Top Quark Pair Production Cross-Sections and Forward-Backward Asymmetry at the Tevatron

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For the CDF and D0 collaborations

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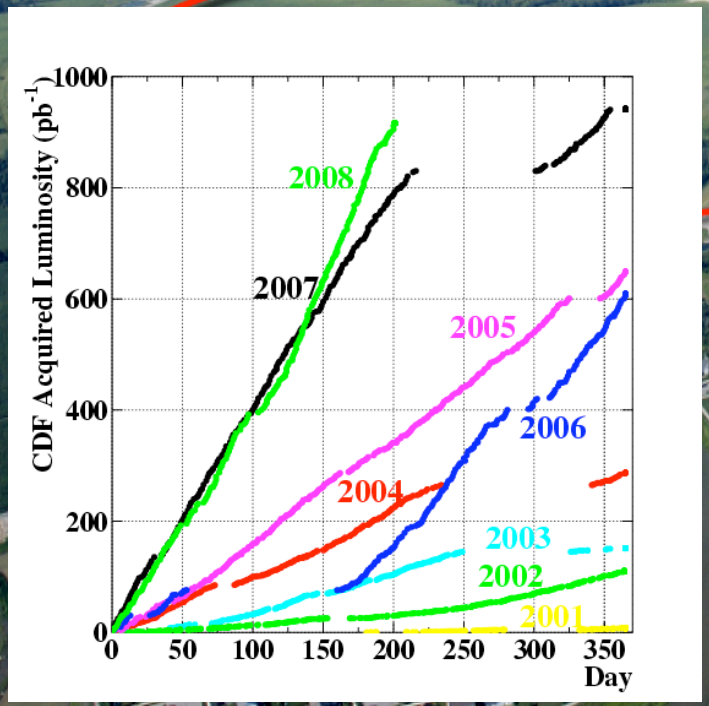
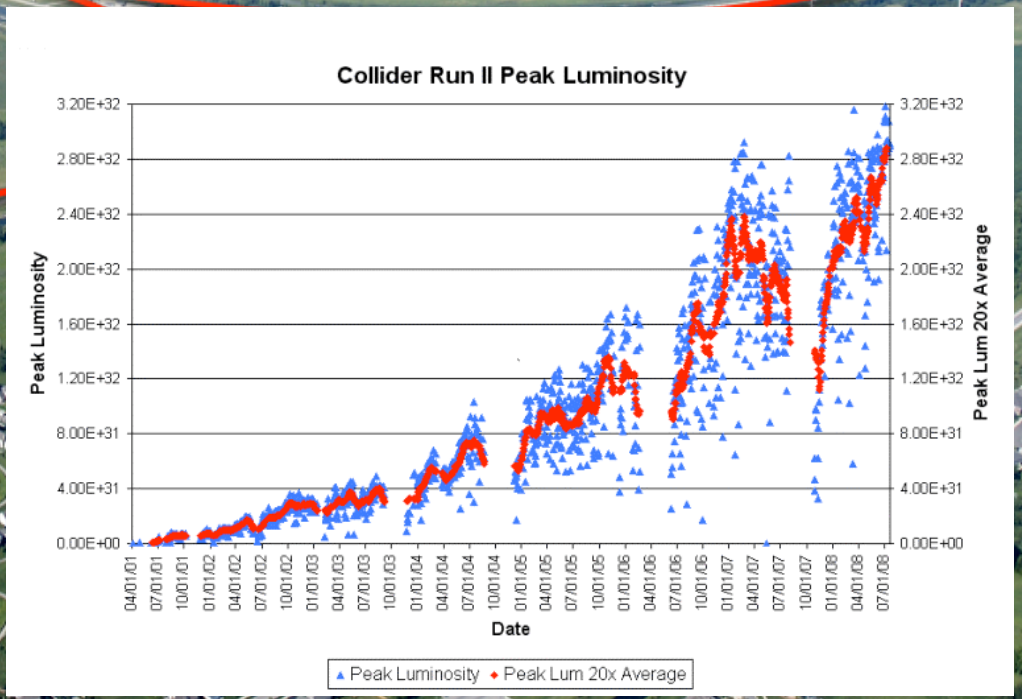
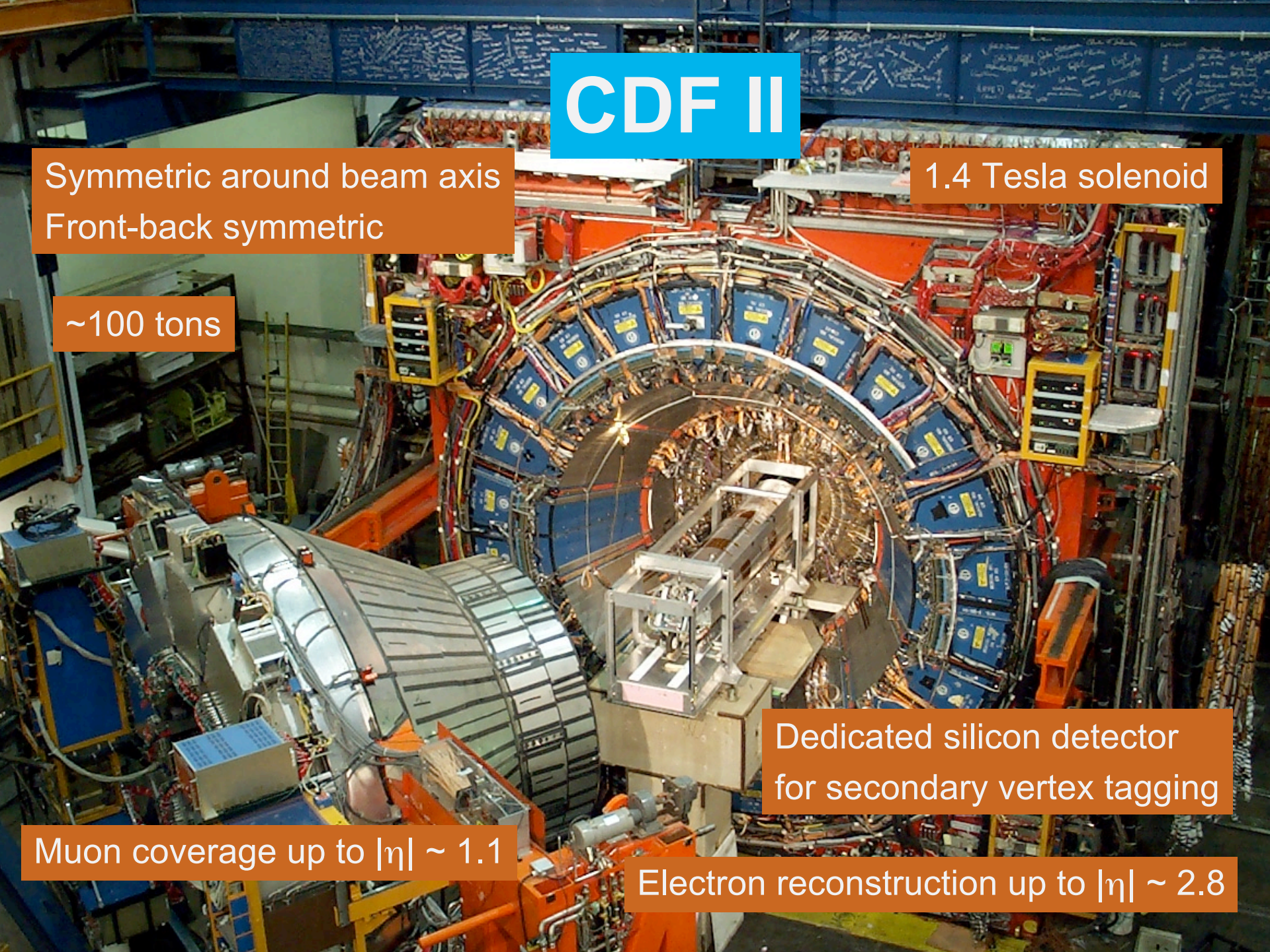
Tevatron Performance

