Higgs Physics at CLIC

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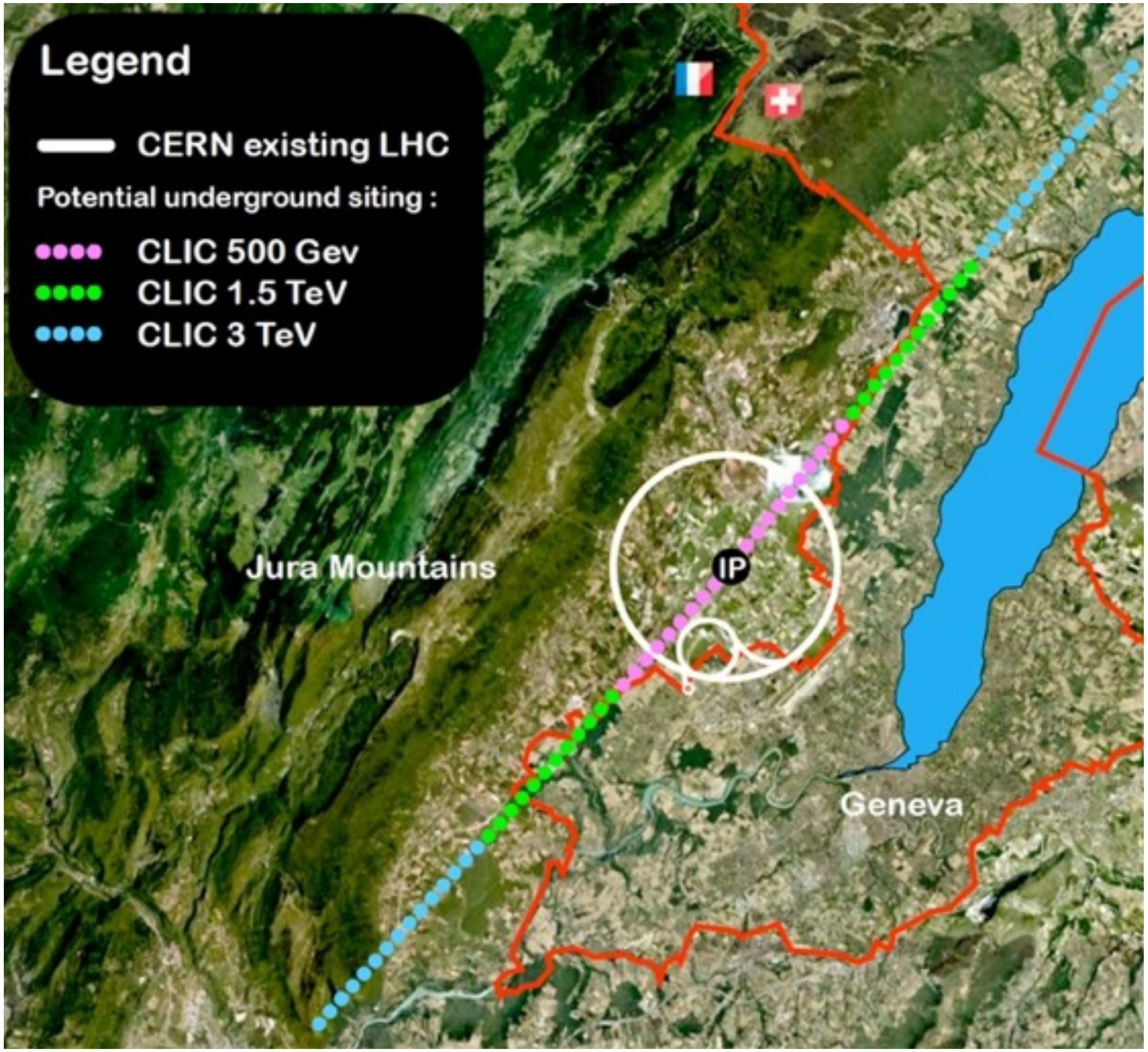
on behalf of CLICdp

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Outline

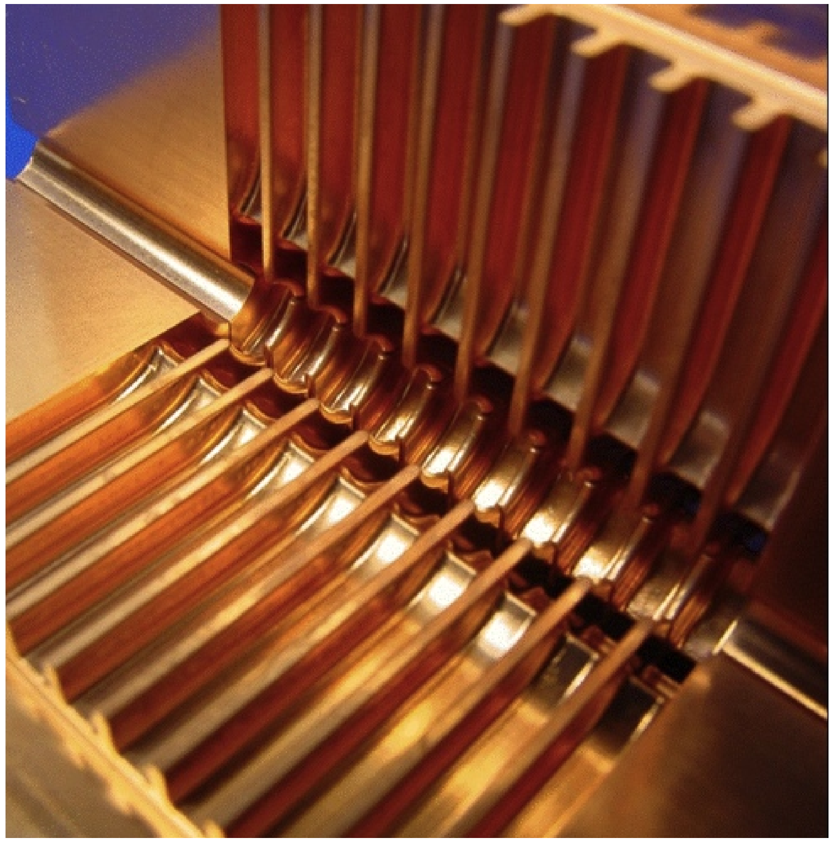
- CLIC: A future TeV-scale e^+e^- Collider
- The Higgs Program at CLIC
  - couplings at 350 GeV, 1.4 TeV and 3 TeV
  - the top Yukawa coupling
  - the Higgs self-coupling
- Global fits
- Summary

CLIC - A Possible Future at CERN



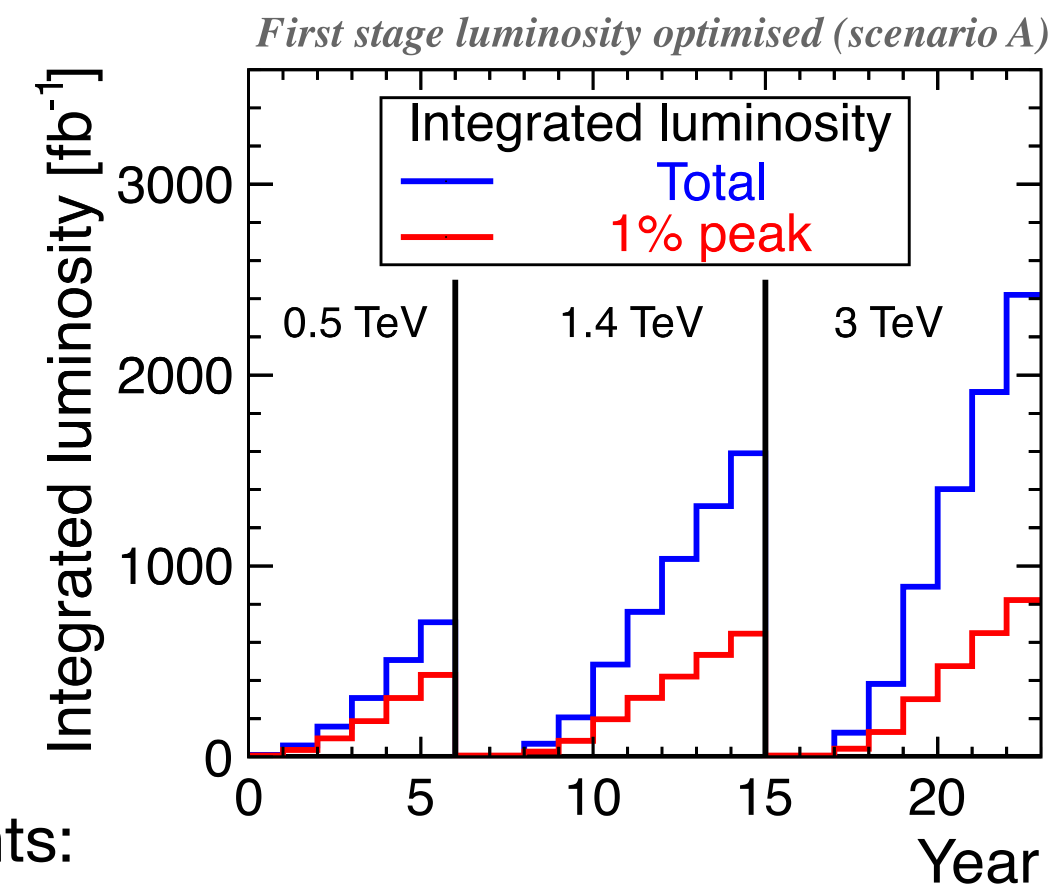
CLIC, a linear e^+e^- collider at the energy frontier

- Based on two-beam acceleration, room-temperatur cavities, gradients of up to 100 MV/m
- Maximum energy 3 TeV, construction in stages
- high luminosity (a few x 10^{34} cm^{-2}s^{-1})



A Staged Program to maximize Physics Potential

- For optimal luminosity, the energy of a collider based on CLIC technology can only be tuned within a factor of ~ 3: Staged construction of the machine



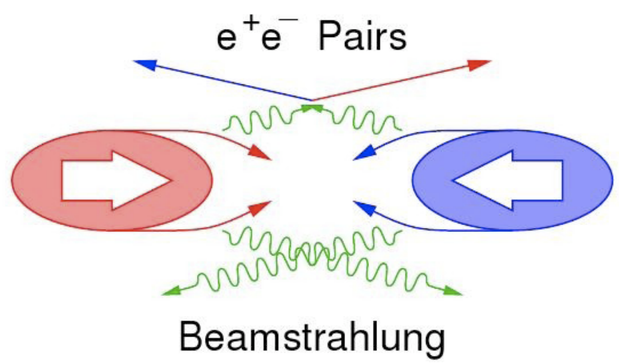
Provides:

- earlier start of physics
- optimal use of physics potential

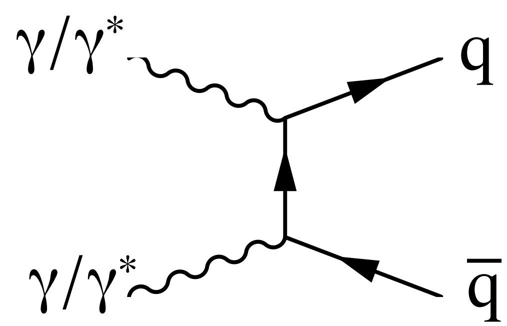
- Precise energy of the stages depends on physics - with considerations for technical constraints:
  - Studied scenario:
    - **350 / 375 GeV (500 fb^{-1})**
      - Higgs (including total width), Top threshold scan
    - **1.4 TeV (1.5 ab^{-1})**
      - BSM physics, ttH, Higgs self-coupling, rare Higgs decays
    - **3 TeV (2 ab^{-1})**
      - BSM physics, Higgs self-coupling, rare Higgs decays

The CLIC Environment

- The main challenge: High energy and high luminosity leads to high rates of photon-induced processes:



e^+e^- pairs drive crossing angle & vertex detector radius



$\gamma\gamma \rightarrow$ hadrons interactions:
3.2 / bunch crossing @ 3 TeV

Combined with bunch structure (0.5 ns between BX):
Pile-up of hadronic background:
~ 19 TeV in HCAL / bunch train
⇨ Needs to be rejected by reconstruction

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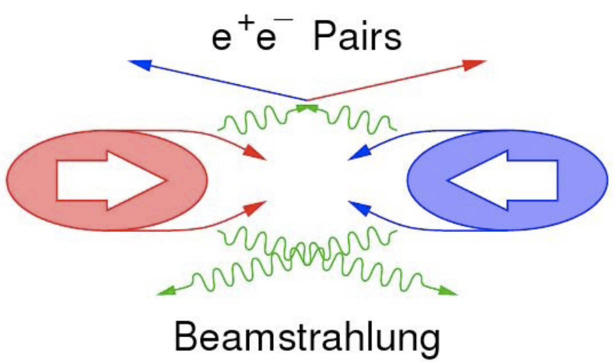

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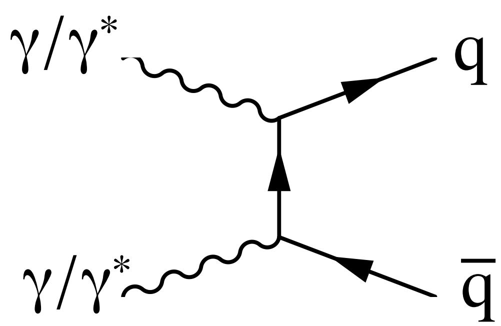

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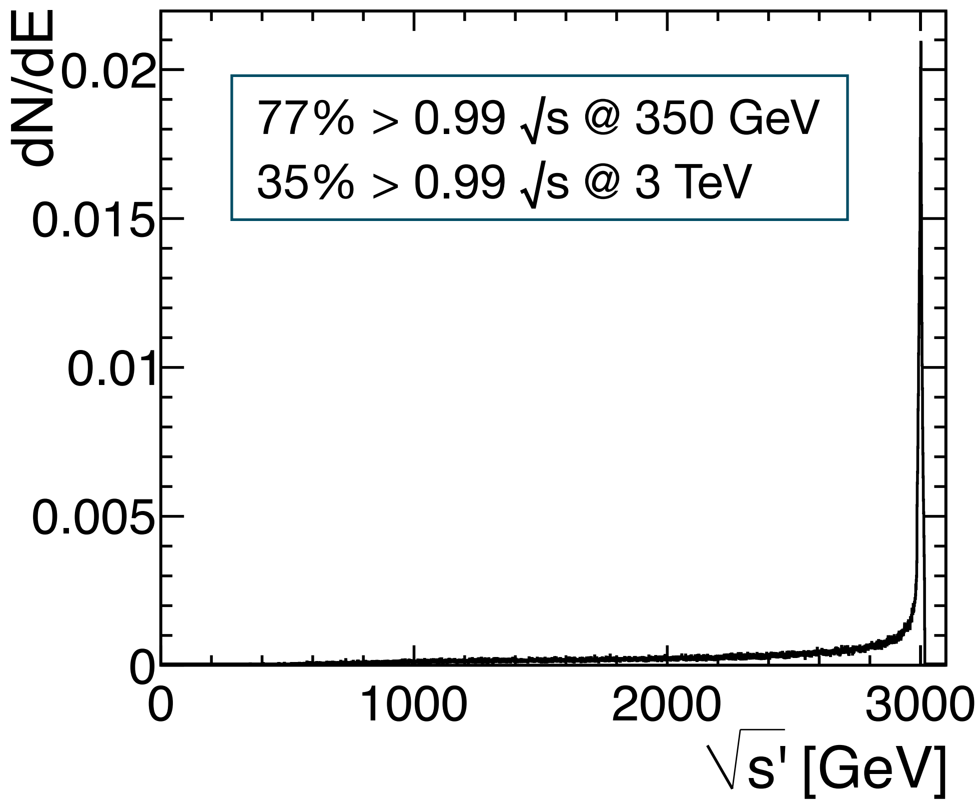
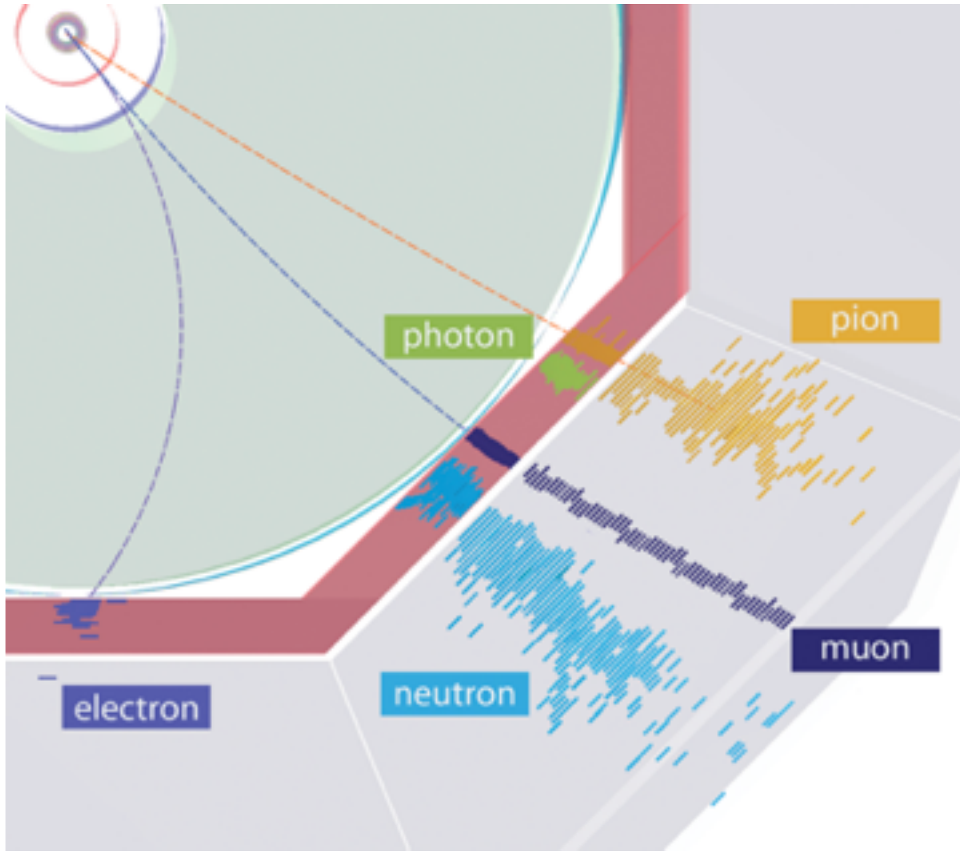
A further consequence of radiative losses: The luminosity spectrum - characterized by a main peak and a tail to lower energies



