Recent Results from DØ

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for the DØ Collaboration

- **Top Quark**
- **Electroweak**
- **New Phenomena**
- b **Physics**
- **QCD**

Madison, PHENO 97

March 1997

DØ Talks

- I. Bertram
  Dijet Production and Angular Distributions at DØ
- P. Bloom
  Search for WW, WZ Production at DØ
- W. Chen
  Di-Photon Production at DØ
- H. da Motta
  DØ Future Plans on Diffractive Studies
- P. Hanlet
  Direct Photon Production at DØ
- D. Hedin
  Leptoquark Results from DØ
- R. Hirosky
  DØ Inclusive Jet Production at $\sqrt{s} = 1800$ GeV
- T. Joffe-Minor
  QCD with W's at DØ (w+1jet/W=0+jet and Coherence)
- S. Jun
  BFKL Physics at DØ
- A. Kostritski
  Charmonium Production
- J. Perkins
  Hard Diffraction and Rapidity Gaps at DØ
- R. Snihur
  Jet Structure Studies at DØ

Top Quark Results

New Results (Feb97) $\Rightarrow$

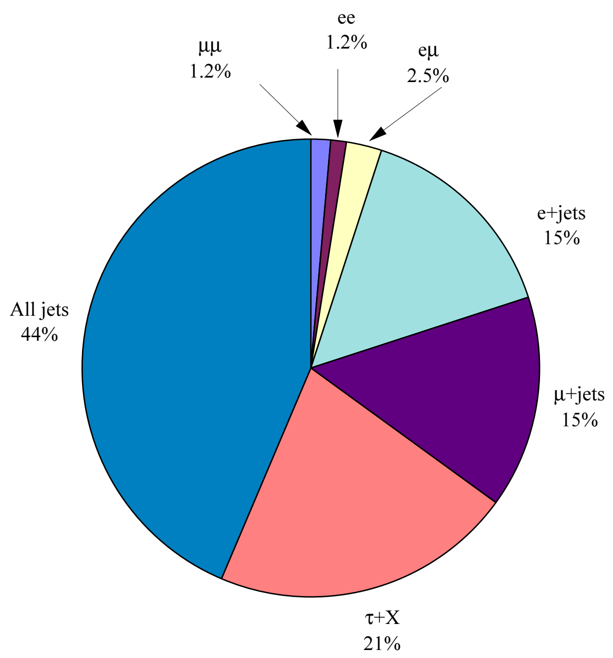
- m_{top} **measurement**
- $t\bar{t}$ **production cross section**

$\star$ **at the Tevatron, top quarks are pair-produced via** $q\bar{q} \rightarrow t\bar{t}$ $(\approx 90\%)$ **and** $gg \rightarrow t\bar{t}$ $(\approx 10\%)$

$\star$ **within the Standard Model, each** t **decays via** $t \rightarrow W + b$ **with a branching fraction of** 100%

$\star$ **each** W **decays either via** $W \rightarrow l\bar{\nu}$ **or** $W \rightarrow q\bar{q}$

$\star$ **classify channels according to** W **decay mode:**
dilepton, lepton + jets, all jets



Top Mass Analysis

- **m_{top} from dilepton channel:**
  - $\Rightarrow m_{top} = 158 \pm 24(stat) \pm 10(syst)$ **GeV**
  - $\rightarrow$ **updated value in progress**

$\star$ **NEW m_{top} measurement from lepton + jets channel**
  - $\Rightarrow$ **submitted to PRL**
    (hep-ex/9703008 or Fnal-Pub-97/059-E)

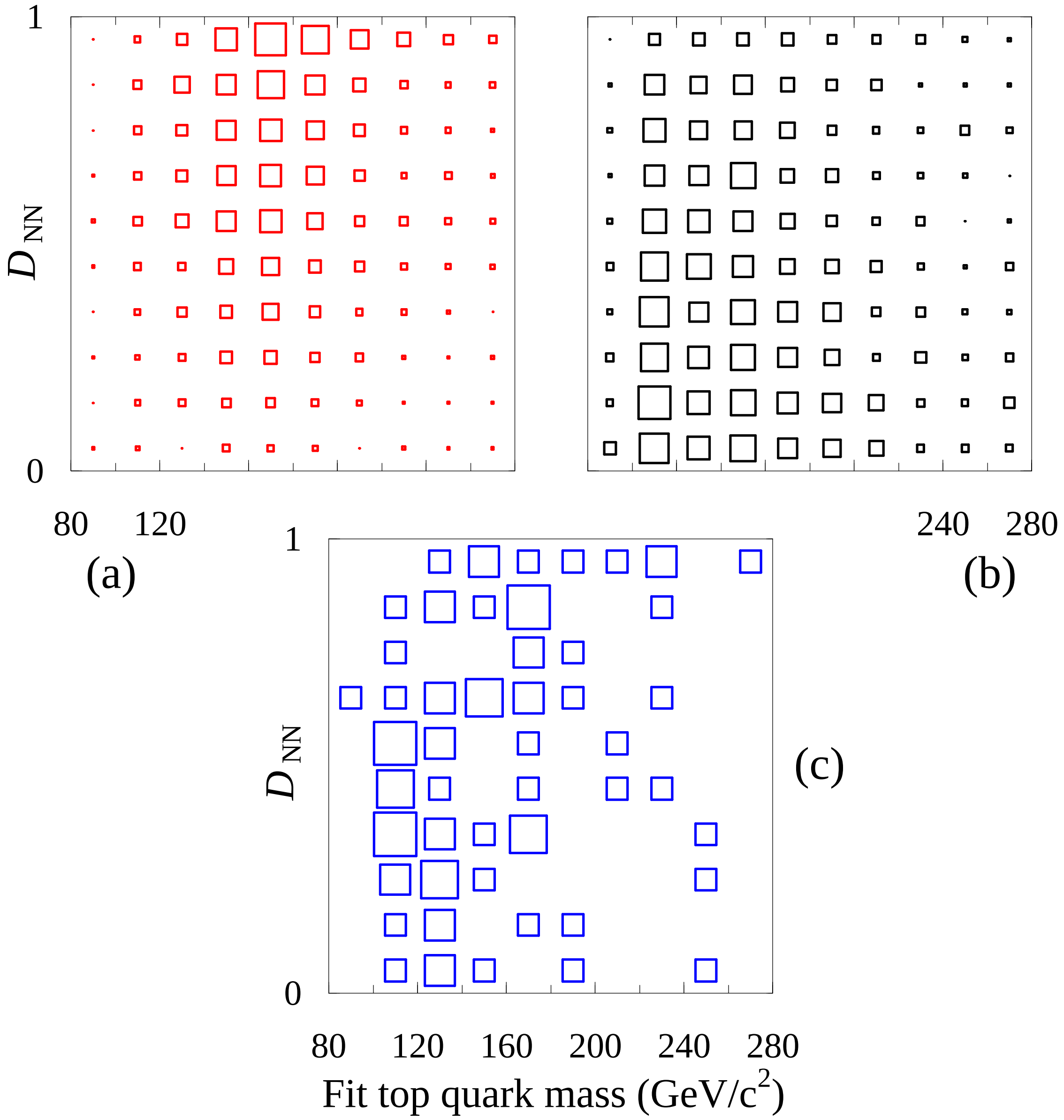
Mass from lepton + jets channel $\Rightarrow$

Changes since value at Warsaw 96:

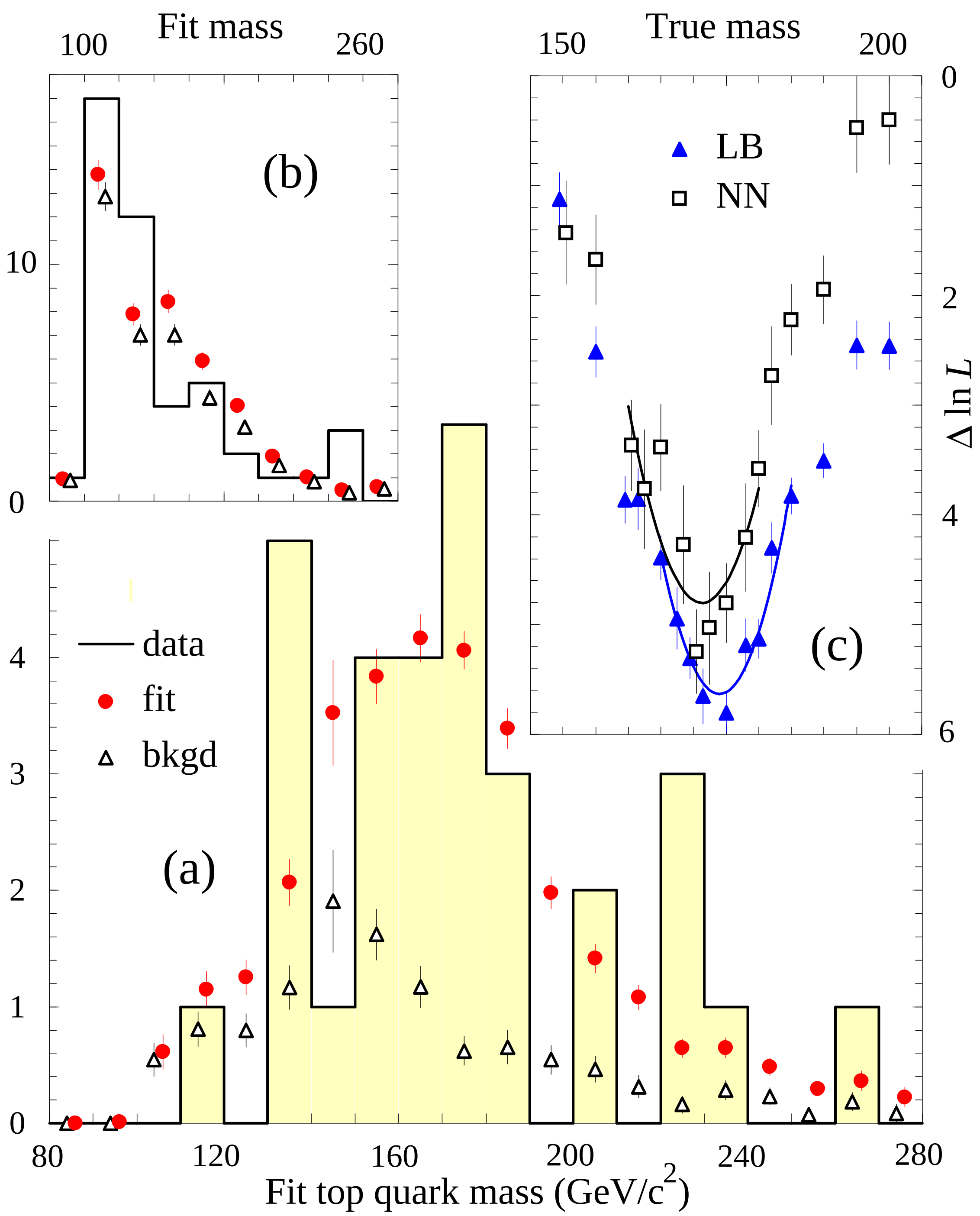
- **jet energy scale error reduced**
- **optimized analysis**
  - **developed multivariate discriminate of signal probability ($\mathcal{D}$) with improved signal to background discrimination**
  - **2 different multivariate analyses used to calculate $\mathcal{D}$**
    - **(LowBias or NeuralNetwork methods)**
  - **do 2D fit using both fitted top mass and $\mathcal{D}$ for each event**

