ICHEP 2026 · HIGGS PHYSICS

Highlights of the Higgs physics program at a future linear e^+e^- collider

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For the LCVision Team

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Linear Collider Vision

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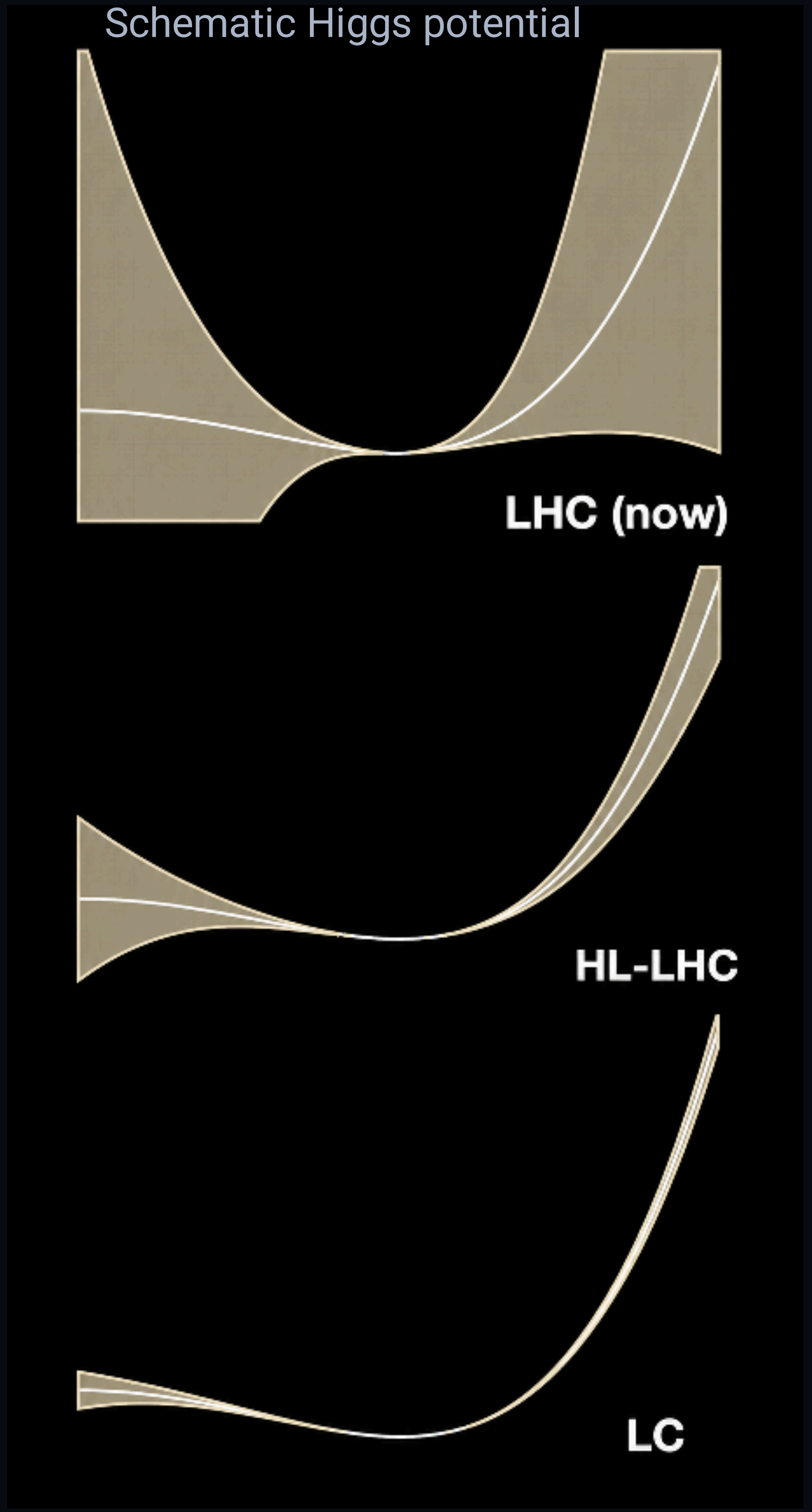
TWO HIGGS QUESTIONS

How does the Higgs interact?

Does the Higgs self-interaction have the Standard Model value?

HIGHLIGHT 1: Global Higgs interaction map
HIGHLIGHT 2: Direct Higgs self-interaction

Recoil fixes the absolute normalization; Higgs, electroweak and top observables complete the global fit.

