Quarks and leptons may share constituents interacting at a scale $\Lambda >> M$. This interaction would interfere with the electroweak interaction causing the coupling to change well below $M=\Lambda$.

The onset of the new interaction can be modeled by adding a point interaction term to the lagrangian.

The size of the effect depends on the interference with the EW amplitudes being positive or negative.

Compositeness Limits

- If quark and lepton are composite particles that share constituents, an effective contact interaction arises between them (ref. Eichten, Lane, Peskin, PRL 50 811 (1983))
- The contact interaction is of the form:

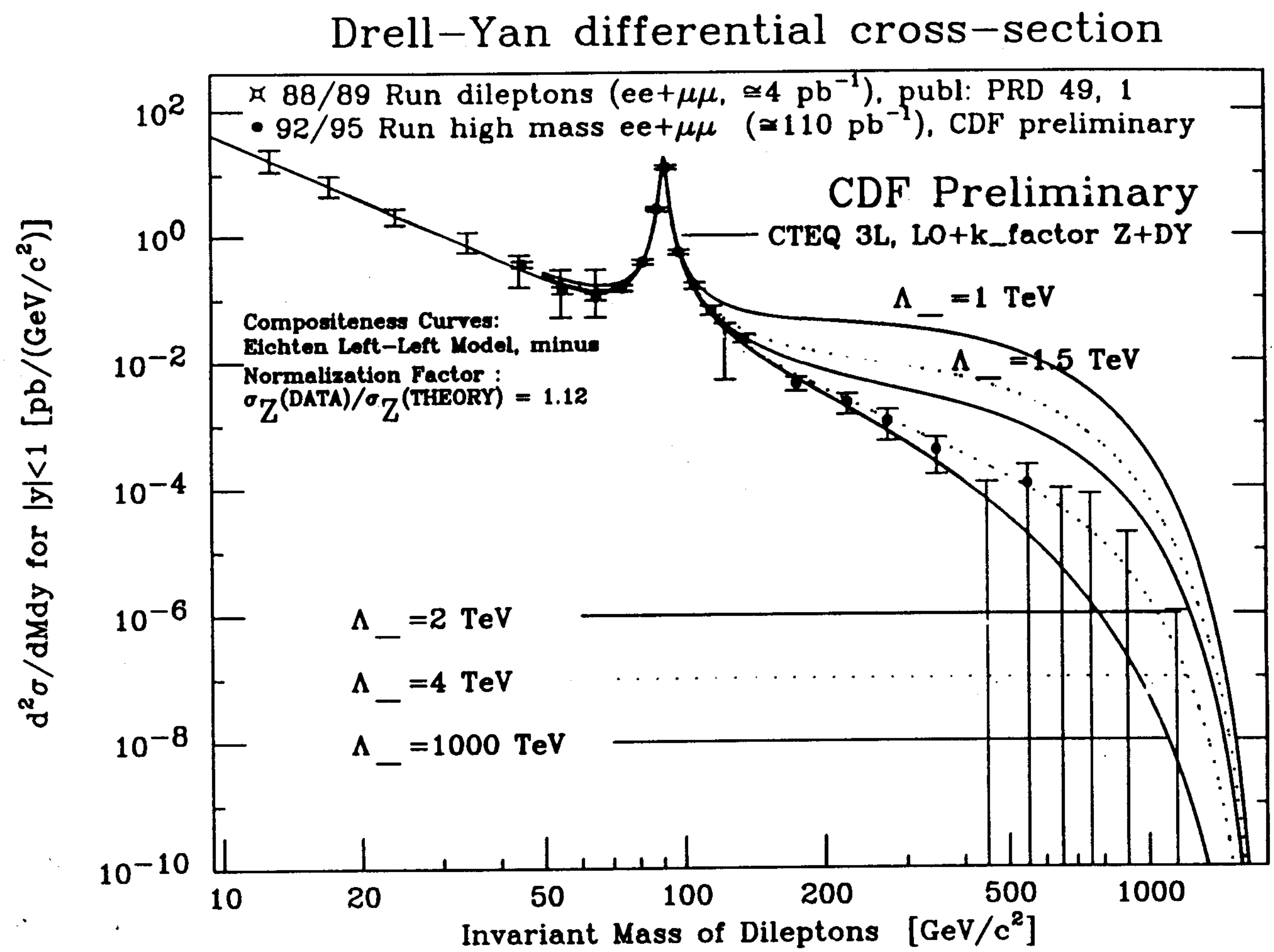
$$L \approx \frac{4\pi\eta}{\Lambda^2}\bar{q}\gamma^{\mu}q\bar{l}\gamma^{\mu}l. \qquad (1)$$

where η is the sign-combinatoric factor indicating a constructive (η=-1) or destructive (η=+1) interference between the photon and contact term Lagrangian and Λ is the compositeness scale.

- This interaction would result in a modified dilepton differential cross section at high invariant mass.

$$\sigma \approx \frac{1}{4}(Q_i - \frac{\eta M^2}{\alpha\Lambda^2})^2 + \frac{3}{4}Q_i^2 + \ldots, \qquad (2)$$

where Q_i is quark charge.



Assuming the interference sign that minimizes the effect, compositeness at a scale Λ≈ 2 TeV could be excluded by CDF and D0.

