Tevatron Top Physics

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Universität Karlsruhe

on behalf of the CDF II *and* DØ *Collaborations*

LHC 2008

Split

Photo: Reidar Hahn, artwork: Jan Lück

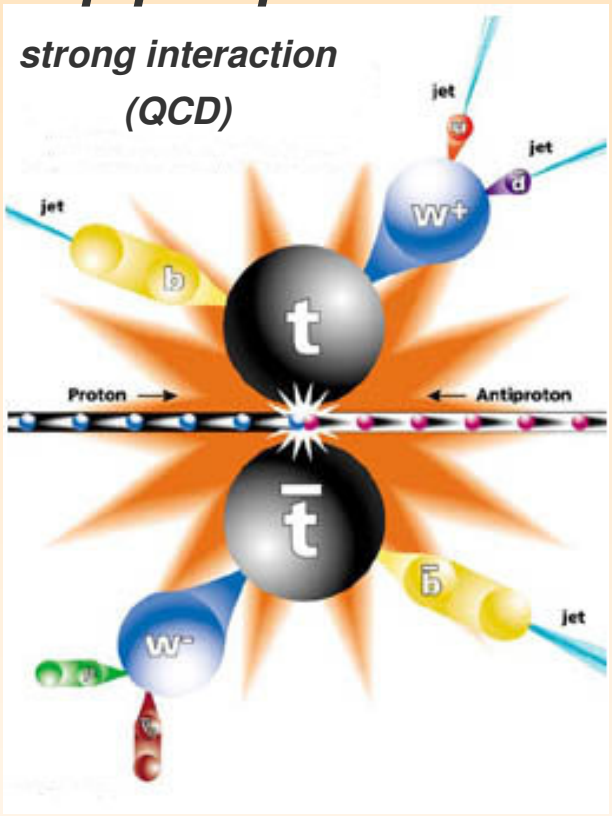
Overview

1995: Discovery of top quark

Is our top = SM top?

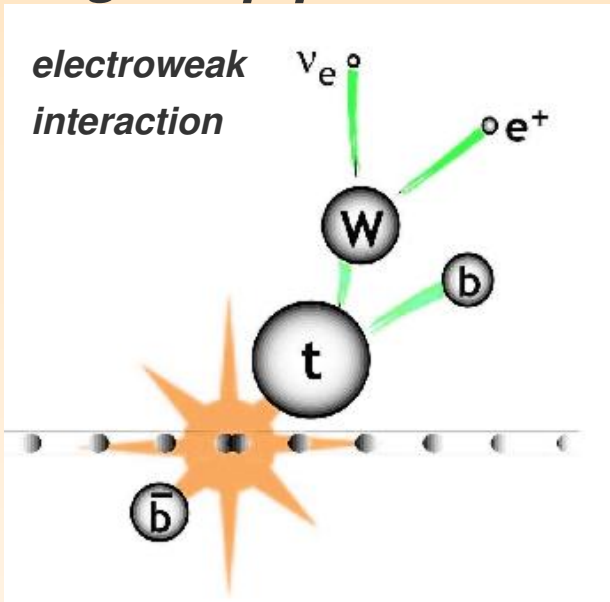
Top quark mass

top pair production



New physics in top events?

single top production



New physics in events with top signature?

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- **cross section** *(single top and top pair)*
- **Properties of production** *(f_{gg}, asymmetry)*
- **Wtb-couplings**
- **Charge, lifetime, branching ratios**

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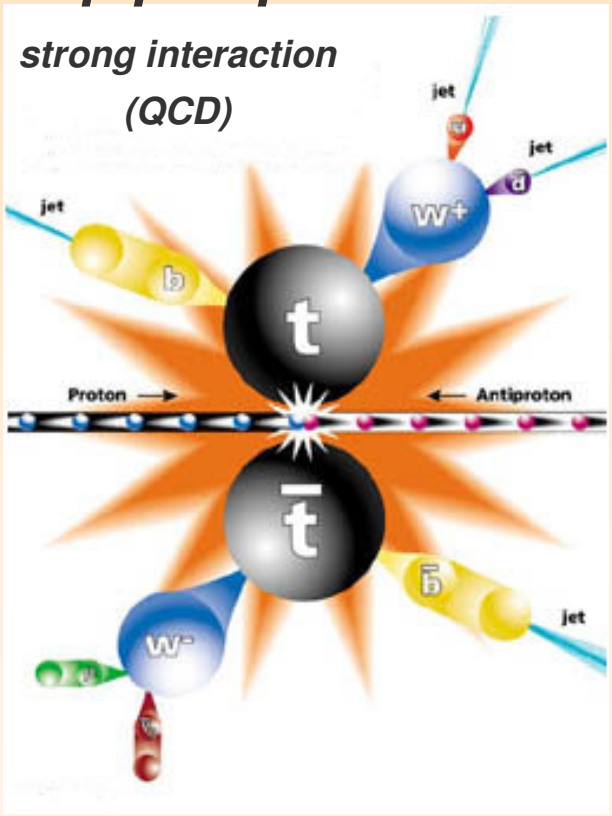

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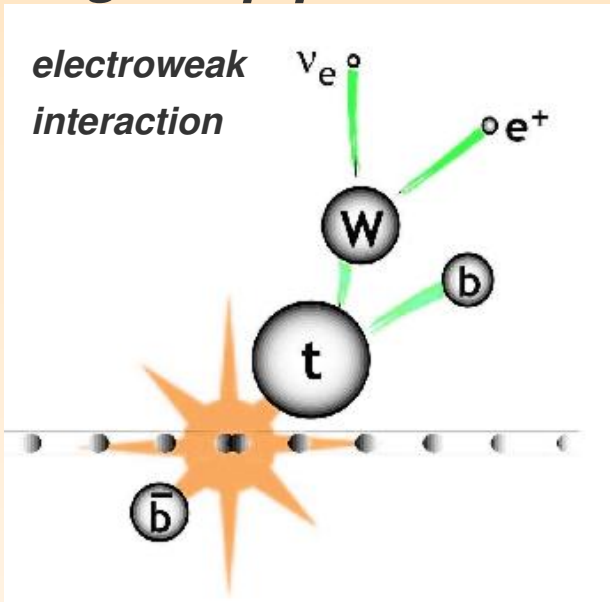

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- **Important SM parameter** *(constraints on Higgs mass)*
- **Precision measurement**
- **Are all results consistent?**

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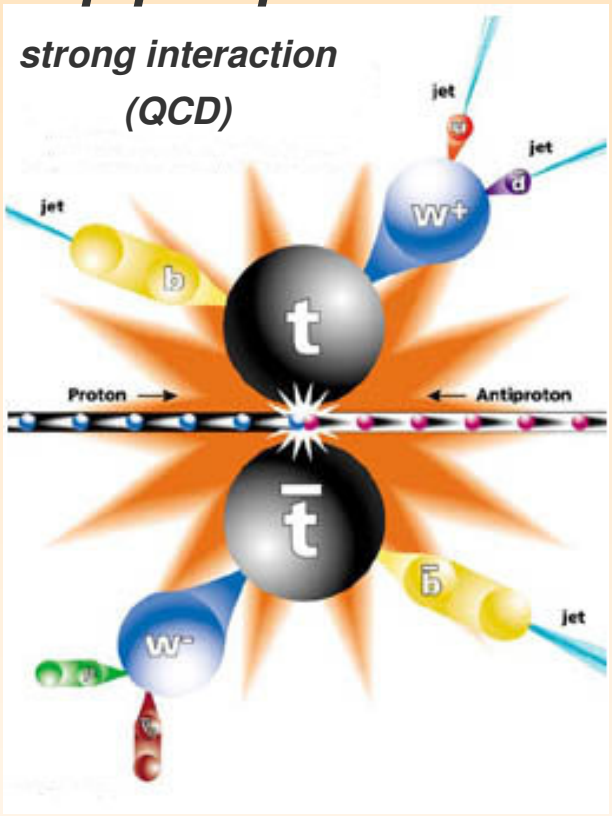

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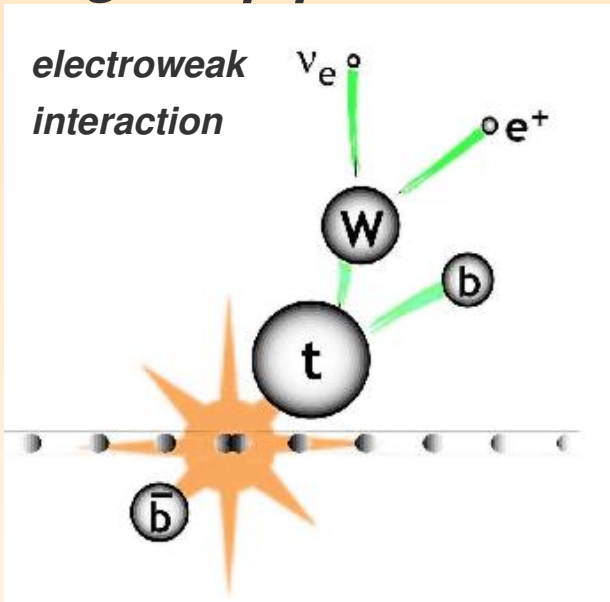

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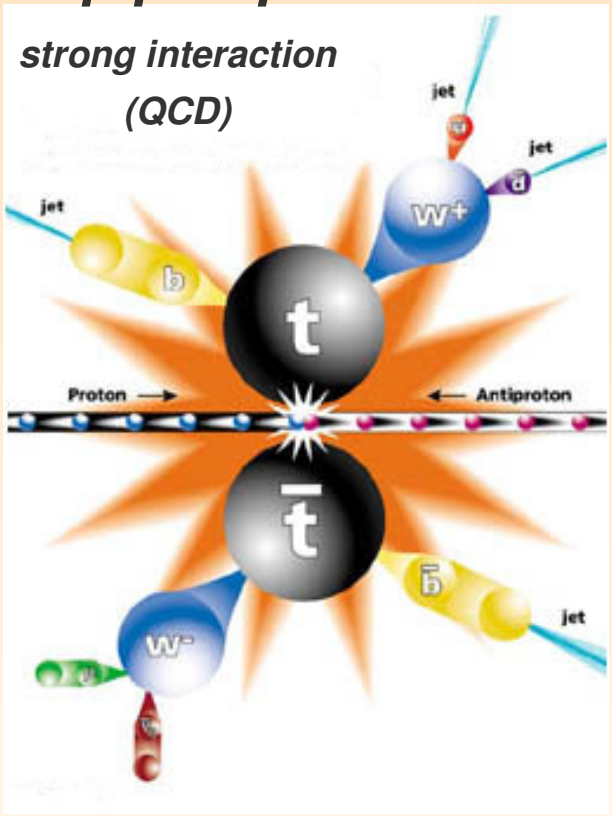
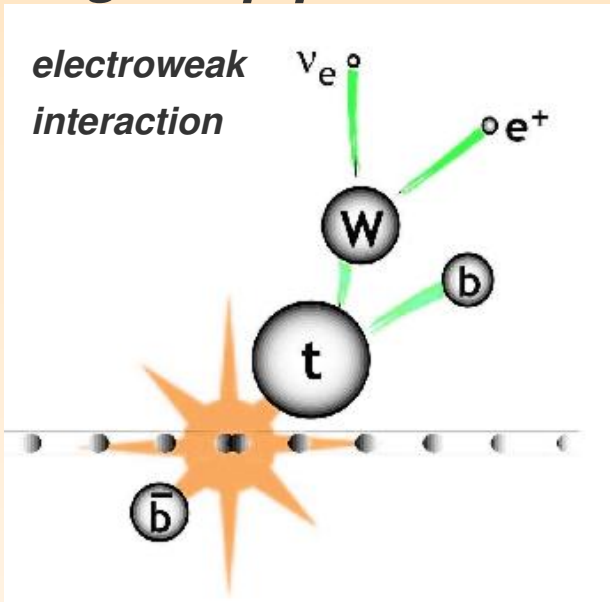


New physics in top events?

