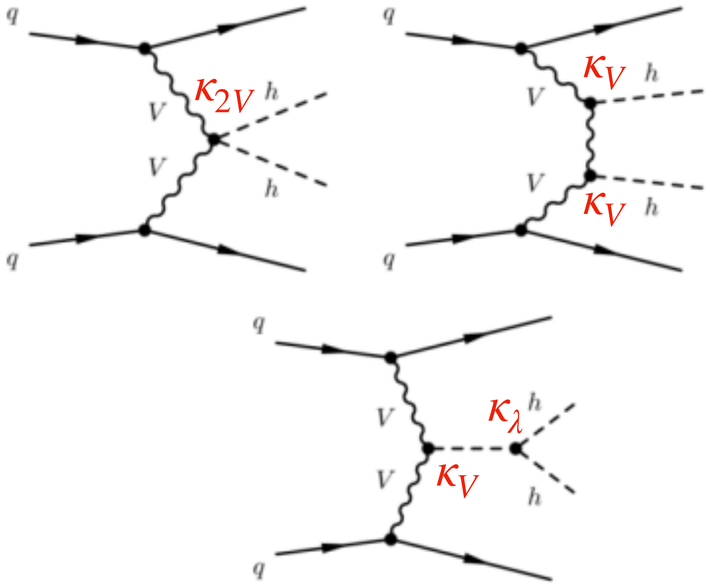
Vector Boson Polarization in VBF di-Higgs Production

Anna Tegetmeier, Joany Manjarres, Giovanni Pelliccioli

Vector Boson Fusion in di-Higgs

- Vector Boson Fusion (VBF) production in di-Higgs is sensitive to three coupling parameters:
  - κ_λ
  - κ_{2V}
  - κ_V



- Limits of the coupling parameters from the last <u>combination paper</u>
  - $\kappa_\lambda \in [-0.4, 6.3]$
  - $\kappa_{2V} \in [0.1, 2.0]$
- <u>Ca. 6% uncertainty</u> on κ_V
  - $\kappa_V \in [0.94, 1.06]$

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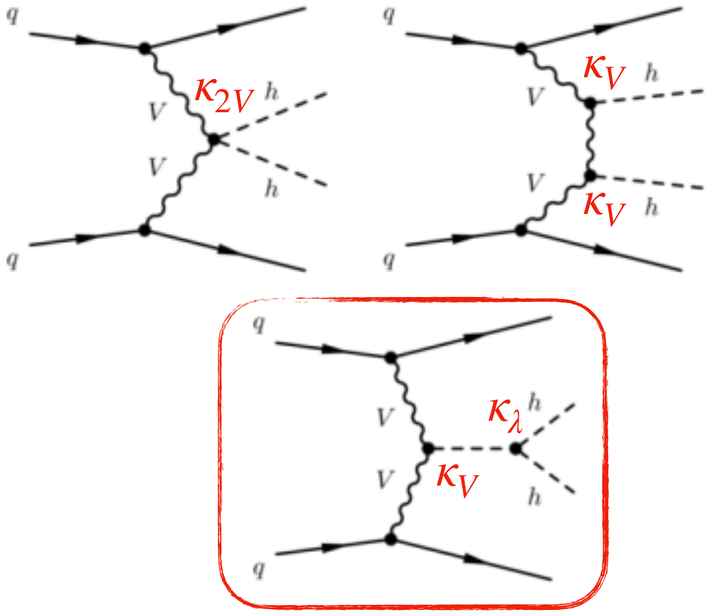

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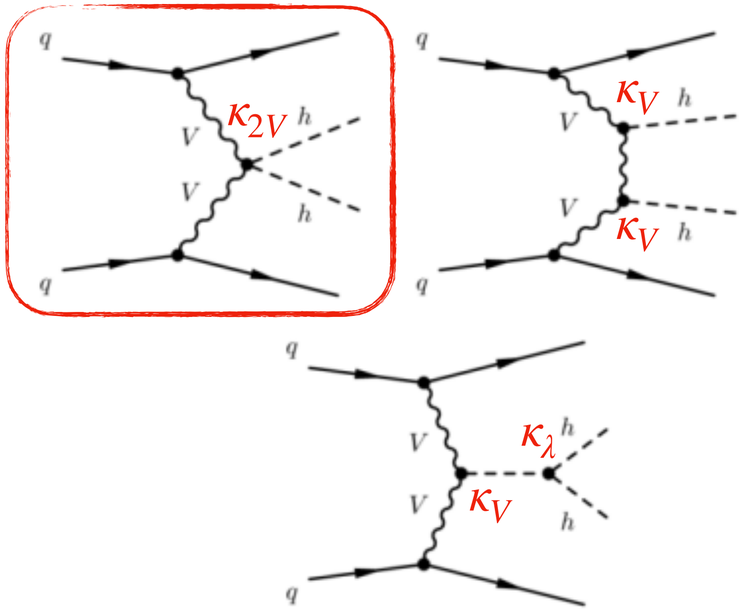

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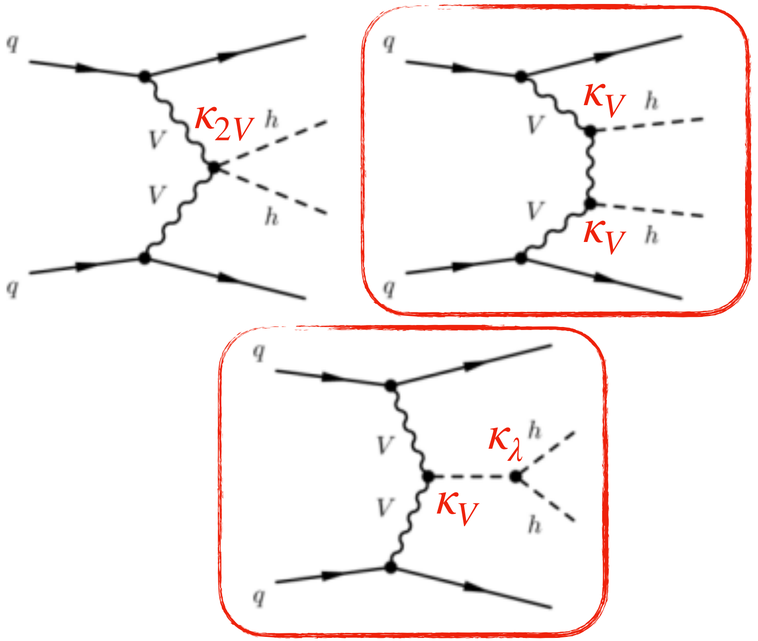

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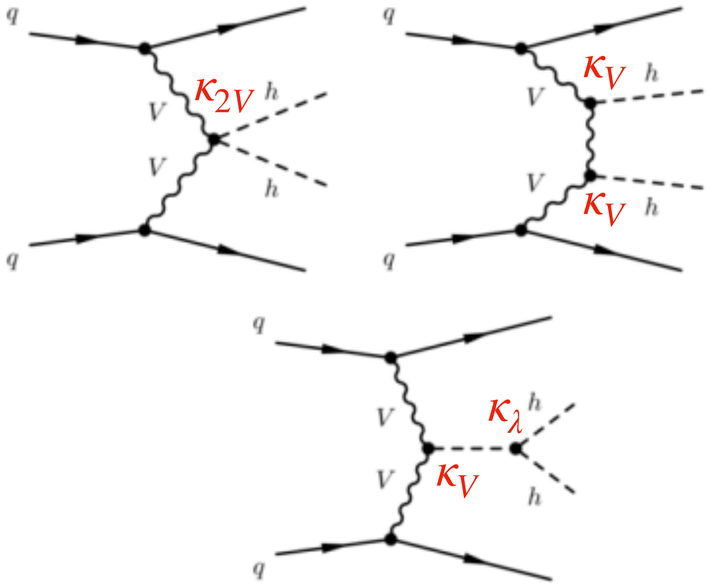

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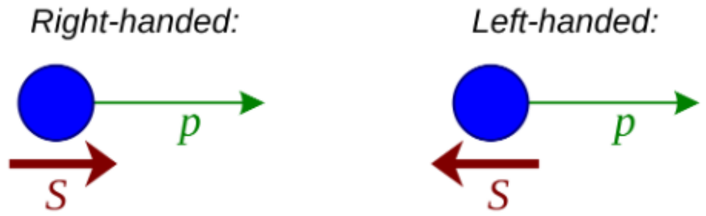
Polarization

- What is polarization?
  - Polarization is the alignment of a particles spin with its momentum
  - This can be quantified by the helicity:

$$h = \vec{S} \cdot \frac{\vec{p}}{|p|}$$

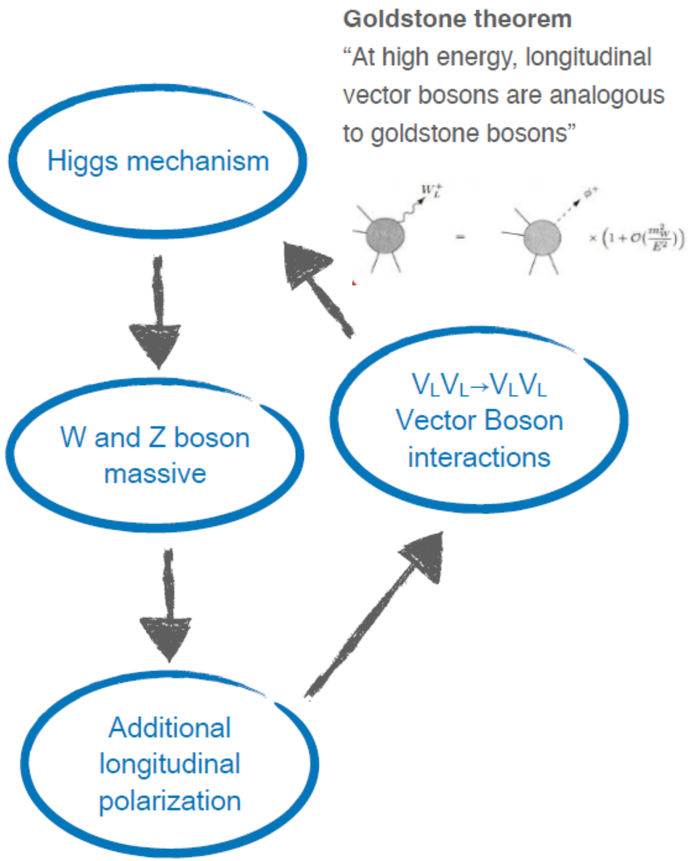


- For massive spin 1 particles three polarizations are possible:
  - $h = \pm 1$: transversal polarized (T)
  - $h = \quad 0$: longitudinal polarized (L)

Why is Polarization Interesting

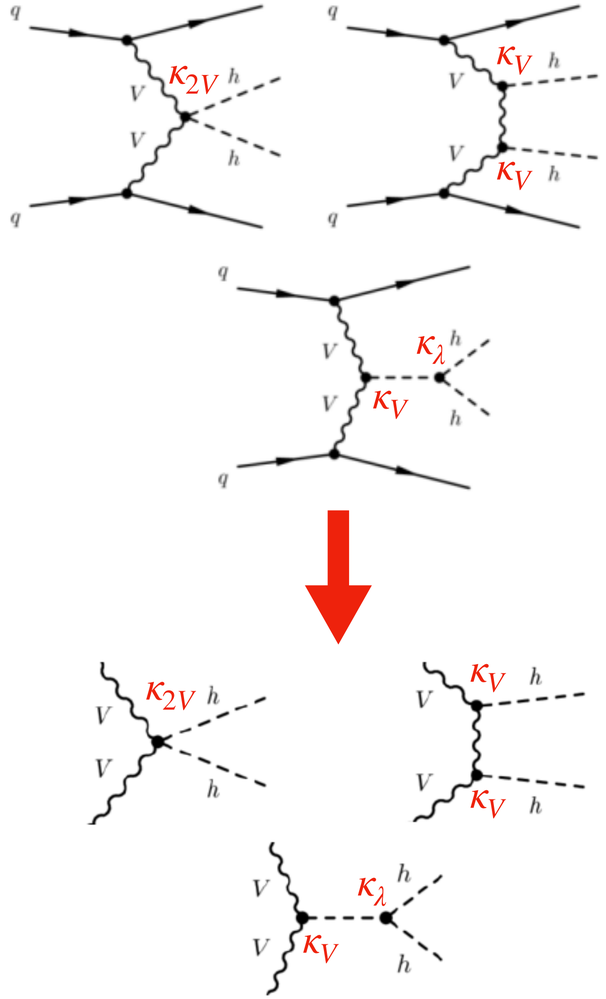
- Longitudinal polarization of the vector bosons is strongly connected to the Higgs mechanism
- The Higgs mechanism predict the existence of additional Goldstone bosons
- These can be interpreted as the longitudinal polarization of the $W^{\pm}$ and Z bosons

➡ Provide test of the electroweak symmetry breaking



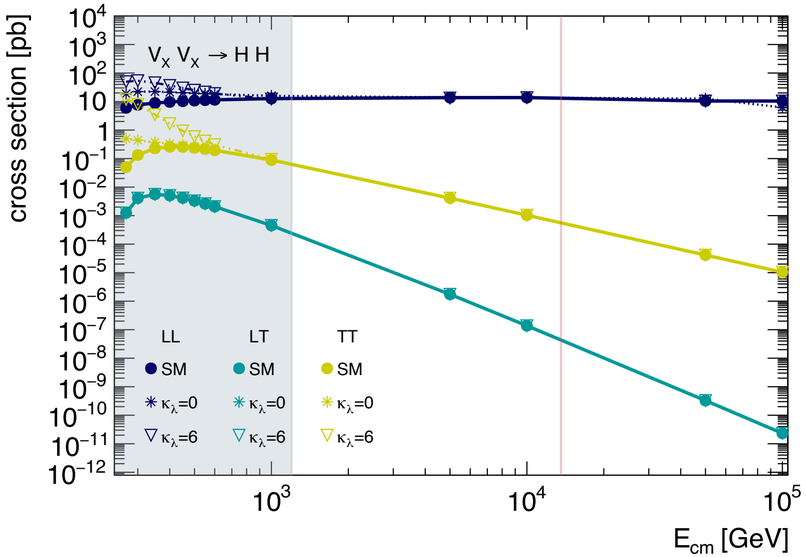
Polarization in VBF di-Higgs

- **Goal**:
  - Simulate VBF HH with polarized vector bosons
- **Problem**:
  - Vector bosons are intermediate particles
  - No generator available to simulate the polarization of that at the moment
- **A temporary fix:**
  - Use Madgraph to directly simulate $V_X V_X \rightarrow HH$
    - $V = W^{\pm}, Z$
    - $X =$ longitudinal (L), transversal (T)
  - This means we are colliding directly the vector bosons and can use Madgraph to get polarized bosons
  - Use the HHVBF_UFO model to change the coupling parameters κ_λ, κ_{2V} and κ_V at the same time

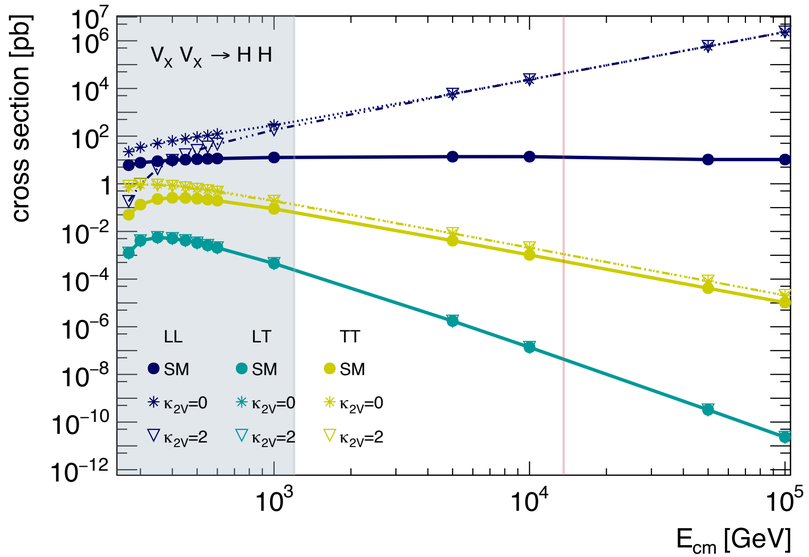


Effect of the Different Coupling Parameters on the Cross Section

Effect of changing κ_λ



Effect of changing κ_{2V}



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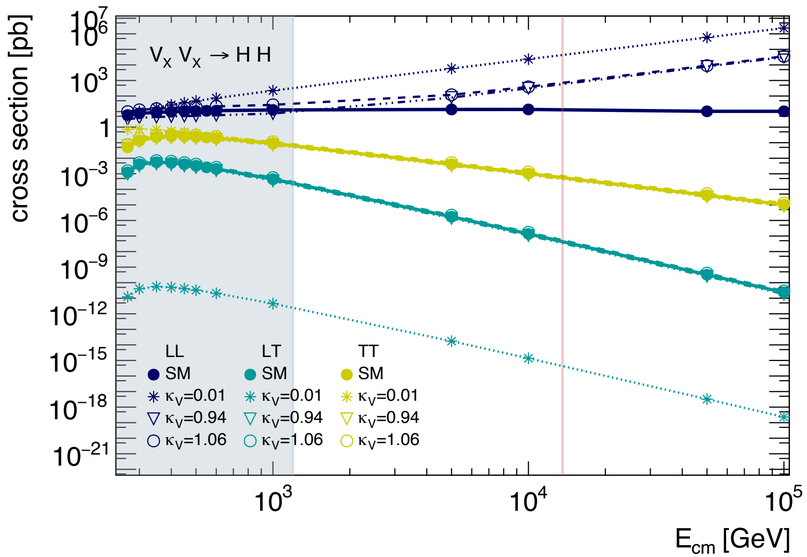

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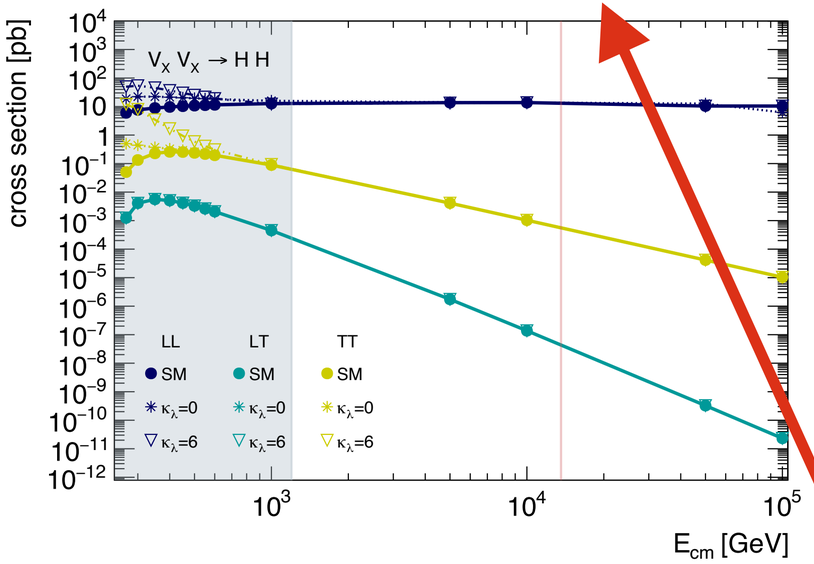

