Introduction and Plans for CEPC Higgs physics

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CEPC physics workshop at Peking University

Higgs white paper @ CDR

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Precision Higgs Physics at the CEPC*

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Property	Estimated Precision CEPC-v1	CEPC-v4
m_H	5.9 MeV	5.9 MeV
Γ_H	2.7%	2.8%
$\sigma(ZH)$	0.5%	0.5%
$\sigma(\nu\bar{\nu}H)$	3.0%	3.2%

Decay mode	$\sigma\times$BR	BR	$\sigma\times$BR	BR
$H\to b\bar{b}$	0.26%	0.56%	0.27%	0.56%
$H\to c\bar{c}$	3.1%	3.1%	3.3%	3.3%
$H\to gg$	1.2%	1.3%	1.3%	1.4%
$H\to WW^*$	0.9%	1.1%	1.0%	1.1%
$H\to ZZ^*$	4.9%	5.0%	5.1%	5.1%
$H\to\gamma\gamma$	6.2%	6.2%	6.8%	6.9%
$H\to Z\gamma$	13%	13%	16%	16%
$H\to\tau^+\tau^-$	0.8%	0.9%	0.8%	1.0%
$H\to\mu^+\mu^-$	16%	16%	17%	17%
$\mathrm{BR}_{\mathrm{inv}}^{\mathrm{BSM}}$	–	$<0.28\%$	–	$<0.30\%$

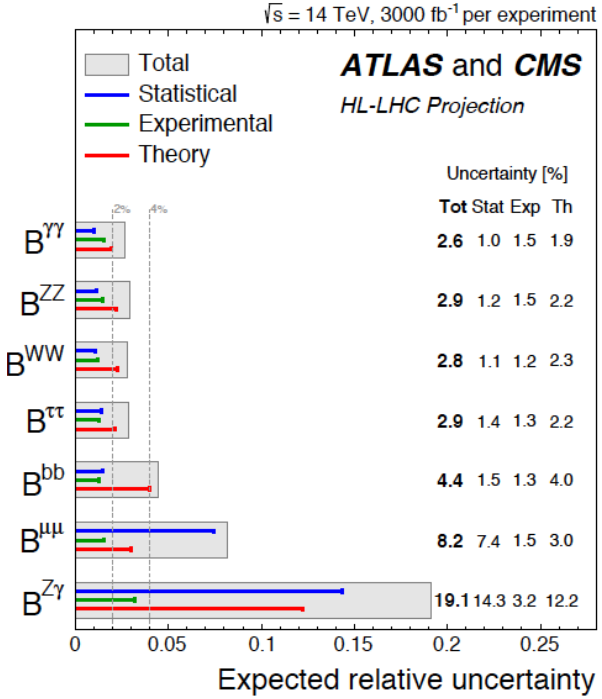
V2 is at arxiv.
CPC : Vol 43, No.4 (2019) 043002

Thanks to those colleagues for great efforts.
Welcome to new colleagues to join in.

Mailing list: cepc-physics@maillist.ihep.ac.cn

Recent news

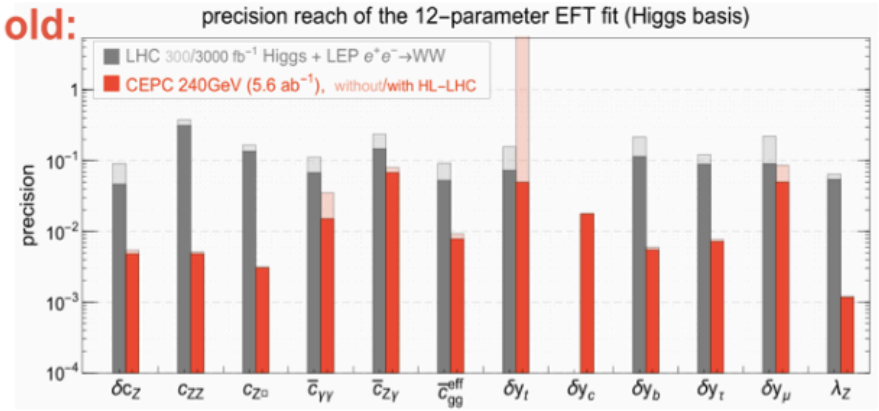
arxiv: [1902.00134](1902.00134)



