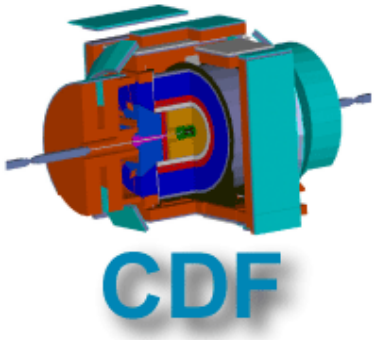
Tevatron:

Top pair production

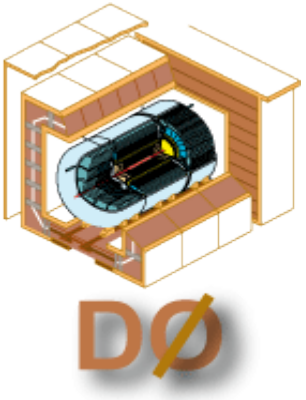
Marc Besançon

CEA-Saclay / IRFU / SPP

For the CDF and D0 collaborations



Rencontres de Moriond EW08



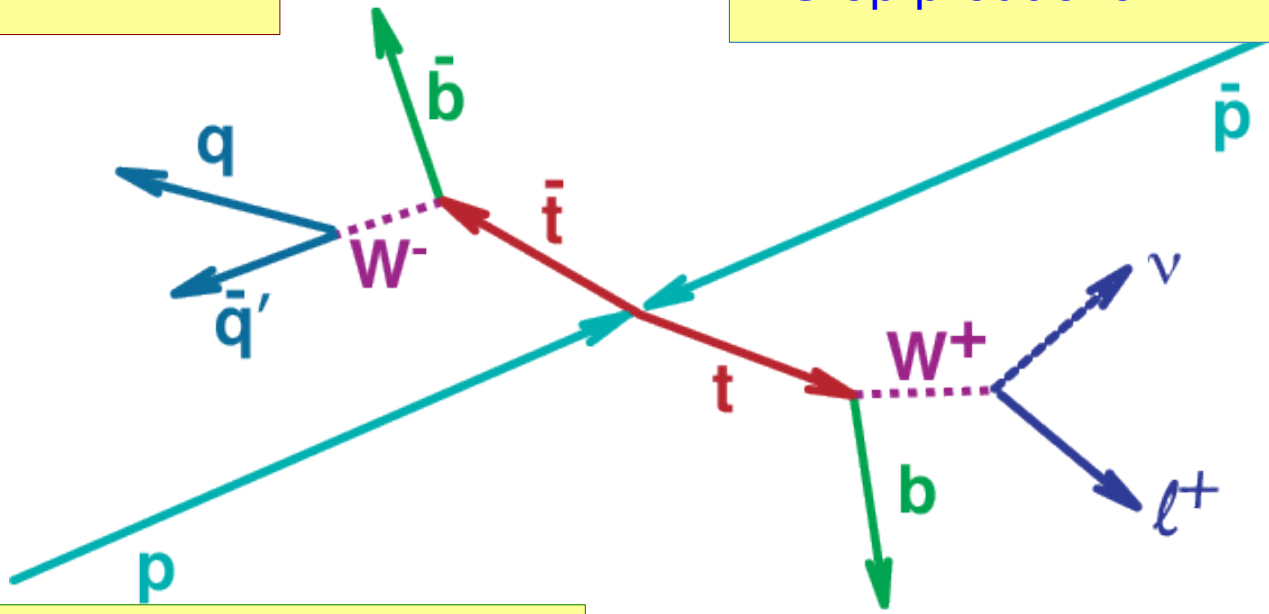
Top quark physics

Top quark decay

- W helicity (V-A)
- Branching Ratios
- Top to charged Higgs
- FCNC

Top quark production

- Production mechanism
- Top pair production cross section
- EW production (single top, Vtb)
- Forward Backward asymmetry
- Spin correlations
- Resonances
- Stop production



Top quark properties

- Top quark mass
- Top quark width
- Top quark charge

Tevatron is the only place to study the top quark until the advent of LHC

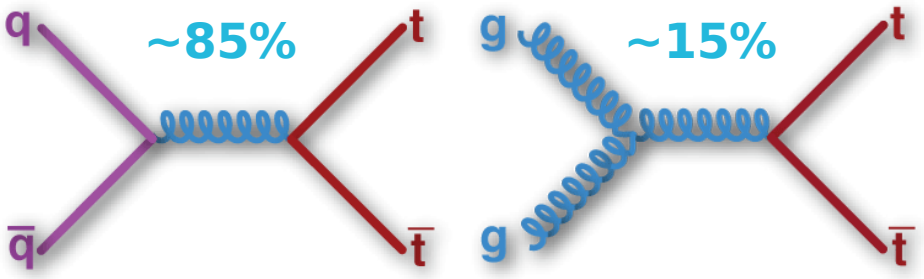
Top pair production: outline

- Production mechanism
- Cross sections measurements
- Forward Backward asymmetry
- Resonances decaying to top

Tevatron doing well: more than 3 fb^{-1} on tape
today's results: between ~ 1 and 2 fb^{-1}

for top mass and other properties: see Yen Chu Chen's talk
single top production: see Reinhard Schwienhorst's talk

SM pair production at the Tevatron via strong interactions



NLO prediction

$$\sigma(p\bar{p}\to t\bar{t}) \approx 6.7 \pm 0.4\ pb \quad @\ M_{top} = 175\ GeV$$
$$\sigma(p\bar{p}\to t\bar{t}) \approx 7.8 \pm 0.5\ pb \quad @\ M_{top} = 170\ GeV$$

Kidonakis *et al.* PRD 68 114014

Cacciari *et al.* JHEP 0404:068

why study top pair production ?

QCD and SM tests

deviations from SM predictions -> indication of non SM mechanisms ?

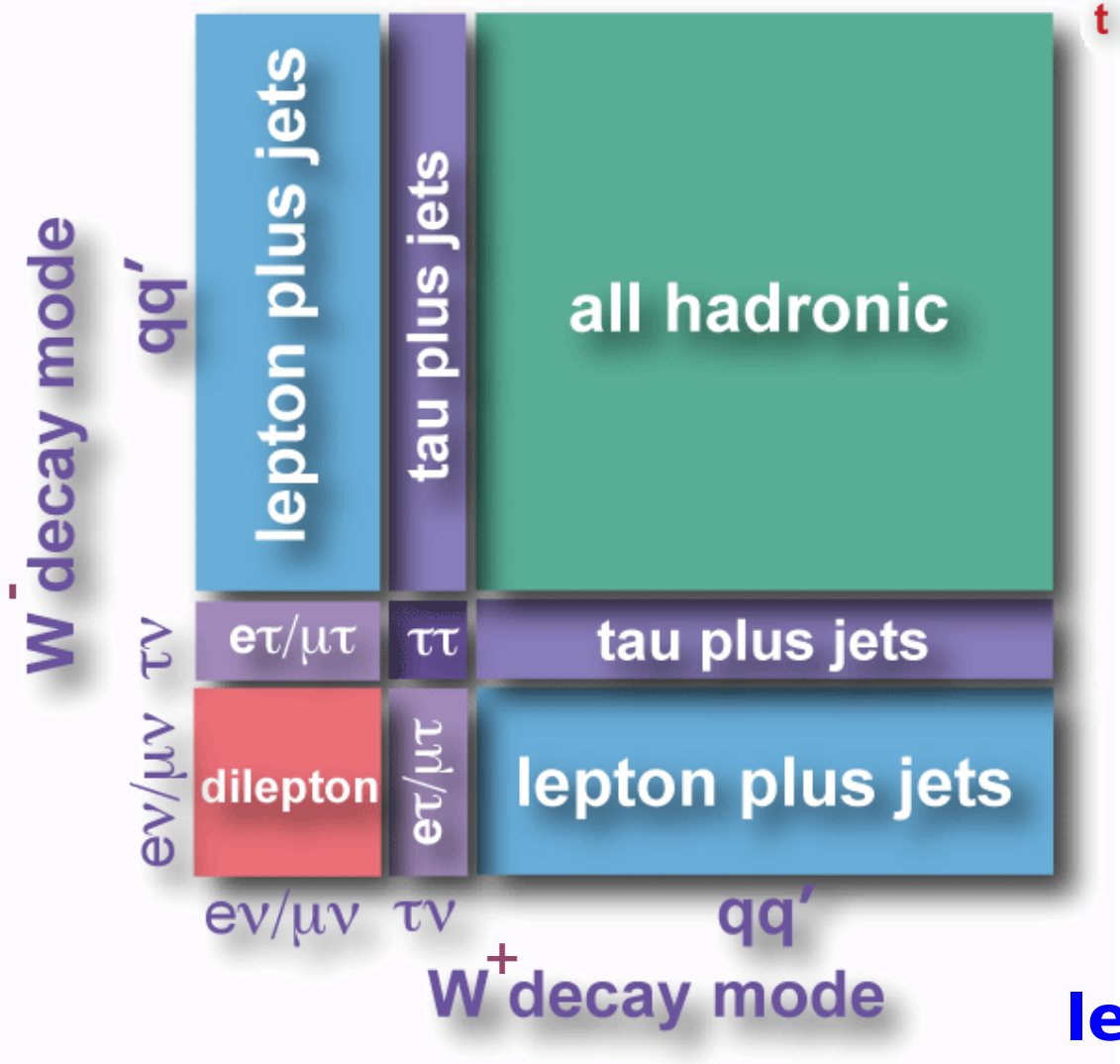
provides sample composition for other top properties measurements

