Background Studies and Performance Evaluation of Tau Identification Working Points in the $\gamma\gamma + 1\tau_{had}$ Final State with ATLAS Data in the mass range 130 – 200 GeV

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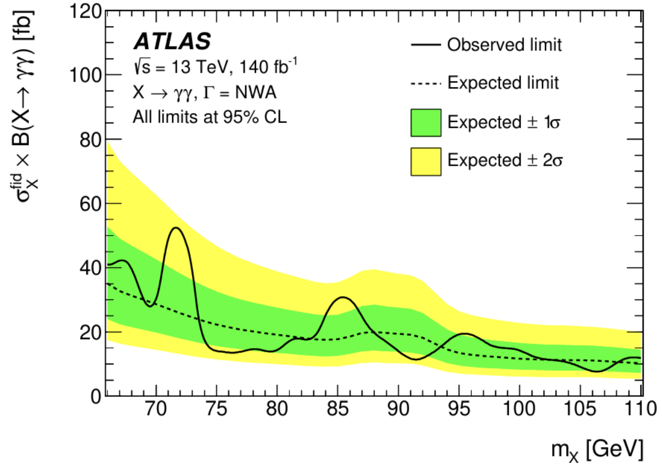
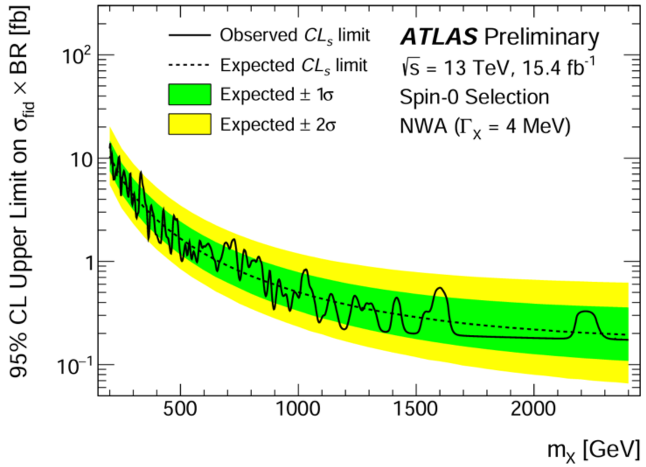
SAIP2026 — 70th South African Institute of Physics Annual Conference

Searches for Di-Photon Resonances at ATLAS and Multi-Lepton Excesses

ATLAS searches for diphoton resonances focused on the Low-mass range of 66–110 GeV, and high-mass range 200-3000 GeV regions



JHEP 01 (2025) 053



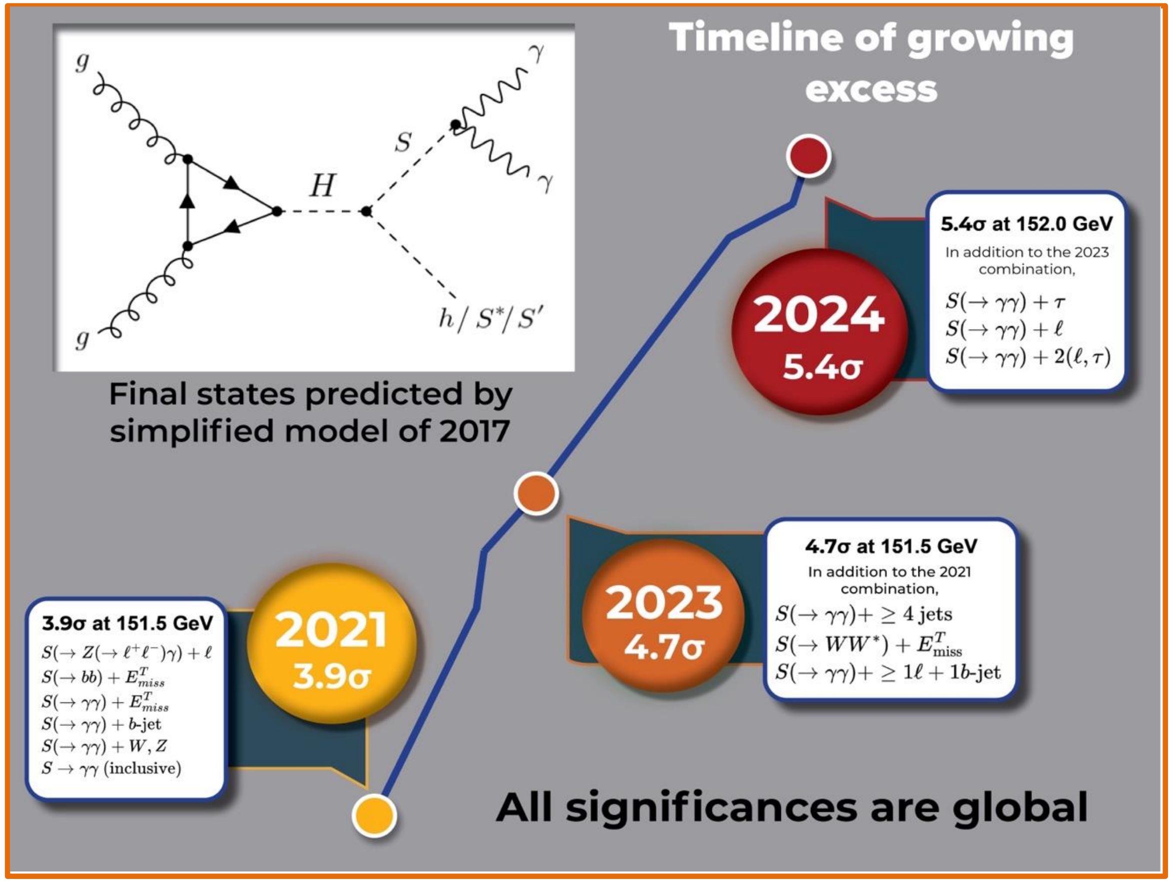
ATL-PHYS-PROC-2016-191

- **Simplified model predicts multi lepton final states which are known as multi lepton anomalies.** Eur.Phys.J.C 76 (2016) 10, 580
- **Run 1 data confirm the multi lepton anomalies.**
- **Using Run 1 data particularly observing the dilepton component of the excesses with an assumption $S(W^+W^-) \to \ell^+\ell^-\nu\nu$, the mass of S is determined to be 150 ± 5 GeV.**

J.Phys.G 45 (2018) 11, 115003

- **Using Run 2 data set these anomalies are further corroborated.** *JHEP* 10 (2019) 157
- **Phenomenological studies using ATLAS and CMS Higgs sidebands suggest a possible narrow scalar resonance near 150 ± 5 GeV in $\gamma\gamma$ and $Z\gamma$ final states.** *Phys.Rev.D* 108 (2023) 11, 115031
- **Thus, the interest in the 130-200 GeV mass region.**

Signal Process Under Investigation and Kinematic Cuts



	H(GeV)	S (GeV)	S' (GeV)
Benchmark masses	250	150	95

$$N = generatorWeight \times PileupWeight \times JVT\ SF \times \frac{\sigma \times gen\ Filt\ Eff \times L}{\sum w_{genrerated}}$$

- **Trigger requirement**
- **Select two analysis photons which pass Tight ID and Loose Isolation.**
- **Eta acceptance:** $|\eta| \leq 2.37$ **excluding crack region 1.37** $< \eta <$ **1.52 for both photons.**
- $P_T^{\gamma_1} \geq$**35 GeV and** $P_T^{\gamma_2} \geq$**25 GeV**
- $P_T^{\gamma_1}/m_{\gamma\gamma}$ **> 0.35 and** $P_T^{\gamma_2}/m_{\gamma\gamma}$ **> 0.25**
- **Signal region: 130 GeV <** $m_{\gamma\gamma}$ **< 200 GeV**
- b**-jet veto**
- **Select** $\gamma\gamma + 1\tau$
- $E_T^{miss} > 35$ **GeV**

Background Studies

Single tau final state: $\gamma\gamma + 1\tau$

Reducible backgrounds

- **$\gamma\gamma$ +jets -** Dominant background, with two prompt photons and a jet misidentified as τ^{had}.
- **$t\bar{t}\gamma\gamma$ -** a jet from top-quark decay is misidentified as a τ^{had}.
- **Single Higgs - H→ $\gamma\gamma$**, produces a real diphoton pair, while an associated jet can fake τ^{had}.

Irreducible backgrounds

- **V$\gamma\gamma$ – $Z\gamma\gamma \rightarrow \tau\tau\gamma\gamma / W\gamma\gamma \rightarrow \tau\nu\gamma\gamma$-** one tau is reconstructed as a τ^{had}.
- **$t\bar{t}\gamma\gamma$-** top-quark decays produce a real τ^{had}.

Single-lepton final states : $\gamma\gamma + 1e/\mu$

Reducible backgrounds

- **$\gamma\gamma$ +jets-** where a jet is misidentified as a lepton, or a non-prompt lepton passes the lepton selection. Photon conversions contribute mainly to the electron channel.
- **Single Higgs - H→ $\gamma\gamma$**, with an associated jet or non-prompt lepton passing the electron/muon selection.

