Search for Higgs: gg $\rightarrow$ h with h $\rightarrow$ W^*W^* $\rightarrow$ lνjj

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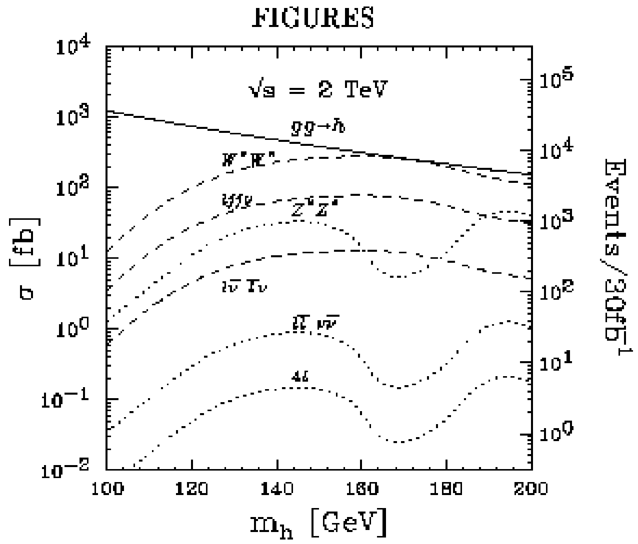
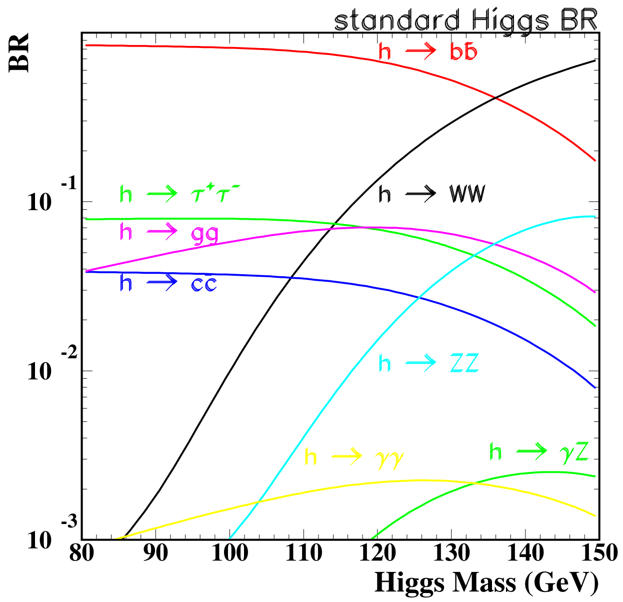
1. Cross-sections and Constraints
   (a) Signal Cross-sections
   (b) Background Cross-sections and constraints
2. The Higgs selection (SHW):
   (a) Pre-selection requirements
      i. Lepton ID and selection, $\not\!\!E_T$ requirements
      ii. Jets ID and selection
   (b) Selection with Likelihood method
      i. Variables used for S/B discrimination
      ii. The Likelihood function
3. Summary of results
   (a) Signal vs Background: pre-selection
   (b) Signal vs Background: likelihood method
   (c) Expected number of events & significance
   (d) Conclusions

Higgs cross-sections (1) and Branching Ratios (2):

(1) HEP-PH/9807424 (2) HDECAY program





Expected cross sections for the signal (e+μ):

Higgs Mass (GeV/c^2)	$m_h = 120$	$m_h = 140$	$m_h = 160$	$m_h = 180$
$\sigma(\mathrm{gg} \to \mathrm{h})$ [fb]	800	480	300	220
$\sigma \times \mathrm{BR}_{\mathrm{gg}\to\mathrm{WW}}$ [fb]	100	210	300	210
$\sigma \times \mathrm{BR}_{\mathrm{WW}} \times \mathrm{BR}_{\mathrm{WW}\to l\nu jj}$ [fb]	18	50	55	40

1. Backgrounds cross-section:

Process	σ(fb) 2.0 TeV (PYTHIA)
QCD jets	
$\mathrm{W + f/g \to l\nu jj}$	1.3×10^6
$\mathrm{WW \to l\nu jj}$	1,348
$\mathrm{t\bar{t} \to l\nu jjb\bar{b}}$	536
$\mathrm{WZ \to l\nu jj}$	158

2. Constraints on the analysis: ratio $S/\sqrt{B}$

For $\mathcal{L} = 10$ / 30 fb^{-1} and σ(signal) = 15 fb:

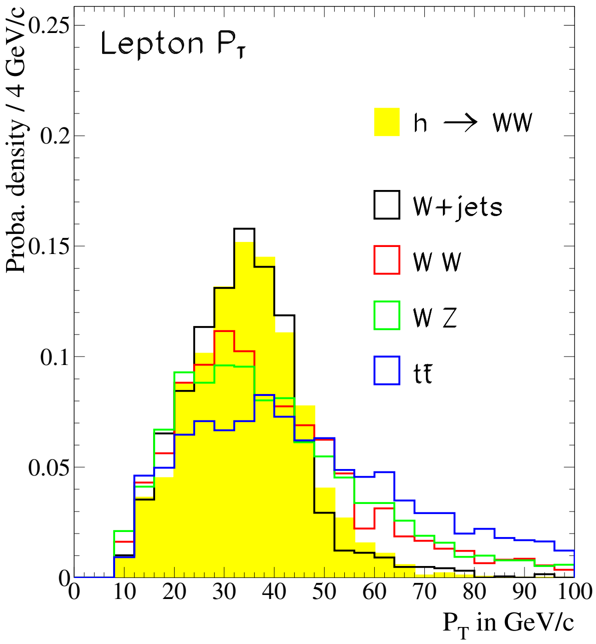
	Ratio $\mathrm{S}/\sqrt{\mathrm{B}}$			
Processus	$\epsilon = 10\%$	$\epsilon = 1\%$	$\epsilon = 0.1\%$	$\epsilon = 0.01\%$
$\mathrm{W + f/g \to l\nu jj}$	0.13 / 0.2	0.4 /0.7	1.3 /2.2	4.1 /7.1
$\mathrm{WW \to l\nu jj}$	4.1 / 7.1			
$\mathrm{t\bar{t} \to l\nu jjb\bar{b}}$	12.0 / 20.8			
$\mathrm{WZ \to l\nu jj}$	6.3 / 10.9			