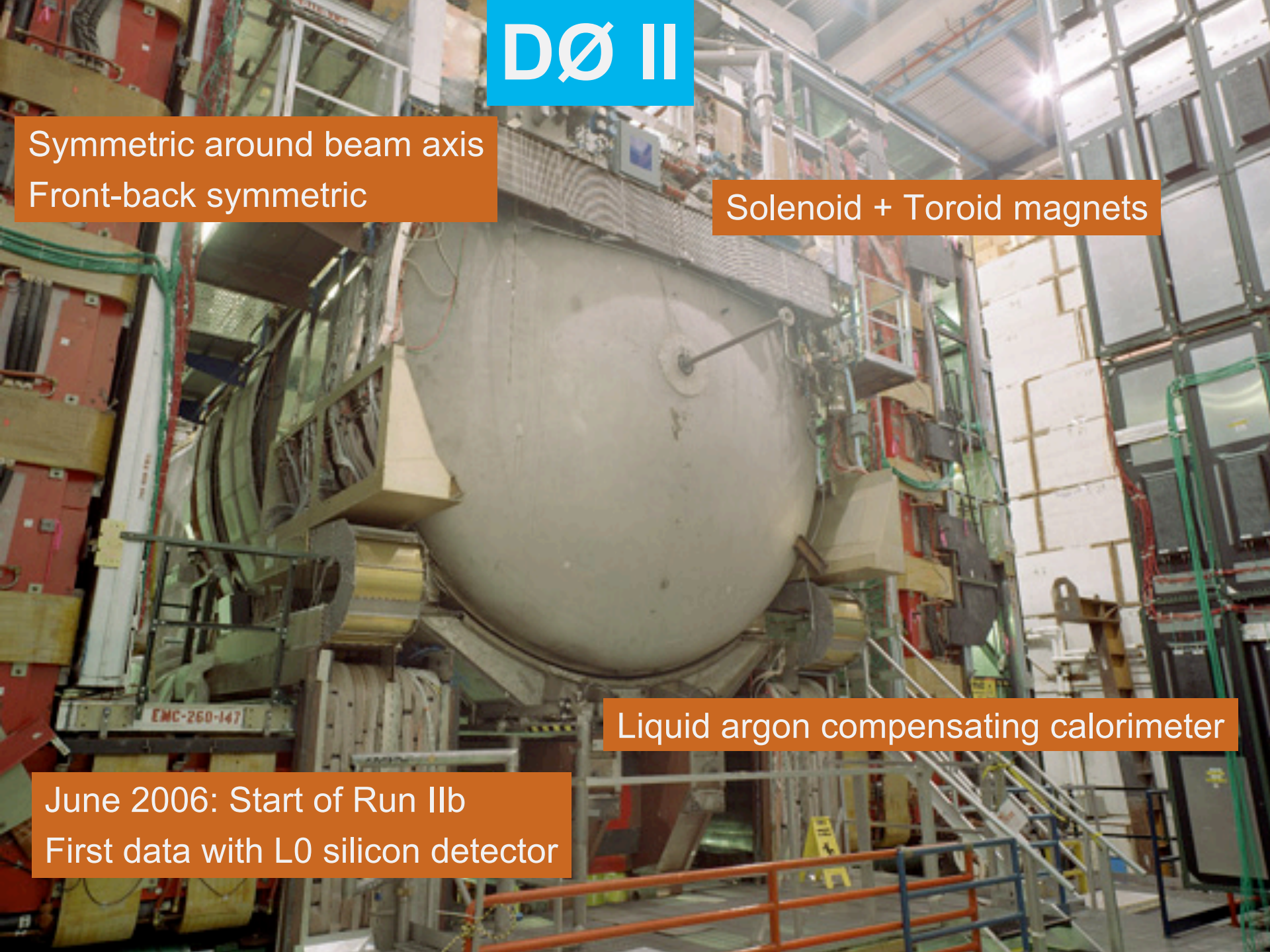
- Accelerator complex breaking records all the time
- Peak Luminosity record $3.18 \cdot 10^{32}$ $cm^{-2}sec$
- Weekly integrated luminosity record 57 pb^{-1}
- Total integrated luminosity delivered ~4.6 fb^{-1}
  - ~3.8 fb^{-1} recorded by each experiment

Thanks to the Accelerator Division!






CDF II
Symmetric around beam axis
Front-back symmetric
1.4 Tesla solenoid
~100 tons
Dedicated silicon detector
for secondary vertex tagging
Muon coverage up to |η| ~ 1.1
Electron reconstruction up to |η| ~ 2.8


DØ II
Symmetric around beam axis
Front-back symmetric
Solenoid + Toroid magnets
Liquid argon compensating calorimeter
June 2006: Start of Run IIb
First data with L0 silicon detector

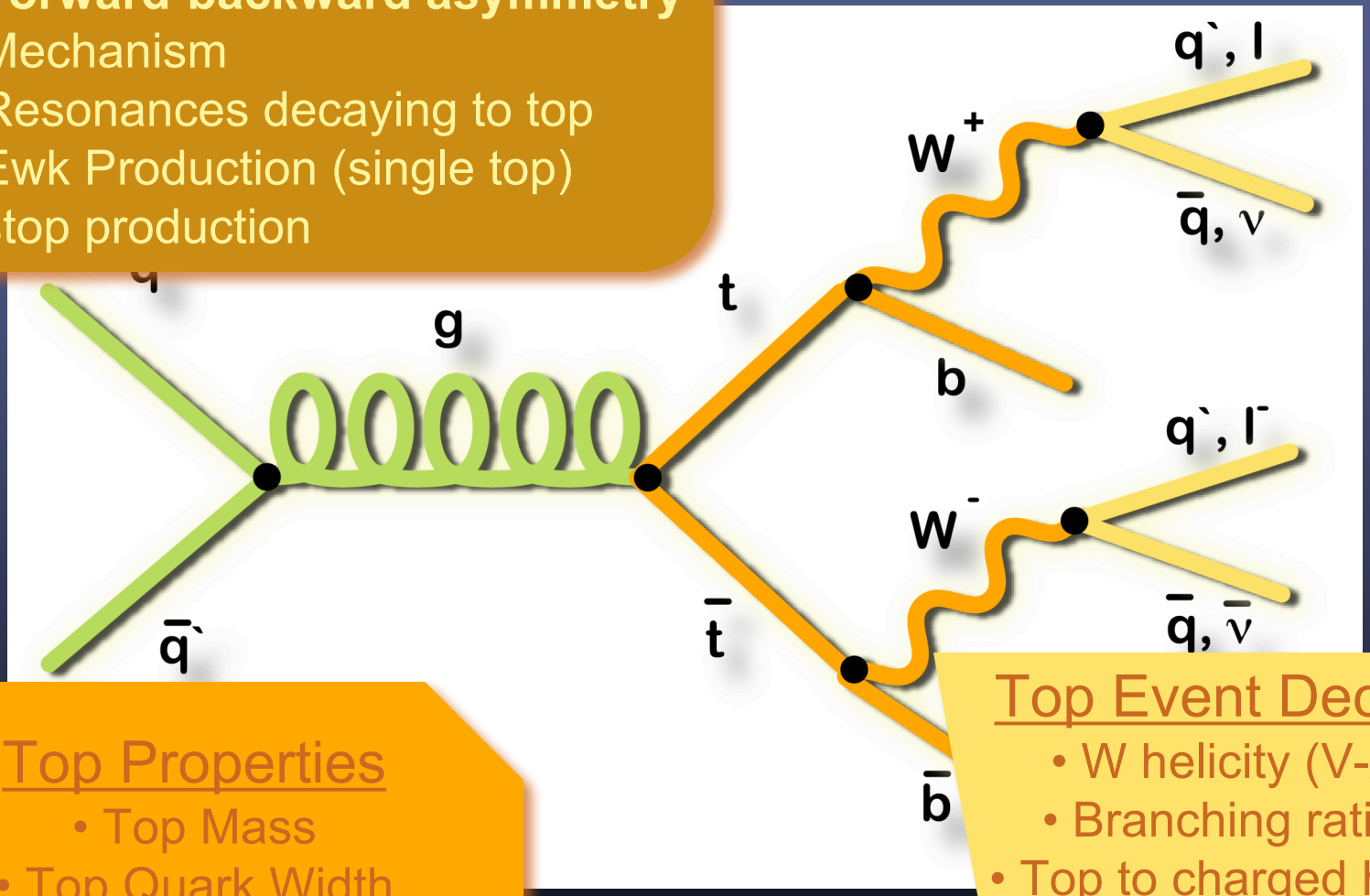
Top Physics

When Trish discovers Ned works exclusively with top quarks, she will be putty in his hands.

