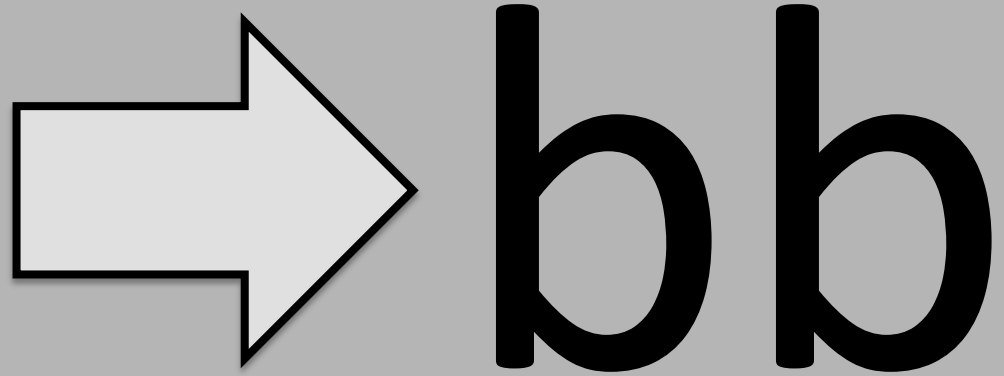


$H \rightarrow b\bar{b}$ @ the Tevatron



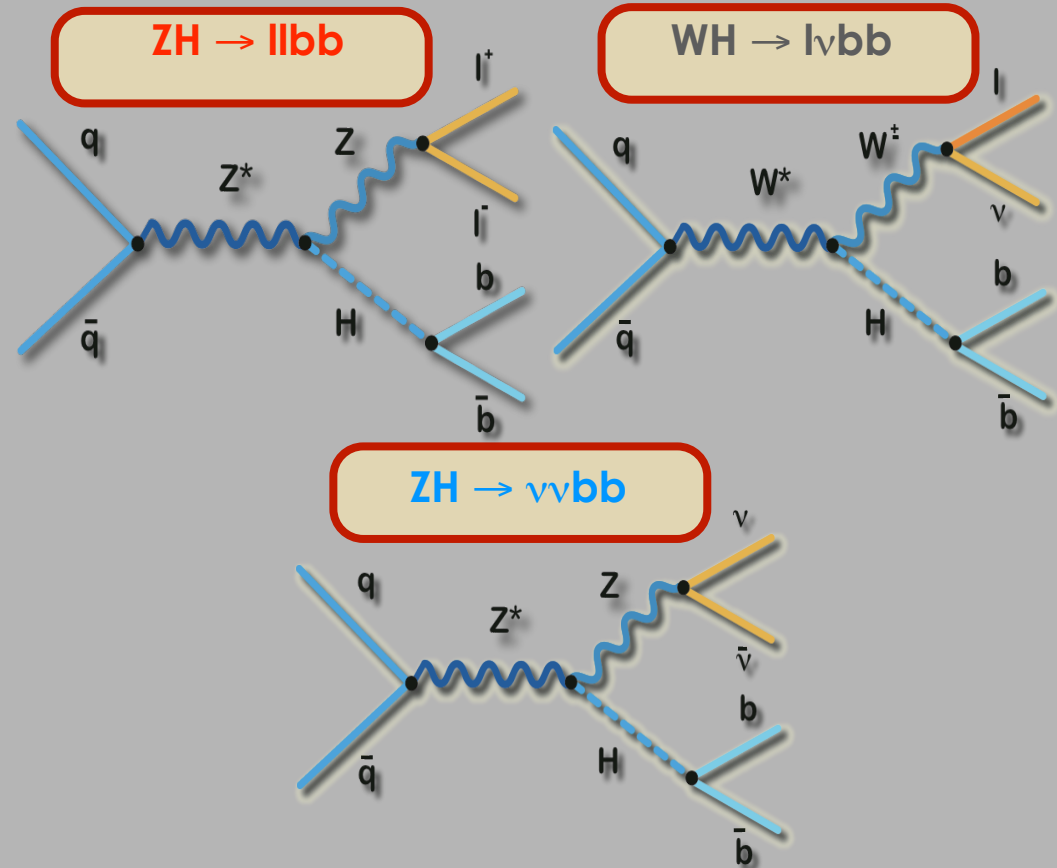
Craig Group

(University of Virginia and Fermilab)

on behalf of the CDF and D0 experiments...

