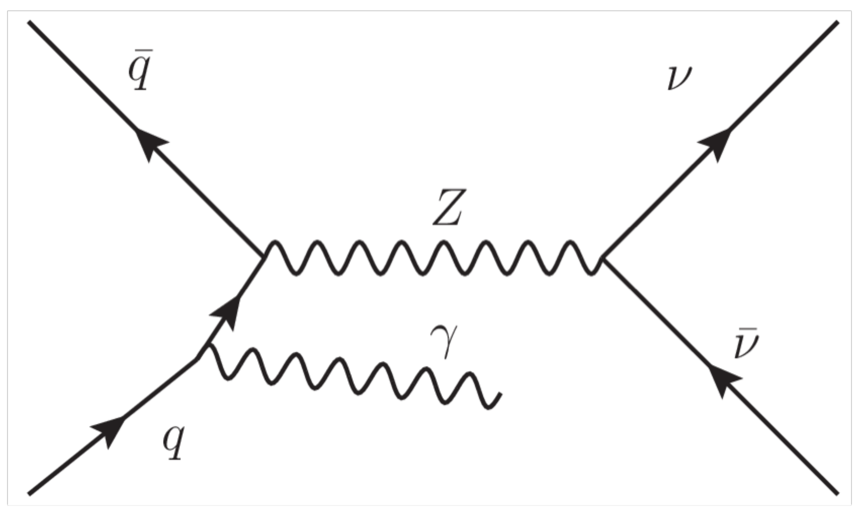
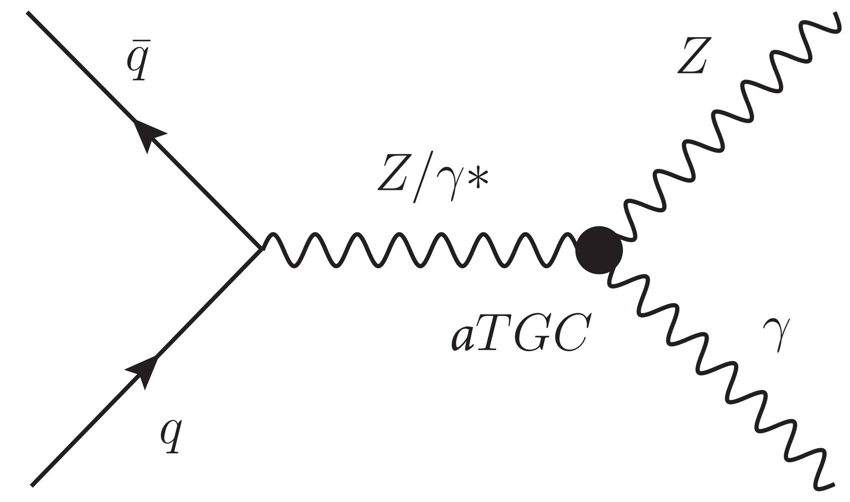
MEASUREMENT OF THE $Z\gamma \rightarrow \nu\bar{\nu}\gamma$ PRODUCTION CROSS SECTION IN *pp* COLLISIONS AT $\sqrt{s} = 13$ TeV WITH THE ATLAS DETECTOR AND LIMITS ON ANOMALOUS TRIPLE GAUGE-BOSON COUPLINGS