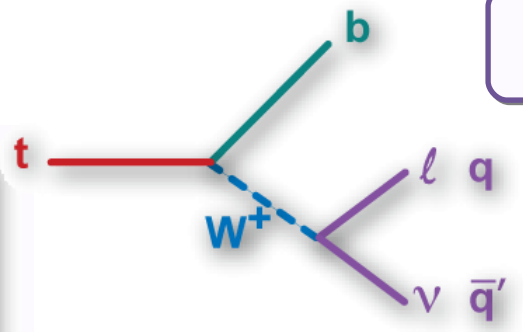
cross section measurements provide another way to measure the top mass

top pair production is background for searches

top pair production measurements in different final states

Final states / channels classification based on W decays





t→Wb ~ 100%

dilepton:
both W's decay via $W \to l\nu$ (l=e or μ, 5%)

lepton+jets:
one W decays via $W \to l\nu$ (l=e or μ, 30%)

all hadronic:
both W's decay via $W \to qq'$ (45%)

tauonic:
one or both W's decaying via $W \to \tau\nu$ (20%)

Today's results :
lepton + jets and dilepton

Top pair production measurements

- **Main physics backgrounds also decay channel dependent :**

Lepton + jets :

- W+jets
- Multi-jets

Dilepton :

- Z -> dilepton
- Drell Yan
- Diboson

- **Typical event selections include**
  - high Pt lepton (> 15 - 20 GeV)
  - large missing Et (> 15 – 20 GeV)
  - high Et jets (> 15 – 20 GeV)
  - kinematical & topological variables cuts
  - b-quark jets identification (in some analyses)
    - displaced vertex (efficiency ~ 50 – 60 %)
    - soft lepton taggers

- **Several techniques at work**
  - event counting
  - shape fit

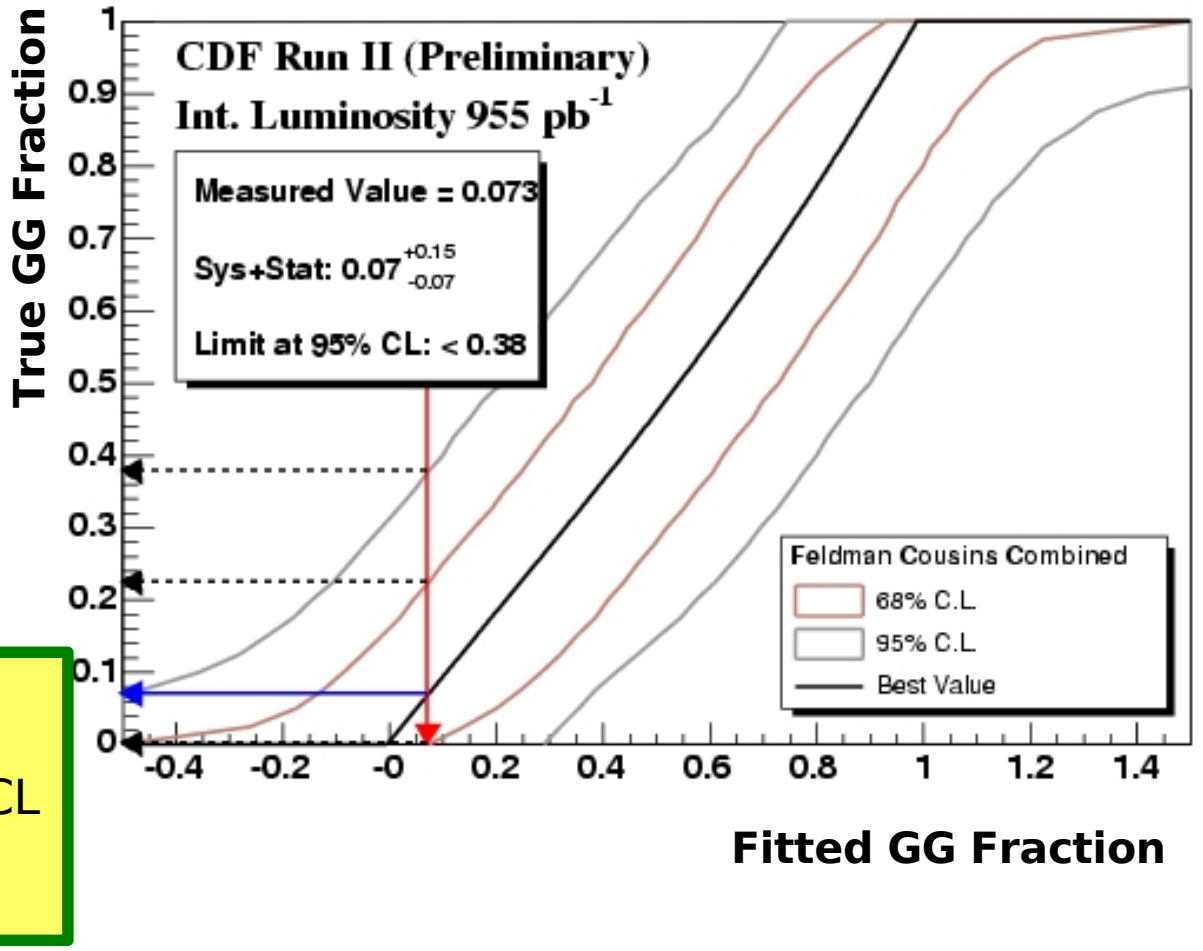
Production mechanism

Contribution of GG fusion have theoretical uncertainties and can vary up to factor of 2 (from 10% - 20%)

CDF measurement of the relative fraction of GG fusion (vs. QQ annihilation) combining two complementary methods

1) using low Pt tracks
data driven method using shapes of GG and QQ component derived from inclusive dijets samples shapes are then fit to data

2) NN from kinematics
kinematic variables of the GG and QQ contributions (MC) used to train NN



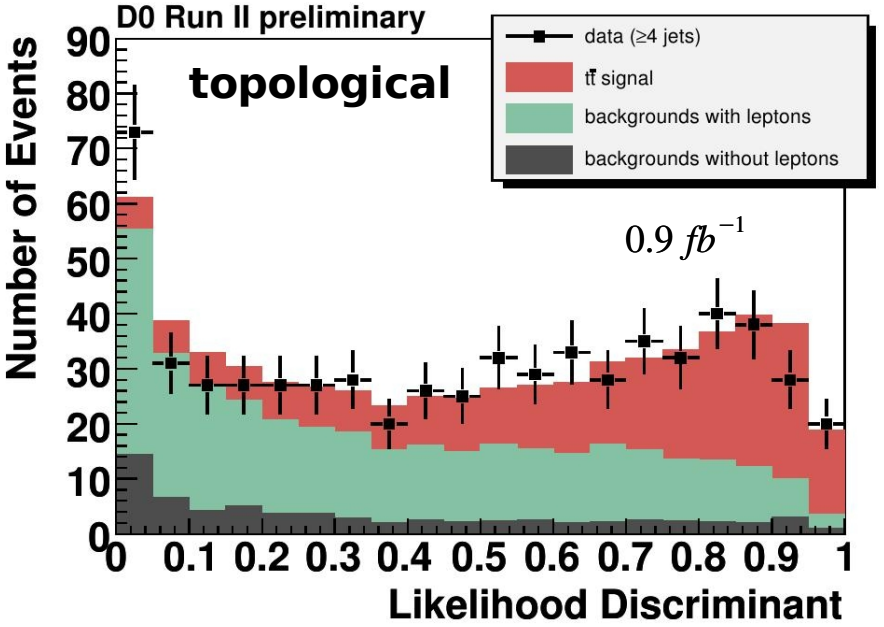
$$\frac{\sigma(GG \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = 0.07^{+0.15}_{-0.07} @\ 68\%\text{CL}$$

Lepton + jets cross section measurements

1) Topological informations

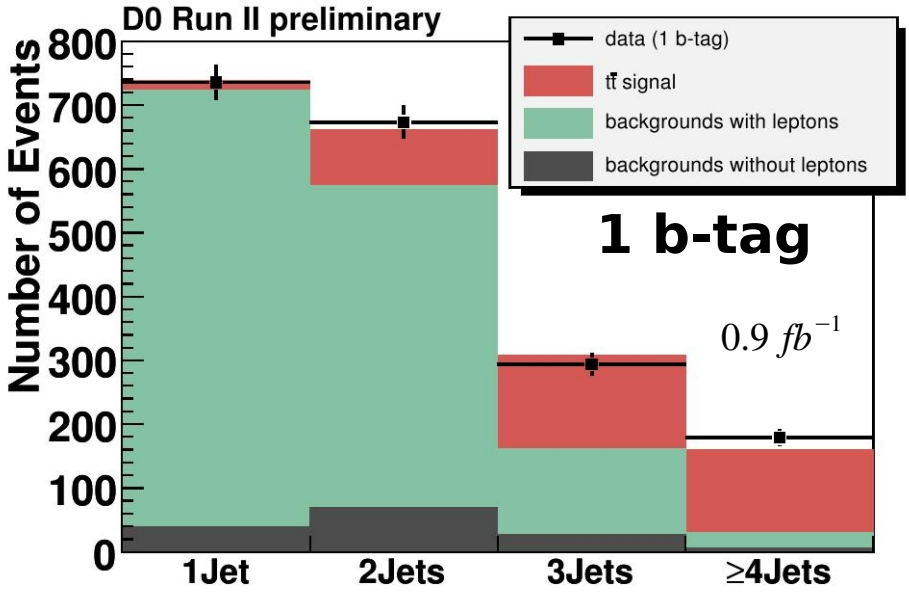
Likelihood discriminant maximizing efficiency
and rejecting multijets background

