



Search for New Physics at ATLAS

T. Berger-Hryn'ova (LAPP)
on behalf of the ATLAS Collaboration

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*I wish I could be
with you in person...*



- Following a discovery of SM Higgs boson in 2012 @ the LHC, Standard Model (SM) is complete and self-consistent
- But certain aspects of SM do not have an explanation
 - What is origin of dark matter?
 - How to accommodate gravity?
 - Why is Higgs light?
 - What is the solution of the hierarchy problem?
 - Why are there three generations?
 - ...

Many theoretical models trying to address different aspects:

no clear guidance from theory

- Following a discovery of SM Higgs boson in 2012 @ the LHC, Standard Model (SM) is complete and self-consistent
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searching blindly...

Search for any deviations from Standard Model predictions

Direct observation:
new (e.g. **Exotic**) resonant or
non-resonant structures



In-direct observation:
discrepancies in rates of rare processes,
couplings measurements, etc.

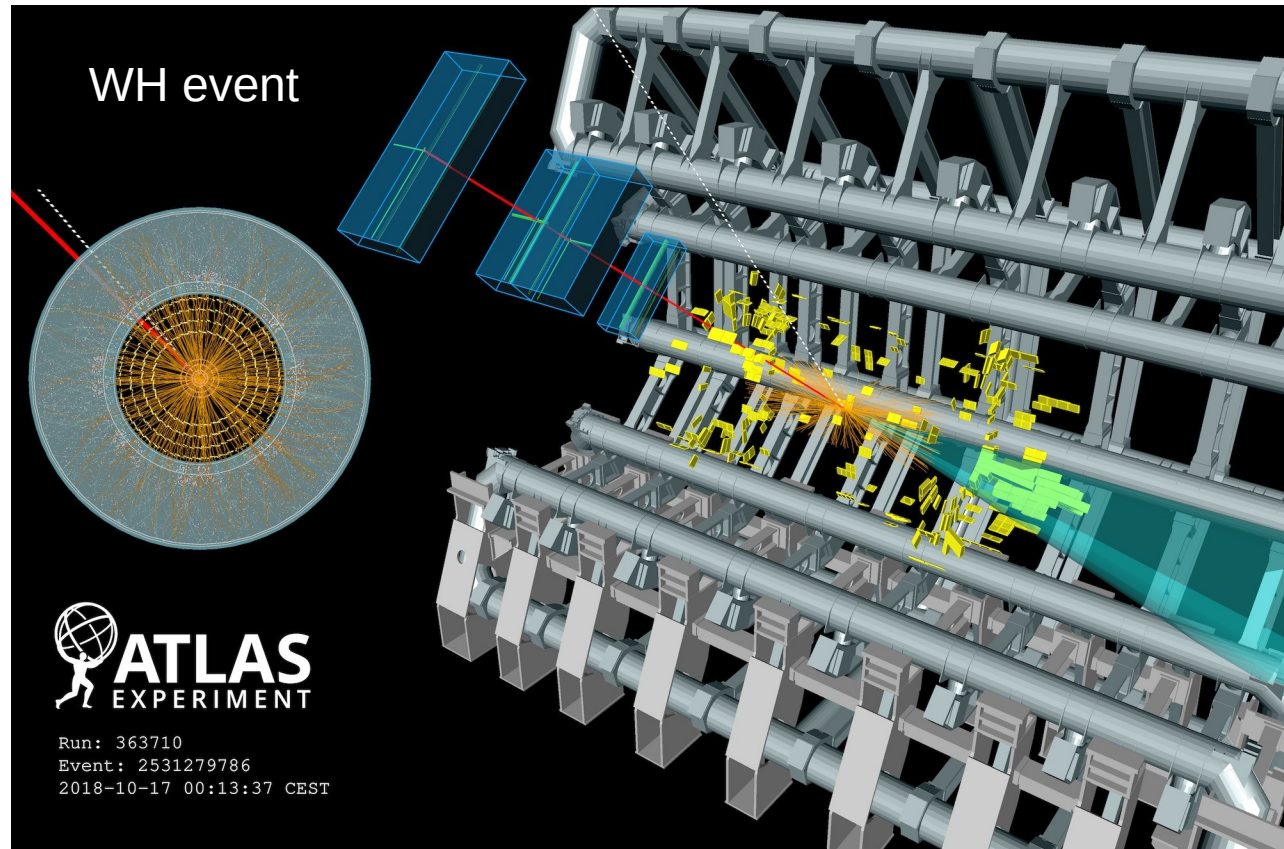


Talks by
E. Soldatov,
Ch. Kato

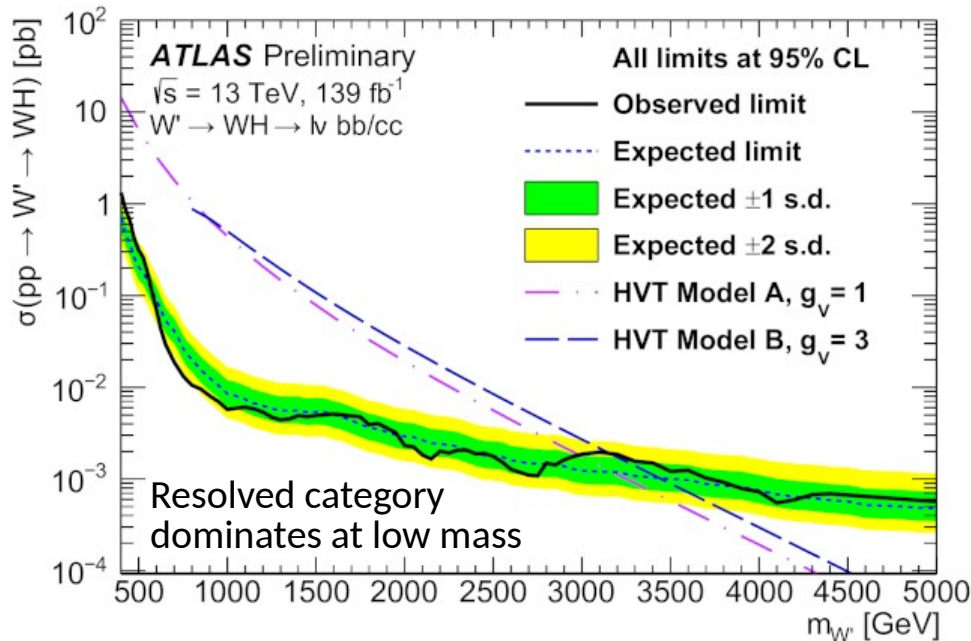
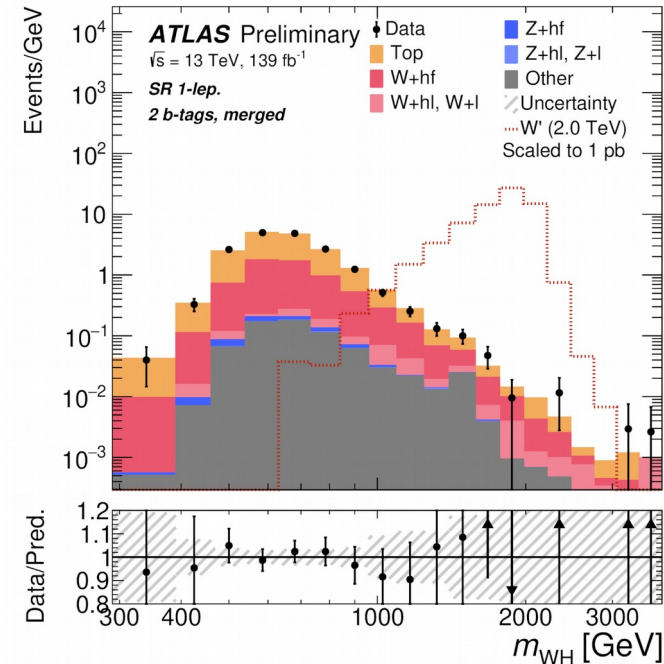
Focus of this talk is on a selection of recent ATLAS results:

- Signature-based searches (WH, mono-jet)
- Higgs as gateway to physics beyond SM (BSM)
- Searches relevant to 'flavour anomalies' discussion

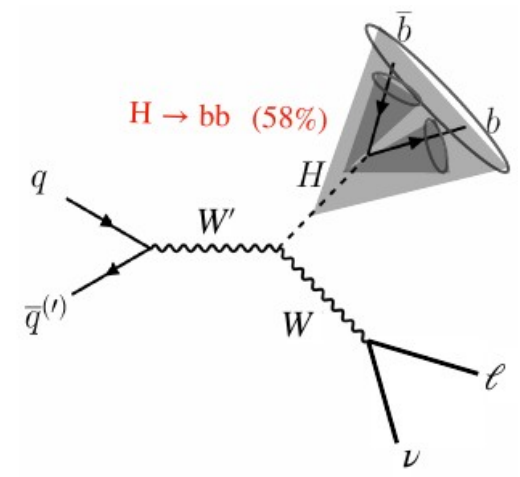
*All analyses
presented use
full Run 2 data
set collected
by ATLAS in
2015-2018
(139 fb⁻¹)*



