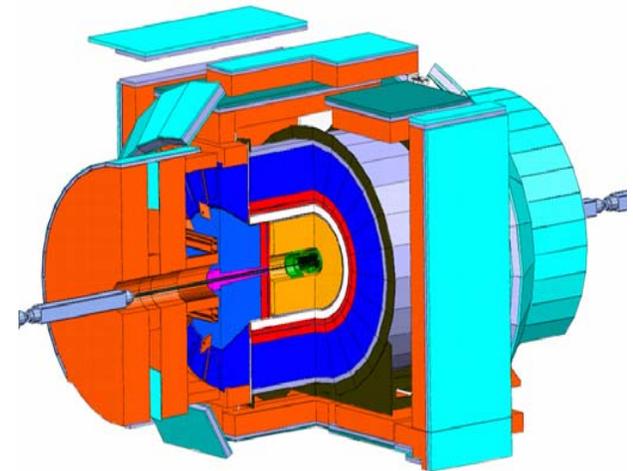
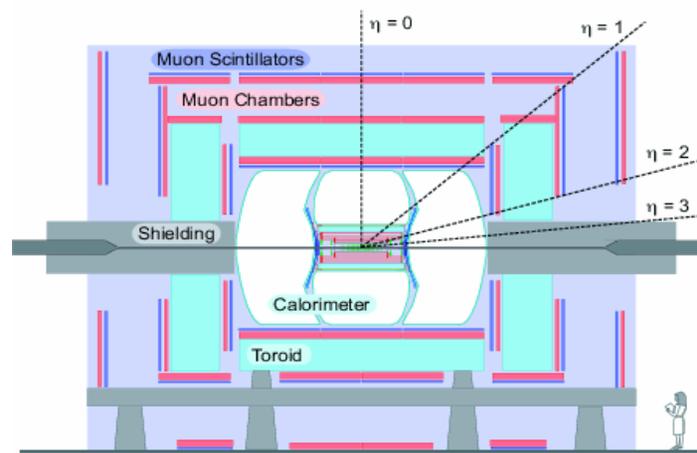


SUSY Searches at the Tevatron



Recontres de Moriond, QCD

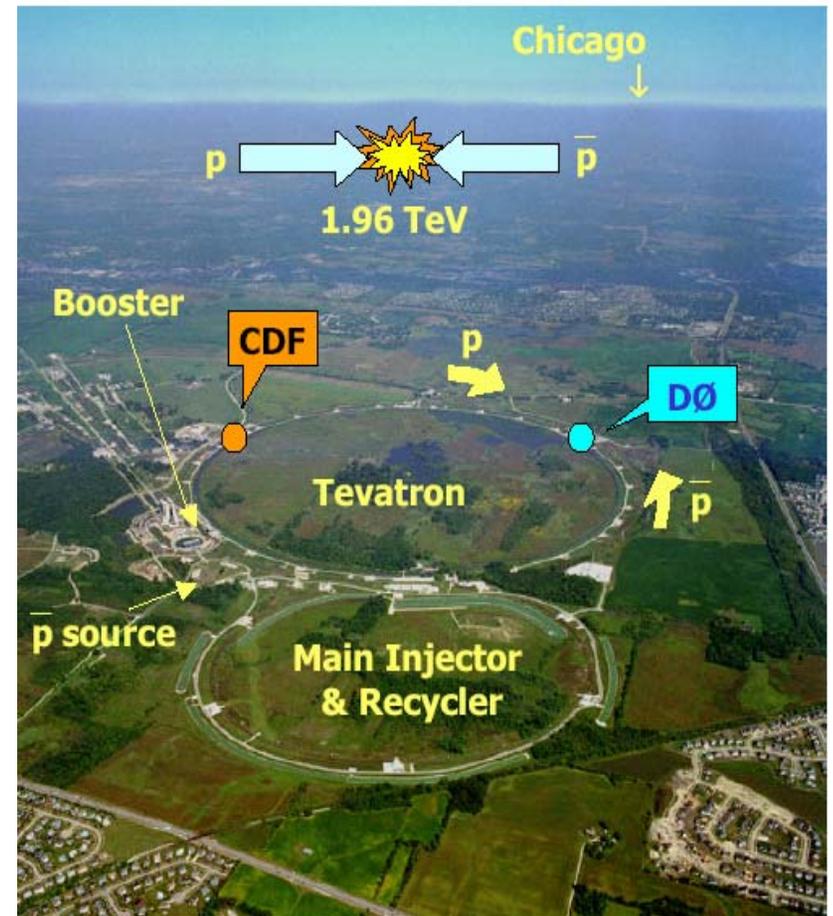
March 2006

**Else Lytken, Purdue University
for the CDF and D0 collaborations**



Outline

- Brief intro to supersymmetry
- SUSY at the Tevatron
- Some selected analyses:
 - Squarks and gluinos
 - Scalar top
 - Photon signatures
 - Lepton signatures,
 - RPV searches
- Conclusion and outlook



Supersymmetry in 60 seconds

Idea: extend SM with symmetry fermions \leftrightarrow bosons
 If realized, lots of **new particles** to be found!

Many attractions: Low scale supersymmetry protects higgs mass, provides dark matter candidate, unification @ 10^{16} GeV, and consistent with precision top mass fits

<i>Spin 0</i>	<i>1/2</i>	<i>1</i>	<i>3/2</i>
5 higgses h^0, H^0, A, H^\pm	gluino \tilde{g}	gauge bosons	gravitino \tilde{G}
sleptons \tilde{l}	leptons		<u>2</u>
squarks \tilde{q}	quarks		graviton G
	gauginos $\tilde{\chi}^\pm$ $\tilde{\chi}^0$		

New quantum number
 often assumed conserved

$$R_P = (-1)^{B+L+2s}$$

$$\begin{cases} +1 & \text{SM} \\ -1 & \text{SUSY} \end{cases}$$

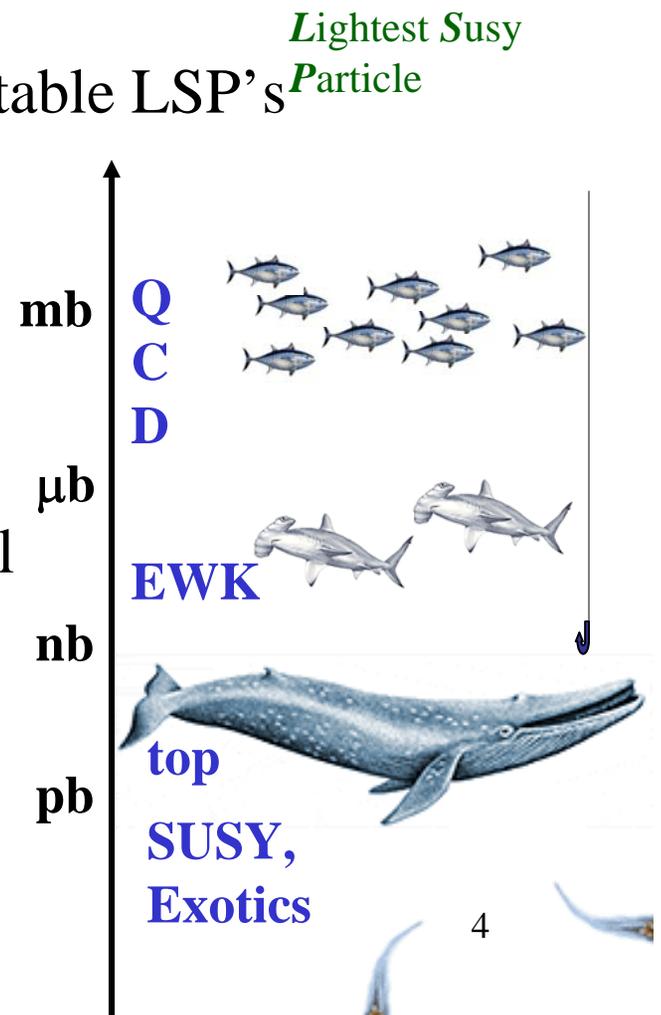
SUSY searches at the Tevatron

SUSY searches attractive from experimental point of view due to variety of signatures:

- Missing transverse energy (MET) from stable LSP's
- multijets from cascade decays
- multileptons

Main challenge is the small expected production cross section

- Need to model SM backgrounds very well
- Most searches check predictions in control regions before looking at data containing possible signal





