Search for MMSM/mSUGRA at DØ

HEP2003 Europhysics Conference in Aachen

Martin Wegner, III. Phys. Inst. A, RWTH Aachen

RHEINISCH-
WESTFÄLISCHE
TECHNISCHE
HOCHSCHULE
AACHEN

- Why SUSY?
- Tevatron and the DØ-Experiment
- Four Analyses:
  - Stop search in the di-jet+ME_T channel
  - MSSM search in the 3 leptons + ME_T channel
  - Tau identification
  - Model independent: Search for eμ
- Conclusion

What is so attractive about SUSY?

- We know that the Standard Model can't be everything: **Somewhere between 10^2 and 10^{19} GeV there has to be "new physics"** .
- A supersymmetrical extension of the SM is not necessary
- **But:**
  - SUSY yields explanations for open questions of the SM
  - SUSY makes a Grand Unified Theory easier
  - String theories imply SUSY

Supersymmetry: What's the idea?

- **"Minimal solution" (MSSM):**
  - **Every fermion (boson) has a bosonic (fermionic) "super-partner".**
  - A second Higgs-doublet is necessary

SM Particle		SUSY Partner	
Quarks	(u_L, d_L)	Squarks	$(\tilde{u}_L, \tilde{d}_L)$
	u_R		$\tilde{u}_R$
	d_R		$\tilde{d}_R$
Fermions	(ν, e_L)	Sfermions	$(\tilde{\nu}, \tilde{e}_L)$
	e_R		$\tilde{e}_R$
Higgs	(H^+_u, H^0_u)	Higgsinos	$(\tilde{H}^+_u, \tilde{H}^0_u)$
	(H^0_d, H^-_d)		$(\tilde{H}^0_d, \tilde{H}^-_d)$
Gluon	g	Gluino	$\tilde{g}$
W-Boson	$W^\pm, W^0$	Wino	$\tilde{W}^\pm, \tilde{W}^0$
B-Boson	B^0	Bino	$\tilde{B}^0$

Is SUSY an exact Symmetry?

- Obviously Supersymmetry is broken; otherwise SUSY particles had the same masses as their SM-partners.
  ⇒ SUSY gauge-eigenstates mix into mass-eigenstates different from SM mass-eigenstates.

- **Mass-Eigenstates**:
  - The super-partners of the gauge bosons and Higgs-particles mix to form 2 charged „Charginos“ $\chi^{\pm}_1$, $\chi^{\pm}_2$ and four „Neutralinos“ χ^0_1, χ^0_2, χ^0_3, χ^0_4
    (sorted by mass)
  - The left- and right-handed heavy quarks
    $\tilde{b}_L$, $\tilde{b}_R$,$\tilde{t}_L$, $\tilde{t}_R$ mix to $\tilde{b}_1$, $\tilde{b}_2$, $\tilde{t}_1$, $\tilde{t}_2$
    $\tilde{\tau}_L$ and $\tilde{\tau}_R$ mix to $\tilde{\tau}_1$ and $\tilde{\tau}_2$

mSUGRA

- It is attractive to assume a spontaneous symmetry breaking
- **One possible model: SuperGravity:**
  - The symmetry breaking takes place in a “hidden sector” and is transmitted to the “visible sector” by gravitons
  - Side effect: The number of free parameters is reduced from 105 (MSSM) to 5:
    - Universal squark and chargino masses at the GUT scale: $\mathbf{m_0}$, $\mathbf{m_{1/2}}$
    - Universal trilinear coupling: $\mathbf{A_0}$
    - Ratio of Higgs VEVs: $\mathbf{\tan \beta}$
    - Sign of the Higgs parameter: $|\mu|$

What does the accelerator look like?

- **Run II** (since 2001):
- CM energy
  1.96 TeV vs.
  1.8 TeV in Run 1
- Luminosity
  - So far deliverd:
    258 pb^{-1}
  - Goal for Run IIa:
    $\mathcal{L}$ fb^{-1}
  - For comparison:
    Run I: $\mathcal{L} = 0.1\ fb^{-1}$

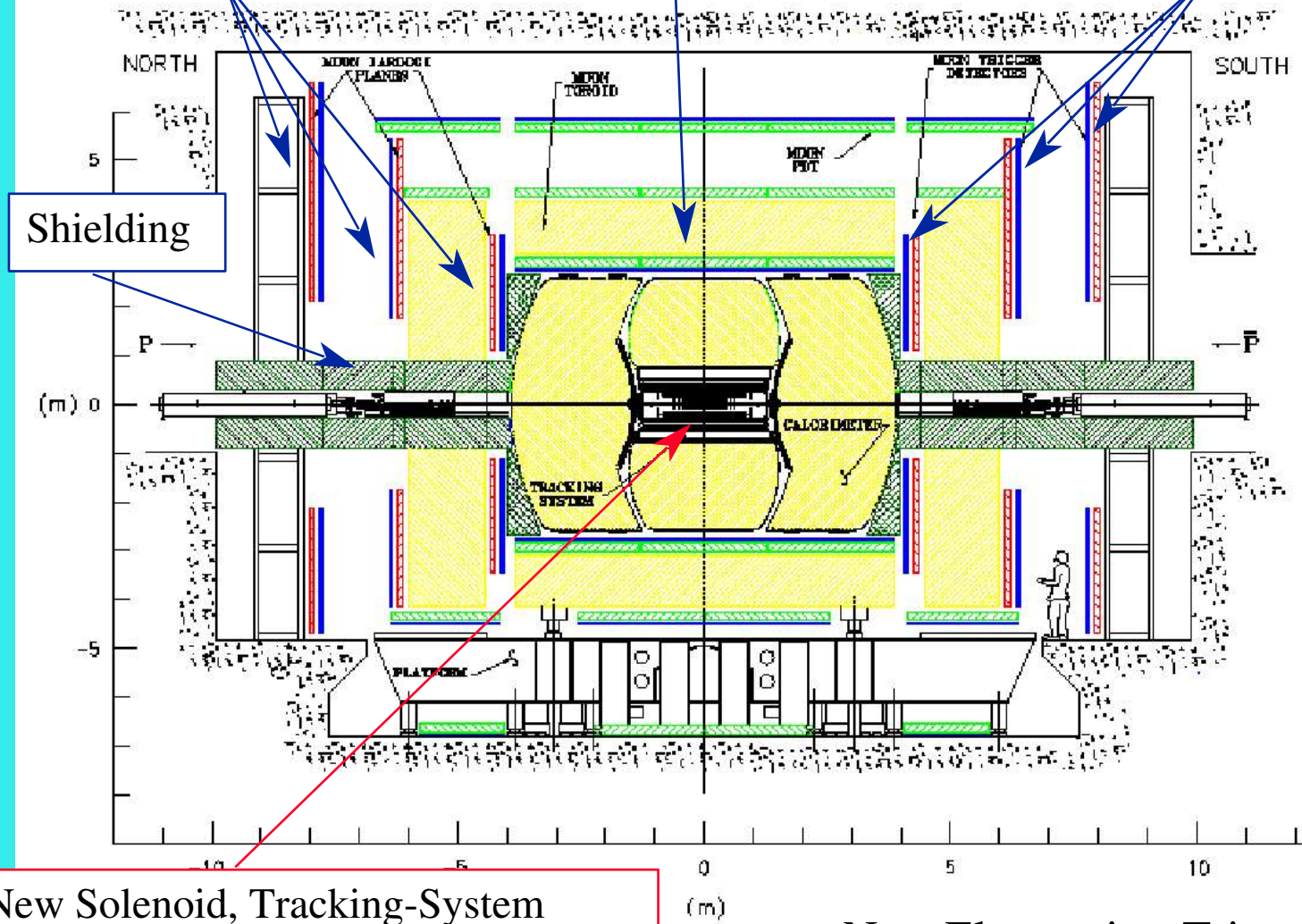
The DØ Detector: What's new?

