Search for R-Parity Violating Supersymmetry in the Dielectron Channel at DØ

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for the

DØ Collaboration

Higgs and Supersymmetry : Search and Discovery

8-11 March 1999

Gainesville, Florida, U.S.A

Outline

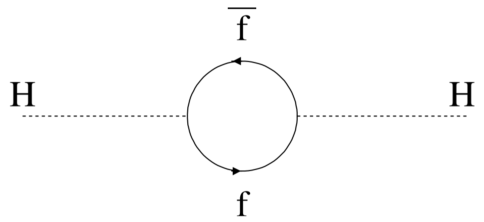
- **Introduction**
- **Analysis and results**
- **Summary of results**
- **Future directions**

Introduction

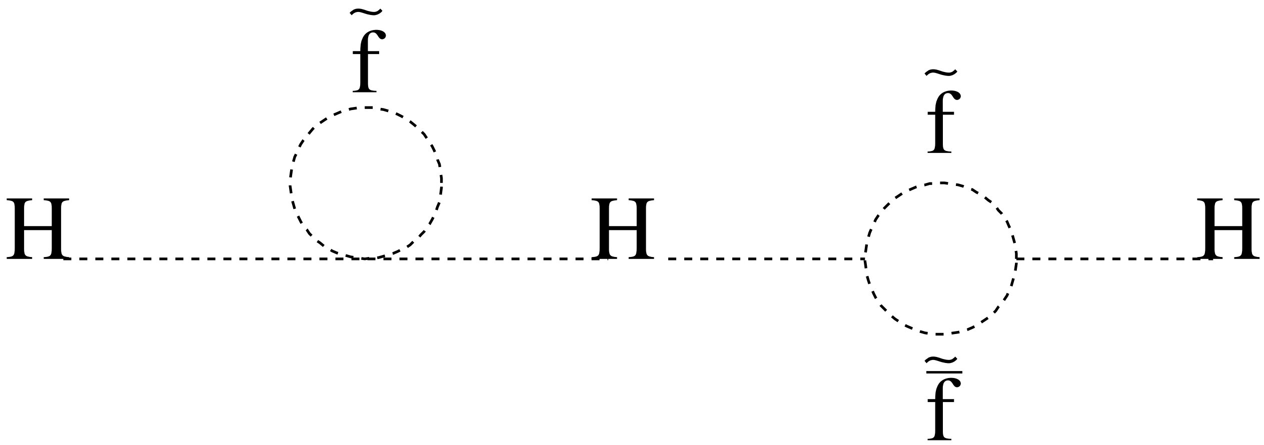
- Higgs mechanism was introduced to give masses to W and Z bosons

  Mass of Higgs $M_H < 1$ TeV

- Radiative corrections to the mass of Higgs diverge quadratically.



- Supersymmetry solves this problem.



Particle Spectrum

SM Particles	SUSY partners
Quarks Leptons	Squarks ($\tilde{q}$) Sleptons ($\tilde{l}$)
Charged Higgs $W^{\pm}$	Charginos ($\tilde{\chi}^{\pm}_{1,2}$)
Neutral Higgs Z^0 Photon	Neutralinos ($\tilde{\chi}^0_{1-4}$)
Gluon	Gluinos ($\tilde{g}$)

- Supersymmetry is a **broken symmetry**

  But $M_{SUSY} <$ 1 TeV

Super Gravity Framework:

To reduce the number of free parameter we choose Super Gravity (SUGRA) Framework.

All the gauge couplings unify at a very high energy scale.

It has five free parameters.

- m_0, **The common mass for scalar fermions at the unification scale.**
- $m_{1/2}$, **The common mass for all gaugions at the unification scale.**
- $tan(\beta)$, **the ratio of the vacuum expectation values of the two Higgs doublets.**
- A_0, **common trilinear coupling constant at the unification scale.**
- $sign(\mu)$, **the Higgsino mixing parameter.**

R-parity

$$R = (-1)^{3B+L+2S}$$

B = Baryon Number

L = Lepton Number

S = Spin

R= +1 for SM particle

R= -1 for SUSY particle

- **Most general superpotential**

$$W = W_{MSSM} + W_{\not R_p}$$

$$W_{MSSM} = h^e_{ij} L_i H_1 \overline{E}_j + h^d_{ij} Q_i H_1 \overline{D}_j + h^u_{ij} Q_i H_2 \overline{U}_j + \mu H_1 H_2$$

