Impact of interference effects for measuring the trilinear Higgs coupling

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Introduction

- The purpose of this work is to quantify the theoretical uncertainty due to commenly used approximations
- Some differences in the simulation data are not fully understood, yet!?
- In this work the process

  e+ e- to μ+ μ- b bbar b bbar

  was used.

Signal and Interference

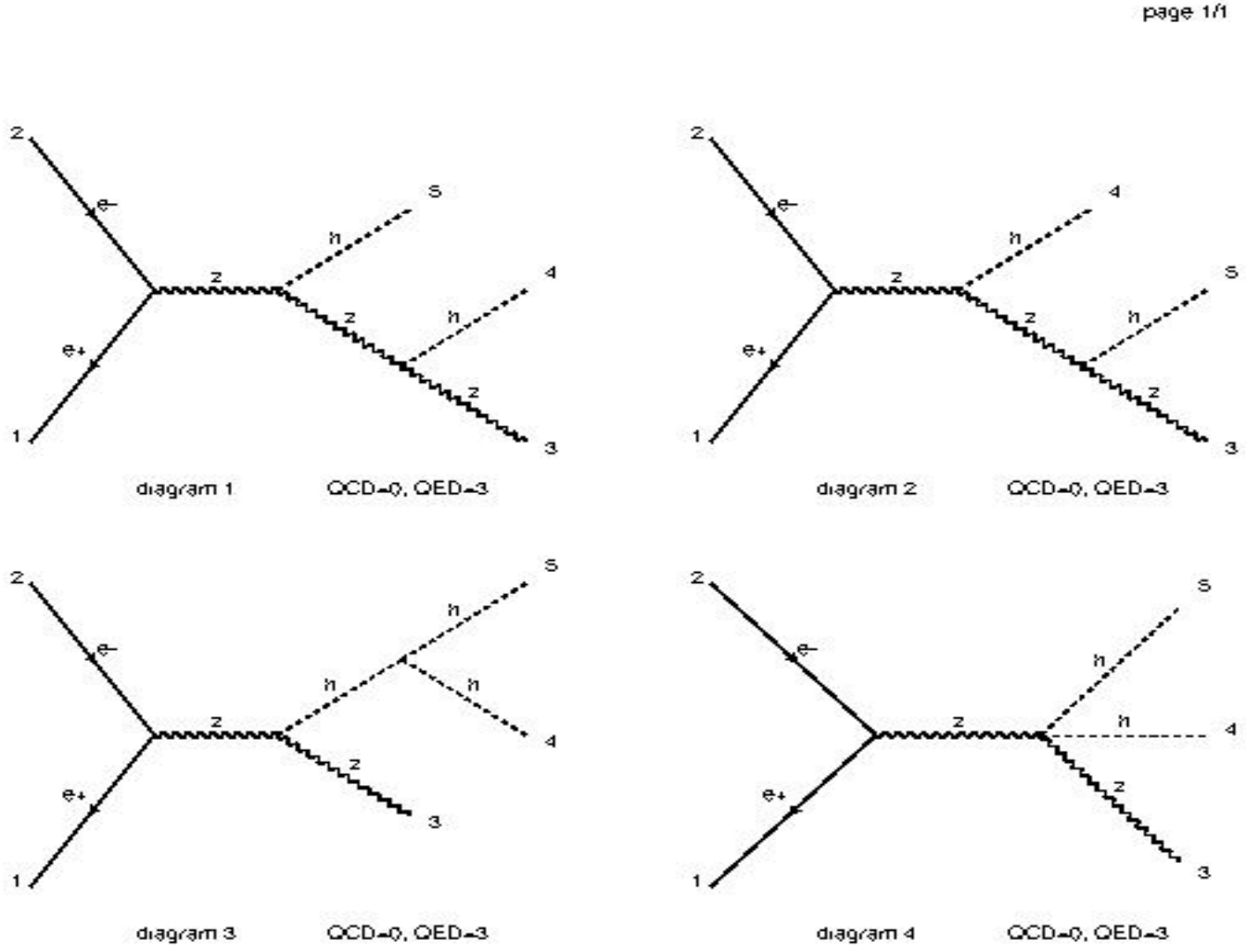
- The total cross section includes contributions from Signal, Interference and Background.

