

## Disclaimer

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# Search for the Top Quark in the Dilepton channel/ at CDF

- Introduction
- Data
- Event Selection Cuts
- Comments on Data
- Expectation (top, backgrounds)
- Summary

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# Introduction

- top quark

$$\begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix} c \\ s \end{pmatrix} \quad \begin{pmatrix} t \\ b \end{pmatrix}$$

- Mass limit

$$M_{\text{top}} \geq 91 \text{ GeV}/c^2$$

(from 1988-89 Run)

- Signature

$$t\bar{t} \rightarrow W^+ b W^- \bar{b}$$

$\rightarrow$  2 high  $P_T$  leptons (e or  $\mu$ )  
+ missing  $E_T$  + jets

(e. $\mu$ ) (e.e) ( $\mu$ . $\mu$ )

- Backgrounds

- $b\bar{b}$ ,  $c\bar{c}$

- $Z \rightarrow \tau\tau$

- $Z$ /Drell-Yan

- $WW$ ,  $WZ$

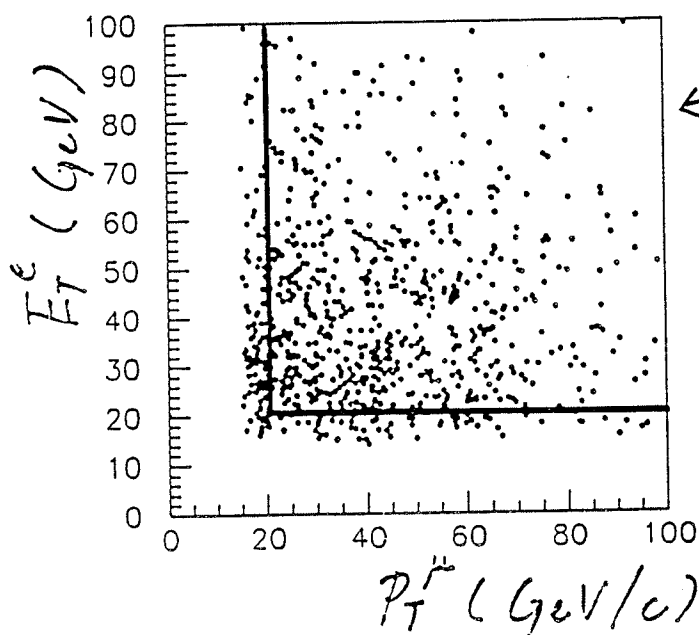
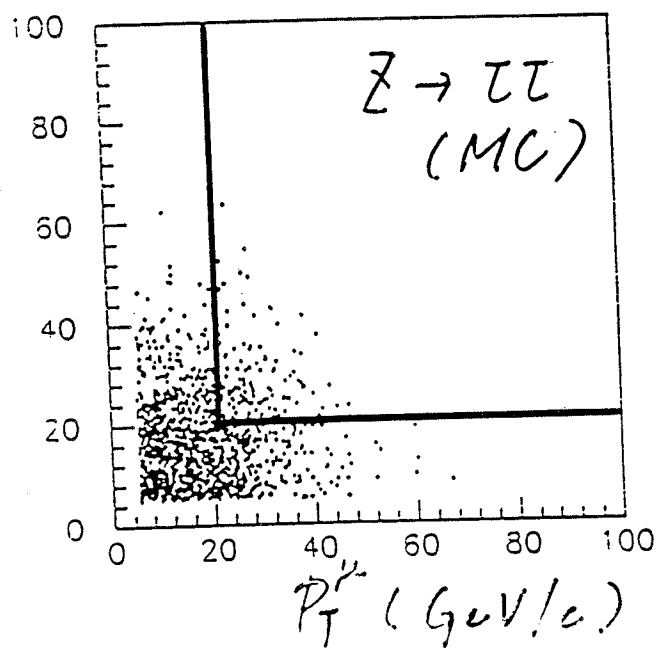
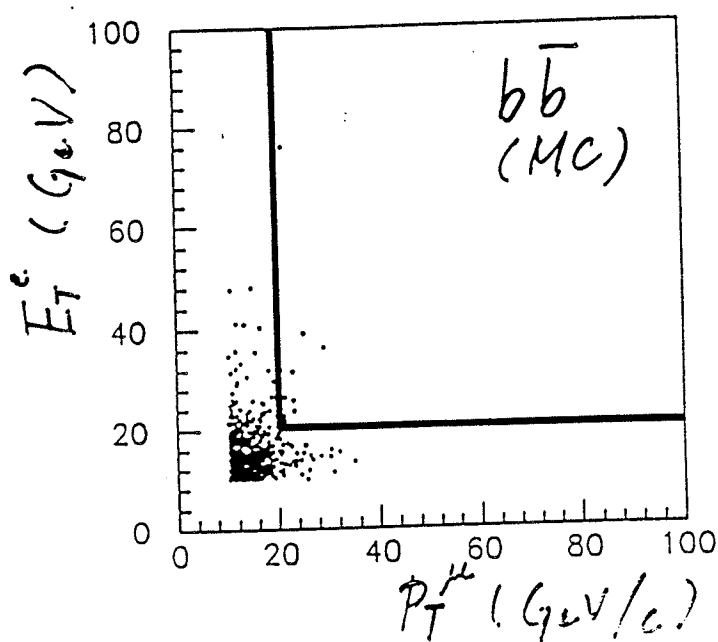
- Particle misidentification

# Event Selection

- Lepton ID
- Lepton  $P_T$  cut
- Track isolation
- Same sign dilepton cut
- Kinematical, Event Topology  
Cut
- Two jet cut

# Dilepton $P_T$ cut

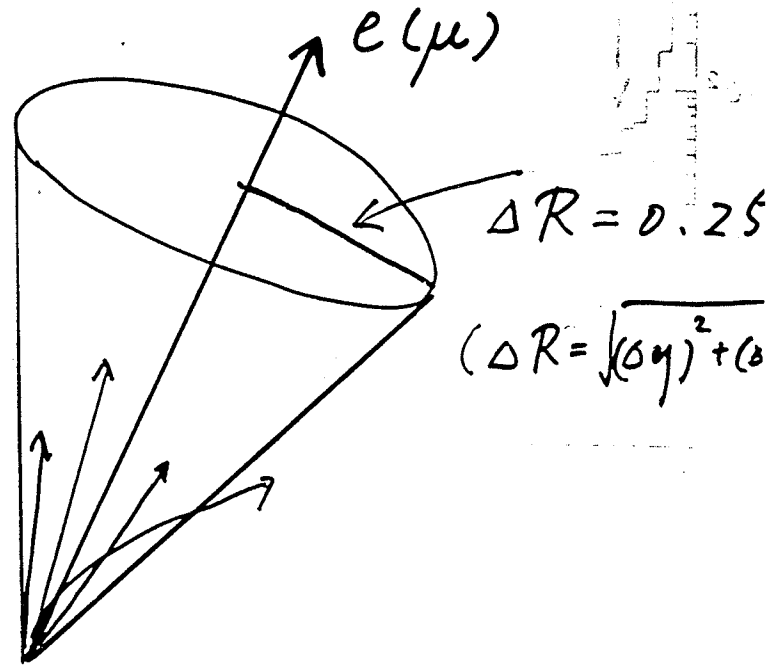
Require  $E_T^e > 20 \text{ GeV}$   
and  $P_T^\mu > 20 \text{ GeV}/c$



← top 140 GeV/c  
(MC)

