Search for Heavy Top-like Quarks Using Lepton + Jets Events at CDF

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On behalf of the CDF collaboration

Outline

- Theoretical Motivation
- Analysis Method
- Results
- Conclusions

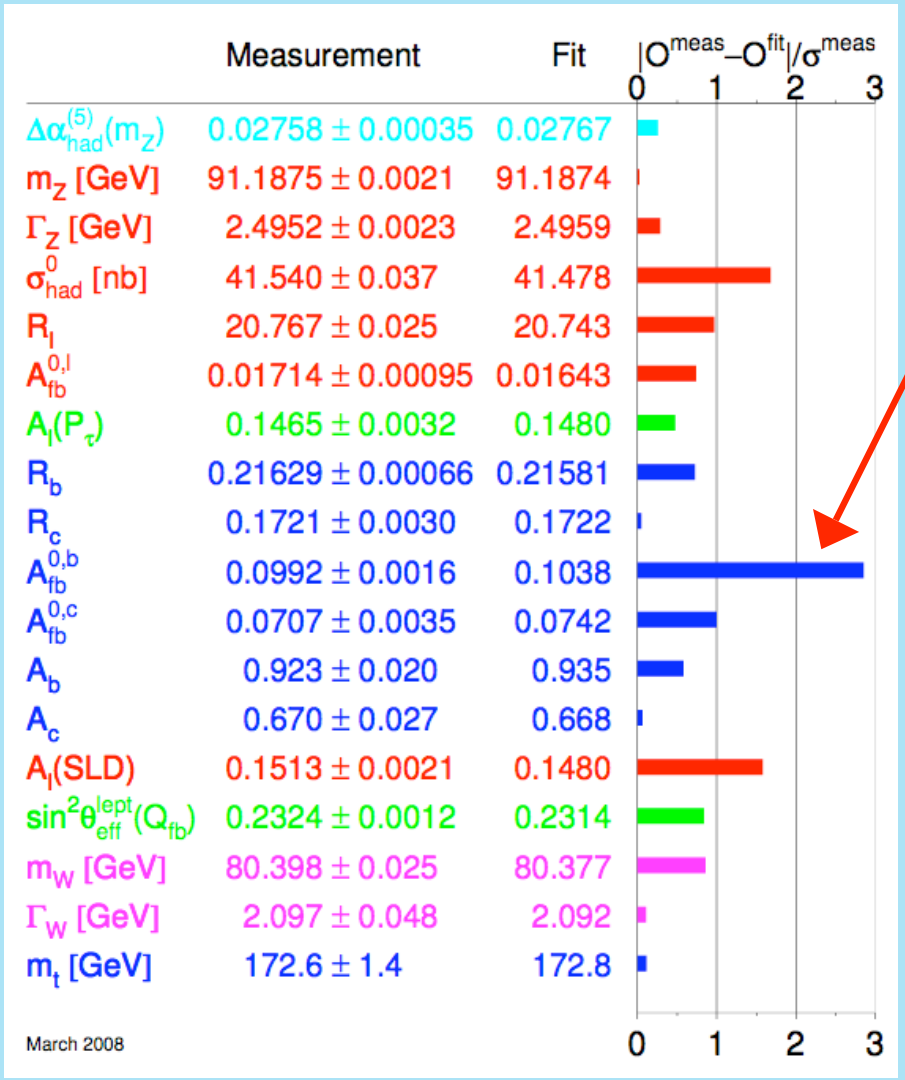
Theoretical Motivation

- Possible 4-th generation quark with mass of few hundreds GeV
  - Consistent with EWK data
  - Oblique corrections drive Higgs Mass to ~ 500 GeV
    - C.He et al, Phys.Rev. D64 (2001) 053004
  - Almost degenerate b´ and t´ masses: M(t´) - M(b´) < M(W)
  - Decays as top: t´ -> Wq (q=d,c,b)

- Heavy top-like quark appears in many theories
- Usually too heavy for Tevatron
  - e. g. Little Higgs (heavy Top with mass ~1-2 TeV)
    - M. Perelstein et al., Phys.Rev. D69 (2004) 075002
    - G. Azuelos et al., Eur.Phys.J. C39S2 (2005) 13-24

- New mirror quarks with not necessarily same properties as first three generations
  - “Beautiful Mirrors”: new heavy quarks decaying into Wb
  - Motivated by data
  - D. Choudhury et al., Phys.Rev. D65 (2002) 053002

EWK Precision Data



- Discrepancy with the SM!
- A_{fb}^{b} - b-quark forward-backward asymmetry

  ~2.9 σ away (LEP)
- As a result:

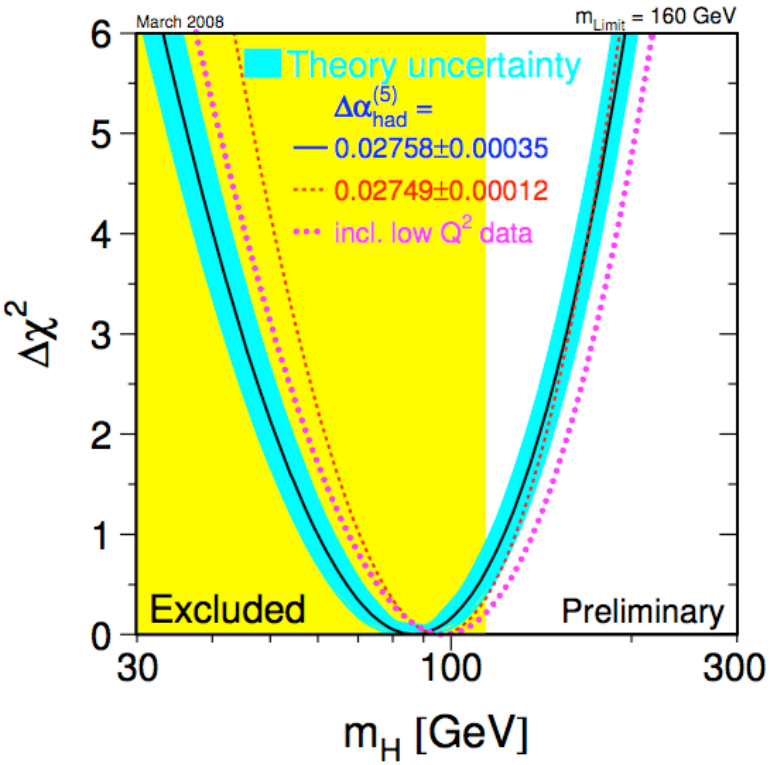
  $\sin\theta_{W,\,lep}$ is ~3.6 σ away from $\sin\theta_{W,\,had}$
- Suppose A_{fb}^{b} measurement has larger uncertainty or systematically off, and we force:

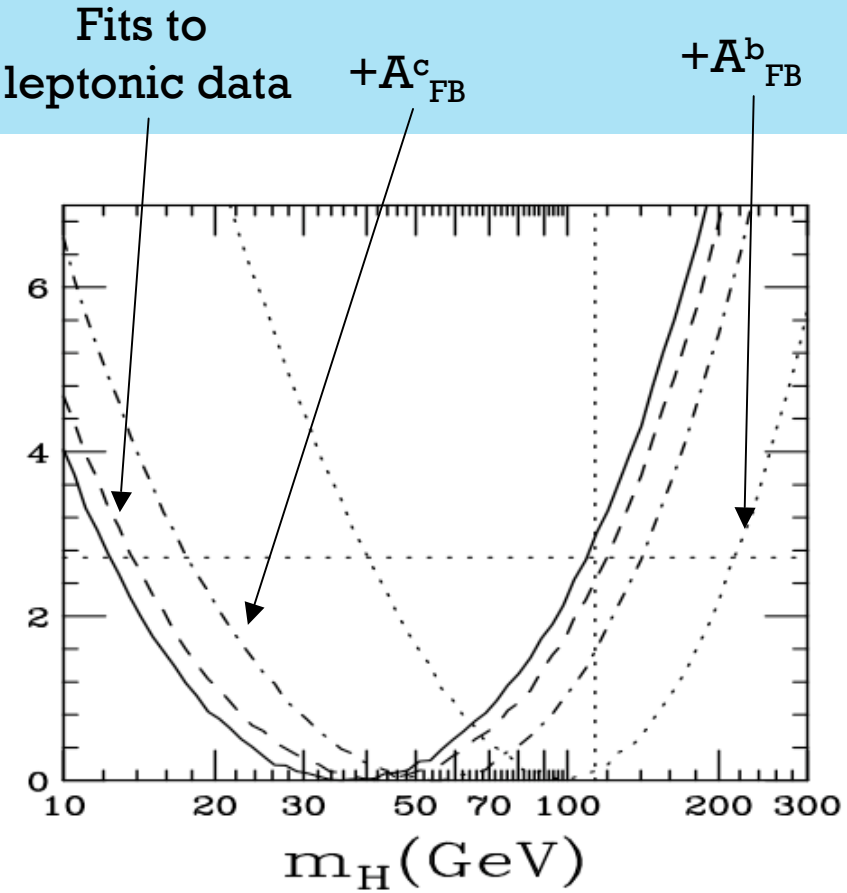
  $$\sin\theta_{W,\,had} = \sin\theta_{W\ ,\,lep}$$