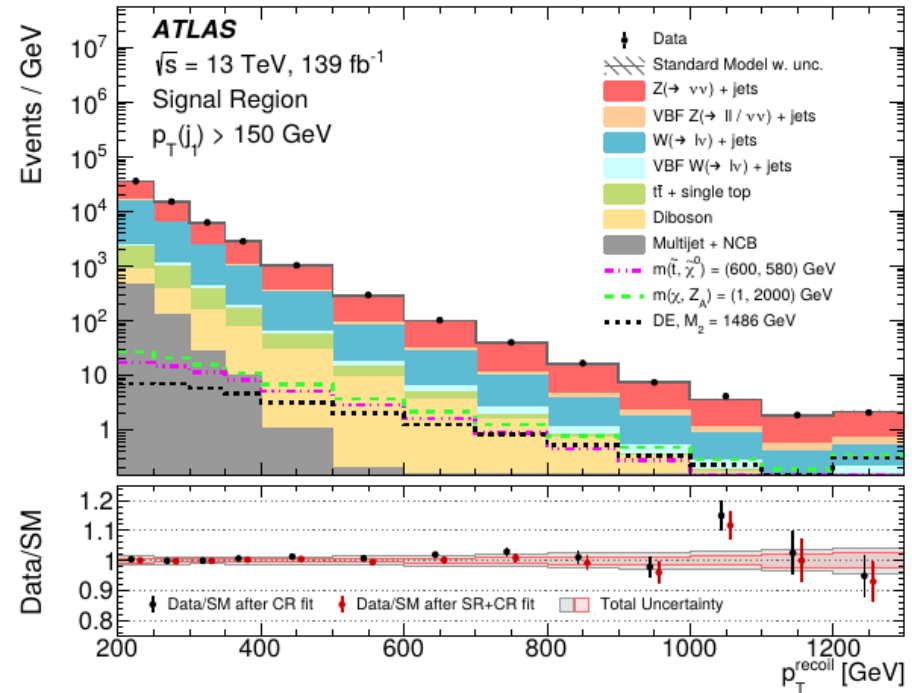
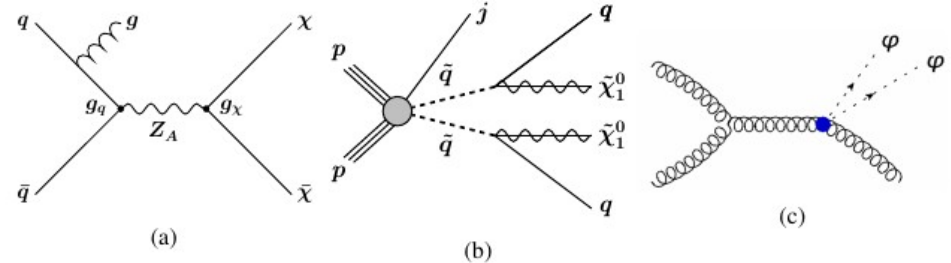
- Models : extended gauge symmetry, Minimal Walking Technicolor, Little Higgs, Composite Higgs, etc.
- Analysis is a bump hunt, but ...collimated decay products, large-R jets : substructure
- Most sensitive probes of $W' \rightarrow WH$ are semileptonic decays
 - Resolved dijets or merged large-R jet: $m_{W'} = [0.4, 5]$ TeV
 - Higgs tagging (1 or 2 b-tagged variable-radius track-jets)
- Results in Simplified Model : Heavy Vector Triplet



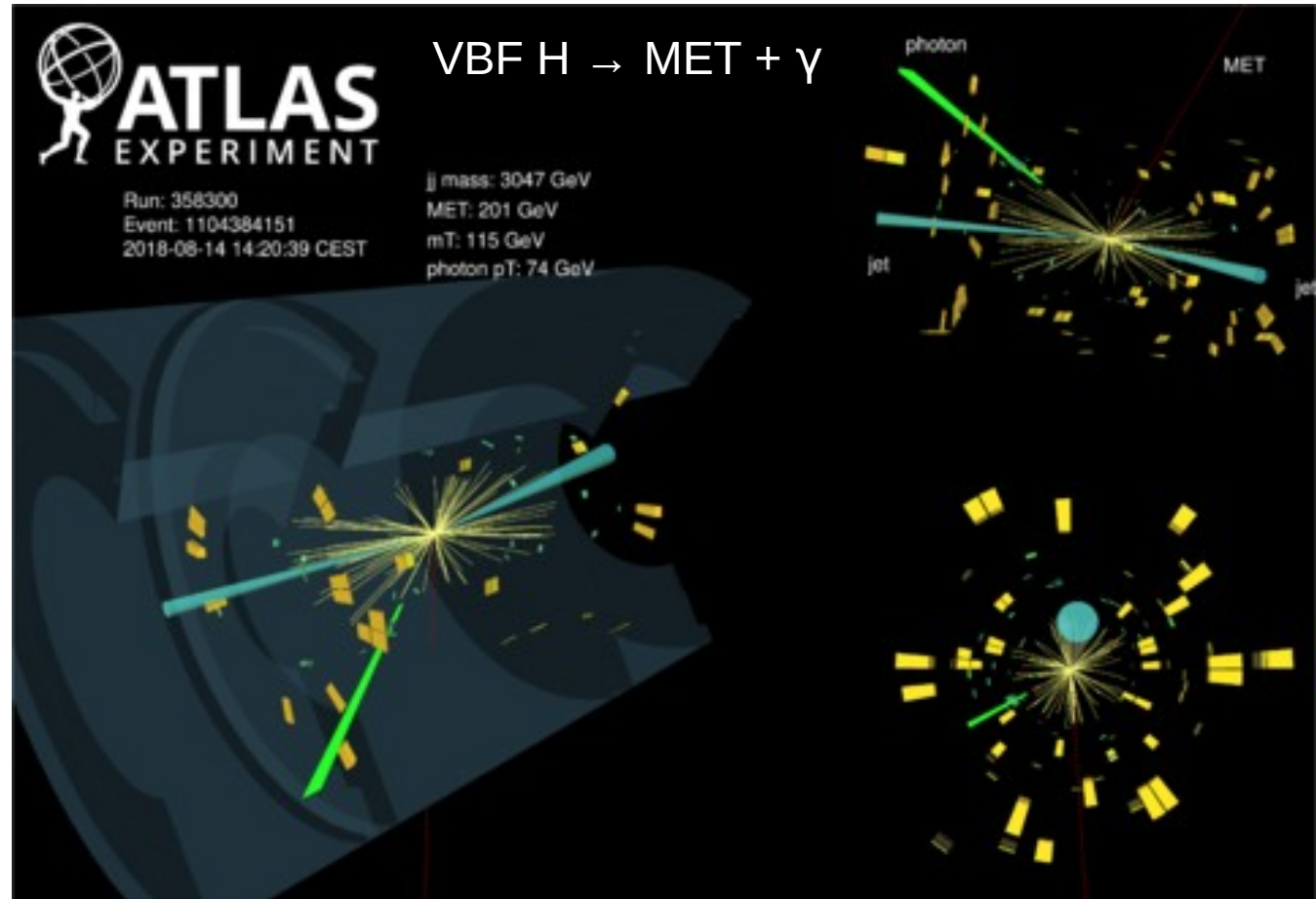
No excess observed
Cross-section limits < 1fb at masses > 3.7TeV



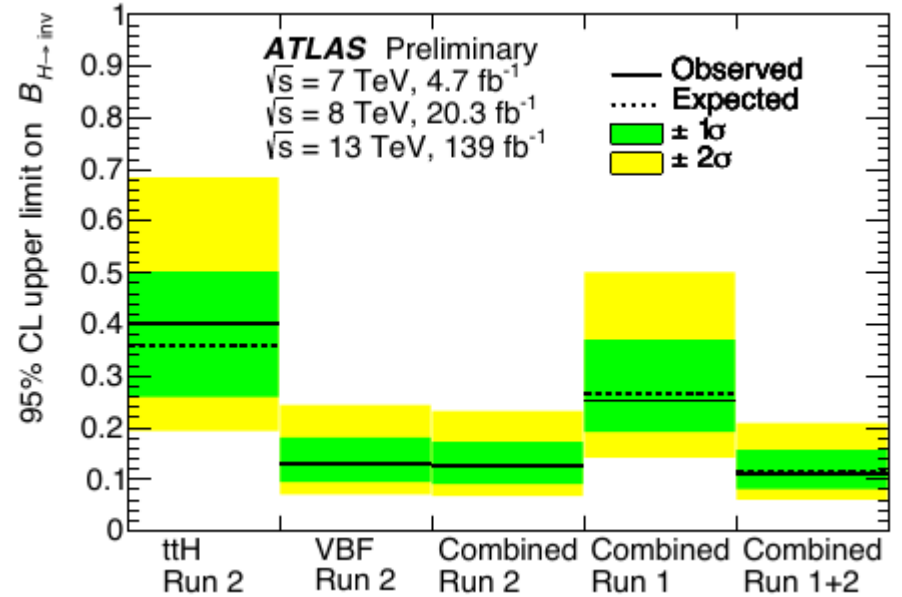
- Selection : at least 1 jet $E_T > 150 \text{ GeV}$, $\text{MET} > 200 \text{ GeV}$, no leptons/photons
- Models : DM production in association with ISR jet (a), large extra spatial dimensions, supersymmetric particles in compressed scenarios (b), axion-like particles, new scalar particles in dark-energy-inspired models (c)
- Backgrounds : $Z(\nu\nu)$, $W(l\nu)$ +jets, $t\bar{t}$, single top from control regions
 - Higher order QCD and EW corrections are applied
- Results : combined fit of SRs and CRs (systematics uncertainties included as nuisance parameters)
 - Model-independent 95% CL on visible cross sections range between 736 fb and 0.3 fb.
 - 95 % CL exclusion on Higgs \rightarrow invisible branching ratio of 0.34(0.39) obs(exp)



Good agreement between data & SM prediction
 “Precision” search: bkg uncertainty 1.5-4.2%

