李政道研究所
TSUNG-DAO LEE INSTITUTE

Recent updates from ATLAS experiment

- selected topics with SJTU/TDLI team's contribution

LIU Kun（刘坤）

Tsung-Dao Lee Institute &
School of Physics and Astronomy,
Shanghai Jiao Tong University

HEPSummerDays@PKU

15.07.2022

上海交大/李政道研究所 对撞机实验团队

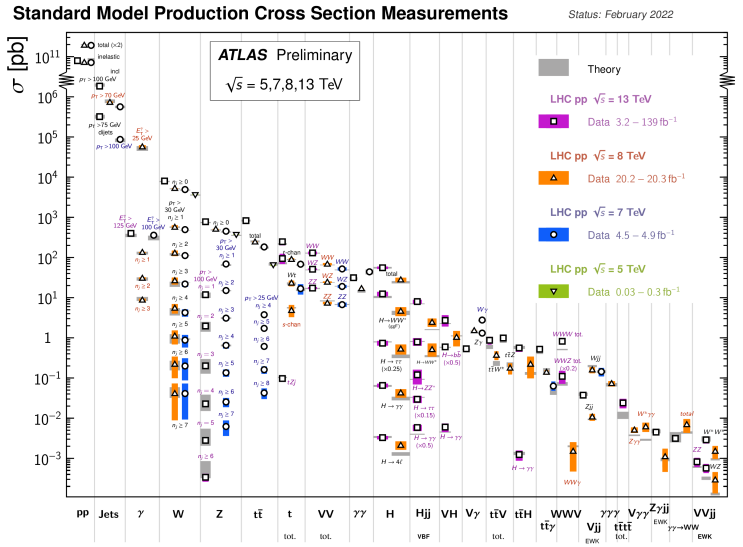
- 目前团队成员包括
  - 8名教师
  - 7名博士后
  - 22名研究生

Outline

- The Higgs Boson Updates
- The SM Measurement Updates
- Searches for BSM Physics
- Performance studies
- Summary

The Higgs Working Group

The Standard Model Working Group



HBSM HLRS DiHiggs DBL Dark Matter HDBS

UEH C D M LPX HQT JDM ATLAS EXOTICS GROUP

1. The Higgs Boson

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The Higgs boson discoveries (2012-2022)

LHC HL-LHC

Run 1 | Run 2 | Run 3 | Run 4 - 5...

LS1 | EYETS | LS2 | EYETS | LS3

7 TeV | 8 TeV | 13 TeV | 13.6 TeV | 13.6 - 14 TeV energy

splice consolidation
button collimators
R2E project

cryolimit interaction regions

Diodes Consolidation
LIU Installation
Civil Eng. P1-P5

pilot beam

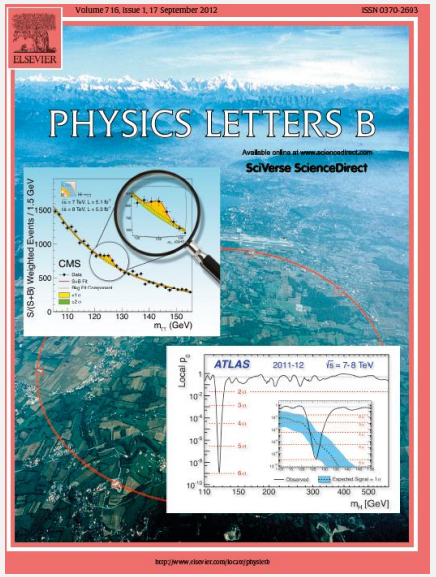
inner triplet radiation limit

HL-LHC installation

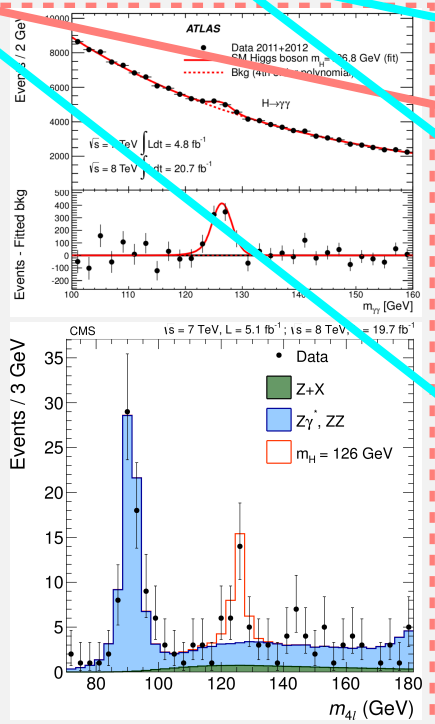
High Luminosity LHC

2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2040

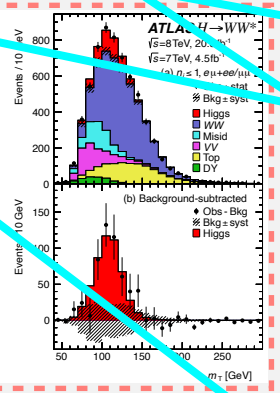
SM-like Higgs discovery (ggF H→γγ + ZZ + WW)



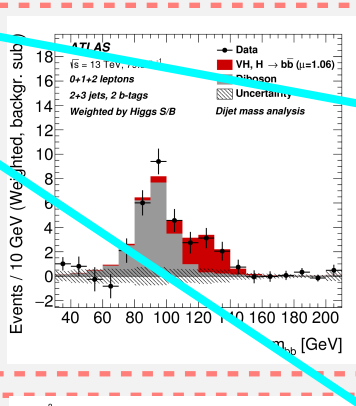
H→γγ, ZZ→4l observation (0+)



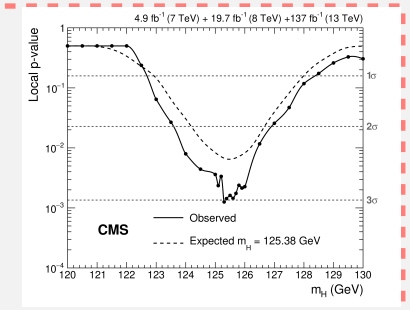
H→WW observation



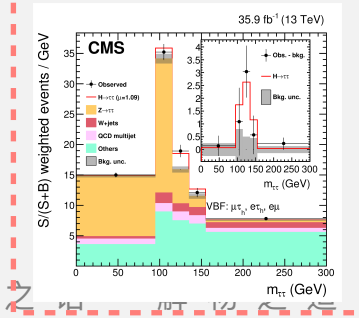
VH, H→bb̄ obs.



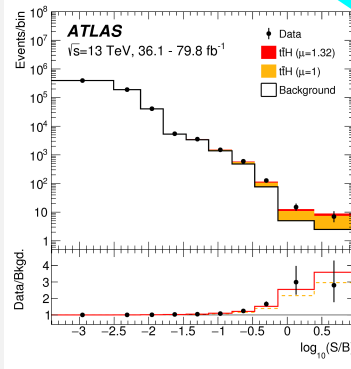
H→μμ evidence



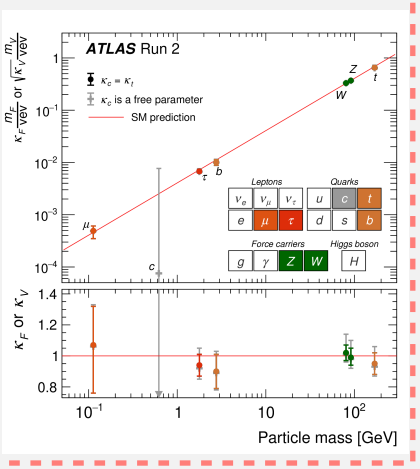
VBF H obs., H→ττ obs.



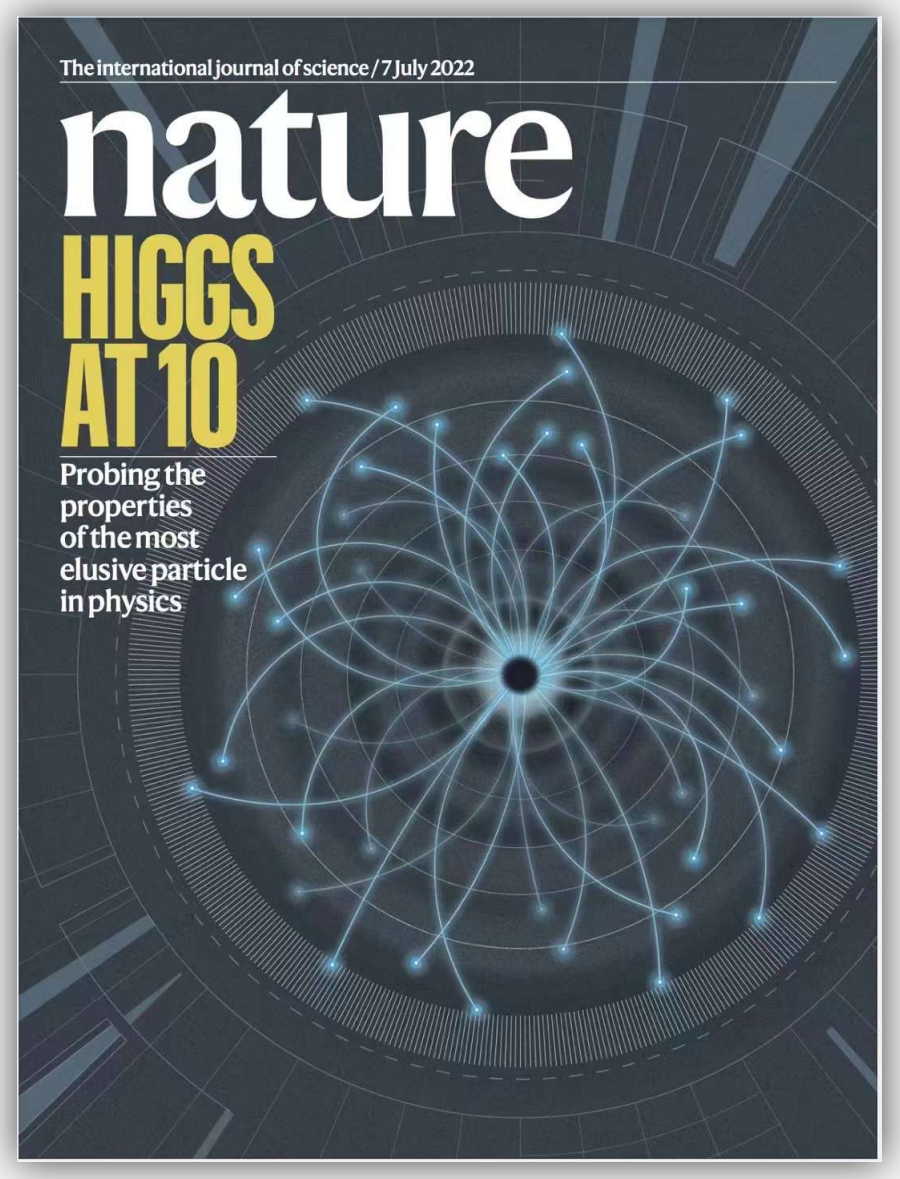
ttH observation



10th year of the Higgs discovery



10th anniversary of Higgs boson discovery



[Scientific Symposium at CERN, July 4th, 2022]

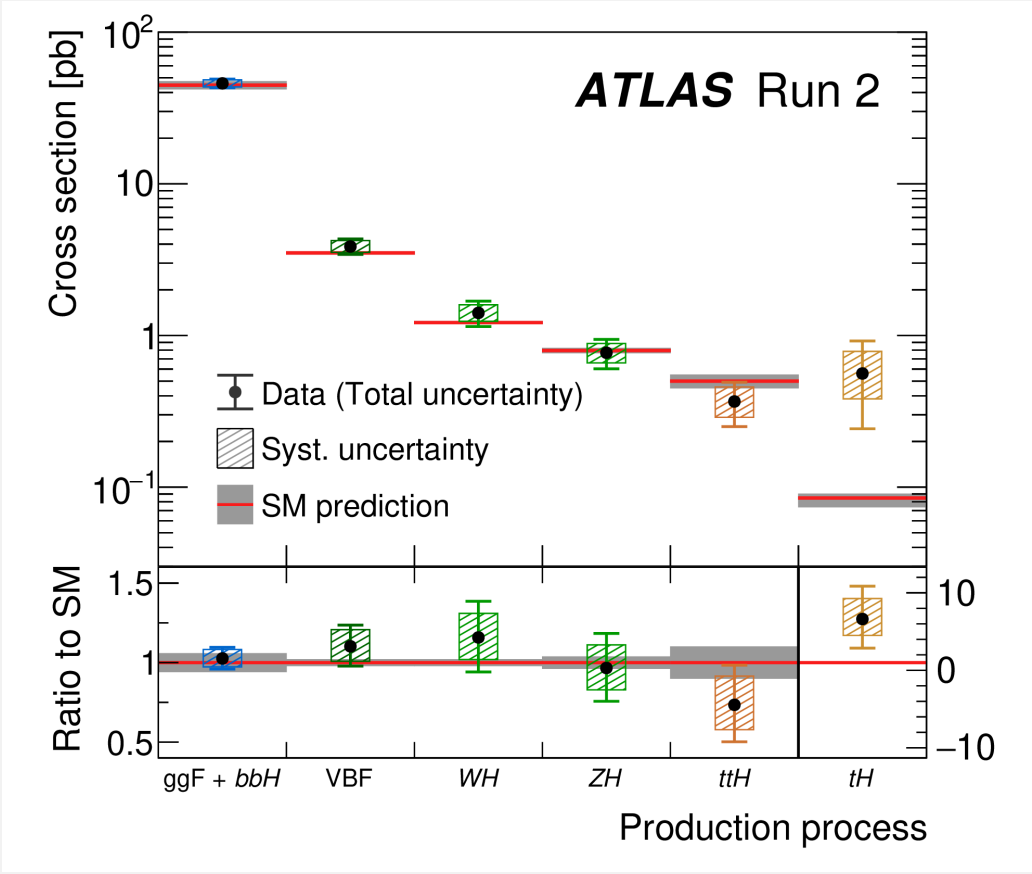
Combined measurement of the Higgs boson properties

- **Inclusive Higgs boson production rate relative to the SM prediction:**

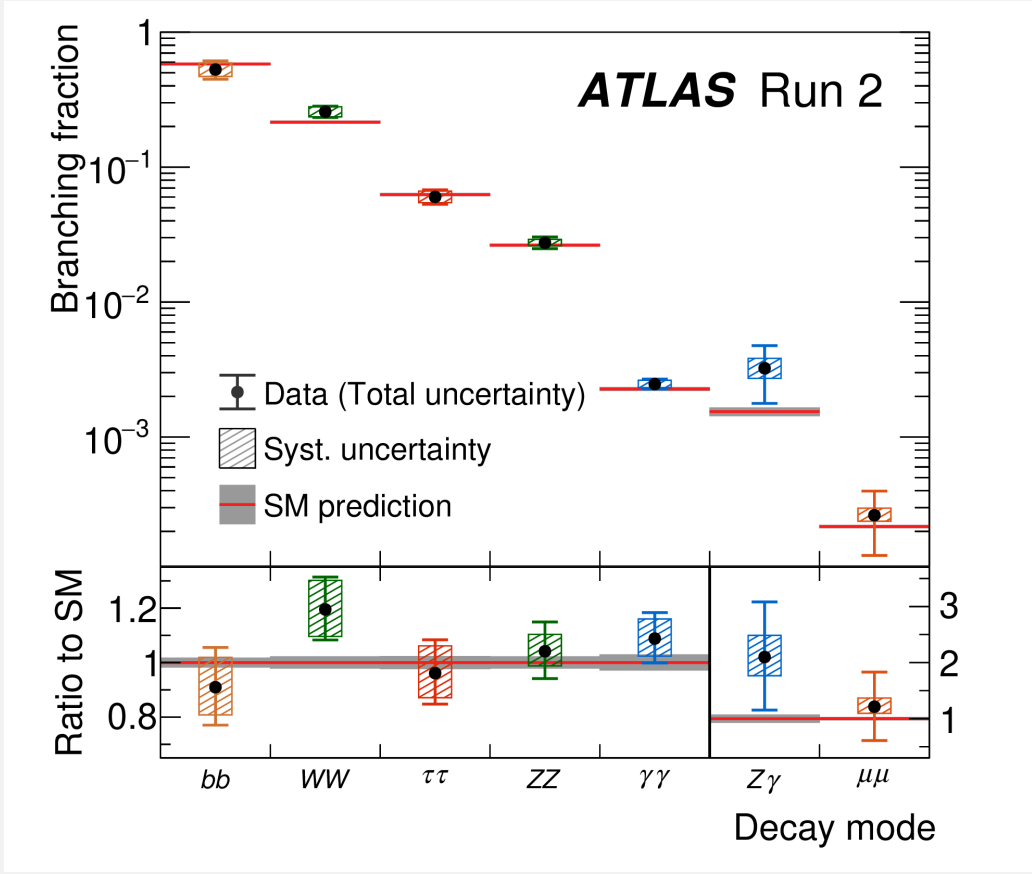
Nature 607 (2022) 52-59

$$\mu = 1.05 \pm 0.06 = 1.05 \pm 0.03\,(\text{stat.}) \pm 0.03\,(\text{exp.}) \pm 0.04\,(\text{sig. th.}) \pm 0.02\,(\text{bkg. th.}).$$

