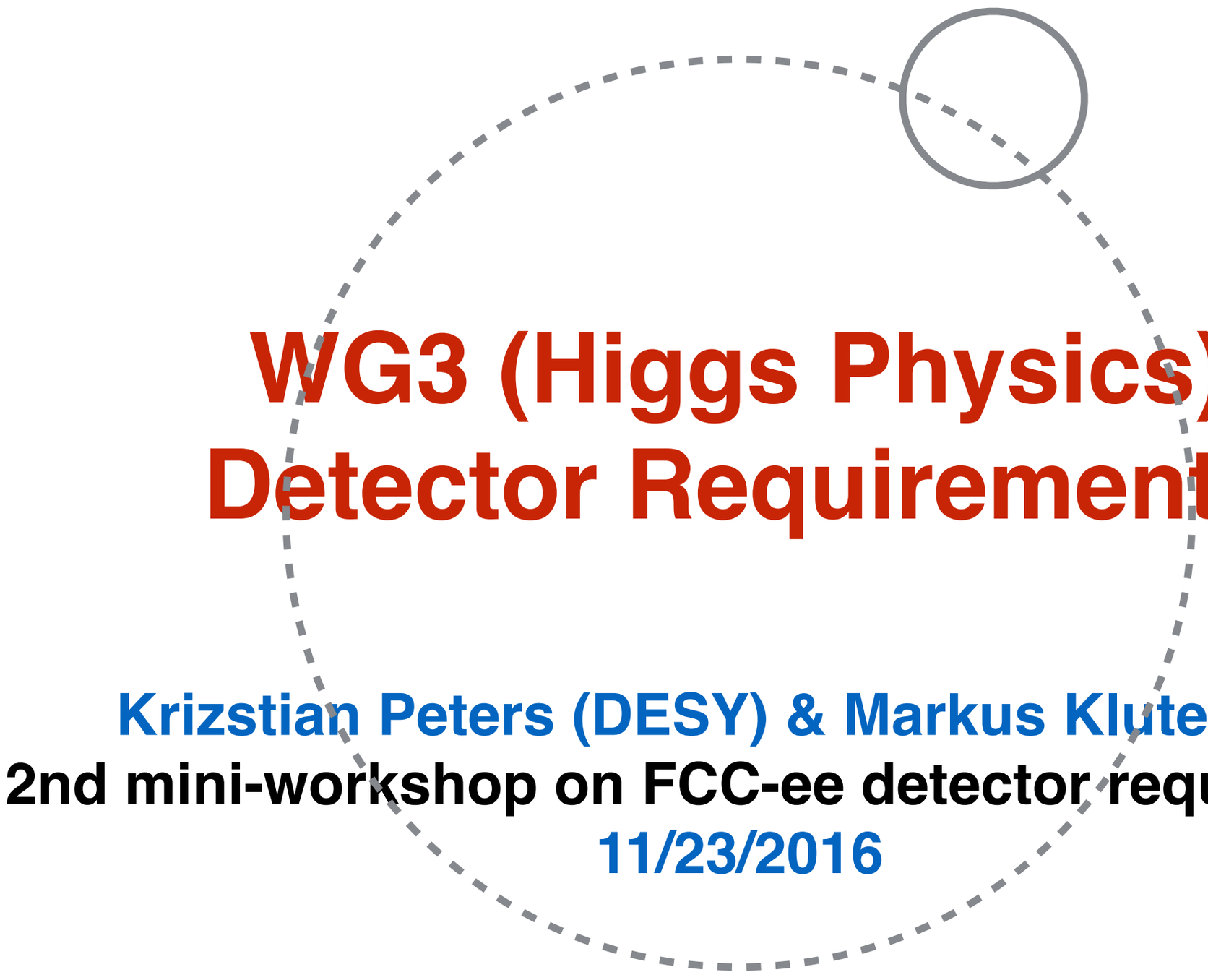


WG3 (Higgs Physics) Detector Requirements

Krizstian Peters (DESY) & Markus Klute (MIT)