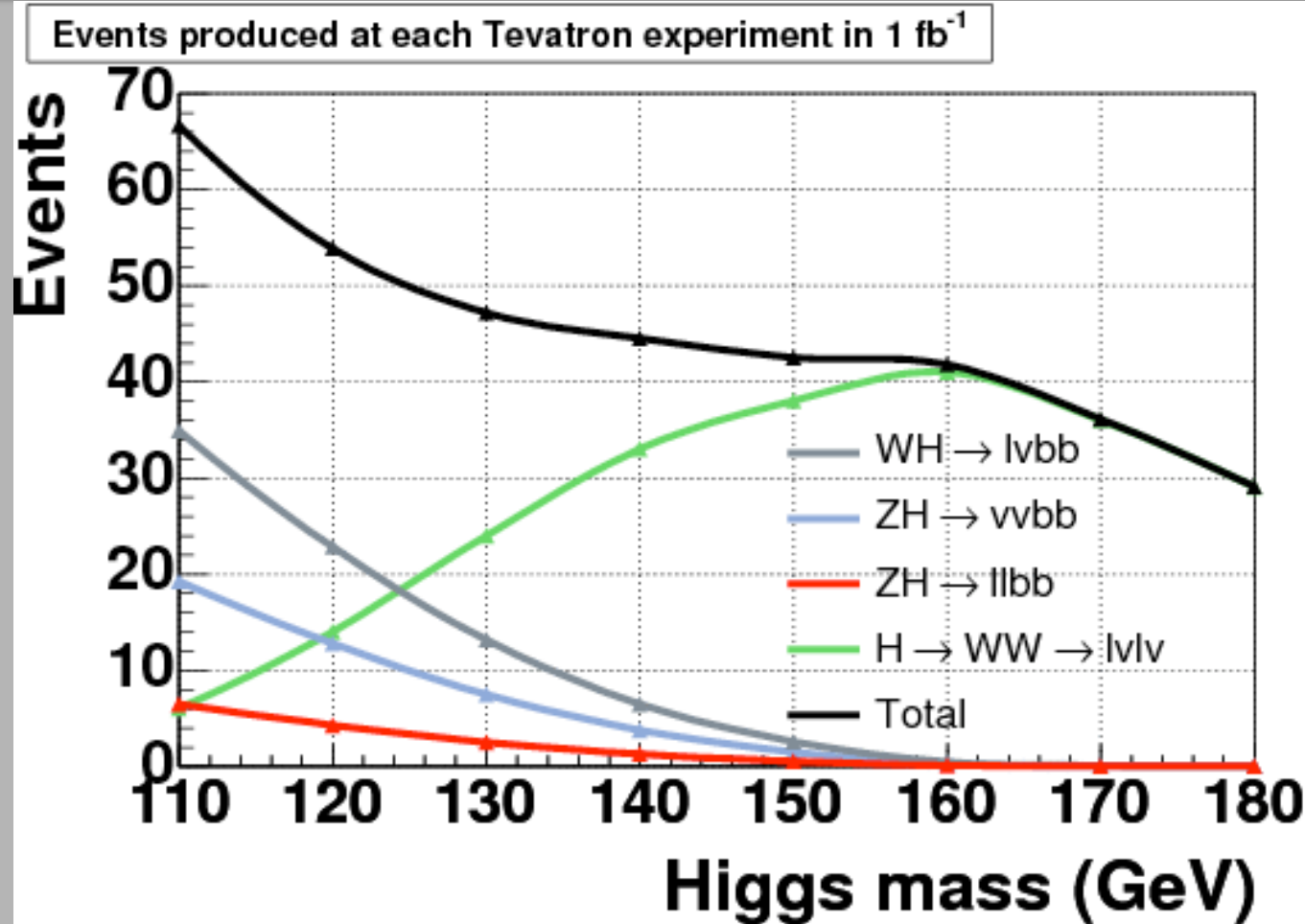
H $\rightarrow$ bb: The basics

	Low Mass
Primary Production:	WH, ZH
Decay:	H $\rightarrow$ bb
Main modes:	bb+lv bb+vv bb+ll
Important features:	• B-tagging • Dijet resolution



Note: These are the most sensitive channels but all non-negligible production and decay modes are considered.

Higgs Production Rates



About 1000 Higgs events expected to be produced at the Tevatron in the full dataset! (10 fb^{-1})

Results: Low Mass ($M_H = 115 \text{ GeV}/c^2$)



Channel	CDF Limit x SM (expected)	D0 Limit x SM (expected)
$WH \rightarrow l\nu bb$	3.5	4.8
$ZH \rightarrow \nu\nu bb$	4.0	4.0 (New!)
$ZH \rightarrow llbb$	5.5	5.7
$H \rightarrow WW \rightarrow l\nu l\nu$	10.8 (New!)	8.6 (New!)
$ZH+WH \rightarrow jjbb$	18	19.9
$H \rightarrow \tau\tau$	15 (New!)	12.8 (New!)
$H \rightarrow \Upsilon\Upsilon$	13 (New!)	11 (New!)

Results: Low Mass ($M_H = 115 \text{ GeV}/c^2$)



Channel	CDF Limit x SM (expected)	D0 Limit x SM (expected)
WH $\rightarrow$ $l\nu bb$	3.5	4.8
ZH $\rightarrow$ $\nu\nu bb$	4.0	4.0 (New!)
ZH $\rightarrow$ $ll bb$	5.5	5.7

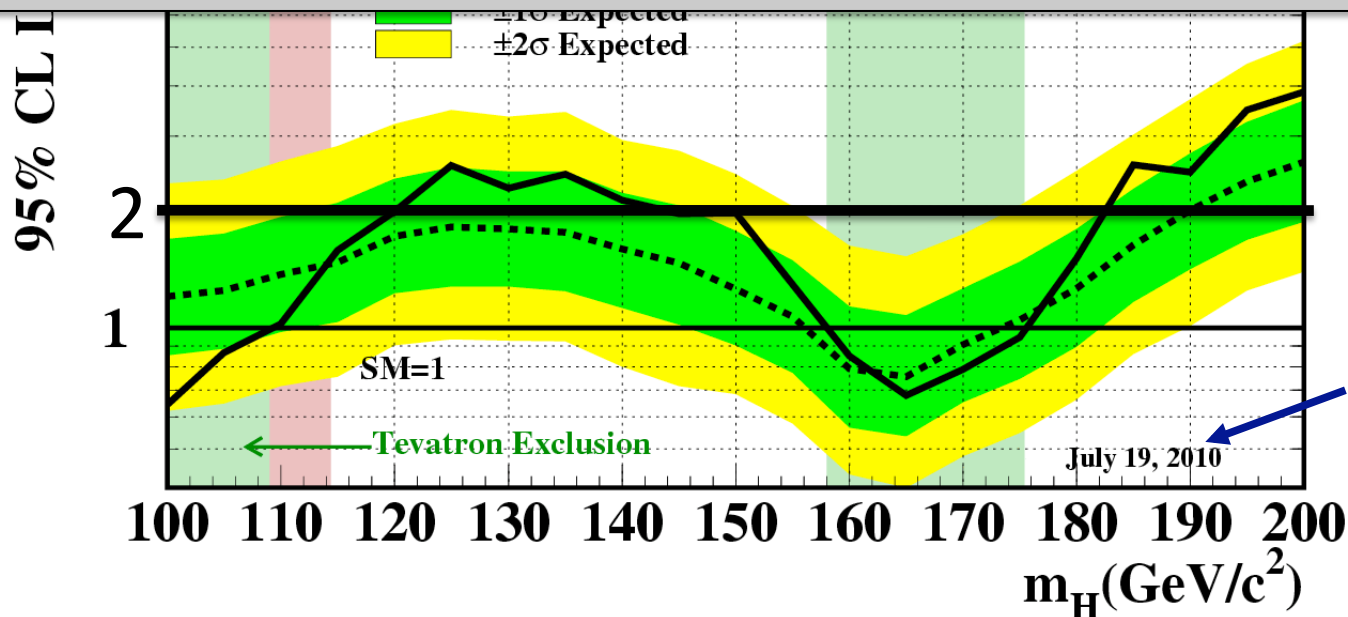
These clearly dominate at low mass for $h \rightarrow bb$,
so I will focus on them.

Low-mass Combination



All channels combined from the CDF and D0 experiments

Within a factor of 2 of exclusion sensitivity to SM over the full interesting mass range!



arXiv:1007.4587

Theory concerns



- Signal cross sections
 - Theorists provide uncertainties for higher order and PDF and we use them consistently for all channels in the combination. (in pretty good shape for low-mass)
- Signal kinematic modeling
 - No control region for this! 😊
 - Some theory help might be good here.
 - What are the limitations of our theory model and what alternative samples could we make to access this uncertainty?

