

Dark Matter searches with the ATLAS detector

Jay Chan

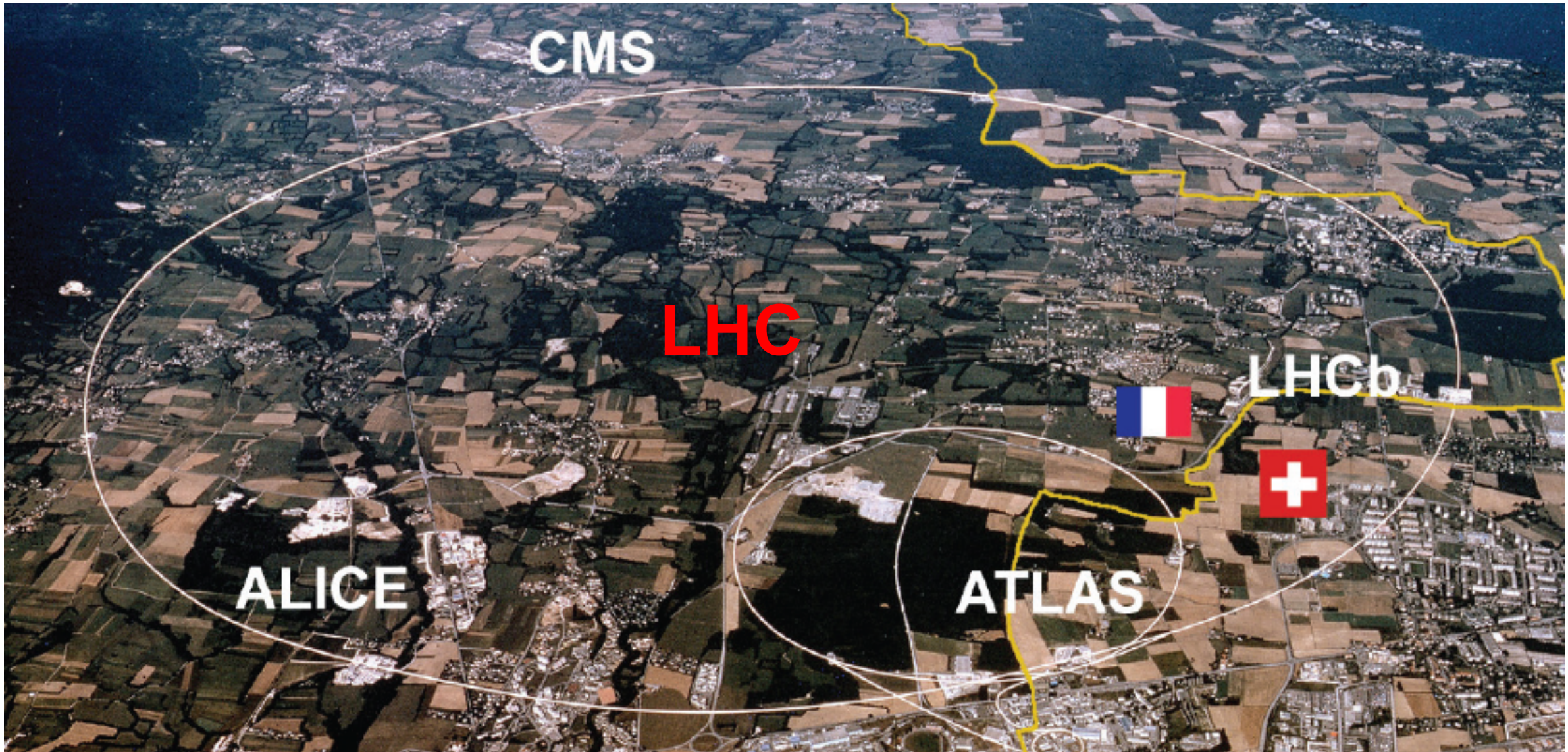
University of Wisconsin-Madison

NCTS Dark Physics Workshop, Hsinchu

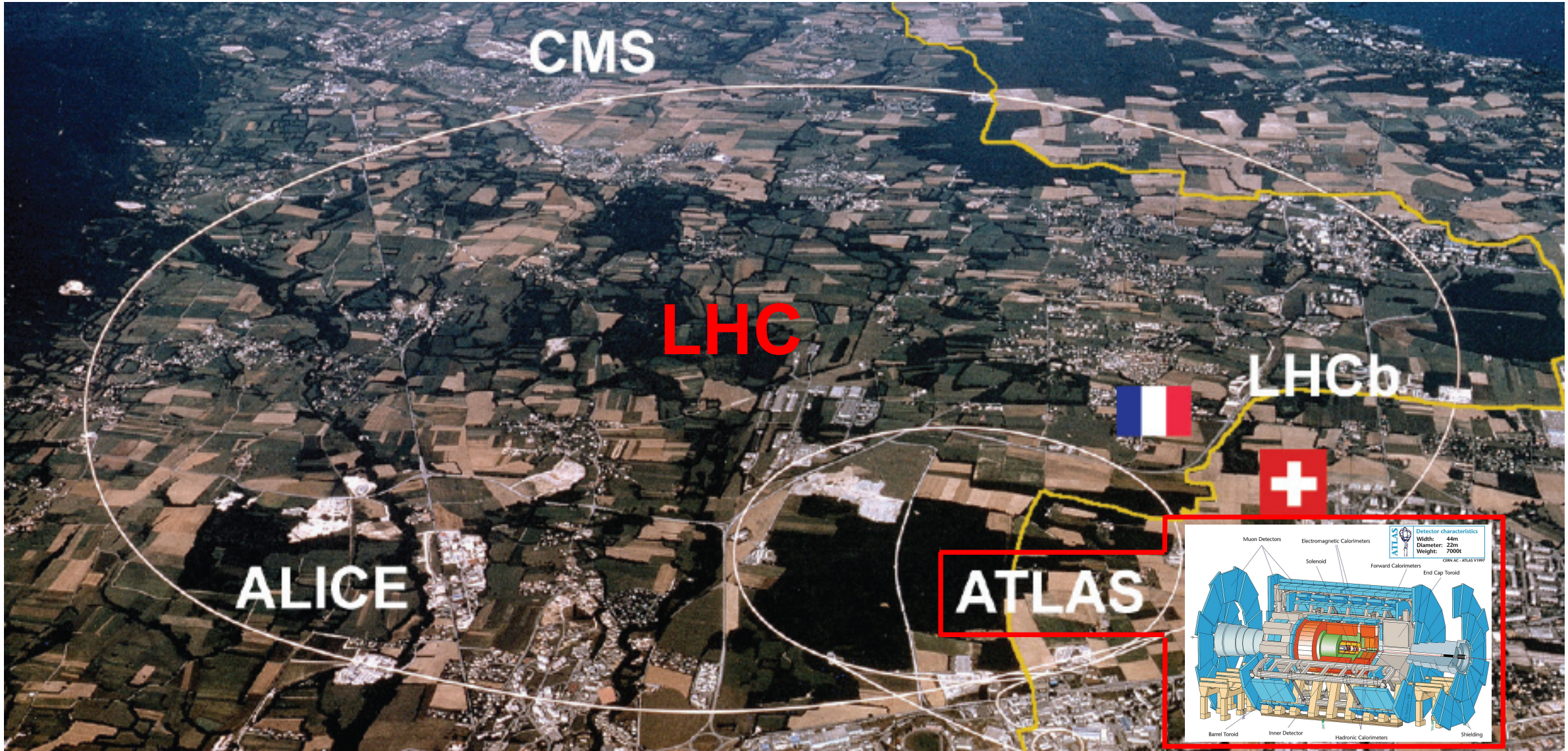
January 9, 2020



ATLAS detector



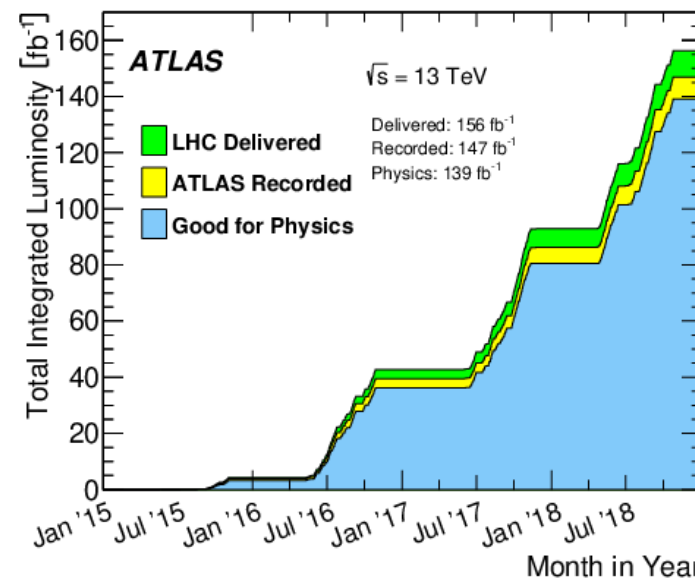
ATLAS detector



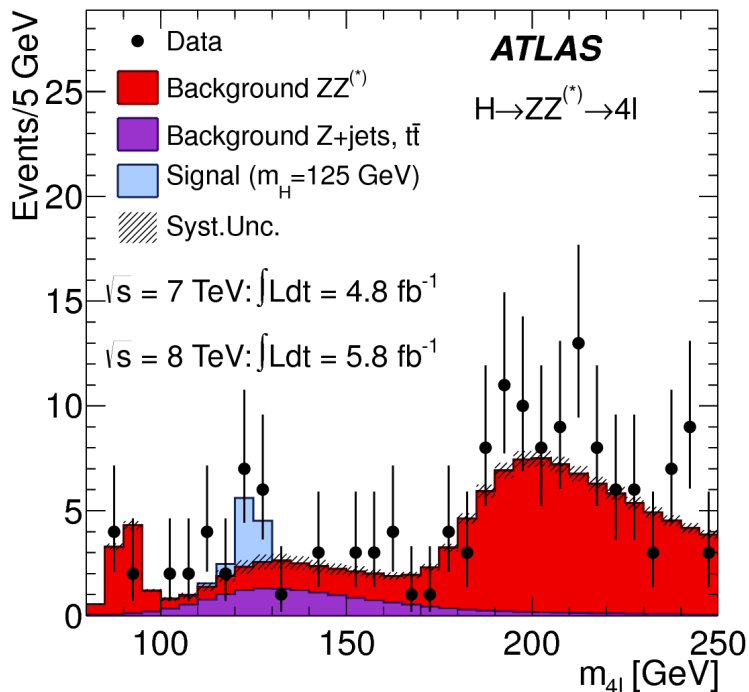
Timelines and dataset



We are here!
The end of run-2: 13 TeV, ~140 fb⁻¹



What has ATLAS found so far?

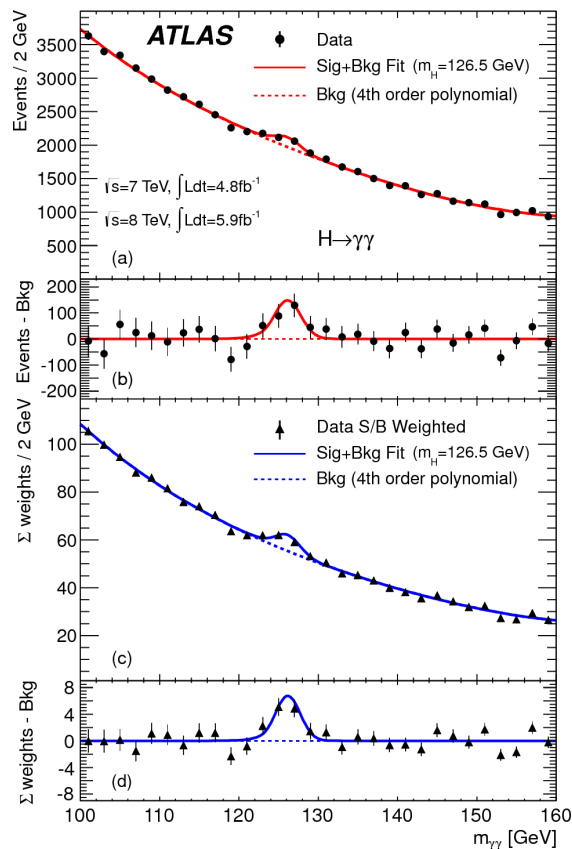


Higgs discovery

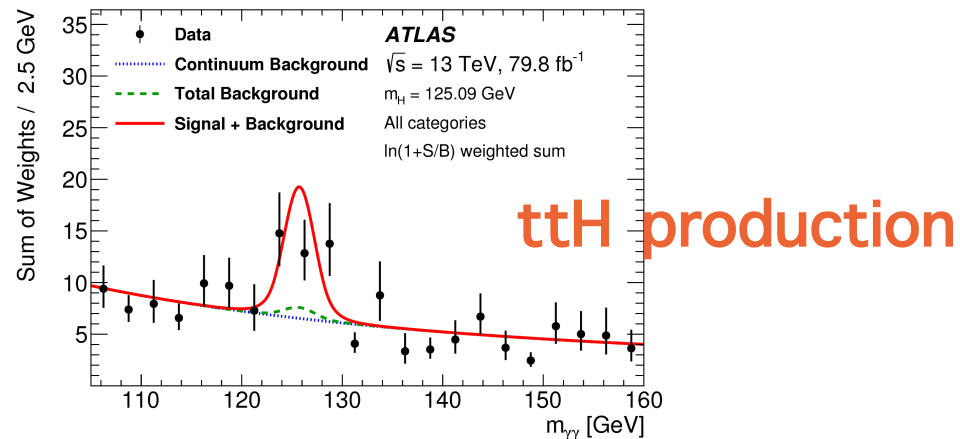
In 2012, ATLAS (together with CMS) discovered the predicted Higgs boson through the decay to diphoton and 4 leptons

January 9, 2020

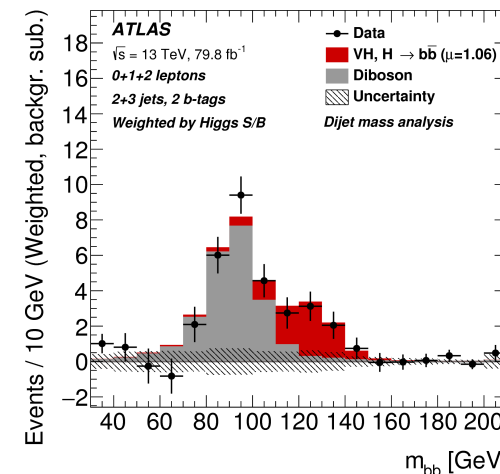
Higgs and Higgs!!