Higgs production cross section *(p-value = 65%)*



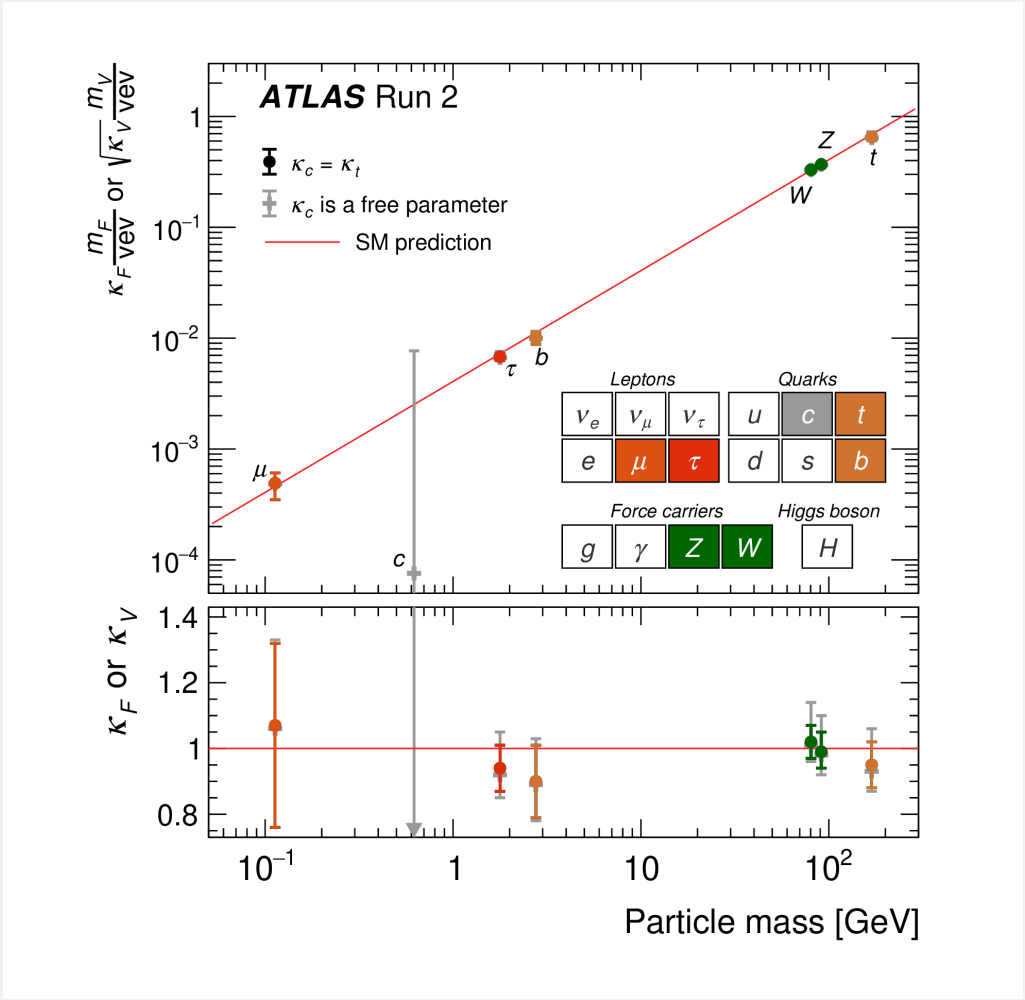
Higgs decay branching fraction *(p-value = 56%)*

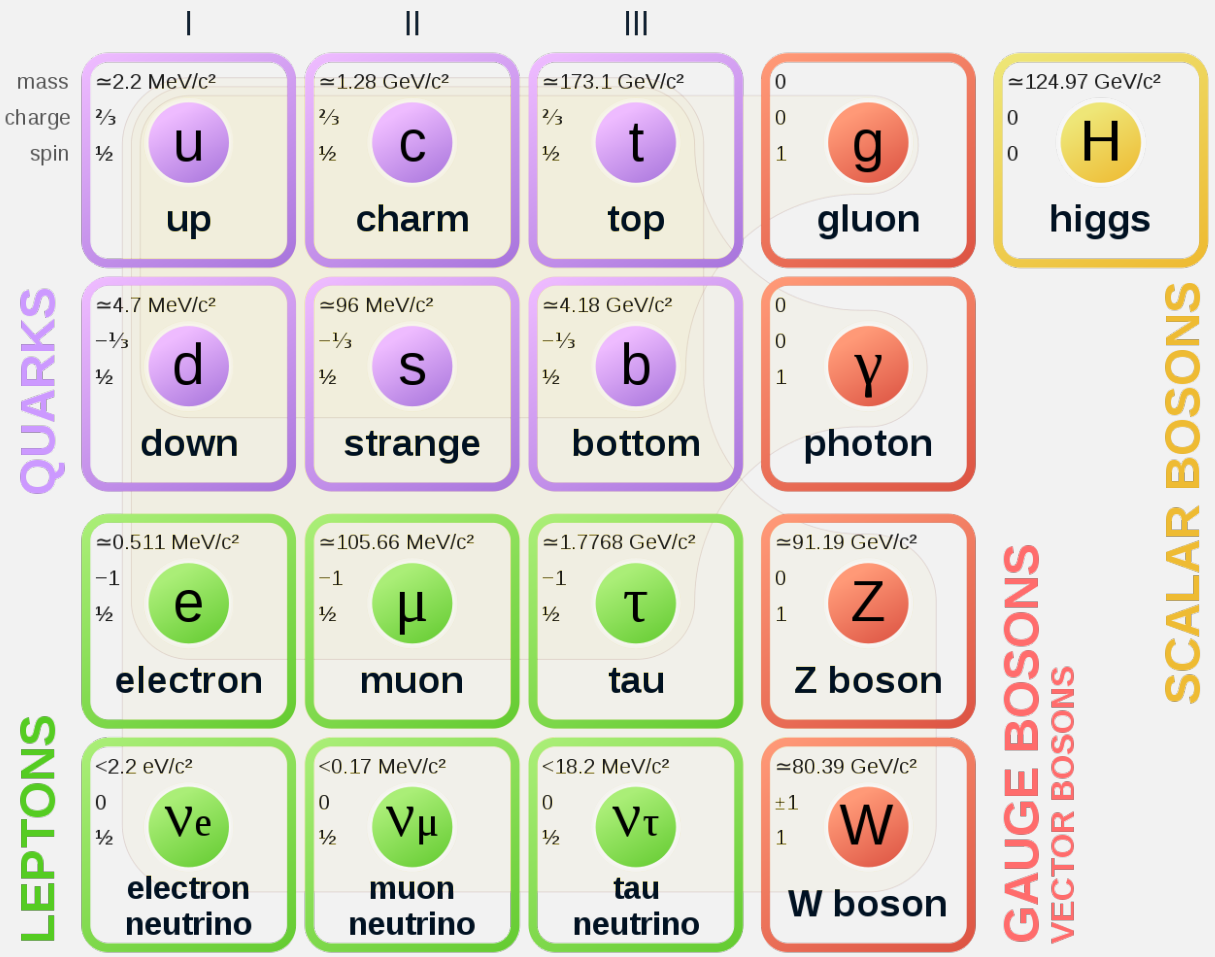


Combined measurement of the Higgs boson properties

Nature 607 (2022) 52-59

- **Measurements of Higgs boson coupling strength modifiers and their uncertainties**





Combined measurement of the Higgs boson properties

Nature 607 (2022) 52-59

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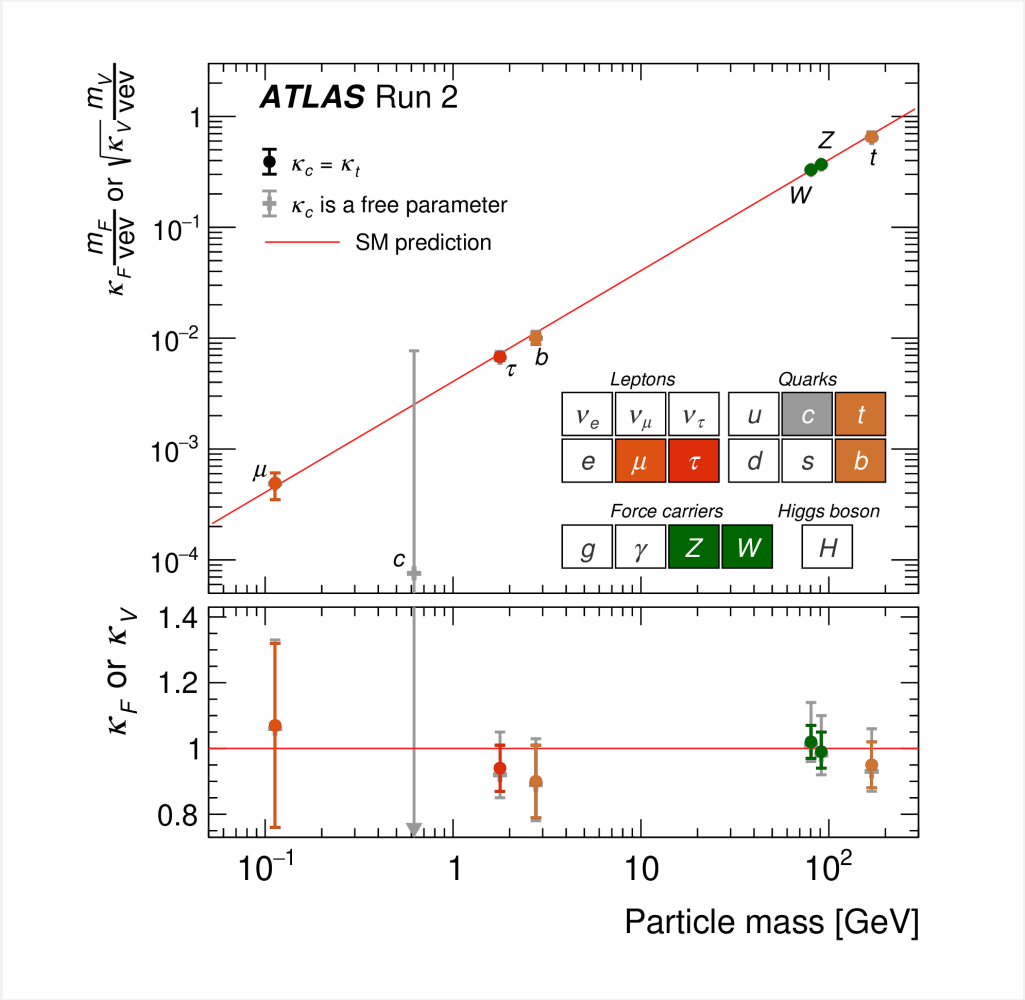

