Chung-Yao Chao Fellow Interview 2021

Mário José Sousa

Supervision: Prof. Zhengguo Zhao

University of Science and Technology of China

June 7th, 2021

Resume (after PhD)

Research experience:

- 2021.1 ∼ present: Postdoc at USTC. Supervision: Prof. Zhengguo Zhao.

Physics Heavy neutrino search, Vector Boson Scattering.

Upgrade HGTD Demonstrator R&D.

- 2017.12 ∼ 2020.12: Postdoc at Shandong University. Supervision: Prof. Lianliang Ma.

Physics $H \to b\bar{b}$, diboson resonances search, heavy neutrino search.

Publications within the ATLAS Collaboration with direct contributions

- "Measurement of the associated production of a Higgs boson decaying into b-quarks with a vector boson at high transverse momentum . . .", Phys. Lett. B 816 (2021) 136204, 2021
- "Search for heavy diboson resonances in semileptonic final states . . .", Eur. Phys. J. C 80 (2020) 1165, 2020
- "Determination of jet calibration and energy resolution . . .", Eur. Phys. J. C 80 (2020) 1104, 2020
- "Observation of $H \to b\bar{b}$ decays and VH production . . .", Phys. Lett. B 786 (2018) 59, 2018.

Talks in international conferences and workshops:

- The 6th China LHC Physics Workshop (CLHCP2020), 6-9 November 2020, On-line,
  "Search for heavy diboson resonances in semileptonic final states with the ATLAS detector"
- QCD@LHC 2018, 27th-31st August, 2018, Dresden, Germany,
  "Effects of parton shower and underlying event modelling in Higgs measurements and searches"

Previous work and achievements

- Higgs coupling measurements and beyond the Standard Model searches.

First $H \to b\bar{b}$ observation
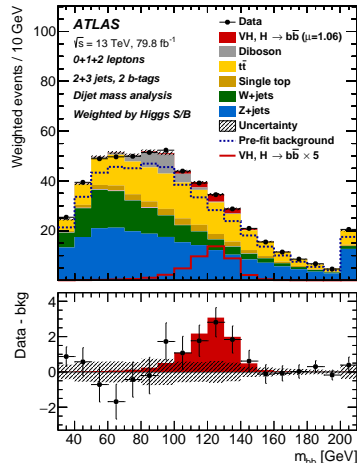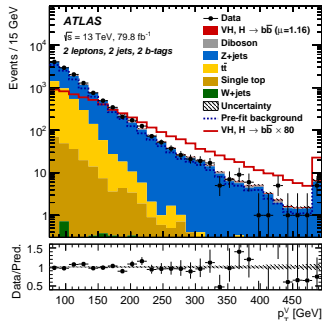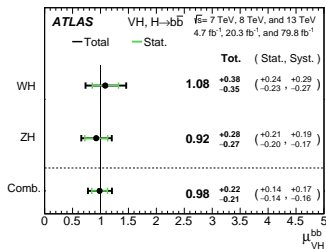
- $H \to b\bar{b}$ dominant decay (58%) for $M_H = 125$ GeV:
  - ▶ Direct test of Yukawa couplings to b-quarks.
  - ▶ Best sensitivity to ZH and WH production modes.
- Contributions on the statistical framework and on producing final plots like the "money" plot.

$H \rightarrow b\bar{b}$ boosted regime
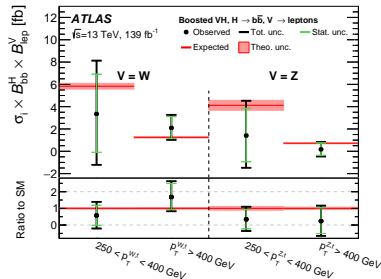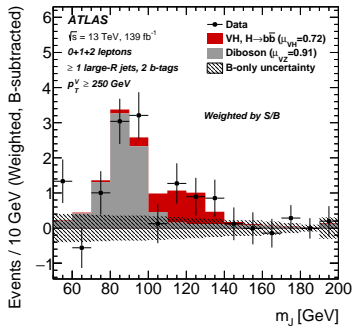
- Boosted regime with higher sensitivity to physics beyond the Standard Model.
- Performance studies for possible improvements to the analysis:
  - Usage of substructure variables to increase sensibility.
  - Usage of tracker and calorimeter based clusters to form large-R jets.
- Evaluation of the diboson modelling uncertainties.
- Event displays for paper
- Results compatible with SM with significance of 2.1 σ.