Higgs Mass Fit

With $\sin\theta_W$ value averaged over leptonic and hadronic measurements

M. Chanowitz, Phys.Rev.Lett. 87 (2001) 231802



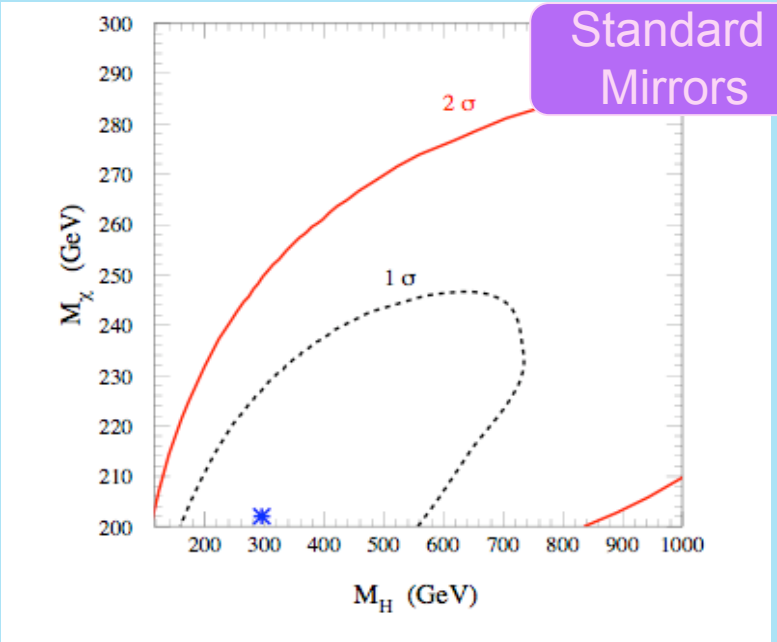


Without hadronic A_{fb}: Should already have seen Higgs

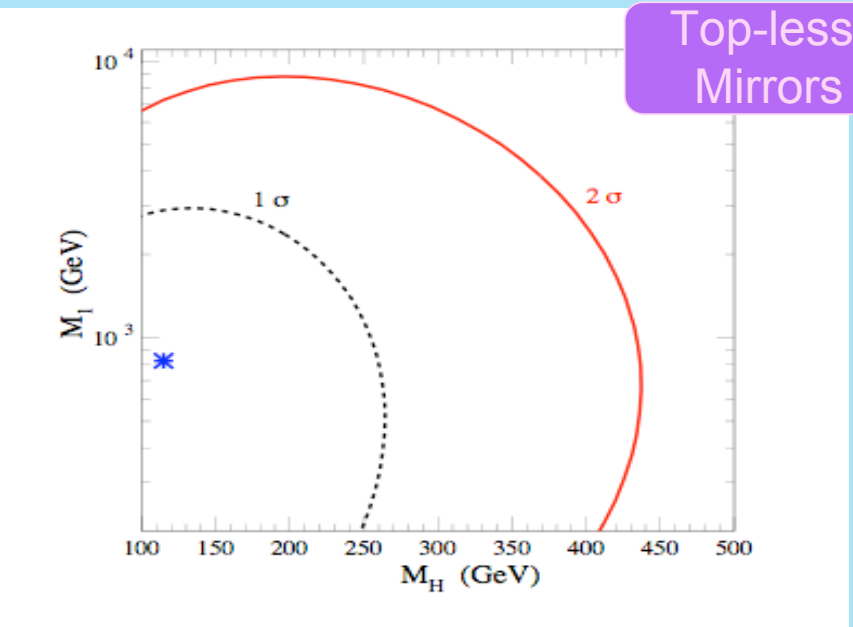
Adding all constraints: Leads to higher expected Higgs mass

Beautiful mirror quarks

- New physics in Z->bb? Different coupling of the b-quark to Z?
  - C. Wagner et al, Phys.Rev. D65 (2002) 053002
- Mirror quarks of b-quarks improve the fit
  - couple to b's and less to d's or c's
- Two scenarios: with and without top mirror quarks



Perfect for Tevatron searches

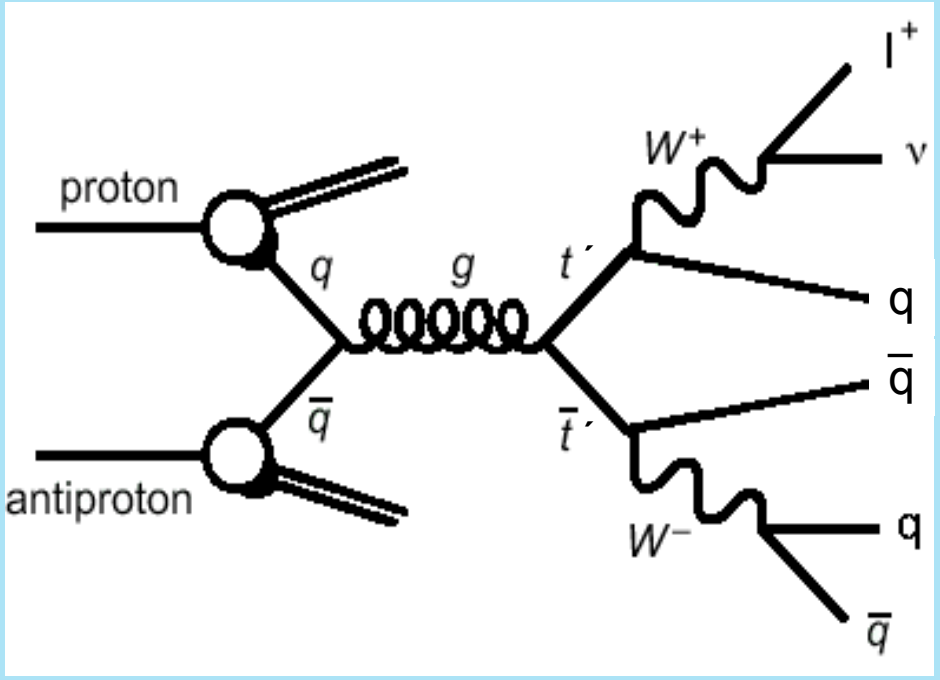


Might have to wait for LHC

This Search

- Assume t´ pair production with strong SM couplings
- Search for new quark decays into Wq: t´ -> 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)
- Missing E_T > 20 GeV
- QCD removal
  - E_T leading jet > 60 GeV