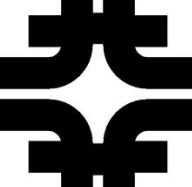
Theory concerns



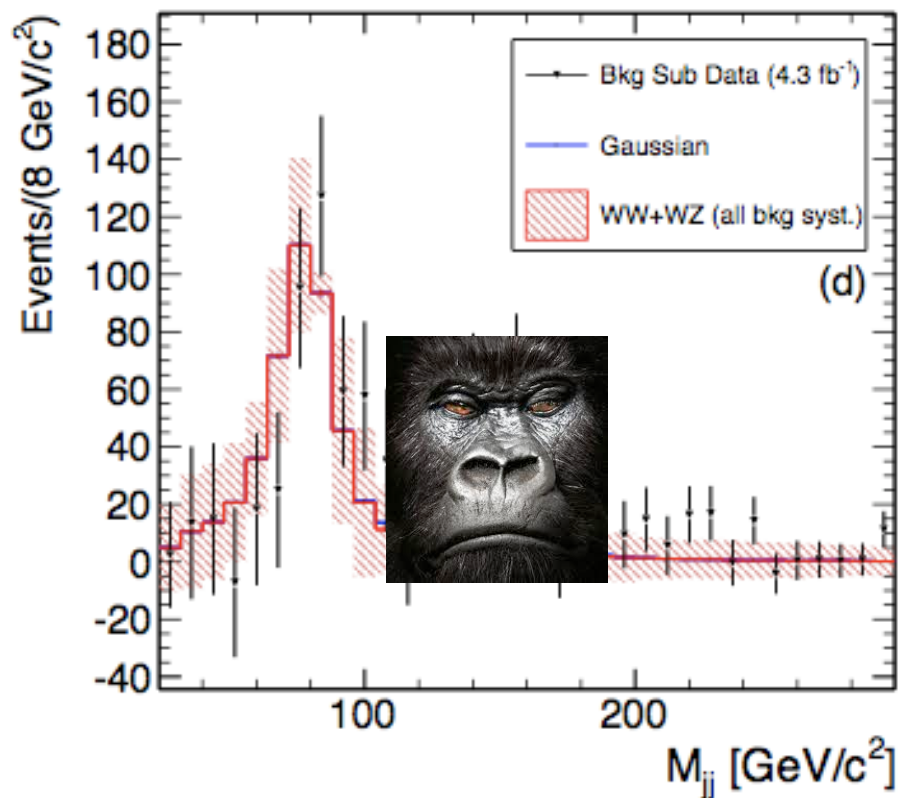
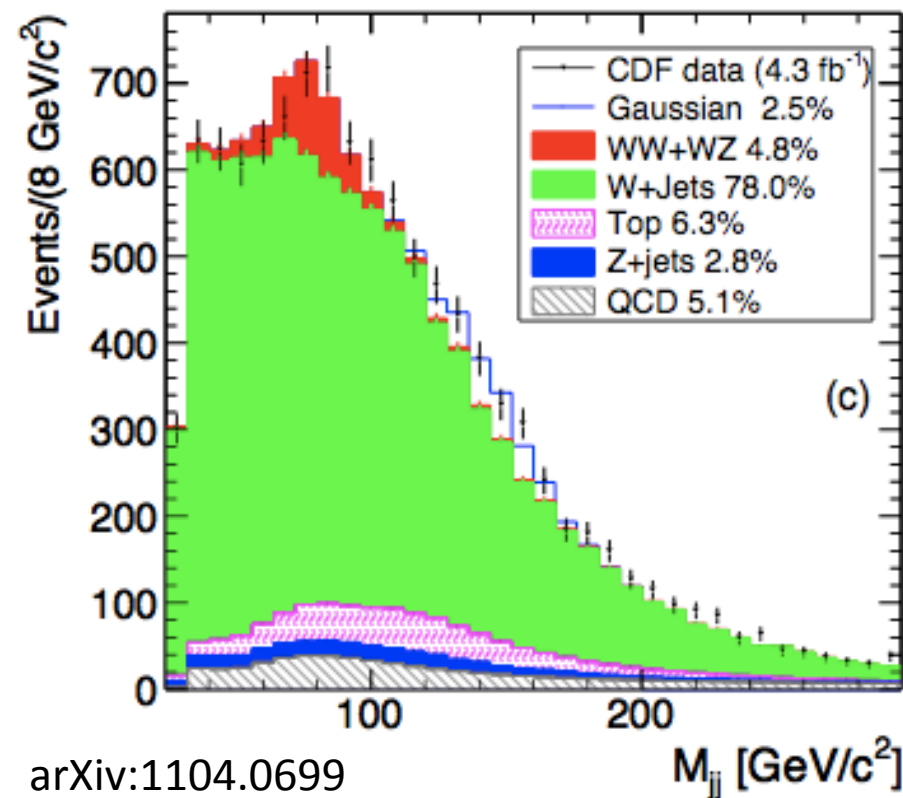
- W+jets modelling
 - Alpgen/Sherpa/PYTHIA/etc...
 - Should we use control regions for correcting, or assessing systematic uncertainties on shapes?
- Uncertainties on signal and background acceptances:
 - PDFs
 - ISR/FSR
 - Reasonably well-defined solutions here. Not a large effect in most cases for $H \rightarrow b\bar{b}$ analyses



**You Can't Ignore the
800 Pound Gorilla**



W+jj



arXiv:1104.0699

- Special Wine & Cheese seminar: [3.2 sigma excess!](#)
 - CDF reports an excess in the dijet mass for W+2 jet events above the W mass peak.
 - If fit to Gaussian of with of mass resolution the significance can be calculated as 3.2 sigma
 - Not consistent with SM Higgs, not seen in Z+jets
 - Provisionally accepted by PRL within 48 hours of submission
- Analysis web page: <http://www-cdf.fnal.gov/physics/ewk/2011/wjj/>

Only two options:



- 1) New physics has been discovered that might be even more interesting than the Higgs boson. So, no need to waste our time here...
- 2) There is some limitation in the background model that doesn't get the kinematics right for the $W+jj$ sample

Since we ARE here, let's assume 2)
and consider possible theory
limitations in the $W+jj$ model.

Some supporting evidence to this strategy:

- No statistically significant deviation from SM expectation in Z+Jets
- No significant excess in W+Jets events with one or more b-tagged jets
- M_{lvjj} and $M_{lvjj} - M_{jj}$ distributions compatible shape to background