Top Physics is "obviously" the sexiest topic at the Tevatron

Top Quark Production

- **Top Pair Cross Section**
- **Forward-backward asymmetry**
- Mechanism
- Resonances decaying to top
- Ewk Production (single top)
- stop production



Top Properties

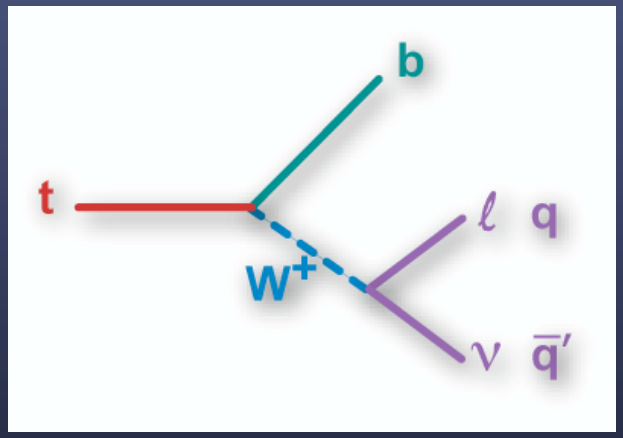
- Top Mass
- Top Quark Width
- Charge of Top Quark

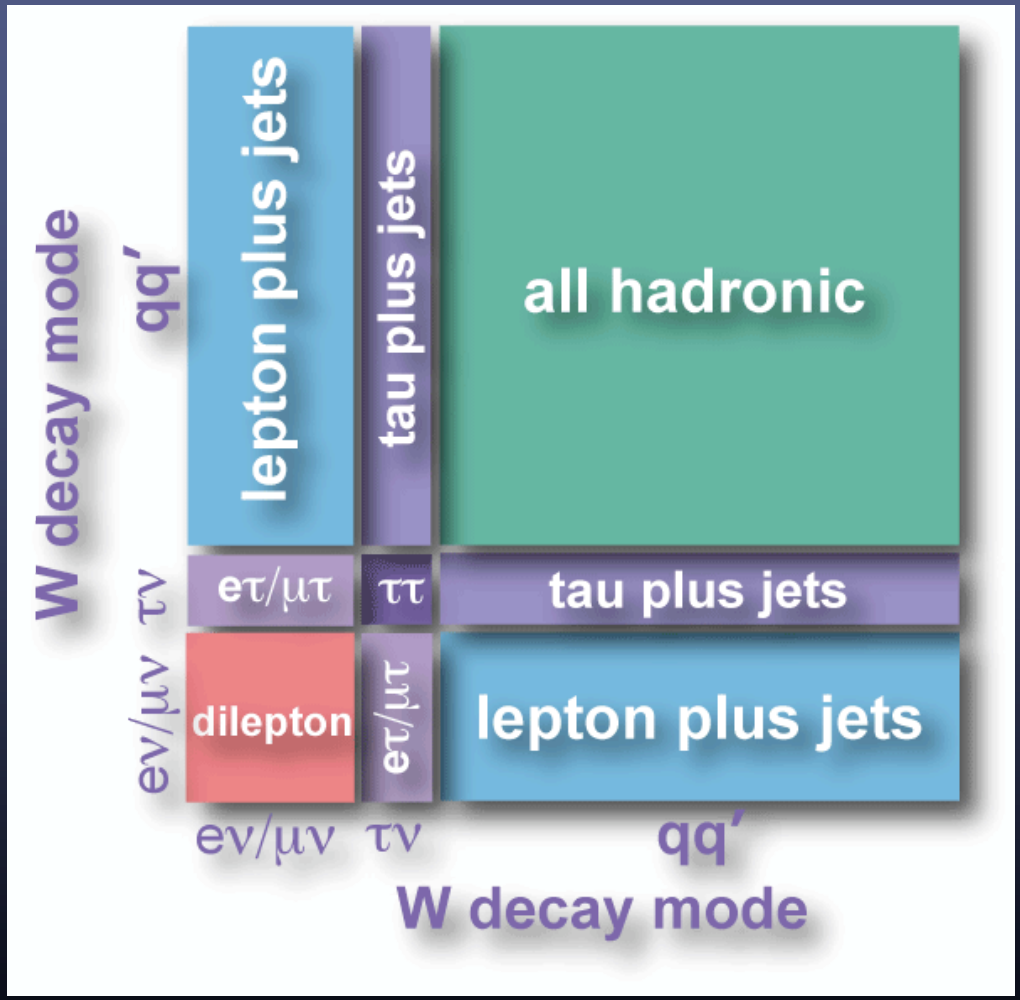
Top Event Decays

- W helicity (V-A)
- Branching ratios
- Top to charged higgs
- Top sample (W+c)
- FCNC

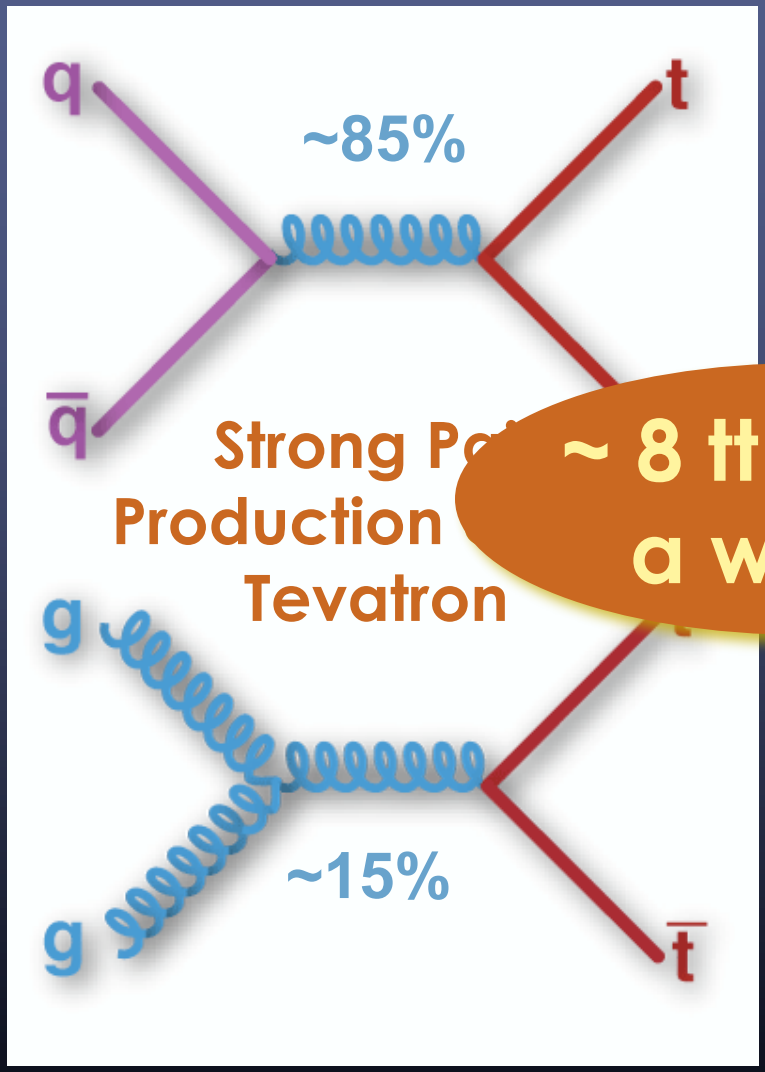
Top events are characterised by the decay mode of the W

