Search for Supersymmetry in Trilepton Final States with the D0 detector

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ALBERT-LUDWIGS-
UNIVERSITÄT FREIBURG

bmb+f - Förderschwerpunkt

Elementarteilchenphysik

Großgeräte der physikalischen Grundlagenforschung

- SUSY, Tri-lepton & Like Sign final states
- ee+track analysis
- Like Sign Muon analysis
- Limits
- Conclusions and Outlooks

SUSY

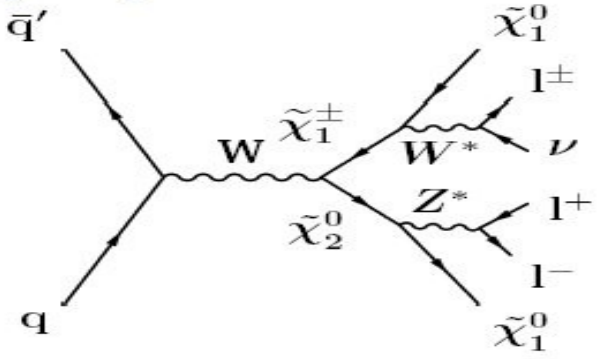
- The Standard Model (SM) is believed not to be a fundamental theory and Super Symmetry is one possible extension to the SM
- Super symmetric particles and their SM partners differ in spin by 1/2.

Quark	q	*Squark*	$\tilde{q}_R,\ \tilde{q}_L$		
Lepton	l	*Slepton*	$\tilde{l}_R,\ \tilde{l}_L$		
Neutrino	ν	*Sneutrino*	$\tilde{\nu}$		
Photon	γ	*Photino*	$\tilde{\gamma}$	}	**4 Neutralinos**
W-,Z-Boson	$W^{\pm}, Z$	*Wino, Zino*	$\tilde{W}^{\pm}, \tilde{Z}$	}	$\tilde{\chi}^0$
Higgs	$H^{\pm}, H^0$	*Higgsino*	$\tilde{H}_1^0\ \tilde{H}_2^+$	}	**2x 2 Charginos**
	h, A		$\tilde{H}_1^-\ \tilde{H}_2^0$	}	$\tilde{\chi}^{\pm}$
Gluon	g	*Gluino*	$\tilde{g}$		

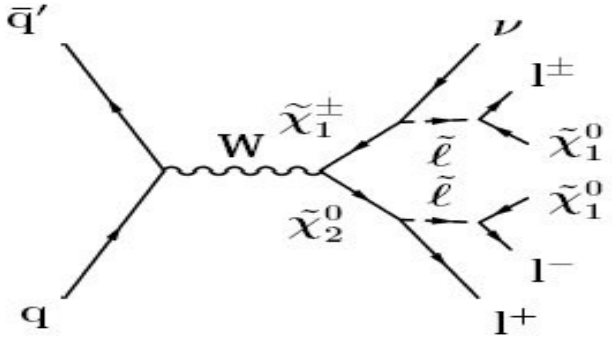
- **mSUGRA**: SUSY model with few parameters at GUT scale:
  - **m_0:** **Masses of scalars** -> sfermion masses
  - **m1/2:** mass of fermions
  - **tanß:** ratio of Higgs vacuum expectation values
  - **mu:** Higgsino mass parameter
  - **A:** trilinear coupling (Higgs-Sfermion$_L$-Sfermion$_R$)

THREE LEPTON FINAL STATE

Heavy sleptons:

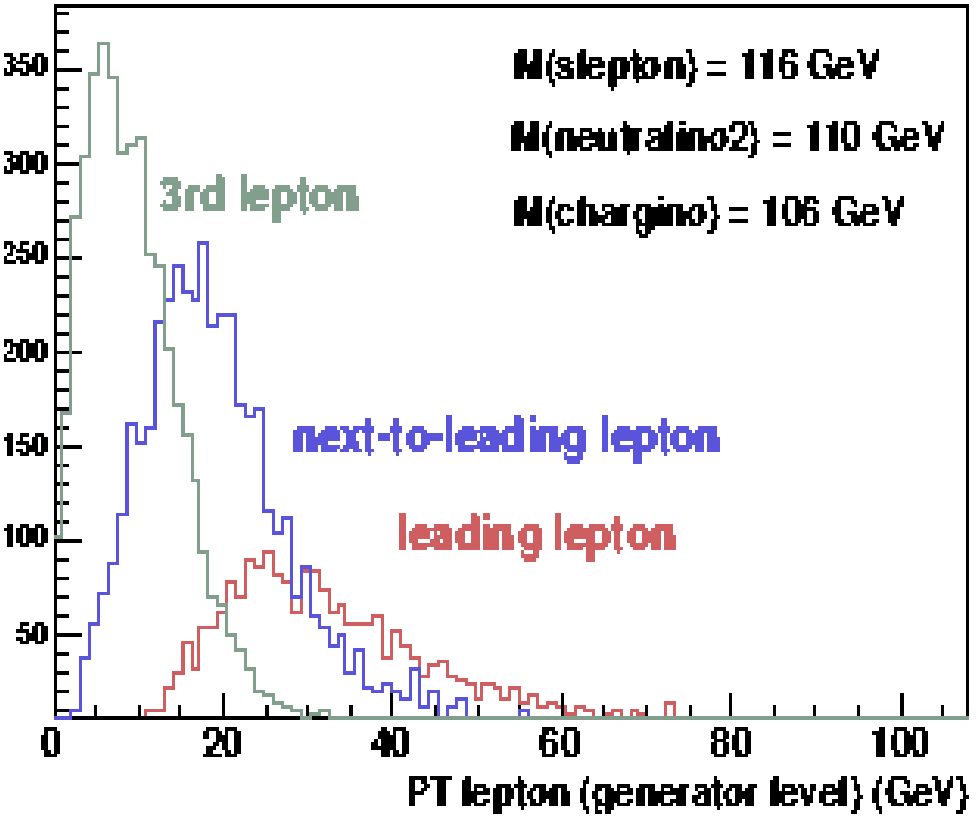


Light sleptons:

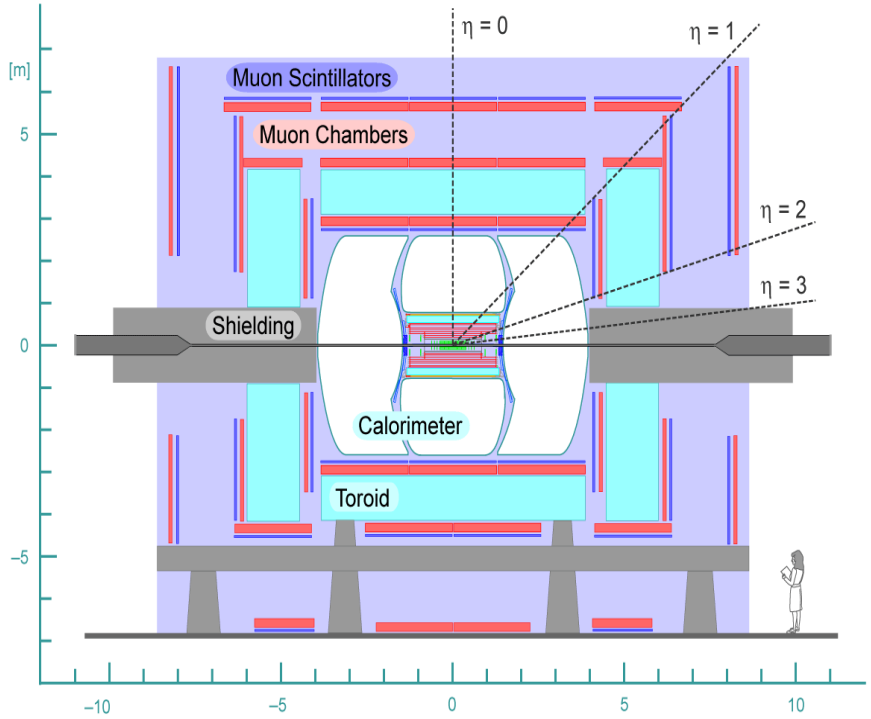


- SUSY characteristica: Two electrons or muons + a third lepton and significant missing transverse energy.
- Look for high quality track or Like Sign muons to increase efficiency

