Studying EWSB at the Tevatron (Lecture #2)

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CDF Experiment

SLAC Summer Institute
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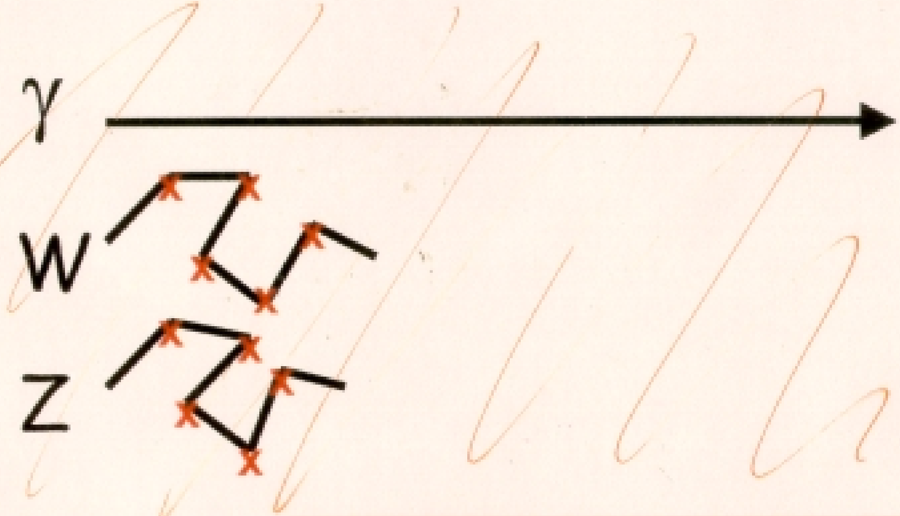
OUTLINE

- Indirect Probe of the Higgs Boson from Precision Electroweak Measurements
  - Overview
  - Electroweak Parameters at Z pole: M_z, $\sin^2\theta_W$, … (Patrick Janot's Lecture)
  - ➡ M_w
    - Tevatron Measurement
    - Comparision to LEP-II Measurement
  - ➡ M_{top}
  - SM Implication of EW Measurements
  - Top Properties.

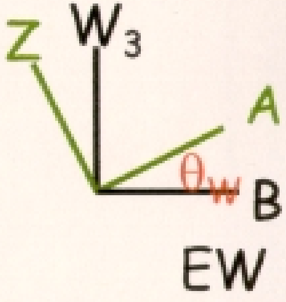
Higgs Particles Condensed



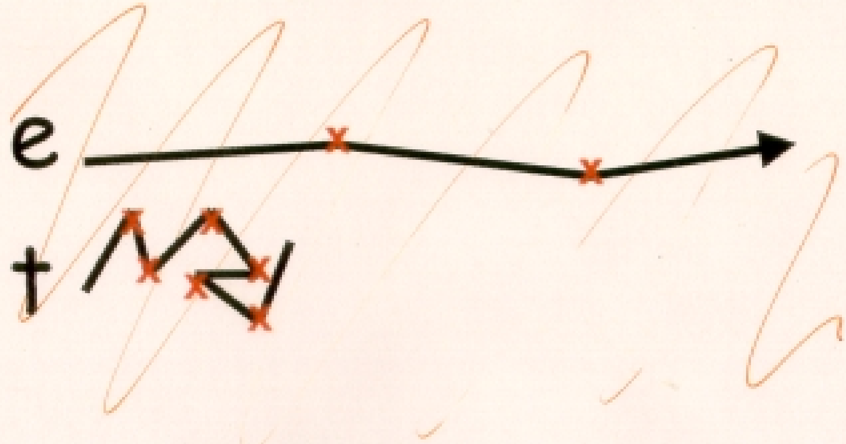
$M_\gamma = 0$

$M_W = \sqrt{\tfrac{1}{2}}\, g \langle\phi\rangle_0$

$M_Z = M_W / \cos\theta_W$



$$\boxed{M_W = 37.3\ \text{GeV} / \sin\theta_W}$$

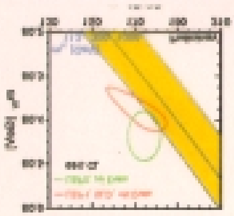


$M_e = g_e \langle\phi\rangle_0$

$M_t = g_t \langle\phi\rangle_0$

$$\boxed{\begin{array}{c} g_e \sim 10^{-6} \\ g_t \sim 1 \end{array}}$$

$g_i \propto M_i^2$



SM Higgs Mass : No specific prediction

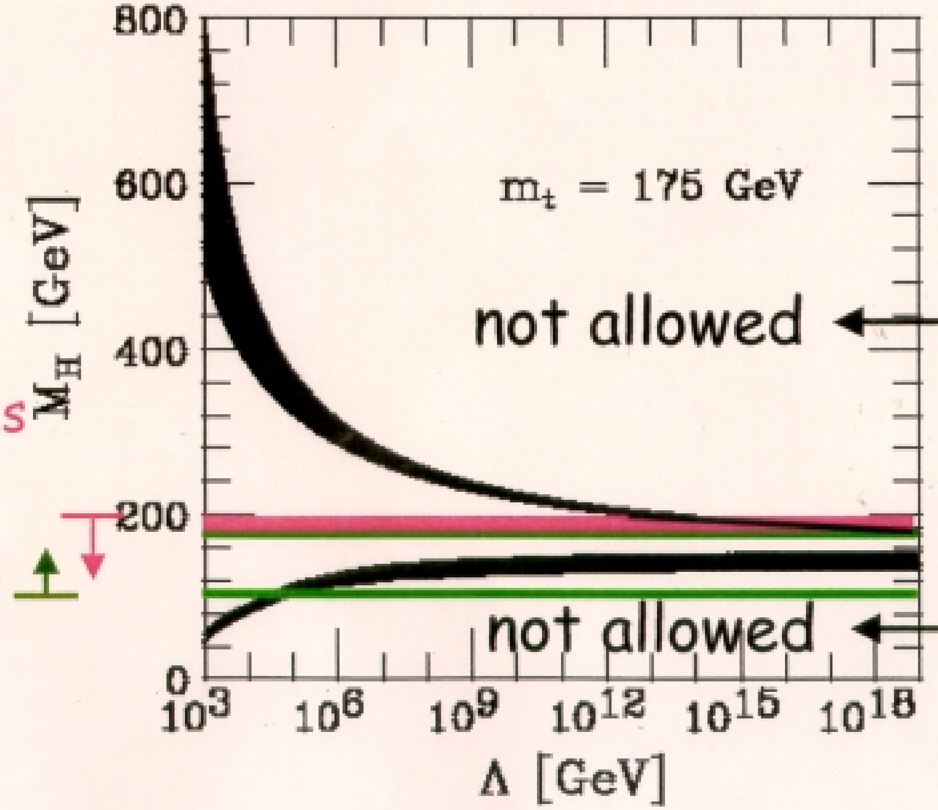
Standard Model Limitations :

~100 < M_H < ~ 1,000 GeV depending on the scale, Λ
where the SM might break down, i.e. new physics must appear.

130 < M_H < 180 GeV @ $\Lambda = M_{Planck}$

Experiments

SM Theory



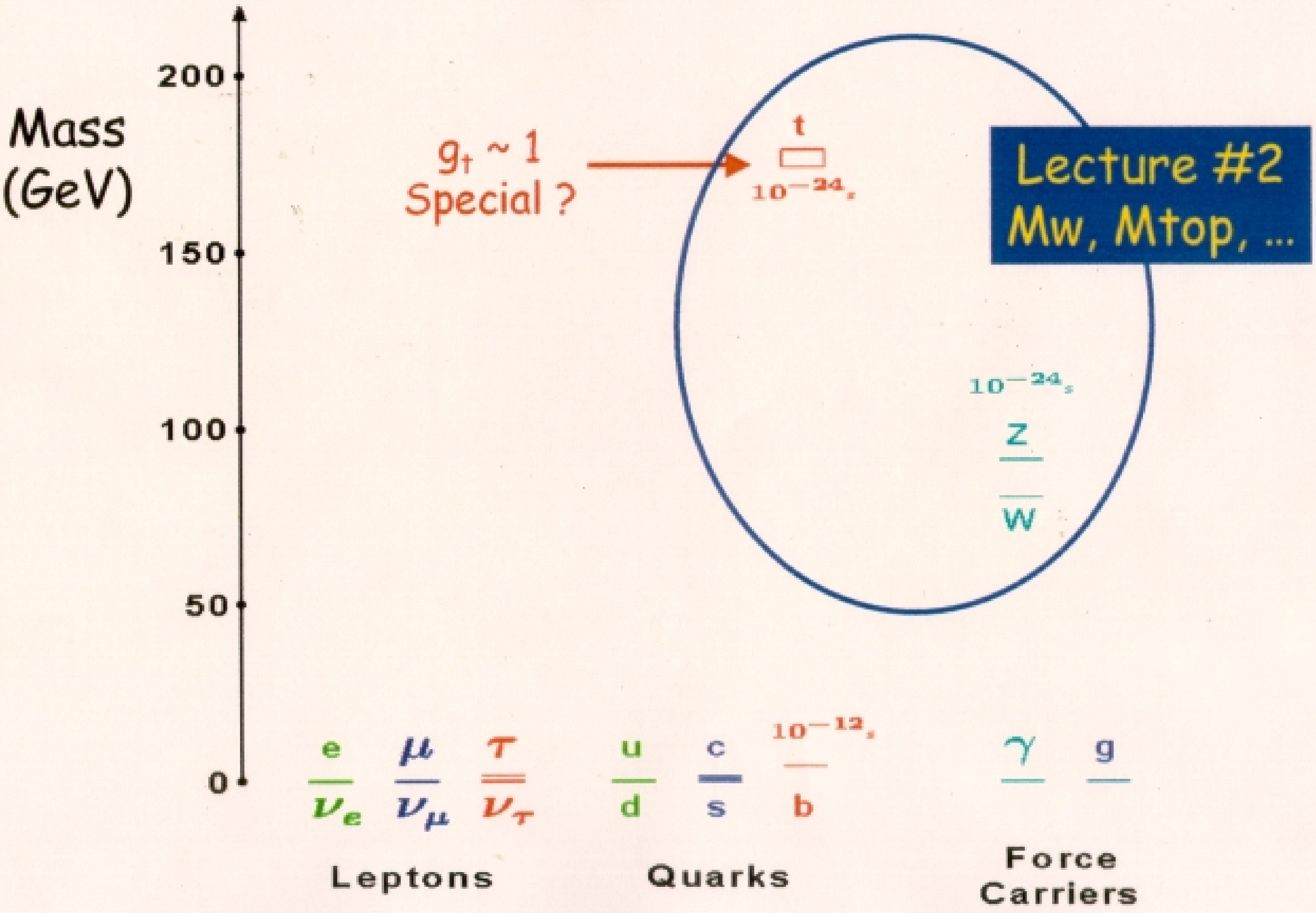
Couplings blow up !

Potential unstable

Precision EW meas.s
M_H < ~200 GeV

Direct searches
M_H > 114 GeV

Elementary particle masses

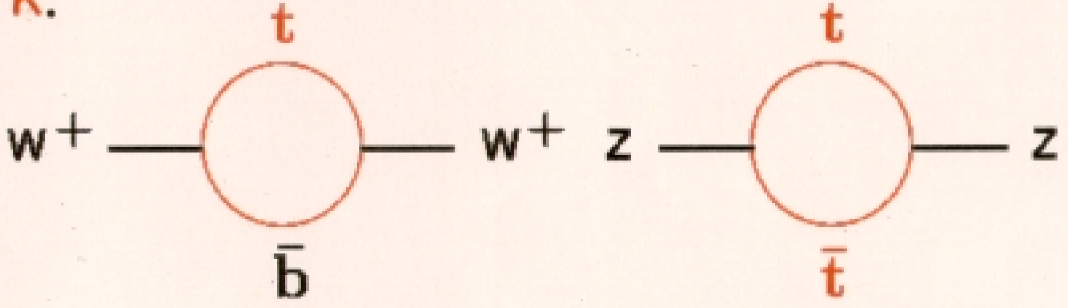


$g_t \sim 1$
Special ?

Lecture #2
Mw, Mtop, ...

EW Precision Measurements

- EW observables probe the Higgs bosons indirectly by means of quantum corrections.
- Large quantum corrections to EW observables come from the top quark.

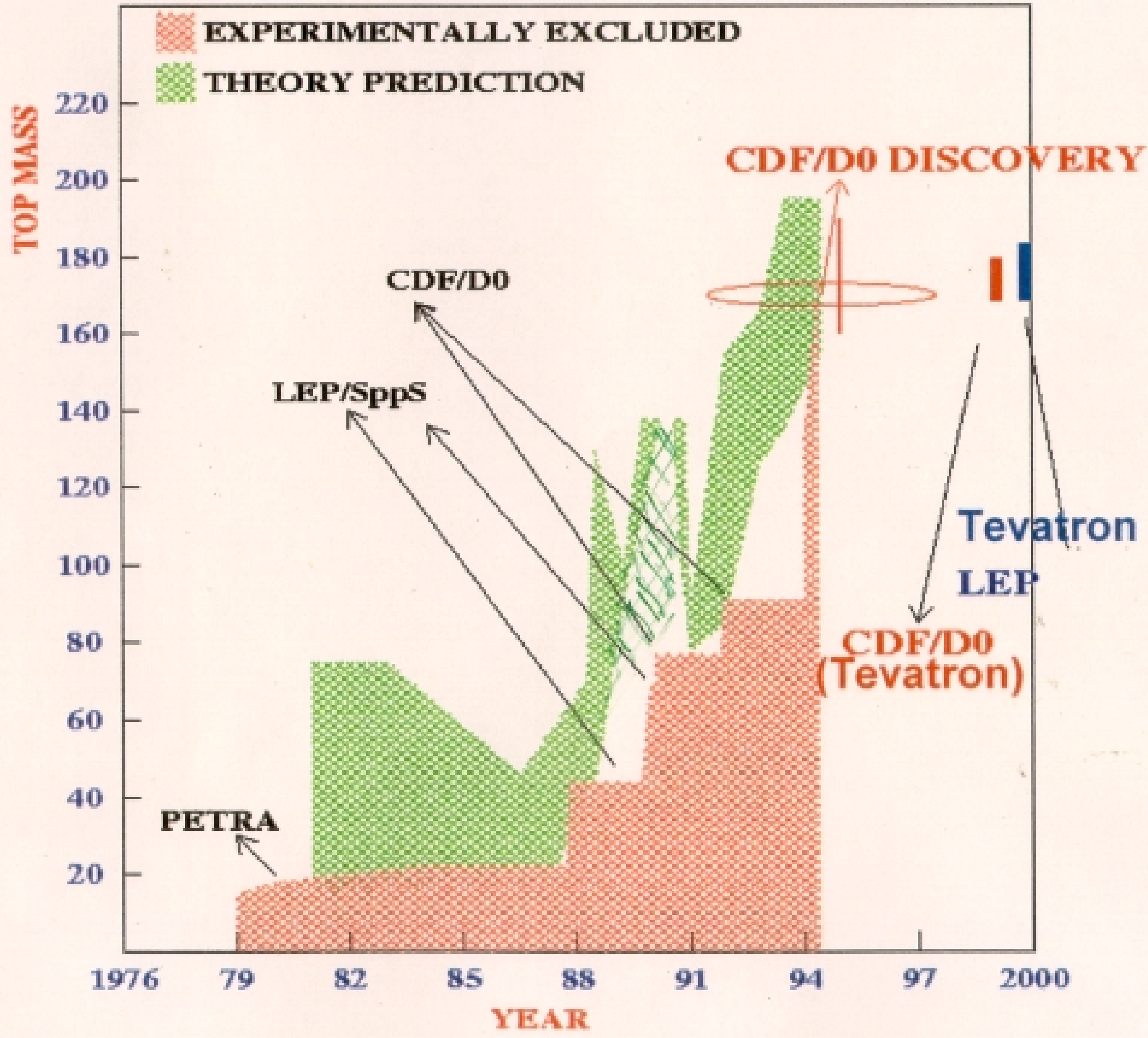


→ different quantum corrections to M_W and M_Z

$$
\begin{aligned}
\left[\frac{M_W}{M_Z \cdot \cos\theta_W}\right]^2 &= 1 + \frac{3 G_F M_t^2}{8\sqrt{2}\pi^2} \\
&= 1 + 0.01\left[\frac{M_t}{175\,\mathrm{GeV}}\right]^2
\end{aligned}
$$

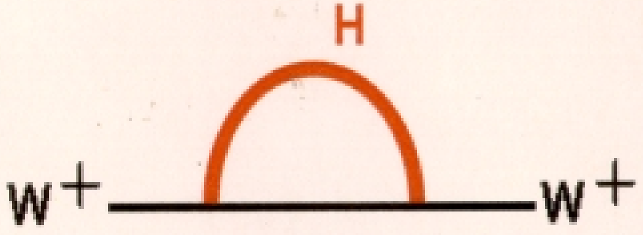
c

M_{top} : measurement vs. predition



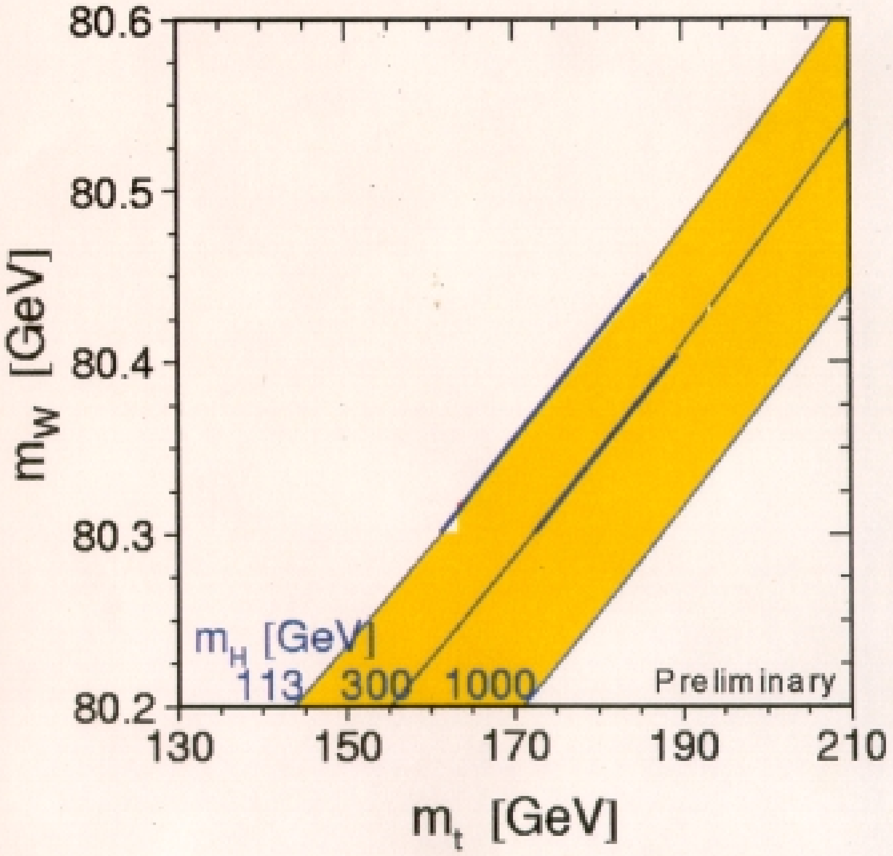
EW Precision Measurements

- Secondary contributions to EW observables are the Higgs boson contributions: $\ln(M_H^2/M_W^2)$



$$
\begin{aligned}
M_W = \;& 80.3767 \\
+ \;& 0.5235[(\frac{M_{top}}{174.3\mathrm{GeV}})^2 - 1] \\
- \;& 0.05613 \ln(\frac{M_{Higgs}}{100\mathrm{GeV}}) \\
- \;& 1.081(\frac{\Delta\alpha}{0.05924} - 1) \\
+- \;& \ldots
\end{aligned}
$$

input parameters : $\alpha_{em}(M_Z^2)$, G_F, M_Z



You should go to the masses,
learn from them, and
synthesize their experience
into better, articulated
principles and methods, ……

