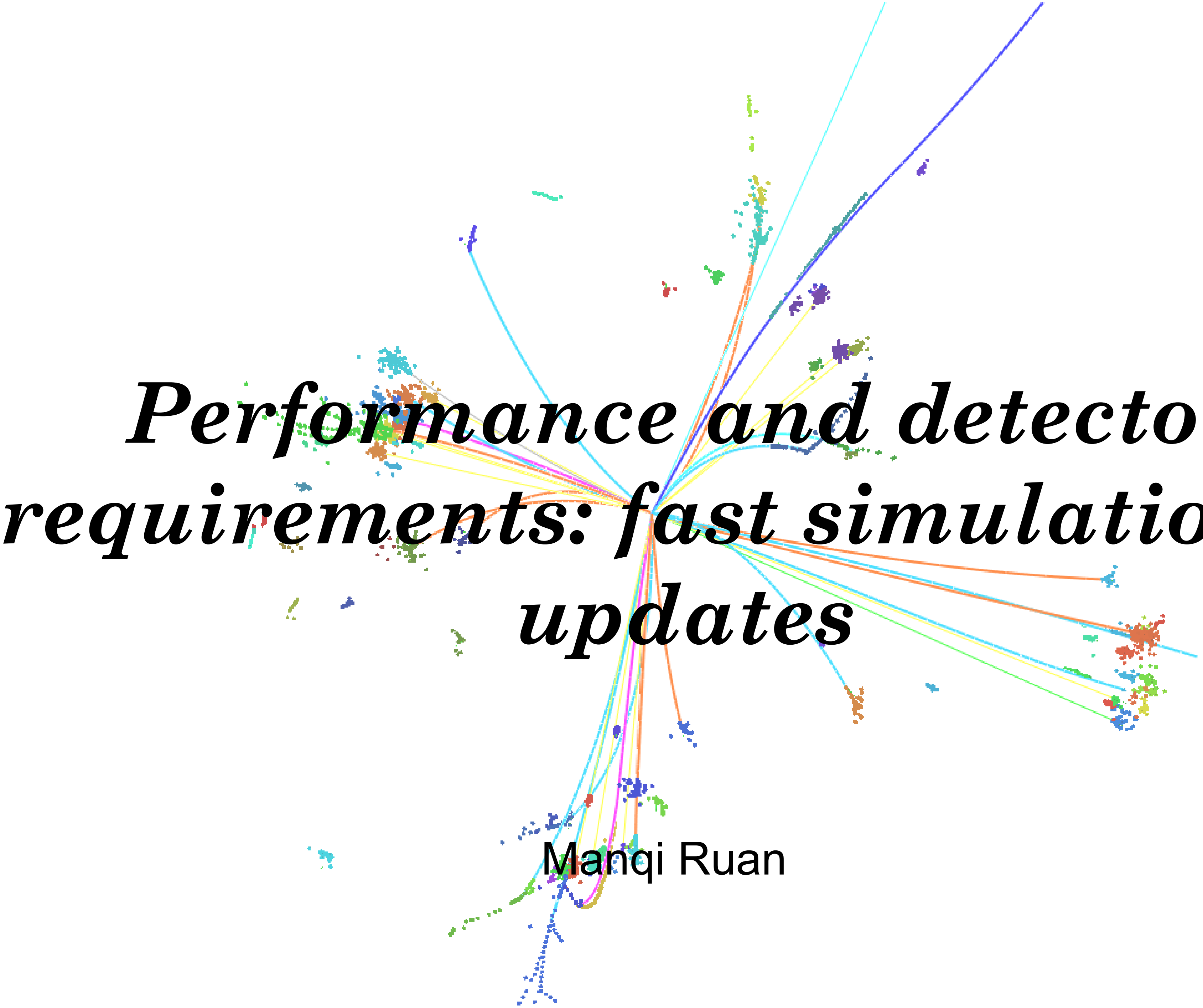


Performance and detector requirements: fast simulation & updates

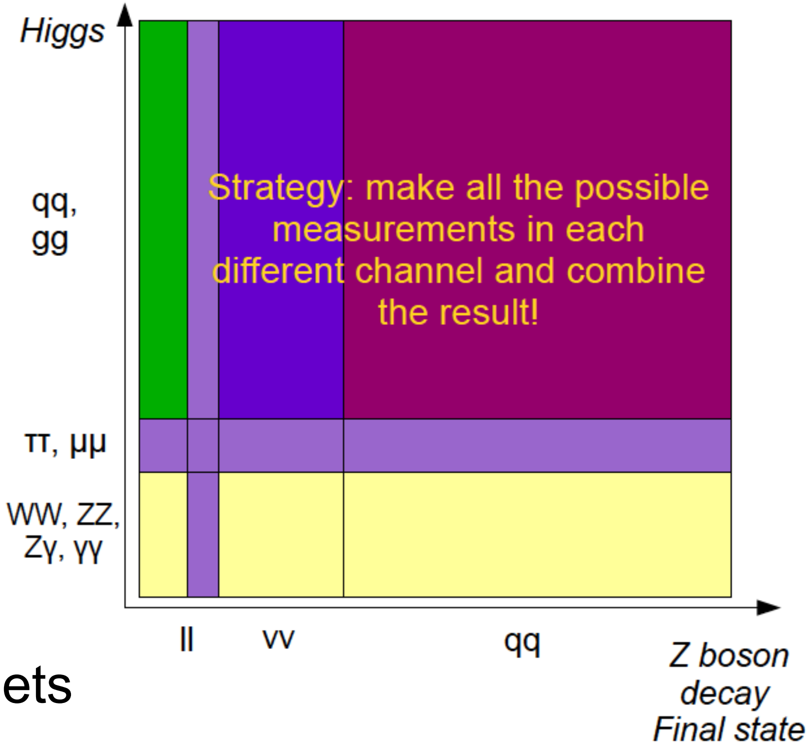
Manqi Ruan

Outline

- Higgs physics benchmarks with 2 jets & requirement analysis on the hadronic system mass measurement
- Estimation on the physics impact of a 360 GeV Higgs runs
- EUSPP interactions & CEPC Physics WS Preparation

Jets at the Higgs Signal

- SM Higgs
  - **0 jets: 3%**
    - Z→ll, νν (30%); H→0 jets (~10%, ττ, μμ, γγ, γZ/WW/ZZ→leptonic)
  - **2 jets: 32%**
    - Z→qq, H→0 jets.
    - Z→ll, νν; H→2 jets.
    - Z→ll, νν; H→WW/ZZ→semi-leptonic.
  - **4 jets: 55%**
    - Z→qq, H→2 jets.
    - Z→ll, νν; H→WW/ZZ→4 jets.
  - **6 jets: 11%**
    - Z→qq, H→WW/ZZ→4 jets.



Strategy: make all the possible measurements in each different channel and combine the result!

- 97% of the SM Higgsstrahlung Signal involves Jets

Jets at the Higgs Signal

- SM Higgs
  - **0 jets: 3%**
    - Z→ll, νν (30%); H→0 jets
  - **2 jets: 32%**
    - Z→qq, H→0 jets.
    - Z→ll, νν; H→2 jets.
    - Z→ll, νν; H→WW/ZZ→semi-leptonic.

- 1/3 of the Higgs events
  - Access to all SM Higgs decay modes
  - Doesn't need color singlet identification: at most 1 color singlet thus naturally identified

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  - **4 jets: 55%**
    - Z→qq, H→2 jets.
    - Z→ll, νν; H→WW/ZZ→4 jets.
  - **6 jets: 11%**
    - Z→qq, H→WW/ZZ→4 jets.

- 2/3 of the Higgs events
  - Dominate statistic of H→bb, cc, gg, WW, ZZ, Zγ
  - Color singlet identification – **potentially a leading systematic, huge impact**

- 2/3 of the events need to group the final state particles into Color-Singlet: currently via Jet Clustering-Matching (analyzed in WW/ZZ separation study ~ 50% of 4-jets event have correct pairing)

Physics benchmarks

- Higgs measurement with 2-jet event
  - qqH, Higgs→ττ;
    - Percentage level accuracy, sensitive probe to NP
  - qqH, Higgs→invisible;
    - Key measurement for the DM search, significant advantage V.S. LHC
  - vvH, H→bb (W fusion Xsec measurement)
    - Key input & Bottleneck for the Higgs width measurement – limitation for Higgs couplings to major decay modes (bb, gg, WW, ZZ, tautau)

- Full Simulation analyses at baseline Detector
- Dedicated Fast simulation tool developed, and validated on Full Simulation result

