Disclaimer

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D∅ NOTE
2084

La Thuile 94'
Lee Lueking
Fermilab
Batavia, Il USA

New Particle and SUSY Searches (CDF & D0)

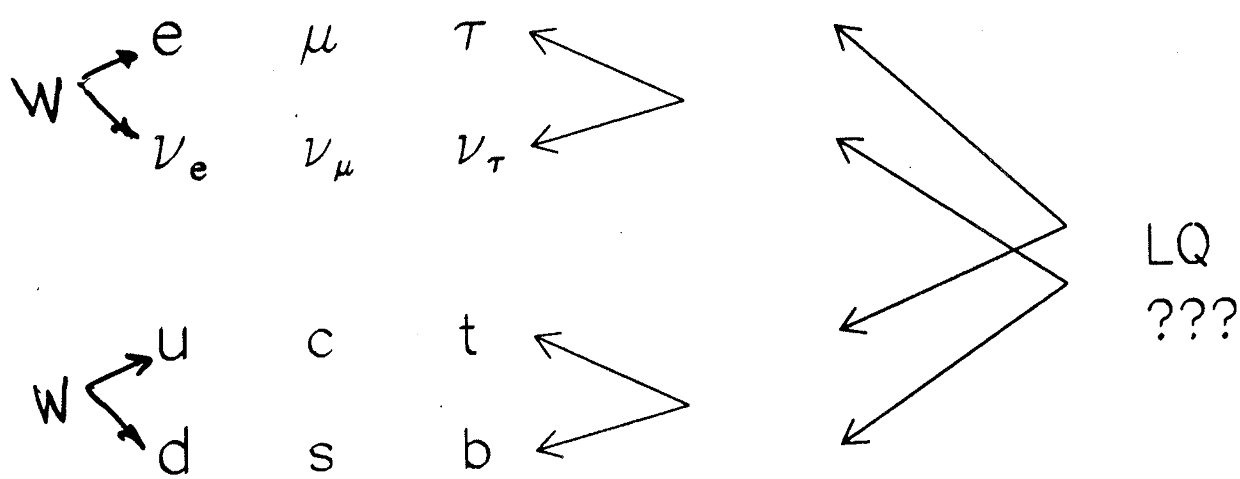
- Lepto Quarks
- Excited Quark States
- SUSY Wino, Zino

+ $\tilde{\tau}_s$ from Opal

LEPTOQUARKS

Search for 1st Gen. Leptoquarks

In SM, leptons, quarks → related



LQs appear naturally in SM extensions

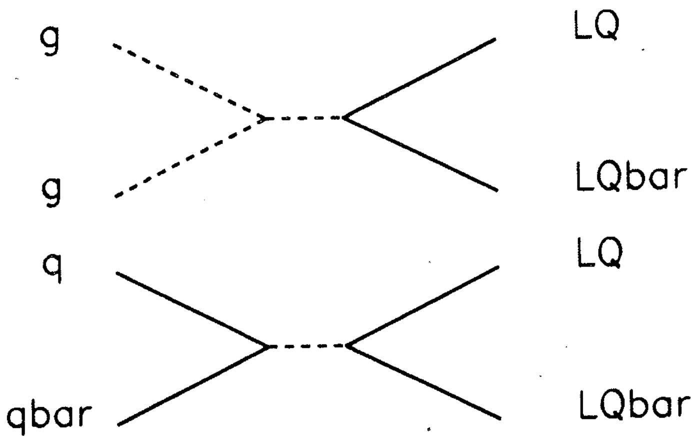
- composite models
- Large Gauge Group extensions

Current Mass Limits (published)

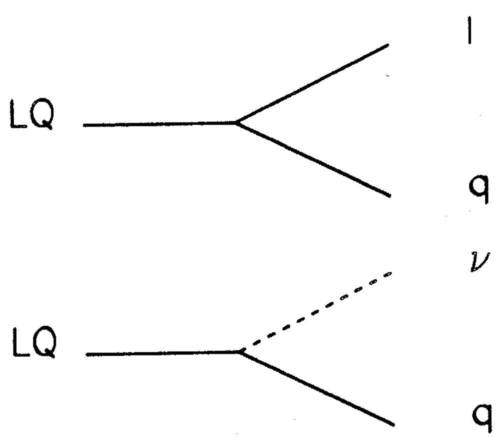
e^+e^- – LEP	45 GeV
p pbar – (CDF)	113 GeV β=1. 80 GeV β=0.5
e p – HERA	180 GeV (assuming EW coupling)
PPbar – (DØ)	133 GeV β=1 120 GeV β=.5

