The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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2400-15

Workshop on Strongly Coupled Physics Beyond the Standard Model

25 - 27 January 2012

W+jj and other hints of technicolor at colliders

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W+jj and other collider hints of Technicolor

Adam Martin
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ICTP - Trieste, Jan 27th 2012

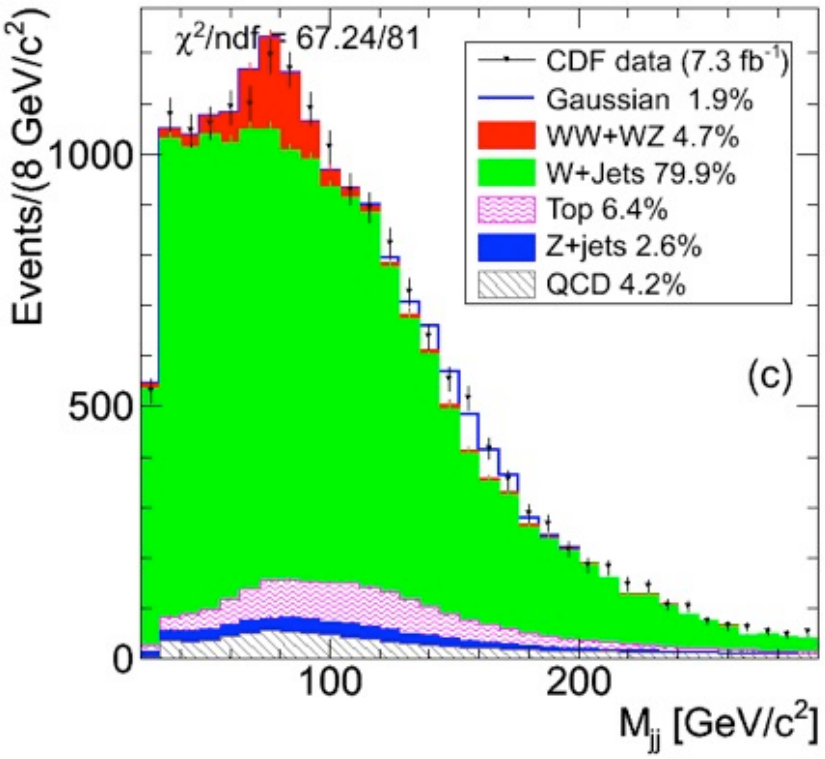
the CDF bump (1104.0699+update)

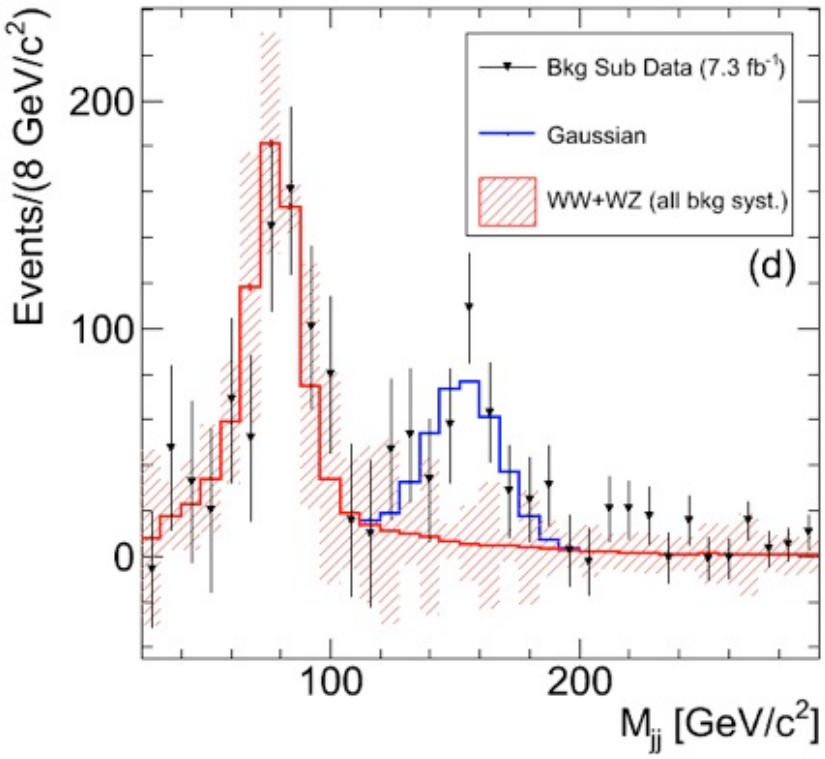
7.3 fb^{-1} data:

central l(e/μ), MET > 25 GeV,
2 jets p_T > 30.0 GeV, $p_{T,jj}$ > 40.0 GeV

look in dijet mass spectrum

4.1 (syst) sigma excess



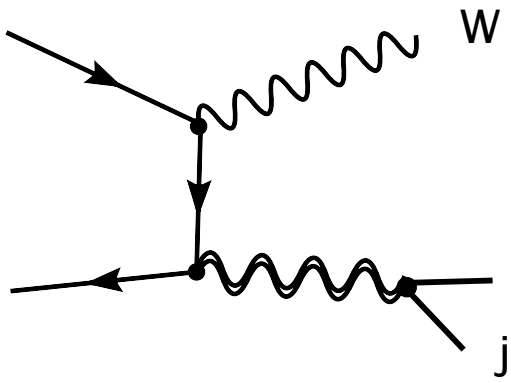


generated much excitement

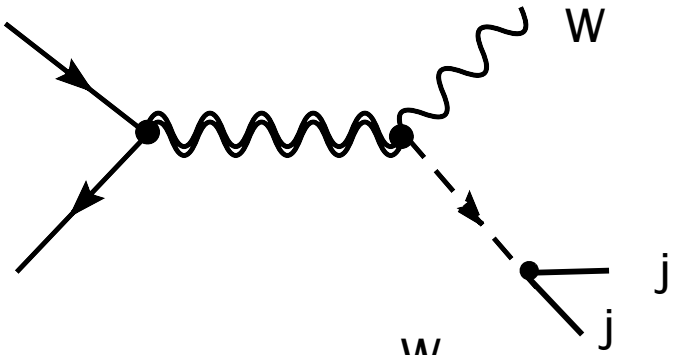
what (new physics) it could be...

tough to get a large enough cross section.. recall $\sigma(p\bar{p} \rightarrow WW/WZ) \sim 18$ pb

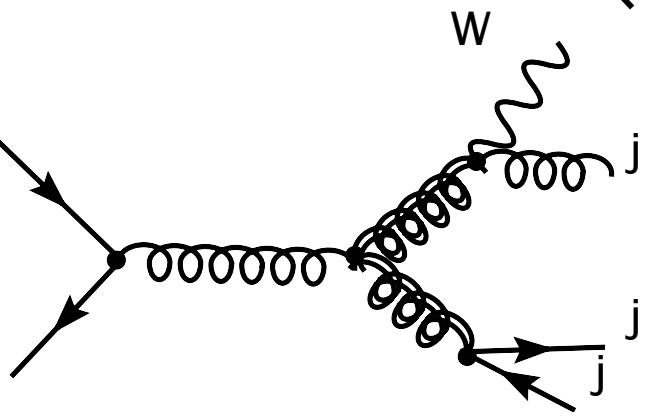
one resonance...



two resonances...



pair production...



more?

wait a minute...

- "I thought this went away...?" or "I heard this went away..."

NOPE

- "I remember something about a task-force/ investigation, what happened with that?"