Analysis Methodology

- Binned likelihood fit of the data to H_T vs M_{rec} distributions
- H_T is the total transverse energy of the event

$$H_T = \sum_{jets} E_{T,jets} + E_{T,lepton} + \not{E}_T$$

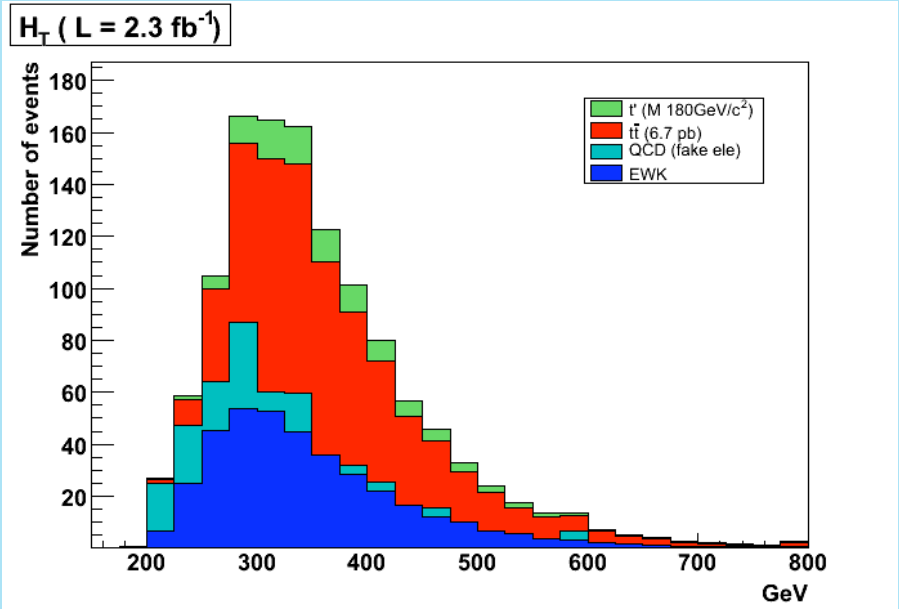
- M_{rec} is the reconstructed mass of the top quark (using width of the top)
  - Use χ^2 function to choose combination of event objects that best fits top decay

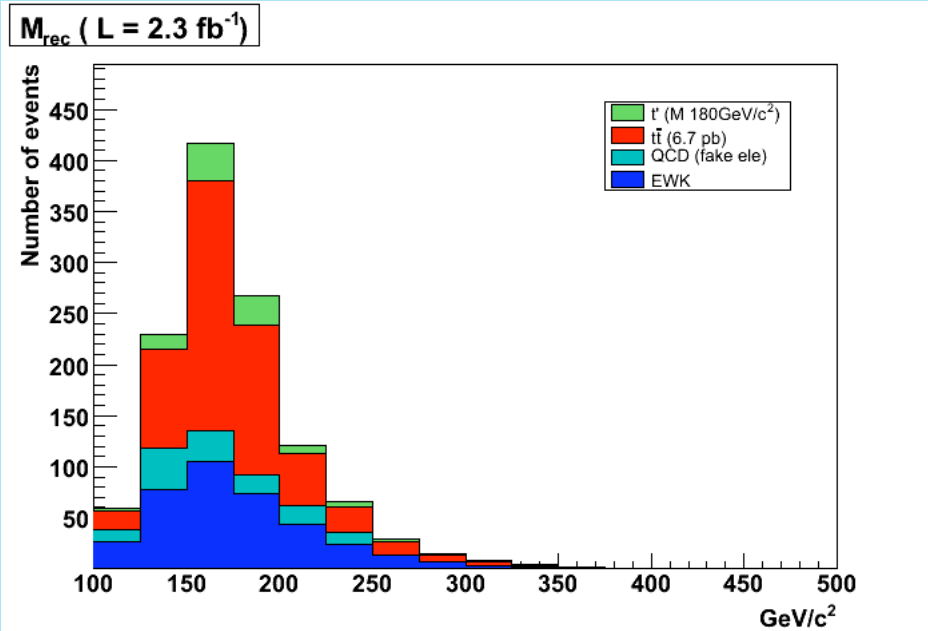
Parameters of the fit

- t'
  - Varies freely
- Top
  - Constrained to SM cross-section
- EWK
  - Varies freely
- QCD
  - Constrained by fit to missing E_T

H_T and M_{rec}

- Distributions with expected number of SM background events
- Constant number of t' events added
  - t' masses 180-500 GeV





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

Handling Systematics

$$\mathcal{L}(\sigma_{t'}|n_i) = \prod_{i,k} P(n_i|\mu_i) \times G(\nu_k|\tilde{\nu}_k, \sigma_{\nu_k})$$

