Precision Higgs Physics and Higgs Self-Coupling Measurements at the XFEL Compton Collider

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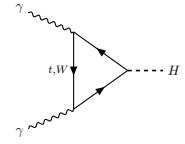
11 November 2026

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Why a $\gamma\gamma$ Higgs Factory?

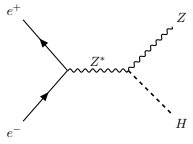
- BSM effects on Higgs couplings are expected at the **%-to-sub-% level**.
- The self-coupling λ_{HHH} sets the shape of the Higgs potential. HL-LHC reach on κ_λ only $\sim$30 %.
- $\gamma\gamma \to H$ is a **resonant *s*-channel** process through t/W loops:
  - Higgs produced alone, at $\sqrt{s} = m_H$
  - Direct access to the $H\gamma\gamma$ vertex
- $\gamma\gamma \to HH$ at 380 GeV: $\approx 2 \times \sigma(e^+e^- \to ZHH)$ at 500 GeV, with **no associated** Z.
- Optical $\gamma\gamma$ colliders (TESLA, CLICHE, SAPHIRE) had broad, asymmetric spectra. **XCC replaces the optical laser with an X-ray FEL.**

XCC: $\gamma\gamma \to H$



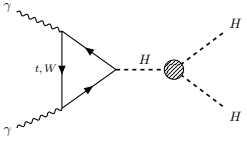
$\sqrt{s} = 125$ GeV

$e^+e^- \to ZH$



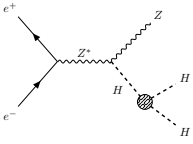
$\sqrt{s} = 250$ GeV

XCC: $\gamma\gamma \to HH$



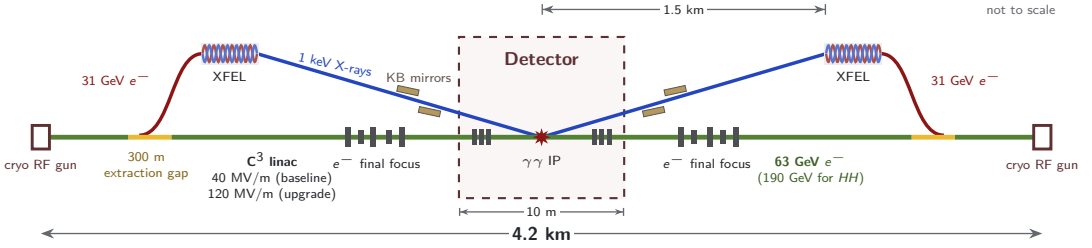
$\sqrt{s} = 280$–380 GeV

$e^+e^- \to ZHH$



$\sqrt{s} = 500$–550 GeV

The XFEL Compton $\gamma\gamma$ Collider (XCC) Concept



Electron and X-ray beams

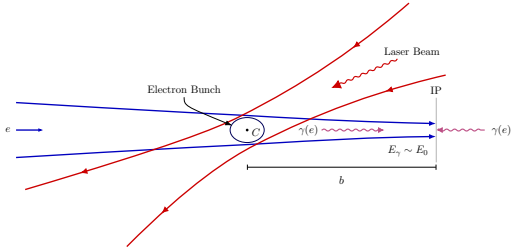
- Polarized e^- from a cryogenic RF photo-injector: **no positrons, no damping rings**
- C^3 (cold-copper, distributed-coupling) C-band linac
- Every other bunch extracted at 31 GeV $\rightarrow$ helical undulator $\rightarrow$ **1 keV** circularly polarized X-rays, focused to 30 nm by KB mirrors
- Main beam: 62.8 GeV (H), 140–190 GeV (HH)

Interaction region

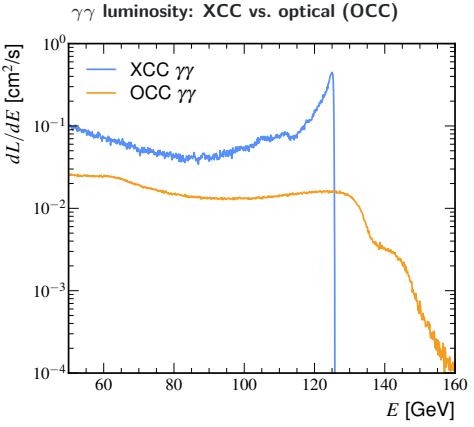
- Compton IP (IPC) only 60 μm upstream of the $\gamma\gamma$ IP
- Low laser strength $\xi^2 \approx 0.1$ limits non-linear QED
- $\sim$20–25 % of e^- convert: residual $e\gamma$, e^+e^-, e^-e^- collisions
- 2 mrad crossing + crab cavities, 5 T solenoid
- **4.2 km** total footprint; **projected cost: 2.3B USD**

Barklow *et al.*, JINST 18 (2023) P07028; schematic adapted from JHEP 09 (2026) 017

Why X-rays? Large x and a Sharply Peaked Spectrum



- $x = 4E_e\omega_0/m_e^2$, $E_\gamma^{\max} = \dfrac{x}{x+1}E_e$
- Optical: $x < 4.82$ to stay below $\gamma\gamma_0 \to e^+e^- \Rightarrow$ broad spectrum
- XCC: $\omega_0 = 1$ keV $\Rightarrow x \sim 10^3$: spectrum piles up at the endpoint; $\lambda_e P_c > 0$ helicity-suppresses pair creation

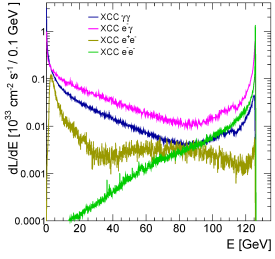


e^+e^--like spectrum than traditional $\gamma\gamma$!