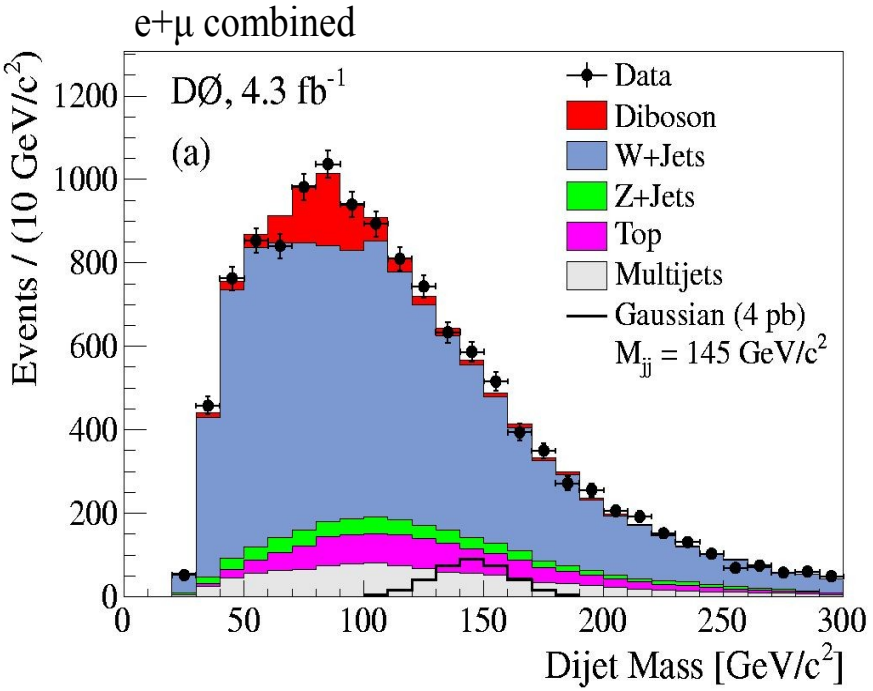
NOTHING

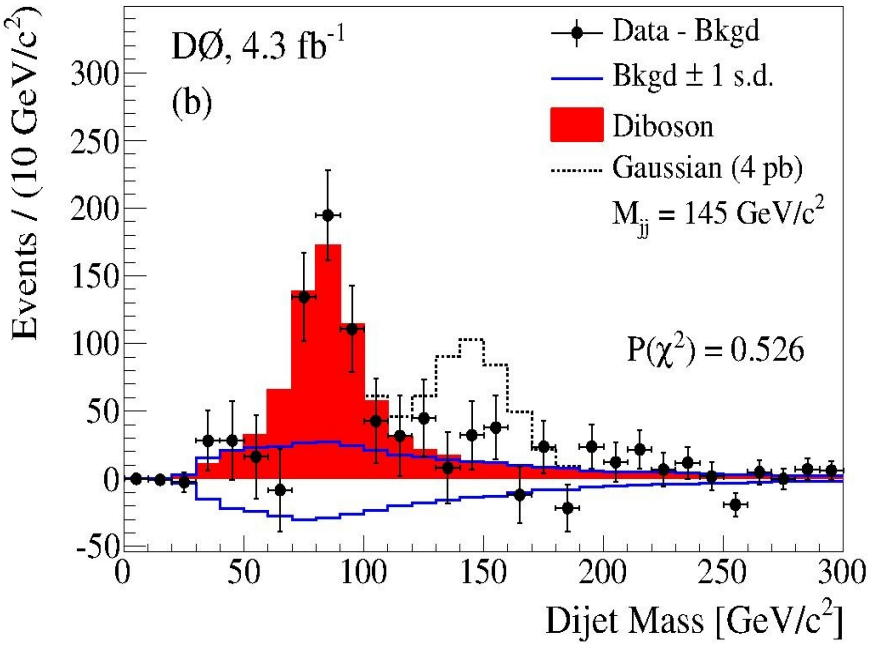
- "should I be worried about other searches: Higgs/BSM with W+jets as a background?"

YES

the D0 response (1106.1921)

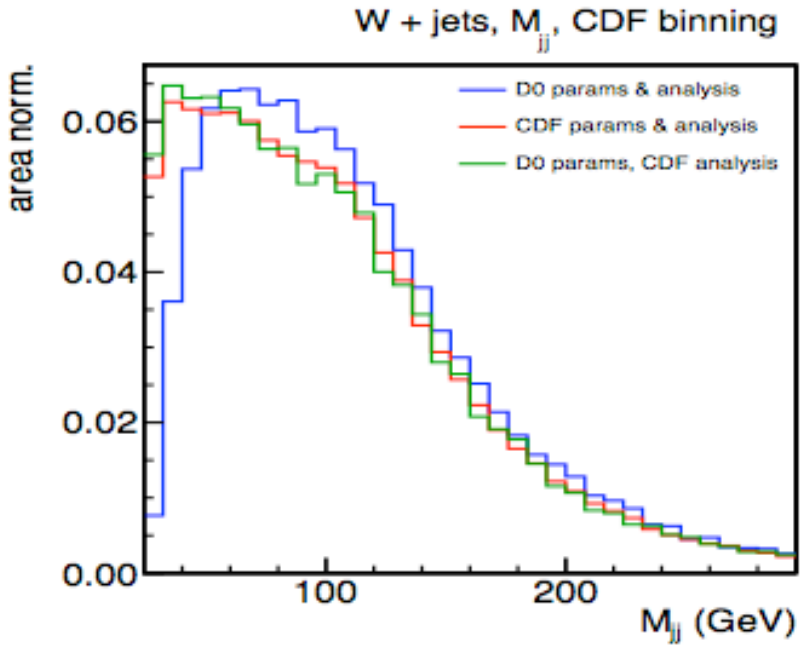
4.3 fb^{-1} data, same analysis as CDF (no reweight!)



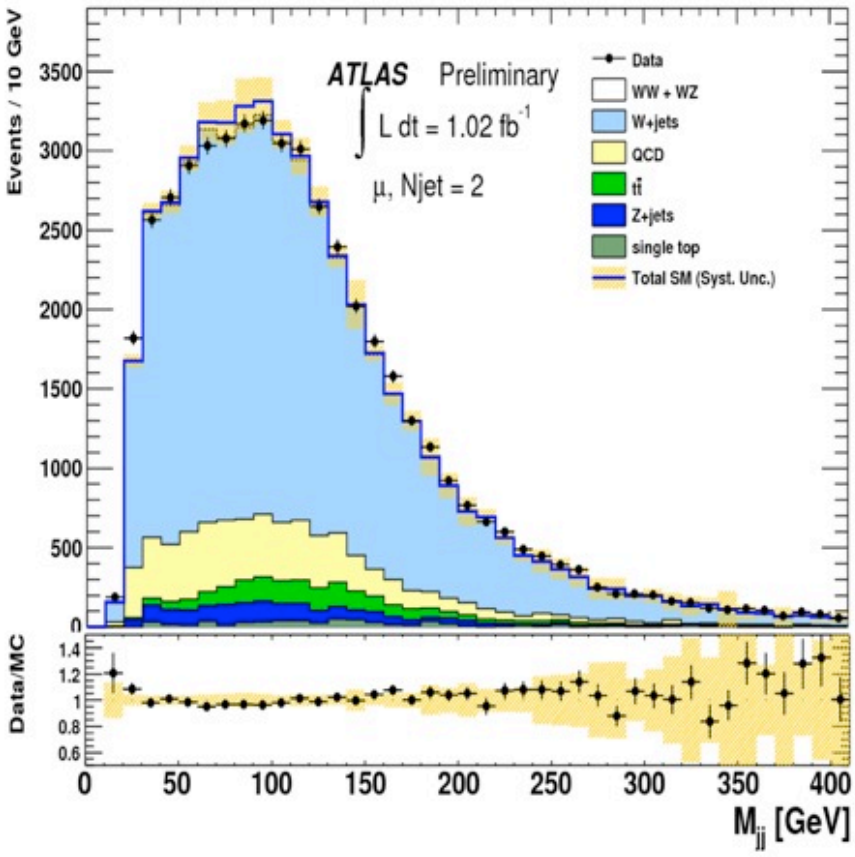


some excess, **BUT consistent with the SM**

the D0 response (1106.1921)



Nothing at the LHC...



ATLAS analysis (1 fb^{-1}) sees no deviation from SM

BUT not yet sensitive to WW/WZ

- W+jets increases by x10,
- qqbar induced processes only increase by ~ x4

difficult to study at the LHC

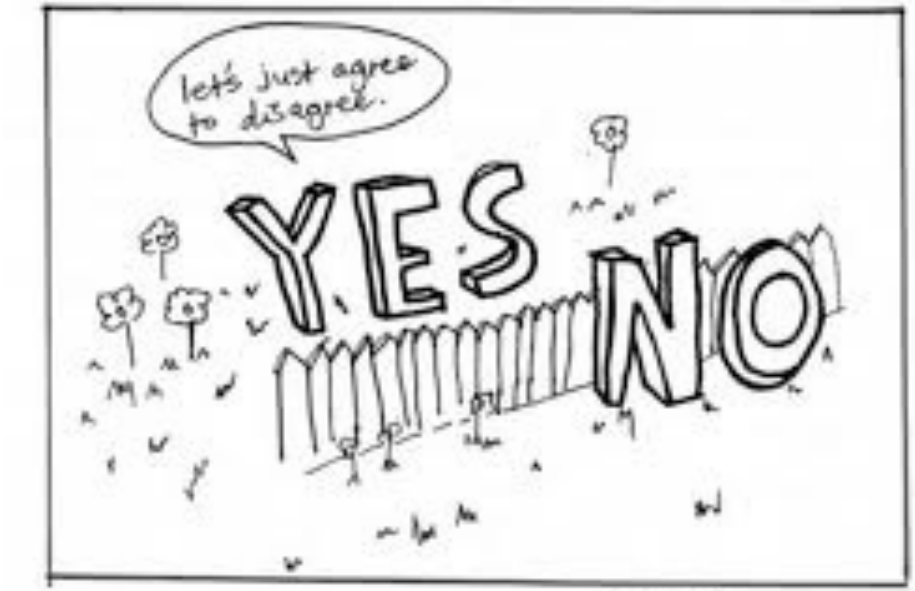
may rule out glue-induced or large coupling new physics

estimate that MUCH more data needed if qqbar induced NP. syst?

(Eichten, AM, Lane 1107.4075, Buckley et al 1107.5799)

what about this task force?

came.. saw... **agreed to disagree**



disbanded when leading SM explanation failed to explain excess

did get better estimates of how consistent/discrepant results are:

CDF: 3.0±0.7 pb

D0: $0.82^{+0.83}_{-0.82}$ pb

($0.42^{+0.76}_{-0.42}$ pb)

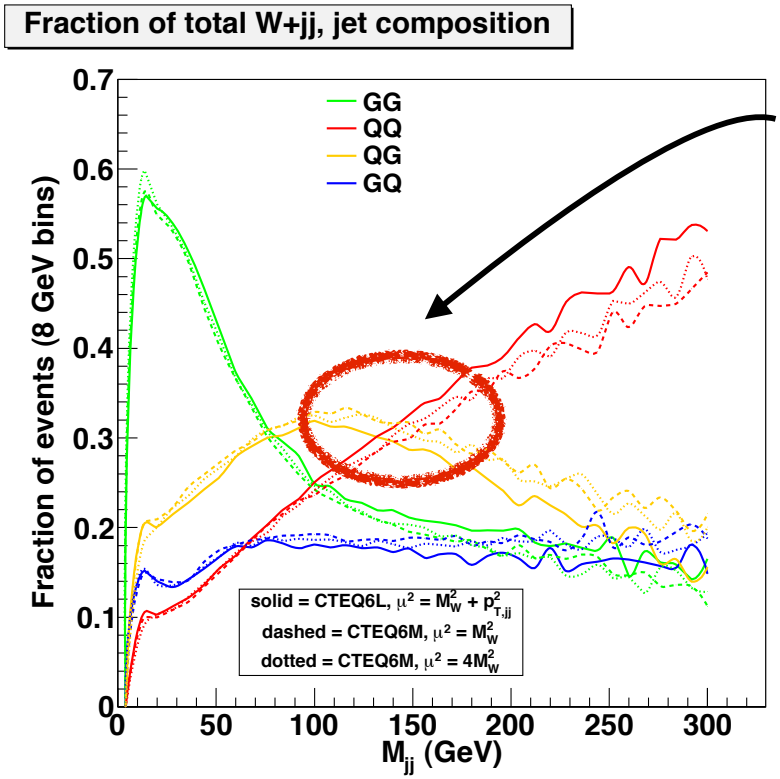
using H(bb)W, m_H = 150 GeV
acceptance*efficiency

& studied how MC choices/tunings effect results

first : quarks vs. gluons

lots of noise about mis-modeled gluon Jet Energy Scale (JES) as an explanation

- JES(p_T, η) known to % level for light quarks (from ttbar), but what about gluon-jets?



could be important ...