Diboson resonance search in semi-leptonic final states

- Probe extensions of the SM that predict heavy resonances decaying into VV.
- Paper editor
- General search for a new resonance (X):
  - Testing three physics models:
    Spin 0 Randall Sundrum radion
    Spin 1 Heavy Vector Triplet Z'/W'
    Spin 2 Randall Sundrum graviton
  - X produced by ggF/DY or VBF
  - $X \to VV \to \{\ell\ell, \ell\nu, \nu\nu\}qq$
    - ★ Semi-leptonic decay
    - ★ Compromise between full hadronic (more BG) and full leptonic (lower BR) decay modes.
  - $V \to qq$ reconstructed with two small-R jets (resolved) or 1 large-R jet (boosted).

Diboson resonance search results
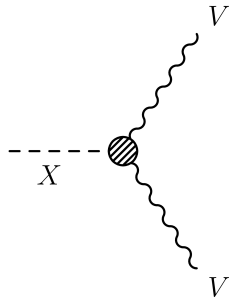
- Contributions in: 1-lepton analysis, signal and background modelling uncertainties, statistical framework.

- First limit set in the RS radion.

- Cross-section limit is a factor of 3 w.r.t the $VV \to JJ$ final state.

- Similar limits to what was obtained with combination of full-leptonic, semi-leptonic and full-hadronic searches with smaller dataset.
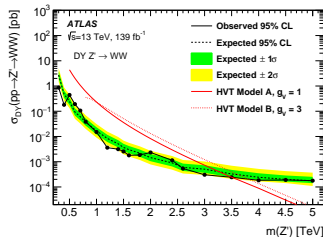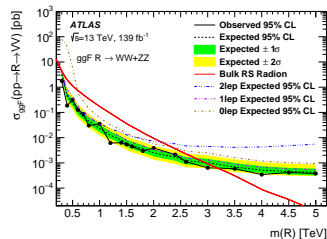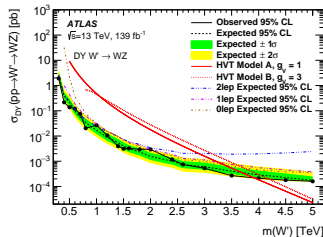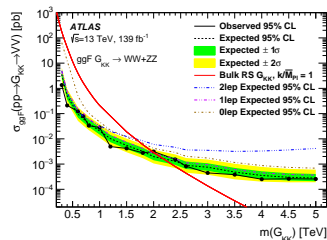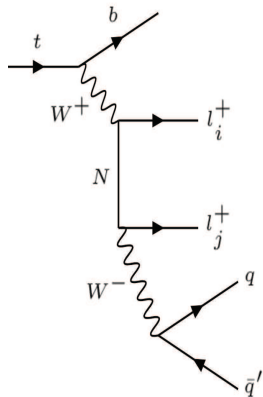
Current work and plans

- Probe electroweak symmetry breaking and search for new physics beyond Standard Model.
- Phase II upgrade of the ATLAS detector.

# Heavy neutral leptons search associated to $t\bar{t}$

- This search probes the Type-I seesaw mechanism to explain the origin mass of neutrinos by introducing three singlet right-handed neutrinos.
- This process has a lepton number violation of $|\Delta L| = 2$ that would be the smoking-gun.
- Both ATLAS and CMS have searches for heavy neutrinos produced with direct W boson.

