Top quark mass measurements at CDF

Top mass in the lepton+jets

ΔM_{top} in the lepton+jets

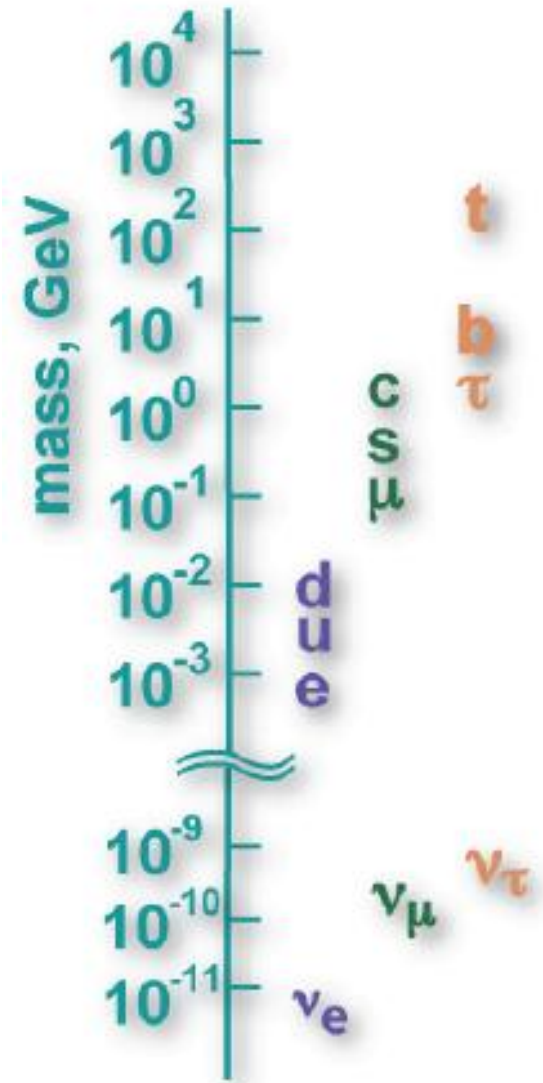
Top mass in the missing E_T+jets

Hyun Su Lee

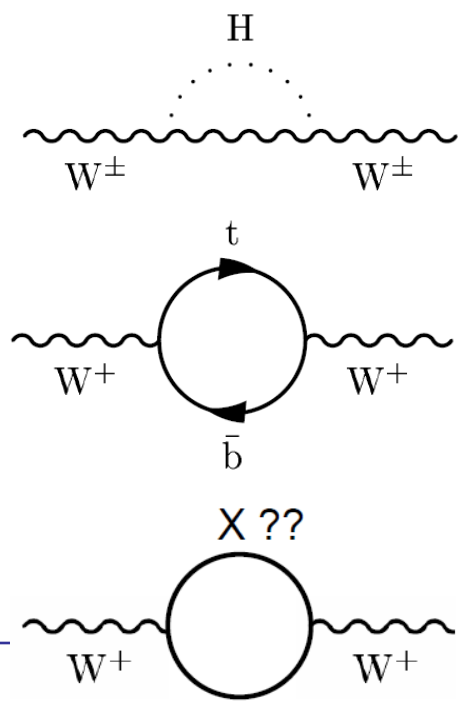
Ewha Womans University

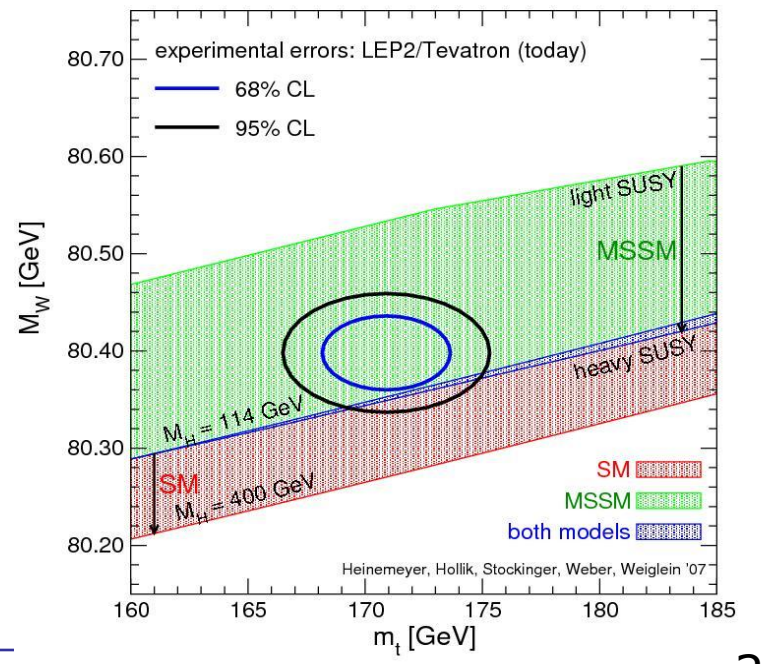
On behalf of the CDF collaboration

Top quark and top mass

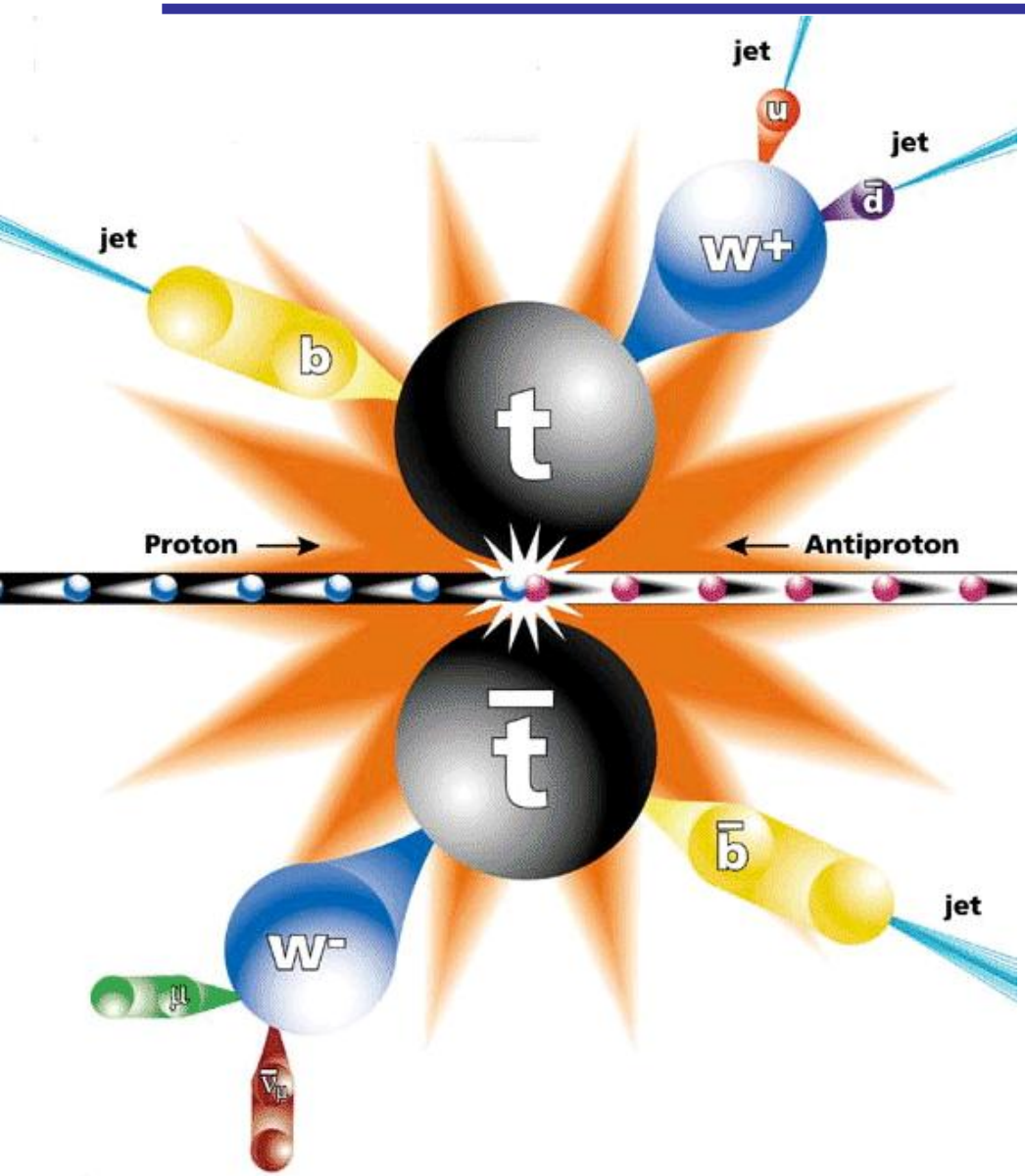


- Top quark is the heaviest known elementary particle
- Top quark mass is not predicted by SM
- Can constrain SM Higgs boson mass
  - ❖ Important contribution in radiative correction of W
  - ❖ Important test of SM





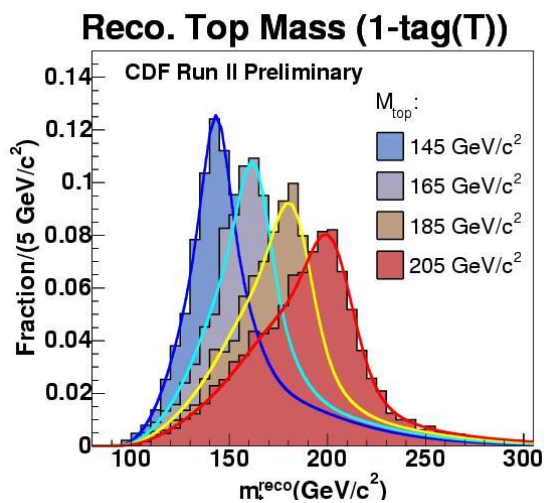
Lepton+Jets channel