Leptoquark Signal

Production – p pbar collisions



Decays



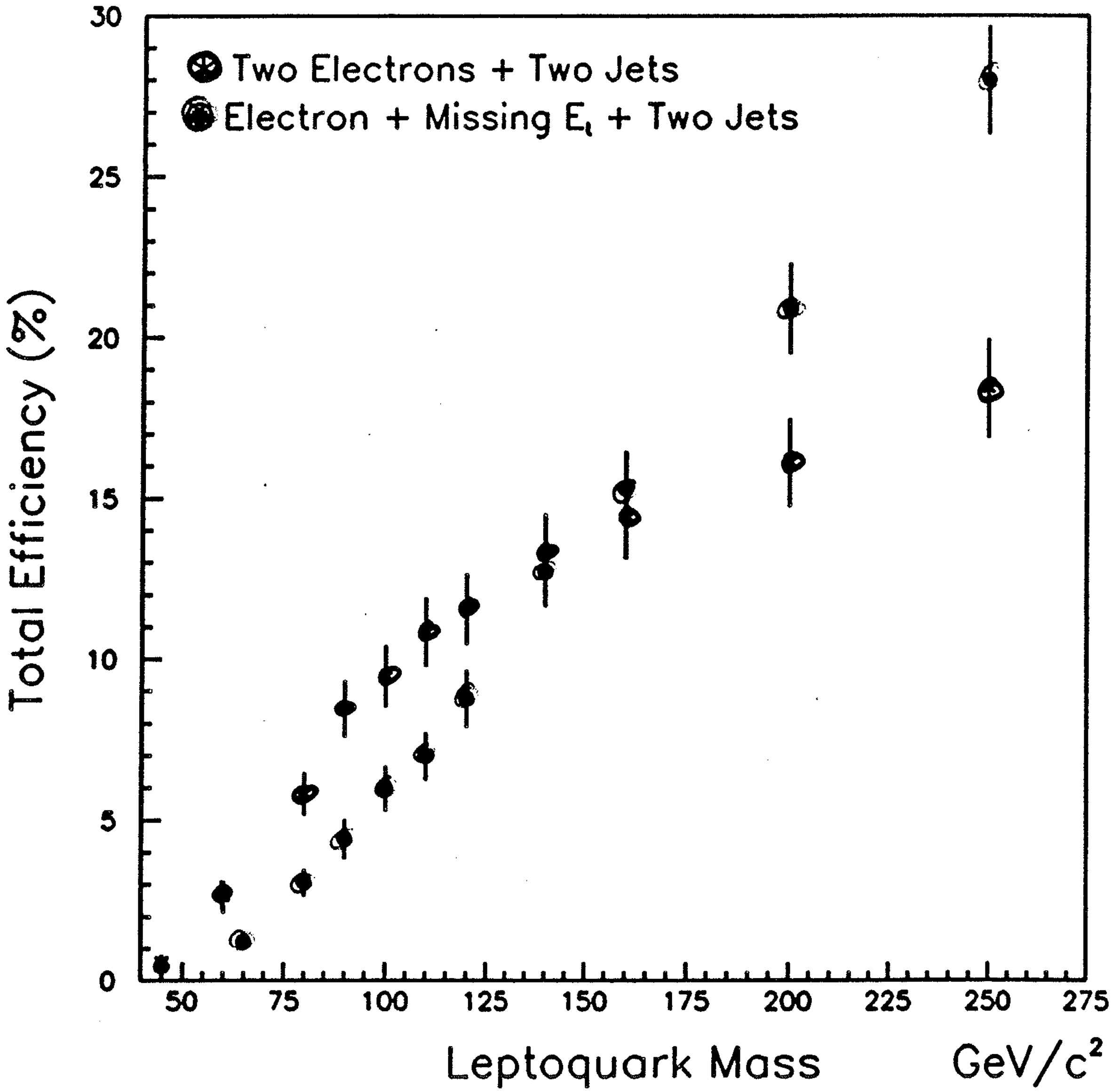
BF = β

BF = $1 - \beta$

Lepto-
Quark

DØ

LQ efficiency

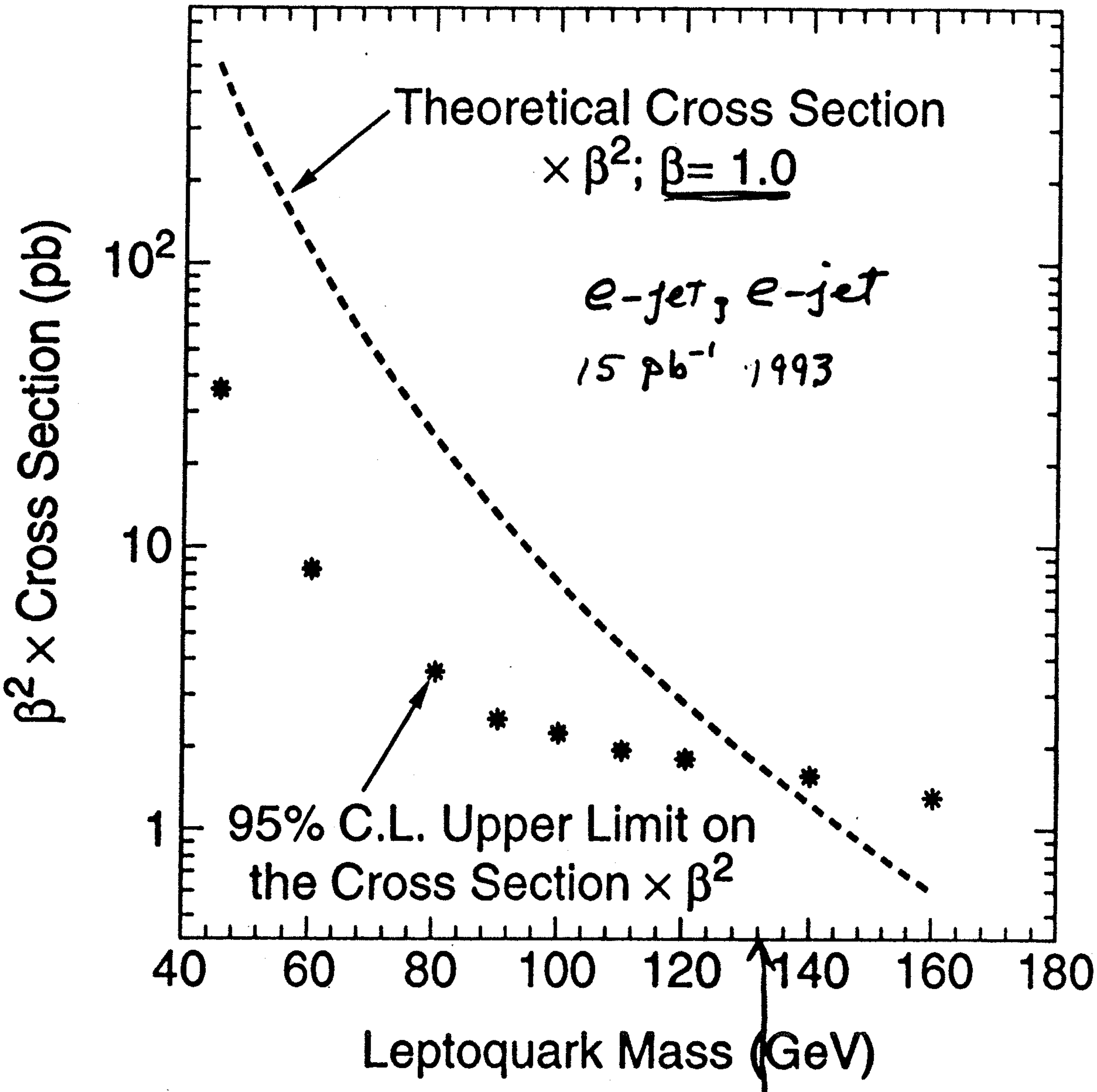


Lepto
Quark

D0

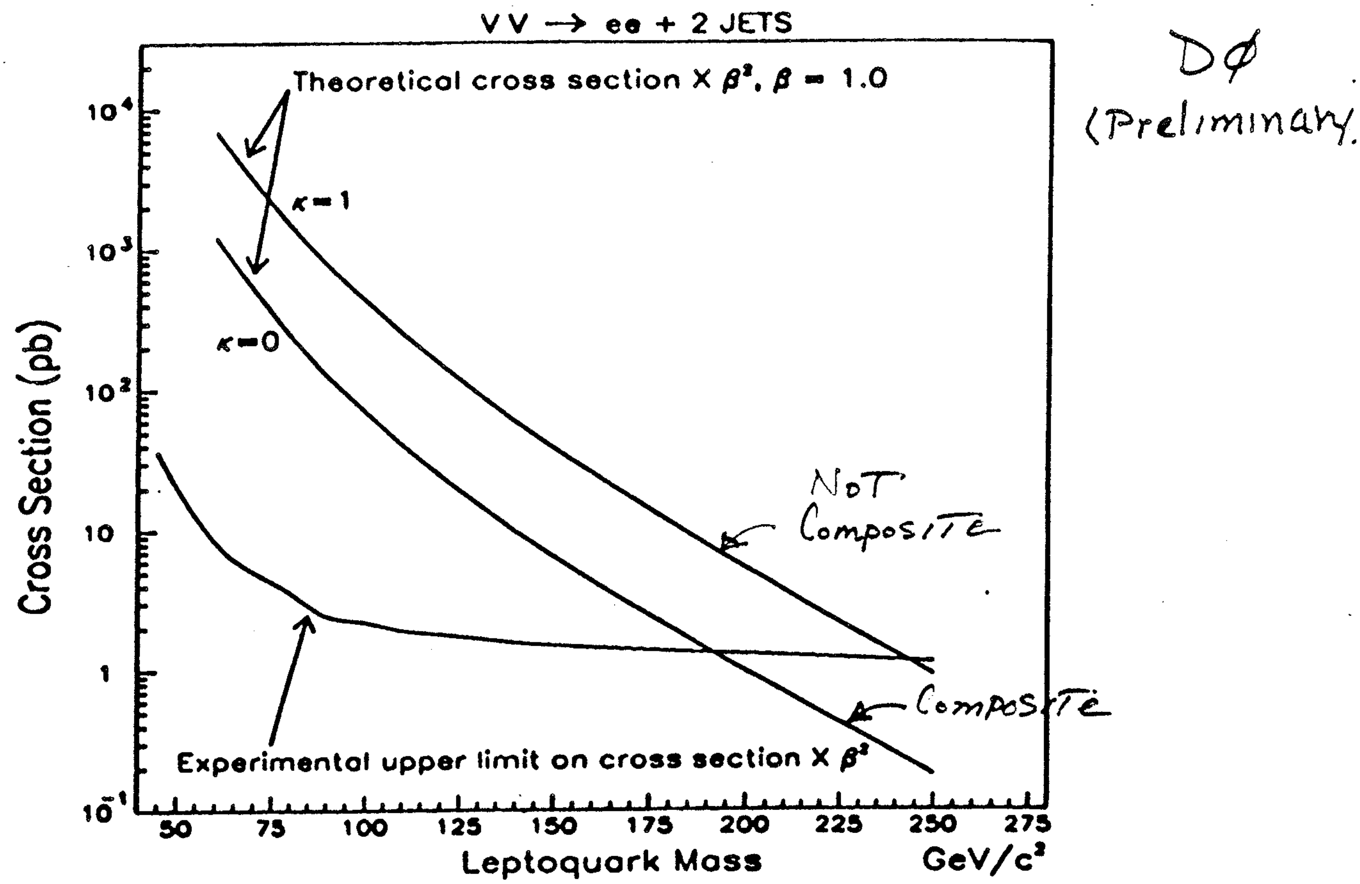
DØ

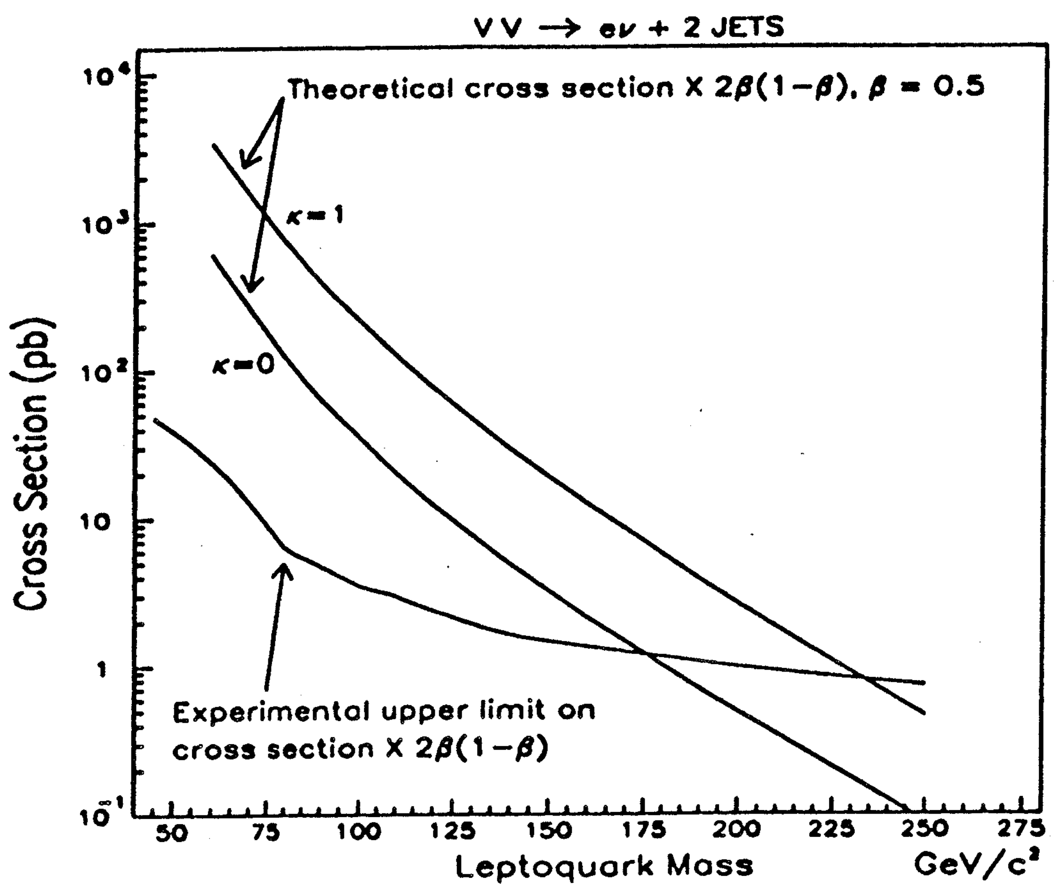
ISAJET 7.?
+ MT-LO



133 GeV/c^2
β = 1

(ALSO e-jet, ν-jet)
15 pb^{-1} 1993



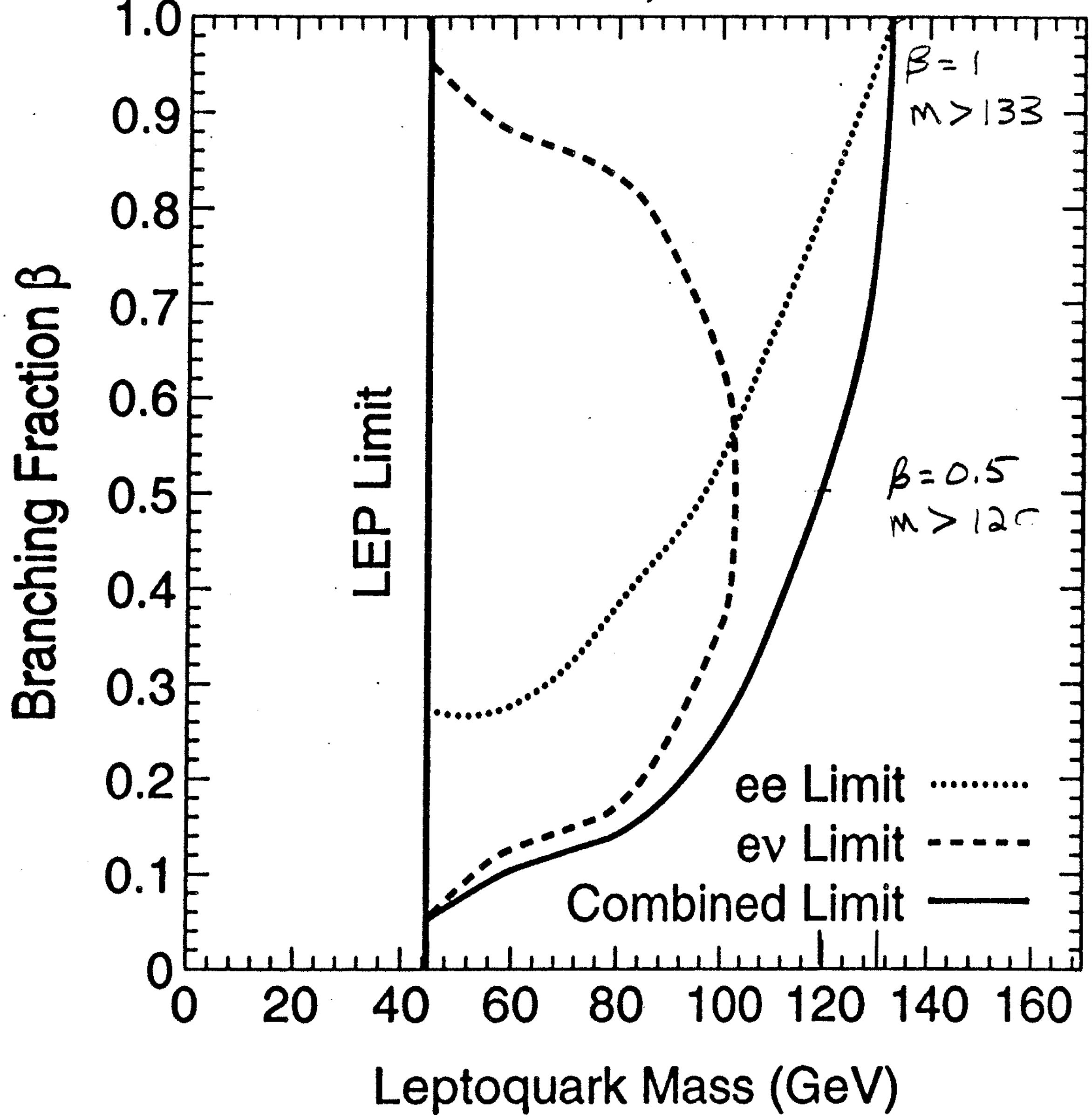


Recent results by Hewett, Rinno, Pakvasa, Harber, Pomarol.
ANL-HEP-CP-93-52

Lepto-
quark
scalar

DØ

scalar Leptoquark

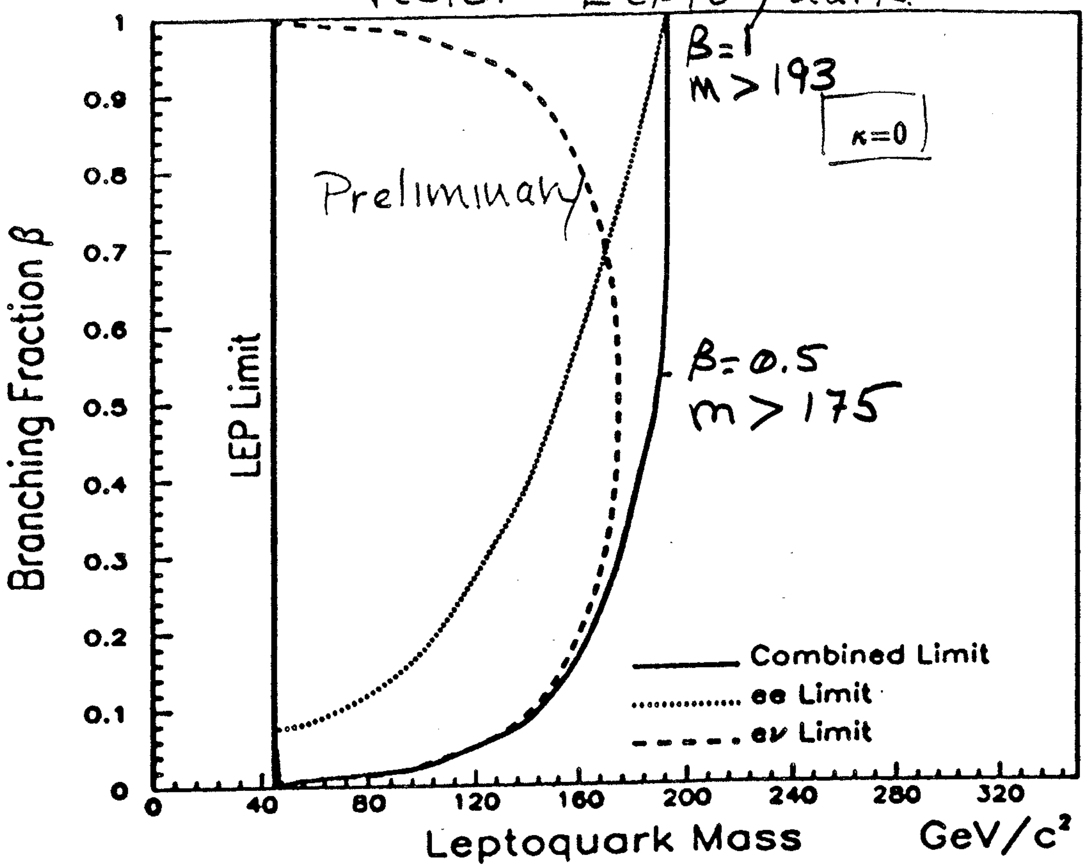


Fermilab-Pub-93/340-E
Phys. Rev. Lett.

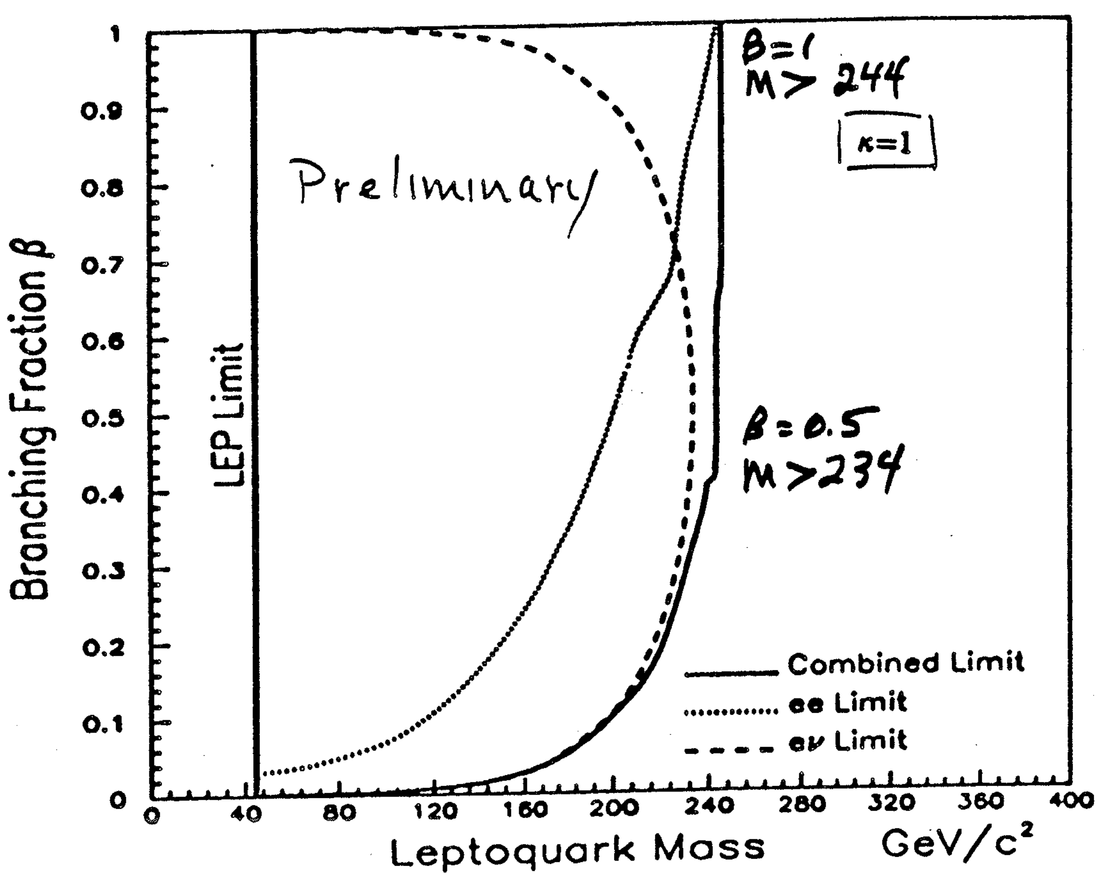
Lepto- Quark Vector

Vector Leptoquark

DØ



Note: This Assumes The <u>SAME</u> detection efficienies as Scalar analysis.