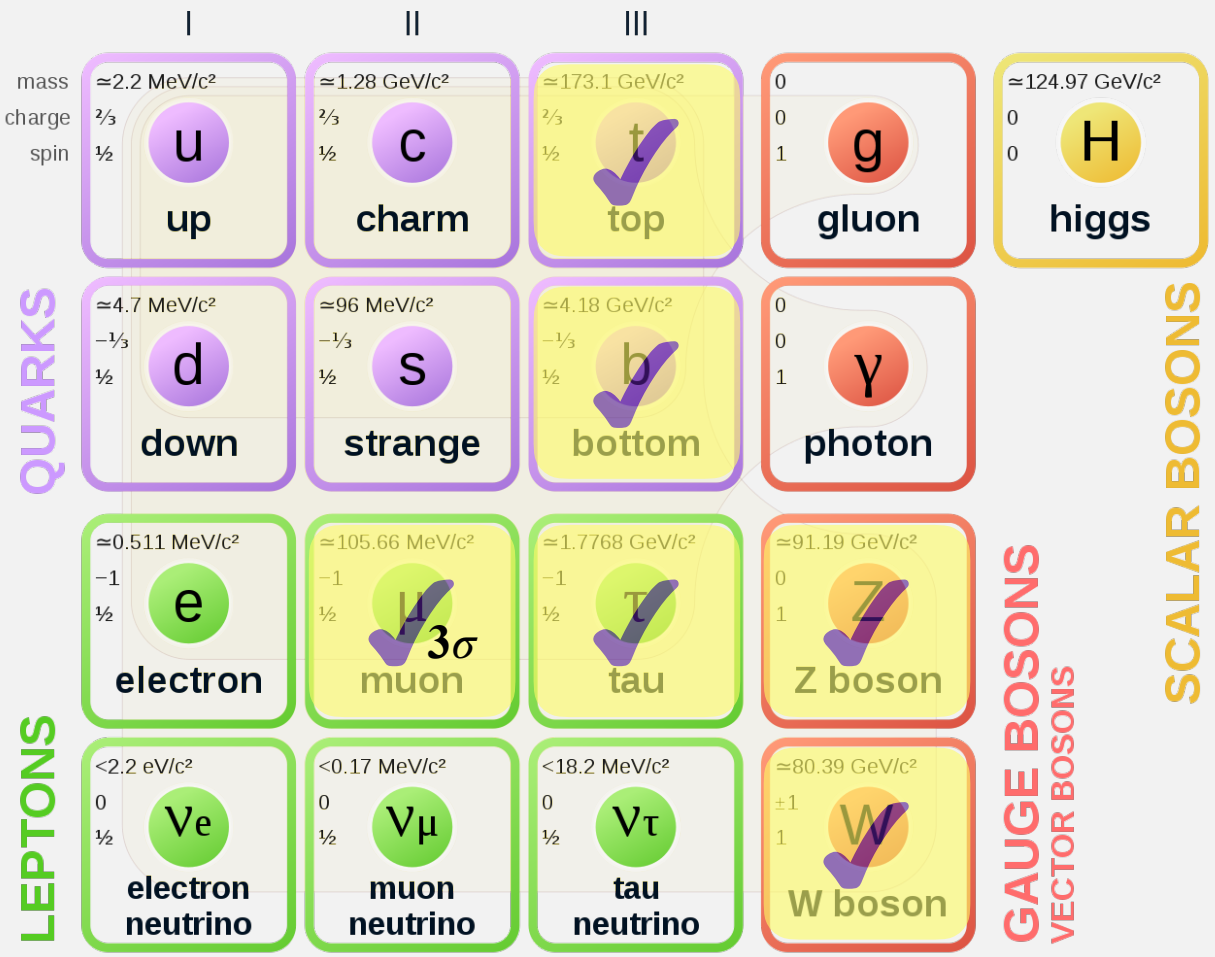

Combined measurement of the Higgs boson properties

Nature 607 (2022) 52-59

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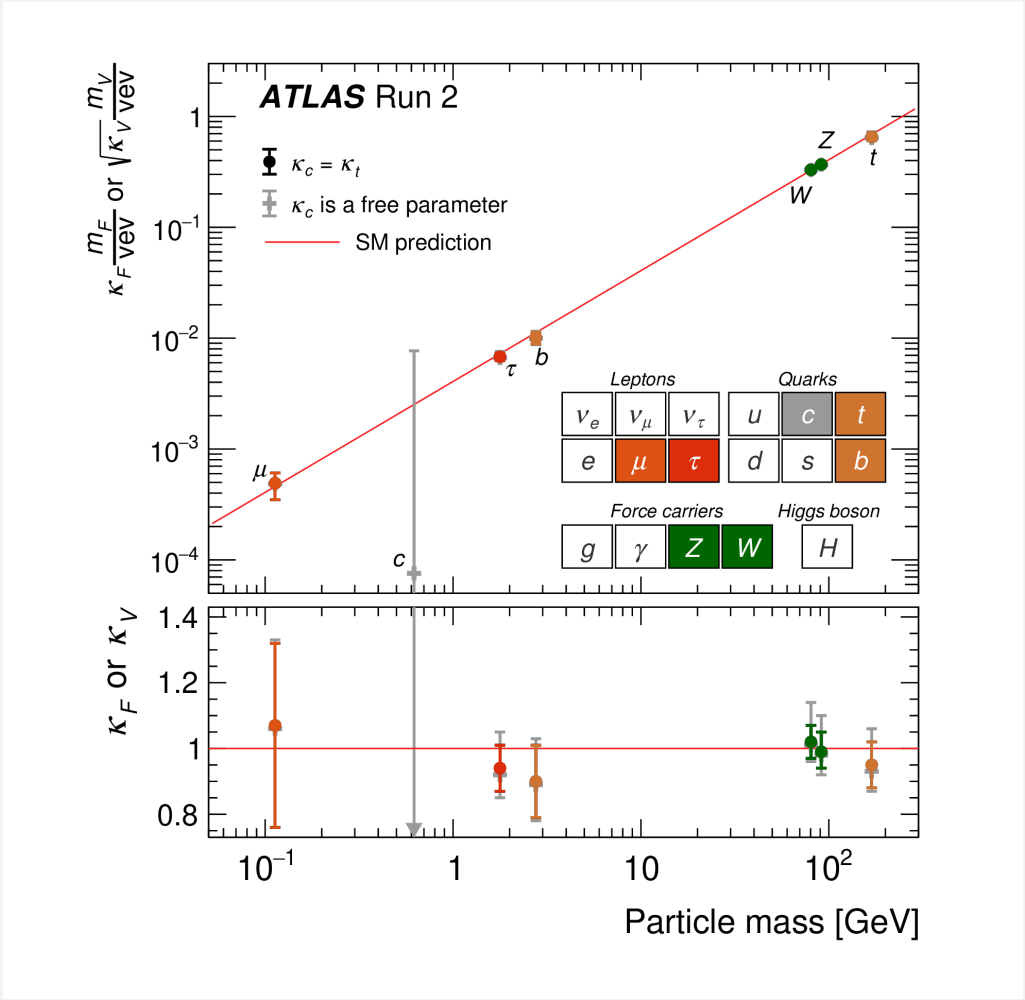
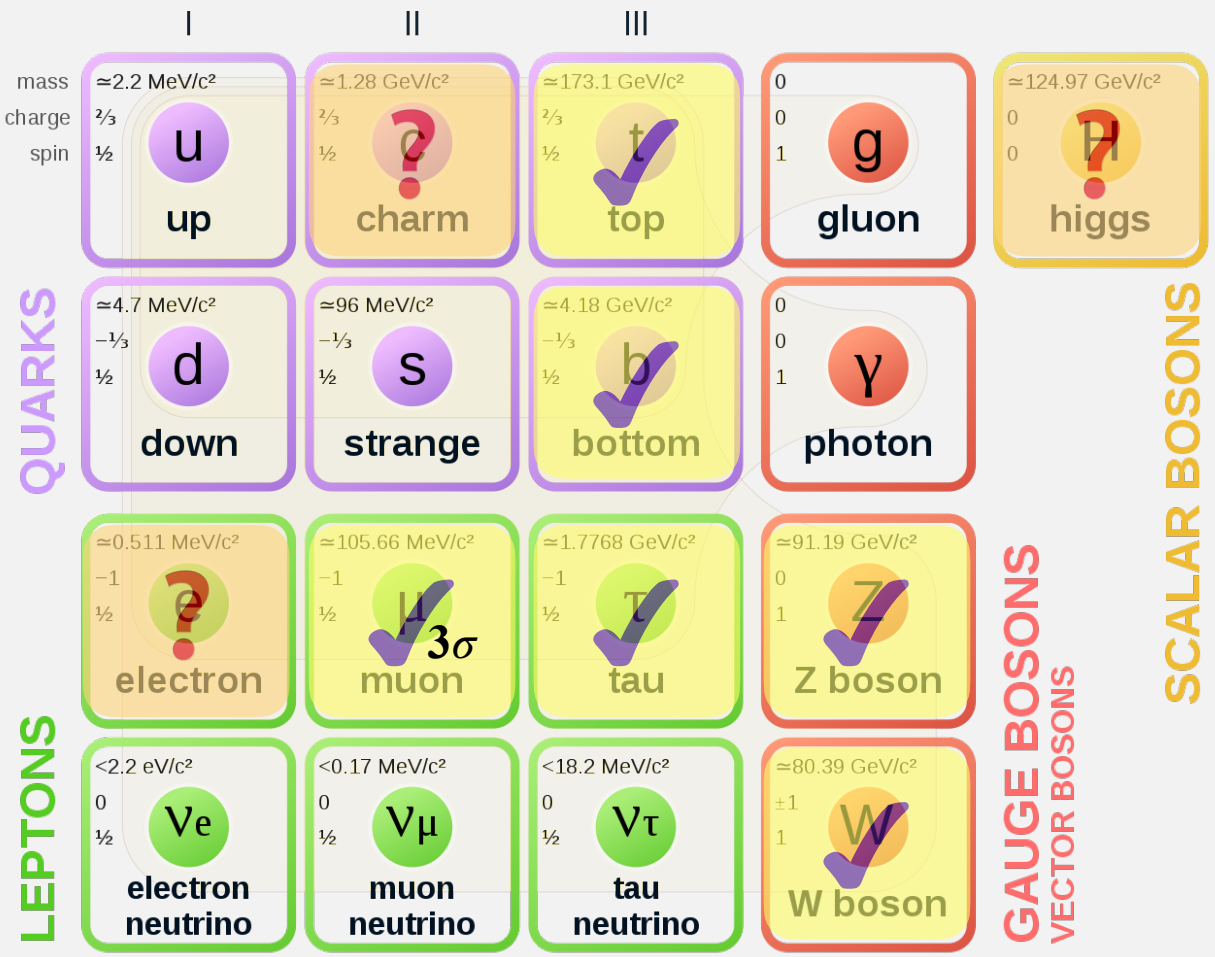
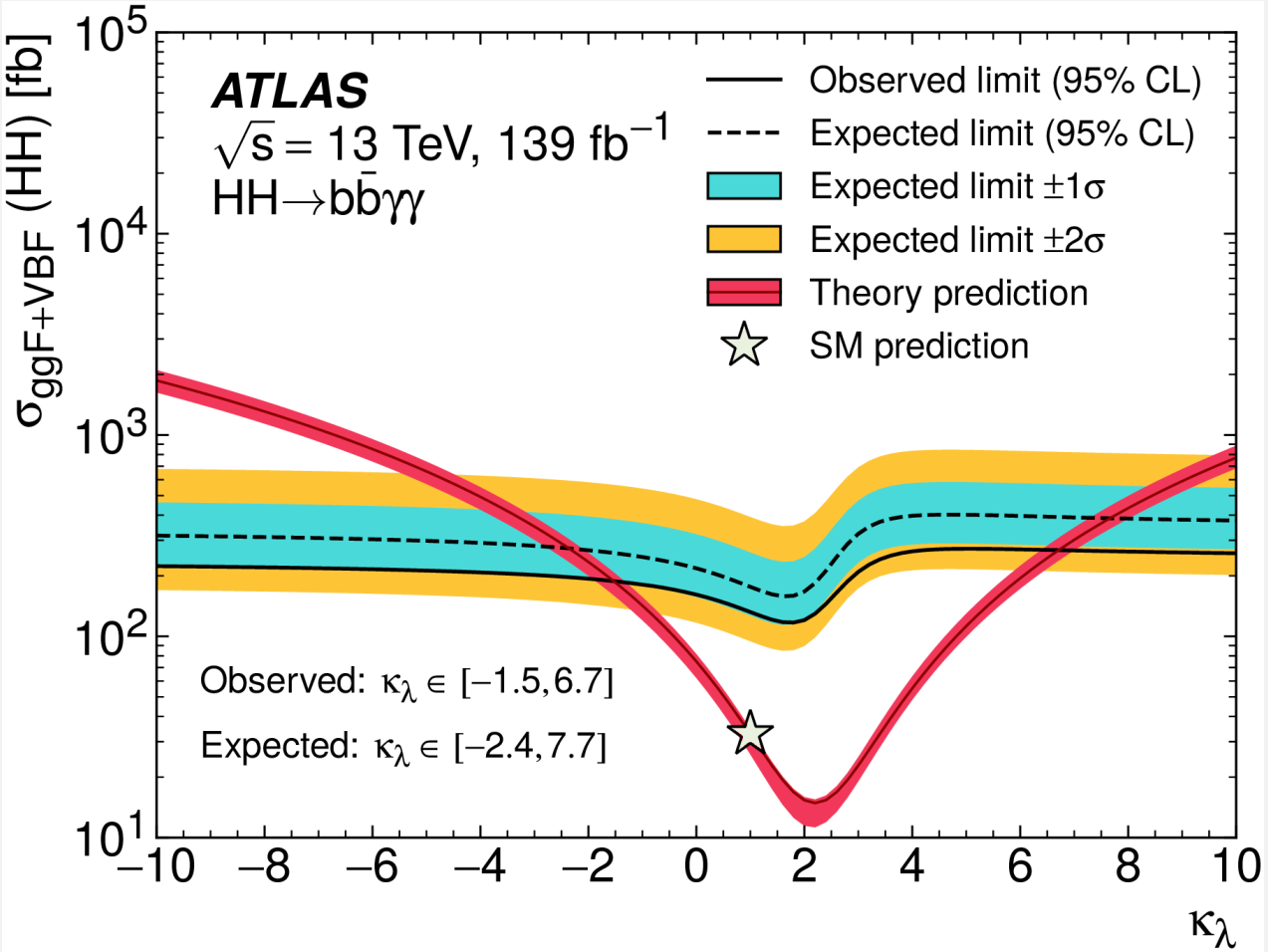


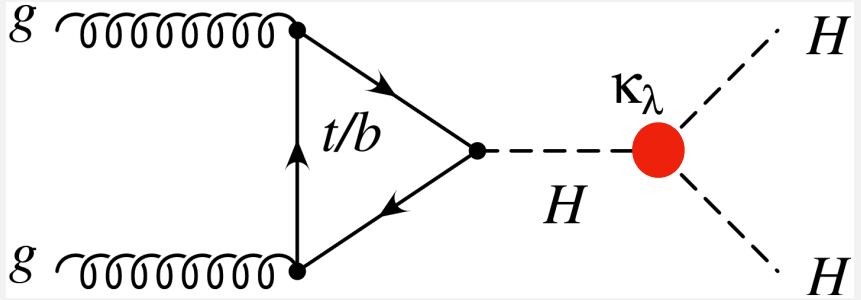


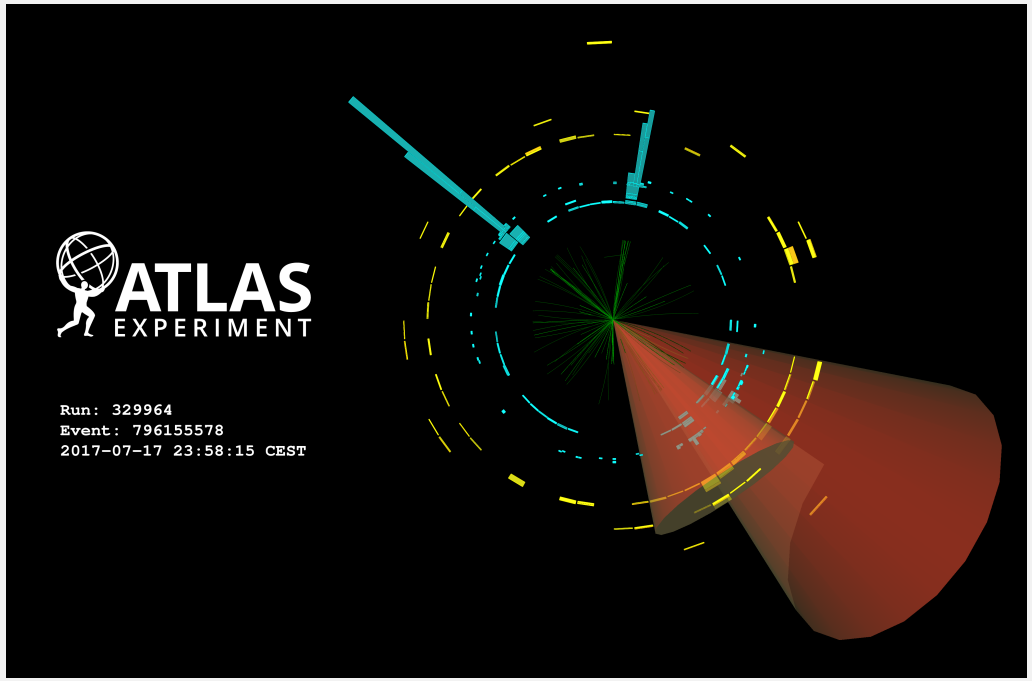
Searching for di-Higgs production in bbγγ channel

- **The observed (expected) constraints on the Higgs boson trilinear coupling modifier κ_λ : $[-1.5, 6.7]$ ($[-2.4, 7.7]$).**

arXiv:2112.11876 (submitted to PRD)