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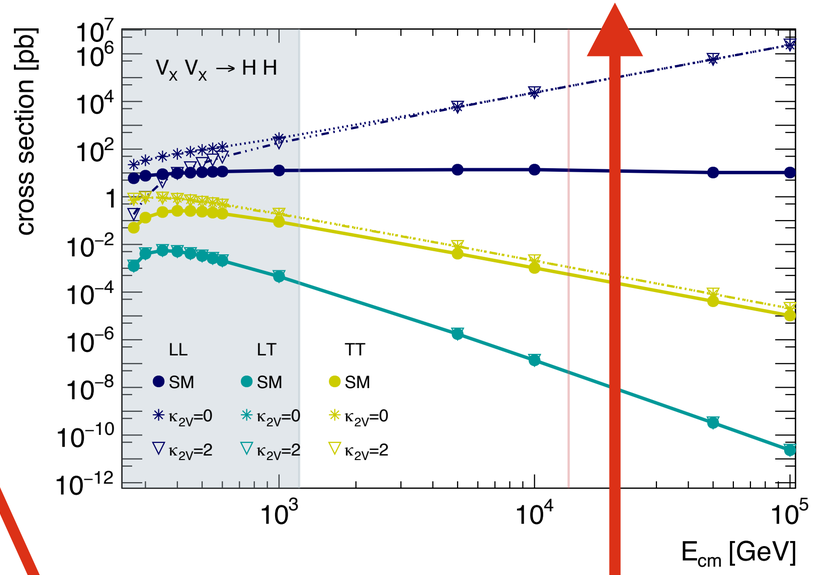

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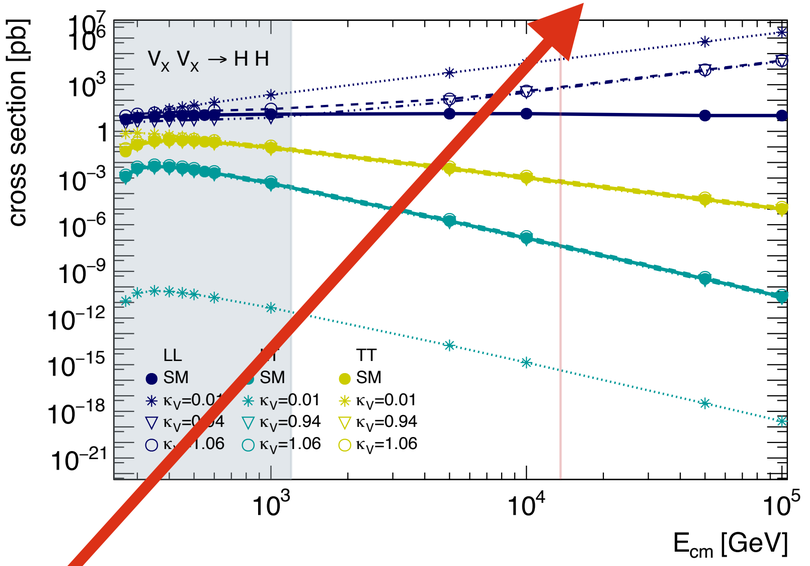

The different coupling modifiers

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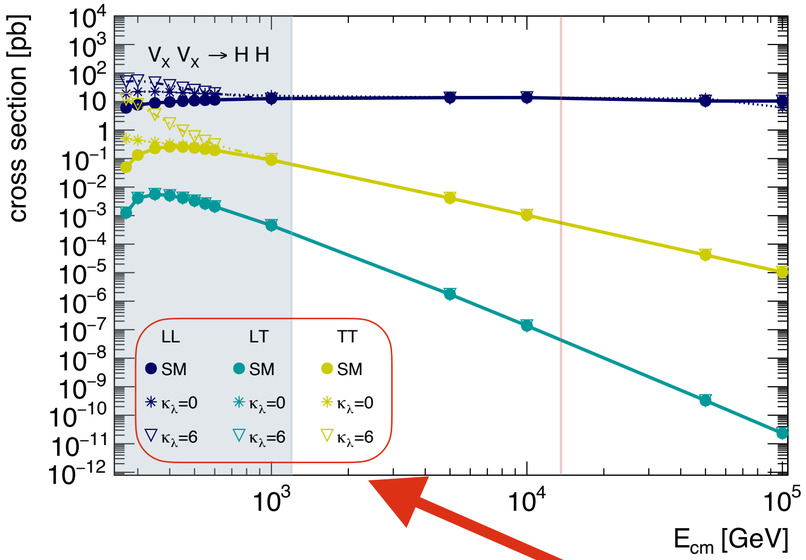
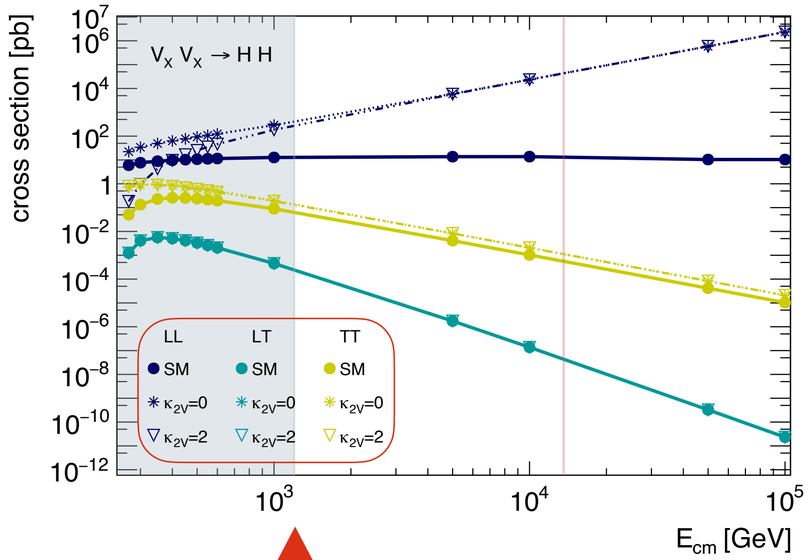
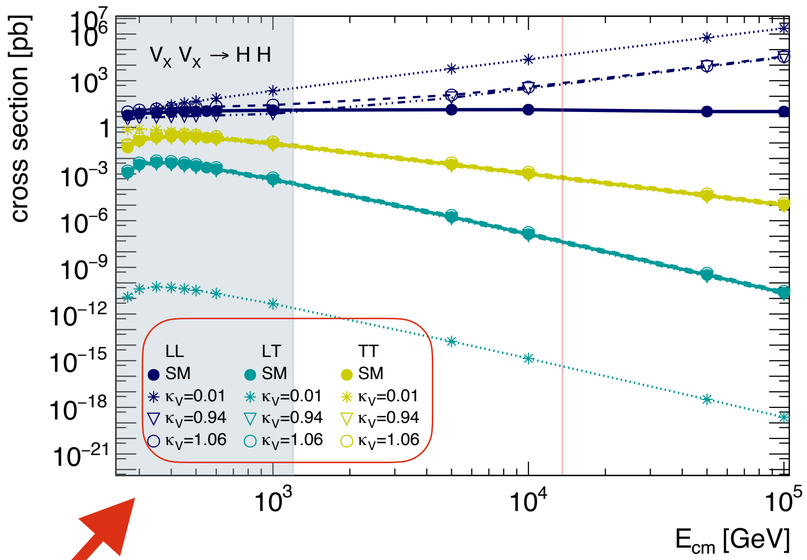


Effect of changing κ_{2V}



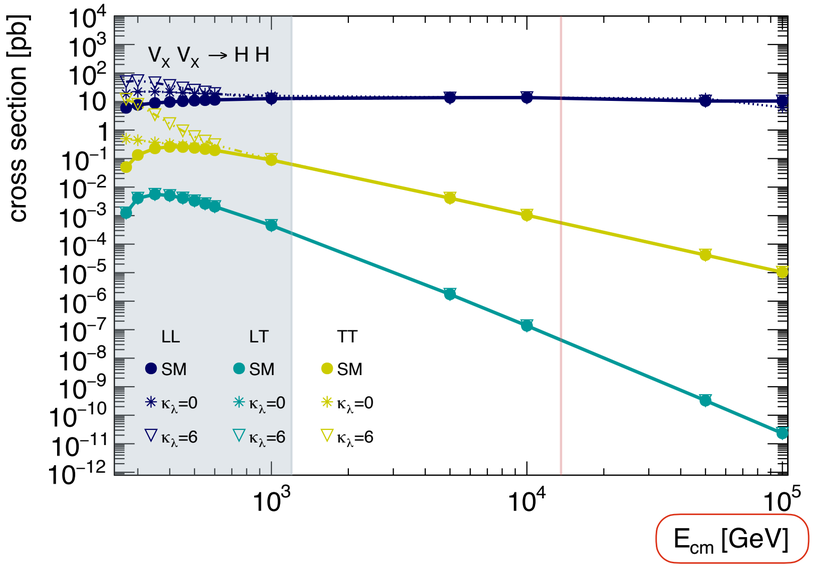
Effect of changing κ_V



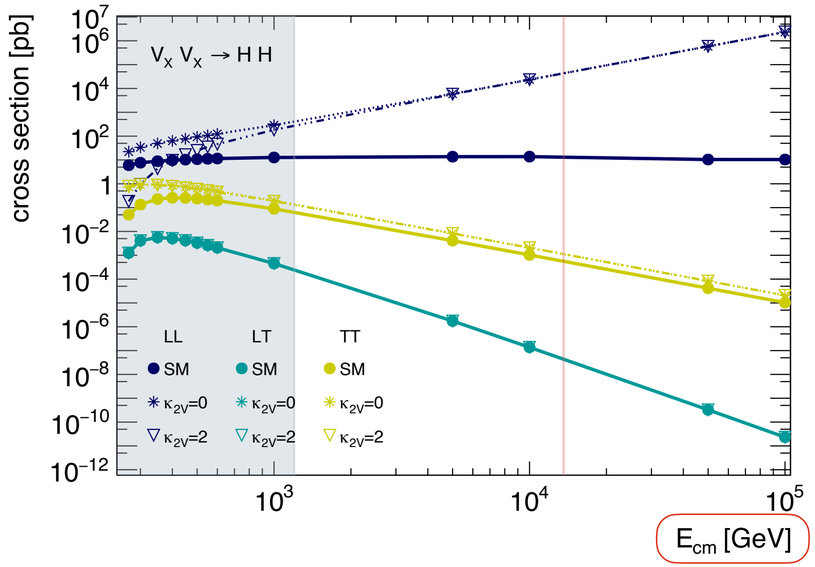
Values of the coupling parameters chosen to be close to the limits

Effect of the Different Coupling Parameters on the Cross Section

Effect of changing κ_λ



Effect of changing κ_{2V}



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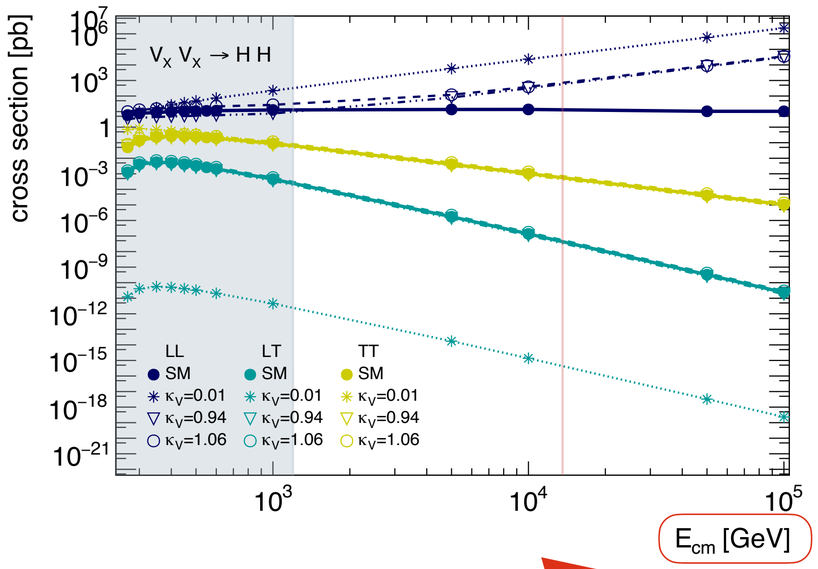
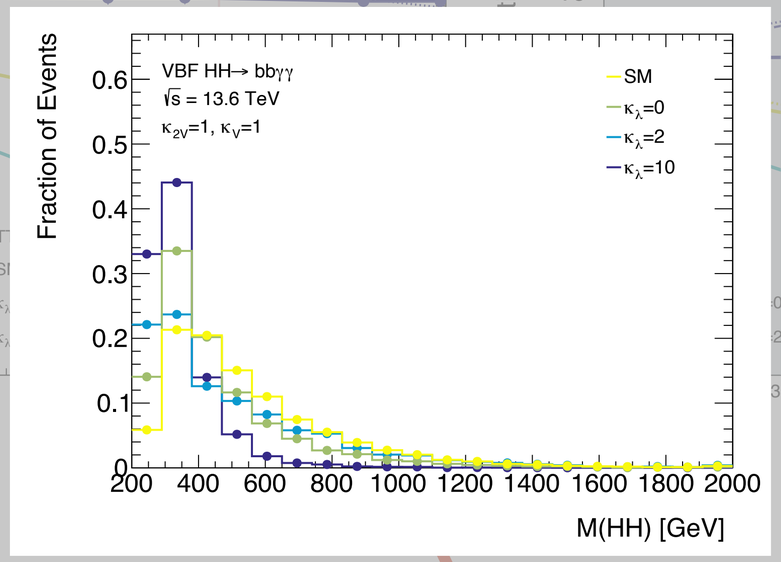


Center of mass energy of the vector bosons

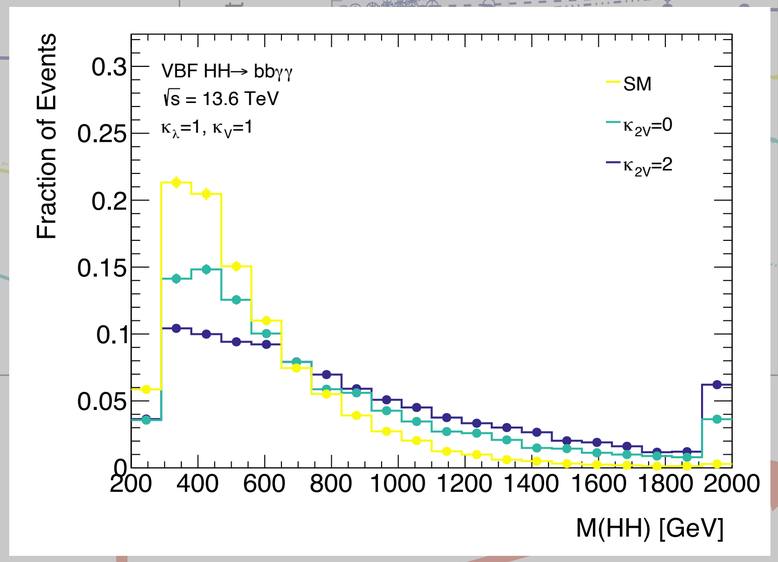
Effect of the Different Coupling Parameters on the Cross Section

How does the center of mass energy of the vector bosons relate to what is happening at the LHC?

Effect of changing κ_λ



Effect of changing κ_V



Look at the normalized truth m_{HH} distributions of the VBF di-Higgs process (here for $HH \rightarrow bb\gamma\gamma$) at center of mass energy for Run 3

Expect most of the events to be lower than $m_{HH} \approx 1200\ GeV$

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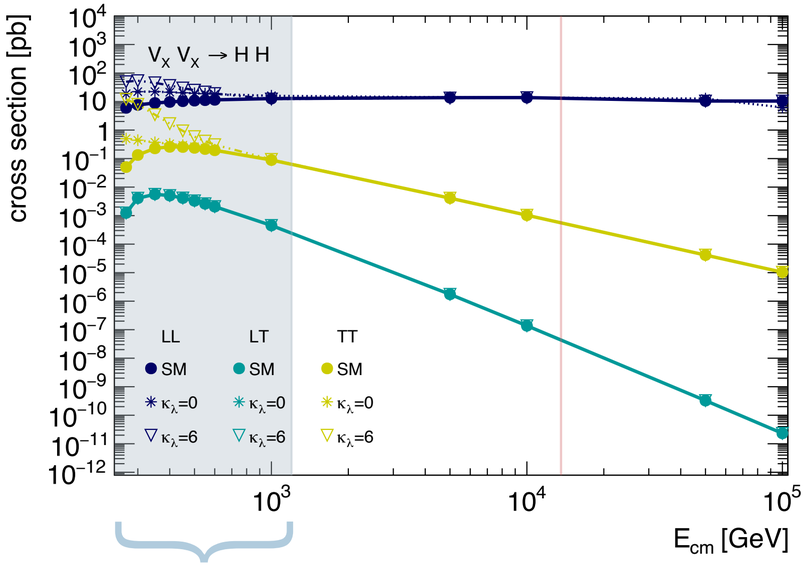
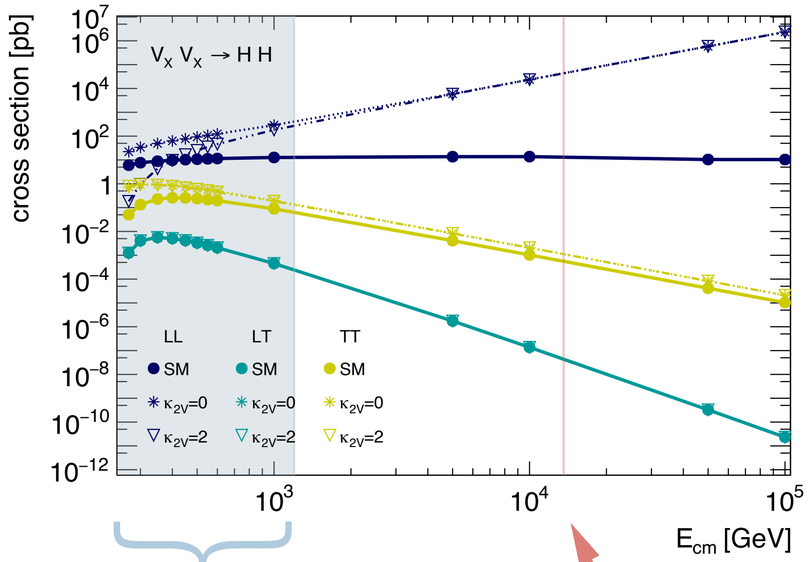
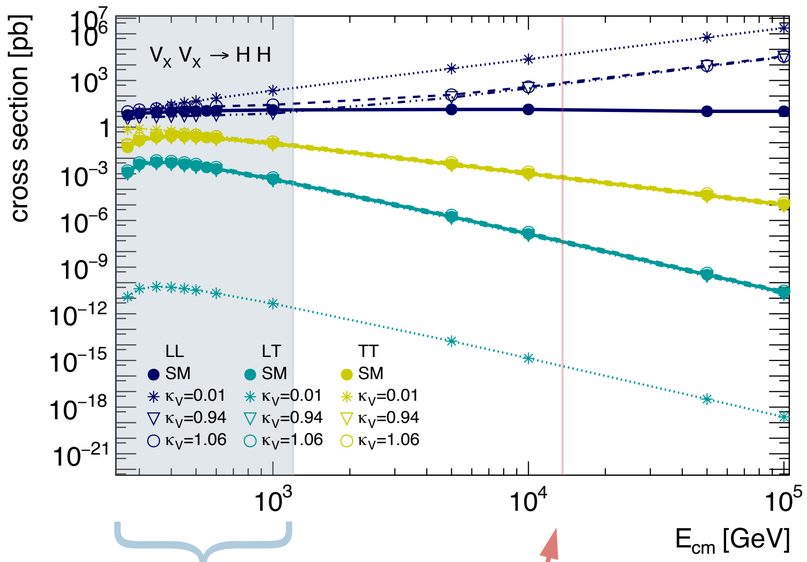


