Multi-lepton and Tau Signatures of New Physics

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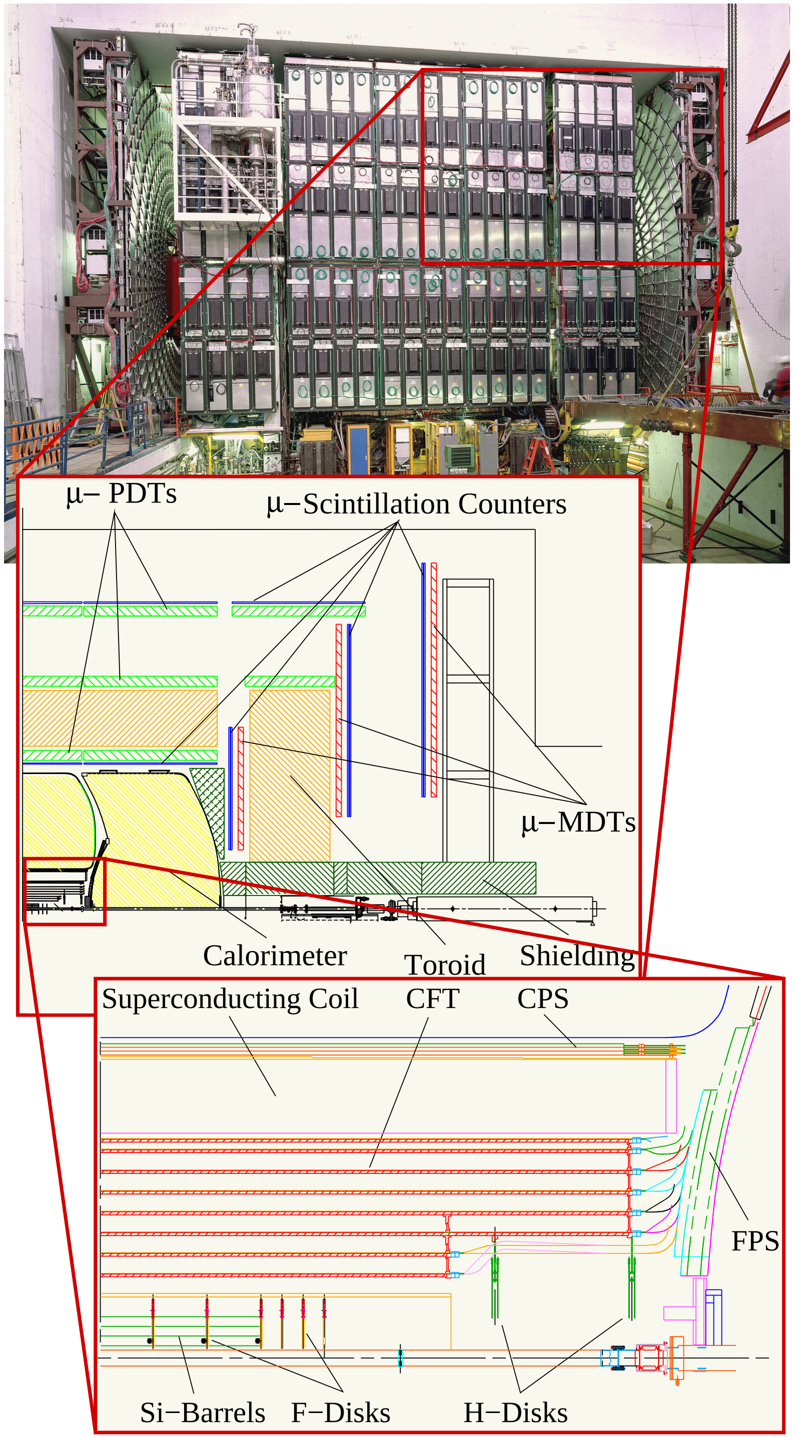
Charge:

- Summary of new results
- Analysis issues in view of LHC conditions
- Impact of potential Tevatron discoveries on LHC

Outline:

- Searches with High-pt Dileptons
- SUSY Multilepton Searches
- Searches with τ-leptons

The Tevatron Experiments



Two General-Purpose Detectors:

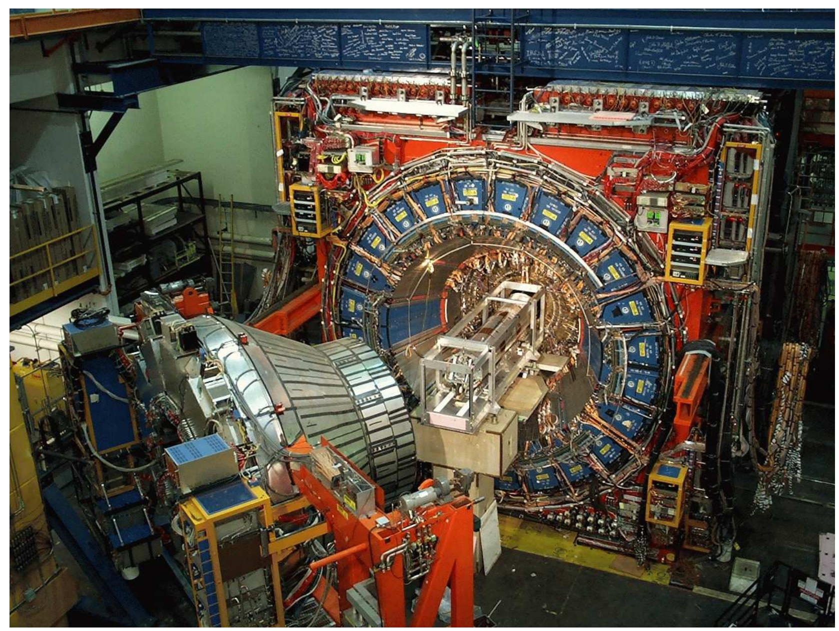
	CDF	DØ
Electron Acceptance	$\lvert\eta\rvert < 2.0$	$\lvert\eta\rvert < 3.0$
Muon Acceptance	$\lvert\eta\rvert < 1.5$	$\lvert\eta\rvert < 2.0$
Precision Tracking (Silicon)	$\lvert\eta\rvert < 2.0$	$\lvert\eta\rvert < 3.0$