Number of ttbar events
from fit to the Likelihood discriminant in data
using templates for the top signal,
physics (W+jets) and multijets backgrounds



2) Neural Network b-tagging

Likelihood fit to the observed number of events
(8 channels: e or μ + 3 or 4 jets 1 or 2 b-tag)



3) COMBINED RESULT

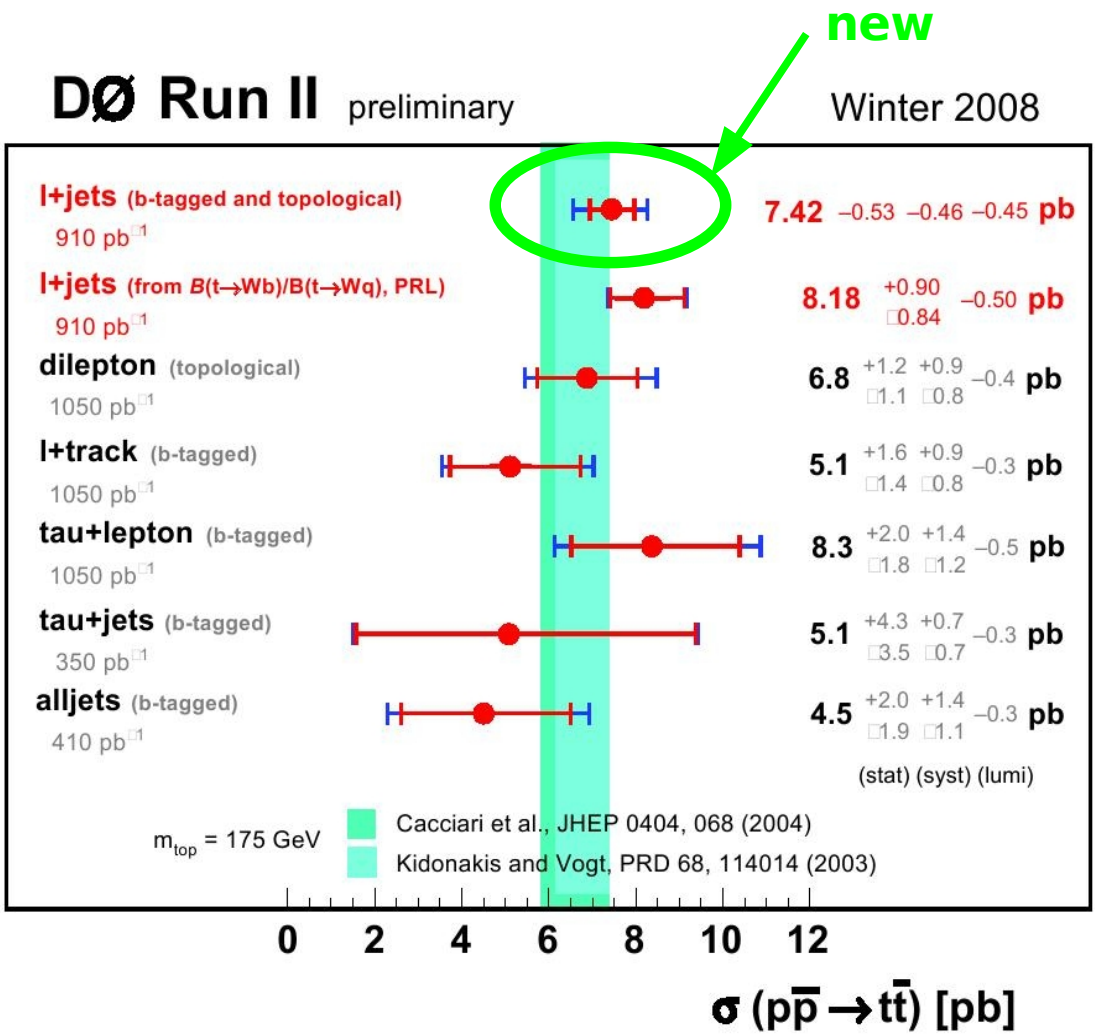
$$\sigma(p\bar{p}\to t\bar{t}) = 7.77 \pm 0.54(stat) \pm 0.47(syst) \pm 0.47(lumi)\ pb$$

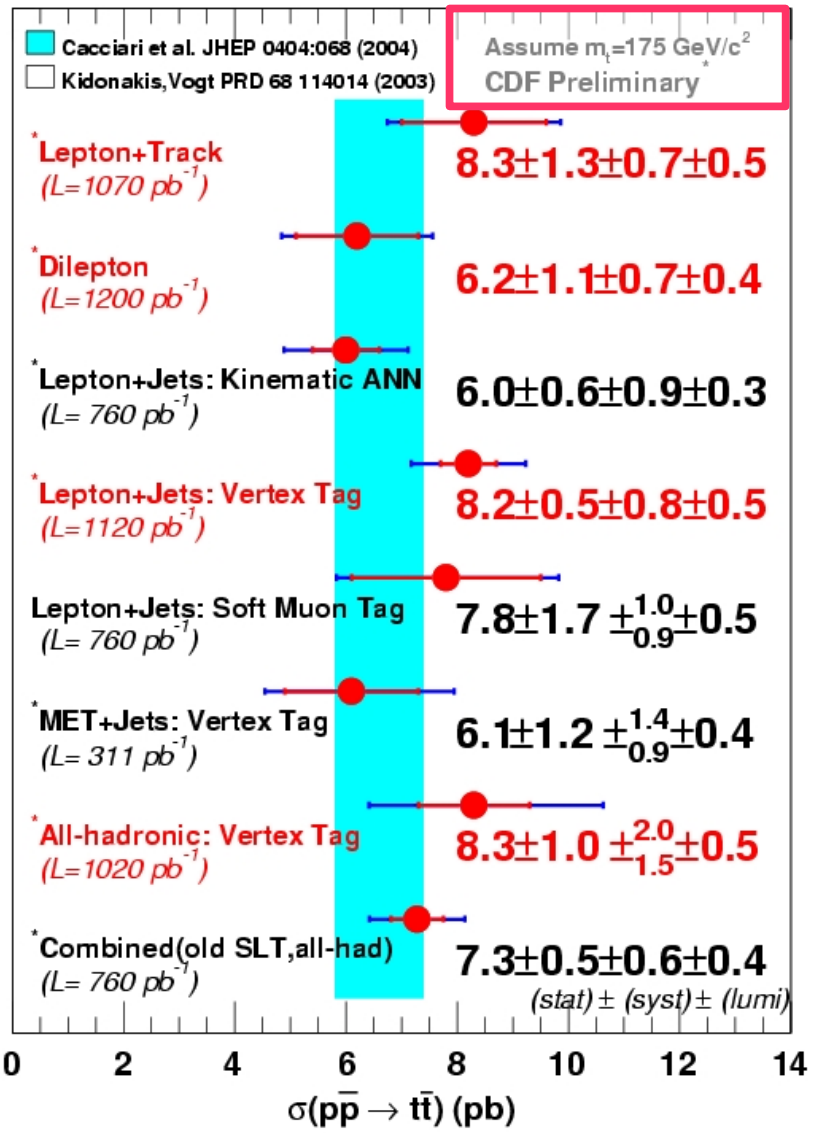
for $m_{top} = 170\ GeV$

$$\sigma(p\bar{p}\to t\bar{t}) = 7.42 \pm 0.53(stat) \pm 0.46(syst) \pm 0.45(lumi)\ pb$$

for $m_{top} = 175\ GeV$

top pair production cross section summary





Measurements consistent with each other

Measurements consistent with SM predictions

New physics would show up as inconsistencies

Top mass measurement from cross-section measurement

- **Motivation :**
  - **provides a complementary measurement**

  - **top mass definition (pole, running, ...)**

  - **not meant to compete in precision with more direct measurements (see Yen Chu Chen's talk)**

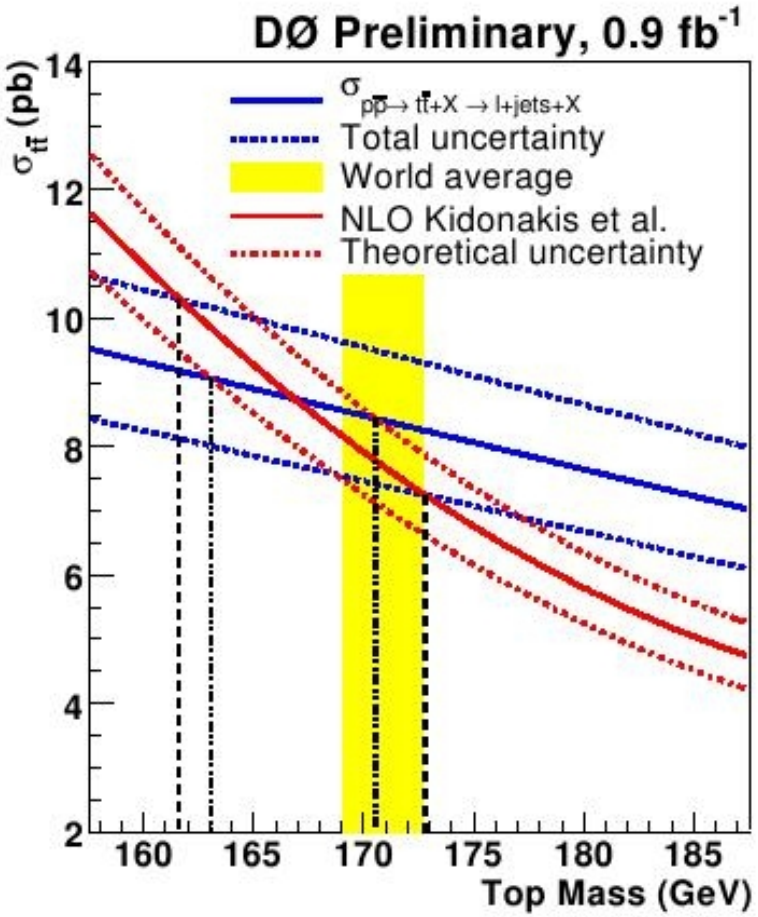
- **Use the cross section measurement in lepton + jets channels and dilepton channels**