W DECAY ASYMMETRY

316 *9 The production of vector bosons*

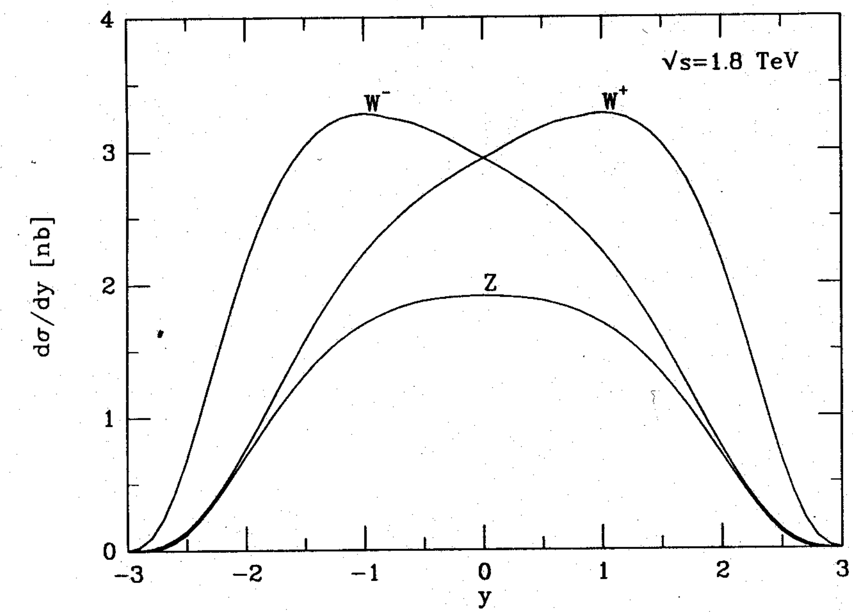
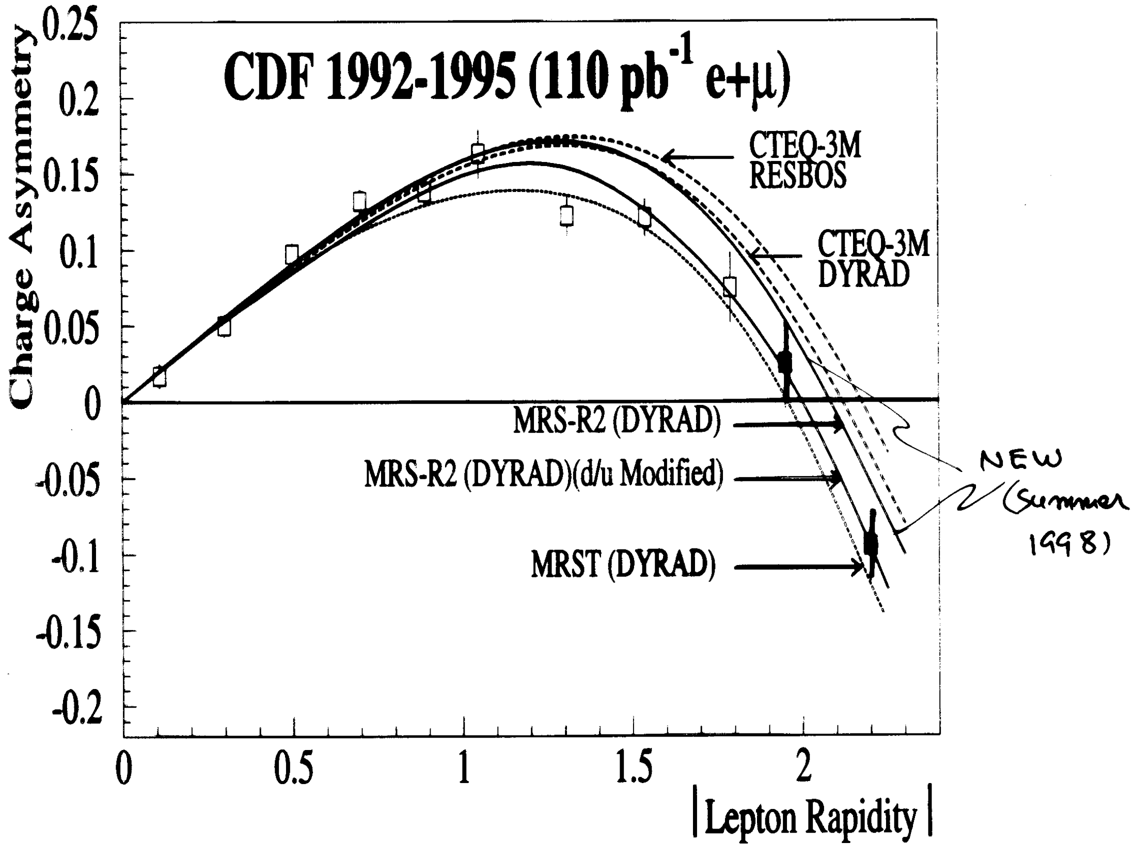


Fig. 9.7. W^+, W^- and Z rapidity distributions in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV.

The W rapidity distribution can be computed as for D.Y. pairs. The W^+ is produced preferentially in the direction of the u quark, that carries in average a larger momentum than the d quark. The measurement of the rapidity asymmetry of the e, μ decay measures the convolution of production with V-A decay. The opposite asymmetry in the decay is a minor effect relative to the asymmetry as determined by quark kinematics.



Since the V-A asymmetry is well understood and is a minor effect, the final asymmetry is still large and measures the ratio u(z)/d(x) of the structure functions. By exploiting the muons in the forward magnetized toroids and plug electrons CDF has been able to measure the u/d ratio up to x ~ 0,35.

THE W + JET EVENT SAMPLE

W production by fusion of up and anti-d quarks can be readily computed in the Standard Model, including higher order terms describing QCD production of additional jets in the event.

A large fraction of W events contain jets. This is an expected phenomenon in QCD, due to the radiation of hard gluons. The jet frequency and angular distributions are natural probes of the theory.

On the other hand, events with jet multiplicity 2 and higher are an irreducible background in the search for pairs of heavy tops.

TOP IS A MUST IN STANDARD MODEL

The study of the beauty-flavored hadrons indicated that the charge of the b was 1/3 and that in its decay the GIM mechanism was obeyed, preventing FCNC beauty decays ($b \rightarrow Z\ s$ forbidden). GIM requires the contribution of an up-type partner of the b quark.

The forward-backward asymmetry in $e^+e^- \rightarrow b\bar{b}$ is due to a $\cos\theta$ term whose weight is proportional to the third component of the b-weak isospin. Data indicate $I_3 = ½$.

M_Z, M_W are sensitive to virtual exchange of all quarks. In order to reproduce the experimental mass values, fits require a contribution by a top quark with mass $m_t \sim 160\text{-}190$ GeV.

