Disclaimer

This note has not been internally reviewed by the DØ Collaboration. Results or plots contained in this note were only intended for internal documentation by the authors of the note and they are not approved as scientific results by either the authors or the DØ Collaboration. All approved scientific results of the DØ Collaboration have been published as internally reviewed Conference Notes or in peer reviewed journals.

DØ NOTE 1947

Search for Supersymmetry and Leptoquark States in DZERO

James T. White
Texas A&M University
DZero Collaboration

October 21, 1993

9th Topical Workshop on Proton–Antiproton Collider Physics
Tsukuba, Japan

THE DØ COLLABORATION

S. Abachi[9], B. Abbott[30], M. Abolins[19], B.S. Acharya[34], I. Adam[8], D. Adams[29], M. Adams[13], S. Ahn[9], H. Aihara[16], G. Alvarez[14], G.A. Alves[6], N. Amos[18], W. Anderson[19], Yu. Antipov[27], S.H. Aronson[3], R. Astur[33], R.E. Avery[24], A. Baden[17], V. Balamurali[28], J. Balderston[13], B. Baldin[27], J. Bantly[4], J.F. Bartlett[9], K. Bazizi[8], T. Behnke[33], J. Bendich[16], V. Bezzubov[27], P.C. Bhat[9], V. Bhatnagar[20], N. Biswas[29], G. Blazey[30], S. Blessing[24], A. Boehnlein[30], F. Borcherding[9], J. Bordere[31], N. Bosko[27], A. Brandt[9], R. Brock[19], A. Bross[9], D. Buchholz[34], V. Burtovoy[27], J.M. Butler[9], O. H. Callot[33], H. Castilla[7], D. Chakraborty[33], S. Chekulaev[27], J. Chen[2], L.-P. Chen[16], W. Chen[33], S. Chopra[20], B.C. Choudhary[8], J. H. Christenson[9], D. Claes[33], A.R. Clark[16], W.G. Cobau[17], J. Cochran[32], W.E. Cooper[9], C. Cretsinger[30], D. Cullen-Vidal[4], M. Cummings[13], D. Cutts[4], O.I. Dahl[16], K. De[35], M. Demarteau[9], R. Demina[22], K. Denisenko[9], N. Denisenko[9], D. Denisov[33] S. Denisov[27], W. Dharmaratna[11], H.T. Diehl[9], M. Diesburg[9], R. Dixon[9], P. Draper[35], Y. Ducros[31], S. Durston Johnson[30], D. Eartly[9], D. Edmunds[19], A. Efimov[27], J. Ellison[8], V.D. Elvira[9], R. Engelmann[33], G. Eppley[29], P. Ermolov[30], O. Eroshin[27], V. Evdokimov[27], S. Fahey[19], G. Fanourakis[30], M. Fatyga[3], J. Featherly[3], S. Feher[33], D. Fein[2], T. Ferbel[30], D. Finley[9], G. Finocchiaro[33], H.E. Fisk[9], Yu. Fisyak[30], E. Flattum[19], G.E. Forden[2], M. Fortner[33], P. Franzini[6], S. Fuess[9], E. Gallas[35], C.S. Gao[9], T.L. Geld[33], K. Genser[9], C.E. Gerber[9], B. Gibbard[3], V. Glebov[33], J.F. Glicenstein[31], B. Gobbi[24], M. Goforth[11], A. Goldschmidt[16], B. Gomes[1], M.L. Good[33], H. Gordon[3], N. Graf[3], P.D. Grannis[33], D.R. Green[9], J. Green[21], H. Greenlee[9], N. Grossman[16], P. Grudberg[16], S. Grünendahl[30], J.A. Guida[33], J.M. Guida[3], W. Guryn[3], N.J. Hadley[17], H. Haggerty[9], S. Hagopian[11], V. Hagopian[11], R.E. Hall[8], J. Hauptman[15], D. Hedin[33], A.P. Heinson[5], U. Heintz[8], G. Hérrata[7], T. Heuring[11], R. Hirosky[30], B. Hoeneisen[1], K. Hodel[30], J.S. Hoftun[4], T. Hu[33], J.R. Hubbard[31], T. Huehn[8], S. Igarashi[9], A.S. Ito[9], E. James[2], J. Jaques[28], J. Jiang[33], T. Joffe-Minor[24], K. Johns[2], M. Johnson[9], A. Jonckheere[9], M. Jones[12], H. Jöstlein[9], C.K. Jung[33], S. Kahn[3], R. Kehoe[28], A. Kernan[8], L. Kerth[16], A. Kholodenko[27], A. Kiryunin[27], E. Kistenev[27], A. Klatchko[11], B. Klima[9], B. Klochkov[27], C. Klopfenstein[33], V. Klyukhin[27], V. Kochetkov[27], J.M. Kohli[26], D. Koltick[28], J. Kotcher[33], I. Kotov[27], J. Kourlas[21], A. Kozelov[27], E. Kozlovsky[27], M.R. Krishnaswamy[34], S. Krzywdzinski[9], S. Kunori[17], S. Lami[33], G. Landsberg[33], R.E. Lanou[4], A. Leflat[20], J. Lee-Franzini[33], H. Li[33], J. Li[36], R. Li[9], Q.Z. Li-Demarteau[9], J.G.R. Lima[6], S.L. Linn[11], J. Linnemann[19], R. Lipton[9], Y.C. Liu[24], F. Lobkowicz[30], P. Loch[3], S.C. Loken[16], S. Lobo[33], L. Lueking[9], A.K.A. Maciel[6], R.J. Madaras[16], R. Madden[11], Ph. Mangeot[31], I. Manning[9], B. Mansoulié[31], H.S. Mao[9], M. Marcin[16], S. Margulies[13], R. Markeloff[33], L. Markosky[3], T. Marshall[14], H.J. Martin[16], M.I. Martin[9], P.S. Martin[9], M. Marx[32], B. May[2], A. Mayorov[27], R. McCarthy[32], J. McKinley[19], X.C. Meng[9], K.W. Merritt[9], H. Miettinen[29], A. Milder[3], A. Mincer[21], N.K. Mondal[34], H.T. Montgomery[9], P. Mooney[19], M. Mudan[21], C. Murphy[14], C.T. Murphy[9], F. Nang[4], M. Narain[9], V.S. Narasimham[34], H.A. Neal[18], J.P. Negret[1], P. Nemethy[21], D. Nešić[4], K.K. Ng[32], D. Norman[11], I. Orech[19], V. Oguri[6], E. Oltman[16], N. Oshima[9], D. Owen[19], M. Pang[18], A. Para[9], C.H. Park[9], R. Partridge[4], M. Paterno[32], A. Petryshkin[9], M. Peters[12], B. Pi[19], H. Piekarz[11], Yu. Pischalnikov[27], D. Pizzuto[33], A. Pluquet[31], V. Podstavkov[27], B.G. Pope[19], H.B. Prosper[9], S. Protopopescu[3], Y.-K. Que[9], P.Z. Quintas[9], G. Rahal-Callot[33], R. Raja[9], S. Rajagopalan[32], M.V.S. Rao[34], L. Rasmussen[33], A.L. Read[9], S. Repond[23], S. Reucroft[22], V. Riadovikov[27], M. Rijssenbeek[33], N.A. Roe[16], J. Roldan[1], S. Rusin[20], P. Rubinov[33], R. Ruchti[28], J. Rutherfoord[2], A. Santoro[6], L. Sawyer[25], R.D. Schamberger[33], J. Sculli[21], E. Shabbalina[27], A. Shukurenkov[27], M. Shupe[2], J.B. Singh[26], V. Sirotenko[33], J. Skeens[29], W. Smart[9], A. Smith[2], D. Smith[3], R.P. Smith[9], G.R. Snow[19], S. Snyder[32], M. Soscbee[35], M. Souza[6], A.L. Spadafora[16], S. Stampke[19], R. Stephens[16], M.L. Stevenson[16], D. Stewart[19], F. Stocker[33], D. Stoyanova[27], K. Streets[13], M. Strovink[16], A. Suhanov[27], A. Taketani[9], M. Tartaglia[9], J. Teiger[31], J. Thompson[32], S. Tisserant[19], T.G. Trippe[16], P.M. Tuts[8], P.R. Vishwanath[34], A. Volkov[27], A. Vorobiev[27], H.D. Wahl[11], D.C. Wang[9], L.-Z. Wang[9], J. Warchol[25], M. Wayne[25], H. Weerts[19], W.A. Wenzel[16], A. White[33], J.T. White[36], J. Wightman[26], J. Wilcox[22], S. Willis[23], S.J. Wimpenny[5], Z. Wolf[31] J. Womersley[33], D.R. Wood[9], Y. Xia [19], D. Xiao[11], P. Xie[9], H. Xu[4], R. Yamada[9], P. Yamin[3], C. Yanagisawa[32], J. Yang[21], M.-J. Yang[9], T. Yasuda[22], C. Yoshikawa[12], S. Youssef[11], J. Yu[33], C. Zeitnitz[2], R. Zeller[27], S. Zhang[18], Y.H. Zhou[9], Q. Zhu[21], Y.-S. Zhu[9], D. Zieminska[14], A. Zieminski[14], A. Zinchenko[19], A. Zylberstejn[31]

