Interview for Chung-Yao Chao Fellowship
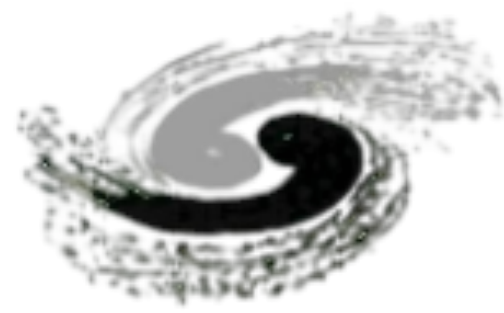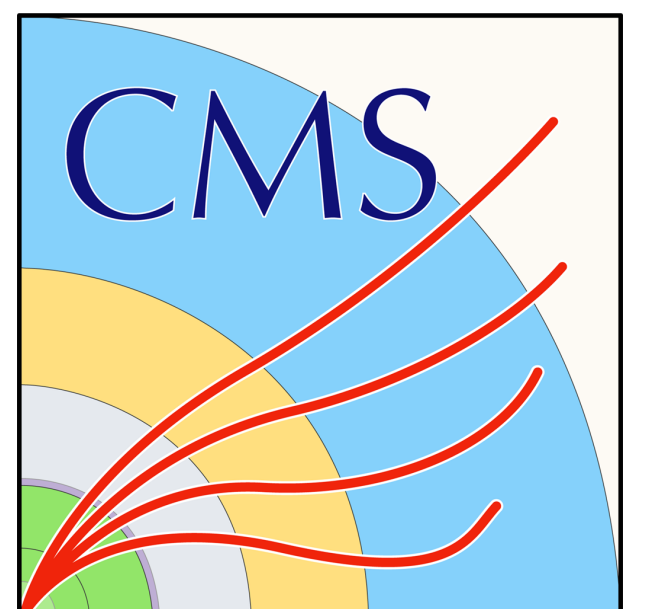
Vukasin Milosevic (IHEP Beijing)

Institute of High Energy Physics
Chinese Academy of Sciences
中国科学院高能物理研究所

5.6.2021.

Introduction: Resume

- **2021 - present:** **IHEP Beijing, postdoctoral researcher (supervisor: Prof. Mingshui Chen)**
    - Co-contact for the $H \to ZZ \to 4l$ differential cross sections measurements effort
    - Estimation of reducible background for various studies of the $H \to ZZ$ channel
    - Level-1 Data Quality Monitoring (DQM) group coordinator

- **2016-2020:** **Imperial College London, PhD studies/Teaching assistant**
    - Lead analyst for the VBF $H \to invisible$ analysis
    - Higgs trigger group coordinator
    - Recipient of the prestigious President's Scholarship
    - Award for the best presentation at the Imperial College postgraduate symposium
    - Poster award at the IOPHEPP 2019 conference

- **2015-2016:** **University of Belgrade, Master studies/Teaching assistant**
    - Graduated with highest honours (10.0/10.0)
    - Thesis results included in two CMS Collaboration publications

- **2011-2015:** **University of Belgrade, Bachelor studies**
    - Graduated first in class with highest honours (10.0/10.0)
    - Joined the CMS Collaboration midway during undergraduate studies
    - Internships in both physics related studies and in the ROOT group

Introduction: Selected list of public talks

- **International conference talks:**

  - **ICHEP2020:** **"Searches for Higgs boson rare and invisible decays at CMS"**
    - First presentation of the evidence for the $H \rightarrow \mu\mu$ channel
    - Proceedings: PoS(ICHEP2020)070

  - **DM@LHC2020: "Higgs to Invisible (ATLAS+CMS)"**

  - **IOPHEPP2019: "The search for invisibly decaying Higgs bosons at the LHC"**

- **Invited talks and international workshops:**

  - **2021: CMS China meeting:** "HIG-20-003: VBF Higgs to invisible"

  - **2020: University of Belgrade Christmas seminar:** "Search for the invisible decays of the Higgs boson"

  - **2018/2019: CMS UK Collaboration meeting:** "Higgs to Invisible - VBF production mode"

  - **2019: Level-1 DQM workshop:** "DQM overview: missing systems / modules - Calo"

  - **2018: CMS Future analyses workshop:** "The search for the invisible decays of the VBF Higgs boson"

Introduction: Selected list of publications

- **Publications:**
  - CMS Collaboration, "Measurements of properties of the Higgs boson in the four-lepton final state in proton-proton collisions at √s=13 TeV",
    - EPJC 81 (2021) 488

  - CMS Collaboration, "Performance of the CMS Level-1 Trigger in proton-proton collisions at 13 TeV"
    - JINST 15 (2020) P10017

  - CMS Collaboration, "Measurements of properties of the Higgs boson decaying into the four-lepton final state in pp collisions at √s= 13 TeV"
    - JHEP 11 (2017) 047

  - CMS Collaboration, "Measurement of the ZZ production cross section and Z→ $llll$ branching fraction in pp collisions at √s=13 TeV",
    - Phys. Lett. B 763 (2016) 280

- **Monographs**:
  - M. Cepeda et al, "Report from Working Group 2 : Higgs Physics at the HL-LHC and HE-LHC",
   - CERN Yellow Rep.Monogr. 7 (2019) 221-584