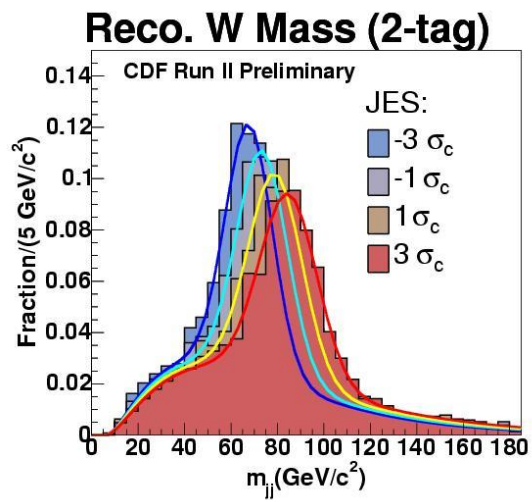


- Pair production
  - ~7.4 pb at Tevatron
- ~100% $t \rightarrow Wb$
- Lepton+jets
  - One $W \rightarrow qq'$
  - The other $W \rightarrow l\nu$
  - Four jets (including two b-quark jets), one charged lepton, and large missing energy(neutrino)
  - Good S/B ratio
  - BR ~ 34%
  - Best channel for top quark mass measurement

Measurement technique (template method)

- Identify variables $\vec{x}$ sensitive to M_{top} (or JES)
- Using MC, generate signal distribution of $\vec{x}$ as a function of M_{top} (or JES)
- Parametrize templates in terms of probability density function then assign the probability for certain mass and JES