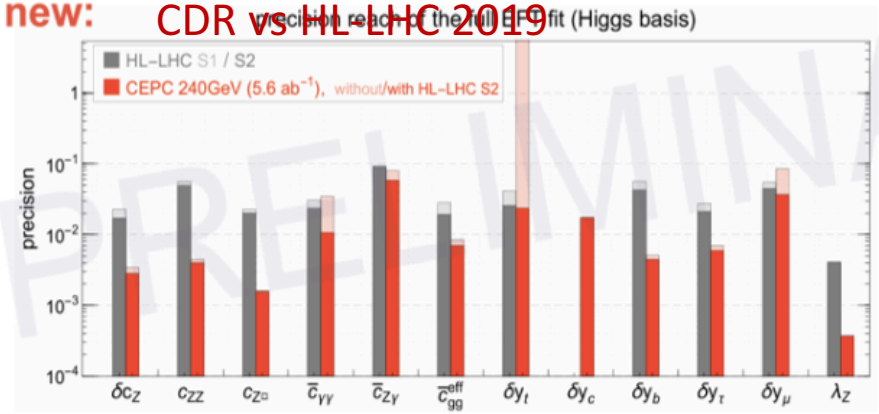
Fcc-ee 240 GeV/365 GeV:
CERN-ACC-2018-0057

$\sqrt{s}$ (GeV)	240		365	
Luminosity (ab^{-1})	5		1.5	
$\delta(\sigma BR)/\sigma BR$ (%)	HZ	$\nu\bar{\nu}$ H	HZ	$\nu\bar{\nu}$ H
$H \to$ any	±0.5		±0.9	
$H \to b\bar{b}$	±0.3	±3.1	±0.5	±0.9
$H \to c\bar{c}$	±2.2		±6.5	±10
$H \to gg$	±1.9		±3.5	±4.5
$H \to W^+W^-$	±1.2		±2.6	±3.0
$H \to ZZ$	±4.4		±12	±10
$H \to \tau\tau$	±0.9		±1.8	±8
$H \to \gamma\gamma$	±9.0		±18	±22
$H \to \mu^+\mu^-$	±19		±40	
$H \to$ invisible	< 0.3		< 0.6	

CDR vs HL-LHC 2014



CDR vs HL-LHC 2019



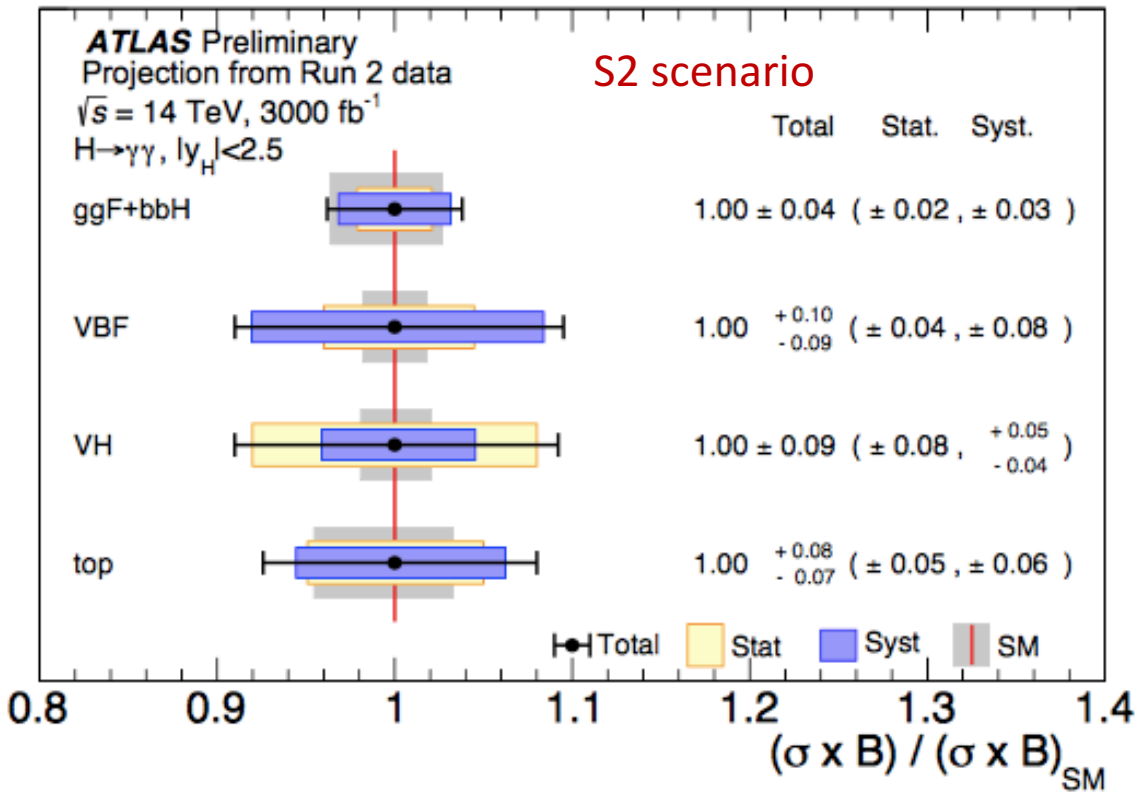
Width: $4.1^{+0.7}_{-0.8}$ MeV.