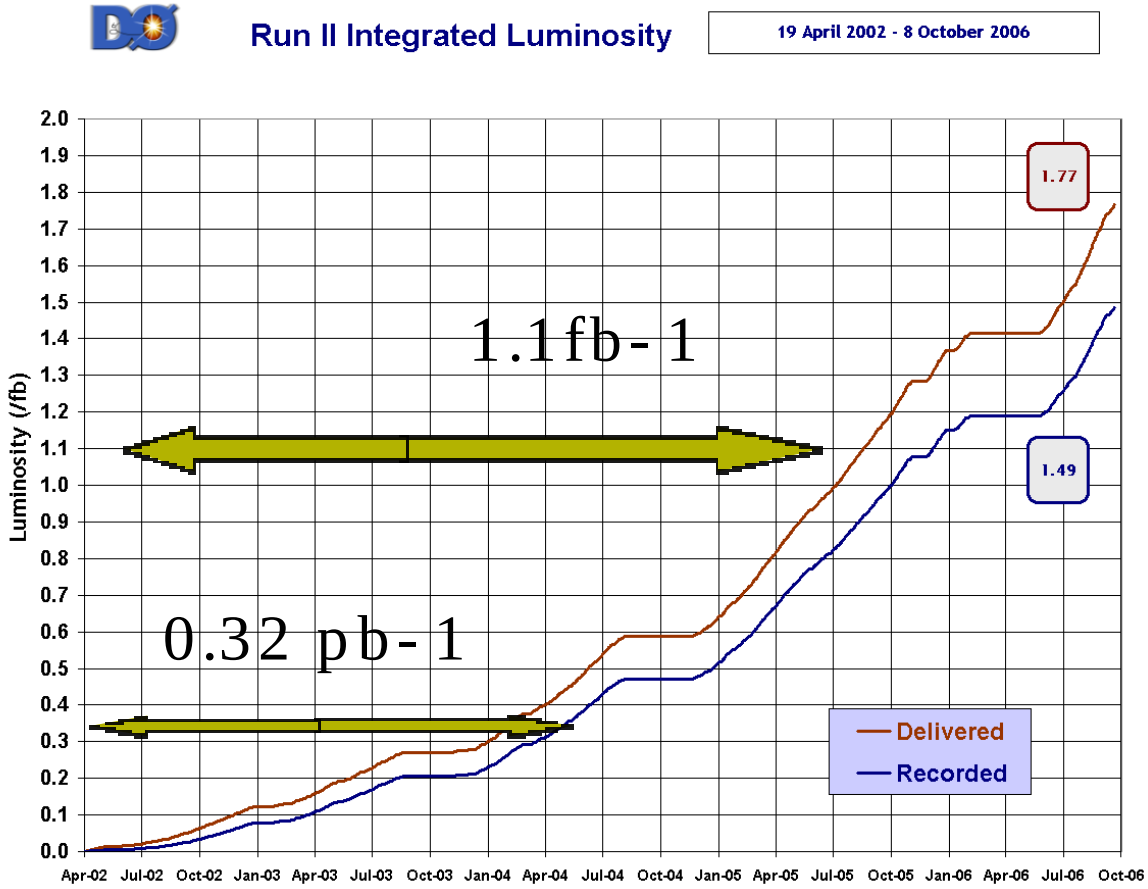
- charginos and neutralinos decay via gauge bosons or sfermions to LSP and SM particles.
- R-parity conserving models => stable LSP
- LSP escapes detection in the detector



DETECTOR and LUMINOSITY



Acceptance:
Electrons: $|\eta| < 3.0$
Muons: $|\eta| < 2.0$
Jets: $|\eta| < 4.2$

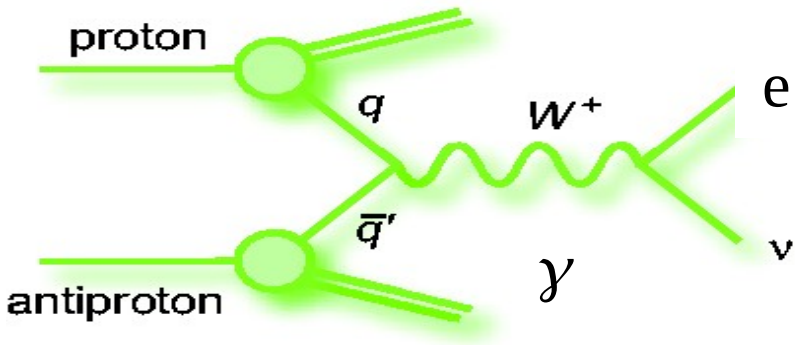


- This is a continuation and extension of the earlier result published by D0 (PRL 95, 151805 (2005)) with $\int \mathscr{L} = 320$ pb-1

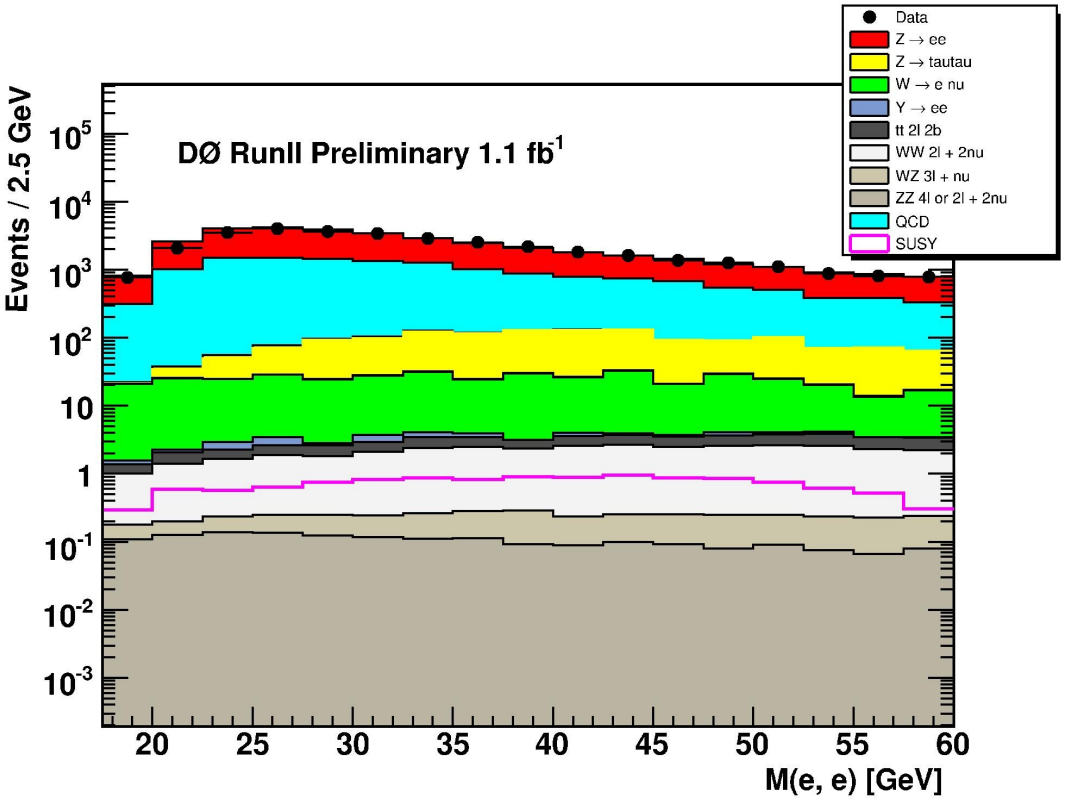
SM BACKGROUNDS ee+track

	# leptons	true ET-miss	xsec(pb)	Remarks
Signal	3	Yes	0.18	
WZ -> lll ν	3	Yes	0.1126	signal like
ZZ -> ll XX	2 – 4	Both	0.0710	Misidentified lepton / mismeasured Etmiss
WW-> ll ν ν	2	Yes	1.2411	fakes
W->l ν + γ /jet	1	Yes	2500	fakes
(Z / γ ->ll)+ γ /je	2	No	250-400	fakes, mismeasurement
ttbar -> ll +2jets	2	Yes	0.7300	fakes, mismeasurement
qqbar -> jets	0	No		fakes, mismeasurement

