REPORT ON THE APC/SJTU PROJECT

TOM FOURNIER

APC, CNRS/IN2P3

GROUP COMPOSITION

French group			Chinese group		
Name	Title	Affiliation	Name	Title	Affiliation
Gregorio Bernardi	DR CNRS	APC	Haijun Yang	Professor	SJTU
Giovanni Marchiori	DR CNRS	APC	Liang Li	Professor	SJTU
			Kun Liu	Associate Professor	TDLI/SJTU
Alexis Maloizel	PhD	CNRS/IN2P3, UPC	Cen Mo	PhD	SJTU
Tom Fournier	PhD	CNRS/IN2P3, UPC	Dian Yu	PhD	SJTU

THESIS SUMMARY

Search for double-Higgs boson production in the $b\bar{b}\tau^+\tau^-$ final state for the measurement of the Higgs boson self-coupling and prospects for Higgs boson coupling studies to quarks and gluons at future colliders

Alexis Maloizel (CNRS, 2023-2026)
Supervisor: Giovanni Marchiori

ATLAS

- Contributed on the fit studies
- Contributed on the systematic uncertainties' implementation

FCC

- Worked on the Higgs coupling to quarks and gluons measurement at FCC-ee
- Completed and improved the existing analysis

Will defend his thesis in next October

FCC ANALYSIS SUMMARY

Measure the Higgs coupling at FCC-ee for $e^+e^- \to ZH(\to jj)$:

- $Z(\to \ell^+\ell^-)$, $Z(\to \nu\bar{\nu})$ and $Z(\to q\bar{q})$
- Measurement made at $240\ GeV$ and $365\ GeV$

Recoil mass method used for $Z(\to \ell^+\ell^-)$ and $Z(\to \nu\bar{\nu})$ channels

- $m^2_{recoil} = s + 2E_{\ell^+\ell^-}\sqrt{s} + m^2_{\ell^+\ell^-}$ for $Z(\to \ell^+\ell^-)$
- $m^2_{recoil} = m^2_{\nu\bar{\nu}} = s - 2E_{jj}\sqrt{s} + m^2_{jj}$ for $Z(\to \nu\bar{\nu})$

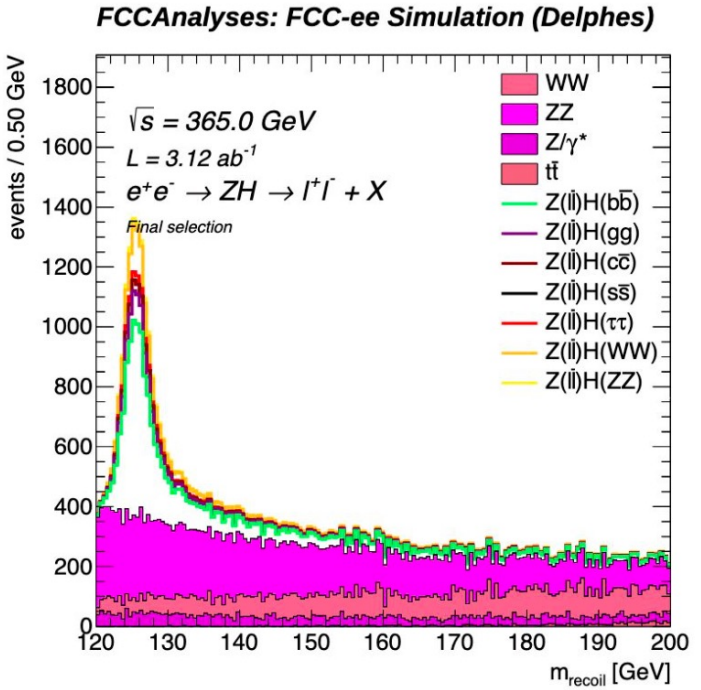
χ^2 based pairing used for $Z(\to q\bar{q})$ depending on jet-tagger score

