CLIC sensitivity to measure CPV Higgs mixing angle in ZZ-fusion at 1.4 TeV

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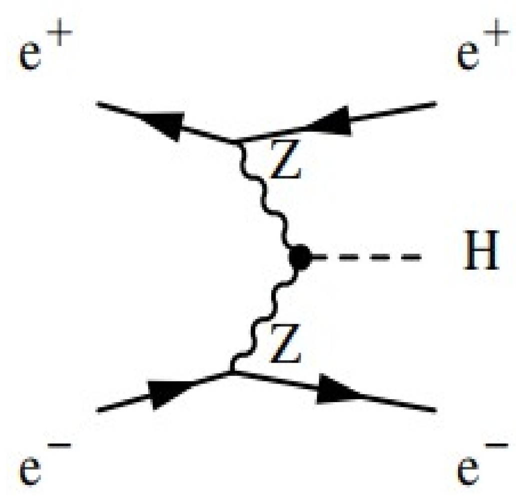
1. Introduction

- Baryon asymmetry of the Universe is still unresolved phenomena;
- SM is insufficient to accommodate observed CPV;
- New source of CP violation can be introduced in the extended Higgs sector, via scalar-pseudoscalar mixing;
- HVV and Hff vertices can be probed in various Higgs production and decay channels at future Higgs factories;



Feynmanan diagram of ZZ-fusion

fermion couplings	
$H \to \tau^-\tau^+$	250+ GeV
$e^-e^+ \to Ht\bar{t}$	500+ GeV
boson couplings	
$e^-e^+ \to HZ$	250+ GeV
$H \to ZZ$	250+ GeV
$H \to WW$	250+ GeV
$e^-e^+ \to He^-e^+$ (ZZ-fusion)	1000+ GeV

HVV and Hff vertices at different center-of-mass energies [1]

- This study is based on generic model of CPV mixing (via angle Ψ_{CP}) of scalar (H) and pseudoscalar (A) states: $h = H \cos \Psi_{CP} + A \sin \Psi_{CP}$;

- Changing the tensor structure of the g_{HZZ} coupling [2]:

$$g_{HZZ} = ig\, M_Z/\cos\theta_W (\cos \Psi_{CP} \cdot g^{\mu\nu} + \sin \Psi_{CP} \cdot \varepsilon^{\mu\nu\rho\sigma} (p_1+p_2)_\rho (p_1+p_2)_\sigma / M_Z^2)$$

where p_1 and p_2 are the 4-momenta of the vector bosons in $e^+e^- \to He^+e^-$ (ZZ-fusion).

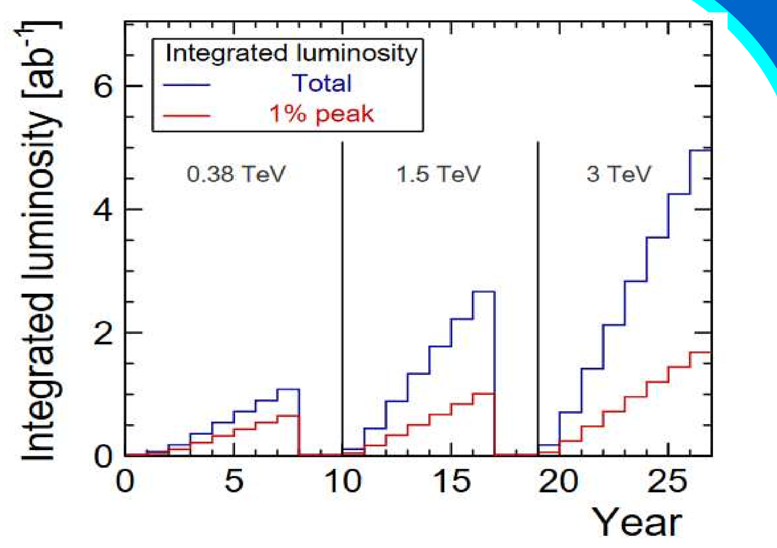
2. Accelerator & Detector

- Two beam acceleration scheme;

- Acceleration gradient up to 100 MV/m;

- Energy staged machine (350 GeV, 1.4 TeV, 3 TeV);

- $3 \cdot 10^6$ Higgs bosons at all stages.



