Swiss National Science Foundation

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Real Higgs triplet at the LHC

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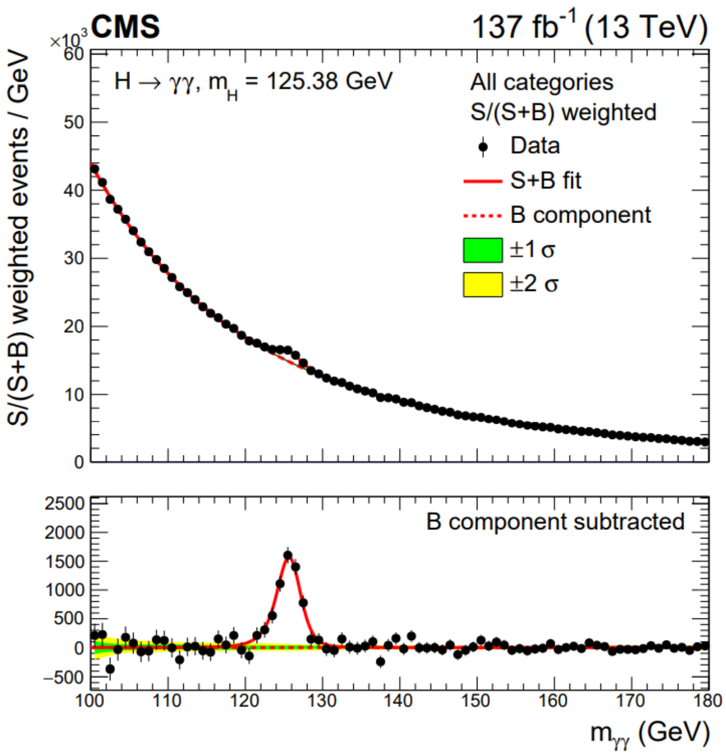
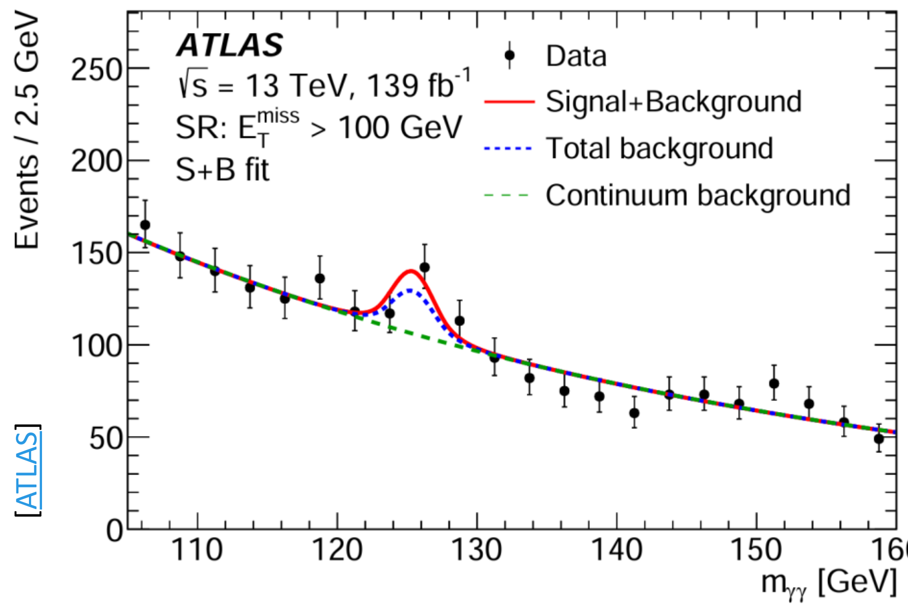
Hints for New Physics @152 GeV

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



[CMS]

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



[ATLAS]

Associated production (AP) mechanism

New physics in the scalar sector?

152 GeV
scalar?

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≈152 GeV mostly produced in association (AP)		

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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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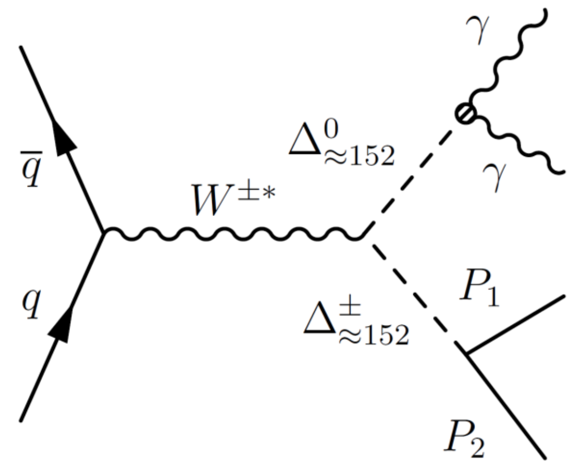

Produced in AP via Drell-Yan (DY)		