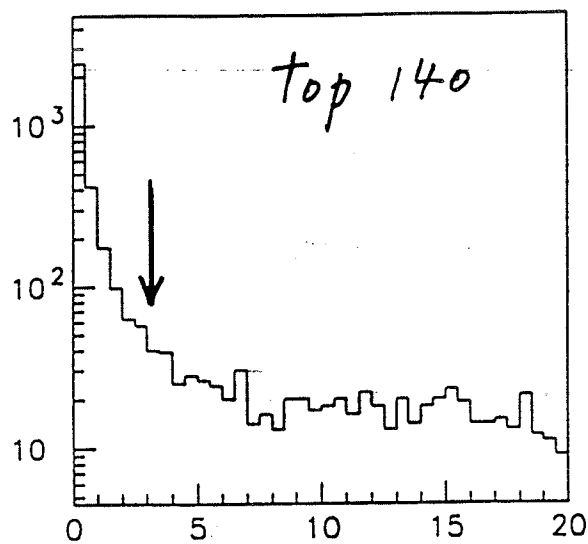
# Isolation

"At least one" lepton be isolated in the tracking chamber.

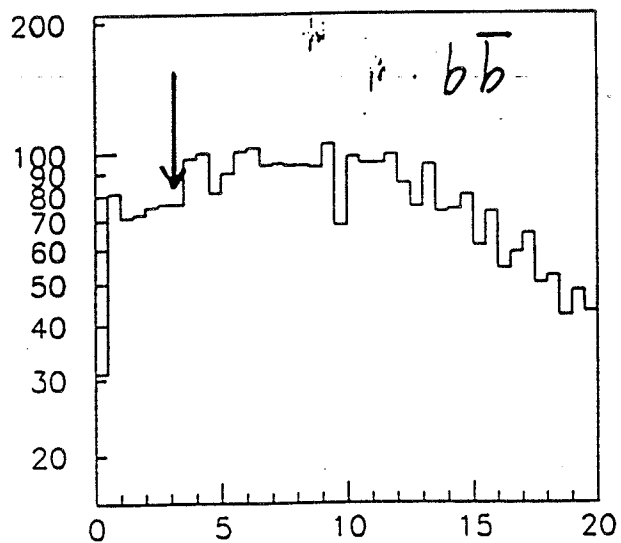


The sum of  $P_T$  over all CTC tracks inside a cone of  $0.25 < 3 \text{ GeV}/c$

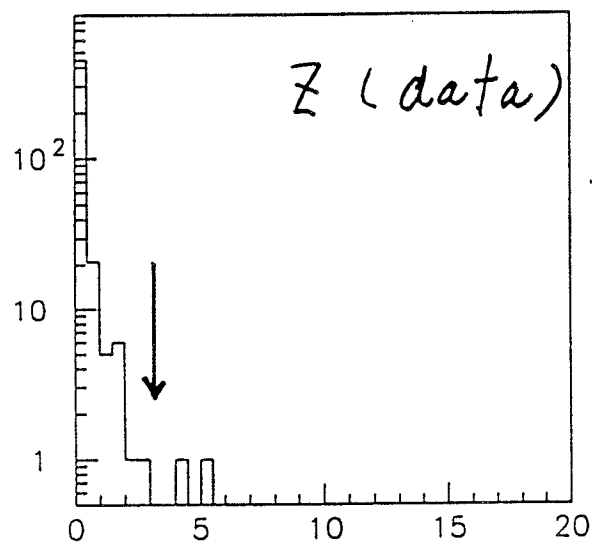
# Track isolation



Track isolation



Track isolation



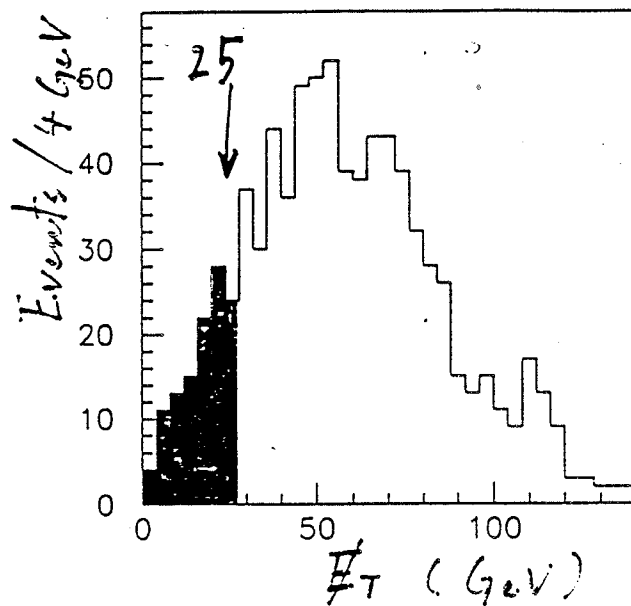
Track isolation

## Same sign dilepton cut

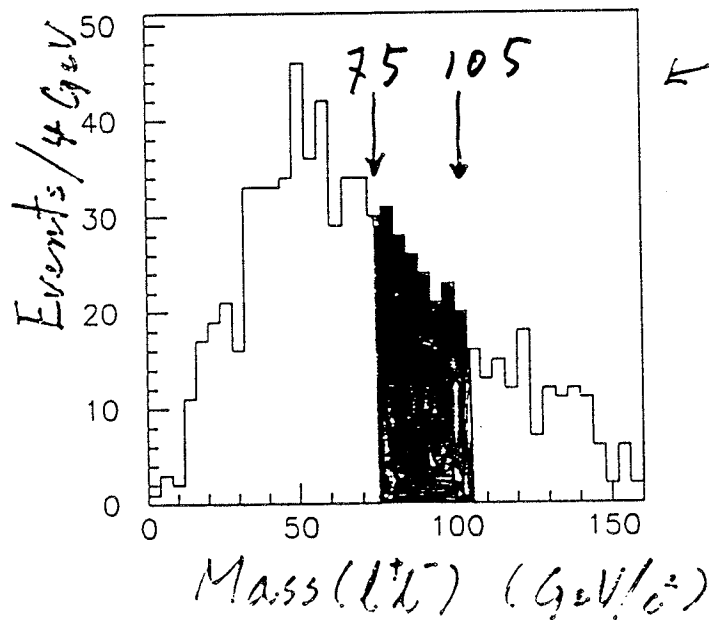
- Require opposite signs for the electric charges of the two leptons
- We can reduce fake lepton background by a factor of two and  $b\bar{b}$  by 30%.
- For a top mass of 120 (160) GeV, this cut reduces the signal by 3 (6) %. Because a small fraction of high  $P_T$  leptons comes from the decay of  $b$  or  $c$  quarks.

