Top Quark Mass: The Latest CDF Results, Tevatron Combination and Electroweak Implications

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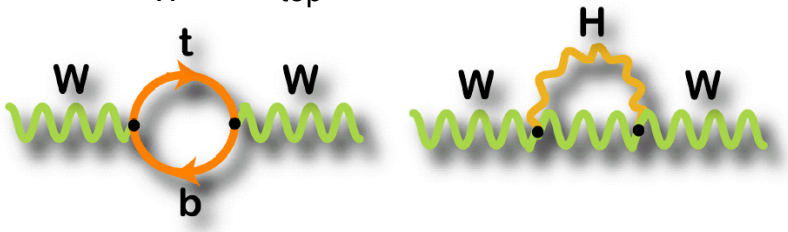
(for the CDF collaboration)

The top quark mass

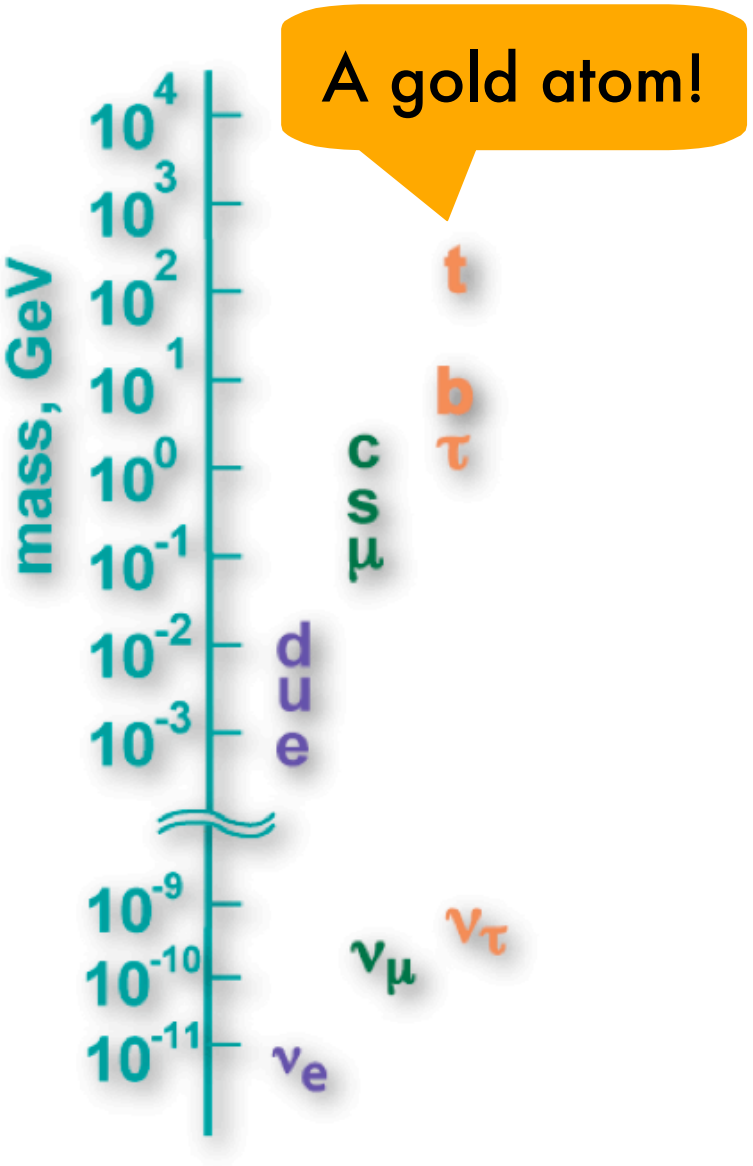
- Fundamental parameter in the SM
- M_{top} enters in radiative corrections:

$\Delta M_W \propto M_{top}^2$ $\Delta M_W \propto \ln M_H$



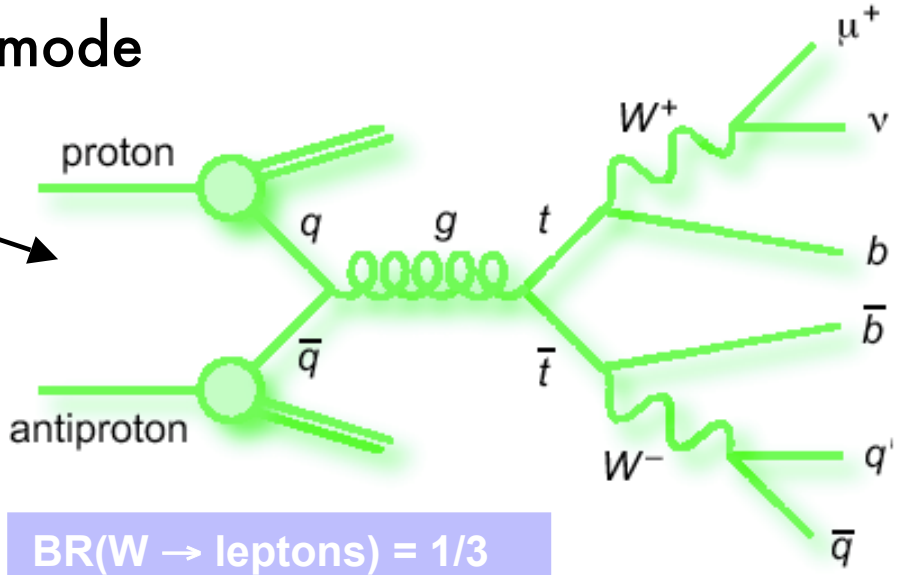
- Yukawa coupling ~1
  - Hint of special role of the top quark?