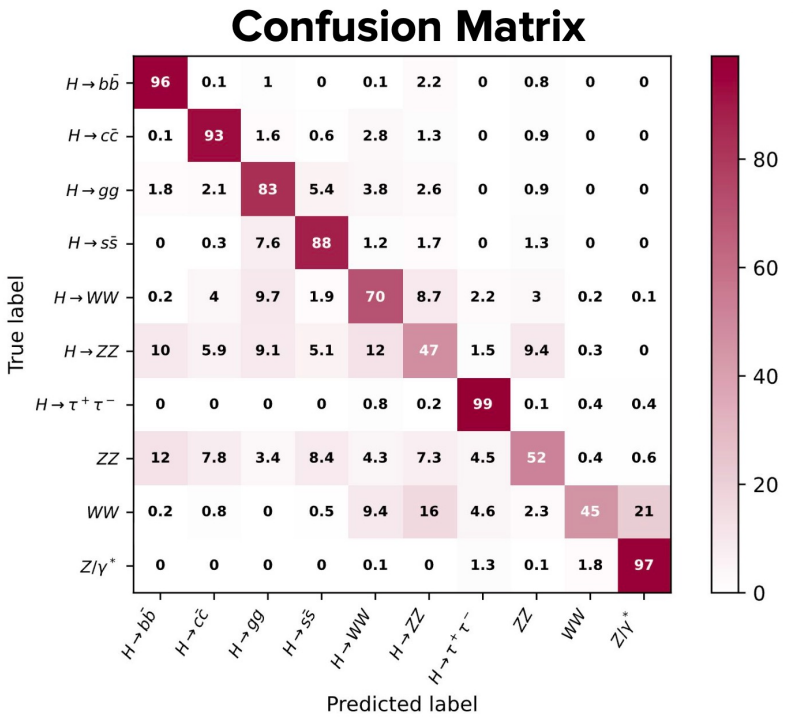
Additional kinematic cuts

- Used to further remove background
- Channel specific cuts
- Also ensure orthogonality between the channels

Neural network used to categorize the Higgs decays

- To separate the Higgs decays
- Also to define control regions





RESULTS

- Monte Carlo stats uncertainties included
- %-level precision on several Higgs decays

$H \to WW^*, ZZ^*, \tau^+\tau^-$ are byproduct of the analysis, dedicated analysis give better precisions

Expected sensitivity (%) of $\sigma_{ZH} \times \mathcal{B}(H \to jj)$ at 68% CL

$\sqrt{s} = 240\ GeV$ $\mathcal{L} = 10.8\ ab^{-1}$		$H \to b\bar{b}$	$H \to c\bar{c}$	$H \to gg$	$H \to s\bar{s}$	$H \to ZZ^*$	$H \to WW^*$	$H \to \tau^+\tau^-$
Combined	**ZH**	0.21%	1.17%	0.85%	110%	6.3%	0.96%	2.45%
	VBF	1.9%	19%	5.50%	990%	130%	15.6%	∞
$\sqrt{s} = 365\ GeV$ $\mathcal{L} = 3.12\ ab^{-1}$		$H \to b\bar{b}$	$H \to c\bar{c}$	$H \to gg$	$H \to s\bar{s}$	$H \to ZZ^*$	$H \to WW^*$	$H \to \tau^+\tau^-$
Combined	**ZH**	0.38%	2.9%	2.1%	350%	26.0%	3.18%	11.0%
	VBF	0.66%	3.4%	2.6%	280%	37.1%	5.36%	24.2%

More details there: arXiv:2511.23149

THESIS SUMMARY

Cen Mo (CSC, 2021-2026)

Supervisors: Liang Li, Gregorio Bernardi

Di-Higgs $b\bar{b}\tau^+\tau^-$:

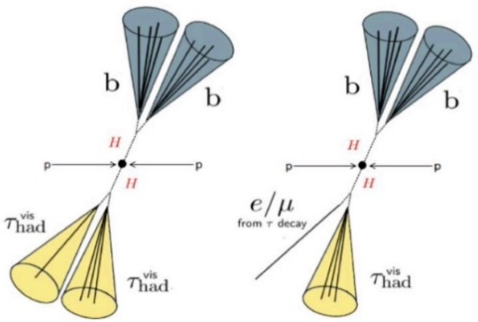
- Contributed to the full analysis chain
- Contributed in the MVA studies
- Also made contributions in the fit studies

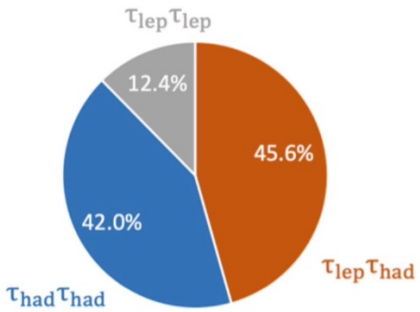
Should defend his thesis at the end of the year

