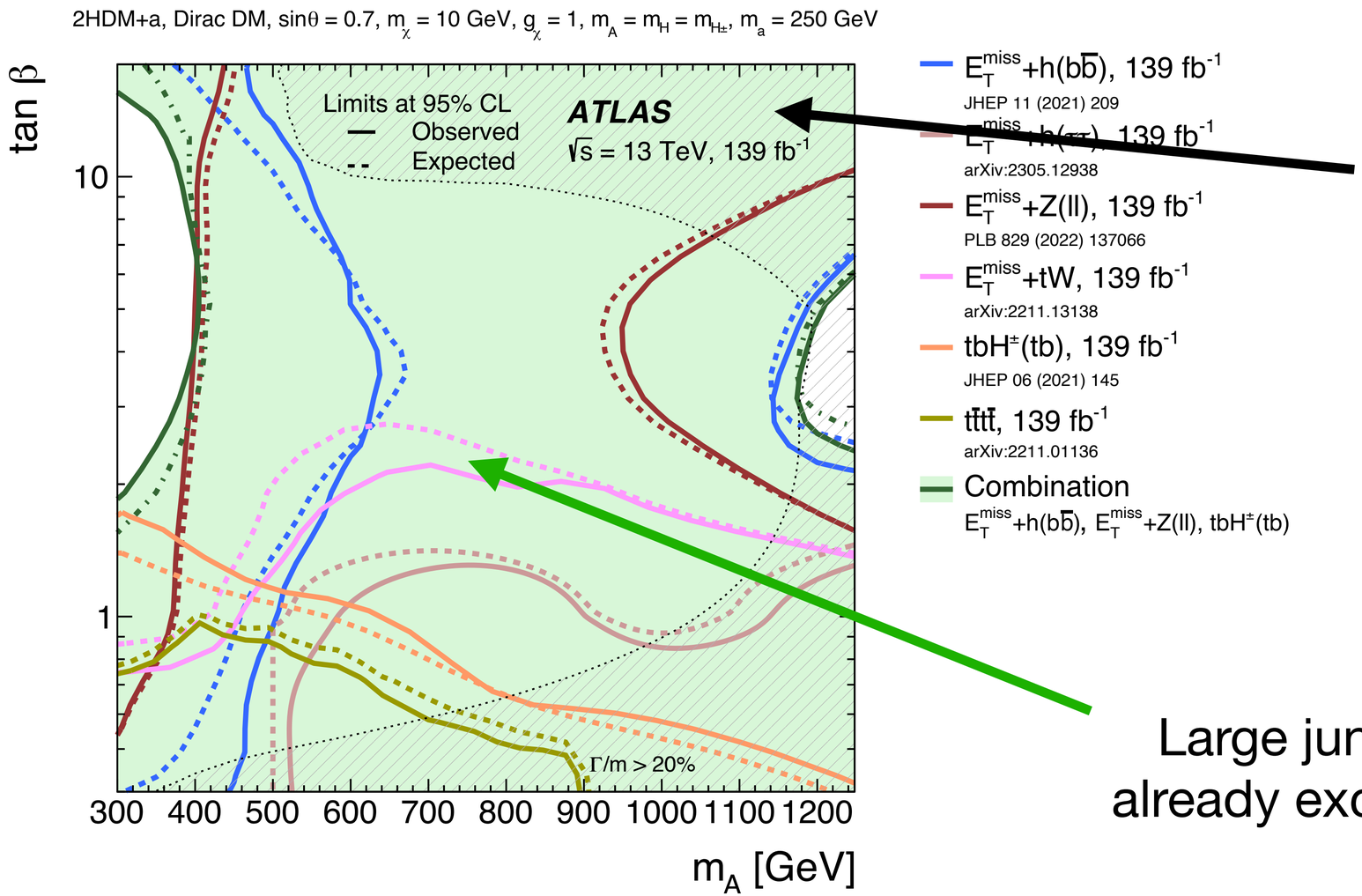
2HDMa kick-off Run 3

Uli Haisch,
MPI Munich

New Run 2-like benchmarks?



Large junks of debatable results, due to large non-decoupling effects

Large junks of 2D planes already excluded after Run 2

[plot from ATLAS, 2306.00641; similar CMS results]

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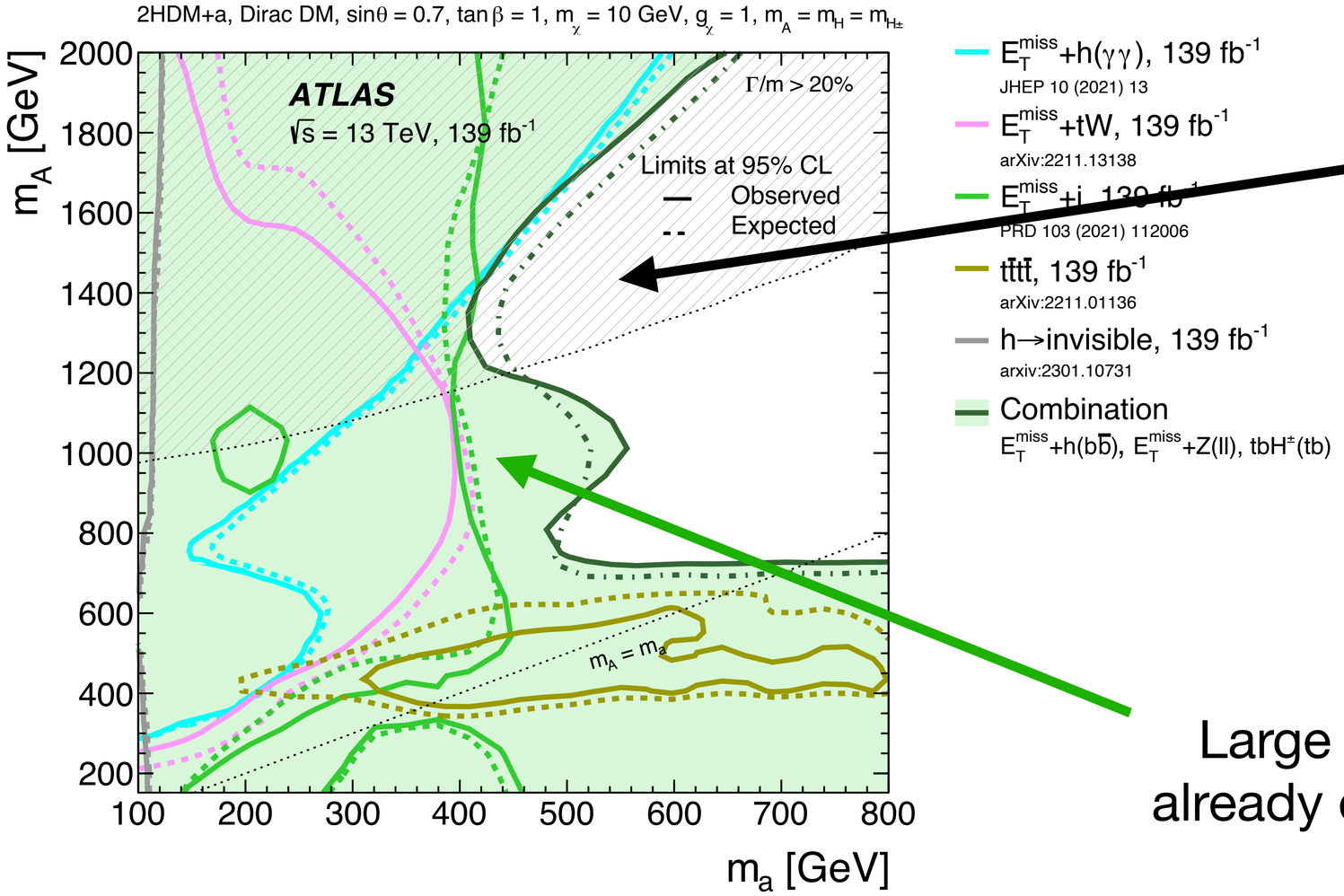

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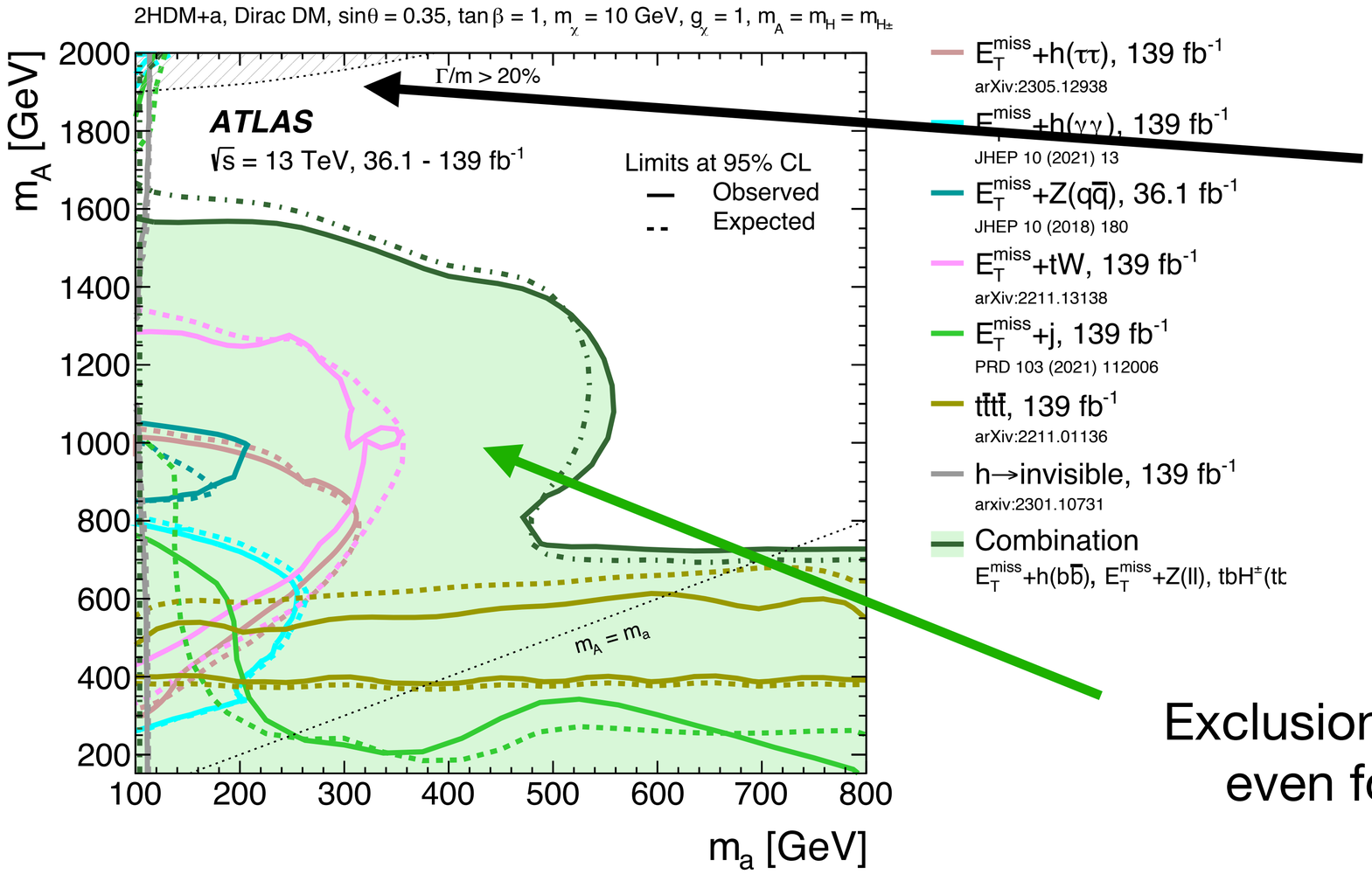

