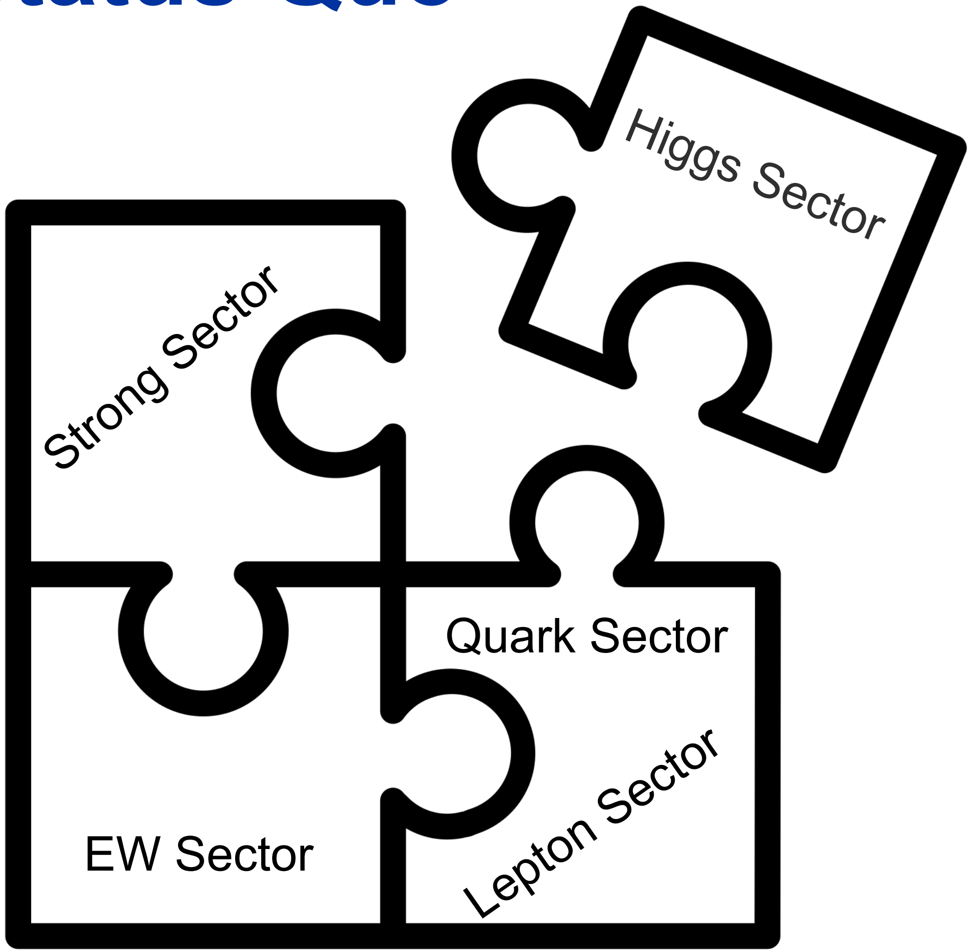
The integrated physics program of FCC-ee and FCC-hh

Lena Herrmann

24.06.2026

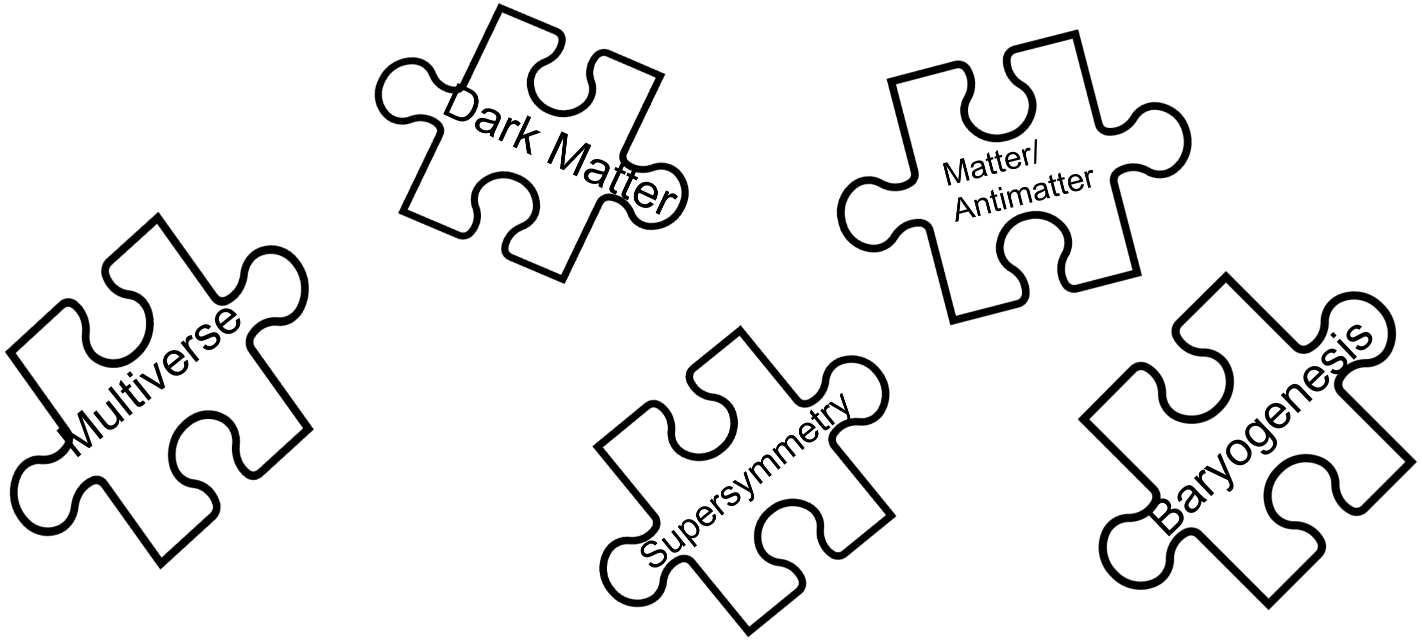
With thanks to Michele Selvaggi, Birgit Stapf, and the FCC Week 2026 speakers for slide inspiration

