

Recent Physics Results from USTC ATLAS Group

Yusheng Wu

University of Science and Technology of China

HEP Summer Days Workshop @ PKU + online, July 15th, 2022

Overview

- USTC ATLAS group has long-term commitments to TeV physics studies in all main areas, with a brief sketch of involvements below:

Higgs Physics

Higgs discovery, $H \rightarrow bb$, $H \rightarrow ZZ$, $H \rightarrow \gamma\gamma$, $H \rightarrow WW$, ttH ,
 $H \rightarrow cc$, $H \rightarrow \mu\mu$, $H \rightarrow$ invisible, HH , combination

Search for new physics

mono-X dark matter, dark photon, extra scalar/vector, graviton, right-handed ν , long-lived particles (FCP, SUSY)

SM measurements

Vector boson scattering, diboson measurements, W/Z precision measurements, W/Z+jets measurements, Effective field theory studies



Overview

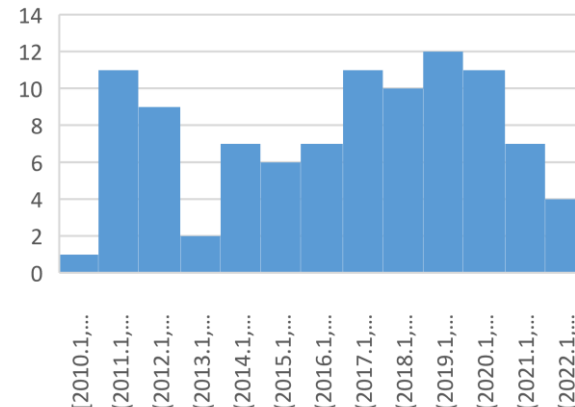
□ Newly joined faculty member

- ❖ **Hongtao Yang** (previously postdoc at Berkeley)

□ Record-wise (from CERN database)

- ❖ Primary authors / contributions to about **100 ATLAS physics/perf. papers**
 - Not counting 20+ individual author detector R&D/Upgrade papers
 - Publication trends observe the focus variations alongside machine/upgrade work
- ❖ Contact editor, analysis contact roles amount to **40**
- ❖ International conf. talks amount to **80** (excluding posters, and not counting national talks)
 - Including 6 at ICHEP, 6 at LHCP, 2 at EPS, 5 at La Thuille/Moriond, ...
 - 7 plenary talks (LHCP, La Thuille, PASCOS, ...)
- ❖ Recent management/leadership roles last 1-2 years)
 - ATLAS Speakers' Committee chair and member (Y. Wu)
 - LHC physics working group subgroup conveners (L. Xu – off-shell Higgs, H. Yang – Higgs XS)
 - ATLAS physics group subgroup conveners (L. Xu – VV modelling, H. Yang – $H\gamma\gamma$, A. Giannini – diboson searches)
 - Plus, additional 10 roles ranging from detector upgrade, performance, to ATLAS early career scientist board

USTC ATLAS Publication Record



Caveats: only count published/submitted physics/perf. papers, not counting preliminary results (conf. note), public notes, etc.

Recent Physics Results (Summer 2021 – Now)

Measurement of the properties of Higgs boson production at $\sqrt{s}=13$ TeV in the $H\rightarrow\gamma\gamma$ channel using 139 fb⁻¹ of pp collision data with the ATLAS experiment

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2020-16/>
- Submitted to JHEP

A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-23/>
- Nature volume 607, pages 52–59 (2022)

Measurements of Higgs boson production by gluon–gluon fusion and vector-boson fusion using $H\rightarrow WW^*\rightarrow e\nu\mu\nu$ decays in pp collisions at $\sqrt{s}=13$ TeV with the ATLAS detector

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-20/>
- Submitted to PRD

Direct constraint on the Higgs–charm coupling from a search for Higgs boson decays into charm quarks with the ATLAS detector

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-12/>
- Accepted by EPJC

Search for associated production of a Z boson with an invisibly decaying Higgs boson or dark matter candidates at $\sqrt{s} = 13$ TeV with the ATLAS detector

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2018-26/>
- Phys. Lett. B 829 (2022) 137066

Search for Resonant $WZ\rightarrow e\nu e'e'$ Production in Proton-Proton Collisions at $\sqrt{s}=13$ TeV with the ATLAS Detector

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HDBS-2018-19/>
- Submitted to PLB

Six recent paper publications:

With a focus on Higgs physics, and search via dibosons

Recent Physics Results (Summer 2021 – Now)

Search for a new Z' gauge boson in 4μ events with the ATLAS experiment

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-041/>

Combination and summary of ATLAS dark matter searches using 139 fb^{-1} of $\sqrt{s}=13 \text{ TeV}$ pp collision data and interpreted in a two-Higgs-doublet model with a pseudoscalar mediator

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2021-036/>

Constraining the Higgs boson self-coupling from single- and double-Higgs production with the ATLAS detector using pp collisions at $\sqrt{s} = 13 \text{ TeV}$

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-050/>

Combined measurement of the total and differential Higgs boson production cross-sections at $\sqrt{s}=13 \text{ TeV}$ in the $H \rightarrow ZZ \rightarrow 4\ell$ and $H \rightarrow \gamma\gamma$ decay channels with the ATLAS detector