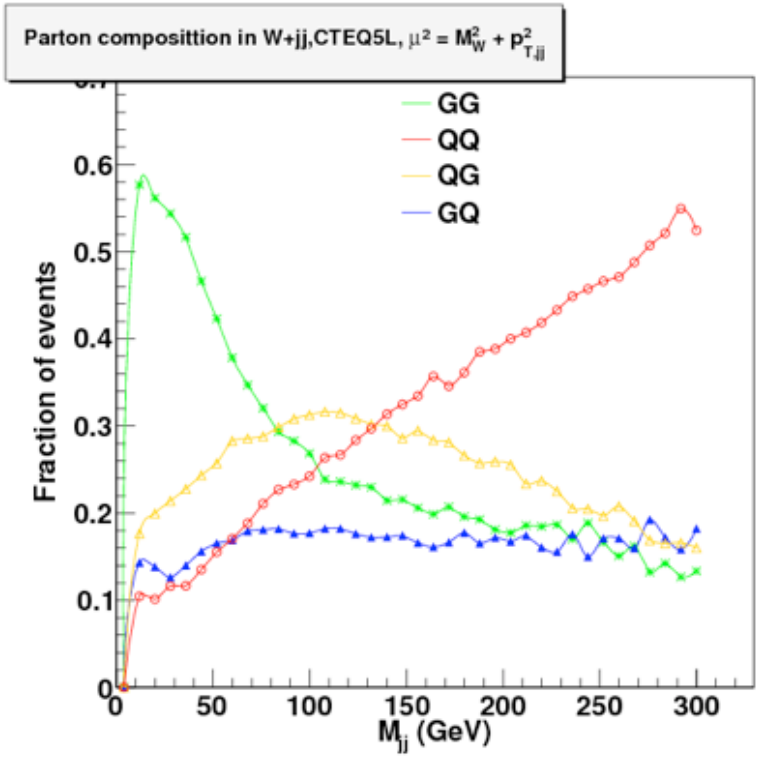
BUT if gluon JES is different, other processes will also be effected (dijets, gamma/Z + jets, etc.), as will other distributions

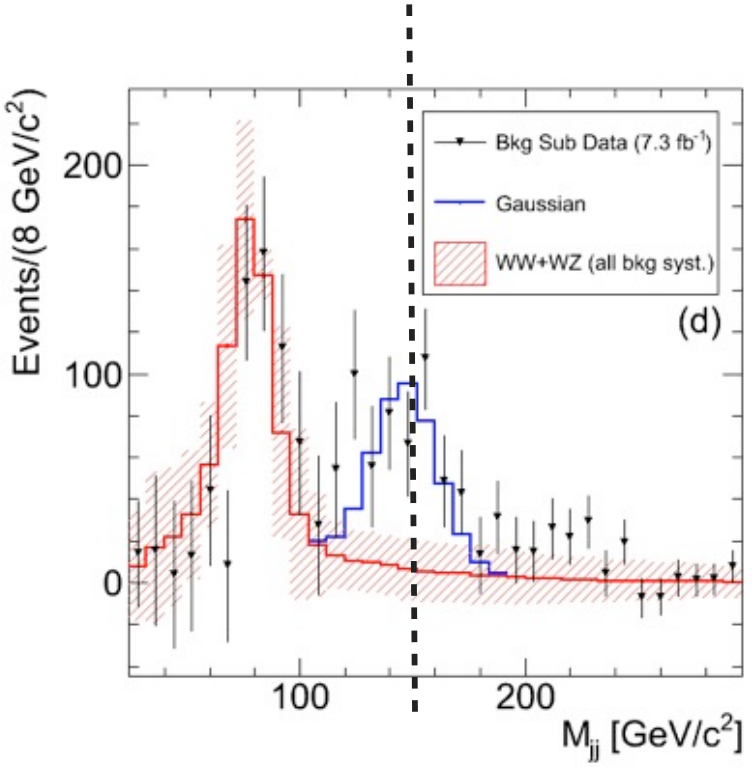
what makes a gluon jet?

SEE: www-cdf.fnal.gov/physics/ewk/2011/wjj/7_3.html

quarks vs. gluons: cross-checks

- vary p_{Tj} , $p_{T,2}/p_{T,1}$, changes gluon content (according to LO parton level)
- excess shape and location (M_{jj}) remains intact





increasing $p_{T,2}/p_{T,1}$

many other checks pursued by CDF (see CDF note 10601 (July '11))

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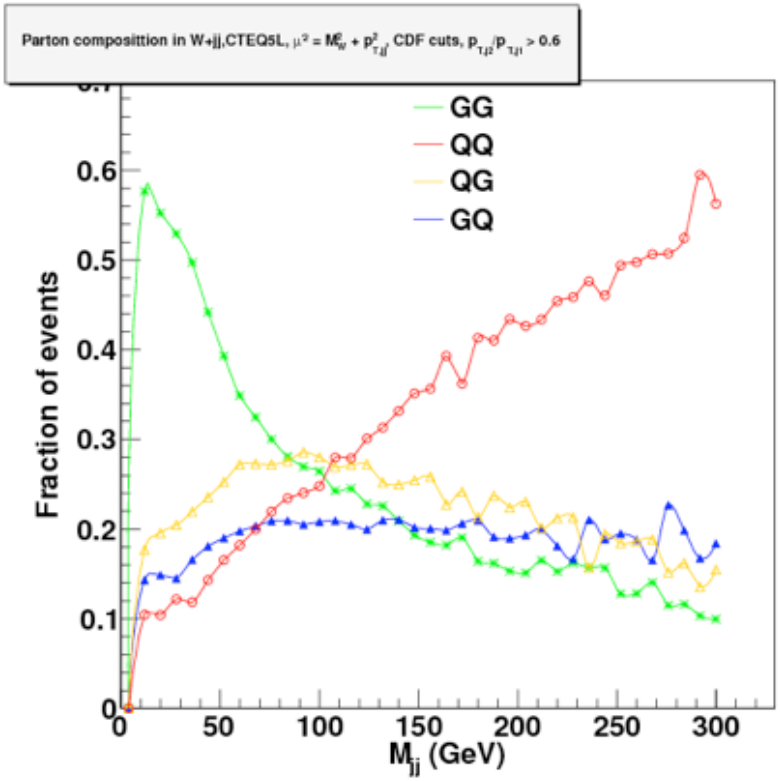

