

DØ Searches

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On behalf of the DØ collaboration

The Standard Model is Incomplete

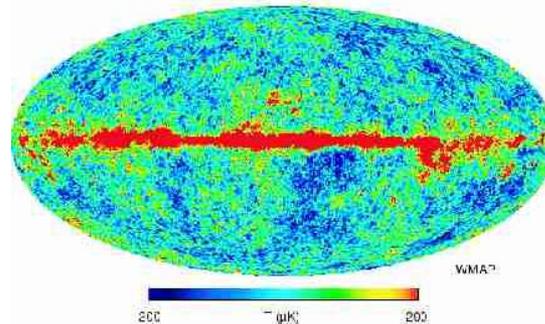
Theoretical problems

- why $M_{EW} \ll M_{planck}$?
- how to achieve grand unification?
- how to include gravity?
- what explains proliferation of quark and lepton types and determines their mixings?

Experimental problems

- SM fit to electro-weak data has probability of 4.4%
- what is dark matter?
 - new type of matter? – can be produced at the Tevatron!
 - “dark” because of undiscovered properties of space-time? – can be probed at Tevatron!

More general theories make predictions that can be tested at Tevatron



$$\Omega_M h^2 = 0.135^{+0.008}_{-0.009}$$

$$\Omega_B h^2 = 0.0224 \pm 0.0009$$

WMAP, astro-ph/0302207



Program of Searches

- Tevatron is the world's highest energy accelerator and is the most likely place to directly discover a new particle or force

- Many analyses are being pursued

- **many are done remotely in the collaborators' home countries**

- in this talk – only the most advanced



- Study of high E_T tails

- *dijet resonances (see talk by M. Wobisch)*

- *dileptons - Z' , Large Extra Dimensions*

- *diphotons – Large Extra Dimensions*

- Search for Leptoquarks

- *first generation $eejj$*

- *second generation $\mu\mu jj$*

- Signature-based searches

- $e+\mu+X$ (cf *Sleuth in Run I*)

- Search for SUSY

- $\text{jets} + \cancel{E}_T$

- $\gamma\gamma + \cancel{E}_T$

- *trileptons*

- *channels with hadronic τ*

Large Extra Dimensions

- Can gravity propagate in more than four dimensions of space-time that other SM forces and particles are confined to?

- solves hierarchy problem
- can explain dark matter

- The size of compactified dimensions can be as large as a fraction of mm depending on the number of extra dimensions

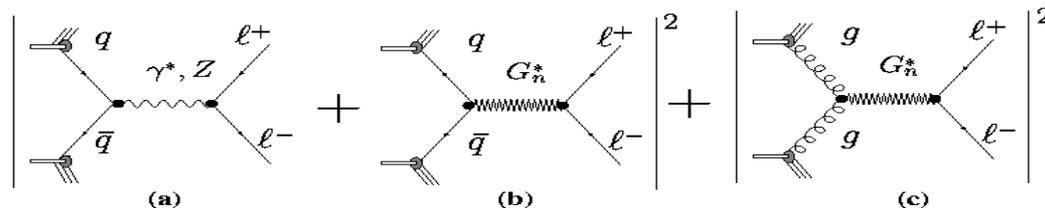
$$R \sim \frac{1}{M_S} \cdot \left(\frac{M_{Planck}}{M_S} \right)^{2/n} \quad M_S \text{ is the new gravity scale } \sim 1 \text{ TeV}$$

- gravitational force is experimentally measured at $l > 0.22 \text{ mm}$

- Tevatron could see effects with real or virtual gravitons:

- Measure the structure of space-time!

- Processes like Drell-Yan and di-photon production are modified at high $s^{1/2}$



- both invariant mass and angular distributions are modified

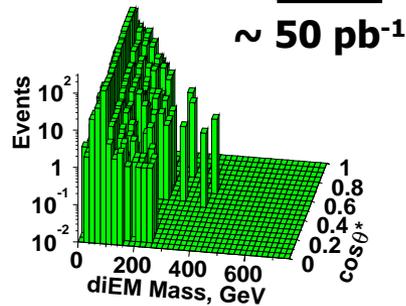
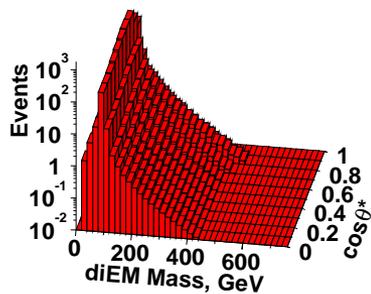
Large Extra Dimensions

Two dimensional analysis:

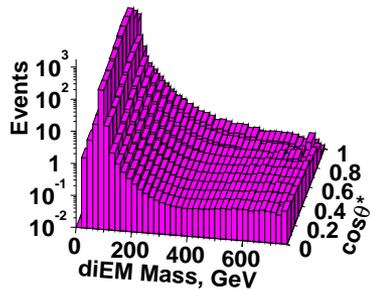
- invariant mass
- cosine of scattering angle in center of mass frame

ee and $\gamma\gamma$: 2 EM objects $p_T > 25$ GeV
missing $E_T < 25$ GeV

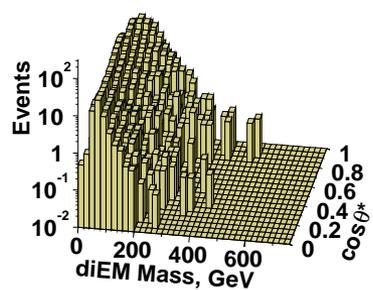
SM Prediction DØ Run II Preliminary Data ~ 50 pb⁻¹



ED Signal

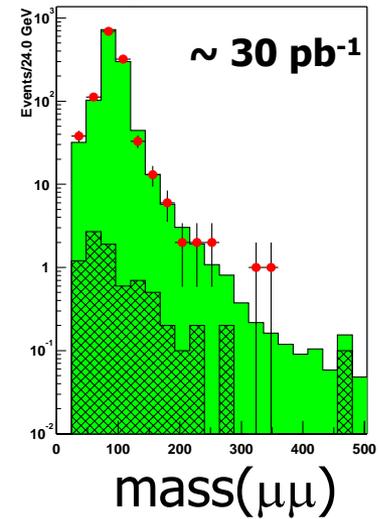
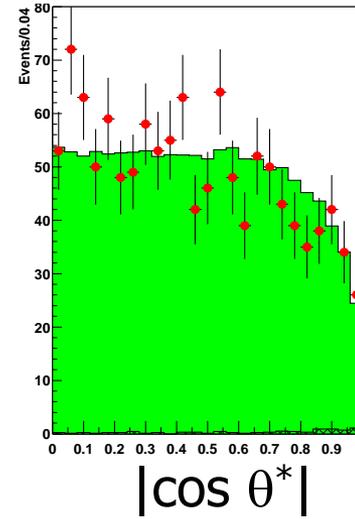


QCD Background



Di-muons: $p_T > 15$ GeV, opposite sign
 $m_{\mu\mu} > 40$ GeV

DØ Run II Preliminary



DØ Run II Preliminary M_S limits

	GRW	HLZ for n:	Hewett
		2 7	$\lambda = +1$
diEM	1.12	1.16 0.89	1.00
diMU	0.79	0.68 0.63	0.71

