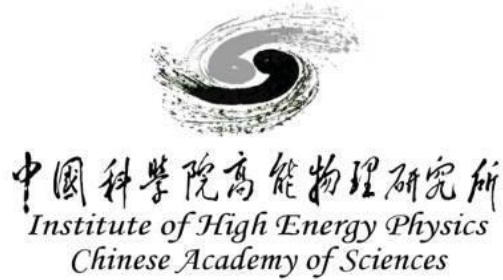


CMS FCPPPL Projects



Junquan Tao

IHEP/CAS Beijing



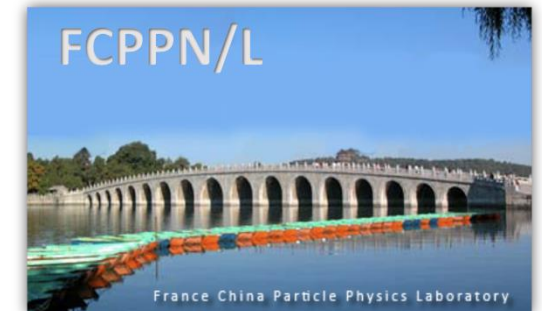
with Jeremy ANDREA (IPHC Strasbourg), Nicolas CHANON (IP2I Lyon), Claude CHARLOT (LLR Palaiseau), Guoming CHEN (IHEP/CAS Beijing), Suzanne GASCON-SHOTKIN (IP2I Lyon) and Qiang LI (PKU)



15th FCPPN/L Workshop

June 10-14, 2024

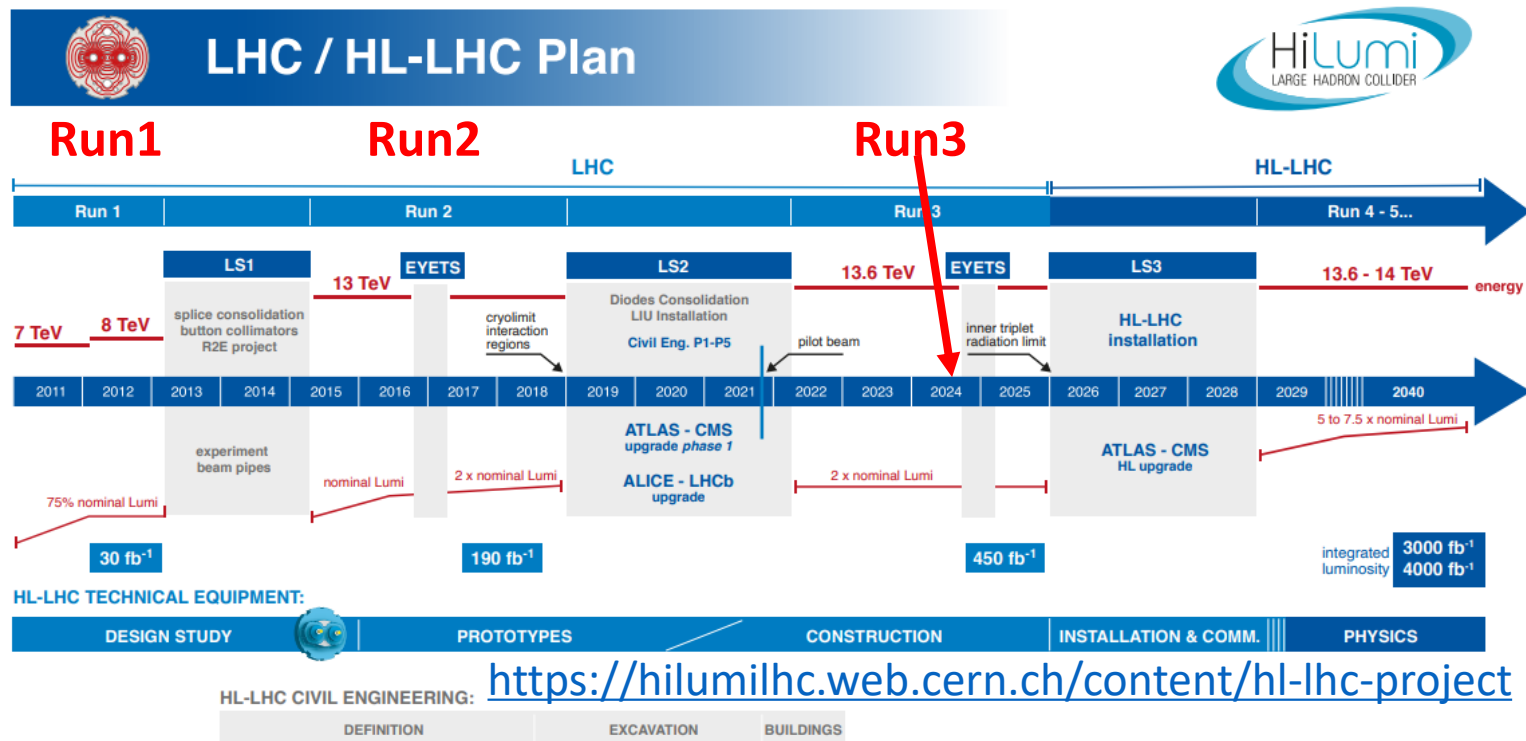
University of Bordeaux, France





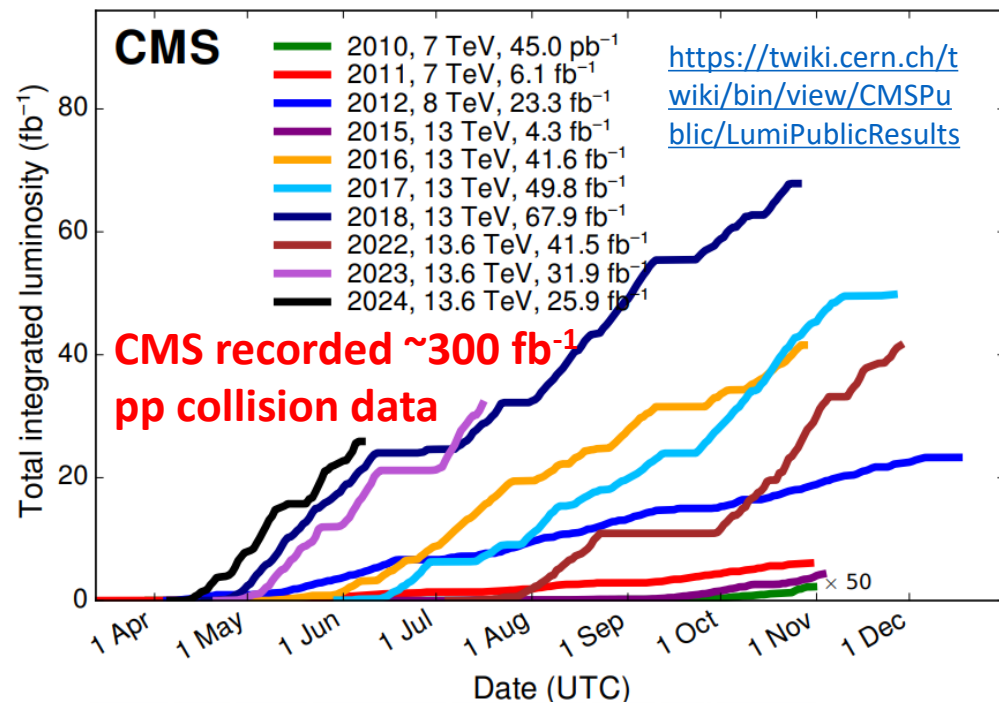
LHC and CMS data taking

➤ Data-taking started in 2010 14 years ago!



