Search for the Vh Production Using Like-Sign Dilepton Events at CDF

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On behalf of CDF collaboration

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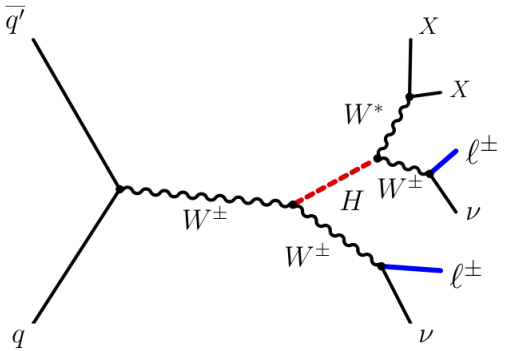
Outline

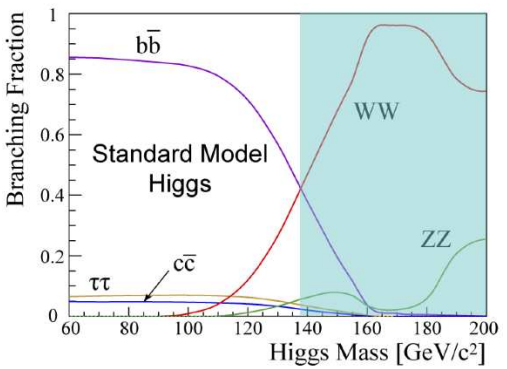
Our Analysis

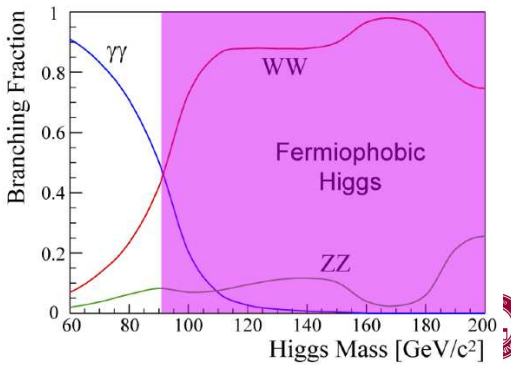
Our Analysis

We are searching for the Fermiophobic (FP) Higgs and the SM Higgs by looking at like-sign (LS) dilepton events.

- Very clean channel at the Tevatron
  - LS requirement reduces fake backgrounds to some extent.
  - However, the dominant backgrounds are fakes.
- High Sensitivity
  - For the FP Higgs, $m_H > 90$ GeV/c^2
  - For the SM Higgs, $m_H > 135$ GeV/c^2







Our Backgrounds

Fake leptons

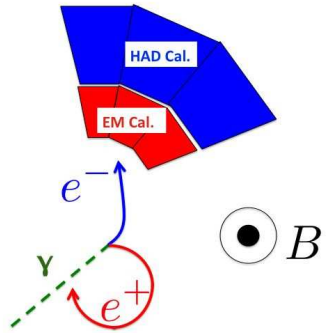
- $\pi^{\pm}$, π^{0} + track, punch-through hadrons
- Semi-leptonic decay of heavy flavor hadrons, decay-in-flight $\pi^{\pm}, K^{\pm}$
- Estimation: Use Data (jet samples)

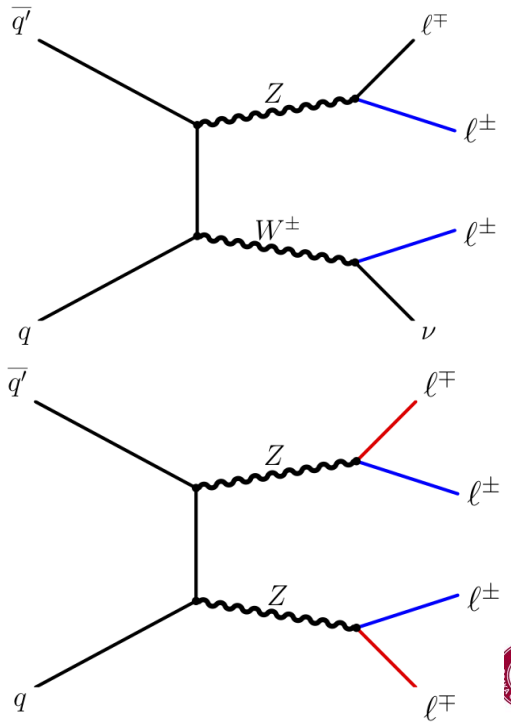
Residual Photon Conversion

- Electron from $\gamma \rightarrow ee$ with unobserved partner track
- Estimation: Use Data and Monte Carlo