End Caps:
Mini Drift Tubes

Central Trigger Counters

End Cap Trigger Counters

Shielding



New Solenoid, Tracking-System
(Silicon, Scint. Fibers, Preshowers)

+ New Electronics, Trigger, DAQ

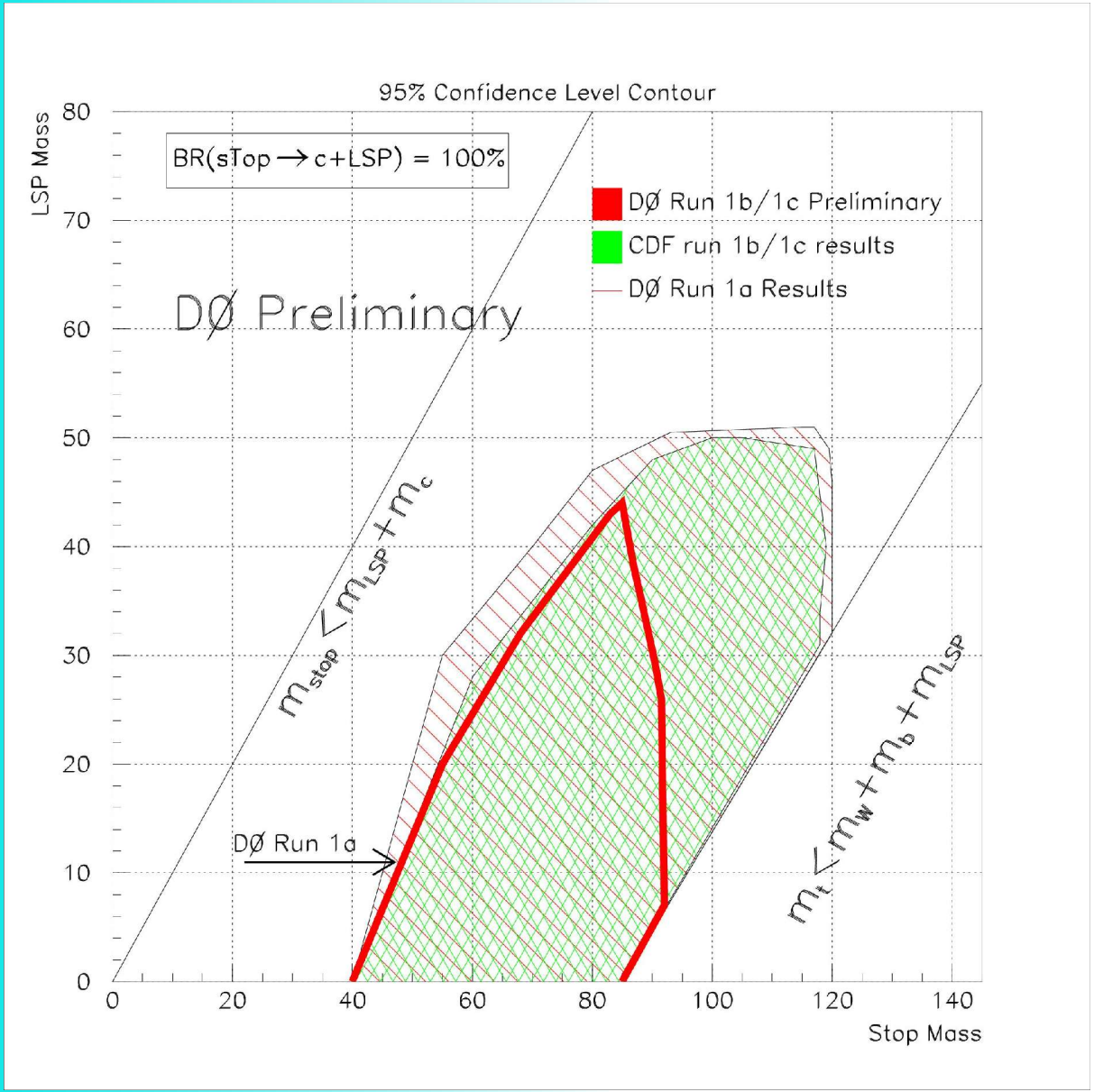
Stop search with Run I data

- **What signal are we looking for?**
  - Assume $m_{stop} > m_{LSP} + m_c$, $m_{stop} < m_W + m_b + m_{LSP}$
    and $m_{stop} < m_{slepton}, m_{sneutrino}$
    ⇒ **BR($\tilde{t}$ → c + LSP) = 100%**
  - ➔ **Search for two jets and large missing energy**
- **What are the backgrounds?**
  1. Standard-Model background (large!):
     - W → lν +jets
     - W → lν, W → qq
     - W → l → anything
     - Z → $\nu\nu$
     - Z → $\tau\tau$
     - $t\bar{t}$ decays
     - ➔ **A lepton may be mis-identified as a jet!**
  2. Detector mis-measurements, leading to fake ME_T

Stop search (2)

