

# Search for ALPs that decay into diphoton at the LHC

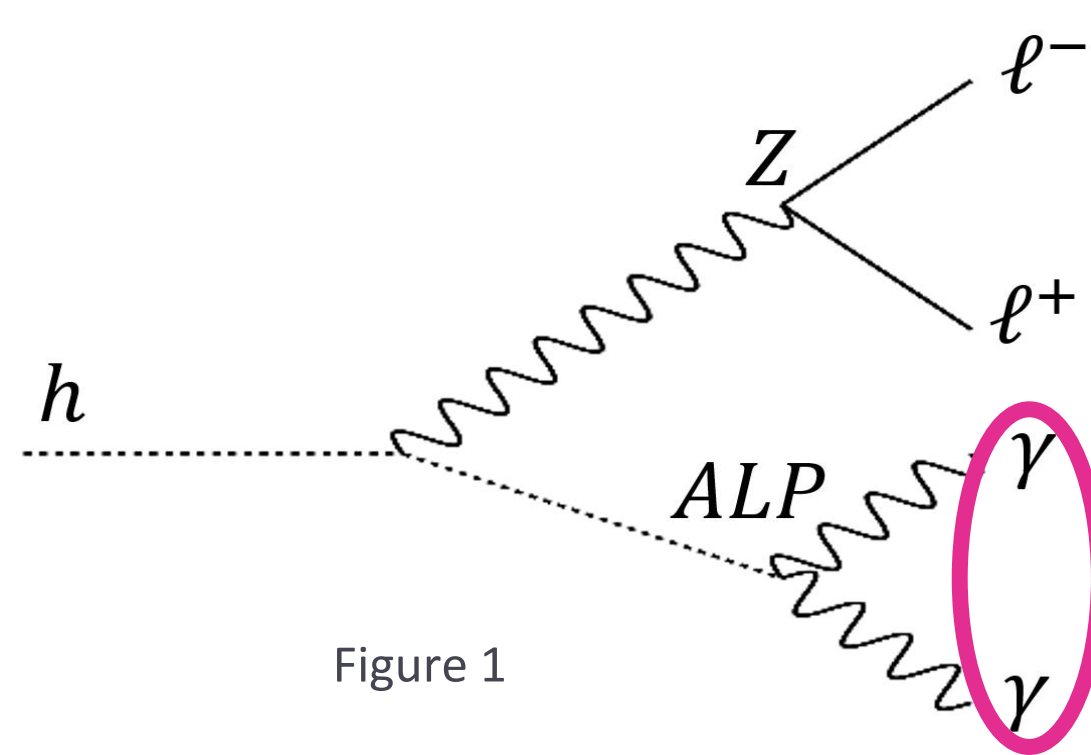
