第三届粒子物理前沿研讨会

New physics hints with 2HDM under the Higgs Precision Measurements

苏伟

2008.05492 (T. Han, S. Li, S. Su, WS, Y. Wu)

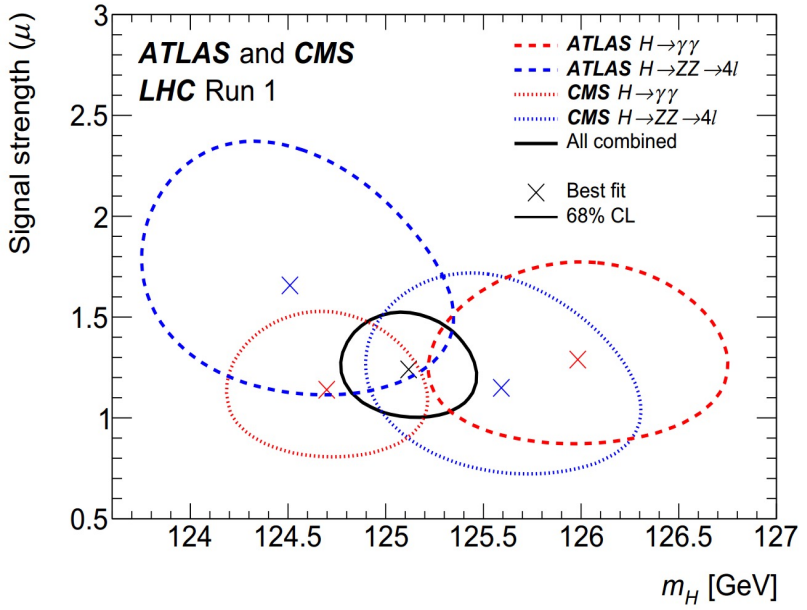
1808.02037 (N. Chen, T. Han, S. Su, WS, Y. Wu)

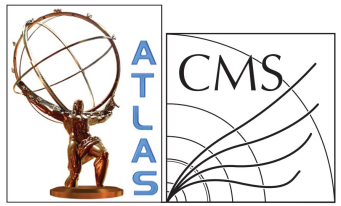
1912.01431 (N. Chen, T. Han, S. Li, S. Su, WS, Y. Wu)

Outline

- Higgs Precision Measurements and 2HDM
- Study Results: exclusion ability
- Study Results: discovery potential
- Study Results: discrimination ability
- Study Results: Compatibility test
- Summary

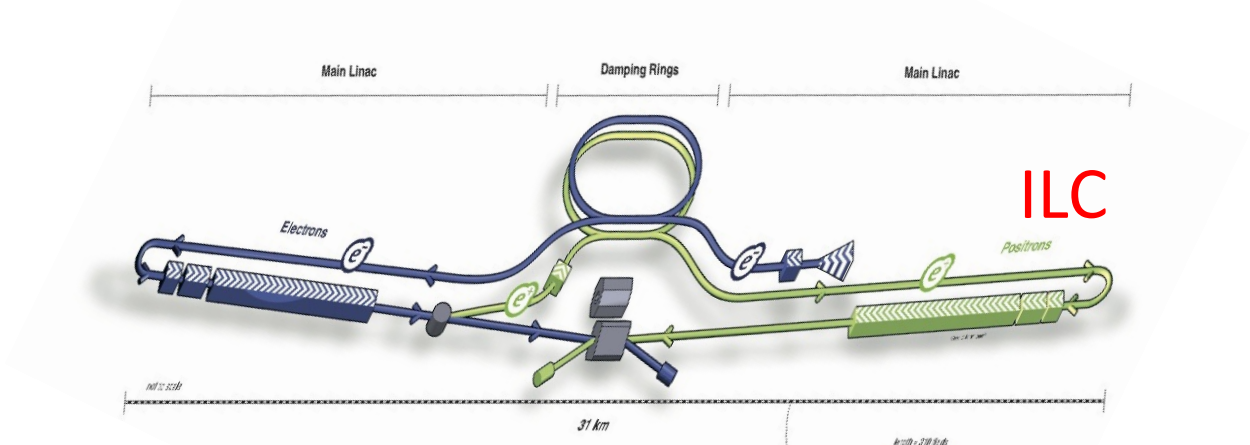
Higgs Precision Measurements



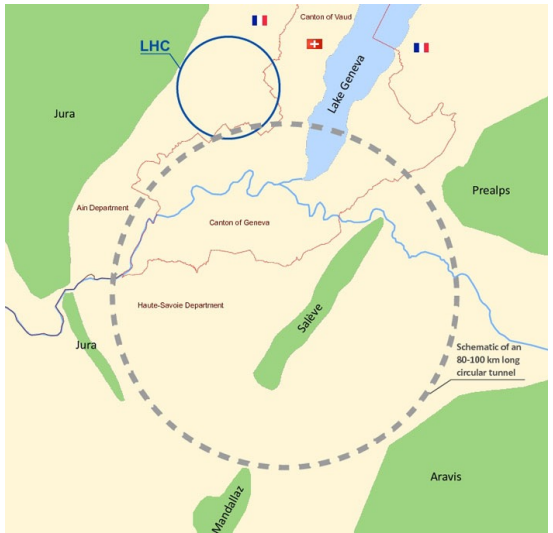


CMS-HIG-14-042
ATLAS-HIGG-2014-14

CEPC



ILC



LHC
HL-LHC
FCC

2HDM: Brief Introduction

- Two Higgs Doublet Model

$$\Phi_i = \begin{pmatrix} \phi_i^+ \\ (v_i + \phi_i^0 + iG_i)/\sqrt{2} \end{pmatrix}$$

$$v_u^2 + v_d^2 = v^2 = (246\text{GeV})^2$$
$$\tan\beta = v_u/v_d$$

$$\begin{pmatrix} H^0 \\ h^0 \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} \phi_1^0 \\ \phi_2^0 \end{pmatrix}, \quad \begin{aligned} A &= -G_1 \sin\beta + G_2 \cos\beta \\ H^\pm &= -\phi_1^\pm \sin\beta + \phi_2^\pm \cos\beta \end{aligned}$$

	Φ_1	Φ_2
Type I	u,d,l	
Type II	u	d,l
lepton-specific	u,d	l
flipped	u,l	d

- Parameters (CP-conserving, Flavor Limit, Z_2 Symmetry)