- Top cross section at 1.96TeV is O(pb)
  → tens of thousands produced!
  - Tevatron is a top factory



The challenges

We use the best known production mode



- Lepton+Jets

  golden channel: high branching ratio *AND* good S/B ratio.

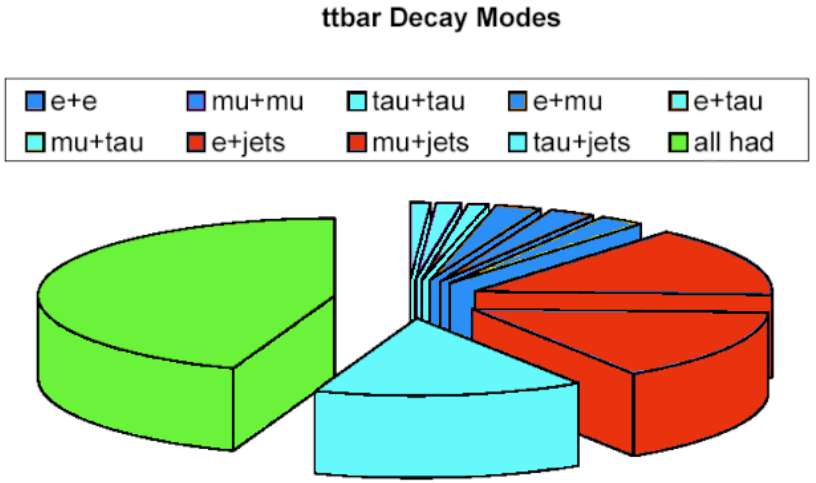
- All hadronic

  challenging channel: highest BR *BUT* huge backgrounds

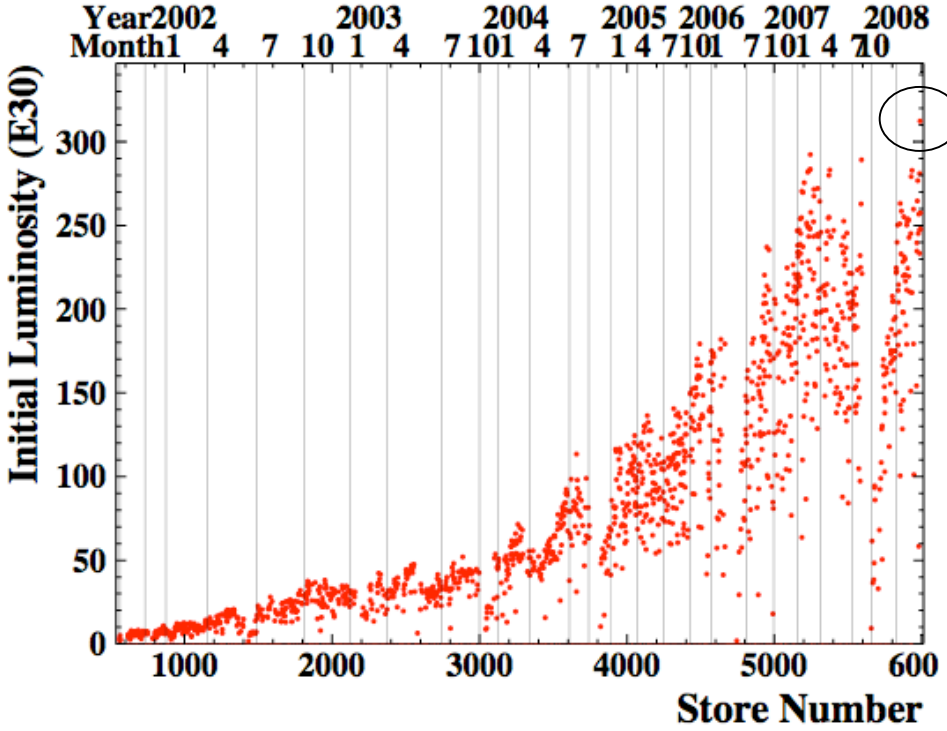
- Dileptonic

  cleanest channel - *BUT* lowest BR & neutrinos make event reconstruction difficult