$t \to Wb \sim 100\%$

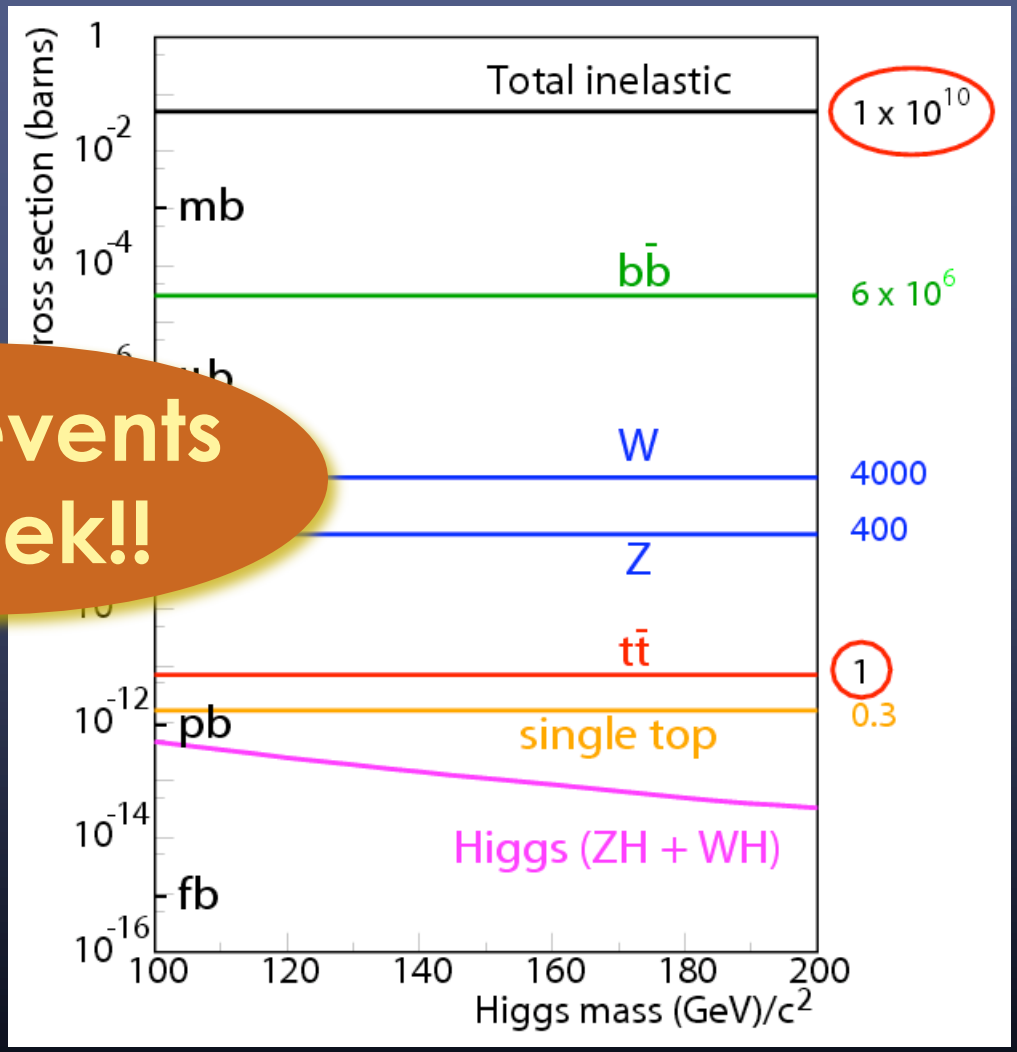




How is top produced?



~ 8 tt events a week!!



One top pair each 10^{10} inelastic collisions at $\sqrt{s}$ = 1.96 TeV

Top Quark Pair Production Cross-Section Measurements

All values assume m_{tt} = 175 GeV/c^2

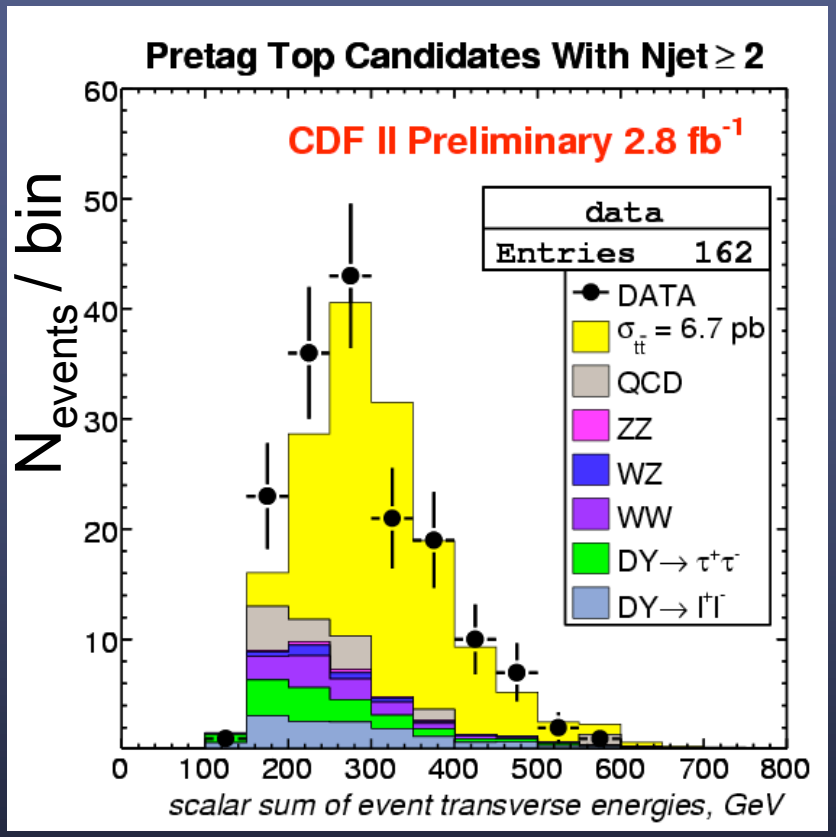
$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bck}}{\epsilon \cdot A \cdot L}$$

$H_T = \sum E_T^{jets} + p_T^{lepton} + \text{Missing } E_T$

Dilepton

2.8 fb^{-1}

- 2 leptons: electron or muon
  - $p_T \geq 20$ GeV/c
  - Opposite charge
  - Dilepton mass (M_{ll}) ≥ 20 GeV/c^2
- $\geq$ 2 Jets: $E_T^{1(2)} \geq 30(15)$ GeV
  - ΔR(lepton - jet) ≥ 0.4
- Missing $E_T \geq 25$ GeV
- Veto Z-like events
  - For $80 < M_{ll} < 100$ GeV/c^2
    - Missing $E_T \geq 40$



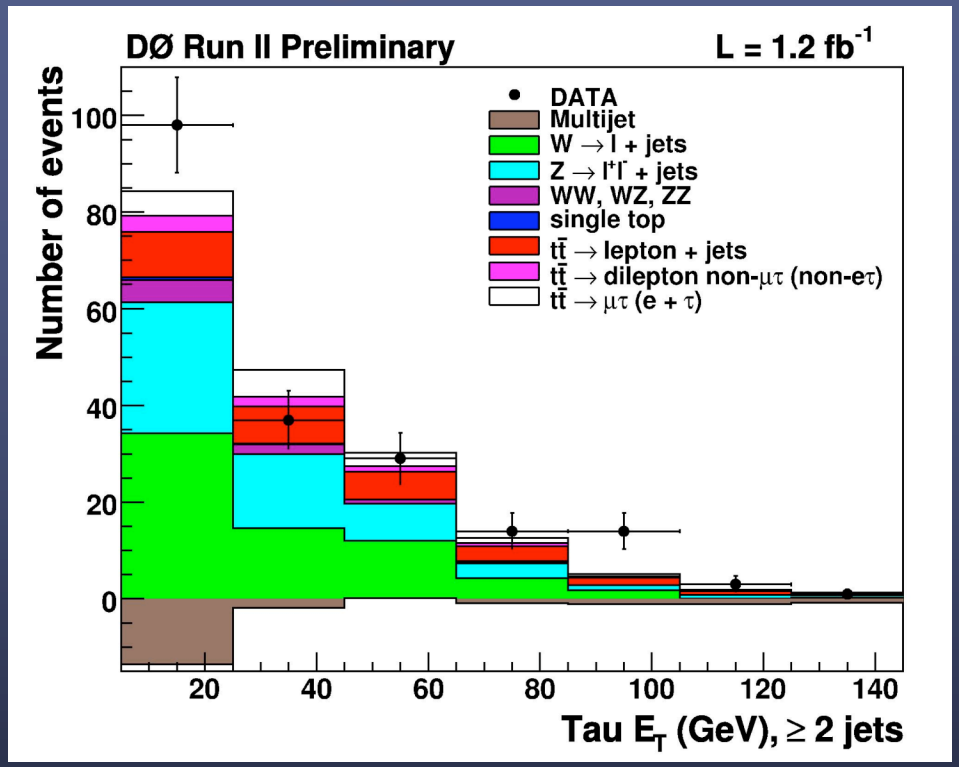
- Dominant systematic
  - Jet energy scale