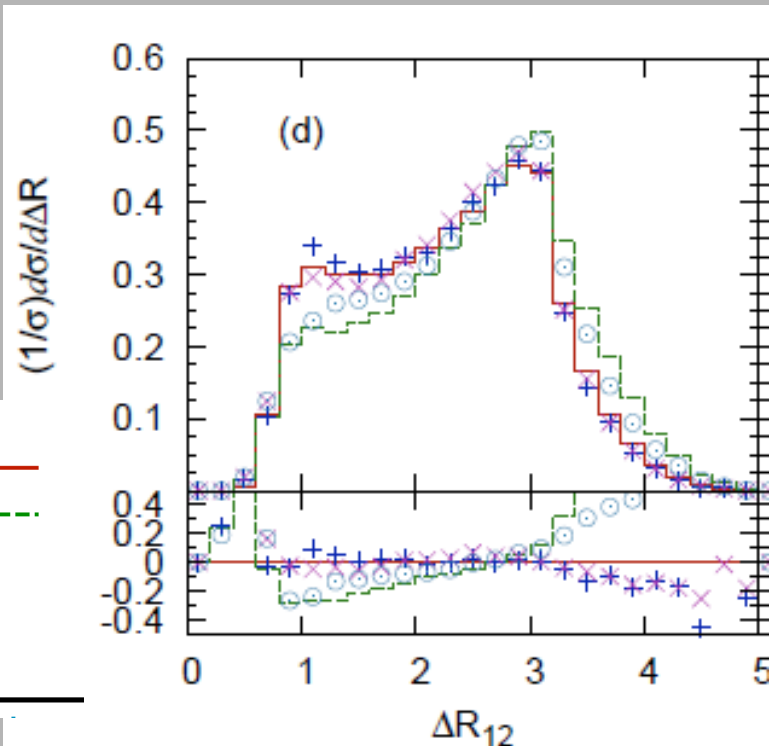
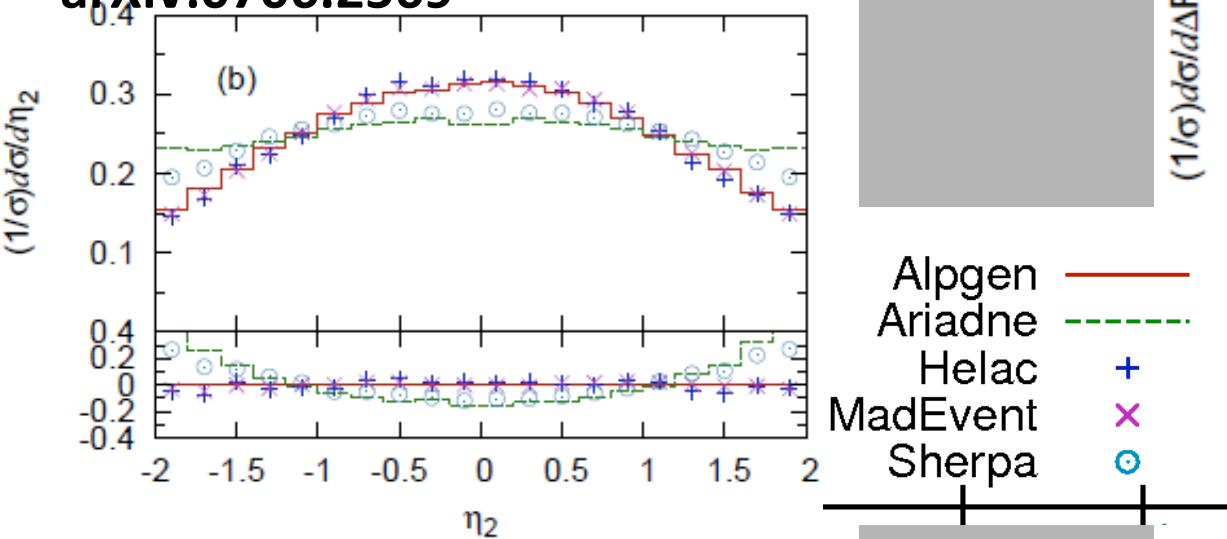
W+jets modeling efforts



Theorists are well aware that different generators predict different distributions:

“Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions”

arXiv:0706.2569



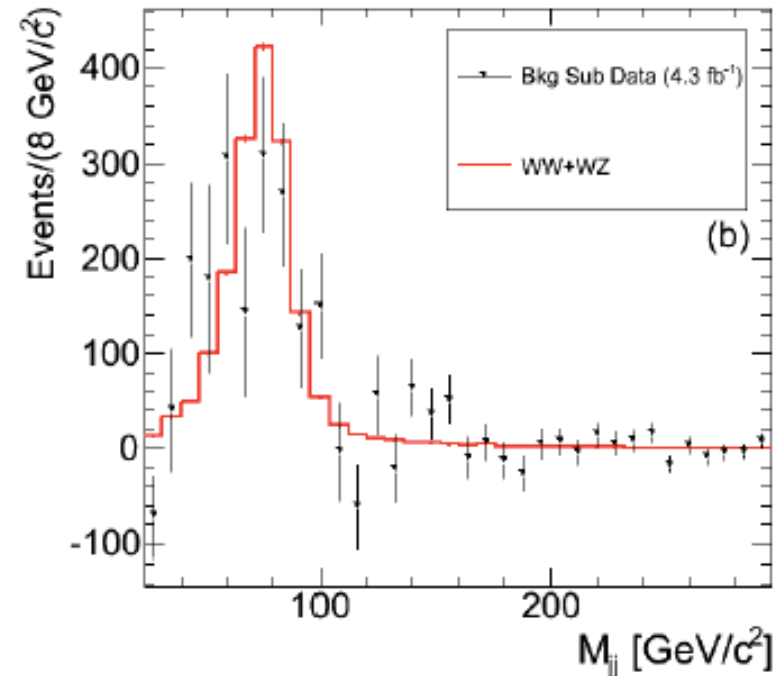
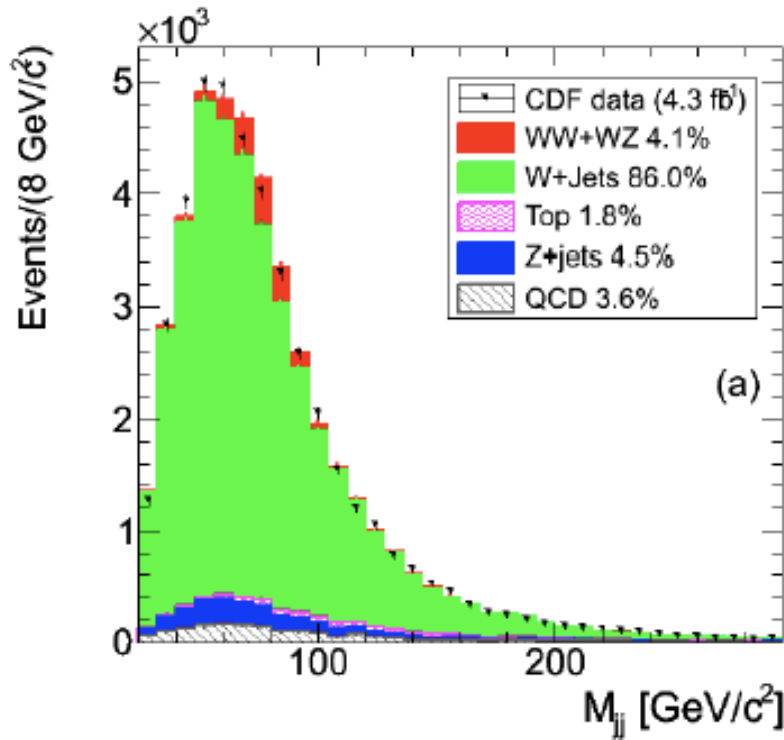
What is the best way to take this into account in our low-mass Higgs analyses?

