Searches for $t' \rightarrow Wq$ and FCNC at CDF

Alison Lister

UC Davis

For the CDF collaboration

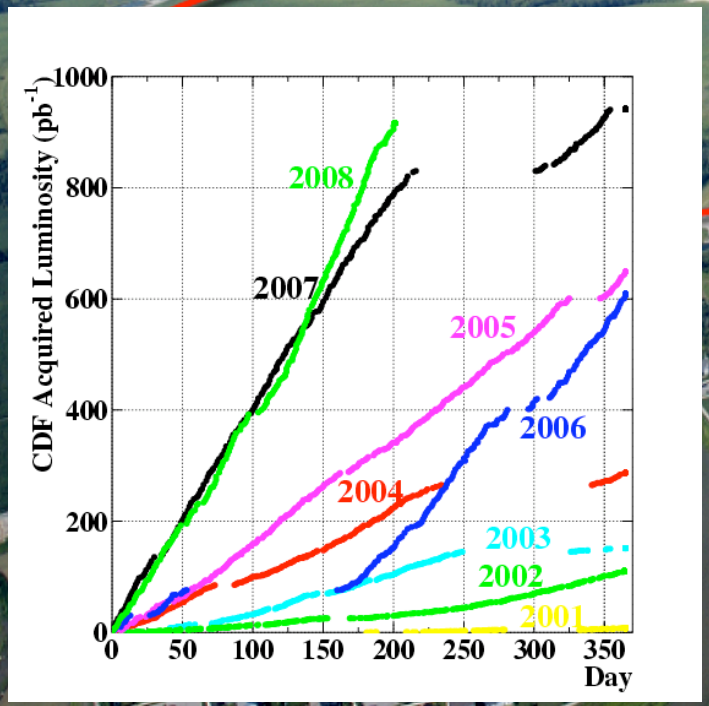
Outline

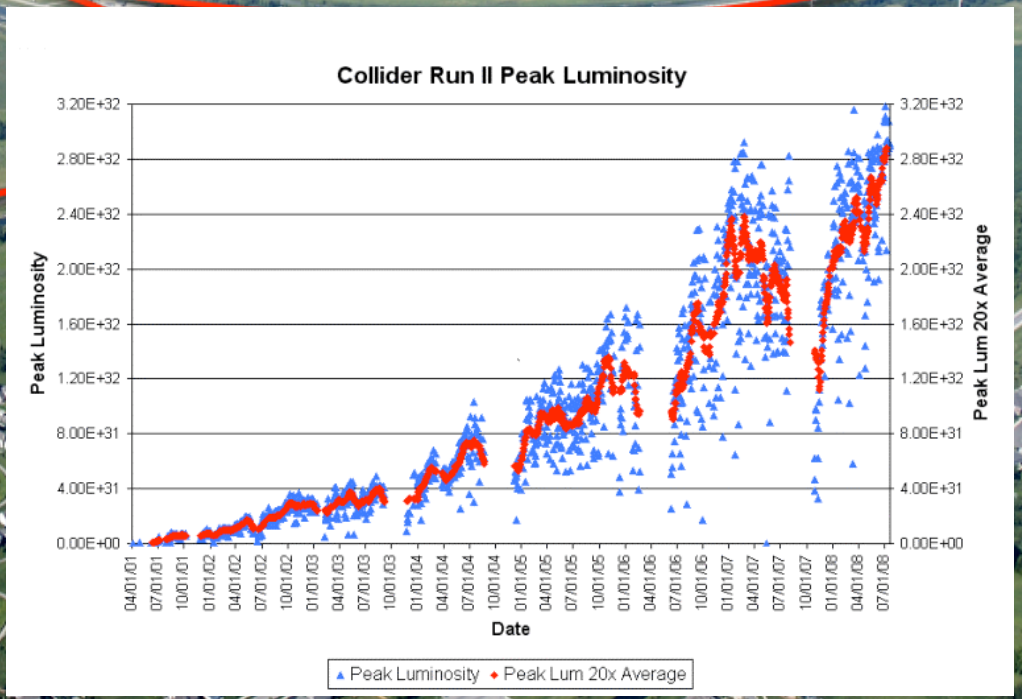
- Tevatron and CDF
- Search for $t' \rightarrow Wq$ in lepton+jets
- Search for FCNC in tt production
- Search for FCNC in single top production
- Conclusions

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

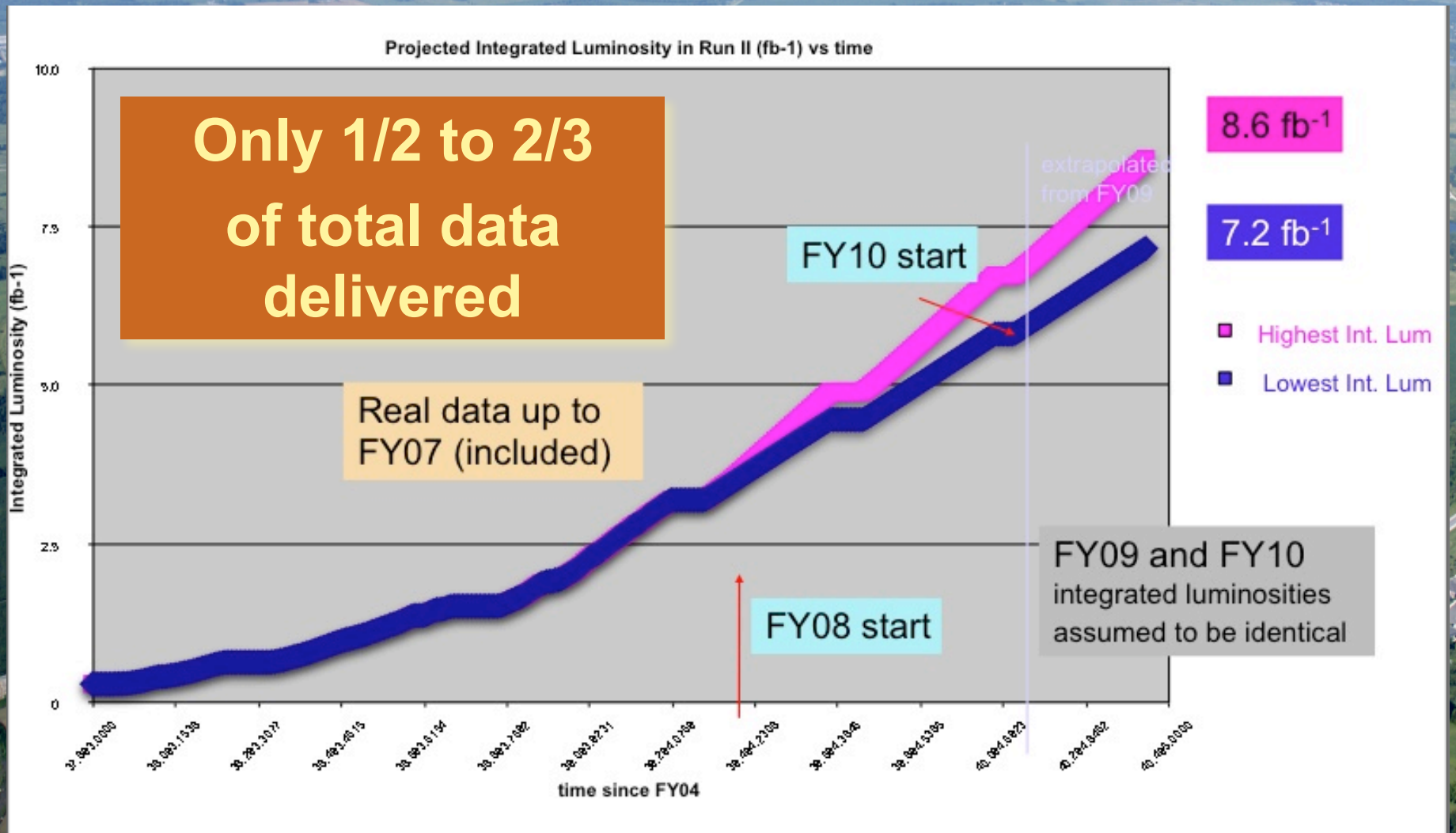
Thanks to the Accelerator Division!