# Kinematical and event topology cuts

- missing  $E_T > 25 \text{ GeV}$
- Reject  $Z$  candidates for  $ee$  and  $\mu\mu$   
( $75 < M_{\ell\ell} < 105 \text{ GeV}/c^2$ )



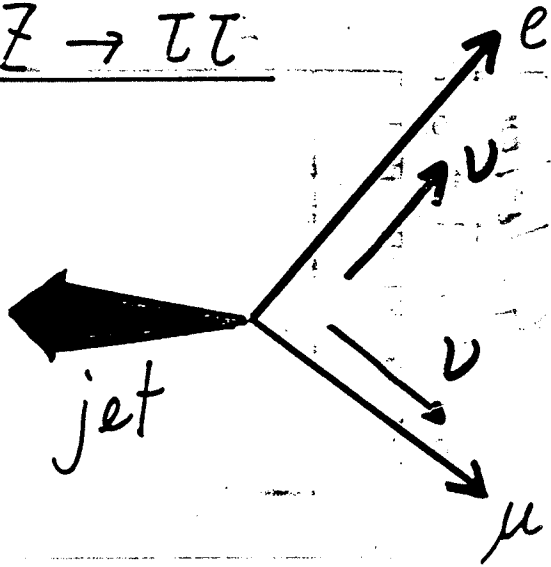
top  $140 \text{ GeV}/c^2$   
← missing  $E_T$   
( $= -|\sum \vec{E}_T|$ )  
 $|\eta| < 3.6$



← Dilepton  
invariant mass

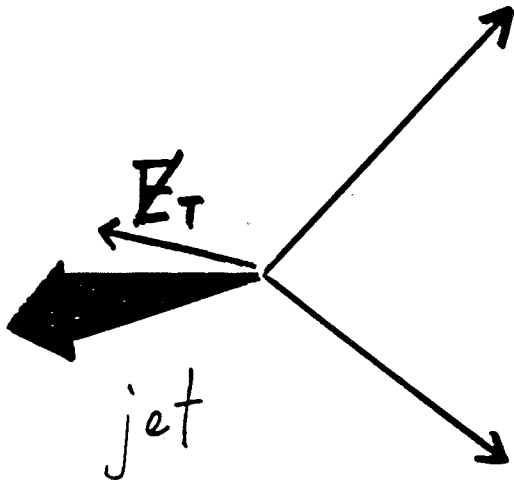
- Azimuthal angle separation between the missing  $E_T$  and a closest lepton or jet

•  $Z \rightarrow \tau\tau$



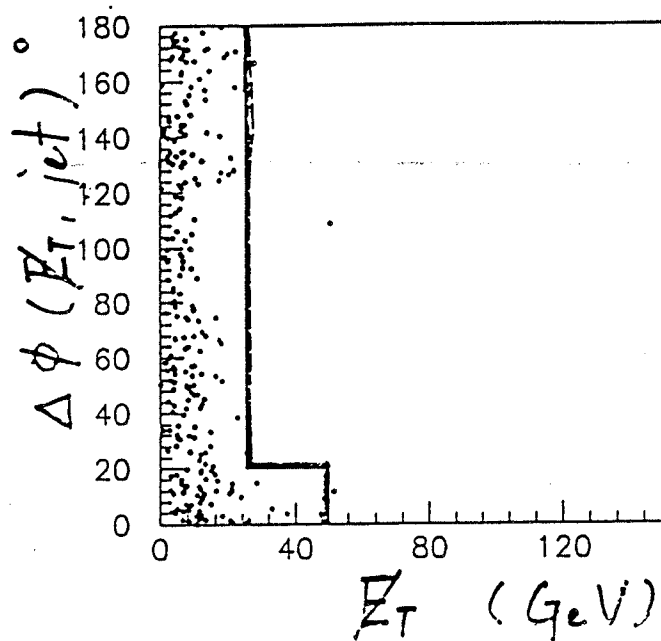
Rejet events with  
 $E_T < 50 \text{ GeV}$  and  
 $\Delta\phi(E_T, \text{lepton}) < 20^\circ$   
 or  
 $\Delta\phi(E_T, \text{jet}) < 20^\circ$

• Drell-Yan

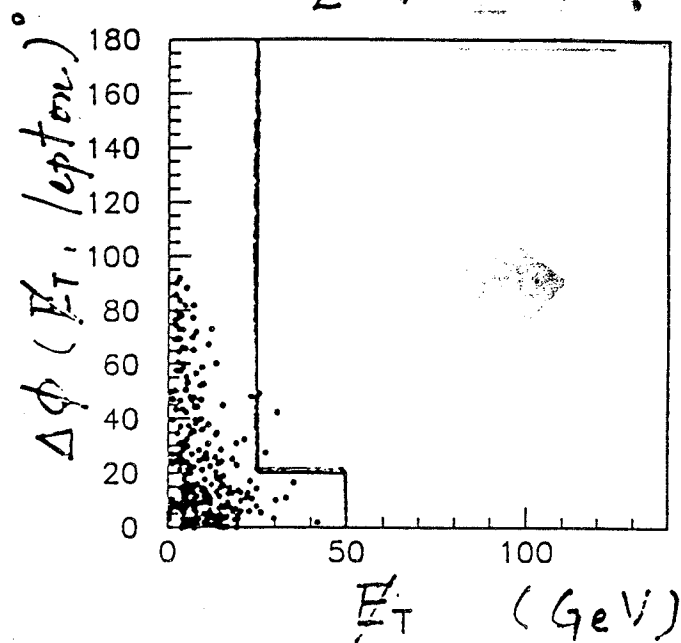


$E_T$  arises from  
 jet mismeasurement.

