Top quark physics at CDF

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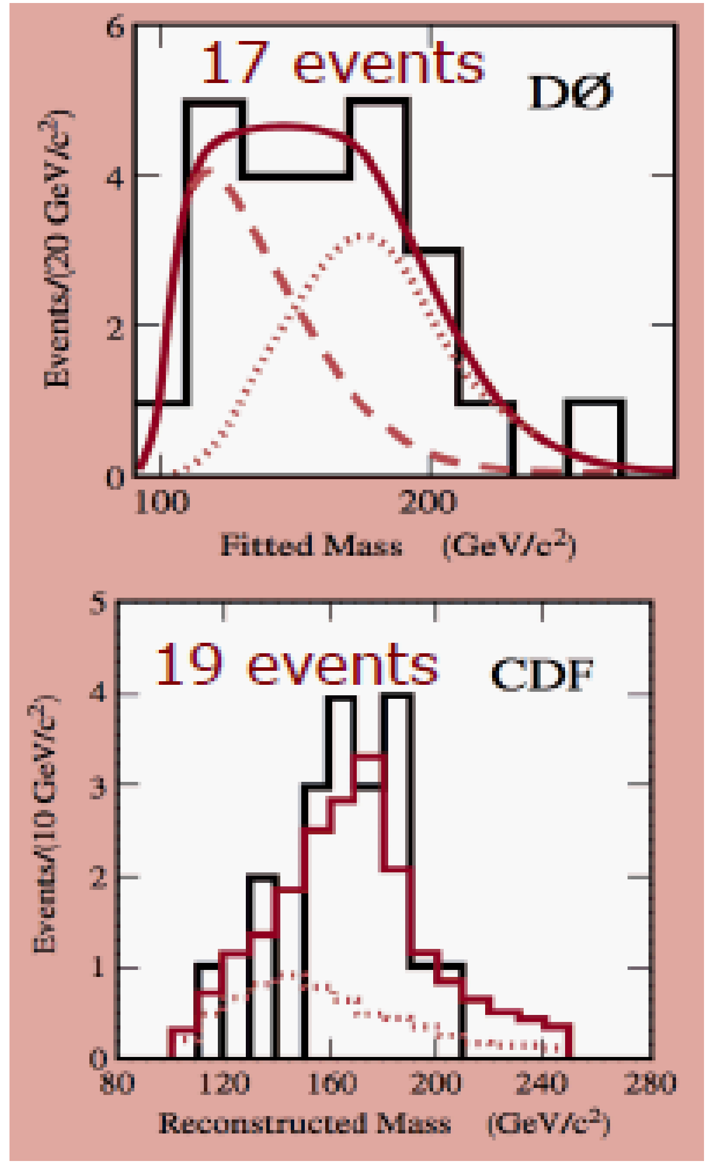
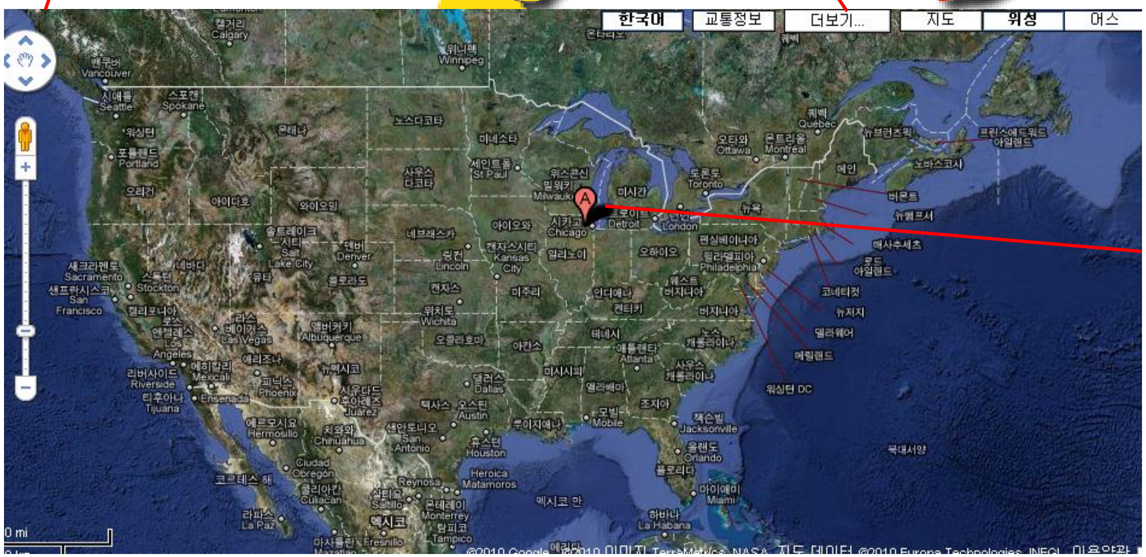
On behalf of the CDF collaboration

Top quark observation

- Observed by both CDF and D0 at 1995
  - ❖ Top quark observation is the main goal of Tevatron (LHC is Higgs)
- Use ~20 top candidate events



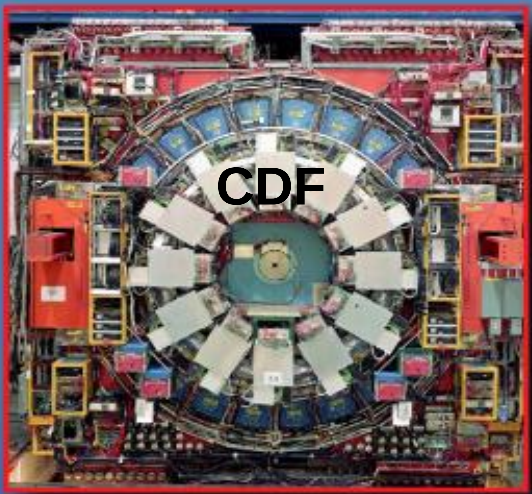
Fermilab/Tevatron

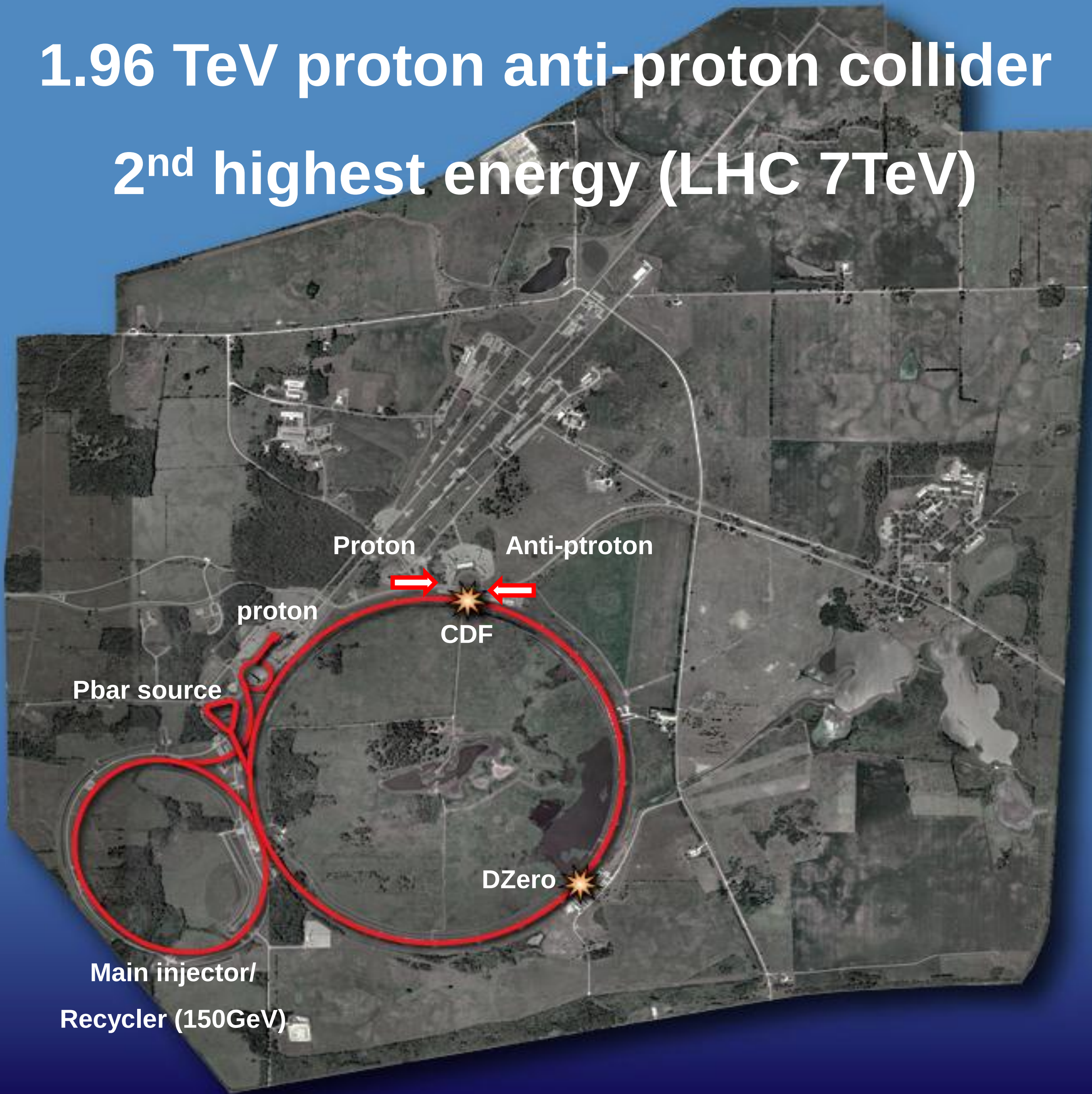


Tevatron

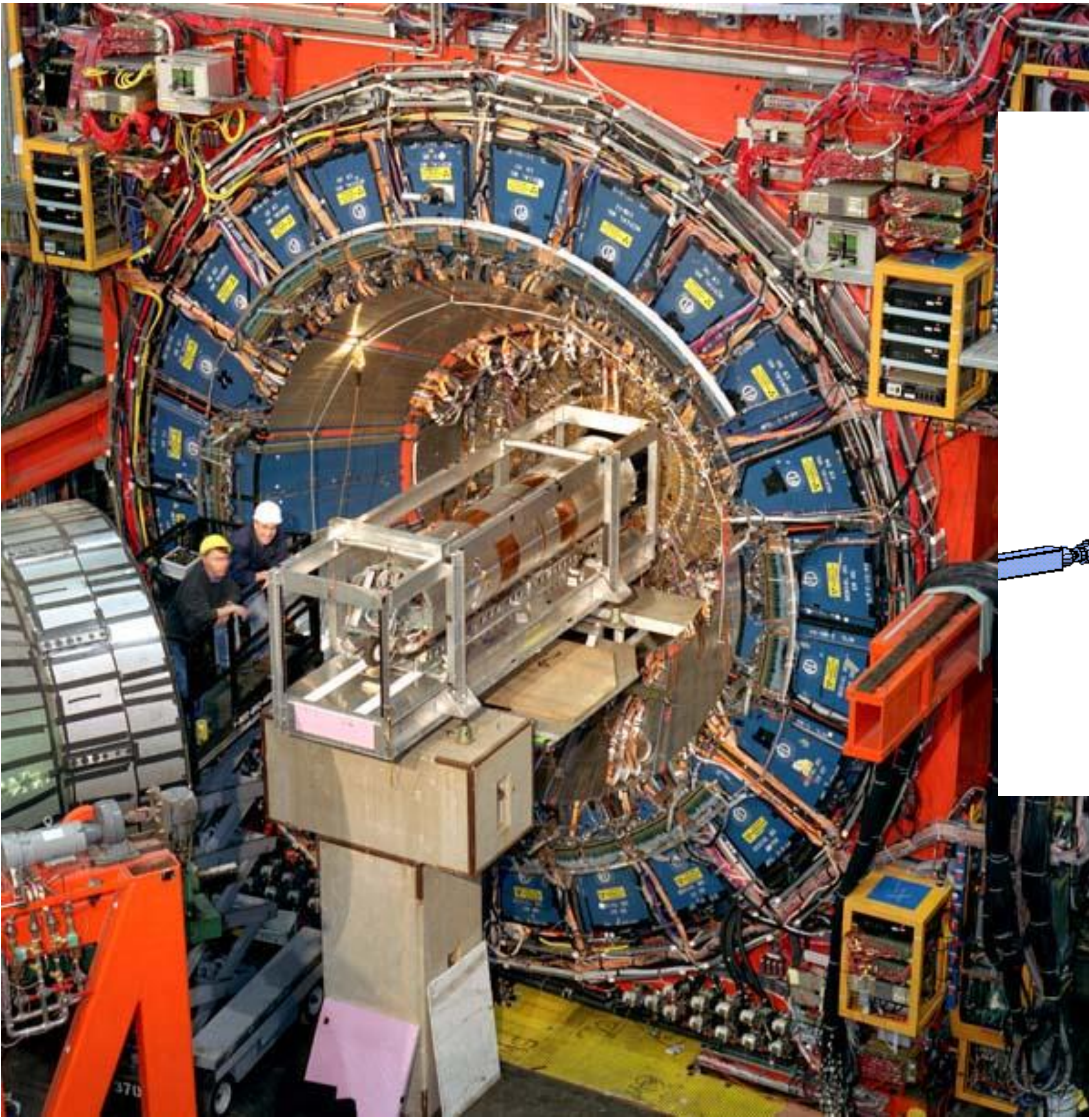
1.96 TeV proton anti-proton collider

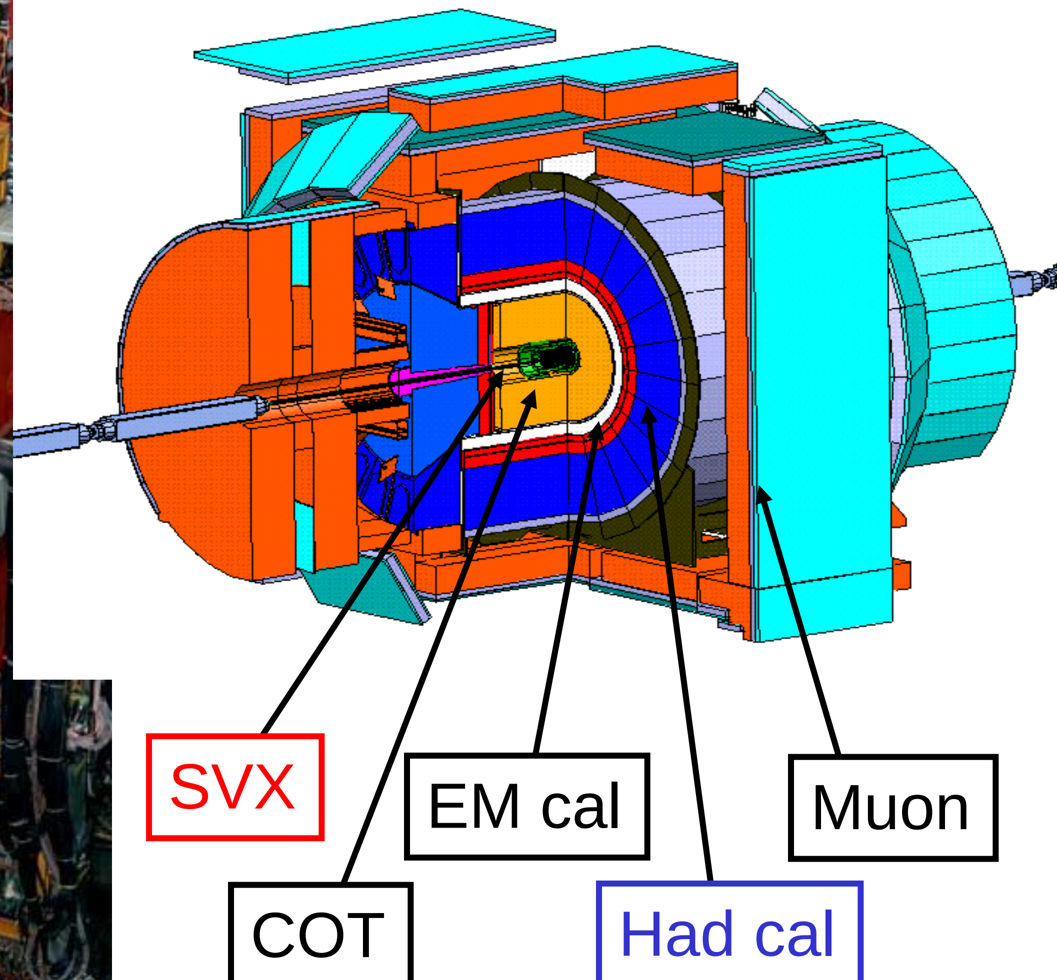
2^{nd} highest energy (LHC 7TeV)





Collider Detector at Fermilab (CDF)

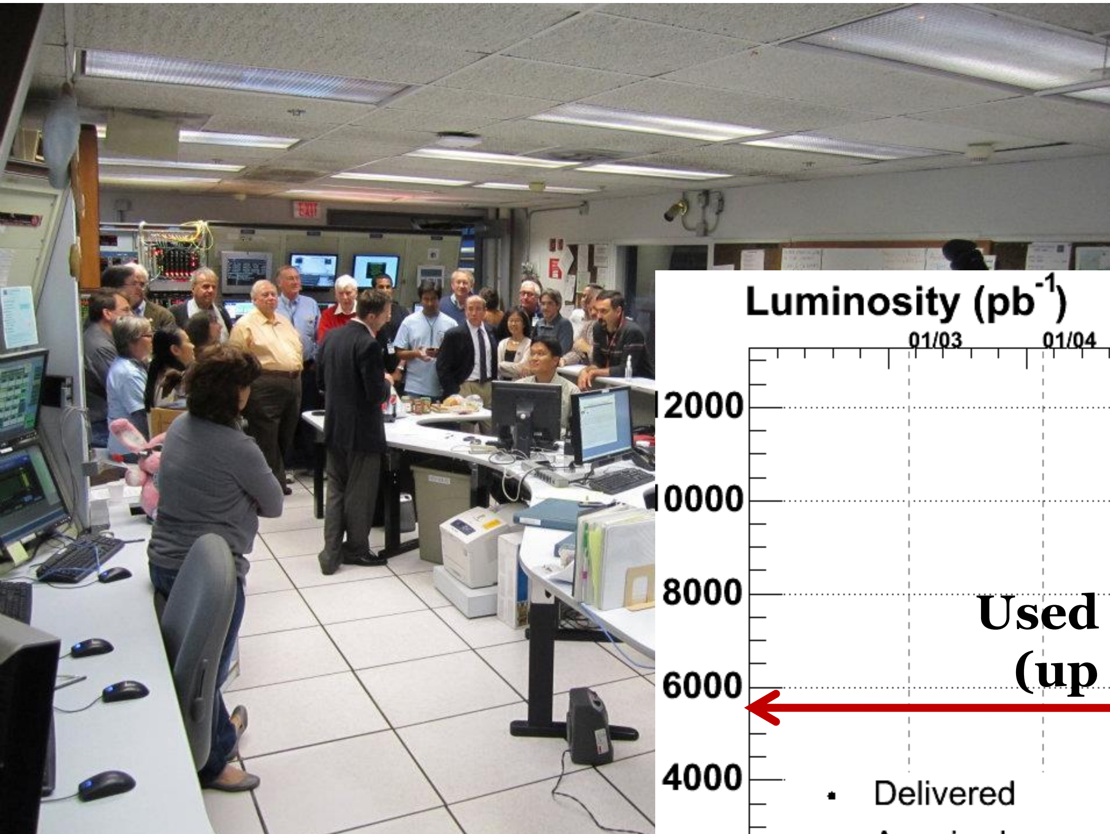




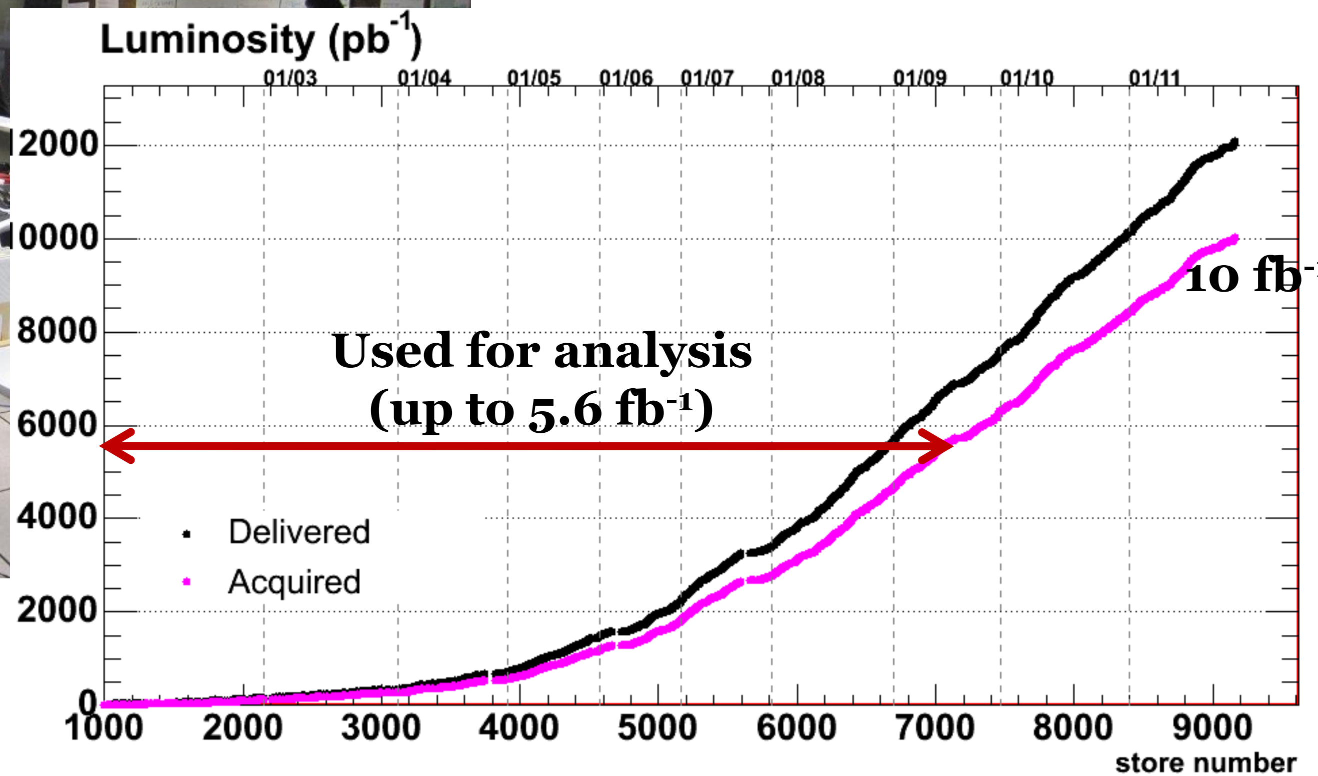
End of Tevatron and CDF

- Tevatron shutdown at Sept/30/2011

End of Tevatron and CDF

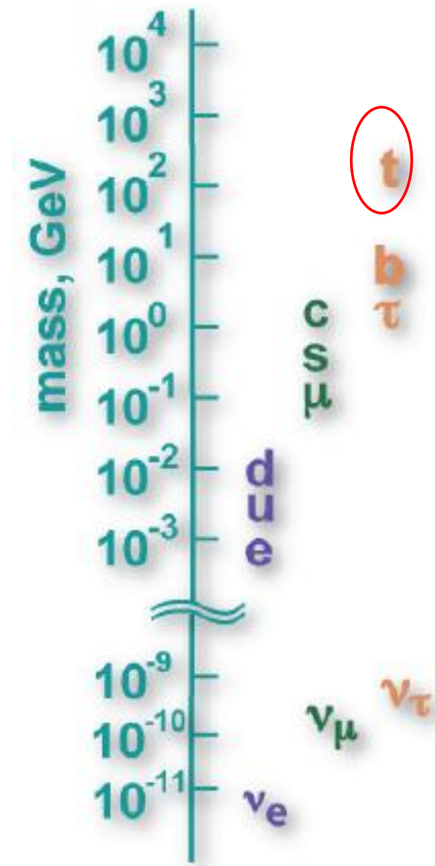


- We should analyze full data



Top quark

- Needed in theory as isospin partner of b-quark
- Properties well defined by standard model
- Mass (unknown) – SM parameter



- **As heavy as atom of gold**
- **Large mass defines its unique properties**

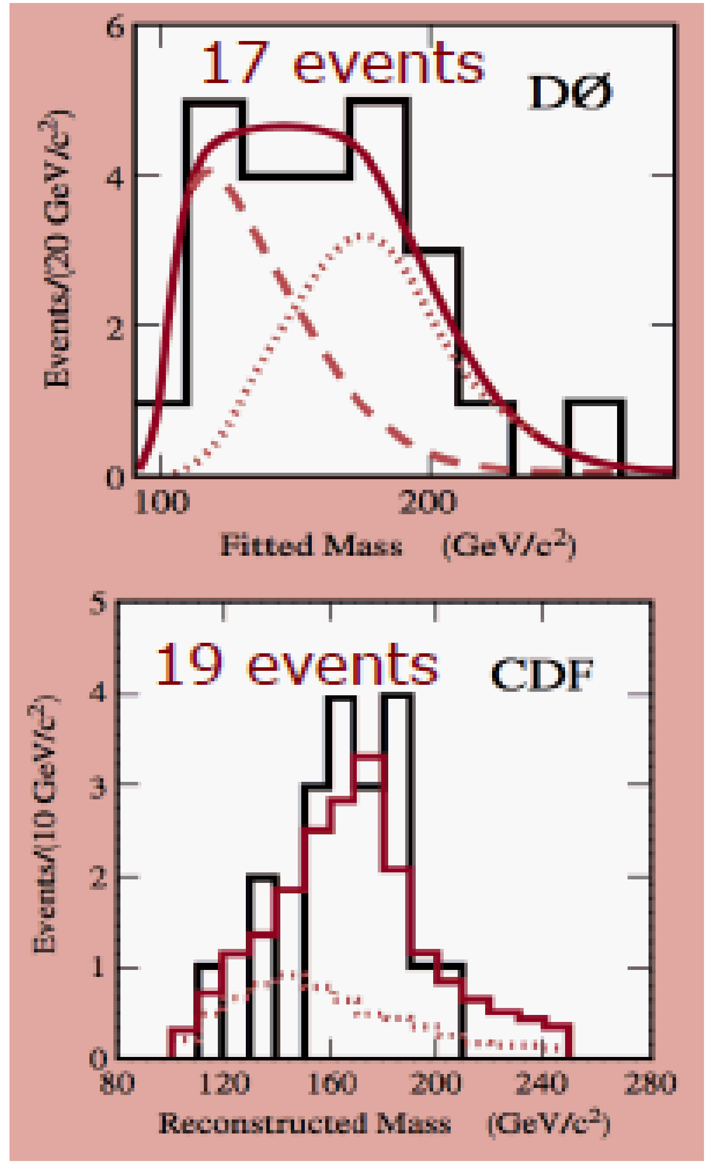
The Top quark

- 1995 : Discovered 1995 by CDF and D0
  - ~20 events
- Now :

  Tevatron : Have an order of 1,000 events

  LHC : Have an order of 10,000 events

- Standard Model
  - Single or pair production
  - Electric charge : +2/3 e
  - Width : 1.4 GeV
  - 100% decay Wb
  - Life time : 0.5 e^{-24} sec



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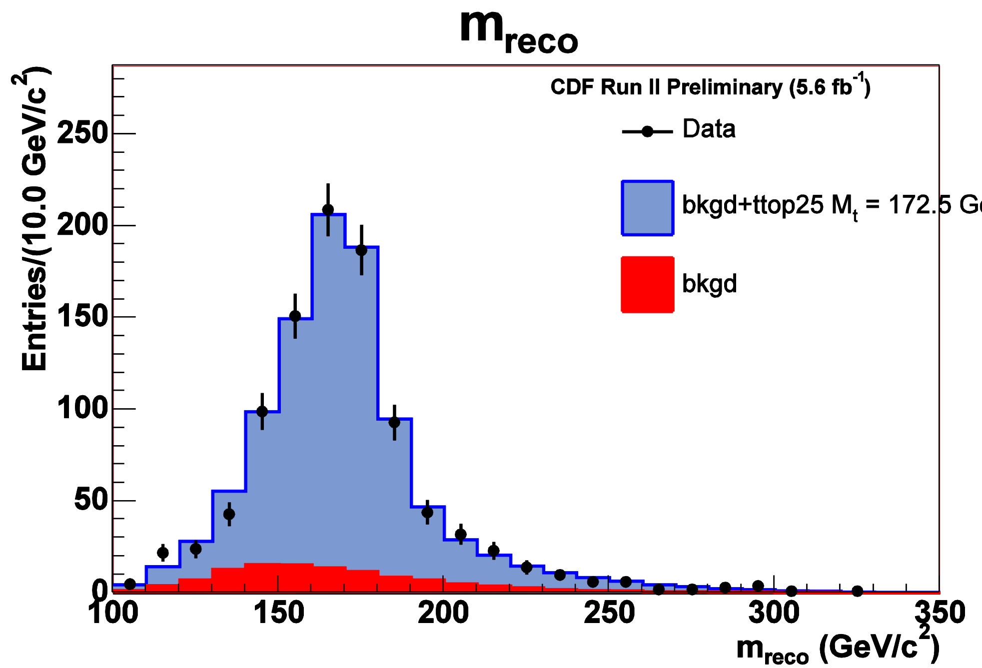

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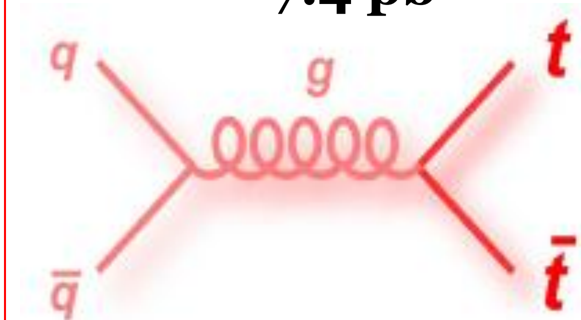
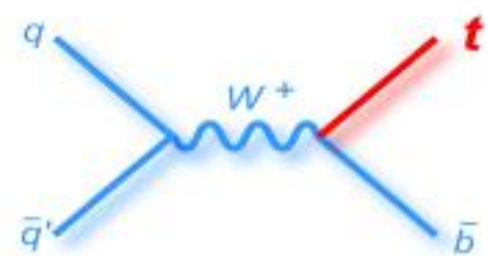
Dominant process

~7.4 pb



~3 pb



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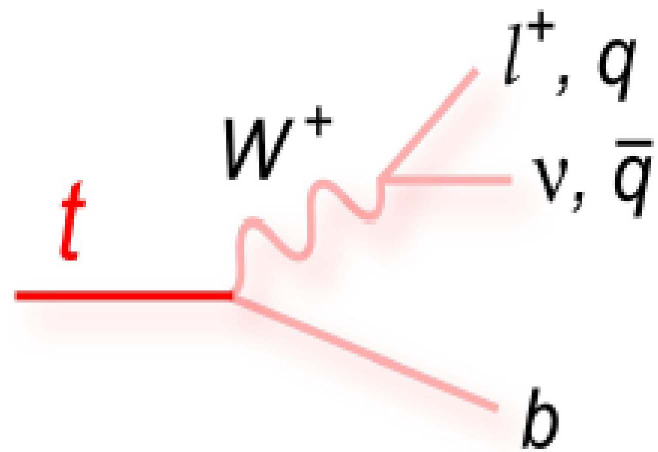
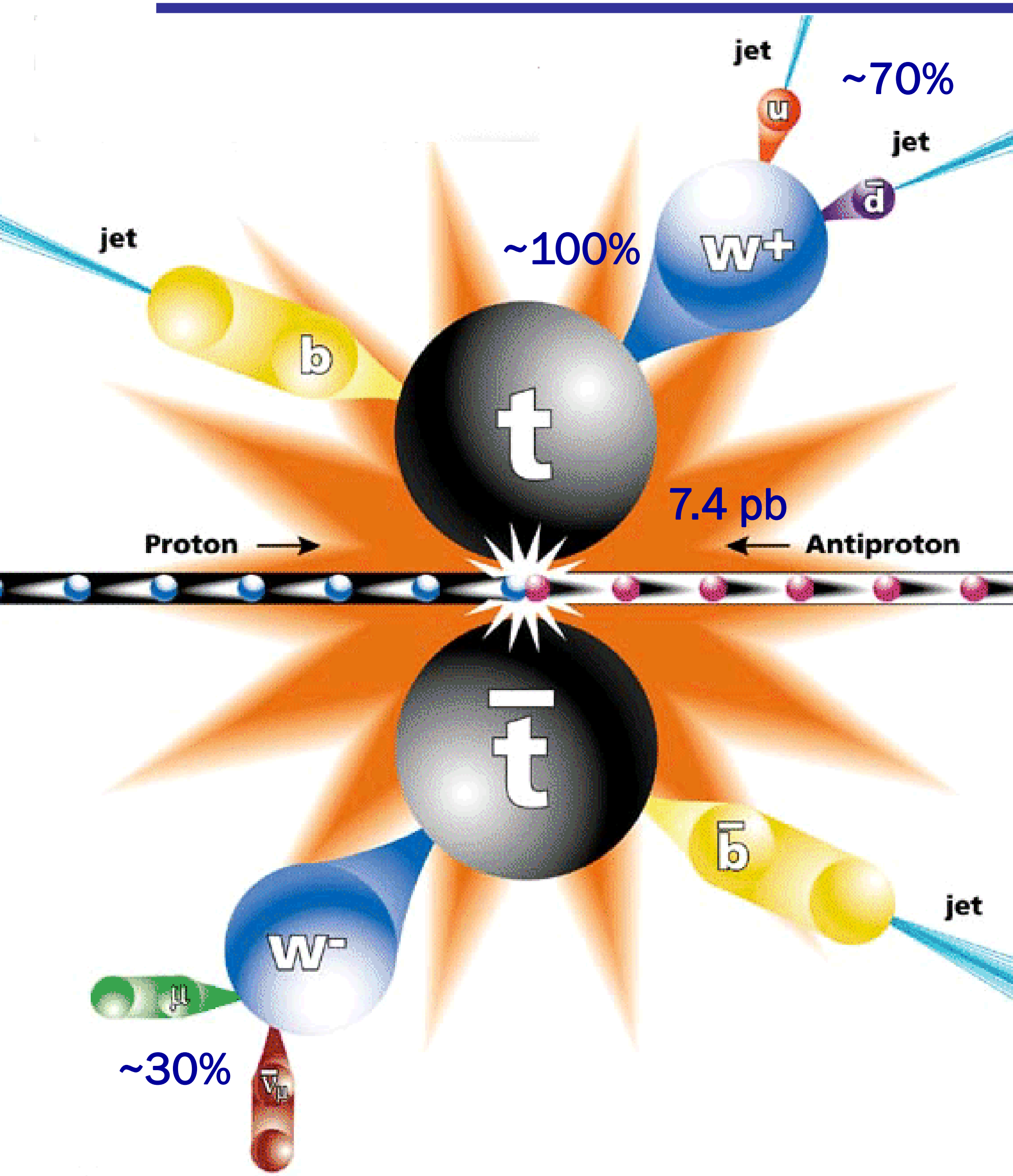


- Very short lifetime < hadronization time
- Unique to study bare quark

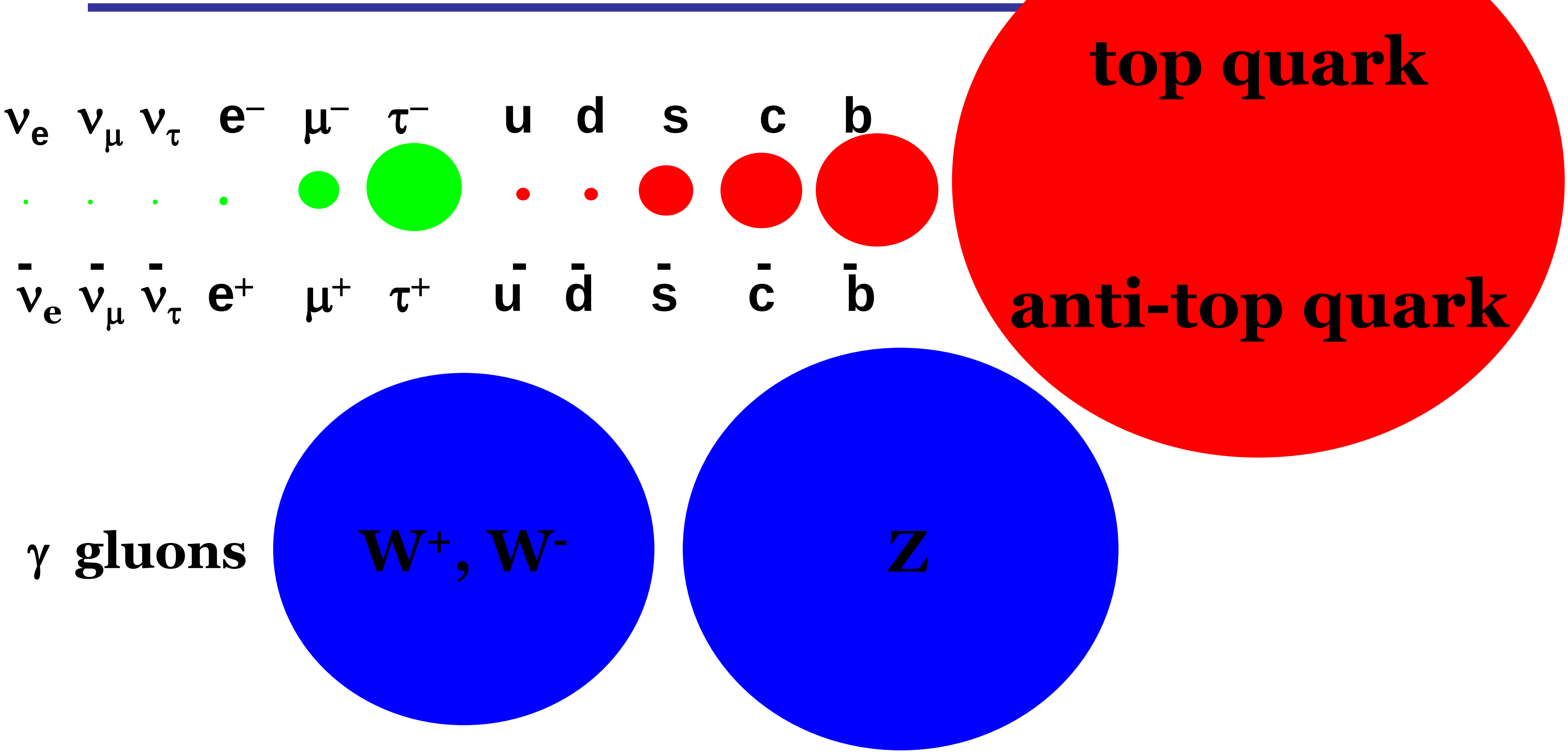
Production and decay



- Lepton+Jets
  - One W decay lepton+neutrino and the other decay two jets
  - BR ~40 %
- Dilepton
  - Both W decay lepton and neutrino
  - BR ~10 %
- All Jets
  - Both W decay two jets
  - BR~50%

Top quark mass measurement

Elementary Particles and Masses



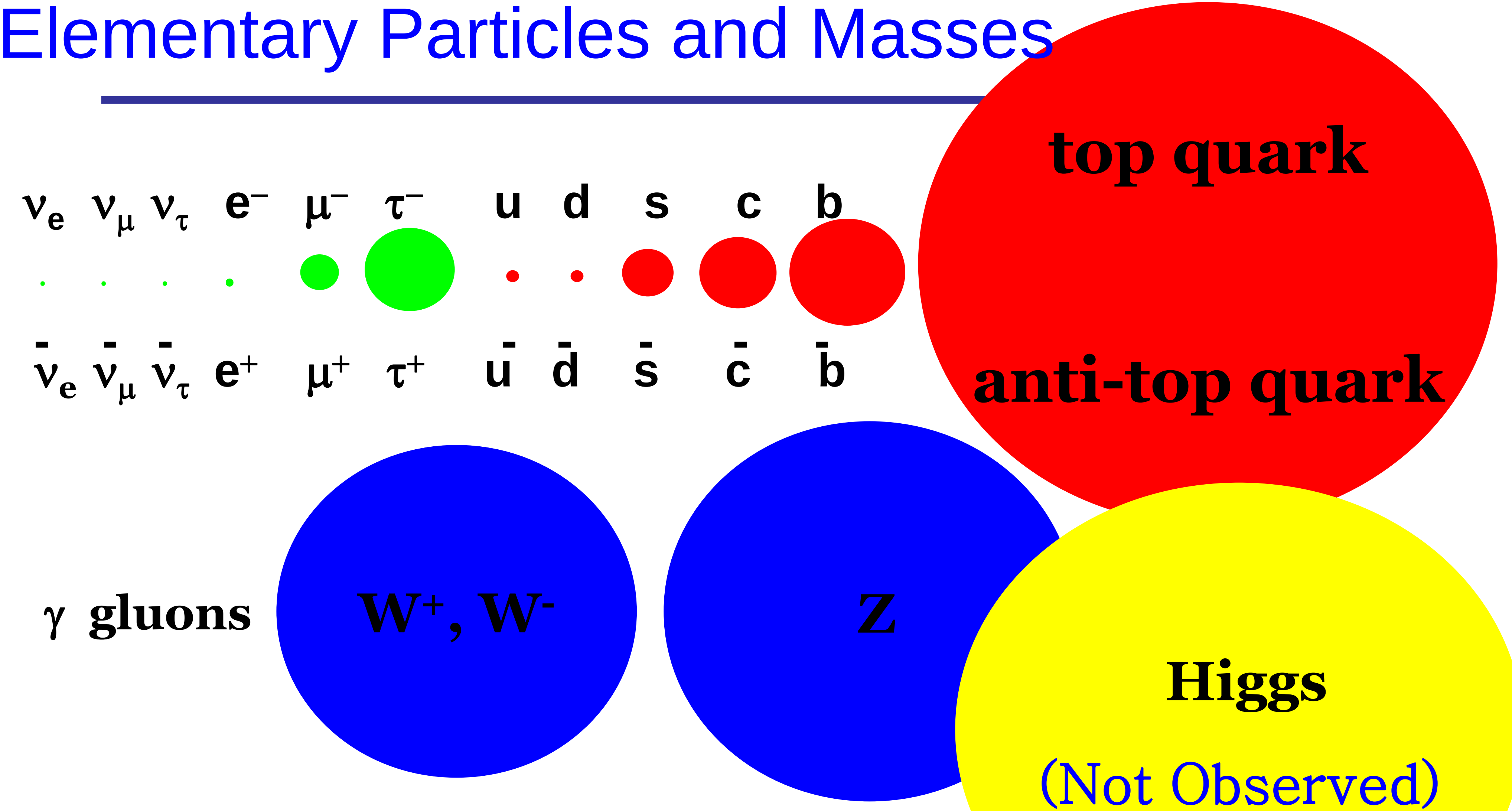
(Mass proportional to area shown: proton mass = ●)

Are they the smallest things?