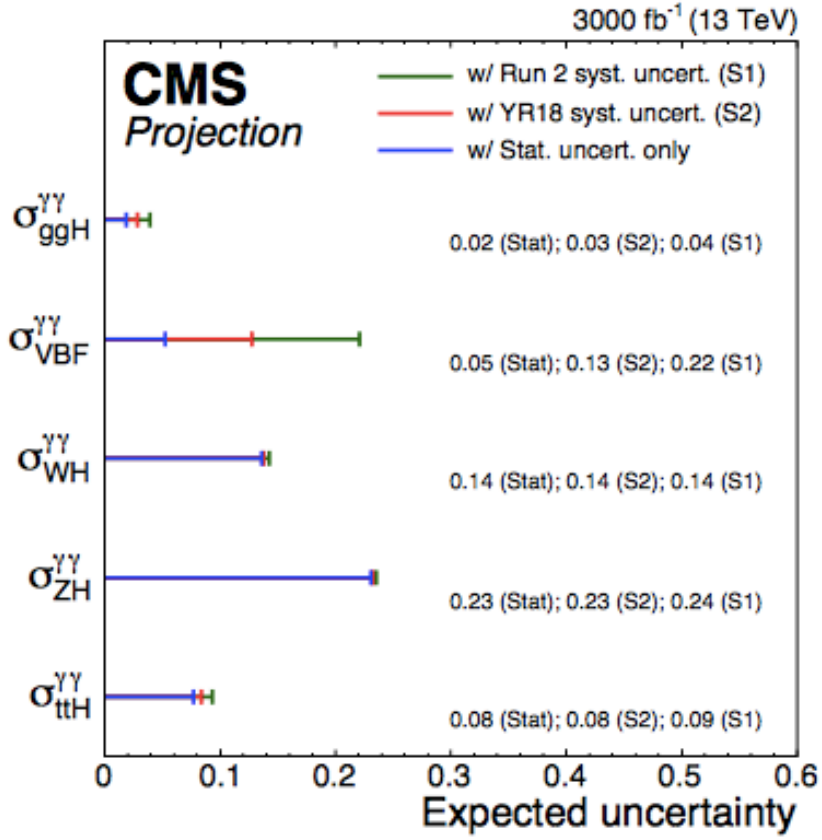
Precision mass of **10-20 MeV plausible**

Width : ~1.3%

- LHC updated their projected results based on current Run 2 studies and possible improvements on uncertainties :
  - theory ½ and experimental systematics 1/sqrt(L) of current ones (check talk at CEPC workshop in Oxford)
- Fcc-ee has similar results as CEPC but including a 365 GeV run improving the measurement of Higgs width.

HL-LHC H->γγ: one example



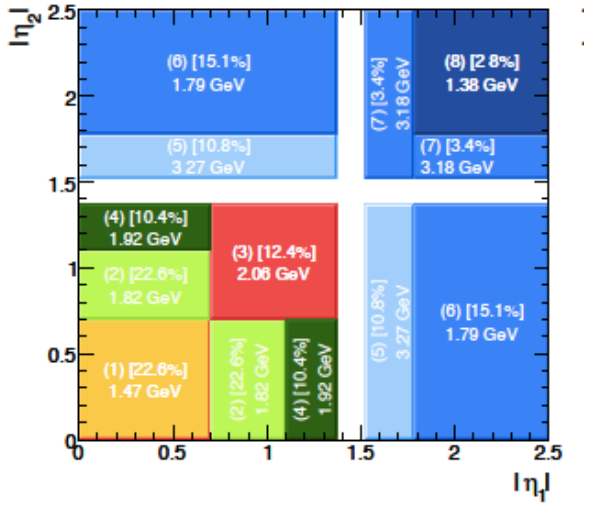


Scenario S1: Total uncertainty is half of the one used for the result of 80 fb^{-1}.
Scenario S2: Total uncertainty is 1/3 of the one for 80 fb^{-1}.