Physics Backgrounds

- Drell-Yan, $t\bar{t}$, WW, WZ, ZZ
- Estimation: Monte Carlo





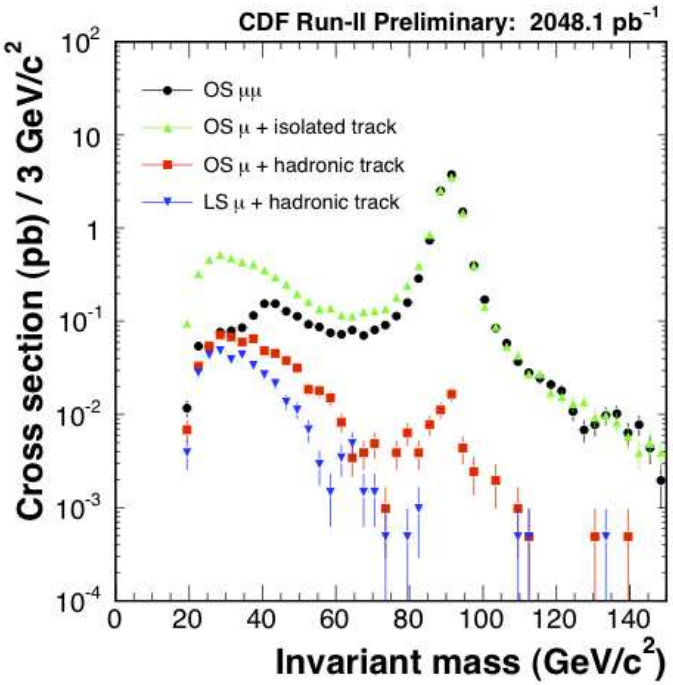
Fake Rate

Assumption

- R_{fake} in jet samples is the same as the one in the inclusive lepton trigger samples.

Hadronic Track

- Isolated track with depositting certain energy to the EM and HAD calorimeters.
  $\longrightarrow$ reduce real lepton contaminations to some extent.



	Jet Samples	Lepton Samples
Numerator	Obj. Passing Lepton ID cuts	Lepton + (fake events)
		$\triangle$
Denominator	Hadronic Tracks	Lepton + Hadronic Tracks
	$\triangledown$	
Fake Rate	$R_{fake(jet)}$	$R_{fake(lepton)} := R_{fake(jet)}$

Bias caused by W veto

Bias

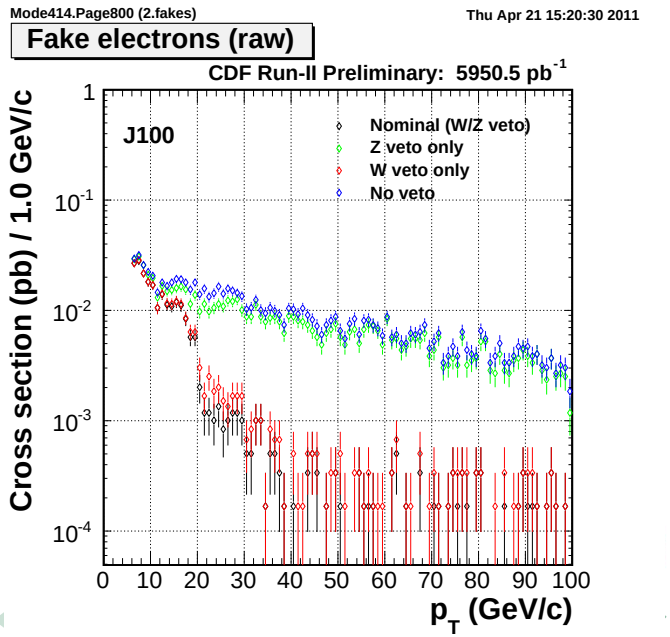
- We need to eliminate the real lepton from W boson in jet samples to estimate the fake rates.
- We found that the nominal W veto causes some biases into the numerator.
- Fake rate is defined

$$R_{\text{fake}} = \frac{(\#\text{ of lepton candidates passing lepton ID cuts})}{(\#\text{ of denominator objects})}$$

- We choose MC-based subtractions instead of the W veto.

Nominal W veto

- e: $E_T > 20$ GeV (μ: $p_T > 20$ GeV$/c$) with passing lepton selection &&
- $\not\!\!E_T > 30$ GeV or (transverse mass) $>$ 40 GeV$/c^2$



MC-based Subtraction

Subtraction Method

- We use MC samples to understand the contents (coming from $W^{\pm}/Z^{0}$) of jet samples.
- Using the spectrum of transverse mass, we estimate the scale A for the MC:

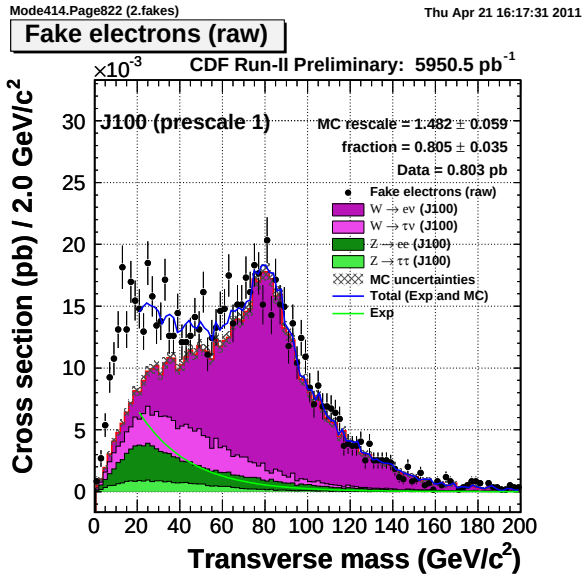
$$\text{Fit}\left((A \times \text{MC}) + (\text{Function for fake leptons})\right)$$