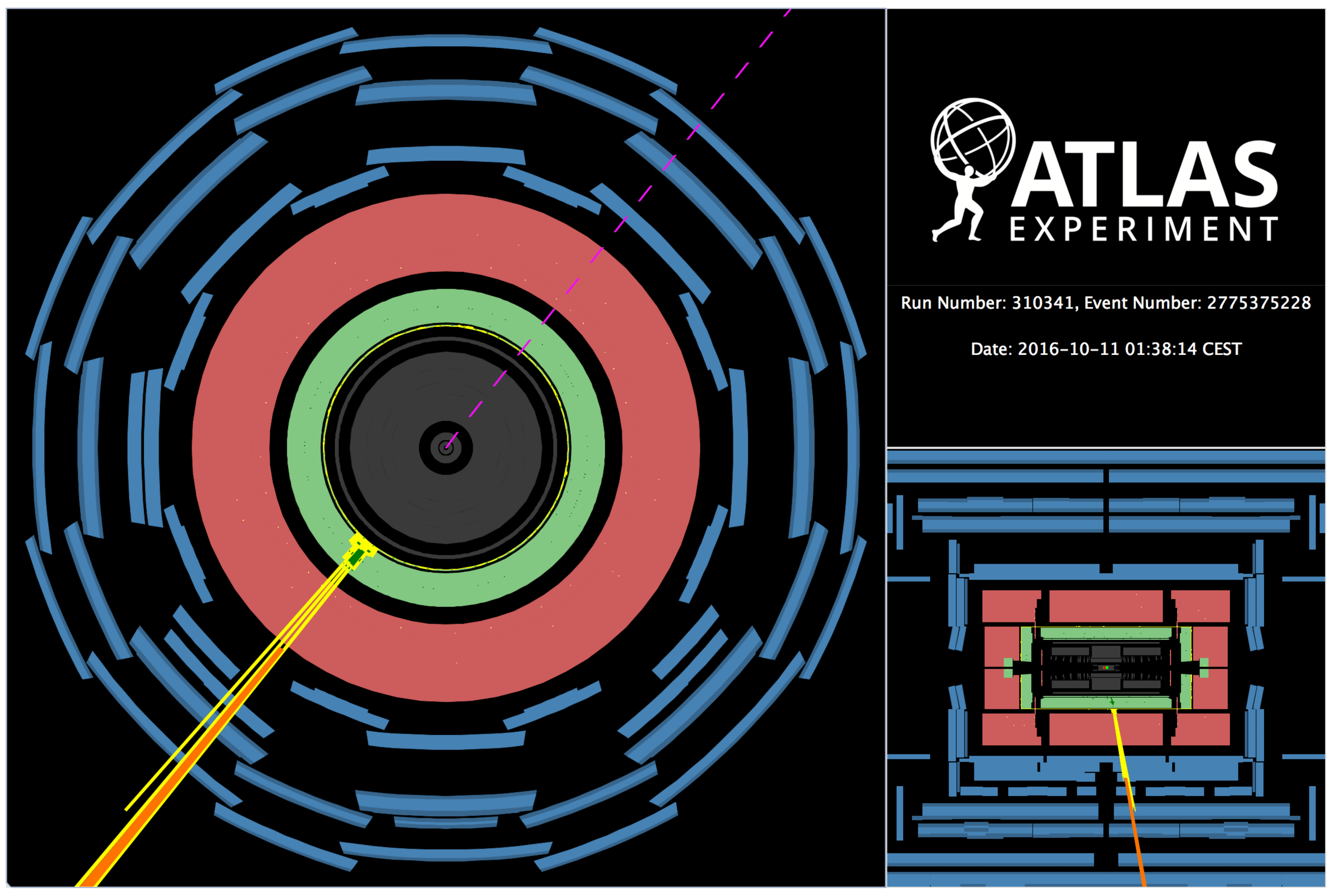
Process topology: $\gamma + p_T^{miss}(+X)$, both objects with high energy (>150 GeV)

$Z\gamma \rightarrow \nu\bar{\nu}\gamma$: initial state radiation (ISR)



$Z\gamma \rightarrow \nu\bar{\nu}\gamma$: anomalous triple gauge coupling (aTGC)





Motivation

$Z\gamma \rightarrow \nu\bar{\nu}\gamma$ process

- allows to test the highest available (NNLO QCD) corrections
- is extremely sensitive to neutral aTGC due to higher Z branching ratio to $\nu\bar{\nu}$ than to l^+l^-

Selection

Jets are reconstructed with anti-k_t algorithm. Selection is optimized in order to suppress backgrounds with the highest possible signal significance and efficiency.