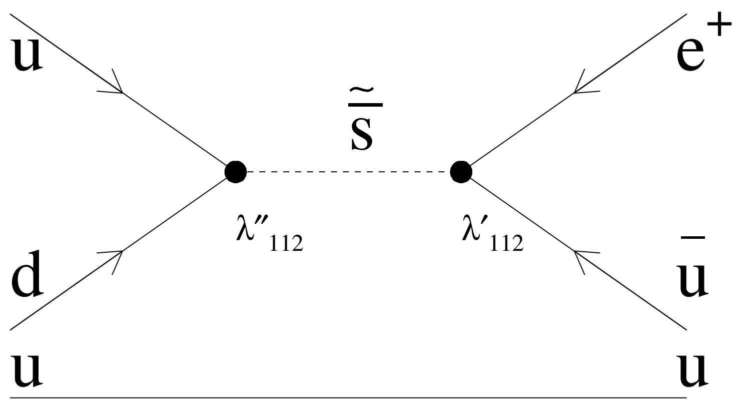
$$W_{\not R_p} = \lambda_{ijk} L_i L_j \overline{E_k} + \lambda^{'}_{ijk} L_i Q_j \overline{D_k} + \lambda^{''}_{ijk} \overline{U_i D_j D_k} + \epsilon_i L_i H_u$$

- **There can be 45 coupling terms**

9 λ_{ijk}, **27** $\lambda^{'}_{ijk}$, **9** $\lambda^{''}_{ijk}$

Consequences of R-parity conservation:

- **Supersymmetric particles can only be pair produced.**
- **The final decay product of SUSY particles is the Lightest Supersymmetric Particle (LSP). LSP escapes the detector leaving the canonical $\not\!\!E_T$ signature.**



For the stability of Proton conservation of either Baryon number or Lepton number is enough

Consequences of $R\!\!\!/_p$

- **Single production of Susy particles possible.**
- **Susy particles can decay into SM particles. LSP is no longer stable.**
- **LSP no longer needs to be a neutralino.**

Assumptions

- **R-parity conservation is assumed everywhere except in the decay of LSP.**
- **LSP is considered to be the neutralino.**
- **Only one R-parity violating term dominates.**
- **LSP decays close to the vertex (**$< 1\ cm$ **)**

Decay length of LSP:

$c\gamma\tau_{\tilde{\chi}_1^0} \sim$
$3\gamma.10^{-3}(m_{\tilde{f}}/100GeV)^4(1GeV/m_{\tilde{\chi}_1^0})^5(1/\lambda)^2$ **metre**

For $m_{\tilde{f}} \sim 200$ **GeV,** $m_{\tilde{\chi}_1^0} \sim 30$ **GeV,** $\gamma \sim 10$
$\lambda > 0.001$

Existing upper bounds on the couplings from low energy experiment. (all numbers should be multiplied by $\frac{m_{\tilde{f}}}{100\ GeV}$).

ijk	λ_{ijk}	ijk	λ'_{ijk}	ijk	λ'_{ijk}	ijk	λ'_{ijk}	ijk	λ''_{ijk}
121	0.05	111	0.001	211	0.09	311	0.16	112	10^{-6}
122	0.05	112	0.02	212	0.09	312	0.16	113	10^{-5}
123	0.05	113	0.02	213	0.09	313	0.16	123	1.25
131	0.06	121	0.035	221	0.18	321	0.20	212	1.25
132	0.06	122	0.06	222	0.18	322	0.20	213	1.25
133	0.004	123	0.20	223	0.18	323	0.20	223	1.25
231	0.06	131	0.035	231	0.22	331	0.26	312	0.43
232	0.06	132	.33	232	0.39	332	0.26	313	0.43
233	0.06	133	0.002	233	0.39	333	0.26	323	0.43

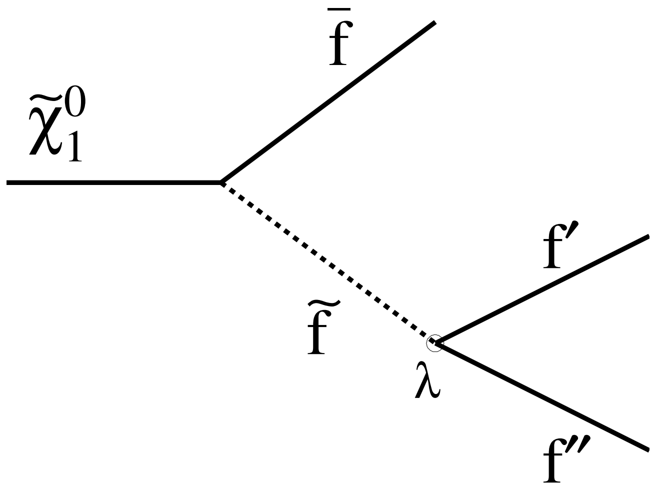
H. Dreiner, hep-ph/9707435,

R. Barbier et. al. hep-ph/9810232

B-violating λ'' terms lead to events with multijet signatures.