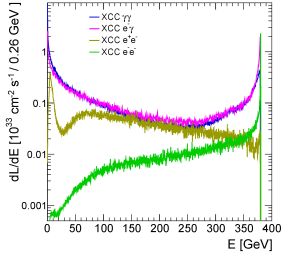
Operating Points and Luminosity Spectra

	Single Higgs	Di-Higgs	
Peak $\sqrt{s}_{\gamma\gamma}$	**125 GeV**	**280 GeV**	**380 GeV**
E_e	62.8 GeV	140 GeV	190 GeV
$\int \mathcal{L}$, 10 yr (peak window)	$0.5\,\mathrm{ab}^{-1}$ (100–125 GeV)	$4.1\,\mathrm{ab}^{-1}$ (250–280 GeV)	$6.5\,\mathrm{ab}^{-1}$ (260–380 GeV)
Pile-up $\langle\mu\rangle$ ($\gamma\gamma \to$ hadrons)	1.1	6.2	9.1
Headline	1.1 M $\gamma\gamma \to H$	steepest $d\sigma_{HH}/d\kappa_\lambda$	max. σ_{HH} at $\kappa_\lambda = 1$
e^+e^- equivalent	ZH at 250 GeV	ZHH at 500–550 GeV	

$\sqrt{s} = 125$ **GeV**



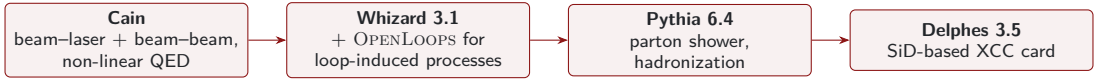
$\sqrt{s} = 380$ **GeV**



All four initial states ($\gamma\gamma$, $e\gamma$, e^+e^-, e^-e^-) come out of CAIN and are simulated as backgrounds.

Same tunnel: gradient upgrade takes E_e from 63 to ∼190 GeV.

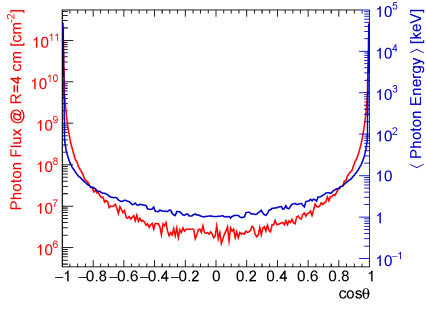
Detector Environment and Simulation Chain



Detector: SiD-based, adapted to the XCC

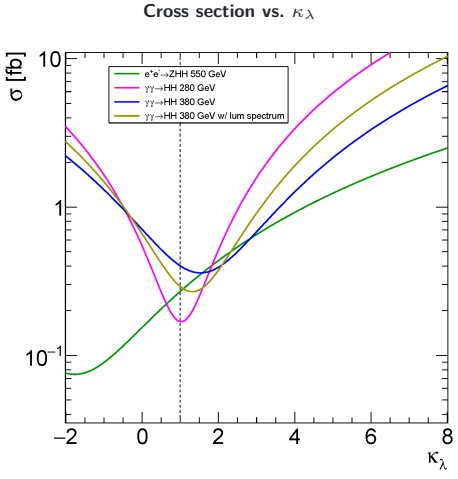
- Incoherent e^+e^- pairs (Bethe–Heitler, Breit–Wheeler, Landau–Lifshitz) constrain: beam pipe 12→15 mm, inner vertex layer 14→**17 mm**
- Compton X-rays flood the forward region: PFOs only for $|\cos\theta| < 0.95$
- Flavour tagging (ParticleNet) deliberately degraded to LHC-like: $\varepsilon_b = 85\,\%$ with 5 % c / 1 % light mistag (actual observed: $< 1\,\%$ / $< 0.5\,\%$)
- Pile-up $\langle\mu\rangle = 1.1$–9.1, mostly outside acceptance; transformer-based mitigation (see backup slides).

Compton photon flux and mean energy vs. $\cos\theta$

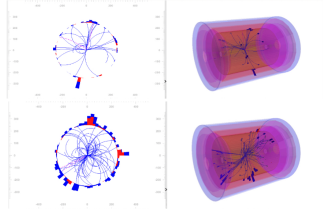


Both acceptance and flavour-tagging assumptions are conservative.

Di-Higgs at the XCC: $\gamma\gamma \to HH$



- Loop-induced (W, t); $\sigma \approx 0.4$ fb at its maximum ($\sqrt{s} \approx 380$ GeV, $J_z = 0$, $\kappa_\lambda = 1$)
- **Strongest κ_λ dependence** of any collider for $\kappa_\lambda \neq 1$, with a shape different from pp and e^+e^-
- At 380 GeV, σ has its minimum near $\kappa_\lambda \approx 1.3$; **280 GeV** has the steepest $d\sigma/d\kappa_\lambda$
- Clean final state: only HH, so four b-jets for $b\bar{b}b\bar{b}$



Top: $\gamma\gamma \to HH \to b\bar{b}b\bar{b}$ (380 GeV). Bottom: $e^+e^- \to ZHH$ (550 GeV).

Samples and Preselection at $\sqrt{s} = 380$ GeV

10-year run, 6.5 ab^{-1} ($260 < \sqrt{\hat{s}} < 380$ GeV)

653 $HH \to b\bar{b}b\bar{b}$ events vs. **9.5 M** background events from 12 processes in $\gamma\gamma$, $e\gamma$ and e^+e^- collisions.