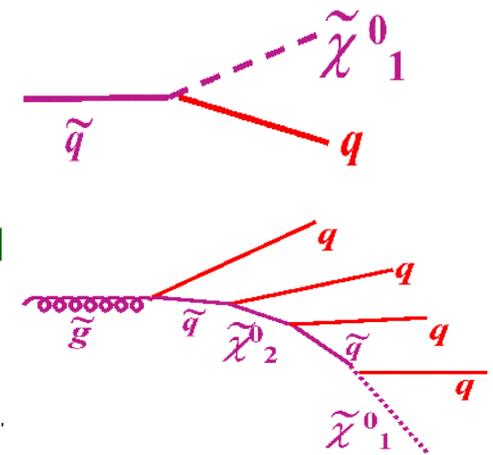
MET + jets: squark and gluino

Generic squarks and gluinos strongly produced

Cross section @ Tevatron: ~ a few pb

Expect cascade decays

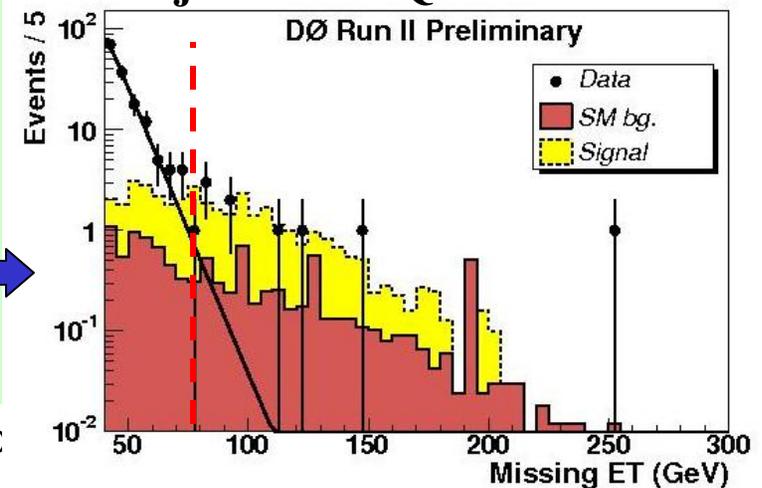
Signature: lots of MET and ≥ 2 jet



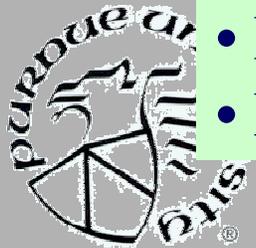
D0 result:

- 2, 3, or 4 jets for the cases:
 $M_{\tilde{g}} > M_q$ $M_{\tilde{g}} \sim M_q$ and $M_{\tilde{g}} < M_q$
- Dominant background differ
 Z+jets, W+jets, tt, QCD
- MET > [75, 100, 175] GeV
- Lepton veto

4 jets: Fit to QCD



Else Lytken, Moriond QCD



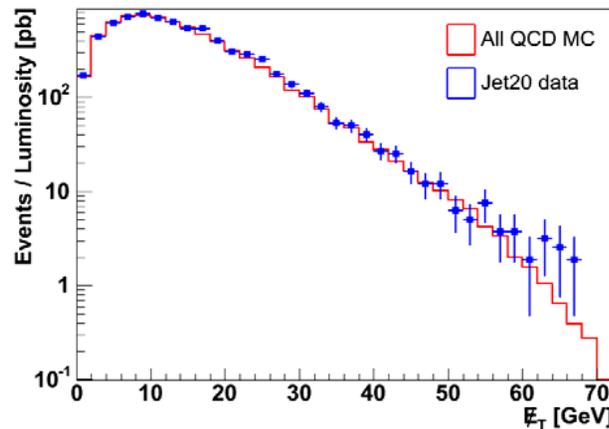
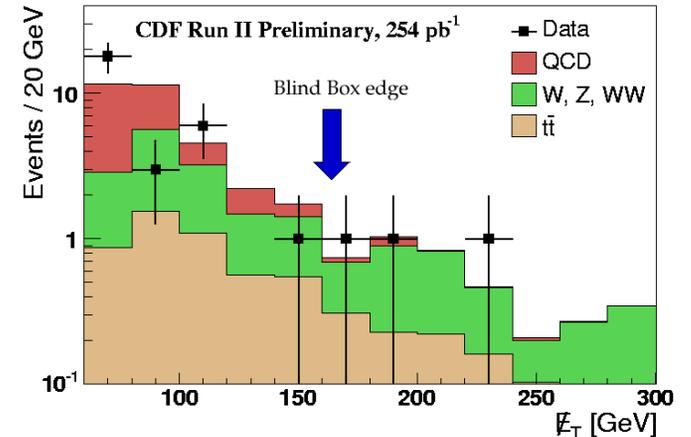


MET+jets continued

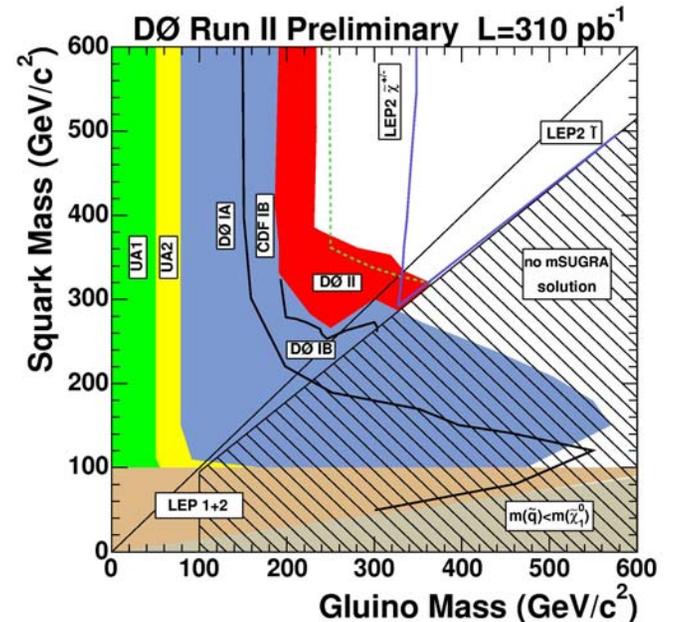
CDF:

- Req. ≥ 3 jets and $MET > 165$ GeV
- Bkg dominated by $Z \rightarrow \nu\nu + \text{jets}$
- Check: compare data and QCD MC in jet dominated region

Expect 4.1 events, observe 3



Else Lytken, Moriond QCD 2006





Search for Scalar top

Look for pair production of lightest stop quark

Assume equal BR to e, μ , τ , and $\tilde{\nu} \rightarrow \nu \tilde{\chi}_1^0$

Current limit: $m_{\tilde{\nu}} \geq 45$ GeV

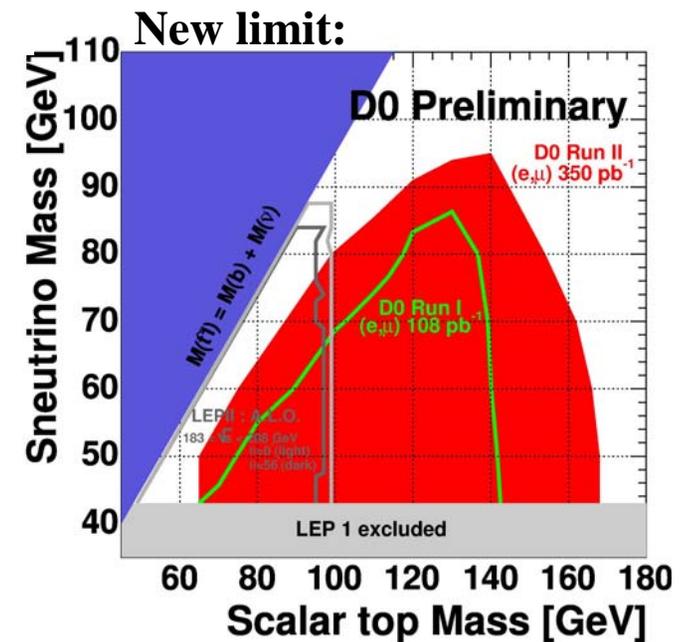
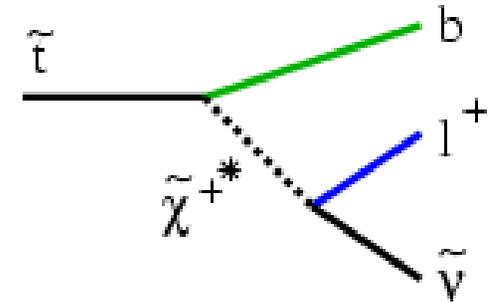
Event signature:

2 b-jets, OS e μ + MET

cut on N
non-iso tracks

Signal regions optimized for $\Delta M = m_{\tilde{t}} - m_{\tilde{\nu}}$

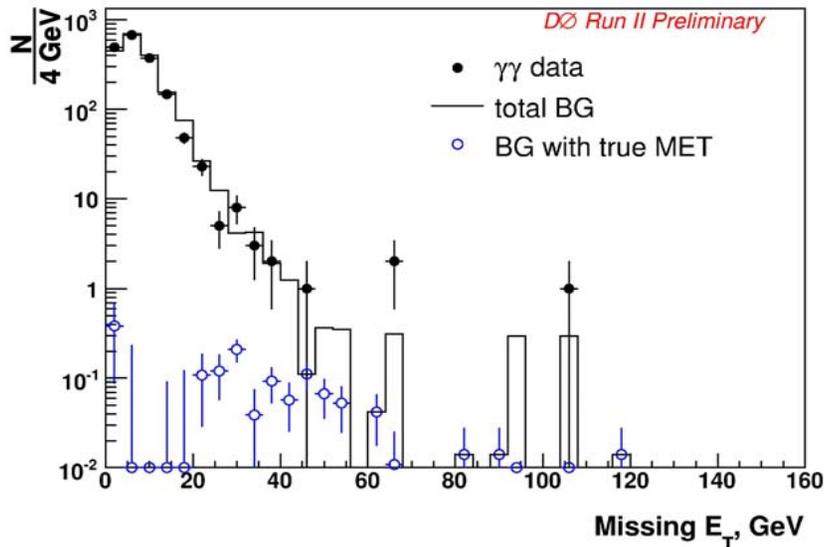
	Signal	SM expected	Obs
ΔM : 20-40 GeV	16.43 ± 1.07	22.99 ± 3.10	21
ΔM : 50-60 GeV	18.28 ± 0.72	34.63 ± 3.96	34
ΔM : > 70 GeV	16.70 ± 0.51	40.66 ± 4.38	42



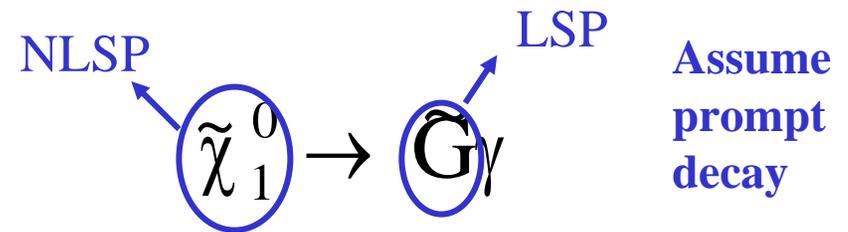
Result will be combined with previous result in the $\mu\mu$ channel



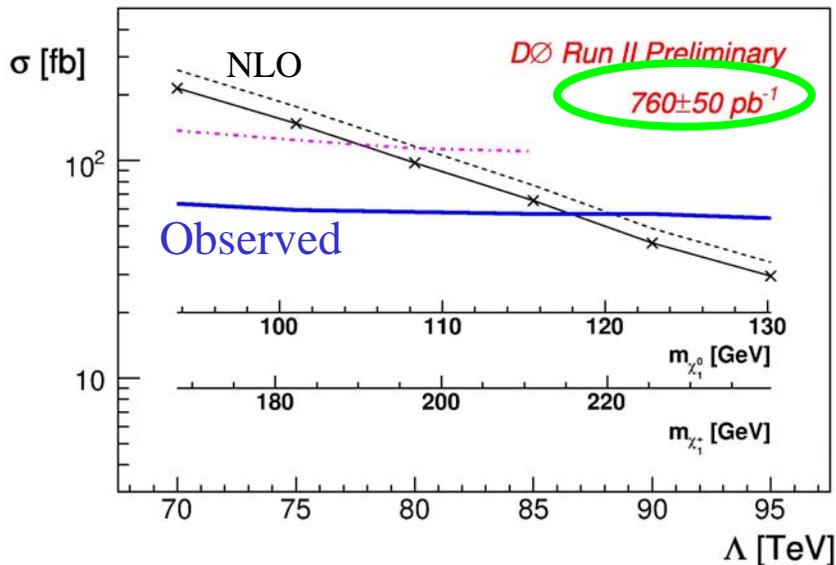
MET + photons



In Gauge Mediated SUSY breaking models, LSP is gravitino.
 Typical signature from χ decay:



Signature: 2 energetic photons + MET



Backgrounds normalized to data below MET of 12 GeV

Observe 4 events with MET ≥ 45 GeV
 Expecting 2.1 ± 0.7

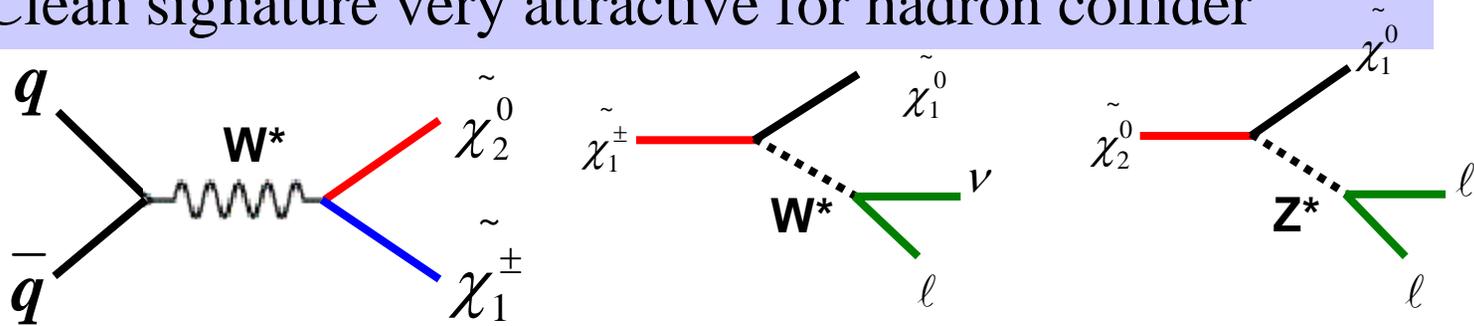
New limit: $m(\tilde{\chi}_1^\pm) \geq 220$ GeV

Previous limit (CDF + DØ): 209 GeV

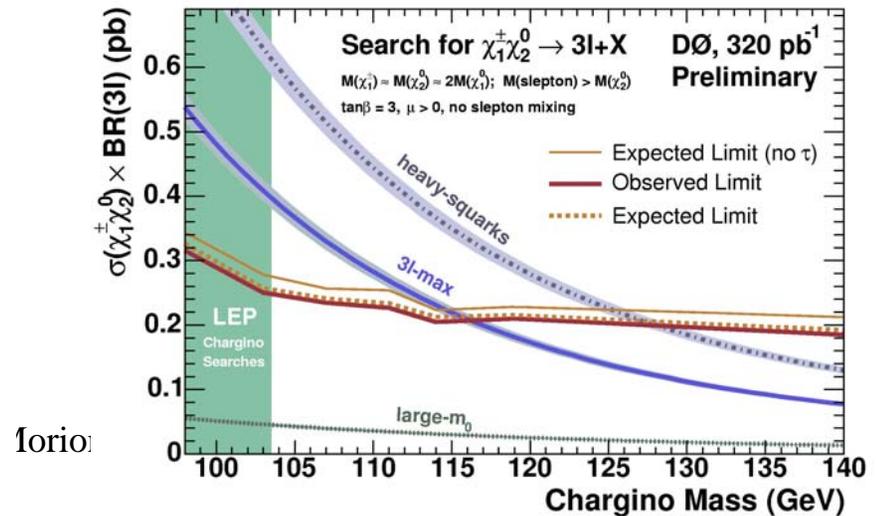
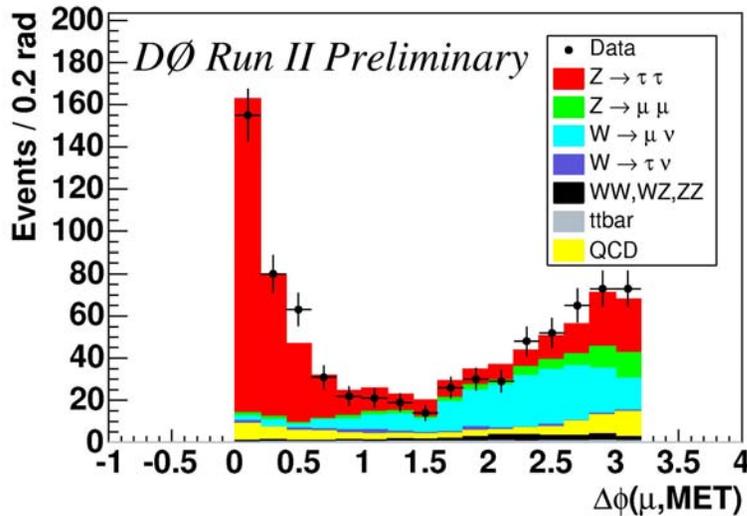