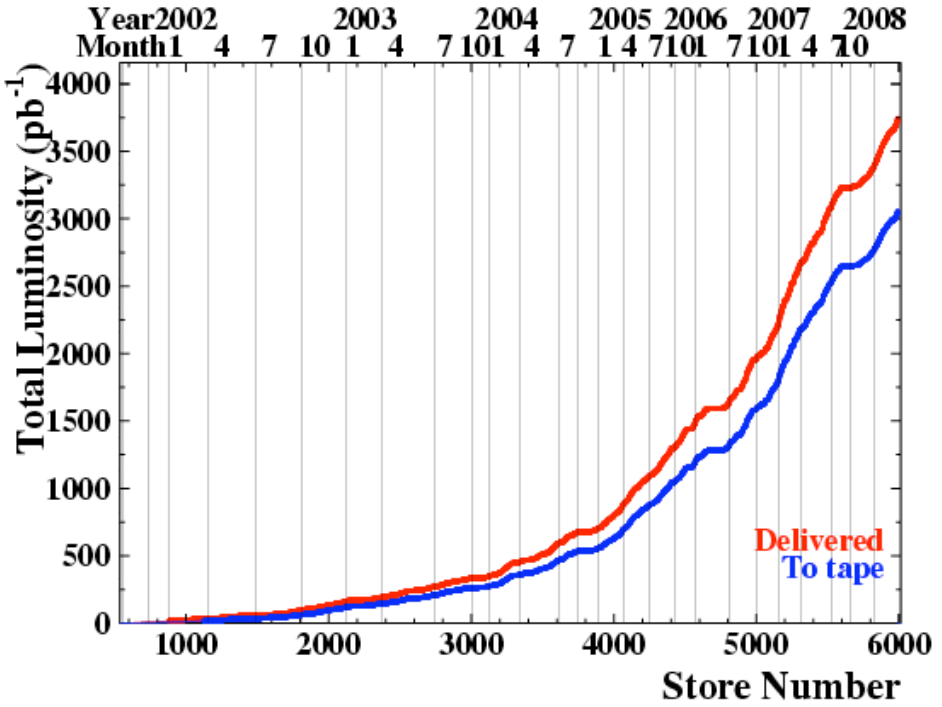
BR(W → leptons) = 1/3
BR(W → quarks) = 2/3



Accelerator performance

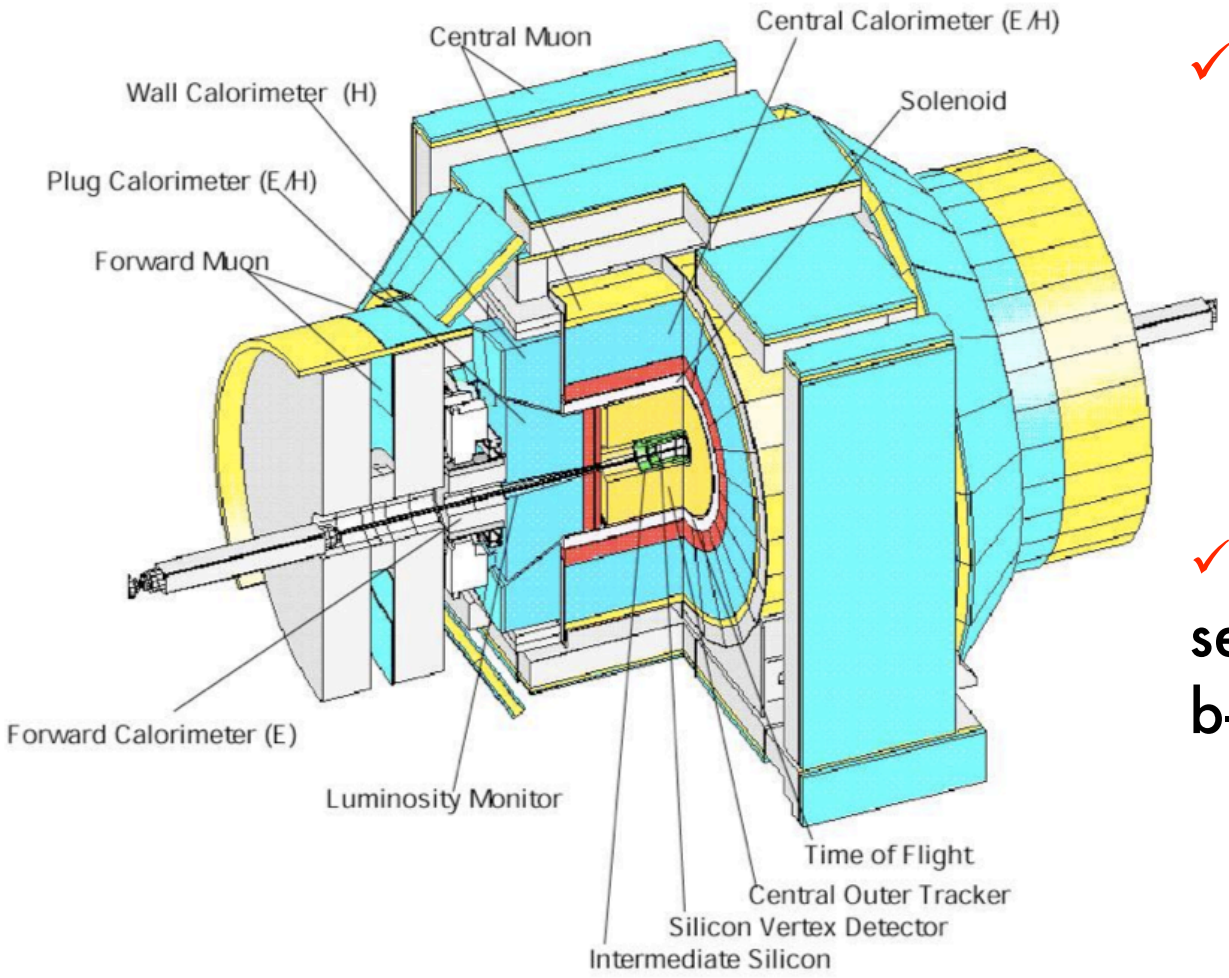


record peak luminosity of $3.15\ 10^{32}\ cm^{-2}sec^{-1}$!