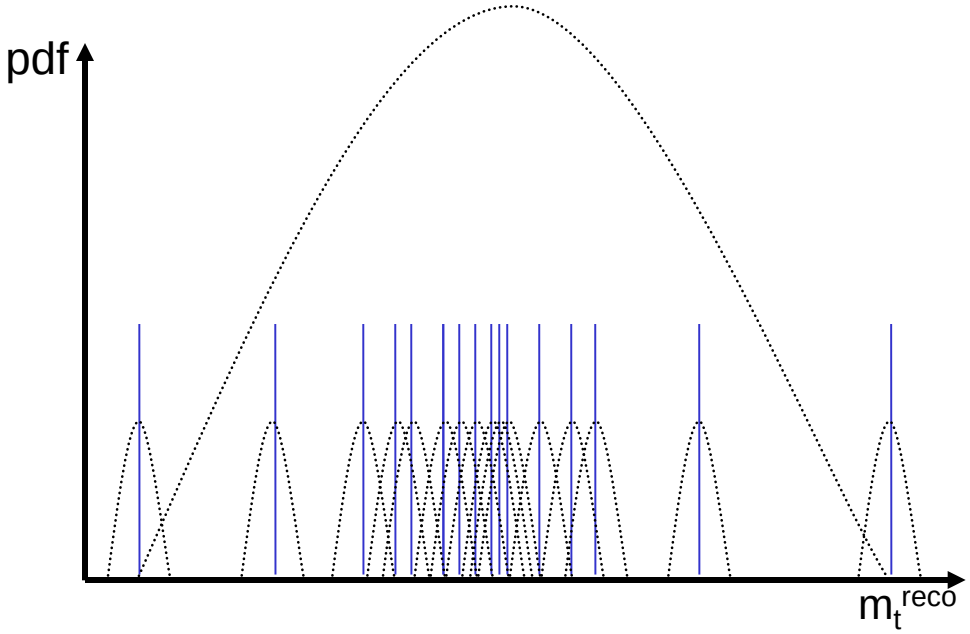
$$P(\vec{x}; M_{top}, \Delta JES)$$

Event reconstruction in the lepton+jets

$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \Sigma_{j=x,y}\frac{(U_j^{fit} - U_j^{meas})^2}{\sigma_j^2} + \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - m_t^{reco})^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu} - m_t^{reco})^2}{\Gamma_t^2}$$

- Construct likelihood based on probabilities

Non-parameteric template technique



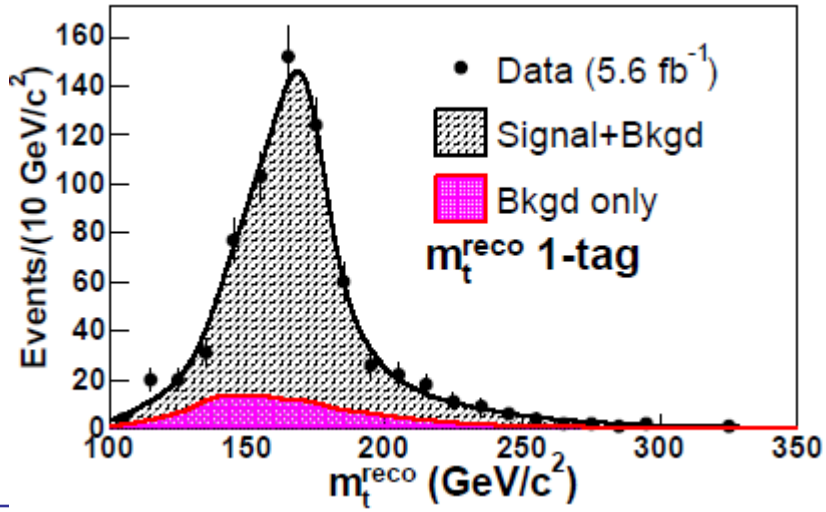
- Use kernel function per event to get probability density function (pdf)
- Easy to extend dimension
  - We used fully 3D pdf
  - Fit both mass and jet energy scale
  - $P(m_t^{reco}, m_{jj}, m_t^{reco(2)}; M_{top}, \Delta JES)$
  - $m_t^{reco(2)}$:2nd minimum χ^2 mass

- CDF 5.6 fb^{-1} measurements

PRD 83 (2011) 111101

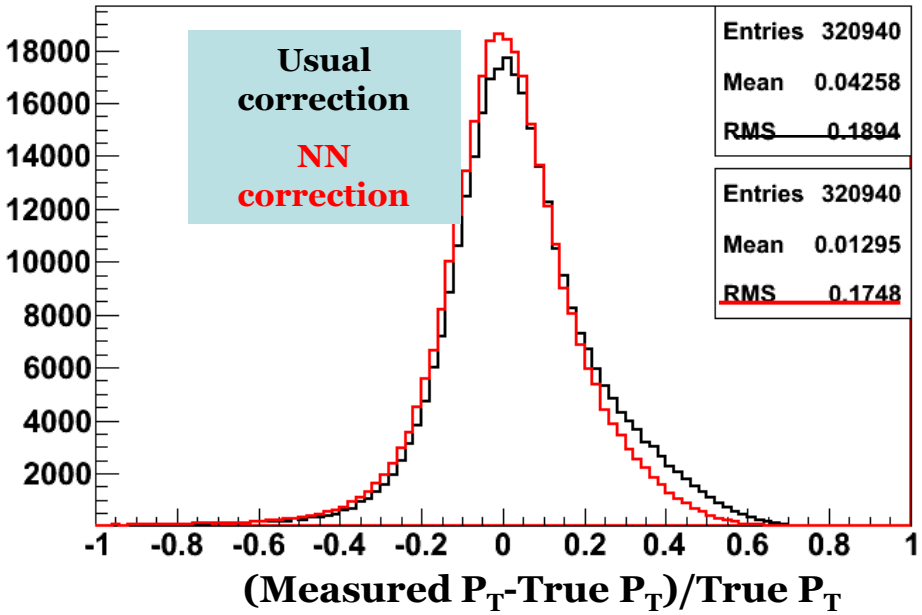
172.2 ± 0.8 (stat) ± 0.8(JES) ± 0.9(syst) GeV/c^2

=172.2 ± 1.5 GeV/c^2



Improvement (jet energy resolution)

- Incorporate Calorimeter Jet information with Track Jet information
  - ❖ Usual correction only use calorimeter one
  - ❖ Use Artificial Neural Network
    - ❑ Same technique have been used in the Higgs search ($H \rightarrow b\bar{b}$)
    - ❑ Same improvements have been happened for $t\bar{t}$



- ~10% improvement of jet energy resolution
- ~10-15% better separation power in the $m_t{}^{reco}, W_{jj}$
- ~13% better statistical precision