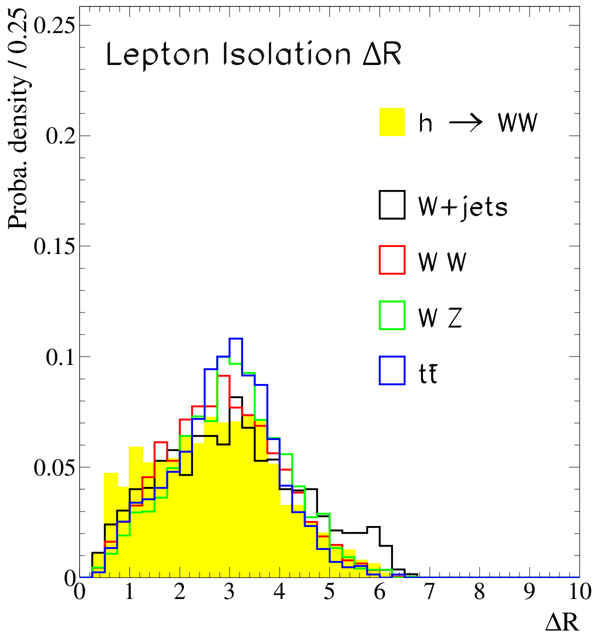
$\Longrightarrow$ Need a rejection of $\geq 1/1000$ for W+jets background

$\Longrightarrow$ Need a rejection $\approx 10\%$ for WW, WZ and $t\bar{t}$ events

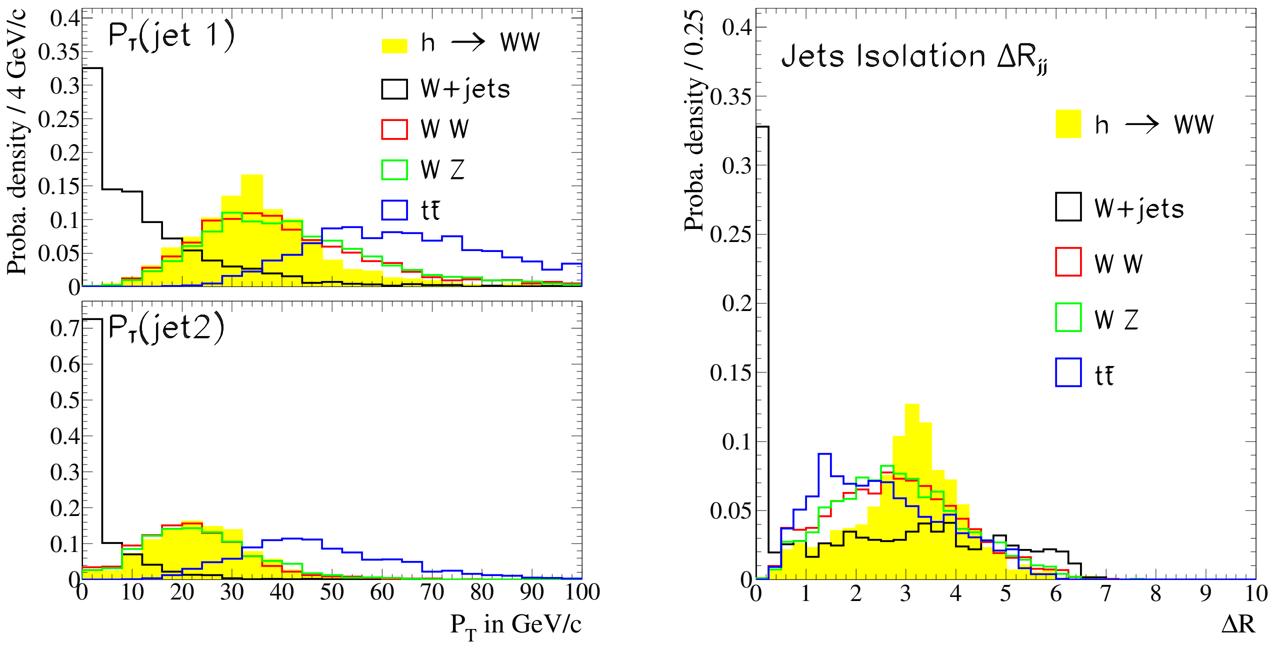
Event Pre-selection: Lepton

1. Lepton ID:
   (a) EM fraction : had/EM ≤ 0.125
   (b) Associated tracks within 30^o cone
2. Lepton selection:
   (a) Lepton p_T : $p_T \geq 15$ GeV/c
   (b) Lepton Isolation : $\Delta R(j,l) > 0.3$
   (c) Lepton rapidity: $|\eta| \leq 2.0$