- <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2022-04/>

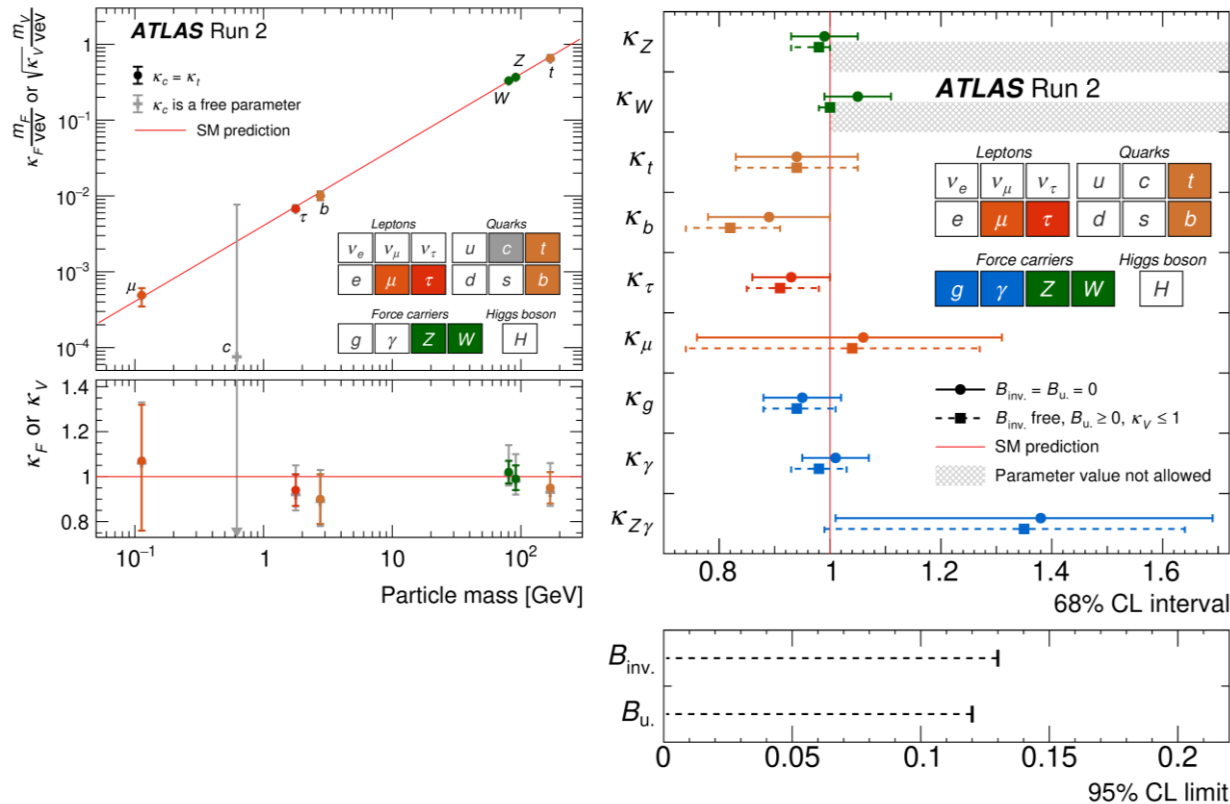
Four recent preliminary results:

With a focus on Higgs and new physics searches

Walkthrough: Higgs 10 paper

A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery

Nature 607, 52–59 (2022)



Direct contribution to the combination itself

- $ZH(\text{inv}), H \rightarrow \mu\mu$ liaisons and validation; stat. framework maintainer

Important and persistent contributions to individual channel analyses

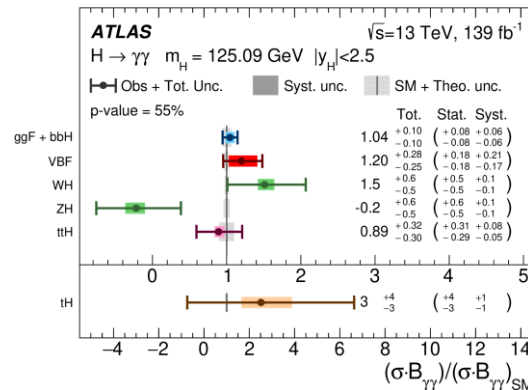
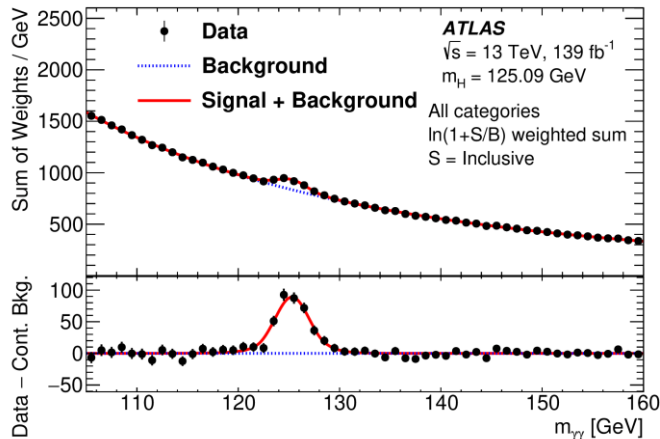
- **bb** (Y. Liu), **ZZ** (L. Xu / Z. Zhao), $\gamma\gamma$ (H. Yang), **ttH** (R. Ospanov), $\mu\mu$ (Y. Wu / H. Yang / Z. Zhao), **cc** (Y. Wu), **invisible** (Y. Wu / L. Xu)

A milestone update/review of Higgs measurements, entering <10% precision era; Impossible (rare channels) becomes likely possible (μ, c, \dots)

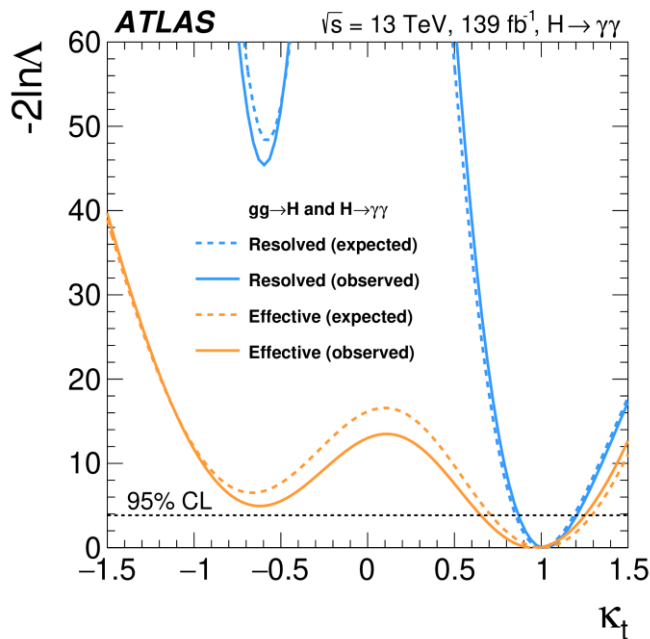
Walkthrough: precision $H \rightarrow \gamma\gamma$

H. Yang (subconvener, categorization, stats., contribution continues after returning to USTC)

Beautiful diphoton spectrum!



