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PAUL SCHERRER INSTITUT PSI

Real Higgs triplet at the LHC

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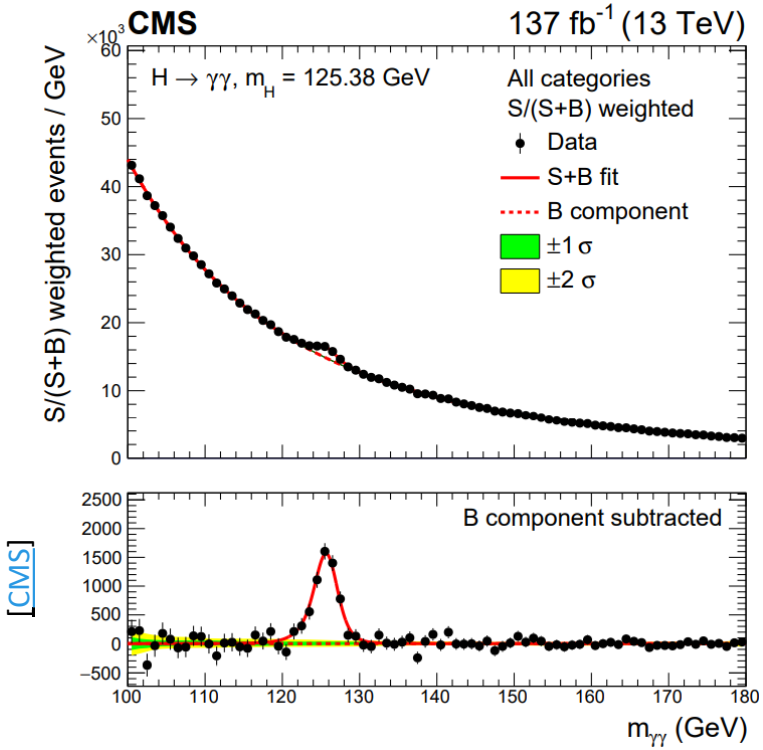
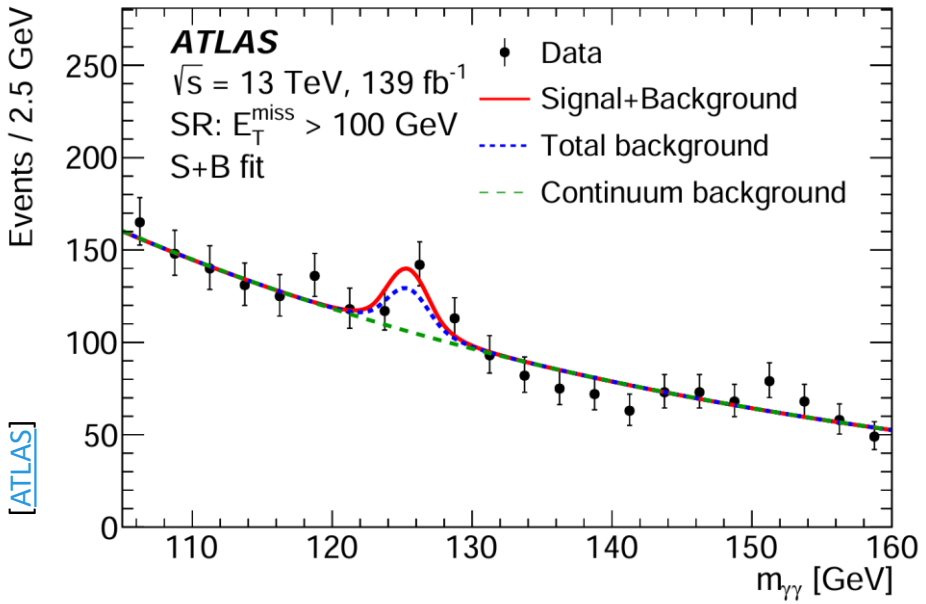
Hints for New Physics @152 GeV

- No significant excess in **inclusive $\gamma\gamma$** searches



- Interesting excesses in $\gamma\gamma + X$ (additional particles in the signal regions)



Associated production (AP) mechanism

New physics in the scalar sector?

152 GeV scalar?

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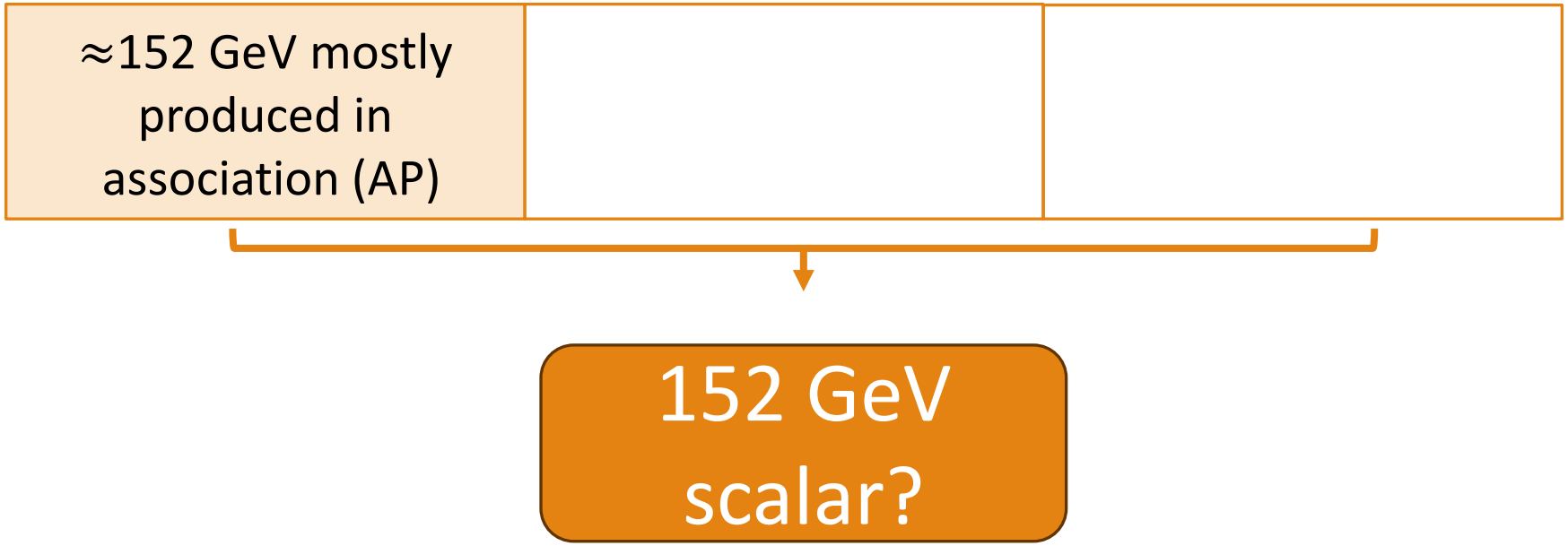

