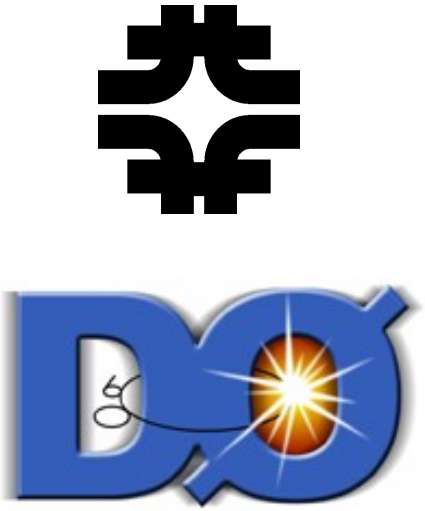


Beyond the SM searches with Top Quarks at D0

Yvonne Peters

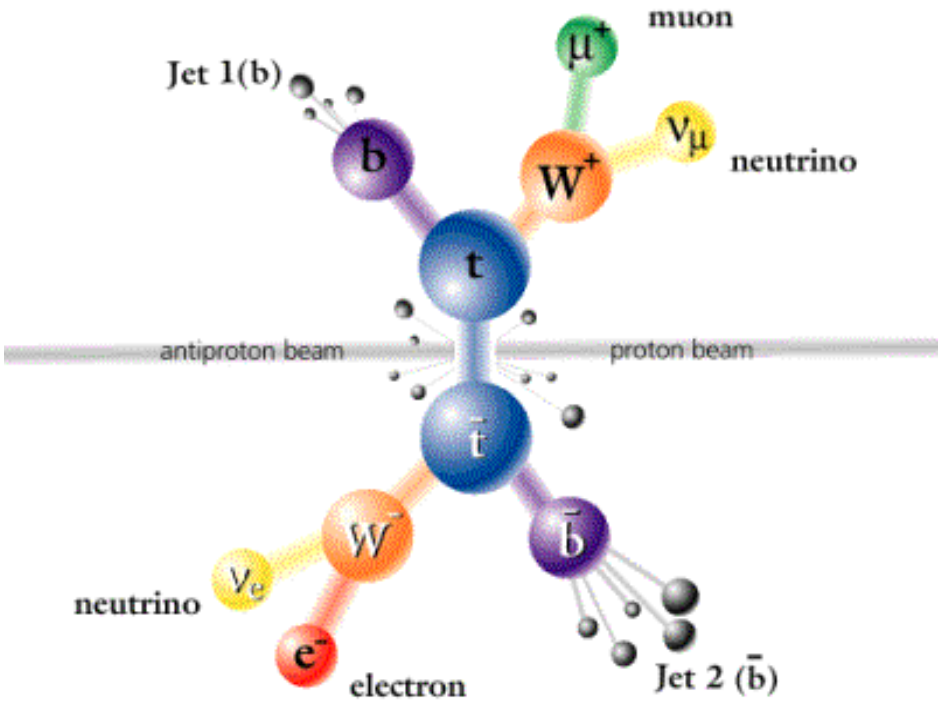
Newton International Fellow @

University of Manchester

On Behalf of the DØ Collaboration

The Top Quark

- Heaviest known elementary particle
  - 173.1±1.3GeV
- Standard Model:
  - Large coupling to Higgs
  - Electric charge +2/3 e
  - Short lifetime 0.5×10^{-24}s
  - 100% decay into W^+b
  - Production in pairs or singly

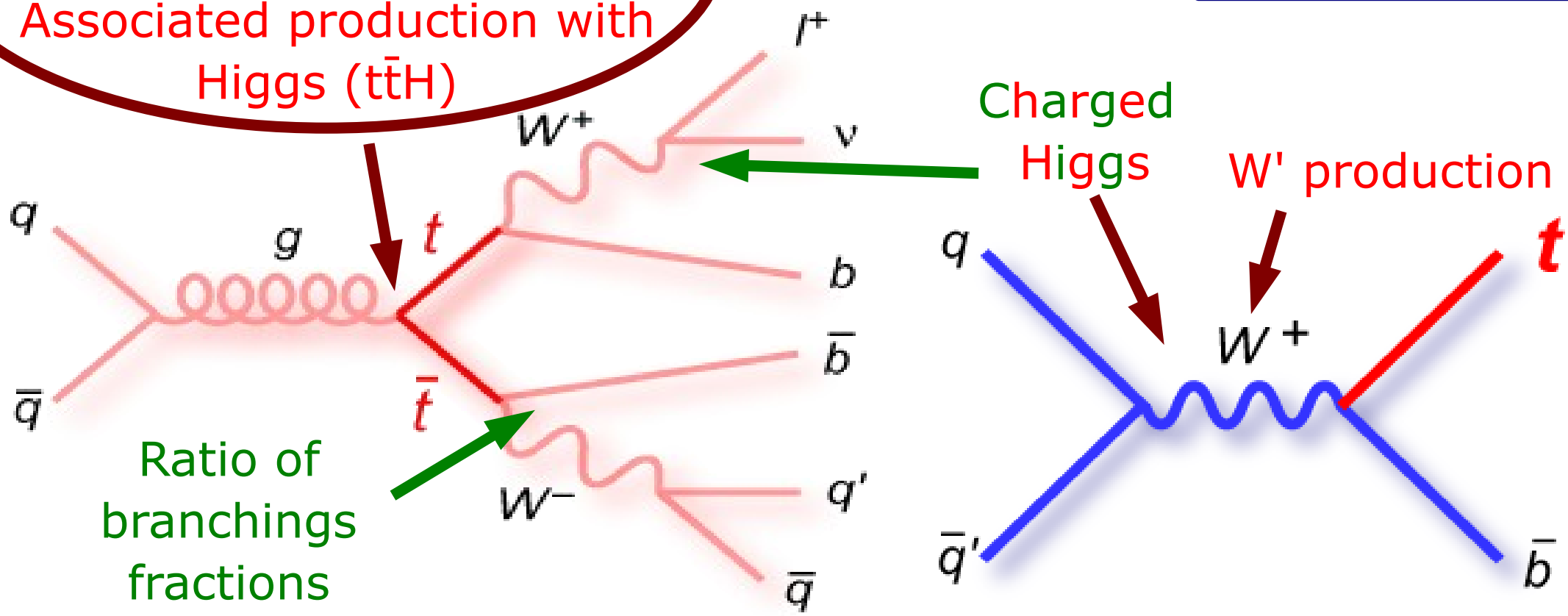


- But:
  Is the top quark the particle we think it is?
- Especially interesting to look for new physics!

Where do we look?

- Forward-Backward Asymmetry
- $t\bar{t}$ resonances (Z' production)
- Associated production with Higgs ($t\bar{t}H$)

Red: production
Green: Decay



Only some selected results (mass difference, spin correlation, W helicity...not shown here)

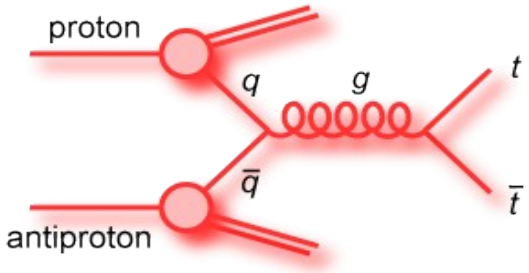
Outline

- $t\bar{t}$ resonances
- forward backward charge Asymmetry
- $t\bar{t}H$ search
- ratio of branching fractions
- charged Higgs
- W' search
- Single top production
- $t\bar{t}$ production
- top decay

Production mechanism

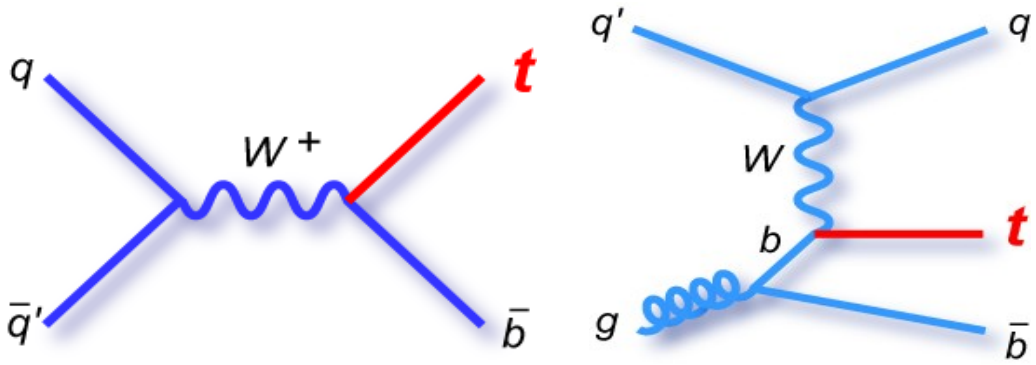
Pair production ($t\bar{t}$)
via strong interaction