final event sample: 77 events selected, 5 with b–tag

Top Mass Analysis
Multi-variate Discriminate vs. m_{top}



Top Quark Mass



$m_{top} = 173.3 \pm 5.6(stat) \pm 6.2(syst)$ **GeV**

Top Quark Production Cross Section

Summary of Analysis

8 Channels

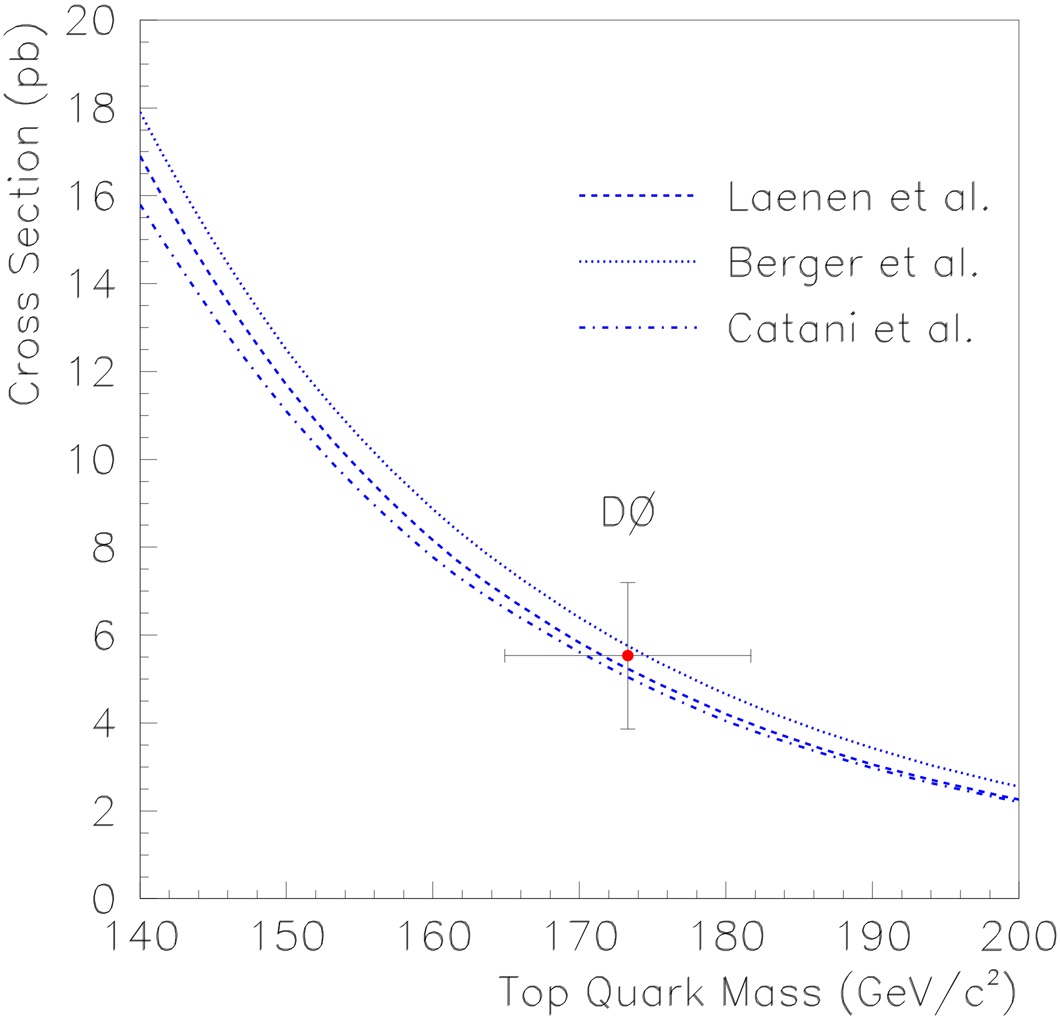
- ~125 pb^{-1} (full 1992 - 1996 statistics)

	Number of Events		
Channel	Top*	Bkg	Data
eμ	2.16±0.46	0.21±0.15	3
ee	1.20±0.16	0.47±0.07	1
μμ	0.64±0.08	0.73±0.20	1
eν	1.66±0.36	1.16±0.34	4
e+jets	8.63±1.16	4.51±0.91	9
μ+jets	5.51±1.48	4.16±1.02	10
e+jets/tag	3.59±0.54	0.97±0.40	5
μ+jets/tag	2.25±0.55	1.40±0.23	6
Total	25.6±3.8	13.6±2.1	39

*Top cross section from Laenen, *et al*, Phys. Lett. **321B**, 254 (1994) with m_t =170 GeV/c^2

at $m_{top} = 173.3$ **GeV** $\Rightarrow \sigma_{tt} = 5.53 \pm 1.67$ **pb**

Top Quark Results



$$m_{top} = 173.3 \pm 5.6(stat) \pm 6.2(syst)\ \textbf{GeV}$$

$$\sigma_{t\bar{t}} = 5.53 \pm 1.67\ \textbf{pb}$$

New World Average:

$$m_{top} = 175.6 \pm 5.5\ \textbf{GeV}$$

Electroweak Results

Have results on:

$\Rightarrow$ W, Z **production cross sections** (e, μ **channels)**

$\Rightarrow$ W **width - indirect**

$\Rightarrow$ W **charge asymmetry from** $W \rightarrow \mu\nu$

$\Rightarrow$ $W \rightarrow \tau\nu$ **production**

$\Rightarrow$ W **mass**

- **Run 1A - published**
- **Run 1B - preliminary**
- **Run 1A - ratio method, preliminary**

$\Rightarrow$ **DiBoson Production - anomalous couplings**

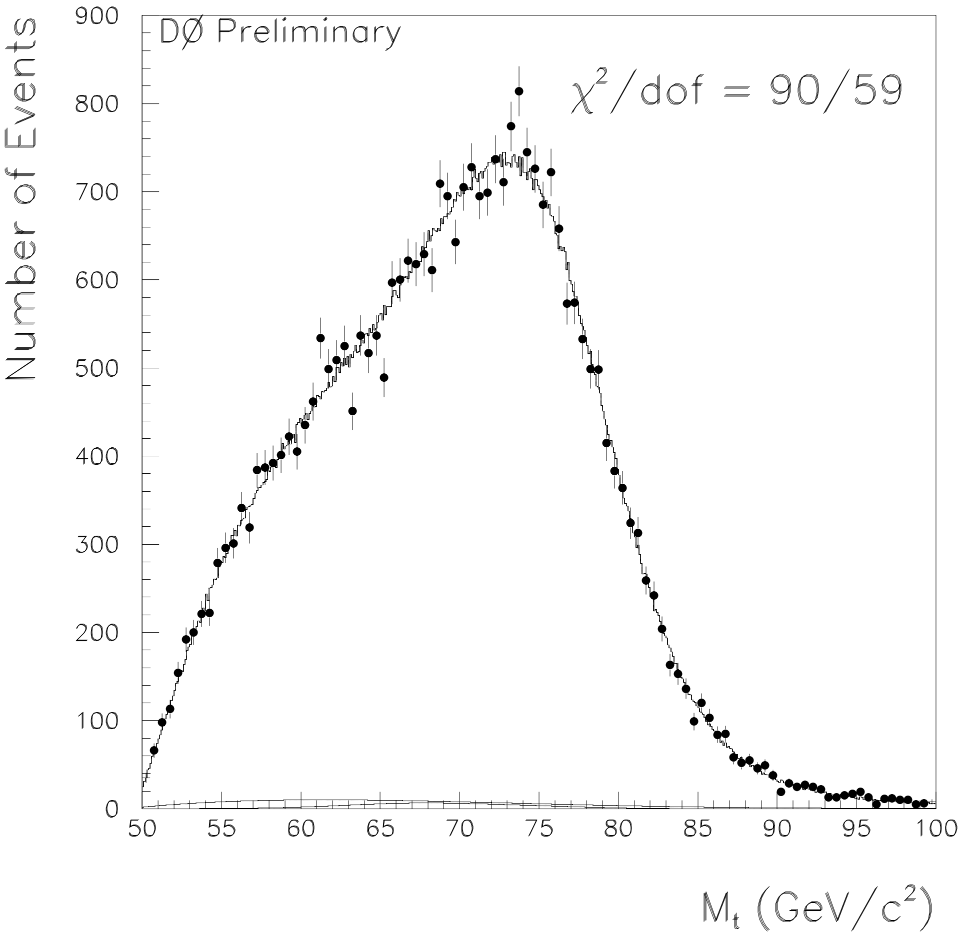
- **study** $W\gamma, WW, WZ, Z\gamma$ **production**

Also working on:

$\Rightarrow$ W **width - direct measurement**

DØ Run 1B:
M_W - from Fit to Transverse Mass Spectrum

(fitting window 60 - 90 GeV)



Preliminary:

$$M_W(\text{Run 1B}) = 80.380 \pm 0.070(stat.) \pm 0.080(scale) \pm 0.130(syst.)\ \text{GeV}/c^2$$

DØ M_W - Errors on $M_T(W)$ Fit

Run 1A: PRL 77 (1996) 3309.

Run 1B (preliminary): FNAL-Conf-96/199-E

Source	$\sigma(M_W)$ (MeV) Run 1B	Run 1A
Statistical	70	140
Energy Scale	80	160
Systematic	130	165
EM Energy Resolution	30	70
Hadronic Energy Resolution	20	65
P_T^W, pdf	65	65
# of Min. Bias Events	40	60
Hadronic Energy Scale	30	50
Electron Angle Calibration	40	50
Underlying Event	30	35
Backgrounds	15	35
Efficiencies	20	30
W Width	10	20
Radiative Decays	20	20
Non-Uniform energy response (η)	10	10
Fit Error	5	5
Luminosity Dependence*	70	
Total	170	270

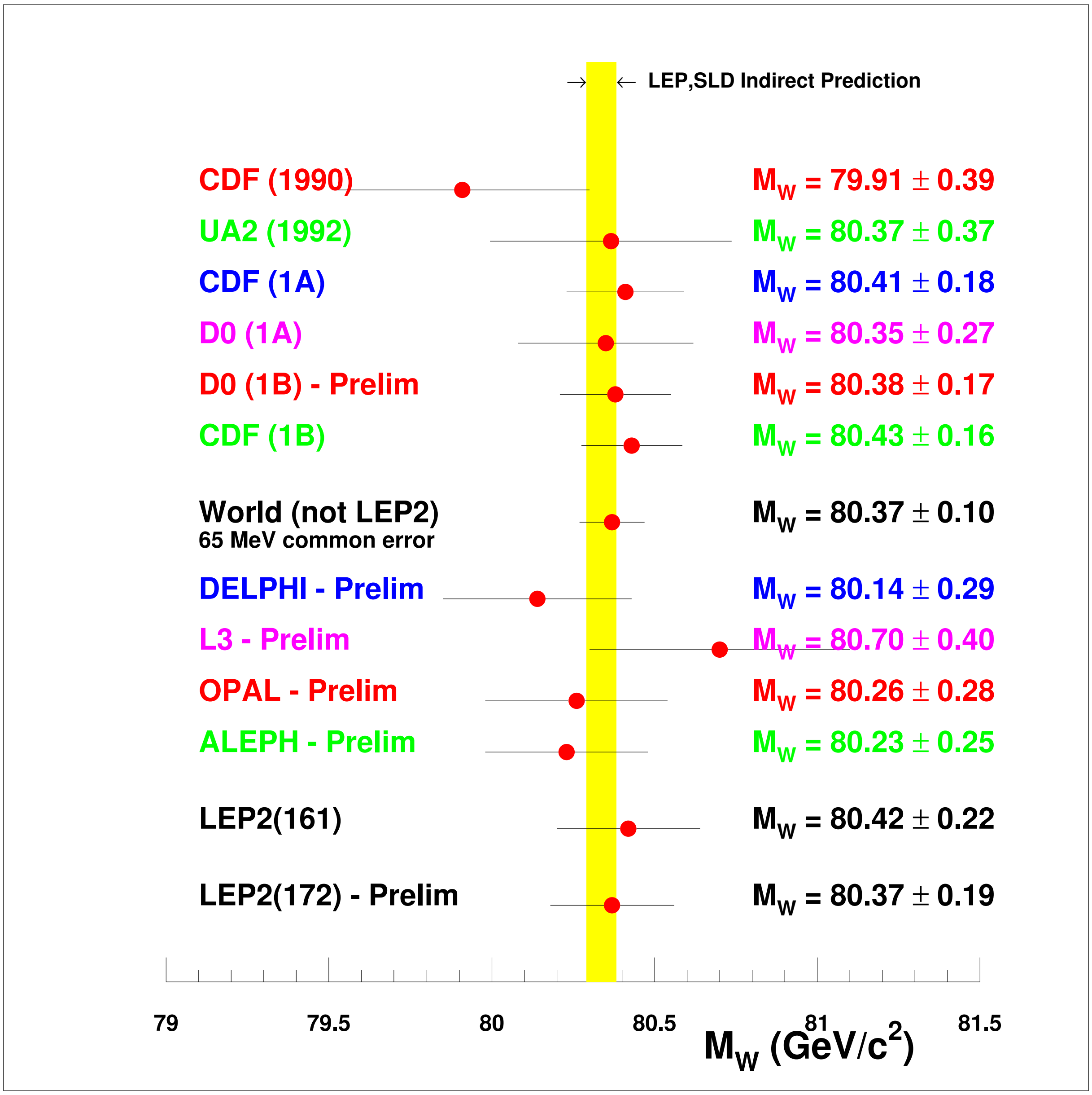
$M_W(\text{Run1A}) = 80.350 \pm 0.140(stat.) \pm 0.160(scale) \pm 0.165(syst.)\ \text{GeV/c}^2$