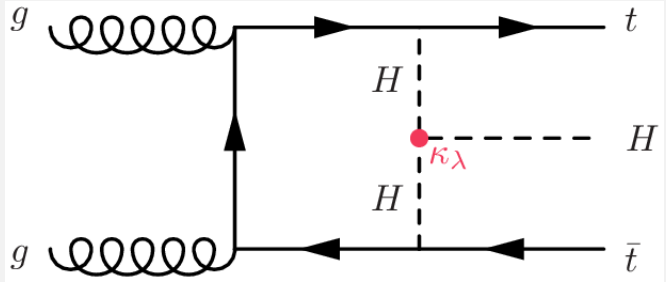


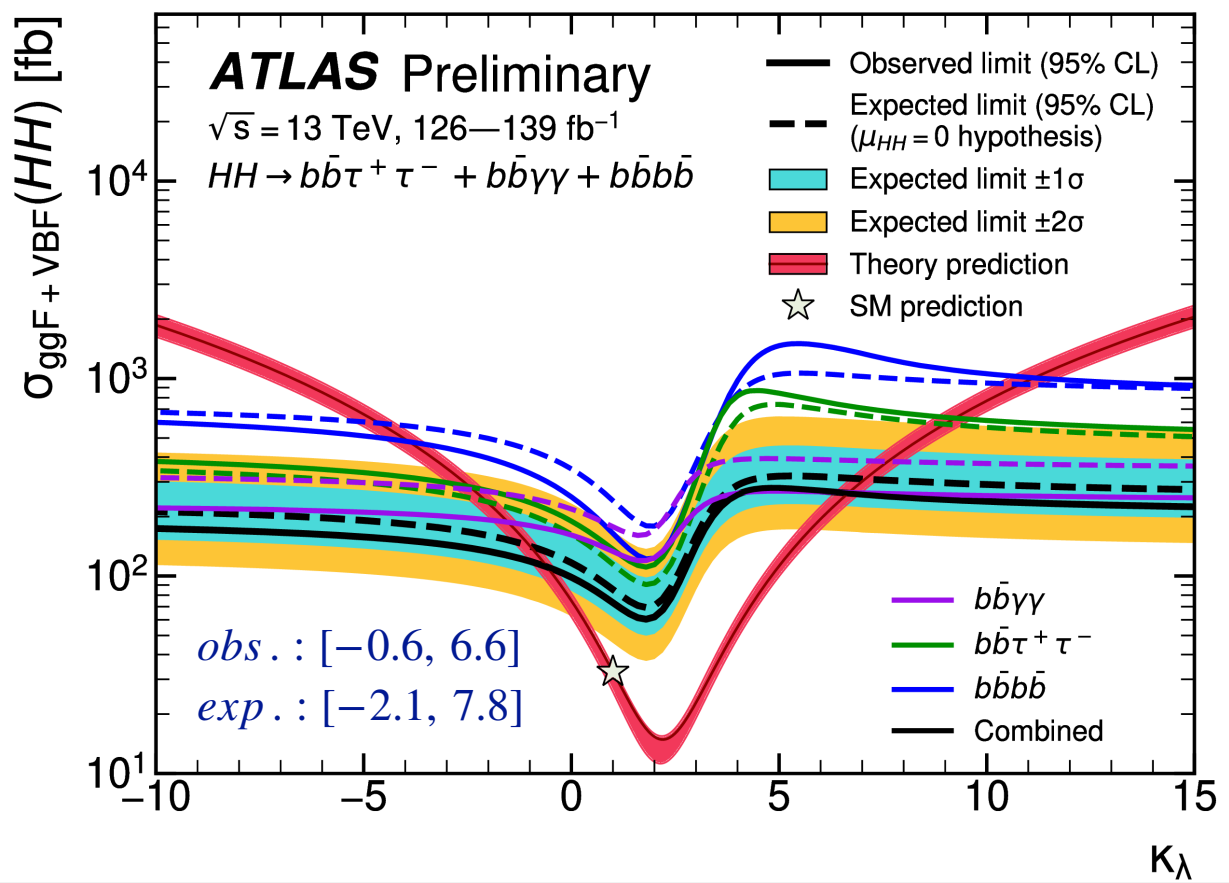


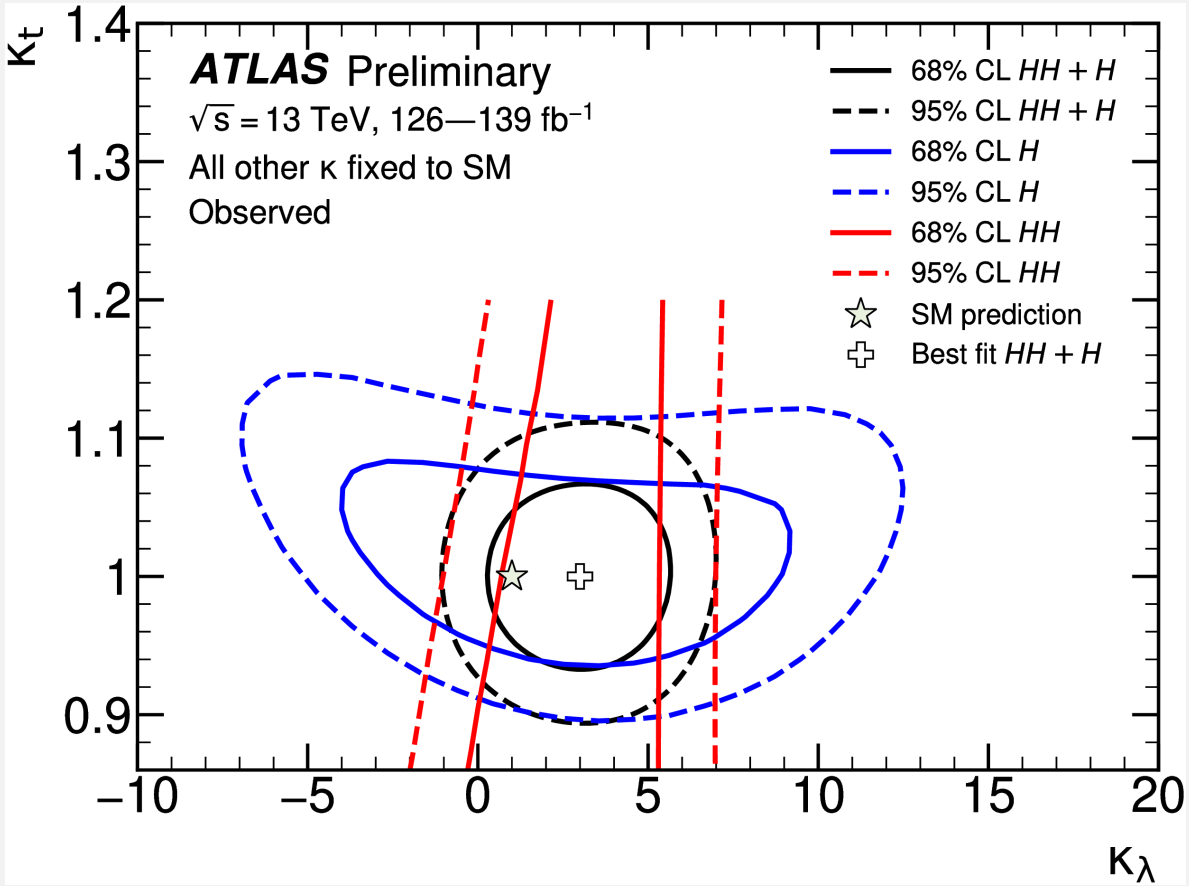


Combined constraints on the Higgs boson trilinear coupling

- **From single-Higgs and di-Higgs combination, the observed (expected) constraints on the Higgs boson trilinear coupling modifier κ_λ : $[-0.4, 6.3]$ ($[-1.9, 7.5]$).** ATLAS-CONF-2022-050

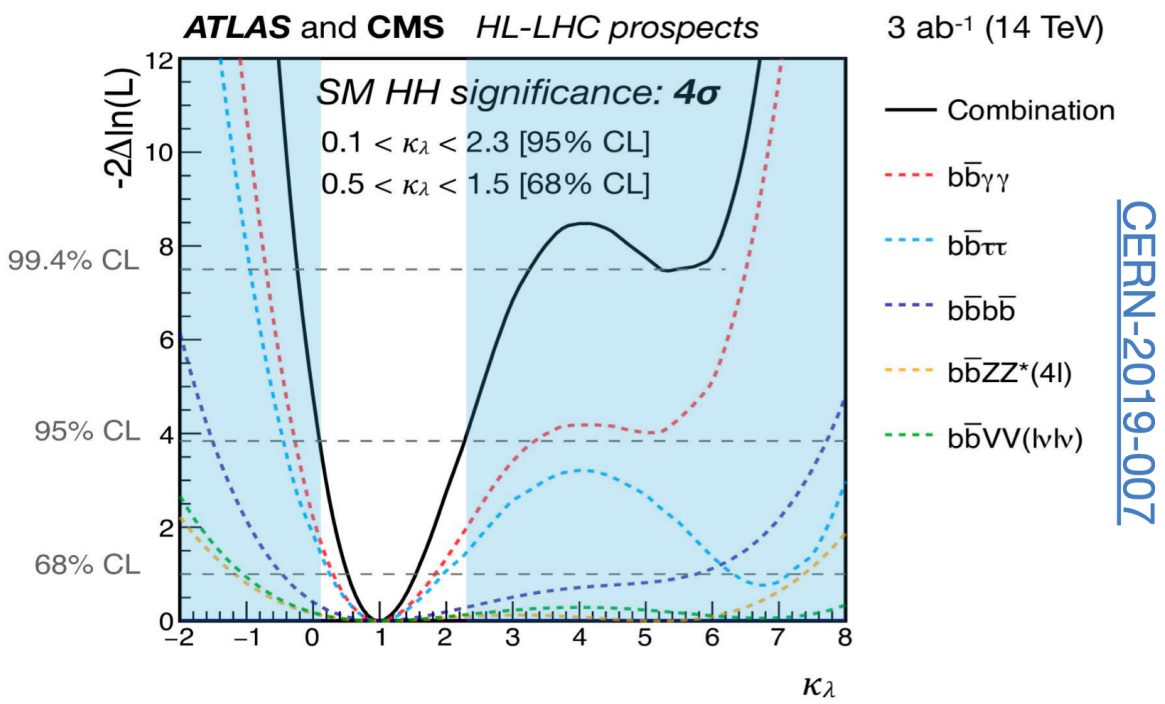




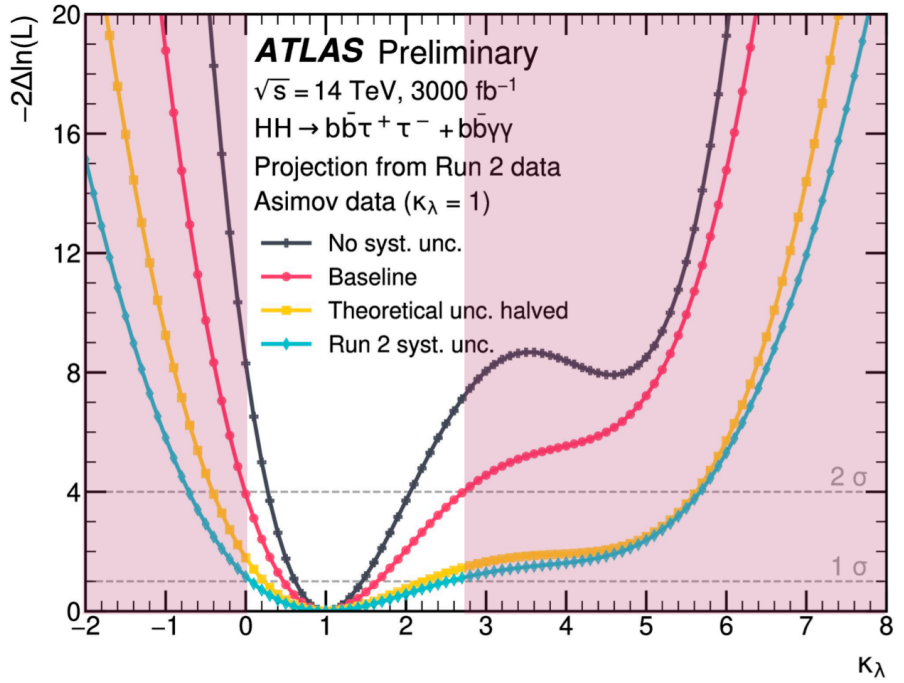


Di-Higgs projections for the HL-LHC

Elizabeth Brost - Higgs@10 Symposium



CERN-2019-007



ATL-PHYS-PUB-2022-005

European Strategy (2018)

- Combination of 5 HH channels, many based on partial Run 2 analysis strategy
- 50% precision on self-coupling
- **4σ SM HH significance** (ATLAS+CMS)

Snowmass update (2022)

- ATLAS γγbb+bbττ combination: 3.2σ
- CMS updated γγbb results, added γγWW, γγττ, ttHH(bbbb)
- **5σ SM HH significance** from back-of-the-envelope combination

上海交大/李政道研究所 参与成员与贡献

1. Nature 607 (2022) 52-59 (Single Higgs combination)

- 成员：杨海军、刘坤、李昌樵、朱逸凡、李数等
- 贡献：内部论文编辑(internal note editor)，希格斯产生截面与衰变分支比拟合，矢量玻色子产生衰变到底夸克对分析道检查，希格斯蒙特卡洛模拟与样本产生等

2. ATLAS-CONF-2022-050 (Di-Higgs and single-Higgs combination)

- 成员：李昌樵、朱逸凡、张宇雷、杨海军、刘坤、李亮、李数、沈秋平等
- 贡献：内部文章编辑(internal note editor)，做评审报告(approval talk)，双希格斯结果联合测量检查，系统误差关联性研究，结果拟合等

3. arXiv:2112.11876 (submitted to PRD) (Di-Higgs to bbγγ search)

- 成员：李昌樵、刘坤、杨海军、沈秋平等
- 贡献：矢量玻色子产生道分析优化，希格斯自耦合系数拟合，非共振态结果拟合等

2. The SM Measurements

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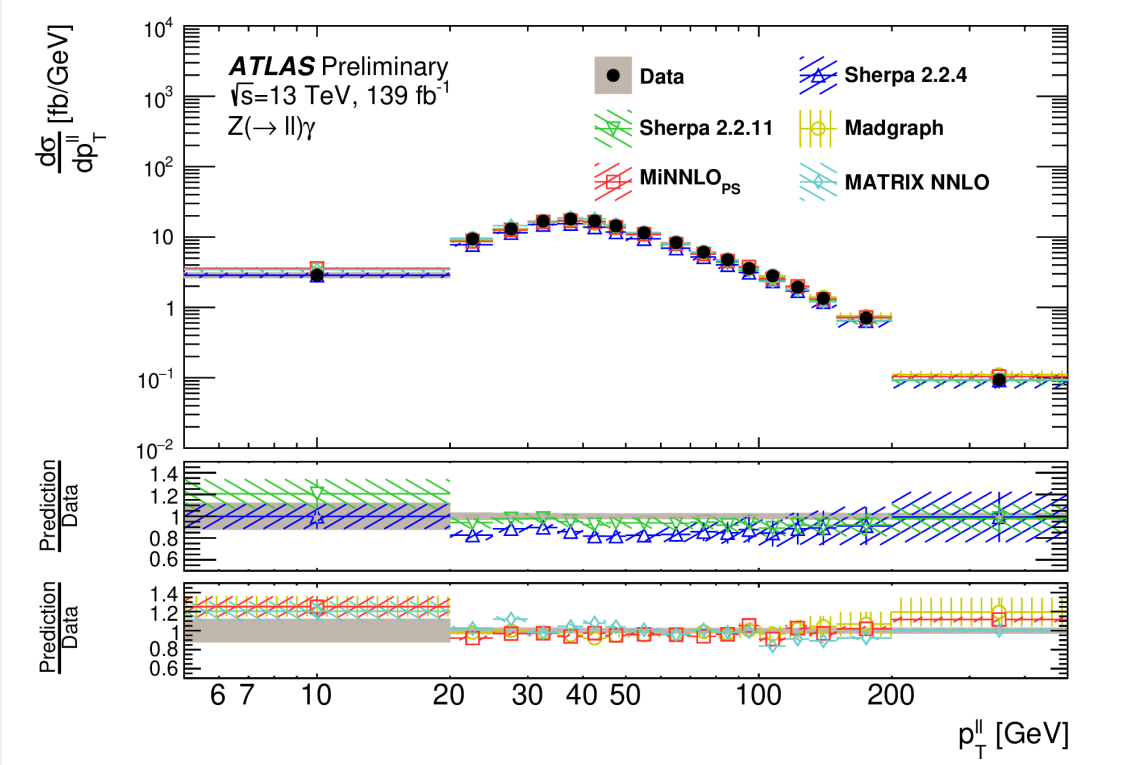
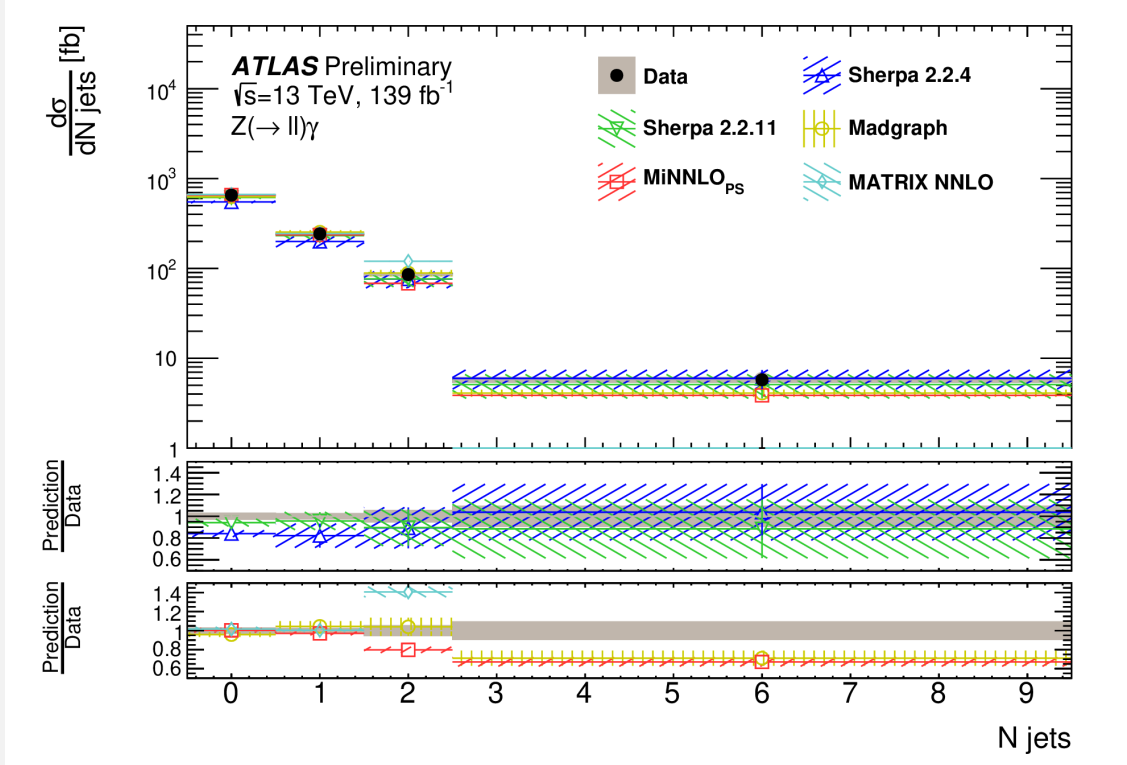
Zγ+jets differential cross section measurements