The DØ Collaboration

[1]Universidad de los Andes, Bogota Colombia
[2]University of Arizona
[3]Brookhaven National Laboratory
[4]Brown University
[5]University of California, Riverside
[6]LAFEX, Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
[7]CINVESTAV, Mexico City, Mexico
[8]Columbia University
[9]Fermi National Accelerator Laboratory
[10]University of Florida
[11]Florida State University
[12]University of Hawaii
[13]University of Illinois, Chicago
[14]Indiana University
[15]Iowa State University
[16]Lawrence Berkeley Laboratory
[17]University of Maryland
[18]University of Michigan
[19]Michigan State University
[20]Moscow State University, Russia
[21]New York University
[22]Northeastern University
[23]Northern Illinois University
[24]Northwestern University
[25]University of Notre Dame
[26]University of Panjab, Chandigarh, India
[27]Institute for High Energy Physics, Protvino, Russia
[28]Purdue University
[29]Rice University
[30]University of Rochester
[31] DAPNIA-CE Saclay,France
[32]State University of New York - Stony Brook
[33]Superconducting Supercollider Laboratory
[34]Tata Institute of Fundamental Research, Bombay India
[35]University of Texas - Arlington
[36]Texas A&M University
[37]ZRL, Bristol Rhode Island

To Be Presented

★ **Search for Leptoquarks:**

1st Generation, Scalar

LQ LQbar $\rightarrow$

e + jet, e + jet

e + jet, ν + jet

★ **Search for Supersymmetry:**

W1 Z2 -> trileptons (Preliminary)

W_1 Z_2 $\rightarrow$

e e e + X

e e μ + X

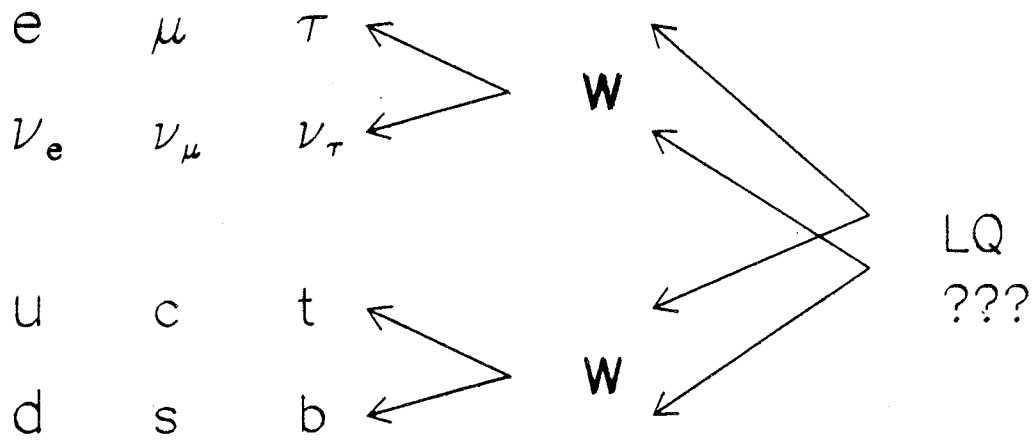
e μ μ + X

μ μ μ + X

★ **Conclusions**

Search for 1st Gen. Leptoquarks

In SM, leptons, quarks → related:



LQs appear naturally in SM extensions

composite models

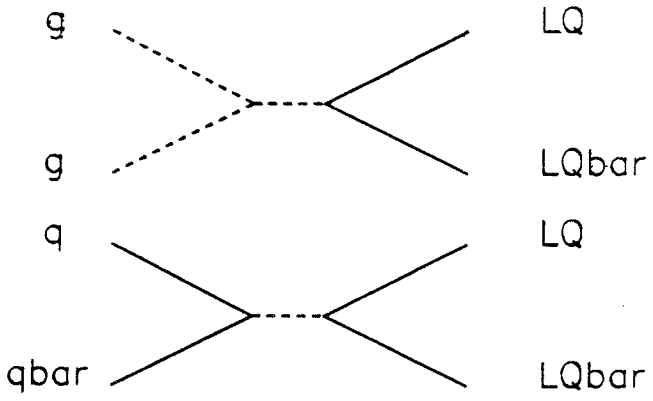
Large Gauge Group extensions

Current Mass Limits (published)

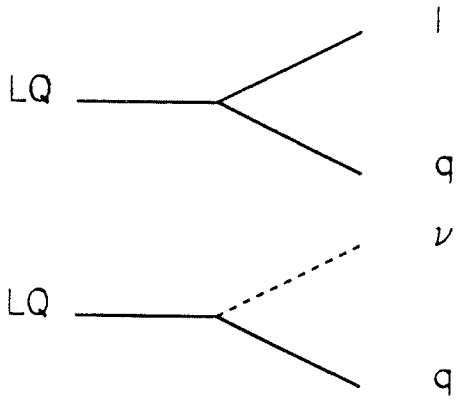
e^+e^- – LEP	45 GeV
p pbar – (CDF)	113 GeV $\beta=1.$ 80 GeV $\beta=0.5$
e p – HERA	180 GeV (assuming EW coupling)

Leptoquark Signal

Production – p pbar collisions

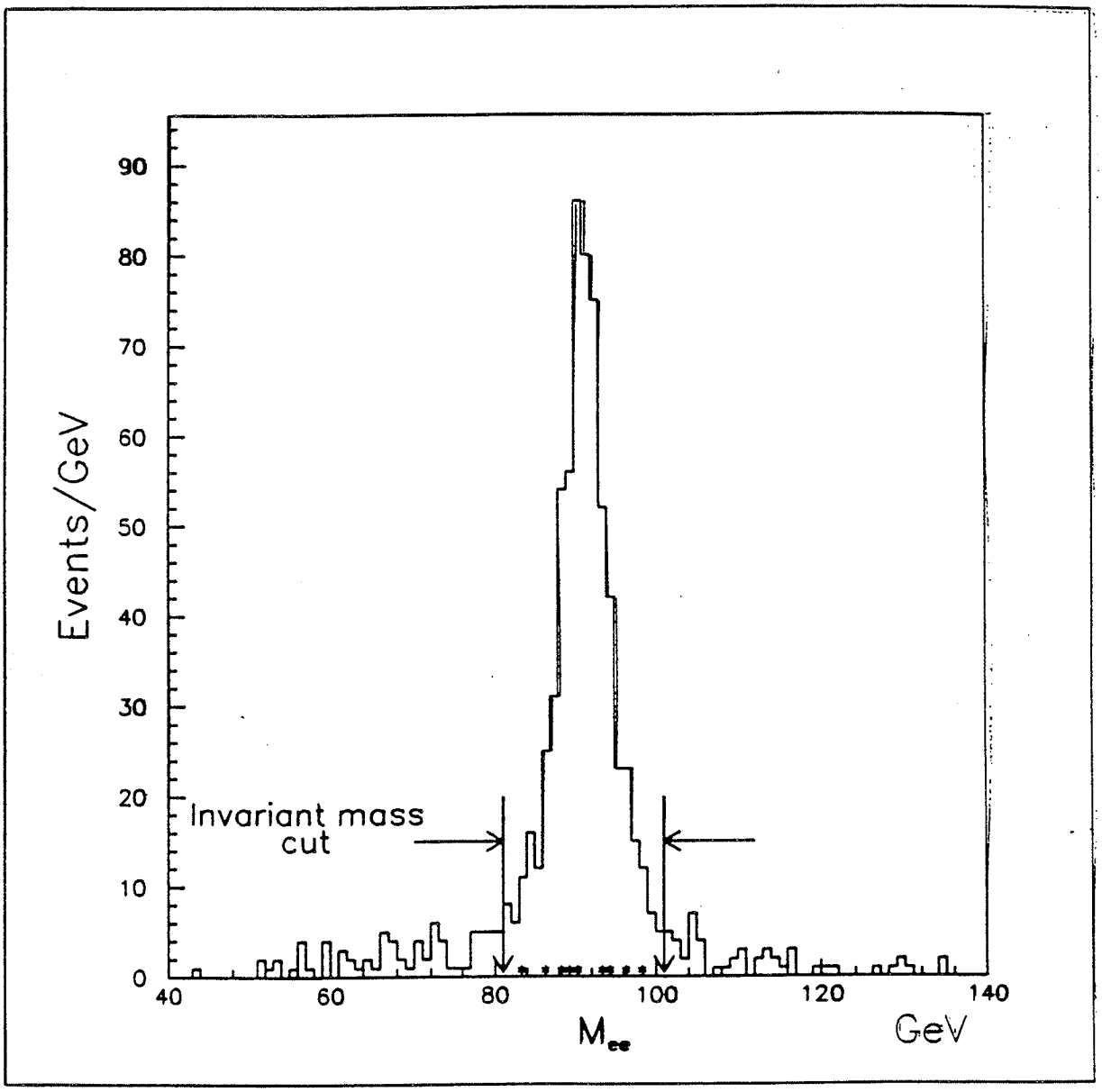


Decays



$BF = \beta$

$BF = 1 - \beta$


Events/GeV
90
80
70
60
50
40
30
20
10
0
Invariant mass
cut
40
60
80
100
120
140
M_{ee}
GeV

