

Searches for Dark Matter with the ATLAS Experiment at the LHC

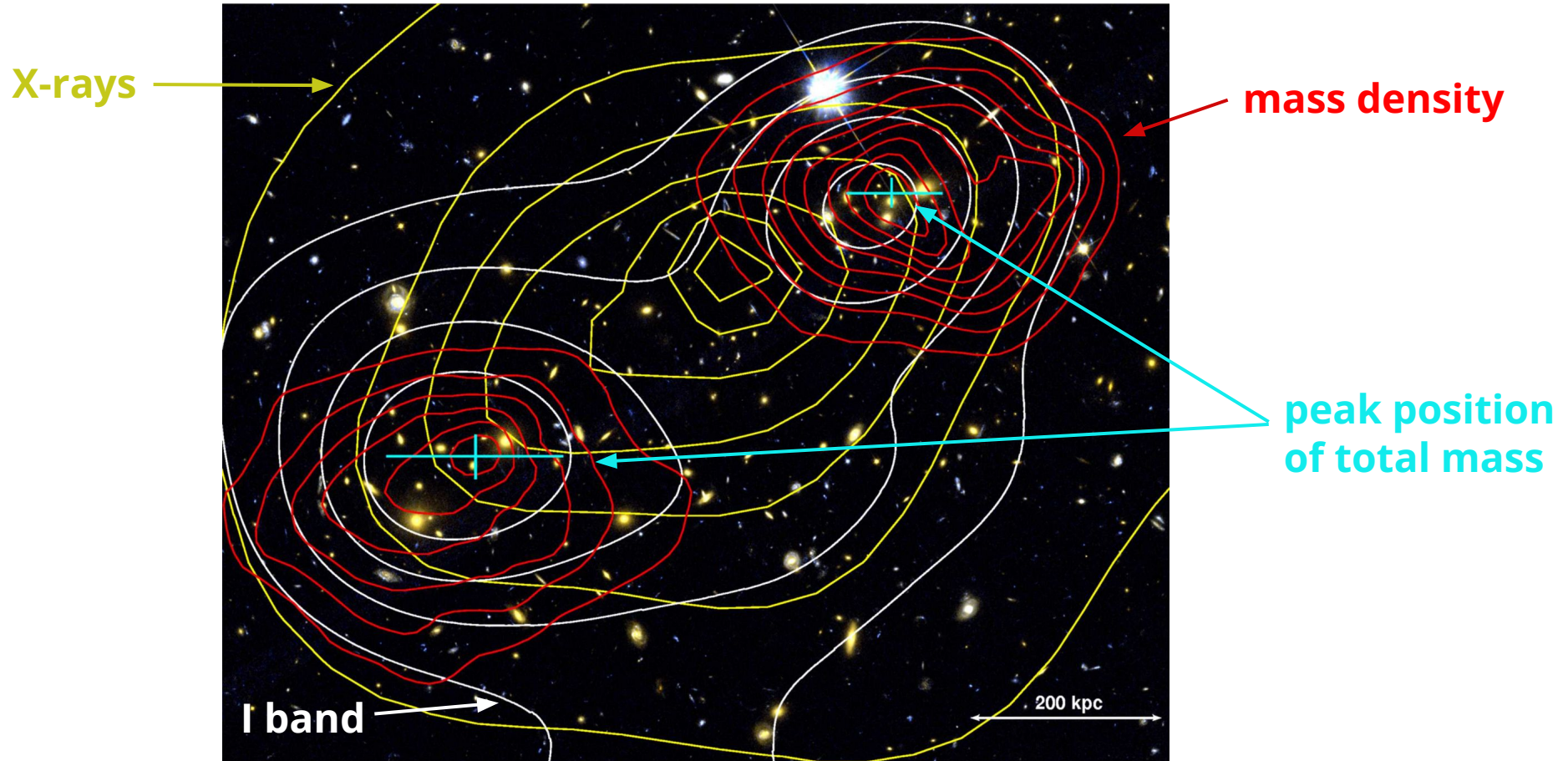
Martin Habedank
on behalf of the
ATLAS Collaboration

TAUP 2023
Dark matter and its detection
29 August 2023



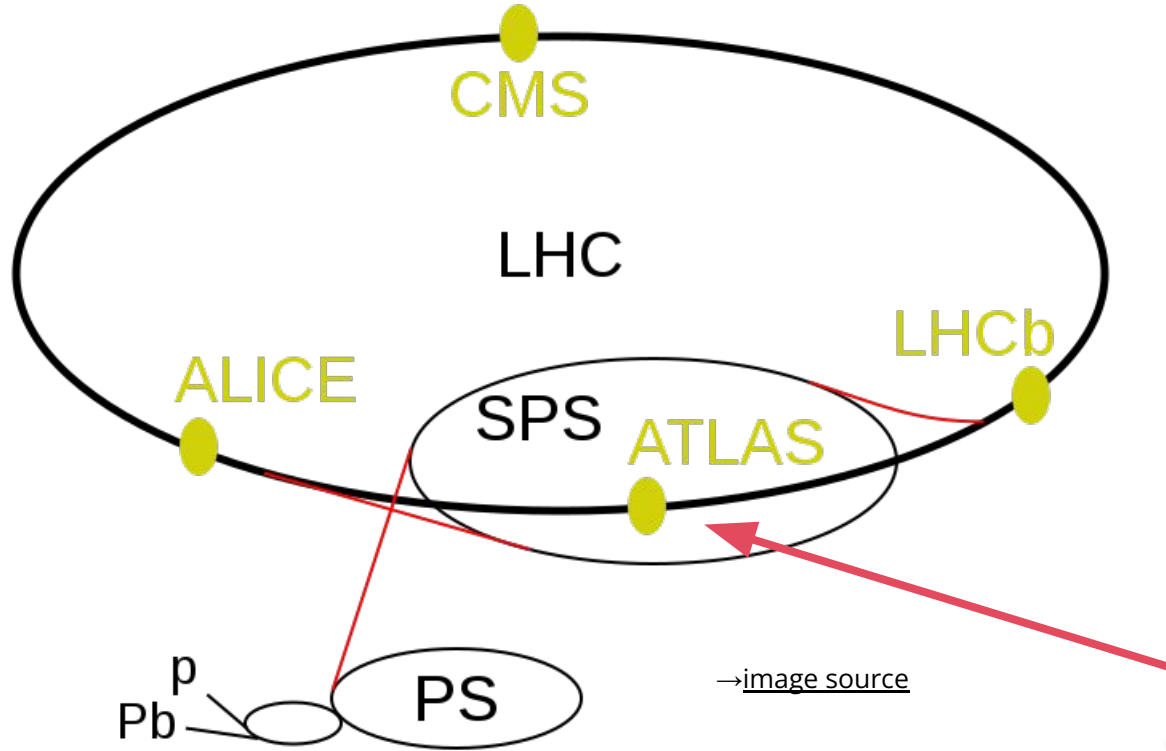
- Plenty of astrophysical evidence for Dark Matter
 - E.g. displacement between **luminous centre** and **gravitational centres** of galaxy mergers