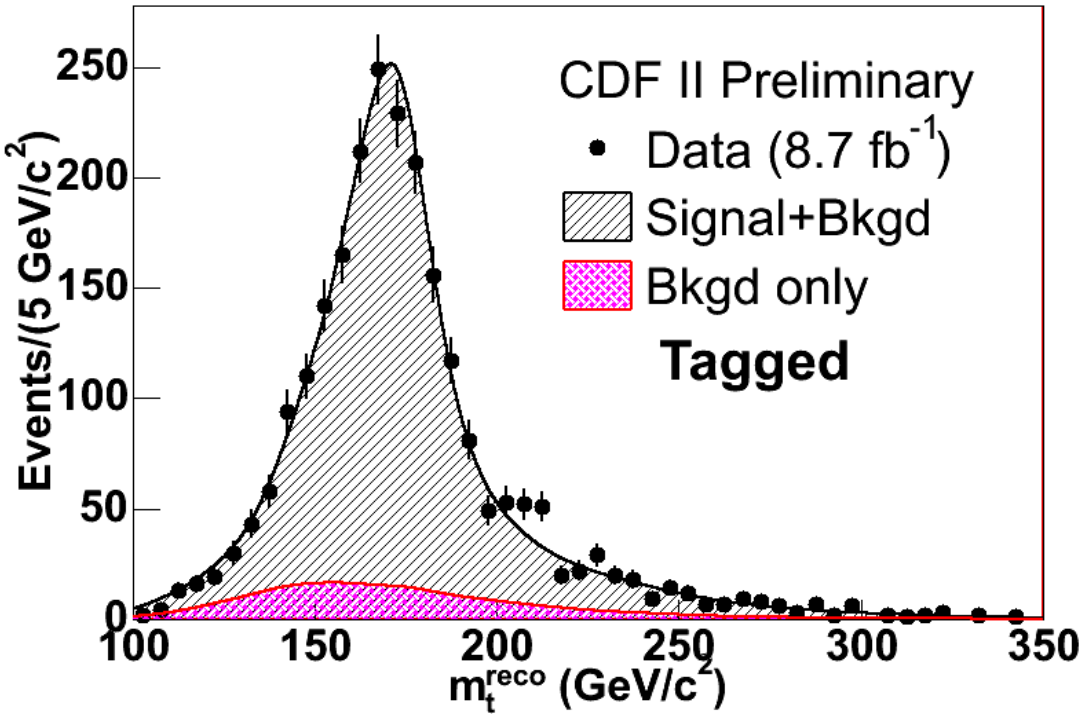
Improvement (increasing signal acceptance)

- Increase signal acceptance by loosening selection criteria
  - ~12% better precision in the statistical uncertainty

	0tag	**1tagL**	1tagT	2tagL	2tagT
Wbb	**37.6±15.9**	**54.4±22.6**	34.0±14.3	8.5±3.6	6.1±2.6
Wcc	**117.8±46.2**	**35.7±13.6**	22.3±9.0	1.4±0.7	1.2±0.5
Wc	**54.2±25.1**	**19.1±10.0**	10.4±5.1	0.8±0.3	0.5±0.2
W(mistag)	**493.6±111.5**	**60.5±13.5**	35.4±9.0	0.9±0.3	0.6±0.2
Z+jets	**52.3±4.4**	**8.9±1.1**	5.9±0.7	0.8±0.1	0.5±0.1
ST	**4.8±0.5**	**10.5±0.9**	6.8±0.6	2.2±0.3	1.7±0.2
Diboson	**60.3±5.6**	**11.1±1.4**	8.5±1.1	1.0±0.2	0.8±0.1
QCD	**143.0±114.4**	**34.5±12.6**	20.7±16.6	4.4±2.5	2.5±2.4
BKGD	**963.5±229.3**	**234.7±61.1**	144.0±40.9	19.9±5.5	13.8±4.2
Top	**644.8±86.3**	**695.0±86.7**	867.3±107.6	192.3±29.7	303.7±46.6
Total(Exp)	**1608±245**	**930±106**	1011.3±115.1	212.2±30.2	317.6±46.8
Observed	**1627**	**882**	997	208	275

Use full dataset (8.7 fb^{-1})

Updated with full data (additional gain of 25% respect to luminosity increasing



172.85 ±0.71(stat.) ±0.85(syst.)=172.85 ± 1.11 GeV/c^2

Most Precise single measurement to data

Working on the publication

Systematic uncertainty

Updated with full luminosity increasing

CDF II Preliminary 8.7 fb^{-1}	
Systematic	GeV/c^2
Residual JES	0.52
Generator	0.56
Next Leading Order	0.09
PDFs	0.08
b jet energy	0.18
b tagging efficiency	0.03
Background shape	0.20
gg fraction	0.03
Radiation	0.06
MC statistics	0.05
Lepton energy	0.03
MHI	0.07
Color Reconnection	0.21
Total systematic	0.85

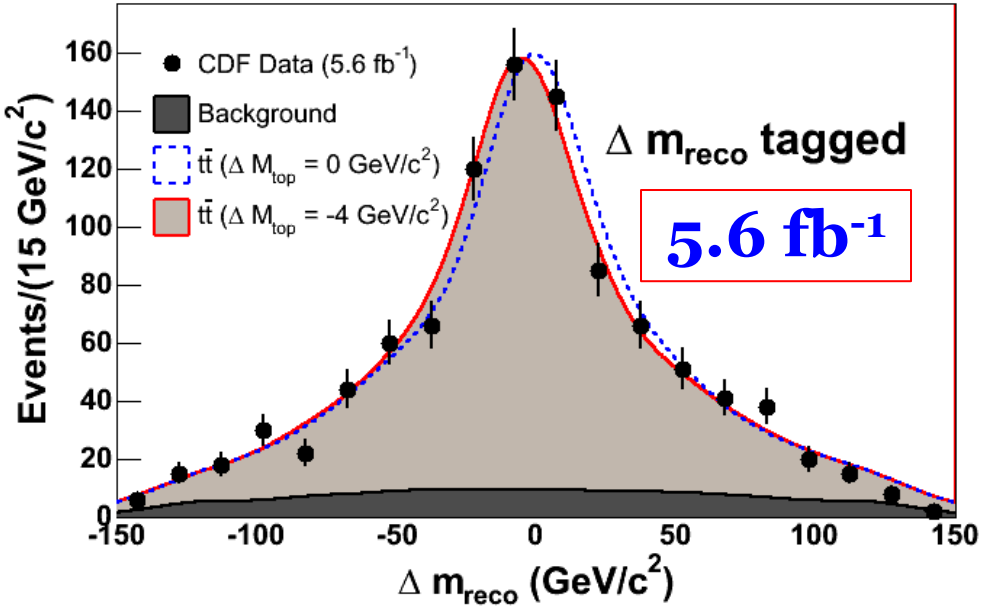
$172.85 \pm 0.71(stat.) \pm 0.85(syst.) = 172.85 \pm 1.11$ GeV/c^2