2nd mini-workshop on FCC-ee detector requirements

11/23/2016

Introduction

- Request by Gigi, Ariella, and Mogens: Physics motivation for
  - muon momentum resolution dp/p = 4-2-1x10^{-3}
  - jet resolution 50, 30, and 20%
  - photon separation for tau identification
  - how important is H→$\gamma\gamma$?
  - is PID for charm tagging important?
- Selected a subset of Higgs analysis and analyzed impact of detector performance parameters on measurements
- The following is still work in progress

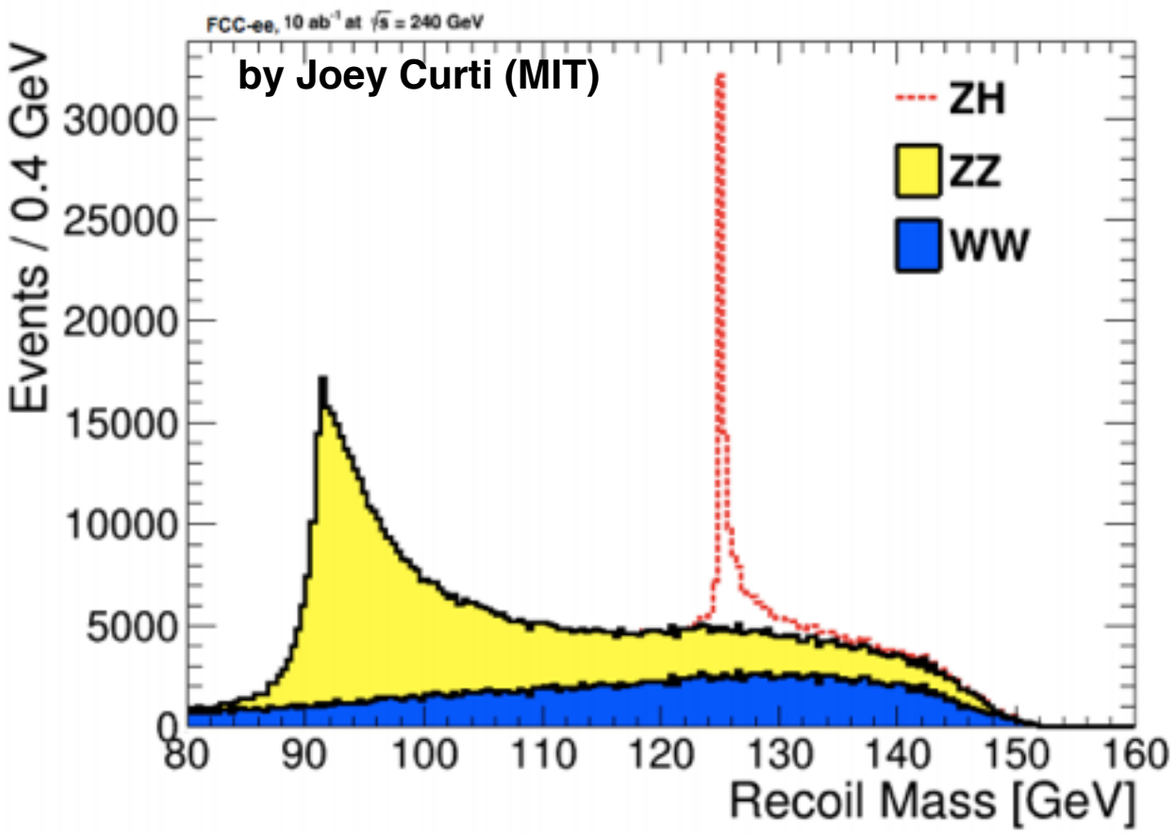
ZH Cross Section

- Key FCC-ee Higgs analysis
  - Sister analysis looking for Higgs to invisible decays
- Selecting two leptons, electrons or muons of opposite charge
- Previously investigated by Gigi et al (arXiv:1605.00100)
- Studied impact of electron and muon resolution
- Parametrizations under study

$$\frac{\Delta E}{E} = 0.011 + A * \frac{0.166}{\sqrt{E}}, \text{ for } |\eta| \leq 2.4$$

$$\frac{\Delta P}{P} = 0.001 + B * \frac{P_T}{10^5}, \text{ for } |\eta| \leq 2.4$$