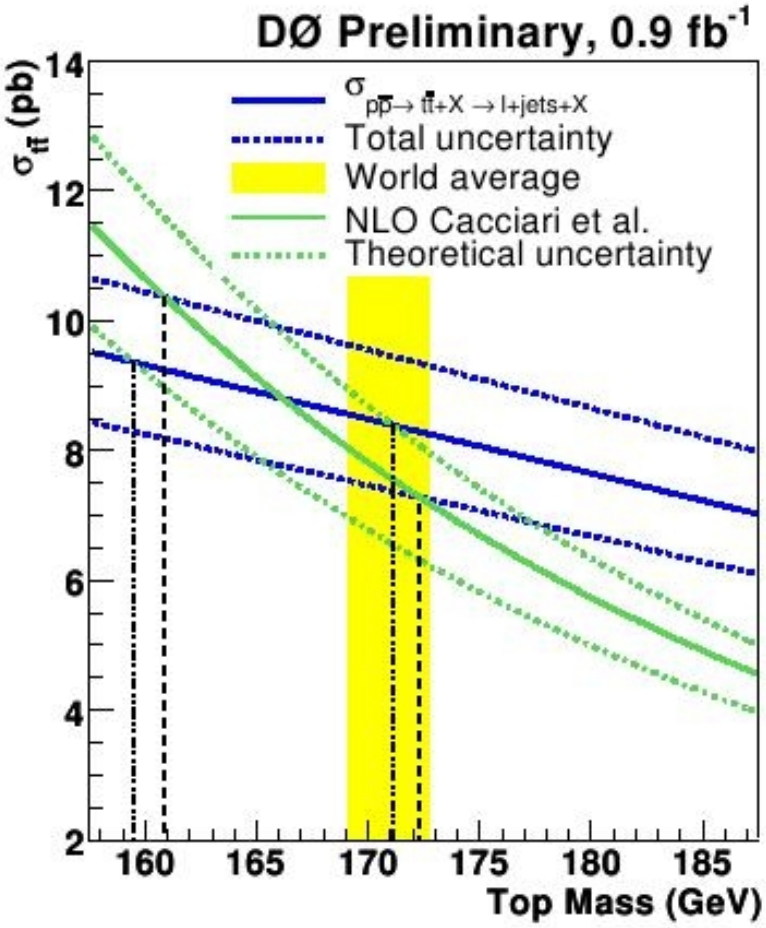
- **Theory from :**

  Kidonakis *et al.* PRD 68 114014

  Cacciari *et al.* JHEP 0404:068

Top mass from cross section measurements lepton + jet channels (summer 2007 results)





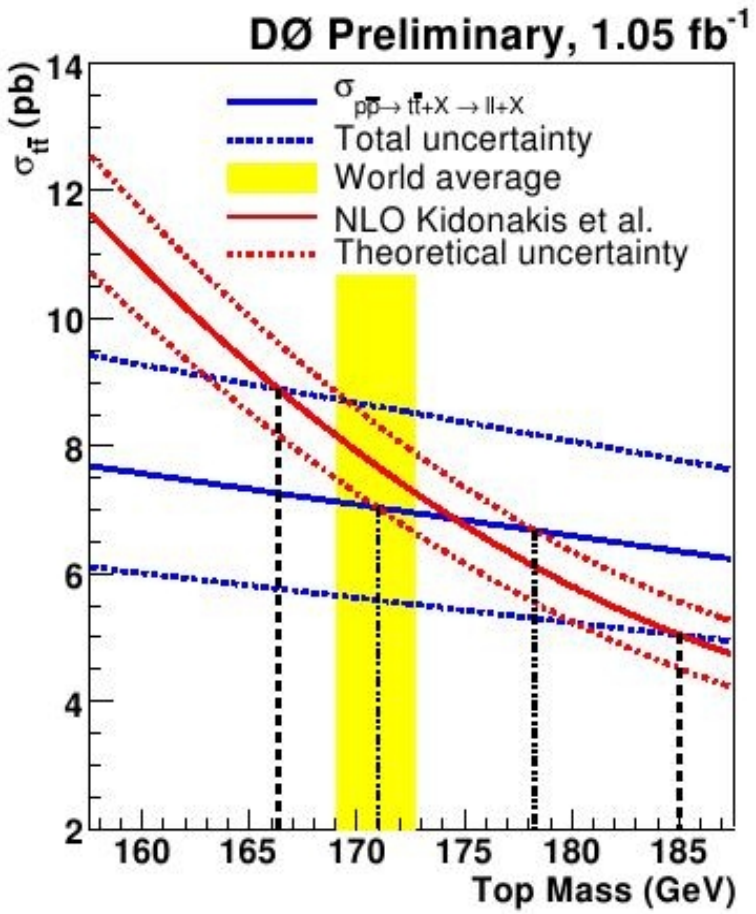
$$M_{top} = 166.9^{+5.9}_{-5.2}(stat+syst)^{+3.7}_{-3.8}(theory)\,GeV$$

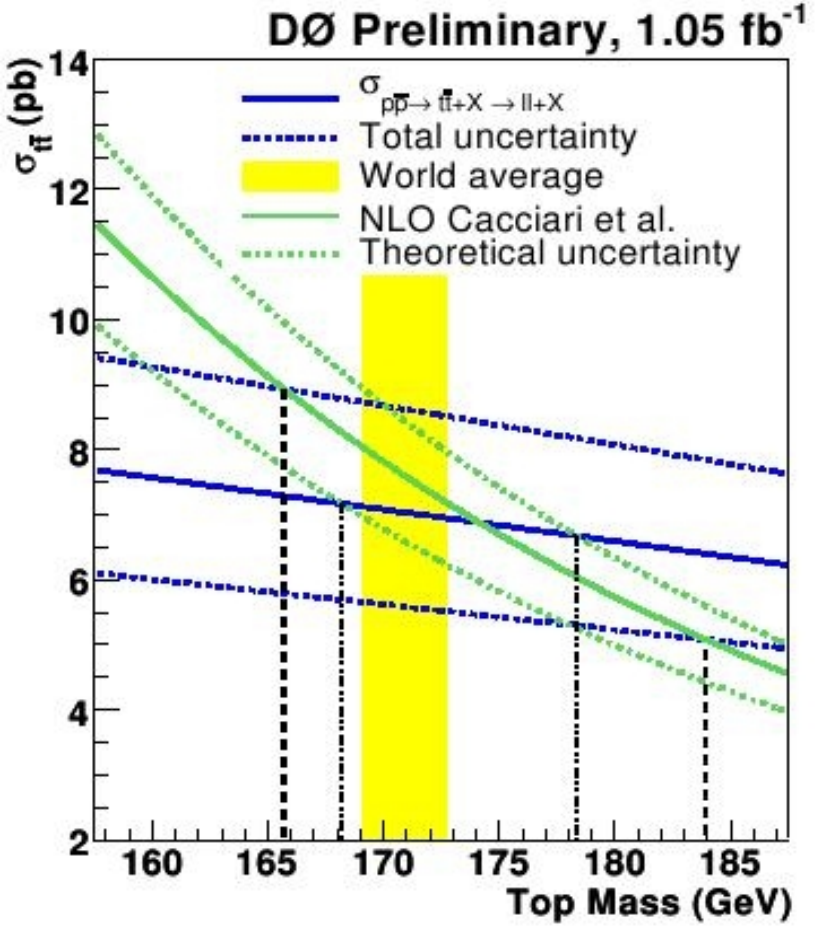
$$M_{top} = 166.1^{+6.1}_{-5.3}(stat+syst)^{+4.9}_{-6.7}(theory)\,GeV$$

D0 direct measurement with ME method : $M_{top} = 170.5 \pm 2.4(stat+JES) \pm 1.2(syst)\,GeV$
(D0 conf 5362)

World average hep-ex/0703034 : $M_{top} = 170.9 \pm 1.1(stat) \pm 1.5(syst)\,GeV$