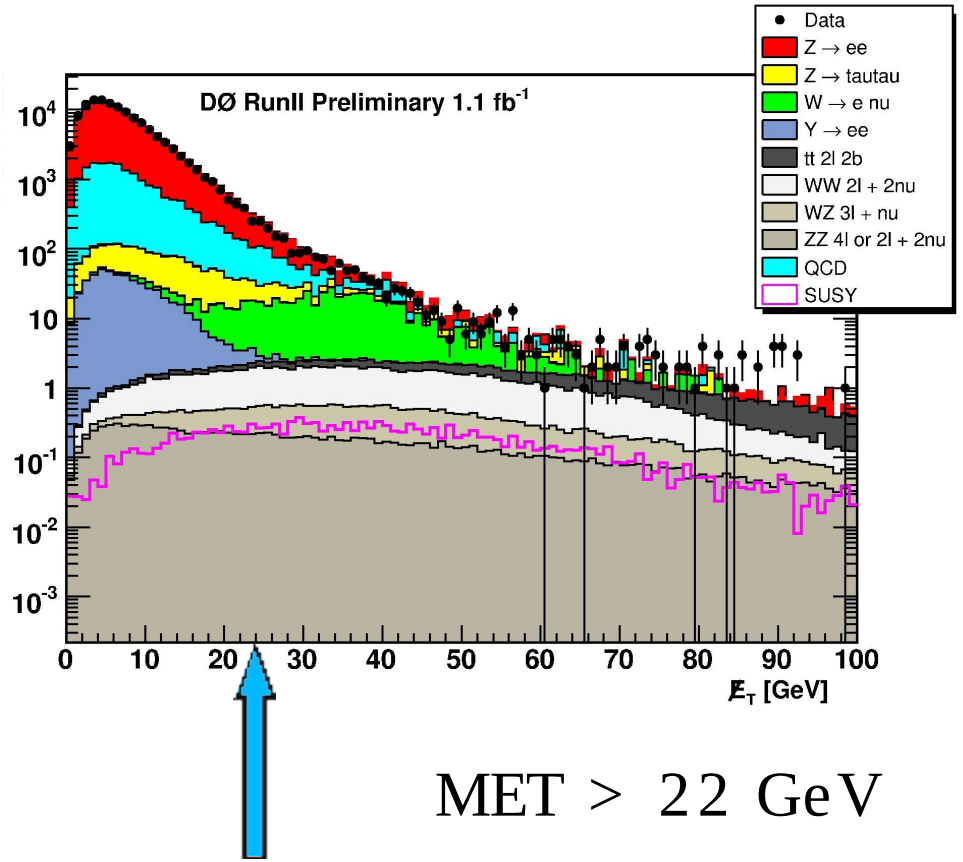
- Start by requiring two leptons in the event.
- Other important cuts: Missing Transverse Energy, require a third, isolated track in the event