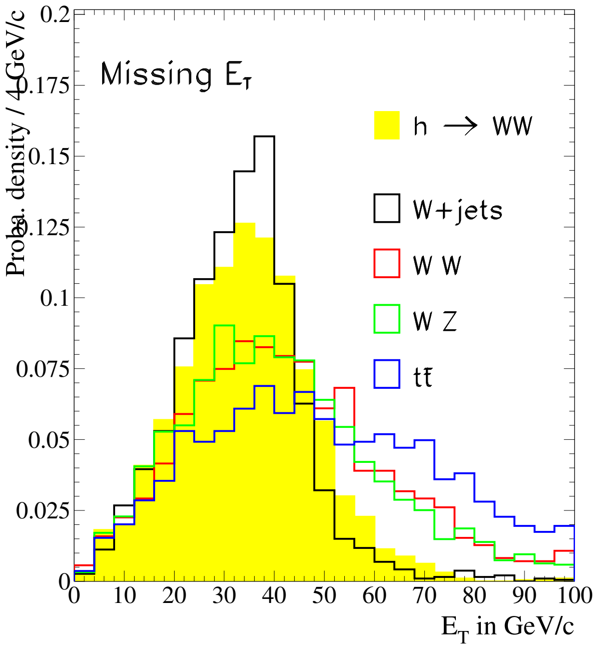


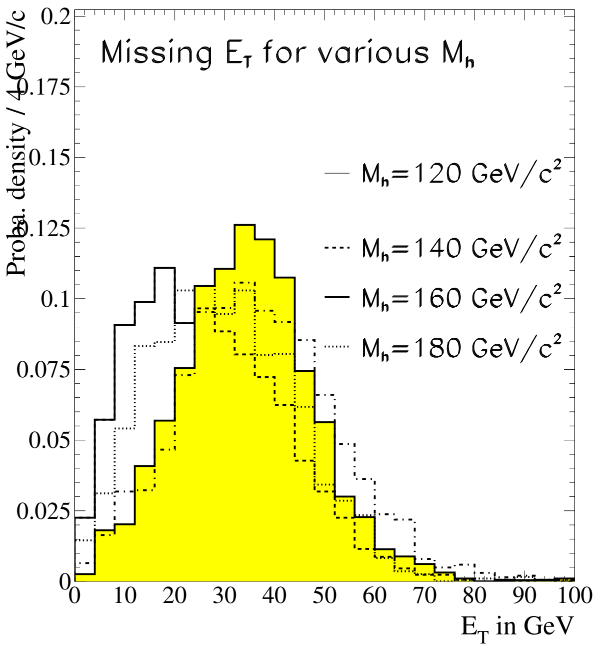
1. Jets ID:
   (a) Cluster in Calorimeter: $E_T \geq 5$ GeV
   (b) Associated tracks within 30^o cone
2. Jet 1 & 2 selection:
   (a) Jet 1& 2 p_T : $p_T \geq 15$ GeV/c
   (b) Jet Isolation: $\Delta R(j, j) > 0.7$
   (c) Jet rapidity : $|\eta| \leq 3.0$



Event Pre-selection: Missing energy

1. Missing Energy
   (a) Total missing energy : $\not{E}_T \geq 15GeV$
2. Dependence in M_h
   (a) On-shell W well selected
   (b) Must keep $\not{E}_T \approx 10$ GeV for off-shell W

