# NNLO+PS ACCURACY USING THE MINNLOPS METHOD

### Silvia Zanoli Max-Planck-Institut für Physik

Young Scientist Workshop - Castle Ringberg, 13-05-2022





## **Precision Physics: why?**

- **O** The SM is a beautiful theory... but it's **not complete**! **O** It has been thoroughly tested at the Large Hadron Collider, but no new physics signal has been observed so far.
- **O** Precise predictions are needed for detecting small deviations from the SM.
- Theory needs to match at least the experimental precision. 0

Precise predictions are mandatory!







### The Scandard Model

] = + iFBY + h.c K: Jii







## **Precision Physics: why?**

рр	$\sigma = 96.07 \pm 0.18 \pm 0.91 \text{ mb (data)}$ COMPETE HPR1R2 (theory) $\sigma = 95.35 \pm 0.38 \pm 1.3 \text{ mb (data)}$	ATLAS Proliminary		·
	COMPETE HPR1R2 (theory) $\sigma = 190.1 \pm 0.2 \pm 6.4$ nb (data)	AILAS Freinniary	- Y	
14/	DYNNLO + CT14NNLO (theory) $\sigma = 112.69 \pm 3.1$ nb (data)			
VV	DYNNLO + CT14NNLO (theory) $\sigma = 98.71 \pm 0.028 \pm 2.191$ nb (data)	$\sqrt{s} = 7.8.13$ TeV		
	$D' = 90.71 \pm 0.02 \pm 2.191$ Hb (data) DYNNLO + CT14NNLO (theory)	<b>v</b> = 1, <b>e</b> , 1 <b>e</b> 1 <b>e</b> 1	Q	
	$\sigma = 58.43 \pm 0.03 \pm 1.66$ hb (data) DYNNLO+CT14 NNLO (theory)		<b>P</b>	
Ζ	$\sigma = 34.24 \pm 0.03 \pm 0.92$ nb (data) DYNNLO+CT14 NNLO (theory)		<b>A</b>	
	$\sigma = 29.53 \pm 0.03 \pm 0.77$ nb (data) DYNNI O+CT14 NNI O (theory)		ö	
	$\sigma = 826.4 \pm 3.6 \pm 19.6 \text{ pb} (\text{data})$	Ċ.		
++	$\sigma = 242.9 \pm 1.7 \pm 8.6 \text{ (filed)}$	Δ Τ		
ιι	$\sigma = 182.9 \pm 3.1 \pm 6.4 \text{ pb (data)}$	<u>م</u>		
	top++ NNLO+NNLL (theory) $\sigma = 247 \pm 6 \pm 46 \text{ pb} (\text{data})$	Y		
<b>L</b>	NLO+NLL (theory) $\sigma = 89.6 \pm 1.7 \pm 7.2 \pm 6.4$ pb (data)	, P		
<sup>L</sup> t–chan	NLO+NLL (theory)	<b>A</b>		
	$O = 00 \pm 2 \pm 0$ pb (data) NLO+NLL (theory)	Q		
	$\sigma = 94 \pm 10 \pm 28 - 23 \text{ pb} (\text{data})$ NLO+NNLL (theory)	. 🖻		
Wt	$\sigma = 23 \pm 1.3 \pm 3.4 - 3.7$ pb (data) NLO+NLL (theory)	4		
	$\sigma = 16.8 \pm 2.9 \pm 3.9$ pb (data) NLO+NLL (theory)	0		
	$\sigma = 55.4 \pm 3.1 \pm 3 \text{ pb (data)}$ LHC-HXSWG YB4 (theory)	Ċ Ċ		
н	$\sigma = 27.7 \pm 3 + 2.3 - 1.9 \text{ pb (data)}$	<u>ل</u> م '		
••	$\sigma = 22.1 + 6.7 - 5.3 + 3.3 - 2.7 \text{ pb (data)}$	6		
	$\sigma = 130.04 \pm 1.7 \pm 10.6 \text{ pb (data)}$		Theory	_
\\/\\/	$\sigma = 68.2 \pm 1.2 \pm 4.6$ pb (data)	× ۲		
~~~~	NNLO (theory) $\sigma = 51.9 \pm 2 \pm 4.4$ pb (data)		$1 \text{HC}$ nn $\sqrt{s} = 13 \text{TeV}$	
	NNLO (theory) $\sigma = 51 \pm 0.8 \pm 2.3$ pb (data)	9		
\ A / 7	MATRIX (NNLO) (theory) $\sigma = 24.3 \pm 0.6 \pm 0.9$ pb (data)	ĻĻ	Data	
VVZ	MATRIX (NNLO) (theory)	<b>A</b>	stat	
	$\frac{\sigma}{MATRIX} (NNLO) (theory)$		stat ⊕ syst	
	$\sigma = 17.3 \pm 0.0 \pm 0.8$ pb (data) Matrix (NNLO) & Sherpa (NLO) (theory)	, <b>p</b>	$I HC nn \sqrt{s} = 8 TeV$	
