$H \to b\bar{b}$ single Higgs production via VBF at future muon colliders

Higgs 2021

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Muon colliders: VBF vs Higgs-strahlung

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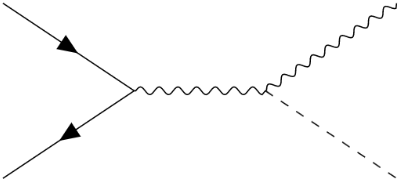

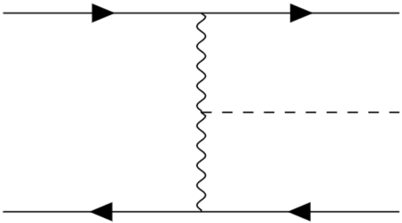

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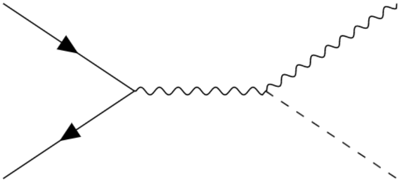
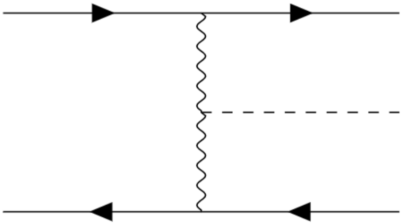
	Inclusive σ	
Energy	Higgs-strahlung	WW Fusion
250 GeV	240 fb	8 fb
500 GeV	57 fb	75 fb
1 TeV	13 fb	210 fb
3 TeV	1.4 fb	498 fb
10 TeV	0.1 fb	850 fb





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For lepton colliders ≥ 3 TeV, VBF provides the overwhelming majority of the single Higgs events

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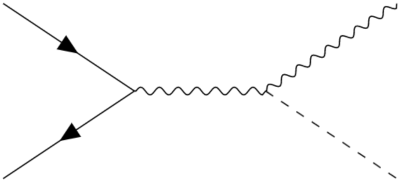

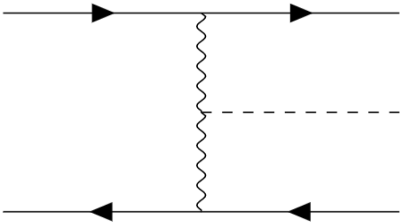

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Some $H \to b\bar{b}$ work including backgrounds has been done:

- 1.5 TeV simulation study for $H \to b\bar{b}$ extrapolated to 10 TeV (2001.04431)

Event Generation and Detector Assumptions

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Use energy/luminosity benchmarks proposed by the Snowmass Muon Collider Forum

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Limits detectors to $|\eta| < 2.5$ roughly corresponding to BIB reducing tungsten nozzles with opening $\theta \approx 10^\circ$

Includes hypothetical forward muon detector from $2.5 < |\eta| < 8.0$ with 10% energy resolution

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We use the Valencia jet clustering algorithm with $\beta = \gamma = 1$ (1607.05039).

$$d_{ij} = min(E_i^{2\gamma}, E_j^{2\gamma})(1 - \cos\theta_{ij})/R^2, \qquad d_{iB} = E_i^{2\beta}(p_{T_i}/E_i)^{2\gamma}$$

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b-tagging is done using the tight working point (50%) inspired by CLIC (1812.07337)

- *c*-quark mis-tagging rate is very small ($\leq 3\%$), negligible for this work

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After jet clustering and p_T rescaling, impose:

- $|\eta_b| < 2.5$
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For *ZZF*, additionally show results with a $N_\mu \geq 2$ cut including the forward muon detector

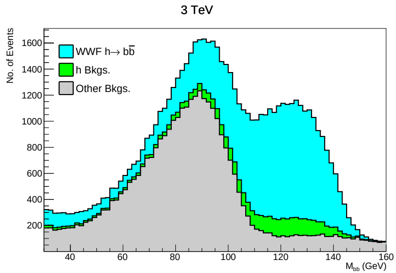
Backgrounds

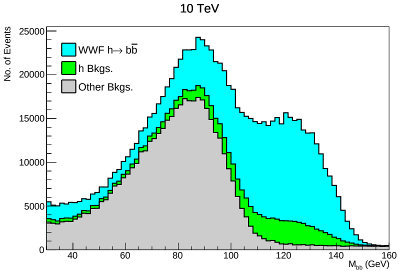
Primary backgrounds: 10 TeV at 10ab^{-1}