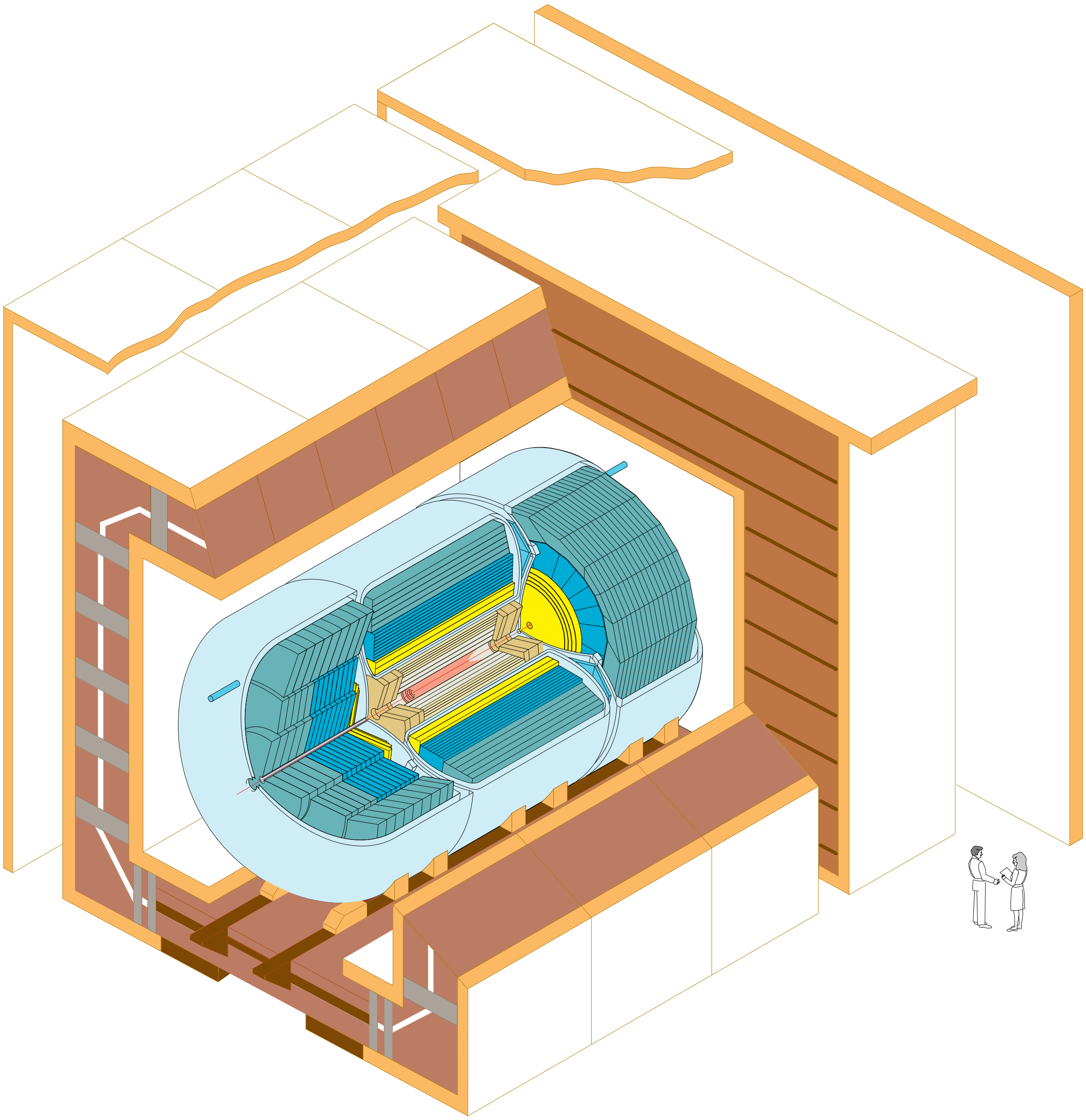
L-violating λ and λ' type couplings will give rise to multilepton and multijet final states.

