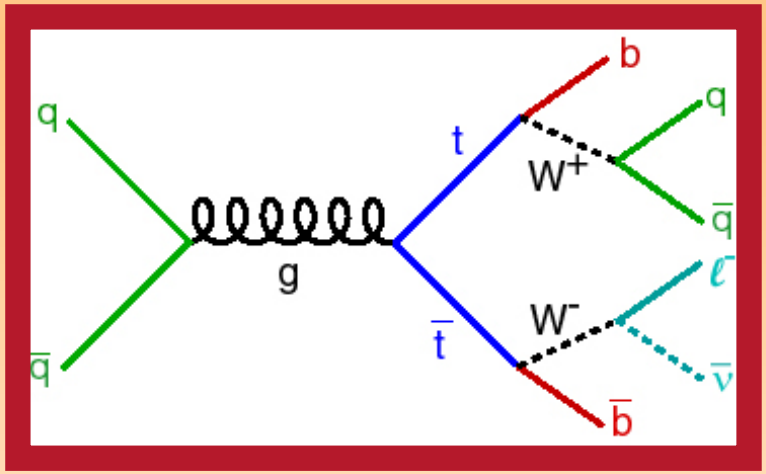
What Should be Understood about Top?

Robin D. Erbacher

University of California, Davis



*Experimental Summary of **Top @ Tevatron 4 LHC** Workshop*
Held November 21, 2009 at UC Davis

Top @ Tevatron 4 LHC

Date:	Nov. 20-21, 2009
Location:	University of California Davis
Building:	Alumni Center, UC Davis

Abstract:

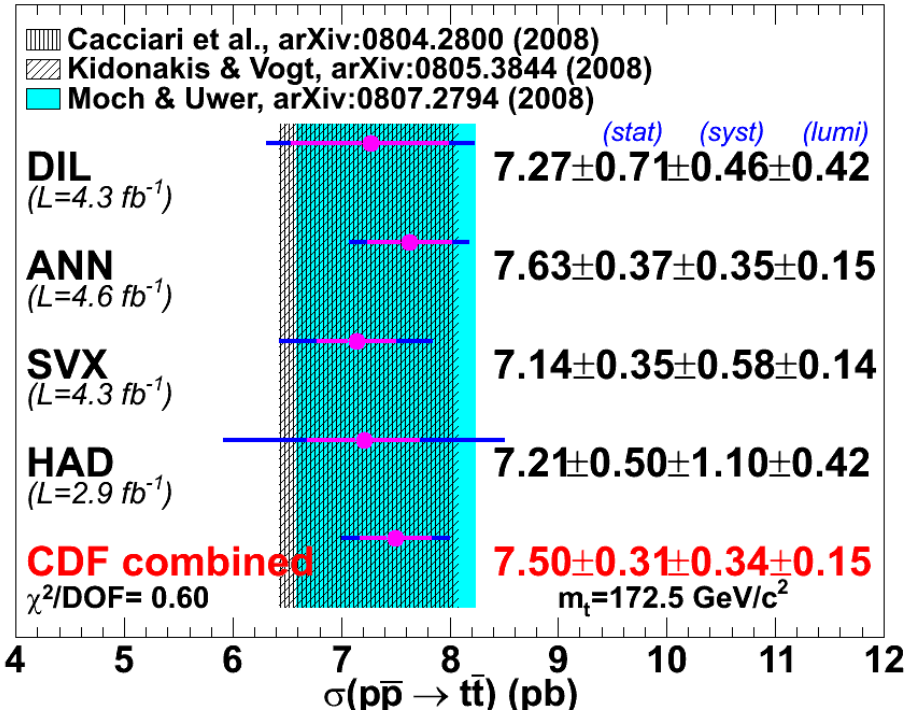
Abstract: As the LHC ramps up, the Tevatron will have high-precision data on the top quark with sensitivity to new physics at the TeV scale. With the LHC ramping up, this workshop will assess whether there are opportunities for top-related physics at the Tevatron that have not been utilized. Main topics: top-related new physics searches at the Tevatron; the possible anomaly in the top forward-backward asymmetry; and boosted top/jet substructure at the Tevatron. The workshop will have approximately equal number of theorists and experimentalists, and the format is informal with lots of time for discussion.

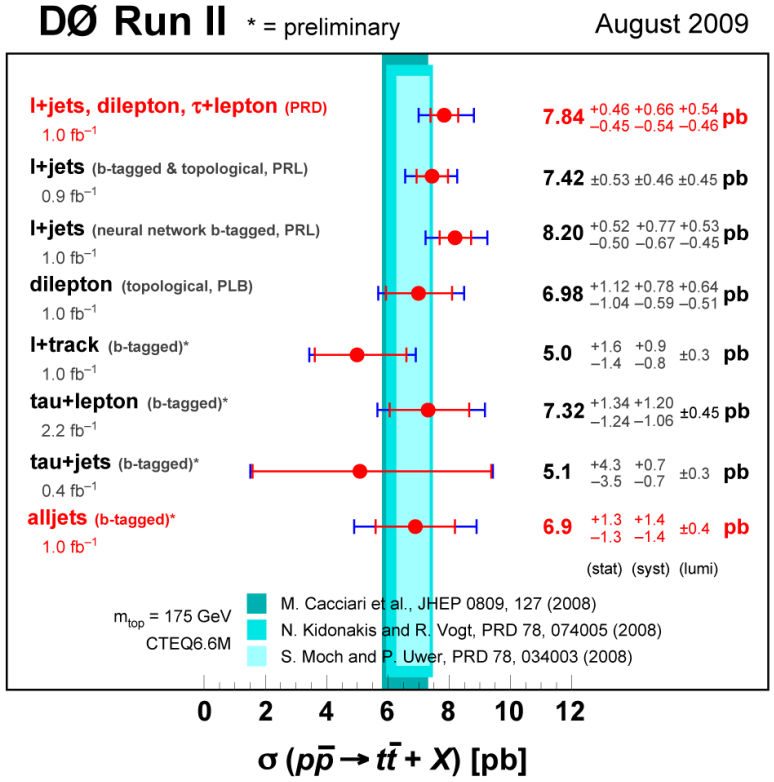
http://particle.physics.ucdavis.edu/workshops/doku.php?id=2009:topattevatron


Tevatron Questions
Tom Schwarz
Top@Tevatron 4 LHC
UCDAVIS
UNIVERSITY OF CALIFORNIA

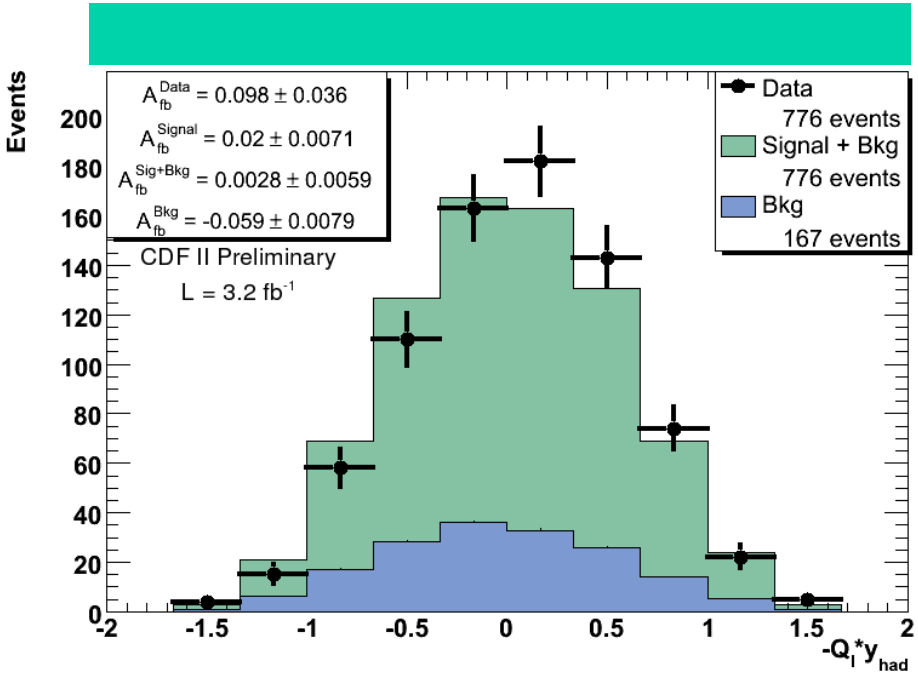
Are we exhausting our phase space at the Tevatron?