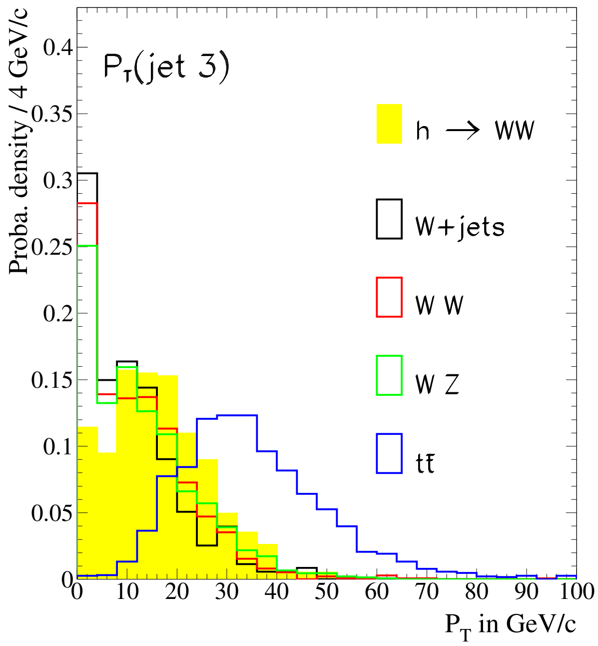


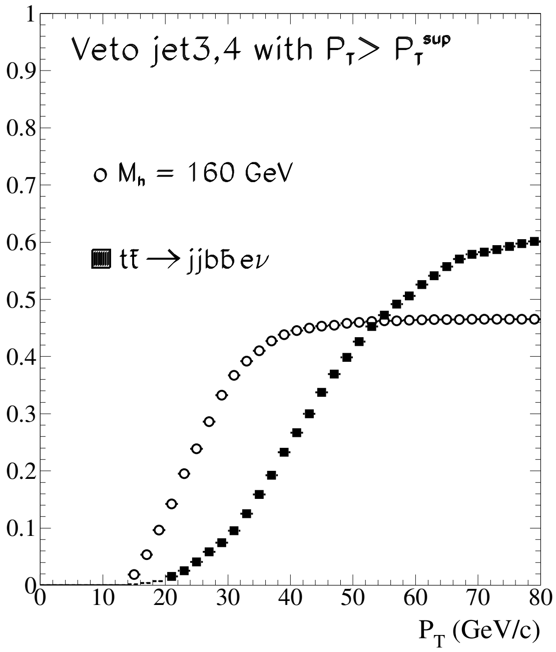


Event Pre-selection: Jet Veto cut

Rejection with a Jet veto cut

Definition: No jet 3,4 with $p_T \geq 25$ GeV/c





Effect on selection efficiency:

1. Background:
   (a) Events $t\bar{t} \rightarrow l\nu jjb\bar{b}$ rejected by a factor 4
2. Signal $h \rightarrow W^*W^* \rightarrow l\nu jj$:
   (a) Loss of $\approx 10\%$ events at $M_h = 160$ GeV
   (b) Affects mostly lower M_h samples

Likelihood Method:

1. Choose discriminant variables: difference in shape used
   (a) Jet 1,2 variables: $p_T^{j1}, p_T^{j2}, \Delta R_{jj} \Rightarrow v_1, v_2, v_3$
   (b) Lepton variable: $P_T^l \Rightarrow v_4$
   (c) Missing energy : $\not{E}_T \Rightarrow v_5$
   (d) Jet opening angle: $\Delta\Phi(j,j) \Rightarrow v_6$
   (e) Jet 3 : $P_T^{j3} \Rightarrow v_7$
   (f) Jet-jet Mass : $M(j_1, j_2) \Rightarrow v_8$
   (g) Cluster Mass : $M_C \Rightarrow v_9$
2. Compute probability for each event to be signal for each variable v_i

$$p^S_{v_i}(x_i) = \frac{v_i^S(x_i)}{\sum_{j=S,B} v_i^j(x_i)}$$

   where

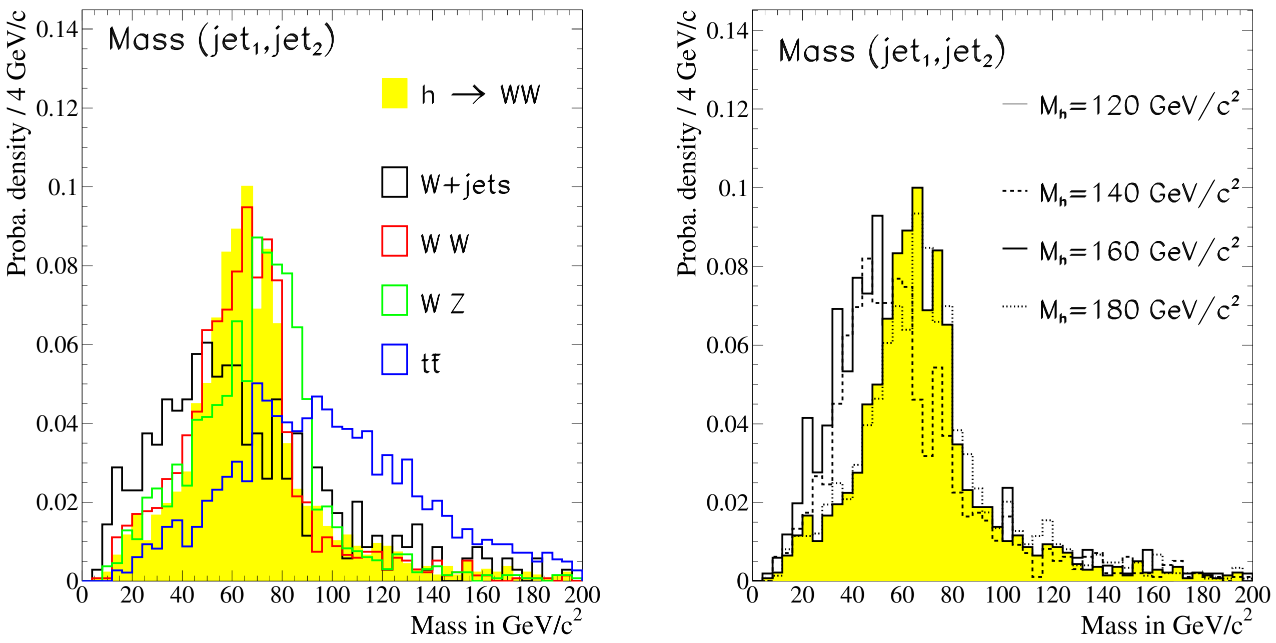
$$v_i^{S/B}(x_i) = \text{ probability density function associated to } v_i \text{ for } S/B$$

3. Compute the likelihood to be Signal using all 9 variables $\vec{x}$:

$$\mathcal{L}(\vec{x}) = \frac{\prod_{i=1}^n p_i^S(x_i)}{\sum_{j=S,B} \prod_{i=1}^n p_i^j(x_i)}$$

Di-jet Invariant Mass M(j, j)

1. Definition:
   (a) 2 jet events: Invariant Mass $M(j_1, j_2)$
   (b) > 2-jet events: Mass from Jet pair with highest M(j,j)