A main channel for the precision era O(10%)

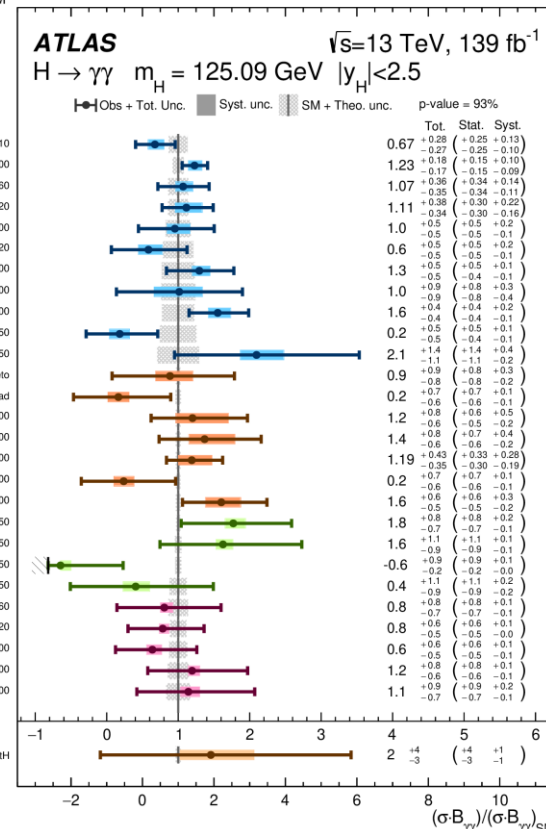


Comprehensive PS measurements in STXS framework, from ggF all the way to tH



Apart from standard measurements, adventures are made into depth, e.g., tH provides sensitivity of κ_t signs

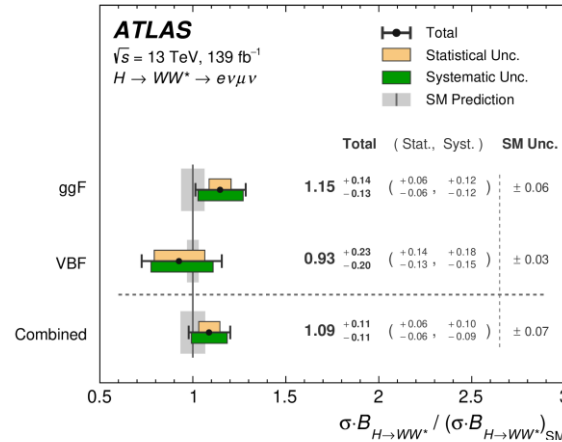
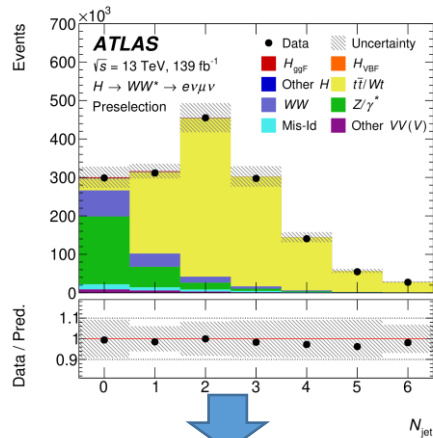
Y. Wu



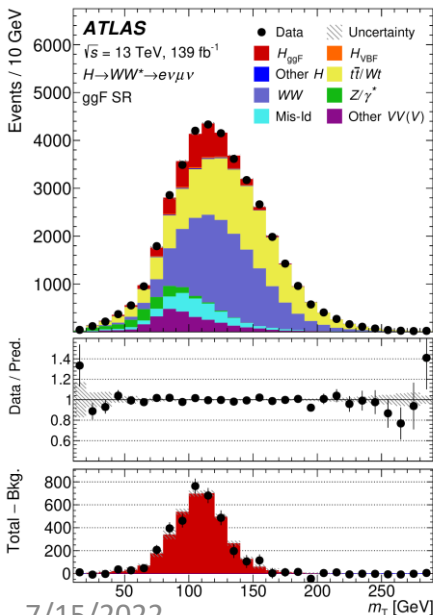
Walkthrough: get out most of $H \rightarrow WW$

D. Du, H. Li, R. Ospanov
(background est., stats.)

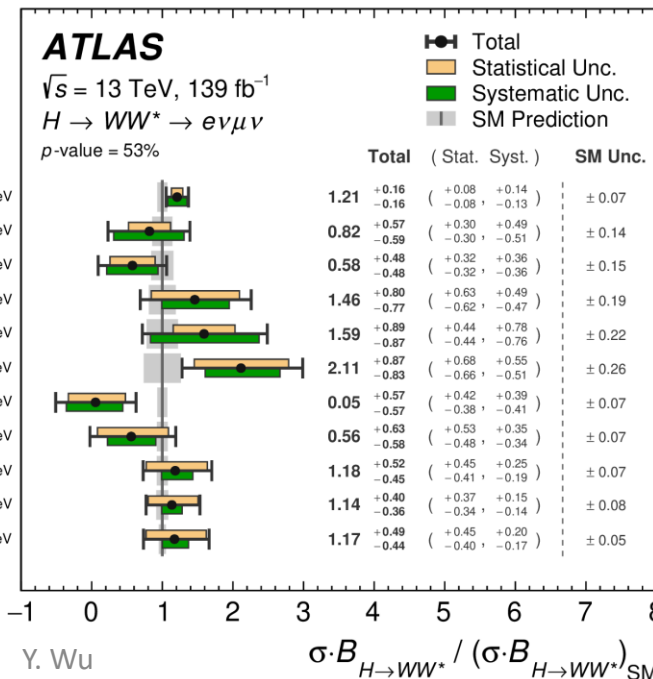
Play with $e\mu$, MET, and jets to
turn impossible to possible



WW enters also
O(10%) era!
systematics rather
important



- $ggH-0j, p_T^H < 200 \text{ GeV}$
- $ggH-1j, p_T^H < 60 \text{ GeV}$
- $ggH-1j, 60 \leq p_T^H < 120 \text{ GeV}$
- $ggH-1j, 120 \leq p_T^H < 200 \text{ GeV}$
- $ggH-2j, p_T^H < 200 \text{ GeV}$
- $ggH, p_T^H \geq 200 \text{ GeV}$
- EW $qqH-2j, 350 \leq m_{jj} < 700 \text{ GeV}, p_T^H < 200 \text{ GeV}$
- EW $qqH-2j, 700 \leq m_{jj} < 1000 \text{ GeV}, p_T^H < 200 \text{ GeV}$
- EW $qqH-2j, 1000 \leq m_{jj} < 1500 \text{ GeV}, p_T^H < 200 \text{ GeV}$
- EW $qqH-2j, m_{jj} \geq 1500 \text{ GeV}, p_T^H < 200 \text{ GeV}$
- EW $qqH-2j, m_{jj} \geq 350 \text{ GeV}, p_T^H \geq 200 \text{ GeV}$