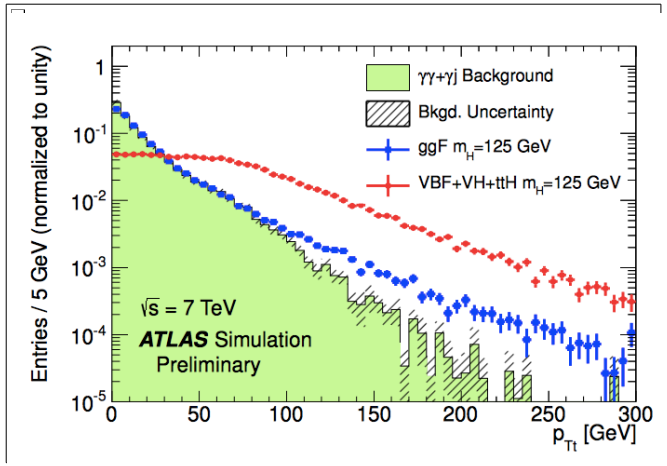
HL-LHC H->γγ: very advanced analyses (example)

- The inclusive analysis is very simple :
  - Photon ID, Isolation, Kinematic cuts on leading/subleading photon.
- Explore other possible improvements ?
  - Divide events into different categories.

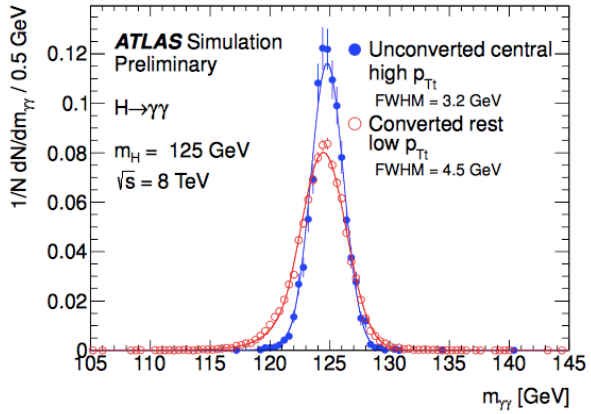
Divide different eta regions for two photons