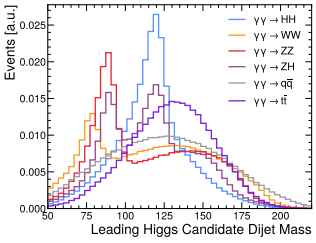
Preselection

- Exactly 4 exclusive Durham jets
- ≥ 3 b-tags, isolated-lepton veto
- Higgs candidates from the pairing that minimizes

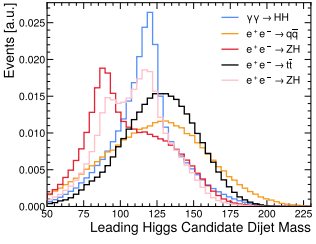
$$\chi^2 = \frac{(m_{ij} - m_H)^2}{\sigma_m^2} + \frac{(m_{kl} - m_H)^2}{\sigma_m^2}$$

After preselection: **254** signal vs. **234 k** background.

Leading Higgs candidate mass: $\gamma\gamma$ backgrounds



Leading Higgs candidate mass: e^+e^- backgrounds



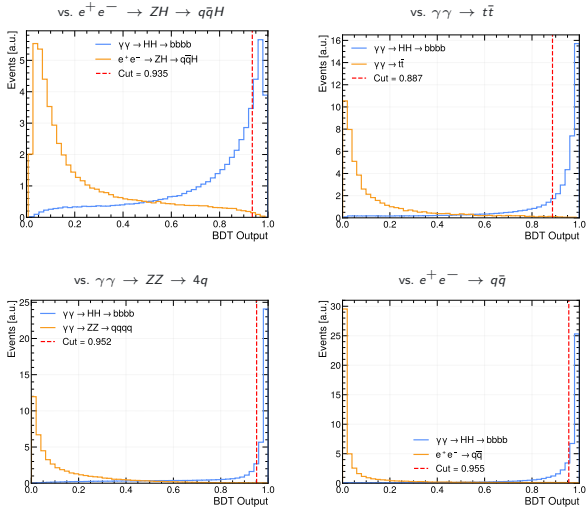
Signal Extraction: BDT Ensemble + Genetic Algorithm

12 XGBoost BDTs, one per background (signal vs. that background)

- ∼50 features: $E, p_{\mathrm{T}}, \cos\theta, \phi, m$ of 4 jets; pairwise ΔR, m_{jj}, Durham y_{ij}; 3- and 4-jet masses; χ^2-paired Higgs candidates; $E_{\mathrm{T}}^{\mathrm{miss}}$
- depth 4, $\eta = 0.05$, 500 rounds with early stopping, L2 regularization

Genetic algorithm (DEAP)

- Finds one cut per BDT output (12-dim.) that maximizes $S/\sqrt{S+B}$
- population 120, tournament selection, blend crossover, Gaussian mutation, 50 generations



Red dashed line: GA cut. All 12 in backup.

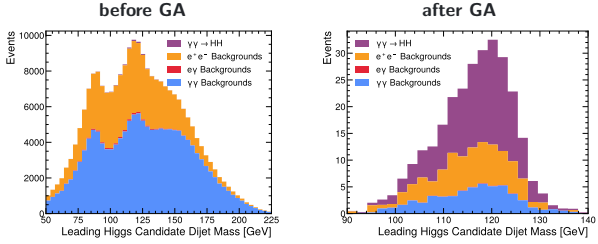
Result: $\gamma\gamma \to HH \to b\bar{b}b\bar{b}$ at 380 GeV

Process	Presel.	After GA
$\gamma\gamma \to HH \to b\bar{b}b\bar{b}$	254	**151**
$\gamma\gamma$ backgrounds (5)	150 055	54
$e\gamma$ backgrounds (3)	1 560	1
e^+e^- backgrounds (4)	82 607	77
of which $e^+e^- \to ZH$	13 771	62
Total background	234 222	**132**

Precision on $\sigma(\gamma\gamma \to HH)$ at $\kappa_\lambda = 1$

$$S/\sqrt{S+B} = \mathbf{8.97} \quad \Rightarrow$$
$$\Delta\sigma_{HH}/\sigma_{HH} = \mathbf{11.1\,\%}$$

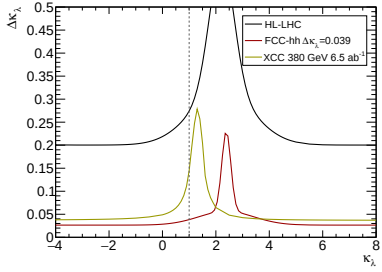
Largest residual background: $e^+e^- \to ZH$, which has a real Higgs.



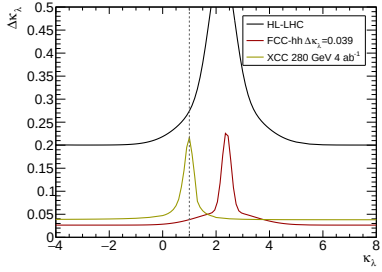
Leading Higgs candidate mass, stacked by initial state.

Higgs Self-Coupling Projections

380 GeV, all *HH* ($\Delta\sigma/\sigma = 6.5\,\%$)



280 GeV, all *HH* ($\Delta\sigma/\sigma = 11.8\,\%$)



$$\frac{\Delta\sigma}{\sigma} = 0.111\sqrt{\frac{\sigma_0}{\sigma}},$$

$$\Delta\kappa_\lambda = \left|\frac{d\sigma}{d\kappa_\lambda}\right|^{-1}\Delta\sigma$$

(double-valued inversion near the σ minimum).

All *HH*: assumes the other topologies ($b\bar{b}WW^*$, $b\bar{b}\gamma\gamma$, …) reach the same figure of merit as $b\bar{b}b\bar{b}$:
$6.5\,\% = 11.1\,\% \times \mathrm{BR}(H \to b\bar{b})$.