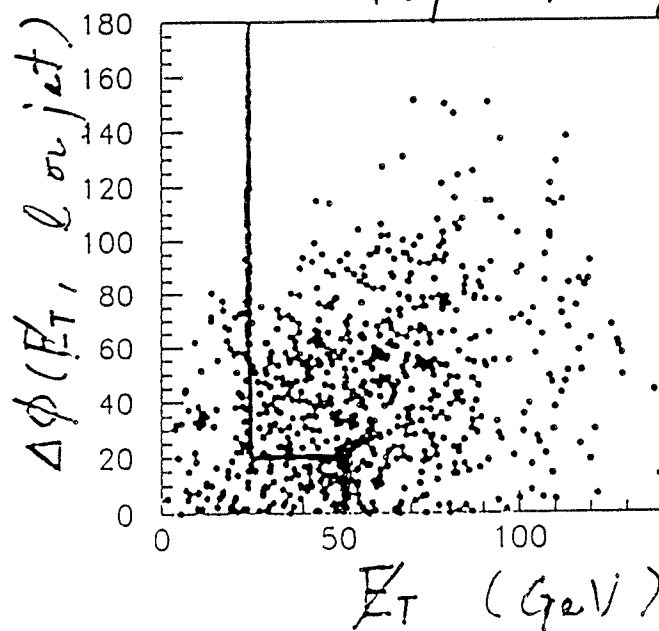
Drell-Yan



$Z \rightarrow \tau\tau$

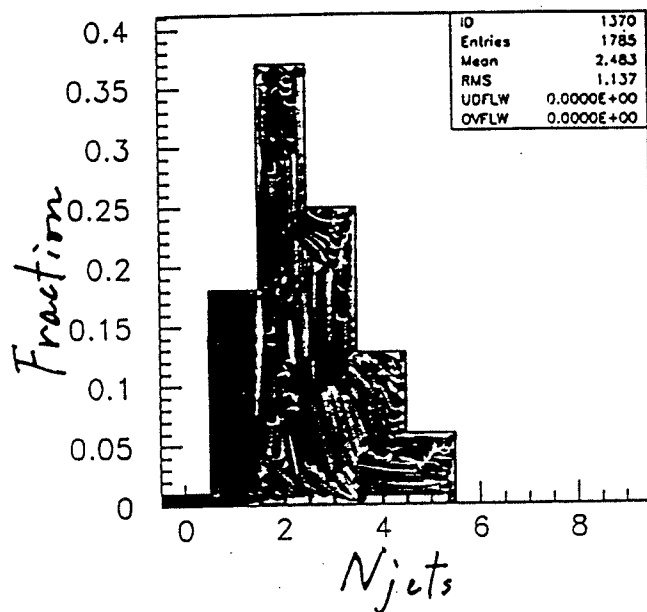


top  $140 \text{ GeV}/c^2$



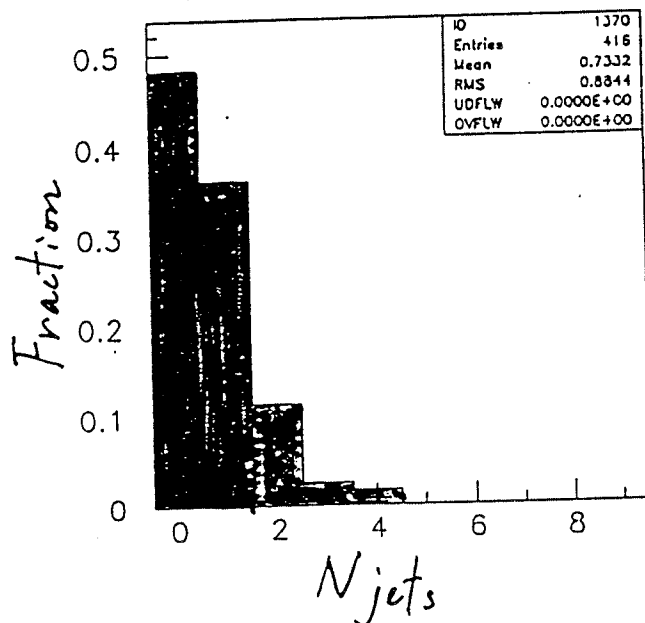
# Two jet cut

Two or more jets with observed  $E_T$   
 $> 10 \text{ GeV}$  and  $|\eta_{\text{detector}}| < 2.4$



Top 140  $\text{GeV}/c^2$

$$\epsilon_{\text{jet}} = 80\%$$



WW

$$\epsilon_{\text{jet}} = 13\%$$

# Data Sample

## Trigger

- Inclusive lepton.

$$E_T^e > 18 \text{ GeV}$$

$$P_T^\mu > 18 \text{ GeV}/c$$

- Dilepton.

$$(E_T^e, P_T^\mu) > (15, 15) \text{ GeV}$$

$$\int L dt = 21.4 \pm 2.1 \text{ pb}^{-1}$$

# Data Analysis

Inclusive lepton trigger  
Dilepton trigger

$$\int L dt = 21.4 \text{ pb}^{-1}$$

$e\mu$

$ee, \mu\mu$

Lepton  $P_T$   
ID, isolation

5

1279

remove Z

—

125

Event topology  
cut

2

0

same sign  
cut

2

0

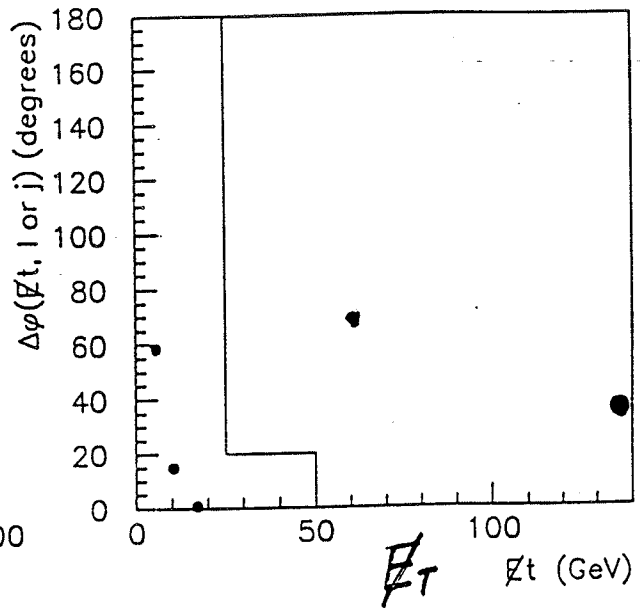
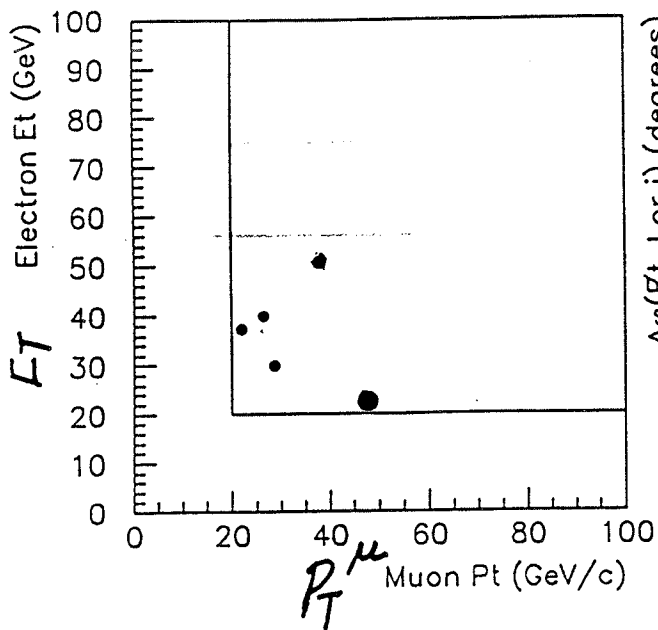
two jet cut

2

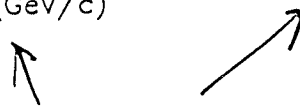
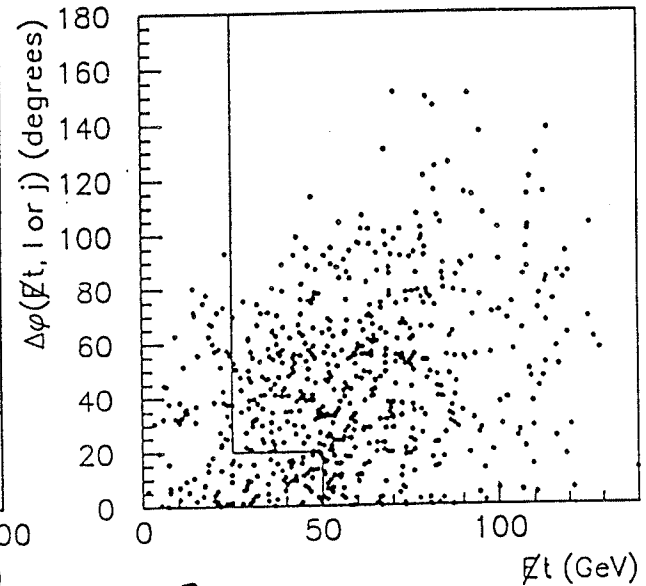
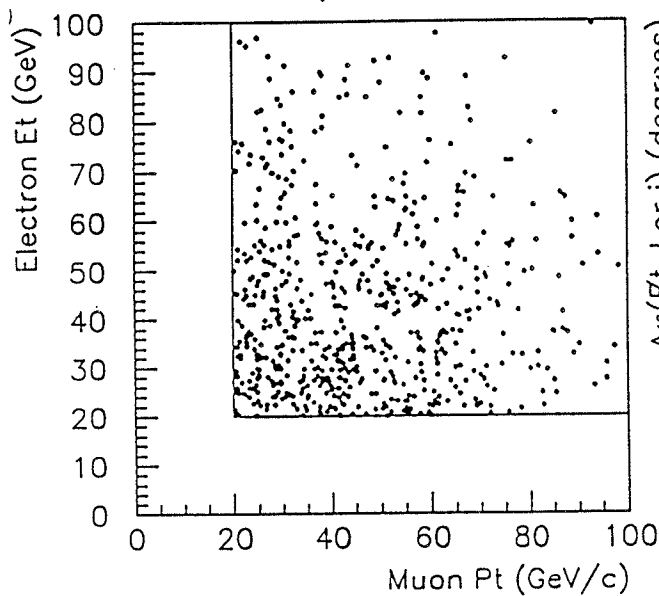
0