Detectors & Event Reconstruction at CLIC

- CLIC detectors: Low-mass, high resolution vertexing & tracking and highly granular calorimeters with time-stamping capability, all in a large high-field solenoid
- Event reconstruction based on Particle Flow Algorithms
  - Provides optimal jet energy reconstruction
  - When combined with ns-level timing in the calorimeters and hadron-collider type jet finders: A powerful tool for the rejection of $\gamma\gamma \to$ hadrons background



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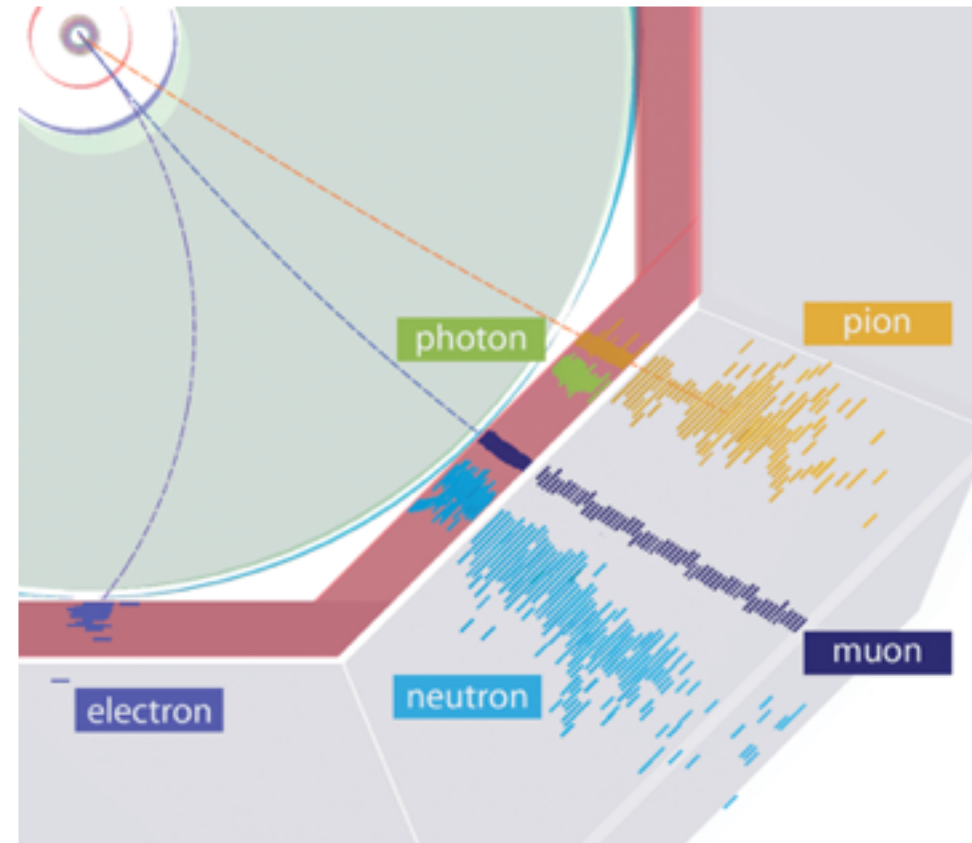
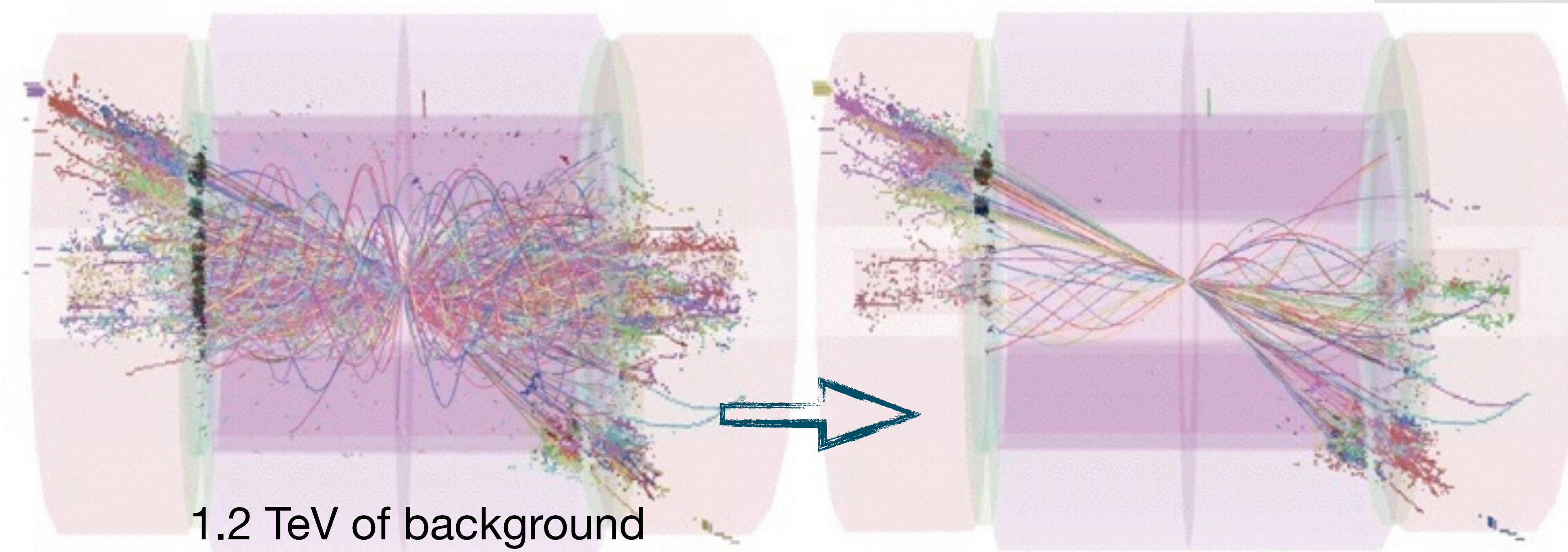


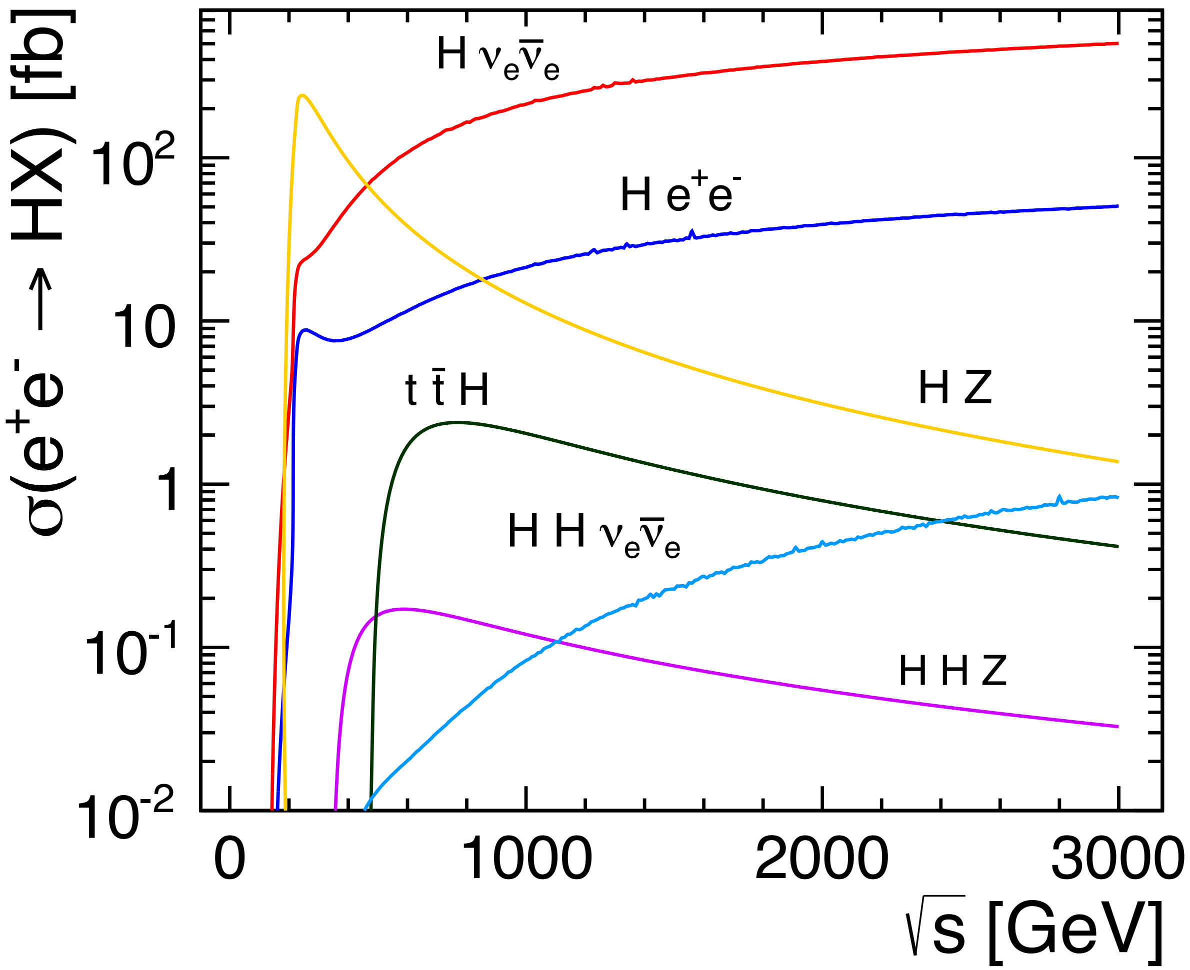


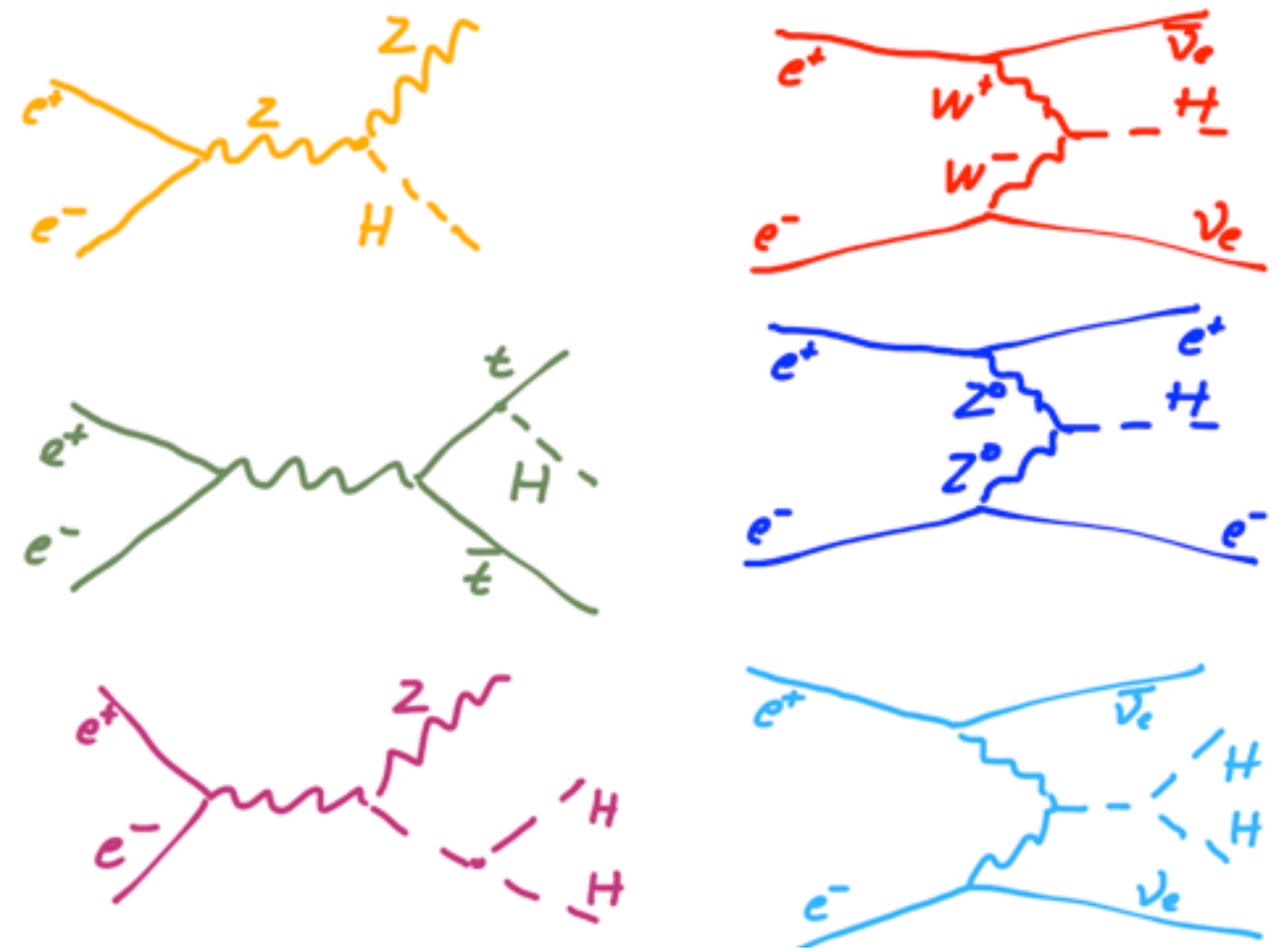
$e^+e^- \to t\bar{t}$ @ 3 TeV

Reduction of background from 19 TeV to 100 GeV: Challenging CLIC environment under control!