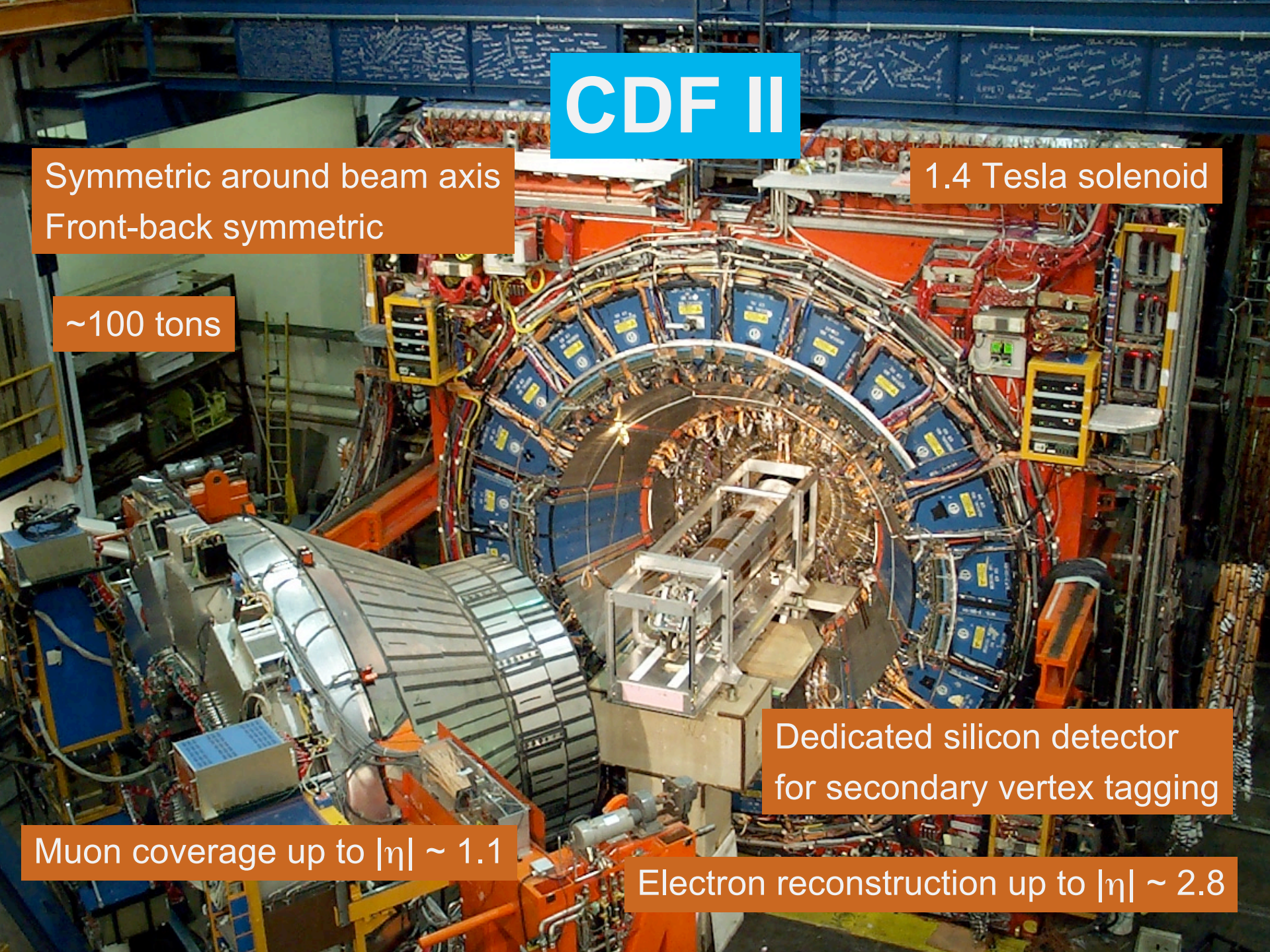




Tevatron Expectations

- 7 fb^{-1} expected per experiment by end of 2009
- 8.6 fb^{-1} if run in 2010




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

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

~300 tt events a week at the Tevatron

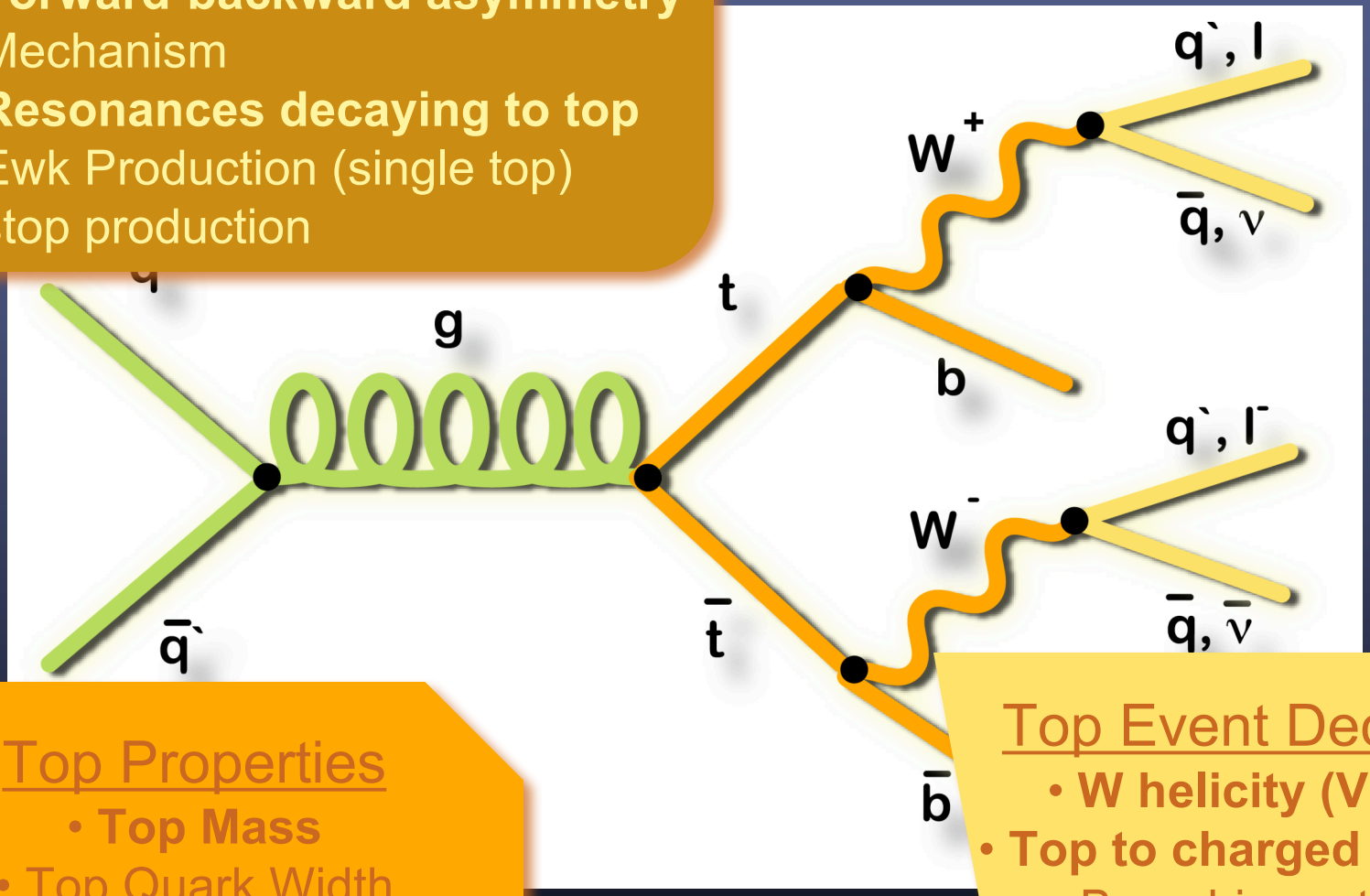
Top Physics is a (the?) hot topic of the Tevatron

Now in the realm of precision physics:
over 1000 tt events in Lepton + Jets channel at CDF

Why not search for new physics there?