CDF e-JET, e-JET

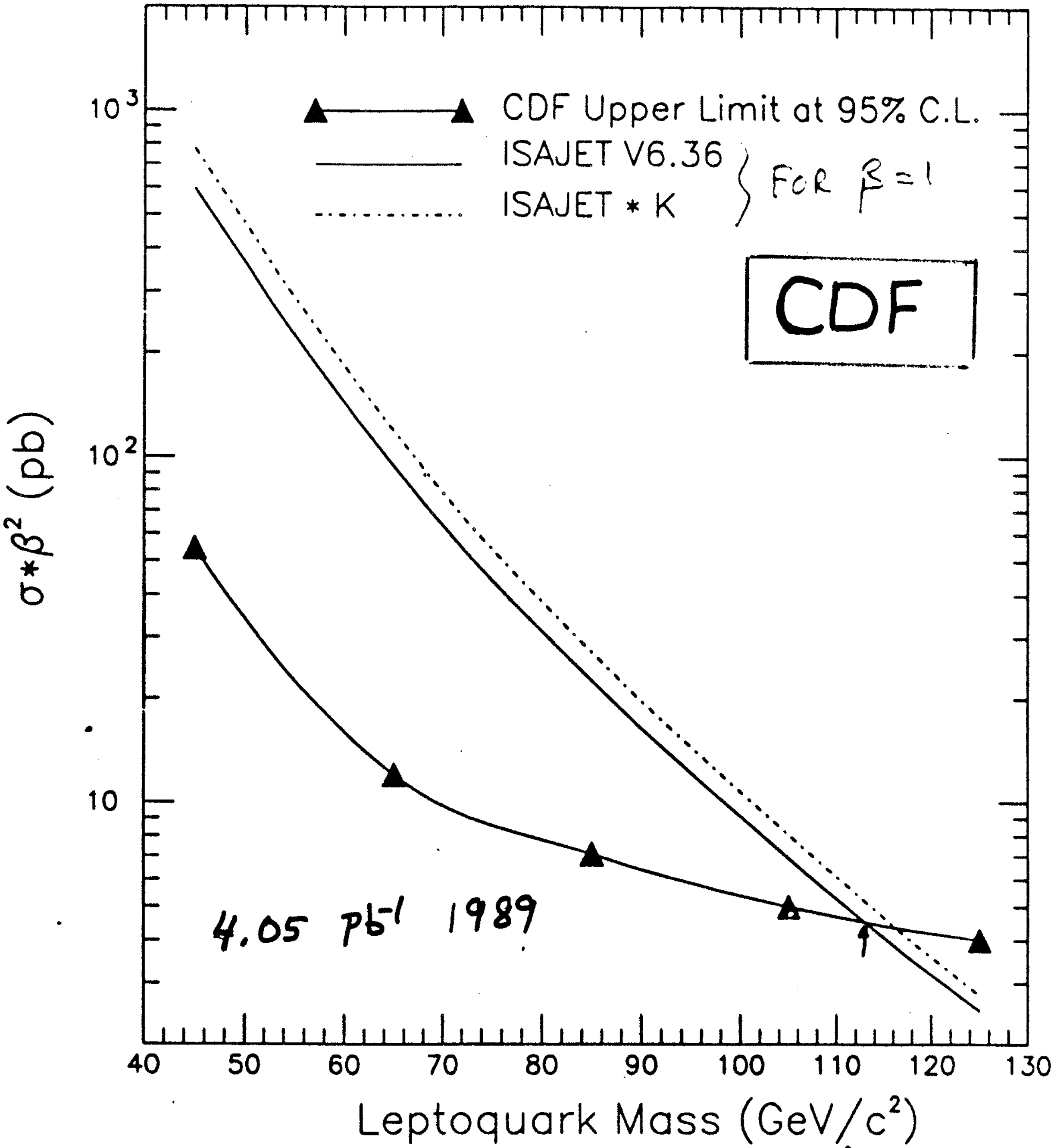


Figure 2

113
For $\beta=1$

$$\sigma \beta^2 \,(95\%\, CL) < \frac{N_{95}}{\mathcal{L} \times Acc.}$$

CDF LIMITS ON β as f(M LQ.

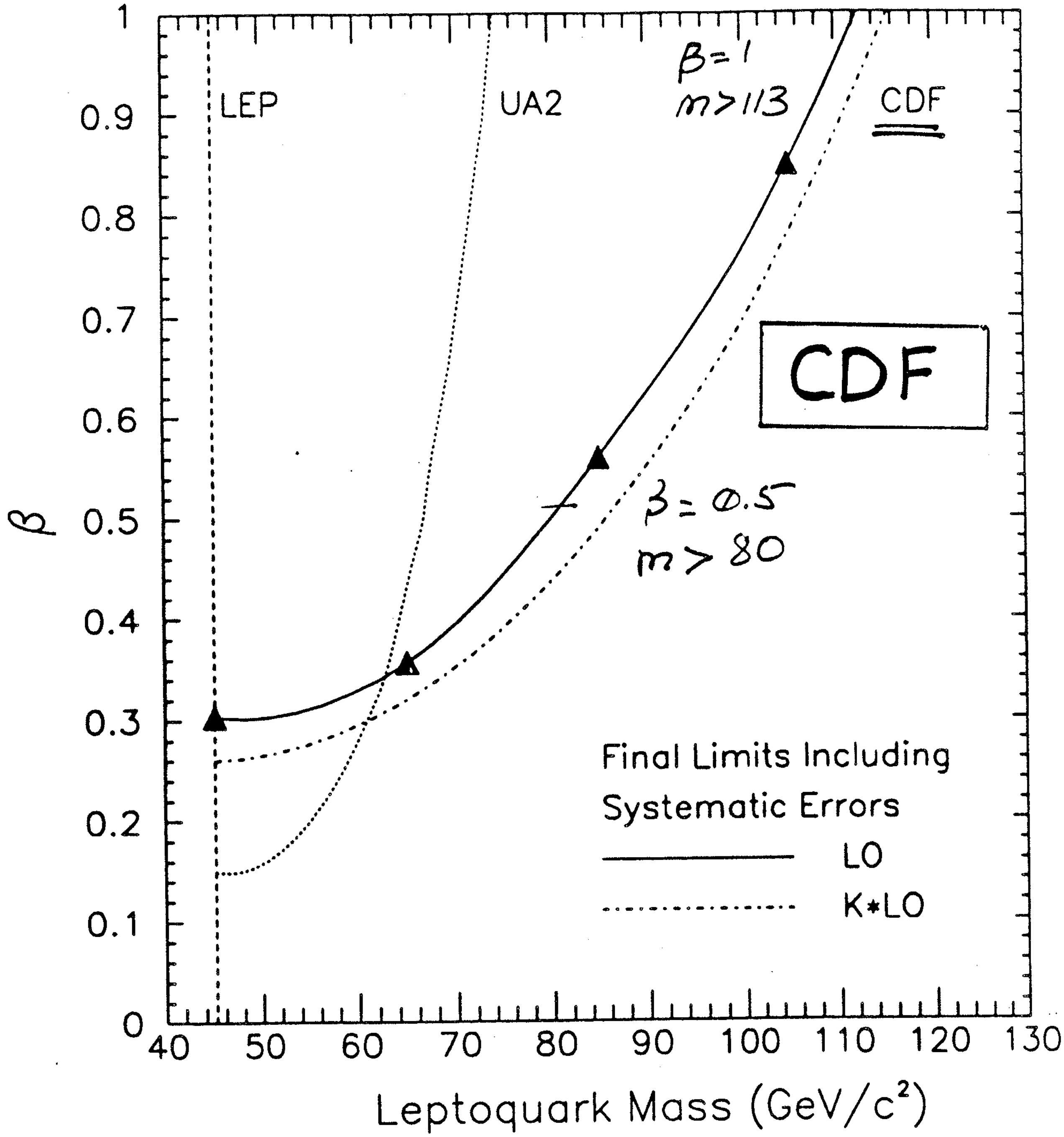


Figure 3

$$\beta^2(95\%\ CL) < \frac{N(95\%\ CL)}{N(MC,\ \beta = 100\%)}$$

Excited Quarks

R. HARRIS
R. KEPHART } CDF

CDF

Excited Quark Theory

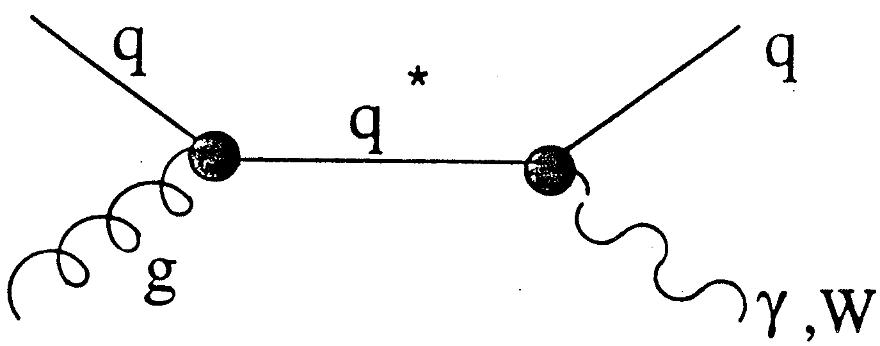
- We compare our data to a model proposed by Baur, Hinchliffe, and Zeppenfeld (**Int. J. Mod. Phys. A2(1987)1285.**)
- Spin 1/2, isospin 1/2, u* and d* are degenerate in mass.
- Lagrangian for $q^* \leftrightarrow q + (\gamma, g, W, Z)$ is of magnetic moment type:

$$L = \frac{1}{2M^*} \bar{q}_R^* \sigma^{\mu\nu} [g_s f_s \frac{\lambda^a}{2} G_{\mu\nu}^a + g f \frac{\tau}{2} W_{\mu\nu} + g' f' \frac{Y}{2} B_{\mu\nu}] q_L$$

where $f_s = f = f' = 1$ times a form factor is assumed.
unknown couplings determined by Preon dynamics

Decay Mode	Br. Ratio (%)	Decay Mode	Br. Ratio (%)
$u^* \to ug$	83.4	$d^* \to dg$	83.4
$u^* \to u\gamma$	2.2	$d^* \to d\gamma$	0.5
$u^* \to dW$	11 (e,μ 2.4)	$d^* \to uW$	11 (e,μ 2.4)
$u^* \to uZ$	3.5 (ee .12)	$d^* \to dZ$	5.1 (ee .18)

- We search for $qg \to q^* \to q\gamma$ and $qg \to q^* \to qW$ in CDF data.



- Breit-Wigner resonance with width $\Gamma = 0.04\, f^2 M^*$ $(f_s = f = f' = 1)$.

PREVIOUS q^* RESULTS.

- Published limits on q* mass are low:
  - Aleph: $e^+e^- \rightarrow q^* \bar{q}^*$ excludes $M^* < 45$ GeV @ 95% CL.
  - Aleph: $e^+e^- \rightarrow q^* \bar{q}$ excludes $M^* < 88$ GeV @ 95% CL.
  - UA1: $p\bar{p} \rightarrow q^* \rightarrow qW$ sets limit $\sigma(q^* \rightarrow qW)/\sigma(W) < .019$ for $M^* > 220$ GeV @ 90% CL, but doesn't state a mass limit.
  - UA2: $p\bar{p} \rightarrow q^* \rightarrow qg$ excludes $140 < M^* < 288$ GeV @ 90% CL in a recent preprint (CERN-PPE/93-66, April 1993).