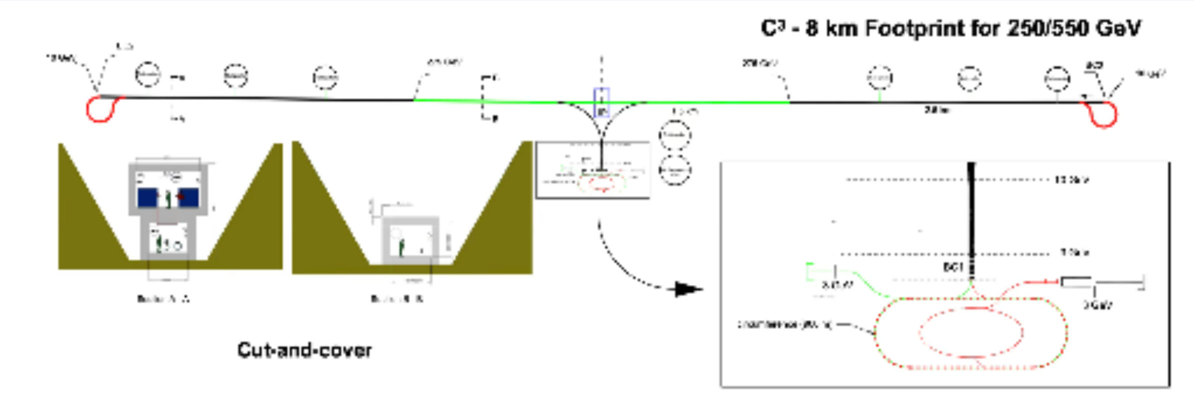


(Nathaniel Craig)

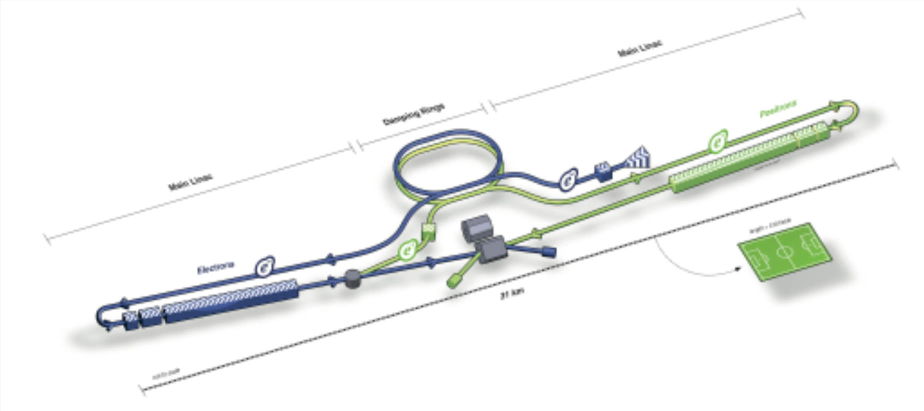
The LC is a tunable, polarized e^+e^- collider with a well-defined initial state

SEVERAL PROJECTS UNDER INVESTIGATION: ILC, CLIC, C^3

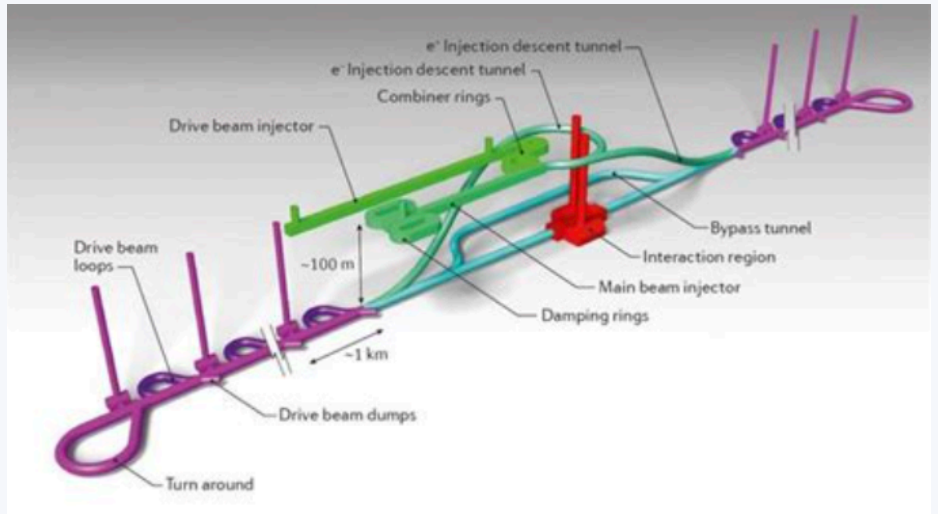
C^3



ILC



CLIC



COMMON FEATURES

- well-characterized beam-energy spectrum
- polarized electron beam; positron polarization depending on design
- staged and upgradeable collision energy