Why are there so many?

Where does mass come from?

Elementary Particles and Masses



(Mass proportional to area shown: p

Where does mass come from?

Higgs mechanism

Nothing in the universe

Something in the universe

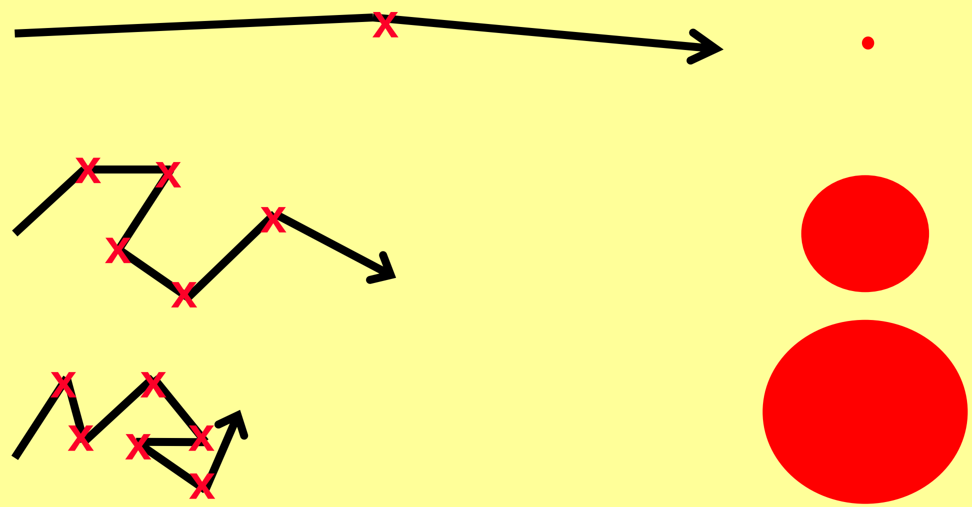
Higgs Particles

mass

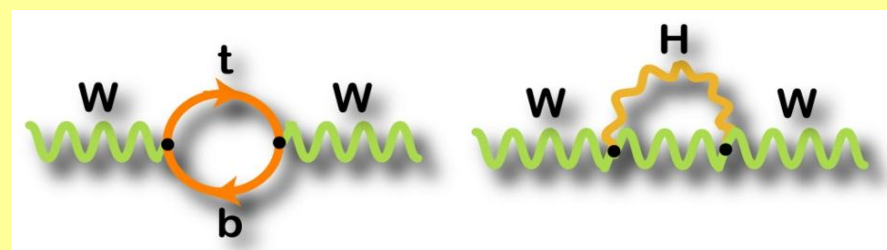
Electron

Z,W Boson

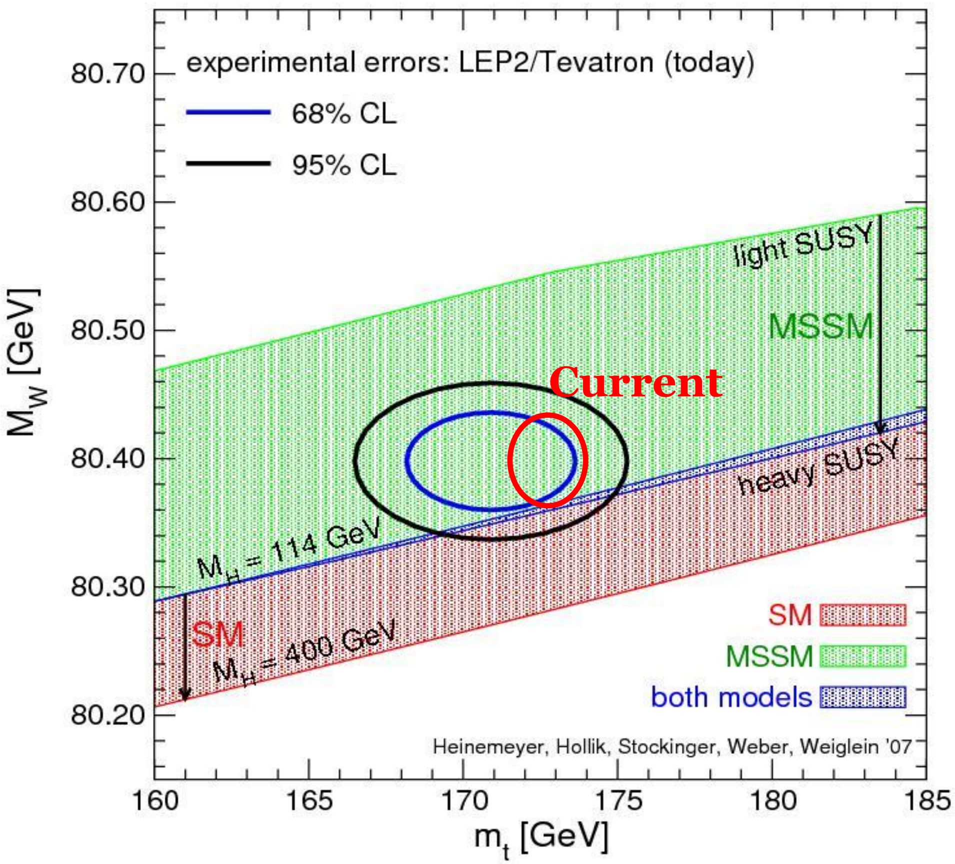
Top Quark

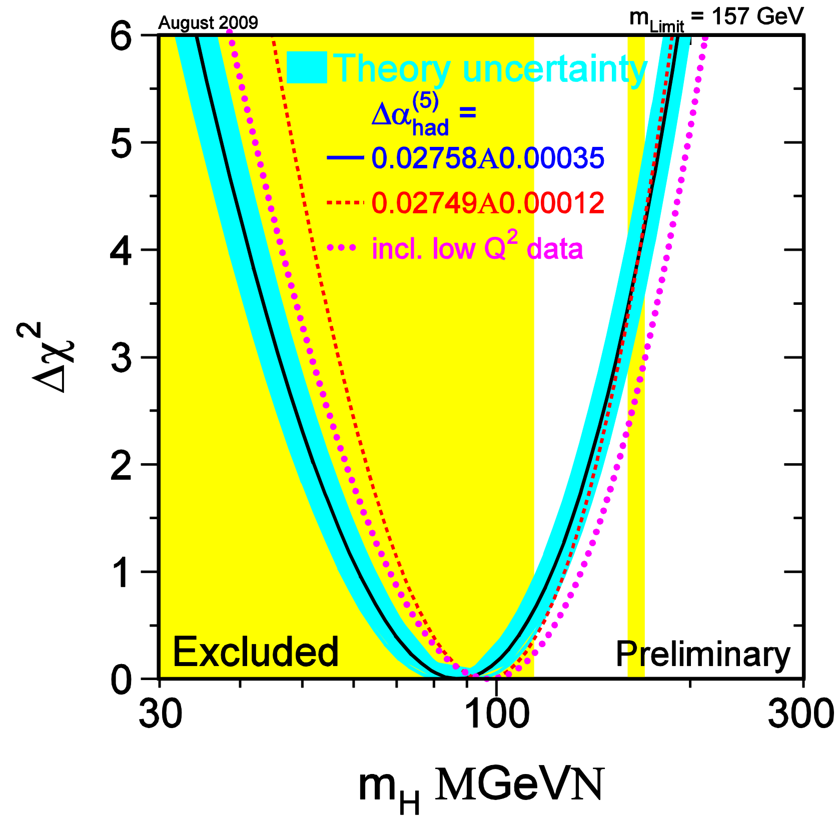


M ∞ coupling strength to Higgs



Why we measure the top quark mass?



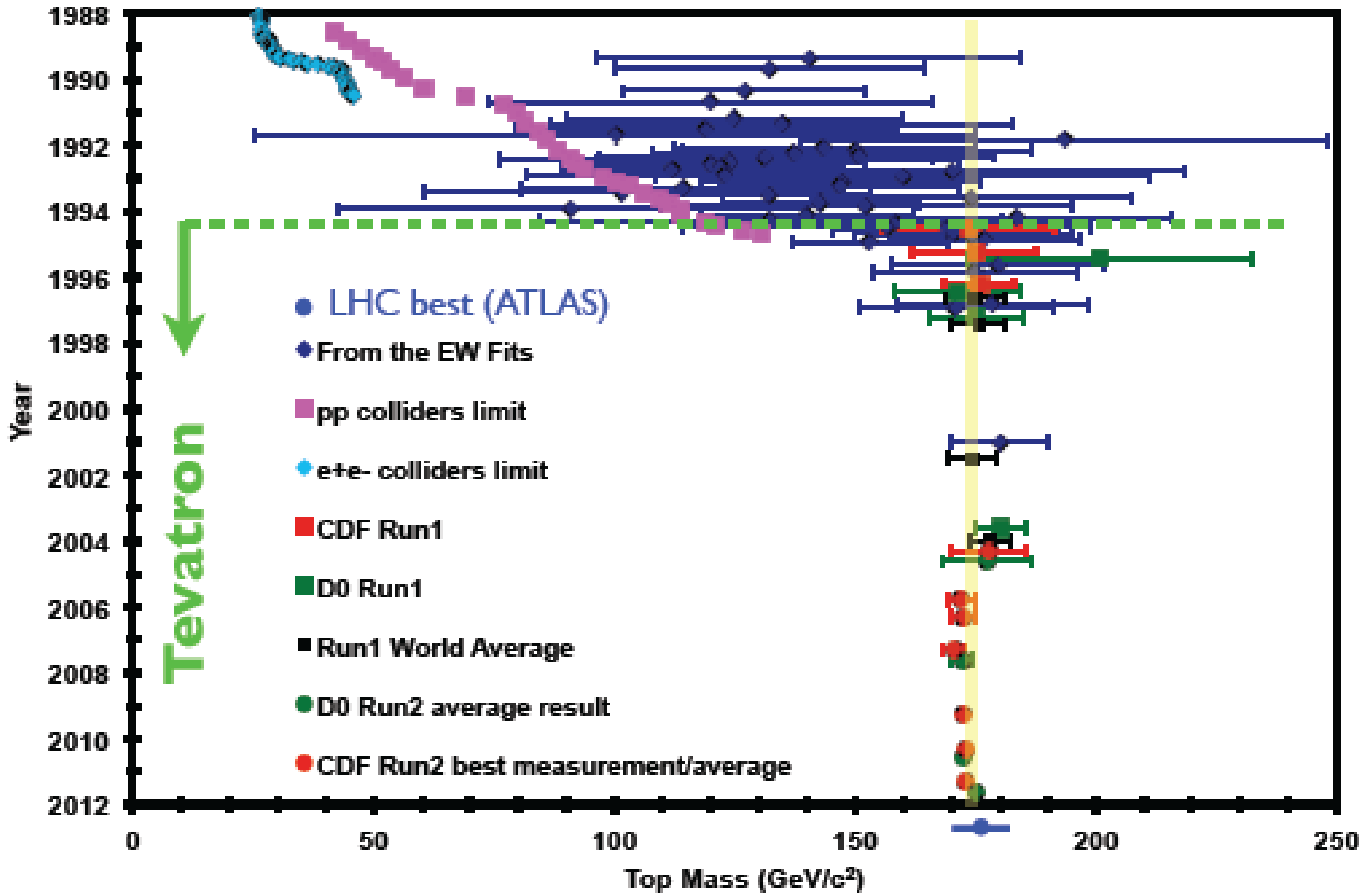


$$m_{\mathrm{H}} = 87^{+35}_{-26}\ \mathrm{GeV/c^2}$$

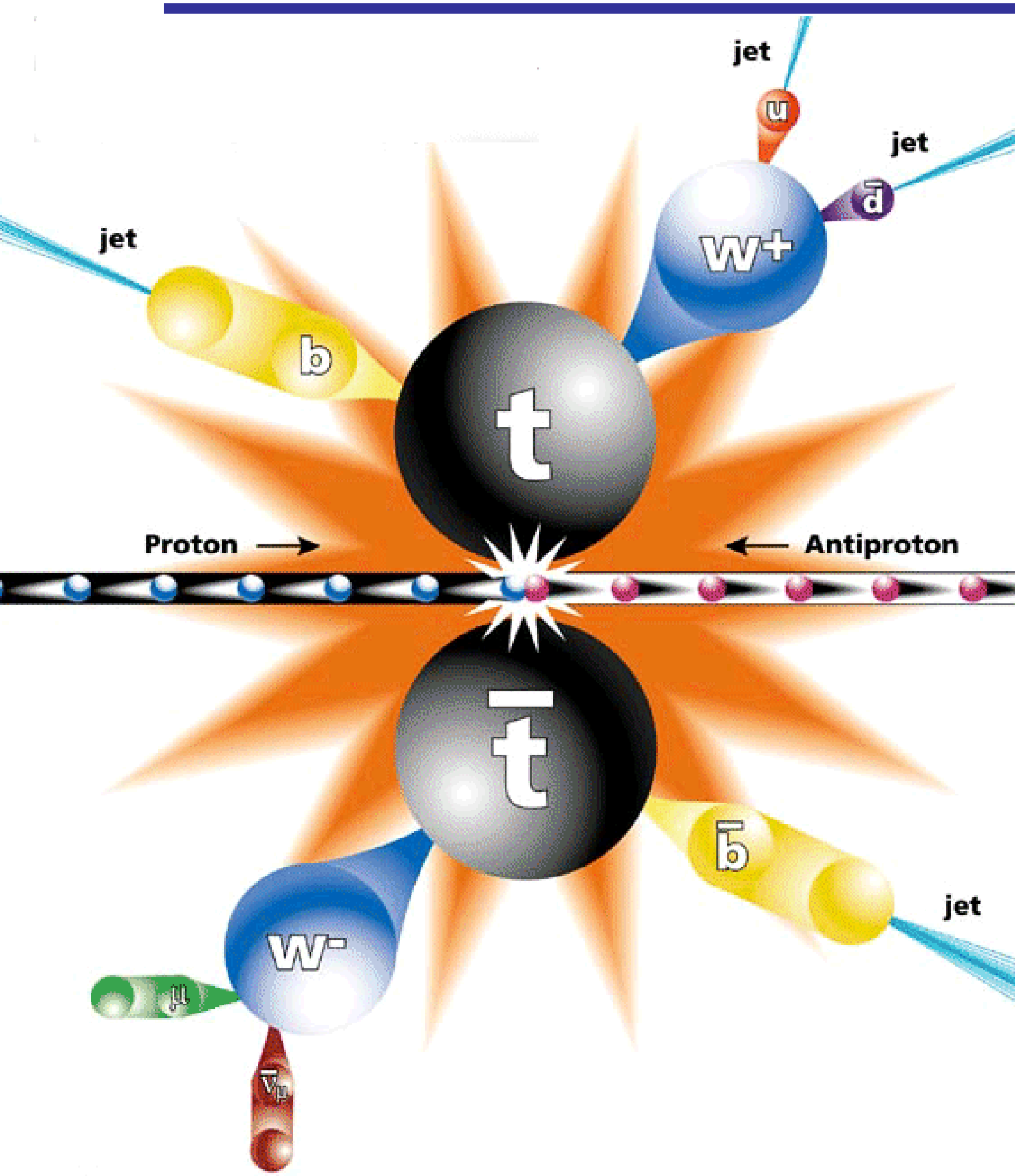
- Predict SM Higgs boson mass
- If we found Higgs boson, we can test the SM

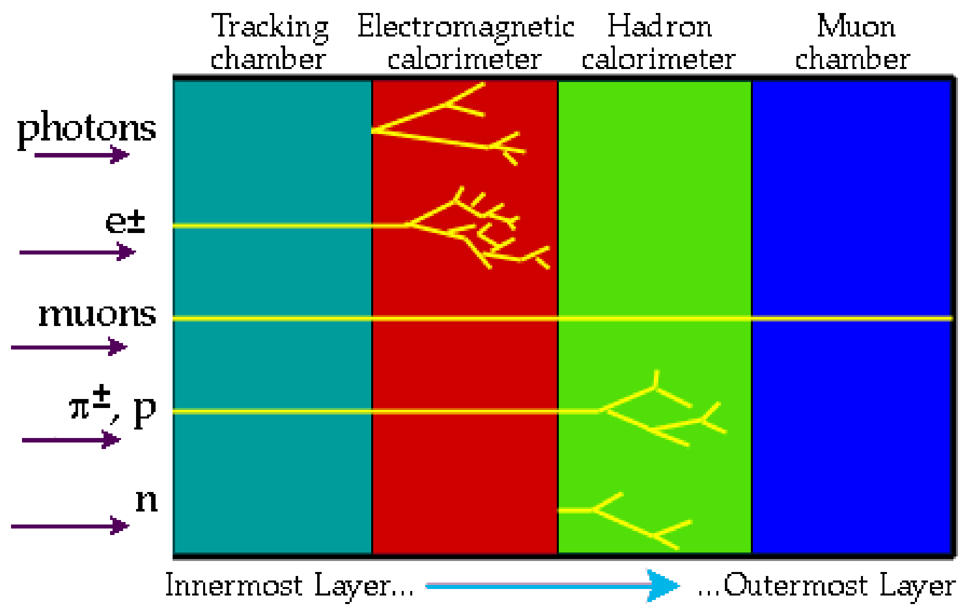
Top quark mass history

- Indirect prediction until 1995
- Very precision results are achived



Detection - Particle identification

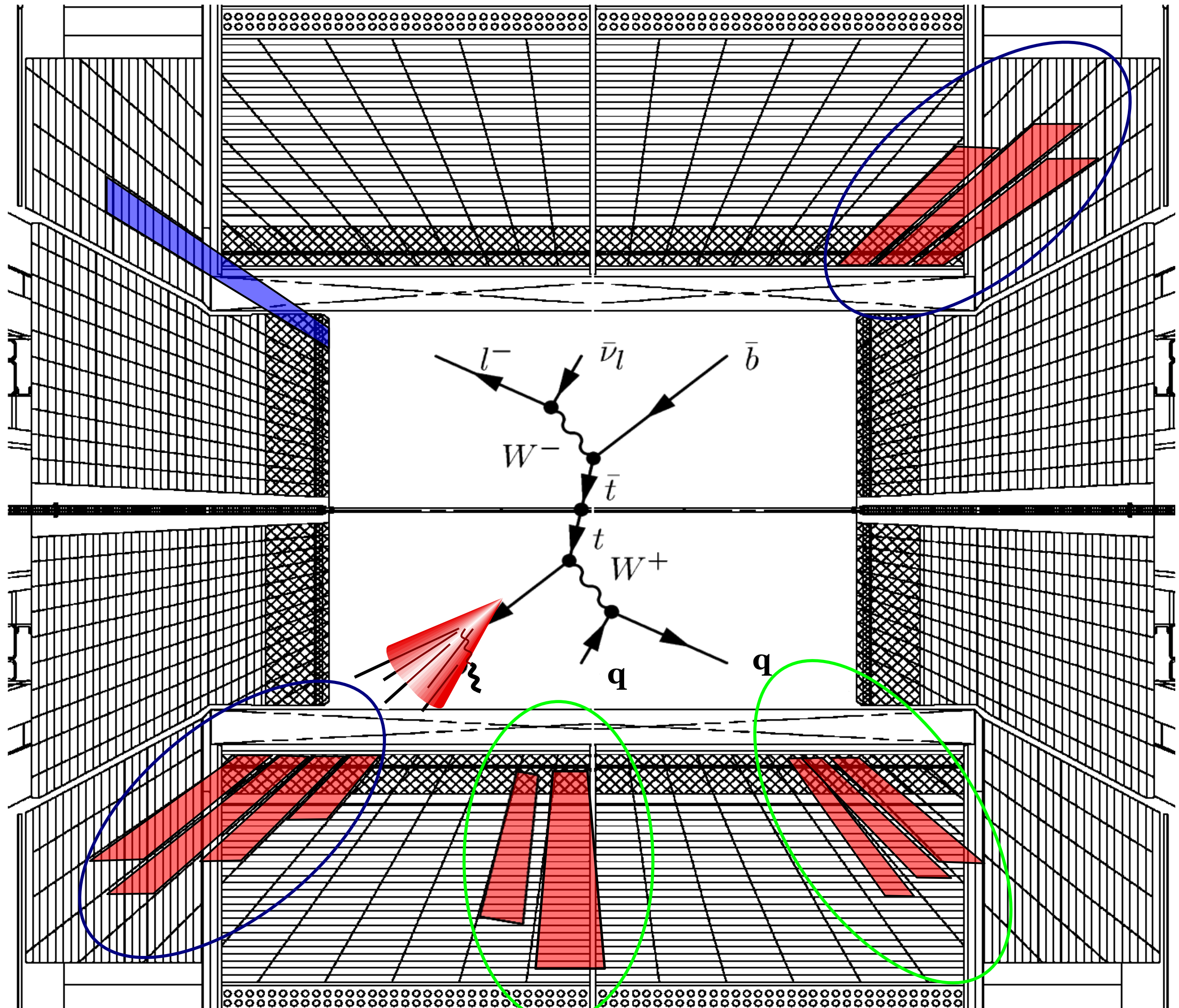




- PID using signature of each detector
- Energy and momentum measurements using signature of calorimeter energy and track momentum

Challenge of top reconstruction

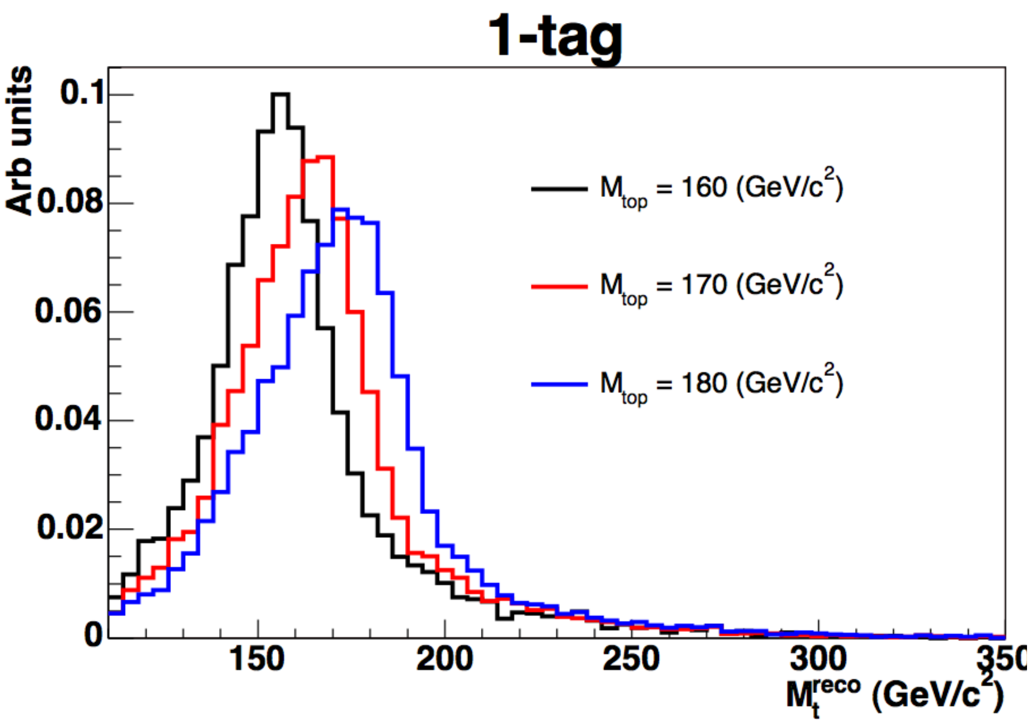
- We measure the track and calorimeter response of charged particles
  - How well estimate energy of particle?
    - Jet energy scale
    - In situ calibration using dijet of W decay
  - Neutrino can not be detected
    - Missing energy
  - Which jet is coming from which parton?
    - Jet-to-parton assignment

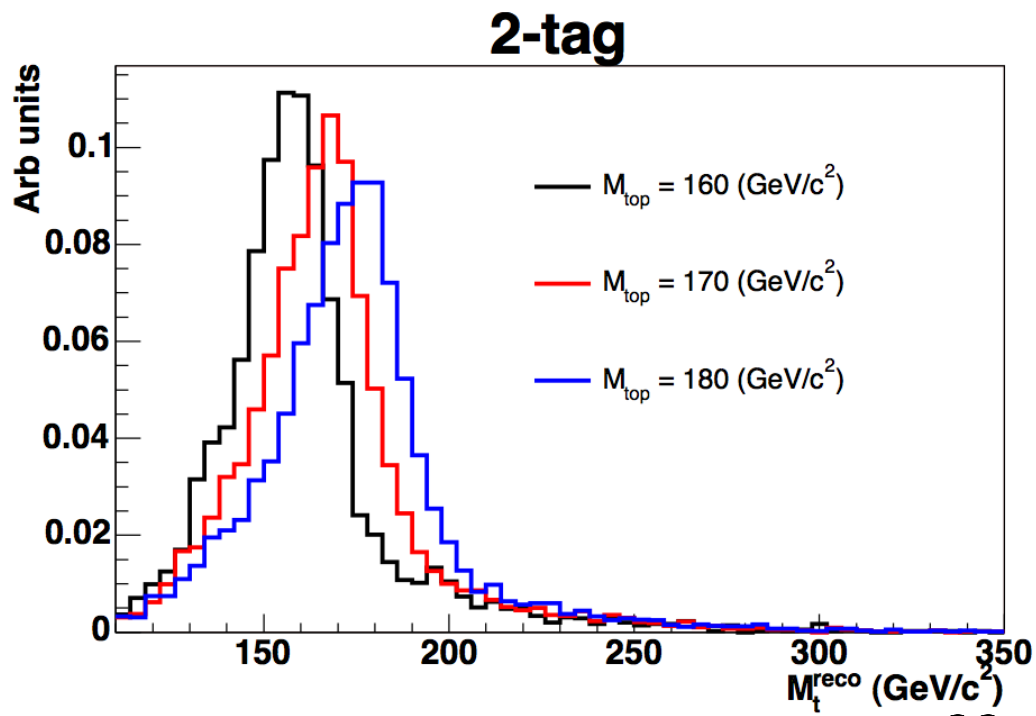


Mass reconstruction

- Lepton+jets channel (24 different combinatoric)

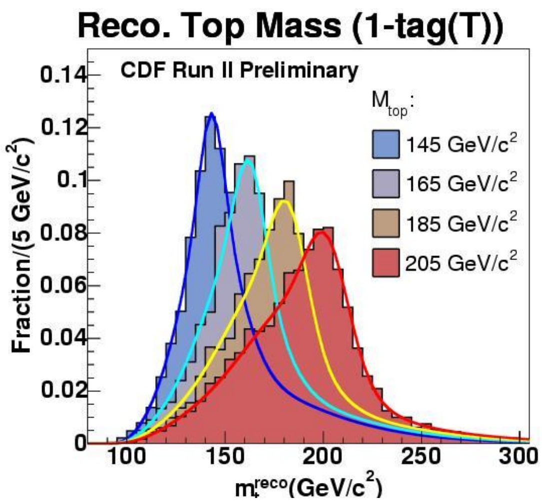
$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i^2}+\Sigma_{j=x,y}\frac{(U_j^{fit}-U_j^{meas})^2}{\sigma_j^2}$$
$$+\frac{(M_{jj}-M_W)^2}{\Gamma_W^2}+\frac{(M_{\ell\nu}-M_W)^2}{\Gamma_W^2}+\frac{(M_{bjj}-M_t)^2}{\Gamma_t^2}+\frac{(M_{b\ell\nu}-M_t)^2}{\Gamma_t^2}$$

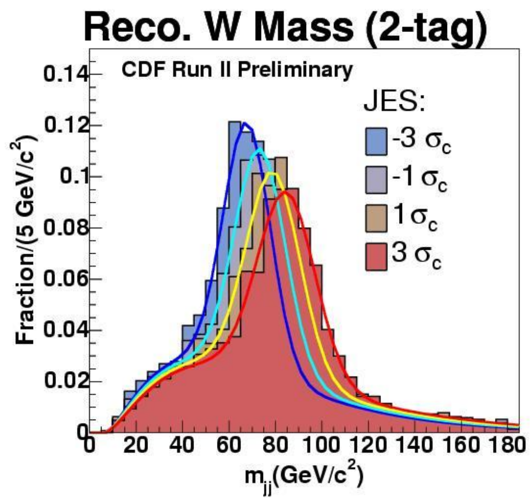




Measurement technique (template method)

- 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





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

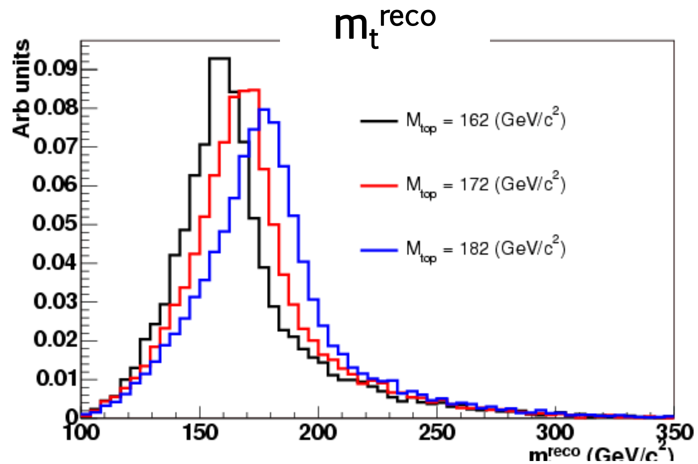
Event reconstruction in the lepton+jets

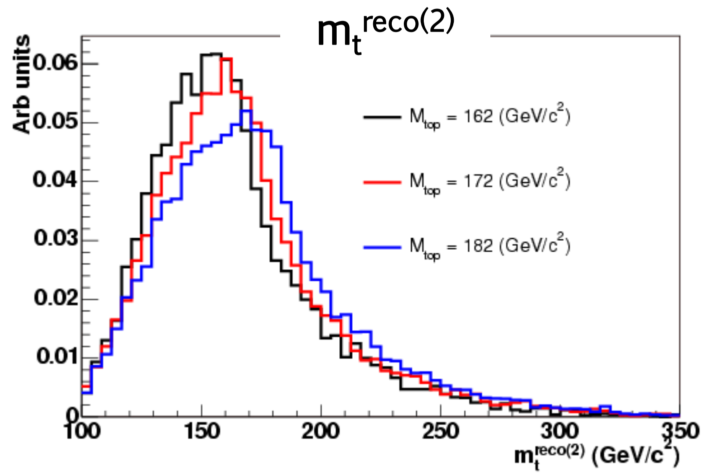
$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i^2} + \Sigma_{j=x,y}\frac{(U_j^{fit}-U_j^{meas})^2}{\sigma_j^2} + \frac{(M_{jj}-M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu}-M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj}-m_t^{\rm reco})^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu}-m_t^{\rm reco})^2}{\Gamma_t^2}$$

- Construct likelihood based on probabilities

Lepton+Jets channel

- 5.6 fb^{-1} data – 981 Candidate events requiring 1b-tag
- Applied chi2 cut(<9) and H_T (H_T>250GeV)
- Fully three dimensional PDF using three observables in LJ
  - 3^{rd} observables is reconstructed mass using kinematic fit with different combinatoric of jet to parton assignment (2^{nd} best fit)
- Matrix element technique
  - 173.0 ± 1.2 GeV/c^2
  - Complement technique, consistent result

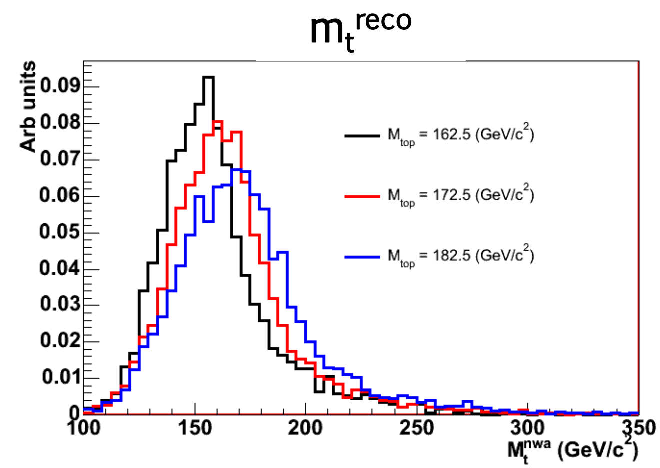


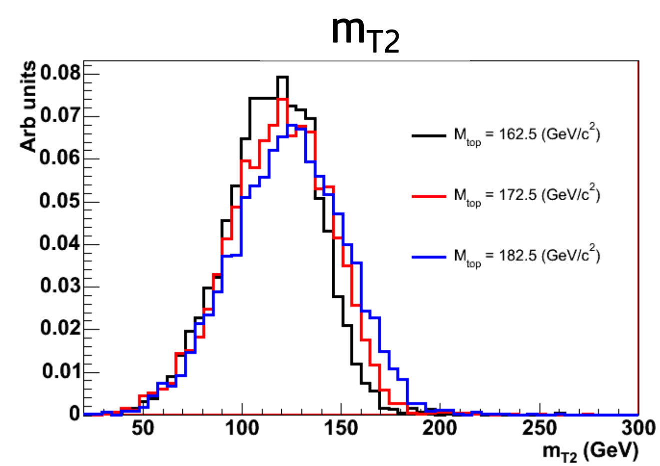


$$172.2 \pm 0.8\,(\text{stat}) \pm 0.8(\text{JES}) \pm 0.9(\text{syst})\ \text{GeV}/c^2$$
$$= 172.2 \pm 1.5\ \text{GeV}/c^2$$