Top mass from cross section measurement dilepton channels (summer 2007 results)





$$M_{top} = 174.5^{+10.5}_{-8.2}(stat+syst)^{+3.7}_{-3.6}(theory)\,GeV$$

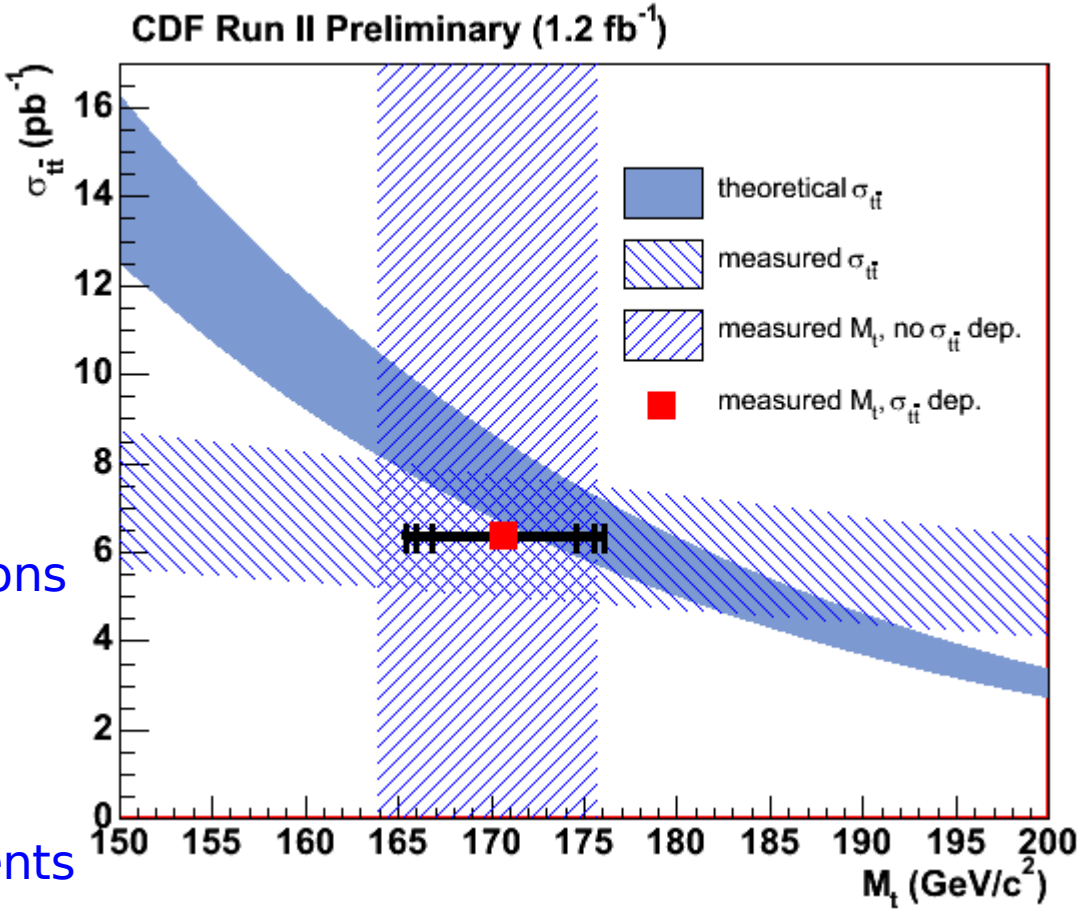
$$M_{top} = 174.1^{+9.8}_{-8.4}(stat+syst)^{+4.2}_{-6.0}(theory)\,GeV$$

D0 direct measurement with neutrino-weighting (D0 conf 5374): $M_{top} = 166.9^{+5.9}_{-5.2}(stat+syst)^{+3.7}_{-3.8}(theory)\,GeV$

World average hep-ex/0703034 : $M_{top} = 170.9 \pm 1.1(stat) \pm 1.5(syst)\,GeV$

Top mass measurement from cross section dependence

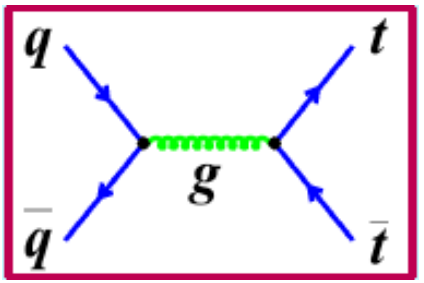
- **Using dilepton events**
- **Top mass info from kinematics**
  event kinematics solved using longitudinal momentum of the ttbar system
- The reconstructed top mass distribution from data is compared to parametrisations of the signal and background templates
- **Likelihood fit** to compare the top mass dependent number of events w/ the expected number of events

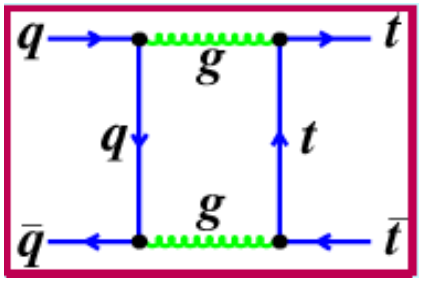


$$m_{top} = 170.7^{+4.2}_{-3.9}(stat) \pm 2.6(syst) \pm 2.4(theory)\,GeV$$

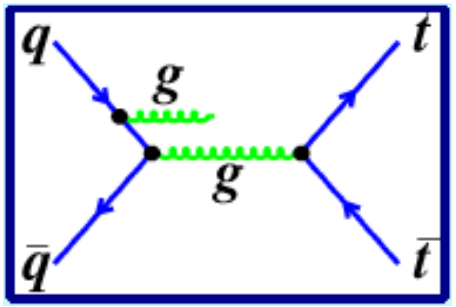
Forward Backward charge asymmetry

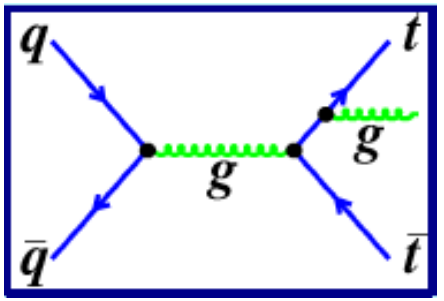
- asymmetry arises from interference between symmetric and antisymmetric contributions under the exchange $t \Leftrightarrow \bar{t}$
- depends on the phase space region probed (additional jet production)
  - no asymmetry expected at LO
  - 5-10% expected at NLO
  - corrections from NNLO for ttbar production in association with a jet