Ultimate Energy Resolution: $\sigma_{m_{jj}} \approx 10\%$

Upgraded Electronics and DAQ:

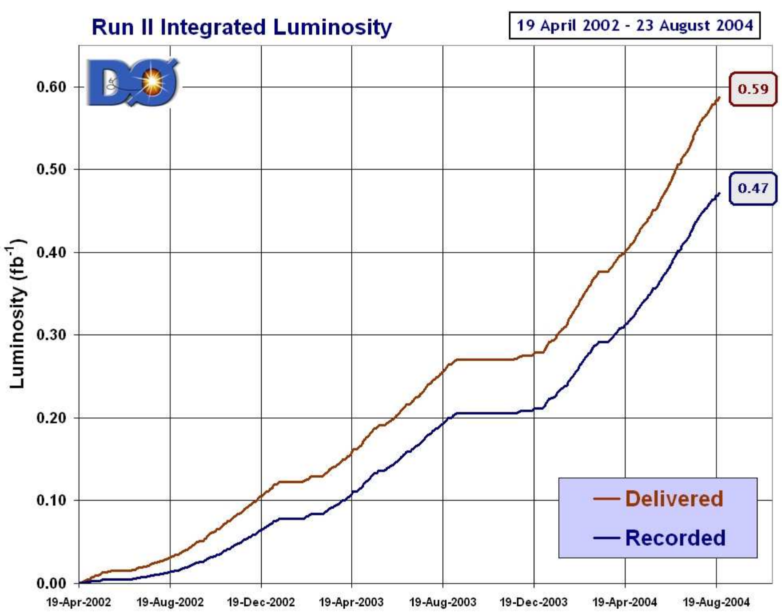
– Collisions every 396 ns

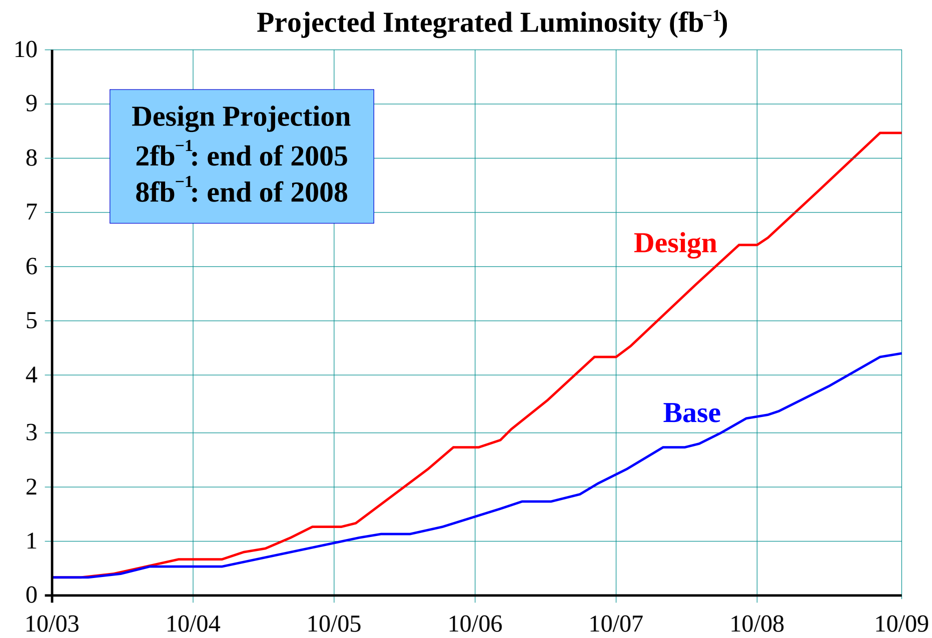
Powerful Trigger Systems (2.5 MHz→50 Hz)



Tevatron Run II – Current Status and Plans

- **Integrated Luminosity (since April 2002):**
  - 600 pb^{-1} delivered, 470 pb^{-1} recorded, so far up to 250 pb^{-1} analyzed