Key physics performance: BMR

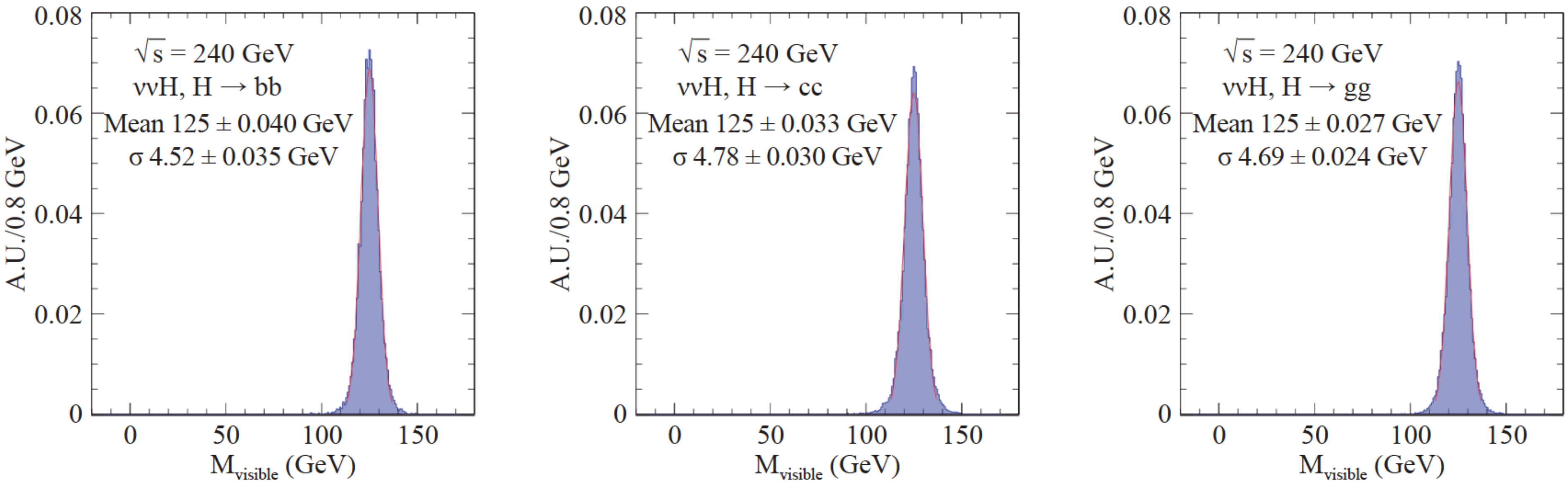
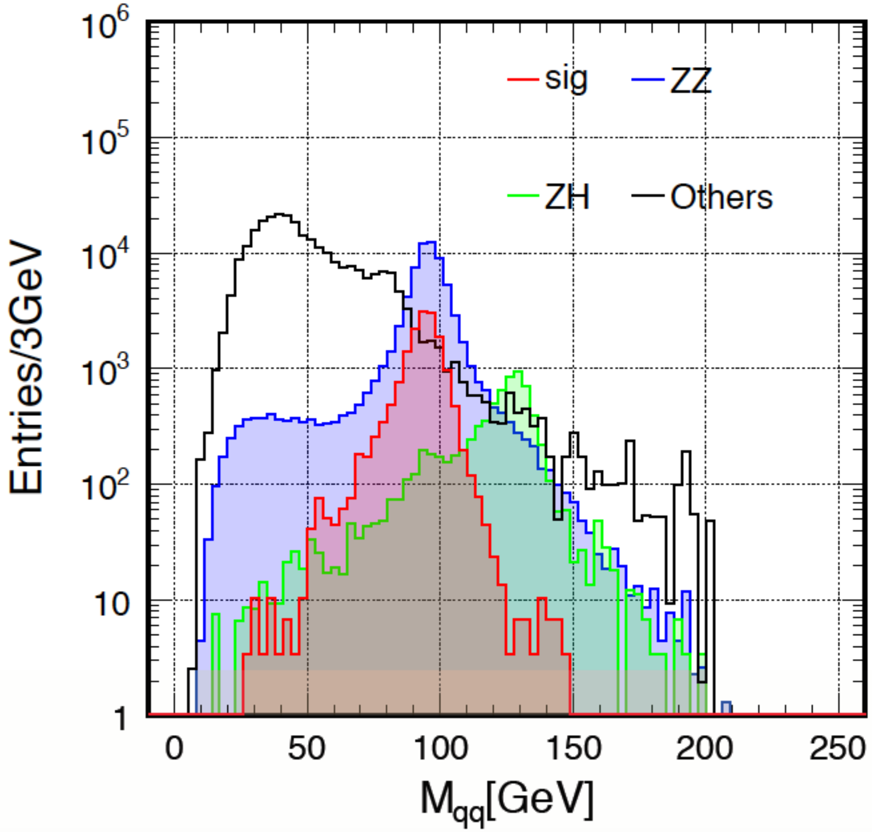
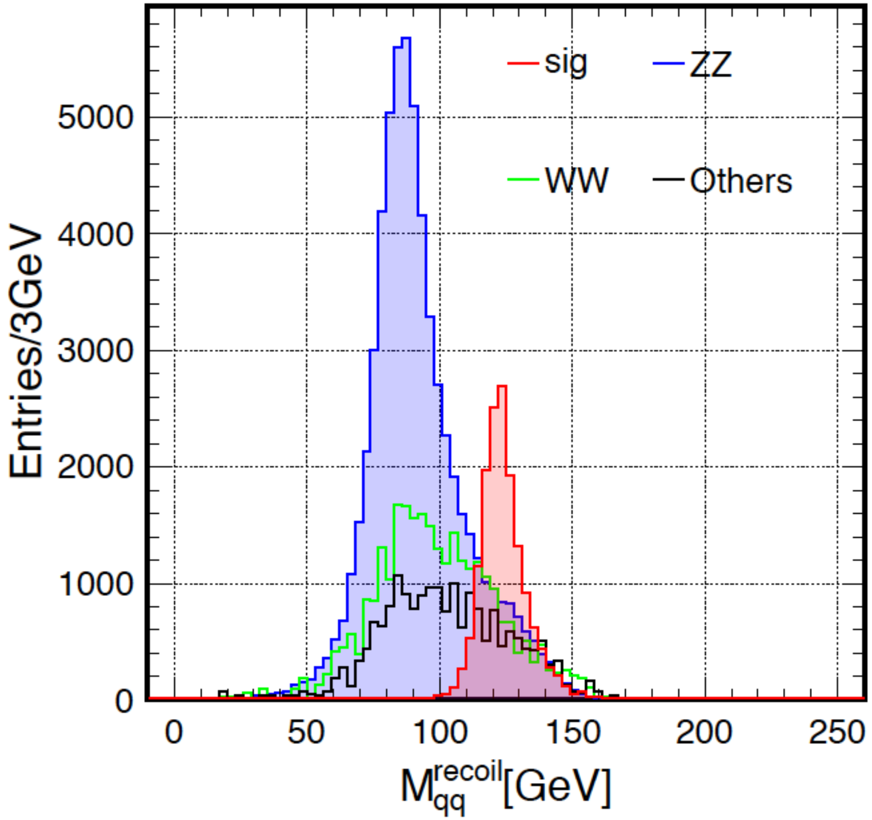


Fig. 8. (color online) Distributions of the reconstructed total visible invariant mass for $H \rightarrow bb, cc, gg$ events after event cleaning and fitted by Gaussian functions. The resolutions (sigma/mean) of the fitted results are 3.63% (*bb*), 3.82% (*cc*), and 3.75% (*gg*).

- Boson Mass resolution:
  - Characterized by the Higgs mass resolution with di-gluon final state
- Baseline reaches a BMR of 3.8%
- Fast Simulation: extract 4 momentum of the hadronic system (di-jet), smear its energy according to BMR (jet direction precision ~ 1%, negligible w.r.t energy reconstruction)