σ_{ttbar} = 6.7 ± 0.8(stat) ± 0.4(syst) ± 0.4(lumi) pb

Lepton + τ B-Tagged

2.1 fb^{-1}

- Hadronic tau decays
  - Several NN used to separate taus from jets and electrons
- 1 electron (p_T > 15 GeV) or 1 muon (p_T > 20 GeV)
- ≥ 2 jets $E_T^{1(2)}$ ≥ 30(20) GeV
- ≥ 1 b-tagged jet
- Missing E_T > 20(15) GeV for electron (muon) events
- Multi-jet veto



Combination of RunIIa and RunIIb analyses

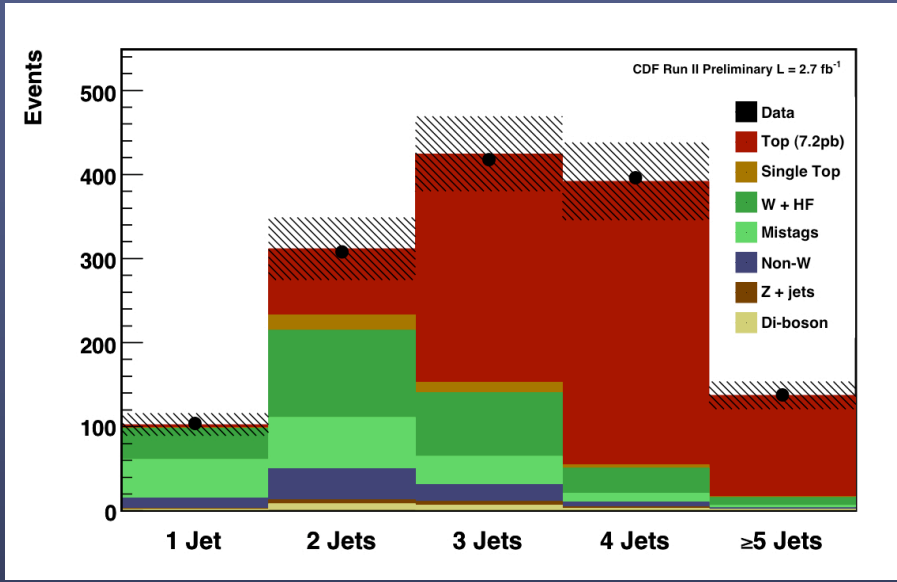
- Dominant systematic
  - Background / MC statistics

$$\sigma_{tt} = 7.3\ ^{+1.3}_{-1.2}(\text{stat})\ ^{+1.2}_{-1.1}(\text{syst}) \pm 0.5(\text{lumi})\ \text{pb}$$

Lepton + Jets B-Tagged

2.7 fb^{-1}

- 1 electron or muon
- Missing $E_T \geq 25$ GeV
- ≥ 3 jets: $E_T \geq 20$ GeV
  - ≥1 heavy flavour tagged jet
- $H_T \geq 250$ GeV
- Estimate heavy flavour background content in 1 jet bin with cross-check in 2 jet bin
- Method relies less on W+jets Monte Carlo cross-sections



- Dominant systematics
  - Heavy flavour tagging
  - Heavy flavour corrections
- 10% total uncertainty

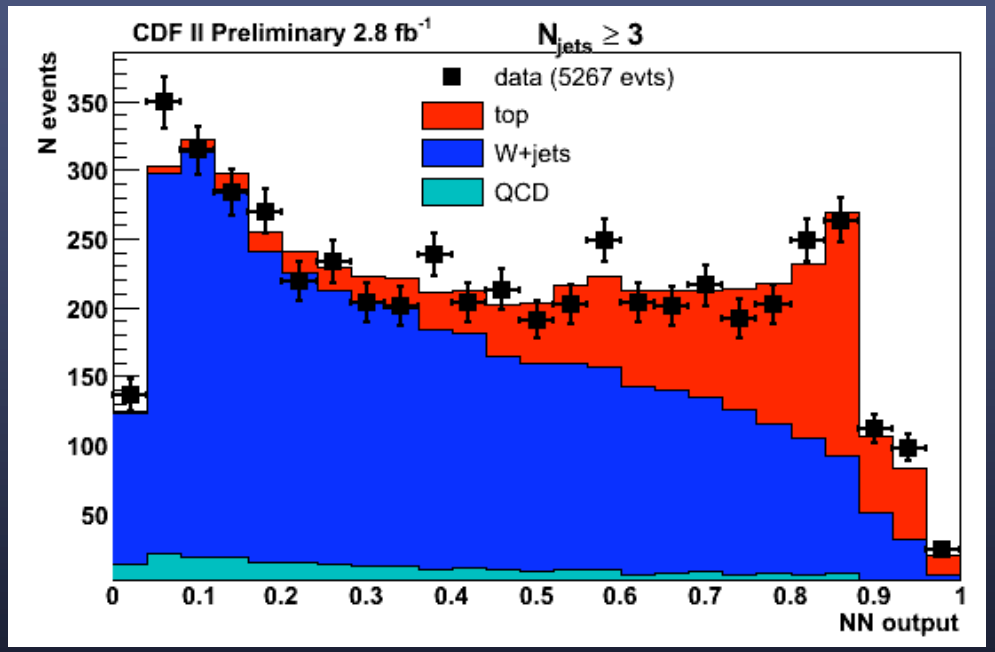
$\sigma_{tt} = 7.2 \pm 0.4\,(stat) \pm 0.5\,(syst) \pm 0.4\,(lumi)$ pb

Lepton + Jets

2.8 fb^{-1}

- Kinematic fit to Neural Network output
- 7 input variables
- Most sensitive variables
  - $\sum E_T$ jets for ≥ 3rd jet
  - H_T
- ≥ 3 jets
  - $E_T^{\geq 2} \geq 20$, $E_T^{1} \geq 35$ GeV
- 1 electron or muon
  - $p_T \geq 20$ GeV/c
- High Missing E_T
  - $ME_T \geq 35$ GeV

- Dominant systematics
  - QCD modelling
  - Parton Shower model



σ_{tt}= 6.8 ± 0.4 (stat) ± 0.6 (syst) ± 0.4 (lumi) pb

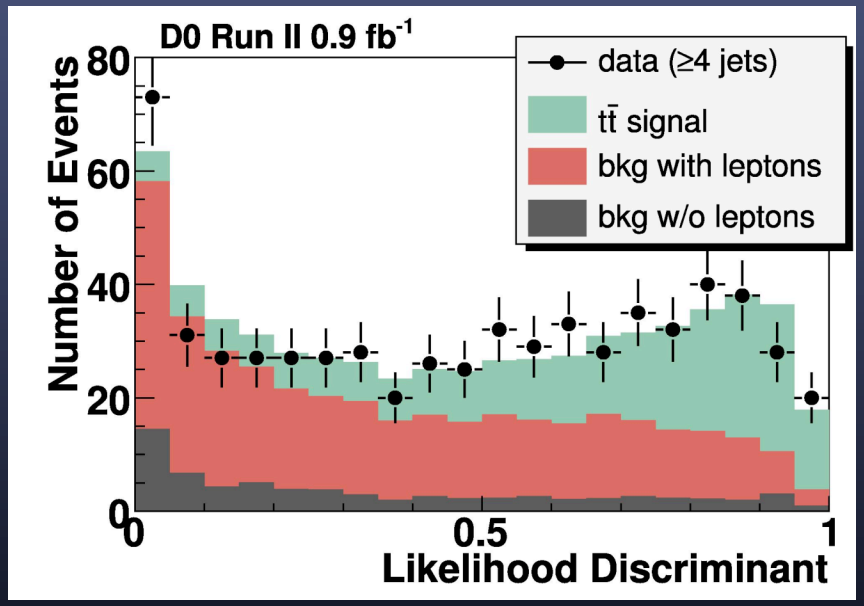
Lepton + Jets Combination

0.9 fb^{-1}

- Kinematic fit to Likelihood discriminant from 5-6 variables
  - Simultaneous fit to 4 channels
    - 3 jets and ≥4 jets
    - Electron and muon
- ≥1 b-tagged jet
- Fit to 8 channels
  - 1 and ≥ 2 b-tags

