Search for new physics in top decays at D0

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for the D0 collaboration

- W' boson resonances
- 4th generation t' quark
- Flavour Changing Neutral Currents

Heavy W' resonances decaying to tb

arXiv:1101.0806v2 [hep-ex] 19 Feb 2011

Heavy W' resonances

- effective $\mathcal{L}$ for W' interactions w/ SM fermions f_{ij} written in a model independent form:

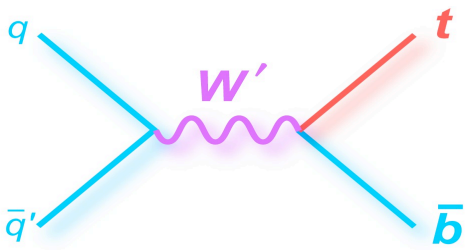
$$\mathcal{L} = \frac{V_{f_i f_j}}{2\sqrt{2}} g_w \bar{f}_i \gamma^\mu (a^R_{f_i f_j}(1+\gamma^5) + a^L_{f_i f_j}(1-\gamma^5)) W'_\mu f_j + h.c.$$

Right and left couplings of W' to the fermion doublet

	a^L_{ud}	a^L_{tb}	a^R_{ud}	a^R_{tb}
purely left-handed couplings	1	1	0	0
purely right-handed couplings	0	0	1	1
equal mixture	1	1	1	1

600 < massW' < 1000 GeV/c^2

- Production



- Decay

search for W′ → 3rd quark generation

- left-handed couplings of W', interference with SM taken into account
- right-handed couplings of W'

✦if $m(W'_R) > m(\nu_R)$ decays to $\ell\nu$ and $\bar{q}q$
✦if $m(W'_R) < m(\nu_R)$ only decays to $\bar{q}q$

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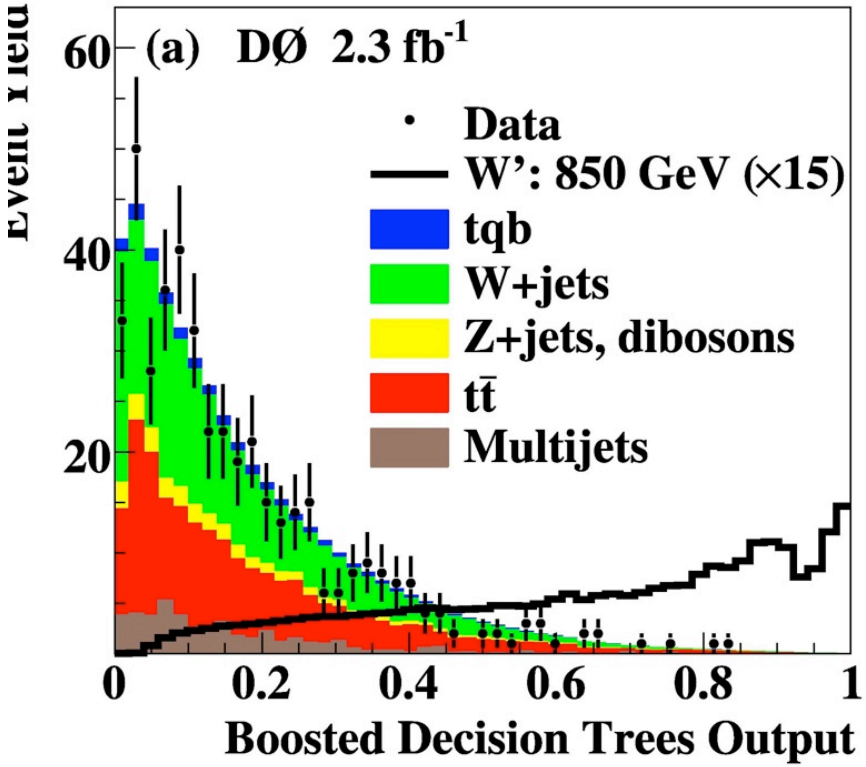
W'→tb : sample selection signal extraction and yields

see C. Gerber's talk
Heavy Flavours session

- single top selection restricted to 2, 3 or 4 jets, (24 channels)
  - 1 isolated lepton p_T>15 GeV/c,
  - MET > 20 (25) GeV from the undetected neutrino,
  - two (three or four) jets p_T> 15 GeV/c, leading jet p_T > 25 GeV/c, one or two b-tagged jet.
  - tb invariant mass : $\sqrt{\hat{s}}$ reconstructed with the invariant mass of the leading two jets, the charged lepton and the neutrino by adding their measured momentum 4-vector, > 400 GeV
- The sensitivity is enhanced through multivariate discriminant based on boosted decision trees

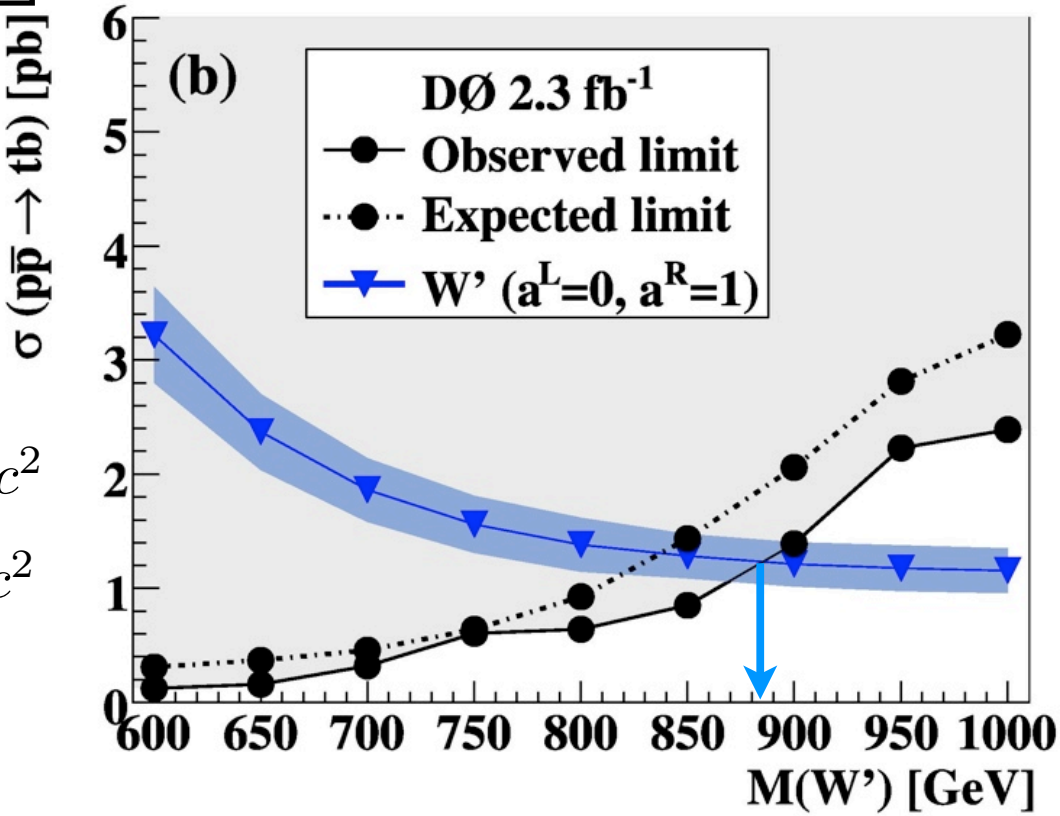
Process	Events
tqb	26.4 ± 2.5
$t\bar{t}$	424.7 ± 58.4
W+jets	279.5 ± 18.3
Z+jets	26.0 ± 3.2
Dibosons	13.0 ± 1.6
Multijets	60.5 ± 10.8
Total background	830 ± 62
Data	831