Status Quo



The Standard Model

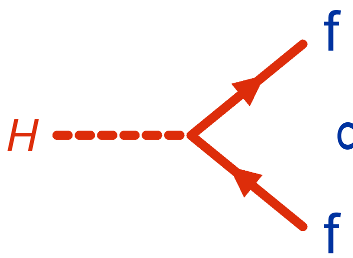
- Solid and proven theory
- Open questions that require physics beyond the Standard model



The Standard Model

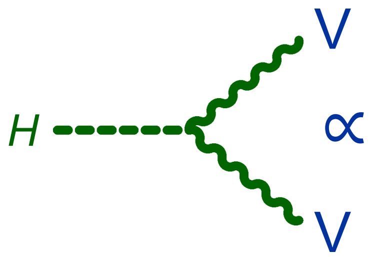
$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu}F^{\mu\nu} + i\bar{\chi}\not{D}\chi + \chi_i Y_{ij}\chi_j\phi + h.c. + |D_\mu\phi|^2 - V(\phi)$$

Yukawa Coupling



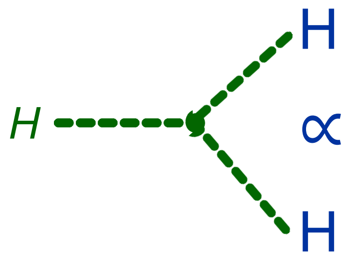
$\propto m_f$

Gauge Coupling



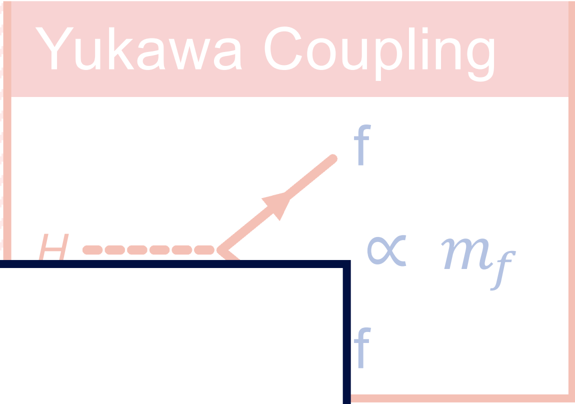
$\propto m_V^2$

Higgs Self-Coupling



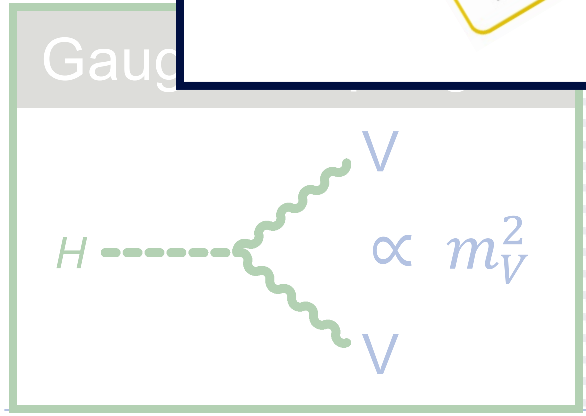
$\propto m_H^2$

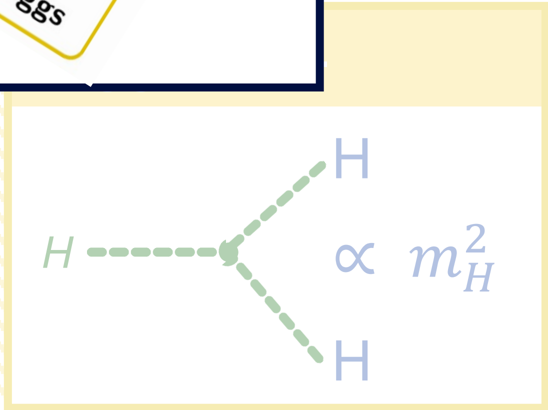
The Standard Model



- before Higgs discovery in 2012
  → theory driven research
- after Higgs discovery
  → experimentally driven research