- The search for HNL production associated with the $t\bar{t}$ process will be pioneered in ATLAS.
- Profits from additional particle (top) mass constraints to reduce backgrounds.
- Objective: set new limits for HNL in 15-75 GeV mass range.
- Leading analyser and paper editor.
- Currently finalizing analysis strategy.
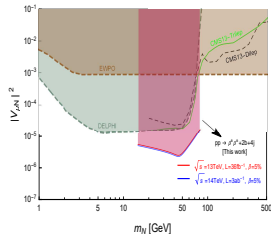
Phys. Rev. D 101, 071701 (2020)

Electroweak Vector Boson Scattering search
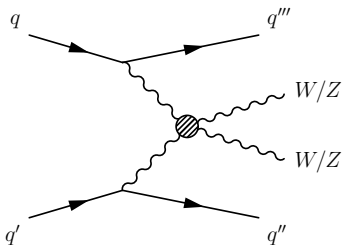
- Probing the electroweak symmetry breaking.
- Integrated luminosity of 35.6 fb^{-1} with an observed significance of 2.7 σ.
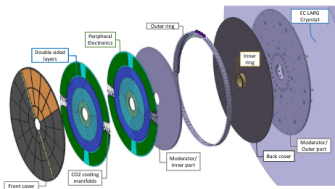
For on-going analysis:

- Using full Run 2 dataset.
- New machine learning algorithms.
- New vector boson tagging on large-R jets.
- Dedicated signal samples to study anomalous quartic gauge coupling.
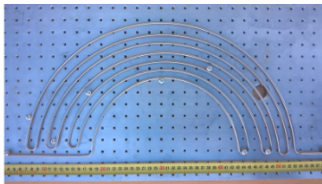- Aiming for the first observation of the EW VVjj process.
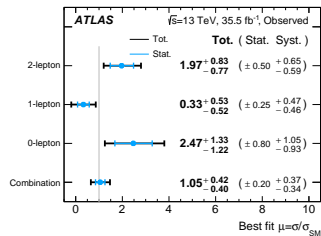
High Granularity Timing Detector (HGTD)

Detector

Cooling loop

- Part of Phase II ATLAS upgrade.
  - USTC involved with the upgrade.
- Covers $2.4 < |\eta| < 4.0$ range.
- Provides high time resolution.
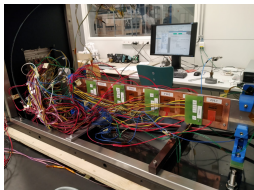- Together with ITk improves particle reconstruction by addressing the extreme pileup expected: $\mu \sim 200$.

- Participation on the HGTD heater demonstrator activities.
  - Uses a cooling plate to validate CO_2 thermal calculation to be used in HGTD cooling loop.
- Participation on the HGTD full demonstrator activities.
  - 5-10 HGTD modules to be tested.

Demonstrator assembled

Temperature of probes during test run

Summary

- Achievements:
  - First observation of the $H \to b\bar{b}$ decay.
  - First analysis of $H \to b\bar{b}$ in boosted regime.
  - Improvement of a factor of 3 in the limits obtained in heavy diboson resonance search.
- Plan:
  - First search of a heavy neutrino in association production with $t\bar{t}$ event.
  - First observation of the electroweak vector boson scattering.
  - Participation in the demonstrator of the HGTD for ATLAS upgrade to HL-LHC.

Thank you for your consideration

Backup

# Supervision and outreach considerations

Supervision of PhD students @ SDU

- Zhongyukun Xu: DBL VV.
- Han Jingyi: Boosted *Vh* and VH legacy.
- Tongbin Zhao: Heavy neutrino search.
- Others students @CERN.
  - ▸ Tong Li: DBL *Vh* resonance.

Outreach

- Participation in IPPOG Master-classes.
- CERN/ATLAS underground guide.
- Participation in CERN Open days.
- Event display for Hbb boosted.