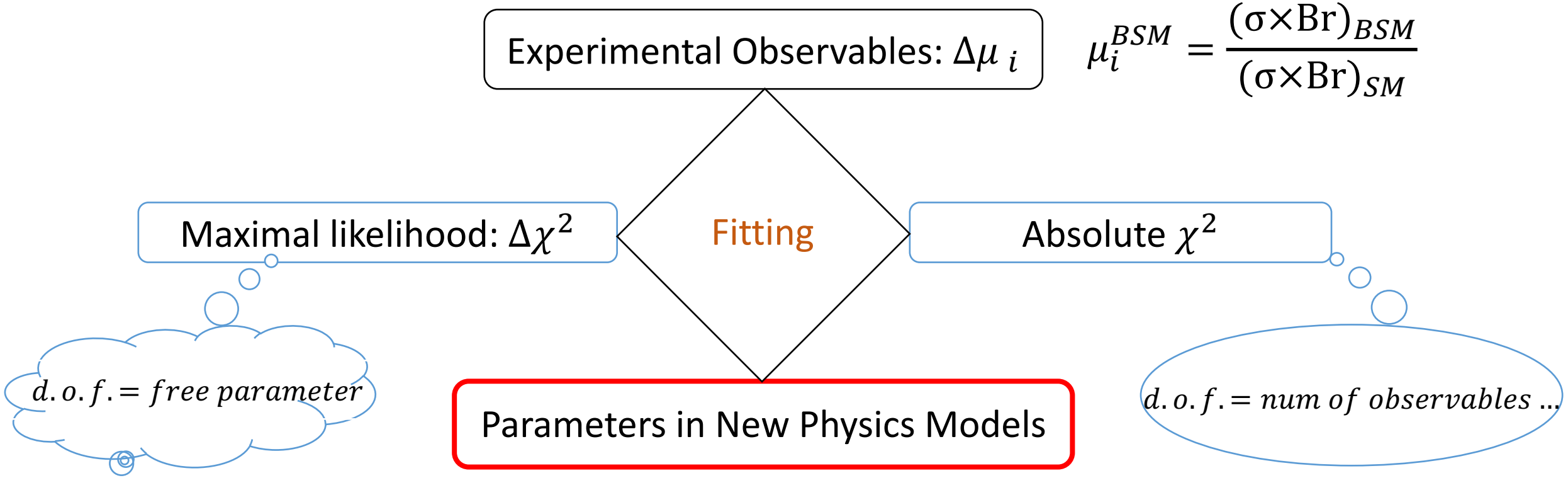
$m_{11}^2, m_{22}^2, \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5$ → $v, \tan\beta, \alpha, m_h, m_H, m_A, m_{H^\pm}$

Soft Z_2 symmetry breaking: m_{12}^2

246 GeV

125. GeV

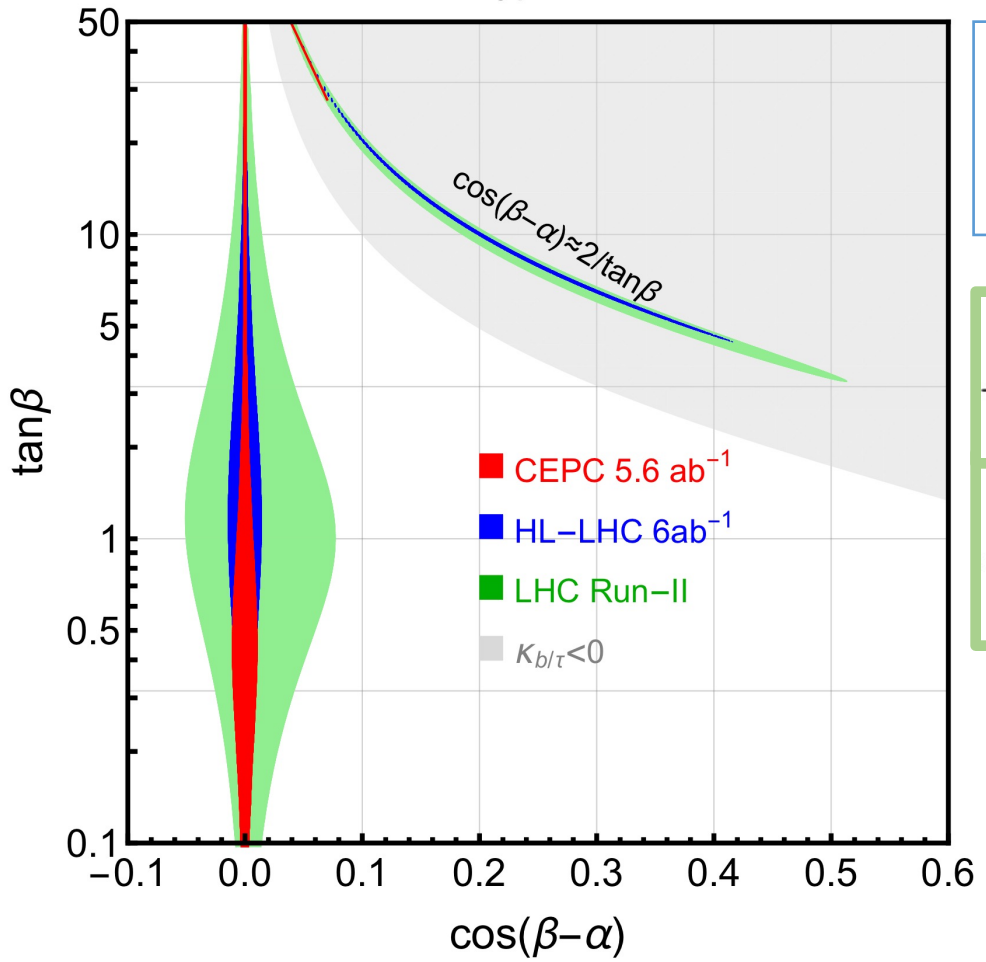
Exclusion ability : Study strategies



Exclusion: Tree Level

Model	κ_V	κ_u	κ_d	κ_ℓ
2HDM-I	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
2HDM-II	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$
2HDM-L	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$
2HDM-F	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$

2HDM Type-II



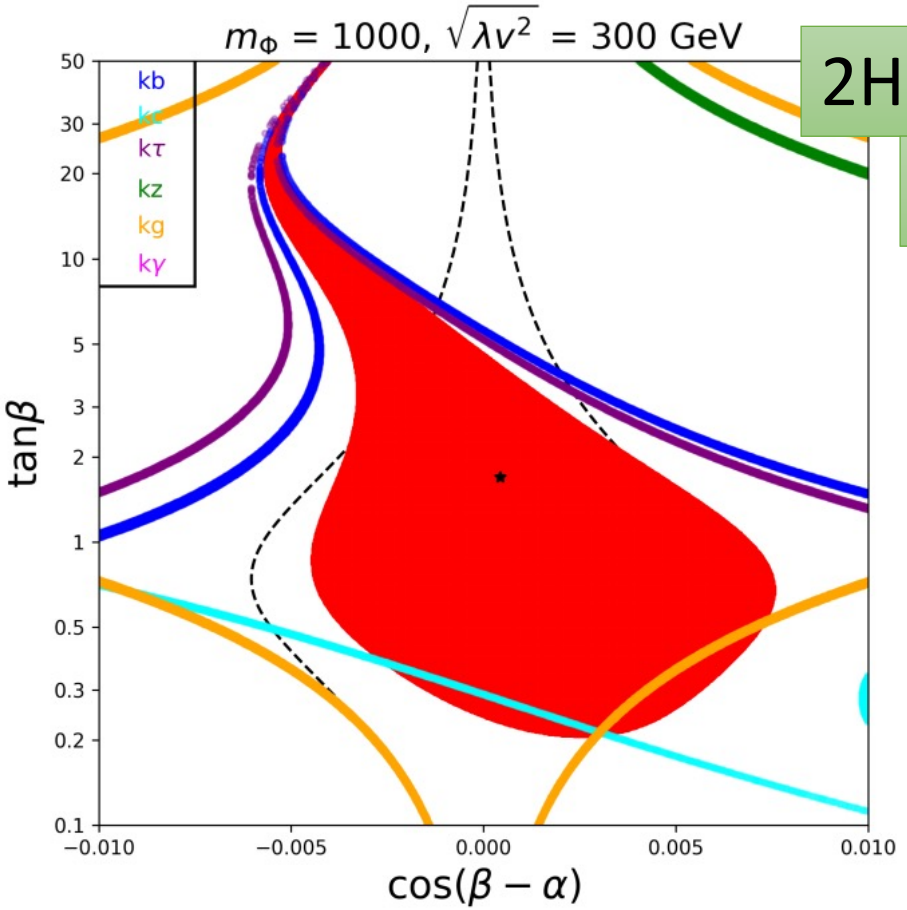
Alignment limit :
$\cos(\beta-\alpha)=0$
$g(2HDM)=g(SM)$