→ Need for next-generation Higgs Factory

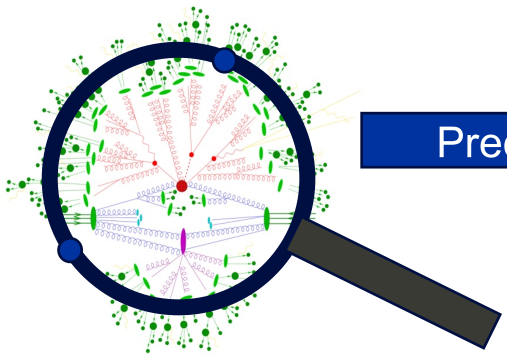




The Two-Fold Strategy

adapted from arxiv.1411.4085

HL-LHC

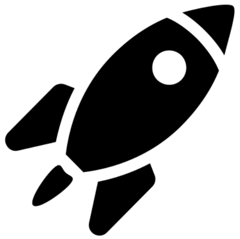


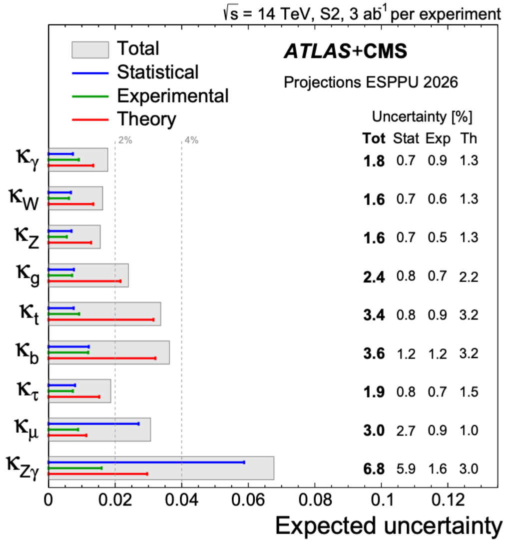
Precision Frontier

FCC-ee

Energy Frontier

FCC-hh

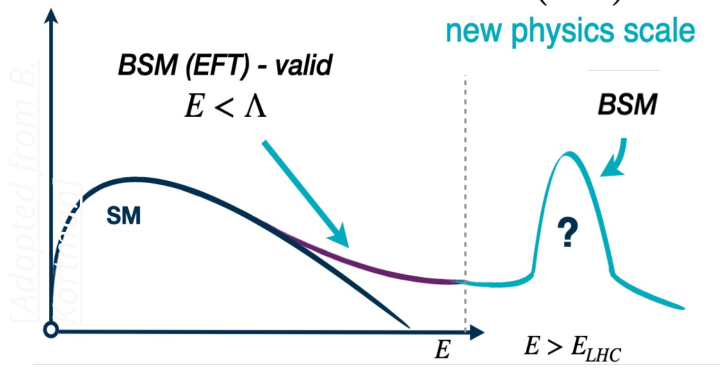




Coupling	HL-LHC	FCC-ee	[illegible]
κ_Z (%)	1.3*	0.10	
κ_W (%)	1.5*	[illegible]	
κ_b (%)	2.5*	[illegible]	
κ_g (%)	[illegible]	[illegible]	
κ_τ (%)	[illegible]	[illegible]	
[illegible]	[illegible]	0.87	
[illegible]	[illegible]	1.1	
[illegible]	[illegible]	4.3	
[illegible]	3.2*	3.1	
[illegible]	4.4*	3.3	
$\lvert\kappa_s\rvert$ (%)	–	$^{+29}_{-67}$	
Γ_H (%)	–	0.78	
$\mathcal{B}_{inv}$ (<, 95% CL)	1.9×10^{-2} *	5×10^{-4}	
$\mathcal{B}_{unt}$ (<, 95% CL)	4×10^{-2} *	6.8×10^{-3}	

Sub-percent precision on most couplings
→ New physics O TeV in tree-level

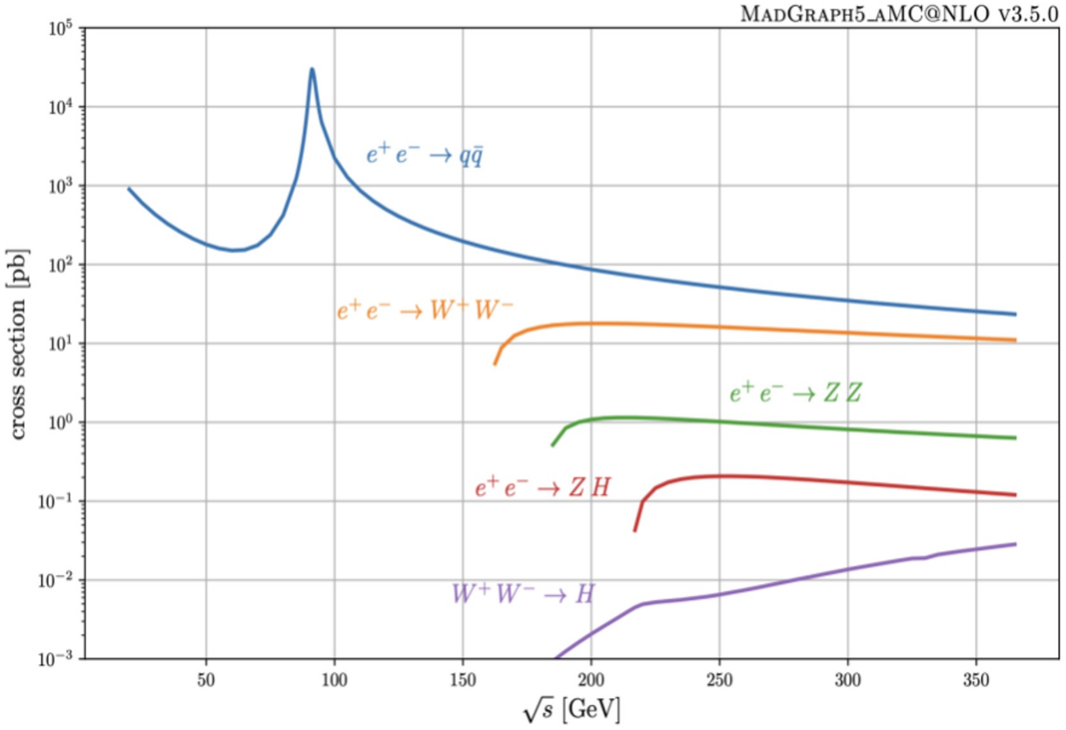
$\Lambda \sim O(TeV)$
new physics scale



Produce new physics on shell?

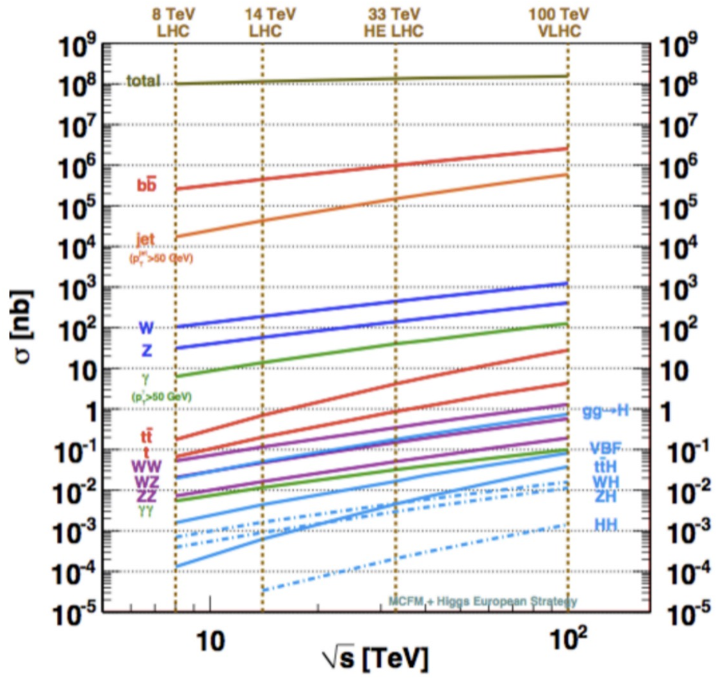
e^+e^- vs pp: The best of Two Worlds

Electron – Positron Machine



- Large signal rates
- Large S/B
- **Clean** experimental environment (no pile-up, low event rate, etc)