LQ LQbar $\rightarrow$ e−jet, e−jet

DATA

$\int Ldt = 15\ pb^{-1}$

TRIGGERS

2 EM* − pt > 10 GeV/c

OFFLINE SELECTION

2 electrons, pt > 25 GeV/c

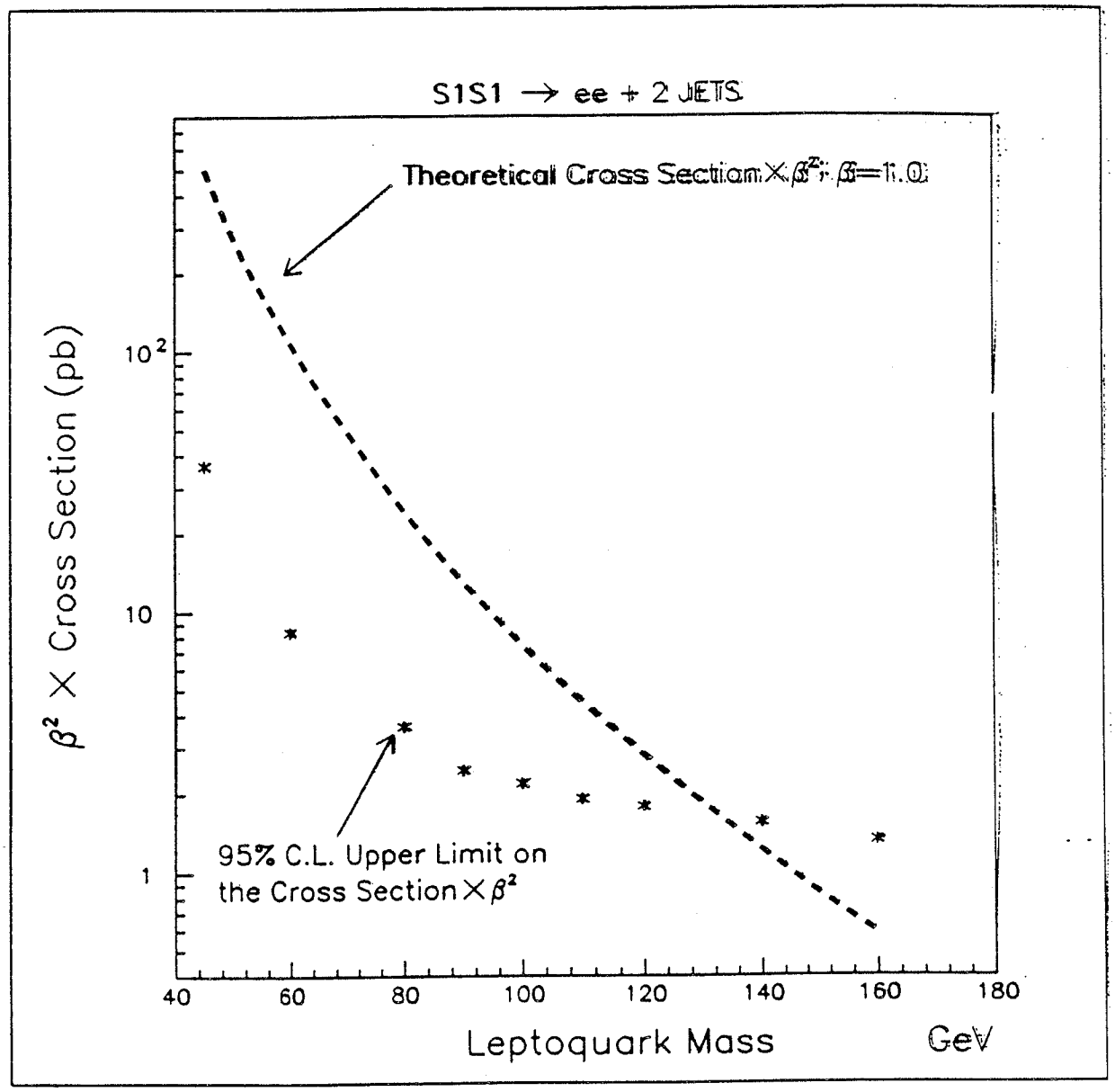
2 jets, pt > 25 GeV/c

$|M_{ee} - M_{Z0}| > 10$ GeV

RESULT

0 events

* EM == cal. cluster with shape consistent with an electron


S1S1 → ee + 2 JETS
Theoretical Cross Section × β², β=1.0
95% C.L. Upper Limit on
the Cross Section × β²
β² × Cross Section (pb)
10²
10
1
40
60
80
100
120
140
160
180
Leptoquark Mass
GeV

LQ LQbar $\longrightarrow$ e−jet, ν−jet

DATA

$\int Ldt = 15\ pb^{-1}$

TRIGGERS

EM* − pt > 20 AND missing Pt > 20 GeV/c

EM − pt > 10 AND 2 jets, pt > 10

AND missing Pt > 10

OFFLINE SELECTION

1 electron, pt > 20 GeV/c

2 jets, pt > 20 GeV/c

$e\nu$ Transverse mass > 105 GeV

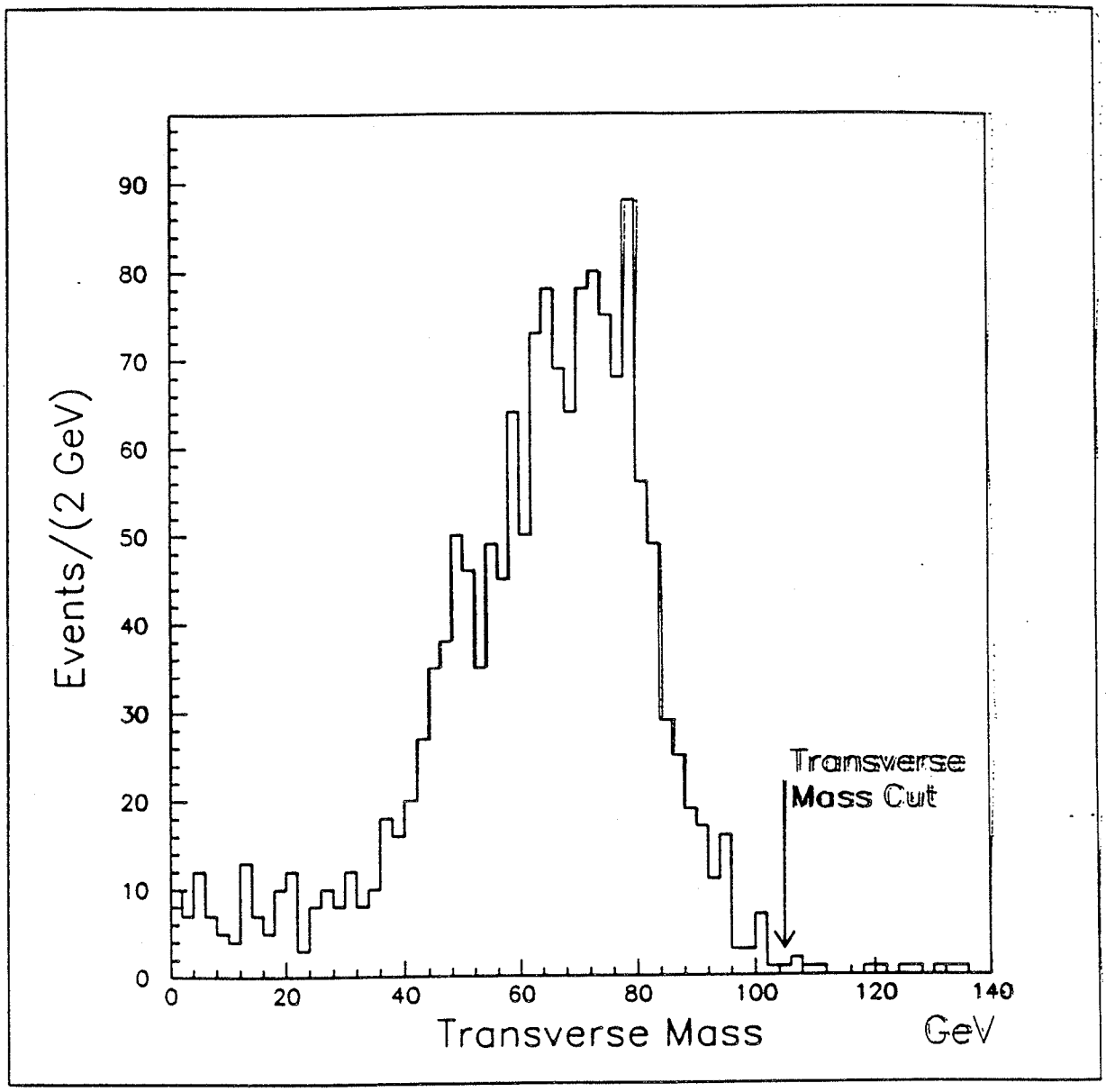
require 0 muons, pt > 15 GeV/c

~~$\not{p}_t$~~ > 40 GeV

RESULT

0 events

* EM == cal. cluster with shape consistent with an electron


Events/(2 GeV)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
Transverse Mass
GeV
Transverse
Mass Cut