For smaller mixing angles, predictions trustworthy in most of parameter space

Exclusions remain strong even for sinθ = 0.35

[plot from ATLAS, 2306.00641; similar CMS results]

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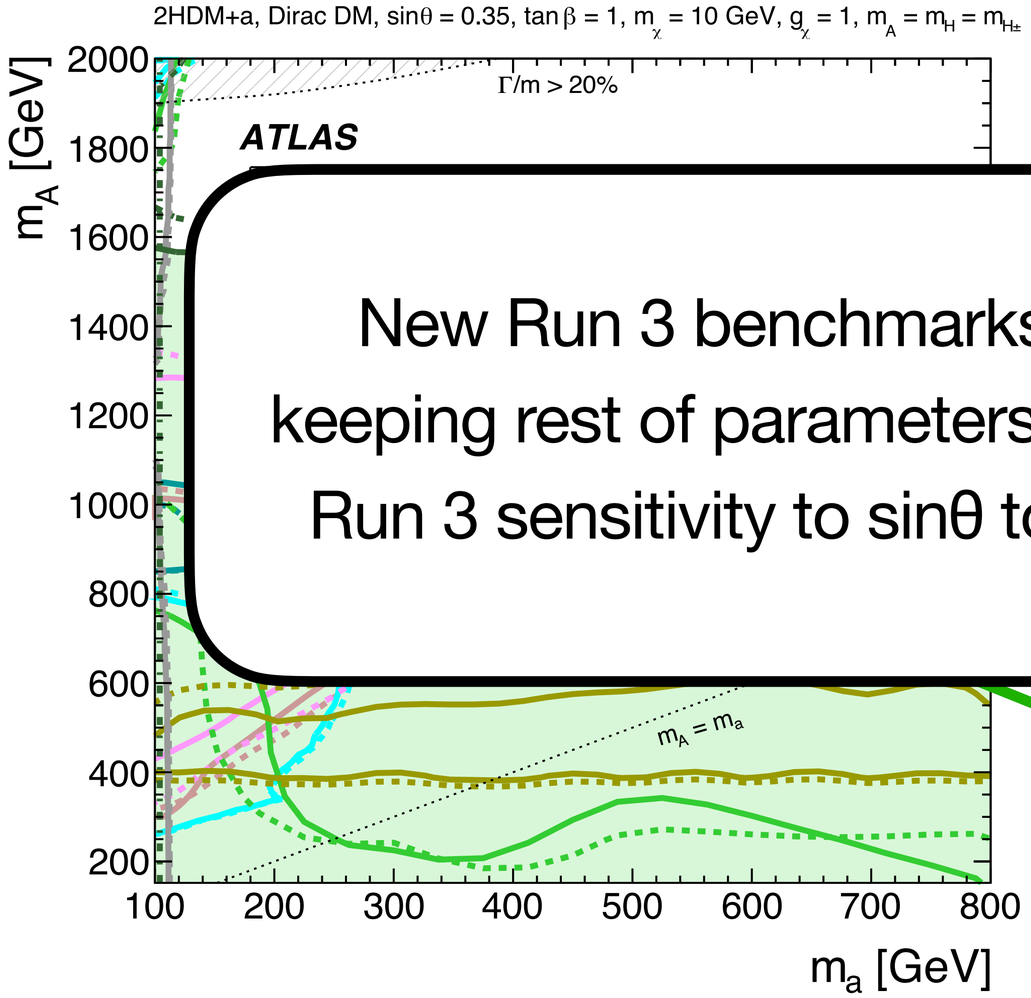


New Run 3 benchmarks could feature sinθ < 0.35, keeping rest of parameters unchanged. Should estimate Run 3 sensitivity to sinθ to come up with good choice

For smaller mixing angles, predictions in most space

Exclusions remain strong even for sinθ = 0.35

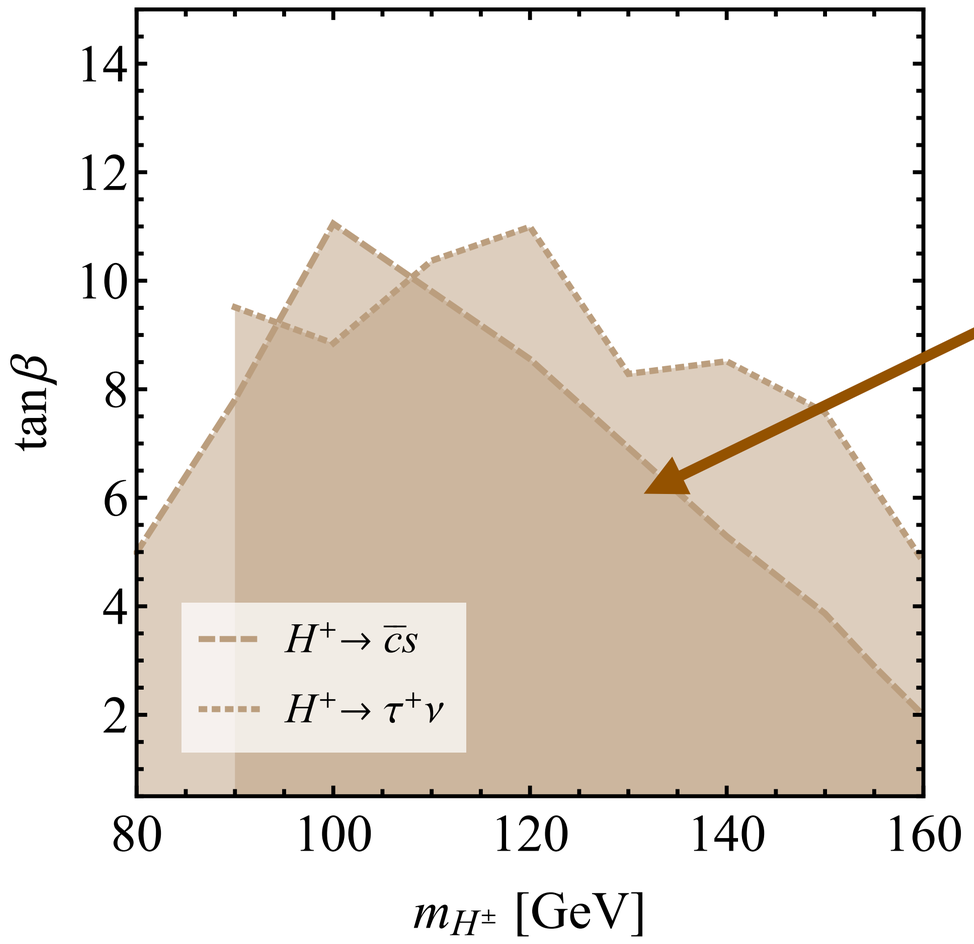
[plot from ATLAS, 2306.00641; similar CMS results]

Going beyond Run 2 benchmarks

- All Run 2 benchmarks feature type-II Yukawas & degenerate 2HDM Higgs mass spectrum. Assumption of degenerate 2HDM Higgs masses avoid constraints from EWPOs, but in type II leads to TeVish 2HDM spectrum, as flavor physics requires charged Higgs to be heavier than about 600 GeV
- However, assumption of degenerate 2HDM Higgs masses artificially limits LHC phenomenology, since certain processes are kinematically impossible