Data

$e\mu$  21.4  $\text{pb}^{-1}$

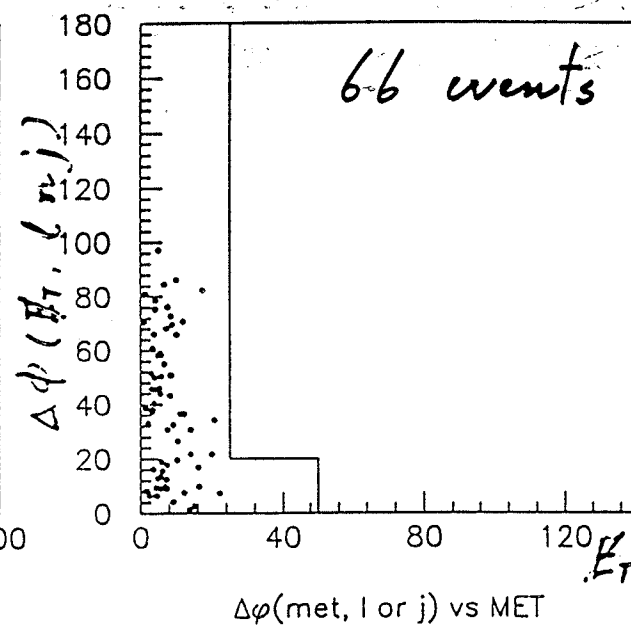
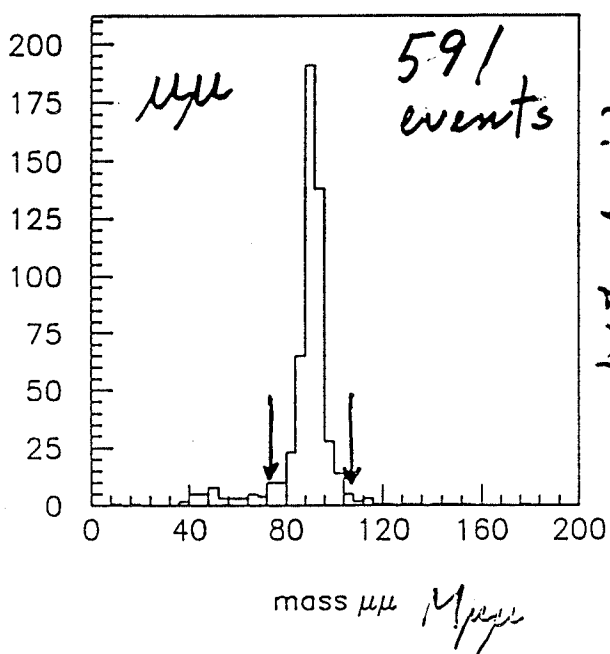
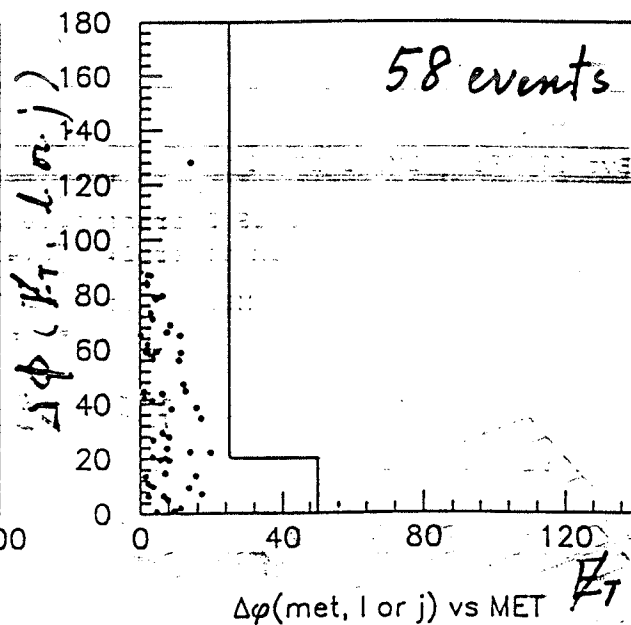
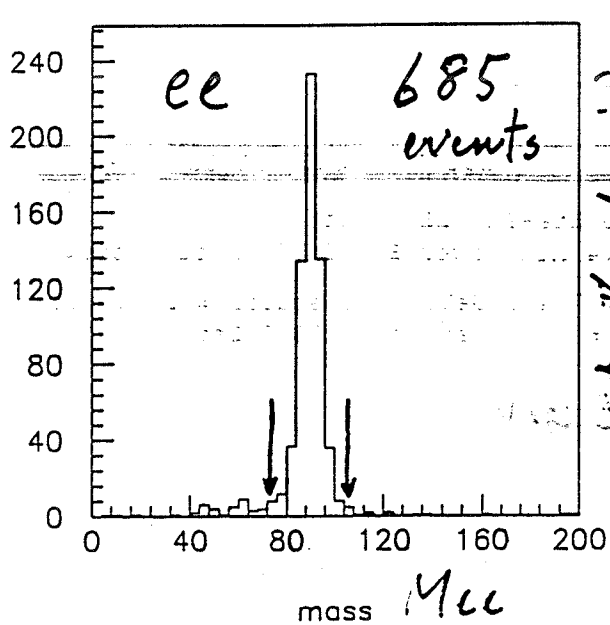


AL



top MC (140 GeV)

Data ( $21.4 \text{ pb}^{-1}$ )