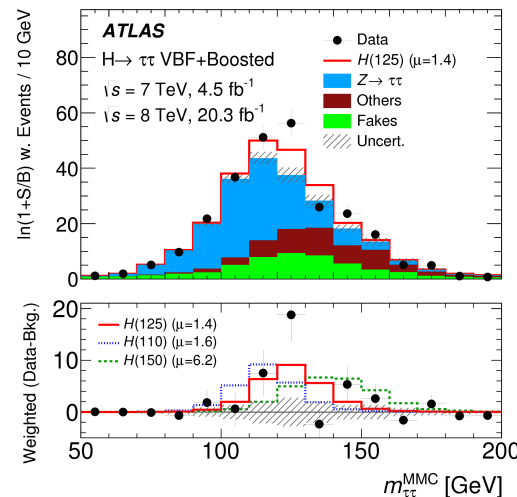
Jay Chan (Wisconsin)



$H \rightarrow b\bar{b}$

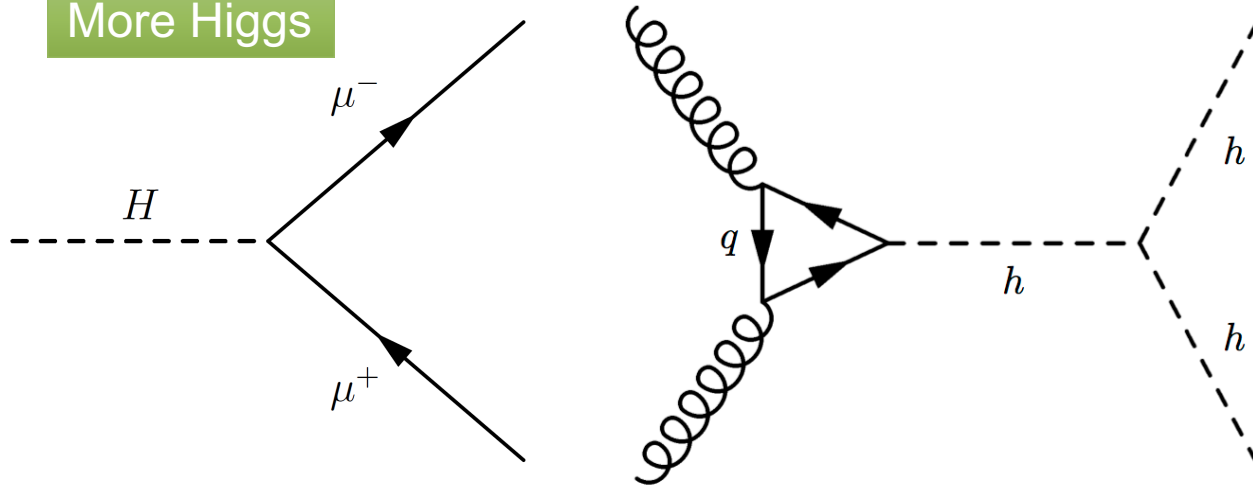


$H \rightarrow \tau\tau$

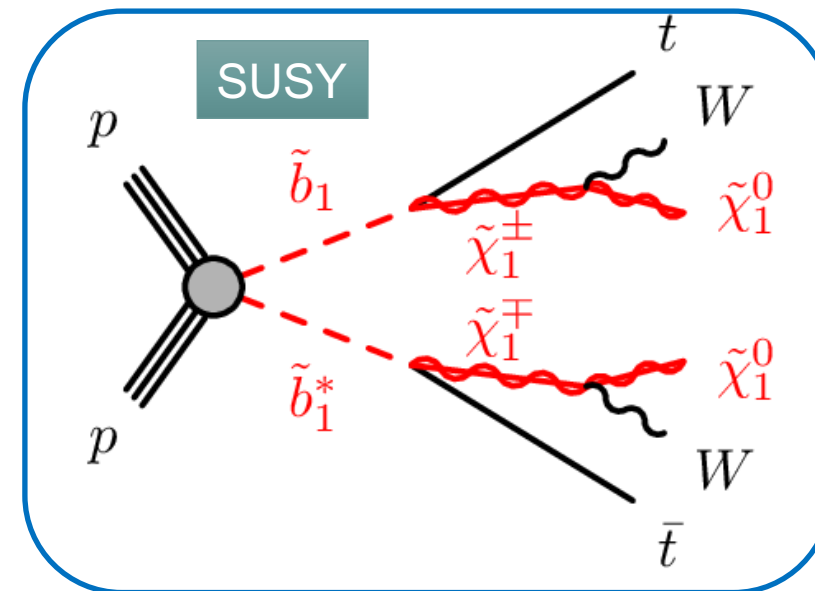
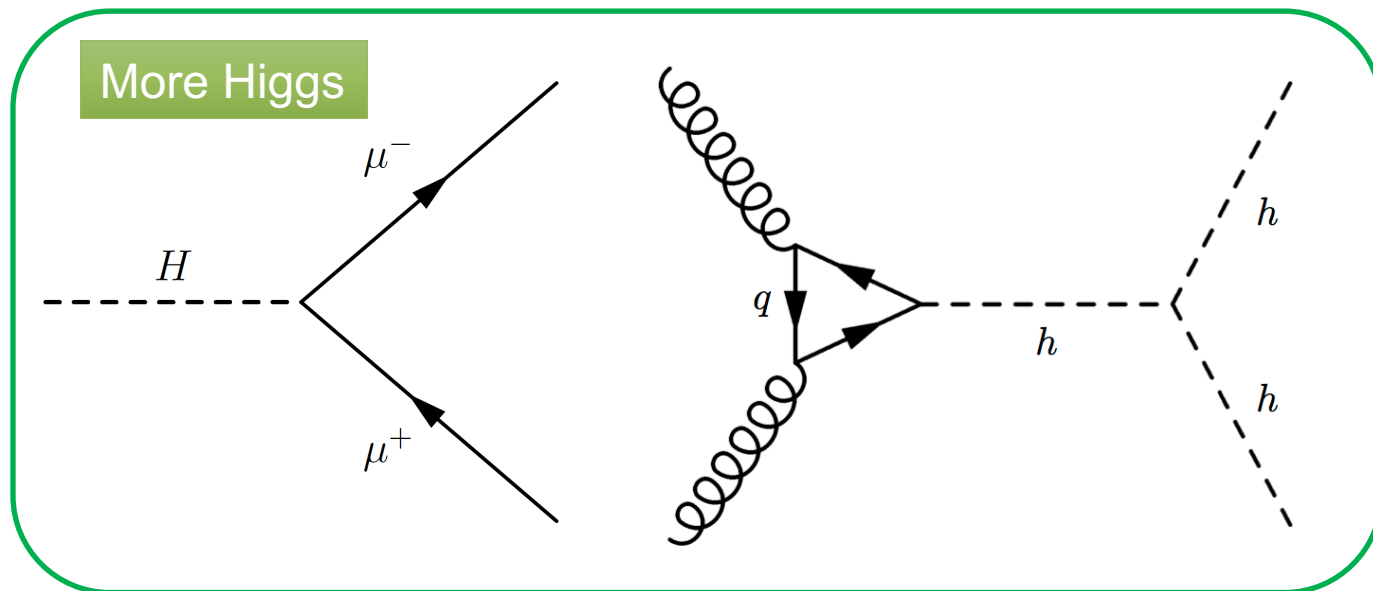


What else can we look for?

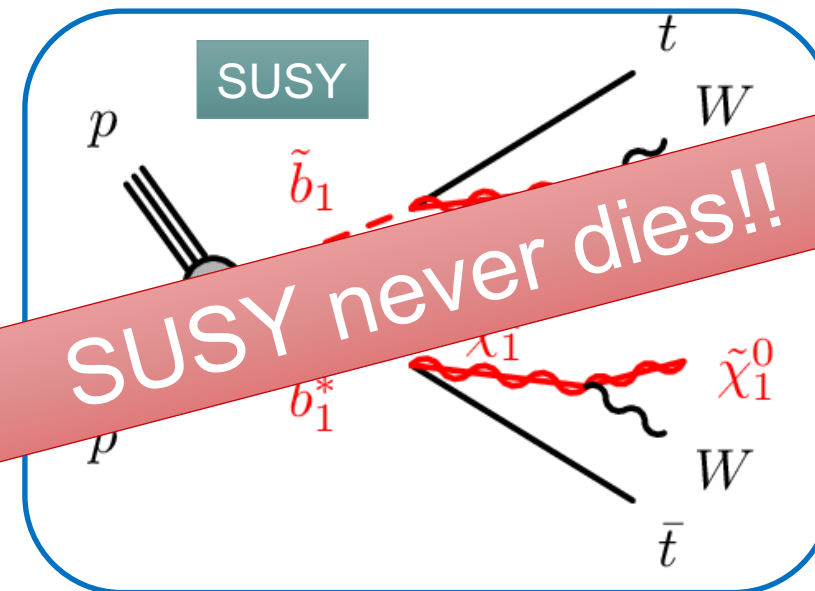
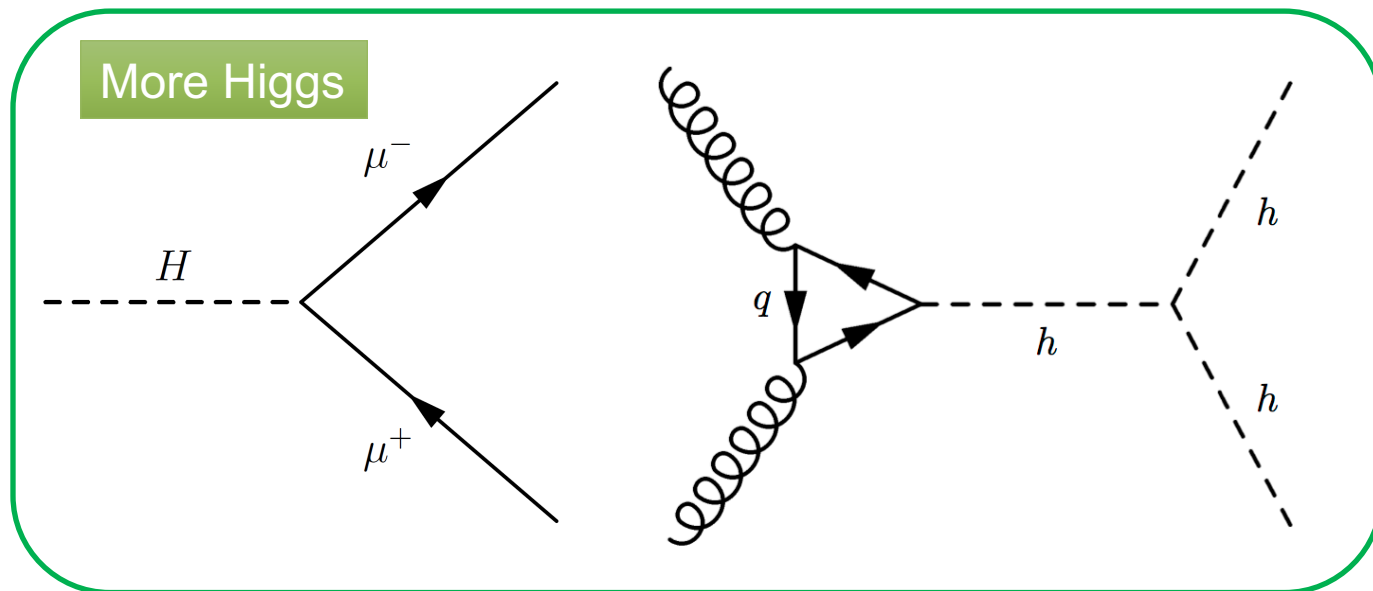
More Higgs