Dilepton channel

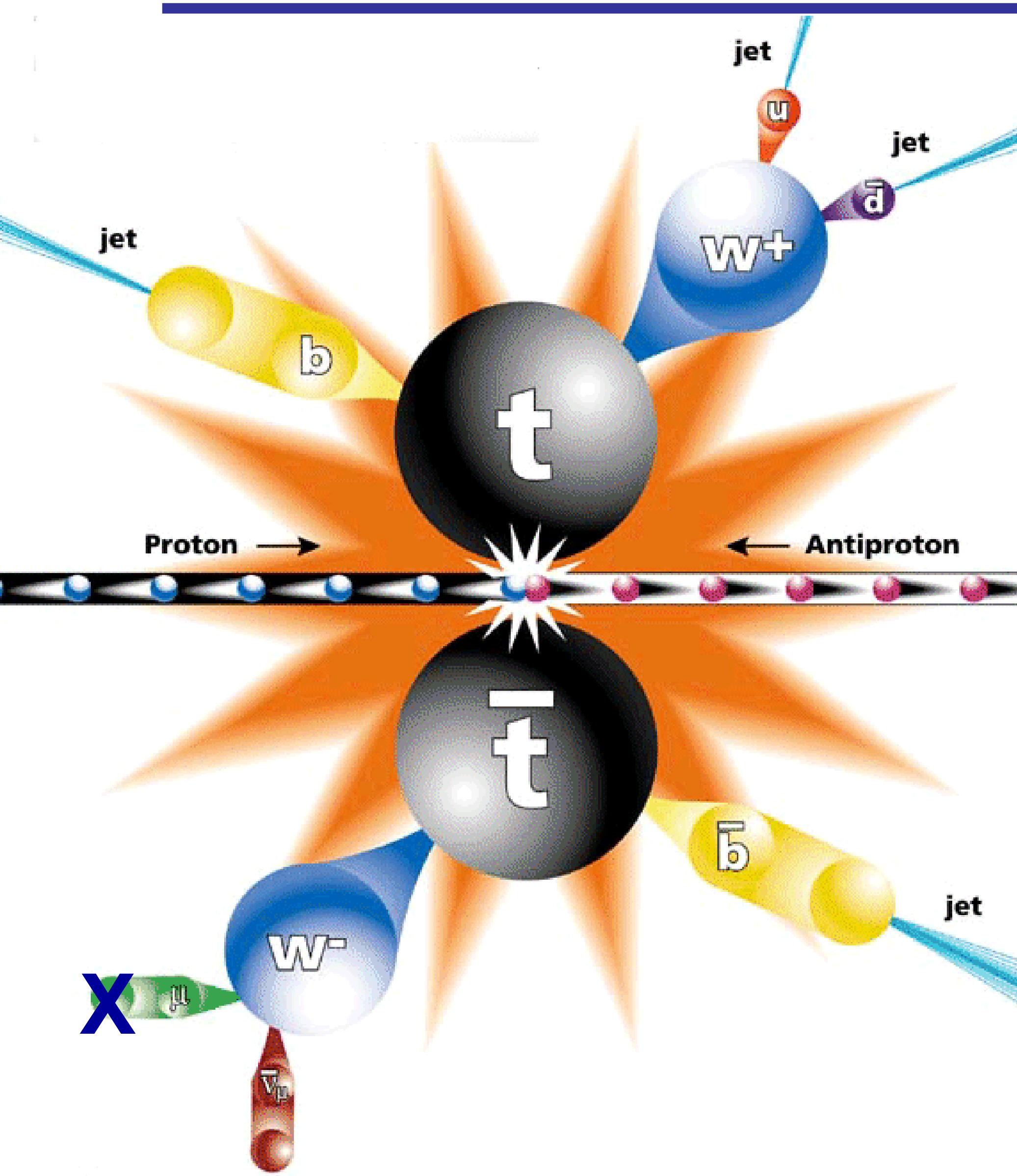
- 5.6 fb^{-1} data – 392 Candidate events
- No *in situ* JES calibration
- Two observables
  - Reconstructed mass using neutrino weighting algorithm (assuming neutrino eta's and give different weight)
  - mT2 – interesting observables to measure the mass of two missing particle system (introduced for new physics particles)
- Best result at CDF
- Good Cross check in different channel





$$170.3 \pm 2.0 \text{ (stat)} \pm 3.1 \text{ (syst) GeV}/c^2$$
$$=170.3 \pm 3.7 \text{ GeV}/c^2$$

Missing energy(MET)+jets final state



- Topology based channel – truth are mostly lepton+jets
- Very nice signal to background ratio and very nice signal acceptance

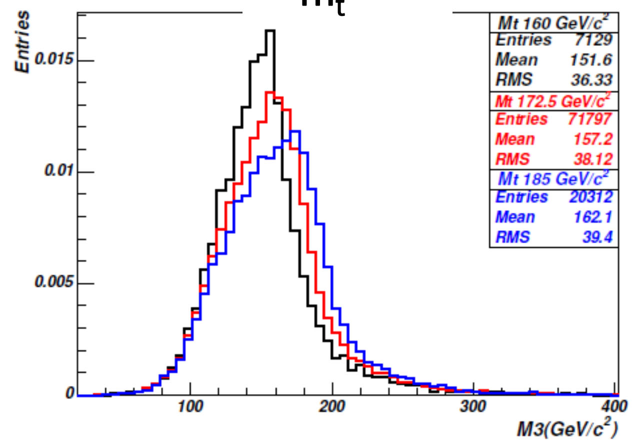
	Signal	**Bkgd**
Lepton+Jets	~900	~120
Dilepton	~170	~90
MET+Jets	~900	~400

- CDF only use this final state in top quark mass measurement

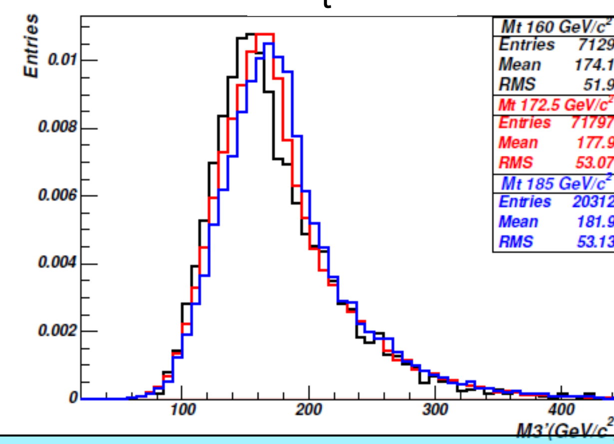
Missing Energy (MET)+Jets channel

- 5.7 fb^{-1} data – 1432 Candidate events requiring 1b-tag
- Three observables are used
  - ❖ Reconstructed hadronic top quark mass
    - ❑Use the largest p_T of three jet
  - ❖ 2nd reconstructed hadronic top quark mass
    - ❑Use different combination
  - ❖ Dijet mass of two untagged jets
- Important input of combination
  - ❖ Third most important channel

m_t^{had}

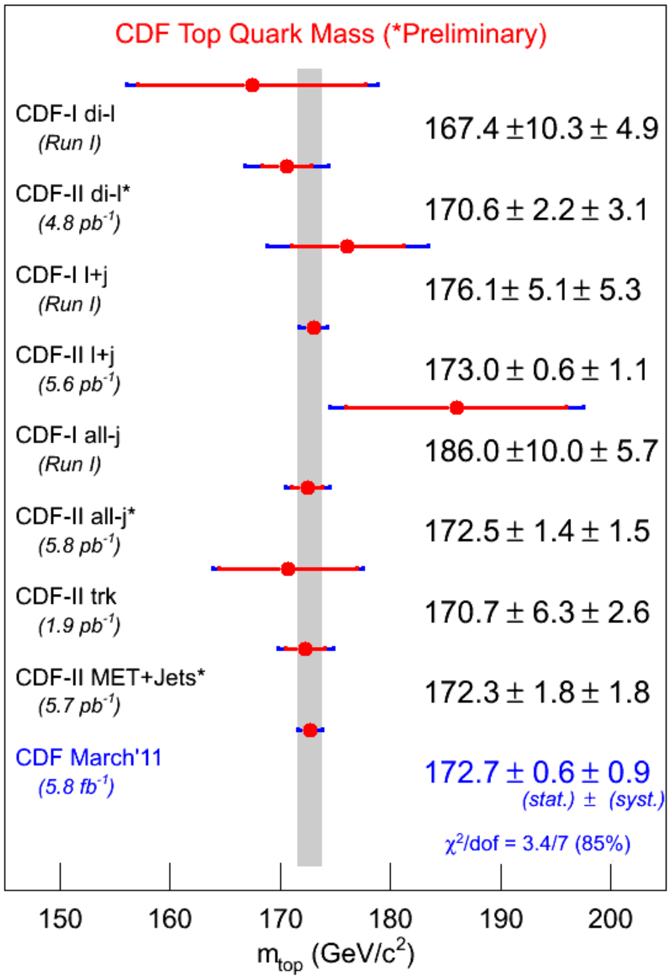


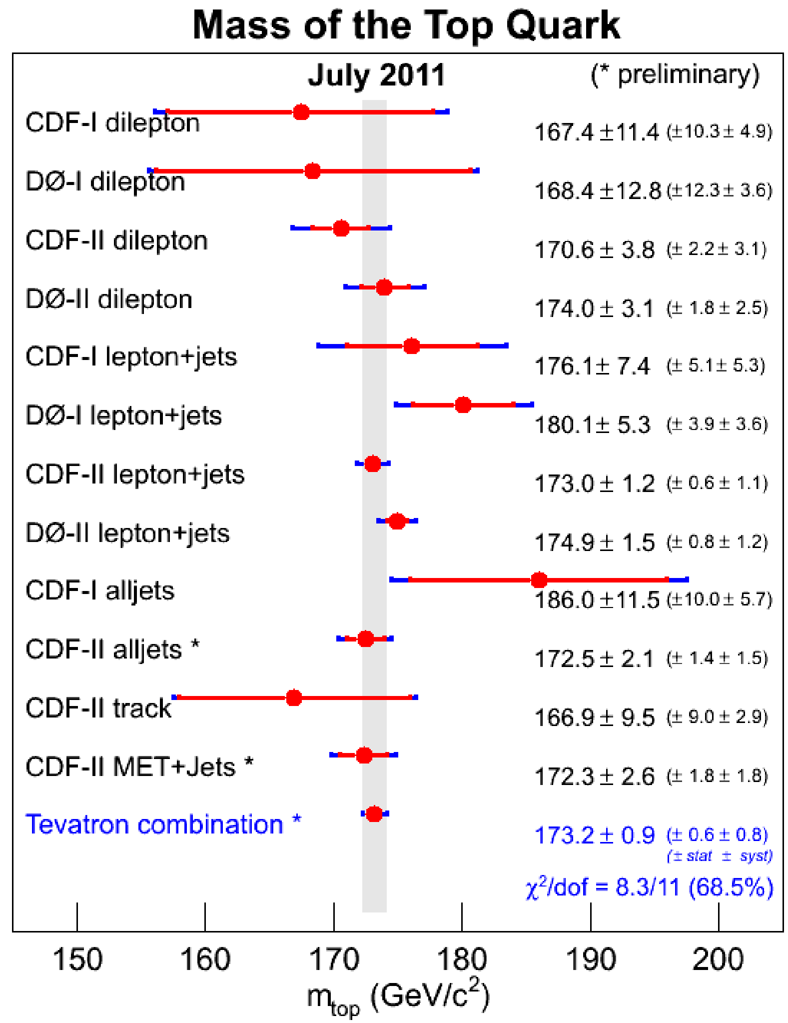
$M_t^{had(2)}$



$$172.3 \pm 1.8\text{ (stat)} \pm 1.5\text{ (JES)} \pm 1.0\text{ (syst) GeV}/c^2$$
$$=172.3 \pm 2.6\text{ GeV}/c^2$$

CDF & Tevatron combination



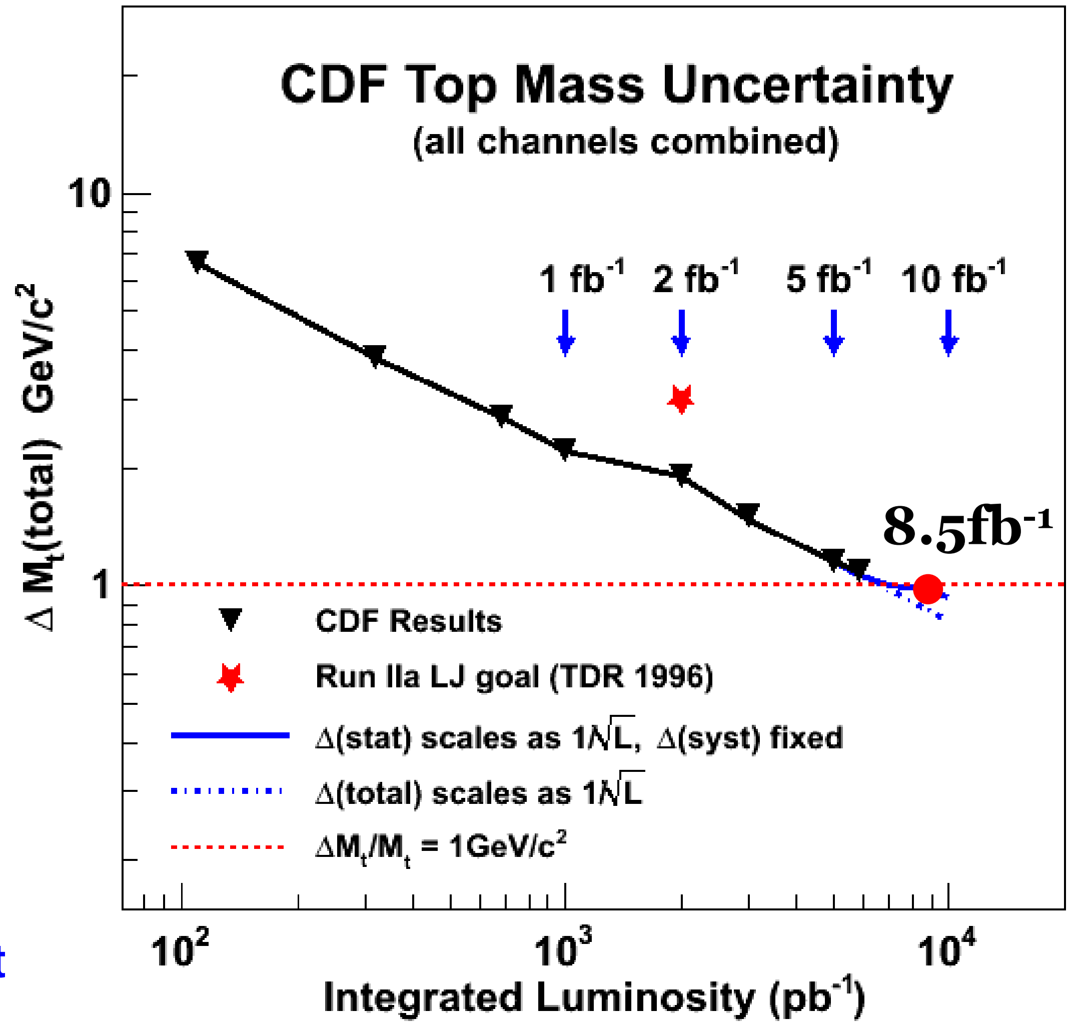


CDF combination =
172.7 +/- 1.1 GeV/c^2

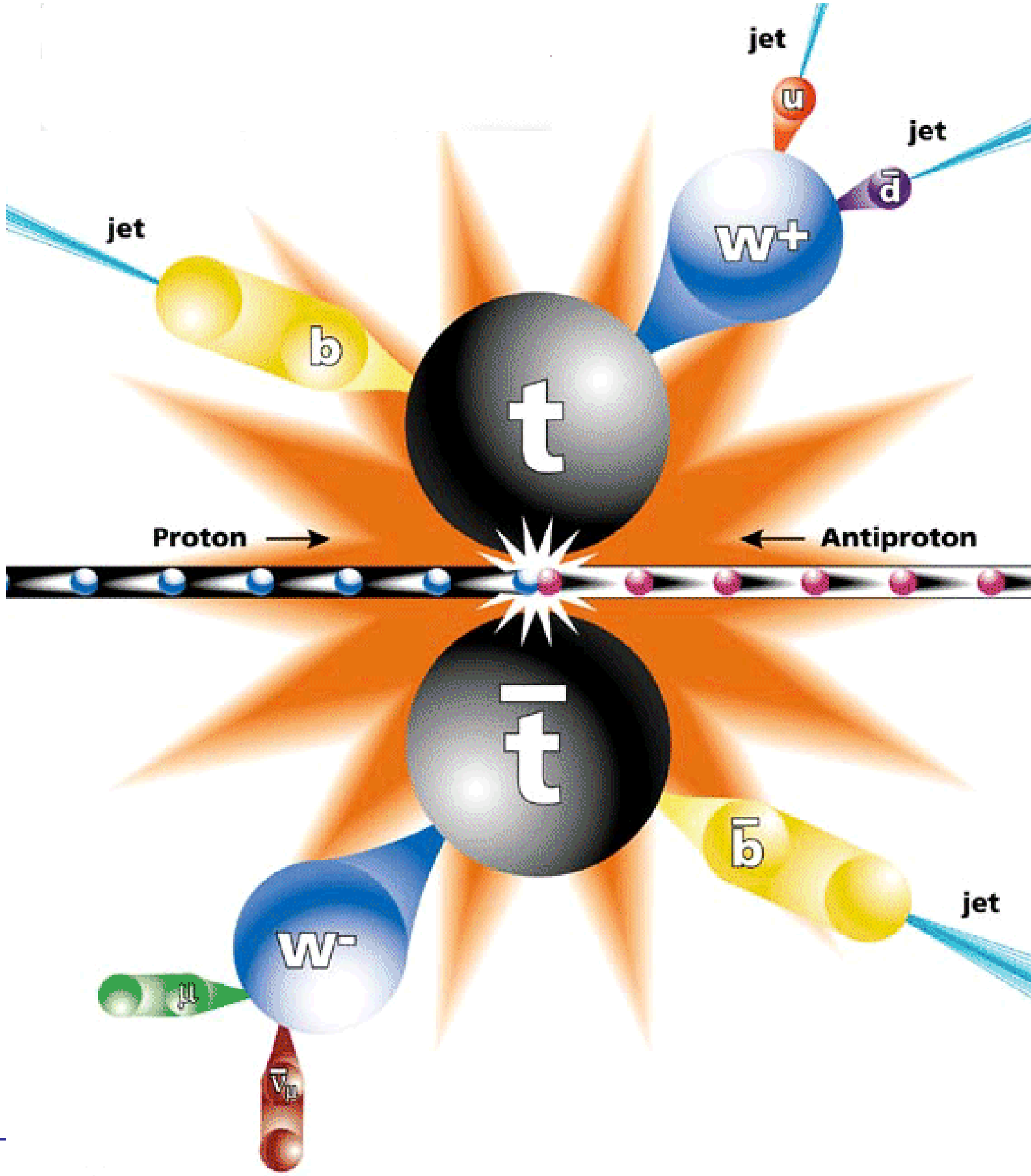
Tevatron combination =
173.2 +/- 0.9 GeV/c^2

End run game of top mass

- **Improvement of jet energy resolution**
  - **Already demonstrate jet resolution improvement about 20% by neural network**
  - **It is corresponding to 20% improvement**
- **Increase signal acceptance**
  - **Expand trigger path and lepton categories**
  - **Increase about 20% statistics using same data set**
- **Improve event reconstruction**
  - **Already demonstrate better reconstruction method at MET+Jets**
  - **We can have ~30% better result in this channel**



Forward backward (Charge) asymmetry



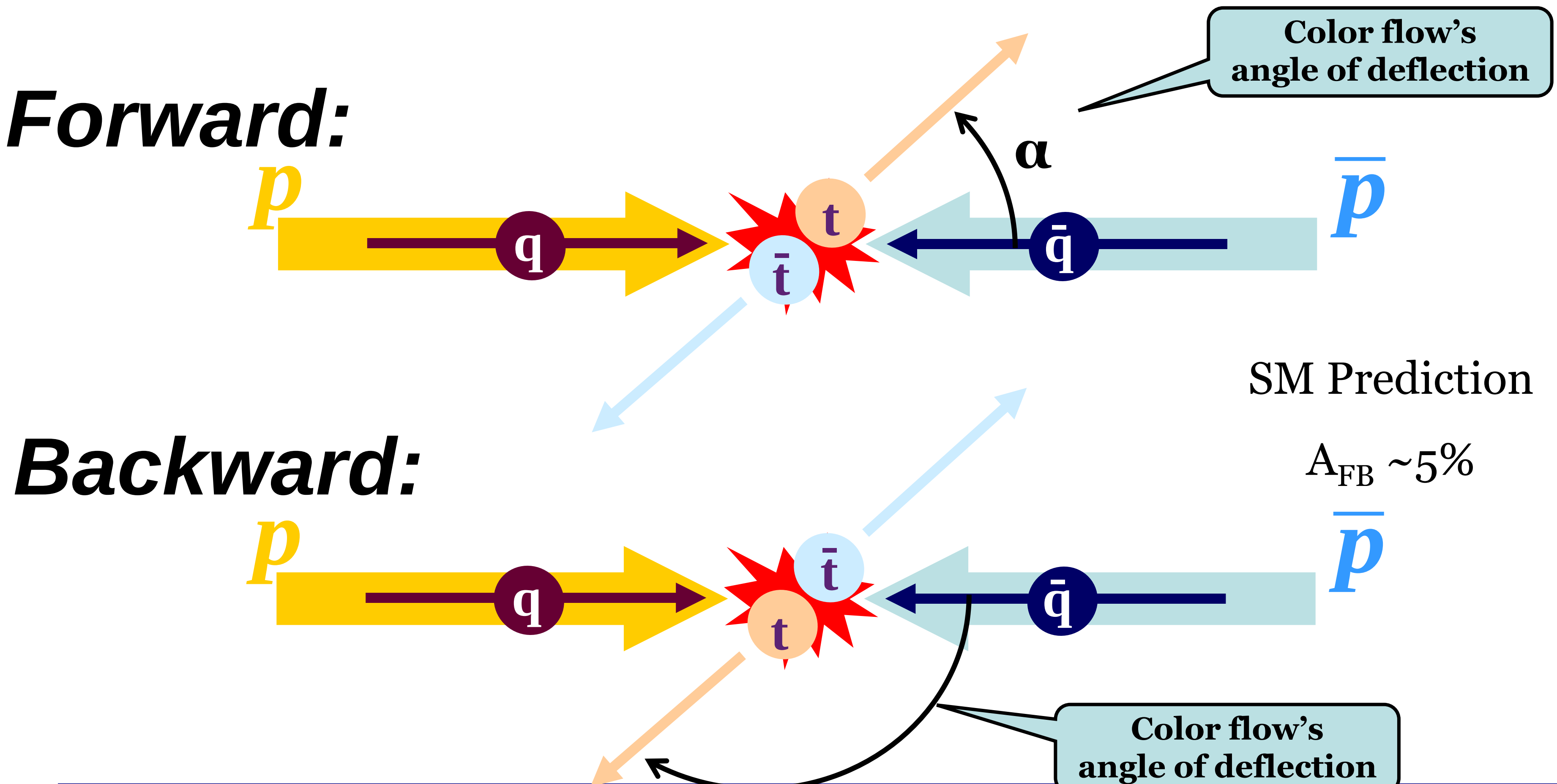
$$A_{FB} = \frac{F - B}{F + B}$$

- F : # of forward events (top in proton direction)
- B : # of backward events (top in anti-proton direction)

Forward backward asymmetry

It's not about the incoming protons

It's about the incoming quarks and their QCD charges



SM Prediction

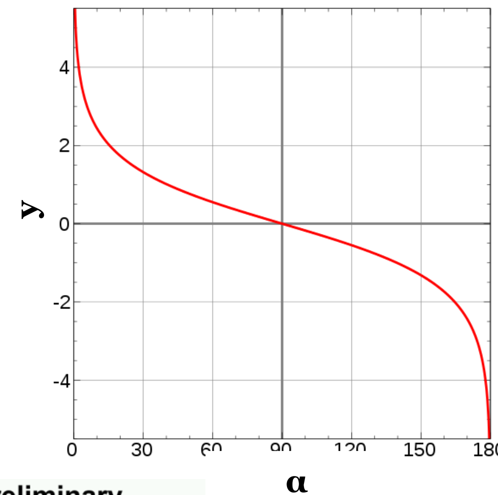
A_{FB} ~5%

Measurement

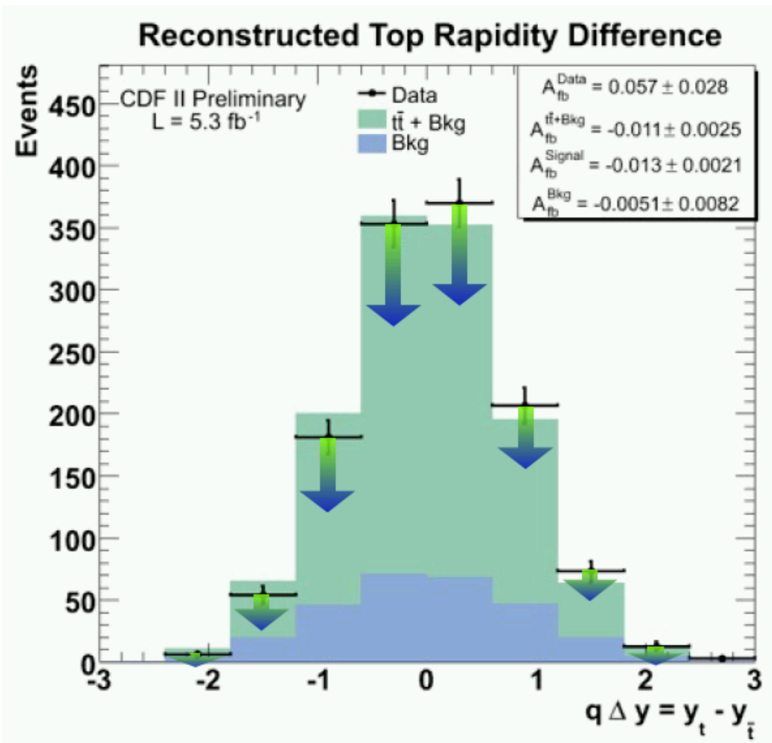
- Reconstruct rapidity difference between top and anti-top
  - Use kinematic fitter for event reconstruction

$$\Delta y = y_t - y_{\bar{t}} = q_l \left(y_{t,\mathrm{lep}} - y_{t,\mathrm{had}} \right)$$

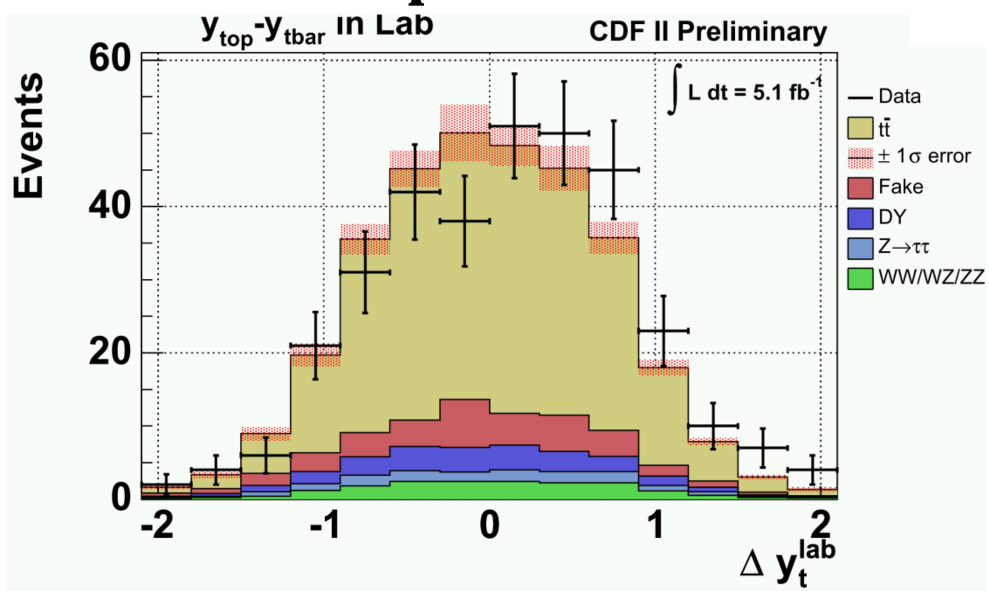
$$y \approx -\ln(\tan \alpha/2)$$



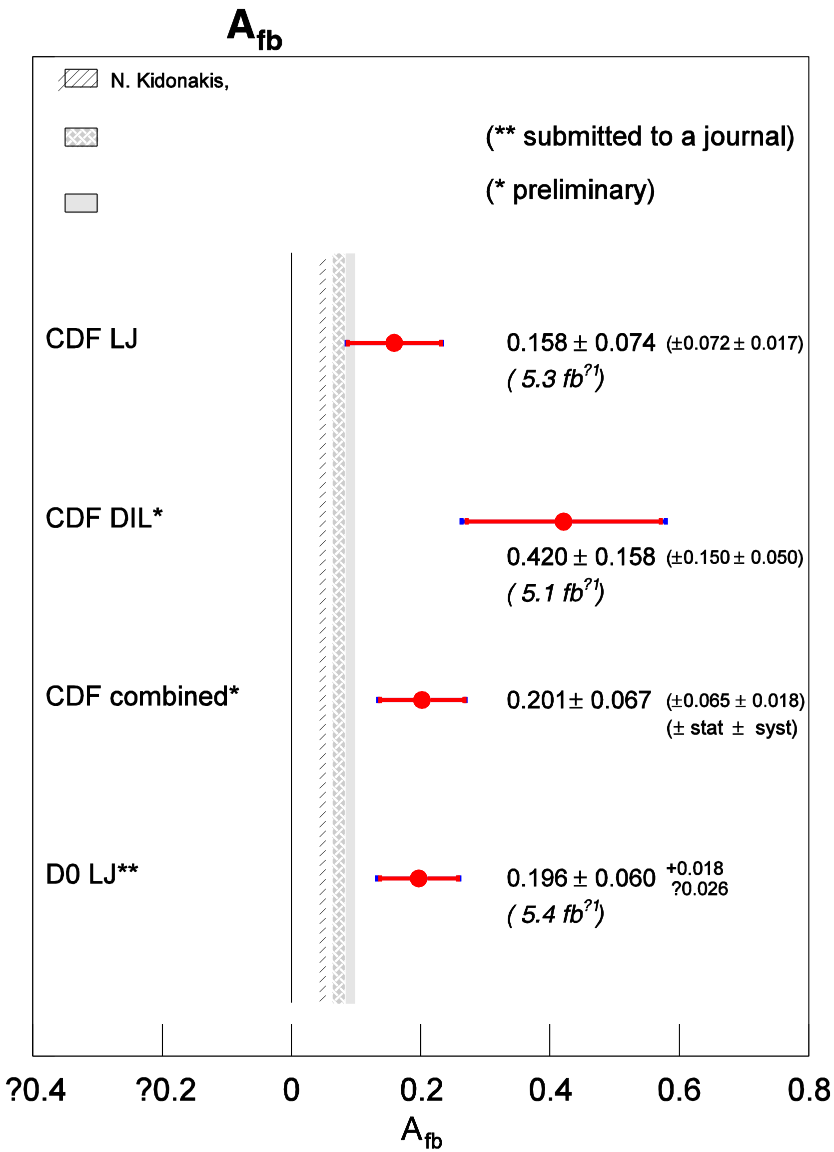
Lepton + Jets



Dilepton



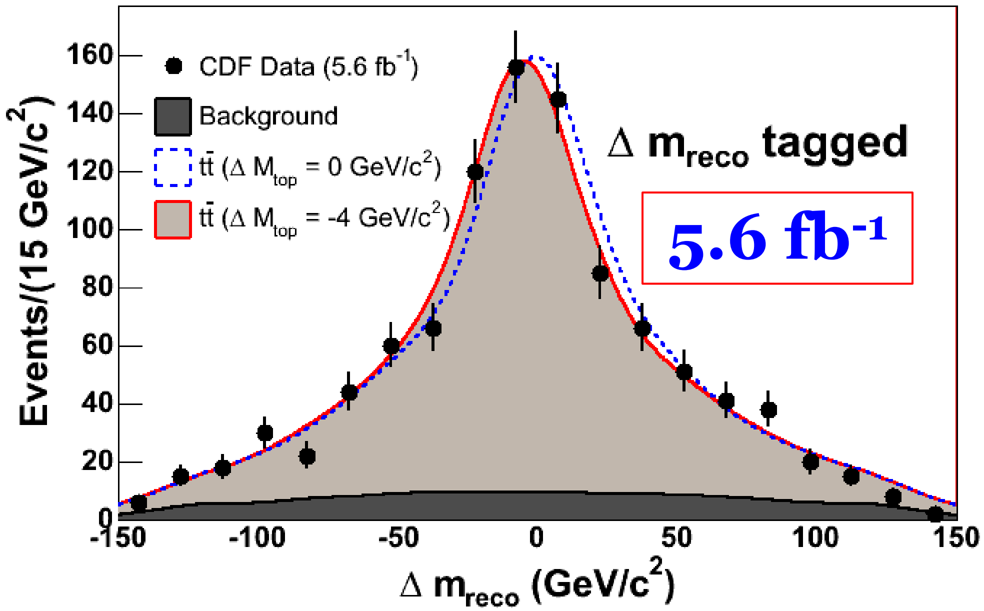
A_{FB} measurements at Tevatron



- Measured AFB is way far from standard model (approximately 3sigma off)
- We do not clearly know the source of new asymmetry
- Possible hints of new physics
  - Heavy particle (resonance) – Axigluon, Z prime …
  - Heavy quark
  - Top prime
  - Mass difference of top and anti-top
  - …..

t and $\bar{t}$ mass difference

- If CPT is conserved, ΔM_{top} should be zero (SM)
- Possible source of charge asymmetry
- We use similar technique to mass measurements



Lepton+Jets

kinematic reconstruction

PRL 106, 152001 (2011)

$$\Delta M_{top} = -3.3 \pm \underset{\text{Stat.}}{1.4} \pm \underset{\text{Syst.}}{1.0}$$
$$= -3.3 \pm 1.7\ \mathrm{GeV/c^2}$$

Short lifetime

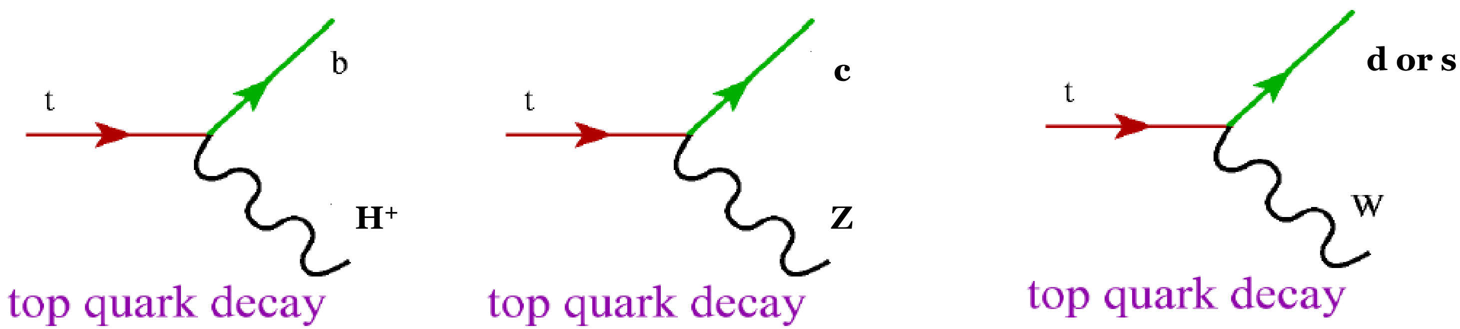
Top width

Why top quark width ?