σ_{tt}=8.1±0.5(stat)±0.7(syst)±0.5(lumi) pb

σ_{tt}=6.6±0.8(stat)±0.4(syst)±0.5(lumi) pb

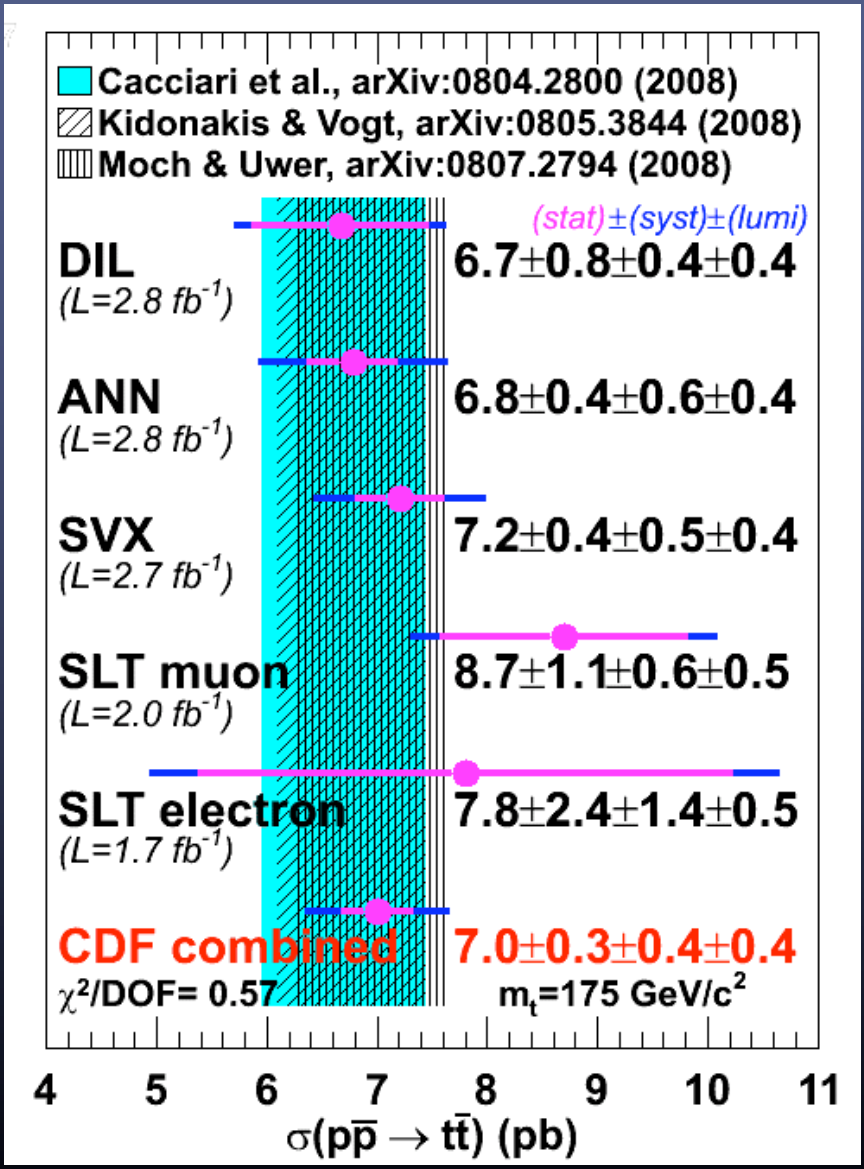


- Combine b-tagged and kinematic fit
- Dominant systematic
  - Selection efficiency
  - B-tagging

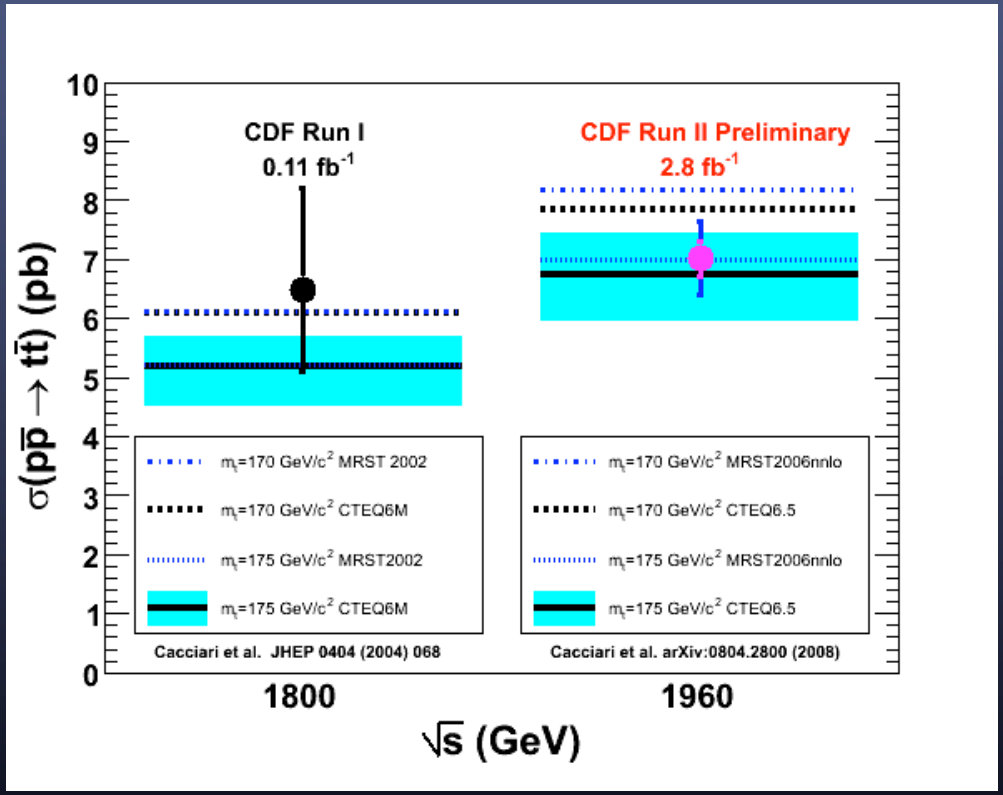
σ_{tt} = 7.4 ± 0.5 (stat) ± 0.5 (syst) ± 0.5 (lumi) pb