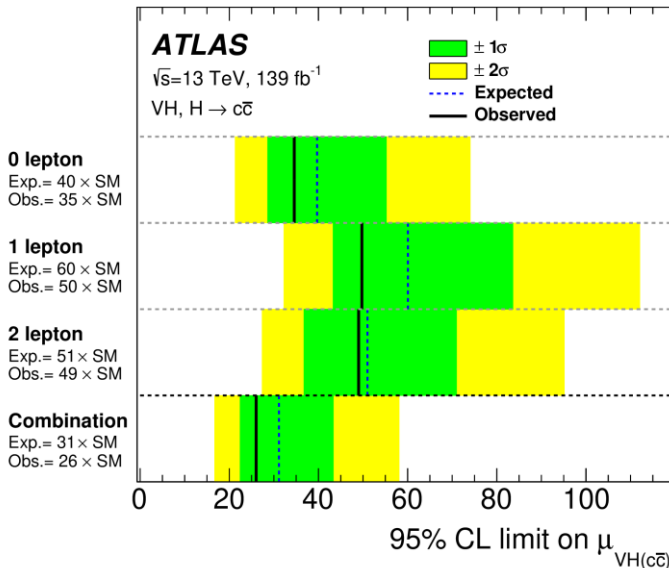


STXS
measurements

Walkthrough: charming ATLAS

T. Wang, Y. Wu
(backgrounds, stats.)

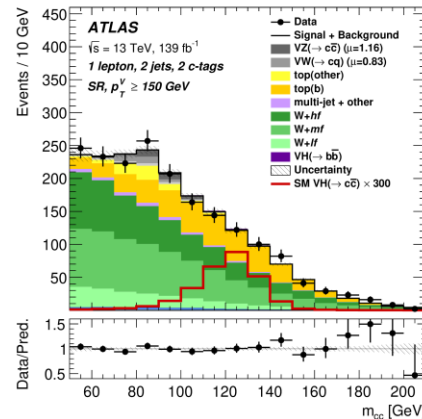
H-c is an interesting coupling, at a boarder of LHC observations for HL-LHC; also, a playground for flavor tagging and ML in depth (c v.s. b v.s. l, topologies)



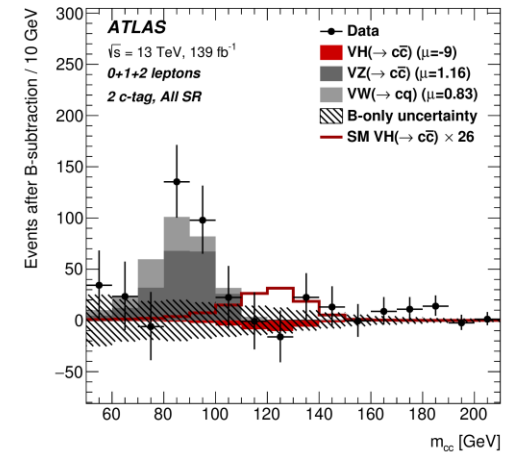
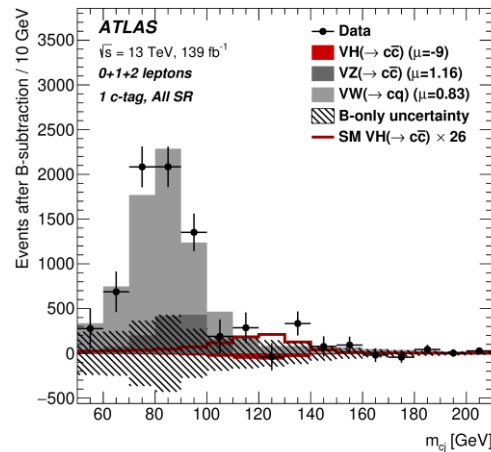
Used VH(cc) process and explored possible final states, reached an upper limit of $\mu < 26$ (95% CL) and then $|k_c| < 8.5^*$

- * assumption of only k_c variations in decays
- * Less sensitive than same data-set CMS results likely due to non MVA technique, no specific boosted region

7/15/2022



Background modelling critical for this search

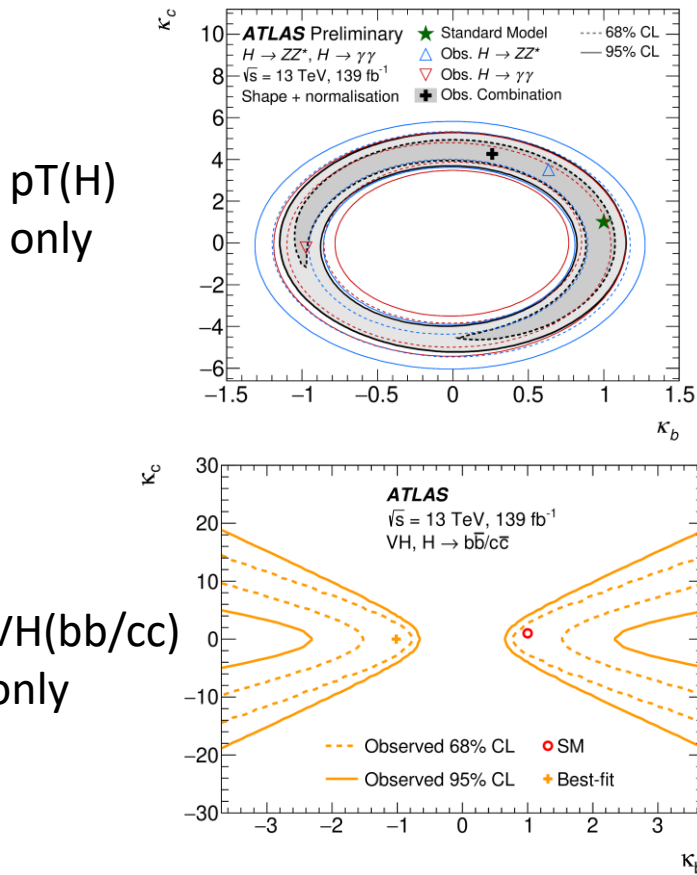


Visible VV peaks (3.8 σ and 4.6 σ for WZ and ZZ)