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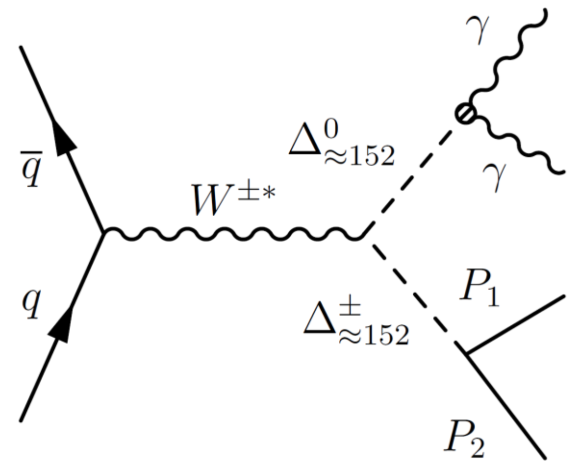

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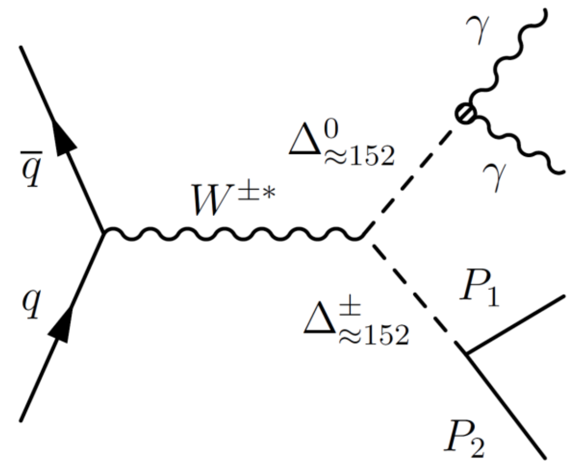


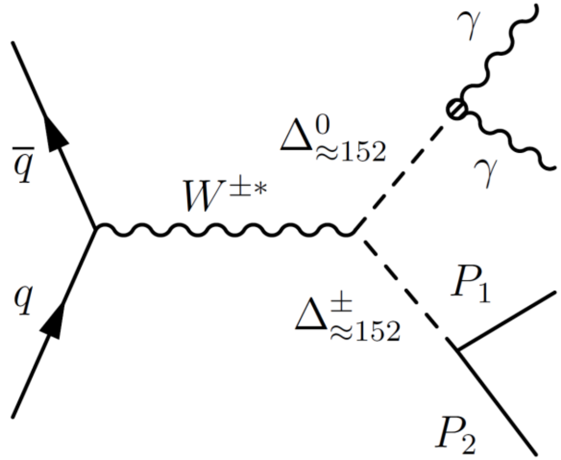
Produced in AP via Drell-Yan (DY)	$\Delta^0 WW$ but no $\Delta^0 ZZ$ (tree level, $\alpha_\Delta = 0$)	$v_\Delta \approx 2.3/3.4$ GeV ($m_{\Delta^0} \approx m_{\Delta^{\pm}}$)