- **New resonances**
- **Anomalous top prod.**
- **New physics in decay**

single top production



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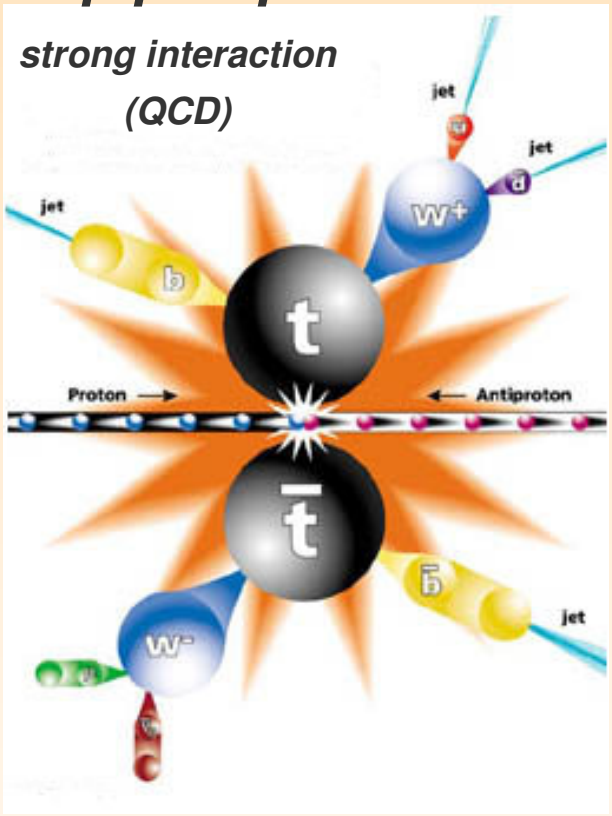

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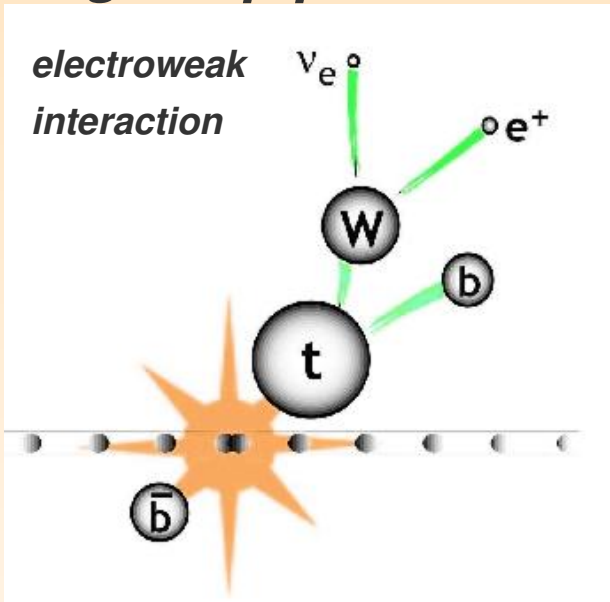


New physics in events with top signature?

- **fourth generation: t'**
- **SUSY partner: stop**

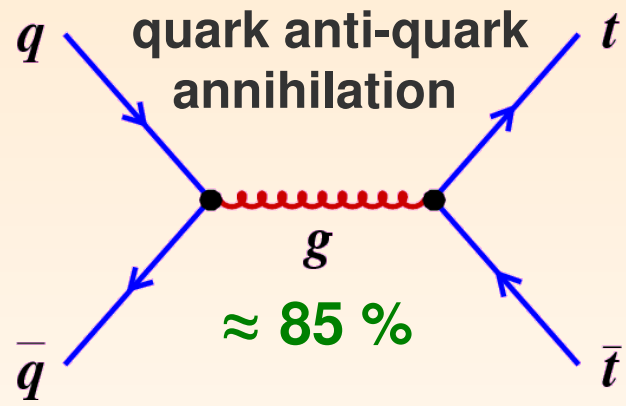
Top Quark Production

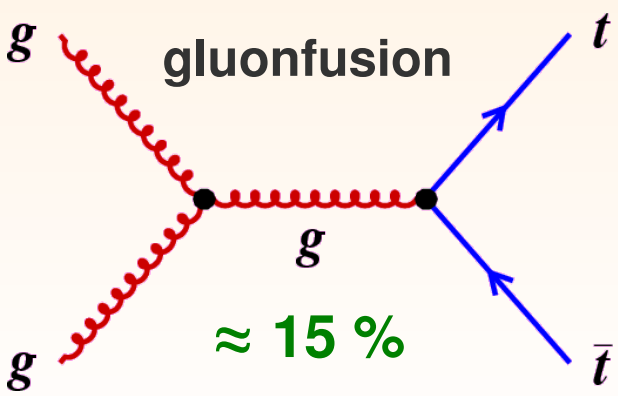
Tevatron: proton anti-proton collisions at $\sqrt{s}$ = 1.96 TeV

Top pair production:

SM: $\sigma = 6.7 \pm 0.8$ pb

M. Cacciari et al., arXiv:0.804.2800, N.Kidonakis et al, arXiv:0805.3844, P. Uwer et al., arXiv:0807.2794



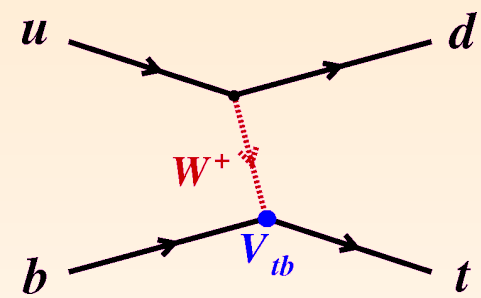


Single top production:

SM: $\sigma = 2.9 \pm 0.4$ pb

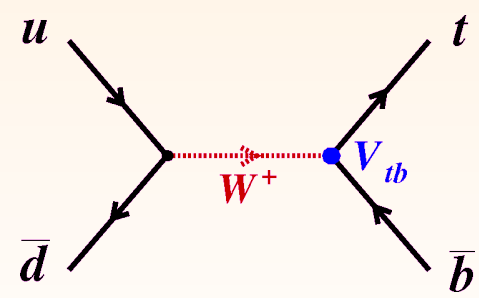
B.W. Harris et al., Phys. Rev. D 66, 054024 (2002), Z. Sullivan, Phys. Rev. D 70, 114012 (2004), N. Kidonakis, Phys. Rev. D74, 114012 (2006)

t-channel:



$\sigma_t = 1.98 \pm 0.25$ pb

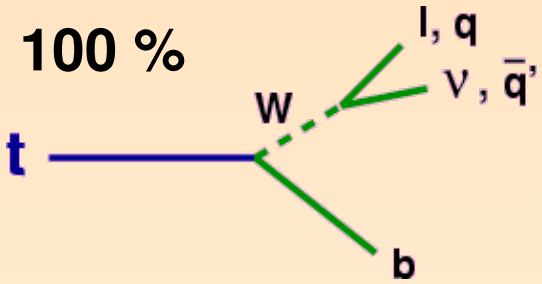
s-channel:



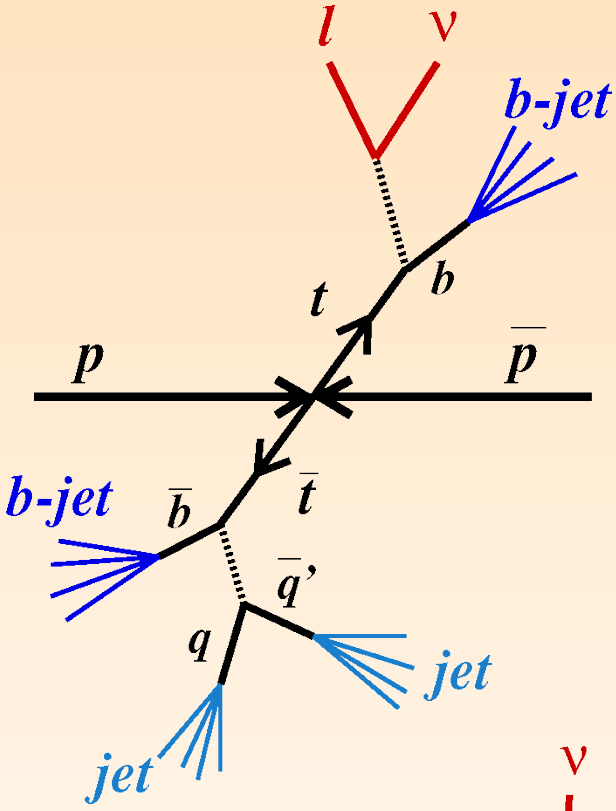
$\sigma_s = 0.88 \pm 0.11$ pb

Decay of Top Quarks

$t \rightarrow bW \approx 100\ \%$



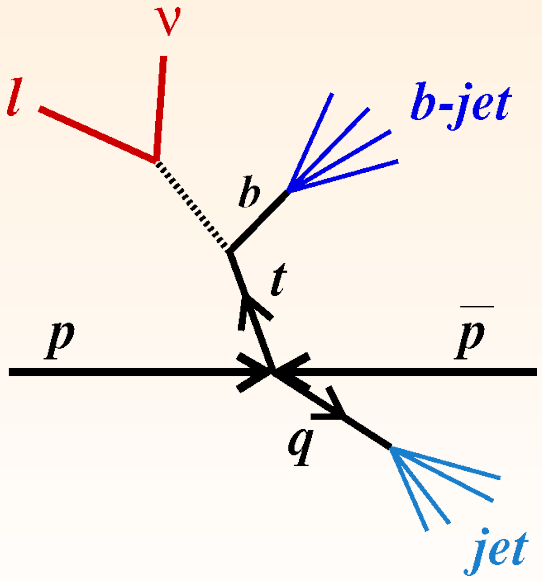
Top pairs:



Top pairs:
lepton+jets

- BR ≈ 30 %
- moderate background

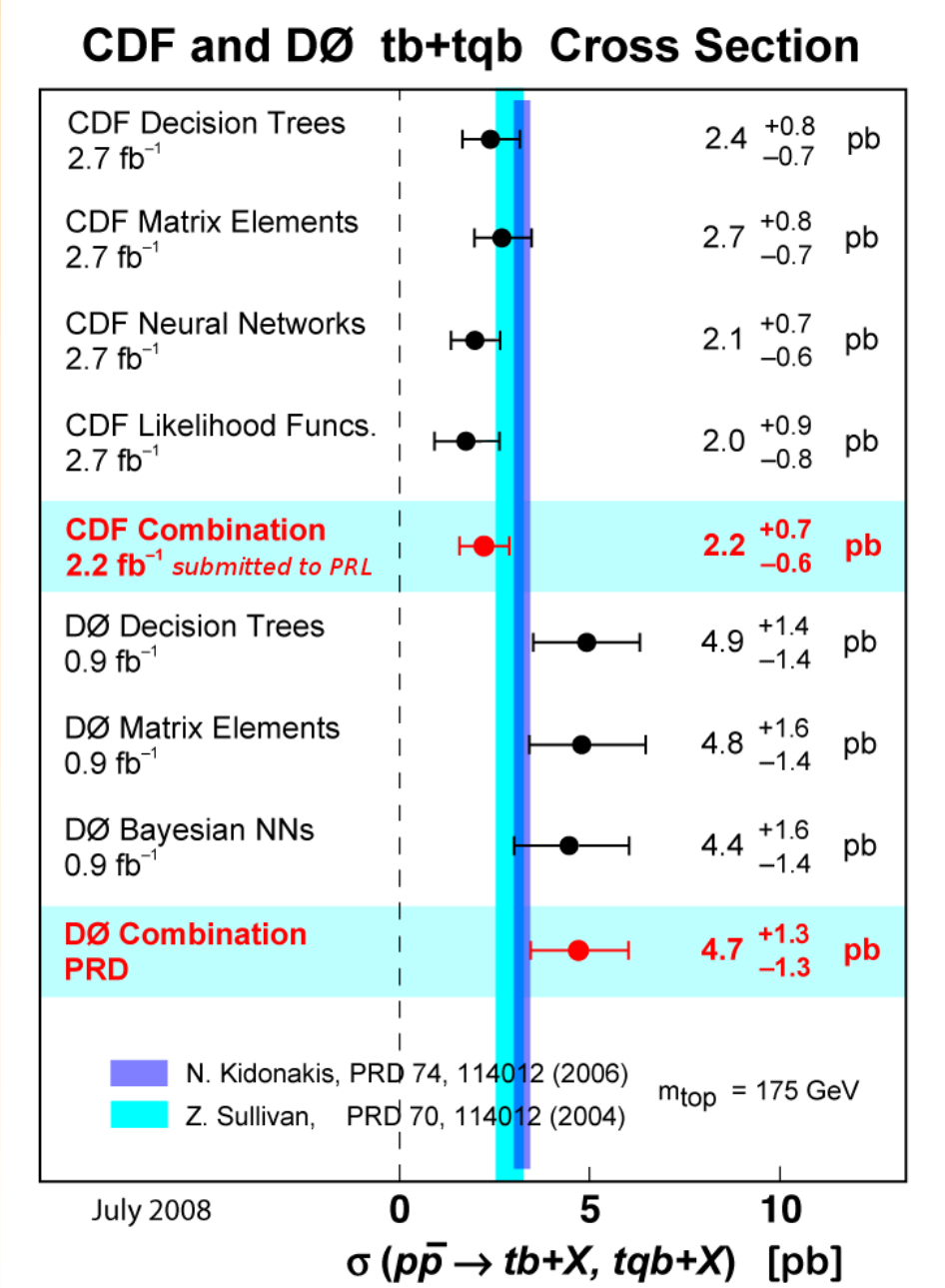
Single top:
t-channel



Single top: Leptonic W decay (e or μ)
(BR≈ 21 %)

Is our top = SM top?