85% $q\bar{q}$ annihilation and
15% gg fusion



For details see Sebastien's talk

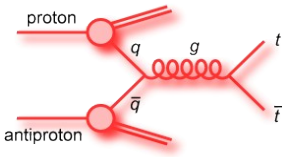
Single top production
via electro-weak interaction



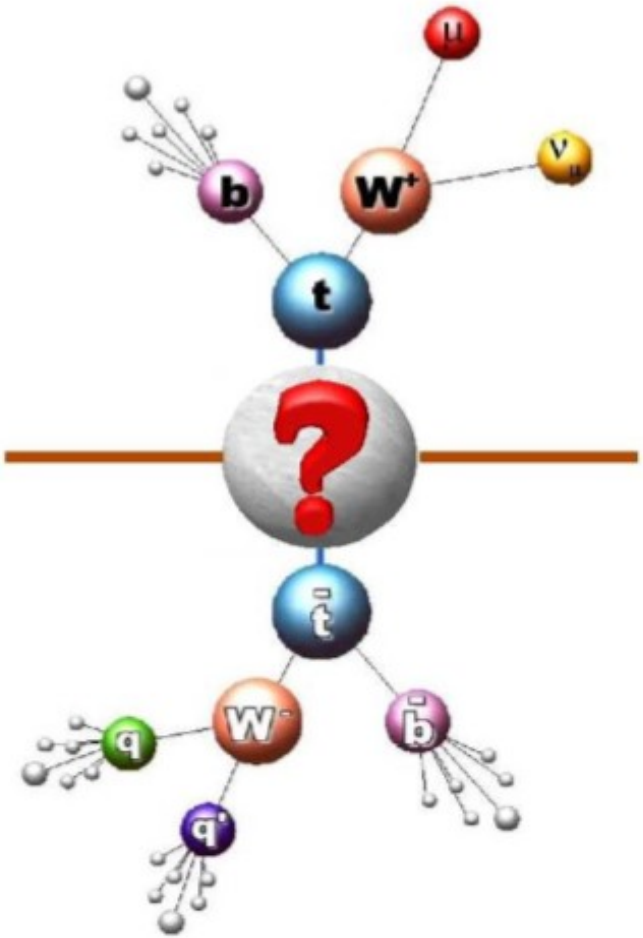
Observed in 2009

For details see Reinhard's talk

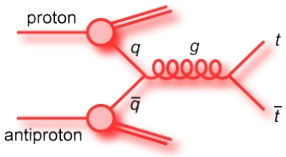
$t\bar{t}$ resonances



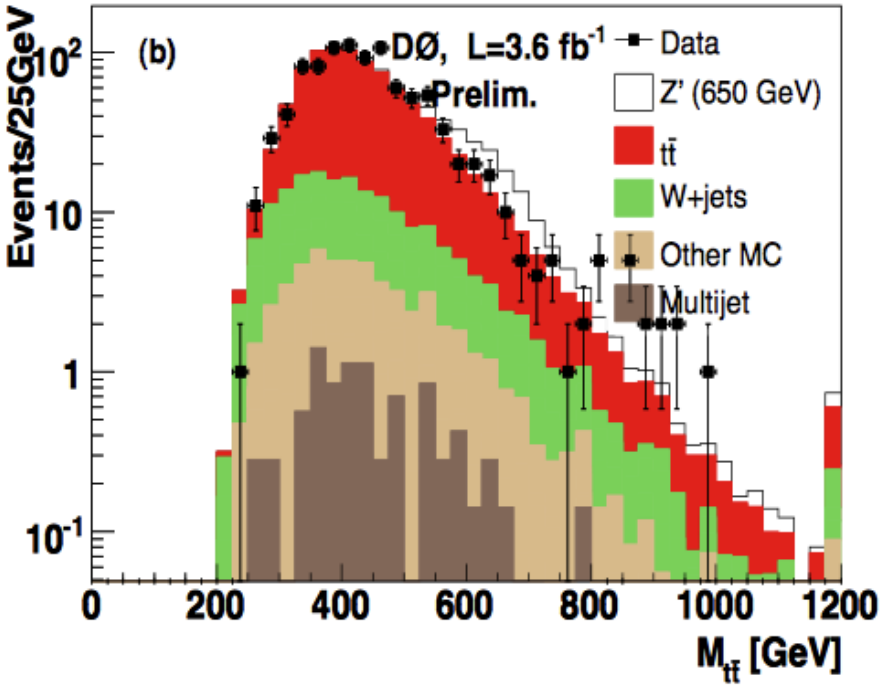
- Is the $t\bar{t}$ produced in the way we think it is?
- SM: No $t\bar{t}$ resonance
- Many models predict a $t\bar{t}$ resonance:
  - Axigluons
  - Colorons
  - Kaluza-Klein gluon
  - G'
  - Topcolor assisted technicolor: Z'
  - ....

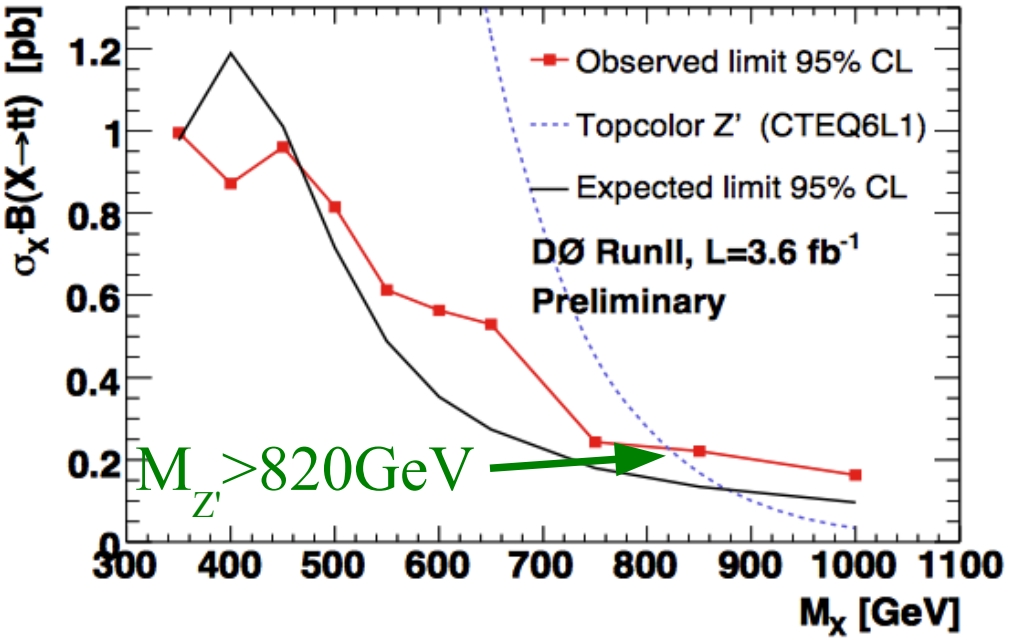


$t\bar{t}$ resonances

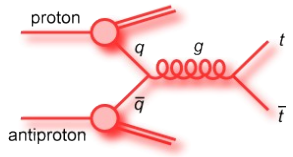


- Model independent search: Expect a bump in $M_{t\bar{t}}$ distribution
- Assume narrow resonance
- Set limits on $\sigma(p\bar{p}\rightarrow X)$ x $B(X\rightarrow t\bar{t})$
- Benchmark model: Topcolor assisted technicolor Z'