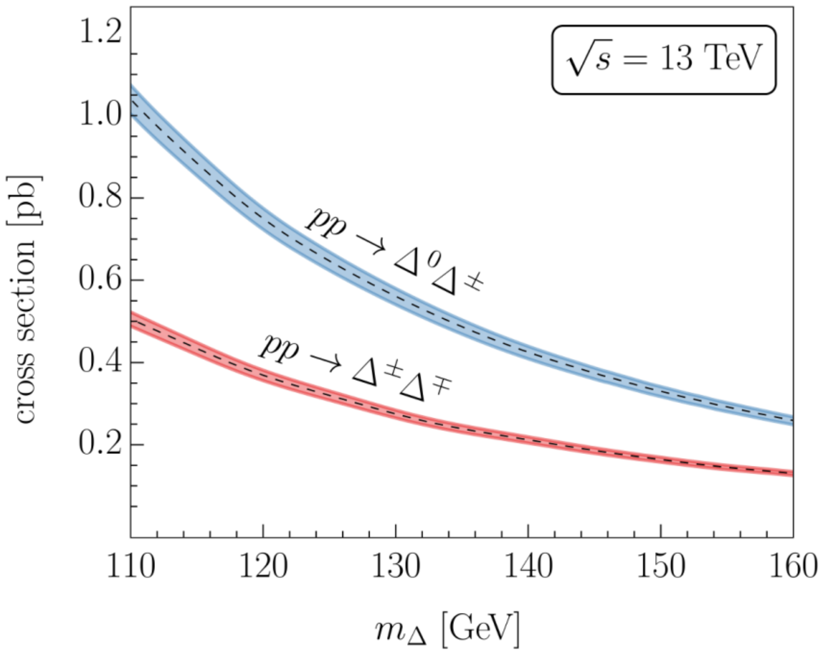
The ΔSM model

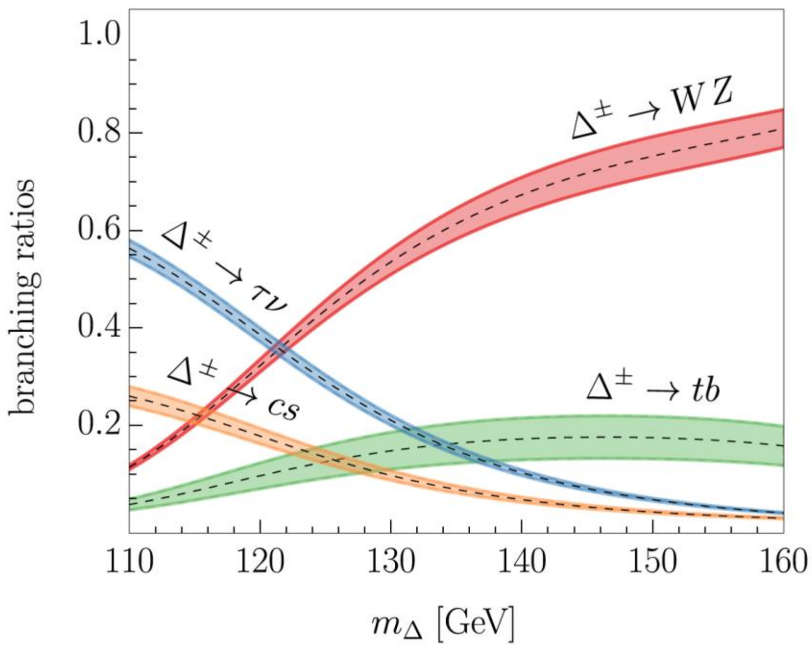
[S. Banik, GC, A. Crivellin et al.]

All relevant parameters are fixed by the model except

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



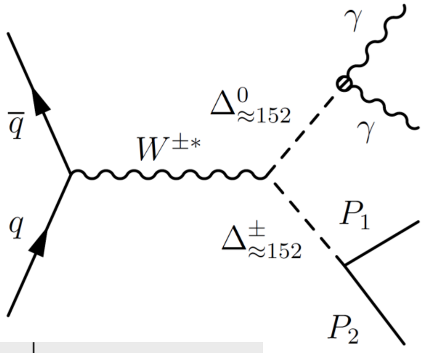




ATLAS: $H \to \gamma\gamma + X$

[ATLAS]