  - Also removed constant terms



ZH Cross Section

- ➡ Analysis can further be optimized (not the point here)
- ➡ Within the range of the variation of detector parameter, we do not observe changes in analysis performance
  - ◉ results needs further study

Modified Parameter	1x	2x	4x	Constant Removed
ZH Electron	0.47%	0.45%	0.48%	0.48%
ZH Muon	0.47%	0.47%	0.48%	0.48%
H to inv Electron	0.34%	0.34%	0.34%	≤0.34%*
H to inv Muon	0.34%	0.34%	0.34%	≤0.34%*

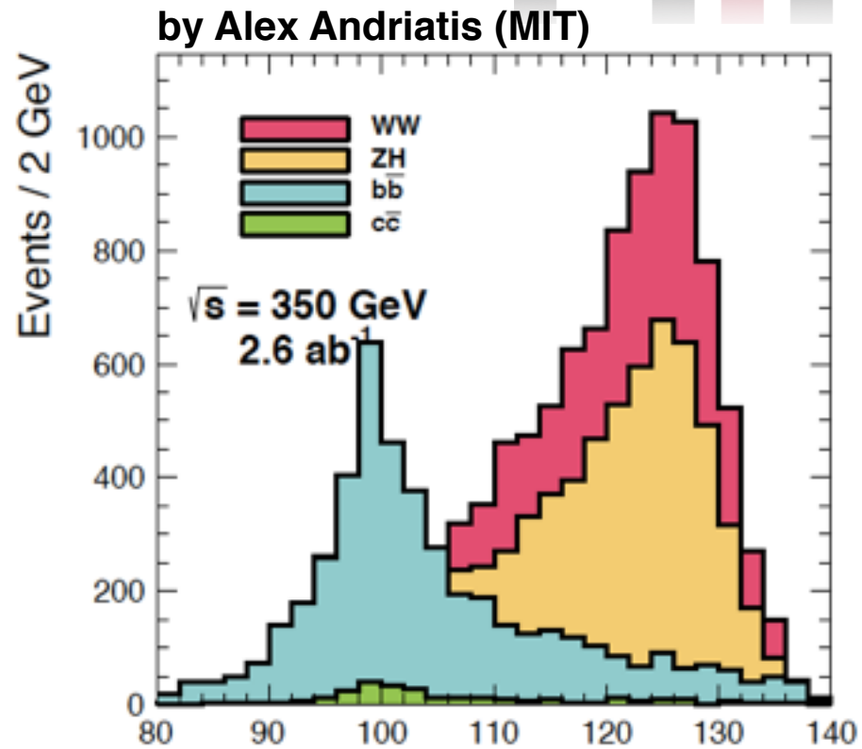
$$\frac{\Delta E}{E} = 0.011 + A^* \frac{0.166}{\sqrt{E}}, \text{ for } |\eta| \leq 2.4$$