Each LC energy stage unlocks different Higgs measurements

01 **250 GeV · ABSOLUTE NORMALIZATION**

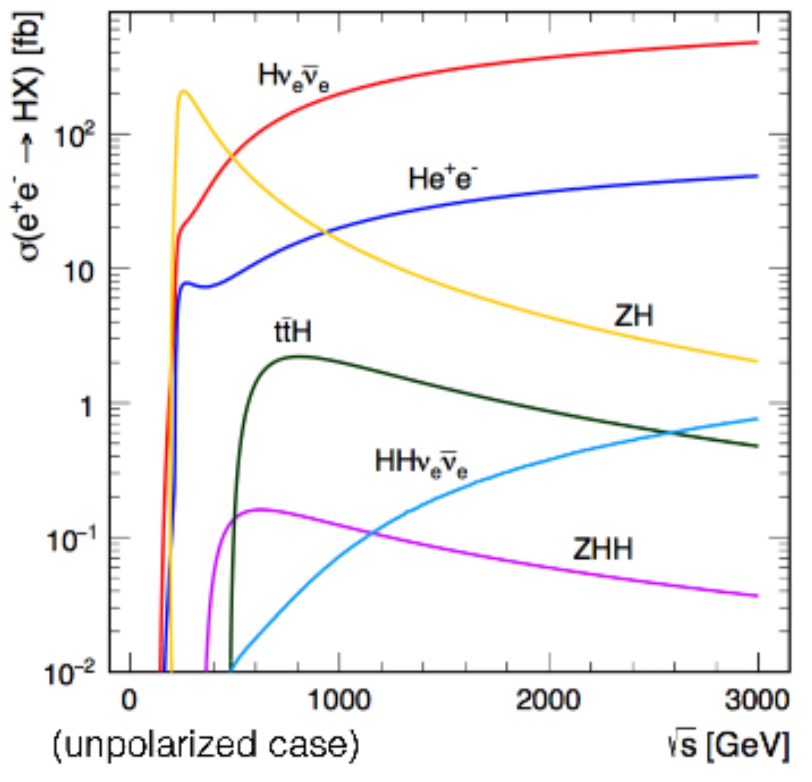
Recoil-tagged ZH measures inclusive Higgs production independently of its decay.

02 **550 GeV · DIRECT ACCESS**

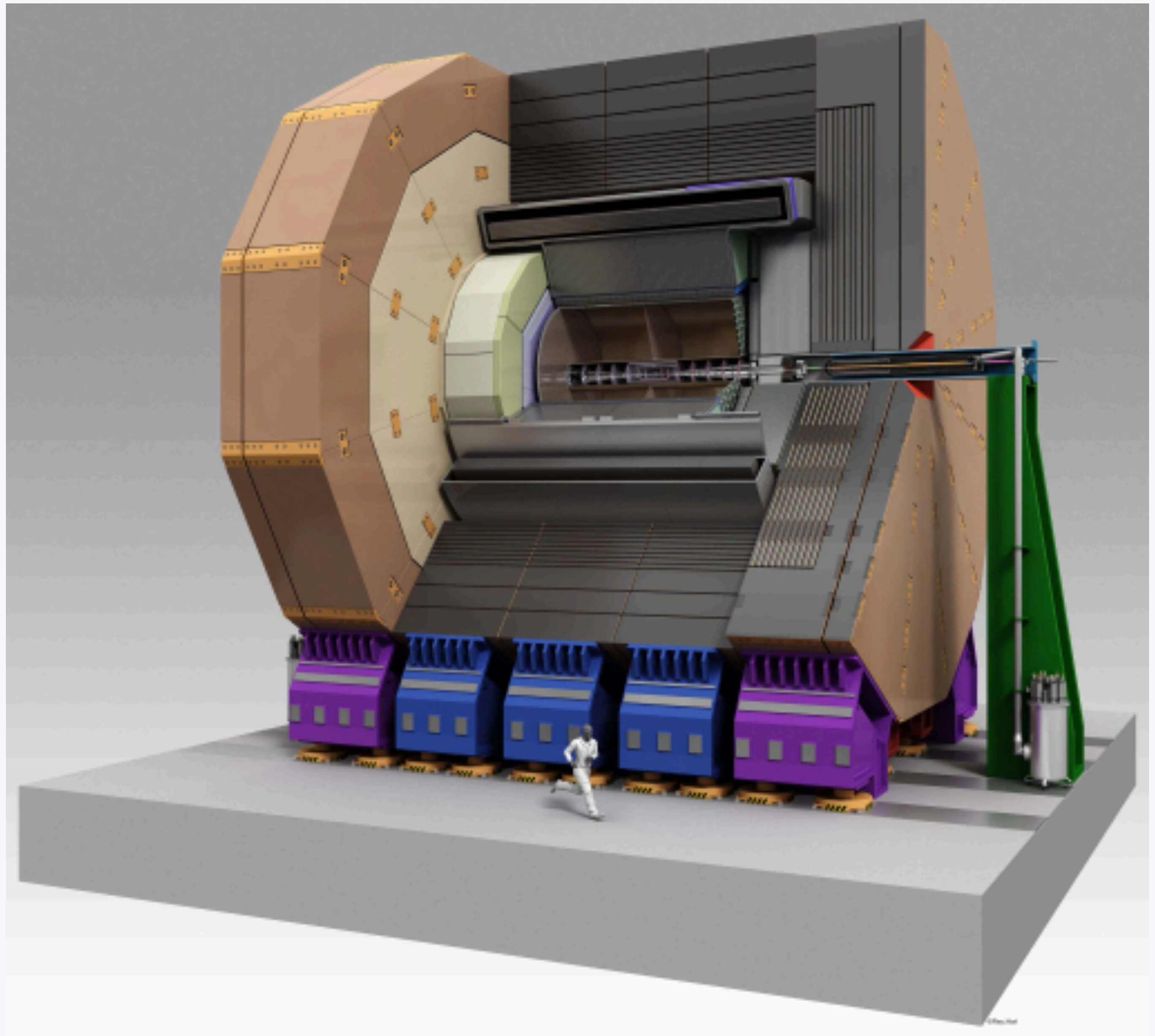
double-Higgs production probes the trilinear Higgs self-coupling at tree level

03 **1 TeV · HIGH ENERGY LEVERAGE**

WW fusion becomes dominant; measurements at different energies distinguish effects that otherwise look alike.