The cold water...X-Section

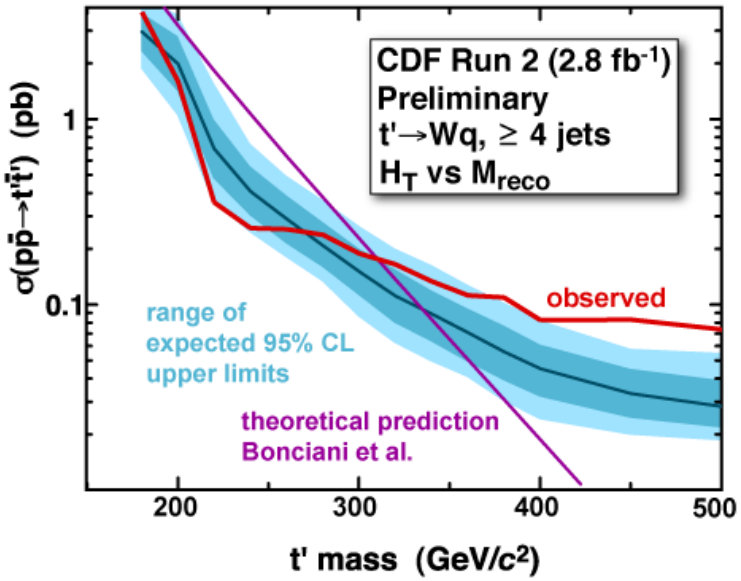


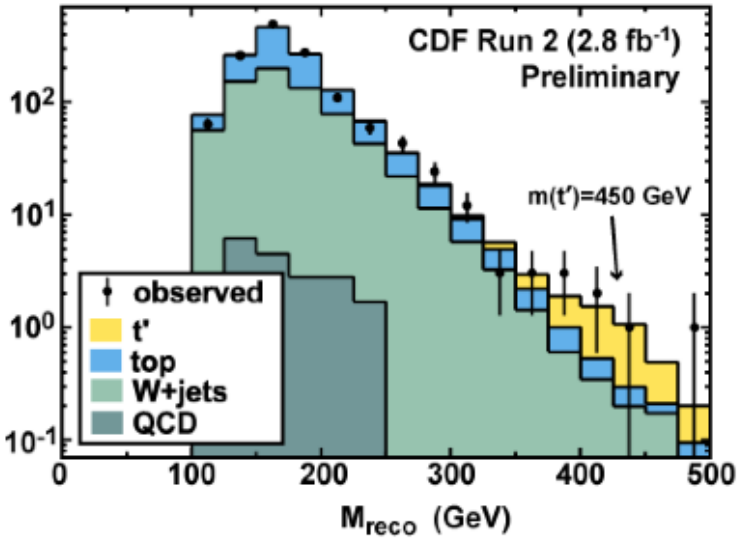


t-tbar A_{fb}

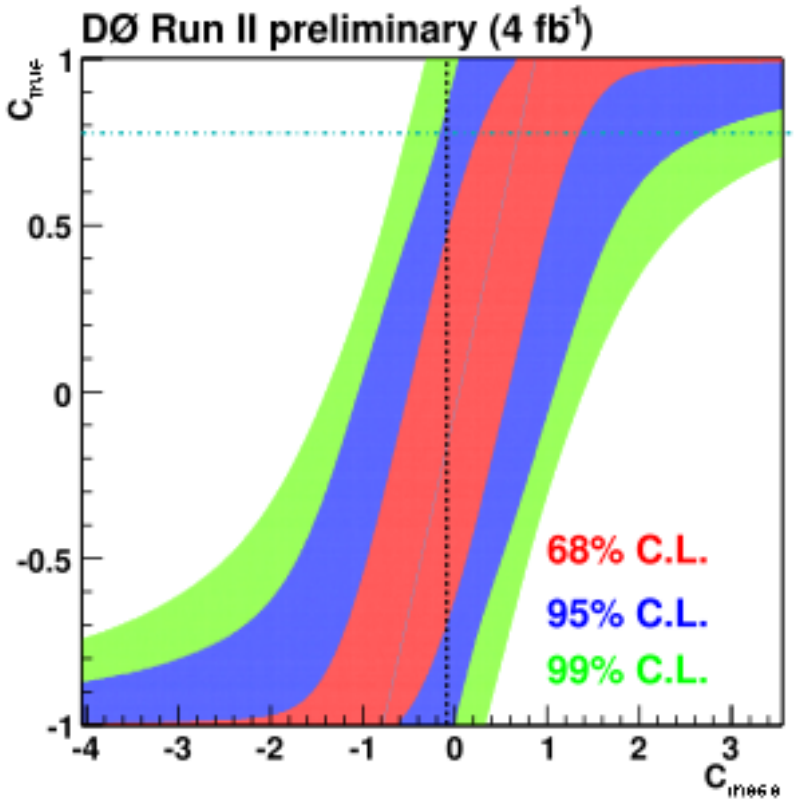


t' Search

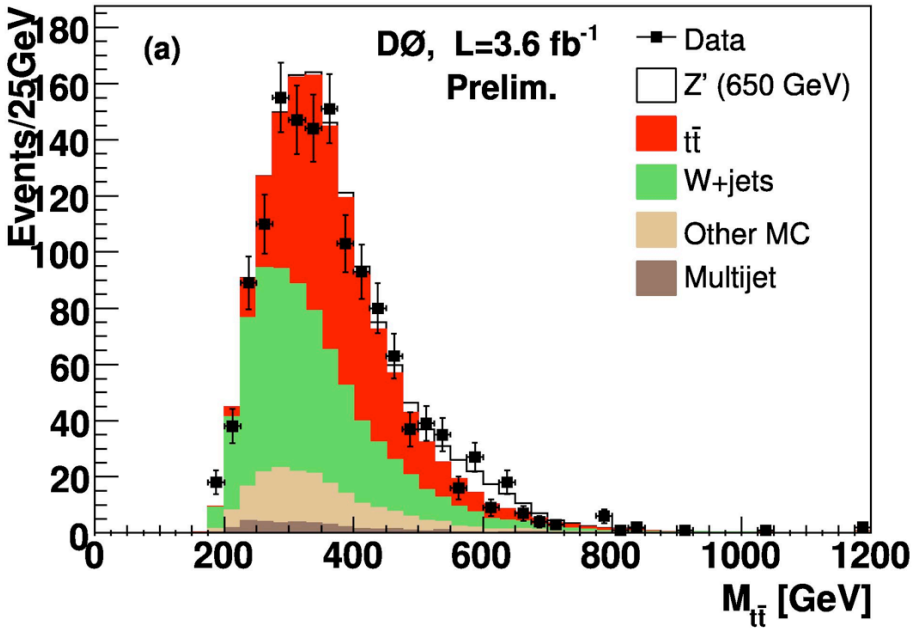


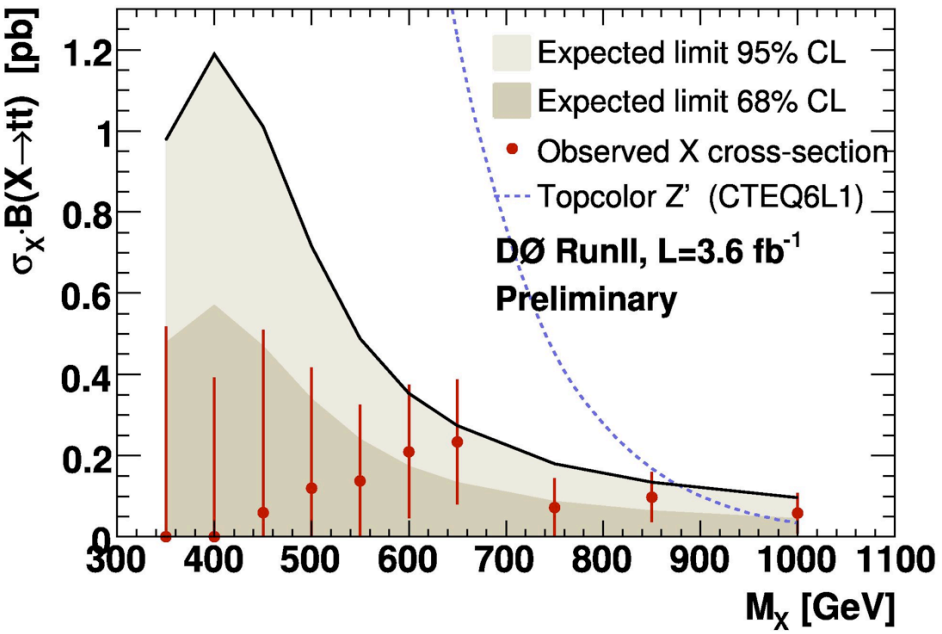


Spin Correlations

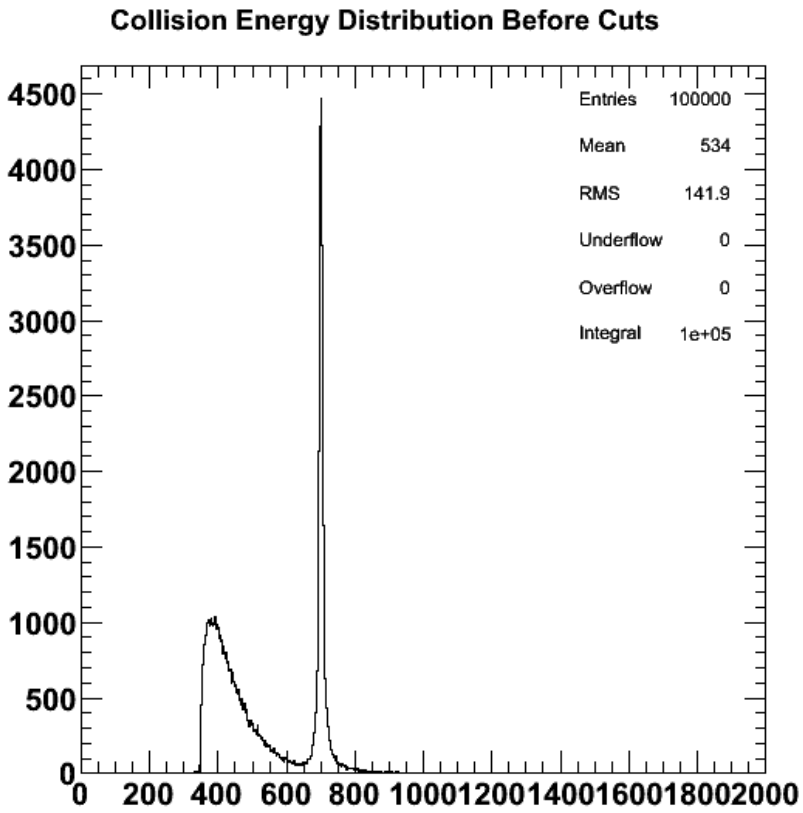


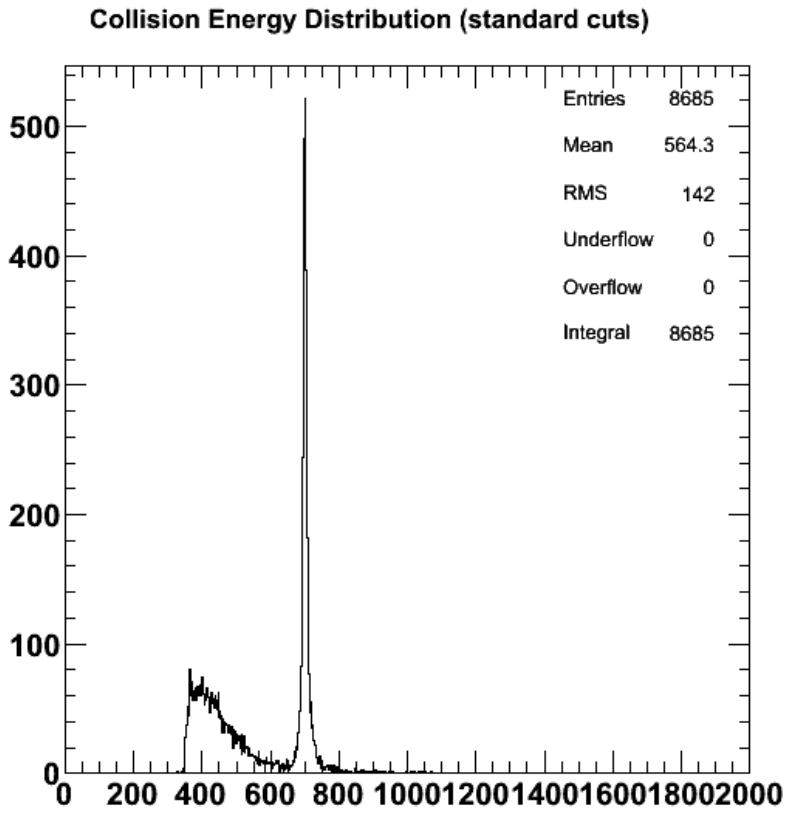
Resonance Search



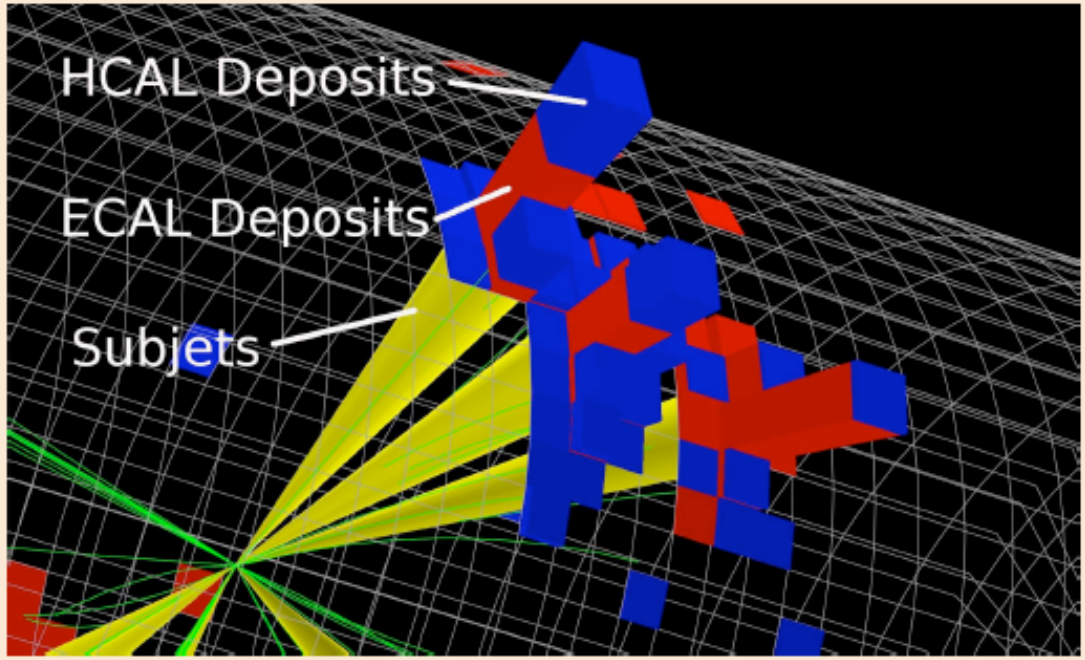


Selection not optimal for high energy resonances?