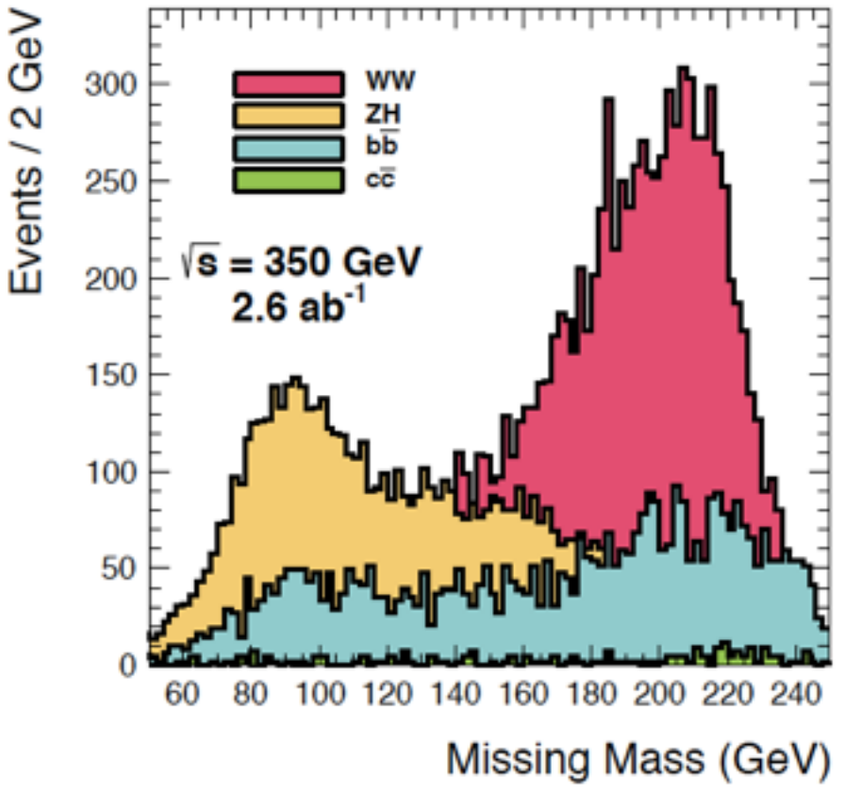
$$\frac{\Delta P}{P} = 0.001 + B^* \frac{P_T}{10^5}, \text{ for } |\eta| \leq 2.4$$

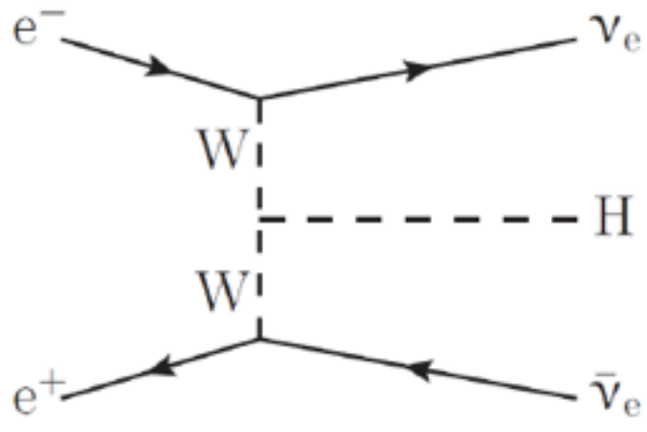
*) investigating some issues with fits

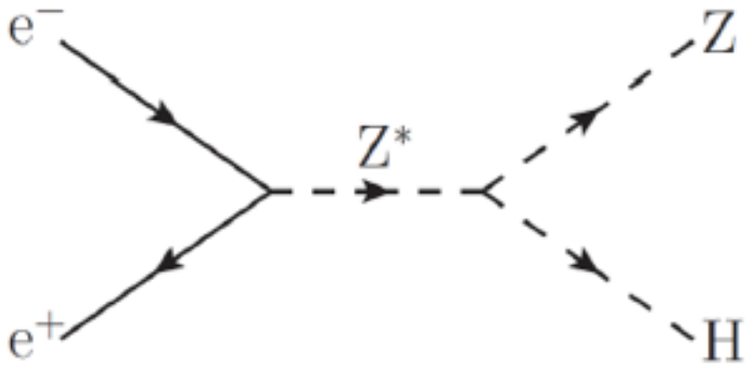
WW and bb coupling

- Investigating vvbb final state
- Di-jet mass and missing mass are discriminating variable
- Checking impact of
  - jet resolution
  - calorimeter performance
  - jet reconstruction algorithm
  - (charm and gluon tagging capabilities)
- Results of this work will be available in January









