Model Dependence Error in Hadronic Recoil ZH Cross Section

Tim Barklow (SLAC)
June 26, 2014

Mark Thomson's analysis of $\sigma(ZH)$ with $Z \to q\bar{q}$ uses two measurements to obtain the cross section:

$$\sigma(ZH) = \sigma(ZH) \bullet BR(visible) + \sigma(ZH) \bullet BR(invisible)$$

$\sigma(ZH) \bullet BR(visible)$

Final(?) Results

Process	σ/fb	ε_{presel}	$\varepsilon_{\mathcal{L}>0.70}$	$N_{\mathcal{L}>0.70}$
$q\bar{q}$	25180	0.5 %	<0.1 %	6211
$q\bar{q}l\nu$	5914	6.4 %	0.1 %	3895
$q\bar{q}q\bar{q}$	5847	4.2 %	0.4 %	10818
$q\bar{q}ll$	1704	1.2 %	0.1 %	1218
$q\bar{q}\nu\bar{\nu}$	325	0.6 %	<0.1 %	35
$H\nu_e\bar{\nu}_e$		- %		
HZ	93.4	44.0 %	20.3 %	9493
$H \to$ invis.		0.6 %	<0.1 %	–
$H \to q\bar{q}/gg$		43.5 %	20.6 %	6211
$H \to WW^*$		44.7 %	19.5 %	2240
$H \to ZZ^*$		40.0 %	18.1 %	254
$H \to \tau^+\tau^-$		47.6 %	21.4 %	738
$H \to \gamma\gamma$		42.8 %	22.1 %	32
$H \to Z\gamma$		41.8 %	17.6 %	17
$H \to \mu^+\mu^-$		39.5 %	20.6 %	3

★ For optimal cut
- signal ~9.5k events
- background ~ 19k events

15 % improvement c.f. LCWS analysis

Efficiencies same to ~10 % !!!

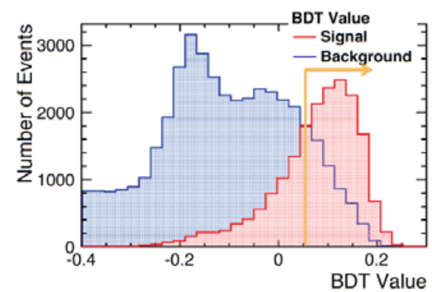
almost model independent

Mark Thomson   Fermilab, May 2014   24

$\sigma(ZH) \bullet BR(invisible)$

BDT Selection

★ Preliminary results (7 variable BDT selection)



Signal

Channel	Efficiency
Z H → qq invis.	20.7 %

Backgrounds

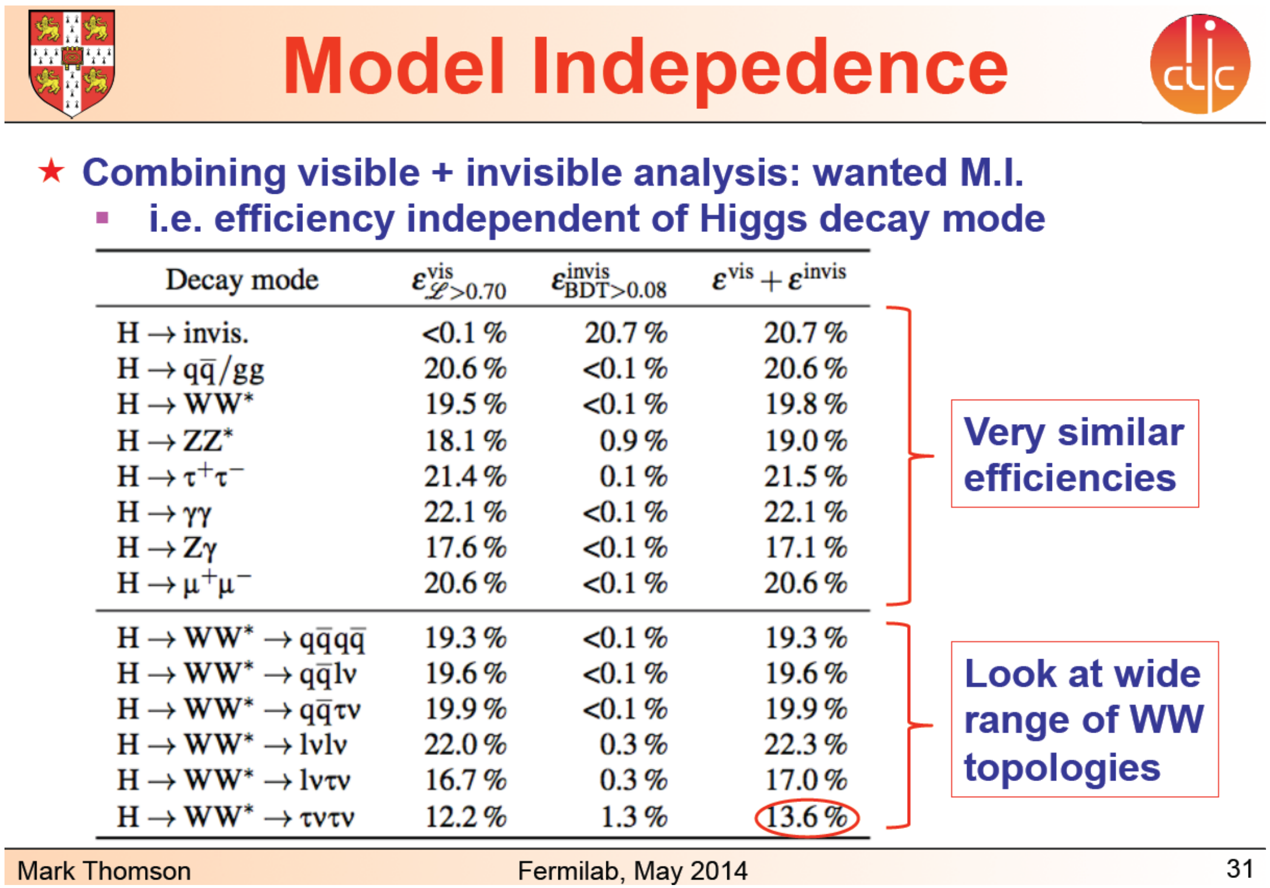
Channel	Efficiency	Events
qqlv	<0.1 %	900
qqll	<0.1 %	4
qqvv	1.5 %	2414