- Mao -

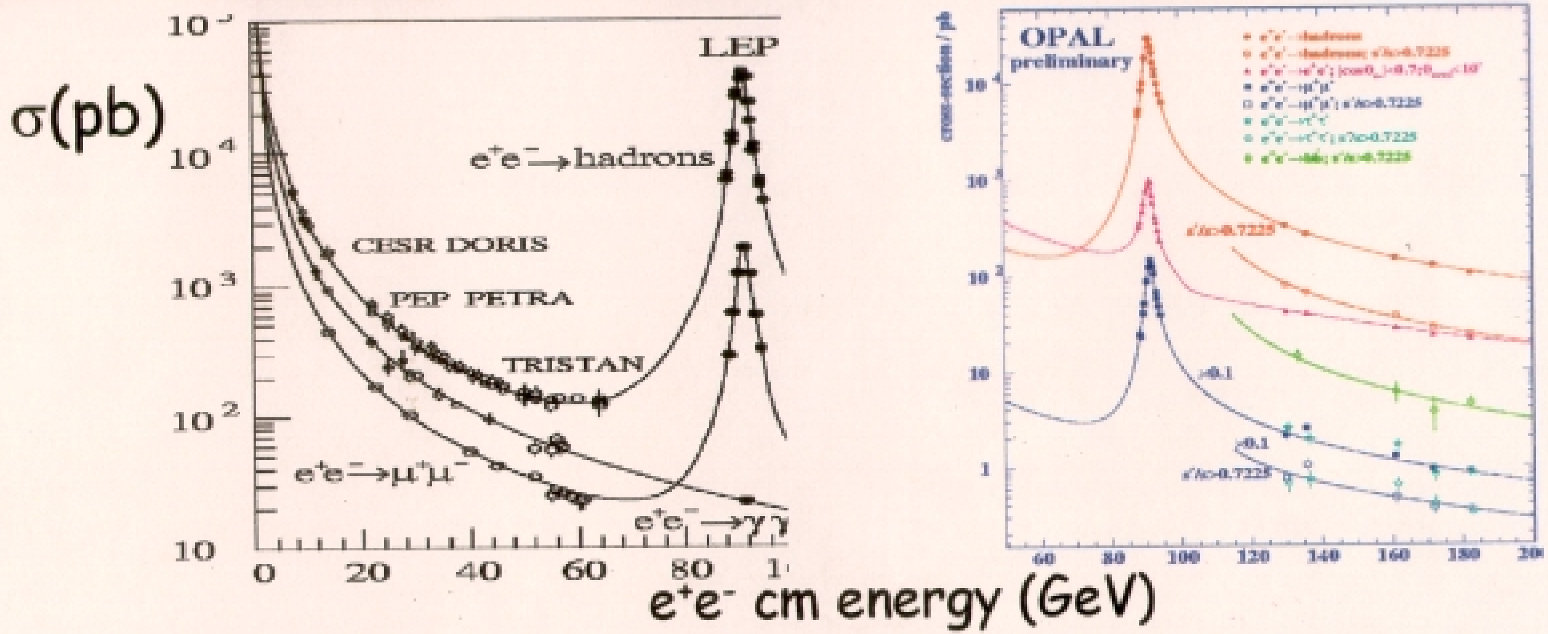
Electroweak Input Parameters

- The EW strengths are specified by 3 parameters:
  - two gauge couple constants: g, g'
  - vacuum expectation value of the Higgs field: v

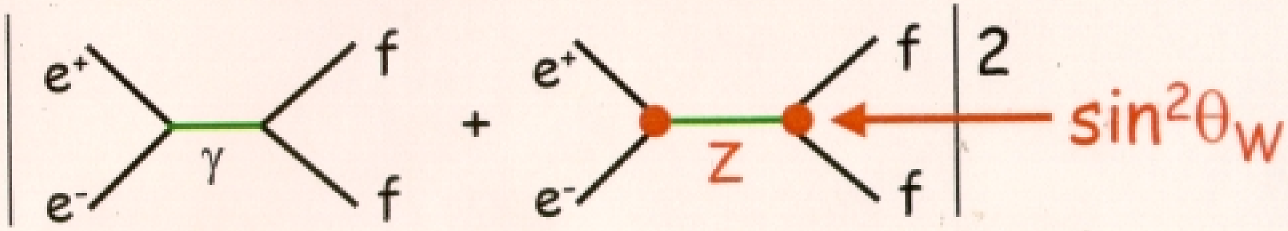
$$\sin^2\theta_W = 1 - \frac{M_W^2}{M_Z{}^2} = \frac{\pi\alpha}{\sqrt{2}G_F M_W^2} = \frac{e^2}{g^2} = 1 - \frac{e^2}{g'^2} \quad \text{(Tree-level)}$$

- The theory is democratic: any 3 variables may be chosen.
  - *Choose the 3 parameters most accurately measured so that the predictions for any other measurements become as precise as possible, allowing sensitive tests of the theory.*
  - In the early 1980s, e or α, G_F, $\sin^2\theta_W$
  - Since August 1989 when δM_Z = 160 MeV (LEP), $\alpha_{em}(M_Z{}^2)$, G_F, M_Z
  - Current accuracy
    - δM_Z : 2.1 MeV (2×10^{-5}) (LEP)
    - δG_F : 1×10^{-5} (μ lifetime)
    - $\delta\alpha(M_Z{}^2)$: 2×10^{-4} : dominant uncertainty

Precision Measurements of M_Z, $\sin^2\theta_W$



$\sigma_{ff} \sim$



$$\sigma_{ff} = \sigma_\gamma + \sigma_{\gamma/Z} + \frac{12\pi}{M_Z^2}\frac{\Gamma_{ee}\Gamma_{ff}}{\Gamma_Z^2}\frac{s\,\Gamma_Z^2}{(s - M_Z^2)^2 + s^2\Gamma_Z^2/M_Z^2}$$

M_Z (LEP1) = 91.1871 +- 0.0021 GeV ~ 2×10^{-5}

$\sin^2\theta_{eff}$ (LEP1 + SLC) = 0.23156 +- 0.00017 ~ 7×10^{-4}

$\alpha_{em}(M_Z^2)$ Evaluation

Dominant uncertainty : hadronic vac. polar. contrib.:

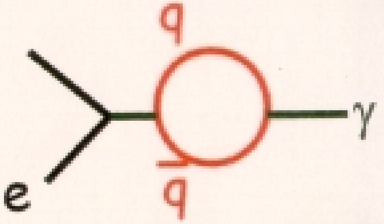
Can not be reliable calculated.

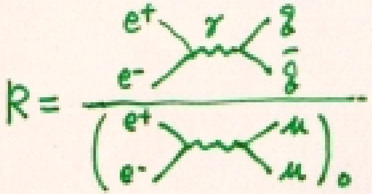
With application of dispersion relations,

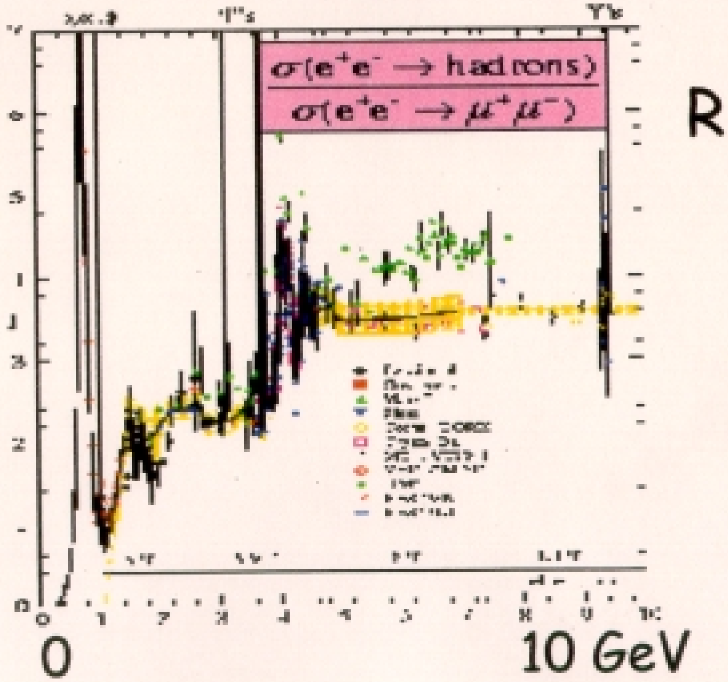
measured R values are used to determine it.

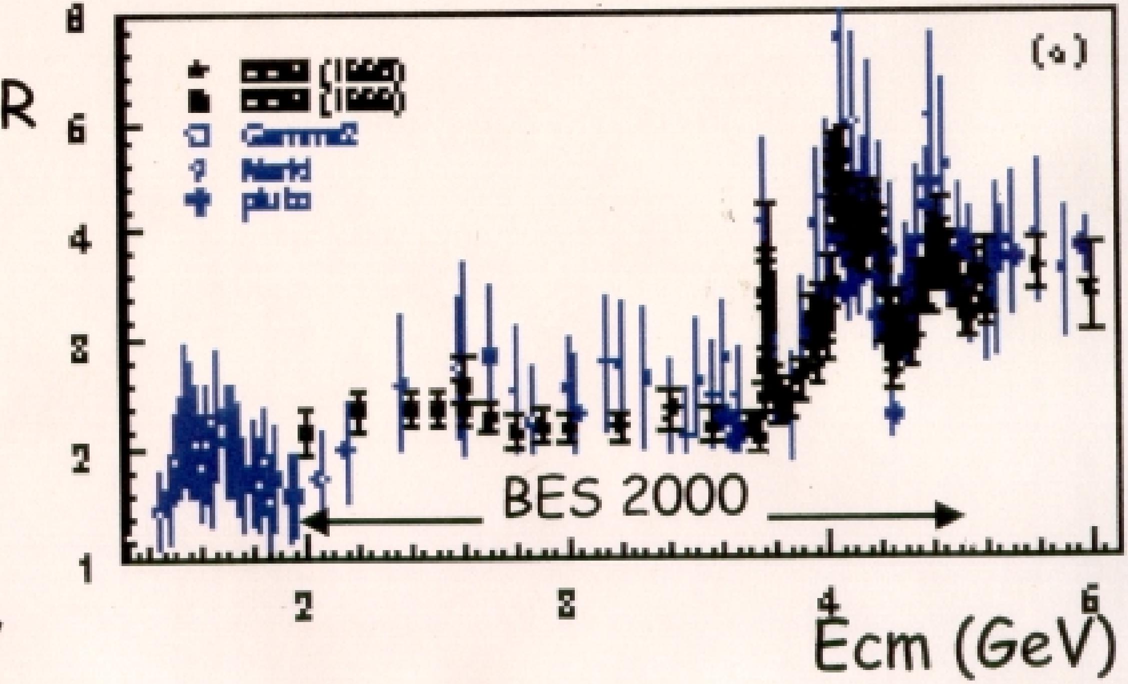
$R = \sigma(e^+e^- \rightarrow qq) / \sigma^0(e^+e^- \rightarrow \mu^+\mu^-)$