Dedicated CMS highlights talk by Jie XIAO

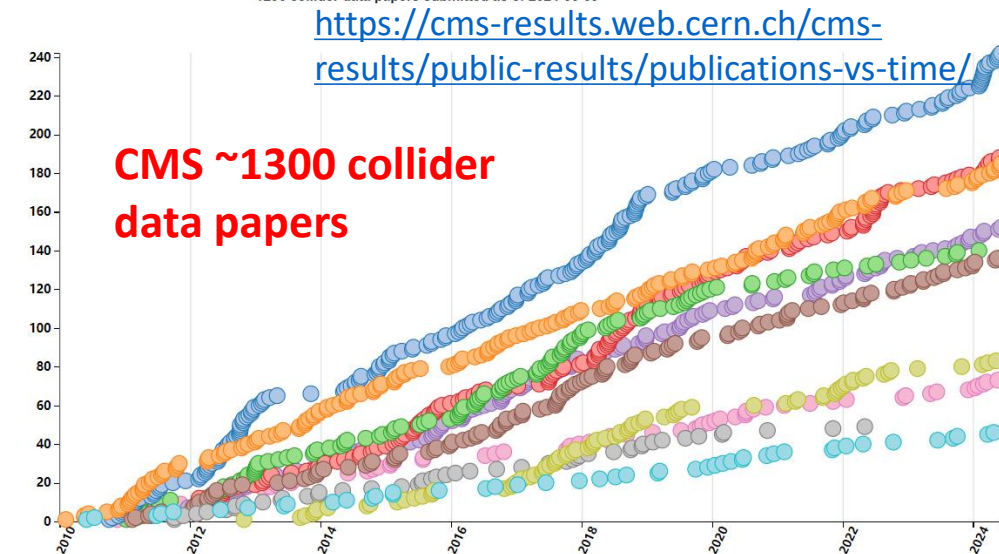
➤ France-China collaboration on CMS since 2007 17 years ago!



Show all Total Exotica Standard Model Supersymmetry Higgs Top Heavy ions

B and Quarkonia Forward and Soft QCD Beyond 2 Generations Detector Performance

1296 collider data papers submitted as of 2024-06-09

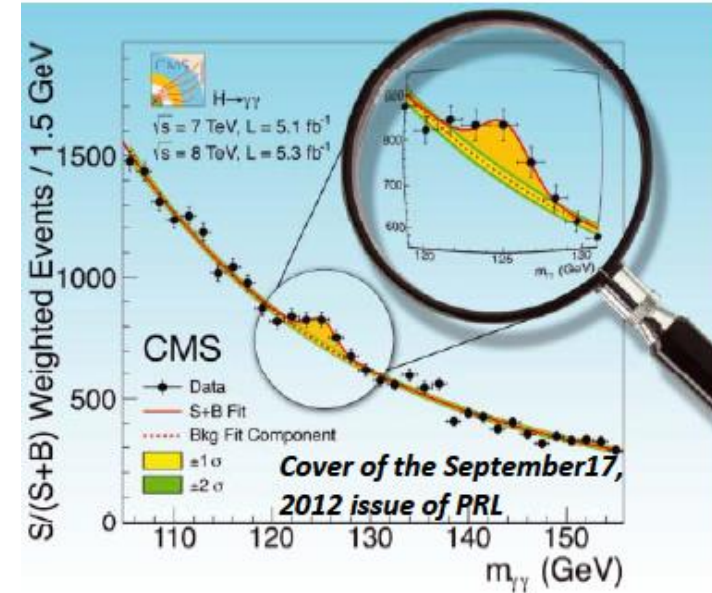




CMS in FCPPL: 17 years of exchanging people + ideas

IHEP-IP2I (former IPNL): Collaboration started in **2007** (one of the longest-lived in FCPPL)

- On virtually **all aspects touching photons in CMS**
- Current focus: **Standard Model Higgs boson property measurements through the $H \rightarrow \gamma\gamma$ channel, searches for a second, low-mass (<125 GeV) Higgs boson in the $\gamma\gamma$ channel, and HH analyses.**
- Since 2007, **FCPPL-financed exchanges** have included:
 - **18 people with some for multiple visits**
 - ✓ 9 IHEP doctoral students (some for multiple visits) and 1 IHEP postdoc to IPNL
 - ✓ 6 IPNL doctoral students (a first for FCPPL) and 2 IPNL postdocs to IHEP
 - Making possible significant contributions to **~ 45 CMS published papers/public results**
 - And support in establishing **2 co-PhD theses** financed by prestigious scholarships (CSC, Eiffel)
 - **No people exchanges in 2020-2022 due to Covid-19** : weekly collaboration meeting
 - **2023 FCPPL grant** was used to support a 6-week stay at IP2I in Nov.-Dec.2023 for IHEP student **Shaowei Song**



Phys. Lett. B 716 (2012)