MET + 3 leptons

Expected signature from chargino-neutralino production
 Clean signature very attractive for hadron collider



DØ, 6 channels: Expects: 3.85 ± 0.75 , Observes : 4. Signal would be 3-10 events



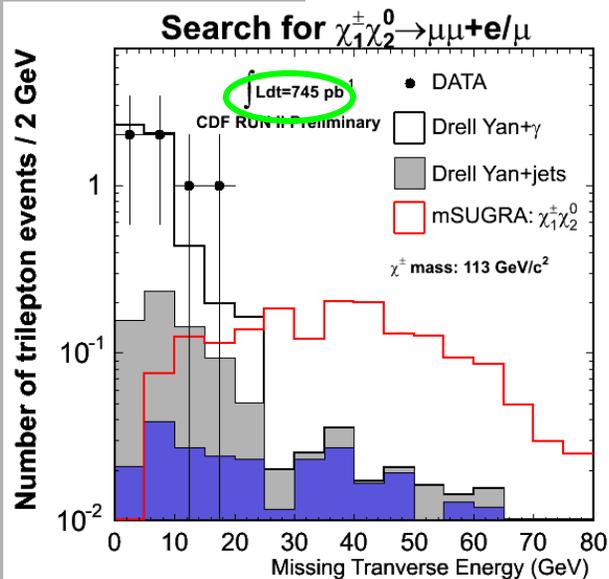
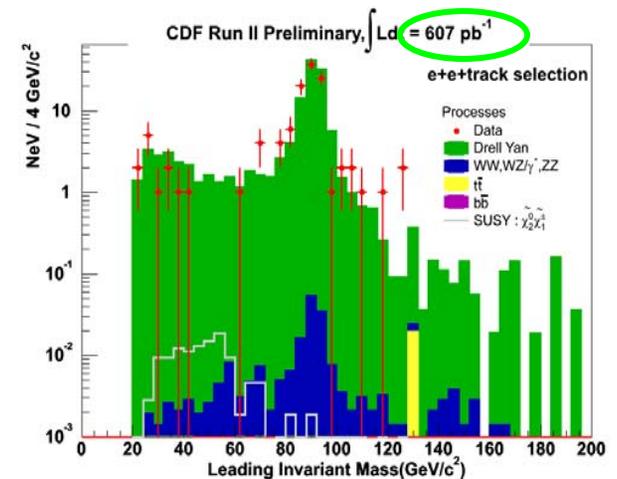
DØ

forio:



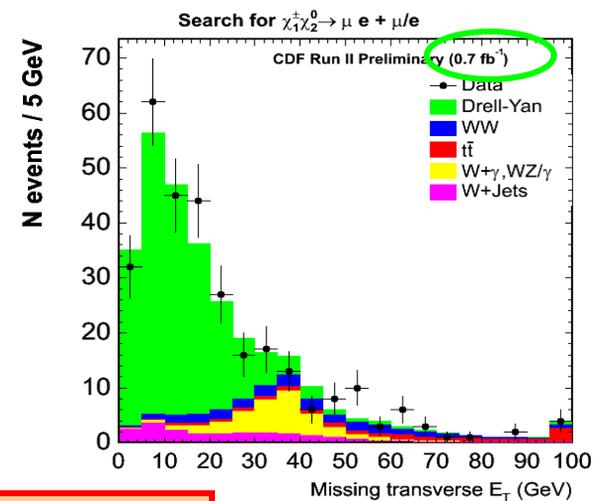
3 leptons: continued

Channel	Example signal	SM expected	Observed
$\mu\mu/e + l$	2.3 ± 0.3	1.2 ± 0.2	1
$ee+l$	0.5 ± 0.06	0.2 ± 0.05	0
$\mu\mu+l$ (low pt)	0.2 ± 0.03	0.1 ± 0.03	0
$ee+trk$	0.7 ± 0.03	0.5 ± 0.1	1



CDF:
All observations in agreement with SM predictions

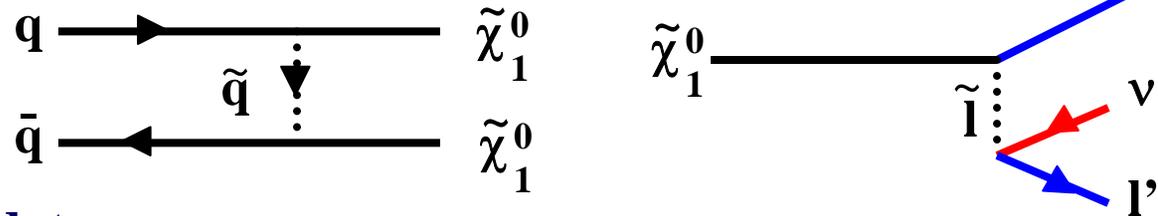
Stay tuned for updated limits!



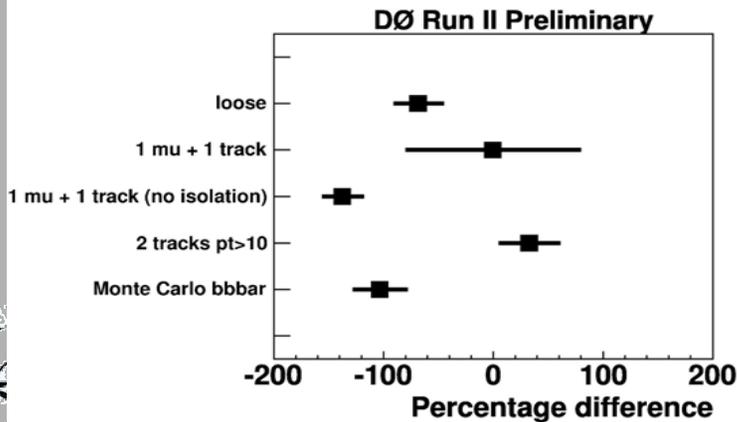


RPV SUSY: Long-lived LSP

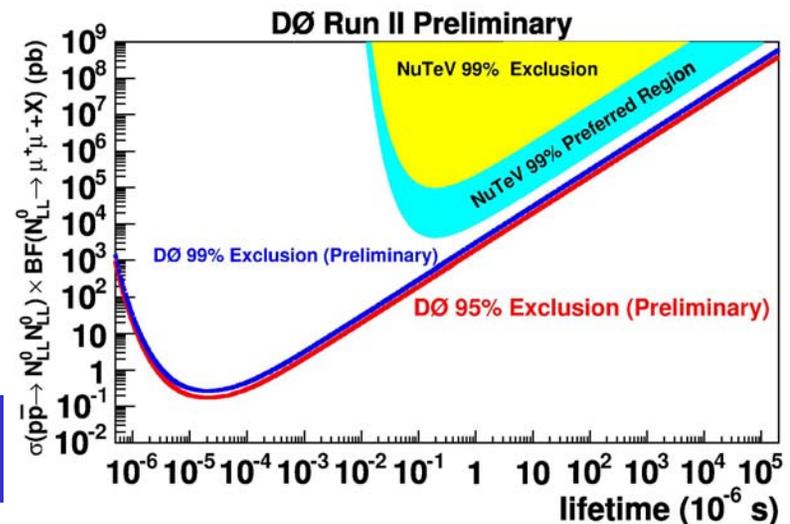
Scenario inspired by NuTeV events: Weak R_p violation
 Low mass LSP decays to $2\mu + \nu$, $r = [5; 20] \text{cm}$, other χ escapes



- ✓ Bkg estimated from data
- ✓ Several cross checks
- ✓ Diff as systematics



Now excluding that these events are SUSY χ :