$\sigma^0(e^+e^- \rightarrow \mu^+\mu^-) = 4\ \pi\alpha^2(0) / 3Ecm^2$

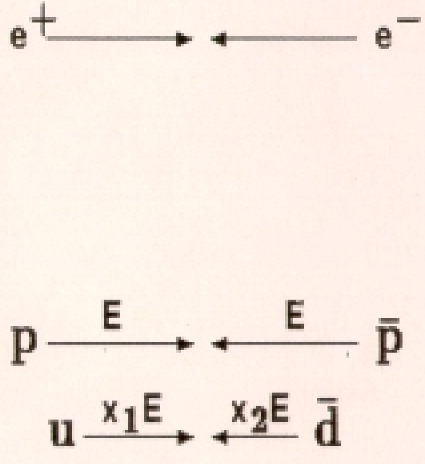


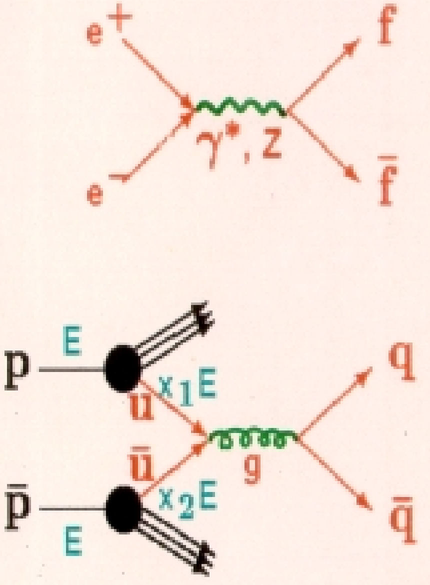




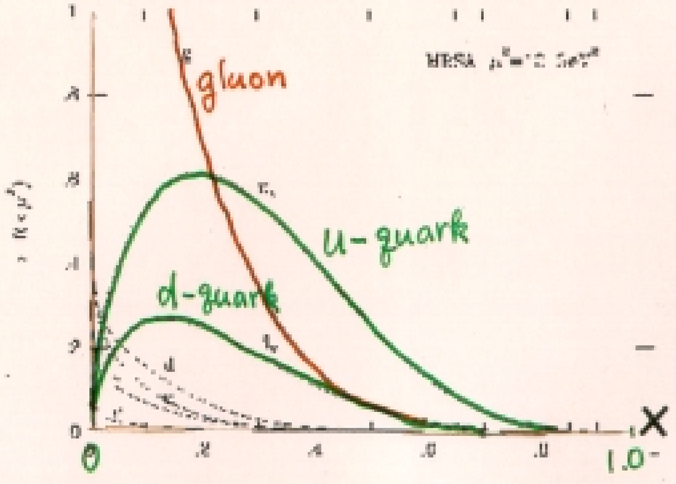


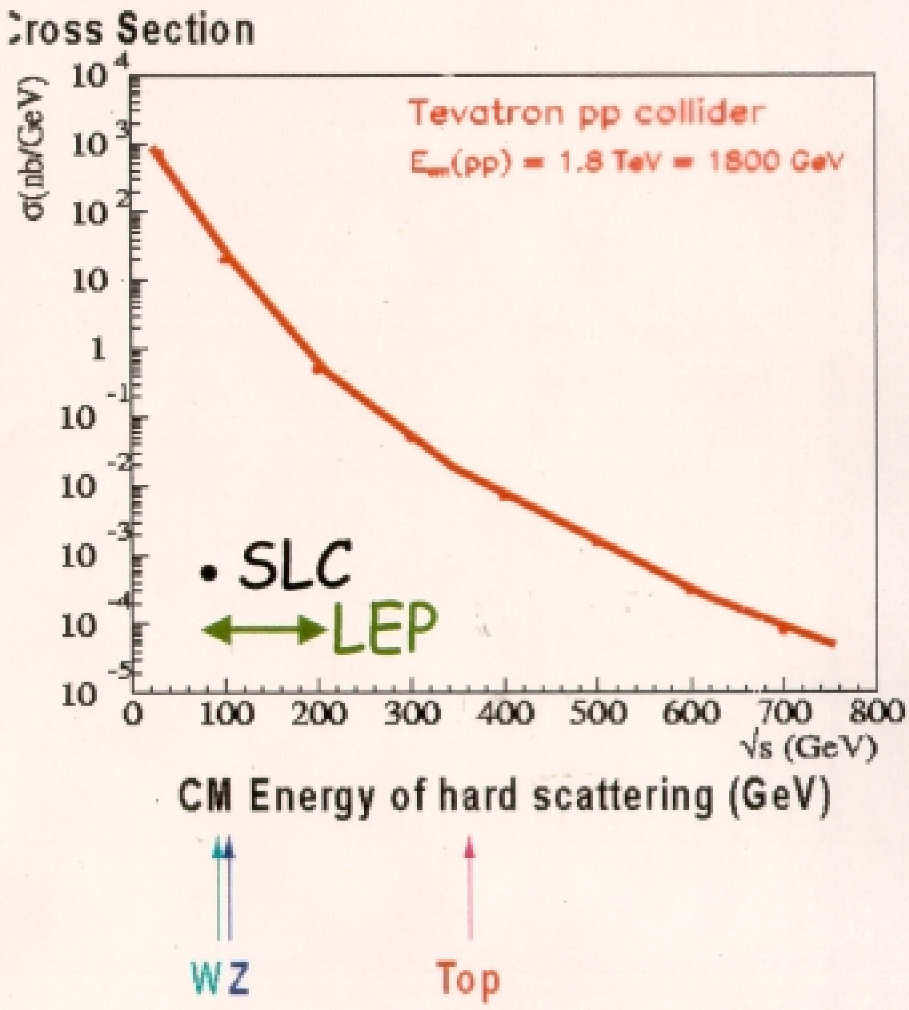
Lepton vs Hadron Colliders

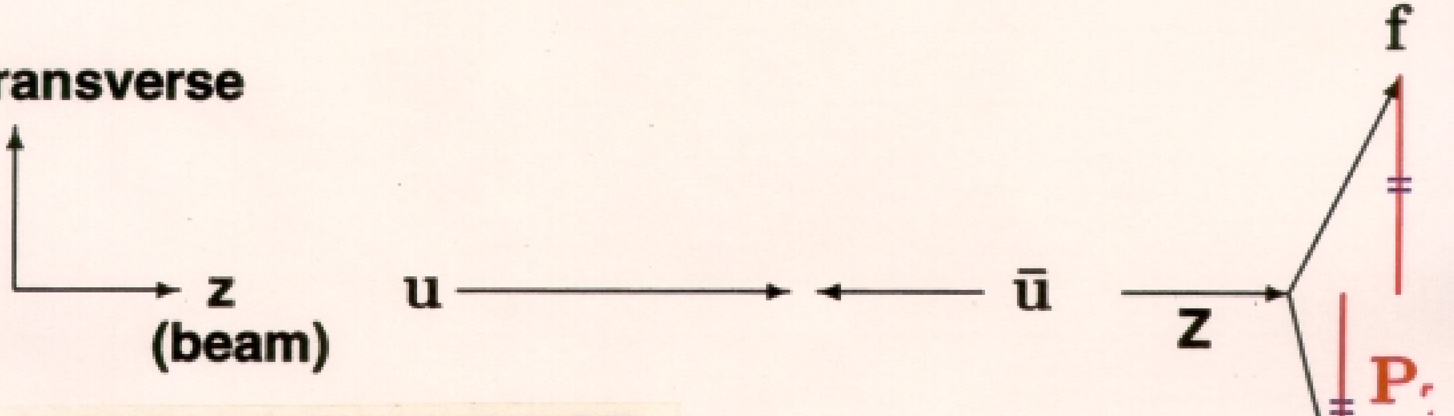


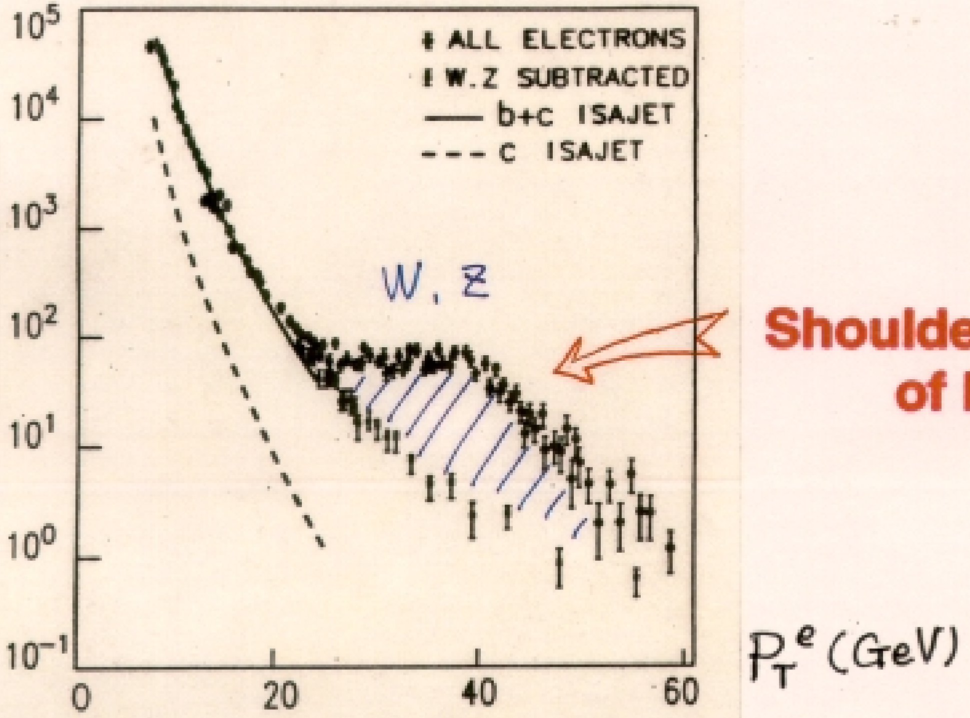


x $f(x,\mu^2)$: q, g energy dist. func.

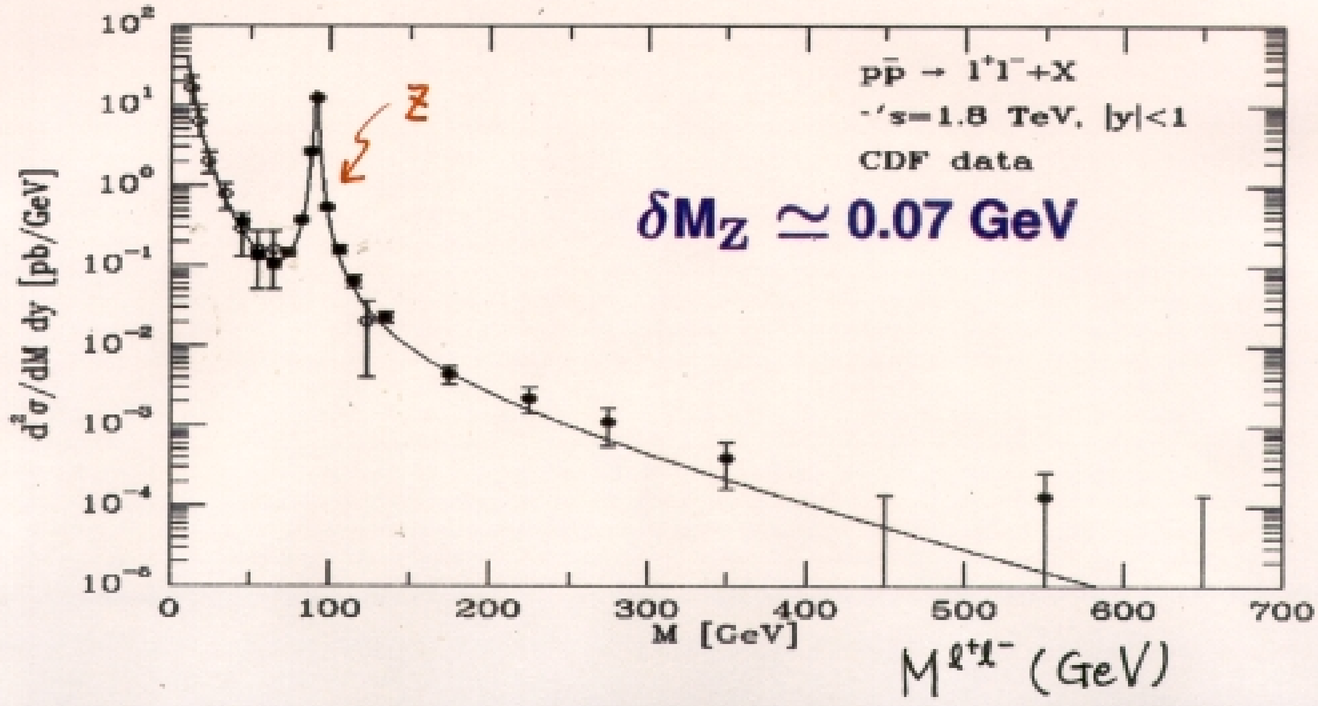








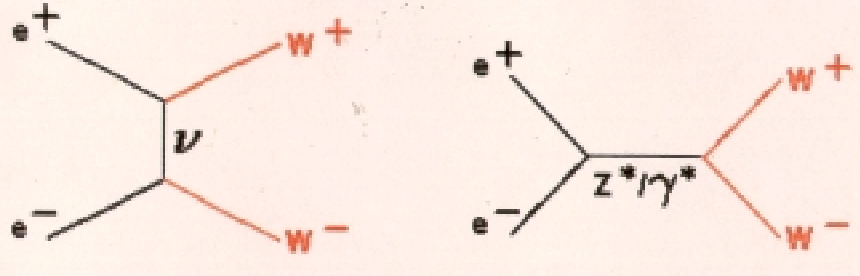
Shoulder ⇒ Production of Massive Objects



$\delta M_Z \simeq 0.07$ GeV

W Production

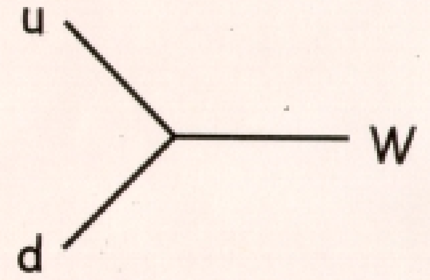
W^+W^- at LEP 2 (e^+e^-)



$WW \rightarrow q\bar{q}q\bar{q}$	46%	~~~2700~~
$WW \rightarrow q\bar{q}\ell\nu$	44%	~~~2700~~
$WW \rightarrow \ell\nu\ell\nu$	10%	~~~600~~

~10k events / expt.

W at Tevatron ($p\bar{p}$)



$W \rightarrow l\,(e,\mu,\tau) + \nu$ (30%)

$W \rightarrow qq'$ (70%)

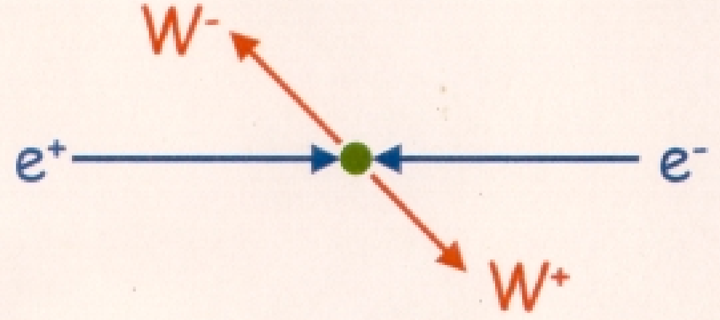
~40k events / expt.

($W \rightarrow e\nu$, $\mu\nu$)

$W \rightarrow q\bar{q}'$: swamped by QCD dijet background.

Precision Measurement of M_W

LEP 2 (e^+e^-)



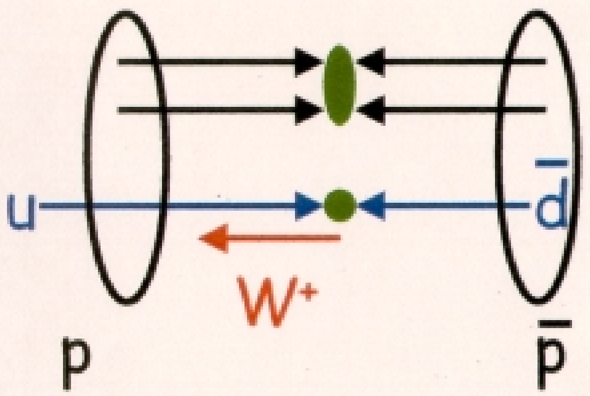
$W^+ \to e^+\nu$, $W^- \to u\overline{d}$

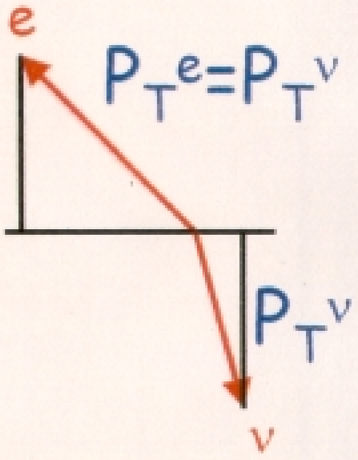
$P_i(W^+) + P_i(W^-) = 0$, i=1,2,3

$E(W^+) + E(W^-) = E(e^+) + E(e^-)$

$$M^W = \sqrt{2P^eP^\nu(1-\cos\theta_{3D})}$$

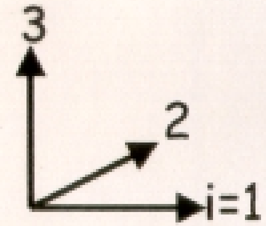
Tevatron ($p\bar{p}$)





$W^+ \to e^+\nu$

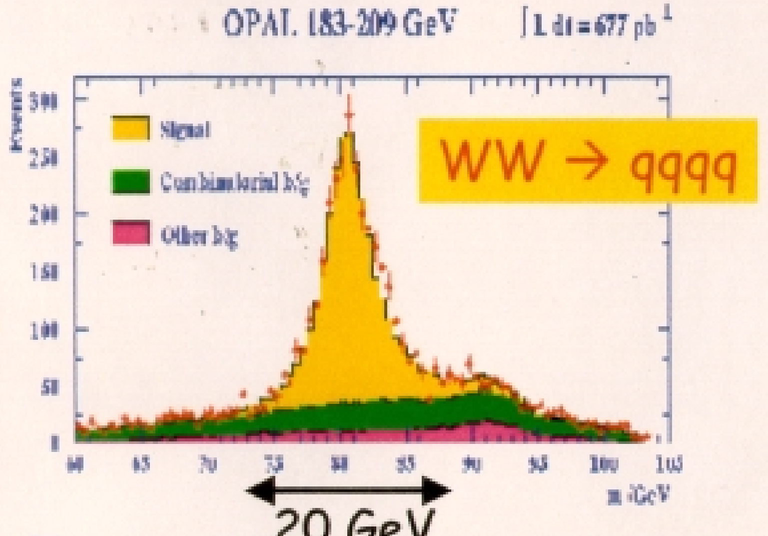
$P_i(W^+) = 0$, i=1,2

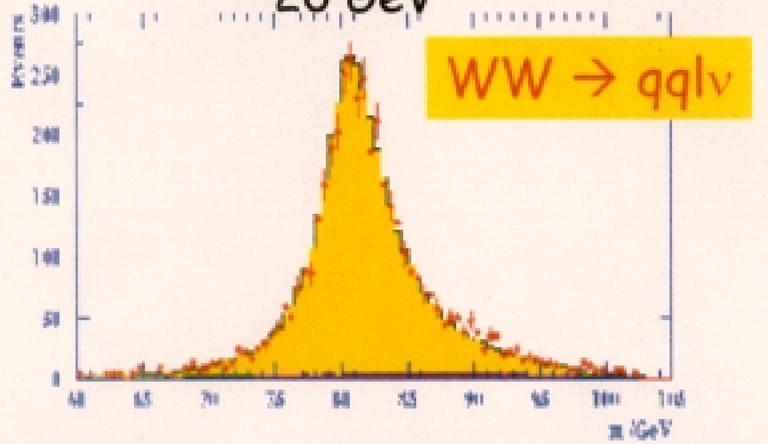


$$M_T^W = \sqrt{2\, P_T^e P_T^\nu\, (1-\cos\theta_{2D})}$$

Precision Measurements of M_W

LEP 2 (e^+e^-)

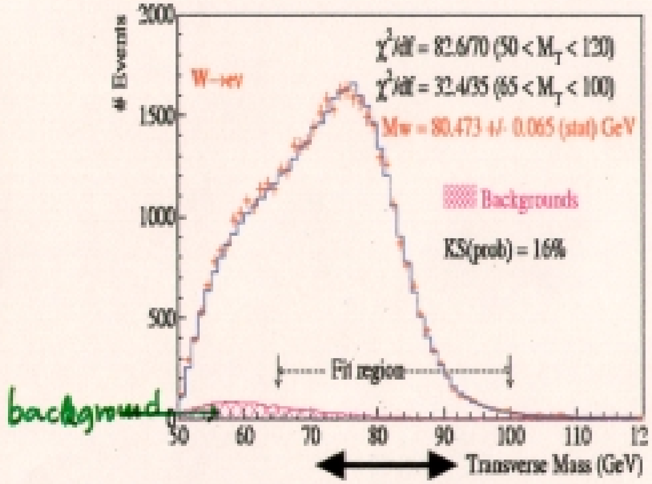




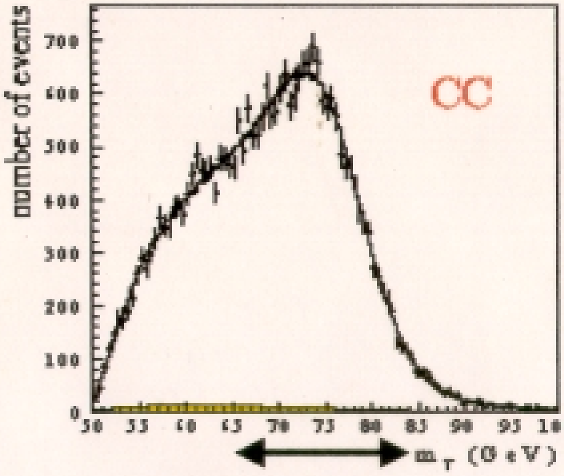
M_W(ALEPH+DELPHI+L3+OPAL)

= 80.450 +- 0.039 GeV

Tevatron ($p\bar{p}$)



CDF
W → eν



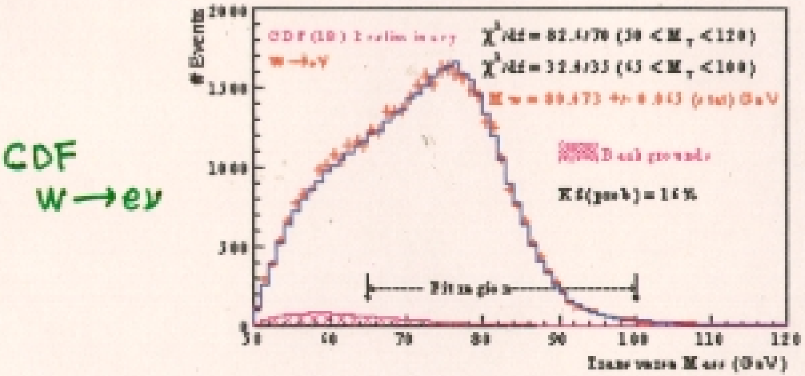
D0
W → eν

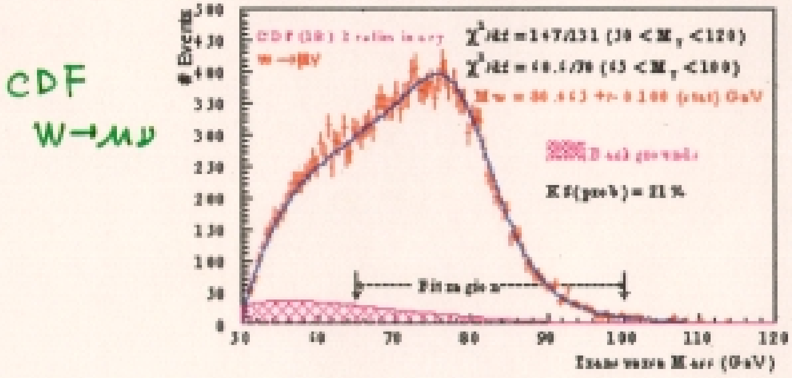
M_W(CDF+D0)

= 80.452 +- 0.062 GeV

Precision Measurements of M_W

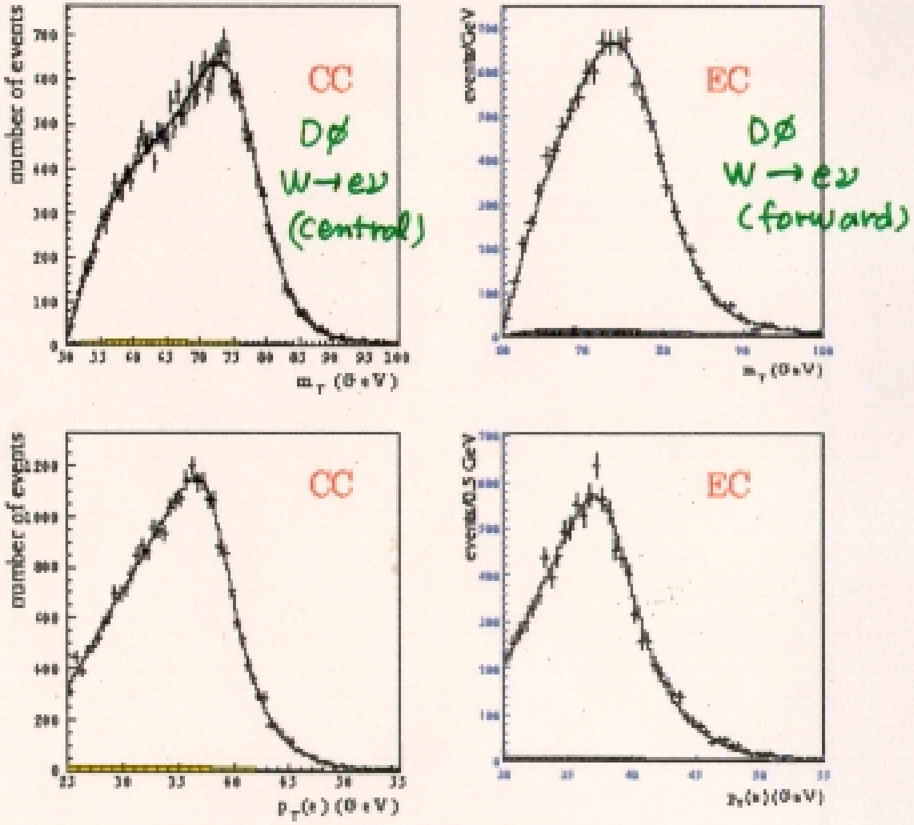
- W mass from fits to the transverse mass spectrum of ~ 30K $W \to e\nu$ events and ~ 15K $W \to \mu\nu$ events.