Higgs Physics at CLIC

- Now a guaranteed physics program - Profits from the wide energy reach of CLIC





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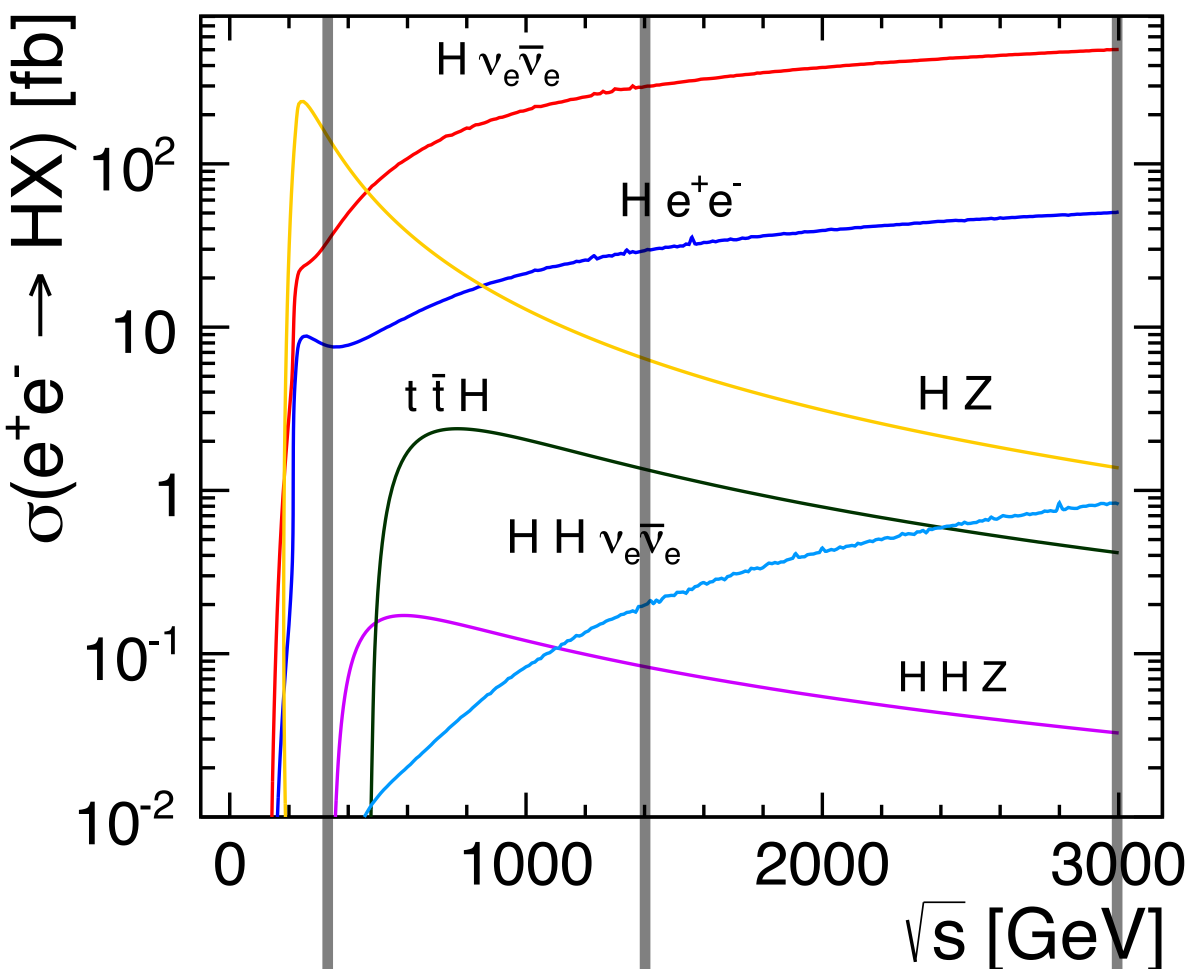

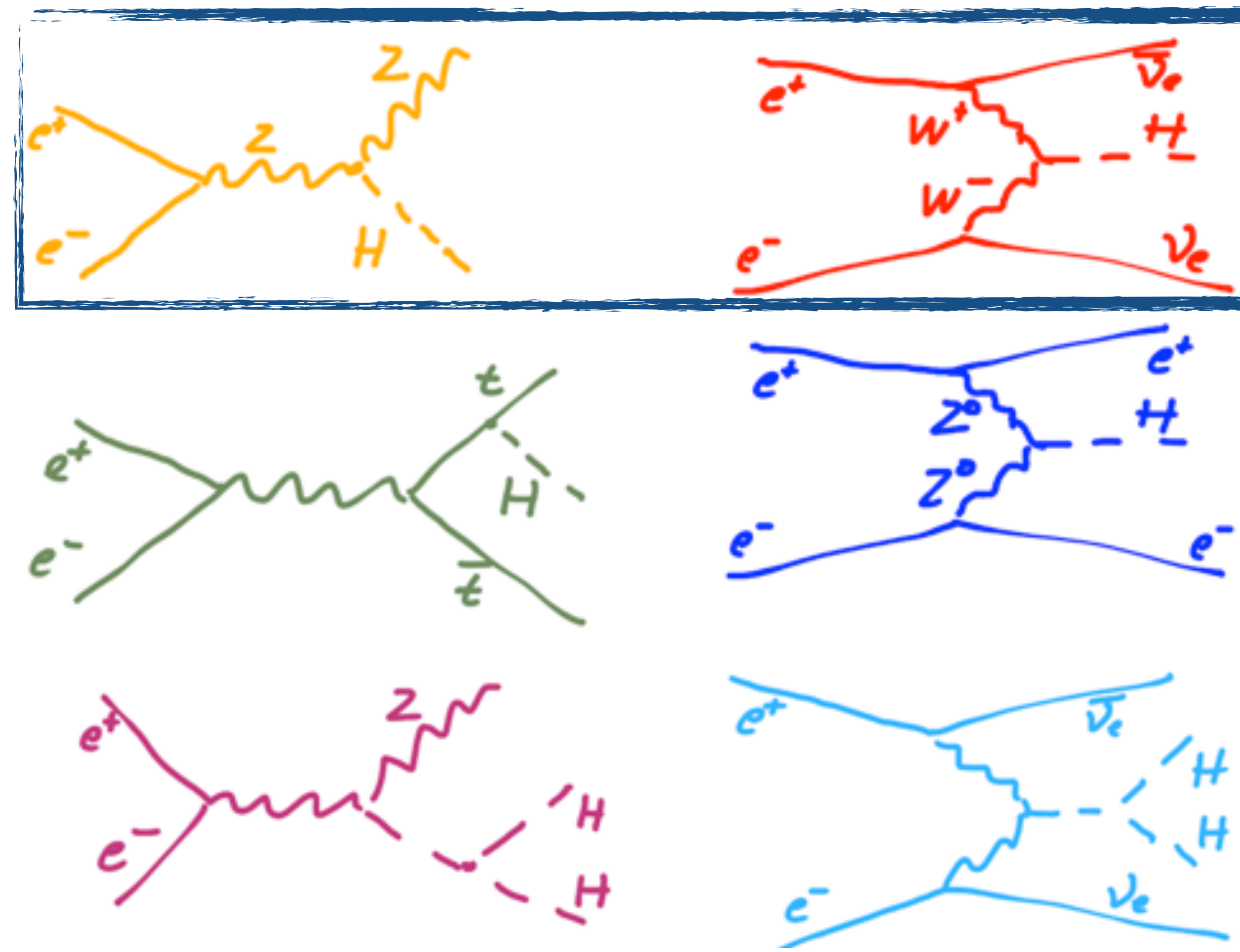

~ 80k

~ 450k

~ 1 M Higgs bosons per stage (w/o polarization)

(Polarization (80%, 0%) provides a boost of 1.8 for WW fusion)

Main production modes - give access to couplings and total width

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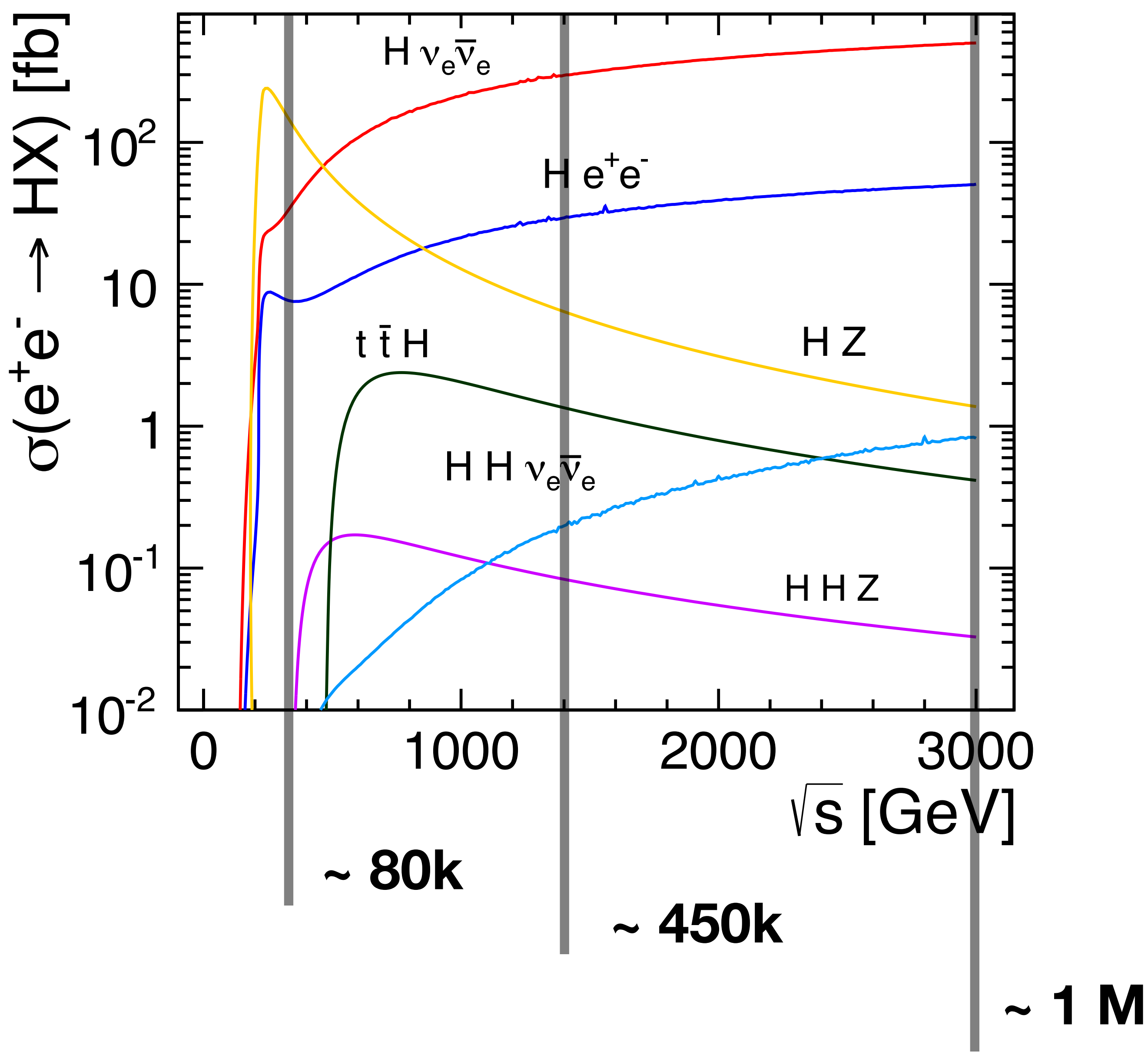
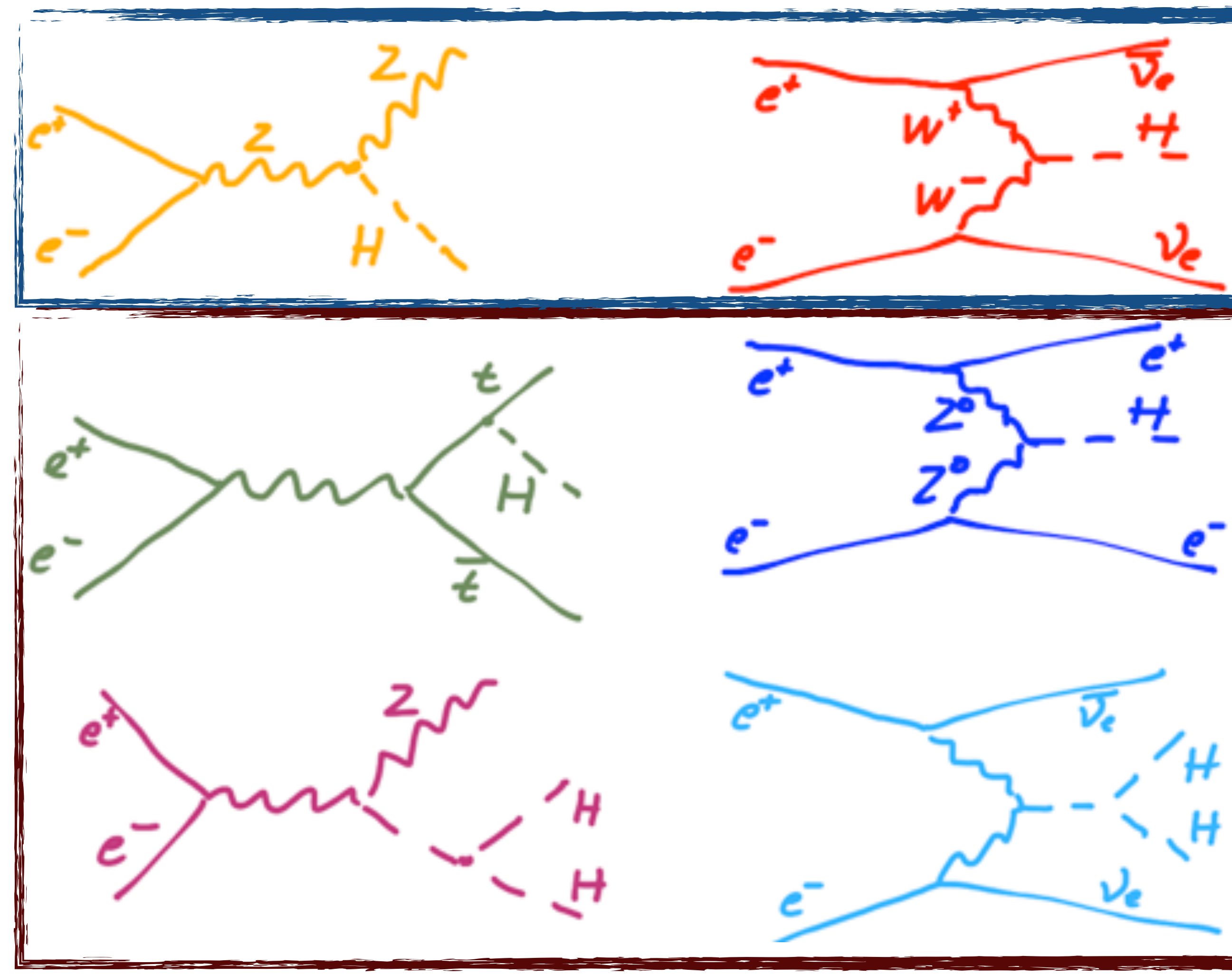




Higgs bosons per stage (w/o polarization)

(Polarization (80%, 0%) provides a boost of 1.8 for WW fusion)

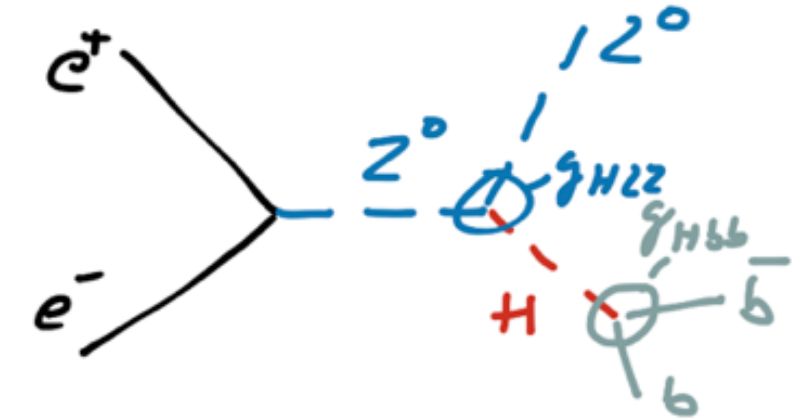
Main production modes - give access to couplings and total width

Rarer Processes - ZZ fusion, direct access to top Yukawa, self-coupling

Exploring the Higgs Sector: Couplings

- The measurements at CLIC (and other lepton colliders) are:

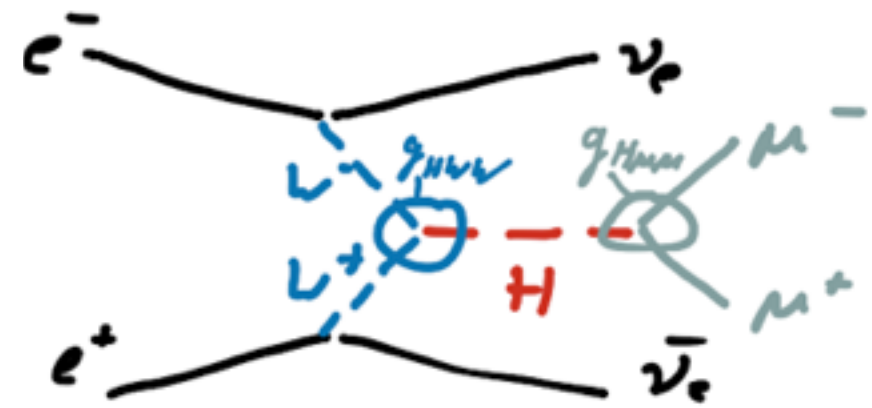
$\boxed{\begin{array}{l}\sigma \times \text{BR (for specific Higgs decays)} \\ \sigma \text{ (for model-independent recoil mass analysis)}\end{array}}$



Both are sensitive to couplings:

$$\sigma_{\mathrm{recoil}} \propto g^2_{\mathrm{HZZ}}$$

$$\sigma \times \mathrm{BR(H}\rightarrow \mathrm{ff)} \propto \frac{g^2_{\mathrm{Hii}} g^2_{\mathrm{Hff}}}{\Gamma_{\mathrm{tot}}}$$