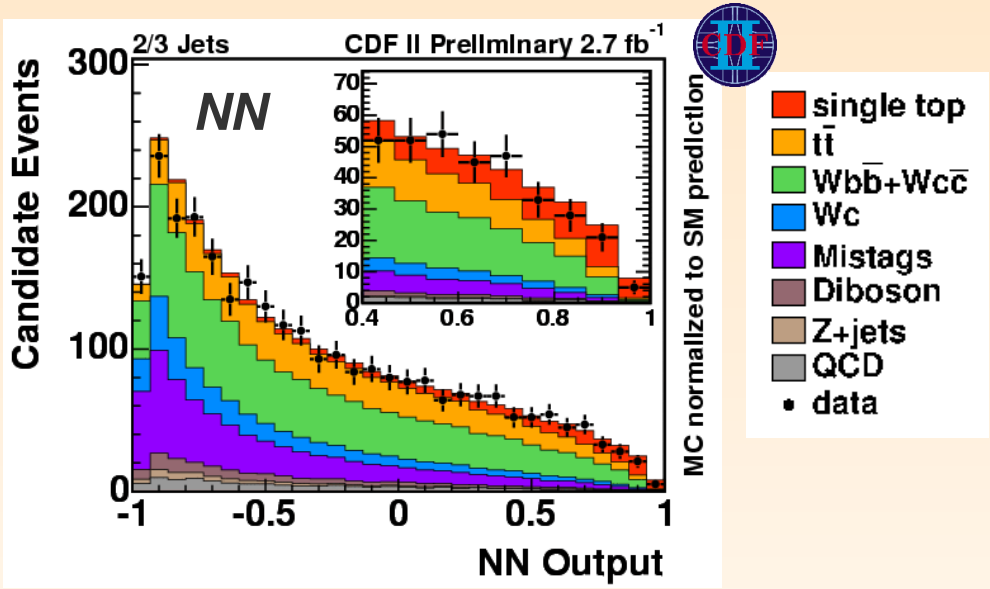
Single Top Quarks - Cross Section



Experimental challenge:

Large background from W+jets

→ Use of multivariate techniques

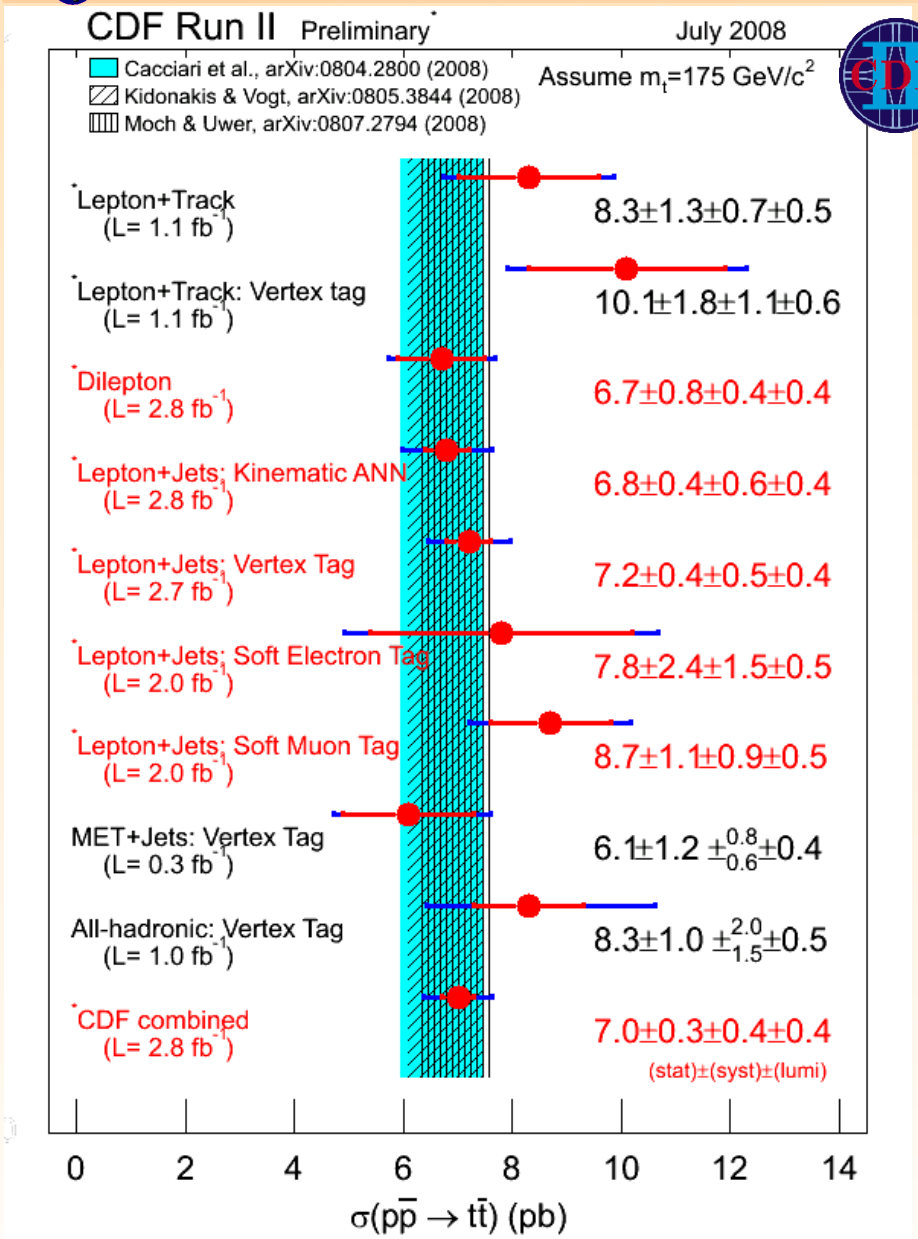


Combination: Exp. p-value: 4.9 σ
arXiv:0809.2581 **Obs. p-value: 3.7 σ**

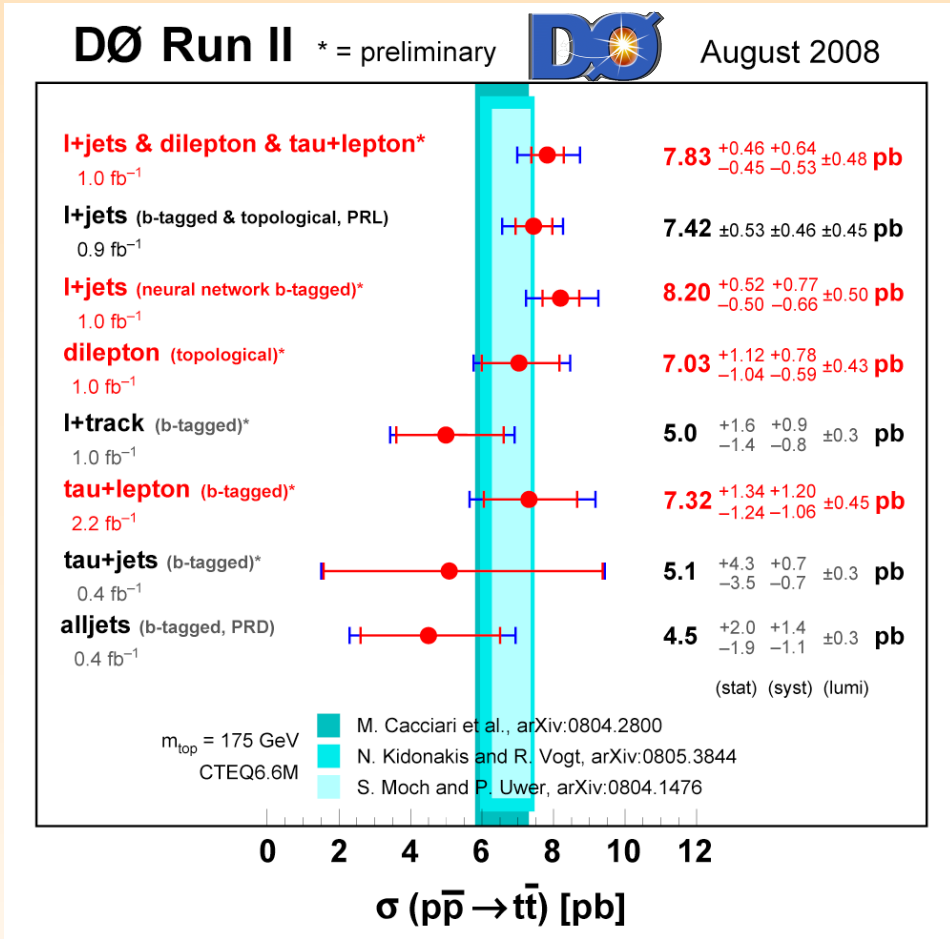
Combination: Exp. p-value: 2.3 σ
Phys. Rev. D78, 012005 (2008) **Obs. p-value: 3.6 σ**

Strong evidence for single top at both Tevatron experiments

Top Pair Cross Section



$\sigma = 7.0 \pm 0.3_{(stat.)} \pm 0.4_{(syst.)} \pm 0.4_{(lumi)}$ pb



$\sigma = 7.8 \pm 0.5_{(stat.)} \pm 0.6_{(syst.)} \pm 0.5_{(lumi)}$ pb

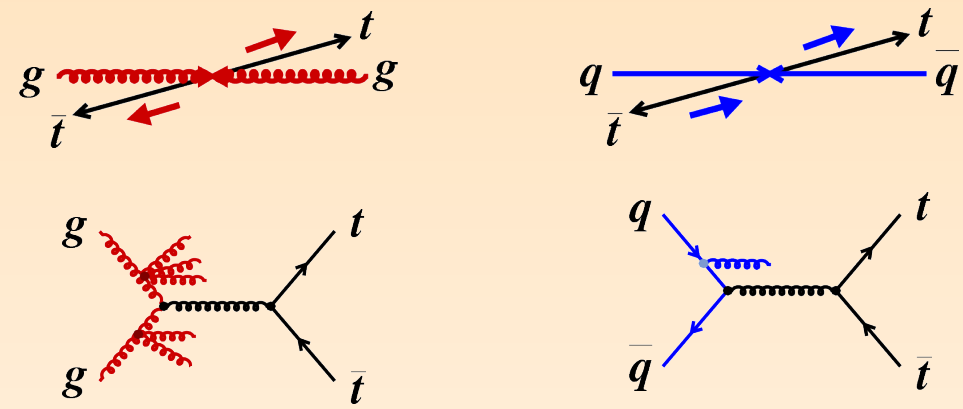
Rel. uncertainty of σ: ~9%

Measurements in all channels and with different methods are consistent

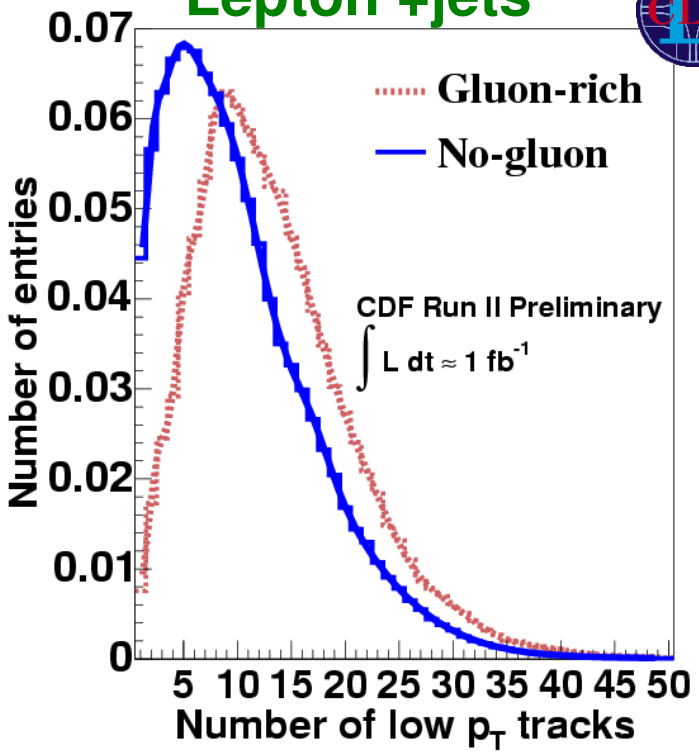
Production via Gluon Fusion

- **Sensitive to spin configuration:**
  l+j: Kinematic of prod. and decay (NN)
  ll : Azimuthal angle difference between leptons