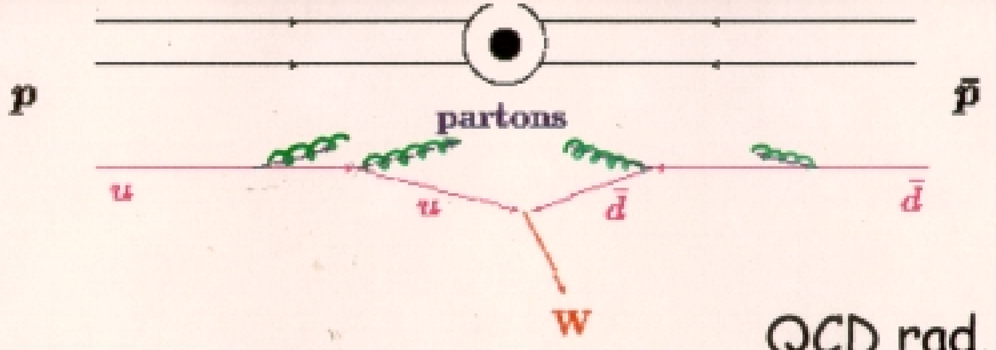
$$M_W^{e+\mu}(\mathrm{Run1B}) = 80.470 \pm 0.089\ \mathrm{GeV}/c^2$$
$$M_W^{e+\mu}(\mathrm{Run1}+0) = 80.433 \pm 0.079\ \mathrm{GeV}/c^2$$

- DØ also include forward electrons in the endcap (EC) calorimeters, and use M_T, P_T^e and P_T^ν.



$$M_W^{e}(\mathrm{EC}) = 80.691 \pm 0.227\ \mathrm{GeV}/c^2$$
$$M_W^{e}(\mathrm{CC}+\mathrm{EC}) = 80.482 \pm 0.091\ \mathrm{GeV}/c^2$$

Precision Measurements of M_W

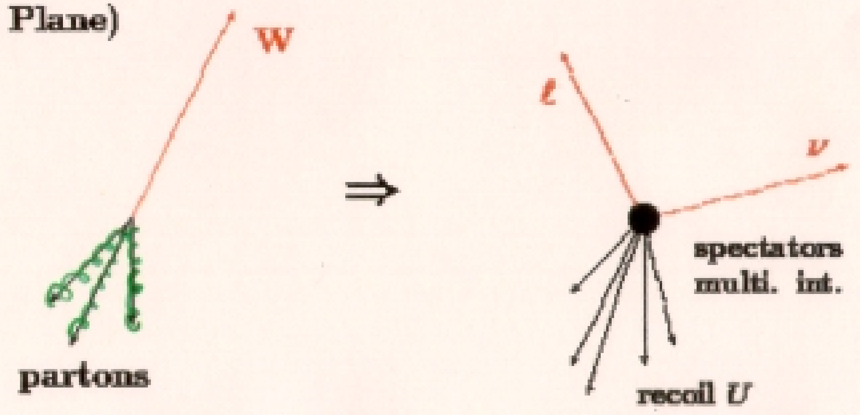


QCD rad.

W Prod. $\left(\frac{d^2\sigma}{dy\,dP_T}\right)$

partons $\rightarrow P_T^W$	P_T^Z
P_u, P_d (PDFs) $\rightarrow y^W$	A^W

$(P_T$ Plane)

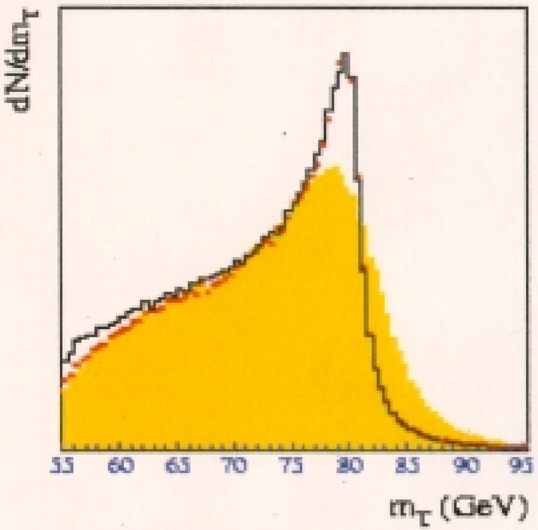


P – tracking momentum, E – calorimeter energy

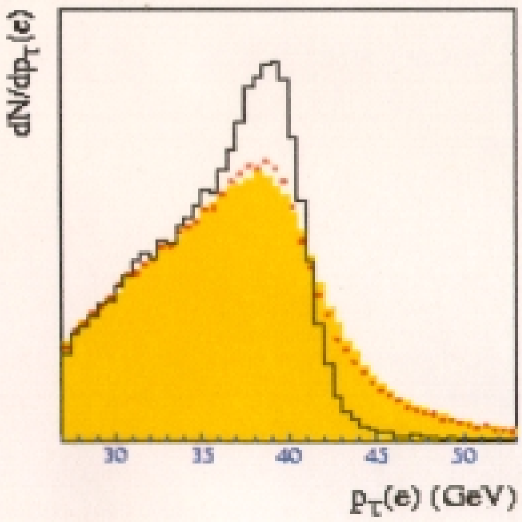
Lepton Meas.	E^e $(Z \rightarrow ee)$, P^μ $(Z \rightarrow \mu\mu)$
Recoil Meas.	Min Bias + $Z \rightarrow ee$ $(e\nu)$, $\mu\mu$ $(\mu\nu)$

$$\vec{P}_T^\nu = -\vec{P}_T^\ell - \vec{U}$$

$$M_T = \sqrt{2 p_T^{lep} p_T^\nu (1 - \cos\phi_{lep\nu})}$$



or p_T(lepton)



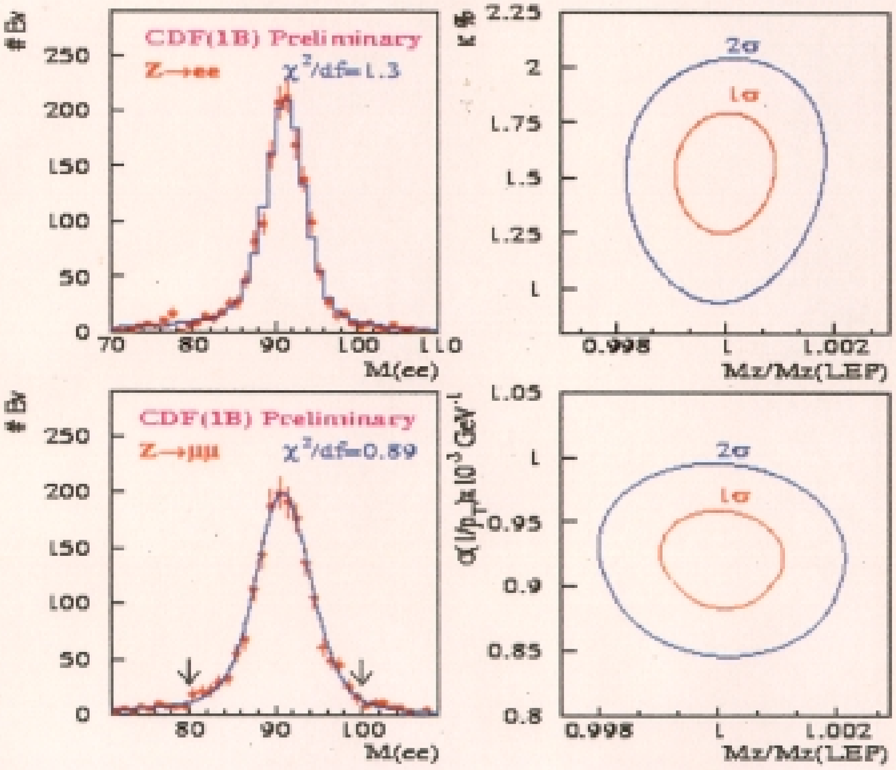
M_W Uncertainties on P,E scale & resolution

P & E Scale and Resolution with Z

P, E scale ← Z Mass

P, E resolution ← width of inv. mass dist.

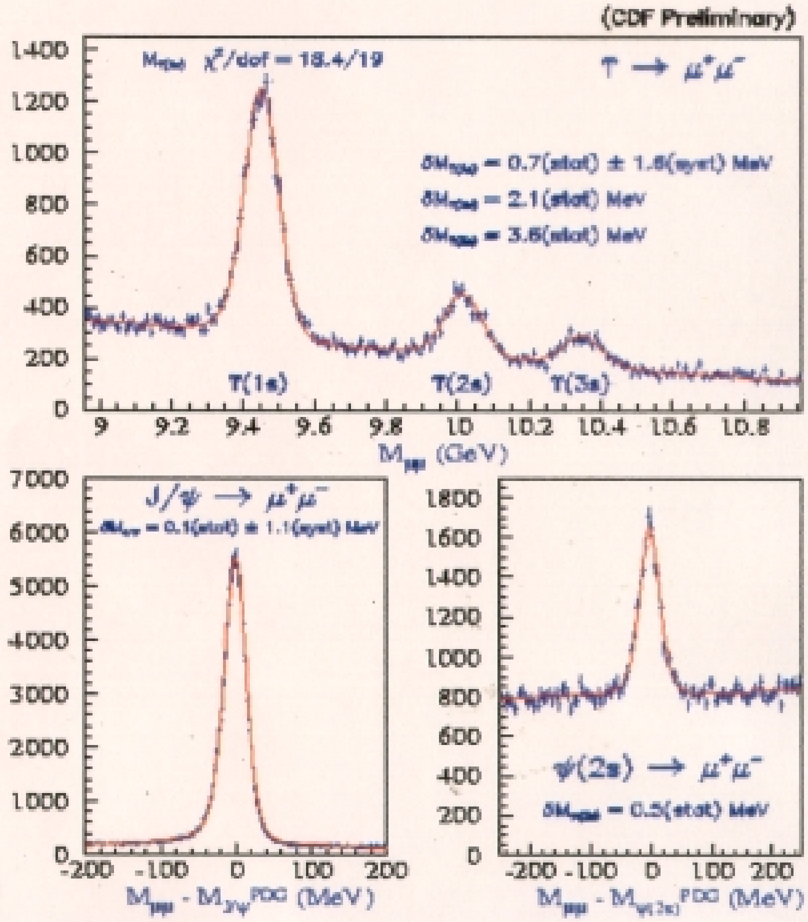
$$\frac{\delta E}{E} = \frac{13.5\%}{\sqrt{E_T}} \oplus \kappa, \quad \frac{\delta P_T}{P_T} = (0.0091 \pm 0.0004) \cdot P_T$$



Lepton	Scale (Z stat.)	Resolution
e	δM_W = 72 MeV	25 MeV
μ	85 MeV	20 MeV

P Scale Checks using known resonances

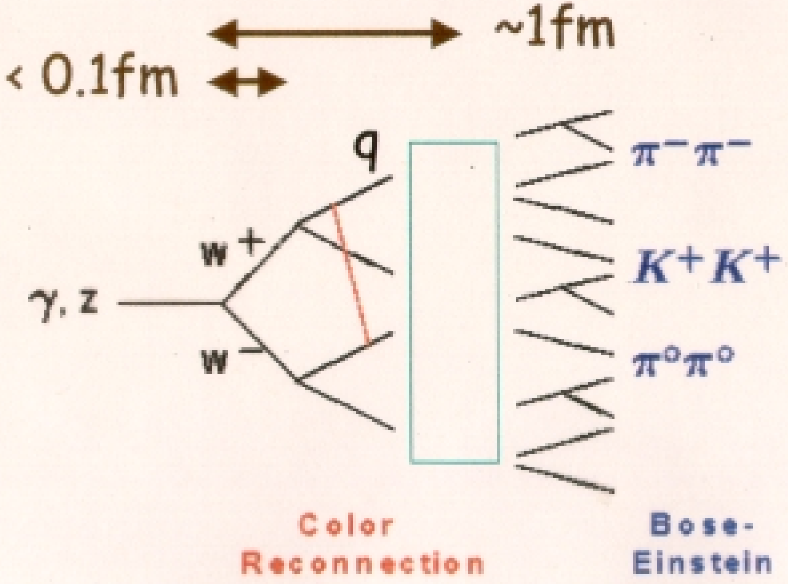
(CDF Preliminary)



P Scale using M_Υ or M_ψ agrees with that using M_Z very well.

M_W Uncertainties

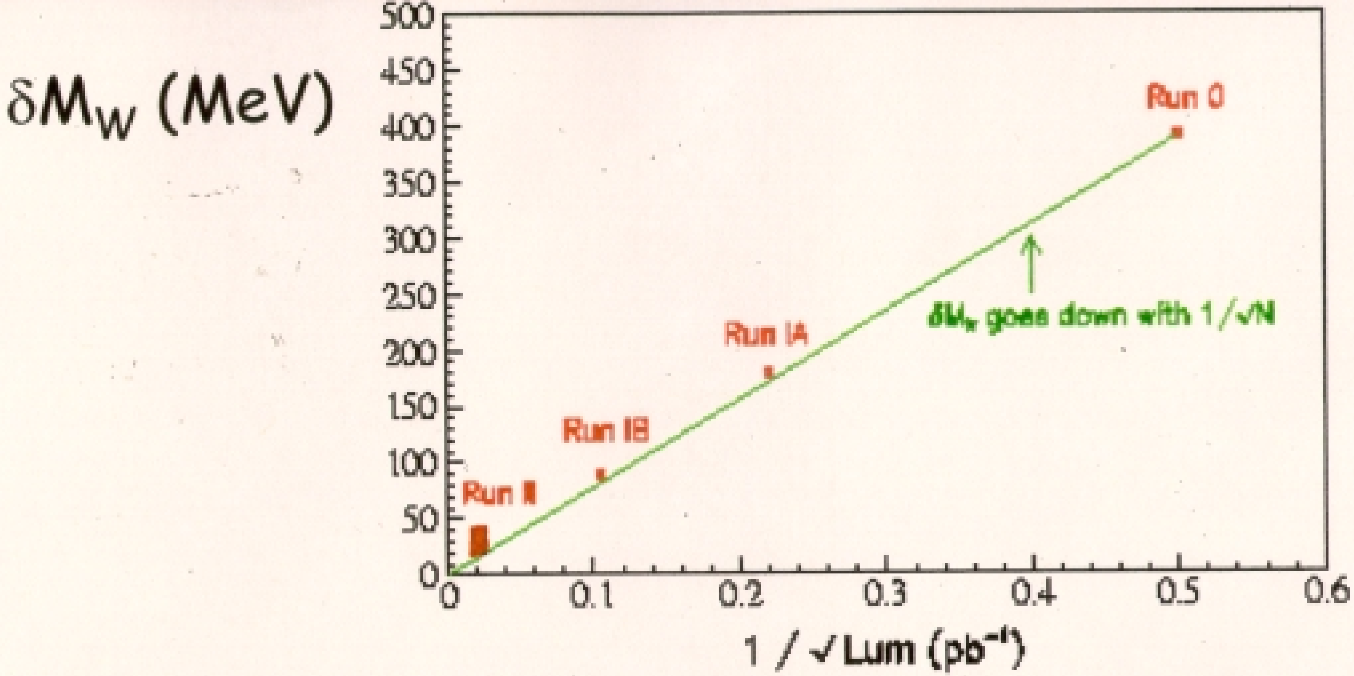
- LEP II
  - 25 MeV (stat.), 30 MeV (syst.)
  - Limited by systematic uncertainties on final state interactions (WW → qqqq)
    - "Hadroniszation" effect may not be independent between W's in WW → qqqq.