Hadron- Hadron Machine

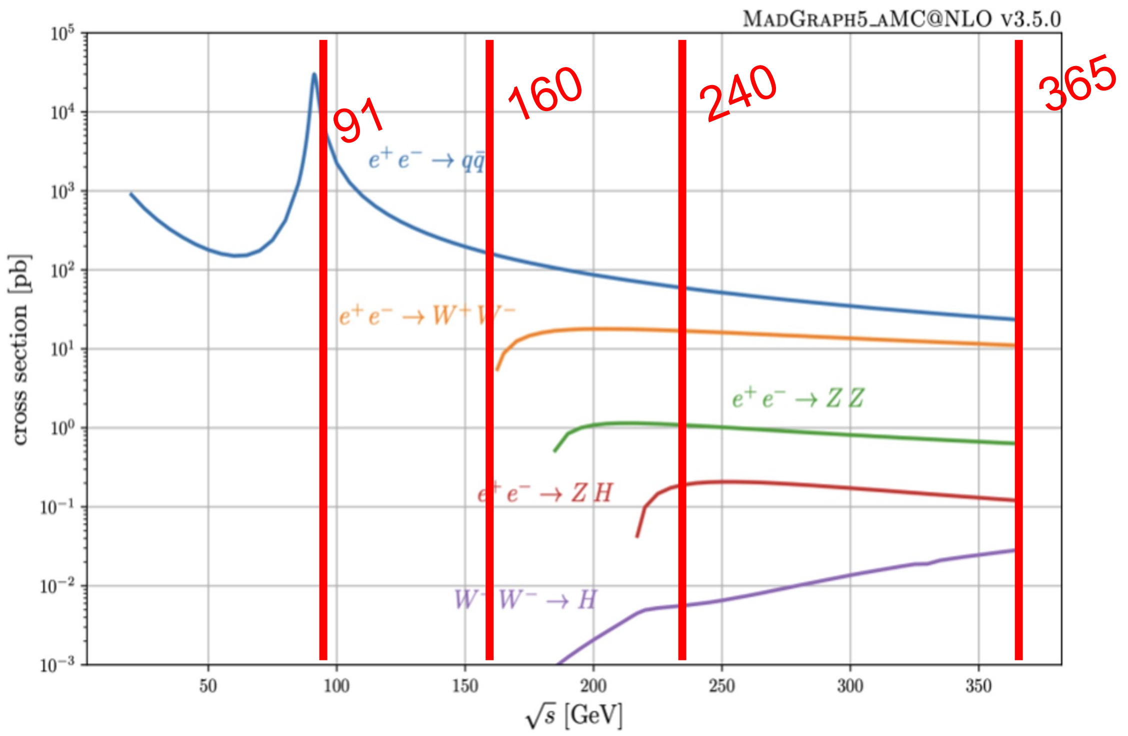


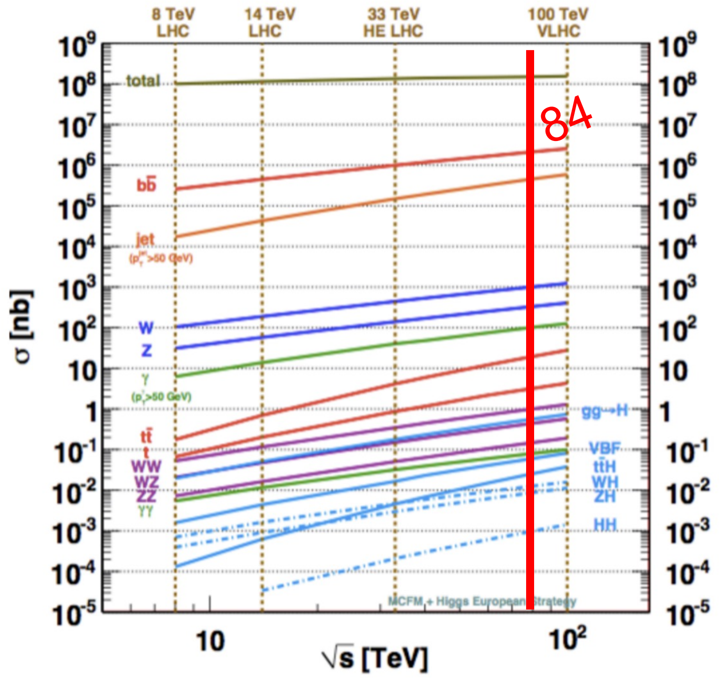
- **Large event rates** (required for rare decays)
- Boosted studies possible
- **Higher energies** accessible