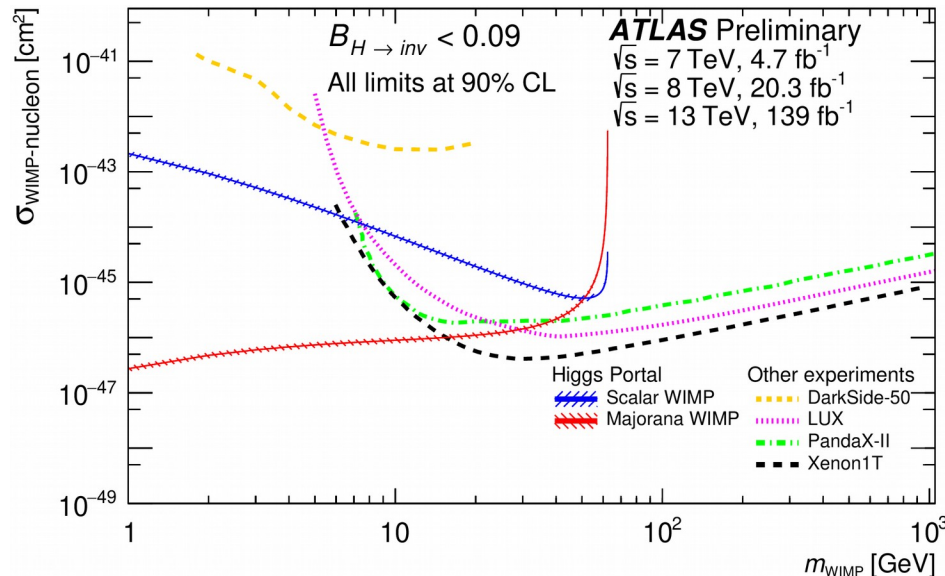


- Dark Matter - SM interactions mediated by Higgs boson could lead to enhancement in $H \rightarrow \text{invisible}$ decays ($\sim 0.1\%$ in SM)
- Higgs production as in SM :
 - Gluon fusion (MET+jet)
 - Associated VH (MET+V), $t\bar{t}H$ (MET+ $t\bar{t}$)
 - **Vector-boson fusion (MET+2jets)**



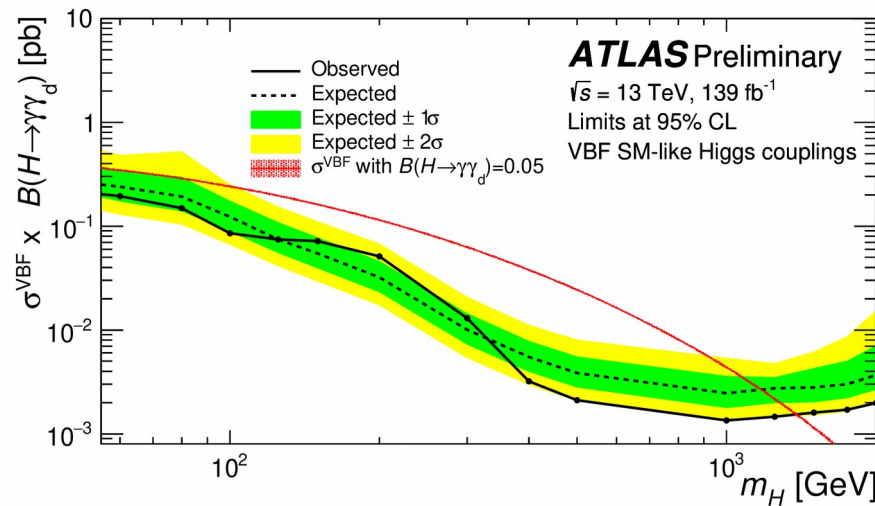
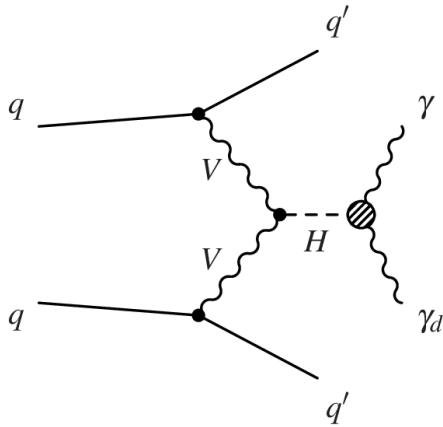
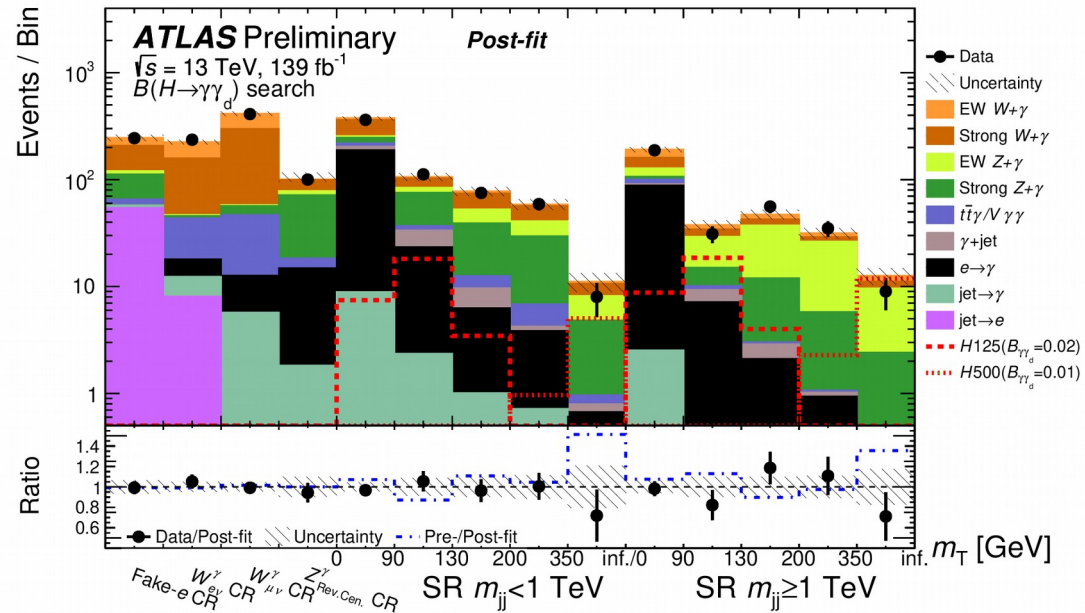
Results of combination from various Higgs productions (Run 1 + 2) : 95 % CL exclusion on Higgs→invisible branching ratio of 0.11 (0.11) observed (expected)*

Combination of results translated into a spin-independent DM-nucleon scattering xsec limit in Higgs portal scenarios: interaction between DM and nucleus mediated by H exchange ($m_{DM} < 1/2 m_H$)



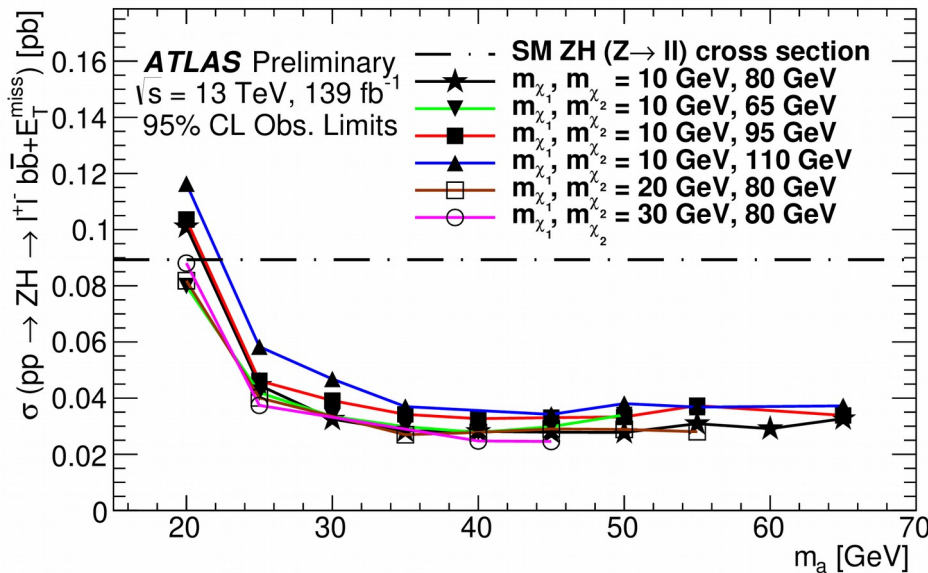
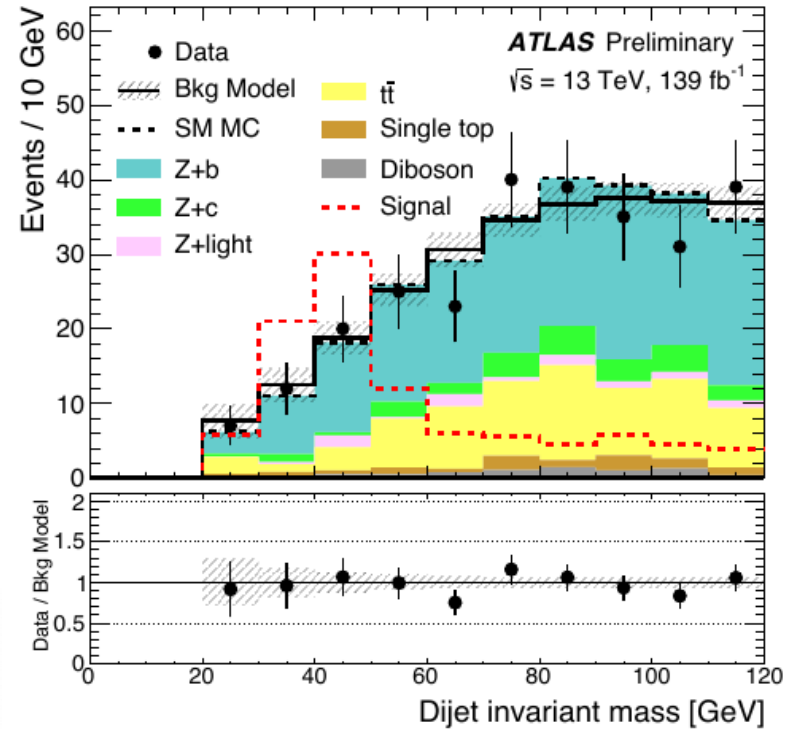
* Global Higgs coupling combination limits < 0.09 [ATLAS-CONF-2020-027]