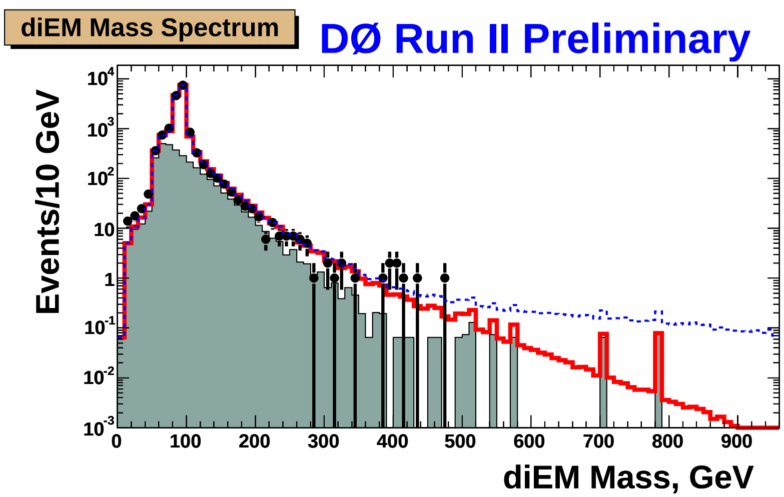


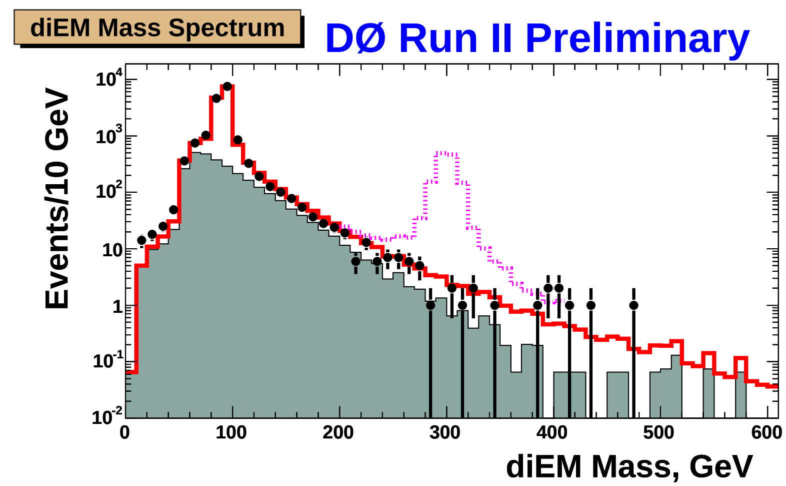
- **Long-term projections:**
  - "Base" (very conservative): 4 fb^{-1} until 2009
  - "Design" (reasonably optimistic): 8 fb^{-1} until 2009
  - requires recycler for accumulation (and cooling) of antiprotons
- **2004: Design Goals have been exceeded**

Searches with high-pt Dileptons

Searches in two categories:

- Dilepton resonances (Z', RS-Gravitons, Technicolor ρ_T, ω_T, little Higgs etc.)
- Contact Interactions (Large ED, Compositeness etc.)
- Note: Searches for ED include photons for maximum sensitivity





- High-pt dilepton selections very clean
- Experimental Issues:
  - maximize acceptance and efficiencies
  - no easy cross-check of efficiencies at high pt (extrapolate from Z)
  - mass resolution (in particular muons):
    - enters signal efficiency for resonances
    - non-gaussian tails have large effect on background level at high mass
    - DØ: cross-checked with cosmics

Searches with high-pt Dileptons – Results

- No evidence for any excess so far

  → Limits on σ x BR → mass limits within various models

Analysis		Channel	Limit	
Sequential Z'	DØ, 200 pb^{-1}	ee	$m_{Z'} > 780$ GeV	(SM-like)
	CDF, 200 pb^{-1}	$\mu\mu$	$m_{Z'} > 735$ GeV	(SM-like)
	CDF, 195 pb^{-1}	$\tau\tau$	$m_{Z'} > 394$ GeV	(SM-like)
Little Higgs	CDF, 200 pb^{-1}	ee	$m_{Z_H} > 800$ GeV	(cot $\theta = 1$)
Technicolor ρ_T, ω_T	DØ, 200 pb^{-1}	ee	$m_{\rho_T} > 340$ GeV	($M_V > 100$ GeV, M_{ρ_T}-$M_{\pi_T} < m_W$)
RS-Gravitons	DØ, 200 pb^{-1}	ee,$\gamma\gamma$	$m_{G_1} > 785$ GeV	($\kappa/M_{Pl} = 0.1$)
Large ED (ADD)	DØ, 200 pb^{-1}	ee,$\gamma\gamma$	$M_S > 1.43$ TeV	(GRW convention)
Compositeness	DØ, 200 pb^{-1}	ee	$\Lambda > 6.2$ TeV	(LL, constructive)

- Dielectron (diphoton) analyses most powerful
- Tevatron sensitivity is reaching $O(1\text{ TeV})$
- Quick confirmation of potential Tevatron discovery by LHC should be possible
- First steps beyond discovery:
  - measure full diff. dilepton cross-section to pin down origin of virtual corrections
  - measure width, branching fractions and spin of new resonances

    → requires understanding of cal. calibration/resolution at multi-TeV energies

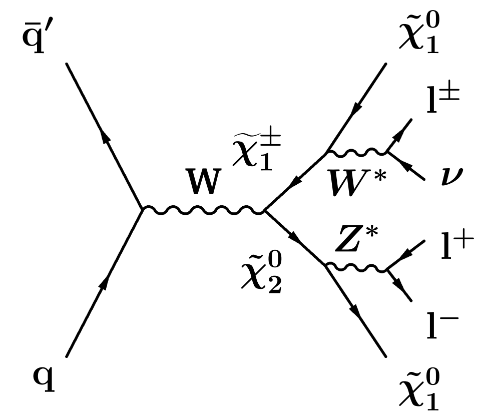
    → ditau, dijet channels will present a challenge

Multilepton SUSY Searches – Charginos/Neutralinos

Golden Channel: leptonic cascade decays $\longrightarrow$ 3 leptons plus $\not\!\!E_t$

Challenges:

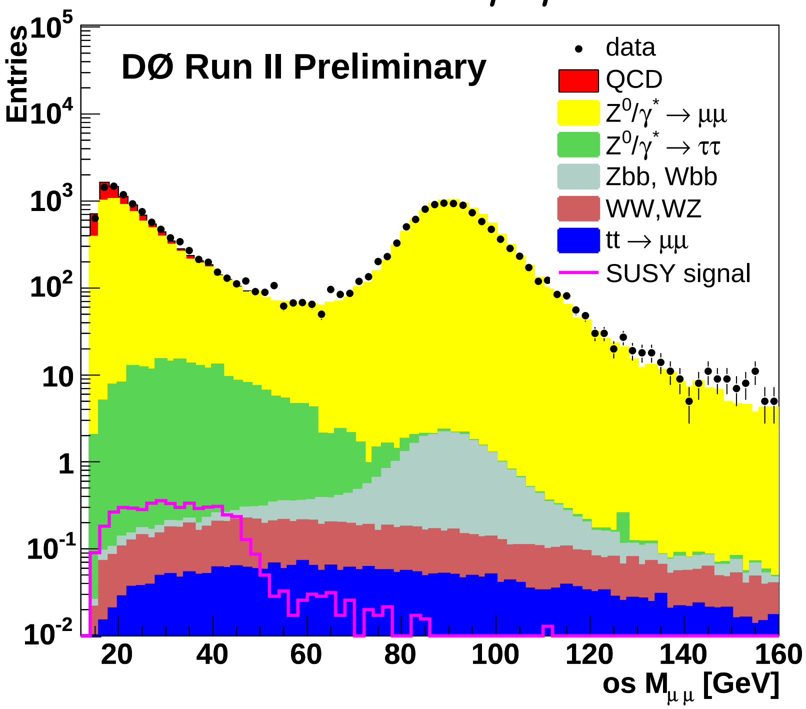
- small event rates ($\sigma \times BR < 0.5$ pb)
- leptons with low transverse momenta