No ee or  $\mu\mu$  events in the signal region

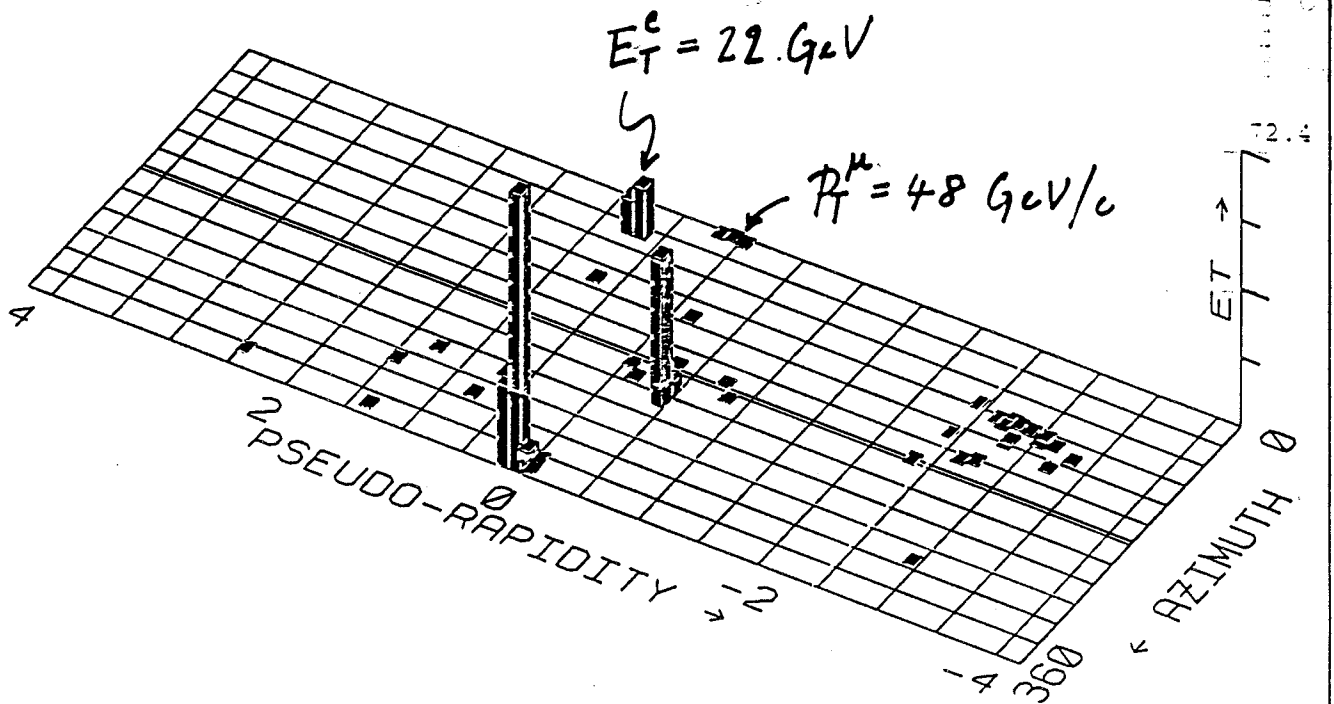
Run 41540 Evt 127085

EMU61.DST;1

29OCT92 3:33:20 12-OCT-93

DAIS E transverse Eta-Phi LEGO Plot

Max tower E= 72.4 Min tower E= 0.50 N clusters=

METS: Etototal = 714.0 GeV, Et(scalar)= 234.9 GeV  
Et(miss)= 10.9 at Phi= 175.0 Deg.

PHI: 269.

ETA: -2.46

Run 41540 Evt 127085

EMU61.DST;1

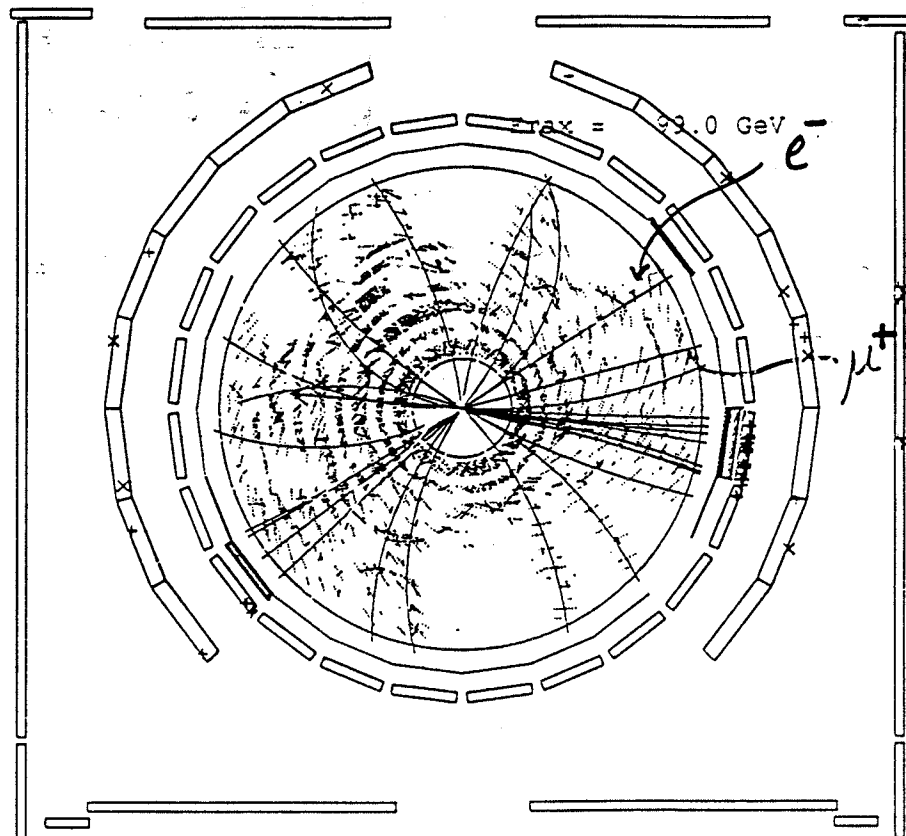
29OCT92 3:33:20 12-OCT-93

| Pt    | Phi | Eta   |
|-------|-----|-------|
| 46.5  | 14  | 0.17  |
| 27.4  | 216 | -0.53 |
| -23.7 | 33  | 0.84  |
| -21.0 | 352 | 0.17  |
| 16.0  | 222 | -0.54 |
| -12.5 | 212 | -0.53 |
| 9.1   | 356 | 0.10  |
| 8.7   | 352 | 0.13  |
| -5.0  | 343 | 0.14  |
| 4.5   | 352 | 0.07  |
| -4.1  | 214 | -0.52 |
| -3.1  | 350 | 0.11  |
| -2.3  | 352 | 0.13  |
| 2.0   | 330 | 0.10  |
| -1.6  | 143 | -0.70 |
| -1.6  | 146 | 1.69  |
| -1.4  | 82  | 0.82  |
| 1.3   | 357 | -0.09 |
| 1.2   | 37  | -0.92 |
| 1.1   | 342 | 1.51  |

| Pt   | Phi | Eta   |
|------|-----|-------|
| -1.0 | 136 | 2d    |
| -0.9 | 334 | 0.32  |
| -0.9 | 314 | 0.87  |
| -0.9 | 182 | -0.54 |
| -0.9 | 223 | -0.47 |
| -0.9 | 133 | -0.99 |
| -0.9 | 227 | -0.66 |
| -0.7 | 235 | 0.67  |
| 0.7  | 50  | -1.02 |