- Selection : 1 photon + 2 jets (large $|\Delta\eta_{jj}|$, small $|\Delta\phi_{jj}|$), MET > 150 GeV, MVA to improve sensitivity
- Bkgs : Z(vv) γ +jets & W(lv) γ +jets from CRs
- Results : combined fit of SRs and CRs
- VBF Higgs \rightarrow dark γ + γ : 5 bins of $m_T(\gamma + \text{MET})$ in 2 m_{jj} categories (<+>1 TeV)



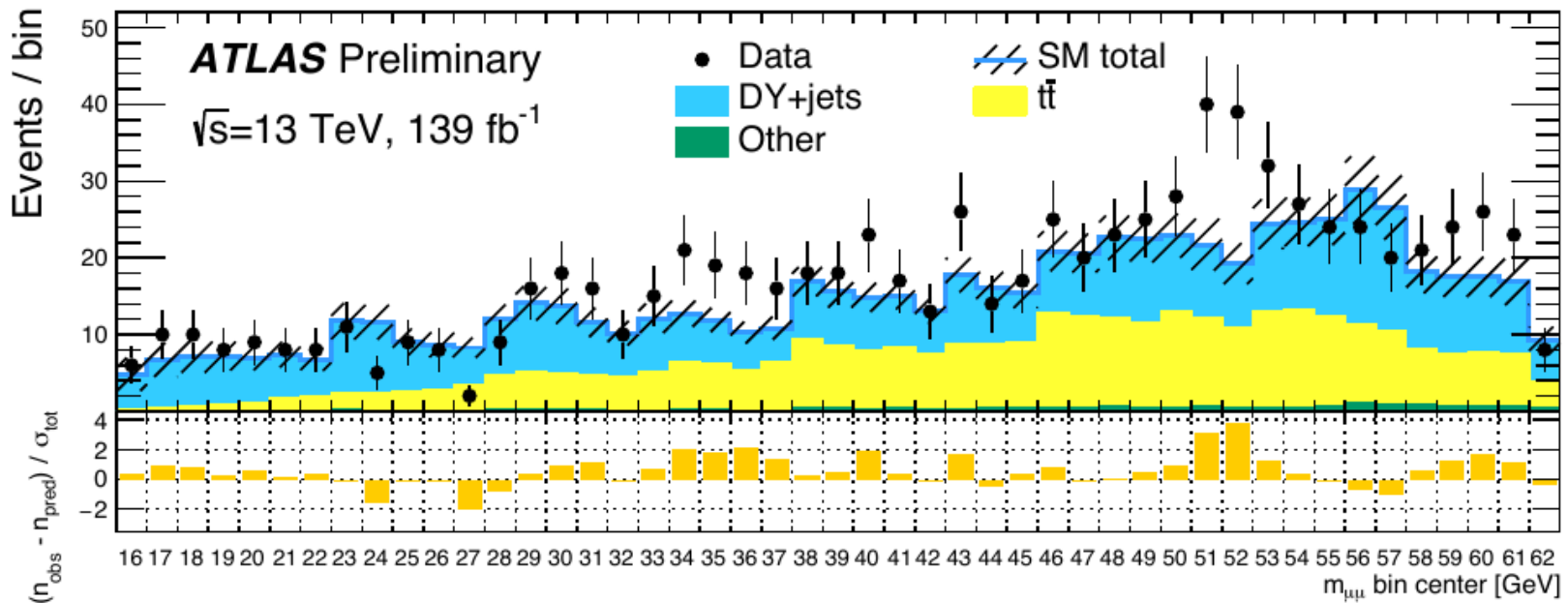
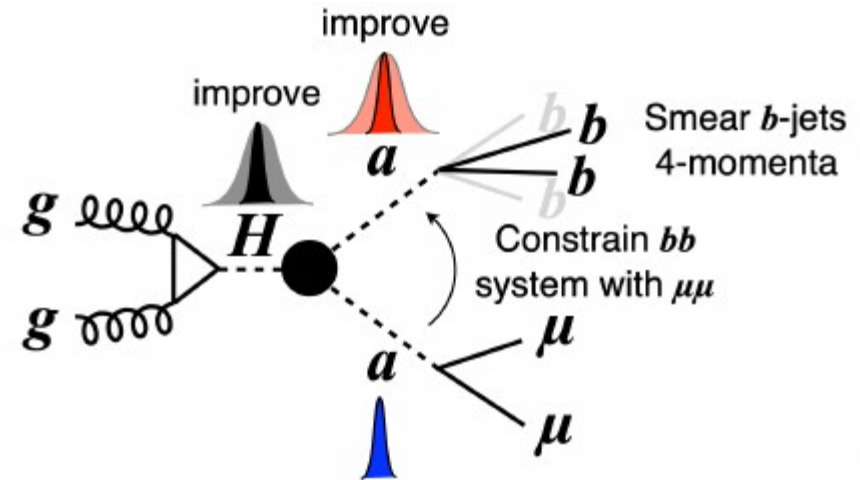
Results:
 Branching ratio
 Higgs (125 GeV) $\rightarrow \gamma_d \gamma$
 < 0.014 (0.017)
 observed (expected)

- Channel : $ZH, H \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^0 \rightarrow a \tilde{\chi}_1^0 \tilde{\chi}_1^0, a \rightarrow bb$
- Selection :
 - $Z \rightarrow ll$ ($81 < m_{ll} < 101 \text{ GeV}, p_{T, ll} > 40 \text{ GeV}$)
 - ≥ 2 jets, $p_{T, j} > 20 \text{ GeV}, 20 < m_{jj} < 120 \text{ GeV}$
 - ≥ 1 b-jets
 - $\text{MET} > 100 \text{ GeV}$
- Backgrounds : Z+HF & ttbar from CRs

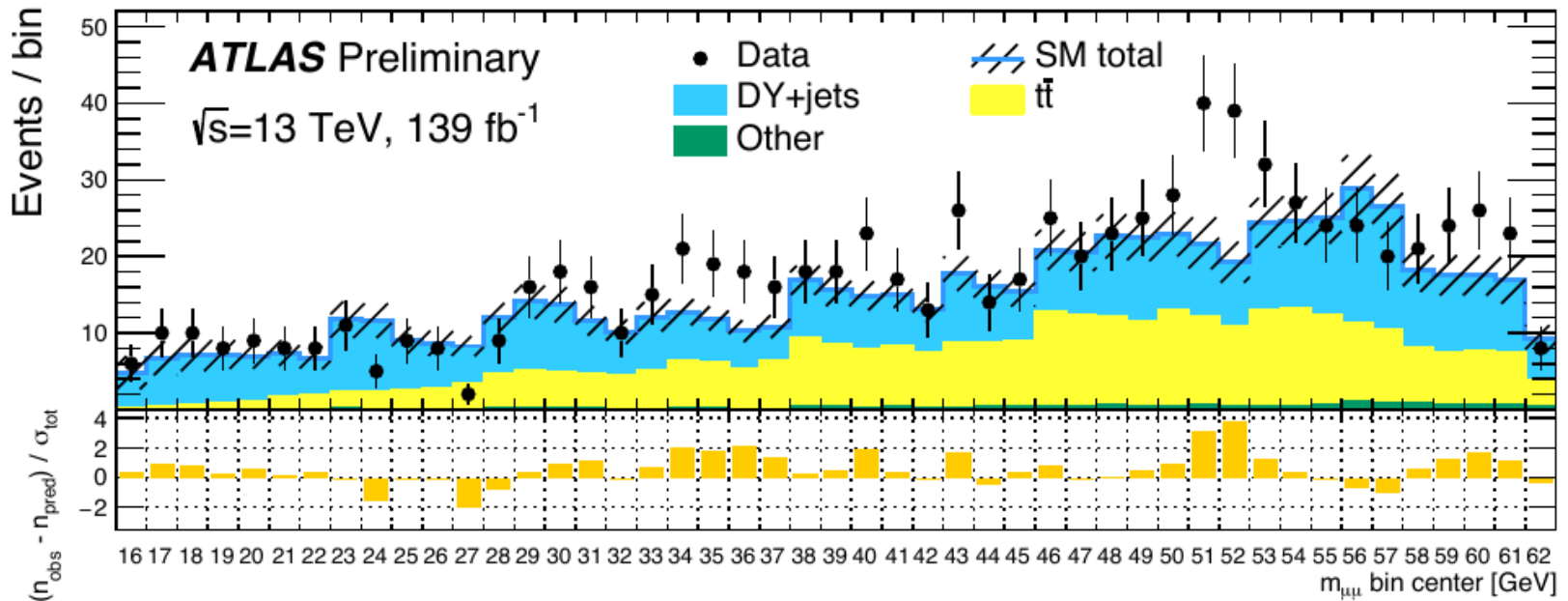
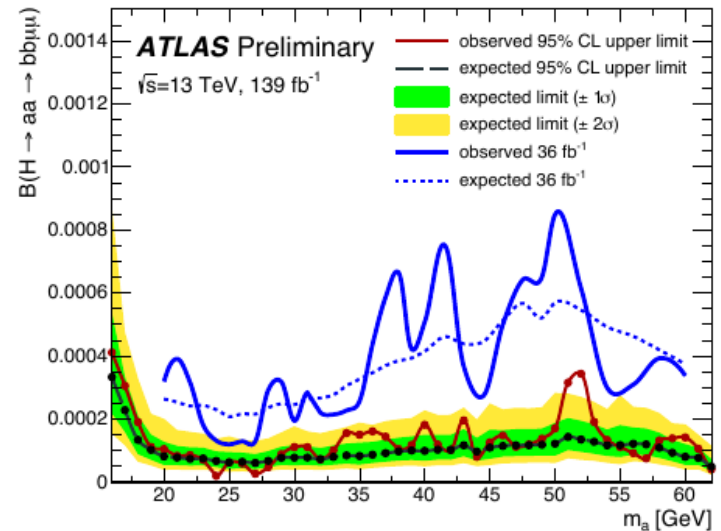