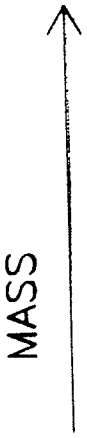
Search for V

SUSY → > 20

→ Relate

Minimal Supe

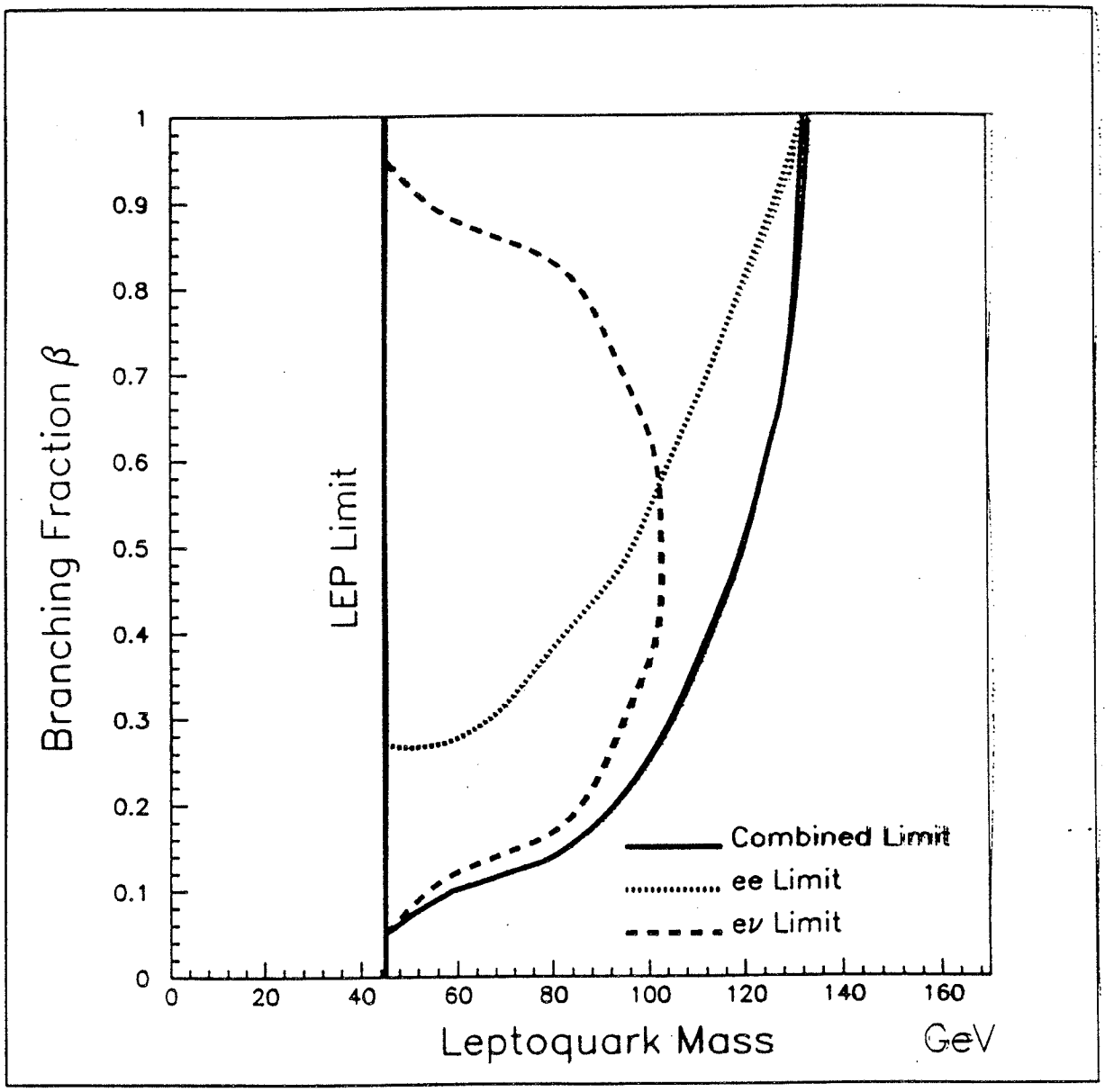
A possible sp



$W_1 \rightarrow \chi^{*\pm}_1$,

$Z_2 \rightarrow \chi^0_2$, :

$Z_1 \rightarrow \chi^0_1$, :


Branching Fraction β
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
LEP Limit
Combined Limit
ee Limit
eν Limit
0
20
40
60
80
100
120
140
160
Leptoquark Mass
GeV

for $W_1 Z_2 \rightarrow$ trileptons

- > 20 years of age, still THRIVING
- Relates internal symmetries to space—time

Solves hierarchy problem

Provides dark matter (WIMPS)

unifies coupling constants

.....lots more

Supersymmetric Standard Model

ble spectrum –

rks ≡

ons ≡

gluino –

W_2 –

Z_4 –

Z_3 –

H_+ –

H_A –

H_h –

W_1 –

Z_2 –

Z_1 –

H_l –

charginos

neutralinos

Higgs

- $\chi_1^{\pm}$, wino
- χ_2^0, zino
- χ_1^0, photino, LSP

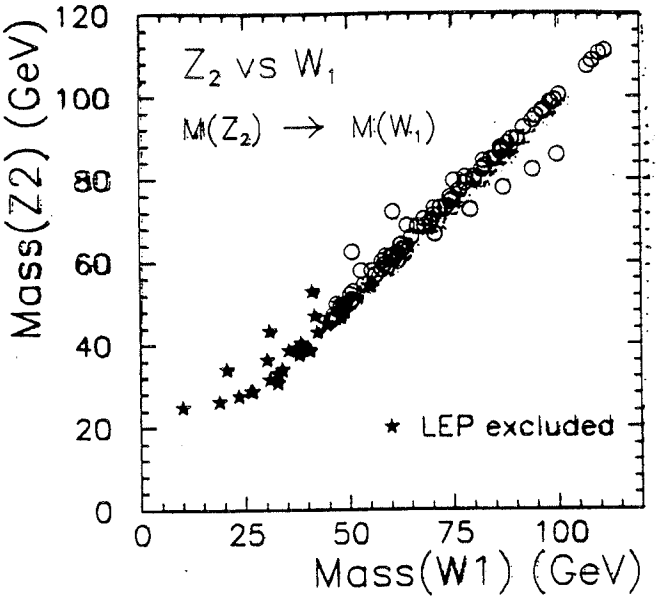
MSSM Mass Correlations

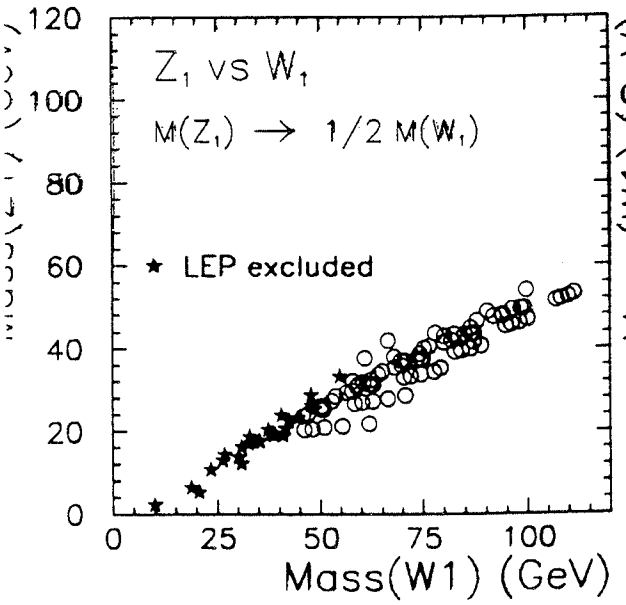
MSSM Correlations
(ISASUSY –Baer, et al)

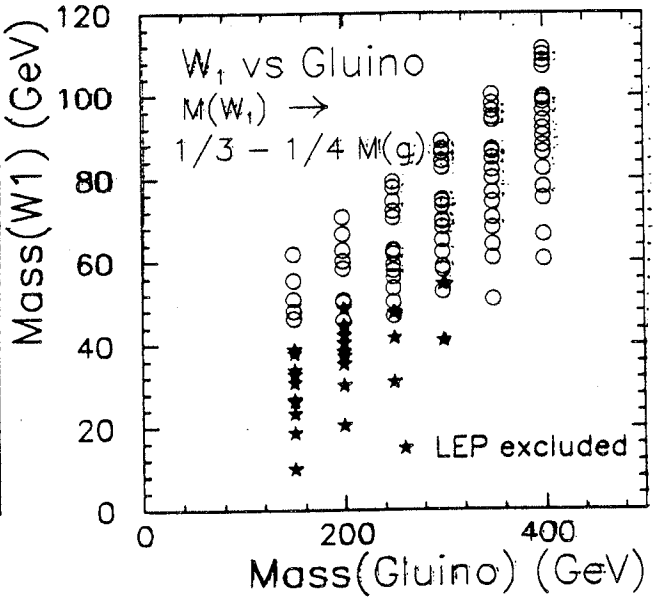
μ $-500 \rightarrow 500$
$\tan\beta$ 2, 10
Mq = 500, Ml = 200 GeV

Current limits (LEP)

$M(W_1) > 45$ GeV

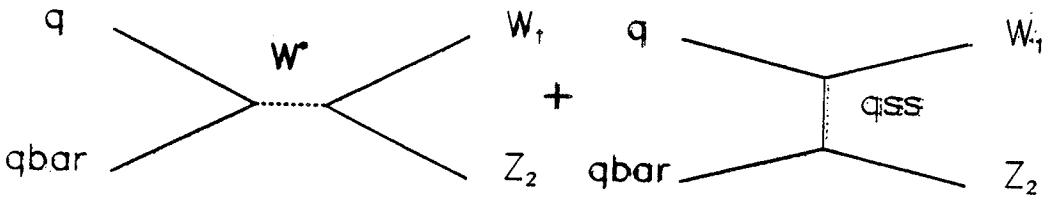




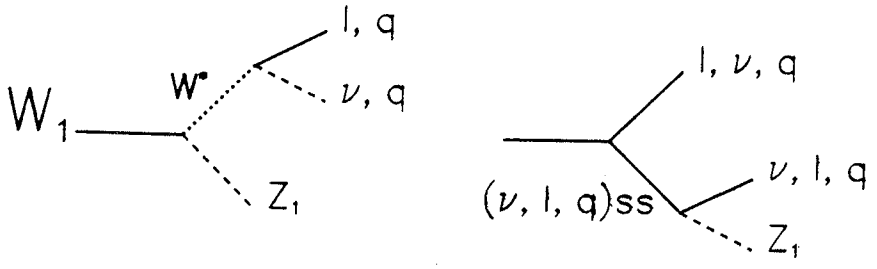


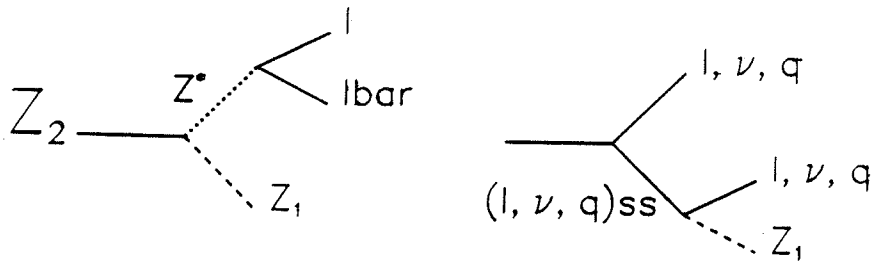
$W_1 Z_2$ Signal

Production – p pbar collisions



Decays (dominant)