Most Precise single measurement to data

Working on the publication

t and $\bar{t}$ mass difference (ΔM_{top})

- If CPT is conserved, ΔM_{top} should be zero (SM)
- So, this measurement tests CPT violation
- We use similar technique of mass measurements



Lepton+Jets

kinematic reconstruction

PRL 106, 152001 (2011)

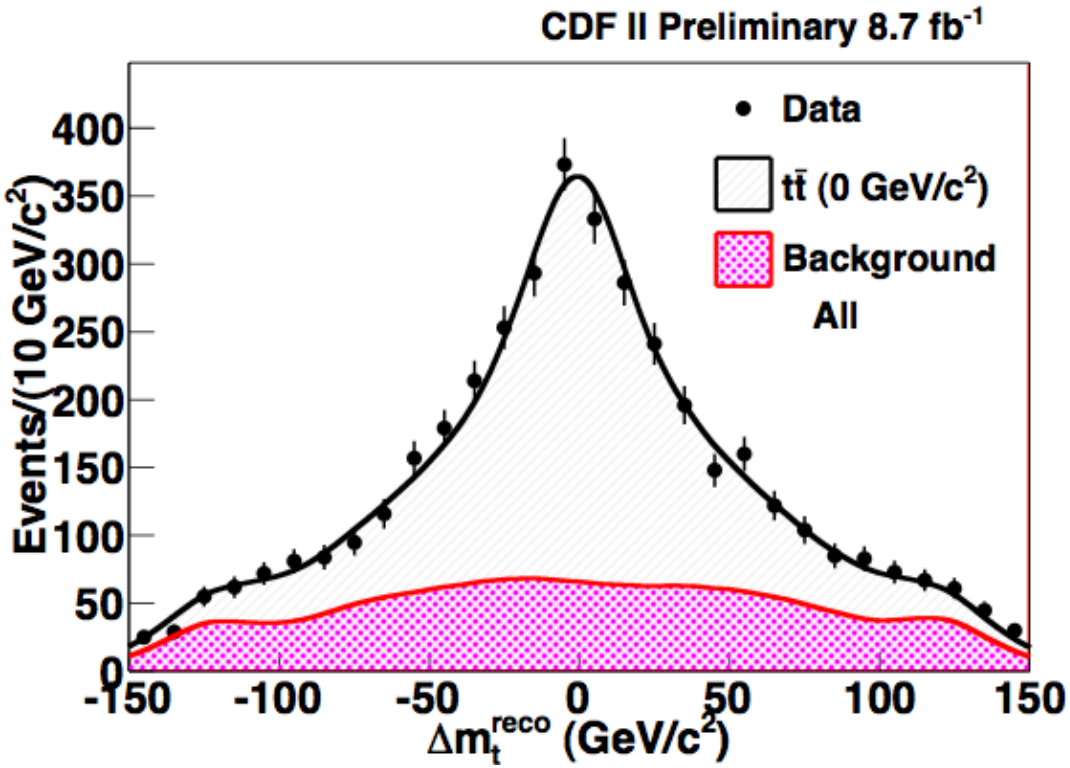
Stat. Syst.

$\Delta M_{top} = -3.3 \pm 1.4 \pm 1.0$

$= -3.3 \pm 1.7$ GeV/c²

Measurement with full data set (8.7 fb^{-1})

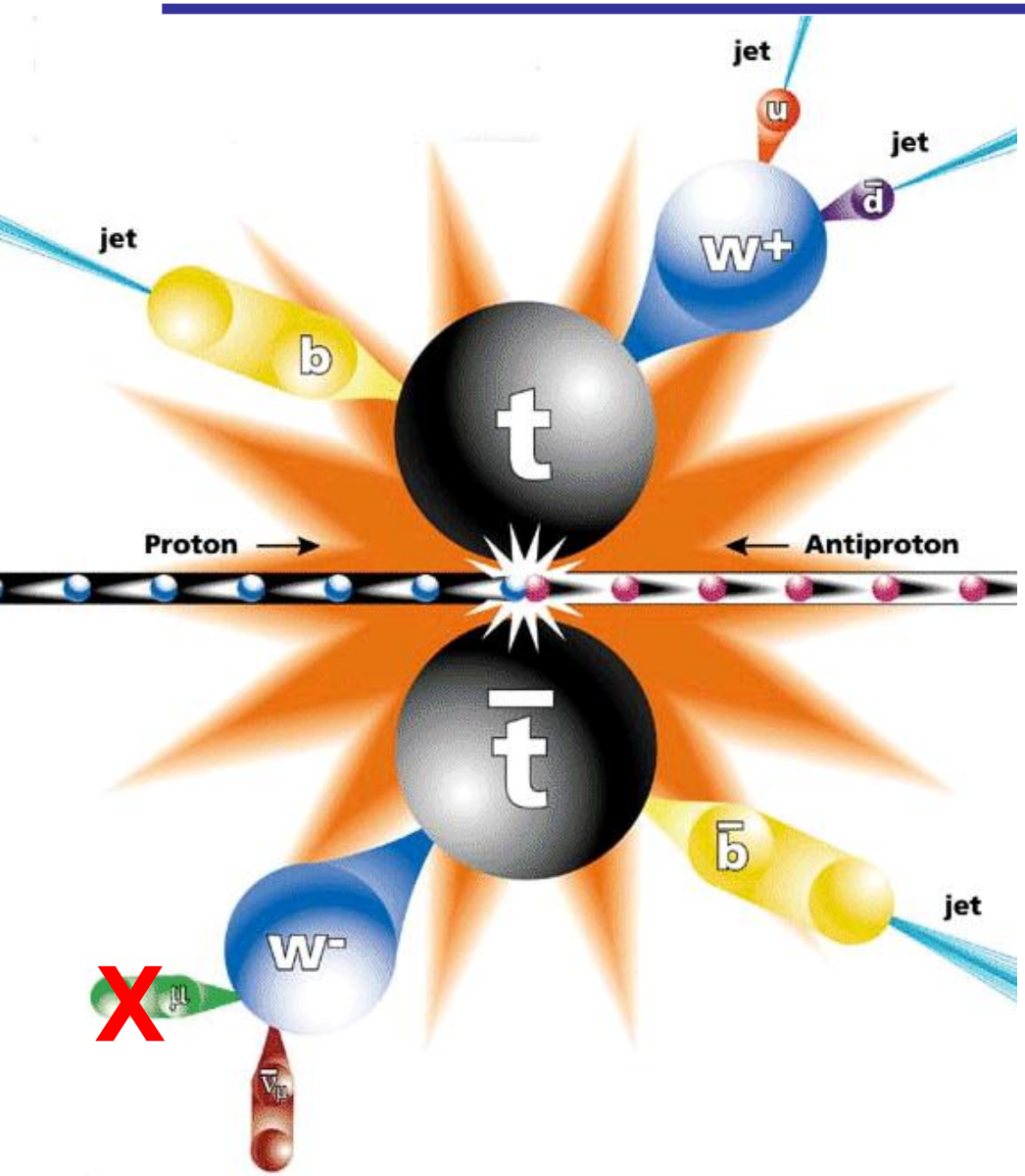
Same improvement with top quark mass measurement