Irreducible backgrounds

- **V$\gamma\gamma$** – Dominant background with $W\gamma\gamma \rightarrow \ell\nu\gamma\gamma$, $Z\gamma\gamma \rightarrow \ell\ell\gamma\gamma$
- **$t\bar{t}\gamma\gamma$** where one W boson decays as **W→$\ell\nu$**

Weighting of the Events

$$N_{\gamma\gamma\mathrm{SF}} = \overbrace{N \times \gamma_1^{\mathrm{effSF\_Tight\_FixedCutLoose}} \times \gamma_2^{\mathrm{effSF\_Tight\_FixedCutLoose}}}^{\text{Single Higgs}} \times \mathrm{BR}_{\gamma\gamma}$$

$$\underbrace{N \times \gamma_1^{\mathrm{effSF\_Tight\_FixedCutLoose}} \times \gamma_2^{\mathrm{effSF\_Tight\_FixedCutLoose}}}_{\gamma\gamma\text{jets},\ V\gamma\gamma,\ t\bar{t}\gamma\gamma}$$

$BR_{H\rightarrow\gamma\gamma}$= 0.002270

$$\mathrm{SF} = \frac{\mathrm{Data} - \left(\mathrm{SingleHiggs} + V\gamma\gamma + t\bar{t}\gamma\gamma\right)}{\gamma\gamma\mathrm{jets}}$$

$$\mathrm{TotalBkg}_{\mathrm{afterSF}} = \mathrm{SingleHiggs} + V\gamma\gamma + t\bar{t}\gamma\gamma + \mathrm{SF}\left(\gamma\gamma\mathrm{jets}\right)$$

$$\mathrm{SF} = \frac{\mathrm{Data} - \left(\mathrm{SingleHiggs} + \gamma\gamma\mathrm{jets}\right)}{V\gamma\gamma + t\bar{t}\gamma\gamma}$$

$$\mathrm{TotalBkg}_{\mathrm{afterSF}} = \mathrm{SingleHiggs} + \mathrm{yyjets} + \mathrm{SF}\left(V\gamma\gamma + t\bar{t}\gamma\gamma\right)$$

Event yields for $\gamma\gamma + 1\tau$

2022 Event yields

Cut no		$V\gamma\gamma$	$t\bar{t}\gamma\gamma$	$\gamma\gamma$+jets	Single Higgs	Signal
0	Weighted no cuts	1739.16	53.36	127288.82	216.30	12.35
1	Trigger requirement	1739.16	53.36	127288.82	216.30	12.35
2	Select two analysis Photons which pass Tight ID and Loose Isolation.	969.39	33.58	87211.66	161.02	9.18
3	Eta acceptance $\|\eta\| \leq 2.37$ + crack veto for both photons	964.34	33.42	86848.86	160.37	9.12
4	$p_T^{\gamma_1} \geq 35$ GeV and $p_T^{\gamma_2} \geq 25$ GeV	960.85	33.40	86663.58	160.30	9.11
5	Photon $p_T/m_{\gamma\gamma}$ ratio: $p_T^{\gamma_1}/m_{\gamma\gamma} > 0.35$ and $p_T^{\gamma_2}/m_{\gamma\gamma} > 0.25$	817.86	28.05	69686.07	143.13	8.20
6	Select events in $m_{\gamma\gamma} \sim 130-200$ GeV: signal region	113.29	8.52	12598.28	3.22	8.13
7	b-jet veto	110.62	1.78	12424.64	3.13	7.93
8	Pass $\gamma\gamma + 0\ell 1\tau_{\text{had}}$ selection	31.81	0.49	11889.69	2.88	2.78
9	$E_T^{\text{miss}} > 35$ GeV	18.10	0.35	2725.09	0.90	1.19

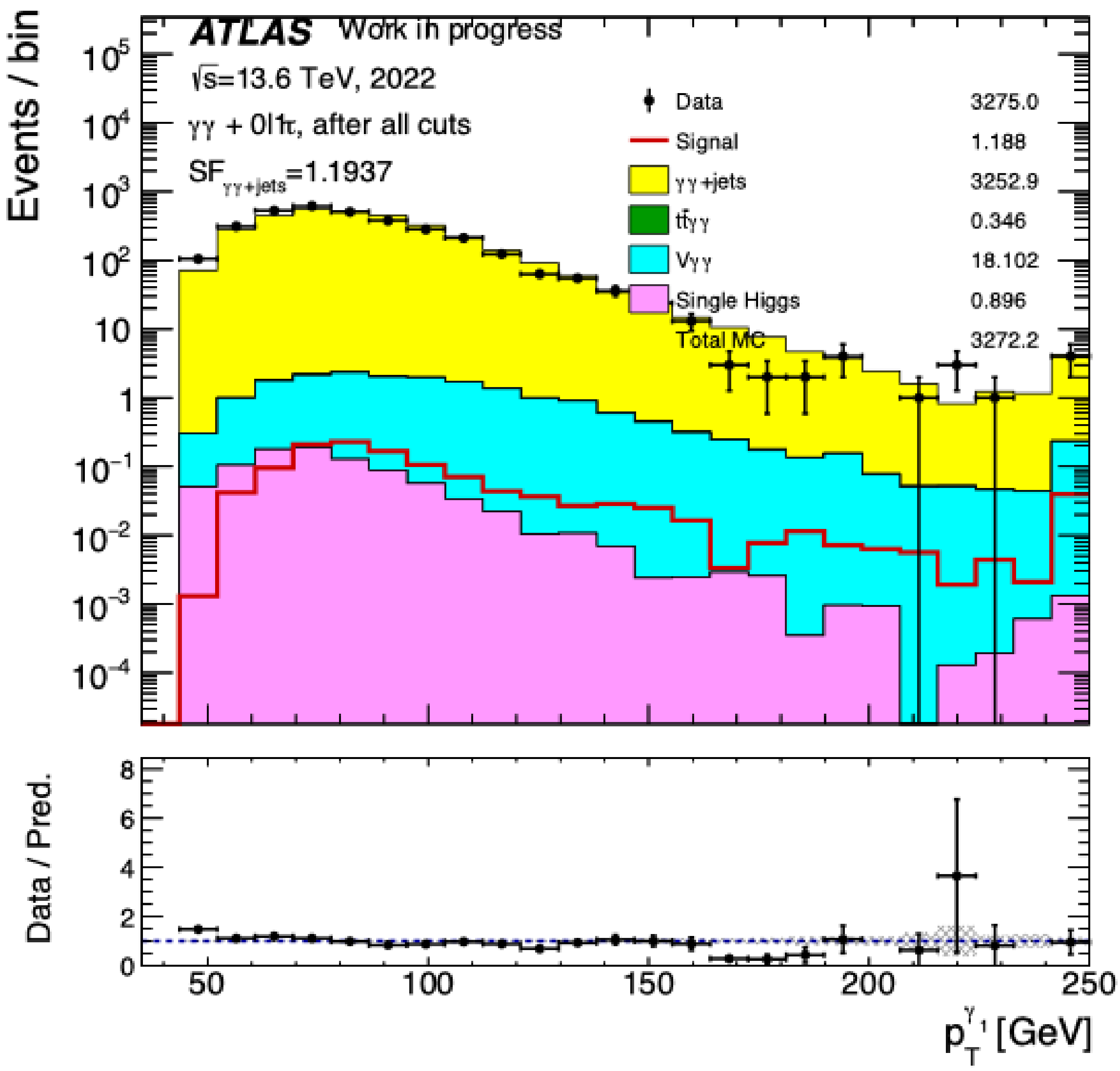
2023 Event yields

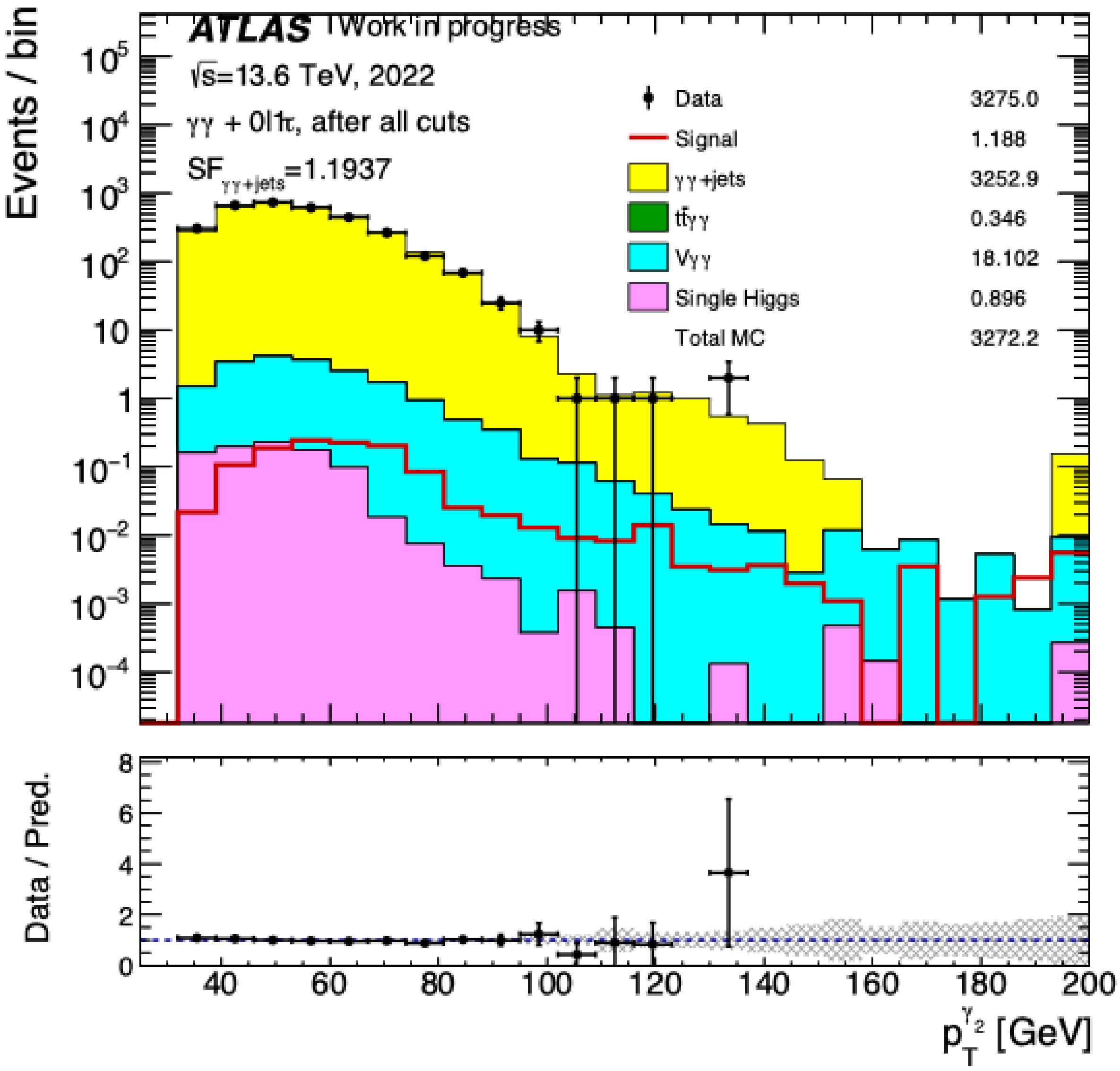
Cut no.		$V\gamma\gamma$	$t\bar{t}\gamma\gamma$	$\gamma\gamma+$jets	Single-Higgs	Signal
0	Weighted no cuts	1516.21	46.59	118475.92	203.48	10.50
1	Trigger requirement	1516.21	46.59	118475.92	203.48	10.50
2	Select two analysis photons which pass Tight ID and Loose Isolation	815.61	28.53	79485.26	148.65	7.61
3	Eta acceptance $\|\eta\| \leq 2.37$ + crack veto for both photons	811.33	28.39	79132.63	148.01	7.57
4	$p_T^{\gamma_1} \geq 35$ GeV and $p_T^{\gamma_2} \geq 25$ GeV	808.15	28.37	78970.90	147.94	7.57
5	Photon $p_T/m_{\gamma\gamma}$ ratio: $p_T^{\gamma_1}/m_{\gamma\gamma} > 0.35$ and $p_T^{\gamma_2}/m_{\gamma\gamma} > 0.25$	688.78	23.85	63931.18	132.77	6.82
6	Select events in $m_{\gamma\gamma} \sim 130–200$ GeV: signal region	96.16	7.32	11955.88	3.32	6.77
7	b-jet veto	93.85	1.51	11792.86	3.23	6.57
8	Pass $\gamma\gamma + 0\ell 1\tau_{\text{had}}$ selection	28.69	0.41	11238.43	2.98	2.37
9	$E_T^{\text{miss}} > 35$ GeV	16.92	0.29	2784.74	1.01	0.99