IMPORTANT DISTRIBUTIONS ee+track



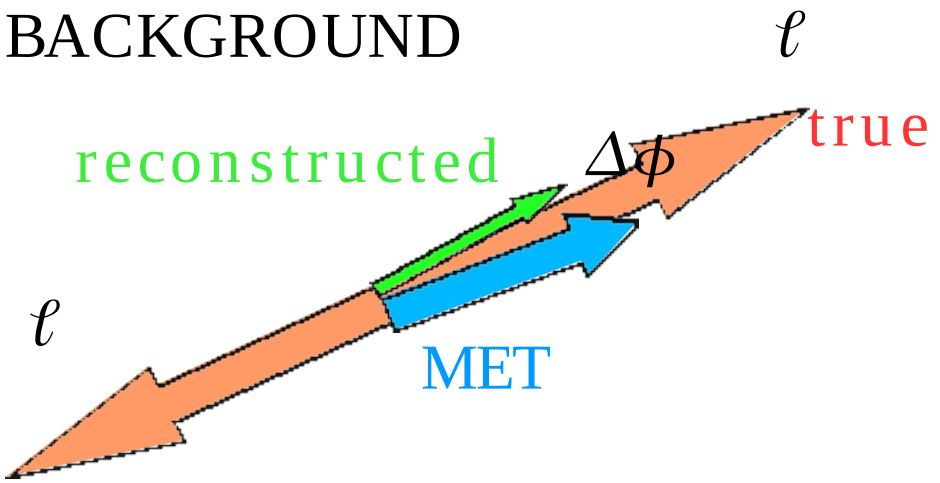
18 GeV < M(e,e) < 60 GeV



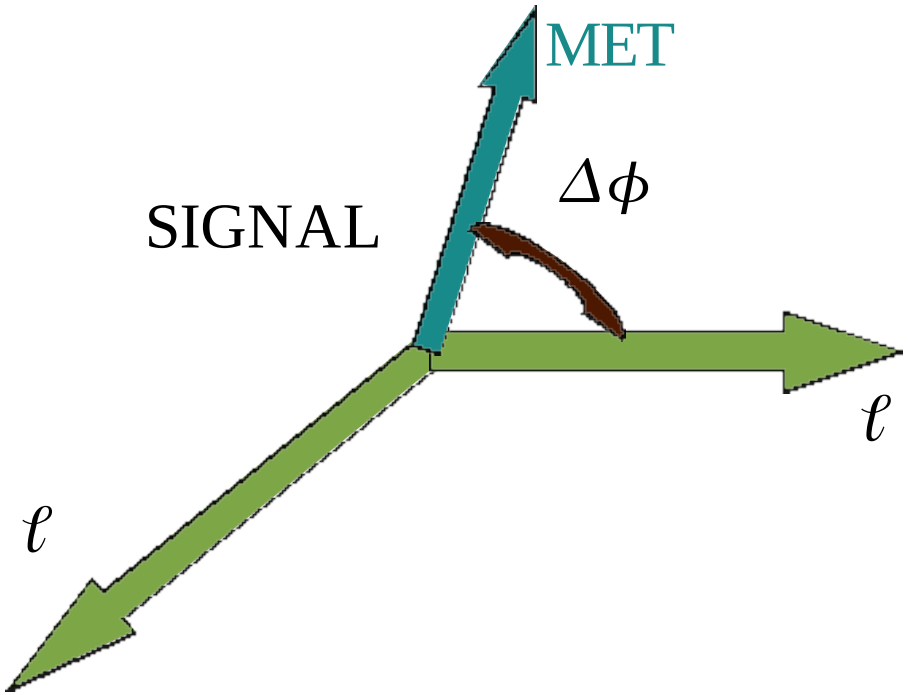
MET > 22 GeV

MET FAKED BY MISMEASURED ENERGY

BACKGROUND

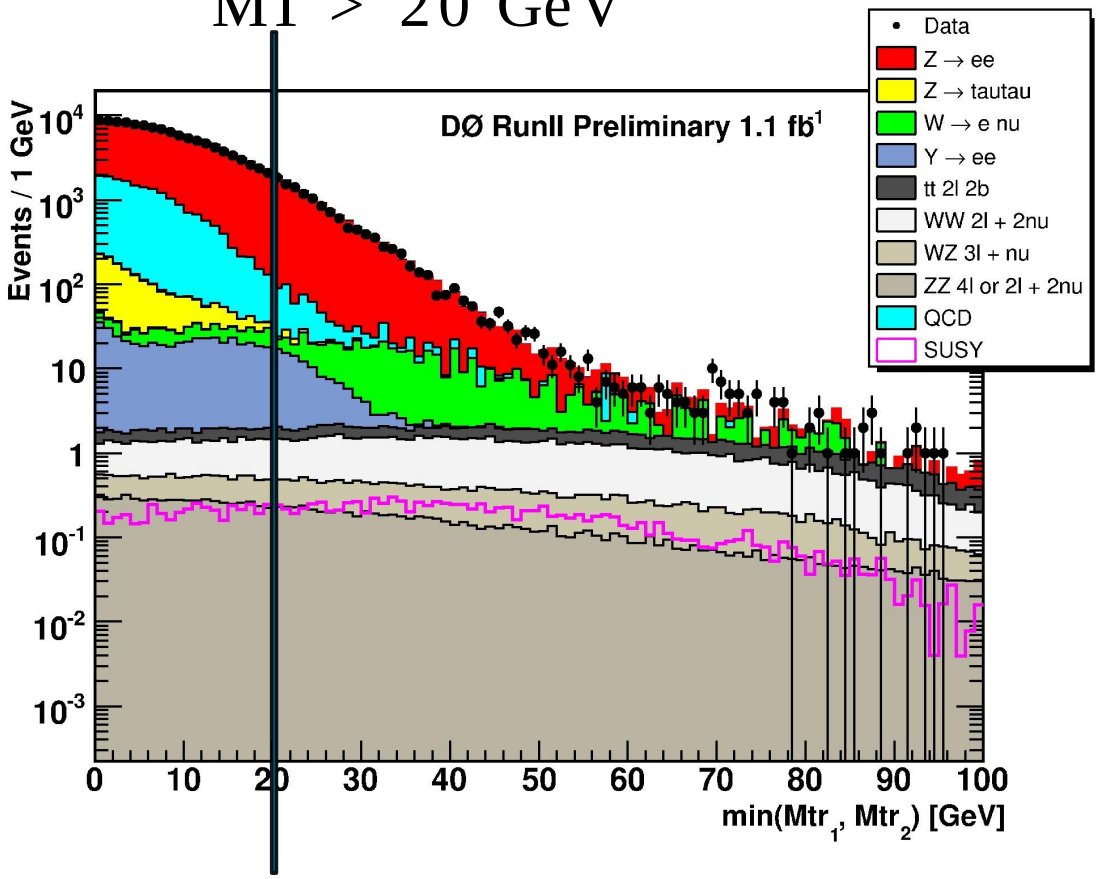


SIGNAL



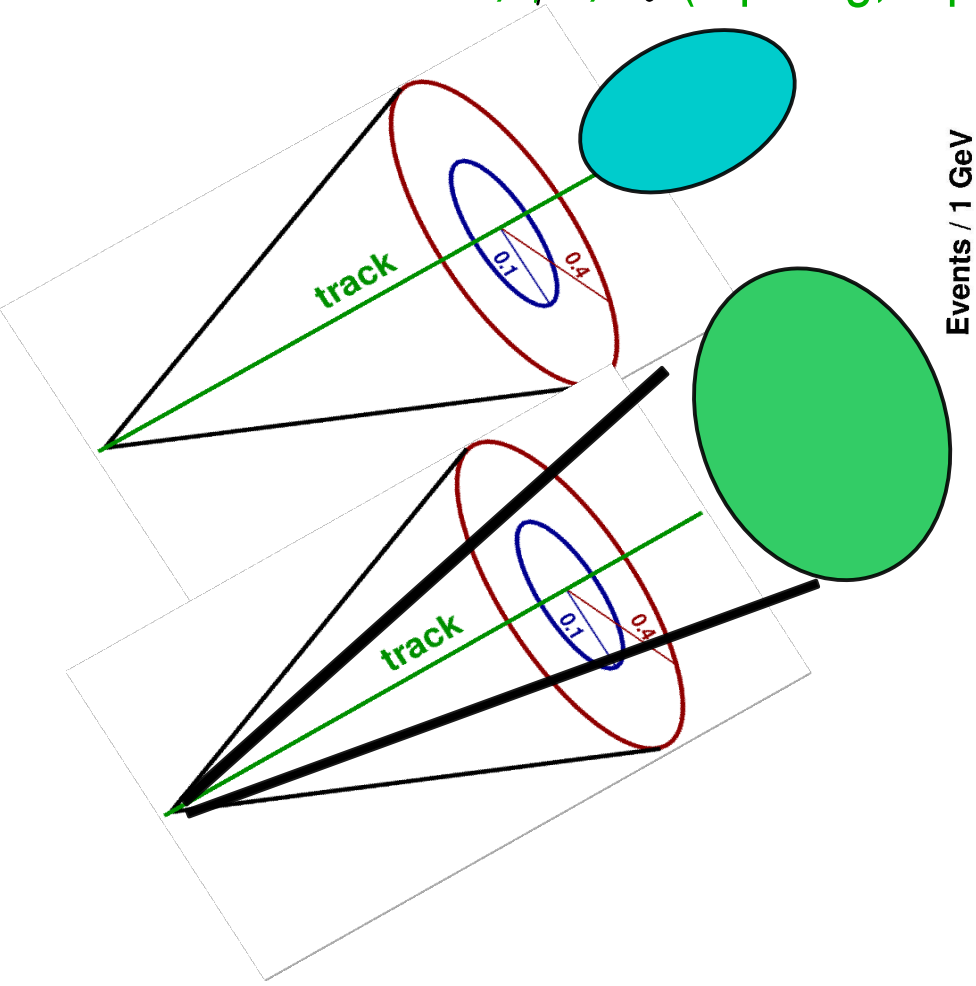
- large MET caused by poorly measured electron energy will be in the same direction as the lepton => small values of MT.
- MT=√2MET* pT * (1-cos(Δφ(MET, Pt))