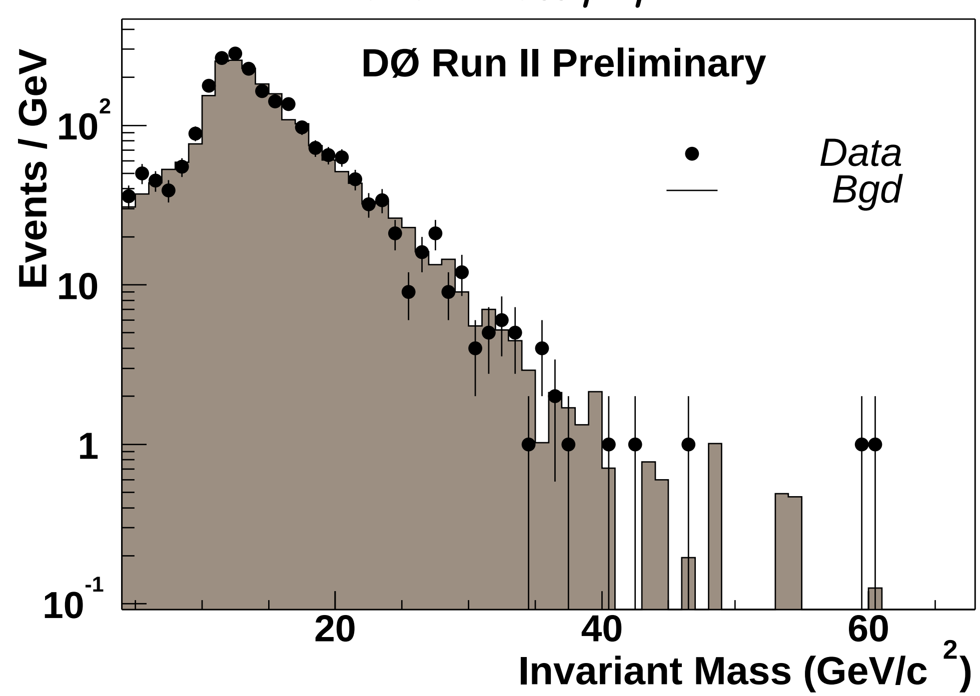
Four selections:

- ll+track (ll=ee,eμ,$\mu\mu$): 220-250 pb^{-1}
- like-sign dimuons: 150 pb^{-1}

Invariant Mass $\mu^+\mu^-$



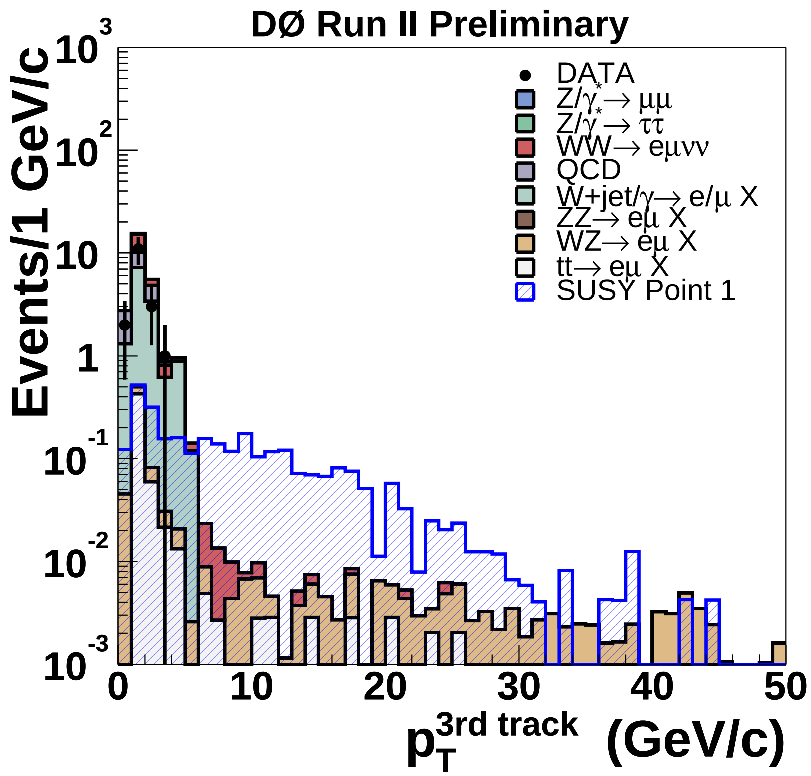
Invariant Mass $\mu^+\mu^+$



Multilepton SUSY Searches – Charginos/Neutralinos

Selection: Two identified leptons plus

- significant missing transverse energy
- additional isolated track (except for ls-$\mu\mu$ selection)
  - very low cut on track pt (3 or 5 GeV)
  - efficient for e,μ and hadronic τ-decays