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Vacuum expectation value of the triplet Δ

Mixing angle between SM Higgs h – neutral component of the triplet Δ^0

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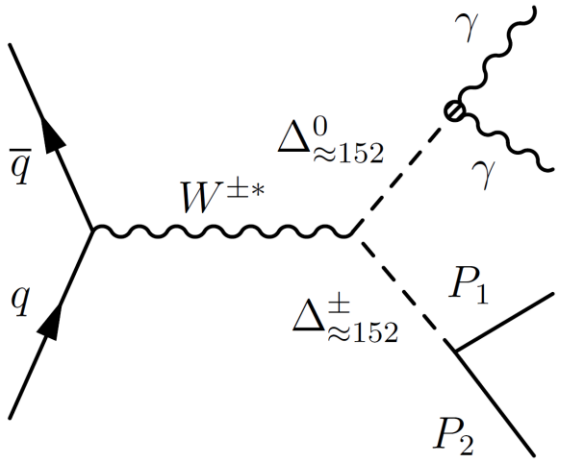

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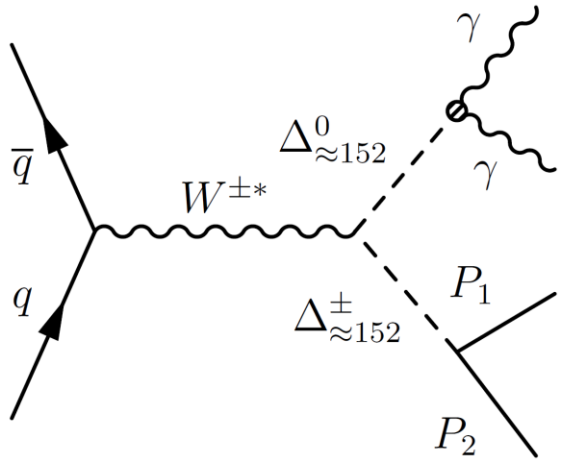

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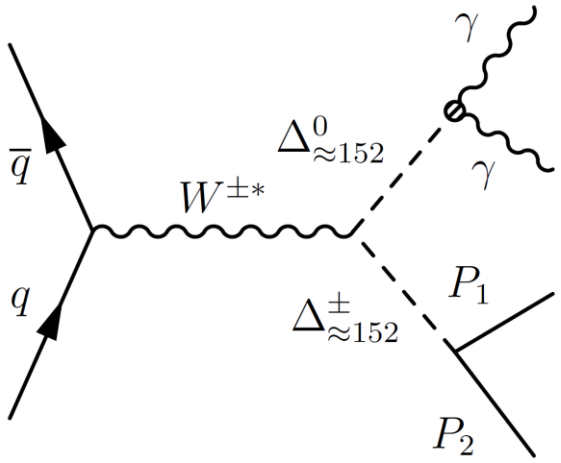


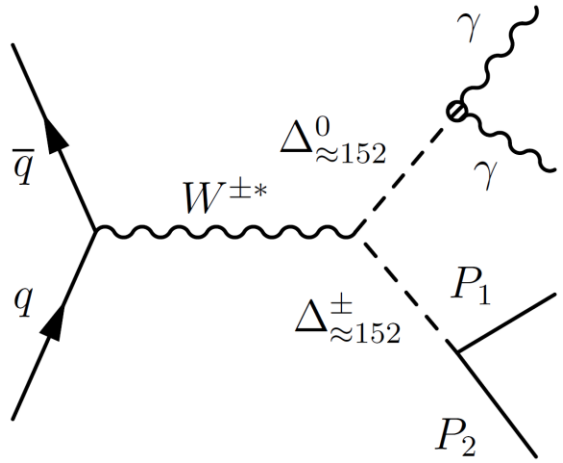
Produced in AP via Drell-Yan (DY)	$\Delta^0 WW$ but no $\Delta^0 ZZ$ (tree level, $\alpha_\Delta = 0$)	$v_\Delta \approx 2.3/3.4$ GeV ($m_{\Delta^0} \approx m_{\Delta^\pm}$)