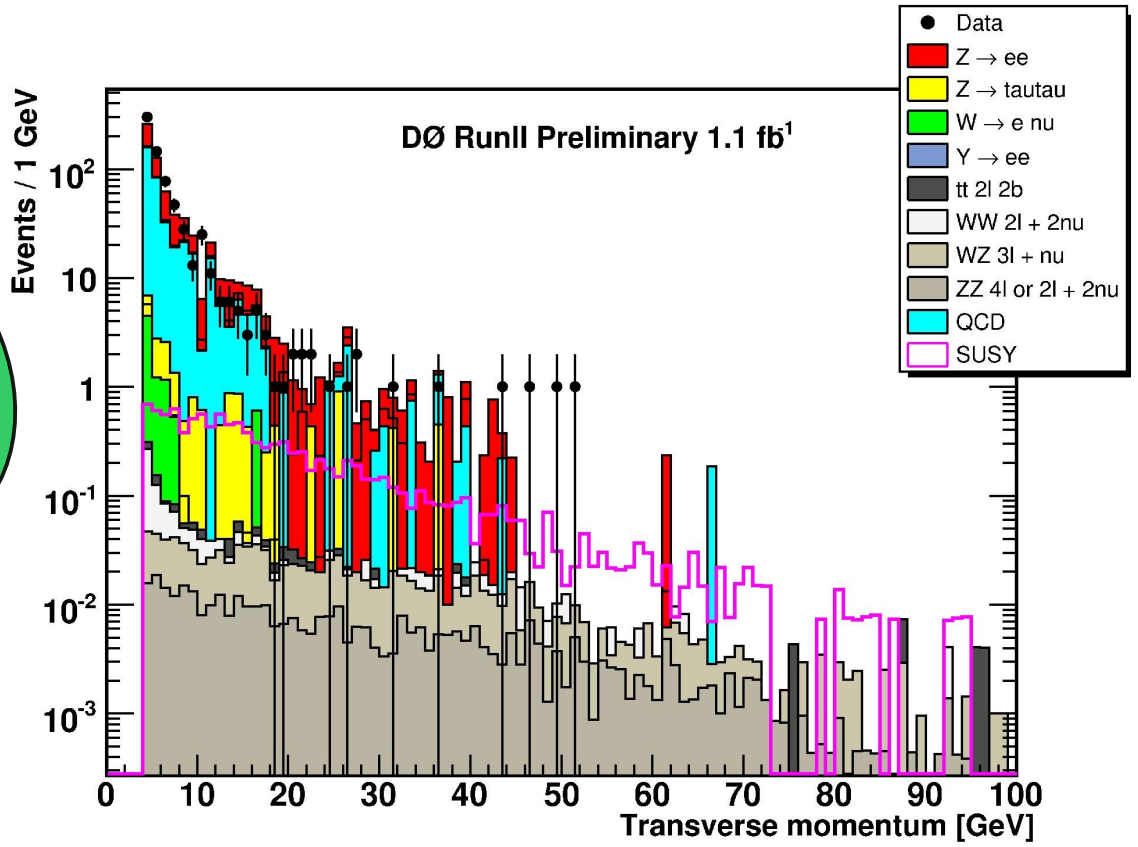
MT > 20 GeV



3rd LEPTON

- To increase efficiency, a track is required instead of lepton.
- Isolation in tracker and calorimeter is required to reject background from jets.
  - ∑pT of other reconstructed tracks in a hollow cone around track < 1 GeV
  - efficient for e, μ , τ (1 prong, 3 prong)





CUT FLOW ee+track

Cut	Data	SM Expected	MSUGRA example
Preselection	118518	113592±119	18
Anti-Z	17459	18306±89	13
Third track	776	650±18	7.6
MET	2	1.97±0.73	4.64
MET x PT(3.track)	0	0.76±0.67	3.45

47% Z- > ττ
7% ttbar
31% WZ
9% WW
6% ZZ

- Signal efficiency 2.6% relative to lepton events with all flavour combinations

- Error dominated by statistical uncertainty

LS μ: BACKGROUNDS and CUTS

Important Standard Model background:

-multijet from QCD processes (b-bbar)

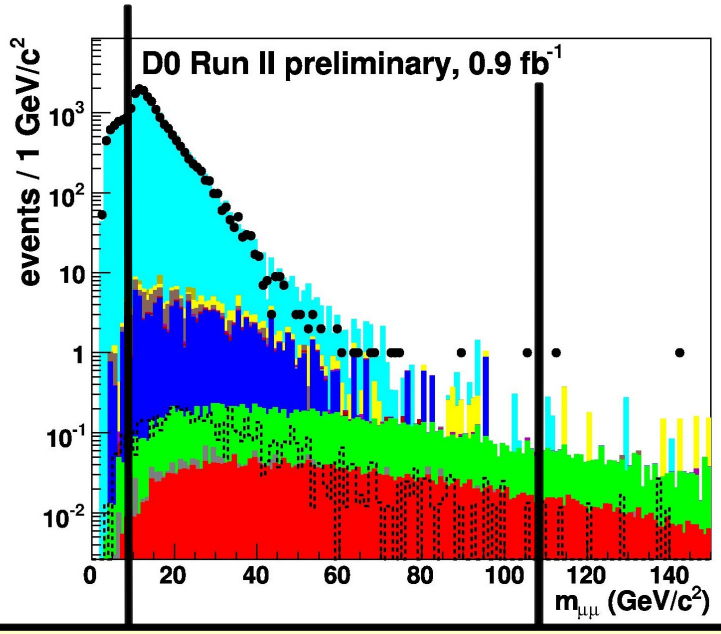
-Z/γ +γ/jet -> ll+γ/jet, W+γ/jet -> lν+γ/jet, tt->ll+jets

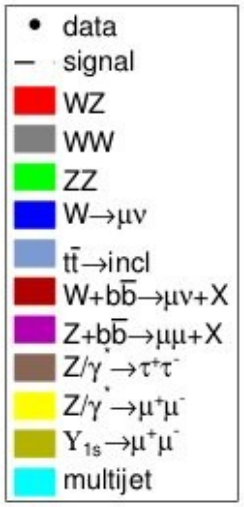
-WZ->lνll, ZZ->llXX, WW->ll$\nu\nu$

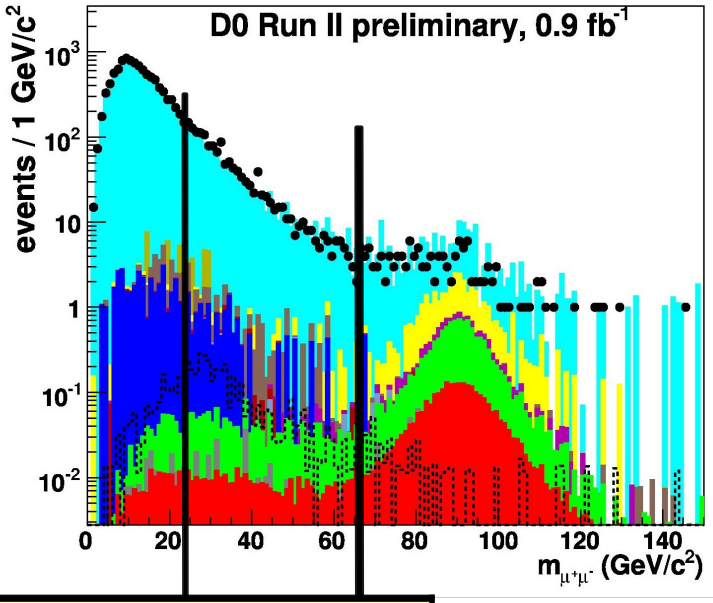
- **Preselection:** Muon ID, two isolated LS μ, $P_T > 5$ GeV, $\Delta\varphi(\mu,\mu)<2.9$
- **Anti-QCD:** $P_T(\mu 1) > 13$ GeV, 35 GeV $> P_T(\mu 2) > 8$ GeV
- **Anti-WZ:** 25 GeV $< M(\mu,\mu)_{OS} < 65$ GeV if OS
- **Anti-Z:** 12 GeV $< M(\mu,\mu)_{LS} < 110$ GeV
- **Large MET:** MET > 10 GeV, 65 GeV$>$Transv. mass (μ2,MET)>15 GeV, MET $> 12 \times \sigma$(jet||MET)
- **MET x $P_T(\mu 2)$:** > 160 GeV^2