Merging Cluster MACS J0025.4-1222*

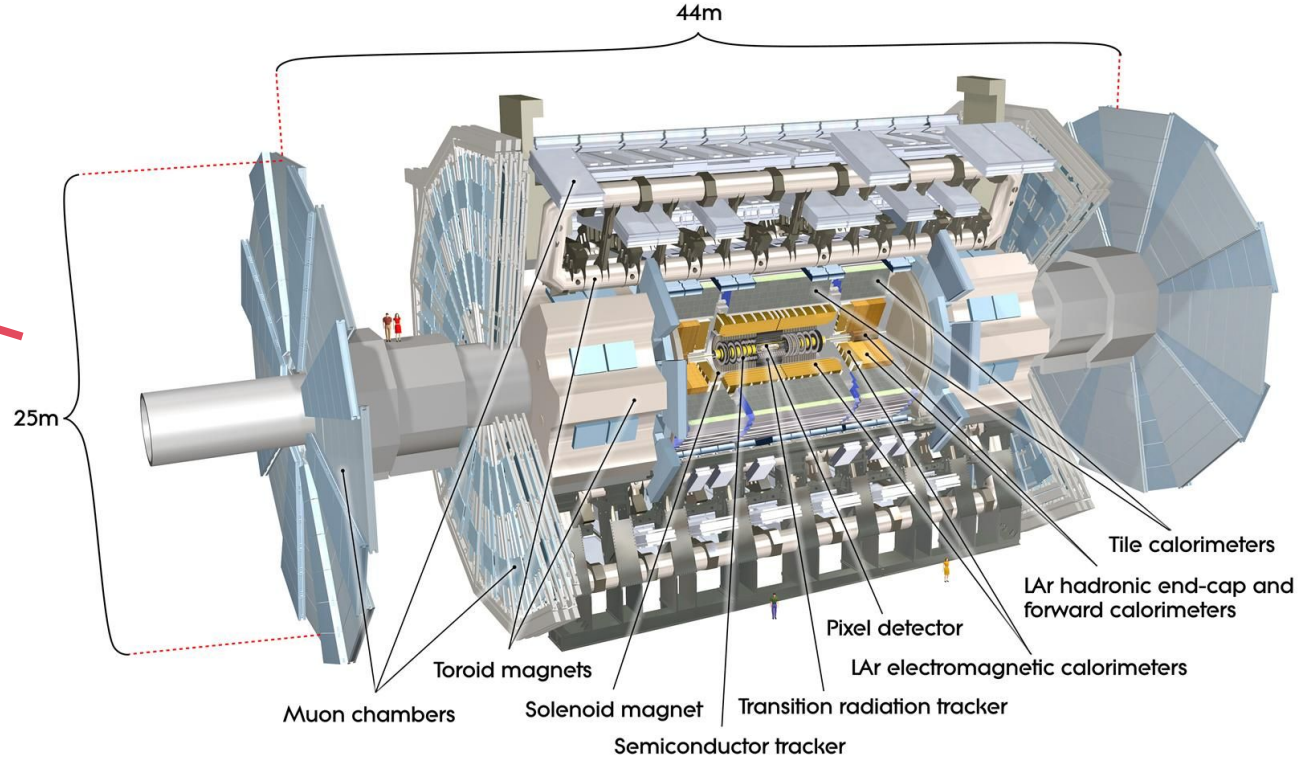


→ Bradač et al: *Astrophys.J.* **687** (2008) 959

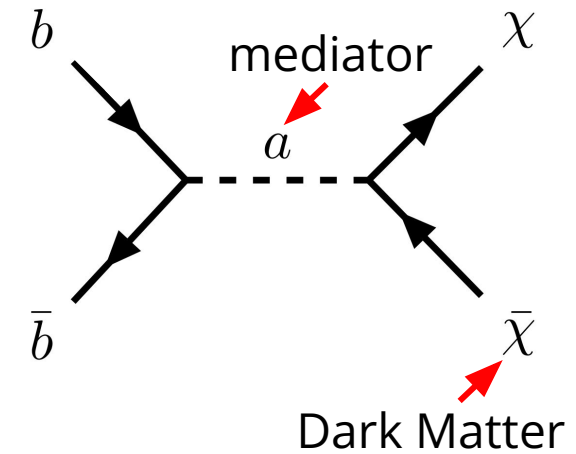
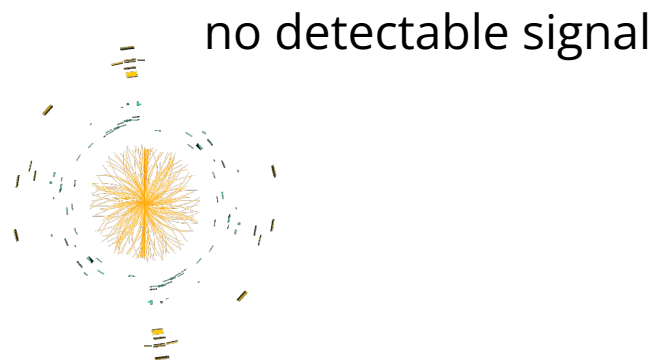
The LHC accelerator complex



The ATLAS detector



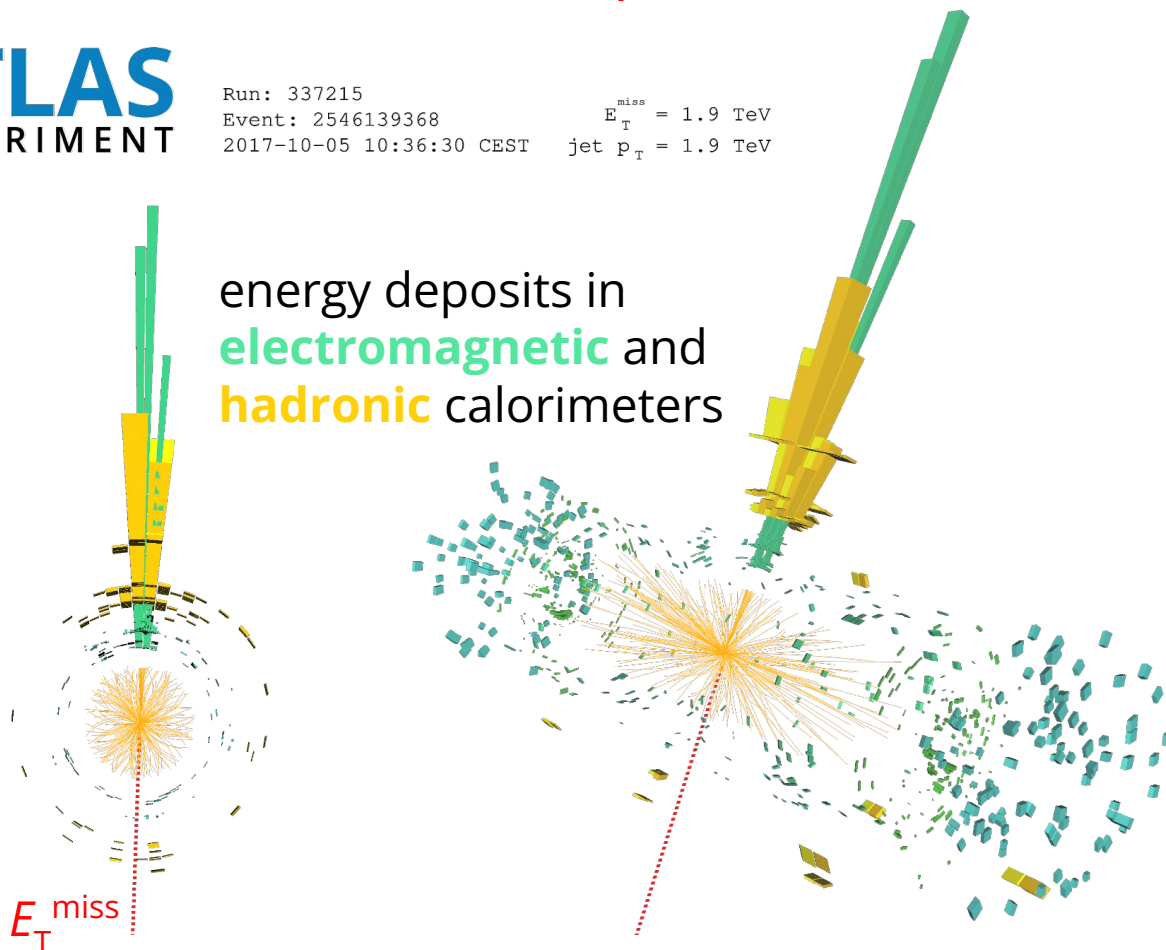
- Small interaction cross section of Dark Matter with detectors at colliders



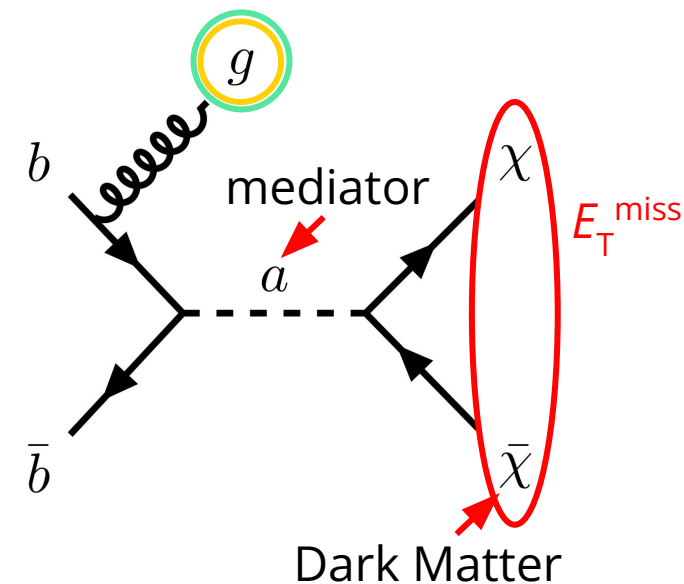
- Small interaction cross section of Dark Matter with detectors at colliders
- Need recoil against **detector-visible object**
- **Missing transverse momentum (E_T^{miss})**