ZZ	$\sigma = 7.3 \pm 0.4 + 0.4 - 0.3$ pb (data) NNLO (theory)	4		
	$\sigma = 6.7 \pm 0.7 + 0.5 - 0.4$ pb (data) NNLO (theory)	0	Data	
t <sub>s-chan</sub>	$\sigma = 4.8 \pm 0.8 \pm 1.6 - 1.3 \text{ pb} (\text{data})$		stat	
	$\sigma = 870 \pm 130 \pm 140 \text{ fb} \text{ (data)}$		$stat \oplus syst$	
ttW	$\sigma = \frac{369 + 86 - 79 \pm 44}{MCEM}$ (theory)		LHC pp $\sqrt{s} = 7$ TeV	
_	$\sigma = 990 \pm 50 \pm 80 \text{ fb} (data)$	- h		
ttΖ	$\sigma = 176 + 52 - 48 \pm 24 \text{ fb (data)}$	<b>M</b>	• Data	
\\/\///	$\sigma = 0.848 \pm 0.098 \pm 0.081$ pb (data)		Stat ⊕ svet	_
	The formula of the orginal of the o		Siai ⊕ Sysi	
	Sherpa 2.2.2 (theory) $\sigma = 24 \pm 4 \pm 5 \text{ fb (data)}$			-
τττ	NLO QCD + EW (theory)	<u>ul , , , , , , , , , , , , , , , , , , ,</u>		
-		-1 1 1 1 1 1 2 1 2 2 1 2 2		
1	$10^{-5}$ $10^{-4}$ $10^{-5}$ $10^{-2}$ $10^{-2}$	$J^{-1}$ I $10^{1}$ $10^{2}$ $10^{3}$	$10^{-1}$ $10^{-1}$ $10^{-1}$	0.5
			r [nh]	da
				ua

Young Scientist Workshop 2022

#### Silvia Zanoli

















Silvia Zanoli



Young Scientist Workshop 2022





Silvia Zanoli



Young Scientist Workshop 2022





Silvia Zanoli

#### Young Scientist Workshop 2022



### Parton Shower (PS)

Description of soft and collinear emissions from the high-energy limit down to the QCD cutoff. Accuracy is low, usually only LL.









Silvia Zanoli

#### Young Scientist Workshop 2022

1000000000000



### Hadronization + decay

Tuned to phenomenological models.

### Parton Shower (PS)

Description of soft and collinear emissions from the high-energy limit down to the QCD cutoff. Accuracy is low, usually only LL.









### NNLO+PS



Young Scientist Workshop 2022

Silvia Zanoli





### **Combination:** NNLO+PS





## **Minnlo**<sub>PS</sub>

- No computationally intense reweighting. Ο
- No unphysical merging scale. Ο
- O LL accuracy of the shower preserved (MiNNLO<sub>PS</sub> is based on the POWHEG framework).
- Numerically efficient. Ο

Master Formula ( $\overline{B}$  function in POWHEG):

$$\frac{d\sigma}{d\Phi_F dp_T} = \frac{d}{dp_T} \left\{ e^{-\tilde{S}(p_T)} \mathscr{L}(p_T) \right\} + R_f(p_T) = e^{-\tilde{S}(p_T)} \left[ D(p_T) + \frac{R_f(p_T)}{e^{-\tilde{S}(p_T)}} \right] = \dots = \\ = e^{-\tilde{S}(p_T)} \left\{ \frac{\alpha_s(p_T)}{2\pi} \left[ \frac{d\sigma_{FJ}}{d\Phi_{FJ} dp_T} \right]^{(1)} \left( 1 + \frac{\alpha_s(p_T)}{2\pi} [\tilde{S}]^{(1)} \right) + \left( \frac{\alpha_s(p_T)}{2\pi} \right)^2 \left[ \frac{d\sigma_{FJ}}{d\Phi_{FJ} dp_T} \right]^{(2)} + \left( \frac{\alpha_s(p_T)}{2\pi} \right)^3 [D(p_T)]^{(3)} + regularized$$

#### Silvia Zanoli



	F	F+J	F+JJ
F@MiNNLO <sub>PS</sub>	NNLO	NLO	LO

[Monni, Nason, Re, Wiesemann, Zanderighi '19]

Young Scientist Workshop 2022









## Higgstrahlung with H→bb decay

- **O** One of the main production channels.