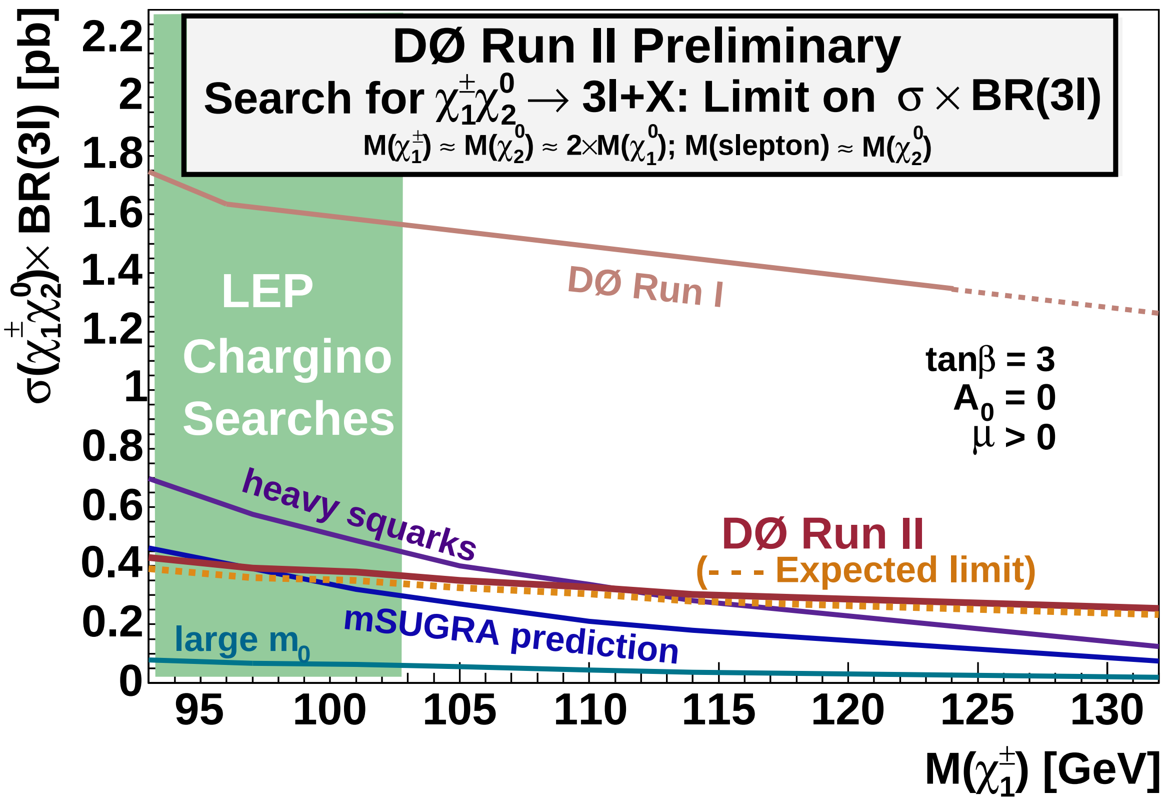
Experimental Issues

- rejection of photon conversions (Wγ, Zγ backgrounds)
- analysis tuning requires huge (inclusive) W/Z MC samples
- estimation of multijet background (ls-$\mu\mu$)
- measurement of low-pt trigger and reconstruction efficiencies (in particular e,τ)
- track isolation requires low-pt tracking (CPU intensive)

Backgrounds mainly dominated by WW, WZ, Wγ:

Selection	Expected Background	Observed	Signal ($m_{\tilde{\chi}^{\pm}}$=100 GeV)
eel	0.68±0.40±0.32	1	1.83±0.08±0.08
eμl	0.29±0.33±0.02	0	1.25±0.06±0.07
$\mu\mu$l	1.83±0.40±0.21	1	1.12±0.04±0.12
ls-$\mu\mu$	0.13±0.06±0.02	1	0.36±0.03±0.03

Multilepton SUSY Searches – Charginos/Neutralinos



Note: Limit on $\sigma\times$BR applicable to general SUSY with similar mass hierarchy

Interpretation in 3 reference scenarios (all: $\tan\beta$=3, A_0=0, $\mu>0$):

- "mSUGRA"
  Parameter choices maximize leptonic BR ($m_{\tilde{\ell}} \approx m_{\tilde{\chi}_2^0} \to$ sfermion decays dominate)
- "Large m_0"
  Decays via W^*/Z^* dominate $\to$ leptonic BR is low
- "Heavy squarks" (relaxing scalar mass unification)
  Enhanced cross-section (destructive interference with squark-exchange suppressed)

Search for Supersymmetry: $B_s \rightarrow \mu^+\mu^-$

- **SM prediction: BR($B_s \rightarrow \mu^+\mu^-$)=$3.8\times10^{-9}$**
- **can be enhanced by non-SM graphs:**

  SUGRA: $\sim (\tan\beta)^6$

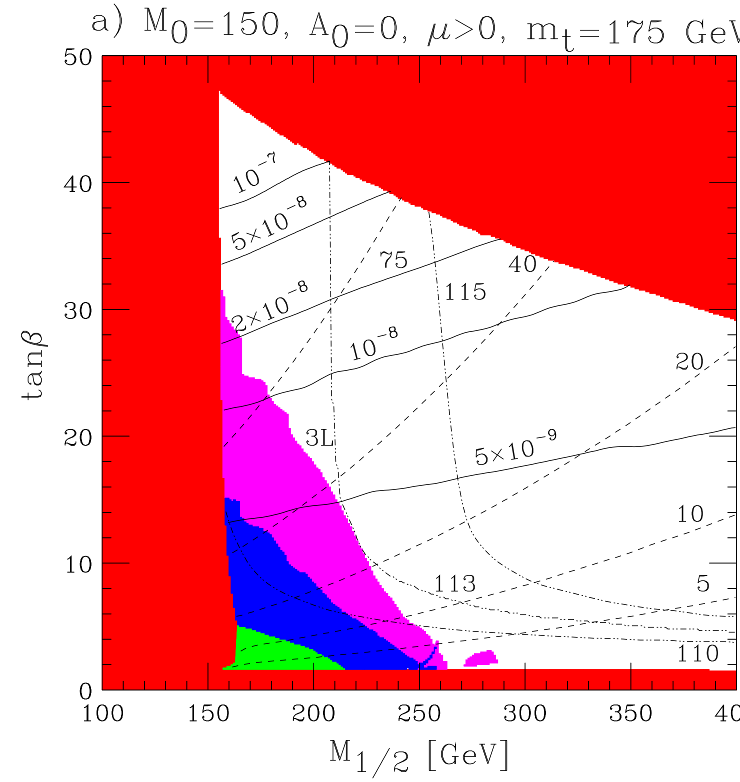
  $\rightarrow$ significant at high $\tan\beta$