Effect of changing κ_{2V}



Effect of changing κ_V

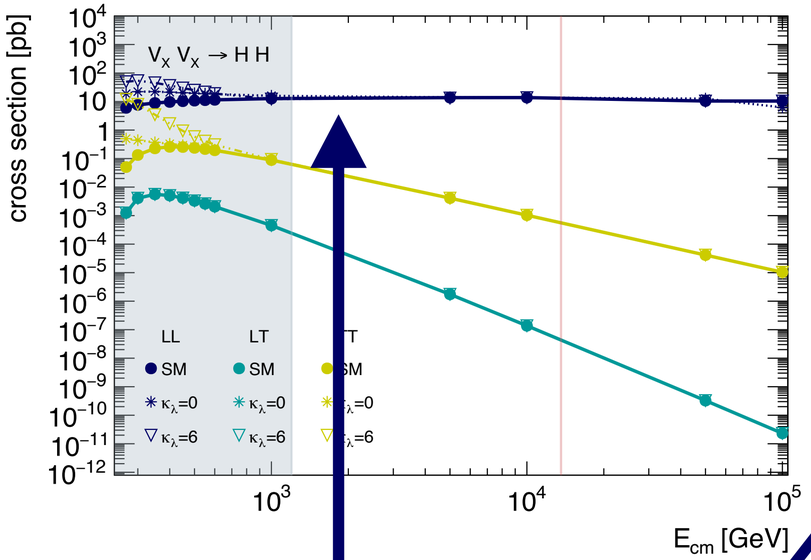


Highlighted Area:
Energy range where the di-Higgs mass of most of the events at the LHC is expected to be for Run 3

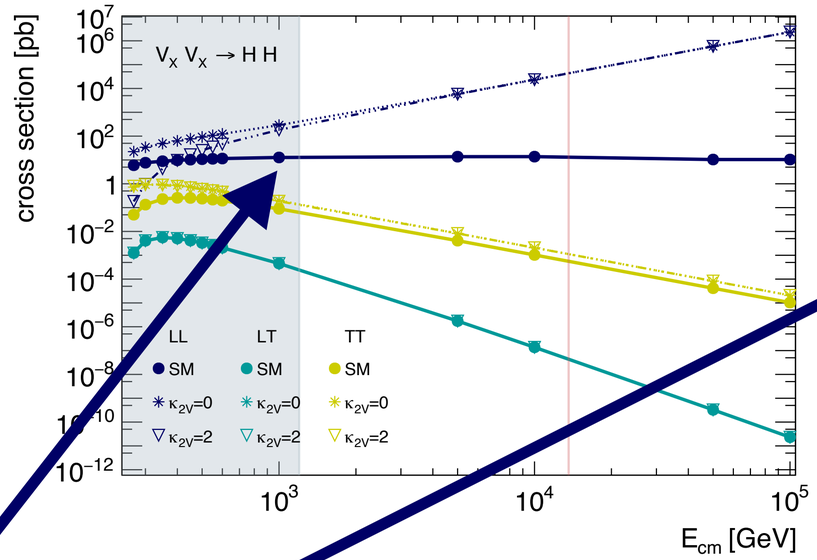
Red Line:
Center of mass energy of the LHC for Run 3 : $\sqrt{s} = 13.6$ TeV

Effect of the Different Coupling Parameters on the Cross Section

Effect of changing κ_λ



Effect of changing κ_{2V}



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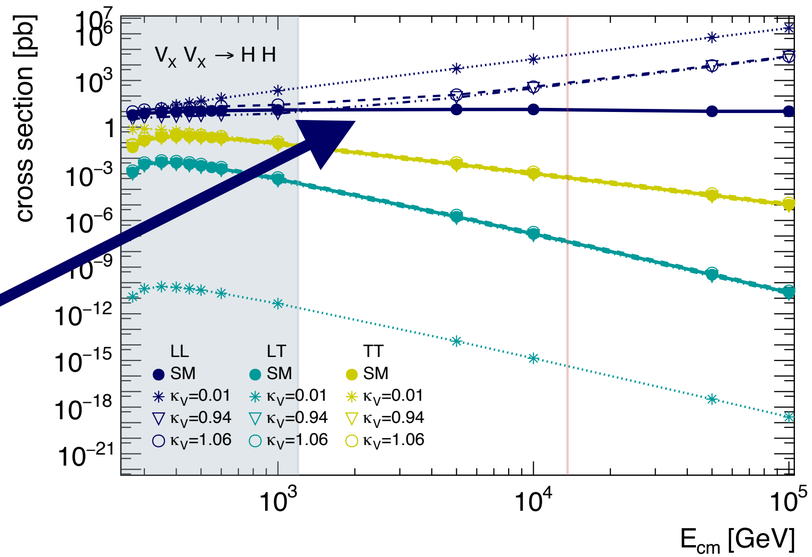


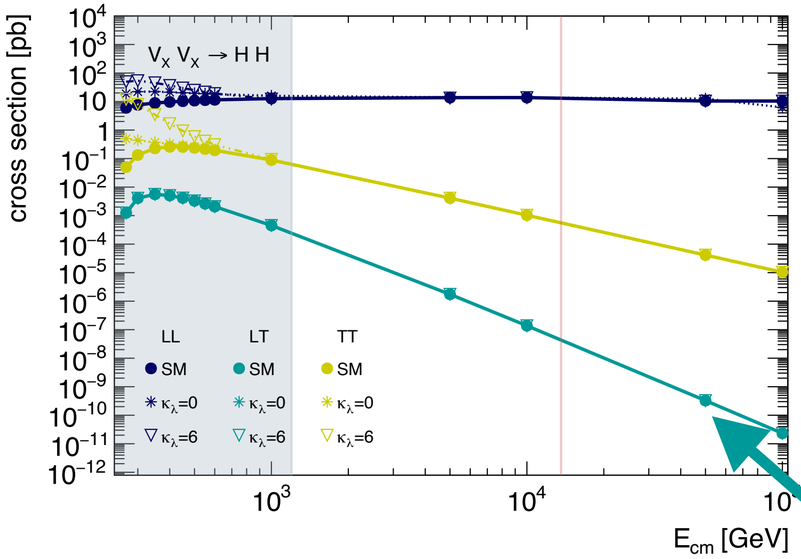
Longitudinal longitudinal (LL)

mixed (LT)

Transversal transversal (TT)

Effect of the Different Coupling Parameters on the Cross Section

Effect of changing κ_λ



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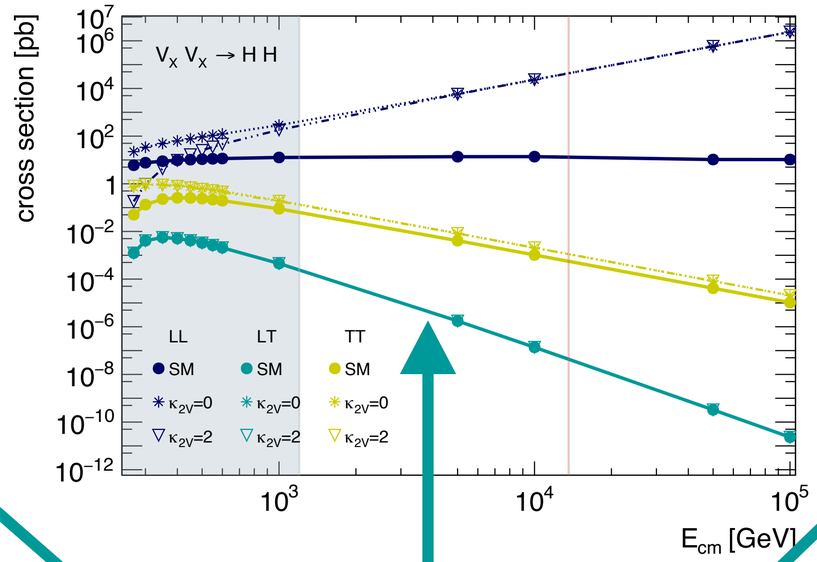

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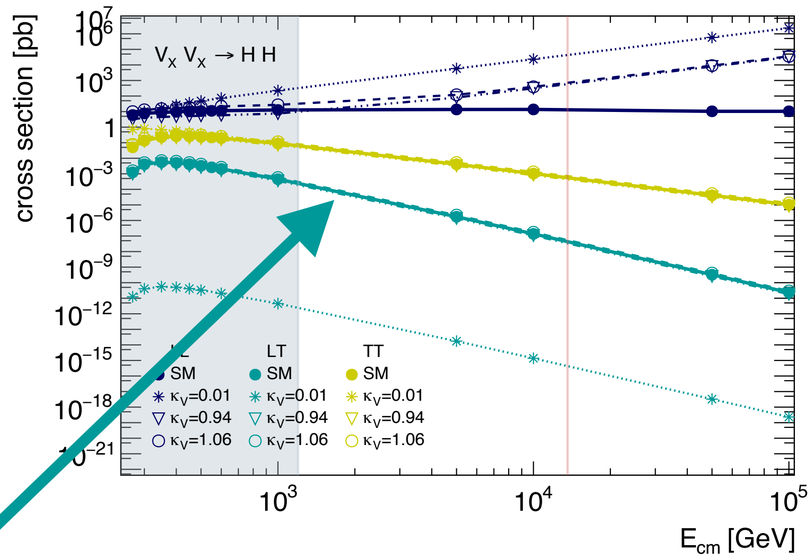

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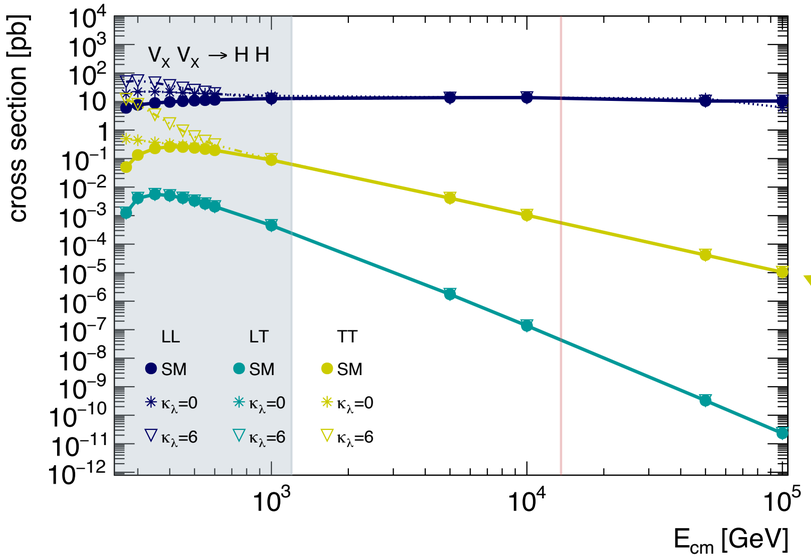

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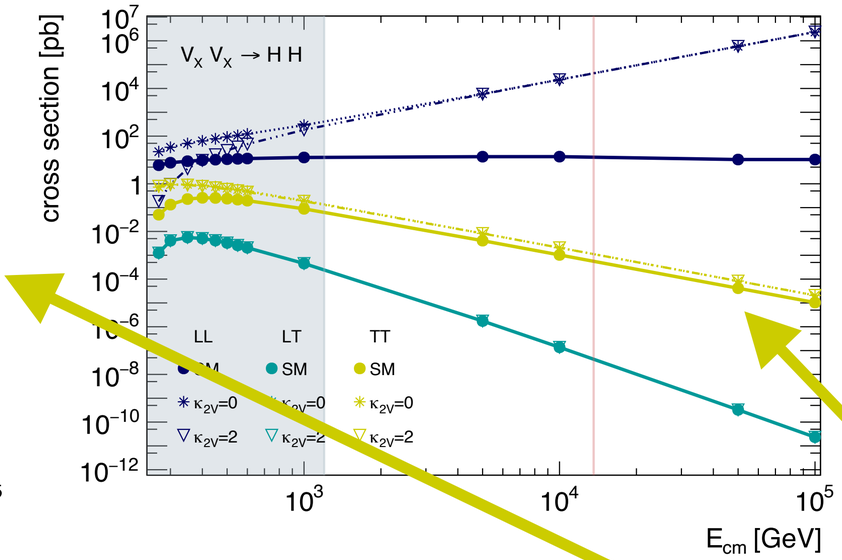

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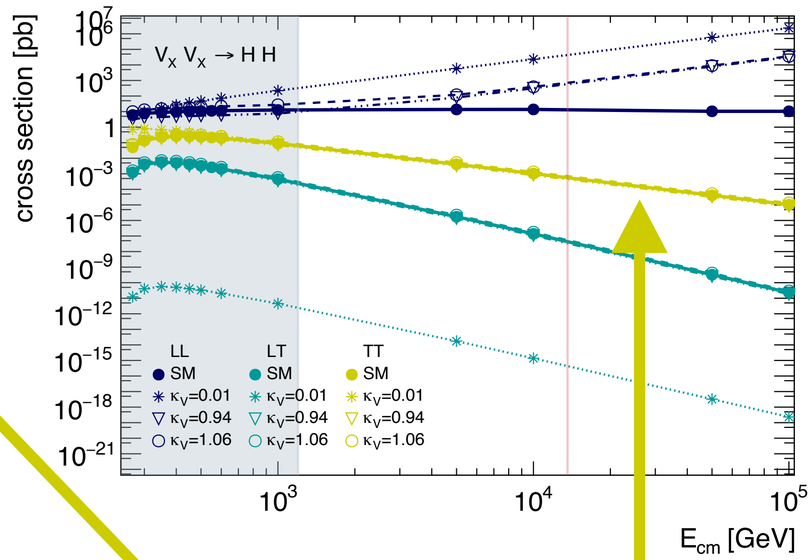

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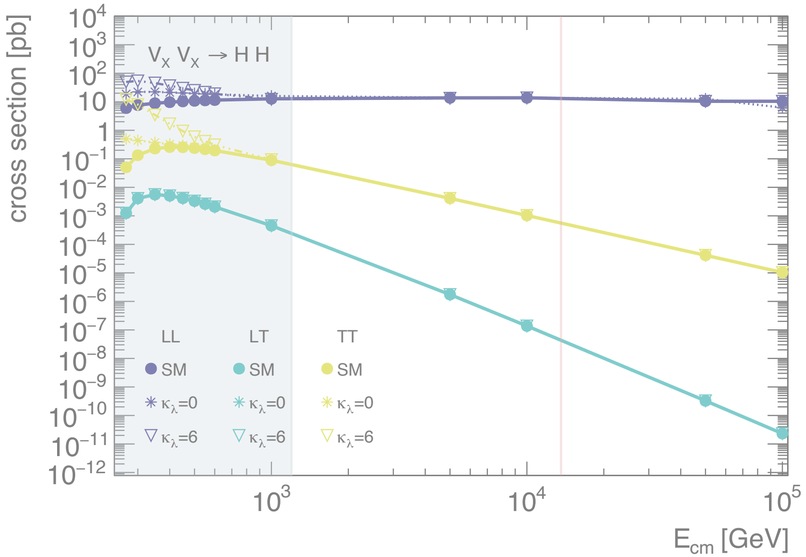

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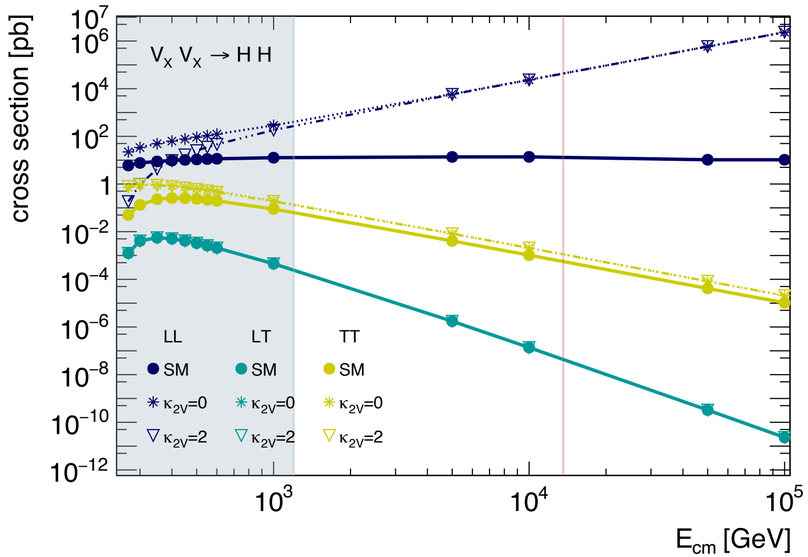

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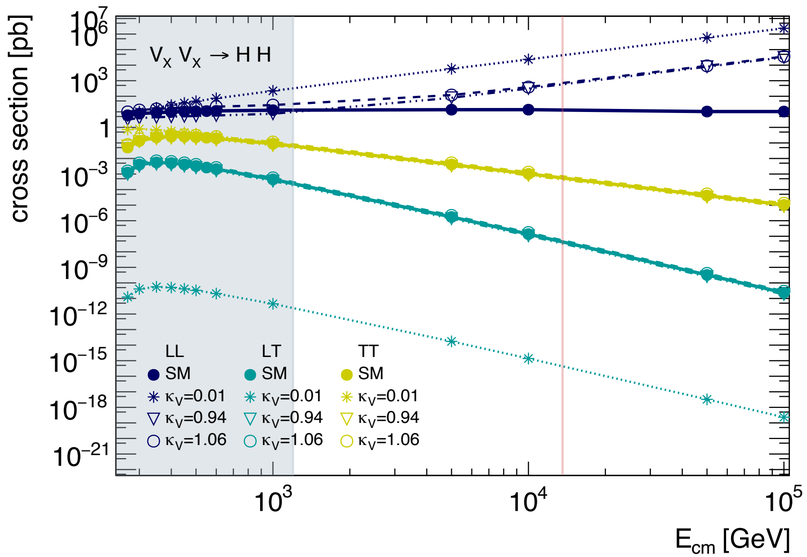
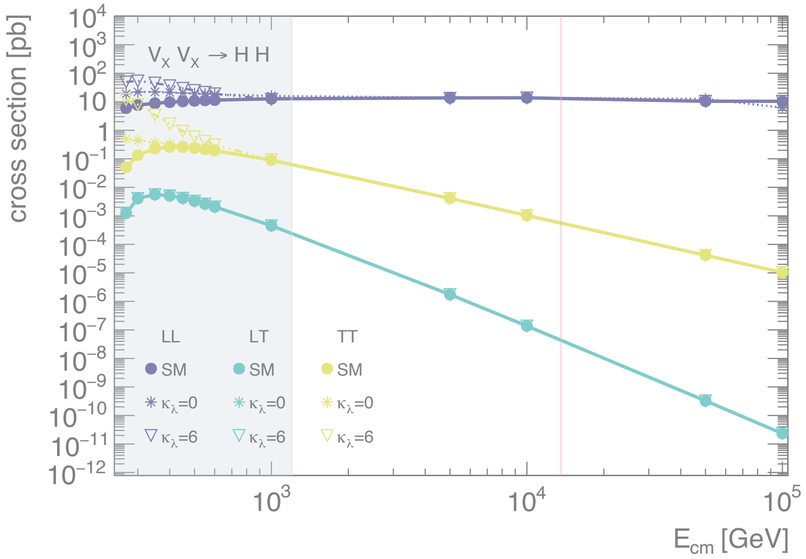