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

W_1 Z_2 signal (cont)

Signatures (excluding $\nu\nu$)

	W_1	Z_2	mode
	q qbar Z_1	q qbar Z_1	4 jets + missing pt
	l ν Z_1	q qbar Z_1	l + 2 jets + missing pt
	q qbar Z_1	l lbar Z_1	2 l + 2 jets + missing p
★★	l ν Z_1	l lbar Z_1	3 l + missing pt

This Analysis -- trilepton channel

W_1 Z_2 $\rightarrow$

e e e + X (X = missing Pt

e e μ + X + initial state radiation)

e μ μ + X

μ μ μ + X

Theoretical discussions (ppbar, 2 TeV)

(Arnowitt and Nath), (Baer and Tata),

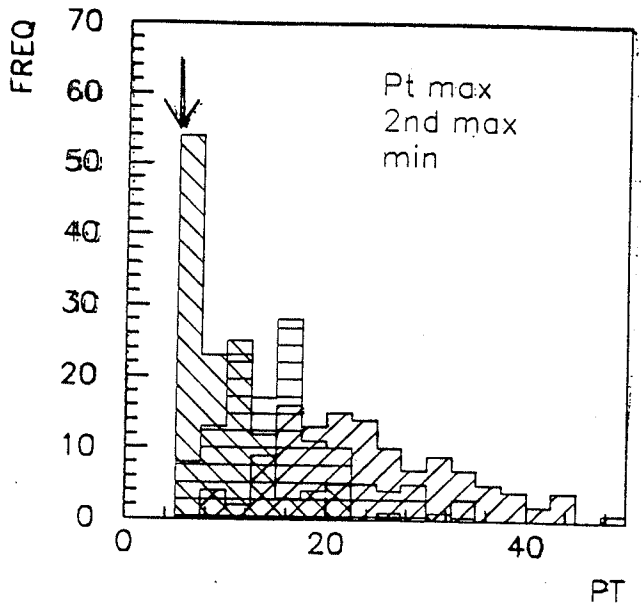
(Barbieri et al), (Lopez, Nanopoulos, Zichichi et al)

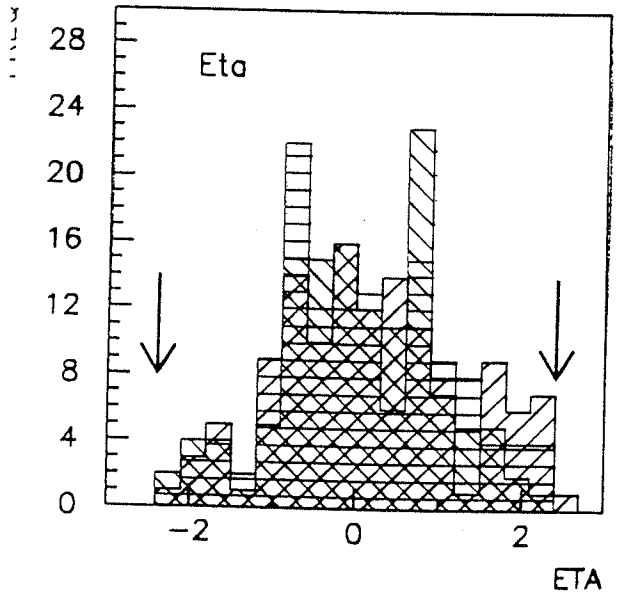
W1 Z2 kinematics – D0 PRELIMINARY

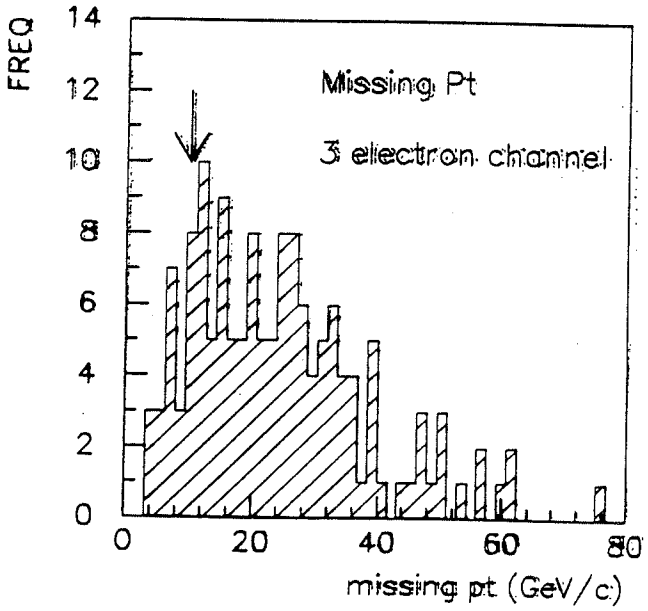
W_1, Z_2 Kinematic variables

$M(W_1) = 65$ GeV

(ISASUSY)