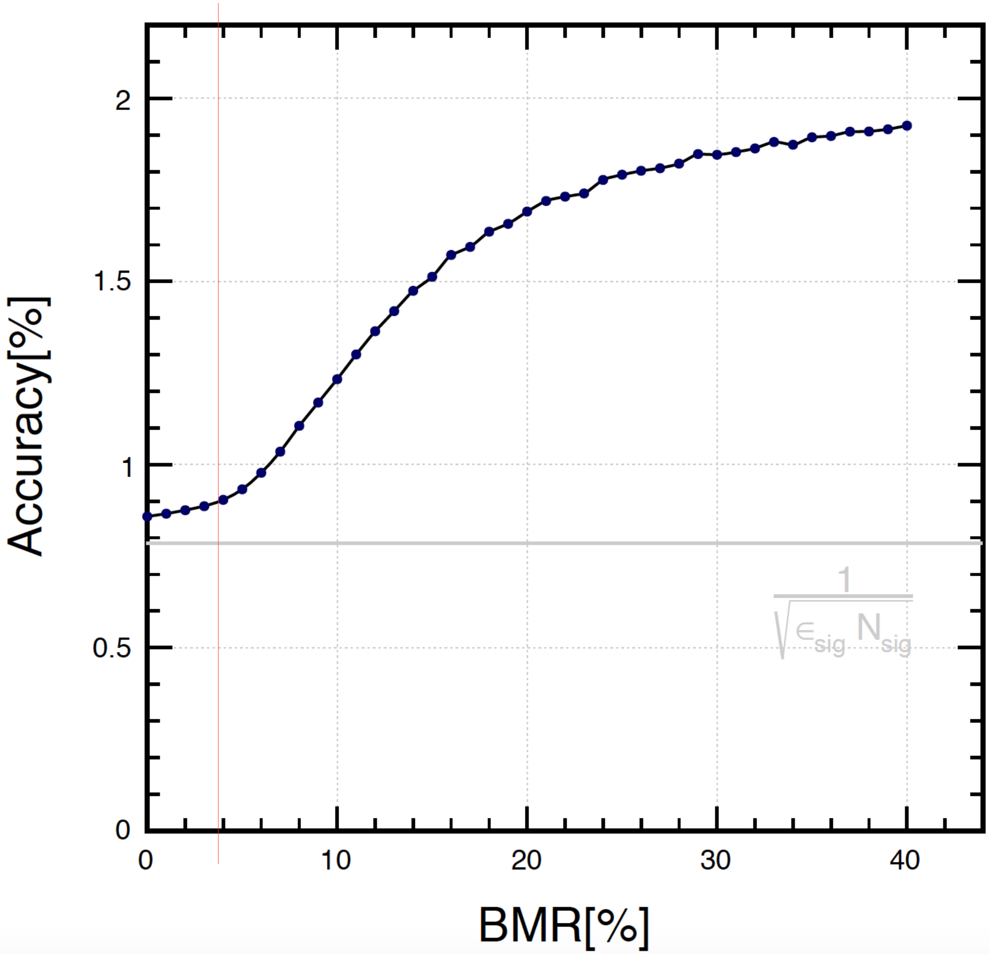
qqH, H->tautau

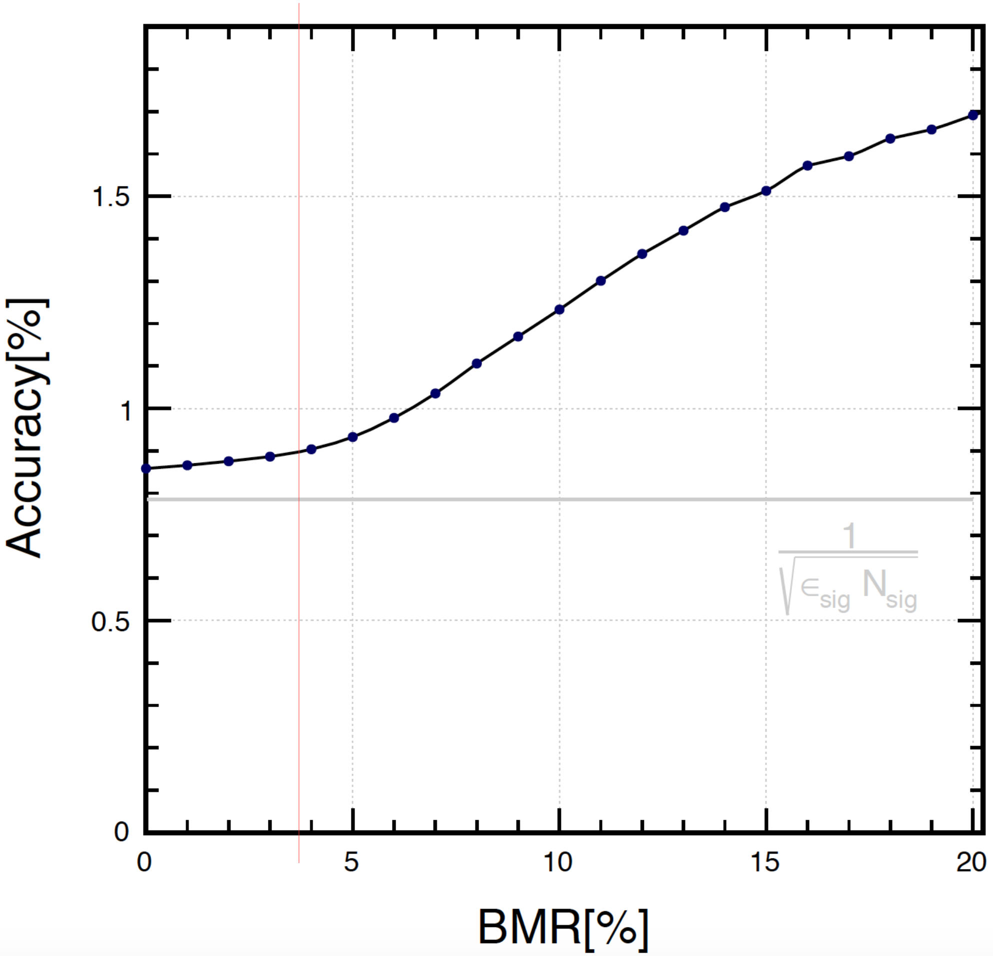




- The recoil mass of the di-jet system is essential for the separation of ZZ background

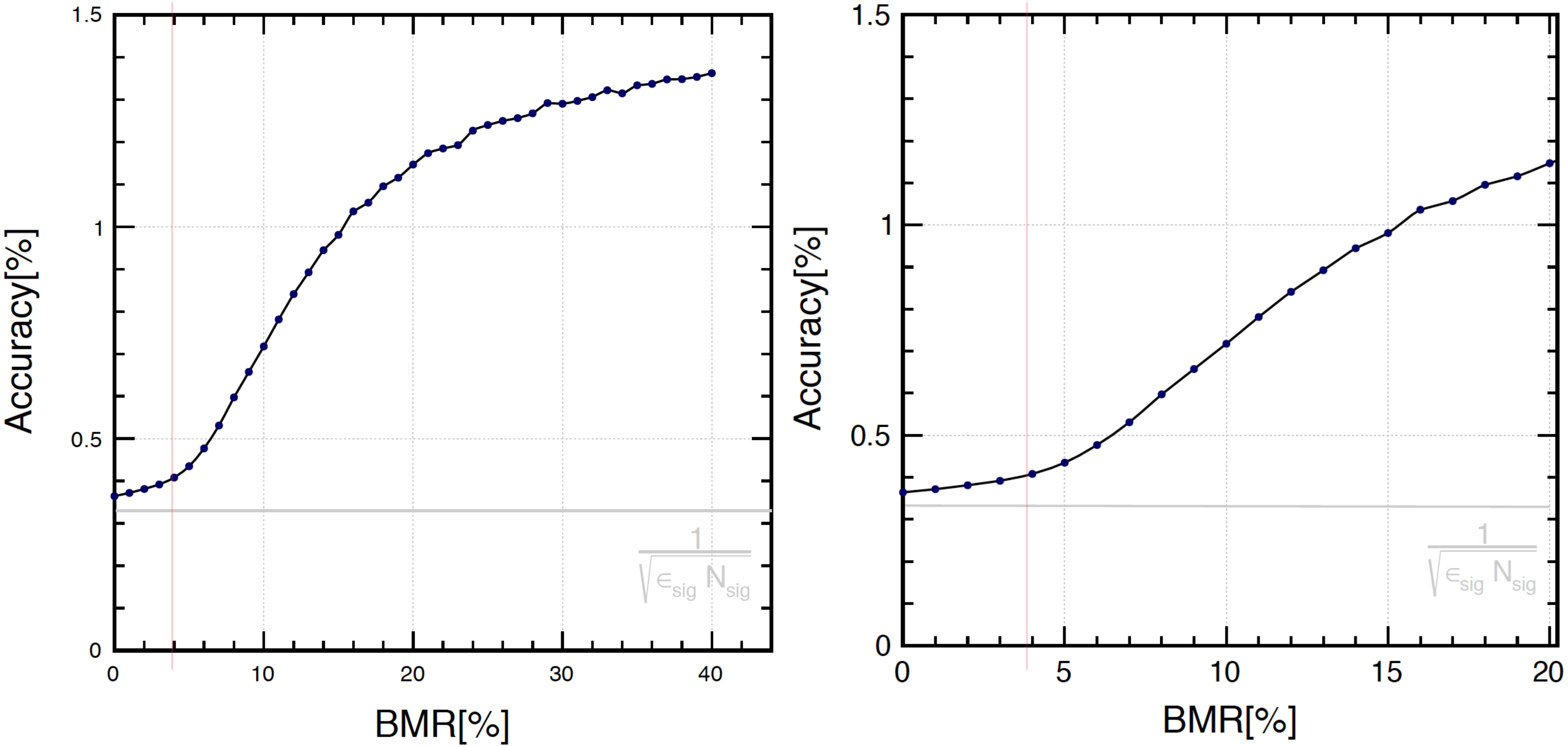
qqH, H->tautau





- Considering Only ZZ background and Normalize according to full sim result (efficiency, statistics, accuracy ~ 0.9% at BMR = 3.8%)