- **In preparation:**
  - CMS Collaboration, "Differential cross-section measurements in the Higgs to 4l channel"
    - HIG-21-009 (CMS AN-2021/065) - Run 2 legacy measurement

  - CMS Collaboration, "Search for invisible decays of a Higgs boson produced via vector boson fusion with 137 fb of proton-proton collisions at √s = 13 TeV",
    - HIG-20-003 (CMS AN-2019/257) - Run 2 legacy result

  - CMS Collaboration, "Search for invisible Higgs in ttH/V(jj)H production"
    - HIG-21-007 (CMS AN-2018/299) - Run 2 legacy result

  - CMS Collaboration, "Performance of the CMS High Level Trigger in proton-proton collisions at 13 TeV"
    - TRG-19-001

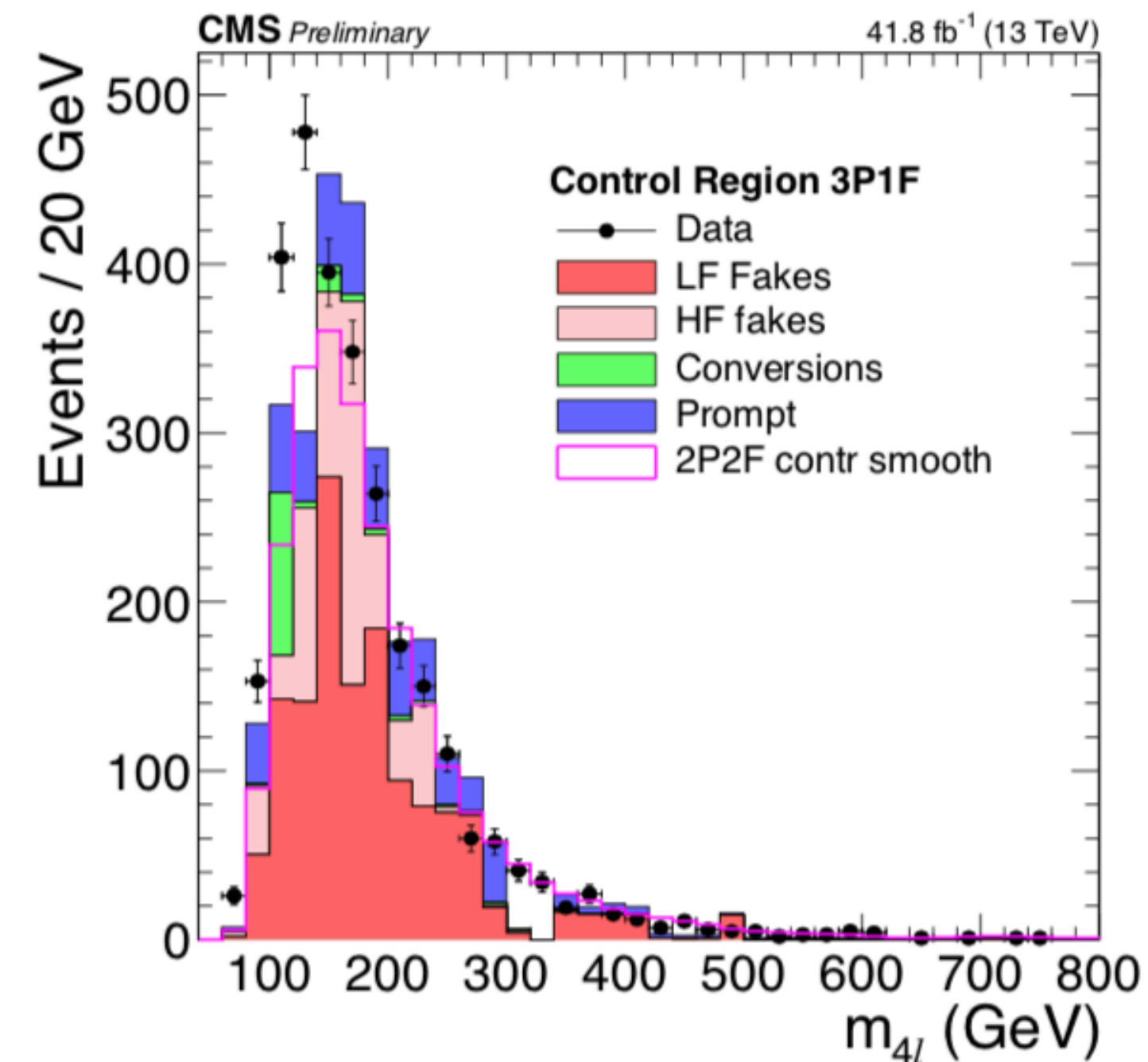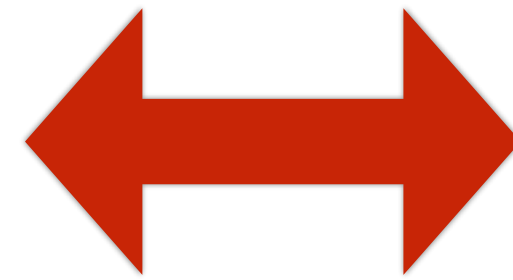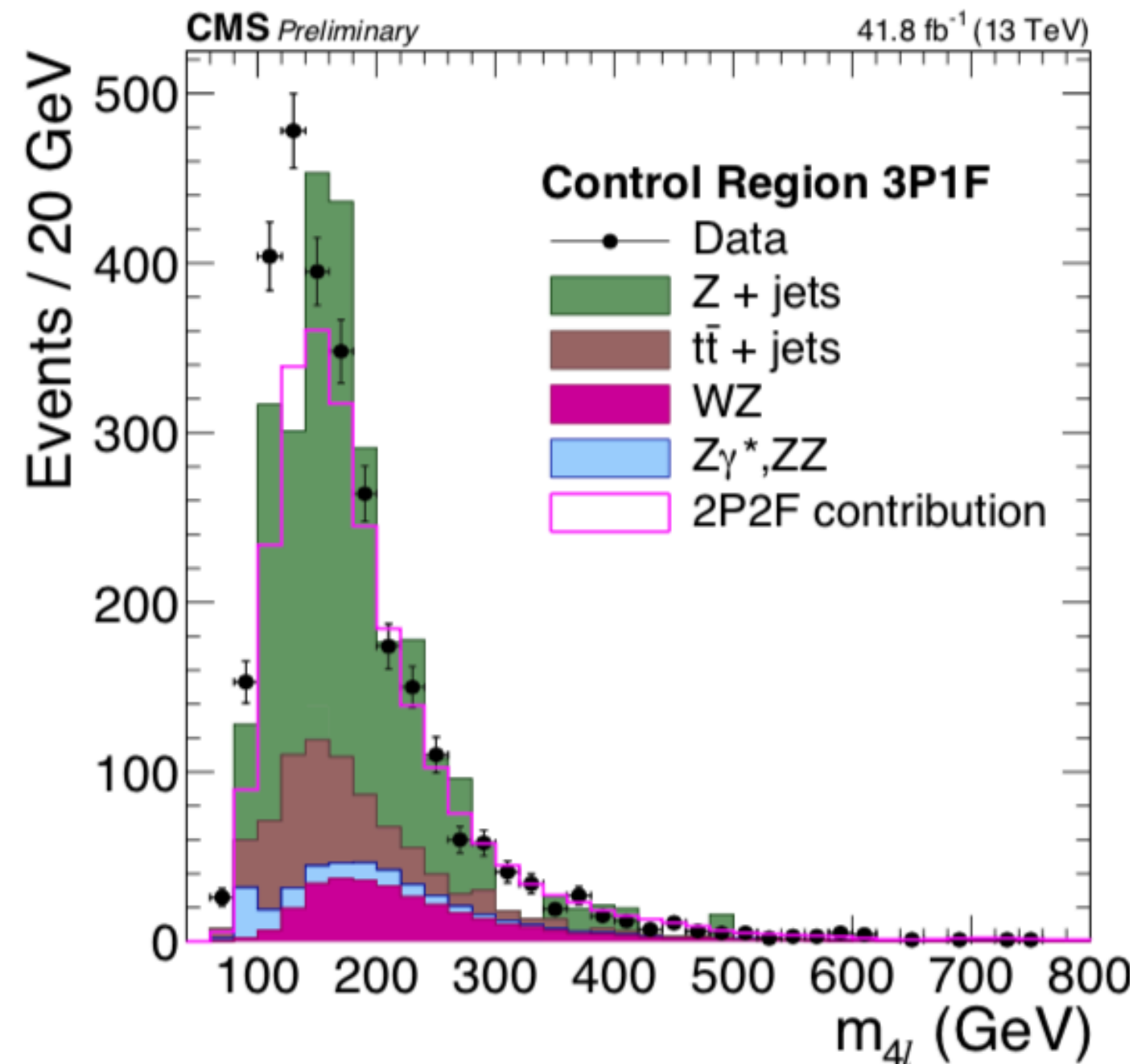# Work achievements: $H \rightarrow ZZ \rightarrow 4l$