W'→tb : results

- Couplings to first and third generation quarks taken as equal
- for each W' mass, construct signal templates varying left/right-handed couplings between 0 and 1 in step of 0.1

Pure right-handed couplings of W'



$M(W') > M(\nu_R)$: $M(W') > 885\ \mathrm{GeV}/c^2$

$M(W') < M(\nu_R)$: $M(W') > 890\ \mathrm{GeV}/c^2$

at 95 % C.L.

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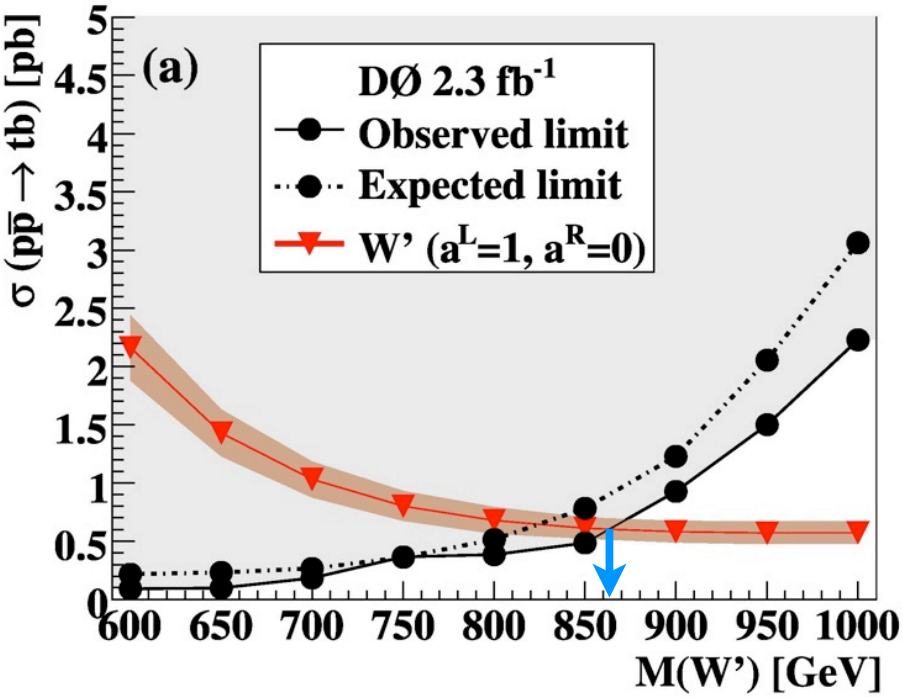
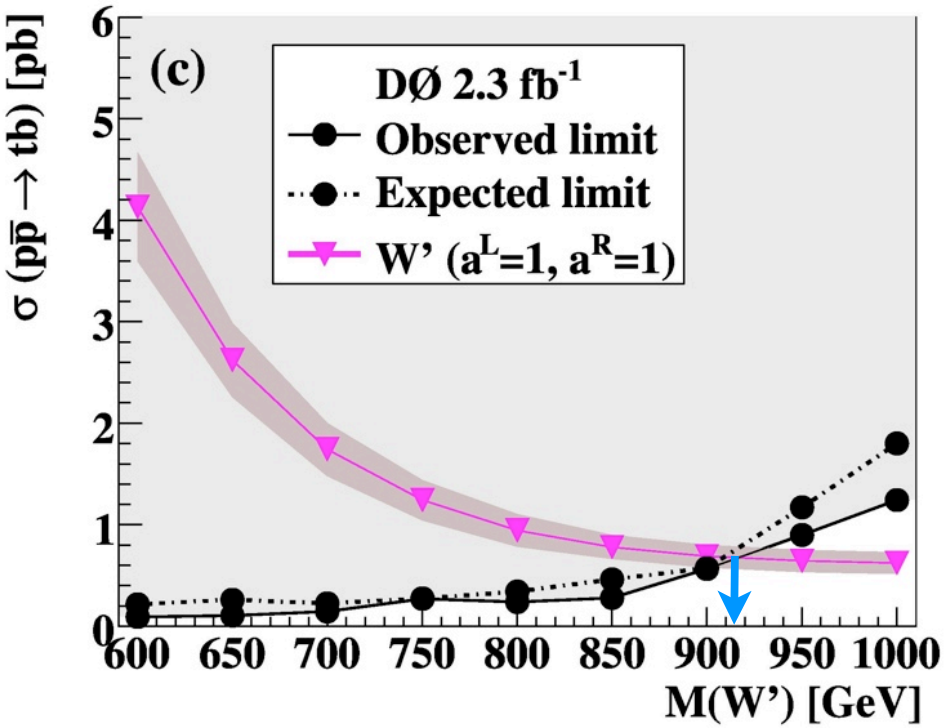
W'→tb : results

Pure left-handed W'



$M(W') > 863\ \mathrm{GeV}/c^2$

Mixed couplings W'



$M(W') > 916\ \mathrm{GeV}/c^2$

at 95 % C.L.