- Results :
- combined fit of SRs and CRs
 - m_{jj} main analysis variable
 - No excess
 - Limits set for various $m_a, m_{\chi_1}, m_{\chi_2}$

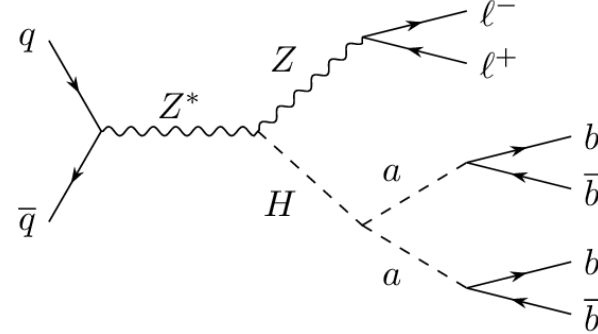
- Exploit the excellent $m_{\mu\mu}$ resolution to improve m_{bb} via a kinematic likelihood fit
- Selection : $\ln(L_{\max}) > -8$, $110 < m_{\mu\mu bb} < 140$ GeV, $MET < 60$ GeV
- 12 BDTs dependent on $m_{\mu\mu}$ to separate signal from Drell-Yan and $t\bar{t}$ backgrounds
- Excess of 3.3σ (1.7σ) local (global) observed at $m_a=52$ GeV



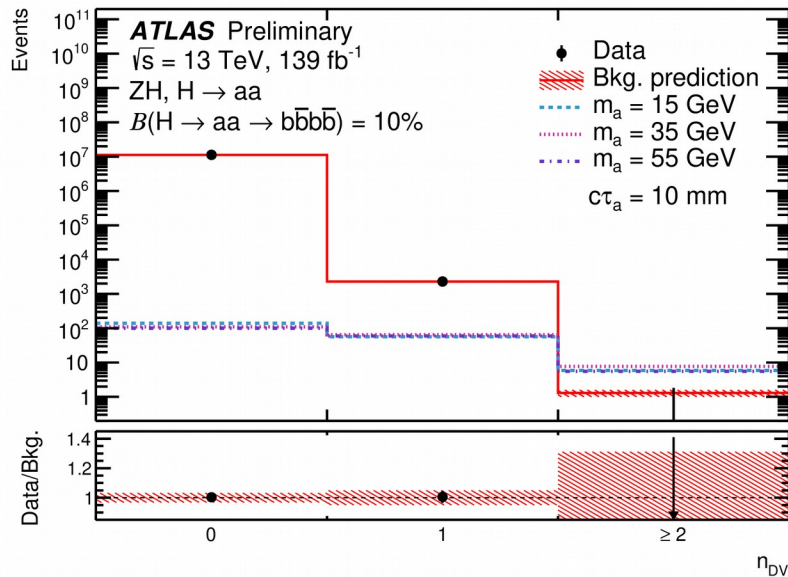
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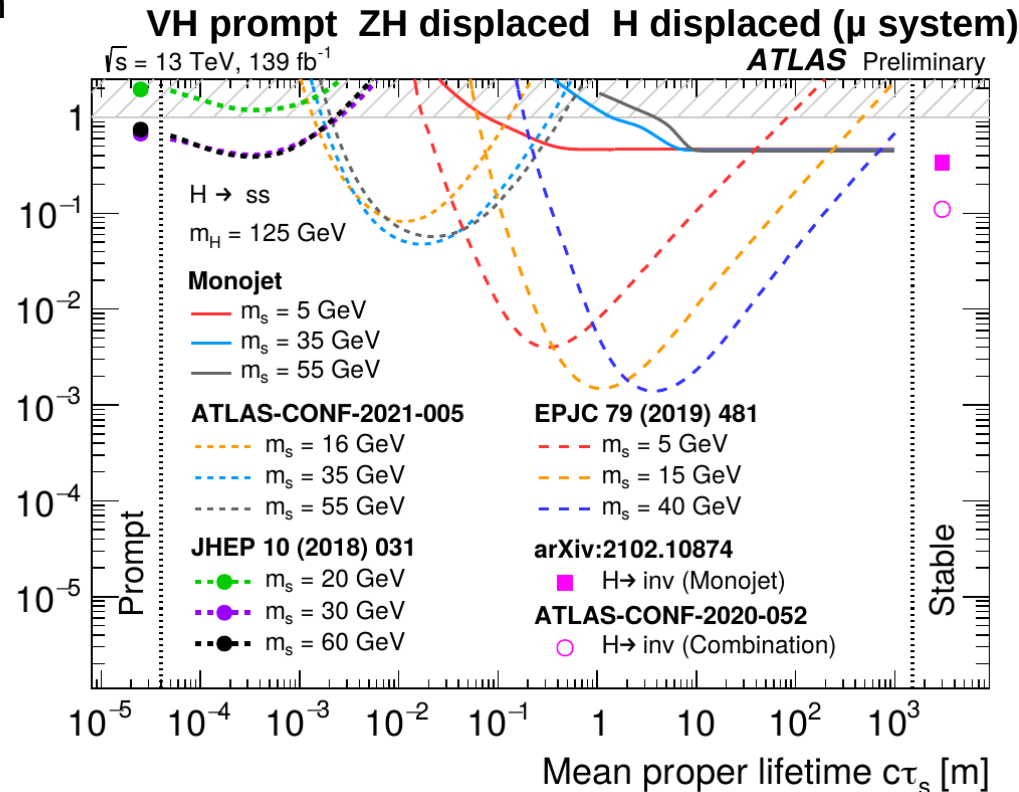
- Channel : ZH, $H \rightarrow aa \rightarrow 4b$, a light, with small couplings \Rightarrow long lived
- Bkg : Z+jets
- Selection : prompt dilepton and jets from 2 displaced vertices
 - Analysis uses Large Radius Tracking and Displaced Vertex (VCI) reconstruction [ATL-PHYS-PUB-2019-013]



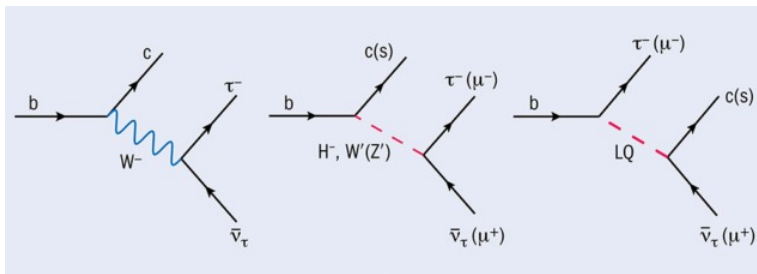
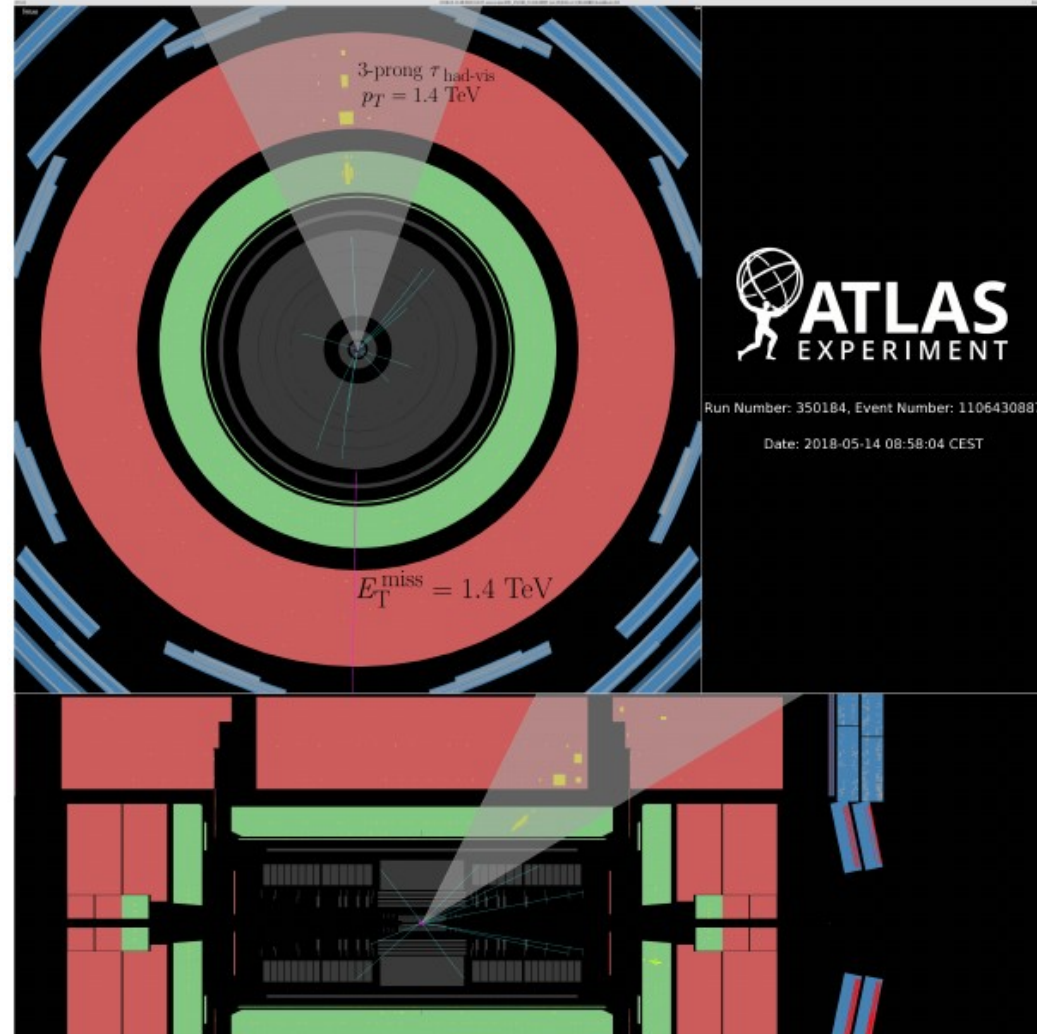
- Results : No excess, set limits