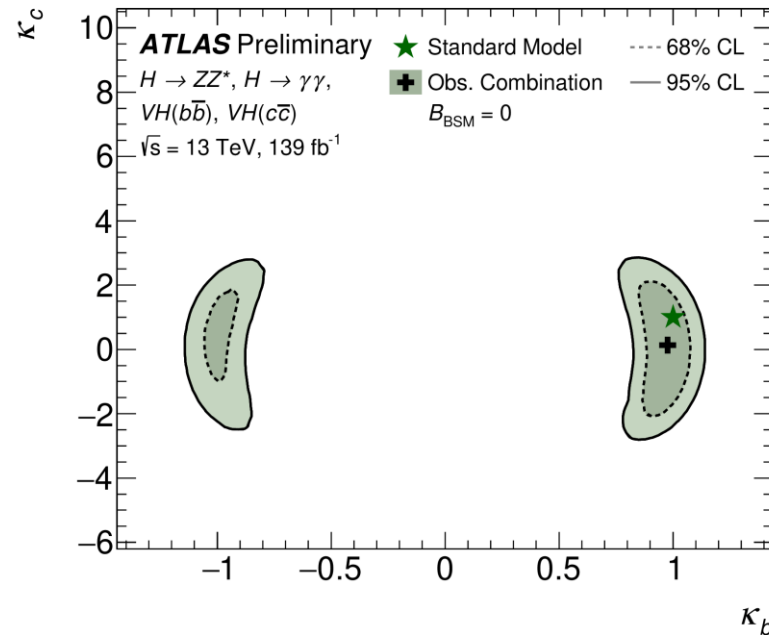
Walkthrough: another look at charm

T. Wang, Y. Hang, Y. Wu (a main analyzer for VH(cc/bb)+pT(H) comb., atlas weekly talk)

Higgs pT provides constraints to c-H couplings due to cH associated channels, it can boost the overall c-H constraint when meeting with VH(cc) results



Combination



Led to rather competitive constraints on κ_c

Scenario	Observed 68% confidence interval	Observed 95% confidence interval
$B_{\text{BSM}} = 0$	[-1.61, 1.70]	[-2.47, 2.53]
B_{BSM} profiled	[-2.63, 3.01]	[-4.46, 4.81]

* Vary only κ_c κ_b in the framework, if allowing B_{BSM} to further vary, results generally worse

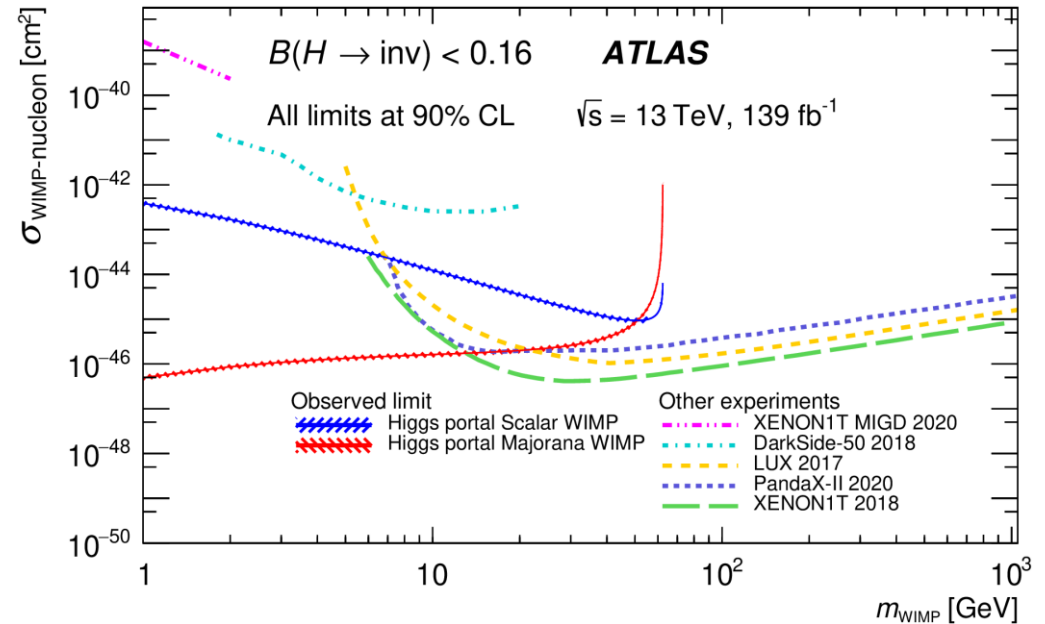
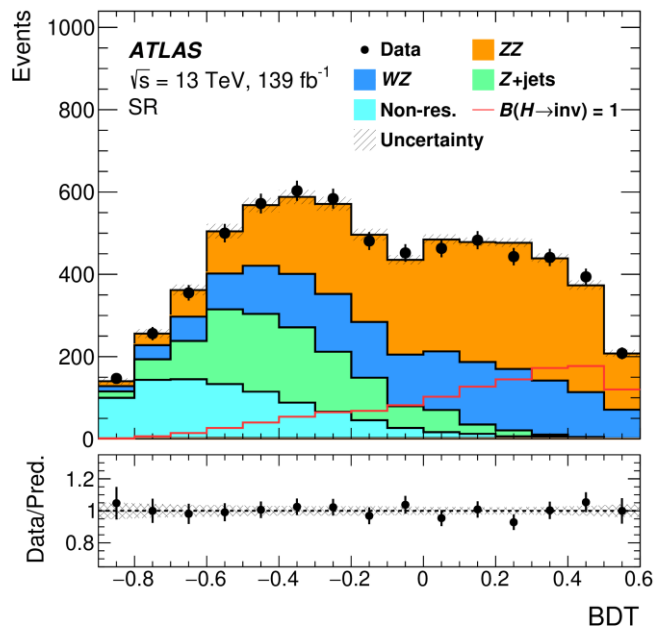
Walkthrough: H and invisible

J. Gao, C. Wei, D. KRASNOPEVTSEV, L. Xu, Y. Wu
(main analyzers, analysis contact)

Try to investigate whether H would be a portal to DM sector???