$\gamma\gamma + 1\tau$	2022	2023
N_{SF}	1.19	1.31
L	29.3 fb^{-1}	26.7 fb^{-1}

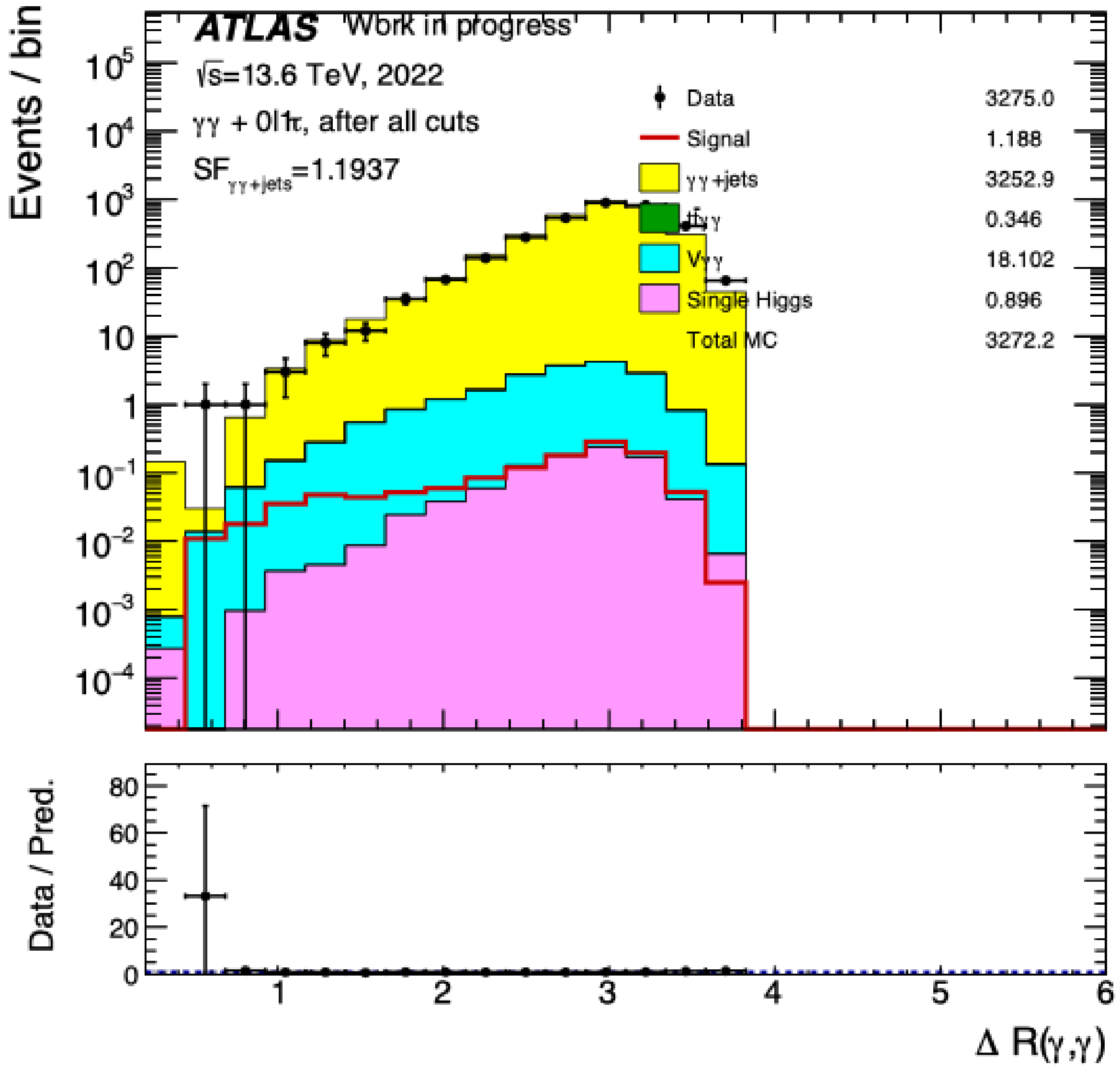
$$\text{TotalBkg}_{\text{afterSF}} = \text{SingleHiggs} + V\gamma\gamma + t\bar{t}\gamma\gamma + \text{SF}\,(\gamma\gamma\text{jets})$$

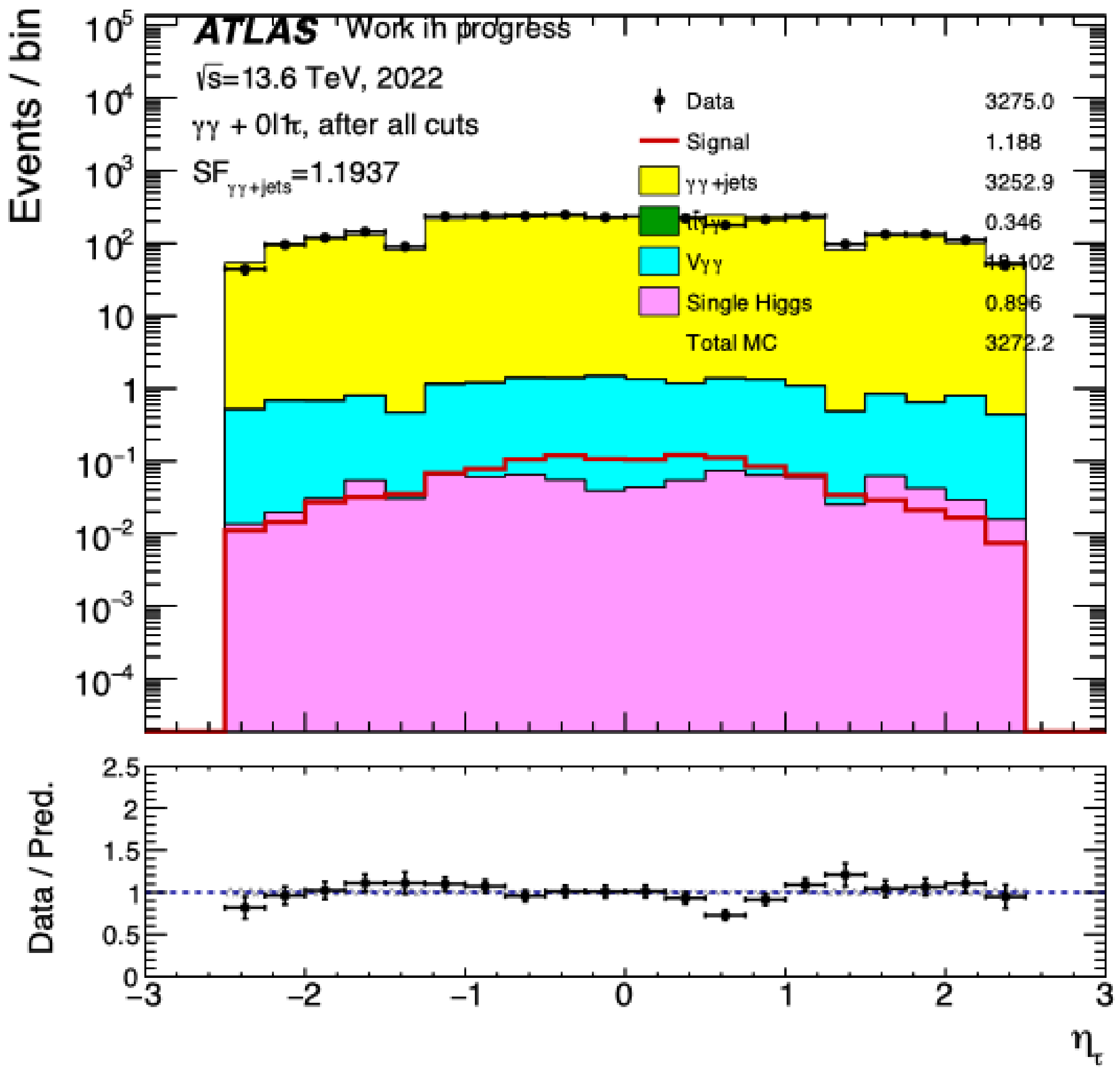
Data and MC comparison for $\gamma\gamma + 1\tau$ 2022



