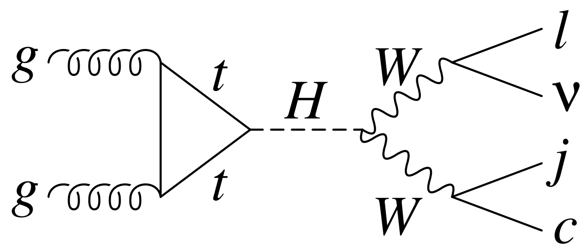
Higgs to Wcj at the Tevatron and LHC



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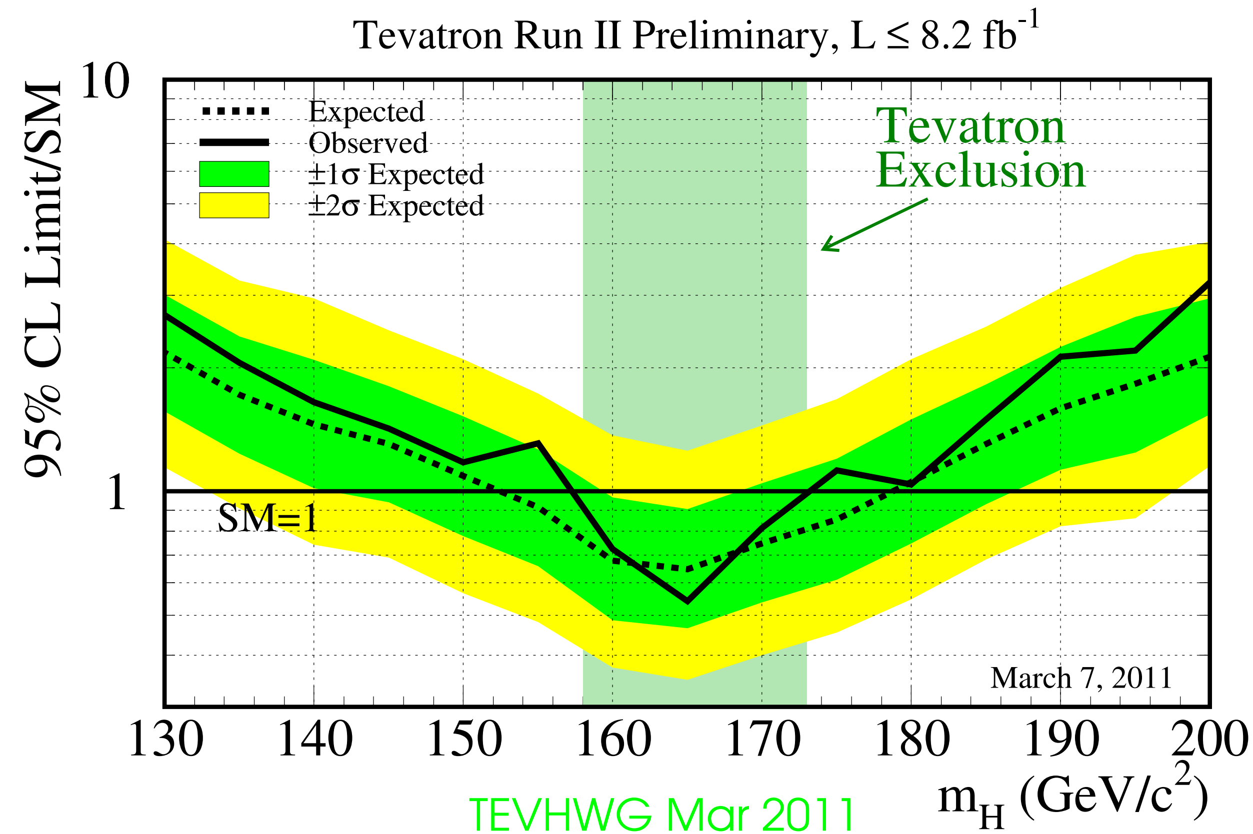
Based on Z.S., Arjun Menon, hep-ph:1006.1078v3 (LHC-update soon); and hep-ph:1106.xxxx (Tevatron)