1910.06269
WS

$$-\frac{\sin\beta}{\cos\alpha}-1=-\frac{1}{2}\cos^2(\beta-\alpha)-\cos(\beta-\alpha)\times\tan\beta$$

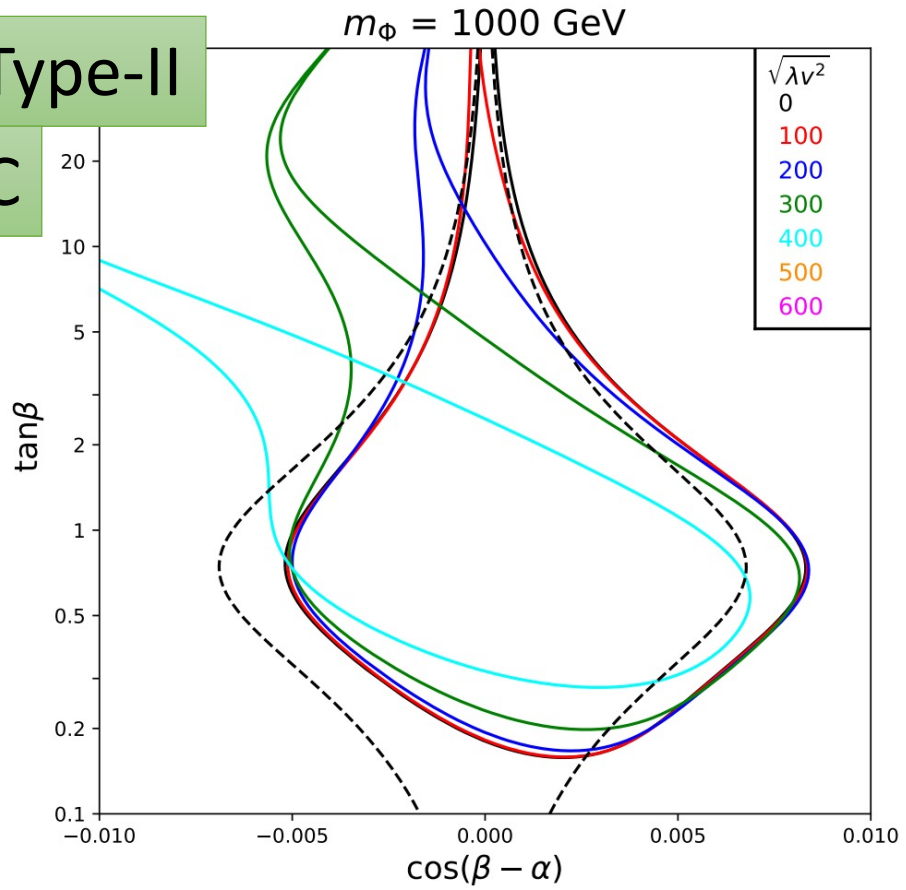
$$\frac{\cos\alpha}{\sin\beta}-1=-\frac{1}{2}\cos^2(\beta-\alpha)+\frac{\cos(\beta-\alpha)}{\tan\beta}$$

