WW Cross Section Measurement and $H \rightarrow WW$ Search

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- CDF *WW* Cross Section
- ATLAS *WW* Cross Section
- ME Method for Signal Extraction
- Higgs Search and Challenges

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WW Cross Section

First step in Higgs search

* Establish standard model process
* Understand detector and backgrounds
* Constrain theoretical uncertainties (PDFs, NLO QCD)

Sensitive to new physics

* New energy regime gives immediate sensitivity to anomalous couplings at multi-TeV scale
* Other new physics (SUSY, LED, ...) can contribute to this final state

First year potential at ATLAS

* Cross section: 5.4 - 5.8 pb
* Acceptance: 5 - 15%
* ~250 - 750 *WW* events/fb^{-1}

~5% statistical uncertainty with 1 fb^{-1}

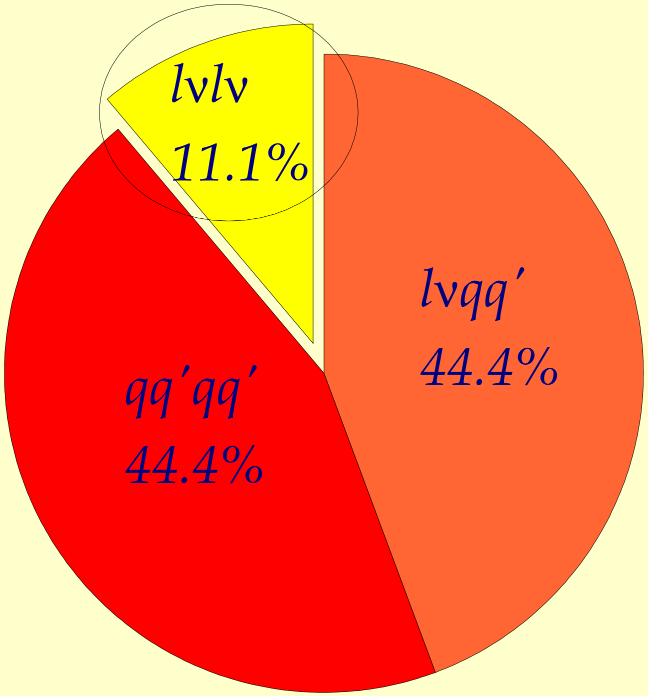
CDF *WW* Production Cross Section

CDF analysis a useful guide to LHC analysis

* Many overlapping backgrounds & acceptance issues

NLO cross section: $\sigma(p\bar{p} \rightarrow WW) = (12.4 \pm 0.8)$ pb

WW decay modes



'Dilepton' channel:

* Low hadronic-jet background
* First observed in ~200 pb^{-1} in Run 2

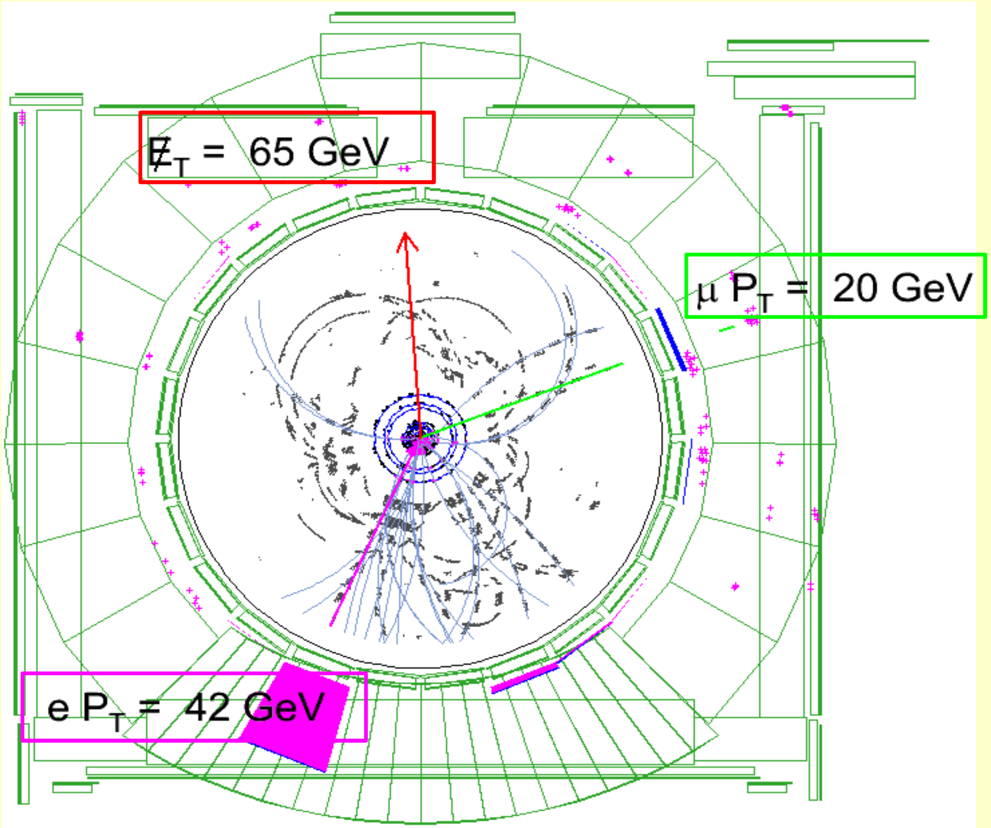
(CDF evidence in Run 1)