THE SOLID EVIDENCE FOR A LARGE TOP MASS IN 1993

M_{top} > 42 GeV at LEP, since $Z \rightarrow t\bar{t}$ was not observed

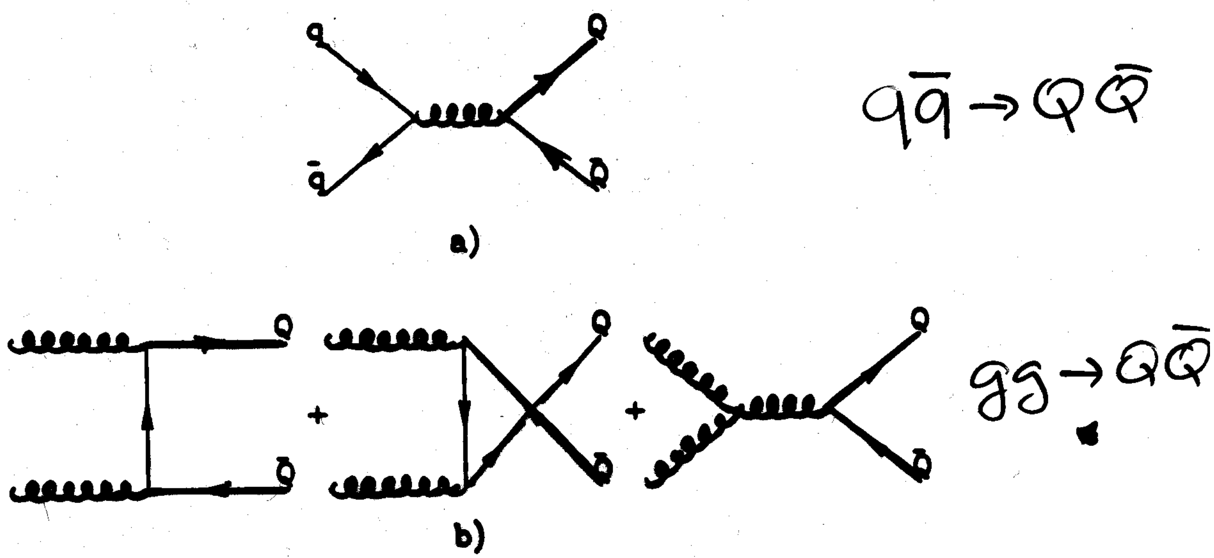
M_{top} > 56 GeV from the UA1 non-observation of $W \rightarrow t\bar{b}$

M_{top} > 62 GeV , independent of its decay modes from the CDF measurement of the W width

M_{top} > 68 GeV from the UA2 non-observation of $W \rightarrow t\bar{b}$ decay

M_{top} > 91 GeV by CDF in 1991, from direct searches of $t\bar{t}$ in channels with leptons, missing E_t and jets

M_{top} > 131 GeV by D0 in 1993, from non observation of any excess in a number of kinematical distributions.



The lowest order diagrams for production of heavy flavors are the same as in D.Y.

At Tevatron energies QCD for a top mass > 130 GeV QCD production of top pairs dominates over EW production of single top through W* exchange.

At the Tevatron production of top pair is ~ 90% from $Q\bar{Q}$, ~ 10% from gluon fusion. The cross section is very small

$\sigma(t\text{-}\bar{t}) \sim 5\text{pb}$, $\sigma(t\text{-}\bar{t})/\sigma_{inel} \sim 10^{-9}$, $\sigma(t\text{-}\bar{t})/\sigma_W \sim 10^{-3}$.

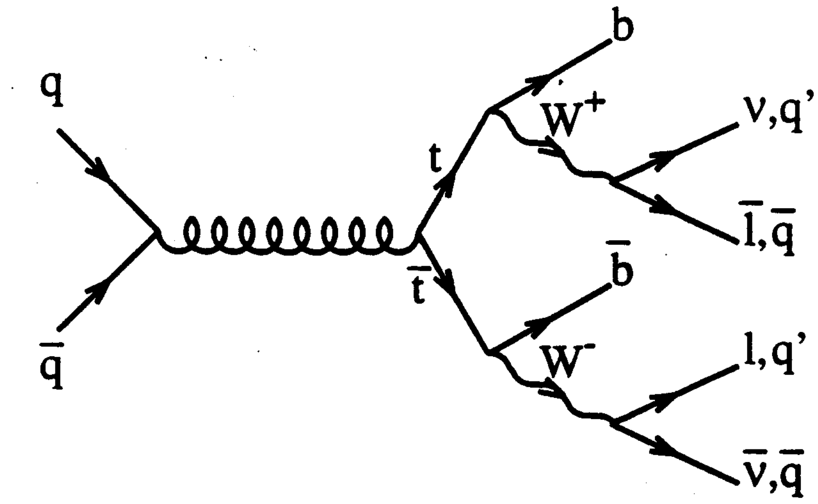


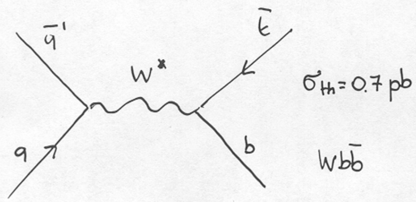
Figure 28: Tree level top quark production by $q\bar{q}$ annihilation followed by the Standard Model top quark decay chain.

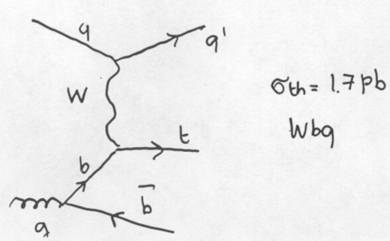
The final states in t-$\bar{t}$ production contains two W`s and two b-jets. The topology of the event is determined by the independent decays of the two W`s.

Single top production is a weak process mediated by a virtual W. One would observe one W and two b jets.

Single Top

- Signal sample is W+2 jet
- W* both jets are b's
- W-gluon one jet is a b, the other is a light quark jet.





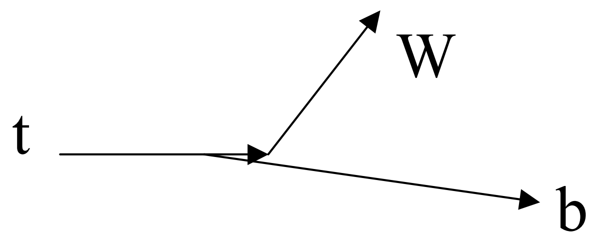
	# of Events Expected
QCD + W*	10.8±2.0
tt	2.2±0.6
W-g	1.2±0.3
Observed	15

The expected rate was ~ 1/20 of t-$\overline{t}$, too small to be seen in run 1.