- It is intrinsic parameter of SM
  - Very precise estimation using NLO calculation (~1% precision)

$$\Gamma_t = \Gamma_t^0 \left(1 - \frac{M_W^2}{m_t^2}\right)^2 \left(1 + 2\frac{M_W^2}{m_t^2}\right)\left[1 - \frac{2\alpha_s}{3\pi}\left(\frac{2\pi^2}{3} - \frac{5}{2}\right)\right]$$

  - 1.3 GeV at M_{top} = 172.5 GeV/c^2
- Deviation from SM indicate new physics
  - Charged Higgs decay, FCNC, and other exotic models



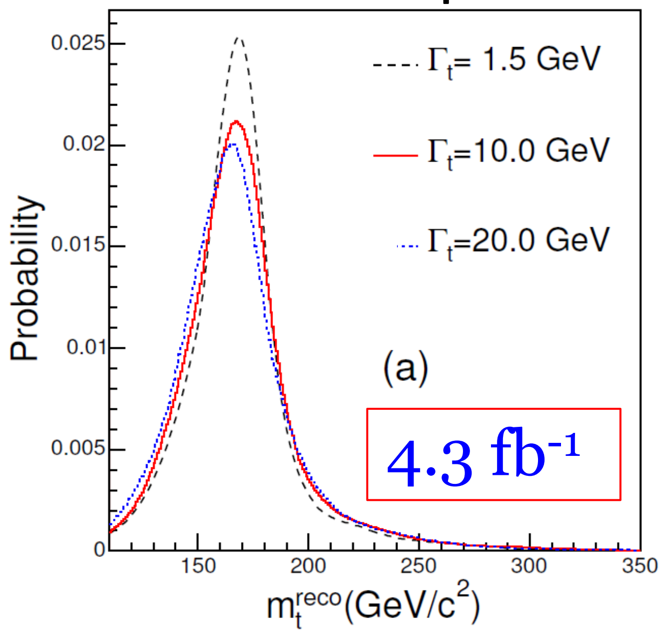
- Resolving Top quark life time

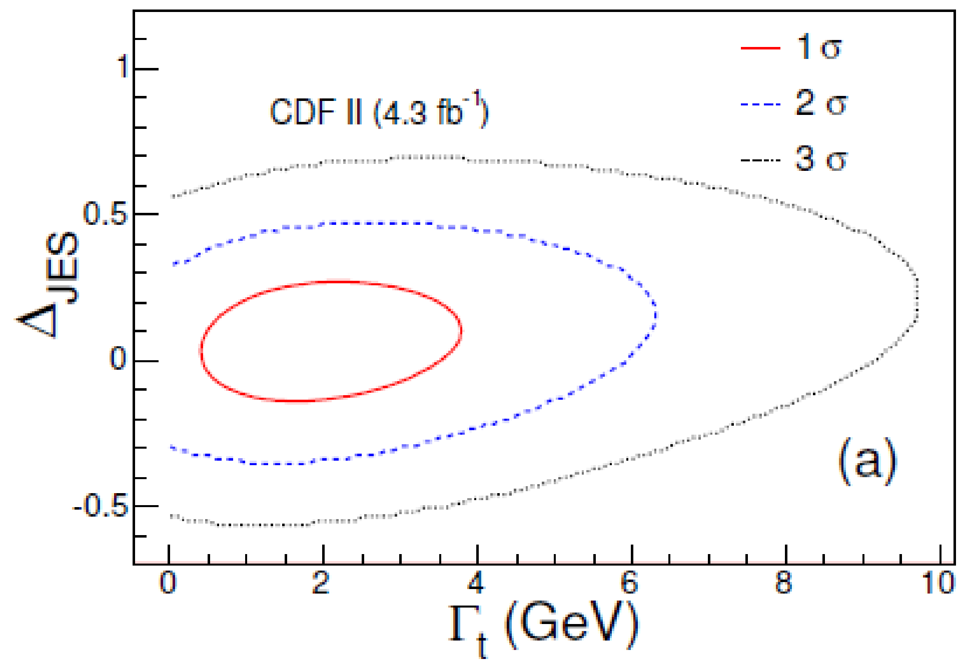
$$\tau = \frac{\hbar}{\Gamma}$$

Short life time (decay before hadronization)

Direct measurement

Reconstructed top mass





Use reconstructed top quark mass shape

PRL 105 (2010) 232003

Γ_{top} < 7.4 GeV @ 95% CL

0.3 < Γ_{top} < 4.4 GeV @ 68% CL

First direct hint of top decay before hadronization

Spin Correlation

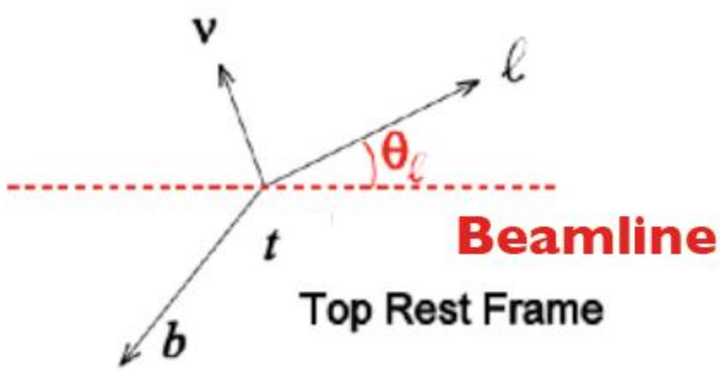
- Top quark decay before hadronization – Spin information of top quark passed to decay products

SM prediction $$\kappa = \frac{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} - N_{\uparrow\downarrow} - N_{\downarrow\uparrow}}{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} + N_{\uparrow\downarrow} + N_{\downarrow\uparrow}} \approx 0.78$$

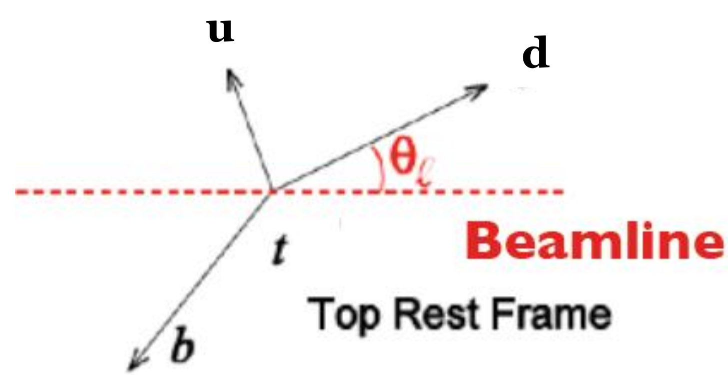
- κ is related with angles of decay products

$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\theta_1 d\cos\theta_2} = \frac{1-\kappa\cos\theta_1\cos\theta_2}{4}$$

- where



or



Spin Correlation

- Top quark decay before hadronization – Spin information of top quark passed to decay products

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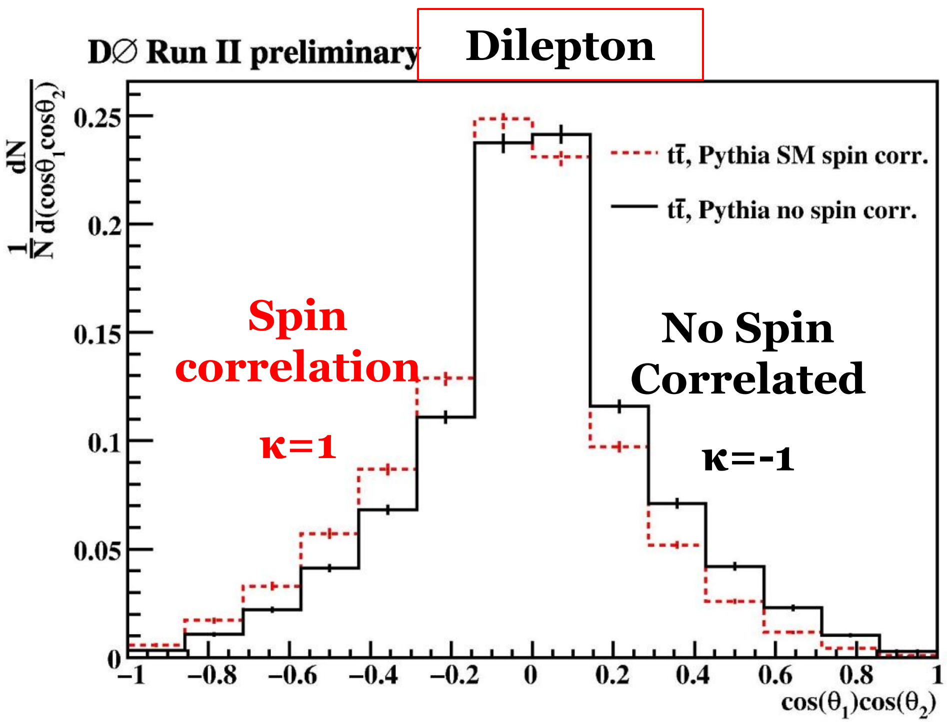
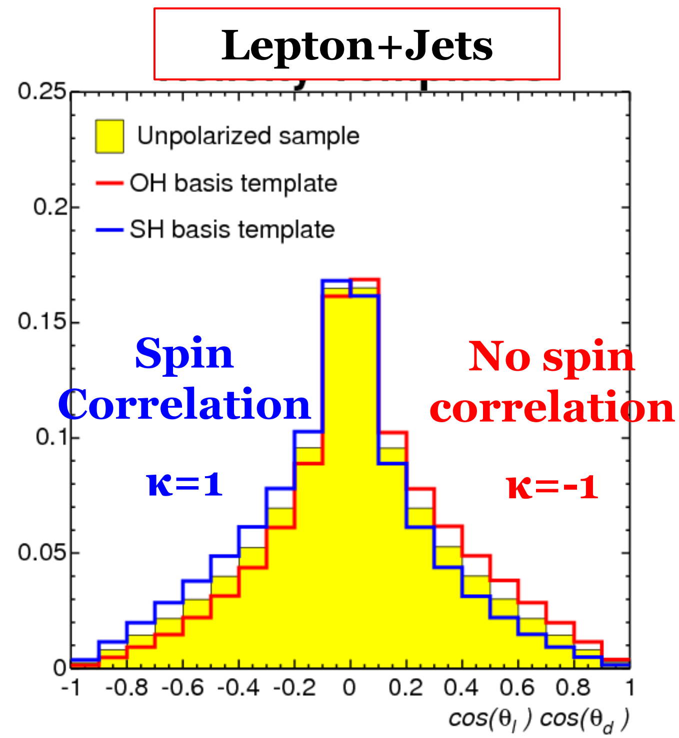
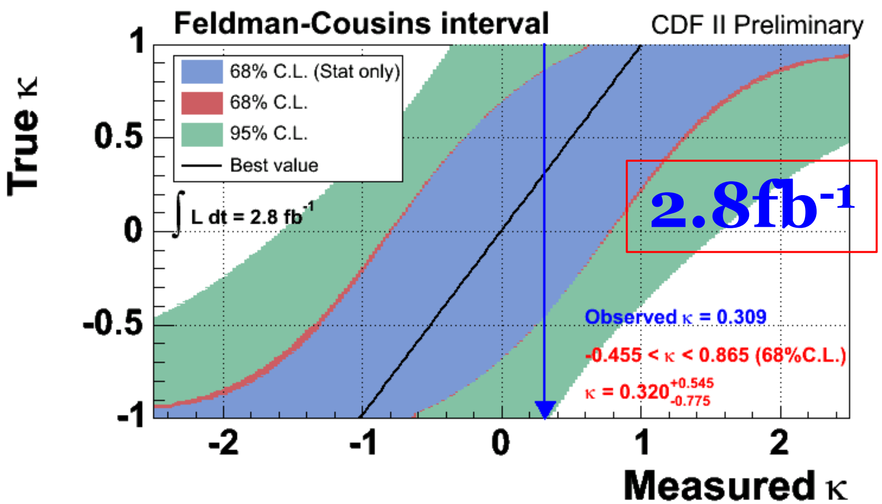




Spin Correlation

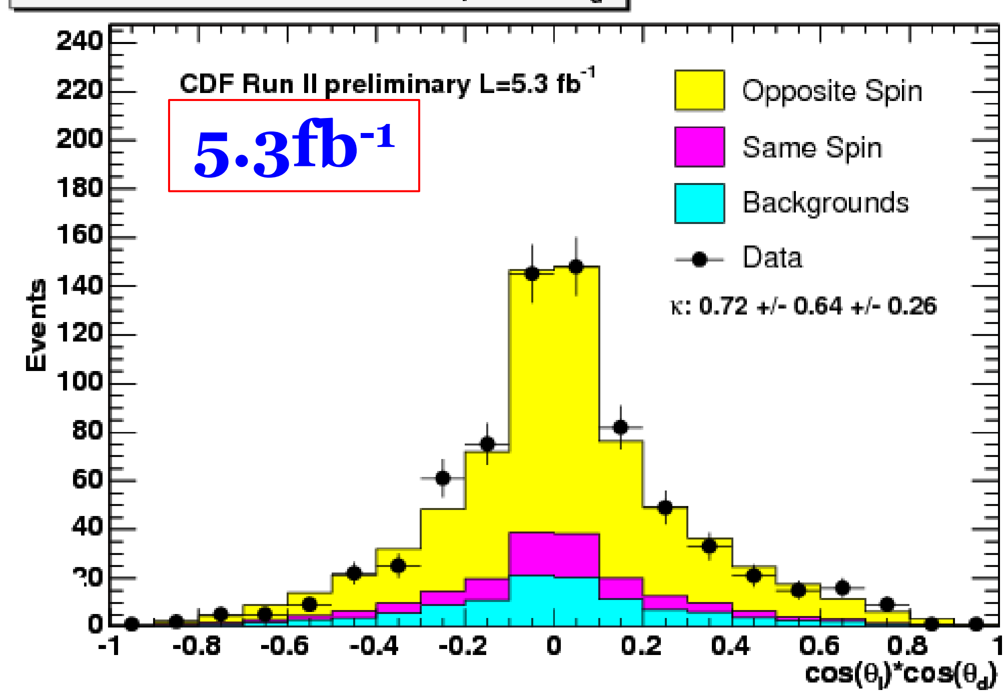
Dilepton



$\kappa = 0.32^{+0.55}_{-0.78}$

Need much more statistics

Lepton+Jets

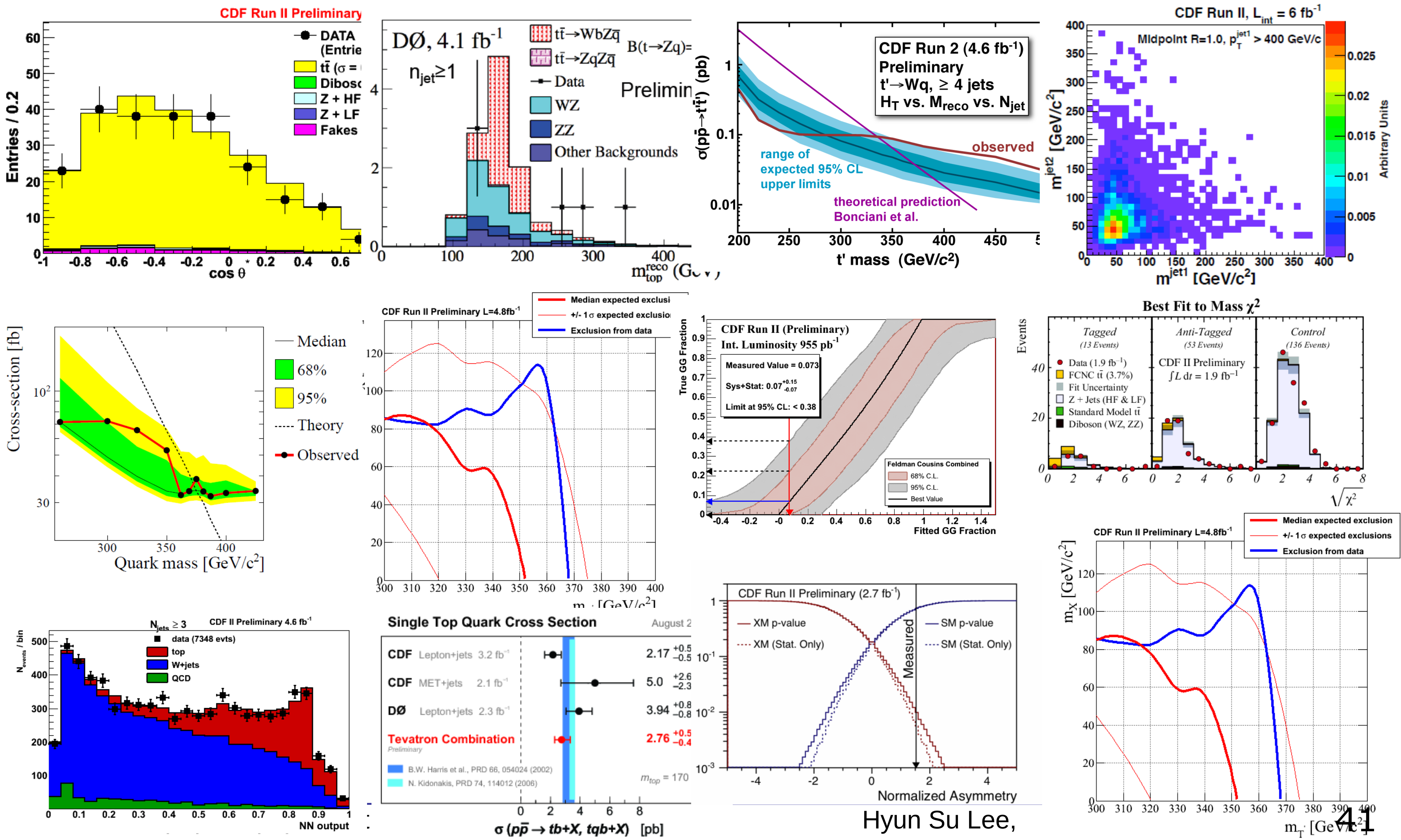


$\kappa = 0.72 \pm 0.62 \pm 0.26$

$\boxed{\kappa_{SM} = 0.78}$

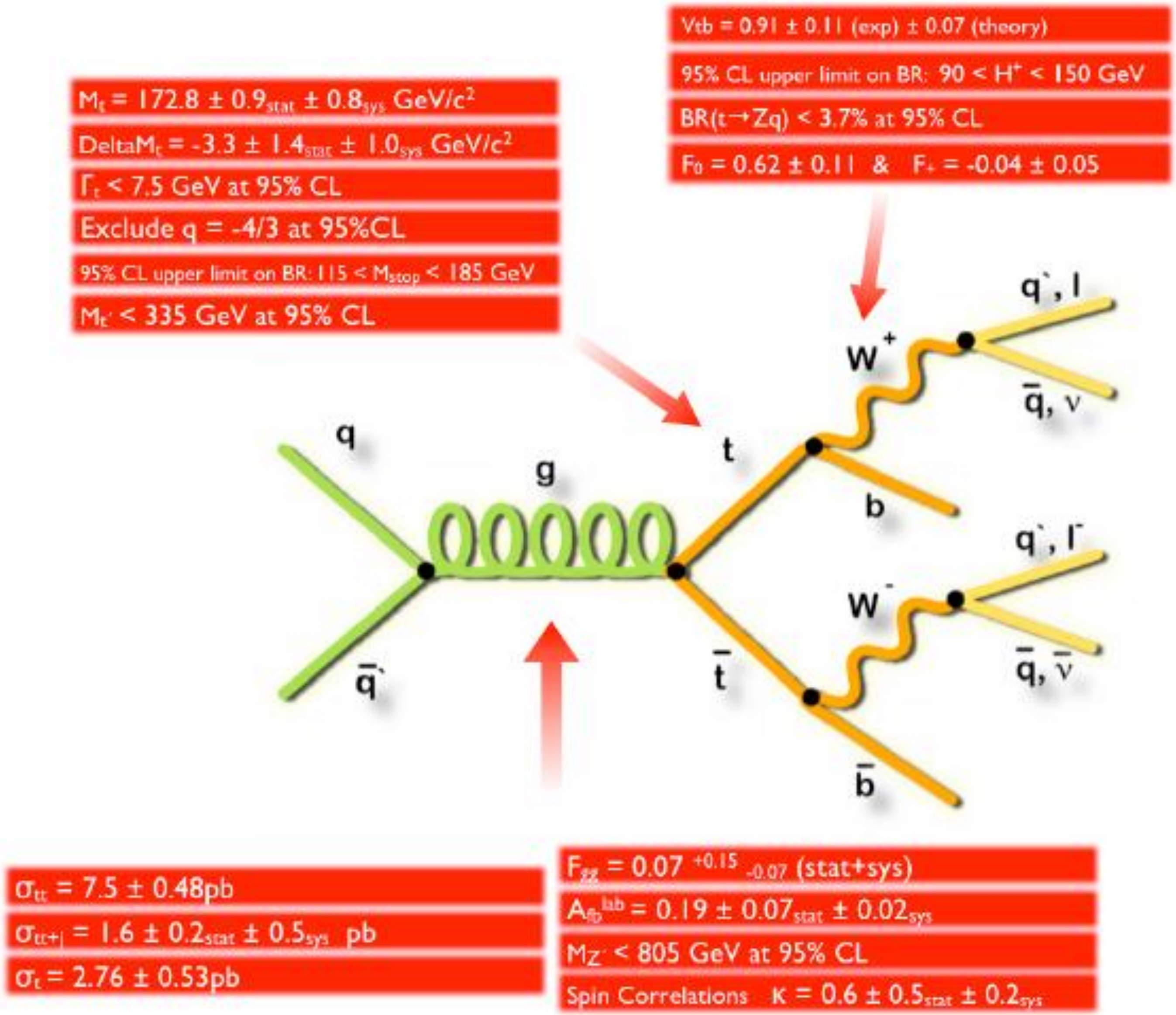
PRD83 (2011) 031104

Lots of top quark studies at CDF



Hyun Su Lee,

What we know about top quark from CDF



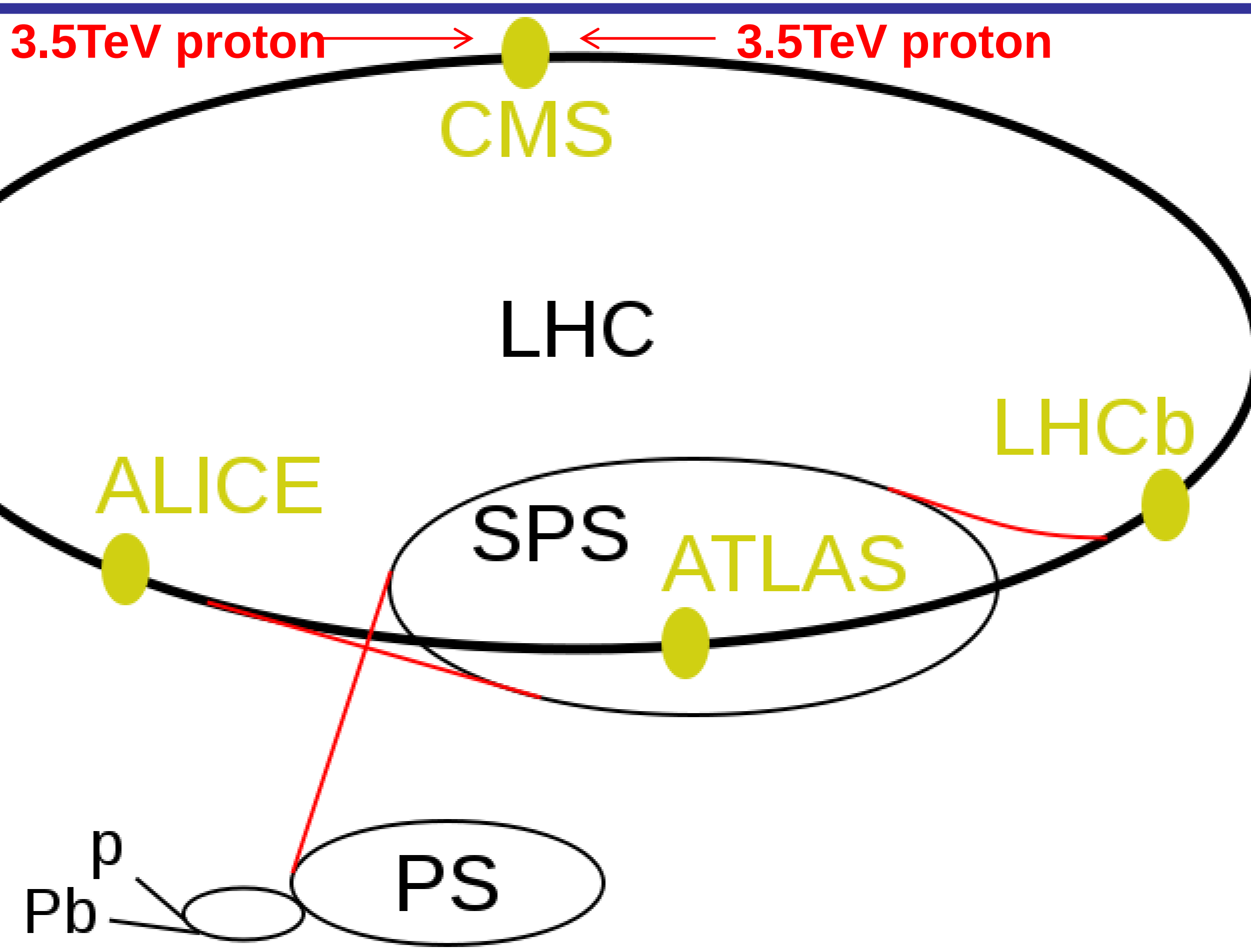
- Lots of top quark properties have been studied
- However, lots of measurements are limited by statistics of top quark
  - ❖ Will use full data set
- Need better machine
  - ❖ Large Hadron Collider

CERN/LHC


CERN

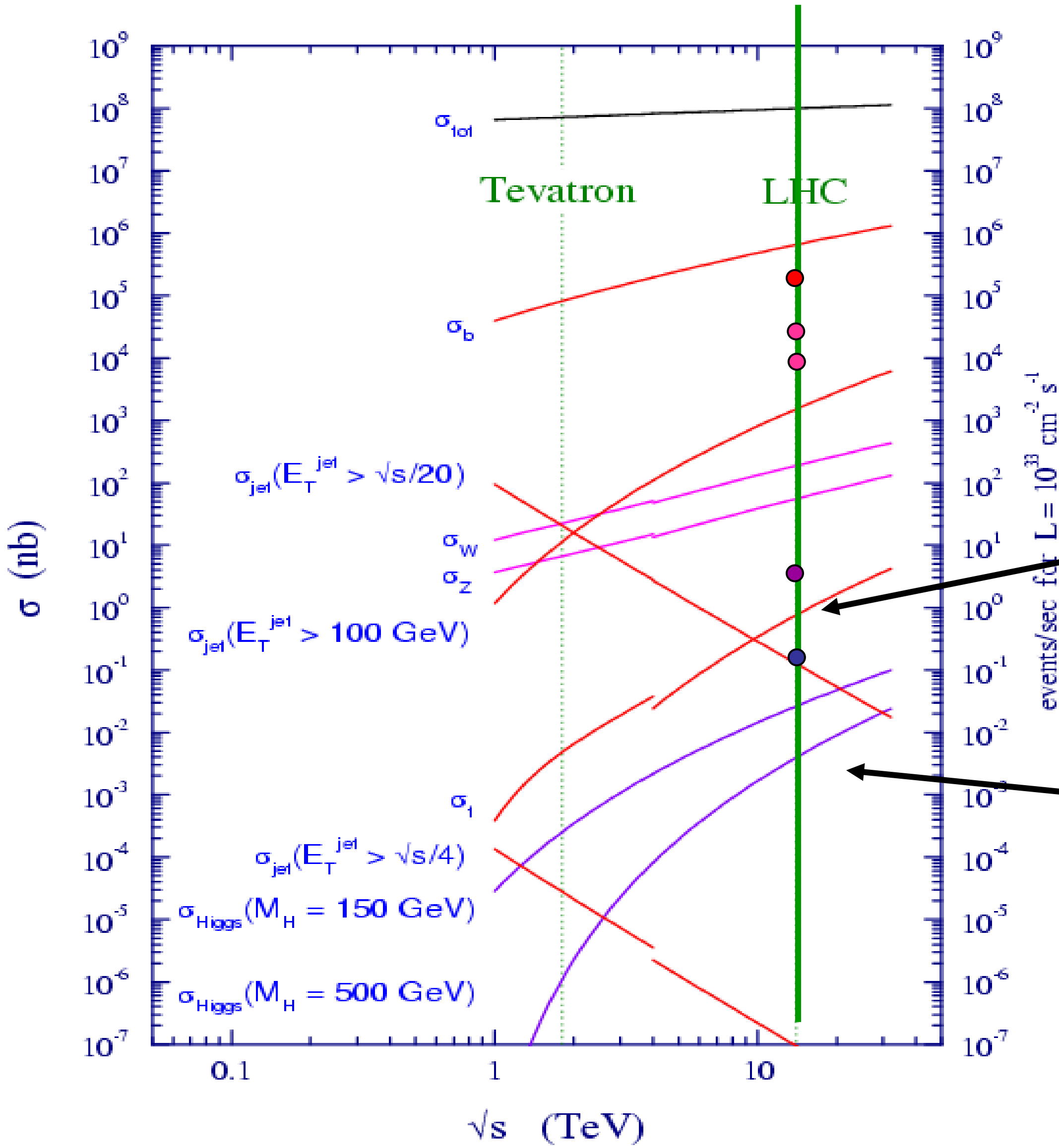

글래스고
Glasgow
에든버러
Edinburgh
북해
코펜하겐
København
벨파스트
Belfast
영국
덴마크
더블린
Dublin
맨체스터
Manchester
함부르크
Hamburg
킬
Kiel
아일랜드
버밍엄
Birmingham
네덜란드
브레멘
Bremen
베를린
Berlin
로테르담
Rotterdam
카디프
Cardiff
런던
London
벨기에
쾰른
Köln
독일
라이프치히
Leipzig
체코 공화국
켈트해
파리
Paris
슈투트가르트
Stuttgart
뮌헨
München
비엔나
Wien
A
오스트리아
낭트
Nantes
프랑스
Zurich
바두츠
Vaduz
베로나
Verona
자그레브
Zagreb
비스케이 만
리옹
Lyon
밀라노
Milano
크로아티아
히혼
Gijón
툴루즈
Toulouse
마르세유
Marseille
니스
Nice
이탈리아
사라예보
Sarajevo
비고
Vigo
사라고사
Zaragoza
포르투
Porto
마드리드
Madrid
바르셀로나
Barcelona
로마
Roma
나폴리
Napoli
포르투갈
스페인
발렌시아
Valencia
팔마데
마요르카
Palma
티레니아 해
리스본
Lisboa
무르시아
Murcia
팔레르모
Palermo
세비야
말라가
카타니아

LHC



- World best energy (7 TeV) proton-proton collider (designed to be 14 TeV)
- CMS is the one of two general purpose detector

LHC is the top factory

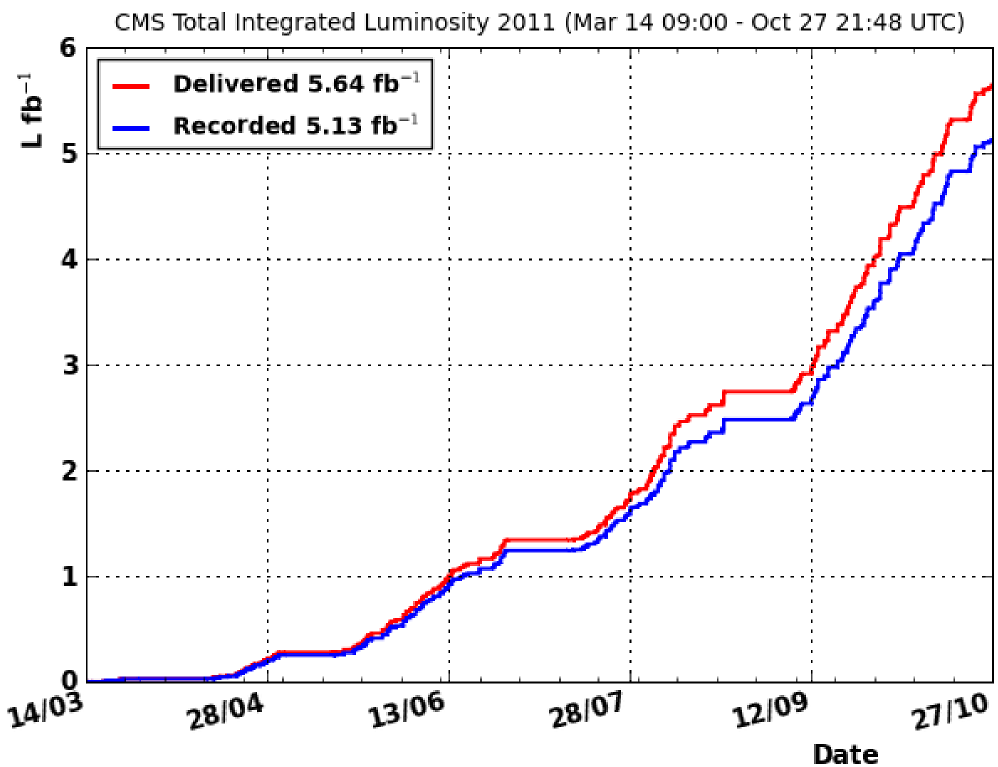


Total inelastic cross section (background) are similar

About 100 times larger top production

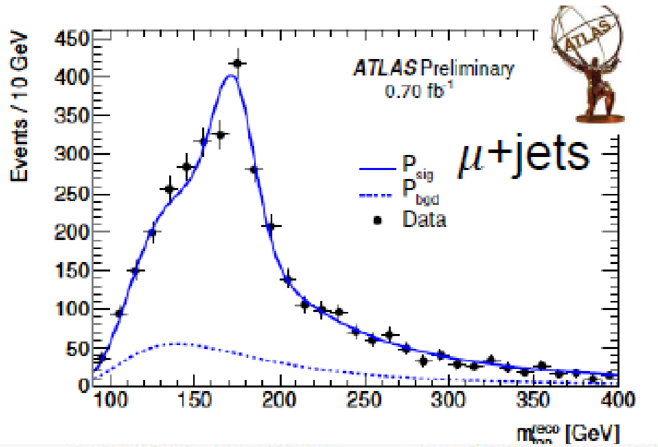
About 100 times larger Higgs production

LHC & CMS operation

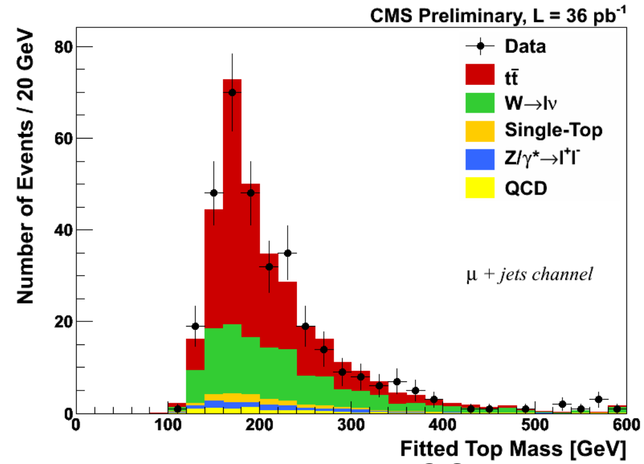


- Already accumulate more than 5 fb^{-1} (2 times less than Tevatron)
- Next year ~20 fb^{-1}
- CMS already have ~10x more top events than CDF
- Lots of top properties can reach sensitive reason
  - Even precision measurement of the properties are possible

Top mass and mass diff. at LHC

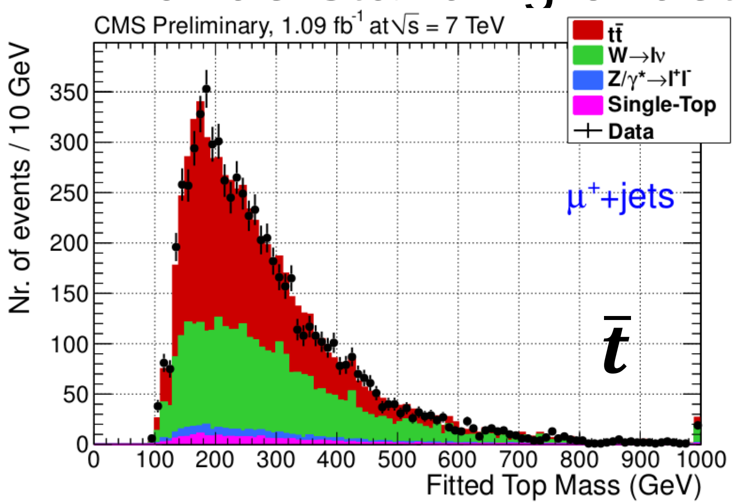


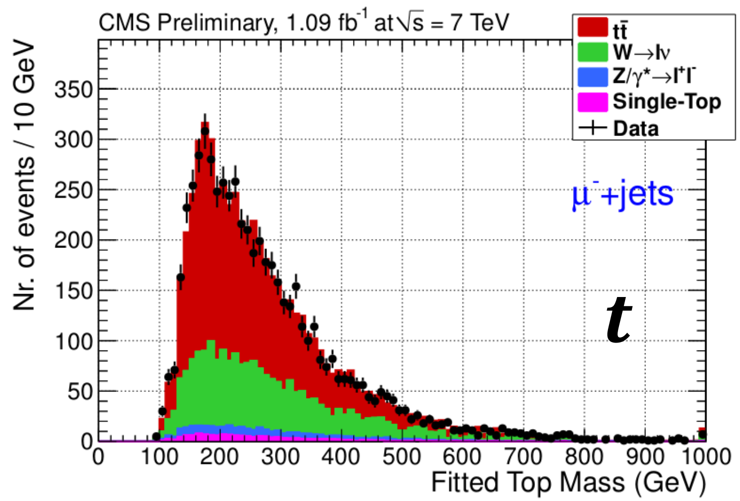
$$m_t = 175.9 \pm 0.9_{\text{stat}} \pm 2.7_{\text{syst}}\ \text{GeV}$$



$$m_t = 173.1 \pm 2.1^{+2.8}_{-2.5}\ \text{GeV}$$

- Already very small stat. uncertainty but, need better understanding of detector





$$\boldsymbol{\Delta m_t = -1.20 \pm 1.21 \pm 0.47}\ \textbf{GeV, Already world best}$$

Prospect of Top physics at LHC

- Already have ~10 times more ttbar events than Tevatron
- Precision measurement need better understanding of systematics
- Statistical uncertainty dominant analysis is already surpass Tevatron measurement
  - Mass difference
- In the near future, lots of properties are well understood with LHC data

Conclusion

- Understanding of top quark are very important and very active field

- Tevatron have made very important understanding of top quark
  - Will have final measurement using full data (~2 times more data)