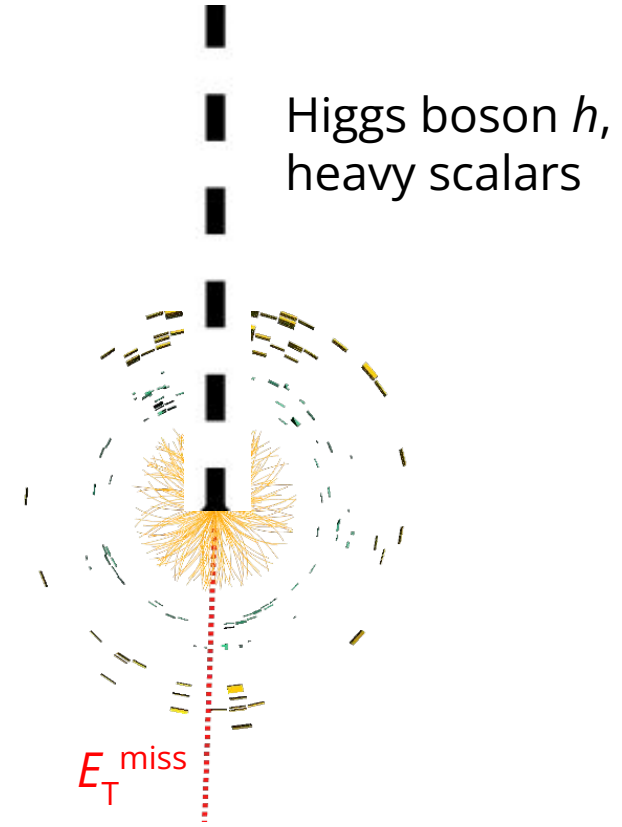
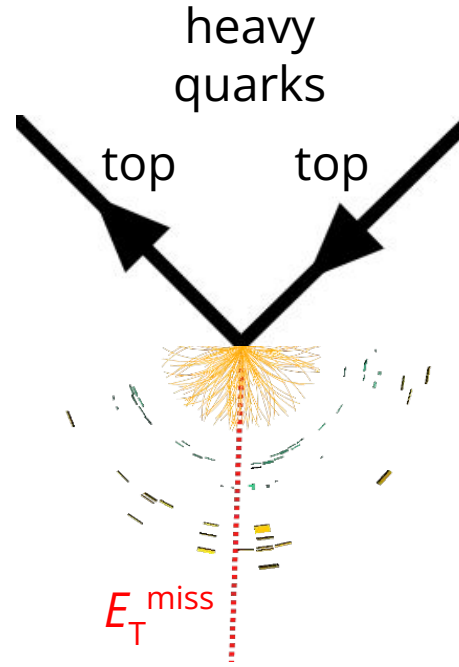
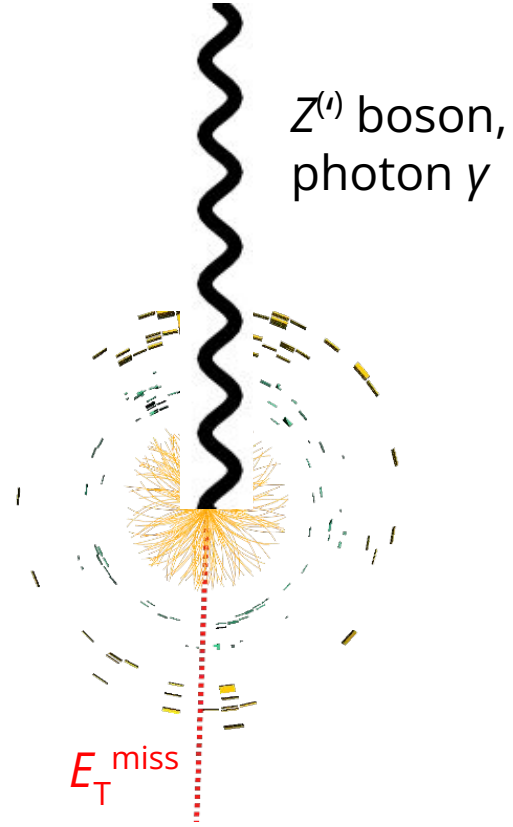
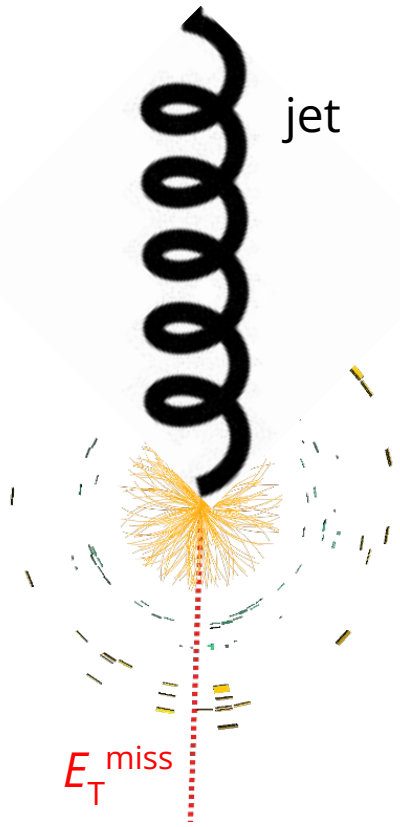


Run: 337215
Event: 2546139368
2017-10-05 10:36:30 CEST
 $E_T^{\text{miss}} = 1.9 \text{ TeV}$
jet $p_T = 1.9 \text{ TeV}$



→ ATLAS event display of a jet recoiling against E_T^{miss}





jet+ E_T^{miss} : \rightarrow 2102.10874

$Z(\rightarrow \ell\ell)+E_T^{\text{miss}}$: \rightarrow 2111.08372

$\gamma+E_T^{\text{miss}}$: \rightarrow 2011.05259

$Z'(\rightarrow \ell\ell)+E_T^{\text{miss}}$: \rightarrow EPS last week

$tW+E_T^{\text{miss}}$: \rightarrow 2211.13138

$tt+E_T^{\text{miss}}$: \rightarrow 2211.05426

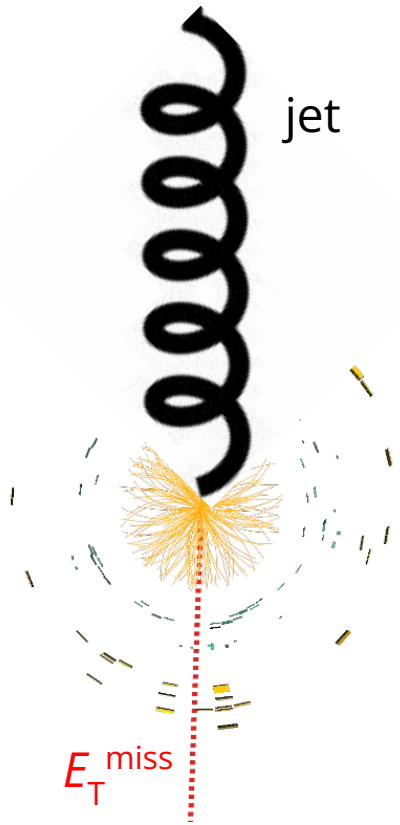
$h(\rightarrow \tau\tau)+E_T^{\text{miss}}$: \rightarrow 2305.12938

$h(\rightarrow bb)+E_T^{\text{miss}}$: \rightarrow 2108.13391

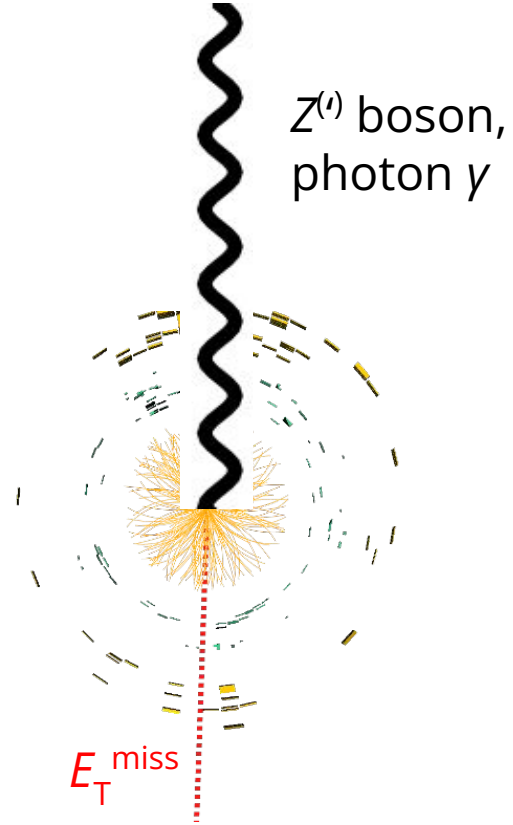
$h(\rightarrow \gamma\gamma)+E_T^{\text{miss}}$: \rightarrow 2104.13240

$s(\rightarrow WW)+E_T^{\text{miss}}$: \rightarrow 2211.07175

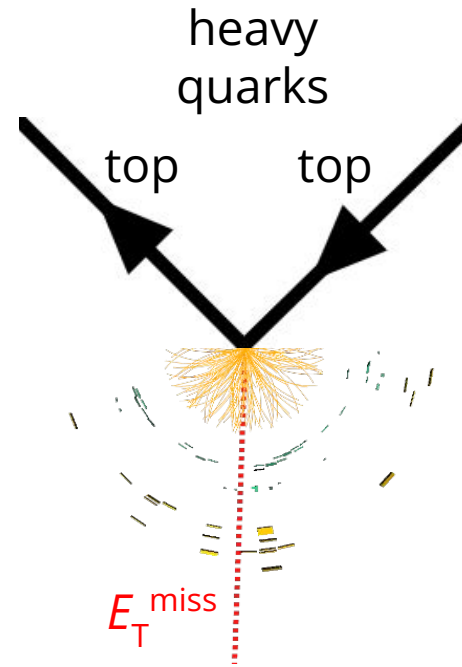
... and many more!