Integrated luminosity for CLIC energy stage [3]

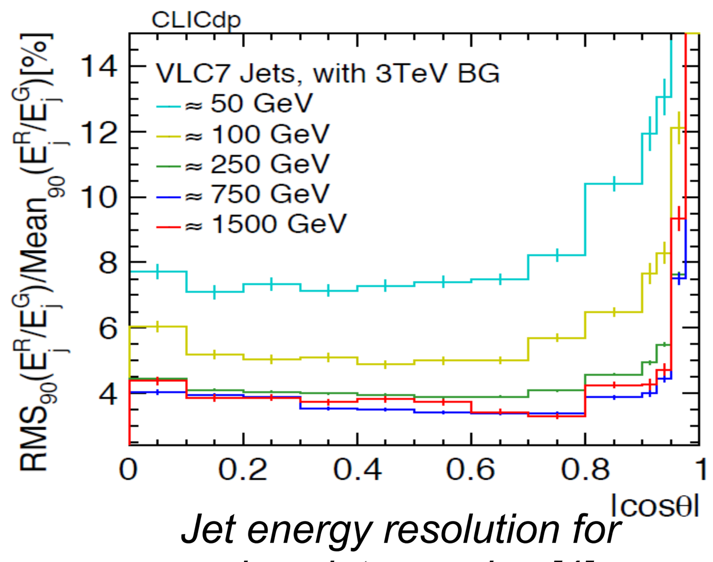
CLICdet

- 4 T field;

- Ultra low-mass Vertex detector;

- All-Si tracking;

- Particle flow calorimetry => jet energy resolution 3-5%; (crucial algorithm for this measurement).



Jet energy resolution for various jet energies [4]

3. Event selection

- Consider exclusive $H \to b\bar{b}$ channel to suppress high cross-section e^+e^- final state background;

1. Isolate 2 electrons per event;

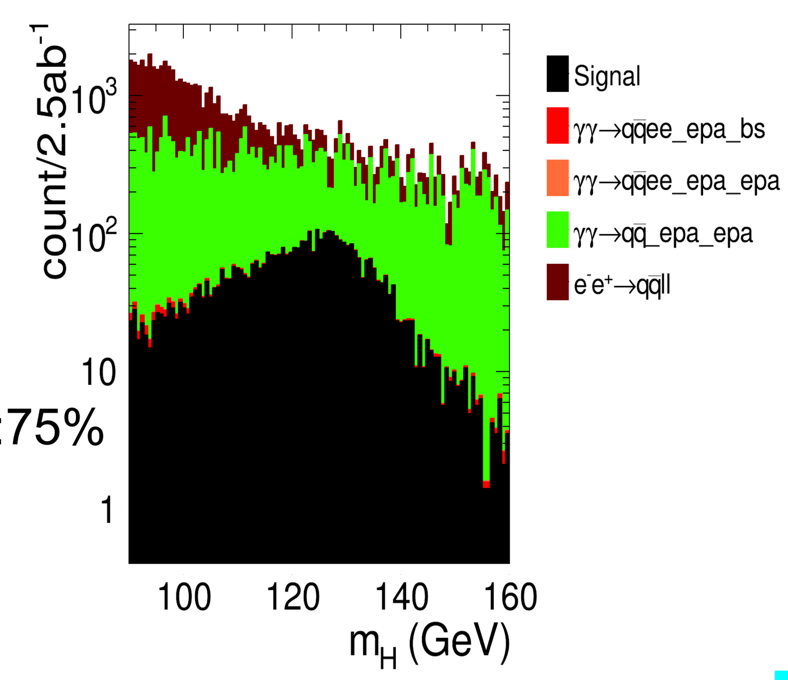
2. Suppress background with MVA;