Photons	Leptons	Jets
$E_T > 150$ GeV $\lvert\eta\rvert < 2.37$, excluding $1.37 < \lvert\eta\rvert < 1.52$	$p_T > 7$ GeV $\lvert\eta\rvert < 2.47(2.7)$ for $e(\mu)$, excluding $1.37 < \lvert\eta^e\rvert < 1.52$	$p_T > 50$ GeV $\lvert\eta\rvert < 4.5$ $\Delta R(\text{jet}, \gamma) > 0.3$
Event selection		
$N^{\gamma} = 1$, $N^{e,\mu} = 0$, $E_T^{miss} > 150$ GeV, E_T^{miss} signif. > 10.5 GeV$^{1/2}$, $\Delta\phi(\vec{E}_T^{miss}, \gamma) > \pi/2$ Inclusive : $N_{jet} \geq 0$, Exclusive : $N_{jet} = 0$		

Cross-section meas. phase space

Category	Requirement
Photons	$E_T^{\gamma} > 150$ GeV $\lvert\eta\rvert < 2.37$
Jets	$\lvert\eta\rvert < 4.5$ $p_T > 50$ GeV $\Delta R(\text{jet}, \gamma) > 0.3$ Inclusive : $N_{jet} \geq 0$, Exclusive : $N_{jet} = 0$
Neutrino	$p_T^{\nu\bar{\nu}} > 150$ GeV

Large Background contribution

- data-driven estimation:
  e→γ (Z-peak), jet→γ (2D-sideband), Wγ and γ+jet (simultaneous fit in CRs);
- MC simulation:
  *Z(ll)*γ.

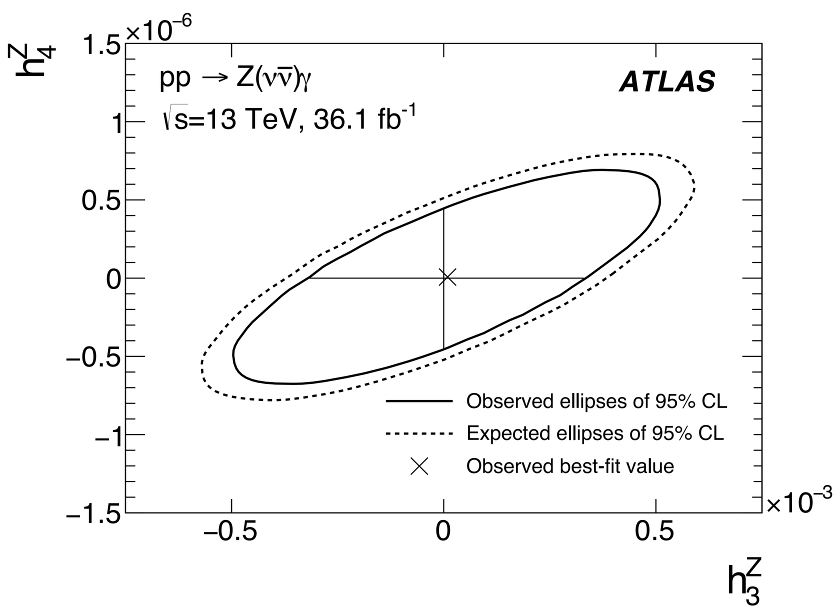
	$N_{jets} \geq 0$	$N_{jets} = 0$
$N^{W\gamma}$	650 ± 40 ± 60	360 ± 20 ± 30
$N^{\gamma+jet}$	409 ± 18 ± 108	219 ± 10 ± 58
$N^{e\rightarrow\gamma}$	320 ± 15 ± 45	254 ± 12 ± 35
$N^{jet\rightarrow\gamma}$	170 ± 30 ± 50	140 ± 20 ± 40
$N^{Z(\ell\ell)\gamma}$	40 ± 3 ± 3	26 ± 3 ± 2
N^{bkg}_{total}	1580 ± 50 ± 140	1000 ± 40 ± 90
N^{sig}(exp)	2328 ± 4 ± 135	1710 ± 4 ± 91
$N^{sig+bkg}_{total}$	3910 ± 50 ± 190	2710 ± 40 ± 130
N^{data}(obs)	3812	2599