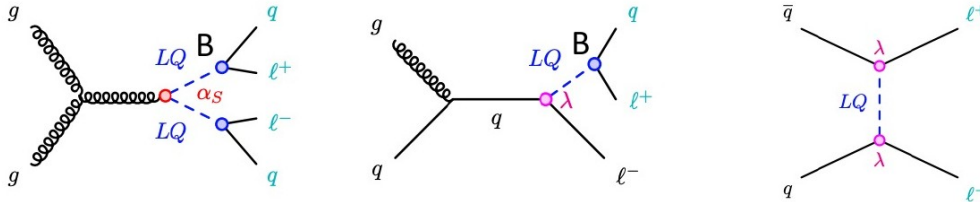


95% CL upper limit on $B(H \rightarrow ss)$



- Lepton Flavor Universality tensions observed in $b \rightarrow sll$ and $b \rightarrow c\tau\nu$ decays could hint at BSM physics involving new bosons or leptoquarks with preferential couplings to third generation SM fermions
- $b \rightarrow sll$ and $b \rightarrow c\tau\nu$ are connected to $bs \rightarrow ll$ and $bc \rightarrow \tau\nu$ through crossing symmetry
- which could indicate presence of new phenomena (Z' , LQ, RPV SUSY*)





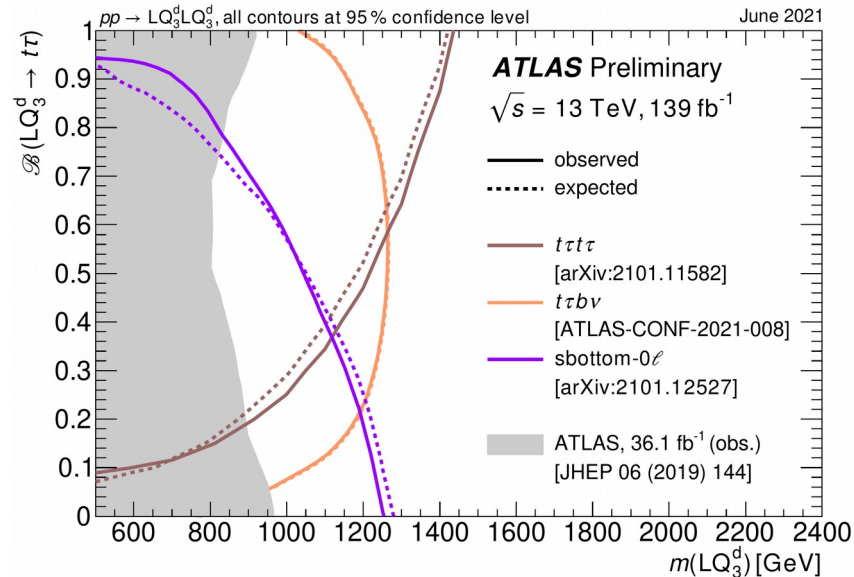
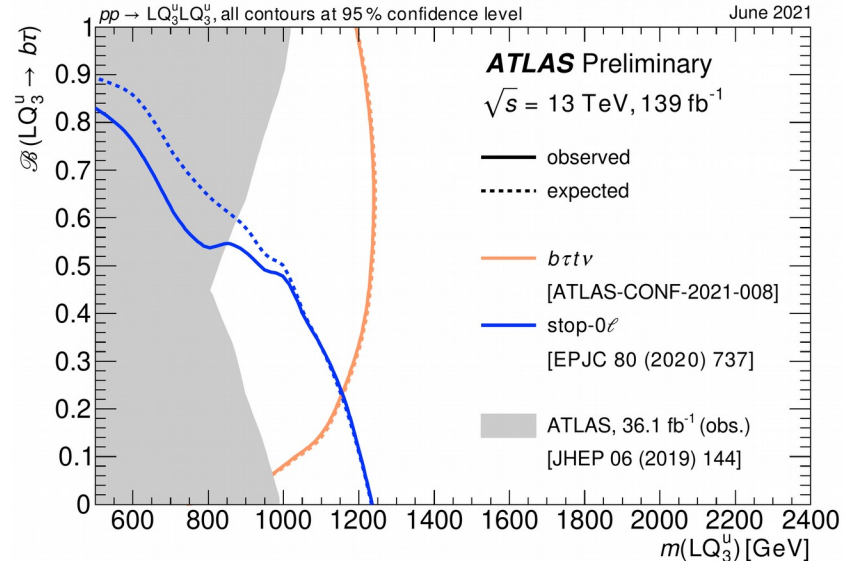
Two scalar or a single vector LQ(s) could explain the LFU anomalies: broad program of searches, focusing on 3d generation & cross-generation final states.

Look for events with high p_T objects in final state, such as 2 jets & 2 leptons or a charged lepton and a neutrino (MET).

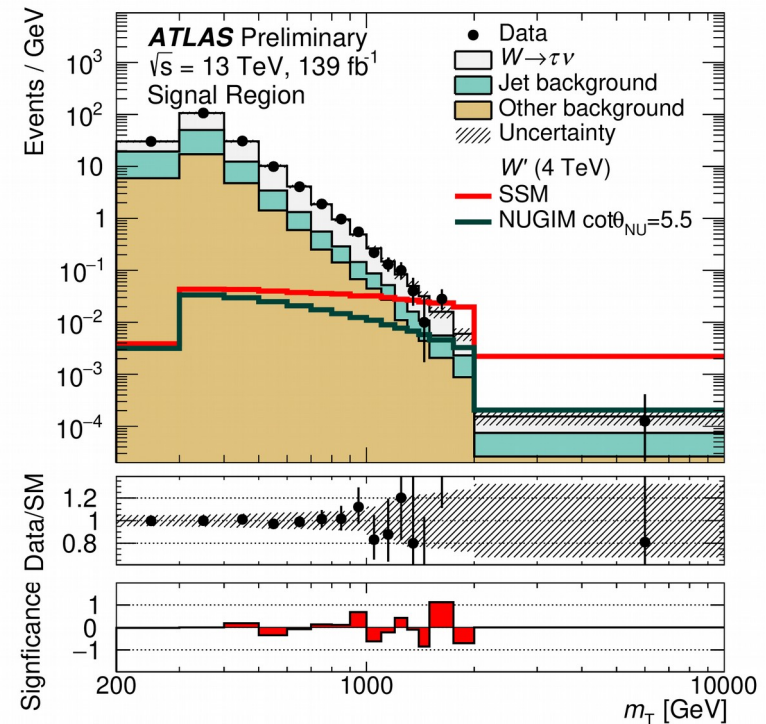
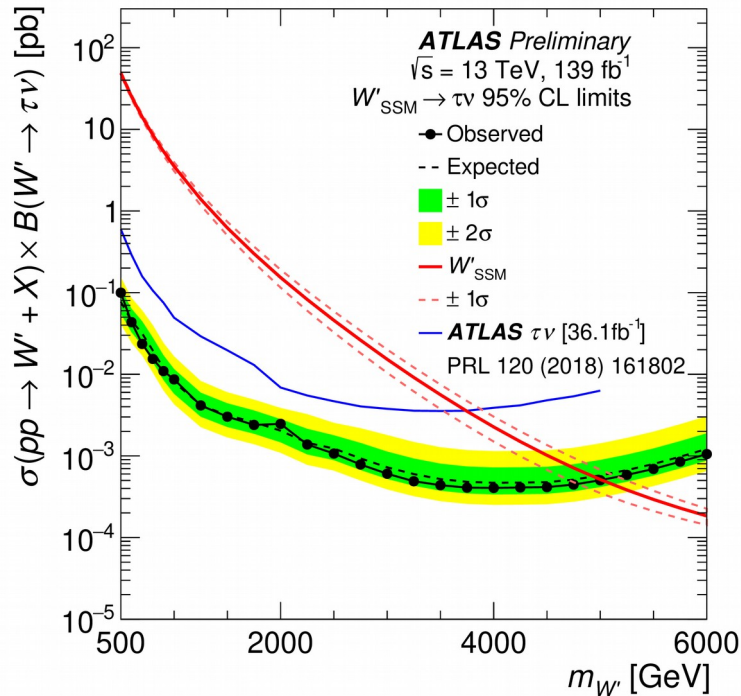
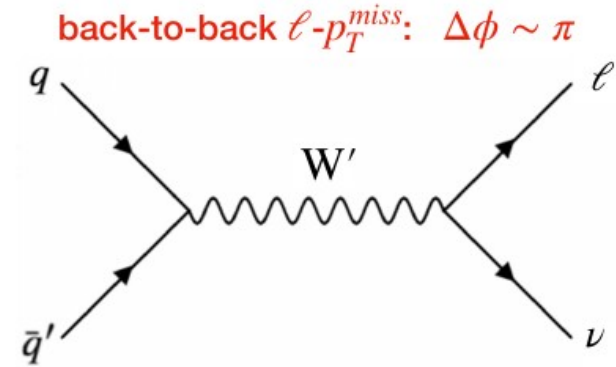
Recent full Run 2 result targeting a LQs and top-squarks in final states with b-jets, tau-leptons and MET.