Contributions in various HZZ analyses in the area of reducible (Z+X) background:

- Lepton fake rate measurement and application
- Reducible background estimation
- Estimation of the uncertainties
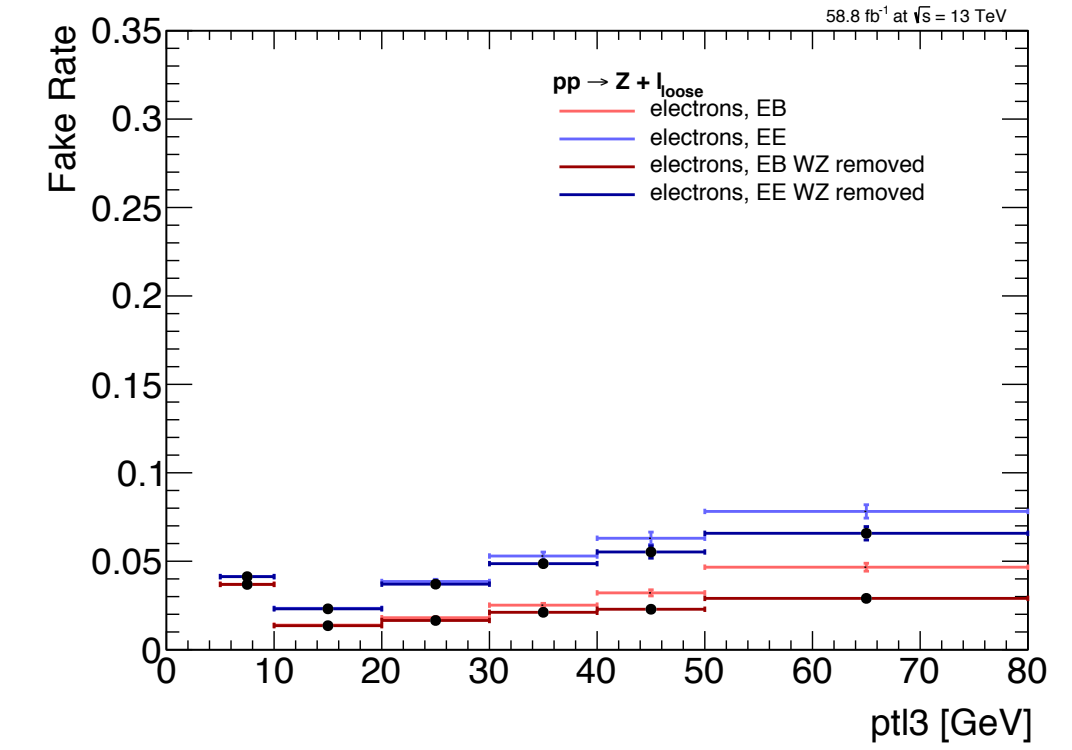
Key additions:

- Inclusion of extrapolation factors which take into account leptons with overlapping isolation cones
- Updated treatment of uncertainties by taking into account the sensitivity of fake rate measurements to background composition

They brought an extension to the sensitive phase space and reduced the overall systematic uncertainty for the measurement

Work achievements: $H \rightarrow invisible$

- Higgs boson can take a role of **a mediator** between **SM and DM particles**
- Detection requires for the **Higgs to recoil against a visible system**
- **SM B($H \rightarrow invisible$) ~ 0.1% - good way to test for BSM physics**