Higgs CP Study

- Use H→$\tau\tau$ events to study small contribution from pseudoscalar component
- Model using effective Lagrangian

$$\mathcal{L}_{hff} \propto h\bar{f}(\cos\Delta + i\gamma_5 \sin\Delta)f$$

- Exploring tau spin correlation to measure CP phase
- Several ee and pp collider studies available
  - e.g. [arXiv:hep-ph/0305082], [arXiv:hep-ph/0204292], [arXiv:hep-ph/0302046], [arXiv:0812.1910]
- Following [arxiv:1308:1094] which shows that Θ is most sensitive variable
- Exploring $\tau^{\pm} \longrightarrow \rho^{\pm}\nu_{\tau} \longrightarrow \pi^{\pm}\pi^{0}\nu_{\tau}$

Higgs CP Study

➡ Reproduced previous generator level study

$\sigma_{e^+e^- \to hZ}$	0.30 pb
$\mathrm{Br}(h \to \tau^+\tau^-)$	6.1%
$\mathrm{Br}(\tau^- \to \pi^-\pi^0\nu)$	26%
$\mathrm{Br}(Z \to \text{visibles})$	80%
$\mathrm{N_{events}}$	990
Accuracy	4.4°

ee collider
$\sqrt{s} = 250$ GeV
$\mathcal{L} = 1\text{ab}^{-1}$

[arxiv:1308:1094]

➡ Study is including detector effects and background contributions

➡ Using ILC-like and CMS-like detector with Delphes

Higgs CP Study

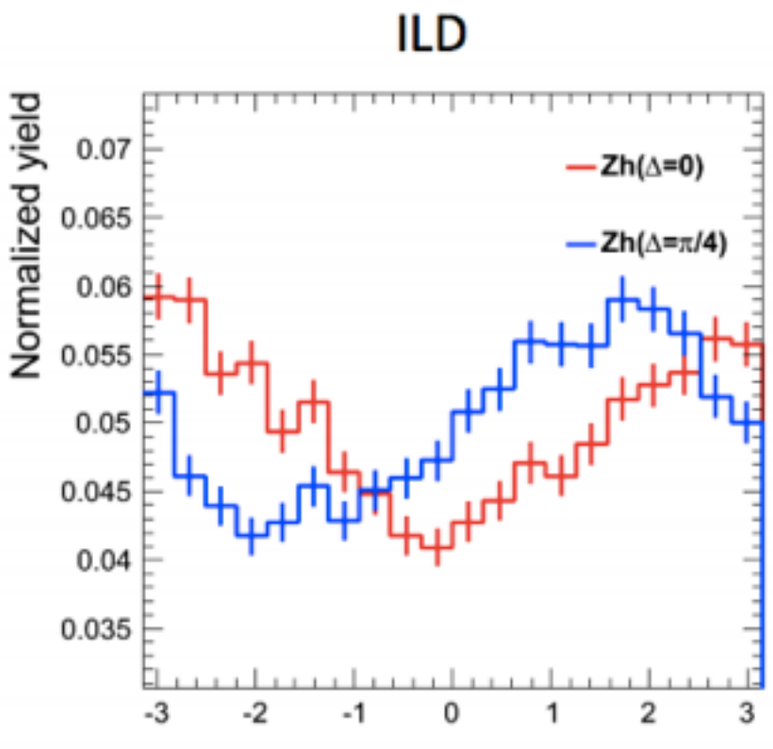
Table I: Cut-flow for Zh events and main backgrounds with the ILC detector and a luminosity of 10 ab^{-1}.