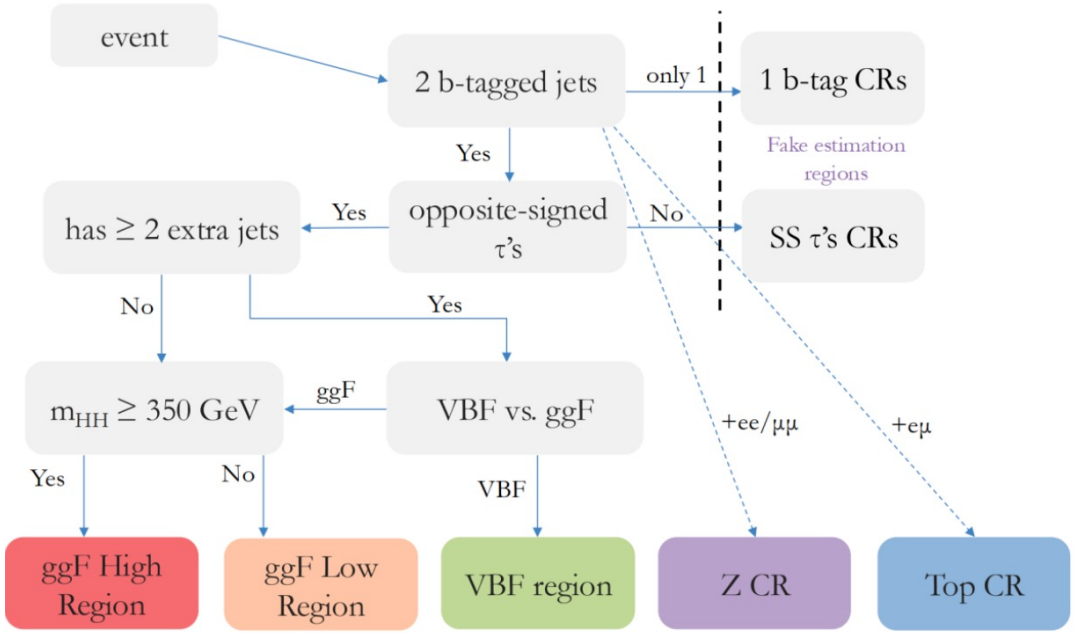
$b\bar{b}\tau^+\tau^-$ ANALYSIS SUMMARY

Analysis separated in 2 channel depending on τ decay:

- $\tau_{lep}\tau_{had}$ for semi-leptonic decay
- $\tau_{had}\tau_{had}$ for fully hadronic decay

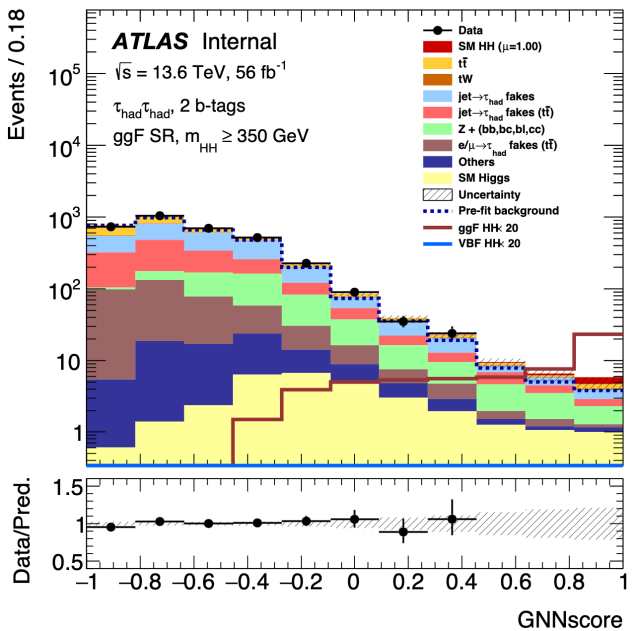






Upgrades since Run 2 analysis:

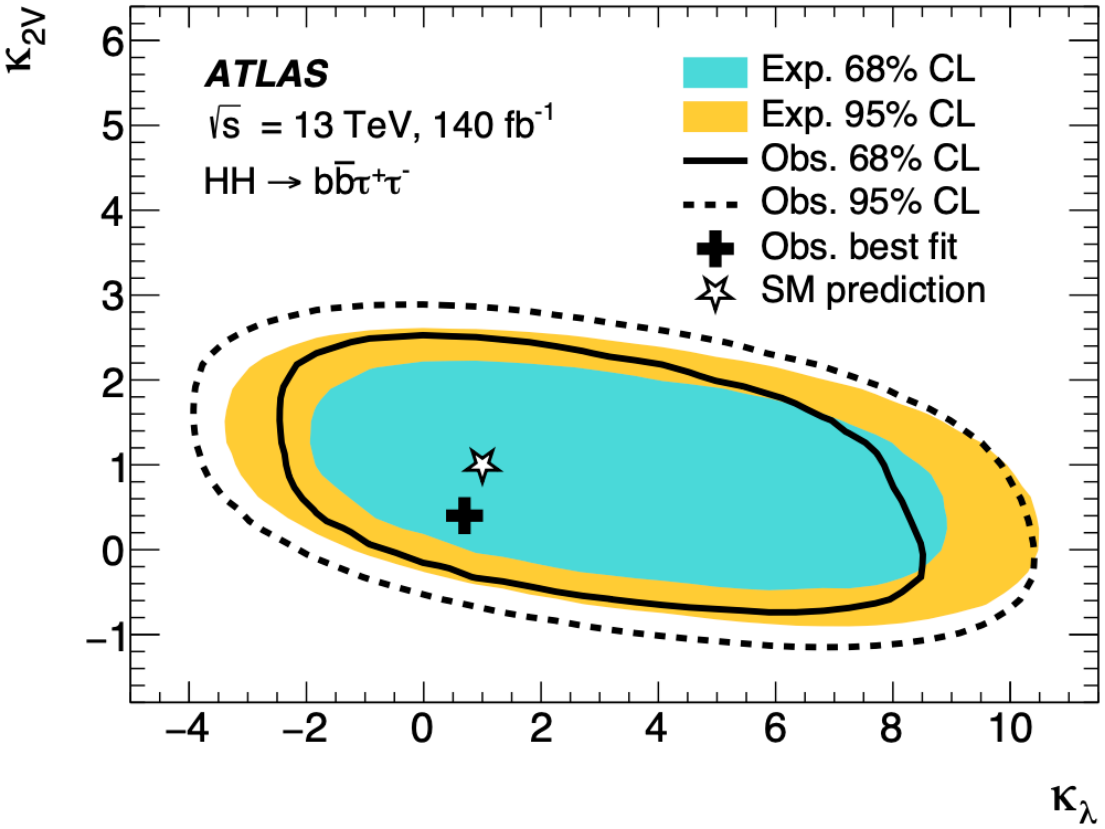
- Increased statistics (data from Run 3)
- New triggers added
- Better b-tagging (DL1r → GN2)
- New control region for tW process
- New MVA strategy (BDT → Graph-Transformer classifier)
- Validation measurements
  - Measure the signal strength for ZZ and ZH production