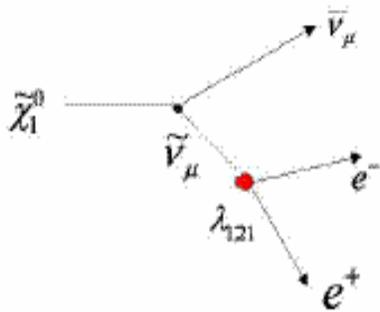


Expect 0.75 ± 1.5 events, see 0



RPV: 4 leptons

Now assume prompt decay
 ≥ 4 leptons from $\tilde{\chi}\tilde{\chi}$ and \tilde{q},\tilde{g} decays

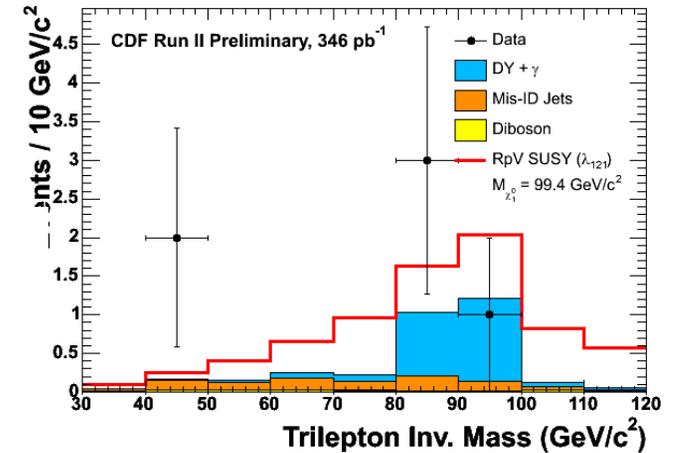


Yukawa term:

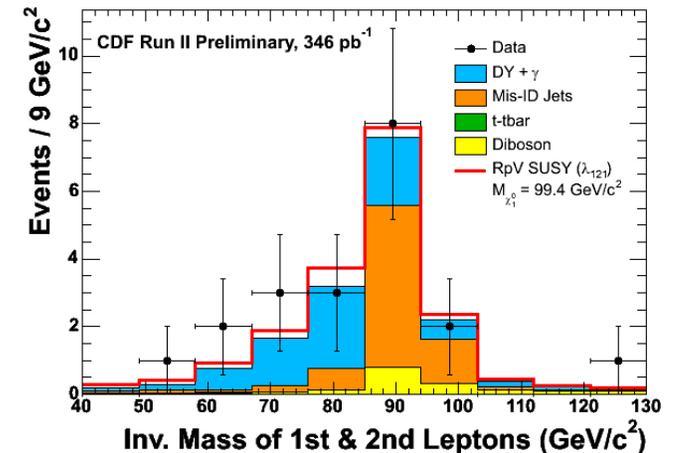
$$\lambda_{ijk} L_i L_j \bar{E}_k$$

Analysis accepts e and μ

\Rightarrow sensitive to λ_{121} and λ_{122}



Trilepton CR's



Striking signature, virtually no SM background

No MET cut

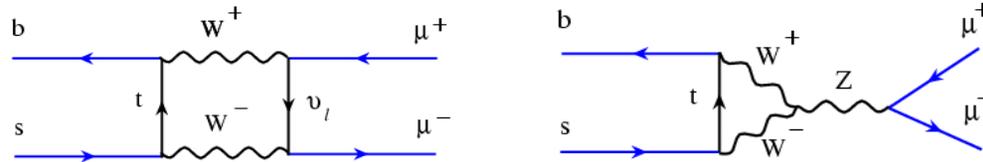
Expects 1.5 ± 0.2 signal, < 0.01 SM, observes 0

\Rightarrow Limits on λ_{121} : 0.21pb, λ_{122} : 0.11pb



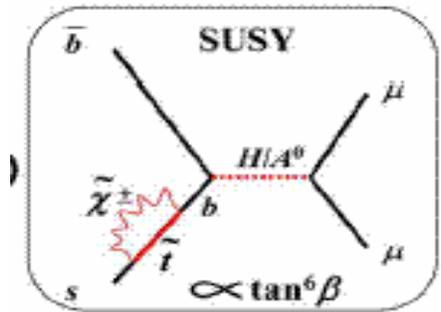


Indirect constraint: $B_s \rightarrow \mu\mu$



Rare decay, in SM branching frac $\sim 10^{-9}$

Loop diagrams with sparticles (or direct decay if RPV) enhance orders of magnitude



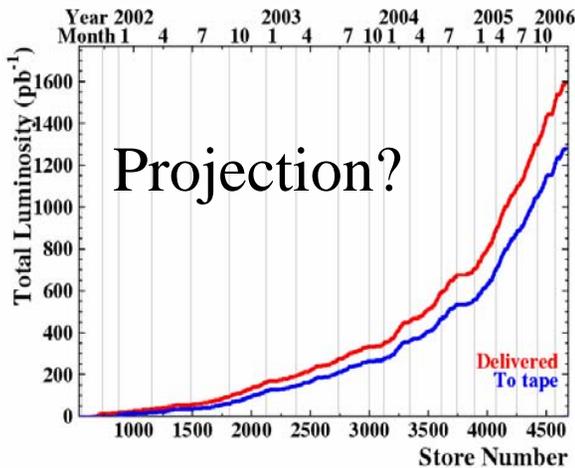
Important at high $\tan\beta$

Nice plot
to be blessed
780 pb⁻¹

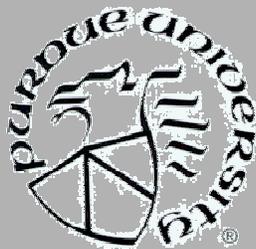
- Look for excess of $\mu\mu$ events in B_s and B_d mass windows
- Background estimation: linear extrapolation from sidebands
- Results compatible with SM backgrounds
--- Closing in on SUSY! ---

Summary and outlook

- CDF and D0 keeps probing new areas of the SUSY parameter space!
- Results can also constrain other models
- It is only limits so far



The hunt continues ...!



→ We have 1fb⁻¹ ready for analysis and the Tevatron is in great shape!
Expect 4-8 fb⁻¹ by end of Run II

Backup

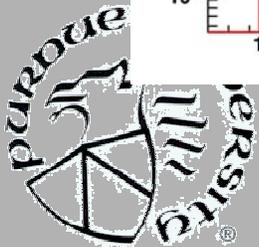
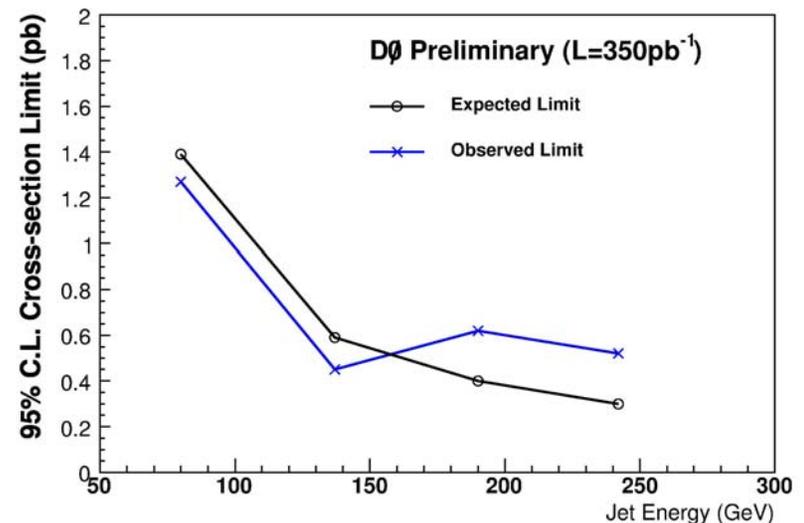
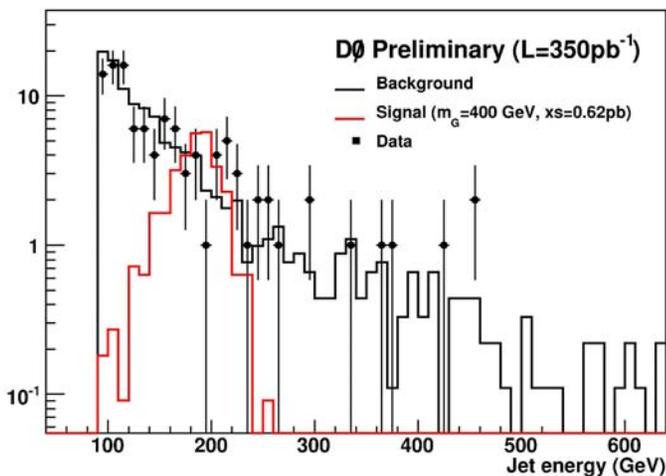