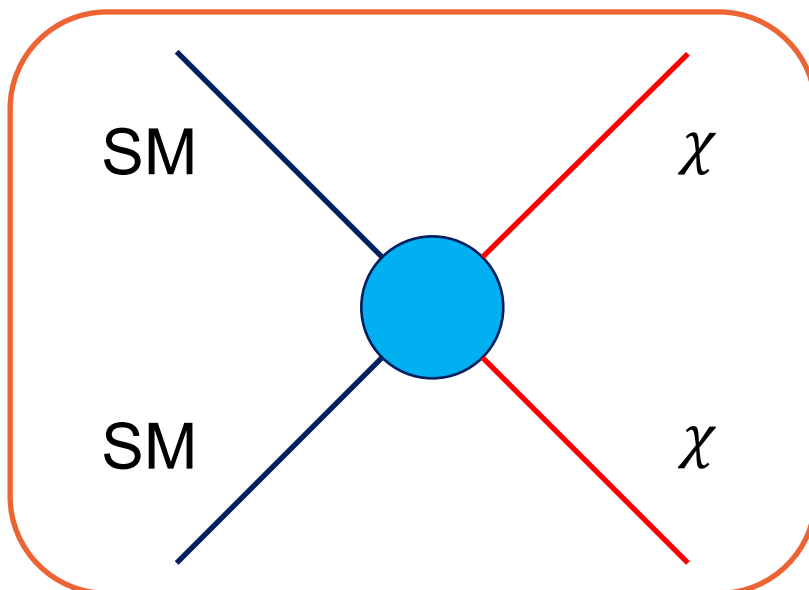
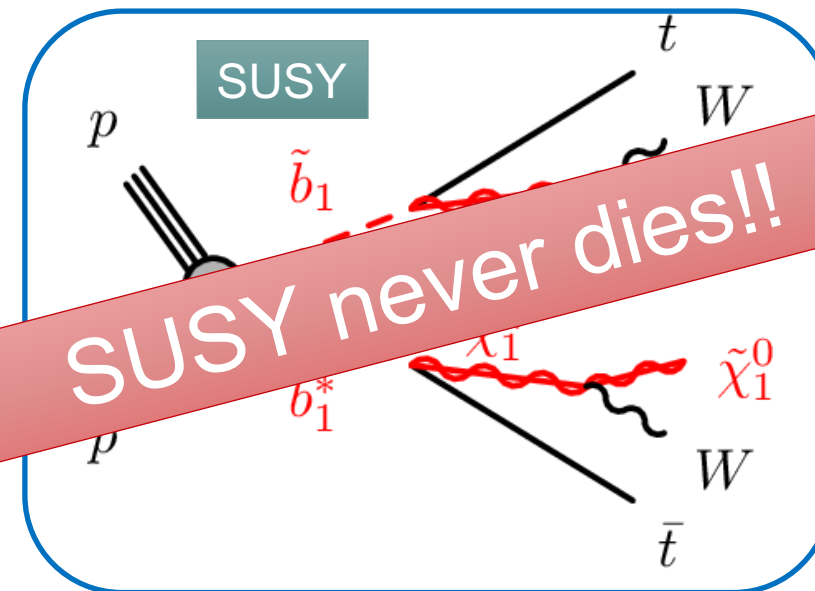
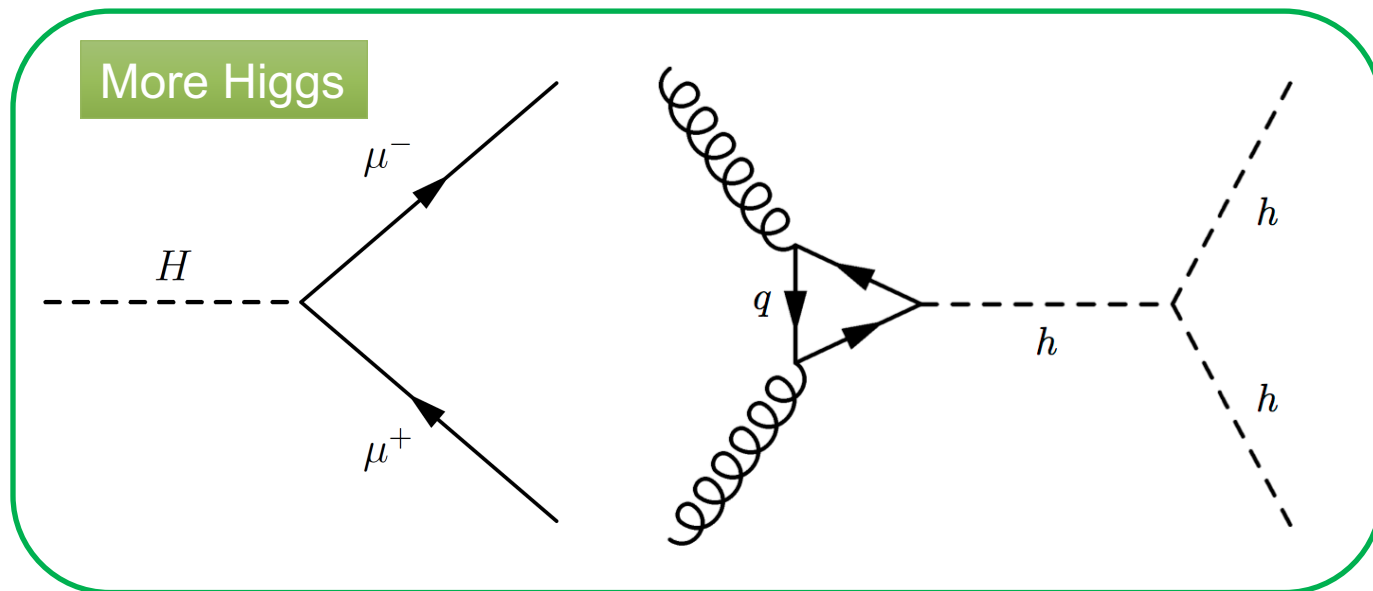
What else can we look for?



What else can we look for?



What else can we look for?



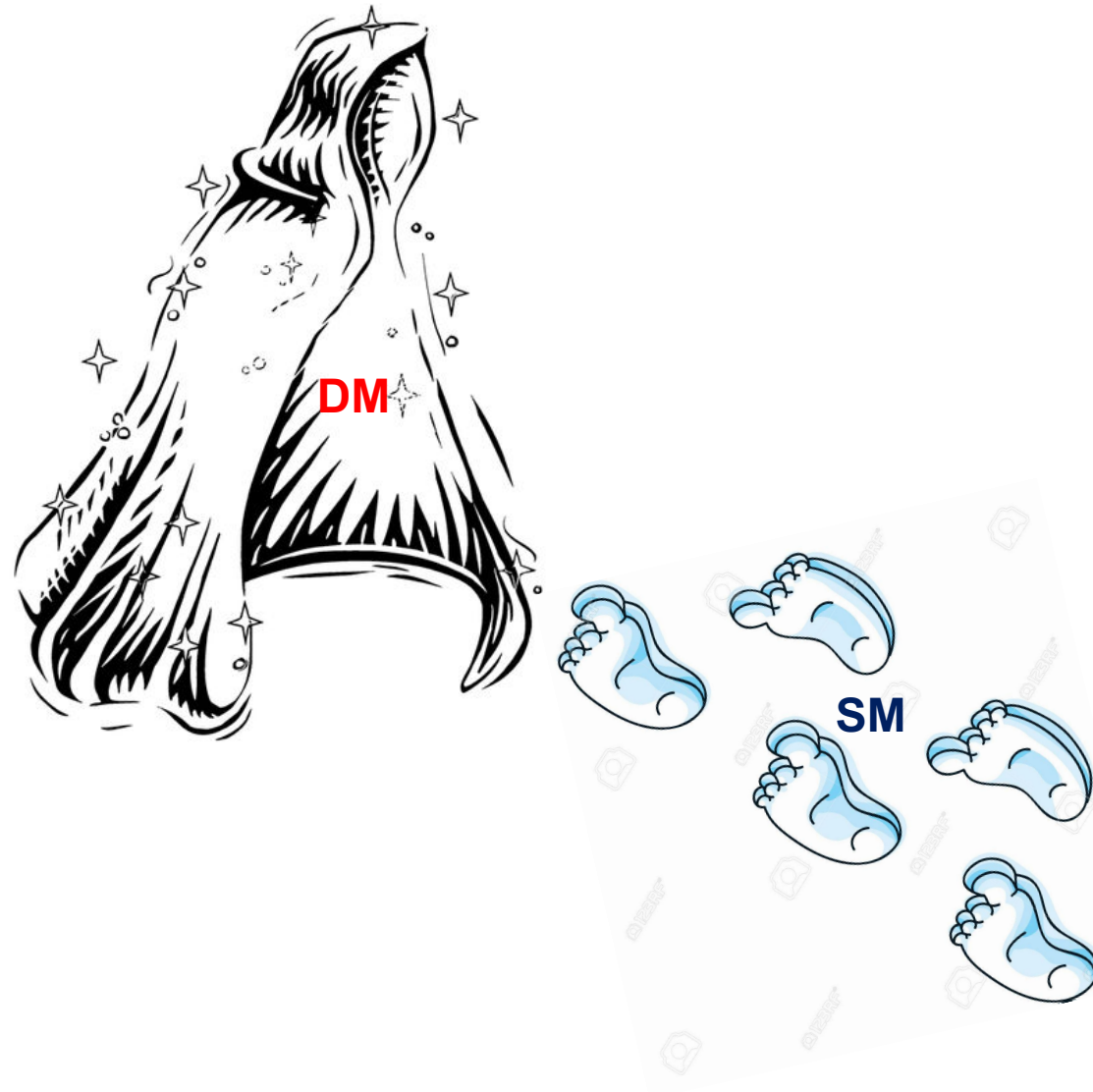
Dark Matter

Strong evidence of existence of DM from the astronomical observations

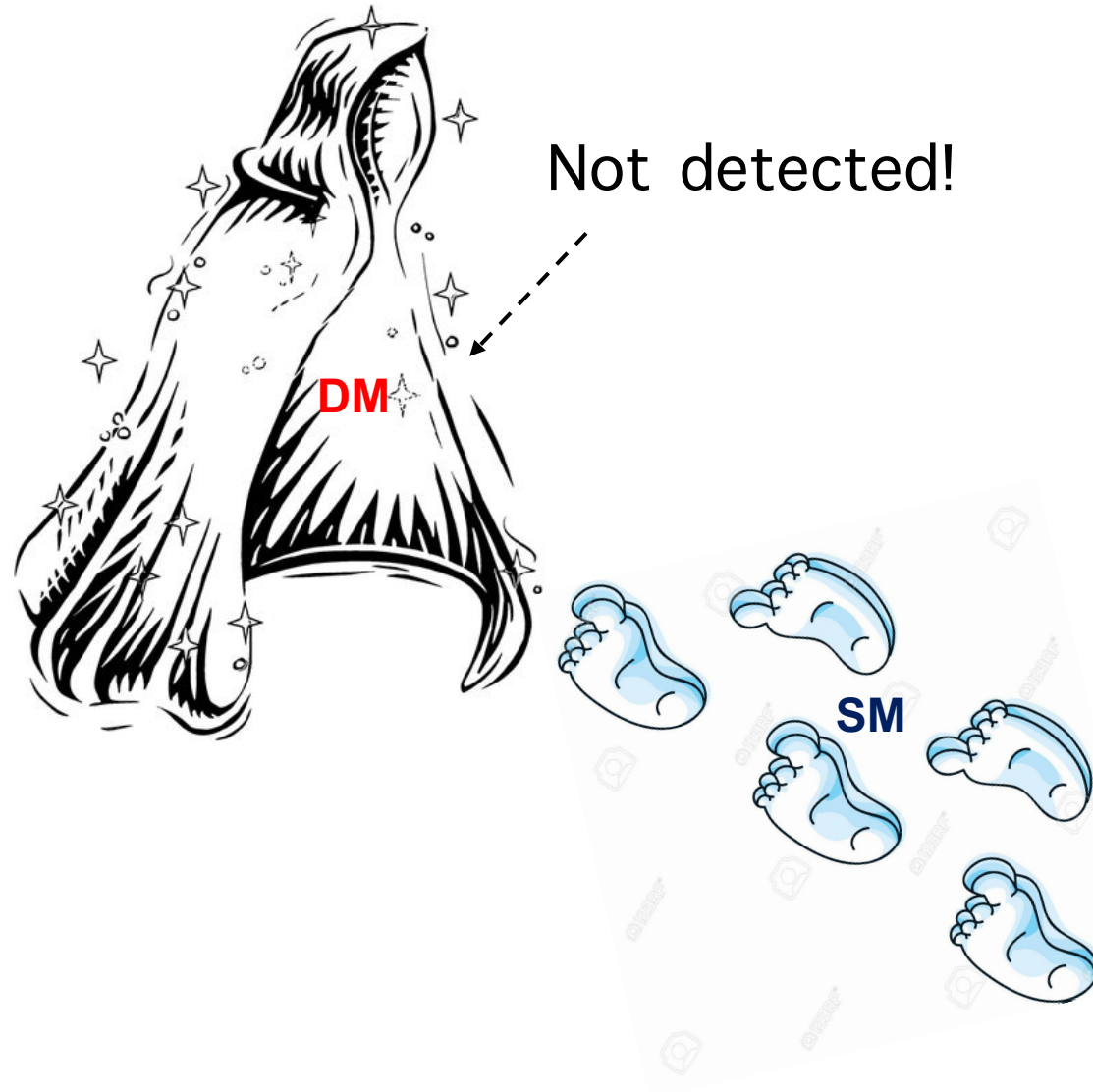
No direct observation of DM so far

DM searches through collider experiments provide great complementarity to the direct and indirect searches