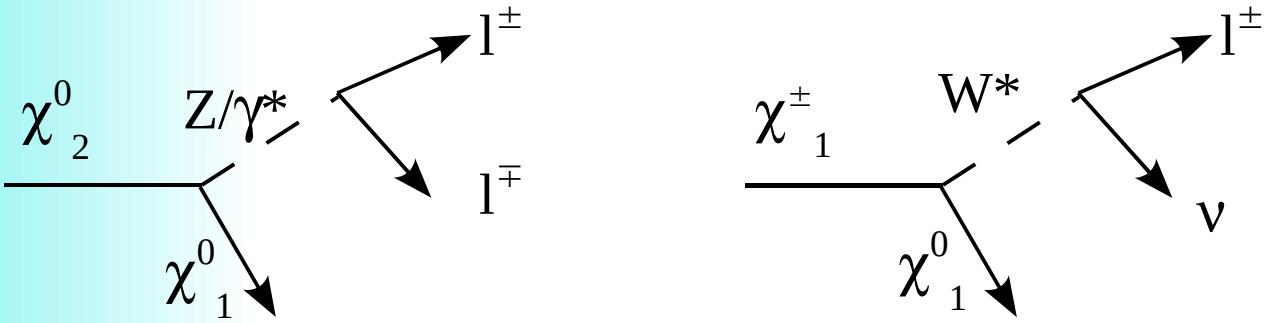
- **What data set has been used?**
  - **85.2 pb^{-1}** of data, taken with a di-jet+MET trigger
- **Which cuts were applied?**
  - Leading Jet E_T > 100 GeV
  - Second Jet E_T > 60 GeV
  - ME_T > 40 GeV
  - Angle between any jet and ME_T > 30 °
  - η of leading jet < 0.8 (central calorimeter only)
  - η of any jet: NOT 0.8 $|\eta|$ < 1.2 (overlap region of central and forward cal.)

Stop search: What do we find?



- After all cuts 12.81± 1.77 events were expected and 12 events were found
- This translates to an excluded region in the m_{LSP}-m_{stop} plane

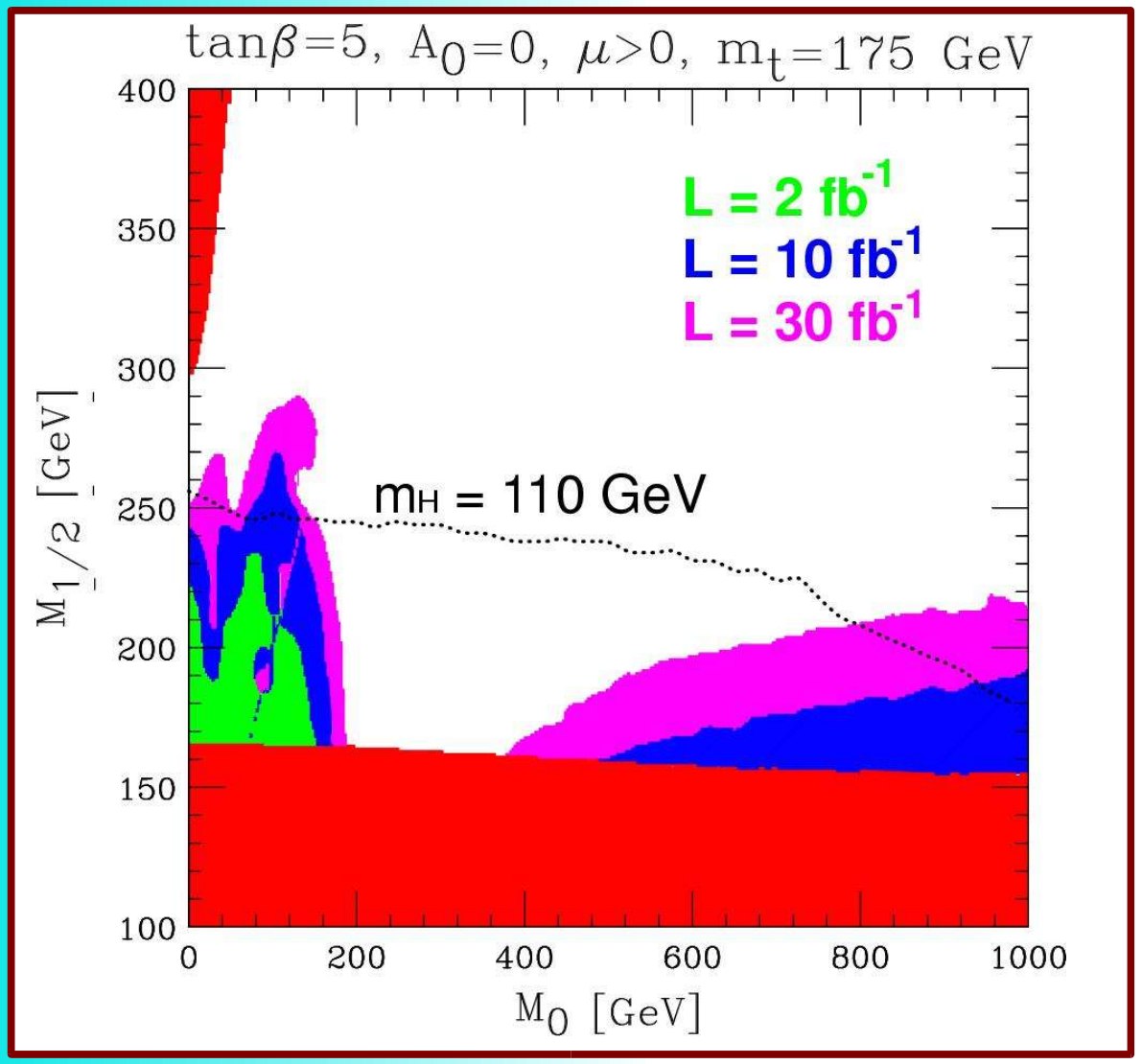
How do we get 3 leptons?



- Chargino and second-lightest neutralino are produced associated and decay into
  3 charged leptons + neutrino + 2 LSPs
- Advantage of this channel:
  - Little Standard Model Background
  - Relatively high X-section, compared to other SUSY channels

➔ **Analysis:**
Search for 2 identified electrons and an isolated third track

3l: Where can we find New Physics?