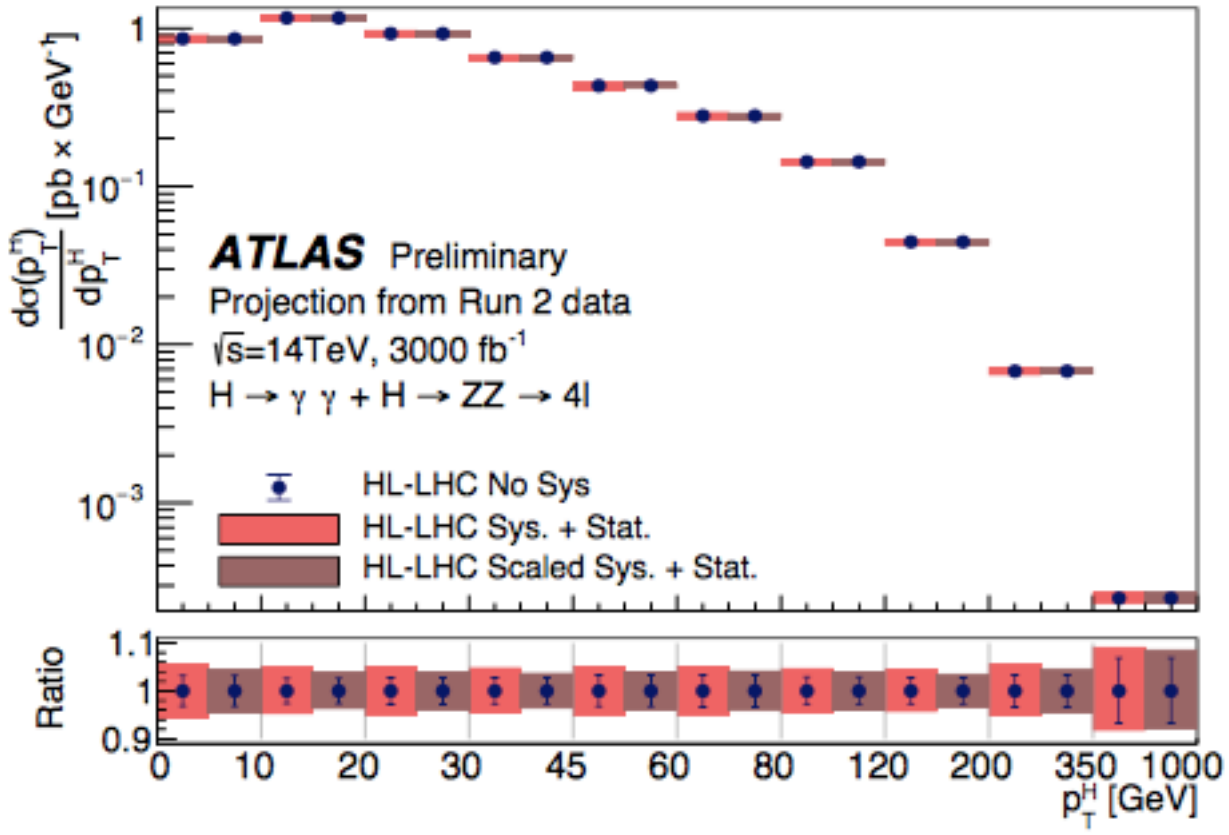
P_T of Higgs (P_{Tt} is perpendicular to the thrust direction of two photon)