Color Octet M_X = 700 GeV

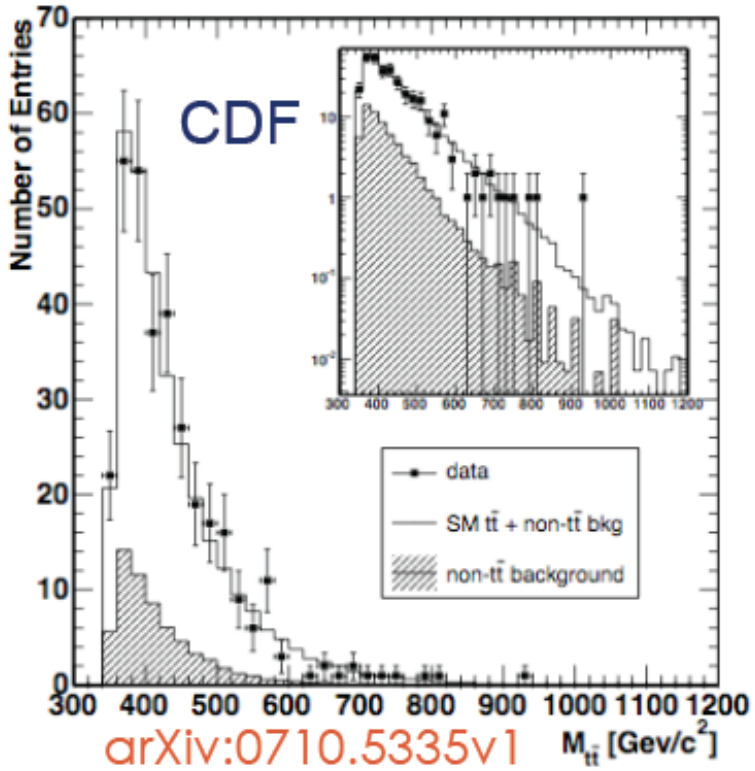


Boosted Top

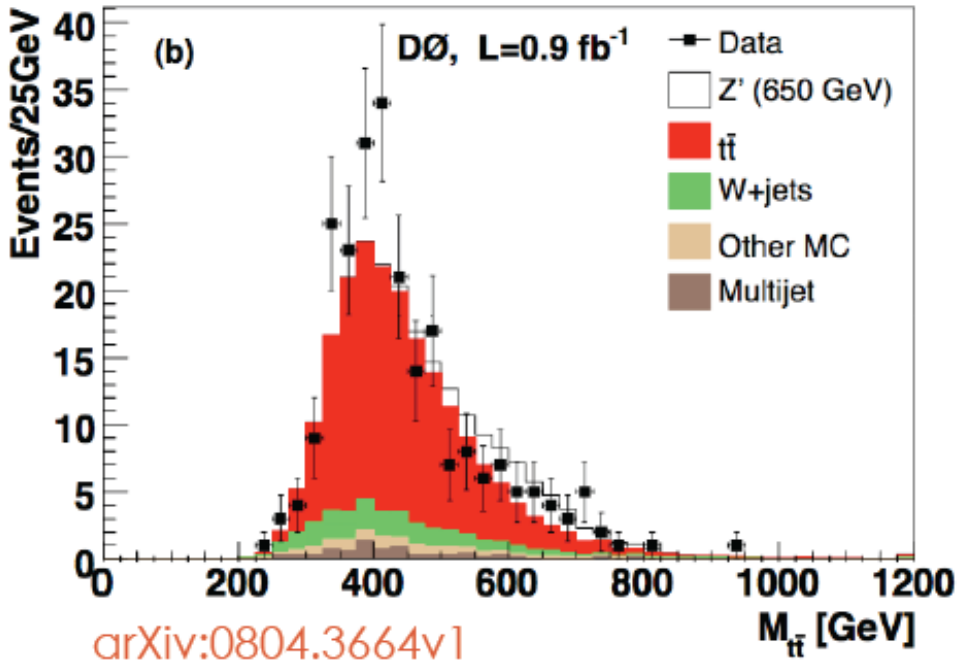
Salvatore Rappoccio

Johns Hopkins University / CMS / CDF

Experimental Status



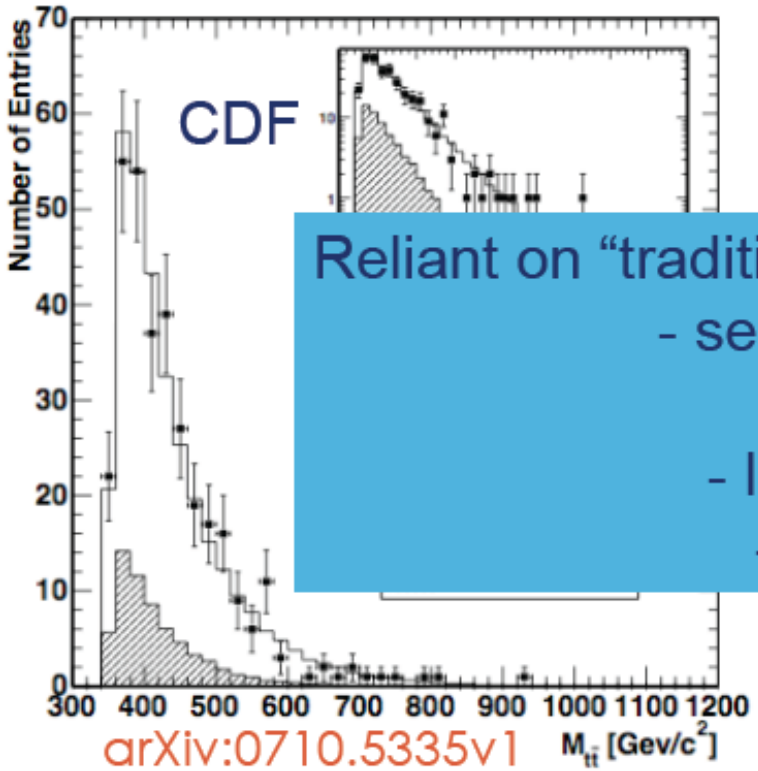
arXiv:0710.5335v1



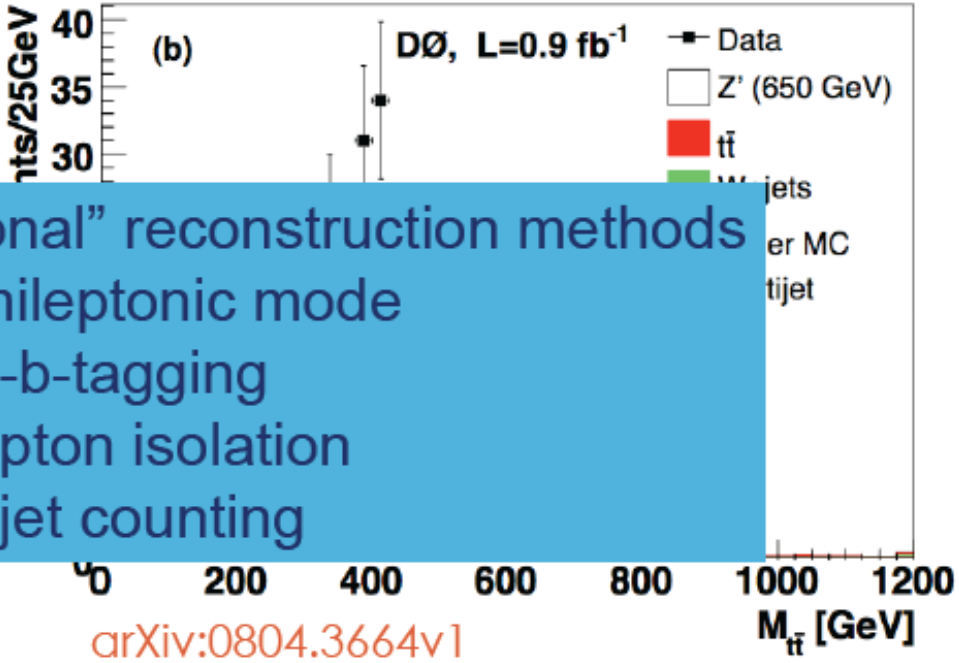
arXiv:0804.3664v1

$M_{Z'} > 700$ GeV/c^2

Experimental Status



arXiv:0710.5335v1

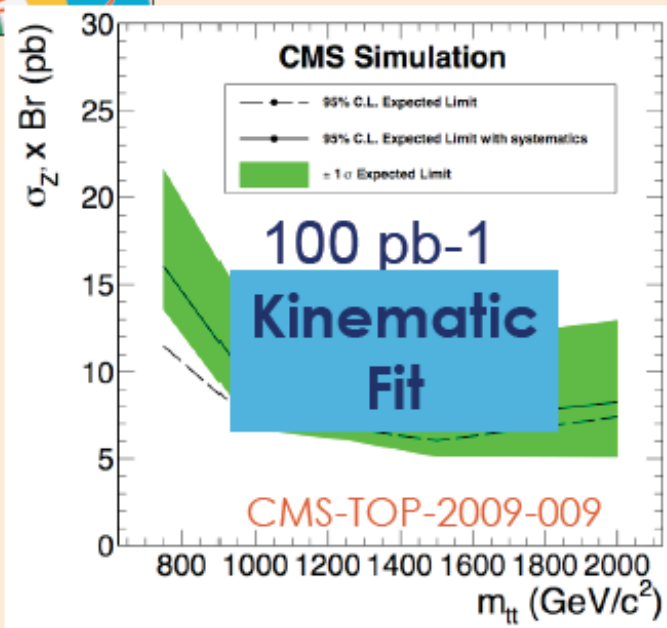


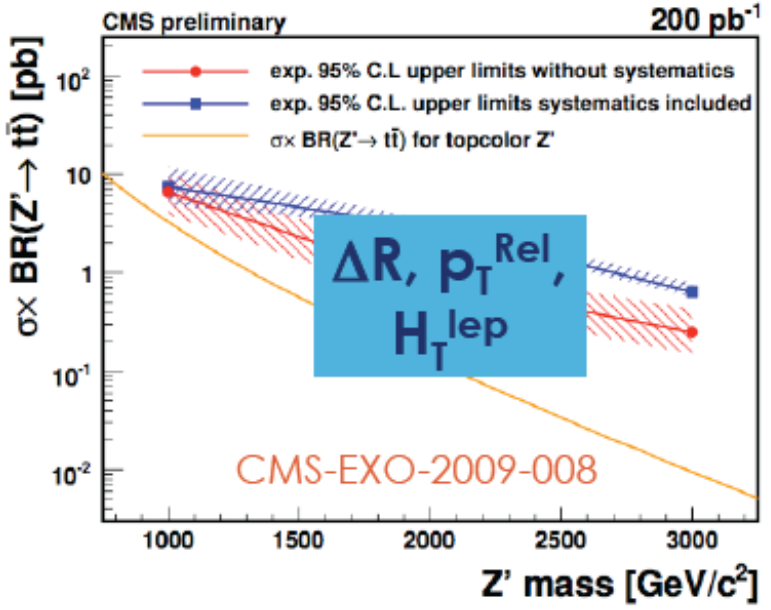
arXiv:0804.3664v1

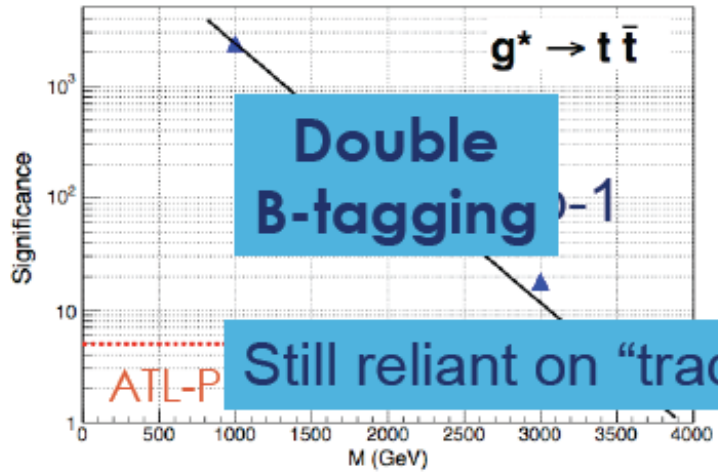
Reliant on "traditional" reconstruction methods
- semileptonic mode
-b-tagging
- lepton isolation
- jet counting

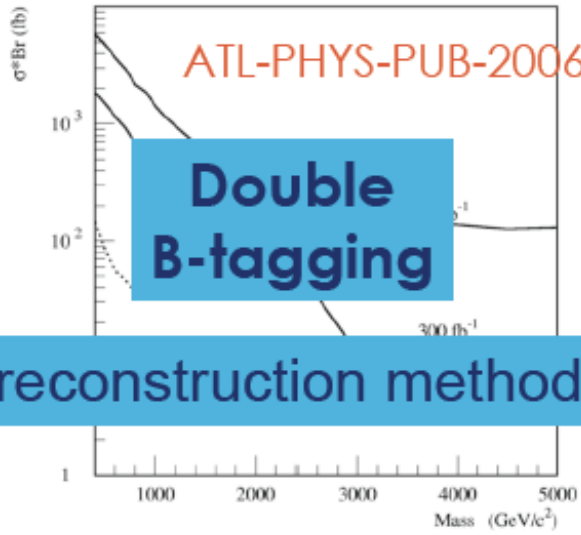
$M_{Z'} > 700$ GeV/c^2

Semileptonic Sensitivities at LHC





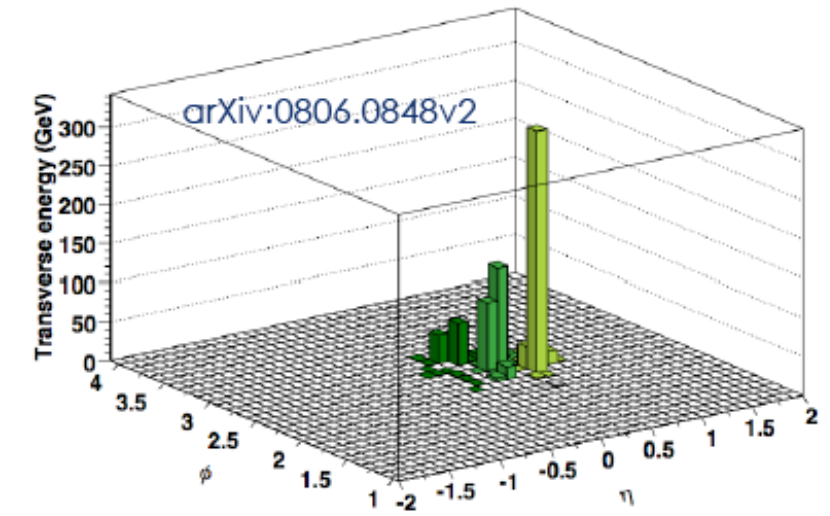


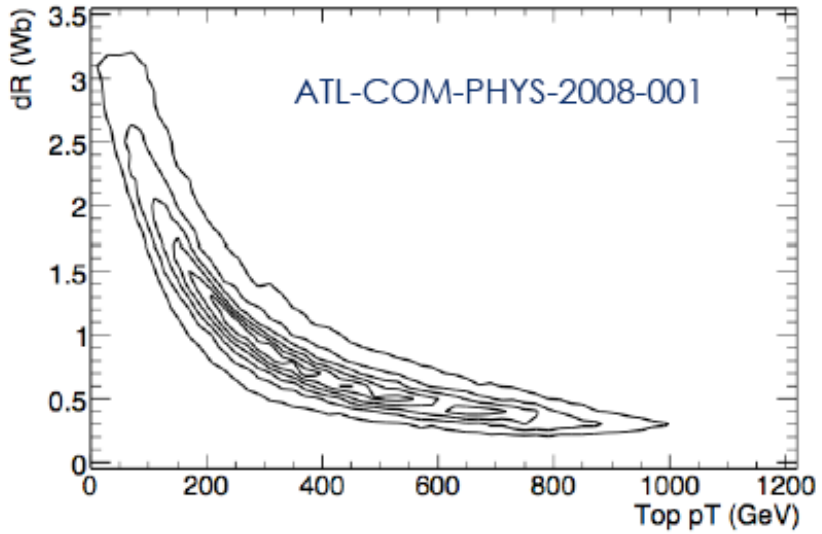


Still reliant on "traditional" reconstruction methods…

New Idea: Top Jets

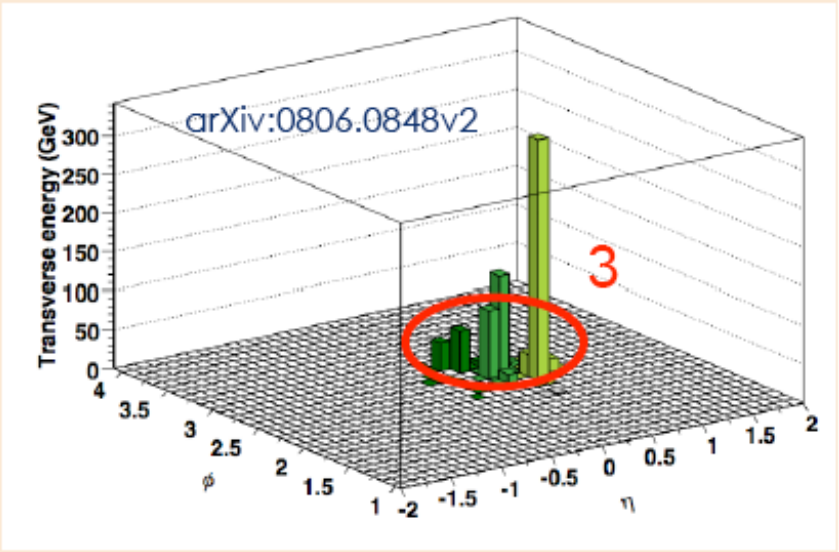
- Even moderate parent masses will result in collimated top "jets"
- Substructure can still be resolved
  - **Subjets**
- Two mass scales involved:
  - Top mass
  - W mass
    - **Affects angular distribution of subjets**
- For QCD, only gluon emission scales
  - Tend toward "zero" mass, smaller anglular separation





New Idea: Top Jets

- How to get at substructure?
- Sequential combination algorithms produce "subjets" naturally in the course of the algorithm!
  - Exploit the clustering sequence



Look at sequential combination in more detail

Substructure Finding

Top-down

- "Peel off" layers of jet clustering sequence
- Throw away soft and colinear clusters

4 -> 3 -> 2 ->1

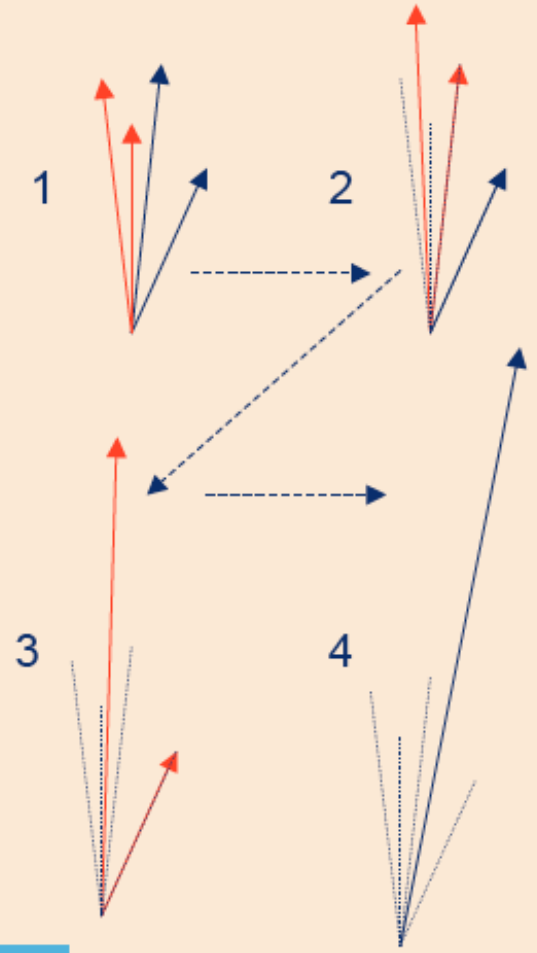
- arXiv:hep-ph/0201098
- arXiv:hep-ph/0702150
- arXiv:0806.0848v2

Bottom-up

- Start from "ground up" of clustering sequence
- Throw away soft and colinear clusters

1 -> 2 -> 3 -> 4

- arXiv:0810.0934

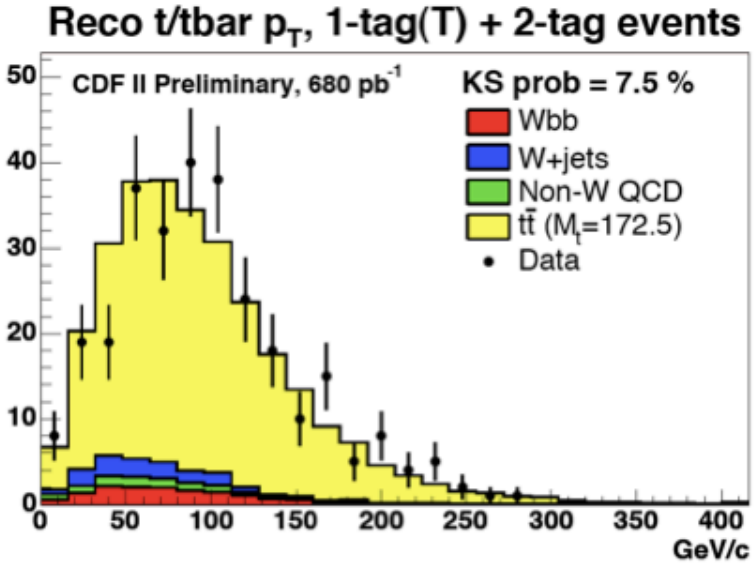


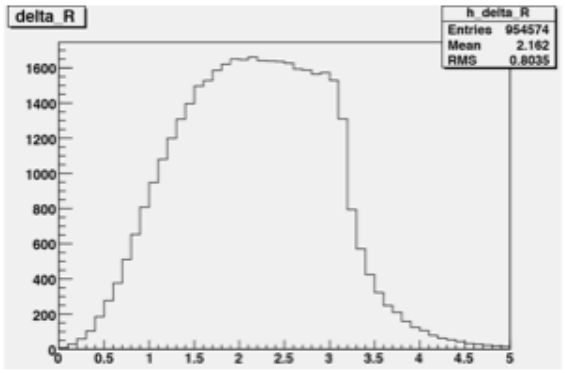
Comparable results for both

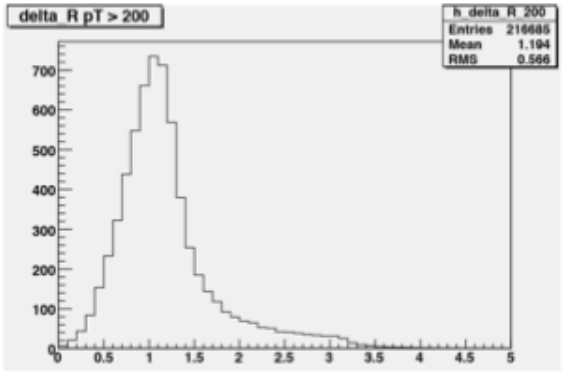
Boosted Top at the Tevatron

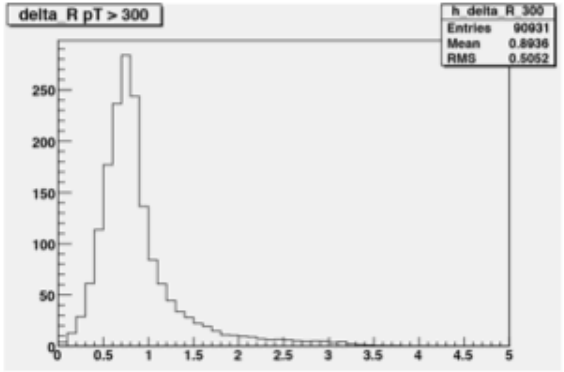
- Can we do this?
- Could be cutting off our tails
  - Delta R cuts on jets
  - Isolation on lepton
- If t′ and A_{fb} are hinting at something, this might be a good direction

But what else?