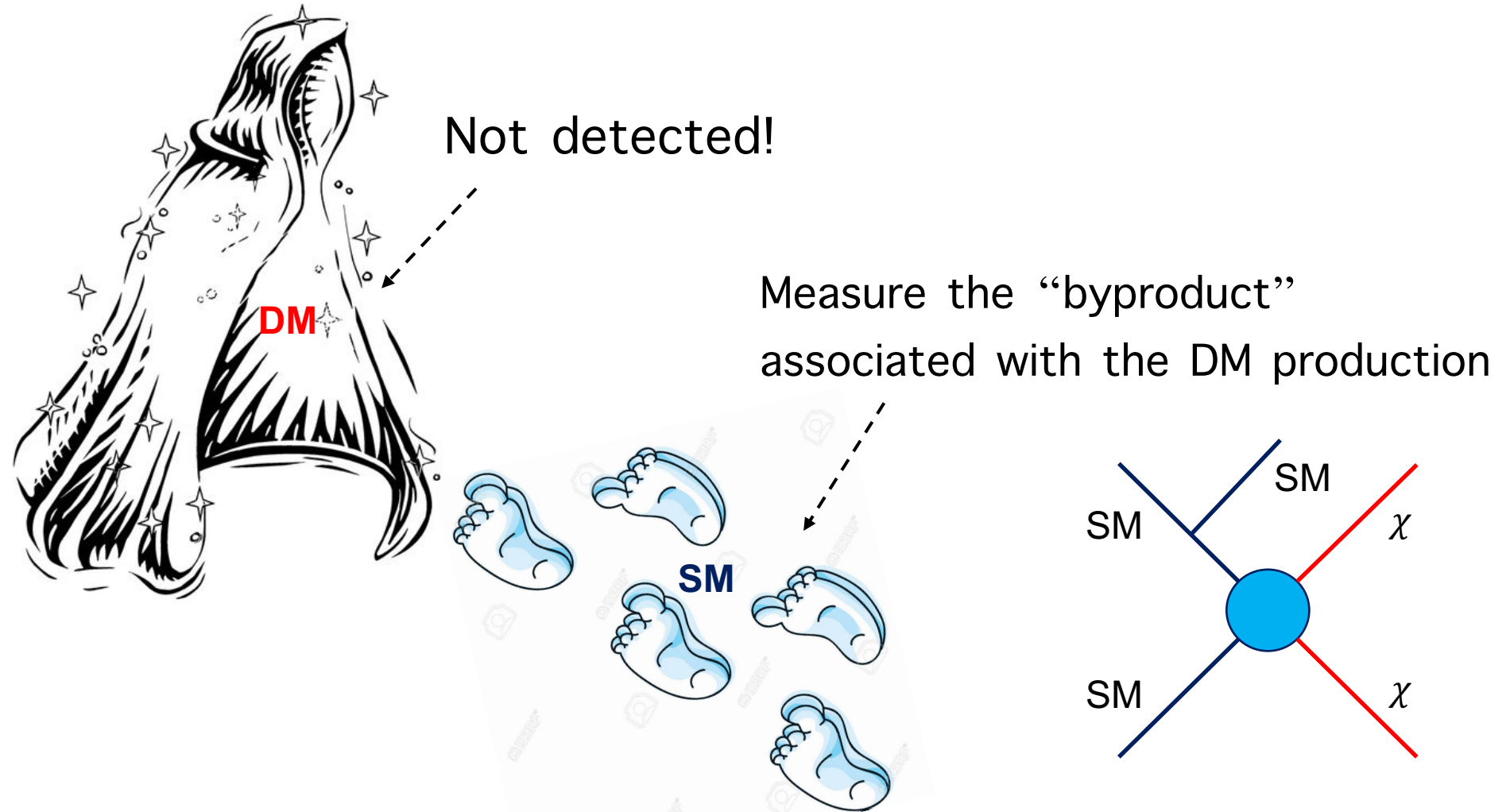
How do we search for DM?



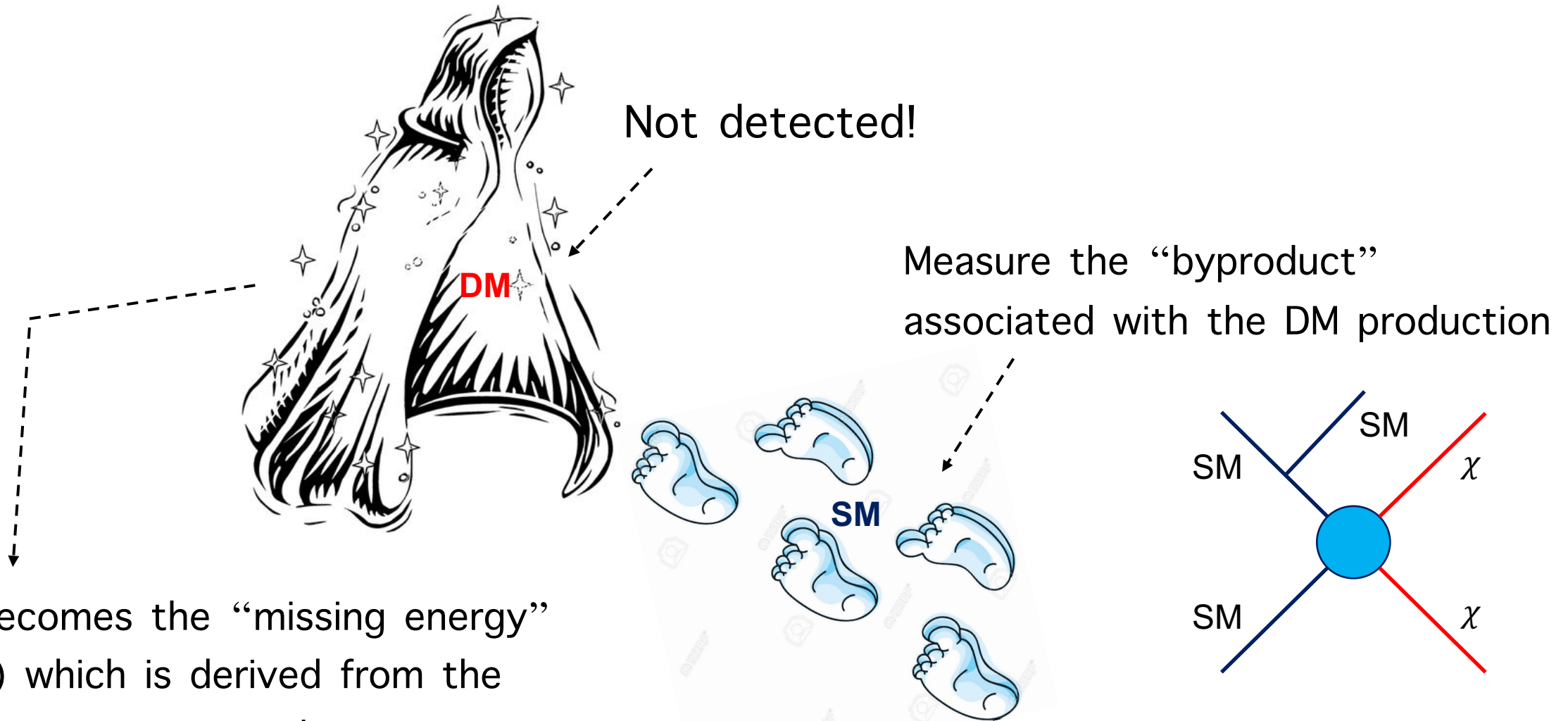
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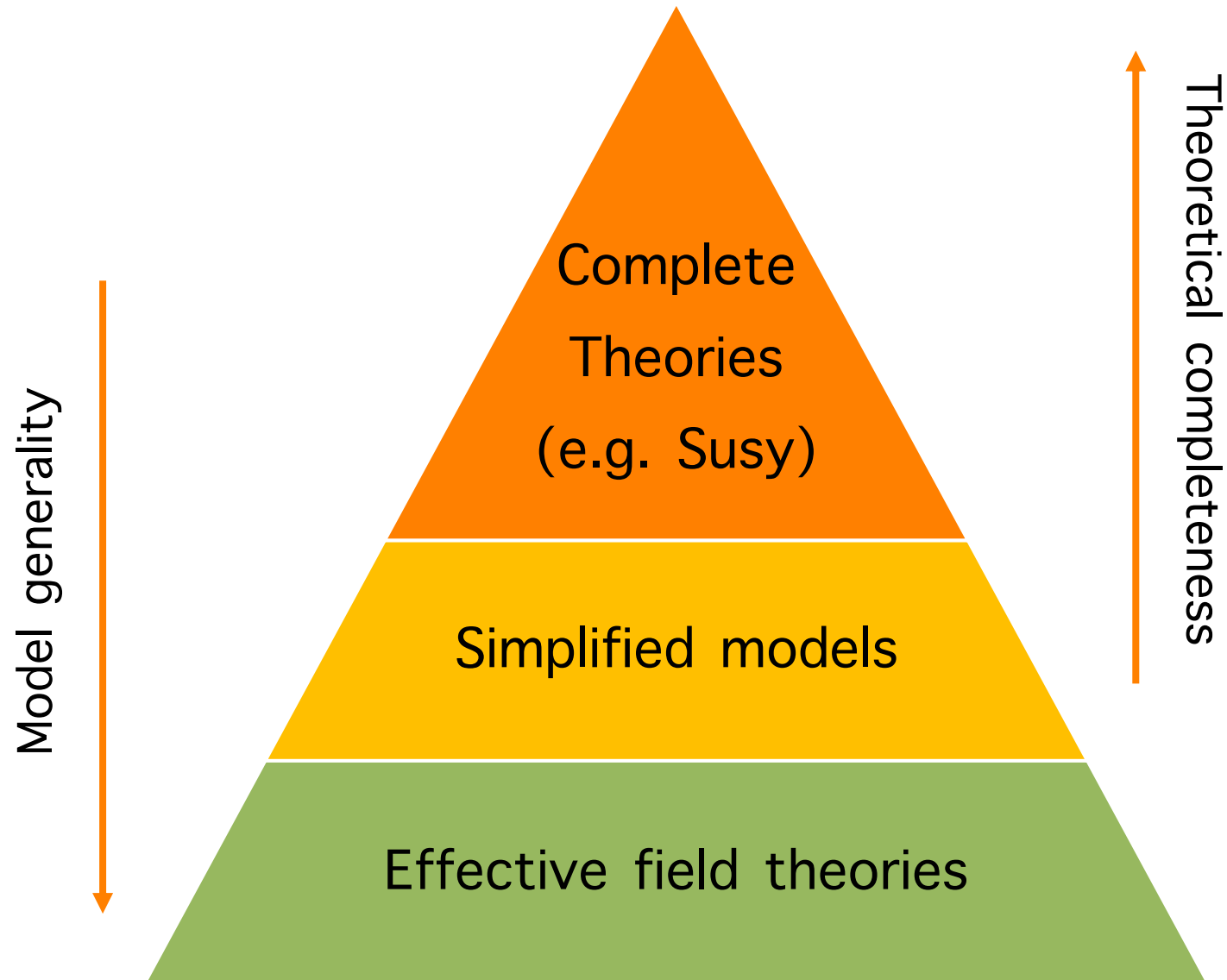
How do we search for DM?



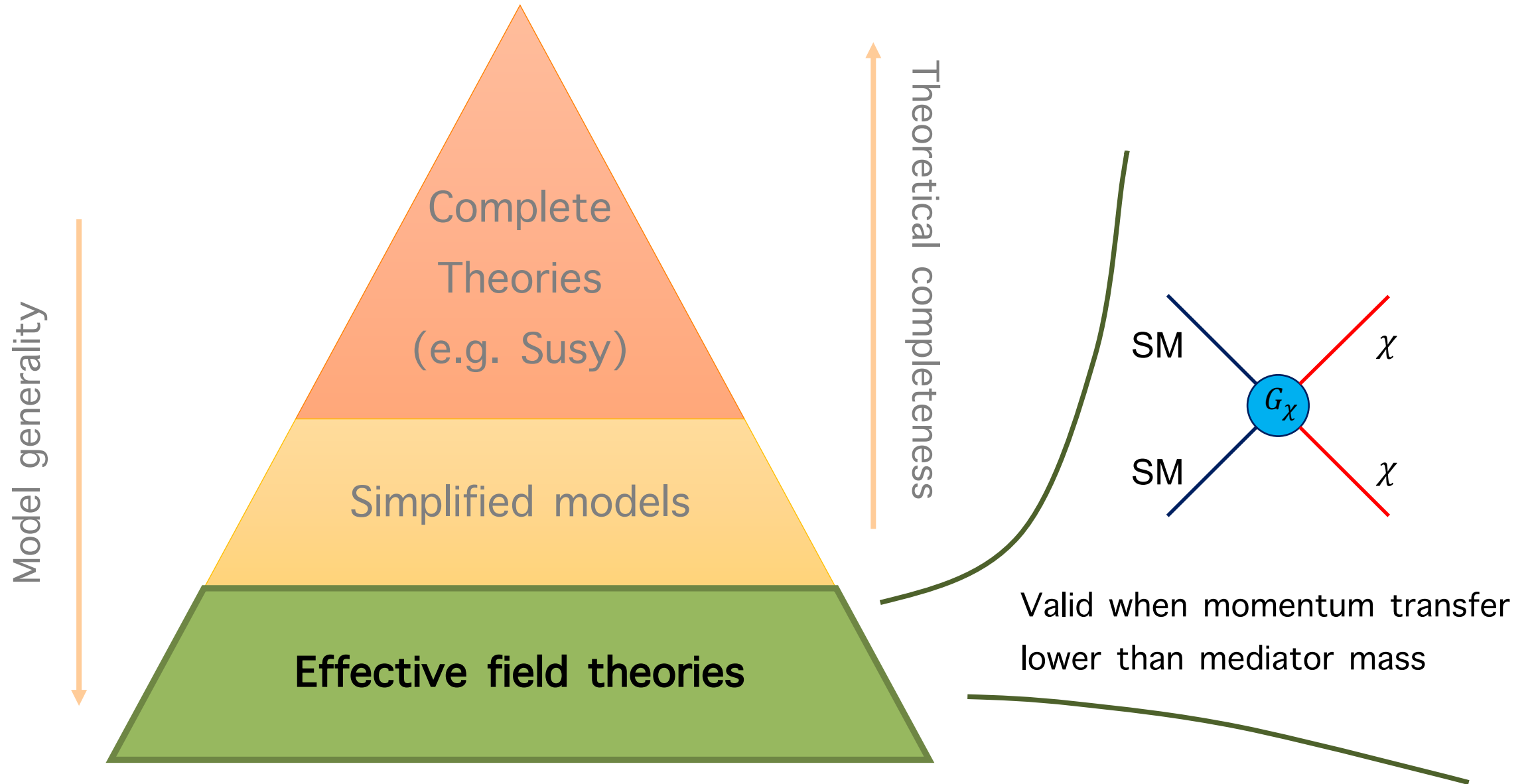
How do we search for DM?