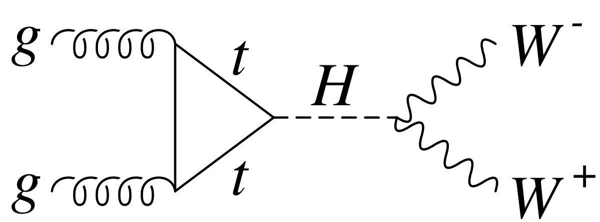
Outline

1. A new Standard Model Higgs discovery mode
   — $gg \to H \to cjl\not{E}_T$
2. Predicted reach at LHC
   — Compares well vs. $gg \to H \to l^- l^+ \not{E}_T$
3. Predicted reach at Tevatron
   — Could play major role in Higgs limits
4. Conclusions

Higgs production and limits



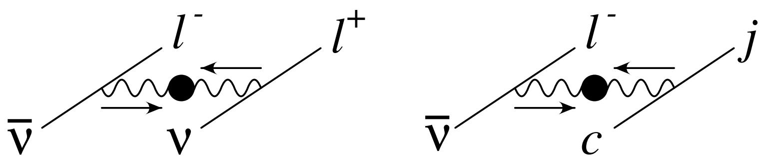
Limits on Higgs production at the Tevatron are currently completely dominated by gluon fusion production, and decays to W^-W^+ — with $W^-W^+ \to l^-l^+\not{E}_T$. Is $l^-l^+\not{E}_T$ all we can do?



Dileptons+$\not\!\!E_T$ vs. Wcj

In 1999, Tao Han and R.J. Zhang showed Wjj was buried by jet backgrounds (PRL 82, 25 (99)).

In 2009, Dobrescu and Lykken re-ignited interest in $H \to Wjj$ with new angular variables, but the backgrounds remain large. (ph/0912.3543)



Key to $l^- l^+ \not\!\!E_T$, angular correlations:

— $\Delta\phi_{ll}$ is small

— $\Delta\phi_{\nu\nu}$ is *also* small, but invisible

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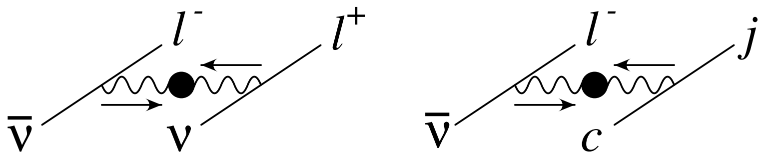

Key to $l^-l^+\not\!E_T$, angular correlations:

— $\Delta\phi_{ll}$ is small

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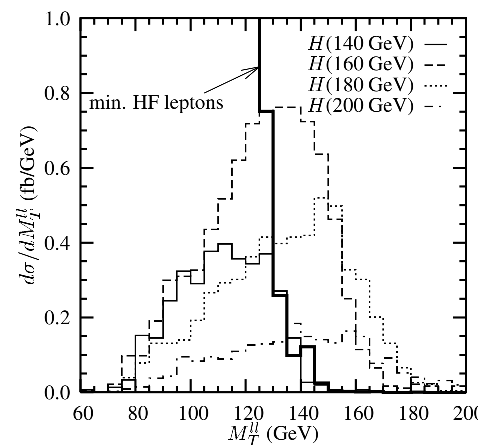
Wcj has the same correlations

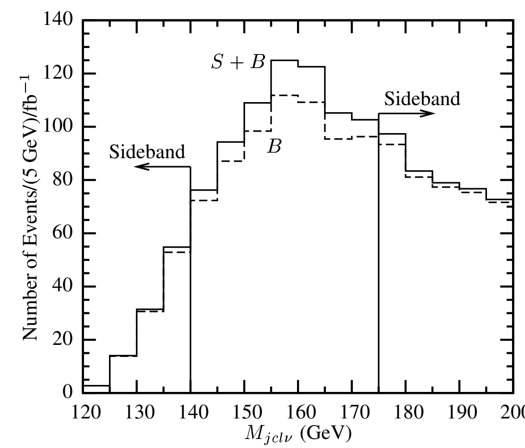
— Can reconstruct $\Delta\phi_{lj}$ *and* $\Delta\phi_{c\nu}$