- **Chargest branching fraction** in decay ( $\approx$ 60%).
- Needed for precision measurements in the Higgs sector.
- **O** Separate study of production and decay.

### **NNLO+PS** accuracy in both production and decay

Silvia Zanoli

Young Scientist Workshop 2022









### Generation of events

### **PRODUCTION:**

<event></event>							
9	10001	1.61798	8E-01	1.56	623E+0	00 -1.00000E+00 4.03689E-01	
-1	-1	0	Θ	Θ	511	0.00000000E+00 0.00000000E+00 7.655294950E+01	
2	-1	0	Θ	501	Θ	0.00000000E+00 0.00000000E+00 -1.149726029E+03	
24	2	1	2	Θ	Θ	5.211805348E-01 7.118662673E-01 -9.897030656E+02	
24	2	3	3	Θ	Θ	7.098090236E+01 -1.423395610E+02 -8.031126759E+02	
25	1	3	3	Θ	Θ	-7.045972182E+01 1.430514272E+02 -1.865903897E+02	
-11	1	4	4	Θ	Θ	6.342590728E+01 -4.142757742E+01 -3.399963187E+02	
12	1	4	4	Θ	Θ	7.554995079E+00 -1.009119835E+02 -4.631163572E+02	
21	1	1	2	501	502	-1.890605848E+00 4.823555713E-02 -1.059077847E+02	
21	1	1	2	502	511	1.369425313E+00 -7.601018244E-01 2.243777045E+01	

### **DECAY:**

<event>

7	10001	4.49807	7E-03	1.069	)34E+0	01 -1.00000E+00	1.92716E-01
12	-1	Θ	Θ	Θ	0	0.00000000E+00	0.000000000E
-12	-1	Θ	Θ	Θ	0	0.00000000E+00	0.000000000E
25	2	1	2	Θ	0	0.00000000E+00	0.000000000E
5	1	3	3	502	0	-3.482558088E+01	-3.087472611E
-5	1	3	3	Θ	511	2.523902727E+01	4.214457839E
21	1	3	3	501	502	-1.784543959E+00	-1.199533279E
21	1	3	3	511	501	1.137109758E+01	7.254805161E

#### Silvia Zanoli





7.655294950E+01 0 1.149726029E+03 0 1.097861941E+03 4 8.223773332E+02 7 2.754846082E+02 1 3.483340159E+02 5 4.740433173E+02 5 1.059246694E+02 2.249236811E+01

.000000000E+00
.000000000E+00
.751714489E+02
.756074276E+01
.250900180E+02
.110000000E-04
.394796609E-06

- 5.046370146E-06
- 8.920806376E-07

0.00000E+00	9.000
0.00000E+00	9.000

0.00000E+00 9.000



0.00000E+00 9.000E 0.00000E+00 9.000E 0.00000E+00 9.000E 0.00000E+00 9.000E 0.00000E+00 9.000E 0.00000E+00 9.000E+

- 6.254500000E+01 +00 +00 -6.254500000E+01 0.00000000E+00 +00 1.355053755E+01 +01
- +01 -1.662090492E+01 5.207952443E+01 4.780000000E+00
- +01 4.241201676E+00 1.284758334E+01 2.308477966E-07
- -01 -1.170834306E+00 1.145421473E+01 1.255594160E-07 0.00000E+00 9.000E+00

- 6.254500000E+01
- 6.254500000E+01
- 1.250900000E+02
- 4.870867750E+01

- 0.00000000E+00
- 0.00000000E+00
- 1.250900000E+02
- 4.78000000E+00



E٠	t	0	0
E٠	t	0	0
E٠	t	0	0
E٠	t	0	0
E٠	t	0	0
E٠	t	0	0
E٠	t	0	0

F	+	Θ	Θ
-		~	~

F+	Θ	Θ
L .	~	v



+	0	0
+	0	0
+	0	0
+	0	0
+	0	0
+	0	0
+	0	0



## Higgstrahlung with H→bb decay

### **PRODUCTION:**

<ever< th=""><th>ıt&gt;</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>1</th><th></th><th></th></ever<>	ıt>										1		
	9	10001	1.617988	E-01	1.566	623E+0	00 -1.00000E+00	4.03689E-01					
	-1	-1	0	Θ	Θ	511	0.00000000E+00	0.00000000E+00	7.655294950E+01	7.655294950E+01	0.00000000E+00	0.00000E+00	9.000