CMS in FCPPL: 17 years of exchanging people+ ideas

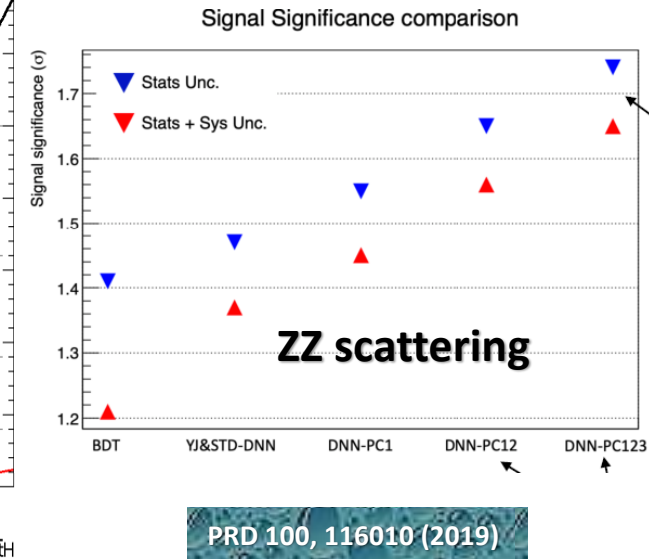
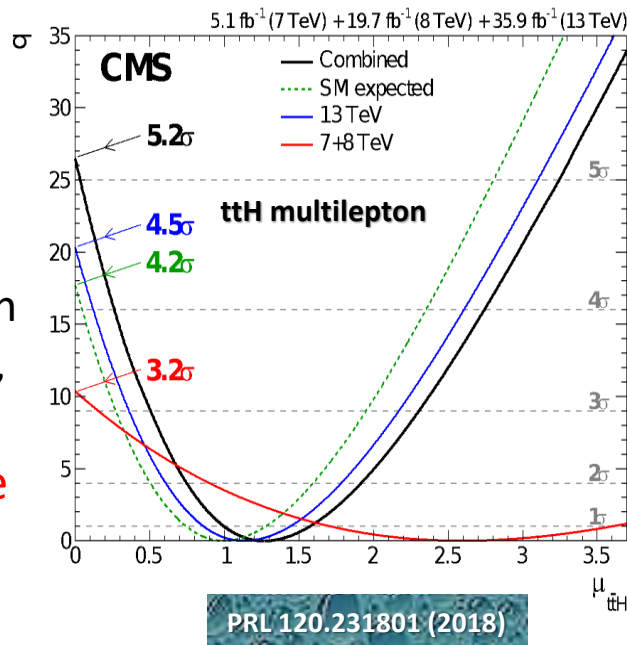
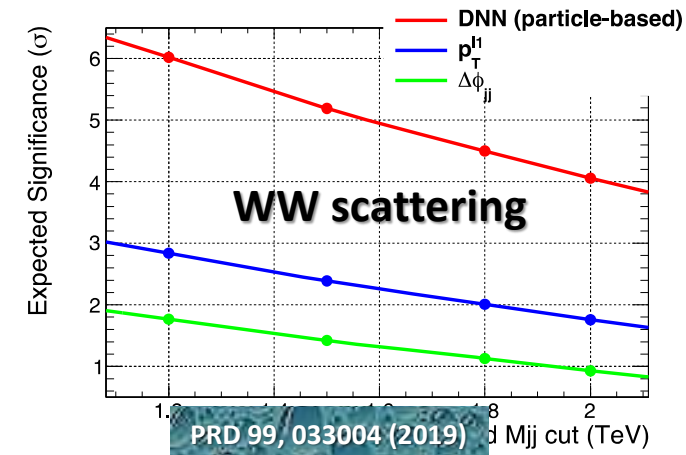
➤ **PKU-IPHC-IP2I:** Collaboration started in **2015** as **PKU-IPHC**, then added **IP2I** in **2017**. Focus: **Matrix element and deep learning techniques for top-Higgs and WW/ZZ scattering**. FCPPL-financed exchanges: **2 PKU students (2 visits each), 1 to each of IPHC and IP2I** making possible significant contributions to **6 published papers/public results**

❖ **Main results: ttH observation, *Phys. Rev. Lett.* **120**, 231801 (2018); Full Run 2, *Eur. Phys. J. C* **81** (2021) 378, direct measurement of the top-Higgs coupling**

❖ **Published two phenomenology studies: “Polarization Fraction Measurement in same sign WW scattering using Deep Learning”, *Phys. Rev. D* **99**, 033004 (2019), “Polarization fraction measurement in ZZ scattering using Deep Learning”, *Phys. Rev. D* **100**, 116010 (2019)**

❖ **Collaboration suspended in 2020-2021 but could be re-activated in the future**

❖ **2015-2019 team: IP2I: Nicolas CHANON IPHC: Jeremy ANDREA, Nicolas TONON PKU: Junho LEE, Jing LI, Qiang LI, Yajun MAO**





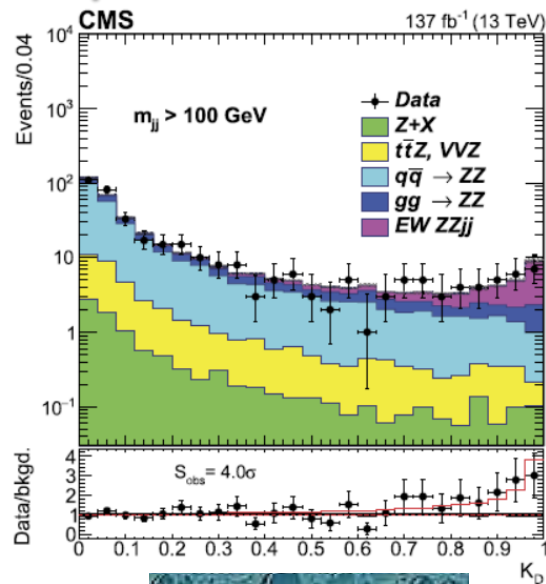
CMS in FCPPL: 17 years of exchanging people+ ideas

➤ **PKU-LLR:** Collaboration started in **2020**. Focused on **EW production of VBS ZZ**, making significant contributions to **1 CMS published paper** and **1 phenomenology paper**; now measurement of the **Z γ production cross section** and search for nTGCs with SMEFT

❖ **2022-2023 team:** LLR: Claude CHARLOT, PKU: Tianyu MU, Zhe GUAN, Qiang LI

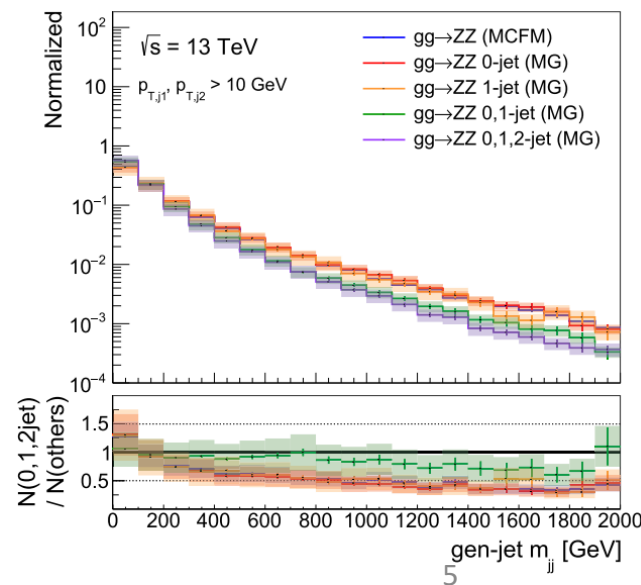
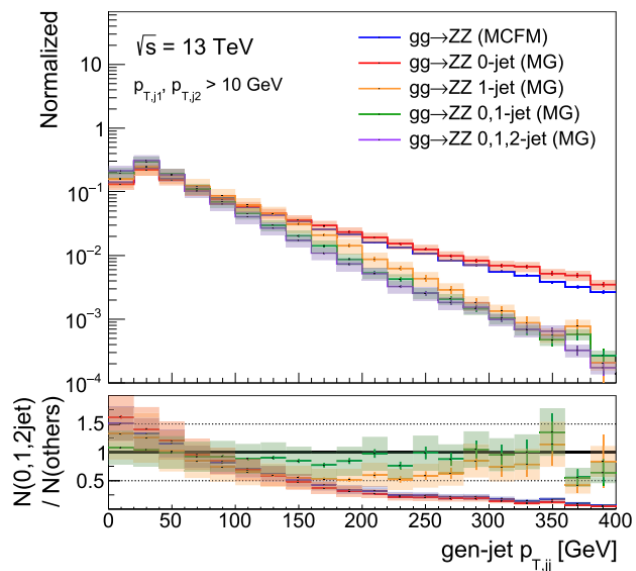
❖ **2023 FCPPL grant** was used to support a **4-weeks stay at LLR** in November 2023 for **PKU student Tianyu MU**