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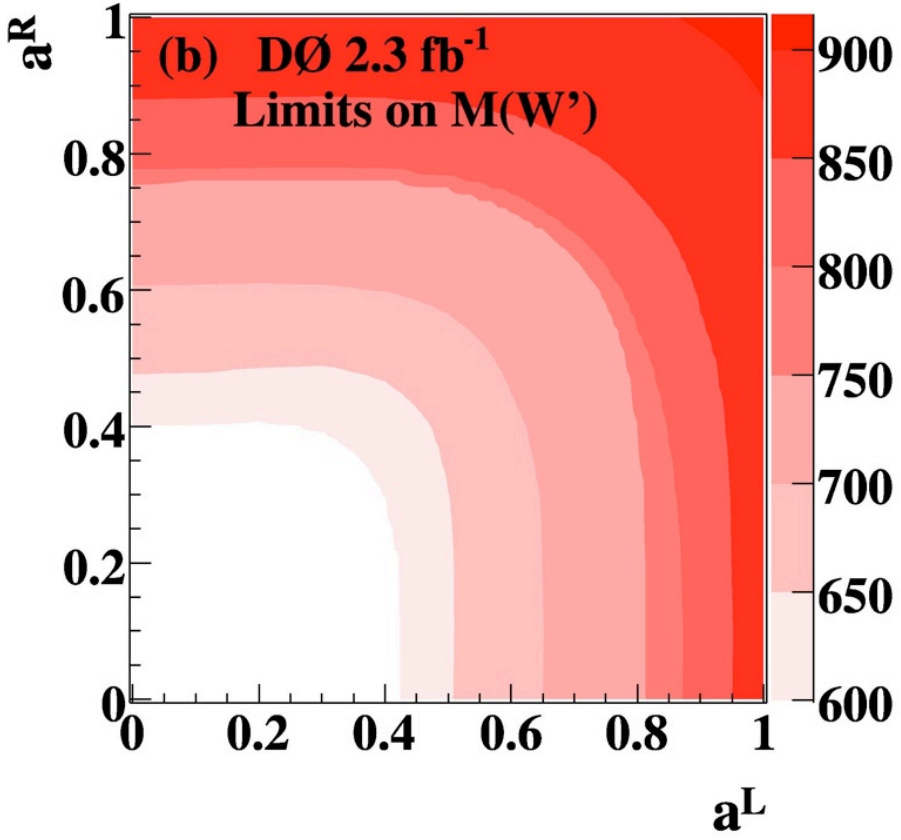
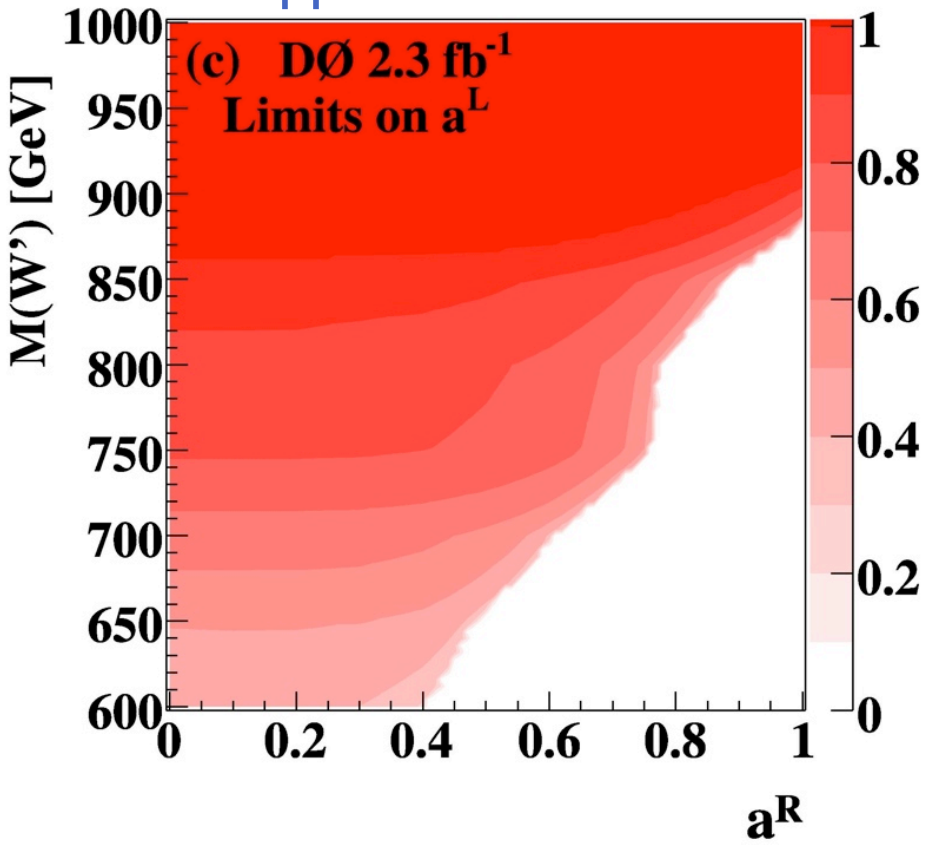
W'→tb : results

- 2 of the 3 parameters, a^L, a^R, M(W') are fixed and the cross-section limit is interpolated in the third parameter value
- Summary plots for the limits on W' mass and couplings

- lower limits on W' mass



- upper limits on a^L



at 95 % C.L.

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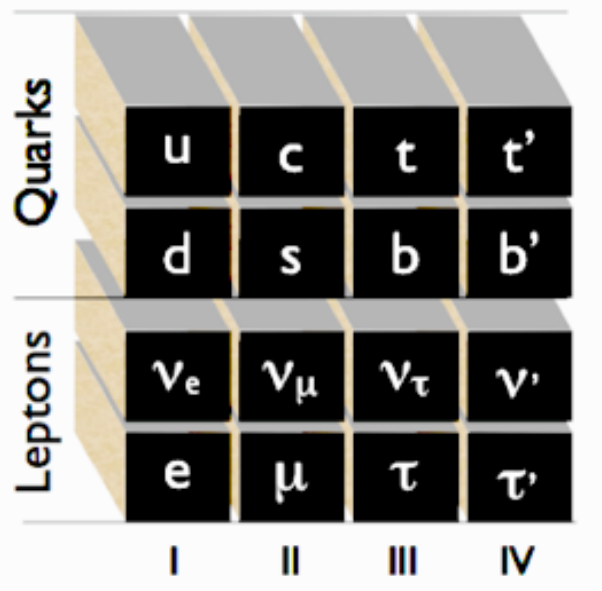
Search for a 4th generation t' quark decaying to a W and a jet