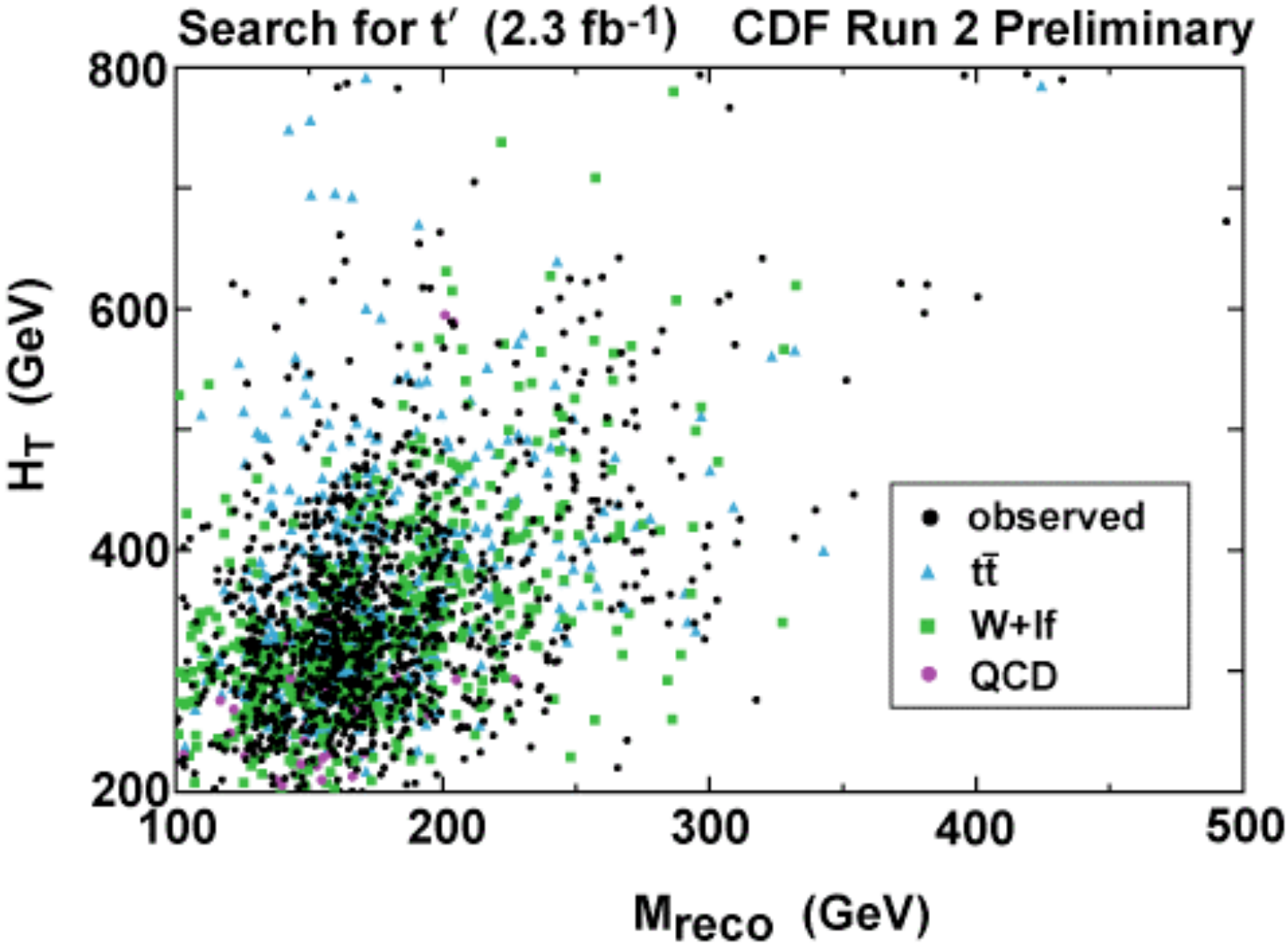
Nuisance parameters

- Effects evaluated based on measuring how the $\sigma_{t'}$ changes given t´ exists
- The shifts measured by drawing "pseudo-experiments" from shifted templates and fitted to nominal

Systematics

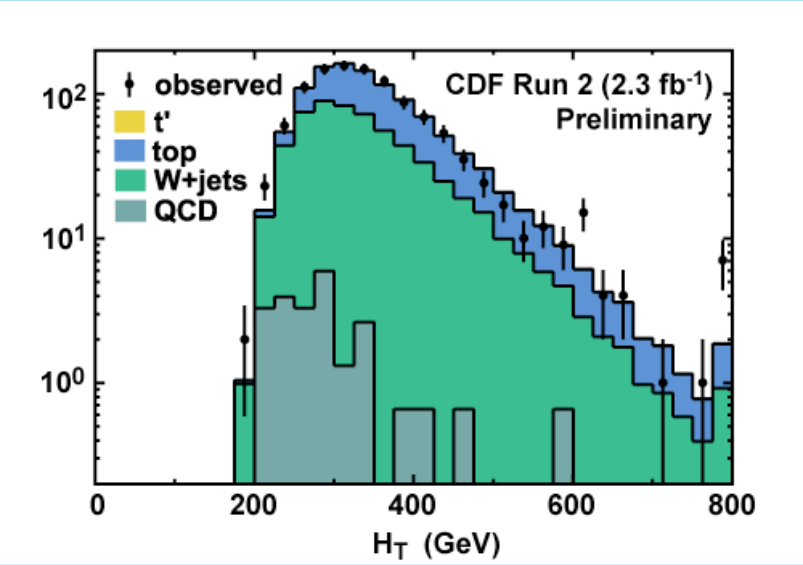
- Q^2 scale for EWK backgrounds
- Jet Energy Scale
- Luminosity
- Theory uncertainty on top and t' cross-sections
- ISR + FSR
- PDFs
- Trigger Efficiencies
- Lepton ID /efficiencies / data vs MC