★ Assuming no invisible decays (1 sigma stat. error):

$$\Delta\sigma_{\rm invis} = \pm 0.57\ \%$$

(CLIC beam spectrum, 500 fb^{-1} @ 350 GeV, no polarisation)

In order to use this cross section measurement in our Higgs analyses we have to quantify the penalty associated with the fact that $\sigma(ZH) \bullet BR(visible)$ is "almost model independent". By how much must we blow up $\Delta\sigma(ZH) \bullet BR(visible)$ to account for the fact that the efficiencies differ by 10% or more?



Model Indepedence

- Combining visible + invisible analysis: wanted M.I.
  - i.e. efficiency independent of Higgs decay mode

Decay mode	$\varepsilon^{vis}_{\mathscr{L}>0.70}$	$\varepsilon^{invis}_{BDT>0.08}$	$\varepsilon^{vis} + \varepsilon^{invis}$
$H \to$ invis.	<0.1 %	20.7 %	20.7 %
$H \to q\bar{q}/gg$	20.6 %	<0.1 %	20.6 %
$H \to WW^*$	19.5 %	<0.1 %	19.8 %
$H \to ZZ^*$	18.1 %	0.9 %	19.0 %
$H \to \tau^+\tau^-$	21.4 %	0.1 %	21.5 %
$H \to \gamma\gamma$	22.1 %	<0.1 %	22.1 %
$H \to Z\gamma$	17.6 %	<0.1 %	17.1 %
$H \to \mu^+\mu^-$	20.6 %	<0.1 %	20.6 %
$H \to WW^* \to q\bar{q}q\bar{q}$	19.3 %	<0.1 %	19.3 %
$H \to WW^* \to q\bar{q}l\nu$	19.6 %	<0.1 %	19.6 %
$H \to WW^* \to q\bar{q}\tau\nu$	19.9 %	<0.1 %	19.9 %
$H \to WW^* \to l\nu l\nu$	22.0 %	0.3 %	22.3 %
$H \to WW^* \to l\nu\tau\nu$	16.7 %	0.3 %	17.0 %
$H \to WW^* \to \tau\nu\tau\nu$	12.2 %	1.3 %	13.6 %

Very similar efficiencies

Look at wide range of WW topologies

Mark Thomson Fermilab, May 2014 31

I propose an approach where we use all of our σ•*BR* measurements for visible Higgs decays to obtain an estimate of the average signal efficiency for σ(*ZH*)•*BR*(*visible*). It is then straightforward to propagate the σ•*BR* errors to the error on σ(*ZH*)•*BR*(*visible*), This means that one must take into account the correlation between the σ•*BR* measurements and our σ(*ZH*) measurement from hadronic Z decays when we fit for couplings and total width. It also means that we must develop σ•*BR* analyses for all possible visible Higgs decays -- but this we have to do anyway to extract the best errors on Higgs couplings and total width.

Let $\alpha \equiv \sigma(ZH) \bullet BR(visible)$

$\omega =$ Number of signal events in $\sigma(ZH) \bullet BR(visible)$ analysis

ξ = Average efficiency for signal events to pass $\sigma(ZH) \bullet BR(visible)$ analysis

$L =$ luminosity

$$\alpha = \frac{\omega}{L\xi} = \frac{1}{\xi}\sum_i \psi_i \eta_i \quad \text{where}$$

$\psi_i = \sigma(ZH) \bullet BR_i$

$\eta_i =$ efficiency for events from Higgs decay i to pass $\sigma(ZH) \bullet BR(visible)$ analysis

$$(\Delta\alpha)^2 = \left(\frac{\partial\alpha}{\partial\omega}\right)^2 V_{\omega\omega} + \left(\frac{\partial\alpha}{\partial\xi}\right)^2 V_{\xi\xi} + 2\frac{\partial\alpha}{\partial\omega}\frac{\partial\alpha}{\partial\xi}V_{\omega\xi}$$

$$V_{\omega\omega} = \sum_i N_{\kappa i} + N_{\varepsilon i}$$

$$V_{\xi\xi} = \frac{1}{L^2(\sum_i \psi_i)^2}\sum_i \frac{(\eta_i - \xi)^2}{(\eta'_i)^2}(N_{\kappa i} + N'_{\varepsilon i})$$

$N_{\kappa i}$ = number of events common to had Z recoil

and $\sigma \bullet BR_i$ analyses

$N_{\varepsilon i}$ = number of events unique to had Z recoil analysis

$N'_{\varepsilon i}$ = number of events unique to $\sigma \bullet BR_i$ analysis

η'_i = efficiency for Higgs decay i to pass $\sigma \bullet BR_i$ analysis