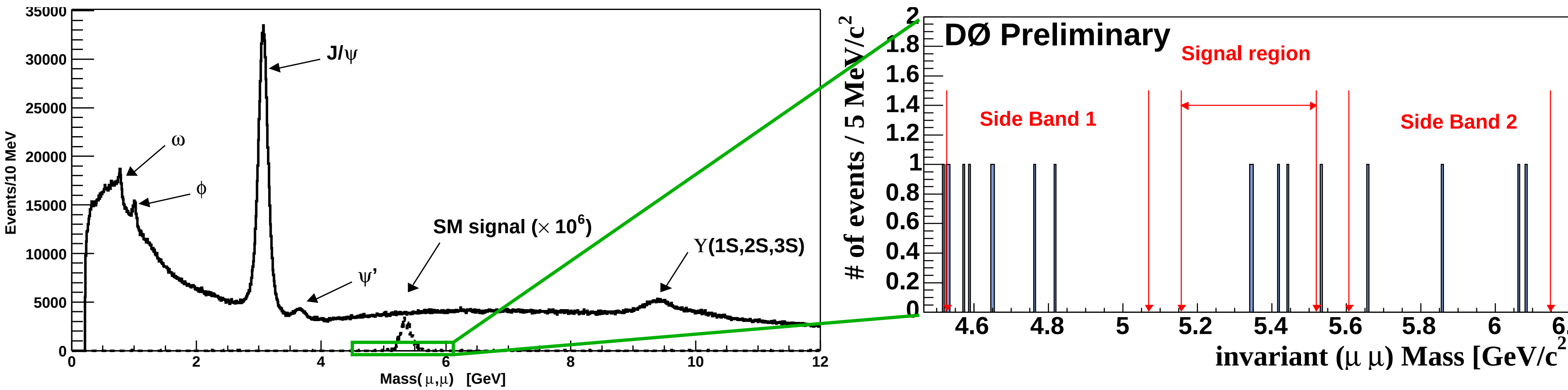
  $\rightarrow$ complementary to trilepton search
- **Tevatron: large production rate for B_s**
- **Selection: two isolated muons, displaced vertex**
- **Results based on 170-240 pb^{-1}:**

  DØ: BR($B_s \rightarrow \mu^+\mu^-$)<$4.6\times10^{-7}$ (at 95% C.L.)

  CDF: BR($B_s \rightarrow \mu^+\mu^-$)<$7.5\times10^{-7}$ (at 95% C.L.)

(Dedes et al., hep-ph/0207026)