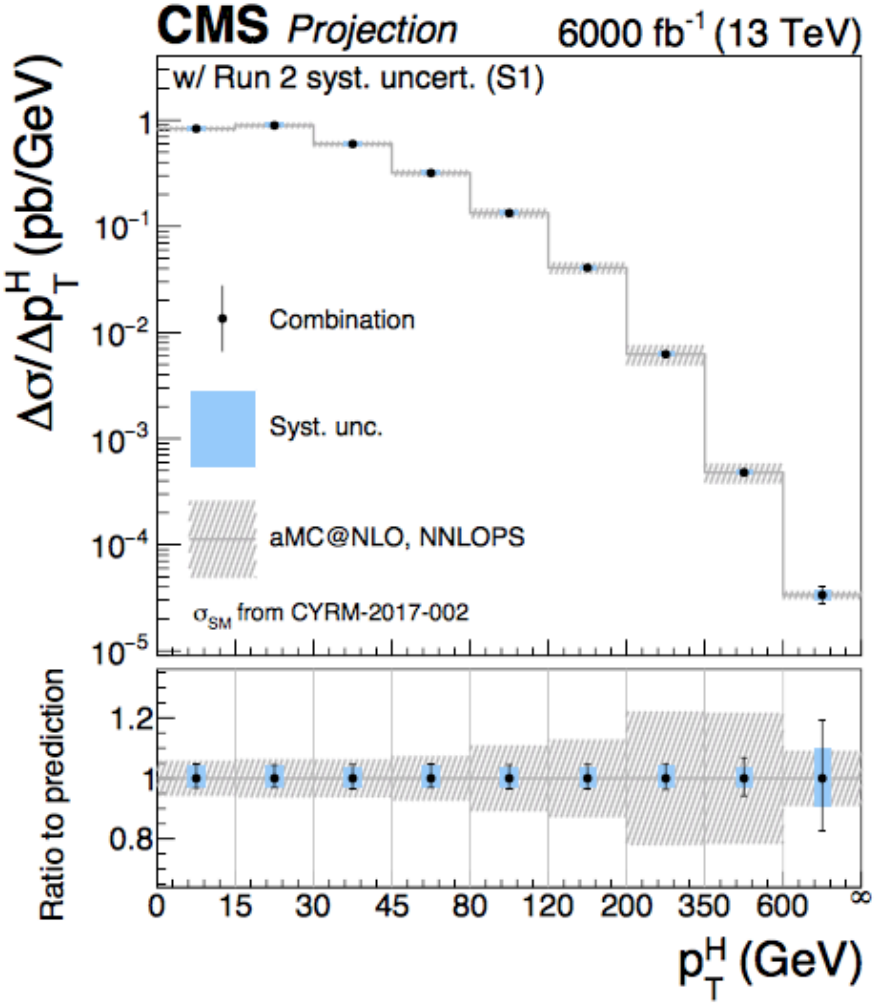


Conversion of the photons



HL-LHC: Differential xsection measurement



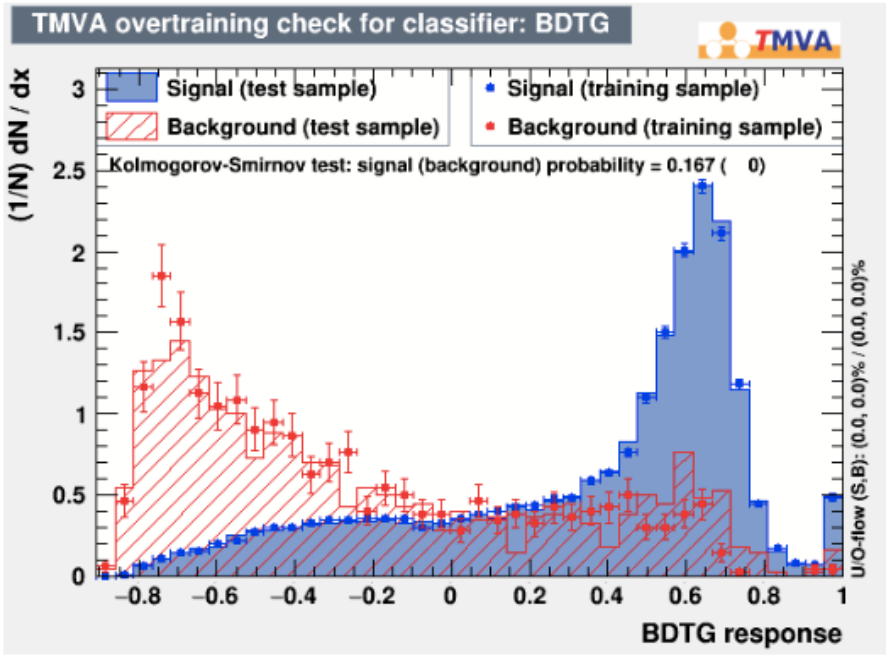


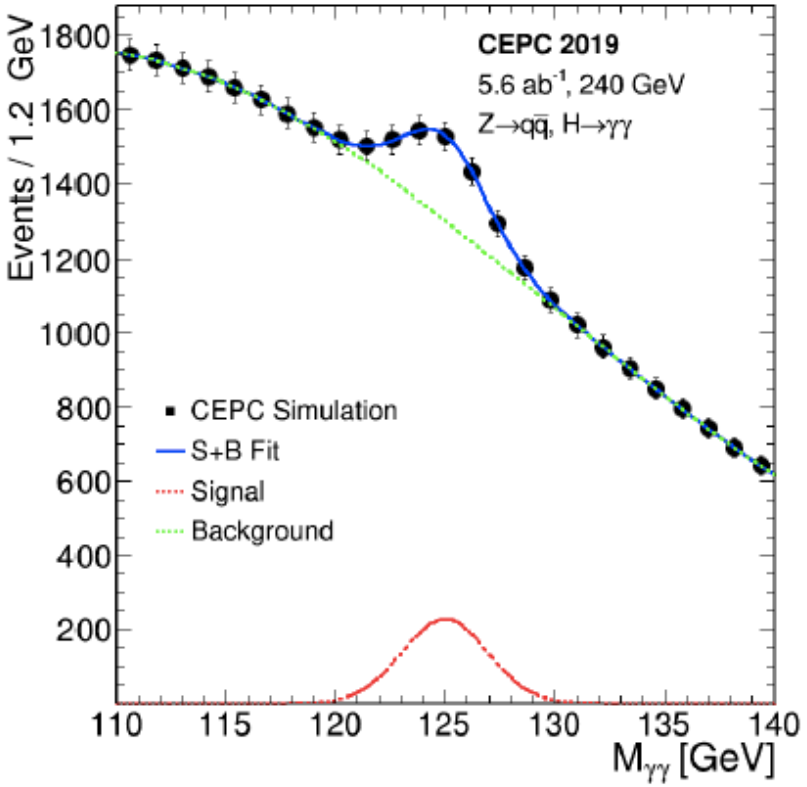
The precision can reach a few percent for different p_T bins.