Stopped gluinos

New (saw it this afternoon!) result from D0 on R-hadrons
stopped gluino \rightarrow jet + χ_{10}

Assume gluino lifetime at least $10 \mu\text{s}$

\rightarrow next bunch crossing: single high Et jet and high MET

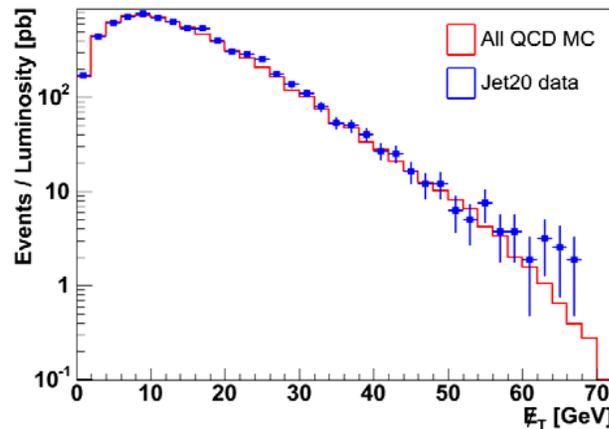




MET+jets continued

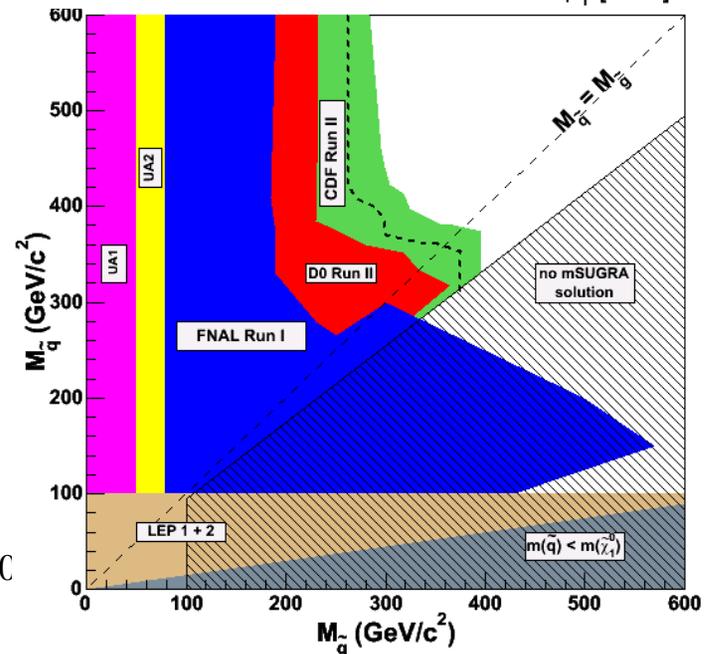
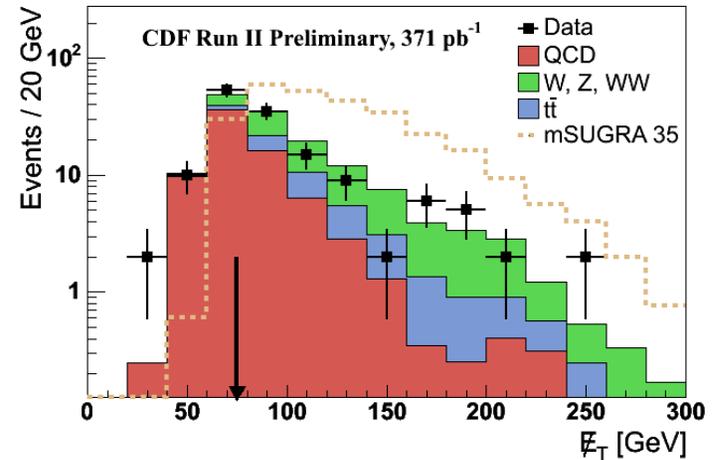
CDF:

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- Check: compare data and QCD MC in jet dominated region



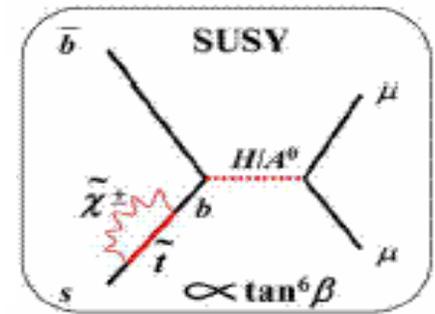
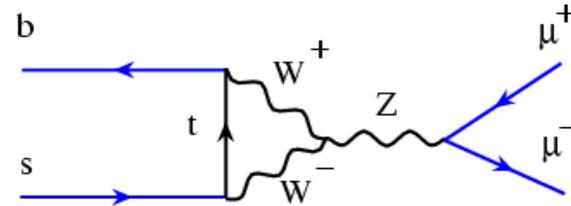
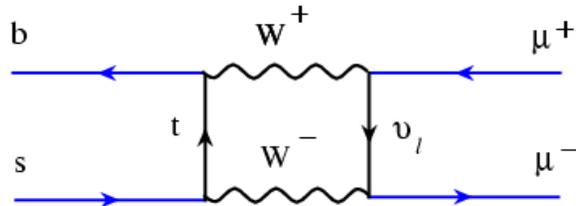
Else Lytken, Moriond QCD 20

NO hints of SUSY

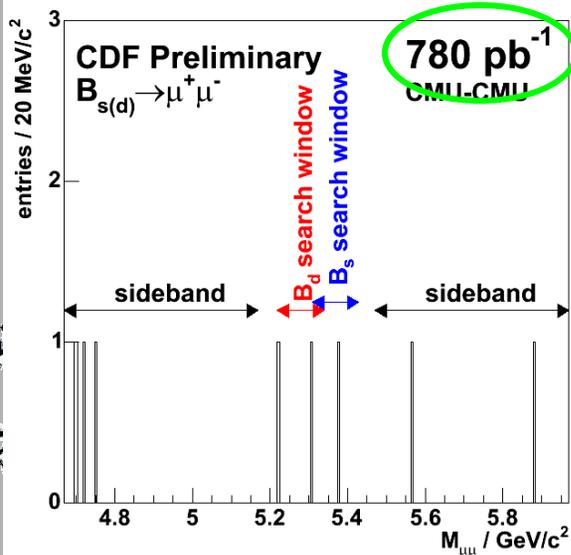




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Rare decay, in SM branching frac $\sim 10^{-9}$
 Loop diagrams with sparticles (or direct decay if RPV) enhance orders of magnitude



Important at high $\tan\beta$

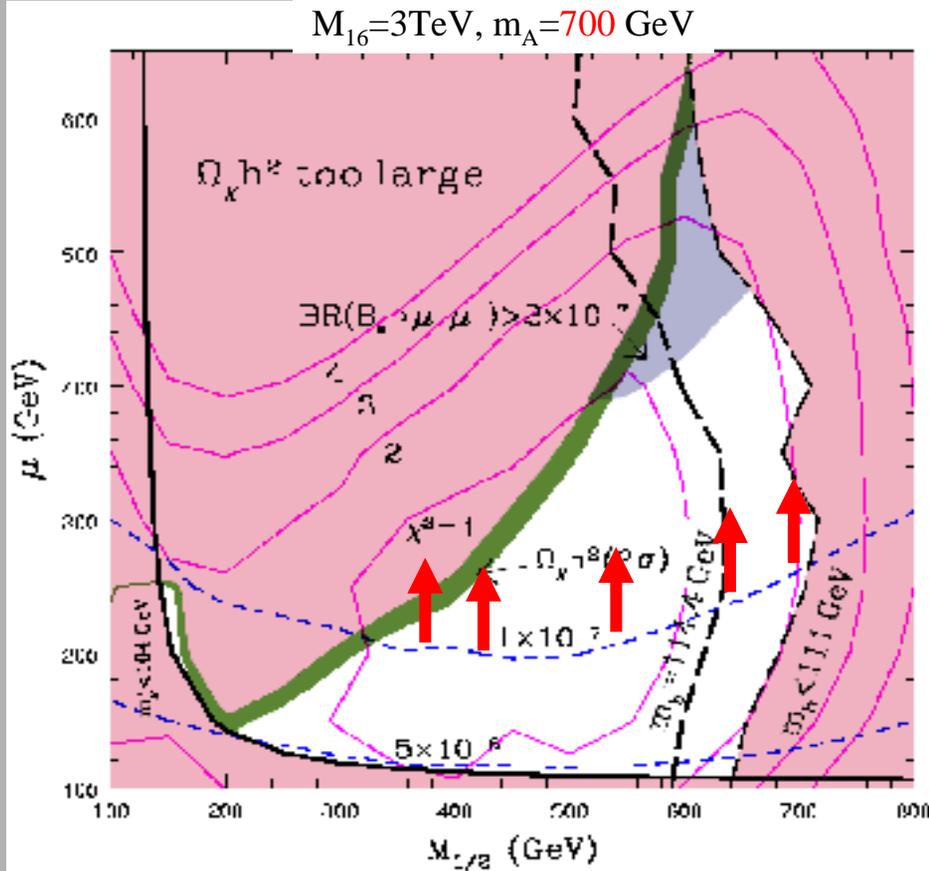
CDF also looks at $B_d \rightarrow \mu\mu$
 Background estimation: linear extrapolation from sidebands
 Normalizing using $B^+ \rightarrow \mu^- \mu^+ K^+$
 - Results compatible with SM backgrounds