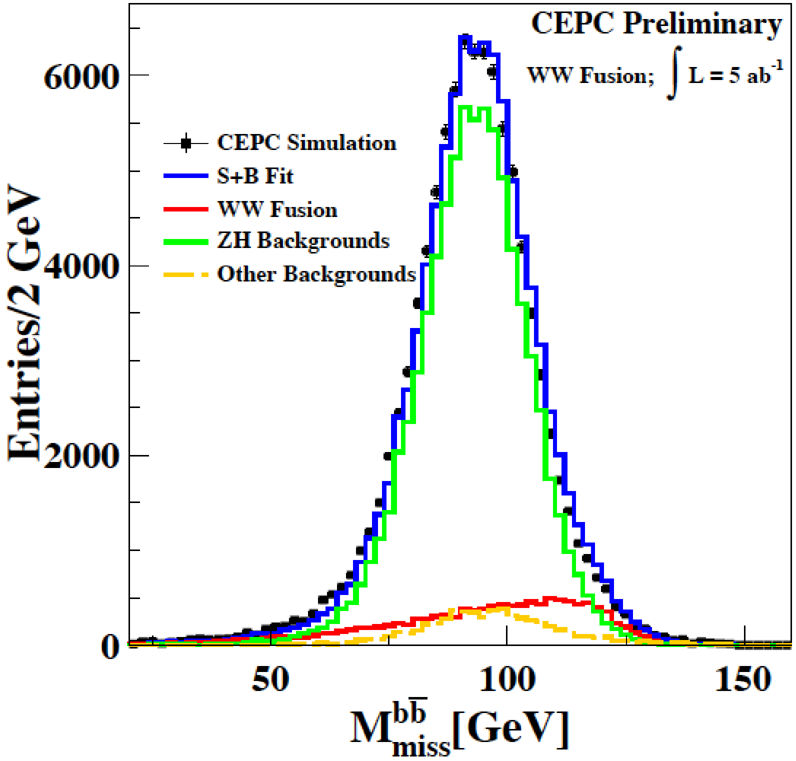
qqH, H->invisible



- Similar behavior as the ZZ is the major background
- *Y axis: accuracy at sigma(ZH)*Br(H->inv) = 100 fb*

vvH, H->bb & total width

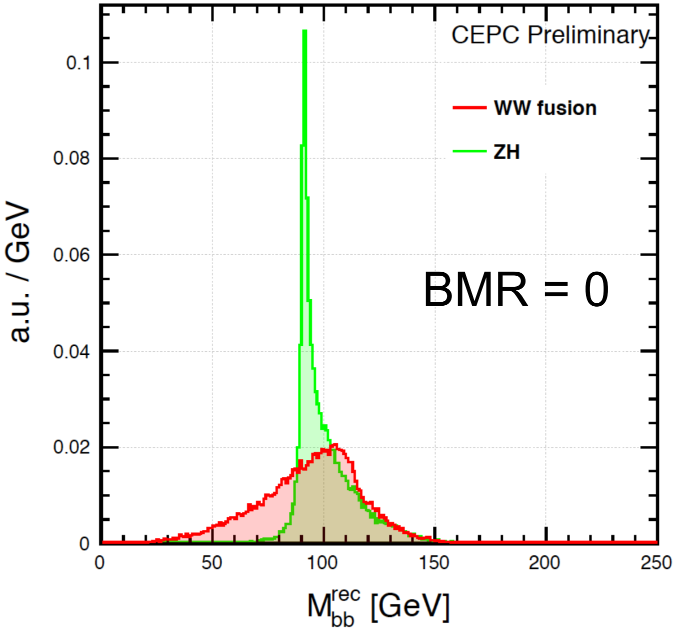
- $g^2(HXX) \sim \Gamma_{H\rightarrow XX} = \Gamma_{total}$*Br(H→XX)
- Branching ratios: determined simply by
  - σ(ZH) and σ(ZH)*Br(H→XX)
- Γ_{total} : determined from:
  - From σ(ZH) (~g^2(HZZ)) and σ(ZH)*Br(H→ZZ) (~$g^4(HZZ)/\Gamma_{total}$)
  - From σ(ZH)*Br(H→bb), σ(vvH)*Br(H→bb), σ(ZH)*Br(H→WW), σ(ZH)

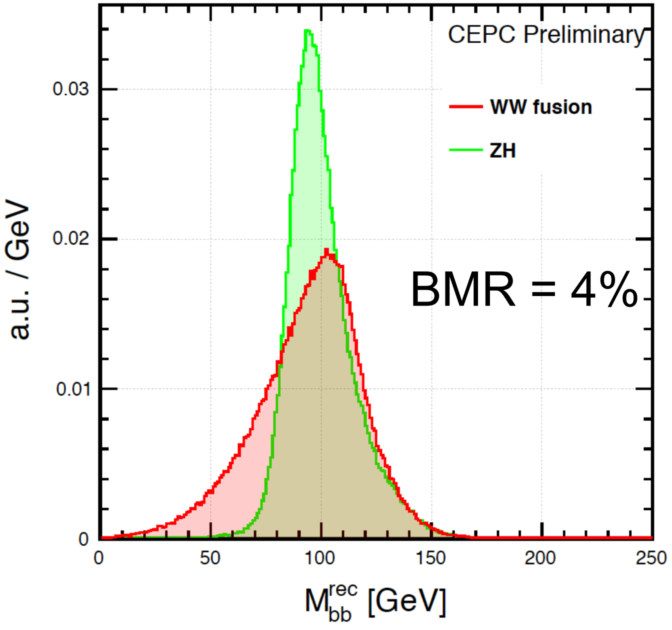


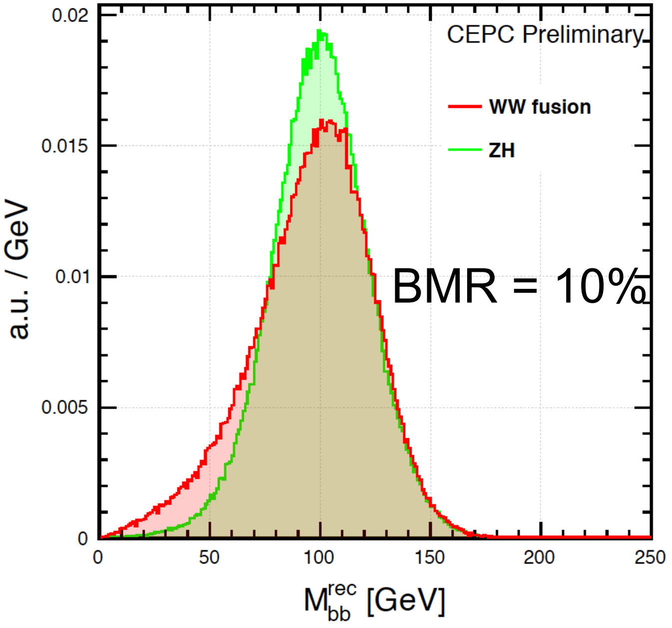
A combined accuracy of 2.8% for the Higgs total width measurements; dominated by W fusion measurement (with accuracy of 2.6%)

σ(vvH)*Br(H->bb): major background are ZZ and ZH (Z->vv)