e^+e^- vs pp: The best of Two Worlds

Electron – Positron Machine

Hadron- Hadron Machine



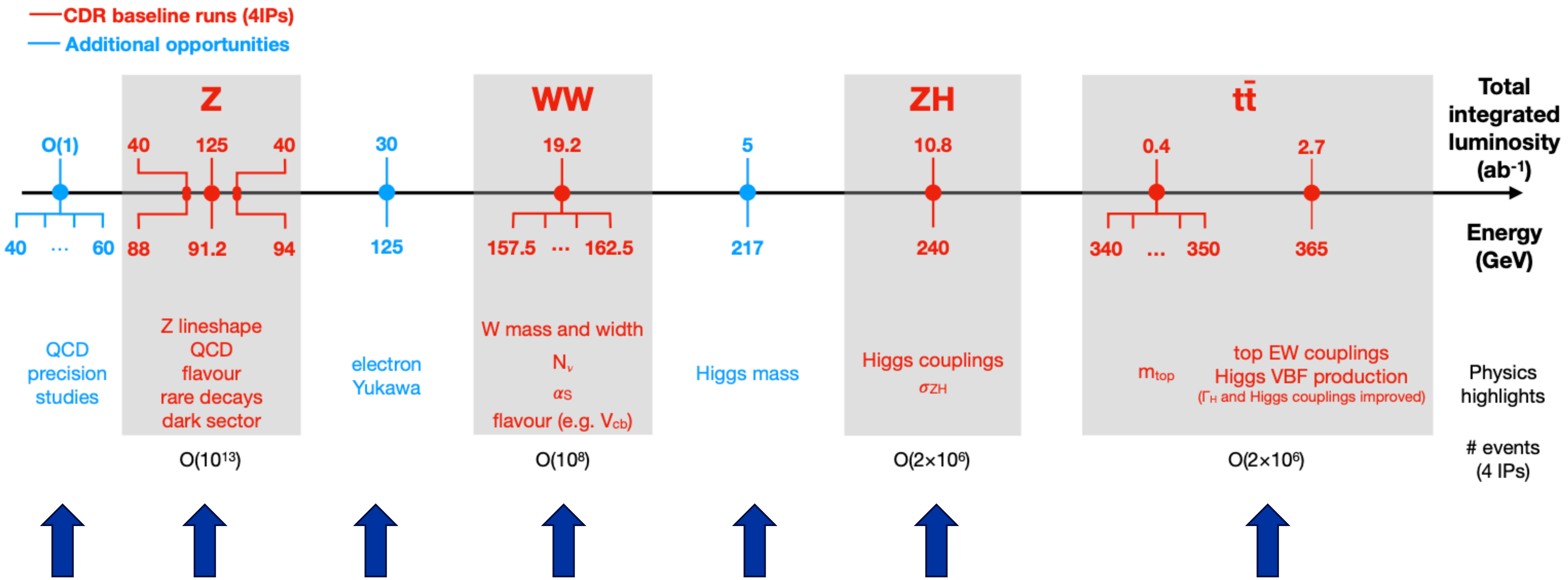


Clean precision baseline

High Statistics/ high energy Higgs frontier

The Physics Landscape at FCC

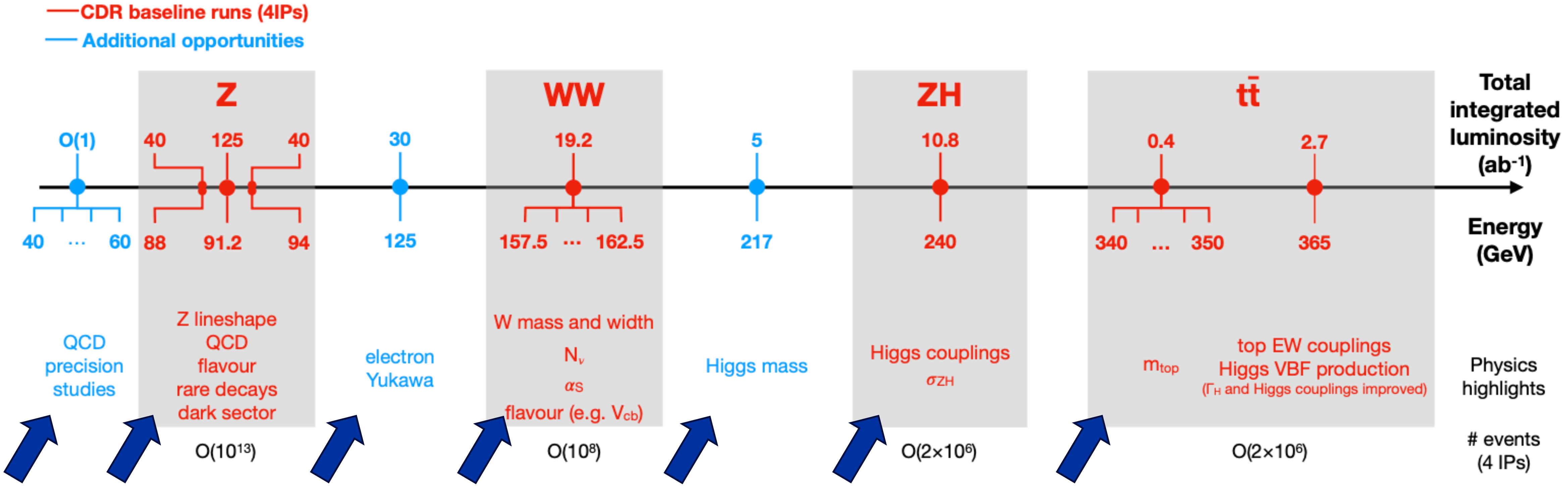
FCC-ee



Various $\sqrt{s}$ scenarios

The Physics Landscape at FCC