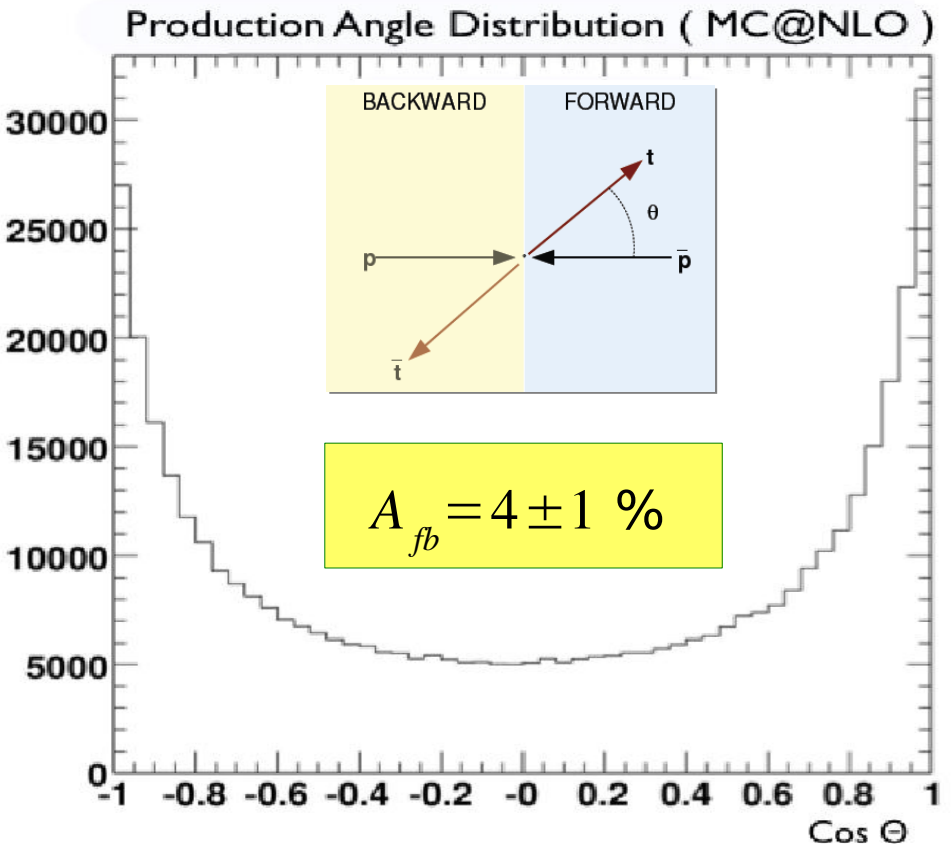


interferences diagram for qq (J. Kuhn *et al.)*





reduced asymmetry in tt+jet (Dittmaier *et al.)*



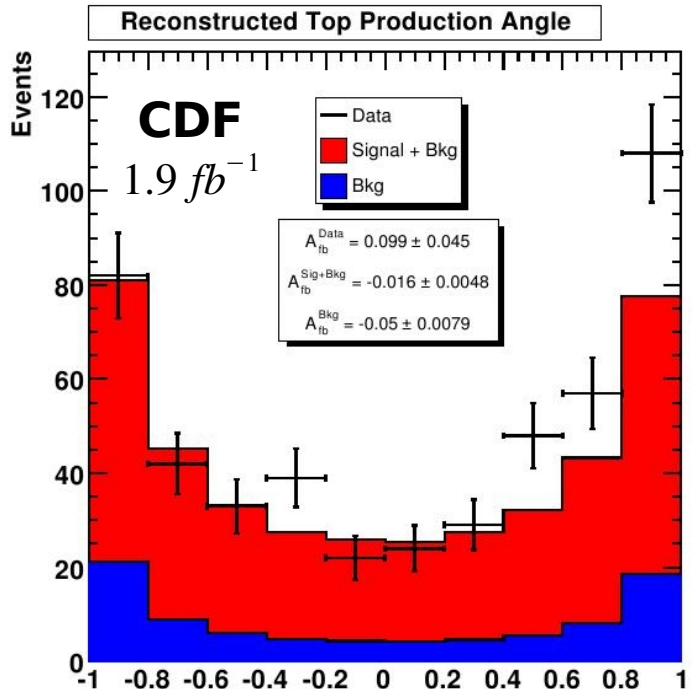
Afb results from CDF

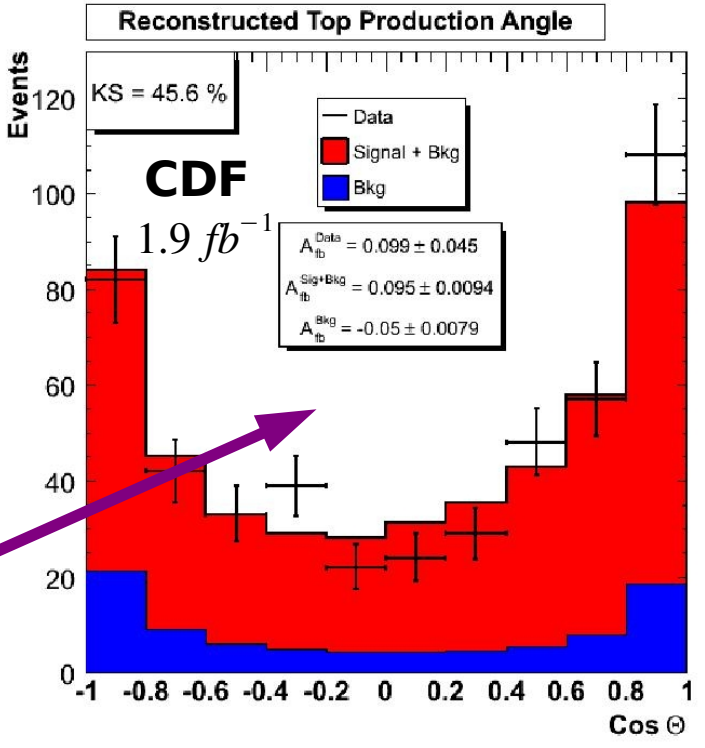
- **lepton + (at least 4) jets events**
  (at least 1 b-tag jet) => 484 candidates
- **top pair reconstruction using a kinematic fitter**

$$A_{fb} = \frac{N_{(-Q_l)\cdot Cos(\Theta)>0} - N_{(-Q_l)\cdot Cos(\Theta)<0}}{N_{(-Q_l)\cdot Cos(\Theta)>0} + N_{(-Q_l)\cdot Cos(\Theta)<0}}$$

$$A_{fb} = 17 \pm 7\,(stat) \pm 4\,(syst)\ \%$$

reconstruction and acceptance corrections





reweighted signal with Afb = 0.17

Afb results from D0

- **lepton +** (at least 4) **jets** (1 b-tag) **events**
- top pair reconstruction using a kinematic fitter
- sample composition and A_{fb} from **Likelihood fit to data**

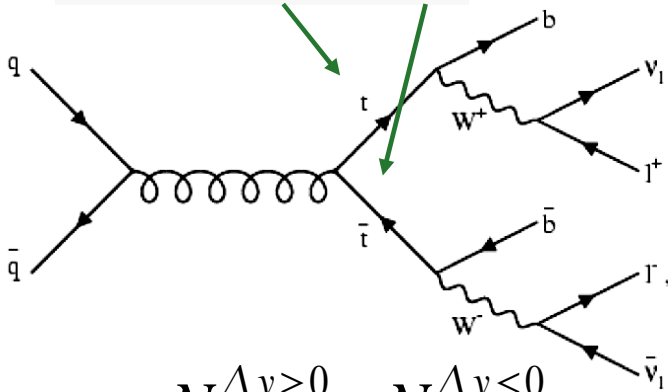
Accepted by PRL

$$A_{fb} = 12 \pm 8(stat) \pm 1(syst)\ \%\quad \text{(for n jets} \geq 4\text{)}$$

$$A_{fb} = 19 \pm 9(stat) \pm 2(syst)\ \%\quad \text{(for n jets} = 4\text{)}$$

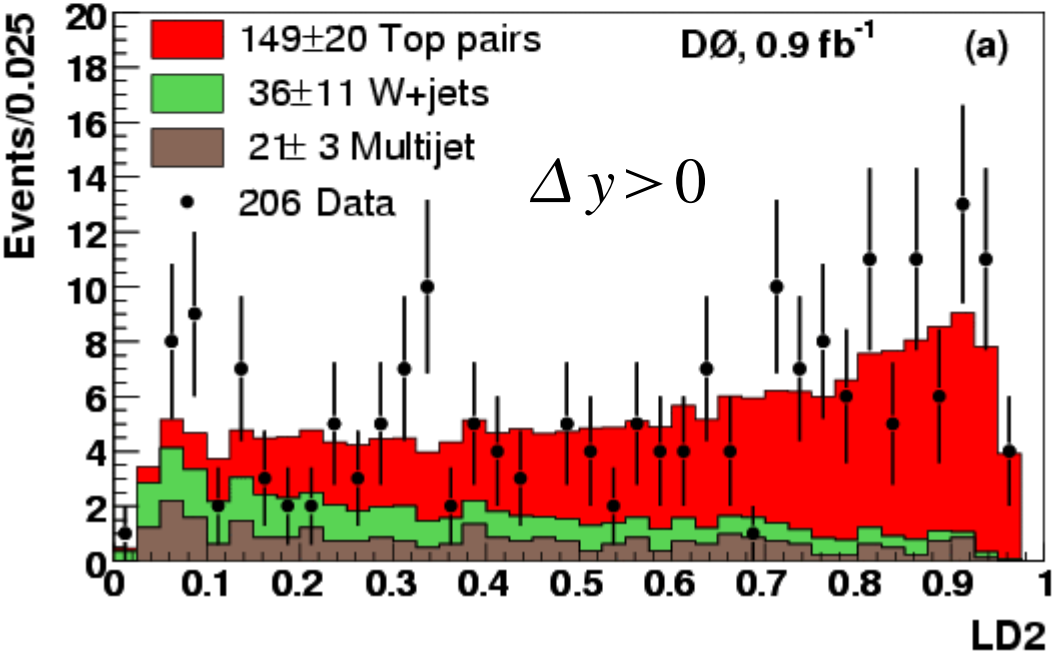
$$A_{fb} = -16^{+15}_{-17}(stat) \pm 3(syst)\ \%\quad \text{(for n jets} \geq 5\text{)}$$

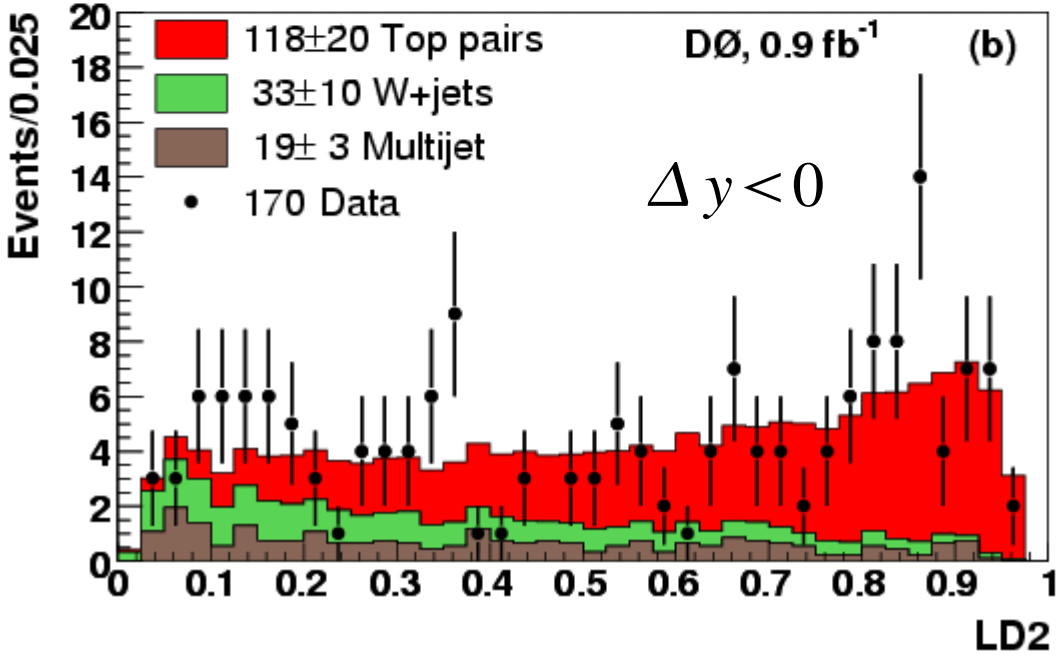
$$\Delta y \equiv y_t - y_{\bar{t}}$$



$$A_{fb} = \frac{N^{\Delta y>0} - N^{\Delta y<0}}{N^{\Delta y>0} + N^{\Delta y<0}}$$

Not to be compared with CDF results





Resonances in the invariant mass distribution ?