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

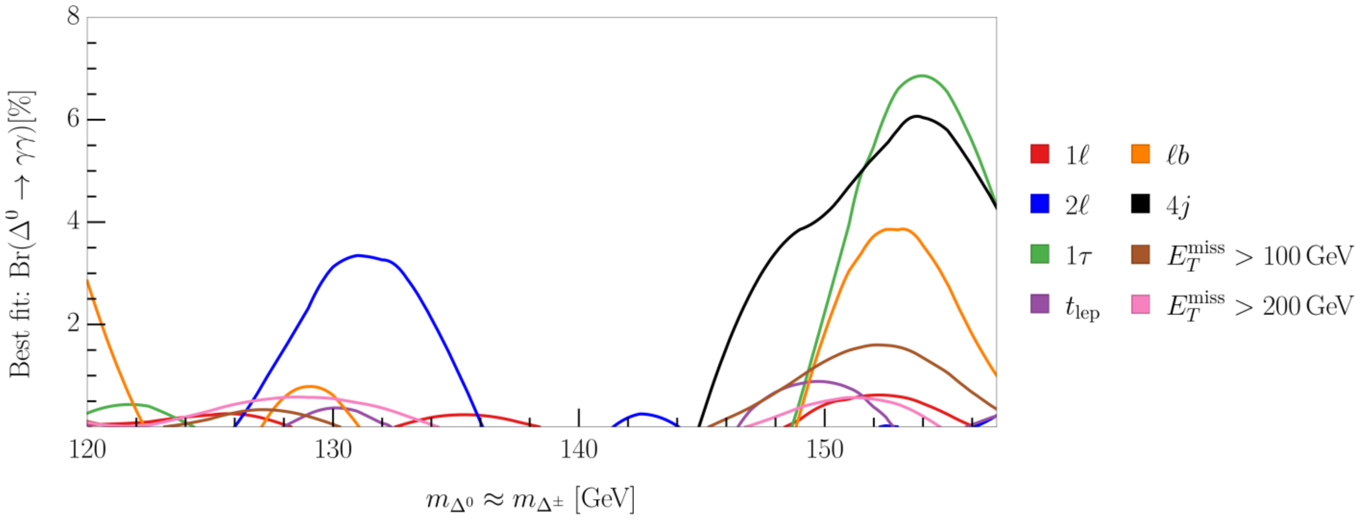


Target	Signal region	Detector level	Correlations
High jet activity	$4j$	$n_j \geq 4$	-
Top	ℓb t_{lep}	$n_\ell \geq 1, n_{b-\text{jet}} \geq 1$ $n_{\ell=e,\mu} = 1, n_{\text{jet}} = n_{b-\text{jet}} = 1$	-
Lepton	2ℓ 1ℓ	$ee, \mu\mu$ or $e\mu$ $n_\ell = 1, n_{t_{\text{had}}} = 0, n_{b-\text{jet}} = 0$	$< 26\%$
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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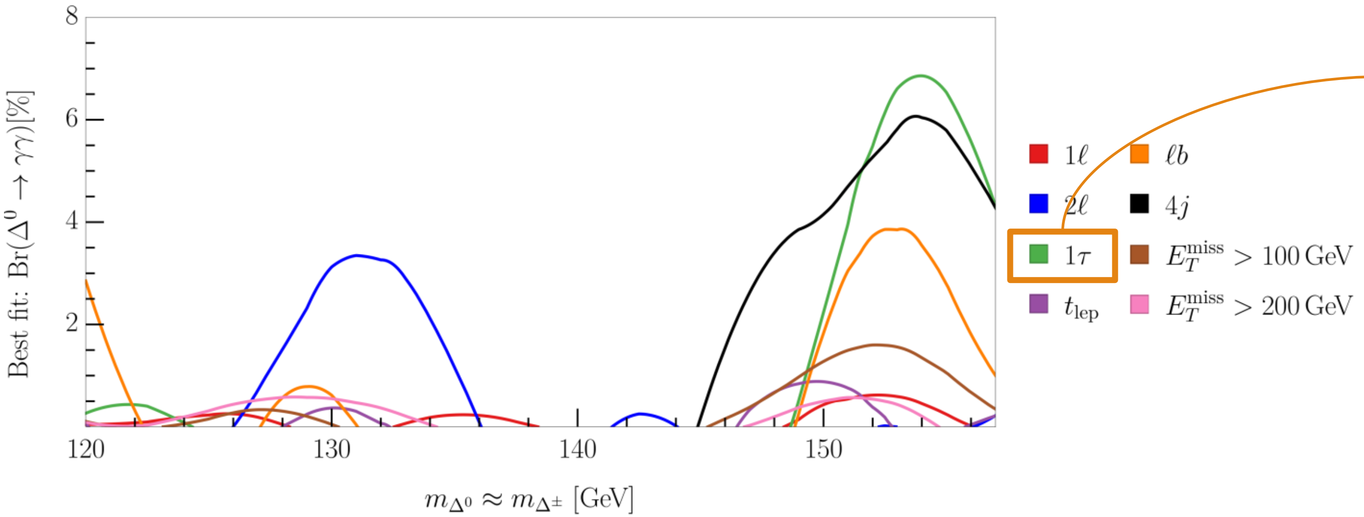

New! Moriond 2024

No excess in $\gamma\gamma + \tau\bar{\tau}$ but excess in $\gamma\gamma + \tau$

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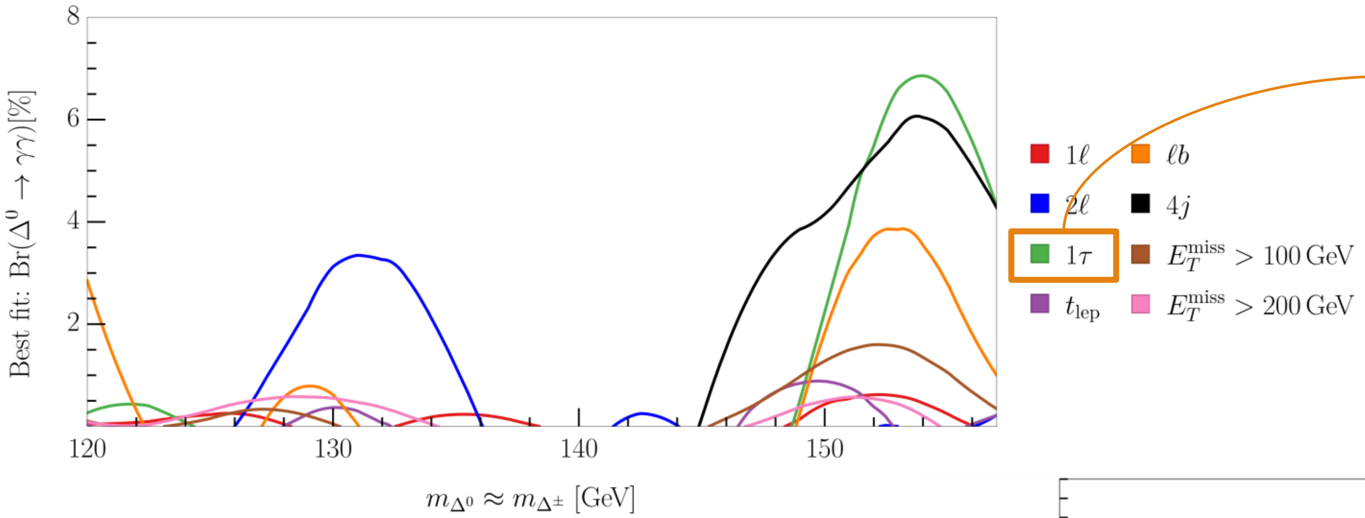