Dedes et al., hep-ph/0207026

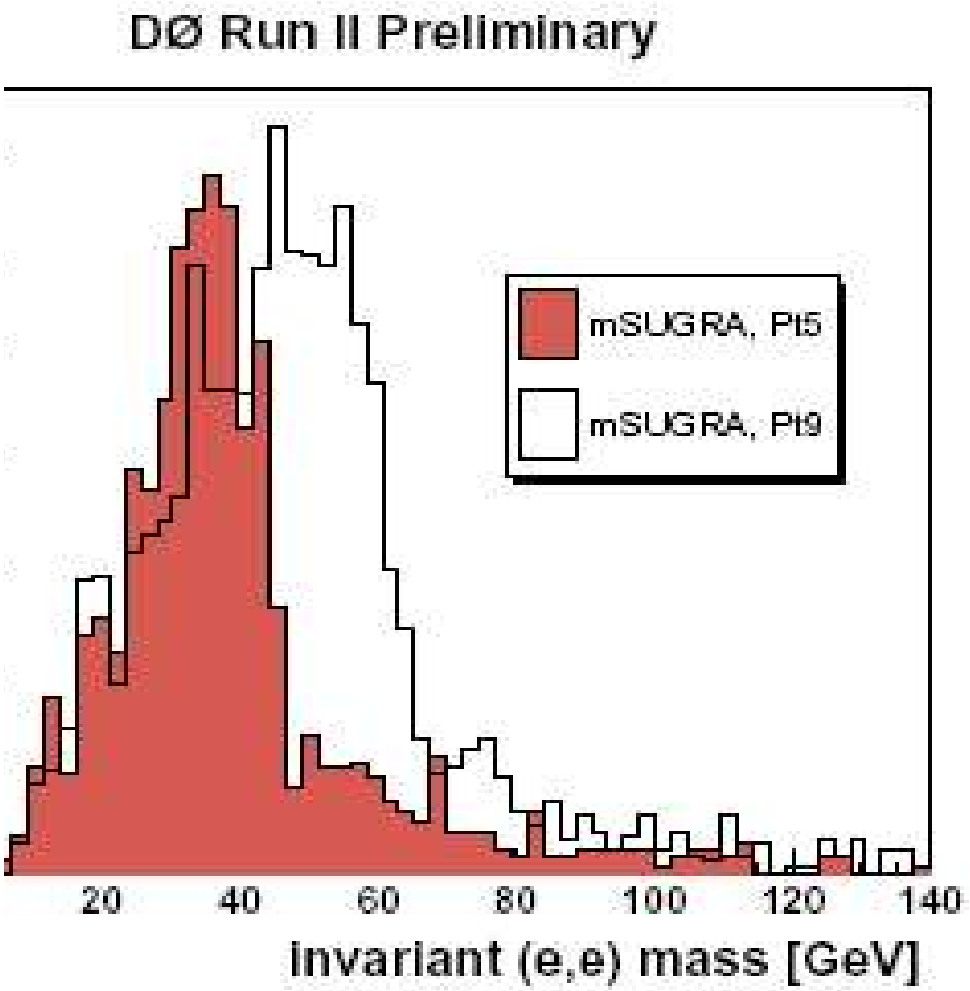
- $\chi^{\pm}_1\chi^0_2 \rightarrow 3l$ is one of the most promising channels for SUSY discovery at Tevatron
- Run 2a and Run 2b will be able to cover new regions of the m_0-$m_{1/2}$ parameter space.
- The potential is greatest for low tan β
- Limits by direct Higgs search at LEP are highly model-dependent.

2e+l: What does the signal look like?

- Generate Monte-Carlo data sets for two mSUGRA points

1. $m_0 = 500$ GeV
   $m_{1/2} = 100$ GeV
   $\tan\beta = 2, \quad \mu > 0$
2. $m_0 = 150$ GeV
   $m_{1/2} = 150$ GeV
   $\tan\beta = 2, \quad \mu > 0$

- The invariant ee-mass peaks between 30 and 60 GeV

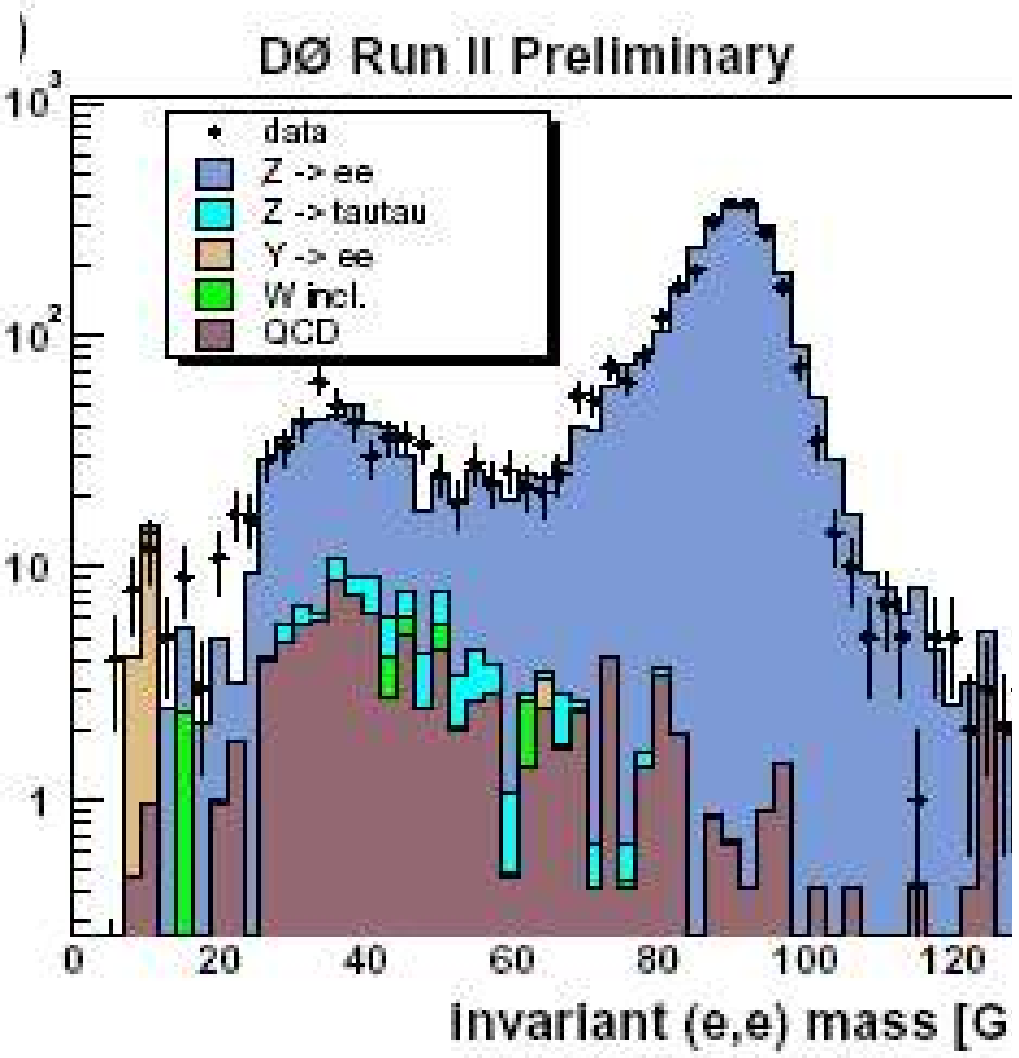


2e+l: What does the BG look like?