$B_s \rightarrow \mu\mu$: Results

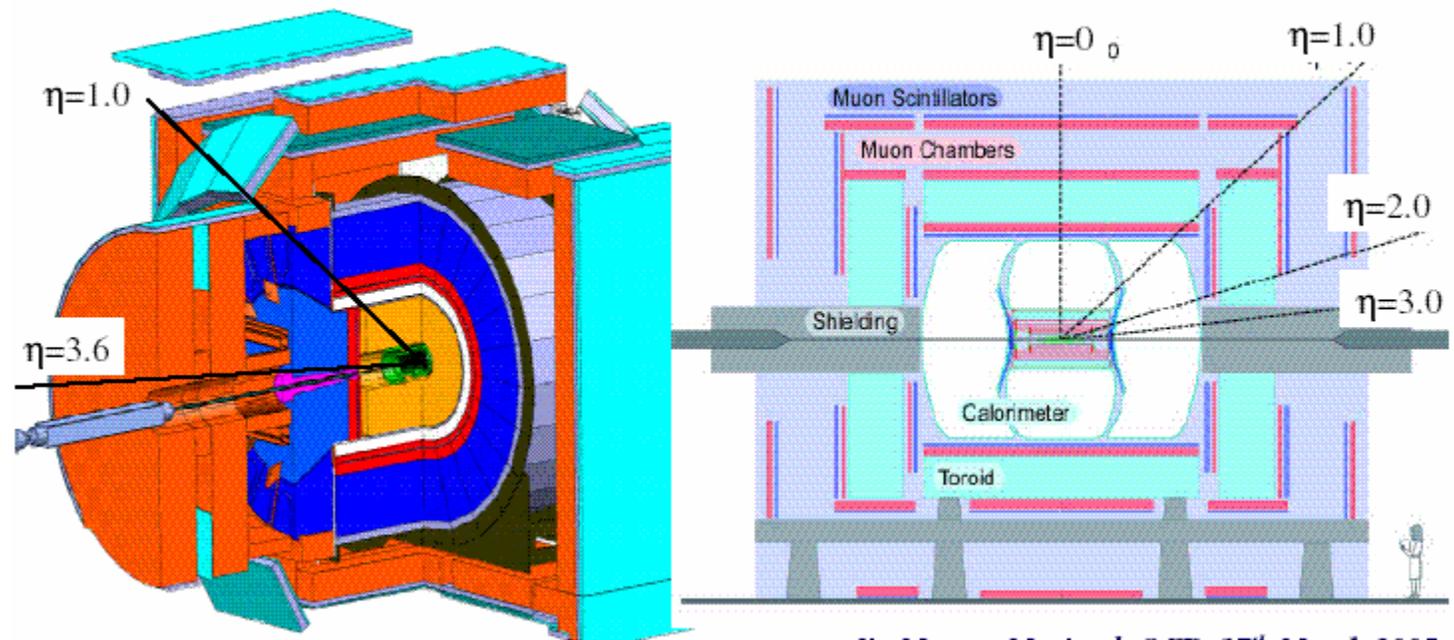
Limits:

$\text{Br}(B_s \rightarrow \mu\mu) < 1.0 \times 10^{-7}$ @ 95%CL
 $\text{Br}(B_d \rightarrow \mu\mu) < 3.0 \times 10^{-8}$ @ 95%CL

Red arrows indicate new limit
 Closing in!

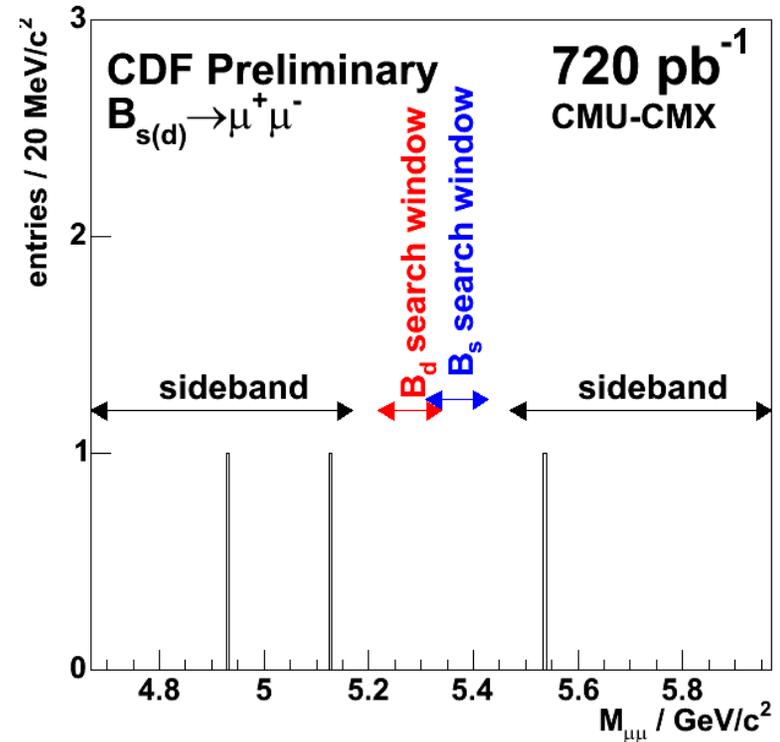
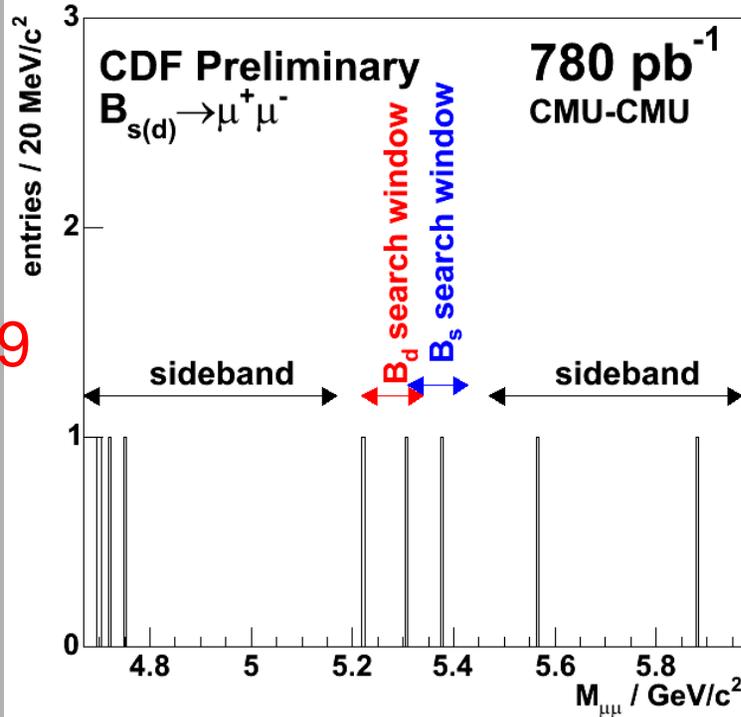