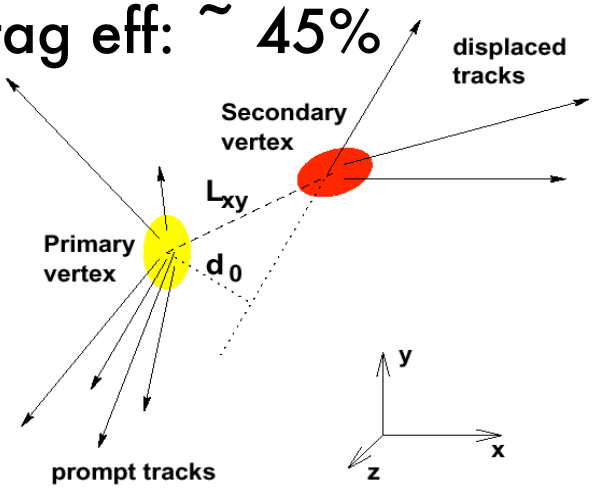


up to 2 fb^{-1} used in the following results

The CDF II detector

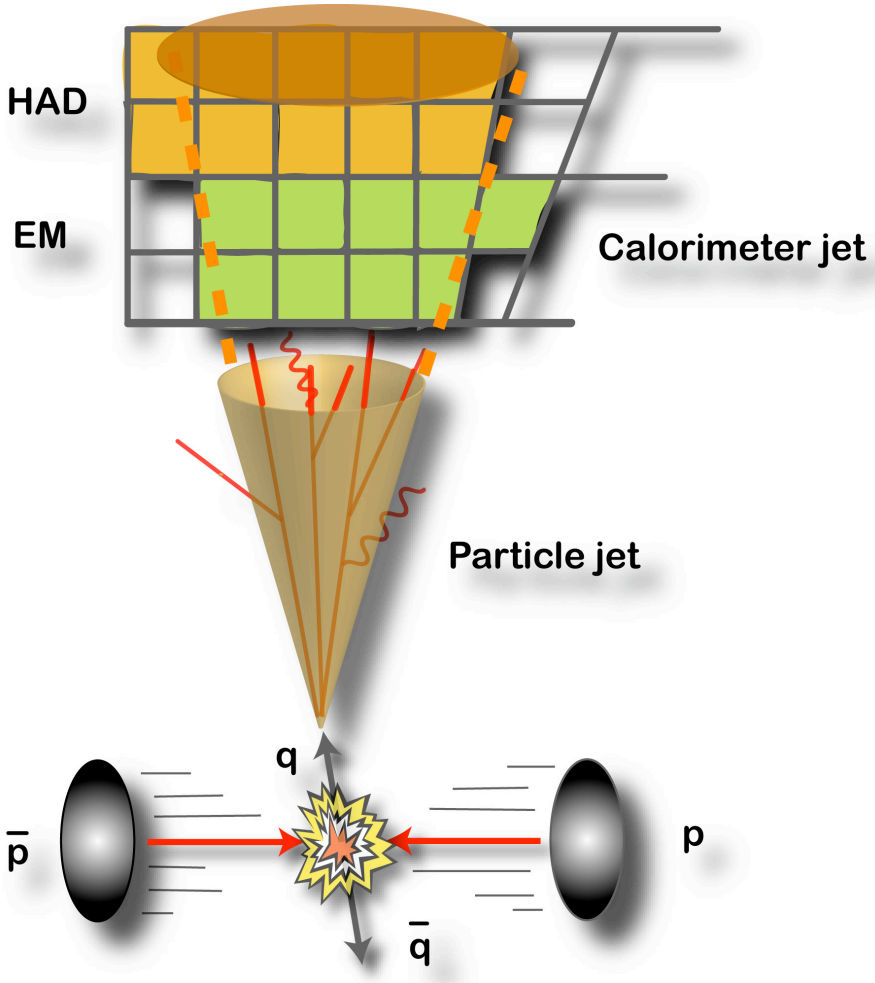


- ✓ Calorimeter coverage: $|\eta|<3.6$
- ✓ Tracking coverage:
  - silicon tracker $|\eta|<2$
  - drift chamber $|\eta|<1$
- ✓ b-quark ID using secondary vertices
  b-tag eff: ~ 45%



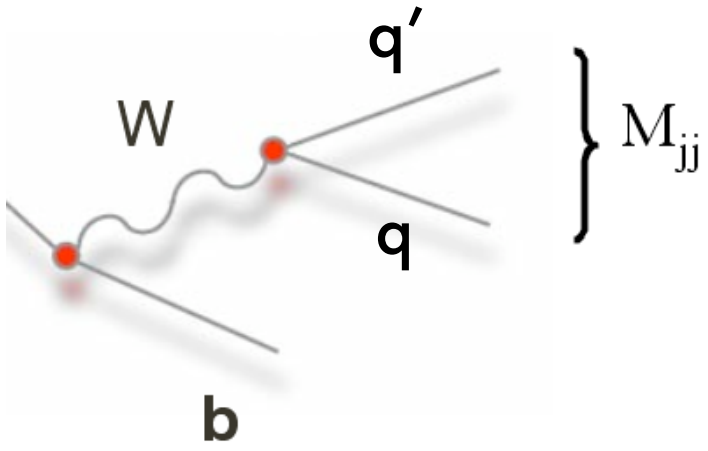
- ✓ Muon coverage $|\eta|<1.5$

Jets at CDF



Jet energy scale uncertainty

- Systematic from differences between data and Monte Carlo
- Biggest limiting systematic…BUT!