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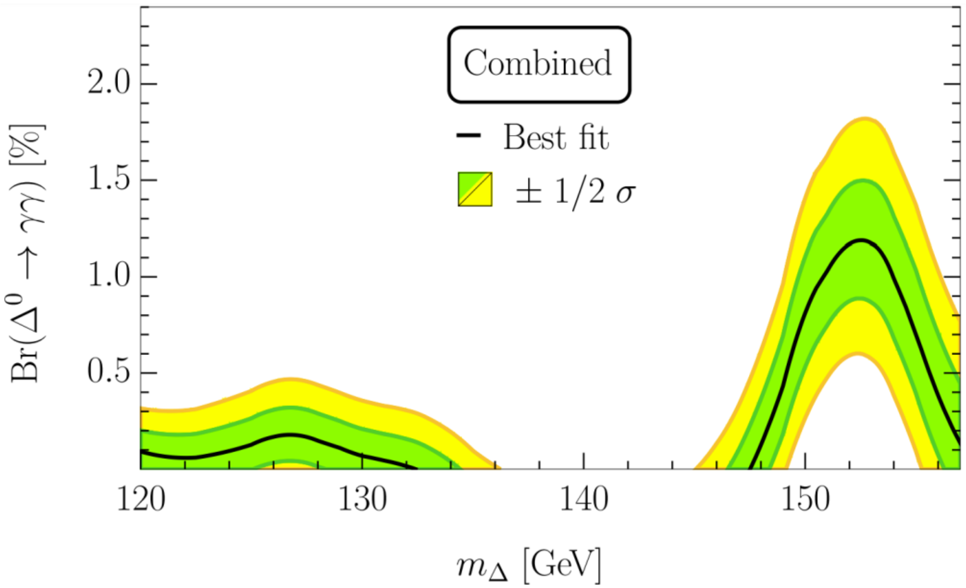


$Br(\Delta^0 \to \gamma\gamma) \approx 1\%$
preferred over SM by $\approx 4\sigma$

Conclusions

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

2. 152 GeV scalar mostly produced in associated production

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

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

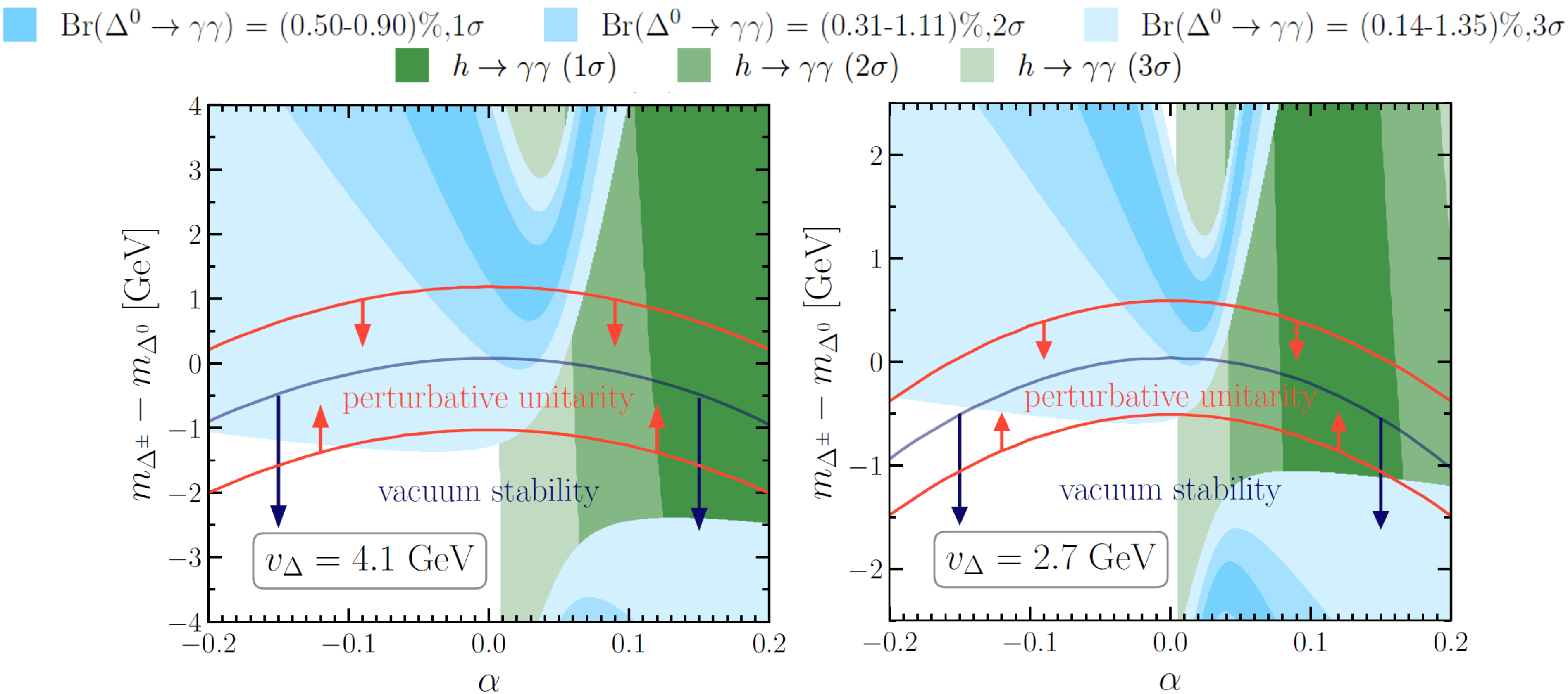
5. $\Delta^{\pm}$ suitable candidate for future colliders (FCCee) searches