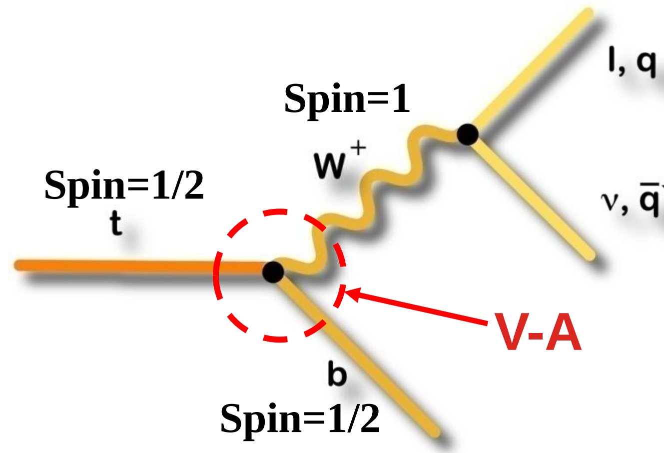
- LHC will bring new era of top quark understanding

Stay tune

Backup

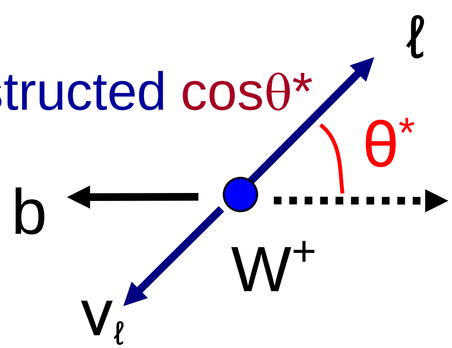
W Helicity

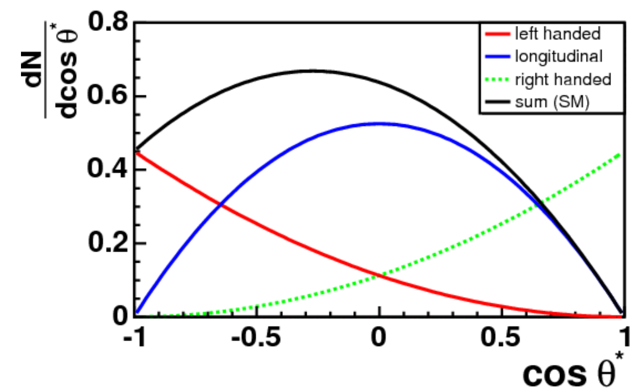
- The SM top decays via EW interaction
  - ❖ Top decays as a bare quark ⇒ spin information transferred to final state particles



- V-A coupling predict
  - ❖ $f_0 = 0.7$ (longitudinal polarization)
  - ❖ $f_+ = 0$ (right handed polarization)
  - ❖ $f_- = 0.3$ (left handed polarization)

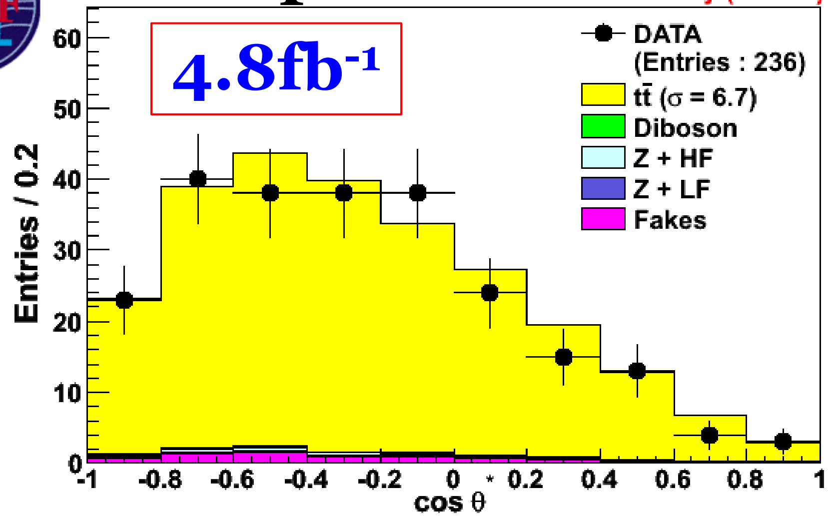
- Measuring the fraction of longitudinally polarized W bosons
  - ❖ Reconstructed cosθ*



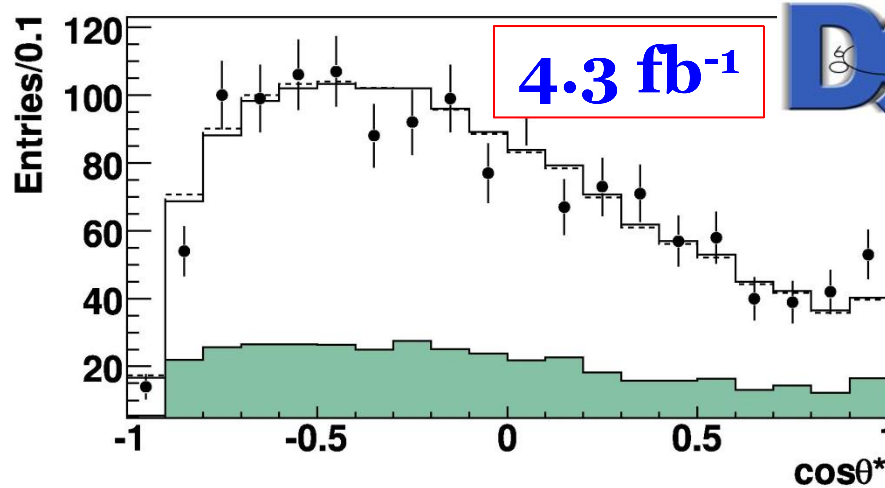


W Helicity

Dilepton



Lepton+Jets & Dilepton



$f_+ = -0.12^{+0.12}_{-0.11}$
$f_0 = 0.78^{+0.20}_{-0.21}$

$f_+(SM) = 0$
$f_0(SM) = 0.7$

$f_+ = 0.02 \pm 0.05$
$f_0 = 0.67 \pm 0.10$

Lepton+Jets

$f_+ = -0.15 \pm 0.13$
$f_0 = 0.88 \pm 0.09$ 2.7 fb-1

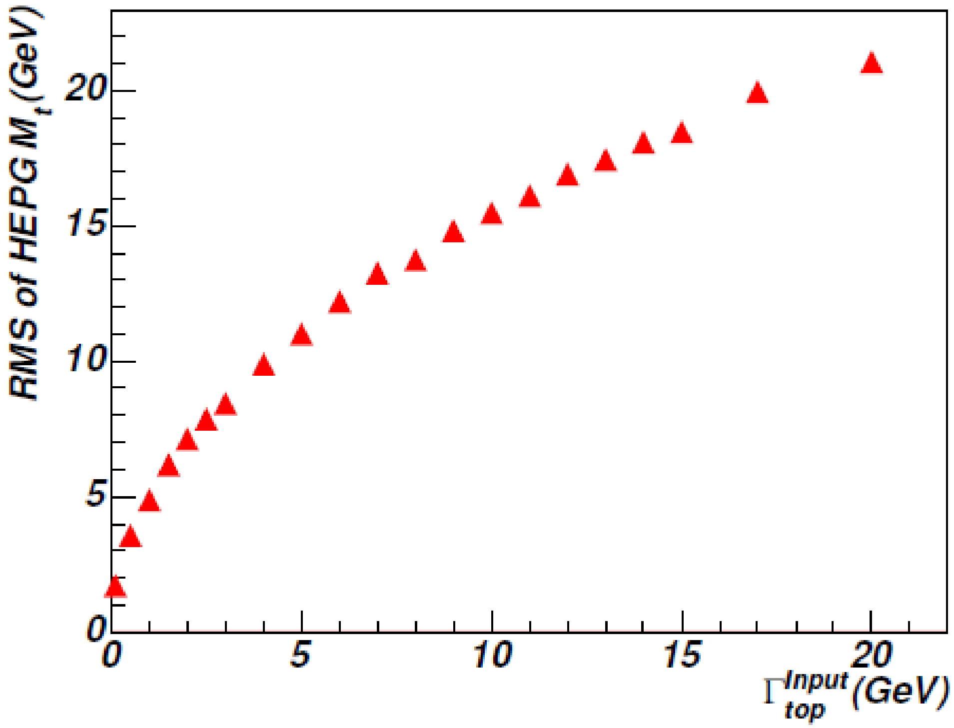
PRL 105 (2010) 042002

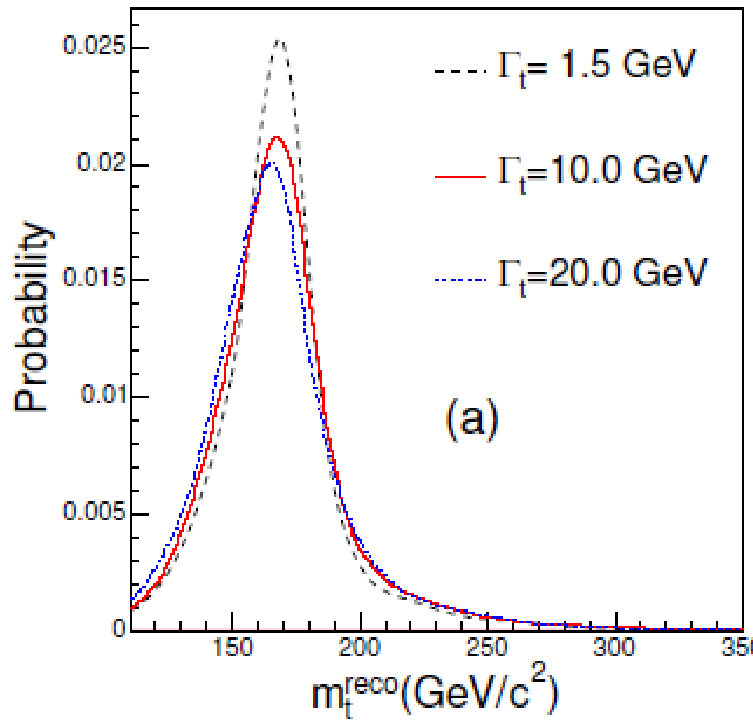
Consistent with SM @ 98% level

arXiv:1011.6549

Analysis method

- Same template with top quark mass measurement but different signal samples (varying top width)

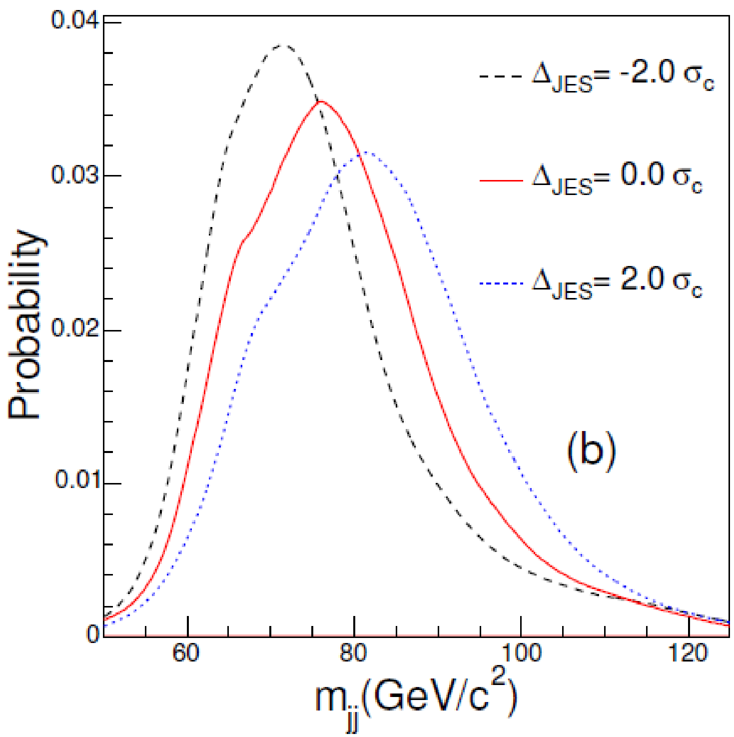




- RMS of reconstructed top mass is measure of top width

Update of top width measurement (4.3 fb^{-1})

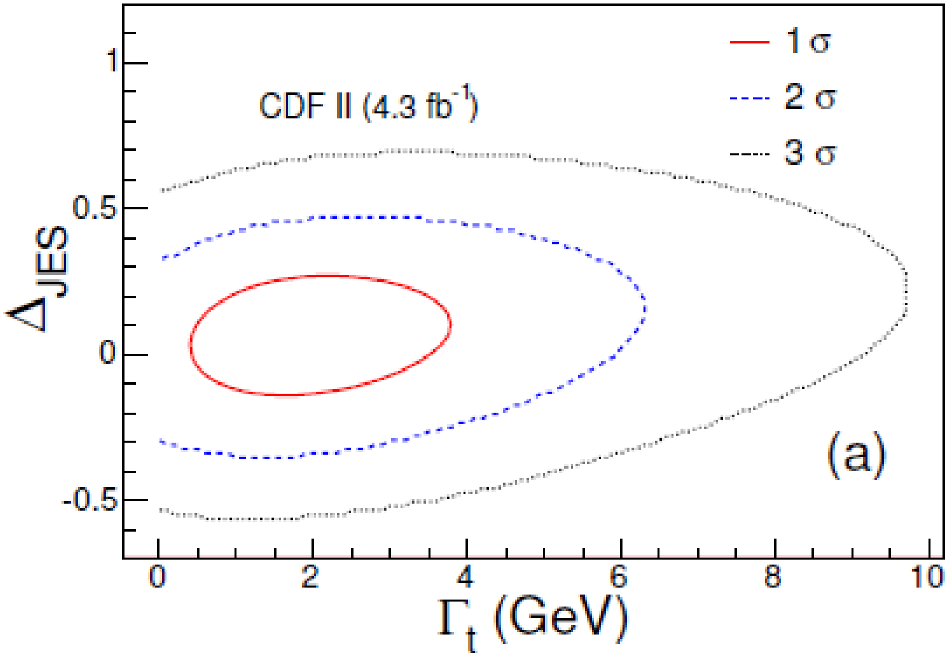
- *In situ* JES calibration using W_{jj}

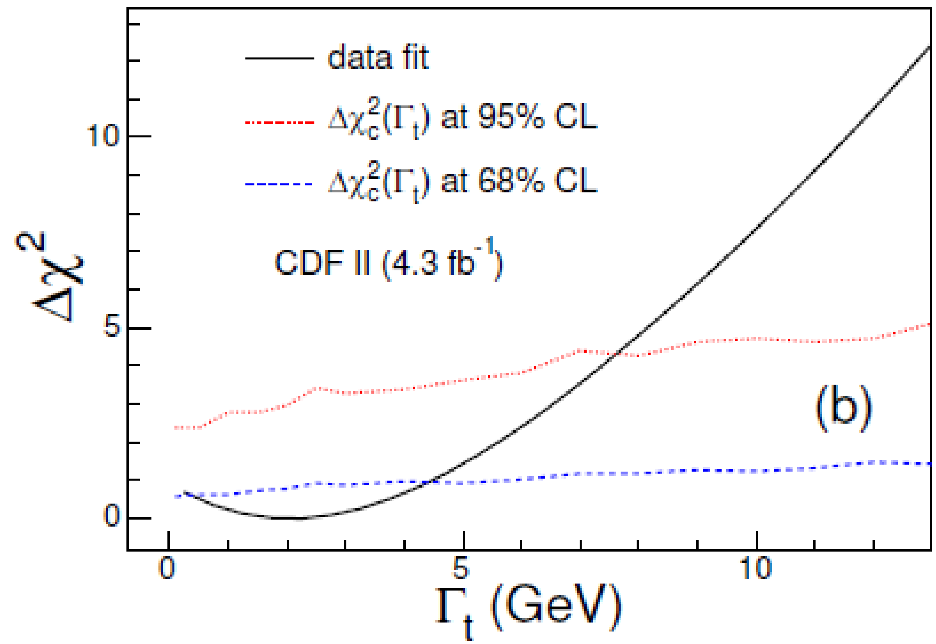


- 2D fit was done

Systematic Effects	Meas. mean top width shift(GeV)
Jet Resolution	1.1
Residual JES	0.3
Generator	0.4
PDF	0.3
B Jet Energy	0.2
LJ Background	0.1
gg Fraction	0.3
IFSR	0.2
Lepton Energy	0.2
Color Reconnection	0.9
Multi. Had. Int.	0.3
Total Systematic	**1.6**

Top quark width measurement with 4.3 fb^{-1}





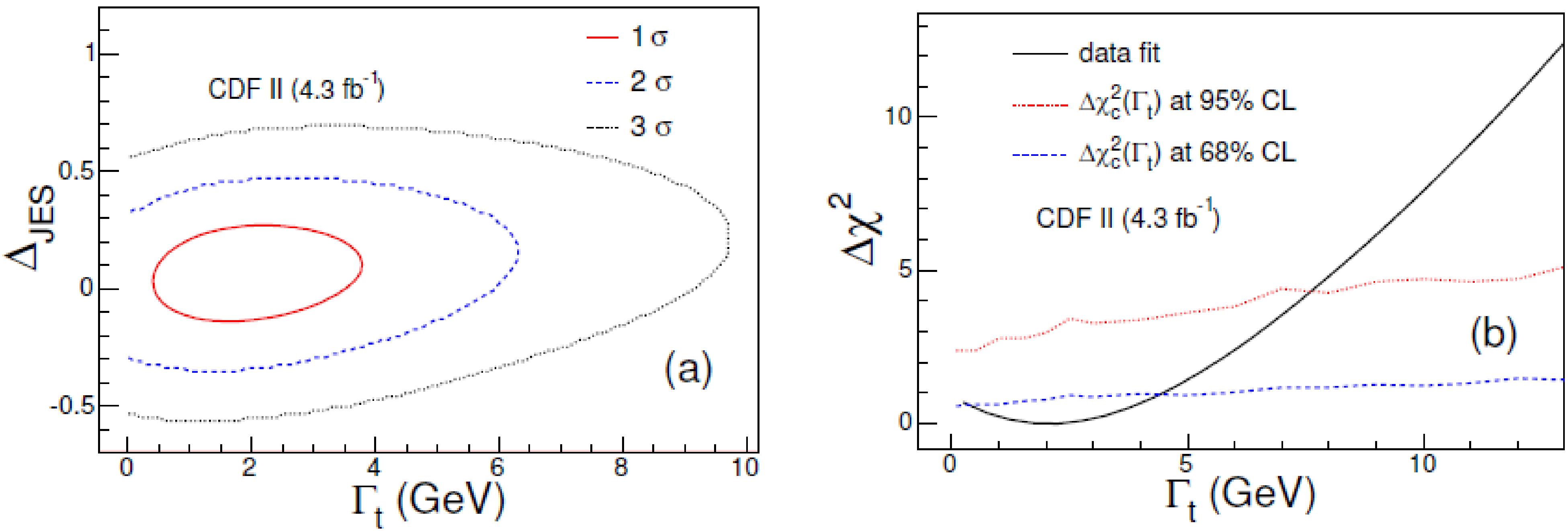
$$0.3 \text{ GeV} < \Gamma_{top} < 4.4 \text{ GeV @ 68\% CL}$$

$$\Gamma_{top} < 7.6 \text{ GeV @ 95\% CL}$$

First set of low bound limit (68% CL)

Phys. Rev. Lett. 105, 232003 (2010)

Top quark width measurement with 4.3 fb^{-1}



0.3 GeV < Γ_{top} < 4.4 GeV @ 68% CL

Hadronization time scale ~0.2 GeV

At 68% CL, this result support that top quark decay before hadronization

ΔM_{top}

Why mass difference?

Our top mass precision allow to test mass difference between top quark and anti top quark

New observed asymmetry between top and anti-top may be explained by mass difference

This is testing CPT theorem

- Well tested in meson, baryon, and boson
- Not very well in quark and high mass particles
- D0 1fb^{-1} measurement using ME technique (Updated with 3.6 fb^{-1})

  $\Delta M = 3.8 \pm 3.7$ GeV/c^2

We modified usual kinematic fitter to allow mass difference in the lepton+jets channel

- Two observables (best, 2nd best)

Event Reconstruction

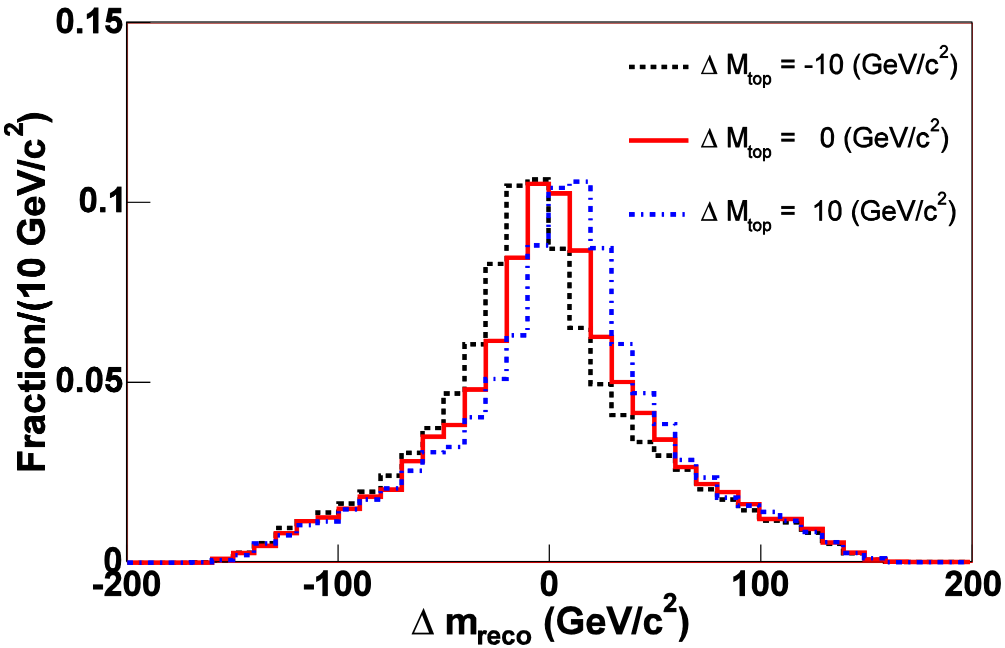
- We modified nominal kinematic fitter to get mass difference

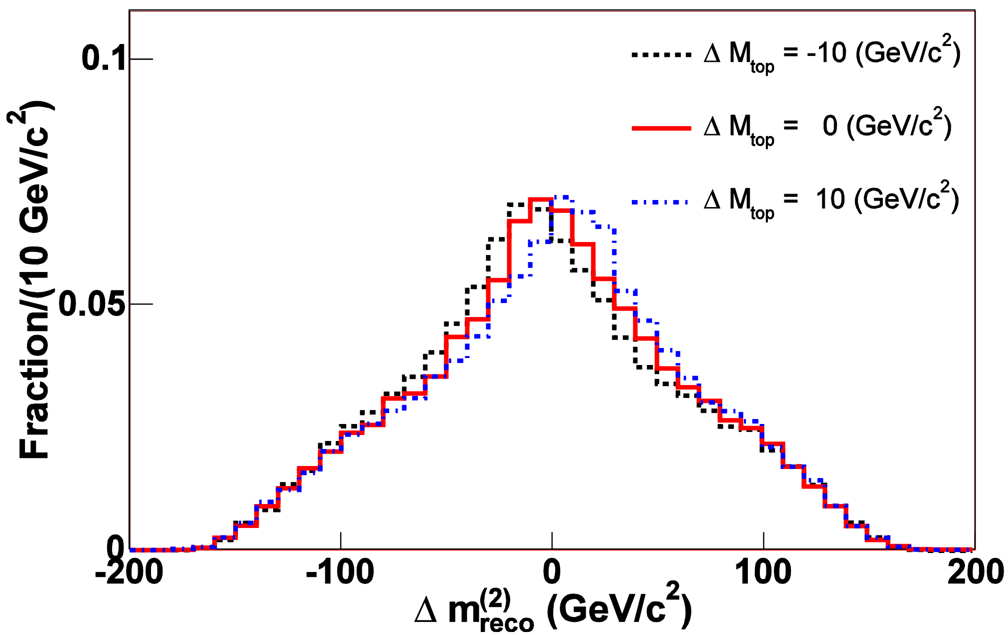
$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i^2} + \Sigma_{j=x,y}\frac{(U_j^{fit}-U_j^{meas})^2}{\sigma_j^2}$$
$$+ \frac{(M_{jj}-M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu}-M_W)^2}{\Gamma_W^2}$$
$$+ \frac{(M_{bjj}-(172.5+dM_{reco}/2))^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu}-(172.5-dM_{reco}/2))^2}{\Gamma_t^2}$$

$$\Delta m_{\mathrm{reco}} = -Q_{lepton} \times dM_{reco}$$

- This variable is corresponding to top quark mass minus anti-top quark mass in reconstruction level

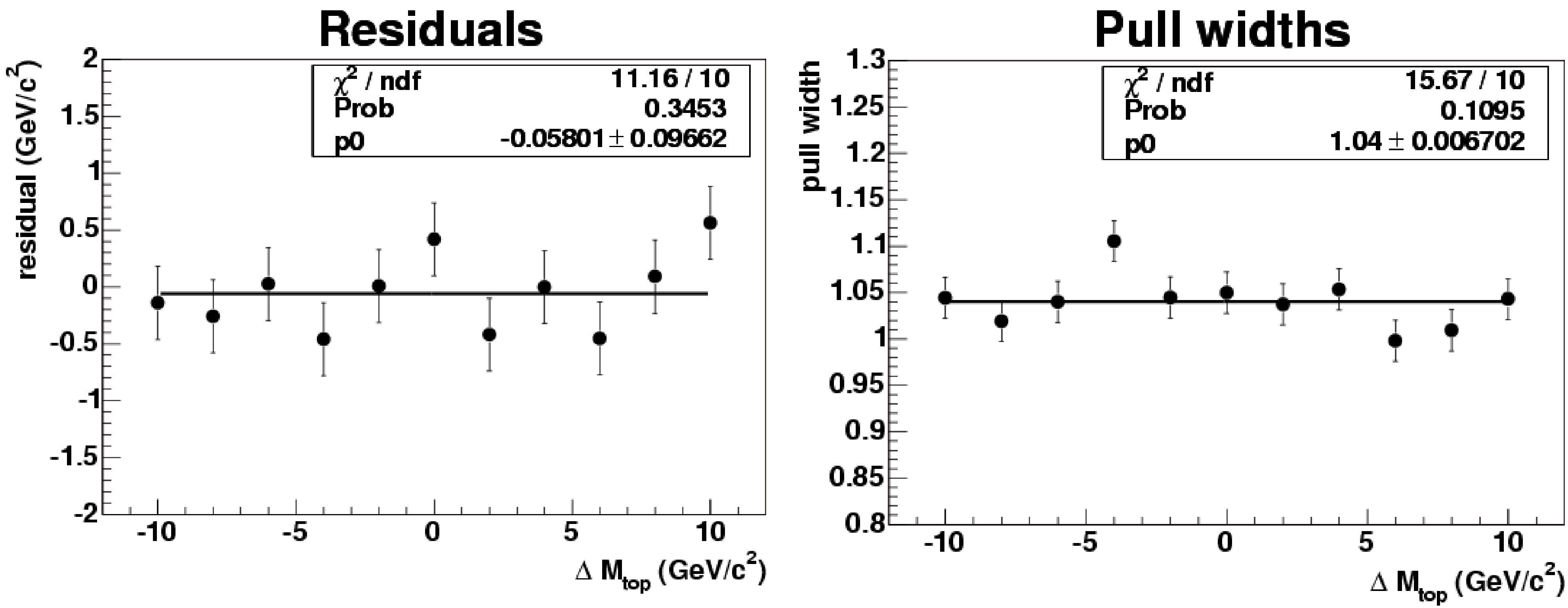
Shape of reconstructed mass diff.





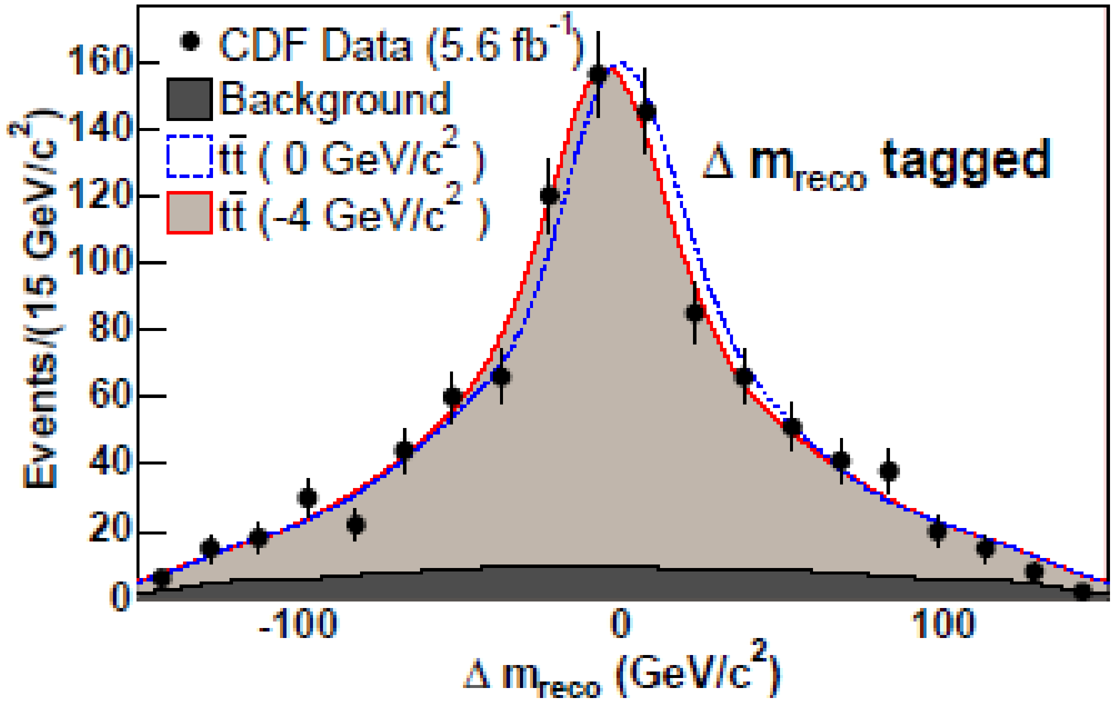
- We use the lowest and 2nd lowest variables to measure the mass differences
  - ~10% improvement by using 2nd observable

Method checks



- We assumed the averaged top quark mass as 172.5GeV/c^2
- Working properly – NO Bias
- We increase uncertainties by 4% based on pull widths

Data fit and results



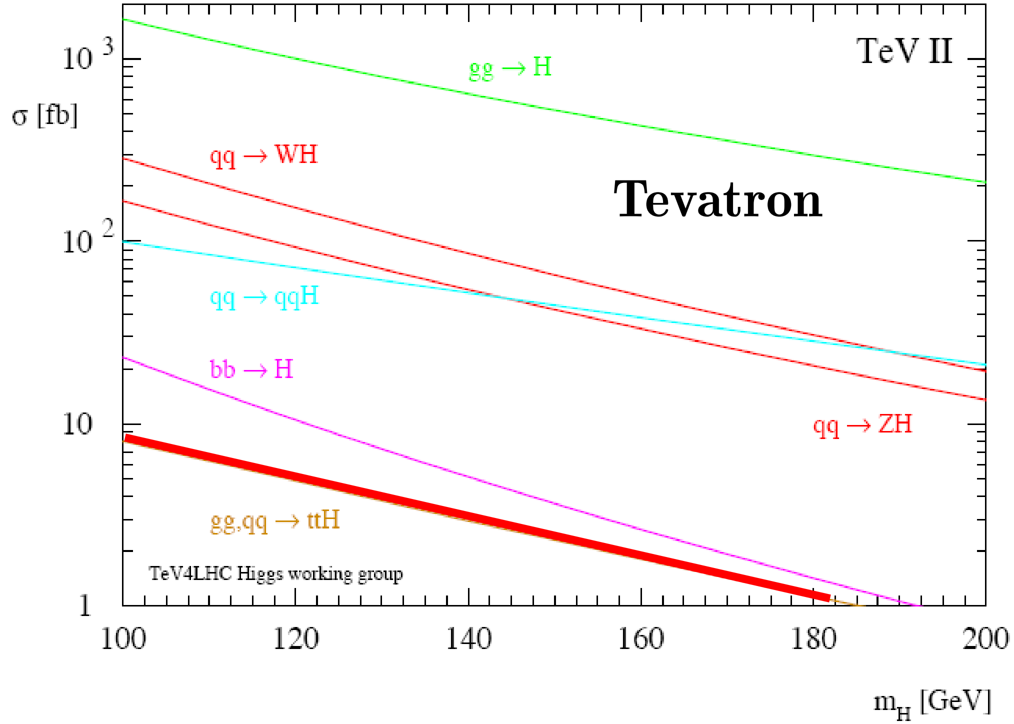
- ~ 2sigma deviation from standard model

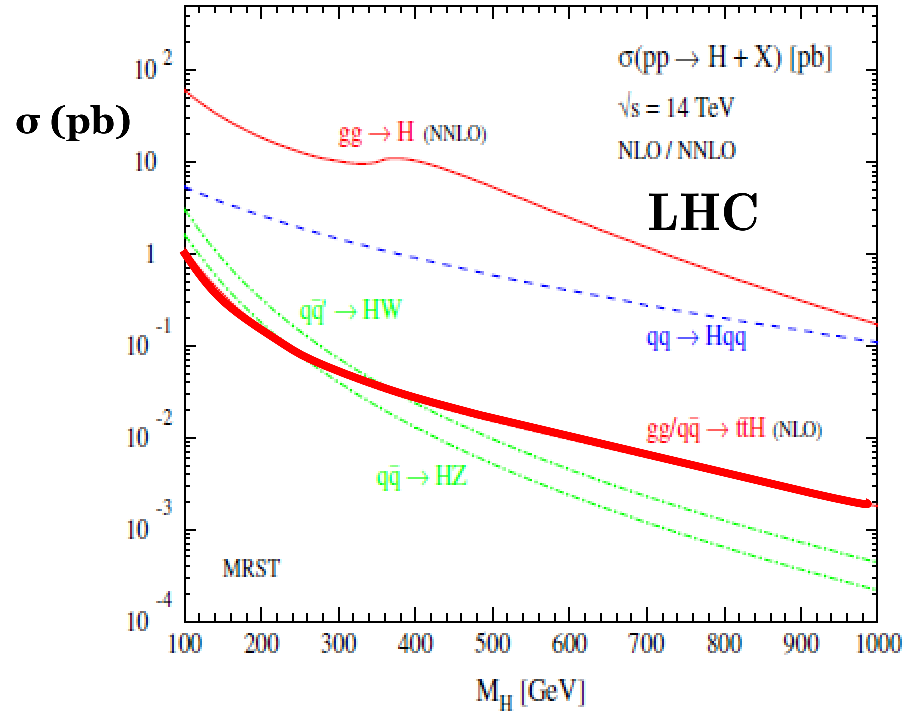
  Phys. Rev. Lett. 106, 152001 (2011)

$$-3.3 \pm 1.4\ (\mathrm{stat}) \pm 1.0\ (\mathrm{syst})\ \mathrm{GeV}/c^2$$
$$= -3.3 \pm 1.7\ \mathrm{GeV}/c^2$$

Higgs production associated with ttbar

ttH production at Tevatron and LHC





- Very small cross section at Tevatron
- However it may be discovery channel at LHC
- Interesting to study yugawa coupling between top and Higgs boson
- New physics can enhance ttH production about 2 order

ttH search @ no lepton channel (5.7 fb^{-1})

- Complementary analysis with lepton channel
- It include not only missing energy+jets final state but also all jets final state
- Results are compatible with lepton channels

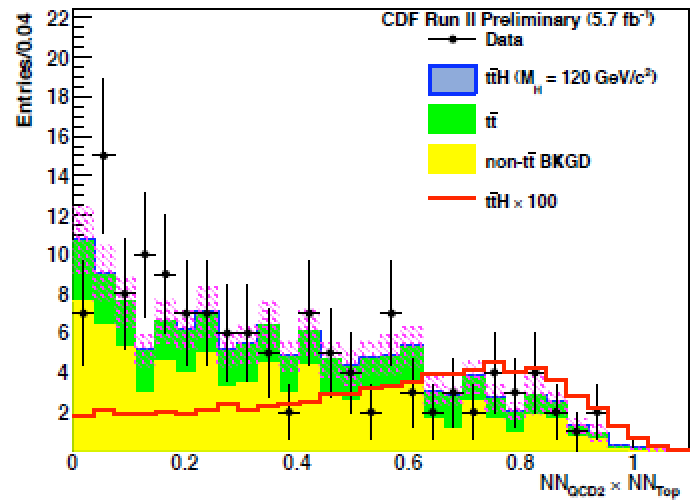
- Limit: 22.9(Exp)/31.4(Obs) x σ_{SM} for M_H=120 GeV/c^2

  Limit: 12.7(Exp)/27.4(Obs) x σ_{SM} for M_H=120 GeV/c^2
  Lepton channel @ 7.5 fb^{-1}

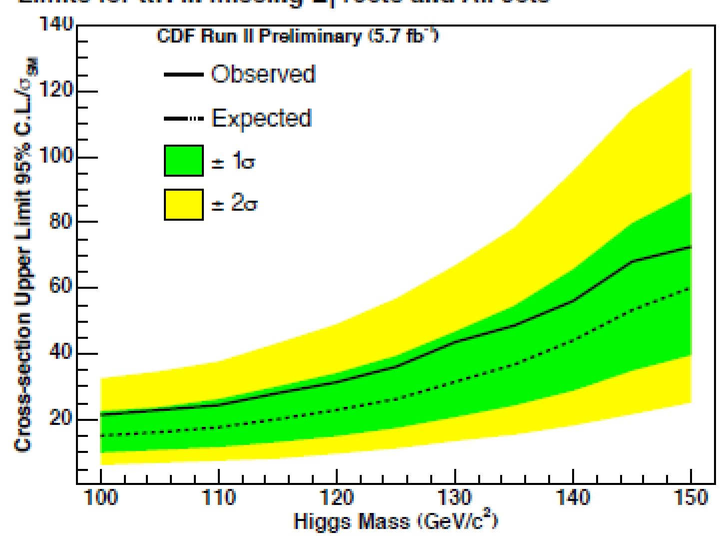
- First search of this final state
  - ❖ Publication is in preparation