Recoil mass PDF at different BMR

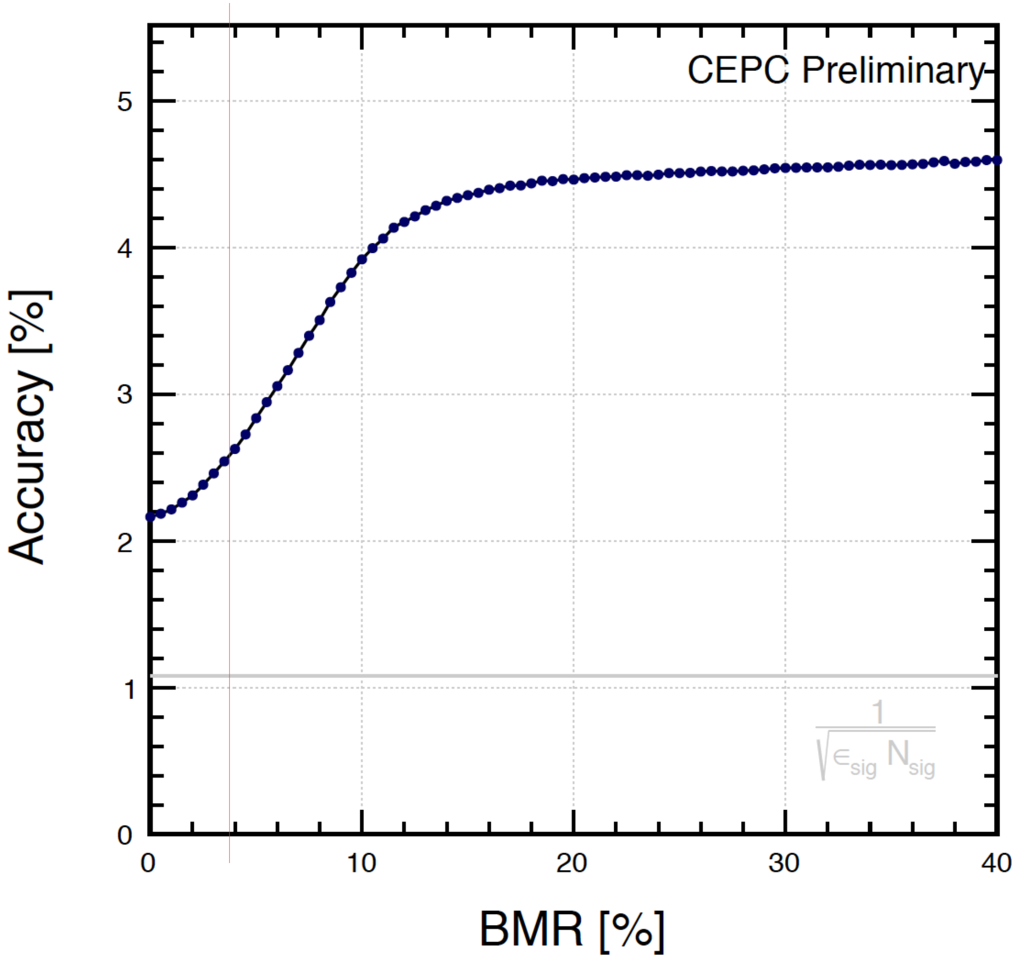


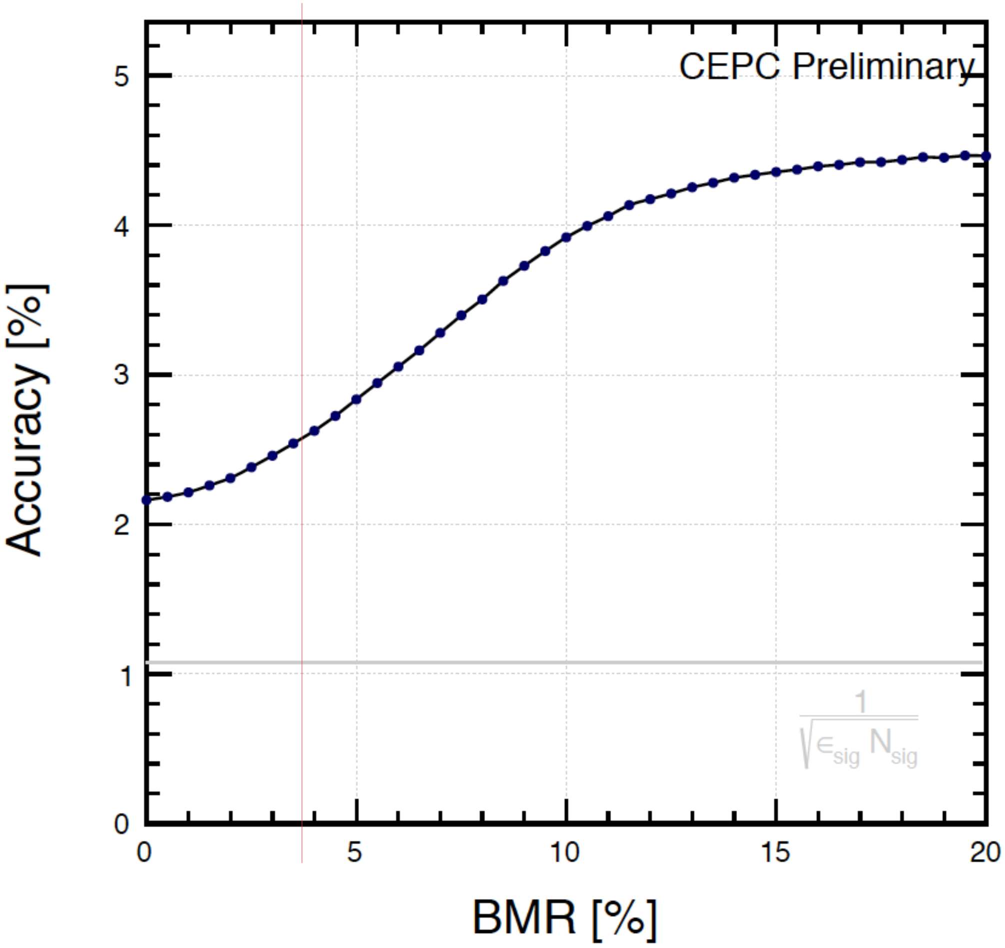




PS: at 240 GeV center of mass energy, the Xsec of ZH, Z->vv is 7 times larger than
The W fusion (40/5.4 fb)

vvH, H->bb





- Similar behavior as the ZZ is the major background
- *Y axis: accuracy at sigma(ZH)*Br(H->inv) = 100 fb*

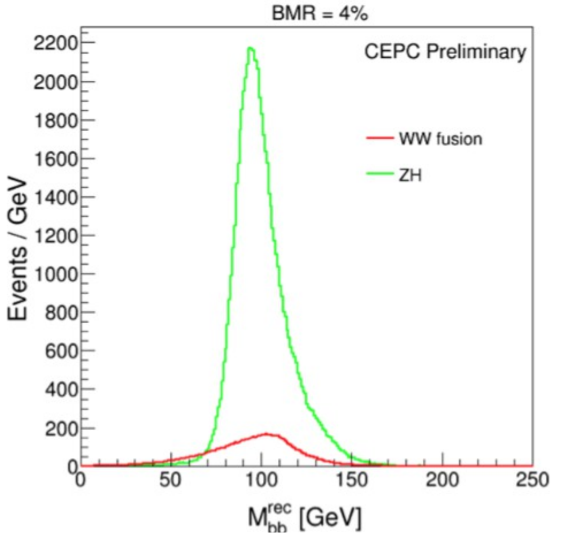
2-jet Higgs benchmarks at 240 GeV

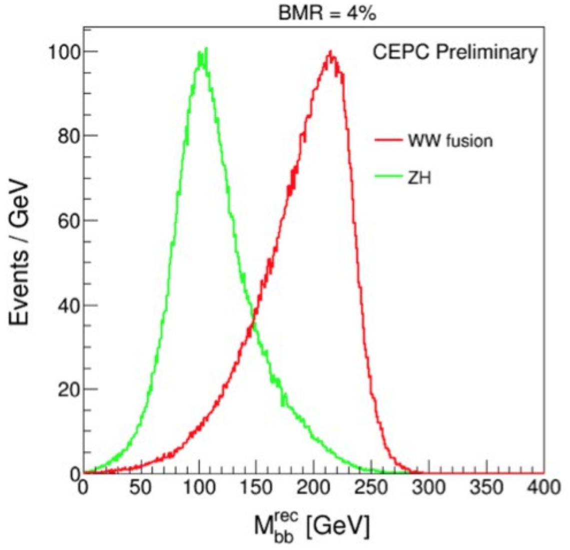
	BMR = 2%	4%	6%	8%
σ(vvH, H→bb)	2.3%	2.6%	3.0%	3.4%
σ(qqH, H→inv)	0.38%	0.4%	0.5%	0.6%
σ(qqH, H→ττ)	0.85%	0.9%	1.0%	1.1%

- From qqH, H->inv/tautau: BMR < 4%
- From W fusion: should pursue better BMR even up to 2%...

360 GeV 下的 Higgs 测量

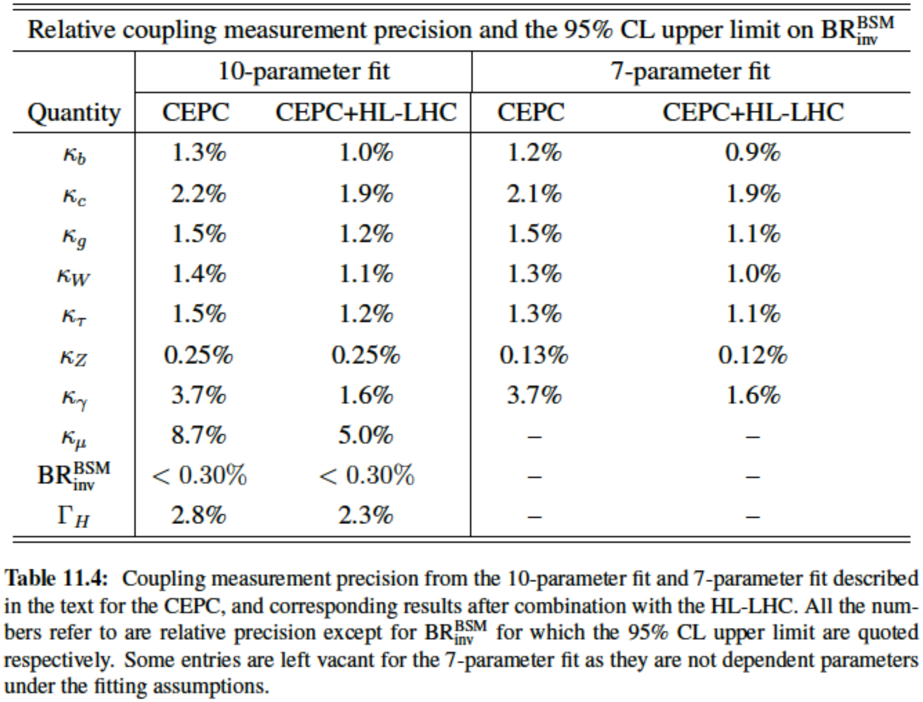
	W boson fusion	ZH, Z->vv	W boson fusion	ZH, Z->vv
$\sqrt{s}$ (GeV)	240		360	
Integral Luminosity (fb^{-1})	5600		1000	
Cross-section (fb)	5.401	40.11	29.83	25.57
Eff. (%)	50	50	50	50
Br($H \to bb$) (%)	57	57	57	57
Number of $vvH, H \to bb$ After Cut	8621	64038	8503	7288
Accuracy (BMR=4%)	2.6%		1.2%	
$1/\sqrt{N_{sig}}$	0.92%		0.92%	





- 假设 360 GeV 能产生 1 ab^{-1} 的数据（相当于 30MW 辐射功率下、CEPC 5 年的取数）
- 能产生～160k 的 Higgs 事例。
- 由于 W fusion 截面增加且 ZH 截面减小，同时在 recoil mass 上清晰可分，W fusion 截面测量精度可大幅提高一倍以上，360 GeV Run 可将 Higgs 粒子宽度测量精度提升一倍，从而将 Higgs 粒子和其主要衰变末态的耦合常数测量精度提高 50%-80%(Hbb, HWW, Hττ, Hgg)