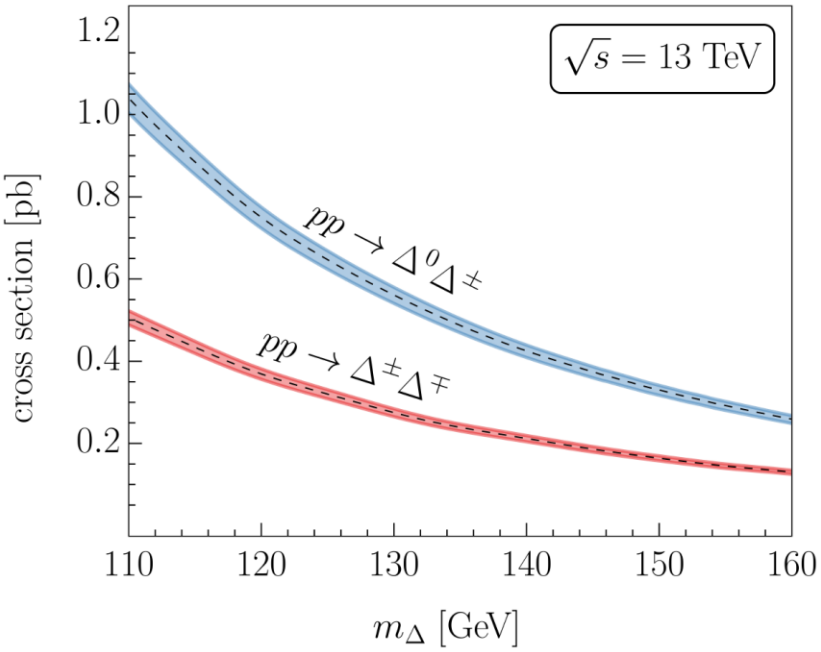
The ΔSM model

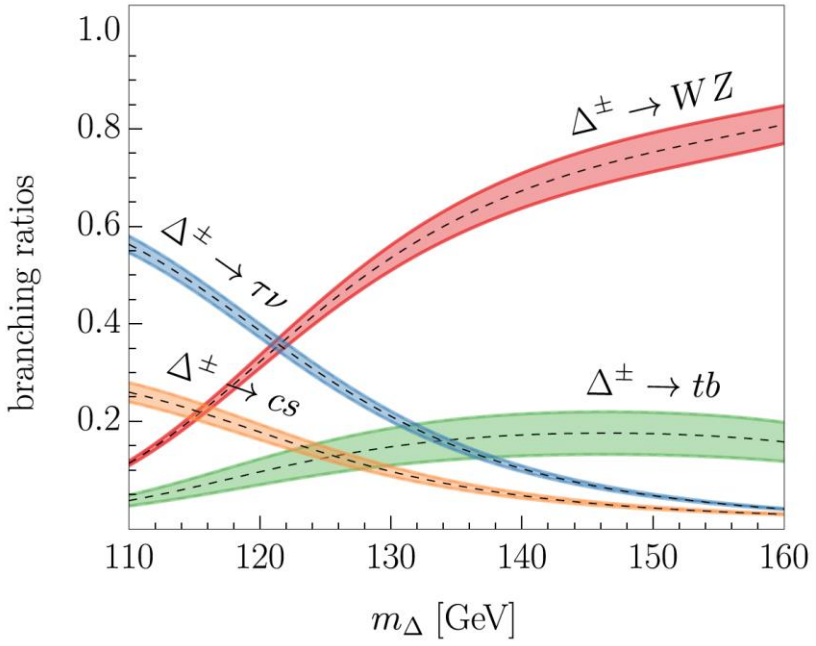
[S. Banik, GC, A. Crivellin et al.]

All relevant parameters are fixed by the model except

- $m_{\Delta^0,\,\Delta^\pm}$
- $\mathbf{Br}(\Delta^0 \to \gamma\gamma)$



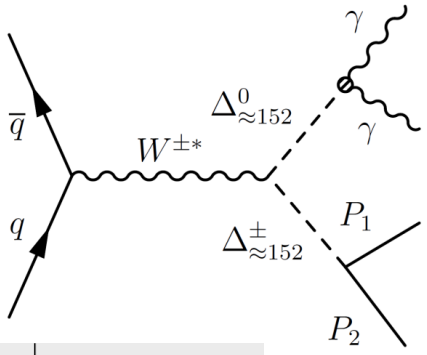




ATLAS: $H \to \gamma\gamma + X$

[ATLAS]

- ATLAS search for AP with full Run2 data
- **SM** $H \to \gamma\gamma + X$ ($m_{\gamma\gamma}$ = 105-160 GeV)
- Multiple categories ($X = l, j, j_b, E_T^{miss}$ ...)