Comparable to Run I and LEP

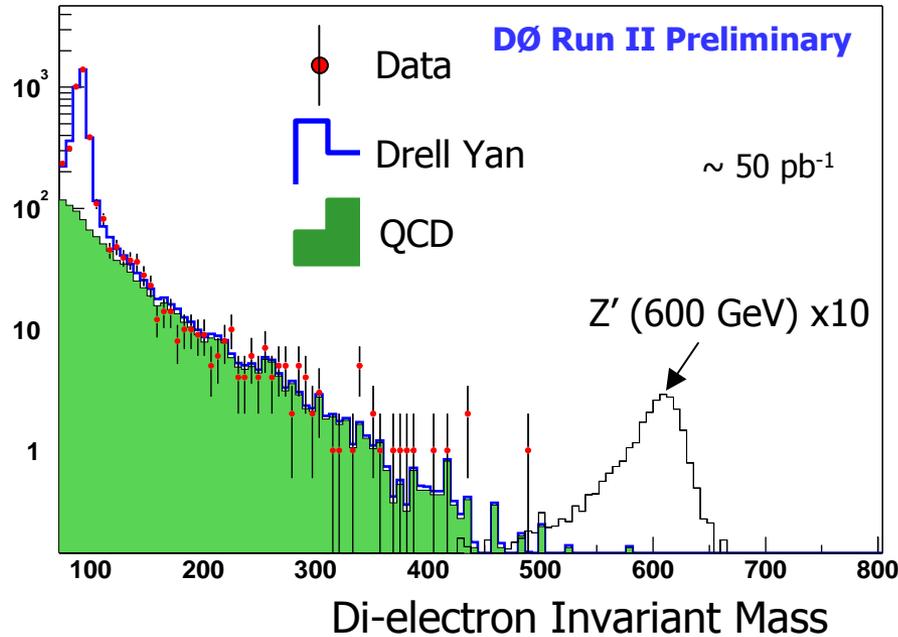
First measurement in this mode

with 300 pb⁻¹ probe up to 1.6 TeV
with 2 fb⁻¹ probe up to 2 TeV



Extra Gauge Bosons

Search for $Z' \rightarrow e^+e^-$

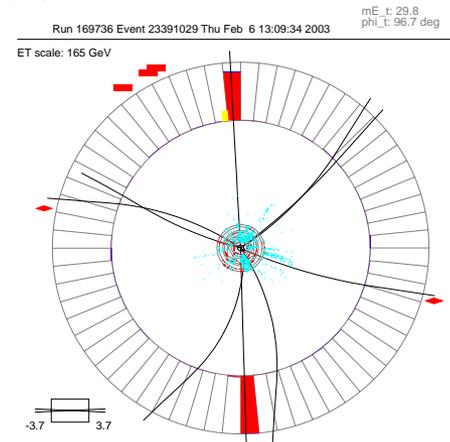
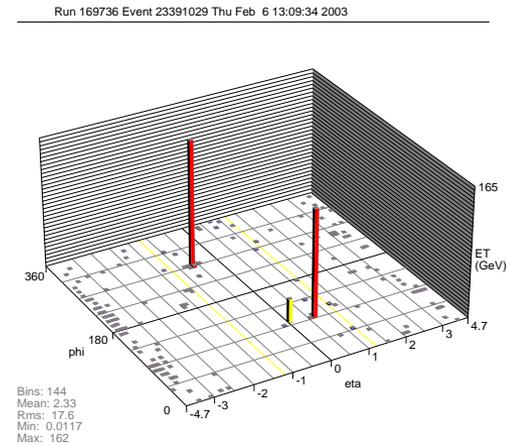


$M(Z') > 620 \text{ GeV @ 95\% CL}$

Run I limit 670 GeV

With 2fb^{-1} sensitive up to 1000 GeV

Highest mass CC-CC candidate



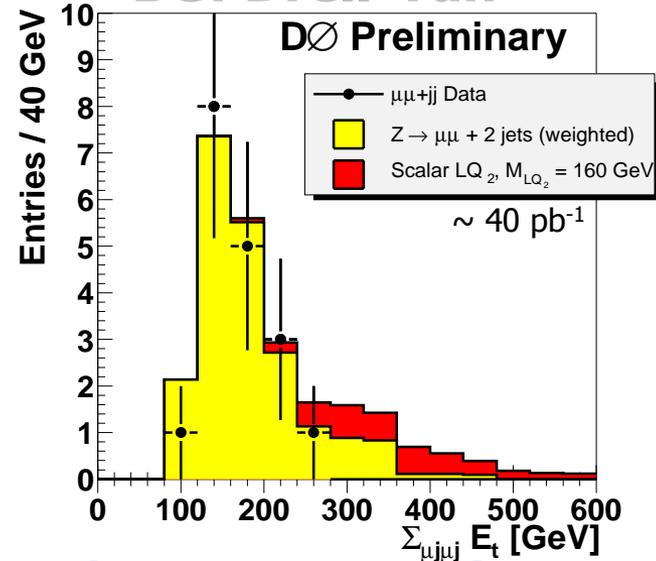
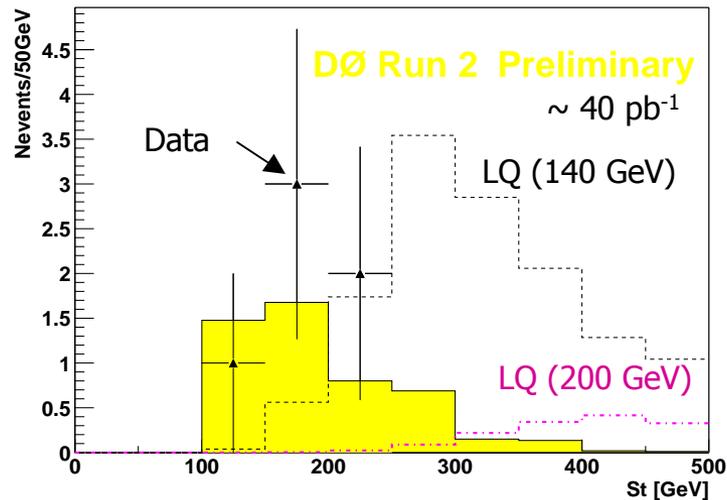
Scalar Leptoquarks

First generation LQ_1 $LQ_1 \rightarrow eejj$

Second generation LQ_2 $LQ_2 \rightarrow \mu\mu jj$

BG: Drell-Yan, QCD

BG: Drell-Yan



2 electrons $p_T > 25$ GeV
 2 jets with $E_T > 20$ GeV
 Exclude $75 < m < 105$ GeV