— Charm tagging is key to breaking jet degeneracy

— Charm tagging also reduces jet backgrounds

Unlike $l^-l^+\not\!E_T$ which relies on normalization of M_T^{ll}



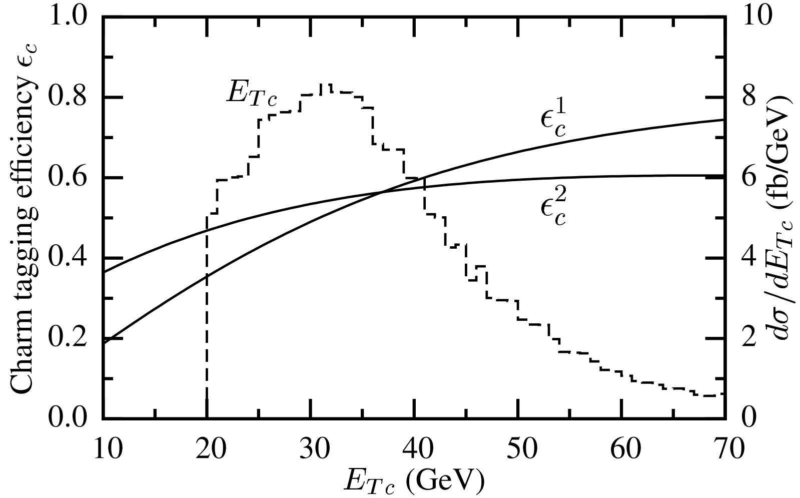


In Wcj, Higgs mass peak can be reconstructed

Charm jet tagging

One way to tag charm jets is to tag b-jets.

Charm "mis-tag" rate ($\times k = 4$) in b-tagging



CDF Run I:

$\epsilon_c^1 = k \times 0.2 \tanh(E_{Tj}/42 \text{ GeV})$

CDF Run II:

$\epsilon_c^2 = k\times$ long formula from PGS 4

We want to see improved k

In the region of kinematics cuts:

$k = 1$ (current):

$\epsilon_c \sim 12\%$

$\epsilon_b \sim 45\%$

$\epsilon_j \sim 0.1\%$

$k = 4$:

$\epsilon_c \sim 48\%$

$\epsilon_b \sim 100\%$ (saturates)

$\epsilon_j \sim 1\%$ ($\times 10$)

This can be accomplished by modifying jet tagging:

— lower track-invariant mass cut, reduce lifetime cut

— These were the dominant factors in developing impact parameter tags, modern neural nets might do better.

Simulation and cuts

Simulation of signals and backgrounds used MadEvent $\rightarrow$ PYTHIA $\rightarrow$ PGS4

Matched signal and backgrounds to NLO after cuts

— Critical: $gg \rightarrow H \rightarrow WW$ in 2-jet channel $K = 1.3$, ATLAS assumed 1.9

Cuts: acceptance cuts for LHC and Tevatron require 2 or 3 j, 1 c-tag, 1 l

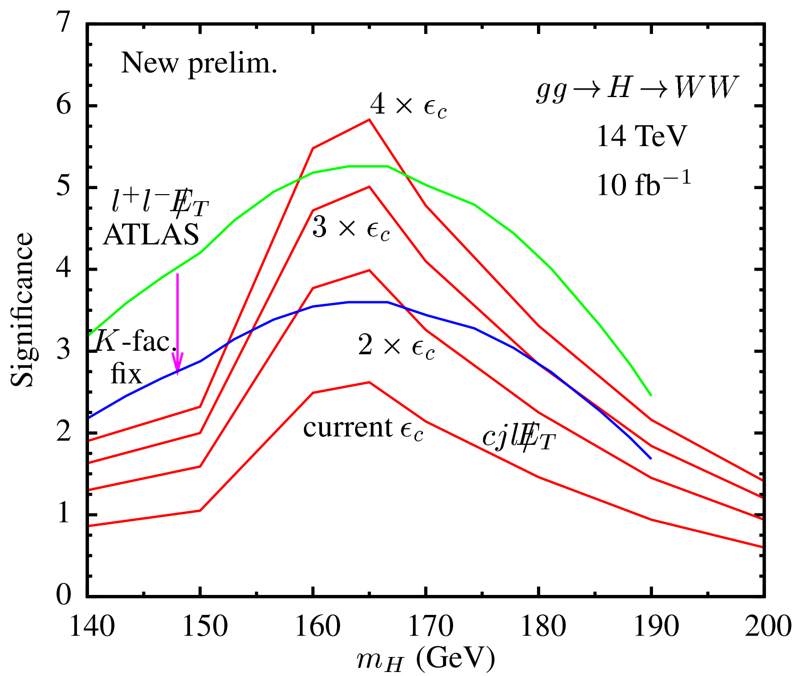
$E_T^j > 20\ \mathrm{GeV},\ |\eta_j| < 2.5;\ p_T^l > 20\ \mathrm{GeV},\ |\eta_l| < 2.5(1\ \mathrm{for}\ \mu\ \mathrm{at\ CDF}),\ \not{E}_T > 20\ \mathrm{GeV}$