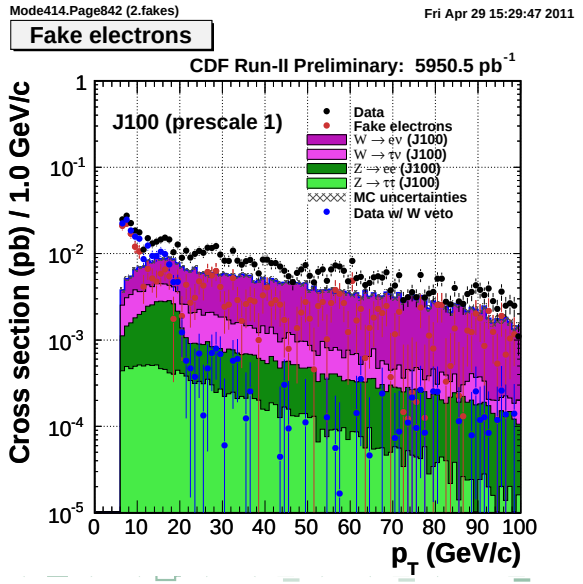
$$\rightarrow \text{Determine } A.$$

- We just apply the scale A to the other histograms:

$$(\text{Raw Electrons}) - (A \times \text{MC})$$

$$\rightarrow \text{Fake leptons}$$

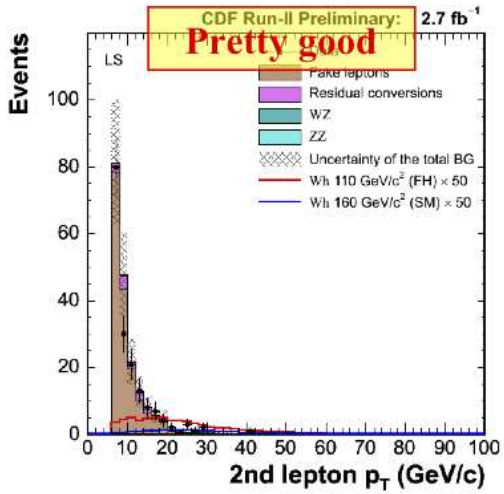


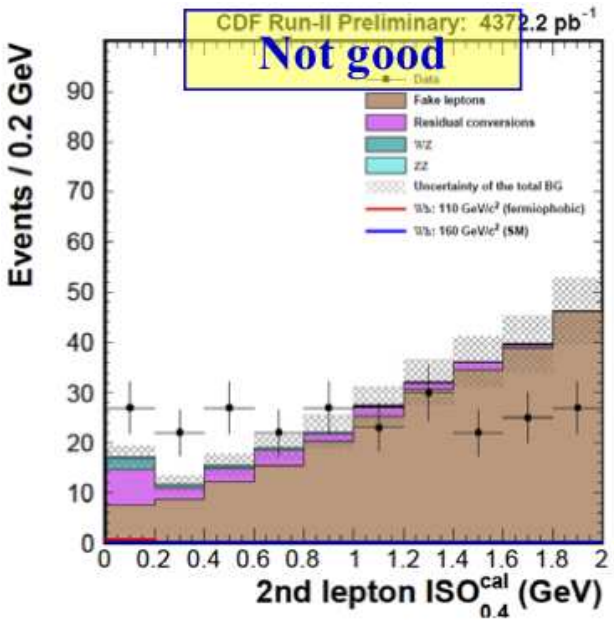


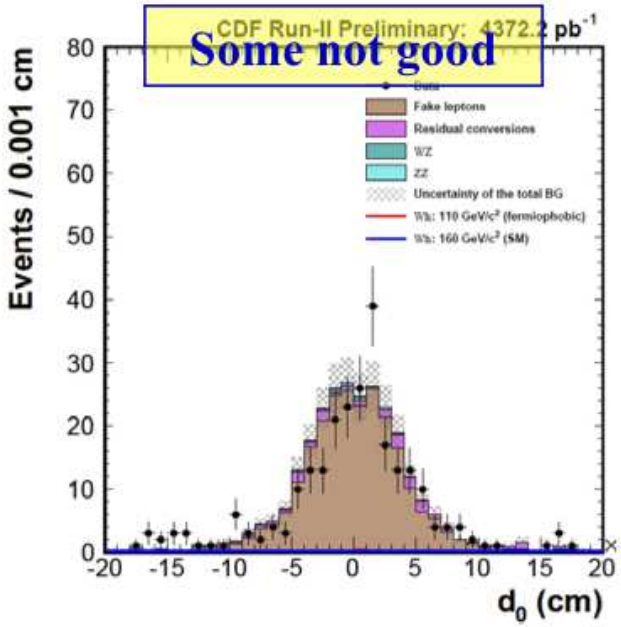
p_T Parametrization (Old Method)

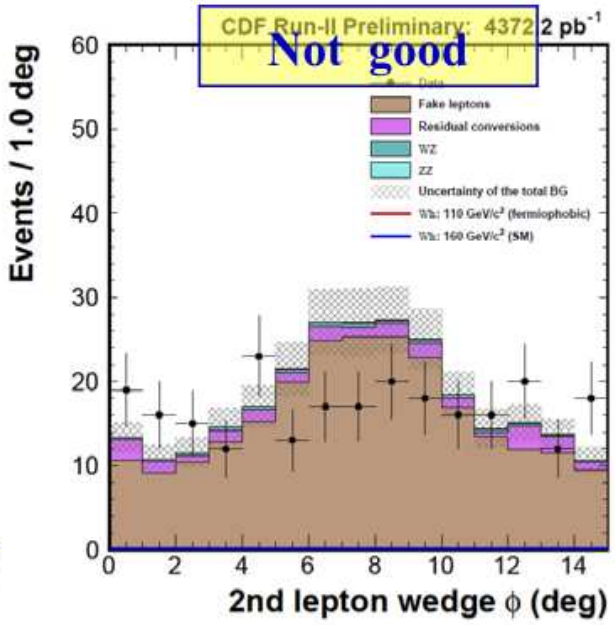
p_T Only Parametrization

- p_T is good.
- However, fake leptons depend on other variables.
  → lead to poor estimations...