➤ **IHEP, IP2I** and **IPHC** have hosted **FCPPL workshop**, regularly contribute members of **scientific committee**



PRD 102, 116003 (2020)

PLB 812 (2020) 135992





IHEP-IP2I: photons and Higgs bosons in Run 1 (2007-2016)

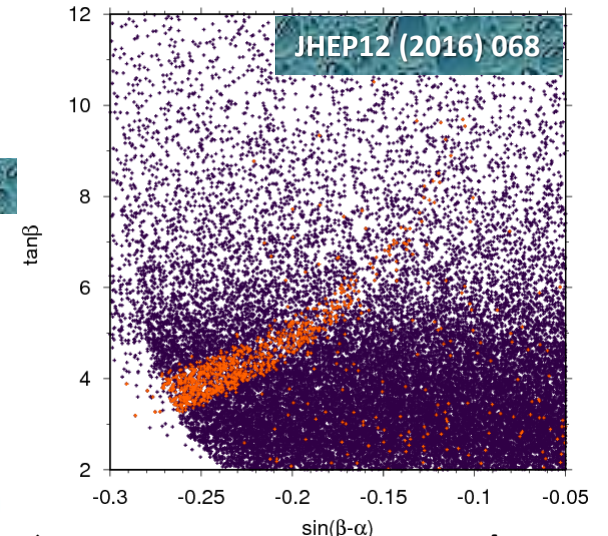
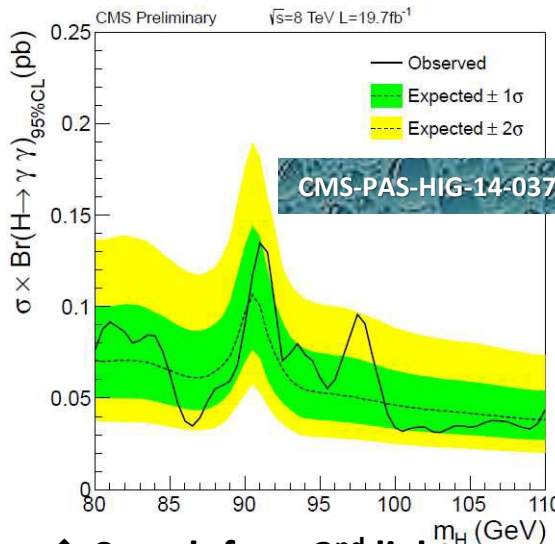
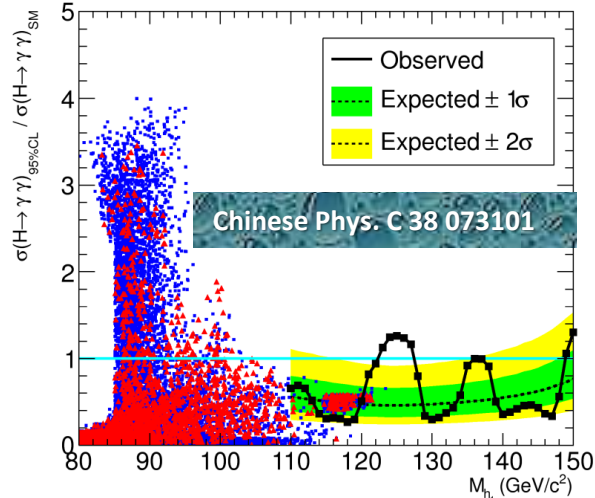
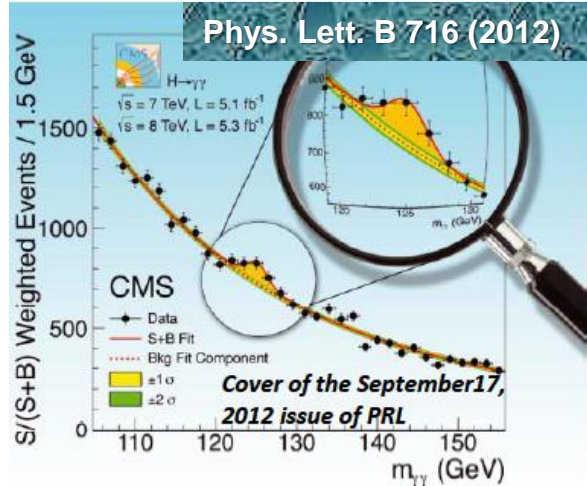
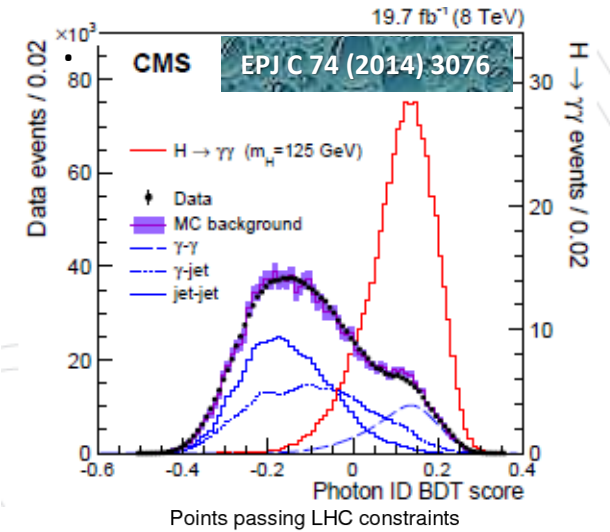
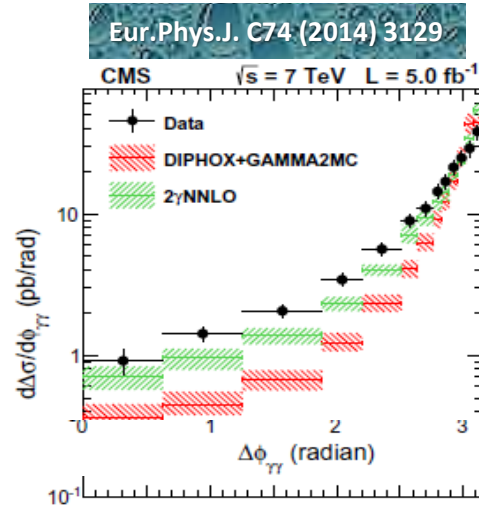
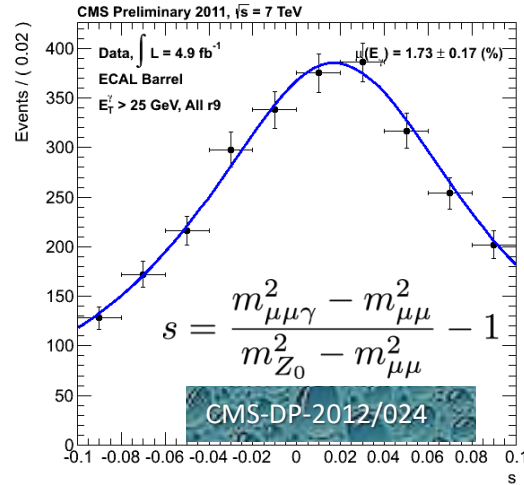
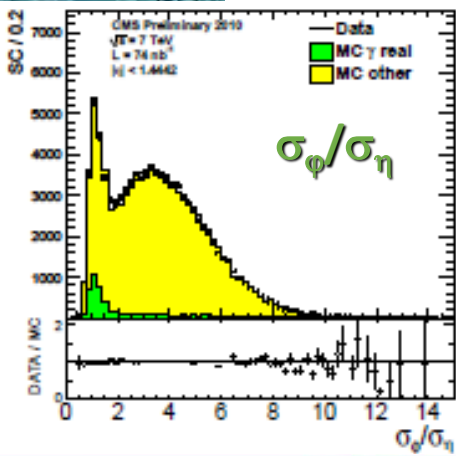
❖ Cluster/Photon commissioning, Runs 1&2 (2008-...)