preliminary results submitted



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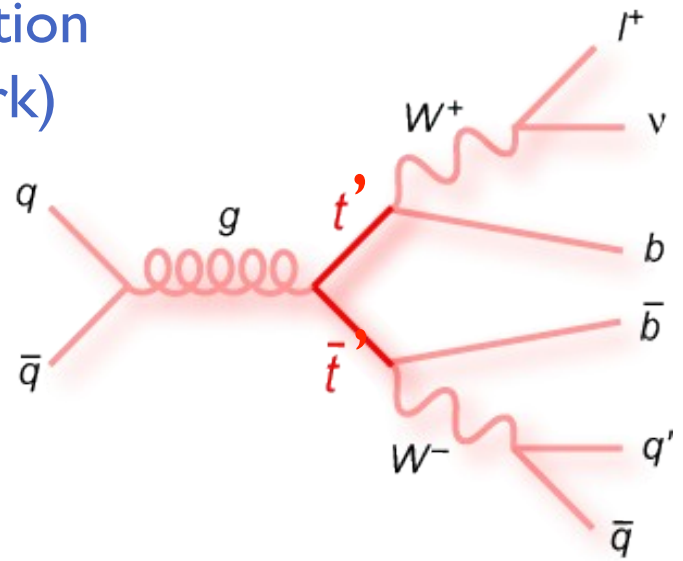
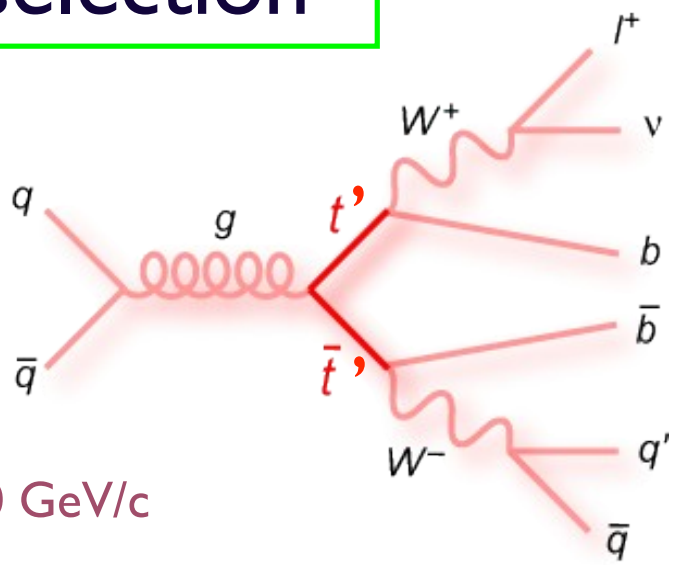
4th generation t' quark

- Constraints on 4th fermion generation from LEP and precision electroweak data :
  - m(ν') > m(Z)/2 Aleph, Delphi, L3, Opal, SLD working groups, Phys. Rep. 427 (2006)
  - m(t')-m(b') < 50 GeV G.D.Kribs, PRD76,075016 (2007)
- but, assuming
  - pair production via strong interaction
  - t' → Wq (q is any down-type quark)



→generic search for new particles that are pair produced and decay to Wq

4th generation t' quark : selection



- one isolated lepton
  - electron P_T> 20 GeV/c |η|<1.1
  - μ P_T > 20 GeV/c |η|<2.0
- MET > 20 (25) GeV
- >= 4 jets with Pt> 20 GeV/c, leading jet Pt > 40 GeV/c

first analyze the e+jets and mu+jets data separately

- use histograms of HT versus mfit to discriminate between t' signal and backgrounds
  - HT= lepton P_T+ P_{Tmiss}+ sum jet P_T

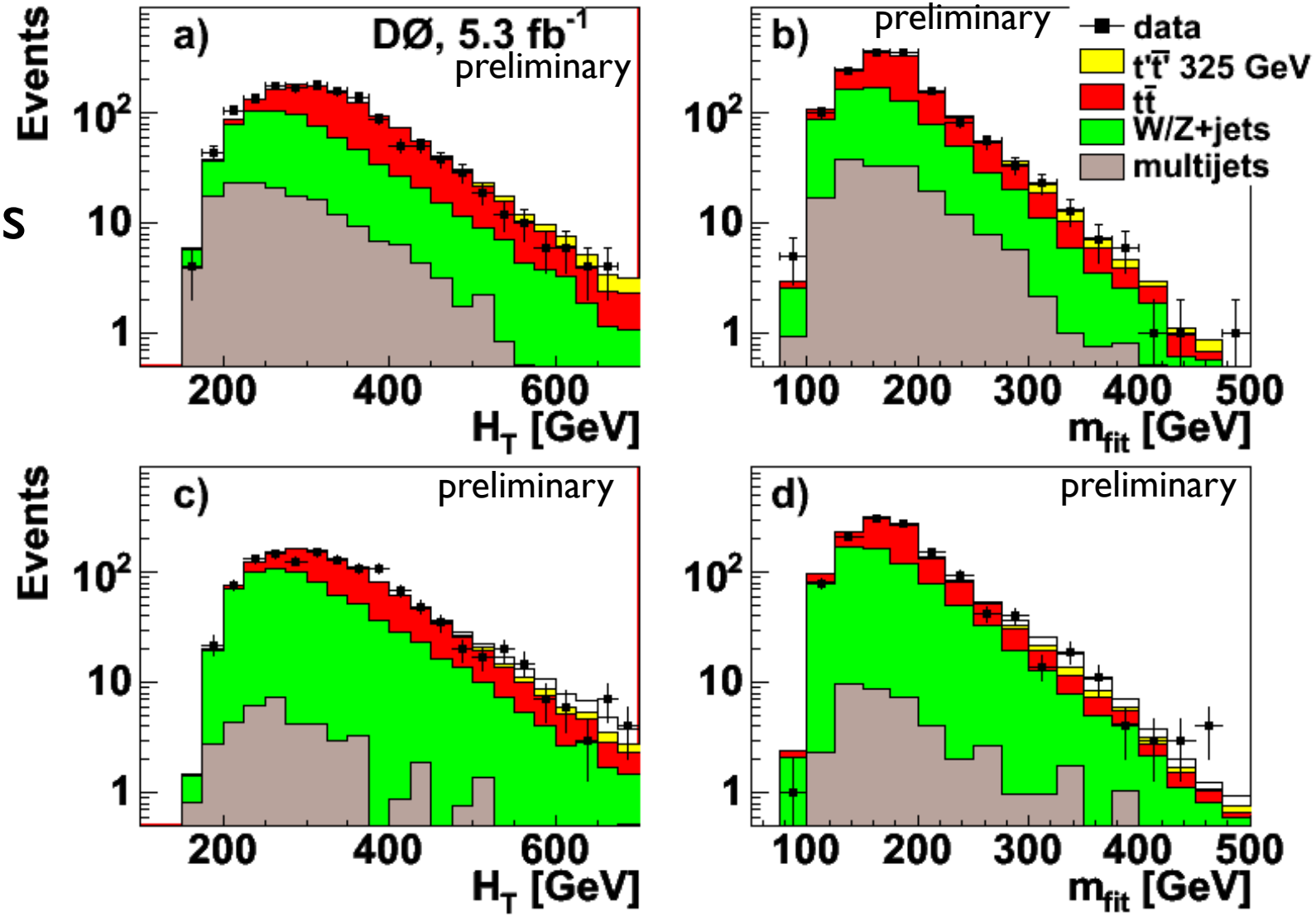
  - mfit= reconstructed mass from kinematic fit to t't'-> WbWb->lvbqq'b

  consider all 12 jet permutations and 2 neutrino pz solutions choose permutation with smallest χ^2