$M_W(\text{Run1B}) = 80.380 \pm 0.070(stat.) \pm 0.080(scale) \pm 0.130(syst.)\ \text{GeV/c}^2$

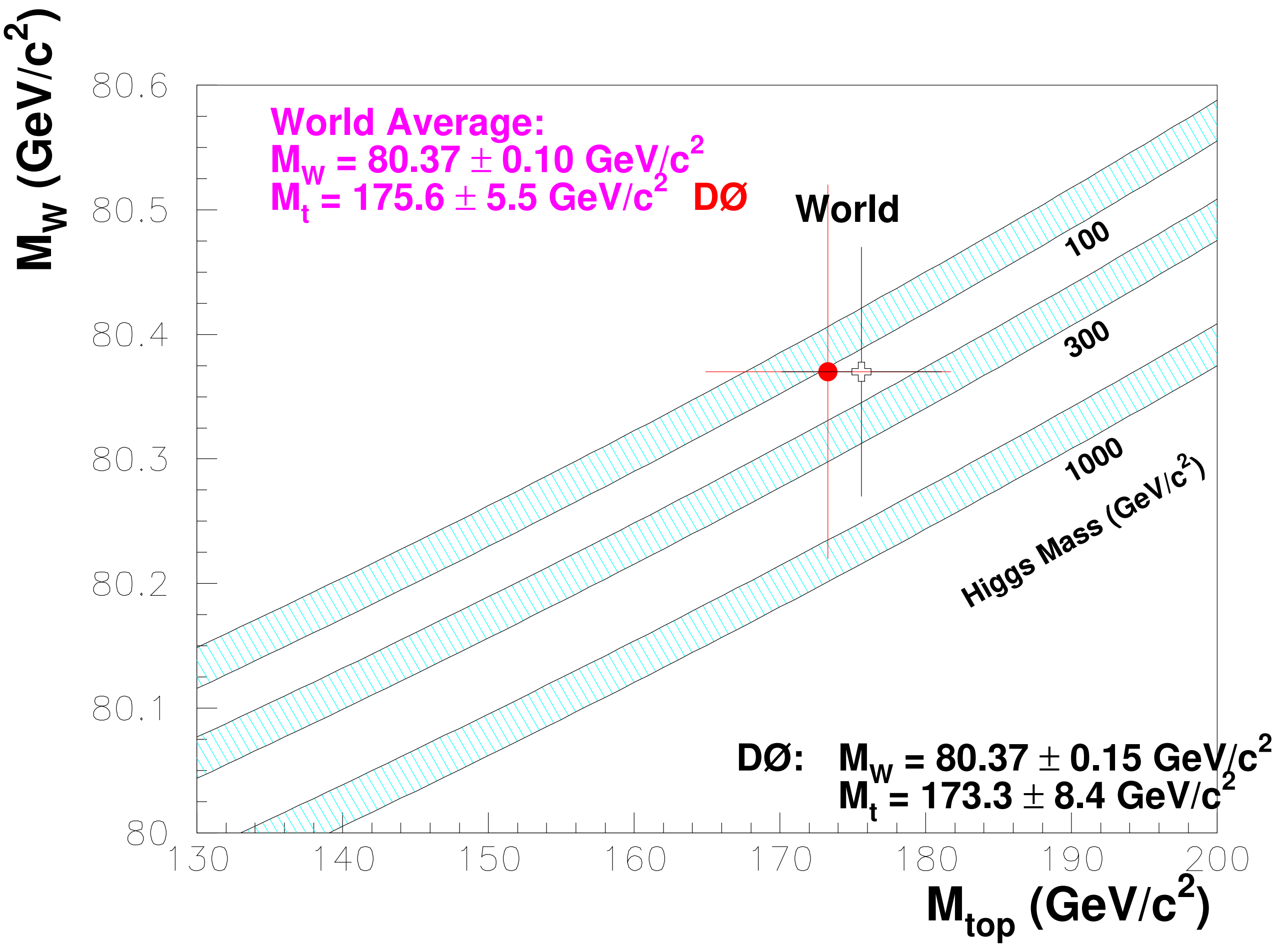
$\Rightarrow$ Expect to know W mass to $\approx$ 100 MeV from DØ Run 1 !!

- ΔM_W(1B) will decrease + have events with forward e's

Current Results of M_W - March 97

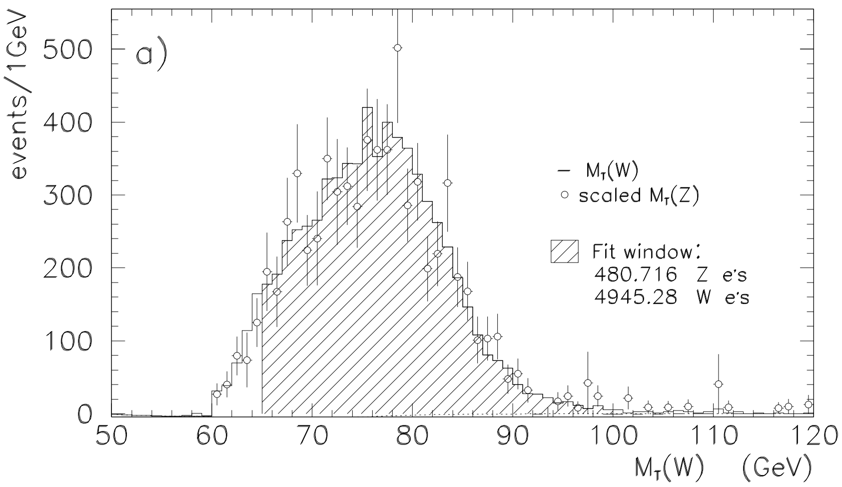


Constraints on Higgs Mass



M_W - Using M_T^W/M_T^Z Ratio Method

- assume W and Z production and decay are similar
- turn Z into W by treating 1 electron as a ν and computing M_T
- scale down and "oversmear" M_T^Z distribution
  - compare with M_T^W
- M_W determined from scale factor that gives best match of M_T distributions



Run 1A - Preliminary (Fnal-Conf-96/452-E)

$\Rightarrow M_W = 80.16 \pm 0.36(stat) \pm 0.075(syst)$ GeV

DiBoson Production
$\rightarrow$ Study of Anomalous Couplings

In **SM**, have triple gauge boson couplings:

$WW\gamma$

$WW\gamma, WWZ$

WWZ

$ZZ\gamma, Z\gamma\gamma$

not allowed in SM

Measurement of self-interaction is crucial test of SM
$\rightarrow$ Deviation is a signature for new physics

- $WW\gamma$ and WWZ coupling parameters in the SM
  $\kappa = 1\ (\Delta\kappa = \kappa - 1 = 0) \qquad \lambda = 0$
- To avoid unitarity violations, the anomalous couplings are parameterized as form factors with scale $\Lambda(= 1.5)$ TeV

$$\Delta\kappa \rightarrow \frac{\Delta\kappa}{(1 + \frac{s}{\Lambda^2})^n} \quad (n = 2)$$

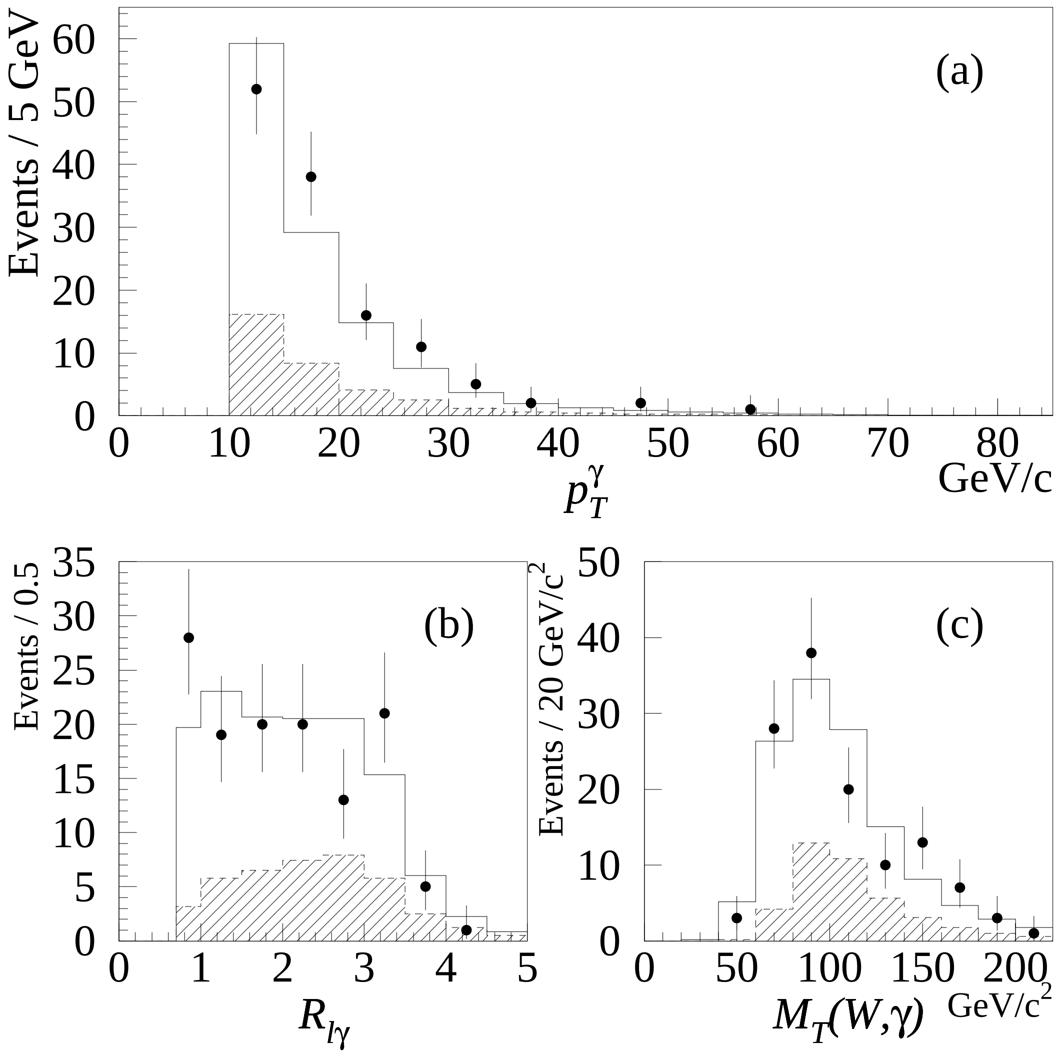
- $ZZ\gamma$ and $Z\gamma\gamma$ coupling parameters in the SM
  $h_{30}, h_{40} = 0$