Exclusion : Loop Level



2HDM Type-II

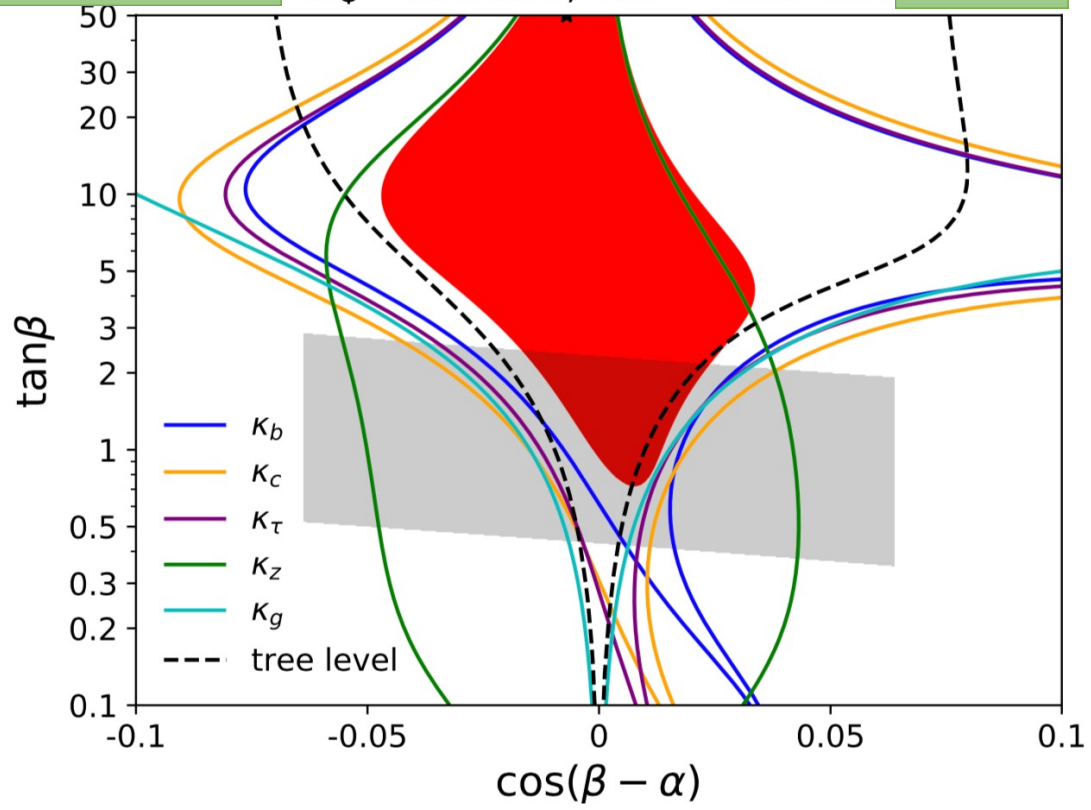
CEPC



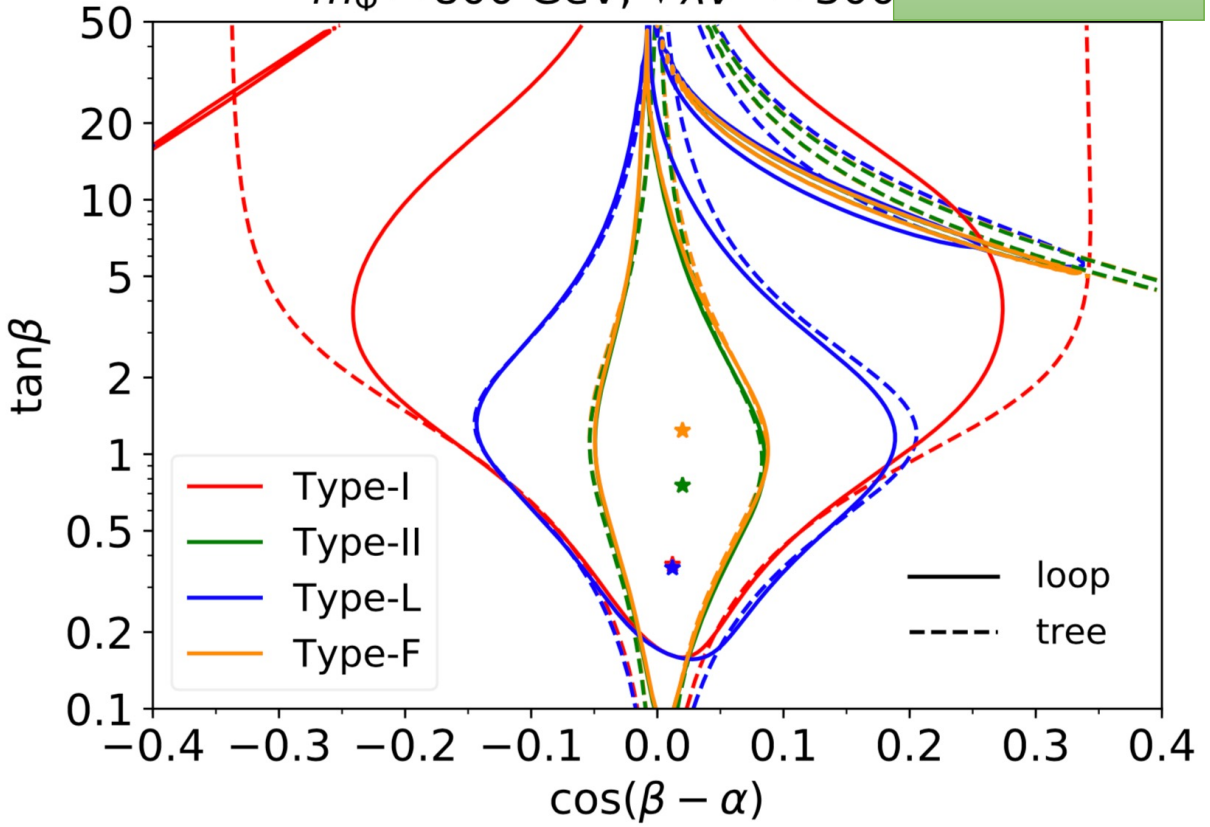
Exclusion : Loop Level

2HDM Type-I

CEPC



LHC Run-II



Study Results: discovery potential

- method

$$\chi^2 = \sum_i \frac{(\mu_i^{\text{hyp}} - \mu_i{}^{\text{obs}})^2}{\sigma^2_{\mu_i}}$$

null hypothesis H0 : SM

To claim the discovery of BSM at 5σ significance : p=5.7*10^(-7)

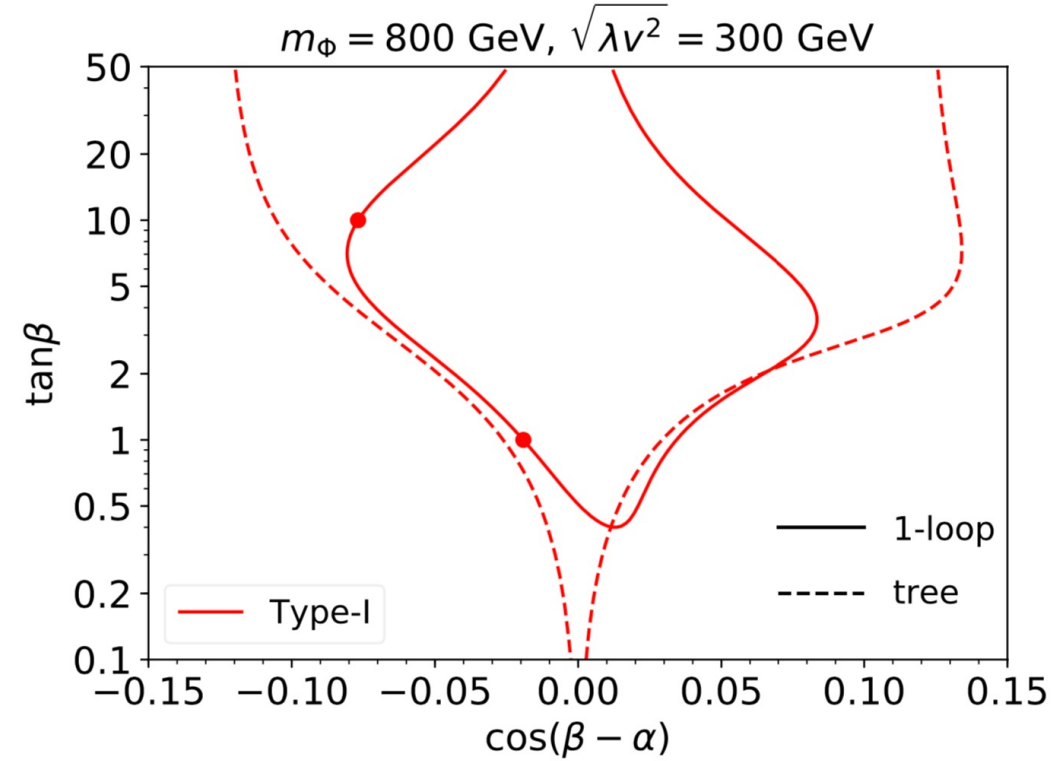
$$\chi^{\text{SM}} > 48.2$$

$$\mu^{\text{hyp}} = \mu^{\text{SM}} = 1$$

degrees of freedom : signal strength modifiers (SSM),
or μ parameter : 10 for CEPC

Study Results: discovery potential

Choose one point of BSM as the observed, to see if SM is rejected.