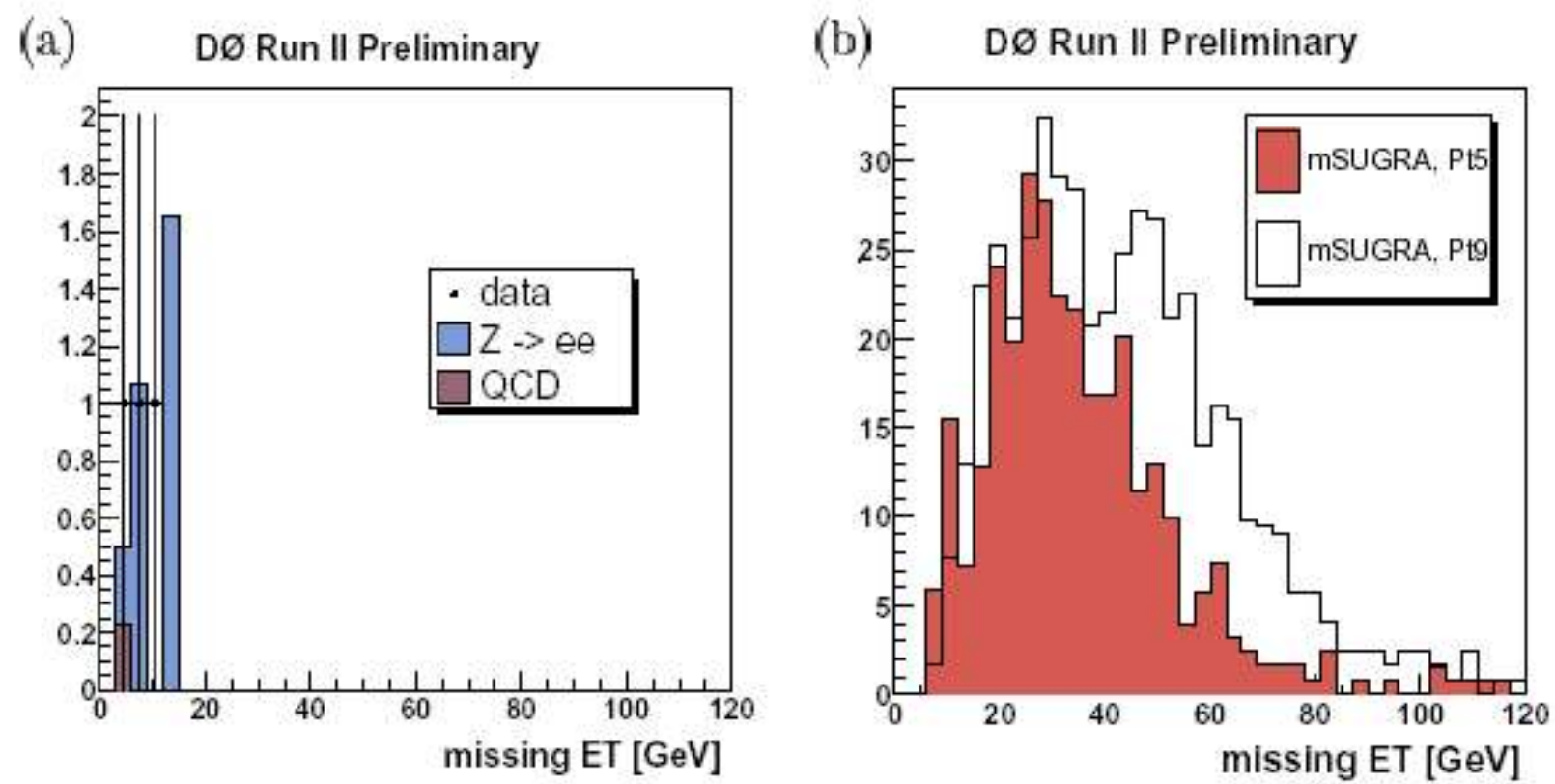
➔Deal with the two-electron background first:

- **Potential background:** All SM-processes with at least 1 electron in the final state (The second e can be faked by a jet or Photon)

  ➔ QCD Background: Extracted from data by inverting the Hmatrix-χ^2 cut



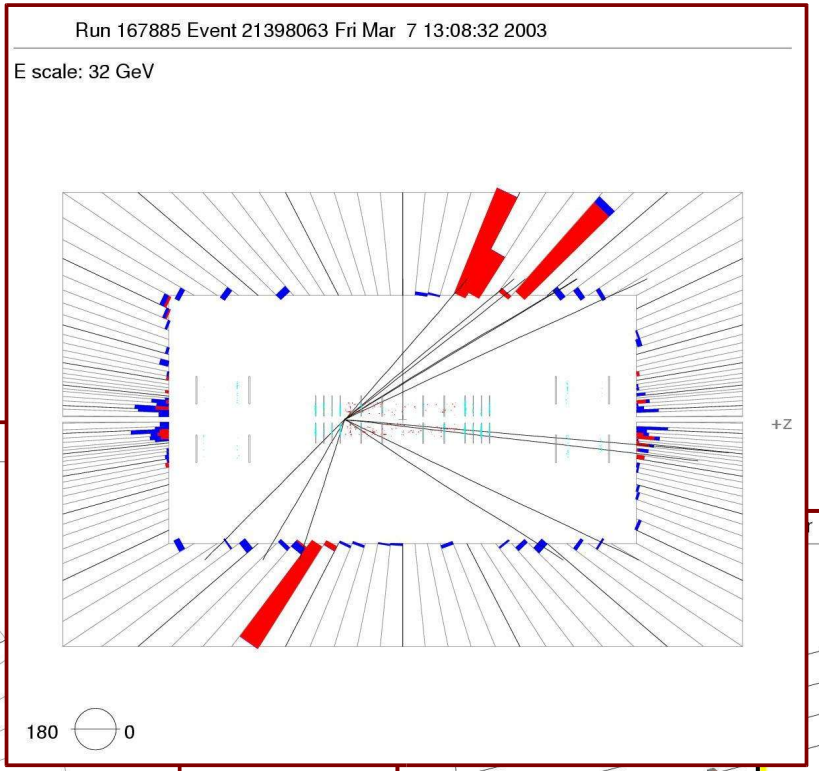
3l: What's left after the cuts?