- BDT efficiency: 94%

- Total signal efficiency (preselection+BDT):75%

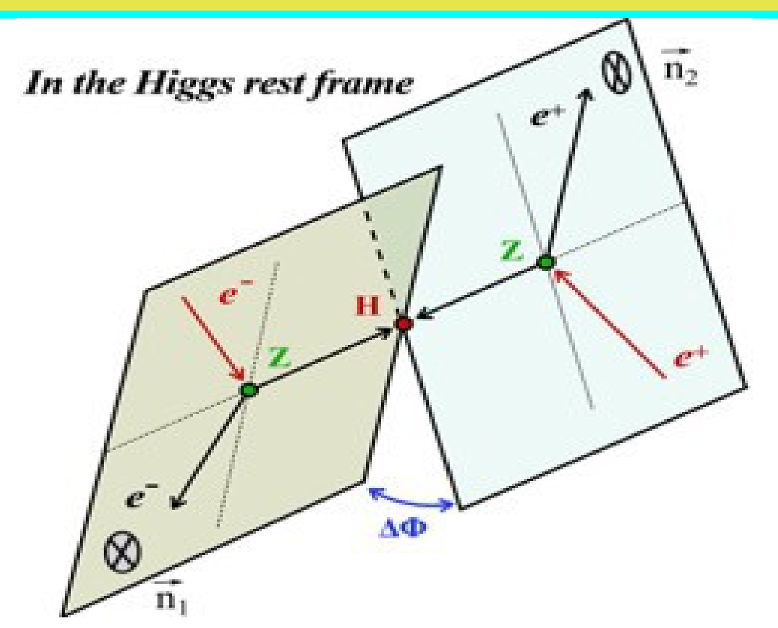
- Signal events after MVA: 7810/2.5 ab^{-1}

- Background events after MVA: <1/2.5 ab^{-1}



Stacked histogram of the Higgs mass distribution after preselection phase

4. Sensitive observable



Definition of CPV sensitive angle ΔΦ in Higgs boson production in ZZ-fusion

- Information on spin orientations of VV states is contained in the angle ΔΦ between production planes;
- ΔΦ can be retrieved as the angle between unit vectors ($\vec{n}_1$ and $\vec{n}_2$) orthogonal to these planes:

$$\Delta\Phi = a \cdot \arccos(\hat{n}_1 \cdot \hat{n}_2), \qquad a = \frac{q_{Z_{e^-}} \cdot (\hat{n}_1 \times \hat{n}_2)}{|q_{Z_{e^-}} \cdot (\hat{n}_1 \times \hat{n}_2)|},$$

$$\hat{n}_1 = \frac{q_{e_i^-} \times q_{e_f^-}}{|q_{e_i^-} \times q_{e_f^-}|}, \qquad \hat{n}_2 = \frac{q_{e_i^+} \times q_{e_f^+}}{|q_{e_i^+} \times q_{e_f^+}|}$$

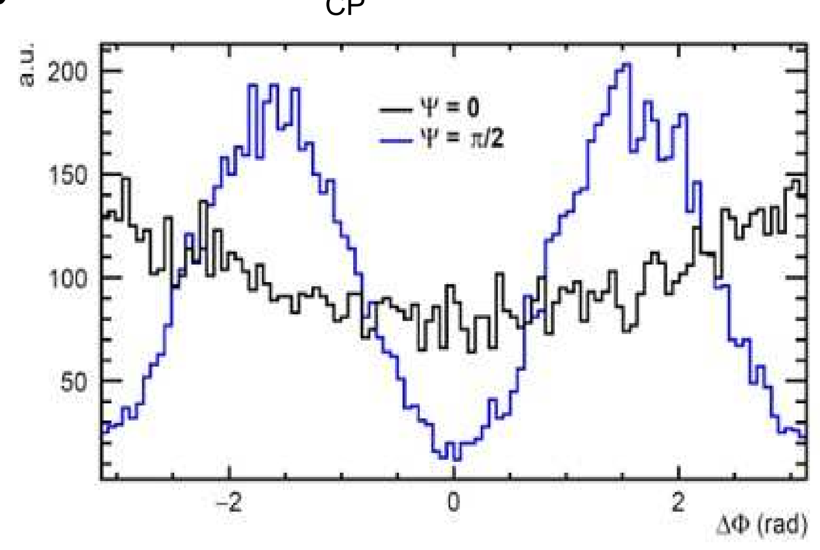
- α defines how the second (positron) plane is rotated w.r.t. the first (electron) plane; If it falls backwards (as illustrated) α = - 1, otherwise α = 1; Direction of Z in the e- plane regulates the notion of direction (fwd. or back.) using the right-hand rule.