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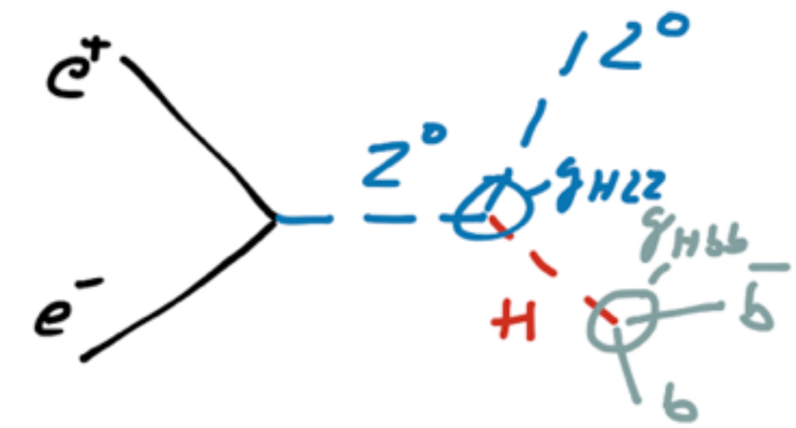

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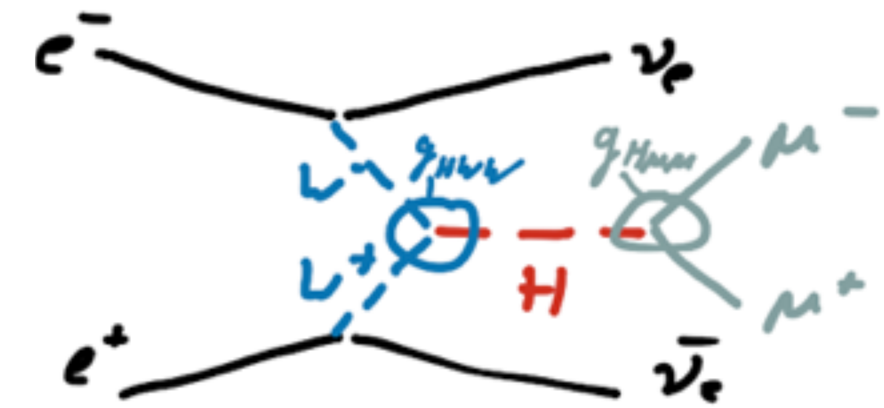


A crucial ingredient: The total width - best results when combining ZH and VBF

$$\sigma(\mathrm{H}\nu_e\nu_e) \times \mathrm{BR}(\mathrm{H} \rightarrow \mathrm{WW}^*) \propto \frac{g^4_{\mathrm{HWW}}}{\Gamma_{\mathrm{tot}}}$$

⇨ Accessible at 350 GeV
(134 fb for ZH, 52 fb for Hνν)

$$\frac{\sigma(e^+e^- \rightarrow \mathrm{ZH}) \times \mathrm{BR}(\mathrm{H} \rightarrow b\bar{b})}{\sigma(e^+e^- \rightarrow \mathrm{H}\nu_e\nu_e) \times \mathrm{BR}(\mathrm{H} \rightarrow b\bar{b})} \propto \frac{g^2_{\mathrm{HZZ}}}{g^2_{\mathrm{HWW}}}$$

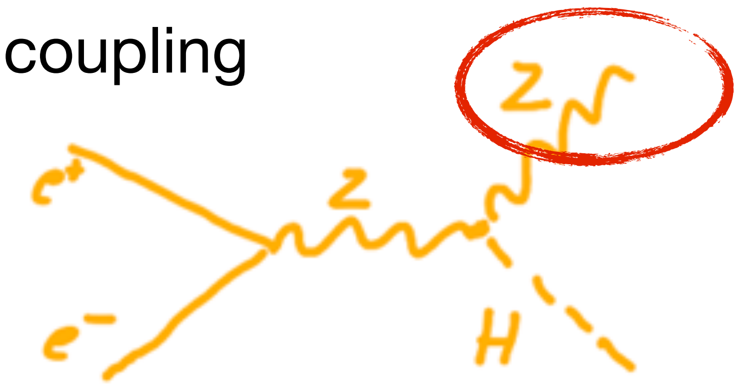
g_{HWW} pinned down with model-independent g_{HZZ} and high-BR H->bb decay

Simulation Studies

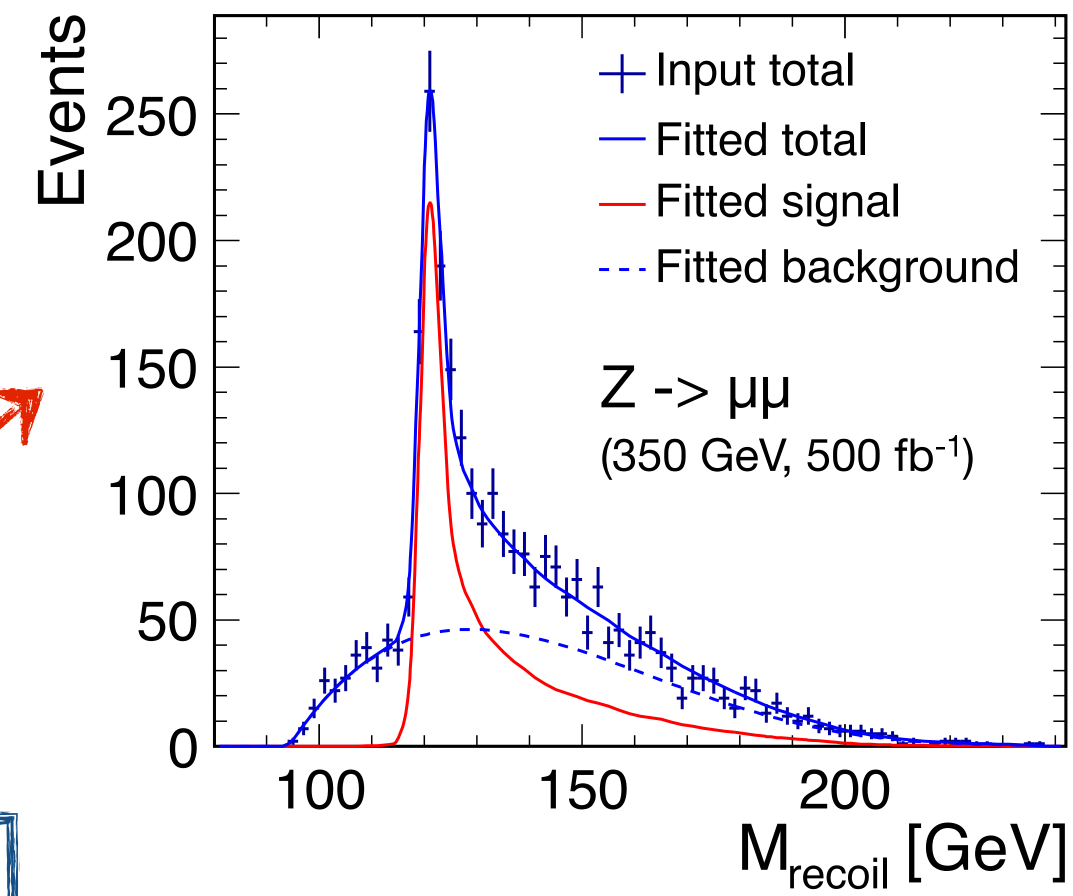
- All based on GEANT4 simulations using detailed detector models and realistic event reconstruction including PFA
- Beam-induced and physics backgrounds included
- Statistical uncertainties assume unpolarised beams

Model-Independent Measurement of Coupling to Z

- A unique feature of lepton colliders: model-independent measurement of HZZ coupling



$$\boxed{m_{rec}^2 = s + m_Z^2 - 2E_Z\sqrt{s}}$$



Absolute measurement of HZ cross section:
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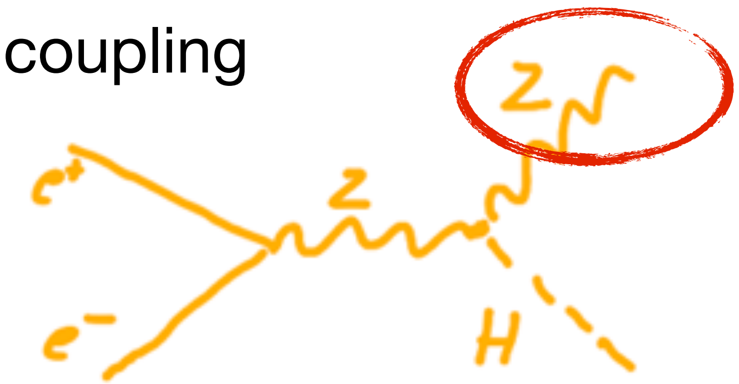

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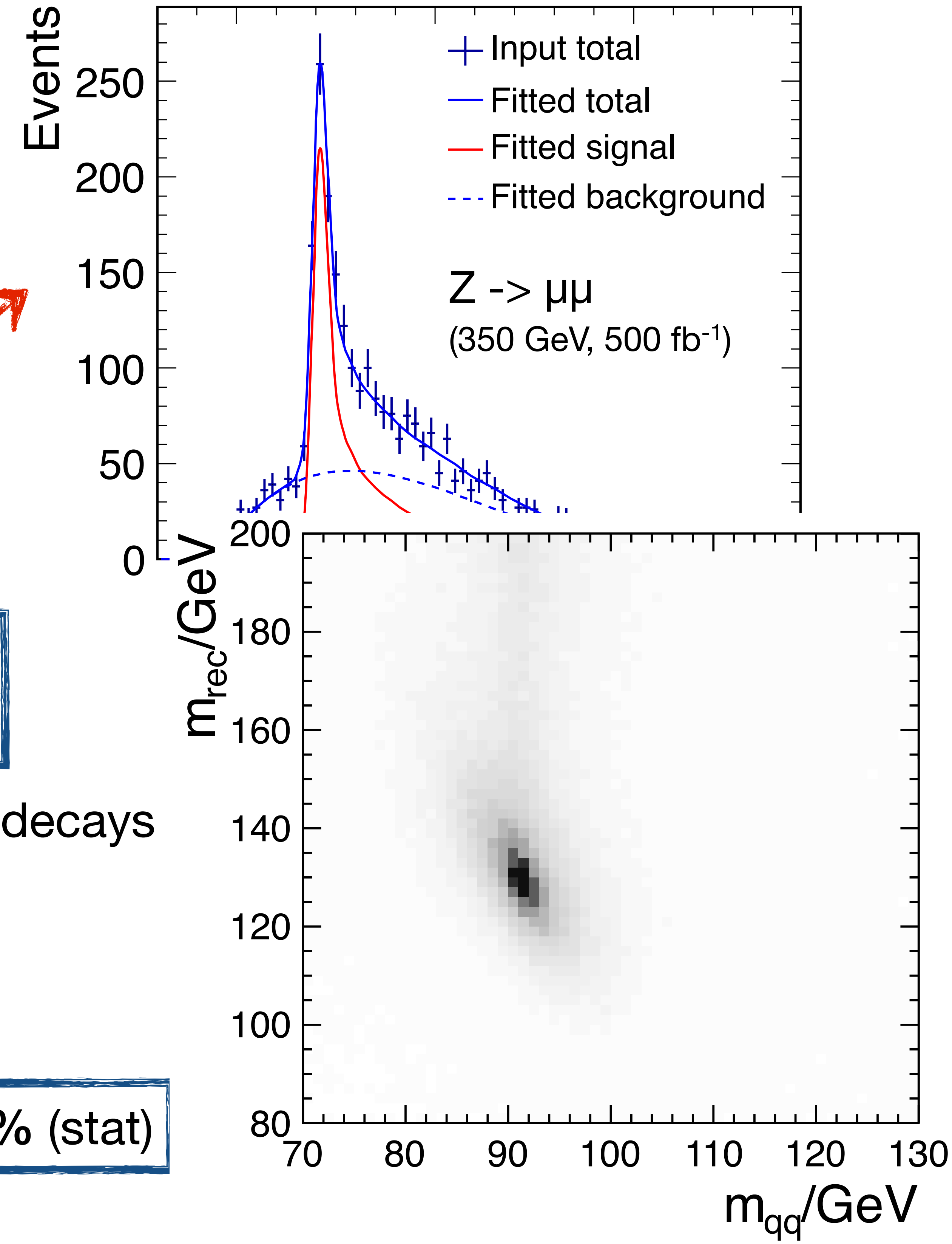

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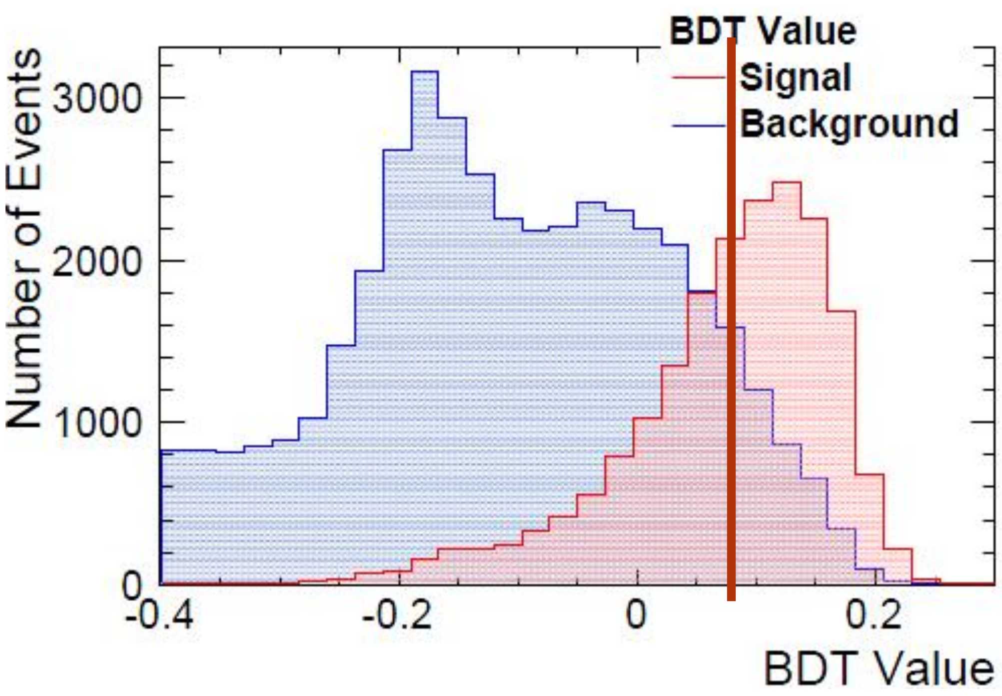
Substantial improvement when using hadronic Z decays

- The challenge: Z->qq reconstruction and event identification may depend on H decay mode
  - ▸ Very small bias through optimised analysis

Including hadronic Z decays: Δσ/σ(HZ) = **1.65%** (stat)

Coupling Measurements at 350 GeV

- Determine limit to invisible BSM Higgs decays based on 2-jet events in HZ, with Z->qq.
  - Resolution on fraction of invisible decays is limited by physics background fluctuations: $\Delta\sigma \times BR_{inv}$ = **0.57%**