We concentrate on λ'_{122} coupling.



$$\tilde{\chi}_1^0 \longrightarrow e^- c\bar{s}, e^+ \bar{c}s$$
$$\nu_e s\bar{s},\ \overline{\nu_e} s\bar{s}$$

Signal : 2 or more electrons and 4 or more jets.



DØ Detector

Background

SM Background

$$t\bar{t} \rightarrow l\bar{l} \rightarrow ee$$

$$Z \rightarrow \tau\tau \rightarrow ee$$

$$DY \rightarrow ee$$

$$WW \rightarrow ee$$

Instrumental Background

Jets misidentified as electrons.

Selection Criteria

Trigger

5 or more jets with $E_T \geq 10$ **GeV**

H_T **(** ΣE_T **of all jets)** $\geq$ **115 GeV**

Offline Cuts

$\geq$ **2 electrons (**$E_T \geq 15$ **GeV**

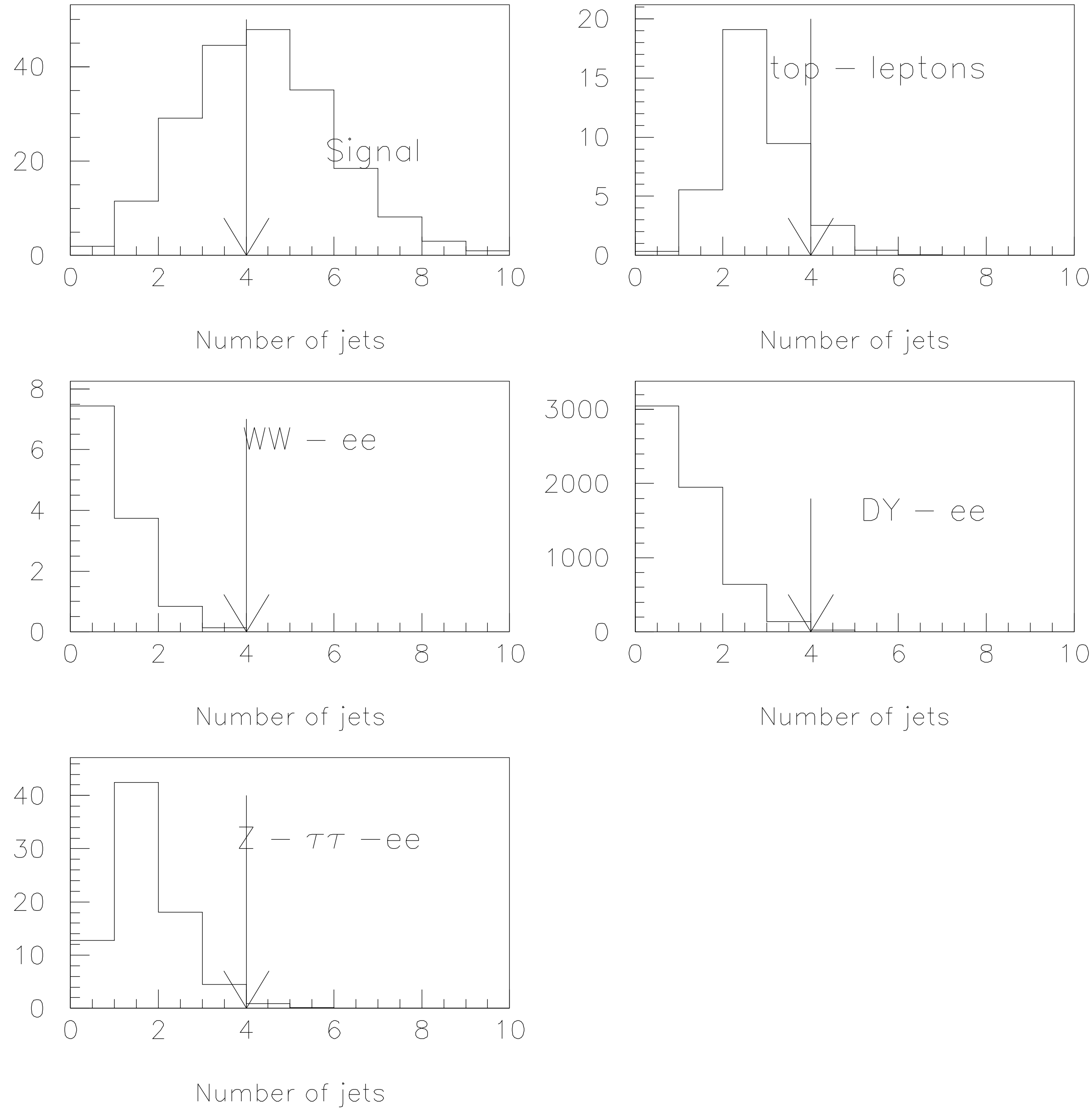
and $E_T \geq 10$ **GeV)**

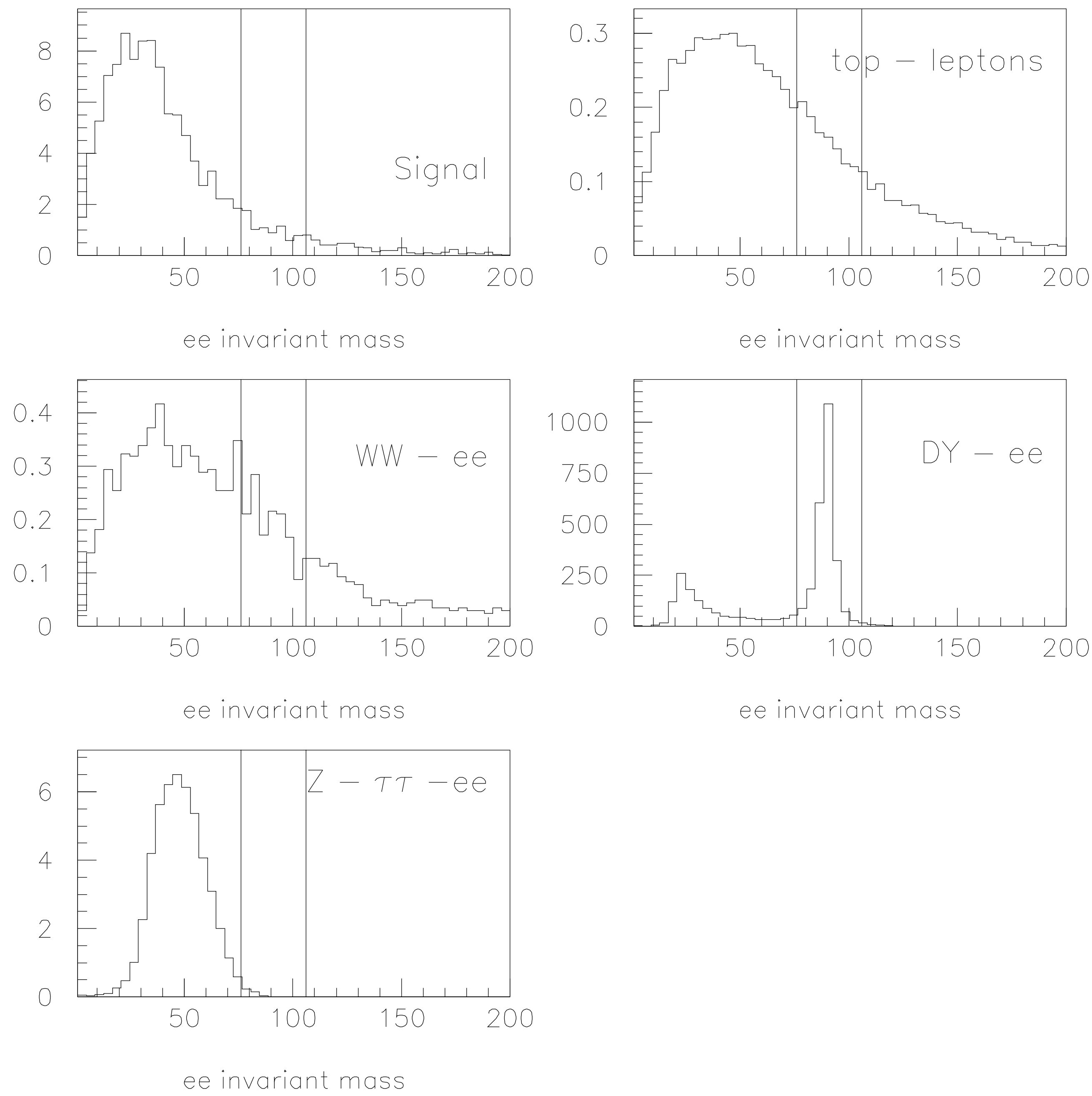
$|\eta| \leq 1.1$ **and** $1.5 \leq |\eta| \leq 2.5$