ΔM_{top} = -1.95 ± 1.11(stat.) ± 0.59 (syst.)
= -1.95 ± 1.26 GeV/c²

Working on the publication

Missing E_T+Jets channel

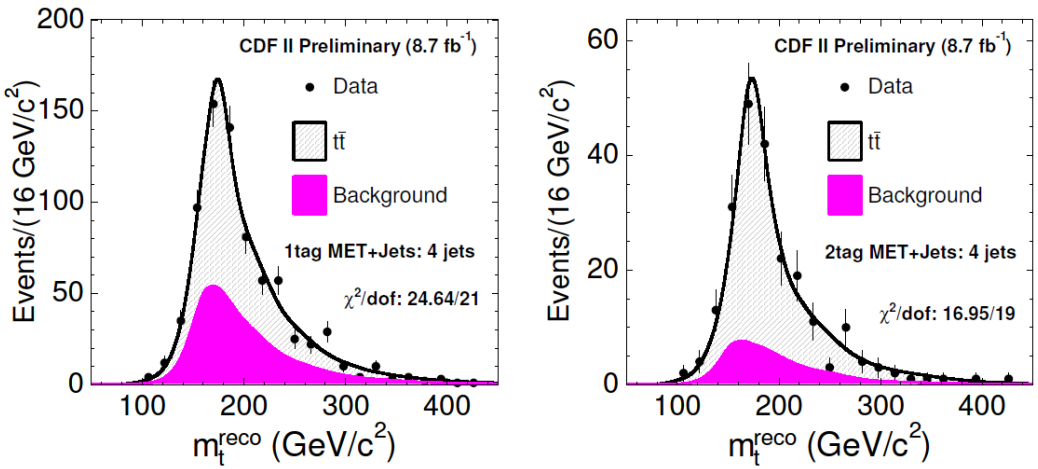


- Topology based channel
  - No lepton, large missing energy, and four jets
  - Orthogonal with the other analysis
- Truths are almost lepton+jets
  - Missing lepton (instrument)
  - Hadronic tau decay
- Previous measurement
  - 5.7fb^{-1} data
  - Use hadronic top mass (three jet and dijet mass (W mass) with *in situ* JES calibration
  - 172.3 ± 2.6 GeV/c^2

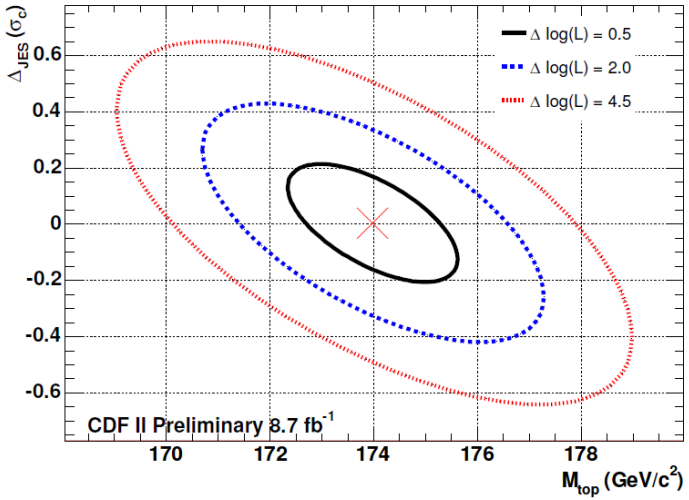
PRL 107, 232002 (2011)

Measurement with full data set (8.7 fb^{-1})

- Full Event Reconstruction
  - Use kinematic fitter
  - Reconstruct leptonic W (not decaying product)
    - Overconstrained system



- 3D pdf using KDE technique
  - Two reconstructed top masses and dijet (W) mass
  - *In situ* JES calibration



$$M_{top} = 173.9 \pm 1.6\ (\text{stat.+JES}) \pm 0.9\ (\text{syst.})\ \text{GeV}/c^2$$
$$= 173.9 \pm 1.9\ \text{GeV}/c^2$$