❖ Photon energy scale extraction with $Z \rightarrow \mu\mu\gamma$ (2007-...)

❖ $\gamma\gamma + X$ differential cross section measurement (2010-...)

❖ γ/π^0 discrimination for photon ID (2008-...)

CMS-PAS-EGM-10-005



❖ Discovery and measurement of a Higgs boson (2012-...)

❖ Feasibility study for a 2nd lighter Higgs boson (2013-...)

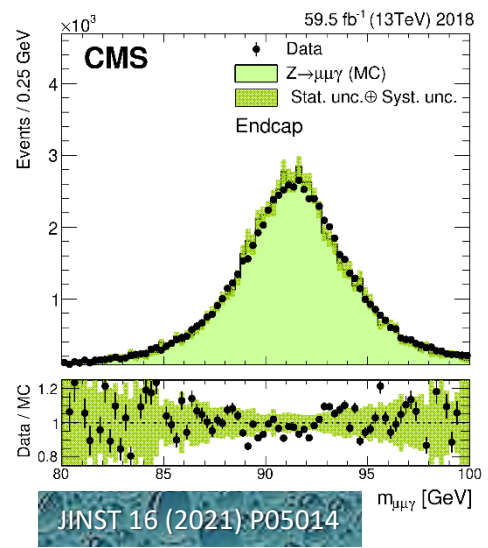
❖ Search for a 2nd lighter Higgs boson in 8 TeV data (2013-.....)

❖ 2HDM interpretation w/Th: Search for a 2nd lighter Higgs boson, 8 TeV data (2016) (orange excluded)

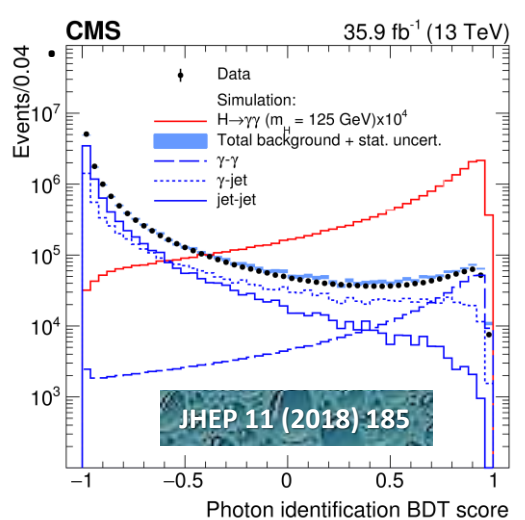
IHEP-IP2I: photons and Higgs bosons in Run 2 (2016-2021)