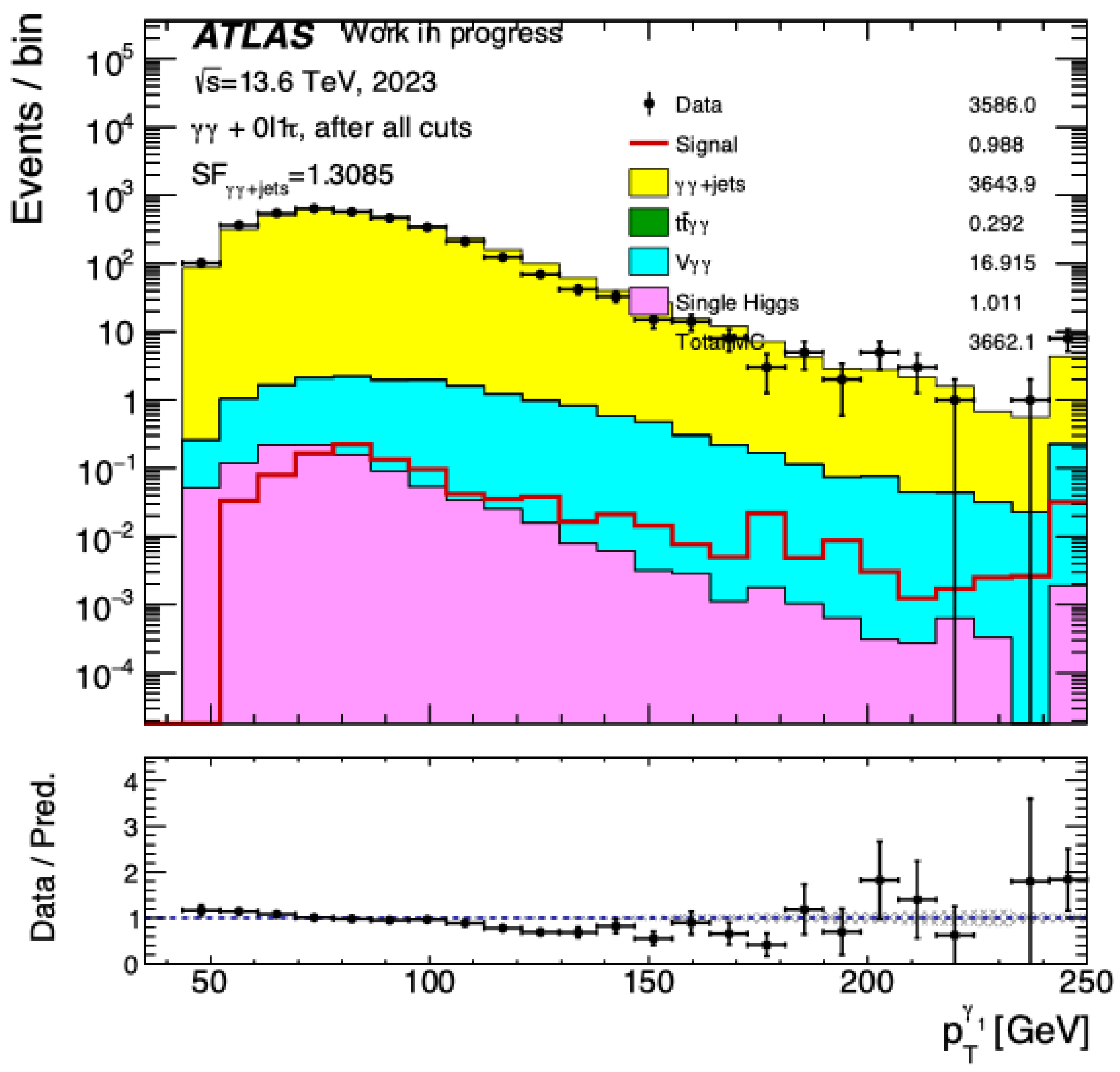


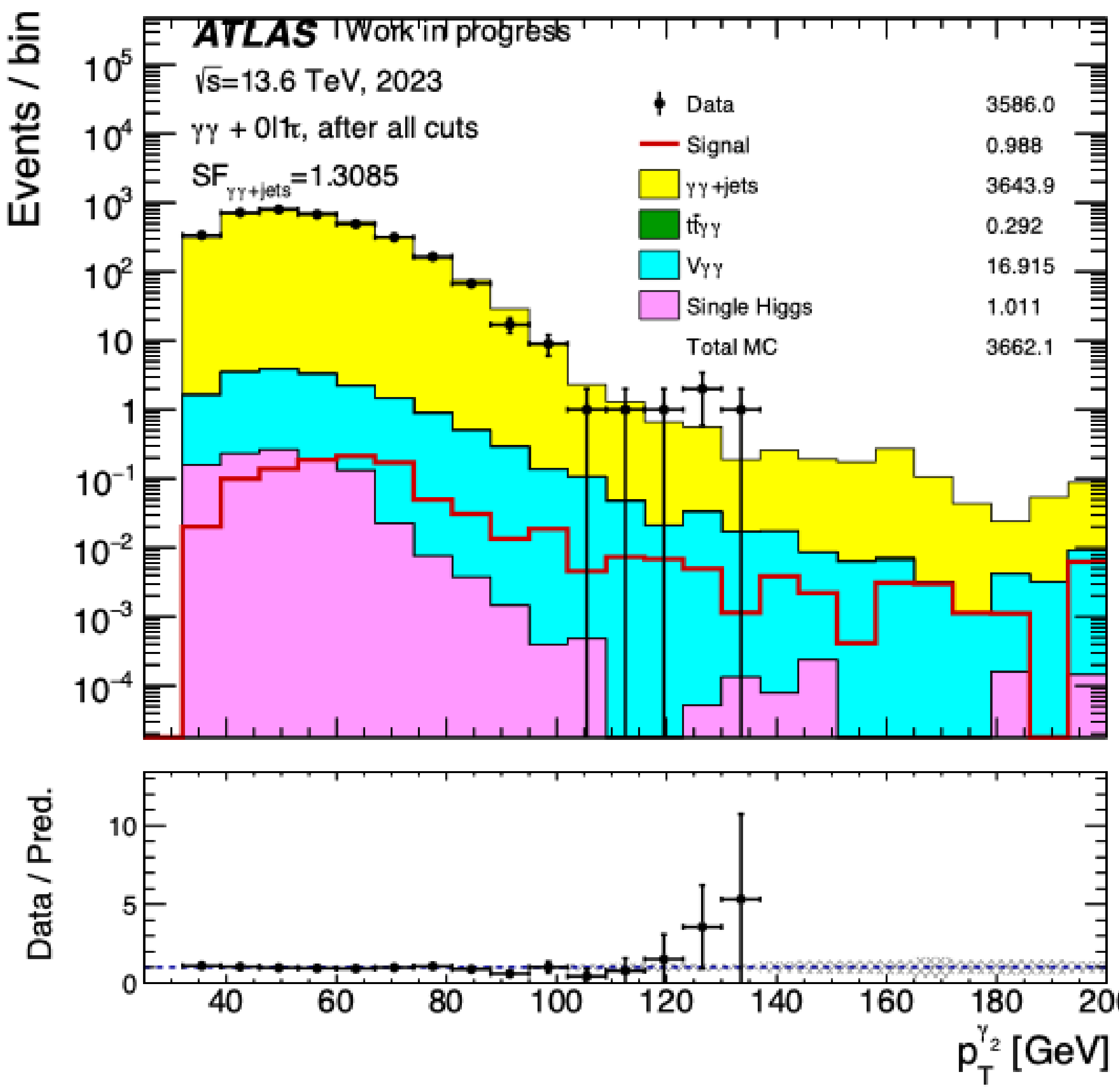
Data and MC comparison for $\gamma\gamma + 1\tau$ 2022