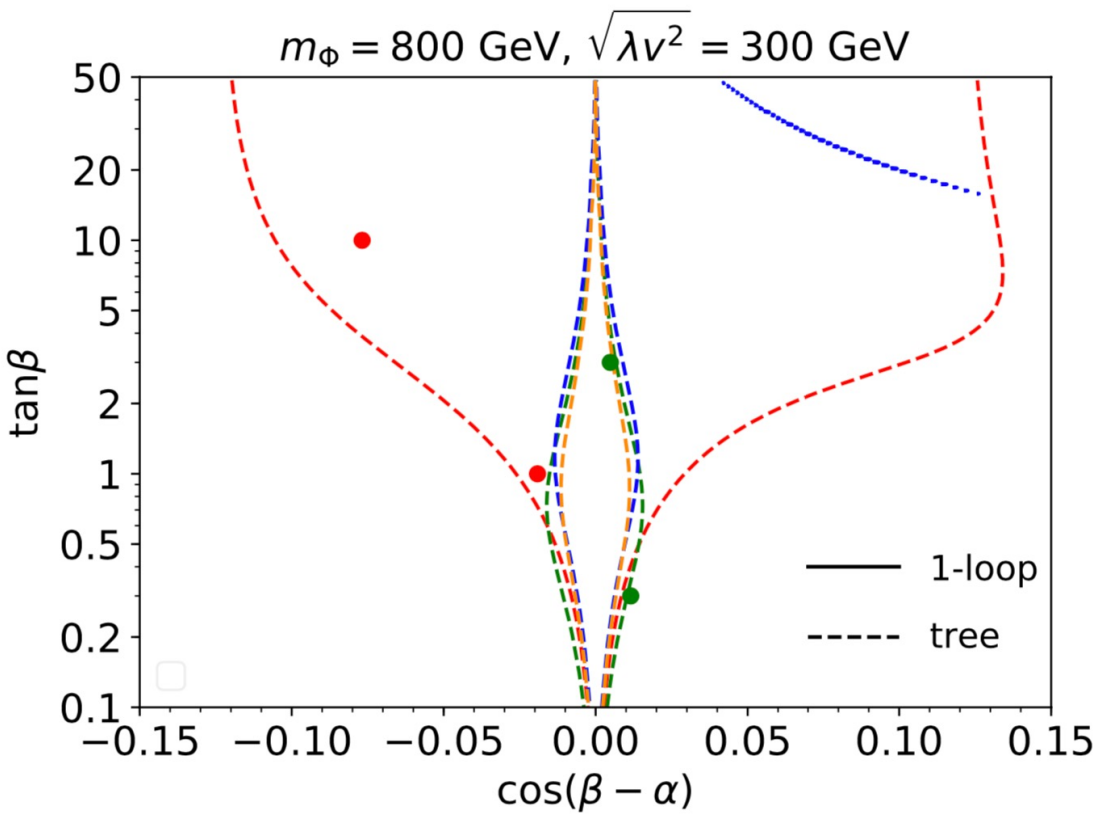


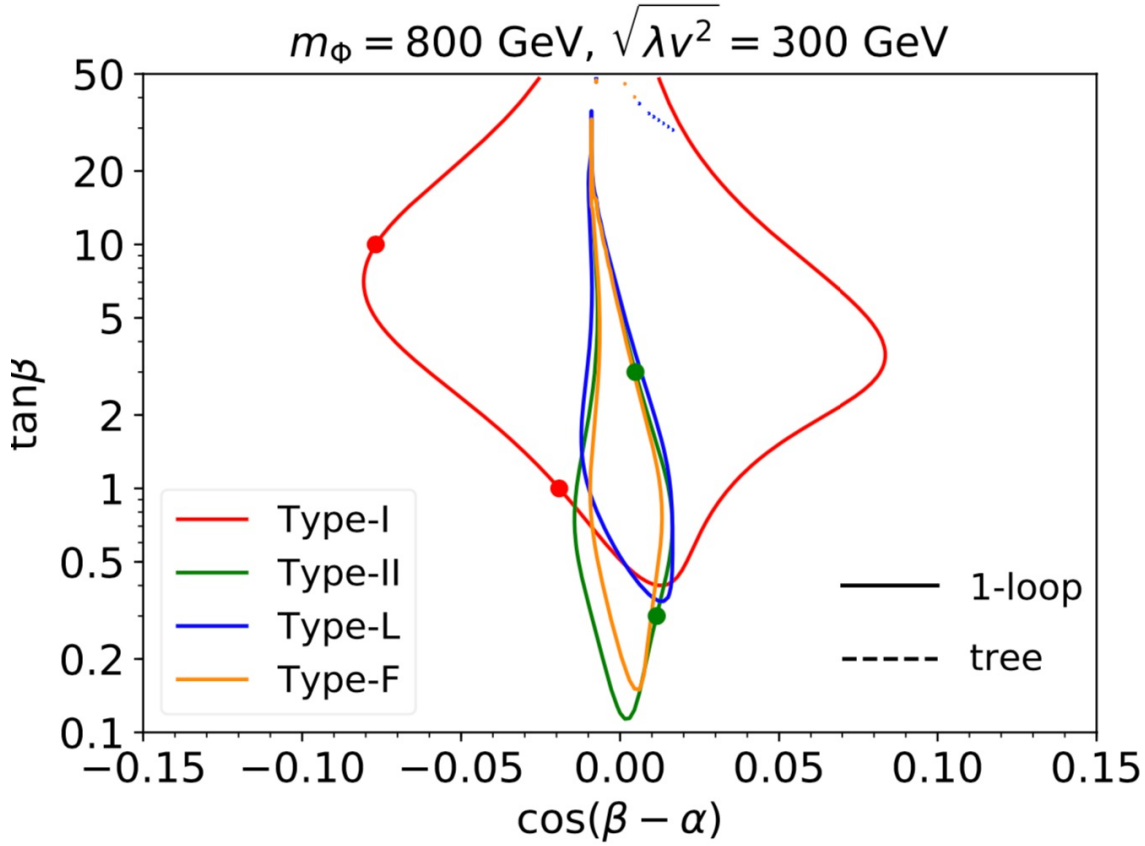
If the future observable is same to Type-I,
The center region can not claim a discovery
The two sides region can claim

$$\cos(\beta-\alpha) \lesssim -0.1$$

$$\cos(\beta-\alpha) \gtrsim 0.08$$

Study Results: discovery potential





Type-II, L, F: $|\cos(\beta - \alpha)| \gtrsim 0.02$ for $\tan\beta \sim 1$

Study Results: discrimination ability

- method

performing the χ^2 statistic

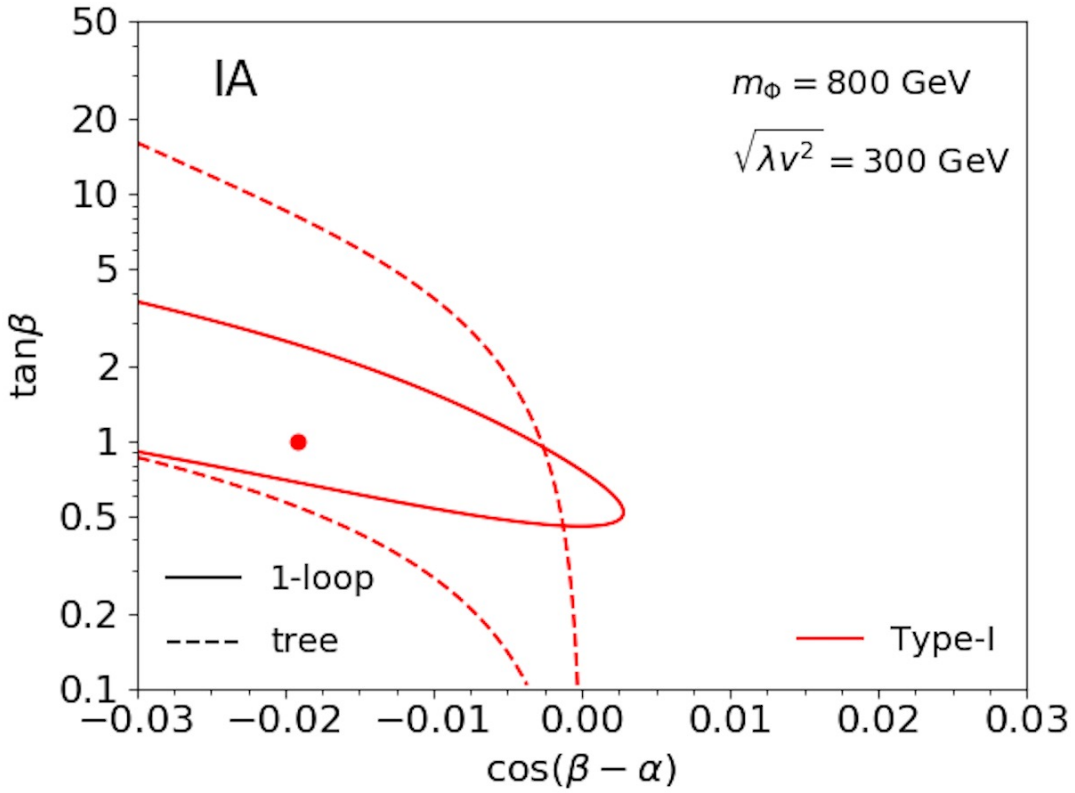
d.o.f. = # SSMs (μ) hypothesized model (Null model): One physical point