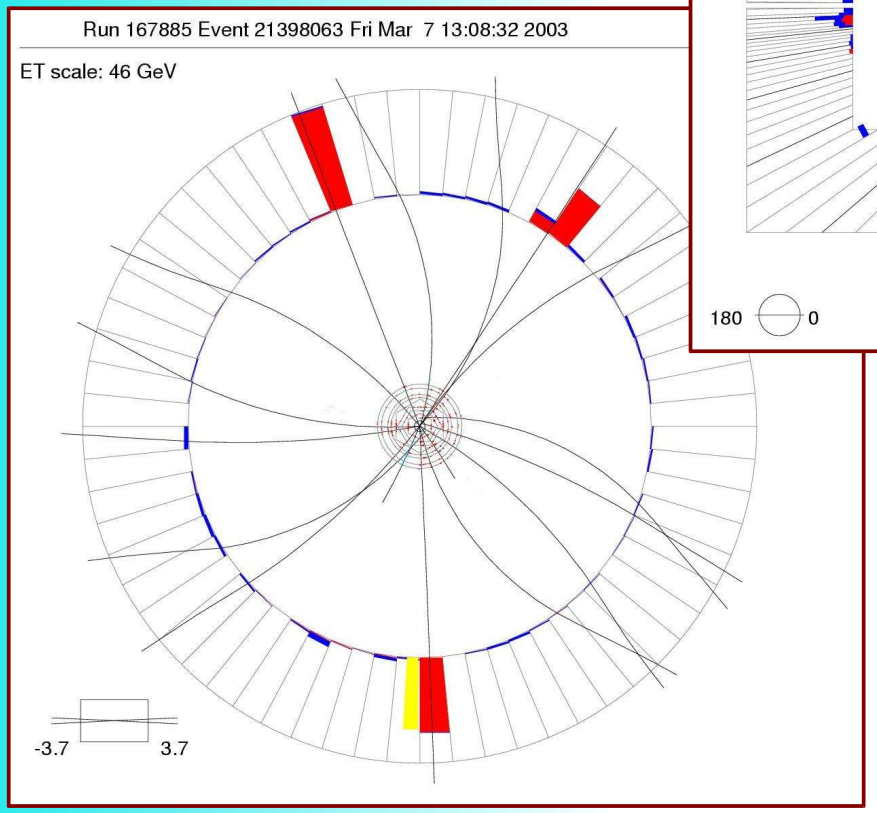


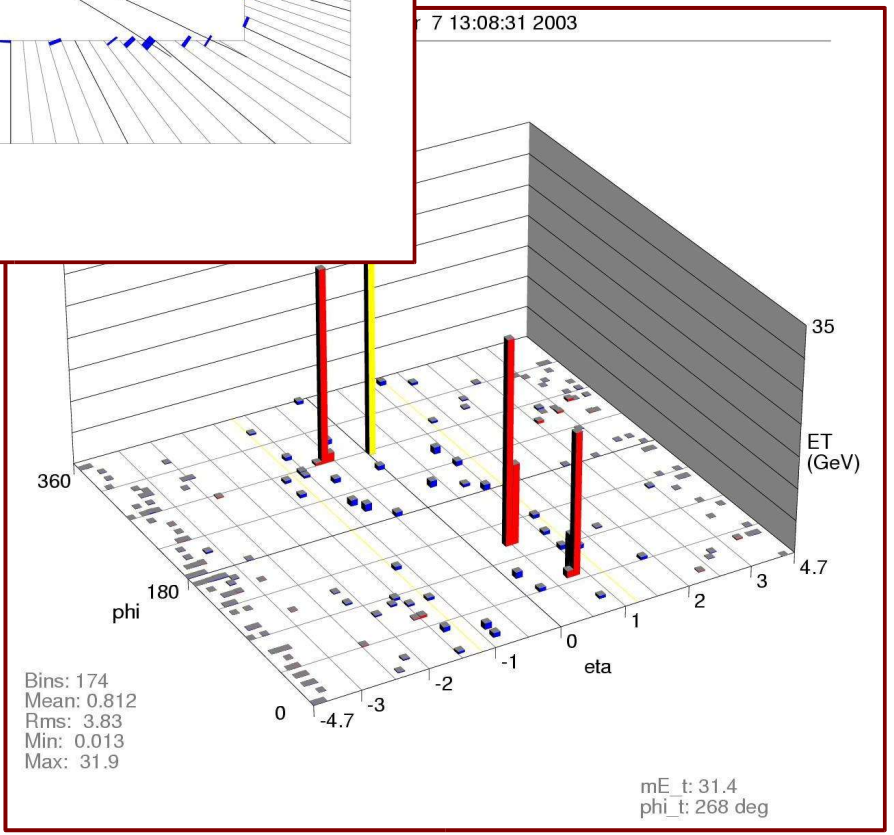
- After cutting on the invariant ee-mass (10GeV<m<70GeV) and the transversal e-MET-mass, one looses nearly the complete background (but only 50% of the signal) by requiring a third isolated track.
- Finally we require ME_T > 15 GeV

A “wannabe candidate”