γ + JET

CDF

Excited Quark γ+Jet

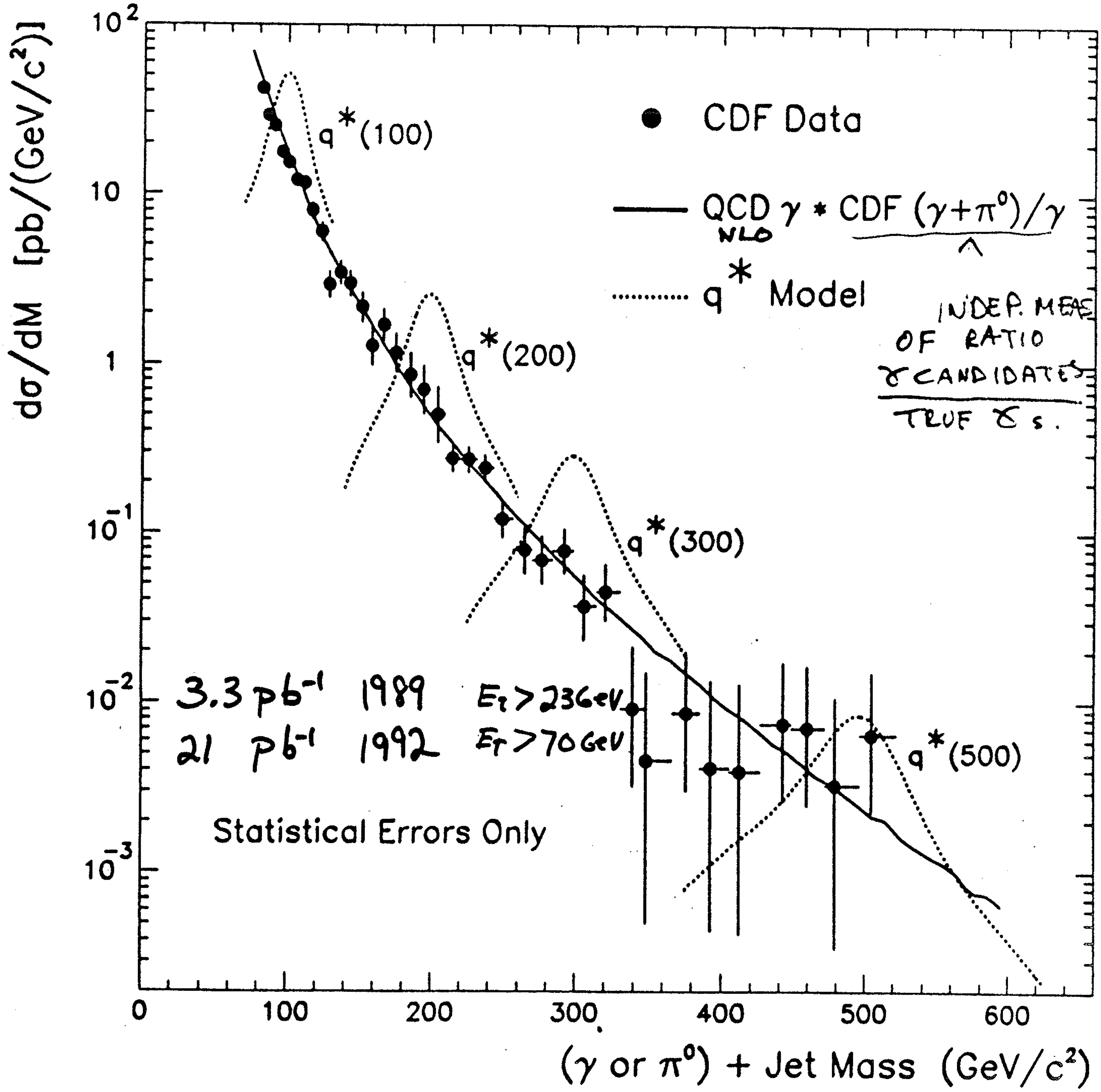


Figure 1: The photon candidate + leading jet invariant mass distribution (points) compared to an estimate of the QCD background (solid curve) and excited quark signal at four different q^* mass values (dotted curves). Corrected for acceptance and efficiency except for the cuts $|\eta_\gamma| < 0.9$ and $|\cos\theta^*| < 2/3$.

W + JET CDF

CDF

Excited Quark W+JeT

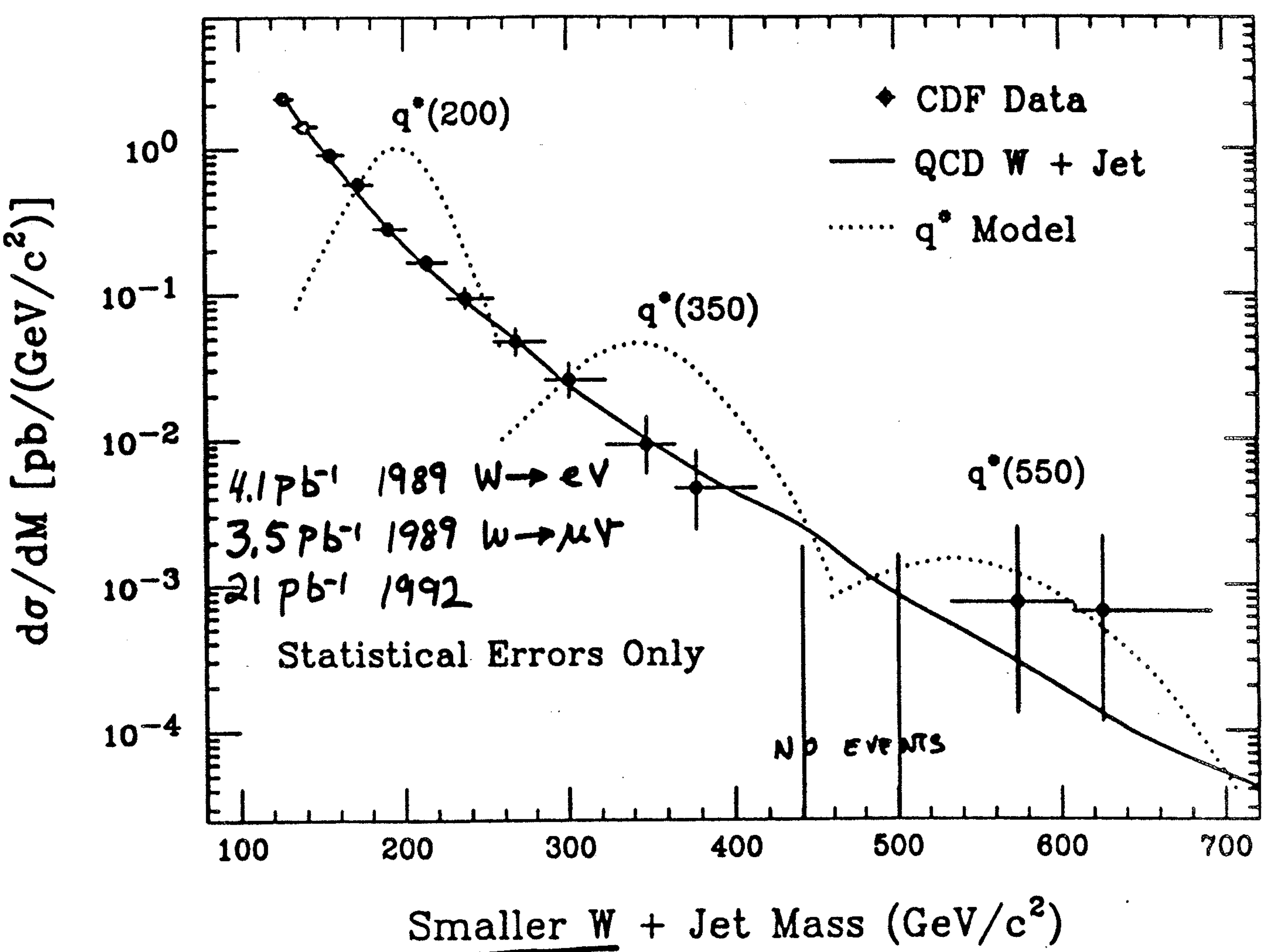
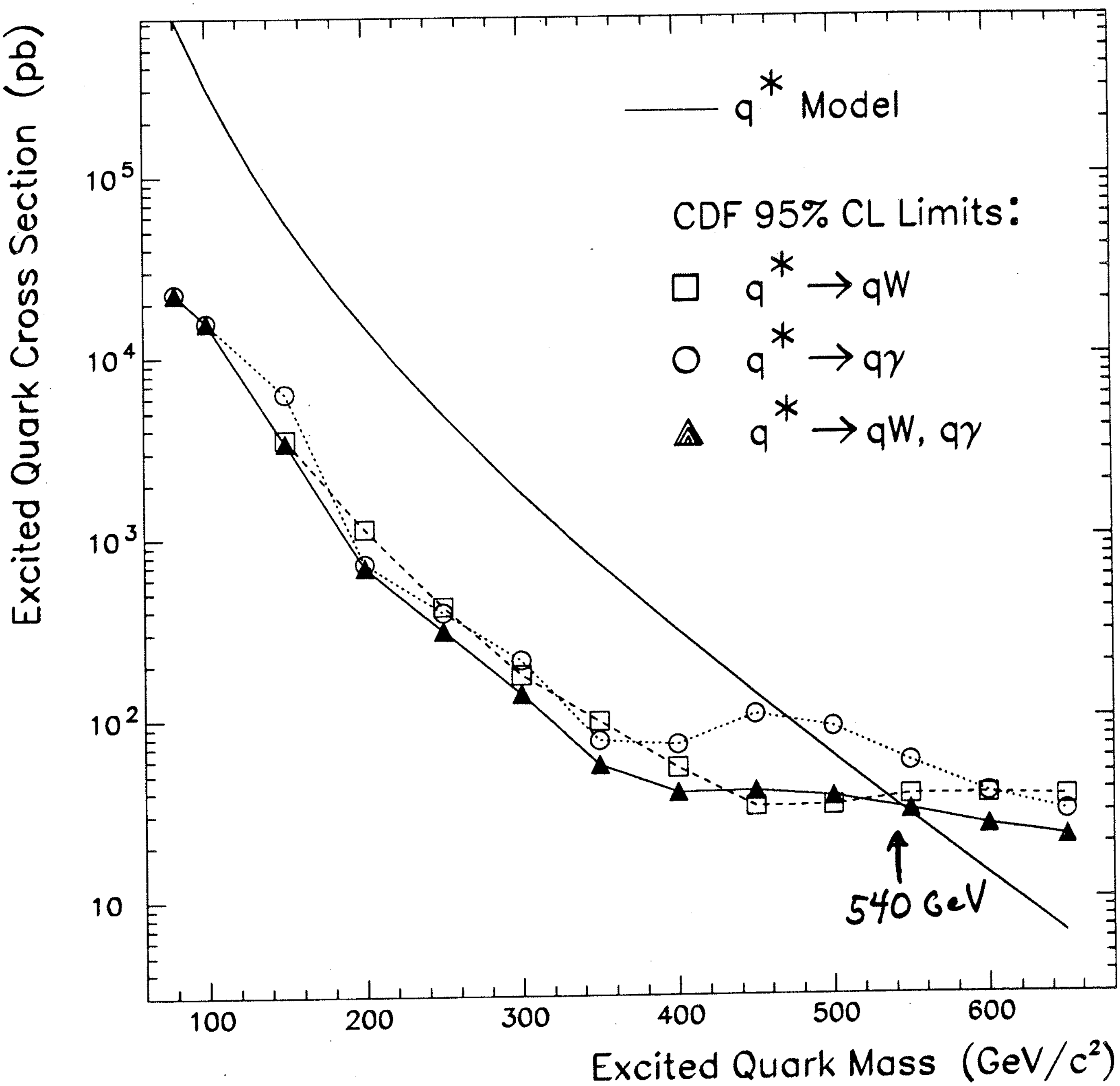


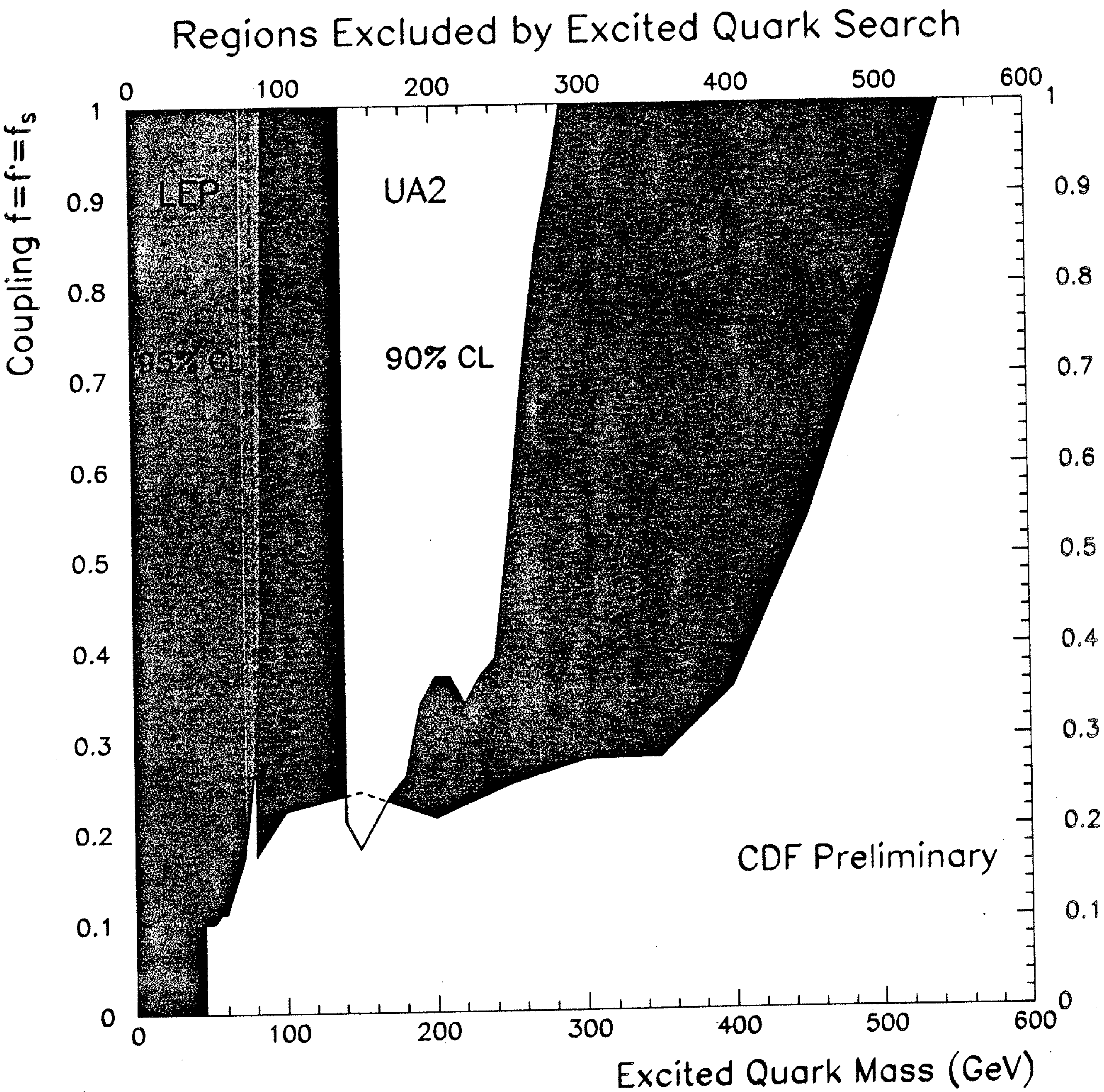
Figure 2: The distribution of the smaller of the two solutions for the W + leading jet invariant mass (points) compared to a Monte Carlo of the QCD background (solid curve) and excited quark signal at three different q^* mass values (dotted curves). Not corrected for acceptance and detector efficiency.