- $\sigma = \lambda^2 \times \text{Signal} + \lambda \times \text{Interference} + \text{Background}$

- If calculations are done using $\lambda=1$, $\lambda=0$, $\lambda=2$ the values for Signal, Interference and Background can be calculated

- ZHH cross section
- ZHH cross section with Brachning Ratios
- Madgraph5
- Whizard
- Comparison
- Conclusion

Diagrams for e+ e- to ZHH



ZHH cross section

√S = 500 Gev, e- polarization -0.8, e+ polarization = 0.3
All Data in femtobarn (fb)

	σ_{sm}	Error	$\sigma_{gh3=0}$	Error	$\sigma_{gh3=2}$	Error
HaLC	2.33E-01	2.32E-04	1.24E-01	1.22E-04	3.87E-01	3.81E-04
Whizard	2.34E-01	6.36E-04	1.13E-01	8.854E-05	3.49E-01	2.45E-04
Madgraph5	2.34E-01		1.24E-01	9.23E-05	3.88E-01	2.84E-04

	Signal	Interference	Signal + Interference
HaLC	2.26E-02	8.62E-02	1.09E-01
Whizard			1.20E-01
Madgraph5	2.23E-02	8.71E-02	1.09E-01

ZHH With Branching Ratios

- BR(Z -> mu+ mu-) = 0.03366 (PDG)
- BR(h -> b bbar) = 0.571 (LHC Higgs XS Working Group)
- Important: Loop corrected BR

- $\sigma_{Total} = \sigma_{ZHH}$ x BR(Z -> mu+ mu-) x BR(h -> b bbar)
  x BR (h -> b bbar)

ZHH cross section with BR

√S = 500 Gev, e- polarization -0.8, e+ polarization = 0.3
All Data in femtobarn (fb)

	σ_{sm}	$\sigma_{gh3=0}$	$\sigma_{gh3=2}$
HaLC	2.55E-03	1.36E-03	4.25E-03
Whizard	2.56E-03		
Madgraph5	2.56E-03	1.36E-03	4.25E-03

	Signal	Interference	Signal + Interference
HaLC	2.48E-04	9.46E-04	1.19E-03
Whizard			1.32E-03
Madgraph5	2.45E-04	9.56E-04	1.20E-03

Madgraph 5

Approximation 1 (4 diagrams)

- e+ e- > z h h
- z > mu+ mu-
- h > b b~
- h > b b~

- Production wavefunction + decay wavefunction
- Includes Breit-Wiegner effectss (J.Alwall et. al
- arxiv 1106.0522)

Approximation 2 (17 diagrams)

- e+ e- > z h h
- e+ e- > z z h
- e+ e- > z z z
- z > mu+ mu-
- z > b b~
- h > b b~

MadGraph5

√S = 500 Gev, e- polarization -0.8, e+ polarization = 0.3
All Data in femtobarn (fb)