The LC defines the collision; ILD reconstructs the final state



Benchmark Detector

- Full MC simulation
- Key detector technologies validated in beam tests

Particle flow reconstruction

Granular tracking/calorimetry reconstruct individual particles, jets and missing energy.

Transformer-based flavour tagging

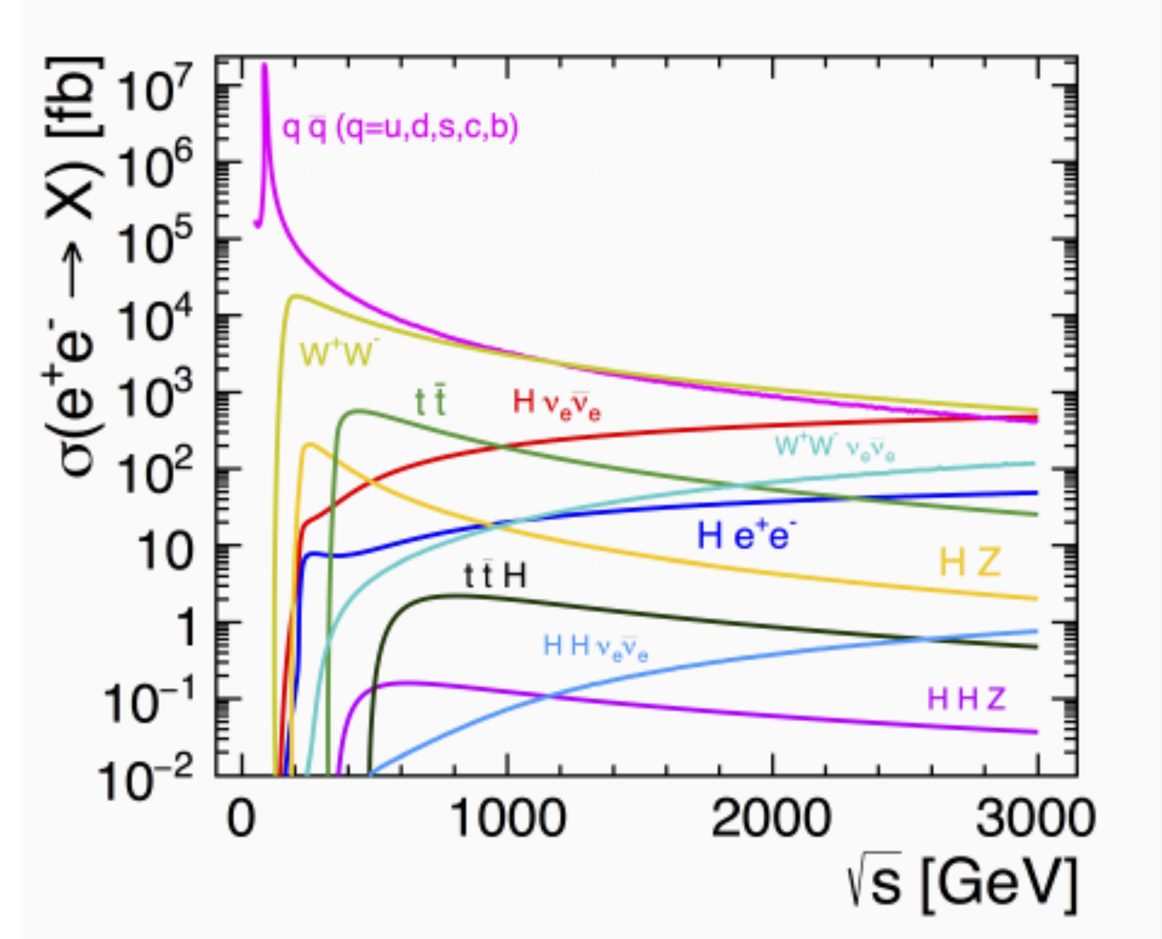
- Applied in current ILD studies
- further optimization ongoing

↗ 2202.03772

WELL-DEFINED COLLISIONS → PRECISION RECONSTRUCTION → GLOBAL HIGGS INTERPRETATION

Five more Higgs observables - and the list continues

1. **Mass:** recoil spectrum, independent of the Higgs decay
2. **Total width:** absolute production rates combined with branching fractions
3. **Top Yukawa:** direct t tH production at 500–550 GeV
4. **Spin and CP:** threshold behaviour, angles and decay correlations
5. **Rare and exotic decays:** invisible and otherwise unclassified modes



κλ is a benchmark parameter SMEFT captures correlated deviations

κλ

Benchmark modifier

$$\kappa_\lambda \equiv \frac{\lambda_3}{\lambda_3^{\mathrm{SM}}}, \qquad \kappa_\lambda^{\mathrm{SM}} = 1$$

- One readable number
- Ideal for collider comparisons
- Other couplings fixed or profiled