- Tevatron
  - δM(stat.) ≈ δM(syst.)
  - δM(syst.) – limited by $Z \rightarrow ee$, $\mu\mu$ sample
    - Lepton E, p scales + resolution
    - W Pt, recoil energy response

Error Source	D0		CDF	
	(C)	(EC)	(e)	(μ)
Statistics	70	105	65	100
ℓ Scale, Resol	70	185	80	90
W Pt, $\not{E}_T$ Model	35	50	40	40
Other Exp.	40	60	5	30
Theory (PDF's,QED)	30	40	25	20
Total Error	120	235	113	143
Mass Value	80.440	80.766	80.473	80.465
Combined Mass	80.497 ± 0.098		80.470 ± 0.089	

Tevatron M_W Measurements since 1990



N_W ← Statistics

N_Z ← ℓ Scale, Resol; W Pt, $\not{E}_T$ Model

N_W ← Theory (PDF's,QED)

Error Source	D0		CDF	
	(C)	(EC)	(e)	(μ)
Statistics	70	105	65	100
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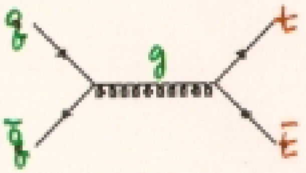
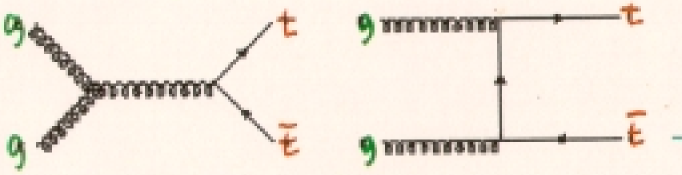
Run IIa ~ 25M
IIb ~ 20M

Top Production at Hadron Colliders

In pairs via the strong interaction

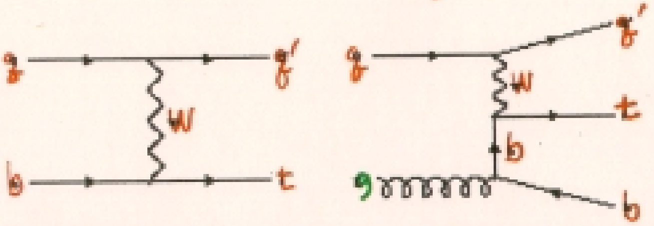


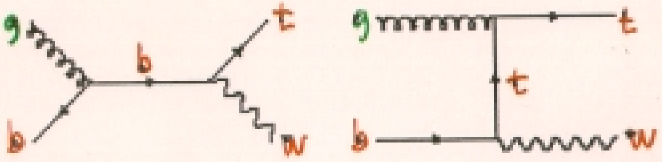


Production Cross Section (pb)

	Run 1 $p\bar{p}$ 1.8 TeV	Run II $p\bar{p}$ 2.0 TeV	LHC pp 14 TeV	
	90%	85%	5%	
	10%	15%	95%	
$\sigma_{t\bar{t}}$ =	5.0	7.0	800	(pb)
		σ_t		
	0.73	0.88	10.2	(pb)
	1.7	2.4	245	
	0.07	0.12	62	

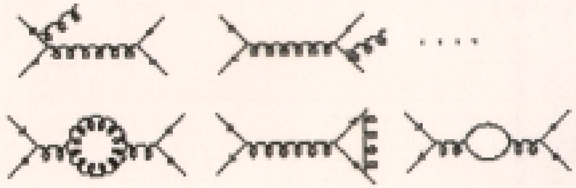
Singly via the electroweak interaction



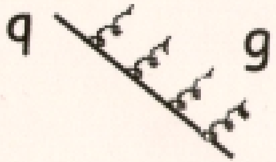


Tevatron ($t\bar{t}$)

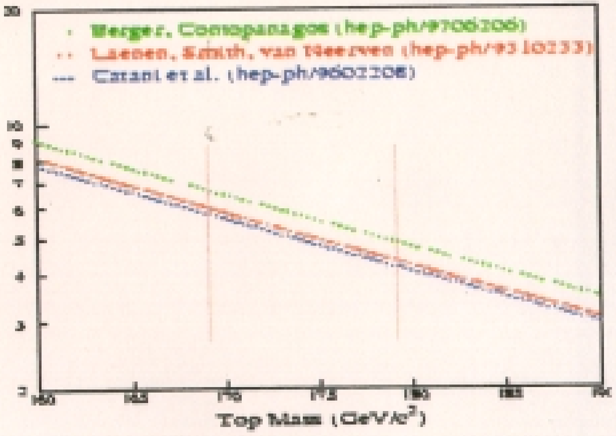
NLO corrections ~20%



Soft gluon resummation



Theor. uncert. 10–20%



Top Decay

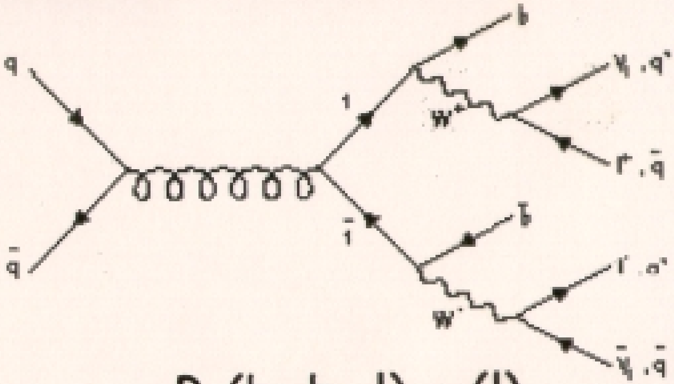
- In SM, assuming V-A coupling with a CKM mixing para. $|V_{tb}|=1$ for the $t \to bW$ dec vertex, one gets (LO) :

  $\Gamma(t \to bW) \approx 175\ \text{MeV}\ (M_t/M_W)^3$

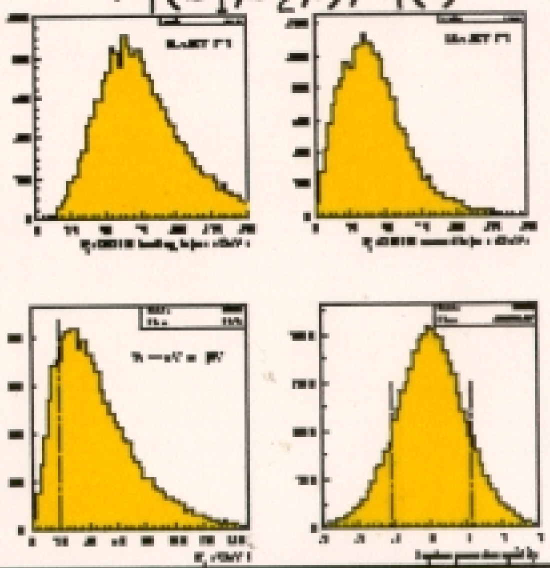
  $(M_t,\ M_W \gg M_b)$

  $\to \Gamma(t \to bW) \approx 1.5\ \text{GeV}$

  $\to \tau(\text{top}) \approx 4 \times 10^{-25}\ \text{s}$
- Non-perturbative QCD hadronization takes place in a time of order $\Lambda_{QCD}^{-1} \sim (100\ \text{MeV})^{-1} \sim 10^{-23}\ \text{s}$
  - Top decays as free quark (no top hadrons, no toponium spectroscopy)
  - Top decay will remember its original spin-1/2 state
- $t \to Ws$ and $t \to Wd$ allowed but suppressed by factors of $\sim 10^{-3}$ and $\sim 5 \times 10^{-5}$, respectively.



$P_T(b_1, b_2, l)$, $\eta(l)$



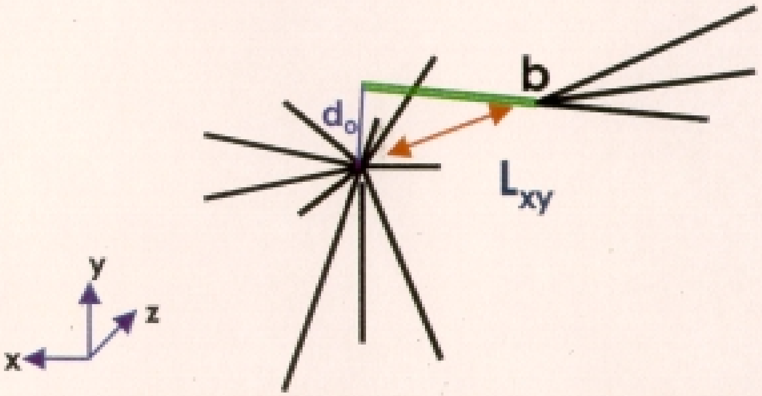
Dilepton	BR = 1/9
Lepton + Jets	BR = 4/9
All-hadronic	BR = 4/9

b-quark identification (b tagging)

- **Displaced vertices** $\tau(b) \sim 1.5$ ps → $L_{xy}(b) \sim O(\text{mm})$

Silicon Vertex Detector (SVX)

CDF



1 vertex =< 2 tracks
$L_{xy}/\sigma_{Lxy} > 3.0$
$\sigma_{Lxy} \sim 100\mu$

ε(b-tag) ~ 25%/b-jet (~4% c-jet)

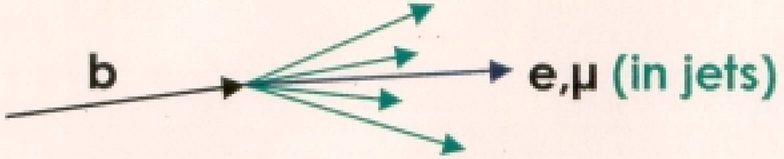
ε(b-tag) ~ 45%/event w/ 2b's

ε(b~~-ta~~g) ~ 0.2%/jet

- **Semileptonic b decays**

$b \to l\bar{\nu}X$	BR ~ 20%
$b \to c \to l\bar{\nu}X$	BR ~ 20%

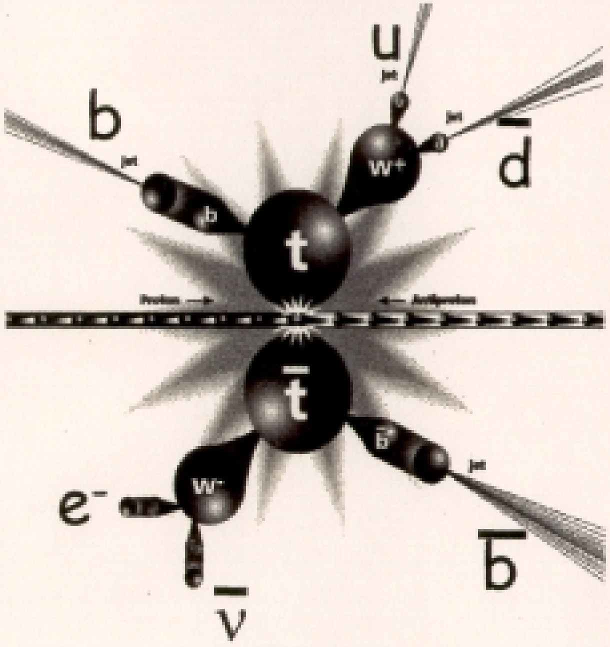
CDF/D0



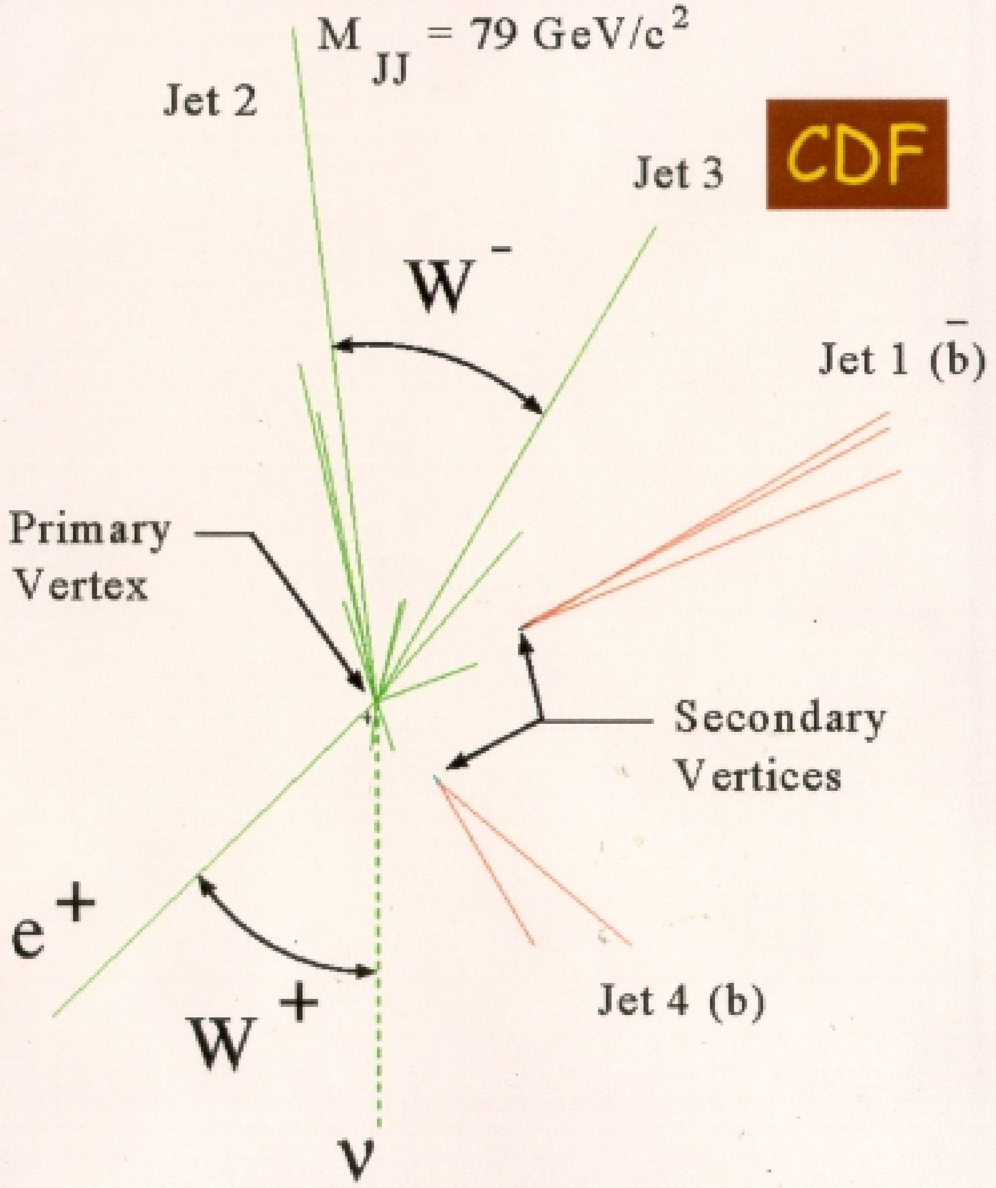
ε(b-tag) ~ 7%/b-jet
ε(b-tag) ~ 16%/event w/ 2b's
ε(b~~-t~~ag) ~ 0.5%/jet

$t\bar{t}$ candidate

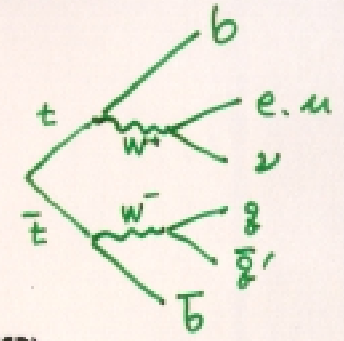
$t\bar{t}$ production



CDF



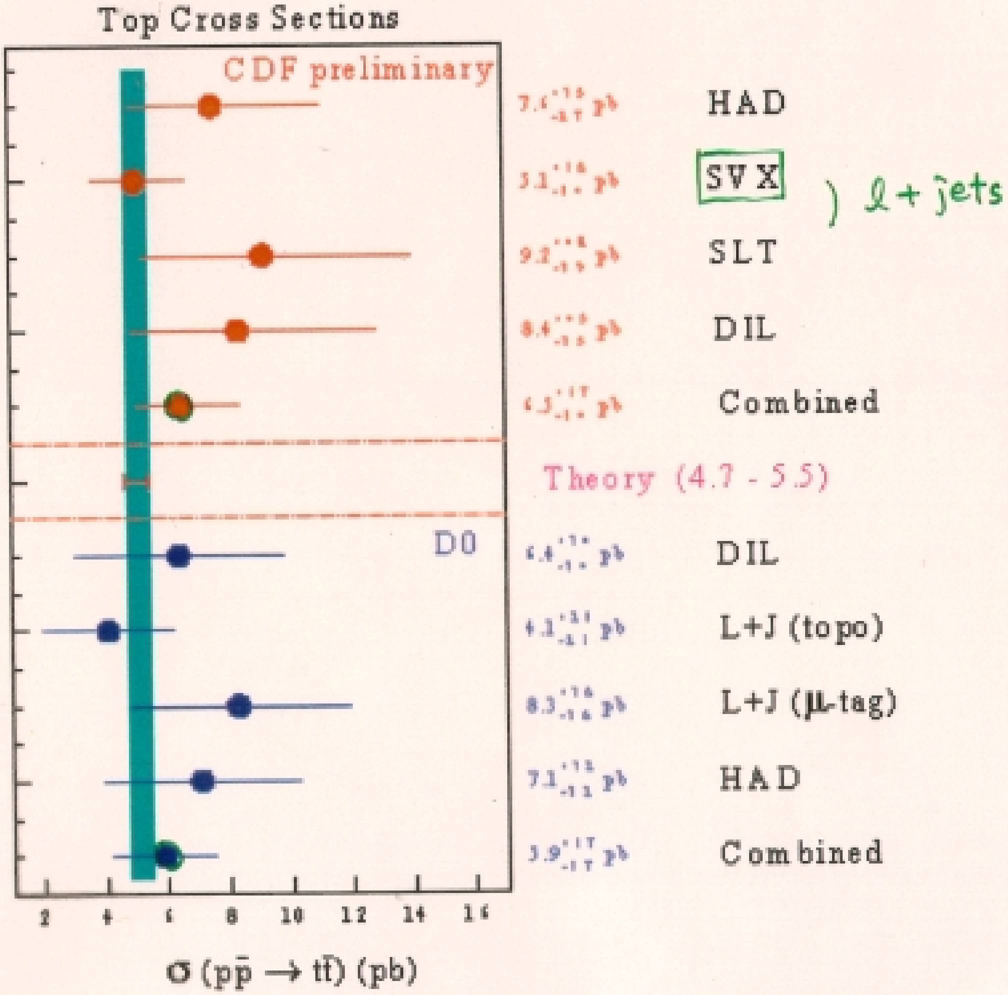
General Selection of tt-bar events in the lepton + jet channel



- $t\bar{t}$ events can be distinguished from other processes by their topology: many particles (leptons, jets, neutrinos) with large transverse energy. e.g. in the lepton + jets channel require:
- Leptons : (from leptonic W decays)
  - → Require 1 electron or muon with large transverse energy(E_T)
  - → events are mostly W's and Z's ($\sim 100\,000$) with some $t\bar{t}$ ($\underline{\sim 100}$)
  - → $S/B \sim 1/1000$
- Missing transverse energy : (from neutrinos)
  - → Require large Missing E_T
  - → events are mostly W's (~ 60000) with some $t\bar{t}$ ($\underline{\sim 80}$)
  - → $S/B \sim 1/750$
- Jets : (from b quarks, hadronic W decays, ISR, FSR)
  - → Require at least 3 jets with large E_T
  - → events are mostly $W + \geq 3\,jets$ (~ 250) with a larger fraction of $t\bar{t}$ ($\underline{\sim 40}$).
  - → $S/B \sim 1/6$
- Jets : (from b quarks, hadronic W decays, ISR, FSR)
  - → Require at least 3 jets with large E_T
  - → events are mostly $W + \geq 3\,jets$ (~ 250) with a larger fraction of $t\bar{t}$ (~ 40).
  - → $S/B \sim 1/6$
- Jets from b quarks
  - → Require at least one jet to be b-tagged using the SVX (CDF)
  - → Require a soft muon tag, together with further event kinematic requirements (DØ)
  - → events are mostly $\underline{t\bar{t}\ (\sim 20)}$ with some $W + jets$, $W + b\bar{b}$, and smaller contributions from various other processes ($\underline{\sim 8}$).
  - → $S/B \sim 2.5/1$
- Kinematic variables which exploit the large top mass can also be used to further strengthen the signal ($t\bar{t}$) over "background" processes.