No deviations from SM prediction was found

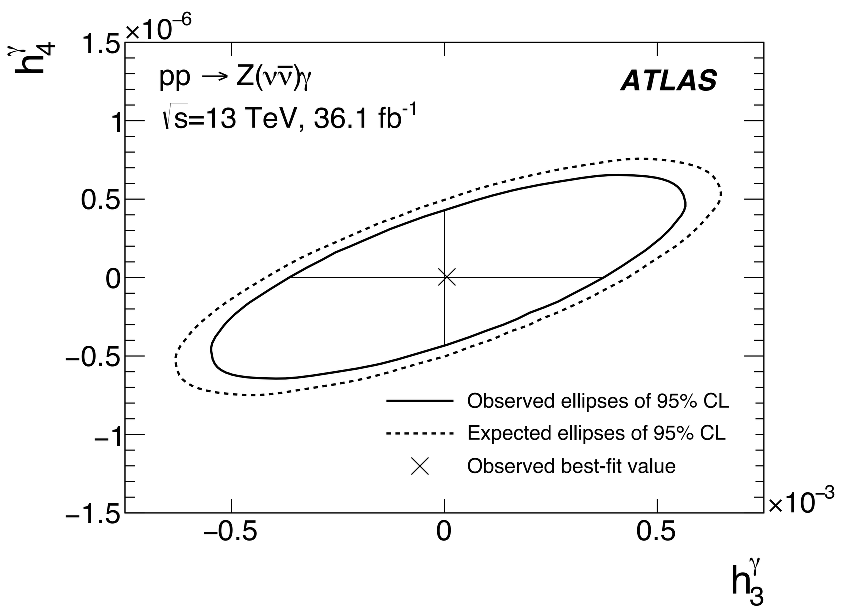
Exclusive events with $E_T^{\gamma} > 600$ GeV were used to set limits on aTGC both in vertex approach and **EFT formalism for the first time**

Feldman-Cousins frequentist two-sided confidence intervals from vertex function approach and recalculated in EFT parameters.