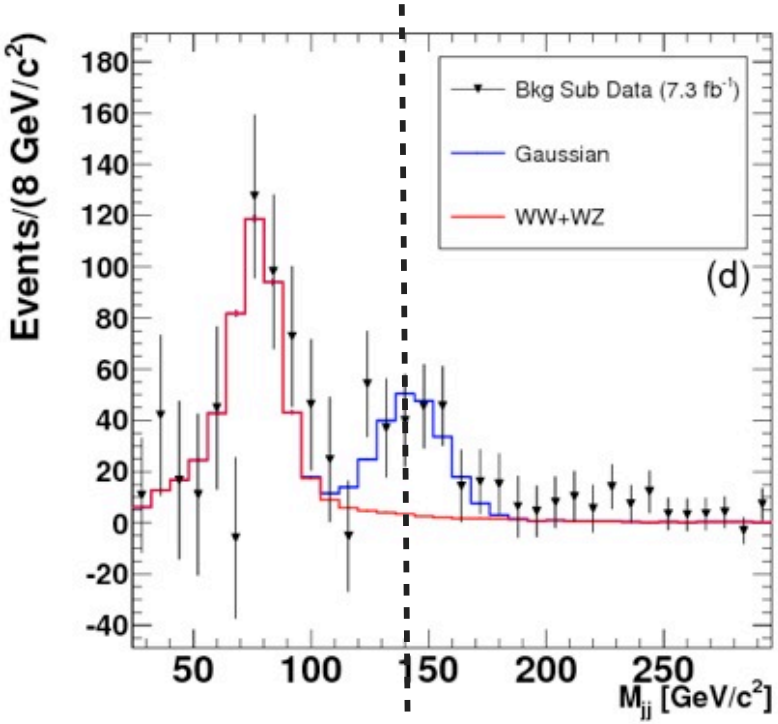

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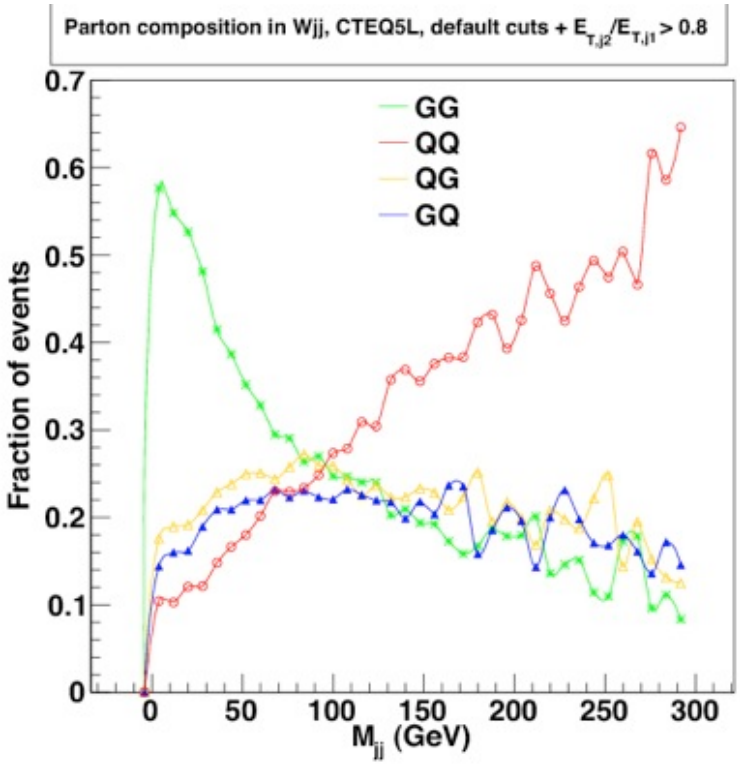
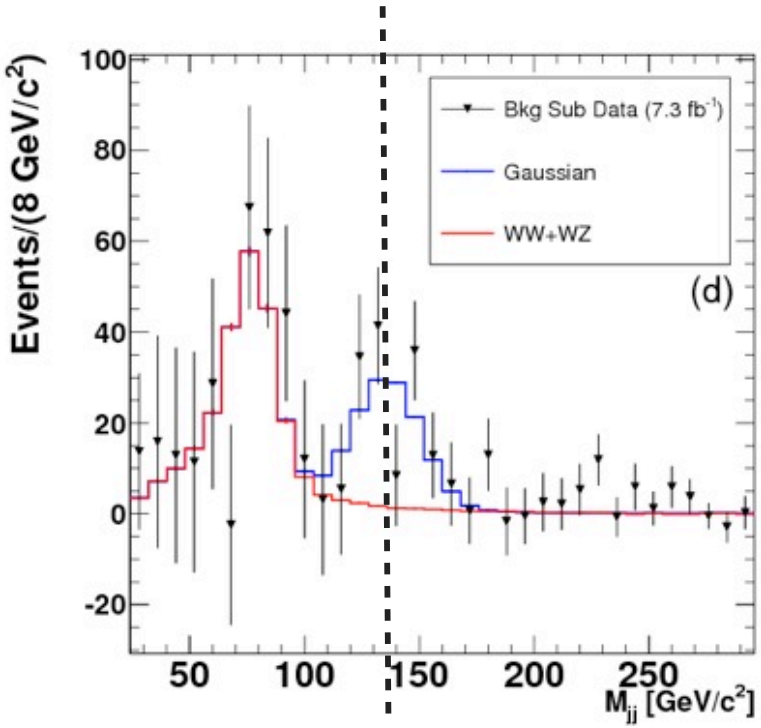




increasing $p_{T,2}/p_{T,1}$

many other checks pursued by CDF (see CDF note 10601 (July '11))

quarks vs. gluons: cross-checks

but NO evidence that different q/g JES qualitatively changes result (despite many rumors)

other MC studies and cross-checks

- changing MC inputs (generator, shower, pdf, matching) has little impact on the region of interest

(AM, J. Winter)

- excess is present in both exclusive (2 jets) and inclusive (2+ jets) samples: rules out ttbar as an explanation

- improved background modeling with NLO tools
  - shape of backgrounds, % consistent with CDF
  - no surprising K factors (MCFM, CDF cuts)

(Campbell, AM, Williams 1105.4594)

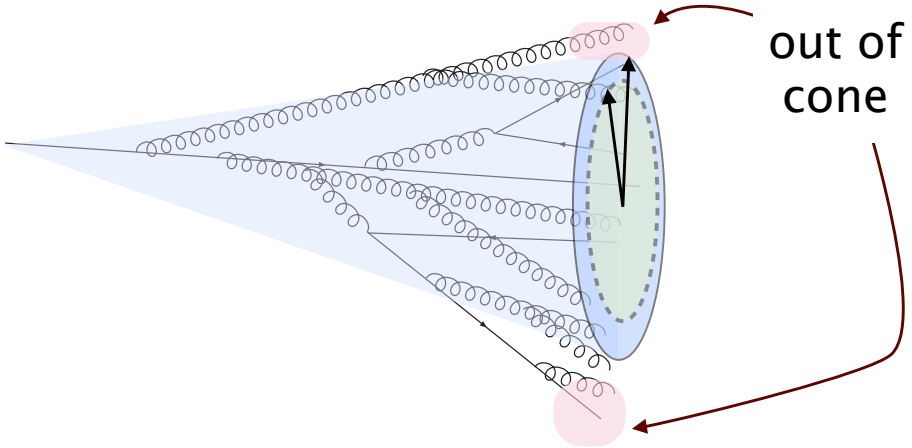
- recent NLO+PS study reaches similar conclusions

(Frederix et al 1110.5502)

what could it be?

biggest difference is systematics: number, treatment

ex.) DØ adds in `out-of cone' radiation, CDF does not
(not clear they have the same definition of 'out-of-cone')



leads to slightly different
definition of jets

CDF excess is quite sensitive to p_T

jet p_T > 30.0 GeV : 3.2 σ at 4.3 fb^{-1}
jet p_T > 20.0 GeV : 1.1 σ

analysis with harder p_T cuts would **really** clear this up.

no matter what: if different treatment of systematics can
cause such effects --> we're in **deep** trouble

where does this leave us?

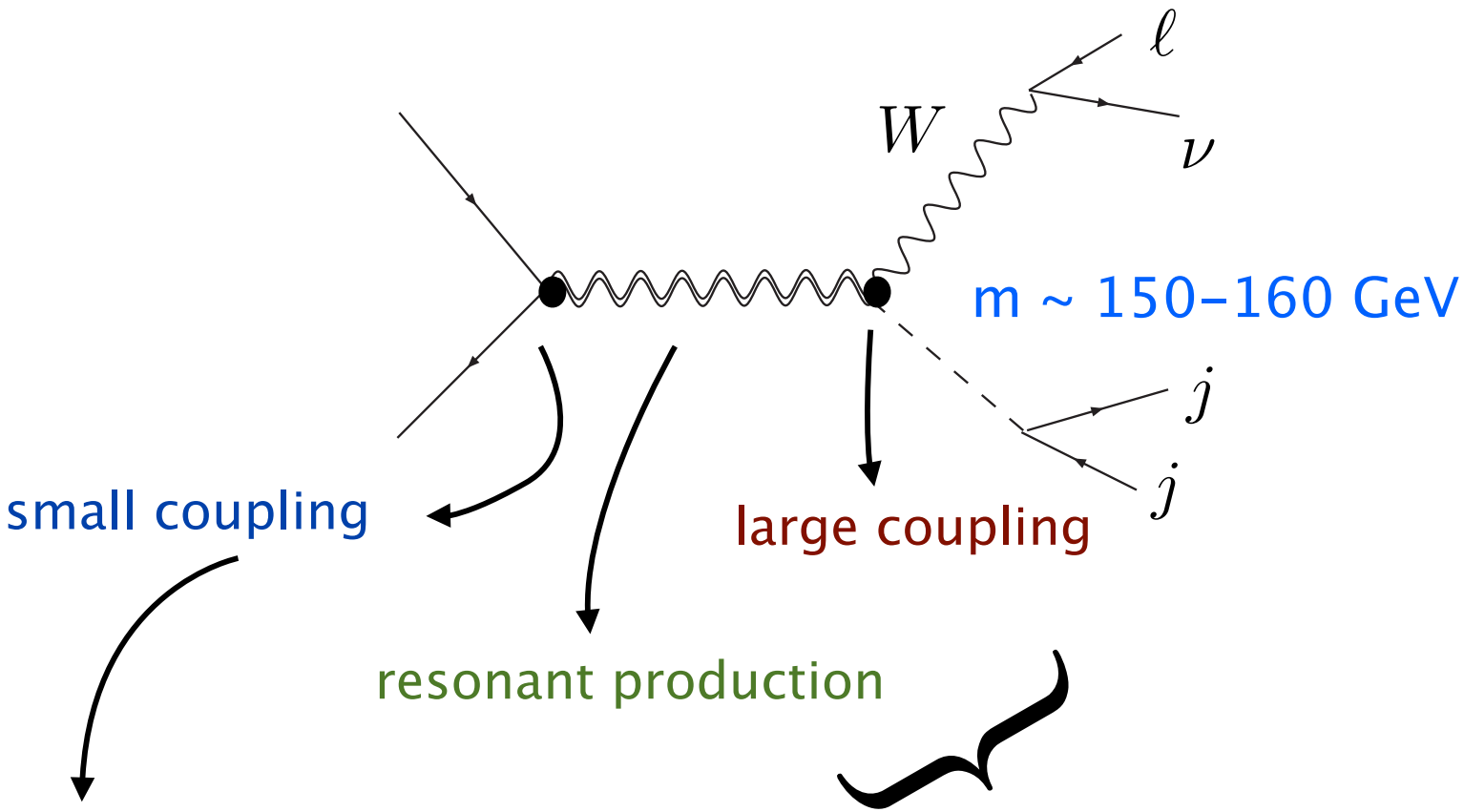
My opinion: CDF & D0 are likely not that incompatible
once compared more equally

& combination will show deviation from backgrounds
consistent with ~1-2 pb new physics cross section

even though it's unexpected, it still NEEDS to be understood

- no SM physics explanation so far
- so, what new physics can explain it? &
  how can we distinguish among models

W + jj from two resonances



needed to avoid direct Z'/W' constraints

light parent resonance

narrow width, large BR to W jj necessary to get enough rate

ingredients all present in 'multi-scale' technicolor models

(Eichten, Lane)

Main idea: there are two sources of dynamical EWSB

$$\langle \bar{T}_{1L} T_{1R} \rangle \propto 2\pi v_1^3$$

$$\langle \bar{T}_{2L} T_{2R} \rangle \propto 2\pi v_2^3$$

...for example, T_1, T_2 in different TC reps.