11 more trks...  
hit & to display

Et (METS) = 80.9 GeV  
Phi = 175.0 Deg  
Sum Et = 234.9 GeV



x CMX east  
+ CMX west

PHI: 269.  
ETA: -2.46

Run 47122 Event38382

EMU47122 38382.DST;1

4MAY93 16:37:24 12-OCT-93

DAIS E transverse Eta-Phi LEGO Plot

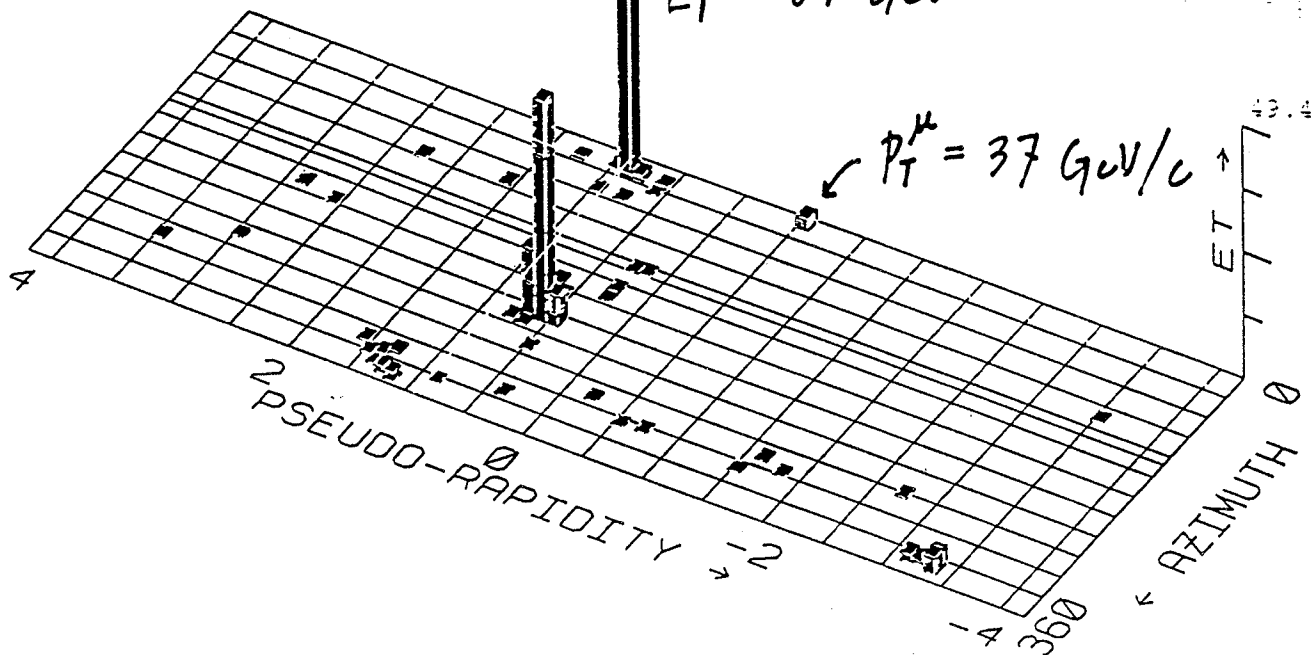
Max tower E= 49.4 Min tower E= 0.50 # clusters=

METS: Etotal = 696.7 GeV, Et/scalar= 199.7 GeV

p(miss)= 34.0 at Phi= 131.7 Deg.

$$E_T^e = 51 \text{ GeV}$$

$$p_T^H = 37 \text{ GeV}/c$$



PHI: 24.

ETA: 0.93

Run 47122 Event38382

EMU47122 38382.DST;1

4MAY93 16:37:24 12-OCT-93

| Pt   | Phi | Eta  |
|------|-----|------|
| 60.5 | 24  | 0.93 |

|      |     |      |
|------|-----|------|
| -3.5 | 219 | 0.54 |
| 7.3  | 219 | 0.77 |

|      |     |      |
|------|-----|------|
| -5.0 | 352 | 1.49 |
|------|-----|------|

|     |     |       |
|-----|-----|-------|
| 1.3 | 9   | -0.01 |
| 1.1 | 217 | 0.76  |

|      |     |       |
|------|-----|-------|
| 0.9  | 24  | 1.05  |
| 0.9  | 66  | -0.32 |
| 0.9  | 30  | 1.00  |
| -0.9 | 189 | -0.14 |
| 0.8  | 305 | 0.89  |
| -0.8 | 346 | 0.36  |
| -0.8 | 197 | 0.27  |

|      |     |      |
|------|-----|------|
| -0.7 | 184 | 0.26 |
|------|-----|------|

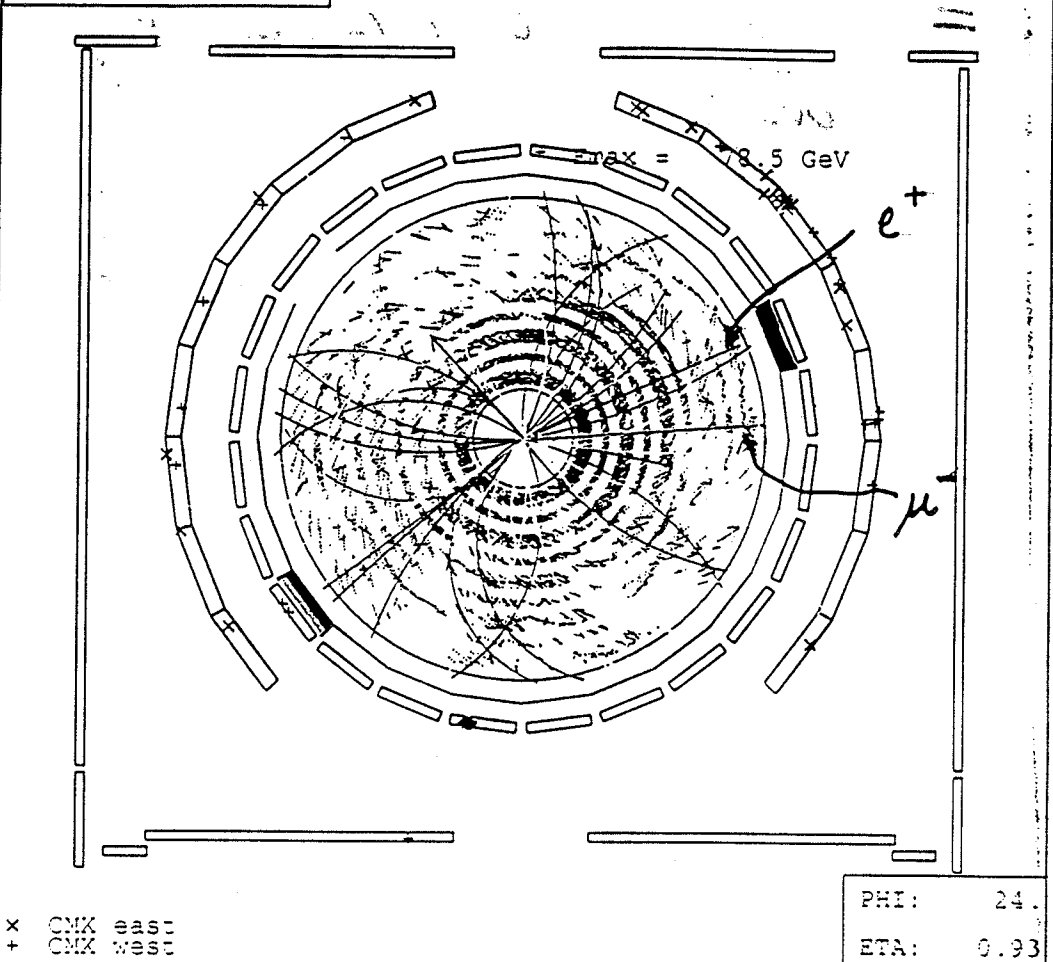
|     |    |       |
|-----|----|-------|
| 0.6 | 48 | -1.01 |
|-----|----|-------|

|     |     |      |
|-----|-----|------|
| 0.5 | 128 | 0.44 |
|-----|-----|------|

|      |     |       |
|------|-----|-------|
| -0.5 | 80  | 1.30  |
| 0.5  | 143 | -0.60 |
| -0.5 | 96  | -0.51 |
| 0.5  | 37  | 0.08  |
| -0.4 | 295 | 0.66  |