qqH: Vector boson fusion production

- Largest sensitivity for the invisible final state
- Main characteristics of this category:
  - **Two jets** separated by **a large η**
  - **Large** dijet invariant mass (**mjj**)
  - **Data driven** estimation of **SM V+jets backgrounds**
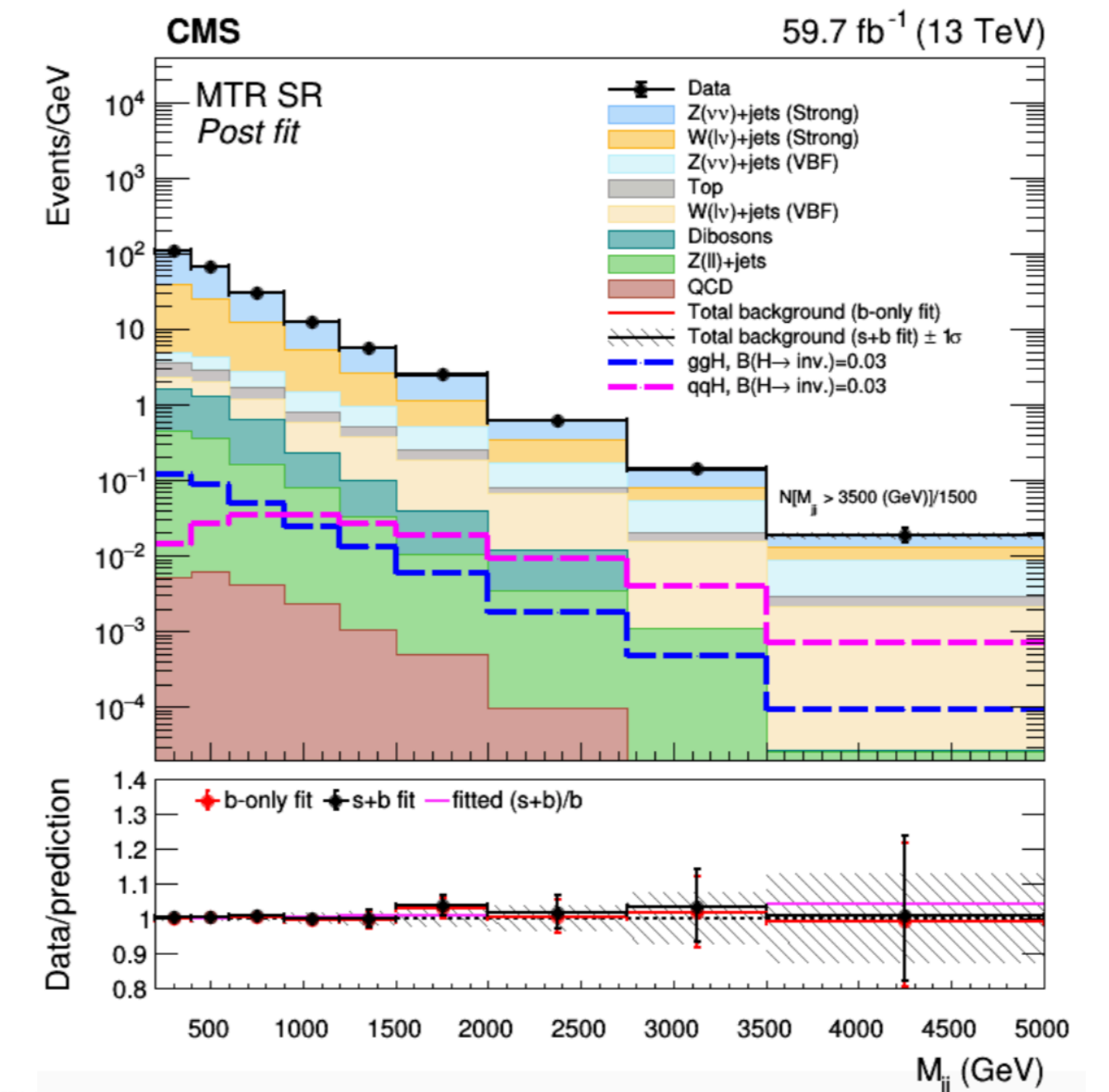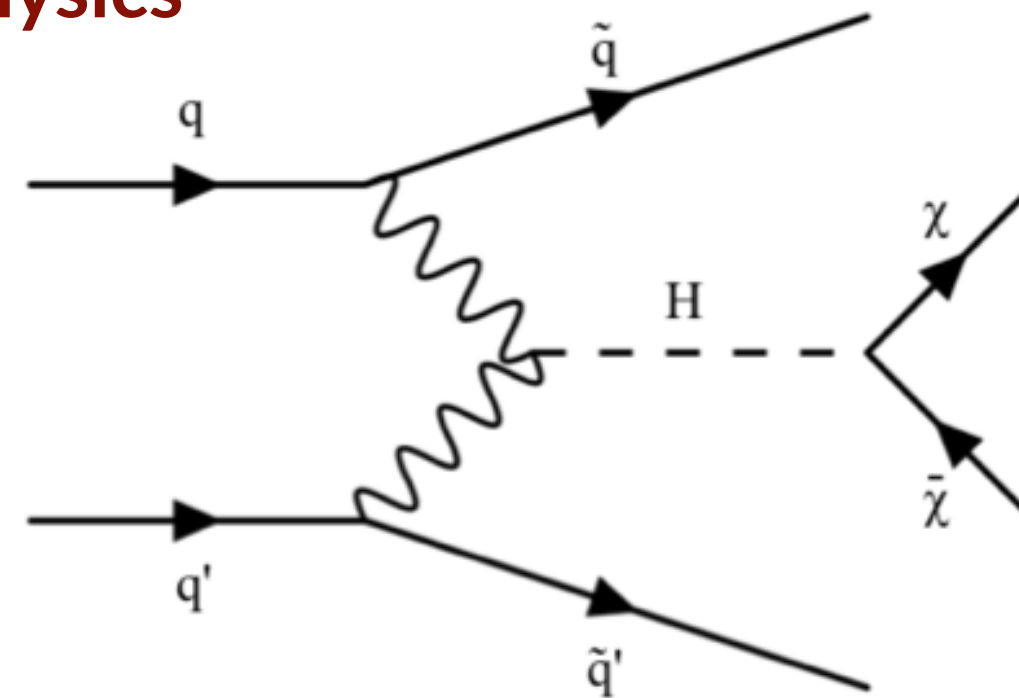
New High level trigger algorithms:

- **Enabled the exploration of the VBF H->inv topology at the HLT level**
  - Previously the analysis relied only on the generic $E_{T,miss}$ algorithms
  - High $E_{T,miss}$ threshold due to the rate control
- Retrieving otherwise lost events by deploying new triggers
- **Creating a new, low $E_{T,miss}$, analysis category**
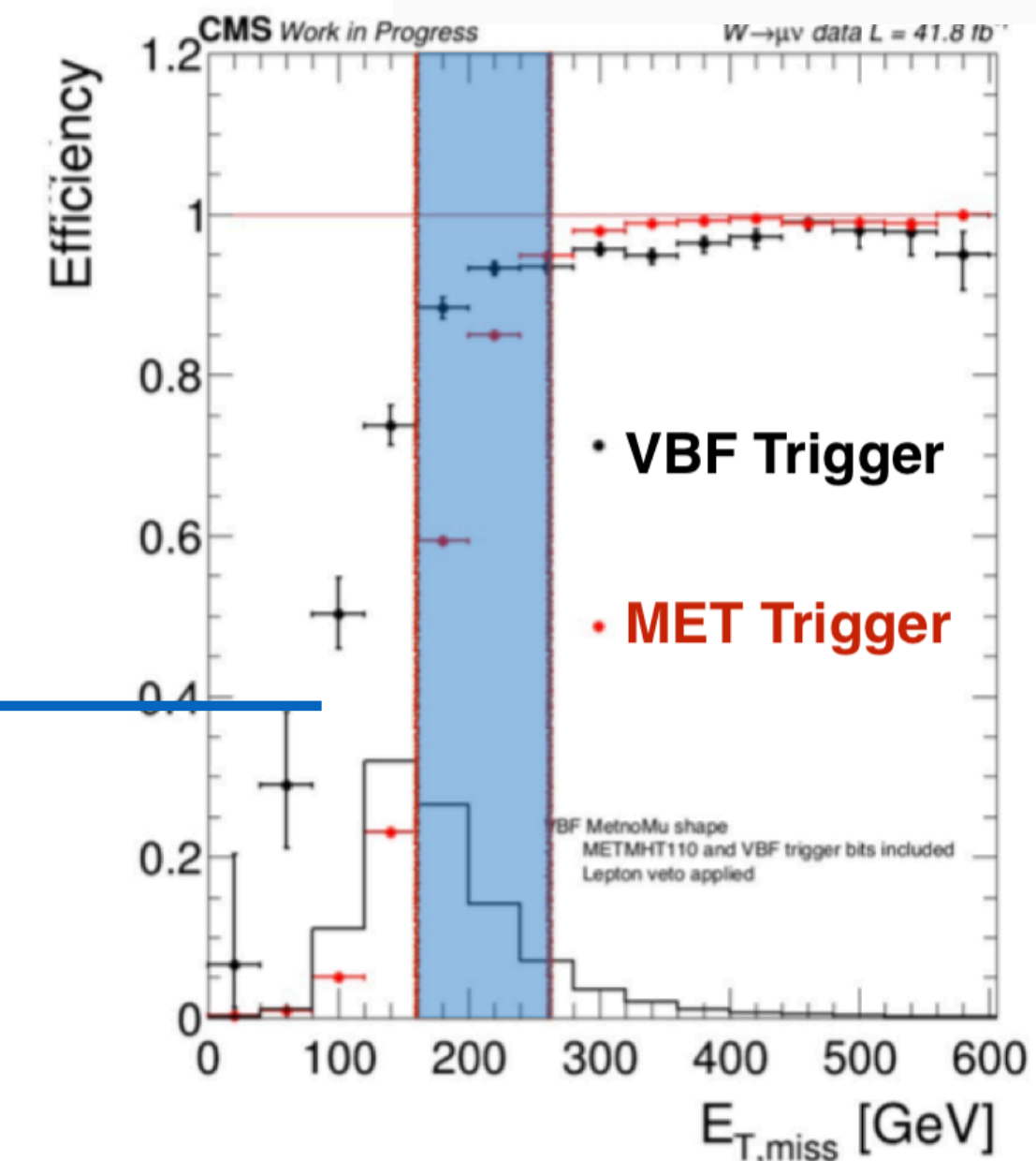
Work achievements: $H \rightarrow invisible$

Studies of future prospects for the $H \rightarrow invisible$ analysis:
- Detailed study off the HL-LHC era (using simulated scenarios for the HGCal upgrade of the CMS detector)
- Published as a part of CERN's HL-LHC Yellow Report monograph
- Lead author in a small team

CMS AN-17-302

Prospects in the search for a VBF-produced Higgs boson decaying to invisible particles with the upgraded CMS detector.

Anne-Marie Magnan, Vukasin Milosevic, Nicholas Wardle
Imperial College London (UK)

Run 2 legacy result for the VBF $H \rightarrow invisible$ analysis:
- Lead and contact author during my PhD studies
- Control and development of the entire framework starting form the data collection until the final result
- Development/optimisation of the analysis strategy, estimation of background processes, treatment of systematics, final limit extraction and interpretation of results
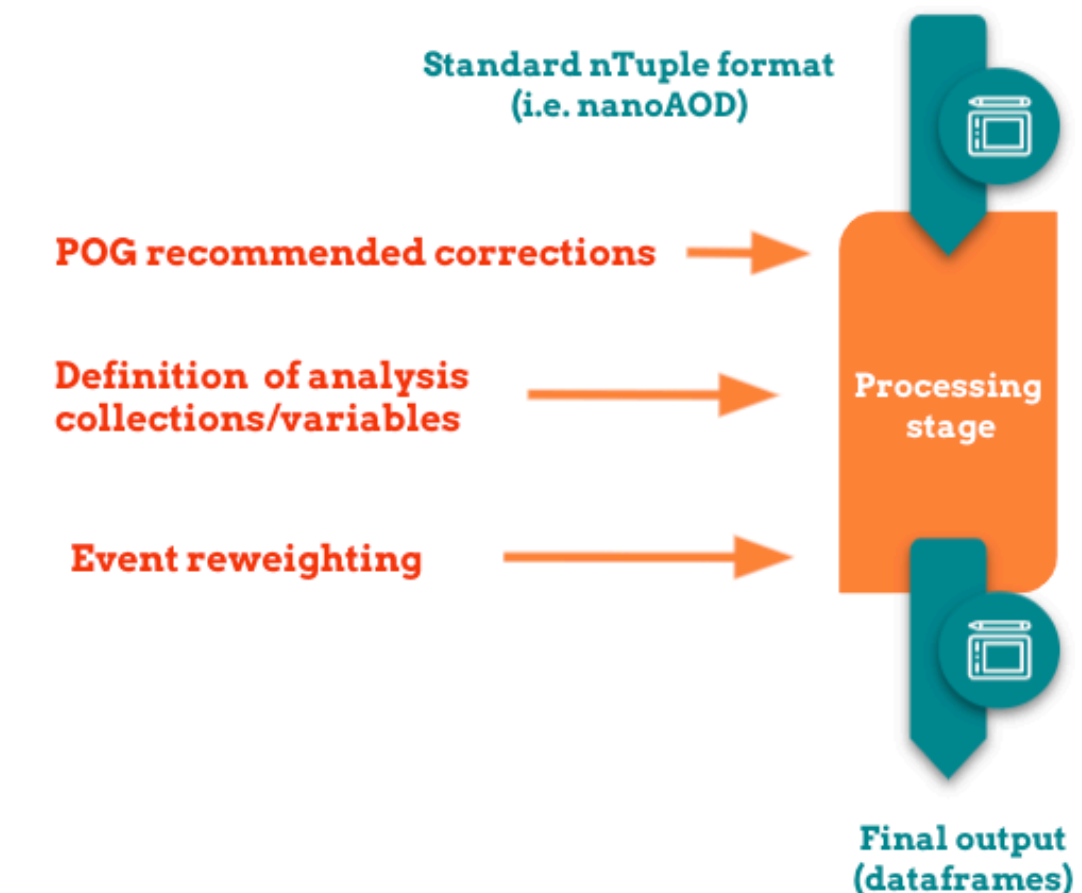
Search for VBF Higgs bosons decaying to invisible particles at 13 TeV with full run 2 data