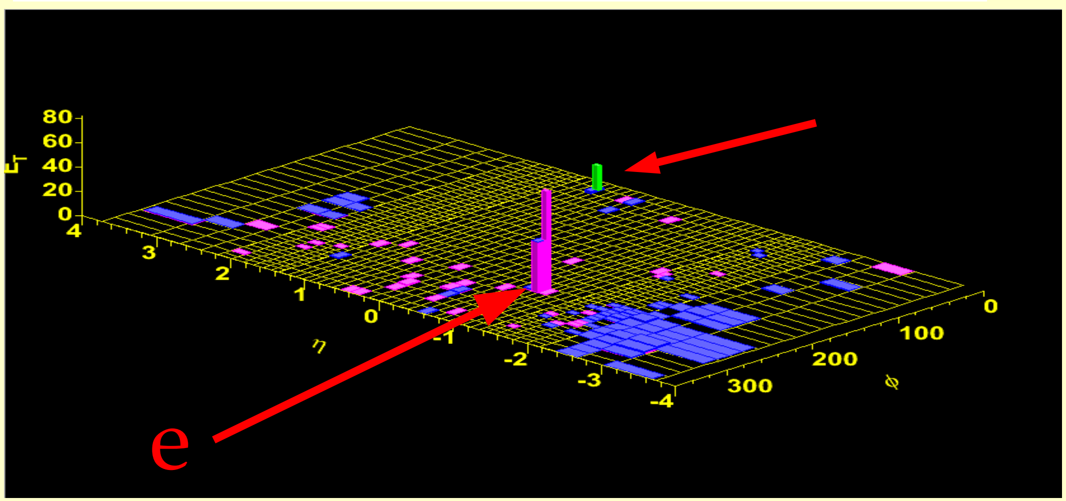
o CDF: 17 events, 5.2 background

o DØ : 25 events, 8.0 background

5.2σ significiance

WW Candidate Selection





Two leptons (**E_T > 20 GeV**)

Large transverse energy imbalance

(**$\not\!\!E_T$ > 25 GeV**)

Remove *Z*, *jet* events:

* If 76 < m_{ll} < 106 GeV, **$\not\!\!E_T/\sqrt{\Sigma E_T} > 3$**

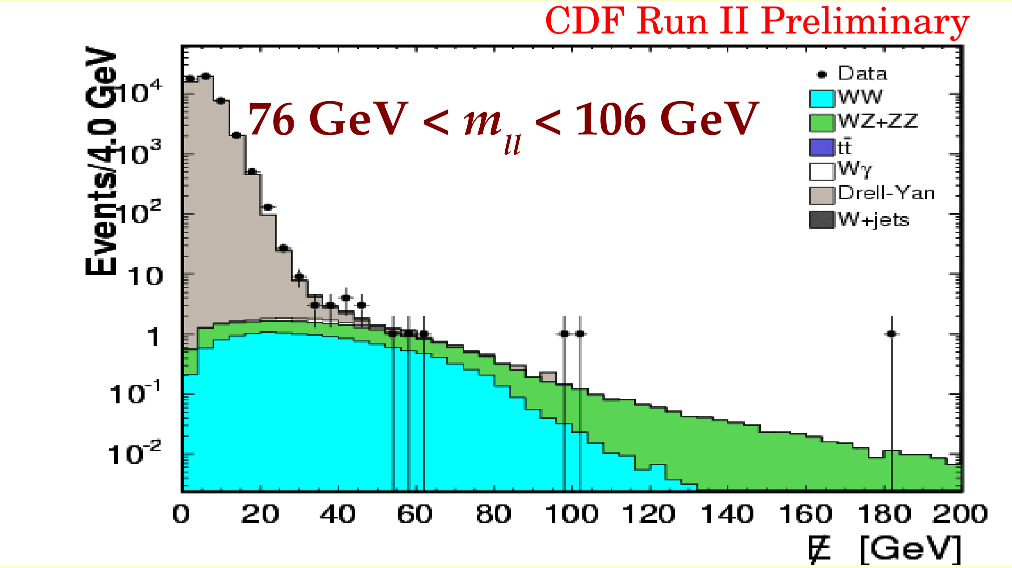
* If $\not\!\!E_T$ < 50 GeV,

minimum **$\Delta\phi(\not\!\!E_T, l, \text{jet}) > 20^o$**

Remove $t\bar{t}$ events:

* **No jets** (E_T > 15 GeV in |η| < 2.5)

WW Backgrounds and Acceptance



Z:

* Use MC to model high $\not\!\!E_T$ tail
* Cross-check ($\not\!\!E_T^{sig} < 3$): data **18**, bd **15.4**

W + jet:

* Measure jet → lepton rate
* Apply rate to jet in *W* + jet events
* Cross-check with like-charge dileptons: data **24**, background **21**

W + γ:

* Photon conversion in detector mimics dilepton + $\not\!\!E_T$ final state

Acceptance and uncertainties:

Two leptons (e $|\eta| < 2$, μ $|\eta| < 1$): **1/5**

Other cuts: **1/2**

Jet Rejection	± 7.8%
Trigger Efficiency	± 2%
PDF	± 1.7%
Electron Identification	± 1%

WW Cross Section Results

Expected signal and backgrounds:

CDF Run II Preliminary

Mode	ee	$e\mu$	$\mu\mu$	ll
WW	$12.8 \pm 0.1 \pm 1.1$	$28.8 \pm 0.1 \pm 2.4$	$10.7 \pm 0.1 \pm 0.9$	$52.4 \pm 0.1 \pm 4.3$
Drell-Yan	$5.0 \pm 0.5 \pm 1.3$	$3.8 \pm 0.4 \pm 1.0$	$3.0 \pm 0.4 \pm 0.8$	$11.8 \pm 0.8 \pm 3.1$
W+jets	$3.0 \pm 0.2 \pm 0.7$	$6.7 \pm 0.4 \pm 2.0$	$1.3 \pm 0.2 \pm 0.5$	$11.0 \pm 0.5 \pm 3.2$
$WZ + ZZ$	$3.6 \pm 0.0 \pm 0.4$	$0.9 \pm 0.0 \pm 0.1$	$3.4 \pm 0.0 \pm 0.3$	$7.9 \pm 0.0 \pm 0.8$
$W\gamma$	$3.6 \pm 0.1 \pm 0.7$	$3.2 \pm 0.1 \pm 0.7$	$0.0 \pm 0.0 \pm 0.0$	$6.8 \pm 0.2 \pm 1.4$
$t\bar{t}$	$0.1 \pm 0.0 \pm 0.0$	$0.1 \pm 0.0 \pm 0.0$	$0.0 \pm 0.0 \pm 0.0$	$0.2 \pm 0.0 \pm 0.0$
Sum Bkg	$15.2 \pm 0.6 \pm 1.7$	$14.8 \pm 0.6 \pm 2.3$	$7.8 \pm 0.4 \pm 1.0$	$37.8 \pm 0.9 \pm 4.7$
Expected	$28.0 \pm 0.6 \pm 2.0$	$43.7 \pm 0.6 \pm 3.3$	$18.5 \pm 0.4 \pm 1.3$	$90.2 \pm 0.9 \pm 6.4$
Data	29	47	19	95

$\sigma_{WW} = 13.6 \pm 2.3\ (\text{stat}) \pm 1.6\ (\text{sys}) \pm 1.2\ (\text{lum})\ \text{pb}$