Sample cuts (other variants in papers)

	LHC	Tevatron
Kinematic	$E_{Tc} < 80$ GeV	$E_{Tc} < 60$ GeV
	$p_{Tl} < 60$ GeV	$p_{Tl} < 60$ GeV
	$50 \leq M_{jc} \leq 85$ GeV	$50 \leq M_{jc} \leq 90$ GeV
Angular	$\Delta\phi_{c\not{E}_T} < 1.5$	$\Delta\phi_{c\not{E}_T} < 2$
	$\Delta\phi_{jl} < 2$	$\Delta R_{jl} < 2$
Mass	$M_H - 20 \leq M_{l\nu cj} \leq m_H + 10$	$M_H - 20 \leq M_{l\nu cj} \leq m_H + 20$

$H \to Wcj$ reach at the LHC

LHC 14 TeV



ATLAS hep-ex/0901.0512

ATLAS assumed Higgs K-factor of 1.9

We find it is 1.3 after cuts at NLO

With no work: $\epsilon_c \sim 12\%$

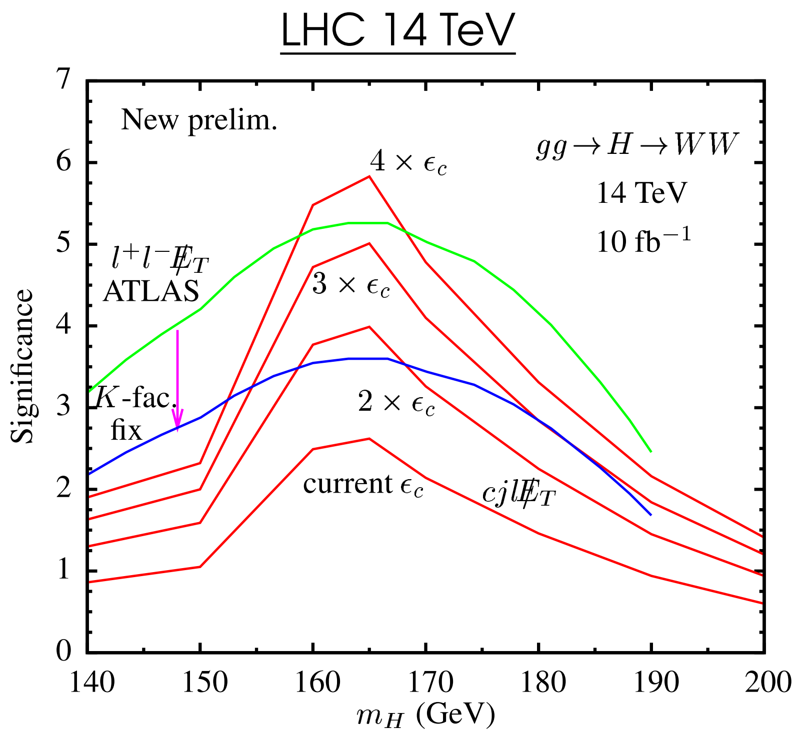
$\Rightarrow$ $1/2$ dilepton significance!