Preliminary Estimation



Relative coupling measurement precision and the 95% CL upper limit on $\mathrm{BR}^{\mathrm{BSM}}_{\mathrm{inv}}$				
	10-parameter fit		7-parameter fit	
Quantity	CEPC	CEPC+HL-LHC	CEPC	CEPC+HL-LHC
κ_b	1.3%	1.0%	1.2%	0.9%
κ_c	2.2%	1.9%	2.1%	1.9%
κ_g	1.5%	1.2%	1.5%	1.1%
κ_W	1.4%	1.1%	1.3%	1.0%
κ_τ	1.5%	1.2%	1.3%	1.1%
κ_Z	0.25%	0.25%	0.13%	0.12%
κ_γ	3.7%	1.6%	3.7%	1.6%
κ_μ	8.7%	5.0%	–	–
$\mathrm{BR}^{\mathrm{BSM}}_{\mathrm{inv}}$	$< 0.30\%$	$< 0.30\%$	–	–
Γ_H	2.8%	2.3%	–	–

Table 11.4: Coupling measurement precision from the 10-parameter fit and 7-parameter fit described in the text for the CEPC, and corresponding results after combination with the HL-LHC. All the numbers refer to are relative precision except for $\mathrm{BR}^{\mathrm{BSM}}_{\mathrm{inv}}$ for which the 95% CL upper limit are quoted respectively. Some entries are left vacant for the 7-parameter fit as they are not dependent parameters under the fitting assumptions.

g(Hbb)	0.75%	~ 80%
g(Hcc)	1.7%	~ 30%
g(Hgg)	1.0%	~ 50%
g(HWW)	0.9%	~ 60%
g(HZZ)	0.23%	~ 8%
g(Hττ)	0.8%	~ 80%
g(Hγγ)	3.4%	~ 10%
g(Hμμ)	8.3%	~ 5%
H_invisible	< 0.28%	~ 8%
Width	1.4%	~ 100%

PS: FCC ttbar runs: 1.7 ab-1, (0.2 + 1.5), 4 years of data taking, 250k Higgs bosons (200 k HZ + 50 k W fusion)

CEPC @ Granada

- CEPC is fairly & friendly described in the working group report
- Higgs part is consistent with other facilities.

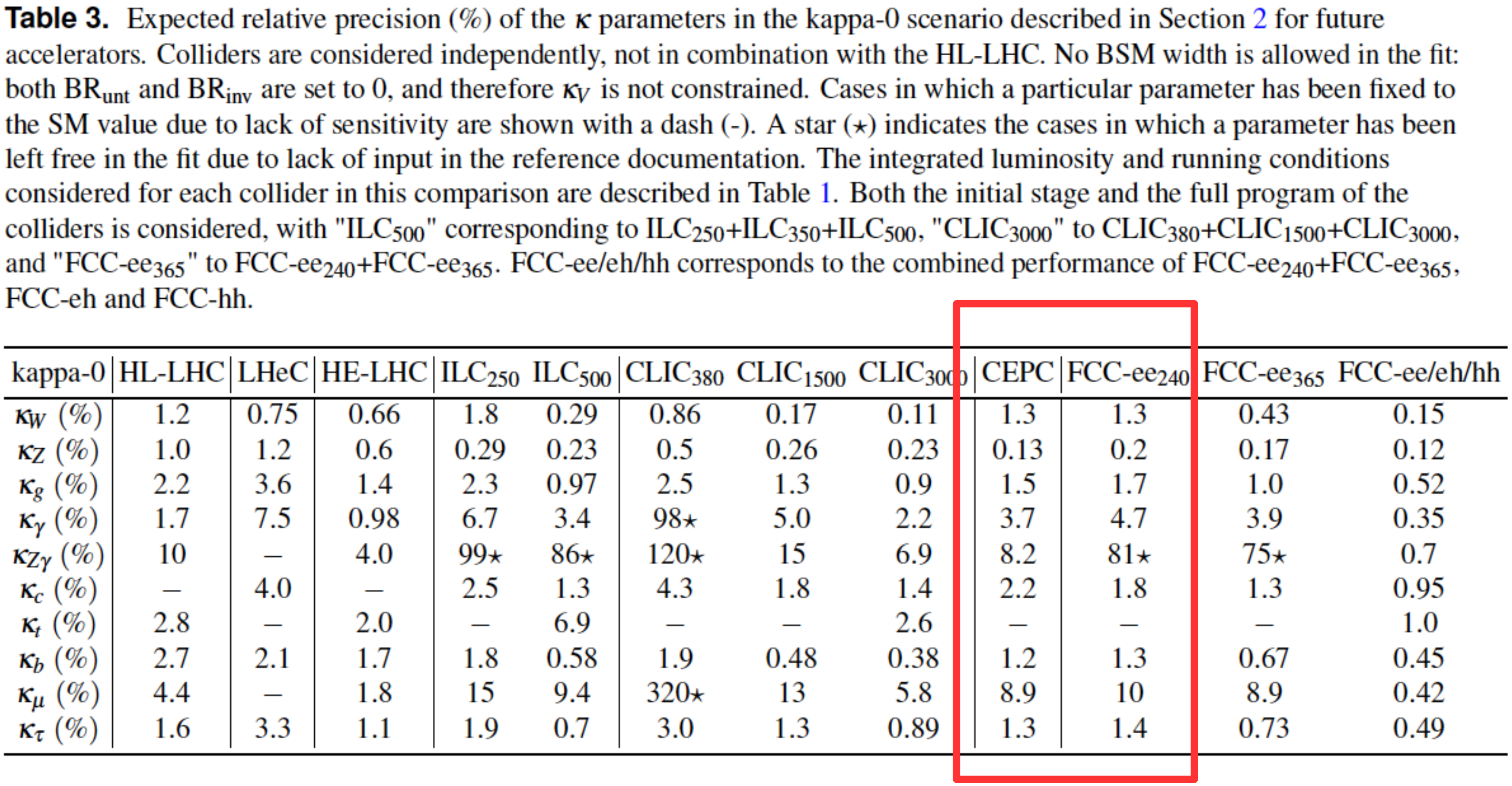
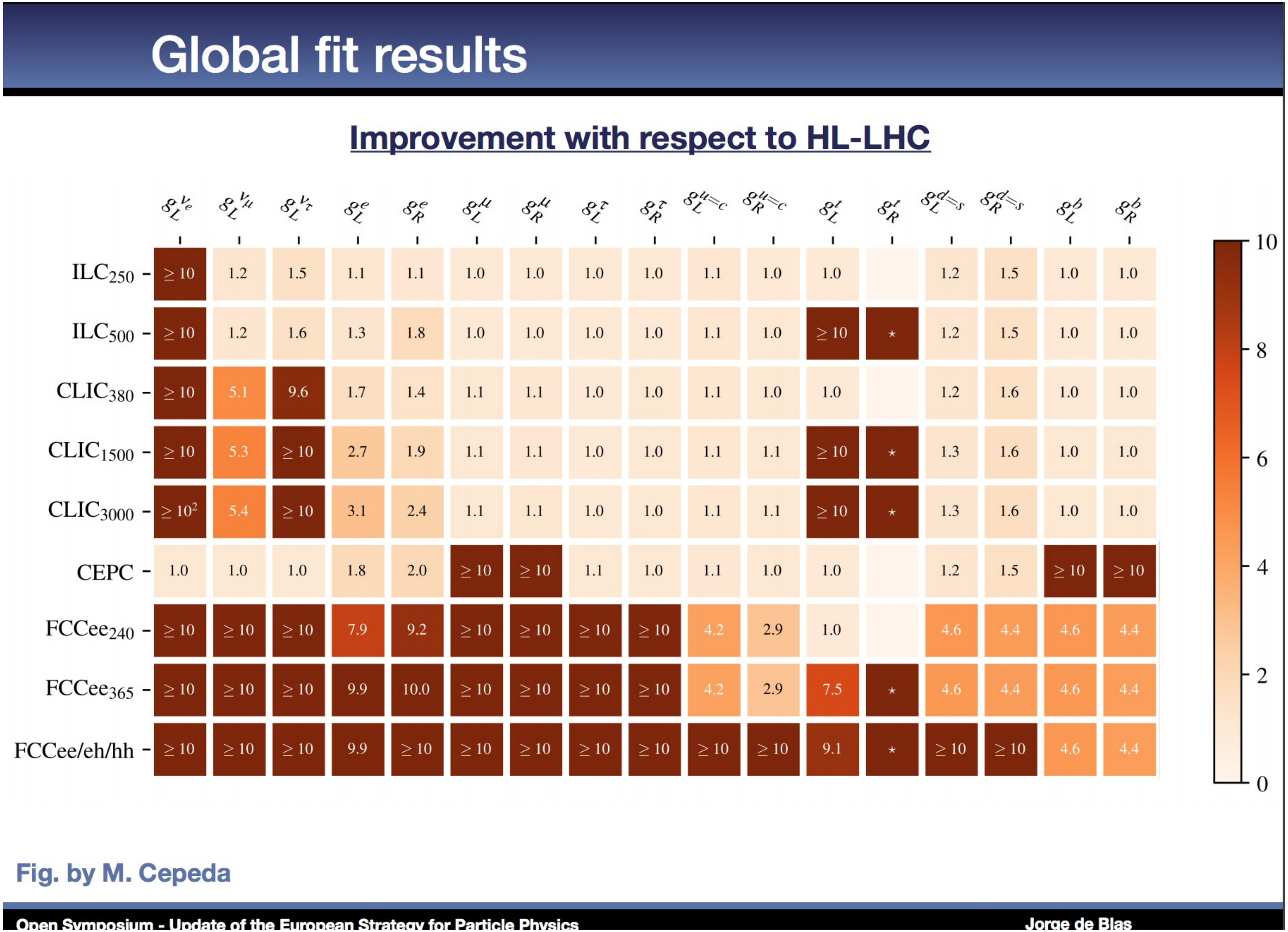