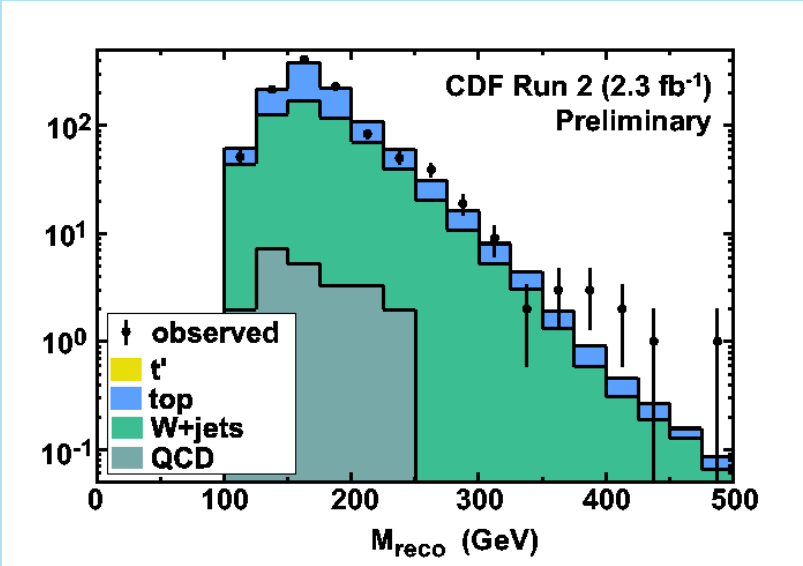
Data: H_T vs M_{rec}



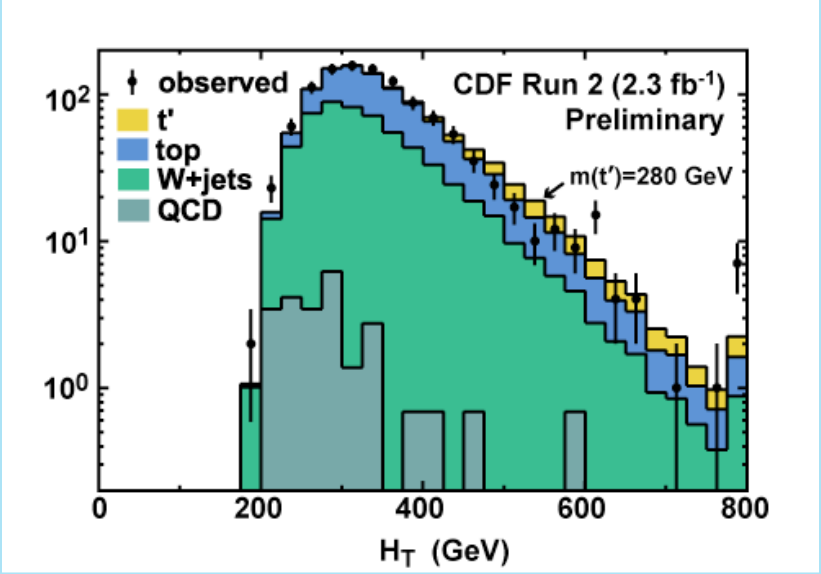
H_T and M_{rec} Projections

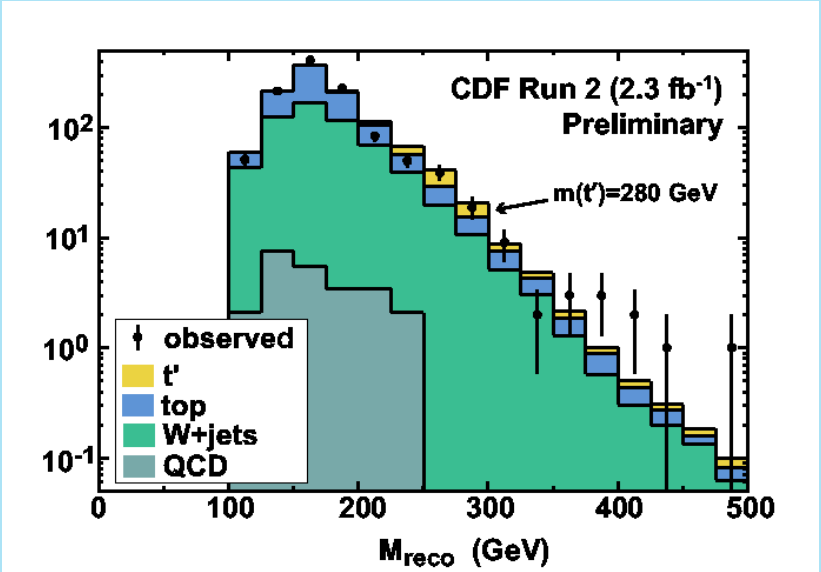
No Signal fit





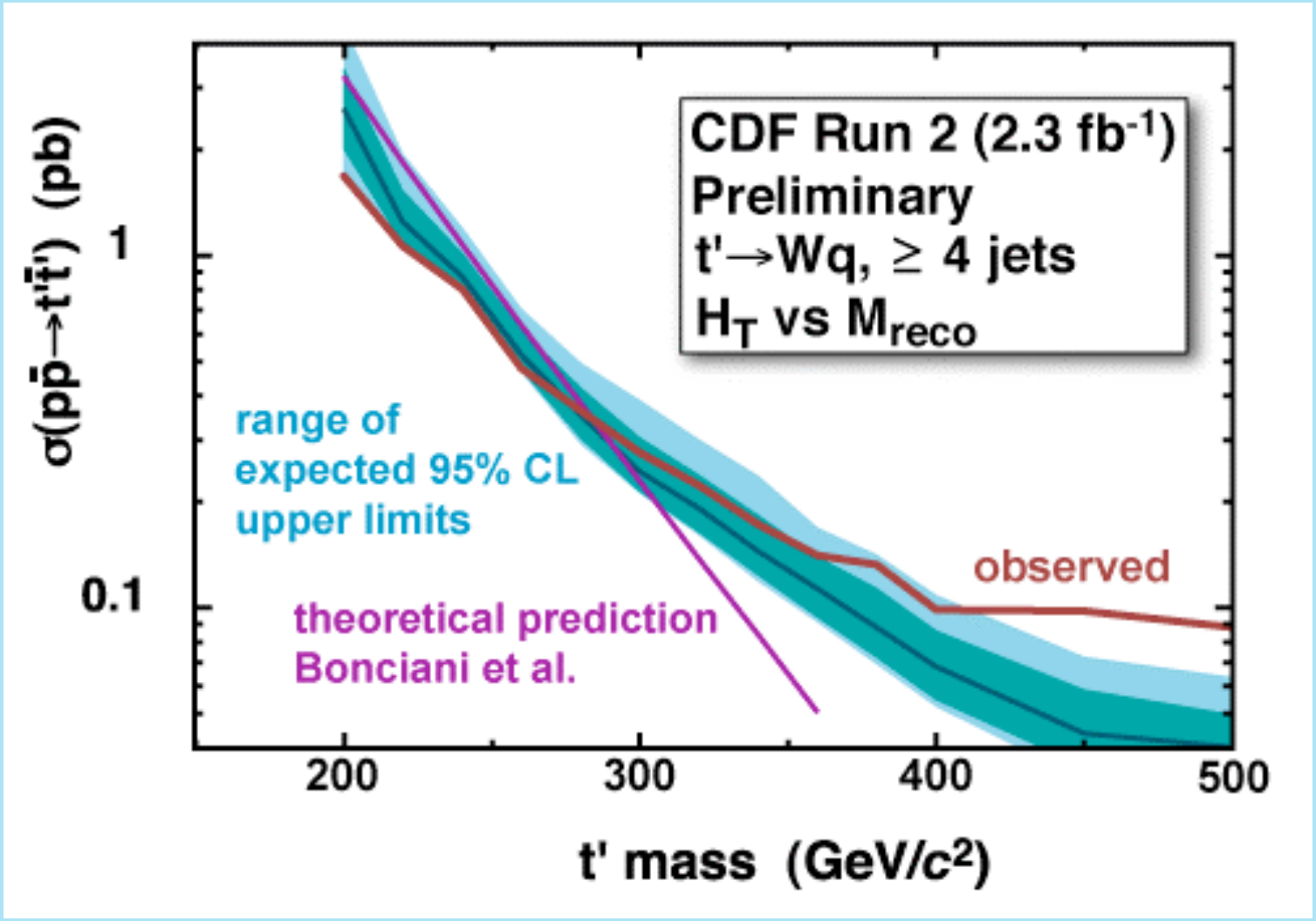
Fit with t' at limit





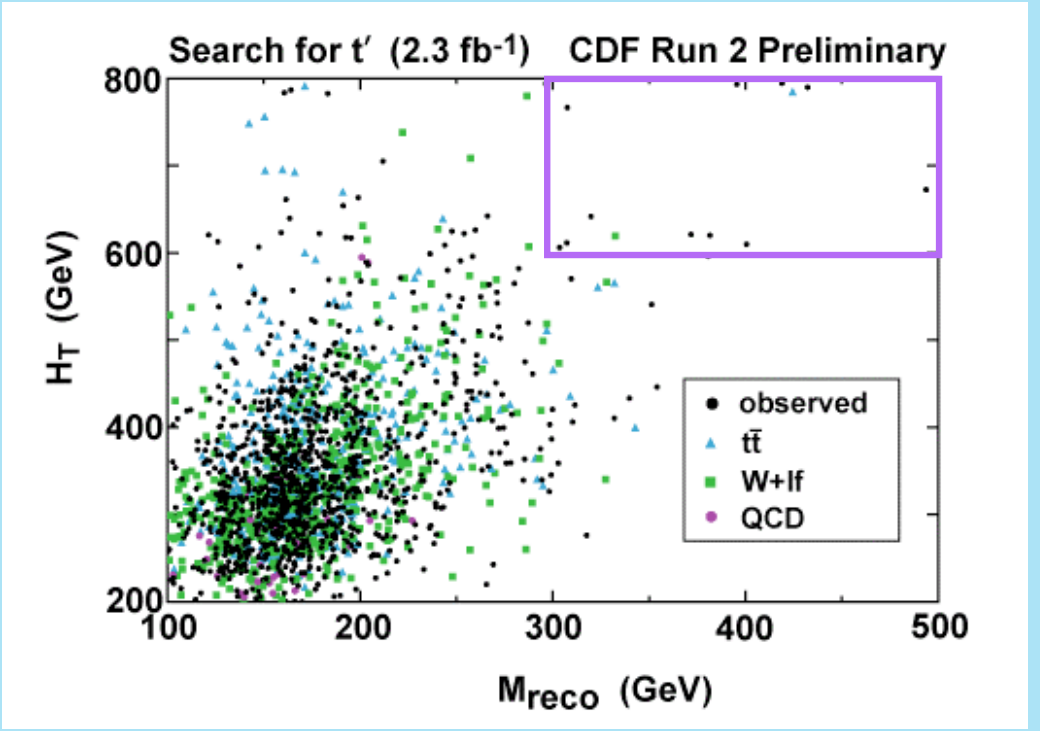
Expected and Observed Limits

Exclude with 95% CL t′ mass below 284 GeV/c^2