	$\int\mathcal{L}$	$\Delta\sigma_{HH}/\sigma_{HH}$	$\Delta\kappa_\lambda$ at $\kappa_\lambda = 1$	$\Delta\kappa_\lambda$ far from σ min.
XCC 380 GeV, $b\bar{b}b\bar{b}$ only (this analysis)	$6.5\,\mathrm{ab}^{-1}$	**11.1 %**	0.25	0.065
XCC 380 GeV, all *HH* (extrapolated)	$6.5\,\mathrm{ab}^{-1}$	6.5 %	0.15	0.04
XCC 280 GeV, all *HH* (extrapolated)	$4.1\,\mathrm{ab}^{-1}$	11.8 %	0.22	0.04
HL-LHC / FCC-hh			0.27 / 0.04	0.20 / 0.03

$\Delta\kappa_\lambda$ values read off the projection curves. 280 GeV: extrapolated from the 380 GeV result by signal statistics; dedicated channel study in progress.

Single Higgs at $\sqrt{s} = 125$ GeV

10-year run, 0.5 ab^{-1} ($100 < \sqrt{\hat{s}} < 125$ GeV)

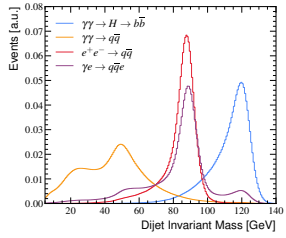
1.1 M $\gamma\gamma \to H$ events. The Higgs is produced alone and nearly at rest, so its decay products are energetic and central.

19 final states

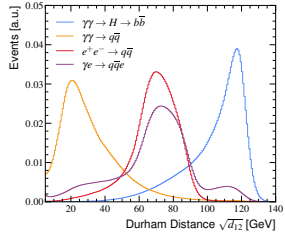
- Hadronic: $b\bar{b}$, $c\bar{c}$, gg, $s\bar{s}$, $WW^*/ZZ^* \to 4q$
- Semi-leptonic: $WW^* \to \ell\nu qq$, $ZZ^* \to qq\nu\nu$, $ZZ^* \to qq\ell\ell$
- Leptonic / photonic: $\tau\tau$, $\mu\mu$, $\gamma\gamma$, $Z\gamma$ ($\ell\ell$, qq, $\nu\nu$), $WW^* \to \ell\ell\nu\nu$, $ZZ^* \to \ell\ell\nu\nu$, 4ℓ

Backgrounds: all SM processes, 5 hadronic + 13 (semi-)leptonic, from $\gamma\gamma$, $e\gamma$, e^+e^-, e^-e^-. Jets: inclusive e^+e^- anti-k_T, $R = 1.5$, $E > 8$ GeV.

$H \to b\bar{b}$: **dijet mass before selection**



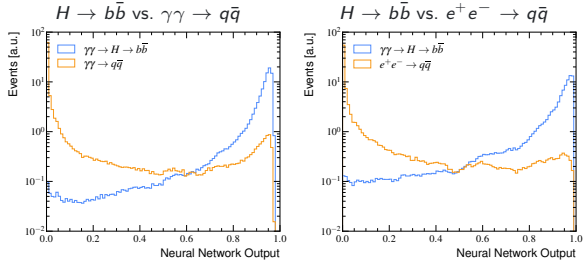
$H \to b\bar{b}$: **Durham distance** $\sqrt{d_{12}}$



Set Transformer on Particle-Flow Point Clouds



- Permutation-invariant over a variable-size set: no jet clustering or hand-built features required
- Per particle: kinematics ($\theta, \phi, \log p_T, \log E$), PID ($q$, e, μ, γ, $h^{\pm}$, h^0), track (d_0, d_z, σ_{d_0}, σ_{d_z})
- Inducing points make attention $\mathcal{O}(mn)$, not $\mathcal{O}(n^2)$, for $\mathcal{O}(100\text{–}1000)$ particles
- 1.78 M parameters, AdamW + cosine warm restarts; GA: 80 generations
- BDTs used for $\mu\mu$, $\gamma\gamma$, $Z\gamma(\ell\ell/\nu\nu)$

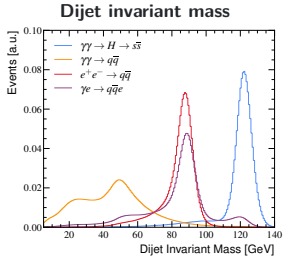


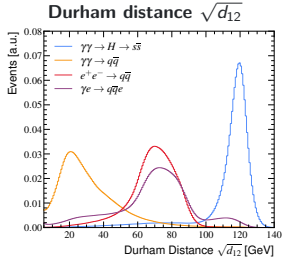
$H \to s\bar{s}$: Access to the Strange Yukawa

- $\mathrm{BR}(H \to s\bar{s}) = \mathcal{O}(10^{-4})$, buried under QCD at pp and e^+e^- machines
- At a $\gamma\gamma$ collider the continuum $\gamma\gamma \to q\bar{q}$ scales as Q_q^4: $\gamma\gamma \to s\bar{s}$ is suppressed by $(1/3)^4 = 1/81$
- Strange tagging (ParticleNet, medium): $\varepsilon_s = 82.5\,\%$; mistag 5 % (c), 2.5 % (b), 50 % (u, d, g)
- Selection: 2 s-tags, lepton veto, $\sqrt{d_{12}} > 95$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}} < 18$ GeV, $m_{jj} > 105$ GeV: 60 % signal efficiency, background down by 10^3–10^4