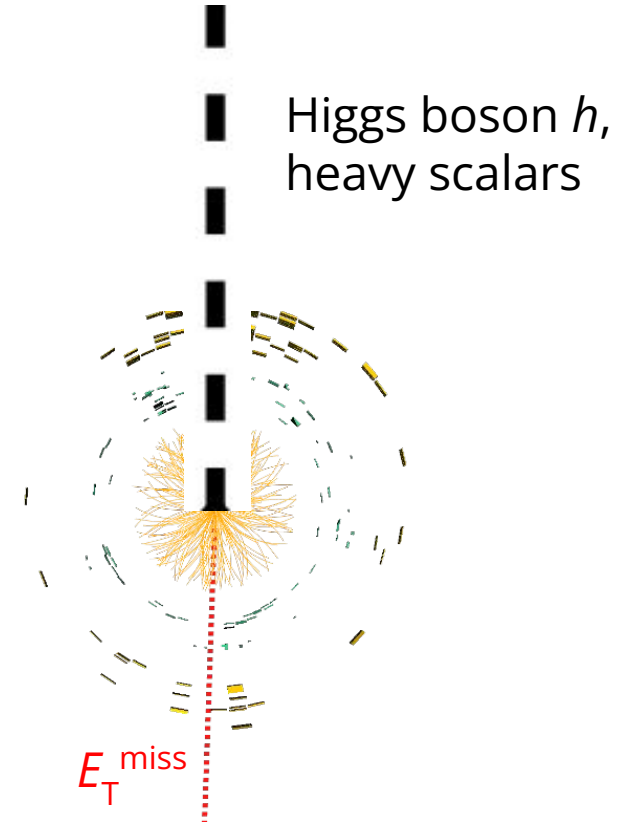
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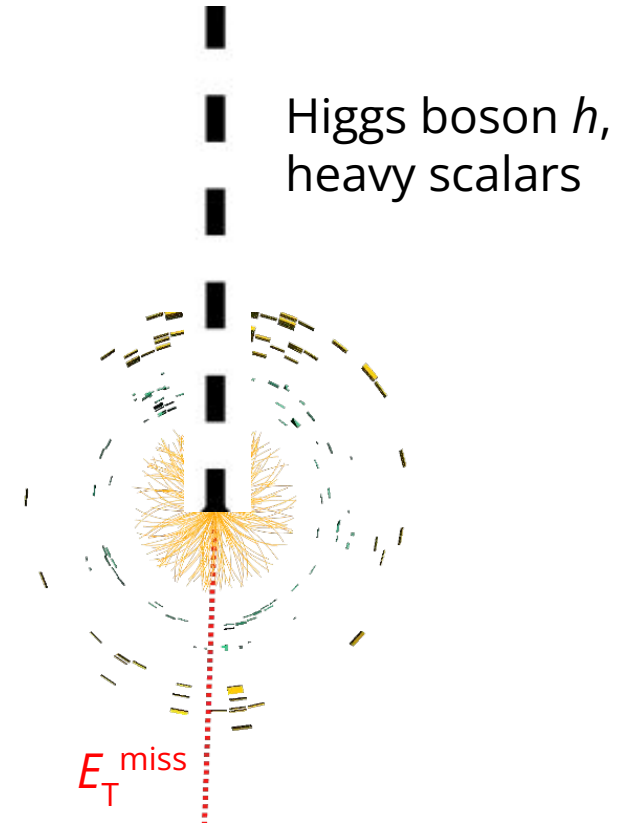
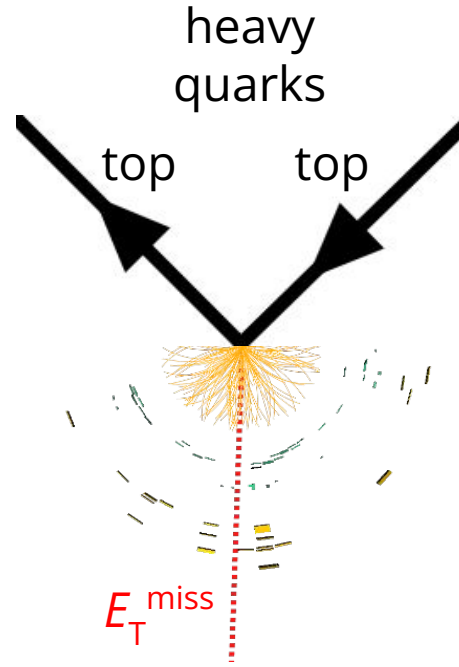
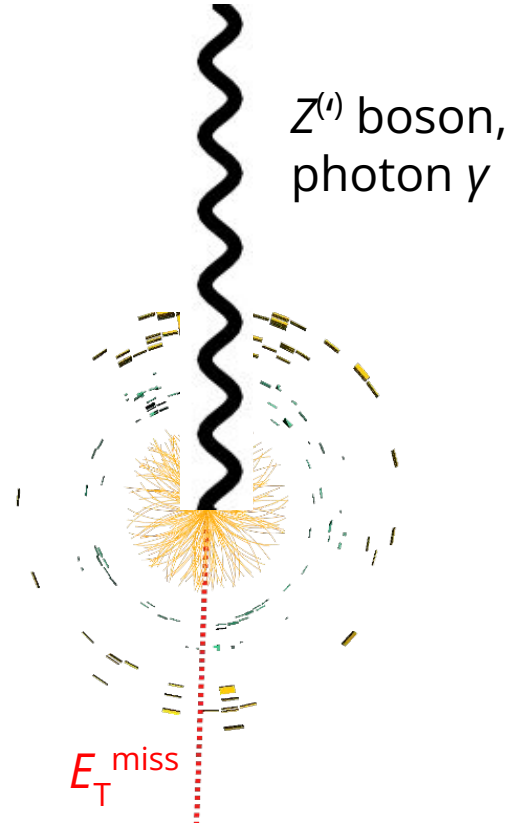
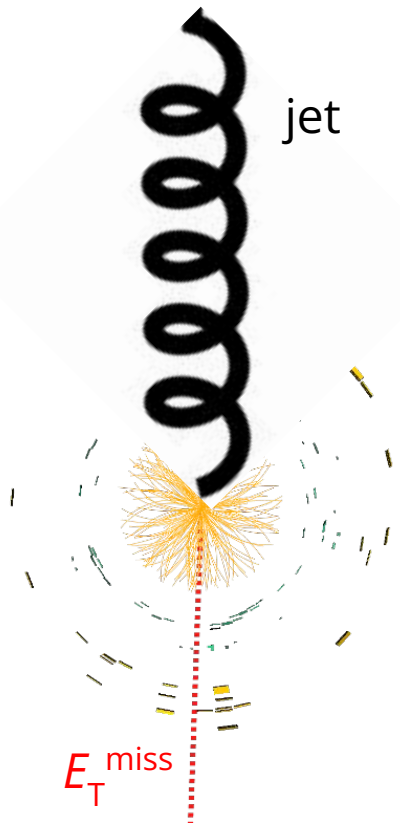
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$h(\rightarrow \tau\tau)+E_T^{\text{miss}}$: \rightarrow 2305.12938
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 $h(\rightarrow \gamma\gamma)+E_T^{\text{miss}}$: \rightarrow 2104.13240
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published within the last 12 months

... and many more!



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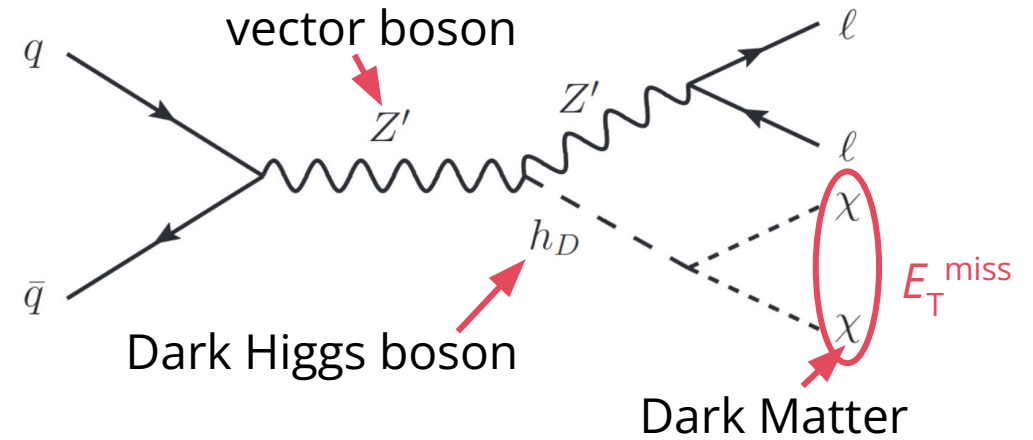
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this talk

- weakly-interact. massive particle (**WIMP**) **Dark Matter**, for non-WIMPs see \rightarrow Peter Krämer's talk
- all searches using \approx **140 fb⁻¹** of ATLAS Run-2 data at \sqrt{s} =**13TeV**