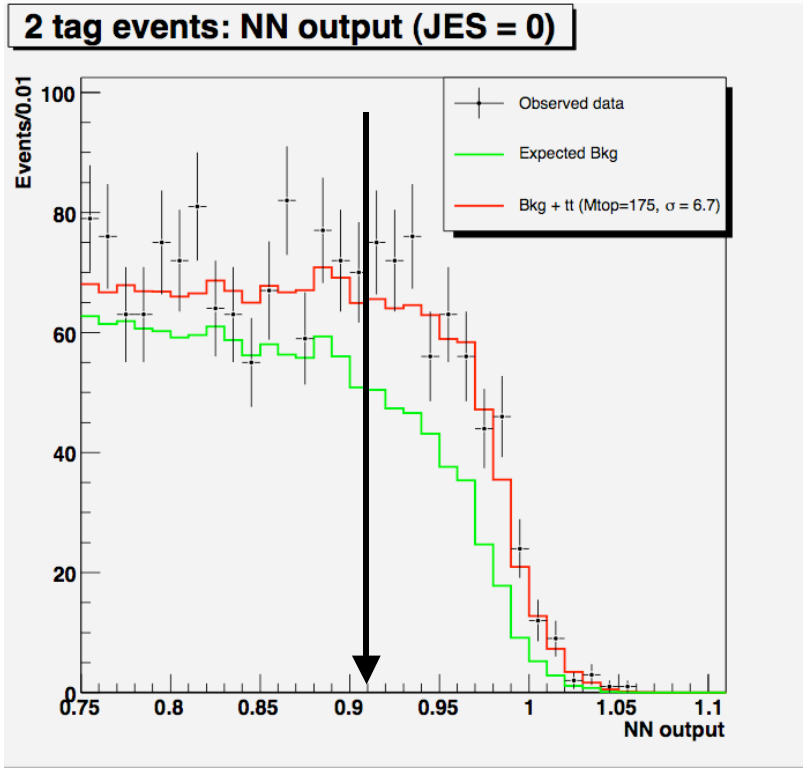


– We can exploit W→qq decays (wherever possible) to measure *in situ* the JES

Event selections and backgrounds

- Leptonic channels have manageable background

- All-hadronic channel suffers from huge QCD→S/B~1/1000
  - Needs dedicated event selection - use Neural Network



- Requiring b-tags help reduce bkg and combinatorics

S/B	Dilepton	Lepton+jets	All-hadronic
0 tag	1:1	Not used	
1 tag	20:1	4:1	1:5
2 tag		20:1	1:2

Measurement techniques(1)

Template Method

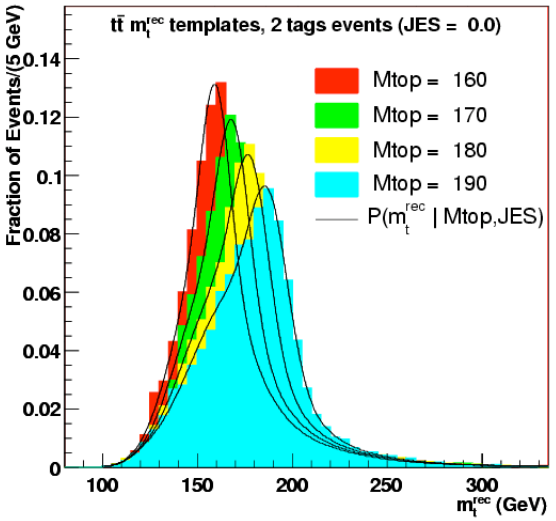
- Kinematically reconstruct events and pick a variable strongly correlated w. the one under study;
- Compare data to simulated S & B through likelihood.
- CDF applies this technique in the all-hadronic channel to find:

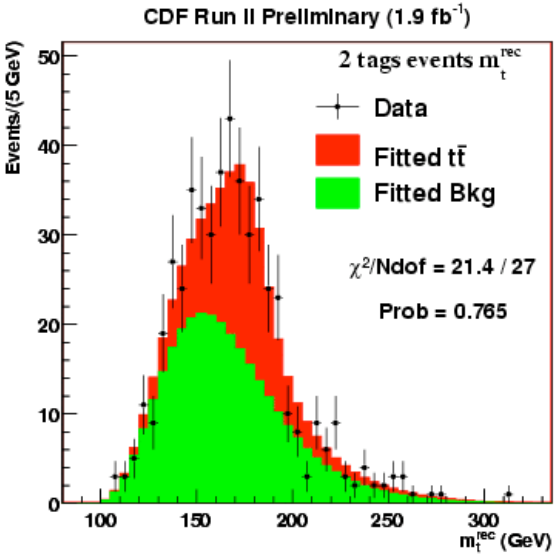
$M_t = 177.0 \pm 3.7(\text{stat+JES}) \pm 1.6(\text{syst}) \text{GeV}/c^2$

Close to 2% resolution!

Precision physics in a background dominated sample!