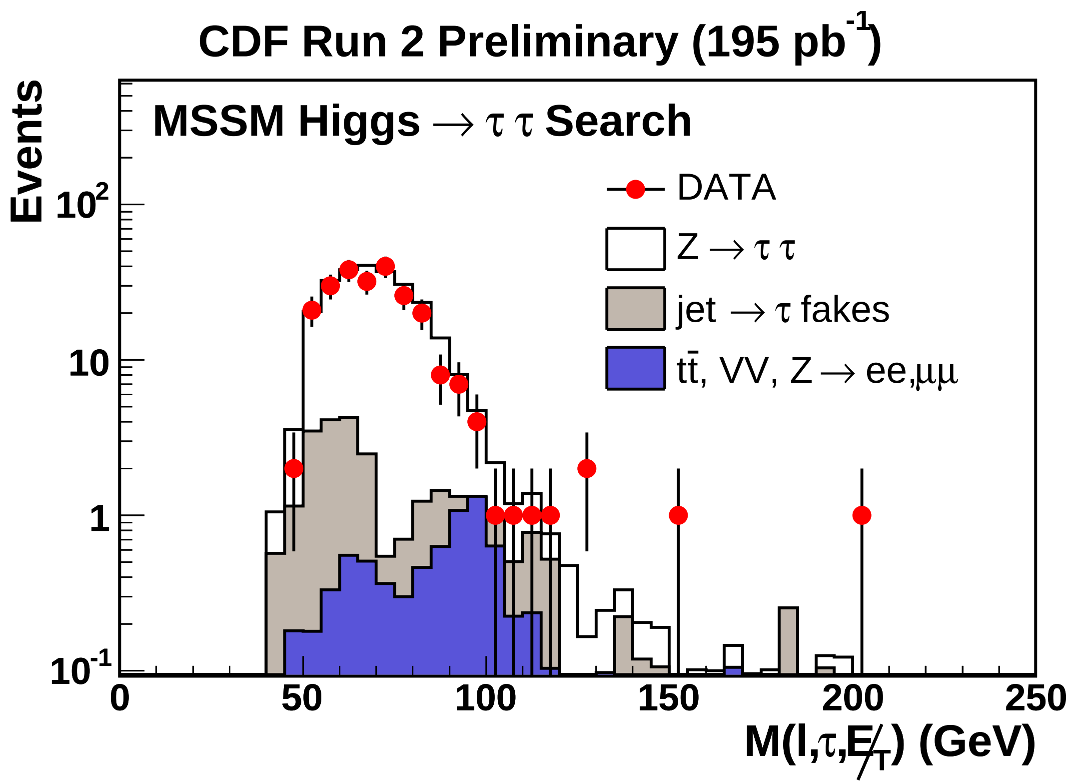


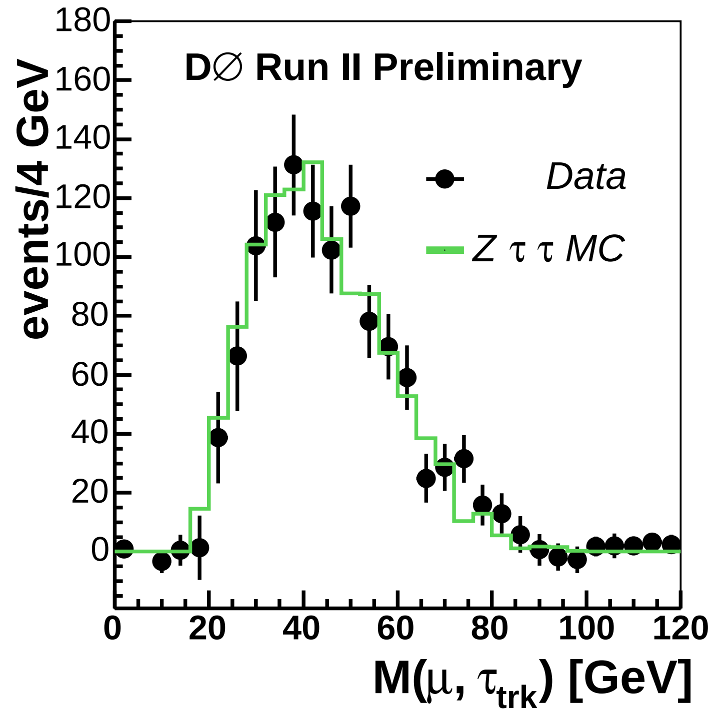
Searches with τ-Leptons

Searches involving τ-leptons are of prime interest

- for instance, SUSY at high $\tan\beta$:
  - Trilepton signal dominated by $\tau\tau\tau$
  - enhanced cross-sections for A$\rightarrow\tau\tau$

First step: reconstruct Z$\rightarrow\tau\tau\rightarrow$e/$\mu$ + hadrons

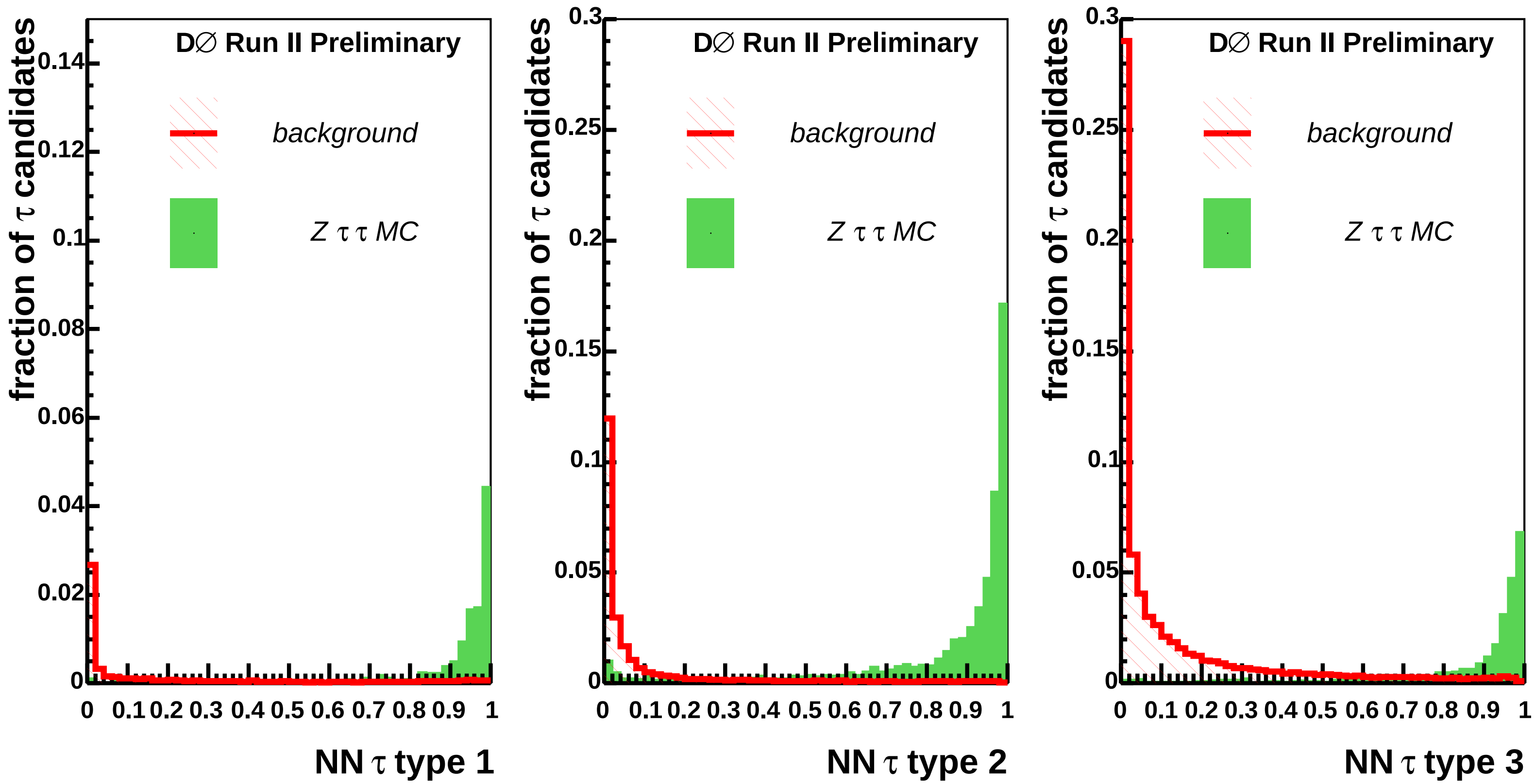




Immediately implies limits on Z' and Higgs (not competitive yet)

Searches with τ-Leptons

- τ-Identification much more challenging than electron/muon-ID
- DØ: set of neural networks to separate τ-leptons from jets, electrons and muons
  - exploiting width, mass, track multiplicity, π^0-content etc.
  - taking into account (plenty of) correlations
  - dedicated networks for three decay categories (1-prong with/without π^0, 3-prongs)