—

WHAT TO EXPECT IN THE SEARCH FOR AN HEAVY TOP

Basic assumption : top decays as in the Standard Model



One can estimate the width in the limit $m_t >> m_W$

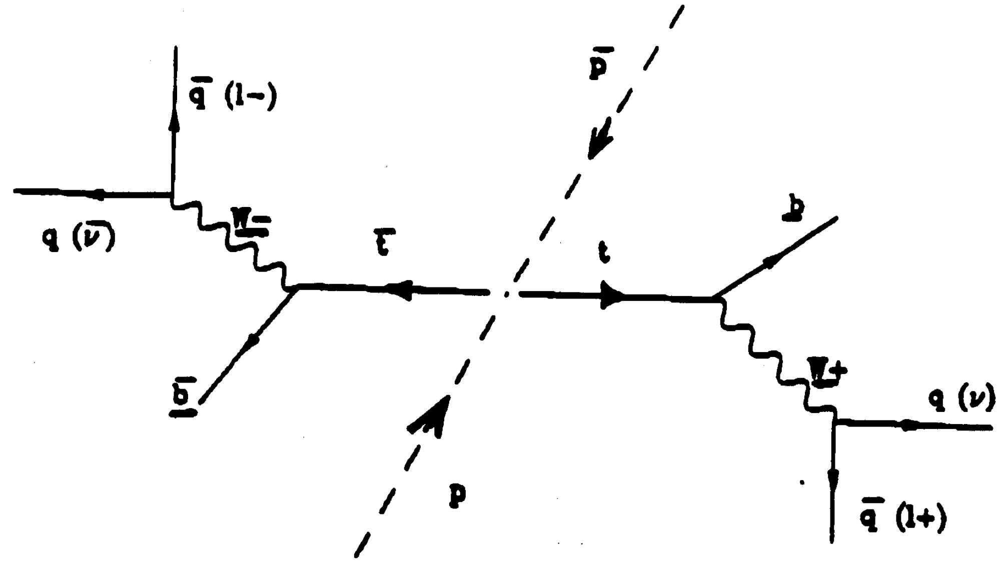
$$\Gamma(t \to bW) = \frac{G_F m_t^3}{8\pi\sqrt{2}} |V_{tb}|^2 \approx 170 MeV \left(\frac{m_t}{m_W} \right)^3$$

For $m_t \sim 2\, m_W$, $\Gamma \sim 1$ GeV, the top lifetime $\tau \sim 10^{-24}$ s, and top decays before binding with other quarks into hadrons.
A b-quark is always present in the final state. The partial widths are as in W decay, for example B(t → eνb) ~ 9%.

The e,μ + jets channel with Br ~ 30% and the ee,eμ,μμ + jets channel with br ~ 5% have been exploited for the discovery.

Later in time top was also seen in the 6 jet channel.

Within the Standard Model:



Branching fractions:

		Backgrounds
• Fully Hadronic Decays	$\frac{36}{81} \approx 44\%$	QCD jets
• $e^{\pm}$ or $\mu^{\pm} + jets + \nu$	$\frac{24}{81} \approx 30\%$	W+jets
• $e^{\pm}\mu^{\mp}$, $e^{\pm}e^{\mp}$, $\mu^{\pm}\mu^{\mp} + \nu + X$	$\frac{4}{81} \approx 5\%$	$b\bar{b}$, WW, $Z \to \tau\tau$

τ's not explicitly included.

B TAGGING WAS ESSENTIAL FOR THE CDF TOP DISCOVERY

CDF used two methods: Soft Lepton Tagging, indicative of a semileptonic b-decay in a jet, and Secondary Vertex Tagging.

Soft Lepton Tagging Algorithm

- lepton from $b \to \ell$ or $b \to c \to \ell$ (also $W \to (\tau\nu \text{ or } c\bar{s}) \to \ell$)
- Track based algorithm
- $P_T \geq 2$ GeV/c

Efficiency:

- μ's: Eff. measured with J/ψ's, Z's, and MC
- e's: Eff. measured with conversions and MC
- Efficiency for tagging an e/μ in a $t\bar{t}$ event: 20%

Once the efficiency for tagging e, μ in jets is known, Monte Carlo simulations can compute what the efficiency will be in t-$\bar{\text{t}}$ events.

Since the very beginning of the experiment the Pisa group had been pushing for a Silicon Vertex Detector to be installed on CDF.

The first proposal was included in the 1981 Design Project. The SVX was installed in 1992.

February 15, 1986
INFN PI/AE 86-4

A SILICON VERTEX DETECTOR FOR CDF

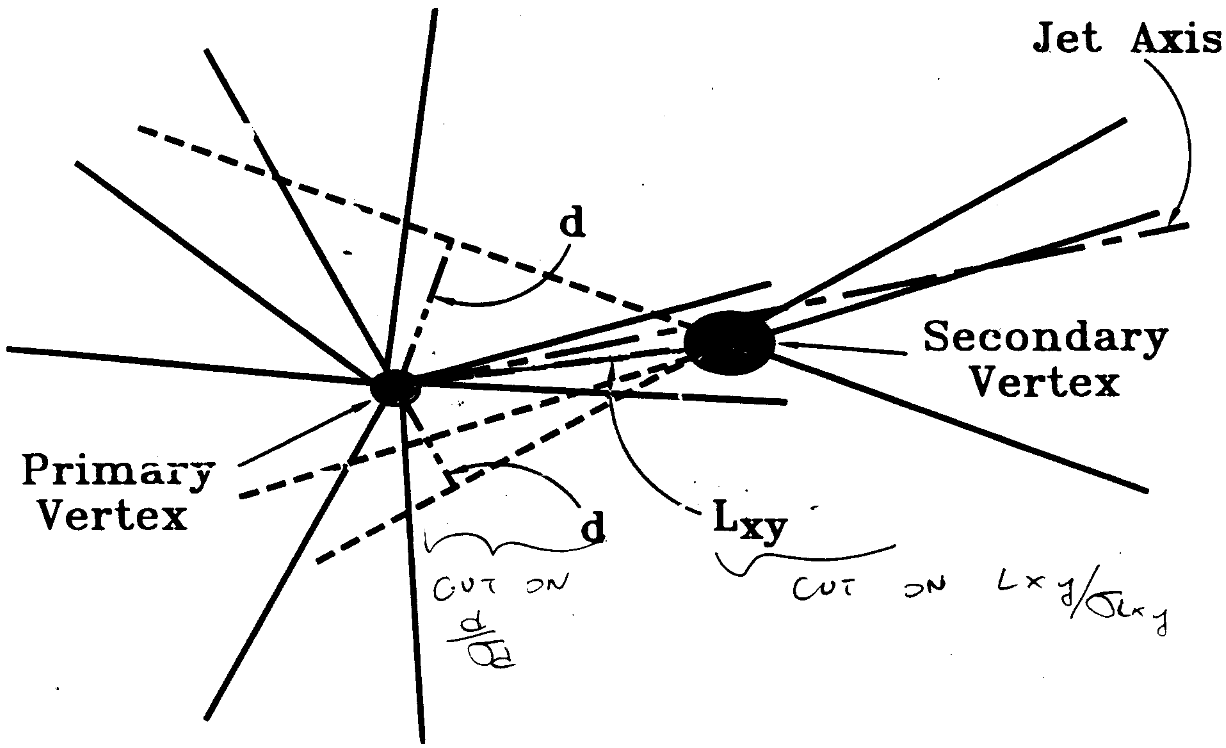
F.Bedeschi[a], S.Belforte[b], G.Bellettini, L.Bosisio, F.Cervelli, G.Chiarelli[c], R.Del Fabbro, M.Dell'Orso[a], A.Di Virgilio, E.Focardi, P.Giannetti, M.Giorgi, A.Menzione, L.Ristori, A.Scribano, P.Sestini[a], A.Stefanini, G.Tonelli, F.Zetti