Longitudinal longitudinal polarization:

- κ_{2V}, κ_V : Unitarity violation visible for deviations from the SM
  - Large cancellations $\kappa_{2V} - \kappa_V$ are expected

Effect of the Different Coupling Parameters on the Cross Section

Effect of changing κ_λ



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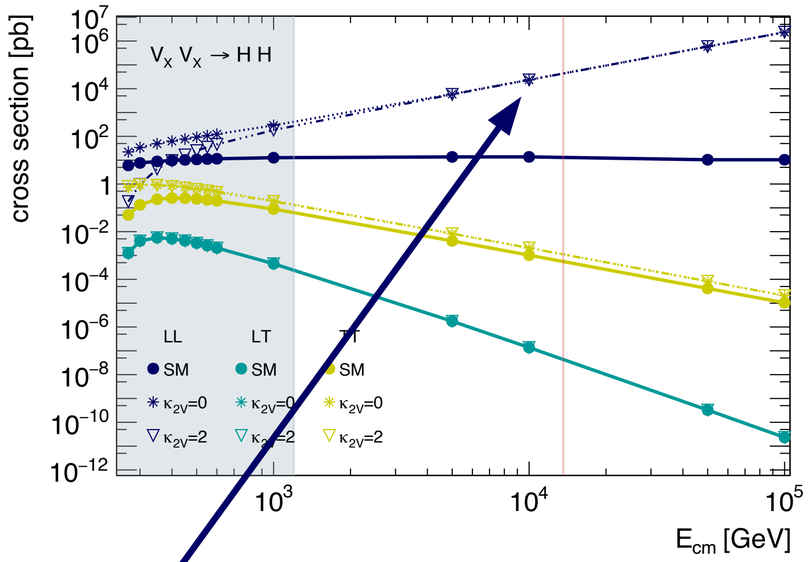

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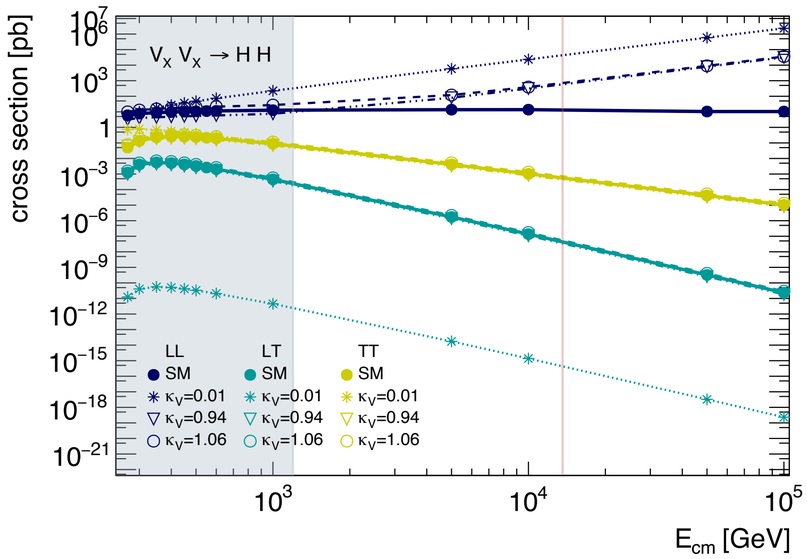

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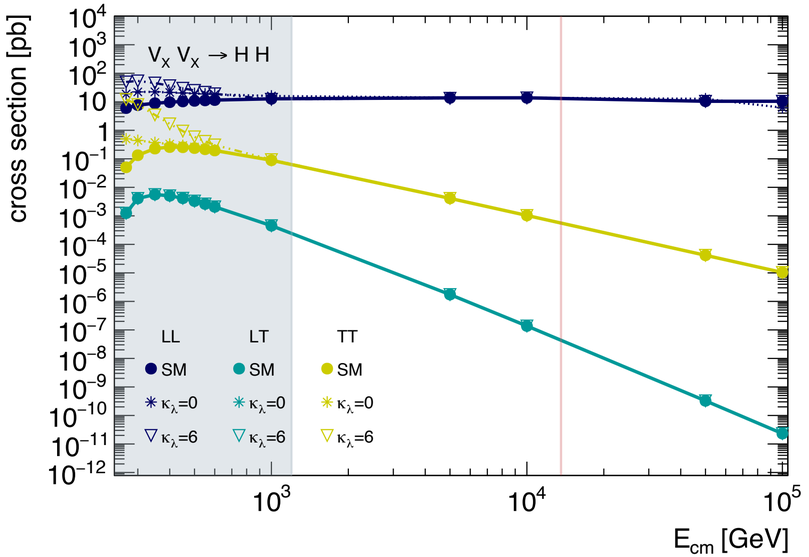

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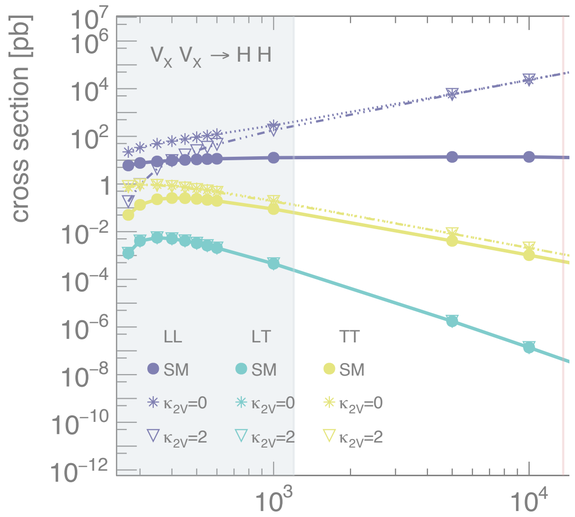

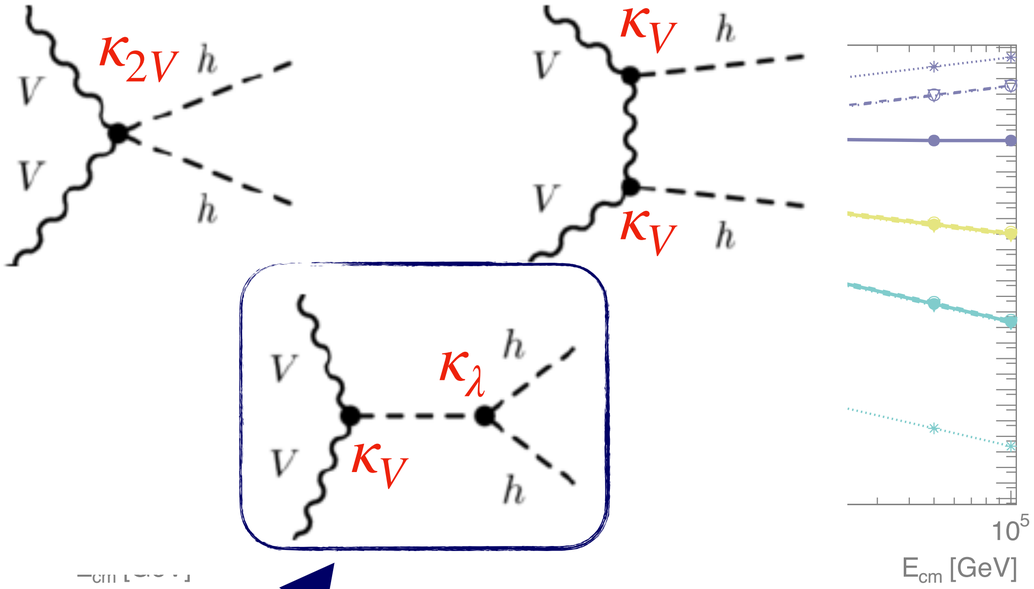

Longitudinal longitudinal polarization:

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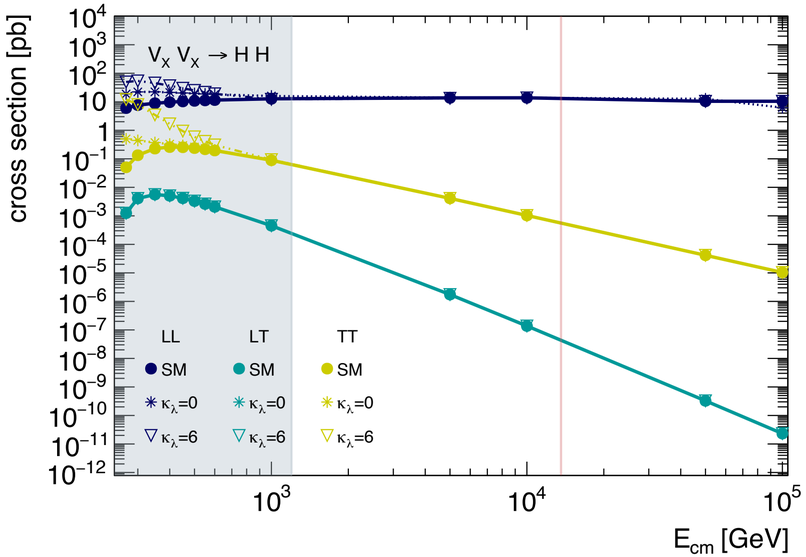
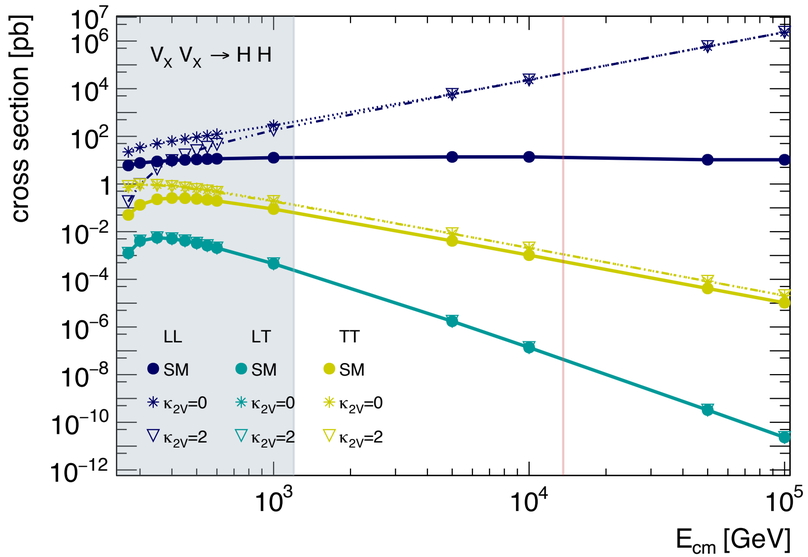
  - Large cancellations $\kappa_{2V} - \kappa_V$ are expected
- κ_λ : No Unitarity violation visible
  - s-channel diagram with off-shell Higgs disappears for high energies

Effect of the Different Coupling Parameters on the Cross Section

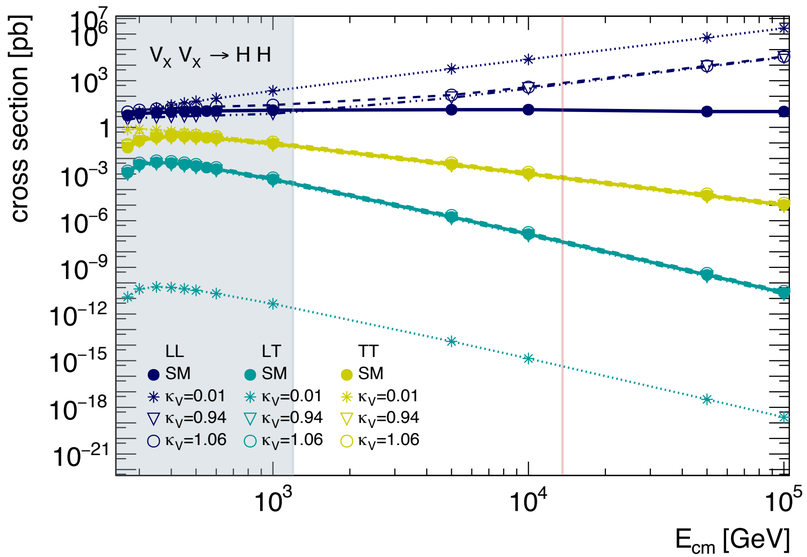
Effect of changing κ_λ



Effect of changing κ_{2V}



Effect of changing κ_V



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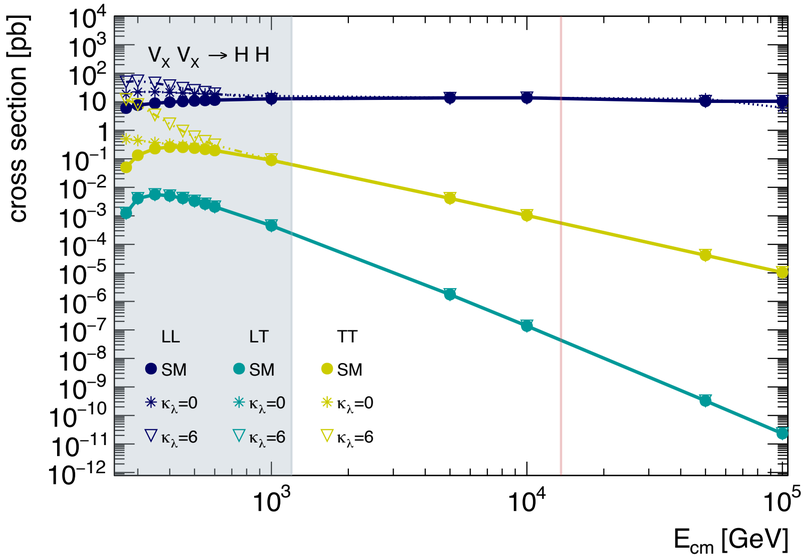
Other polarizations (LT and TT):

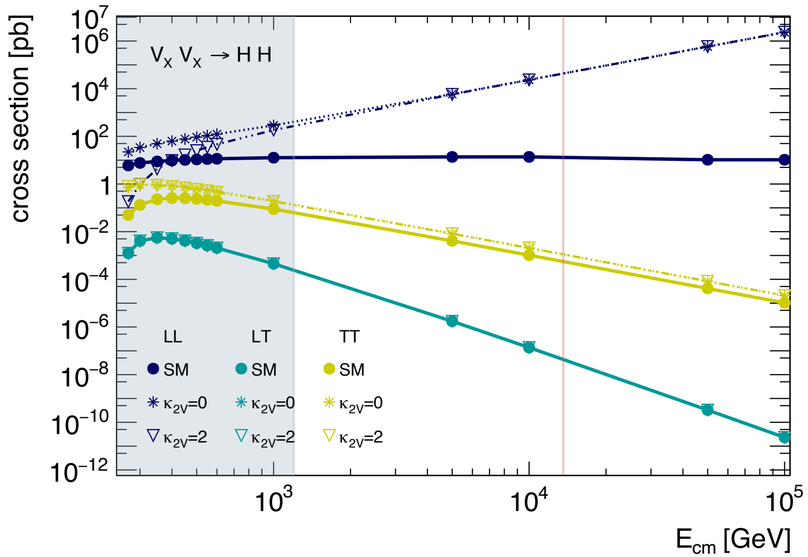
- No unitarity violation

Effect of the Different Coupling Parameters on the Cross Section

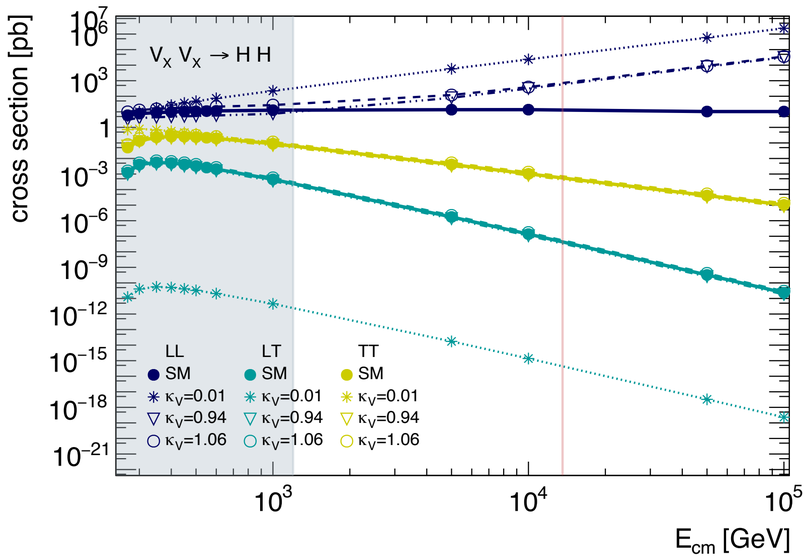
Effect of changing κ_λ



Effect of changing κ_{2V}



Effect of changing κ_V



Longitudinal longitudinal polarization:

- κ_{2V}, κ_V : Unitarity violation visible for deviations from the SM
  - Large cancellations $\kappa_{2V} - \kappa_V$ are expected
- κ_λ : No Unitarity violation visible
  - s-channel diagram with off-shell Higgs disappears for high energies

Other polarizations (LT and TT):

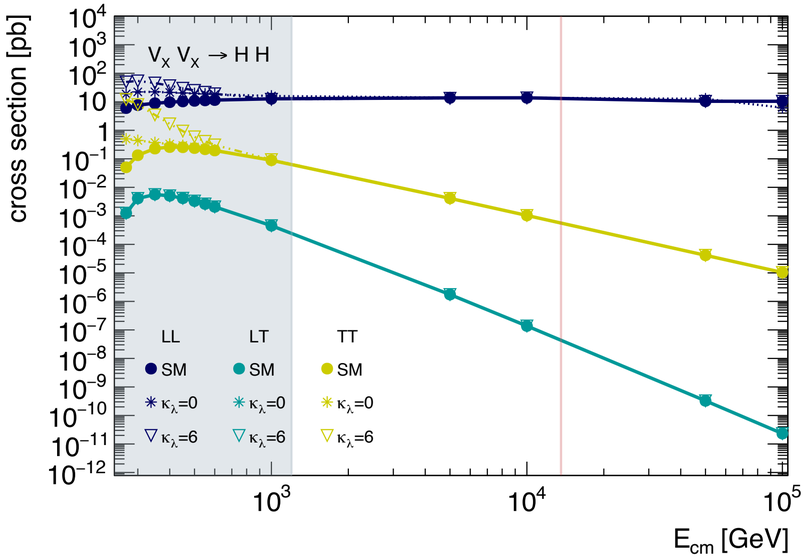
- No unitarity violation

Mixed polarization (LT):