- **Sensitive to radiation of soft gluons:**
  l+j: Number of tracks with small p_T

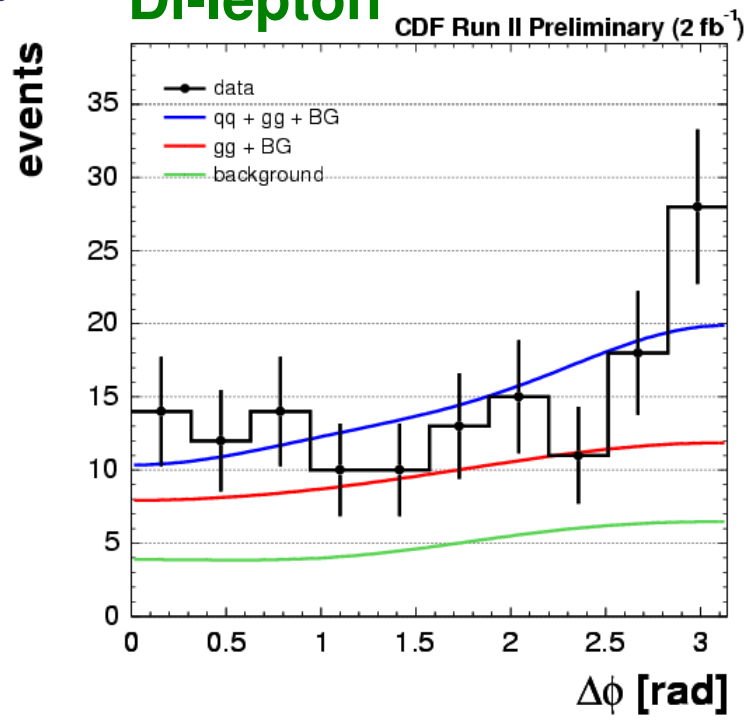


Lepton +jets



arXiv:0807.4262

Di-lepton



l+j combination:

$$f_{gg} = 0.07^{+0.15}_{-0.07}$$

ll: $f_{gg} = 0.53^{+0.36}_{-0.38}$

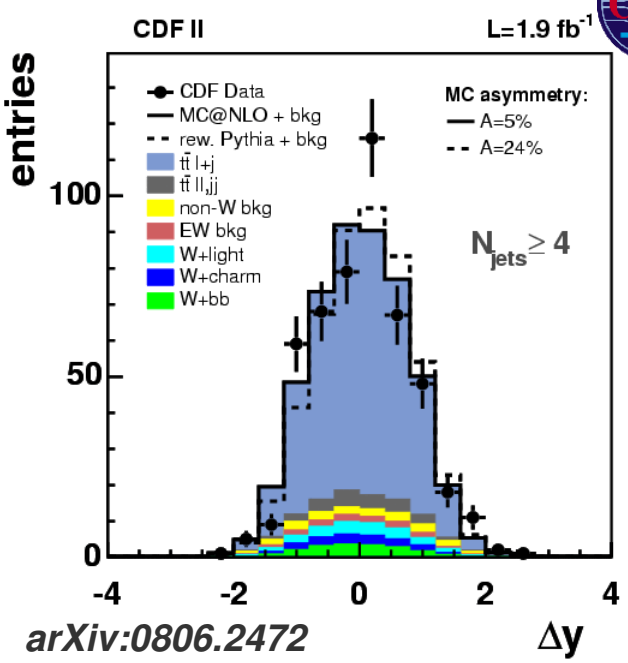
NLO: $f_{gg} = 0.15 \pm 0.05$

Measurements consistent with SM

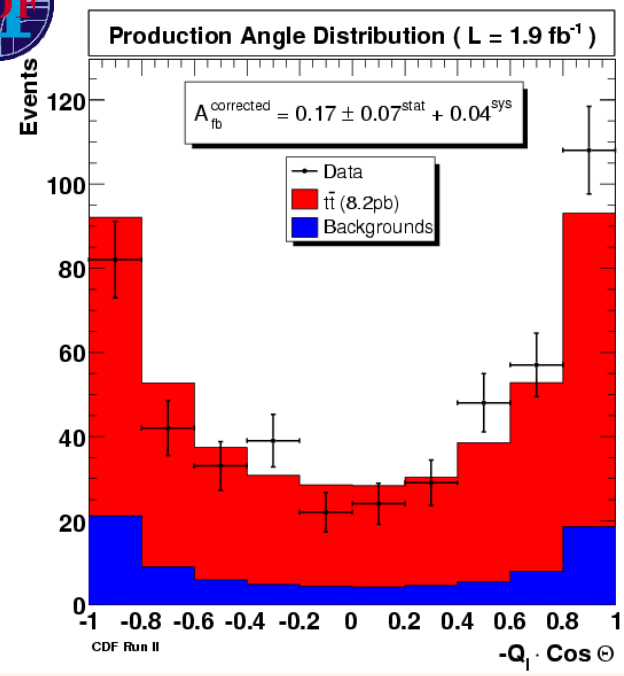
Forward-Backward Asymmetry

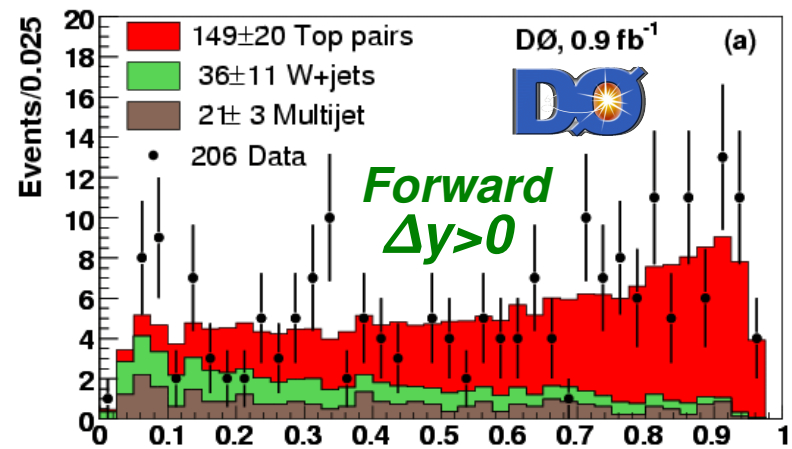
- SM: small asymmetry of ~5% caused by NLO ttX effects
- New physics (Z' or axigluons) might enhance asymmetry

lepton+jets



arXiv:0806.2472





Phys. Rev. Lett. 100, 142002 (2008)

Uncorrected:

$A_{ttbar,vis} = (12 \pm 8 \pm 1)\ \%$

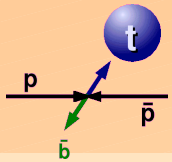
SM: $A_{ttbar,vis} = (0.8 \pm 0.2 \pm 1.0)\%$

Corrected for acceptance and measurement dilutions:

$A_{ttbar} = (24 \pm 13 \pm 4)\ \%$ $A_{lab} = (17 \pm 7 \pm 4)\ \%$

SM: $A_{ttbar} = (6 \pm 1)\%$, $A_{lab} = (4 \pm 1)\%$

Asymmetries larger than SM pred., but consistent with pred. within uncertainties



Wtb coupling

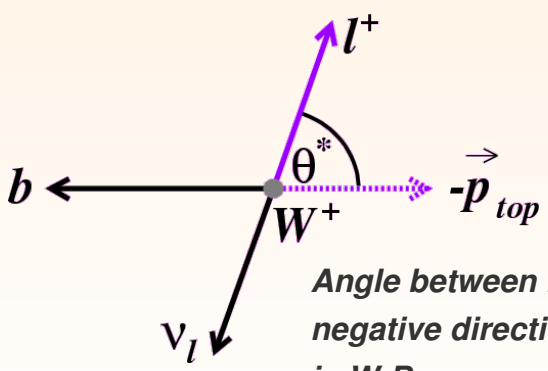
Wtb vertex ***(interaction Lagrangian)***

$$\mathcal{L} = \frac{g_w}{\sqrt{2}}\left[W_\mu^- \bar{b}\gamma^\mu(f_1^L P_L + f_1^R P_R)t - \frac{1}{m_W}\partial_\nu W_\mu^- \bar{b}\sigma^{\mu\nu}(f_2^L P_L + f_2^R P_R)t\right] + h.c.$$

SM couplings: $f_1^L=1$, $f_2^L = f_1^R = f_2^R = 0$

Non-SM couplings would affect:

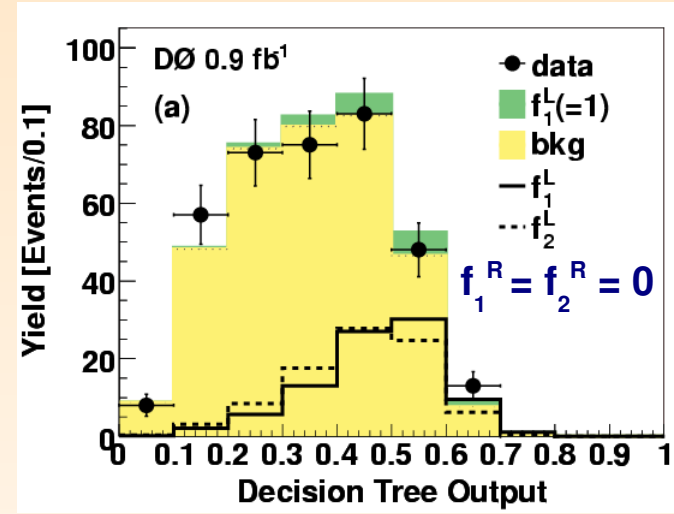
- **Single top production:**
  Rate and kin. distributions
- **Top pair events:**
  W-helicity in top decay,
  sensitive variable cosΘ*:



Angle between lepton and negative direction of top quark in W-Boson rest frame

Single top, boosted decision trees

arXiv:0807.1692



Coupling	Measured Value	limits at 95% C.L.
f_1^L, f_2^L	$\lvert f_1^L\rvert^2 = 1.4^{+0.6}_{-0.5}$,	$\lvert f_2^L\rvert^2 < 0.5$
f_1^L, f_1^R	$\lvert f_1^L\rvert^2 = 1.8^{+1.0}_{-1.3}$,	$\lvert f_1^R\rvert^2 < 2.5$
f_1^L, f_2^R	$\lvert f_1^L\rvert^2 = 1.4^{+0.9}_{-0.8}$,	$\lvert f_2^R\rvert^2 < 0.3$