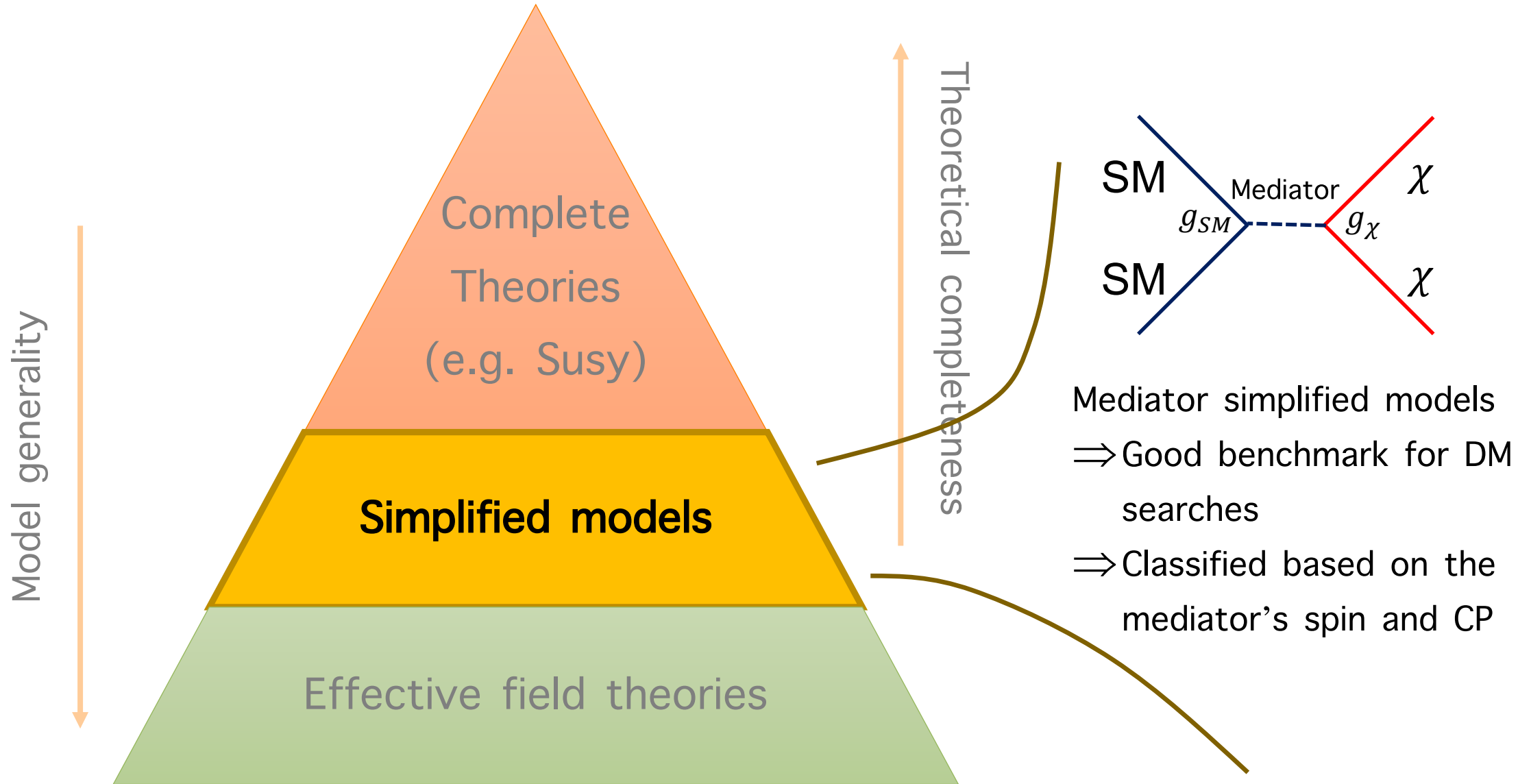
Theoretical framework



Theoretical framework

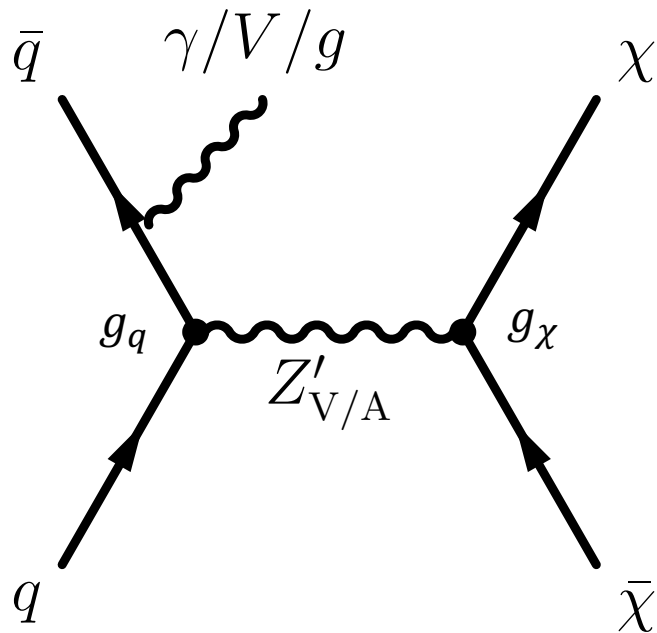


Theoretical framework



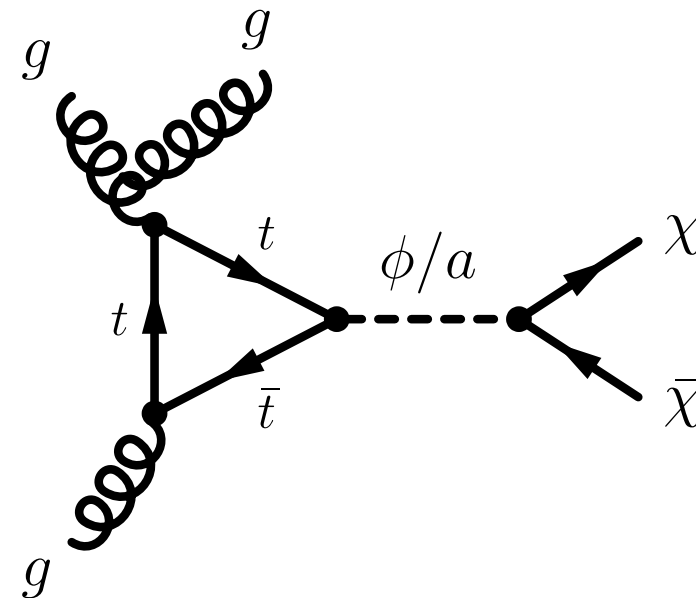
One-mediator simplified models

Vector/axial-vector mediator



Parameters: $m_{Z'}$, m_χ , g_q , g_l , g_χ

Scalar/pseudo-scalar mediator

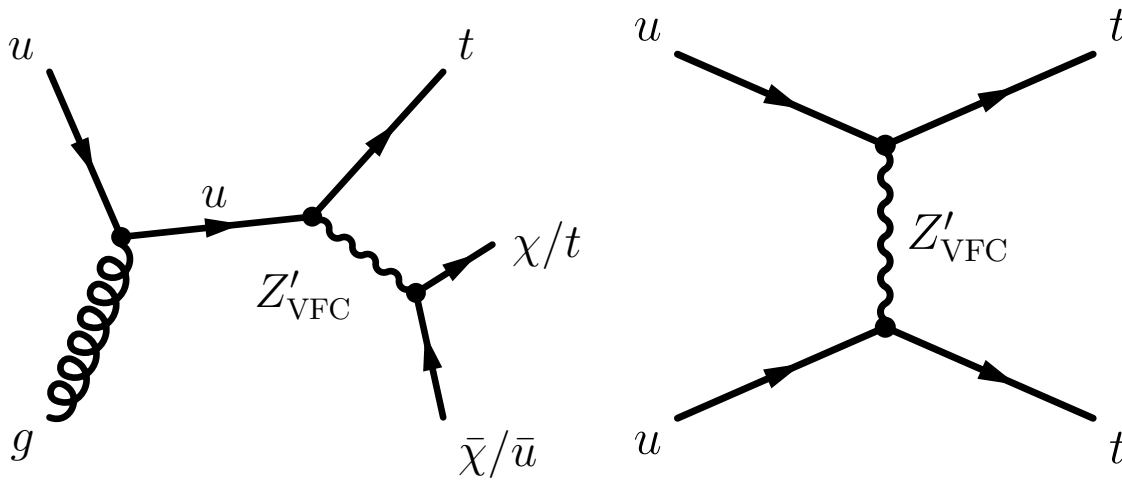


Parameters: $m_{\phi(a)}$, m_χ , g_f , g_χ

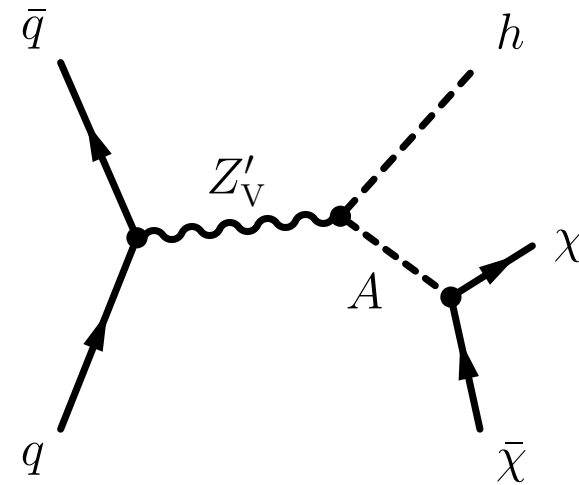
Less simple simplified models

The simplified models can be made “less simple”, which can result in some exotic final states

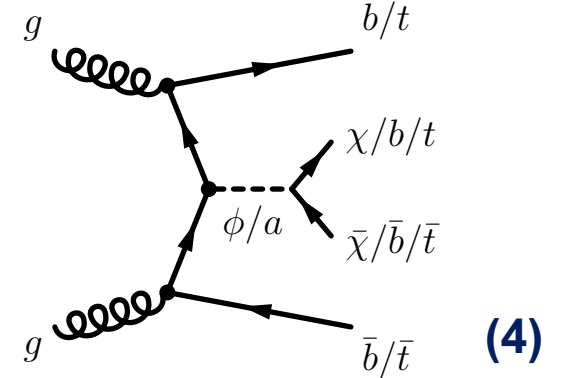
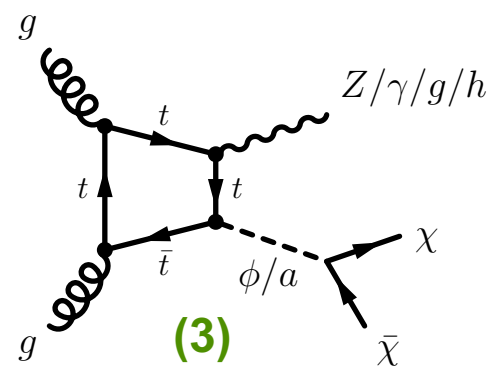
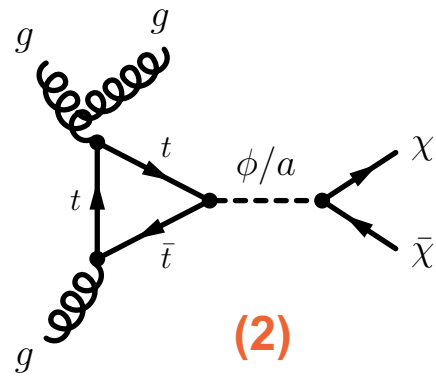
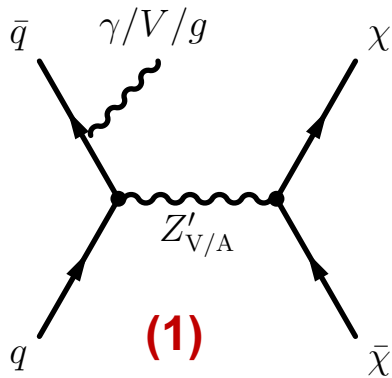
Flavor-changing vector mediator model