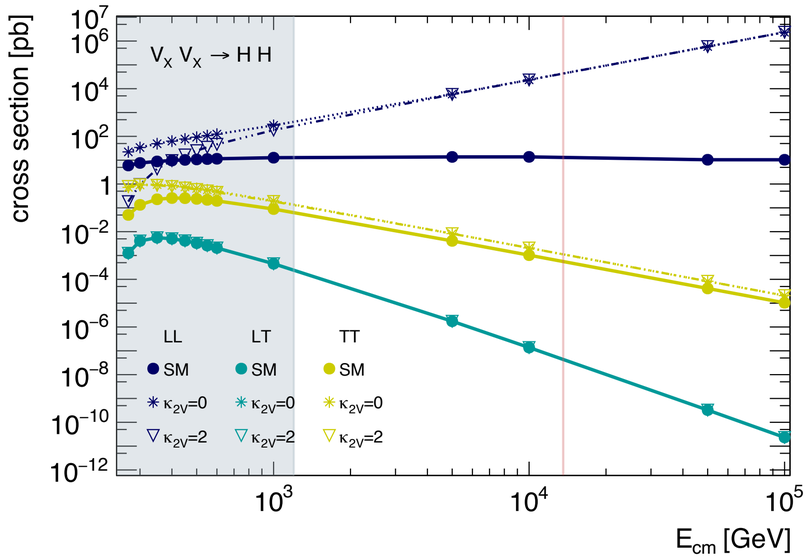
- Very strongly suppressed

Effect of the Different Coupling Parameters on the Cross Section

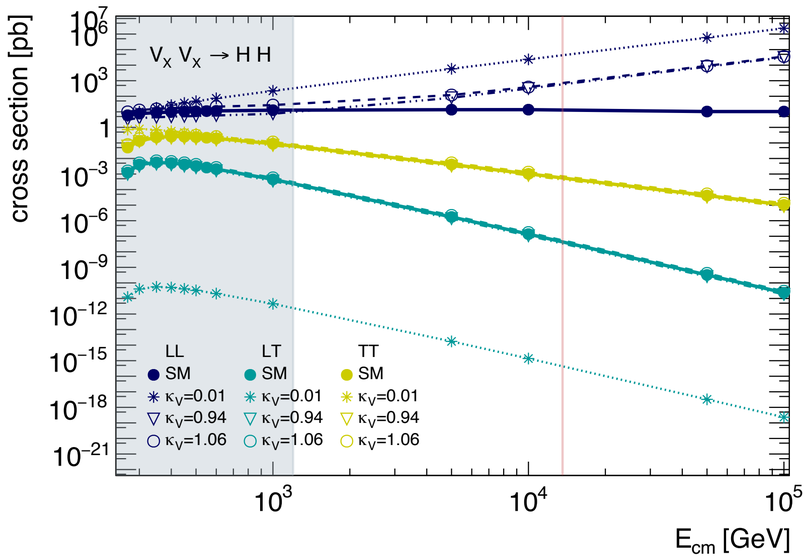
Effect of changing κ_λ



Effect of changing κ_{2V}



Effect of changing κ_V

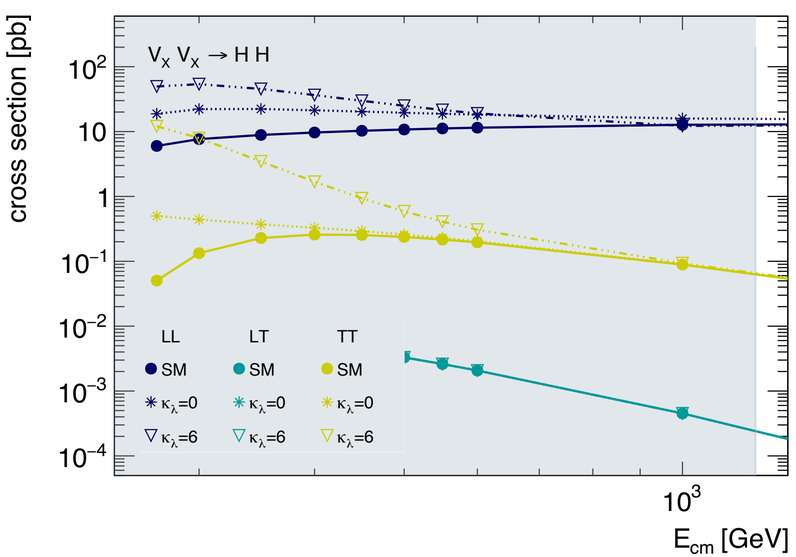


- The LL polarization dominates for most of the coupling values over large energy regimes
- But for some values of the coupling parameters the relative fraction of TT compared to LL gets larger at low energies

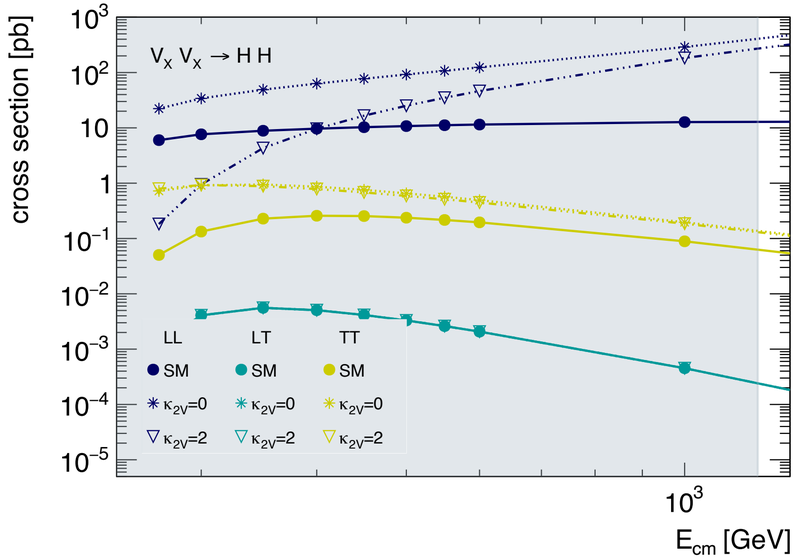
Effect of the Different Coupling Parameters the Cross Section

Zoomed in

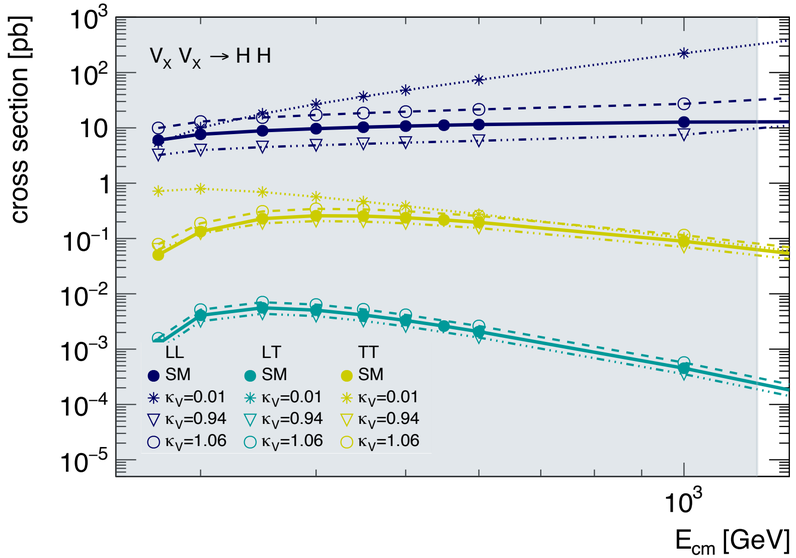
Effect of changing κ_λ



Effect of changing κ_{2V}



Effect of changing κ_V

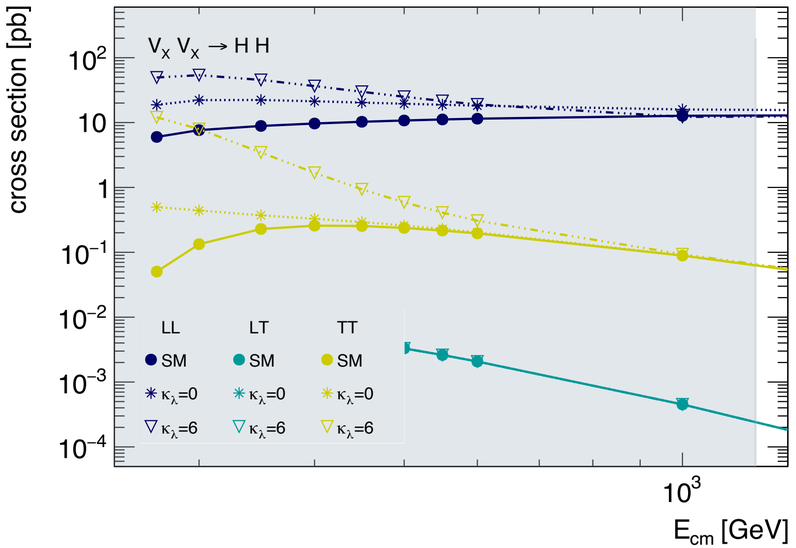


- The LL polarization dominates for most of the coupling values over large energy regimes
- But for some values of the coupling parameters the relative fraction of TT compared to LL gets larger at low energies

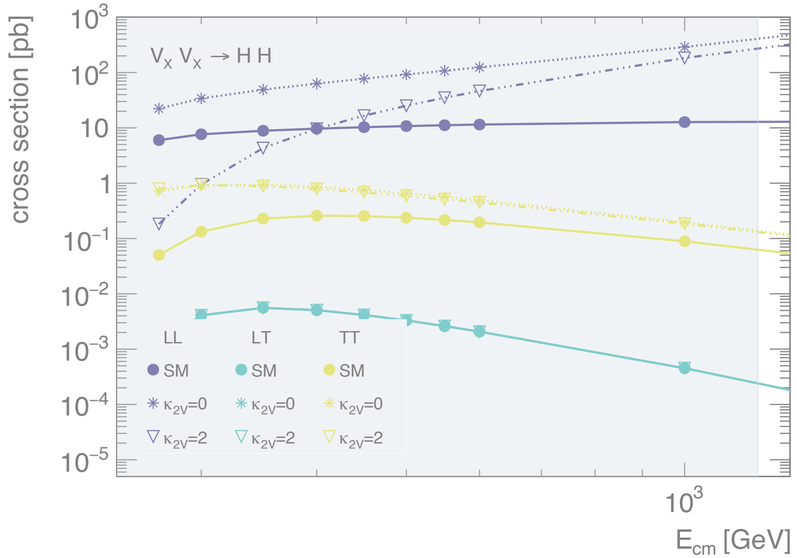
Effect of the Different Coupling Parameters on the Cross Section

Zoomed in

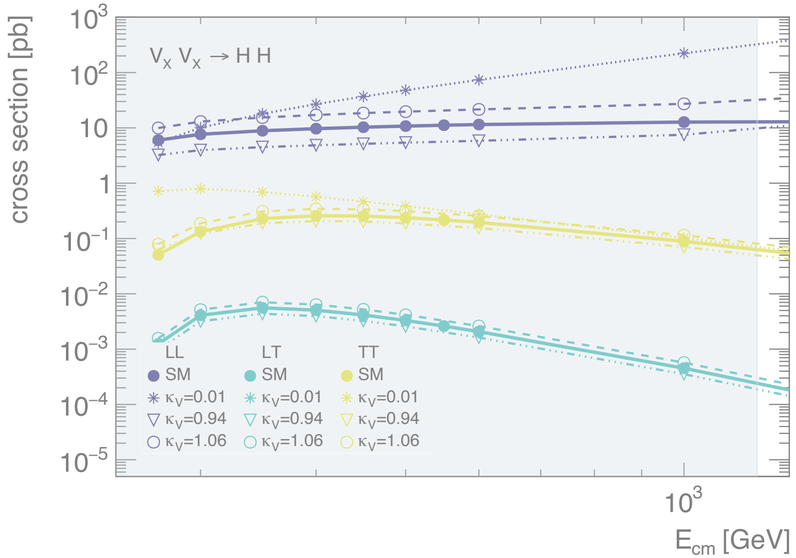
Effect of changing κ_λ



Effect of changing κ_{2V}



Effect of changing κ_V

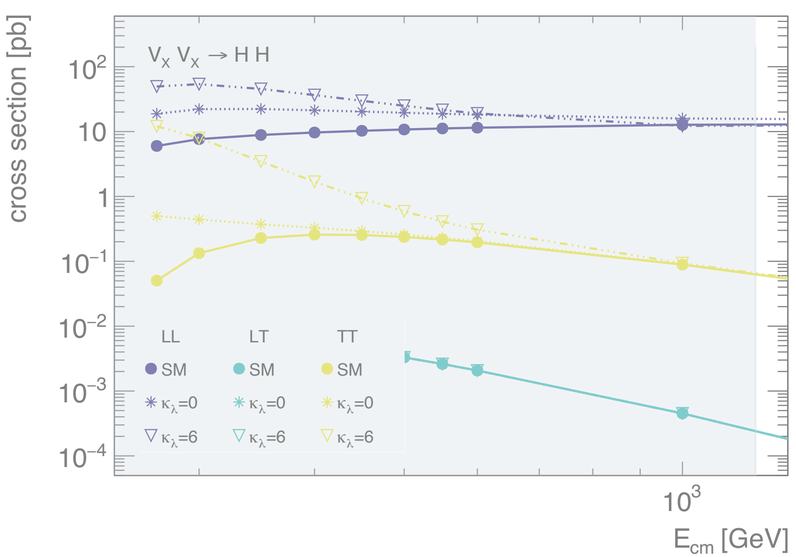


- The LL polarization dominates for most of the coupling values over large energy regimes
- But for some values of the coupling parameters the relative fraction of TT compared to LL gets larger at low energies
- Closer look at κ_λ at low energies
  - $\kappa_\lambda = 0$: Still large difference between LL and TT
  - $\kappa_\lambda = 6$: Cross section of TT gets close to LL for very low energies

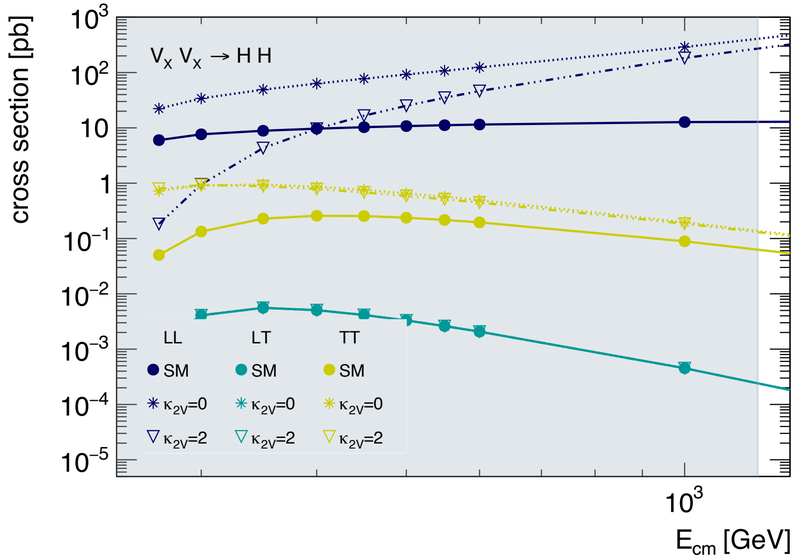
Effect of the Different Coupling Parameters on the Cross Section

Zoomed in

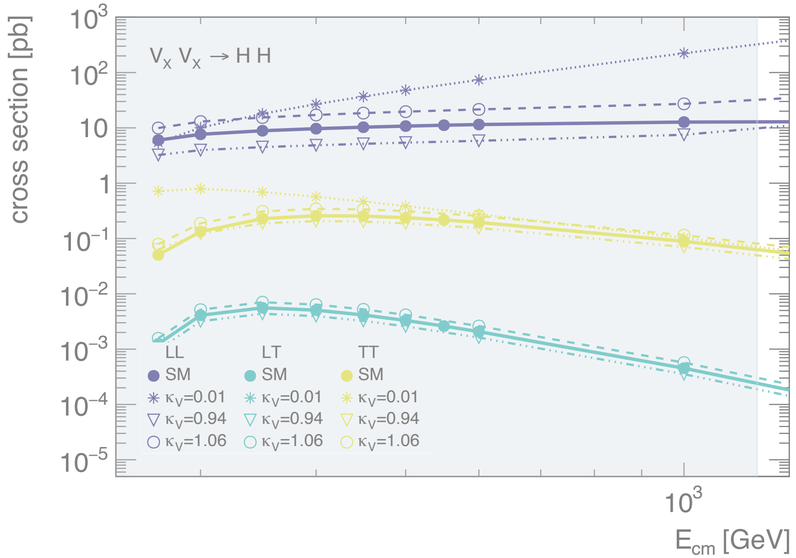
Effect of changing κ_λ



Effect of changing κ_{2V}



Effect of changing κ_V



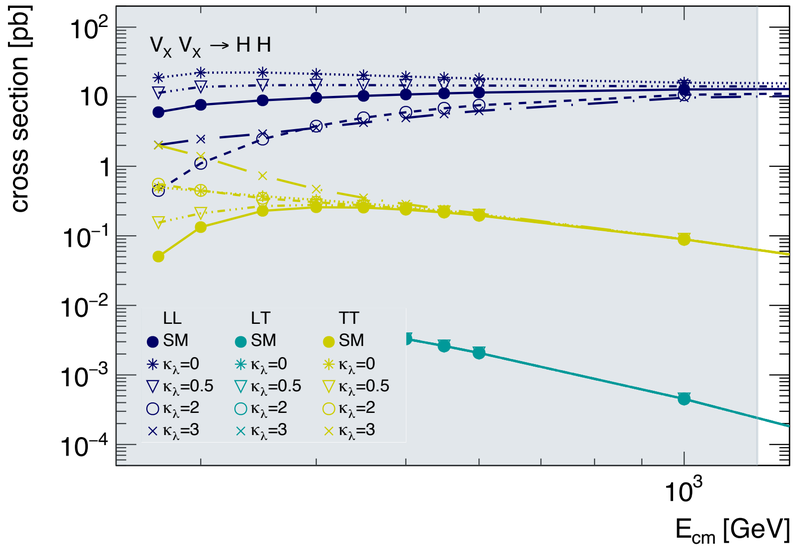
- The LL polarization dominates for most of the coupling values over large energy regimes
- But for some values of the coupling parameters the relative fraction of TT compared to LL gets larger at low energies
- Closer look at κ_{2V} at low energies
  - $\kappa_{2V} = 0$: Still large difference between LL and TT
  - $\kappa_{2V} = 2$: Cross section of TT gets close to and even larger than LL for very low energies