Combination

2.8 fb^{-1}



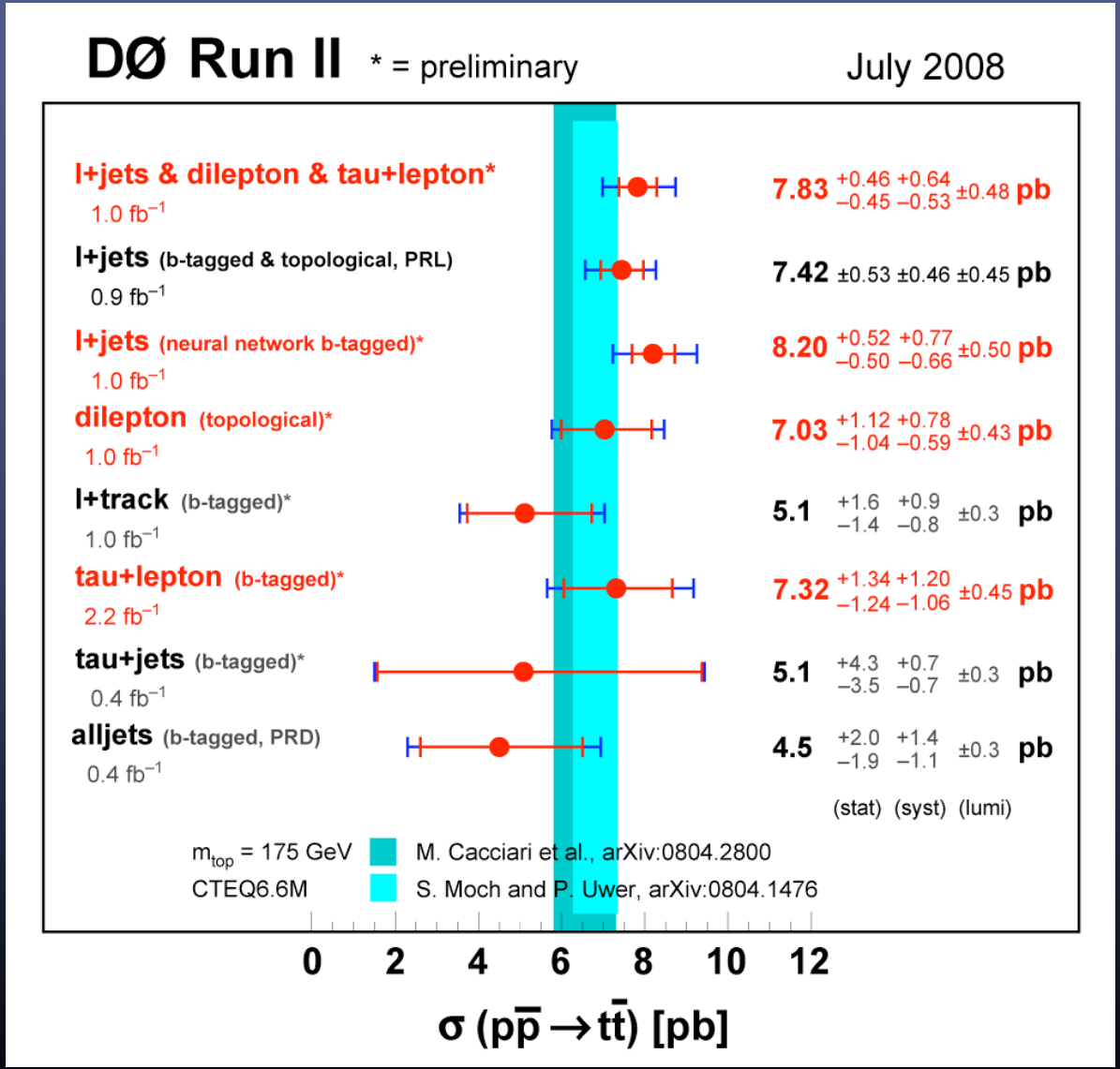
- 9% total CDF uncertainty
- 8% is latest theory uncertainty



Combination

2.2 fb^{-1}

- Total uncertainty of D0 combined channels
  - ~11%



Forward-Backward Charge Asymmetry in Top Pair Production

Charge Asymmetry

SM

Asymmetry caused by interference of ME amplitudes for same final state

- Predictions in parton rest frame
- tt (general)
  - A_{NLO} = 4-7%
  - A_{LO} = 0%

(J. Kühn et al.: arXiv:0709.1652)

- tt + g
  - A_{NLO} = -(0-2)%
  - A_{LO} = - (9-10)%

(P. Uwer et al.: hep-ph/0703120)

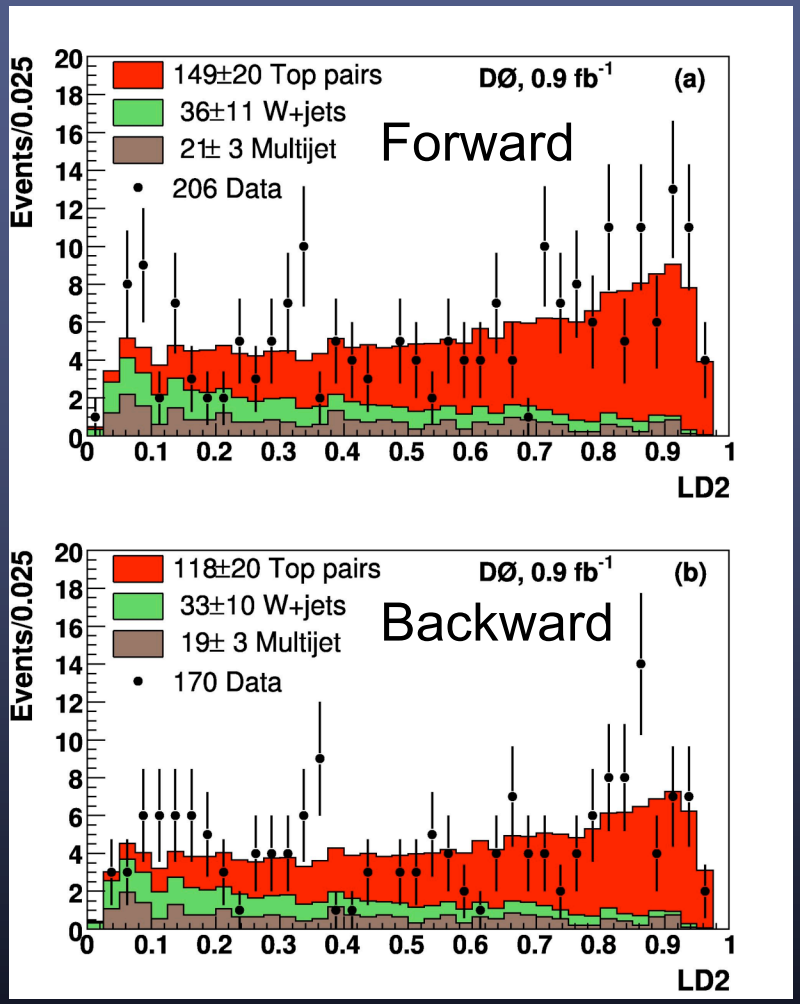
Test of discrete symmetries of strong interaction at high energy

$$A_{fb} = \frac{N_f - N_b}{N_f + N_b}$$

Significant deviation would be an indication for new physics, e.g. Z' or axigluon

A_{fb} in tt Frame

0.9 fb^{-1}



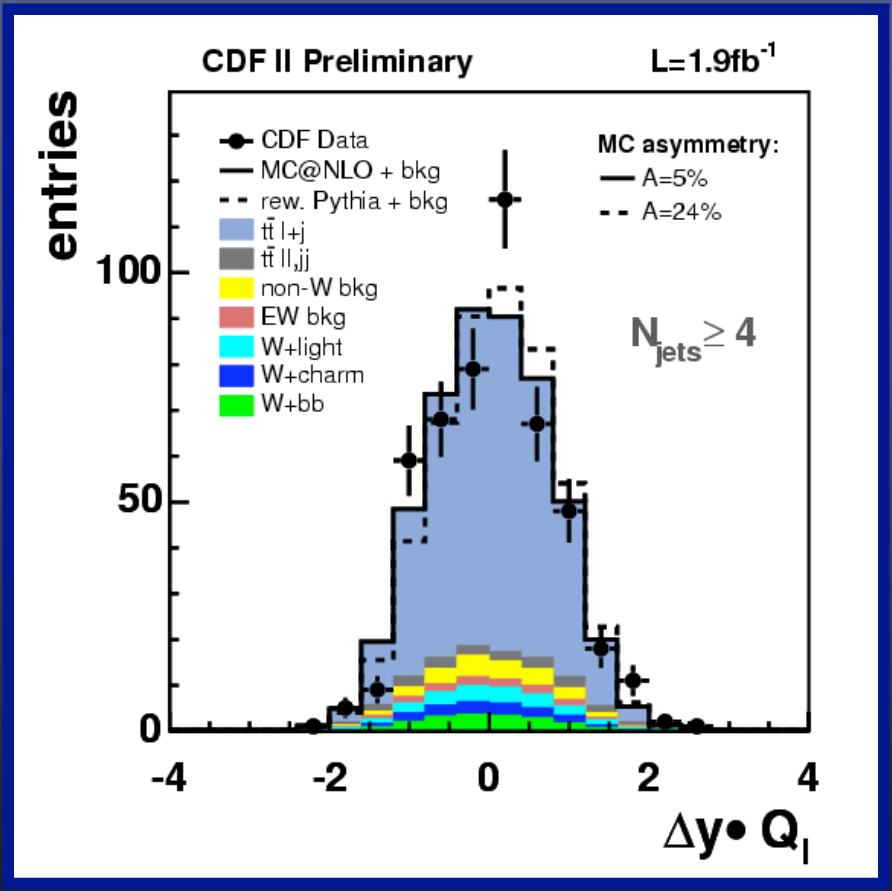
- Lepton + ≥ 4 jets event selection
  - ≥ 1 b-tagged jets
  - Leading jet ≥ 35 GeV
- Not corrected for acceptance and reconstruction effects
- Prescription provides acceptance at parton level
- Kinematic fitter to reconstruct top pairs
- Likelihood discriminant to estimate W+jets background