Two-Higgs-doublet models with a vector mediator

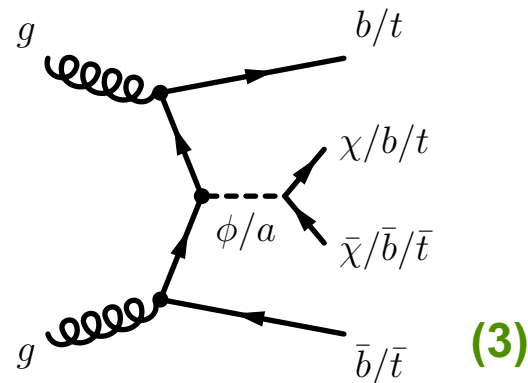
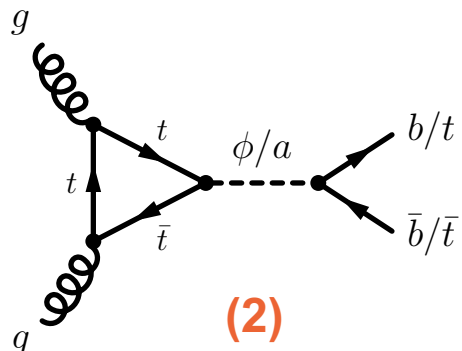
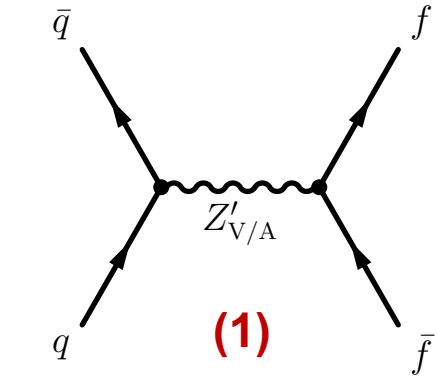


X + MET analysis



Signatures	Interpretation	Publications
jet + MET	(1) (2) (3)	JHEP 01 (2018) 126
γ + MET	(1) (3)	Eur. Phys. J. C 77 (2017) 393
V + MET	(1) (3)	JHEP 10 (2018) 180
$t\bar{t}$ + MET	(4)	JHEP 06 (2018) 108
$b\bar{b}$ + MET	(4)	EPJC 78 (2018) 18

Visible final state analysis (resonance searches)

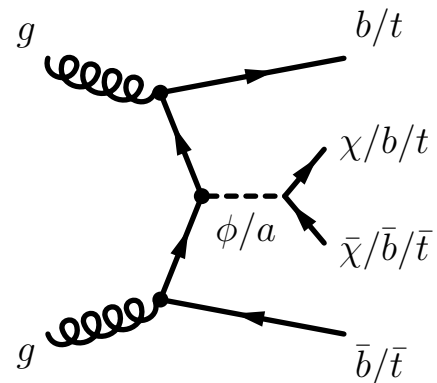
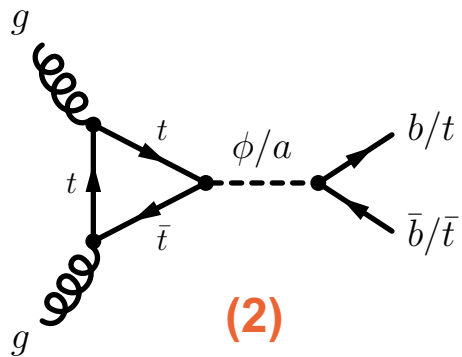
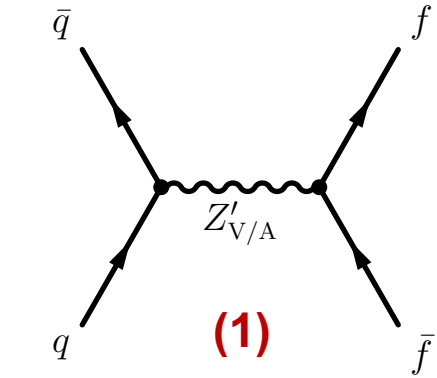


Signatures	Interpretation	Publications
Dijet	(1)	ATLAS-CONF-2019-007
Dijet + ISR*	(1)	ATLAS-CONF-2016-070
Dijet TLA**	(1)	PRL 121 (2018) 0818016
Dilepton	(1)	Phys. Rev. B 796 (2019)
Dibjet	(2)	PRD 98 (2018) 032016
$t\bar{t}$ resonance	(2)	EPJC 78 (2018) 565
4t	(3)	JHEP 09 (2017) 088

*ISR = initial state radiation

**TLA = trigger level analysis

Visible final state analysis (resonance searches)

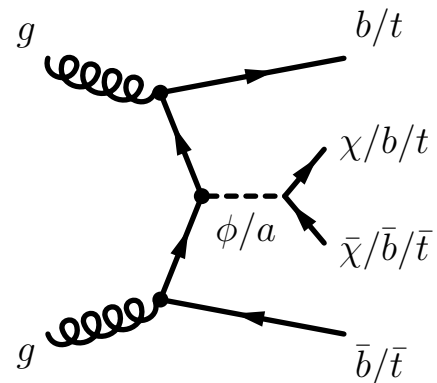
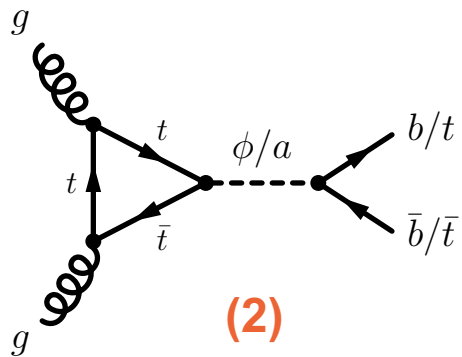
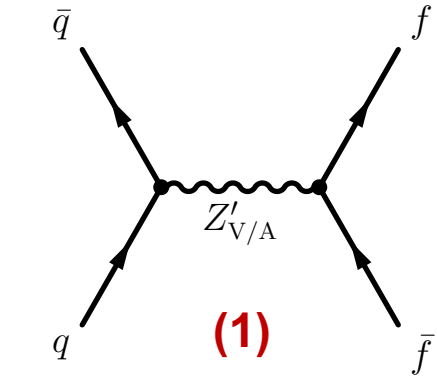


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Limitation in low mediator mass due to the required triggers

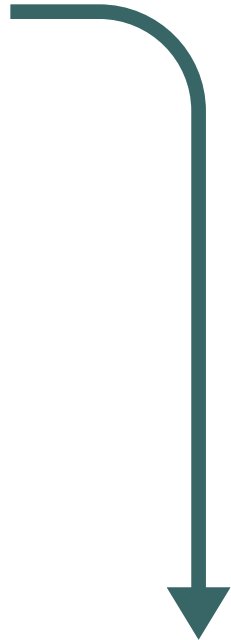
Visible final state analysis (resonance searches)



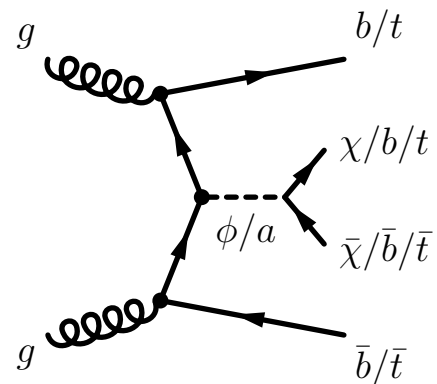
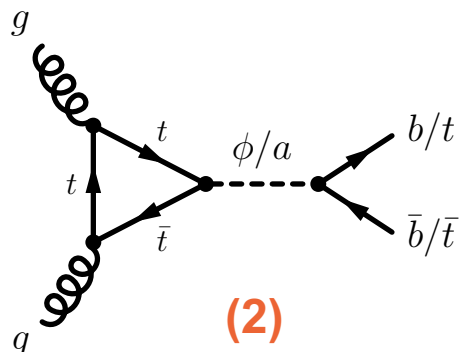
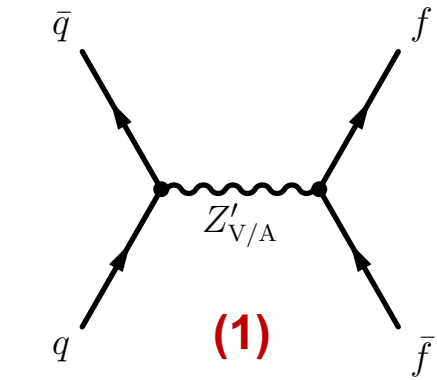
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Dibjet	(2)	PRD 98 (2018) 032016
$t\bar{t}$ resonance	(2)	EPJC 78 (2018) 565
4t	(3)	JHEP 09 (2017) 088

*ISR = initial state radiation
 **TLA = trigger level analysis

Search for dijet + ISR jets provides sensitivity to lower mediator mass



Visible final state analysis (resonance searches)



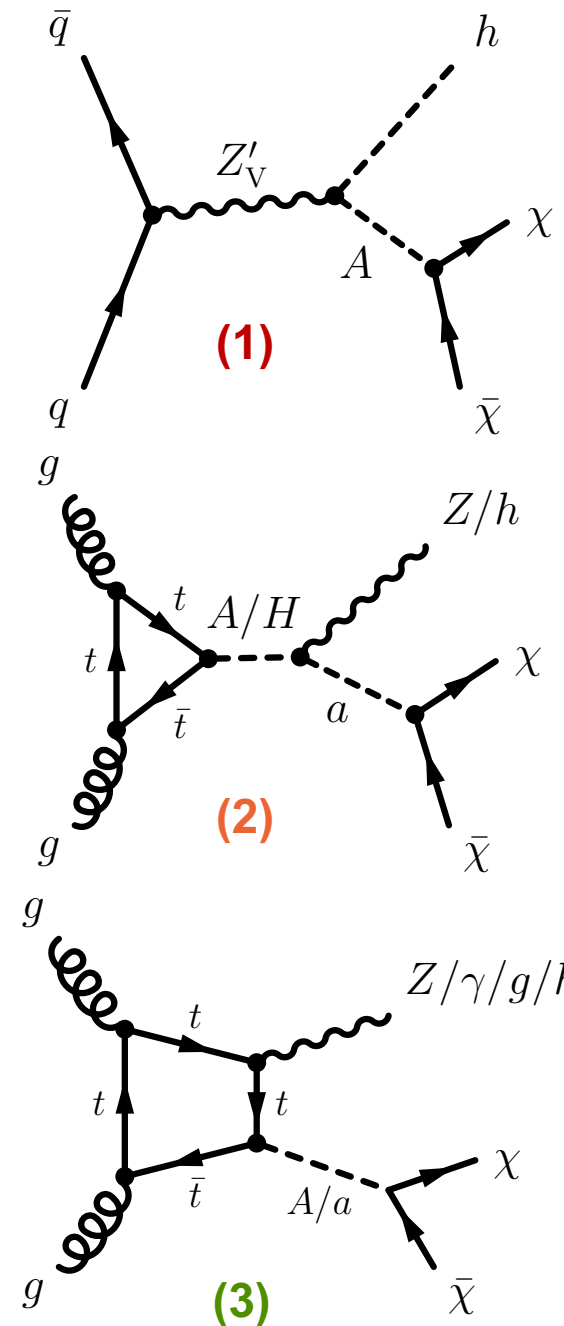
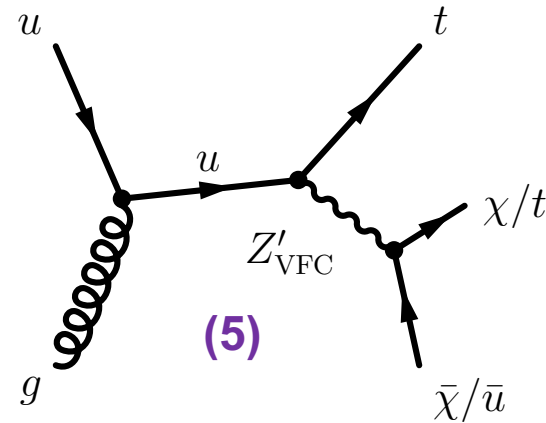
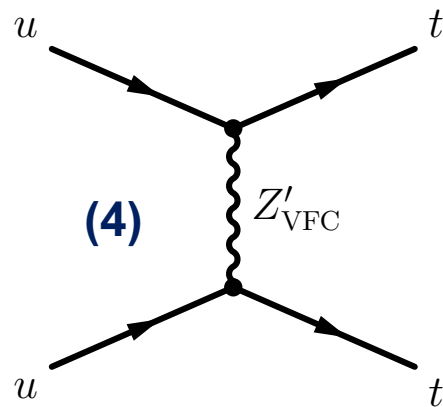
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$t\bar{t}$ resonance	(2)	EPJC 78 (2018) 565
4t	(3)	HEP 00 (2017) 000

*ISR = initial state radiation
 **TLA = trigger level analysis

Requires only the level 1 trigger and uses partially reconstructed data (trigger level object) to reduce data size and increase event rates (also allows sensitivity to lower mediator mass)

More exotic final states

Signatures	Interpretation	Publications
H(bb) + MET	(1) (2) (3)	ATLAS-CONF-2018-039
H($\gamma\gamma$) + MET	(1) (2) (3)	Phys. Rev. Lett. D 96 (2017)
Same sign tt	(4)	JHEP 12 (2018) 039
t + MET	(5)	JHEP 05 (2019) 41