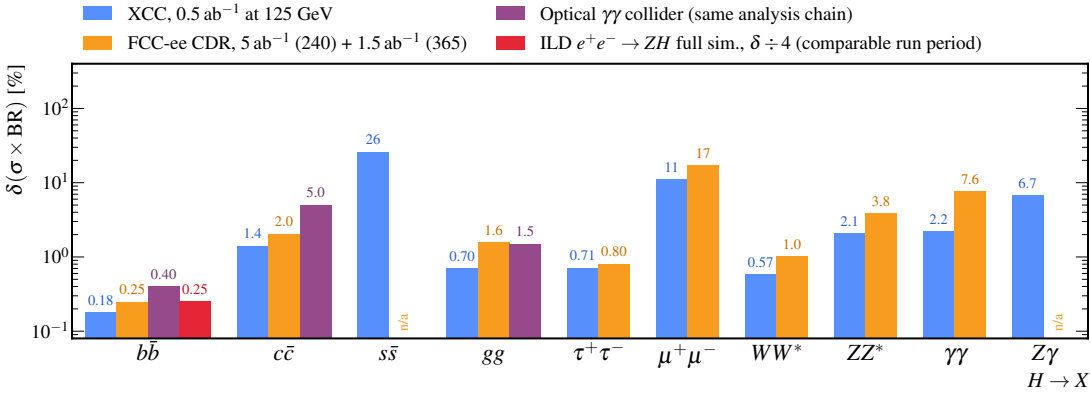
Result (10 years)

$S = 164$, $B = 1\,543 \Rightarrow S/\sqrt{S+B} = \mathbf{3.97}$
$\delta(\sigma \times \mathrm{BR}) = 26\,\% \;\Rightarrow\; \delta\kappa_s \approx 13\,\%$





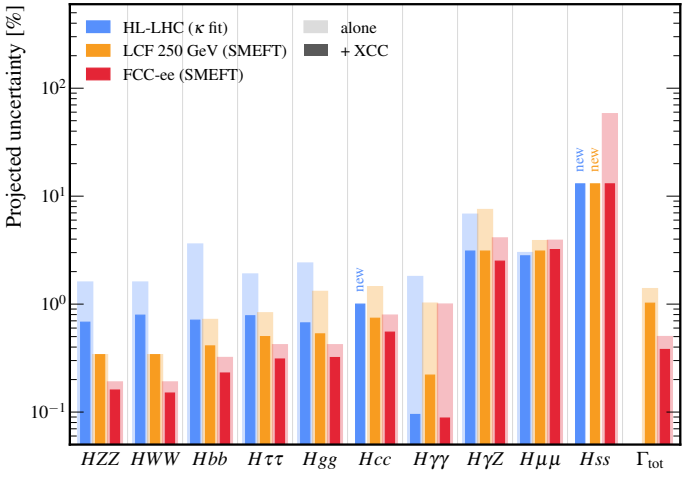
Single Higgs Results: $\sigma(\gamma\gamma \to H) \times \mathrm{BR}$



FCC-ee CDR Table 4.1 $HZ + \nu\bar{\nu}H$ at 240 and 365 GeV (no $s\bar{s}$, $Z\gamma$ entries). XCC $\gamma\gamma$: dual-readout calorimeter. Optical $\gamma\gamma$: $x = 4.82$, same simulation and analysis chain. ILD: full-simulation $\sigma(ZH) \times \mathrm{BR}(b\bar{b}) \approx 1.0\,\%$ (0.9–1.1 %).

$H \to c\bar{c}$ at 1.4 % is a first for any $\gamma\gamma$ collider (optical: 5 %). $S/B \approx 10$ for $H \to b\bar{b}$.

Higgs Coupling Projections



XCC $= 0.5\,\mathrm{ab}^{-1}$ at 125 GeV; HL-LHC included in every fit.

- $H\gamma\gamma$ **to 0.1 %**: $\times$19 beyond HL-LHC, $\times$11 beyond FCC-ee alone
- *Hss* **at 13 %**: the best direct probe of the strange Yukawa
- *Hbb*, *Hcc*, *Hgg*, $H\tau\tau$ improve even on top of FCC-ee
- *HZZ* / *HWW* stay anchored by the e^+e^- recoil measurement: **XCC and e^+e^- are complementary**

Summary and Outlook

Established

- **XCC**: a $\gamma\gamma$ Higgs factory at $\sqrt{s} = 125$ GeV in a 4.2 km footprint, initial cost estimate ≈2.3 B$, upgradable to 280–380 GeV for HH.
- **Single Higgs** ($0.5\,\mathrm{ab}^{-1}$): 19 channels; $\sigma \times \mathrm{BR}(b\bar{b})$ to 0.18 %; $H\gamma\gamma$ coupling to 0.1 %; Hss to 13 %.
- **Di-Higgs** (380 GeV, $b\bar{b}b\bar{b}$ alone): 8.97σ, $\Delta\sigma_{HH}/\sigma_{HH} = 11\,\%$. Full HH program: 6.5 % (380) / 11.8 % (280); $\Delta\kappa_\lambda \approx 0.04$ away from the σ minimum, close to FCC-hh.
- ML (set transformers, BDT + GA) controls the $\gamma\gamma$ backgrounds long cited against photon colliders.

Next steps

- Full GEANT4 simulation with incoherent pairs and beam backgrounds; validate flavour tagging at $r = 17$ mm.
- Extend acceptance to $|\cos\theta| < 0.98$–0.99; pile-up mitigation.
- Dedicated HH analyses beyond $b\bar{b}b\bar{b}$ ($b\bar{b}WW^*$, $b\bar{b}\gamma\gamma$, …), and at 280 GeV.
- Systematic and theory uncertainties; photon-polarization observables for CP in $H\gamma\gamma$.