Re-weighting the W+jj MC



- D0 does some re-weighting to the MC based on control regions in the data for low-mass Higgs.
 - pre-b-tag control region
 - 2nd jet eta and some other variables are used
- This weighting function can change a lot based on the specific final state and event selection.
- Signal injection studies can be done to make sure it doesn't bias your sensitivity (if signal model is known)
- CDF currently does no such re-weighting

Excess with WH cuts at CDF



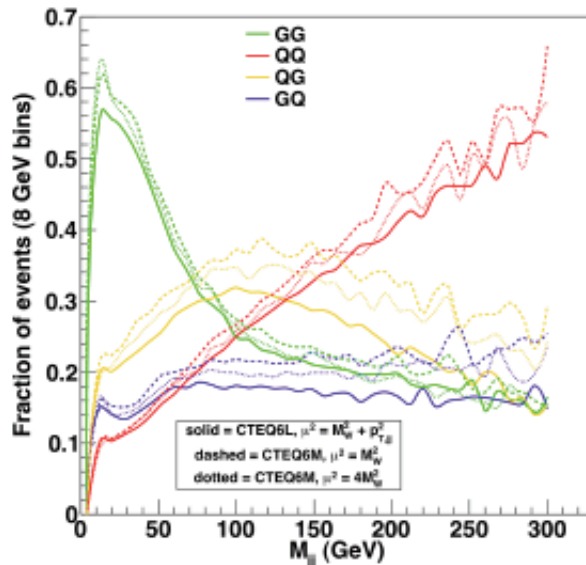
- Excess still exists but is not significant using standard Higgs search selection criteria (lowering jet E_T cut from 30 to 20 GeV and removing dijet $p_T > 40$ GeV cut)
- However, high p_T region (where excess exists) could contain events that are more Higgs-like

-
- The figure displays the impact of reweighting on the distribution of $\Delta R(j_1, j_2)$ for the Wbb template in the Central Lepton Pretag region.
- Top Row: $\Delta R(j_1, j_2)$ Distribution**
- Left:** Histogram of $\Delta R(j_1, j_2)$ for various processes. The Wbb process is highlighted in green. The distribution is peaked around $\Delta R(j_1, j_2) \approx 3.2$.
 - Right:** Histogram of $\Delta R(j_1, j_2)$ after reweighting. The distribution is shifted towards lower $\Delta R(j_1, j_2)$ values.
- Middle: Reweighting Factors**
- Plot of reweighting factors for different processes. The factors are generally close to 1.0, indicating that the reweighting is effective in adjusting the distribution.
- Bottom Row: Wbb Template Distribution**
- Left:** Histogram of $\Delta R(j_1, j_2)$ for the Wbb template. The distribution is peaked around $\Delta R(j_1, j_2) \approx 3.2$. The default distribution (black) is compared with the dR reweighted distribution (red).
 - Right:** Logarithmic plot of the BNN ST+ST distribution for the Wbb template. The distribution is peaked around $\Delta R(j_1, j_2) \approx 0.7$. The default distribution (black) is compared with the dR reweighted distribution (red).

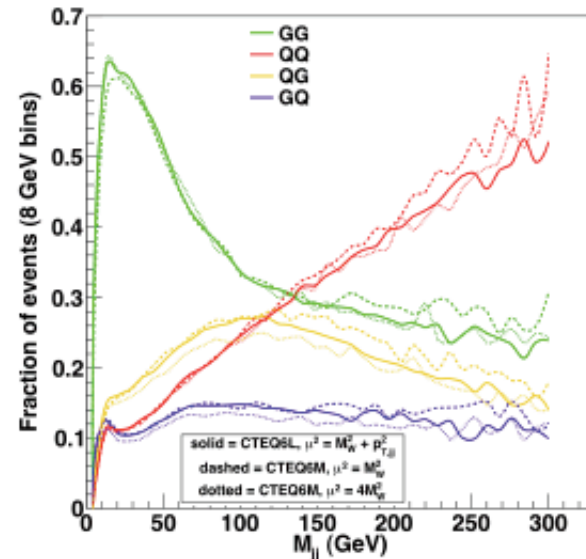
More work in progress



Fraction of total W+jj, jet composition



Fraction of total Z+jj, jet composition



- ALPGEN plots from Adam Martin
- Different diagrams contribute to each final state category (sample different PDF components and different scales?)
- Mis-modeling of detector acceptance and/or JES for quark versus gluon jets could also effect background shape
- Currently, investigating SHERPA and MADGRAPH

Tevatron $H \rightarrow b\bar{b}$ Summary



- Dataset should reach $\sim 10 \text{ fb}^{-1}$
- Tevatron has sensitivity to a SM Higgs boson!
- So, uncertainties on theory model must be handled properly
 - > Should be able to exclude at 95% confidence level over the entire mass range with $\sim 10 \text{ fb}^{-1}$

Or, we might just see something!
(besides the 800 pound Gorilla)

For more details on Higgs searches:

- <http://www-cdf.fnal.gov/physics/new/hdg/hdg>
- <http://www-d0.fnal.gov/Run2Physics/higgs/>





Backup (slowly!)

Wjj: Selection of events



- **Leptonic W candidate**

- one lepton (electron or muon) with $ET > 20 \text{ GeV}$,
- $MET > 25 \text{ GeV}$
- $MT(W) > 30 \text{ GeV}/c$

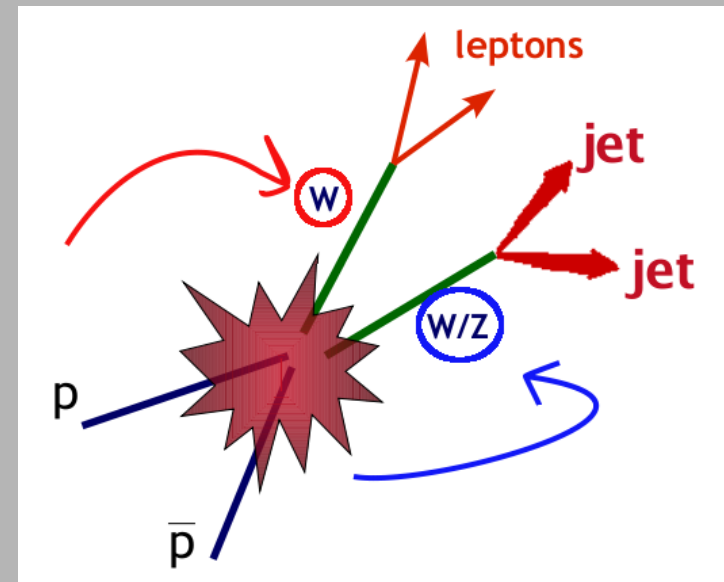
- **Hadronic W/Z candidate**

- Exactly 2 jets (reconstructed using JETCLU, $R = 0,4$)
- $ET > 30 \text{ GeV}$ (corrected for detector inefficiencies) and $\eta < 2.4$
- $P_{T\{jj\}} > 40 \text{ GeV}/c$