Anomalous Couplings:
$\rightarrow$ increased cross section
$\rightarrow$ different kinematic configurations
(harder p_T spectrum)

$W\gamma$ Production

DØ run 1A results - [PRL 75, 1034 (1995)]

Preliminary run 1B results (Fnal-Pub-96/434-E, accepted by PRL)



Fit p_T^{γ} spectrum from data to MC simulation

(MC: event generator by Baur et al. + detector modeling)

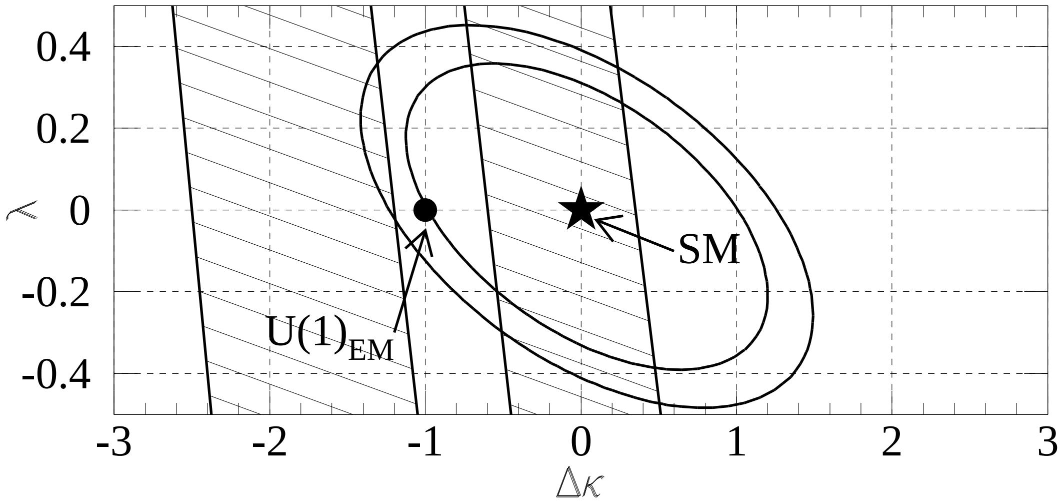
Extract limits on anomalous couplings

$W\gamma$ Production

1 DOF and 2 DOF 95% CL exclusion contours

DØ run 1A results - [PRL 75, 1034 (1995)]

Preliminary run 1B results (accepted by PRL)



⇒ DØ 1A & 1B combined limits

$$-0.98 < \kappa - 1 < 1.01 \quad (\lambda = 0)$$

$$-0.33 < \lambda < 0.31 \quad (\kappa = 1)$$

⇒ at 88% CL, it is ruled out that γ couples only to U(1) electric charge (and not weak charge) of the W boson (95% CL if assume $\lambda = 0$)

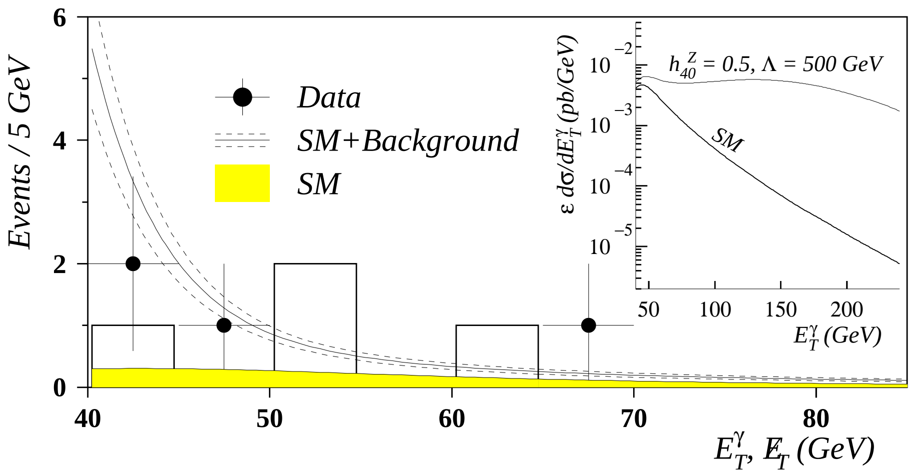
$Z\gamma$ Production

DØ 1A: $Z\gamma \rightarrow ee\gamma, \mu\mu\gamma$ limits published [PRL 75, 1028 (1995)]

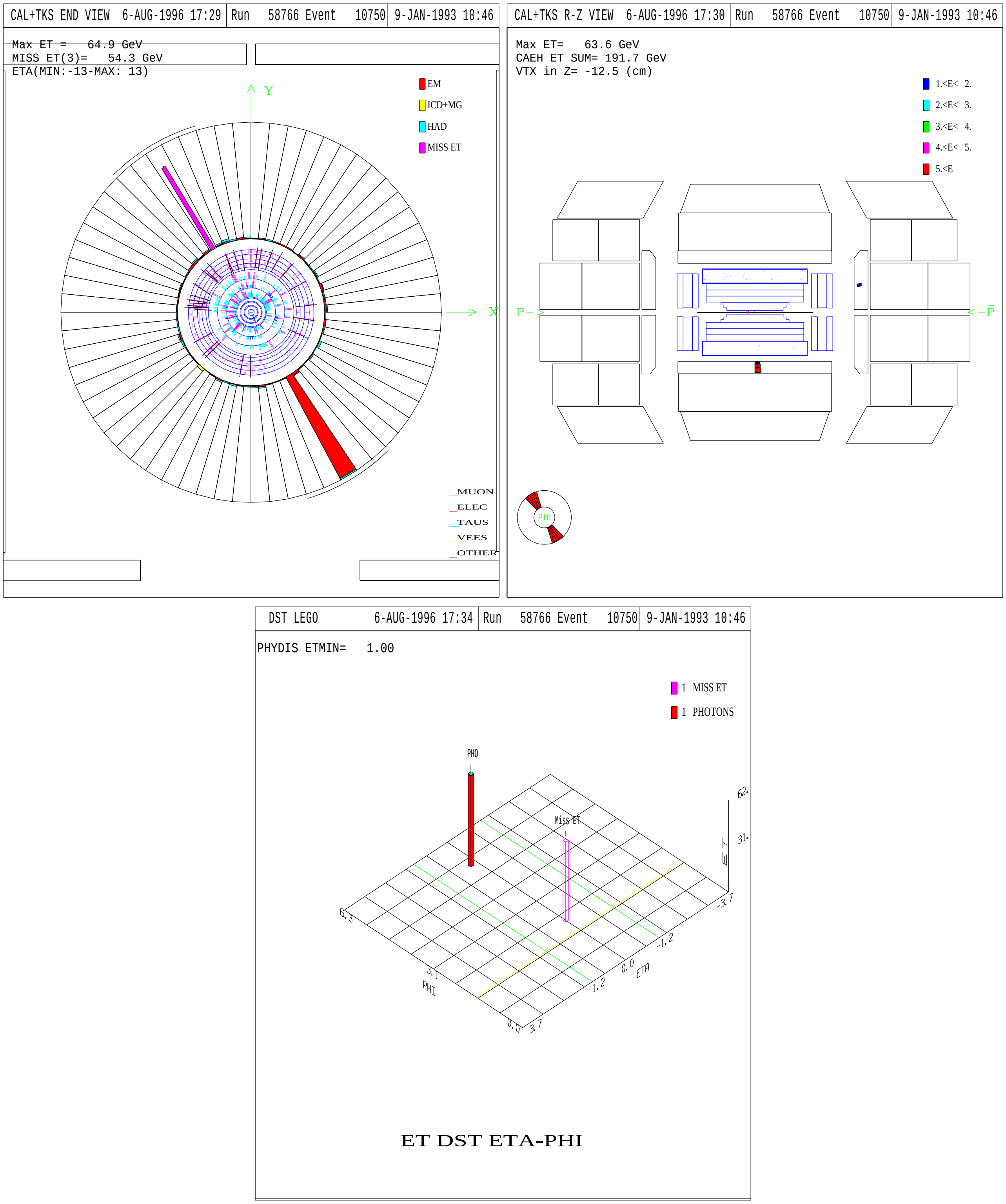
1B analysis: Select events with $Z(\rightarrow ee)$ and γ

NEW 1A analysis (Fnal-Pub-97/047-E, submitted to PRL)

- Select events with $Z(\rightarrow \nu\nu)$ and γ
- has high branching fraction, absence of radiative decay diagrams

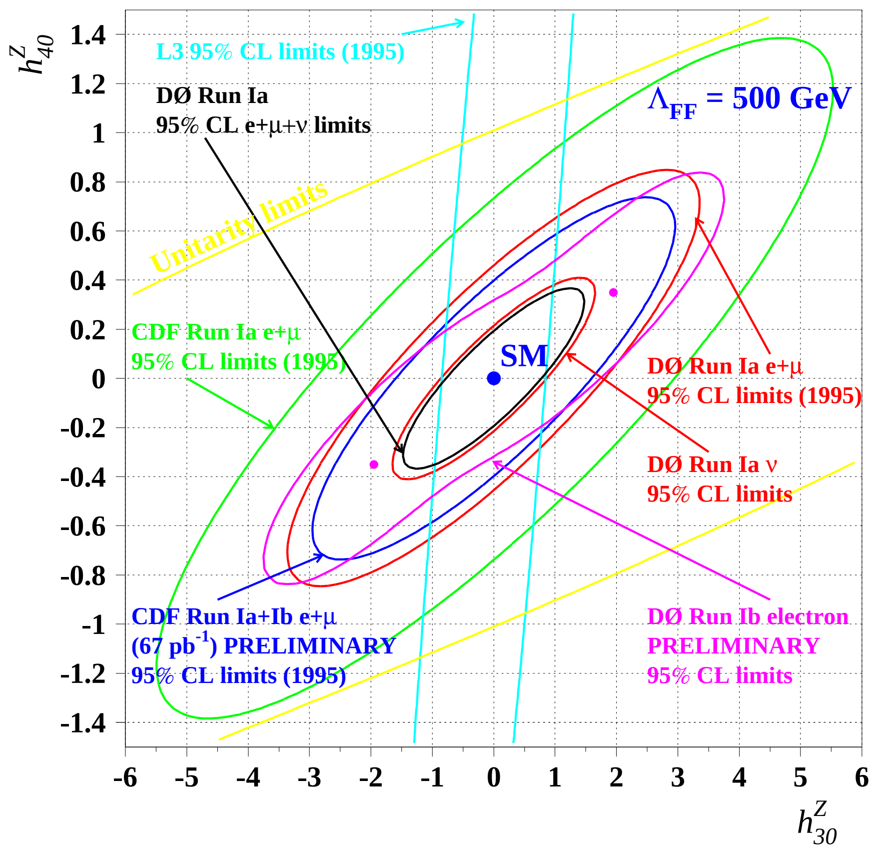


A $Z\gamma \to \nu\nu\gamma$ Candidate



$$E_T^{\gamma} = 69 \text{ GeV}$$

$Z\gamma$ Production Limits



Run 1B $ee\gamma$ **limits(**$\Lambda = 500$ **GeV):**

$$-1.9 < h_{30}^{Z,\gamma} < 1.9 \quad -0.4 < h_{40}^{Z,\gamma} < 0.4$$

Run 1A $\nu\nu\gamma$ **limits (**$\Lambda = 750$ **GeV)** $\Rightarrow$

$$|h_{30}^{Z,\gamma}| < 0.5 \quad |h_{40}^{Z,\gamma}| < 0.07$$

Run 1A $Z \to (ee + \mu\mu + \nu\nu)\gamma$ **limits (**$\Lambda = 750$ **GeV)** $\Rightarrow$

$$|h_{30}^{Z,\gamma}| < 0.44, 0.45 \quad |h_{40}^{Z,\gamma}| < 0.06$$

New Particle Searches at DØ

Will show results:

- **Leptoquark searches**
- **SUSY with γ search**
- **QCD search for dijet resonances**

Leptoquarks

- present in many extensions to SM
- carry both lepton and color quantum numbers
- searching for LQ which couple to single generation only

We have results for channels:

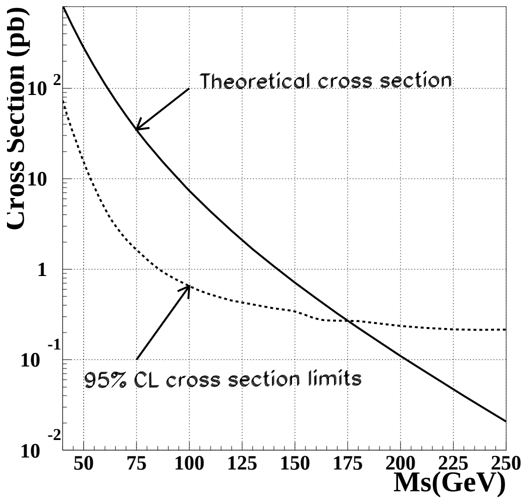
$\star$ **First Generation** $\rightarrow eejj, e\nu jj, \nu\nu jj$

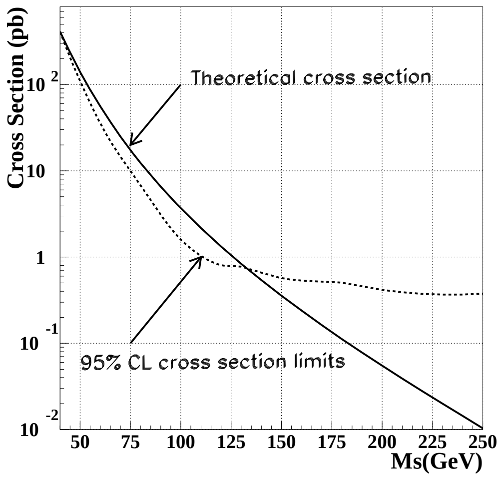
$\star$ **Second Generation** $\rightarrow \mu\mu jj$

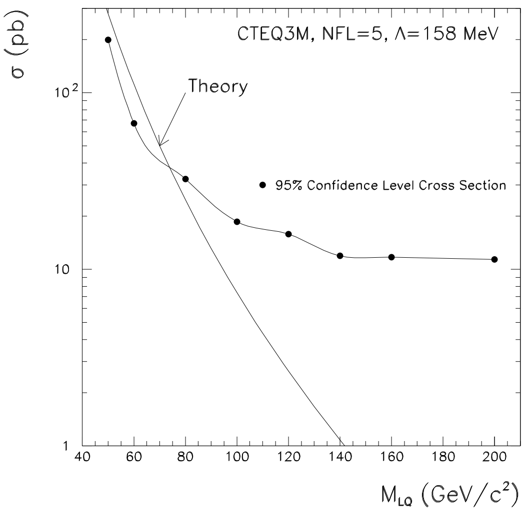
$\star$ **Third Generation** $\rightarrow \nu\nu bb$

Scalar Leptoquarks - First Generation

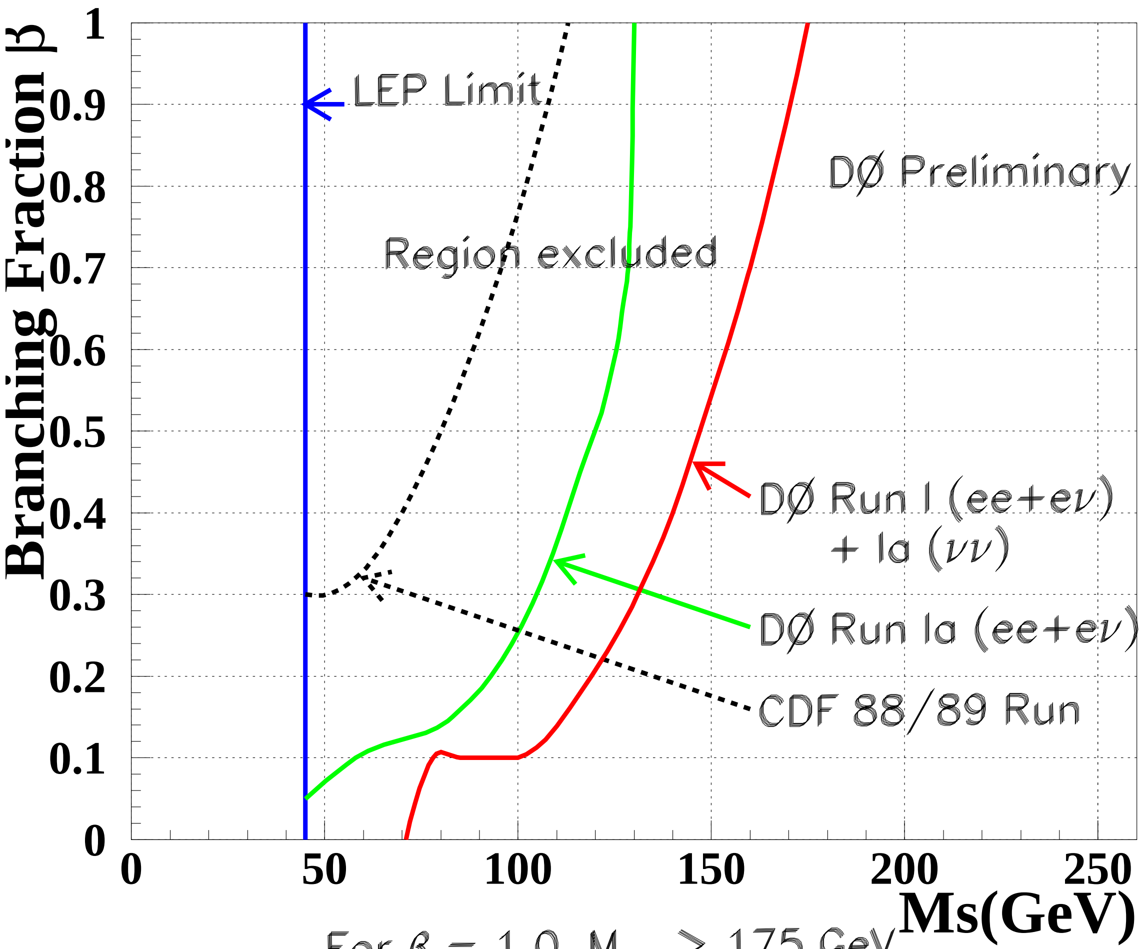
$eejj, e\nu jj, \nu\nu jj$ **channels:**