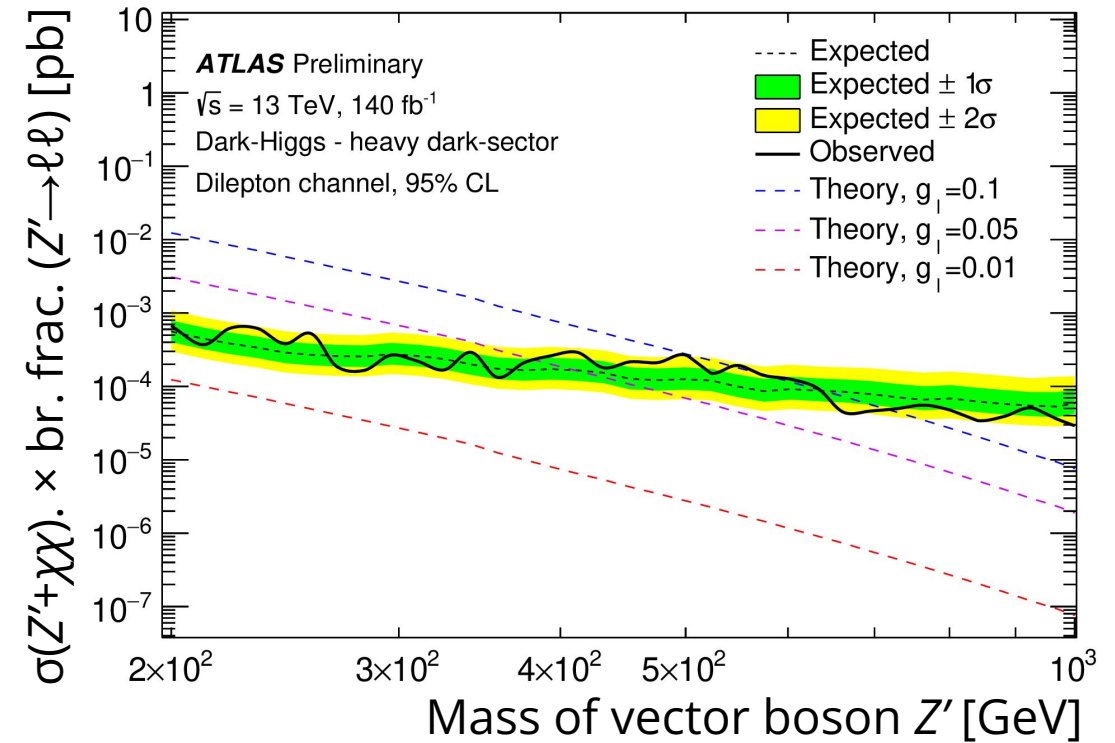
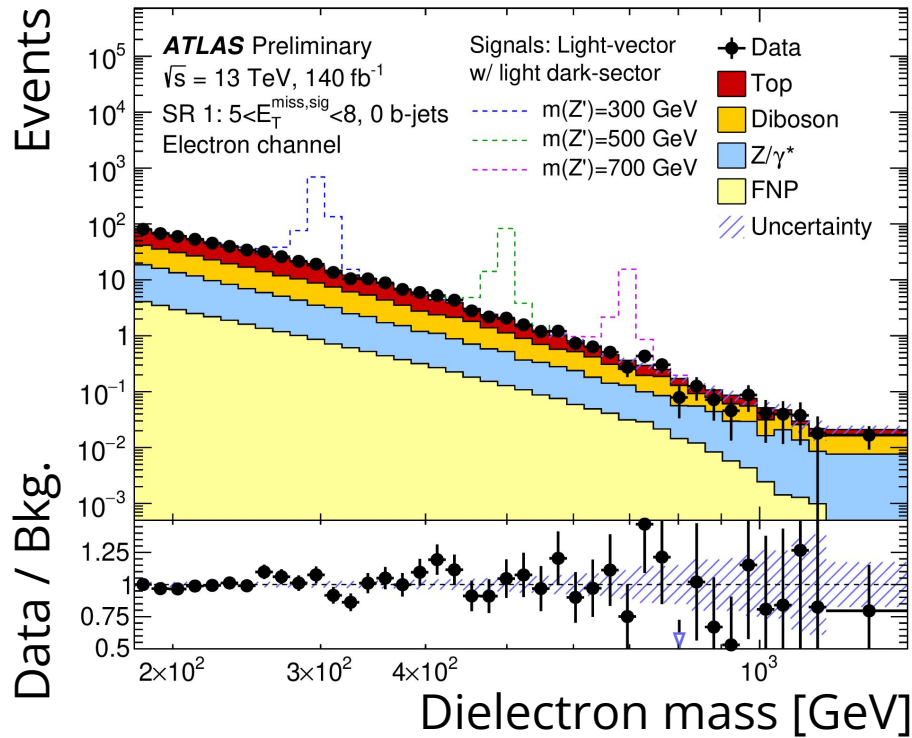
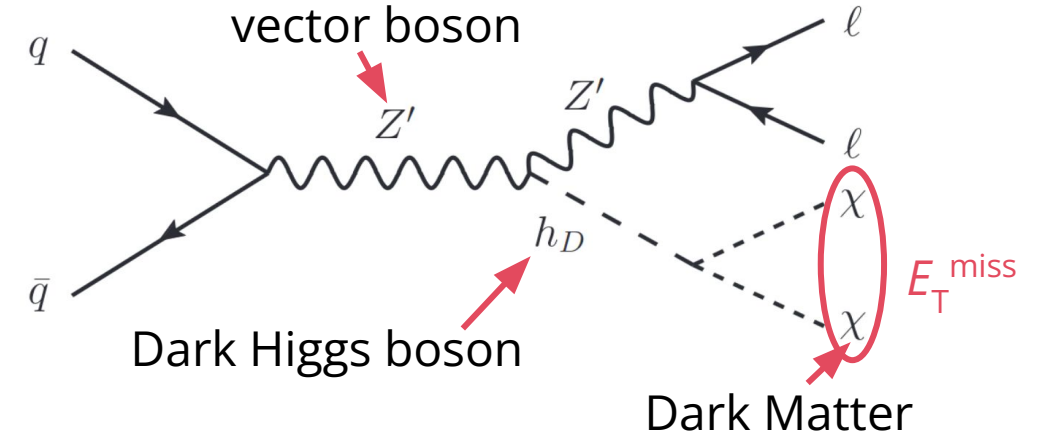
$Z'(\rightarrow\ell\ell)+E_T^{\text{miss}}$ search

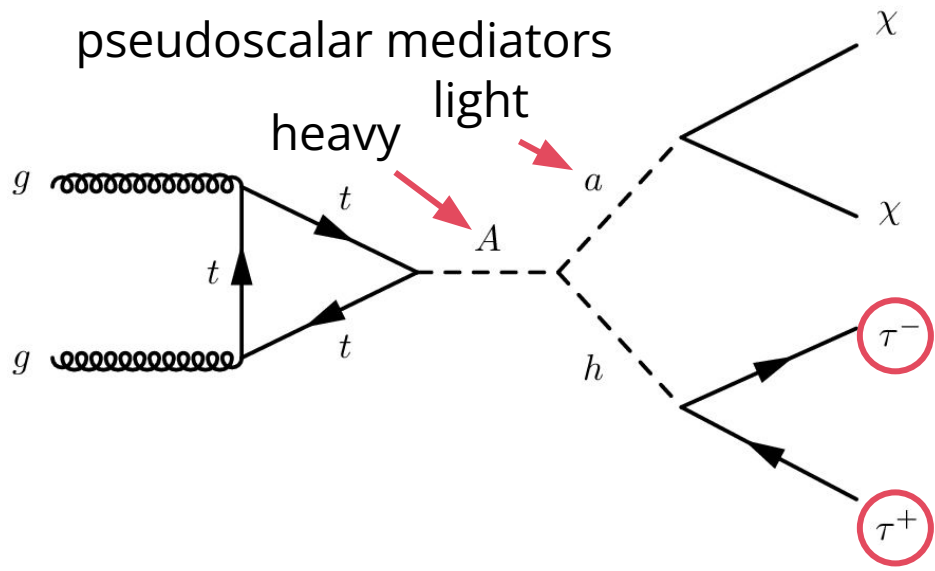
- Target: neutral vector boson $Z'(\rightarrow\ell\ell)$ and large E_T^{miss}
- Main selection
 - **Dimuons** or **dielectrons**
 - $E_T^{\text{miss}} > 55$ GeV



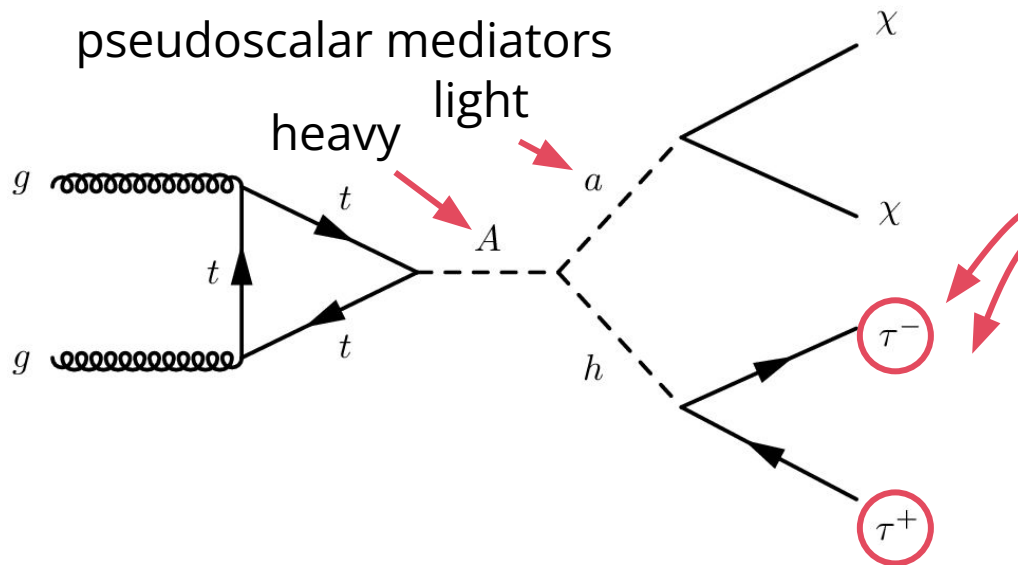
$Z'(\rightarrow\ell\ell)+E_T^{\text{miss}}$ search

- Target: neutral vector boson $Z'(\rightarrow\ell\ell)$ and large E_T^{miss}
- Main selection
 - **Dimuons** or **dielectrons**
 - $E_T^{\text{miss}} > 55$ GeV
- Search for resonance in invariant mass distribution $m_{\ell\ell}$
- Data in **good agreement** with Standard Model
- **Exclusion limits** on dark-Higgs and light-vector model

