CERN Japan Fellow
Second Report
Dec. 2018 - Nov. 2019

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Quick recap

- Fellowship: September 2018 - August 2020
- Second postdoctoral job
  - Ph.D. Carnegie Mellon University, 2015
  - First postdoc at MIT, 2015-2018
- Had planned to join ATLAS as a CERN fellow, but decided to continue on CMS to maximize output

- Interests
  - Exploration of exotic properties of the Higgs boson
  - Physics analyses with photons in the final state
  - Software and computing technologies for HEP
Projects

- Planned at the start of the year
  - Measurement of the differential production cross section of the Higgs boson in the WW decay channel
  - Search for an exotic decay of the Higgs boson into a photon and a dark photon
  - CMS Phase-II endcap calorimeter (HGCal) trigger development
  - Study of deep learning application to complex calorimetry
- New involvements
  - Measurement of electroweak-exclusive single photon production (qqγ) cross section
  - Subconvenership at the SUSY Photons group
H→WW differential cross section

• Indirect probe of non-SM Higgs couplings
  • Was an uncovered topic with straightforward prospect
  • Good opportunity to absorb know-how in SM Higgs analyses
• Original plan: have a preliminary result for Moriond (March) with 2016 + 2017 data, publication with full Run 2 data in summer
• Problem in background estimation method found in February
  • Method revision required 4 months of work
  • Meanwhile, decided to include 2018 data already for preliminary result
• Presented at Higgs Couplings 2019 (September)
• Now working on the paper manuscript
  • Expected to be the first full Run 2 Higgs paper from CMS
H→WW differential cross section

Full run 2 H → WW Differential analysis

Fiducial and differential cross sections with 137/fb in H → WW

$$\mu_{\text{fid}} = 1.03^{+0.12}_{-0.11} (\text{stat.}) +0.08 (\text{theo.}) +0.03 (\text{lumi.}) +0.07 (\text{exp.})$$

$$\sigma_{\text{fid}} = 85.0^{+9.9}_{-9.3} \text{ fb.}$$

Uncertainties of the same order as di-photon analyses in #jets and similar in high ptH.

Unfolding with Tichonov regularization embedded as a constraint in the likelihood function

Overall fiducial measurement competitive with di-photon (with larger theoretical uncertainties)

• Presented by P. Lenzi (INFN Firenze)
Search for $H \rightarrow \gamma\gamma_D$

- "Higgs cannot be the end of the story"
- New physics naturally couples to Higgs ("portal")
  - Non-SM coupling induces non-SM decays of $h(125)$
- $H \rightarrow \gamma\gamma_D$ predicted by an interesting model with a dark sector and a dynamic origin of Yukawa couplings [1]
- Started a search program while at MIT, continuing

![Graph showing exclusion limits for SM-Unpredicted decay unexcluded branching](image)

[1] Gabrielli et al. 1405.5196
Search for H\rightarrow\gamma\gamma\rightarrow D

• Search in three Higgs production modes: ggH, qqH, ZH

• ZH search completed in May by MIT colleagues
  • YI was in supporting role
  • Featured by the collaboration as one of the first full Run-2 data analyses

• Now working on the qqH channel
SMP EWK gamma

• Joined members of the CERN CMS group (CMG) in the project to measure the cross section of electroweak-exclusive single photon production

• Final state similar to $qqH \rightarrow \gamma\gamma_D$
  • Similar challenges, similar solutions

• In particular: largest obstacle = modeling QCD background
  • Need higher-order simulation
  • CMS-standard NLO calculation ("FxFx merging") not applicable
  • Introducing new method ("UNLOPS") from literature
SUSY photons subconvenership

- CMS supersymmetry search group organized by final state signatures: hadronic, leptons, photons, etc. → Facilitate analysis knowledge sharing
- Previous photon subgroup coordinator ("subconvener") got a job outside CMS → YI recruited as replacement
  - Have experience with Ph.D. thesis work: SUSY with photon + lepton
- Coordinating and advising 4 analyses
- Also launching a new analysis project for first year of Run 3
Deep learning for HGCal reconstruction

- Joint effort by subsets of CMG & FNAL CMS groups
- Focus on graph neural network (GNN) architecture
  - Most well-known DL architecture = convolutional (CNN)
  - CNN only works on regular grid (e.g. images)
  - GNN allows pattern recognition over irregular geometry
- Paper on prototype model published in February [1]
- Real-life application to HGCal under development
- Will present at NeurIPS '19

[1] Qasim et al. 1902.07987
HGCal trigger development

• Lower activity level than planned; prioritized physics analysis
• Also explored GNN application in this context
• Problem: running high-level machine learning inference at level-1 trigger → FPGA implementation of neural networks
• HLS4ML [1] framework allows translating neural network architectures specified in python into FPGA firmware
• GNN not supported yet, helping expand

[1] Duarte et al. 1804.06913
Prospects for the next year

- Winter & spring: complete $H \rightarrow \gamma \gamma_D$ and EWK $\gamma jj$ analyses
- Continue with more Higgs exotics analyses
- Publish $H \rightarrow WW$ differential measurement paper in spring
  - Another paper planned for later in the year with more observables and interpretations
- SUSY photons subconvenership through end of August
- HGCal trigger
  - Continue the current GNN investigation
  - Also perform more "grounded" studies: algorithm tuning, calibration, etc.
Summary

• Work load distribution and timespan of projects somewhat diverged from original plan
  • HWW took longer with higher level of required commitment
  • Additional analysis involvements and responsibilities
• Nevertheless, first year has been fruitful
  • Most importantly, acquired many new skills
• Would like to have more physics output in the second year