- **General good agreement is observed between data and state-of-the art theoretical NNLO predictions MATRIX/MiNNLO$_{PS}$ and with MADGRAPH5_aMC@NLO and SHERPA multiage NLO generators.**

ATLAS-CONF-2022-047

与IHEP紧密合作

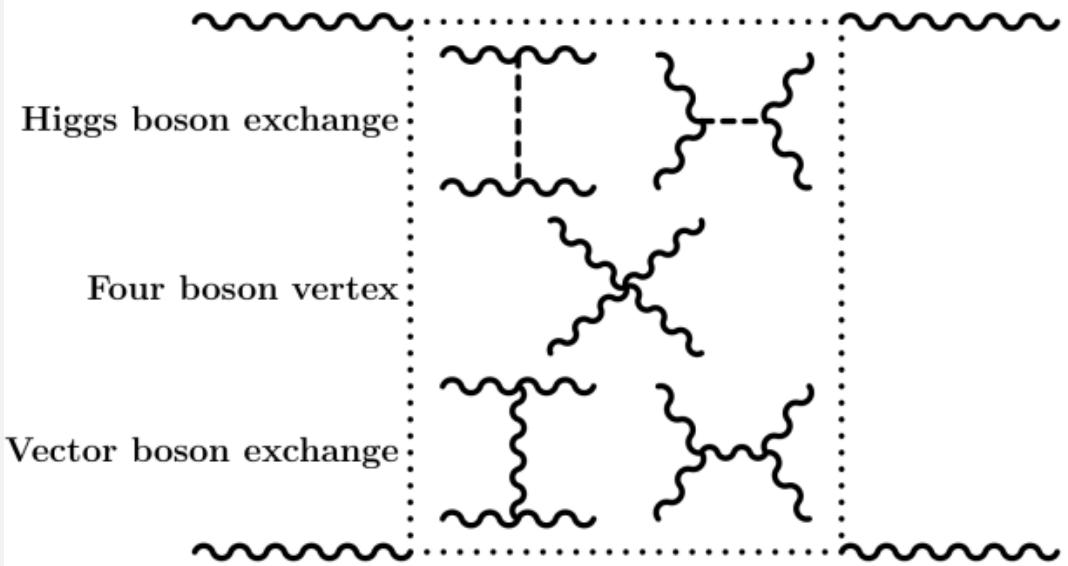


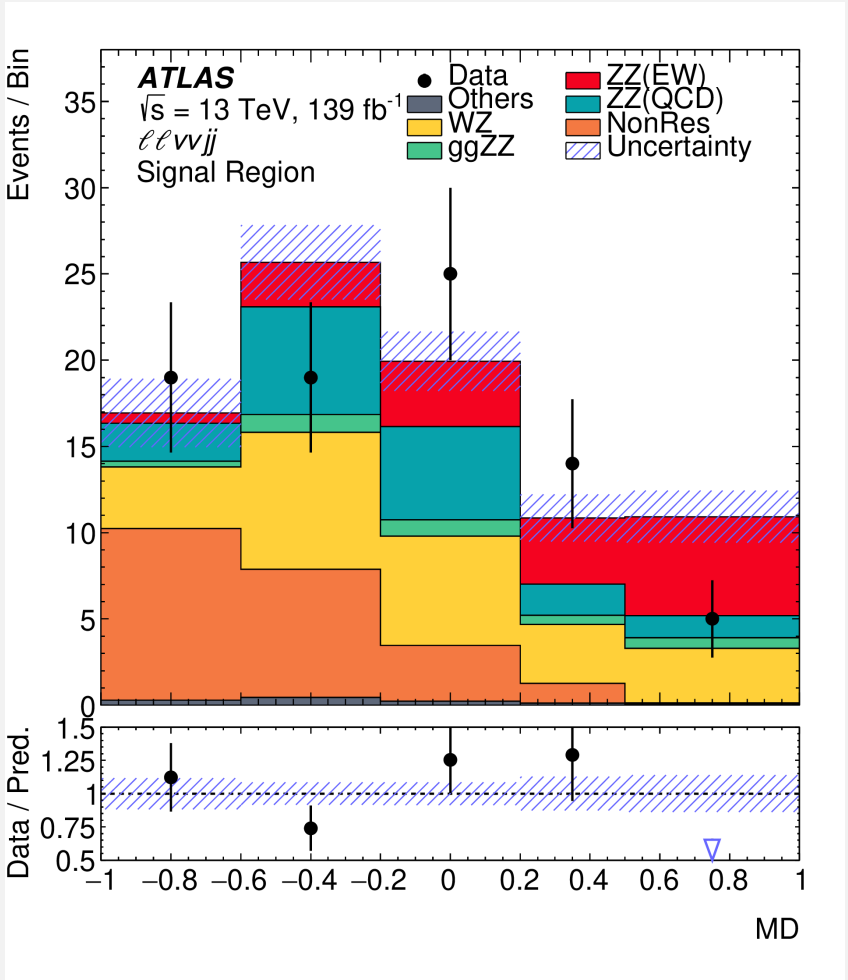


1st observation of EW production of ZZjj

- A key avenue to probing electroweak symmetry breaking, whose production rate would grow indefinitely without the cancellation from Higgs boson exchange! 与USTC/SDU紧密合作
- The first observation of ZZ VBS process. The measured X-section is in good agreement with the SM prediction.

arXiv:2004.10612 (accepted by Nature Physics)

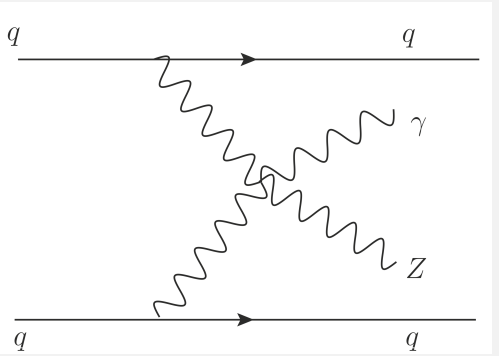




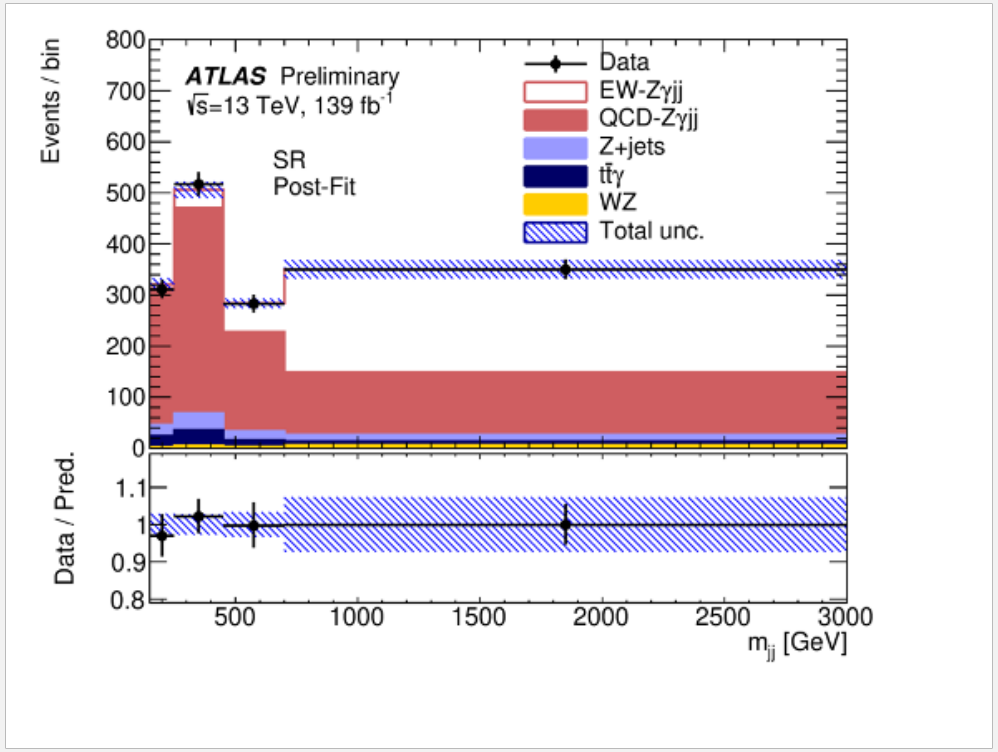
"电弱对称性破坏研究新里程碑" （Physics briefing）:
https://atlas.cern/updates/briefing/milestone-electroweak-symmetry-breaking

Observation of the EW production of Zγ+2jets

- **The total fiducial $pp \to Z(\to ee/\mu\mu)\gamma jj$ cross section is measured to be 4.49±0.58 fb, which is in consistent with the SM prediction.**
- **The $pp \to Z(\to \nu\nu)\gamma jj$ channel: the 1st observation at LHC and sensitive to Higgs invisible decay and dark photon decay searches.**

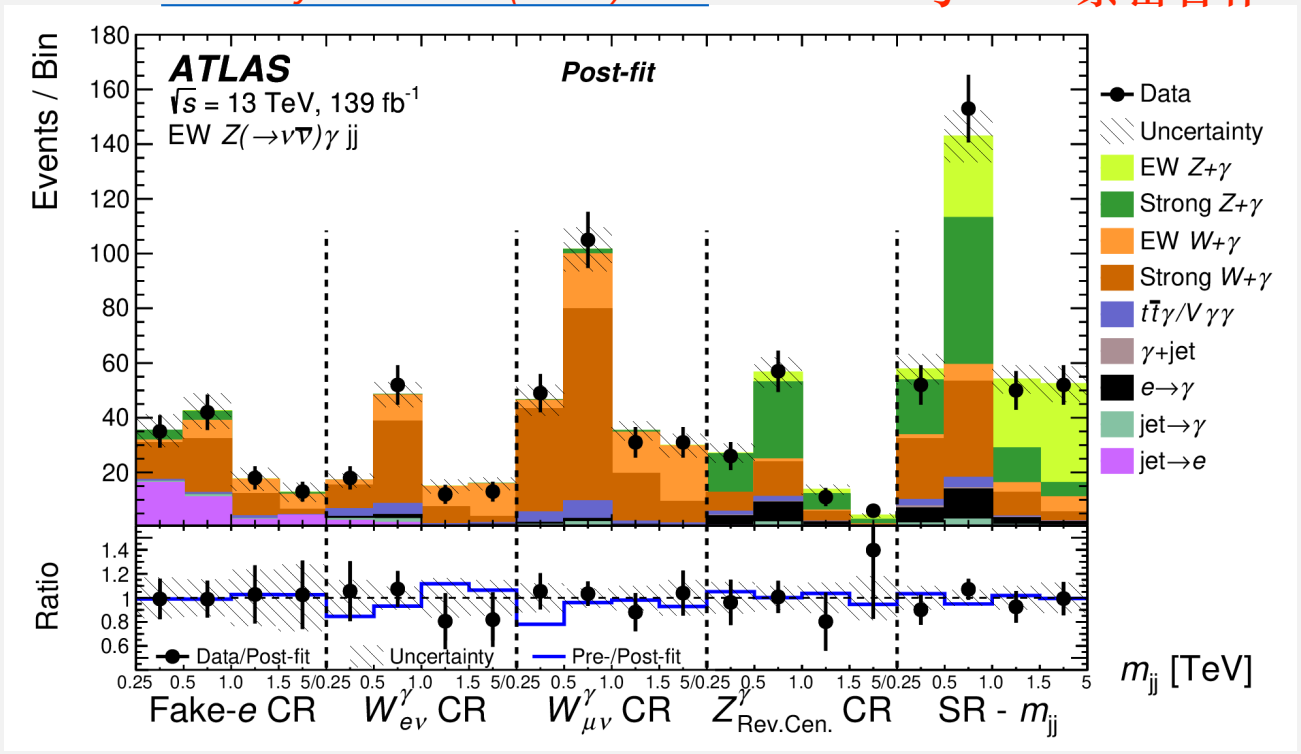


ATLAS-CONF-2021-038



Eur. Phys. J. C 82 (2022) 105

与IHEP紧密合作



上海交大/李政道研究所 参与成员与贡献

1. ATLAS-CONF-2022-047 (Differential cross section for Zγ+jets)

- 成员：刘丹宁、李数、刘坤、刘齐斌等
- 贡献：做评审报告(approval talk)，理论误差研究，有效场理论模型等

2. arXiv:2004.10612 (accepted by Nature Physics) (Observation of VBS in ZZ channel)

- 成员：陈婧、李京、杨海军、李数、郭军等
- 贡献：做评审报告(approval talk)，ATLAS weekly报告，主要参与双轻子双中微子道分析等

3. Eur. Phys. J. C 82 (2022) 105, ATLAS-CONF-2021-038 (Observation of Zllγ VBS)

- 成员：刘齐斌、刘丹宁、李数、刘坤等
- 贡献：$ee\gamma, \mu\mu\gamma$分析道多元变量分析优化，系统误差分析，担任$\upsilon\upsilon\gamma$分析EB等