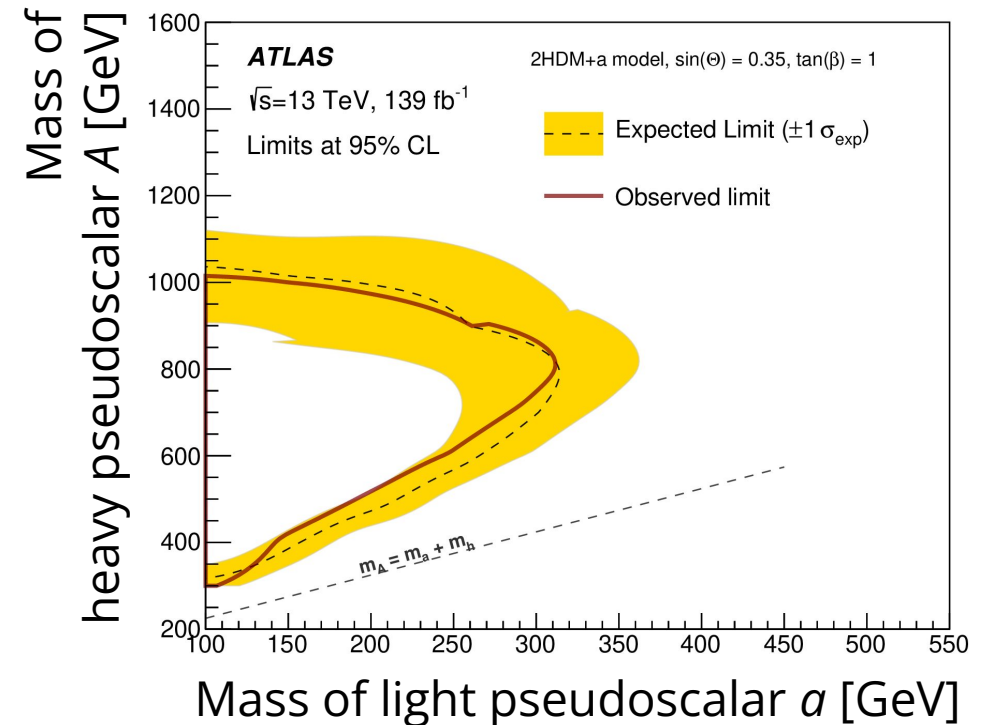
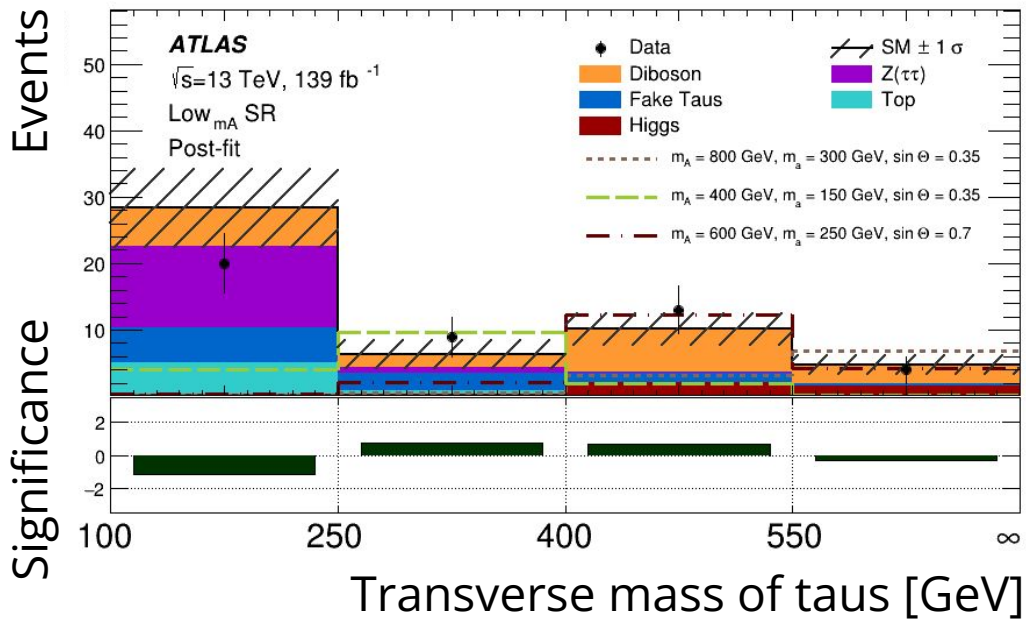




- Target: SM Higgs boson $h(\rightarrow\tau\tau)$ and large E_T^{miss}
- Main selection
 - $E_T^{\text{miss}} > 150$ GeV
 - Two **hadronically decaying taus** (using \rightarrow **RNN**)



- Target: SM Higgs boson $h(\rightarrow\tau\tau)$ and large E_T^{miss}
- Main selection
 - $E_T^{\text{miss}} > 150$ GeV
 - Two **hadronically decaying taus** (using \rightarrow **RNN**)
- Data in **good agreement** with Standard Model
- ➔ Exclusion limits:
two-Higgs-doublet model with pseudoscalar a (2HDM+ a)



arXiv:→[2305.12938](https://arxiv.org/abs/2305.12938) (submitted to *JHEP*)

- Target: single top quark, energetic W boson and large E_T^{miss}
- Main selection
 - $E_T^{\text{miss}} > 250$ GeV
 - 1 b -jet

0 ℓ -channel:

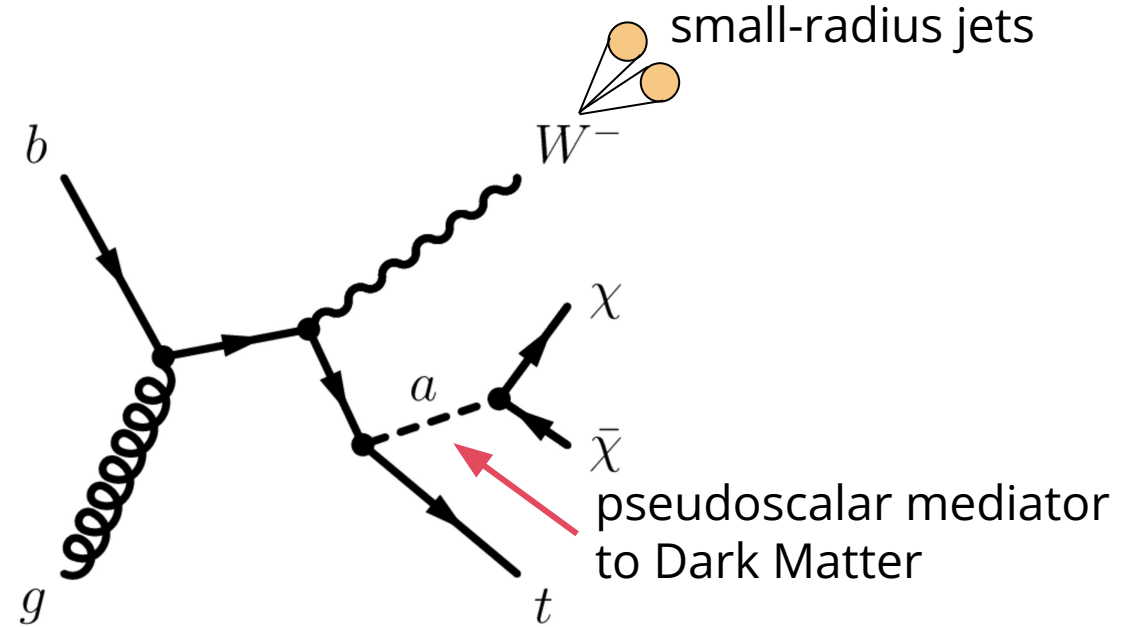
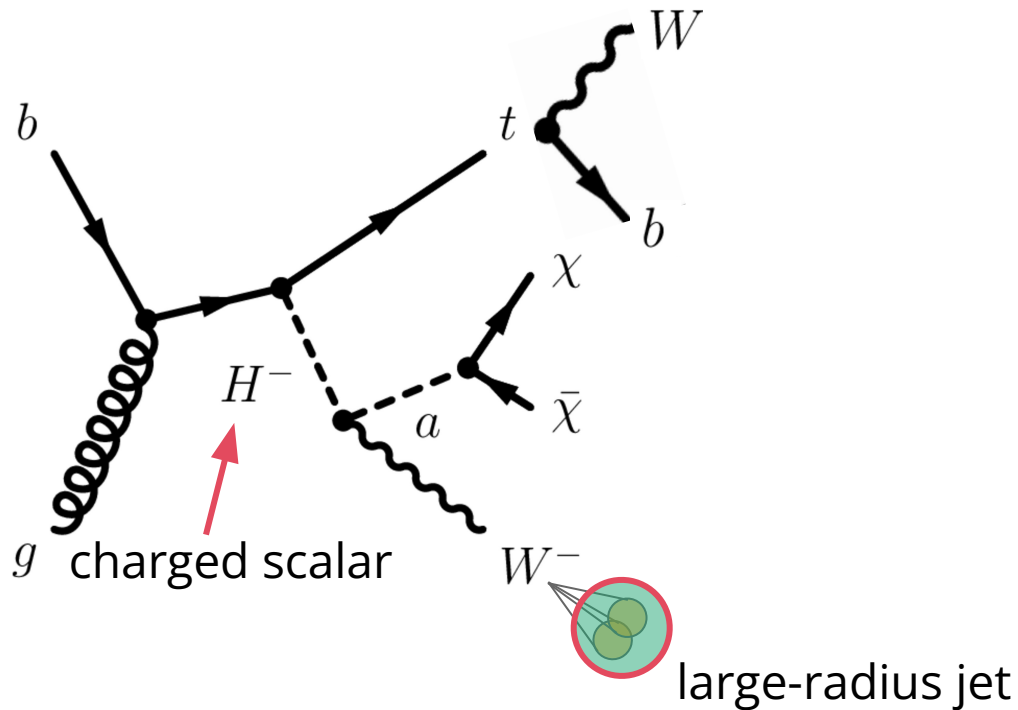
- 0 leptons
- ≥ 4 small-radius jets
- ≥ 1 **W-tagged** large-radius jet