Top Quark Production

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



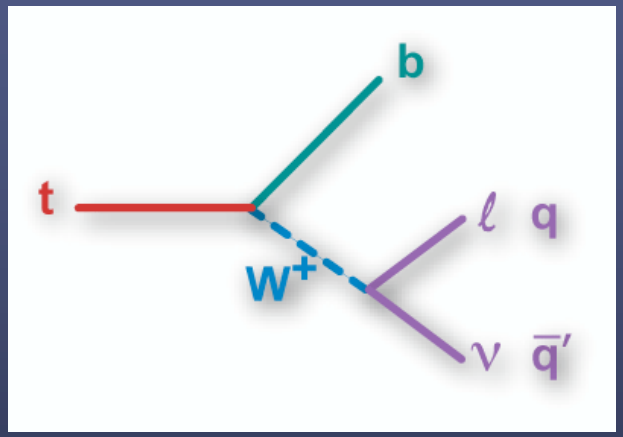
Top Properties

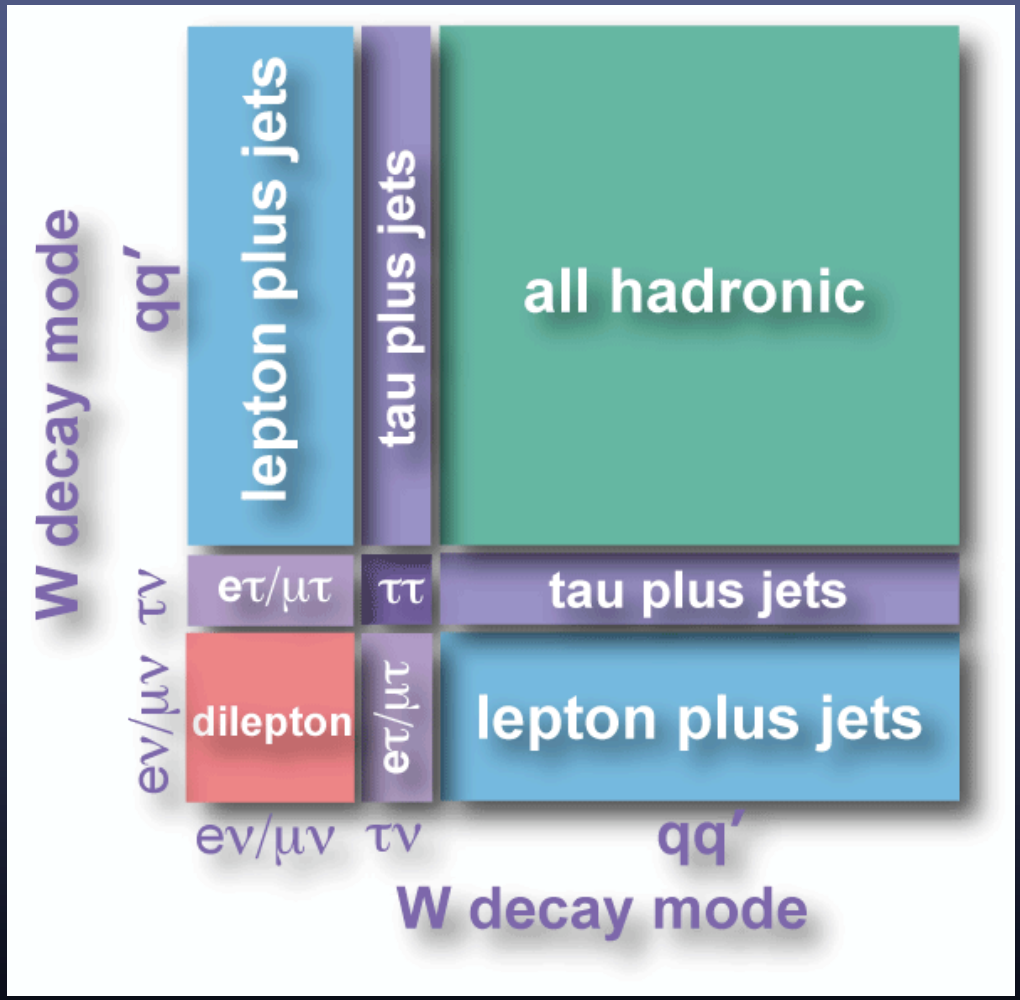
- **Top Mass**
- Top Quark Width
- **Charge of Top Quark**

Top Event Decays

- **W helicity (V-A)**
- **Top to charged higgs**
- Branching ratios
- **FCNC**

Top events are characterised by the decay mode of the W

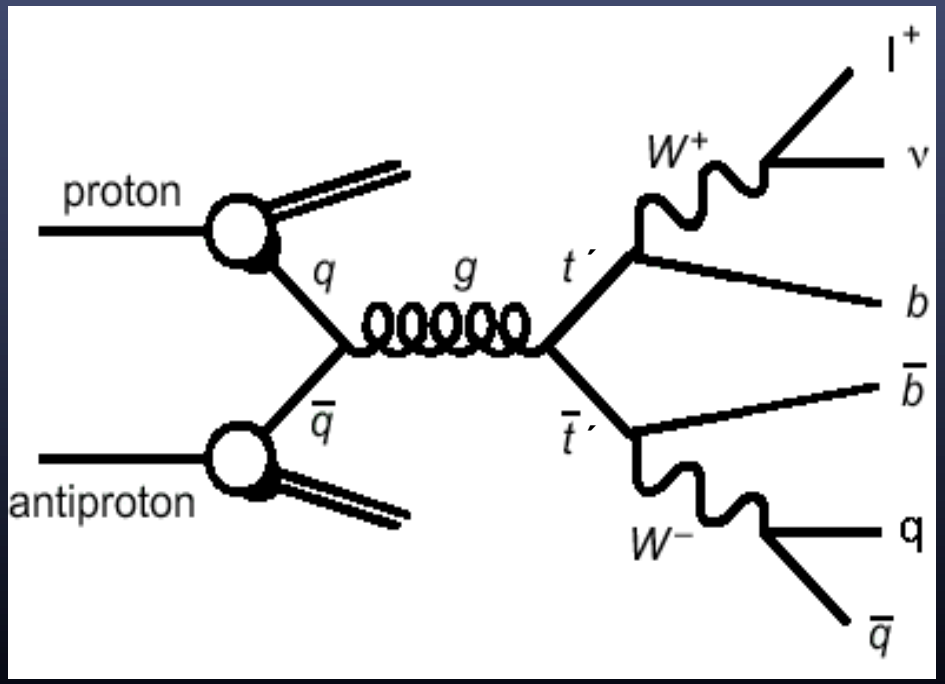




t´→ Wq in Lepton + Jets Using 2.8 fb^{-1}

This Search

- Assume t´ pair production with strong SM couplings
- Search for new quark decays into Wq
- Assume t´ ->Wb´ is kinematically suppressed and $V_{t'b} \sim V_{t'q}$
- Assume BR(t´->Wq) ~ 100%
- Look for lepton + jet events



Event Selection

- One isolated central electron or muon
  - Lepton P_T > 20 GeV
- ≥ 4 jets (E_T > 20 GeV)
- E_T leading jet > 60 GeV
  - Remove QCD background and large fraction of W+jets
- Missing E_T > 20 GeV
- Conversion/cosmic/Z/dilepton/QCD removal
- Mis-reconstructed muon removal
  - $\Delta\phi$(MET->Lepton) < 3.05

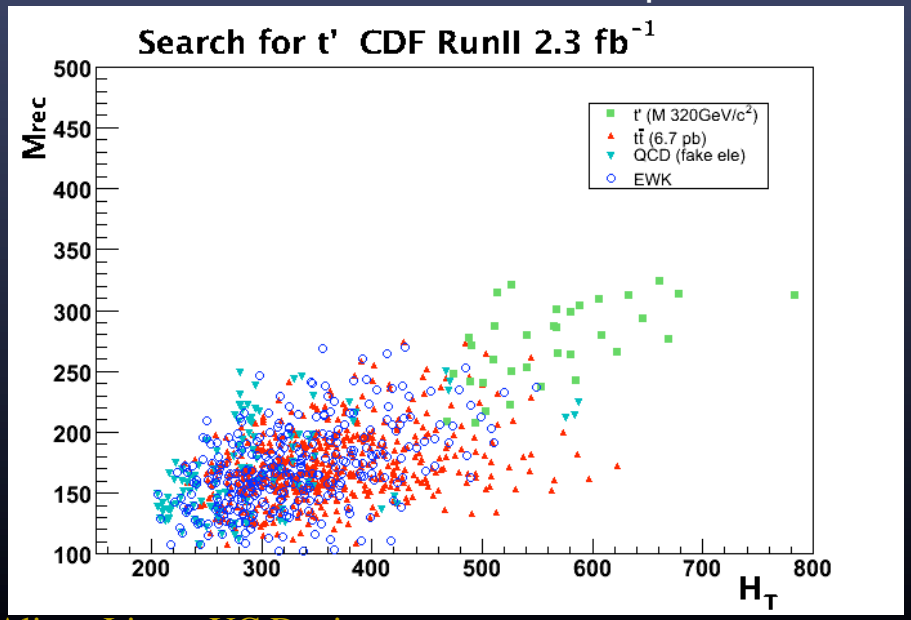
Analysis Methodology

- Likelihood fit of the data to H_T vs M_{rec} distributions
- H_T is the total transverse energy of the event: $H_T = \sum E_T^{jets} + p_T^{lepton} + \text{Missing } E_T$
- M_{rec} is the reconstructed mass of the top quark (using width of the top)
  - Use χ^2 function to choose combination of event objects that best fits top decay

$$\chi^2 = \sum_{i=l,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i} + \sum_{j=x,y} \frac{(p_j^{UE,fit} - p_j^{UE,meas})^2}{\sigma_j} + \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - Mt)^2}{\Gamma_t^2} + \frac{(M_{bl\nu} - M_t)^2}{\Gamma_t^2}$$