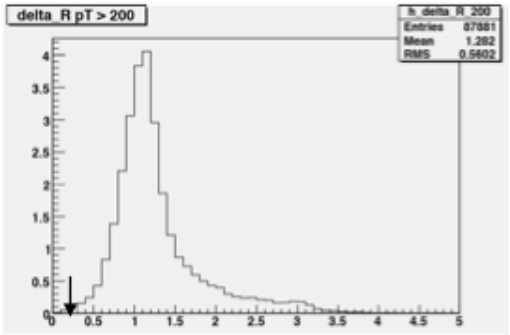


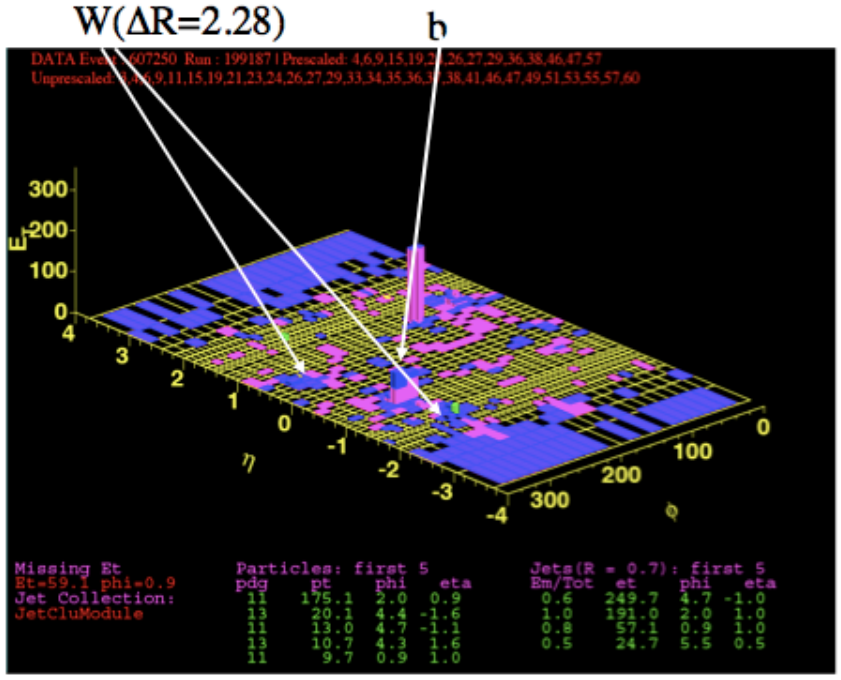


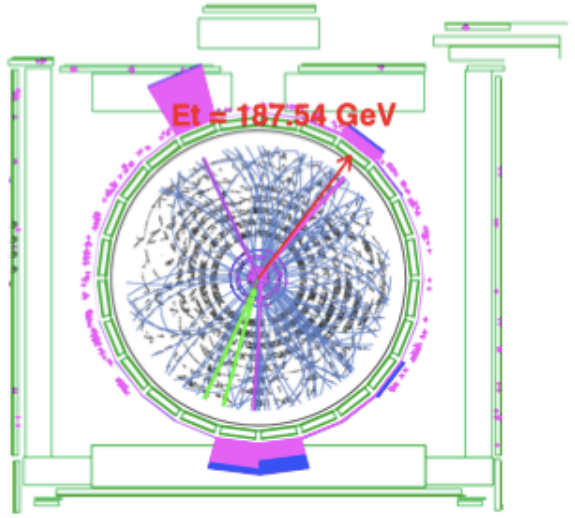
Tom Schwarz
Top@Tevatron 4 LHC

- Joey Huston (MSU)

p_T=270 GeV/c







Tom Schwarz

Top@Tevatron 4 LHC

- Joey Huston (MSU)

Do we understand backgrounds or are they just contained?

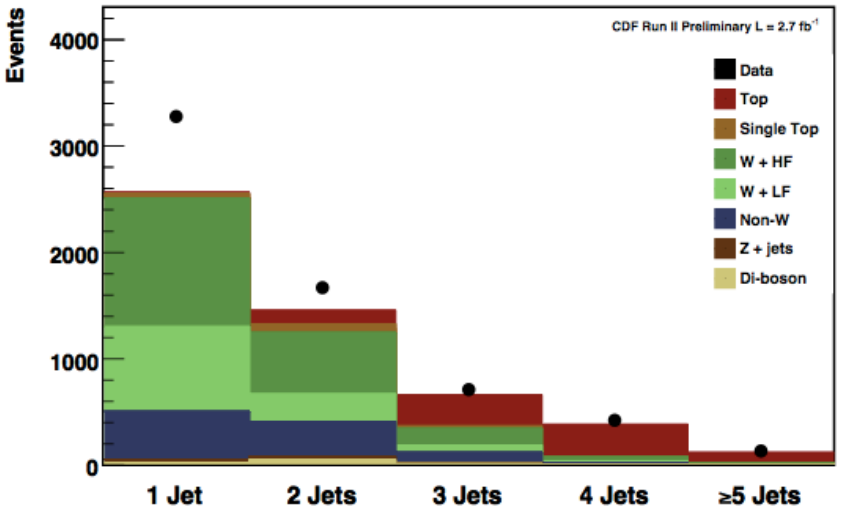
4.1 fb^{-1}

Why should we care?

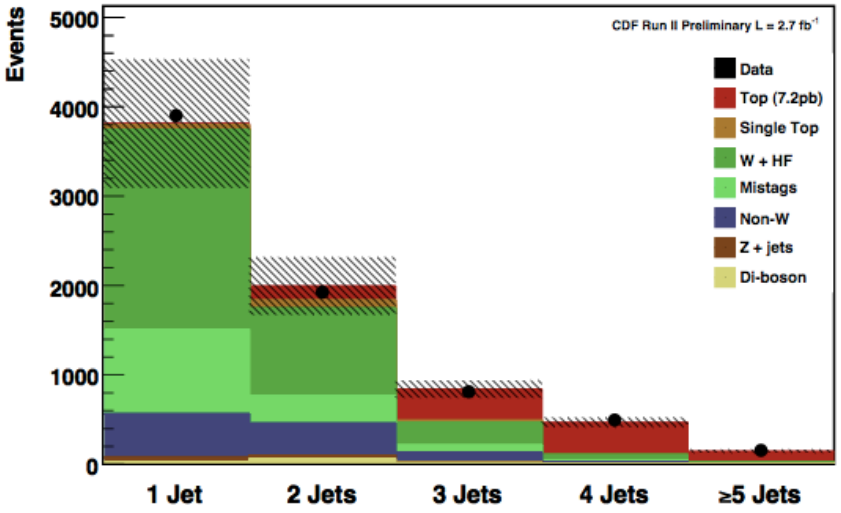
- Today's signal is tomorrow's background $H + 2\ jets$ $t\bar{t}H$
- tt+j is to the LHC what W + heavy flavor is to the Tevatron

The W+HF problem

before corrections



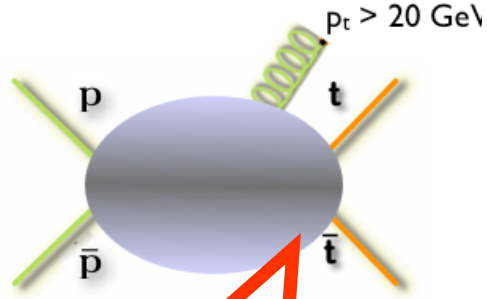
after corrections

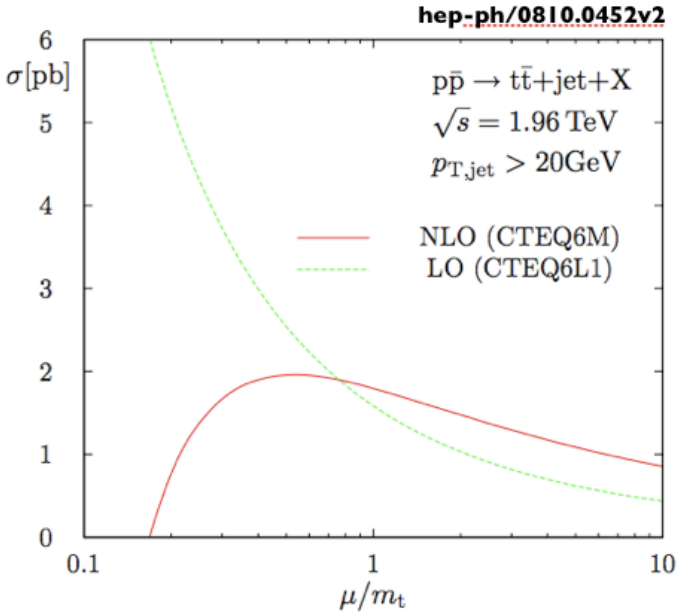


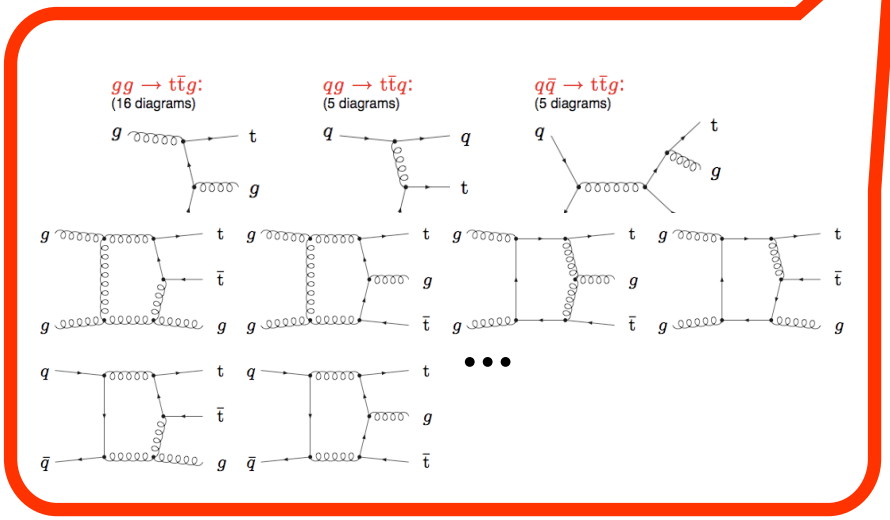
Measurement of the $t\bar{t} + j$ Cross Section

4.1 fb^{-1}

- Idea is to quantify the production of top anti-to pairs in association with a hard jet