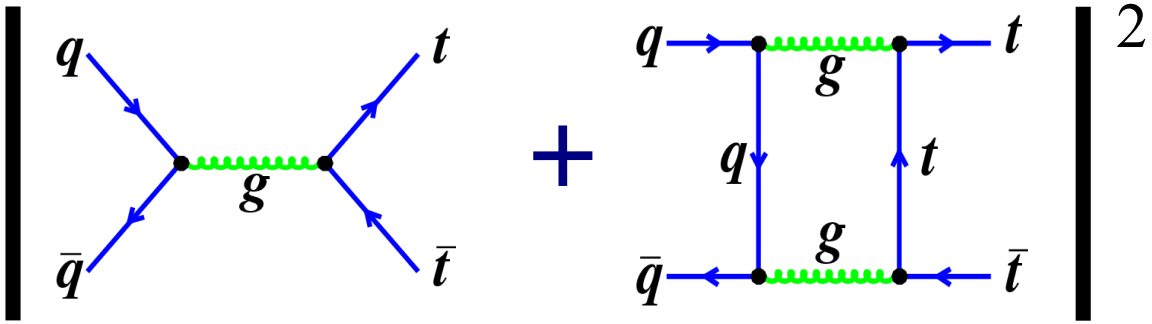




Asymmetry

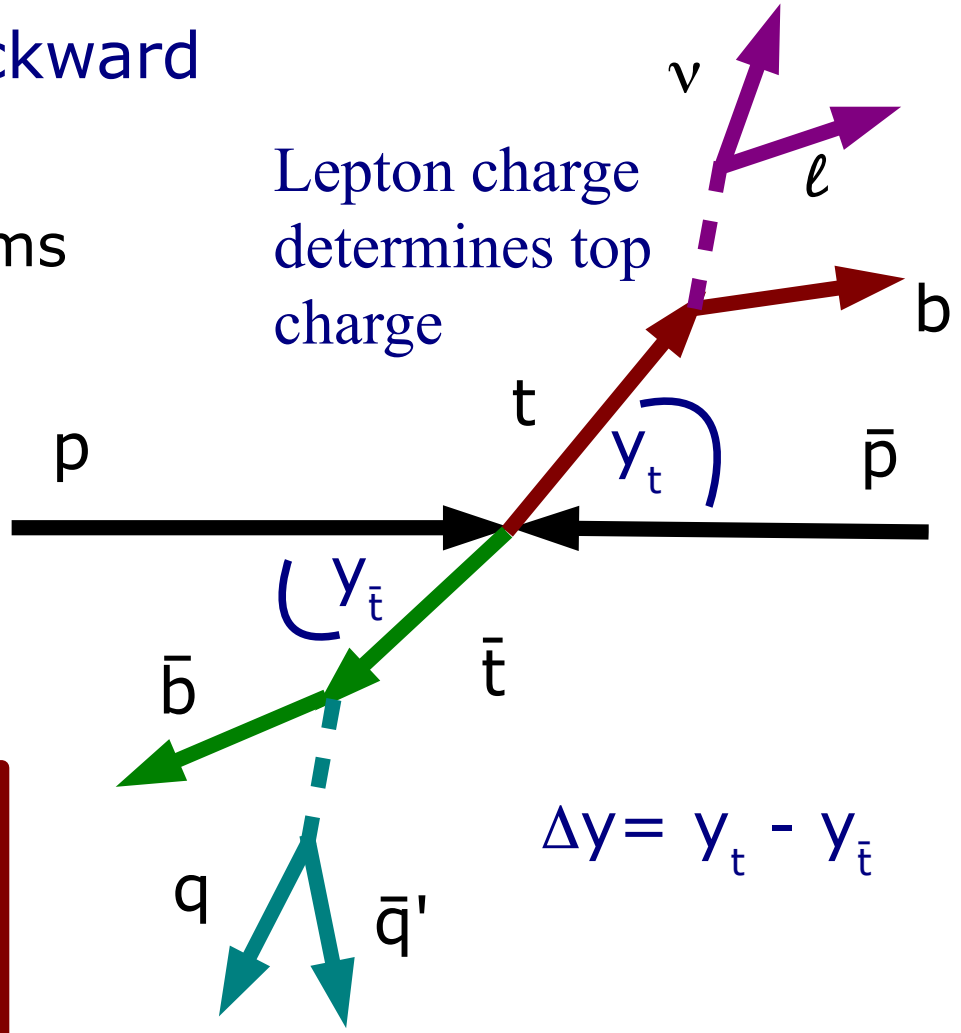


- Is the $t\bar{t}$ production what we think it is?
- NLO QCD calculations: Forward-backward charge asymmetry of ~5%
  - From interferences between diagrams



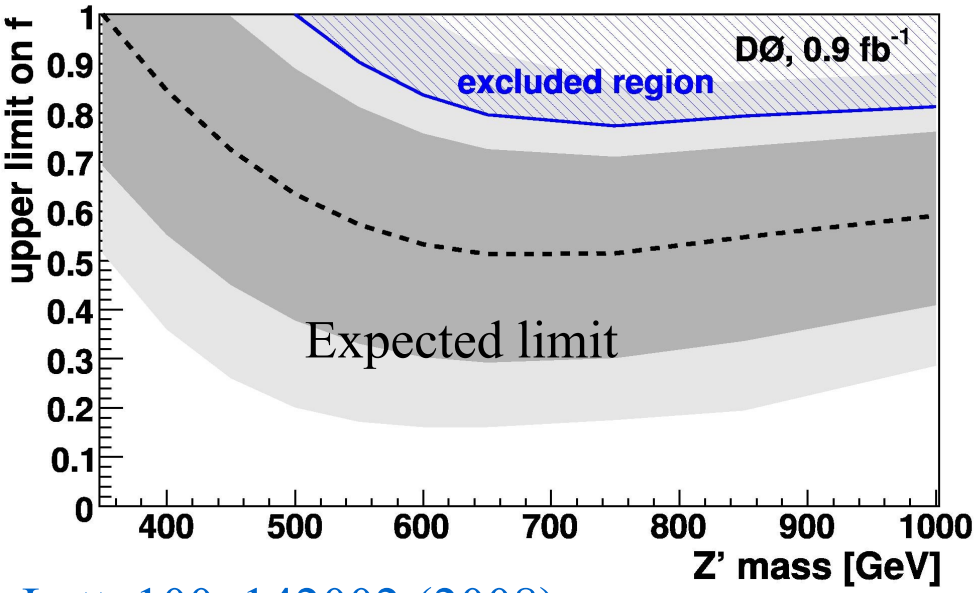
- Measure

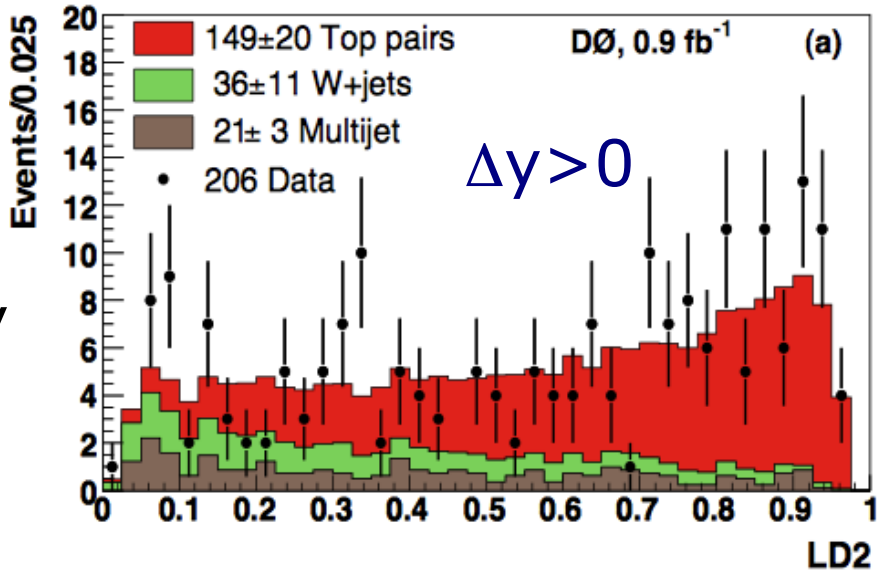
$$A_{fb} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

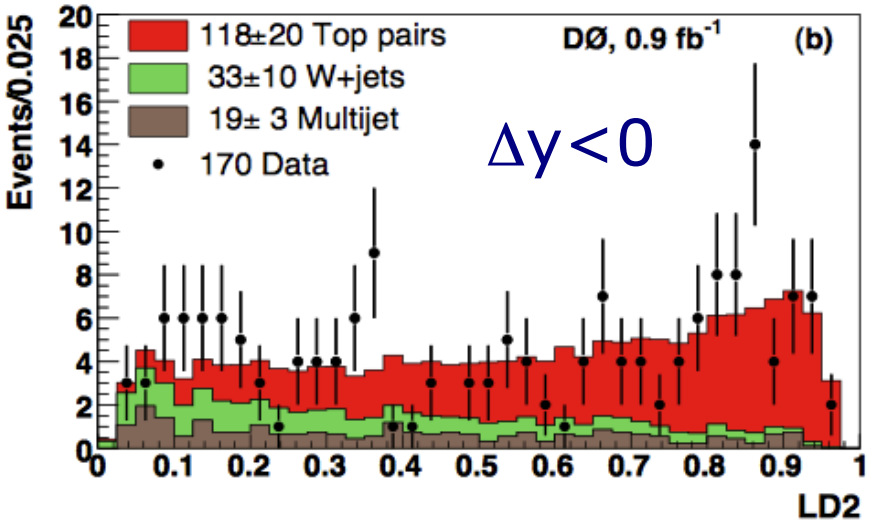


Asymmetry

- A_{fb} = 12 ± 8 (stat) ± 1(syst) %
  - In agreement with SM A_{fb}=5±1.5 %
- Search for Z': Left-handed decay would give large positive asymmetry
  - Limit on f=N(pp̄→Z'→tt̄)/N(pp̄→tt̄)