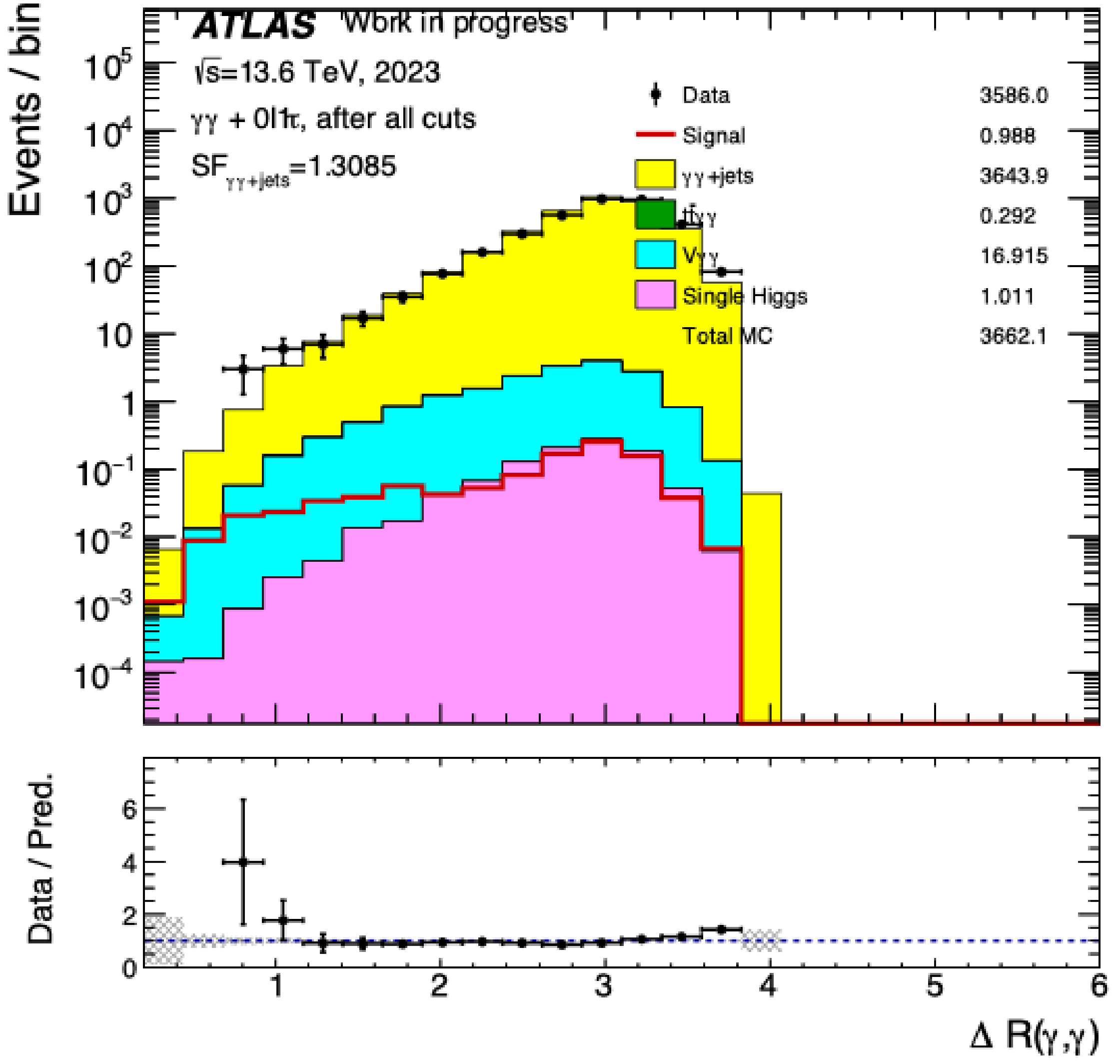


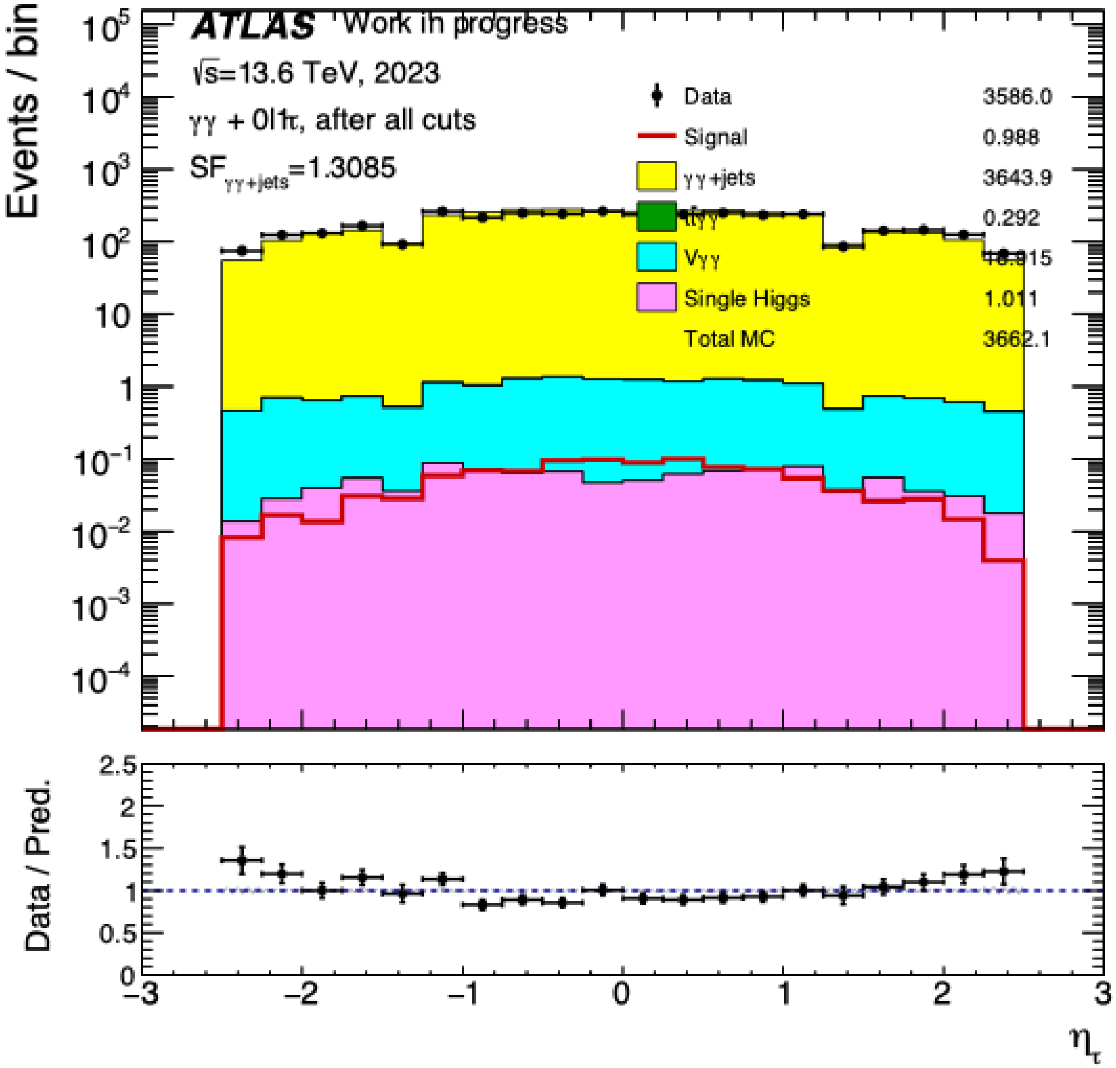
Data and MC comparison for $\gamma\gamma + 1\tau$ 2023





Data and MC comparison for $\gamma\gamma + 1\tau$ 2023





Tau Working-Point Optimisation

Tau identification working-points used for the optimisation

- Tau RNN Loose ID
- RNNLoose eleid→Loose tau RNN ID+electron-fake rejection
- Medium Tau RNN ID
- Tight Tau RNN ID

Weighting of the events when appliying working-points

$$N_{\gamma\gamma\mathrm{SF}} = N \times \gamma_1^{\mathrm{effSF\_Tight\_FixedCutLoose}} \times \gamma_2^{\mathrm{effSF\_Tight\_FixedCutLoose}} \times \mathrm{effSF\_RNN\_Tau\_workingpoint} \times \mathrm{BR}_{\gamma\gamma}.$$

Tau identification working-points that are not going to be used for the optimisation

- GNTau Loose ID
- GNTau Medium
- GNTauTight

Will be implemented in future work

Significance formula used for the optimisation

$$Z_A = \sqrt{2\left[(S+B)\ln\left(1+\frac{S}{B}\right)-S\right]}$$

Tau Working-Point Optimisation

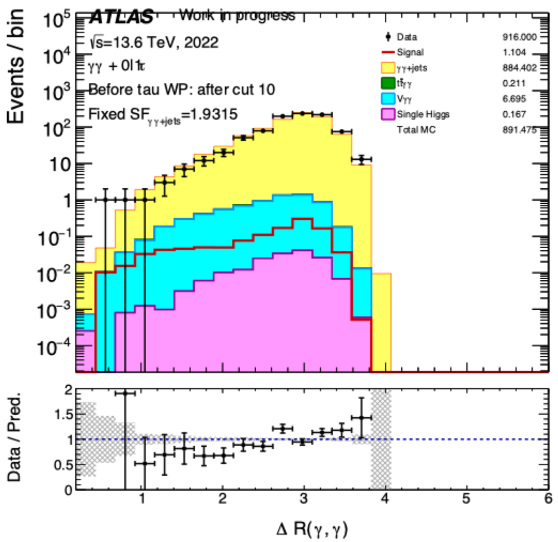
- Trigger requirement
- Select two analysis Photons which pass Tight ID and Loose Isolation.
- Eta acceptance: $|\eta| \leq 2.37$ excluding crack region $1.37 < \eta < 1.52$ for both photons.
- $P_T^{\gamma_1} \geq 35$ GeV and $P_T^{\gamma_2} \geq 25$ GeV
- $P_T^{\gamma_1}/m_{\gamma\gamma} > 0.35$ and $P_T^{\gamma_2}/m_{\gamma\gamma} > 0.25$
- Signal region: 130 GeV < $m_{\gamma\gamma}$ < 200 GeV
- Resonance region: 145 GeV < $m_{\gamma\gamma}$ < 155 GeV
- b-jet veto
- Select $\gamma\gamma + 1\tau$
- $E_T^{miss} > 35$ GeV
- Pass tau working-point selection

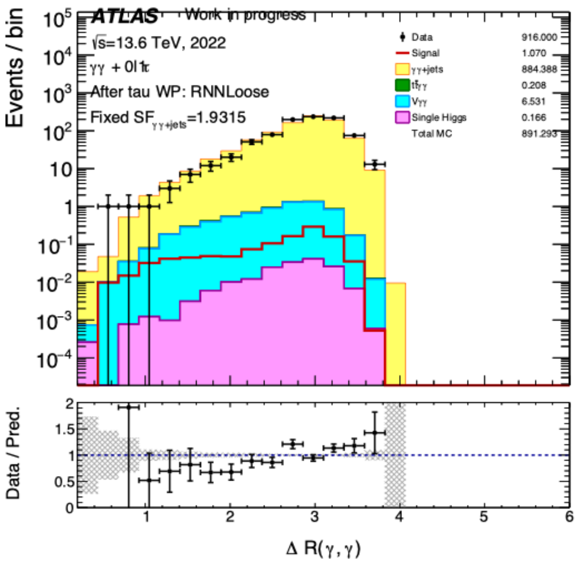
$$Z_A = \sqrt{2\left[(S+B)\ln\left(1+\frac{S}{B}\right) - S\right]}$$

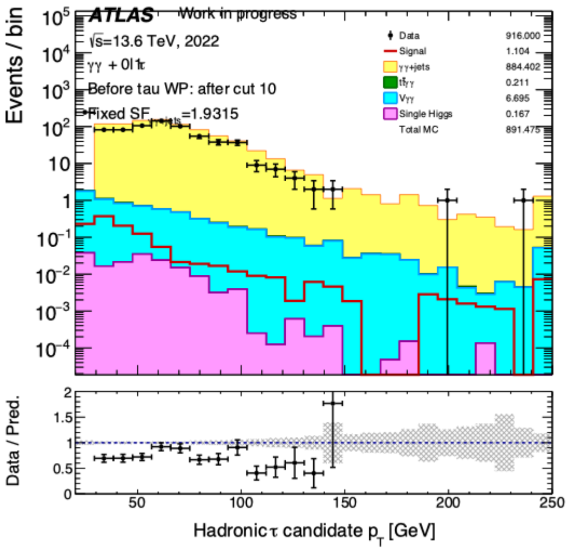
SF = 1.9315

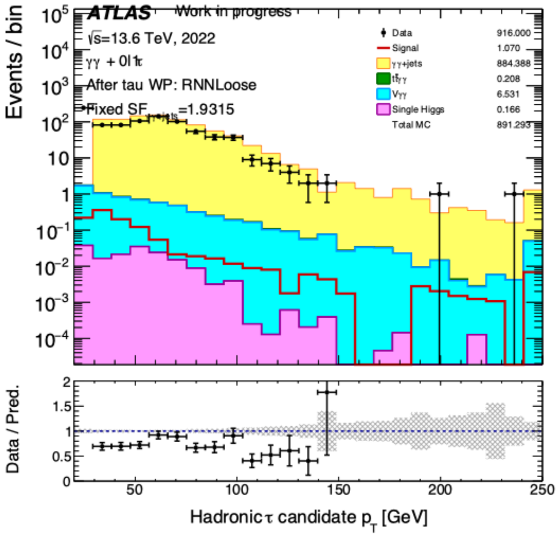
Working point	Signal	Total Background	Significance
Tau RNN Loose ID	1.070	891.293	0.079
RNNLoose eleid	1.070	891.270	0.079
Medium Tau RNN ID	0.910	571.848	0.084
Tight Tau RNN ID	0.720	310.890	0.090