2 muons $p_T > 15$ GeV
 2 jets with $E_T > 20$ GeV
 $m > 110$ GeV

$S_T = \sum E_T$ of leptons and both jets > 300 GeV

Assuming 100% branching into charged lepton

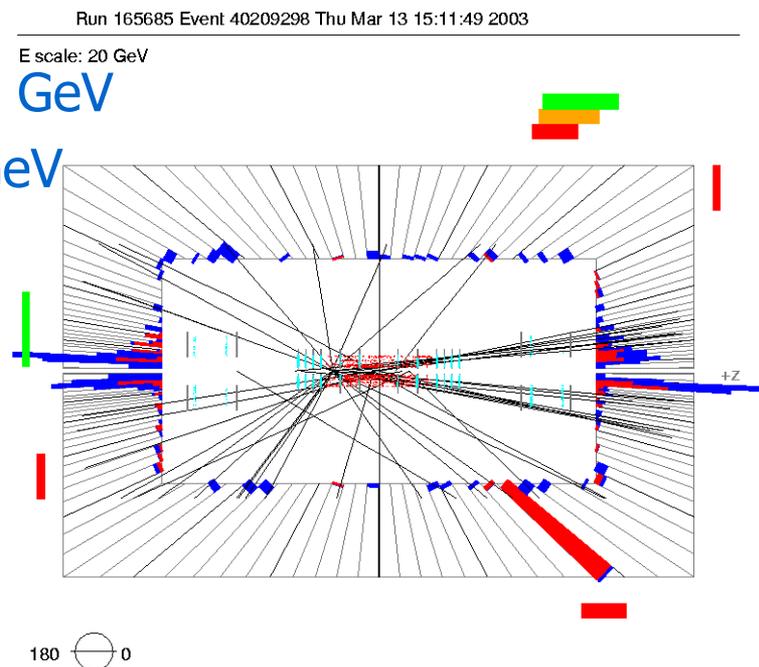
$M(LQ_1) > 179$ GeV @95%CL

$M(LQ_2) > 157$ GeV @95%CL



Signature Searches

- The goal is to produce model-independent limits for searches in all final states
- $e+\mu$ is a very clean channel due to different flavour of the leptons in the final state – easiest to completely understand
- Select events with
 - at least one isolated electron, $p_T > 15$ GeV
 - at least one isolated muon, $p_T > 15$ GeV
 - no jets with $E_T > 20$ GeV
- Main backgrounds
 - $Z \rightarrow \tau\tau \rightarrow e\mu$
 - lepton misidentification

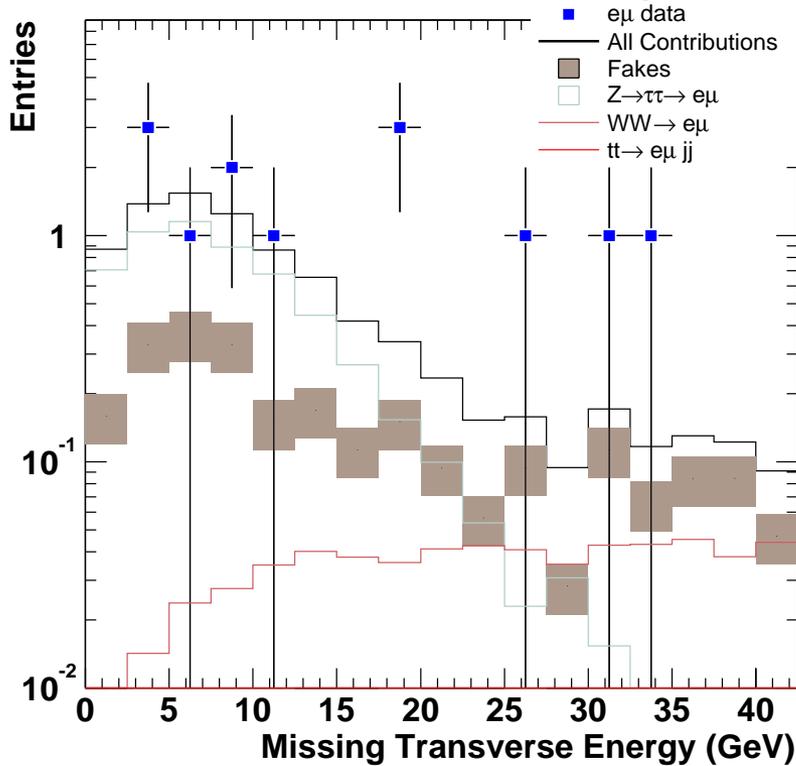


New Physics in $e\mu$ Final State

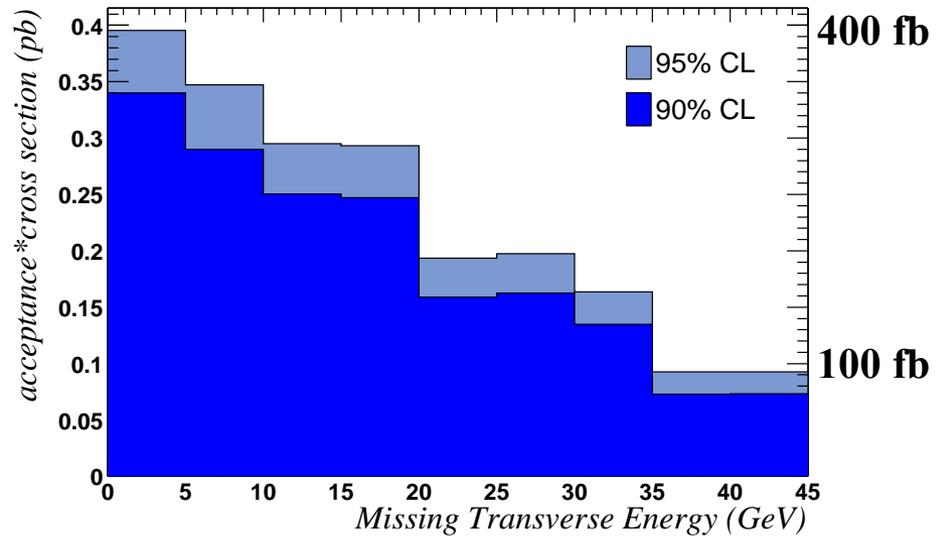
The data is described by SM

$A \times \sigma$ for new physics

DØ Run II Preliminary $\sim 30 \text{ pb}^{-1}$



DØ Run II Preliminary



Benchmark process:

$$A(WW \rightarrow \mu e) = 17\%$$



Quest for SUSY

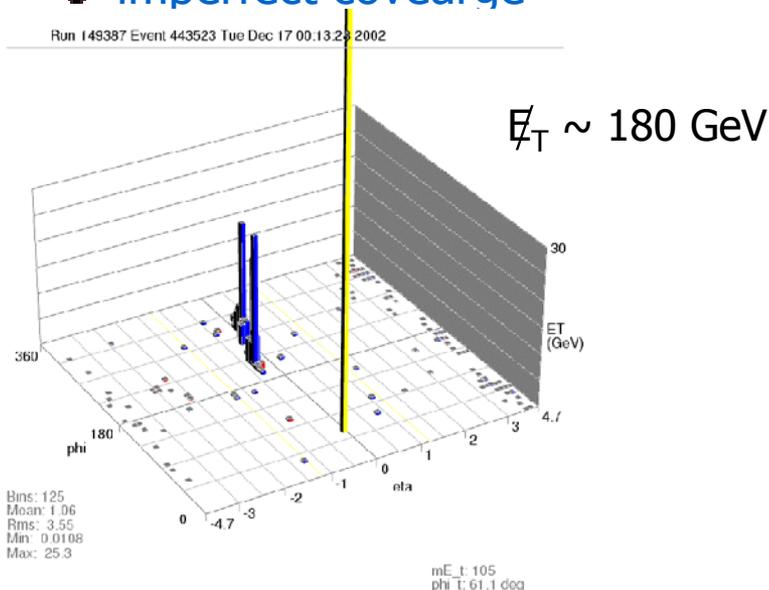
- (broken) symmetry between fermions and bosons
- Allows for Grand Unification and provides a path for eventual incorporation of gravity into the theory
- Introduces a lot of new parameters but **predicts correct value of $\sin \theta_W$**
- Solves hierarchy problem
- Predicts light Higgs boson
- R-parity: if conserved, SUSY particles can not decay into SM particles, i.e. lightest SUSY particle (LSP) is stable and weakly interacting – **perfect dark matter candidate**

Jets+missingET signature

$p\bar{p} \rightarrow \text{gluinos} / \text{squarks} \rightarrow$

$\rightarrow \text{quarks} / \text{gluons} + \chi_1^0 \chi_1^0$

- **LSP escapes detection** $\Rightarrow \cancel{E}_T$
- Main background – instrumental effects in \cancel{E}_T
 - gross jet mis-measurements
 - imperfect coverage

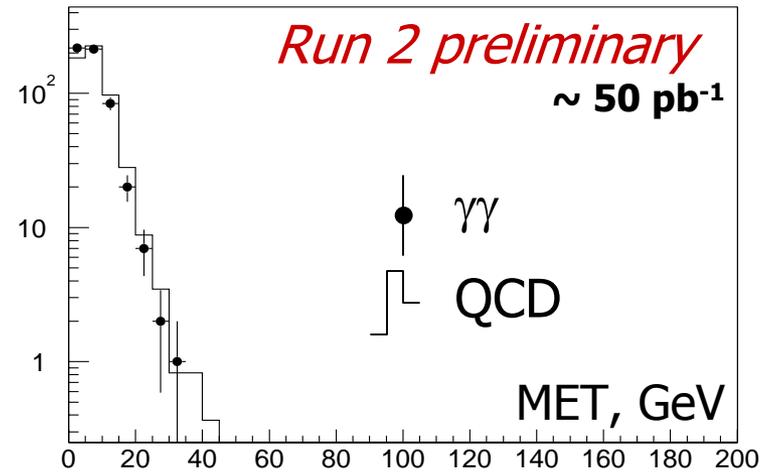


Search for Gauge Mediated SUSY

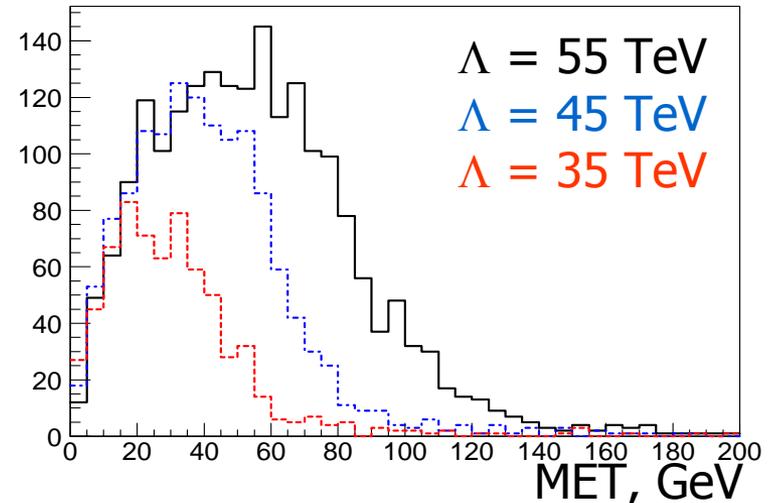
- Gravitino is LSP and very light
- If next to lightest is neutralino expect events with photon pairs