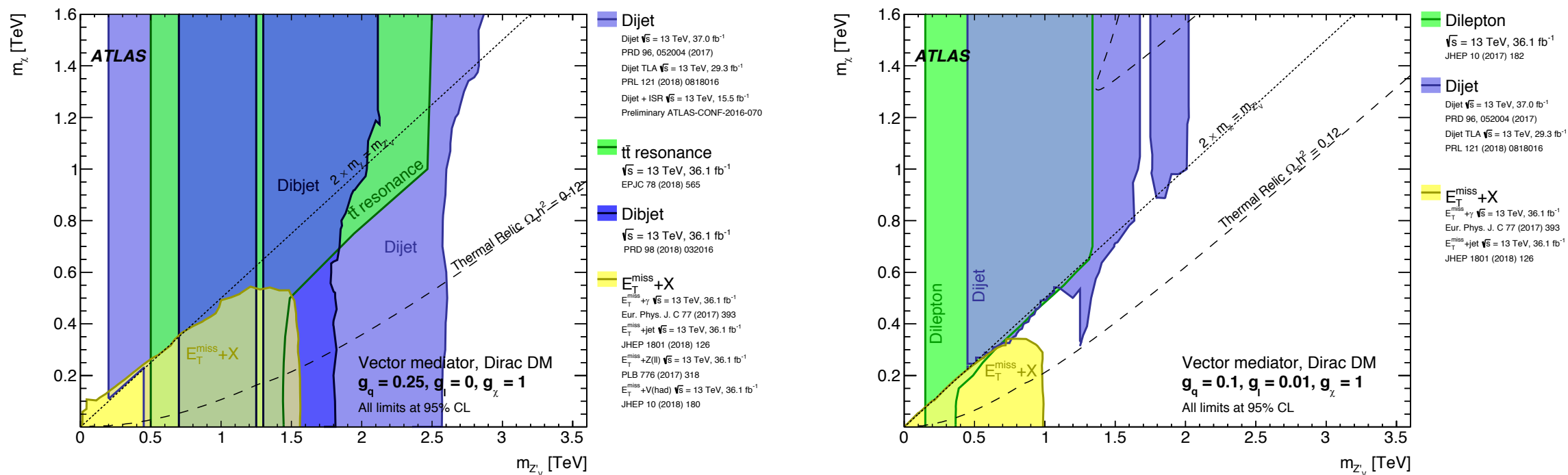
Results

- *No evidence of DM has been found*
- *Constraints on various simplified DM models, including a set of spin-0 and spin-1 single-mediator models, and a second set of models involving an extended Higgs sector, are summarized (JHEP 1905 (2019) 142)*

Results

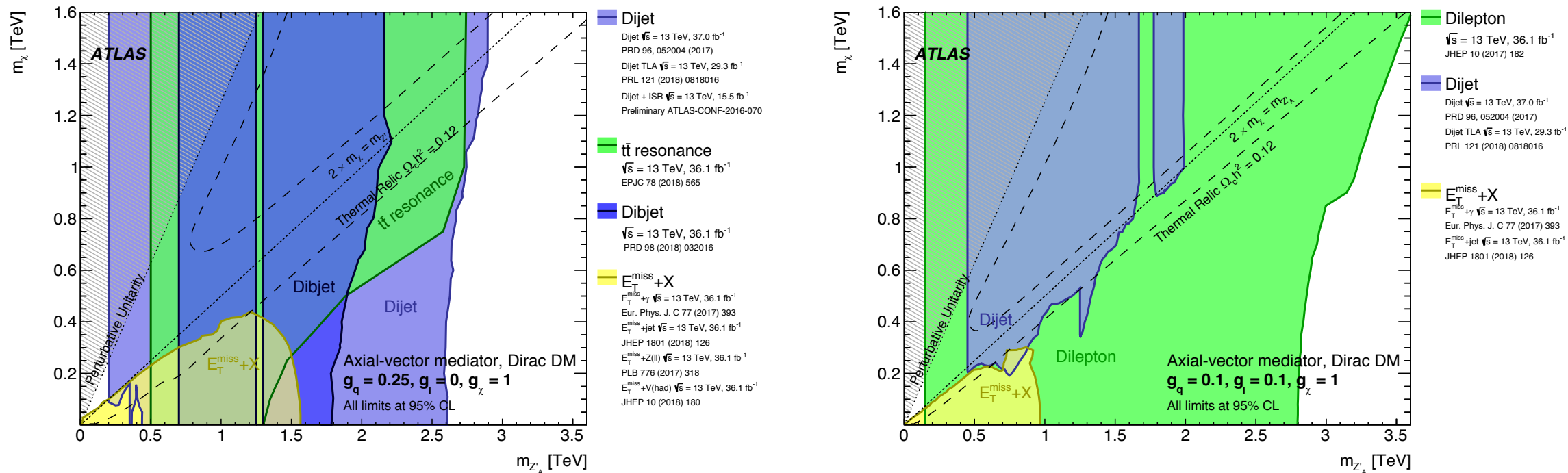
- *No evidence of DM has been found*
- *Constraints on various simplified DM models, including a set of spin-0 and spin-1 single-mediator models, and a second set of models involving an extended Higgs sector, are summarized (JHEP 1905 (2019) 142)*
- *The following will focus on the neutral interaction spin-0 and spin-1 single-mediator models*

Results – Vector mediator



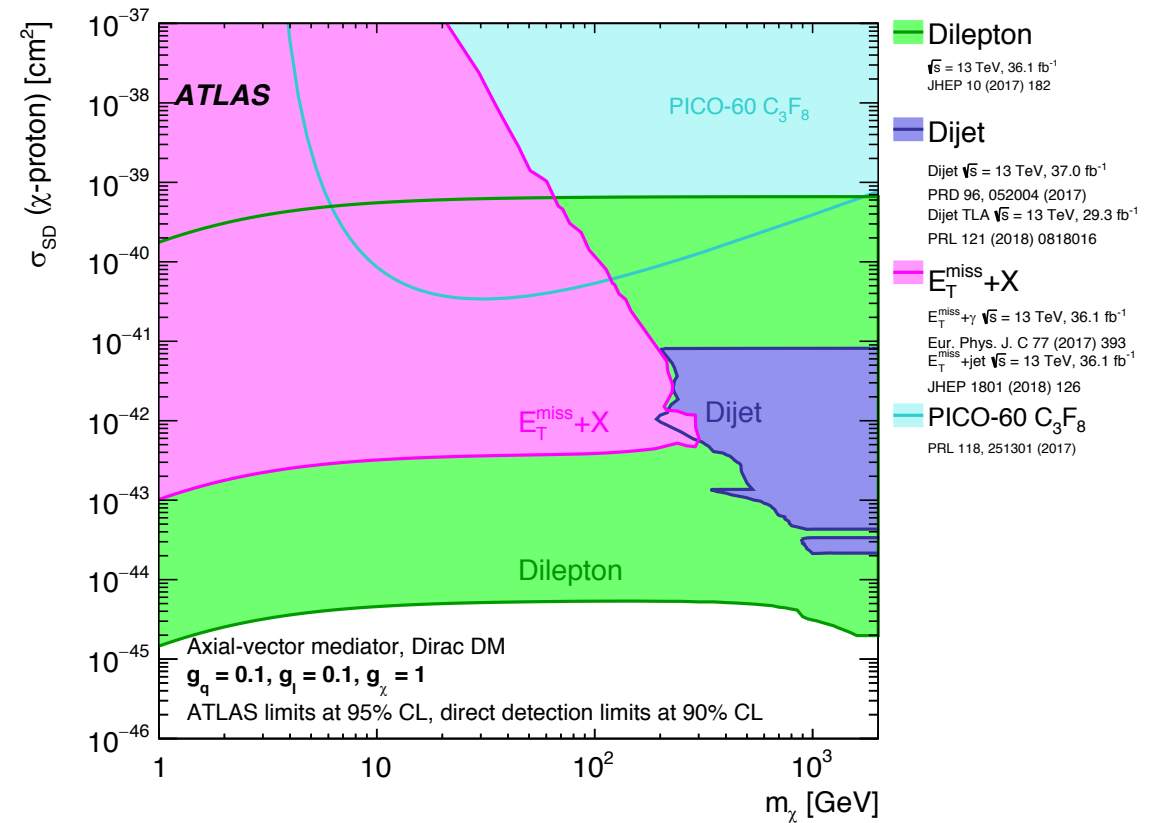
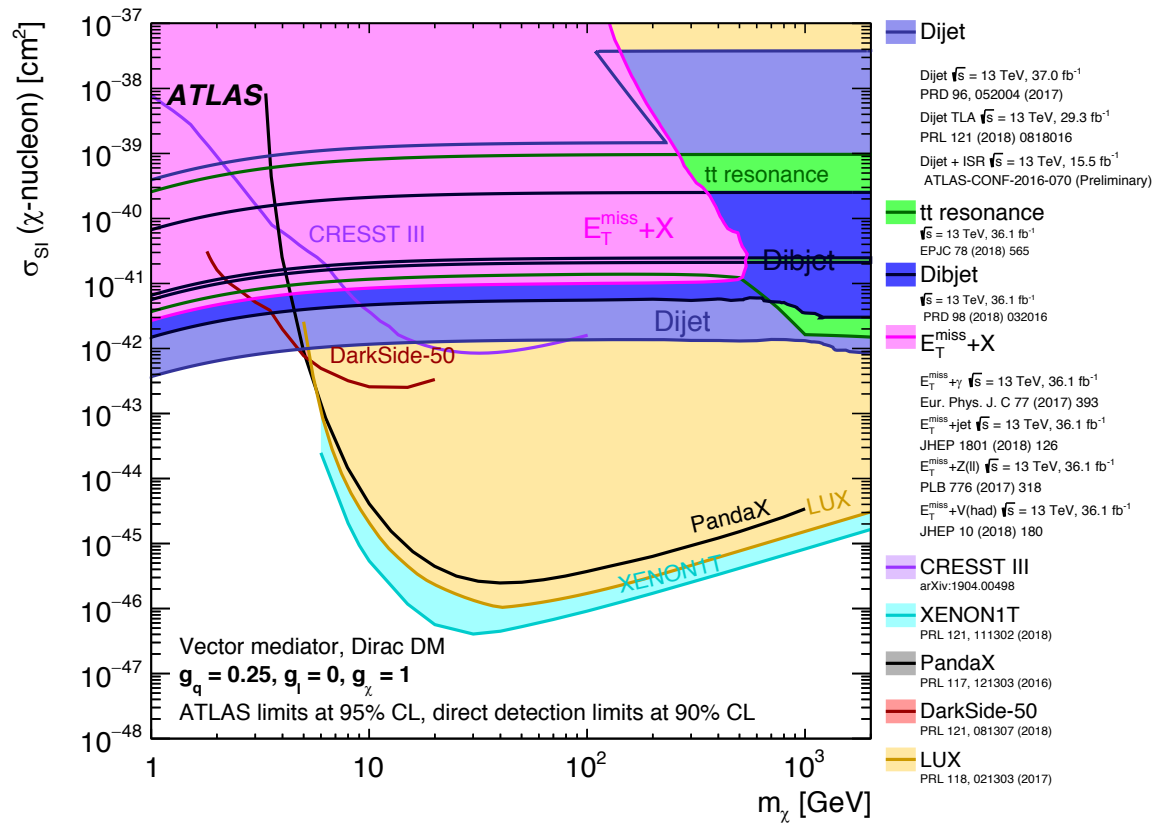
- Resonance searches dominate the sensitivity due to relatively high coupling to quarks
- MET+X analyses are complementary to the resonance searches in the on-shell region