All jets signal region (3-tag)

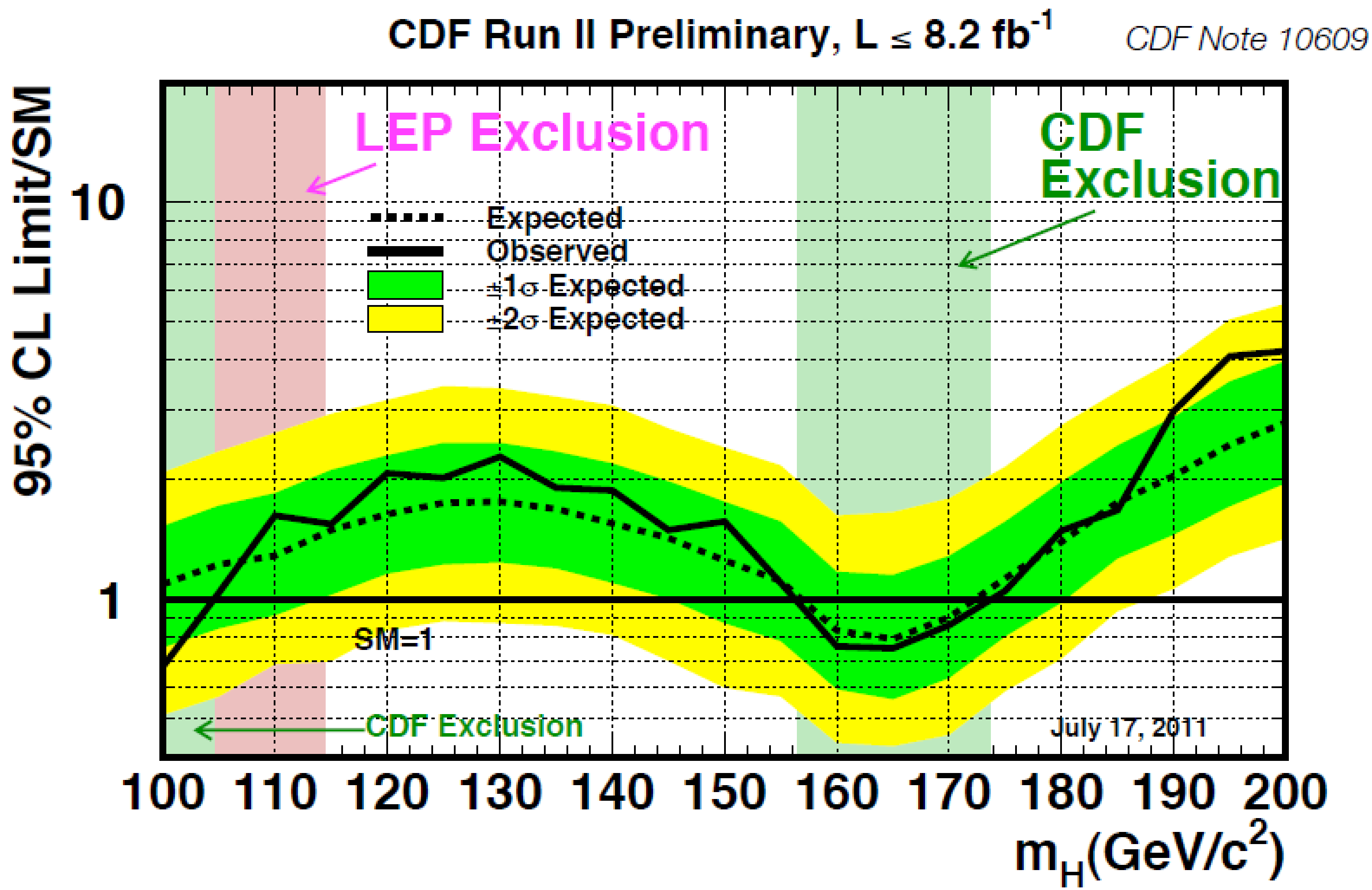
CDF Note 10582



Limits for $t\bar{t}H$ in missing E_T+Jets and All Jets



CDF combination of Higgs boson limit



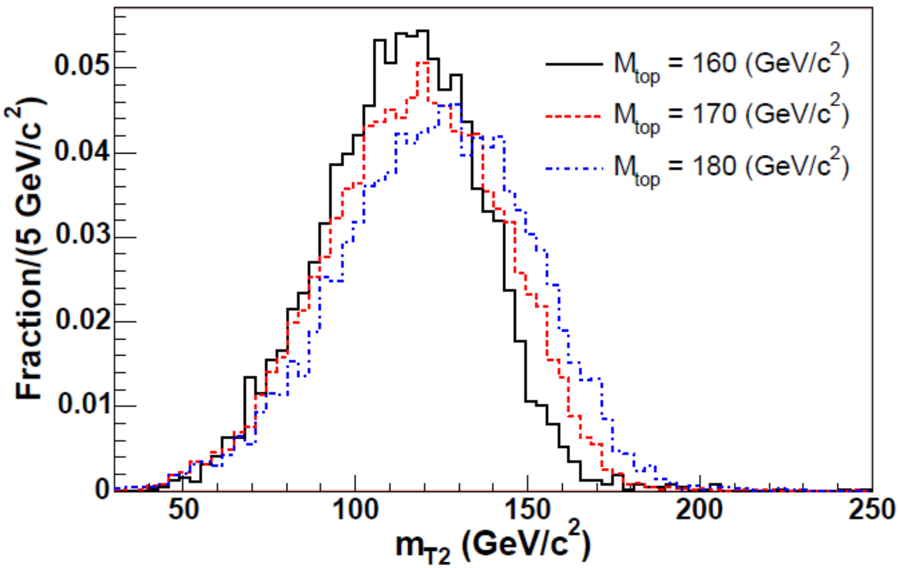
- Our result was included in this combination

Systematics uncertainty

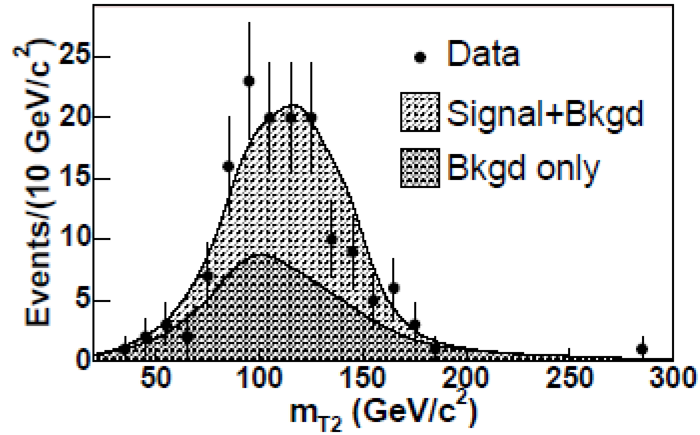
CDF II Preliminary 5.6 fb^{-1}	
Systematic	Result (GeV/c^2)
Signal Modeling	0.7
JES	0.2
PDFs	0.1
b jet energy	0.1
$b/\bar{b}$ asymmetry	0.3
Background shape	0.2
gg fraction	0.1
Radiation	0.1
MC statistics	0.1
Lepton energy	0.1
MHI	0.4
Color Reconnection	0.2
Total systematic	1.0

- Very similar way with other top properties
- Possible b/bbar(lepton/anti-lepton) difference was added

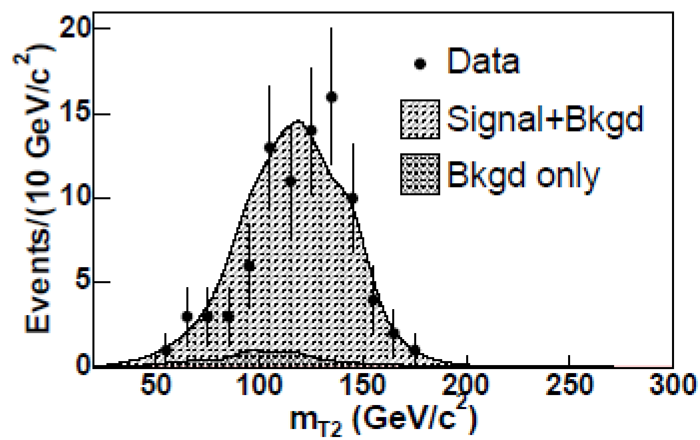
m_{T2} at dilepton channel



CDF data (3.4 fb^{-1})



non-tagged m_{T2}

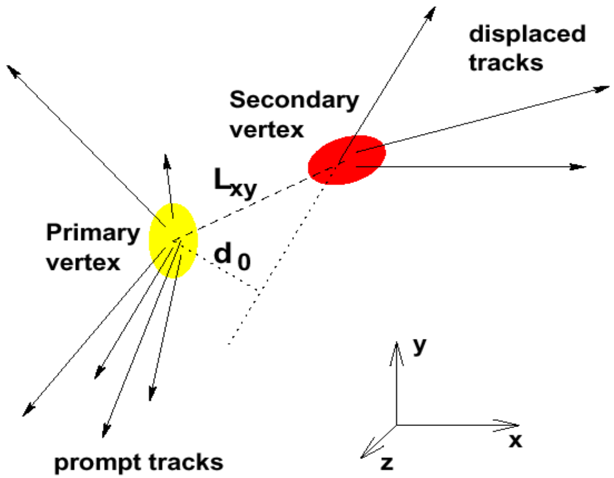


tagged m_{T2}

- m_{T2} is a quantity of missing transverse mass in two missing particle system
  - It was introduced for the mass determination of new physics particle
- We firstly use this interesting observable in real data

Phys. Rev. D 81 031102 (2010)

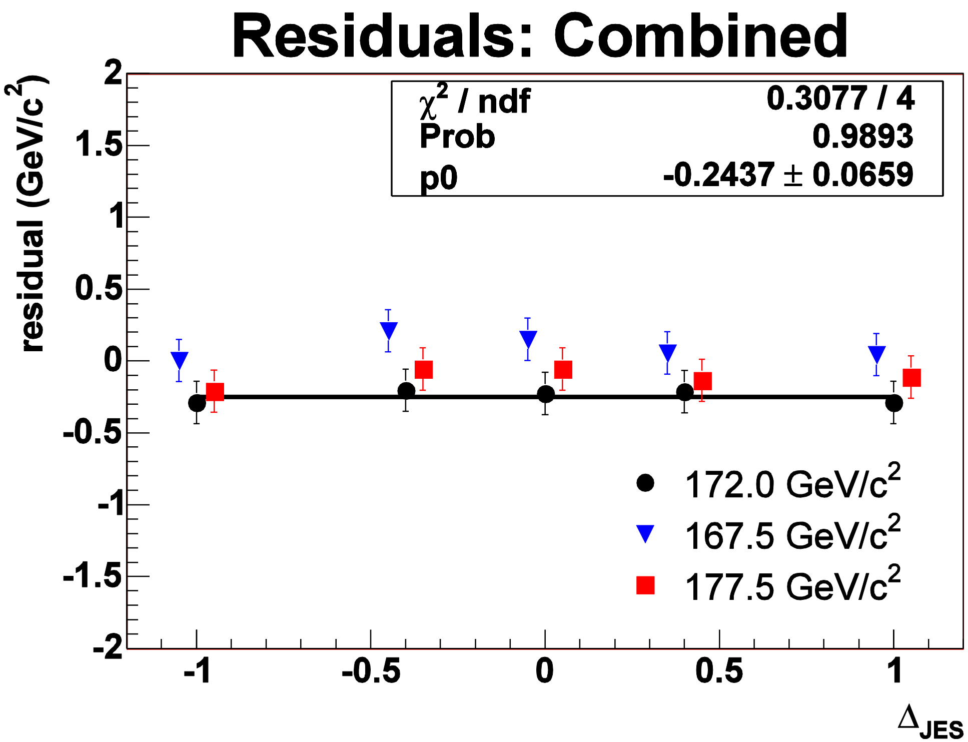
b-tagging

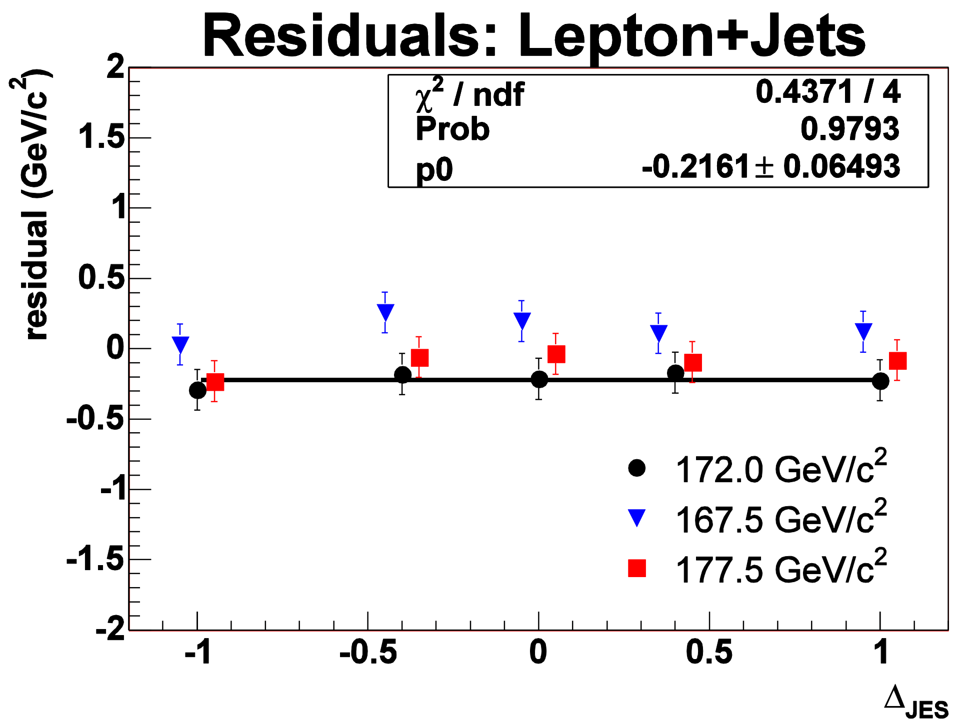


- B hadron can be identified by long displacement
- b tagging reduce # of jet-to-parton assign.
  - Ex) lepton+jets channel
  - 24 (0-btags), 6(1-btags), 2(2-btags)
- b tagging improve signal to background ratio significantly – 40% effi., 0.5% fake

Sample	Di-lepton (e,μ)	Lepton+jets (e,μ)	All Hadronic NN selection
0-b-tags S/B	1:1	1:4	1:20
1-b-tags S/B	4:1	4:1	1:5
2-b-tags S/B	20:1	20:1	1:1
Events in 1 fb^{-1} ($\geq$ 1 b-tag)	25	180	150 (2 b-tags)

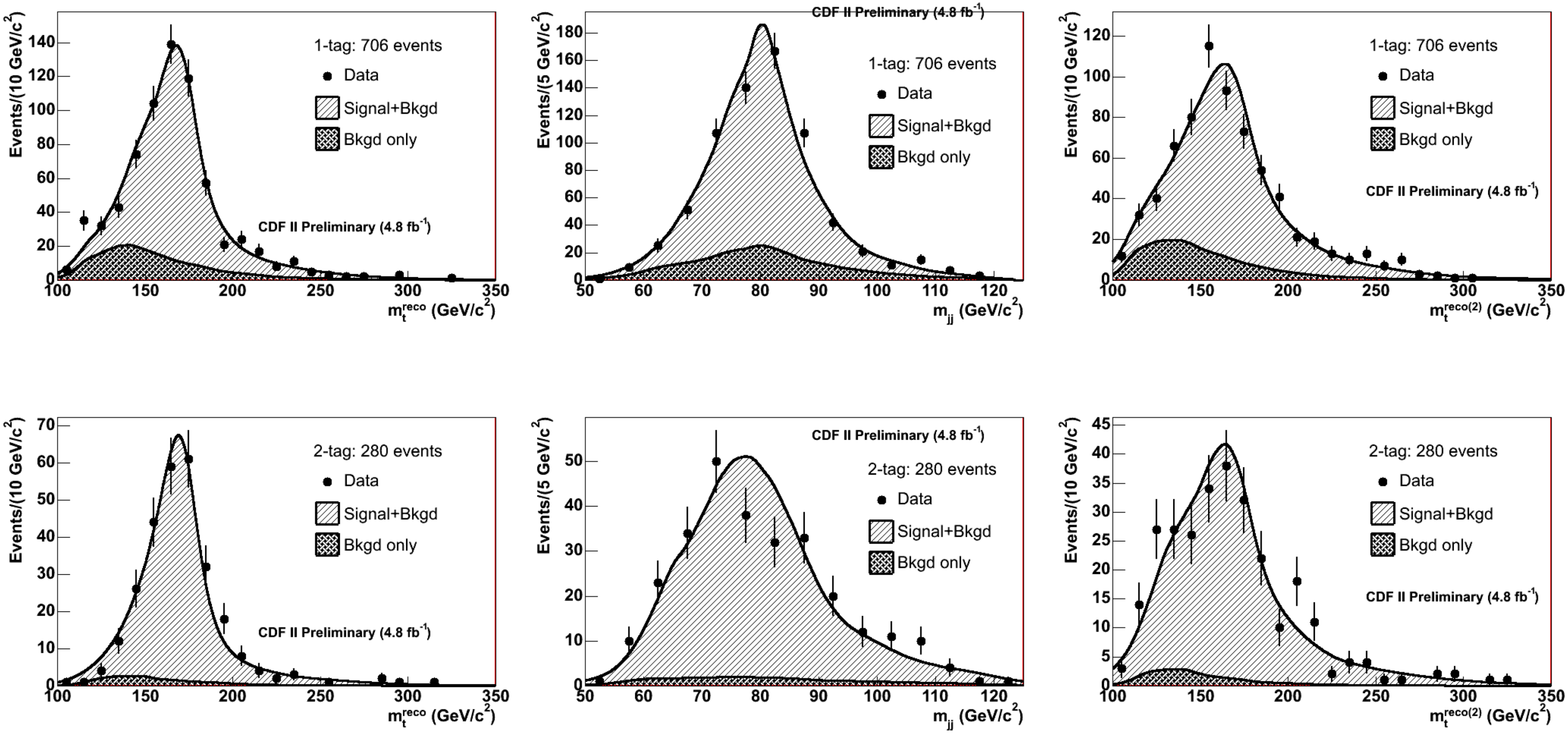
Residual on JES



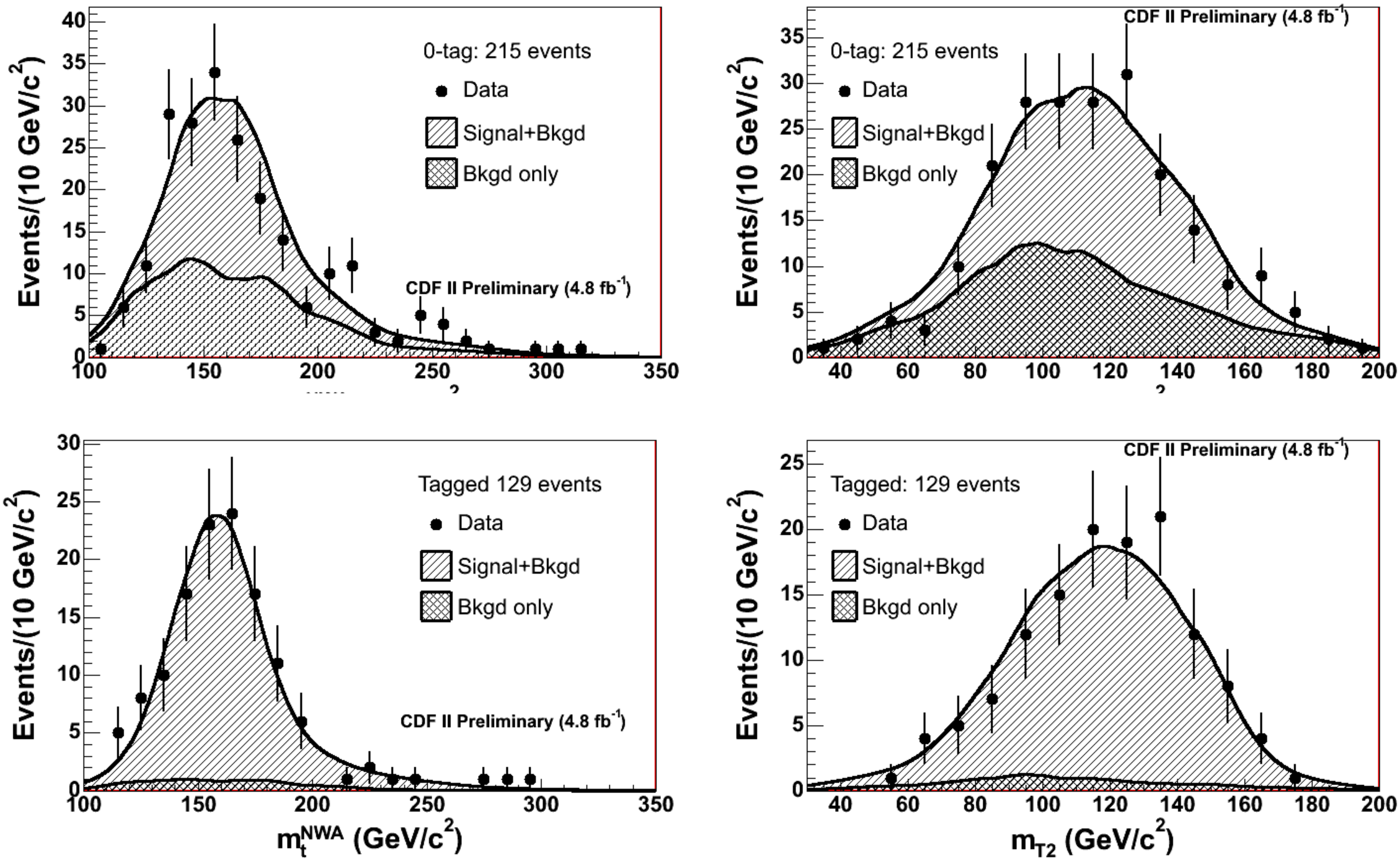


No significant shape on residual

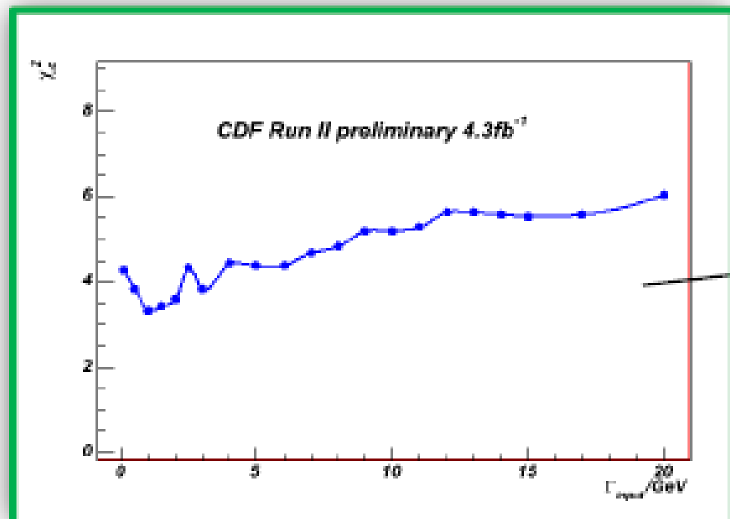
Data and Fit (LJ)

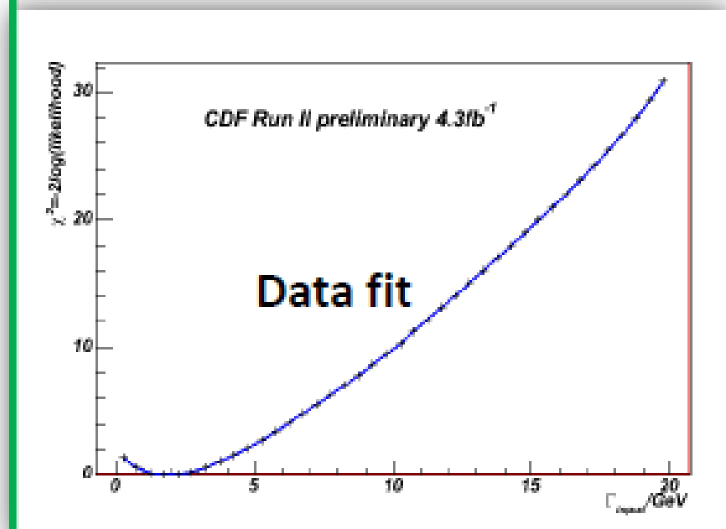


Data and Fit (DIL)



Feldman-Cousins method



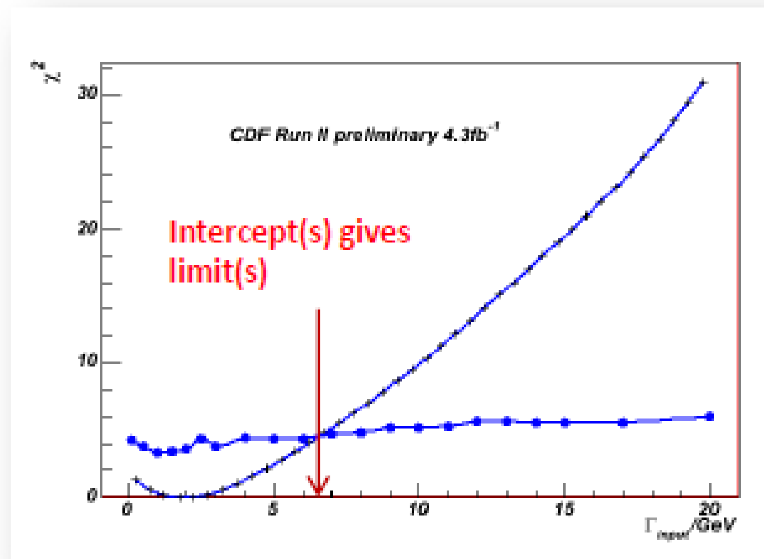


overlap

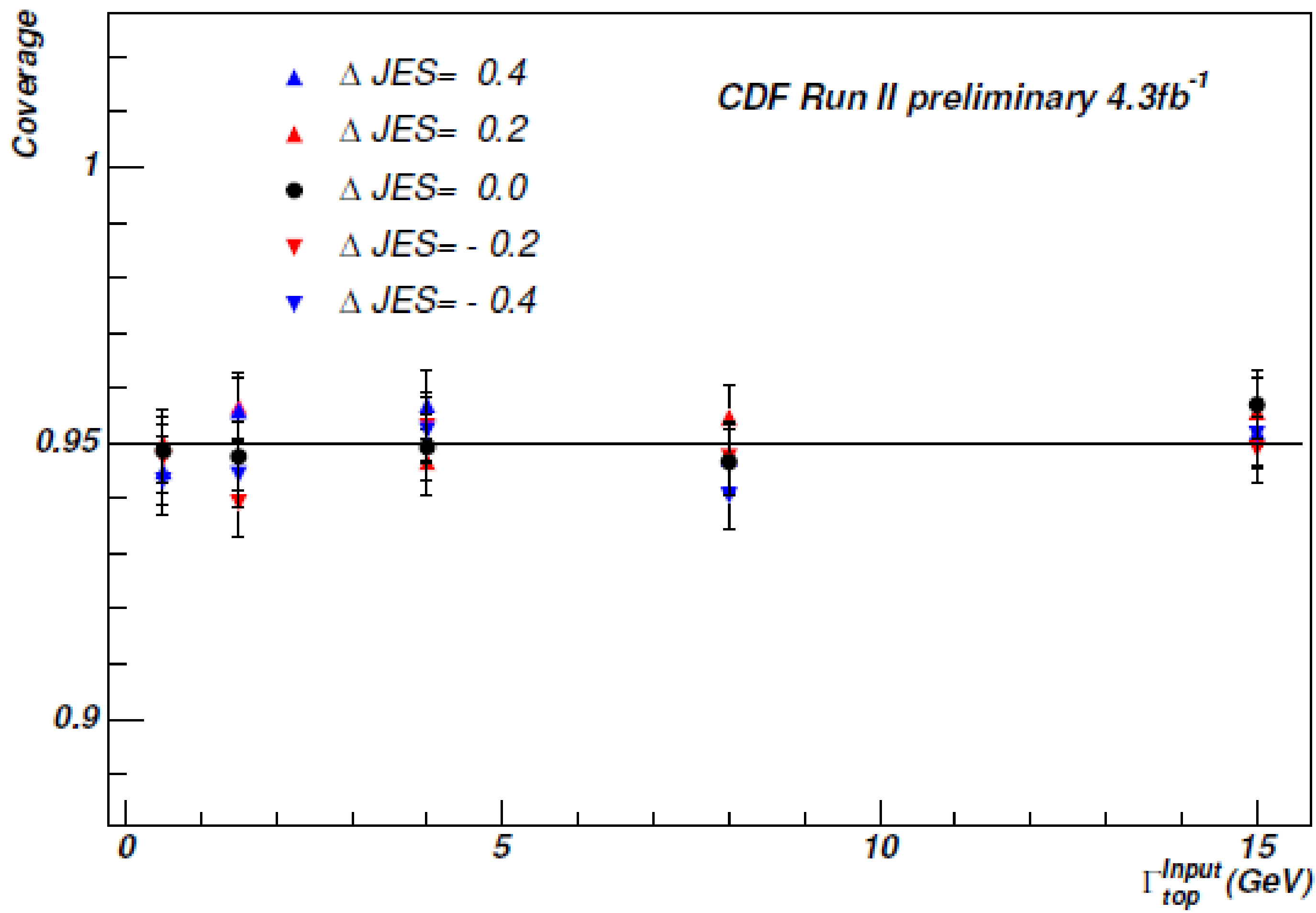
- *"ordering principle "* $\Delta\chi^2$

χ^2= -2 Log(Likelihood)

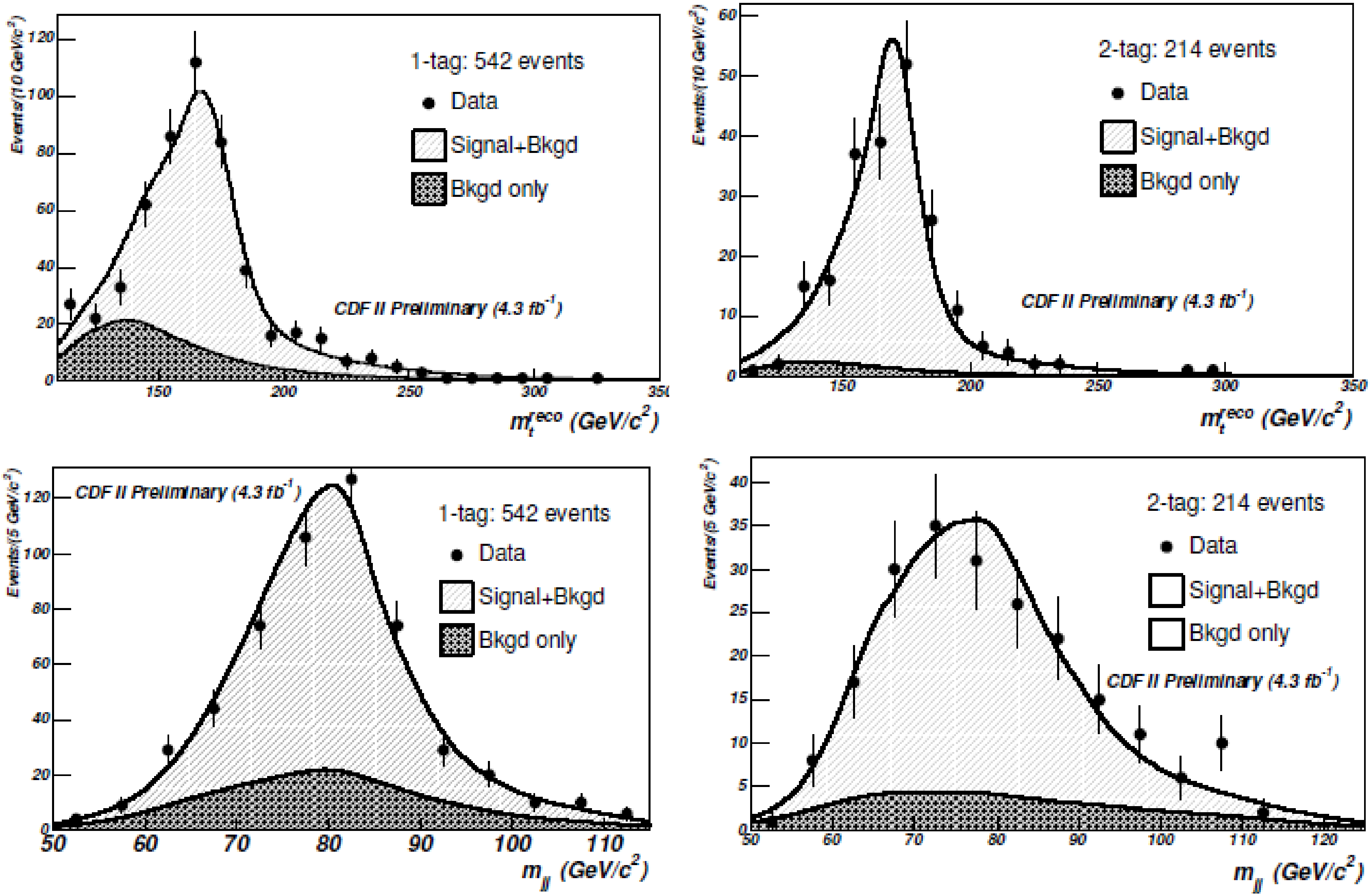
- Each MC sample generates a $\Delta\chi_c^2$
- plot $\Delta\chi_c^2$ **vs true Γ**
- Overlap with data fit



Coverage with different JES

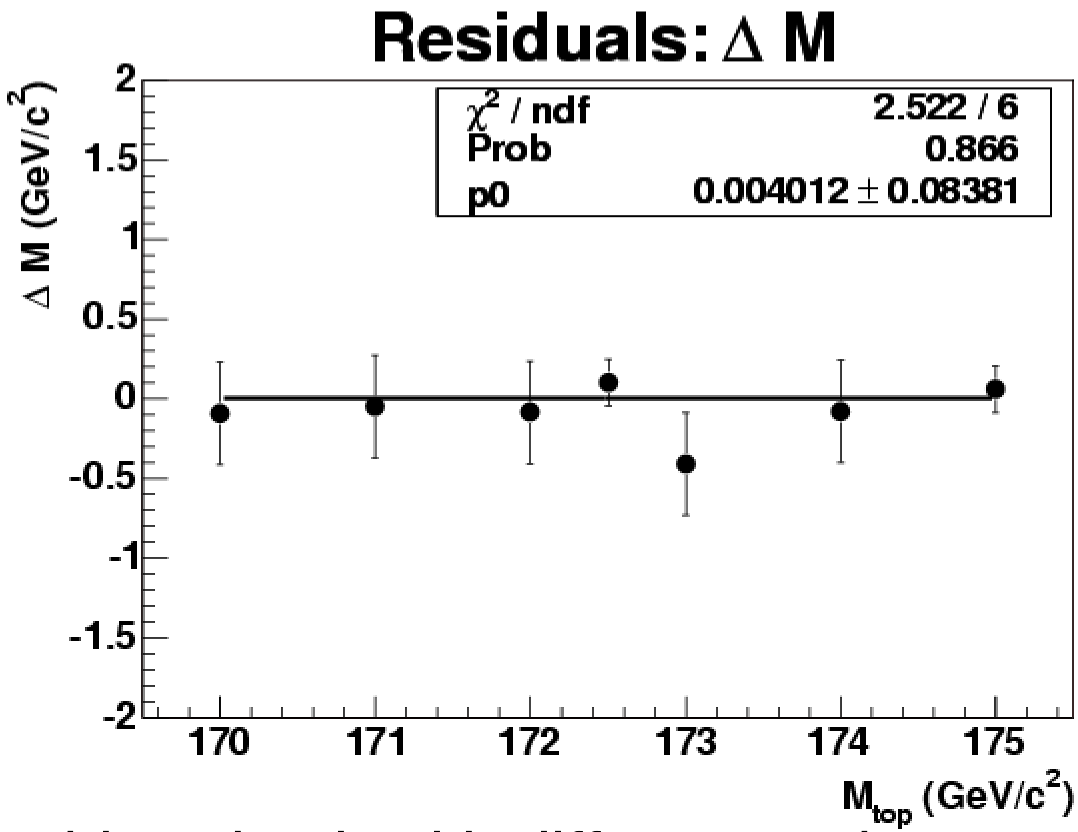


Data fit



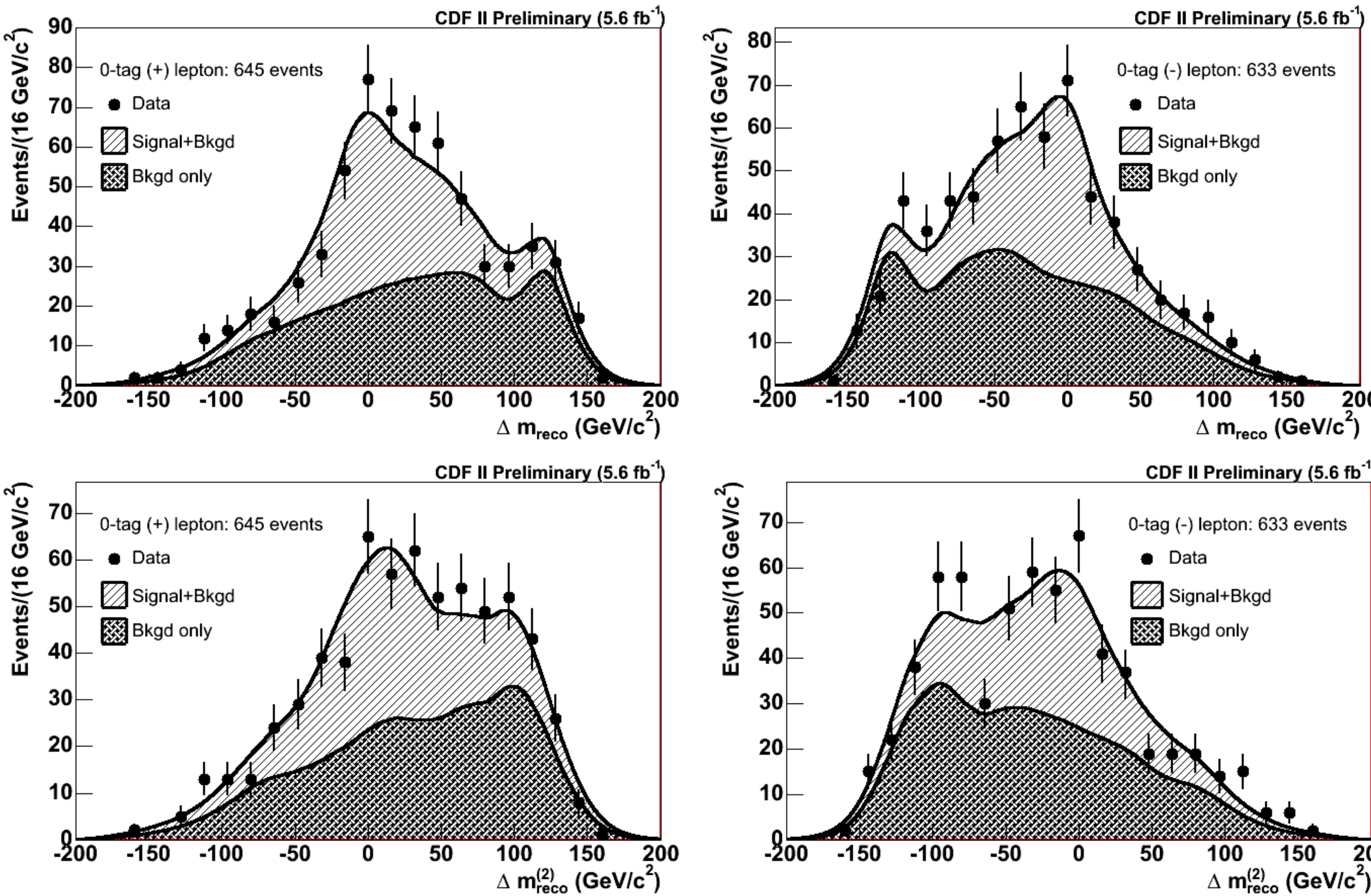
1-tag: 542 events
Data
Signal+Bkgd
Bkgd only
CDF II Preliminary (4.3 fb^{-1})
Events/(10 GeV/c^2)
m_t^{reco} (GeV/c^2)
2-tag: 214 events
Data
Signal+Bkgd
Bkgd only
CDF II Preliminary (4.3 fb^{-1})
Events/(10 GeV/c^2)
m_t^{reco} (GeV/c^2)
CDF II Preliminary (4.3 fb^{-1})
1-tag: 542 events
Data
Signal+Bkgd
Bkgd only
Events/(5 GeV/c^2)
m_{jj} (GeV/c^2)
2-tag: 214 events
Data
Signal+Bkgd
Bkgd only
CDF II Preliminary (4.3 fb^{-1})
Events/(5 GeV/c^2)
m_{jj} (GeV/c^2)