Effect of the Different Coupling Parameters on the Cross Section

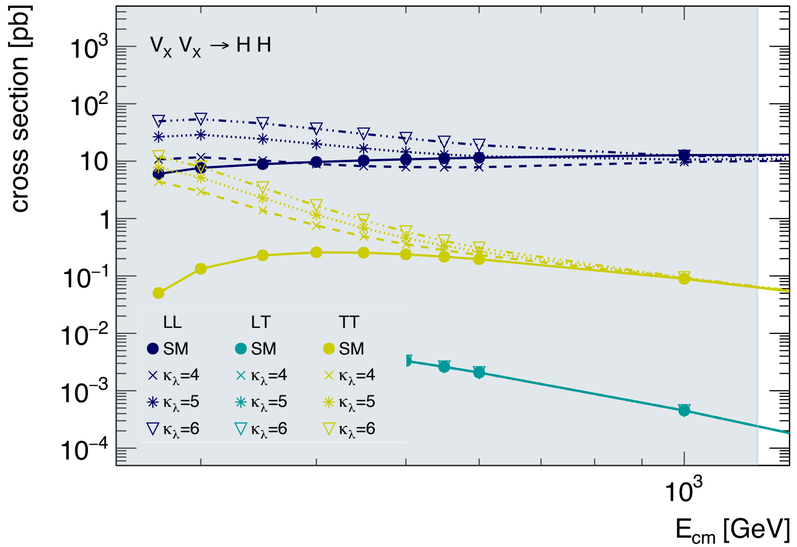
Zoomed in

More values between the limits

Effect of changing κ_λ at low energies
Low values



Effect of changing κ_λ at low energies
High values



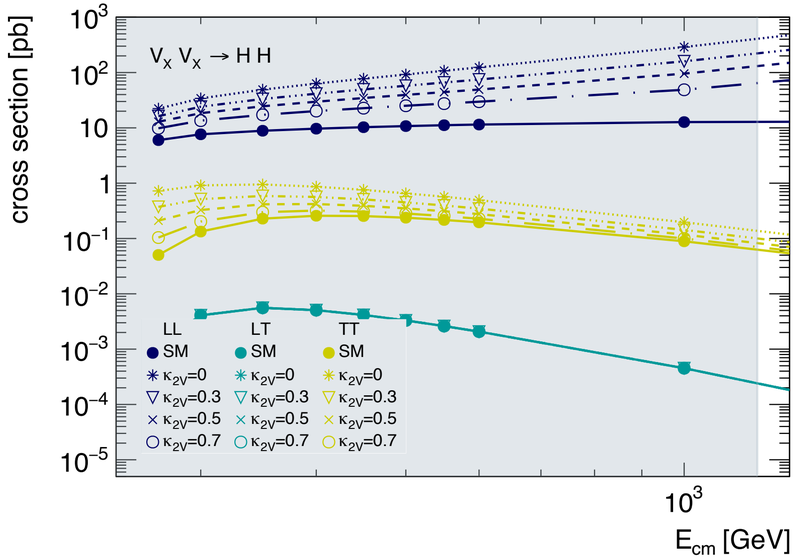
- The LL polarization dominates for most of the coupling values over large energy regimes
- But for some values of the coupling parameters the relative fraction of TT compared to LL gets larger at low energies
- Closer look at more coupling values of κ_λ between the limits
  - Relative fraction of TT at very low energies seems to be largest for $\kappa_\lambda \approx 2$
  - For values of κ_λ between 2 and 6 the cross sections of LL and TT gets close

Effect of the Different Coupling Parameters on the Cross Section

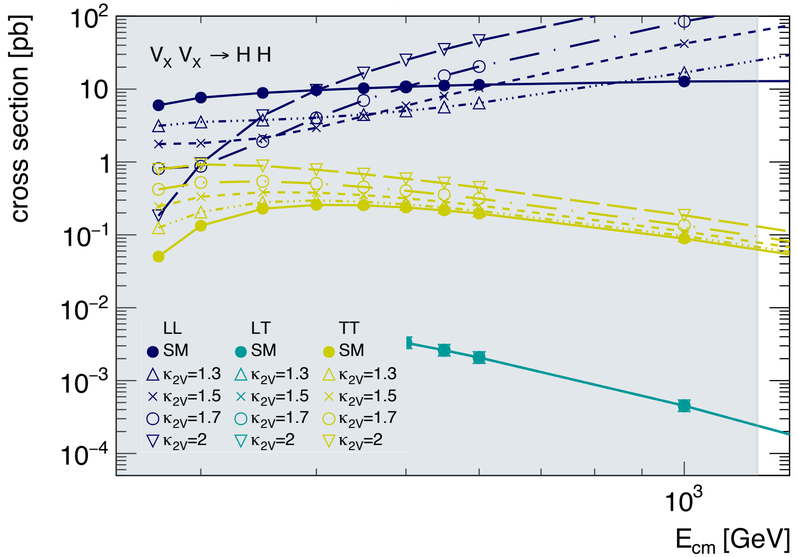
Zoomed in

More values between the limits

Effect of changing κ_{2V} at low energies
Low values



Effect of changing κ_{2V} at low energies
High values

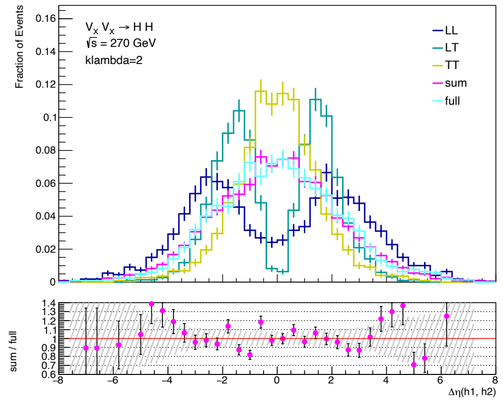


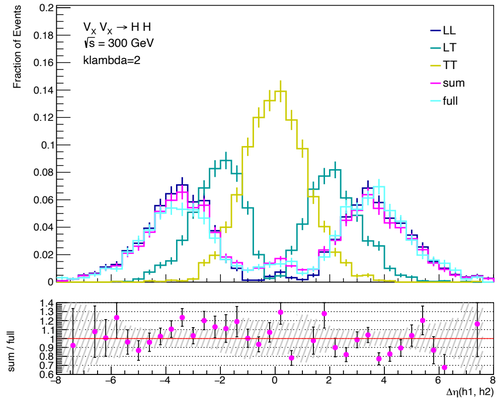
- The LL polarization dominates for most of the coupling values over large energy regimes
- But for some values of the coupling parameters the relative fraction of TT compared to LL gets larger at low energies
- Closer look at more coupling values of κ_{2V} between the limits
  - Relative fraction of TT at very low energies seems to be largest for $\kappa_{2V} \approx 2$
  - Large difference of the cross sections for $\kappa_{2V} < 1$

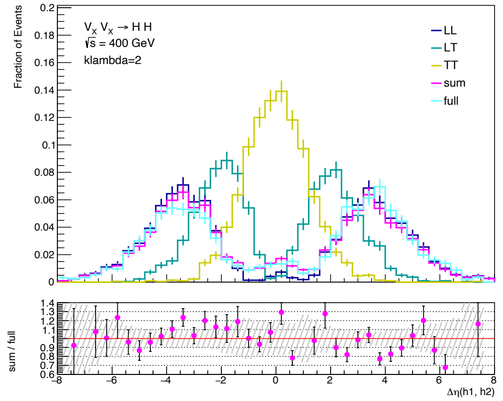
Polarization Distributions

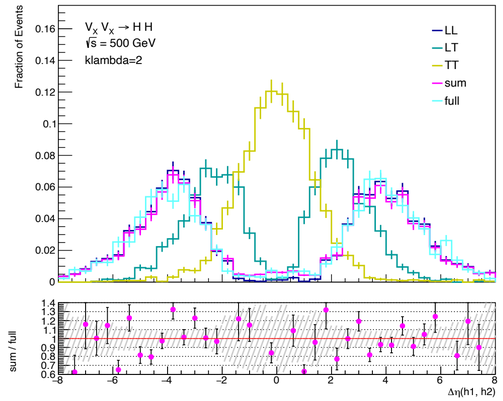
270 GeV | 300 GeV | 350 GeV | 500 GeV

$\kappa_\lambda = 2$

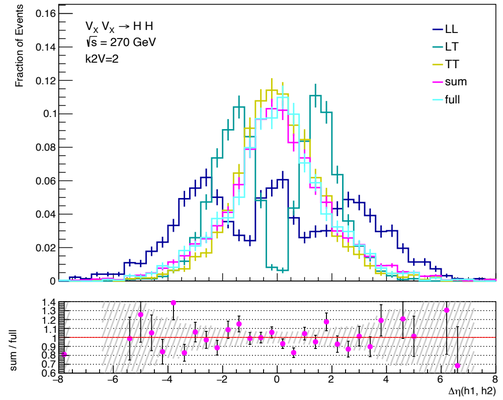


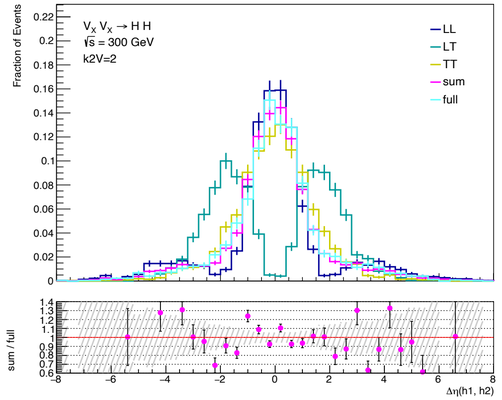


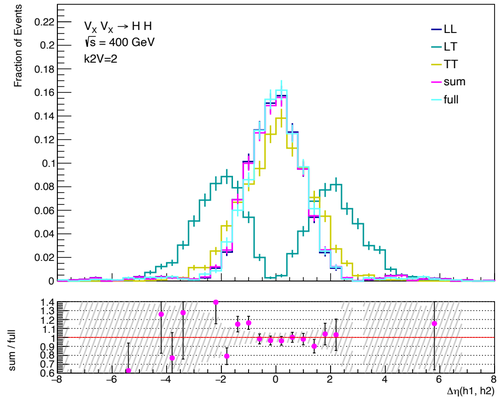


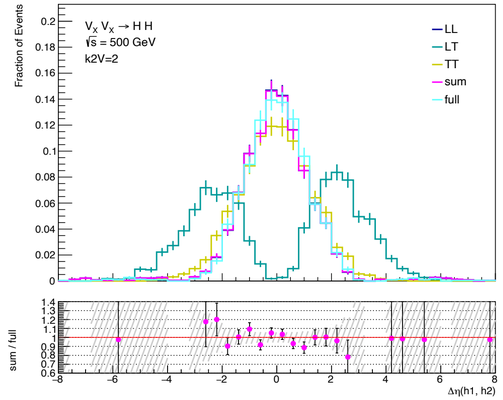


$\kappa_{2V} = 2$









- Good agreement of shape of the distribution of the sum of the polarizations and the unpolarized (full) sample
- $\kappa_\lambda = 2$: Some shape differences visible between LL and TT
- $\kappa_{2V} = 2$: Distributions of LL and TT very similar

Conclusion

- Unitarity violation can be seen for the longitudinal longitudinal boson interactions with modified coupling parameters
- The longitudinal longitudinal boson interaction is strongly preferred for VBF di-Higgs production (true for most energies)
  - Great news! We seem to be already looking at the interesting polarizations when doing VBF di-Higgs
  - However is this conclusion true at the LHC? Could be that one of the polarizations is preferably scattered off from the protons which could change the composition of the polarization fractions of di-Higgs at the LHC?
    - How to investigate that?
- At very low energies the fraction of the transversal transversal polarization can get close to the longitudinal longitudinal one for some values of the coupling parameters
- We do not see a big effect of the polarizations in the di-Higgs observables for κ_{2V}
- Some sensitivity to the different polarizations visible in the di-Higgs observables for some values of κ_{λ}
  - Is it possible to exploit this?

Backup

Closure Test of the Cross Sections

SM

Center of mass energy [GeV]	Sum	Full	Ratio sum/full
270	6.05	6.091	0.9938
300	7.78	7.844	0.9924
350	9.10	9.21	0.9880
400	9.93	10.06	0.9872
450	10.54	10.68	0.9868
500	11.00	11.14	0.9877
550	11.38	11.54	0.9865
600	11.67	11.82	0.9877
1000	12.811	13.06	0.9810
5000	13.71	13.78	0.9953
10000	13.77	13.8	0.9977
50000	10.43	13.85	0.75230
100000	10.41	6.224	1.6729

$\kappa_\lambda = 0$

Sum	Full	Ratio sum/full
19.29	19.14	1.0078
22.63	22.48	1.0069
22.67	22.53	1.0060
21.62	21.61	1.0006
20.63	20.58	1.0024
19.76	19.71	1.0027
19.04	19	1.0023
18.44	18.4	1.0021
16.01	15.83	1.0115
14.03	14.09	0.9955
13.82	14.03	0.9853
12.68	13.92	0.9108
6.22	10.66	0.5839

$\kappa_\lambda = 6$

Sum	Full	Ratio sum/full
61.57	61.5	1.0012
61.80	61.82	0.9997
48.85	48.9	0.9991
38.20	38.27	0.9981
30.76	30.84	0.9975
25.59	25.6	0.9997
21.93	21.95	0.9993
19.34	19.37	0.9986
12.34	12.87	0.9587
13.30	13.37	0.9951
13.70	13.72	0.9986
10.39	13.83	0.7515
10.43	6.22	1.6776

$\kappa_{2V} = 0$

Sum	Full	Ratio sum/ full
23.00	23.25	0.9893
35.01	35.34	0.9908
50.05	50.31	0.9948
64.00	64.2	0.9969
78.10	78.45	0.9956
92.84	92.93	0.9991
108.21	108.4	0.9983
124.49	124.6	0.9992
289.64	289.5	1.0005
5955.56	5950	1.0009
23622.22	2.354E+04	1.0035
587000.00	5.87E+05	1.0000
2342222.22	2.342E+06	1.0001

$\kappa_{2V} = 2$

Sum	Full	Ratio sum/ full
0.98	0.98	0.9973
1.88	1.87	1.0016
5.20	5.16	1.0073
10.42	10.39	1.0029
17.28	17.24	1.0025
25.67	25.64	1.0011
35.54	35.47	1.0018
46.75	46.68	1.0015
183.52	182.8	1.0039
5762.23	5758	1.0007
23311.11	2.331e+04	1.0000
585222.22	5.852e+05	1.0000
2342222.22	2.342e+06	1.0001

- Compare the cross sections of the sum of the individual polarization combinations with the cross section of the unpolarized (full) sample
  - Individual polarizations are divided by a factor (see next slide) to account to Madgraph averaging over initial state polarizations
- Good agreement for most energies
- For some coupling parameters differences can be seen at very high energies
  - These energies are out of the reach of the LHC at the moment

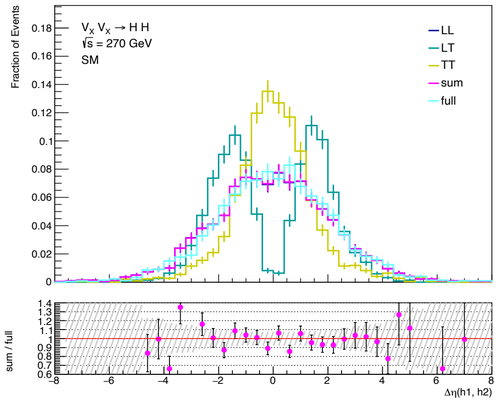
Comparison of the sum of the polarizations and the full sample

- Compare the cross section of the sum of all the polarizations to the cross section of the unpolarized sample (full)
- Need to account for the fact that Madgraph averages over the initial state polarizations
  - Need to apply an averaging factor to the individual polarizations before adding them
- There are three polarizations for the VV->HH process
  - Longitudinal (L), left-handed (l) and right-handed (r)
  - This means that there are 9 polarization combinations in the initial state
    - LL, Ll, lL, Lr, rL, ll, lr, rl, rr
    - Need to divide each polarization combination by 9
  - In my samples the left- and right-handed polarization are combined into the transversal (T) polarization
    - Likely in the transversal sample Madgraph already averages over the left- and right-handed polarizations, meaning 4 combinations of the polarizations for LT and TT each
    - That means that the averaging factor needs to be adjusted
      - LL: 1/9
      - LT: 1/2.25 = 1/4 * 1/9
    - Contacted Madgraph authors to confirm these fractions (https://answers.launchpad.net/mg5amcnlo/+question/708414)
    - Test with simulating the left- and right-handed polarizations separately seems to confirm that
      - In this case dividing all the polarizations by 9 leads to a good closure with the cross section of the full sample

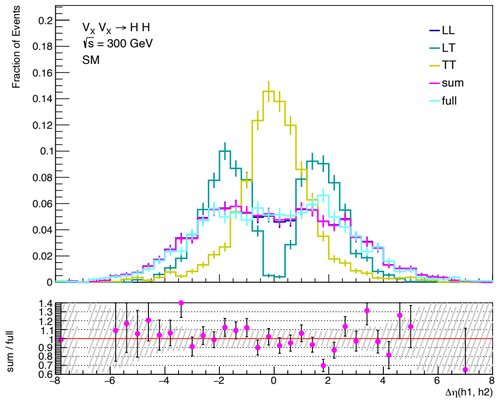
Distributions for the SM case

Center of mass energy

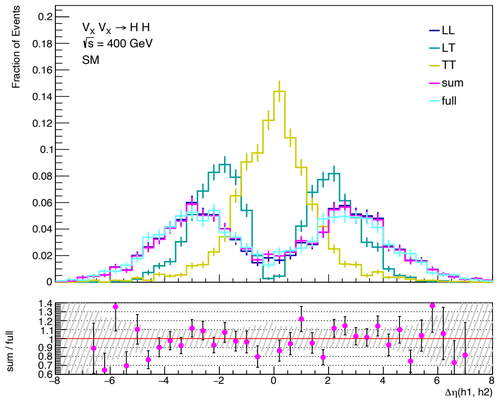
270 GeV



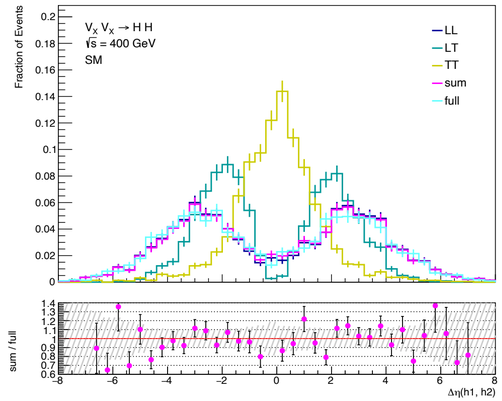
300 GeV



400 GeV

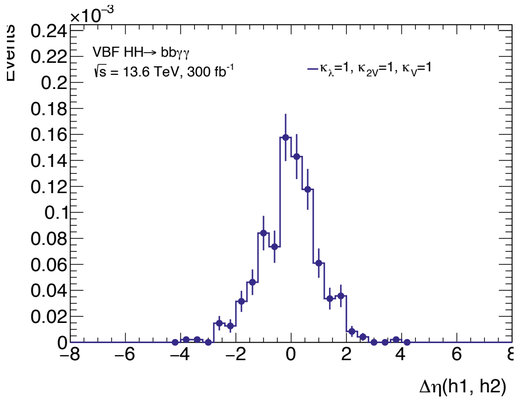


500 GeV

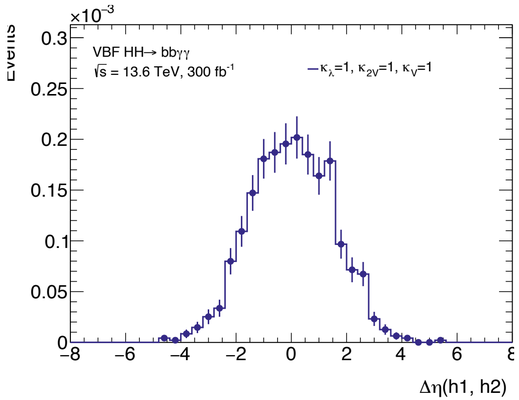


m_{HH}

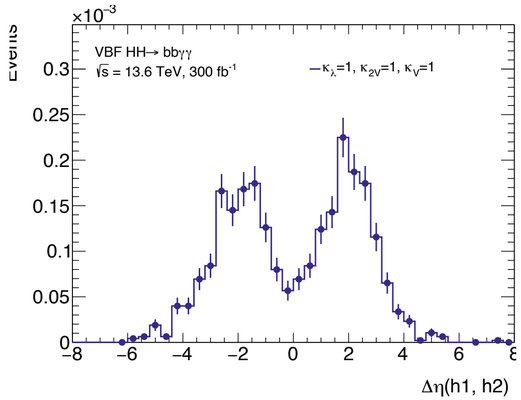
0 - 280 GeV



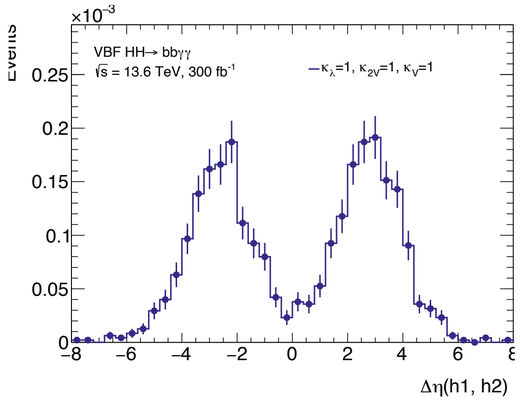
280 - 325 GeV



375-425 GeV



475 - 550 GeV

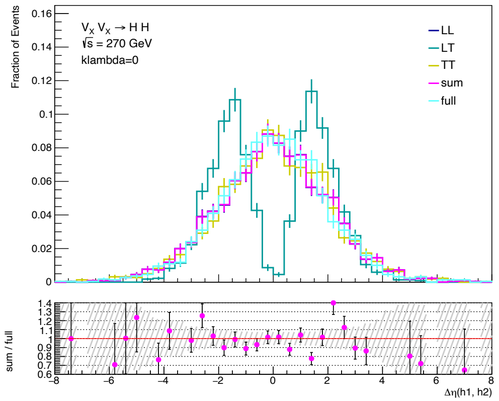


- Distribution of LL and sum almost identical due to dominating cross section of LL
- Comparison to Run 3 VBF $HH \to bb\gamma\gamma$ distribution in slices of m_{HH}
  - The shapes of the distributions follow a similar trend as the shapes of the distributions of the full sample