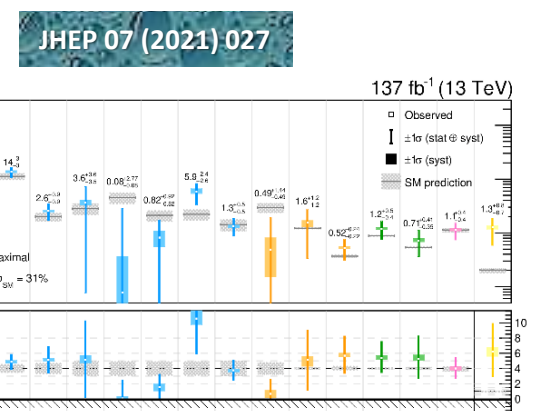
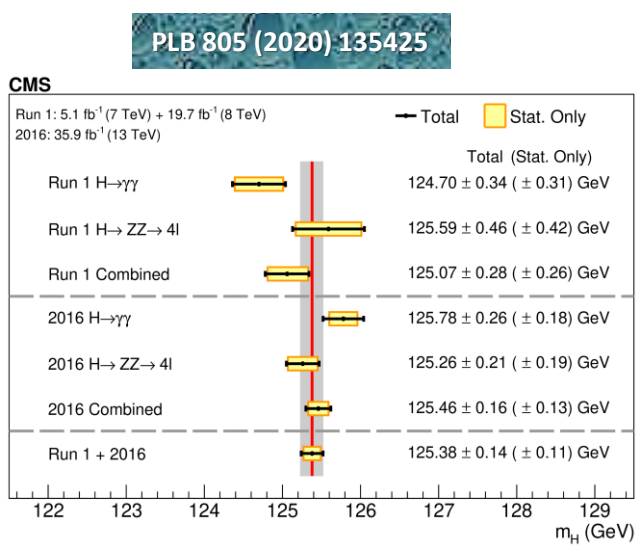
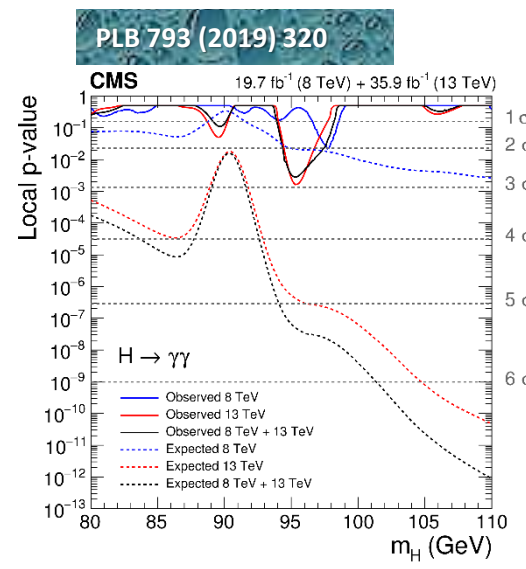
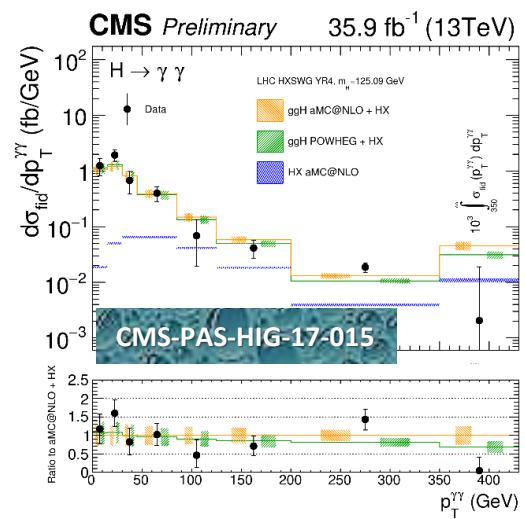
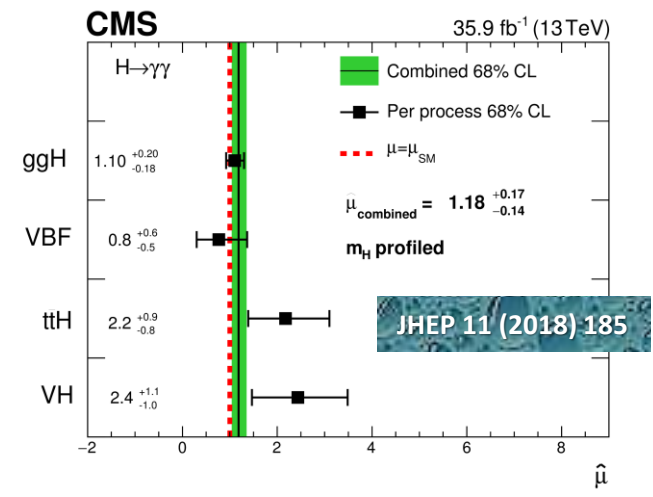
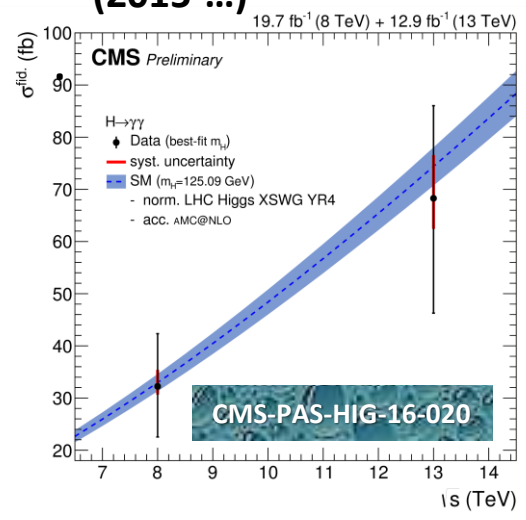
❖ Photon energy scale extraction with $Z \rightarrow \mu\mu\gamma$ (2007-...).



❖ γ/π^0 discrimination for photon ID (2008-...)



❖ ReDiscovery and measurement of a Higgs boson (2015-...)

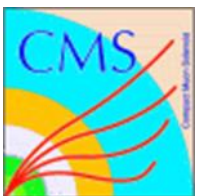


❖ Fiducial and differential cross section measurements (2016-...)

❖ Search for a 2nd lighter Higgs boson in 8+13 TeV data (2013-...)

❖ Mass measurement with 13 TeV 2016 data (2020-...)

❖ Strengths, couplings, STXS with Full Run 2 data (2019-...)



IHEP-IP2I: Run2 Higgs measurements (2021-2024), Run3 progress and plan

➤ $H \rightarrow \gamma\gamma$ property measurements

✓ **Published results:** Full Run 2 fiducial/differential cross section measurements (JHEP 07 (2023) 091), "A portrait of the Higgs boson by the CMS experiment ten years after the discovery" (Nature 607 (2022) 60-68)

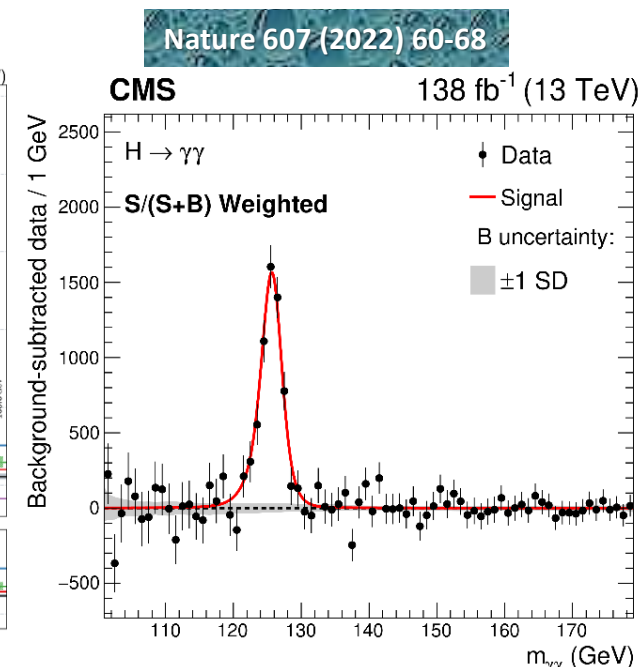
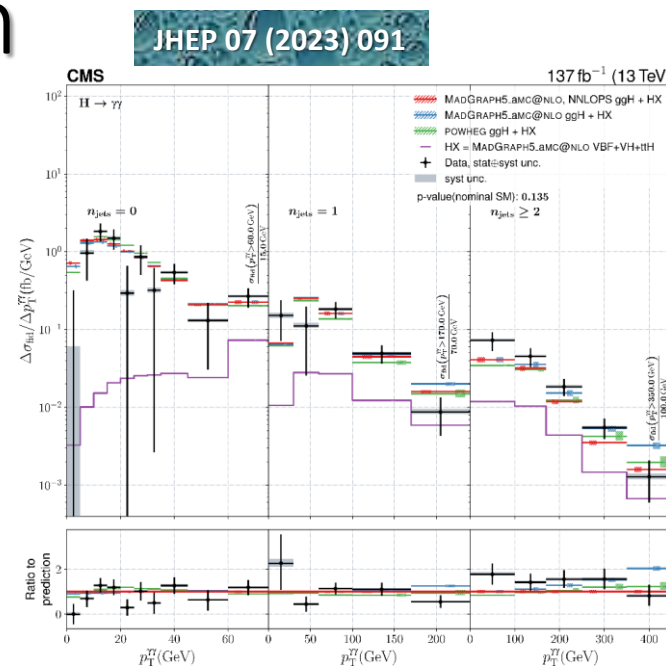
✓ **Preliminary result:** HL-LHC mass precision projection (CMS-PAS-FTR-21-008) $m_H = 125.38 \pm 0.02$ (stat) ± 0.07 (syst) GeV