14 more trks...  
hit & to display

Et (METS) = 34.0 GeV  
Phi = 131.7 Deg  
Sum Et = 199.7 GeV



PHI: 24  
ETA: 0.93

# Total Detection Efficiency

$$\epsilon(\text{total})$$

$$= \sum_{\text{event class}}$$

$$\epsilon(\text{Geom. Pr})$$

$$M_T = 140 \text{ GeV}$$

$$55 (\%)$$

$$\times \epsilon(\text{Lepton ID}) \quad 52 (\%)$$

$$\times \epsilon(\text{Isolation}) \quad 95 (\%)$$

$$\times \epsilon(\text{Event}) \quad 67 (\%)$$

$$\times \epsilon(\text{Two-jet}) \quad 75 (\%)$$

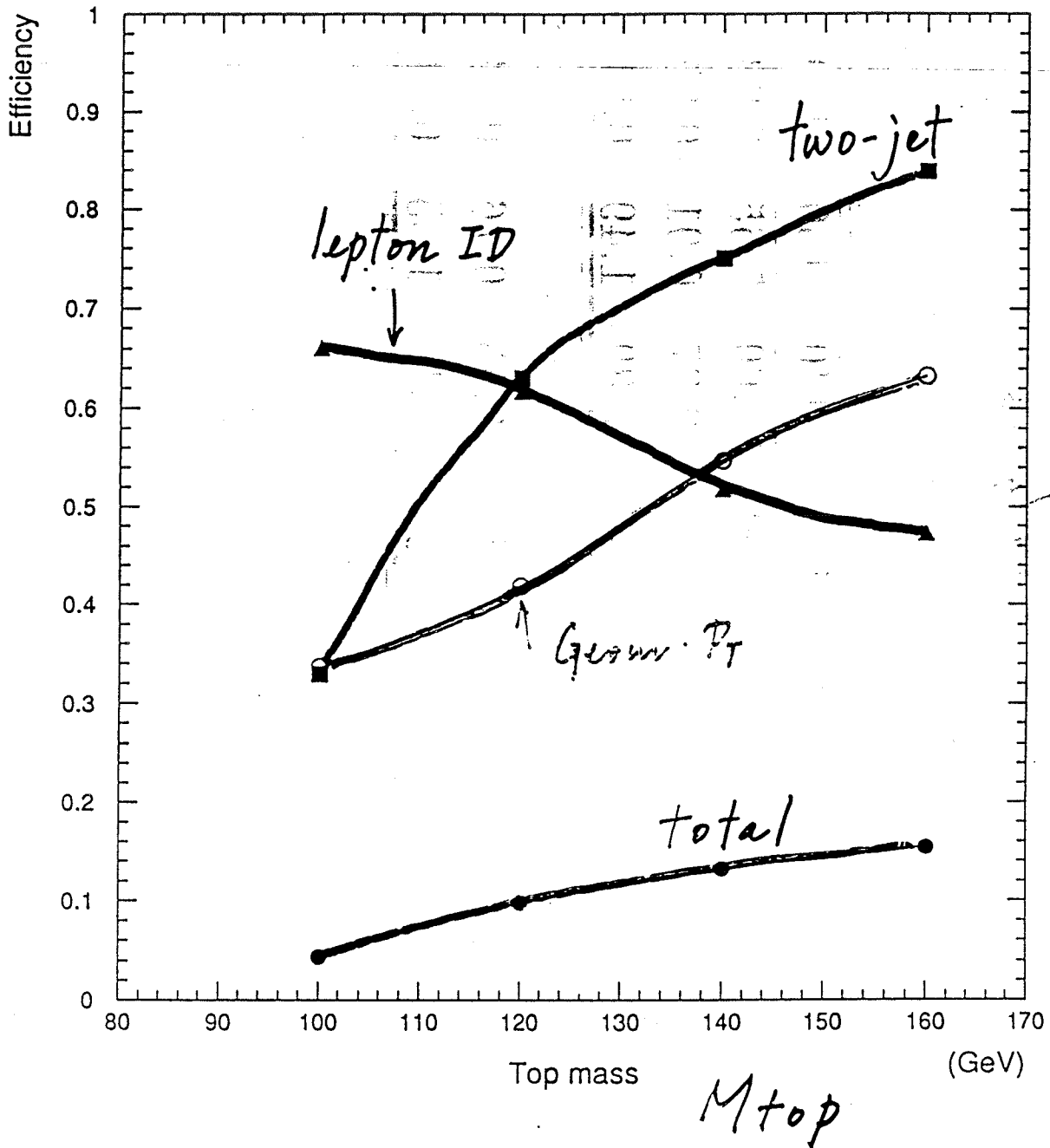
$$\times \epsilon(\text{trigger}) \quad 97 (\%)$$

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$$13.2 (\%)$$

$$N_{\text{event}} = \sigma \cdot \text{Br} \cdot \epsilon_{\text{tot}} \cdot L$$

Dilepton efficiency as a function of  $M_{top}$



Efficiency for isolation, event topology cut and trigger is flat as a function of  $M_{top}$ .

# Efficiencies and expectations in the dilepton analysis

| $M_{\text{top}}$                | 100   | 120   | 140   | 160  | 180                                  |
|---------------------------------|-------|-------|-------|------|--------------------------------------|
| $\sigma_{t\bar{t}}$ (pb)        | 90.90 | 35.30 | 15.60 | 7.65 | 3.98                                 |
| $\epsilon_{\text{total}}$ B (%) | 0.67  | 0.77  | 0.87  | 0.91 | 0.95                                 |
| Number (21.4 pb <sup>-1</sup> ) | 12.95 | 5.81  | 2.89  | 1.49 | 0.81                                 |
| (with two jet cut)              |       |       |       |      | $\leftarrow \text{No jet cut}$       |
| $\epsilon_{\text{total}}$ B (%) | 0.22  | 0.48  | 0.65  | 0.76 | 0.84                                 |
| Number (21.4 pb <sup>-1</sup> ) | 4.27  | 3.66  | 2.17  | 1.25 | 0.71                                 |
|                                 |       |       |       |      | $\leftarrow \text{with two-jet cut}$ |

# Number of backgrounds.

*Number of events for 21.4 pb<sup>-1</sup>*

|                  |                          |                                   |
|------------------|--------------------------|-----------------------------------|
| $e\mu$           | WW                       | $0.10 \pm 0.04$                   |
|                  | $Z \rightarrow \tau\tau$ | $0.07 \pm 0.02$                   |
|                  | $b\bar{b}$               | $0.04 \pm 0.02$                   |
|                  | Fake lepton              | $0.03 \pm 0.03$                   |
| Total Background |                          | <u><math>0.23 \pm 0.05</math></u> |
| Observed Events  |                          | <u>2</u>                          |

$ee, \mu\mu$

|                  |                                    |                 |
|------------------|------------------------------------|-----------------|
| $ee, \mu\mu$     | WW                                 | $0.06 \pm 0.02$ |
|                  | $Z \rightarrow \tau\tau$           | $0.06 \pm 0.02$ |
|                  | $Z, \gamma \rightarrow ee, \mu\mu$ | $0.10 \pm 0.10$ |
|                  | $b\bar{b}$                         | $0.05 \pm 0.03$ |
|                  | Fake lepton                        | $0.04 \pm 0.03$ |
| Total Background |                                    | $0.32 \pm 0.11$ |
| Observed Events  |                                    | 0               |

# Summary

- We have searched for the top quark in the dilepton channel using data collected during the 1992-1993 run.
- We found 2  $e\mu$  events and the number of total dilepton backgrounds expected is  
 $0.55 \pm 0.13$  event.

$$\left\{ \begin{array}{l} e\mu \quad 0.23 \pm 0.05 \\ ee.\mu\mu \quad 0.32 \pm 0.11 \end{array} \right.$$