Conclusion

- Top quark mass measurement in the lepton+jets channel

  M_{top}=172.85$\pm$1.11 GeV/c^2

  ❖ Most precise single measurement to date

- ΔM_{top} measurement in the lepton+jets using full dataset

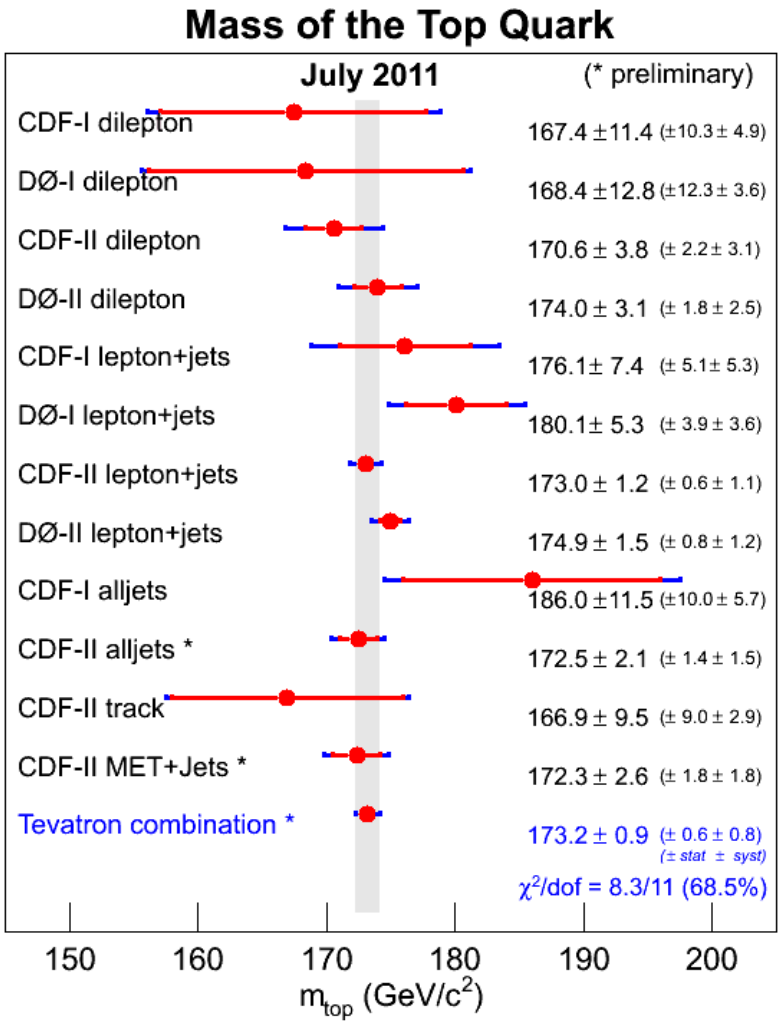
  ΔM_{top}=-1.95$\pm$1.26 GeV/c^2

- Top quark mass measurement in the missing E_T+jets

  M_{top}=173.9$\pm$1.9 GeV/c^2

  ❖ Most precise measurement in this event topology

The latest top quark mass measurement



ATLAS

- ***Lepton + Jets***: arXiv:1203.5755, Mar 2012
  174.5 ± 0.6(stat.) ± 2.3(syst.) GeV/c^2
- ***All-Hadronic***: ATLAS-CONF-2012-030, Mar 2011
  174.9 ± 2.1(stat.) ± 3.8(syst.) GeV/c^2

CMS

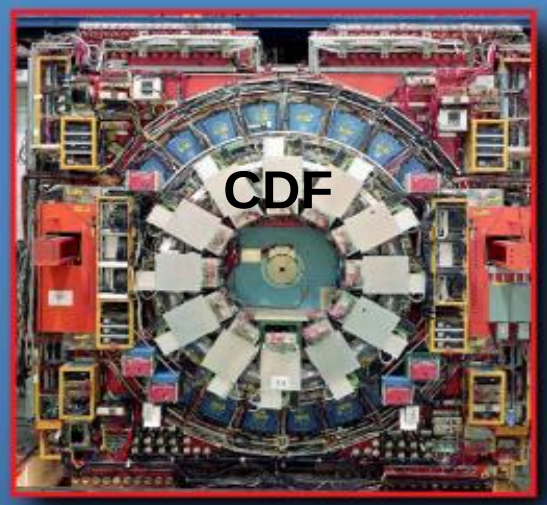
- ***Lepton + Jets***: CMS-PAS-TOP-11-015, Feb 2012
  172.6 ± 0.6(stat.) ± 1.2(syst.) GeV/c^2
- ***Dilepton***: CMS-PAS-TOP-11-016, Feb 2012
  175.5 ± 1.2(stat.) ± 2.6(syst.) GeV/c^2

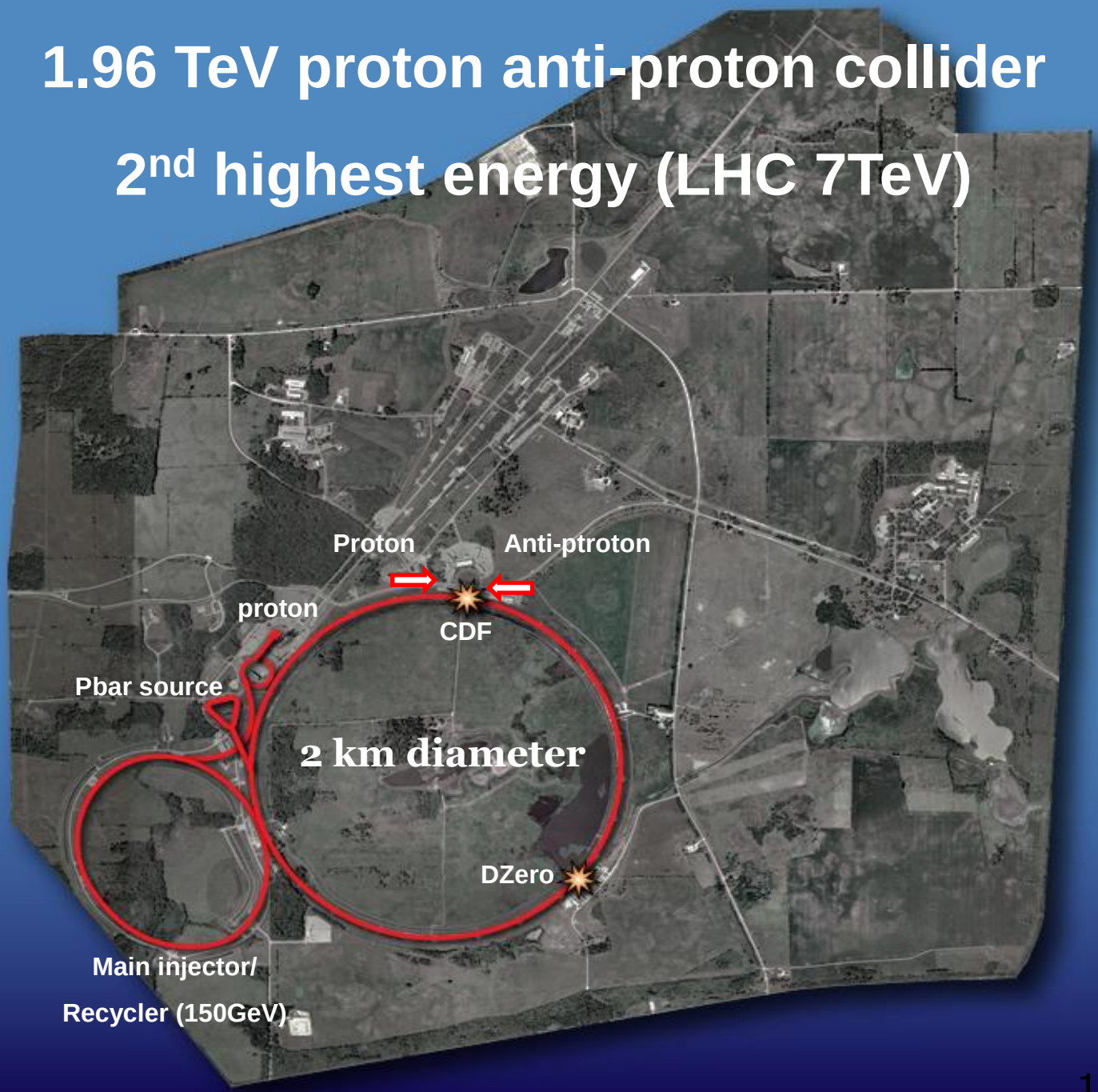
- Tevatron average : 173.2 ± 0.9 GeV/c^2