SMEFT

Correlated framework

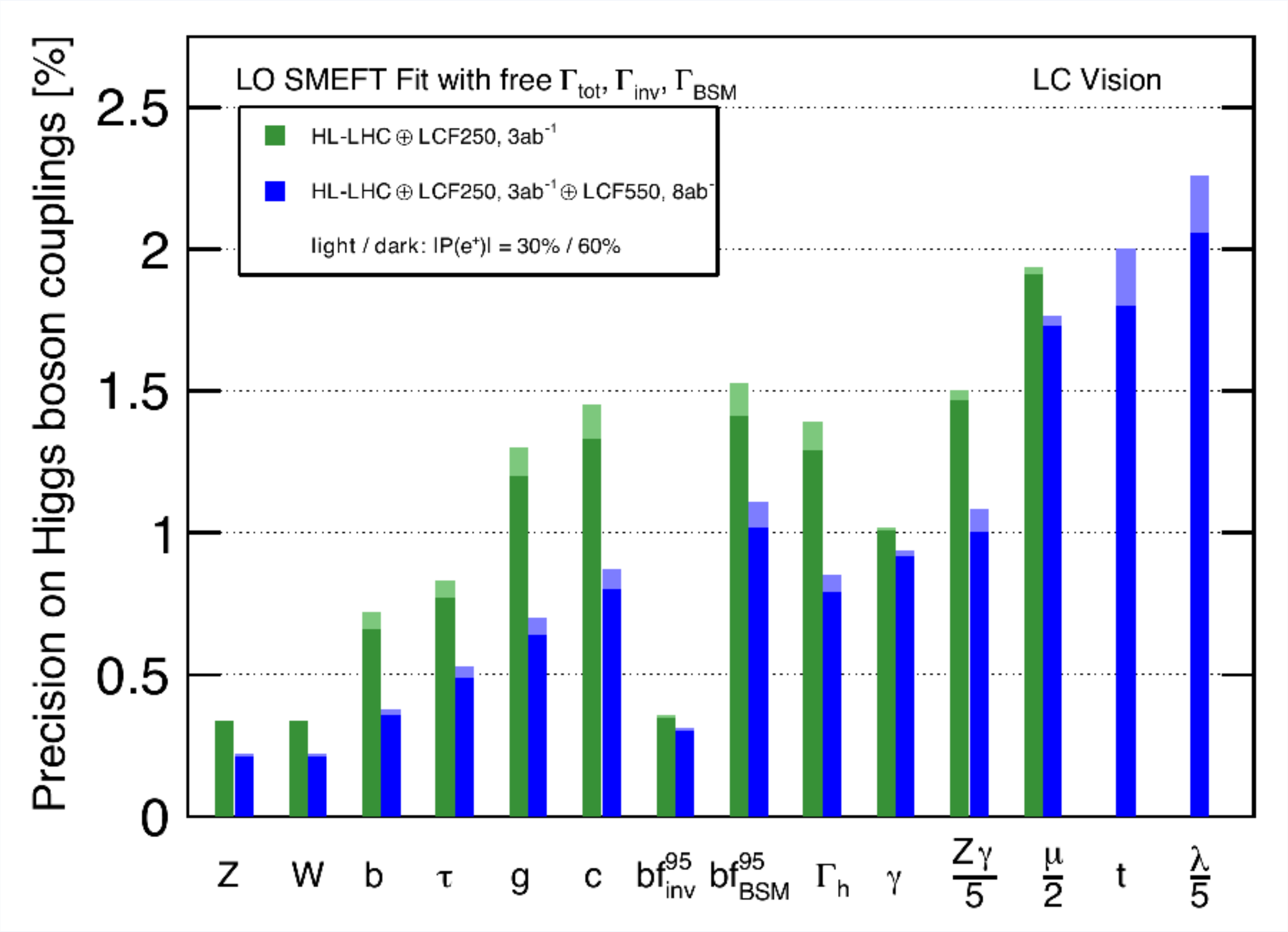
$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{C_i^{(6)}}{\Lambda^2} \mathcal{O}_i^{(6)}$$

- Gauge symmetry correlates shifts across Higgs, EW and top observables
- Global data constrain C_i / λ^2
- Valid when new particles are heavy compared with the energies probed

κλ QUOTES A BENCHMARK · SMEFT TESTS THE CORRELATED PATTERN

Recoil anchors absolute Higgs rates; complementary observables lift SMEFT degeneracies

LO dimension-6 SMEFT, within the stated operator and flavour assumptions



HOW DEGENERACIES ARE LIFTED

- **recoil σ(ZH)**
  decay-independent normalization
- **beam polarization**
  separate left- and right-handed currents
- **multiple energies**
  distinguish coupling shifts from contact interactions

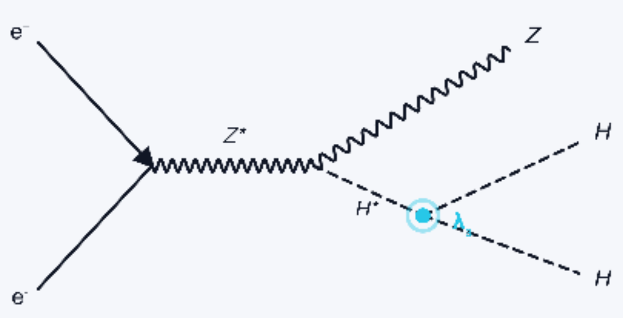
LO SMEFT projection with free total, invisible and unclassified Higgs widths; HL-LHC + LCF250/550. ↗2503.19983