$$p\bar{p} \rightarrow \text{gauginos} \rightarrow W, Z, \gamma + \chi_1^0 \chi_1^0 \rightarrow \gamma\gamma + \tilde{G}\tilde{G} + X$$

- *Run I: CDF had an interesting event $\gamma\gamma ee + \text{missing } E_T$*
- *two central photons $E_T > 20$ GeV*
- *topological cuts to improve resolution in missing E_T*
- *use data to determine QCD background*



Snowmass Slope E: mGMSB(Λ)
 $M=2\Lambda; N_{\text{mess}}=1; \text{tg}\beta=15; \mu>0$

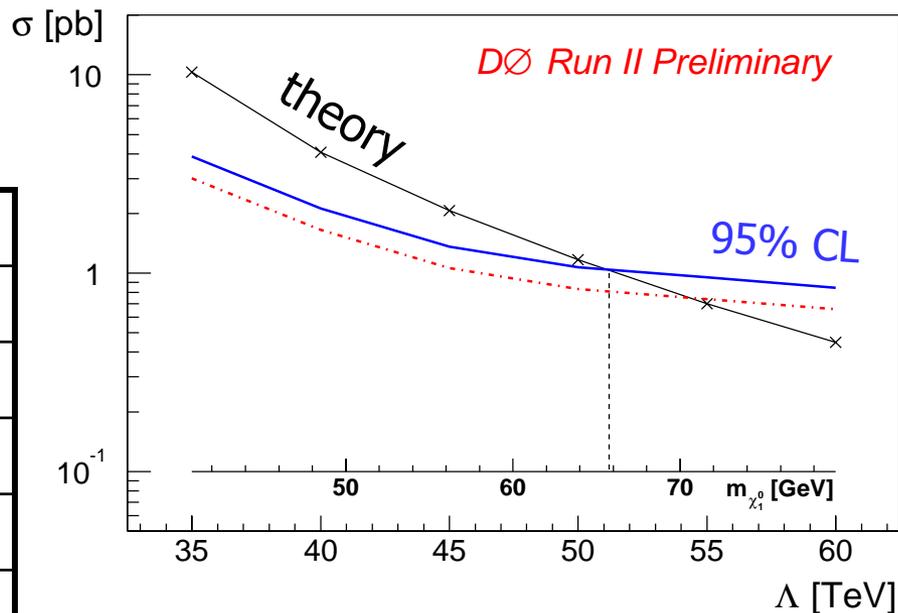


Limit on GMSB SUSY

$$\begin{aligned}\mathcal{E}_{SUSY} &= \mathcal{E}_{trig} \cdot \mathcal{E}_{vtx} \cdot \mathcal{E}_{EMID}^2 \cdot A = \\ &= 0.66 \pm 0.09 \cdot A\end{aligned}$$

Λ , TeV	σ , pb	Acceptance, %		
		$\cancel{E}_T > 25$	$\cancel{E}_T > 30$	$\cancel{E}_T > 35$
35	10.3	4.6	3.8	2.7
40	4.06	8.3	6.9	5.5
45	2.07	12.1	10.8	9.0
50	1.17	15.1	13.7	12.3
55	0.70	16.8	15.3	14.0
60	0.45	18.6	17.4	16.3

Cut: missing $E_T > 30$ GeV



$\Lambda > 51 \text{ TeV}$ @ 95% CL

$m_{\chi_1^0} > 66 \text{ GeV}$ @ 95% CL

close to Run I limits

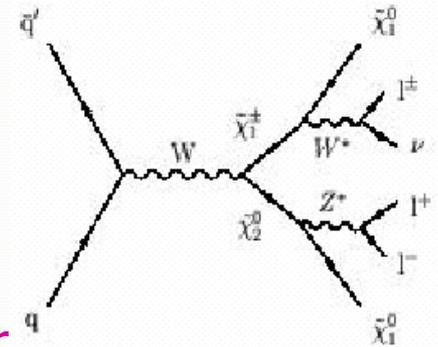


SUSY Trileptons

- “Golden” channel with low backgrounds

- Challenge:

- leptons are soft
- at $\tan\beta > 8$ most of the leptons are taus
 - ➔ e and μ from cascade decays are even softer