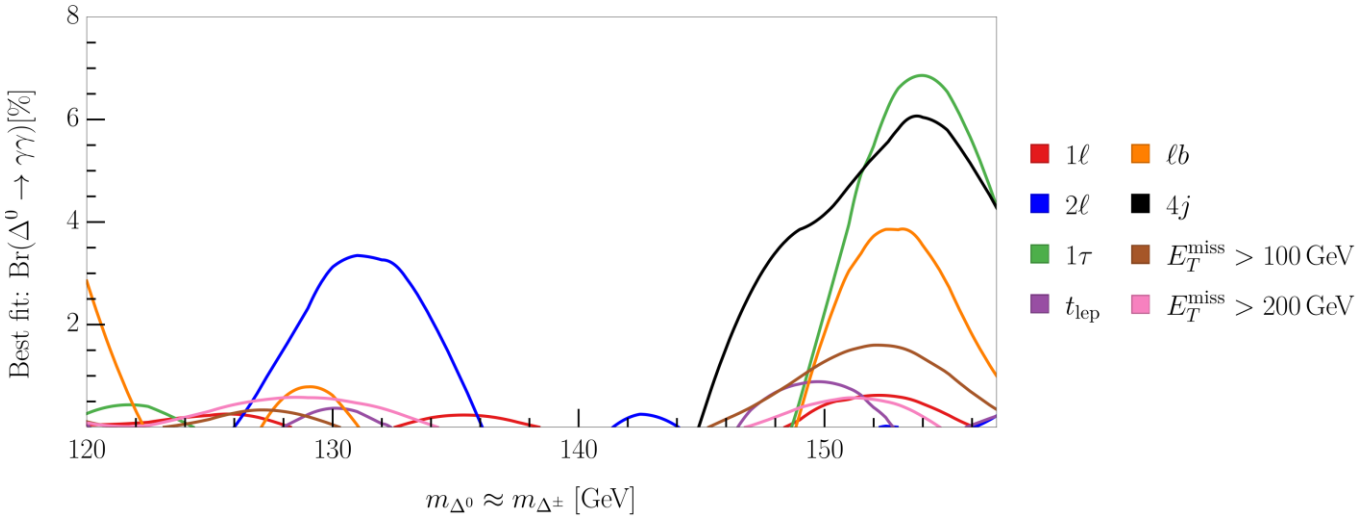


Target	Signal region	Detector level	Correlations
High jet activity	$4j$	$n_j \geq 4$	-
Top	ℓb t_{lep}	$n_\ell \geq 1, n_{b-\text{jet}} \geq 1$ $n_{\ell=e,\mu} = 1, n_{\text{jet}} = n_{b-\text{jet}} = 1$	-
Lepton	2ℓ 1ℓ	$ee, \mu\mu$ or $e\mu$ $n_\ell = 1, n_{t_{\text{had}}} = 0, n_{b-\text{jet}} = 0$	$< 26\%$
Tau	$1\tau_{\text{had}}$	$n_\ell = 0, n_{\tau_{\text{had}}} = 1, n_{b-\text{jet}} = 0$	–
$E_{\text{T}}^{\text{miss}}$	$E_{\text{T}}^{\text{miss}} > 100$ GeV $E_{\text{T}}^{\text{miss}} > 200$ GeV	$E_{\text{T}}^{\text{miss}} > 100$ GeV $E_{\text{T}}^{\text{miss}} > 200$ GeV	29%

Reduced SM background and enhanced NP sensitivity

Results: $\Delta^0 \to \gamma\gamma + X$

[S. Banik, GC, A. Crivellin et al.]



- 22 channels analyzed by ATLAS
- 8 relevant for a real triplet

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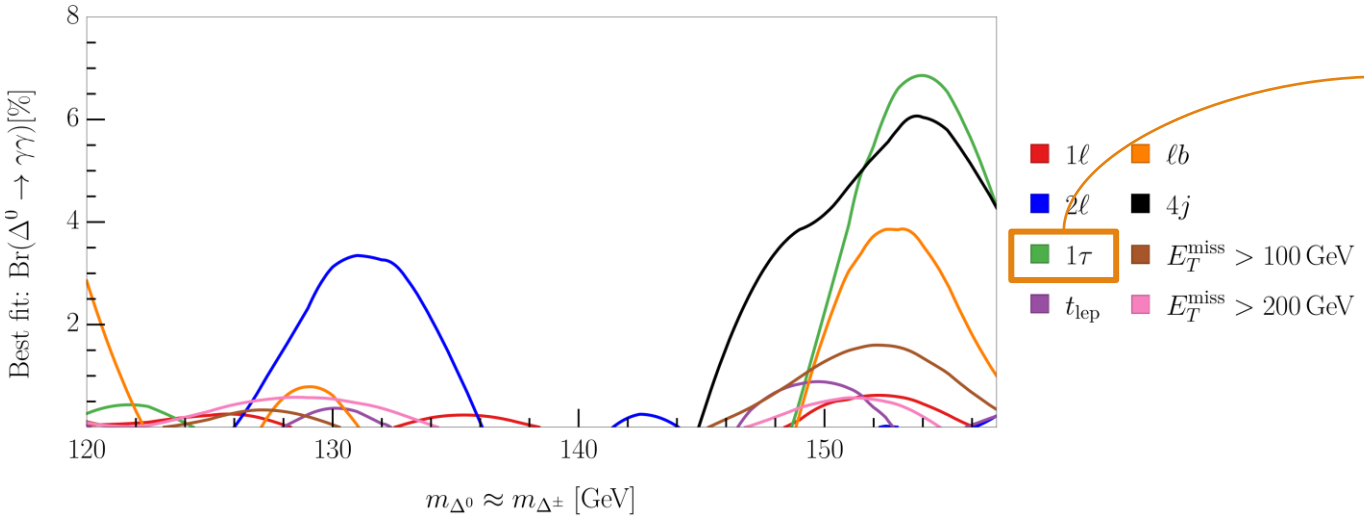

New! Moriond 2024

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but excess in $\gamma\gamma + \tau$

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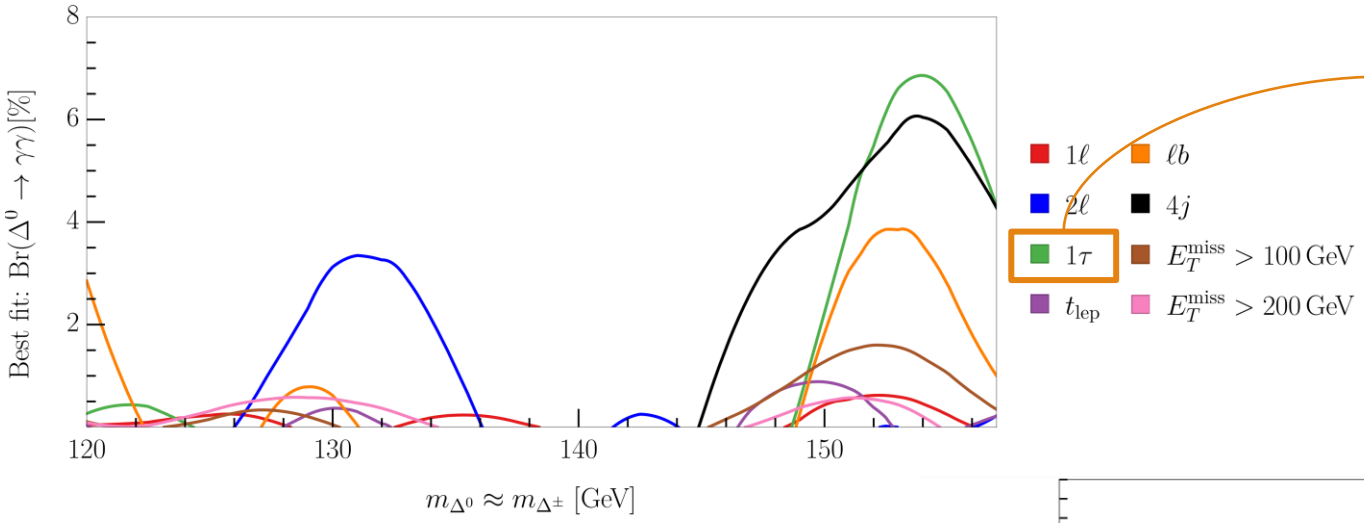