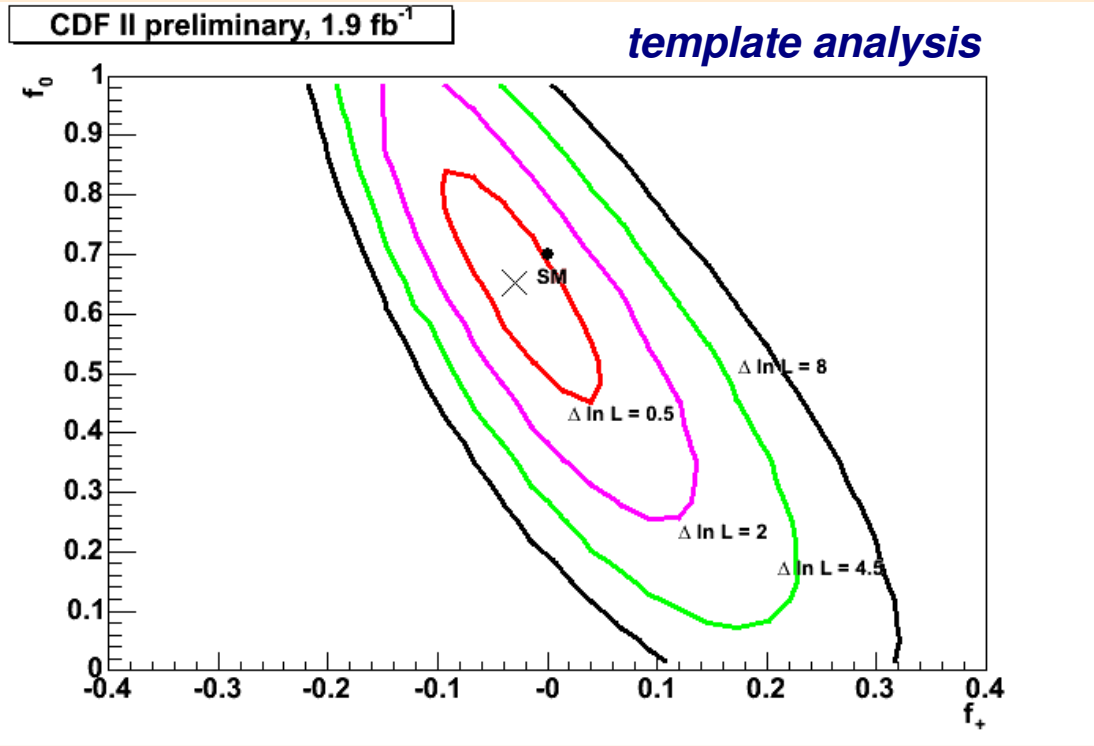
Results consistent with SM

Wtb coupling: W-Helicity

SM prediction: $f_0 = 0.7$, $f_- = 0.3$, $f_+ = 0$

Longitudinal *left-handed* *right-handed*

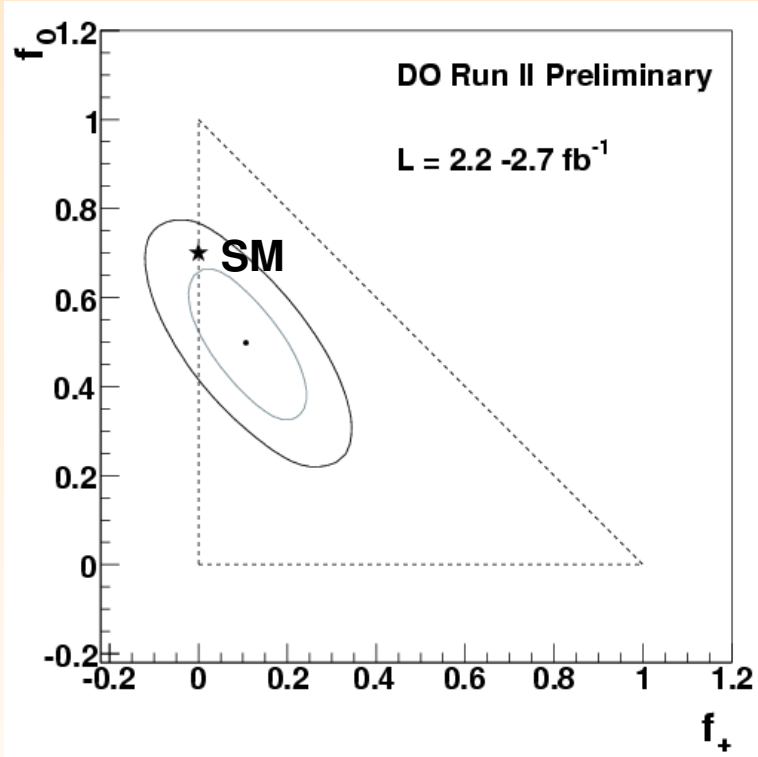
- **Lepton+jets channel**
- **Combination of two analyses**
  (template and convolution analysis)



$f_0 = 0.66 \pm 0.16$, $f_+ = -0.03 \pm 0.07$

$f_0 = 0.62 \pm 0.11$ (SM f_+), $f_+ = -0.04 \pm 0.05$ (SM f_0)

- **Lepton+jets and di-lepton**
- **Use both W's in each event**

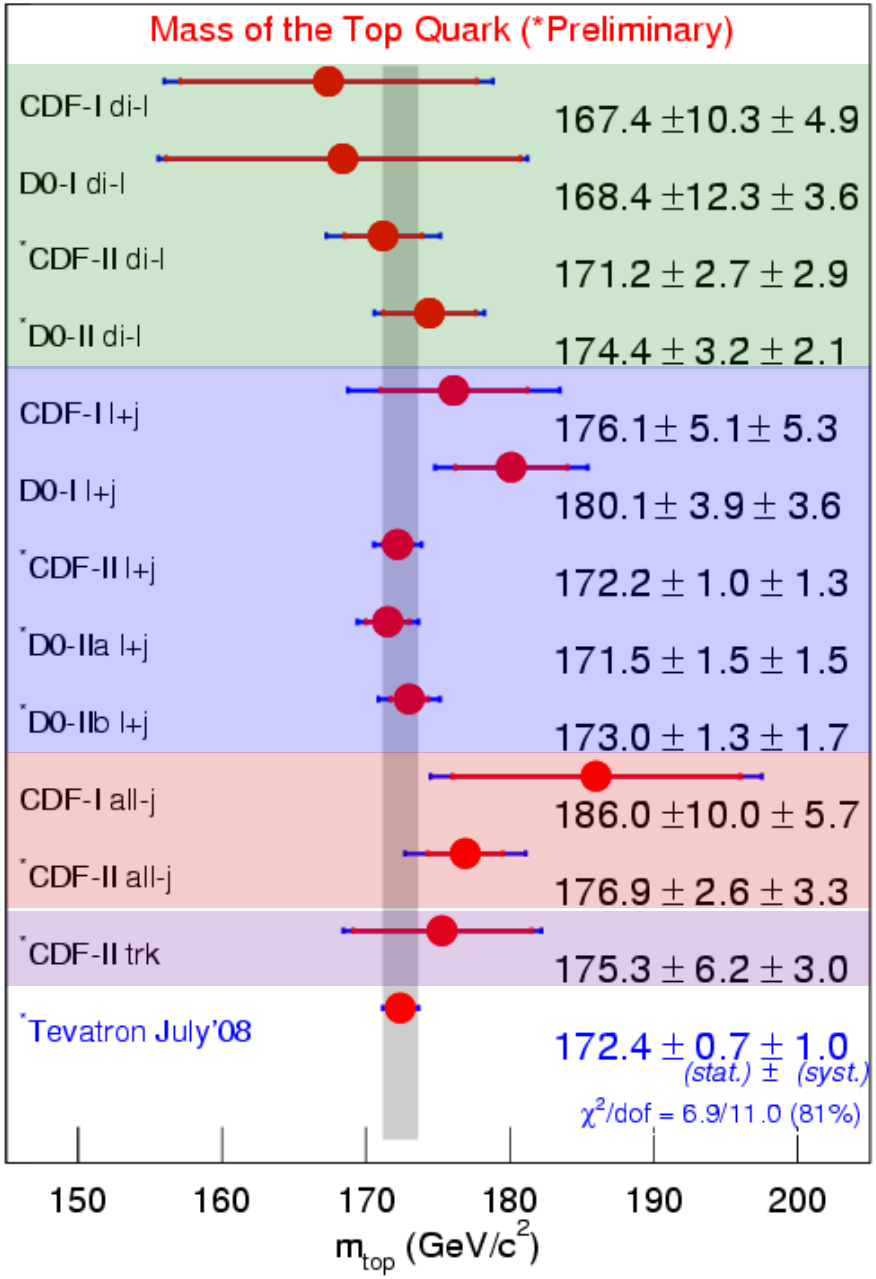


$f_0 = 0.49 \pm 0.13$, $f_+ = 0.11 \pm 0.07$

Results compatible with SM

Top Quark Mass

Tevatron Top Mass Combination



Di-lepton

Lepton+Jets

All hadronic

l+j: p_T^l, L_{xy}

almost entirely JES independent

- **Use of top pair candidates in different decay channels**
- **Calibrate jet energy scale with in-situ measurement of W→jj (l+j, all j)**

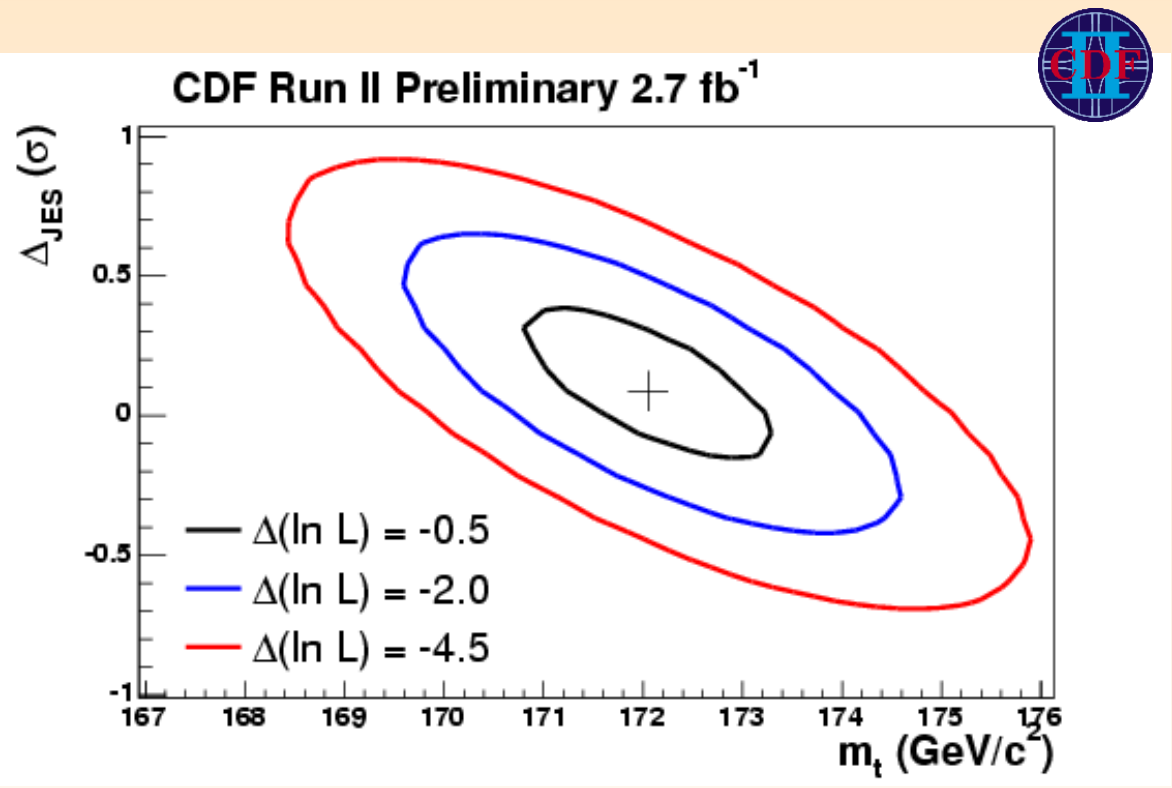
Relative precision of top quark mass: 0.7%

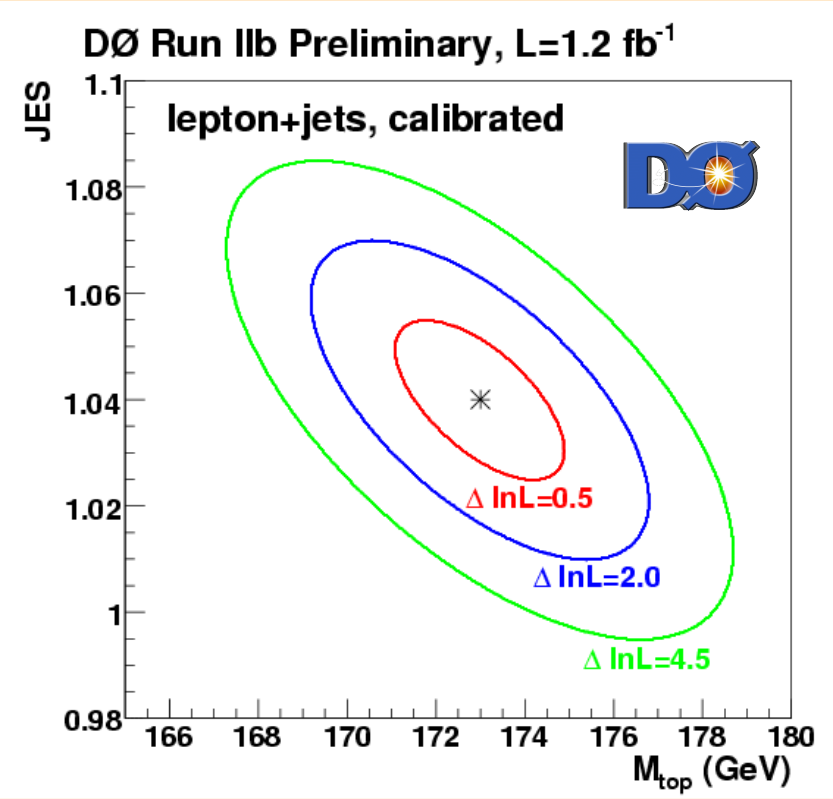
Consistent results in all decay channels and for different methods