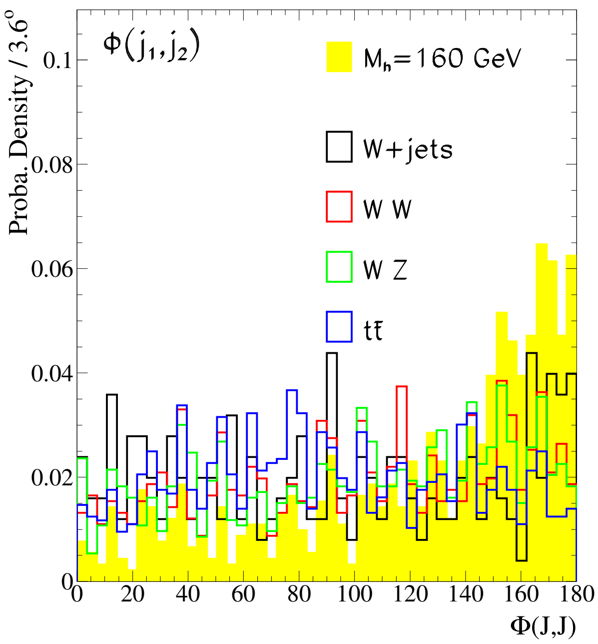


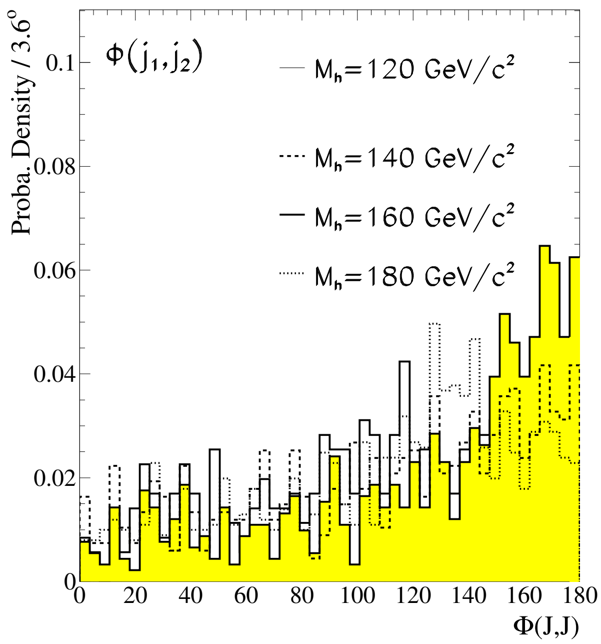
2. Discrimination S/B:
   (a) Events W+jets affected by lower part of distribution
   (b) Events $t\bar{t} \rightarrow l\nu jjb\bar{b}$ affected by upper part of distribution

Likelihood function: variables used

Azimuthal angle between jets: $\Phi(\mathrm{j},\mathrm{j})$

1. Definition:
   (a) 2 jet events: $\Phi(\mathrm{j},\mathrm{j}) = \Phi(\mathrm{j}_1,\mathrm{j}_2)$
   (b) $>$ 2-jet events: $\Phi(\mathrm{j},\mathrm{j})$ from Jet pair with highest M(j,j)

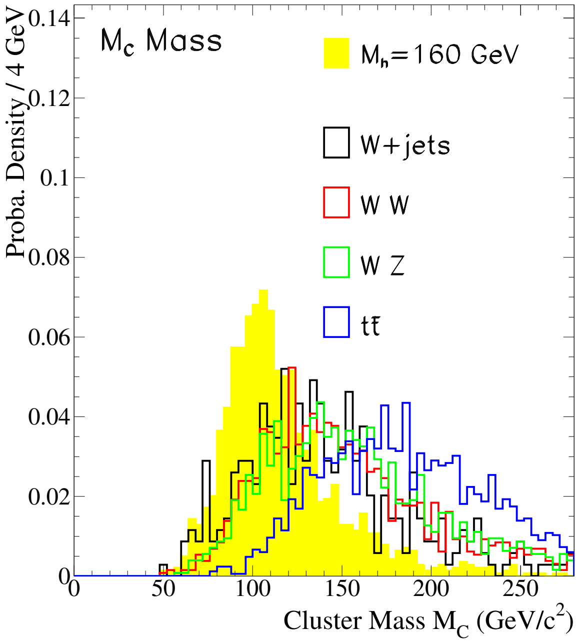


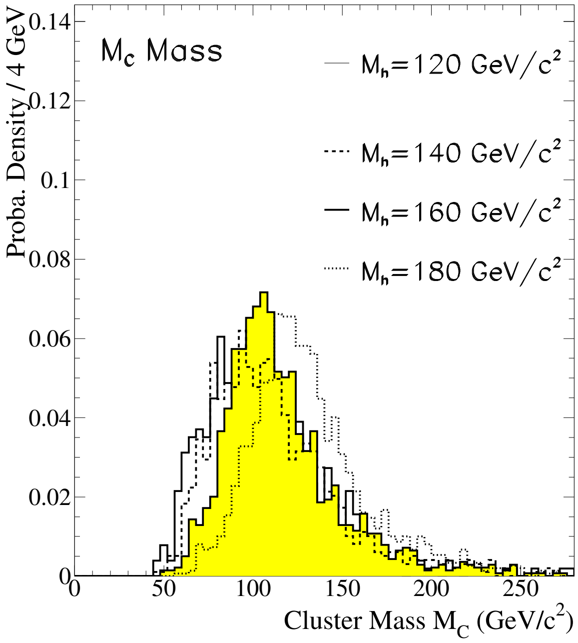


2. Discrimination S/B:
   (a) Events $h \to W^*W^*$ have j,j almost back-to-back
   (b) Events W+jets, WW $\to l\nu jj$, WZ $\to l\nu jj$ with uniform distribution