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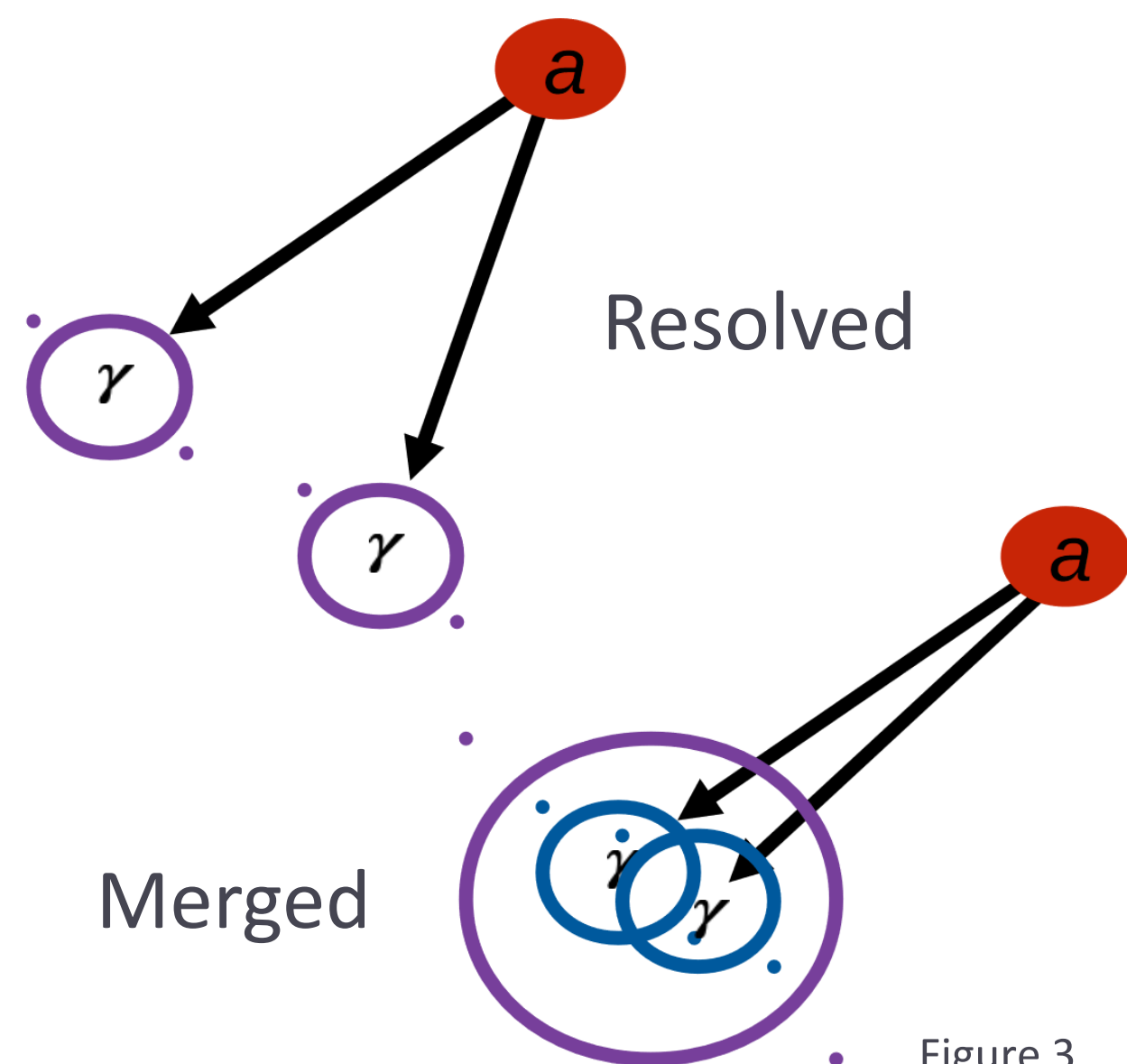
## Signature