Our Fake Rate Estimation (Five Dimensional)

- We estimate fake rates as

$$R_{\text{fake}} = \frac{n}{d} \cdot r(p_T) \cdot r(\eta) \cdot f(\text{ISO}_{0.4}) \cdot f(d_0) \cdot f(\phi_w)$$

where

$\frac{n}{d}$: Scalar component ← determines the variable-independent ratio

r: Binned Function ← gives some probability

f: Fitted Function ← gives some probability

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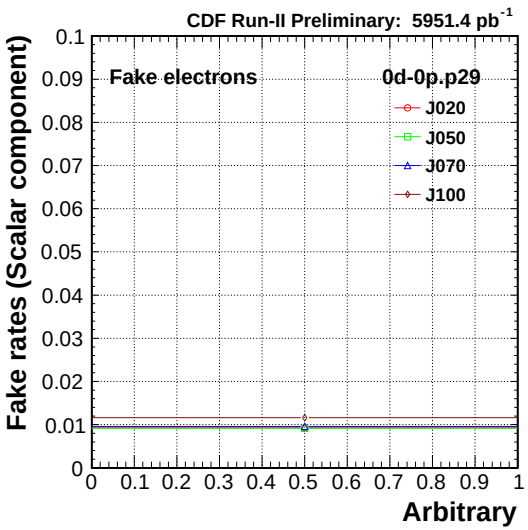

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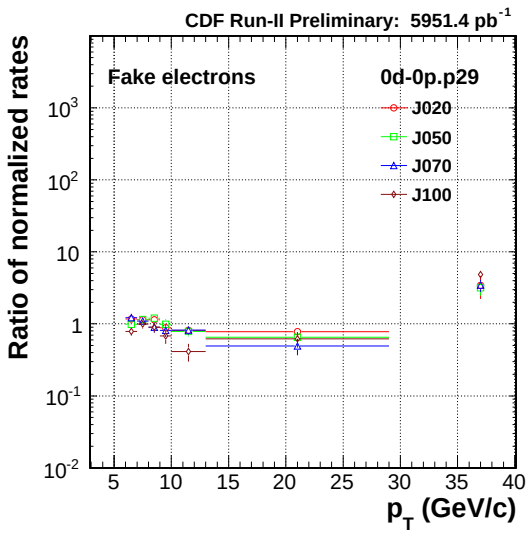

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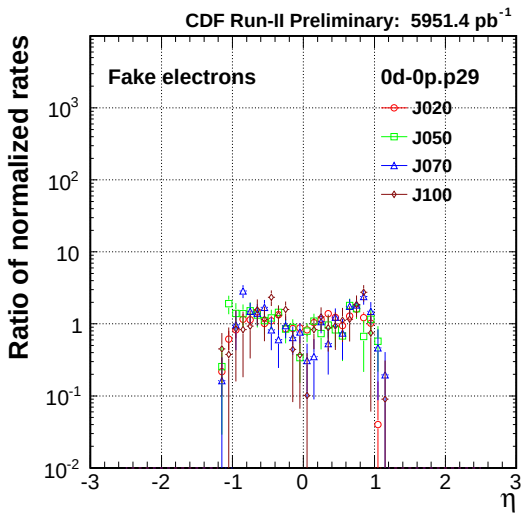