Measurement accuracy ~20% in 825 pb^{-1} (from ~40% in 200 pb^{-1})

* 10σ significance

Background Reduction at ATLAS

Need 10^3 reduction from $\not{E}_T$
CDF: $O(10^3)$

Need 10 reduction from jet veto
CDF: $O(10^2)$

	W + jets	*Z*	*W* + gamma	*ttbar*	*WW*
Xsec (pb) x BR	8000	4000	80	41.1	5.4

Need 10^3 reduction from lepton id
CDF: $O(10^3)$

Need 20 reduction from conversion id
CDF: $O(40)$

CDF: signal to background O(1)

Could be worse for LHC

* $t\bar{t}$ much larger relative cross section

* more tracker material: higher $\gamma \rightarrow e$ misidentification rate

Can ATLAS do better with lepton id and $\not{E}_T$?

Steps to Background Reduction

W + *jets* production:

* Understand sources of *jet* → lepton misidentification
* Can multivariate techniques reduce rates?

Z production:

* Understand detector sources of large missing energy
* Methods to target and reduce sources?

$W\gamma$ production:

* Study conversion-finding efficiency
* Road search to improve efficiency?

$t\bar{t}$ production:

* Compare recoil cut to jet cut: theoretical uncertainties vs rejection factor

Signal Acceptance

Theoretical issues:

* WW p_T distribution and N_{jets} spectrum
* PDF acceptance uncertainties

Experimental issues:

* Lepton identification efficiency
* Uncertainty of $\not{E}_T$ cut
* Luminosity
* Quote ratio of WW to Z cross sections to reduce uncertainty?

Matrix-Element-Based Searches

Determine a per-event probability for signal based on the matrix element and measured quantities

Output equivalent to a neural network

→ But uses the matrix element rather than an empirical training procedure from fully-simulated events

Can determine probability for each Higgs mass hypothesis

After discovery, use method to measure the Higgs mass

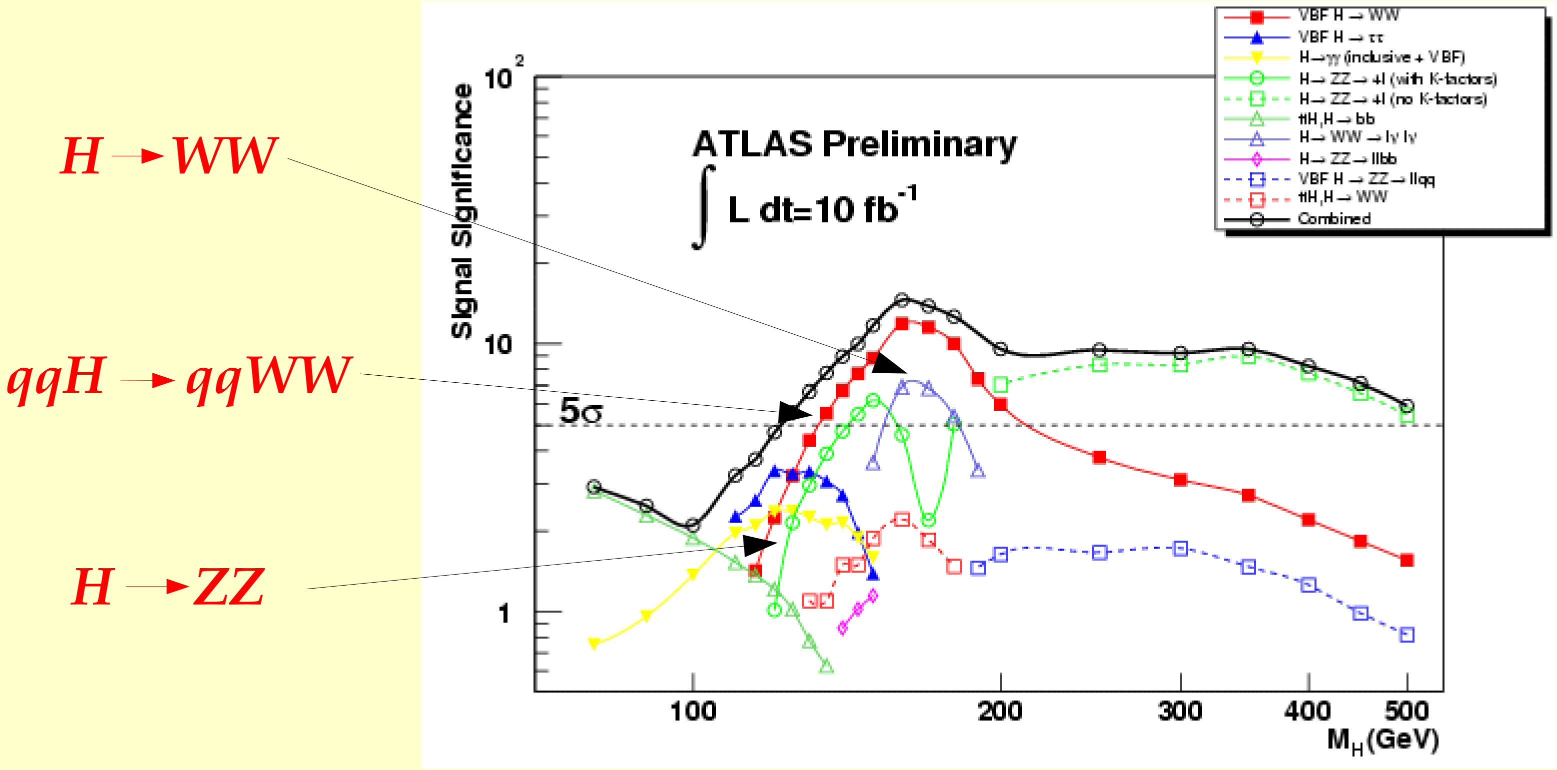
Technique originally developed at Fermilab to measure the top quark mass