Table 3. Expected relative precision (%) of the κ parameters in the kappa-0 scenario described in Section 2 for future accelerators. Colliders are considered independently, not in combination with the HL-LHC. No BSM width is allowed in the fit: both BR_{unt} and BR_{inv} are set to 0, and therefore κ_V is not constrained. Cases in which a particular parameter has been fixed to the SM value due to lack of sensitivity are shown with a dash (-). A star ($\star$) indicates the cases in which a parameter has been left free in the fit due to lack of input in the reference documentation. The integrated luminosity and running conditions considered for each collider in this comparison are described in Table 1. Both the initial stage and the full program of the colliders is considered, with "ILC$_{500}$" corresponding to ILC$_{250}$+ILC$_{350}$+ILC$_{500}$, "CLIC$_{3000}$" to CLIC$_{380}$+CLIC$_{1500}$+CLIC$_{3000}$, and "FCC-ee$_{365}$" to FCC-ee$_{240}$+FCC-ee$_{365}$. FCC-ee/eh/hh corresponds to the combined performance of FCC-ee$_{240}$+FCC-ee$_{365}$, FCC-eh and FCC-hh.

kappa-0	HL-LHC	LHeC	HE-LHC	ILC$_{250}$	ILC$_{500}$	CLIC$_{380}$	CLIC$_{1500}$	CLIC$_{3000}$	CEPC	FCC-ee$_{240}$	FCC-ee$_{365}$	FCC-ee/eh/hh
κ_W (%)	1.2	0.75	0.66	1.8	0.29	0.86	0.17	0.11	1.3	1.3	0.43	0.15
κ_Z (%)	1.0	1.2	0.6	0.29	0.23	0.5	0.26	0.23	0.13	0.2	0.17	0.12
κ_g (%)	2.2	3.6	1.4	2.3	0.97	2.5	1.3	0.9	1.5	1.7	1.0	0.52
κ_γ (%)	1.7	7.5	0.98	6.7	3.4	98$\star$	5.0	2.2	3.7	4.7	3.9	0.35
$\kappa_{Z\gamma}$ (%)	10	–	4.0	99$\star$	86$\star$	120$\star$	15	6.9	8.2	81$\star$	75$\star$	0.7
κ_c (%)	–	4.0	–	2.5	1.3	4.3	1.8	1.4	2.2	1.8	1.3	0.95
κ_t (%)	2.8	–	2.0	–	6.9	–	–	2.6	–	–	–	1.0
κ_b (%)	2.7	2.1	1.7	1.8	0.58	1.9	0.48	0.38	1.2	1.3	0.67	0.45
κ_μ (%)	4.4	–	1.8	15	9.4	320$\star$	13	5.8	8.9	10	8.9	0.42
κ_τ (%)	1.6	3.3	1.1	1.9	0.7	3.0	1.3	0.89	1.3	1.4	0.73	0.49



Global fit results

Improvement with respect to HL-LHC

	$g_L^{\nu_e}$	$g_L^{\nu_\mu}$	$g_L^{\nu_\tau}$	g_L^e	g_R^e	g_L^μ	g_R^μ	g_L^τ	g_R^τ	$g_L^{u=c}$	$g_R^{u=c}$	g_L^t	g_R^t	$g_L^{d=s}$	$g_R^{d=s}$	g_L^b	g_R^b
ILC_{250}	≥ 10	1.2	1.5	1.1	1.1	1.0	1.0	1.0	1.0	1.1	1.0	1.0		1.2	1.5	1.0	1.0
ILC_{500}	≥ 10	1.2	1.6	1.3	1.8	1.0	1.0	1.0	1.0	1.1	1.0	≥ 10	⋆	1.2	1.5	1.0	1.0
CLIC_{380}	≥ 10	5.1	9.6	1.7	1.4	1.1	1.1	1.0	1.0	1.1	1.0	1.0		1.2	1.6	1.0	1.0
CLIC_{1500}	≥ 10	5.3	≥ 10	2.7	1.9	1.1	1.1	1.0	1.0	1.1	1.1	≥ 10	⋆	1.3	1.6	1.0	1.0
CLIC_{3000}	$\geq 10^2$	5.4	≥ 10	3.1	2.4	1.1	1.1	1.0	1.0	1.1	1.1	≥ 10	⋆	1.3	1.6	1.0	1.0
CEPC	1.0	1.0	1.0	1.8	2.0	≥ 10	≥ 10	1.1	1.0	1.1	1.0	1.0		1.2	1.5	≥ 10	≥ 10
FCCee_{240}	≥ 10	≥ 10	≥ 10	7.9	9.2	≥ 10	≥ 10	≥ 10	≥ 10	4.2	2.9	1.0		4.6	4.4	4.6	4.4
FCCee_{365}	≥ 10	≥ 10	≥ 10	9.9	10.0	≥ 10	≥ 10	≥ 10	≥ 10	4.2	2.9	7.5	⋆	4.6	4.4	4.6	4.4
FCCee/eh/hh	≥ 10	≥ 10	≥ 10	9.9	≥ 10	≥ 10	≥ 10	≥ 10	≥ 10	≥ 10	≥ 10	9.1	⋆	≥ 10	≥ 10	4.6	4.4

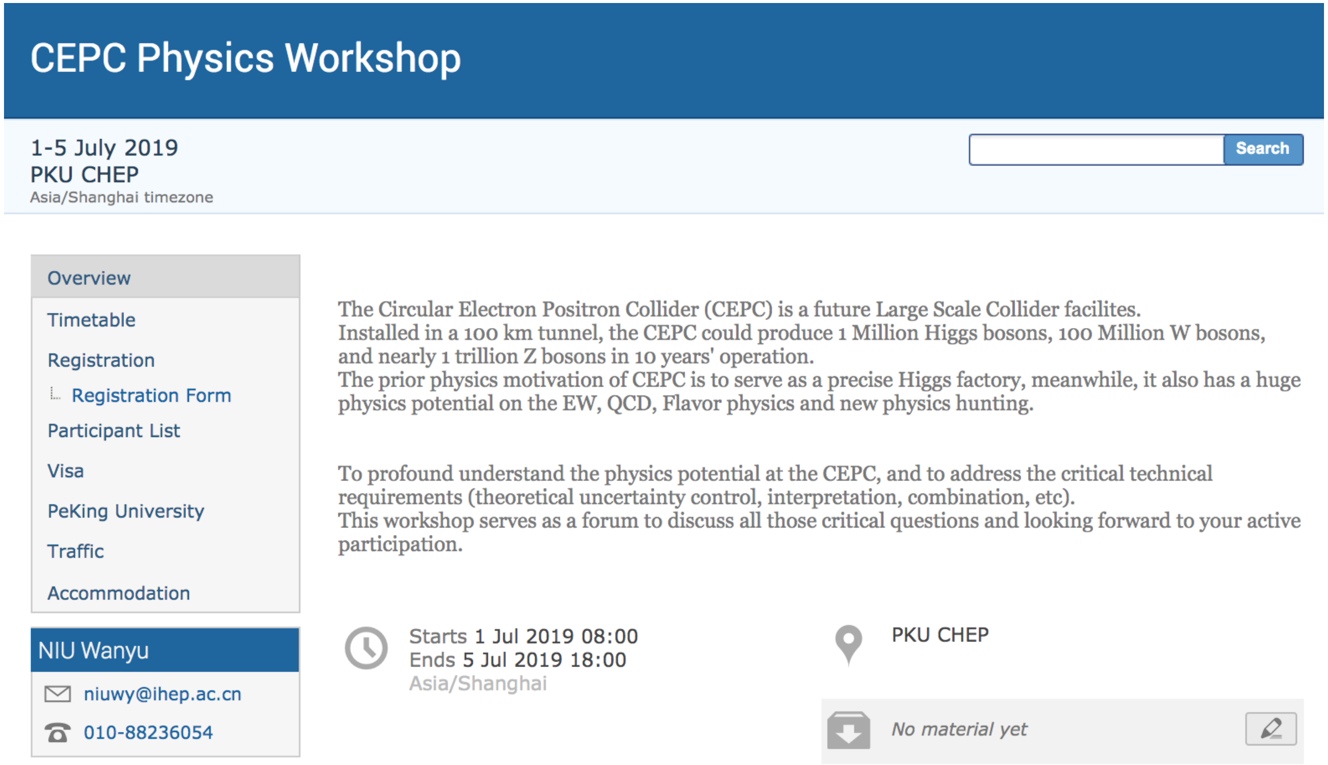
Fig. by M. Cepeda

Open Symposium - Update of the European Strategy for Particle Physics

Jorge de Blas

- EW part is somehow problematic as the input is not complete
  - In communicate with the working group, and We (Zhijun, Gang) starts to look into it
  - Hopefully, by July this can be settled

Physics WS Preparation



CEPC Physics Workshop

1-5 July 2019
PKU CHEP
Asia/Shanghai timezone

NIU Wanyu
niuwy@ihep.ac.cn
☎ 010-88236054

The Circular Electron Positron Collider (CEPC) is a future Large Scale Collider facilites.
Installed in a 100 km tunnel, the CEPC could produce 1 Million Higgs bosons, 100 Million W bosons, and nearly 1 trillion Z bosons in 10 years' operation.
The prior physics motivation of CEPC is to serve as a precise Higgs factory, meanwhile, it also has a huge physics potential on the EW, QCD, Flavor physics and new physics hunting.