$\geq$ **4 Jets (**$E_T \geq 15$ **GeV,** $|\eta| \leq 2.5$**)**

$H_T \geq$ **150 GeV**

$|M_{ee} - M_Z| \geq$ **15 GeV**


Signal
Number of jets
top − leptons
Number of jets
WW − ee
Number of jets
DY − ee
Number of jets
Z − ττ −ee
Number of jets


Signal
top – leptons
WW – ee
DY – ee
Z – ττ –ee
ee invariant mass
ee invariant mass
ee invariant mass
ee invariant mass
ee invariant mass

Effects of cuts on data

Data corresponding to Luminosity 96 pb^{-1} has been analysed.

Cut	No. of events
Passed trigger requirement	163140
2 good electrons	38
4 good jets	6
Invariant mass cut	2
H_T	2

Analysis of MC events

Number of events expected

$$< N >= \mathcal{L}.\sigma.\epsilon$$

$$\epsilon = \epsilon_{sel}.\epsilon_{el-id}$$

$$\epsilon_{sel} = \frac{Events\ passing\ all\ the\ cuts\ except\ el-id}{Number\ of\ events\ generated}$$

ϵ_{el-id} **obtained from $Z+$ jets data.**

Estimation of Error:

- **Statistical: Finite size of MC sample + Electron ID error.**
- **Systematic error due to Jet energy scale uncertainty.**

  For Background estimation Cross section error is also added.
- **Luminosity error.**

Estimation of Background

For estimating SM background experimentally measured values for Cross-sections are used wherever available.

Determination of Instrumental of Background

This is done in two steps.

- **Estimate the probability of a jet to be misidentified as an electron.**

Misidentification probability is found to be stable with E_T threshold but it is different in two different parts of the calorimeter.

For CC $(4.56 \pm 0.37) \times 10^{-4}$

For EC $(1.38 \pm 0.22) \times 10^{-3}$

- **Calculate the number of events that mimic the signal.**

Background Summary

Background Processes	**Expected Contribution to 96pb^{-1}**
$DY \to ee$	$0.42 \pm 0.15 \pm 0.16$
$Z \to \tau\tau \to ee$	$0.08 \pm 0.02 \pm 0.02$
$t\bar{t} \to ll \to ee$	$0.08 \pm 0.01 \pm 0.03$
Instrumental	$1.27 \pm 0.01 \pm 0.24$
Total	$1.8 \pm 0.2 \pm 0.3$

Signal Event Simulation

- **Events have been generated for different values of m_0 and $m_{1/2}$ and fixed values of $tan(\beta) = 2$, $A_0 = 0$ and $\mu < 0$**

- **ISAJET is used as event simulator.**

- **We have modified ISAJET to include LSP decay.**

- **The branching ratio depends on the composition of the LSP which in turn depends on the SUGRA input parameters.**

Ref: PRD,49,3270,1994

H. Dreiner, M. Guchait, D.P Roy

- **ISAJET events are passed through detector simulator, trigger simulator and reconstruction package.**