Truth mass dependence

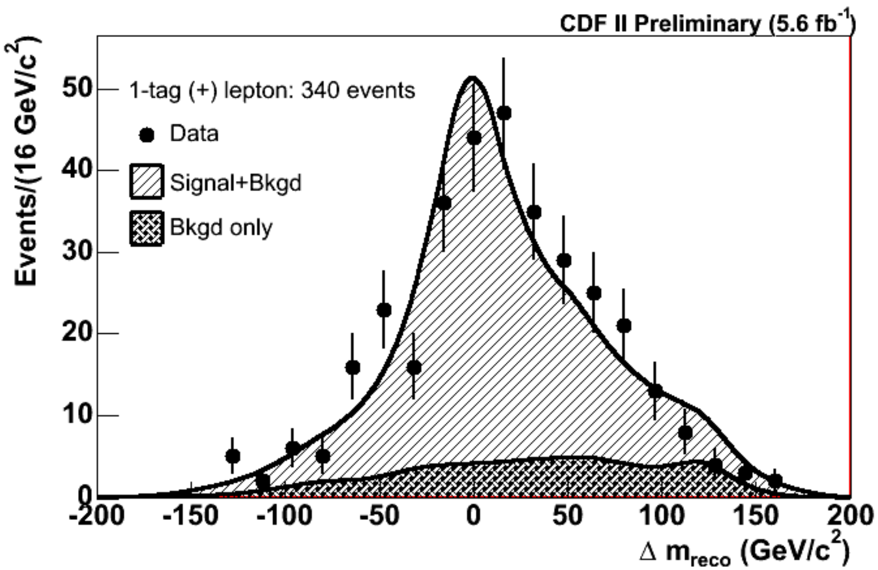


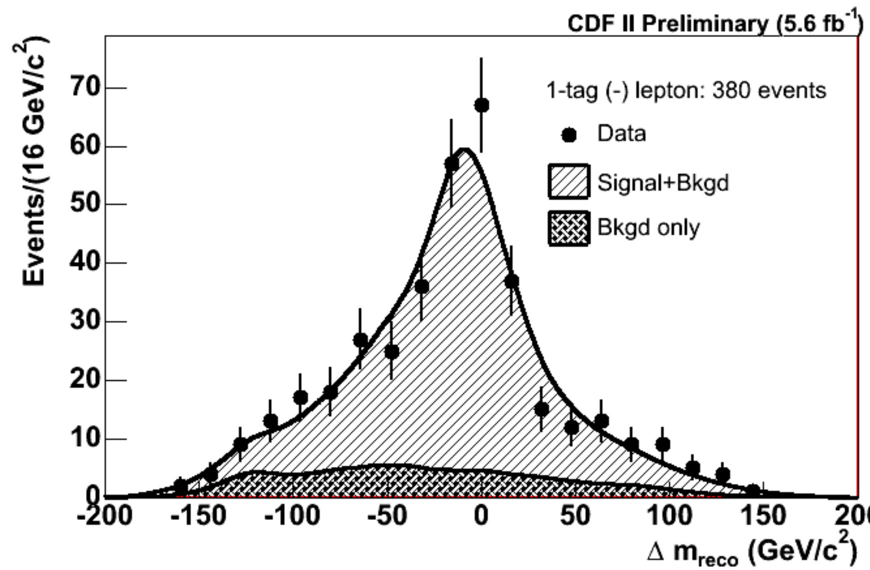
- We perform bias check with different truth top quark mass with ΔM_{top} = 0 GeV/c^2

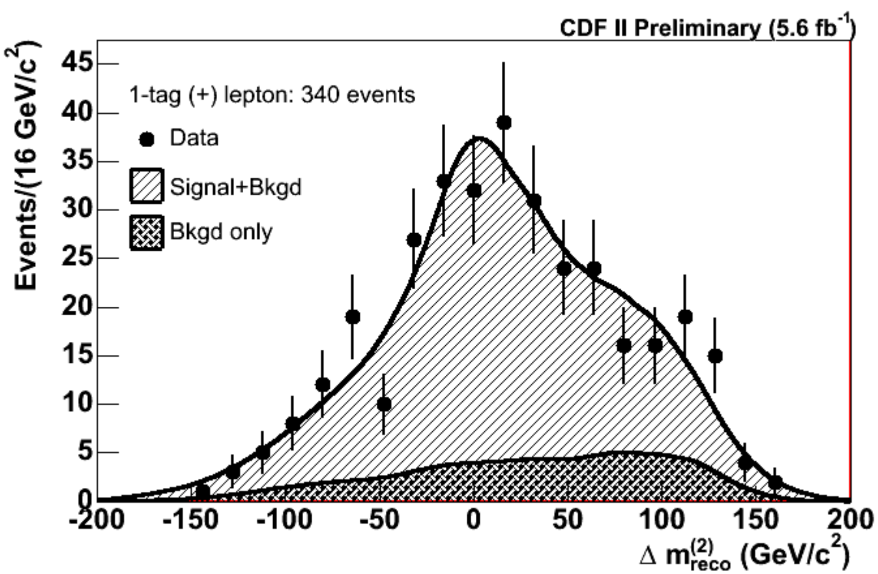
0tag : Data distribution

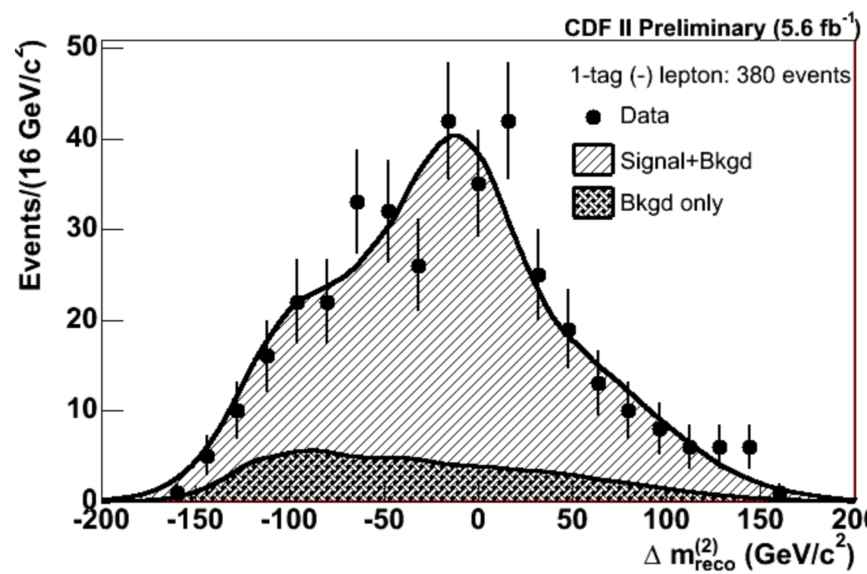


1tag : Data distribution

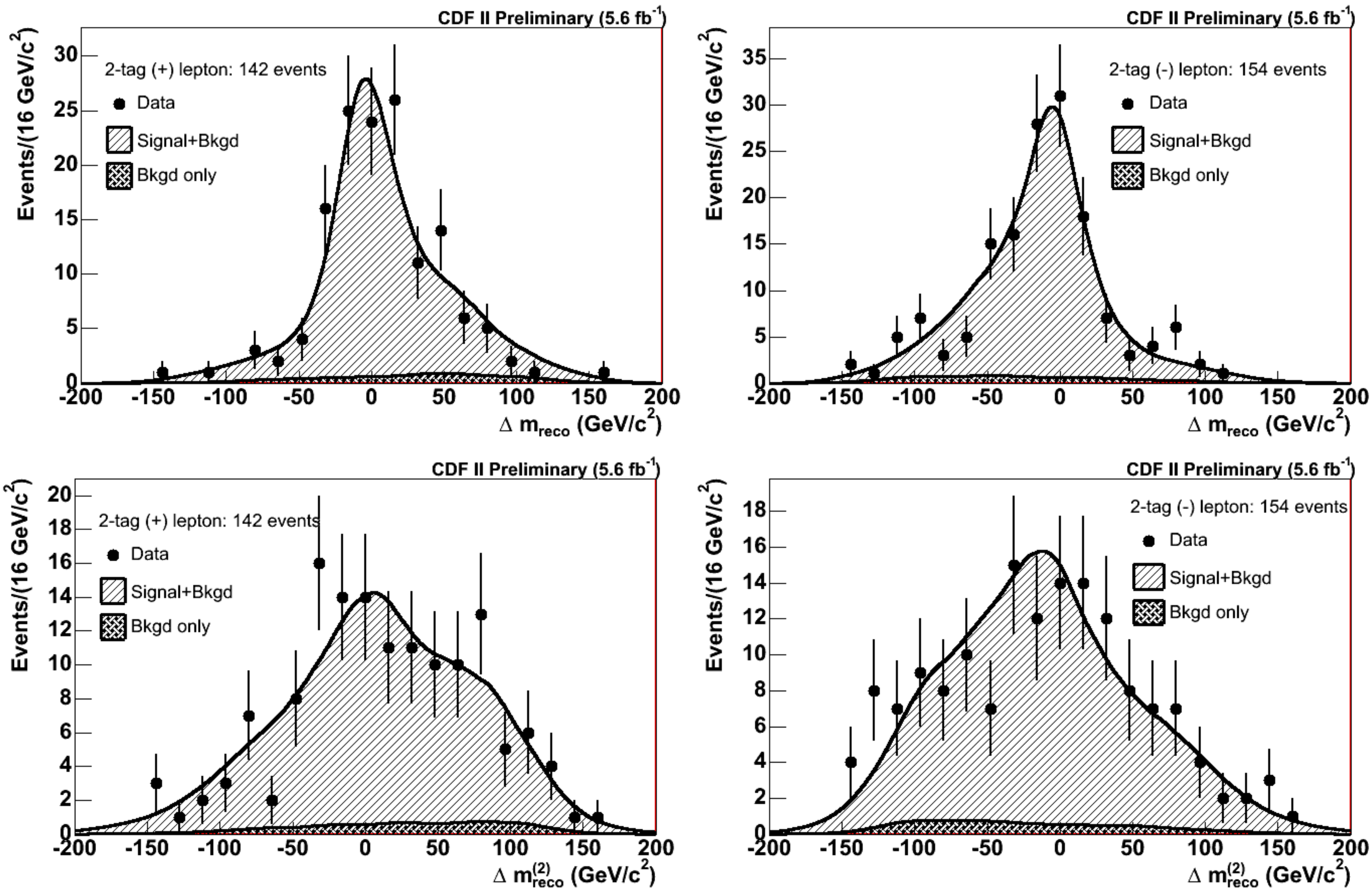






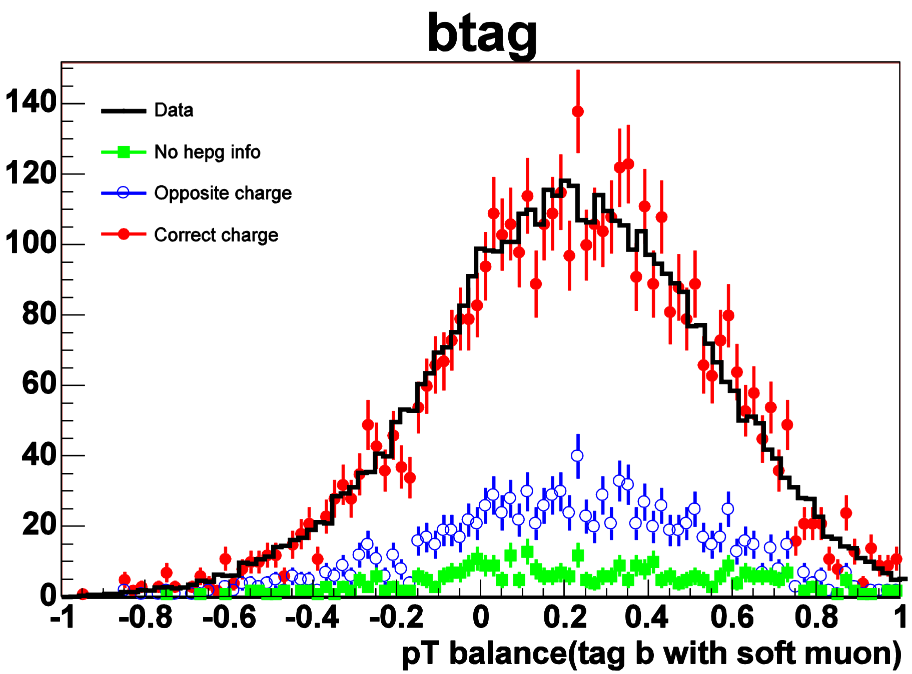


2tag : Data distribution

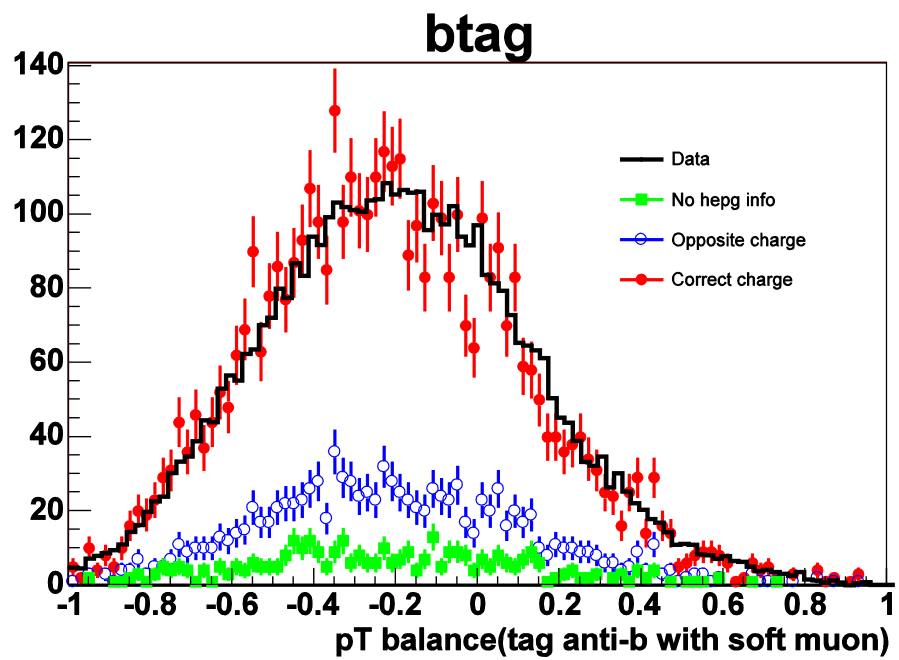


pT balances and assigning systematics

Tag b using soft muon



Tag anti- b



Good agreement between data and MC
Averaged deviation = -0.44 +-0.40%
If we consider anti-tagged(~20%) events, we can assign 0.73% deviation as systematic

B-tagging check for each flavor

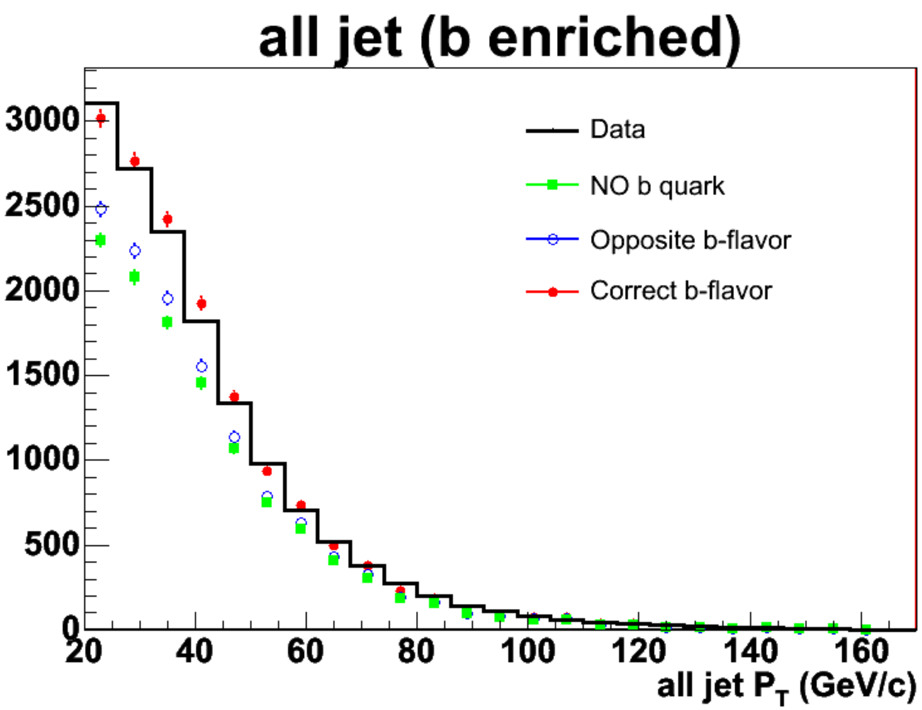
- Use dijet sample from low pt muon triggered data and MC (We require exactly two tight jet in offline)

Tagged jet : SECVTEX tag + soft muon tag

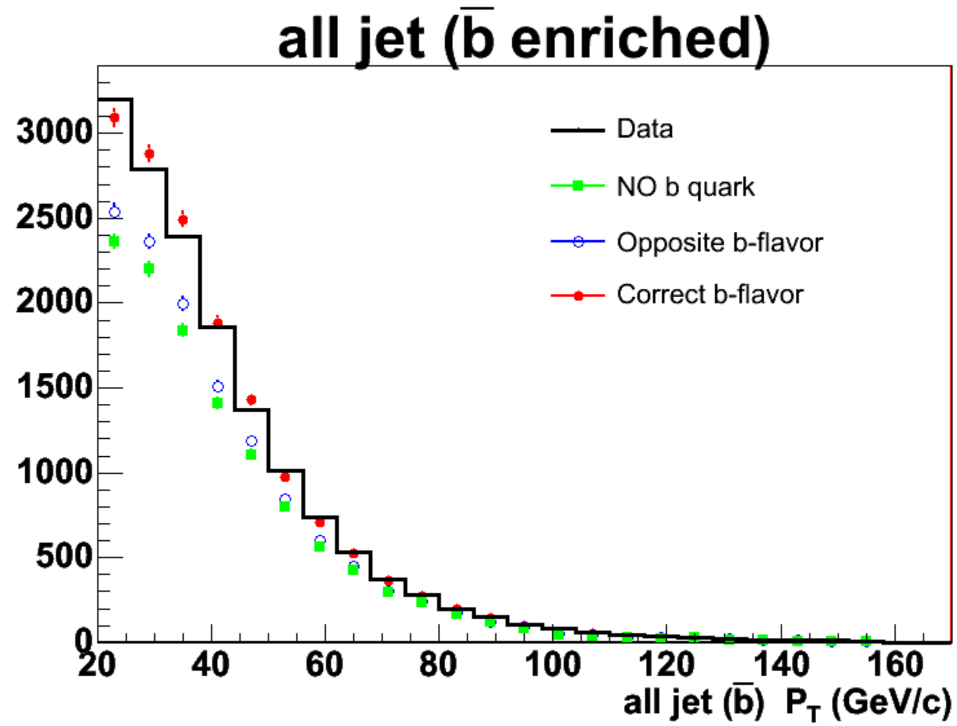
Away jet : jet PT>20GeV

- Depending on charge of soft muon, we can have b or anti b enriched samples

pT distribution of away jets

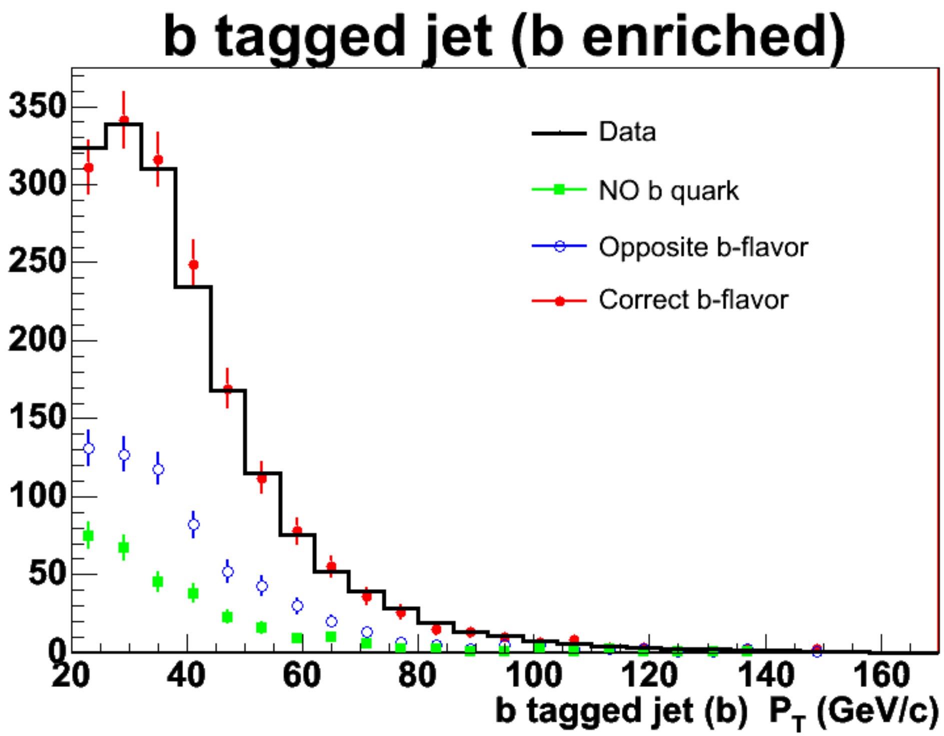


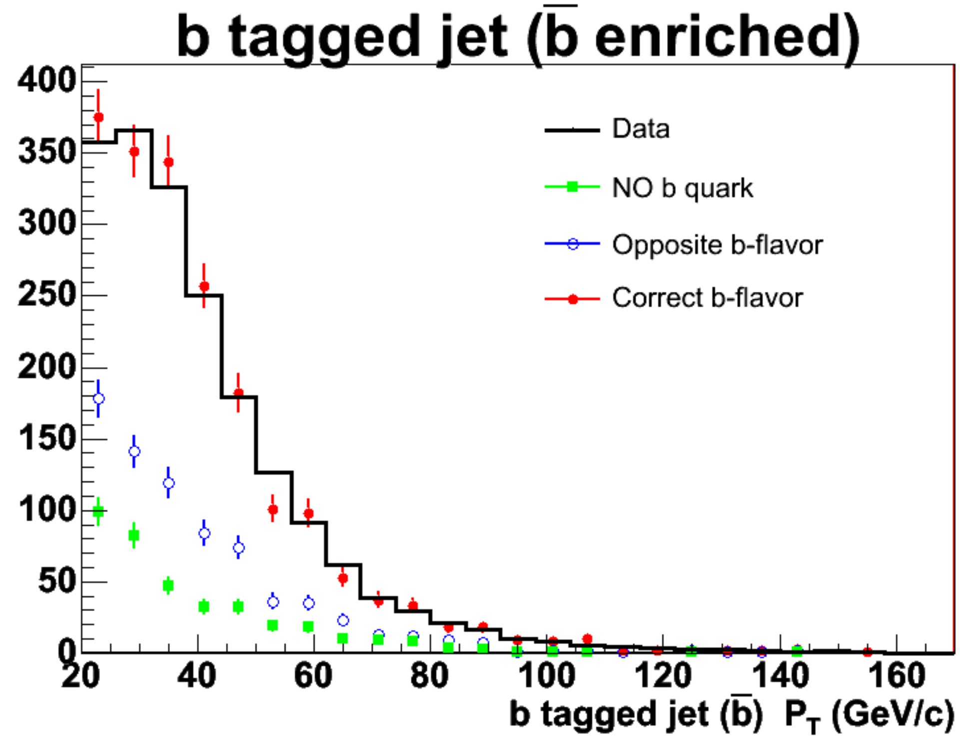
- b : 18%
- Anti b : 5%
- LF : 77%



- Anti b : 17%
- b : 5%
- LF : 77%

pT distribution of away b-jets(btagging)

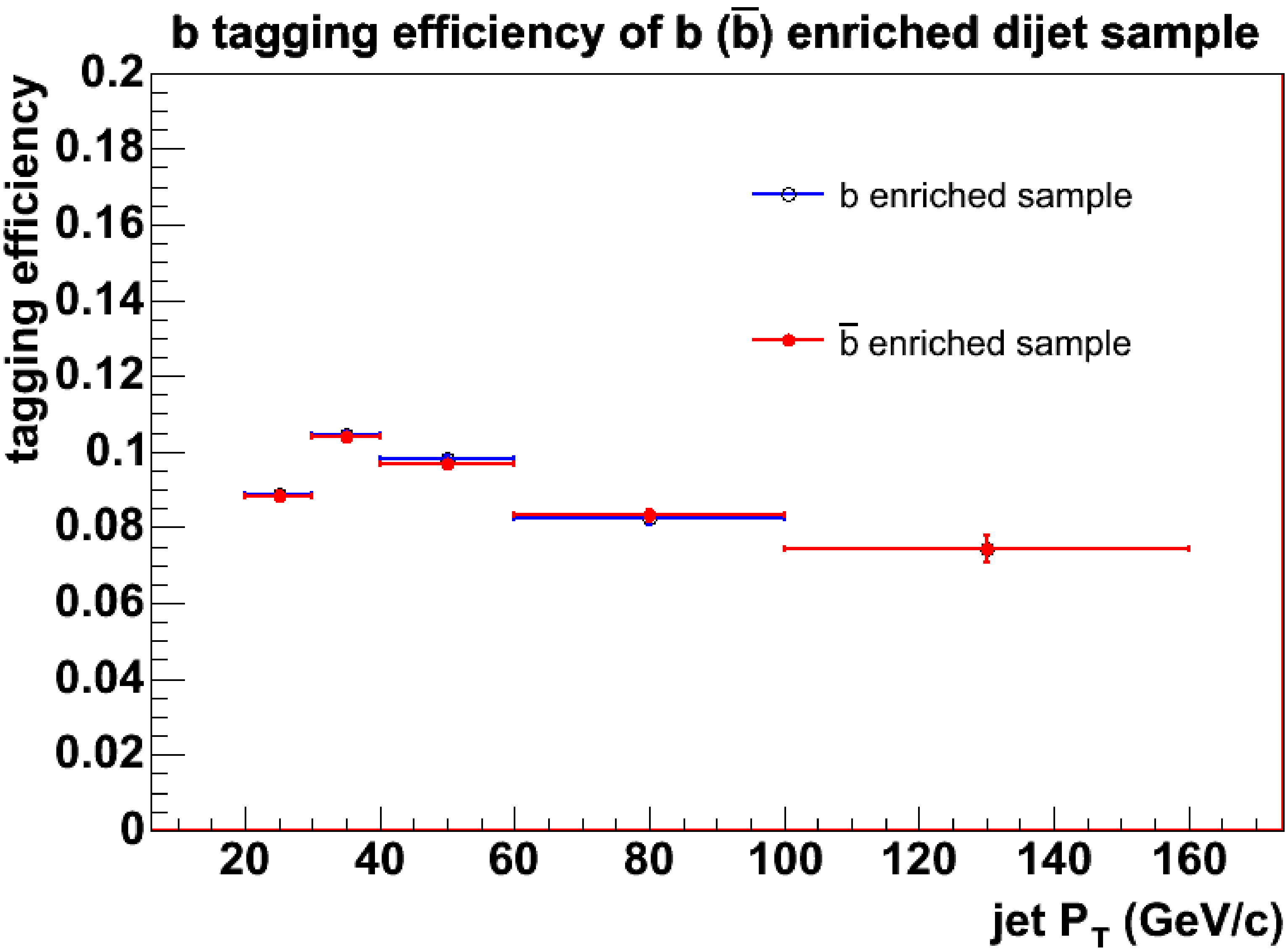




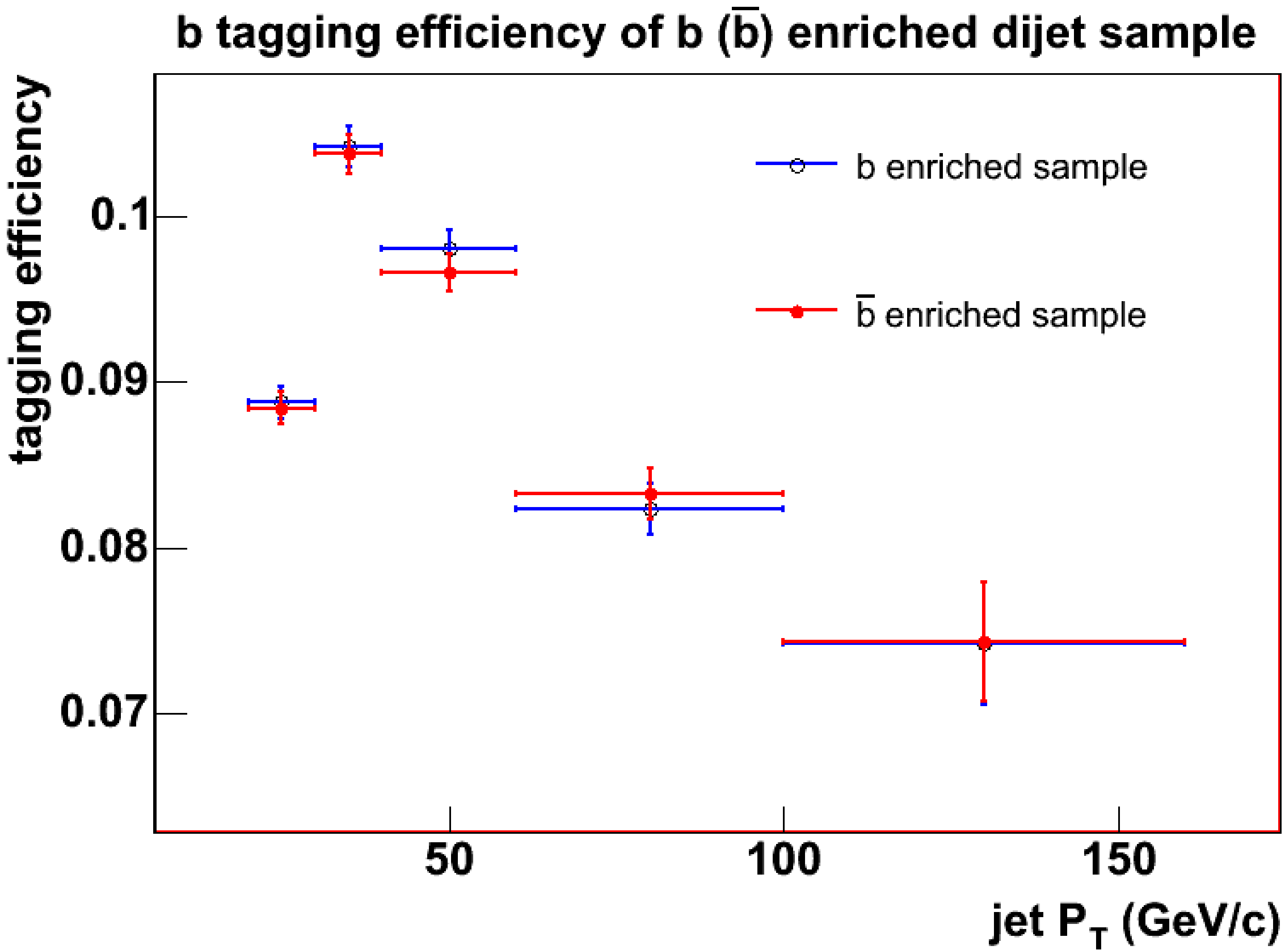
- b : 63(+-3)%
- Anti b : 20(+-2)%
- LF : 17(+-2)%

- Anti b : 61(+-3)%
- b : 20(+-2)%
- LF : 19(+-2)%

B tagging efficiency comparison for two samples



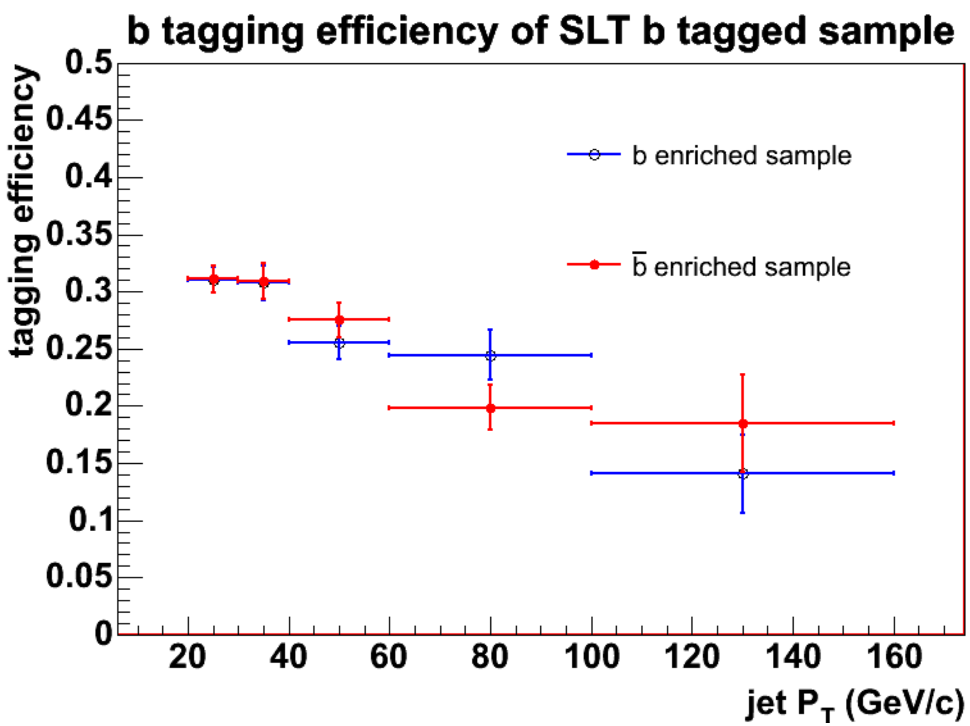
Zoomed plot


b tagging efficiency of b ($\bar{b}$) enriched dijet sample
tagging efficiency
0.1
0.09
0.08
0.07
50
100
150
jet P_T (GeV/c)
b enriched sample
$\bar{b}$ enriched sample