- Similar sensitivity in dilepton channel





Measurement techniques(2)

Matrix Element

- Extract per-event probability from the knowledge of dynamics of the signal and background
  - needs a set of simplifying assumptions, and transfer functions from recontructed objects to tree-level objects.

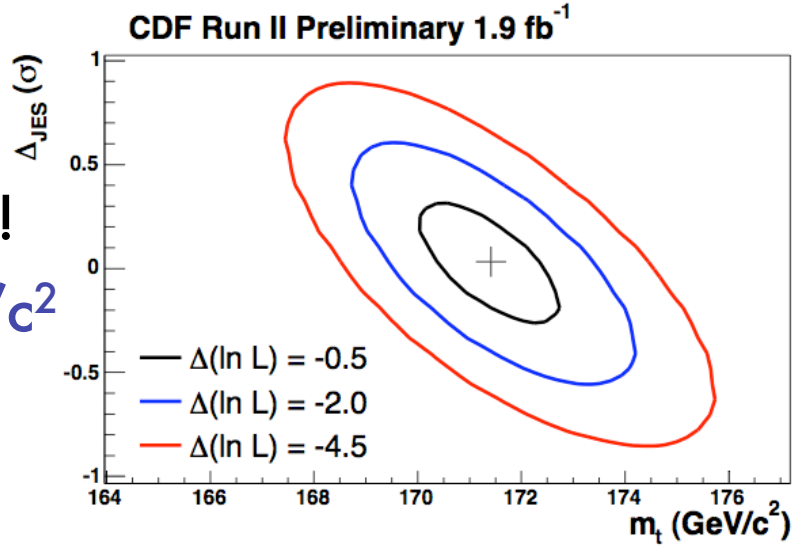
$$P_{t\bar{t}}(M_{top}, JES) = \frac{1}{N} \sum_{comb} \int d\sigma_{t\bar{t}}(y, M_{top}) dq_1 dq_2 f(q_1) f(q_2) W(x, y, JES)$$

- Application of the ME technique to lepton+jets channel gives world best M_t!

M_t=171.4±1.5(stat+JES)±1.0(syst)GeV/c^2

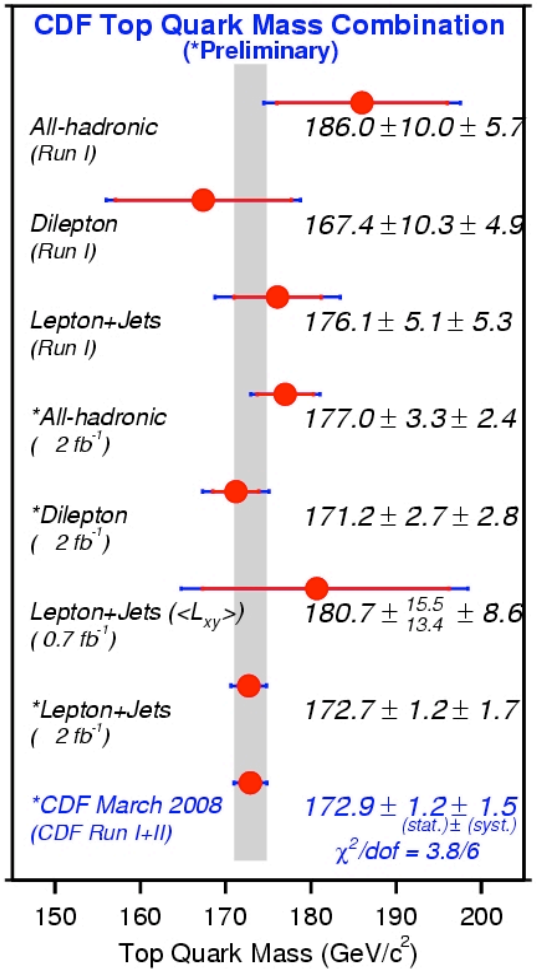
Almost 1% precision!

(Not yet used in the combination)

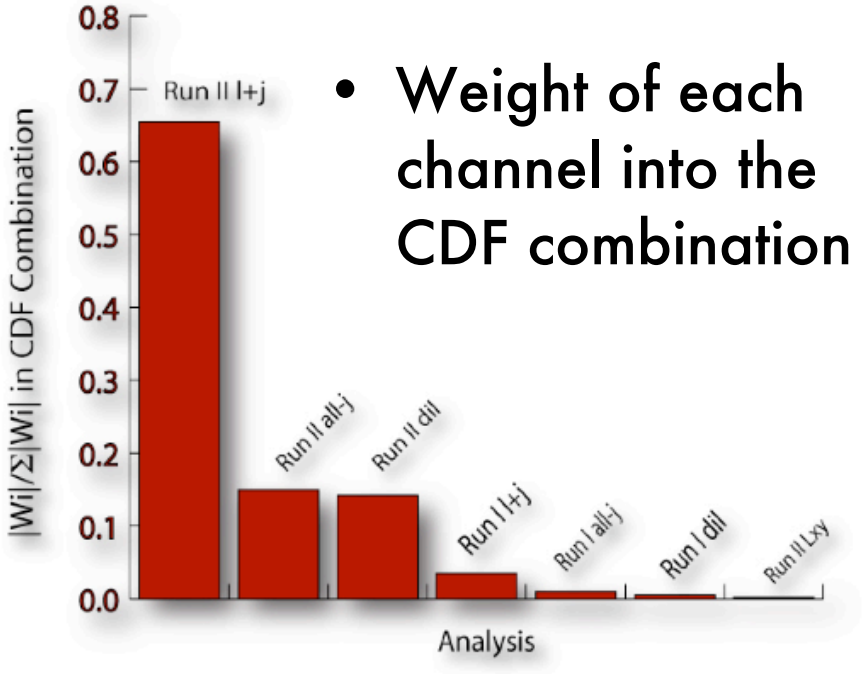


CDF combination

- We pick the best measurement in each channel to check compatibility and improve precision