- ET_{jj1}

- $> 0:4$

- $5 PT(jj) > 40 \text{ GeV}/c$



Wjj: Background model

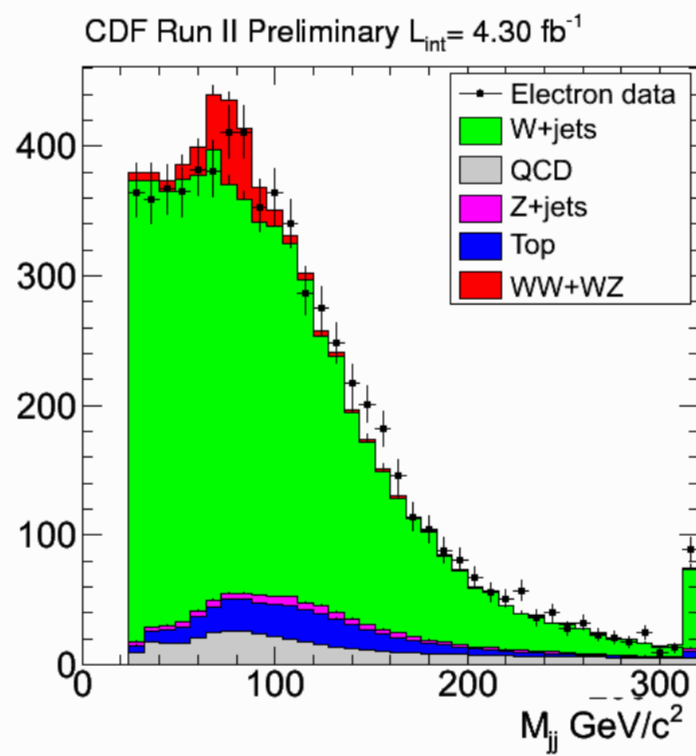
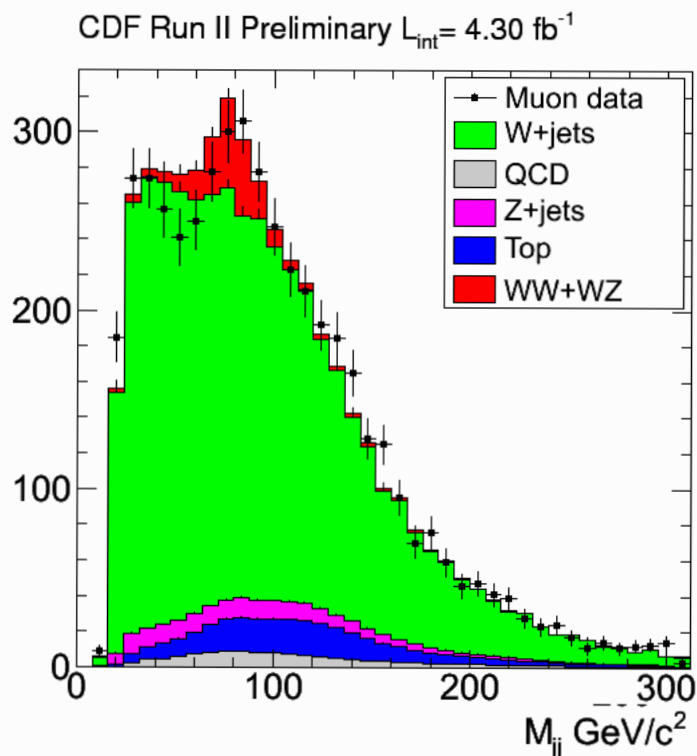


QCD events modeled using orthogonal selection

Normalization extracted from fitting the MET distribution of data

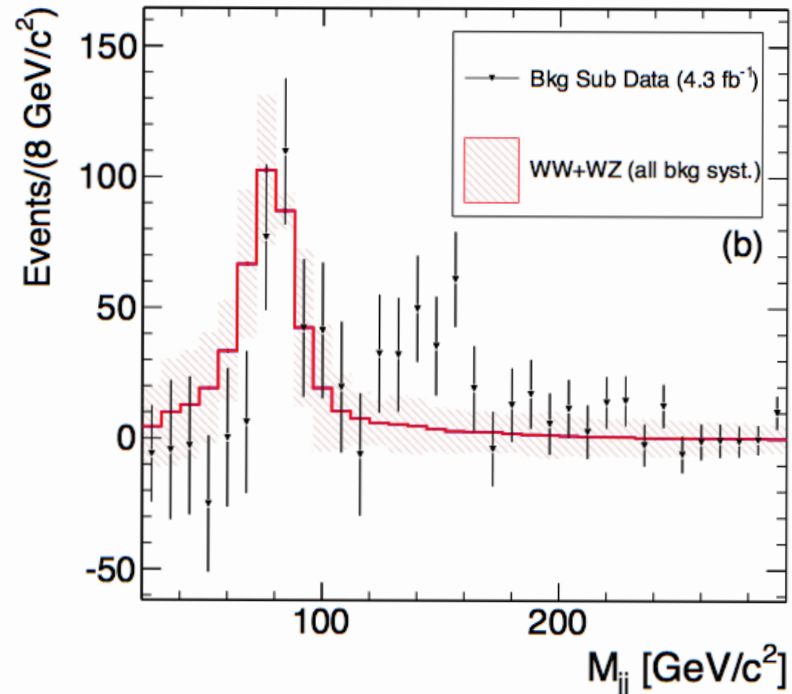
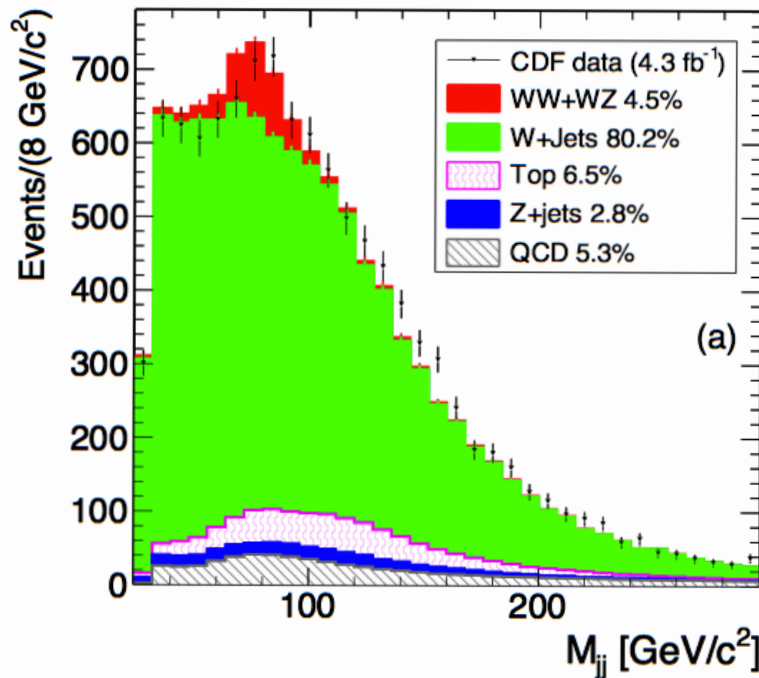
For control region plots please refer to public webpage