$$\sigma_{t\bar{t}+j} = 1.6 \pm 0.2_{stat} \pm 0.5_{syst} \text{ pb}$$

$$\sigma_{t\bar{t}+j} = 1.79^{+0.16}_{-0.31}$$

Dittmaier, Uwer, and Weinzierl hep-ph/0810.0452v2

A_{fb}/A_c and A vs M_{tt} in tt Pair Production

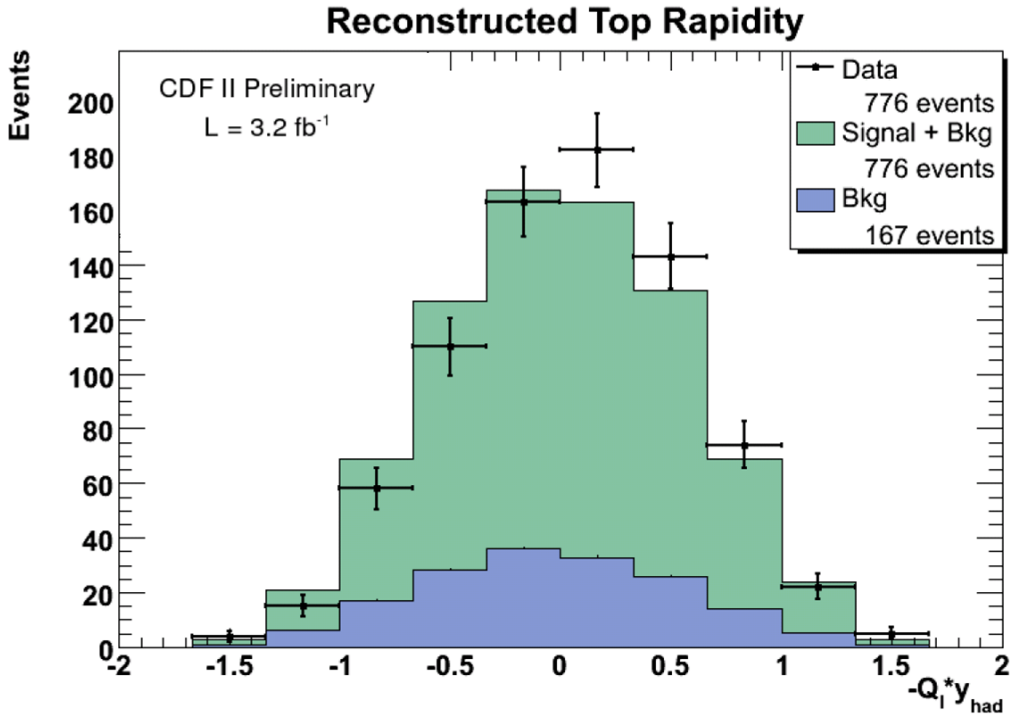
The CDF-II Collaboration

including

U Michigan: G. Strycker, M. Tecchio, D. Amidei

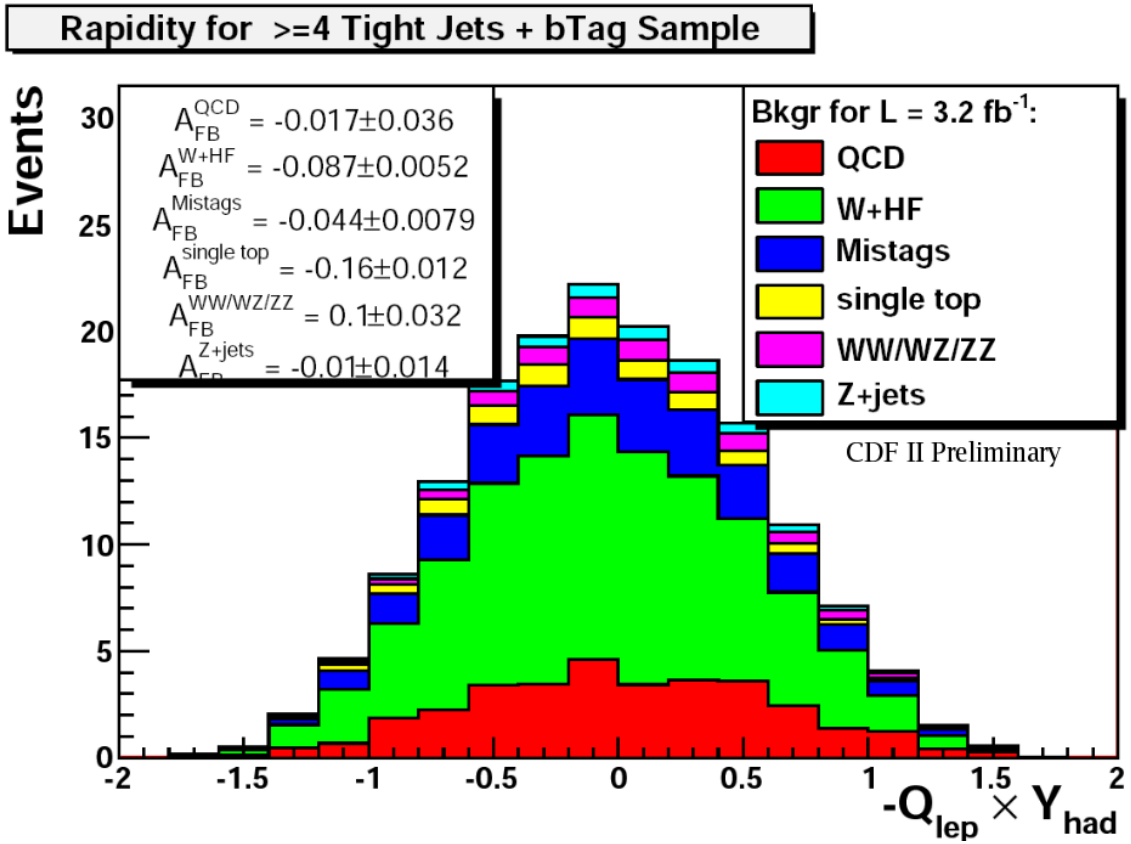
UC Davis: T. Schwarz, R. Erbacher, J. Conway

Universitat Karlsruhe: J. Wagner, T.Chwalek, W. Wagner



Speaker: Dan Amidei, U. Michigan

Subtract (somewhat asymmetric) Backgrounds



Process	>=4 jets
W+HF Jets	-0.087±0.0052
Mistags (W+LF)	-0.044±0.0079
Non-W (QCD)	-0.017±0.036
Single Top	-0.16±0.012
WW/WZ/ZZ	0.1±0.032
Z+Jets	-0.01±0.014
Total Prediction	-0.059±0.0079

Measurements

-Q*Y (pp frame) with 3.2 fb^{-1}

$A_{FB} = 0.19 \pm 0.07 \pm 0.02$

ΔY (tt frame) with 1.9 fb^{-1}

$A_{FB} = 0.24 \pm 0.13 \pm 0.04$

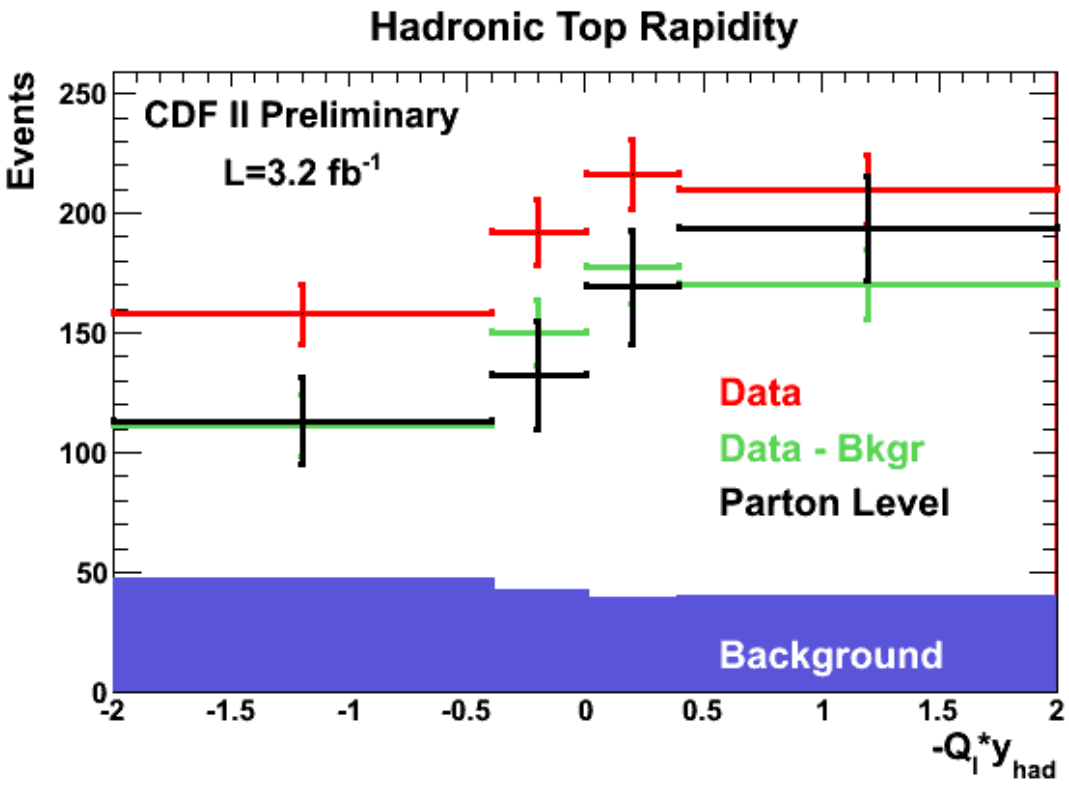
D0 has measured

ΔY (uncorrected) with 0.9 fb^{-1}

$A_{FB} = 0.12 \pm 0.08 \pm 0.01$

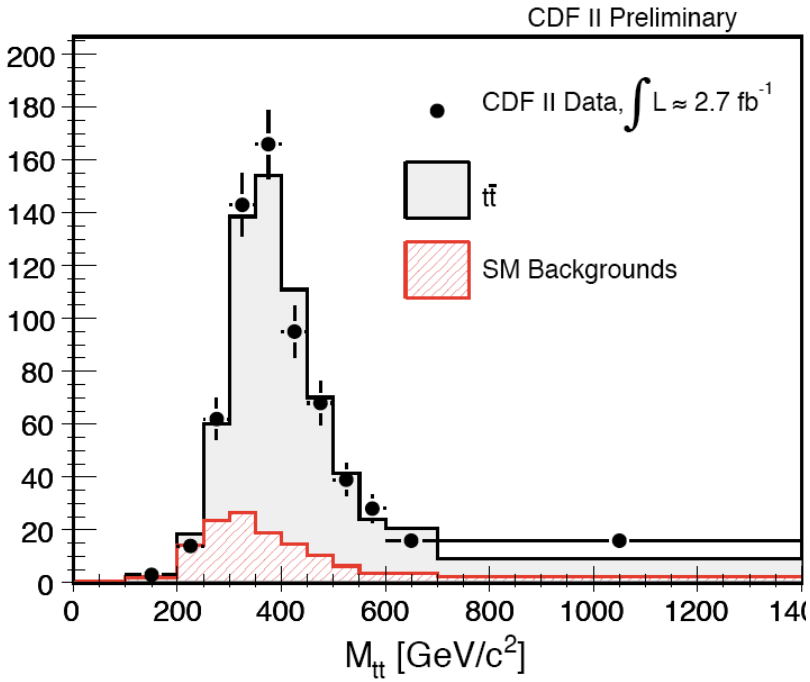
compare CDF ΔY uncorrected

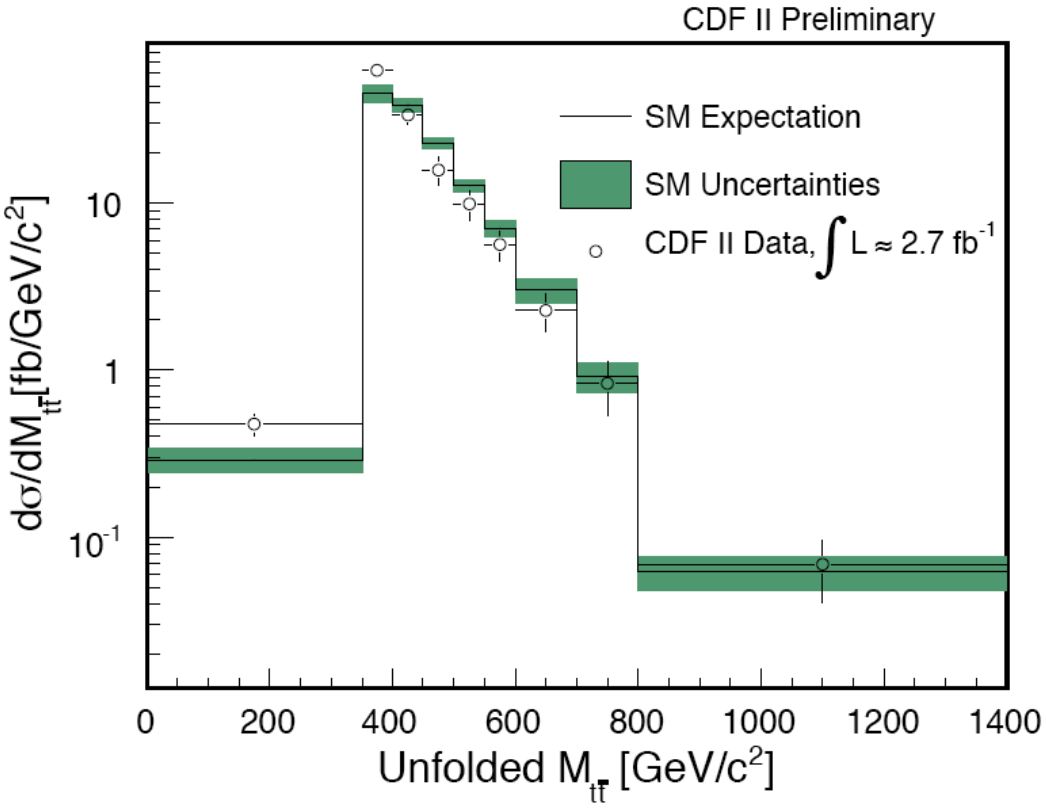
$A_{FB} = 0.11 \pm 0.04$



The M_{tt} distribution: Bridgeman, Liss (CDF) (with Schwarz)

- A proper unfold to parton level
  - "no evidence of departure from SM"





Mass Dependence of the Asymmetry M. Tecchio, T. Schwarz

- unfold in M_{tt} *and* A_{fb}

for some mass cut

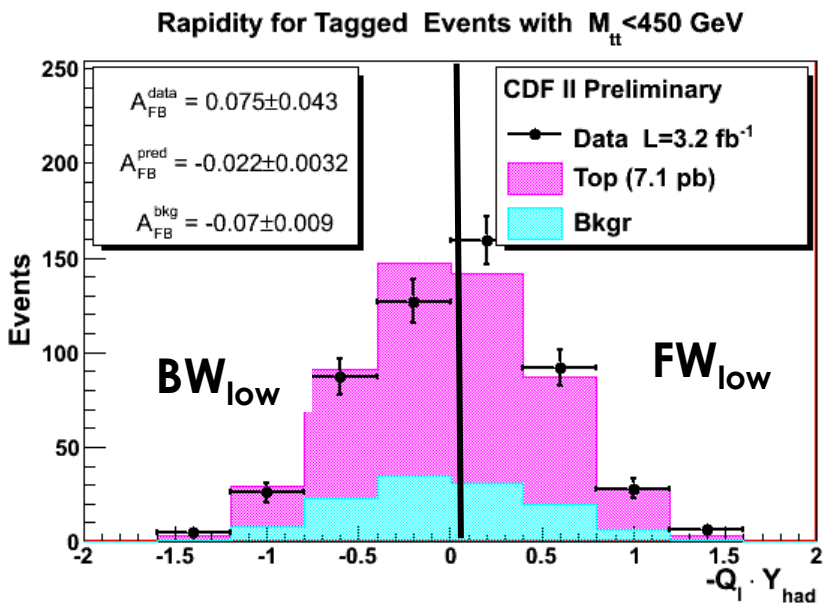
- reconstructed data divided into 4 exclusive bins
  - low mass FW
  - low mass BW
  - high mass FW
  - high mass BW

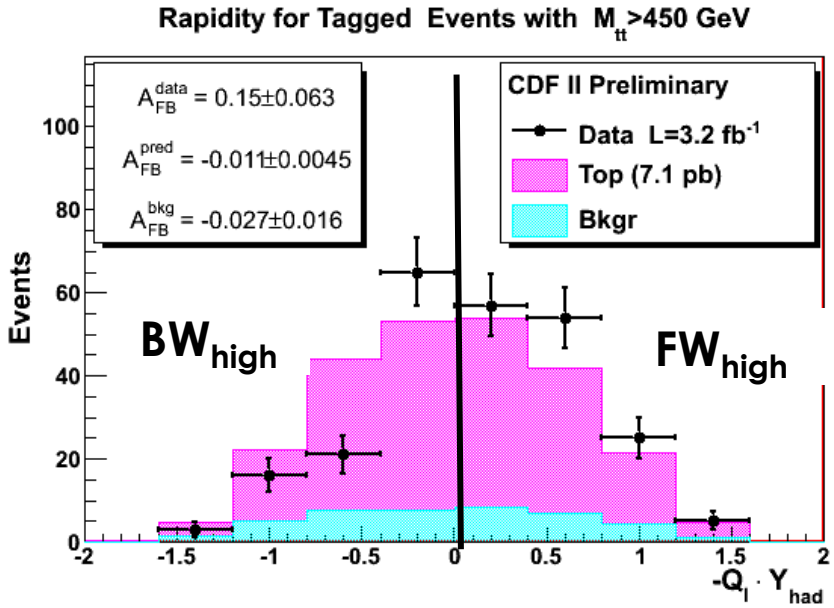
- backgrounds subtracted

- selection bias, reco slews corrected simultaneously in mass and Y with 2x2 unfold