Alp Akpinar[2], Andreas Albert[2], David Anthony[4], Eshwen Bhal[4], Robert Bainbridge[1], Jim Brooke[4], David Colling[1], Gavin Davies[1], Olivier Davignon[3], Zeynep Demiragli[2], Henning Flächer[4], Benjamin Krikler[4], Anne-Marie Magnan[1], Vukašin Milošević[5], Alexander Tapper[1], Nicholas Wardle[1], Samuel Webb[1], Siqi Yuan[2] and Laurent Thomas[6]

[1] Imperial College London
[2] Boston University
[3] LLR - Ecole Polytechnique
[4] Univeristy of Bristol
[5] IHEP Beijing
[6] Universite Libre de Bruxelles

Combined $H \rightarrow invisible$ project:
- Combination of results from all hadronic production modes of the Higgs boson into a legacy publication for the invisible final state
- Novel analysis framework based around industry standard python libraries and dataframe formats
- Enabling other channels to easily share recipes/studies developed for the VBF analysis
- Out of the box orthogonality - **new analysis of ttH and V(jj)H channels!**

Standard nTuple format (i.e. nanoAOD)

POG recommended corrections

Definition of analysis collections/variables

Event reweighting

Processing stage

Final output (dataframes)

Work achievements: Coordination and detector operation

Higgs Trigger Group coordination:
- CMS Level 3 contact position (2018-2021)
- Management and organization of work within the group (15-20 people)

- Responsible for the development, monitoring and maintenance of new algorithms
- Review and coordination with physics analysis groups regarding correct measurement of efficiencies and the usage of HLT algorithms

- Editor of the group's contribution to the CMS Run-2 HLT performance paper
- Studies of future prospects for HLT in Higgs related analyses

Performance of the CMS High Level Trigger during LHC Run 2

The CMS Collaboration

489 **5.1 Performance of the $e\mu$ Cross Triggers**

490 **Editor(s):** Vukasin Milosevic, Amandeep Kaur

491

Level-1 Data Quality Monitoring:
- Maintenance and development of the CMS Level-1 CaloLayer2 online DQM system

- Creation of different representative scenarios depending on the level of detail needed (expert or shifter)
- Implementation of run specific information such as performance plots for properties relevant to the Heavy Ion research.

Operation of the CMS experiment:
- Direct involvement in the data collection during the Run 2 phase

- Technical shifter with more than 2 years of experience
  - Experience in both the run and upgrade/fix periods