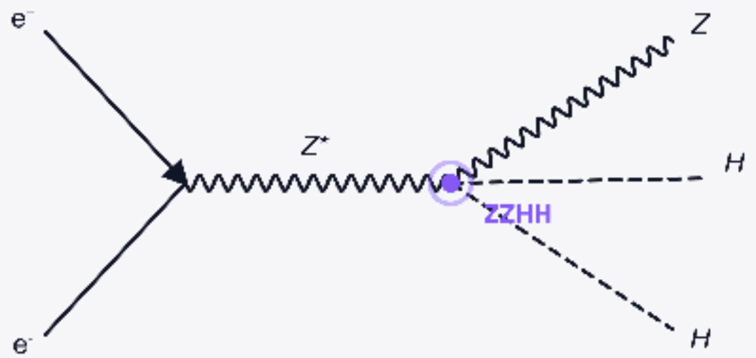
HIGHLIGHT 2 · DIRECT HIGGS SELF-INTERACTION

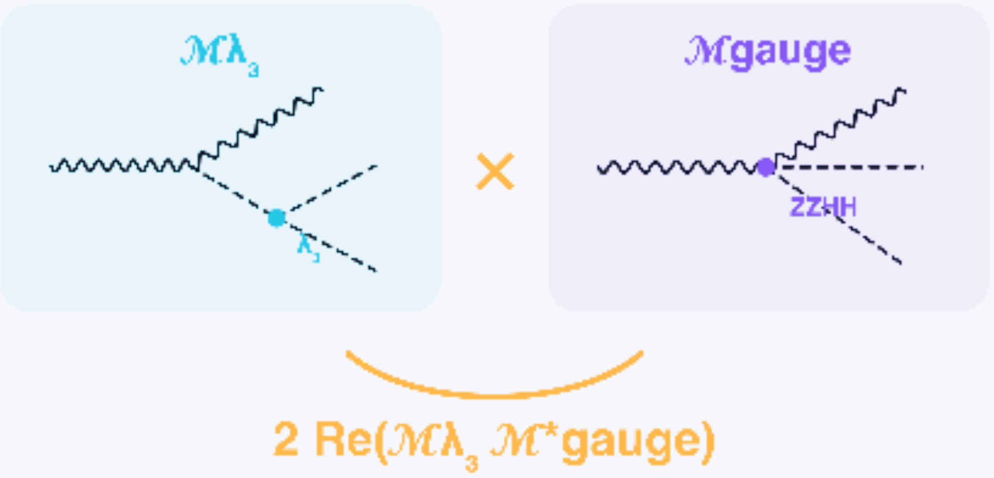
At 550 GeV, double-Higgs production probes the trilinear Higgs self-coupling at tree level.

λ_3 is the cubic term in *V(h)* expanded around the electroweak vacuum.
ZHH and *ννHH* provide complementary sensitivity.

Double-Higgs production probes λ_3 through interference







1

λ_3 dependent amplitude

An off-shell Higgs splits into HH.

2

Gauge amplitudes

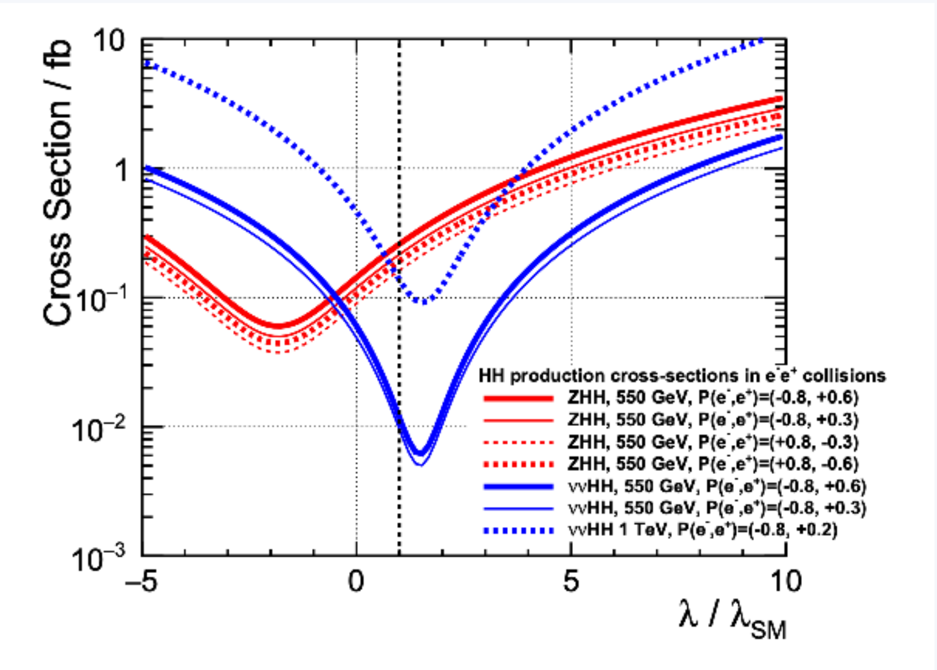
Same final state through quartic contact interaction.

Noλ_3 vertex (HHH).