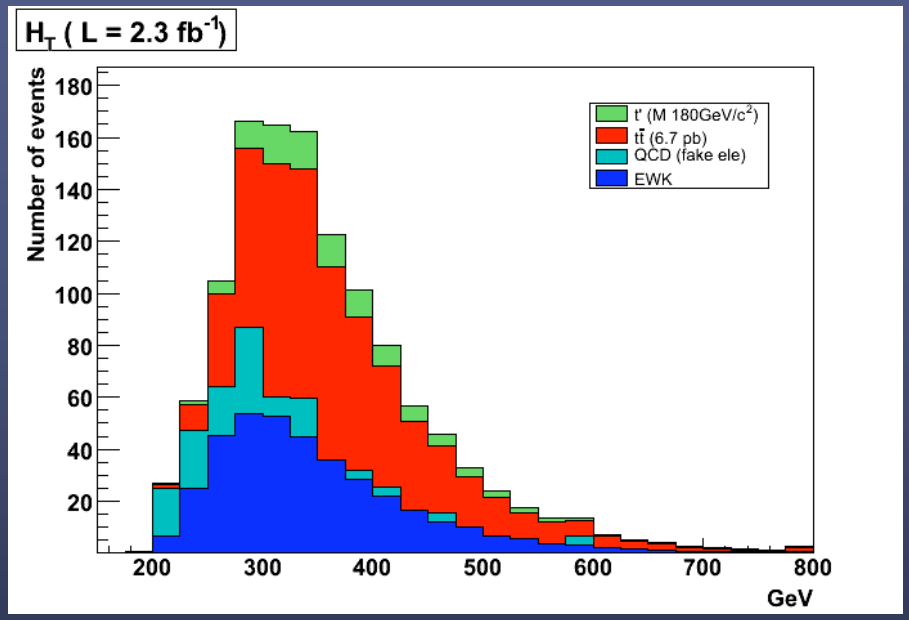
- t'
  - Varies freely
- Top
  - Constrained to SM cross-section
  - Theoretical error
- EWK
  - Varies freely
- QCD
  - Constrained by fit to missing E_T
  - Error 50%

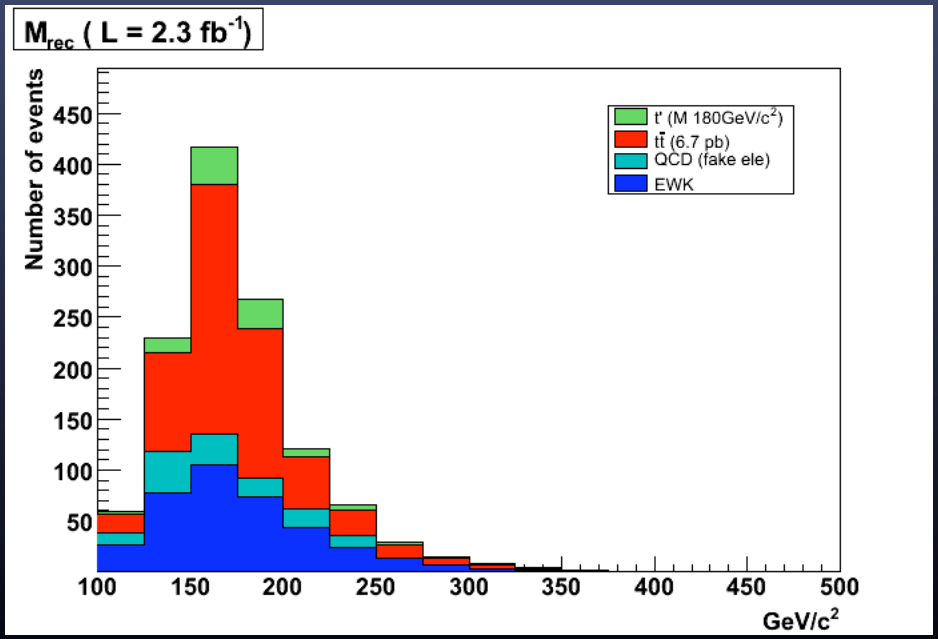
Number entries normalised to expected events



H_T and M_{rec}

- Distributions with expected number of SM background events
- Arbitrary constant number of t' events added
  - t' masses 180-450 GeV