→ Search for $H \rightarrow$ invisible associated with a visible state

→ $Z(\rightarrow \text{dilepton}) + H(\rightarrow \text{inv.} \rightarrow \text{MET})$ is a clean, leading channel



Try to achieve good sensitivity via MVA.

Led to a single channel constraint on

$B(H \rightarrow \text{inv}) < 19\%$ at 95% CL

Interesting mapping to the global pic., eyeing the low mass region

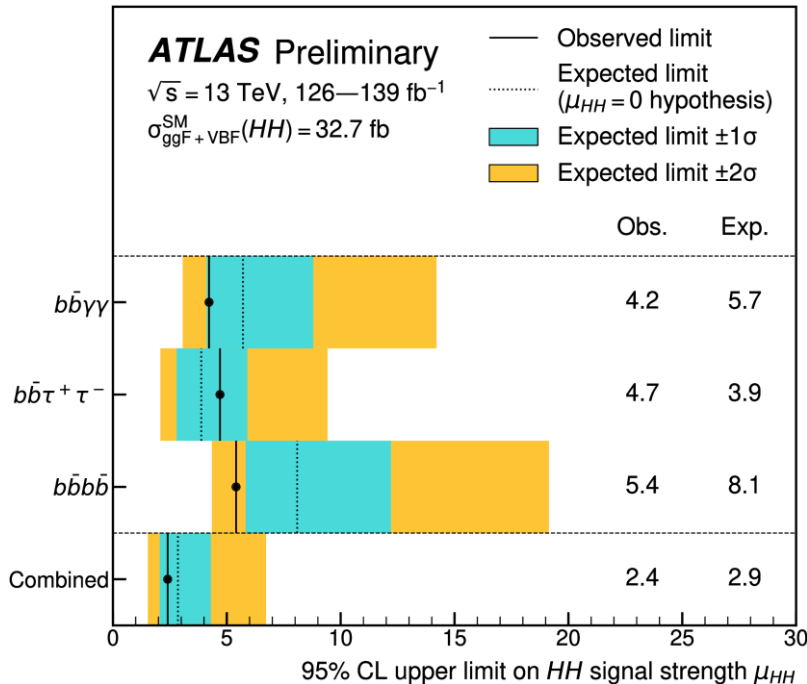
Currently, $Z(\text{ll})H(\text{inv})$ sensitivity has equally contribution from stat. and syst. unc., large room to improve for Run-3

Walkthrough: HH combination

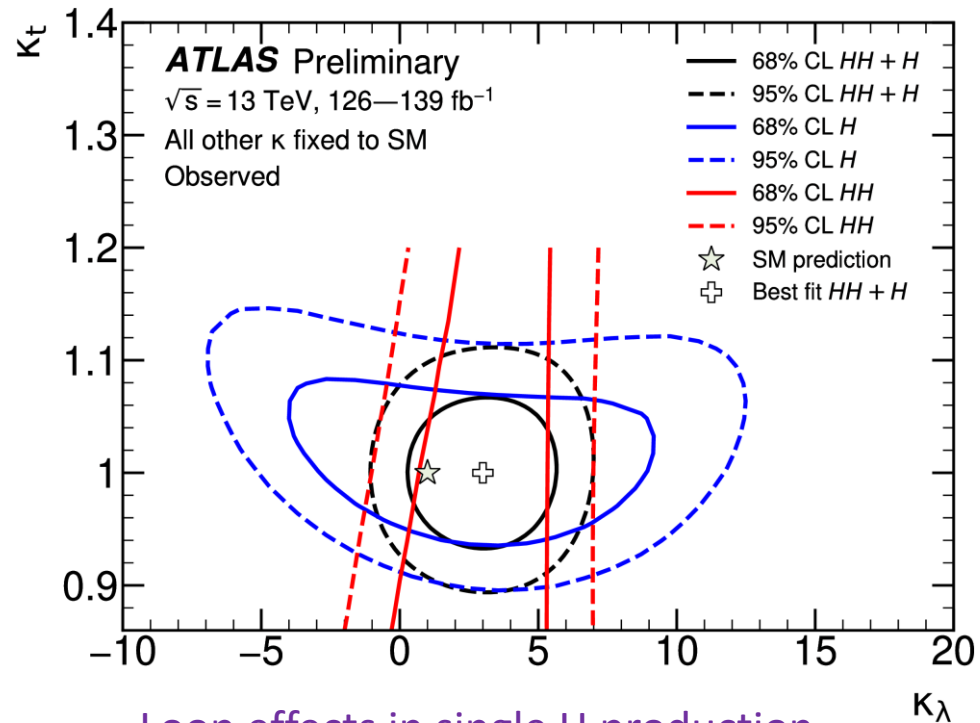
X. Ye (statistical studies)

Studying HH production is a long-wanted approach to explore Higgs self-coupling and eventually have a peek to the potential structure

➔ Several main channels combined into a great constraint on HH production: 2.4 x SM prediction at 95% CL