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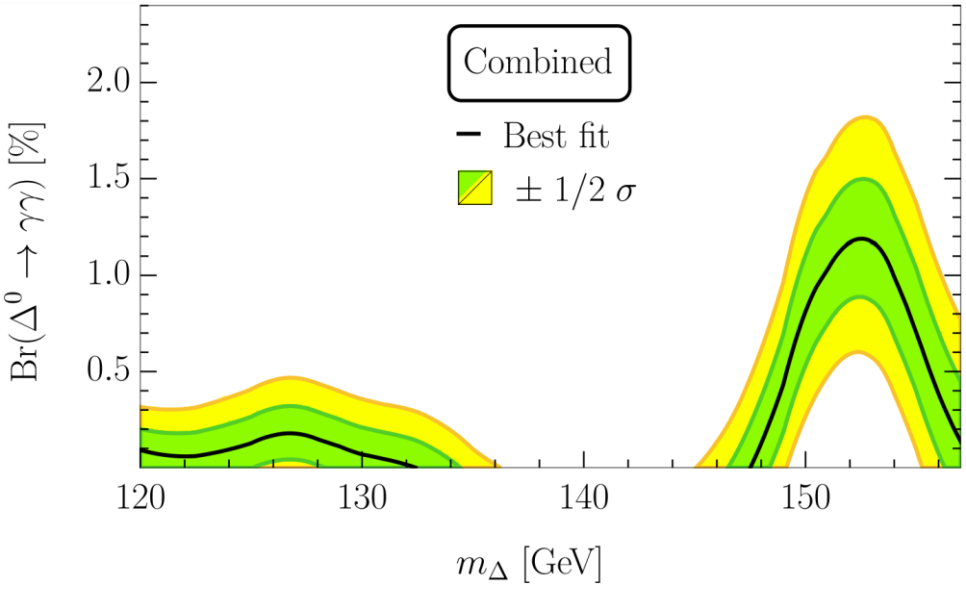


$\mathrm{Br}(\Delta^0 \to \gamma\gamma) \approx 1\%$

preferred over SM by $\approx 4\sigma$

Comparison

2HDM type-I

- Several parameters and fields as input
- Included in multiple new physics model
- Best fit for the $\gamma\gamma + X$ excesses at 152 GeV

ΔSM

- Minimal set of parameters and fields
- Most degrees of freedom fixed by the model
- $H^{\pm} \to W^{\pm}Z$ affects goodness of the 152 GeV excesses fit

Common requirements is a neutral scalar with a mass of 152 GeV mostly produced via Drell-Yan

Conclusions and outlook

1. Interesting hints for NP at 152 GeV in associated production (resonant di-photon searches, multi-lepton anomalies)

2. Real Higgs triplet explains such excesses and is preferred over SM by $\approx 4\sigma$

3. Run3 data and HL-LHC will scrutinize such NP scenario

4. **$\Delta^{\pm}$ suitable candidate for future $e^{+}e^{-}$ colliders**

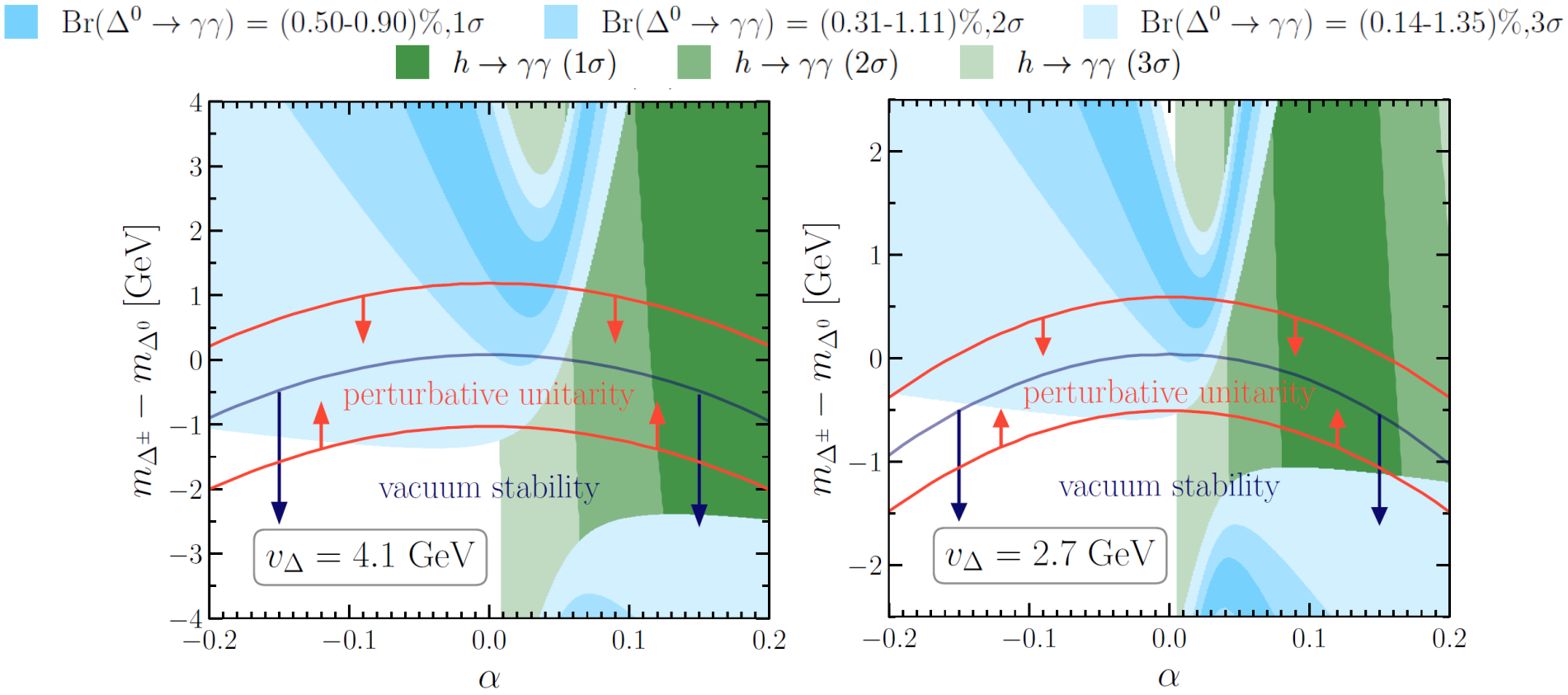
5. A real triplet is enough for **a strong first order EW phase transition** [Bandyopadhyay et al.]