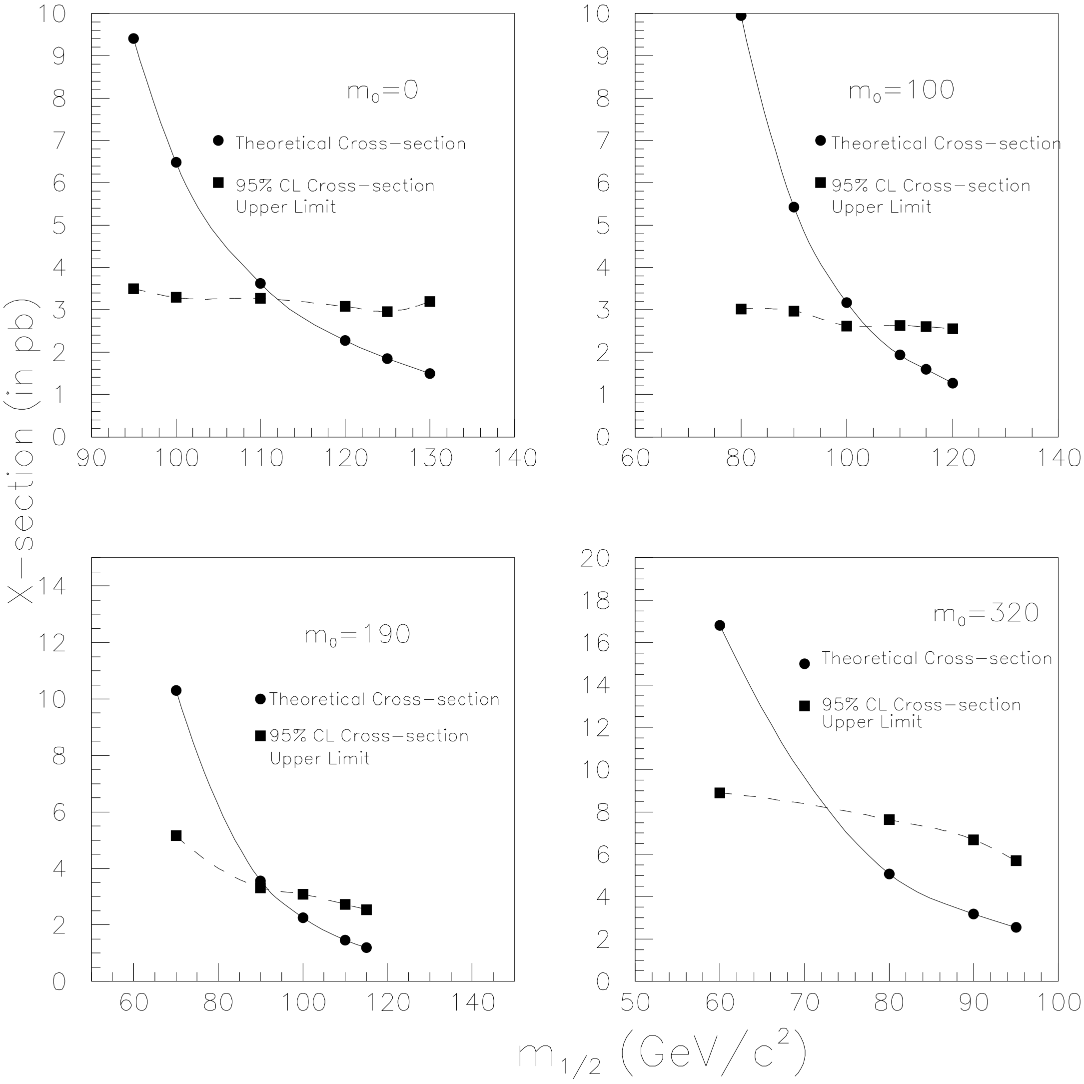
Efficiencies and event yield at few points.

Luminosity = 96 pb^{-1}

m_0	$m_{1/2}$	$\epsilon B.R.(\%)$	**X-sec (pb)**	$< N >$
0	**125**	$1.96 \pm 0.23^{+0.05}_{-0.07}$	**1.85**	3.5 ± 0.4
0	**110**	$1.78 \pm 0.21^{+0.09}_{-0.10}$	**3.62**	5.8 ± 0.7
30	**100**	$1.85 \pm 0.21^{+0.05}_{-0.04}$	**5.26**	9.4 ± 1.1
50	**90**	$1.58 \pm 0.18^{+0.07}_{-0.05}$	**7.67**	11.5 ± 1.3
50	**110**	$1.75 \pm 0.21^{+0.07}_{-0.02}$	**2.64**	3.3 ± 0.4
100	**90**	$1.96 \pm 0.22^{+0.02}_{-0.08}$	**5.44**	10.2 ± 1.1
320	**80**	$0.65 \pm 0.09^{+0.04}_{-0.02}$	**5.08**	3.2 ± 0.5