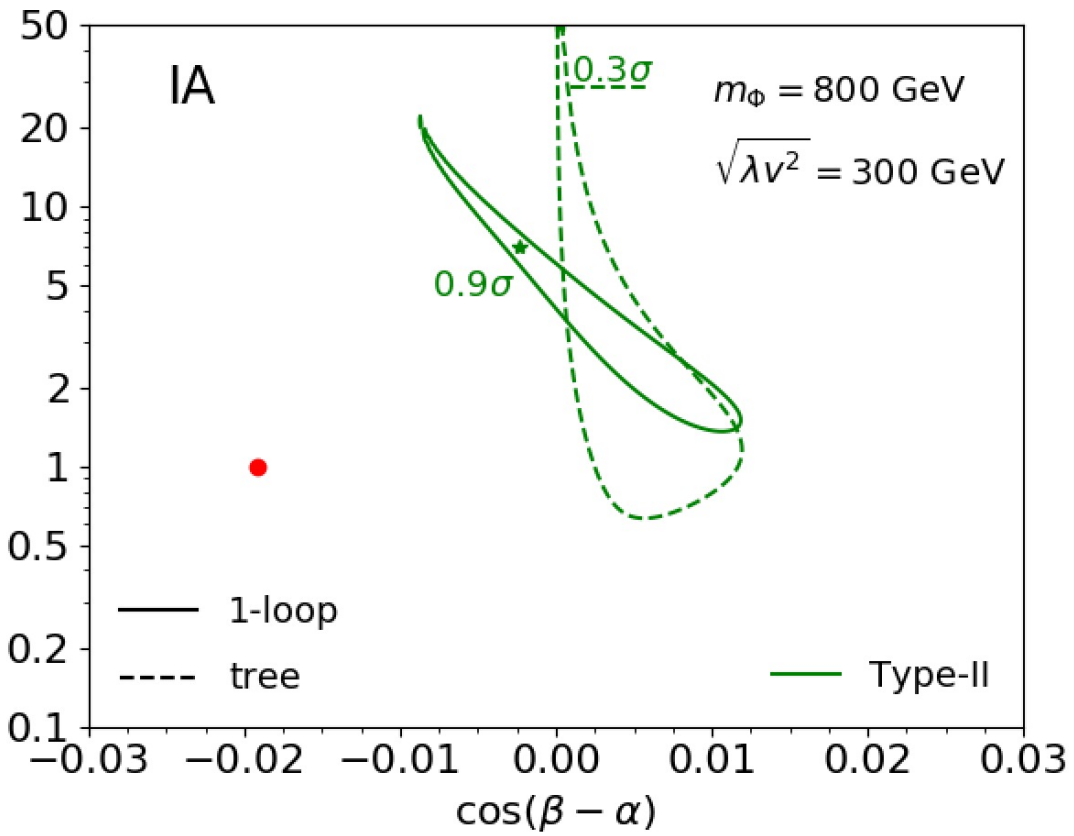
d.o.f.	1	2	3	4	5	6	7	8	9	10
$\chi^2(p = 0.05)$	3.84	5.99	7.81	9.49	11.1	12.6	14.1	15.5	16.9	18.3

BMs:

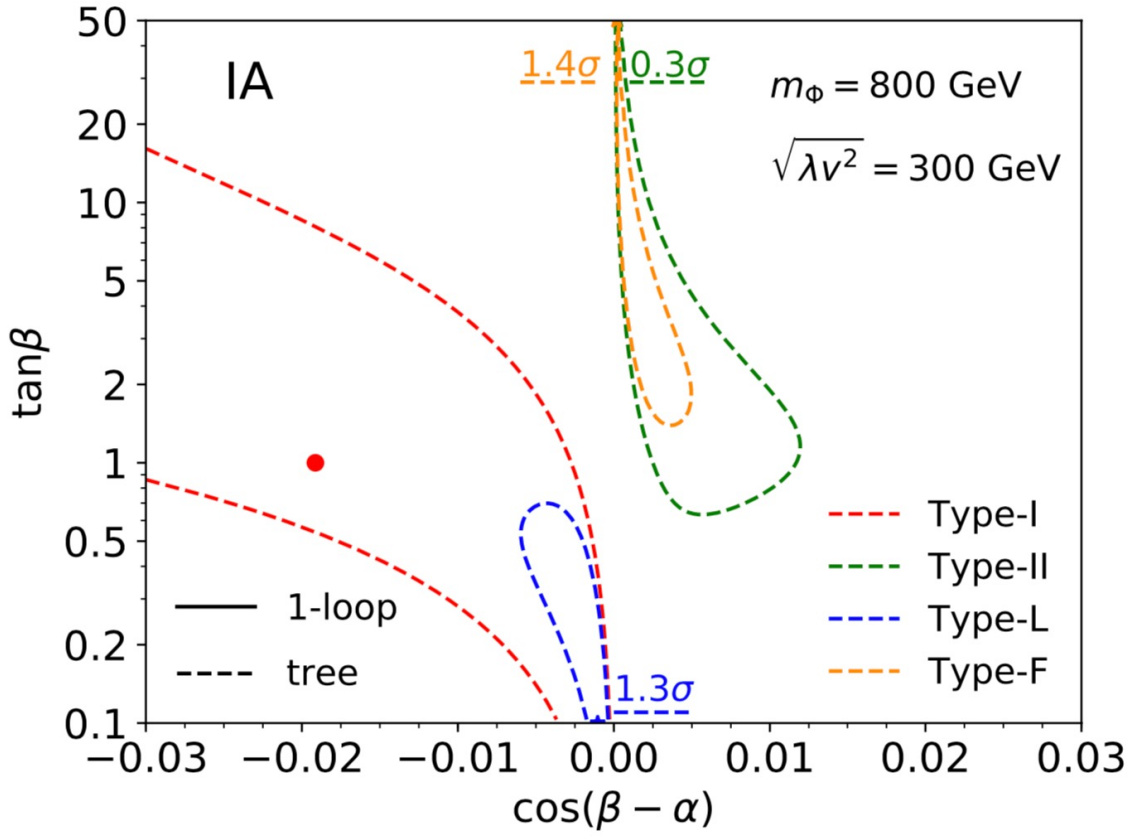
$(\cos(\beta-\alpha), \tan\beta)$	Small $\tan\beta$	Large $\tan\beta$
Type-I	**IA:** $(-0.019, 1.0)$	**IB:** $(-0.077, 10)$
Type-II	**IIA:** $(0.012, 0.3)$	**IIB:** $(0.005, 3.0)$