$W_1 Z_2 \rightarrow e\ e\ e$

DATA

ALL stream – $\int Ldt = 14.8 \pm 1.8\ pb^{-1}$

TRIGGERS

1 EM* – pt > 20 GeV/c

2 EM – pt > 10 GeV/c

OFFLINE SELECTION

3 electrons, pt > 7 + trigger

missing pt > 10 GeV/c

RESULT

0 events

PRELIMINARY estimated background < 1.1 events

* EM == cal. cluster with shape consistent with an electron

$W_1 Z_2 \rightarrow e\ e\ \mu$

DATA

Express– top $\rightarrow e\mu$ selection

$\int Ldt = 15.2 \pm 1.8\ pb^{-1}$

TRIGGERS

1 EM cluster, pt > 7 + 1 μ, pt > 5 GeV/c

2 EM clusters, pt > 20 GeV/c

1 EM cluster, pt > 20, missing pt > 20 GeV/c

OFFLINE SELECTION

1μ, pt > 10, $|\eta| < 1.7$

1 electron, pt > 10, $|\eta| < 2.4$

2nd electron, pt > 5, $|\eta| < 2.4$

$\Delta R\ \mu$ – jet, electron, photon > 0.4

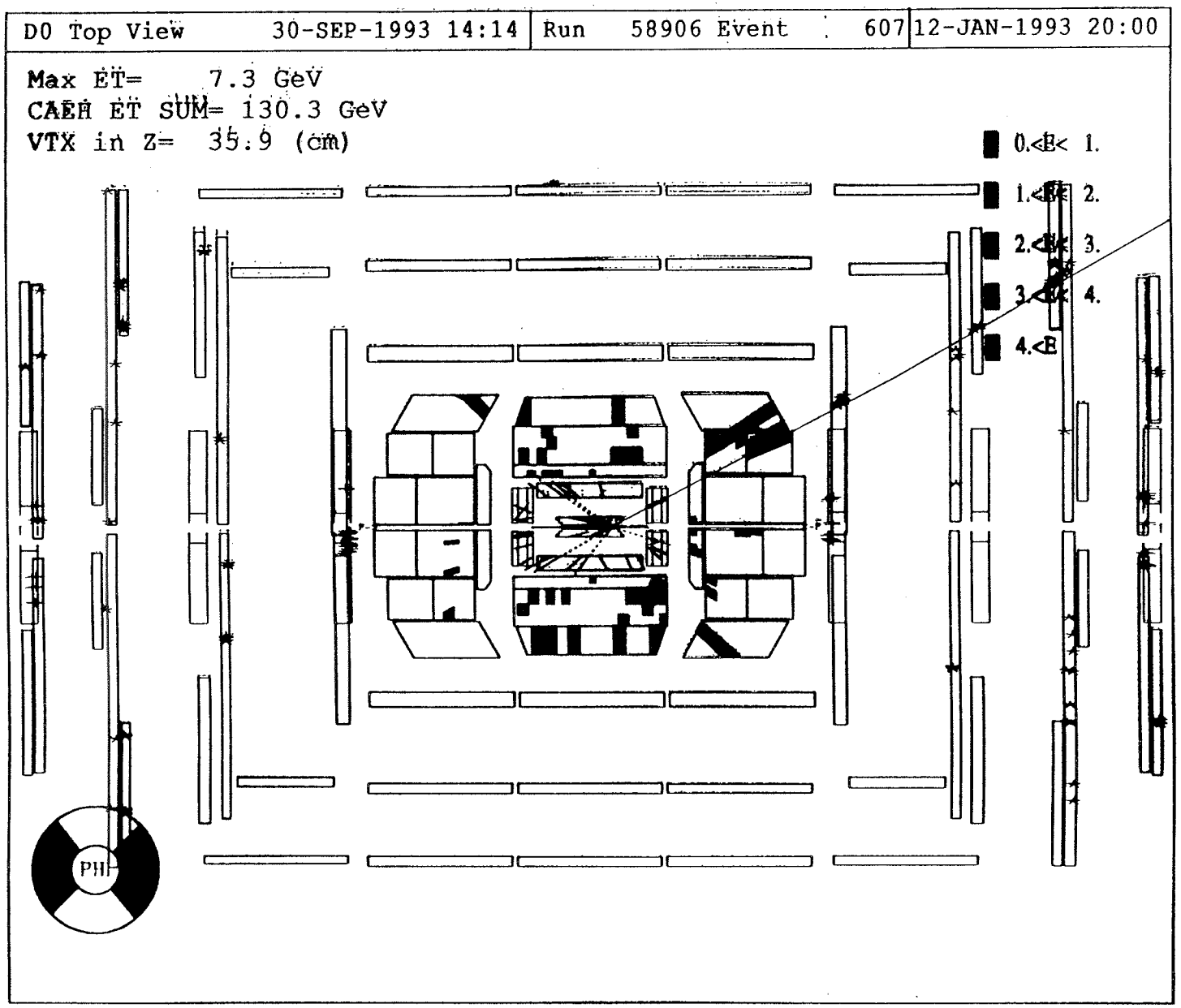
RESULT

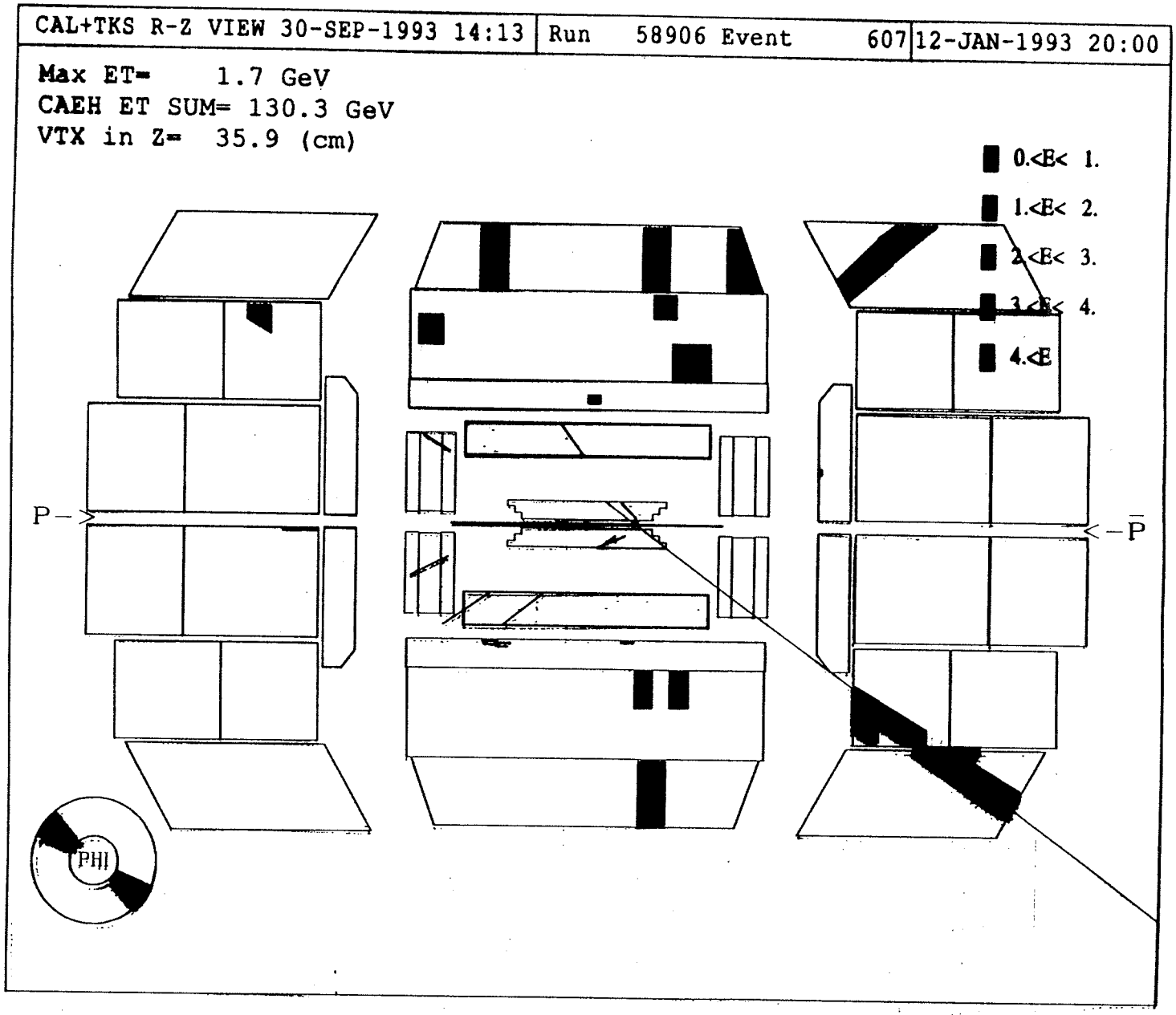
1 event passes cuts

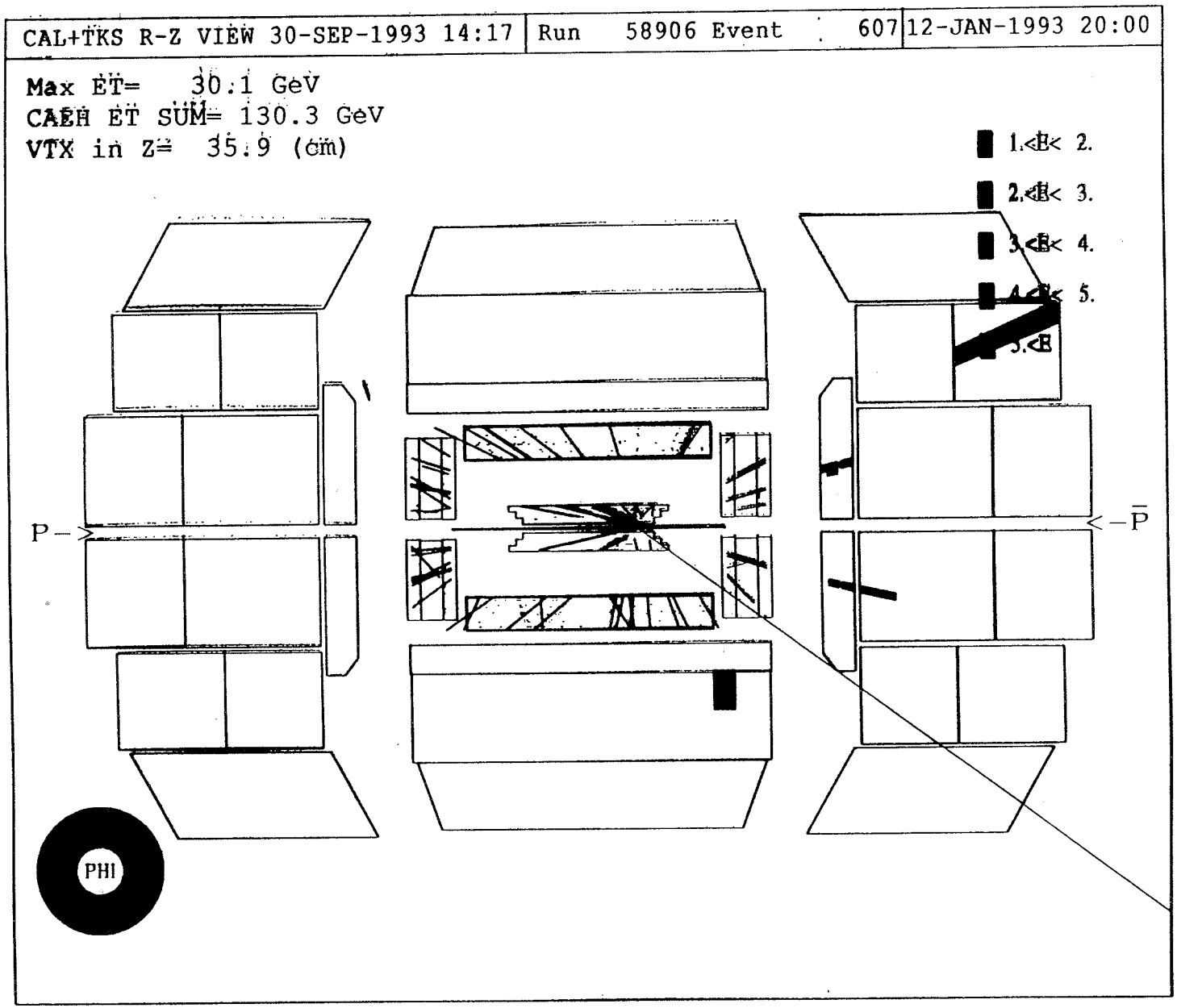
PRELIMINARY estimated background < 0.5 events