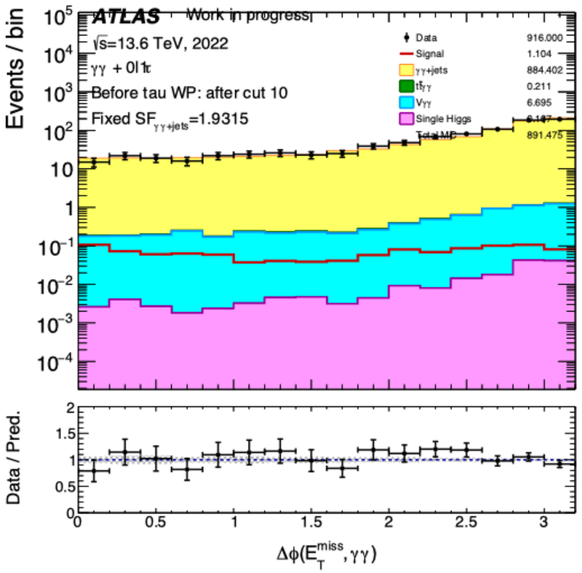
Tau Working-Point Optimisation

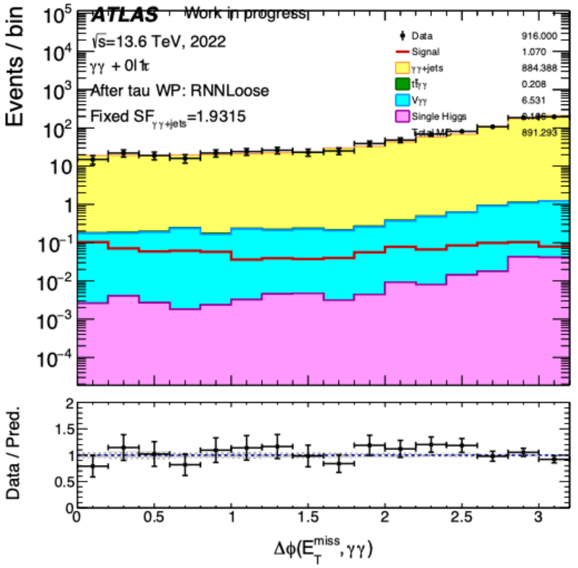


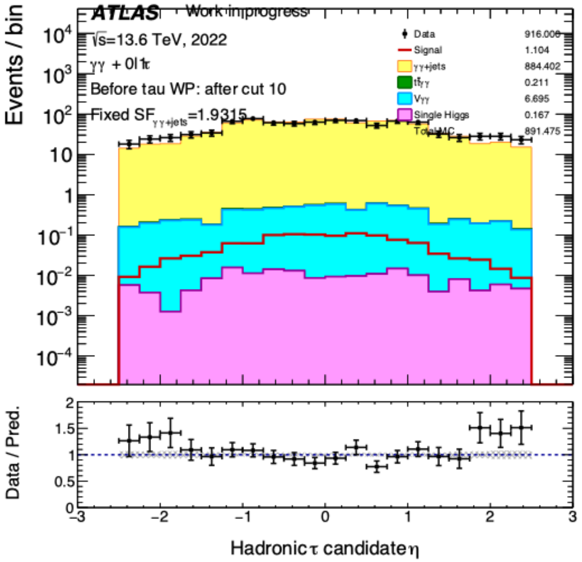


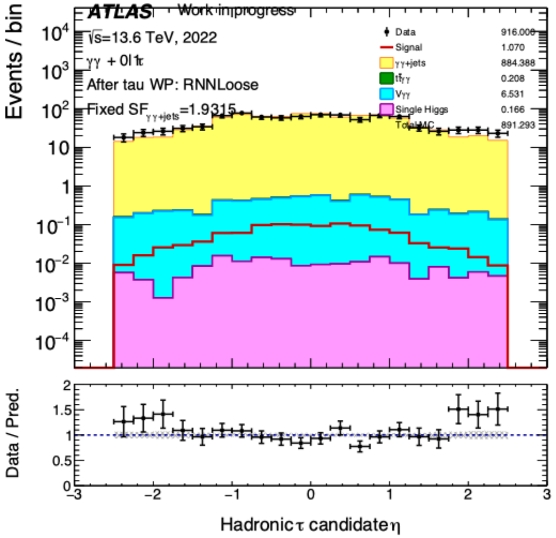












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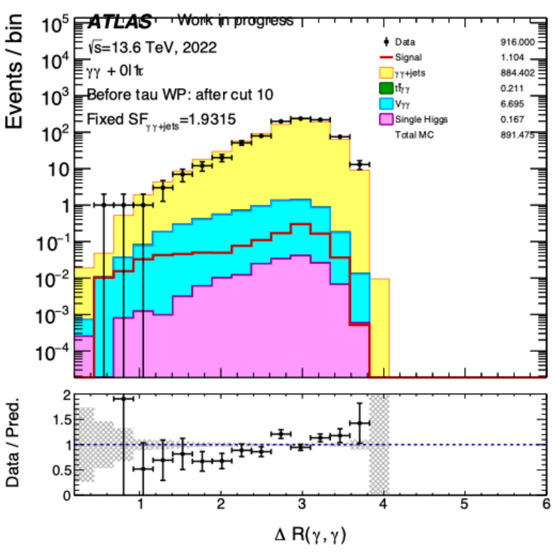