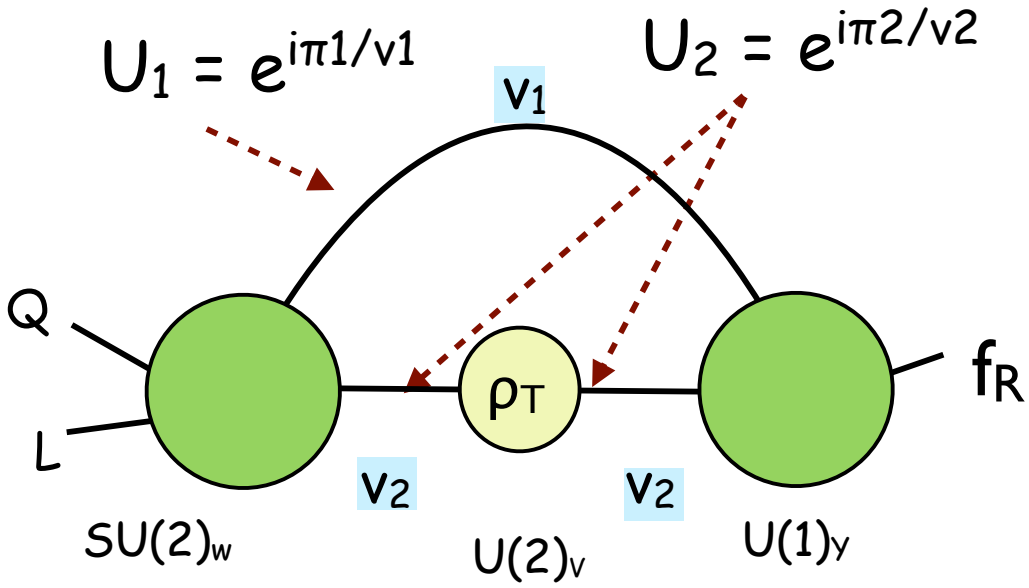
$$\sin\chi = v_2/v_1 \ll 1$$

resonances (ρ_T, a_T, ω_T ..) associated with the v_2 scale are **light**

two vevs -> extra NGBs = **technipions**

model w/ deconstructed language

(Dominici, DeCurtis Chivukula et al)



- ρ_T modeled as massive gauge boson
- one combination of π_i remains uneaten

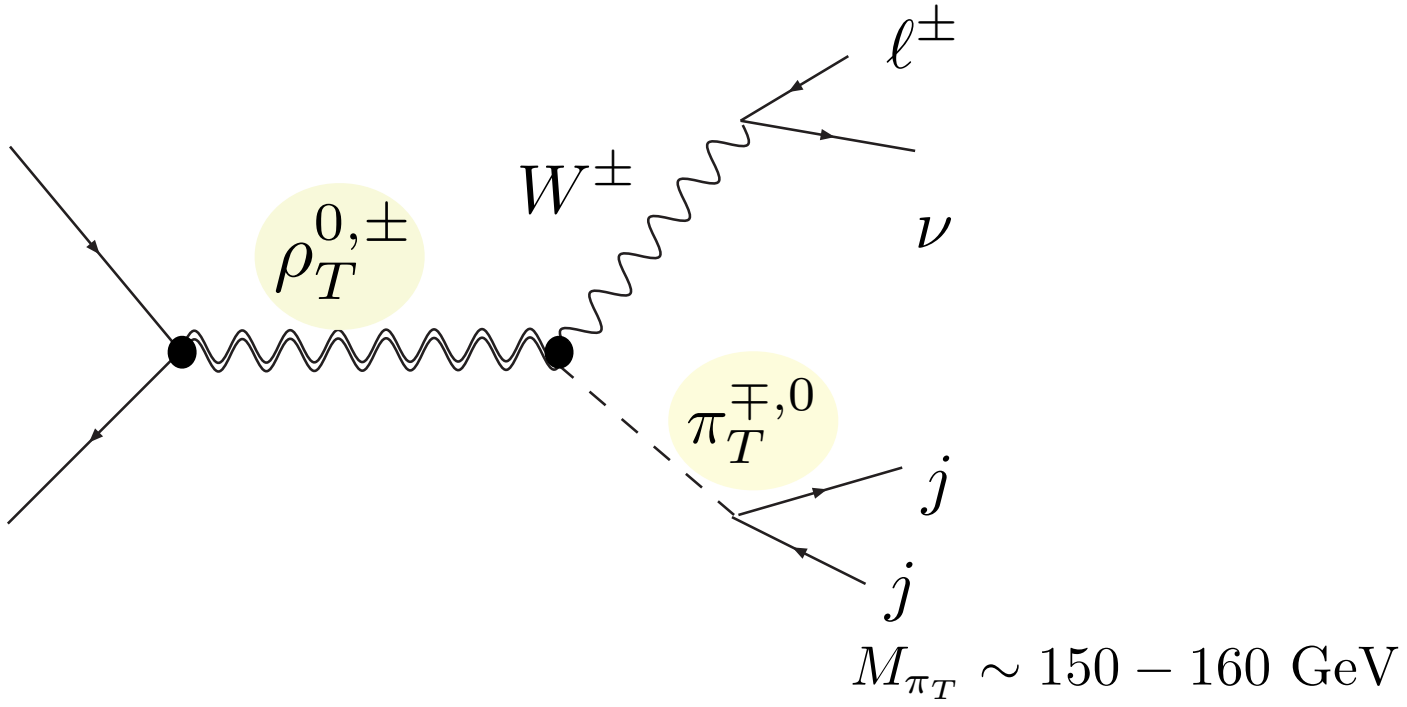
fermion - ρ_T coupling suppressed by $\dfrac{M_W}{M_{\rho_T}} \sin\chi \ll 1$

- technipions couple to SM fermions w/ strength ~ m_f

$$\frac{1}{\Lambda^2}\langle \bar{T}_{1L} T_{1R}\rangle \bar{f}_L f_R \longrightarrow m_f\left(+i\frac{\pi_T}{v}+\cdots\right)\bar{f}_L f_R$$

though model dependent

W + jj from two **techni-**resonances



if $M_{\rho T} < 2\ M_{\pi T}$, dominant decay is to $W\pi$

expected from walking TC lore, as $\langle \bar{T}T \rangle$ can have a large anomalous dimension, which effects $M_{\pi T}$, not $M_{\rho T}$

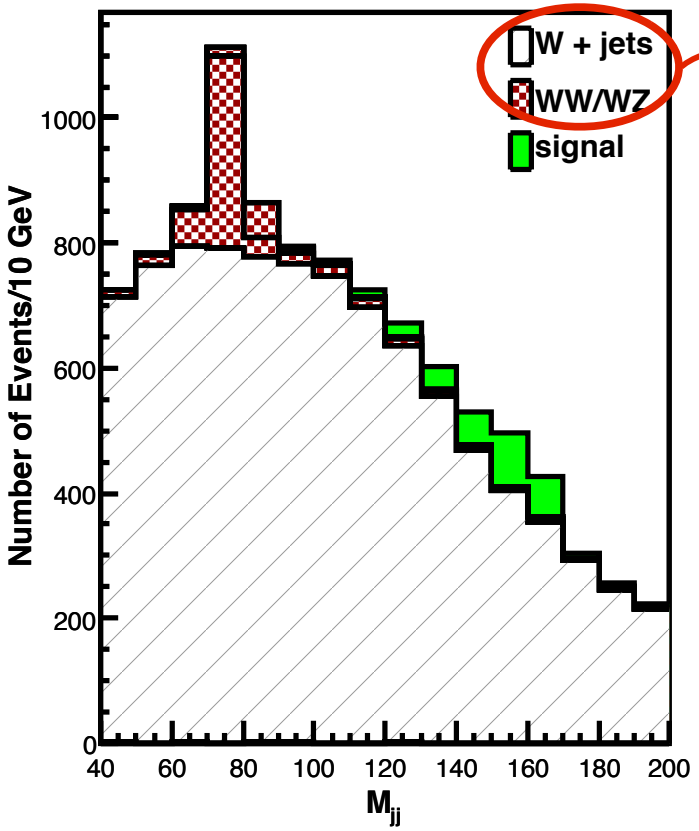
Does it fit: W + jj

signal parameters:

$$M_{\rho_T} \cong 290\,\mathrm{GeV},\ M_{\pi_T} \cong 160\,\mathrm{GeV}$$

$$\sigma(p\bar{p} \to \rho_T^{\pm,0} \to W + jj) \sim 2.4\,\mathrm{pb}$$

CDF cuts:



ALPGEN, MLM matched

↓

PYTHIA 6.4

↓

granularity

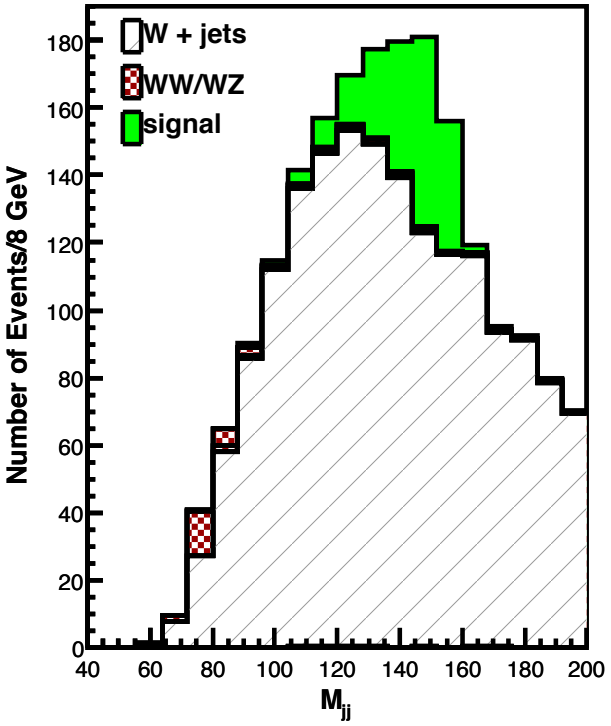
$\delta\eta \times \delta\phi = 0.1 \times 0.1$

(ELM '11)

extra cuts: $\Delta\phi_{jj} > 1.75,$

$p_{T,W} > 60\,\mathrm{GeV}$

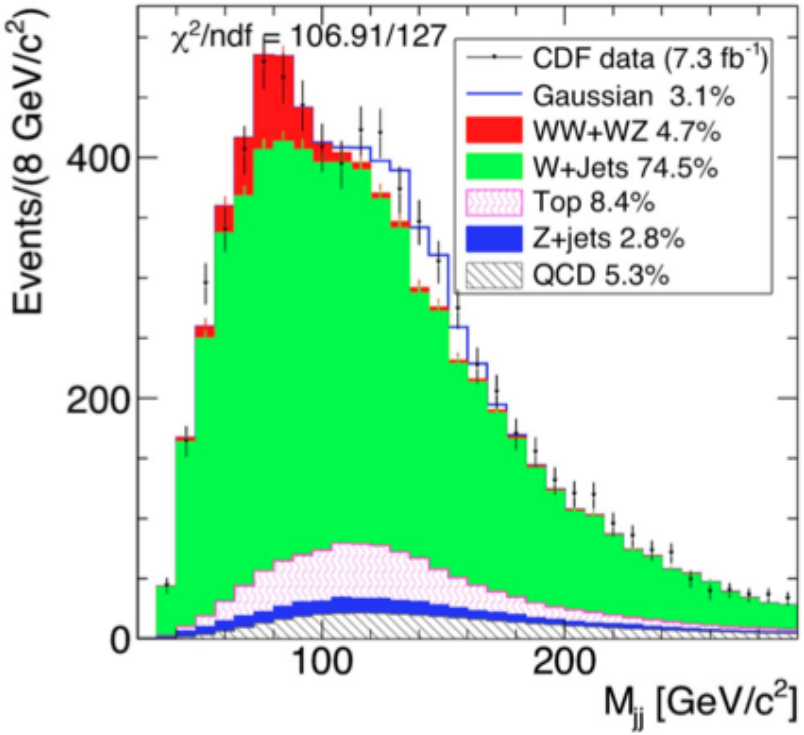
enhance signal



Annovi's talk at LP 2011

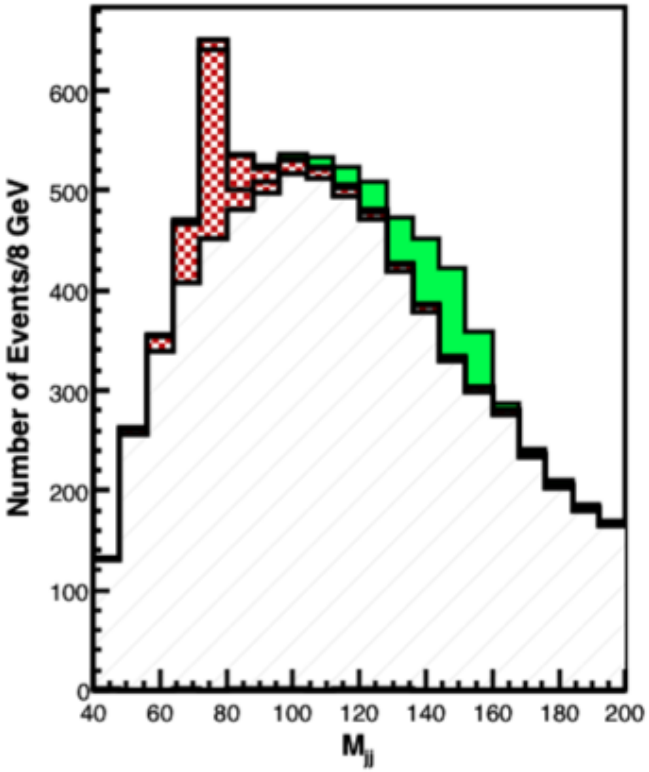
$P_T(\text{dijet}) > 60$ & $\Delta\phi > 1.0$

Excess stable w.r.t. changes in selection, despite change in bkg shape at low mass



ρ_T -> W + π_T
Eichten, Lane, Martin

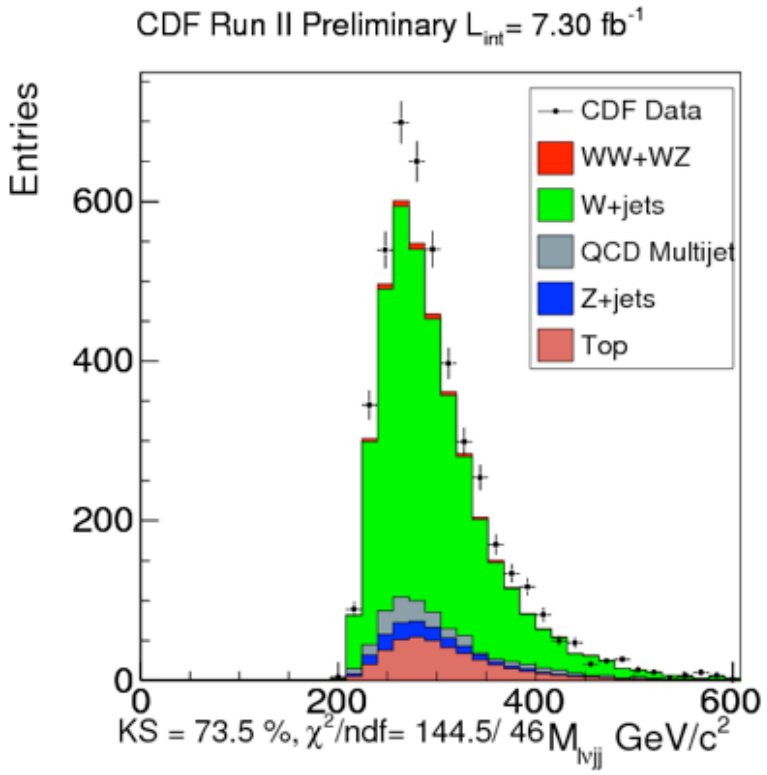
PRL 106, 251803 (2011)



Particle level, no detector simulation

Does it fit: W + jj

For the two resonance story to make sense there **must** be a peak in the total Wjj invariant mass near ~300 GeV



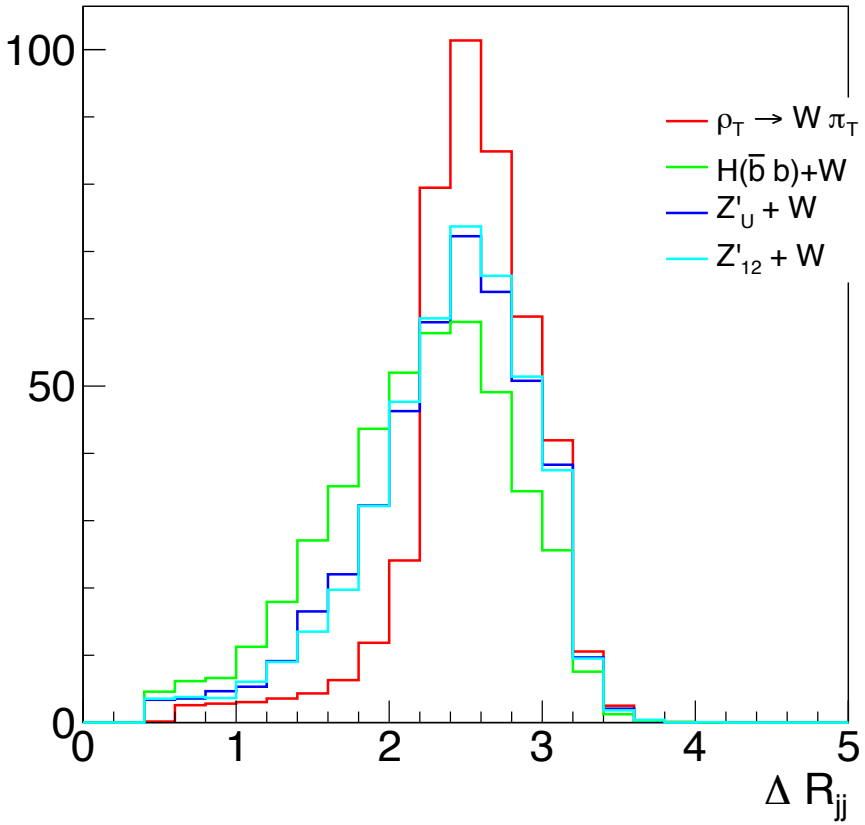
L = 7.3 fb^{-1} +
dijet mass window cut
115 GeV < M_{jj} < 175 GeV