Tevatron

1.96 TeV proton anti-proton collider

2nd highest energy (LHC 7TeV)



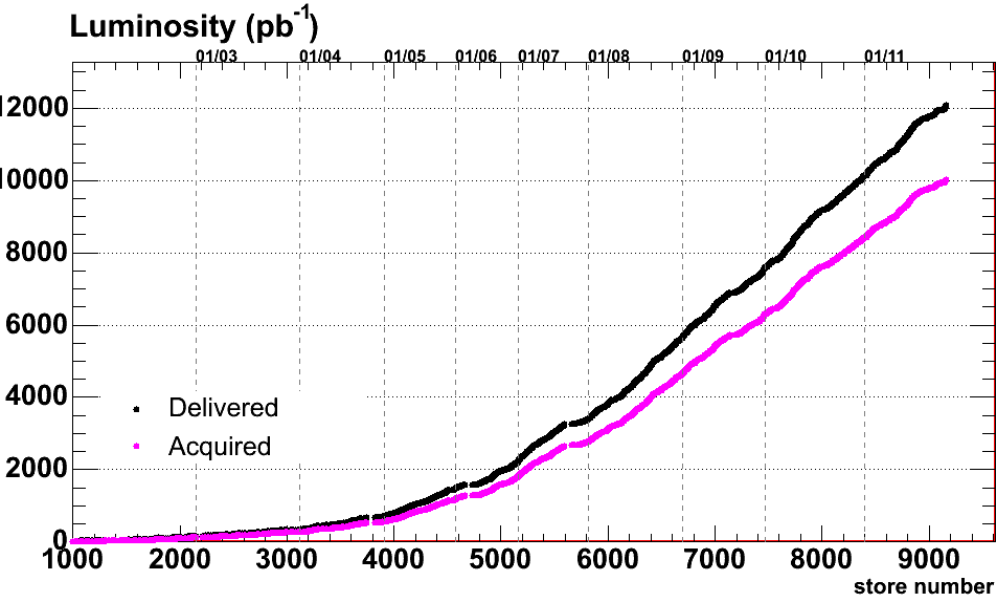
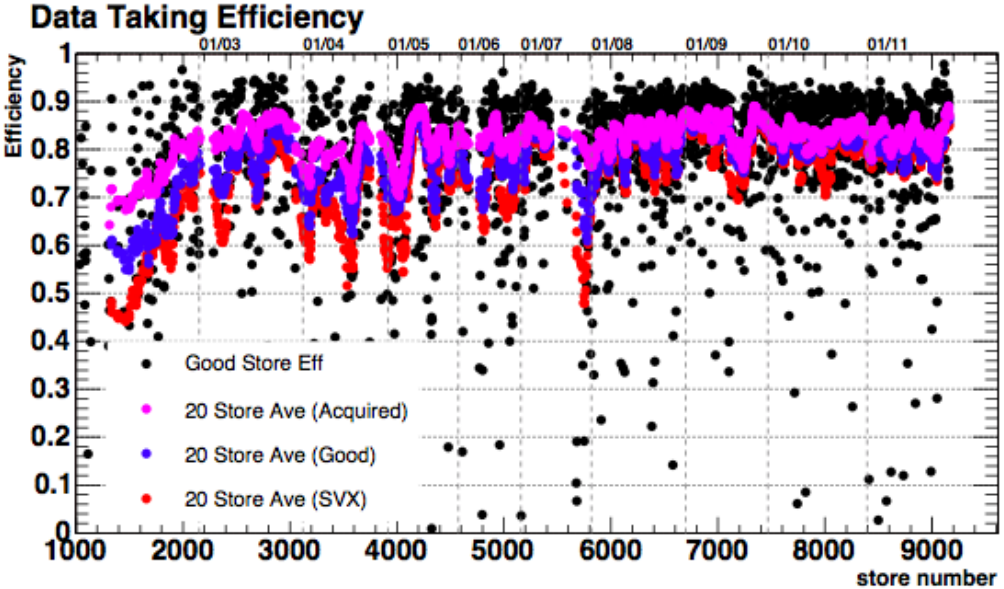


Farewell Tevatron
Shutdowned at Sept/31/2011

CDF Luminosity

Delivered >12.0 fb^{-1}

Acquired 10 fb^{-1} (10% less with silicon)

8.7 fb^{-1} for top physics

Use full data