Run I tt-bar cross section measurements

$$\sigma(p\bar{p} \to t\bar{t} \to \text{channel}_i) = \frac{N^i_{obs} - N^i_{bkgd}}{\epsilon^i \cdot \int L\,dt}$$



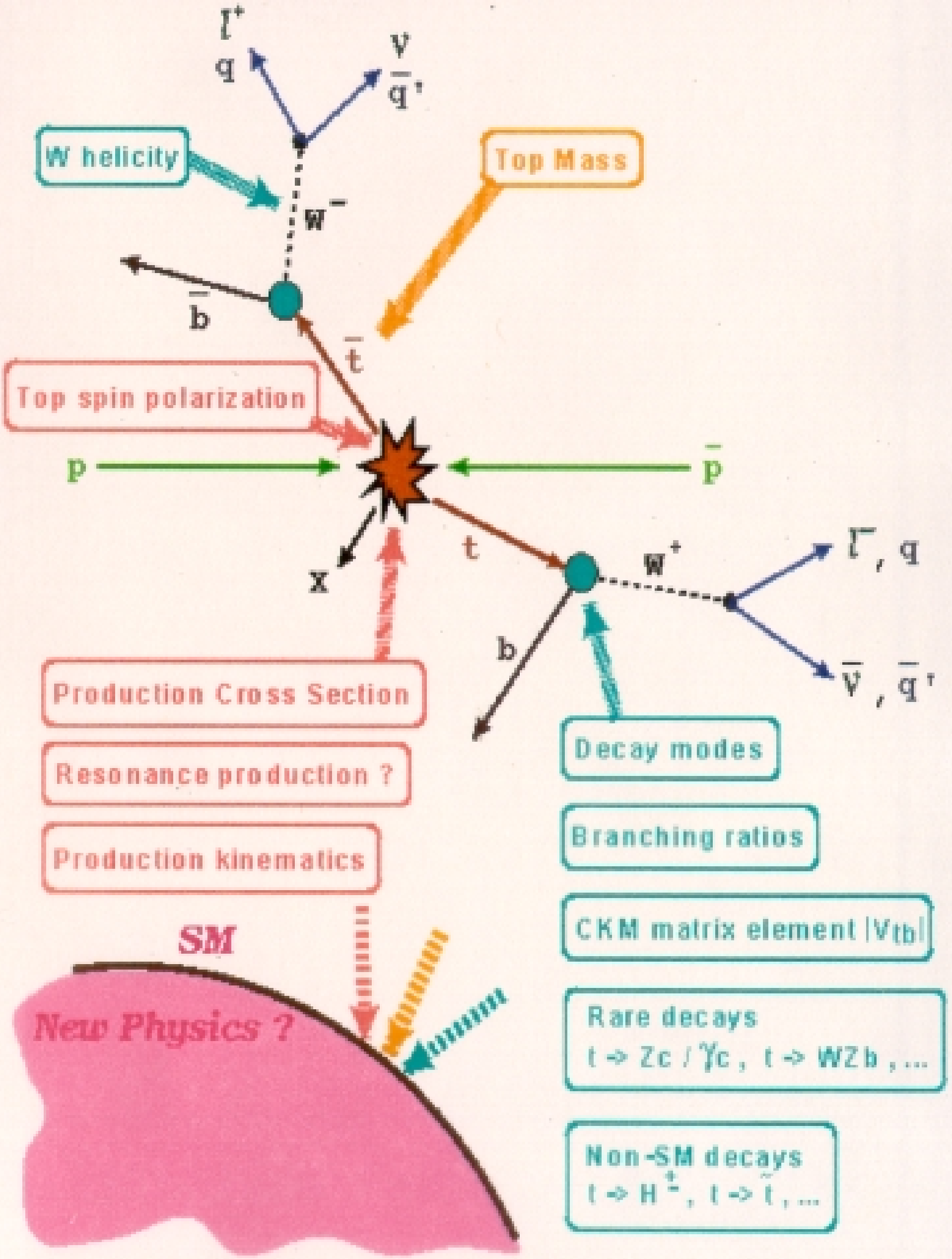
No excess observed.

What we can measure from tt-bar

- $M_{top} \rightarrow M_{Higgs}$ information via higher order corrections
  - M_W-M_{top}-M_{higgs} Relation
- Top is very heavy, g_t ($ttH \sim M_t^2 / M_W^2$) ~ 1, so understanding its properties may lead to clues about the mechanism behind EWSB.

- Everything we currently know about the top quark is based on ~100 tt-bar events / experiment from Run I.
- Run II :

  ~100k top events expected.



W helicity

Top Mass

Top spin polarization

Production Cross Section

Resonance production ?

Production kinematics

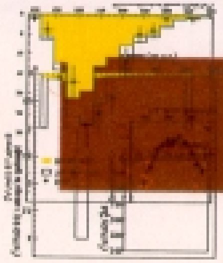
Decay modes

Branching ratios

CKM matrix element $|V_{tb}|$

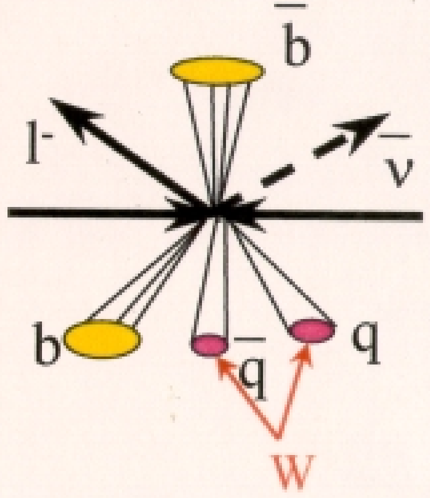
Rare decays
$t \rightarrow Zc / \gamma c$, $t \rightarrow WZb$, ...

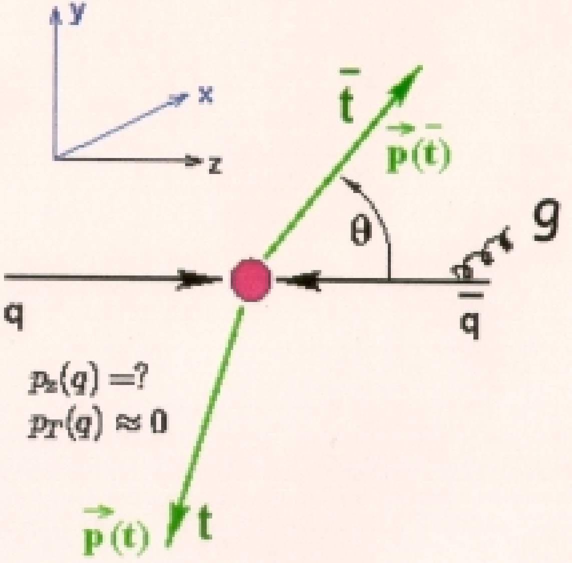
Non-SM decays
$t \rightarrow H^{\pm}$, $t \rightarrow \tilde{t}$, ...

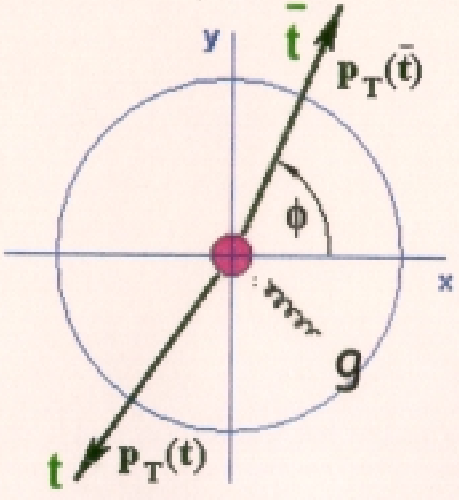


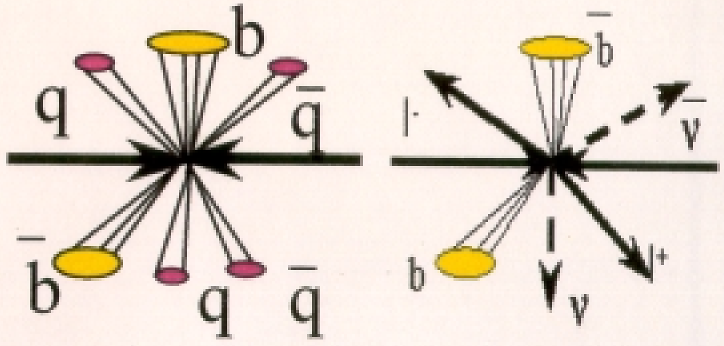
Top mass measurement

- The Transverse view & Pt(ν)
  - We don't know the total longitudinal momentum in any event.
  - The total transverse momentum of all "detected" particles ~ 0.
  - $Px^{\nu} = - \Sigma Px^{i}$, $Py^{\nu} = - \Sigma Py^{i}$
- Constraints
  - $M_{W+} = M_{W-}$
  - $M_{top}(W^{+}b) = M_{anti\text{-}top}(W^{-}b)$

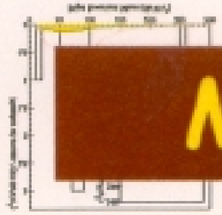


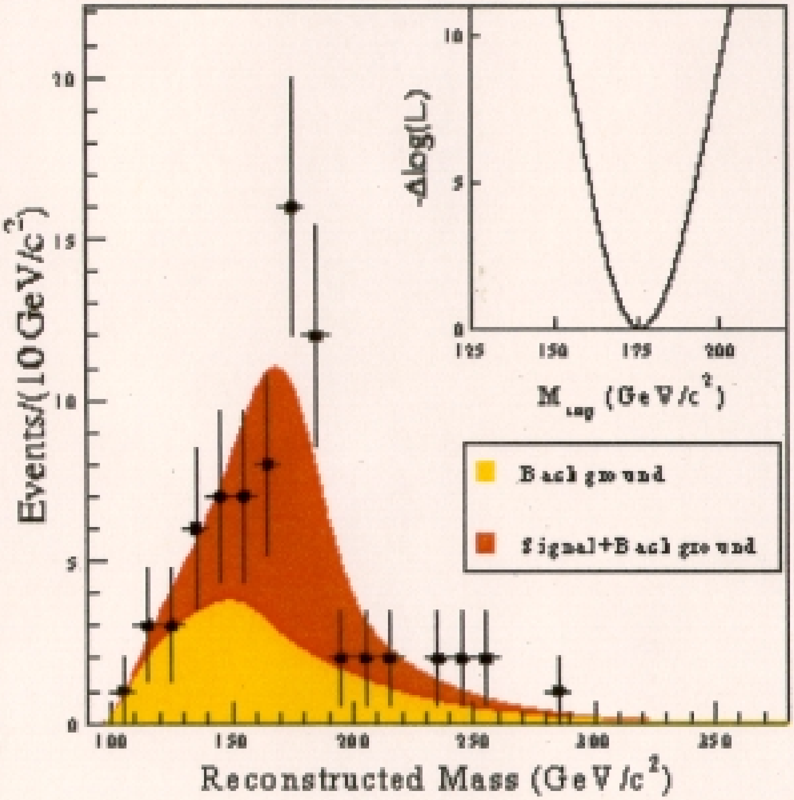


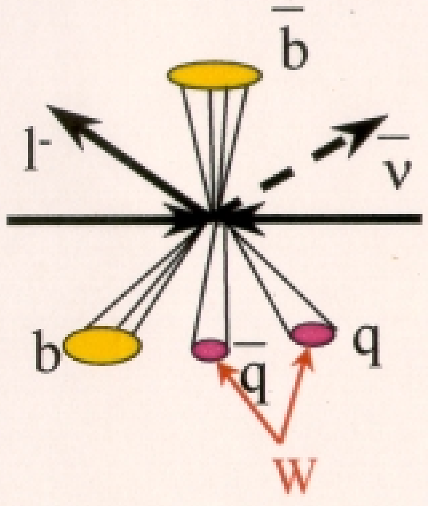


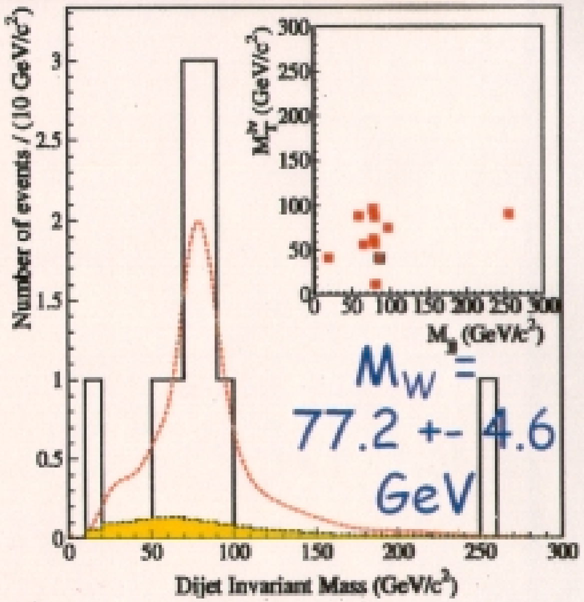


Measurement of M_{top} CDF (l + jets)





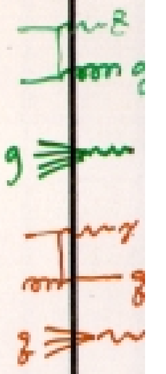




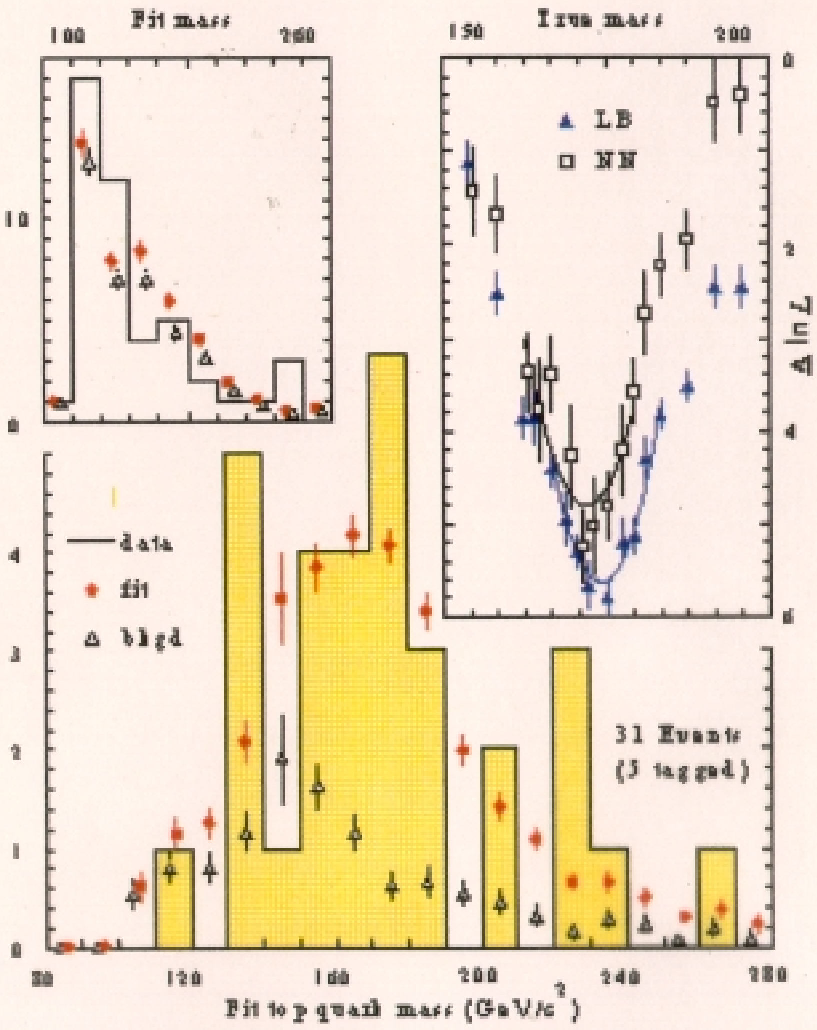
M_W = 77.2 +- 4.6 GeV

M_{top}= 176.1 +- 5.1 (stat.)
+- 5.3 (syst.)
Gev

Systematic	δM_{top}(GeV)
Jet energy scale	4.4
Initial, Final state rad.	2.6
Background spectrum	1.3
b-tagging bias	0.4
Parton distribution func.	0.3
Monte Carlo generators	0.1
Total	5.3

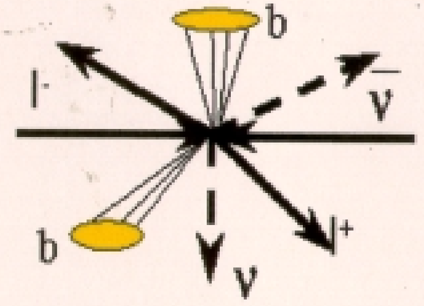


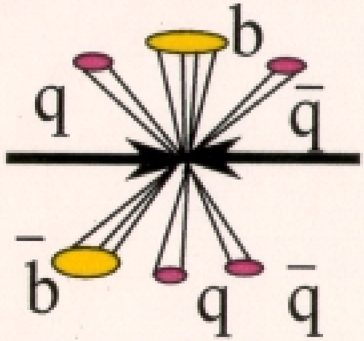
Measurement of M_{top} D0 (l + jets)