BACK UP SLIDES

Scalar potential

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

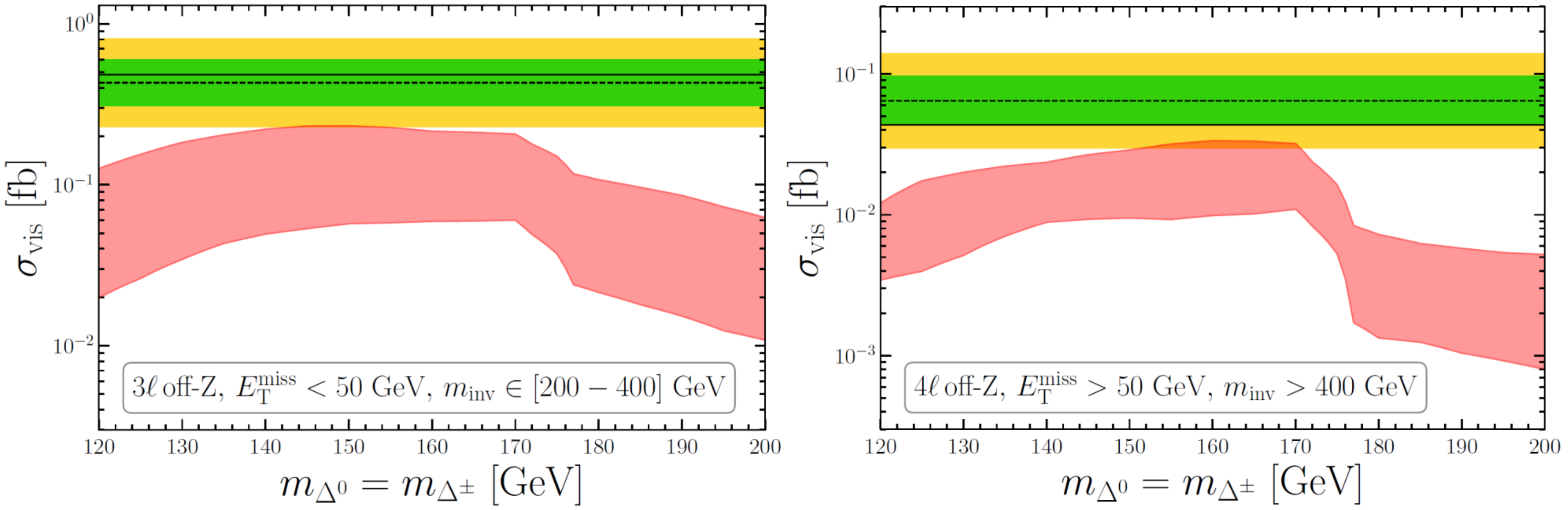
- Vacuum stability and perturbative unitarity in slight tension with other phenomenological observables
- Pointing to additional fields at or above the EW scale



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

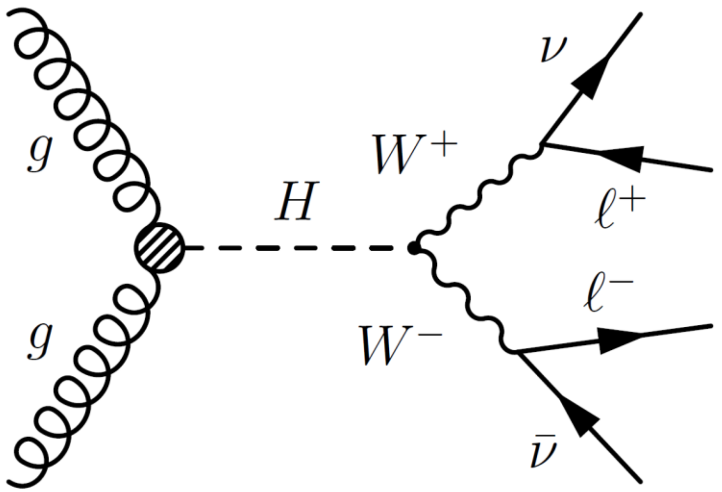
[GC, A. Crivellin et al.]

