Status of $h \to \mu^+\mu^-$ analysis

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2020/September/23

ILD Software & Analysis Meeting

Preprint available (2009.04340)

High Energy Physics - Experiment

[Submitted on 9 Sep 2020]

Prospects of measuring the branching fraction of the Higgs boson decaying into muon pairs at the International Linear Collider

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The prospects for measuring the branching fraction of $H \to \mu^+\mu^-$ at the International Linear Collider (ILC) have been evaluated based on a full detector simulation of the International Large Detector (ILD) concept, considering centre-of-mass energies ($\sqrt{s}$) of 250 GeV and 500 GeV. For both $\sqrt{s}$ cases, the two final states $e^+e^- \to q\bar{q}H$ and $e^+e^- \to \nu\bar{\nu}H$ have been analyzed. For integrated luminosities of 2 ab^{-1} at $\sqrt{s} = 250$ GeV and 4 ab^{-1} at $\sqrt{s} = 500$ GeV, the combined precision on the branching fraction of $H \to \mu^+\mu^-$ is estimated to be 17{\%}. The impact of the transverse momentum resolution for this analysis is also studied.

Comments: 21 pages, 10 figures, 11 tables. This work was carried out in the framework of the ILD concept group
Subjects: **High Energy Physics - Experiment (hep-ex)**
Cite as: arXiv:2009.04340 **[hep-ex]**
(or arXiv:2009.04340v1 **[hep-ex]** for this version)

Bibliographic data

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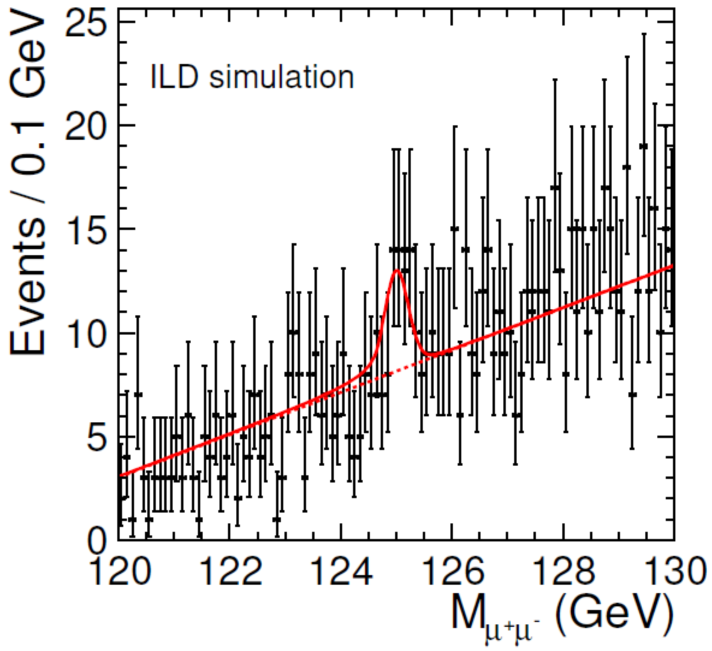
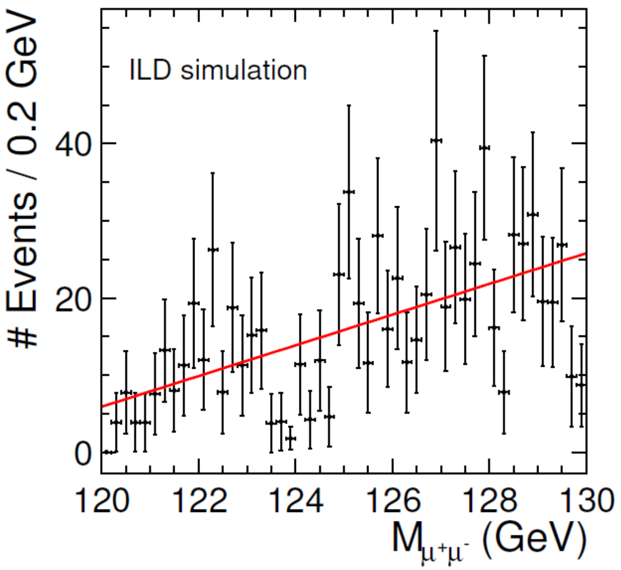
- Under Review