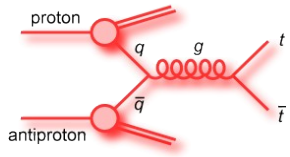




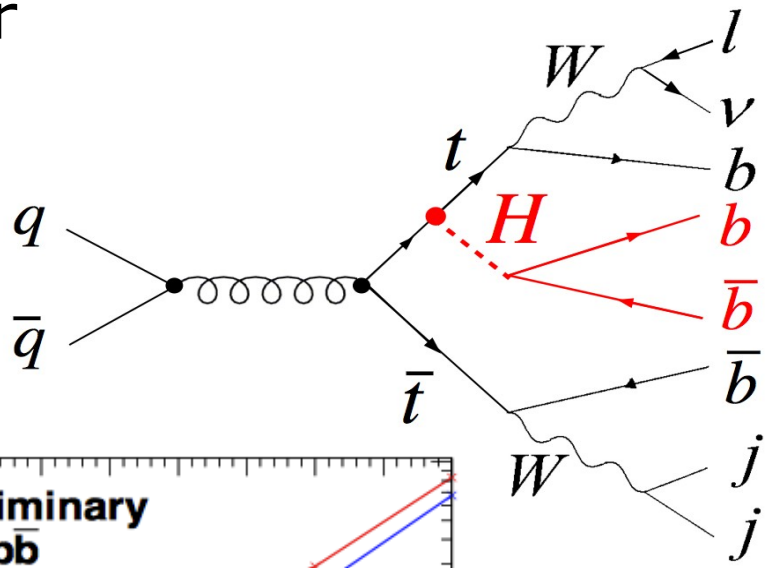


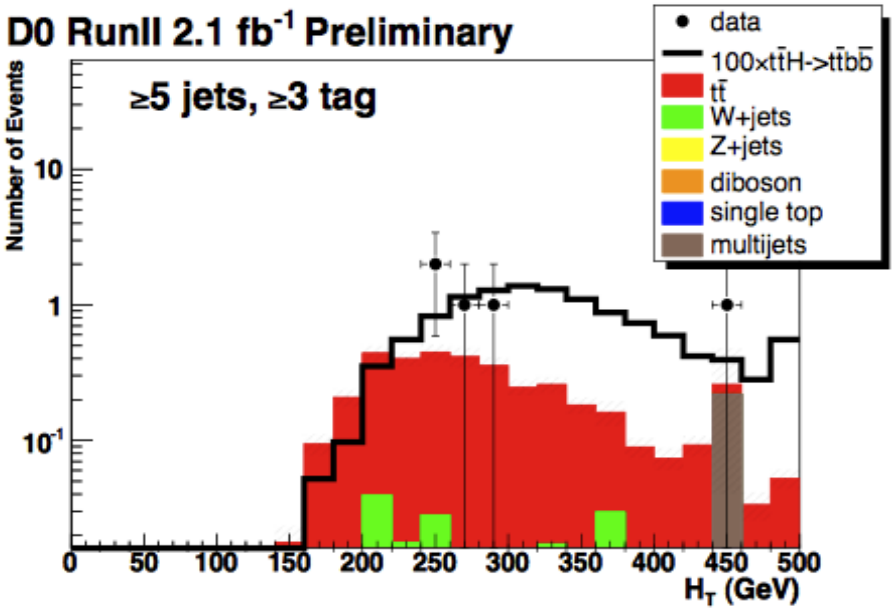
Phys. Rev. Lett. 100, 142002 (2008)

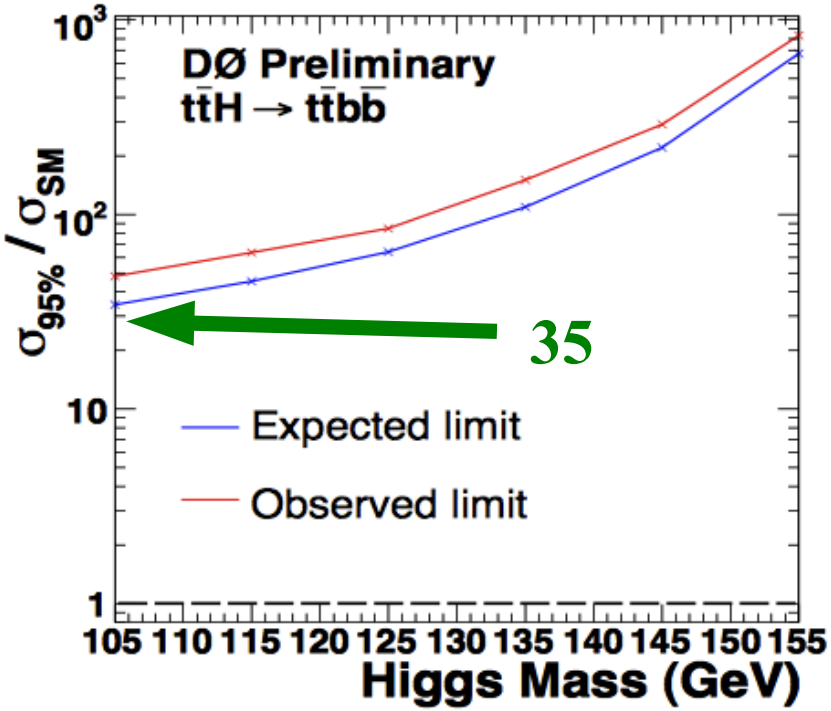
$t\bar{t}H$ search



- Associated production of Higgs and $t\bar{t}$ pair
- Expect more jets, more b-jets than in $t\bar{t}$
  - Use additional topological information