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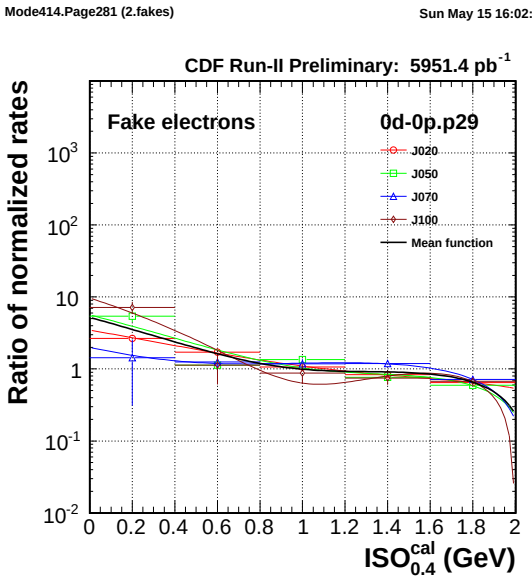
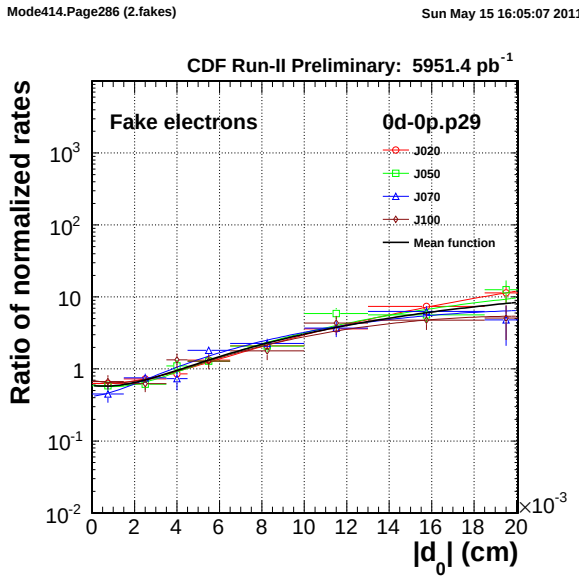
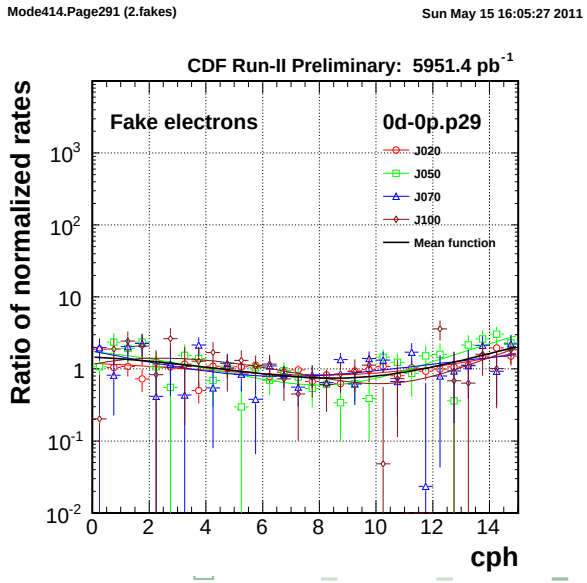
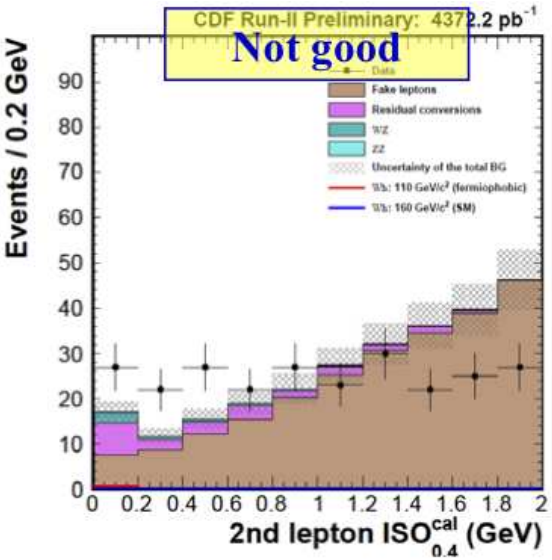






LS dilepton (Signal) Comparison (Top: p_T, Bottom: 5D)



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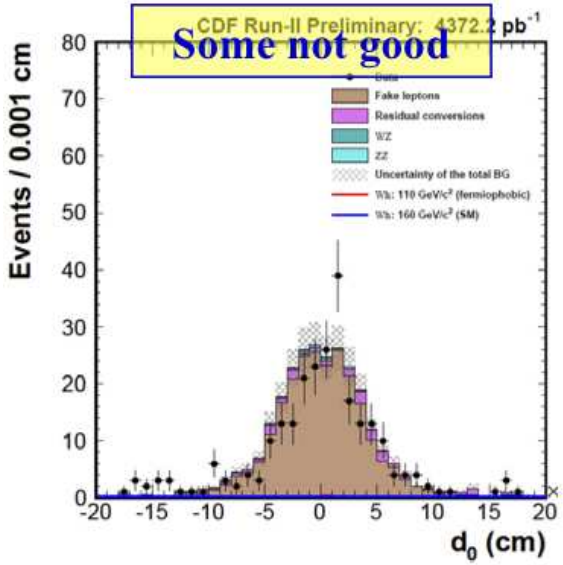