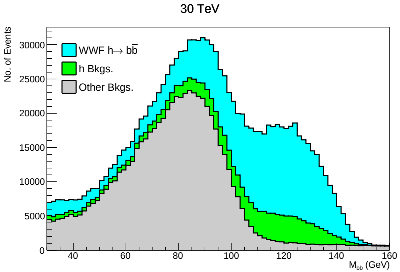
Process	σ (fb)	$A \cdot \epsilon$ (%)	Events
$\mu^+\mu^- \to \nu_\mu\bar{\nu}_\mu H;\ H \to b\bar{b}$	490	5.2	2.5×10^5
$\mu^+\mu^- \to \nu_\mu\bar{\nu}_\mu Z;\ Z \to b\bar{b}$	570	0.40	2.9×10^4
$\mu^+\mu^- \to \mu^+\mu^- H;\ H \to b\bar{b}$	50	5.2	2.7×10^4
$\mu^+\mu^- \to \mu\nu_\mu WH;\ H \to b\bar{b}$	40	3.9	1.5×10^4
$\mu^+\mu^- \to \mu\nu_\mu ZH;\ H \to b\bar{b}$	20	4.2	8.6×10^3
Others	-	-	1.1×10^4

Where "Others" includes ZZ, $t\bar{t}$, $t\bar{b}$, $b\bar{b}$, HH, and ZZF Z.

WW Fusion signal

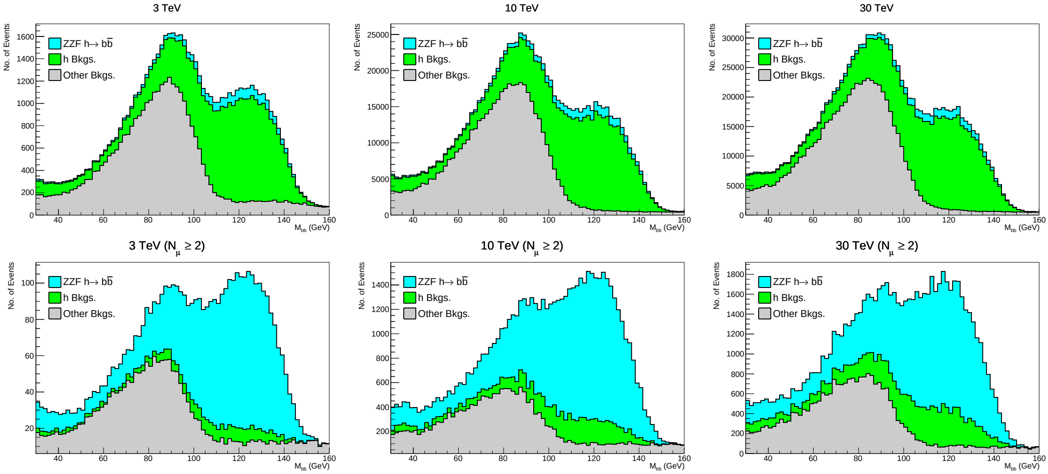






Energy	N_{sig}	N_{bkg}
3 TeV	1.9×10^4	6.3×10^3
10 TeV	2.5×10^5	9.0×10^4
30 TeV	2.8×10^5	1.2×10^5

ZZ Fusion signal



ZZ Fusion signal

The forward muon cut eliminates the vast majority of the WW Fusion and WZ Fusion backgrounds

			$N_\mu \geq 2$	
Energy	N_{sig}	N_{bkg}	N_{sig}	N_{bkg}
3 TeV	2000	2.3×10^4	1800	310
10 TeV	2.7×10^4	3.2×10^5	2.5×10^4	6200
30 TeV	3.0×10^4	3.7×10^5	2.7×10^4	1.0×10^4

Results

Estimate precision using $\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{N_{sig}+N_{bkg}}}{N_{sig}}$

Precision (%)

Energy	*WWF*	*ZZF*	*ZZF* ($N_\mu \geq 2$)
3 TeV	0.84	7.9	2.5
10 TeV	0.23	2.1	0.71
30 TeV	0.23	2.1	0.72
	Smasher's guide (signal only):		
10 TeV	0.17	0.49	-

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Room for optimisation: conservative from the perspective of BIB

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An optimised detector design for high energies doesn't exist yet: the DELPHES card and this analysis both have a lot of room for optimisation