3. Beyond SM Searches

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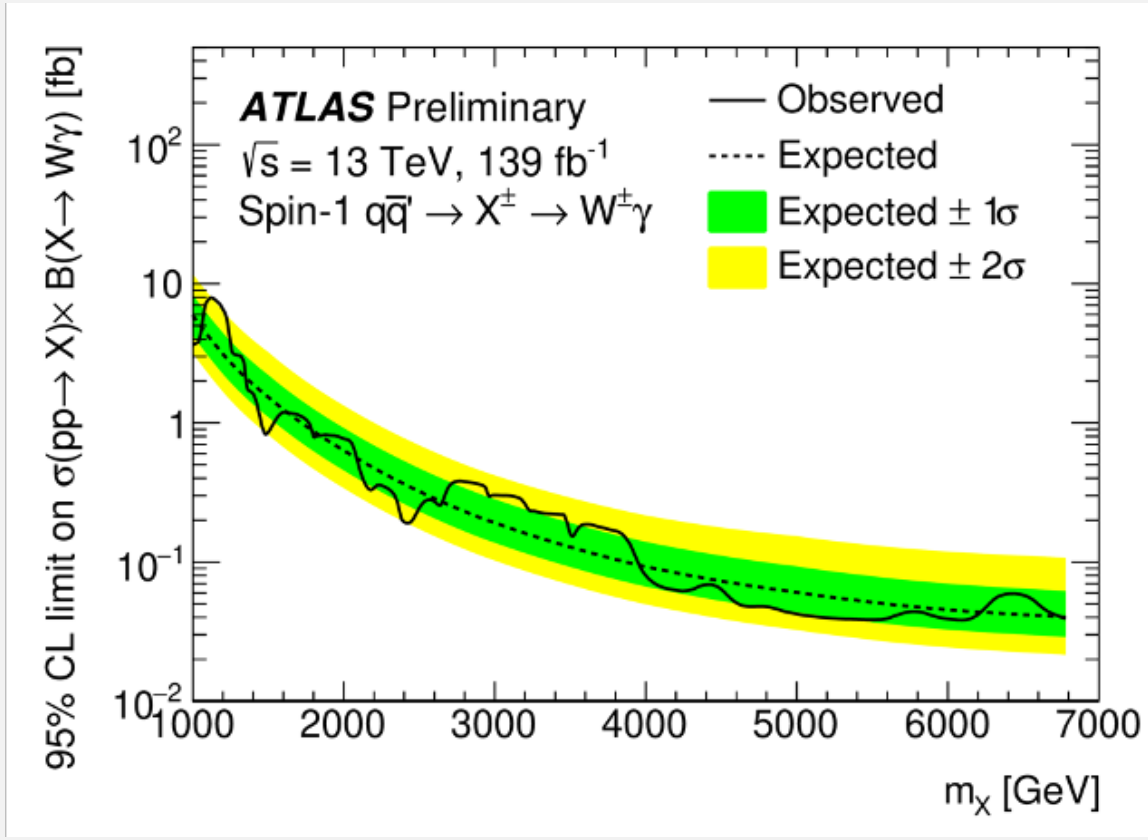
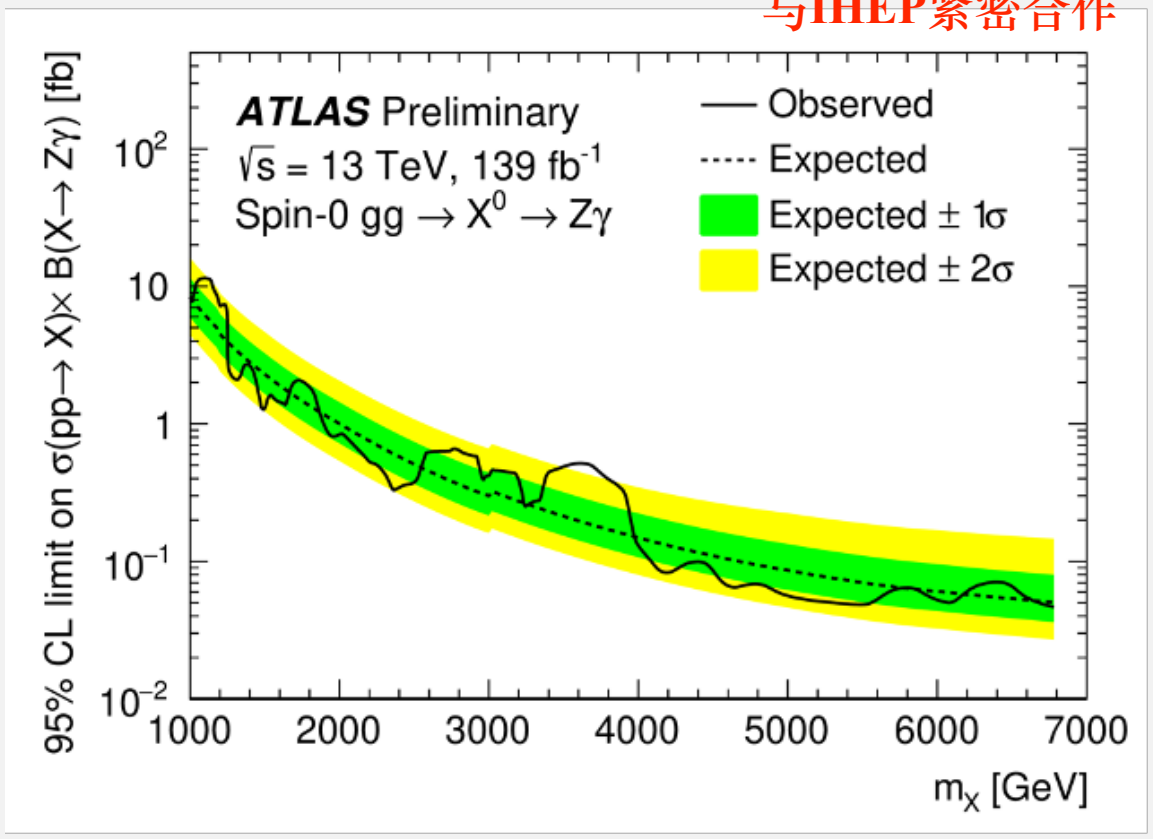
Search for high-mass Wγ and Zγ resonances

- A search for high-mass charged and neutral bosons decaying to Wγ and Zγ final states.
- No evidence of signals is observed ➔ setting upper limit!

ATLAS-CONF-2021-041

与IHEP紧密合作

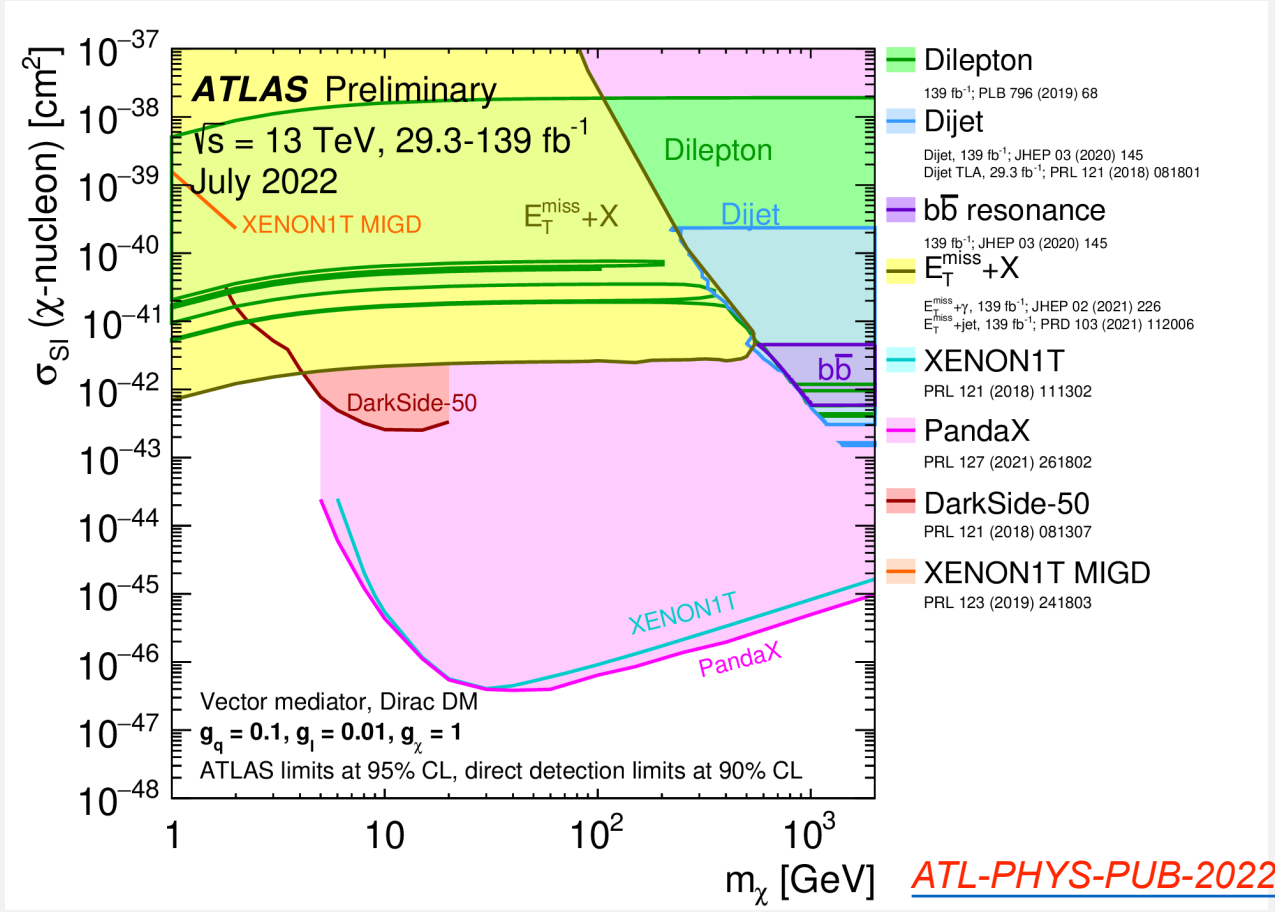




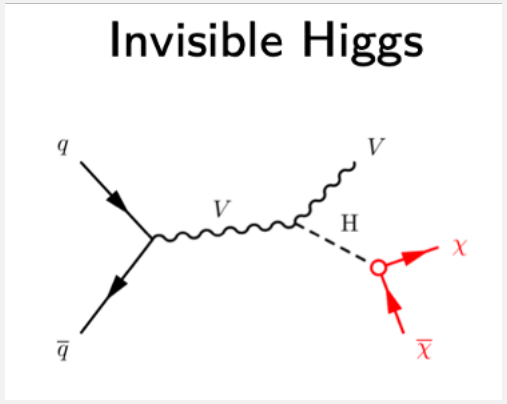
Phys. Rev. Lett. 125 (2020) 251802 （ "X→Higgs+Gamma" 共振态新物理寻找的延伸 ）
Briefing: https://atlas.cern/updates/physics-briefing/searching-forces-beyondstandard-model

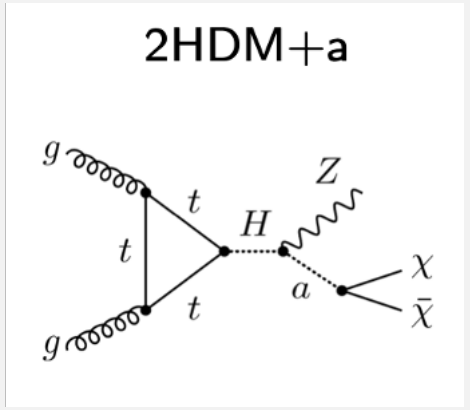
Mono-V(→jj) dark matter searches

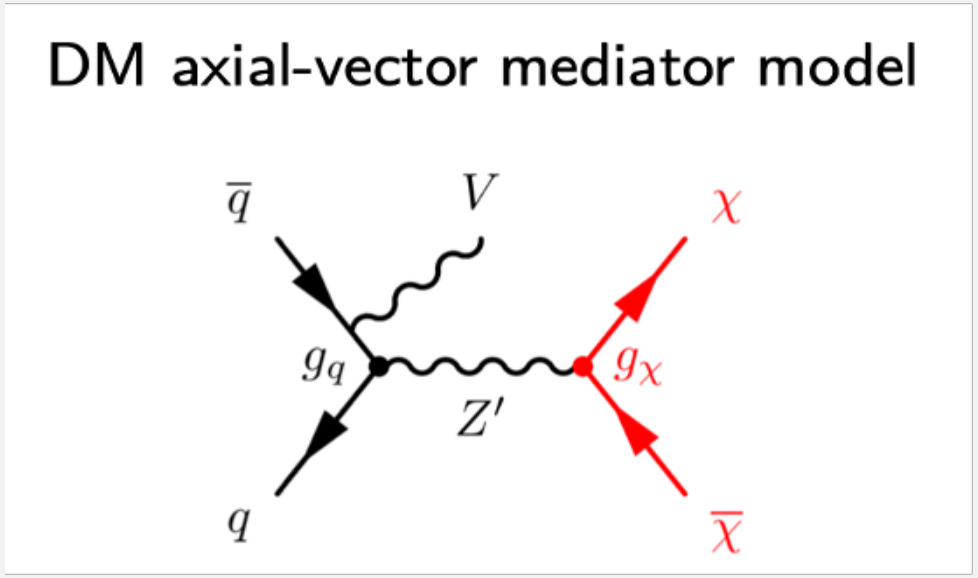
- **Searching for dark matter produced in association with a hadronically decaying vector boson.**
- **Fully Run 2 analysis is ongoing (ANA-EXOT-2019-27).**