- The event only fails the last MET cut







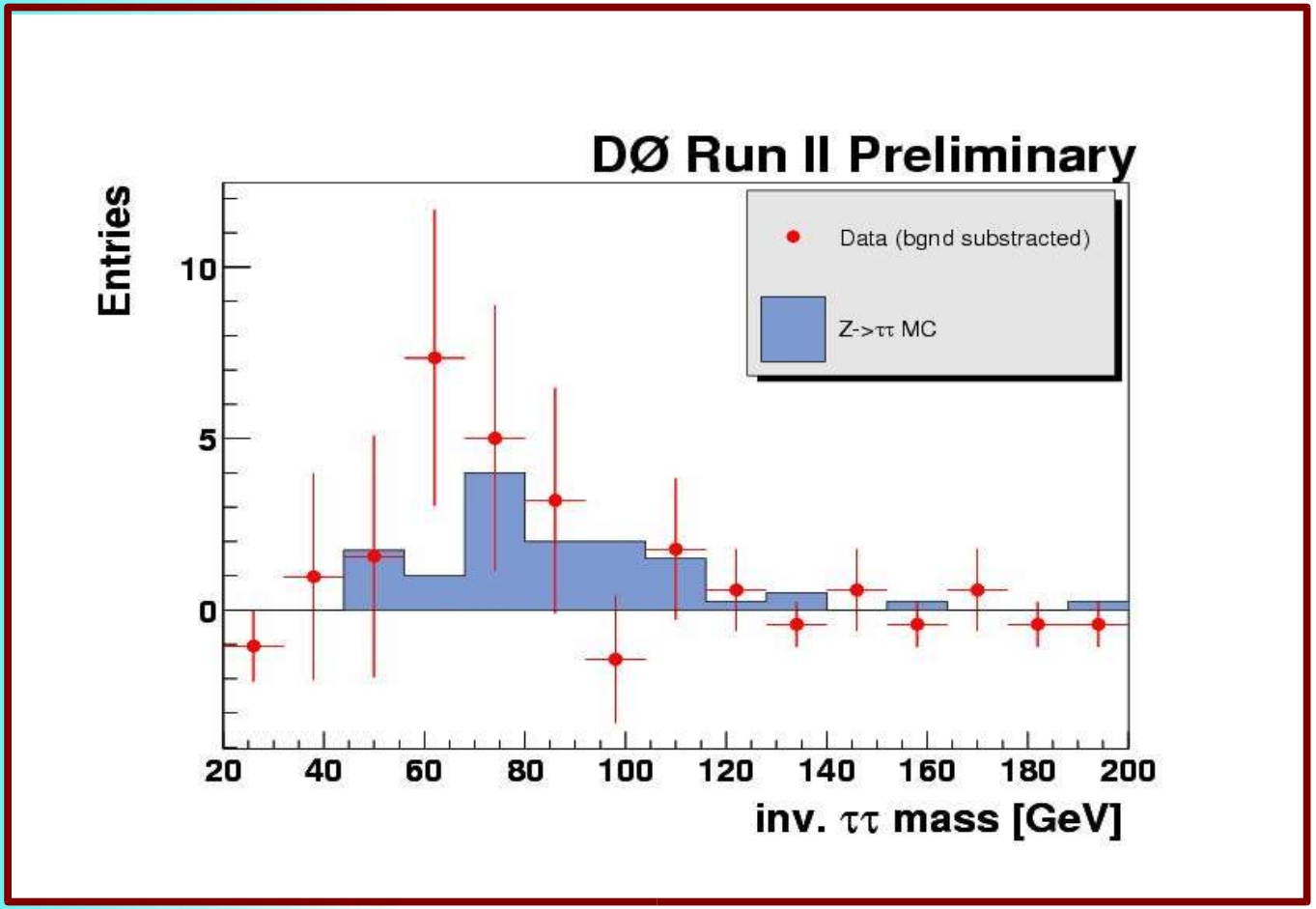
3 leptons: Results

- After all cuts one expects 0 ± 2 events and finds 0 events
- For the mSUGRA-point
  $m_0 = 500$, $m_{1/2} = 100$, $\tan\beta = 2$, $\mu < 0$
  this corresponds to a 95% C.L. limit of
  $\sigma_{prod} \times BR = 3.54$ pb.
- For the mSUGRA-point
  $m_0 = 150$, $m_{1/2} = 150$, $\tan\beta = 2$, $\mu < 0$
  this corresponds to a 95% C.L. limit of
  $\sigma_{prod} \times BR = 2.20$ pb.

What about Taus?

- **The identification of τs is crucial for high tan β**
- **Strategy**:
  - Search for Z → $\tau\tau$ → e + hadrons
  - Electron is identified using standard cuts
  - Use a **Neural Network** to identify τ-jet
  - Apply the following extra cuts:
    - Exactly one track matching the τ-cluster
    - $p_T(\tau) > 7$ GeV (remove low p_T QCD jets)
    - Transverse mass of electron and $ME_T < 60$ GeV (remove Ws)
    - Transverse mass of e and $\tau < 60$ GeV (remove Zs)
    - (ME_T, τ) <0.5 (remove evts w/ poorly measured e energy)

Do we find $Z \rightarrow \tau\tau$?



$\mathscr{L}$ = 50 pb^{-1}

- The invariant-mass distribution shows a peak with a clear excess of unlike-sign events