	2	-1	0	Θ	501	Θ	0.00000000E+00	0.00000000E+00	-1.149726029E+03	1.149726029E+03	0.00000000E+00	0.00000E+00	9.000
	24	2	1	2	Θ	Θ	5.211805348E-01	7.118662673E-01	-9.897030656E+02	1.097861941E+03	4.751714489E+02	0.00000E+00	9.000
	24	2	3	3	Θ	Θ	7.098090236E+01	-1.423395610E+02	-8.031126759E+02	8.223773332E+02	7.756074276E+01	0.00000E+00	9.000
H1997	25	1	3	3	Θ	Θ	-7.045972182E+01	1.430514272E+02	-1.865903897E+02	2.754846082E+02	1.250900180E+02	0.00000E+00	9.000
	-11	1	4	4	Θ	Θ	6.342590728E+01	-4.142757742E+01	-3.399963187E+02	3.483340159E+02	5.110000000E-04	0.00000E+00	9.000
	12	1	4	4	Θ	Θ	7.554995079E+00	-1.009119835E+02	-4.631163572E+02	4.740433173E+02	5.394796609E-06	0.00000E+00	9.000
	21	1	1	2	501	502	-1.890605848E+00	4.823555713E-02	-1.059077847E+02	1.059246694E+02	5.046370146E-06	0.00000E+00	9.000
	21	1	1	2	502	511	1.369425313E+00	-7.601018244E-01	2.243777045E+01	2.249236811E+01	8.920806376E-07	0.00000E+00	9.000

### **DECAY:**

<eve< th=""><th>ent&gt;</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>0</th></eve<>	ent>												0
	7	10001	4.4980	7E-03	1.069	934E+0	01 -1.00000E+00	1.92716E-01					
	12	-1	Θ	Θ	Θ	Θ	0.00000000E+00	0.00000000E+00	6.254500000E+01	6.254500000E+01	0.00000000E+00	0.00000E+00	9.000
	-12	-1	Θ	Θ	Θ	0	0.00000000E+00	0.00000000E+00	-6.254500000E+01	6.254500000E+01	0.00000000E+00	0.00000E+00	9.000
<b>x</b>	25	2	1	2	Θ	Θ	0.00000000E+00	0.00000000E+00	0.00000000E+00	1.250900000E+02	1.250900000E+02	0.00000E+00	9.000
11:99 <sup>5</sup>	5	1	3	3	502	Θ	-3.482558088E+01	L -3.087472611E+01	1.355053755E+01	4.870867750E+01	4.78000000E+00	0.00000E+00	9.000
nus-ra'	-5	1	3	3	Θ	511	2.523902727E+01	4.214457839E+01	-1.662090492E+01	5.207952443E+01	4.78000000E+00	0.00000E+00	9.000
Dee	123	1	3	3	501	502	-1.784543959E+00	) -1.199533279E+01	4.241201676E+00	1.284758334E+01	2.308477966E-07	0.00000E+00	9.000
Produ	21	1	3	3	511	501	1.137109758E+01	7.254805161E-01	-1.170834306E+00	1.145421473E+01	1.255594160E-07	0.00000E+00	9.000

#### Silvia Zanoli

#### Young Scientist Workshop 2022

















## Higgstrahlung with H→bb decay

#### **FULL EVENT:**

	<event></event>												
	13	10001	1.49468	E-01	1.56	623E+0	0 -1.00000E+00 4	4.03689E-01					
	-1	-1	Θ	Θ	Θ	511	0.00000000E+00	0.00000000E+00	7.655294950E+01	7.655294950E+01	0.00000000E+00	0.00000E+00	9.000E+00
	2	-1	Θ	Θ	501	Θ	0.00000000E+00	0.00000000E+00	-1.149726029E+03	1.149726029E+03	0.00000000E+00	0.00000E+00	9.000E+00
	24	2	1	2	Θ	Θ	5.211805348E-01	7.118662673E-01	-9.897030656E+02	1.097861941E+03	4.751714489E+02	0.00000E+00	9.000E+00
	24	2	3	3	Θ	Θ	7.098090236E+01	-1.423395610E+02	-8.031126759E+02	8.223773332E+02	7.756074276E+01	0.00000E+00	9.000E+00
1:09 <sup>5</sup>	25	2	3	3	Θ	Θ	-7.045972182E+01	1.430514272E+02	-1.865903897E+02	2.754846082E+02	1.250900180E+02	0.00000E+00	9.000E+00
HUSS	-11	1	4	4	Θ	0	6.342590728E+01	-4.142757742E+01	-3.399963187E+02	3.483340159E+02	5.110000000E-04	0.00000E+00	9.000E+00