Istituto Nazionale di Fisica Nucleare
Pisa, Italy

Presented by F.Bedeschi

at the IEEE Nuclear Science Symposium
San Francisco, October 1985

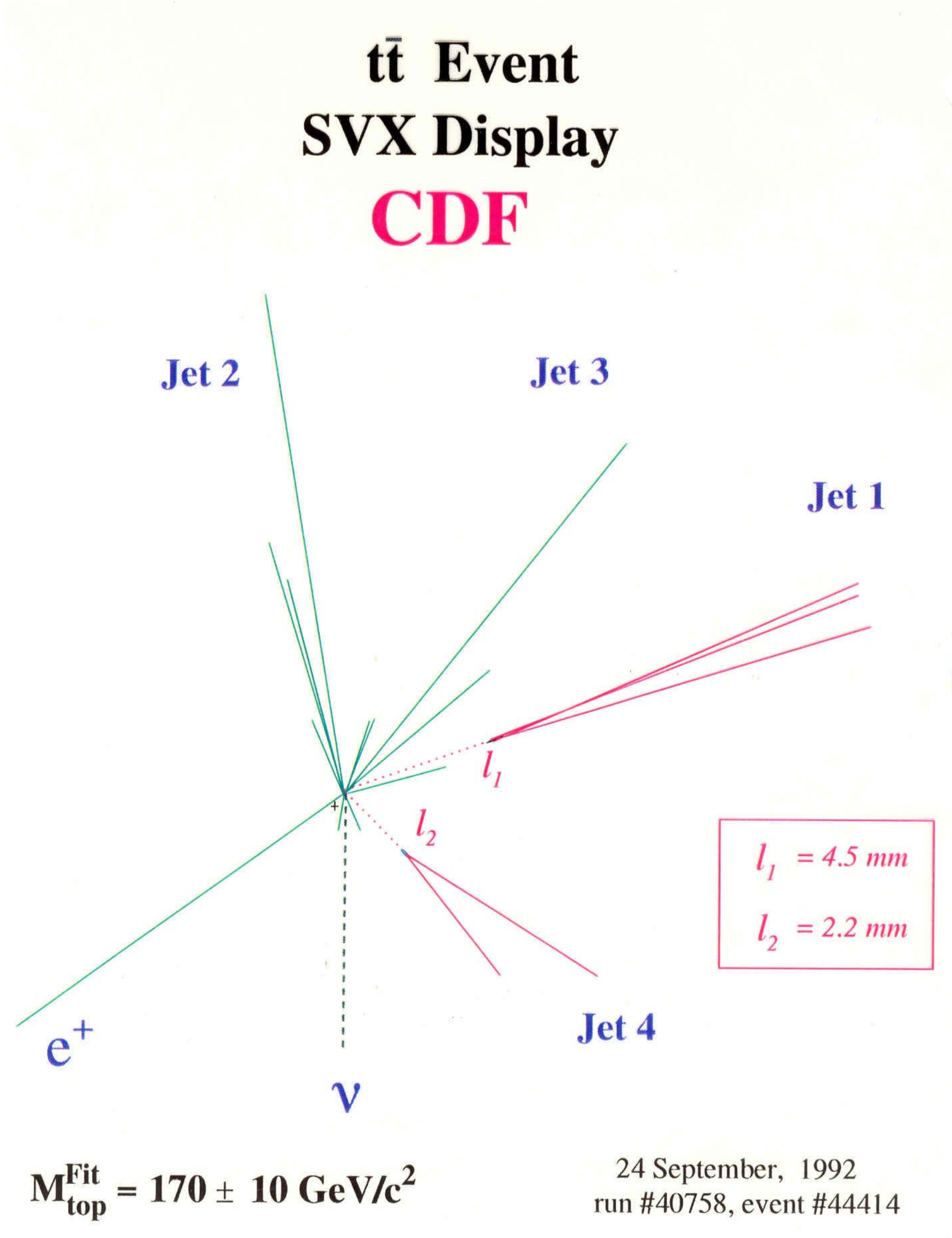
U.S.A. {
a) Now at Fermi National Accelerator Laboratory.
b) INFN and Rockefeller University.
c) Now at Rockfeller University.



The search for a secondary vertex is made in the transverse event plane.

If a bunch of tracks miss the primary vertex both in distance L_{xy} and in impact parameter d by several times the resolution, a secondary vertex is declared as found.

In some events the secondary vertices and the expected topology for top pairs appeared very clear.



THE STRONGEST "KINEMATIC TAG" IS THE MASS.

In order to attempt a fit in term of $t\text{-}\bar{t}$ production, the single lepton events must contain 4 jets. A sample of 7 b-tagged events was found in 1984 by requesting a fourth jet above a minimum energy.

Each event was fitted to the top hypothesis:

$$
\begin{aligned}
pp &\rightarrow t_1 + t_2 + X \\
t_1 &\rightarrow W_1 + b_1 \\
t_2 &\rightarrow W_2 + b_2 \\
W_1 &\rightarrow l + \nu \\
W_2 &\rightarrow j_1 + j_2
\end{aligned}
$$

The tagged jet is one of the b. All other jet assignments are tried.

There are 2 solutions for $p_z(\nu)$. Both are tried.

The solutions with acceptable χ^2 are found, the best one is entered into a mass distribution. A maximum likelihood technique fits this distribution in terms of a background and of a mass-dependent top template, and finds the top template and mass that best fit the data.

F.Abe et al., Phys. Rev.D50, No.2, 1994, p.2966.