Process	Model	σ (pb)
WW/WZ inclusive	PYTHIA	15.9 ± 0.9
$Z \rightarrow e, \mu, \tau$ +jets	ALPGEN+ PYTHIA	787 ± 85
$t\bar{t}$	PYTHIA	7.5 ± 0.83
single top	MADEVENT + PYTHIA	2.86 ± 0.36
W+jets	ALPGEN+ PYTHIA	from data
QCD multijet	from data	from data



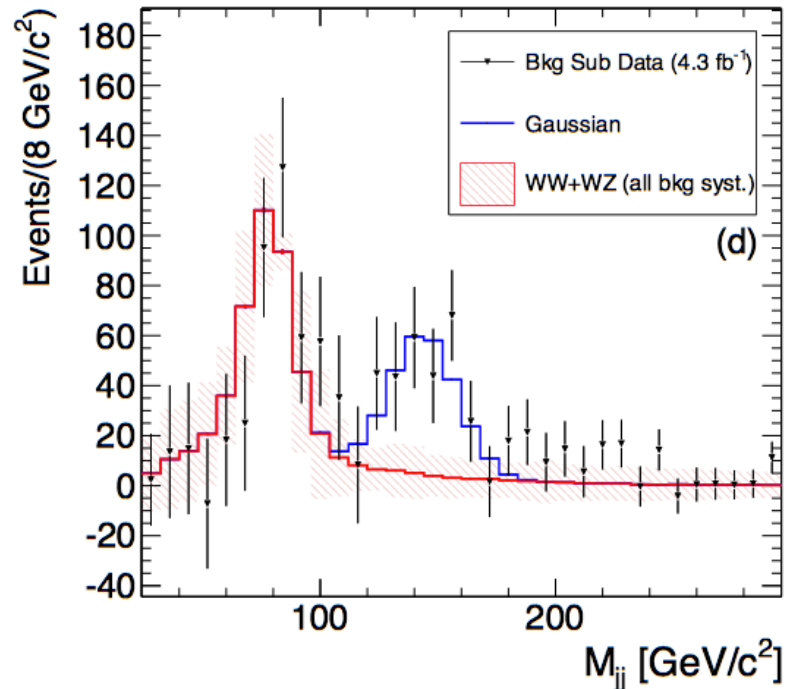
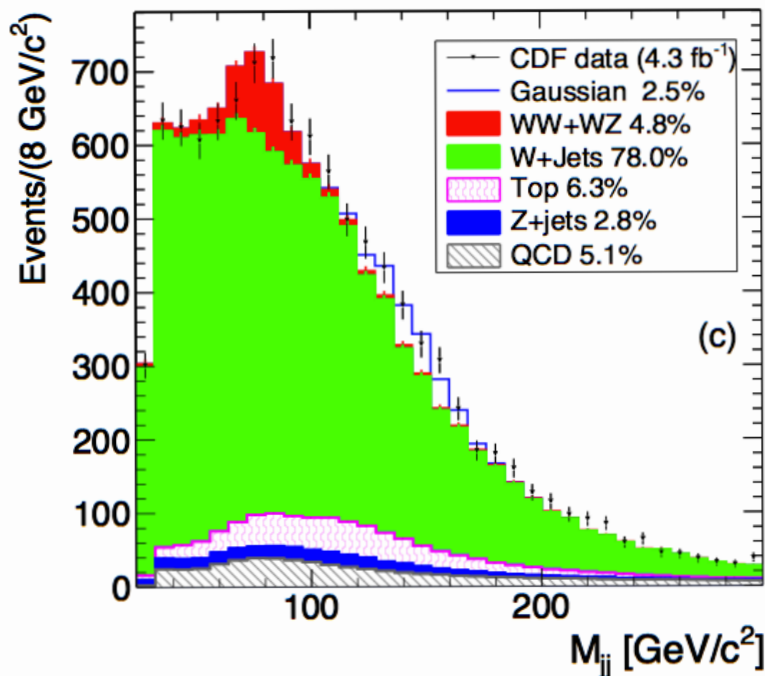
Wjj: Fit to the dijet mass

- Combined chi2 fit to the dijet mass distribution in electron and muon samples.
 - **W + jets** (unconstrained, normalization determined from the fit)
 - **QCD** (normalization constrained to its fraction with 25 % error)
 - Z + jets** (normalization constrained to the measured cross section)
 - top & single top** (normalization constrained to the theoretical cross section)
 - WW+WZ** (normalization constrained to the theoretical cross section)



Wjj: Fit SM template + gaussian

- Chosen to estimate the significance of the excess assuming an additional gaussian component
- The gaussian assumption is a simplified model, since the exact shape would depend on the specific physics process and the heavy flavor content of the decay products.
- Search for a peak compatible with the detector resolution
- Delta chi2 between two fits is 20.31. 3.7 standard deviations (including trial factor)



Wjj: Systematics

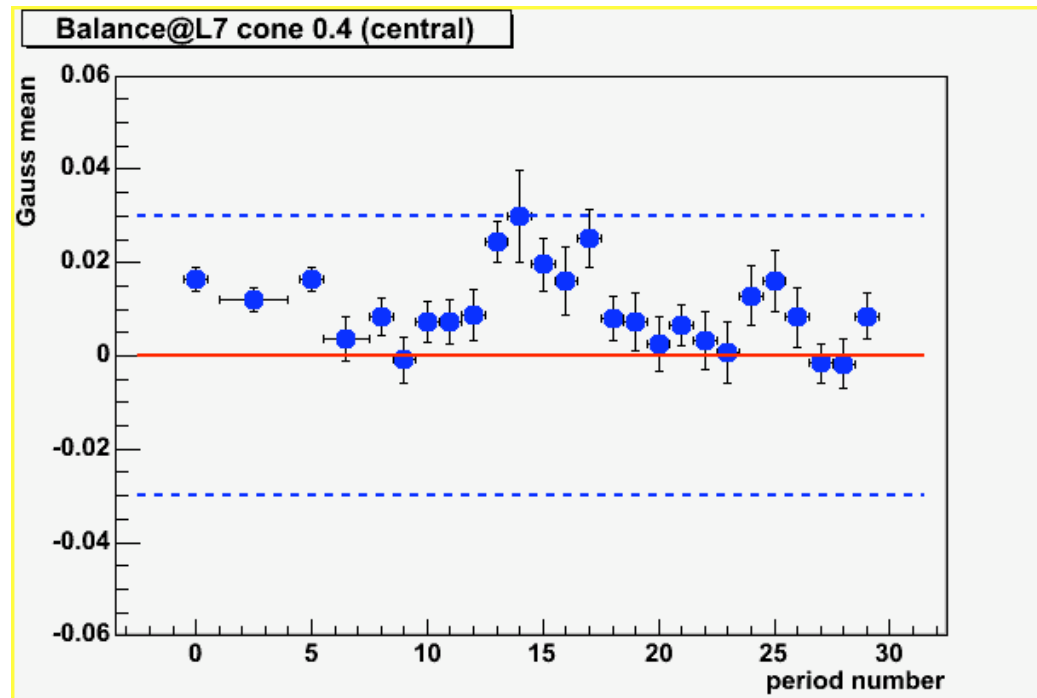
- Apply Jet energy scale syst to all MC based processes
- QCD shape systematic evaluated using different data sidebands
- for W+jets change the renormalization and factorization scale (Q^2)
- To evaluate the significance of the resonance, we apply a procedure called “supremum p-value”
- If N_{syst} is the number of systematics sources, we generate a toy MC sample for each combination of the N_{syst} , i.e. in each sample, some of the systematics are varied.
- For each sample, we evaluate the corresponding p-value using the D_{chi^2} between the background only and signal hypothesis as test statistics. The significance we quote for our final result is the largest among the p-values
- Taking into account the trial factor the largest pvalue is 7.4×10^{-4} corresponding to a significance of 3.2 standard deviations