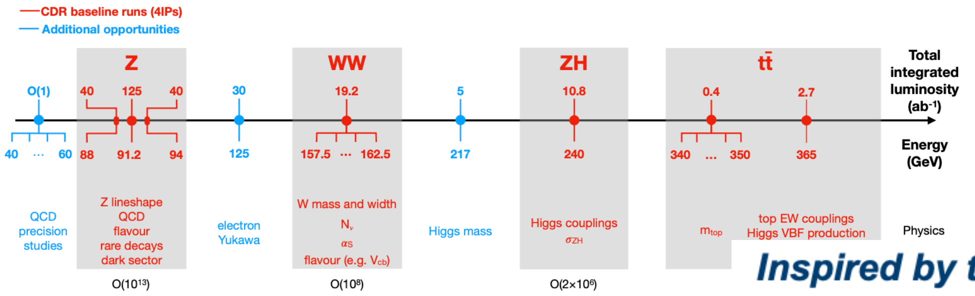
FCC-ee



Various $\sqrt{s}$ scenarios, with complementary physics program

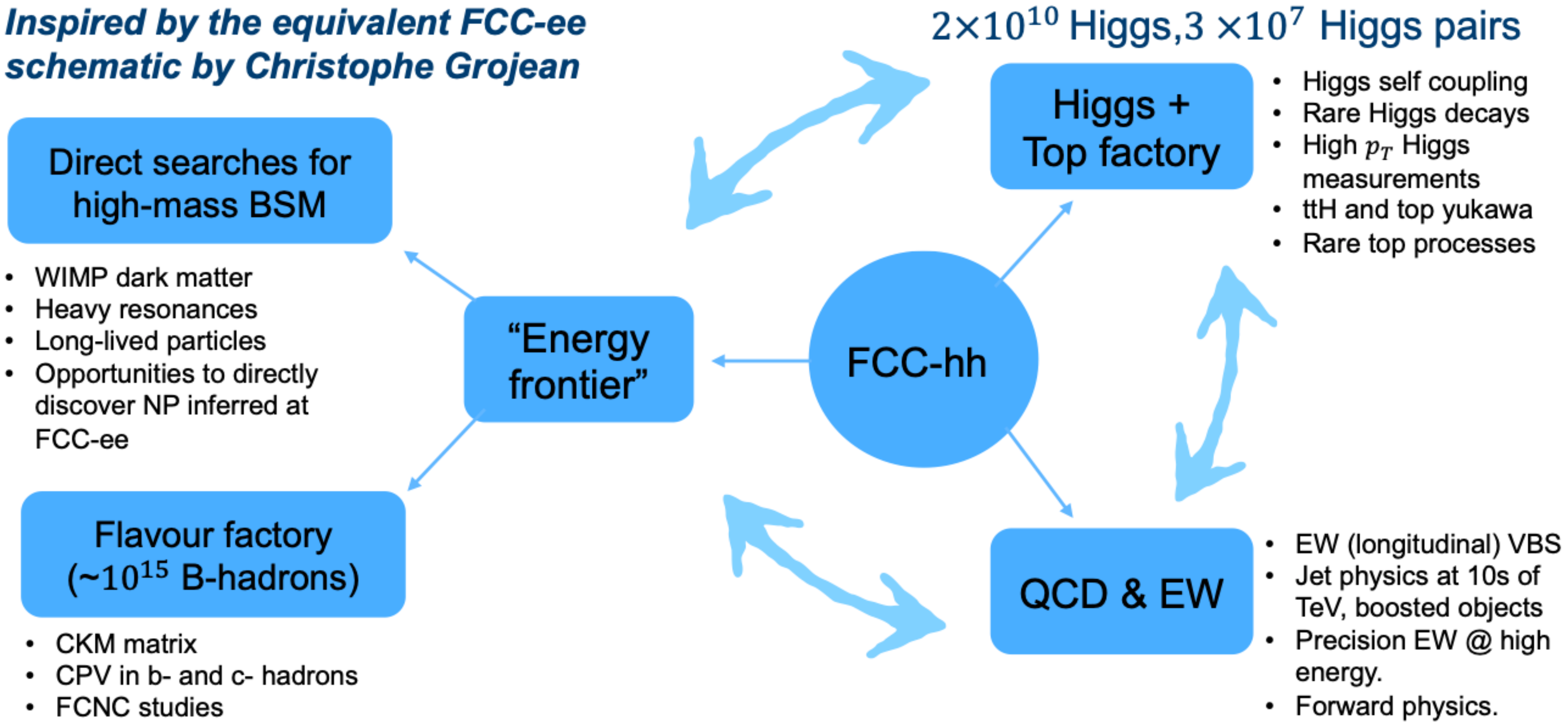
The Physics Landscape at FCC

FCC-hh



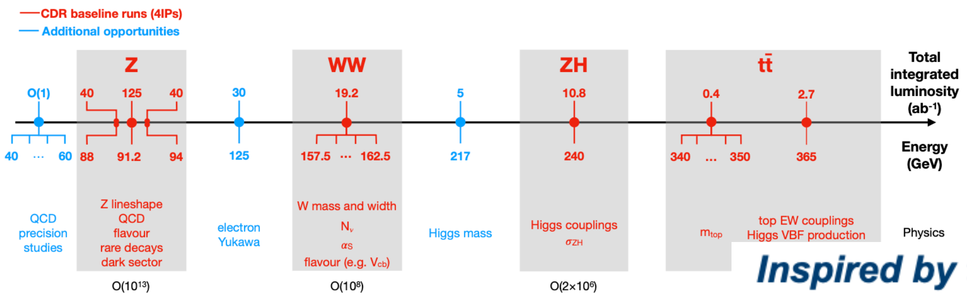
FCC-hh builds on previous findings/ refines them further and makes new observables accessible