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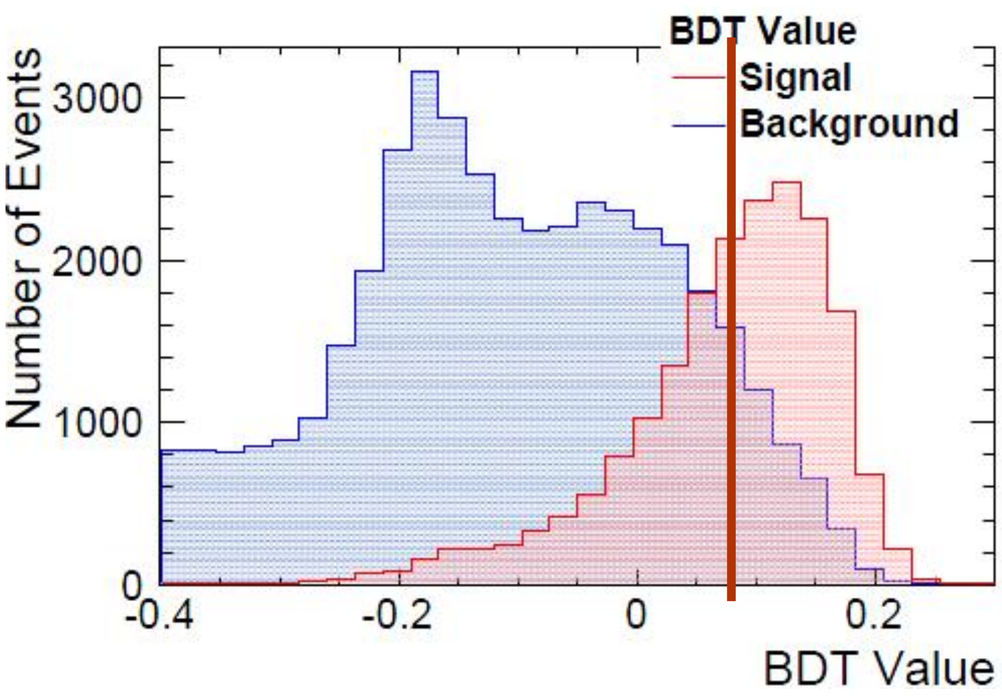
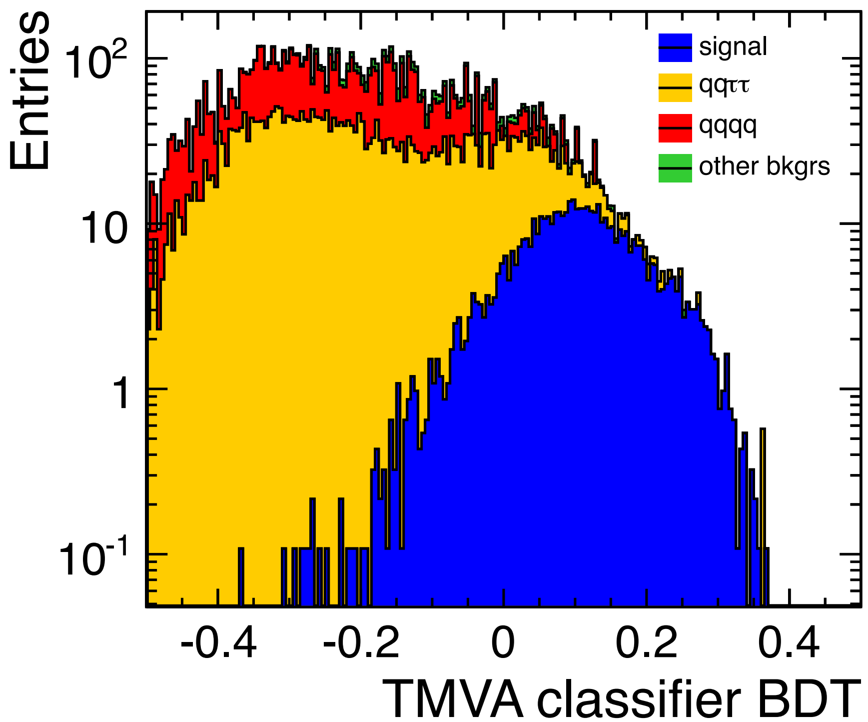


- σ(HZ) x BR(H-> ττ)

signal selection
in hadronic τ decays



precision of
σ(HZ) x BR(H-> ττ): **5.7%** (preliminary)

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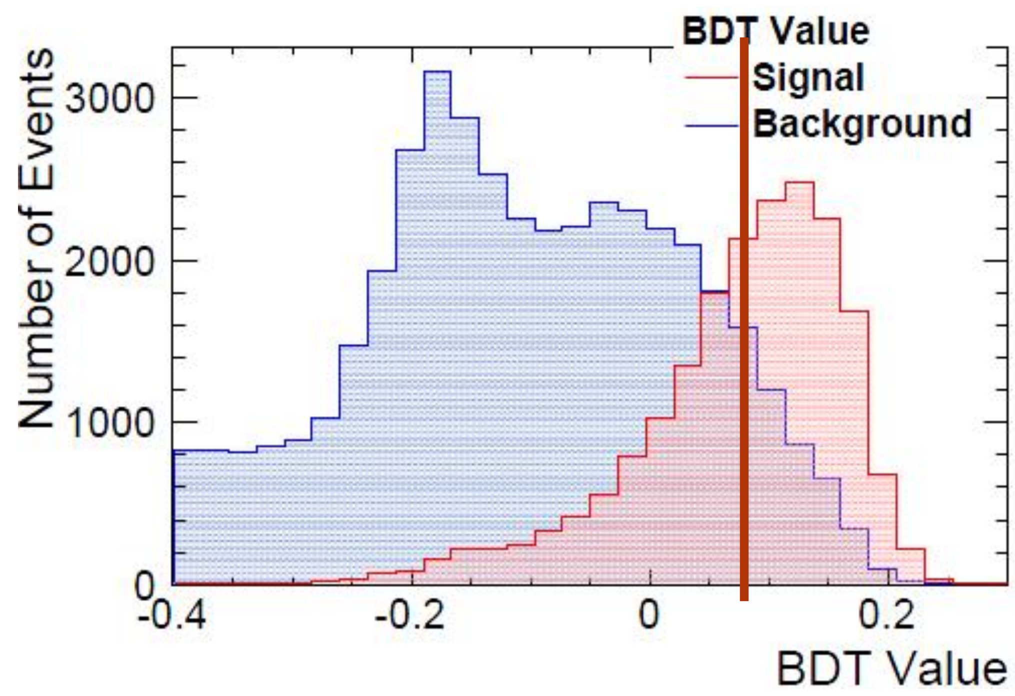

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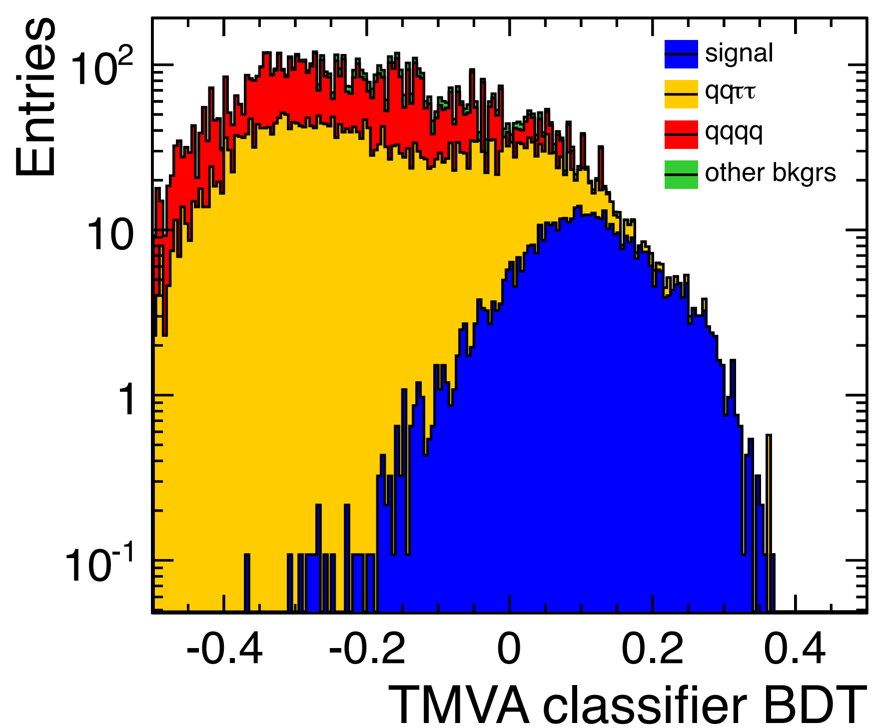


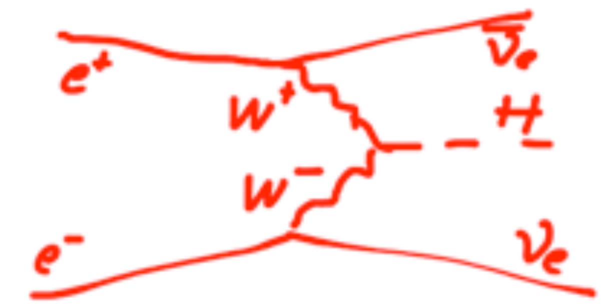
precision of
σ(HZ) x BR(H-> ττ): **5.7%** (preliminary)

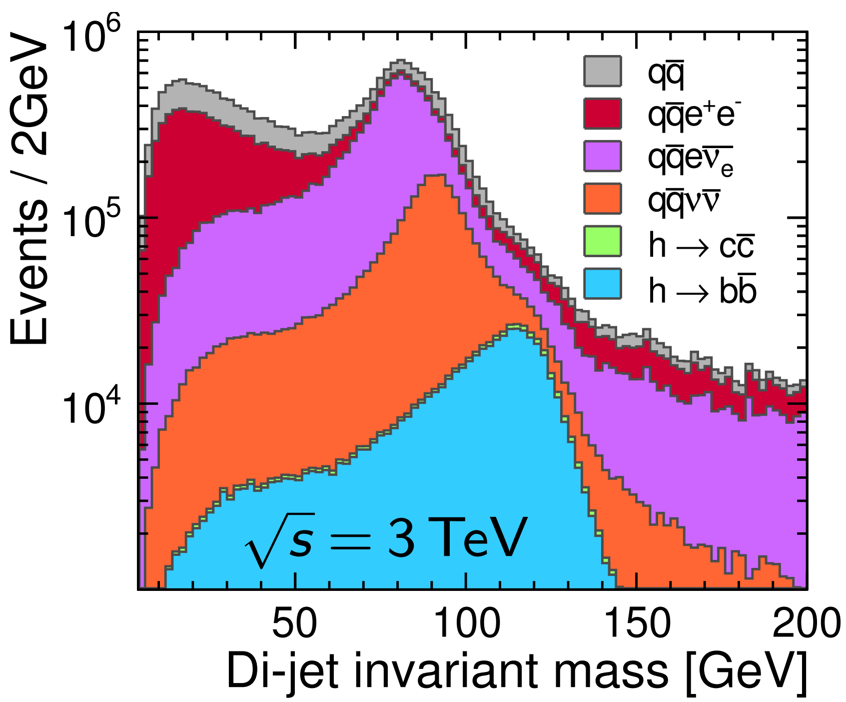
- Ongoing analyses:
  - σ(HZ) x BR(H-> WW*) - estimated precision **2%**
  - Combined extraction of H -> bb, cc, gg in HZ and Hνν
    - Crucial for the determination of the total width at 350 GeV
    estimated precision **1%**, **5%**, **6%**

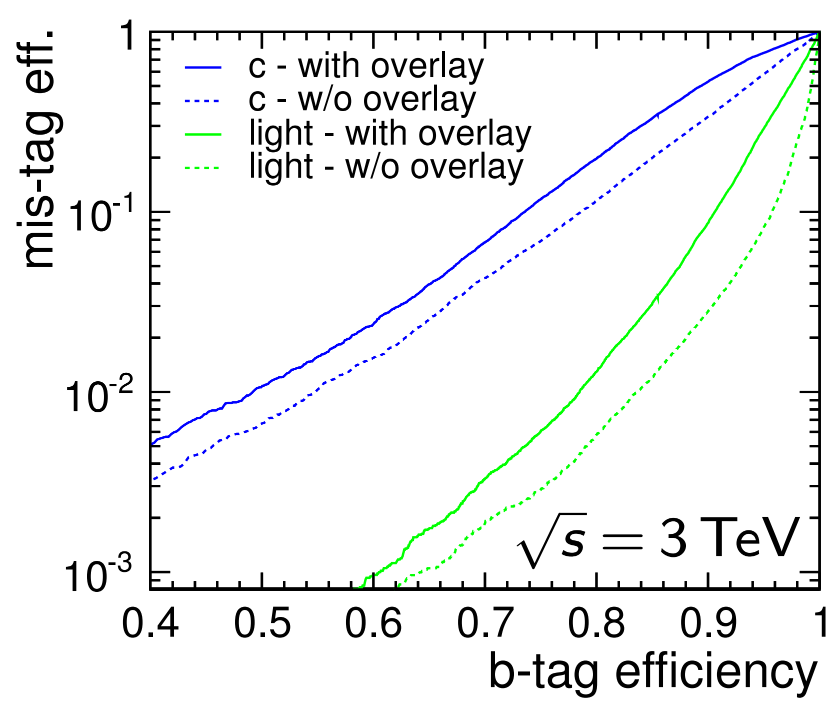
conservative estimates used in global fits at present, full studies nearing completion

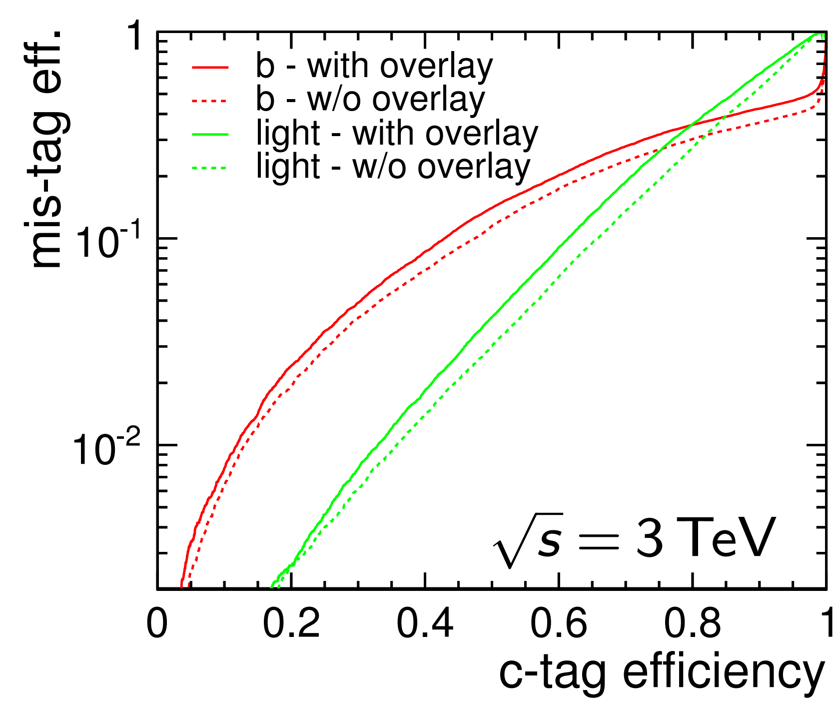
Measurements in WW fusion at 1.4 & 3 TeV

- Increasing cross section of WW fusion provides high statistics at high energy:
  ~ 430k (750k with e^- polarisation) H at 1.4 TeV with 1.5 ab^{-1}
  ~ 930k (1.7M with e^- polarisation) H at 3 TeV with 2 ab^{-1}
  - Possibility to access rare H decays
  - High-precision measurements of common decays







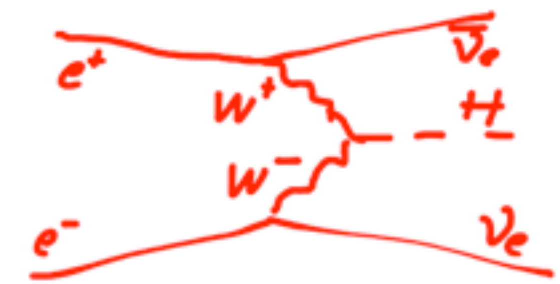


- One example: H->bb, cc, gg at 3 TeV
  - profits from flavor-tagging capability and high statistics

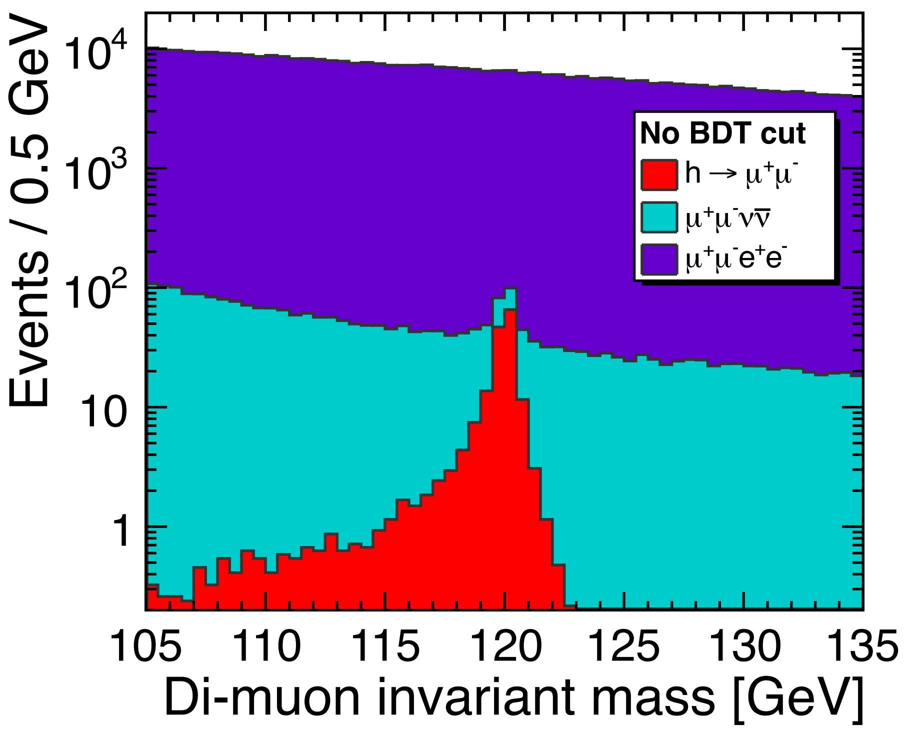
Results:

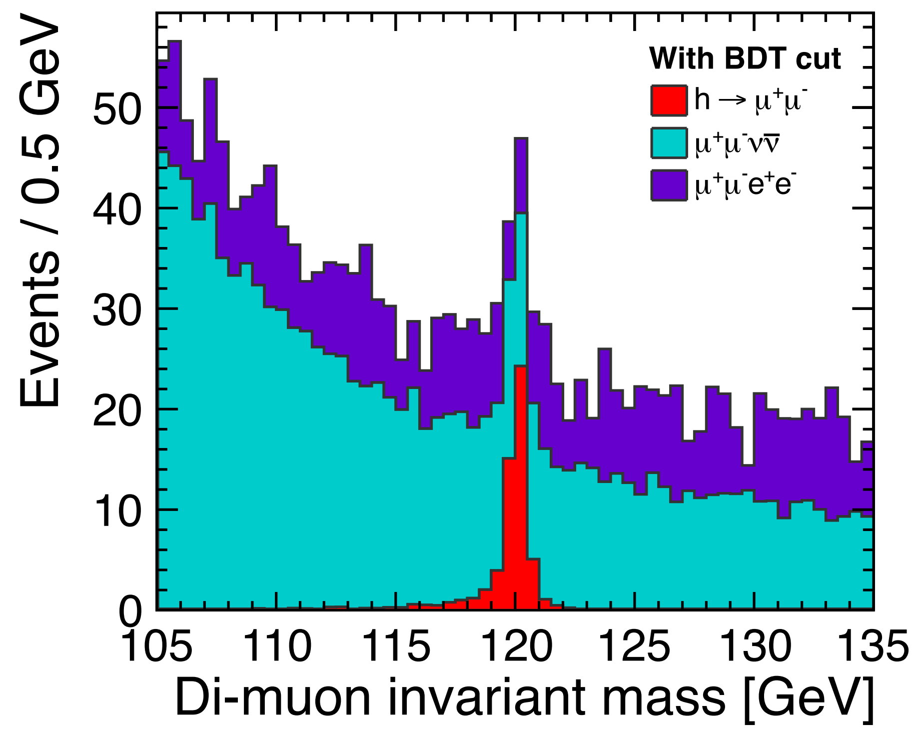
- σ(Hνν) x BR(H->bb): **0.3%**
- σ(Hνν) x BR(H->cc): **2.9%**
- σ(Hνν) x BR(H->gg): **1.8%**

Measurements in WW fusion at 1.4 & 3 TeV



- Measuring rare processes:
  - H->$\mu^+\mu^-$ at 3 TeV:





σ(Hνν) x BR(H->$\mu^+\mu^-$) with
16% precision at 3 TeV
(at 1.4 TeV: 38%)
BR: 2.1 x 10^{-4}

- H->γγ

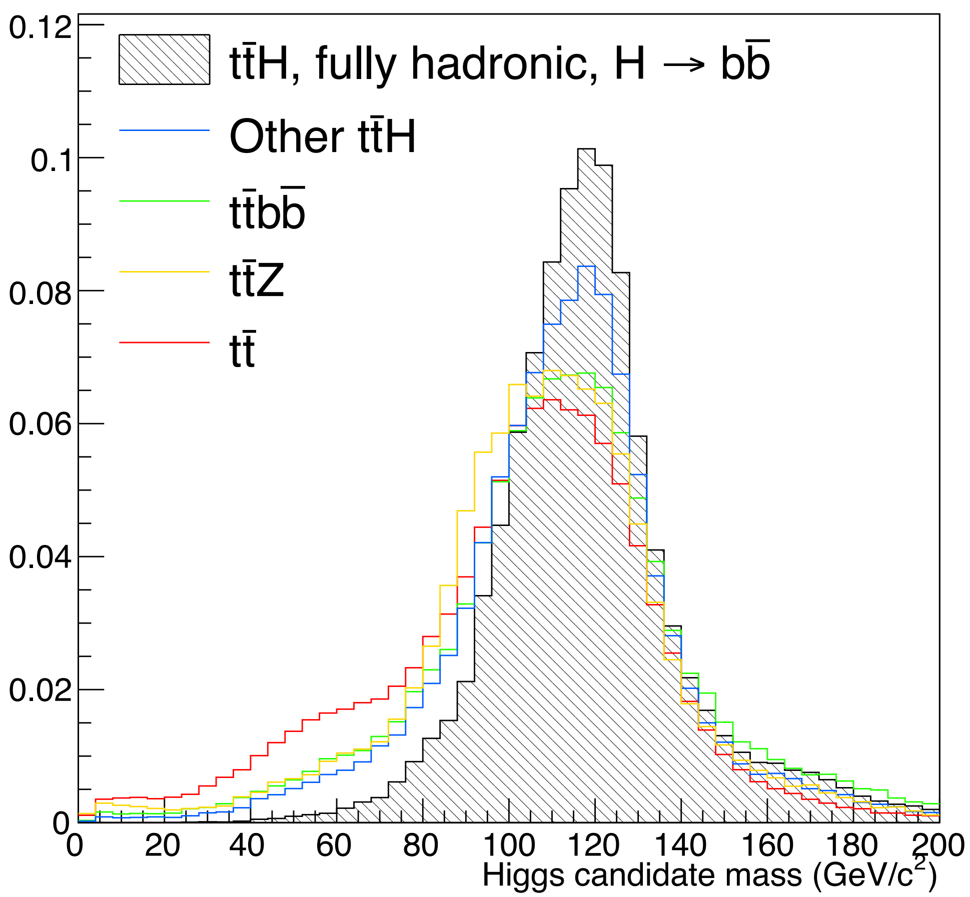
σ(Hνν) x BR(H->γγ) with
15% precision at 1.4 TeV
BR: 2.3 x 10^{-3}

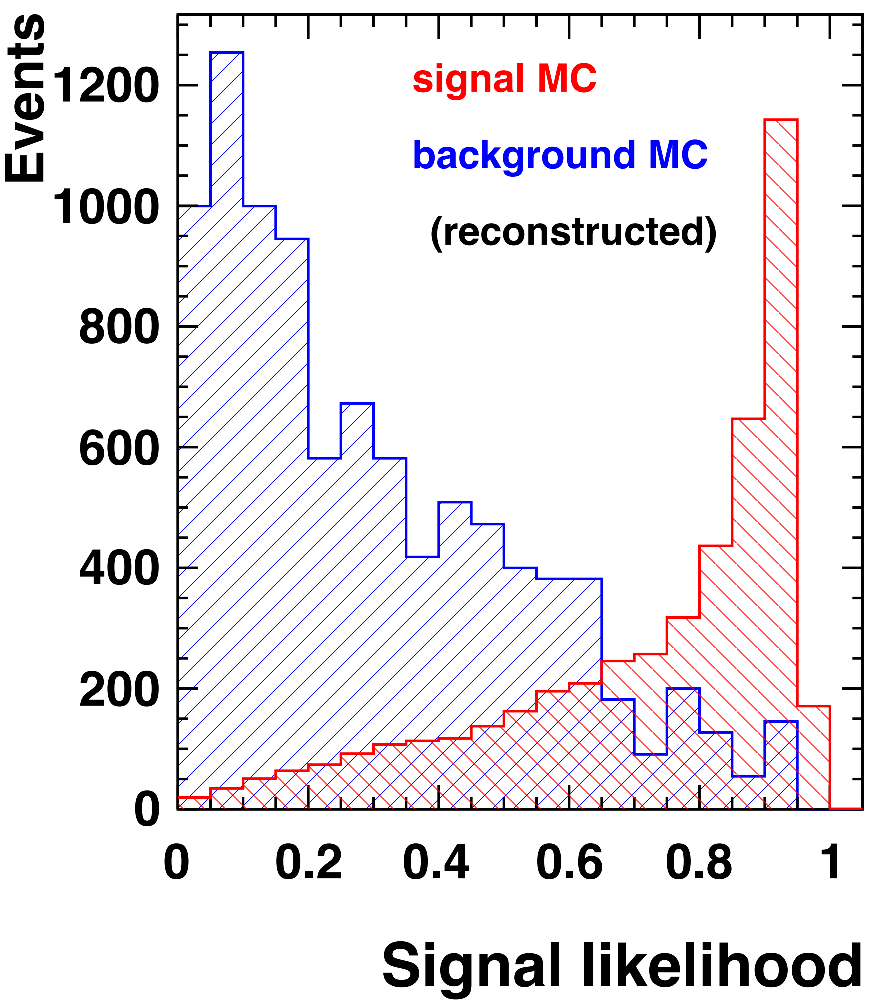
- H->Zγ

σ(Hνν) x BR(H->Zγ) with
42% precision at 1.4 TeV (Z -> qq, e^+e^-, $\mu^+\mu^-$)
BR: 1.6 x 10^{-3}

The Top Yukawa Coupling at 1.4 TeV

- Direct access to the top Yukawa coupling
- ▸ Reconstruction in H -> bb, with both tops decaying hadronically or one top decaying hadronically, one into blv





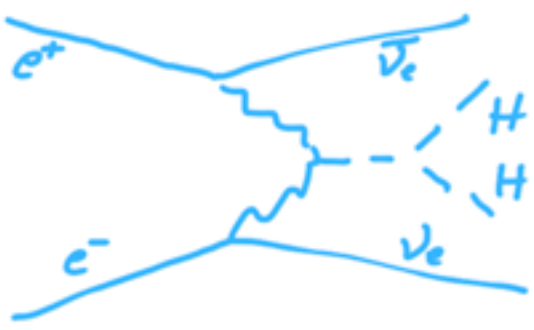
Multivariate signal selection in both channels - combined uncertainty on σ(ttH) x BR(H-> bb): **8.1%**

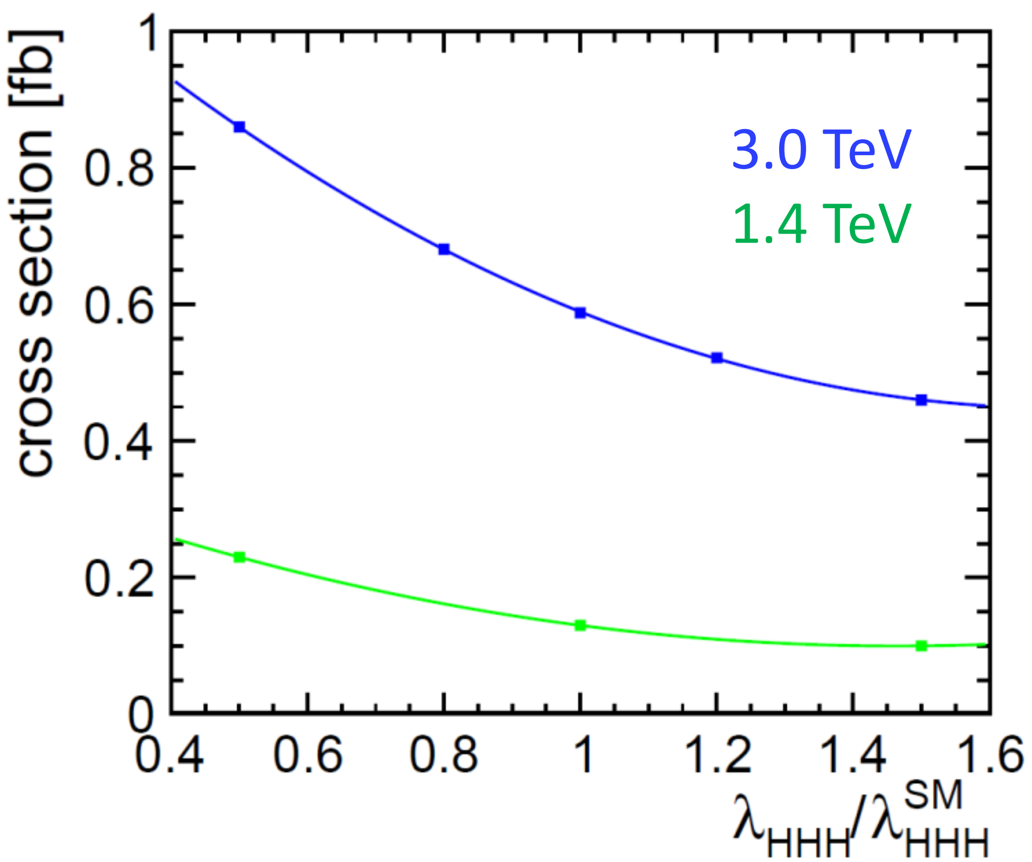
The Higgs Self-Coupling

- The ultimate challenge in Higgs physics: Direct access to the Higgs potential

At CLIC: Measurement in WW fusion - increasing cross-section at high energies

0.16 fb at 1.4 TeV, 0.63 fb at 3 TeV
(increases by 1.8 for 80% e^- polarization)





Cross section of HHνν final state depends on self-coupling (with a "dilution" by other processes)

$\Delta\lambda_{HHH}$ ~ 32% (stat) with 1.5 ab^{-1} at 1.4 TeV
$\Delta\lambda_{HHH}$ ~ 16% (stat) with 2 ab^{-1} at 3 TeV
unpolarized

$\Delta\lambda_{HHH}$ ~ **24%** (stat) with 1.5 ab^{-1} at 1.4 TeV
$\Delta\lambda_{HHH}$ ~ **12%** (stat) with 2 ab^{-1} at 3 TeV
80% e^- pol.

~11% accuracy of self-coupling with the full (polarized) CLIC program

Extracting Results: Global Fits

- Each σ x BR measurement alone does not directly provide the underlying coupling parameters - A global analysis of all results is required to assess the impact of the CLIC program on the understanding of the Higgs sector

The Full Picture: Global Fits

- From the measurements of σ and σ x BR the couplings and the total width are determined by a global fit:

$$\chi^2 = \sum_i \frac{(\boxed{C_i} - 1)^2}{\boxed{\Delta F_i^2}}$$

ΔF$_i$: uncertainty of measurement (σ or σxBR)

$$C_{\mathrm{ZH}} = g^2_{\mathrm{HZZ}}$$

$$C_{\mathrm{ZH,H}\to b\bar{b}} = \frac{g^2_{\mathrm{HZZ}} g^2_{\mathrm{Hbb}}}{\Gamma_{\mathrm{H}}}$$

$$C_{\mathrm{H}\nu_e\bar{\nu}_e,\mathrm{H}\to b\bar{b}} = \frac{g^2_{\mathrm{HWW}} g^2_{\mathrm{Hbb}}}{\Gamma_{\mathrm{H}}}$$

...