First Generation Scalar LeptoQuark Limits

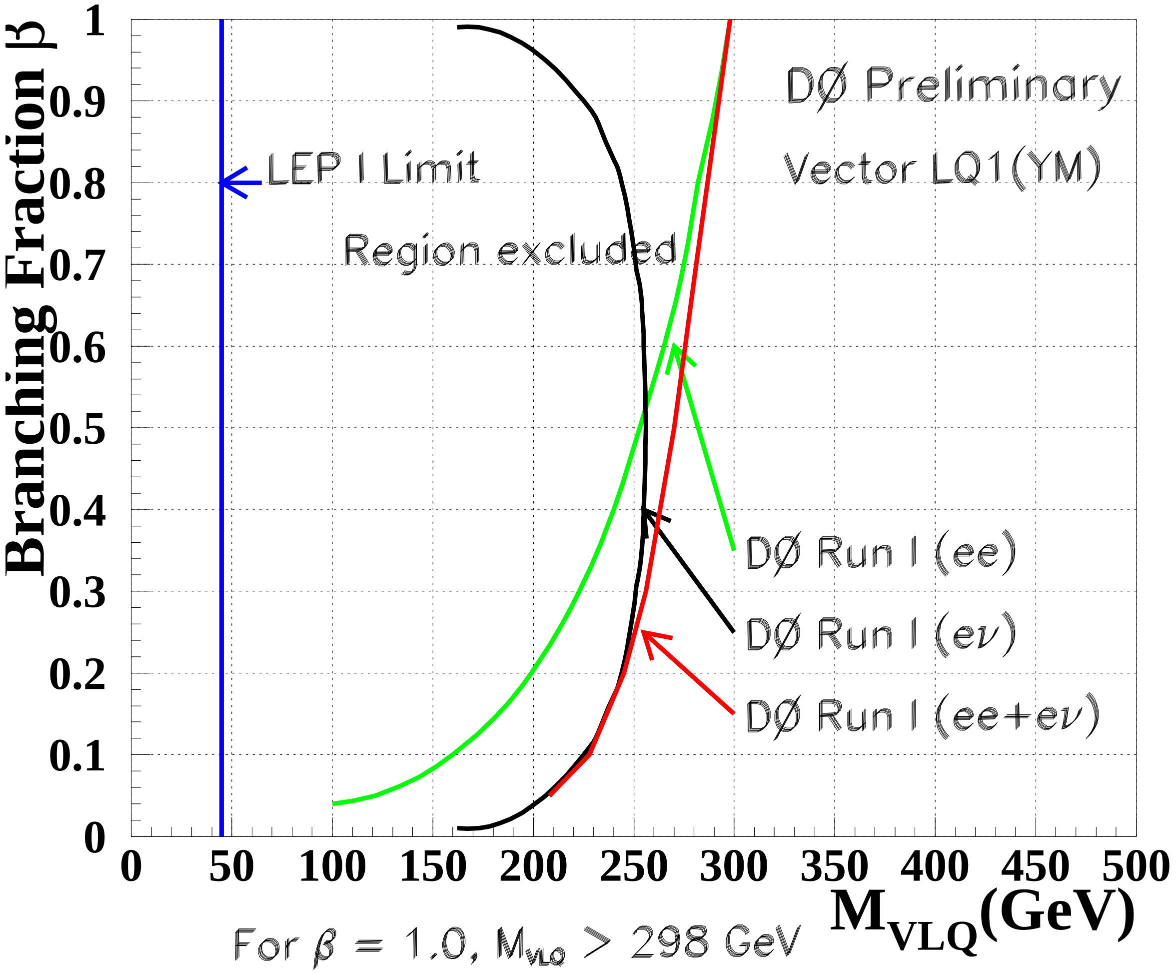


For $\beta = 1.0$, $M_{SLQ} > 175$ GeV

For $\beta = 0.5$, $M_{SLQ} > 147$ GeV

For $\beta = 0.0$, $M_{SLQ} > 71$ GeV

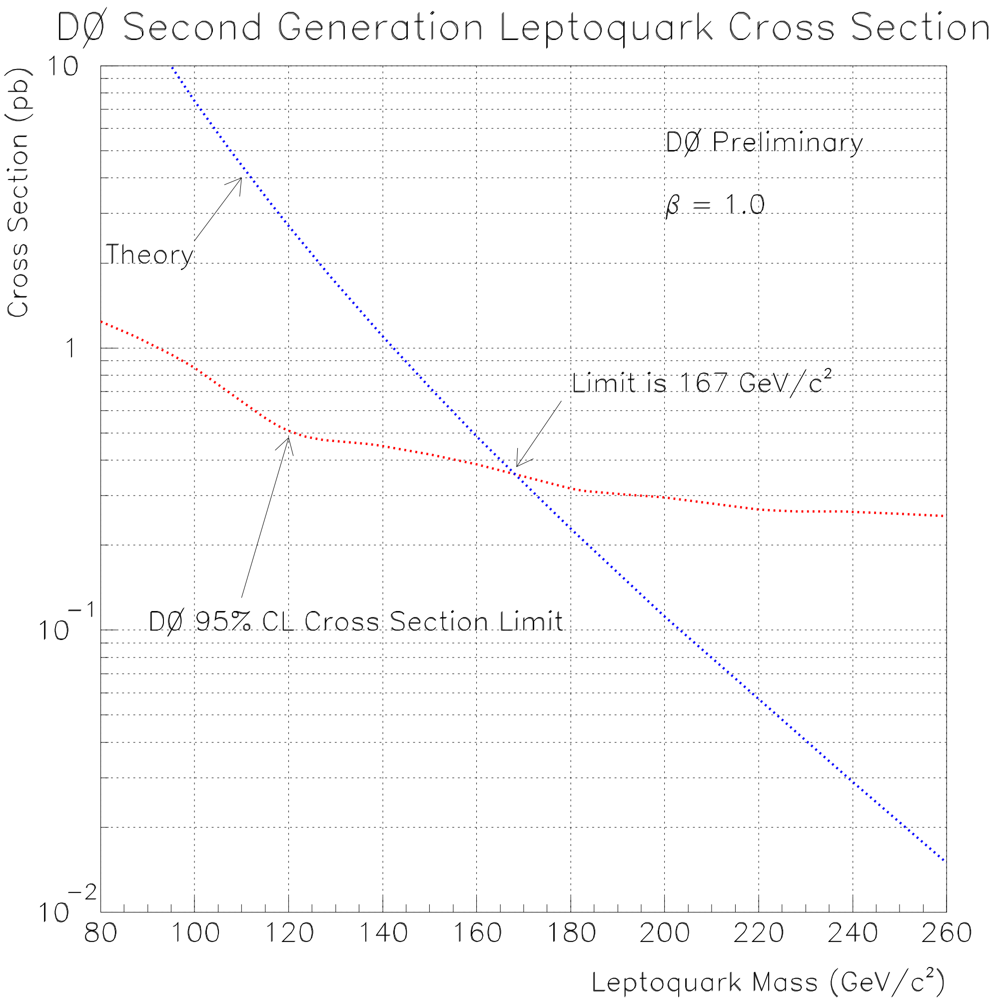
First Generation Vector LeptoQuark Limits



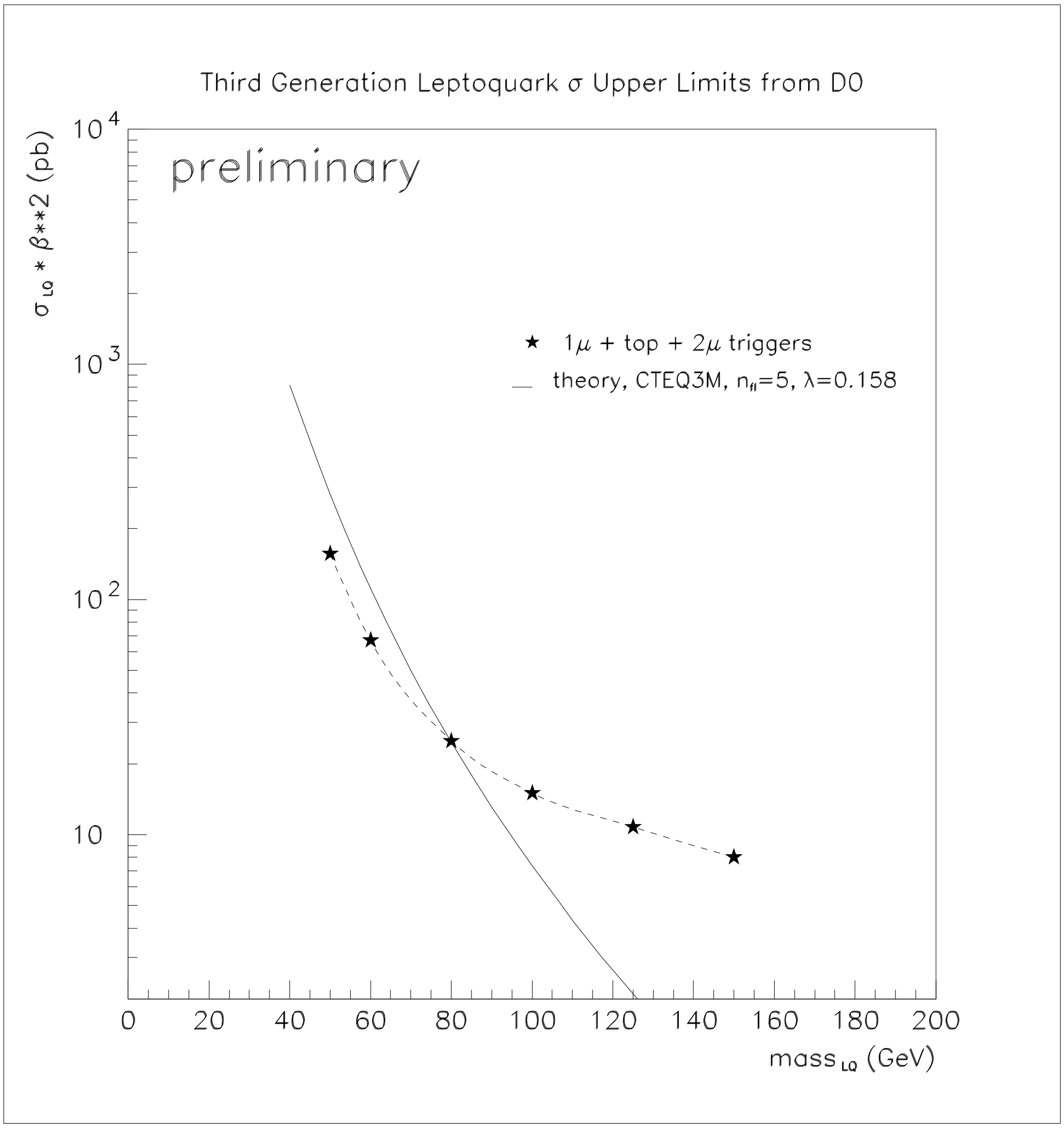
For β = 1.0, M_{VLQ} > 298 GeV

For β = 0.5, M_{VLQ} > 270 GeV

Leptoquarks - 2nd Generation
$(LQ\ LQ \rightarrow \mu\mu jj)$



Leptoquarks - 3rd Generation
($LQ\ LQ$ (charge 1/3) $\rightarrow \nu\nu bb$)



SUSY with γ's

Search for MSSM with light gravitino signatures

- **Gauge mediated SUSY models suggest signals containing $\gamma\gamma$ and $\not{E}_T$:**
  gravitino $\tilde{G}$ is LSP, $\tilde{\chi}_1^0(\rightarrow \gamma\tilde{G})$ is NLSP

  Stump et al., PRD 54 (1996) 1936.

  Dimopoulos et al., PRD 54 (1996) 3283.

  Ambrosanio et al., PRD 54 (1996) 5395.

  Ellis et al., hep-ph/9610470

- **study $\gamma\gamma + \not{E}_T$ events to search for chargino and neutralino production $\rightarrow \tilde{\chi}_2^0\tilde{\chi}_2^0, \tilde{\chi}_2^0\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$**