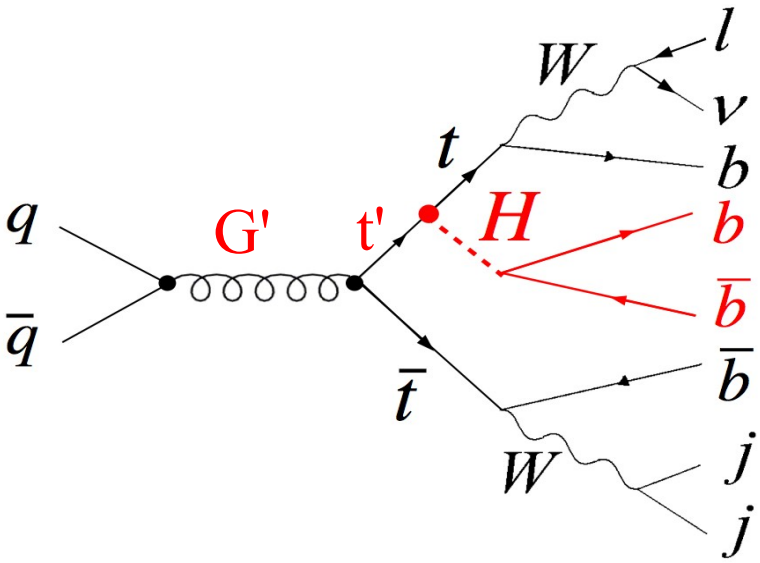


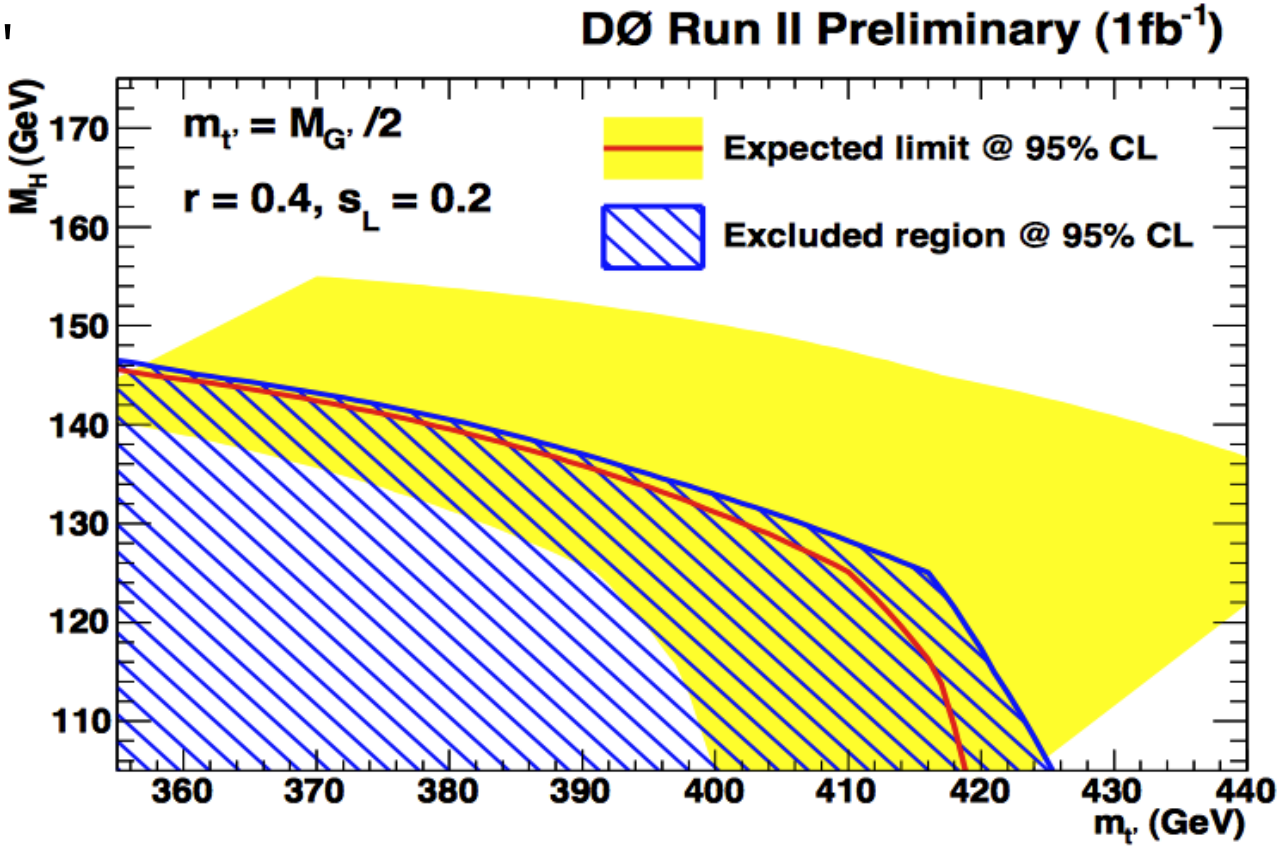




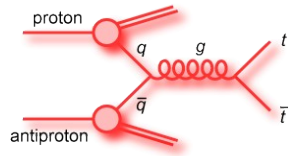
$t\bar{t}H$ search

- t' produced via a heavy color-octet vector particle (G'):
  - Enhanced cross section wrt. SM $t\bar{t}H$
  - Use $t\bar{t}H$ search to exclude region on ($m_{t'}$, M_H) parameter space
- s_L: mixing angle between t and t'
- r: coupling strength

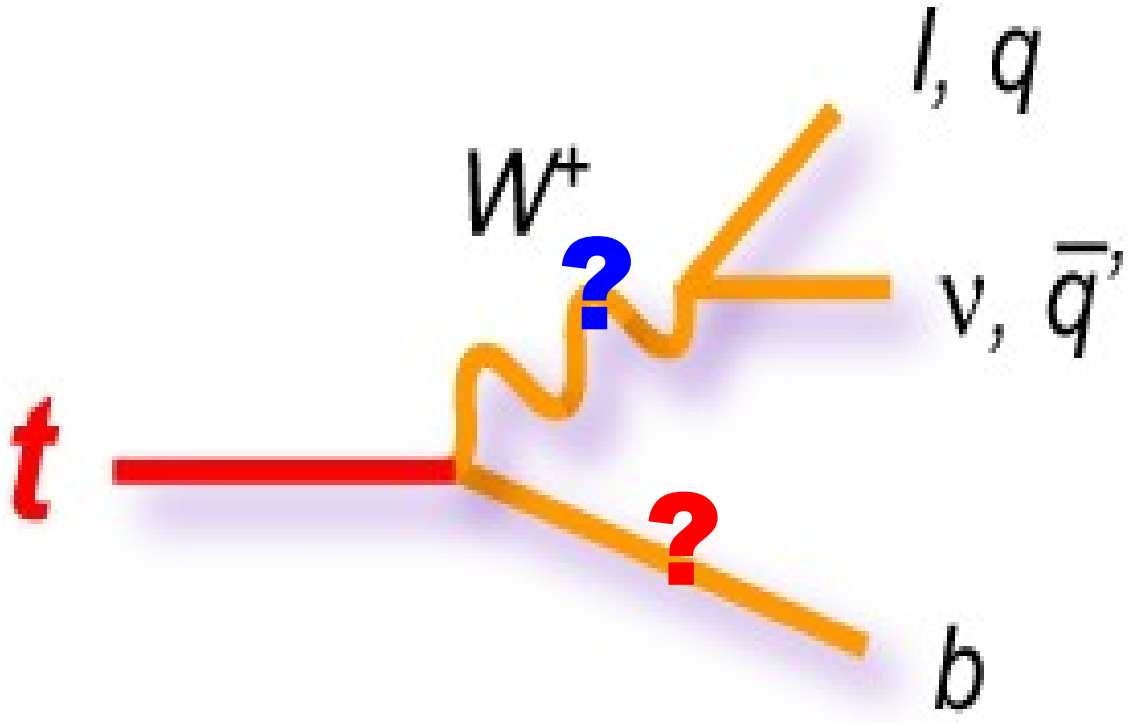




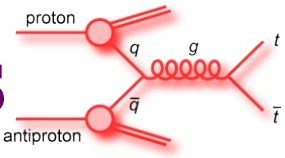
The Top Quark Decay



- And does the top quark decay as expected?



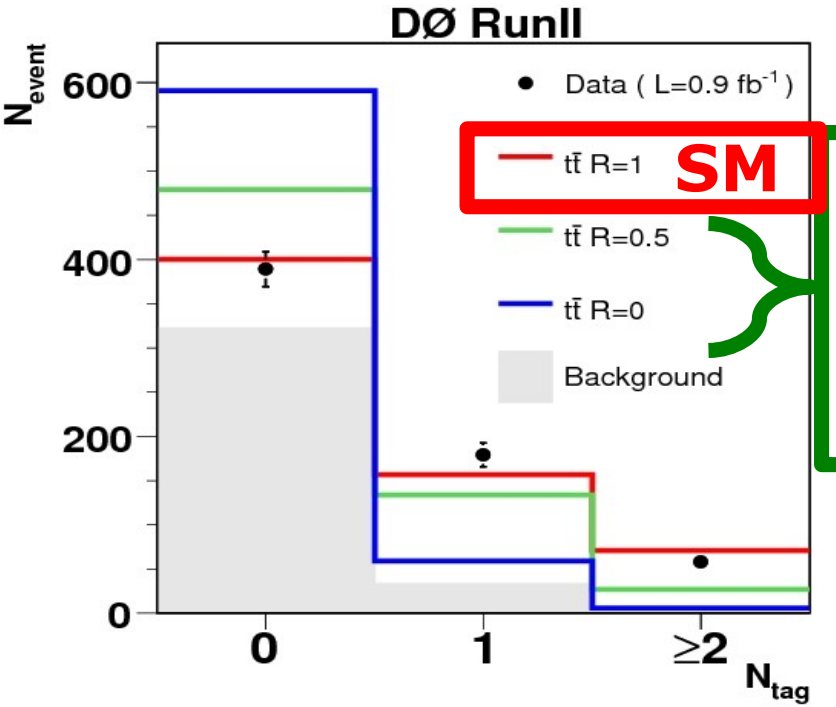
Ratio of branching fractions



- Measure $\sigma_{t\bar{t}}$ and the ratio of branching fractions

$$R = \frac{BR(t \to Wb)}{BR(t \to Wq)} = \frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2}$$

- Measure distribution of events with 0,1, ≥2 b-jets



additional quark families?
new physics?

$$\sigma_{t\bar{t}} = 8.18^{+0.90}_{-0.84}(stat+syst) \pm ..(lumi)\ pb$$

$$R = 0.97^{+0.09}_{-0.08}(stat+syst)$$

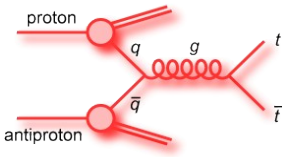
R>0.79 @ 95% C.L.

Under assumption of unitary 3x3 CKM Matrix:
$|V_{tb}|>0.89$ @ 95% C.L.