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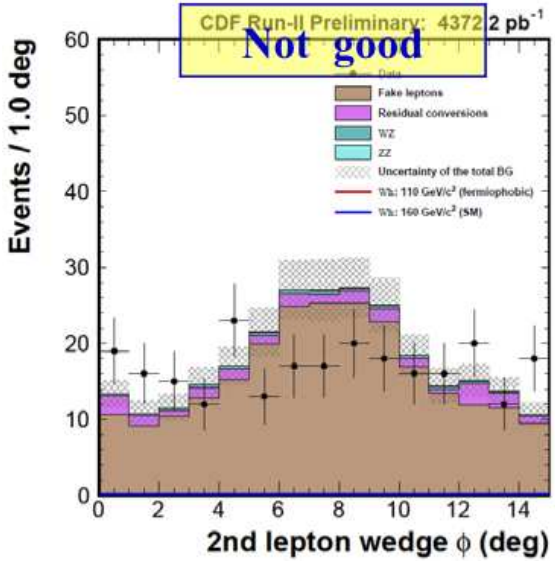
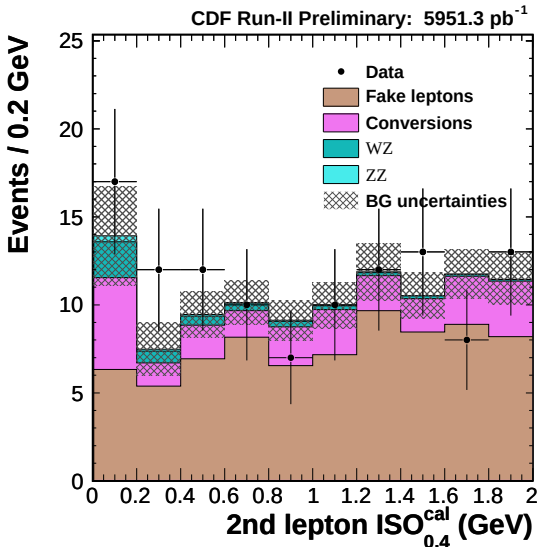
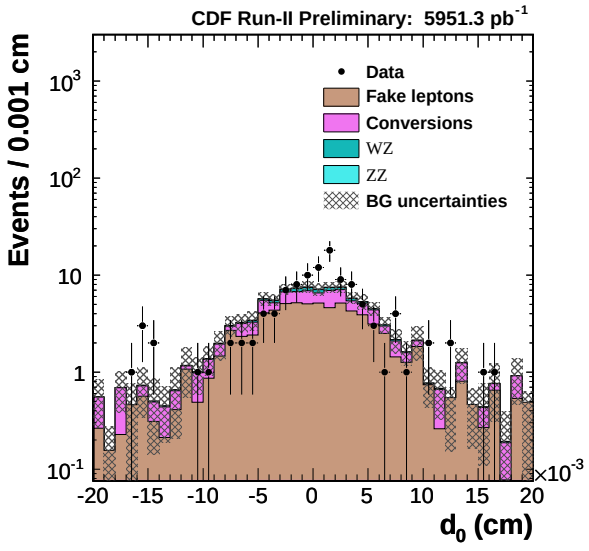
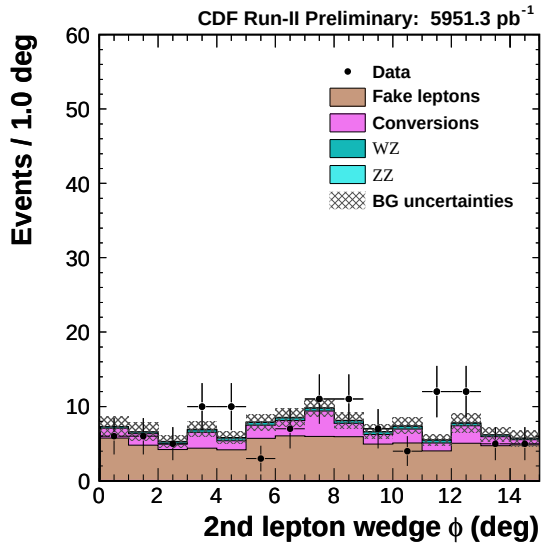


Mode400.Page308 (3.dilepton) Sat May 28 15:00:59 2011







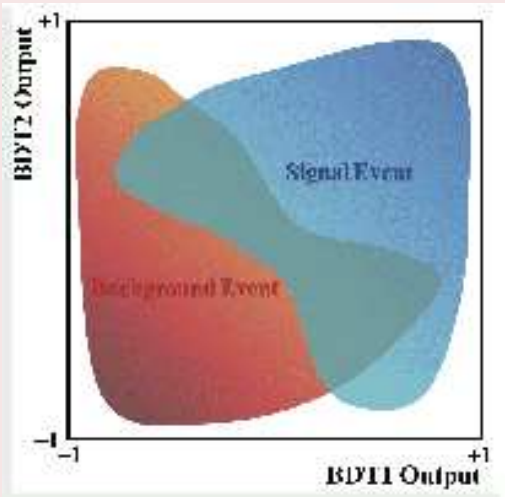
Summary & Plan

Summary

- We parametrize the fake rates using 5 variables with MC-based W subtraction.
- Apparent biases in the fake ratios caused by the W veto were removed.

Plan

- To get more sensitivity, apply 2D Boosted Decision Tree.



Back Up

Back Up Slides

Back Up (Overview)

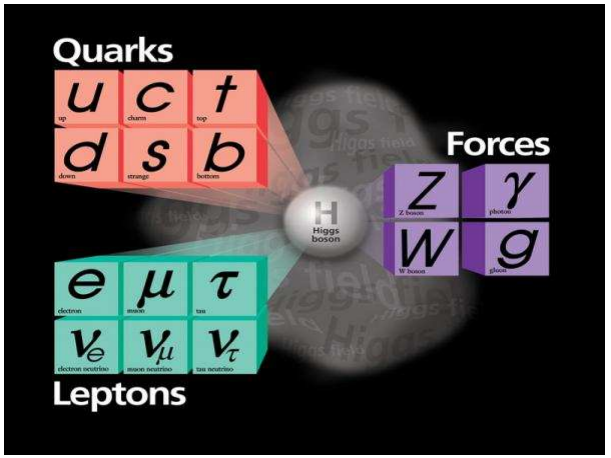
The Standard Model

- stems from the gauge theories.
- has a symmetry

$$SU(3)_C \bigotimes SU(2)_L \bigotimes U(1)_Y$$

→ Explicit mass terms break the gauge invariance.
→ Generate by Higgs mechanism.

- Higgs Mechanism:
  - Spontaneous Symmetry Breaking (SSB)
  - Eat Goldstone boson by gauge symmetries
  - Need scalar boson (Higgs Boson)
  - Higgs boson has not been observed yet!