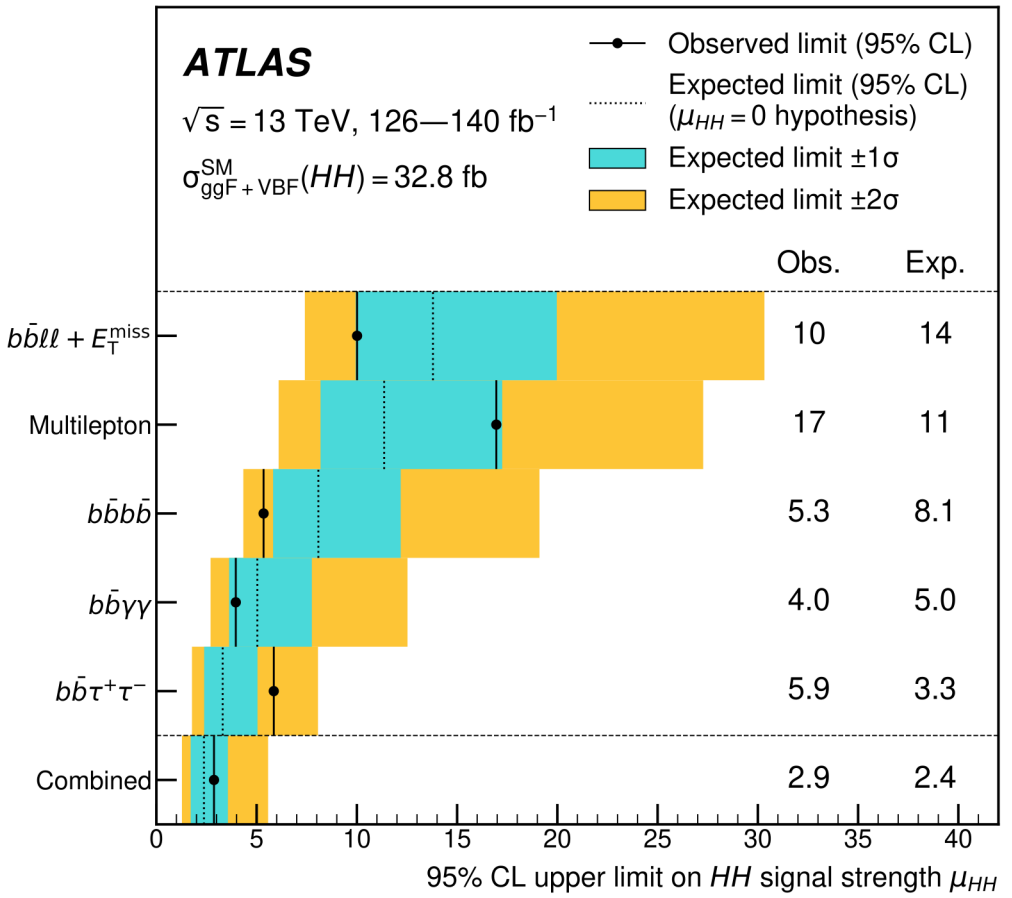
RESULTS

Status of the analysis:

- Analysis still in progress
- Not ready for the public yet



ATLAS combined result (Run 2)



THESIS SUMMARY

Di-Higgs production using the ATLAS Run 3 data and R&D for FCC-ee

Dian Yu (CSC, 2024-2029)
Supervisors: Kun Liu, Giovanni Marchiori
Stay in Paris: 01/2026-12/2027

ATLAS:

- Contribute in the $b\bar{b}\gamma\gamma$ channel of the di-Higgs analysis
- Study GN2 and GN3 b-tagging algorithms
- Development of Transformer-based event categorization (to replace BDT)

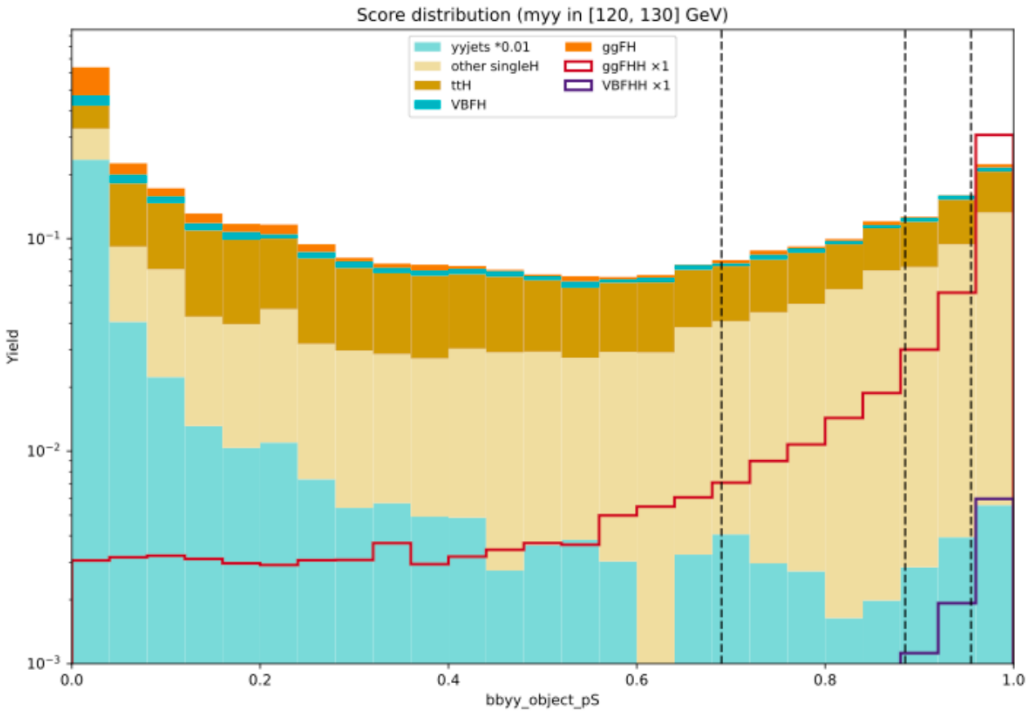
CEPC

- Worked on particle identification using dN/dx and TOF information
- Significant improvement in K/π and K/p separation performance