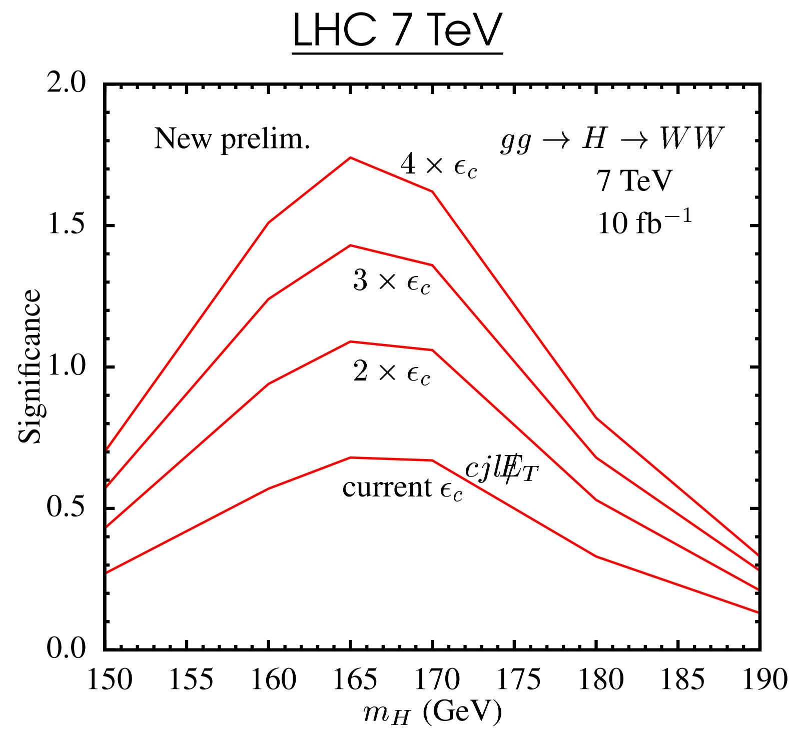
$2\times\epsilon_c \sim 24\%$

$\Rightarrow$ Comparable to $l^+l^-\not{E}_T$

3–4$\times\epsilon_c$ more powerful than $l^+l^-\not{E}_T$

$H \to Wcj$ reach at the LHC





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Wcj is complementary at LHC

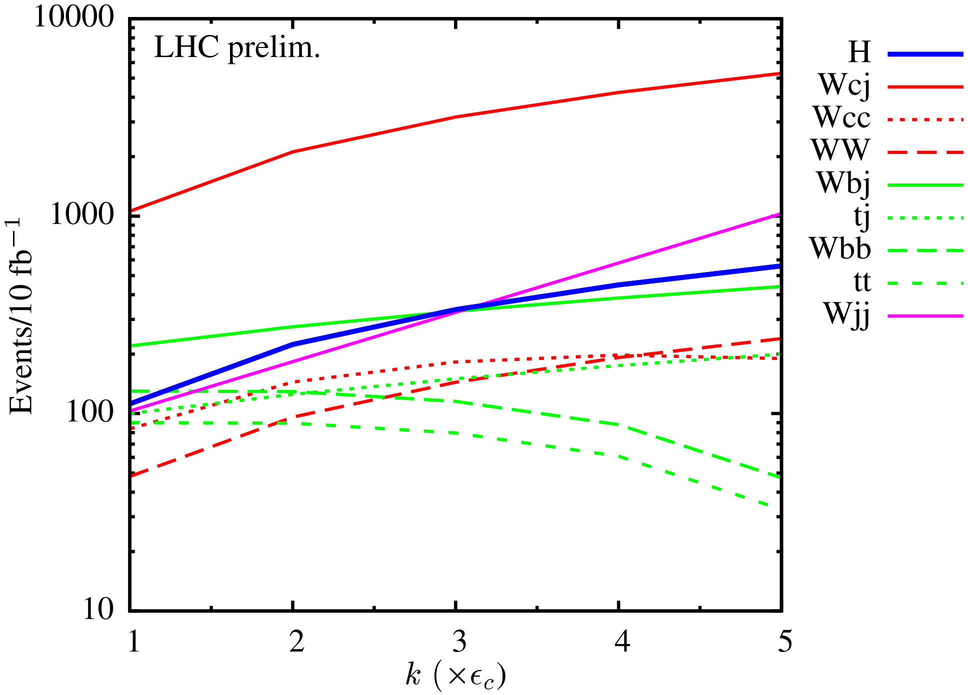
Overall significance $\approx \sqrt{k} \times \sigma_{\epsilon(k=1)}$