- CDF M_{top}=172.9±1.2(stat)±1.5(syst)GeV/c^2
  - Improve precision by 10%
  - Good chi2/ndof=3.8/6



- Weight of each channel into the CDF combination

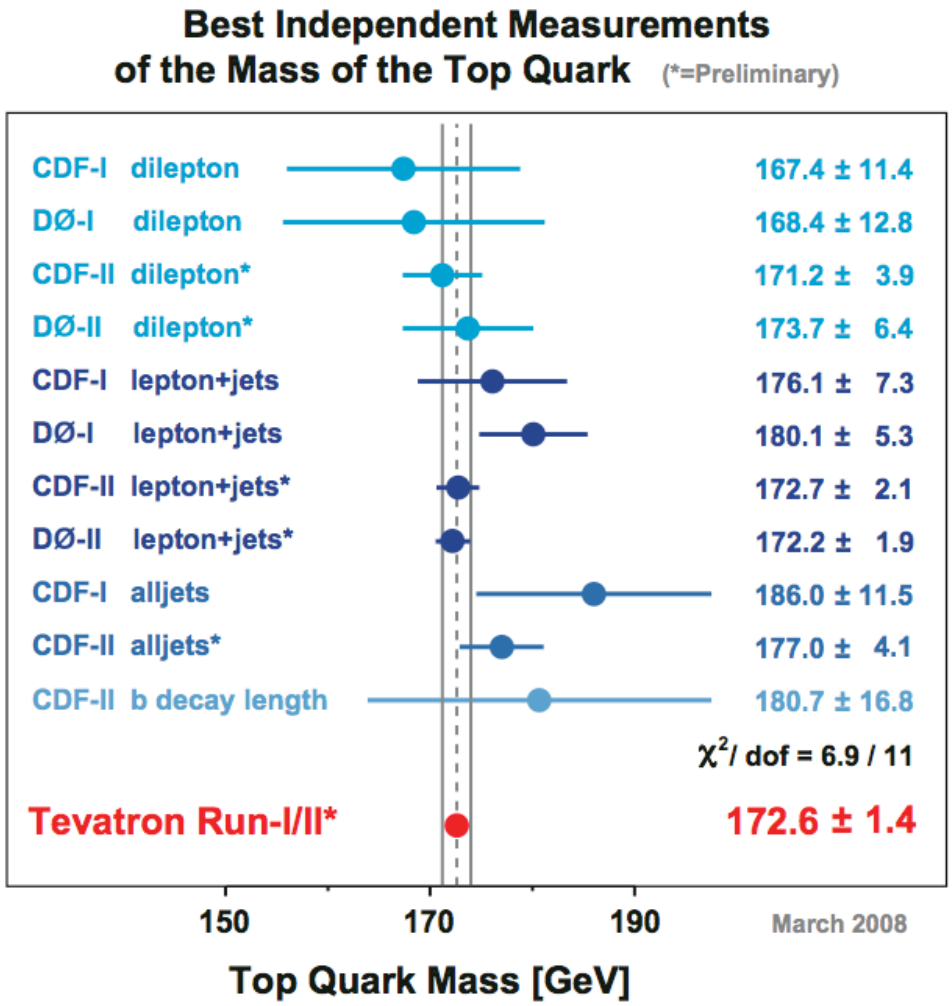
Tevatron combination

- CDF and D0 combined measurement in march 2008 to give:

$172.6 \pm 0.8(\text{stat}) \pm 1.1(\text{syst})\ \text{GeV}/c^2$

- Top mass measurement is now precision physics → 0.8%

- Needs constant control of systematics sources
  - Ongoing effort to double-check systematics list - definitons