Going beyond Run 2 benchmarks

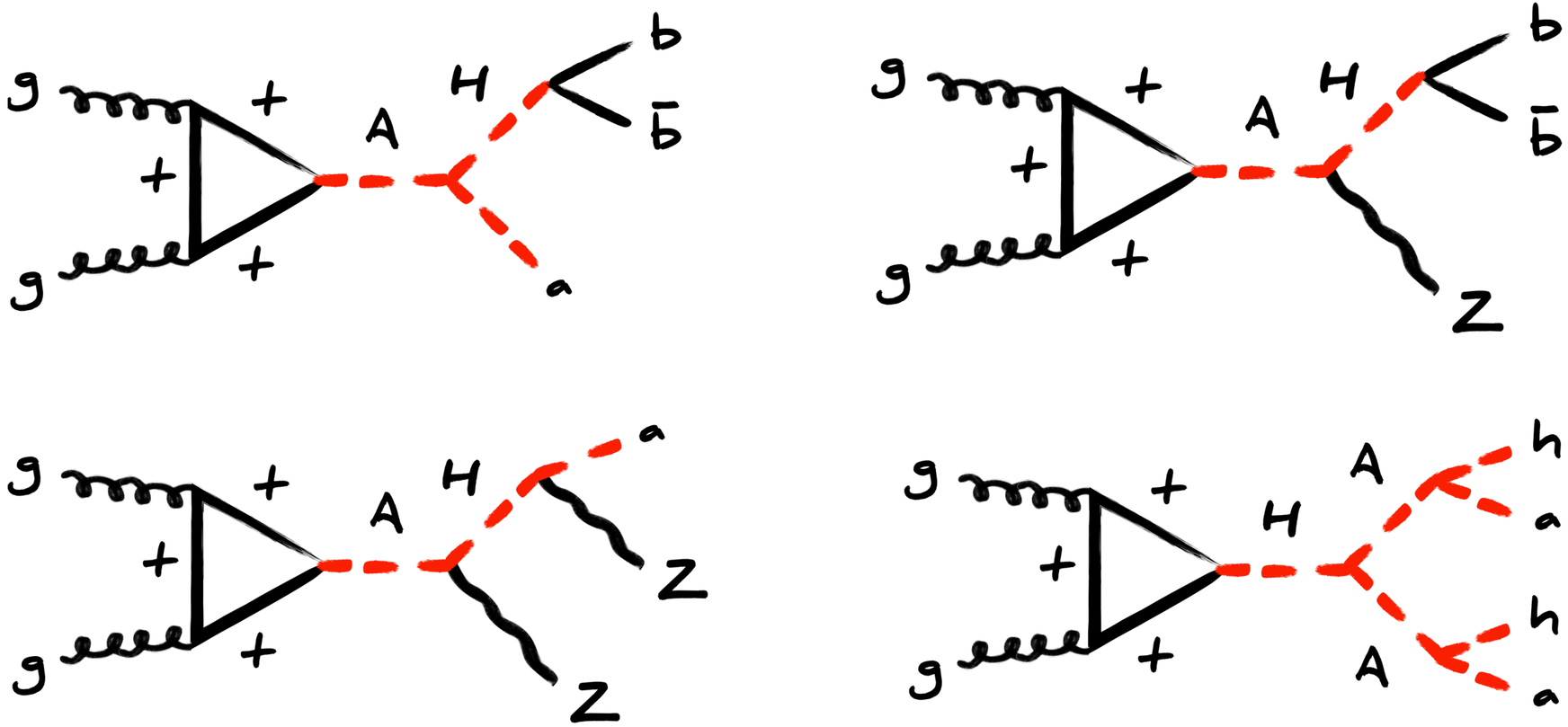
[Ilia et al., 2404.05704]



Light charged Higgses can be probed in top decays, but in type-I 2HDMs bounds are weak

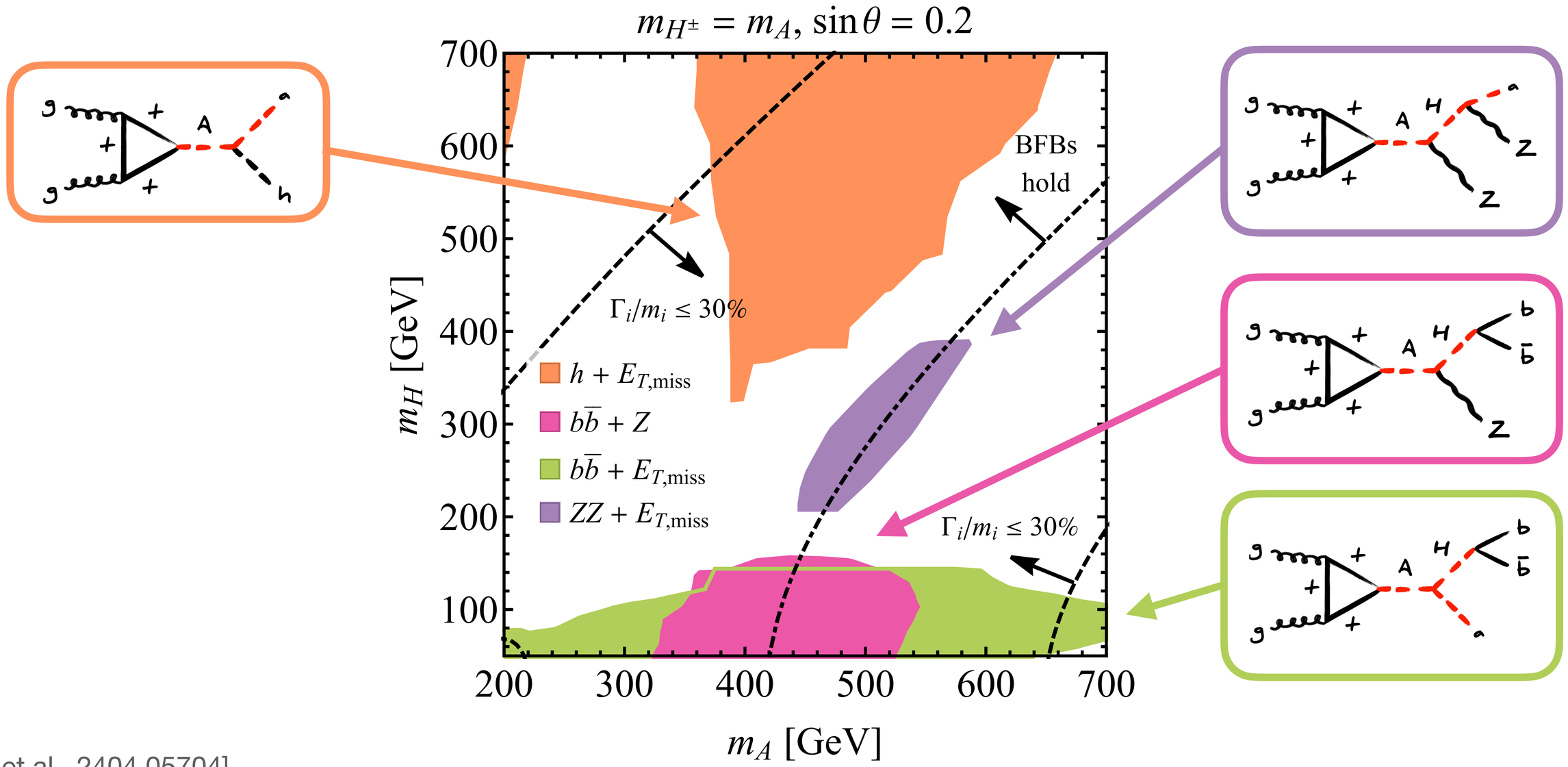
A light & non-degenerate 2HDM sector is allowed in type I, if tanβ is not too small

Going beyond Run 2 benchmarks



In case of non-degenerate 2HDM Higgses, new MET & non-MET channels open up

Old & new 2HDM+a signatures in type I



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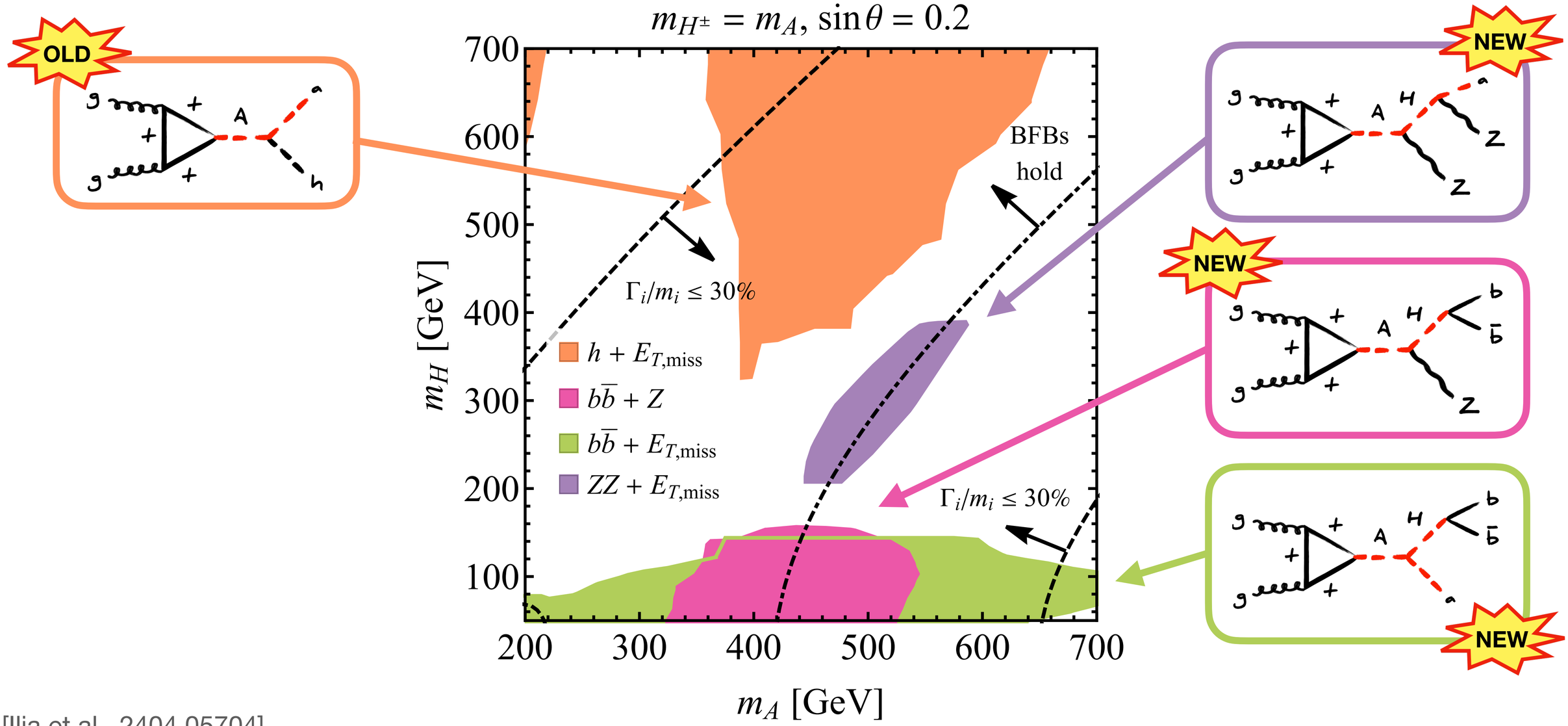