Ivanka’s comment

- For instance, since the tiny signal is sitting on the top of background (Figure 7.a), the number of extracted signal events will vary if the slope of background is different. Just from Fig. 6.b, it is clear that p1 can vary from the existing 2 to 4. I would take i.e. the p1 and p0 extremes from the fit, and check what happens with Ys for different strait lines that can be pulled through background data with the same chi2.



(a) example of one pseudo-experiment

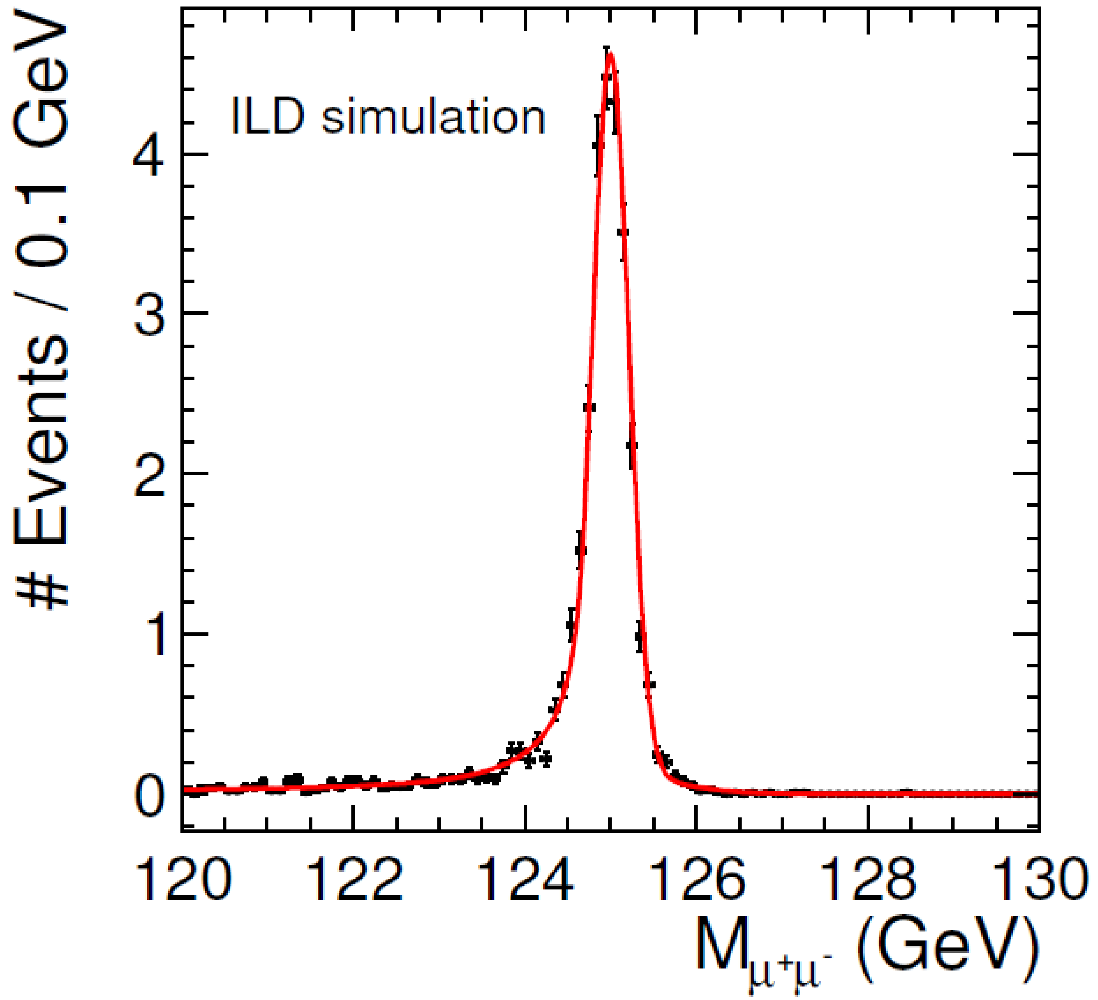


(b) background with result of f_B fit

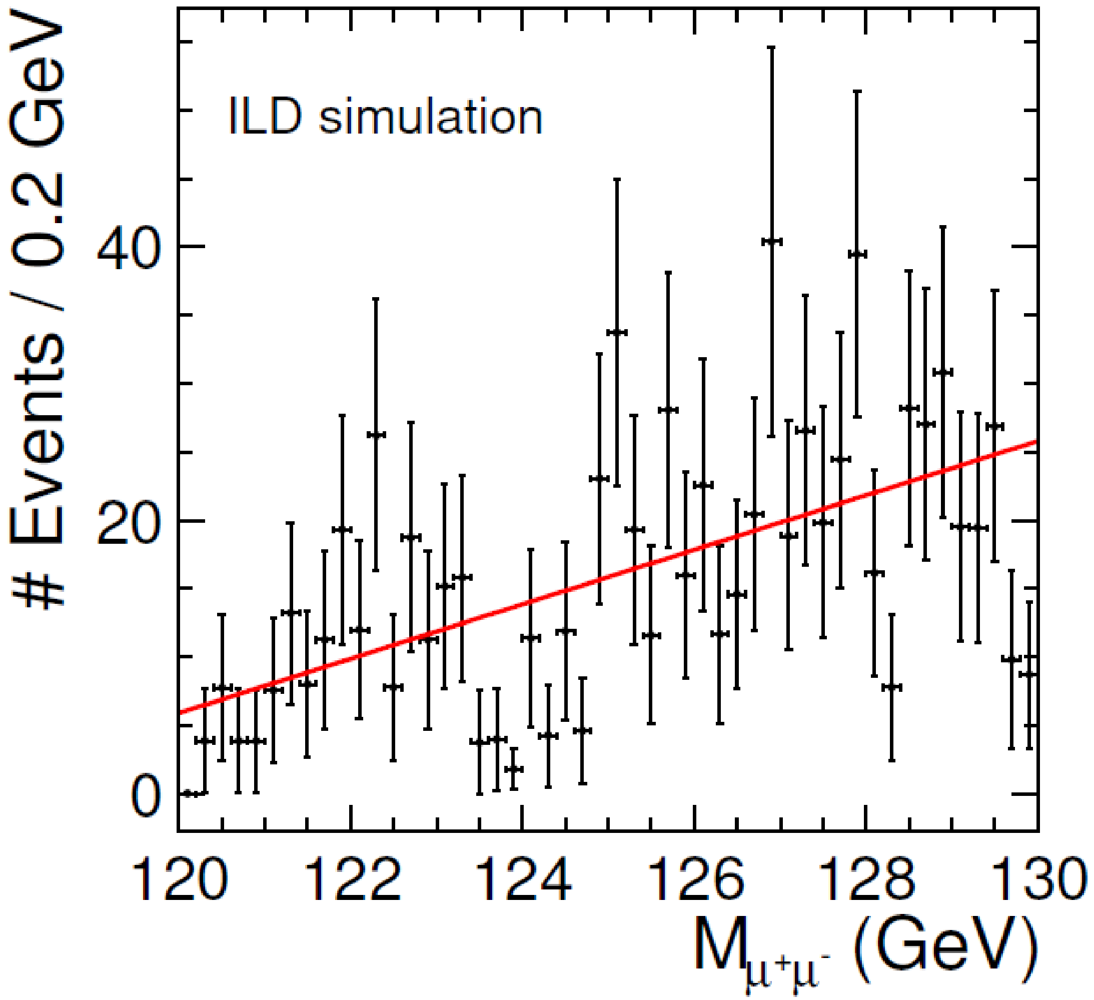
Check the effect when function is changed