EWK fits and implications

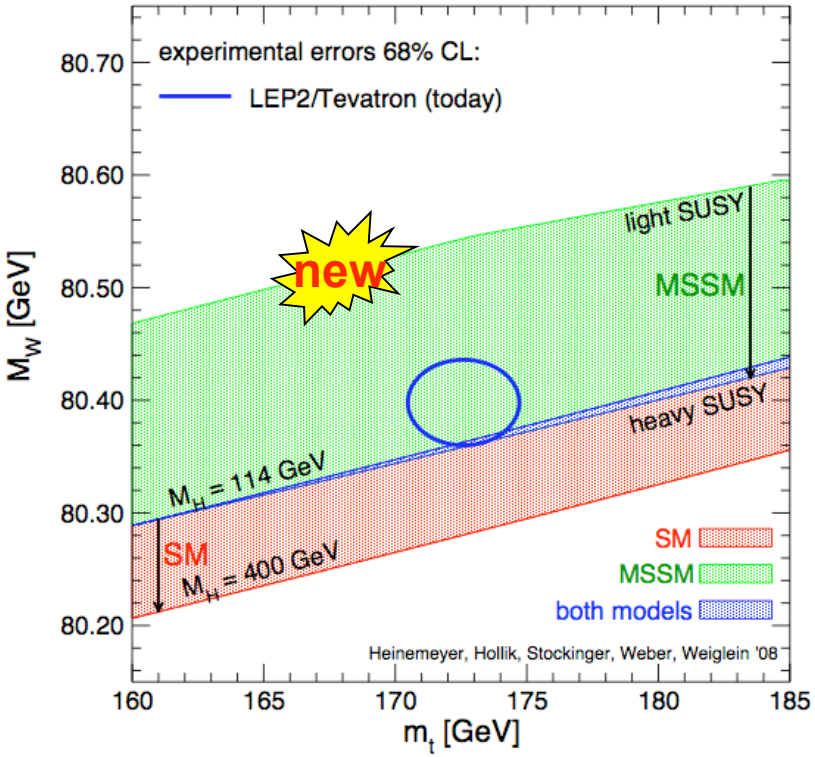
- Running traditional LEP EWK constraints, updated using latest Tevatron W boson (2007) and top quark mass (march 2008)

  Fit value=87^{+36}_{-27} GeV

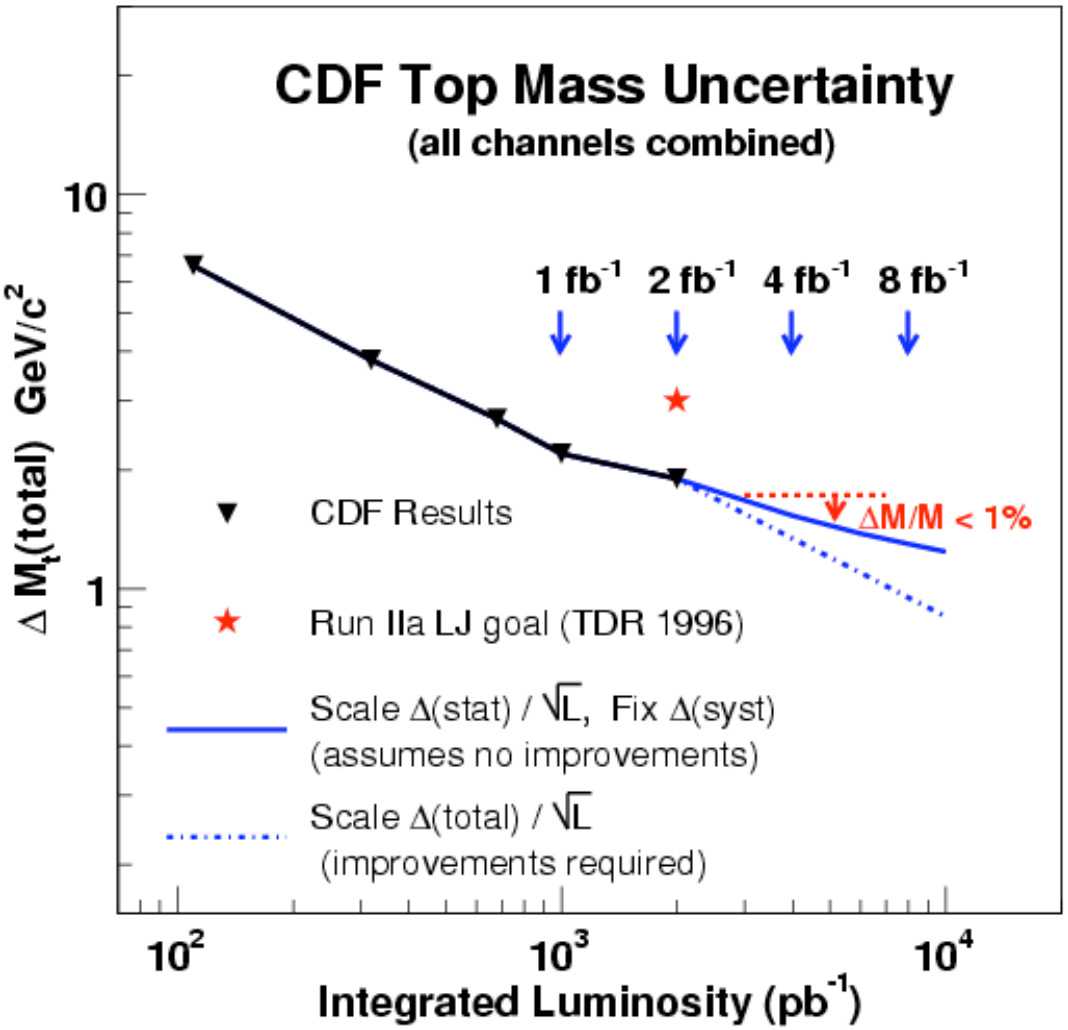
  (@ 68% c.l.)

  mH < 160 GeV @ 95%

- Top mass was found to be in good agreement with SM
  - Will it happen for the Higgs-(if it exists)?



Conclusions



BACK UP SLIDES

Some comments

- Huge amount of work on every single piece of the analysis
- After in situ calibration, most results are still limited by statistics
- CDF provides world best single measurement
- Combined measurement is limited by systematics though

Compatibility