- Backgrounds to soft leptons

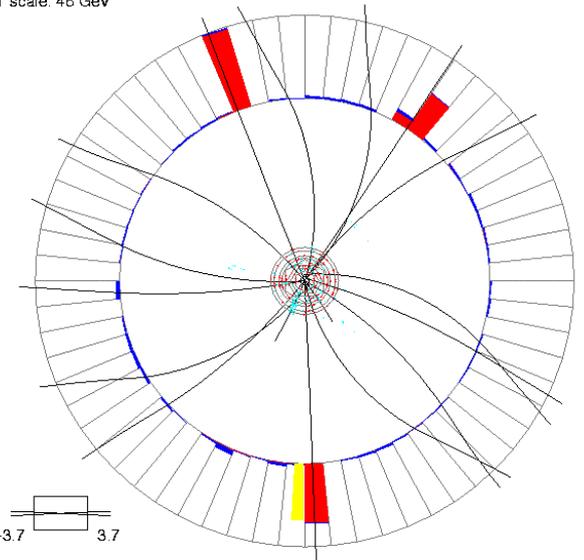
- electrons - asymmetric photon conversions
- muons - b/c jets
- hadronic taus – QCD jets

- Preparatory work and calibration:

- Study $Y \rightarrow ee, \mu\mu$ production
- Study $Z \rightarrow \tau\tau$ production

Run 167885 Event 21398063 Fri Mar 7 13:08:32 2003

ET scale: 46 GeV

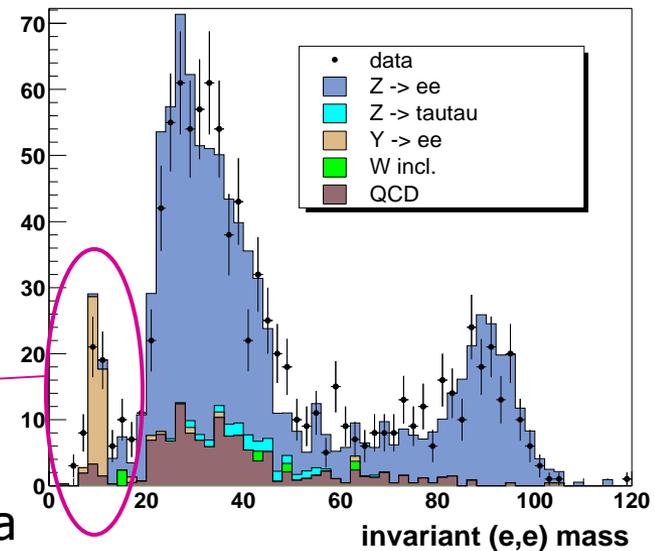


SUSY Trileptons

DØ Run II Preliminary

- Understanding soft electrons
 - Two electrons $p_T > 10$ GeV
 - At least one electron $p_T < 20$ GeV
- Good agreement with MC
Mis-identification is small

$Y \rightarrow ee$ signal



● $e+e+l$

$p_T^{e1} > 15$ GeV, $p_T^{e2} > 10$ GeV
 $10 < m(ee) < 70$ GeV
 $M_T > 15$ GeV
 Isolated track, $p_T > 5$ GeV
 Missing $E_T > 15$ GeV

	Backgrounds	Data
	3216 ± 43	3132
	660 ± 19	721
	96 ± 8	123
	3.2 ± 2.3	3
	0 ± 2	0

- $e+\mu+l$ - similar analysis
 - expect 1.5 ± 1.5 evts, see 2

The limits are still factors of 5-10 larger than SUSY cross-section at the edge of excluded region

Need $> 300 \text{ pb}^{-1}$ to significantly improve over LEP-2



Hadronic Decays of Tau Leptons

- $Z \rightarrow \tau\tau \rightarrow (\mu\nu\nu)$ (hadrons ν)
 - isolated muon $p_T > 15$ GeV
 - jet with $E_T > 7$ GeV
 - track with $p_T > 7$ GeV pointing to the jet