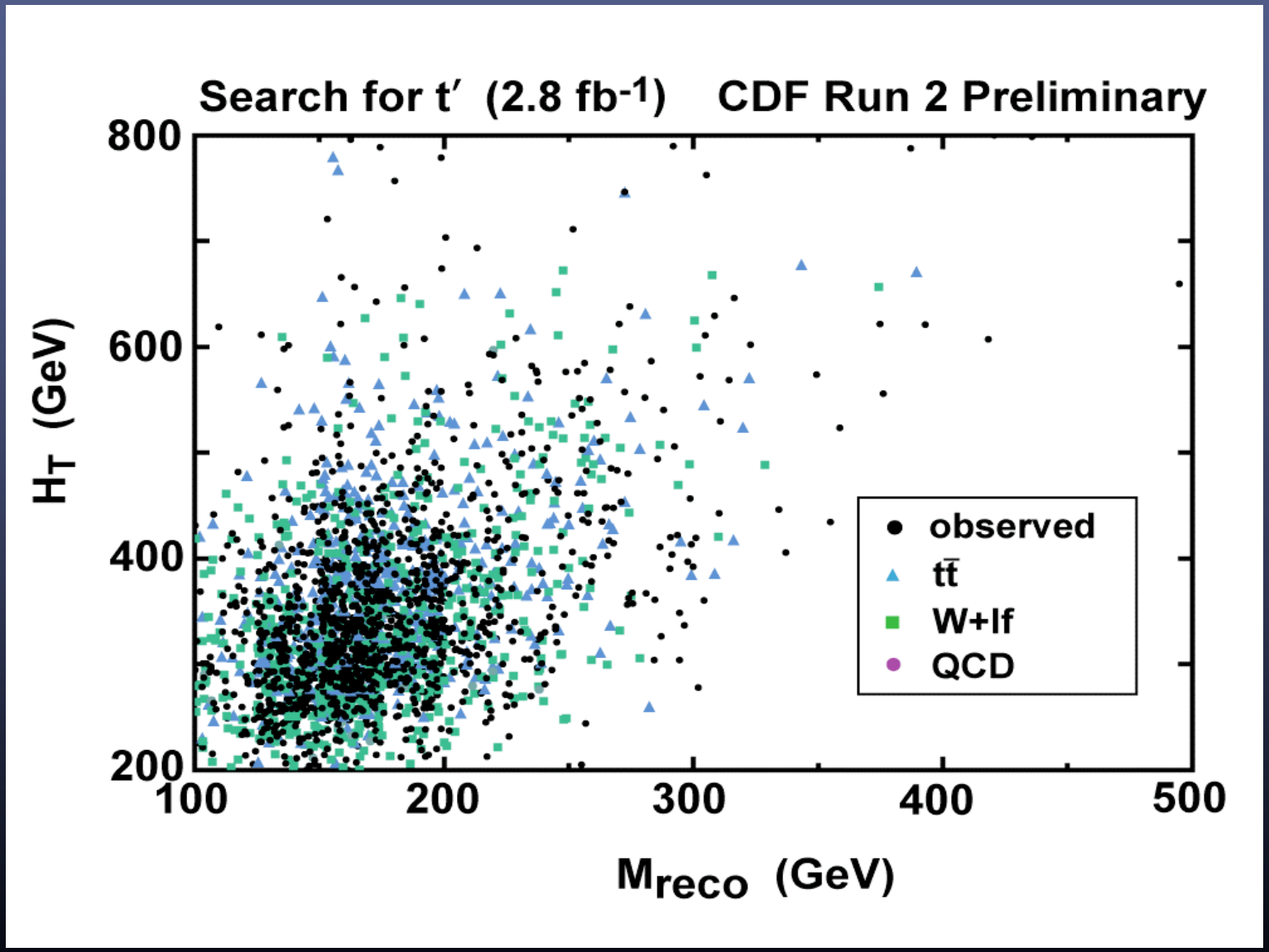


- Better separation at higher masses
- But lower expected cross-sections

Systematics

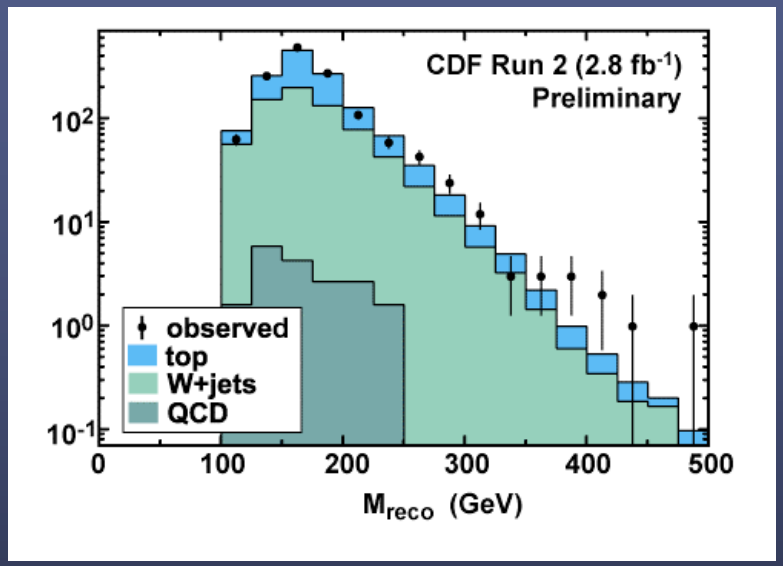
- Jet Energy Scale
  - Increase and decrease energy scale by uncertainty on measurement
  - Take 1/2 of the largest difference and symmetrize
- Q^2 Scale choice for EWK background modeling
  - Increase scale by factor 2, decrease scale by factor 2
  - Take 1/2 of the largest difference and symmetrize
  - Additive parameter
- Initial and final state radiation (ISR+FSR)
  - Increase both up and both down
  - Take 1/2 of the largest difference and symmetrise
  - Additive parameter
- PDFs
  - Re-weight events according to set of 46 PDFs
  - 1.1%
- Trigger Efficiencies
- Lepton ID /efficiencies / data vs MC scale factors
- Luminosity (5.9%)
- Theory uncertainty on top and t' cross-sections
  - 10%

H_T vs M_{rec}

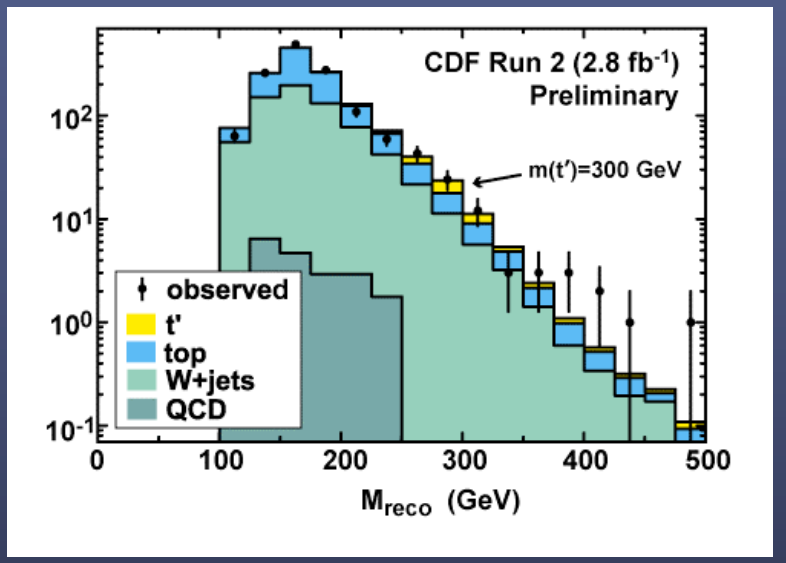

Search for t′ (2.8 fb-1) CDF Run 2 Preliminary
800
600
400
200
100
200
300
400
500
HT (GeV)
Mreco (GeV)
observed
tt̄
W+lf
QCD