- Since the total number of events are basically small (and lack of MC statistics), changing the parameter of fitting function will affect to the result.
- Procedure to obtain final precision
    1. Make $M_{\mu^+\mu^-}$ histogram and do fitting with f_S (Crystal Ball + Gaussian) for signal and f_B (pol1) for background.
    2. Do pseudo-experiment based on parametrized f_S and f_B. Make toy signal based on f_S and toy background based on f_B. Do fitting with $f = Y_S f_S + Y_B f_B$ (fixed Y_B) to toy data and obtain Y_S. Repeat these many times and get Y_S distribution.
    3. Do Gaussian fit to Y_S distribution. Precision = width / mean.

Procedure 1

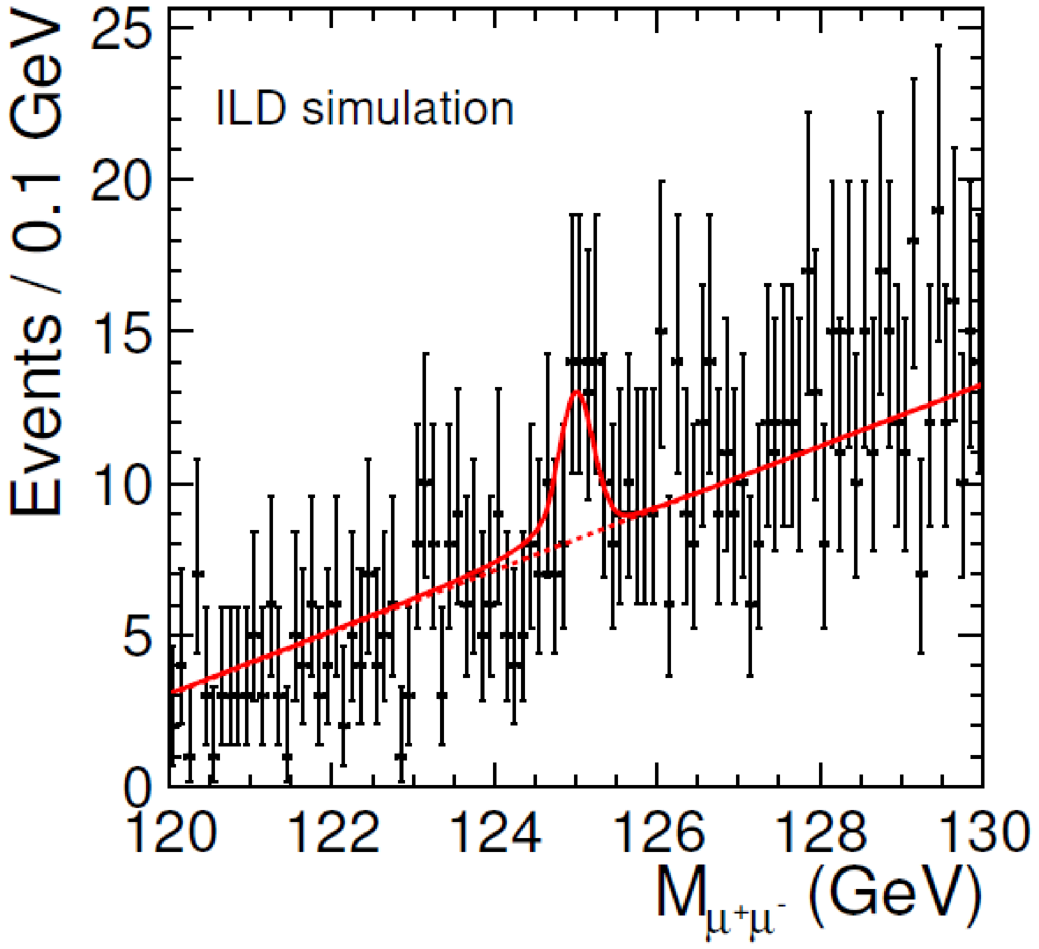


(a) signal with result of f_S fit

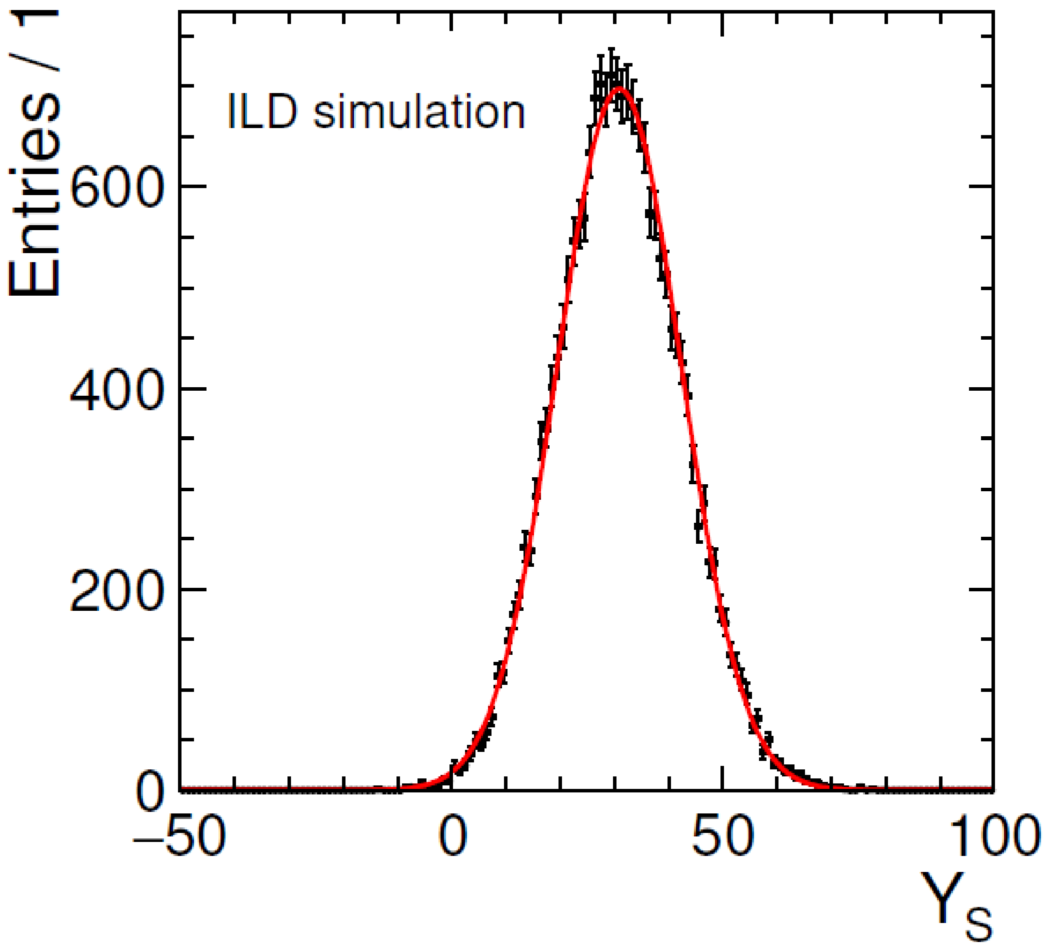


(b) background with result of f_B fit

Procedure 2 and 3



(a) example of one pseudo-experiment



(b) distribution of yield of signal events Y_S from 2×10^4 pseudo-experiments.