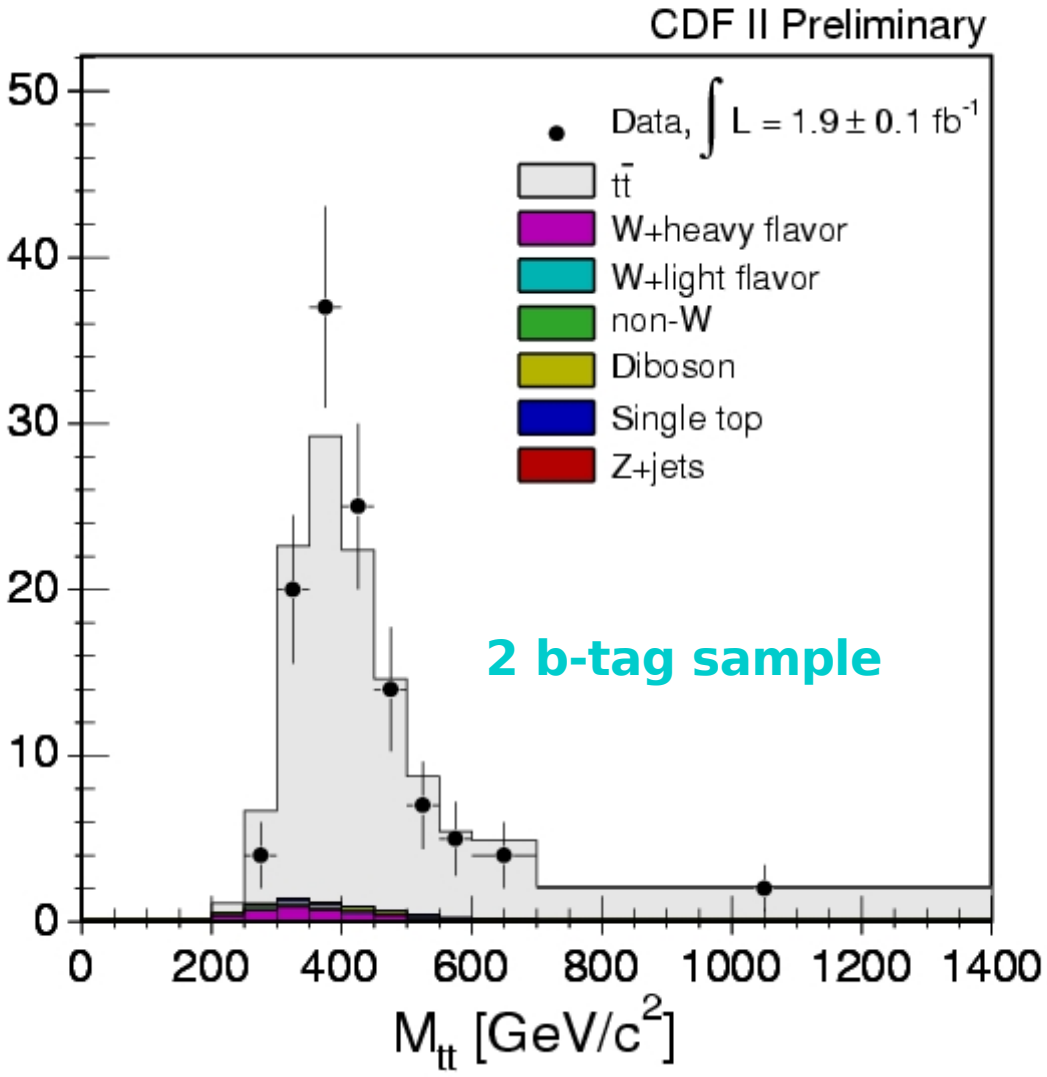
- **Select: lepton +** (at least 4) **jets** (1 and 2 b-tag) **events**
  484 candidates events (1 b-tag sample)

- **Reconstruct invariant mass from lepton, 4 leading jets and MET**

- **Perform SVD unfolding to account for acceptances and resolutions**
  (SVD: Singular Value Decomposition
  A. Hocker *et al.* ph/9509307, NIMA372-469)

- **Shape sensitive to new physics**

No deviations from SM found



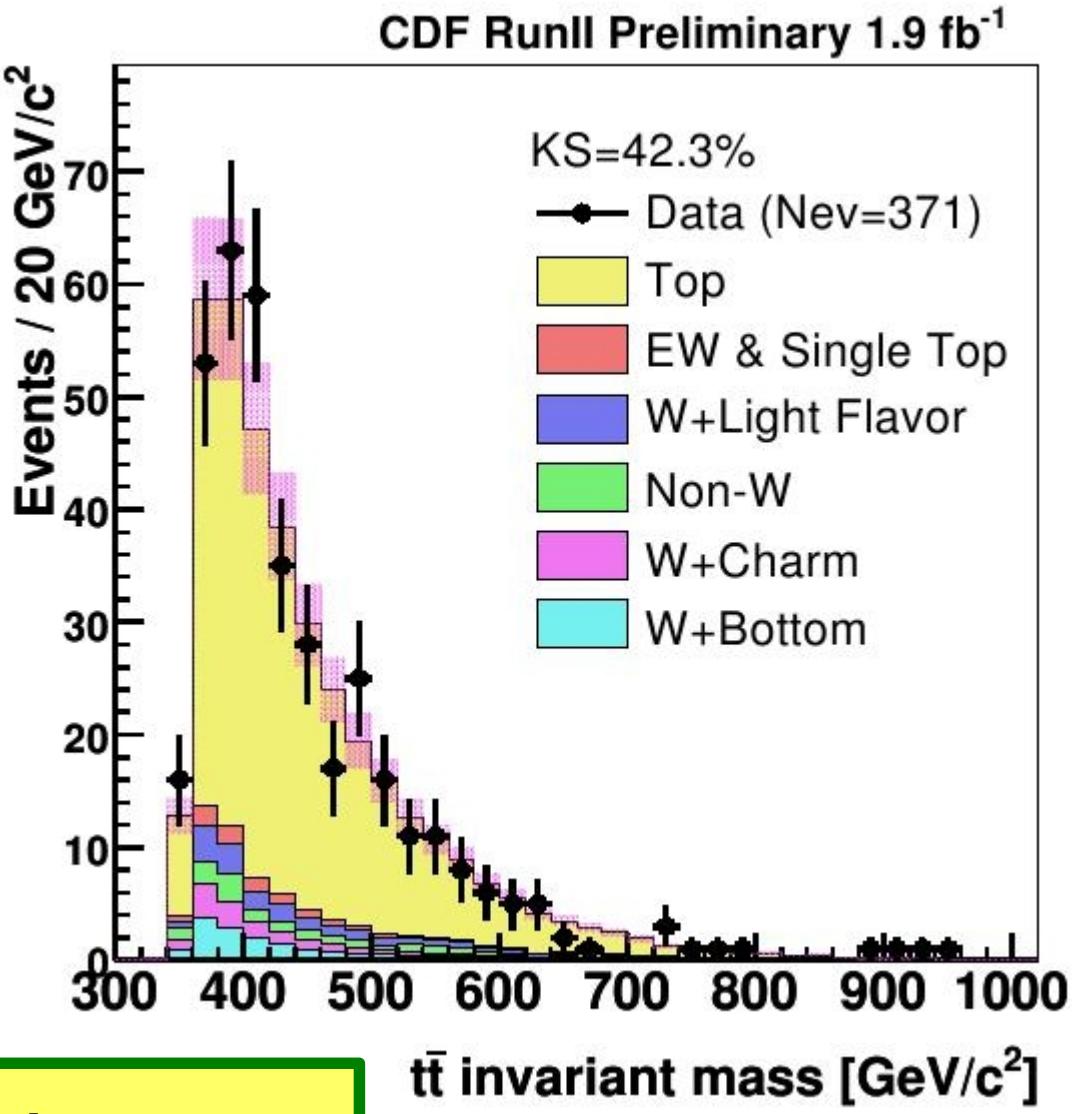
consistency with SM with p-value = 0.45

Resonance decaying to top ?
The massive gluon approach

- **Reconstruct tt invariant mass in the lepton+jets channel using Matrix Element type techniques**
  (see Yen Chu Chen's talk)

  Kondo arXiv:hep-ex/0508035
  and CDF, Abulencia *et al.*
  top mass measurement in lepton+jets with b-tag PRD73(2006)092002

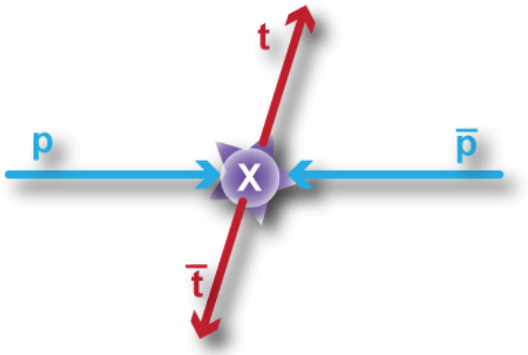
- **after invariant mass reconstruction perform a Likelihood fit to extract massive gluon mass, width, coupling**



fitted coupling strength consistent with SM within 1.7 sigma in the (width/mass) range from 0.05 to 0.5