Inspired by the equivalent FCC-ee schematic by Christophe Grojean



The Physics Landscape at FCC

FCC-hh

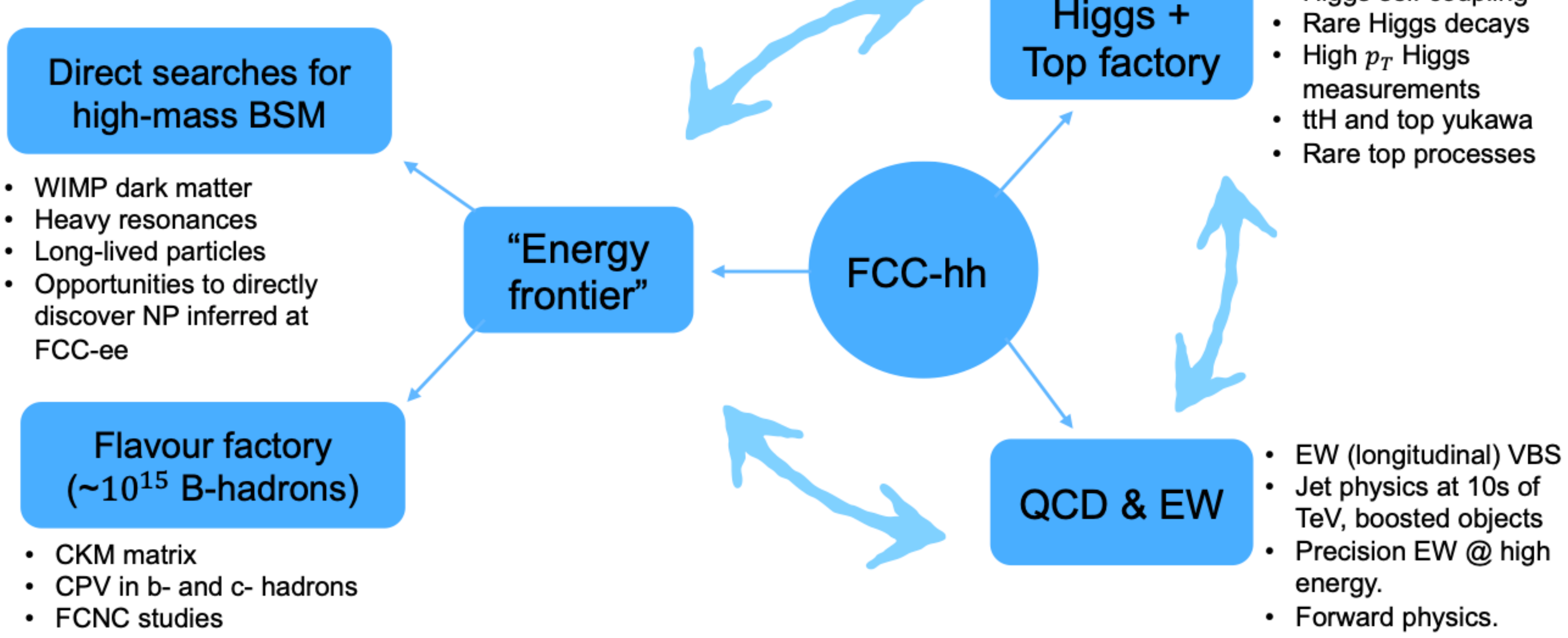


FCC-hh builds on previous findings/ refines them further and makes new observables accessible

Only a selection will be shown, with focus on Higgs program

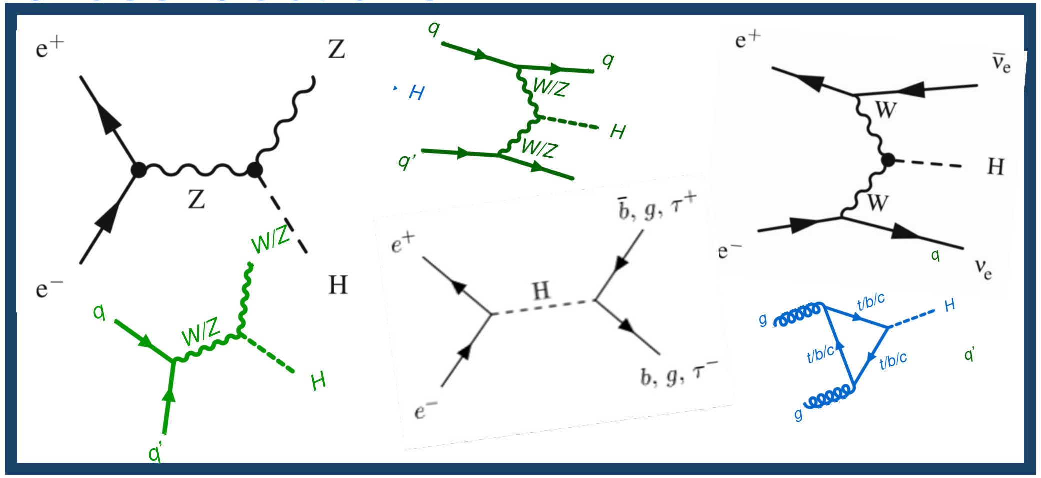
Inspired by the equivalent FCC-ee schematic by Christophe Grojean