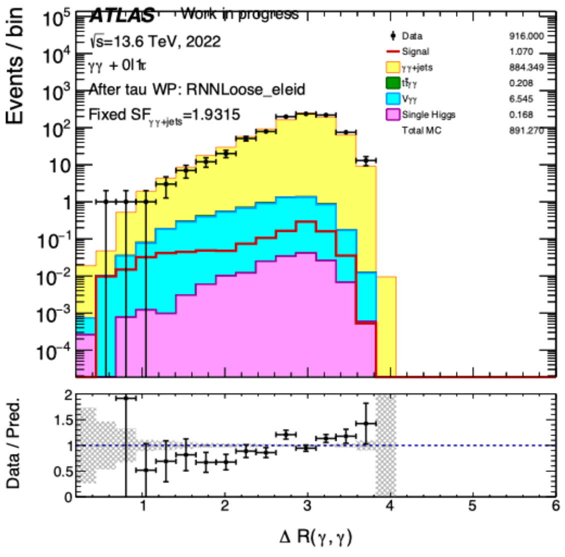

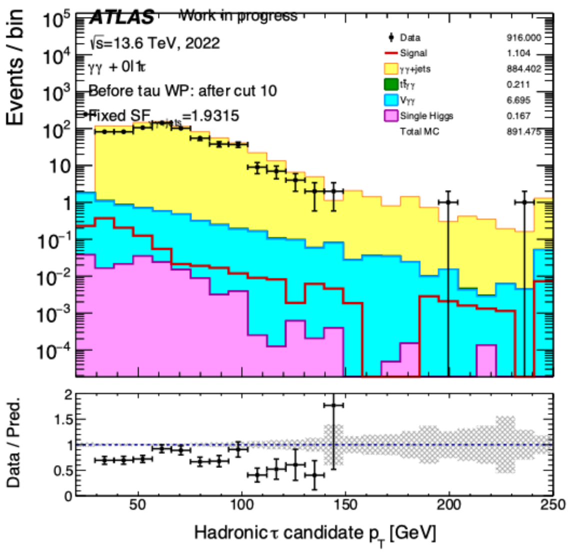

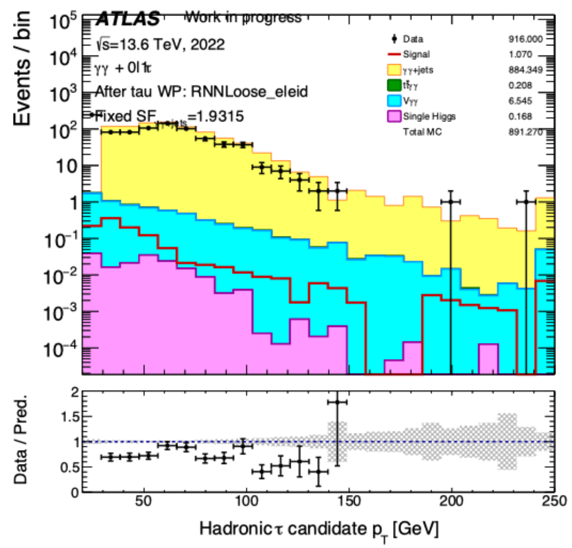

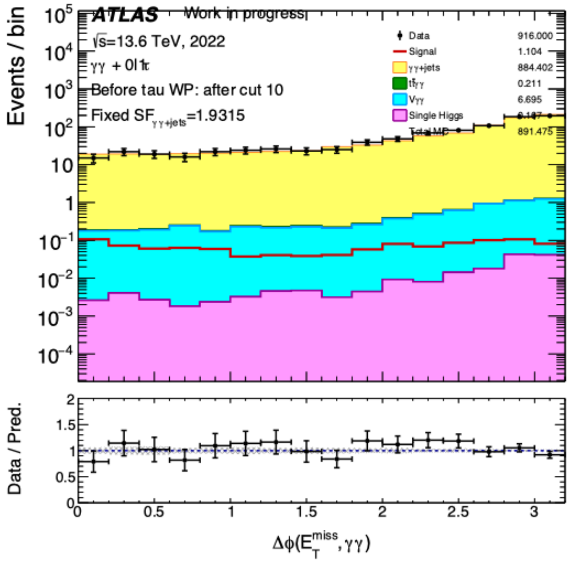

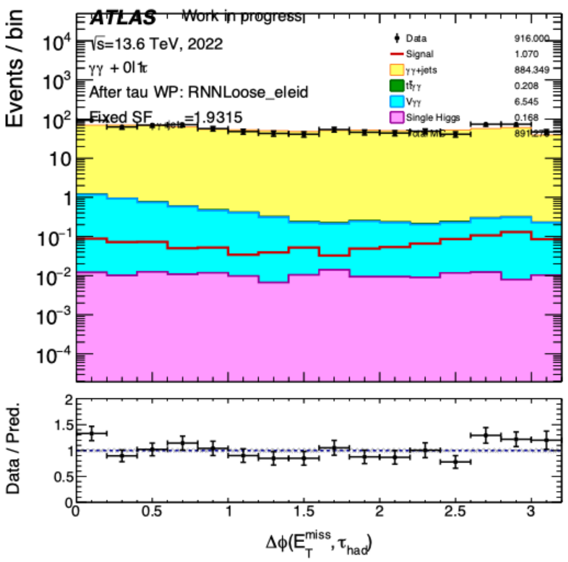

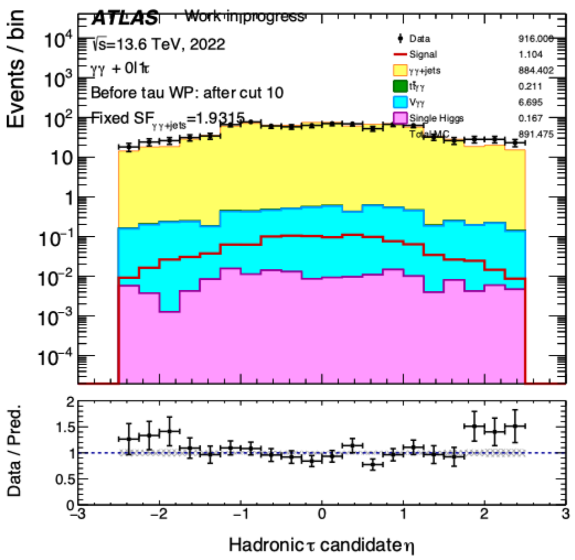

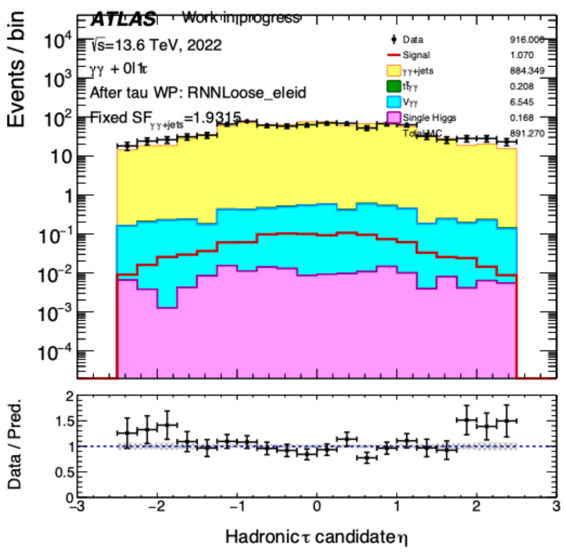

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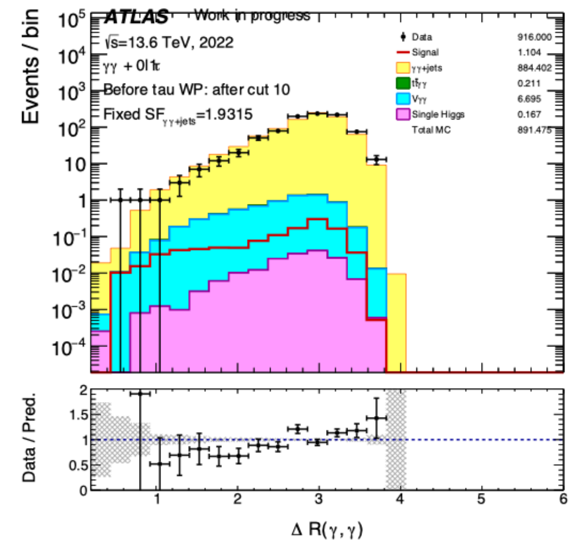