- **select events:**

$$\gamma\gamma + \not{E}_T + X$$

$\star$ **use SPYTHIA & GEANT with 4 parameters:**

m_1 - $U(1)$ **gaugino mass**

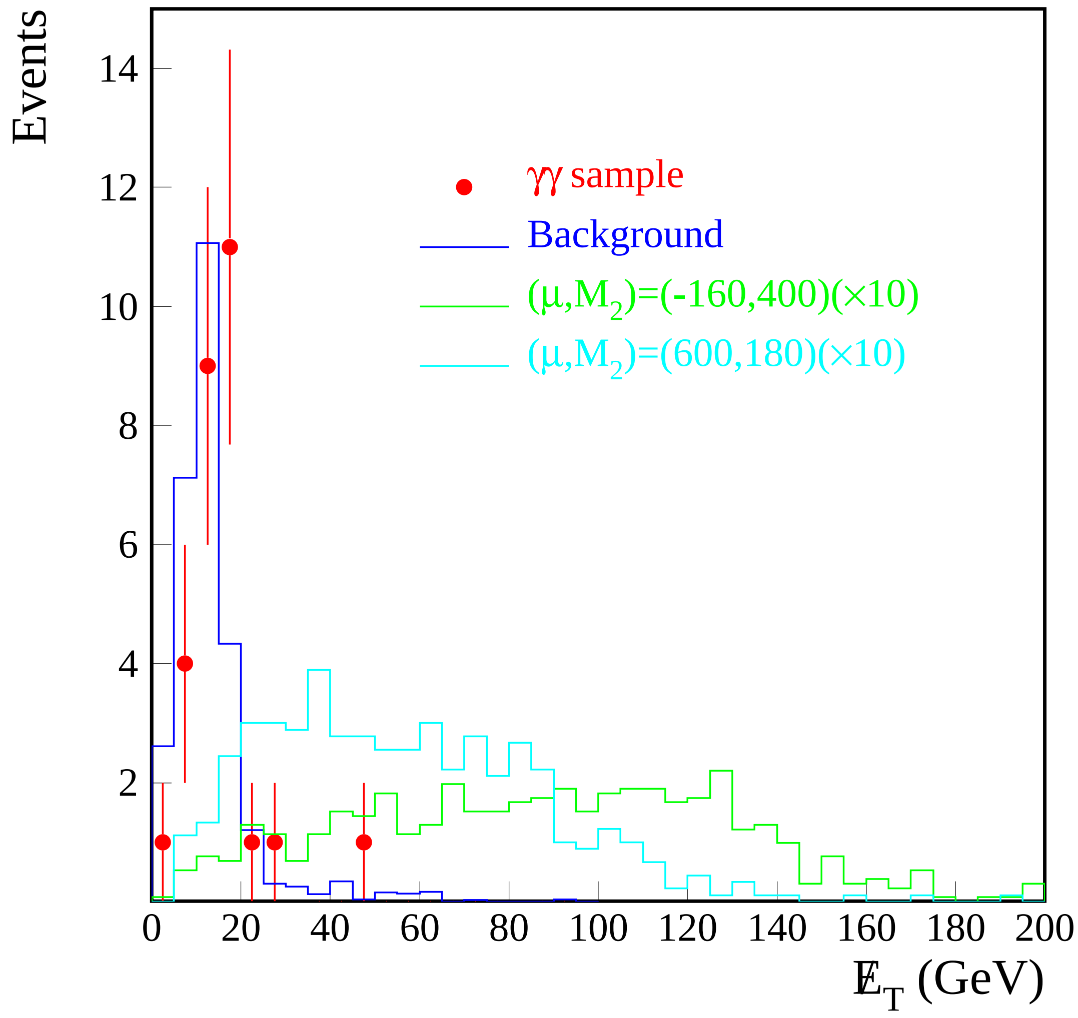
m_2 - $SU(2)$ **gaugino mass**

μ - **higgsino mass**

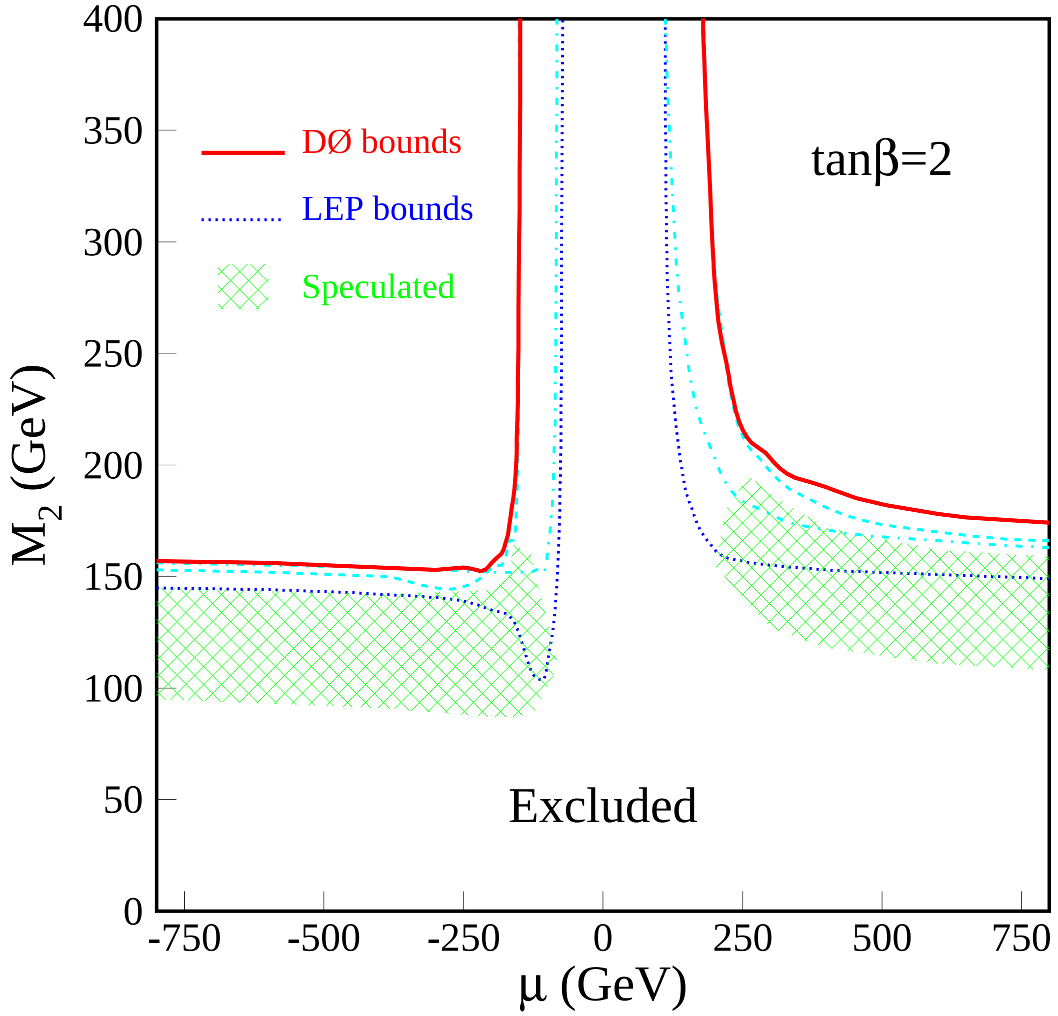
$\tan\beta$ - **ratio of vev of the two higgs doublets**

$\star$ **work in μ, m_2 plane and keep $\tan\beta$ fixed**

SUSY with γ's



SUSY with γ's



b Physics Results

Have Results $\Rightarrow$

- **b-quark cross section**
  - $\rightarrow$ **central**
    - **- dimuons**
    - **- inclusive muons**
    - **- muon + jets**
    - **- $J/\psi \rightarrow \mu^+\mu^-$**
  - $\rightarrow$ **forward**
    - **- inclusive muons**
  - $\rightarrow$ **central vs forward**
    - **- inclusive muons**
  - $\rightarrow$ **$b\bar{b}$ correlations**

- **charmonium production**

- **upsilon production**

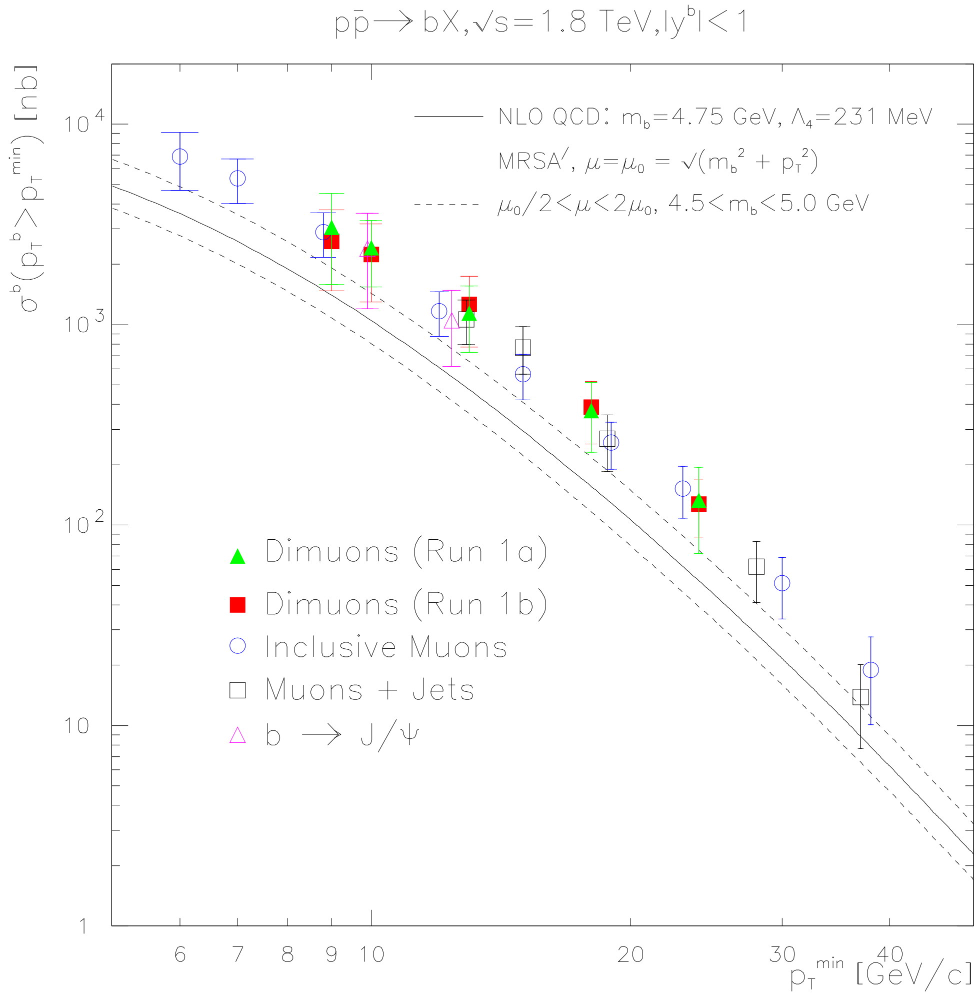
- **rare decays**

In Progress $\Rightarrow$

$\star$ **$b-$quark cross section at $\sqrt{s} = 630$ GeV**
$\Rightarrow$ at Moriond-QCD!

central b production cross section: $d\sigma/dp_T$ vs p_T

(PRL 74 (1995) 3548, Fnal-Conf-96/248-E)



NLO prediction: Mangano,Nason, Ridofi - MRSA pdf
Data is taken to parton level ⇒

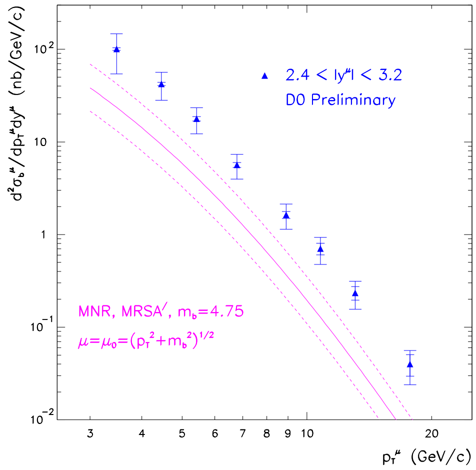
- **measure inclusive μ spectrum**
- **derive b quark component using Isajet (particle level)**
- **take to parton level by unfolding fragmentation**

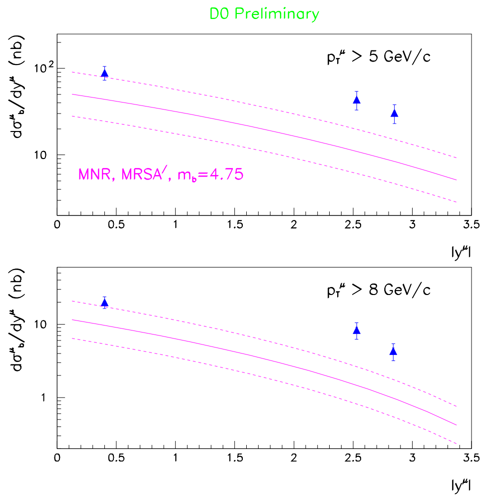
Data is factor of 2 above theory!

b **production cross section (Fnal-Conf-96/252-E)**
Forward ($2.4 < |y^{\mu}| < 3.2$) & Central vs. Forward

⋆ **NLO theoretical pred. is fragmented and decayed**

⋆ **Data is taken to particle level**





Data is factor of 2 above theory!

QCD Results

Have results on:

⇒ **Inclusive jet production at $\sqrt{s} = 1800$ GeV**

⇒ **Dijet angular distribution**

⇒ **Dijet Production**

⇒ **BFKL physics**

⇒ **Direct Photons**

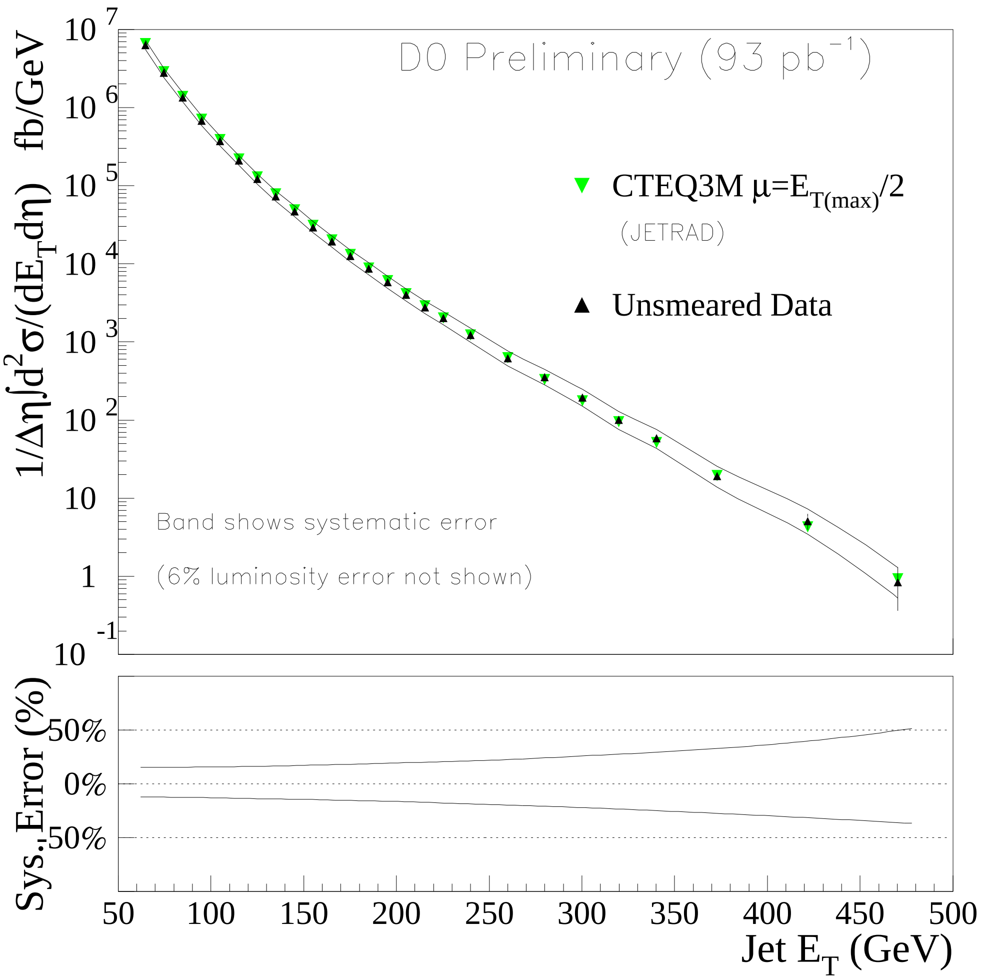
⇒ **Diffraction and Rapidity Gaps**

+ **MUCH MORE!**

Inclusive Jet Cross Section

- shown at LaThuile97 & Moriond97

Run 1B data - Central ($|\eta| < 0.5$)