ATL-PHYS-PUB-2022-036

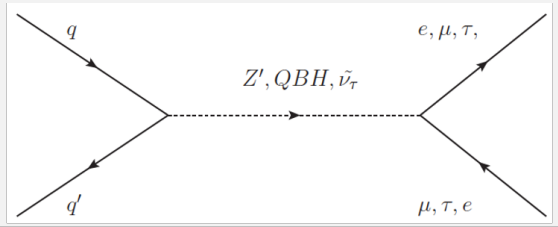




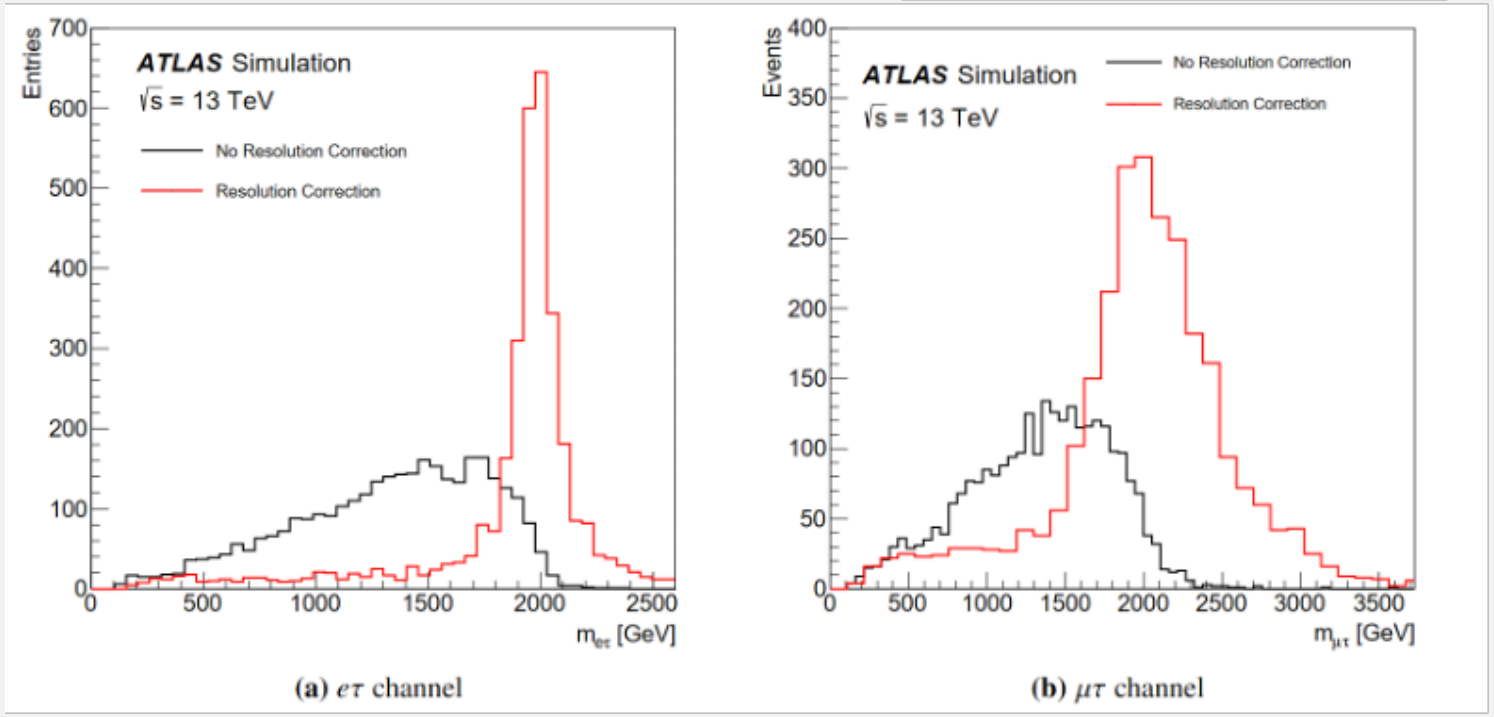


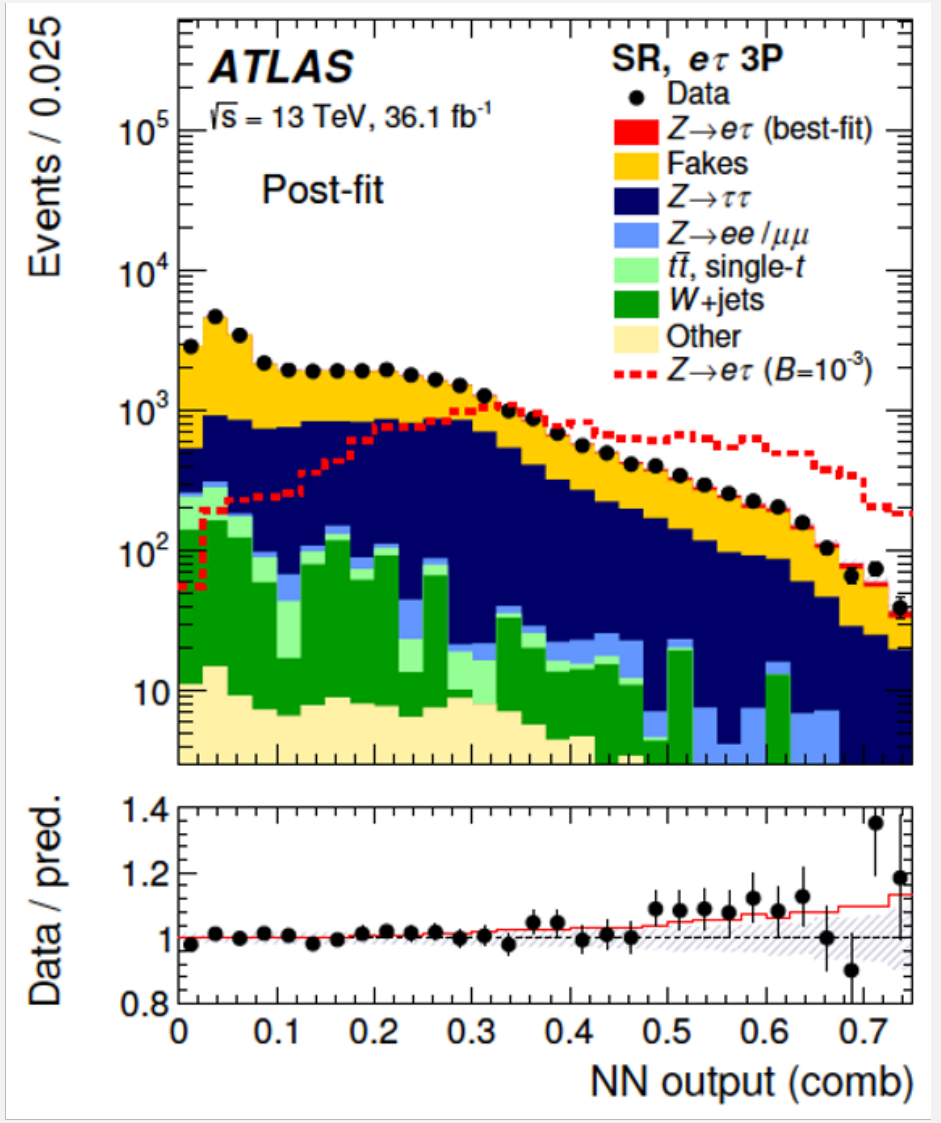
Searching for Lepton Flavor Violation (LFV)

- **Searching for LFV in different flavor lepton pair final states:** $e\mu, e\tau, \mu\tau$ *(hadronic decay)*.
- **Fully Run 2 analysis is ongoing (ANA-EXOT-2019-20).**



Hadronic tau reconstruction





上海交大/李政道研究所 参与成员与贡献

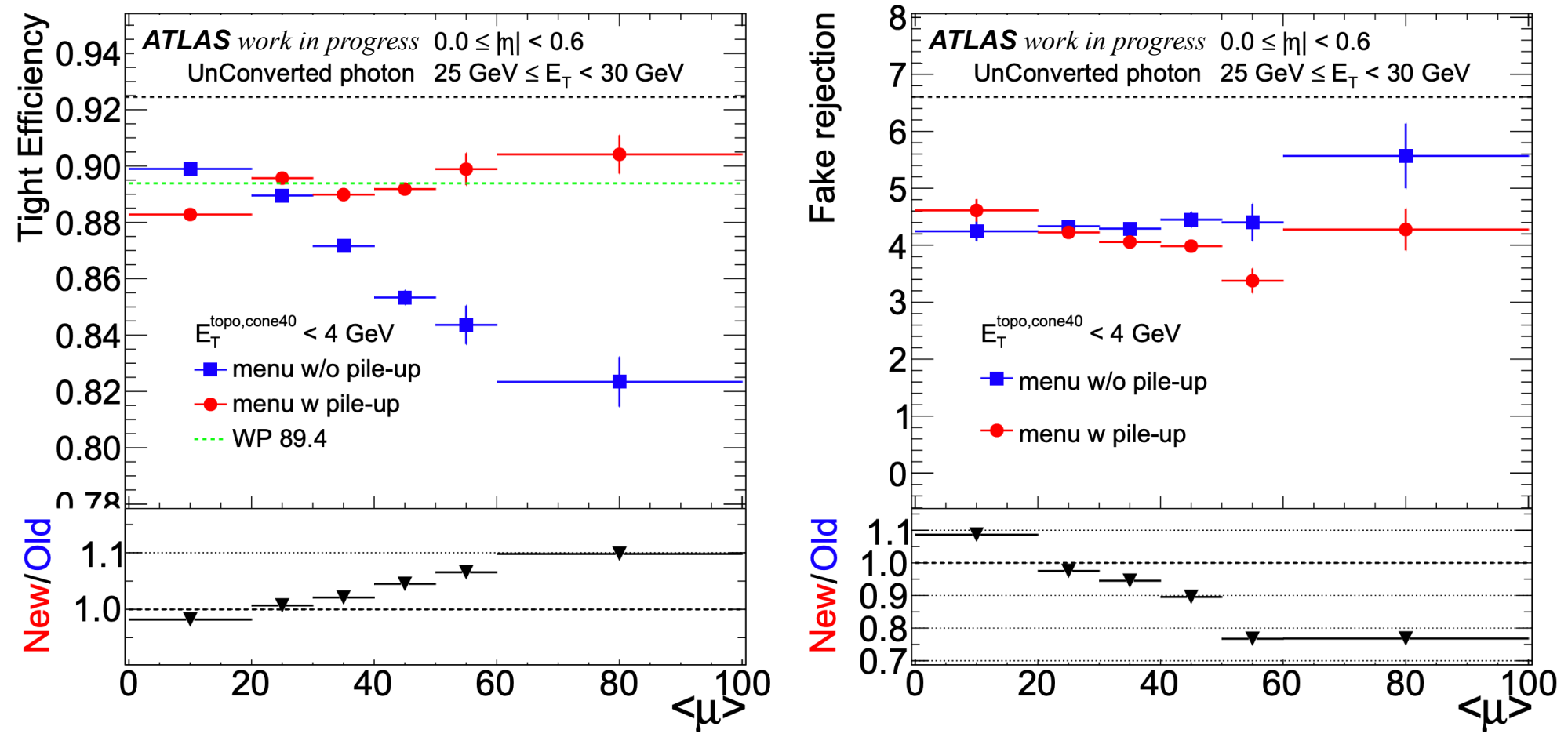
1. **ATLAS-CONF-2021-041 (high mass W/Z+γ searches in hadronic final state)**
   - 成员：李数
   - 贡献：analysis contact，新物理信号模拟与分析方法设计，标准模型背景计算等
2. **ANA-EXOT-2019-27, fully Run 2 analysis ongoing (Mono-V(jj) dark matter searches)**
   - 成员： 周宁、洪江刘、张翔科等
   - 贡献：信号产生，本底估计，灵敏度结果计算等
3. **ANA-EXOT-2019-20, fully Run 2 analysis ongoing (Searching for lepton flavor violation)**
   - 成员：郭军、杨海军、张翔科等
   - 贡献：analysis contact, 文章编辑(contact editor)，信号选择优化、背景研究、结果拟合等

4. Performance Studies

TSUNG-DAO LEE INSTITUTE

Photon performance studies

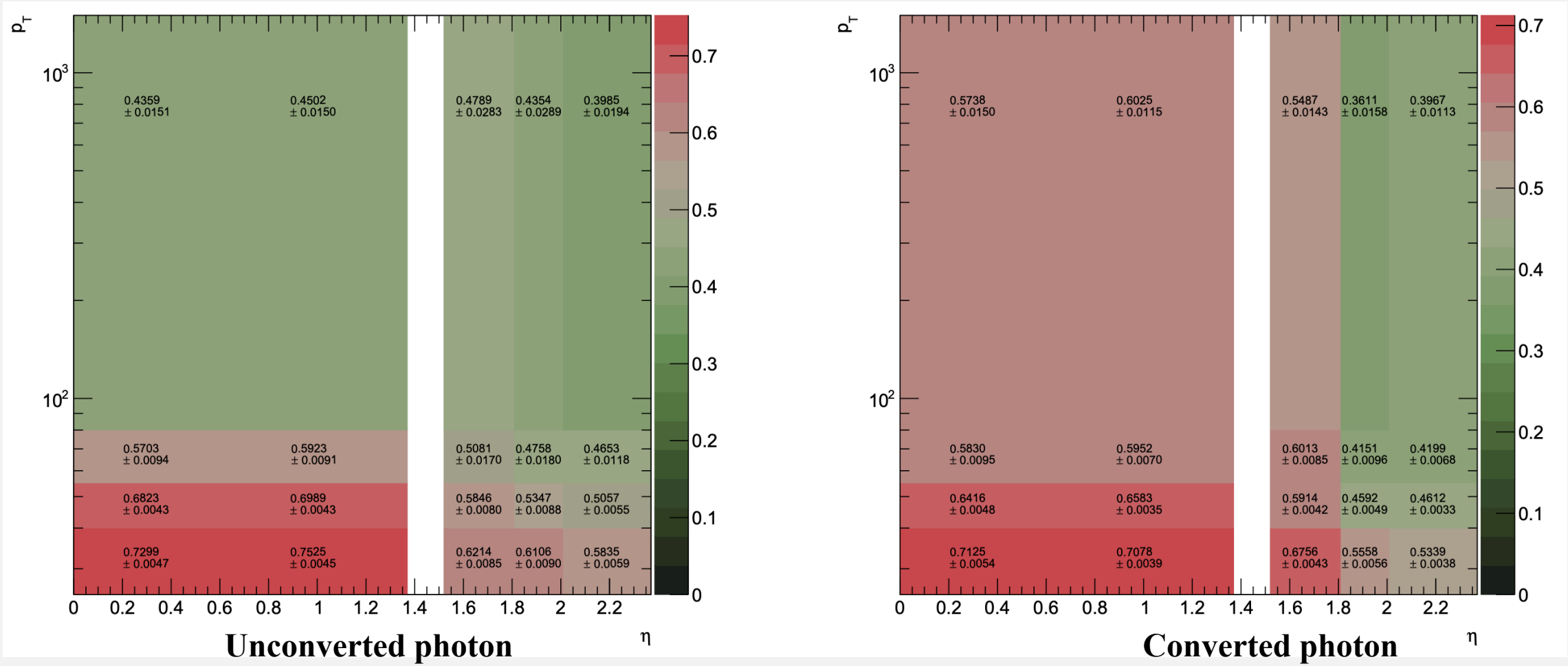
- **Mitigation of the pile-up dependence of photon identification criteria ➔ robust photon ID criteria again pile-up whilst having similar fake rejection.**



Photon performance studies

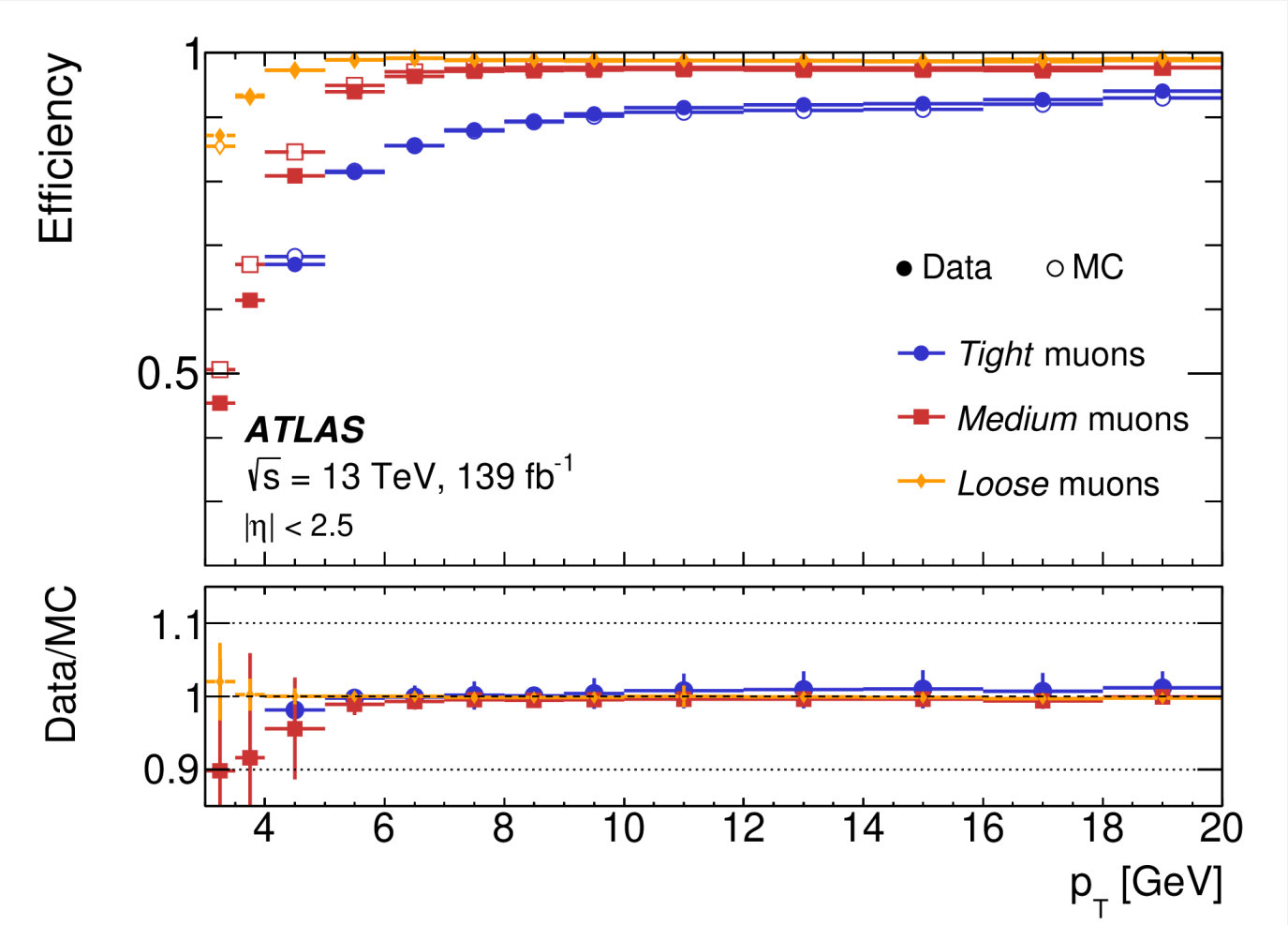
张宇雷's Qualification Task
导师：李亮

- Improvement of photon identification against misidentified electrons ➔ with 80% prompt photon efficiency, ambiguity electrons can be reduced significantly!