3

Interference sensitivity

- cross term linear in κ_λ
- full rate is non-linear

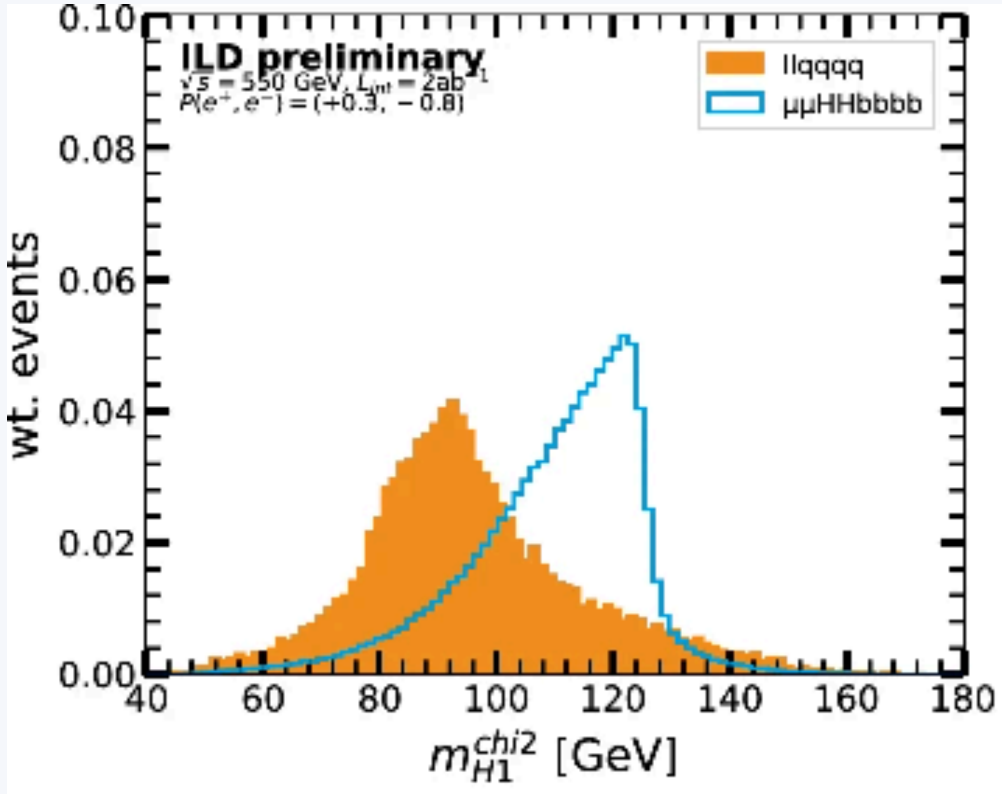


ZHH and WW FUSION $\nu\nu$HH: DIFFERENT INTERFERENCE PATTERNS → COMPLENTARY (κ_λ) SENSITIVITY

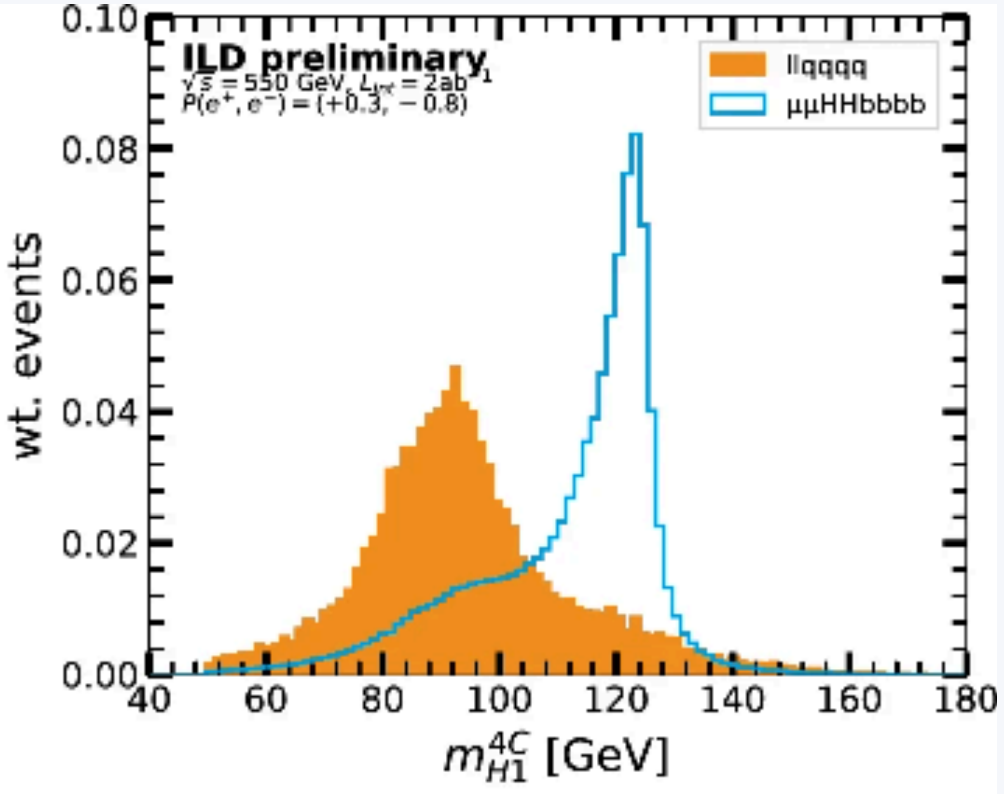
Kinematic fits sharpen Higgs reconstruction in (ZHH)