What I did for the check (1)

- checked with nnH500-L: the slope in the fitting for background was 0.627385, and its fitting error was (+0.0564834, -0.0584683)
- I changed the slope by +-1sigma and +-2sigma (f_{Bch}), then perform toy MC (toy background generation and f fit) with f_{Bch}. Signal function kept as full simulation.
- I also changed # of toy MC: 2k (~40 seconds), 20k (normal, ~40 minutes), 80k (~20 hours, 200k needs too long time, maybe 3 days)

Result (1): precision

Precision	2k *10 smaller	20k normal	80k *4 larger
+2sigma	36.67 +- 0.65%	36.95 +- 0.21%	36.81 +- 0.10%
+1sigma	36.32 +- 0.65%	37.11 +- 0.21%	36.90 +- 0.10%
full sim.	35.90 +- 0.64%	**37.00 +- 0.21%**	36.87 +- 0.10%
-1sigma	36.79 +- 0.66%	36.51 +- 0.21%	36.90 +- 0.10%
-2sigma	36.54 +- 0.65%	36.82 +- 0.21%	36.94 +- 0.10%

The effect of changing the slope is nothing.
Error of precision is simply scaled as expected when # toy MC is changed.
(*10 less stat. -> ~*3 large error, *4 more stat. -> ~*2 small error)

Result (1): mean value Y_S

Precision	2k *10 smaller	20k normal	80k *4 larger
+2sigma	30.64 +- 0.25	30.689 +- 0.080	30.737 +- 0.040
+1sigma	30.86 +- 0.25	30.905 +- 0.080	30.768 +- 0.040
full sim.	31.10 +- 0.25	**30.899 +- 0.081**	30.819 +- 0.040
-1sigma	30.82 +- 0.25	30.840 +- 0.081	30.843 +- 0.040
-2sigma	30.94 +- 0.25	30.723 +- 0.080	30.734 +- 0.040

The fluctuation of Y_S is close to nothing.
---> Will not affect final precision

What I did for the check (2)

- checked with nnH500-L: the slope in the fitting for background was 0.627385, and its fitting error was (+0.0564834, -0.0584683)
- I changed the slope by +-1sigma and +-2sigma (f_{Bch}), and then generate toy data with f_{Bch}, but fitting to toy data is performed with $f = Y_S f_S + Y_B f_B$. Signal function kept as full simulation.
- I also changed # of toy MC: 2k, 20k (normal), 80k
- Same normalization applied.

Result (2): precision

Precision	2k *10 smaller	20k normal	80k *4 larger
+2sigma	37.06 +- 0.66%	37.81 +- 0.21%	37.78 +- 0.11%
+1sigma	36.45 +- 0.65%	36.94 +- 0.21%	37.37 +- 0.11%
full sim.	35.90 +- 0.64%	**37.00 +- 0.21%**	36.87 +- 0.10%
-1sigma	36.04 +- 0.64%	36.59 +- 0.21%	36.42 +- 0.10%
-2sigma	35.58 +- 0.63%	36.01 +- 0.20%	36.00 +- 0.10%

In this case, the effect is larger than (1), but maximum difference is ~1%.
Larger slope will give worse precision, lower slope better precision.
Systematic error of slope difference: ~+-1% (+-2sigma)
---> small enough for 37% precision

Result (2): mean value Y_S

Precision	2k *10 smaller	20k normal	80k *4 larger
+2sigma	29.99 +- 0.25	29.597 +- 0.080	29.662 +- 0.040
+1sigma	30.60 +- 0.25	30.372 +- 0.079	30.231 +- 0.040
full sim.	31.10 +- 0.25	**30.899 +- 0.081**	30.819 +- 0.040
-1sigma	31.63 +- 0.25	31.400 +- 0.081	31.409 +- 0.040
-2sigma	32.10 +- 0.26	31.847 +- 0.081	31.862 +- 0.041

In larger (smaller) slope case, Y_S is evaluated smaller (larger) value.
But the level of Y_S differ is ~ +-1.
Systematic error of Y_S estimation: ~+-1 (+-2sigma)
---> Small enough for ~31 yield

Summary

- Studied systematic effect when we change the background modeling function (slope of pol1)
  - Generating toy data and f fit with f_{Bch} gives no effect
  - Generating toy data with f_{Bch} and f fit with f_B will shift the result, but its effect is small enough for 37% precision
- Addressed all comments from ILD
- The paper is under review in EPJC. I hope it will be accepted soon...