SEE: www-cdf.fnal.gov/physics/ewk/2011/wjj/7_3.html

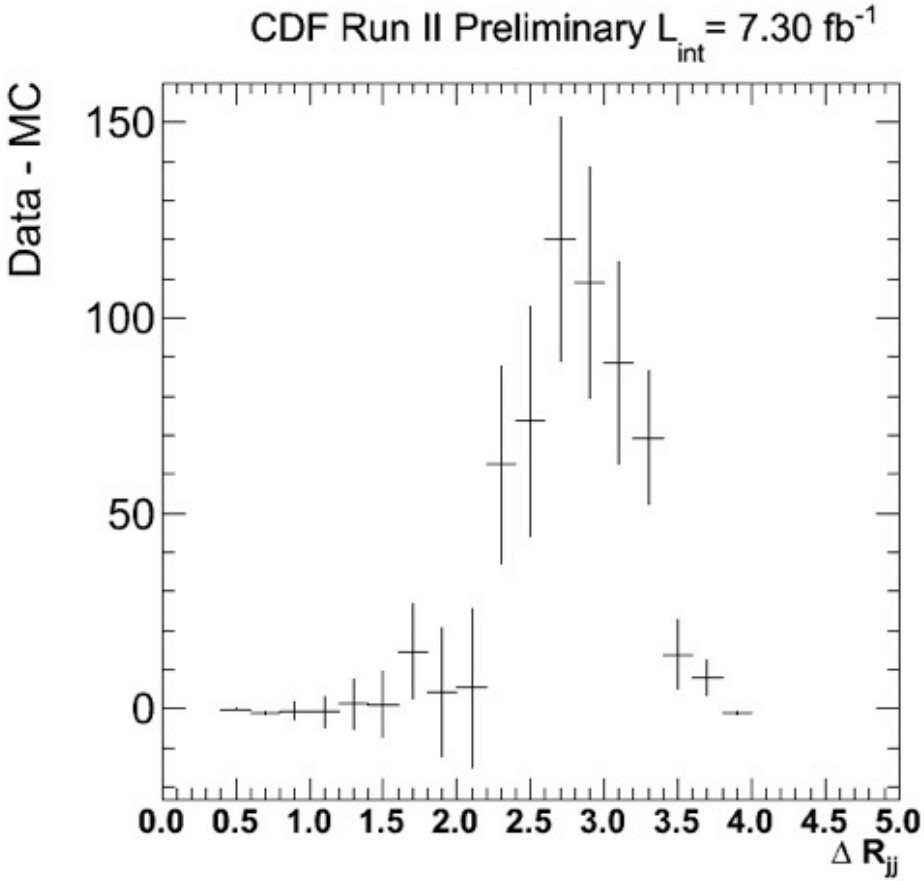
with CDF cuts alone, ρ_T peak sits on top of sculpted background.. additional cuts can help

what can kinematic distributions tell us?

various signals,
$\sigma(Wjj) = 2$ pb



CDF data in excess region
$115 \text{ GeV} < M_{jj} < 175 \text{ GeV}$

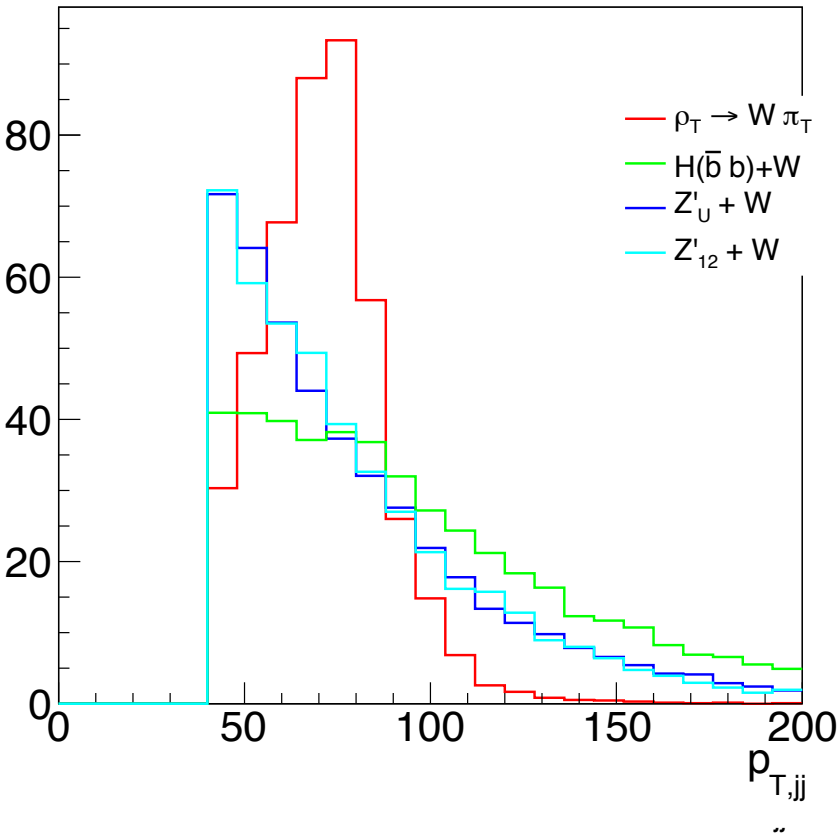


H(b bbar)W -- model used by CDF/D0 to estimate acceptance

Z' with flavor preserving/violating couplings

what can kinematic distributions tell us?

various signals,
$\sigma(Wjj) = 2$ pb



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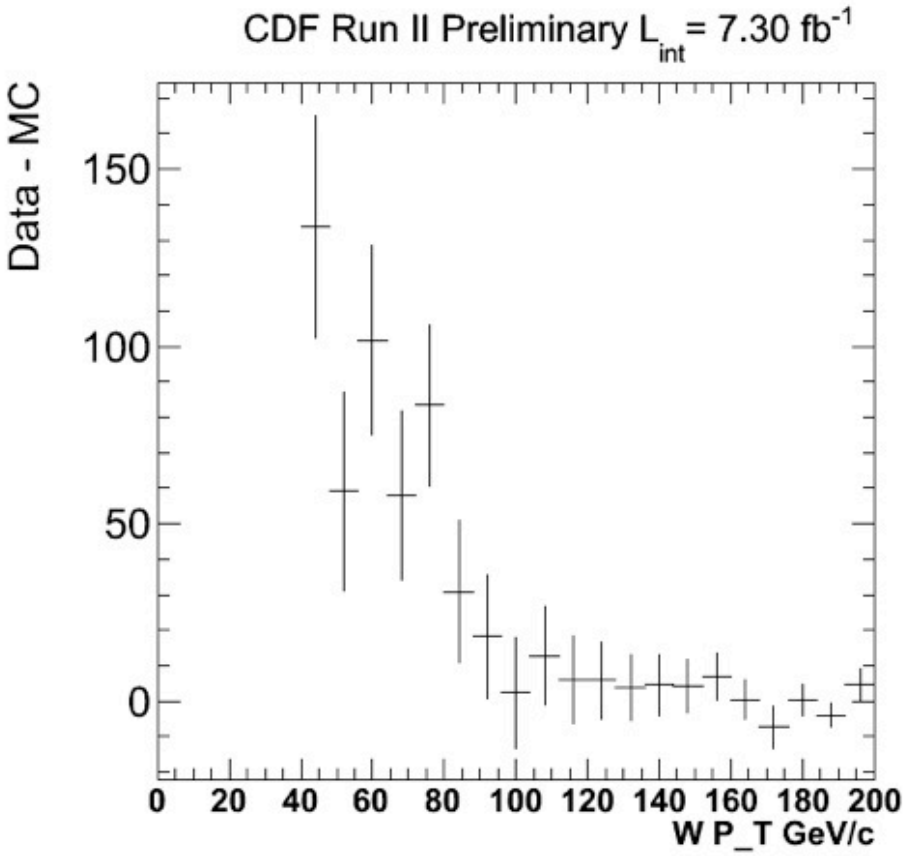
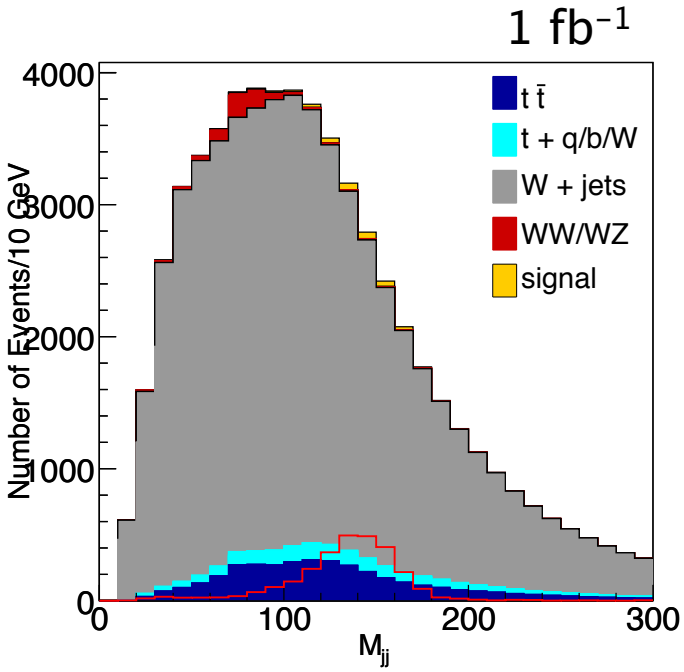