5. Reconstructed information

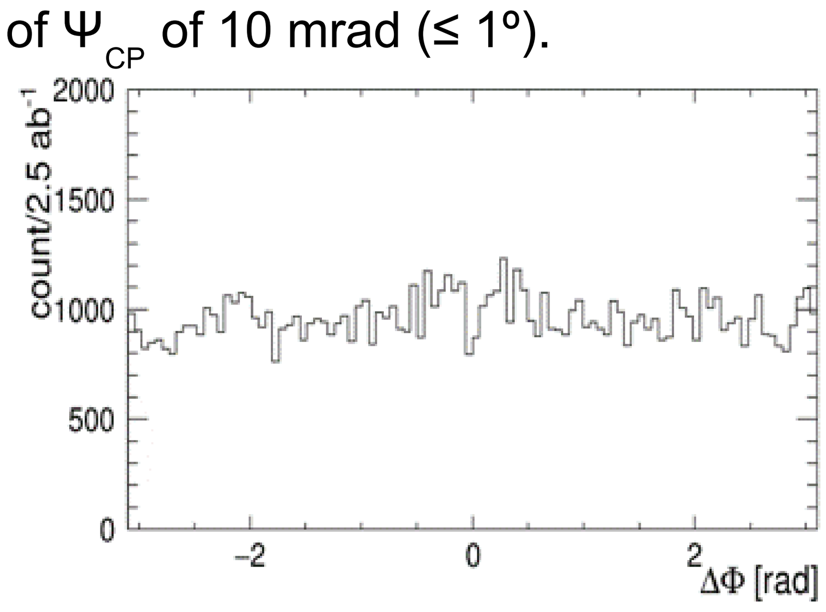
- Reconstructed ΔΦ is corrected for the overall acceptance and detector performance function;

- Background (given before MVA since it is completely suppressed after MVA) is CP insensitive (figure left);

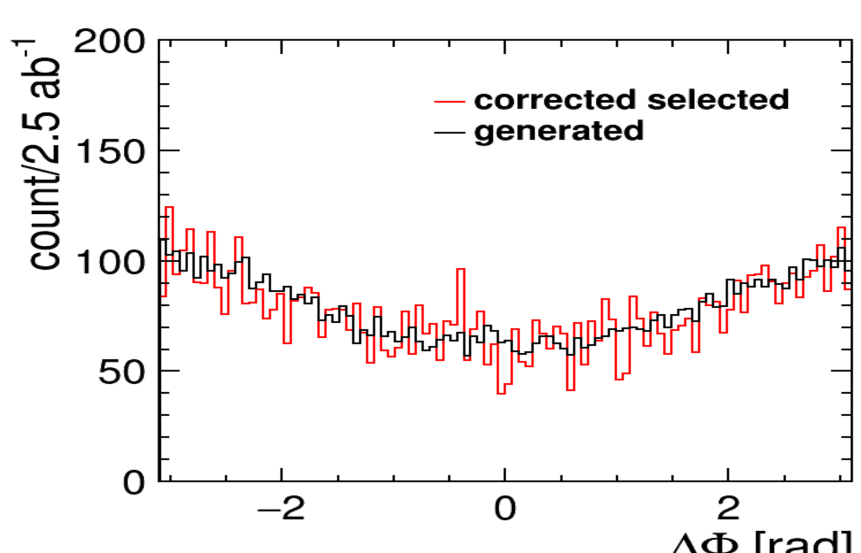
- Preliminary fit of ΔΦ at $\Psi_{CP} = 0$ indicates statistical precision of Ψ_{CP} of 10 mrad (≤ 1°).



Pure scalar (black) and pseudoscalar (blue)



CP insensitive background



ΔΦ distribution, reconstructed, selected, corrected for acceptance effects and detector reconstruction (red) vs. generated information (black)

References can be found at: https://tinyurl.com/References-CPV-CLIC

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