* Now being applied to single-top search (results this fall) and Higgs to *WW* search (results next spring)

Higgs → *WW* Search Challenges

Best sensitivity for m_H ~ 160 GeV

* Good lepton id for p_T ~ 10 GeV can extend down to m_H ~ 140 GeV
* Gain sensitivity at low masses through vector-boson fusion channel



Higgs → *WW* Search Challenges

Backgrounds

	W + jets	*Z*	*W* + gamma	*ttbar*	*WW*
Xsec (pb) x BR	8000	4000	80	41.1	5.4

H → WW

	120 GeV	160 GeV	300 GeV
Xsec (pb) x BR	0.25	1.1	0.33

Need 5 reduction from ME technique

qqH → qqWW

	120 GeV	160 GeV	300 GeV
Xsec (pb) x BR	0.026	0.14	0.044

Need 10 reduction from 'tag' jets

Need extra 4 reduction for low-mass Higgs

Summary

WW channel promising for Higgs discovery

* Staged approach:

  Measure *WW* cross section with 1 fb^{-1}

  Discover Higgs with 10 fb^{-1}

Matrix-element approach

* Physics-based method to maximize statistical power for discovery

Challenges:

* Maintain high S/B for *WW* cross section

  Need good lepton id & conversion rejection; small $\not{E}_T$ *tails*

* Obtain sensitivity to low m_H through low-p_T lepton id

Backup

Anomalous Triple-Gauge Couplings

Parametrize new physics in effective Lagrangian:

$$L_{WWV}/g_{WWV} = i g_1^V (W^\dagger_{\mu\nu} W^\mu V^\nu - W^\dagger_\mu V_\nu W^{\mu\nu}) + i\kappa_V W^\dagger_\mu W_\nu V^{\mu\nu} + i\lambda_V/M_W^2 \, W^\dagger_{\lambda\mu} W^\mu_\nu V^{\nu\lambda}$$

SM: $g_1^\gamma = g_1^Z = 1$

AC: Δg_1^Z ($= g_1^Z - 1$)

SM: $\kappa_\gamma = \kappa_Z = 1$

AC: $\Delta\kappa_Z$, $\Delta\kappa_\gamma$ ($= \kappa_V - 1$)

SM: $\lambda_\gamma = \lambda_Z = 0$

AC: λ_Z, λ_γ

Impose unitarity by introducing a 'new physics' energy scale:

$$\alpha(s) = \alpha_0 / (1 + s/\Lambda^2)^2$$

Anomalous couplings increase as new physics scale approaches

Manifested in additional cross section at high boson p_T in WW/WZ events