4th generation t' quark : distributions

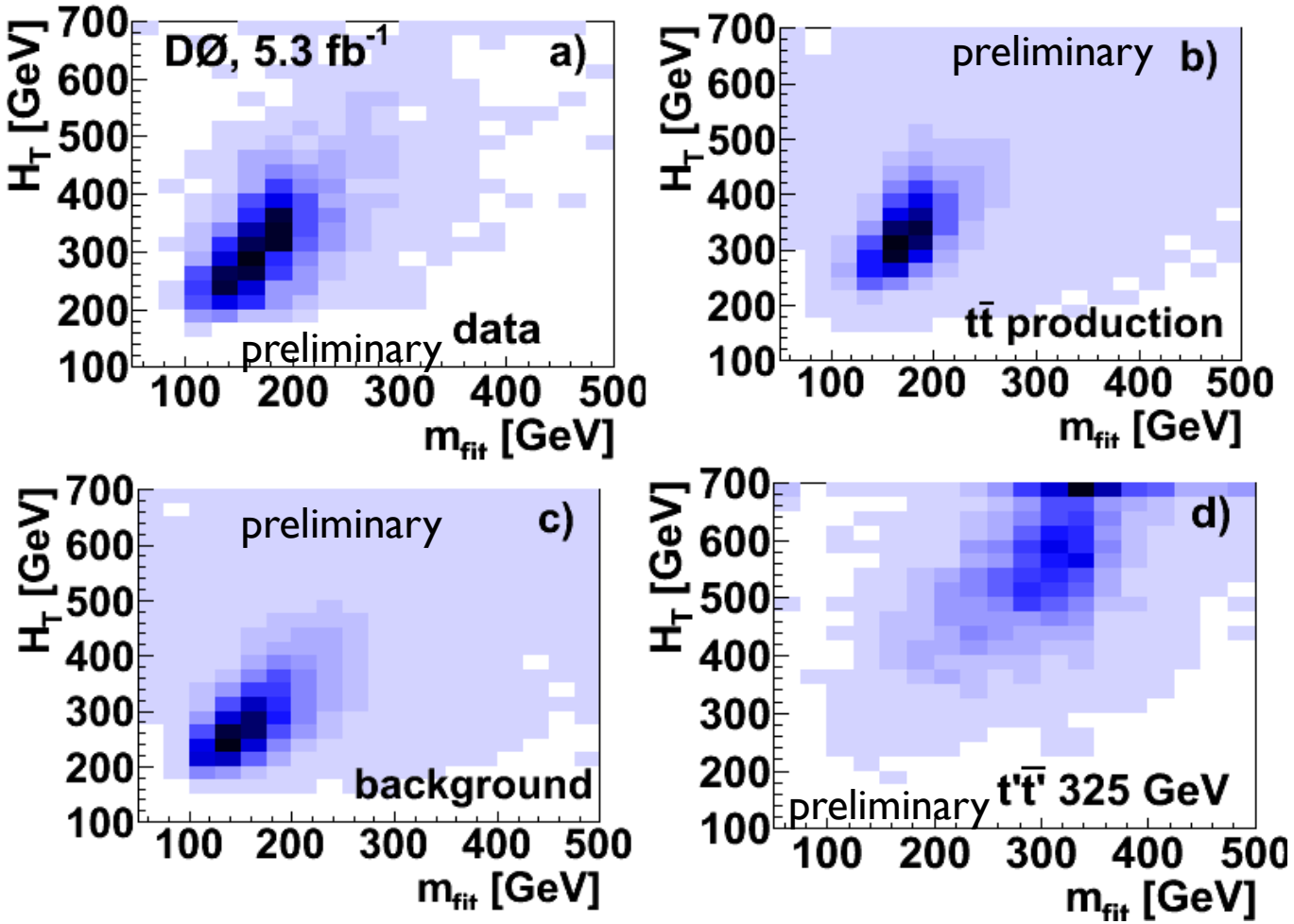
electrons

muons



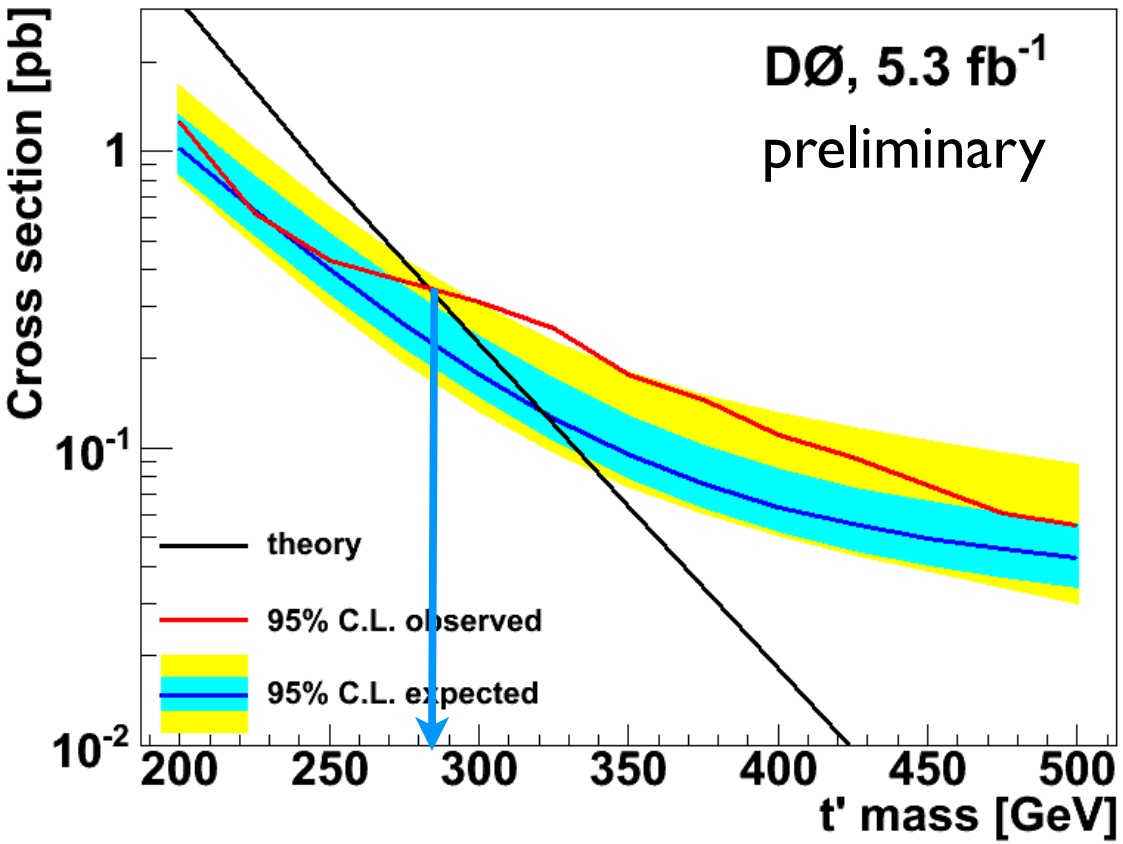
we observe a slight excess in mu+jets data over the standard model prediction