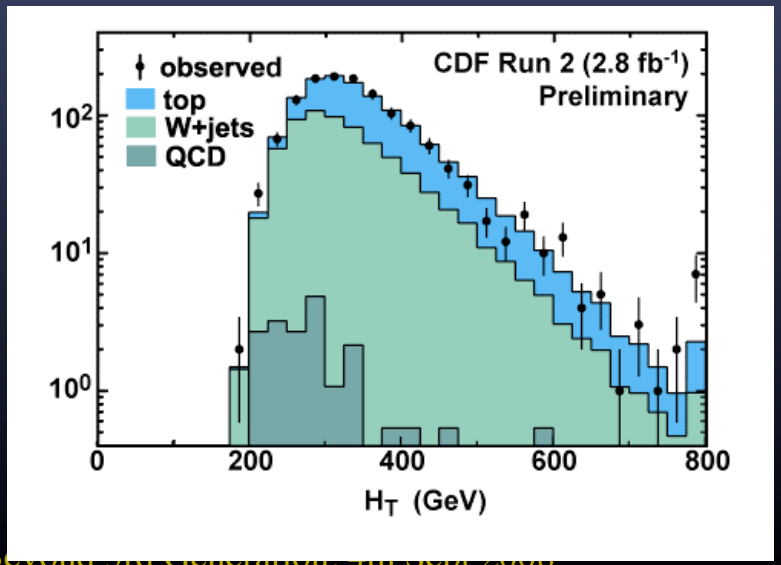
H_T and M_{rec} Projections

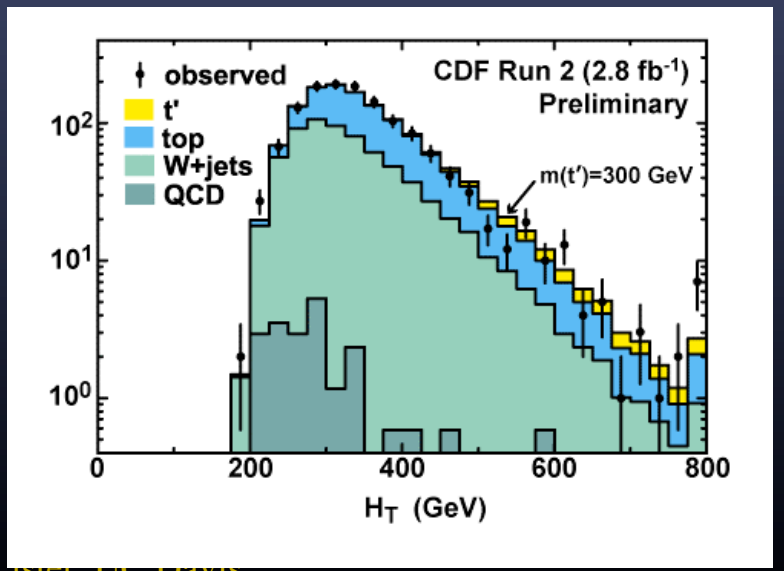
Zero Signal fit



Fit with t' at limit

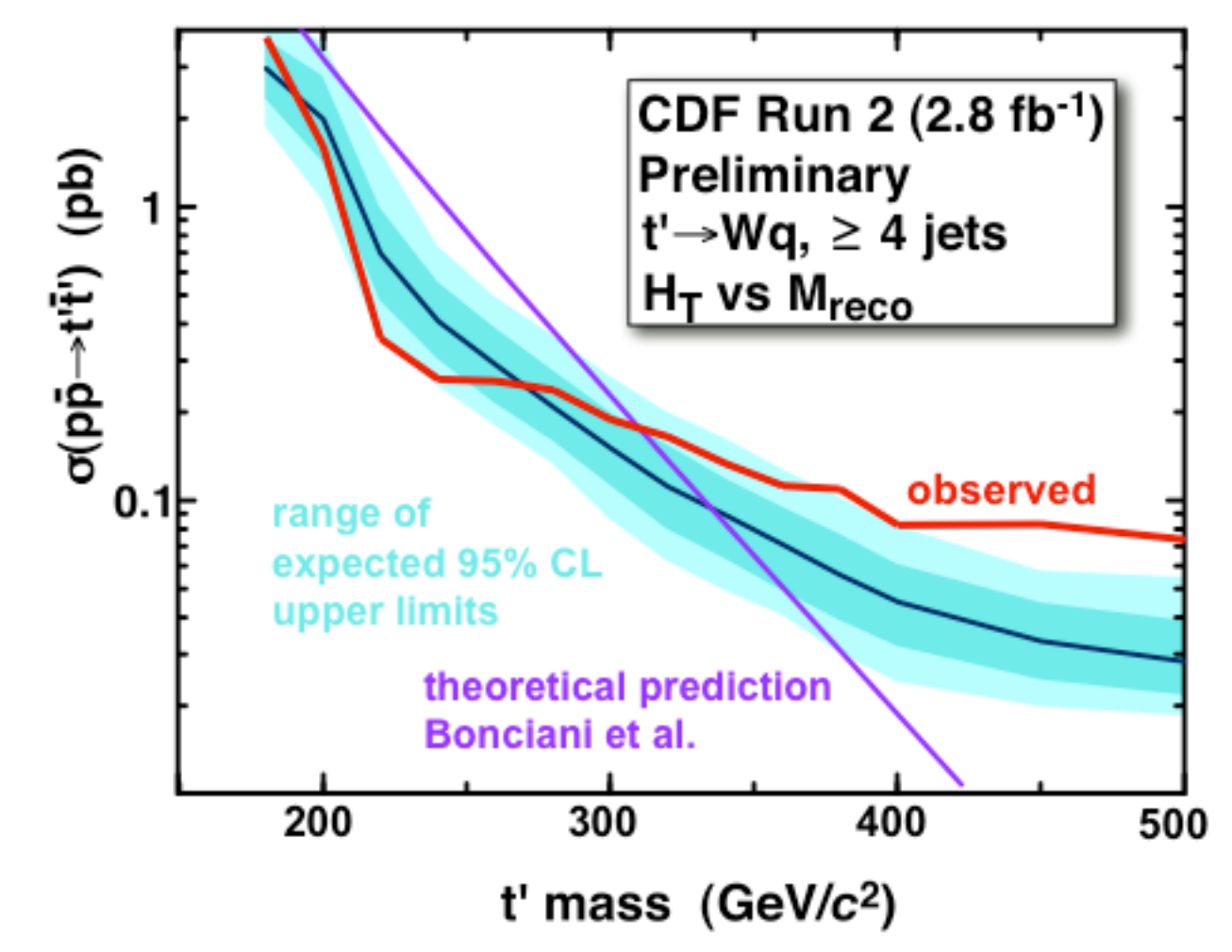






Expected and Observed Limits

Exclude at 95% CL t′ mass below 311 GeV/c^2



Is there a signal of some new possibly non-t' signal at high H_T and high M_{rec}?

- In bins of 25 GeV x 25 GeV/c^2
- Start with the upper-right 1x1 bin, then 2x2, then 3x3, ... up to 15x15
  - Calculate number of events and background
  - Get the significance
- Find the choice with the greatest significance: 10x10
- Use MC pseudo-experiments to find the p-value for seeing that great a significance in 1 bin
  - Accounts for the trials factor
  - Global p-value
  - Sigma significance
  - In 2.3 fb^{-1} lowest p-value 0.089
    - 1.9 sigma

n	Min M_{rec} [GeV/c^2]	Min H_T [GeV]	observed	expected	p-value
1	475	775	0	0.021	1.000
2	450	750	0	0.116	1.000
3	425	725	1	0.228	0.2040
4	400	700	2	0.371	0.0540
5	375	675	3	0.718	0.0364
6	350	650	4	1.503	0.0660
7	325	625	4	2.876	0.3251
8	300	600	12	5.498	0.0110
9	275	575	14	9.885	0.1273
10	250	550	29	18.03	0.0105
11	225	525	41	31.34	0.0555
12	200	500	58	52.05	0.2219
13	175	475	92	91.14	0.4779
14	150	450	152	158.7	0.7141
15	125	425	222	231.0	0.7318

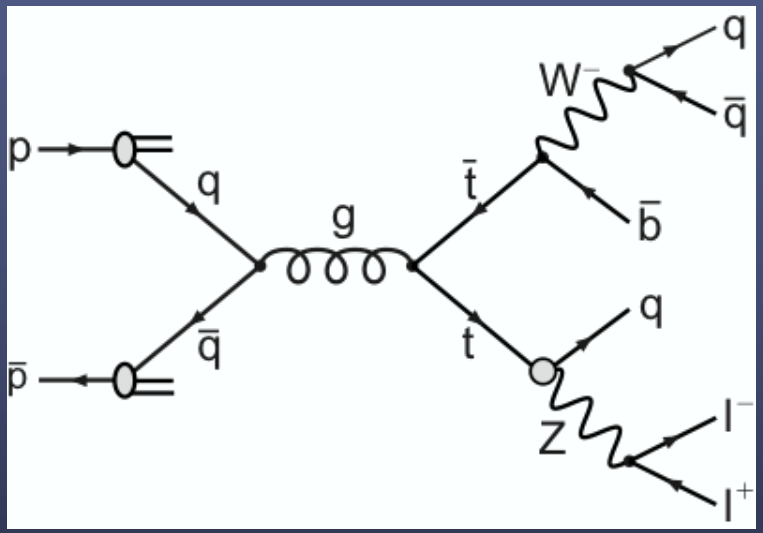
Unfortunately we didn't find any significant excess!

FCNC in tt Production
Search for t→Zq
in 1.9 fb^{-1}

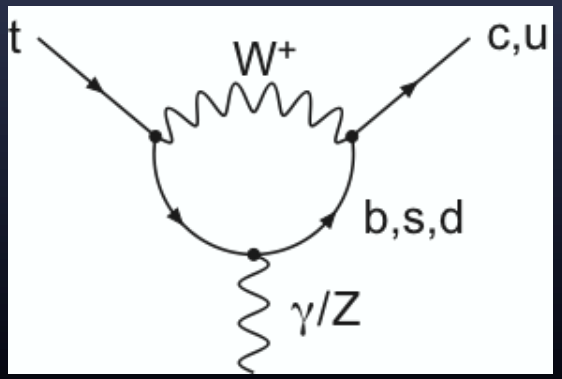
Top Flavor Changing Neutral Currents

- No Flavor Changing Neutral Current (FCNC) interactions at tree level in the Standard Model
- Further suppression: GIM mechanism, CKM suppression
- Top FCNC extremely rare: $B(t \rightarrow Zq) = O(10^{-14})$
- Beyond SM models predict higher branching fractions, up to $O(10^{-4})$
- Best published limit on $B(t \rightarrow Zq)$: 13.7%, from non-observation of $e^+e^- \rightarrow tq$ at LEP (L3)
- Any signal at the Tevatron: New Physics

Top FCNC Decay: Z + 4 Jets



Top FCNC Decay via Penguin Diagram



Measurement

- Signature: Z + 4 Jets,
- Standard Model backgrounds
  - Dominant background: Z+Jets production
  - Smaller backgrounds: tt and diboson (WZ, ZZ) production