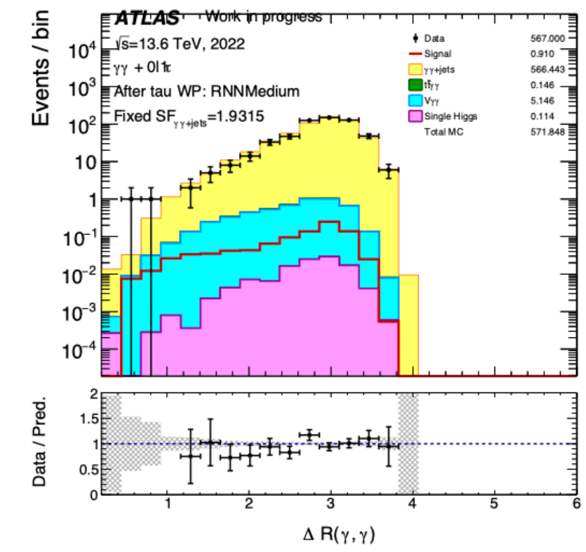

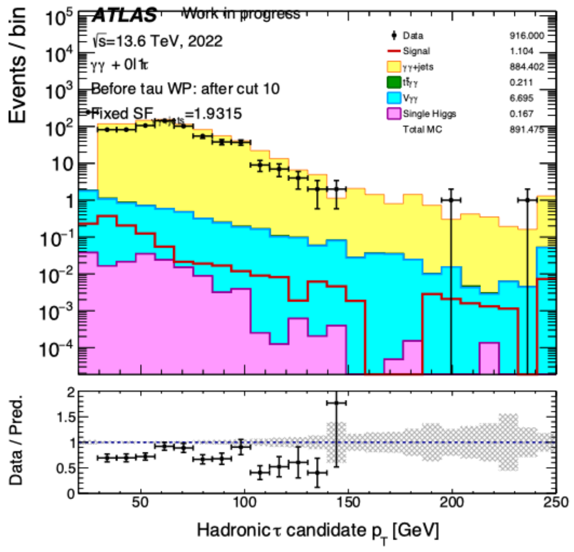

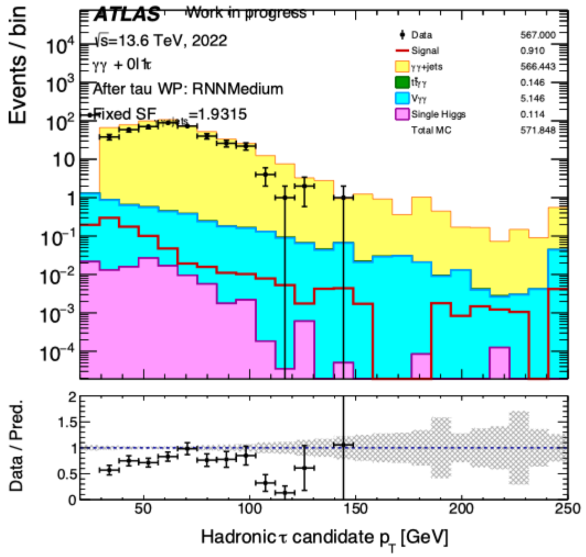

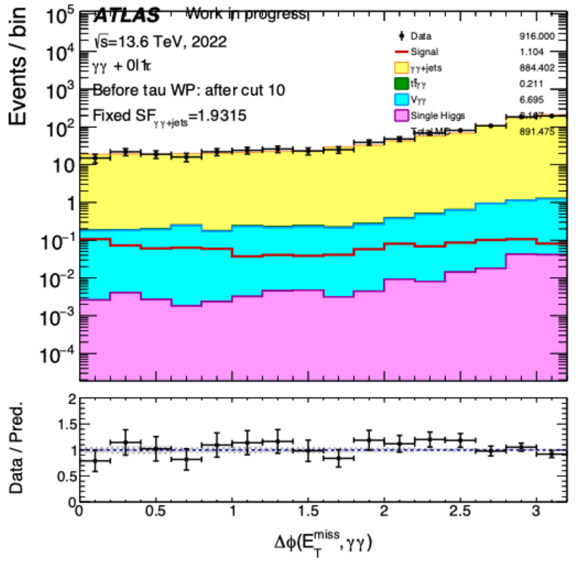

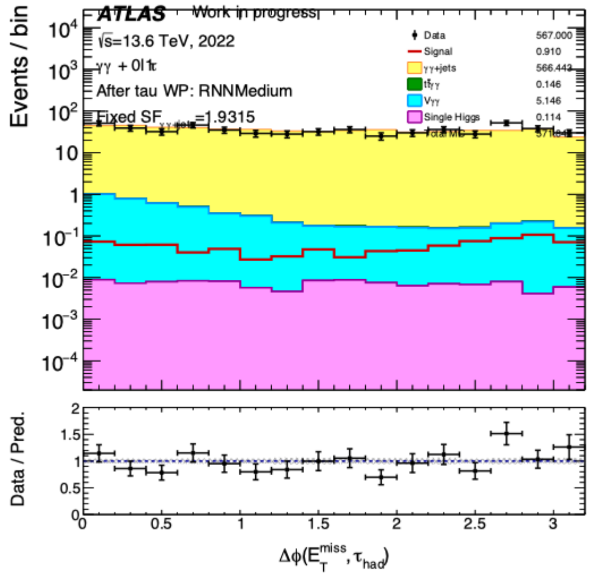

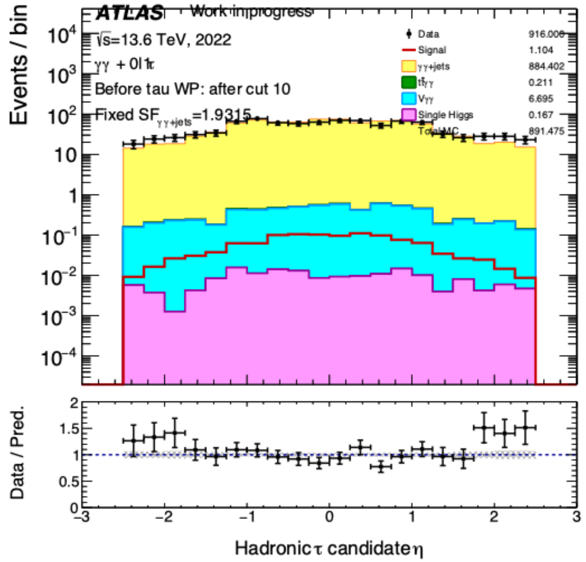

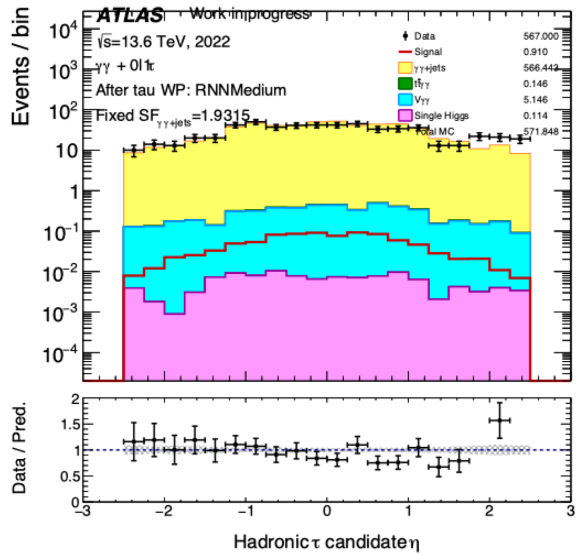

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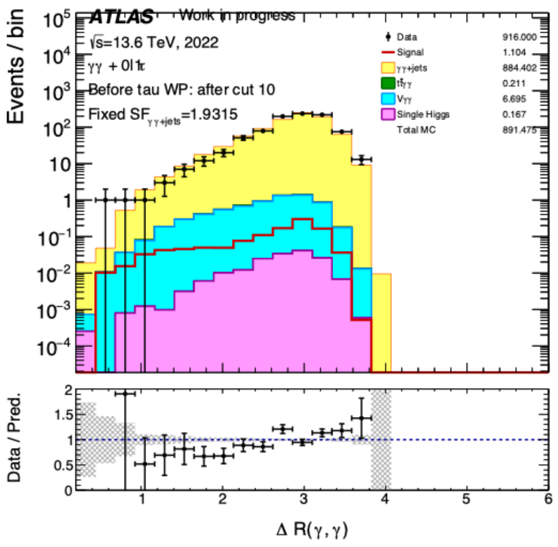

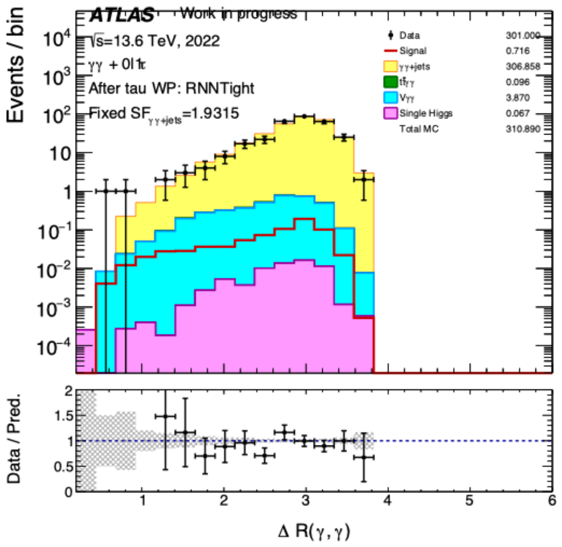

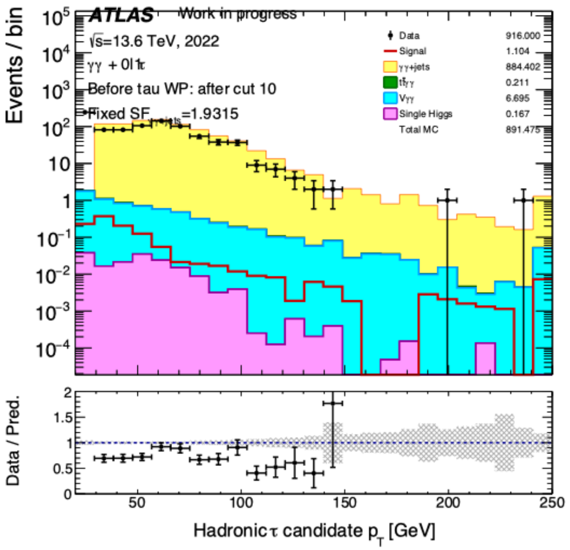

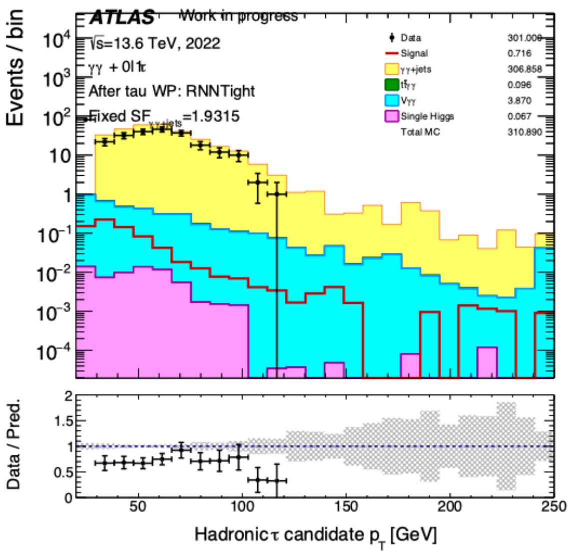

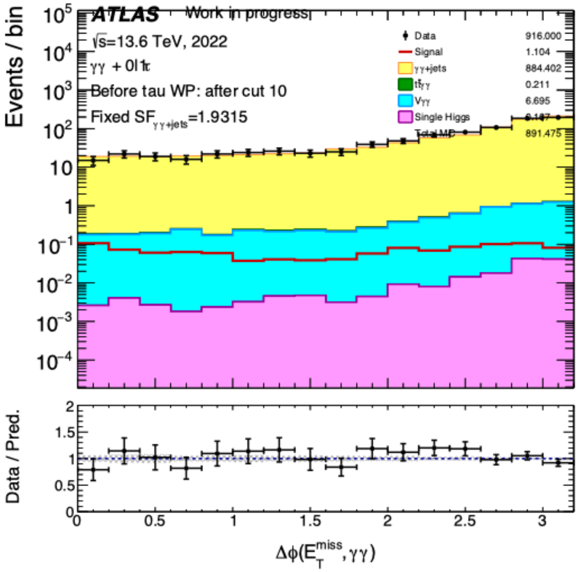

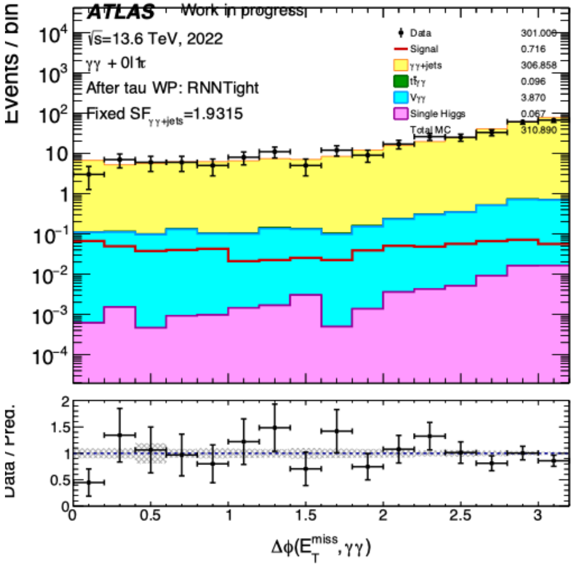

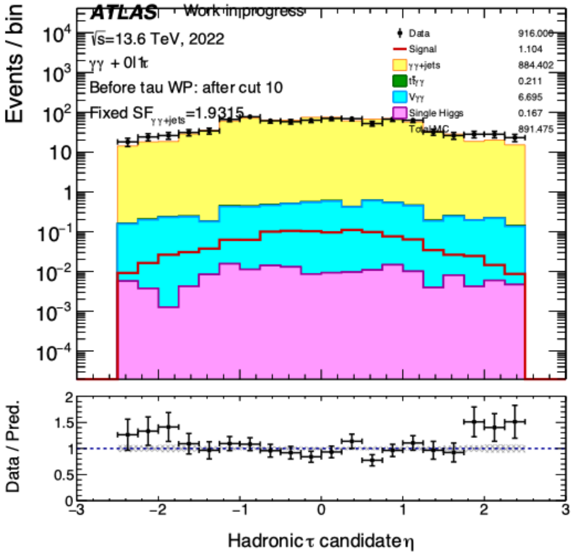

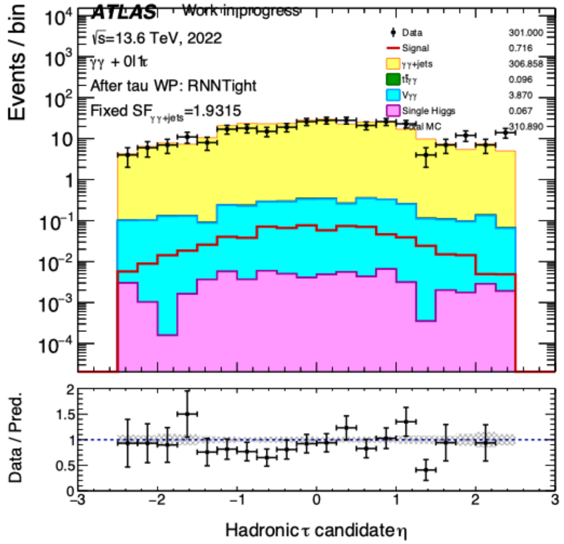

Summary

- ✓ **The 2022 and 2023 data show good agreement with the Monte Carlo predictions after applying the scale factors derived using the single-bin normalisation method with the recent ntuples.**

- ✓ **For the working-point optimisation, the RNNTight working-point performs better than the other working points, yielding the highest significance of Z_A = 0.090σ. This suggests that RNNTight provides the best balance between retaining signal events and suppressing background contributions among the working-points considered.**

Future Prospects

Steps to complete for the analysis in the coming months

- ❑ **We are going to perform Background fake estimation studies where we will use the ABCD method for the $\gamma\gamma + 1e/\mu$ and the Fake Factor method will be employed for estimating fakes for $\gamma\gamma + 1\tau$**

THANK YOU