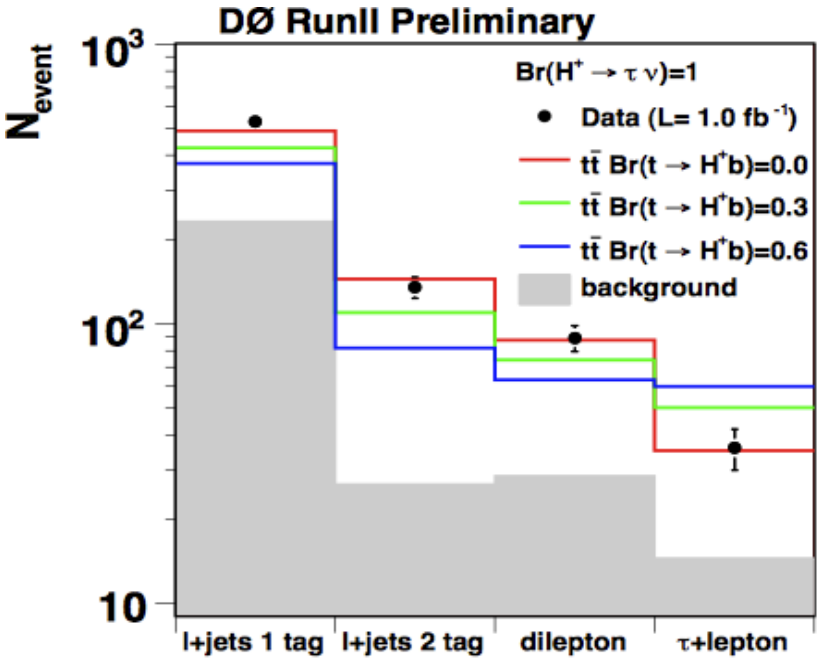
W/O assumption of unitarity or 3 generations:
$(1-R)/R = (|V_{ts}|^2 + |V_{td}|^2)/|V_{tb}|^2 < 0.27$ @ 95% C.L.

Phys. Rev. Lett. 100, 192003 (2008)

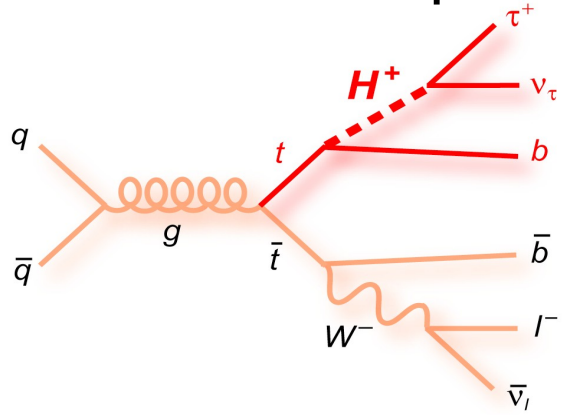
Light charged Higgs



- $m_t > M_{H+}$: Decays $t \to W^+b$ and $t \to H^+b$ can compete

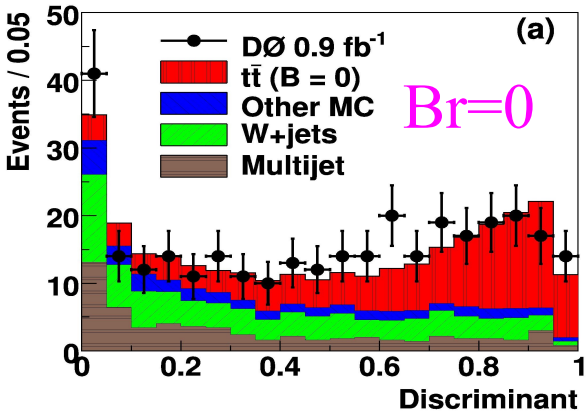


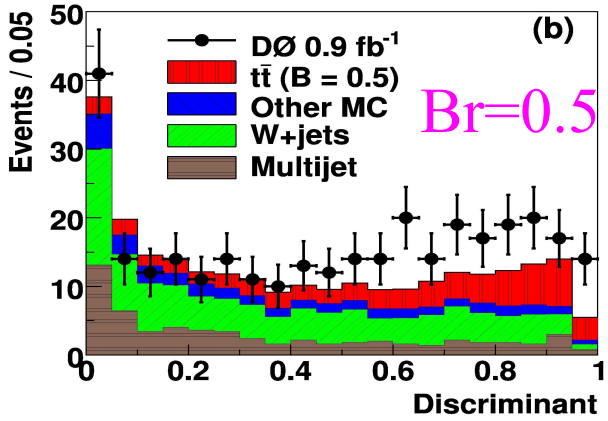
Different behavior in different final states for increasing Br($t \to H^+b$)



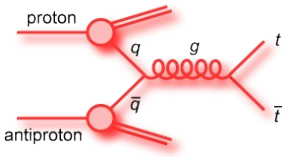
Consider $H^+ \to \tau^+\nu$ and $H^+ \to c\bar{s}$ decay

Different behaviour in the same final state for increasing Br($t \to H^+b$)

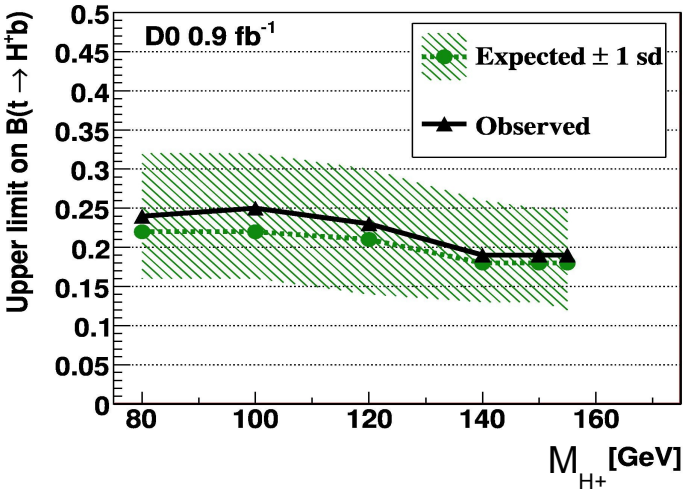


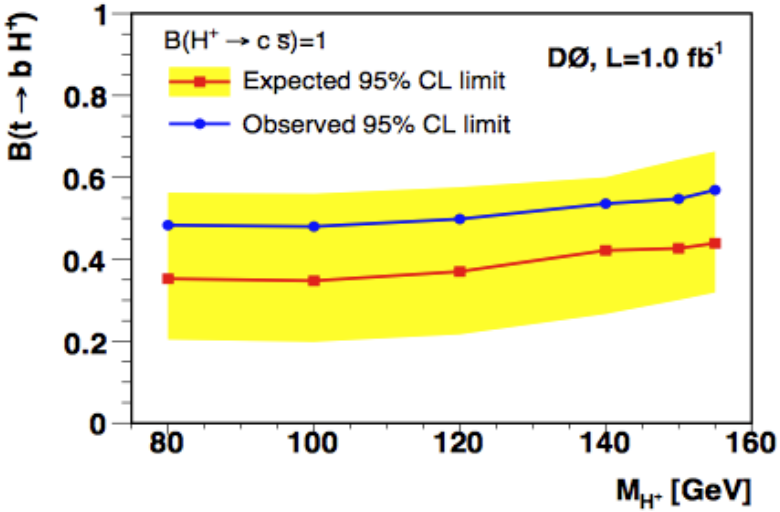


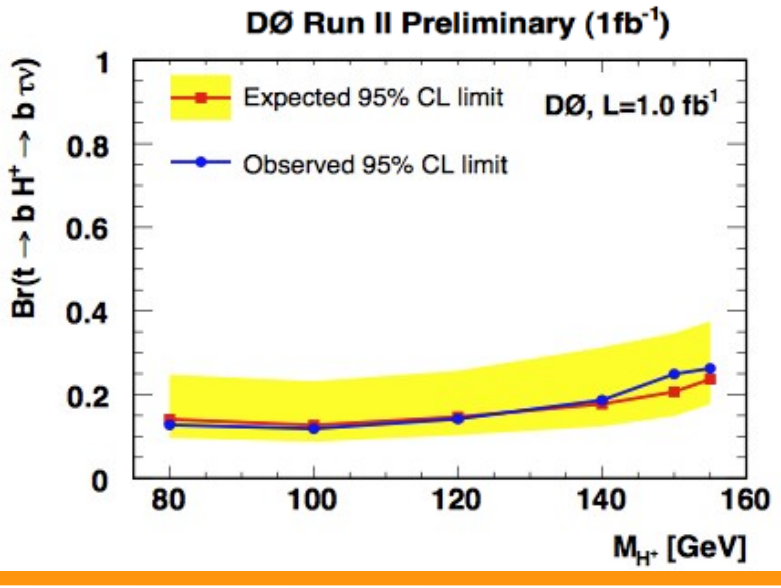
Light charged Higgs



- We explore different methods:
  Extract limits on Br(t→ H^+b) from
  - Cross section ratios:
    $\sigma_{t\bar{t}}(\tau\ell)/\sigma_{t\bar{t}}(\ell\text{jets}+\ell\ell)$ & $\sigma_{t\bar{t}}(\ell\ell)/\sigma_{t\bar{t}}(\ell\text{jets})$
  - Topological information