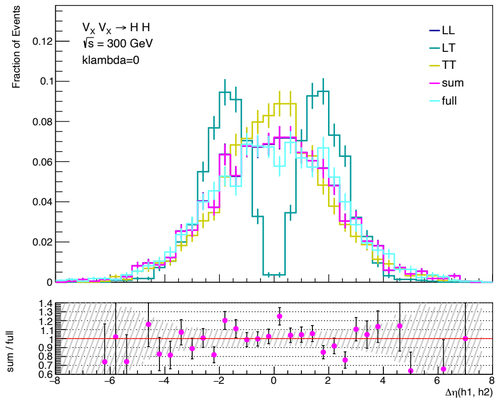
Distributions for $\kappa_\lambda = 0$

Center of mass energy

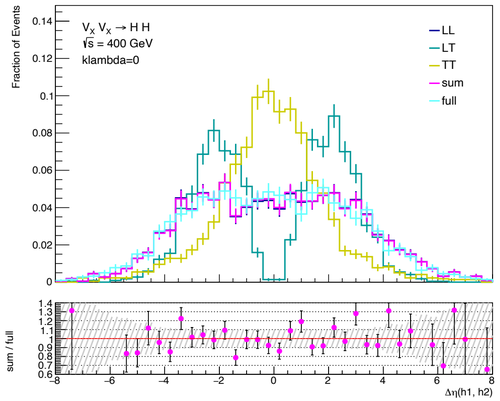
270 GeV



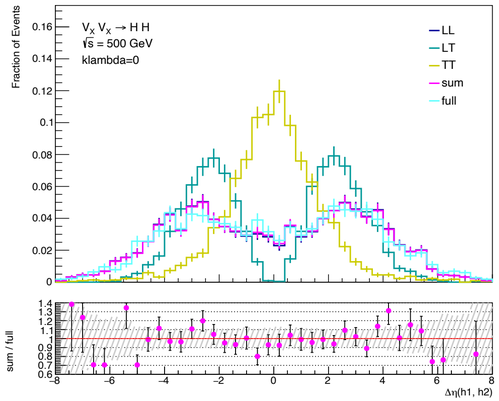
300 GeV



400 GeV

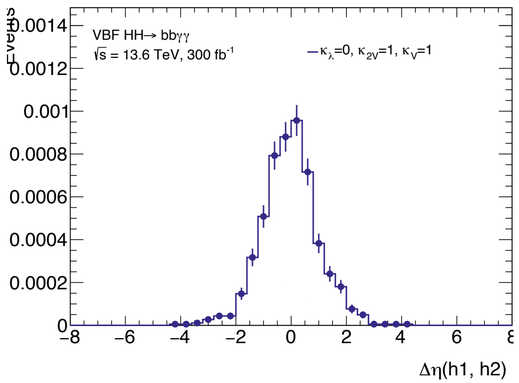


500 GeV

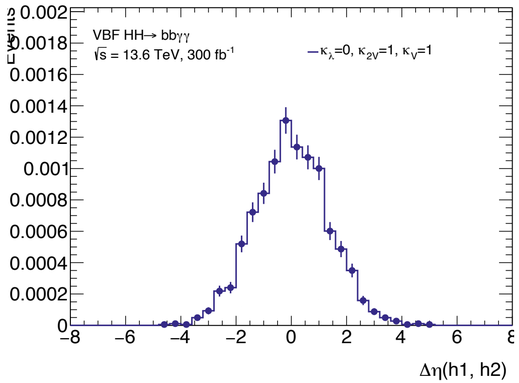


m_{HH}

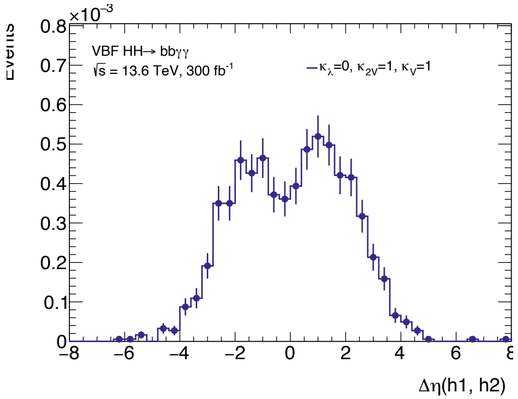
0 - 280 GeV



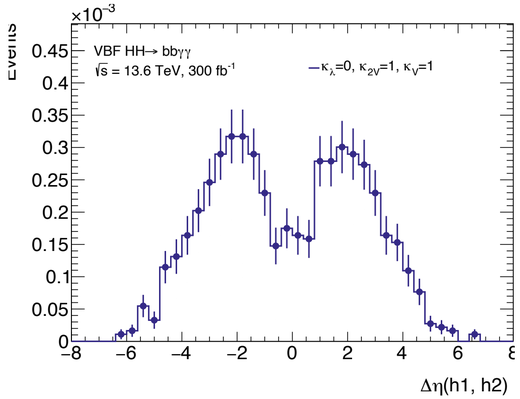
280 - 325 GeV



375-425 GeV



475 - 550 GeV

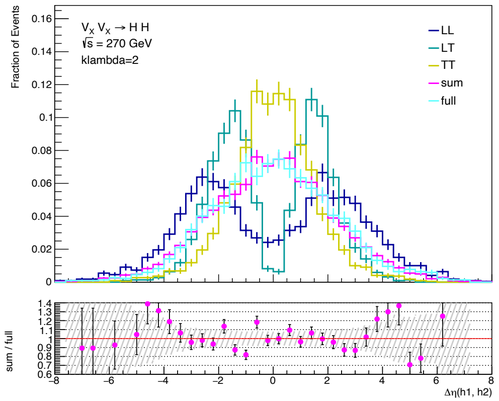


- Distributions of LL and TT very similar
- Comparison to Run 3 VBF $HH \to bb\gamma\gamma$ distribution in slices of m_{HH}
  - The shapes of the distributions follow a similar trend as the shapes of the distributions of the full sample

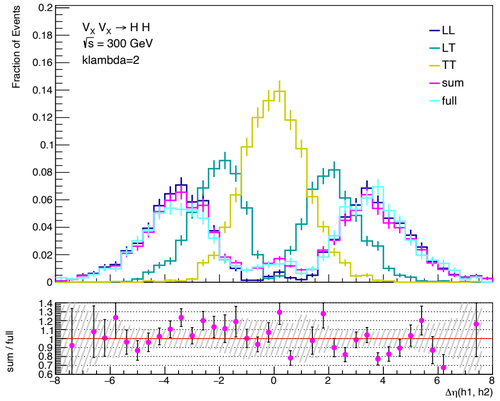
Distributions for $\kappa_\lambda = 2$

Center of mass energy

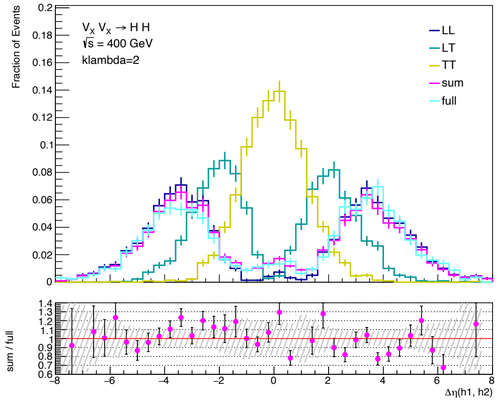
270 GeV



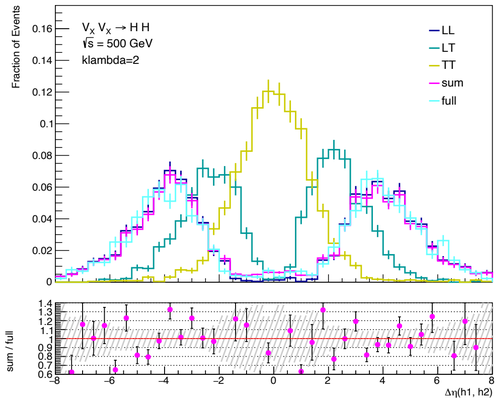
300 GeV



400 GeV

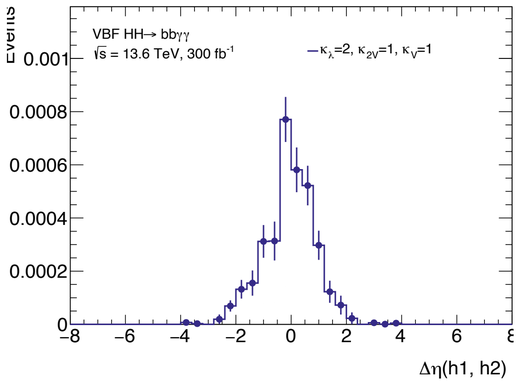


500 GeV

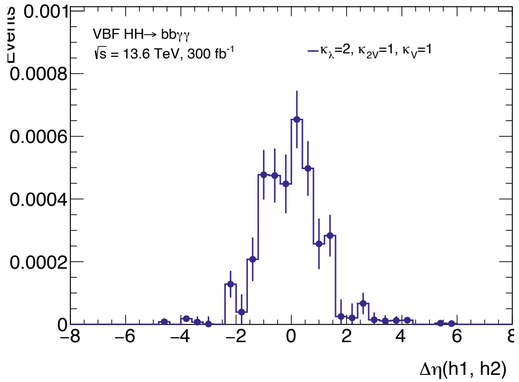


m_{HH}

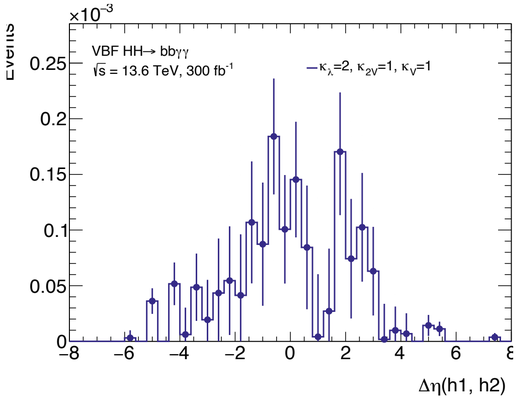
0 - 280 GeV



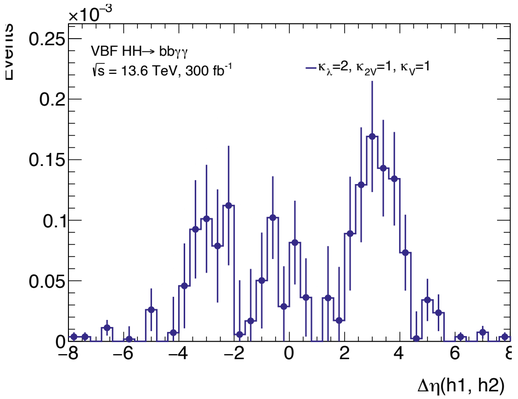
280 - 325 GeV



375-425 GeV



475 - 550 GeV

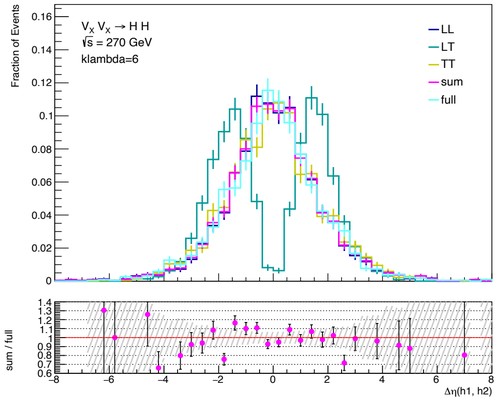


- Some shape differences visible between LL and TT
- Comparison to Run 3 VBF $HH \to bb\gamma\gamma$ distribution in slices of m_{HH}
  - Distributions of the Run 3 VBF $HH \to bb\gamma\gamma$ sample more central
  - Possible that the vector bosons that are scattered off from the protons are preferrable transversal polarized

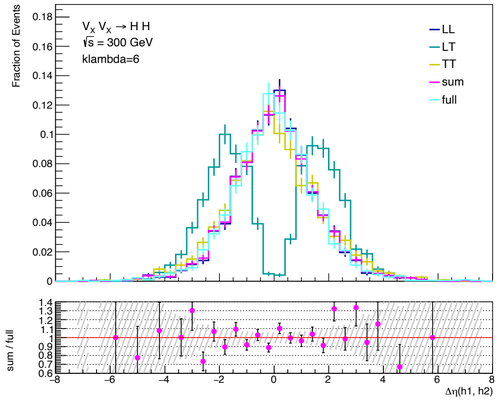
Distributions for $\kappa_\lambda = 6$

Center of mass energy

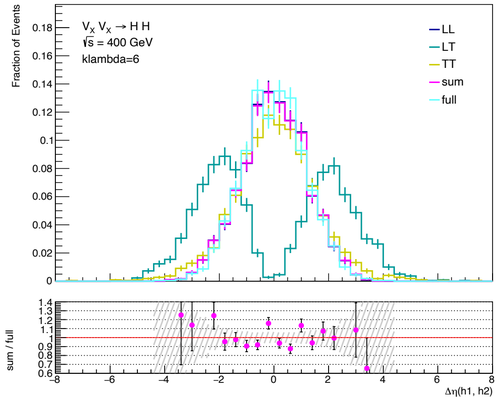
270 GeV



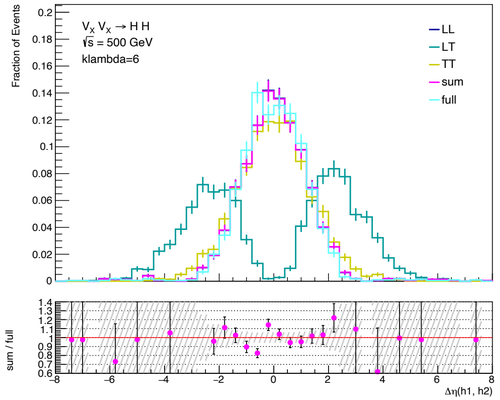
300 GeV



400 GeV

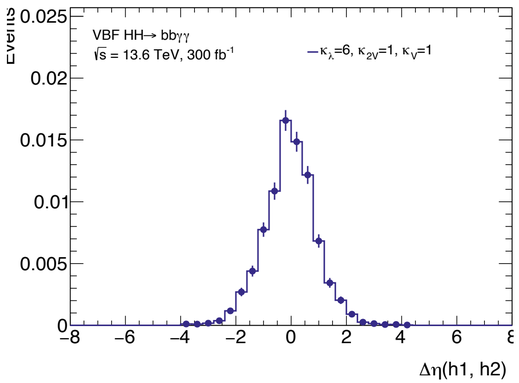


500 GeV

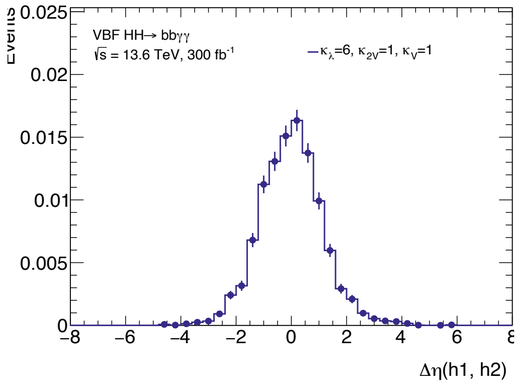


m_{HH}

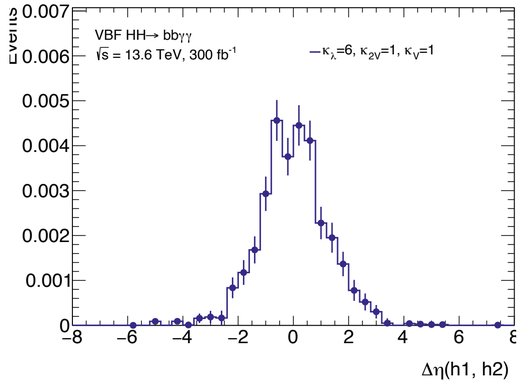
0 - 280 GeV



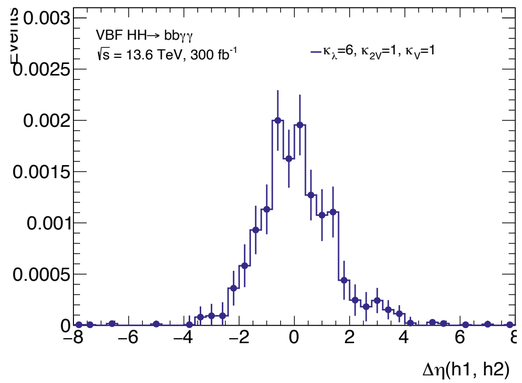
280 - 325 GeV



375-425 GeV



475 - 550 GeV

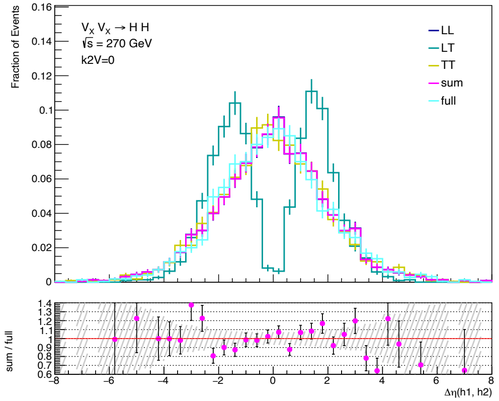


- Distributions of LL and TT very similar
- Comparison to Run 3 VBF $HH \to bb\gamma\gamma$ distribution in slices of m_{HH}
  - The shapes of the distributions follow a similar trend as the shapes of the distributions of the full sample