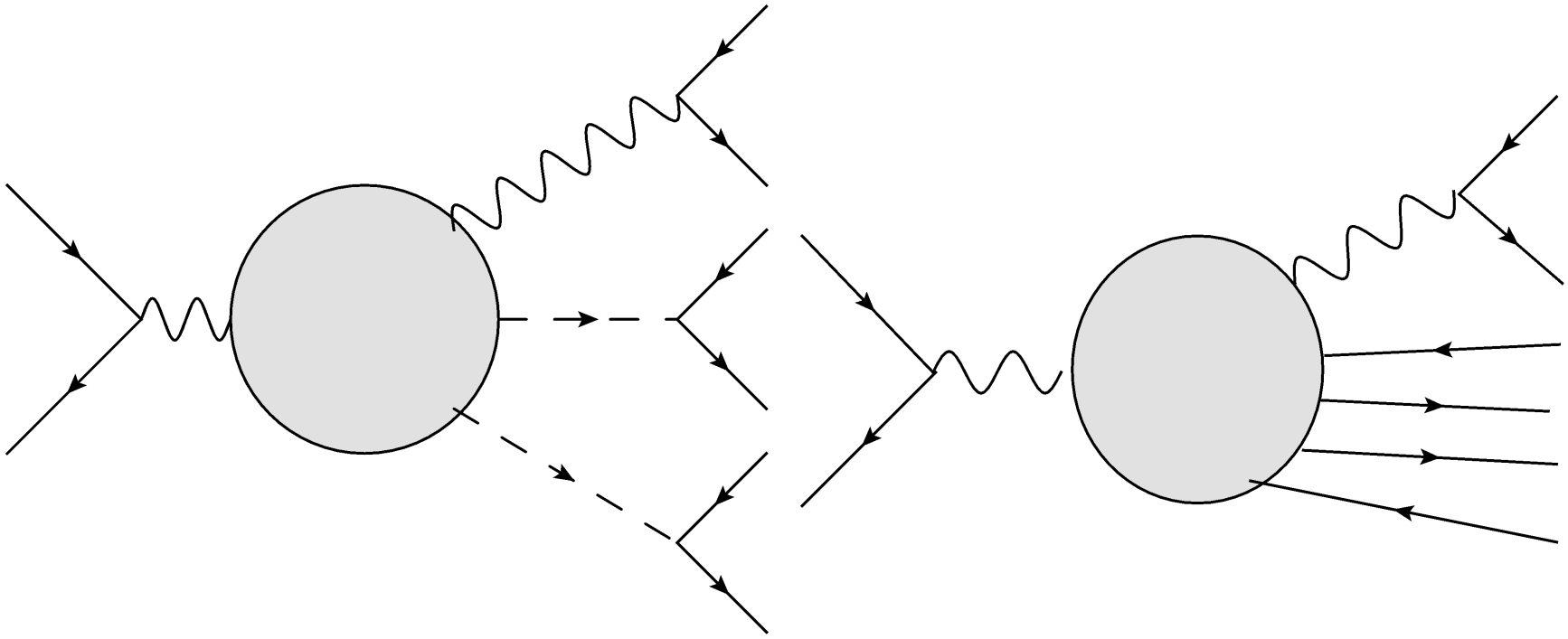
	σ_{sm}	Error	$\sigma_{gh3=0}$	Error	$\sigma_{gh3=2}$	Error
Approximation 1	5.00E-03	1.50E-05	2.66E-03	1.50E-05	8.34E-03	2.12E-05
Approximation 2	1.61E-02	4.80E-05	1.38E-02	3.80E-05	9.49E-03	7.17E-05
Full Process	5.05E-02	1.20E-05	4.79E-02	1.52E-04	5.40E-02	1.86E-04

	Signal	Interference	Signal + Interference
Approximation 1	4.99E-04	1.85E-03	2.34E-03
Approximation 2			2.37E-03
Full Process	2.45E-04	2.16E-03	2.60E-03

Whizard

Approximation 1

Approximation 2



Whizard

√S = 500 Gev, e- polarization -0.8, e+ polarization = 0.3
All Data in femtobarn (fb)

	σ_{sm}	Error	$\sigma_{gh3=0}$	Error	$\sigma_{gh3=2}$	Error
Approximation 1	4.29E-03	1.30E-06	2.28E-03	7.02E-07	7.13E-03	2.13E-06
Approximation 2	2.19E-02	2.77E-05	1.78E-02	2.11E-05	2.75E-02	3.22E-05
Full Process	1.06E-01	4.64E-05	1.02E-01	6.51E-05	1.11E-01	6.71E-05

	Signal	Interferences	Signal + Interferences
Approximation 1	4.15E-04	1.59E-03	2.01E-03
Approximation 2	7.92E-04	3.27E-03	4.06E-03
Full Process	8.87E-04	2.59E-03	3.48E-03

Comparison

√S = 500 Gev, e- polarization -0.8, e+ polarization = 0.3
All Data in femtobarn (fb)

	Signal	Interference	Signal + Inter.	S + I compared to ZHH with BR
ZHH with BR	2.48E-04	9.46E-04	1.19E-03	
MG5 Approx. 1	4.99E-04	1.85E-03	2.34E-03	+ 96.23%
MG5 Full	4.45E-04	2.16E-03	2.60E-03	+ 117.66%
Whizard App. 1	4.15E-04	1.59E-03	2.01E-03	+ 68.09%
Whizard App. 2	7.92E-04	3.27E-03	4.06E-03	+ 240.05%
Whizard Full	8.87E-04	2.259E-03	3.48E-03	+ 190.99%

ZHH with BR is using loop corrected BR
Some differences in the simulation data are not fully understood, yet!?

Conclusion

- Impact of interference not fully understood, but might have significant impact on measuring the trilinear coupling.
- These results do not take NLO corrections into account