<https://atlas.cern/Updates/Physics-Briefing/Higg-Self-Interaction>



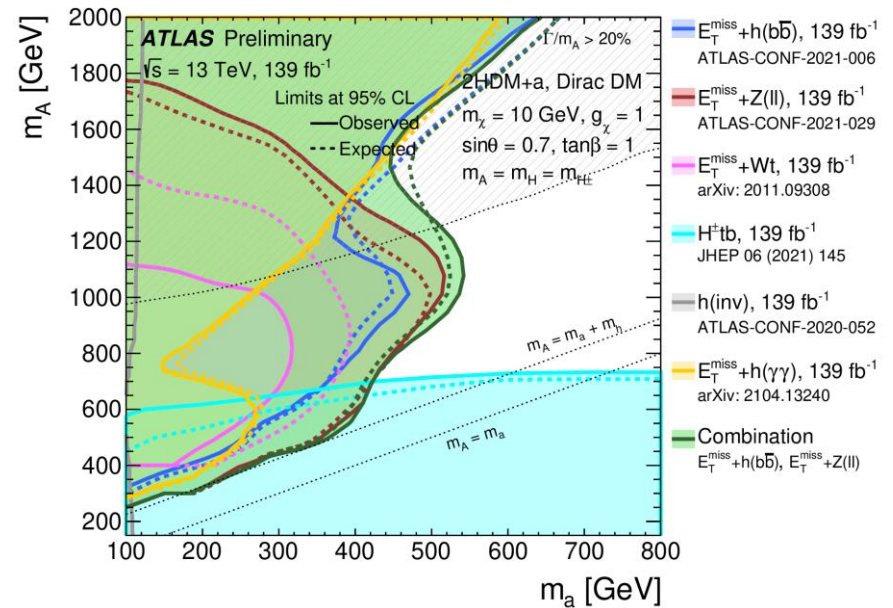
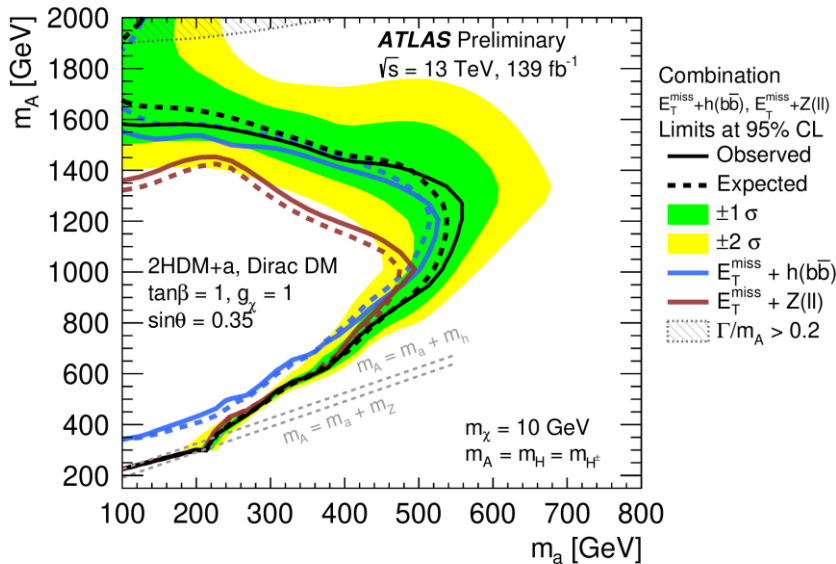
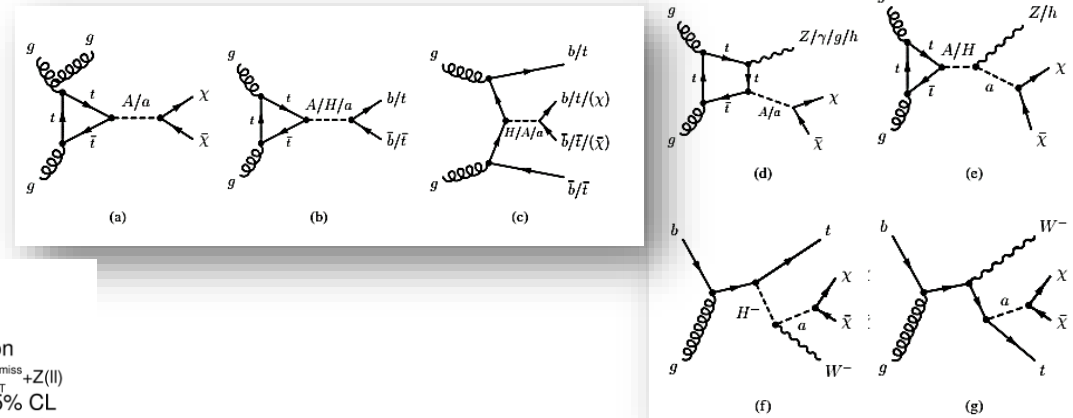
Loop effects in single H production brings good sensitivity too

Walkthrough: Combined searches for DM

C. Wei, L. Xu
(analysis contact,
signal studies)

A “complete” model for collider
DM searches based on 2HDM, with
a pseudoscalar a coupling to DM
(see [LHC DM White Paper](#))

Allows global analysis of many sensitive channels



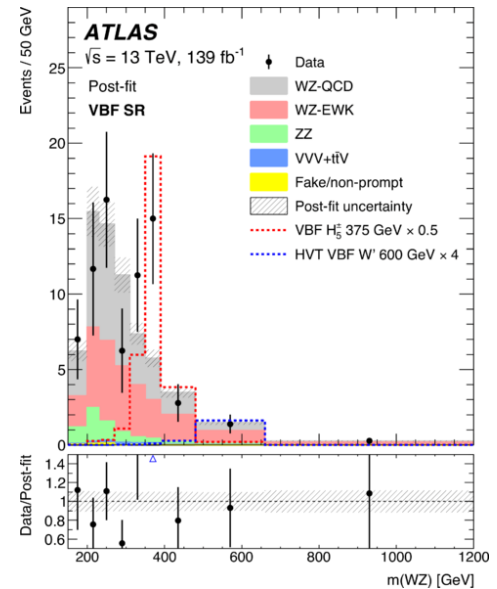
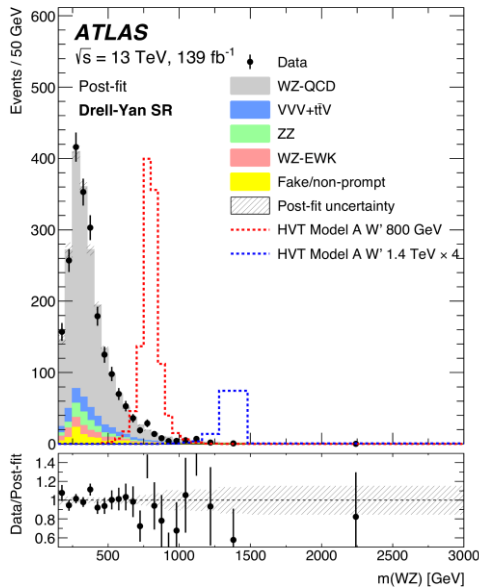
Push further the constraints in
parameter spaces and understanding
the interplays between channels, to
watch further the picture in the future