	12	1	4	4	Θ	0	7.554995079E+00	-1.009119835E+02	-4.631163572E+02	4.740433173E+02	5.394796609E-06	0.00000E+00	9.000E+00
	21	1	1	2	501	502	-1.890605848E+00	4.823555713E-02	-1.059077847E+02	1.059246694E+02	5.046370146E-06	0.00000E+00	9.000E+00
	21	1	1	2	502	511	1.369425313E+00	-7.601018244E-01	2.243777045E+01	2.249236811E+01	8.920806376E-07	0.00000E+00	9.000E+00
ay	5	1	5	5	702	Θ	-7.654277374E+01	9.828619533E+01	-1.413293817E+02	1.884564006E+02	4.78000000E+00	0.00000E+00	9.000E+00
" Dec	-5	1	5	5	Θ	711	1.308120069E+01	4.864606448E+00	8.538335619E+00	1.704505155E+01	4.78000000E+00	0.00000E+00	9.000E+00
n Juch	21	1	5	5	701	702	-1.334729692E+01	2.944741792E+01	-4.185354346E+01	5.288685902E+01	0.00000000E+00	0.00000E+00	9.000E+00
910am	21	1	5	5	711	701	6.349148171E+00	1.045320749E+01	-1.194580015E+01	1.709629699E+01	0.00000000E+00	0.00000E+00	9.000E+00
X T	#rwgt		1		1 :	5.3448	772136252189E-002	2 1	156	0 1	Θ		

Silvia Zanoli

#### Young Scientist Workshop 2022







#### We can now interface the full event with the shower and obtain a realistic result!







### **Results: cross sections**

[2112.04168]	$pp  ightarrow W^+H  ightarrow e^+  u_e b ar{b}$				
	$\sigma$ [fb]	inclusive	fiducial-YR		
	MiNLO'	$54.04^{+6.6\%}_{-3.6\%}$	$20.13^{+2.3\%}_{-3.1\%}$		
	$MiNNLO_{PS}$	$57.44^{+1.7\%}_{-0.8\%}$	$21.27^{+1.3\%}_{-1.3\%}$		
	$pp  ightarrow W^- H  ightarrow e^- ar{ u}_e b ar{b}$				
	$\sigma$ [fb]	inclusive	fiducial-YR		
	MiNLO'	$33.82^{+6.6\%}_{-3.6\%}$	$13.07^{+2.4\%}_{-3.3\%}$		
	$MiNNLO_{PS}$	$35.87^{+1.5\%}_{-0.7\%}$	$13.77^{+1.5\%}_{-1.6\%}$		
	$pp  ightarrow ZH  ightarrow e^+e^-bar{b}$				
	$\sigma$ [fb]	inclusive	fiducial-YR		
	MiNLO'	$14.88^{+6.7\%}_{-3.7\%}$	$5.21^{+2.2\%}_{-3.0\%}$		
	$MiNNLO_{PS} (no \ gg \rightarrow ZH)$	$15.79^{+1.8\%}_{-0.9\%}$	$5.48^{+1.2\%}_{-1.2\%}$		
[Yellow Report (YR) 1610.07922]	MiNNLO <sub>PS</sub> (with $gg \to ZH$ )	$16.99^{+3.6\%}_{-2.3\%}$	$6.07^{+3.4\%}_{-2.9\%}$		

Silvia Zanoli

#### Young Scientist Workshop 2022





### **Results: cross sections**

$pp  ightarrow W^+ H$	$ ightarrow e^+  u_e b \overline{b}$	
$\sigma$ [fb]	inclusive	fiducial-YR
MiNLO'	$54.04^{+6.6\%}_{-3.6\%}$	$20.13^{+2.3\%}_{-3.1\%}$
$MiNNLO_{PS}$	$57.44^{+1.7\%}_{-0.8\%}$	$21.27^{+1.3\%}_{-1.3\%}$
$pp  ightarrow W^- H$	$ ightarrow e^- ar{ u}_e b ar{b}$	
$\sigma$ [fb]	inclusive	fiducial-YR
MiNLO'	$33.82^{+6.6\%}_{-3.6\%}$	$13.07^{+2.4\%}_{-3.3\%}$
$MiNNLO_{PS}$	$35.87^{+1.5\%}_{-0.7\%}$ /	$13.77^{+1.5\%}_{-1.6\%}$
pp  ightarrow ZH –		
$\sigma$ [fb]	inclusive	fiducial-YR
MiNLO'	$14.88^{+6.7\%}_{-3.7\%}$	$5.21^{+2.2\%}_{-3.0\%}$
$MiNNLO_{PS} (no \ gg \rightarrow ZH)$	$15.79^{+1.8\%}_{-0.9\%}$	$5.48^{+1.2\%}_{-1.2\%}$
MiNNLO <sub>PS</sub> (with $gg \to ZH$ )	$16.99^{+3.6\%}_{-2.3\%}$	$6.07^{+3.4\%}_{-2.9\%}$ $\leftarrow$ Included at LO only!