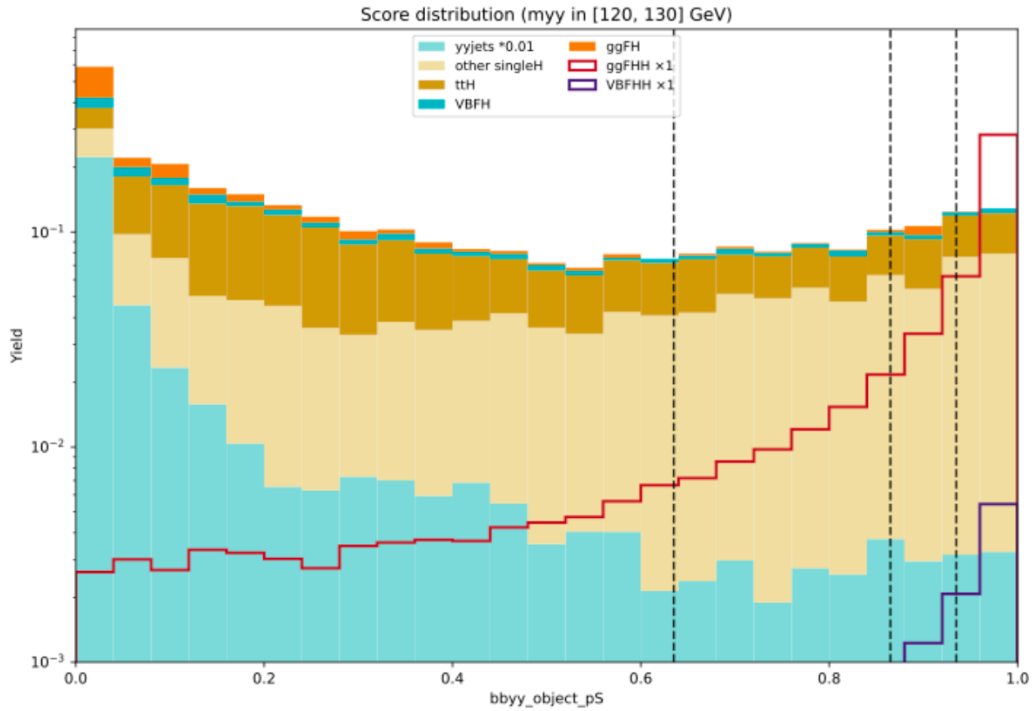
FCC

- Working on ML-based particle reconstruction
- ECAL geometry optimization and detector performance

A RESULT



MVA score without aux task



MVA score with aux task

Use a transformer to do event categorization in the $m_{HH} > 350\ GeV$ signal region

- Introducing an auxiliary task during the training
- Suppress background in high score region while leaving signal unchanged
- Improve significance by 4.94%

THESIS SUMMARY

Search for double Higgs production for the Higgs self-coupling measurement, and prospects for the Higgs mass and self-coupling measurement at FCC-ee

Tom Fournier (CNRS, 2025-2028)
Supervisor: Gregorio Bernardi

ATLAS

- Will contribute in the $b\bar{b}\tau^{+}\tau^{-}$ analysis
- Will start contributing after finishing the qualification task

FCC

- Work on the ZH production cross-section measurement and the Higgs mass measurement at FCC-ee
- Improved a part of the cross-section analysis, working on improving the rest
- Starting to implement the Higgs mass measurement
- Plan to redo both analysis with full simulation

ZH ANALYSIS SUMMARY

Measure ZH production cross-section at FCC-ee for 240 GeV and 365 GeV

- Important to have access to most of the Higgs properties (g_{HXX}, Γ_H, m_H, κ_λ)
- Essential to measure it at 240 GeV and 365 GeV for κ_λ measurement