4th generation t' quark : 2D distributions



- use histograms of HT versus mfit to discriminate between t' signal and backgrounds

4th generation t' quark : limits



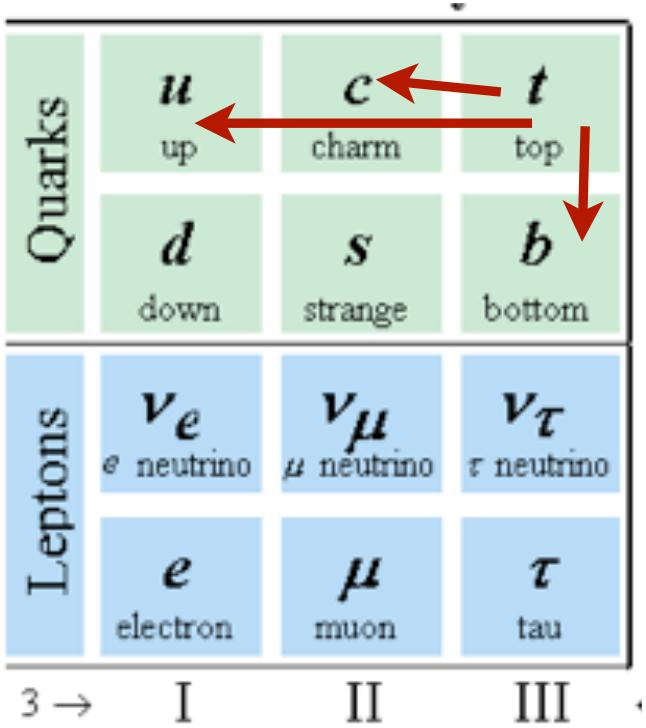
$$M(t') \leq 285\mathrm{GeV/c^2} \ @ \ 95\% \ \mathrm{C.L.}$$

- we achieve the best fit to the data with a t't' production cross section of 1.1+/-0.5 times the theoretical cross section for $m_{t'}$ = 325 GeV (2.2 standard deviations)

Flavour Changing Neutral Currents

arXiv:1103.4574v1 [hep-ex] 23 Mar 2011

transitions between quarks of different flavour but same electric charge



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Search for FCNC coupling in decays of top quark

Standard Model

- SM lagrangian contains no FCNC terms.
  t→Zq (q = u,c) is only possible through radiative corrections
  the branching fraction is ~ 10^{-14}

FCNC modelling

- beyond SM : BR as high as 10^{-4}
- any top quark that does not decay via t→Zq is assumed to decay via t→ Wb
- t→Zq is generated by an anomalous FCNC term

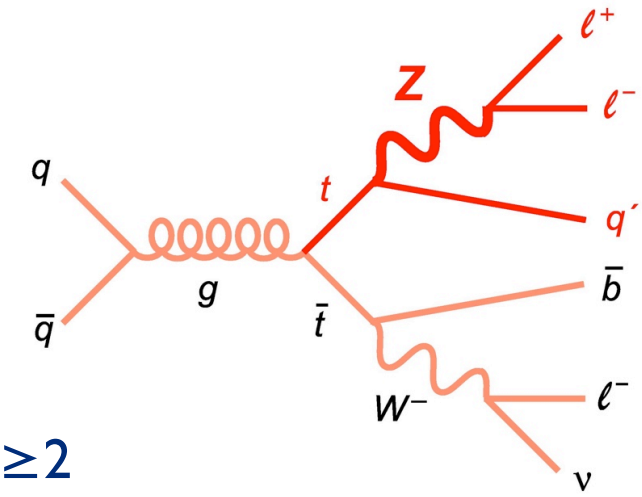
$$\mathcal{L}_{\mathrm{FCNC}} = \frac{e}{2\sin\theta_W\cos\theta_W}\bar{t}\gamma_\mu(v_{tqZ} - a_{tqZ}\gamma_5)qZ^\mu + h.c.$$