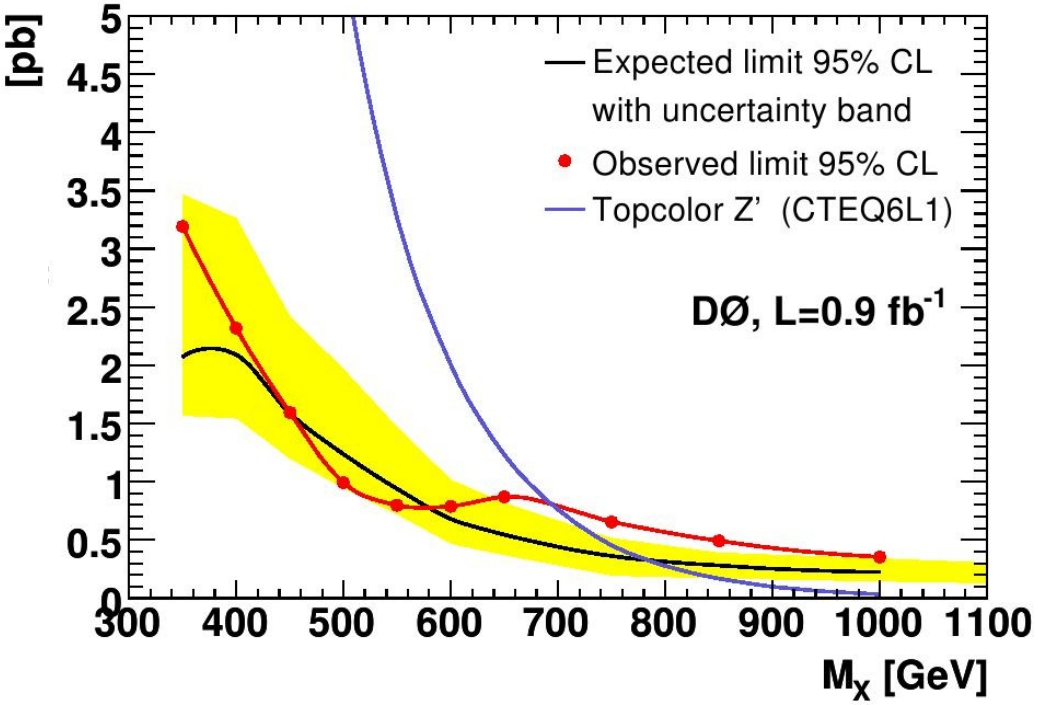
Resonance decaying to top ?

Model independent search for a narrow resonance (X→ttbar) in the lepton+jets channel



- **at least 1 b-tagged jet**
- **ttbar invariant mass from 4 leading jets and lepton**
- neutrino momentum from MET
- P_z from solving $M_W^2=(p^l+p^\nu)^2$

Upper limit on $\sigma_X \times Br(X \to t\bar{t})$



leptophobic Z' (topcolor assisted technicolor model)

with $M_{Z'}<690\,GeV$ and $\Gamma_{Z'}=0.012\,M_{Z'}$ excluded at 95%C.L.

Summary
(and take away message)

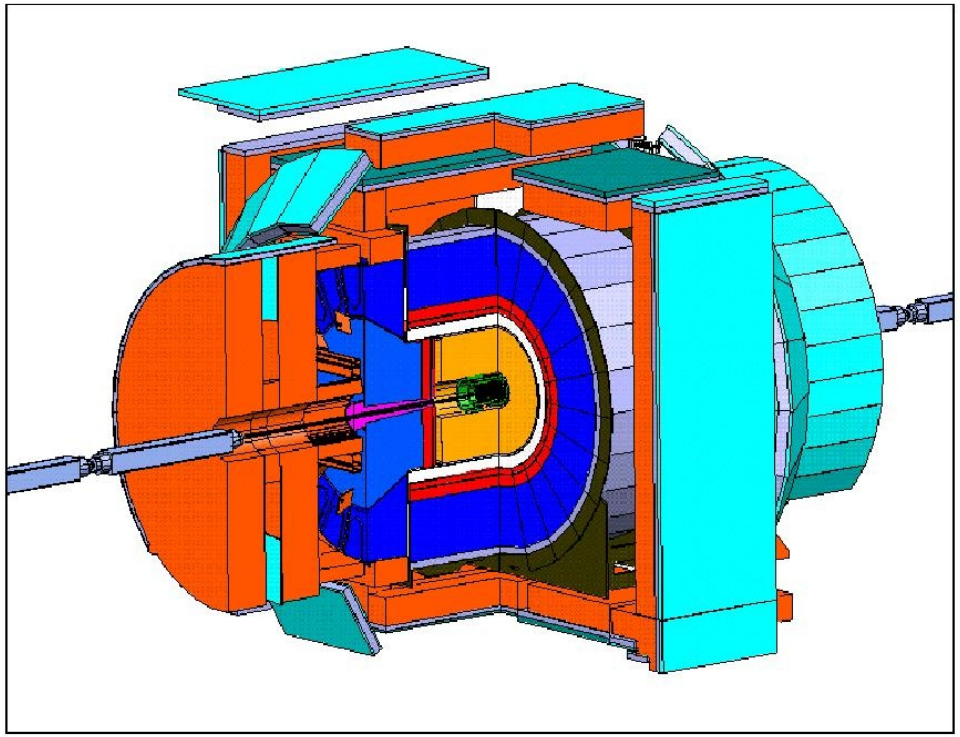
- measured GG fraction consistent with SM expectations
- top cross section consistent with SM
- get top mass measurements from cross section
  compare to direct measurements
- measured asymmetries are consistent with NLO predictions
- so far no evidence of resonances decaying into top quarks
- more data and results later this year (winter and summer)

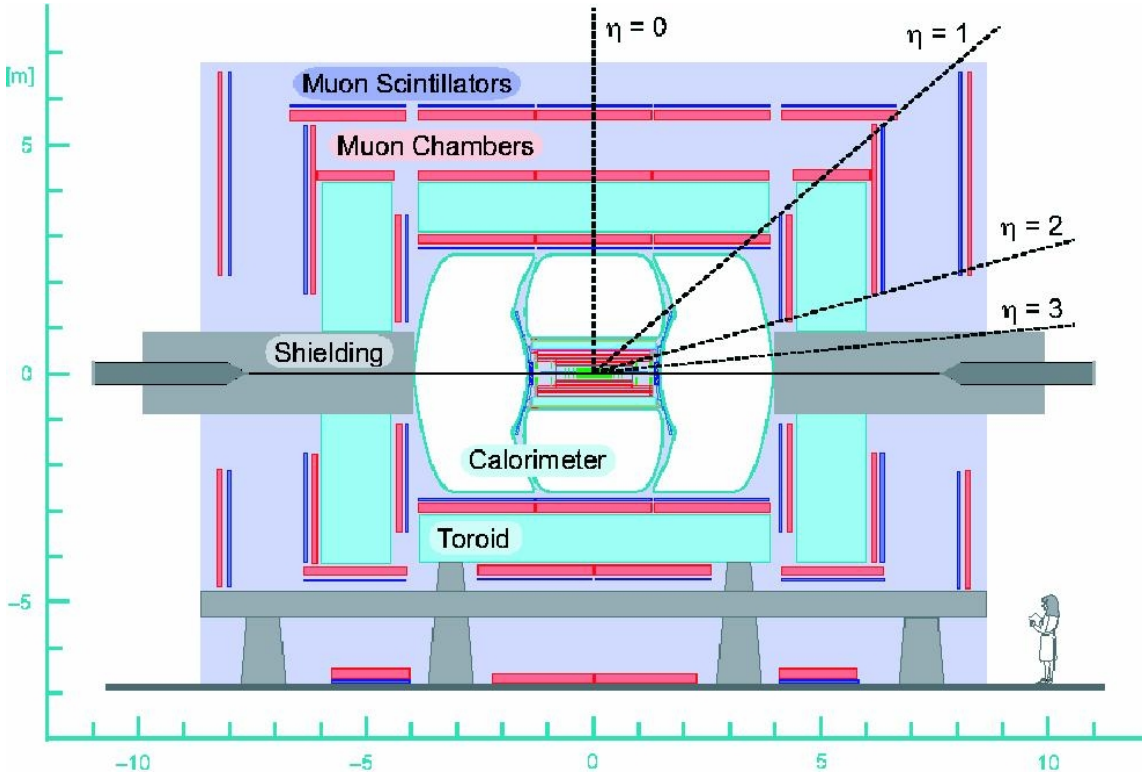
Stay tuned ... Tevatron is performing well

Backup

12 nations
60 institutions
~800 physicists

20 nations
92 institutions
~700 physicists





- **silicon detector**
- **COT: drift chamber**
- **solenoid**
- **calorimeters**
  central, wall, plug
- **muon**
  scintillator + chamber

- **8 layers silicon (SMT)**
- **16 layers scintillating fibers**
- **2T solenoid**
- **calorimeter:**
  central+endcap
- **1.8 toroid**
- **3 layers muon scintillators**
  + drift tubes

Forward backward asymmetry and sensitivity to new physics ?

- prediction of Forward Backward asymmetry as a function of f

where f is fraction of top pair events produce via Z' resonance
of a particular mass from ensembles of simulated datasets