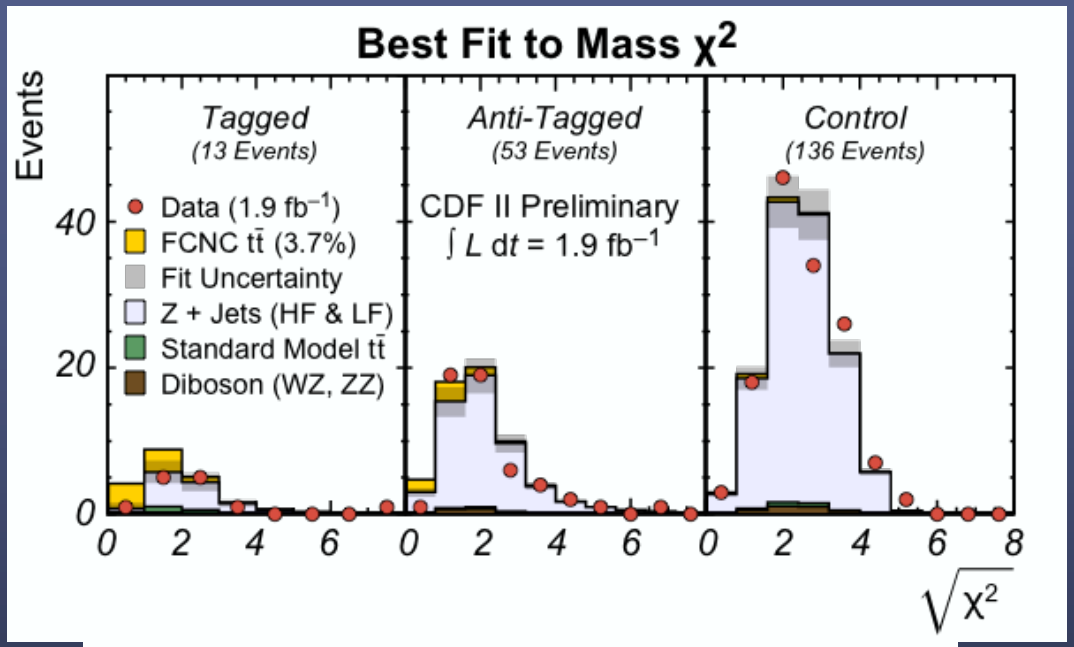
$$t\bar{t} \rightarrow Zq\,Wb \rightarrow \ell^+\ell^- q\,q'\bar{q}''b$$

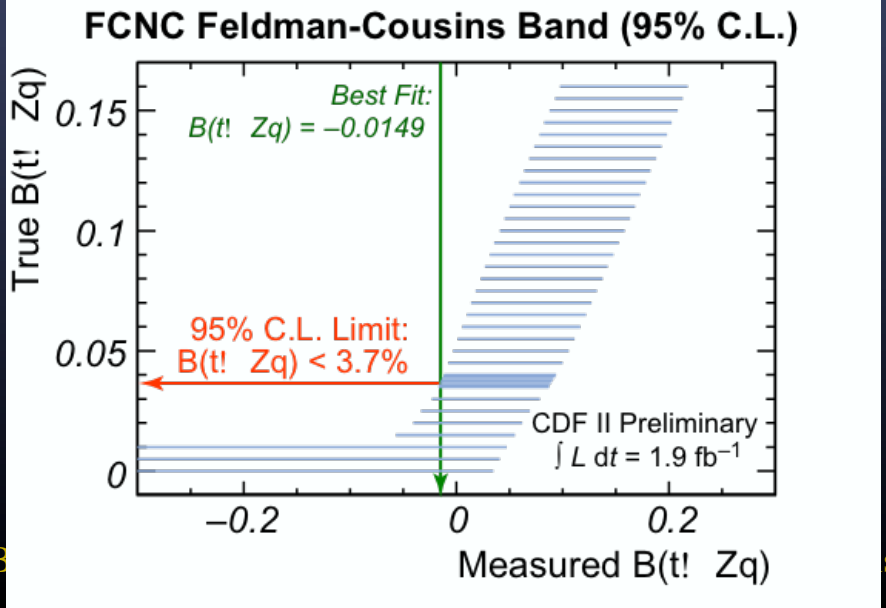
- Summer 2007: first preliminary CDF Run II result with 1.1 fb^{-1}
  - Blind counting experiment: needed absolute background predictions
  - Full event kinematics reconstructed: mass χ^2 variable using W decay, standard model top decay, and FCNC top decay

$$\chi^2 = \left(\frac{m_{W,\mathrm{rec}} - m_W}{\sigma_W}\right)^2 + \left(\frac{m_{t\rightarrow Wb,\mathrm{rec}} - m_t}{\sigma_{t\rightarrow Wb}}\right)^2 + \left(\frac{m_{t\rightarrow Zq,\mathrm{rec}} - m_t}{\sigma_{t\rightarrow Zq}}\right)^2$$

- Winter 2008 update with 1.9 fb^{-1}: exploit full shape of mass χ^2
  - Same event selection and systematic rate uncertainties
  - Systematic shape uncertainties controlled via “template morphing”

Results





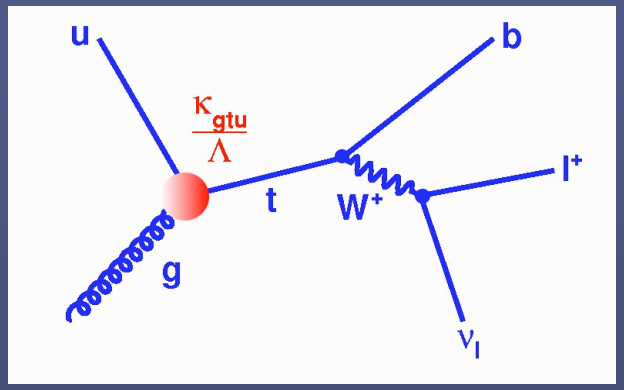
- Limit on B(t→Zq) obtained from template fit to mass χ^2 distribution
  - Simultaneous fit to two signal regions and one control region
  - Feldman-Cousins limit with systematic uncertainties
- New world's best limit:

B(t→Zq) < 3.7% (95% C.L.)

- Best published limit (13.7%) improved by factor of 3.5

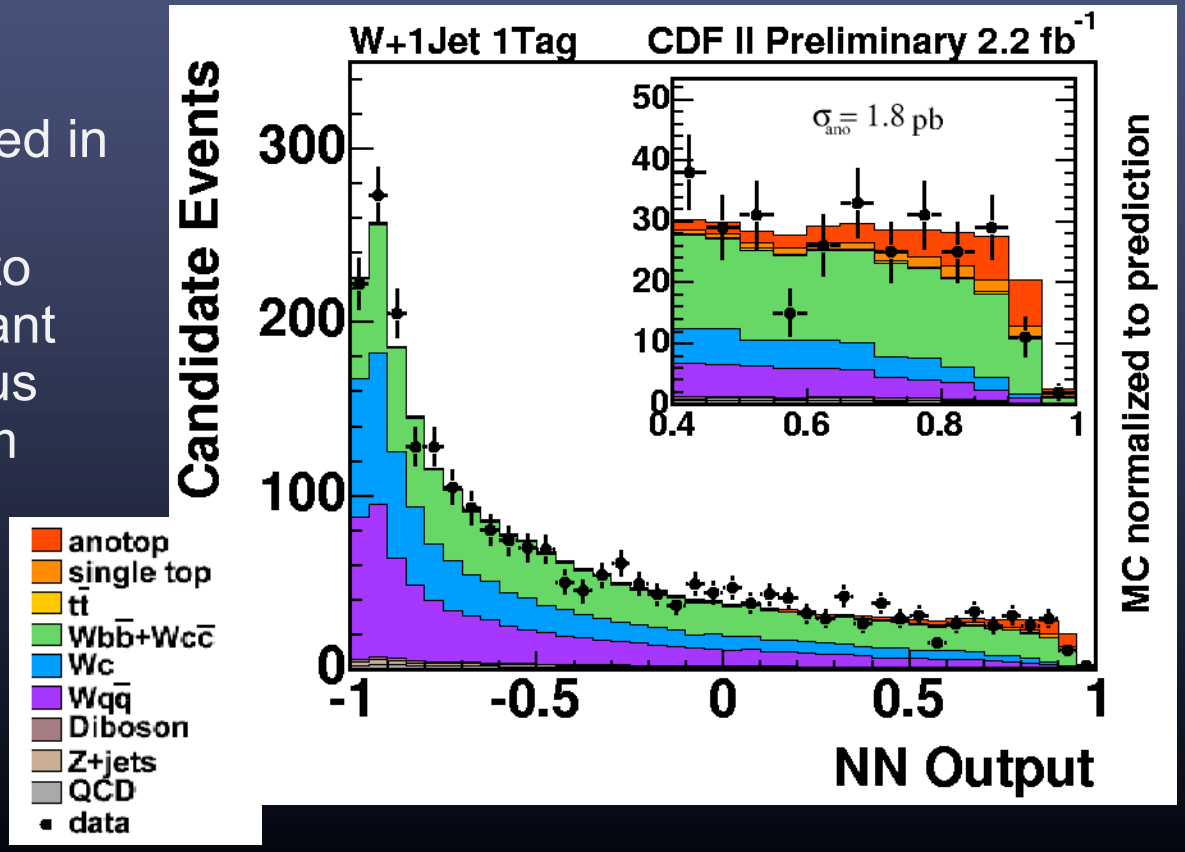
FCNC in Single Top Production: u(c)+g→t Using Neural Networks in 2.2 fb^{-1}