2D limits h^Z_4 vs h^Z_3



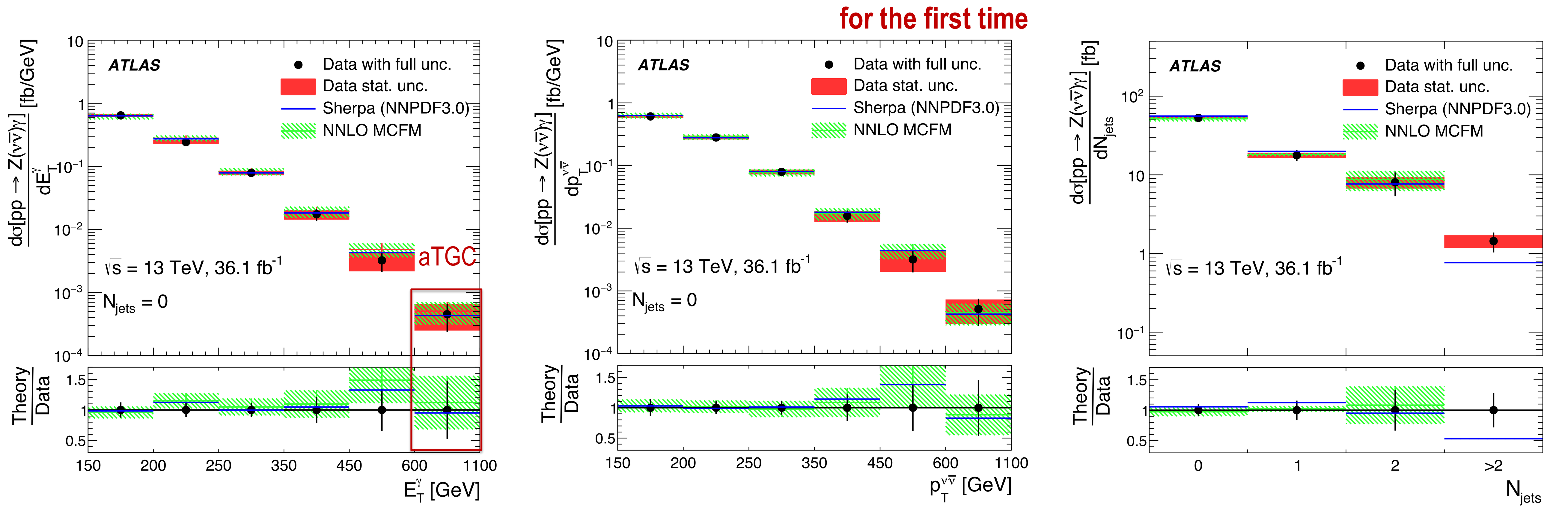
2D limits h^{γ}_4 vs h^{γ}_3



Integrated cross section (maximization of profile likelihood ratio) **is measured with precision order of 10% (30-50% in Run Ⅰ)**

$\sigma^{ext.fid.}$ [fb] Measurement	$\sigma^{ext.fid.}$ [fb] NNLO MCFM Prediction
$N_{jets} \geq 0$	
$83.7^{+3.6}_{-3.5}$ (stat.)$^{+6.9}_{-6.2}$ (syst.)$^{+1.7}_{-2.0}$ (lumi.)	78.1 ± 0.2(stat.)± 4.7(syst.)
$N_{jets} = 0$	
$52.4^{+2.4}_{-2.3}$ (stat.)$^{+4.0}_{-3.6}$ (syst.)$^{+1.2}_{-1.1}$ (lumi.)	55.9 ± 0.1(stat.)± 3.9(syst.)

Unfolded differential cross-section (via iterative Bayesian unfolding): $E_T^{\gamma}, p_T^{\nu\bar{\nu}}, N_{jets}$ **for the first time**



Vertex function approach:

Parameter	Limit 95% CL Measured	Limit 95% CL Expected
h_3^{γ}	$(-3.7 \times 10^{-4}, 3.7 \times 10^{-4})$	$(-4.2 \times 10^{-4}, 4.3 \times 10^{-4})$
h_3^{Z}	$(-3.2 \times 10^{-4}, 3.3 \times 10^{-4})$	$(-3.8 \times 10^{-4}, 3.8 \times 10^{-4})$
h_4^{γ}	$(-4.4 \times 10^{-7}, 4.3 \times 10^{-7})$	$(-5.1 \times 10^{-7}, 5.0 \times 10^{-7})$
h_4^{Z}	$(-4.5 \times 10^{-7}, 4.4 \times 10^{-7})$	$(-5.3 \times 10^{-7}, 5.1 \times 10^{-7})$

Effective field theory (EFT) approach:

Parameter	Limit 95% CL Measured [TeV^{-4}]	Limit 95% CL Expected [TeV^{-4}]
$C_{\tilde{B}W}/\Lambda^4$	$(-1.1, 1.1)$	$(-1.3, 1.3)$
C_{BW}/Λ^4	$(-0.65, 0.64)$	$(-0.74, 0.74)$
C_{WW}/Λ^4	$(-2.3, 2.3)$	$(-2.7, 2.7)$
C_{BB}/Λ^4	$(-0.24, 0.24)$	$(-0.28, 0.27)$

ATGC limits are 3-7 times stronger than previous results from Run Ⅰ.

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