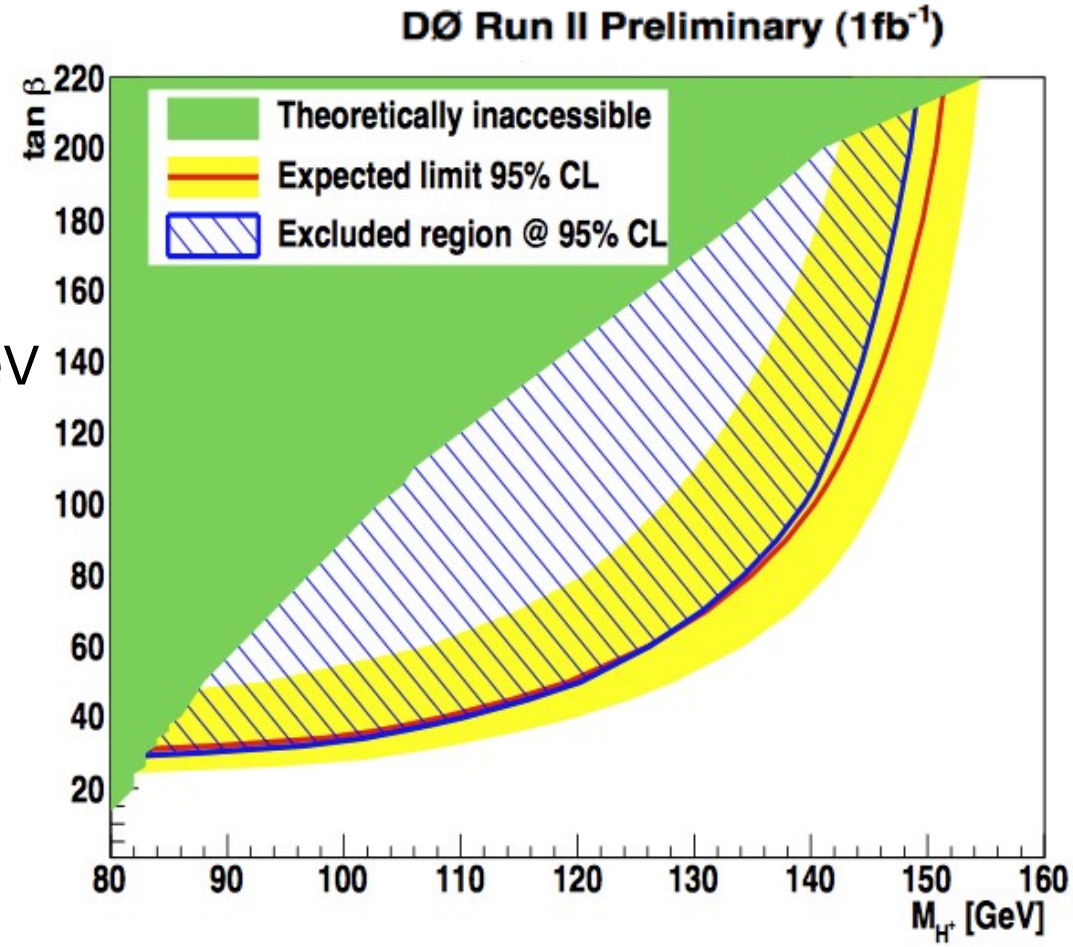




  - A global fit to all final states
    - Simultaneous fit of $\sigma_{t\bar{t}}$ and Br(t→ H^+b) for tauonic model

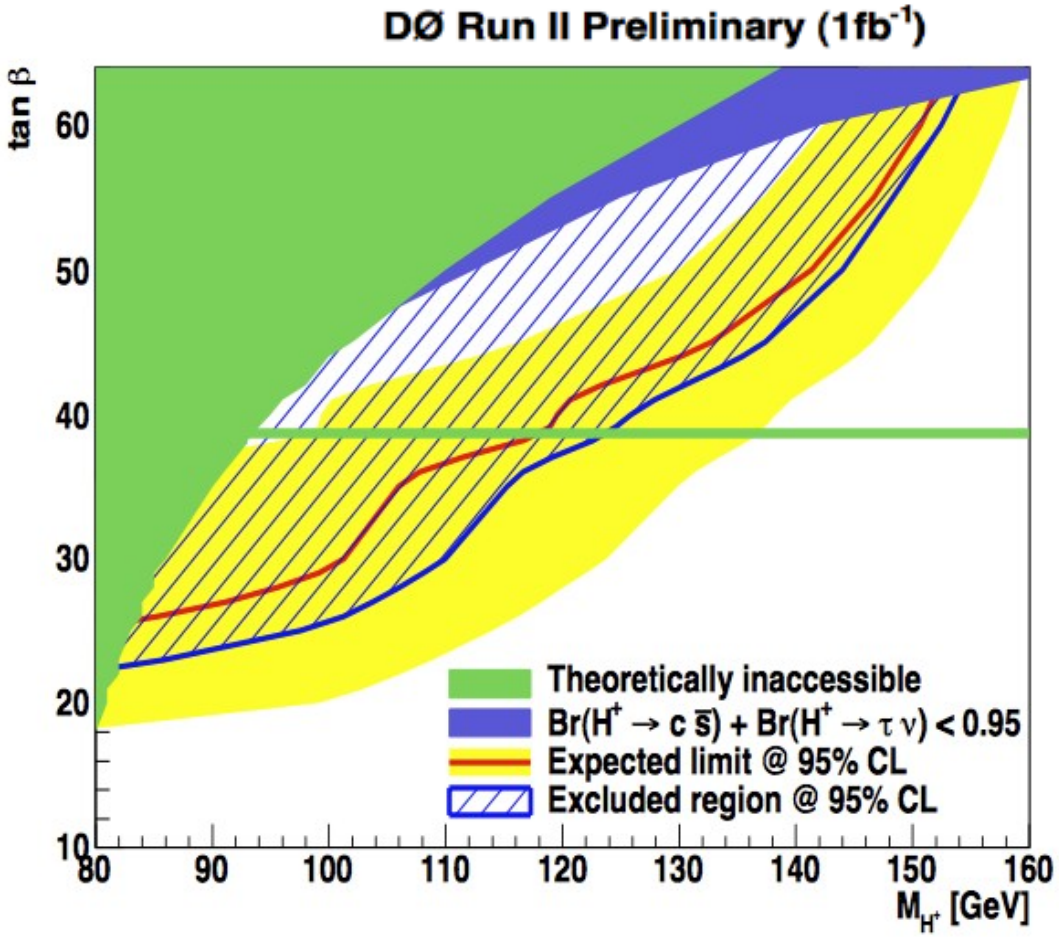
Light charged Higgs

- Use the limits on the top to charged Higgs branching ratio to exclude MSSM parameter space
- Benchmark: M_hMax scenario
  - Strength of supersymmetric Higgs mixing: μ=200 GeV
  - Sfermion mass scale M_{SUSY}=1000 GeV
  - Gaugino mass M_2=200 GeV
  - Gluino mass M_3=800 GeV
  - Trilinear Higgs-squark coupling A
  - Stop mixing parameter large
    - $X_t=A-\mu\cot(\beta)=2M_{SUSY}$
    - Provides largest parameter space in direction of M_h

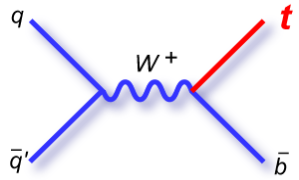


Light charged Higgs

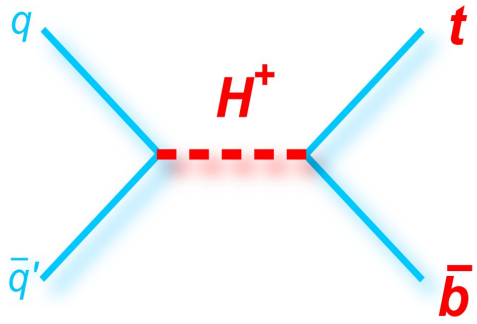
- Benchmark: CPX scenario
  - Increased τν and cs̄ decay, t*b decay suppressed
  - Hierarchy between first two and third generation introduced
- Parameters:
  - μ = 2000 GeV, M_{SUSY} = 500 GeV,
    A_t = 1000*exp(i pi/2),
    M_2 = 200 GeV,
    M_3 = 1000*exp(i pi)
- First limits from Tevatron on CPX model!