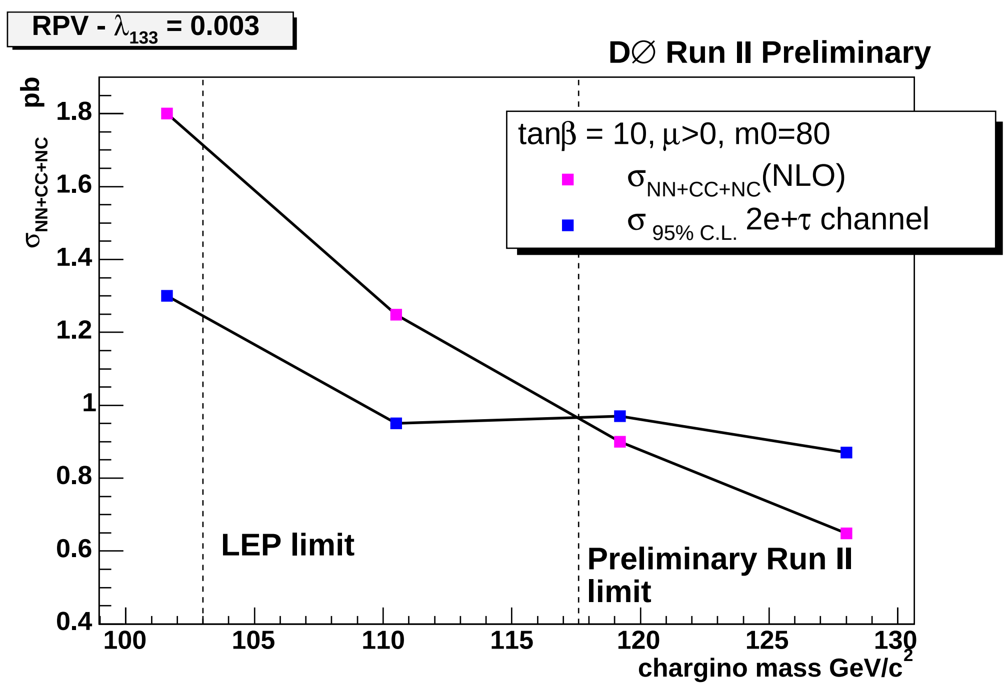
Searches with τ-Leptons

DØ: first results of trilepton analysis with τ-leptons (200 pb^{-1})

- **Selection:**
  - two electrons with pt$>$10 GeV
  - at least one hadronic τ with pt$>$7 GeV
  - significant $\not\!\!E_t$
- **0 events observed, about 1 bkgd. event expected (dominated by Z+fakes)**
- **Interpretation within RPV SUSY ($LL\bar{E}$ coupling)**

$\longrightarrow$ final states with 4 charged leptons from LSP decays

$\longrightarrow$ no suppression from branching fractions (for single coupling)

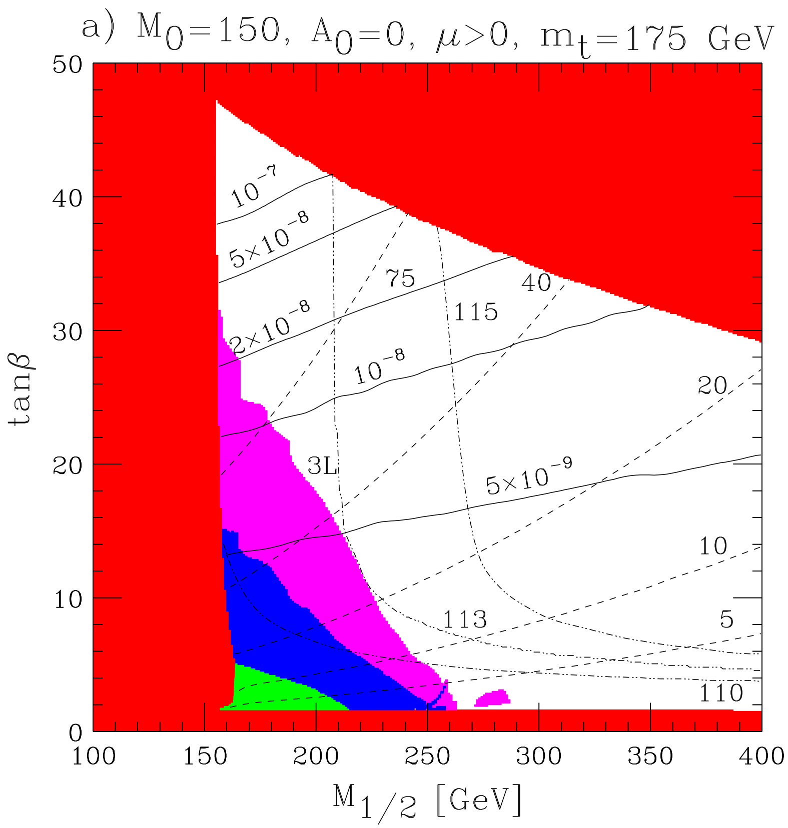


$\longrightarrow$ **Mass Limit for $\lambda_{133} > 0$: $m_{\tilde{\chi}^{\pm}} > 119$ GeV** ($\tan\beta$=10, $\mu>0$, m_0=80, A_0=0)

SUSY Multileptons – Discovery Scenario

Tevatron multilepton signal would imply:

- **lightest chargino mass 100<m<200 GeV**
- **likely fairly light sleptons**
- **squarks/gluinos tested (excluded?) up to 400 GeV, squarks likely very heavy**



LHC confirmation could be challenging if squarks/gluinos ultra-heavy

- **slepton reach limited**
- **trilepton reach for non-SUGRA mass hierarchies (low Δm, soft leptons)?**

Conclusions

CDF/DØ Multilepton analyses probing new physics beyond existing limits

First results from searches using τ-leptons look promising

Potential Tevatron Signal generally easy to confirm at LHC

Analysis aspects relevant to both colliders:

- maximizing lepton acceptance is key
- understanding of tracking and calorimeter at extreme pt
- low pt lepton triggers (rate, efficiency measurements)
- estimation of multijet background
- background MC statistics for analysis tuning