1 ℓ -channel:

- 1 electron or muon
- ≥ 2 small-radius jets

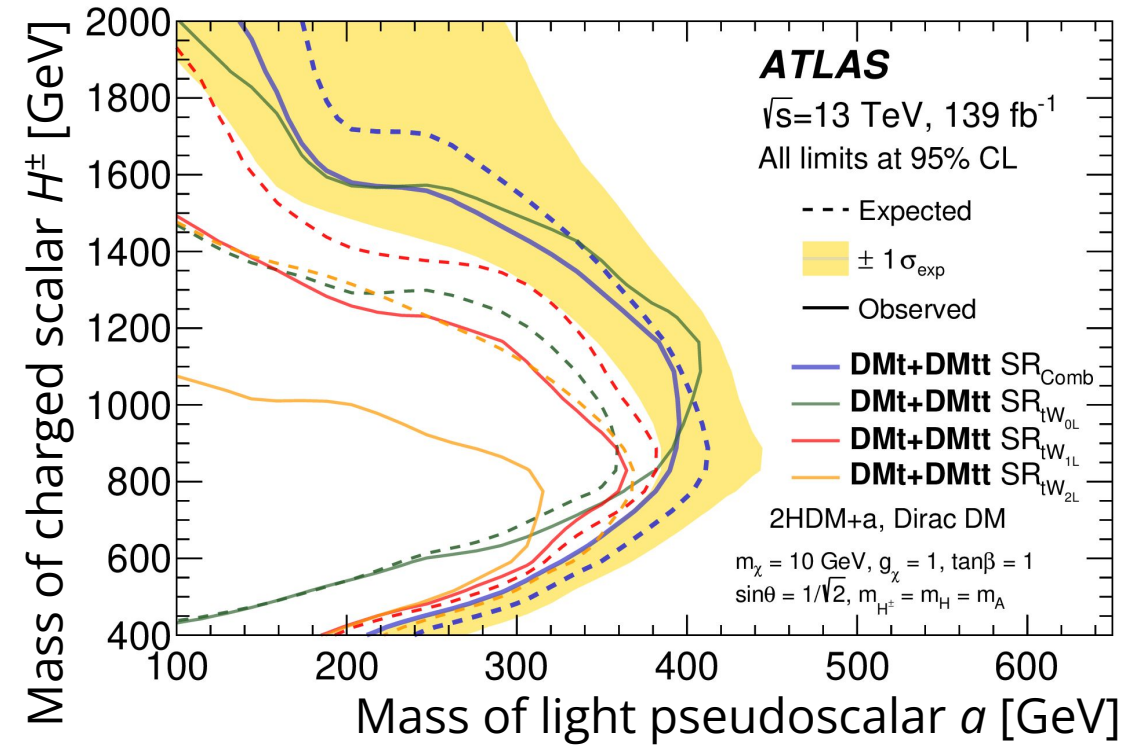
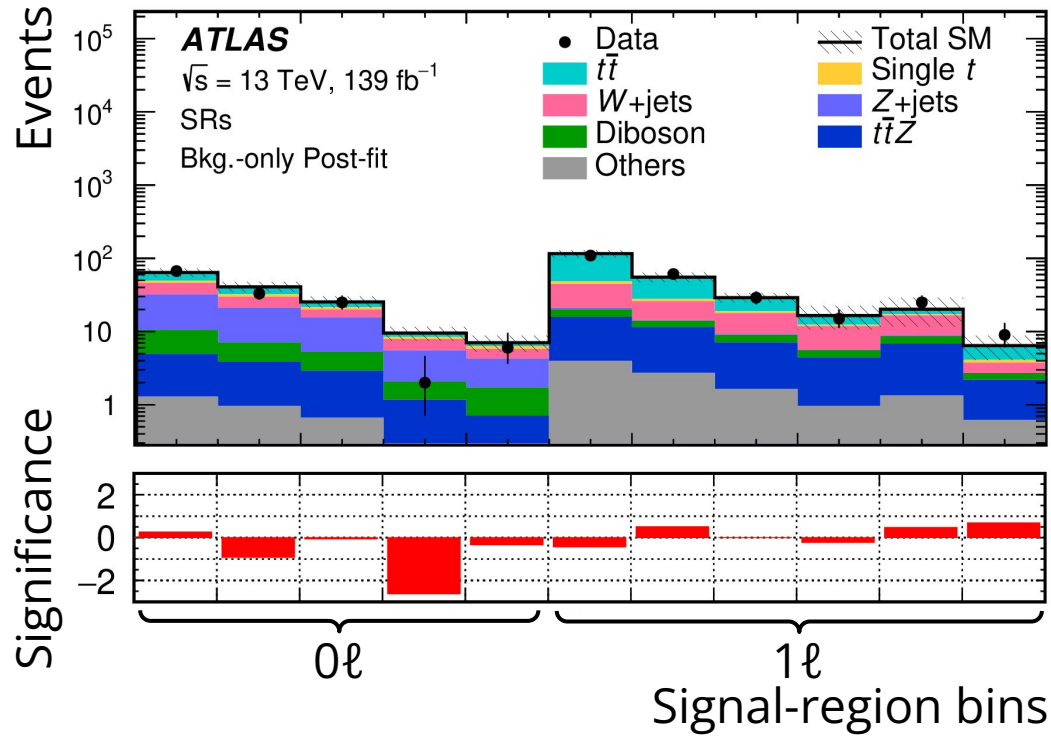
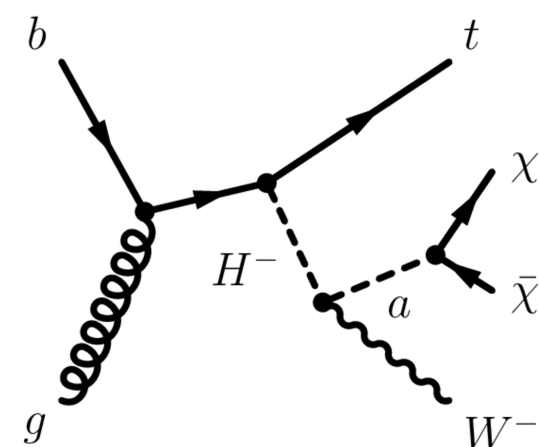
2 ℓ -channel:

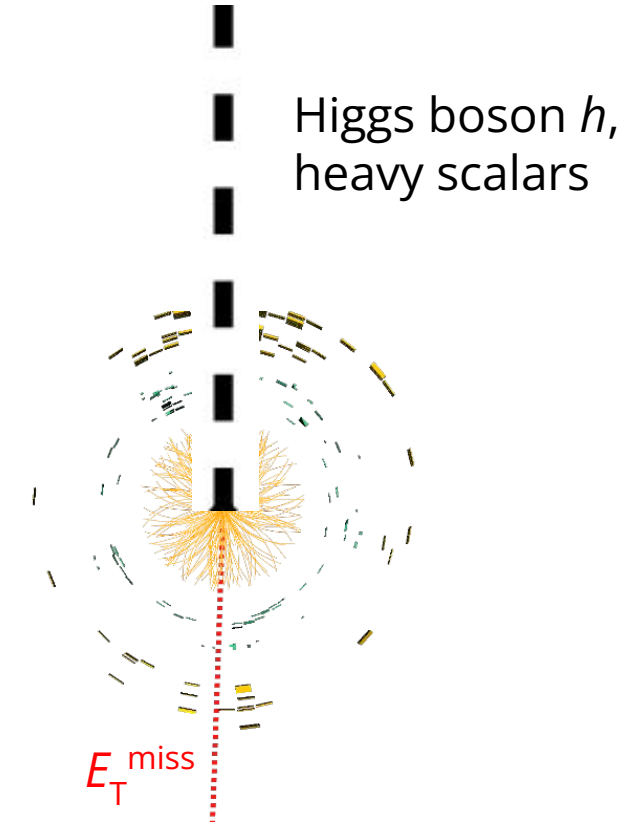
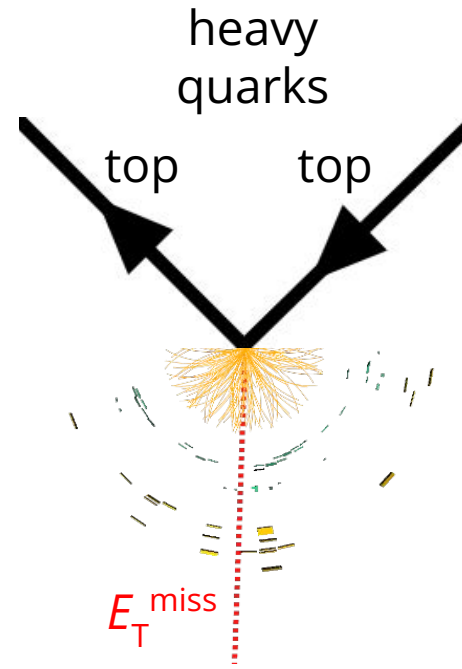
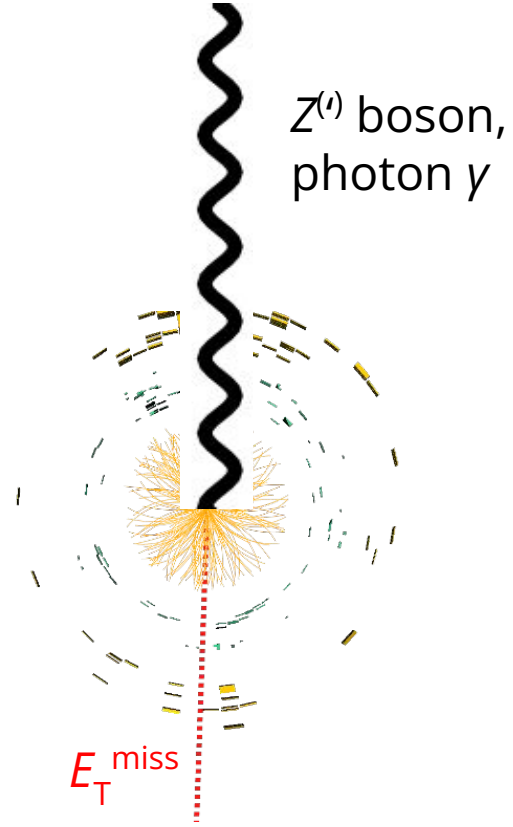
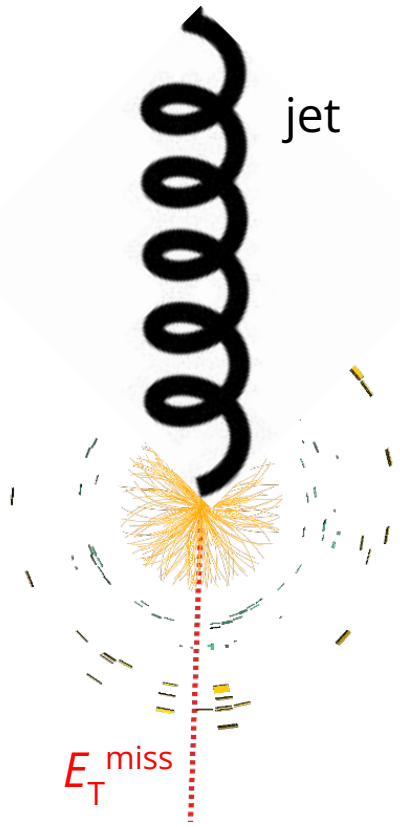
→ [*Eur.Phys.J.C* **81** \(2021\) 860](#)