- Served as the Level-1 CaloLayer2 expert on call during the Run 2 phase
  - Responsibility of being a 24h/7 expert on the phone
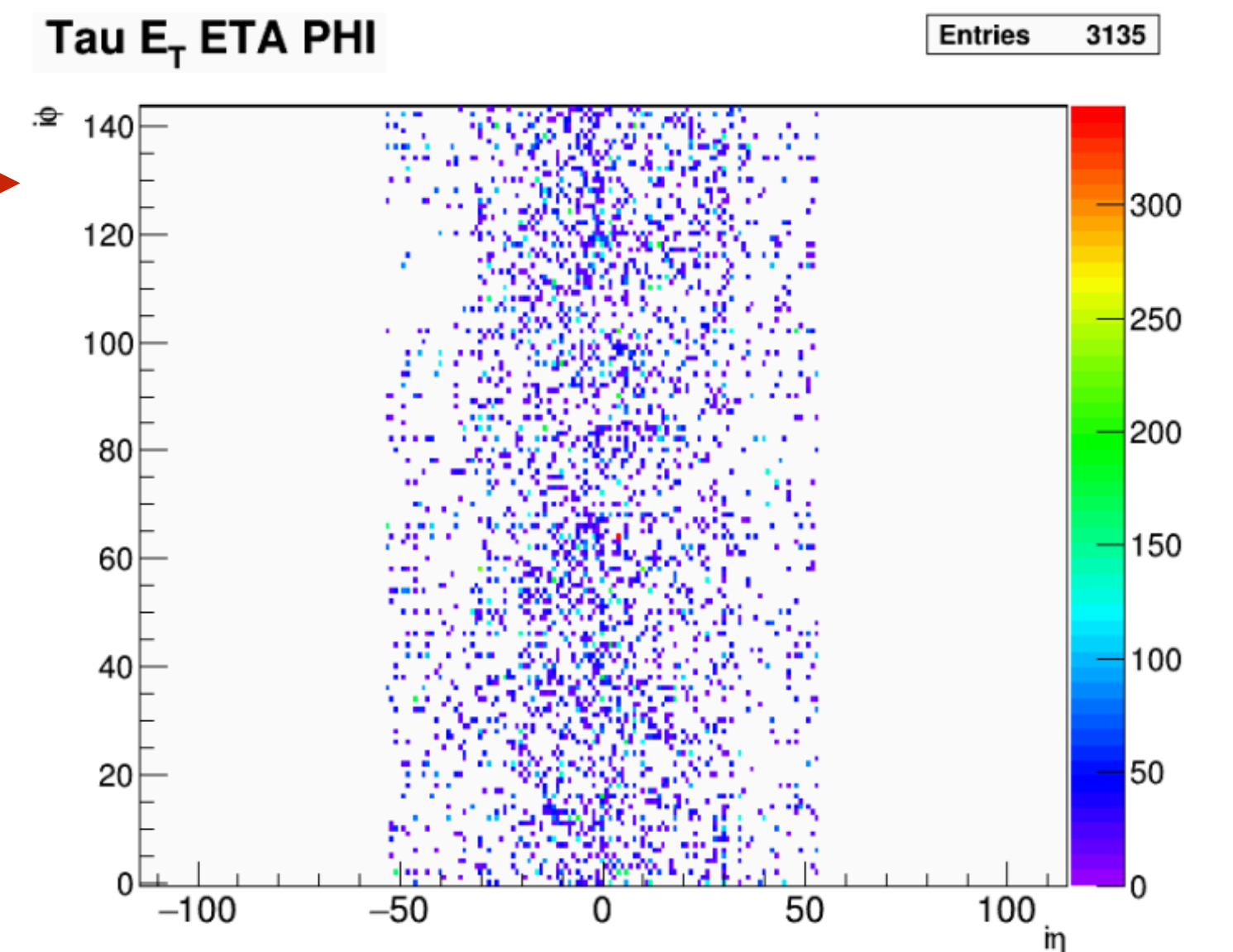
Work plan and conclusion

Ongoing work:

- $H \rightarrow ZZ \rightarrow 4l$ **analyses:**
  - Became a co-contact author for the differential cross-section measurements for the 4l channel
  - The analysis is currently targeting end of summer finish date

  - Creation of a more generalised reducible background estimation framework
  - Modular design, easy to benefit many other 4l studies - differential cross-section, mass and off shell measurements

- $H \rightarrow invisible$ **analyses:**
  - Two analyses moving forward with the review

    - HIG-20-003: VBF $H \rightarrow invisible$ is currently in ARC review and is targeting completion by the end of summer

    - HIG-21-007: ttH and V(jj) $H \rightarrow invisible$ study is currently being prepared for the pre-approval
      - Benefiting from the common framework shared with the VBF channel - O(1-2 months)

Work plan and conclusion

<u>**Technical work:**</u>

- <u>**Level-1 DQM subgroup coordination (2021-present):**</u>
    - Management of a group of ~20 people responsible for maintaining and developing a straightforward and easy to use online monitoring system

    - Creation of various tasks - crucial for Run 3:
        - Direct monitoring of the pre-fire effect
        - Auto DQM - raising alarms if suspicious behaviour is noticed
            - Making work easier for the on call shifters and experts

    - Currently formulating a list of tasks - this work can become institutional contribution
        - Allocated EPR tasks and building an expertise within the CMS experiment

- Exploration of new ML based VBF triggers
    - Optimising algorithms for the VBF topology at the first, Level-1, triggering step

- Developing new opportunities for the institute by building on my previous experience, while also taking a more prominent role in other studies within our institute in order to widen the scope of my abilities

Thank you for your time!

BACKUP

List of awards

- (2019) Award for the best talk at the Postgraduate research symposium, Imperial College London

- (2019) Award for the best poster at the IOP HEPP conference, Institute of Physics, UK

- (2016-2019) Award given by the government of the Republic of Serbia for best PhD students studying abroad, Foundation "Dositeja"

- (2016-2020) Recipient of the prestigious President's Scholarship for PhD Studies, Imperial College London

- (2016) Award given by the University of Belgrade for the first in class student of the Faculty of Physics, University of Belgrade

- (2015-2016) Scholarship of the government of the Republic of Serbia for best Master students, "Dositeja" foundation

- (2014-2015) Scholarship of the government of the Republic of Serbia for best final year Undergraduate students, "Dositeja" foundation

- (2013-2014) Award given by the Faculty of Physics for the best 3rd year student, "Prof. Dr Djordje Živanović" foundation

- (2008-2010, 2012-2013), Scholarship of the city of Belgrade for talented students, City of Belgrade

- (2009) Special award given by the Republic of Serbia for the outstanding results achieved in high school student competitions, Republic of Serbia