Wjj: Further checks

- We checked the effects of NLO and found them to be negligible
- Using the expectations from a simulation of a W boson plus a particle with a mass of 150 GeV/c² and decaying isotropically into two jets we estimate a cross section of 4pb.
- Tried to look at the flavour composition of the jets:
 - Compared the **fraction of events with b-jets** in the sidebands to that in the excess region: no significant deviation is found
 - Looked at the total mass distribution in order to investigate quasi resonant behavior and found the distribution shape to be compatible with the background only hypothesis

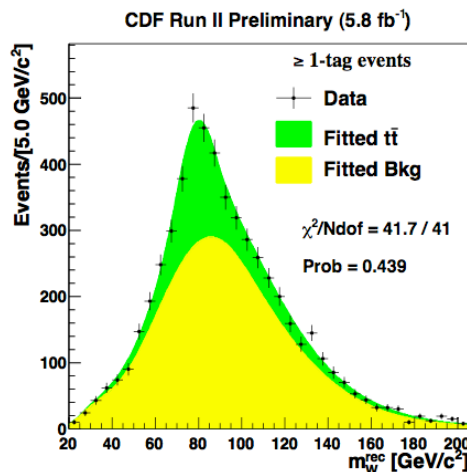
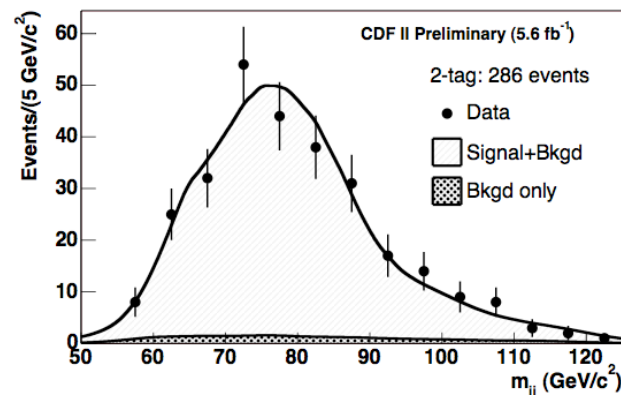
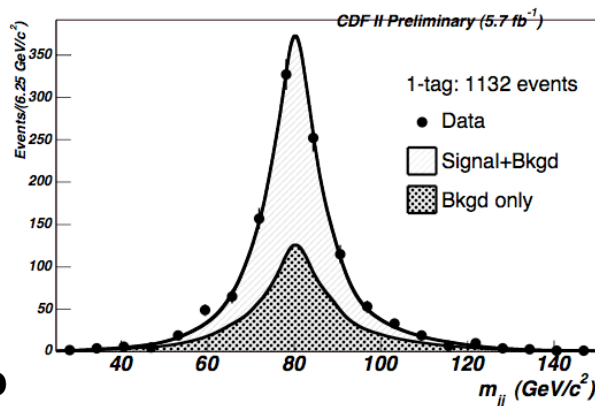
Wjj: JES from gamma+jets

- JES validated period-by-period using gamma+jet events(mixture of quark and gluon jets)
- Shown below is $Pt(\text{gamma})-Pt(\text{jet})/Pt(\text{gamma})$



JES from $t\bar{t}$ events

- Pure samples of light quark jets
- A few 1000s hadronic W s, from three different $t\bar{t}$ decay modes.
- All right on the spot!
- JES for light quarks known to 1% level



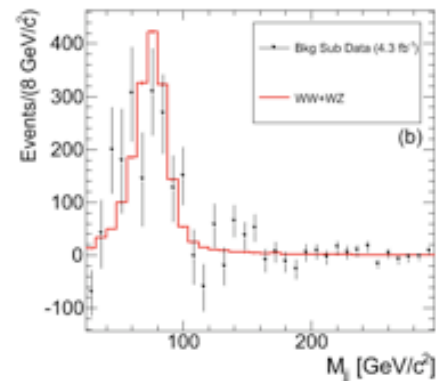
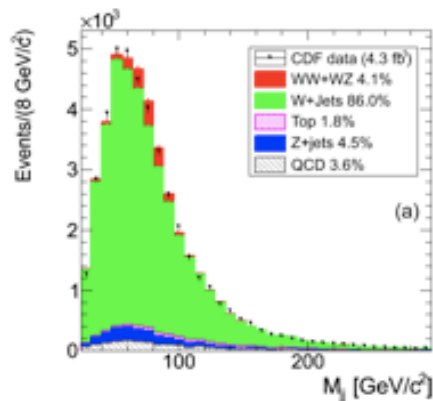
More plots/infos

on http://www-cdf.fnal.gov/physics/new/top/public_mass.html

Mjj details

- **Variation with E_T threshold**

The number of excess events is determined as a function of the jet E_T threshold. The number reduces from 262 ($E_T=30$ GeV) to 37 ($E_T=65$ GeV). If the E_T threshold is reduced to 20 GeV and the requirement on pT_{jj} removed (as is the case in CDF Higgs analyses) then the significance of the excess is reduced and becomes 1.1 sigma (see plots below).



Mjj details



- **ΔR distributions.**

The ΔR distribution is studied to investigate possible effects that could result in a mismodeling of the dijet invariant mass distribution. Two control regions are studied: the first defined by events with $M_{jj} < 115$ and $M_{jj} > 175 \text{ GeV}/c^2$ and the second defined by events with $pT_{jj} < 40 \text{ GeV}/c$. We use these regions to derive a correction as a function of ΔR so that ΔR agrees with the Monte-Carlo and apply this reweight to the events in the excess region. We find that the statistical significance of the result is reduced by one sigma for reweightings from the M_{jj} sidebands and increased by one sigma using reweights based on the $pT_{jj} < 40 \text{ GeV}/c$ sample.

Z+jj

Z+jj check