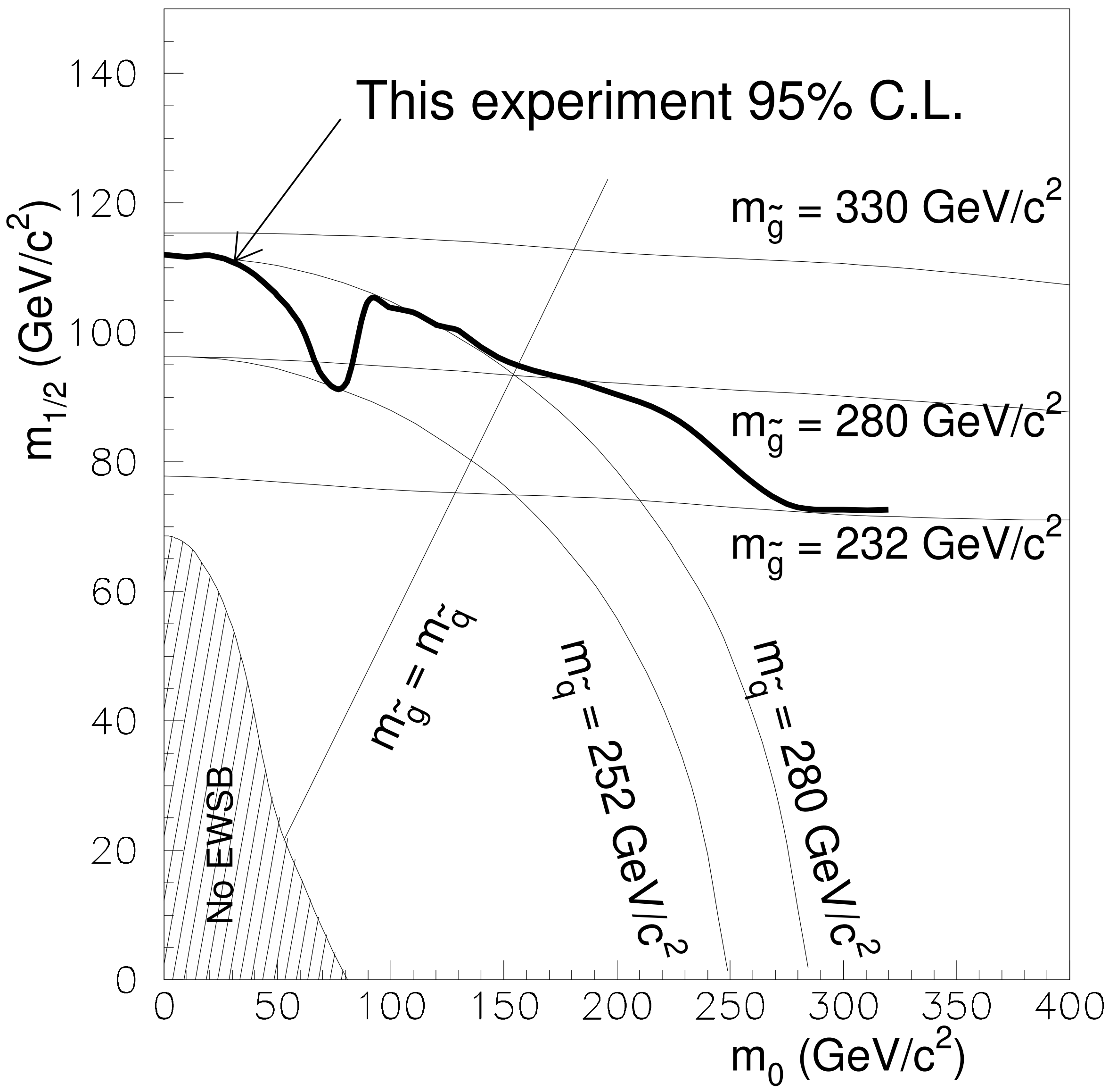
Cross Section Limit

$A_0 = 0, \tan\beta = 2, \mu < 0$



Exclusion Contour

$A_0 = 0, \tan\beta = 2, \mu < 0$



Summary of results

Within the SUGRA framework masses of Squarks below 252 GeV/c^2 and Gluinos below 232 GeV/c^2 are ruled out for fixed values of $A_0 = 0$, $\mu < 0$, $tan(\beta) = 2$ and finite values of $\lambda^{'}_{122}$ Coupling.

For equal masses of Squarks of Gluinos the corresponding limit is 283 GeV/c^2.

Future Directions.

- Sensistivity of the result with $tan\beta$
- Study λ' couplings with muons (i.e. λ'_{2jk})
- Study finite λ couplings.
- In Run II with a much larger data set ($\sim 2\ fb^{-1}$) and improved detector a much higher region of the parameter space is expected to be explored.
- Study for Run II shows, for fixed values of $A_0 = 0$, $\mu < 0$, $tan(\beta) = 2$ and finite values of λ'_{122} coupling $m_{\tilde{q}} < 520\ GeV/c^2$ and $m_{\tilde{g}} < 575\ GeV/c^2$ can be searched.