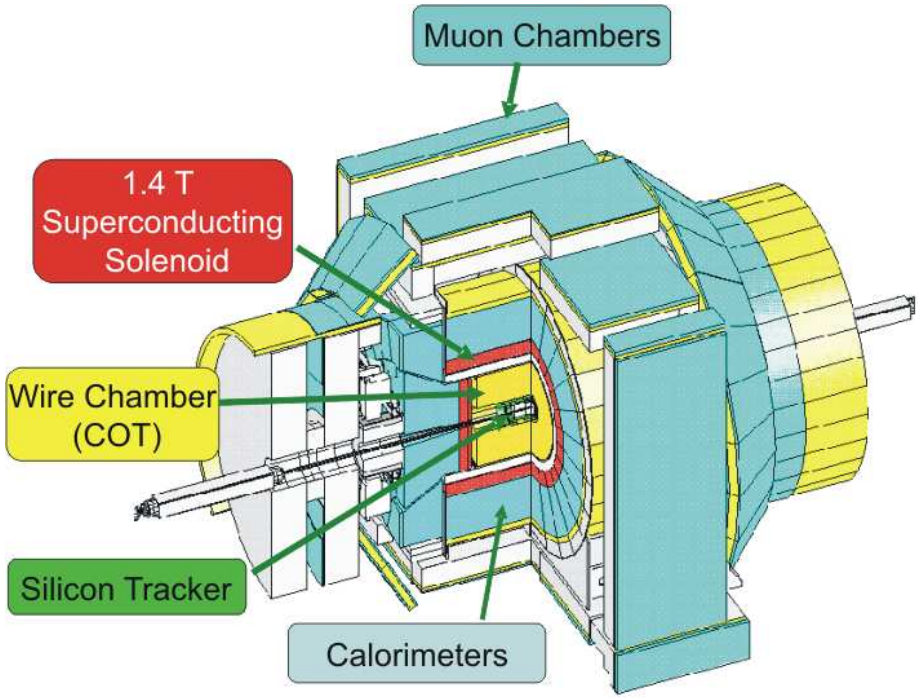


Higgs Production at the Tevatron

1. The gluon-gluon fusion production
2. The associated production via vector boson
3. The vector boson fusion production
4. The associated production via heavy quarks

CDF Detector

- **Silicon Vertex Detector**
  → Reconstruct decay position
- **Tracking Chamber** & **1.4T Solenoid**
  → Measuire particle momenta & charges
- **Electromagnetic** & **Hadron Calorimeters**
  → Measure particle energies
- **Muon Detectors**
  → Detect muons



Control Regions

There are four control regions for validations of background expectation.

Opposite-sign dilepton events (rich SM events)

- OS dilepton events passing lepton selection cuts

Low-MetSpec & High-Met OS events (rich fake lepton events)

- OS dilepton events passing lepton selection cuts
- Low-MetSpec: $15 < \text{MetSpec} < 50\text{GeV}$
- High-Met: $\not\!\!E_T > 25\text{GeV}$
- Low dilepton mass: $20 < M_{\ell\ell} < 40\text{GeV}/c^2$

Lepton side-band events (rich fake lepton events)

- LS dilepton events
- 1st lepton passing lepton selection cuts
- 2nd letpon failing at least one lepton selection cuts

Zero Silicon (rich conversion events)

- 1st lepton with no silicon hit requirement
- 2nd lepton with zero-silicon hit requirement
- Silicon fiducial cut: 2nd lepton passing through SVX 5 layers and $|z_0| < 47.25$ cm at $R = 10.645$

Fake Rates for Muon

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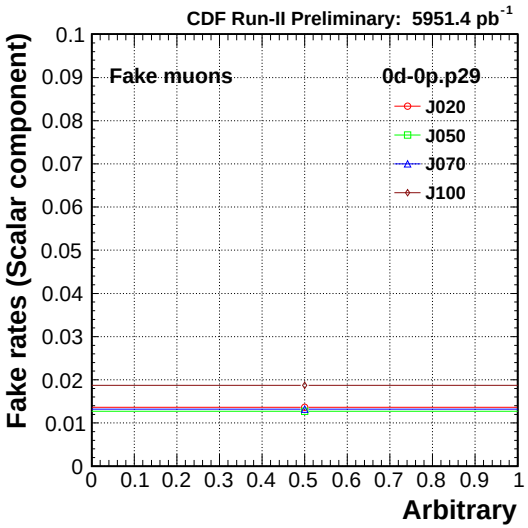

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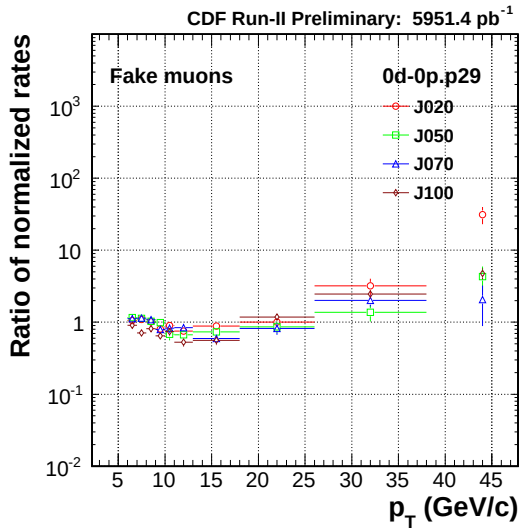