✓ **Major contributions:** High-level trigger development and maintenance, photon ID MVA development, electron veto efficiency, $Z \rightarrow \mu\mu\gamma$ validation, sub/chief editor of CMS notes

➤ HH combinations: X- \rightarrow HH/YH

✓ IHEP, IP2I worked together with PKU and USTC, and other institutes/universities, on this topic: submitted to *Physics Reports* ([arXiv:2403.16926](https://arxiv.org/abs/2403.16926))

✓ See dedicated talks by **Elise JOURD'HUY** and **Chu WANG**



➤ Ongoing $H \rightarrow \gamma\gamma$ analyses: in good shapes

✓ Full Run 2 mass measurement (HIG-24-007, F. Lemmi from IHEP as contact person)

✓ Run3 2022 data: fiducial and differential cross section (HIG-23-014)

➤ Future plans with Run3 data:

✓ $gg \rightarrow \gamma\gamma/gg \rightarrow H \rightarrow \gamma\gamma$ interference: mass shift/cross section reduction to **constrain H width**, measure **spin** (BSM?)

✓ Non-resonant and resonant **HH**: $bb\gamma\gamma$ and $WW\gamma\gamma$



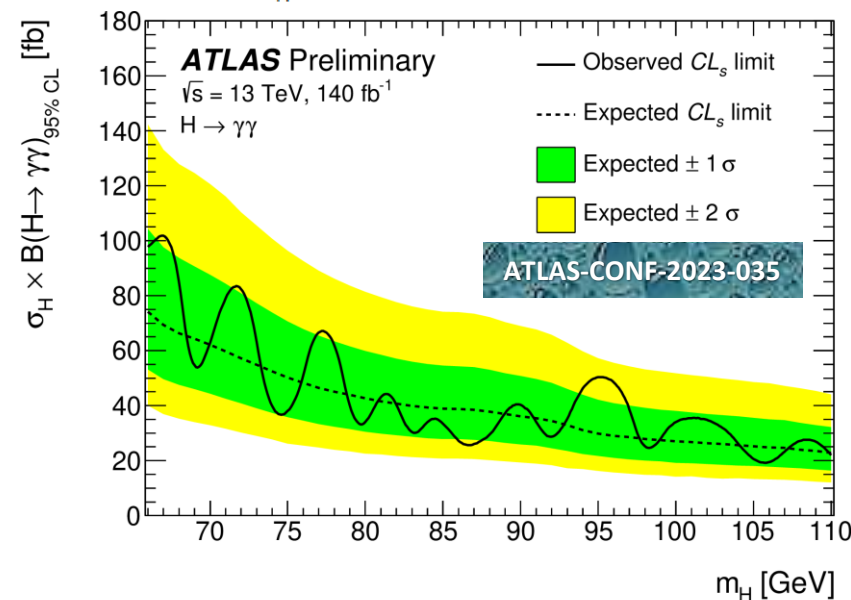
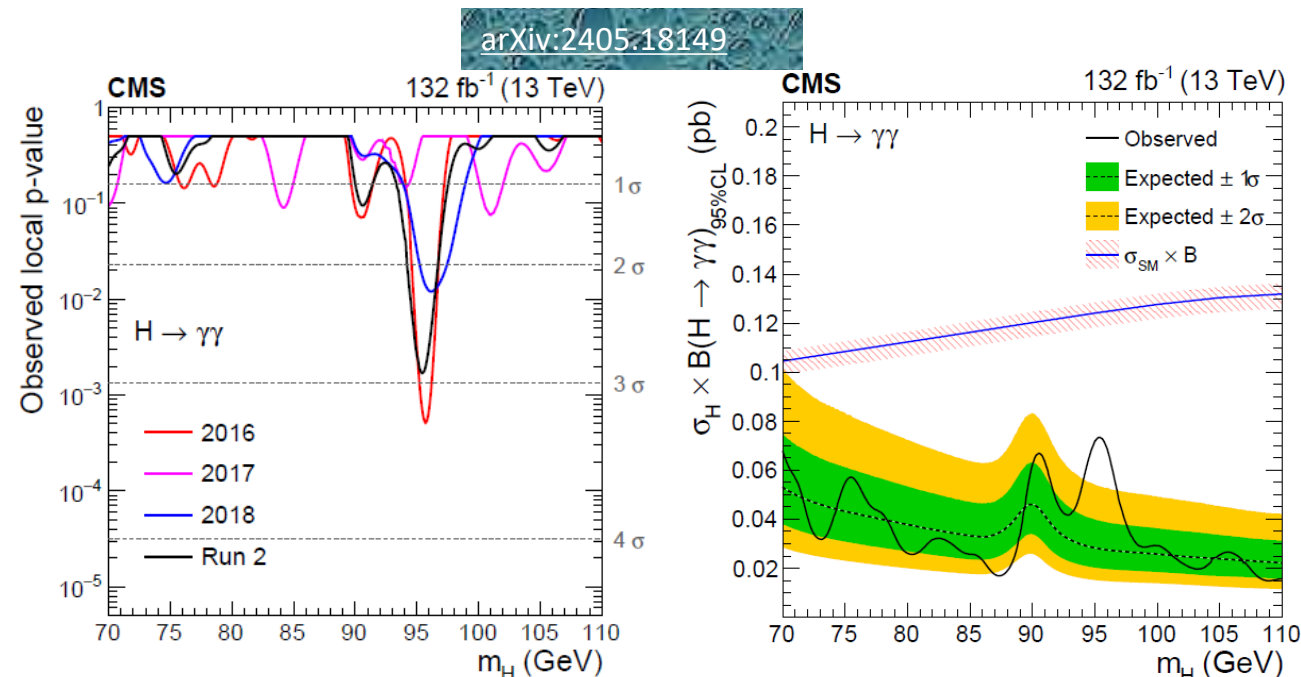
IHEP-IP2I: Low-mass (<125 GeV) $H \rightarrow \gamma\gamma$ search in 2023-2024

➤ **Initiators and leaders** of this search in CMS: any 2nd Higgs boson \rightarrow unequivocal proof of BSM

➤ Full Run 2 (2016-2018) results: **2.9σ observed at mass ~ 95.4 GeV** (CMS-PAS-HIG-20-002), was excluded by preliminary ATLAS Full Run 2 result (ATLAS-CONF-2023-035)

✓ Submitted to arXiv ([arXiv:2405.18149](https://arxiv.org/abs/2405.18149)) and PLB in 28 May 2024

➤ **Ongoing and future plans:** Results with **Run 3** data (2022-2023) in progress, plan for more interpretations (e.g. IPNL theorists), prepare prospects for HL-LHC





IHEP-IP2I : 2024 collaboration

➤ Enhanced efforts on the ongoing and the planned analyses

➤ **2024 team: 15 people**

IP2I (6): Suzanne GASCON-SHOTKIN, Maxime GOUZEVITCH, Elise JOURD'HUY, Benjamin MASSOTEAU, Alejandro SALINAS, Jie XIAO