Two fits:

Model-independent fit - total width as a free parameter

Model-dependent fit - LHC-like constraints

Assumptions: No BSM decays, the total width can be described by a few parameters which parametrize deviations of partial widths from the SM expectation

$$\kappa_i^2 = \frac{\Gamma_i}{\Gamma_i|_{\mathrm{SM}}} \qquad \Gamma_{\mathrm{H,md}} = \sum_i \kappa_i^2 \, BR_i$$

In the fit: replace g_{Hii} with κ_{Hii}, Γ_{H} with $\Gamma_{\mathrm{H,md}}$

Measurement Summary

work in progress - current status

Channel	Measurement	Observable	Statistical precision 350 GeV $500\ \mathrm{fb}^{-1}$
ZH	Recoil mass distribution	m_{H}	120 MeV
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \text{invisible})$	Γ_{inv}	0.6%
ZH	$\mathrm{H} \to \mathrm{b\bar{b}}$ mass distribution	m_{H}	tbd
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{Z} \to \ell^+\ell^-)$	g^2_{HZZ}	4.2%
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{Z} \to \mathrm{q\bar{q}})$	g^2_{HZZ}	1.8%
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	$1\%^{\dagger}$
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \mathrm{c\bar{c}})$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{Hcc}} / \Gamma_{\mathrm{H}}$	$5\%^{\dagger}$
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \mathrm{gg})$		$6\%^{\dagger}$
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \tau^+\tau^-)$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{H\tau\tau}} / \Gamma_{\mathrm{H}}$	5.7%
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \mathrm{WW}^*)$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{HWW}} / \Gamma_{\mathrm{H}}$	$2\%^{\dagger}$
ZH	$\sigma(\mathrm{HZ}) \times BR(\mathrm{H} \to \mathrm{ZZ}^*)$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{HZZ}} / \Gamma_{\mathrm{H}}$	tbd
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	$3\%^{\dagger}$

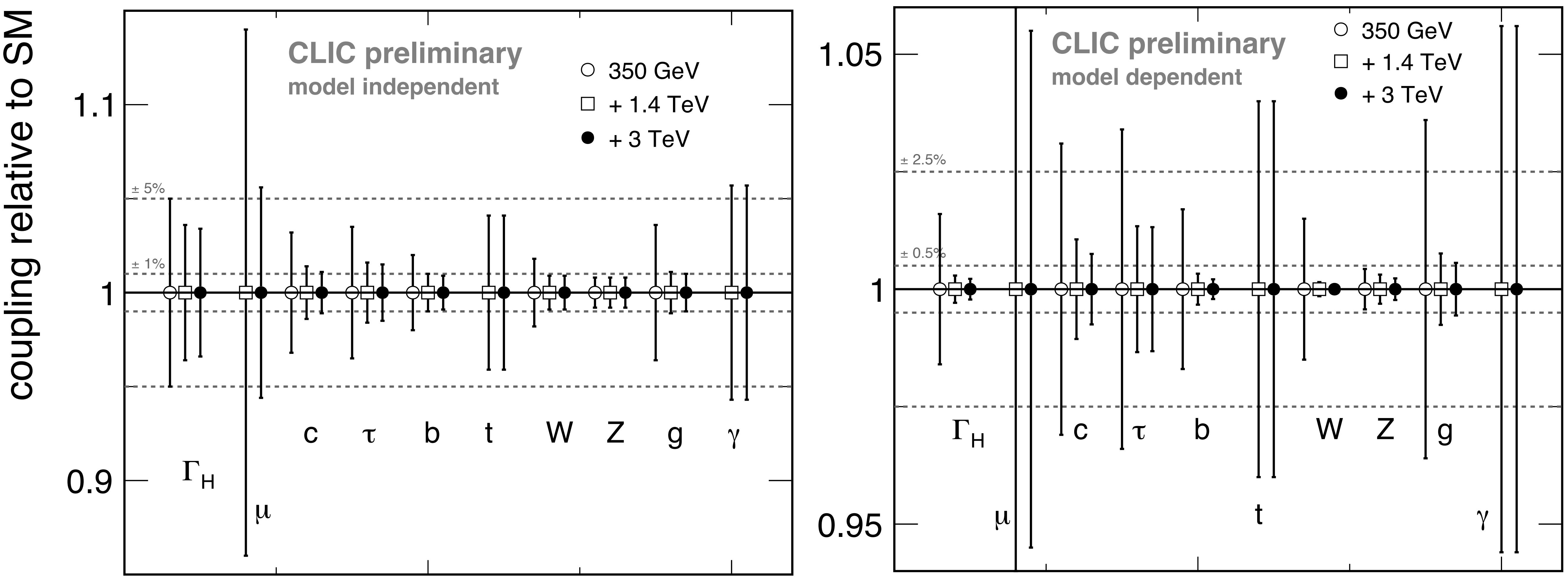
- Full summary of CLIC Higgs studies - all results show expected statistical uncertainties assuming SM values and unpolarised beams

Channel	Measurement	Observable	Statistical precision 1.4 TeV $1.5\ \mathrm{ab}^{-1}$	3.0 TeV $2.0\ \mathrm{ab}^{-1}$
$\mathrm{H}\nu_e\bar{\nu}_e$	$\mathrm{H} \to \mathrm{b\bar{b}}$ mass distribution	m_{H}	40 MeV*	33 MeV*
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	0.3%	0.2%
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{c\bar{c}})$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{Hcc}} / \Gamma_{\mathrm{H}}$	2.9%	2.7%
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{gg})$		1.8%	1.8%
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \tau^+\tau^-)$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{H\tau\tau}} / \Gamma_{\mathrm{H}}$	3.7%*	tbd
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mu^+\mu^-)$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{H\mu\mu}} / \Gamma_{\mathrm{H}}$	38%	16%
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \gamma\gamma)$		15%	tbd
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{Z}\gamma)$		42%	tbd
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{WW}^*)$	$g^4_{\mathrm{HWW}} / \Gamma_{\mathrm{H}}$	1.1%*	0.8%*
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e) \times BR(\mathrm{H} \to \mathrm{ZZ}^*)$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{HZZ}} / \Gamma_{\mathrm{H}}$	$3\%^{\dagger}$	$2\%^{\dagger}$
$\mathrm{He^+e^-}$	$\sigma(\mathrm{He^+e^-}) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	$1\%^{\dagger}$	$0.7\%^{\dagger}$
$\mathrm{t\bar{t}H}$	$\sigma(\mathrm{t\bar{t}H}) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{Htt}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	8%	–
$\mathrm{HH}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{HH}\nu_e\bar{\nu}_e)$	g_{HHWW}	7%*	3%*
$\mathrm{HH}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{HH}\nu_e\bar{\nu}_e)$	λ	32%	16%
$\mathrm{HH}\nu_e\bar{\nu}_e$	with -80% e^- polarization	λ	24%	12%

- Some analyses are still in progress "*"- missing results are labelled "tbd" estimates from preliminary studies "†"

Global Fits: Results

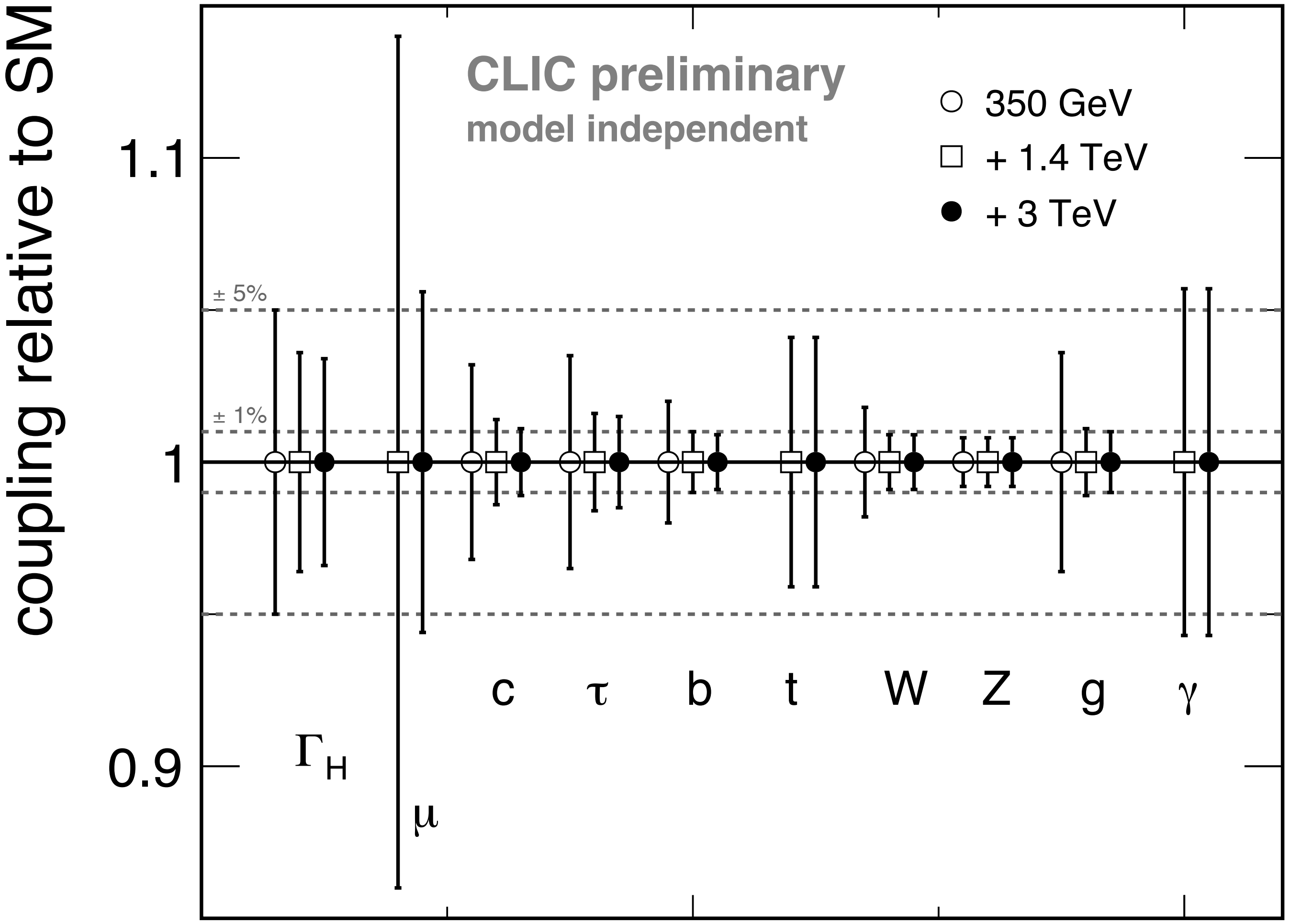
work in progress - current status

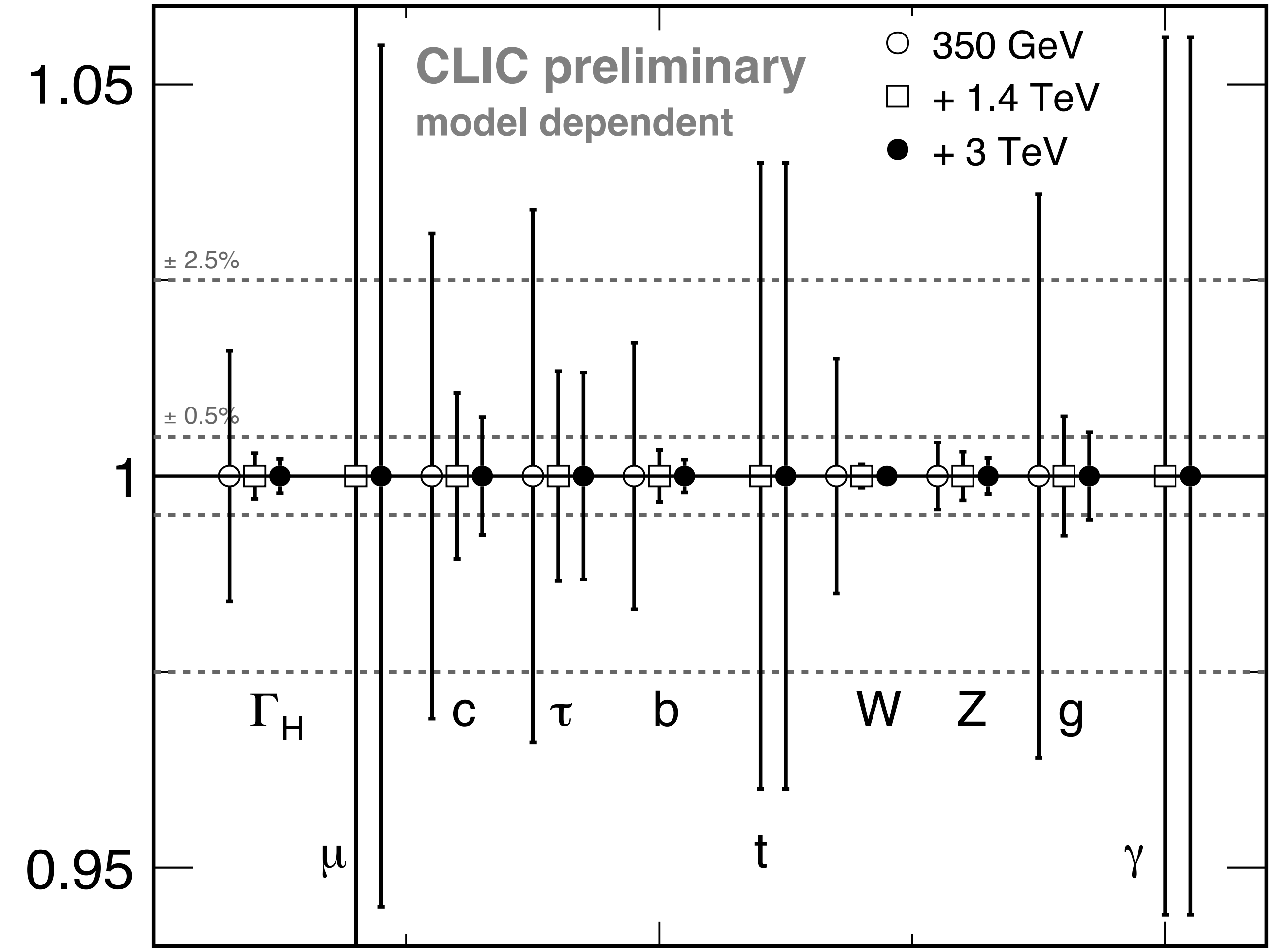


correlations of measurements not included in fit, input measurements include preliminary estimates

Global Fits: Results

work in progress - current status





correlations of measurements not included in fit, input measurements include preliminary estimates

➪ model-independent 1% - level determination of most couplings in full program
(all limited by the model-independent measurement of the ZH coupling)
➪ 1% to few ‰ with LHC-like model-dependence

Summary

- CLIC is a possible future energy frontier machine at CERN - and currently the only mature option for multi-TeV e^+e^- collisions

- It offers the opportunity for a comprehensive Higgs program:
  - A first stage at 350 GeV provides a model-independent determination of most couplings and of invisible decays
  - Subsequent running at higher energy (here: 1.4 TeV and 3 TeV)
    - improves the precision of most observables due to higher statistics
    - enables a direct measurement of the ttH coupling
    - provides the potential to measure the Higgs self coupling on the ~10% level
  - Combined fits to all measurements at all three energy stages were performed to determine the expected precision of all relevant couplings and of the total width
    - model-independent measurements of most couplings on the 1% level, a few per mille with LHC-like constraints

Backup

CLIC - Long-Term Plan

2012-16 Development Phase

Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors.

2017-22 Preparation Phase

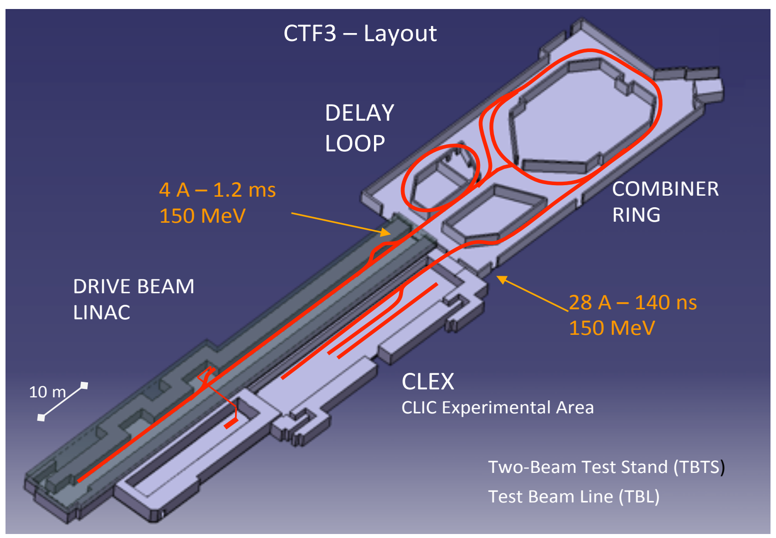
Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

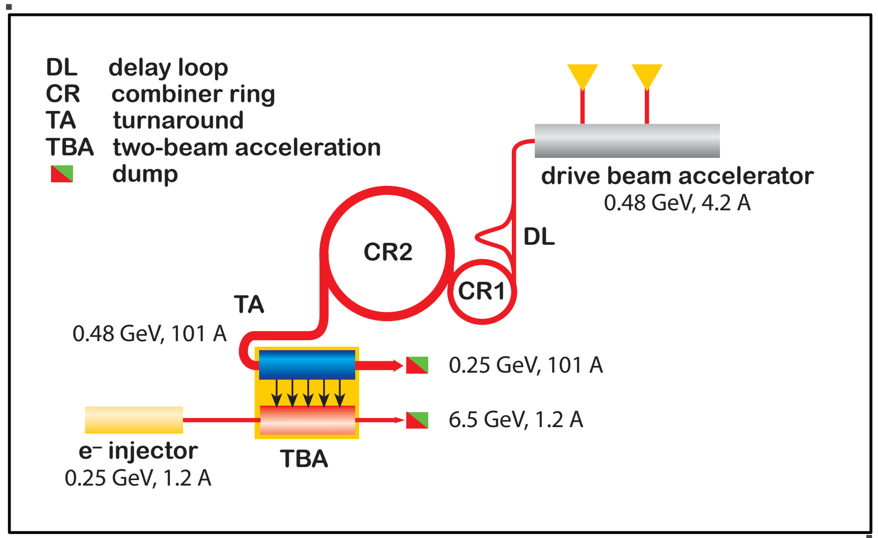
Prepare detailed Technical Proposals for the detector-systems.