Cluster Mass M_C

1. Definition
   (a) 2-jets: $M_C = \sqrt{p_T^2(ljj) + m^2(jjl)} + \not{E}_T$
   (b) >2-jets: idem with jets with highest Mass M(j, j)

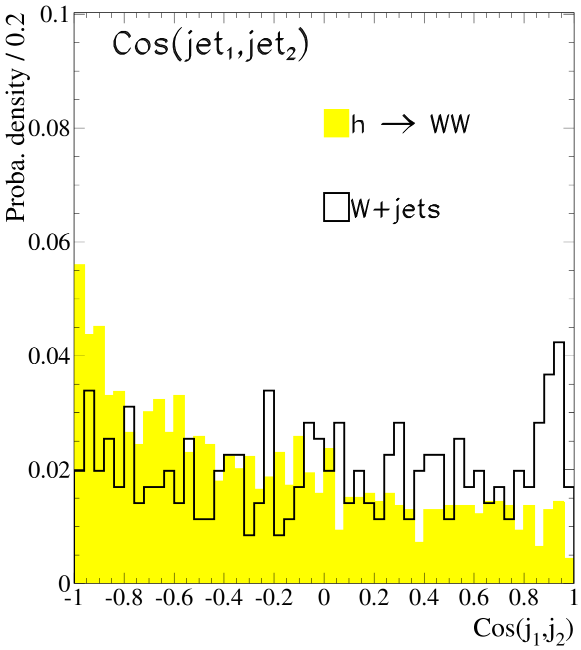


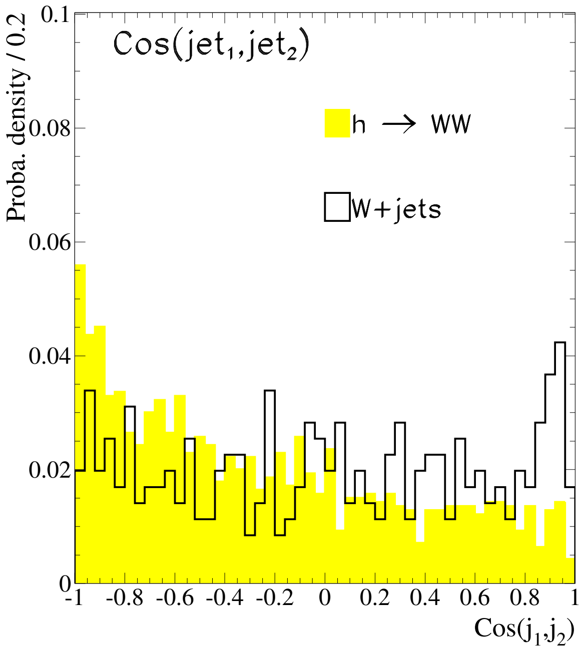


2. Discrimination S/B:
   (a) Good discrimination against $t\bar{t} \to l\nu jjb\bar{b}$ and $W+f/g \to l\nu jj$ events
   (b) Good discrimination against $WW \to l\nu jj$ and $WZ \to l\nu jj$

Cosine of Opening angle (j,j):