IHEP (9): Guoming CHEN, Mingshui CHEN, Fabio IEMMI, Shaowei SONG, Junquan TAO, Chu WANG, Jin WANG, Zhenxuan ZHANG, Tianyu CAO

➤ **2024 FCPPL grant “CMSHIGPHO”** will be used to support

✓ **4-week stays at IHEP** in July 2024 for IP2I postdoc **Jie Xiao** and IP2I student **Elise JOURD'HUY**

✓ **a 8-week stay at IP2I** in Nov.-Dec.2024 for IHEP student **Tianyu CAO**

➤ **Other source of financing: ANR-ESDIR ‘HIGGSENLIGHTENED’ project** (PhD scholarship +1 yr postdoc) for 2023-2026; China **CSC** (2021-2025) and **MoST** (2023.11-2028.10) related projects



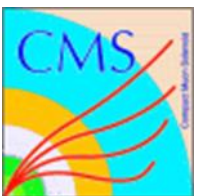
Jie



Elise



Tianyu



PKU-LLR 2024: Run3 Z+γ production and Search for

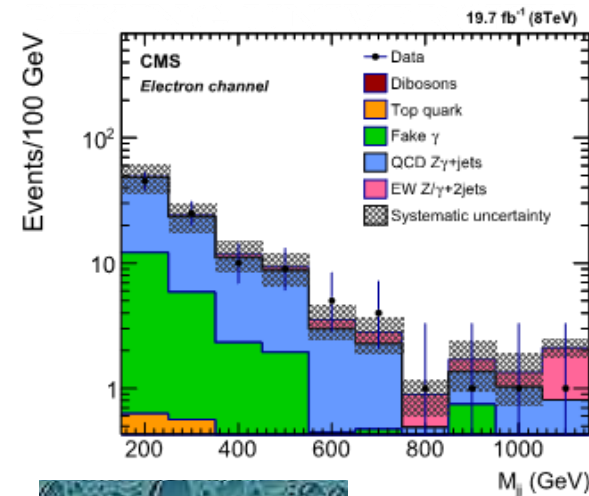
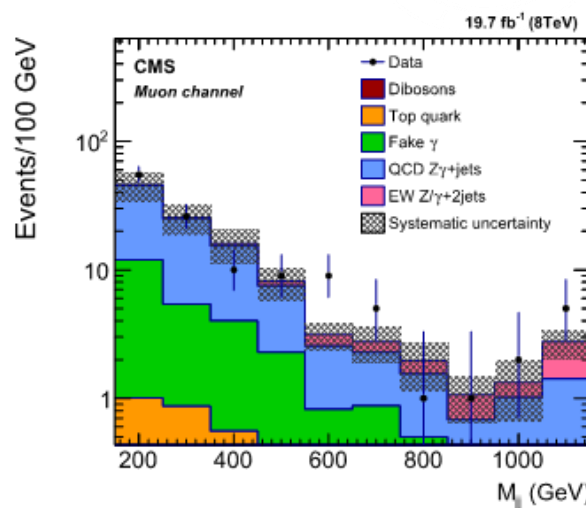
nTGCs with SMEFT

- **2024 team** : Tianyu Mu (PKU), Andrea Levin (PKU), Qiang Li (PKU), Claude Charlot (LLR)
- **Ongoing**: The **measurement of the Zγ production** with leptonic final states in proton-proton collisions at a center-of-mass energy of 13.6 TeV, using CMS Run3 **2022 data** (34.7 fb^{-1})

✓ **SMP-24-002**: in good shape

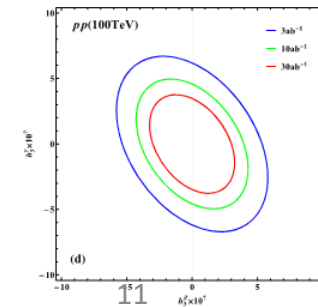
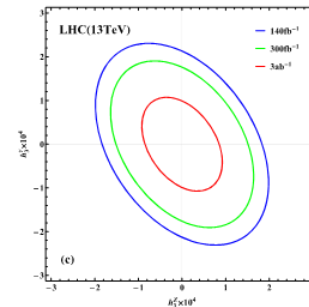
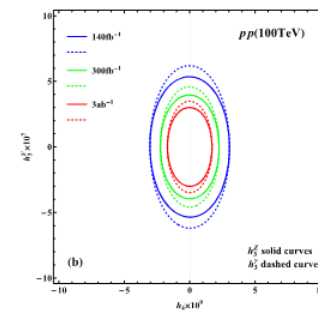
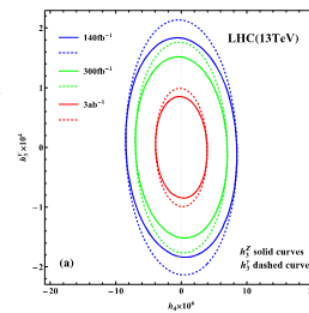
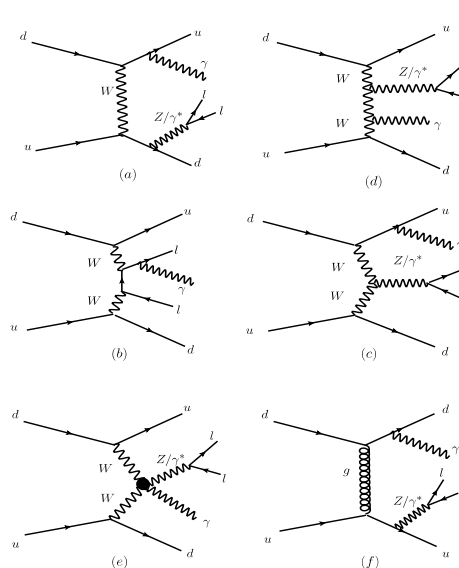
- Also exploring the **Neutral Triple Gauge Couplings** (nTGC), comparing the performance between the form factor model and the up-to-date model that can match dim-8 **SMEF** (*PRD 107.035005 (2023)*)

- **2024 FCPPL grant** "MultiBoson" is being used to support a **2-month stay at LLR** in April-June 2024 for **PKU student Tianyu MU** on these topics



PLB 04 (2017) 071

Phys.Rev.D107.035005 (2023)

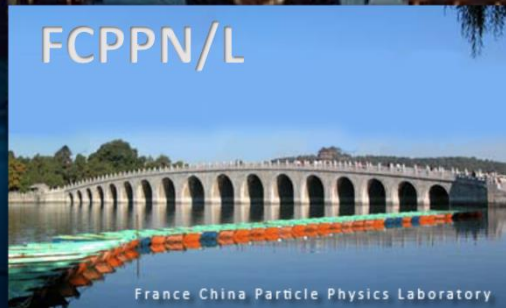


Acknowledgements

- ❖ THANKS to the FCPPN/L and to the local organizers!
- ❖ We are looking forward to your continued support!
- ❖ For many more years!

Merci

FCPPN/L



谢谢