Most Precise M_{top} Measurements

lepton+jets

ME-method, in-situ calibration, use of neural networks





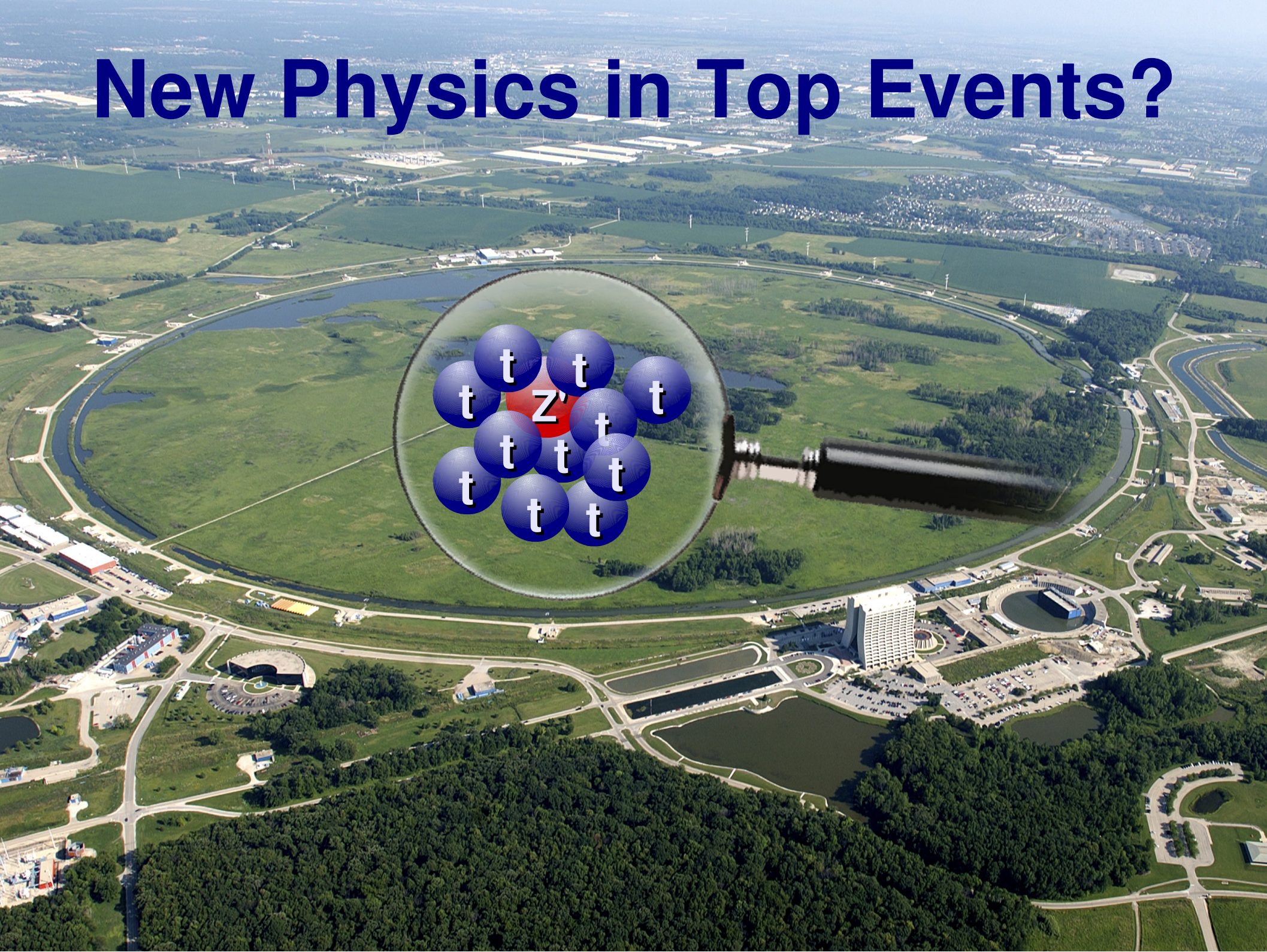
RunIIa+b, L=2.2/fb:

M_{top} = (172.2 ± 1.0 ± 1.3) GeV

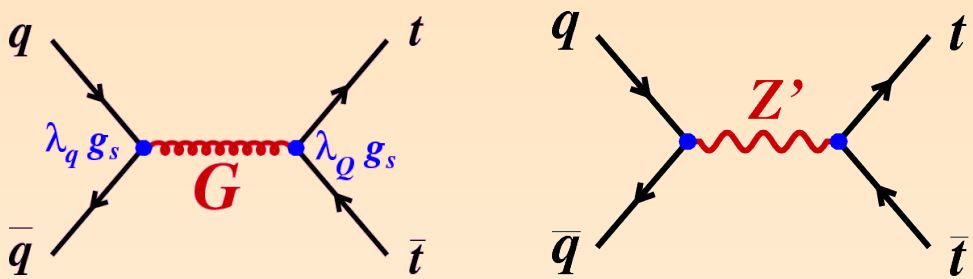
M_{top} = (172.2 ± 1.0 ± 1.4) GeV

Relative precision of most precise individual top mass measurements: ~1%

New Physics in Top Events?



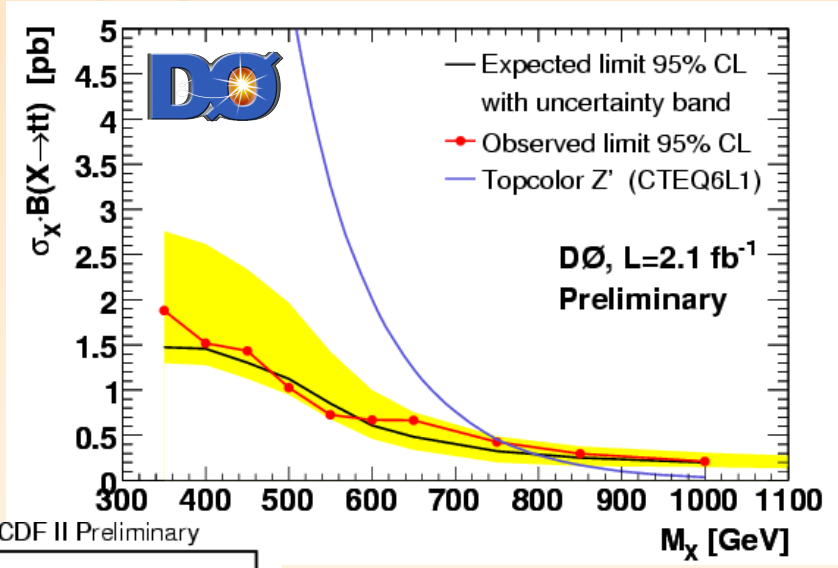
Top Pairs - Massive Resonances?



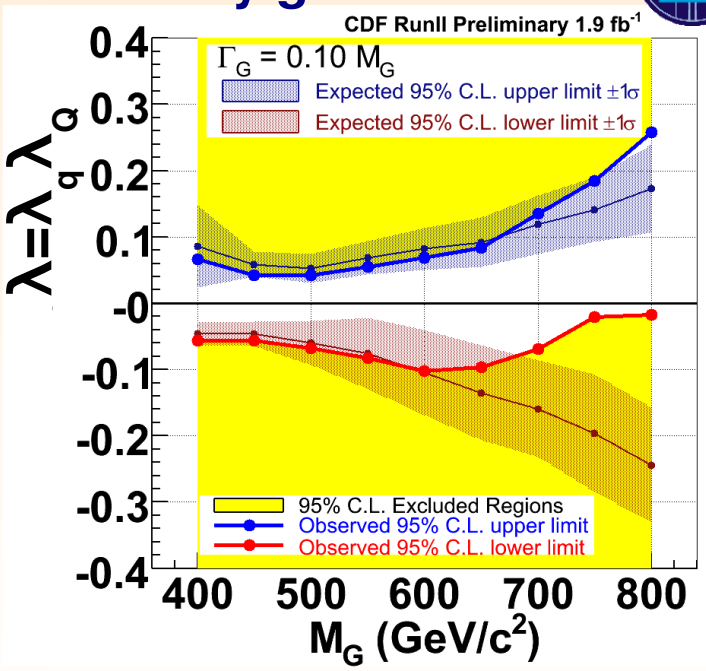
Sensitive variable: Reconstructed mass of top pair

lepton+jets

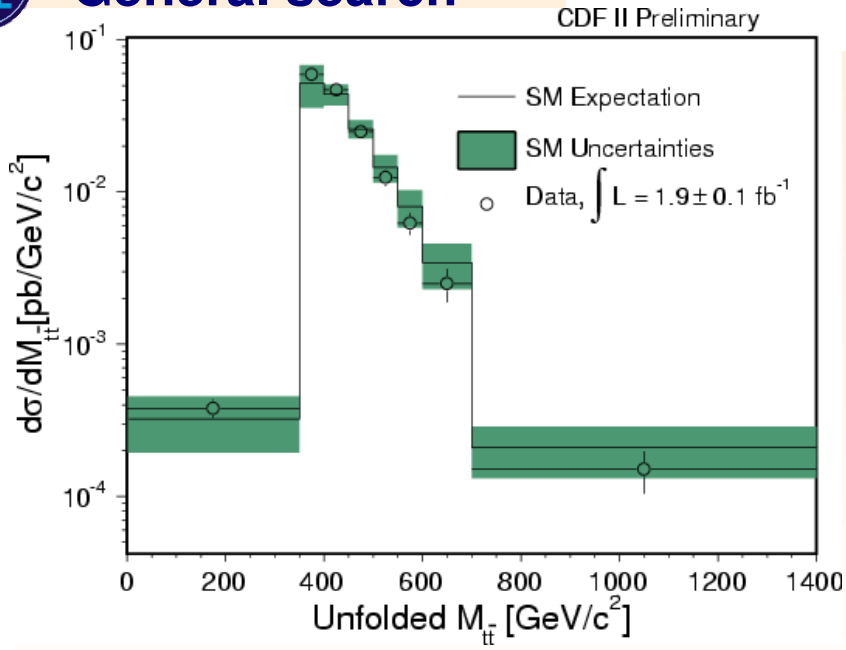
Leptophobic Z'



Heavy gluon



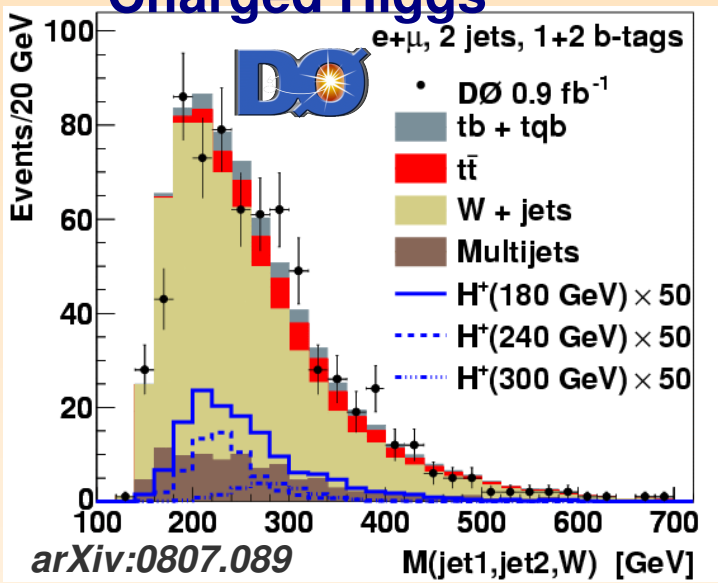
General search

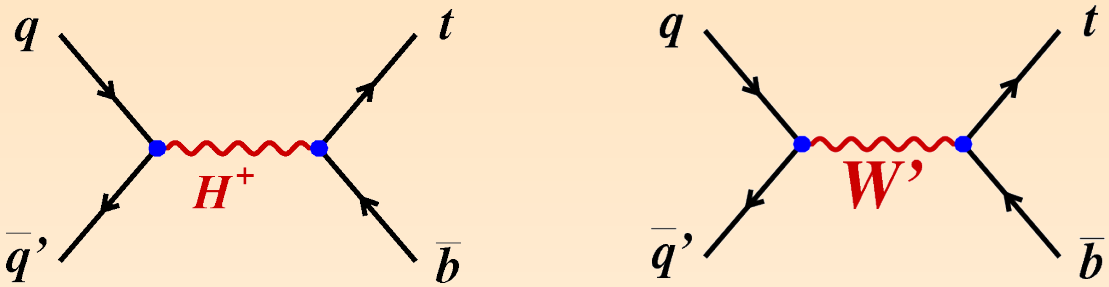


No hints for massive resonances in top pair production

Single Top – Massive Resonances?