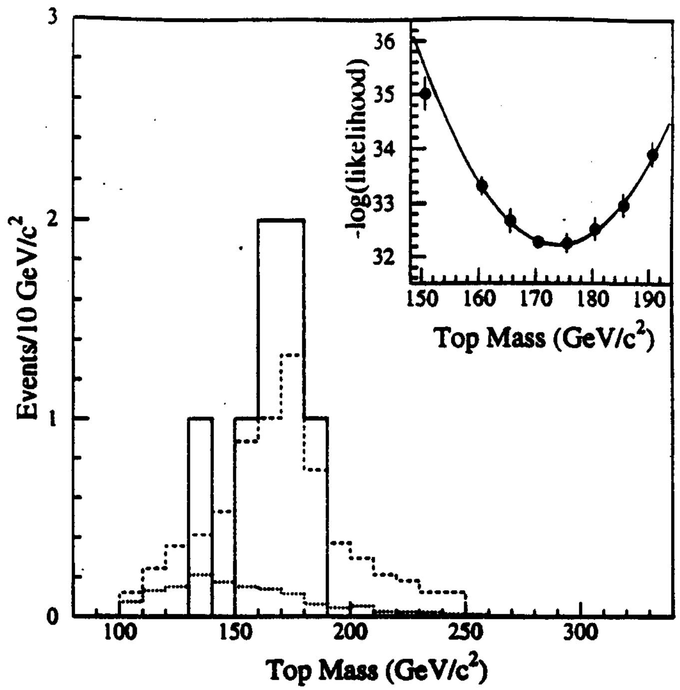


Figure 35: CDF top mass distribution (solid histogram) compared with the W + jets background prediction (dots) and the predicted signal+background distribution normalized to the data for m_t = 175 GeV (dashed). The inset shows the likelihood fit results.

Although only 7 events could be used the result contained a clear indication for a mass peak.

The 1994 "evidence" result was

$$m_{top} = 174 \pm 10(\text{stat.}) \pm 13(\text{syst})\ \text{GeV}.$$

with a corresponding t-$\bar{t}$ cross section of $\sigma_{t\text{-pair}} = 13{,}9\ (+6{,}1)(-4{,}8)$ pb, slightly larger than the expectation of 5,1 pb.

THE OBSERVATION

In 1995 the data sample collected by CDF was large enough to allow to turn an evidence into a discovery.
By means of kinematical studies of several channels, also D0 claimed the discovery.

- A total of 67 pb^{-1} of data was used.
- The samples:

channel		events	bkg
l+jets	SVX	27	6.7 ± 2.1
	SLT	23	15.4 ± 2.0
dilepton (DIL)		6	1.3 ± 0.3

- The numbers:

$$P = 1 \times 10^{-6} \quad (4.8\,\sigma)$$

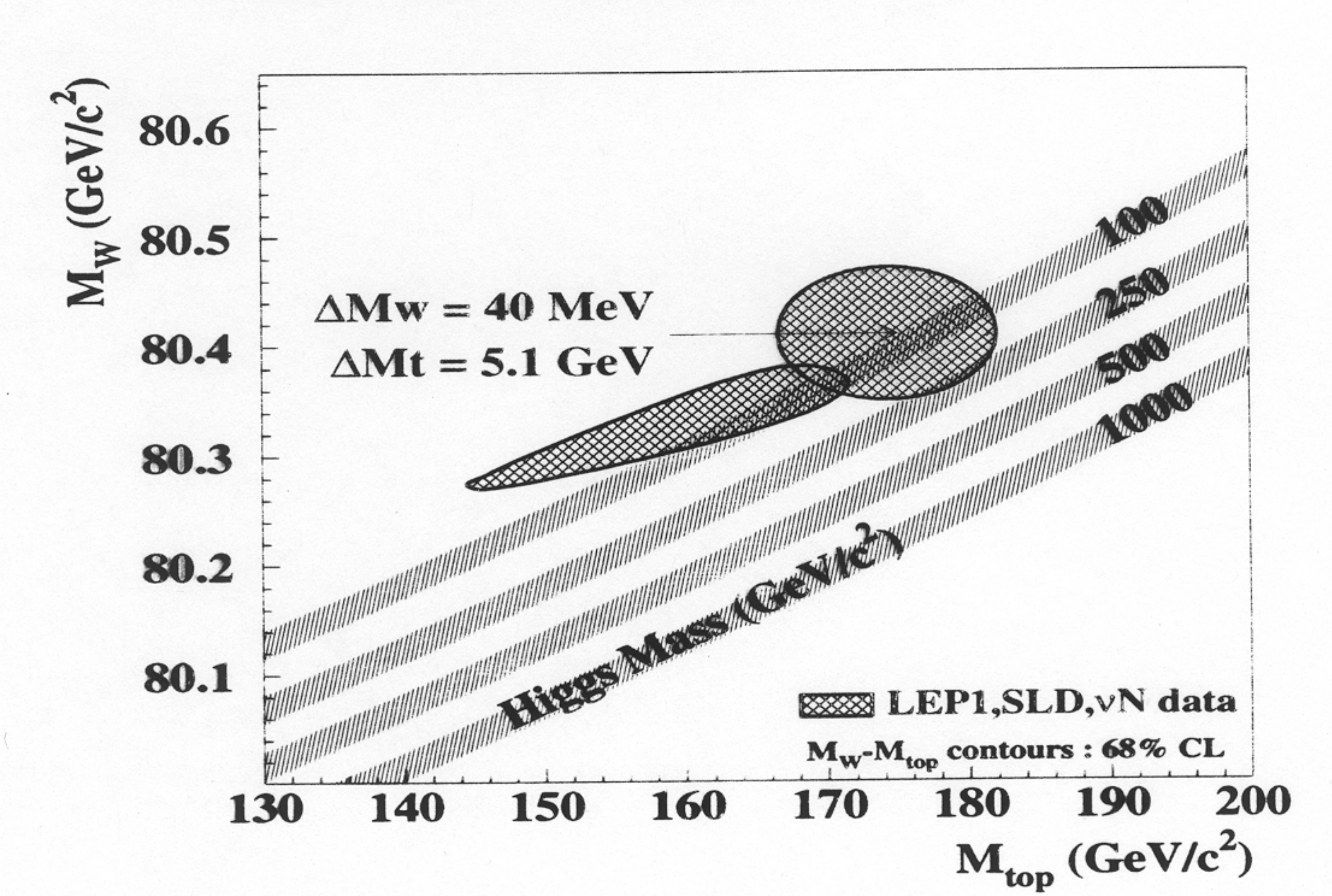
$$M_{top} = 176 \pm 8(\text{stat}) \pm 10(\text{syst})\ \text{GeV}/c^2$$

$$\sigma_{t\bar{t}}(M_{top} = 176) = 6.8^{+3.6}_{-2.4}\ \text{pb}$$

Table 1. Summary of CDF and D0 measurements of the top quark mass

Experiment	Top event topology di-lepton GeV/c^2	 lepton+jet GeV/c^2	 all hadronic GeV/c^2	Combined GeV/c^2
D0	168.4±12.8	173.3±7.8		172.1±7.1
CDF	167.4±11.4	175.9±7.1	186.0±11.5	176.0±6.5
Combined				174.3±5.1