	$pp \rightarrow W^+H$ $\sigma \text{ [fb]}$ $MiNLO'$ $MiNNLO_{PS}$ $pp \rightarrow W^-H$ $\sigma \text{ [fb]}$ $MiNLO'$ $MiNNLO_{PS}$ $pp \rightarrow ZH -$ $\sigma \text{ [fb]}$ $MiNLO'$ $MiNNLO_{PS} (no \ gg \rightarrow ZH)$ $MiNNLO_{PS} (with \ gg \rightarrow ZH)$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

Silvia Zanoli

#### Young Scientist Workshop 2022







## Results: comparison with data



#### Silvia Zanoli





### [2112.04168]

$pp  ightarrow W^{\pm}H  ightarrow \ell^{\pm}  u_\ell b ar b$						
$\sigma$ [fb]	$p_T^W \in [250,\!400]\mathrm{GeV}$	$p_T^W \in [400,  \infty] \mathrm{GeV}$				
MINNLO <sub>PS</sub>	$6.52^{+2.4\%}_{-1.8\%}$	$1.46^{+2.5\%}_{-1.9\%}$				
ATLAS [130]	$3.3^{+3.6(\text{Stat.})+3.2(\text{Syst.})}_{-3.4(\text{Stat.})-3.0(\text{Syst.})}$	$2.1^{+1.0(\text{Stat.})+0.6(\text{Syst.})}_{-0.9(\text{Stat.})-0.5(\text{Syst.})}$				
$pp  ightarrow ZH  ightarrow (\ell^+\ell^-,  u_\ell ar u_\ell) bar b$						
$\sigma$ [fb]	$p_T^Z \in [250,\!400]\mathrm{GeV}$	$p_T^Z \in [400, \infty] \mathrm{GeV}$				
$\sigma$ [fb] MINNLO <sub>PS</sub>	$p_T^Z \in [250, 400] \text{GeV} \\ 3.98^{+7.6\%}_{-5.4\%}$	$p_T^Z \in [400, \infty] \text{GeV}$ $0.79^{+6.5\%}_{-4.2\%}$				

[ATLAS data taken from 2008.02508]









## **Results: fiducial distributions**



Silvia Zanoli







Young Scientist Workshop 2022



## WZ production

- O Interesting for testing the gauge structure of the EW sector.
- **O** Background in many BSM studies.
- O Different possibilities when matching QCD and EW corrections and QCD and QED showers.

### NNLO+PS QCD accuracy + NLO+PS EW accuracy

Silvia Zanoli

Young Scientist Workshop 2022







## Validation



**NLO** EW:





#### Silvia Zanoli

#### Young Scientist Workshop 2022











## **Results: fiducial distributions**



Silvia Zanoli

**MAX PLANCK INSTITUTE** FOR PHYSICS



Young Scientist Workshop 2022





- **O NNLO+PS** predictions are **strongly needed** for a realistic description of LHC events.
- **O** MiNNLO<sub>PS</sub> is a powerful tool for reaching this accuracy.
- **O** I showed and discussed results for Higgstrahlung with  $H \rightarrow bb$  decay, which is needed for precision measurements in the Higgs sector.
- **O** I showed and discussed results for WZ production, which is needed for testing the gauge structure of the EW sector.



Young Scientist Workshop 2022