Excited Quark γ+Jet W+Jet

CDF



CDF



Regions Excluded by Excited Quark Search
LEP
95% CL
UA2
90% CL
CDF Preliminary
Coupling f=f'=f_s
Excited Quark Mass (GeV)
0
100
200
300
400
500
600
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Super Symmetry

Wino, Zino Search

- **Nomenclature:**

  Wino – $\tilde{W}_1^{\pm}$, $\tilde{\chi}_1^{\pm}$, (Charge–ino)
  Zino – $\tilde{Z}_2^{0}$, $\tilde{\chi}_2^{0}$, (Neutral–ino)
  LSP – $\tilde{Z}_1^{0}$, Lightest SUSY Particle

- **$\tilde{W}_1^{\pm}$ and $\tilde{Z}_2^{0}$ are mass eigenstates in the mixing of ($\tilde{W}^{\pm}$, $\tilde{H}^{\pm}$) with ($\tilde{B}$, $\tilde{W}^3$, $\tilde{H}_1^0$, $\tilde{H}_2^0$)**

- **Production and decay are based on <u>Minimal SUSY Standard Model</u> (MSSM).**

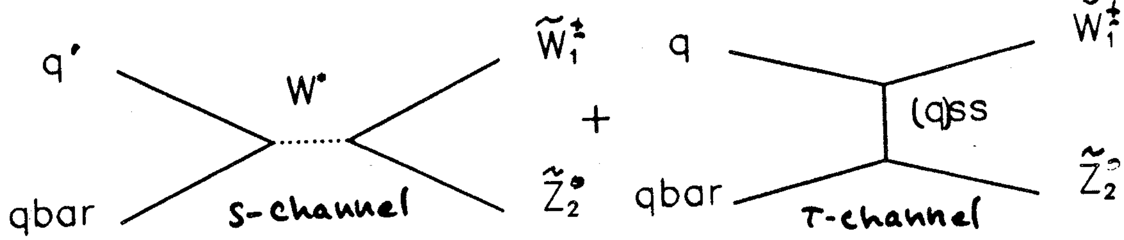
- **$M_{\tilde{W}_1^{\pm}} \cong M_{\tilde{Z}_2^{0}} \cong 2M_{\tilde{Z}_1^{0}}$**

- **$M_{\tilde{g}} \cong$ 3–4 $M_{\tilde{W}_1^{\pm}}$**

- **Current Limits**

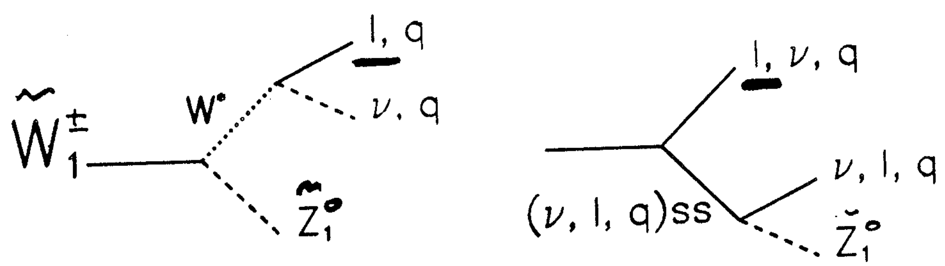
$\tilde{W}_1^{\mp}\ \tilde{Z}_2^{\circ}$ Signal

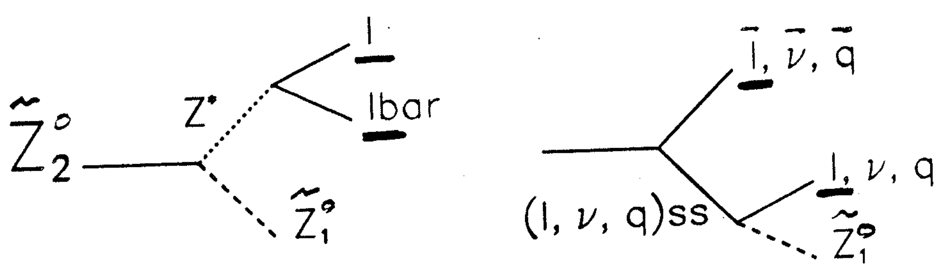
Production – p pbar collisions



Decays (dominant)

SS= SuperSymmetric





★★ BF → 3ℓ strongly depends on Masses of Sleptons, Sneutrinos, and Squarks

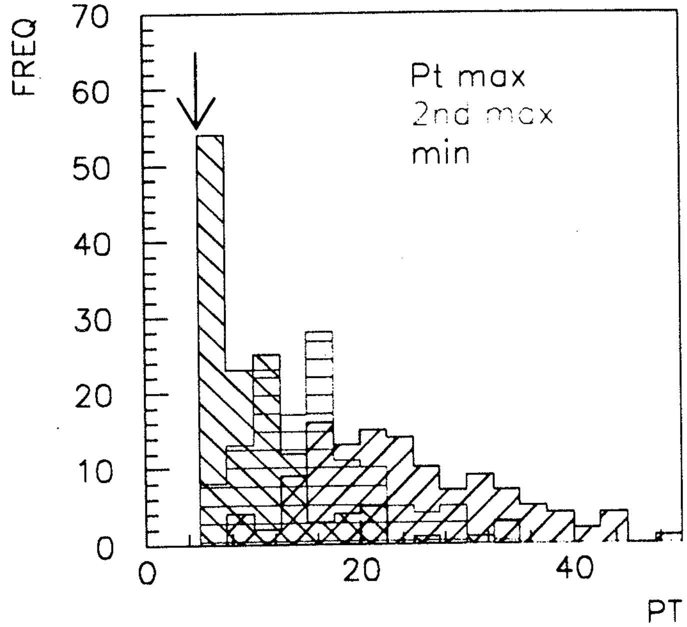
$\tilde{W}1\ \tilde{Z}2$ kinematics — D0 PRELIMINARY

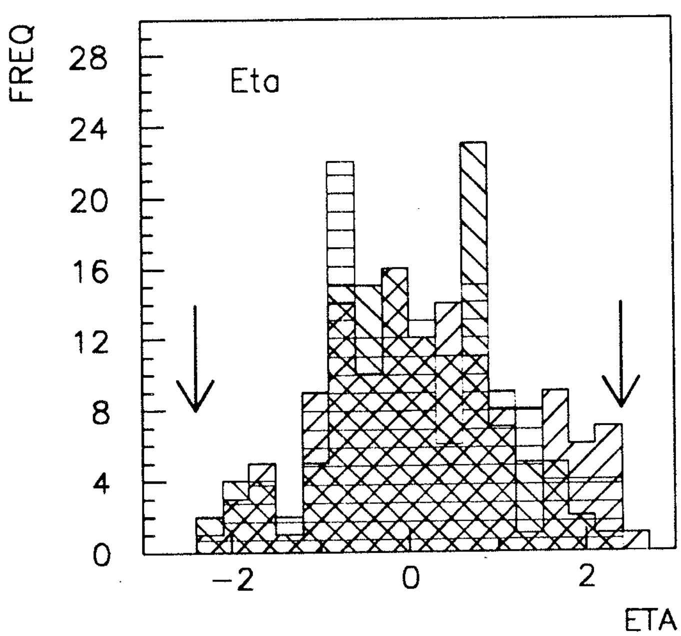
3ℓ

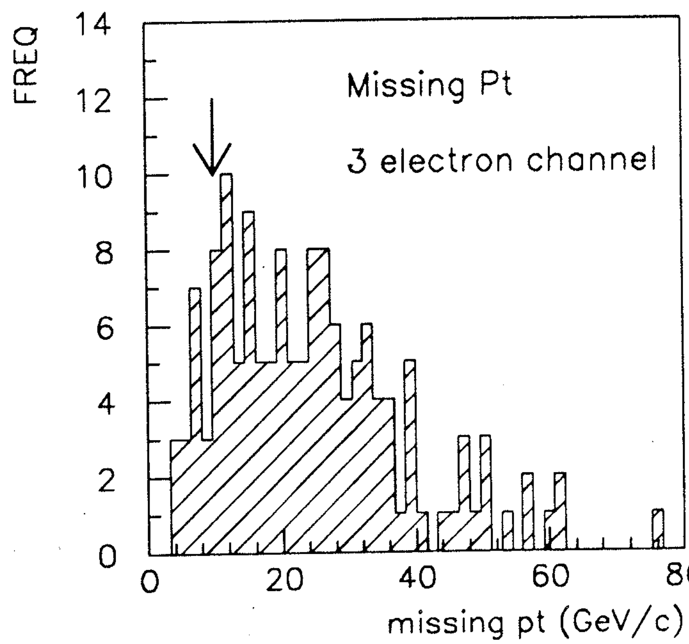
W_1, Z_2 Kinematic variables

$M(W_1) = 65$ GeV

(ISASUSY)







zino

CDF

Trilepton Event selection

We analyzed ~~$\int \mathcal{L}dt = 18$ pb^{-1}~~ data at this time.
(CDF has $\int \mathcal{L}dt = 21$ pb^{-1} from 1992-93 run).

Events Left After Trilepton Cuts

Cut	Data Sample	
	Muon	Electron
Original Sample	2,404,920	3,166,571
Dilepton Selection	25,483	29,361
Trilepton Selection	172	94
Trilepton Event Selection (with event tpology cut)	2	2
Z^0 removal (80-100 GeV/c^2)	1	0
Υ removal (9-11 GeV/c^2)	0	0
J/ψ removal (2.9-3.3 GeV/c^2)	0	0

- Data sample: Inclusive muon and electron trigger sample. (Muon $P_T > 7$ GeV/c, Electron $E_T > 9$ GeV)
- Lepton selection: Gold lepton($P_T(\mu) > 10$ GeV/c or $E_T(e) > 10$ GeV) and 2(or more) ordinary leptons (muon $P_T > 4$ GeV/c, electron $E_T > 5$ GeV)
- Event topology cut: lepton isolation, $dR(\ell\ell)$, sum of lepton charge, require $(\mu^+\mu^-)$ or (e^+e^-) pair.

Wino
Zino

CDF

MSSM Parameters

$\tan\beta\ (= v_2/v_1)$	Ratio of vacuum expectation values (= 4)
$M(H^+)$	Higgs boson mass (= 500 GeV/c^2)
μ	Higgsino mass (= −300, −350, −400, −450 GeV)
$M(\tilde{g})$	Gluino mass (= 140, 160, 180, 200 GeV/c^2)
$M(\tilde{q})$	Squark mass (= $1.2 \times M(\tilde{g})$)
$M(\tilde{\ell}), M(\tilde{\nu})$	Slepton and sneutolino masses under GUT hypothe $M(\tilde{\ell}_L)^2 = M(\tilde{q})^2 - 0.73\ M(\tilde{g})^2 - 0.27\ M(Z^0)^2 \cos$ $M(\tilde{\ell}_R)^2 = M(\tilde{q})^2 - 0.78\ M(\tilde{g})^2 - 0.23\ M(Z^0)^2 \cos$ $M(\tilde{\nu}_L)^2 = M(\tilde{q})^2 - 0.73\ M(\tilde{g})^2 + 0.5\ M(Z^0)^2 \cos 2$
$M(top)$	Top quark mass (= 160 GeV/c^2)

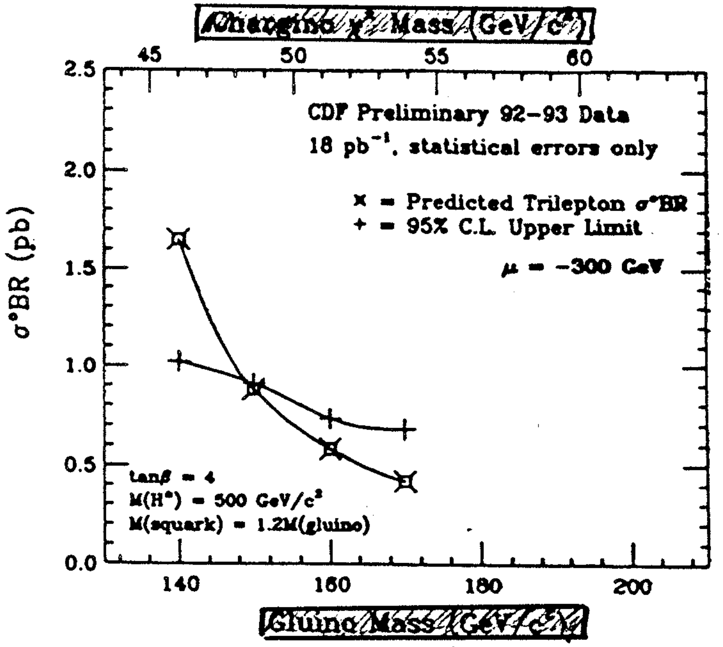
Monte Carlo Program

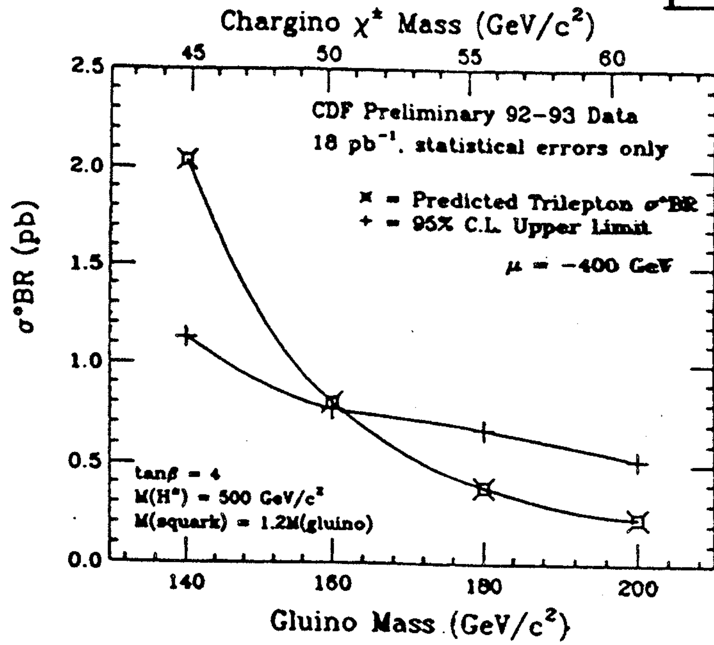
ISAJET V7.02 with SUSY Generator of Baer et al.