Last 5 cuts used in optimization for best σ X Br

LIKESIGN MUON





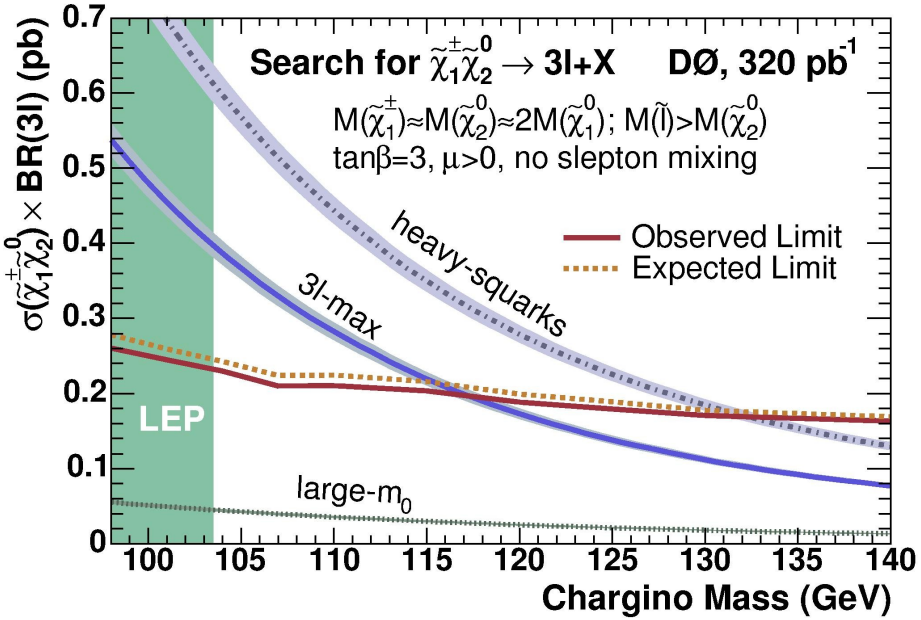


Cut	Data	SM Expected	MSUGRA example
Preselection	15234	14922±981	8.4±0.6
Minv OS	3569	3479±232	7.6±0.6
Minv LS	2	2.9±0.8	5.7±0.5
MET	1	1.7±0.6	4.6±0.4
MET x PT(μ2)	1	1.1±0.4	4.0±0.4

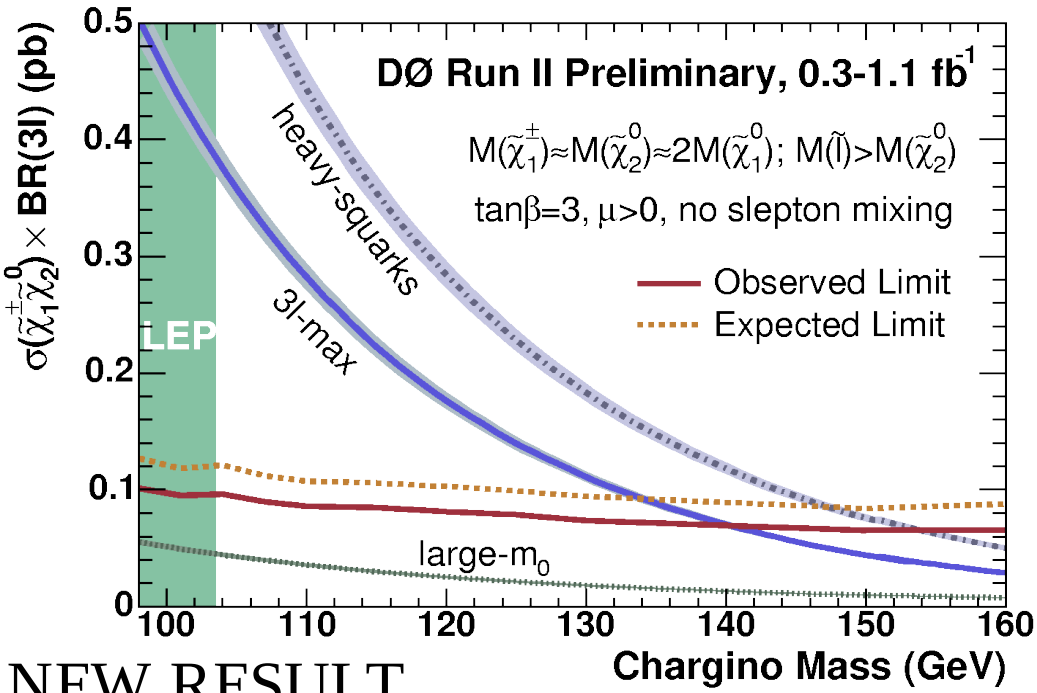
17% QCD
20% W
17% WZ
9% WW
15% ZZ
15% Zbb

LIMITS

- Combination of ee+l and LS muon with older D0 mu mu and e mu:
  - upper limit σ x BR(3l) (modified freq., overlap subtracted from weakest analysis)
- Chargino mass limit of 140 GeV in scenario with enhanced BR into leptons:
  - (3l-max, m(slepton) > m(neu2))