→ [*Eur.Phys.J.C* **83** \(2023\) 7, 603](#)

- Target: single top quark, energetic W boson and large E_T^{miss}
- Main selection
 - $E_T^{\text{miss}} > 250$ GeV
 - 1 b -jet
 - 0ℓ -, 1ℓ -, 2ℓ -channels
- Data in **good agreement** with Standard Model
- Exclusion limits on 2HDM+ a





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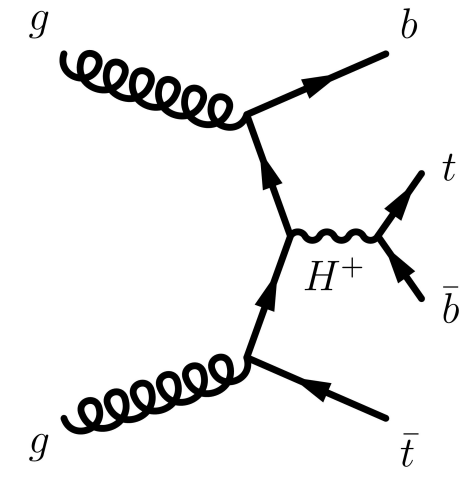
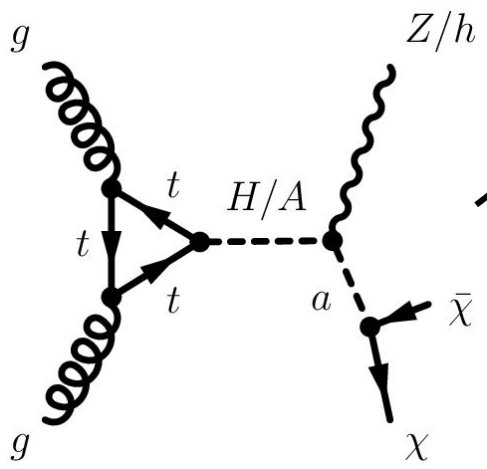
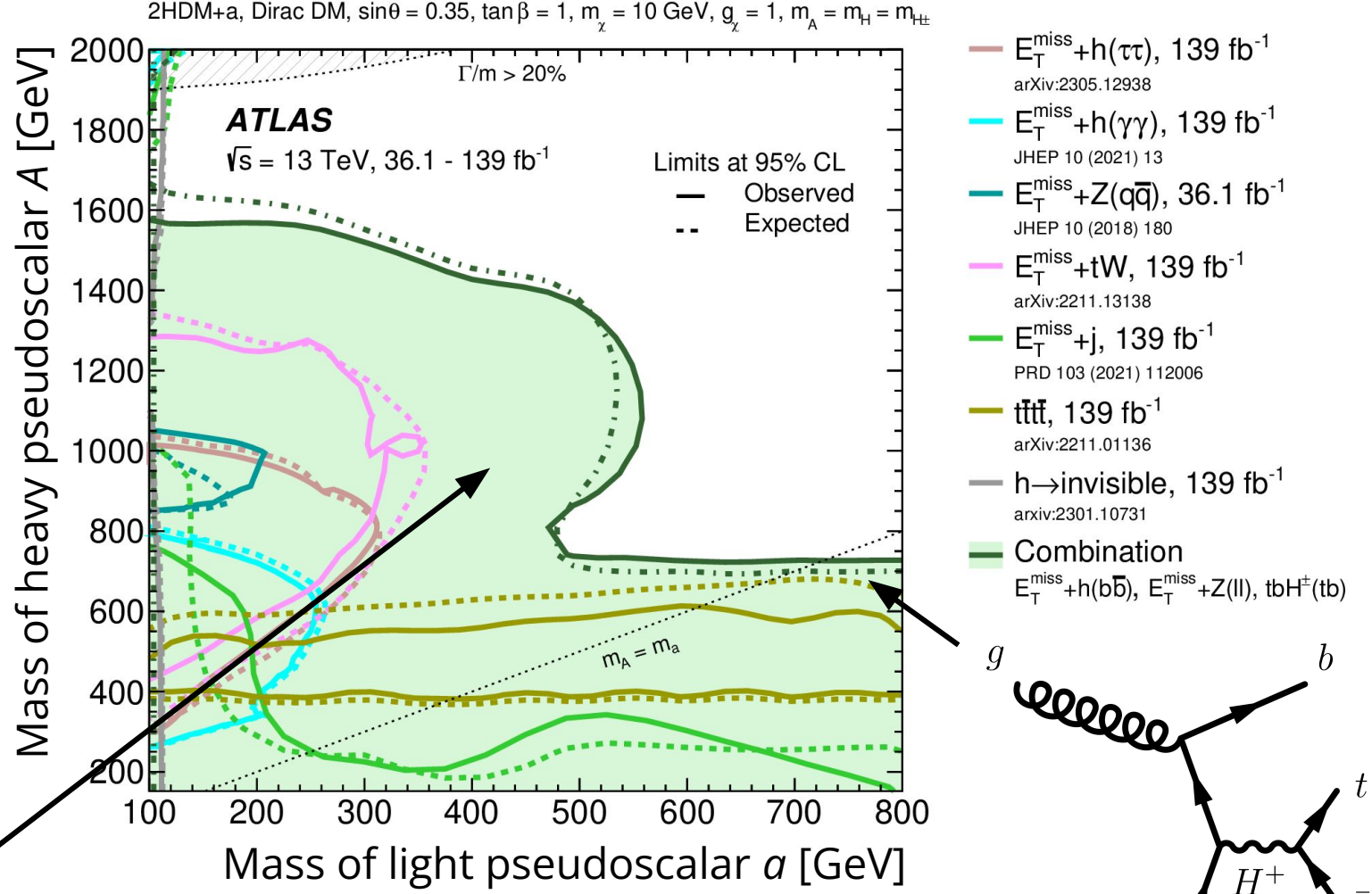
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combinations:

$2\text{HDM}+\alpha$: \rightarrow 2306.00641

$h\rightarrow\text{inv.}$: \rightarrow 2301.10731

- For two-Higgs-doublet model with pseudoscalar mediator a
- **Statistical combination:**
 - $Z(\rightarrow \ell\ell) + E_T^{\text{miss}}$
 - $h(\rightarrow bb) + E_T^{\text{miss}}$
 - $tbH^\pm(\rightarrow tb)$
- Overlay of 14 other searches, i.a.
 - $h(\rightarrow \tau\tau) + E_T^{\text{miss}}$
 - $tW + E_T^{\text{miss}}$



arXiv: [→2306.00641](https://arxiv.org/abs/2306.00641) (submitted to *Sci.Bull.*)

- **Multitude of ATLAS searches** for WIMP Dark Matter
- Analysis of LHC Run-2 data coming to an end
- ➔ **More intricate final states and methods** (e.g. taus, W tagging) investigated
- ➔ **Combinations** of searches as ATLAS Run-2 legacy

- **LHC Run 3** started last year
- ➔ Results with reduced statistical uncertainty and new methods incoming
- ➔ Stay tuned!