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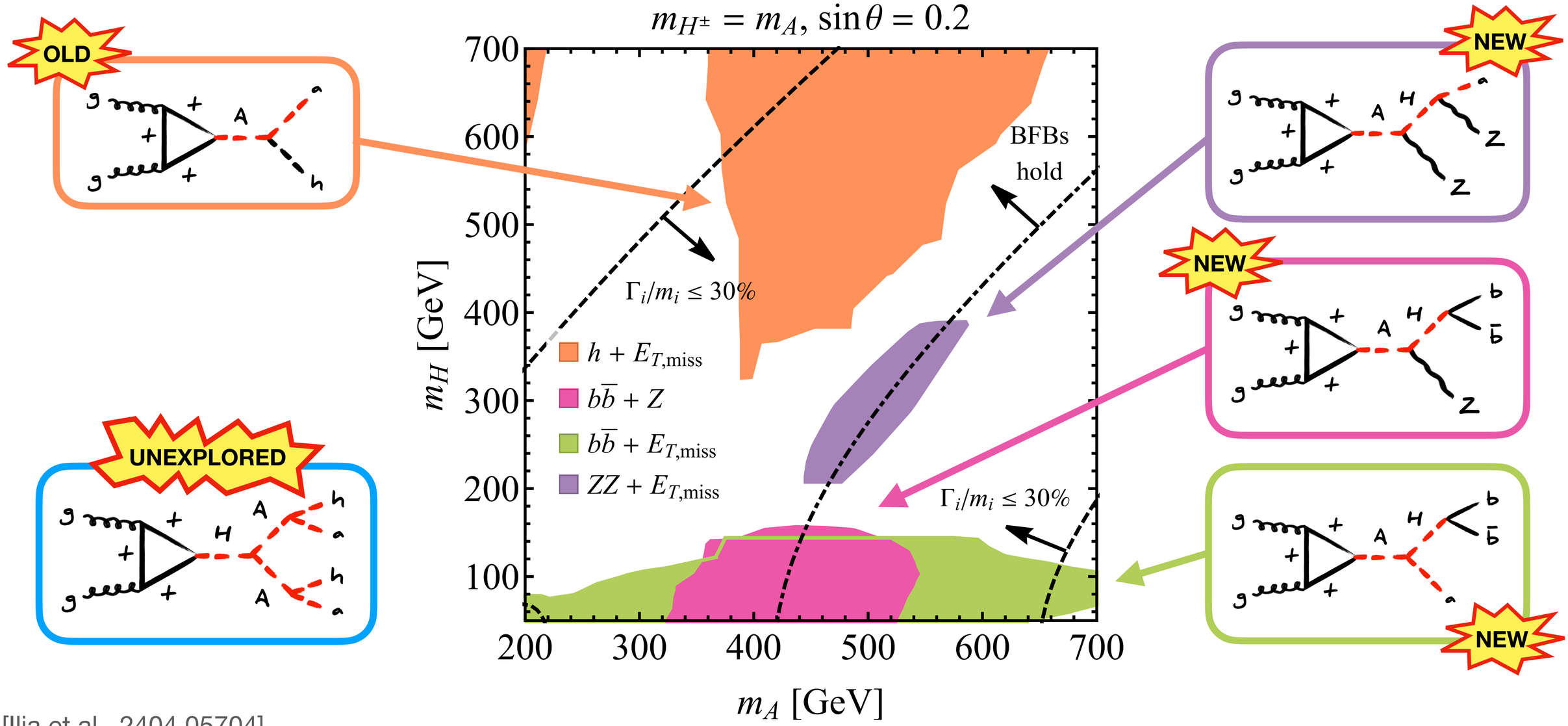

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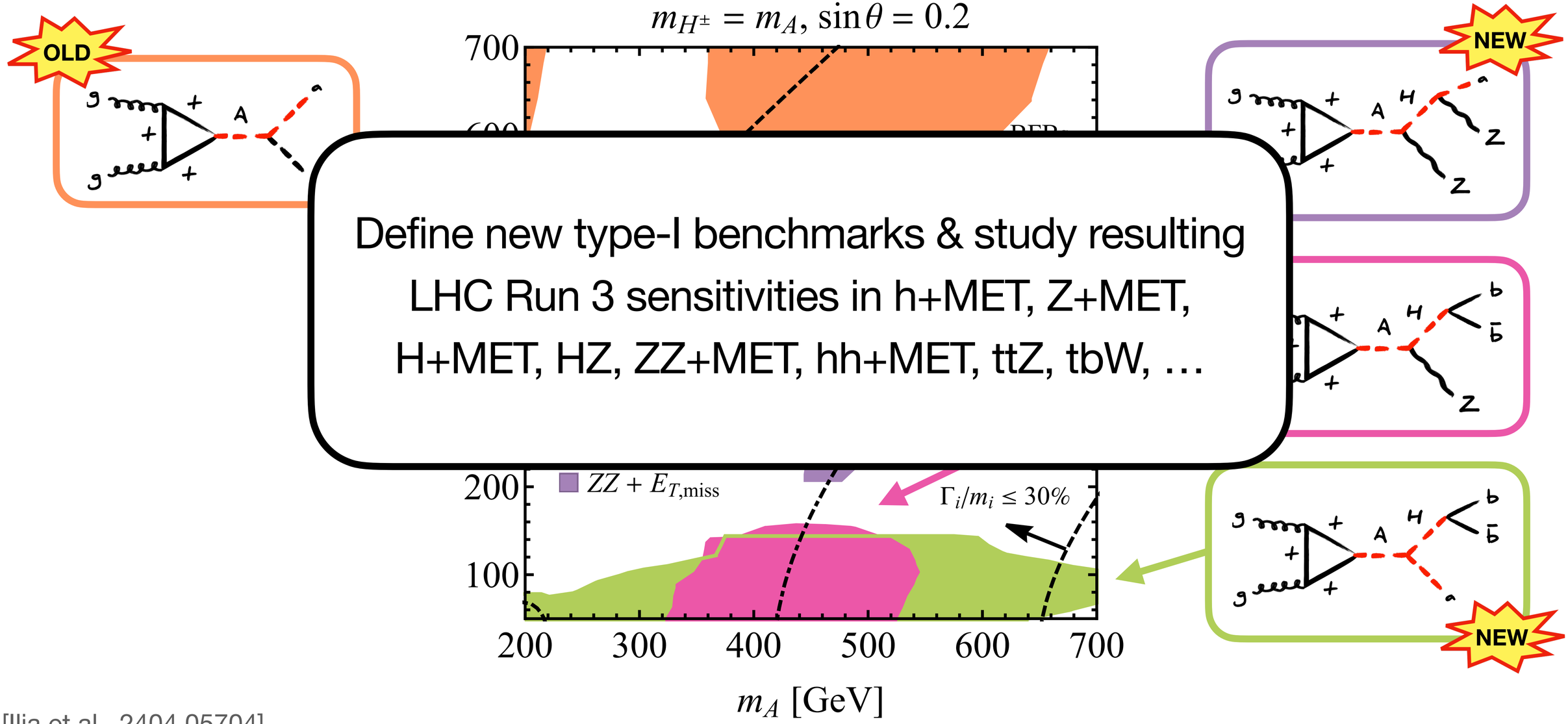


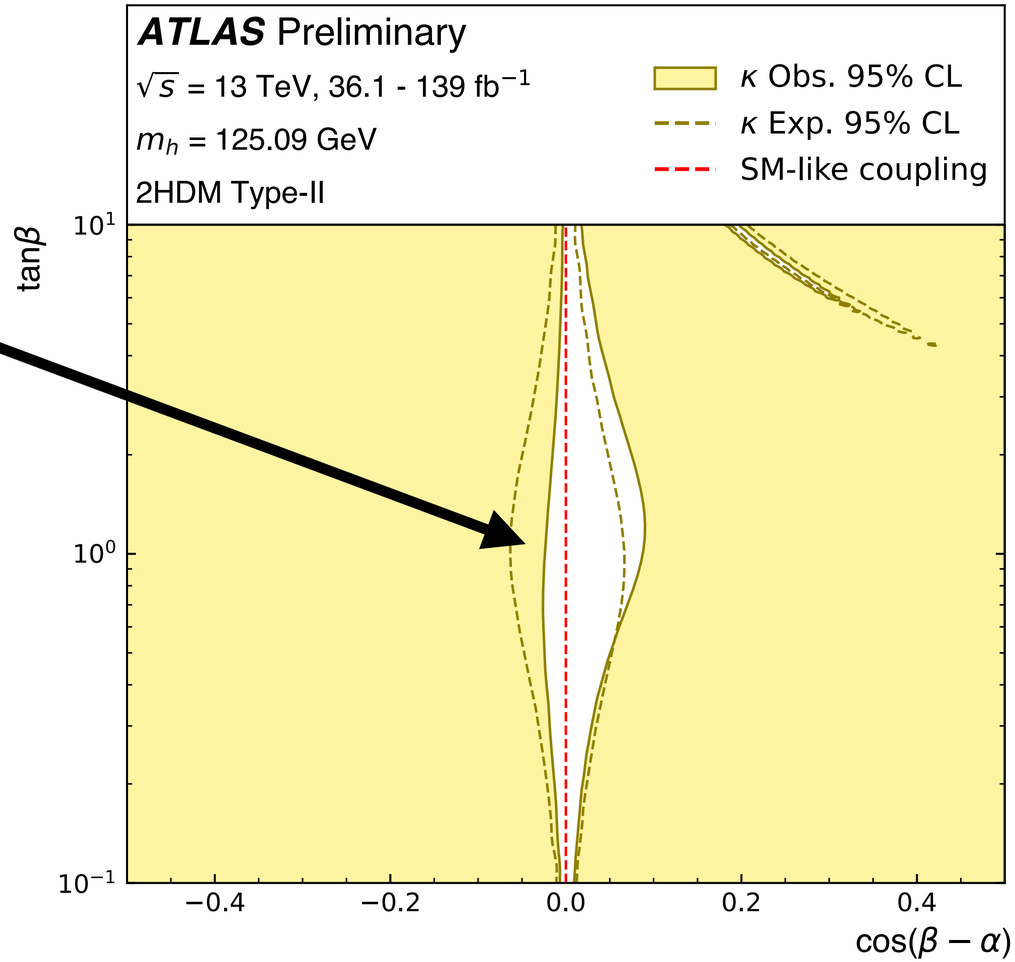
Define new type-I benchmarks & study resulting LHC Run 3 sensitivities in h+MET, Z+MET, H+MET, HZ, ZZ+MET, hh+MET, ttZ, tbW, …

[Ilia et al., 2404.05704]

Benchmarks with mis-alignment?