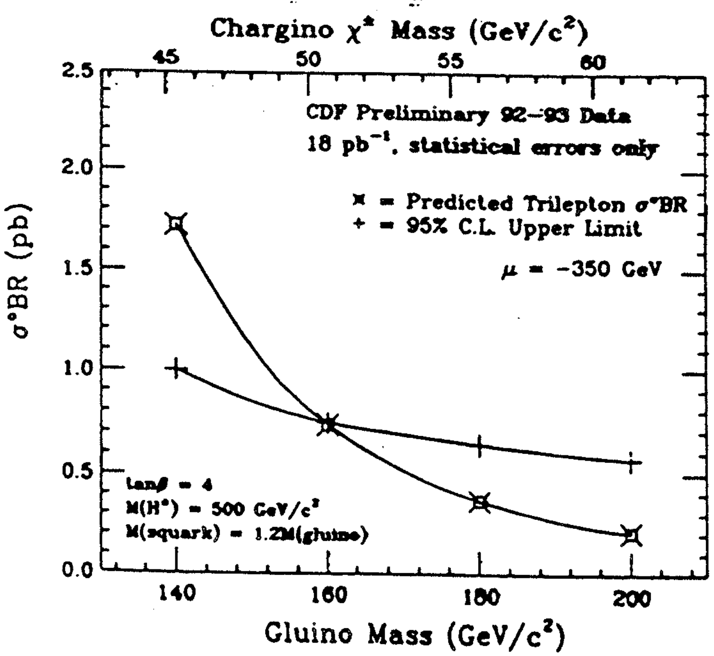
- Generator for fundamental processes in the MSSM
- s and t-channel graphs of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production
- $\alpha_3 = 0.120$ (from the 1993 lepton-photon symposium)
- CTEQ1M structure function

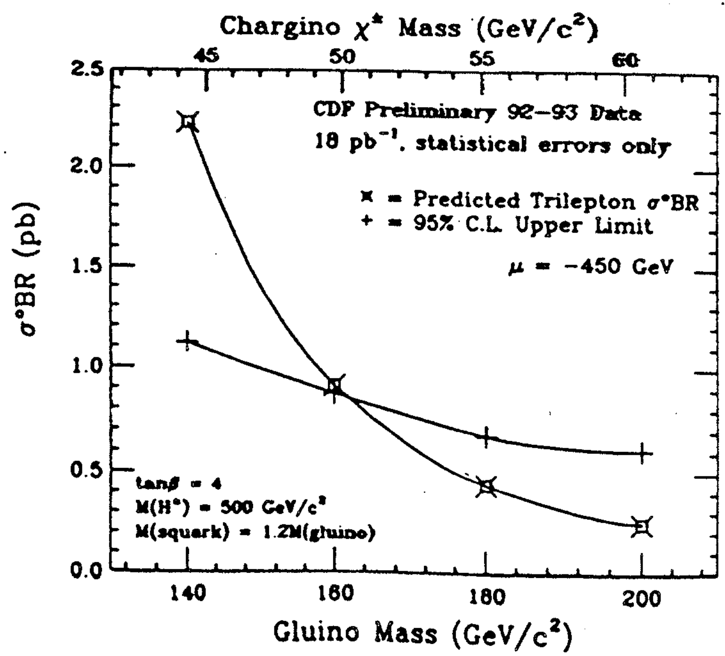
wino
tino

CDF





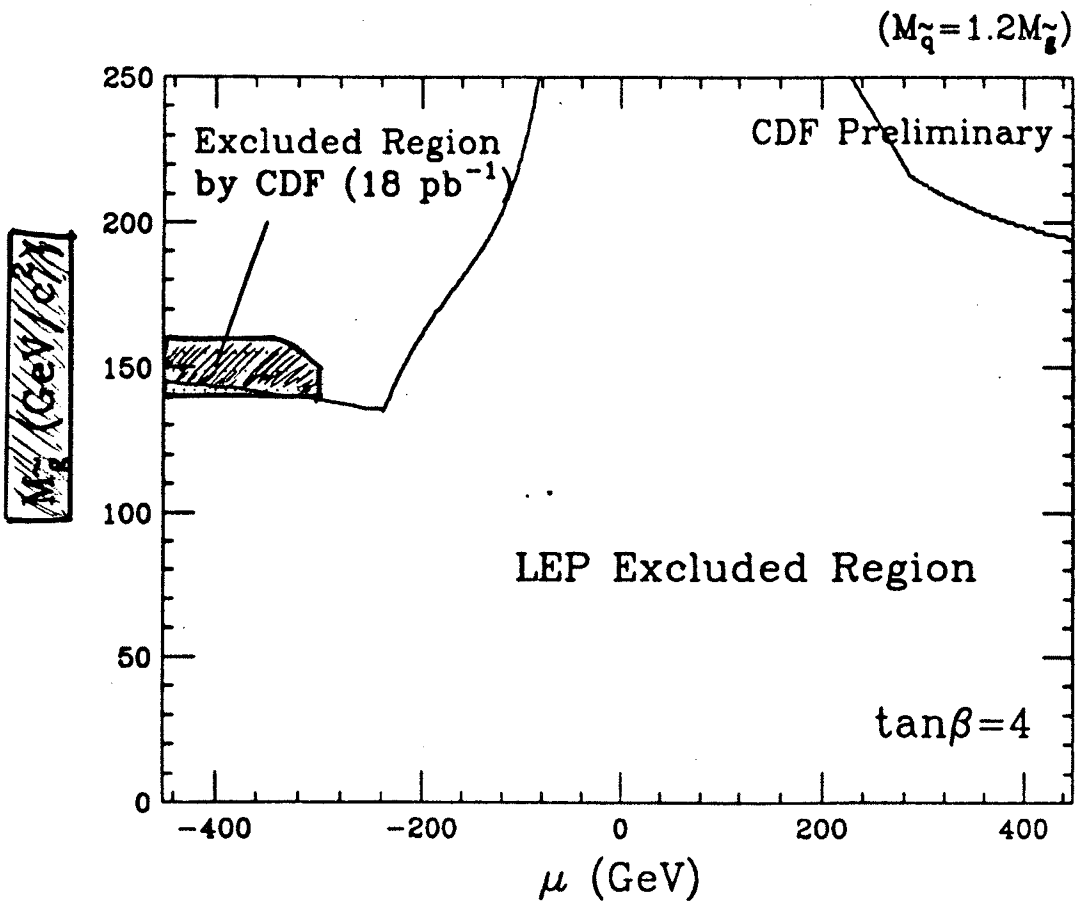




Wino
Zino

CDF

CDF

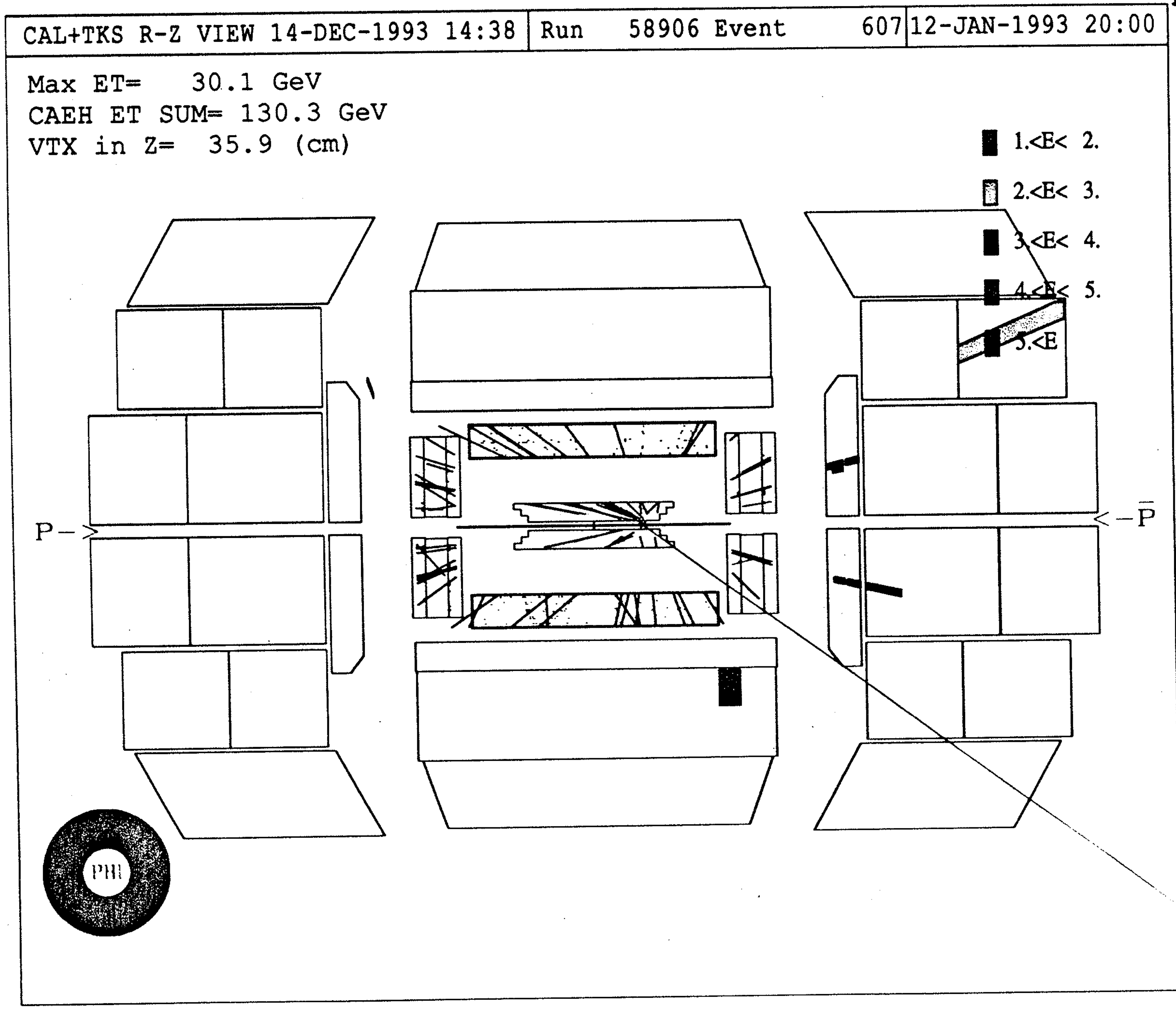


wino
zino

DØ

Process	eee	$ee\mu$	$e\mu\mu$	$\mu\mu\mu$
Trigger	1 EM > 20 or 2 EM > 10	EM > 7, μ > 5 GeV/c or 2 EM > 20 GeV/c or EM > 20, $\not{p}_T$ > 20	EM > 7, μ > 5 or μ > 15, μ > 10 or EM > 20, $\not{p}_T$ > 20	1 μ > 15 or 2 μ > 3
Offline Selection	3 e's, > 7 + $\not{p}_T$ > 10	1 μ > 10 + 1 e > 10 + 1 e > 7	1 μ > 10 + 1 e > 10 + 1 μ > 5 + $m_{\mu\mu}$ > 5	e μ's > 5 + $m_{\mu\mu}$ > 5
$\int Ldt$	$(14.8 \pm 1.8)pb^{-1}$	$(15.2 \pm 1.8)pb^{-1}$	$(15.2 \pm 1.8)pb^{-1}$	$(5.0 \pm 0.6)pb^{-1}$
Result	0 events	1 event	0 events	0 events
Est. Bkg. (PRELIM.)	< 1.1 events	< 0.5 events	< 0.5 events	< 0.2 events

Table 1: Required trigger, offline selection criteria, integrated luminosity, number of events passing selection and estimated backgrounds for the four trilepton combinations. The background estimate for each channel is preliminary.



Muon
$\eta = 1.1$
$P_T = 17.2$

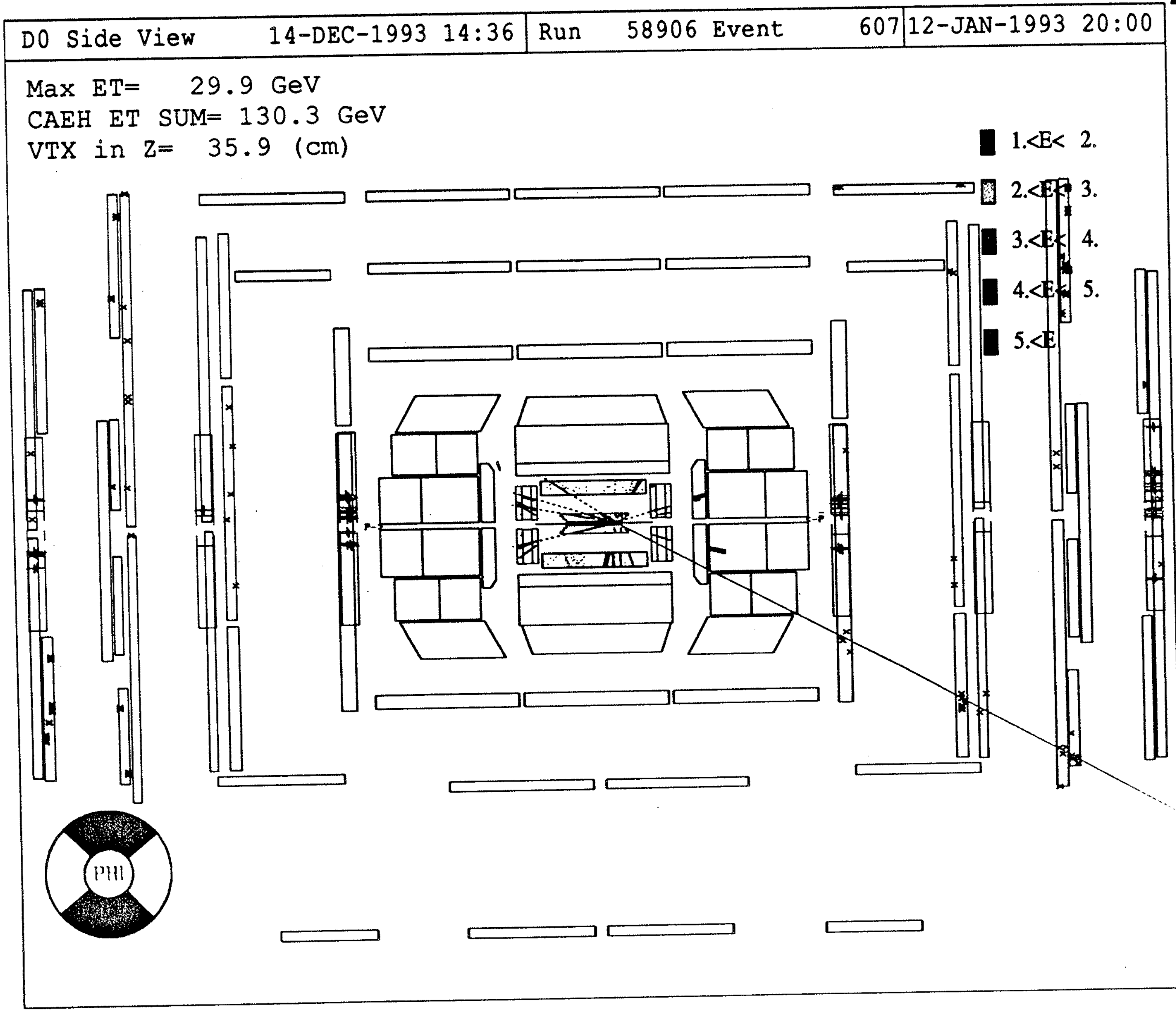
Electron Candidates
$\eta = 2.0$
$P_T = 37.8$