- vector v_{tqZ} and axial vector a_{tqZ} couplings
- θ_W Weinberg angle

→ the search is performed in top pair production

FCNC selection

First search for FCNC in $t\bar{t}$ decays with trileptons

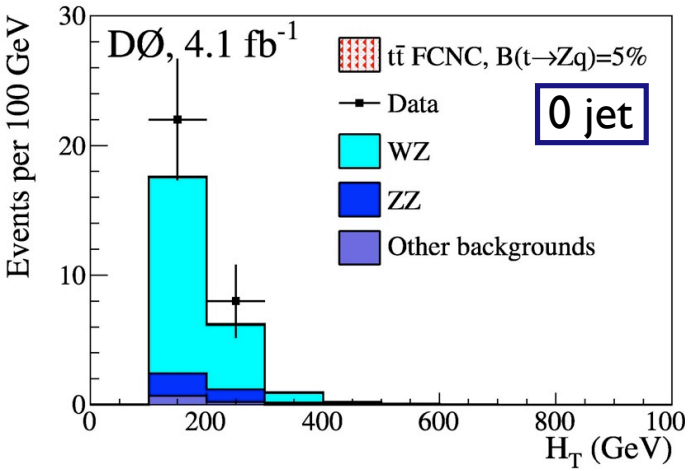


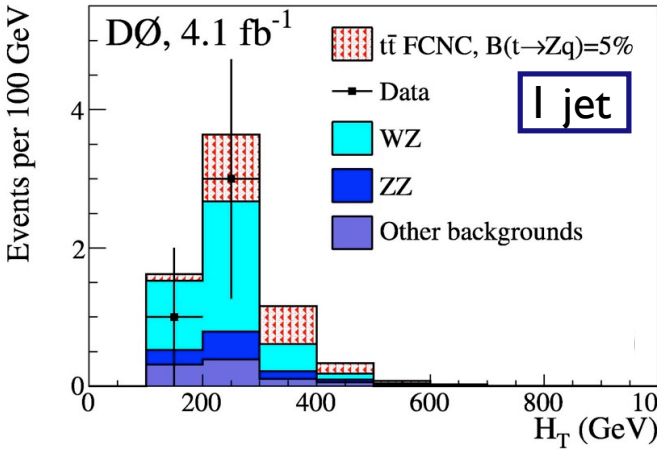
- high p_T isolated electrons or muons
- large missing transverse energy
- break sample into three jets multiplicity bins : 0, 1, ≥2

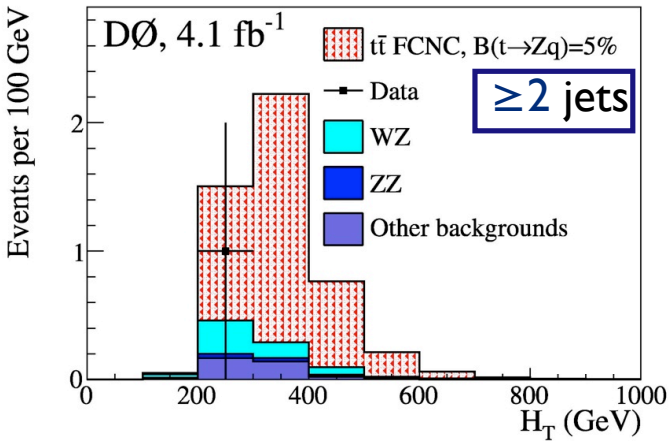
  require jets to have E_T> 20 GeV, ΔR (l,jets)≥0.4(0.5) for muons (electrons)

$H_T = \Sigma\, p_T(\text{leptons}) + \text{MET} + \Sigma\, p_T(\text{jets})$

n_{jet}	0	1	≥2
Background	25.66 ±0.28 ±3.26	5.06 ±0.14 ±0.56	0.92 ± 0.08 ± 0.09
$t\bar{t} \to WbZq$	0.20±0.03	1.80 ± 0.27	3.87± 0.56
$t\bar{t} \to ZqZq$	0.002 ± 0.001	0.020 ± 0.003	0.050±0.007
Observed	30	4	1







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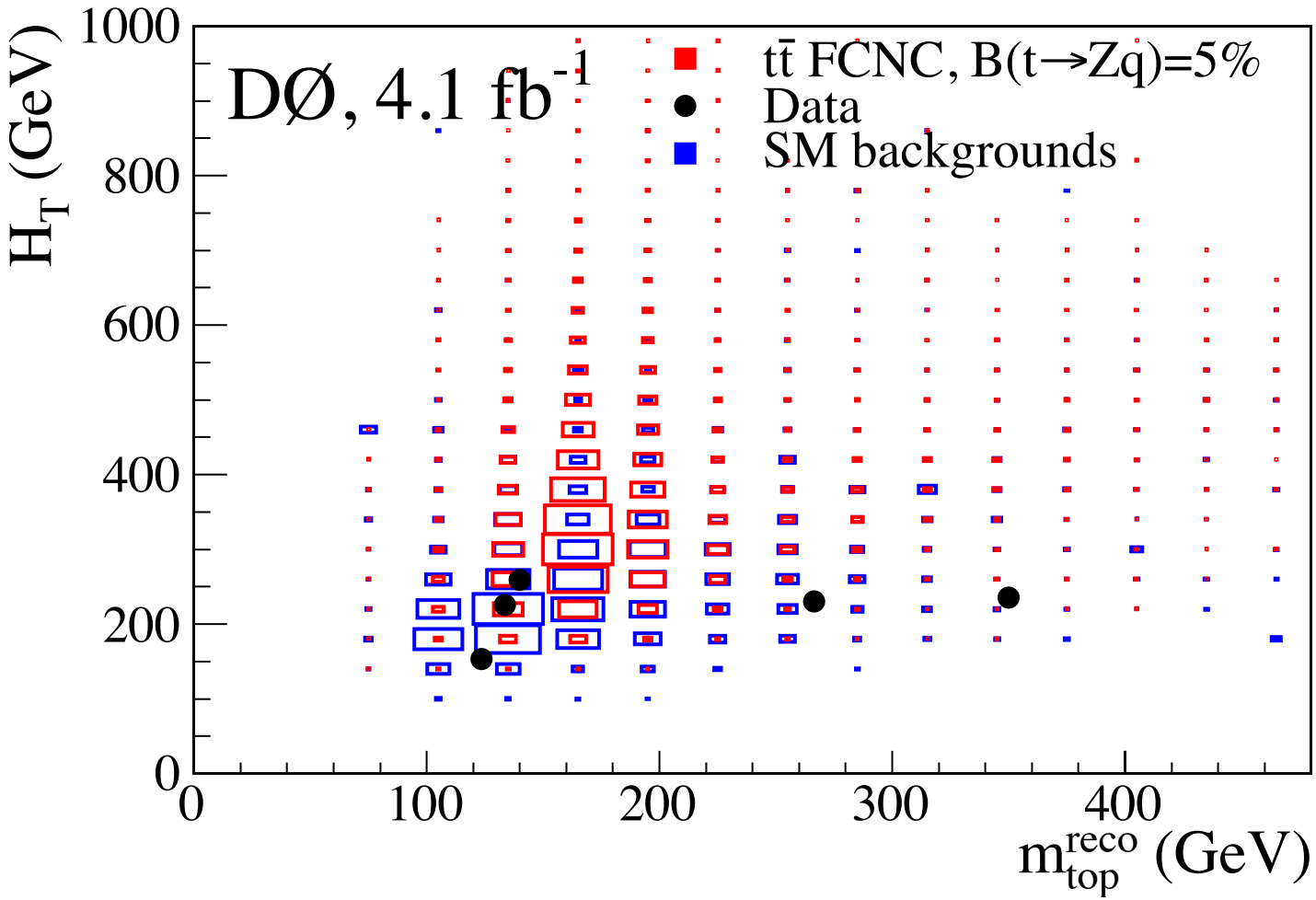
FCNC : H_T % reconstructed m_{top} distribution

- use $H_T = \Sigma\ p_T$(leptons) +MET+$\Sigma\ p_T$(jets)
- and reconstructed top quark mass (from the Z leptons and jets) to separate signal from background.