Measurement

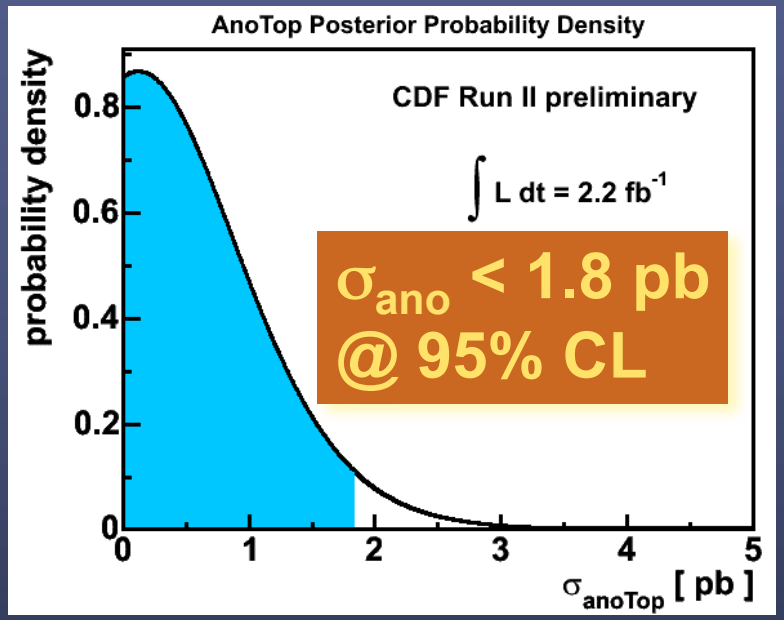


- Search for anomalous production of single top
- If measure anything: sign of new physics

- Similar method as used in single top NN search
- Use Neural Network to construct a discriminant to separate anomalous single top events from backgrounds

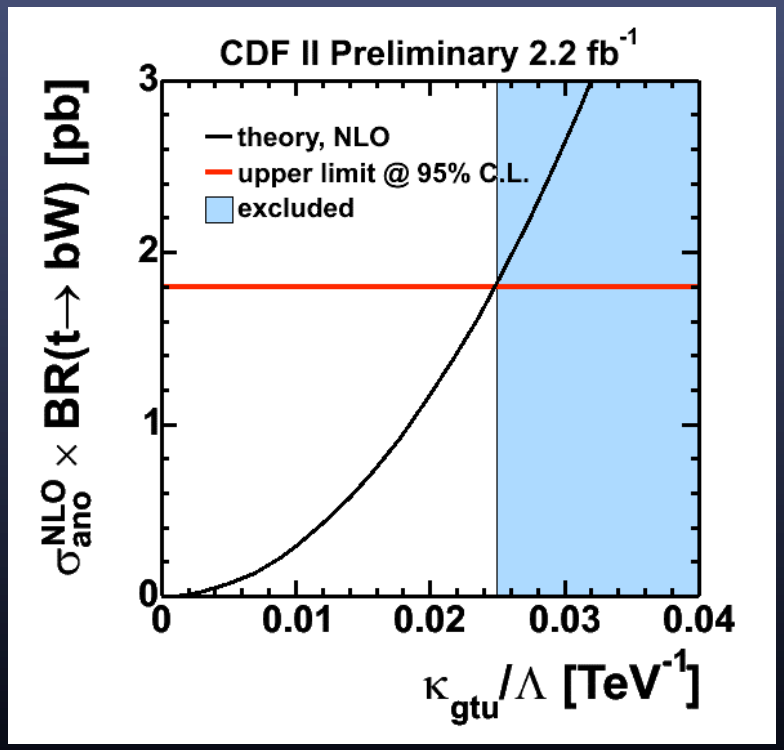


Results



- No sign of anomalous production of single top is found
- Limit placed on anomalous production

- Can also place limits as a function of the anomalous coupling
  - NLO calculation



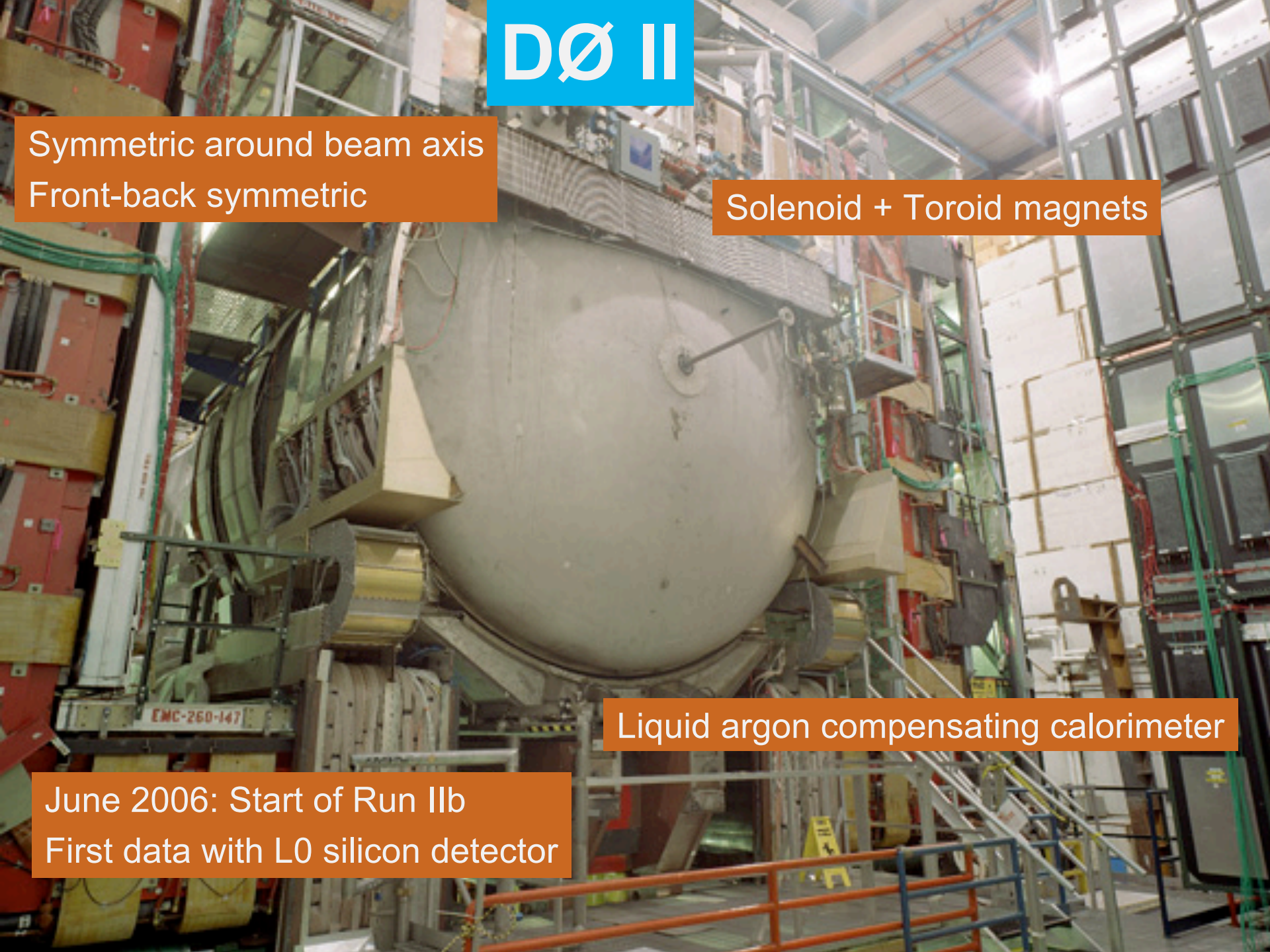
$\kappa_{gtu} / \Lambda < 0.025$ TeV^{-1}
$\kappa_{gtc} / \Lambda < 0.105$ TeV^{-1}

Conclusions

- t´ search
  - Limits now above 300 GeV/c^2 assuming 100% BR to Wq
  - Improvements forseen
    - Use of NN to increase sensitivity: additional variables
    - Inclusion of dilepton channel to add sensitivity
    - Use of heavy flavour tagging to investigate explicitly t´→Wb
  - Interesting (but not significant) features appearing at high mass but not compatible with strong production of t´
    - Could still be detector effects….
- FCNC in tt
  - Limit in the few percent level
  - No signs of new physics
- FCNC in single top production
  - Cross-section of new physics must be below 1.8 pb

Keep your ears and eyes open for more Tevatron results in next couple of years!

Backup Slides


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