BACK UP SLIDES

Scalar potential

[S. Banik, GC, A. Crivellin et al.]

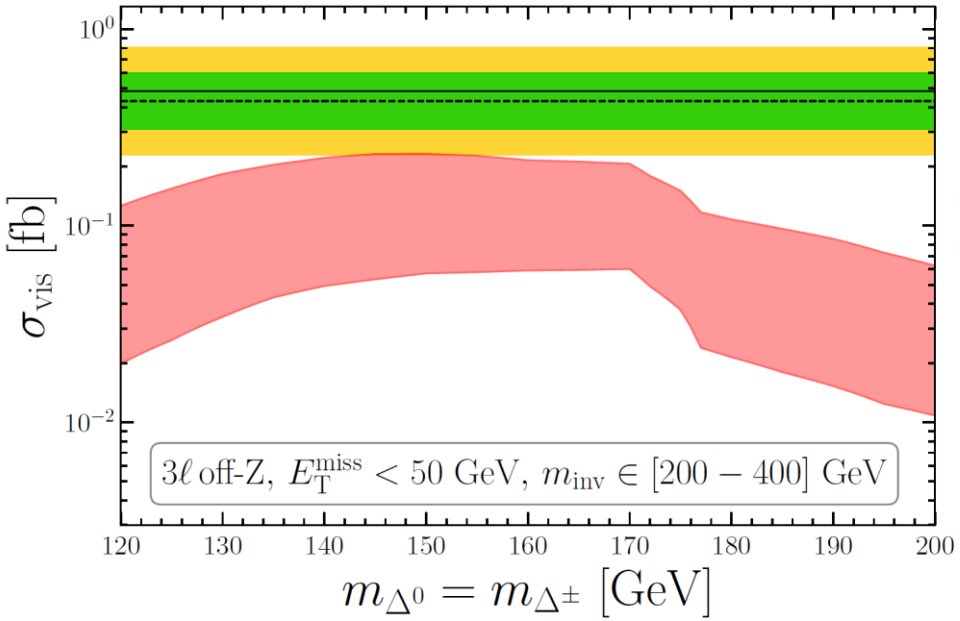
- Vacuum stability and perturbative unitarity in slight tension with other phenomenological observables
- Pointing to additional fields at or above the EW scale

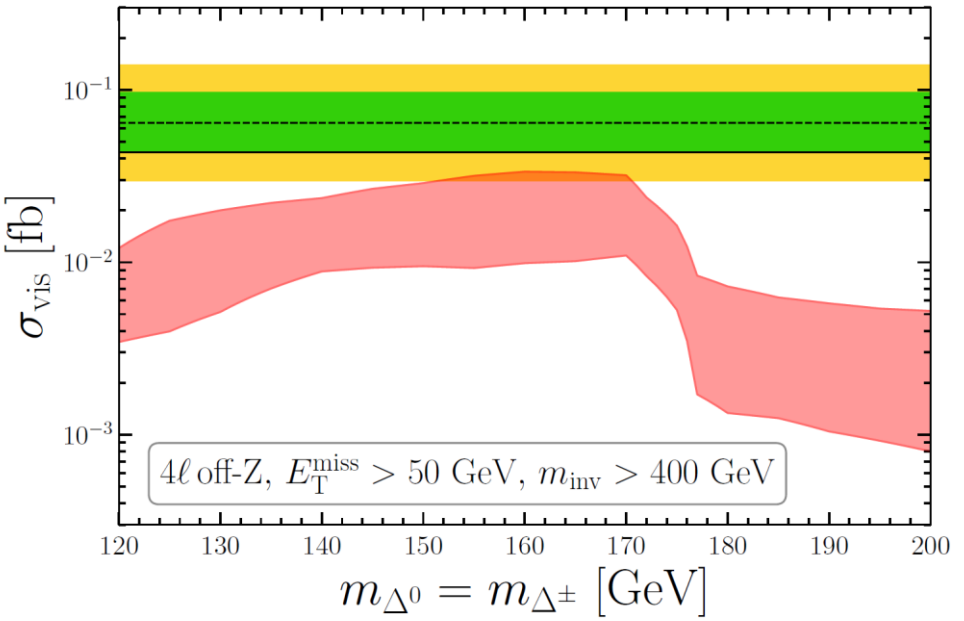


3 and 4 – leptons bounds

[In prepation…]

- Multi-lepton searches with 3 and 4 leptons as final states are not excluding a real Higgs triplet at low masses



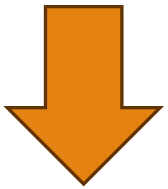


[ATLAS]