ZHH -> μμ bb bb: mass of the “least Higgs-like” dijet candidate

Before fit · simple χ^2 jet pairing



After 4C fit · pairing selected by 6C hypotheses



WHY THE PEAK SHARPENS

- known initial four-momentum
- per-jet uncertainties and neutrino corrections
- 4C fit enforces energy–momentum conservation
- 6C hypotheses select the pairing and test ZHH and ZZH hypotheses

SHARPER SECOND HIGGS CANDIDATE → BETTER SIGNAL–BACKGROUND SEPARATION

↗2509.14148

ZHH ⊕ ννHH → ONE κλ CONSTRAINT

EXPECTED 68% CL PRECISION AT THE SM POINT $\kappa_\lambda = 1$

$\Delta\kappa_\lambda = \pm 0.11$

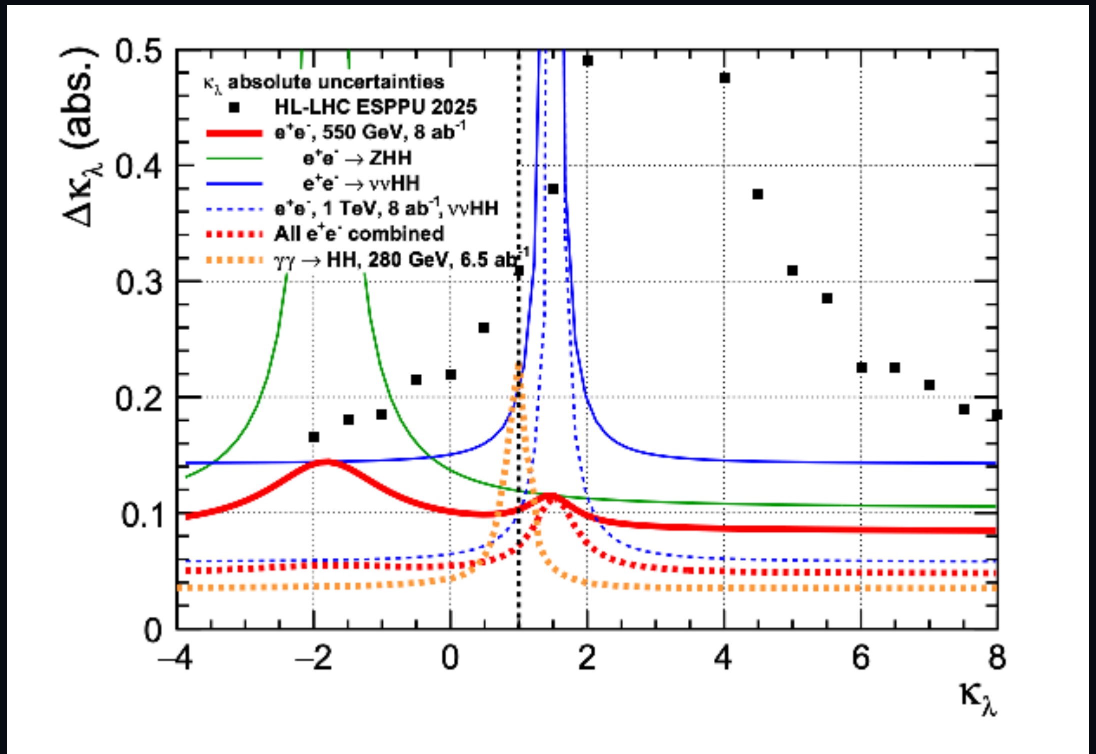
EXTRAPOLATED PROJECTION

Equivalent to ±11% on λ_3

Updated end-to-end analyses of all channels are ongoing.

COMPLEMENTARY INTERFERENCE PATTERNS

ZHH AND WW FUSION LOSE SENSITIVITY IN DIFFERENT REGIONS → THE COMBINATION REMAINS ROBUST



↗ 2603.19884

Different machines answer different Higgs questions

01 HL-LHC · DIRECT HH IN pp

Combined ATLAS+CMS projections exceed 7σ for SM HH and reach better than 30% precision on κ_λ, assuming no other BSM effects.

02 FCC-ee · HIGHEST SINGLE-HIGGS STATISTICS

κ_λ is constrained indirectly through NLO effects in single-Higgs and electroweak observables; the 365 GeV stage is important.

03 LCF · ABSOLUTE NORMALIZATION + DIRECT HH

Recoil, polarization and staged energies enable a global interpretation; 550 GeV adds tree-level double-Higgs sensitivity.

COMPLEMENTARY PROGRAMMES · ONLY AN ENERGY-UPGRADABLE LC COMBINES RECOIL, POLARIZATION AND DIRECT HH

A linear collider maps Higgs interactions and directly probes the trilinear self-coupling.

250 GeV: SMEFT anchor · 550 GeV: direct ttH + HH · high energy: EFT leverage

Additional Information

Assumptions, formalism and reconstruction

Run plan · recoil · SMEFT interpretation · κ_λ response · analysis status