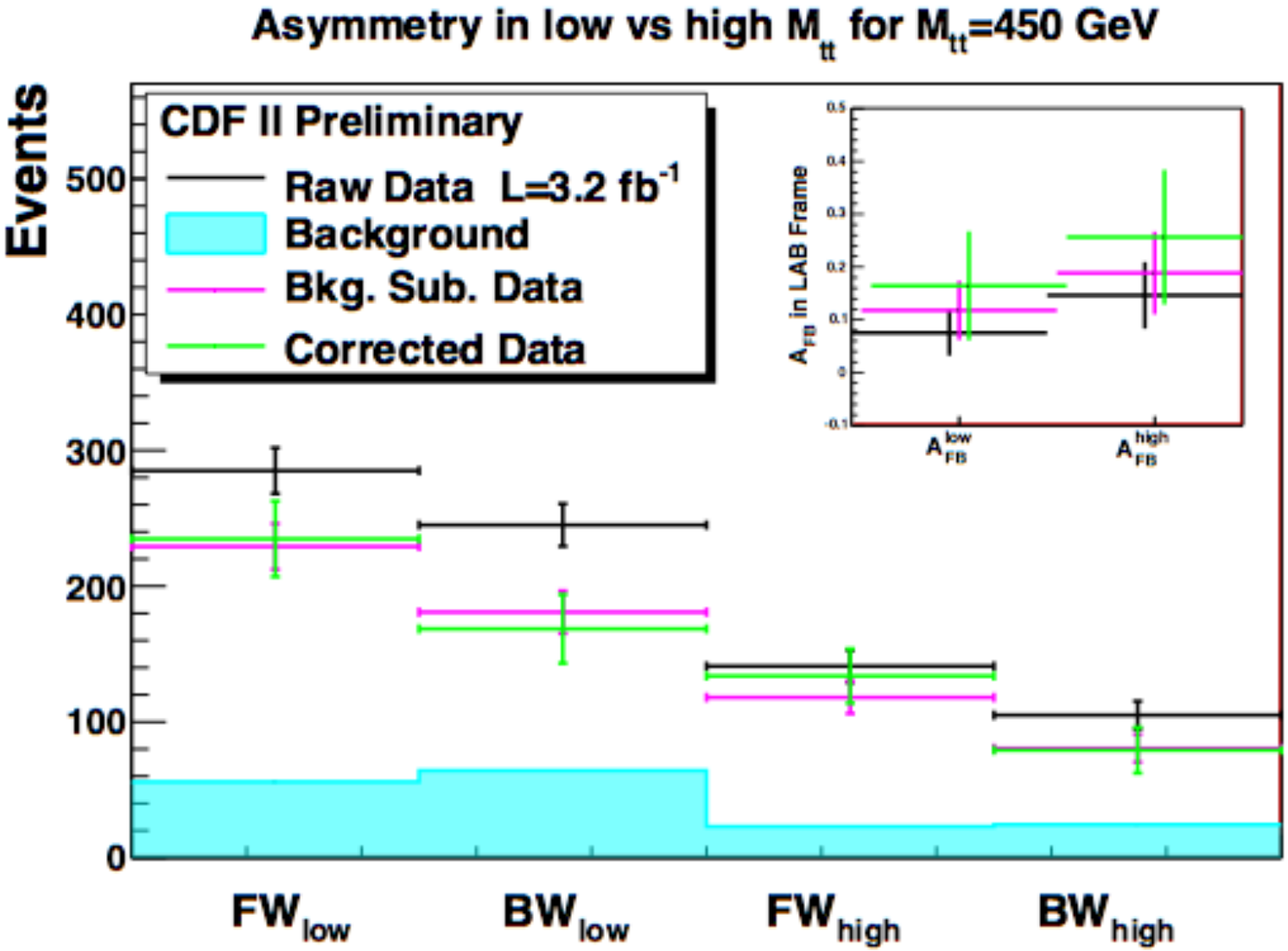
- parton level A_{fb} for 2 mass bins "high and low"

- can study as function of cut



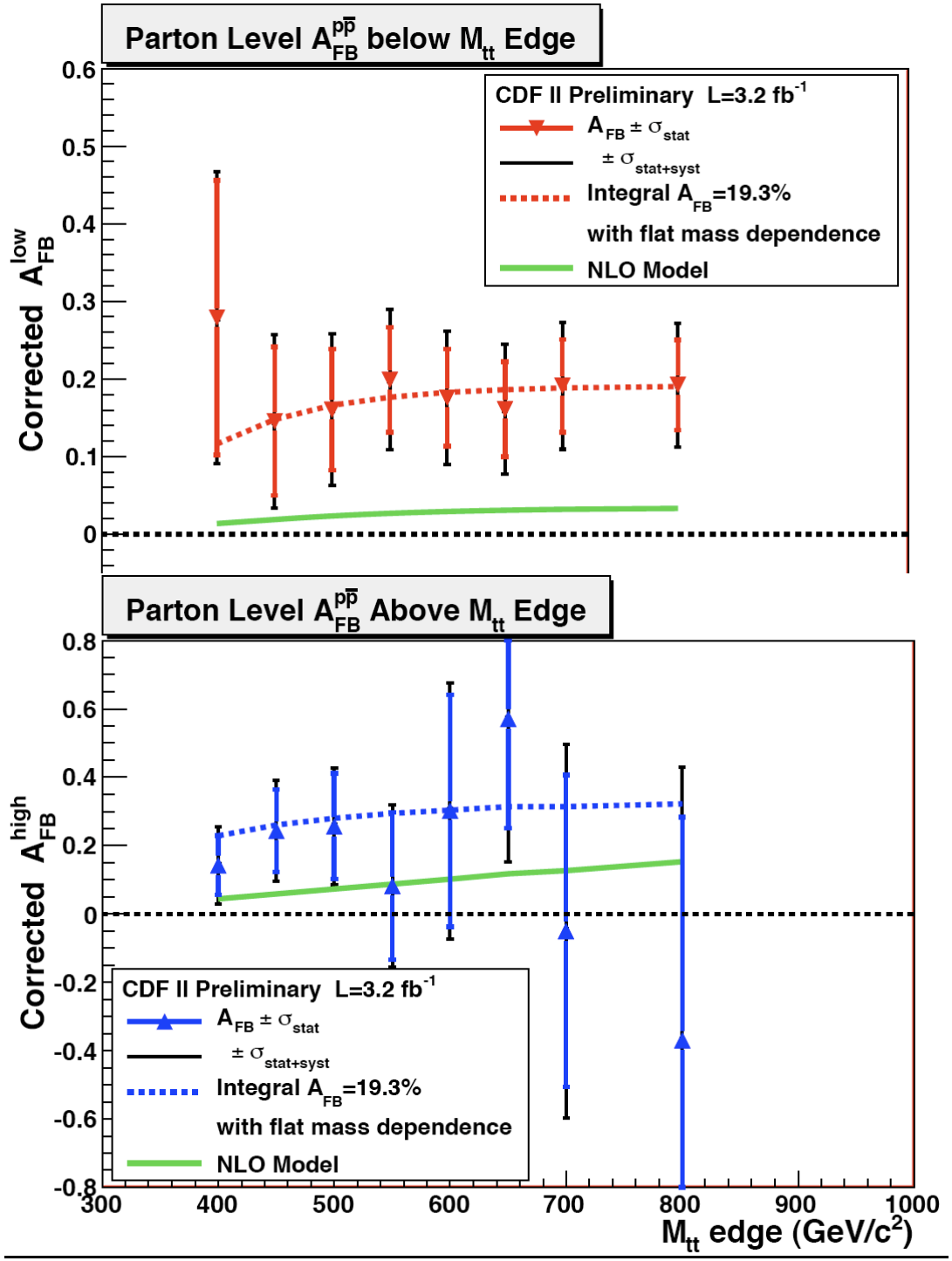


Data Measurement with Mass Cut at 450 GeV



Now Scan the Cut

- points: data
- dashed: Pythia reweighted with flat Acosθ asymmetry
  - A = 19%
  - no mass dependence
- green: "NLO model", Pythia reweighted with A_{FB} linearly dependent on M_{tt} as per fit to NLL calculation
- awaiting more data!



Now what?

- A_{FB} in pp frame

- Procedure for study of mass dependence
- it's all 2σ

- more studies
  - ΔY for full data set
  - understand systematics
  - A_{FB} vs M_{tt}
  - A_{FB} vs Y
  - asymmetries of decay products
  -
- more data!!

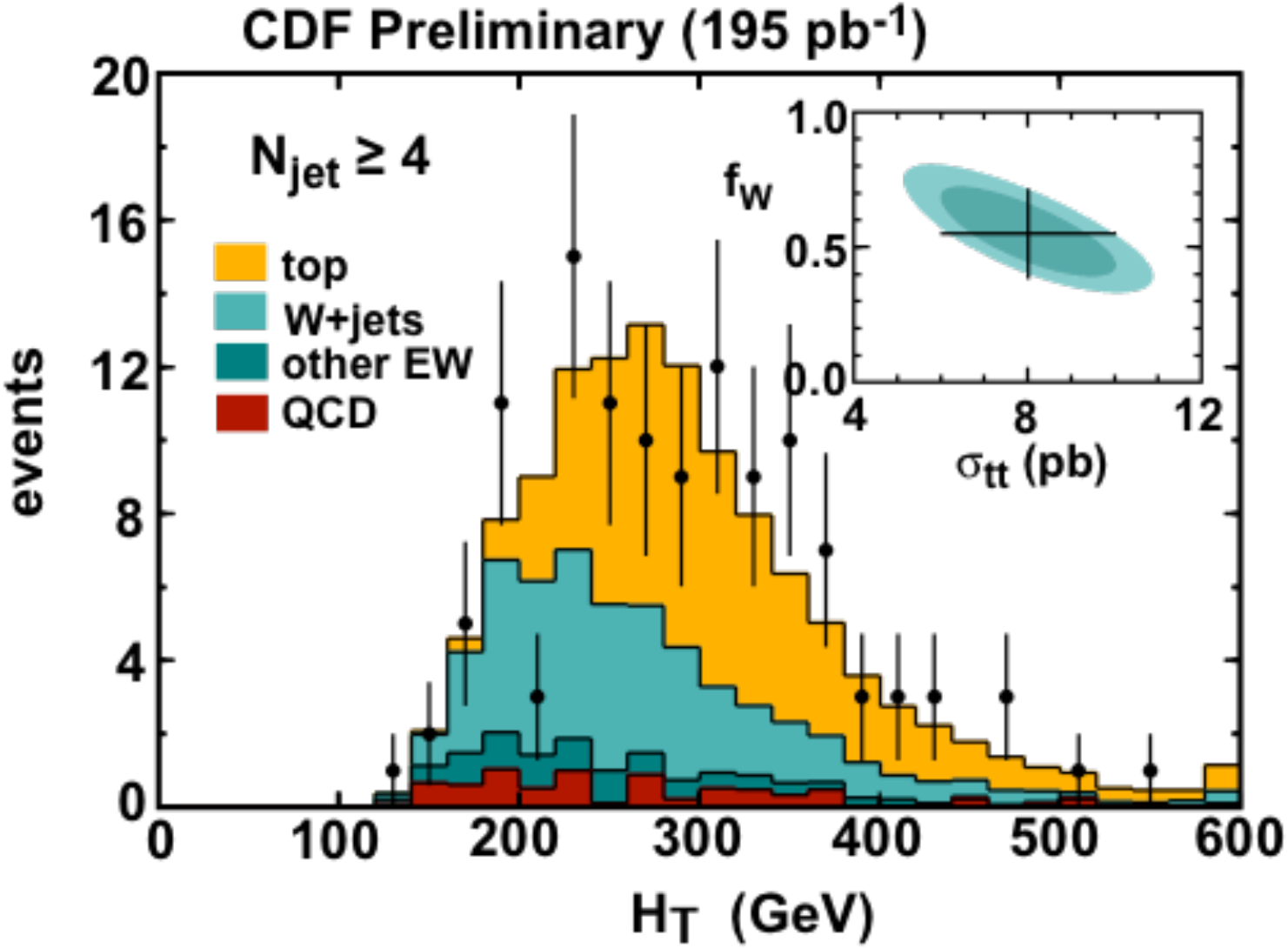
New physics in top samples

New physics in top samples

New physics in top samples

- While on the energy frontier, we look for interesting events on the tails of the top quark distributions
- Can a t′ exist? Can it mimic top?
- Generic 4th chiral generation is consistent with EWK data; can accommodate a heavy Higgs (500 GeV) without any other new physics
  - Masses of 4th generation quarks ~ few hundreds of GeV
  - Oblique corrections drive Higgs Mass to ~ 500 GeV
  - Almost degenerate b′ and t′ masses: M(t′) - M(b′) < M(W)
  - Two Higgs Doublets N=2 SUSY (C.He et al, hep-ph/0102144)

Total Transverse Energy (Scalar)



New physics in top samples

- While on the energy frontier, we look for interesting events on the tails of the top quark distributions

- Little Higgs models predict a heavy t' -like particle

- Several SUSY models provide for a 4th generation t' or mimic top-like signatures *(Beautiful Mirrors: Choudhury, Tait, Wagner)*

This Analysis ~2.8 fb^{-1}

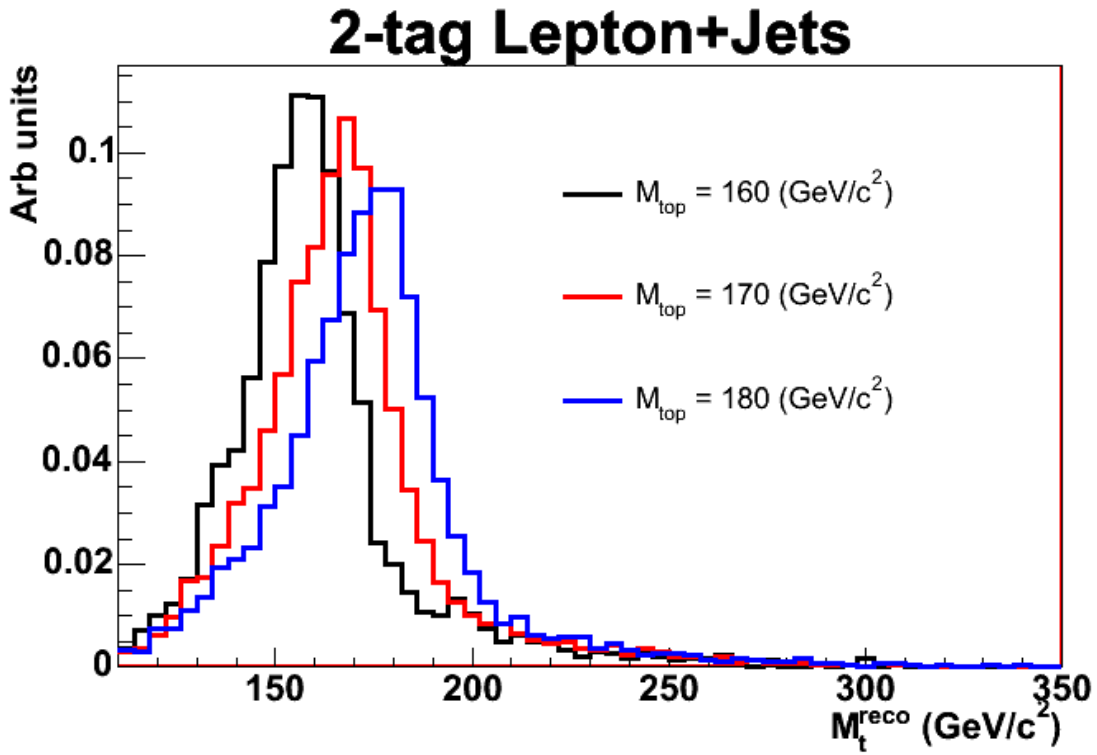
Idea: use kinematics again to separate t′ from t

- We search for new quark decays into Wq: t´ -> Wq
  - t´ ->Wb´ is kinematically suppressed and $V_{t'b} \sim V_{t'q}$
- Use lepton+jets events (no b-tagging requirements)
- Assume BR(t'->Wq) ~ 100%
- Model new signal with 4-generation t´ quark pair production (Pythia)
- Assume strong t´ pair production with strong SM couplings