$\eta = 1.8$
$P_T = 8.0$

Missing P_T
23.3 ± 11.6

Wino
Zino

DØ


D0 Side View 14-DEC-1993 14:36
Run 58906 Event 607
12-JAN-1993 20:00
Max ET= 29.9 GeV
CAEH ET SUM= 130.3 GeV
VTX in Z= 35.9 (cm)
1.<E< 2.
2.<E< 3.
3.<E< 4.
4.<E< 5.
5.<E
PHI

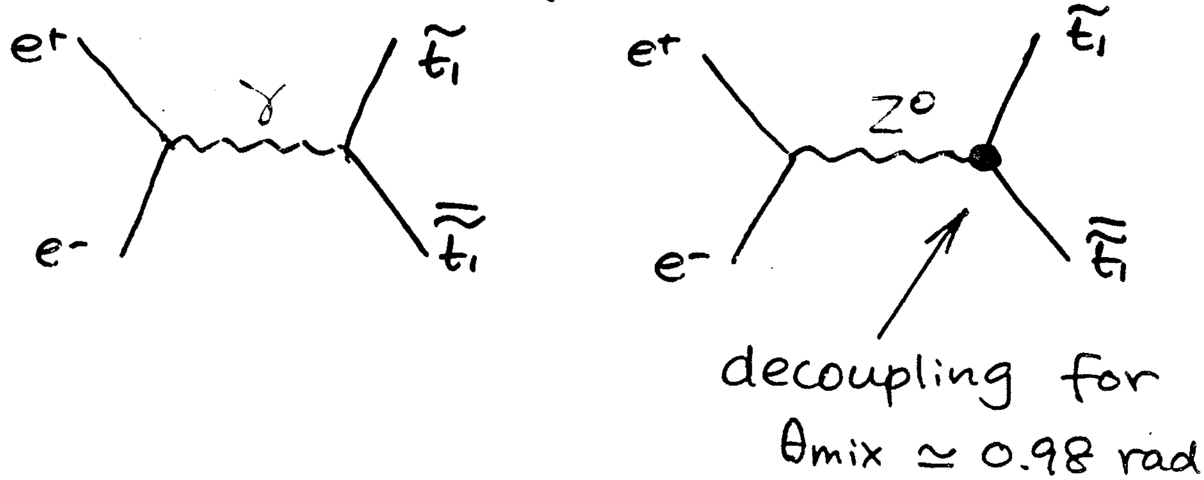
SCALAR TOP QUARK SEARCH
OPAL

① SCALAR TOP CAN BE THE LIGHTEST CHARGED SUSY PARTICLE.

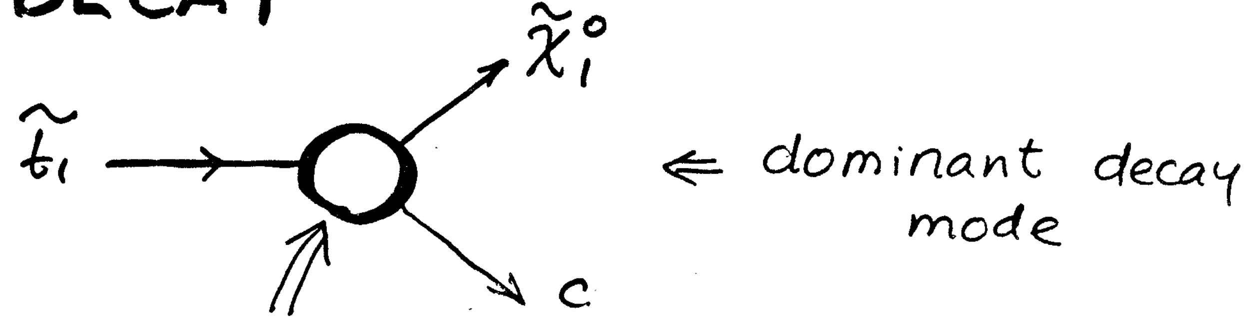
- LARGE RADIATIVE CORRECTION DUE TO HEAVY TOP QUARK
- $\tilde{t}_R$ AND $\tilde{t}_L$ MIX $\longrightarrow \tilde{t}_1, \tilde{t}_2$

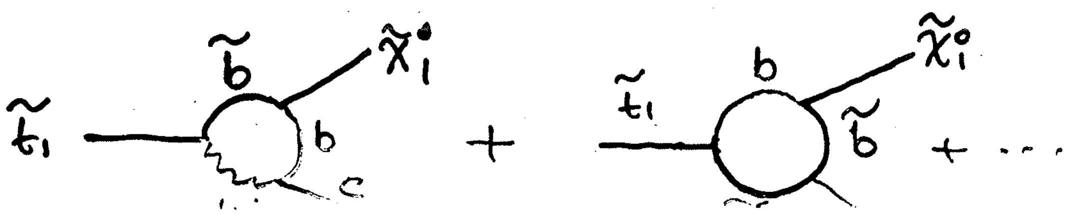
LIGHTER MASS EIGEN-STATE $\rightarrow$ $\tilde{t}_1 = \tilde{t}_R \cos\theta_{mix} + \tilde{t}_L \sin\theta_{mix}$

② PRODUCTION



③ DECAY





$e^+e^- \to \tilde{t}_1\bar{\tilde{t}}_2 \to c\tilde{\chi}^0_1 \ \bar{c}\tilde{\chi}^0_1$

invisi

OPAL Run 9012 Event 21 Date 931129 Time 00:19:44
TH403.01 MC data 45.640GeV Fill 0001 Period 00

RVIS	RBAL	.292	−.093
PCHG	ESHW	14.05	12.61
NCHG	NSHW	8	13
EEB	EEE	12.61	.00
FDL	FDR	.00	.00
NTOF	EHAD	14	1.41
THRU	COST	.807	.361

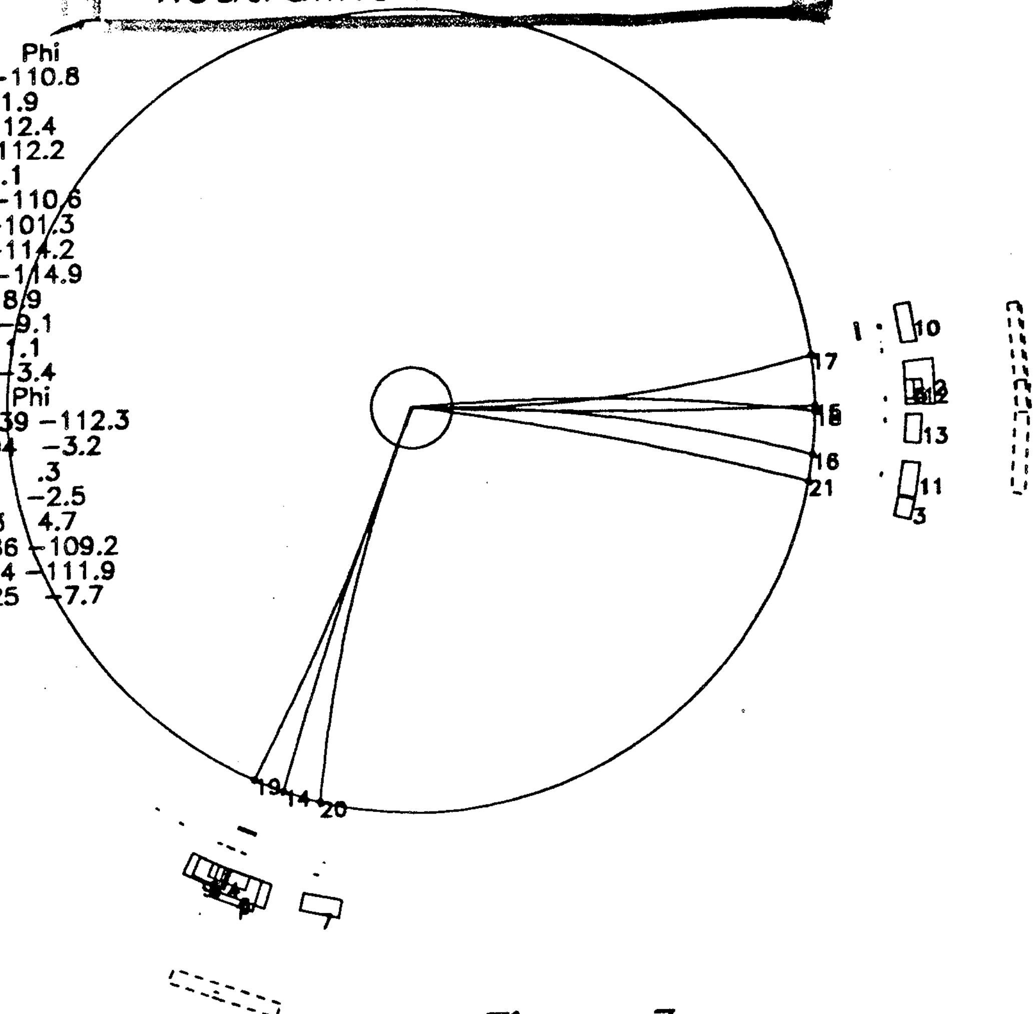
A Monte Carlo Event

stop mass = 42 GeV

neutralino mass = 32 GeV

cls	blk	Eraw	Ecor	cosT	Phi
1	4	2.39	2.66	−.211	−110.8
2	5	2.03	2.31	.306	1.9
3	1	.66	.87	−.119	−12.4
4	4	.46	.70	−.444	−112.2
5	1	.17	.50	.342	1.1
6	8	1.50	1.90	−.609	−110.6
7	4	.76	1.09	−.595	−101.3
8	3	.94	1.26	−.519	−114.2
9	4	1.18	1.44	−.280	−114.9
10	4	.57	.80	.342	8.9
11	3	.69	.93	.351	−9.1
12	1	.69	.90	.196	1.1
13	2	.58	.80	.293	−3.4

trk	hit	Pabs	Pt	cosT	Phi
14	152	−2.99	2.69	−.439	−112.3
15	170	−3.05	2.98	.204	−3.2
16	147	1.02	.97	.322	.3
17	161	−.88	.83	.331	−2.5
18	161	1.27	1.21	.293	4.7
19	149	1.73	1.65	−.286	−109.2
20	60	−1.06	.95	−.434	−111.9
21	165	2.06	2.04	−.125	−7.7