Luminosity to achieve given significance $\mathcal{L} \sim 1/k$

Power of charm tagging at LHC and Tevatron

Why is significance determined by charm tagging?

LHC S and B



— Only Wcj matters at LHC

— $H \to l\nu jc$ and Wcj have 1 c-tag
hence they scale together

— Wbj, Wjj are comparable to signal, BUT they have no peak at M_H

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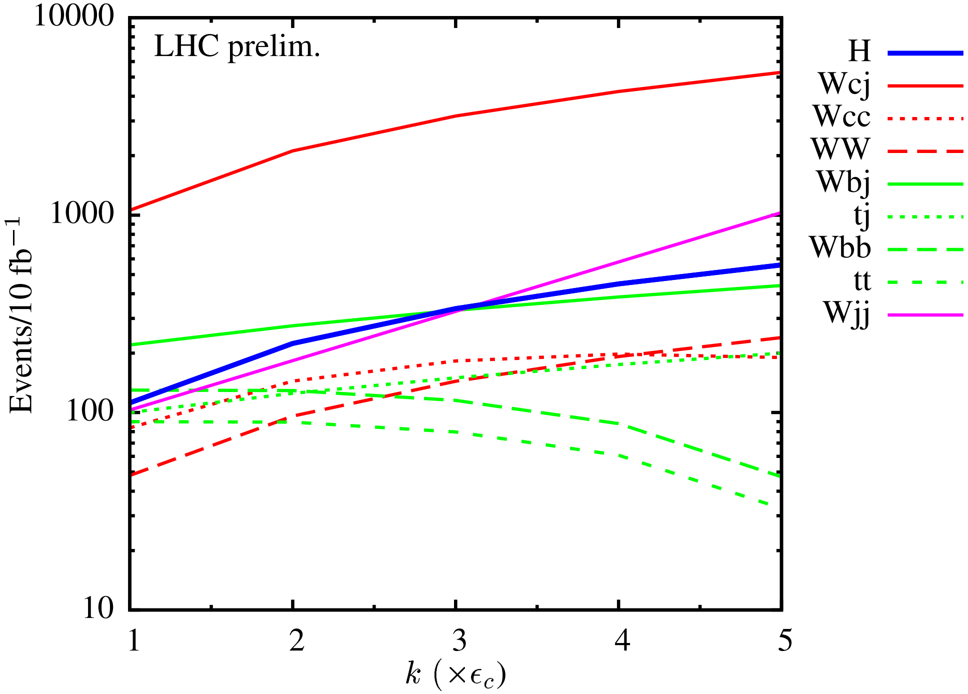
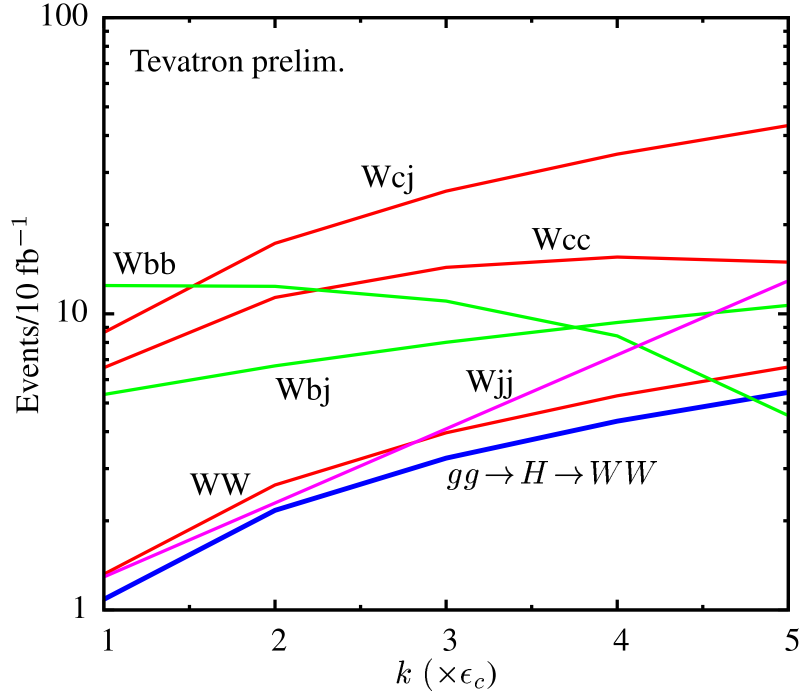


