, $M_{1/2}$=180, tanβ=5, μ>0
∫ L dt = 0.70 fb^{-1}
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/n jets
Number of jets

Projections



mSUGRA limit