Use the recoil mass method to reconstruct the Higgs

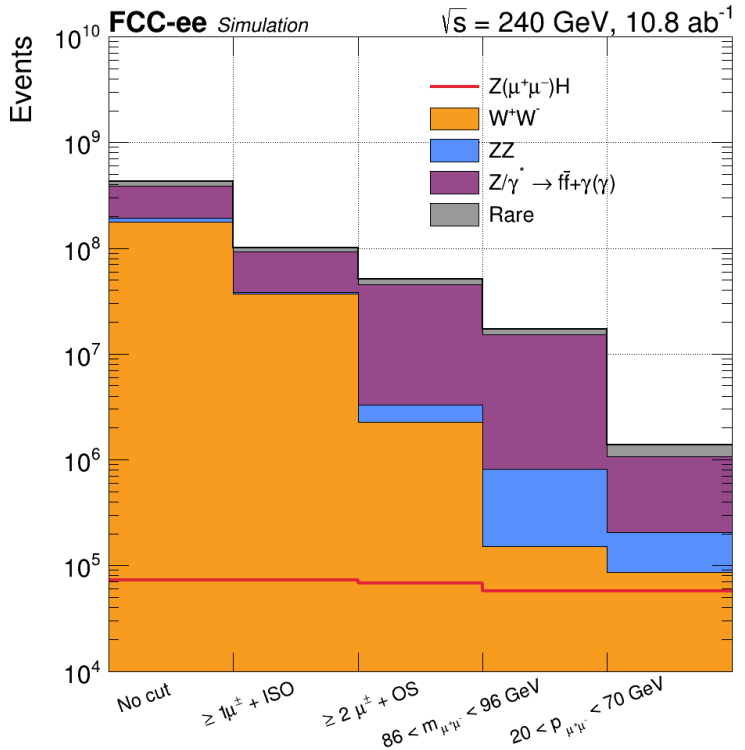
- $m^2_{recoil} = s - 2E_{f\bar{f}}\sqrt{s} + m^2_{f\bar{f}}$
- Give access to model-independent measurement

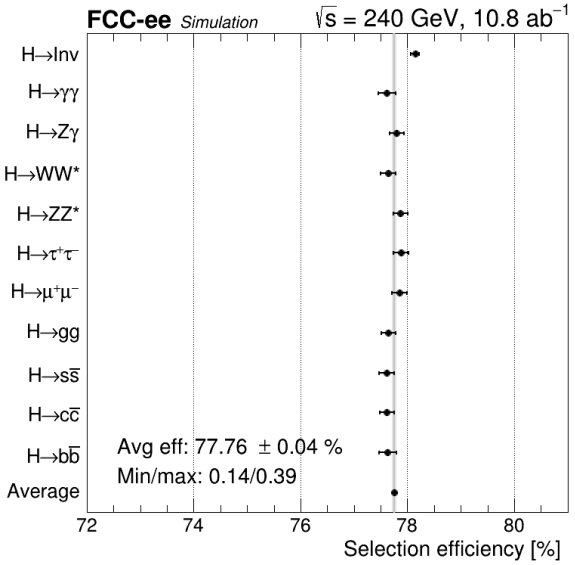
Analysis done in 3 channels

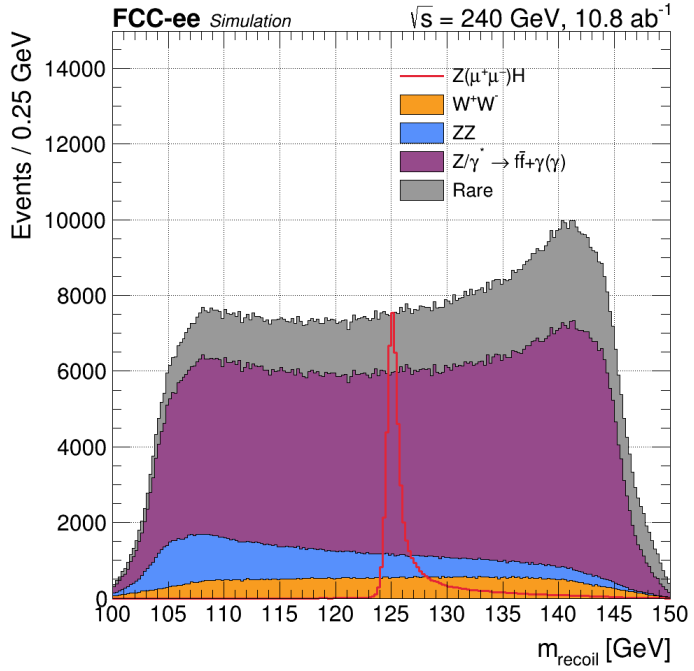
- $Z(\rightarrow e^+e^-)$, $Z(\rightarrow \mu^+\mu^-) \rightarrow$ leptonic channel $Z(\rightarrow \ell^+\ell^-)$
- $Z(q\bar{q}) \rightarrow$ hadronic channel

Analysis structure

- Determine the $f\bar{f}$ pair to reconstruct the Z
- Reconstruct the Higgs with the recoil mass method
- Do some kinematic cuts to remove background
- Use a BDT to categorize events
- Fit the m_{recoil} in 2 bins of the BDT distribution