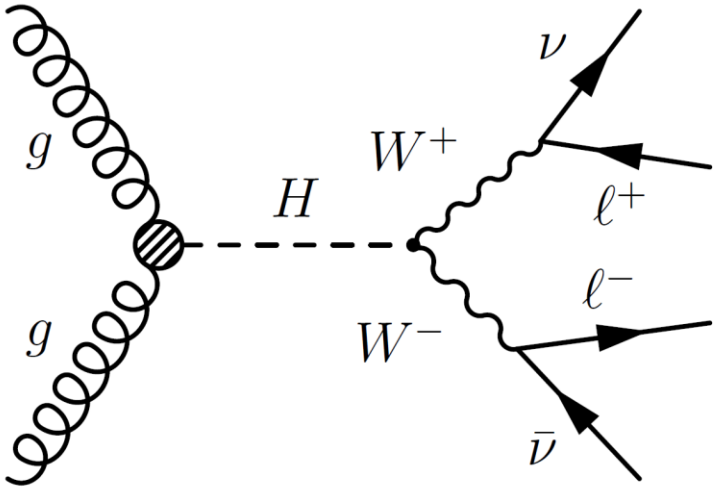
WW analysis

[GC, A. Crivellin et al.]

- **No dedicated BSM search for $gg \to H \to WW$** with full luminosity and including 90 GeV for the range of m_H
- CMS and ATLAS analyses available for **SM Higgs (135 $\mathbf{fb^{-1}}$)**



- Re-casting analyses to search **for new scalars**
- **Simulation with MadGraph5_aMC@NLO (Pythia8, Delphes)**