Charged Higgs

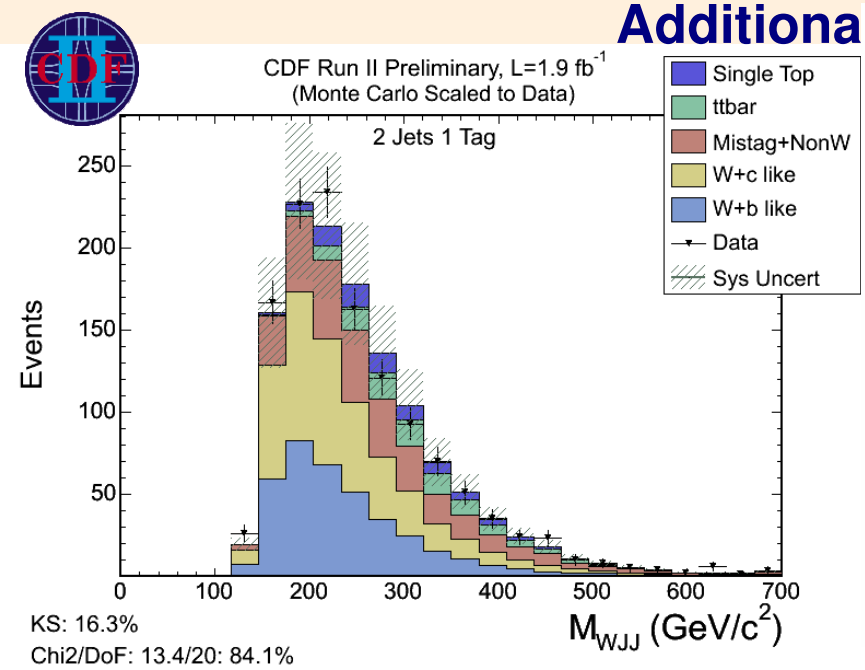


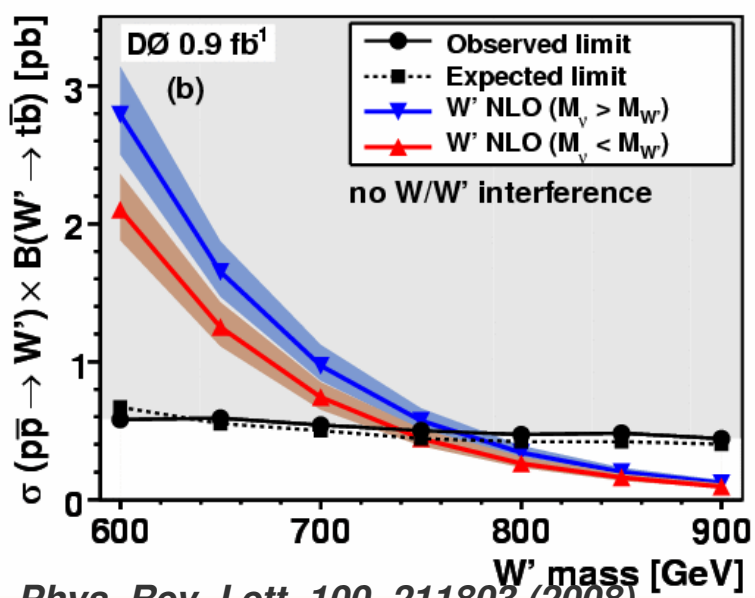


Sensitive variable:

Reconstructed mass of the tb-pair (M_{Wjj})

Additional boson: W'



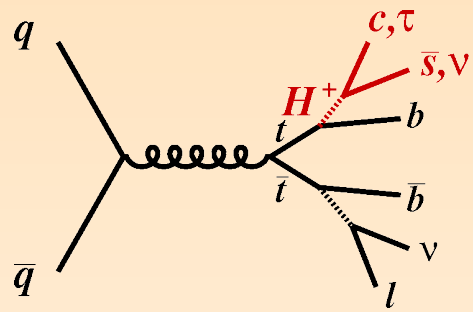


Phys. Rev. Lett. 100, 211803 (2008)

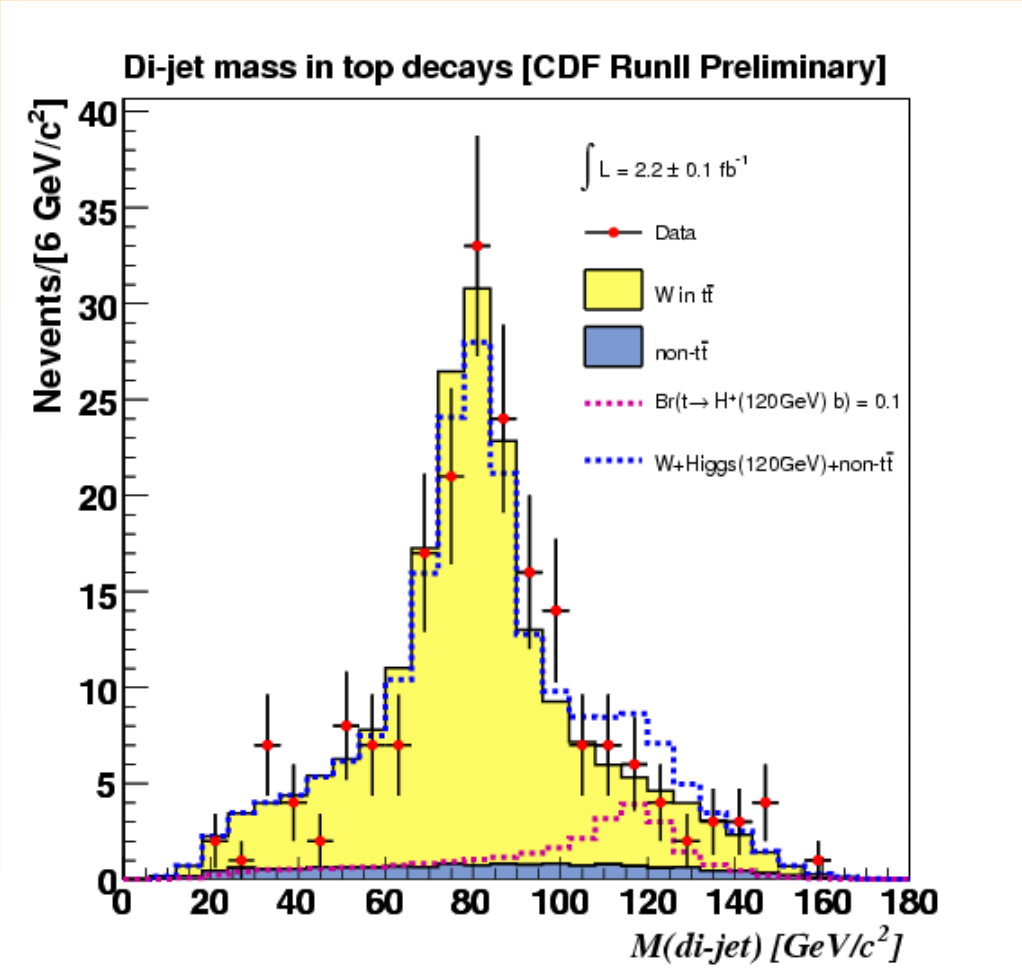
No hints for massive resonances in single top production

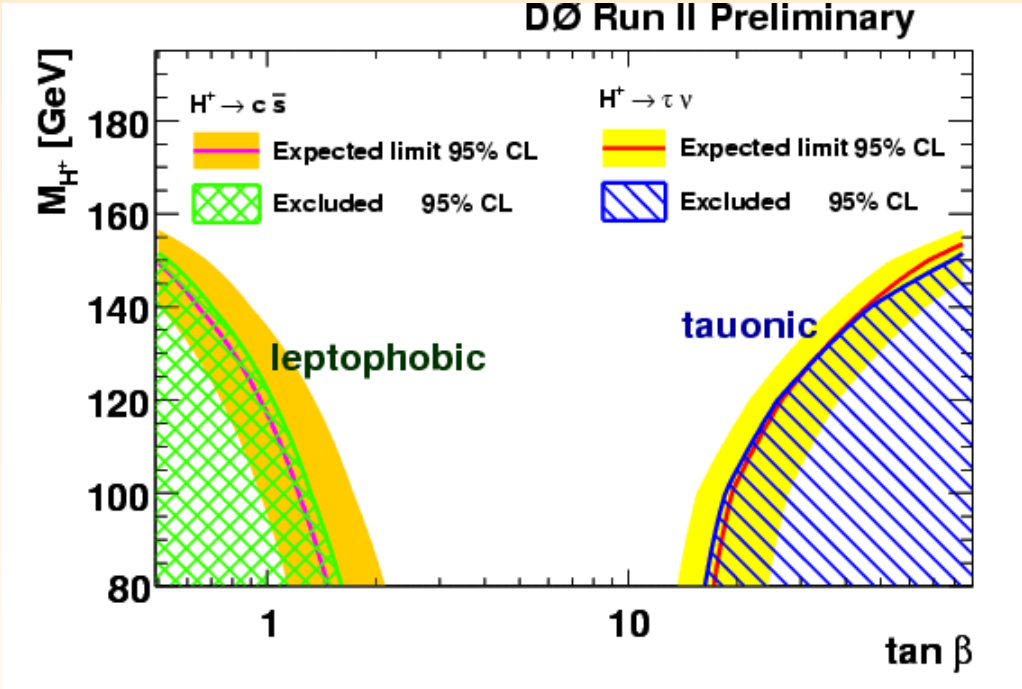
Top Pairs - Search for H^+ in Decay

- Search for $H \to cs$
- Sensitive variable: M_{jj}



- Search separately for $H \to cs$ and $H \to \tau\nu$
- Measure rate across several decay modes

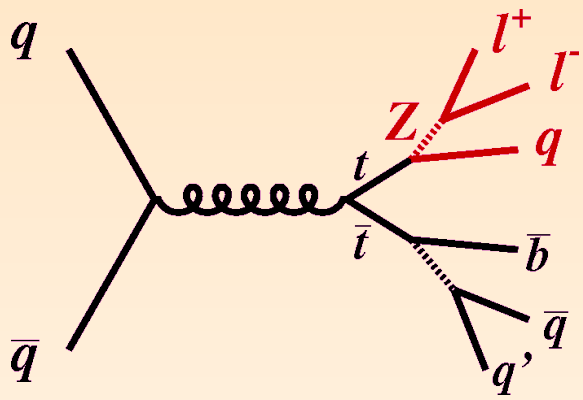




No hints for a charged Higgs in decays of top pair events

Search for FCNC

FCNC in top pair decays



Sensitive variable:

X^2 of kinematic fit with FCNC hypothesis

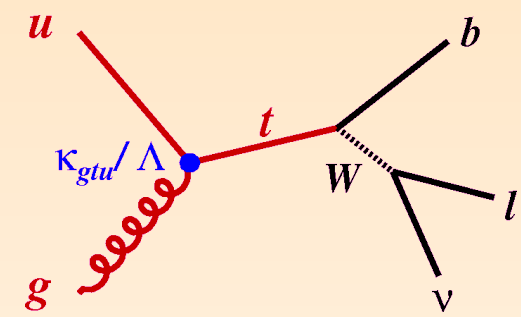
B(t→Zq) < 3.7% (95% C.L.)