1. Definition:
   (a) 2-jet events: $\mathrm{Cos}(j_1, j_2)$





2. Discrimination S/B:
   (a) good discrimination against $W + f/g \rightarrow l\nu jj$ events

Efficiency on Signal and Background

Traditional Method

1. Effect on Signal efficiency:

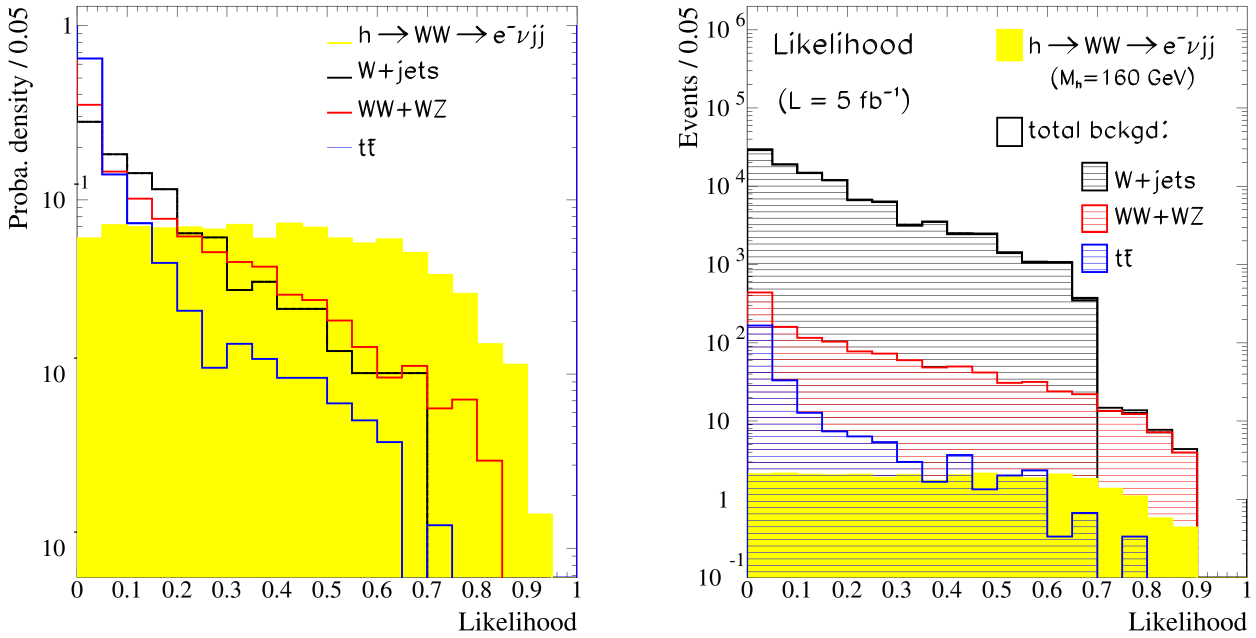
$\mathrm{M_h}$ (GeV/c^2)	120	140	160	180
Initial # events	3,000	3,000	3,000	3,000
Lepton ($\mathrm{p_T}$, η, ΔR)	1,455	1,758	1,848	1,955
Jets ($\mathrm{p_T}$ and $\eta, \Delta R$)	777	1,200	1,497	1,636
Missing Energy cut	514	988	1,396	1,507
Jet Veto Cut	471	862	1,124	1,164
Pre-selection (%)	15.7±0.7%	28.7±0.8%	37.5±0.9%	38.8±0.9%
$40 <$ M(j,j) < 110	198	441	792	822
$140 < \Phi(j,j)$	198	438	792	819
$40 < \mathrm{M_C} < \mathrm{M_h} + 10$ GeV	153	390	597	726
Full Selection (%)	5.1±0.4	13.0±0.6	19.9±0.7	24.2±0.8

2. Effects on Background efficiency:

Backgrounds	W+jets	WW $\rightarrow$ lνjj	WZ $\rightarrow$ lνjj	$\mathrm{t\bar{t}} \rightarrow$ lνjjb$\mathrm{\bar{b}}$
Pre-selection (%)	3.35±0.1%	39.6±0.5%	38.0±0.9%	15.6±0.4%
Full Selection (%)	1.10±0.07%	17.7±0.4%	15.8±0.7%	4.3±0.2%

$\Longrightarrow$ Background rejection insufficient

1. Likelihood Function: proba. density and Nb events



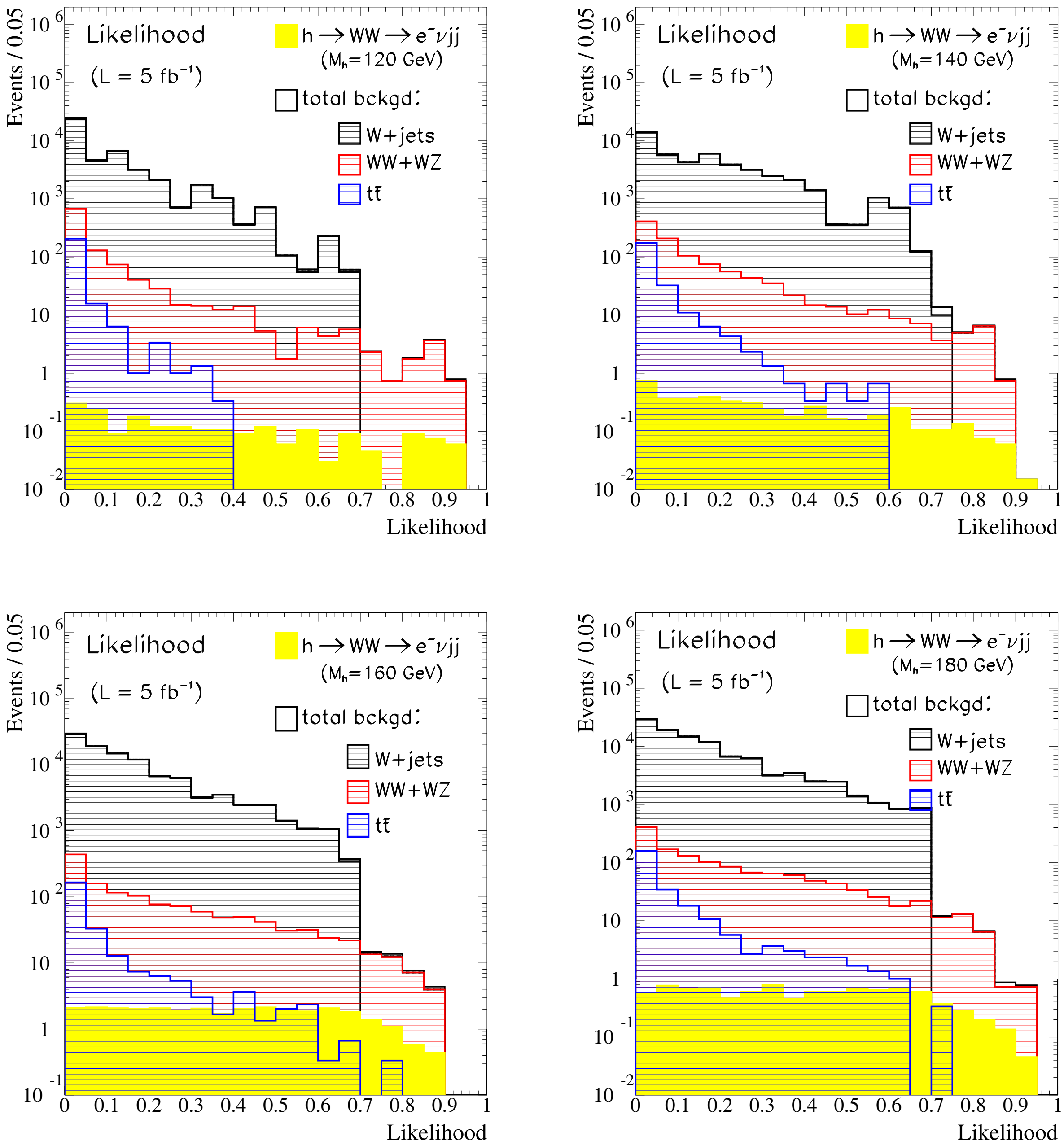
2. Expected Cross-sections for $M_h = 160$ GeV/c^2