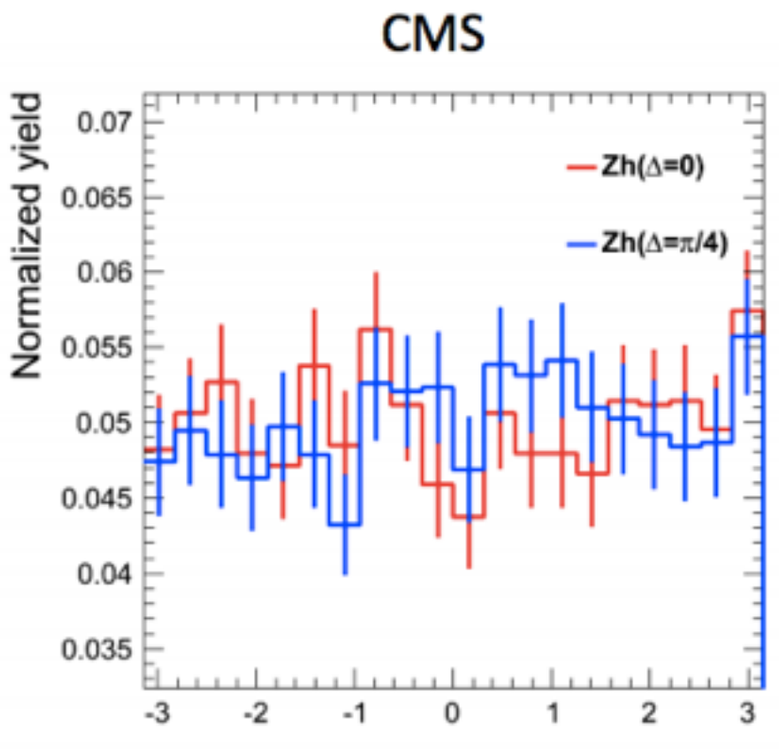
Requirement	Leptonic		Hadronic	
	$Zh \to Z\tau^+\tau^-$	Zll^a	$Zh \to Z\tau^+\tau^-$	Zll^a
Object selection	266 ± 6	4506 ± 25	3907 ± 24	19751 ± 370
Mass cuts	197 ± 5	139 ± 31	1995 ± 17	724 ± 71
Kinematic cuts	191 ± 5	14.9 ± 9.8	1494 ± 15	20.9 ± 12.0

[a]ZZ and Zh events are excluded here.

Table II: Same as Table I for CMS detector.

Requirement	Leptonic	Hadronic
	$Zh \to Z\tau^+\tau^-$	$Zh \to Z\tau^+\tau^-$
Object selection	101 ± 4	2016 ± 17
Mass cuts	68.8 ± 3.2	545 ± 9
Kinematic cuts	63.3 ± 3.1	223 ± 6