In type-II 2HDMs little room for mis-alignment. Similar picture in lepton-specific & flipped variants

[ATLAS-CONF-2023-052]



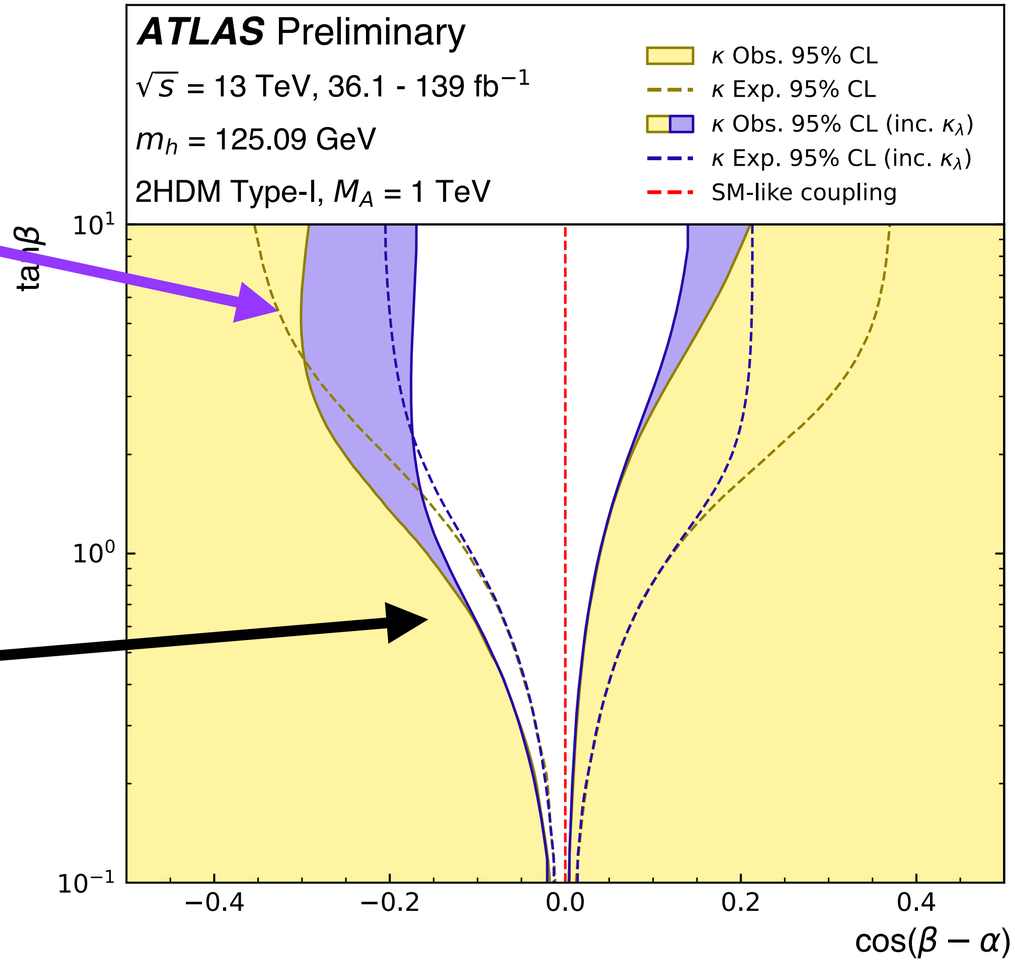
[also CMS results]

Benchmarks with mis-alignment?

[ATLAS-CONF-2023-052]

Inclusion of double-Higgs measurements via κ_λ improve constraints

In type-I 2HDMs significantly more space for mis-alignment due to possible fermiophobia



[also CMS results]

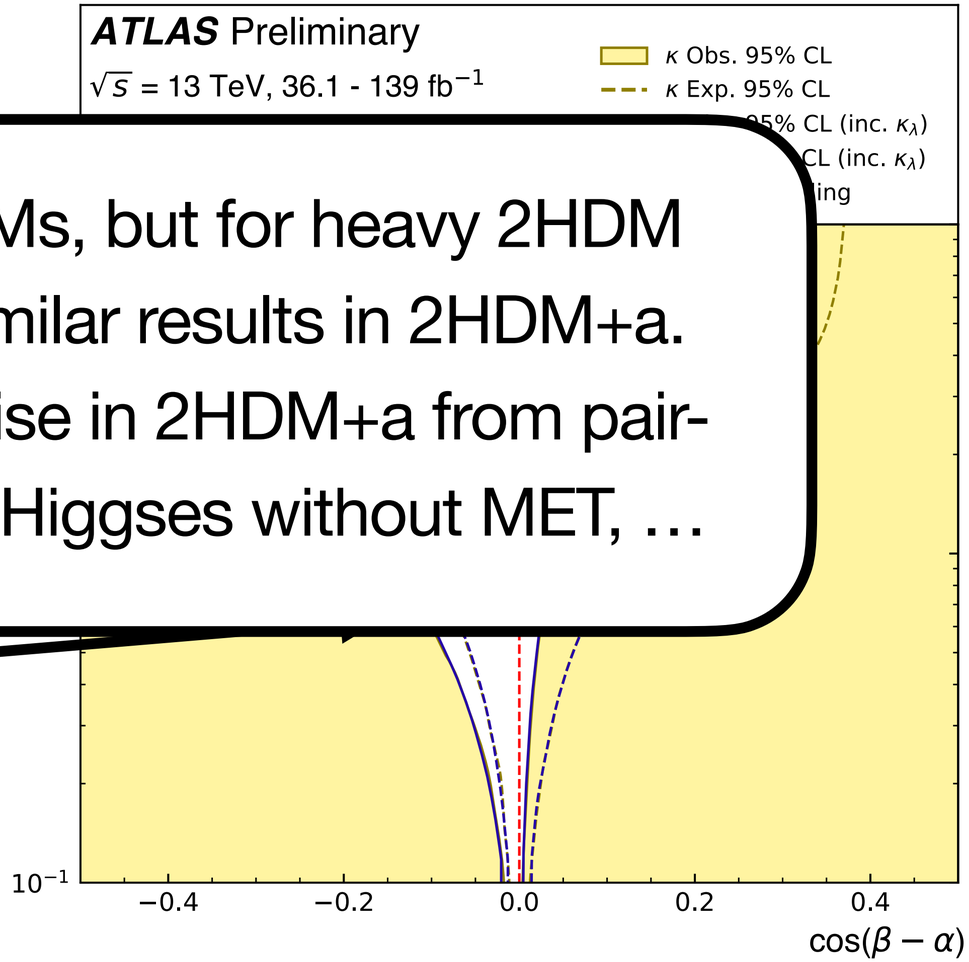
Benchmarks with mis-alignment?

[ATLAS-CONF-2023-052]

Inclusion of double-Higgs
mea
im

LHC results are for pure 2HDMs, but for heavy 2HDM Higgses naively should get similar results in 2HDM+a. New phenomenology could arise in 2HDM+a from pair-production of lightish non-SM Higgses without MET, …

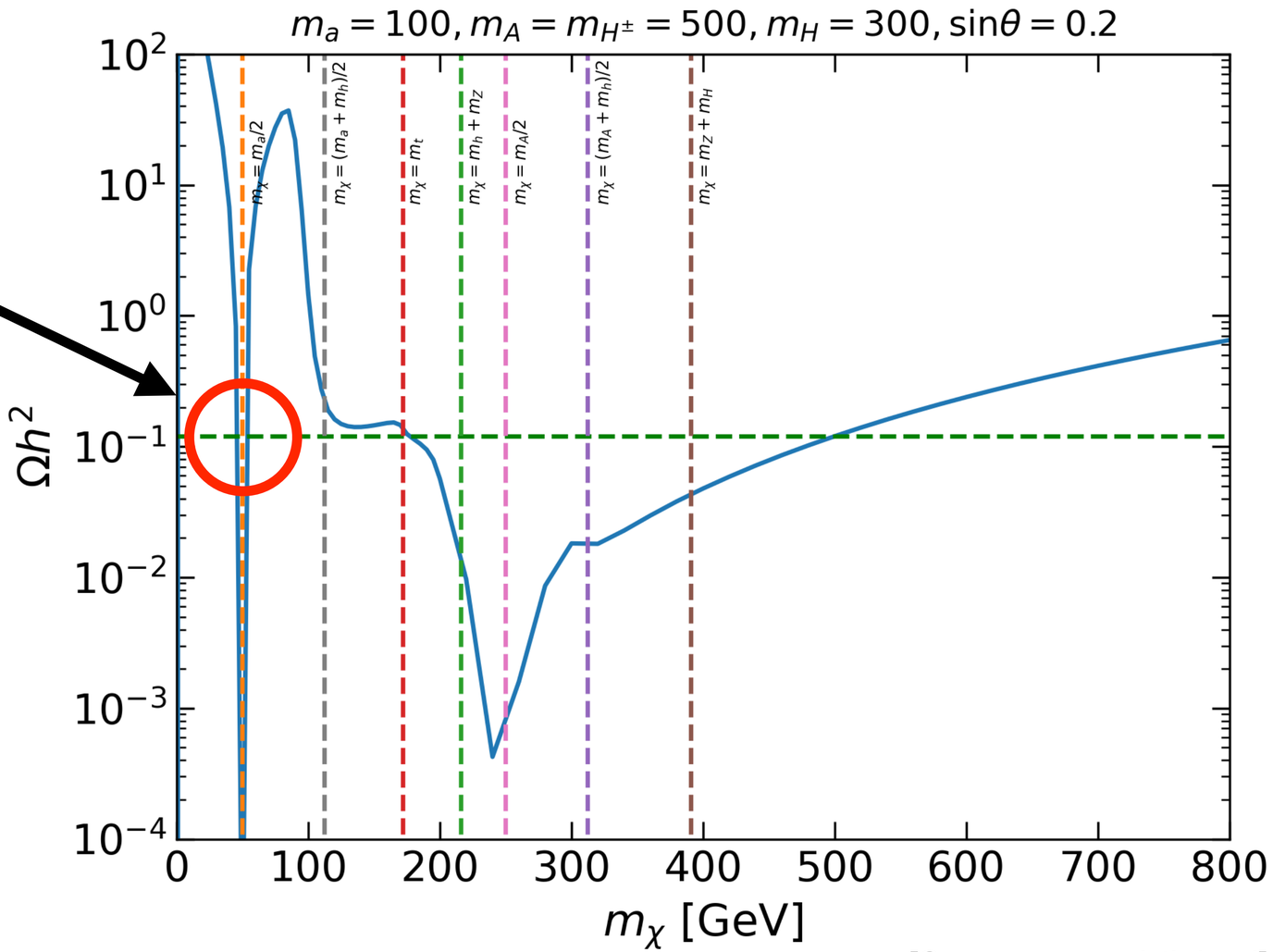
In type-
more space for mis-alignment
due to possible fermiophobia