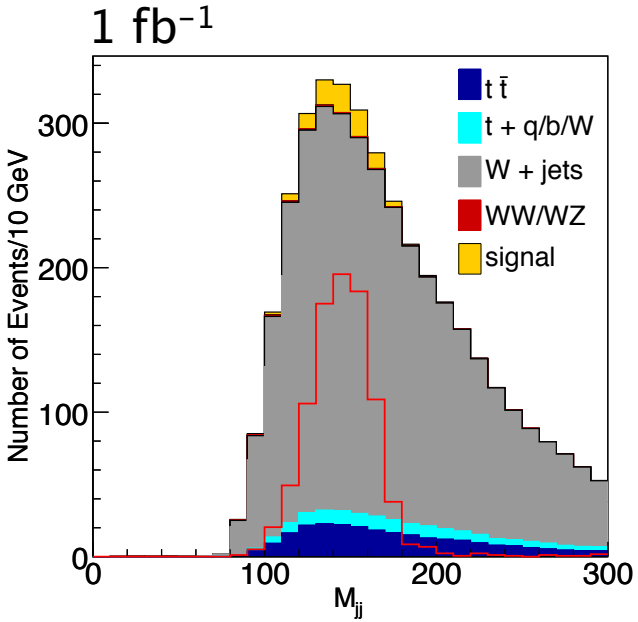
H(b bbar)W -- model used by CDF/D0 to estimate acceptance

Z' with flavor preserving/violating couplings

hard to see at the LHC

- with cuts similar to CDF, $q\bar{q}$ induced sources of Wjj are barely visible... W+jets is just too big





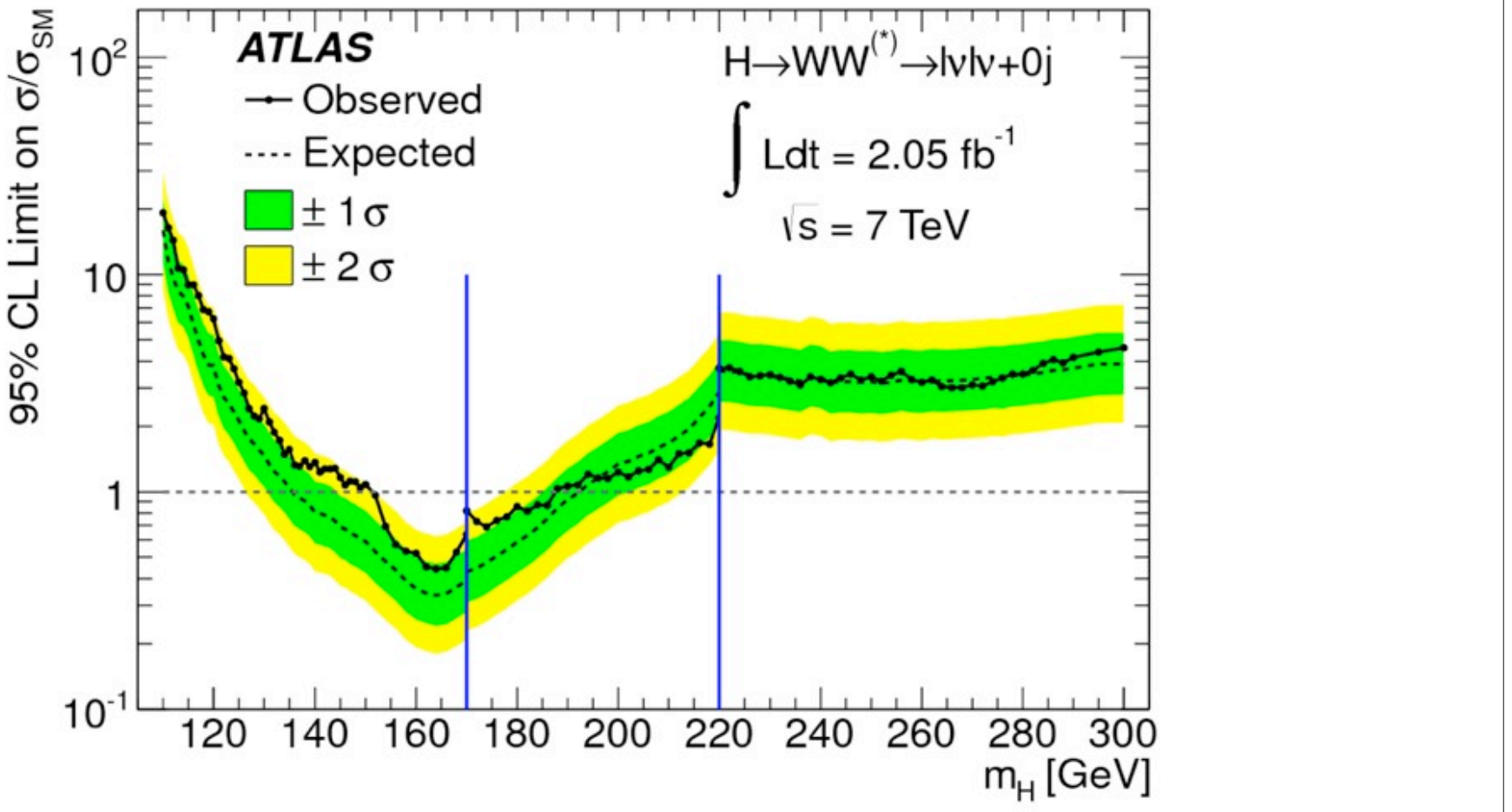
- harder p_T cuts suppress background, but sculpt a peak right under the signal
  - better signals in related channels ρ_T -> $Z(l^+l^-)+jj$, $W(l\nu)Z(l^+l^-)$

(Eichten, Lane, AM, 1107.4075)

or maybe we're already seeing something...

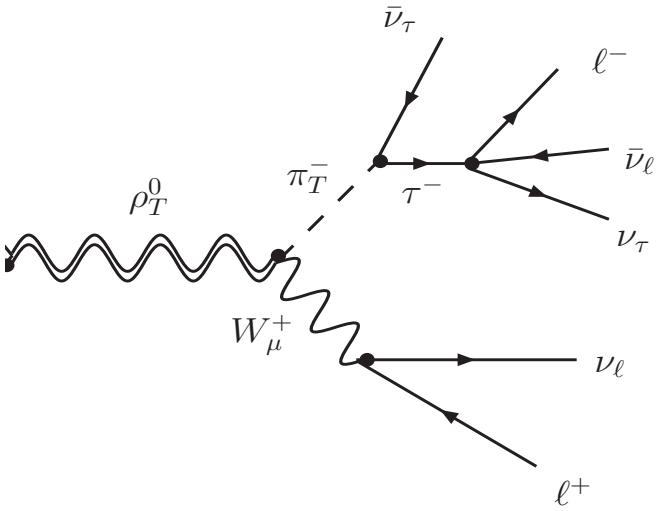
one of the most studied channels is l^+l^- + MET, (for h->WW)

~2 sigma discrepancy between expected & observed limits for m_H ~100-200 GeV



or maybe we're already seeing something...

ρ_T -> Wπ can give the same final state

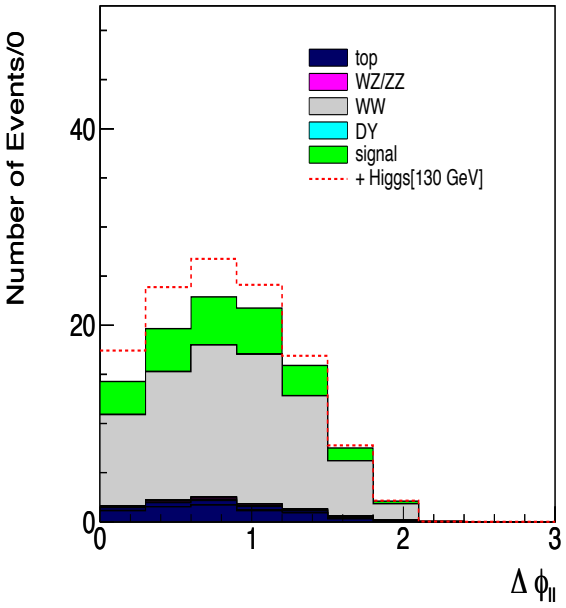


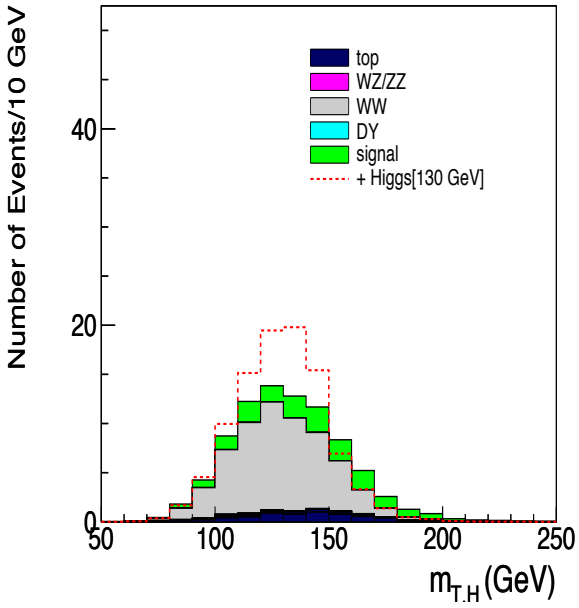
for M_π, M_ρ masses that fit CDF excess, get an LHC l^+l^- + MET signal with strength O(0.1-0.5) x SM Higgs

(AM, 1108.4025)

...could be what we see in WW

improved WW limits can rule in/out this setup





Conclusions

the CDF bump is absolutely not "wrong", W+jj issue not settled

may be new physics ...

.. but if not, it exposes a mismodeling/misunderstanding in QCD/ detectors that is necessary to understand for future searches (& not just at the Tevatron).

two resonance topology:

- large rate in Wjj with small fermion-resonance coupling
- must see peak in total M_{Wjj}, related signals in $Z(l^+l^-)jj, \bar{f}f$

parameters from Multi-Scale Technicolor fit surprisingly well:

- multiple EWSB scales -> light resonances
- coupling to SM suppressed by $v_2/v_1 << 1$

THANK YOU