- Search for axion like particle (ALP) produced in association with a Z boson from Higgs decay.
- Signature: 2 leptons and 2 collimated photons.



## Reconstructed photons

- The photon pair from the ALP decay can be reconstructed as two different photons (resolved) or a single photon (merged) depending on the ALP boost.
- < 2 GeV, the ALP is more boosted, therefore the photons are more merged.



## A long lived target?

Trigger on the Z boson

Use a photon tagger for signal/background discrimination

Define SR/CR Cut and count analysis

## Long lived signature

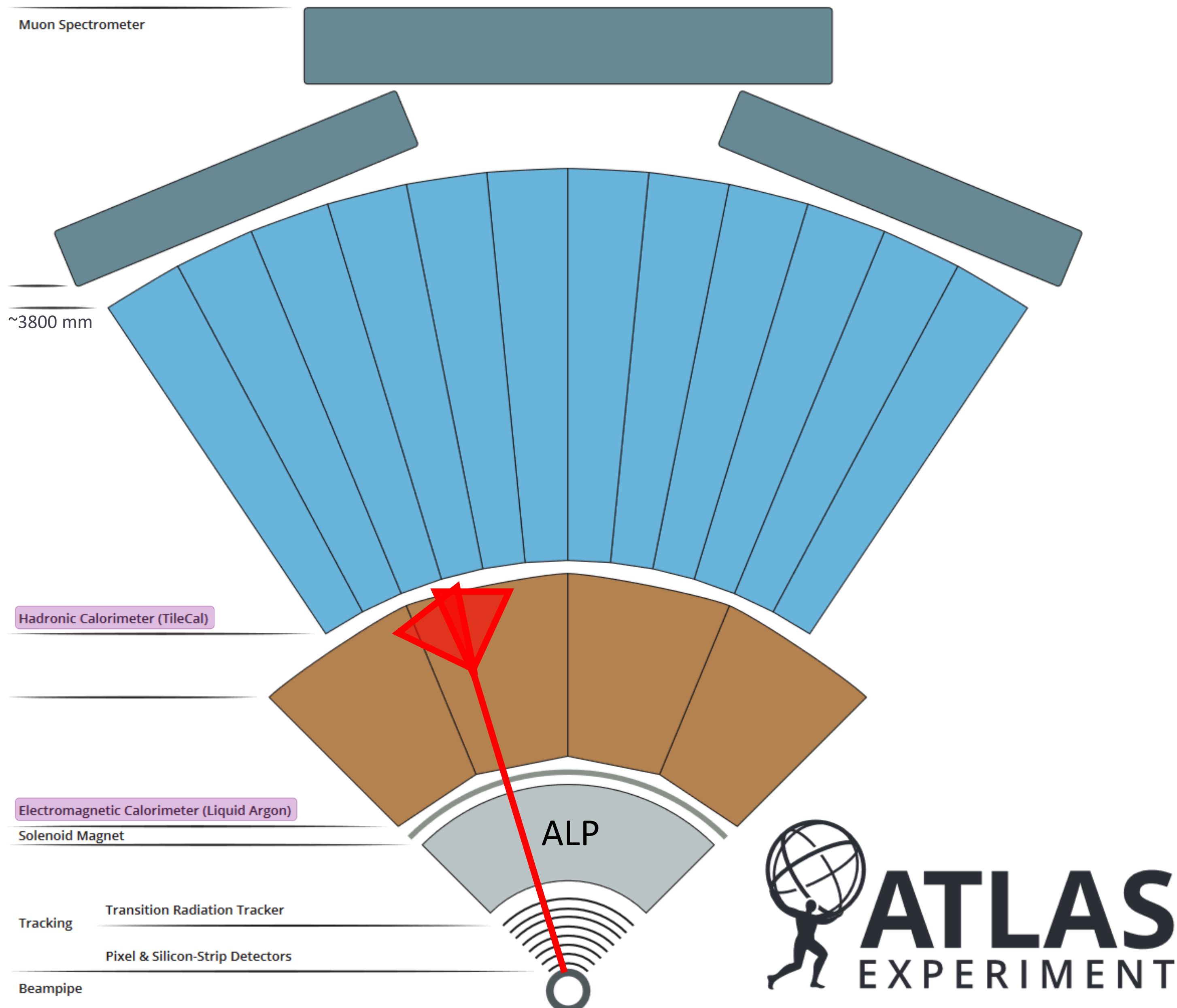


Figure 6: Slice of ATLAS detector, showing potential long lived ALP decay path [3].

- Lifetime of long lived ALPs  $\rightarrow$  0-3800 mm.
- Displaced secondary vertex.
- Decay inside calorimeters.
- Highly collimated photon pairs in ECAL.
- Possible that energy is only deposited in last layers of calorimeters.
- Photon standard reconstruction is not built to reconstruct collimated  $\gamma$  pairs.
- ALP decay photons won't pass the usual identification criteria (or will be reconstructed as one  $\gamma$ ).

## Axion-like Particles (ALPs)

ALPs are hypothetical light particles that may be a component of the dark sector. They can decay promptly or be long lived.