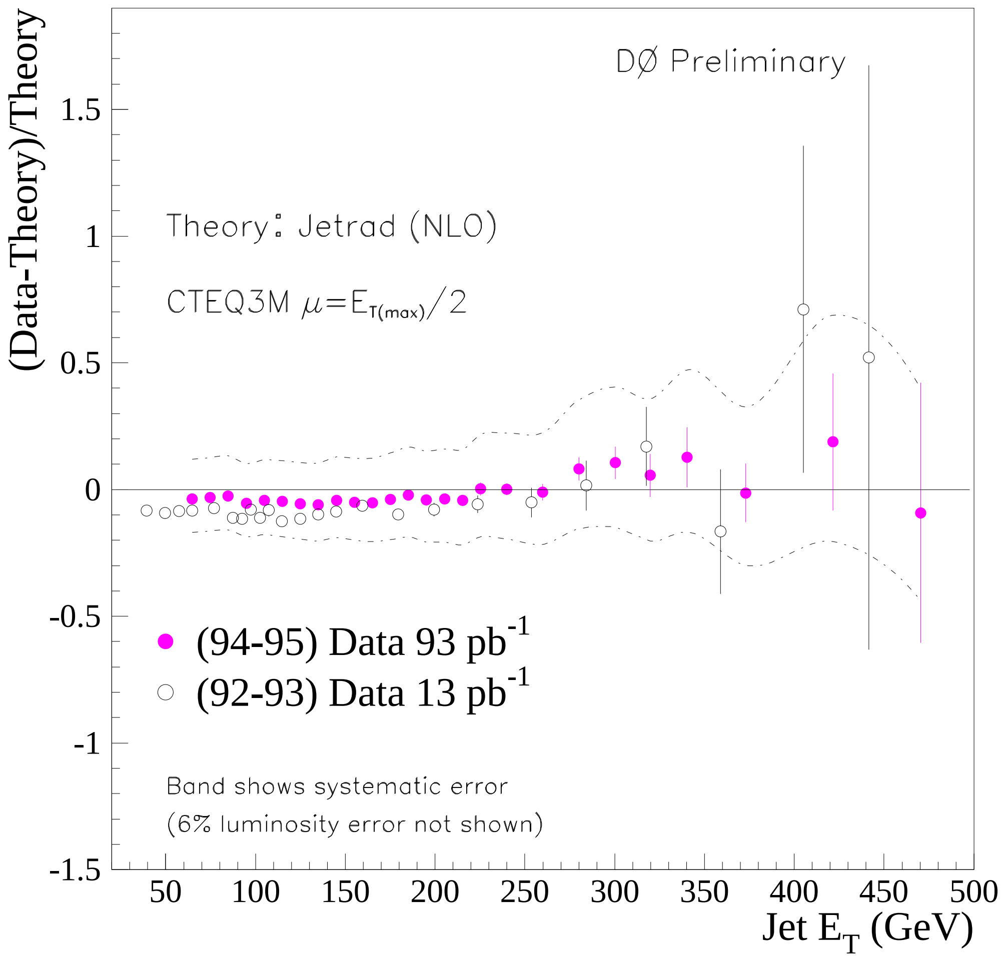


→ **jet energy scale reevalutated ⇒ much lower errors**

→ **Data: jets (conesize $R = 0.7$ corrected to particle level)**

→ **Prediction: JETRAD (NLO),$R_{sep} = 1.3$, CTEQ3M, Giele et al.**

Inclusive Jet Cross Section

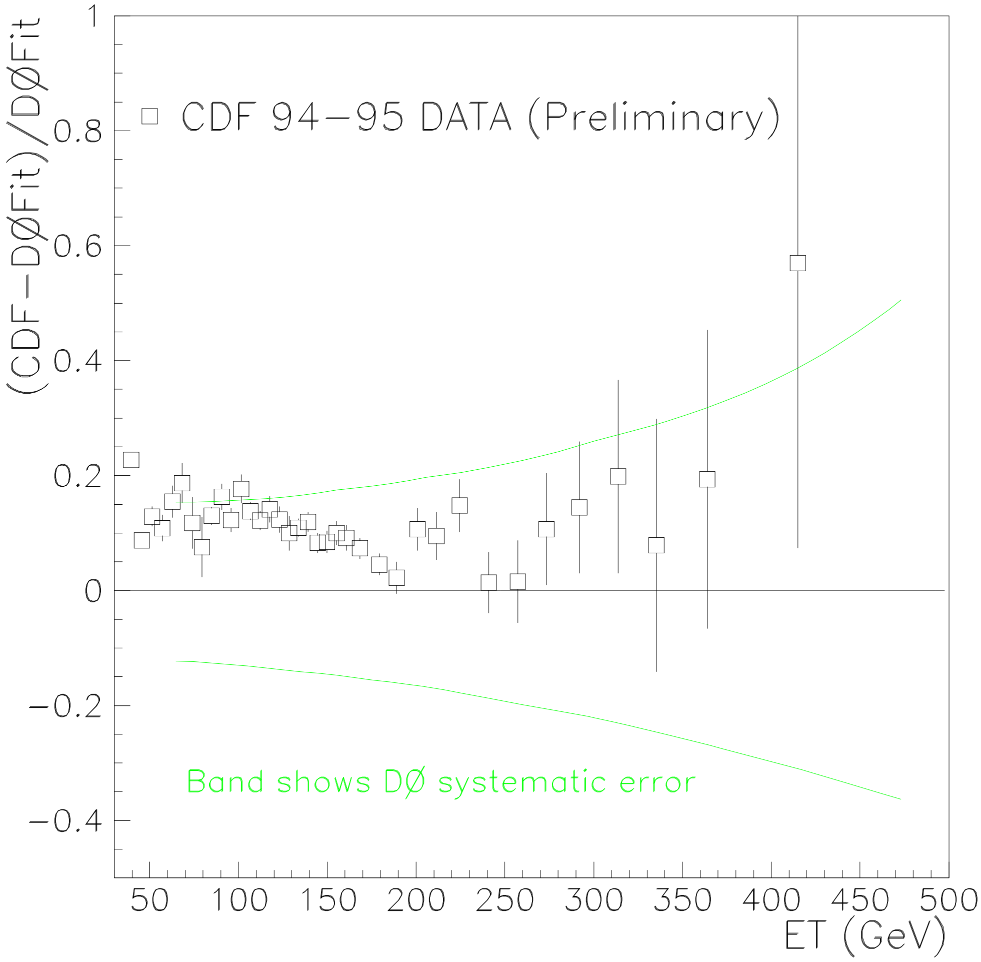


→ **(data-theory)/theory for 1B data with syst. errors**

→ **1A data also shown**

→ **Excellent agreement with NLO QCD and current pdfs over full kinematic range!**

Inclusive Jet Cross Section - DØ vs CDF

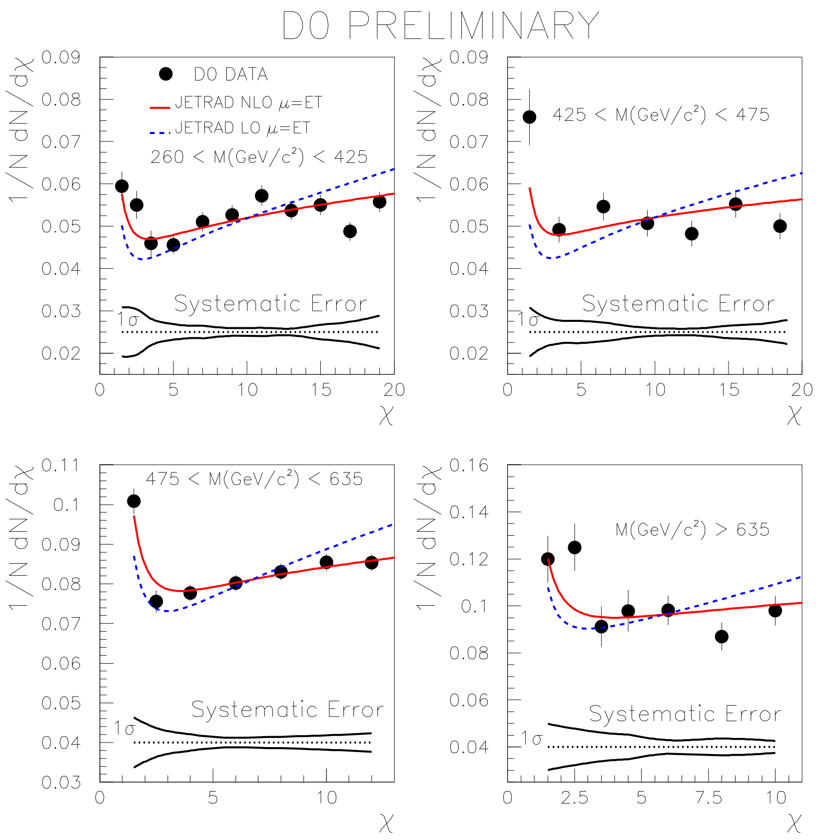


→ **reanalyse DØ data in range $.1 < |\eta| < .7$ (same as CDF) and fit to functional form**

→ **shown (squares) is CDF data minus fit to DØ data**

Dijet Angular Distributions (NLO and LO comparison)

$$\chi = e^{2|\eta|^\star} = \frac{1+\cos\theta^\star}{1-\cos\theta^\star}$$



→ use χ because it flattens out angular distribution & facilitates comparison with theory

→ $dN/d\chi$ is insensitive to *pdf* choice
- shape is unaffected by boost of system

→ $dN/d\chi$ sensitive to contact interactions introduced by compositeness models

Limit on Compositeness: $\Lambda_c > 1.9$ TeV

Recent DØ Results - Summary

- **Top mass (Feb97)** $\rightarrow 173.3 \pm 5.6(stat) \pm 6.2(syst)$ **GeV**
- σ_{tt} **(Feb97)** $\rightarrow 5.53 \pm 1.67$ **pb**
- W **Boson mass**
  Run 1A(published) $\rightarrow 80.350 \pm 0.270$ **GeV**
  Run 1B(prelim) $\rightarrow 80.380 \pm 0.170$ **GeV**
  Run 1A + 1B $\rightarrow 80.37 \pm 0.15$ **GeV**
- **Limits on anomalous couplings from diboson production:** $W\gamma, Z(\nu\nu)\gamma$
  - no deviations from SM observed
- **Leptoquarks - mass limits**
  $m_{LQ} > 175, 147, 71$ GeV$(\beta = 1.0, .5, 0)$ **- 1rst gen.**
  $m_{LQ} > 167$ GeV$(\beta = 1.0)$ **- 2nd gen.**
  $m_{LQ} > 80$ GeV **- 3rd gen.**
- **SUSY with** γ**'s**
- **Dijet mass spectrum bump hunt**
  - no signals seen for $q^\star, W', Z' \rightarrow$ **limits set**
- b **quark cross section - both central and forward results consistently** $\times 2$ **theory prediction**
- **Jet inclusive cross section (new, more precise measurement) & Dijet angular distribution**
  - excellent agreement w/NLO & current PDF
  - no significant excess seen in kinematic range
  - limit on compositeness: $\Lambda_c > 1.9$ **TeV**