Detectors



Look in the Bs and Bd Signal Window

$L_R > 0.99$



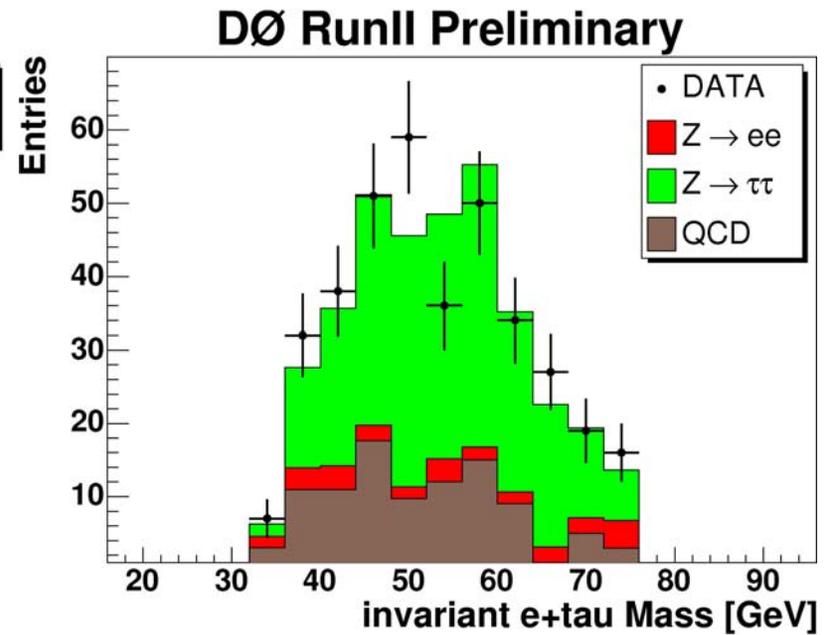
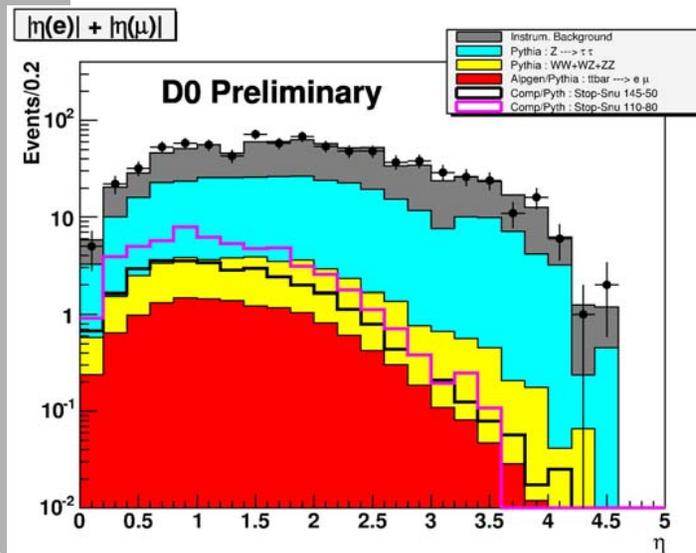
CMU-CMU Channel:

	Expect	Observed	Prob
B_s	0.88 ± 0.30	1	67%
B_d	1.86 ± 0.34	2	63%

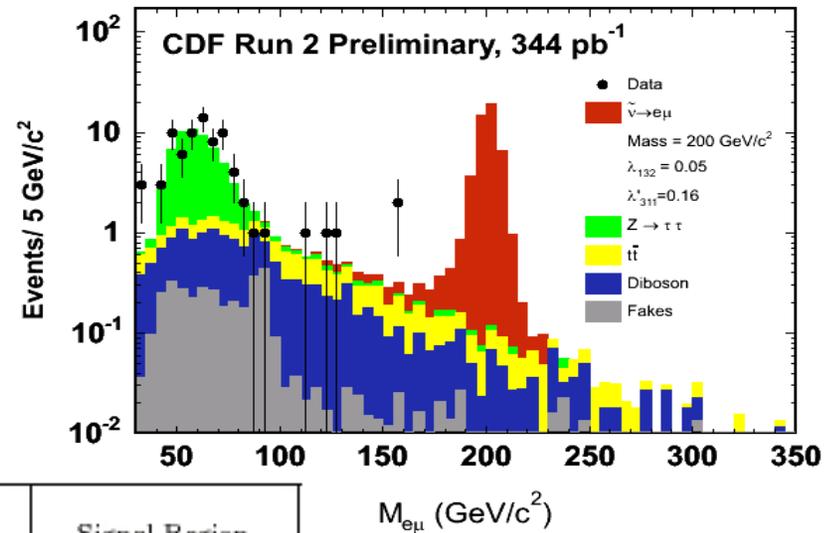
CMU-CMX Channel:

	Expect	Observed	Prob
B_s	0.39 ± 0.21	0	68%
B_d	0.59 ± 0.21	0	55%

Plots from d0 stop analysis, cn ana



sneutrino search Rpv



Channel	Control Region	Signal Region
Z → ττ	38.77 ± 0.63 ± 2.33	0.57 ± 0.01 ± 0.03
diboson	6.63 ± 0.18 ± 0.37	3.48 ± 0.10 ± 0.19
t̄t̄	3.57 ± 0.05 ± 0.21	3.16 ± 0.05 ± 0.19
fake lepton	2.90 ± 1.10 ± 1.33	0.44 ± 0.40 ± 0.40
Prediction	51.87 ± 1.11 ± 2.72	7.66 ± 0.41 ± 0.48
Observation	56	5

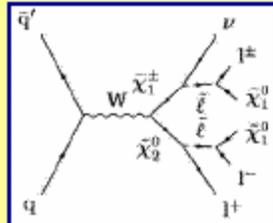


Chargino Mass Limits

mSUGRA "small m_0 "

$$M(\tilde{\ell}) > M(\tilde{\chi}_2^0)$$

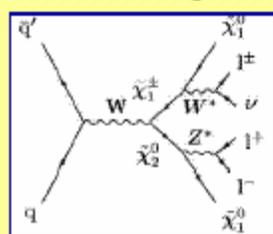
No slepton mixing



$\sigma \times BR < 0.2 \text{ pb}$

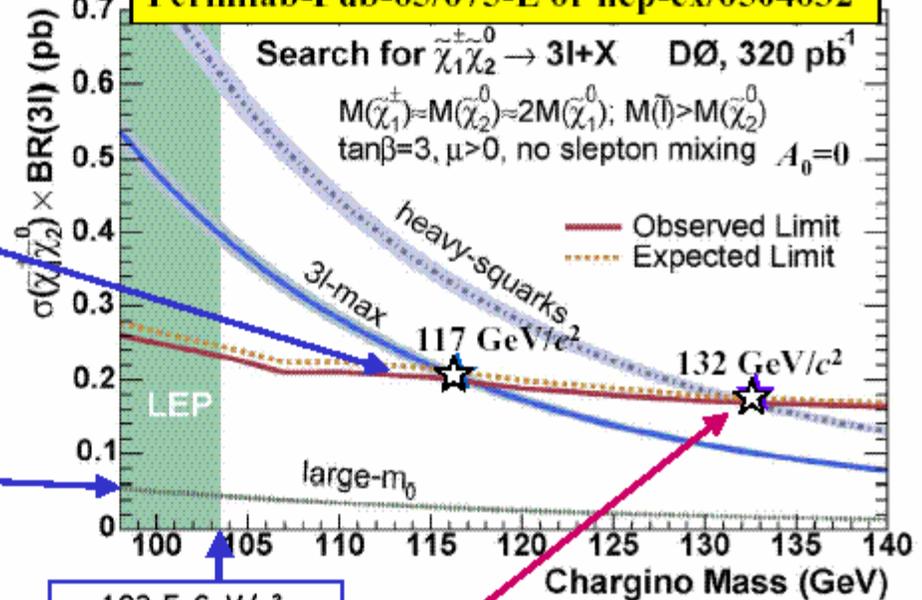
mSUGRA "large m_0 "

$$M(\tilde{\ell}) \gg M(\tilde{\chi}_2^0)$$



No sensitivity

Fermilab-Pub-05/075-E or hep-ex/0504032

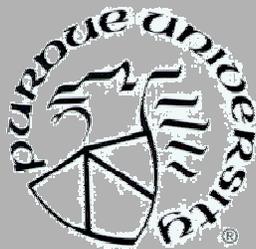


Those limits are improved by ~10% if tau's are included.

Scenario

light sleptons but heavy squarks

$$M(\tilde{\chi}_2^0) \approx 3M(\tilde{q})$$



Trilepton events CDF



spørgsmål

- cheng-ju: det med de 700 GeV
- Alon: i figur, er det alt sammen l_121
- eksemple paa 122: $e^- \rightarrow \mu + \nu_\mu$