Walkthrough: WZ resonance

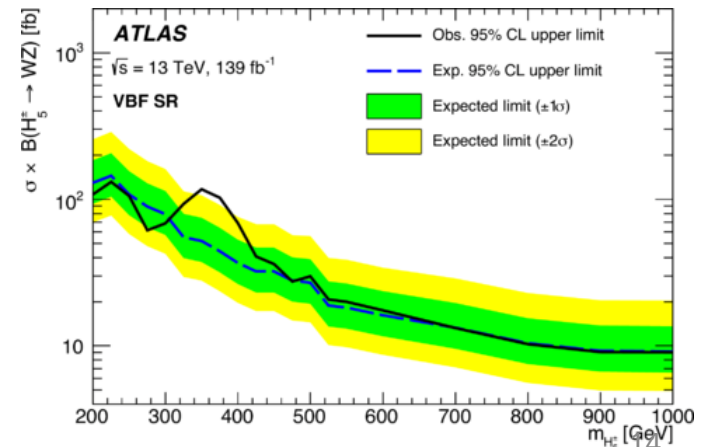
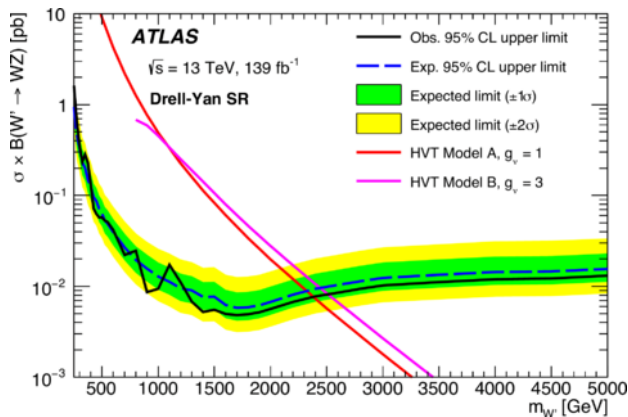
M. Lu*, M. Liu, L. Han (analysis contact, framework, backgrounds)

* Recently join Iowa group as postdoc

VV searches are traditional channels to seek for new physics. WZ has its unique place due to charged final states and clean signature



Explored both DY production as well as VBF production, constrained HVT W', charged Higgs signals

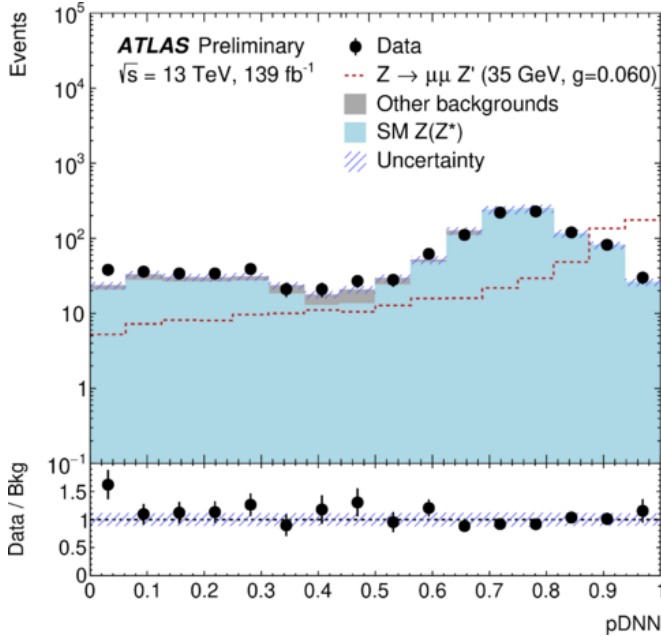
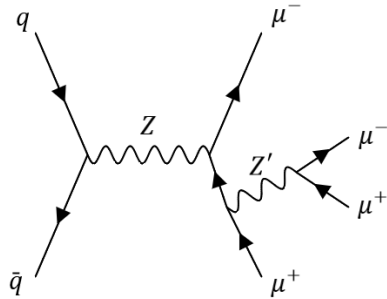


Walkthrough: Z' in four-muons

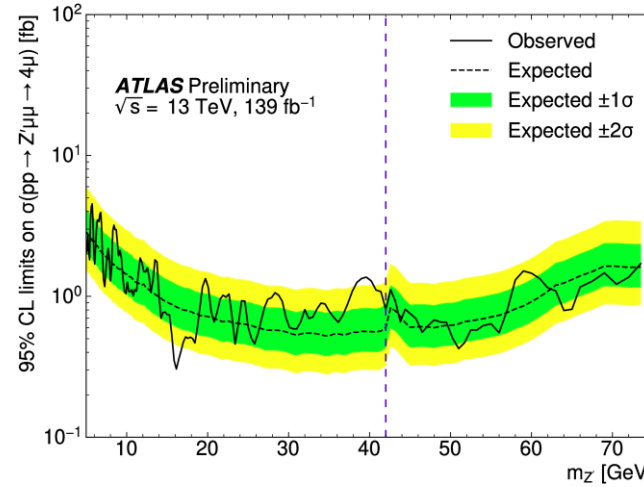
Z. Yang*, H. Zhu, Z. Zhao (contact editor, backgrounds, DNN)

* Now postdoc at UM

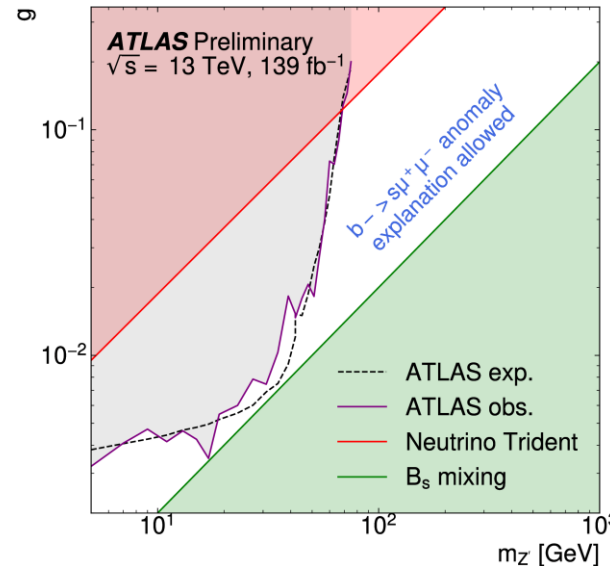
Motivated by muon $g-2$ and rare B decay anomalies, one can search for a possible, relevant new phenomena of low mass $Z' \rightarrow \mu\mu$ inside a rare $Z \rightarrow 4\mu$ decays



MVA methods to discriminate S over B



Cross-section upper limits



Map to a more global picture

Bonus

We have been excited about Higgs!!!



Designed by USTC for
Higgs 10th anniversary
outreach events

More excitements?



Let's see ... and stay tuned for
future results