Appendix

Di-Higgs: Full Event Yields at 380 GeV

Process	Initial	After preselection	After GA
$\gamma\gamma \to HH \to b\bar{b}b\bar{b}$	**653**	**254**	**151**
$\gamma\gamma \to W^+W^- \to q\bar{q}q\bar{q}$	3 813 000	4 717	2
$\gamma\gamma \to t\bar{t}$	2 866 000	34 695	29
$\gamma\gamma \to ZZ \to q\bar{q}q\bar{q}$	1 378 000	98 527	8
$\gamma\gamma \to q\bar{q}$	307 700	11 112	6
$\gamma\gamma \to ZH \to q\bar{q}H$	8 202	1 004	9
$e\gamma \to eq\bar{q}$ or $\nu q\bar{q}$	41 195	1 206	1
$e\gamma \to eq\bar{q}q\bar{q}$ or $\nu q\bar{q}q\bar{q}$	7 681	137	0
$e\gamma \to eq\bar{q}H$	3 282	217	0
$e^+e^- \to q\bar{q}$	753 615	54 067	12
$e^+e^- \to W^+W^-/ZZ \to q\bar{q}q\bar{q}$	152 212	14 121	2
$e^+e^- \to ZH \to q\bar{q}H$	123 698	13 771	62
$e^+e^- \to t\bar{t}$	57 001	648	1

$6.5\,\mathrm{ab}^{-1}$ for $260 < \sqrt{\hat{s}} < 380$ GeV (10 years). Generator filter: $N_b \geq 1$ or $N_c \geq 3$, $m_{\mathrm{hadrons}} > 250$ GeV. e^-e^- processes contribute negligibly.

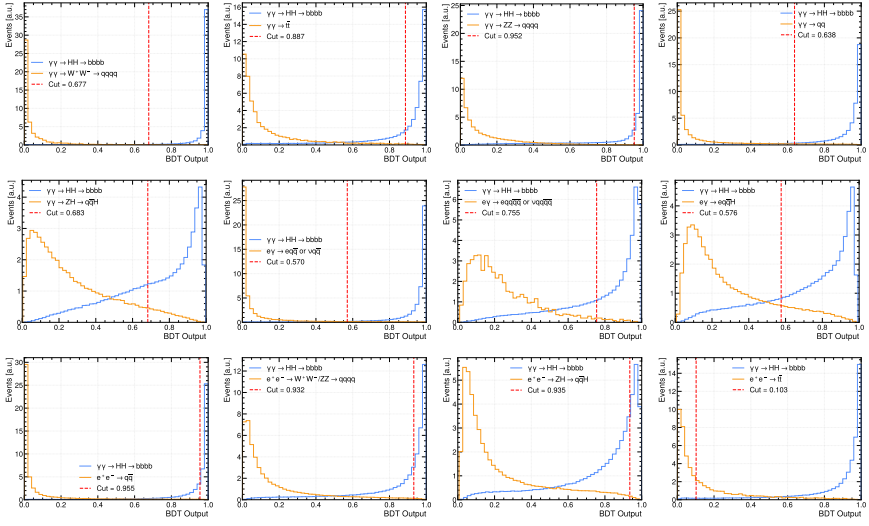
Projected Cost

Domain	Sub-domain	%	%
Sources	Injectors	9	
	FEL	9	**26**
	Beam transport	9	
Main linac	Cryomodule	9	**30**
	C-band klystron	22	
BDS	Beam delivery + FF	7	**15**
	IR	8	
Support infra.	Civil engineering	5	
	Common facilities	18	**28**
	Cryo-plant	6	
Total	**2.3 B$** ($C^3$-250 cost model)		

- Initial estimate: $\approx$ **2.3 B$** for the 125 GeV Higgs factory.
- Largest single item: C-band klystrons (22 %).
- Cost drivers removed relative to e^+e^- Higgs factories:
  - electron beam energy **half** (62.8 vs. 125 GeV)
  - no positron source
  - no damping rings (bright cryo-RF photo-injector)
- Upgrade path: higher linac gradient $\rightarrow$ $\sqrt{s} = 280$–380 GeV for HH; $\sim$10 TeV with wakefield acceleration.

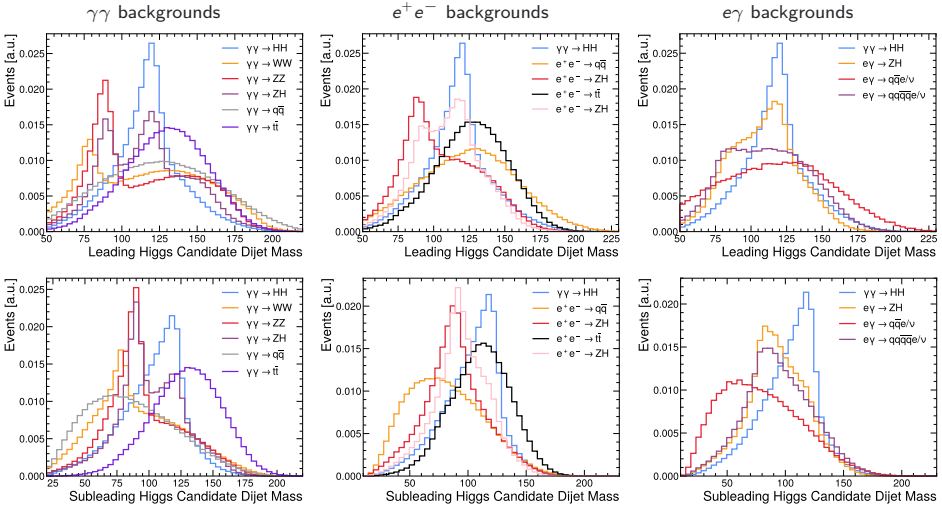
T. Barklow *et al.*, JINST 18 (2023) P07028, Table 5

Di-Higgs: All 12 BDT Output Distributions



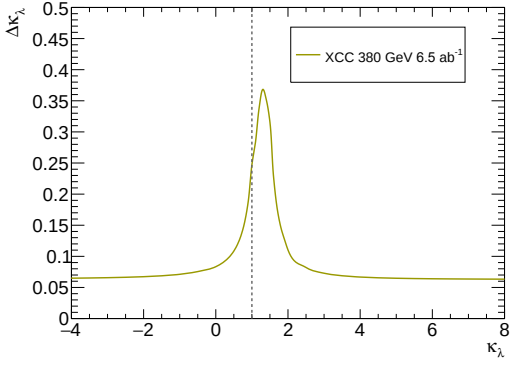
Rows: $\gamma\gamma$ (WW, $t\bar{t}$, ZZ, $q\bar{q}$), $\gamma\gamma \to ZH$ and $e\gamma$ ($q\bar{q}$, $4q$, $q\bar{q}H$), e^+e^- ($q\bar{q}$, WW/ZZ, ZH, $t\bar{t}$). Red dashed line: GA cut.