ATLAS ALP prompt search region

ALP displaced region

ATLAS can probe region where  $(g-2)_\mu$  anomaly can be explained

ALPs mass range: 0.1-35 GeV

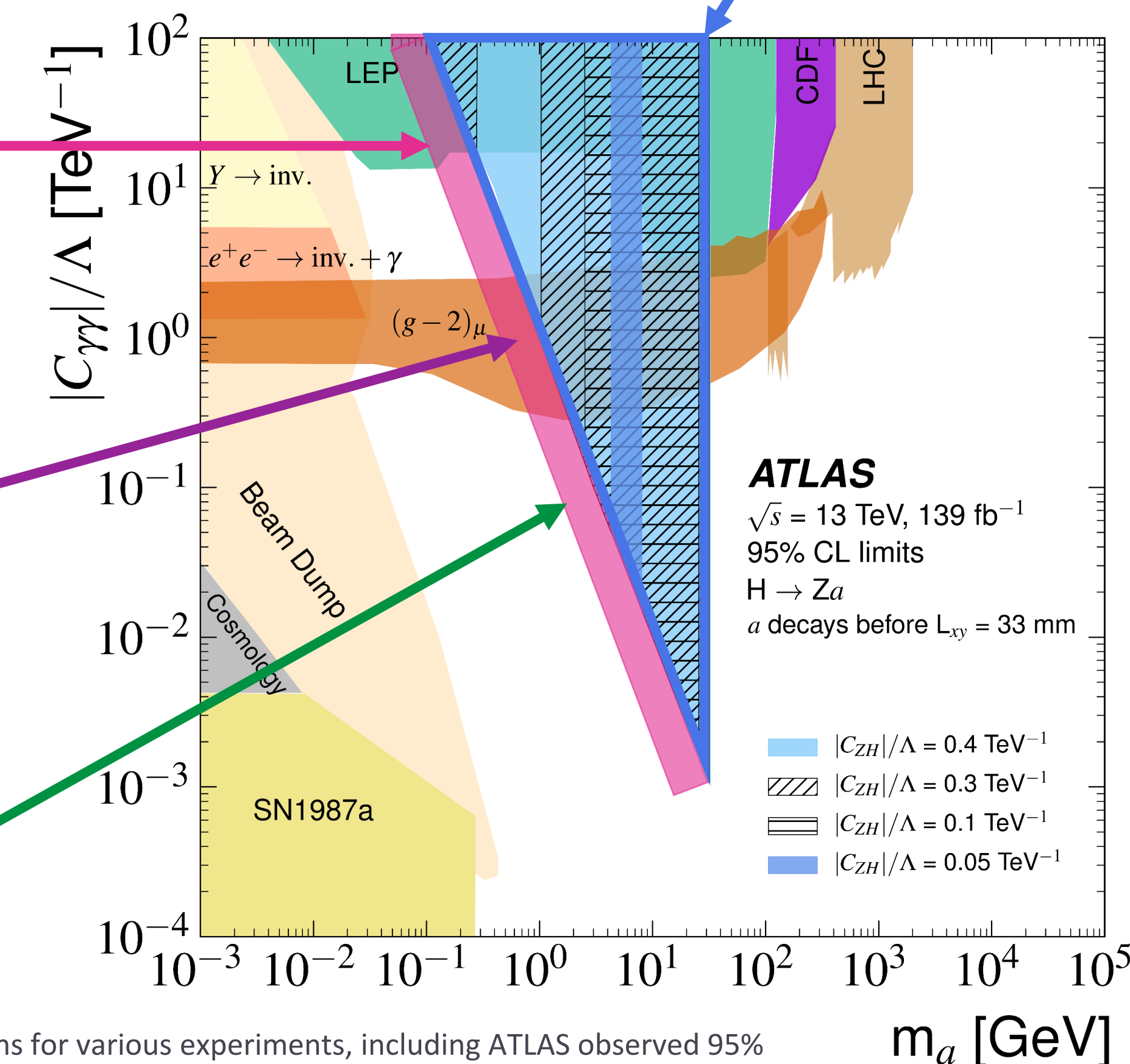
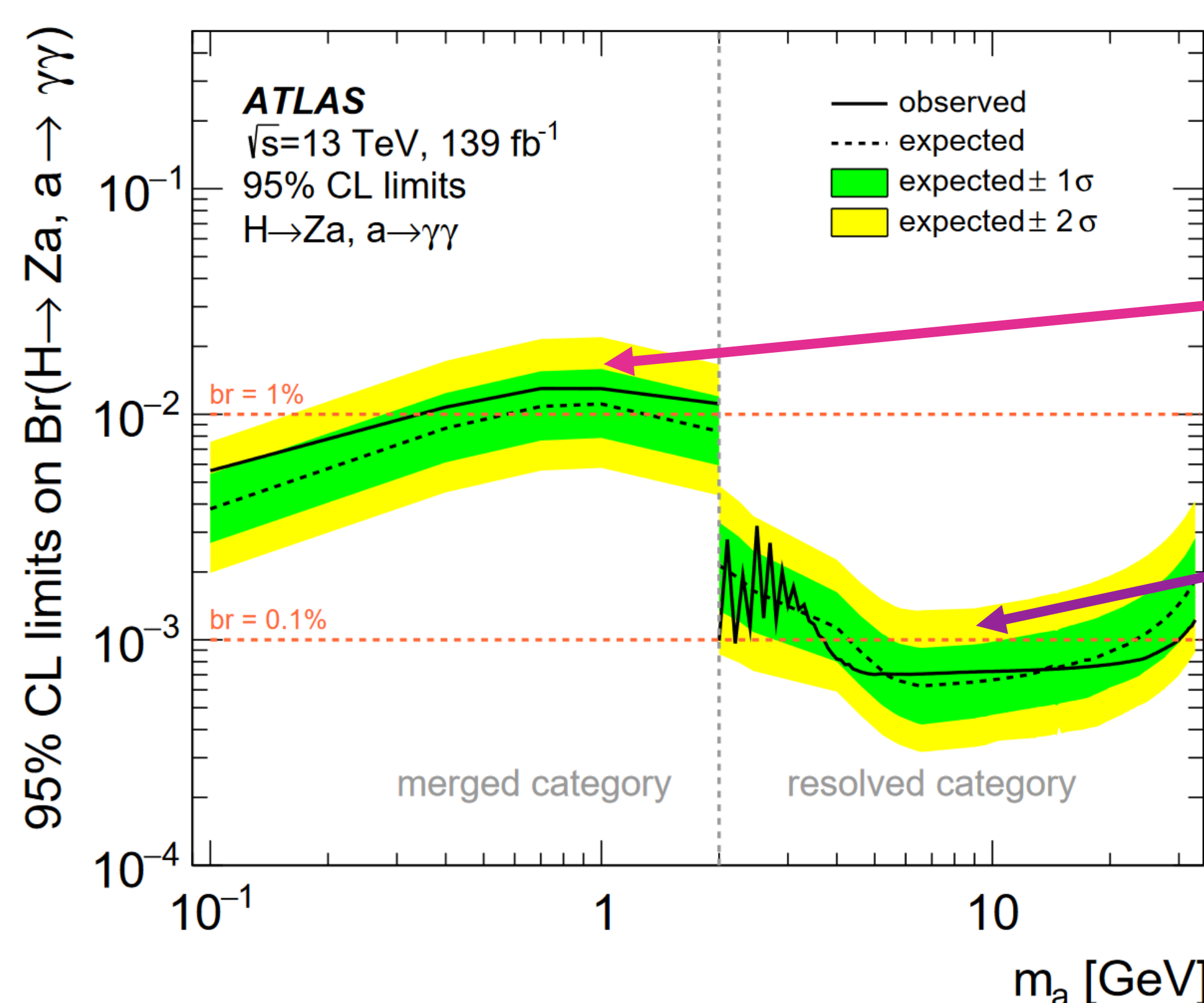