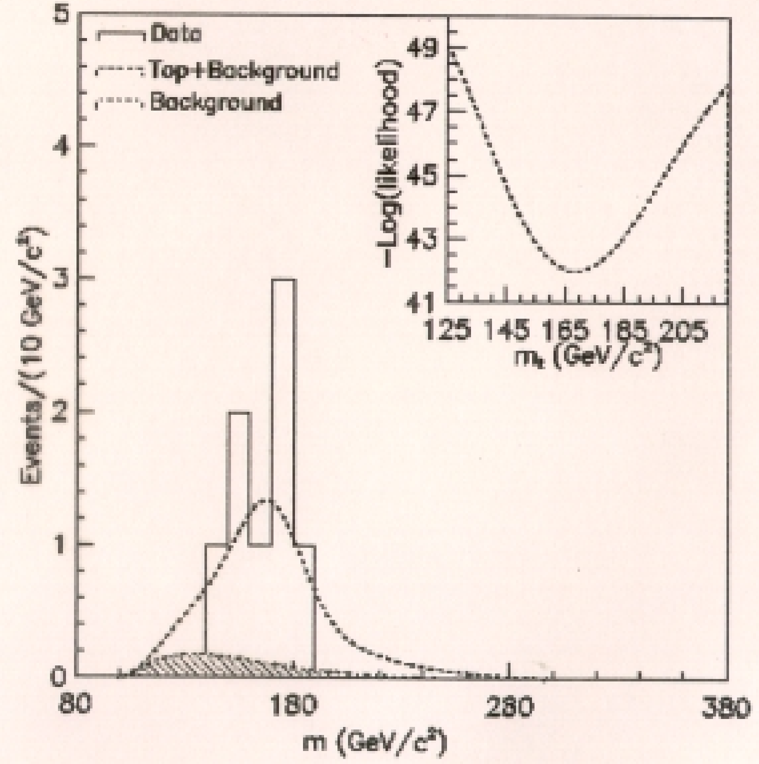


M_{top}= 173.3 +- 5.6 (stat.)
+- 5.5 (syst.)
Gev

Measurement of M_{top} CDF
Two leptons, All hadrons

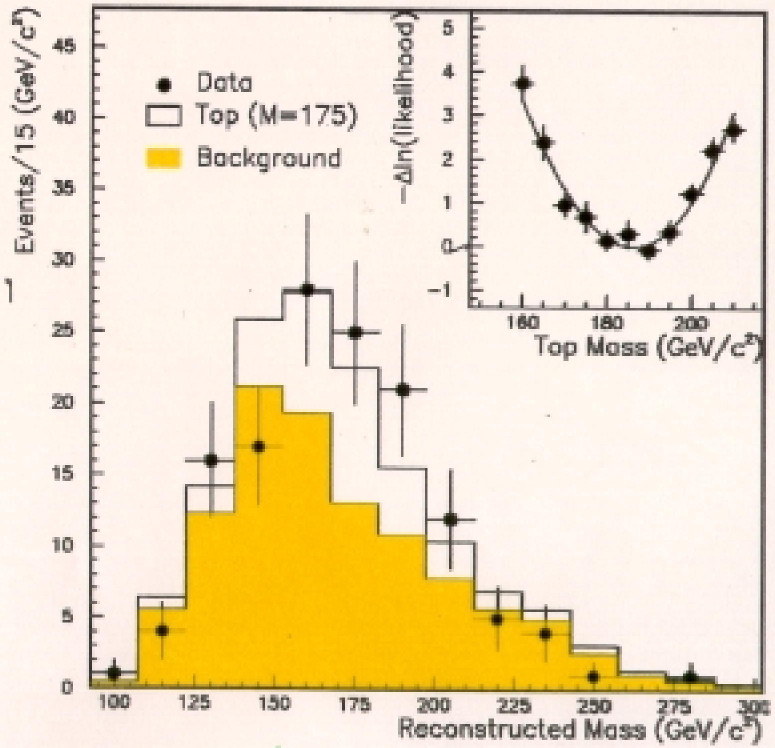






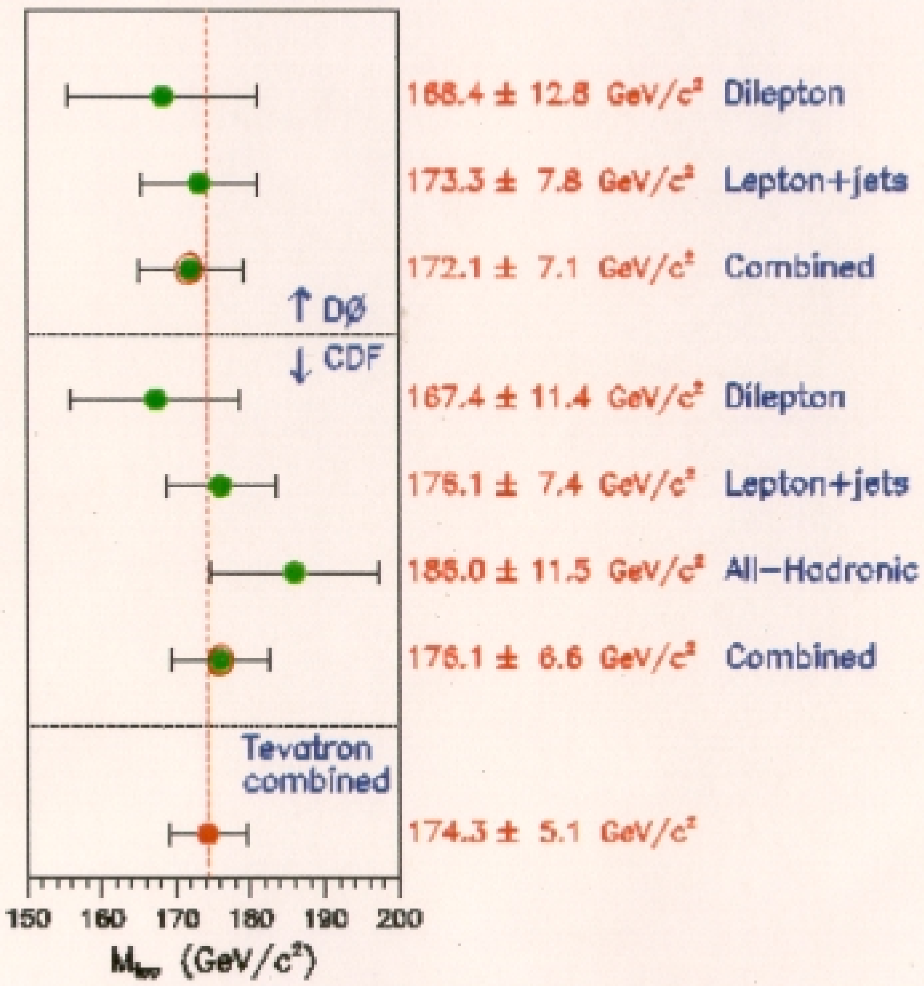
Small Statistics

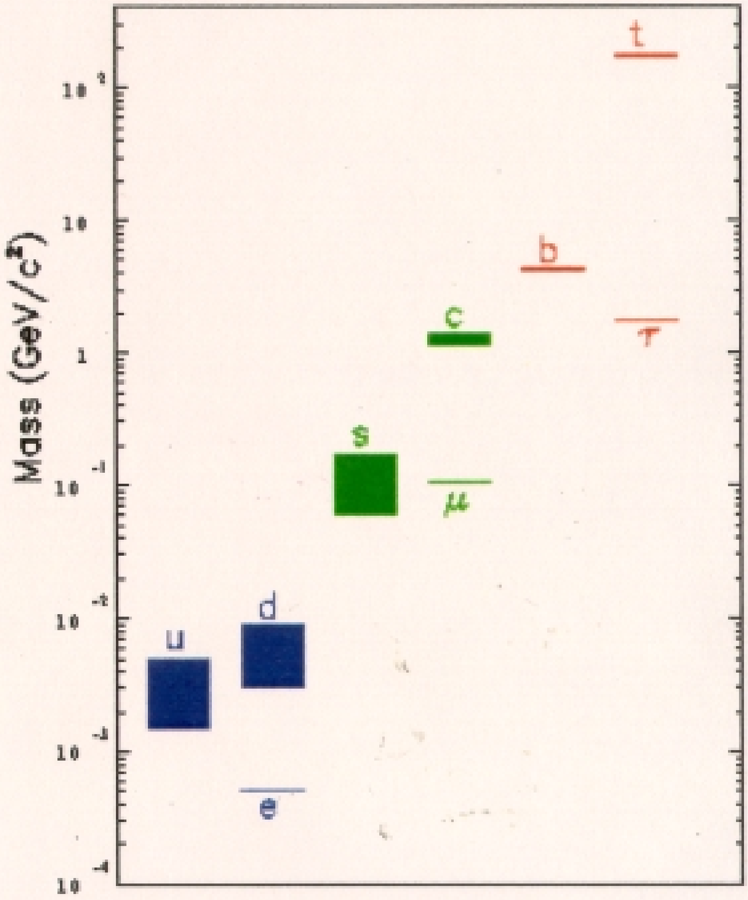
Small background



large Statistic

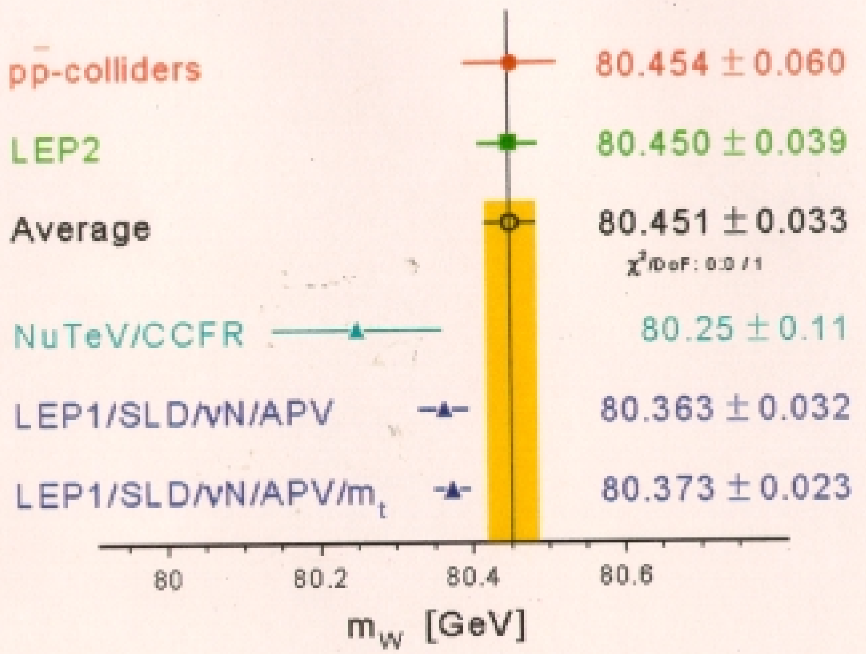
Summary of Run I M_{top} measurements



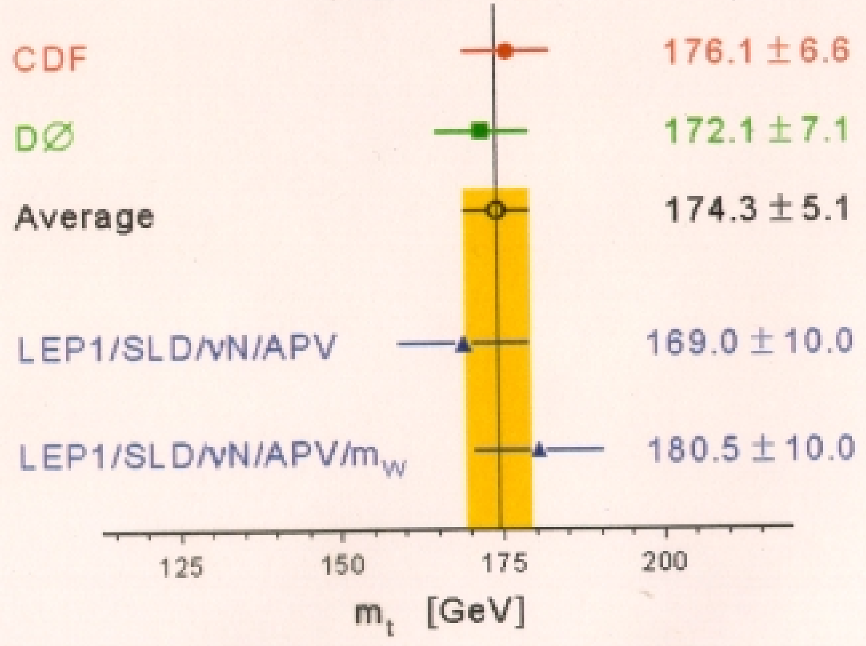


The Top quark has the best measured mass of all quarks

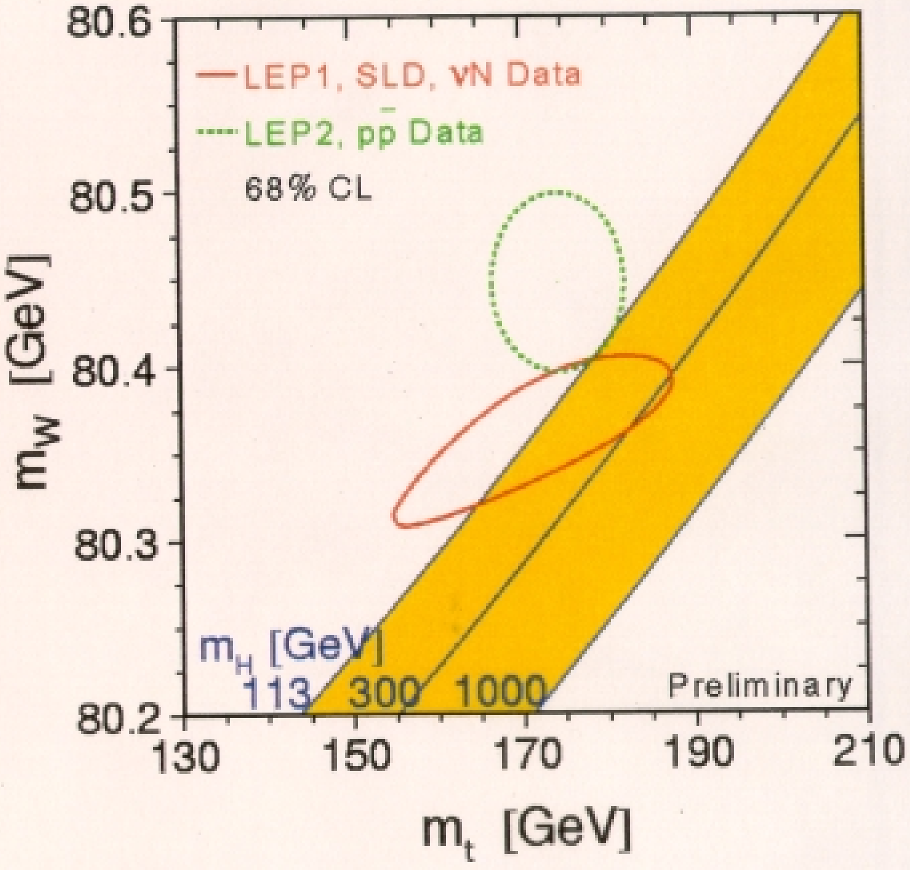
$\frac{\delta M_t}{M_t} \sim 3\%$



pp̄-colliders
80.454 ± 0.060
LEP2
80.450 ± 0.039
Average
80.451 ± 0.033
χ²/DoF: 0.0 / 1
NuTeV/CCFR
80.25 ± 0.11
LEP1/SLD/νN/APV
80.363 ± 0.032
LEP1/SLD/νN/APV/m_t
80.373 ± 0.023
80
80.2
80.4
80.6
m_W [GeV]

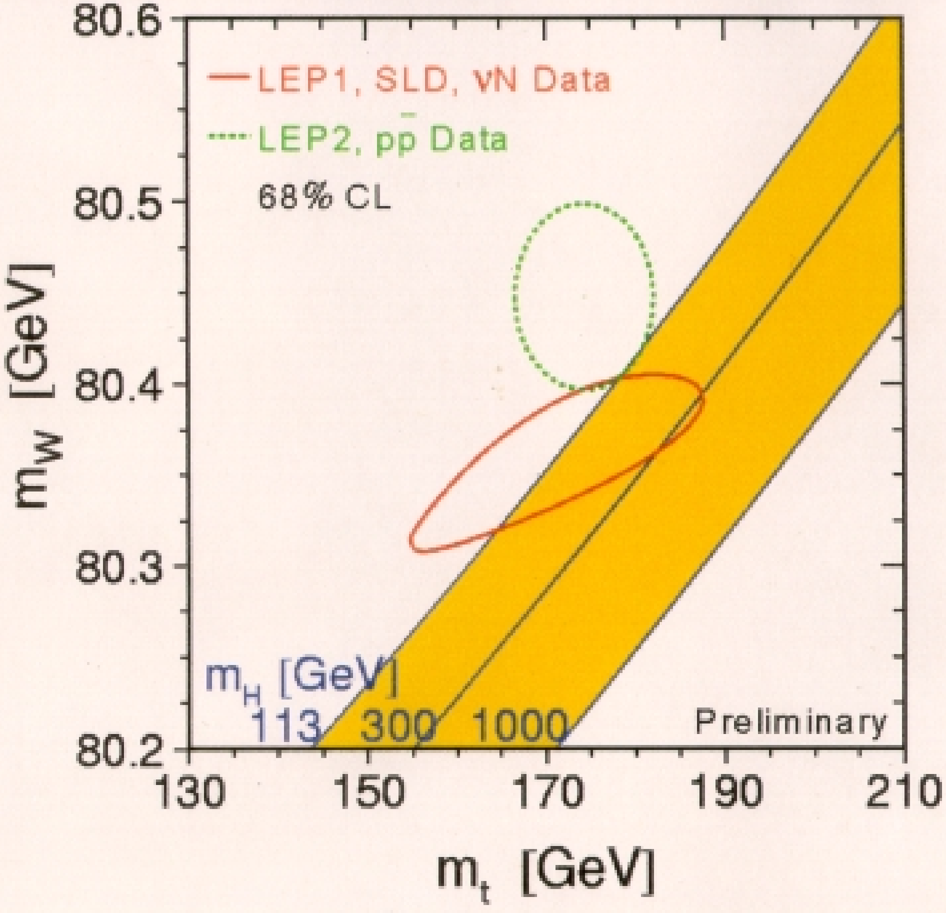


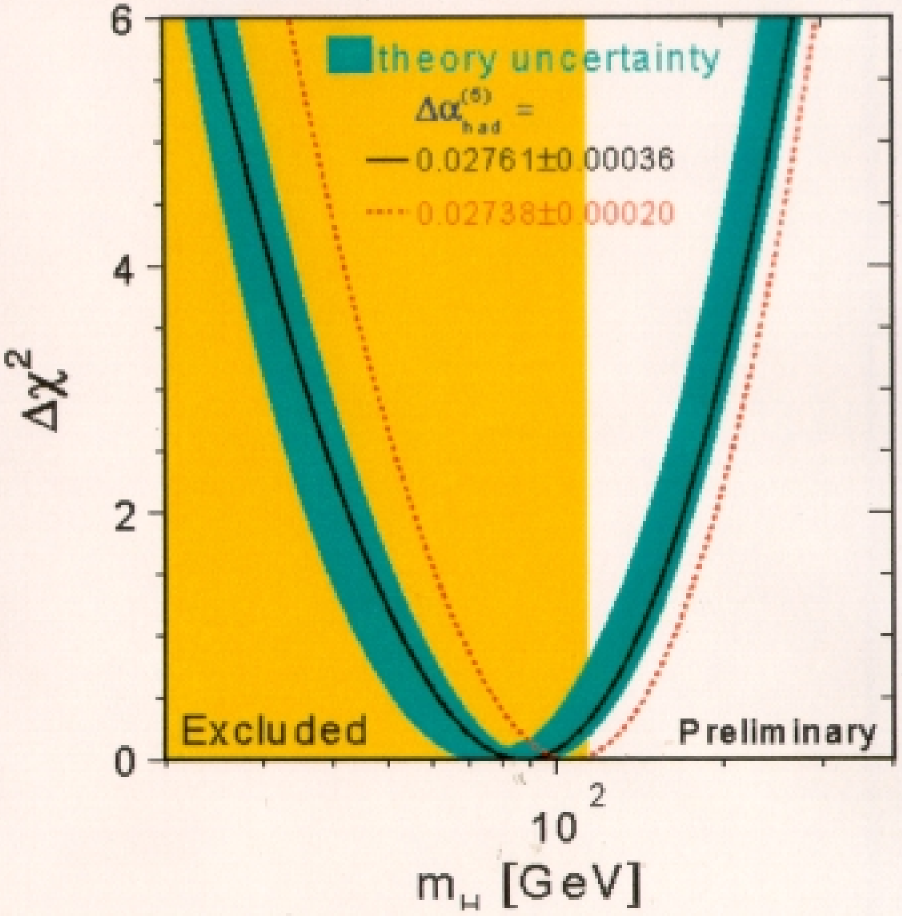
CDF
176.1 ± 6.6
DØ
172.1 ± 7.1
Average
174.3 ± 5.1
LEP1/SLD/νN/APV
169.0 ± 10.0
LEP1/SLD/νN/APV/m_W
180.5 ± 10.0
125
150
175
200
m_t [GeV]