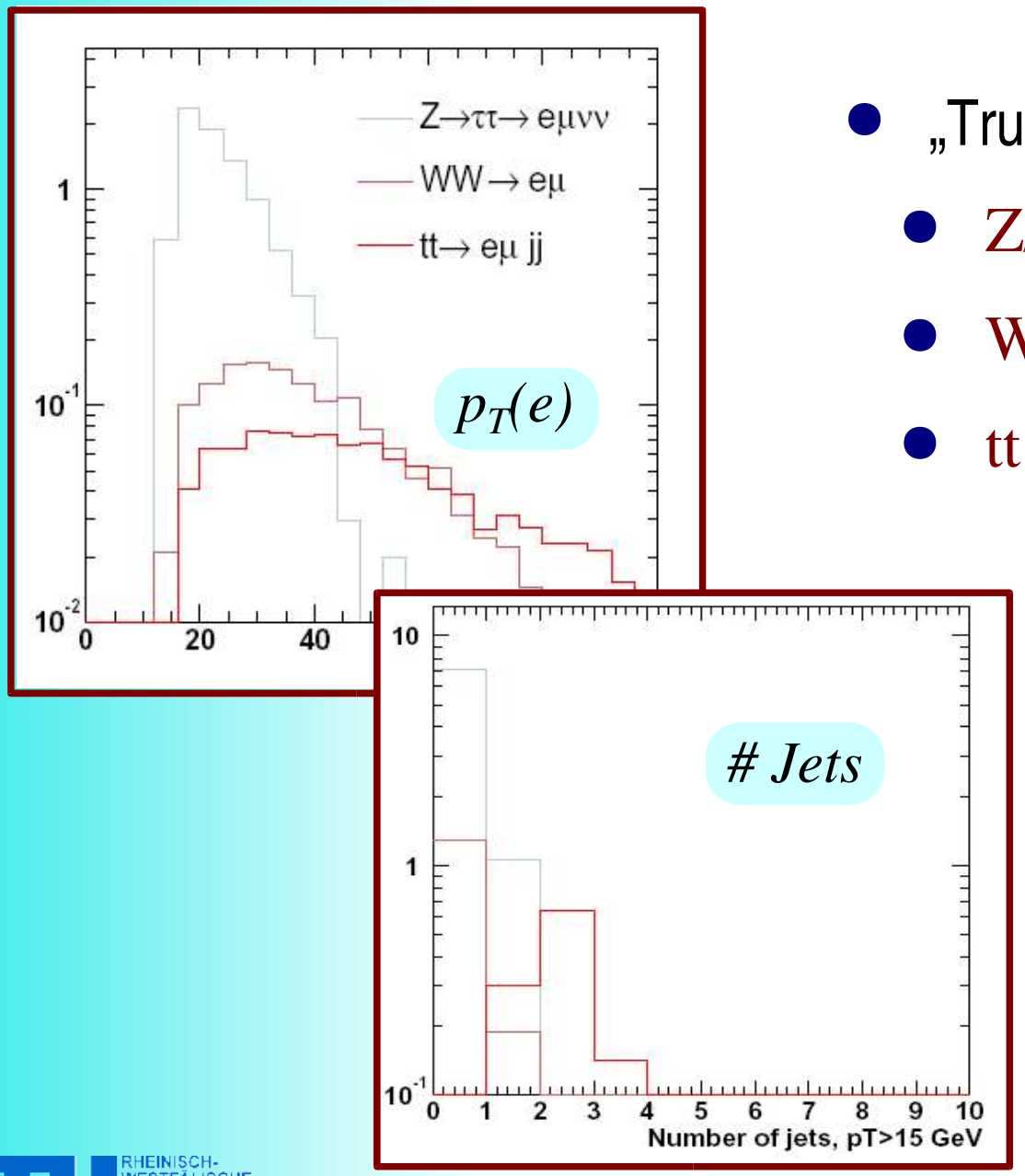
➔ **Evidence for τ at DØ!**

What's the charm of the eμ-channel?

- Very low Standard Model background
- Especially in comparison with other multi-lepton analyses:
  No Z-Resonance
- Discovery potential in several physics scenarios

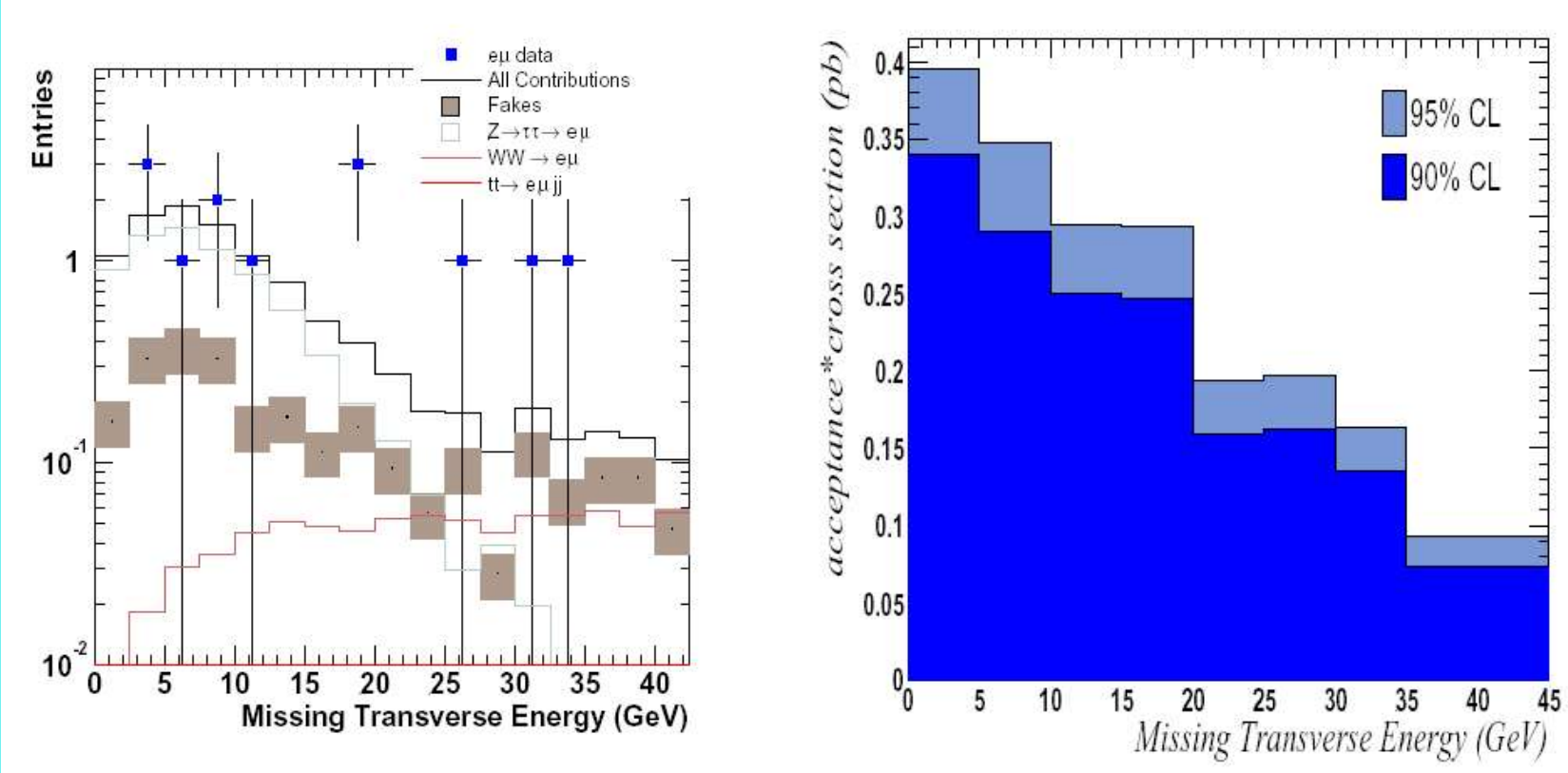
➔ Idea:
Model-independent search for „New Physics“

eμ :Which physics backgrounds do exist?



- „True“ backgrounds are mostly:
  - $Z/\gamma^* \rightarrow \tau\tau \rightarrow e\mu\nu\nu$
  - $WW \rightarrow e\mu\nu\nu$
  - $tt \rightarrow e\mu\nu\nu\ j\ j$
- Z-background differs from the rest in lepton-p_T and ME_T
- WW and tt differ in the number of jets

eμ :What does this mean for New Physics?



- Within error bounds the data is compatible with the known background.
- Limits for the product of cross section and acceptance for new physics can be quoted as a function of ME_T.
- For comparison: Acceptance for WW $e\mu$: 16.9%

Conclusions

- Run II at Tevatron will cover new regions in the MSSM parameter space
- New limits were set for the existence of a stop-particle (Run I data).
- A search for 3 leptons + MET is proceding
- Taus can be identified ad DØ
- A model independent search for e + μ is setting limits for “new physics”
- Challenging times are ahead of us.