Di-Higgs: Higgs Candidate Masses by Initial State



Top: leading candidate. Bottom: subleading candidate. Unit-normalized, after χ^2 pairing.

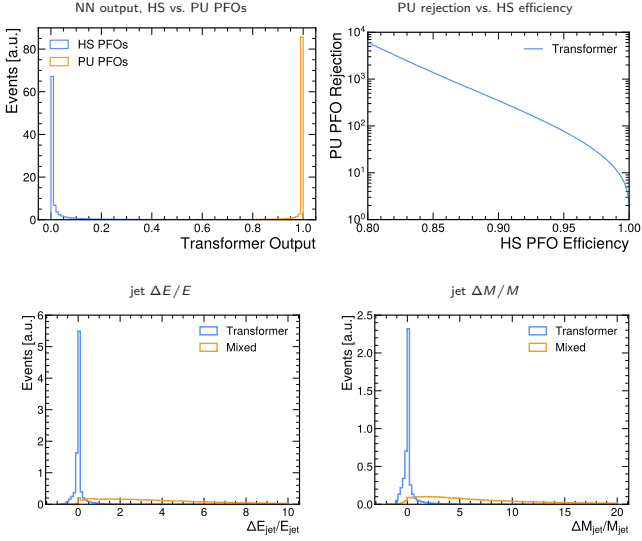
Di-Higgs: $\Delta\kappa_\lambda$ from the $b\bar{b}b\bar{b}$ Channel Alone



- 11.1 % on σ_{HH} at $\kappa_\lambda = 1$, $6.5\,\mathrm{ab}^{-1}$ at 380 GeV
- Signal scales with $\sigma(\kappa_\lambda)$; background assumed to scale with signal (fixed S/B). Conservative except $1 < \kappa_\lambda < 1.6$, where the two assumptions differ by at most 2 %
- $\Delta\kappa_\lambda$ peaks at the cross-section minimum ($\kappa_\lambda \approx 1.3$) and plateaus at $\approx$0.065 away from it

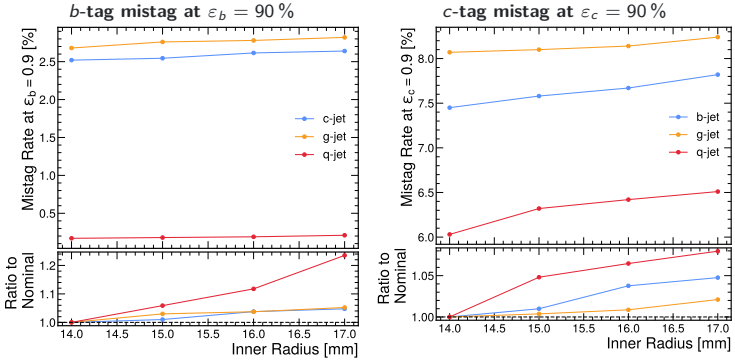
Pile-up Mitigation with a Transformer

- PUPPI-like per-particle HS vs. PU classifier on PFO four-momenta
- 6-layer encoder, $d = 128$, 8 heads; focal loss
- $\gamma\gamma \to$ hadrons overlaid with $n_{\mathrm{PU}} \sim \mathrm{Poisson}(9.1)$
- Trained on $\gamma\gamma \to H$, tested on every HH signal and background
- Jet energy resolution after subtraction: mean < 0.03, median 0 for all processes



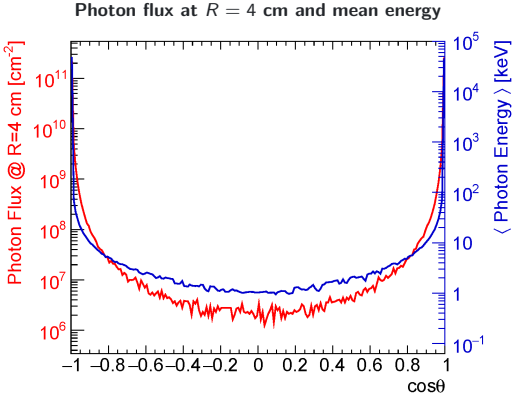
S. Ampudia Castelazo, U. Qureshi *et al.*, JHEP 09 (2026) 017, Appendix A

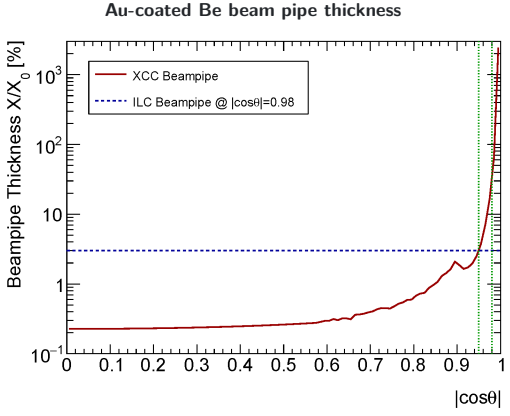
Flavour Tagging vs. Inner Vertex Radius



- ParticleNet on SiD, inner radius 14–18 mm
- 14→17 mm: c mistag 2.5→2.7 %, light 0.15→0.21 % at $\varepsilon_b = 90\,\%$
- Analyses use far worse, LHC-like working points as a worst case