Figure 2: Reach in mass vs coupling to photons for various experiments, including ATLAS observed 95% CL exclusion contours limits for different values of the Higgs coupling to  $Za$ , where the ALP is prompt [1].

## Prompt analysis results



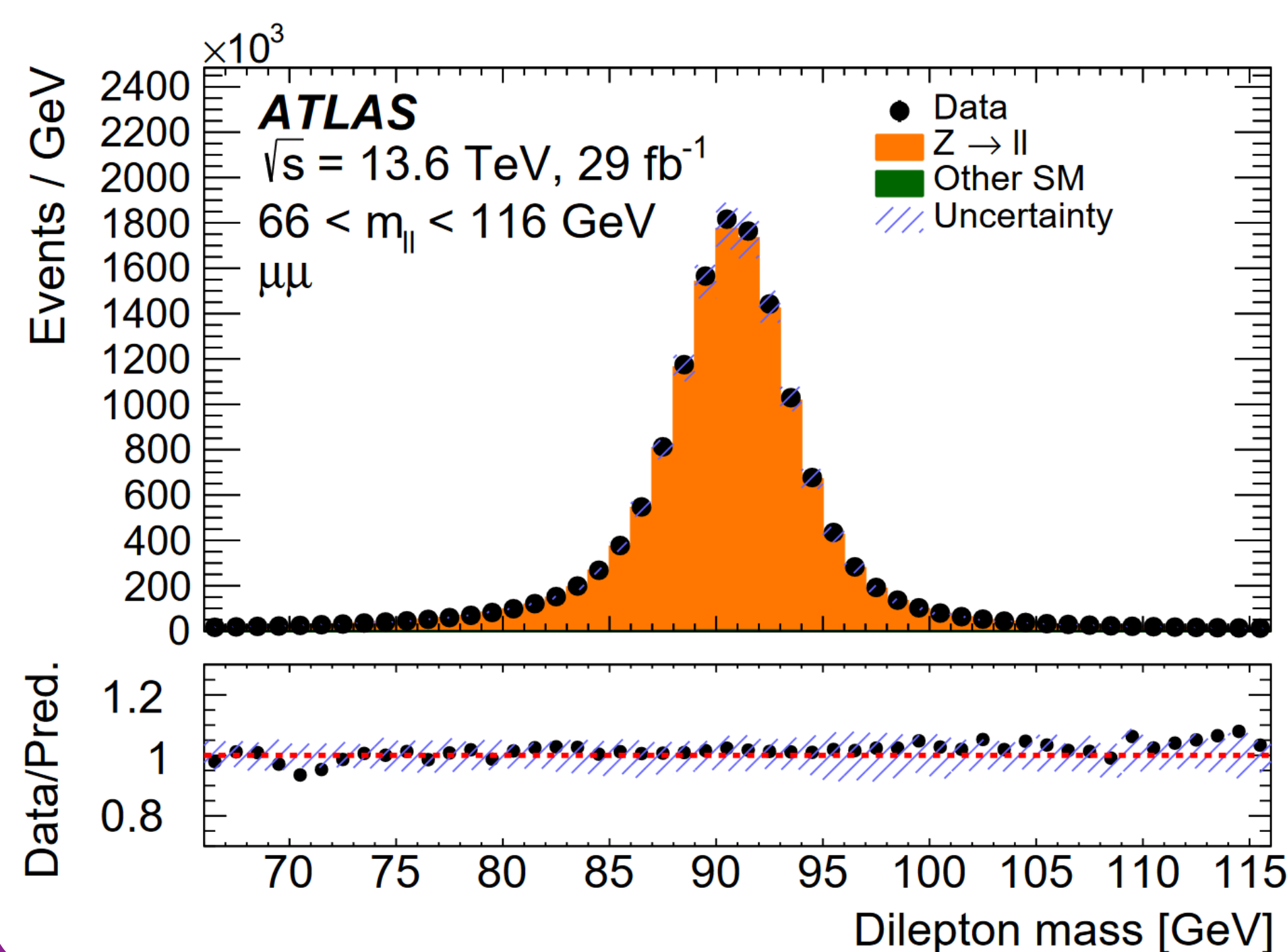
Search for  $h \rightarrow Za$  using Run 2 data.

Merged category for  $m_A < 2$  GeV

Resolved category for  $m_A > 2$  GeV

Figure 4: Expected and observed 95% CL upper limits on the branching ratio of  $h \rightarrow Za$ , multiplied by the branching ratio of  $a \rightarrow \gamma\gamma$ , as a function of the  $a$  particle mass in the merged and resolved categories [1].

## Background



- Backgrounds:  $Z$ +jets,  $Z$ +gamma.
- Need to ensure good data/MC agreement for the Run 3 long lived analysis.

Figure 5: Run 3 background data/MC plot for the invariant mass of muons from Z boson [2].

## Conclusion and future plans

- Prompt analysis search for  $h \rightarrow Za$  using Run 2 data planning to be extended to a long lived search.
- Dedicated ID procedures being developed for long lived ALP analysis, studying reconstruction tools.

## References

- [1] ATLAS Collaboration. Search for the decay of the Higgs boson to a Z boson and a light pseudoscalar particle decaying to two photons. arXiv:2312.01942
- [2] ATLAS Collaboration. Measurement of the  $t\bar{t}$  cross section and its ratio to the Z production cross section using  $pp$  collisions at  $\sqrt{s}=13.6$  TeV with the ATLAS detector. arXiv:2308.09529
- [3] ATLAS Collaboration. ATLAS detector slice. cds:2770815



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ATLAS EXPERIMENT