B = relative branching fraction of qv and ql :
 $B(LQ \rightarrow bv) = 1 - B(LQ \rightarrow \tau\tau)$; λ = coupling

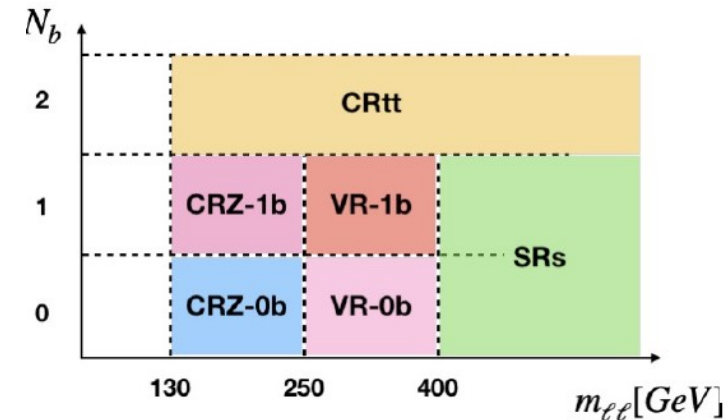
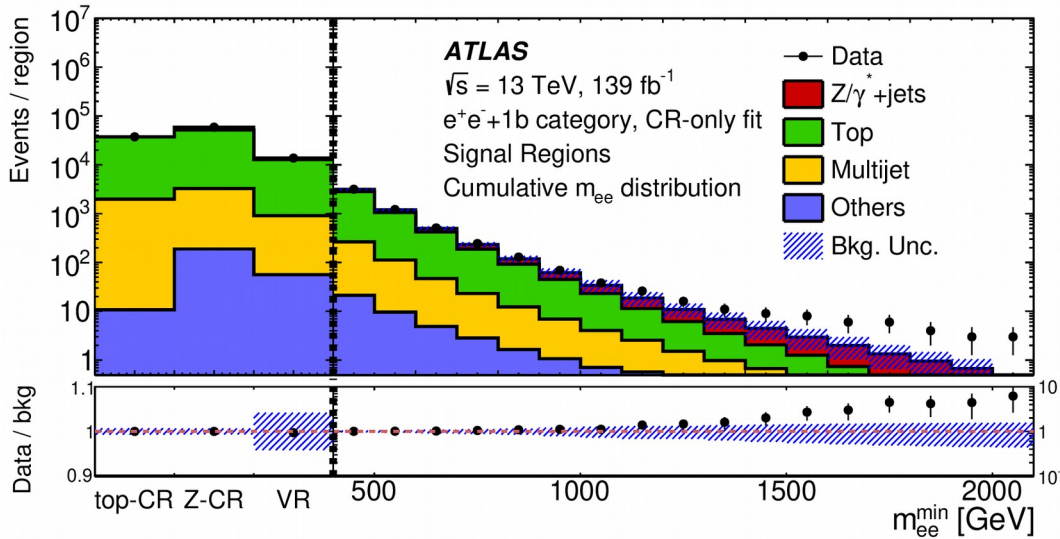
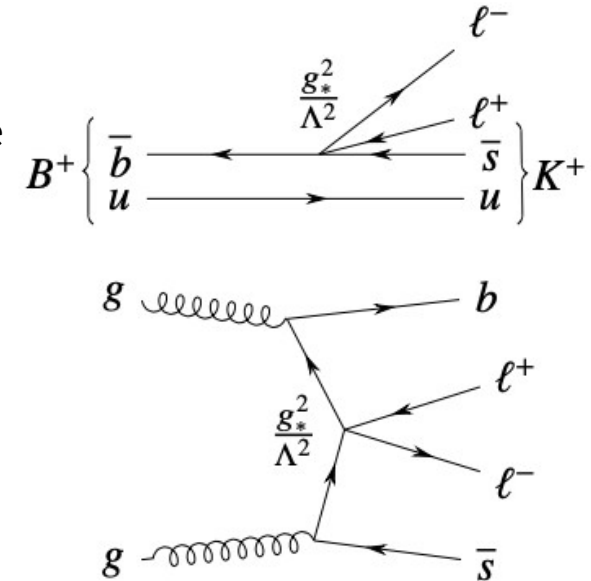
For $B(LQ_3^u \rightarrow b\tau) = 0.5$ and $B(LQ_3^d \rightarrow \tau\tau) = 0.5$, limits for m_{LQ} reach 1.25 TeV



- Probe the m_{τ} spectrum for a very wide kinematic endpoint - detector effects / calibration are particularly important
- Selection : $p_{\tau}^{\tau} > 30 \text{ GeV}$, electron/muon veto, $\text{MET} > 150 \text{ GeV}$ (due to trigger), $0.7 < p_{\tau}^{\tau} / \text{MET} < 1.3$
- Bkg : $W \rightarrow \tau \nu$ (simulation), jets - data driven
- No excess seen, cross-section limits $\sim 1 \text{ fb} > 3 \text{ TeV}$



- B-anomalies inspired search
- Selection : one or no b-tagged jets, 2 leptons of opposite charge and the same flavor (electrons or muons), and large invariant mass.
- Bkgs : Z+jets, ttbar
- No excess is observed in the data [largest is in SR ee1b corresponding to 2.6σ (1.5σ) local (global) significance]
- Contact interactions with Λ/g^* lower than 2.0 (2.4) TeV are excluded for electrons (muons) at the 95% CL [still below the values favored by B-anomalies $\sim 30\text{TeV}$]



- Several highlights presented from a broad program searching for Physics Beyond the Standard Model :
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults>
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HDBSPublicResults>
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults>
- No large deviations from Standard Model observed yet
 - Vibrant activity on the mature Run-2 dataset in the months to come
 - New innovative techniques and practices for Run 3 expected to start in 2022
- A discovery could be around the corner !



Questions? Contact
Tetiana.Hryn'ova At
cern.ch

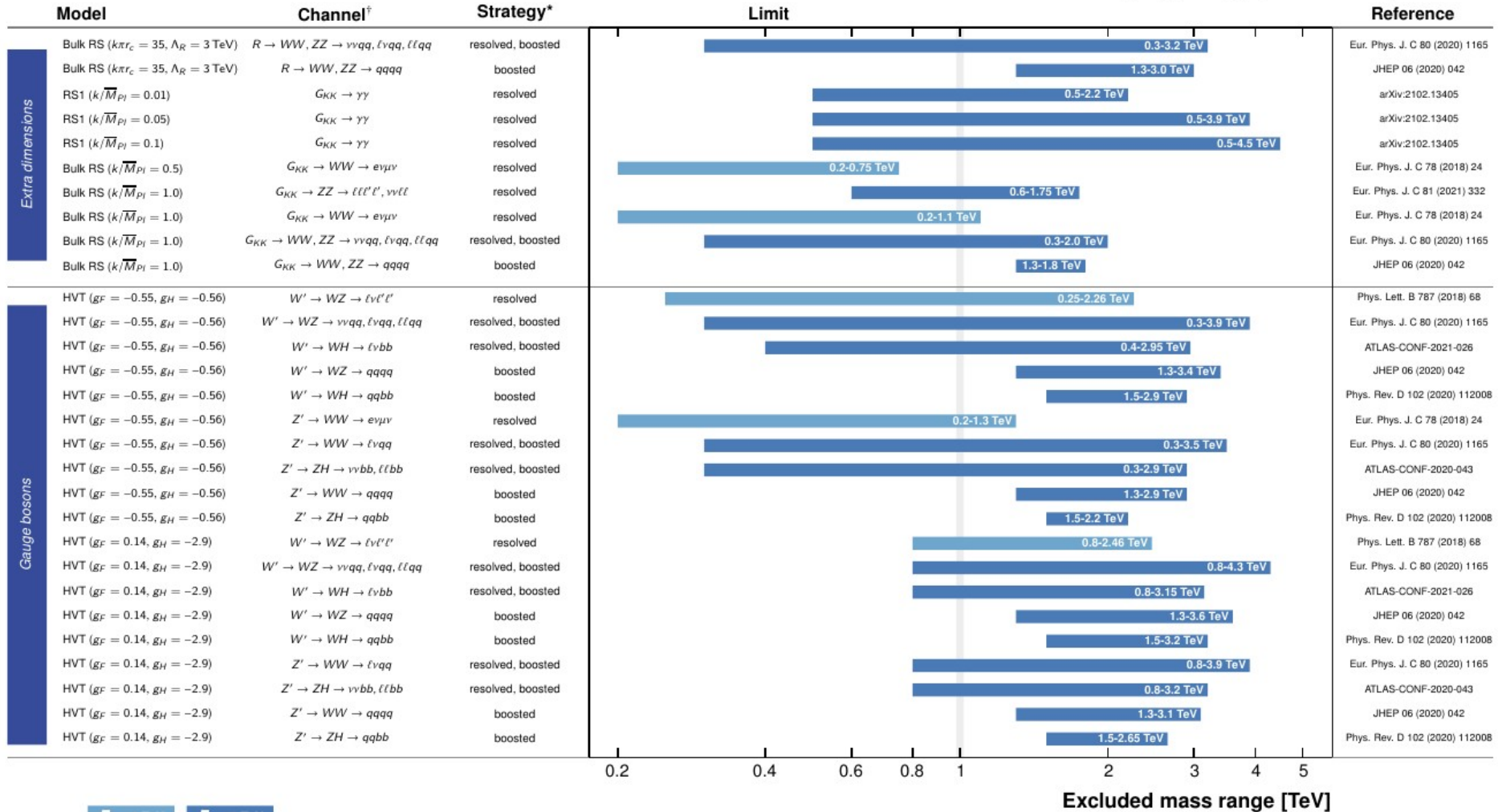
ATLAS Diboson Searches - 95% CL Exclusion Limits

Status: June 2021

ATLAS Preliminary

$\sqrt{s} = 13 \text{ TeV}$

$\mathcal{L} = (36.1 - 139) \text{ fb}^{-1}$



$\sqrt{s} = 13 \text{ TeV}$
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$\sqrt{s} = 13 \text{ TeV}$
 $\mathcal{L} = 139 \text{ fb}^{-1}$