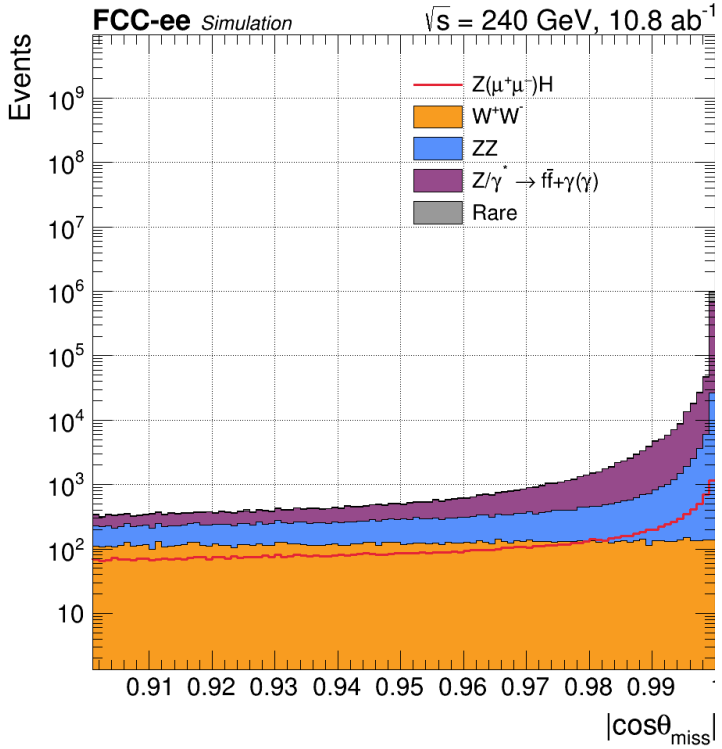


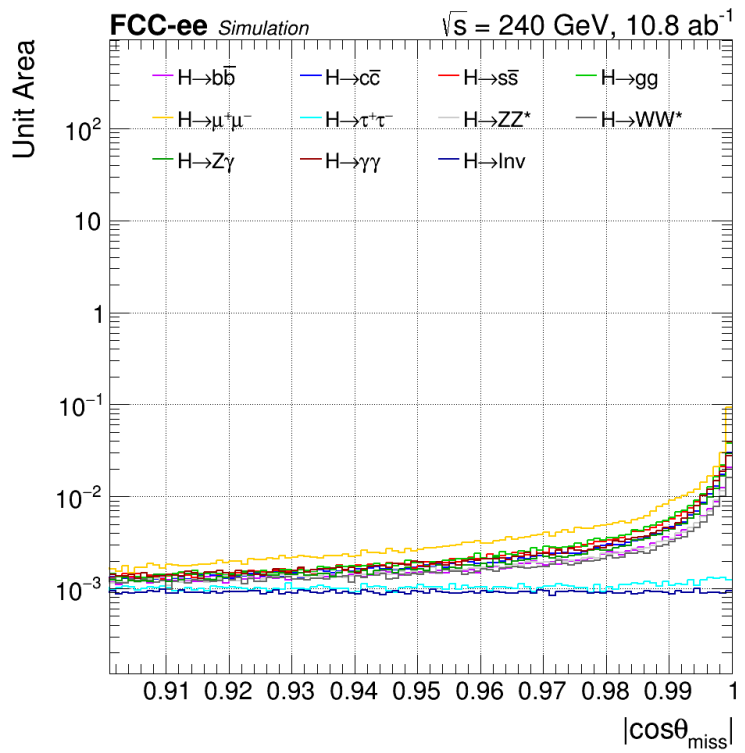


RESULTS

Improved the current measurement for the leptonic channel

- Used $\cos\theta_{miss}$ variable to remove background
- Did it while keeping model-independence





Improved the current selection for the leptonic channel for both energies

Channel	$\Delta\sigma_{ZH}, 240\ GeV$			$\Delta\sigma_{ZH}, 365\ GeV$		
	Baseline	New selection	Improvement	Baseline	New selection	Improvement
$Z(\rightarrow e^+e^-)H$	0.79%	0.58%	**26.6%**	1.89%	1.47%	**22.2%**
$Z(\rightarrow \mu^+\mu^-)H$	0.68%	0.57%	**16,2%**	1.77%	1.46%	**17.5%**
$Z(\rightarrow \ell^+\ell^-)H$	0.52%	0.41%	**21.2%**	1.31%	1.05%	**19.8%**

CONCLUSION

- APC-SJTU collaboration is producing a great amount of results
- Still get some difficulties for visa deliveries (Cen)
  - Fortunately, Dian had no problem to get one
- Producing good results on ATLAS di-Higgs studies
- SJTU is starting to make contributions on FCC-ee studies (Dian)