To profound understand the physics potential at the CEPC, and to address the critical technical requirements (theoretical uncertainty control, interpretation, combination, etc).
This workshop serves as a forum to discuss all those critical questions and looking forward to your active participation.

Starts 1 Jul 2019 08:00
Ends 5 Jul 2019 18:00
Asia/Shanghai

PKU CHEP

No material yet

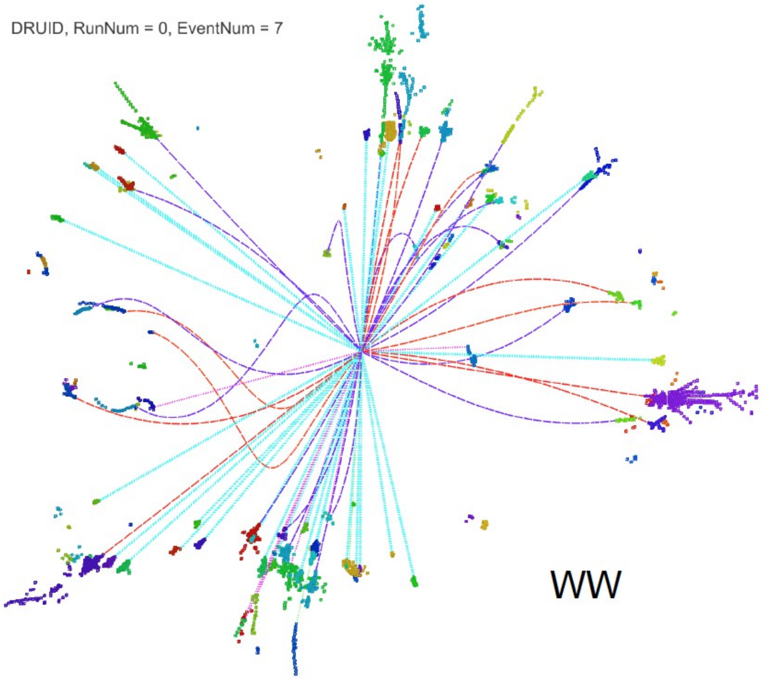
- Key objective:
  - Promote the white paper preparations (Higgs, EW, Flavor, QCD)
  - Emphasize on EW: provide input for EUSPP Physics group
- 43 registrant now (including 10 invitees): expect 50 ppl

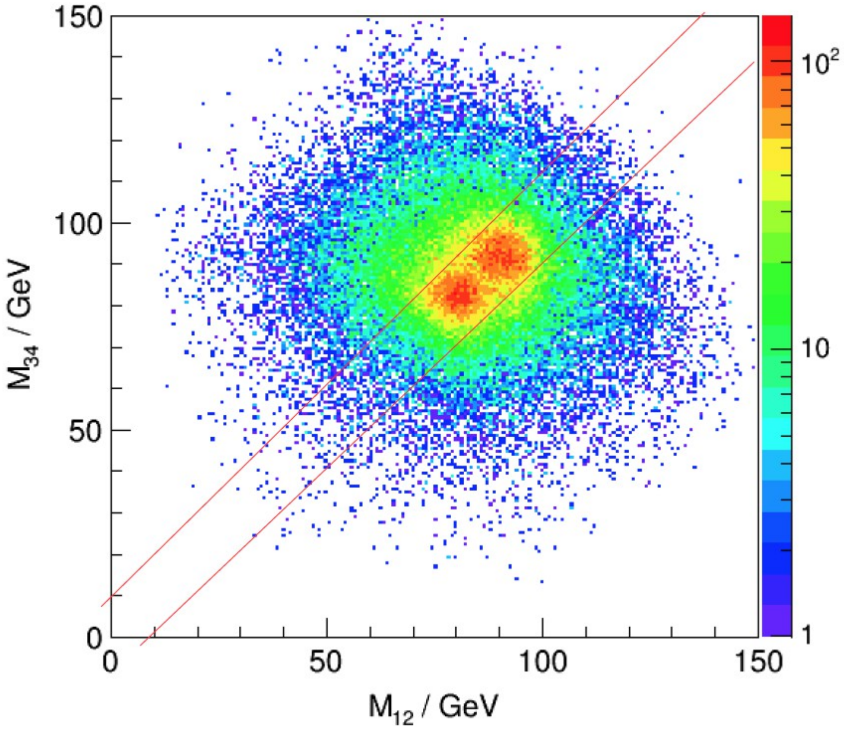
Summary

- BMR (mass resolution of hadronic system) is critical for Higgs measurement
  - Physics measurement with qqH, require BMR < 4%, to efficiently suppress the ZZ background
  - At 240 GeV c.m.s., BMR helps significantly the W fusion measurement, and affect directly all the coupling constant determinations
- At 360 GeV:
  - With 1 ab^{-1}, the Higgs width can be improved by 2 times. Meanwhile, couplings to major SM decay modes can be improved significantly, especially g(Hbb), g(HWW), g(Hgg) and g(Htautau)
- Higgs: development of new analysis technologies, and coverage of more final states could improve the current accuracy... but to 1st order not significantly.
- Started to iterate with EUSPP Physics Group on the EW inputs.

Backup

近期亮点2：多喷注事例重建 - WW/ZZ 全强事例分离性能研究

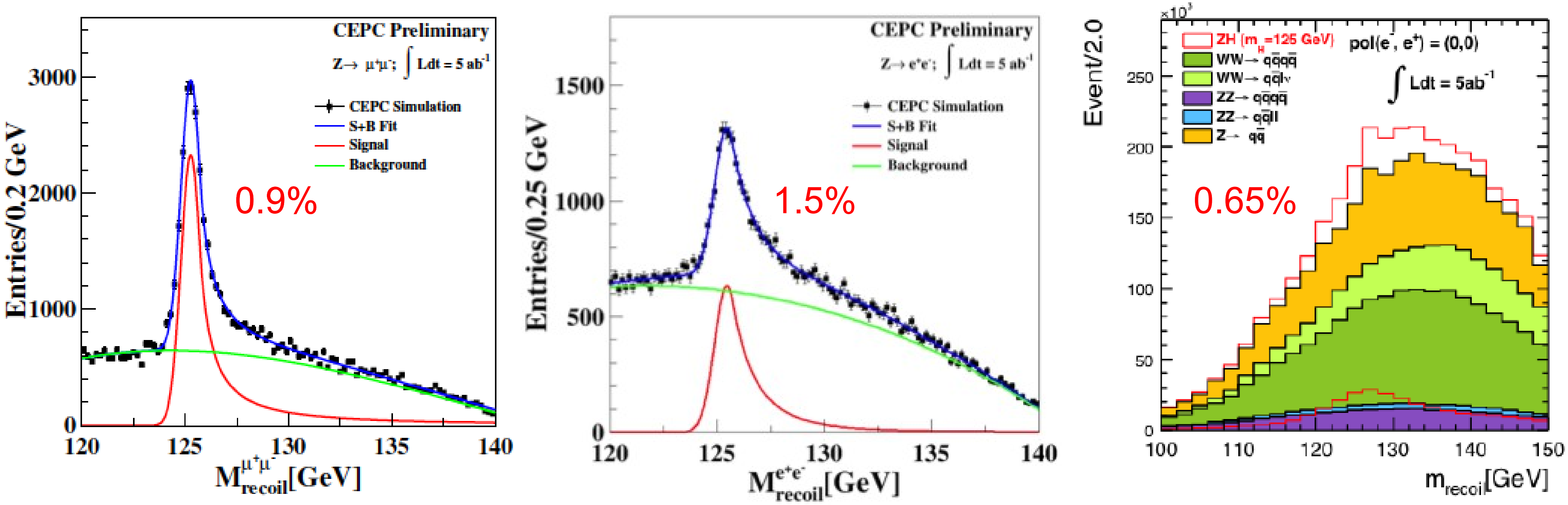




- 2/3 的 CEPC Higgs 事例、1/2 的 WW/ZZ 事例末态中有至少 4 个喷注。这些事例的重建需要将末态粒子分组（Color Singlet Identification：可通过 Jet Clustering, Matching 等实现）
- 通过全强衰变的 WW/ZZ 事例分析了 CEPC 基线探测器性能及粒子分组算法的影响
- 结论：CEPC 基线探测器能分开 WW/ZZ 全强事例；但有约一半事例的末态粒子分组极差，需开发更好的分组算法（发表于 EPJC）

Model-independent measurement of σ(ZH)

Zhenxing Chen & Yacine Haddad



- Recoil mass method. Combined precision: δσ(ZH)/σ(ZH) = 0.5% - δg(HZZ)/g(HZZ) = 0.25%

Mass:

mumuH: accuracy 6.5 MeV
eeH: accuracy, 14 MeV
Combined: 5.9 MeV