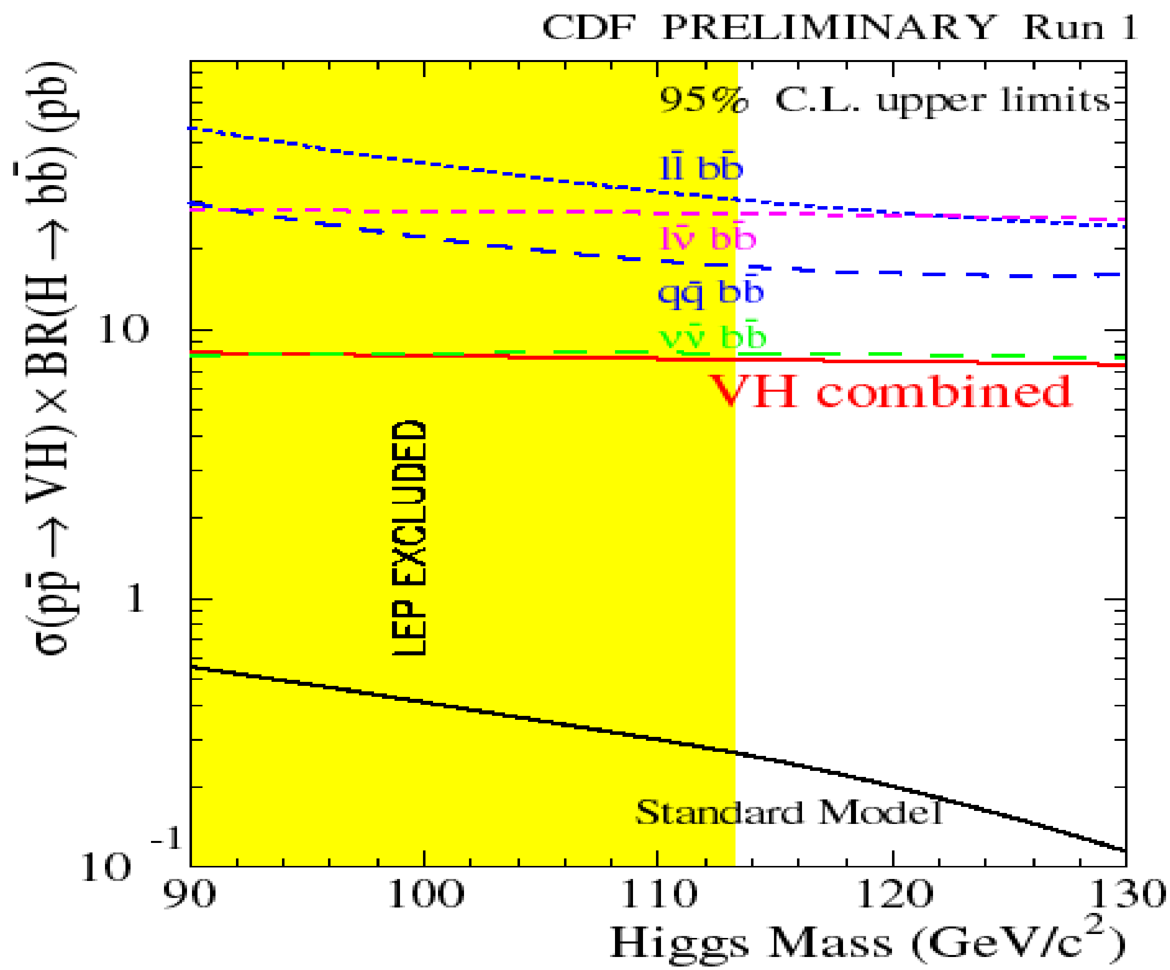
By combining CDF and D0 results, in 1999 the error on the top mass could be reduced to 5,1 GeV.



The combined CDF+D0 results measured M_W with a 80 MeV error. This was about 1,5 times worse than the present (2001) LEP2 result. The indication for the S.M.Higgs mass was consistent with that derived from an analysis of the precision EW data.

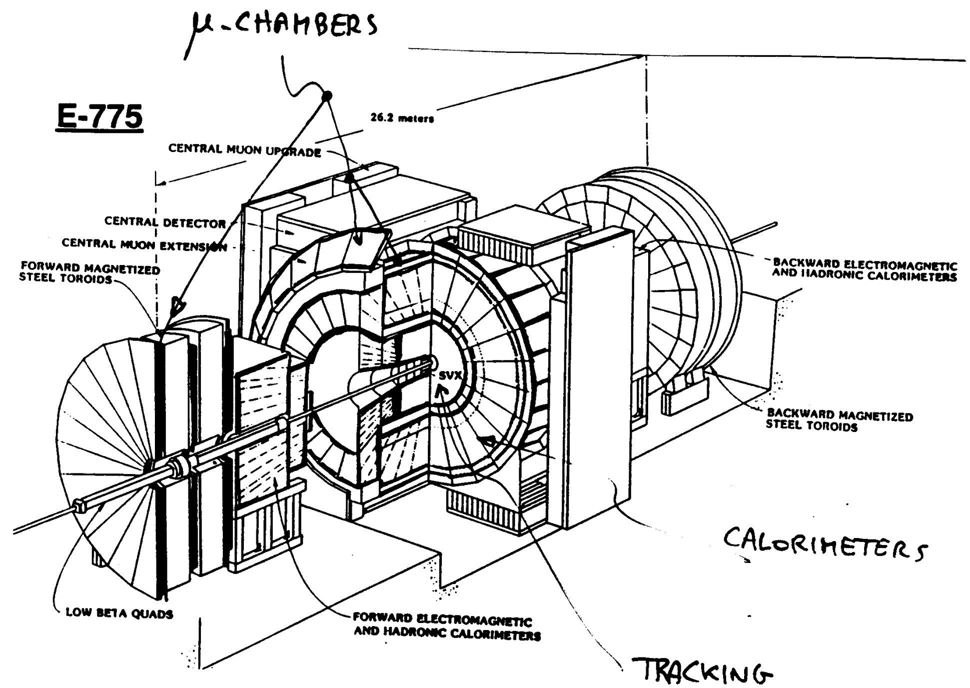
A $\gamma\gamma ee$ candidate event: was this a hint for SUSY?