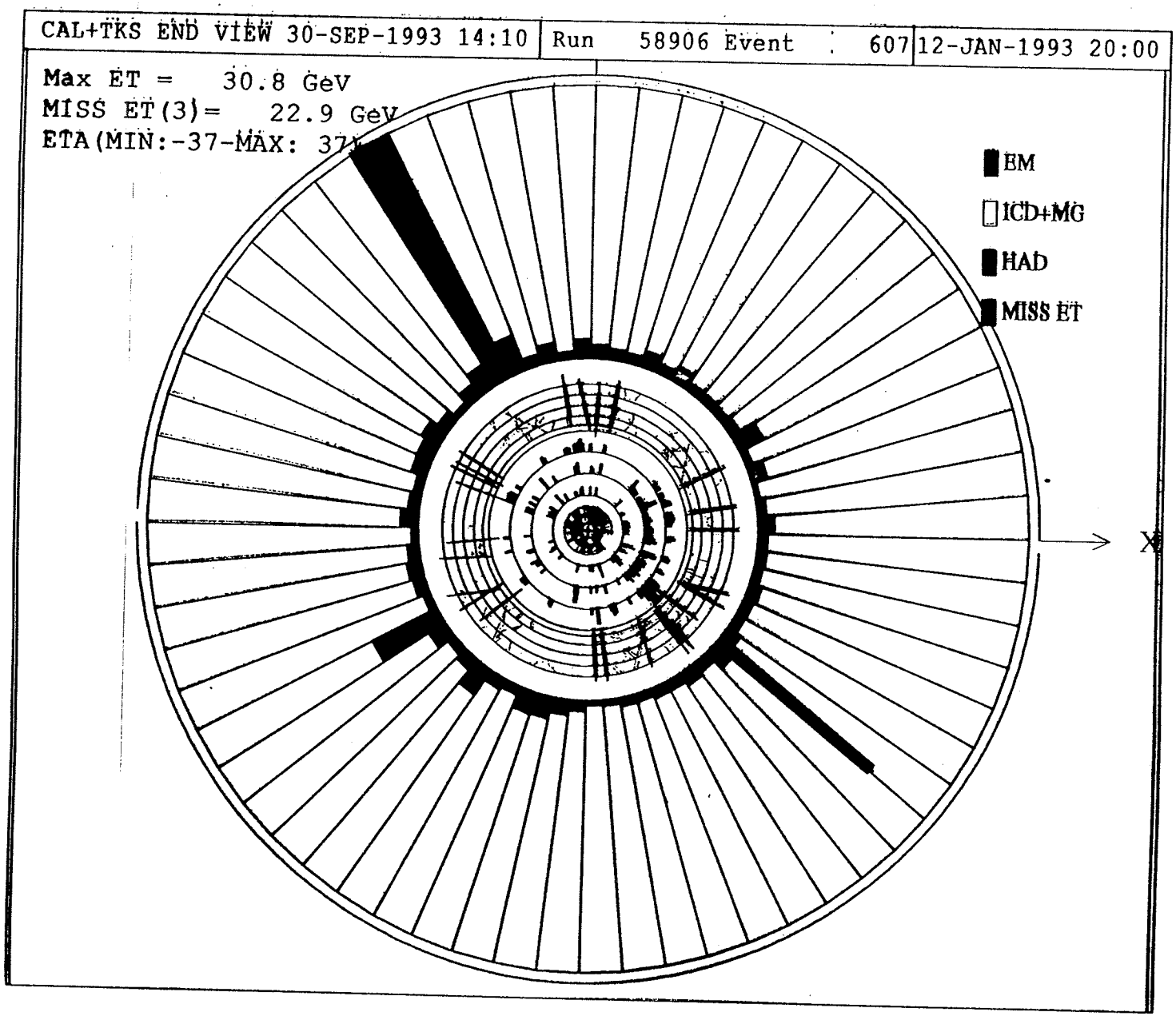
DOMINANT $Z^0 \rightarrow \tau\tau\gamma$, 0.3 events

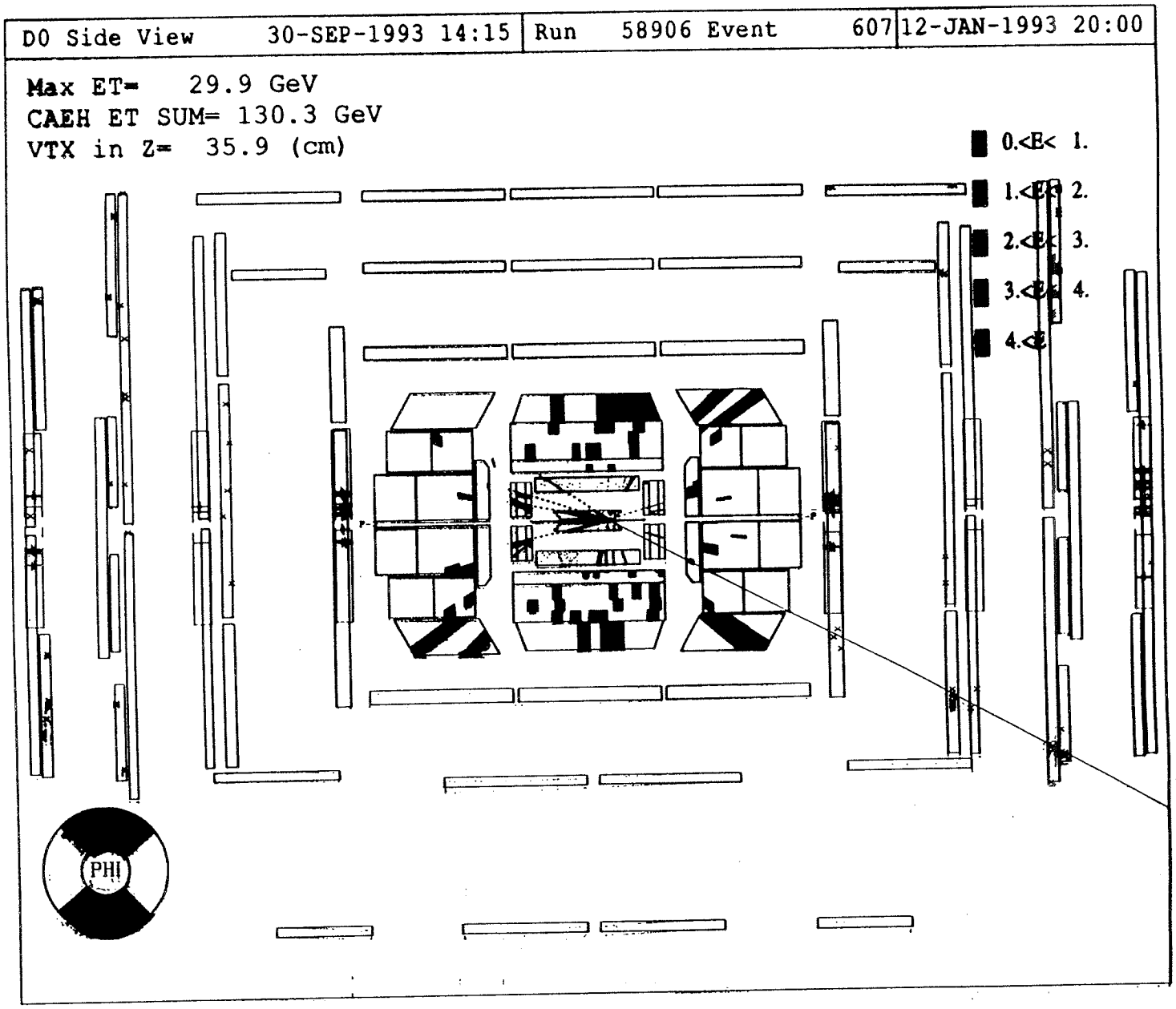
($\tau \rightarrow e$, $\tau \rightarrow \mu$, γ–convt)


D0 Top View
30-SEP-1993 14:14
Run 58906 Event 607
12-JAN-1993 20:00
Max ET= 7.3 GeV
CAEH ET SUM= 130.3 GeV
VTX in Z= 35.9 (cm)
0.<E< 1.
1.<E< 2.
2.<E< 3.
3.<E< 4.
4.<E
PH


CAL+TKS R-Z VIEW 30-SEP-1993 14:13
Run 58906 Event 607
12-JAN-1993 20:00
Max ET= 1.7 GeV
CAEH ET SUM= 130.3 GeV
VTX in Z= 35.9 (cm)
0.<E< 1.
1.<E< 2.
2.<E< 3.
3.<E< 4.
4.<E
P
$\bar{P}$
PHI


CAL+TKS R-Z VIEW 30-SEP-1993 14:17
Run 58906 Event 607
12-JAN-1993 20:00
Max ET= 30.1 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
P
P
PHI


CAL+TKS END VIEW 30-SEP-1993 14:10
Run 58906 Event 607
12-JAN-1993 20:00
Max ET = 30.8 GeV
MISS ET(3)= 22.9 GeV
ETA(MIN:-37-MAX: 37)
EM
ICD+MG
HAD
MISS ET
X


D0 Side View 30-SEP-1993 14:15 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)
0.<E< 1.
1.<E< 2.
2.<E< 3.
3.<E< 4.
4.<E
PHI