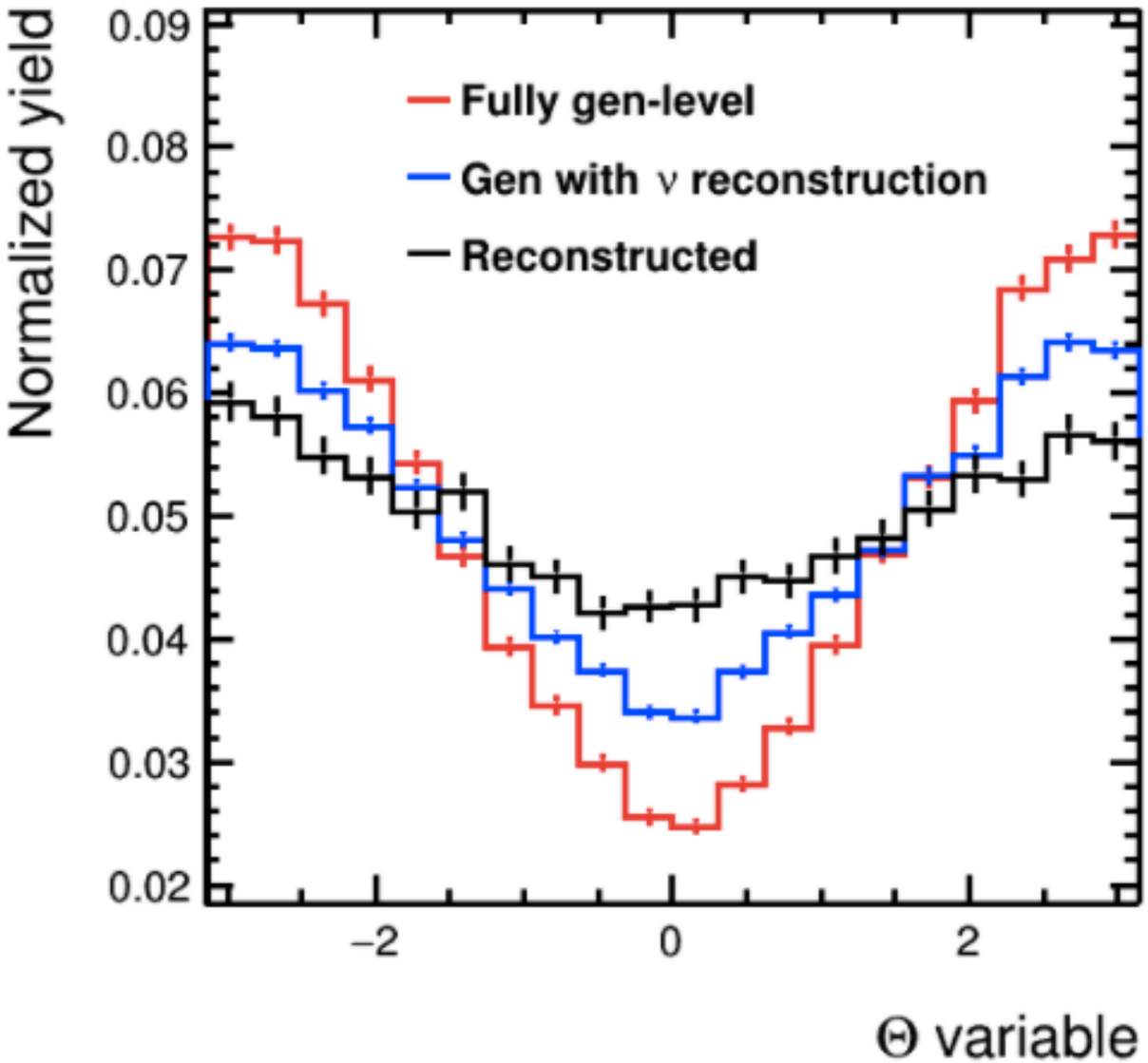




by Andres Rios (MIT)

Higgs CP Study

- ➡ Detector performance has large impact on analysis performance
  - for 1ab^{-1} we see 22.7 compared to 4.4 degree
  - impact on selection efficiency and performance of Θ variable
- ➡ Mass resolution is leading effect, follow by tau selection
- ➡ Work in progress to map this to detector performance