Reconstructed Mass

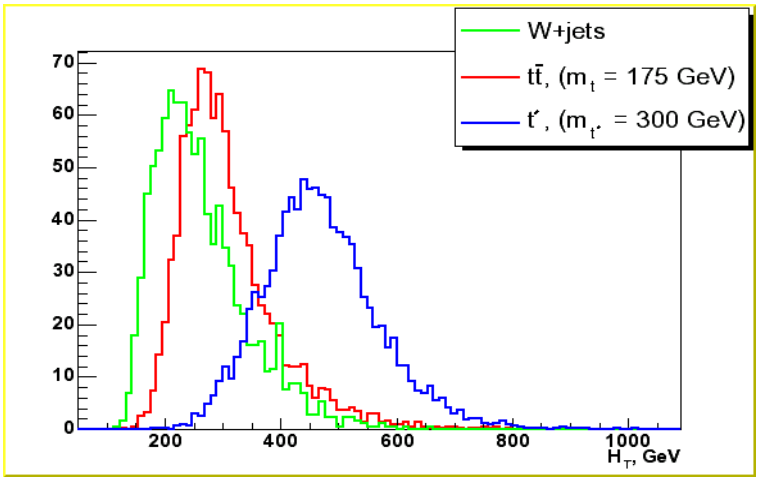
$$\chi^2 = \sum_{i=l,jets} \frac{(p_t^{i,meas} - p_t^{i,fit})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,meas} - p_j^{UE,fit})^2}{\sigma_j^2}$$

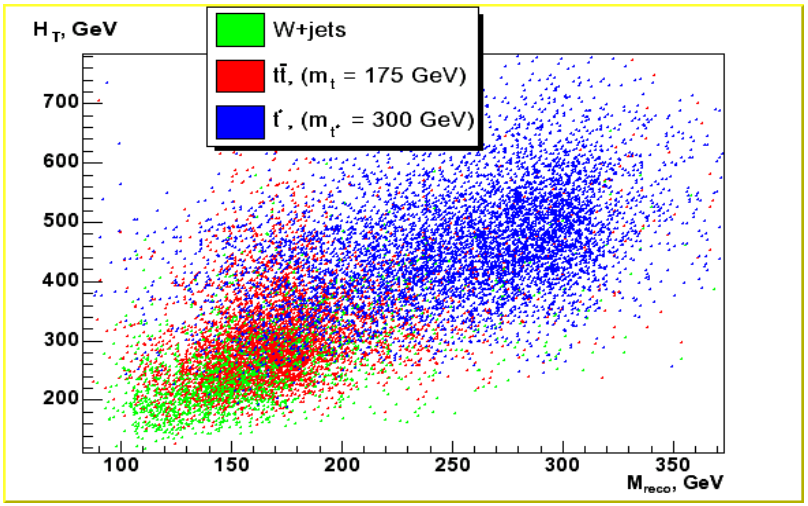
$$+ \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{lv} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_{fit})^2}{\Gamma_t^2} + \frac{(M_{blv} - M_{fit})^2}{\Gamma_t^2}$$

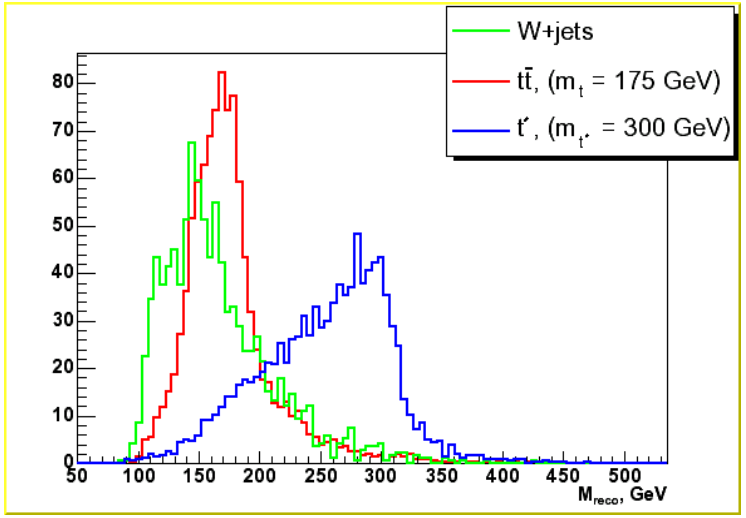


Search for massive top

- We use the top mass fitter, and fit observed 2D data distribution of H_T vs M_{recon}

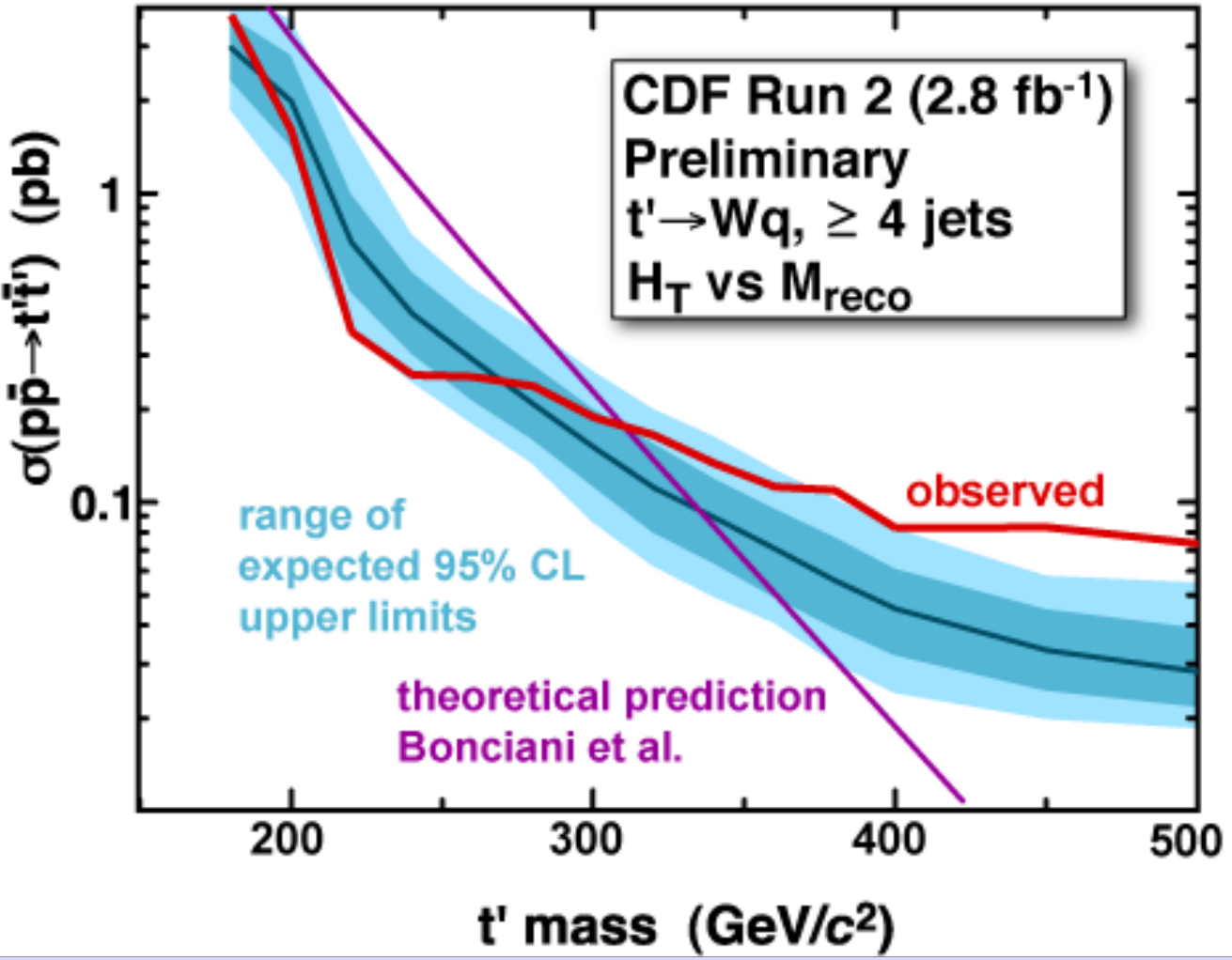






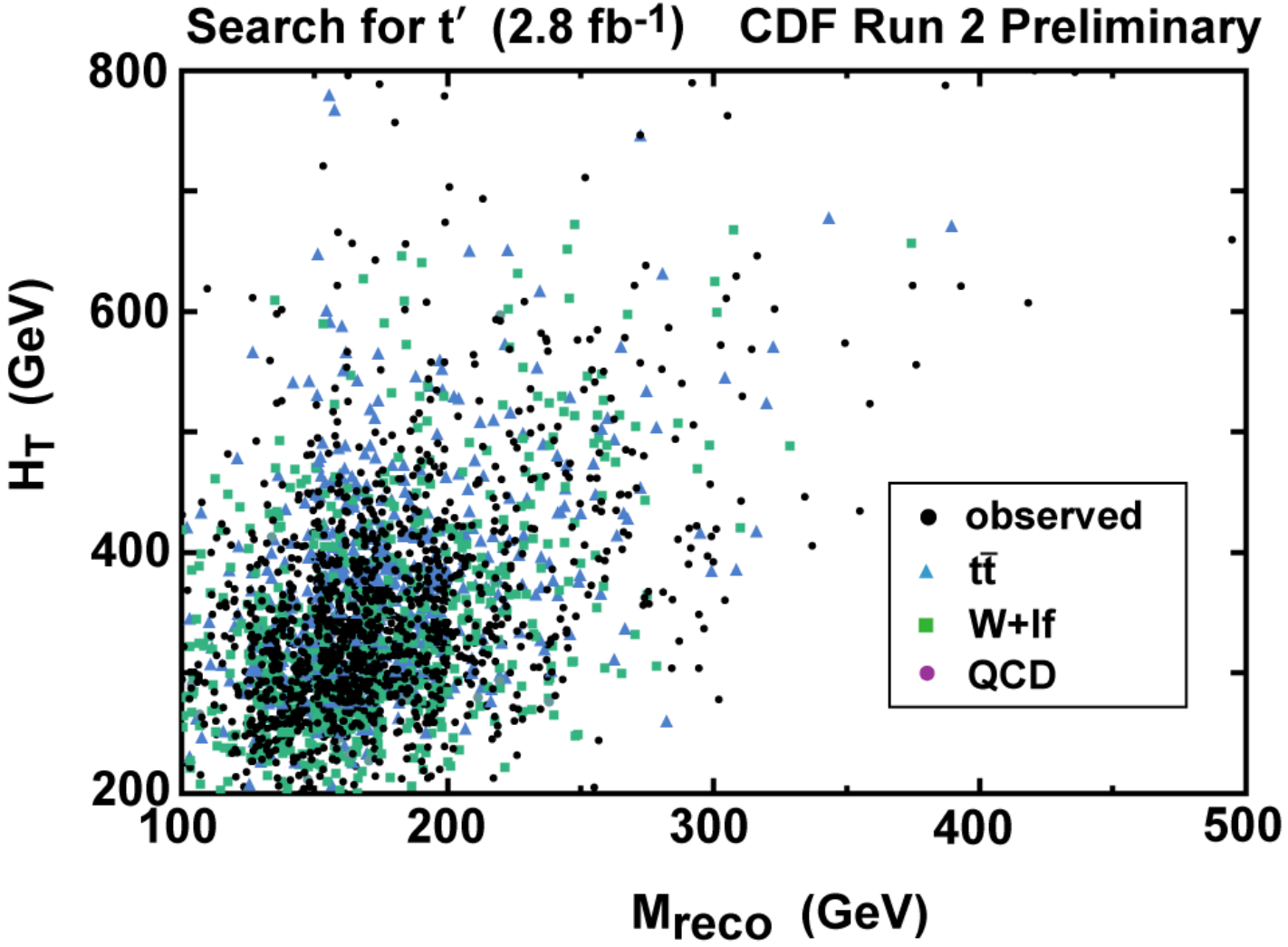
Variables are ~model-independent, to maintain sensitivity to many BSM scenarios

Limits on t'



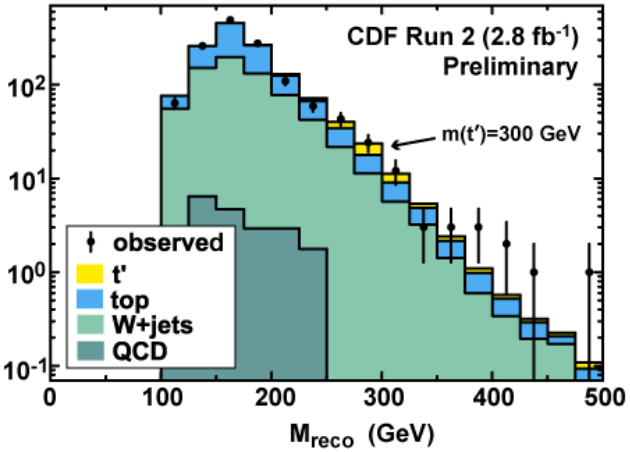
Exclude with 95%CL region of t′ masses below 311 GeV

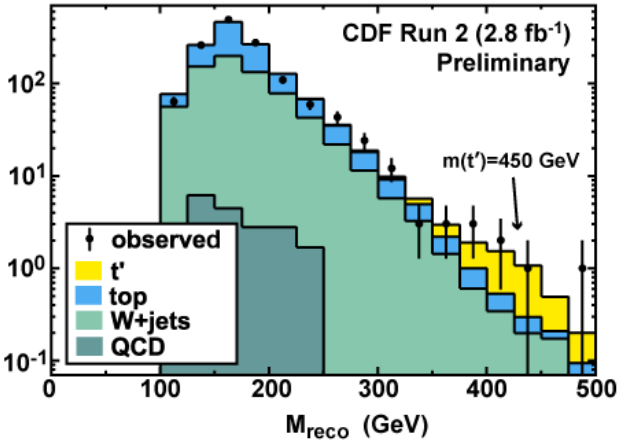
2-D Scatter Plot

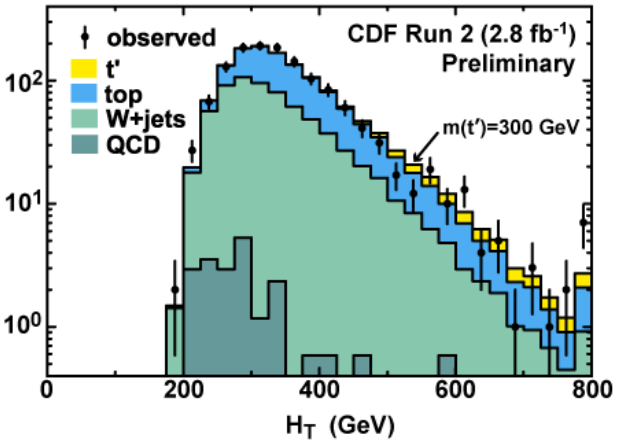


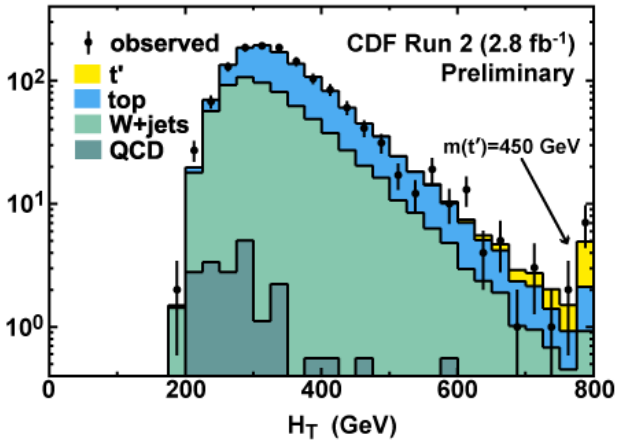
Expected (MC) v. data (black)