LEP1, SLD, νN Data
LEP2, pp̄ Data
68% CL
m_H [GeV]
113
300
1000
Preliminary
80.6
80.5
80.4
80.3
80.2
m_W [GeV]
130
150
170
190
210
m_t [GeV]

Implication of Precision EW Measurements





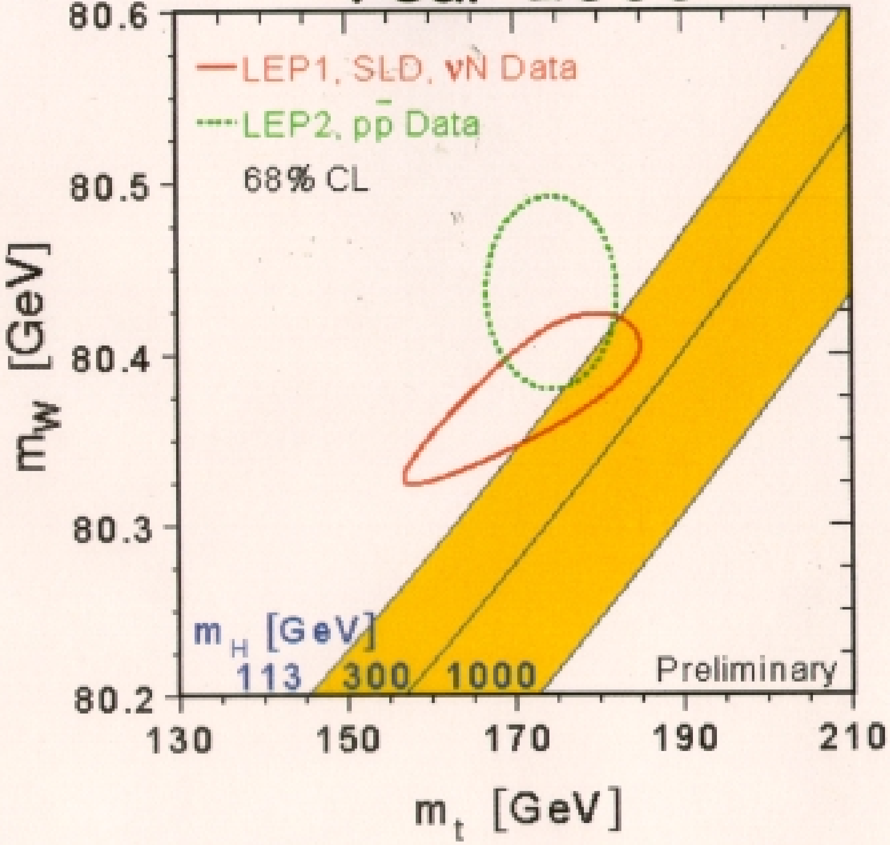
Precision EW measurements favor Light Higgs.

$M_{Higgs} = 88^{+60}_{-37}$ GeV, $M_{Higgs} = 108^{+57}_{-38}$ GeV

$M_{Higgs} <$ 196~222 GeV at 95% CL

Implication of Precision EW Measurements

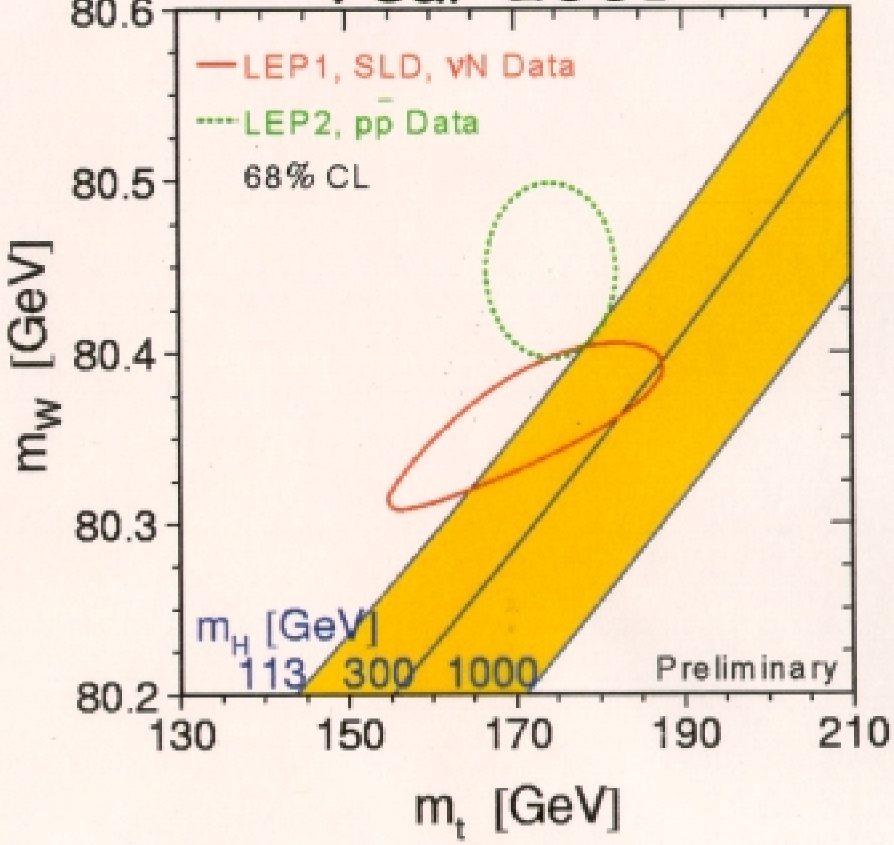
Year 2000



$M_{Higgs} = 60^{+52}_{-29}$ GeV

$M_{Higgs} < 165 - 196$ GeV @95%CL

Year 2001

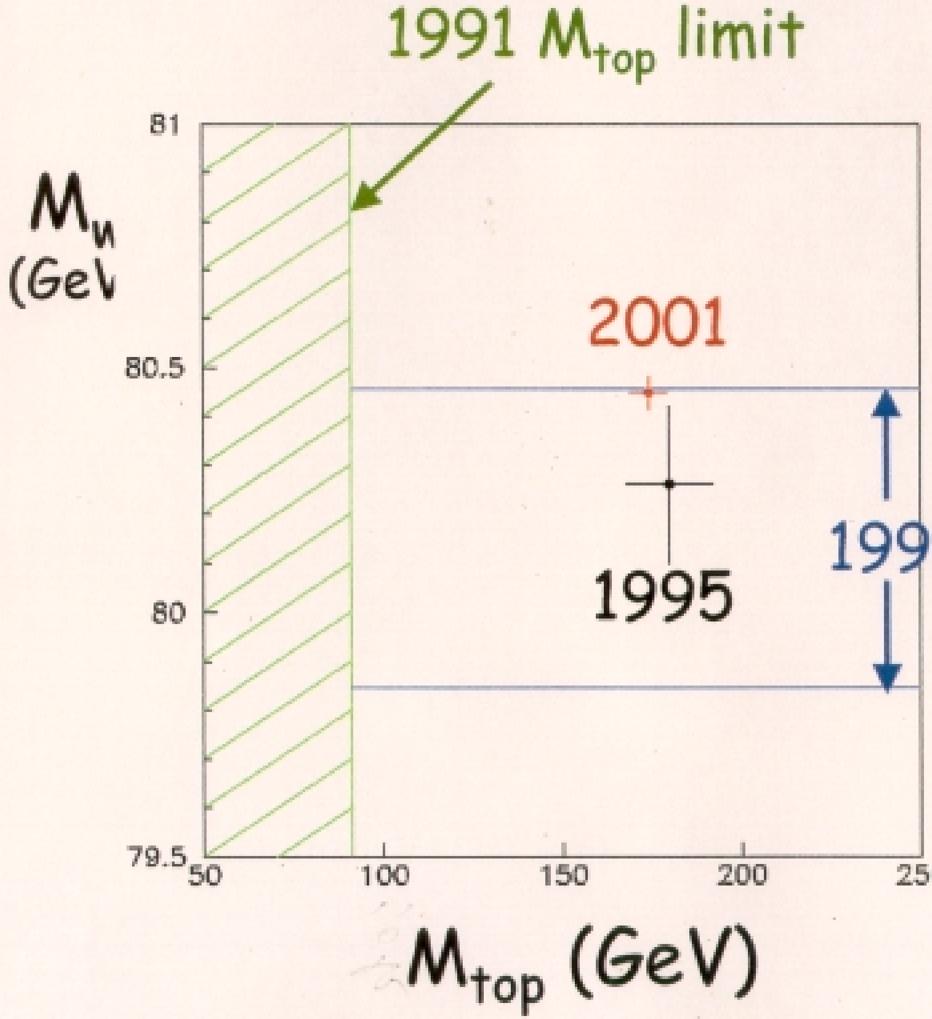


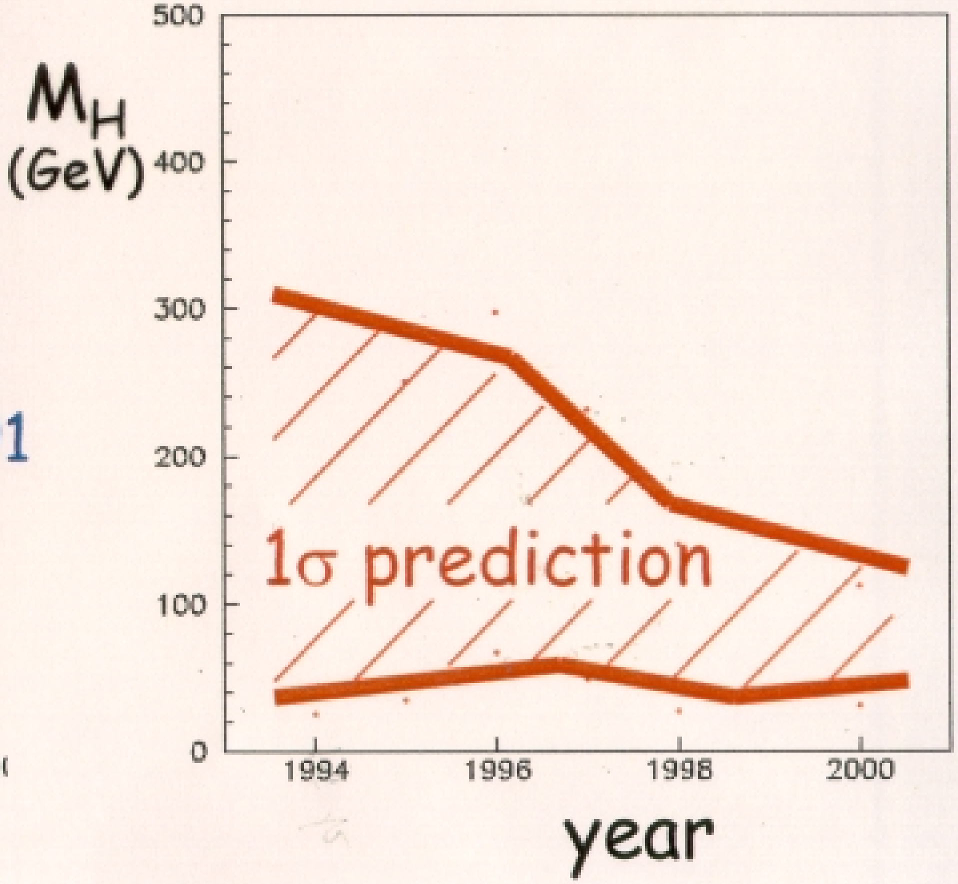
$M_{Higgs} = 88^{+60}_{-37}$ GeV

$M_{Higgs} = 108^{+57}_{-38}$ GeV

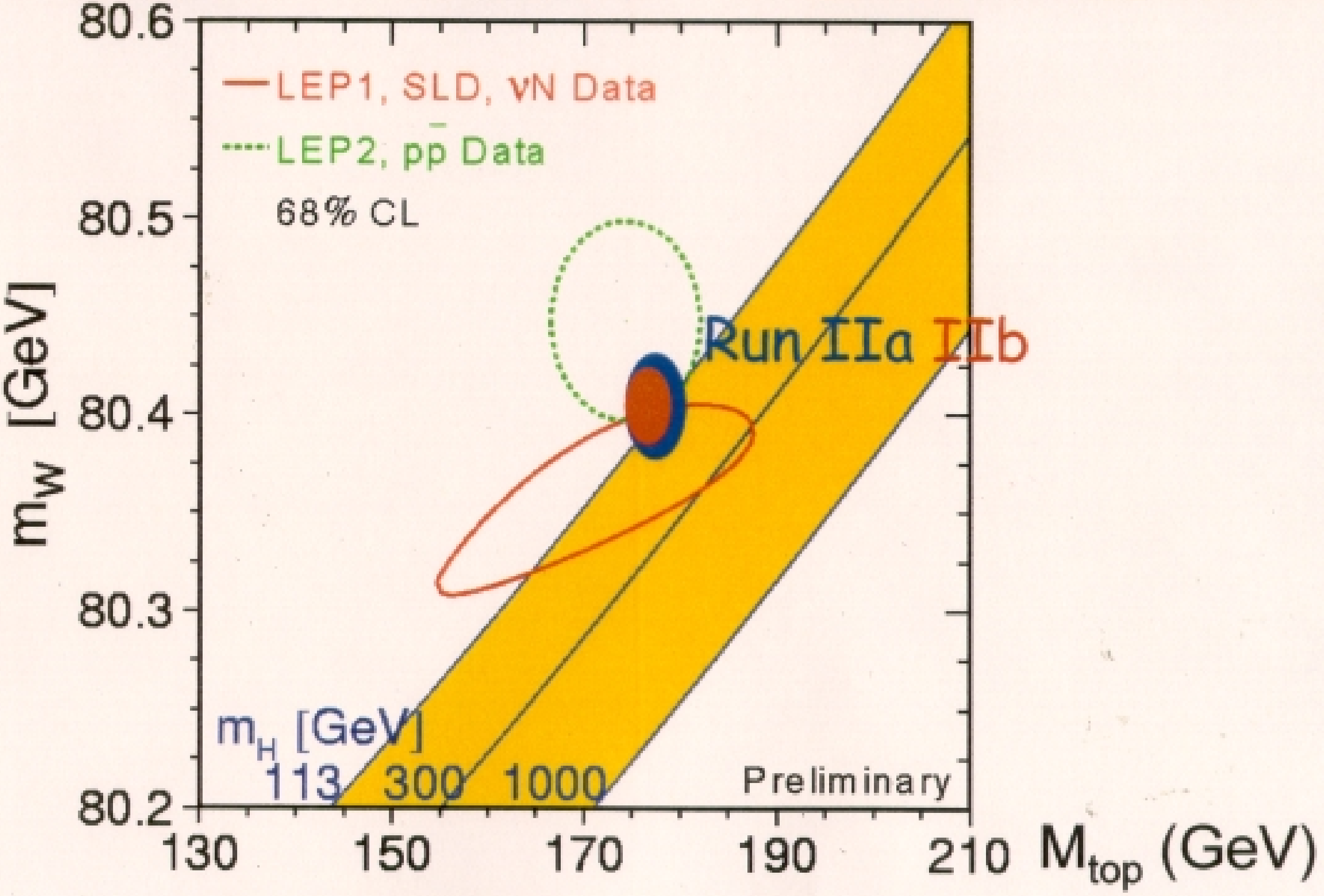
$M_{Higgs} < 206 - 222$ GeV @95%CL

EW Measurements (last ~10 years)





Tevatron Run II EW Measurements → SM test and $\delta M_{Higgs} / M_{Higgs}$



$\delta M_W \sim 25$ MeV - 20 MeV, $\delta M_{top} \sim 2$ GeV - 1.5 GeV

$\delta M_{Higgs} / M_{Higgs} \sim 30\% - 20\%$

Summary of Top measurements and Future expectations

Top quark Property	Run 1 measurement	Precision			
		Run 1	Run IIa	Run IIb	LHC
Mass (CDF)	$176.1 \pm 4.2 \pm 5.1\,\mathrm{GeV}/c^2$	3.8%	1.7%	1.0%	1%
Mass (DØ)	$172.1 \pm 5.2 \pm 4.9\,\mathrm{GeV}/c^2$				
Mass (CDF + DØ)	$174.3 \pm 3.3 \pm 3.9\,\mathrm{GeV}/c^2$	2.9%	1.2%	1.0%	
$\sigma_{t\bar{t}}$ (CDF)	$6.5^{+1.7}_{-1.4}\,\mathrm{pb}$	25%	10%	5%	5%
$\sigma_{t\bar{t}}$ (DØ)	$5.9^{+1.7}_{-1.7}\,\mathrm{pb}$				
W helicity, F_0	$0.91 \pm 0.37 \pm 0.13$	0.4	0.09	0.04	0.01
W helicity, F_+	$0.11 \pm 0.15 \pm 0.06$	0.15	0.03	0.01	0.003
$R \equiv \frac{B(t \to Wb)}{B(t \to Wq)}$	$0.94^{+0.31}_{-0.24}$	30%	4.5%	0.8%	0.2%
	> 0.61 at 90% C.L.				
$\lvert V_{tb} \rvert$	$0.96^{+0.16}_{-0.12}$ (3-gen.)				
	> 0.051 at 90% C.L.	> 0.05	> 0.25	> 0.50	> 0.90
σ(single top)	$< 18.6\,\mathrm{pb}$	–	20%	8%	5%
$\Gamma(t \to Wb)$		–	25%	10%	10%
$\lvert V_{tb} \rvert$	–	–	12%	5%	5%
$BR(t \to \gamma q)$ 95% CL	0.03	0.03	2×10^{-3}	2×10^{-4}	2×10^{-5}
$BR(t \to Zq)$ 95% CL	0.30	0.30	0.02	2×10^{-3}	2×10^{-4}

All top quark measurements have been consistent within SM framework, though are presently limited by low statistics.

Run II top measurements will provide much stiffer tests for SM, and because of the proximity of the top mass to the EWSB scale could be sensitive to new physics.

LEP, SLC, Tevatron Run I EW Measurements

→SM : Higgs around the corner !!

→ Lecture #3 (Monday)