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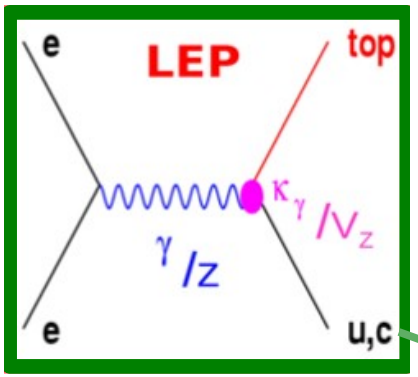
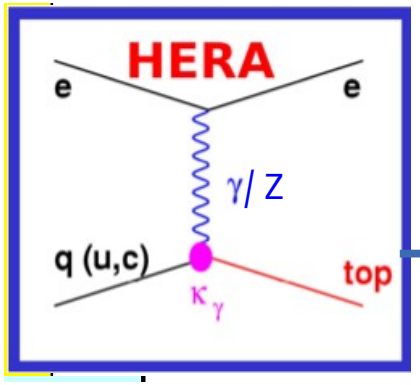
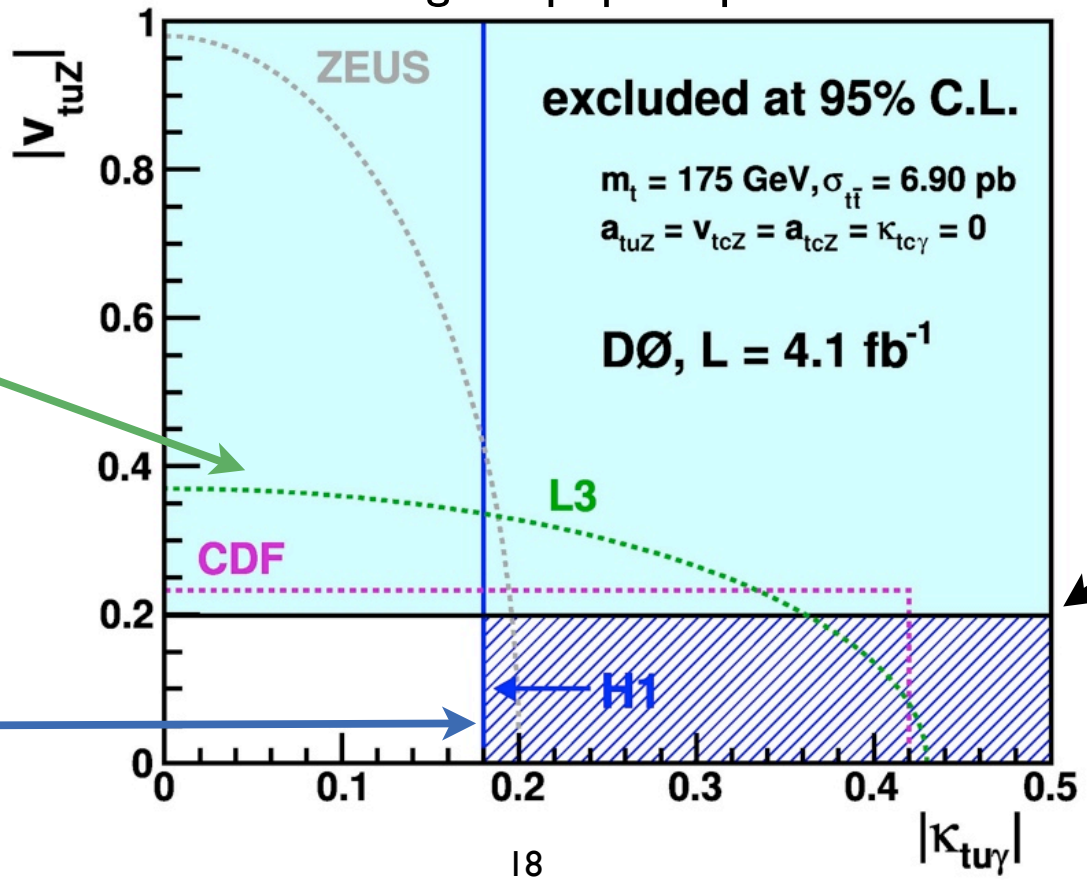
limits on v_{tqZ} couplings

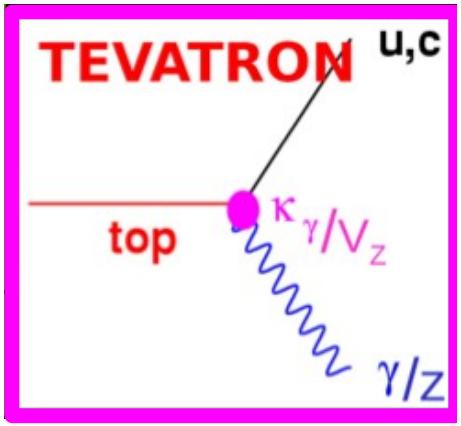
- observed (expected) limit of B(t→Zq) < 3.2 % (3.8 %) at the 95 % C.L.
- the limits on the branching ratio are converted to limits on the FCNC vector v_{tqZ} and axial vector a_{tqZ} couplings.
- assuming only one non vanishing v_{tqZ} coupling, an observed (expected) limit of v_{tqZ} < 0.19 (0.21) for m_{top}=172.5 GeV/c^2

limits on single top quark production via FCNC









new limit

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Summary

- Heavy W' resonances decaying to tb

  model-independent approach in which the W' may couple to fermions with any combinations of left- and right-handed couplings

purely left-handed couplings	M(W') > 863 GeV
purely right-handed couplings	M(W') > 885 GeV
equal mixture	M(W') > 916 GeV

CDF M(W')> 800 GeV

- 4th generation t' quark

$$M(t') \leq 285\,\mathrm{GeV}$$

CDF $M(t') \leq 315\,\mathrm{GeV}$

- Flavour Changing Neutral Currents

$$BR(t \to Zq) < 3.2\ \%$$

CDF $BR(t \to Zq) < 3.7\ \%$

- More data available in the full dataset