$W_1 Z_2 \rightarrow e \mu \mu$

DATA

Express– top $\rightarrow e\mu$ selection

$\int Ldt = 15.2 \pm 1.8\ pb^{-1}$

TRIGGERS

1 EM cluster– PT > 7 + 1 μ, pt > 5 GeV/c

1 μ– pt > 15, 1 μ– pt > 10 GeV/c

1 EM cluster– PT > 20, missing pt > 20 GeV/c

OFFLINE SELECTION

1 electron– pt > 10, $|\eta| < 2.4$

1 μ – pt > 10, $|\eta| < 1.7$

2nd μ– pt > 5, $|\eta| < 1.7$

Mass $\mu\mu$ min > 5 GeV

ΔR μ – jet, electron, photon > 0.4

RESULT

0 events

PRELIMINARY estimated background < 0.5 events

$W_1 Z_2 \rightarrow \mu\mu\mu$

DATA

ALL Stream– latest reconstruction

$\int Ldt = 5.0 \pm 0.6\ pb^{-1}$

TRIGGERS

1 μ– pt > 15 GeV/c, $|\eta| < 1.7$

2 μ– pt > 3 GeV/c $|\eta| < 1.7$

SELECTION

3μ– pt > 5, $|\eta| < 1.7$

ΔR μ–jet,electron, photon > 0.4

Mass $\mu\mu$ min > 5 GeV

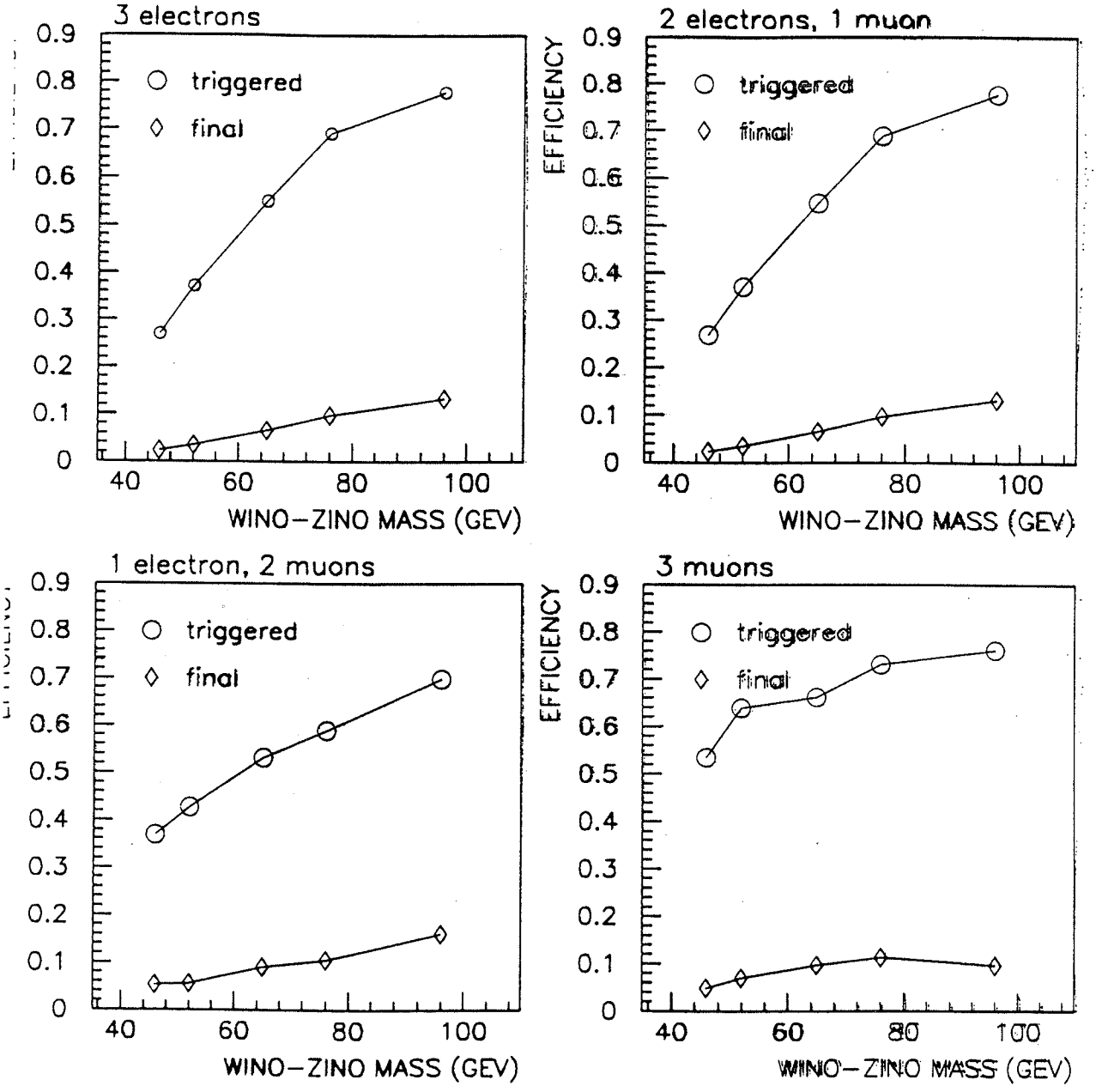
RESULT

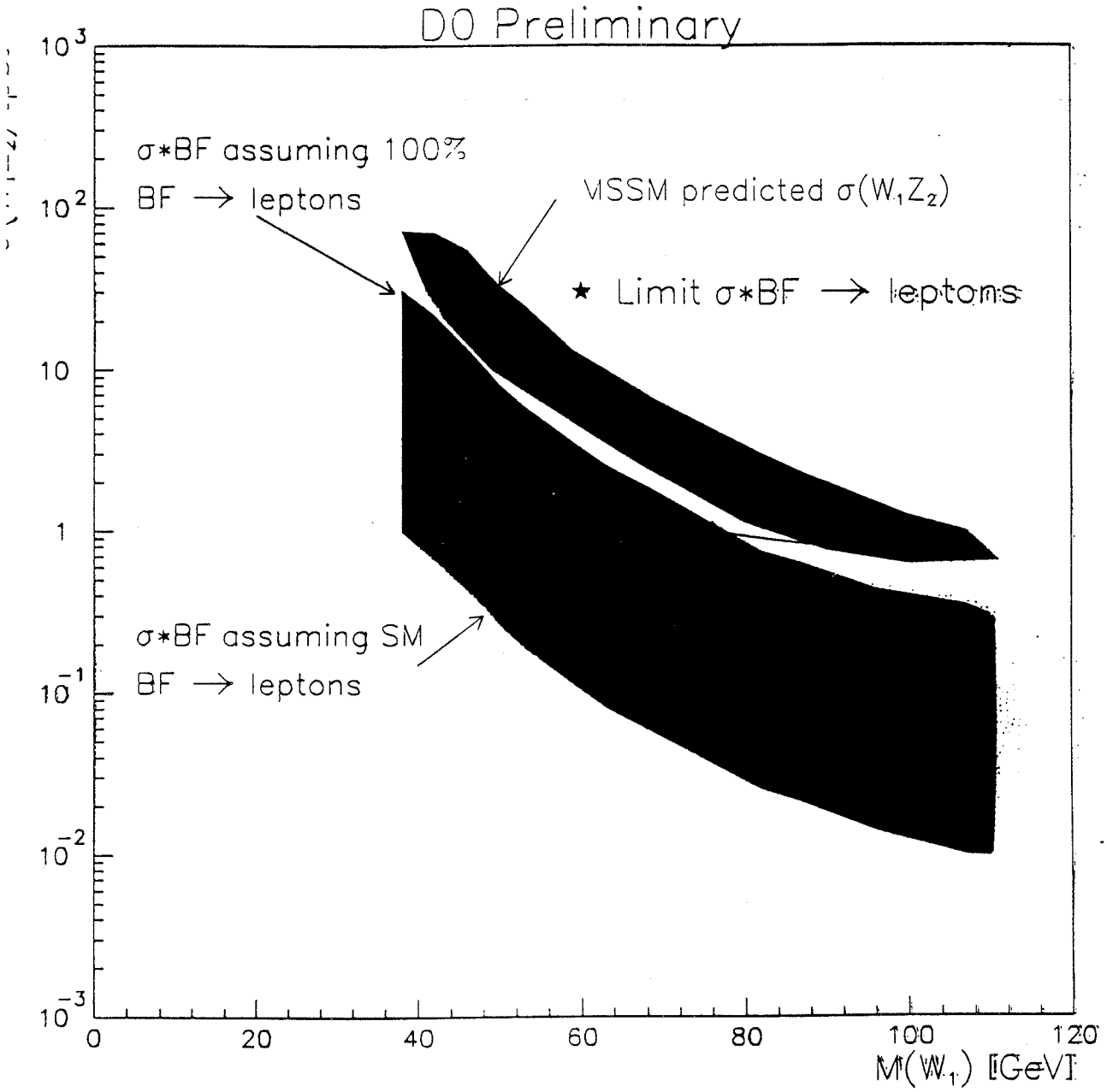
7 events pass cuts

event scan – all cosmic rays/ misc

0 events pass scan

PRELIMINARY est. physics background < 0.2 events


3 electrons
triggered
final
EFFICIENCY
WINO–ZINO MASS (GEV)
2 electrons, 1 muon
triggered
final
EFFICIENCY
WINO–ZINO MASS (GEV)
1 electron, 2 muons
triggered
final
WINO–ZINO MASS (GEV)
3 muons
triggered
final
EFFICIENCY
WINO–ZINO MASS (GEV)


D0 Preliminary
σ*BF assuming 100%
BF → leptons
MSSM predicted σ(W1Z2)
★ Limit σ*BF → leptons
σ*BF assuming SM
BF → leptons
10^3
10^2
10
1
10^-1
10^-2
10^-3
0
20
40
60
80
100
120
M(W1) [GeV]

Conclusions

★ **1st Generation Leptoquarks:**

→ Final Results Presented

→ Mass Limits 95pct CL

$M(LQ) > 133$ GeV $- \beta=1$

$M(LQ) > 120$ GeV $- \beta=0.5$

★ **W1 Z2 -> trileptons**

→ Results PRELIMINARY

→ Limits on $\sigma \times BF \rightarrow$ leptons – 95pct CL

(based on subset of 15 pb^{-1}, 1 signal event)

< 1.9 pb $-$ $M(W_t) = 52$ GeV

$< .99$ pb $-$ $M(W_1) = 76$ GeV

→ Analysis of full data set in progress

★ **Run 1b begins Nov. 93**

→ Expect ≥ 50 pb^{-1} at Ecm = 2 TeV

→ Reach increase $\times$ 3 $\rightarrow$ 5 – estimated

Conclusions

★ **1st Generation Leptoquarks:**

→ Final Results Presented

→ Mass Limits 95pct CL

$M(LQ) > 133$ GeV $- \beta = 1$

$M(LQ) > 120$ GeV $- \beta = 0.5$

★ **W1 Z2 -> trileptons**

→ Results PRELIMINARY

→ Limits on $\sigma \times BF \rightarrow$ leptons – 95pct CL

(based on subset of 15 pb^{-1}, 1 signal event)

< 1.9 pb $- M(W_1) = 52$ GeV

$< .99$ pb $- M(W_1) = 76$ GeV

→ Analysis of full data set in progress

★ **Run 1b begins Nov. 93**

→ Expect ≥ 50 pb^{-1} at Ecm = 2 TeV

→ Reach increase $\times$ 3 $\rightarrow$ 5 – estimated