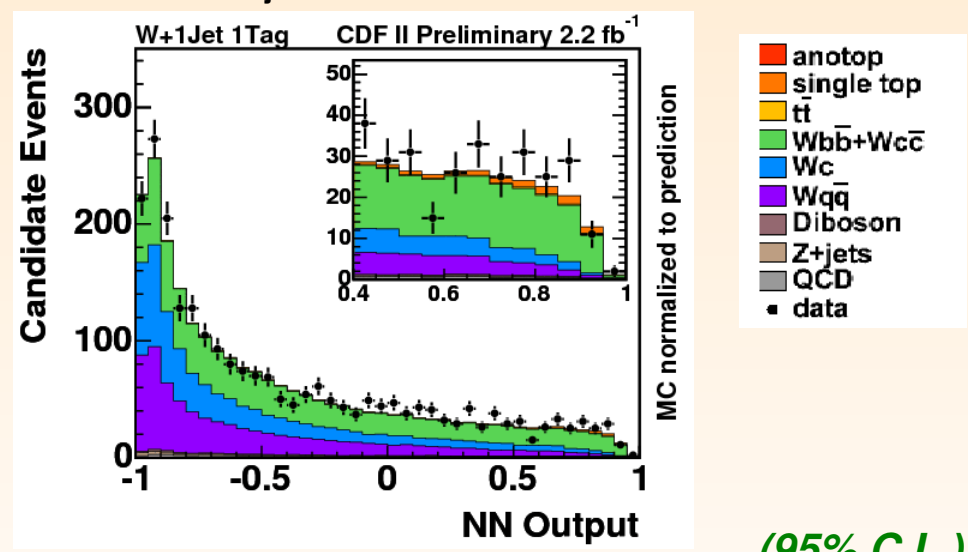
arXiv:0805.2109

FCNC in single top production

Phys. Rev. Lett. 99, 191802 (2007)

Use standard single top selection, but require N_{jets}=1



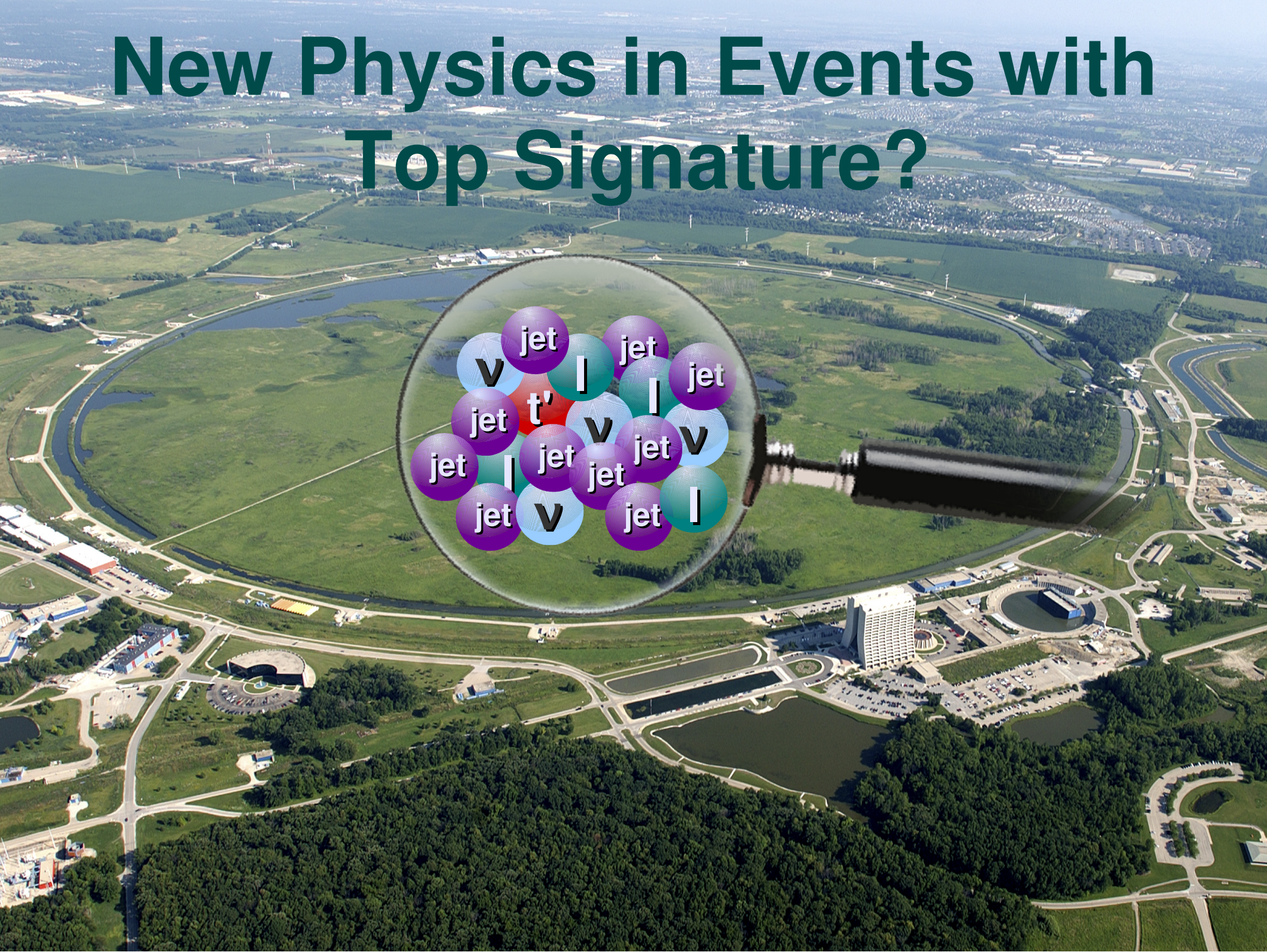


(95% C.L.)

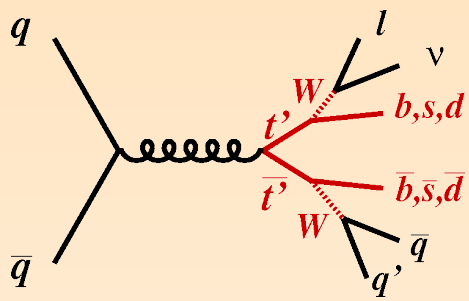
σ_{ano} < 1.8 pb, κ_{gtu}/Λ < 0.025 /TeV

No hints for FCNC in top events

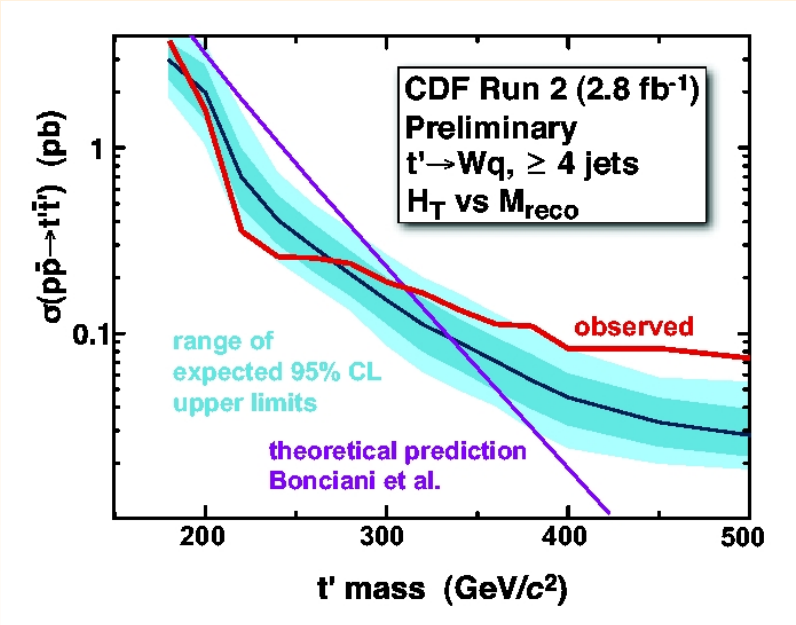
New Physics in Events with Top Signature?

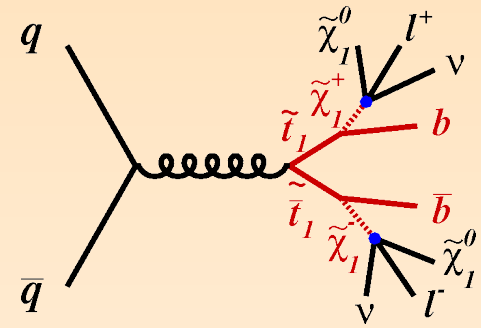


Heavy Top - t' & Top Partner - stop



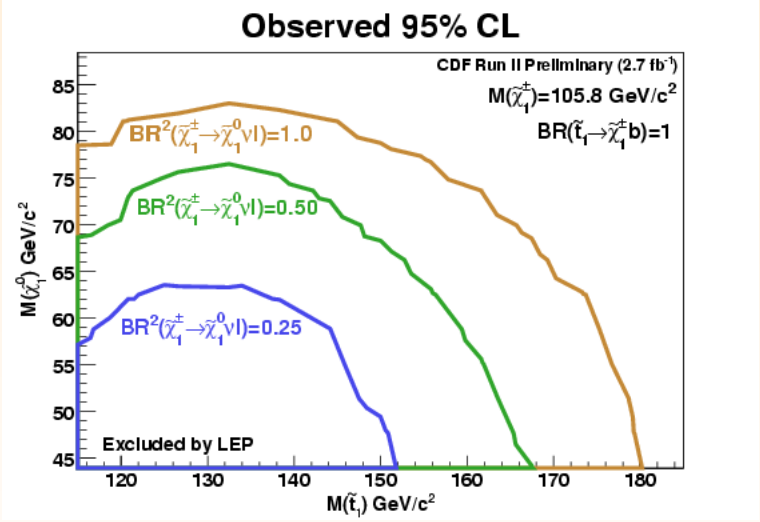
- **Search for a t' in events with top pair lepton+jets signature**
- **Sensitive variables:** ***Rec. t' mass M_{reco}, total trans. energy in event H_T***





conf. note 5600

- **Search for a light stop in events with top pair di-lepton signature**
- **Sensitive variable:** ***Rec. stop mass (assume $(\tilde{\chi}_1^0 + \nu)$ as pseudo-particle)***

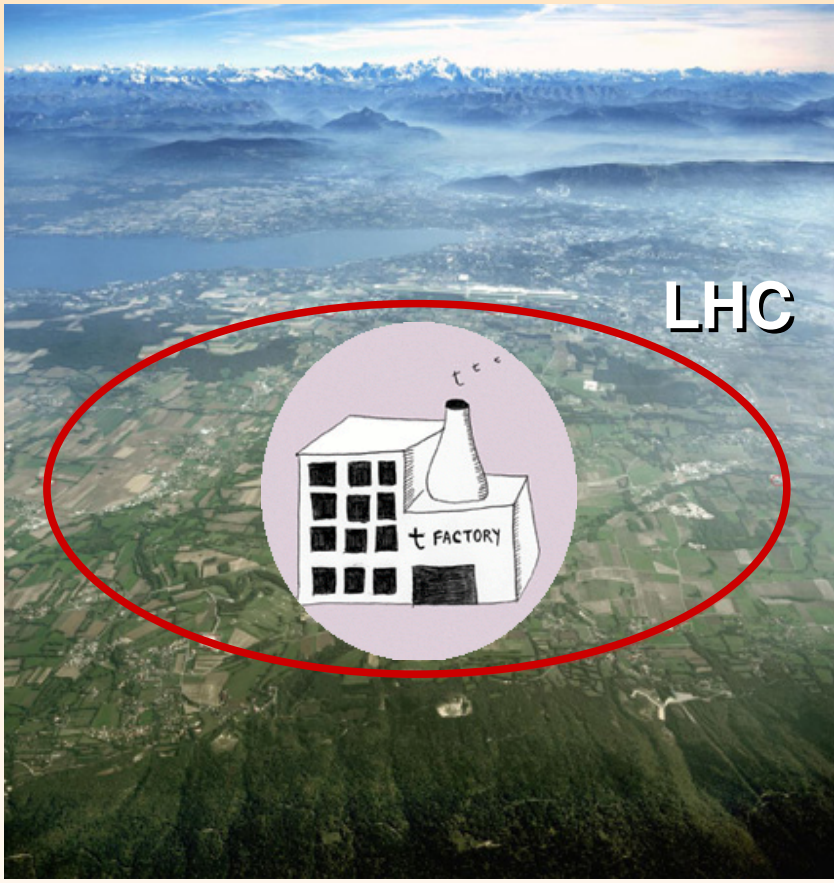


No hints for new physics with top signature

Summary

Most recent results on top quark physics from Tevatron:

- **Our top quark behaves like the SM top quark**
- **Relative precision of top mass measurement: 0.7%**
- **No hints of new physics in top events**
- **No hints of new physics in events with top signature**



Still potential to improve precision and sensitivity for new physics