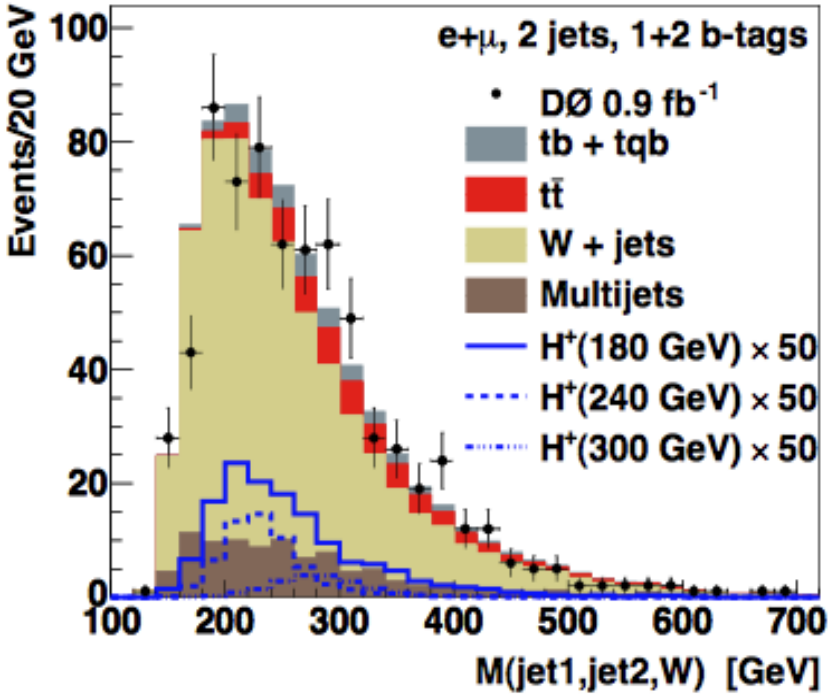


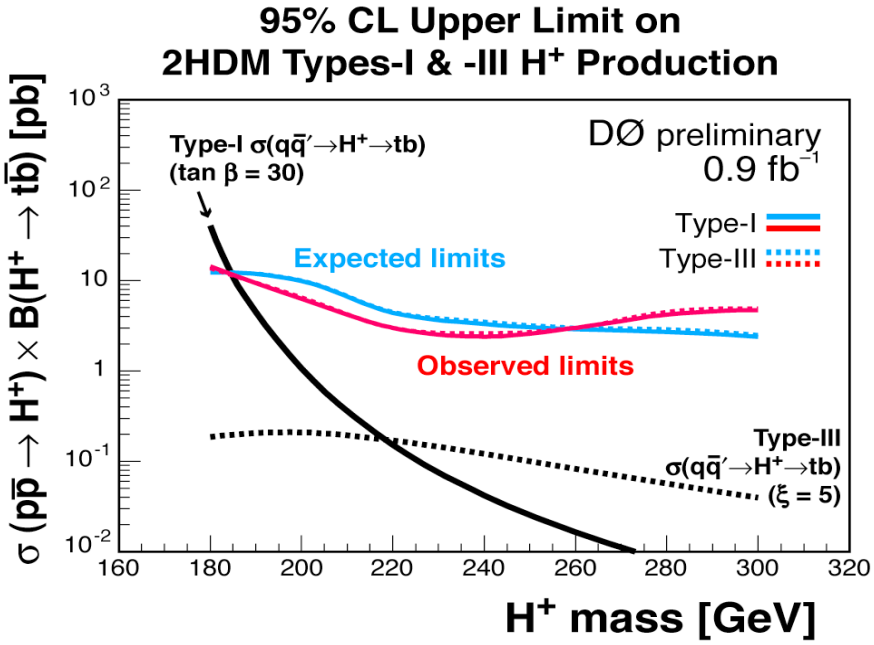
Heavy charged Higgs



- For $m_t < M_{H+}$: Single top production via H^+ possible
- Search for bump in $t\bar{b}$ invariant mass distribution
- Limits on $\sigma(p\bar{p}\rightarrow H^+)xB(H^+\rightarrow t\bar{b})$

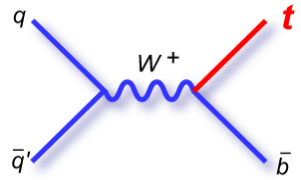






Phys. Rev. Lett. 102, 191802 (2009)

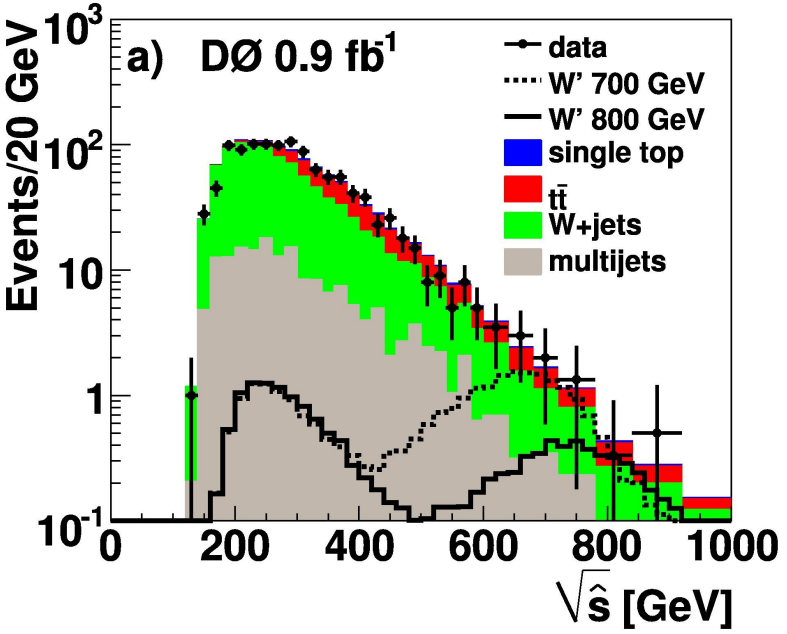
W' search

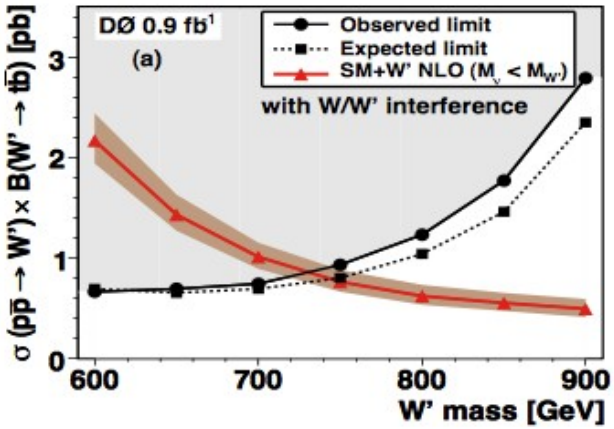


- Search for heavy gauge boson W' in single top production
  - Look for bump in invariant $t\bar{b}$ mass

$$\mathcal{L} = \frac{V_{ij}}{2\sqrt{2}} g_w \bar{f}_i \gamma^\mu [a_{ij}^R (1+\gamma^5) + a_{ij}^L (1-\gamma^5)] W'_\mu f_j + \text{H.c.}$$

- SM-like W': $a^L=1$, $a^R=0$
  - Interference with SM W
  - $M_{W'}>731$GeV
- Alternative model:
  Right handed W' ($a^L=0$, $a^R=1$)





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

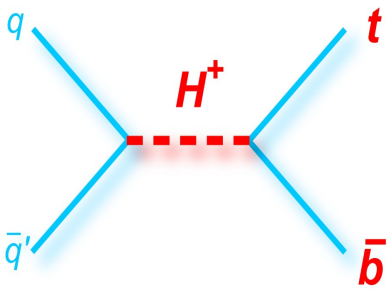
Conclusion and outlook

- The top quark is an ideal place to search for new physics!
- Extended search program at D0
  - W', Z', G', t', H^+, H, ...
- More data to analyze, more new physics to explore!
  - More than 6fb^{-1} of data on disk now!
- For the latest results of the full top program go to:

http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html

Run II Integrated Luminosity

19 April 2002 - 14 June 2009



Stay tuned!

BACKUP

Two Higgs Doublet Model (2HDM)

- Extension of the Standard Model with a second complex Doublet
  - Two vacuum expectation values v_1 and v_2
  - In total five physical Higgs Bosons: A^0, h^0, H^0, $\mathbf{H^{\pm}}$
- Higgs-Fermion couplings not fixed by the model – but requirement: Avoid FCNC
  - TYPE I: only one Higgs doublet couples to Fermions
  - TYPE II: one Higgs doublet couples to up-type Fermions, the other to down-type Fermions
  - Type III: both Higgs doublets couple to fermions
- MSSM: Type II 2HDM needs to be realized
  - Leading order: independent parameters: m_A and $\tan(\beta)=v_1/v_2$

$t\bar{t}$ resonances

- Some more info: measured cross section and expected limits