Tevatron S and B



— Only Wcj matters at LHC

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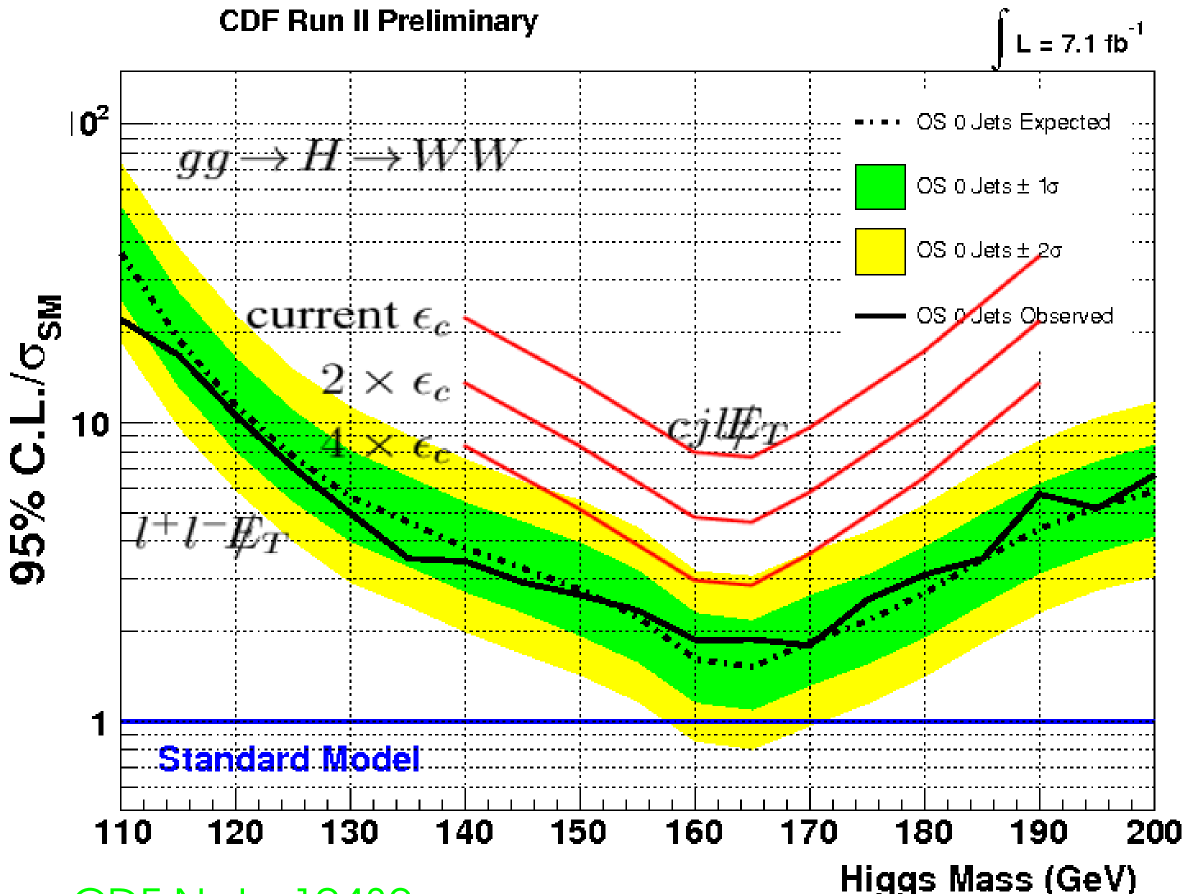
Tevatron bknd. more interesting

$k = 1$ ($\epsilon_c \sim 12\%$) Wbb/Wbj important

$k \geq 2$ Wcj/Wcc take over

How well can the Tevatron do?