More pure samples

Tagged jet : SECVTEX tag + soft muon tag

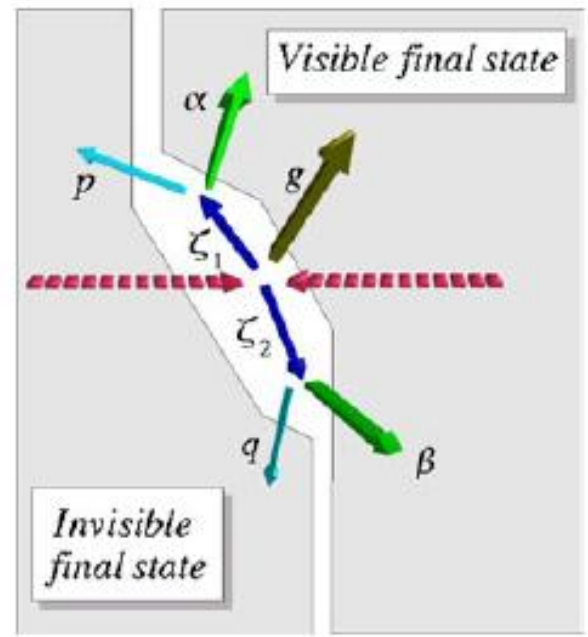
Away jet : jet PT>20GeV+soft muon tag



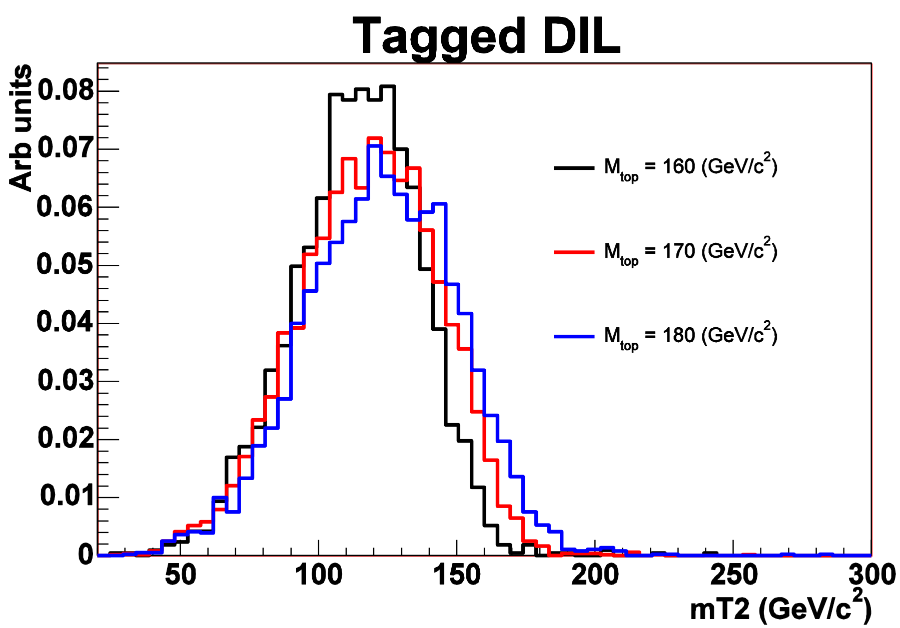
- ~60% of correct b events without b-tagging but low statistics
- Generally good in agreement

m_{T2} in dilepton channel (3.4 fb^{-1})

- m_{T2} was introduced for mass determination of new physics particle pair productions
- We use it as 2nd observable and improve ~15% statistical uncertainty

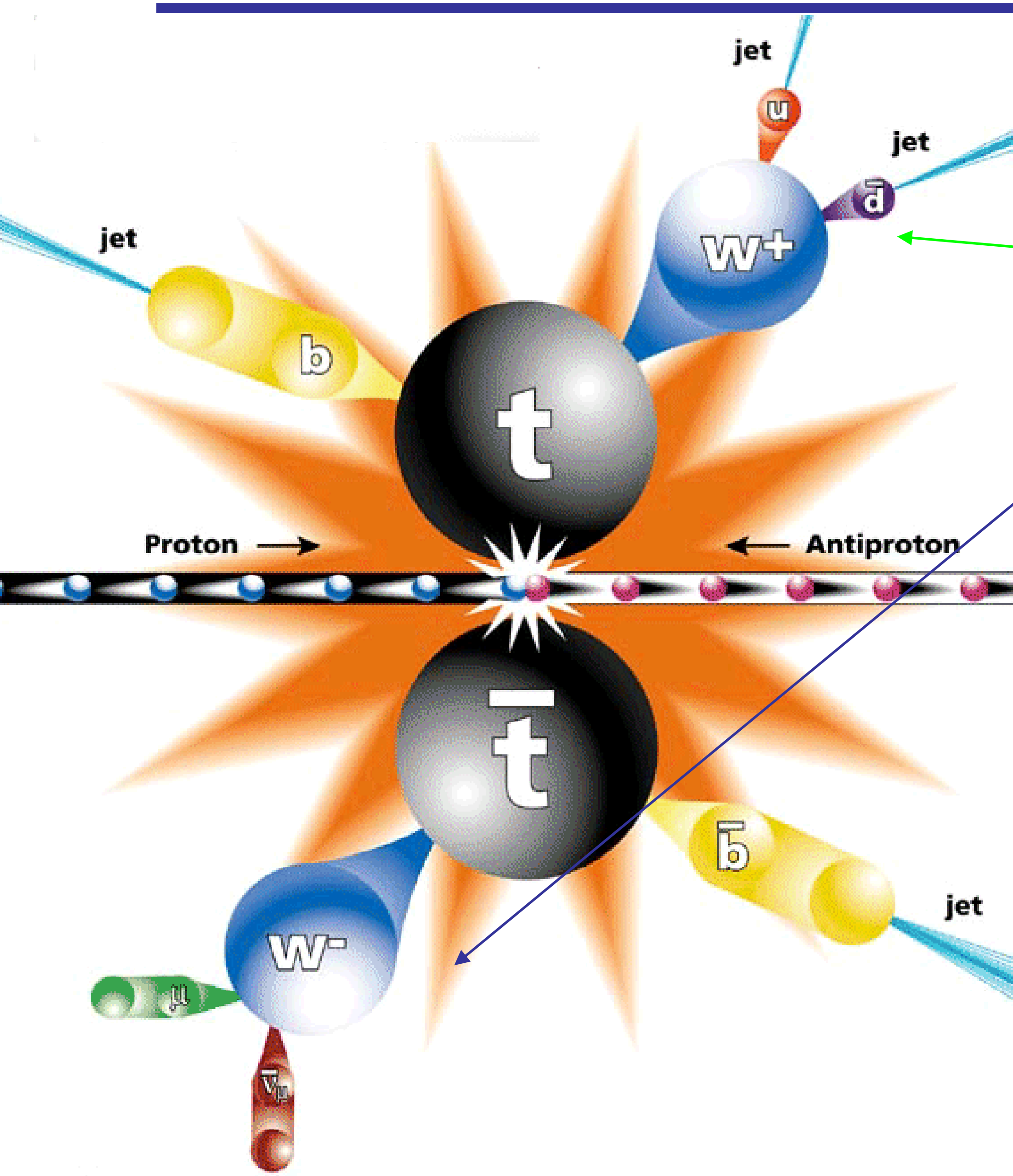


$$m_{T2} = \min[\max(m_{T(1)}, m_{T(2)})]$$
$$q_T + p_T = \text{missing } p_T$$



- We use m_{T2} first time in data (3.4 fb^{-1})
  - ❖ Phys.Rev.D 81 (2010) 031102

Top quark Production and decay



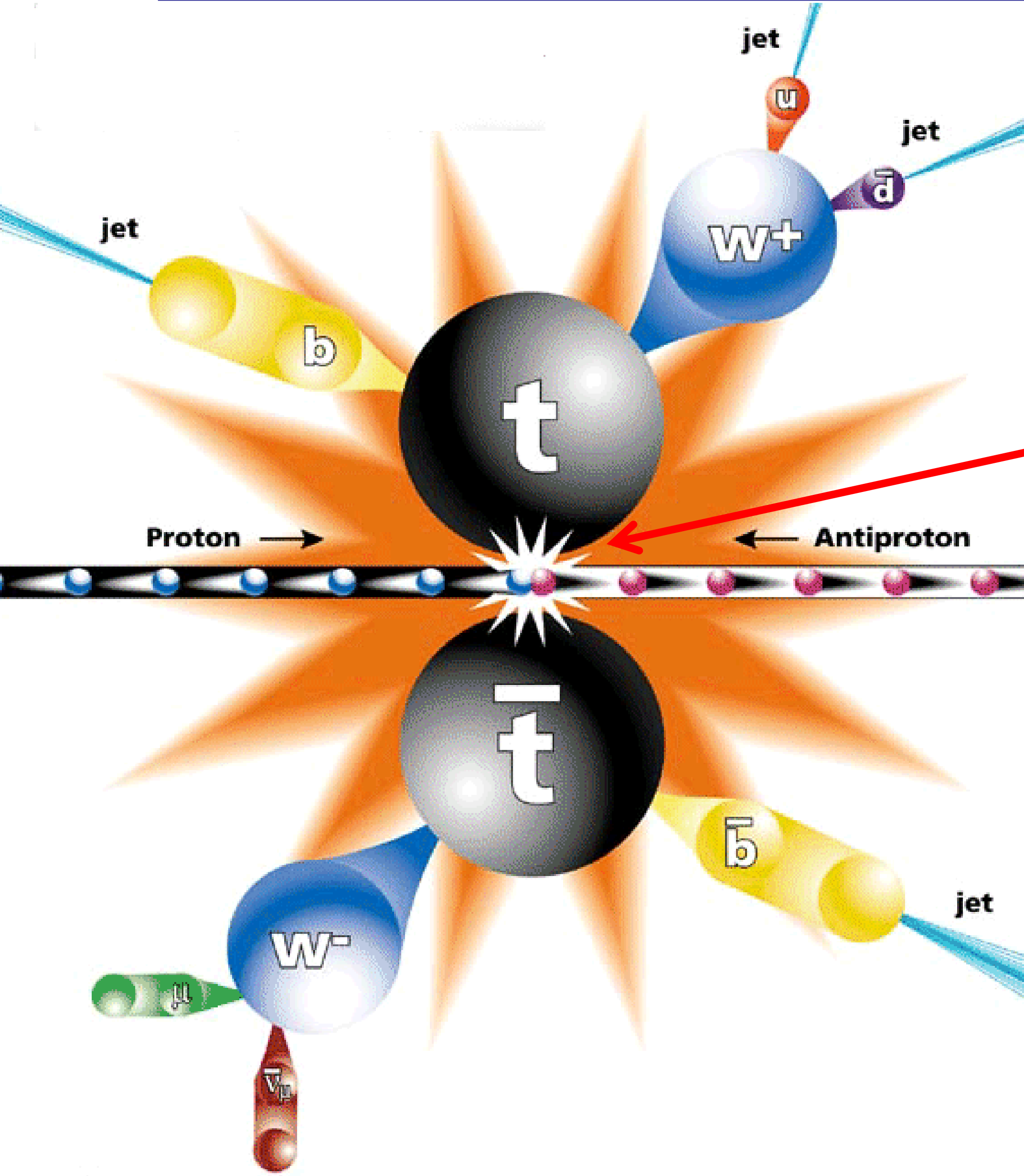
- Tops always decay via t->Wb
- Event topology then depends on W decays
  - Hadronic (quarks)
  - Leptonic (electron or muon + neutrino)

All Jets channle (44%)
6jets

Lepton+Jets channel(30%)
4 quarks, 1 charged lepton + undetected neutrino

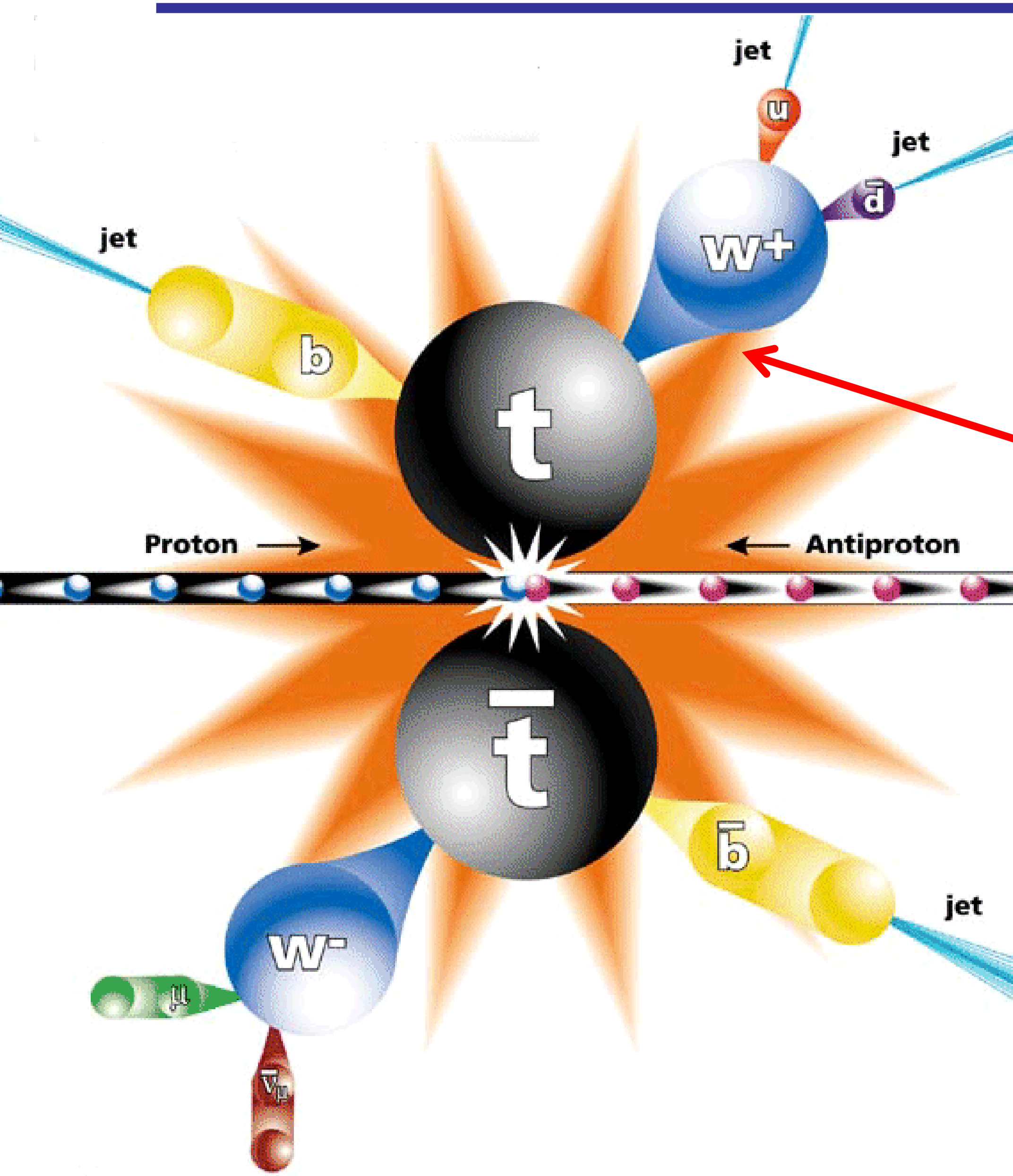
Dilepton(5%)
- Both W decay to leptons
- Signature = 2b quarks, 2 charge lepton+2 undetected

Top quark study (Production)



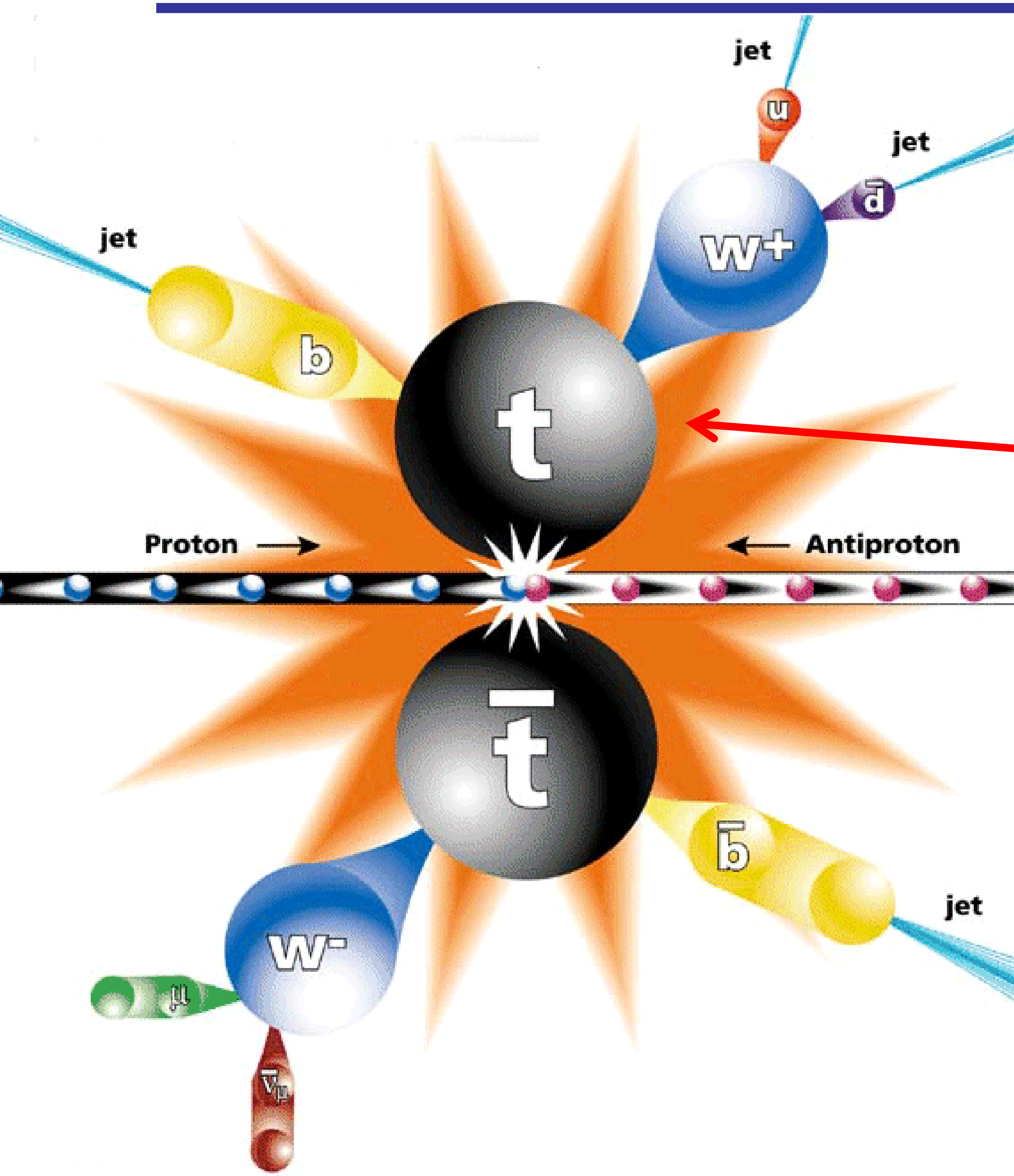
- Production Cross Section
- Production Mechanism
- Forward-Backward Asymmetry
- Resonance Production
- Spin Correlation

Top quark study (Decay)



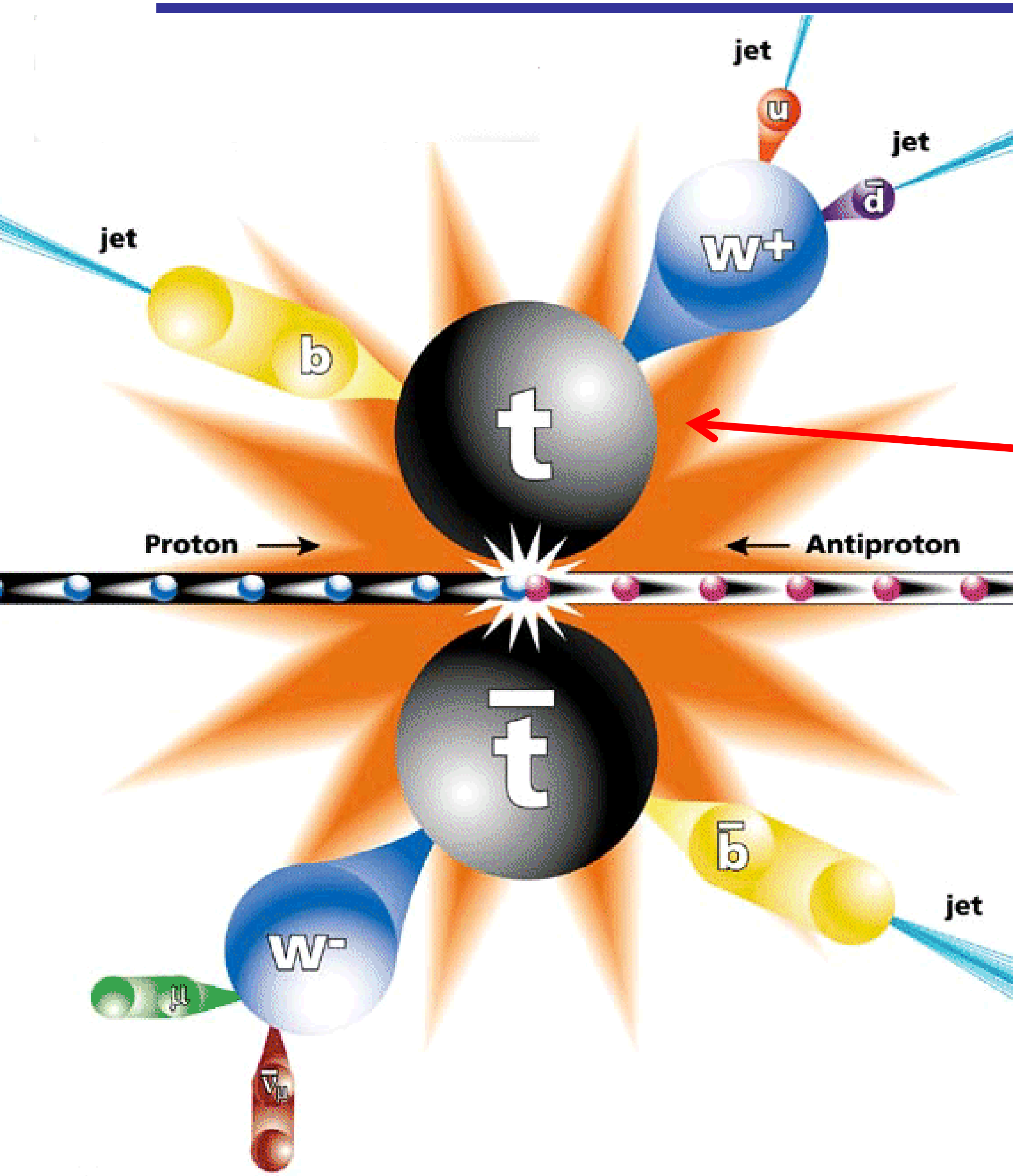
FCNC ?
Charged Higgs ?
Branching fraction of b

Top quark study (Search)



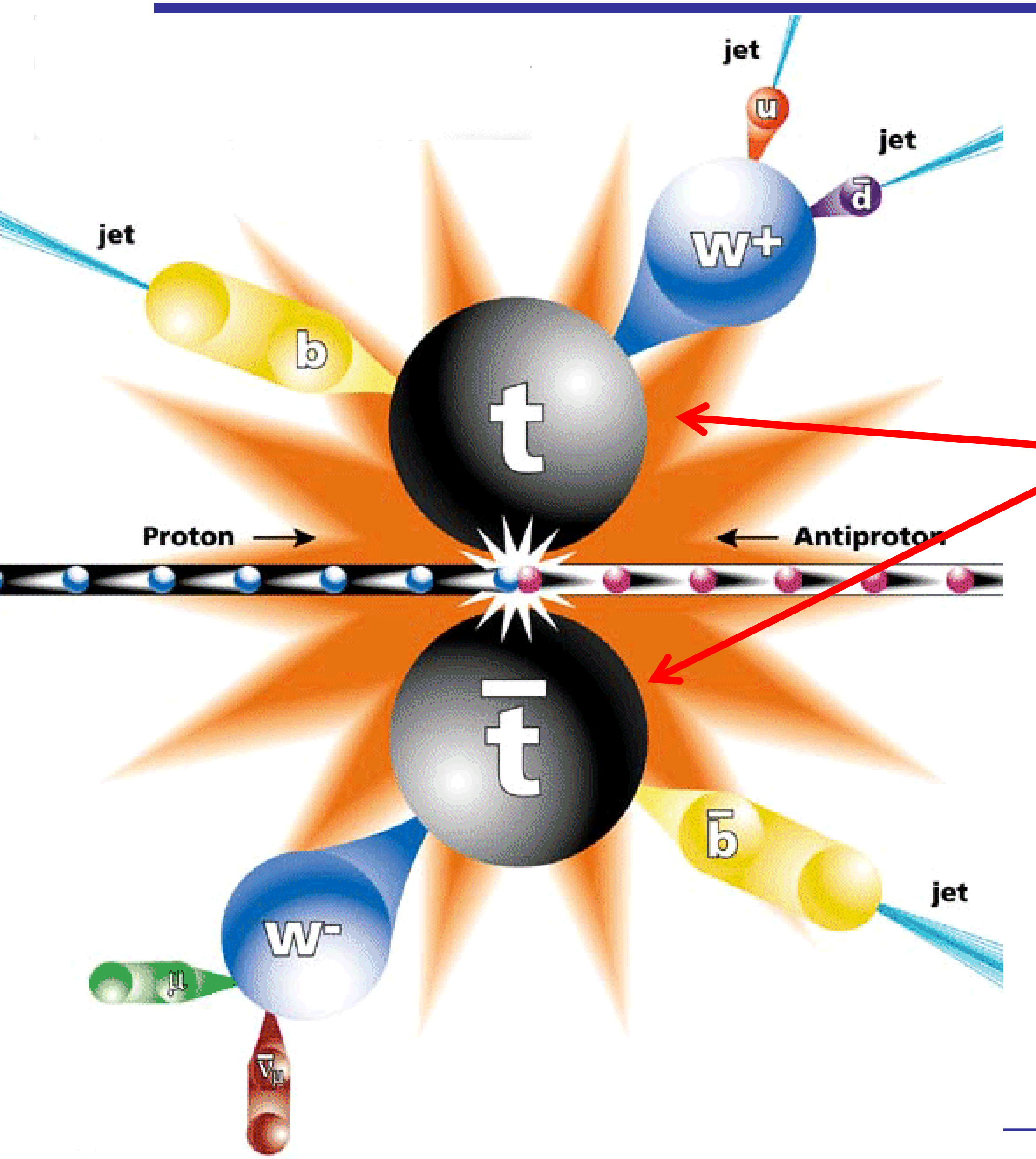
Forth generation ?
SUSY particle ?

Top quark study (Properties)



Mass
Width
Charge

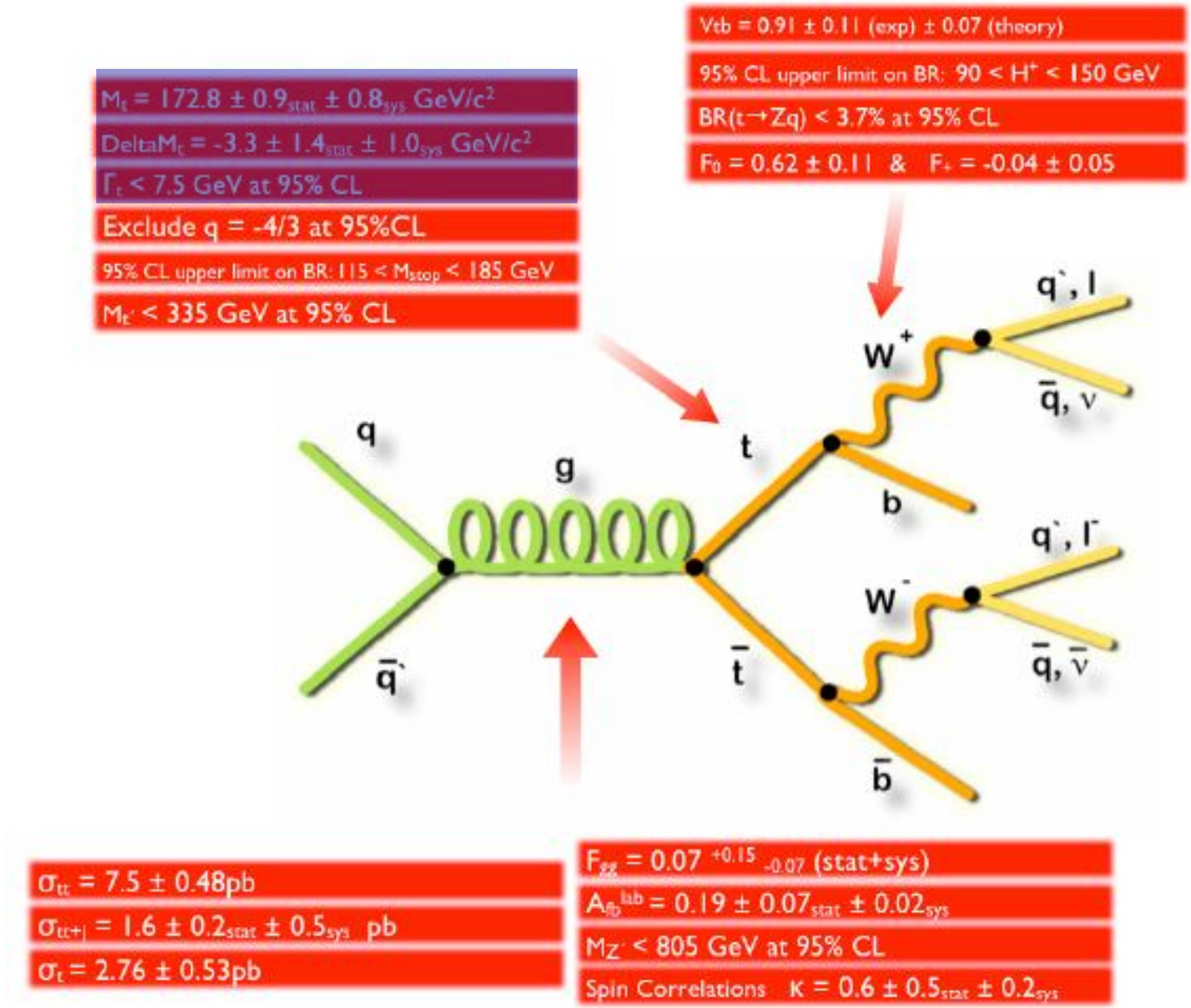
Top quark study



Same mass?

Where we stand (CDF) now

- Today's topic
  (my analysis)



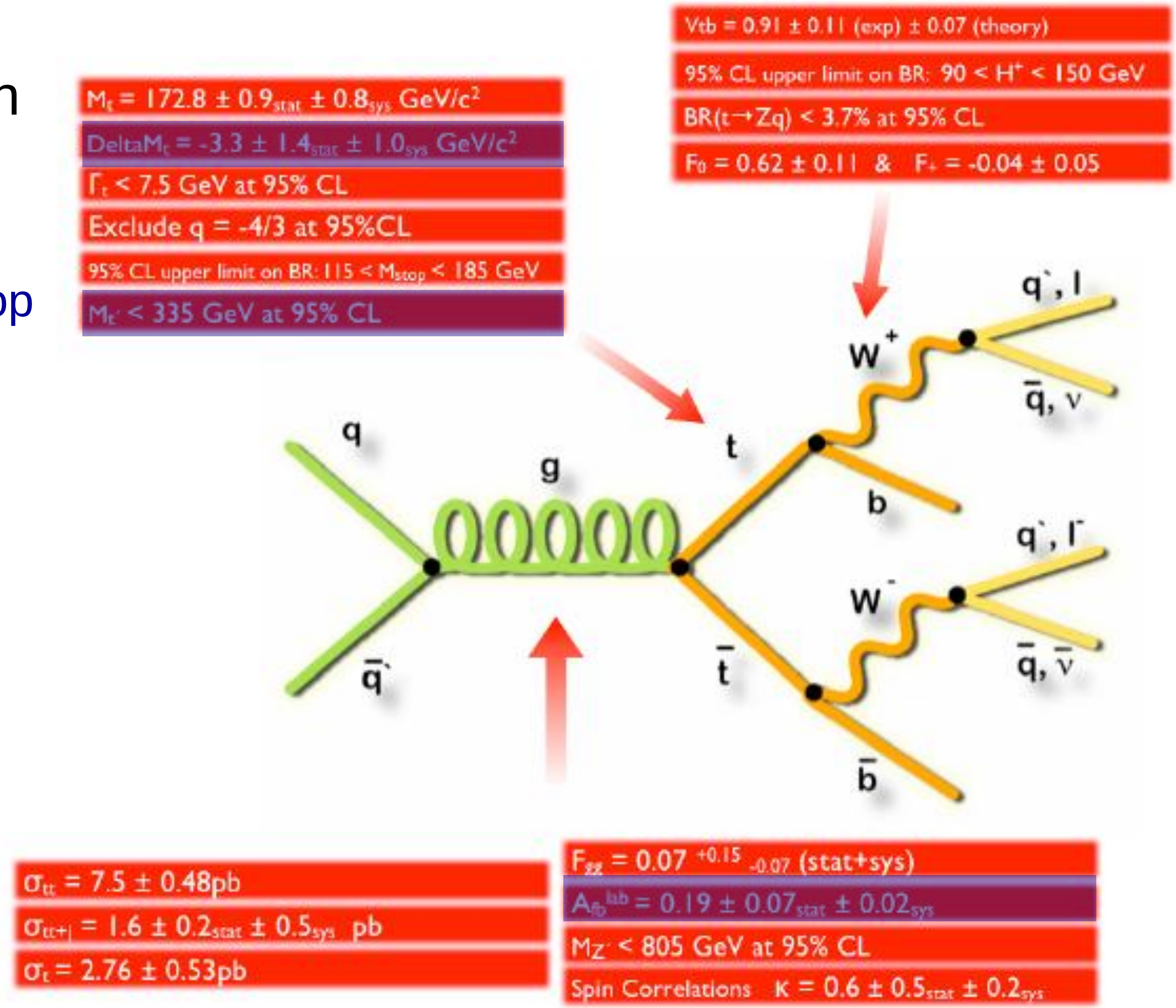
Where we stand (CDF) now

- ~2sigma deviation

Mass difference

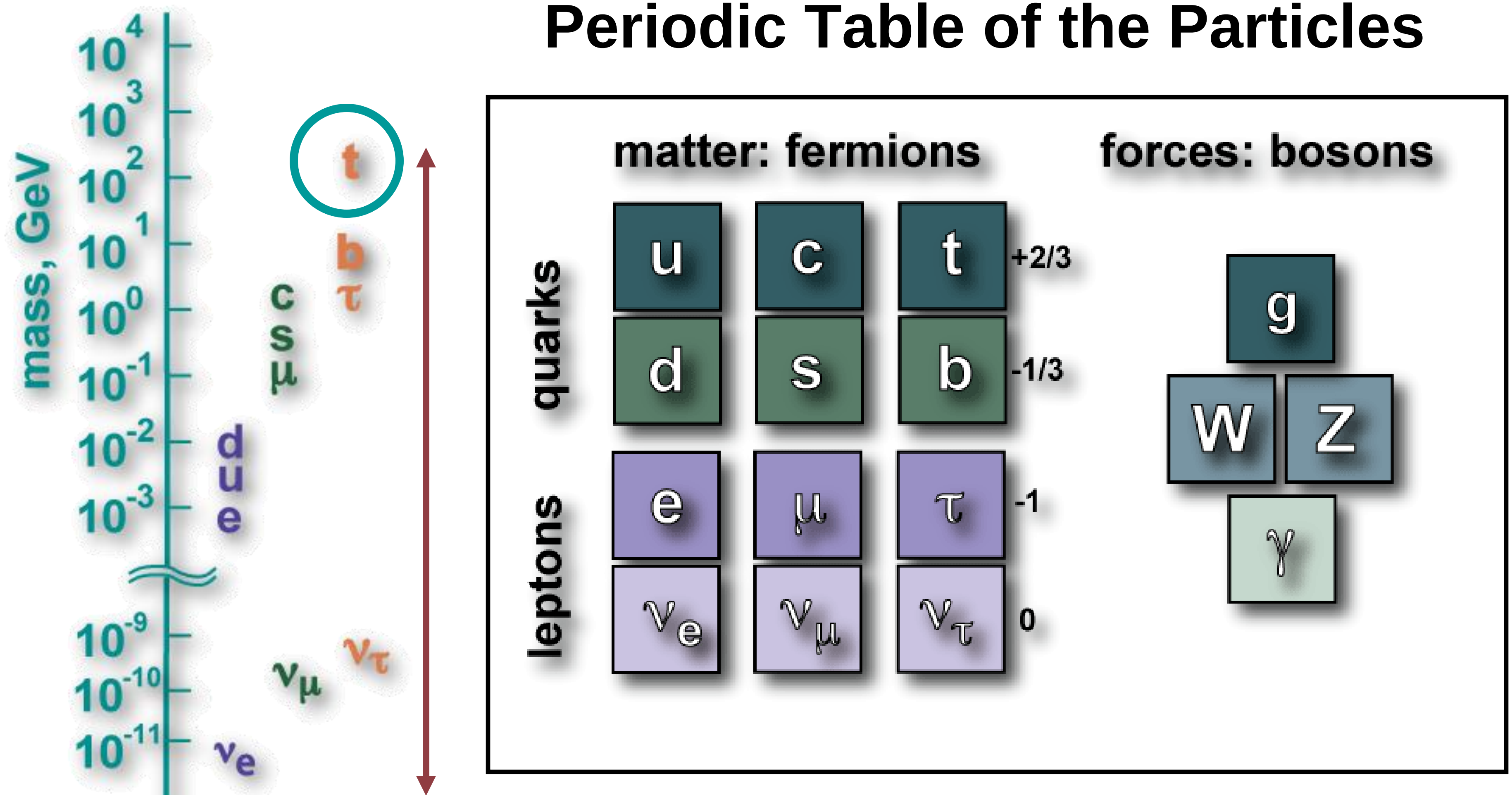
Fourth generation top

F/B asymmetry



Top quark

Periodic Table of the Particles



5 orders of magnitude!