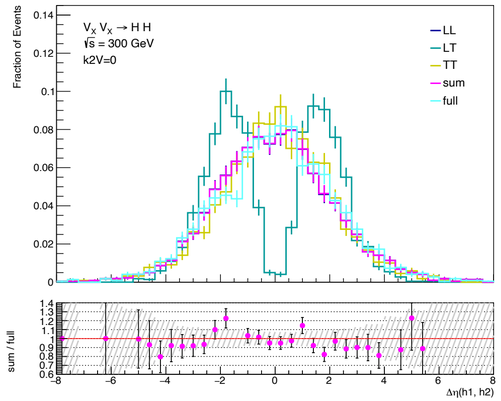
Distributions for $\kappa_{2V} = 0$

Center of mass energy

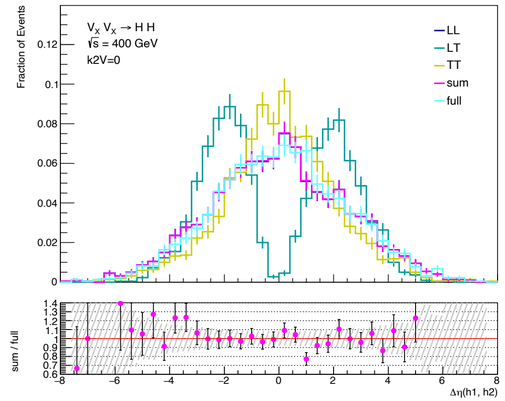
270 GeV



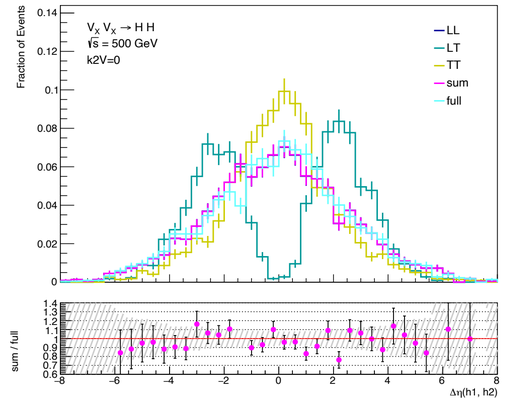
300 GeV



400 GeV

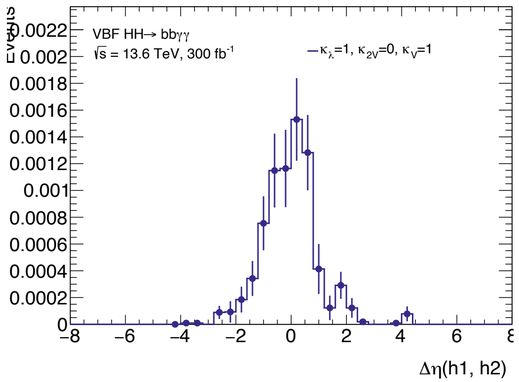


500 GeV

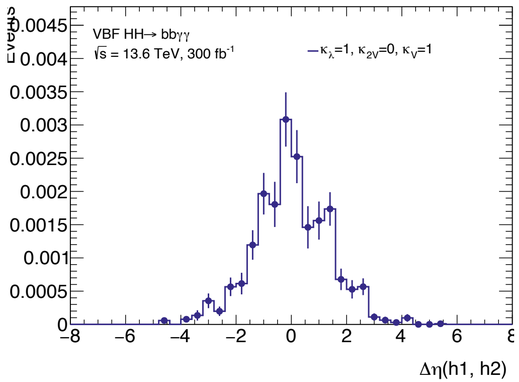


m_{HH}

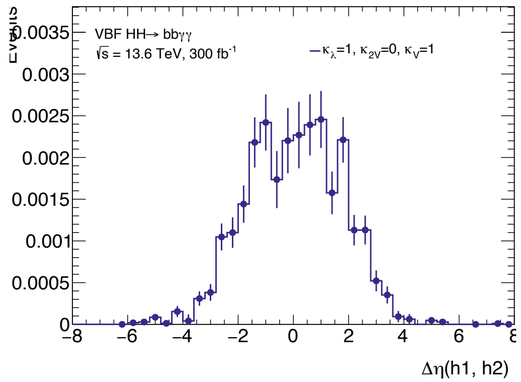
0 - 280 GeV



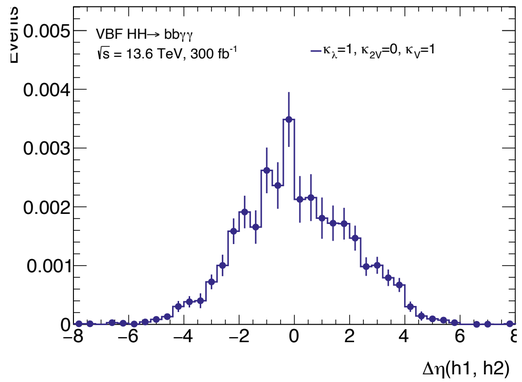
280 - 325 GeV



375-425 GeV



475 - 550 GeV

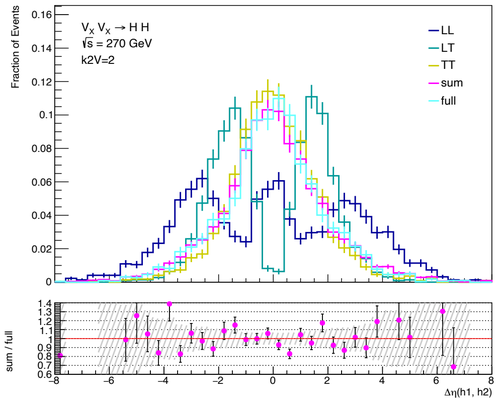


- Distributions of LL and TT very similar
- Comparison to Run 3 VBF $HH \to bb\gamma\gamma$ distribution in slices of m_{HH}
  - The shapes of the distributions follow a similar trend as the shapes of the distributions of the full sample

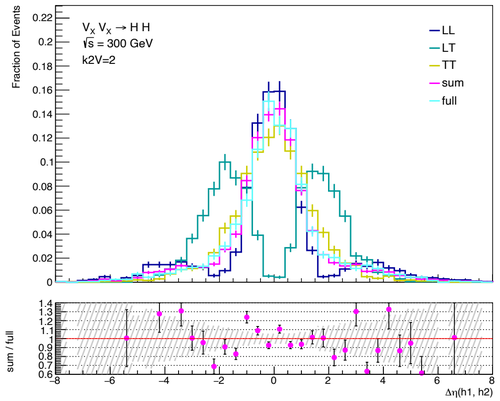
Distributions for $\kappa_{2V} = 2$

Center of mass energy

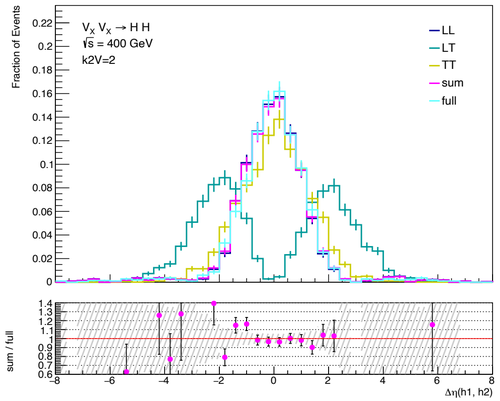
270 GeV



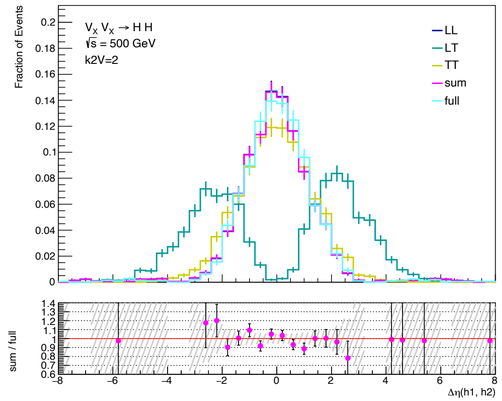
300 GeV



400 GeV

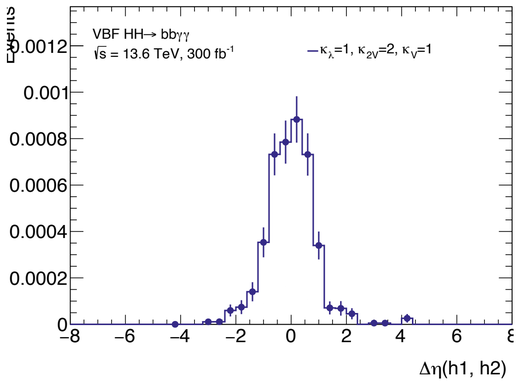


500 GeV

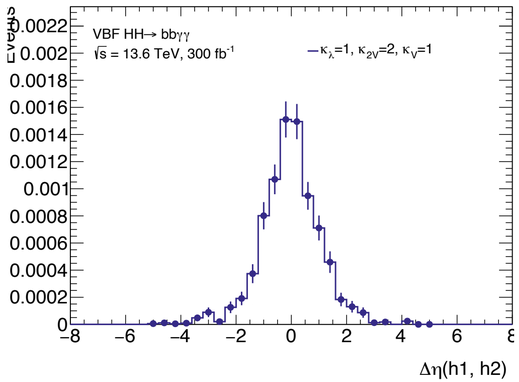


m_{HH}

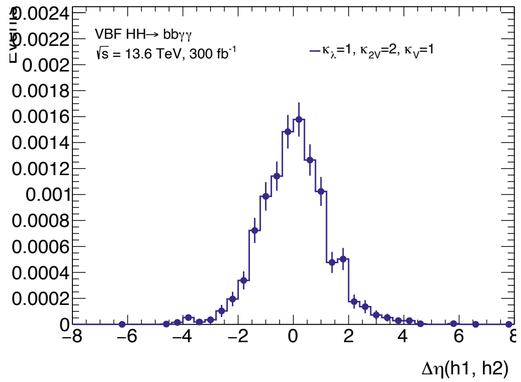
0 - 280 GeV



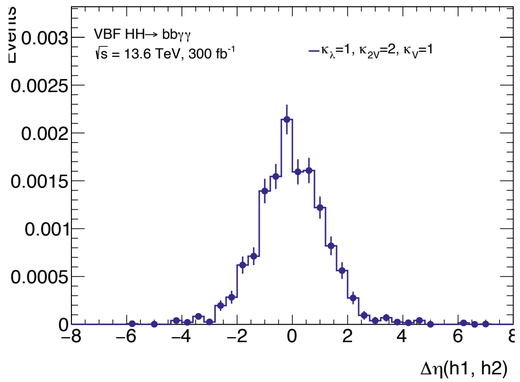
280 - 325 GeV



375-425 GeV



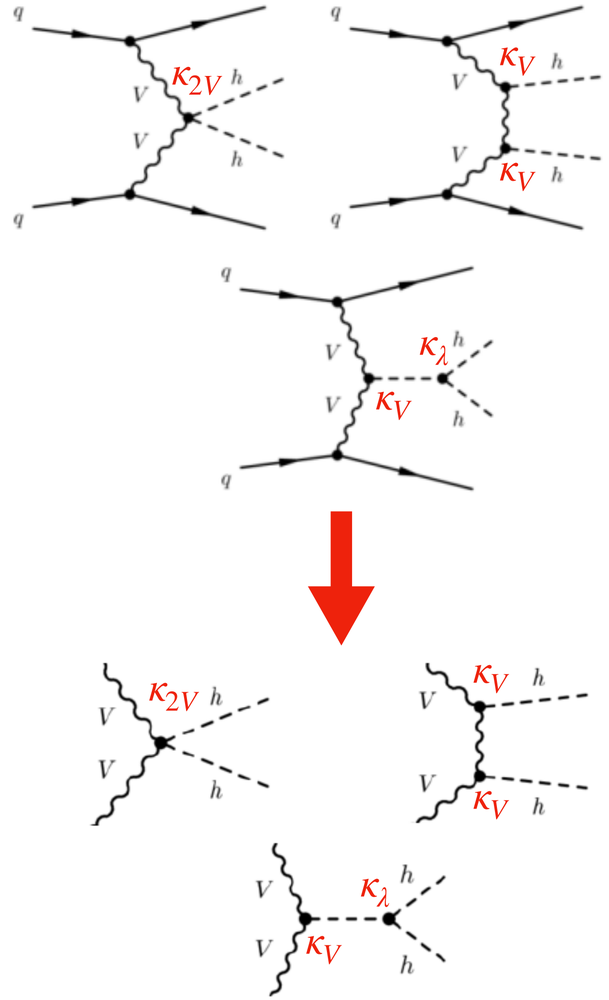
475 - 550 GeV



- Distributions of LL and TT very similar
- Comparison to Run 3 VBF $HH \to bb\gamma\gamma$ distribution in slices of m_{HH}
  - The shapes of the distributions follow a similar trend as the shapes of the distributions of the full sample

Polarization in VBF di-Higgs

- **Simulated 4 samples for each coupling value**
  - LL: both bosons are longitudinal polarized
  - LT: one boson is longitudinal and one transversal polarized
  - TT: both bosons are transversal polarized
  - Full: unpolarized process



Closure test of the Cross Sections

SM

Center of mass energy [GeV]	LL/9	LT/2.25	TT/2.25	Sum	Full	Ratio sum/full
270	6.00	0.00062	0.05	6.05	6.091	0.9938
300	7.65	0.0020	0.13	7.78	7.844	0.9924
350	8.87	0.0028	0.23	9.10	9.21	0.9880
400	9.67	0.0025	0.26	9.93	10.06	0.9872
450	10.28	0.0021	0.25	10.54	10.68	0.9868
500	10.76	0.0017	0.24	11.00	11.14	0.9877
550	11.17	0.0013	0.22	11.38	11.54	0.9865
600	11.48	0.0010	0.20	11.67	11.82	0.9877
1000	12.72	0.00023	0.089	12.811	13.06	0.9810
5000	13.71	0.00000087	0.0041	13.71	13.78	0.9953
10000	13.77	0.000000069	0.0010	13.77	13.8	0.9977
50000	10.43	0.00000000016	0.000041	10.43	13.85	0.75230
100000	10.41	0.000000000012	0.000010	10.41	6.224	1.6729

Closure test of the Cross Sections

$$\kappa_\lambda = 0$$

Center of mass energy [GeV]	LL/9	LT/2.25	TT/2.25	Sum	Full	Ratio sum/full
270	18.79	0.0012	0.50	19.29	19.14	1.0078
300	22.19	0.0041	0.44	22.63	22.48	1.0069
350	22.29	0.0056	0.37	22.67	22.53	1.0060
400	21.29	0.0050	0.33	21.62	21.61	1.0006
450	20.33	0.0041	0.29	20.63	20.58	1.0024
500	19.5	0.0033	0.26	19.76	19.71	1.0027
550	18.81	0.0026	0.23	19.04	19	1.0023
600	18.23	0.0021	0.20	18.44	18.4	1.0021
1000	15.92	0.00045	0.090	16.01	15.83	1.0115
5000	14.02	0.0000017	0.0041	14.03	14.09	0.9955
10000	13.82	0.00000014	0.0010	13.82	14.03	0.9853
50000	12.68	0.00000000033	0.000042	12.68	13.92	0.9108
100000	6.22	0.000000000023	0.000010	6.22	10.66	0.5839

Closure test of the Cross Sections

$$\kappa_\lambda = 6$$

Center of mass energy [GeV]	LL/9	LT/2.25	TT/2.25	Sum	Full	Ratio sum/full
270	49.53	0.0012	12.04	61.57	61.5	1.0012
300	53.84	0.0041	7.96	61.80	61.82	0.9997
350	45.39	0.0056	3.46	48.85	48.9	0.9991
400	36.51	0.0051	1.68	38.20	38.27	0.9981
450	29.82	0.0041	0.94	30.76	30.84	0.9975
500	25	0.0033	0.59	25.59	25.6	0.9997
550	21.52	0.0026	0.41	21.93	21.95	0.9993
600	19.03	0.0021	0.31	19.34	19.37	0.9986
1000	12.24	0.00045	0.093	12.34	12.87	0.9587
5000	13.3	0.0000017	0.0041	13.30	13.37	0.9951
10000	13.7	0.00000014	0.0010	13.70	13.72	0.9986
50000	10.39	0.00000000033	0.000041	10.39	13.83	0.7515
100000	10.43	0.000000000023	0.000010	10.43	6.22	1.6776

Closure test of the Cross Sections

$$\kappa_{2V} = 0$$

Center of mass energy [GeV]	LL/9	LT/2.25	TT/2.25	Sum	Full	Ratio sum/full
270	22.28	0.00062	0.72	23.00	23.25	0.9893
300	34.1	0.0020	0.91	35.01	35.34	0.9908
350	49.1	0.0028	0.95	50.05	50.31	0.9948
400	63.13	0.0025	0.86	64.00	64.2	0.9969
450	77.34	0.0021	0.78	78.10	78.45	0.9956
500	92.19	0.0017	0.65	92.84	92.93	0.9991
550	107.64	0.0013	0.57	108.21	108.4	0.9983
600	124	0.0010	0.49	124.49	124.6	0.9992
1000	289.44	0.00023	0.20	289.64	289.5	1.0005
5000	5955.55	0.00000087	0.0082	5955.56	5950	1.0009
10000	23622.22	0.000000069	0.0021	23622.22	2.354E+04	1.0035
50000	587000	0.00000000016	0.000083	587000.00	5.87E+05	1.0000
100000	2342222.22	0.000000000012	0.000021	2342222.22	2.342E+06	1.0001

Closure test of the Cross Sections

$$\kappa_{2V} = 2$$

Center of mass energy [GeV]	LL/9	LT/2.25	TT/2.25	Sum	Full	Ratio sum/full
270	0.18	0.00062	0.79	0.98	0.98	0.9973
300	0.95	0.0020	0.93	1.88	1.87	1.0016
350	4.31	0.0028	0.88	5.20	5.16	1.0073
400	9.63	0.0025	0.78	10.42	10.39	1.0029
450	16.6	0.0021	0.68	17.28	17.24	1.0025
500	25.08	0.0017	0.59	25.67	25.64	1.0011
550	35.02	0.0013	0.51	35.54	35.47	1.0018
600	46.3	0.0010	0.45	46.75	46.68	1.0015
1000	183.33	0.00023	0.18	183.52	182.8	1.0039
5000	5762.22	0.00000087	0.0082	5762.23	5758	1.0007
10000	23311.11	0.000000069	0.0021	23311.11	2.331e+04	1.0000
50000	585222.22	0.00000000016	0.000083	585222.22	5.852e+05	1.0000
100000	2342222.22	0.000000000012	0.000021	2342222.22	2.342e+06	1.0001