[also CMS results]

Relic density in 2HDM+a

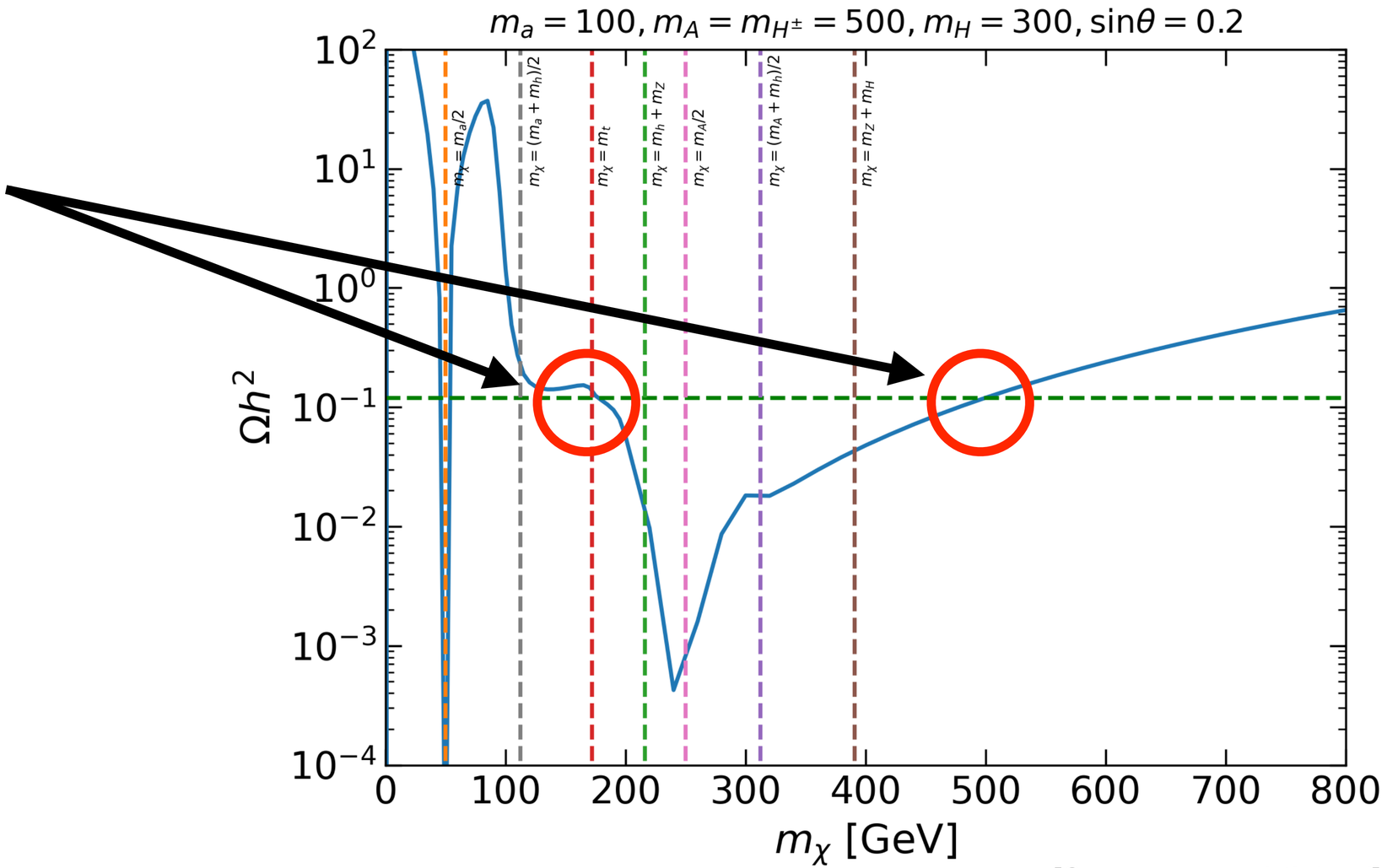
Correct relic density in 2HDM+a most always achieved by tuning DM mass to “a funnel”



[Spyros, unpublished]

Relic density in 2HDM+a

But other parameter points with a viable DM phenomenology exist in general



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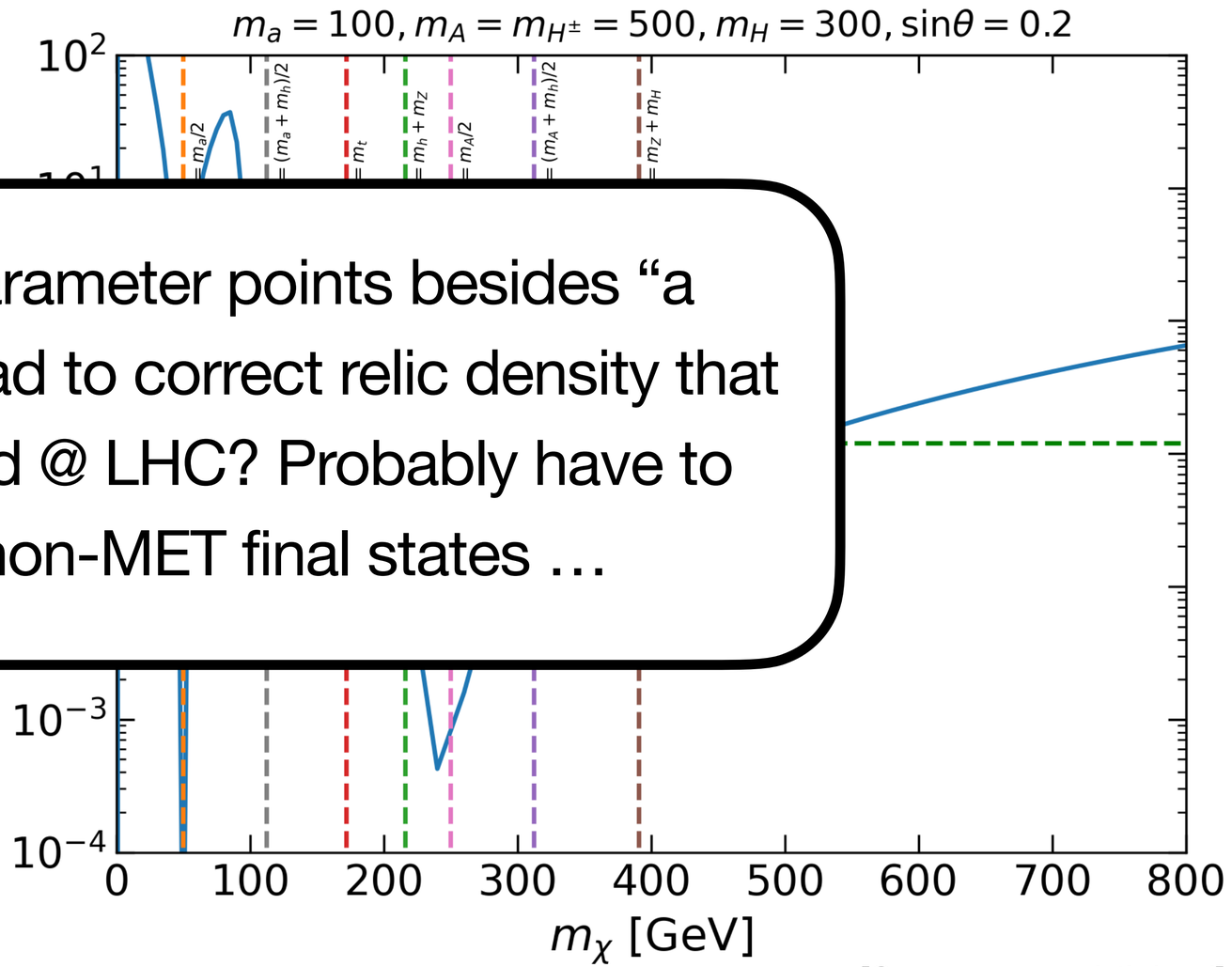
Relic density in 2HDM+a

But other parameter points with a viable DM phenomenol exist in genera

Are their parameter points besides “a funnel” that lead to correct relic density that can be tested @ LHC? Probably have to look @ non-MET final states …