Plan for CEP Higgs physics

- Improve the analyses with different technologies:
  - MVA, multi-dim fit.
  - Improve the performance b-tagging, photon ID/conversion etc.
  - Test different setup-of the detectors
- Test the analyses with different colliding energy
  - Benchmark : 360 GeV/1.5(2.0) ab^{-1}
  - Improvement of ww fusion on the Higgs width as well as the precision measurement.
  - *ttbar run*
- Differential xsection measurements
  - Start to do that.
- Interpretation on the results
  - Further cooperation with theorists (in particular the domestic theorists)
- Wrap up with a post CDR Higgs paper.

Some preliminary progresses (H->γγ)





- Variables having low correlations with Mγγ are chosen as inputs to MVA
- Two dimensional fit is implemented to extract the precision of the measurement.
- The improvement is ~30% in the channel of Z(->qq)H->γγ for the precision measurment.
- See more in Fangyi Guo's talk.

High energy (360 GeV) Run

Results

Kaili's talk

	5.6ab^{-1}, 240	2ab^{-1}, 360	1.5ab^{-1}, 360
$\sigma(ZH)$	**0.50%**	**1% ?**	
$\sigma(ZH) * \mathrm{Br}(H \to bb)$	**0.27%**	**0.63%**	**0.71%**
$\sigma(ZH) * \mathrm{Br}(H \to cc)$	**3.3%**	**6.2%**	**7.2%**
$\sigma(ZH) * \mathrm{Br}(H \to gg)$	**1.3%**	**2.4%**	**2.7%**
$\sigma(ZH) * \mathrm{Br}(H \to WW)$	**1.0%**	**2.0%**	**2.3%**
$\sigma(ZH) * \mathrm{Br}(H \to ZZ)$	**5.1%**	**12%**	**14%**
$\sigma(ZH) * \mathrm{Br}(H \to \tau\tau)$	**0.8%**	**1.5%**	**1.7%**
$\sigma(ZH) * \mathrm{Br}(H \to \gamma\gamma)$	**5.4%**	**8%**	**9.2%**
$\sigma(ZH) * \mathrm{Br}(H \to \mu\mu)$	**12%**	**29%**	**33%**
$\sigma(\nu\nu H) * \mathrm{Br}(H \to bb)$	**3%**	**0.79%**	**0.91%**
$\mathrm{Br}_{\mathrm{upper}}(H \to \mathrm{inv.})$	**0.2%**	\	\
$\sigma(ZH) * \mathrm{Br}(H \to Z\gamma)$	**16%**	**25%**	**29%**
Width	**2.8%**	**~0.8%**	

*: $\sigma(ZH)$ estimated as 1%.

Mostly from WW fusion (Hao Liang's talk)

Fcc:

$\sqrt{s}$ (GeV)	240		365	
Luminosity (ab^{-1})	5		1.5	
$\delta(\sigma\mathrm{BR})/\sigma\mathrm{BR}$ (%)	HZ	$\nu\bar{\nu}$ H	HZ	$\nu\bar{\nu}$ H
$H \to$ any	± 0.5		± 0.9	
$H \to b\bar{b}$	± 0.3	± 3.1	± 0.5	± 0.9
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$H \to W^+W^-$	± 1.2		± 2.6	± 3.0
$H \to ZZ$	± 4.4		± 12	± 10
$H \to \tau\tau$	± 0.9		± 1.8	± 8
$H \to \gamma\gamma$	± 9.0		± 18	± 22
$H \to \mu^+\mu^-$	± 19		± 40	
$H \to$ invisible	< 0.3		< 0.6	

Generally, since the extrapolation is not so accurate, results are comparable.