$Wh \to \mu\nu + 1$ fat jet.
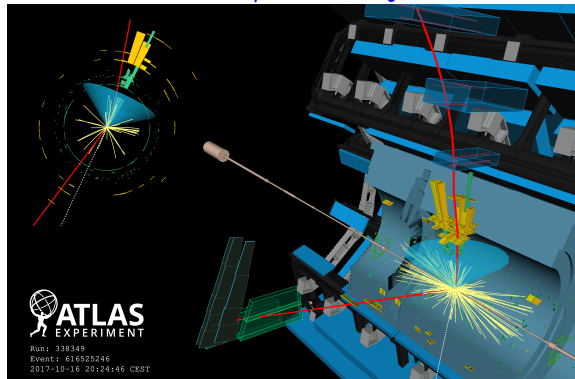
Diboson VV resonance search VBF results

- First limit set in the RS radion.
- Cross-section limit is a factor of 3 w.r.t the $VV \rightarrow JJ$ final state
- Similar limits to what was obtained with a combination of full-leptonic, semi-leptonic and full-hadronic searches with a smaller dataset.
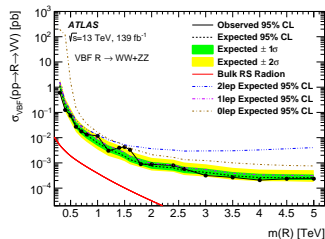
Excluded mass limit

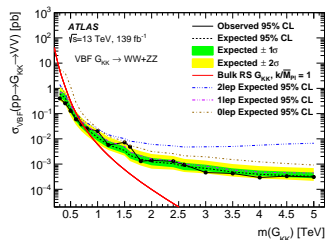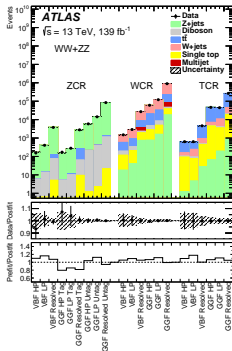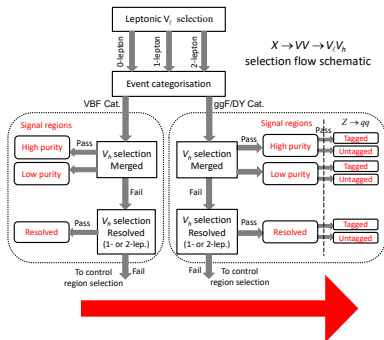| Production process | RS radion | HVT | | RS graviton |
		W′	Z′	
ggF/DY	3.2 (2.9)	Model A 3.9 (3.8)	3.5 (3.4)	2.0 (2.2)
		Model B 4.3 (4.0)	3.9 (3.7)	
VBF	–	Model C –	–	0.76 (0.77)
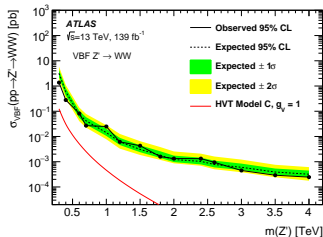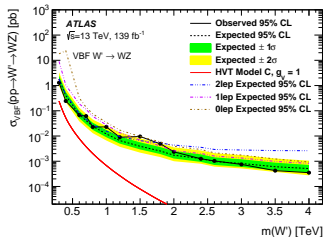
Diboson resonance search strategy

Selection flow of the analysis

- Event production topology classified by a recurrent NN score.
- In the merged categorization, use of TCC jets with a dedicated V-tagger.
- 40 signal regions.
- 24 control regions to extract normalizations for the leading backgrounds:
  - ▸ Top and V+jets.
- Fit in signal and control regions.
- Final discriminants: $m_T(\nu\nu qq)$, $m(\ell\nu qq)$ and $m(\ell\ell qq)$.