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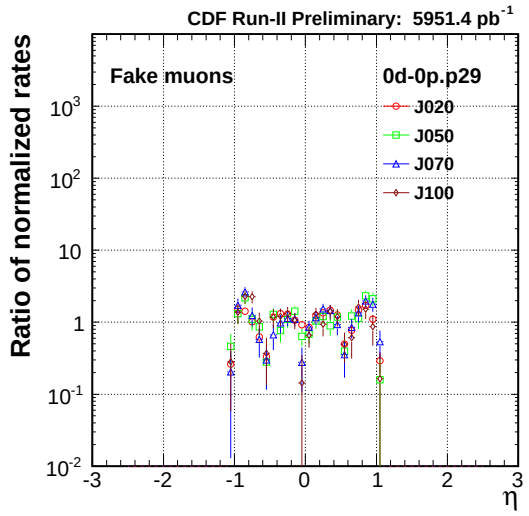

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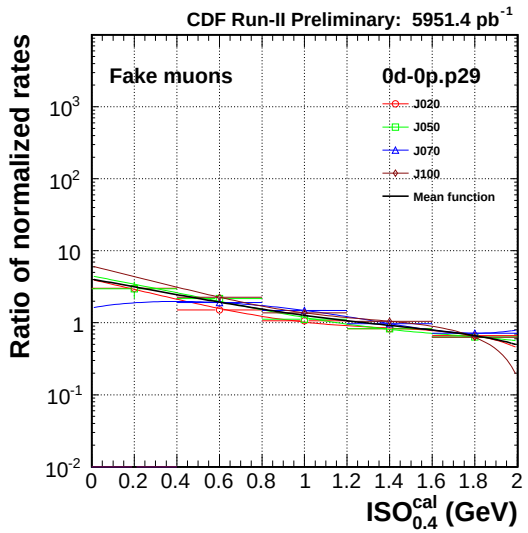

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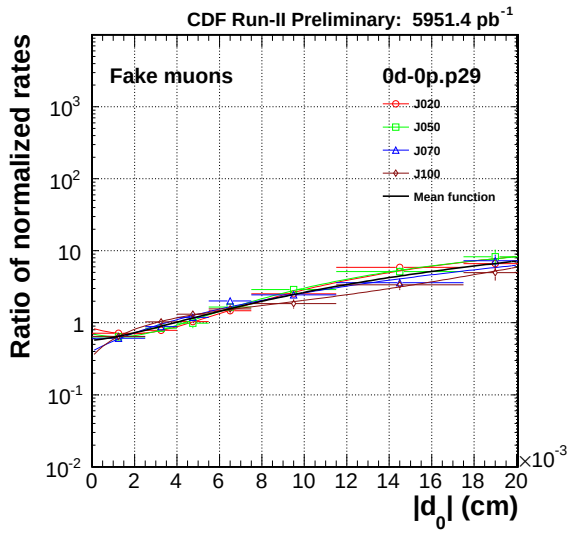

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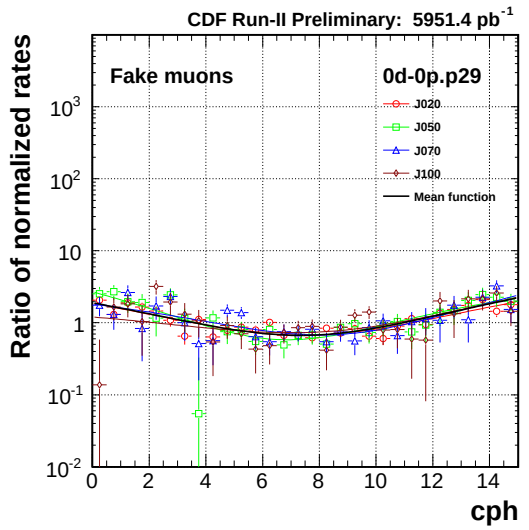

Nominal Cut for the 1st electron

Pre-event Selection

- $|z_{pv}| < 60$ cm
- Cosmic-ray veto

Other Cuts

- Conversion veto

1st Electron Selection

- Geometrical and kinematical cuts
  - CEM
  - Fiducial
  - $E_T > 20$ GeV ($p_T > 10$ GeV/c)
- Track quality cuts
  - Axial ≥ 3 and Stereo $\geq 3 (\geq 7 hits)$
  - $|z_0 - z_{\rm pv}| < 2$ cm
  - Silicon hits ≥ 3
  - $|d_0| < 0.02$ cm
- Isolation cut
  - $\mathrm{ISO}^{\rm cal}_{0.4} < 2$ GeV
- Identification cuts
  - Had/Em $< 0.055 + 0.00045 \times E$
  - $\mathrm{L_{shr}} < 0.2$ ($E_T < 70$ GeV)
  - $E/p < 2$ ($E_T < 50$ GeV)
  - $\chi^2_{\rm strip} < 3$ cm
  - $-3.0 < Q \times \Delta x_{\rm CES} < 1.5$ cm

Residual Photon Conversion

- The residual photon-conversion events are enhanced by the asymmetric energy sharing.
- Estimated by

$$N_{\text{res}} = N_{\text{conv}} \times R_{\text{res}}, \quad R_{\text{res}} = \frac{1-\varepsilon_{\text{conv}}}{\varepsilon_{\text{conv}}} \qquad (1)$$

N_{res}: # of residual-conversion events
N_{conv}: # of conversion events
$\varepsilon_{\text{conv}}$: conversion detection efficiency

- $\varepsilon_{\text{conv}}$ is separeted as

$$\varepsilon_{\text{conv}}(p_T) = \varepsilon_{\text{part}}(p_T) \times \varepsilon_{\text{nomi}} \qquad (2)$$

$\varepsilon_{\text{part}}(p_T)$: Partner track finding efficiency
$\varepsilon_{\text{nomi}}$: Nominal conversion tagging efficiency