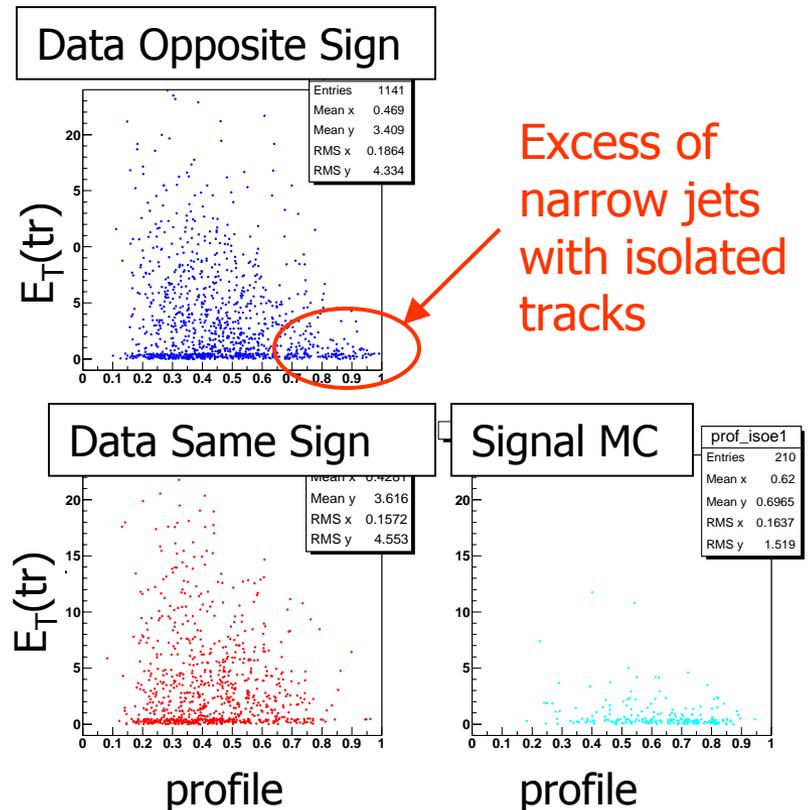
Backgrounds

- bb QCD
- W+jet

μ -h charge symmetric

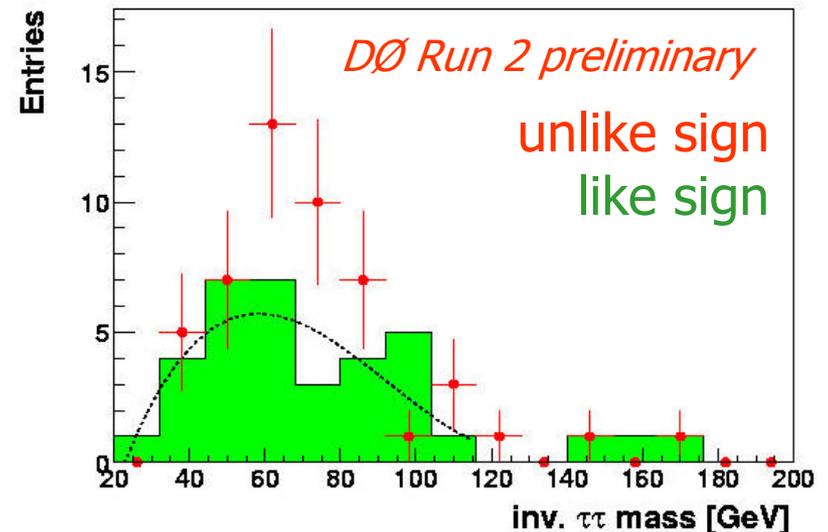
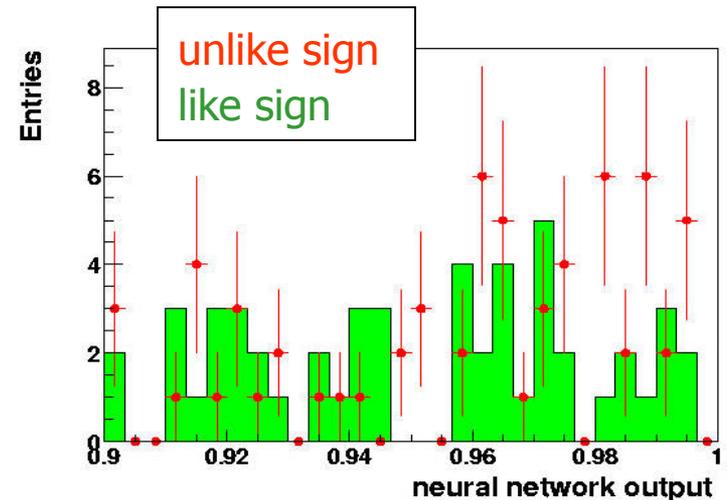
Observables:

- narrow jet: $\text{profile} = E_T(\text{two highest towers})/E_T(\text{total})$
- isolated track: $E_T(\text{tr}) = \sum \text{track } p_T$ (except the leading)



Hadronic Decays of Tau Leptons

- $Z \rightarrow \tau\tau \rightarrow (e\nu\nu)$ (hadrons ν)
 - isolated electron $p_T > 12$ GeV
 - jet with $E_T > 7$ GeV
 - jet and electron not back-to-back (for mass reconstruction)
 - anti $Z \rightarrow ee$ cuts
- Backgrounds
 - QCD
 - W+jet
- Use NN to identify taus
 - separate networks for one prong with and without reconstructed π^0



Summary

- Many analyses with $\sim 50 \text{ pb}^{-1}$
- Similar or better sensitivity than in Run I
 - higher E_{CM} and upgraded detector
 - New signals not seen in Run I: $Y \rightarrow ee$ and $Z \rightarrow \tau\tau$
- Improvements to come
 - better triggering on soft leptons (L1 tracking)
 - better calibration and understanding of the detector
- Looking forward to a long and productive program
 - have $\sim 140 \text{ pb}^{-1}$ on tape
 - *this summer – supersede most of Run I results*
 - 300 pb^{-1} – significant improvement in reach over LEP-2
 - ...

Tevatron is the world's highest energy accelerator and is the most likely place to directly discover a new particle or force