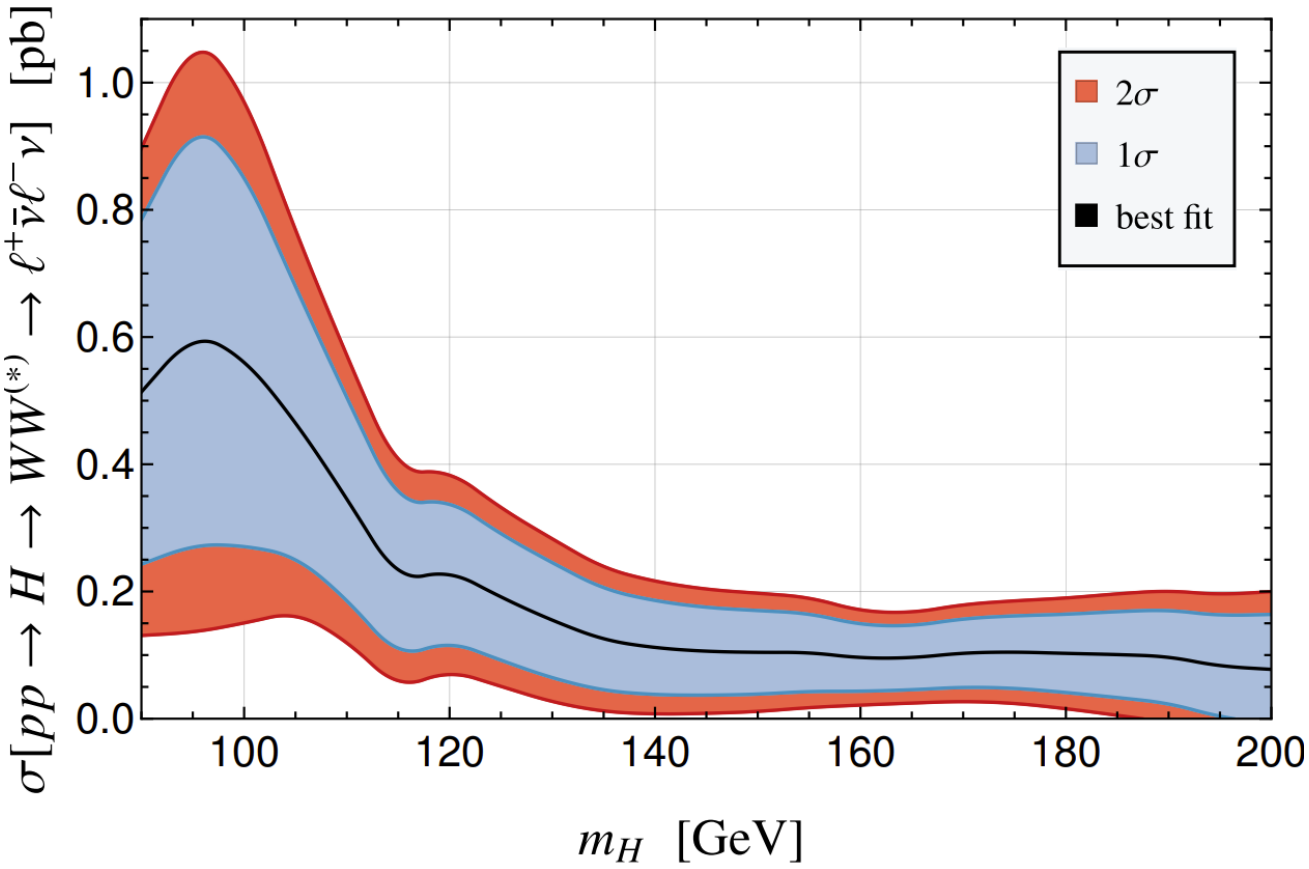


Leptonic decays → jet veto

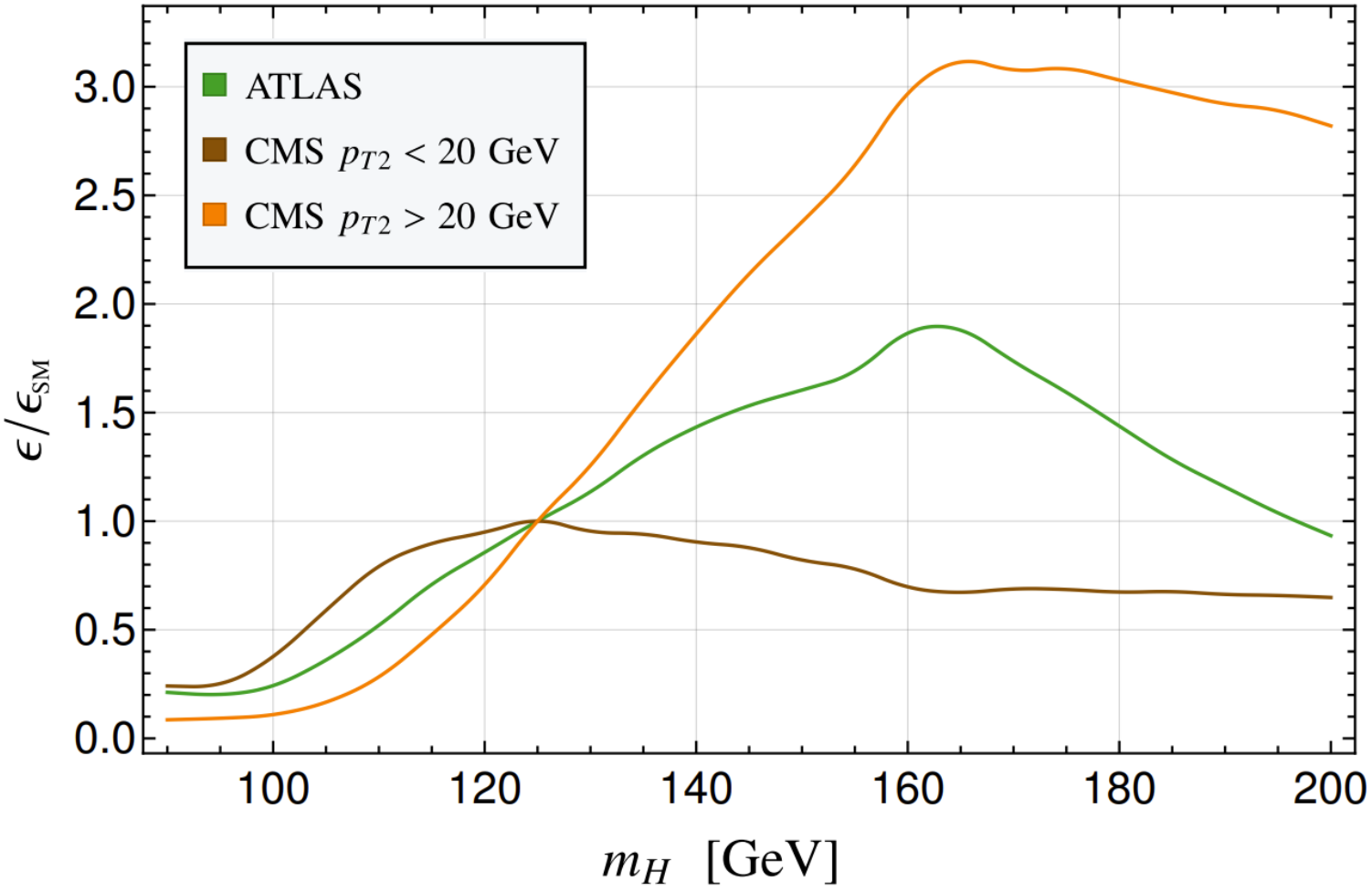
WW results

[GC, A. Crivellin et al.]

- Observed limit is weaker than expected over the whole mass range (**room for BSM $\geq 2\sigma$**)

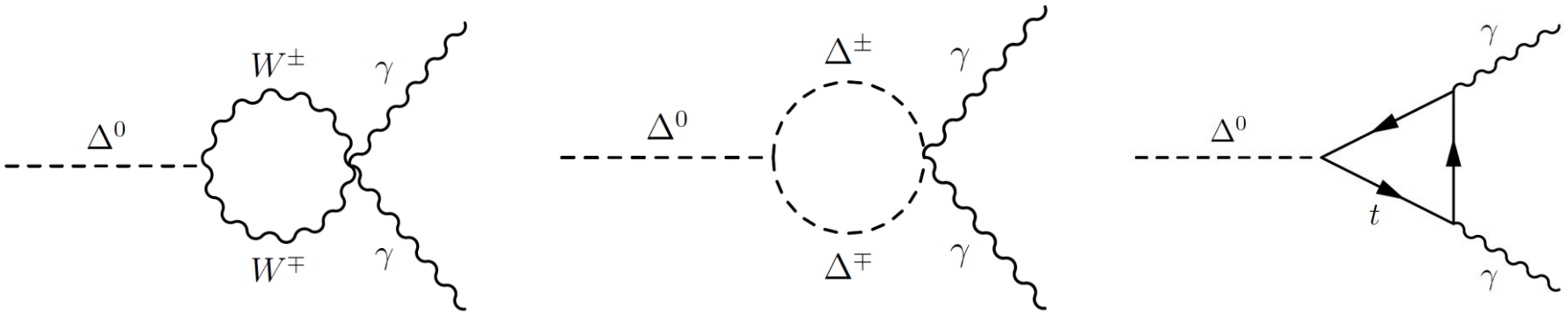


WW simulation efficiency [GC, A. Crivellin et al.]



Fit: $\Delta^0 \to \gamma\gamma$

[S. Banik, GC, A. Crivellin et al.]



$$f\left(m_{\Delta^0}\,,\ \alpha\,, m_{\Delta^\pm} - m_{\Delta^0}\,, v_\Delta\,; \ldots\right)$$

For the fit, all parameters subsumed into single relevant phenomenological one

$$\mathrm{Br}[\Delta^0 \to \gamma\gamma]$$

(although explicit formulae used to compute, for instance, bounds on SM $h \to \gamma\gamma$)