$A_{fb}^{uncorr} = 12 \pm 8\ (stat) \pm 1\ (syst)\ \%$

A_{fb} In tt Frame

1.9 fb^{-1}

- Asymmetry in parton rest frame is largely recovered by asymmetry in $\Delta y Q_l$
  - y is rapidity
- Lepton + jets event selection
  - ≥ 4 jets
  - ≥ 1 b-tagged jets
- Full reconstruction of top 4-vectors
- Correct for selection efficiency, ttbar reconstruction and background
- **A_{NLO}= 4-7 %**

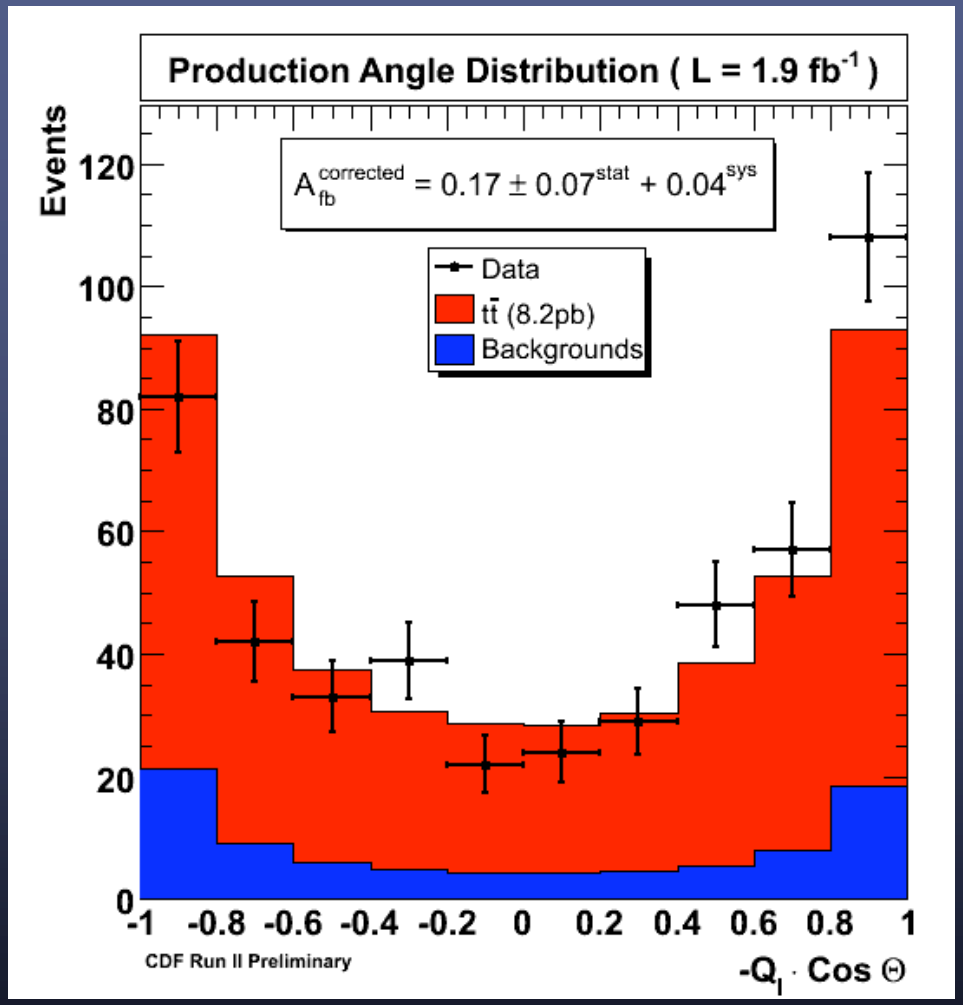


A_{fb}^{corr} = 24 ± 13 (stat) ± 4 (syst) %

A_{fb} in pp Rest Frame

1.9 fb^{-1}

- Lepton + jets event selection
  - ≥ 1 b-tagged jets
- Kinematic fitter fully reconstructs top events
- Reconstruct production angle
- Resulting asymmetry corrected for backgrounds, selection and angle reconstruction effects
- Value directly comparable to theoretical value
  - **A_{NLO} = 4 ± 2 %**

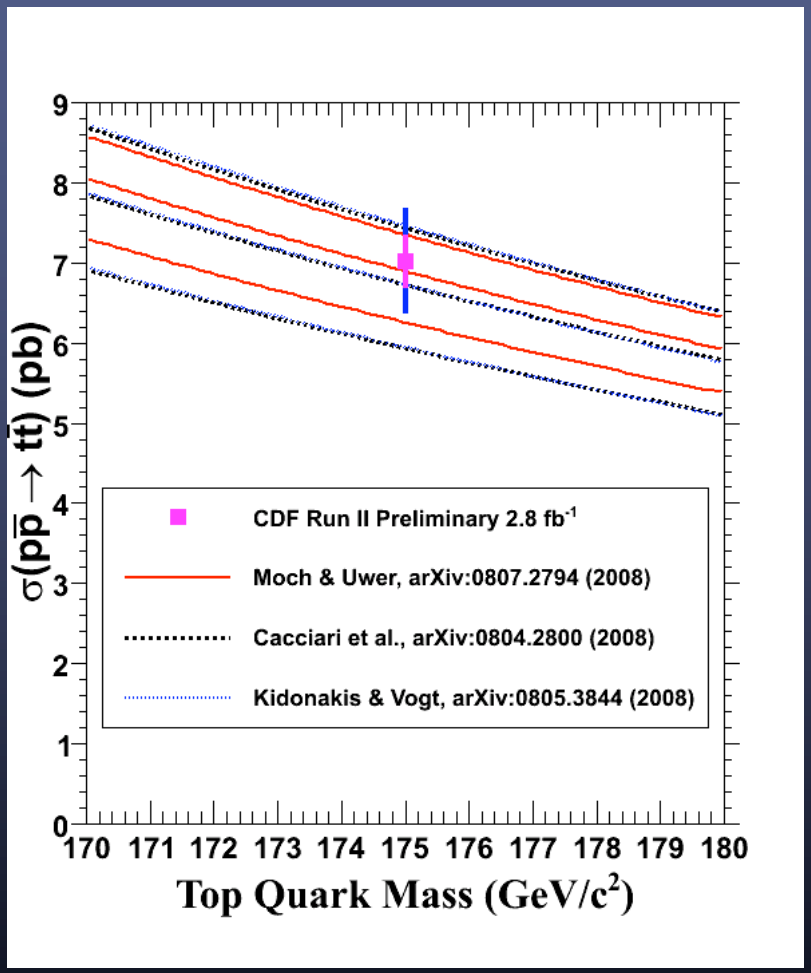


A_{fb}^{corr} = 17 ± 7 (stat) ± 4 (syst) %

Conclusions

- Important to measure tt cross-section in many different channels
  - Different sensitivity to new physics
  - Improves combined measurement as different systematics
- Entering the realm of high statistics top physics
  - Many top properties measurements now systematics limited
- More data needed to determine if slight excess in A_{fb} measurements become more (or less) significant
- More information on these and other analyses
- http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html
- http://www-cdf.fnal.gov/physics/new/top/public_tprop.html

Backup Slides

Combination vs. Mass

2.8 fb^{-1}