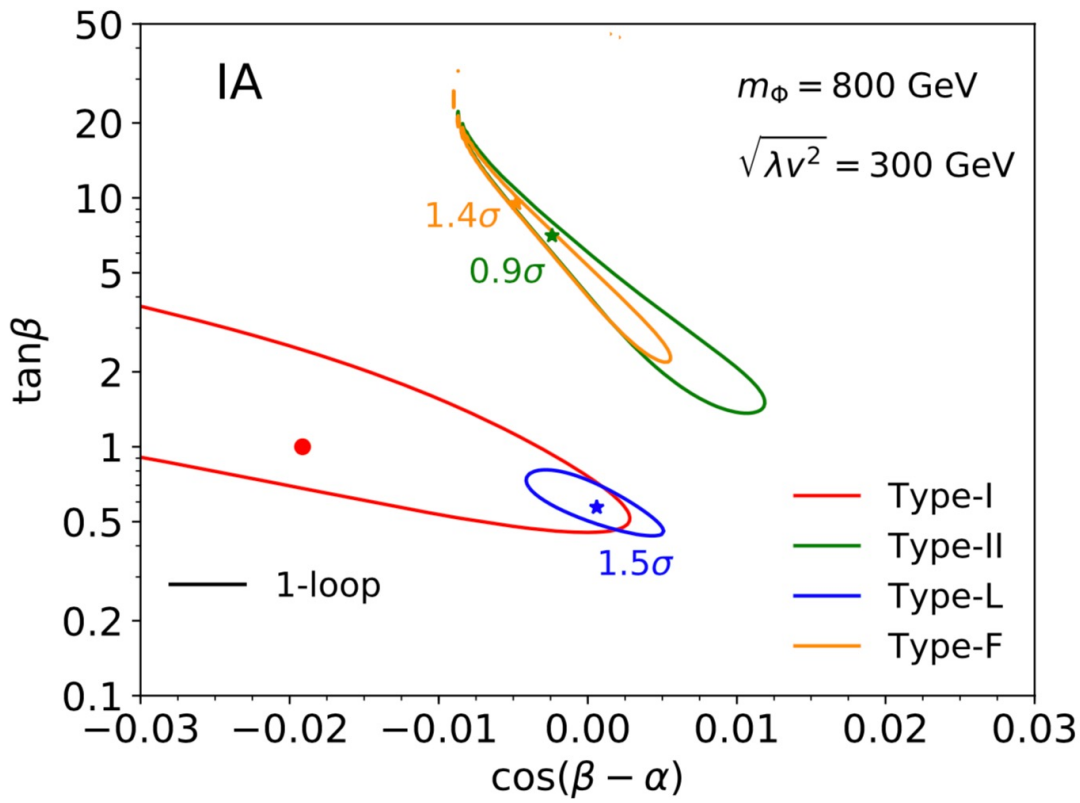
Study Results: discrimination ability





Study Results: discrimination ability





Study Results: compatibility test

- compatibility test method

Test Type-I with Type-II:

observable : one point of type-II (accepted model),

test type-I by performing the χ^2 statistic

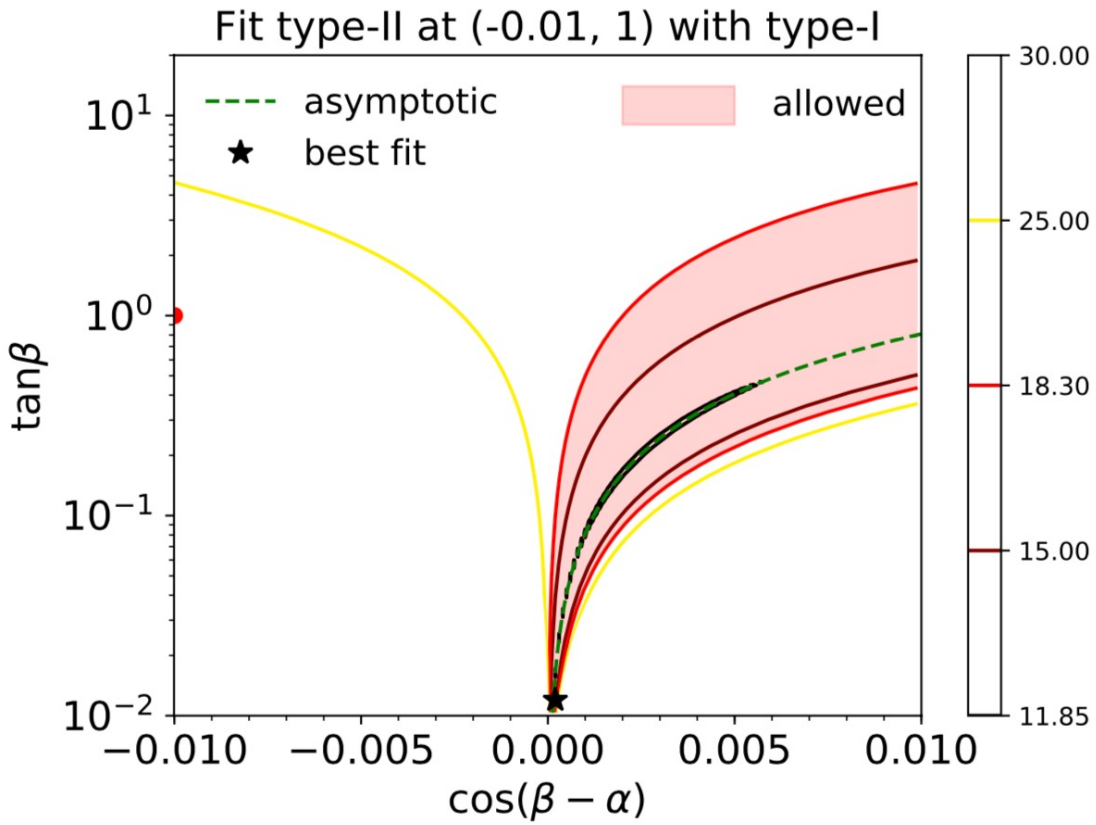
d.o.f. = # SSMs (μ)

hypothesized model (Null model): Type-II, instead of SM

d.o.f.	1	2	3	4	5	6	7	8	9	10
$\chi^2(p = 0.05)$	3.84	5.99	7.81	9.49	11.1	12.6	14.1	15.5	16.9	18.3

Study Results: compatibility test

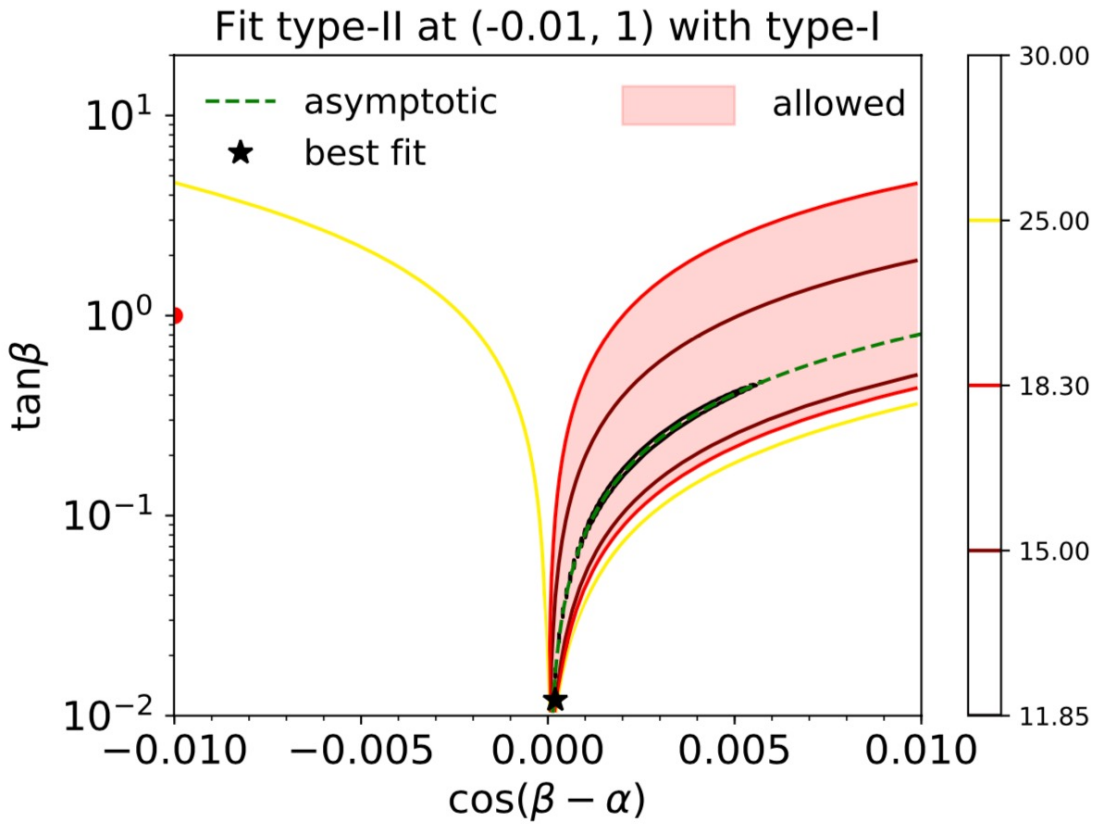
- Type-II $(\cos(\beta-\alpha), \tan\beta) = (-0.01, 1)$