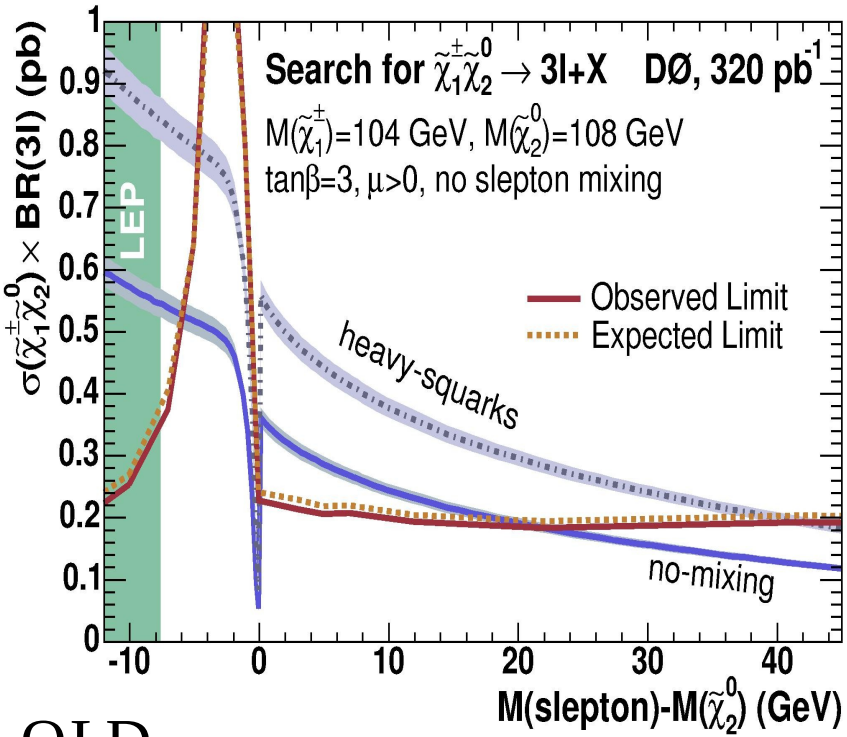
OLD RESULT



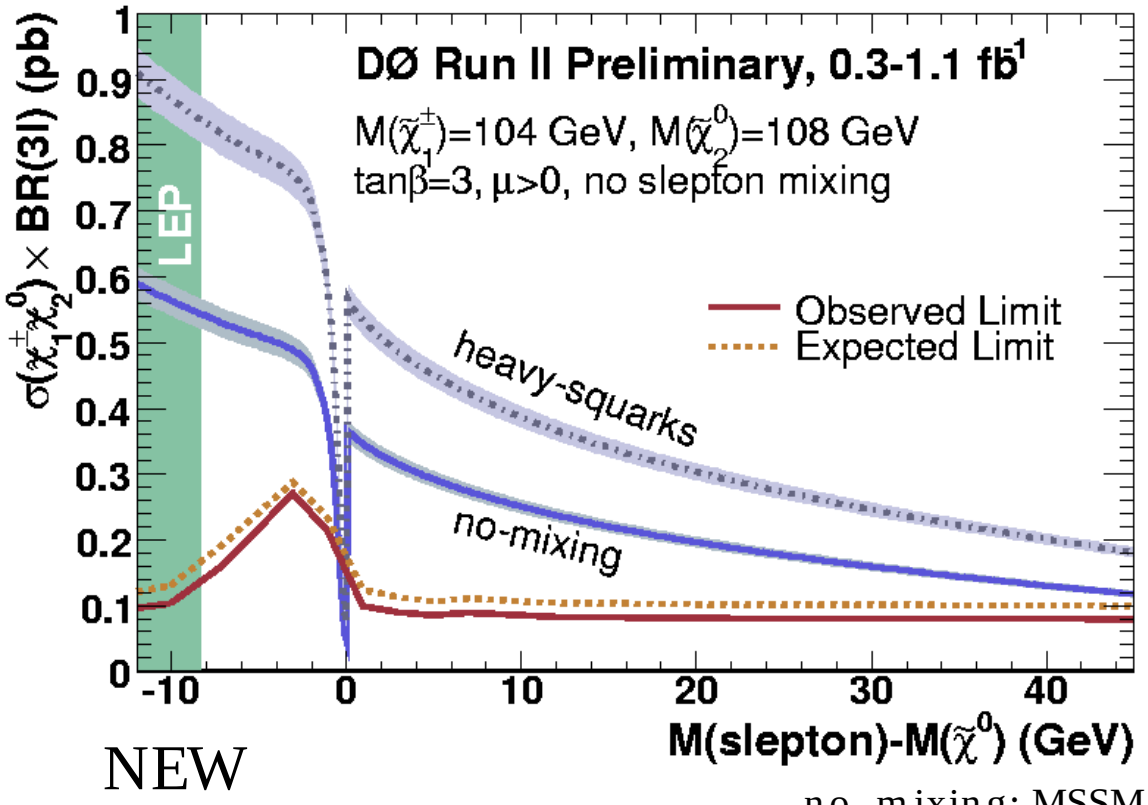
NEW RESULT

- large m0: W/Z exchange dominates (small Br(3l))
- heavy-squarks: maximal cross section, t-channel contribution from squarks relaxing scalar mass unification

LIMITS II



OLD

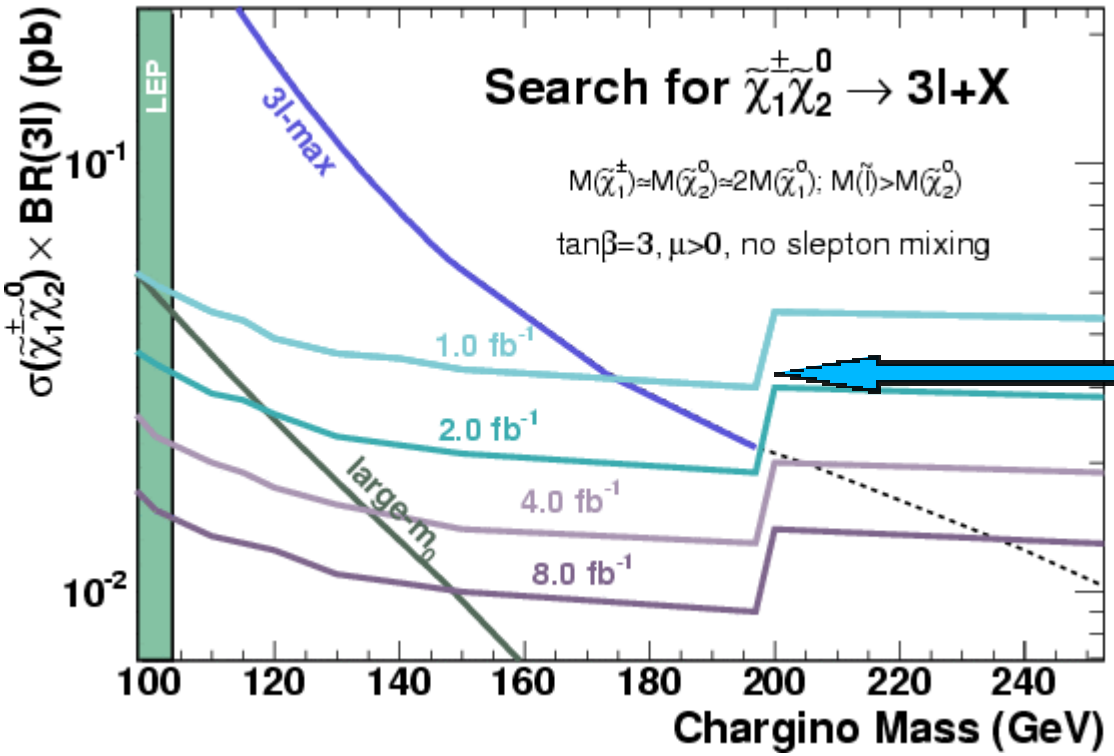


NEW

no-mixing: MSSM

- Light sleptons => two body decays into letpons and LSP => soft lepton
- Significant improvement
- Limit stable as a function of mass

CONCLUSION and OUTLOOK



starting to probe difficult region of phase space with more luminosity

-NO SUSY OBSERVED => LIMIT SET

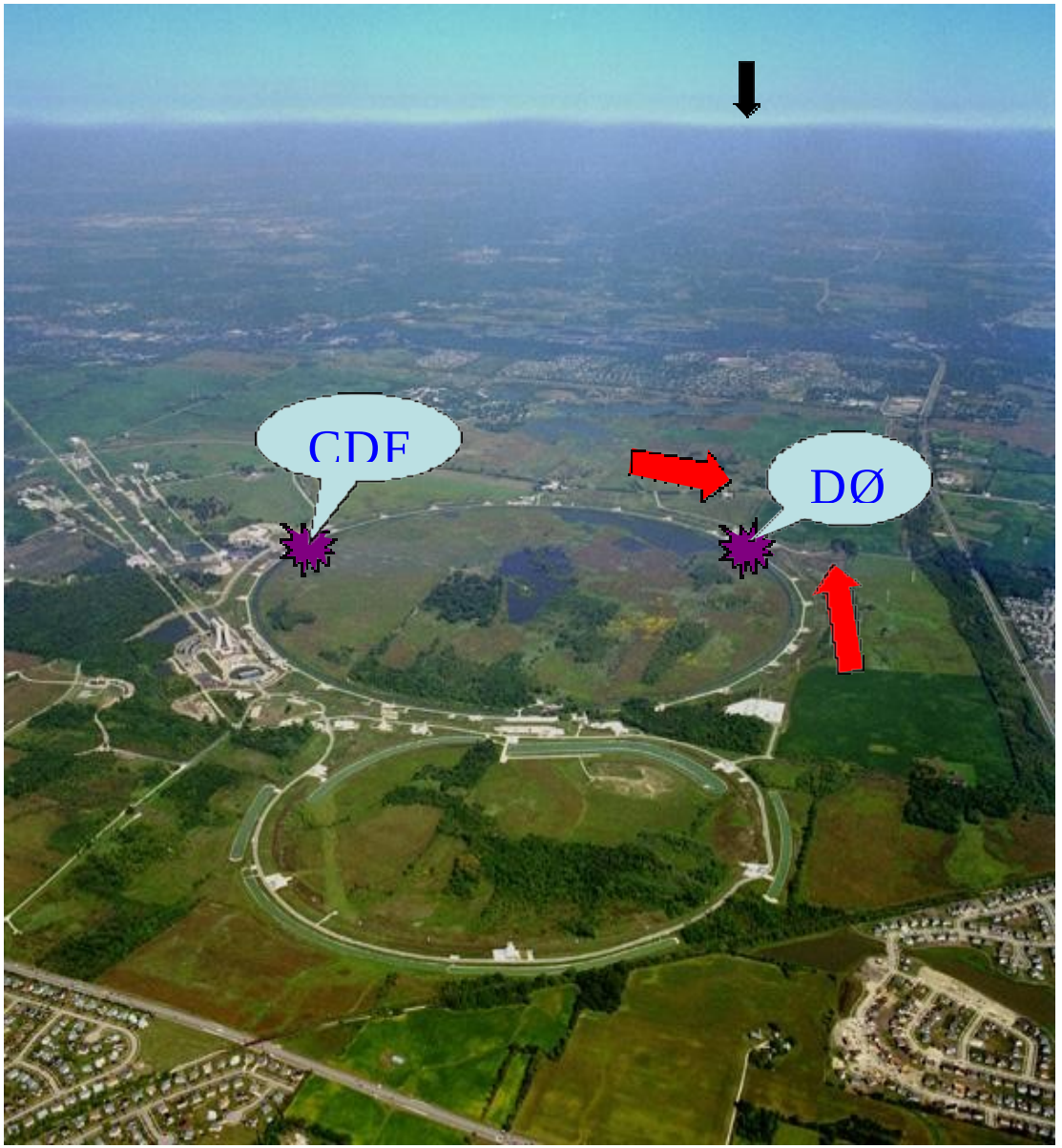
-Combine ee+track and Like Sign muon with mumu+track and e+mu+track