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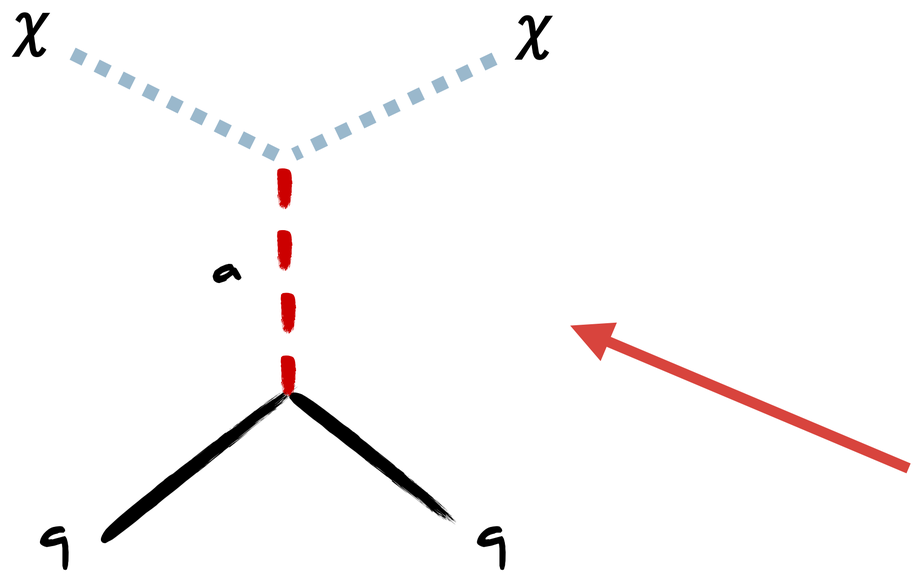
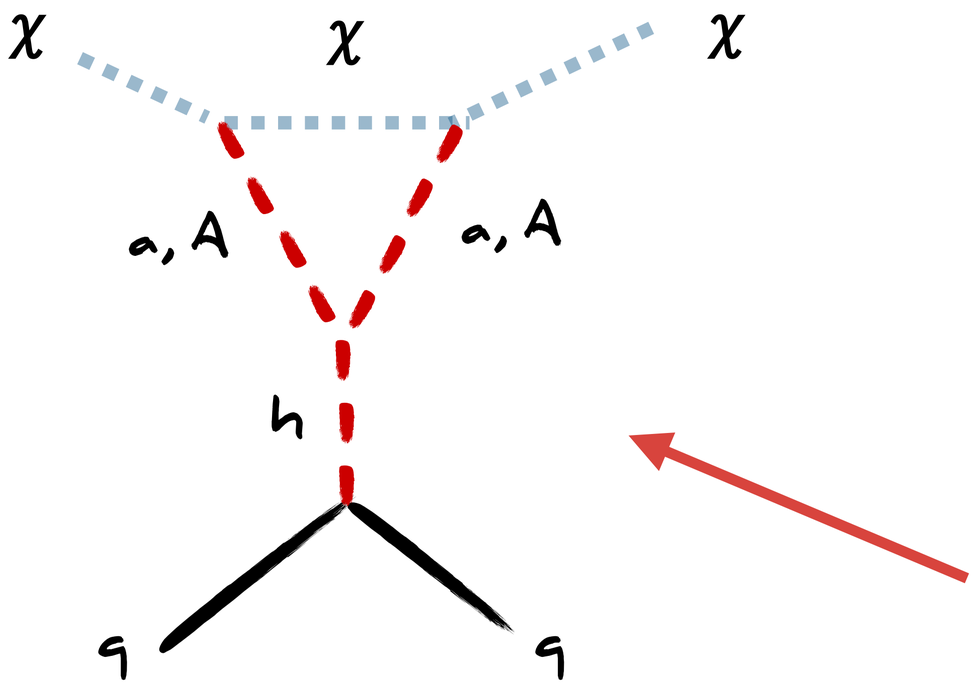
Direct detection (DD) in 2HDM+a



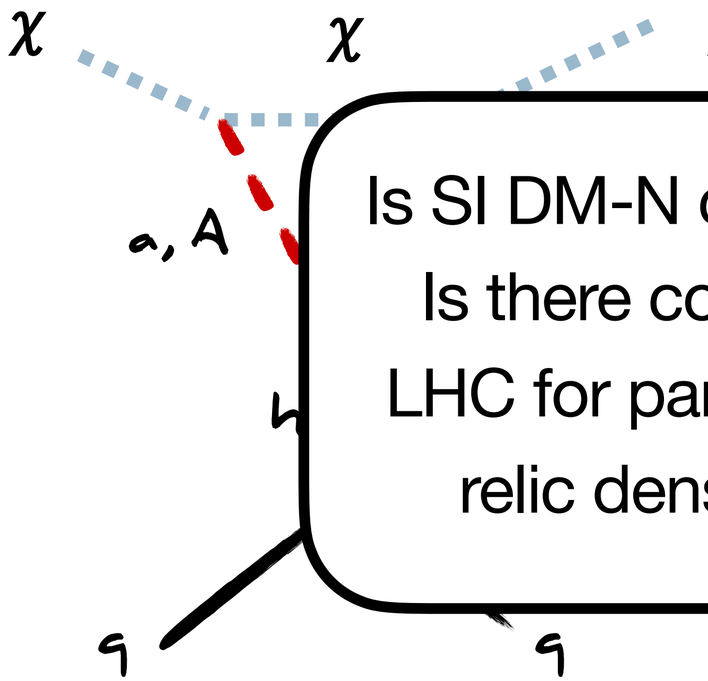
Due to pseudo-scalar nature of a, tree-level DM-N cross section spin-dependent (SD) & momentum-suppressed

Direct detection (DD) in 2HDM+a



Spin-independent (SI) DM-N cross section arises @ 1-loop level from “Higgs penguin” & typically provides strongest DD constraints

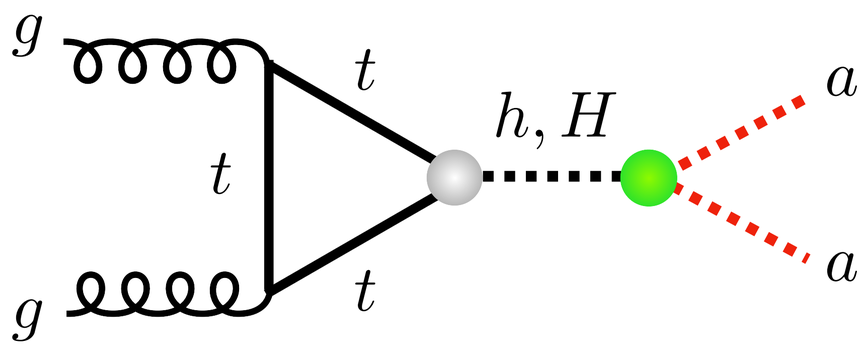
Direct detection (DD) in 2HDM+a

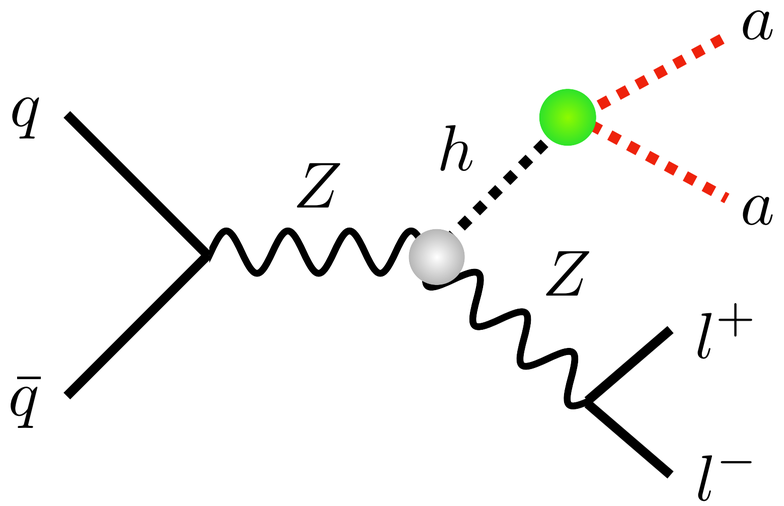


Is SI DM-N cross section always dominant? Is there complementarity between DD & LHC for parameter points that give correct relic density? Many open question …

DM-N cross section arises @ 1-loop level from "Higgs penguin" & typically provides strongest DD constraints

LLPs in 2HDM+a



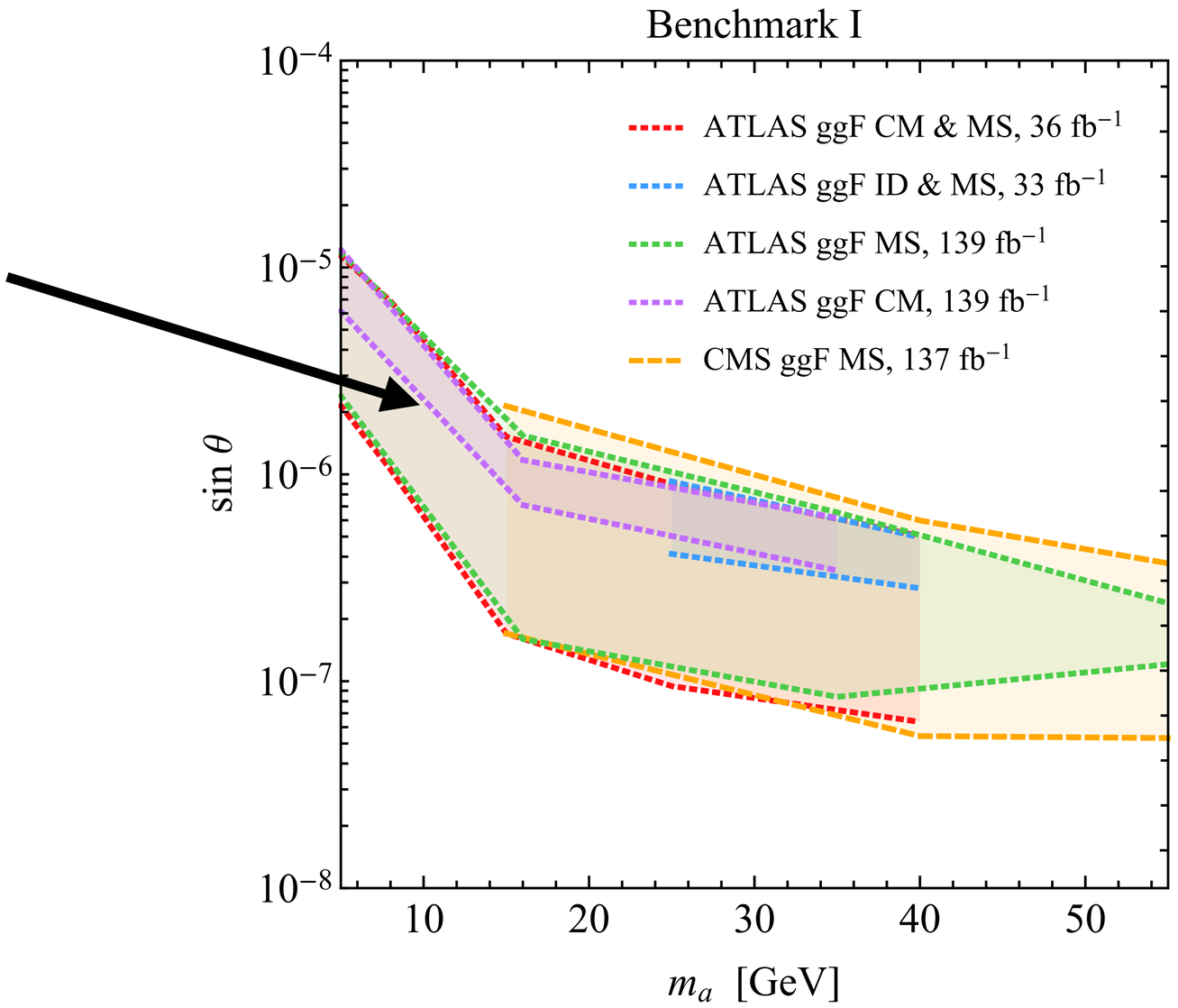


If sinθ is small & DM is decoupled or kinematically inaccessible in decay of a, a is long-lived. Dominant production is ggF or associated production of h, H (h)