Results – Axial-vector mediator



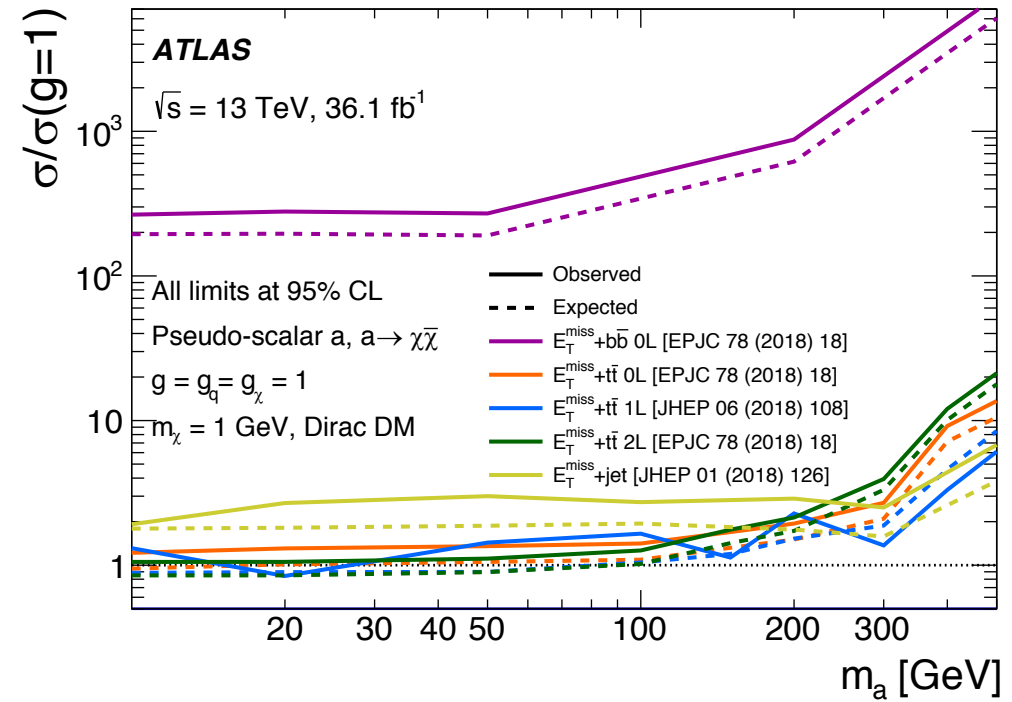
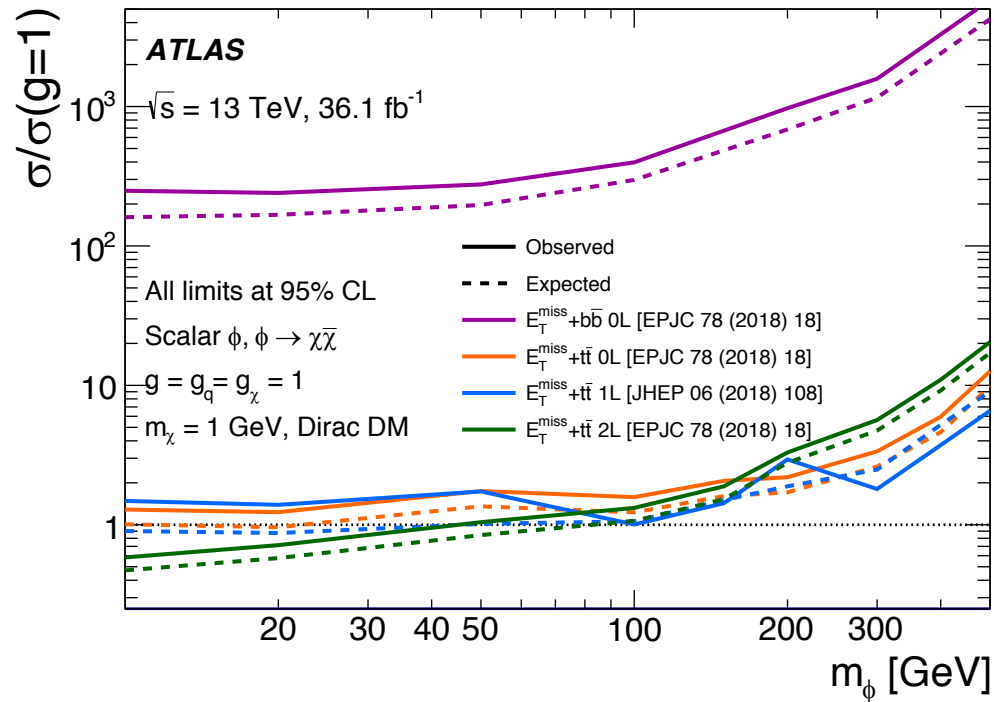
- Dominated by the dilepton search with a non-vanishing coupling to leptons

Results – Vector/axial-vector mediator



- ATLAS limits can be converted to the χ -nucleon cross sections and compared with the direct/indirect searches

Results – Scalar/pseudo-scalar mediator



- Scalar/pseudo scalar limits provided by MET+ $t\bar{t}/b\bar{b}$ analyses
- Scalar mediator with mass up to 45 GeV is excluded, while pseudo-scalar mediator in the range 15-25 GeV is excluded
- Results do not depend on the DM mass as long as the DM is on-shell

Summary

- Dark Matter searches with colliders are well physically motivated and provide great complementarity to the direct/indirect searches
- Focus on more complicated theories than the effective field theories in run-2
- DM searches results with the interpretations of neutral interaction single spin-0 or spin-1 mediator models are presented; no excess has been found so far
- More complementary scenarios are being investigated; look forward to the future results!

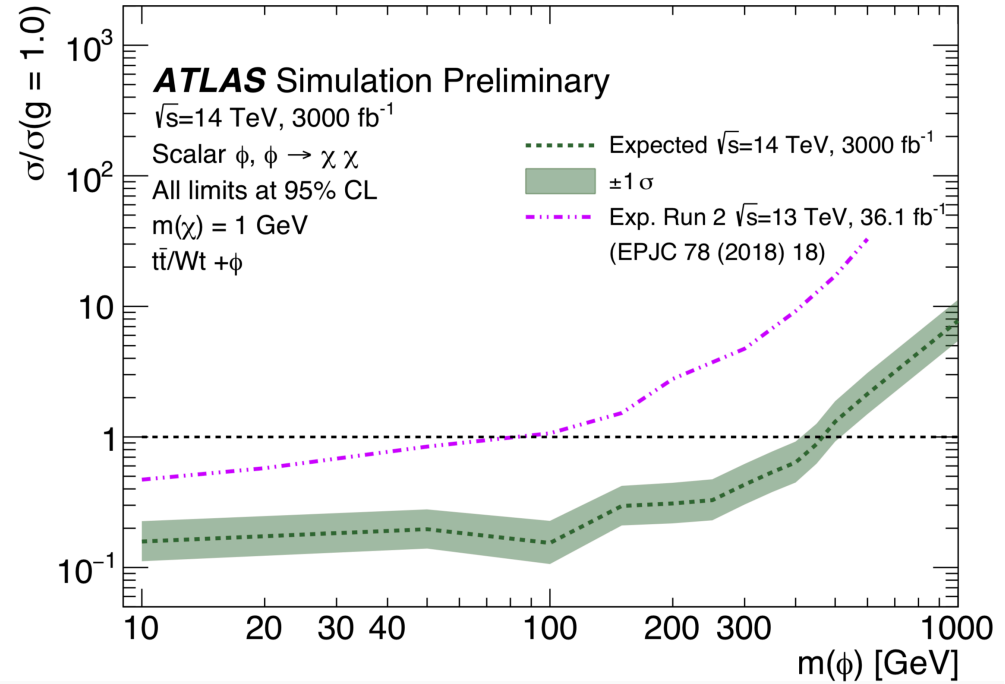
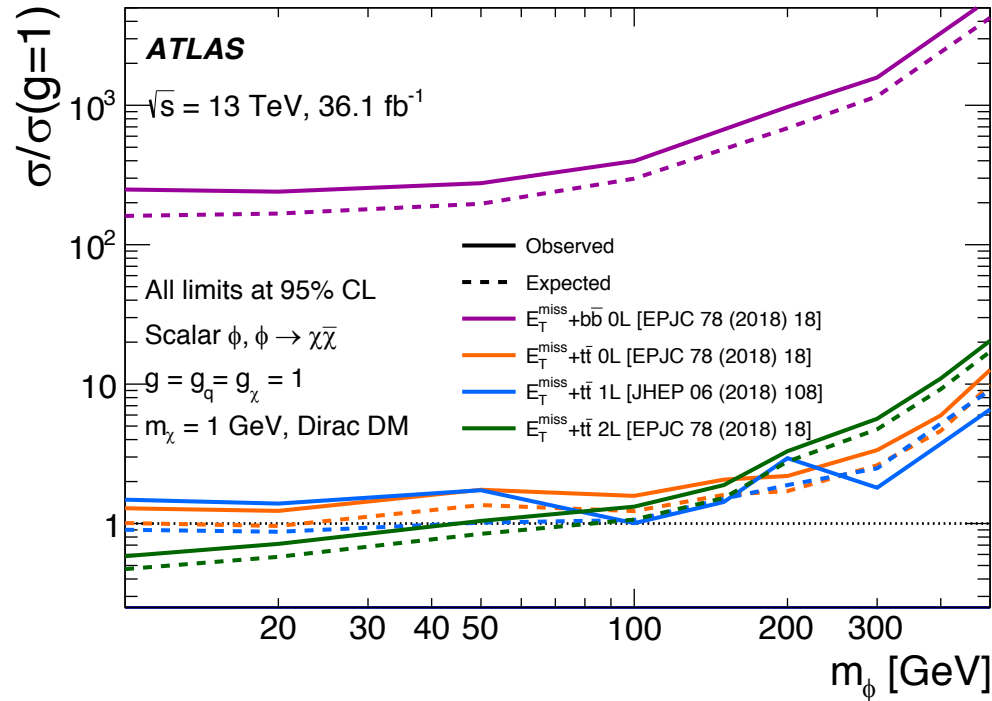


Backup slides



Estimated sensitivity with 3000 fb⁻¹ at 14 TeV

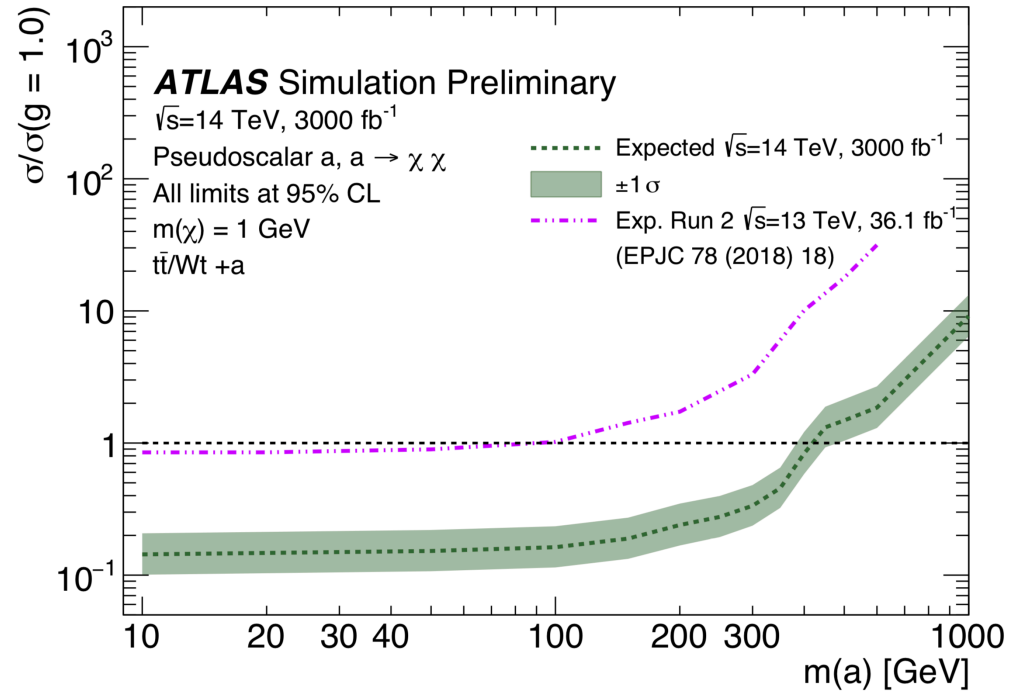
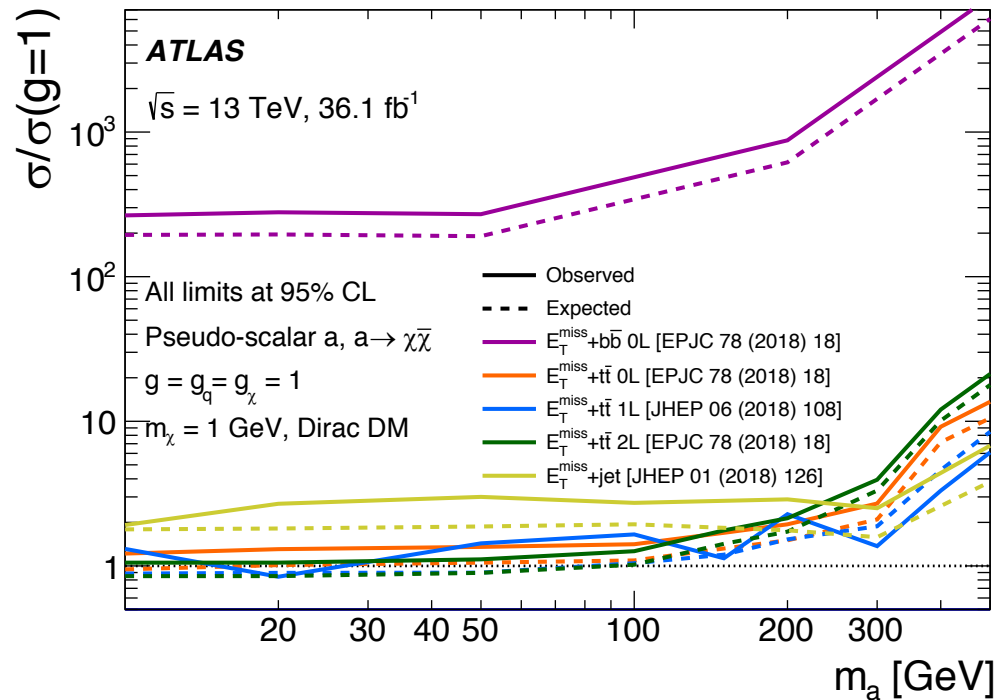
ATL-PHYS-PUB-2018-036



In comparison to results obtained with 36 fb⁻¹ in Run 2, the exclusion potential at the HL-LHC is found to improve by a factor of $\sim 3-8.7$

Estimated sensitivity with 3000 fb⁻¹ at 14 TeV

ATL-PHYS-PUB-2018-036



In comparison to results obtained with 36 fb⁻¹ in Run 2, the exclusion potential at the HL-LHC is found to improve by a factor of $\sim 3-8.7$