Muon object reconstruction and identification

- **Forward muon identification and efficiency measurement using Run 2 dataset.**



Eur. Phys. J. C 81 (2021) 578

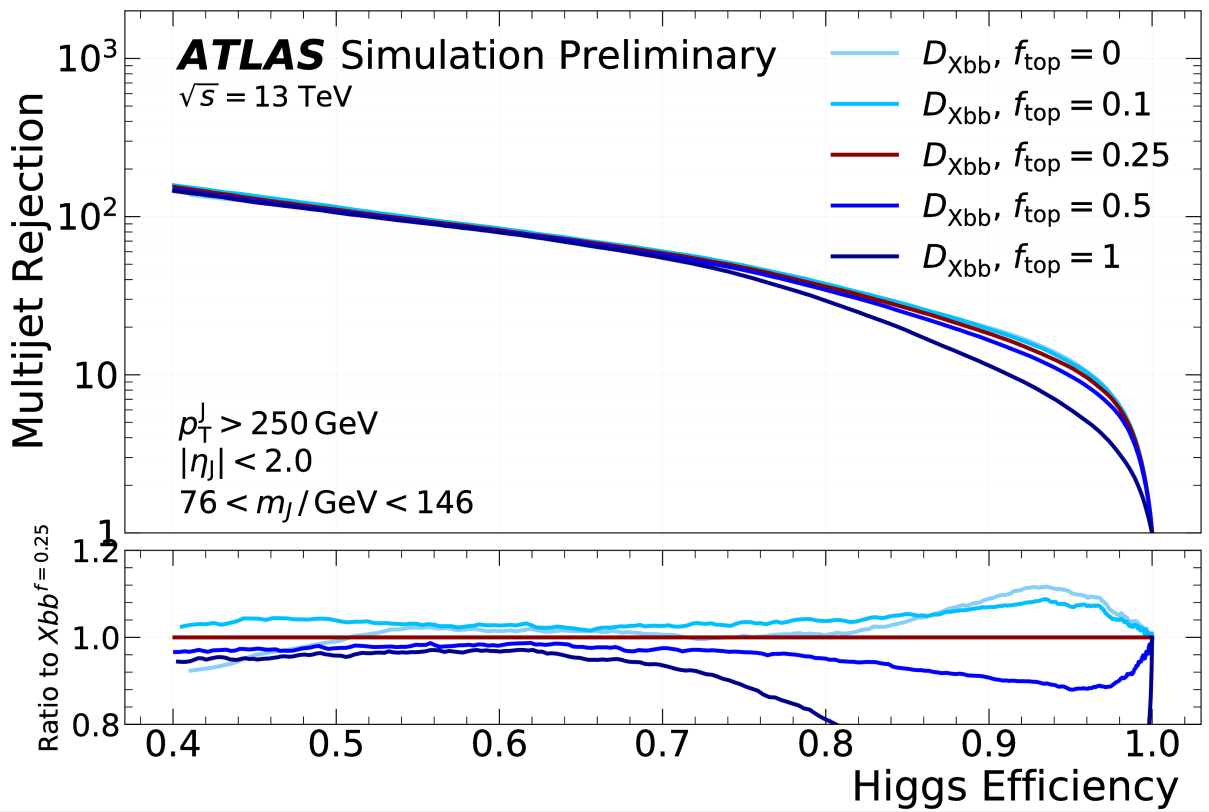
- Despoina Sampsonidou负责前向缪子鉴别和效率测量；
- Chikuma Kato是文章的EB成员。

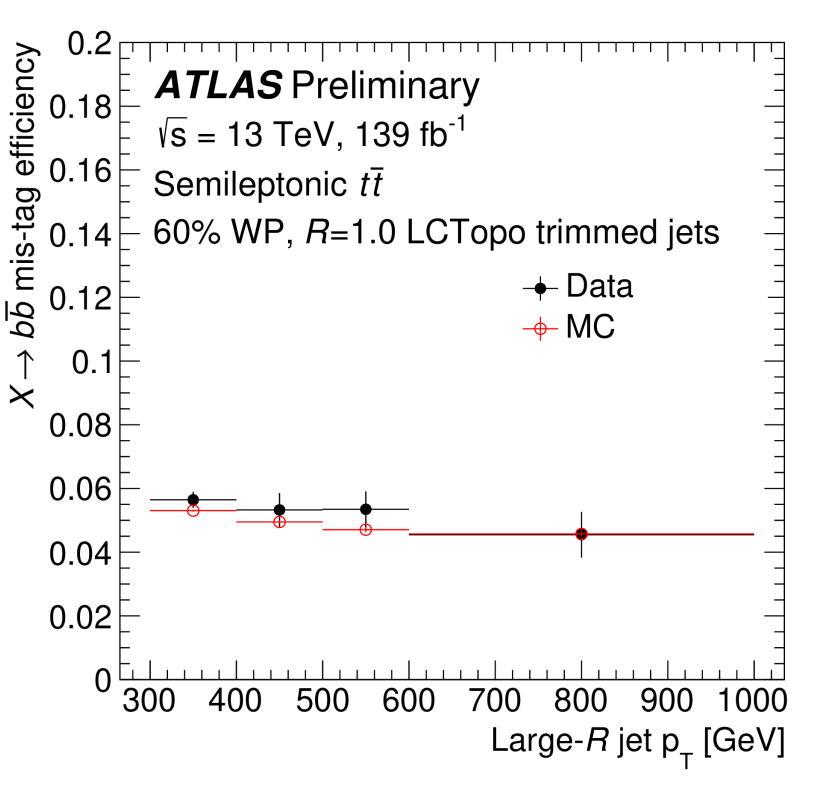
Calibrations of X→bb tagger in Run 2

- **The identification of massive particles decaying into bottom-quark pair at high transverse momenta using multivariate algorithm, namely X→bb tagger.**
- **Calibrations using Z(→bb)+jets and Z(→bb)γ events and ttbar events:**

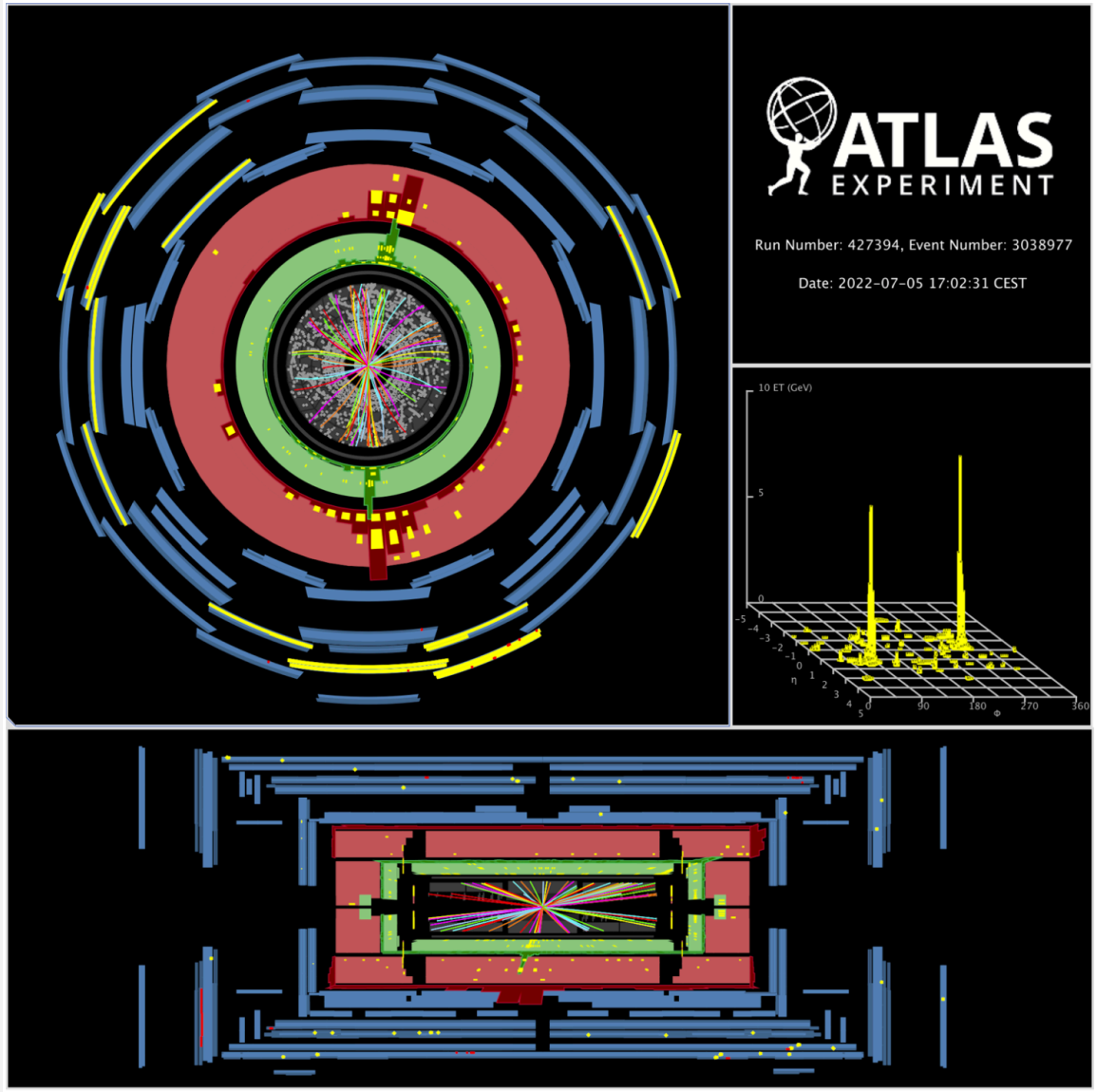
李昌樵、刘齐斌、李数:
Contact editor, 负责PUB Note主体编辑，全面负责和完成ttbar过程刻度工作。

ATL-PHYS-PUB-2021-35



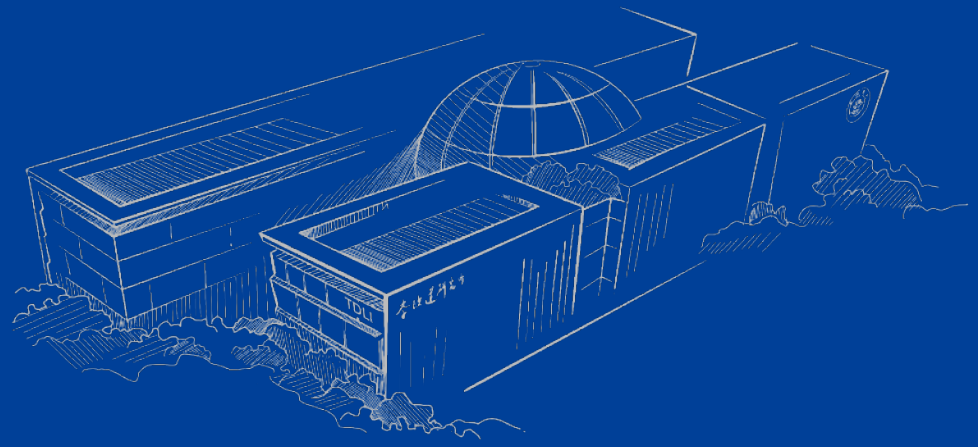


First 13.6 TeV stable beam collision on July 5th, 2022



- 上海交大/李政道研究所成员在Run3光子触发、pre-recommendation光子鉴别效率测量等起到重要作用!

Thanks



Collaborations with theorist colleagues

KEK-TH-2392

Deeply Learned Preselection of Higgs Dijet Decays at Future Lepton Colliders

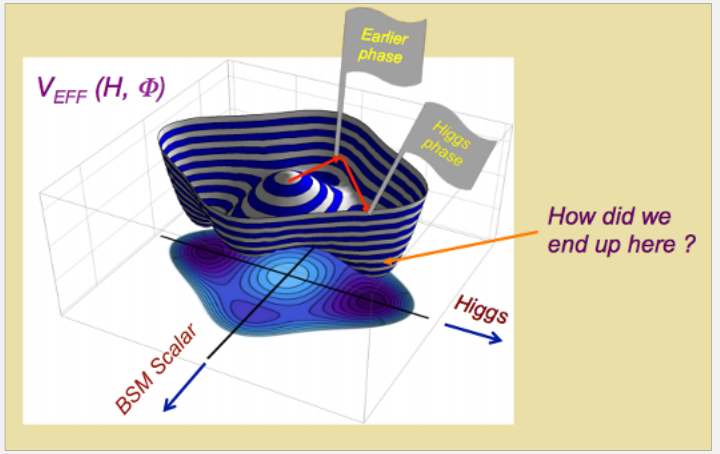
So Chigusa[1,2,3], Shu Li[4,5,6,7], Yuichiro Nakai[4,5], Wenxing Zhang[4,5], Yufei Zhang[4,5] and Jiaming Zheng[5,4]

arXiv:2202.02534 [hep-ph]
Phys. Lett. B已确认接收发表

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Study of Electroweak Phase Transition in Exotic Higgs Decays at the CEPC

Zhen Wang,[a,b,g] Xuliang Zhu,[a,b] Elham E Khoda,[f] Shih-Chieh Hsu,[f] Nikolaos Konstantinidis[h] Ke Li,[f] Shu Li,[a,b,e,i] Michael J. Ramsey-Musolf,[a,b,c,d] Yanda Wu,[a,b] Yuwen E. Zhang[h]



arXiv:2203.10184 [hep-ex]
SnowMass2021 WhitePaper

ATLAS合作组主要任职（目前）

Management

杨海军：

- Search Committee for ATLAS Speaker Committee Advisory Board Member, 2021
- Search Committee for ATLAS Collaboration Board Chair, 2022

郭军：

- Calorimeter IB Representative, 2020.12-至今

李数：

- LHC Electroweak multi-boson group convener, 2018-2022
- Higgs Working Group Monte Carlo Production Manager and Physics Modeling contact, 2016-至今
- Tracking CP Group Monte Carlo Manager, 2016-至今
- LHC Yellow Report Editor, 2018-至今

刘坤：

- Egamma Working Group photon ID subgroup convener, 2022.04-至今
- Higgs Working Group photon contact, 2021.11-至今

董彬彬：

- Flavour Tagging Working Group physics validation contact, 2021.09-至今
- Falvour Tagging Working Group software convener, 刚任命

ATLAS合作组主要任职（目前）

Physics analysis contact:

李数：

- W/Z/H+γ resonances analysis contact, 2017-至今

郭军：

- Lepton Flavour Violation search contact, 2019-至今

李数/陈婧：

- VBS W+γ analysis contact, 2020-至今

Despoina Sampsonidou:

- ZZ(ll$\nu\nu$) VBS analysis contact, 2020-至今
- Same-sign WW and WZ VBS EFT re-interpretation analysis contact, 2020-至今

李昌樵：

- mono-S(bb) analysis contact, 2020-至今
- X→bb tagger Calibration contact, 2021-至今

Nihal Brahimi:

- ttH→multi-leptons analysis contact, 2022.03-至今

陈婧：

- Triple Higgs→6b analysis contact, 2022-至今