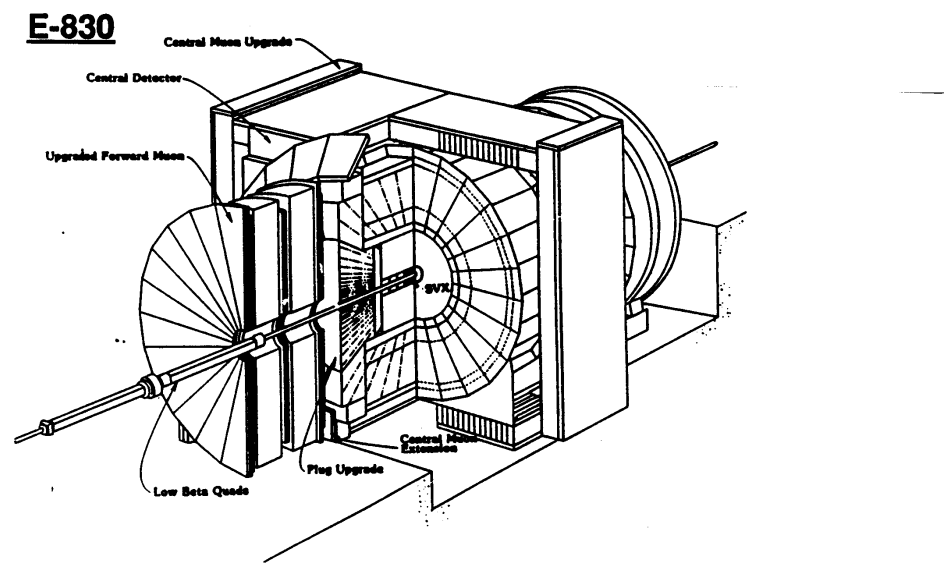
In a search for lepton-photon events some excess was found in the $e\gamma E_{t,miss}$

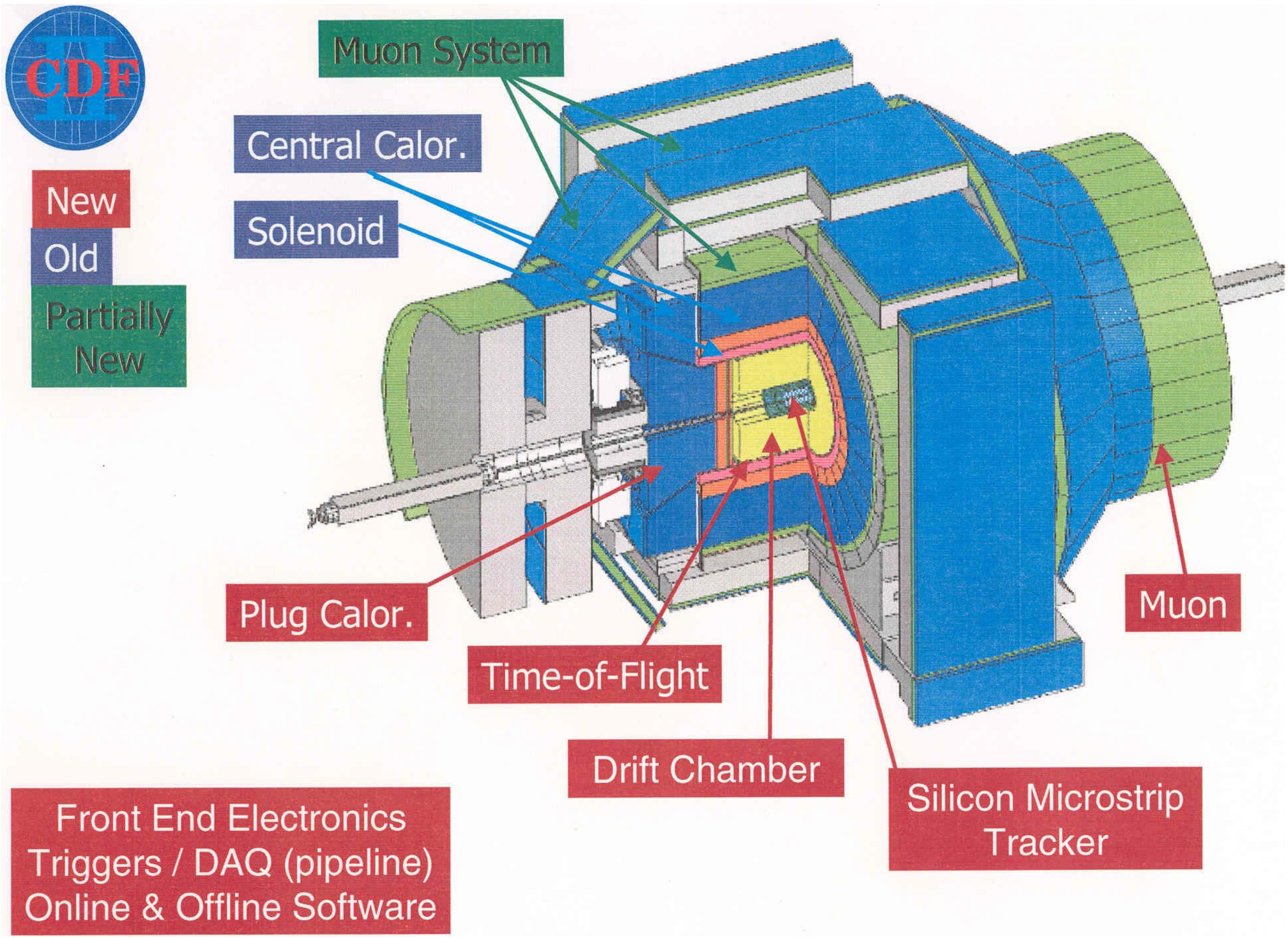


The S.M.light Higgs boson was searched in associated production with W, Z and in the b-$\bar{\text{b}}$ decay channel. The upper limit reached was at about 1/20 of the expected cross section.

For the new Tevatron run2 the CDF detector was made more compact and all calorimeters employ plastic scintillator as sensitive medium.






CDF II
New
Old
Partially New
Muon System
Central Calor.
Solenoid
Plug Calor.
Time-of-Flight
Drift Chamber
Silicon Microstrip Tracker
Muon
Front End Electronics
Triggers / DAQ (pipeline)
Online & Offline Software

CAN WE SEE THE HIGGS BOSON IN RUN2?

At Tevatron Collider energy:

$\sqrt{s}$ = 2.0 TeV

assume **M_H=120 GeV/c^2**

•Cross section for VH production is ~ 0.1 pb

•Run 2a integrated luminosity (by 2002?) will be ~ 2 fb^{-1}

•Expected rate of VH events is ~ 200

•Trigger+analysis efficiency is ~ 2%

•Only a few observed events expected, more from background

•Only limits to the S.M. Higgs mass will be set

HOWEVER

We will be getting near to it …