- ROOM FOR IMPROVEMENTS

BACK UP

TEVATRON and D0

- Fermilab, Batavia, IL
- 1 km radius
- 2 experiments:
  CDF and DØ
- Run I (1992-1995)
  $\sqrt{s}$ = 1.8 TeV
  $\int$ Ldt = 125 pb^{-1}
- Run II (since 2002)
  $\sqrt{s}$ = 1.96 TeV
  $\int$ Ldt = 1.5 fb^{-1} recorded so far
- Run II b just started -> upgrade of D0 and accelerator

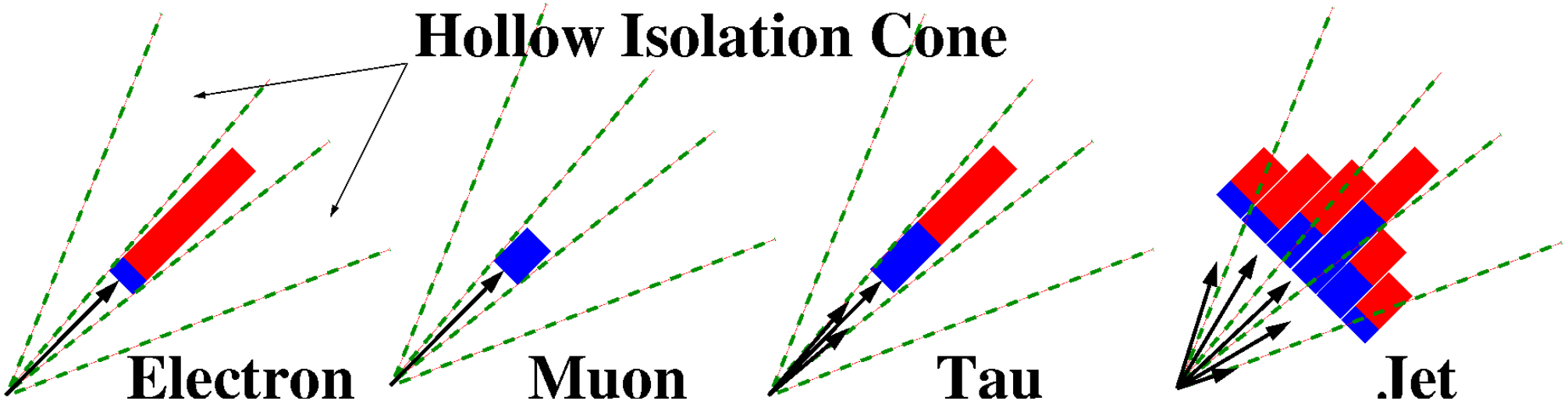


OVERVIEW OVER CUTS ee+track

- **Preselection:** Electron-identification, 2 electrons with P_T > 12 GeV+8 GeV
- **Anti-Z/DrellYan->ll:** M(Y) << M(e,e) << M(Z), $\Delta\phi$ (e,e) < 2.9
- **Anti Top:** Sum Jet-P_T < 80 GeV
- **Well identified third track,** P_T > 4 GeV, isolation in tracker and calorimeter
- **Large MET:** MET > 22 GeV, Transv. mass (e,MET)>20 GeV, MET > 8 xσ(jet||MET)
- 2-D cut: MET x P_T(3. track) > 220 GeV^2

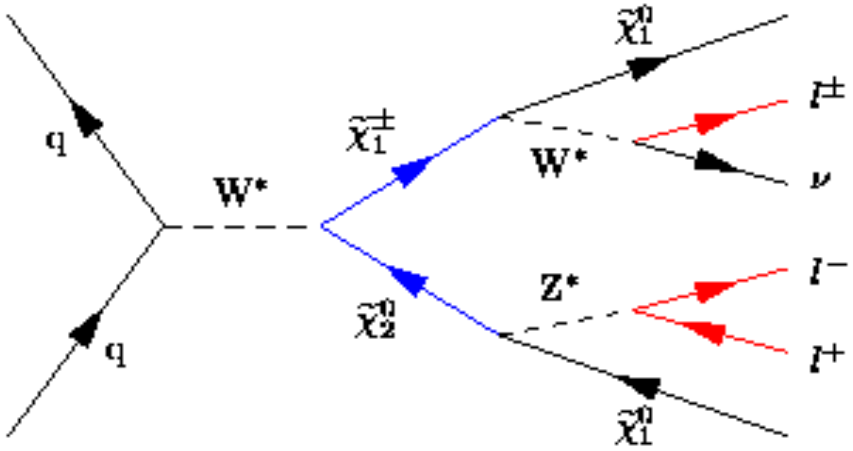
3rd LEPTON -> isolation

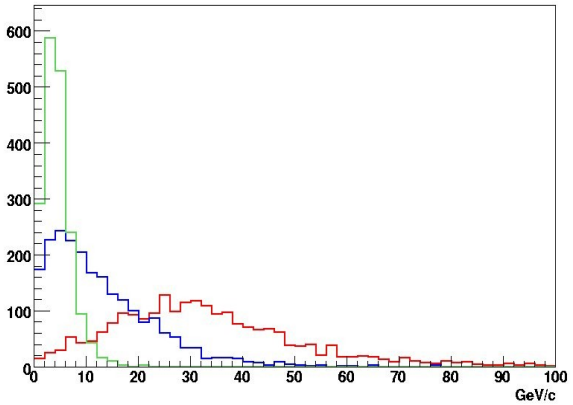
- efficient for e, μ , τ (1 prong, 3 prong):



LIKESIGN μ

- Large slepton masses -> decay via W/Z dominates
- m(slepton) < m(neu2): two body decays of neu2 -> slepton + lepton
  - => very soft third lepton





Instead of requiring two leptons + track

- =>require two leptons of same sign

- Two QCD samples:
  - one tight and one loose muon (sample S)
  - one tight and one that fails loose cuts (sample Q)
- Re-weight sample Q as a function of transverse momentum in a QCD enriched region of phase space ($\Delta\phi$ >2.9).

OPTIMIZATION OF CUTS

- Optimaztion of cuts performed to obtain a best expected limit on σ x BR(3l)
  - SUSY point with very soft third lepton used in the optimization