$H \to Wcj$ reach at the Tevatron



CDF Note 10432

Backgrounds are more challenging at Tevatron

With no work: $\epsilon_c \sim 12\%$

$\Rightarrow 3.5\times$ dilepton limit

$2 \times \epsilon_c \sim 24\%$

$\Rightarrow 2\times$ dilepton limit

$4 \times \epsilon_c \sim 48\%$

$\Rightarrow 1.5\times$ dilepton limit

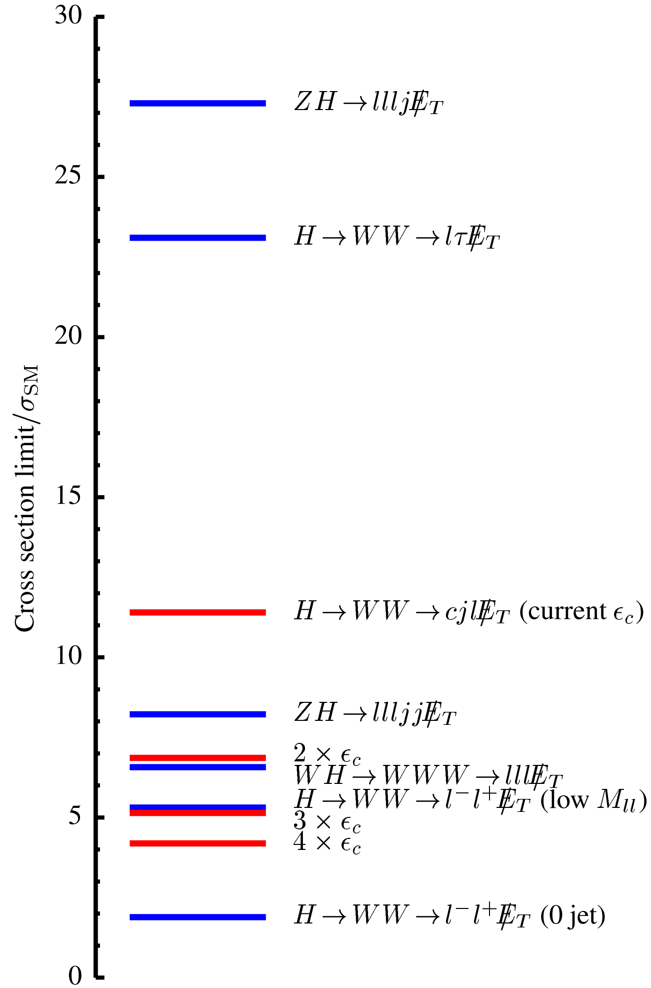
Dileptons: $S/B \sim 1/75$

Wcj: current $\epsilon_c \Rightarrow S/B \sim 1/40$; $4 \times \epsilon_c \Rightarrow S/B \sim 1/20$;

Wcj is a complementary channel w/ different backgrounds and systematic errors that could greatly improve Tevatron Higgs limits.

Where Wcj fits into Tevatron analyses

How does the Wcj compare at $M_H = 160$ GeV?



With a little work on improved charm tagging, this could be the second most powerful channel for Tevatron limits.

The take away

Z.S., A. Menon, arXiv:1006.1078, 1106.xxxx

$H \to WW \to cjl\not{E}_T$ is a powerful channel to look for SM Higgs

- We can reconstruct a Higgs mass peak
- $H \to cjl\not{E}_T$ is complementary to dileptons$+\not{E}_T$
- With modest improvements to charm tagging, could be more effective than dileptons$+\not{E}_T$ at LHC
- At Tevatron, could significantly improve current Higgs mass limits

We encourage our experimental colleagues to incorporate this channel into the standard searches.

THANK YOU