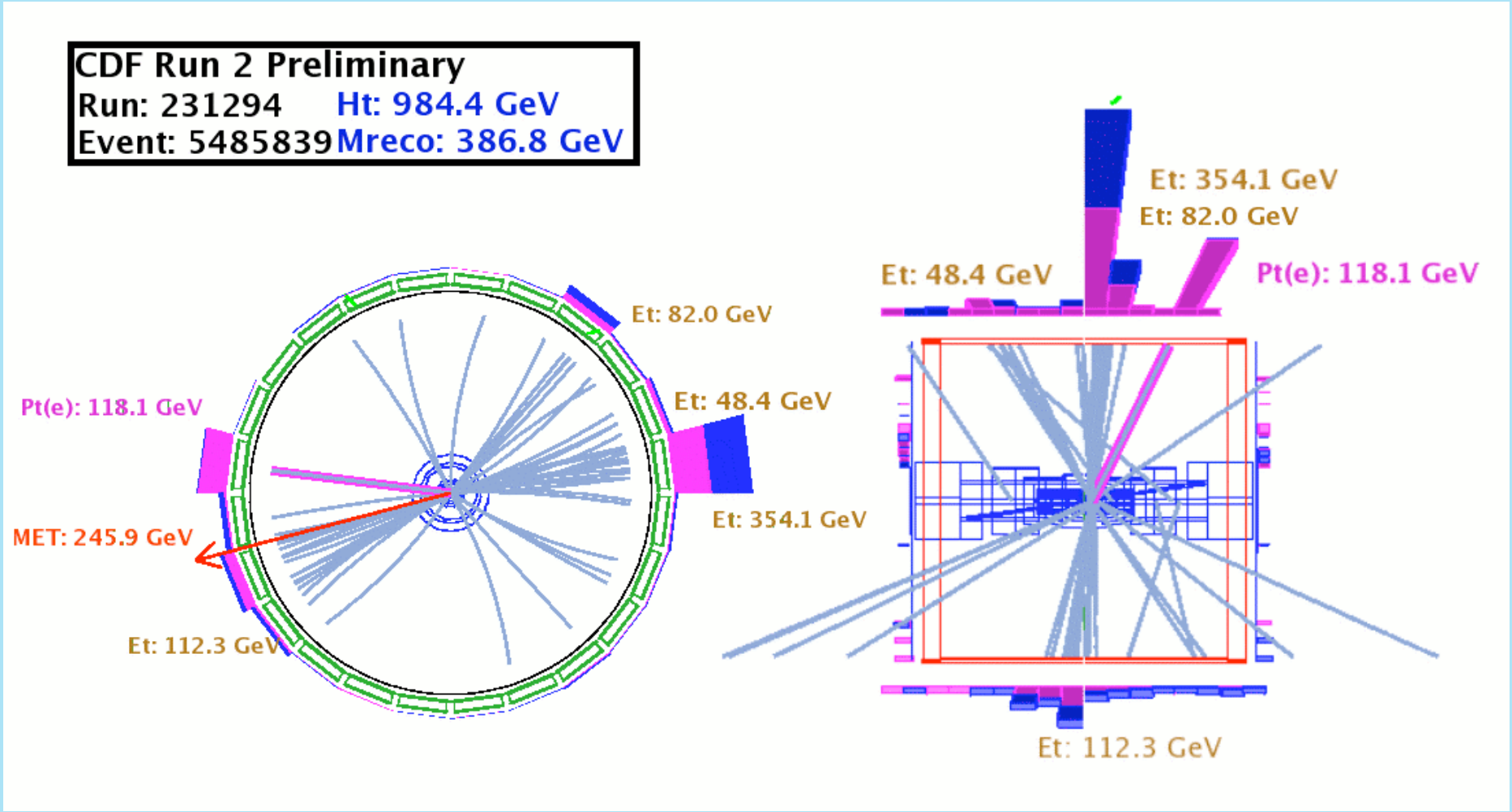
Is there a sign of some new physics at high H_T and high M_{rec}?

- 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: 8x8
  - Observe 11
  - Expect 4.7
  - p-value 0.0089
- 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 2.8%
  - Sigma ~1.9



No significant excess observed

Event Display



Conclusions

- Search for massive fourth generation up-type quarks
- Likelihood fit to 2D distribution
  - Total transverse energy of the event
  - Reconstructed mass of the top-like object
- Exclude t' masses up to 284 GeV/c^2
- Sensitive to excess data in the tails of the distribution
- No significant excess observed
- More details

  http://www-cdf.fnal.gov/physics/new/top/2008/tprop/Tprime2.3/public.html