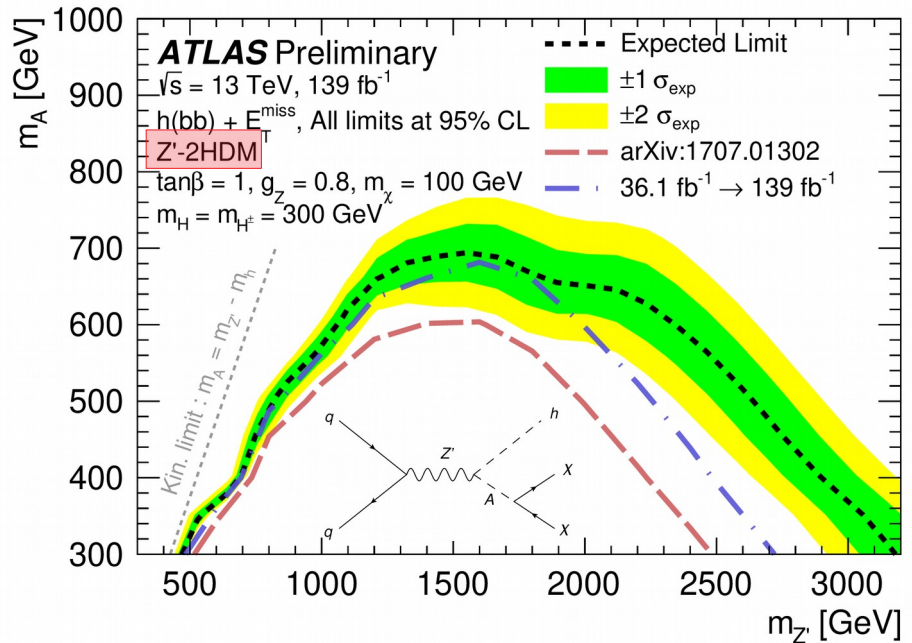
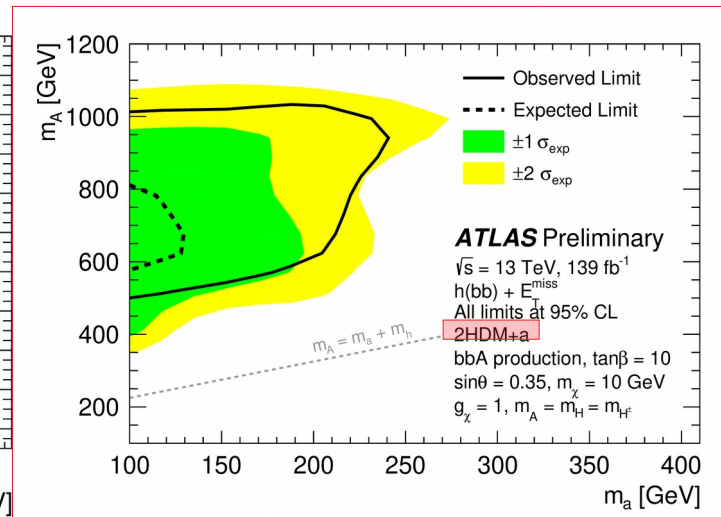
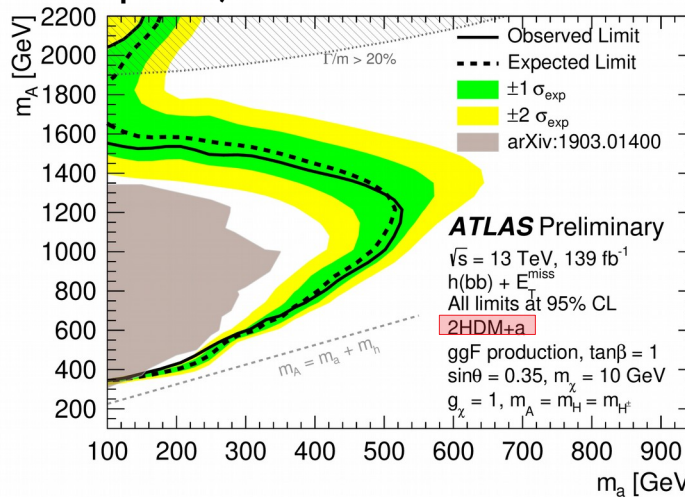
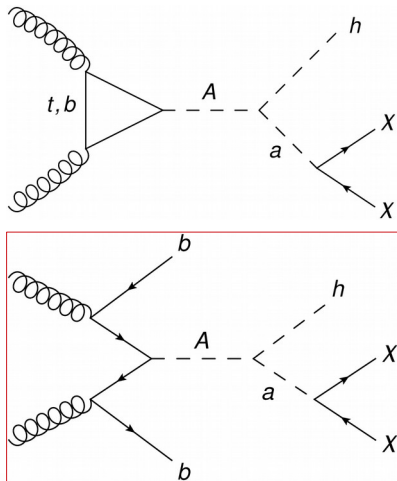
*small-radius (large-radius) jets are used in resolved (boosted) events

[†]with $\ell = \mu, e$

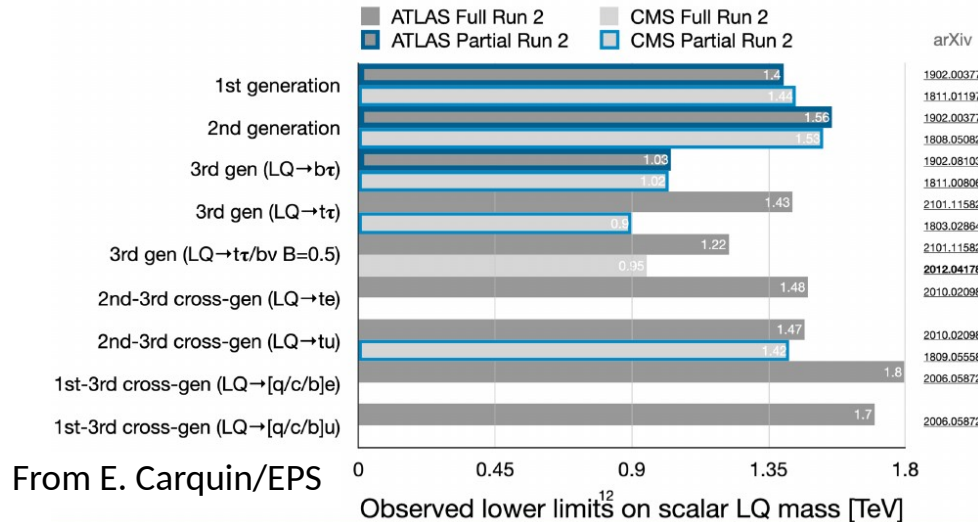
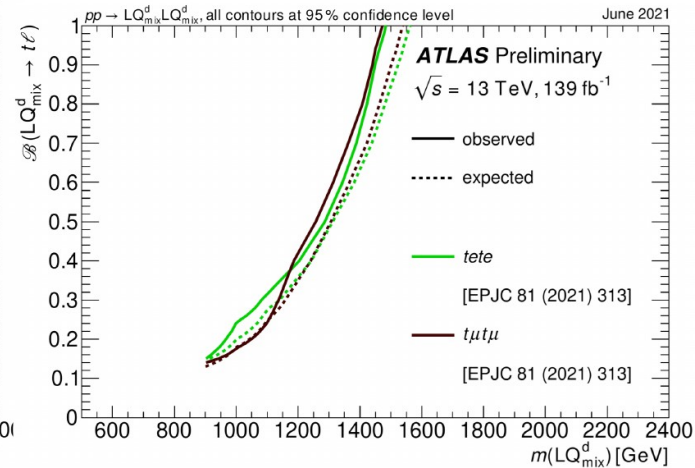
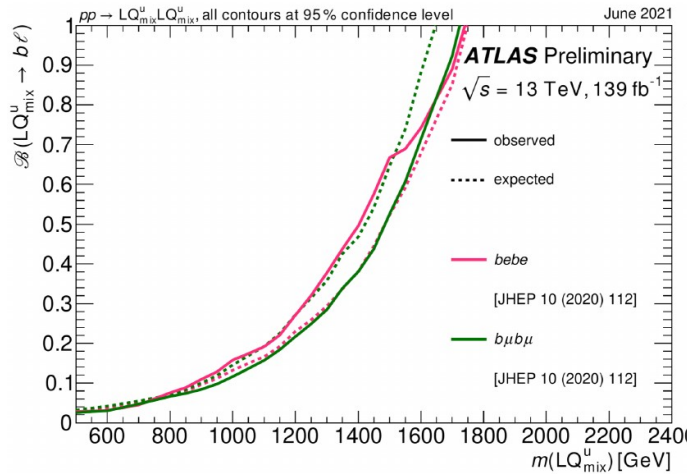
ATL-PHYS-PUB-2021-018

- Selection resolved (merged) :
 - ≥ 2 (1 large-R) jets,
 - =2 & ≥ 3 b-(sub)jets categories, (**variable radius track jets for boosted Higgs ID**)
 - 3 regions for $150 < MET < 500 \text{ GeV}$ ($MET > 500 \text{ GeV}$)
- Backgrounds : V+jets (HF), tt from CRs
- Results : combined fit of SRs & CRs m_j or m_{bb}

2HDM+a model allows to go beyond simplified models (UV complete)



- Lepton Flavor Universality tensions observed by LHCb could hint at BSM physics involving new bosons or leptoquarks with preferential couplings to third generation SM fermions



arXiv

- 1902.00377
- 1811.01197
- 1902.00377
- 1808.05082
- 1902.08103
- 1811.00806
- 2101.11582
- 1803.02864
- 2101.11582
- 2012.04178
- 2010.02098
- 2010.02098
- 1809.05558
- 2006.05872
- 2006.05872

From E. Carquin/EP5

Observed lower limits¹² on scalar LQ mass [TeV]

What would new long-lived physics look like?