[Uli & Luc, 2302.02735]

LLPs in 2HDM+a

Depending on mass of a, sinθ in range of 10^{-7} to 10^{-5} excluded by LHC LLP searches for displaced jets in ggF Higgs production



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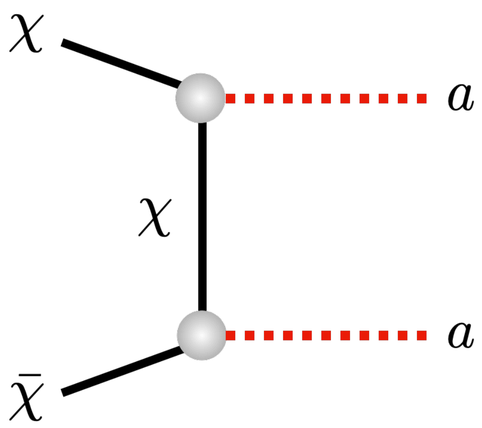
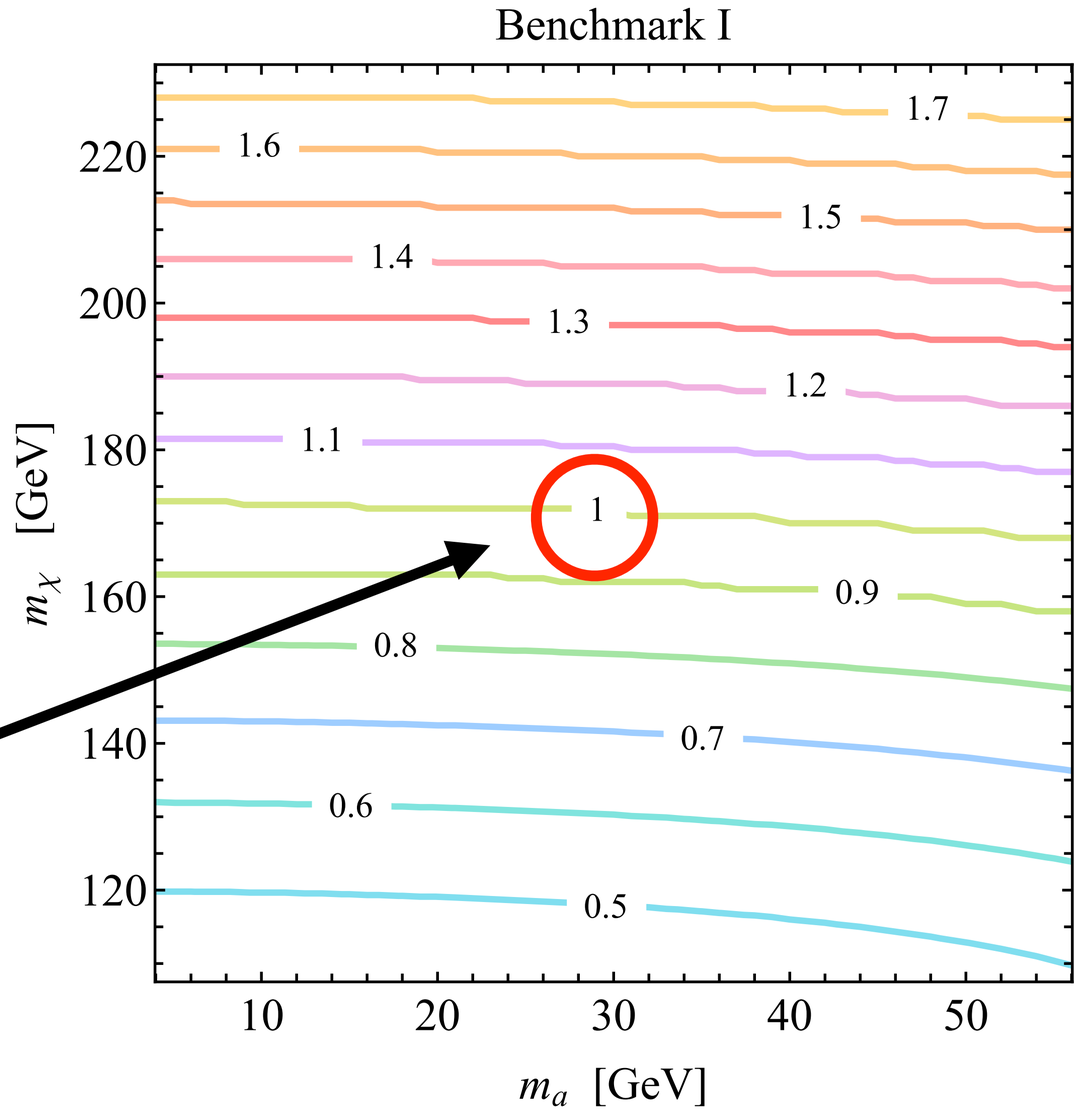


Interestingly, 2HDM+a realisations that give LLP observable @ LHC, can also explain observed DM relic density



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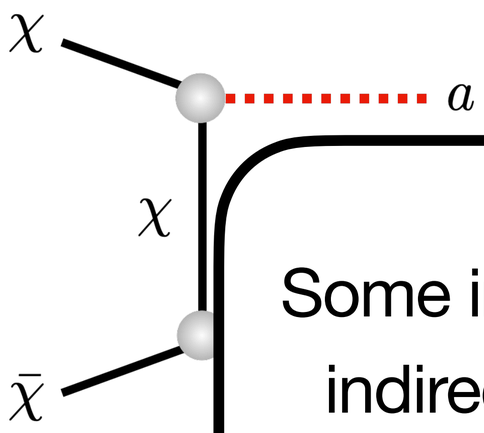

Some interesting aspects like connection to indirect detection have not been studies. But maybe outside scope of LHC DM WG?

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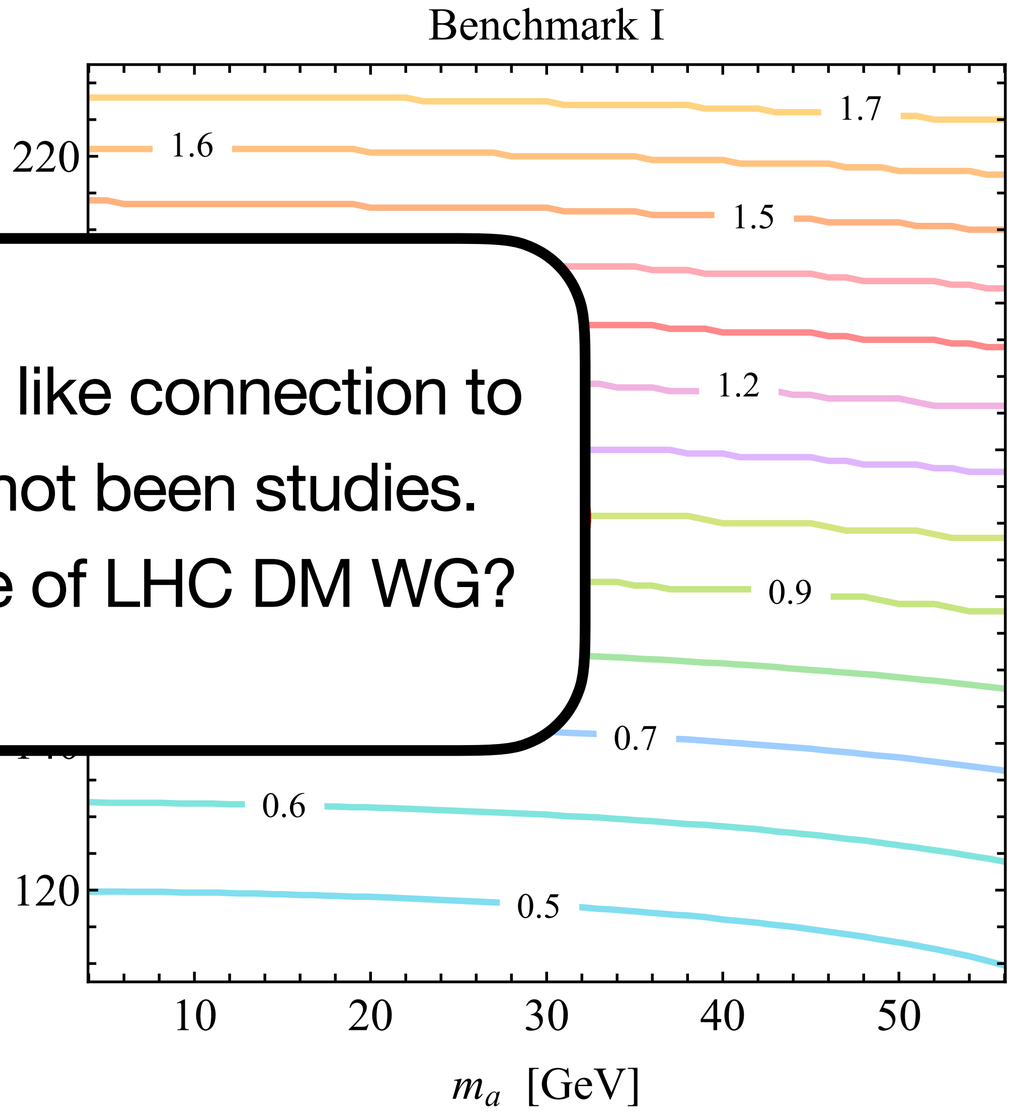

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… this was my garbage dump of ideas