For $H \to \gamma\gamma$ and $H \to \mu\mu$, resolution changes considered.
Keep diphoton resolution ~(2.5GeV) : 10.2%
2.5GeV to 2GeV: 9.20%

Keep dimuon resolution ~(0.3GeV): 23%
0.3GeV to 1GeV: 29%

Talks in Higgs section

14:00 - 15:30 **Higgs**

Conveners: Liantao Wang (University of Chicago), WANG Jianchun

- 14:00 **Introduction and plan for Higgs physics** *25'*
  Speaker: Prof. Yaquan FANG Yaquan (高能所)
- 14:25 **Kappa measurement on CEPC Higgs** *25'*
  Speakers: Zhen Liu (FNAL), Zhen Liu (University of Pittsburgh)
- 14:50 **EFT on CEPC Higgs physics** *20'*
  Speaker: Dr. Jiayin Gu (JGU Mainz)
  Material: Slides nf3.pdf
- 15:10 **Alternative me r Higgs measurement** *20'*
  Speaker: Dr. Gang LI (EPD, IHEP, CAS)

15:30 - 15:50 Coffee Break

15:50 - 17:15 **Higgs**

Convener: Jianming Qian (University of Michigan)

- 15:55 **WW fusion with 360 GeV** *25'*
  Speaker: Hao Liang
- 16:20 **Combination for Higgs measurement with 360 GeV** *25'*
  Speaker: Kaili Zhang (IHEP)
  Material: Slides
- 16:45 **Update on the mesurement of bb, cc, gg** *25'*
  Speaker: Yu Bai (Southeast University)

Wednesday, 3 July 2019

09:00 - 10:30 **Higgs**

Convener: Xin Shi (IHEP)

- 09:00 **Update on H->tautau** *25'*
  Speakers: Mrs. Dan YU (LLR), YU Dan
  Material: Slides
- 09:25 **Status of H->mumu** *20'*
  Speaker: Kunlin RAN (Beijing)
- 09:45 **the study of Higgs invisible decay** *20'*
  Speaker: TAN Yuhang (高能所)
- 10:05 **Higgs decaying into ZZ*** *20'*
  Speaker: Ryuta Kiuchi

10:30 - 10:50 Coffee Break

10:50 - 12:20 **Higgs**

Convener: Prof. Yaquan FANG Yaquan (高能所)

- 10:50 **MVA anlsysi on H->gamma gamma** *20'*
  Speaker: Fangyi Guo (IHEP)
  Material: Slides
- 11:10 **Differential measurement on Higgs** *20'*
  Speaker: ABDUALAZEM FADOL MOHAMMED EBRHIM (高能所)
- 11:30 **Review and Discussion on Higgs physics** *40'*
  Speaker: Jianming Qian (University of Michigan)

Conclusion

- The Higgs CDR is done and the studies post CDR toward TDR start
- Different topics will be addressed (page 7).
- Manpower needed (welcome to join)

backup slides

One example

ATLAS-CONF-2016-017

Category	Events	B_{90}	S_{90}	f_{90}	Z_{90}	S_{90}^{fit}
Central low-$p_{\text{T}t}$	31907	3500	180	0.05	3.04	120
Central high-$p_{\text{T}t}$	1319	140	20	0.13	1.66	15
Forward low-$p_{\text{T}t}$	85129	13000	310	0.02	2.73	200
Forward high-$p_{\text{T}t}$	3977	540	33	0.06	1.38	25

The improvement of significance w.r.t. inclusive one is from 4.0 to 4.6, corresponding 13% improvement on the precision.

Measurement of Higgs width

- **Method 1: Higgs width can be determined directly from the measurement of σ(ZH) and Br. of (H->ZZ*)**

$$\Gamma_H \propto \frac{\Gamma(H \to ZZ^*)}{\mathrm{BR}(H \to ZZ^*)} \propto \frac{\sigma(ZH)}{\mathrm{BR}(H \to ZZ^*)}$$

Precision : 5.1%

  - **But the uncertainty of Br(H->ZZ*) is relatively high due to low statistics.**

- **Method 2: It can also be measured through:**

$$\Gamma_H \propto \frac{\Gamma(H \to bb)}{BR(H \to bb)} \qquad \sigma(\nu\bar{\nu}H \to \nu\bar{\nu}b\bar{b}) \propto \Gamma(H \to WW^*) \cdot \mathrm{BR}(H \to bb) = \Gamma(H \to bb) \cdot \mathrm{BR}(H \to WW^*)$$

$$\Gamma_H \propto \frac{\Gamma(H \to bb)}{\mathrm{BR}(H \to bb)} \propto \frac{\sigma(\nu\bar{\nu}H \to \nu\bar{\nu}b\bar{b})}{\mathrm{BR}(H \to b\bar{b}) \cdot \mathrm{BR}(H \to WW^*)}$$

3.0%

Precision : 3.5%

- **These two orthogonal methods can be combined to reach the best precision.**

Precision : 2.8%