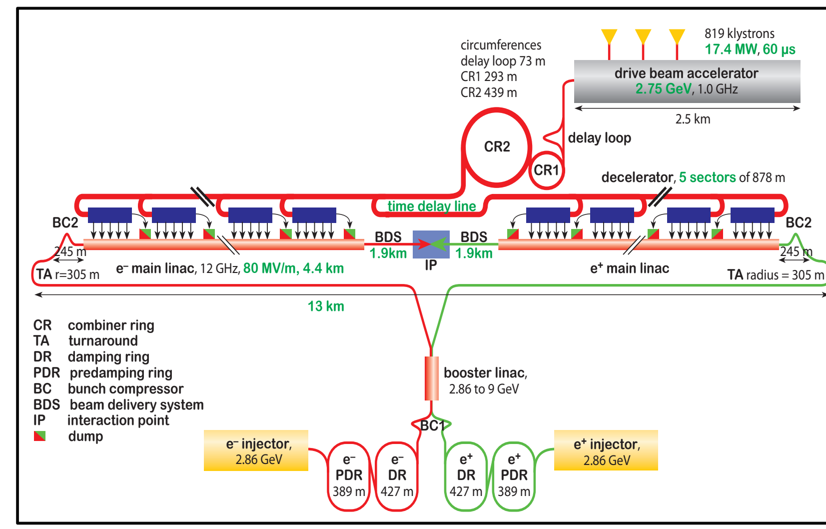
2023-2030 Construction Phase

Stage 1 construction of a 500 GeV CLIC, in parallel with detector construction.

Preparation for implementation of further stages.







2016-17 Decisions

On the basis of LHC data and Project Plans (for CLIC and other potential projects), take decisions about next project(s) at the Energy Frontier.

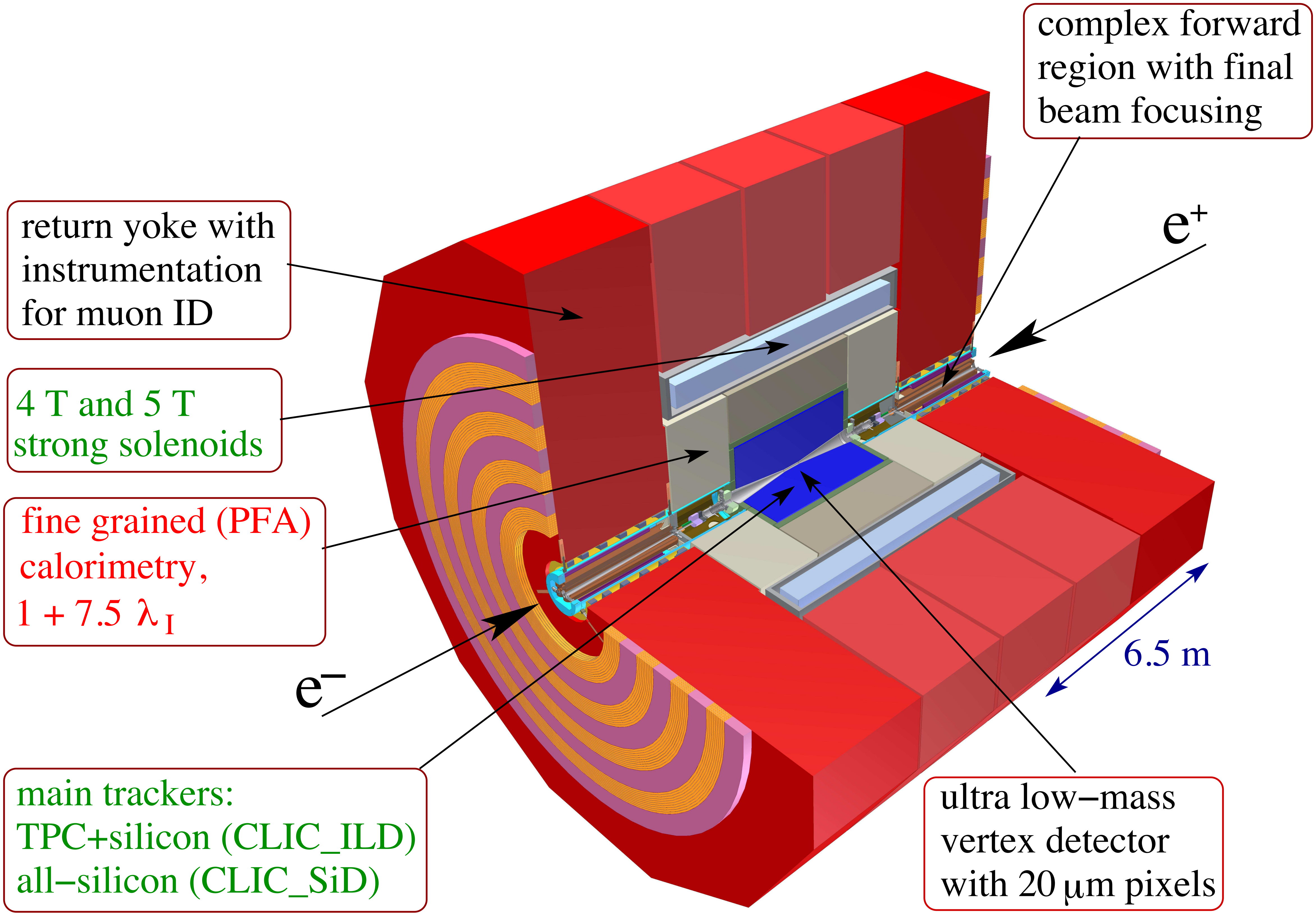
2022-23 Construction Start

Ready for full construction and main tunnel excavation.

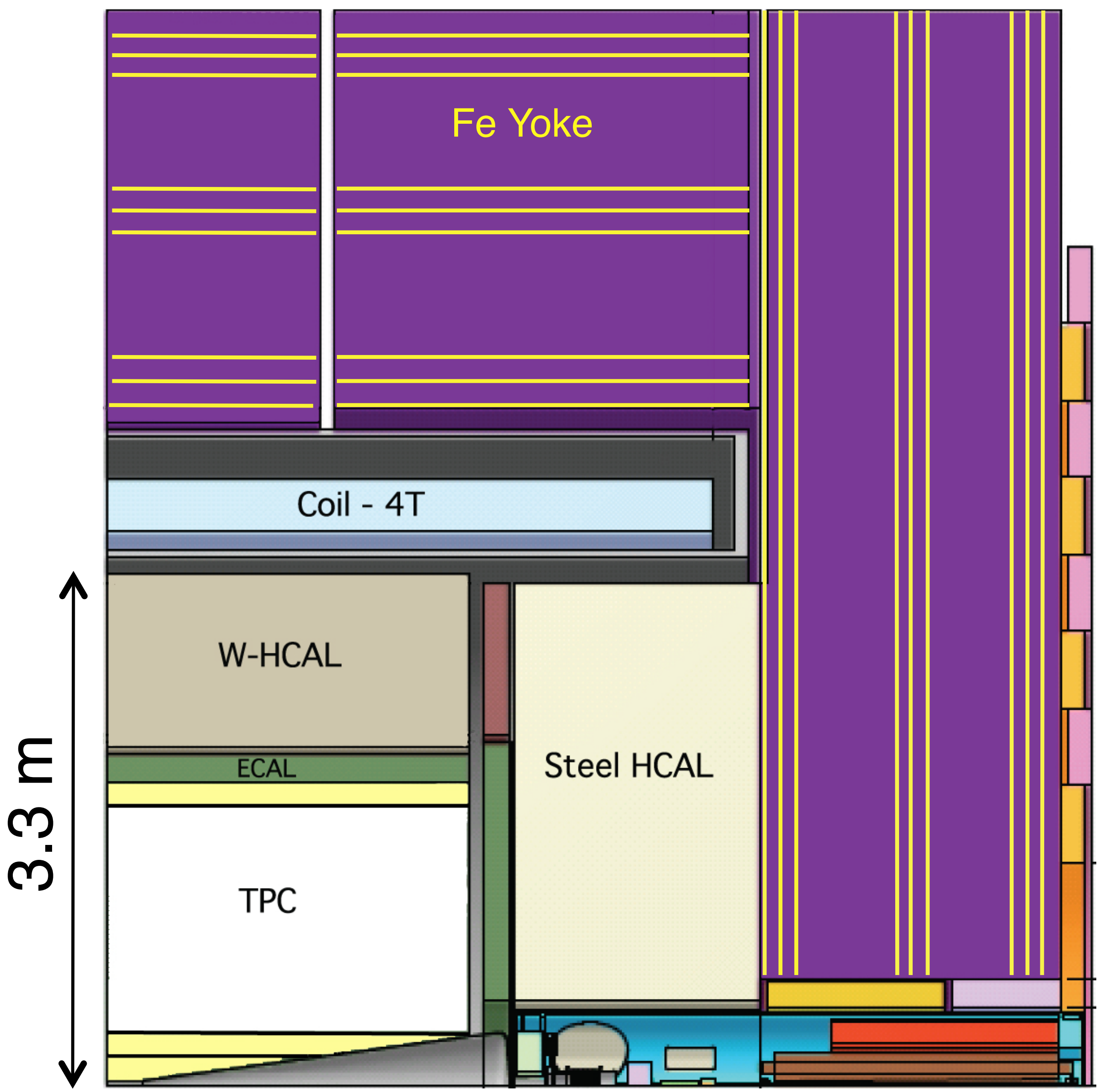
2030 Commissioning

From 2030, becoming ready for data-taking as the LHC programme reaches completion.

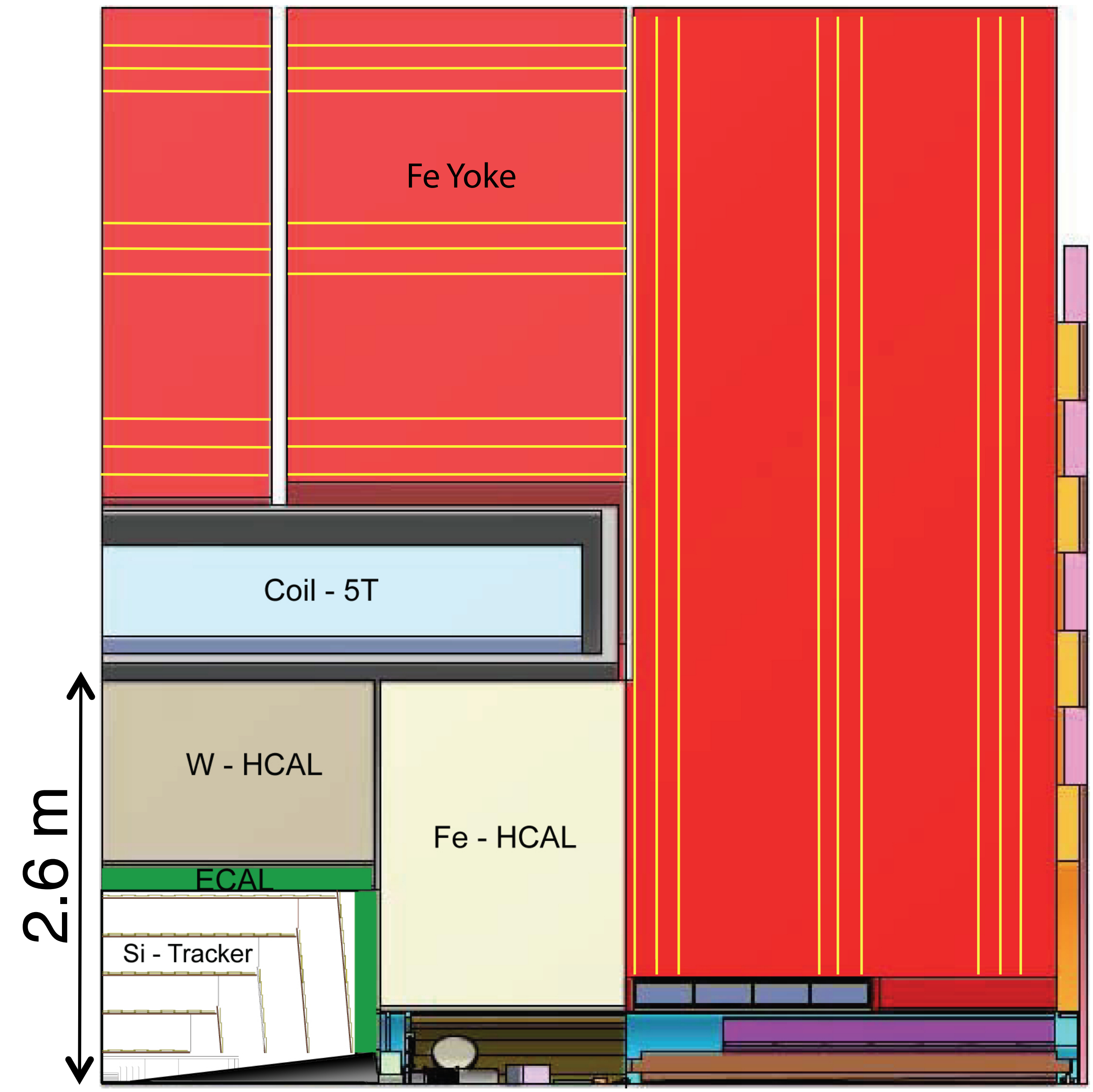
CLIC Detectors



CLIC Detectors



CLIC_ILD



CLIC_SiD

The Studies

- Full simulations with beam-induced ad physics background in CLIC_ILD and CLIC_SiD detector concepts
- Particle flow event reconstruction with PandoraPFA
- Events generated with WHIZARD
  Cross sections including ISR and luminosity spectrum:

	350 GeV	1.4 TeV	3 TeV
$\sigma(e^+e^- \to ZH)$	134 fb	9 fb	2 fb
$\sigma(e^+e^- \to H\nu_e\bar{\nu}_e)$	52 fb	279 fb	479 fb
$\sigma(e^+e^- \to He^+e^-)$	7 fb	28 fb	49 fb

- Additional gain by polarization: substantial for WW fusion

Polarization	Enhancement factor	
$P(e^-) : P(e^+)$	$e^+e^- \to ZH$	$e^+e^- \to H\nu_e\bar{\nu}_e$
unpolarized	1.00	1.00
$-80\% : 0\%$	1.18	1.80
$-80\% : +30\%$	1.48	2.34

Global Fits - Result Summary Tables

Model-independent:

Parameter	Measurement precision		
	350 GeV $500\ \mathrm{fb}^{-1}$	+ 1.4 TeV $+1.5\ \mathrm{ab}^{-1}$	+3.0 TeV $+2.0\ \mathrm{ab}^{-1}$
m_H	120 MeV	30 MeV	20 MeV
λ	–	24%	11%
Γ_H [%]	5.0	3.6	3.4
g_{HZZ} [%]	0.8	0.8	0.8
g_{HWW} [%]	1.8	0.9	0.9
g_{Hbb} [%]	2.0	1.0	0.9
g_{Hcc} [%]	3.2	1.4	1.1
g_{Htt} [%]	–	4.1	4.1
$g_{H\tau\tau}$ [%]	3.5	1.6	< 1.5
$g_{H\mu\mu}$ [%]	–	14	5.6
g_{Hgg} [%]	3.6	1.1	1.0
$g_{H\gamma\gamma}$ [%]	–	5.7	< 5.7

Model-dependent (9/7 parameters):

Parameter	Measurement precision		
	350 GeV $500\ \mathrm{fb}^{-1}$	+ 1.4 TeV $+1.5\ \mathrm{ab}^{-1}$	+3.0 TeV $+2.0\ \mathrm{ab}^{-1}$
$\Gamma_{H,\mathrm{model}}$ [%]	1.6	0.29	0.22
κ_{HZZ} [%]	0.43	0.31	0.23
κ_{HWW} [%]	1.5	0.15	0.11
κ_{Hbb} [%]	1.7	0.33	0.21
κ_{Hcc} [%]	3.1	1.1	0.75
κ_{Htt} [%]	–	4.0	4.0
$\kappa_{H\tau\tau}$ [%]	3.4	1.3	< 1.3
$\kappa_{H\mu\mu}$ [%]	–	14	5.5
κ_{Hgg} [%]	3.6	0.76	0.54
$\kappa_{H\gamma\gamma}$ [%]	–	5.6	< 5.6

Parameter	Measurement precision		
	350 GeV $500\ \mathrm{fb}^{-1}$	+ 1.4 TeV $+1.5\ \mathrm{ab}^{-1}$	+3.0 TeV $+2.0\ \mathrm{ab}^{-1}$
$\Gamma_{H,\mathrm{model}}$ [%]	1.6	0.29	0.22
κ_{HZZ} [%]	0.43	0.31	0.23
κ_{HWW} [%]	1.5	0.15	0.11
κ_{Hbb} [%]	1.7	0.33	0.21
κ_{Htt} [%]	3.1	1.0	0.74
$\kappa_{H\tau\tau}$ [%]	3.4	1.3	< 1.3
κ_{Hgg} [%]	3.6	0.76	0.56
$\kappa_{H\gamma\gamma}$ [%]	–	5.6	< 5.6