Higgs to Photons

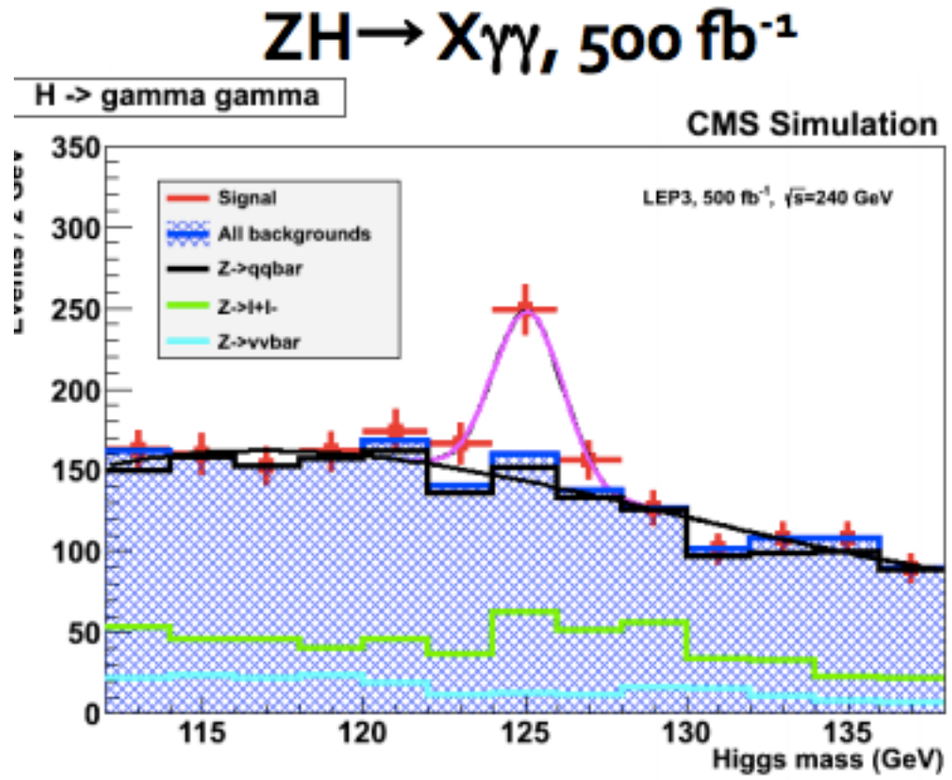
Uncertainties	HL-LHC*	μ-	CLIC	ILC**	CEPC	FCC-ee
m_H [MeV]	40	**0.06**	40	30	5.5	8
Γ_H [MeV]	-	0.17	0.16	0.16	0.12	**0.04**
g_{HZZ} [%]	2.0	-	1.0	0.6	0.25	**0.15**
g_{HWW} [%]	2.0	2.2	1.0	0.8	1.2	**0.2**
g_{Hbb} [%]	4.0	2.3	1.0	1.5	1.3	**0.4**
$g_{H\tau\tau}$ [%]	2.0	5	2.0	1.9	1.4	**0.5**
$g_{H\gamma\gamma}$ [%]	2.0	10	6.0	7.8	4.7	**1.5**
g_{Hcc} [%]	-	-	2.0	2.7	1.7	**0.7**
g_{Hgg} [%]	3.0	-	2.0	2.3	1.5	**0.8**
g_{Htt} [%]	**4.0**	-	4.5	18	-	-
$g_{H\mu\mu}$ [%]	4.0	**2.1**	8.0	20	8.6	6.2
g_{HHH} [%]	30	-	**24**	-	-	-

* Estimate for two HL-LHC experiments
** ILC lumi upgrade improves precision by factor 2

For ~10y operation. Lots of "!,*,?"
Every number comes with her own story.

Higgs to Photons

- Precision measurements, beyond the LHC, will be challenging due to low BR
- Results for LEP3 study assuming CMS performance



- Studies just started aiming for results in January (by Kevin Tang (MIT))
  - Similar story for H→μμ (by Aimane Ahmed (Saclay))

Conclusion

- ➡ Studying impact of detector performance on Higgs measurements
- ➡ Guided by requests from Gigi, Ariella, and Morgans
- ➡ Menu includes
  - ➡ ZH cross section
  - ➡ Higgs to invisible decays
    - ➡ vvbb final state
    - ➡ 4-jet channel
    - ➡ CP study with $H \to \tau\tau$
- ➡ Starting with $H \to \gamma\gamma$ and $H \to \mu\mu$
- ➡ Overall status: work in progress