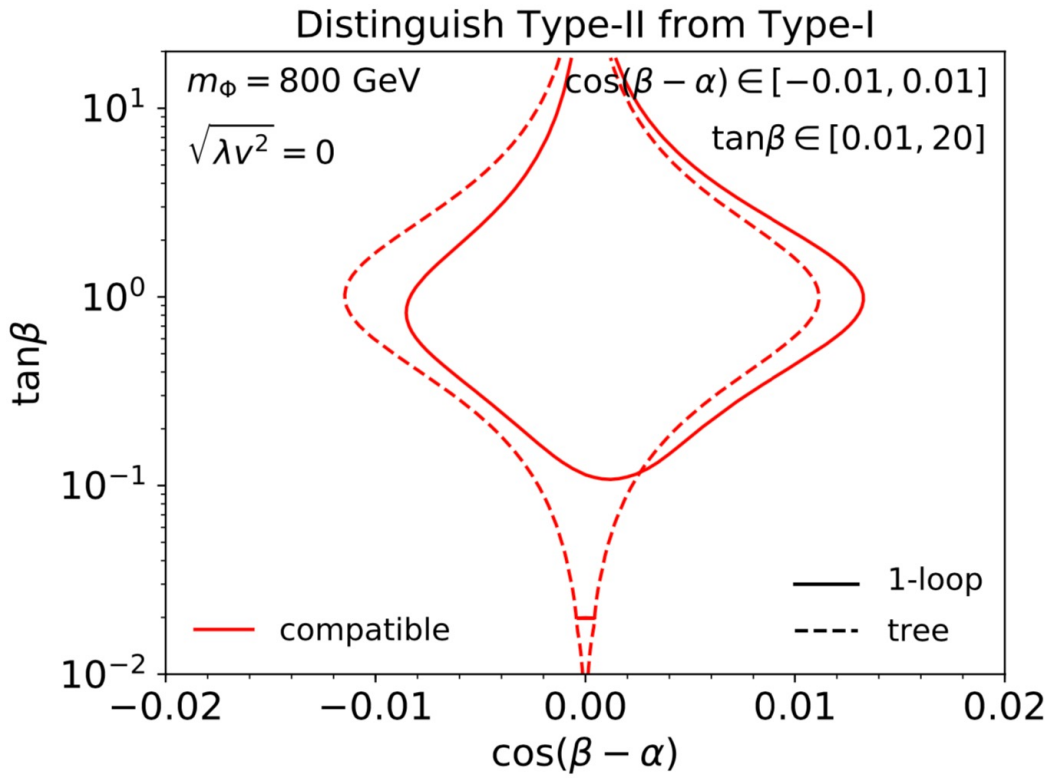


If there is points of Type-I is allowed, then BM of Type-II is compatible under CEPC precision

Study Results: compatibility test

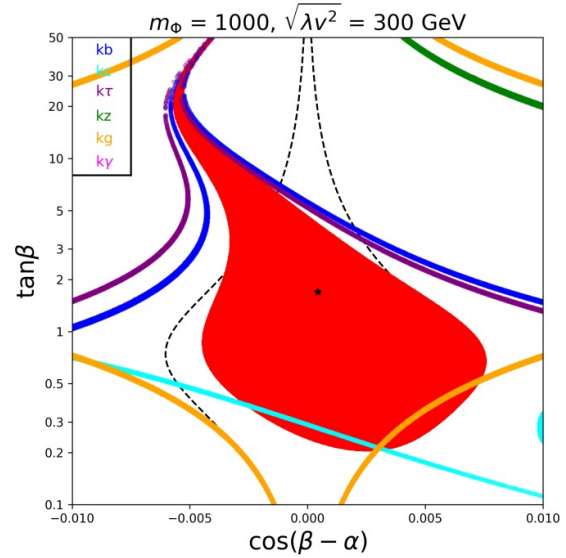
- Type-II $(\cos(\beta-\alpha), \tan\beta) = (-0.01, 1)$

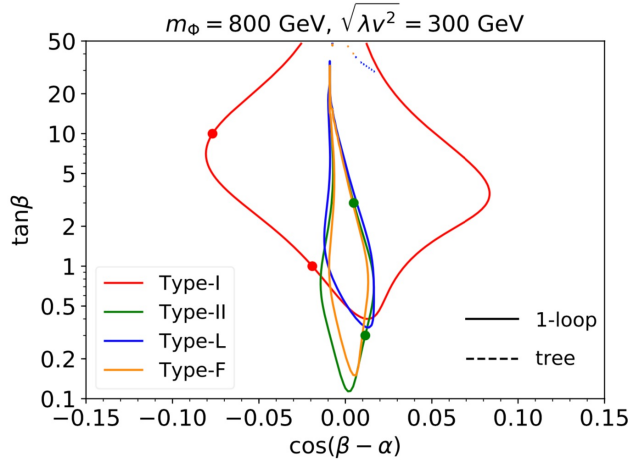


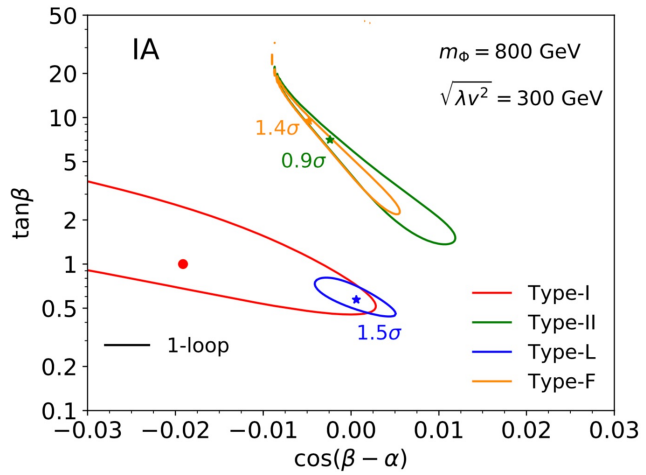


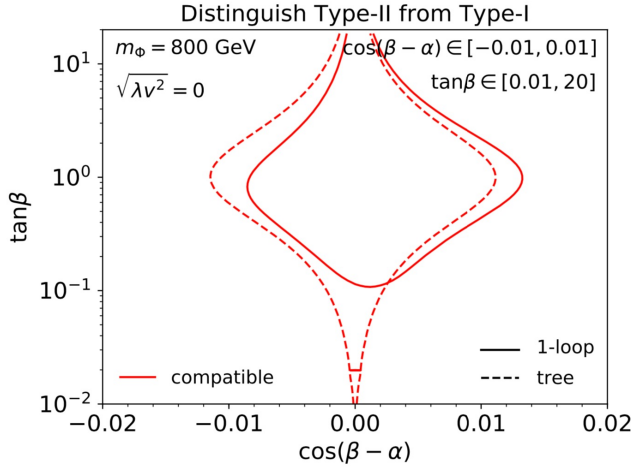
Summary: Higgs precision measurements

- Exclusion :Maximal likelihood vs. absolute χ^2 study
- Discovery potential: test null model SM
- Discrimination ability: a deviation observed
- Compatibility test: different BSMs









Thanks !