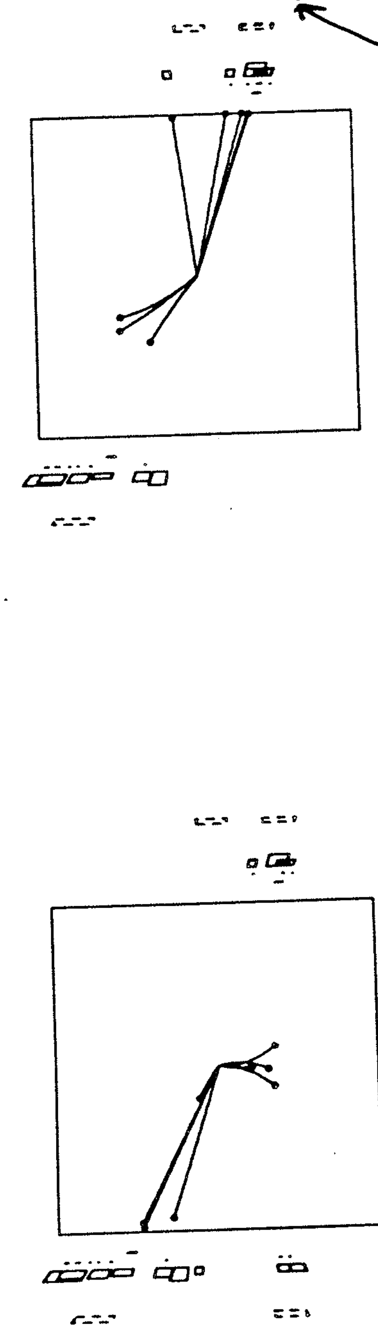


Figure 3a

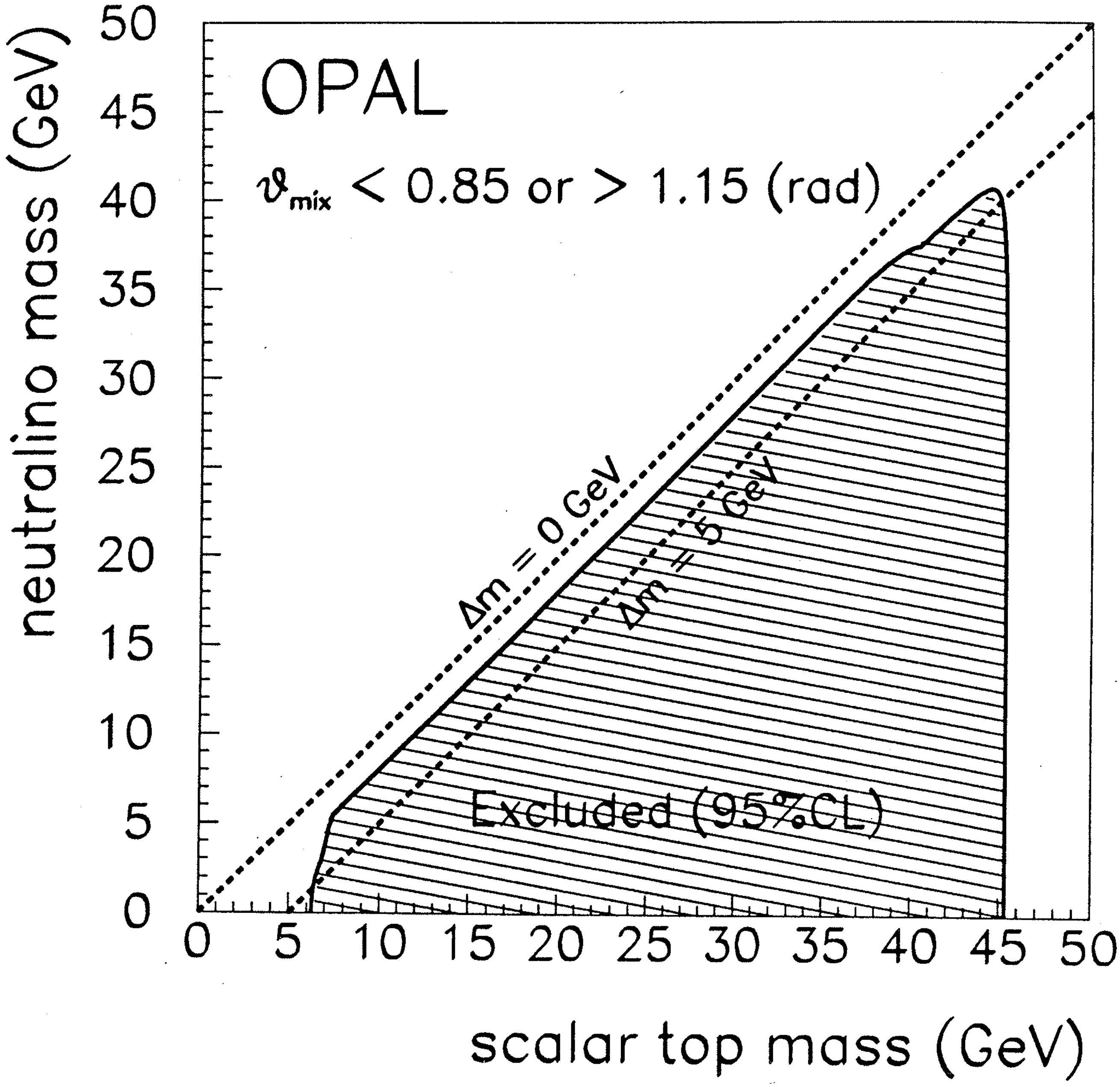

OPAL
ϑ_{mix} < 0.85 or > 1.15 (rad)
Δm = 0 GeV
Δm = 5 GeV
Excluded (95%CL)
neutralino mass (GeV)
scalar top mass (GeV)
0
5
10
15
20
25
30
35
40
45
50

Figure 8a

VERY SMALL MASS DIFFERENCE CASE

$\Delta m = m_{\tilde{t}_1} - m_{\tilde{\chi}^0_1} = 2.2$ GeV

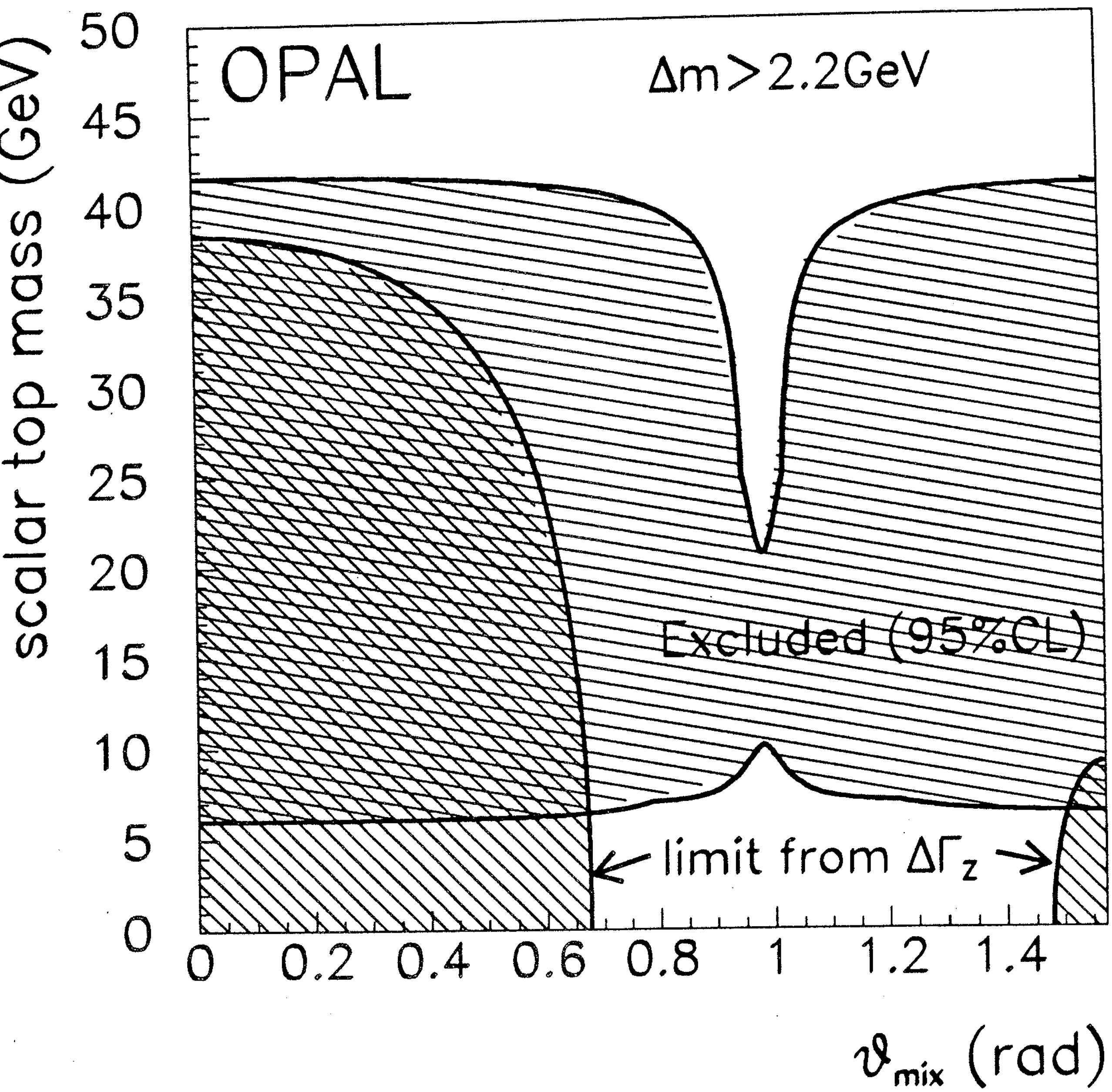


Figure 7a

Summary

■ Lepto Quarks

		DØ (e-jet, e-jet / e-jet ν-jet)	CDF (ee-jet)	
Scalar	$\beta = 1$	$m > 133$	$m > 113$	GeV/c^2
	$\beta = 0.5$	$m > 120$	$m > 80$	
Vector	$\beta = 1$	$m > 193$ (244) $K=0$		
	$\beta = 0.5$	$m > 175$ (234) $K=1$		

■ Excited Quark States

$q^* \to q\gamma$ + $q^* \to q\,W$

CDF + LEP $\quad m > 540$ GeV/c^2 for $f = f' = f_s = 1$

■ SUSY Wino, Zino, stop

CDF

μ	$M(\tilde{g})$ GeV/c^2	$M(\tilde{\chi}_1^\pm)$ GeV/c^2
$-450 \sim -350$	> 160	> 50

OPAL

$\Theta < 0.85$ rad & $\Theta > 1.15$ rad $\quad \Delta M > 5$ GeV

$45.0 < M < 6.3$ GeV

PRELIMINARY PROGRAMME

(March 6, 1994)

Monday, March 7

8.30-11.30

I - ASTROPHYSICS AND COSMOLOGY

- I.1 Solar Neutrino Data (Till Kirsten, Heidelberg)
- I.2 High Energy Neutrino Sources (Venia Berezinsky, Gran Sasso)
- I.3 Cosmic Ray Experiments (Alan Watson, Leeds)
- I.4 The RELIC Search for Cosmic Background (Mikhail V. Sazhin, Moscow)

16.30-19.30

- I.6 Brown Dwarfs (Alvaro De Rujula, CERN)
- I.7 Cosmic Microwave Background and Structure of the Universe (Nicola Vittorio, Roma II)
- I.8 OMEGA: Proposal for a Spherical Gravitational Wave Detector (Eugenio Coccia, Roma II)

II - NEUTRINO PHYSICS AND CP VIOLATION

- II.1 Neutrino Oscillation Experiments (Henry T. Wong, CERN)
- II.2 The Bugey Neutrino Oscillation Experiment (Elemer Nagy, Marseille)

Tuesday, March 8

8.30-11.30

II - NEUTRINO PHYSICS AND CP VIOLATION

- II.3 Neutrino Masses (François Vannucci, LPNHE)
- II.4 CP Violation in B-Decays (Icaros Bigi, Notre Dame/CERN)
- II.5 T/CP/CPT Violation Searches at CPLEAR (Anne Ealet, Marseille)
- II.6 Neutrino Radiation in Strong External Fields (Karen A. Ter-Matirosyan, ITEP)

III - STRUCTURE FUNCTIONS

- III.1 Polarized Structure Functions (Ricardo Piegaia, Yale)

16.30-19.30

III - STRUCTURE FUNCTIONS

- III.2 F_2 and High Q^2 Physics at HERA (David Newton, Lancaster)
- III.3 Jet and Direct Photon production at CDF/D0 (Bernard Pope, Michigan)
- III.4 Low-x Structure Functions (Stefano Catani, Firenze)
- III.5 Drell-Yan Production on Protons and Neutrons (Bruno Alessandro, Torino)

IV - ELECTROWEAK PHYSICS

- IV.1 CP Violation Tests in Tau/Top Processes (Charles A. Nelson, SUNY)
- IV.2 High Precision Luminosity Measurement at OPAL (Julie Hart, CERN)

Wednesday, March 9

8.30-11.30

IV - ELECTROWEAK PHYSICS

- IV.3 New ARGUS and CLEO Results on Tau Lepton and Charm (Michael Danilov, ITEP)
- IV.4 Beauty Decays (Jim Smith, Colorado)
- IV.5 Beauty Production in Z_0 Decays (Sijbrand De Jong, CERN)
- IV.6 Electroweak Results at LEP (Michael Koratzinos, Oslo)
- IV.7 Electroweak Studies at CDF/D0 (Yves Ducros, Saclay)
- IV.8 Updated Electroweak Parameters and Physics Beyond the Standard Model (Riccardo Barbieri, Pisa)

16.30-19.30

V - HADRON PHYSICS

- V.1 Low - Q^2 Physics at HERA (Riccardo Brugnera, Padova)
- V.2 Understanding Total Hadronic Cross-Sections (Andre' Martin, CERN)
- V.3 QCD Physics at LEP (Demetris Pandoulas, Aachen)
- V.4 Hadro and Photo-Production of Charmed Hadrons (Gianpaolo Bellini, Milano)
- V.5 Studies of Jet Parameters at CDF/D0 (Anwar Bhatti, Rockefeller)

Thursday, March 10

8.30-11.30

VI - HEAVY FLAVOURS

- VI.1 Heavy Flavour Production (Jack Smith, Stony Brook)
- VI.2 Exclusive B-Physics at CDF/D0 (Johnatan Lewis, FNAL)
- VI.3 Inclusive B-Physics at CDF/D0 (Andrzej Zieminski, Indiana)
- VI.4 Beauty Lifetime and Mixing at LEP(André Roussarie, Saclay)
- VI.5 A New Measurement of the B°s Mass (Yannick Arnoud, Saclay)
- VI.6 Top Search with D0 (Roger Dixon, Fermilab)

16.30-19.30

VII - ROUND TABLE "The Future of Supercollider Physics in the Post-SSC Era" Michael Danilov (ITEP), Roger Dixon (Fermilab), Walter Hoogland (CERN), Sachio Kamamiya (Tokyo), Luciano Maiani (Roma), Martin Perl (SLAC),Volker Sörgel (Heidelberg).

Friday, March 11

8.30-11.30

VIII - SEARCHING FOR NEW PHENOMENA

VIII.1 CP Violation in CPT-Invariant and CPT-Noninvariant Worlds (Eugene Shabalin, ITEP)
VIII.2 Low Energy Bremmshahlung of Ultra Relativistic Particles (Martin Perl, SLAC)
VIII.3 Higgs Search at LEP (Jean-Paul Martin, Lyon)
VIII.4 New Particle and SUSY Searches (Lee Lueking, FNAL)
VIII.5 SUSY Particles (Pran Nath , Northeastern/CERN)

16.30-19.30

IX - PROSPECTS AT FUTURE FACILITIES

IX.1 The PEP II Asymmetric B-Factory Program (David Leith, SLAC)
IX.2 Physics Prospects with CLEO (Ritchie Patterson, Cornell)
IX.3 Physics at the Next e+e- Linear Collider (Peter Zerwas, DESY)
IX.4 On a Possible Breakdown of QFT at LHC (Nicola Khuri, Rockefeller)
IX.5 On a Possible Breakdown of Perturbation Theory (Adrian Patrascioiu, Arizona)
IX.6 Physics Prospects at LHC (Peter Jenni, CERN)

Saturday, March 12

8.30-11.30

X - OUTLOOK

X.1 Supercollider Physics (Chris Quigg, FNAL)
X.2 Supergravity (Sergio Ferrara, CERN)
X.3 Energy Amplification Driven by a High Energy Particle Beam (Carlo Rubbia, CERN)