Data v. Projections



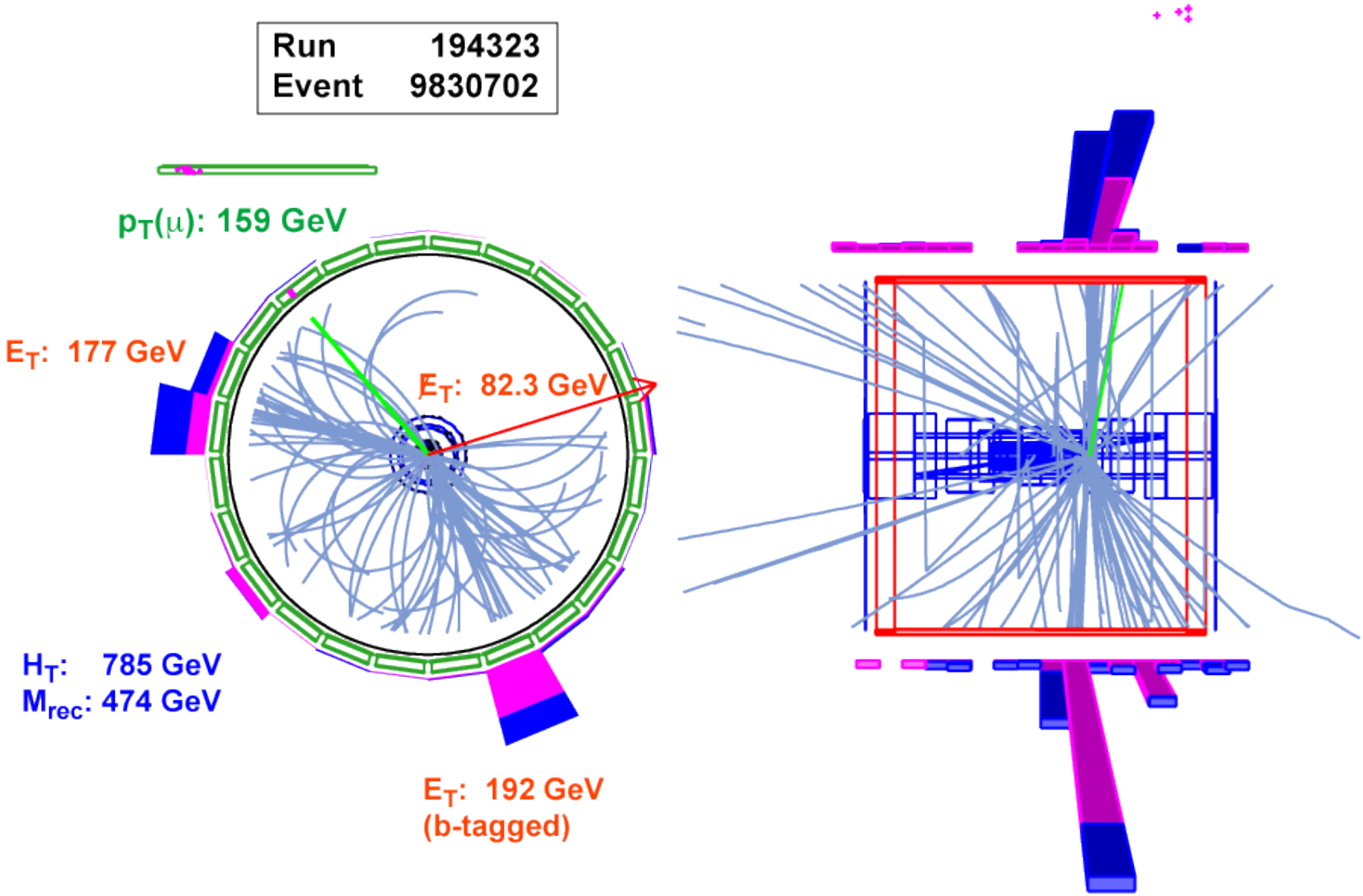






1-d Projection: Fit results for M(t′) = 300, 450 GeV

Couple of strange ones…



Significance Test nxn

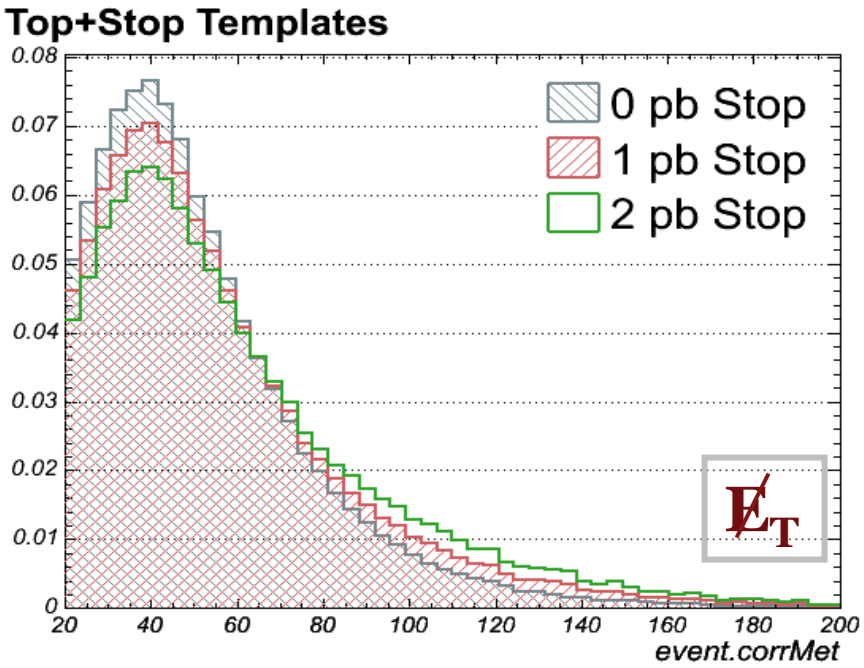
- measure significance of excess by looking at upper-right-most n x n bins
- let n increase from n=1,2,… and find the n x n region with most significant excess
- then ask "how probable is it that we get such a most significant excess?"

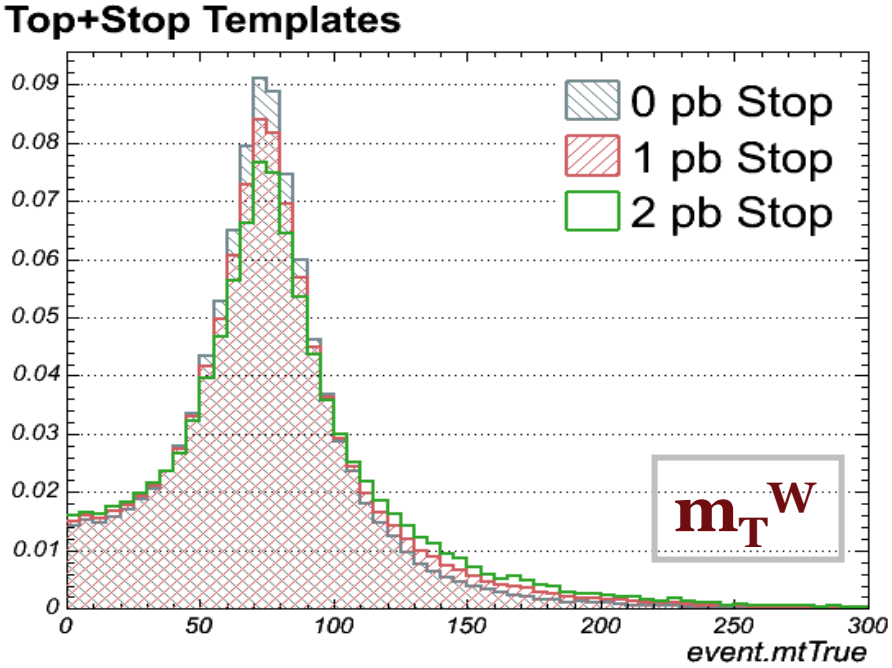
CDF Run 2 (2.8 fb^{-1}) Preliminary

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

Other ideas: Top plus missing E_T

- Search for anomalous events that look like top+MET.
  - →SUSY cascades, T→A_ht *(L. Wang)*, …
- Similar (*based on*) t' search but optimize for extra MET.
- Search underway at CDF.





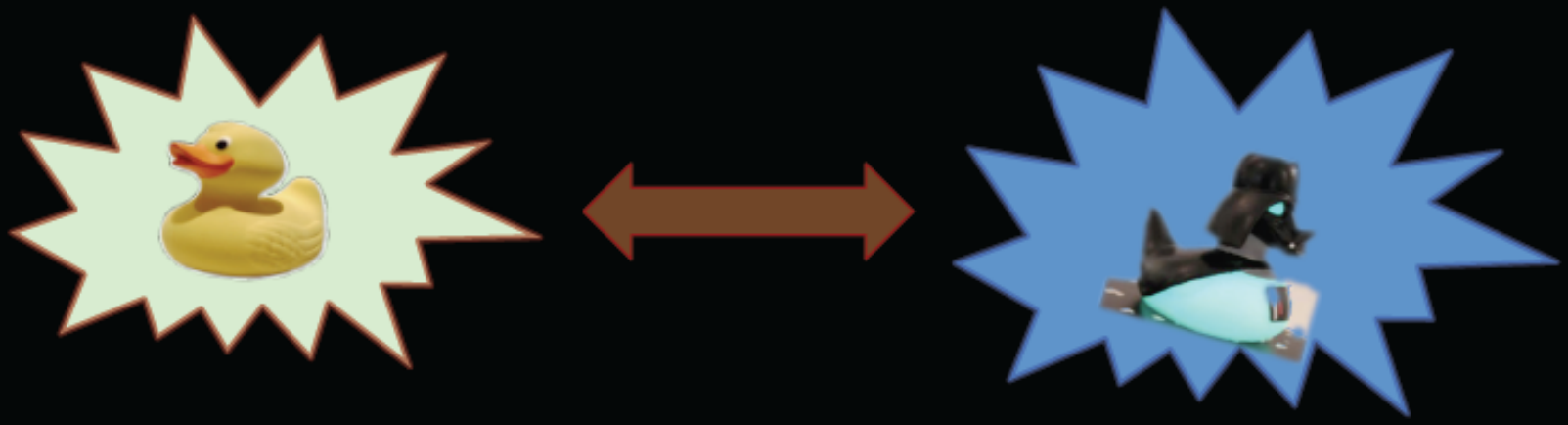
Eric Chabert

Jorgen D'Hondt

First Top Quark convenor in CMS (2007 & 2008)

Testing Top Topologies

(The T^3 strategy)



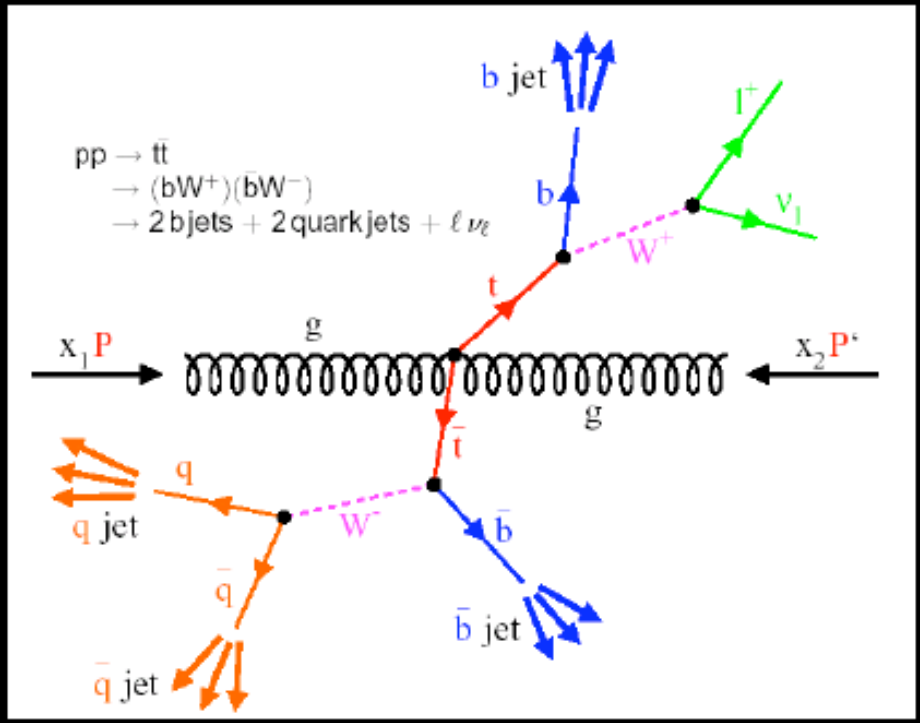
This talk is a" food-for-discussion" presentation. Many of the items can be developed for the Tevatron and the LHC settings. First tests of the principle can be performed at the Tevatron…

How to characterize the top topology ?

- Minimize the set of "T^3 variables"
- The kinematics of the events can be projected into few variables
- Develop a criteria to define the "best" minimal set of variables

- *Add the "extra multiplicity" variables (eg. # extra jets, # b-tags, # extra lepton, …)*
- *Add differences between decay channels…*
- *Add differences between top and anti-top (eg. CPT symmetry)*

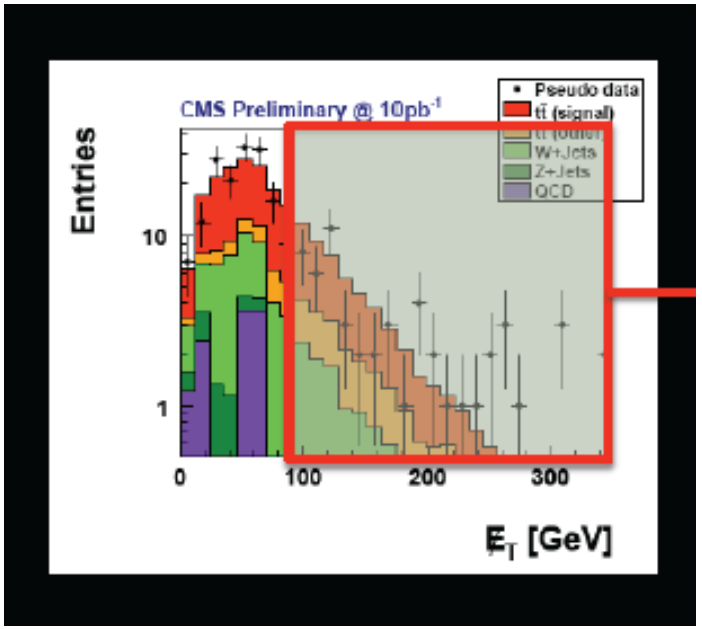
- *Apply a basic event selection…*



Early Tevatron reference "Search for Anomalous Kinematics in ttbar Dilepton Events at CDF II" - arXiv:hep-ex/0412042v2

Four phase strategy for searches

- Phase 1: Simple blind goodness-of-fit tests
- Phase 2: Rank the events (still general)
- Phase 3: Model-dependent goodness-of-fit tests
- Phase 4: Zoom in and check relevant distributions in interesting ranges



- Top Quark physics is the key topic for the Tevatron and will be the key physics topic for 2-10TeV LHC collisions
- An understanding on the full process, from production over properties to decays, has still to arise

- Goodness-of-fit techniques can be developed and tested at the Tevatron, in order to be applied with confidence at the LHC
- The "*T^3 strategy*" involves lots of work from both the Tevatron and the LHC side