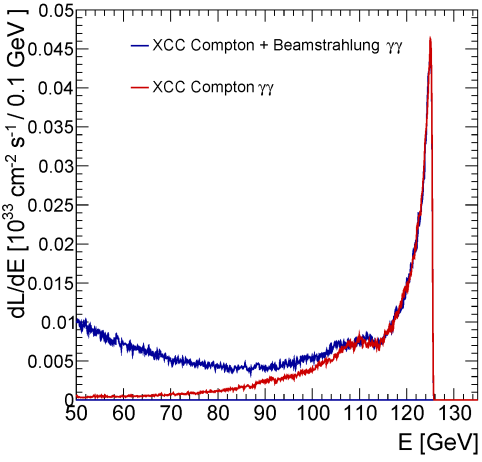
Compton X-ray Background and Beam Pipe





Central region ($|\cos\theta| < 0.85$): moderate soft X-ray flux, absorbed by 0.2–1.0 % X_0. Forward: up to 3 % X_0 at $|\cos\theta| = 0.95$, essentially no instrumentation beyond 0.99. Thickness chosen for $\leq$60 hits/cm^2 in 100 μm Si at $R = 4$ cm.

The 125 GeV $\gamma\gamma$ Spectrum: Compton vs. Beamstrahlung



- Compton photons dominate for $\sqrt{\hat{s}} > 100$ GeV, Beamstrahlung below
- "Integrated $\gamma\gamma$ luminosity" $\equiv$ $100 < \sqrt{\hat{s}} < 125$ GeV: $0.5\,\mathrm{ab}^{-1}$ in 10 years
- Convolution with $\sigma(\gamma\gamma \to H) = 3$ nb (monochromatic, $J_z = 0$) gives 1.1 M Higgs bosons
- CAIN extended with the trident process and large-x non-linear QED

Single Higgs Results: Full Table

Channel	S	B	$\frac{S}{\sqrt{S+B}}$	δ [%]
$H \to b\bar{b}$	342 144	34 292	557.7	**0.18**
$H \to c\bar{c}$	16 642	34 437	73.6	**1.4**
$H \to gg$	53 283	85 359	143.1	0.70
$H \to s\bar{s}$	164	1 543	3.97	**26**
$H \to WW^* \to 4q$	33 094	32 566	129.2	0.77
$H \to ZZ^* \to 4q$	3 719	34 419	19.0	5.3
$H \to \tau^+\tau^-$	27 088	10 023	140.6	0.71
$H \to \mu^+\mu^-$	98	17	9.14	11
$H \to WW^* \to \ell\nu qq$	15 420	5 565	106.4	0.94
$H \to WW^* \to \ell\ell\nu\nu$	9 157	32 084	45.1	2.2

Channel	S	B	$\frac{S}{\sqrt{S+B}}$	δ [%]
$H \to \gamma\gamma$ (DRO calo)	2 177	201	44.6	**2.2**
$H \to \gamma\gamma$ (no DRO)	1 781	299	39.1	2.6
$H \to Z\gamma$, $Z \to \ell\ell$	69	103	5.26	19
$H \to Z\gamma$, $Z \to qq$	212	228	10.1	9.9
$H \to Z\gamma$, $Z \to \nu\nu$	116	32	9.54	10.5
$H \to ZZ^* \to \ell\ell\nu\nu$	73	43	6.78	15
$H \to ZZ^* \to qq\nu\nu$	1 718	111	40.2	2.5
$H \to ZZ^* \to qq\ell\ell$	793	1 216	17.7	5.7
$H \to ZZ^* \to 4\ell$	125	118	8.02	12

$\delta = \delta(\sigma \times \mathrm{BR})$, statistical, 10-year XCC run ($0.5\,\mathrm{ab}^{-1}$ at 125 GeV).

Higgs Coupling Projections: Full Table

	κ fit		LO SMEFT fit			
[%]	HL-LHC	+XCC	LCF 250	+XCC	FCC-ee	+XCC
HZZ	1.6	0.68	0.34	0.34	0.19	0.16
HWW	1.6	0.79	0.34	0.34	0.19	0.15
Hbb	3.6	0.71	0.72	0.41	0.32	0.23
$H\tau\tau$	1.9	0.78	0.83	0.50	0.42	0.31
Hgg	2.4	0.67	1.31	0.53	0.42	0.32
Hcc	–	1.0	1.45	0.74	0.79	0.55
$H\gamma\gamma$	1.8	**0.095**	1.02	**0.22**	1.0	**0.088**
$H\gamma Z$	6.8	3.1	7.51	3.1	4.1	2.5
$H\mu\mu$	3.0	2.8	3.87	3.1	3.9	3.2
Hss	–	**13**	–	**13**	58	**13**
Γ_{tot}	–	–	1.39	1.02	0.50	0.38

Uncertainties in %. XCC $= 0.5\,\mathrm{ab}^{-1}$ at 125 GeV; HL-LHC included in every fit.

References

1. T. Barklow *et al.*, "XCC: an X-ray FEL-based $\gamma\gamma$ Compton collider Higgs factory", JINST **18** (2023) P07028 [arXiv:2306.10057].
2. S. Ampudia Castelazo, U. Qureshi, T. Barklow, A. Schwartzman, "Probing the Higgs self-coupling with an XFEL Compton $\gamma\gamma$ collider at $\sqrt{s} = 380$ GeV", JHEP **09** (2026) 017 [arXiv:2603.20591].
3. U. Qureshi, T. Barklow, A. Schwartzman, "Higgs physics with the XFEL Compton $\gamma\gamma$ collider concept at $\sqrt{s} = 125$ GeV", arXiv:2605.16756, submitted to JHEP.