Analysis for $e + \mu$ optimized for on-shell W's

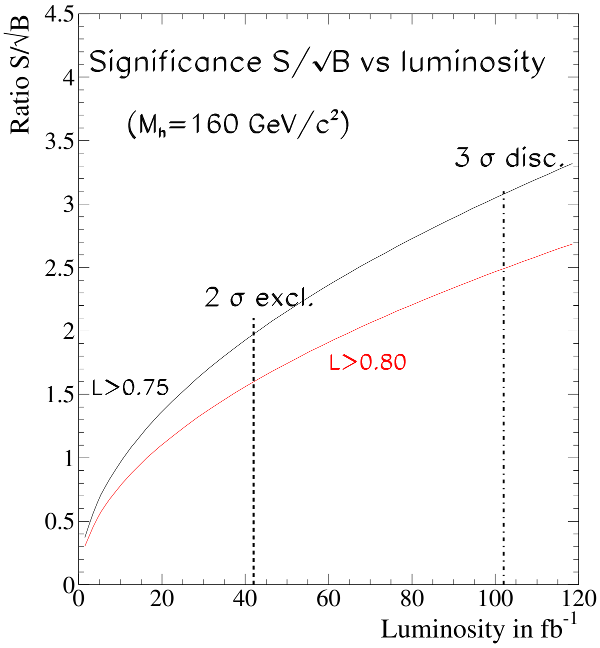
Likelihood	L > 0.75	L > 0.80	L > 0.85
Signal (fb)	0.86±0.09	0.42±0.04	0.20±0.02
Background (fb)	7.96±0.80	2.90±0.30	0.54±0.05

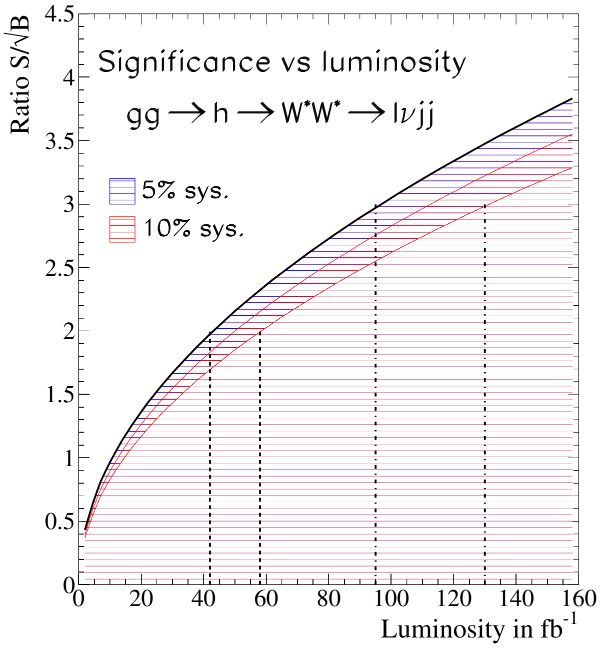
Likelihood function: Signal vs Background

Likelihood function: Signal vs Background



1. Significance versus luminosity for $M_h = 160$ GeV/c^2





2. Significance dependence in systematics:

   5-10 % Effects needs extra ≈ 10-20 fb^{-1}

3. Significance dependence in M_h:

M_h	120 GeV	140 GeV	180 GeV
Signal (fb)	0.16±0.01	0.40±0.04	0.52±0.05
Background (fb)	5.01±0.52	4.53±0.45	8.01±0.81

Conclusions

Study of $h \rightarrow W^*W^* \rightarrow l\nu jj$ channel with l=e,μ

1. Signal Selection:
   (a) Algorithm optimized for ON-shell Ws
   (b) Efficiency: 15-25% / 1-2% before/after Likelihood cut
2. Main Background:
   (a) QCD and W+jets manageable with a likelihood method
   (b) WW events almost irreducible
3. Signal/Background Significance:
   (a) 3σ significance needs around 100-120 fb^{-1} (with sys.)
   (b) 2σ significance needs around 40-50 fb^{-1} (with sys.)

Study that remains to be done:

1. Improvement of Likelihood function method (increase stat.)
2. Improvement of WW events rejection: use of spin info.

The $h \rightarrow W^*W^* \rightarrow l\nu jj$ channel may be used
as a confirmation of another signal
or in a multi-channel combination