- **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)**

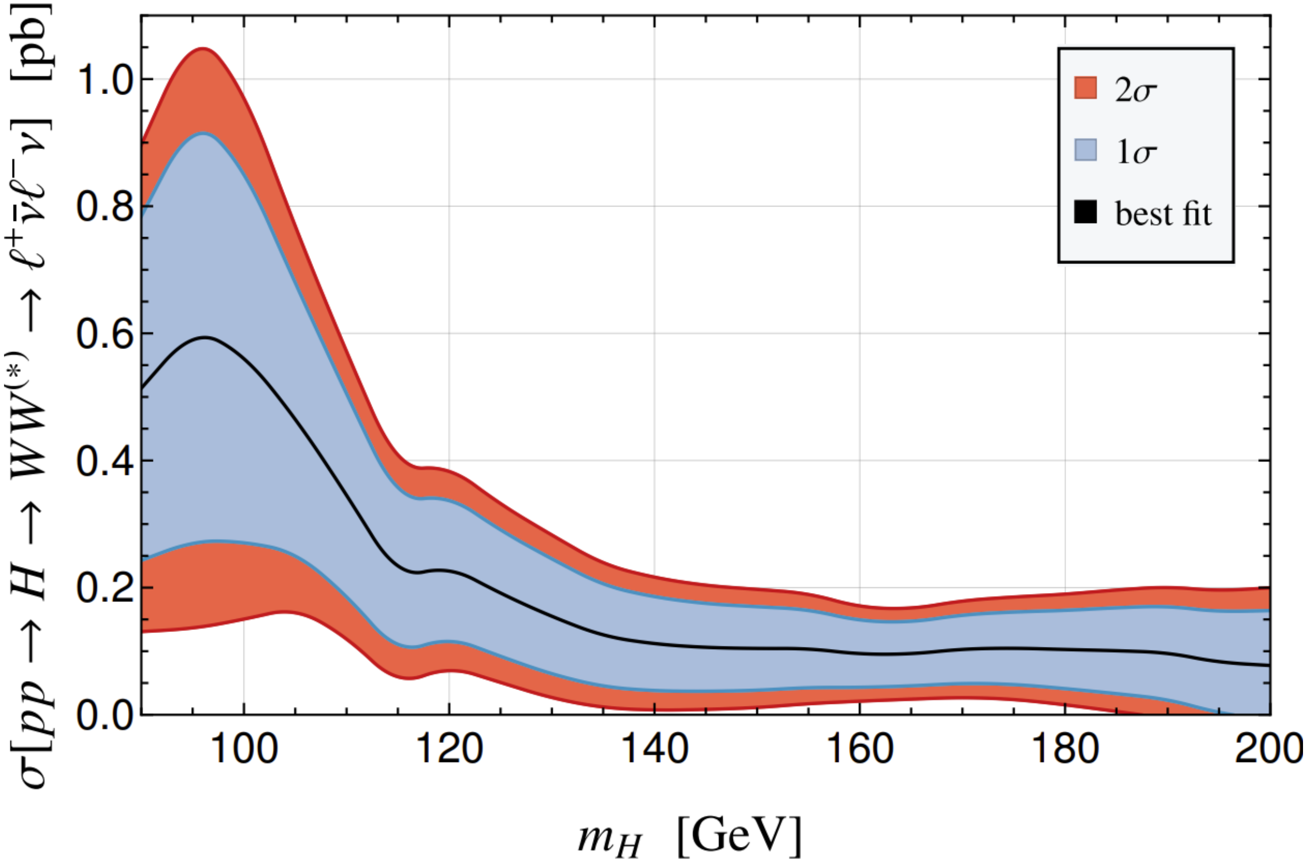


Leptonic decays → jet veto

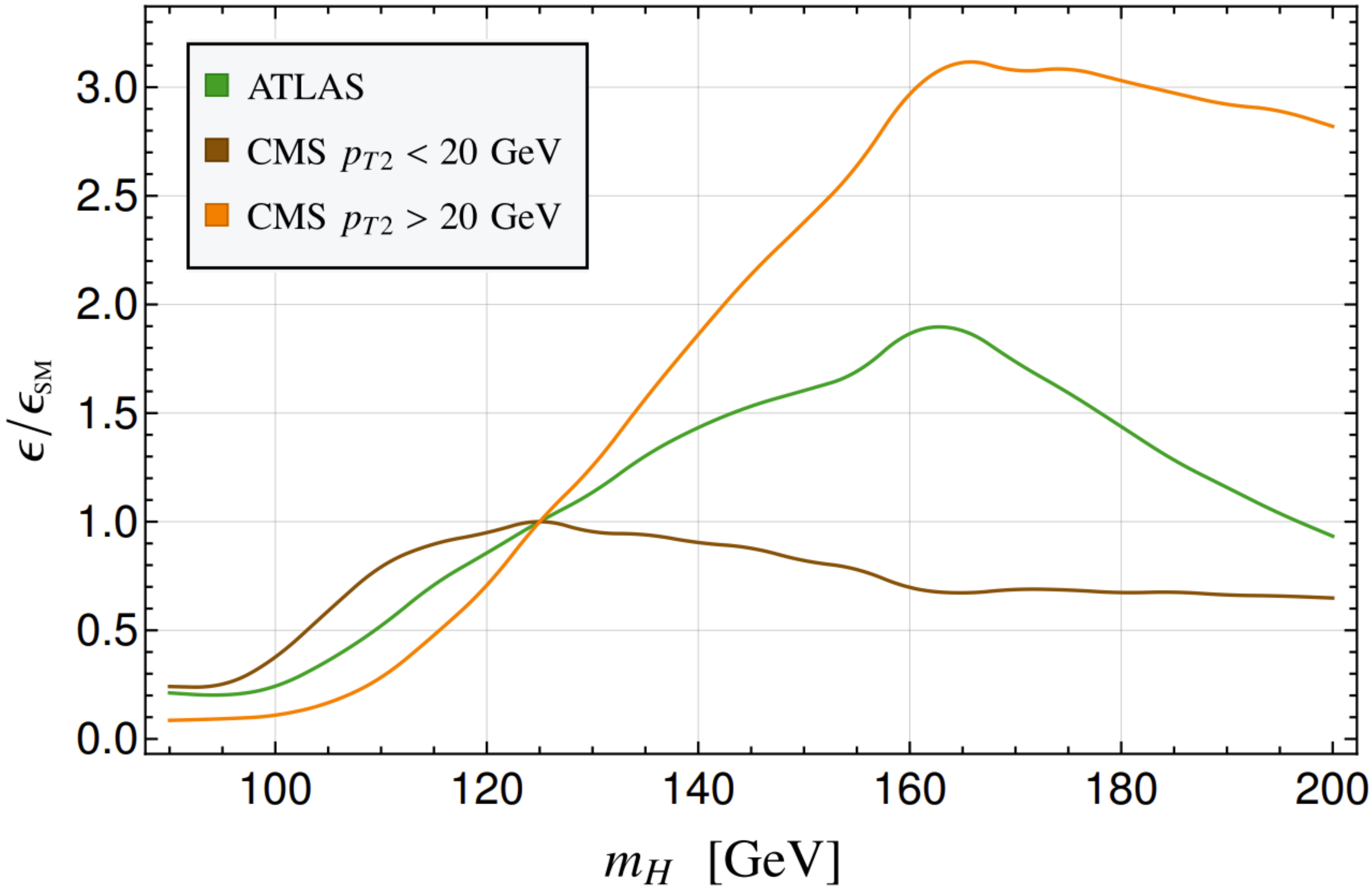
WW results

[GC, A. Crivellin et al.]

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

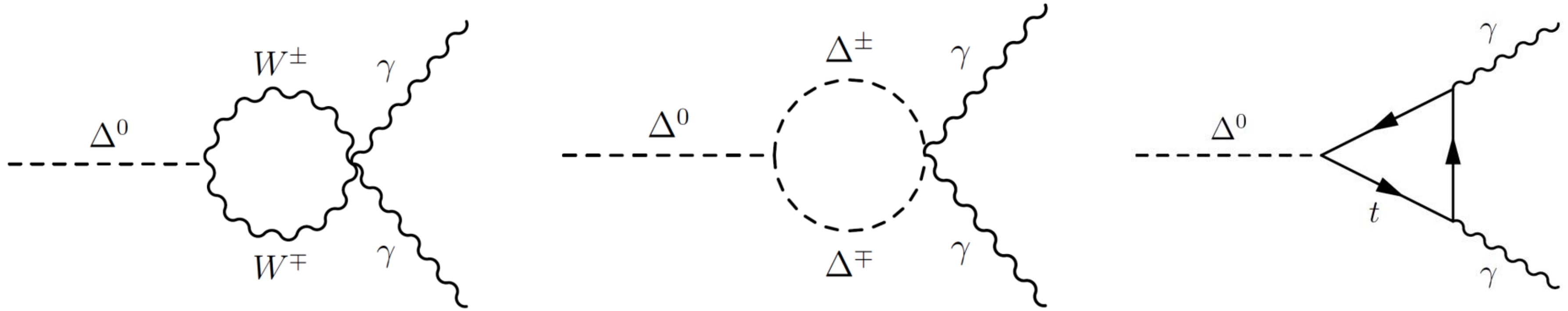


WW simulation efficiency [GC, A. Crivellin et al.]



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

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



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

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 $h \to \gamma\gamma$)