2×10^{10} Higgs, 3×10^{7} Higgs pairs

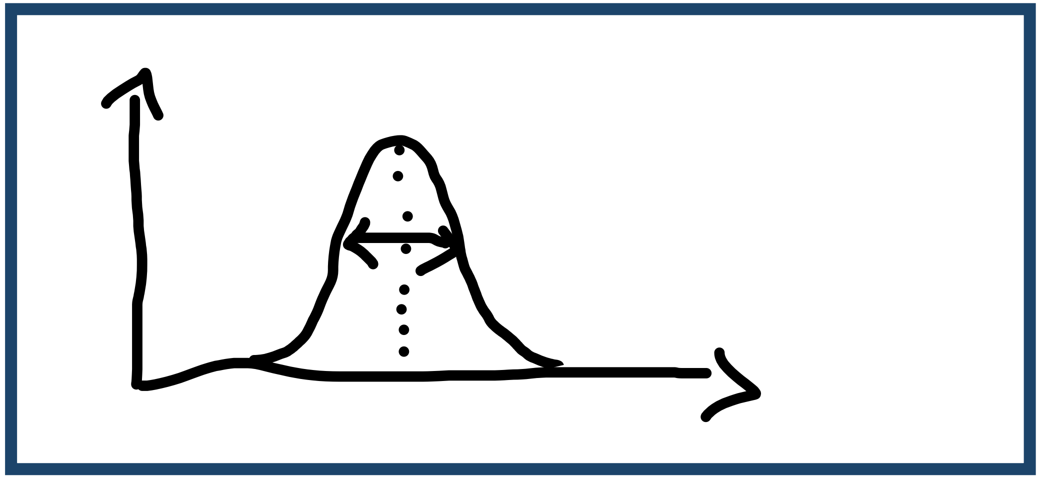


The Higgs Program

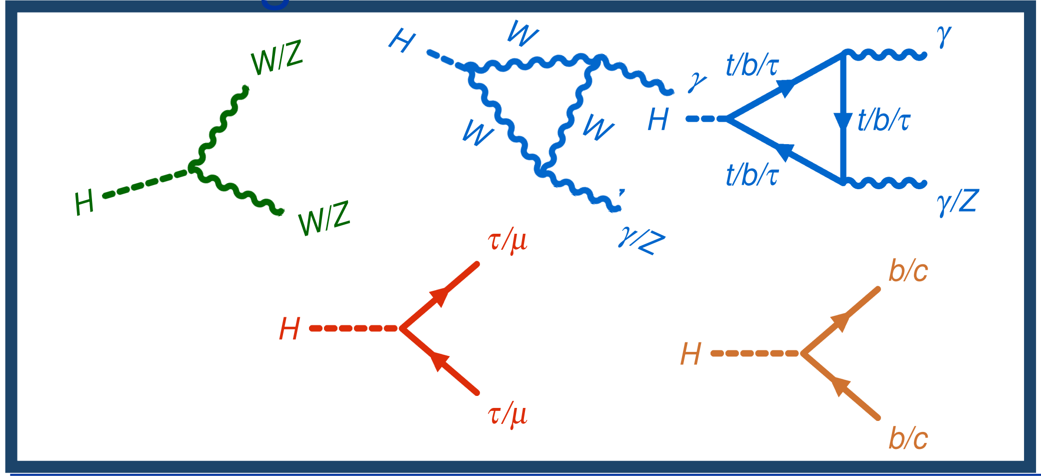
Cross-Sections



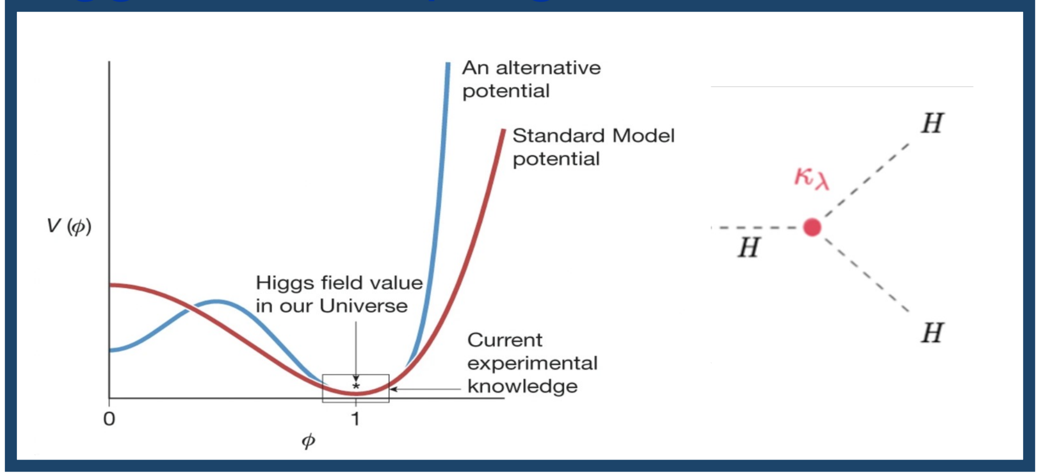
Higgs Mass & Width



Branching-Ratios

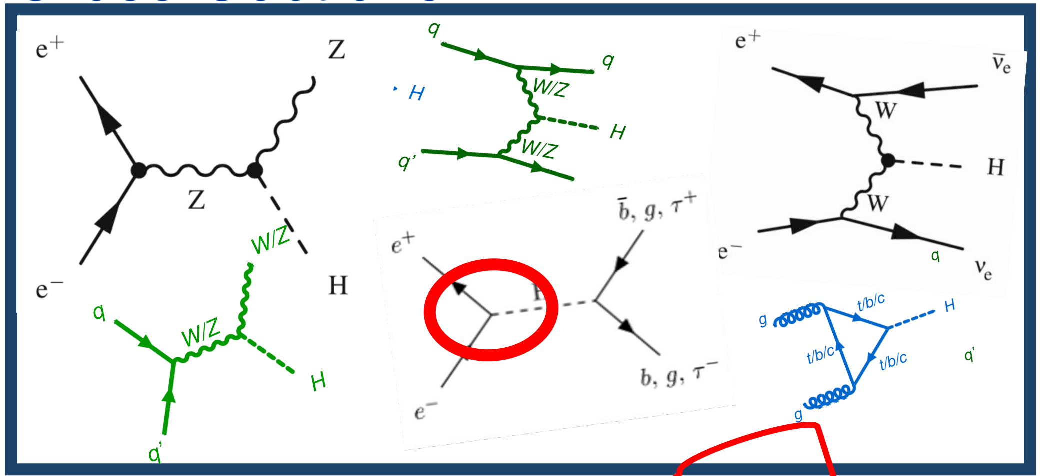


Higgs Self-coupling

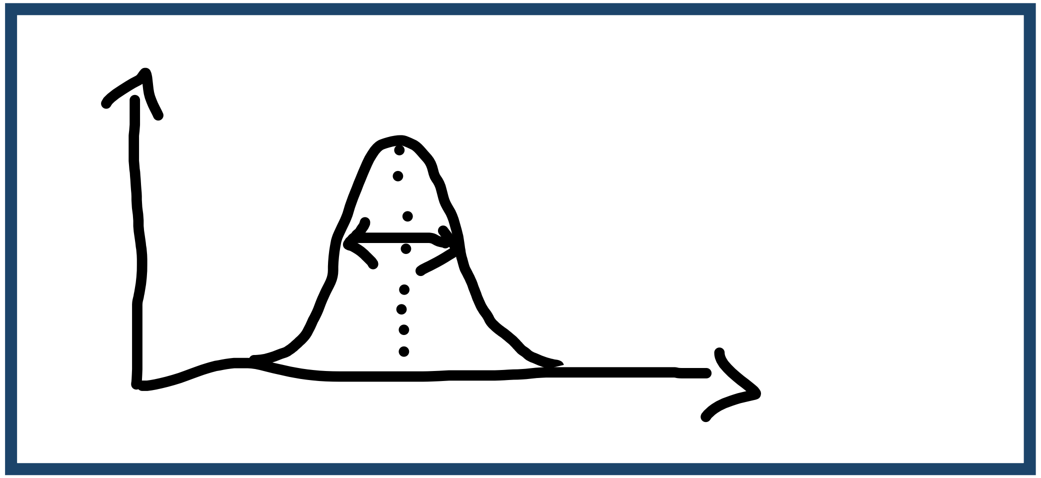


The Higgs Program

Cross-Sections

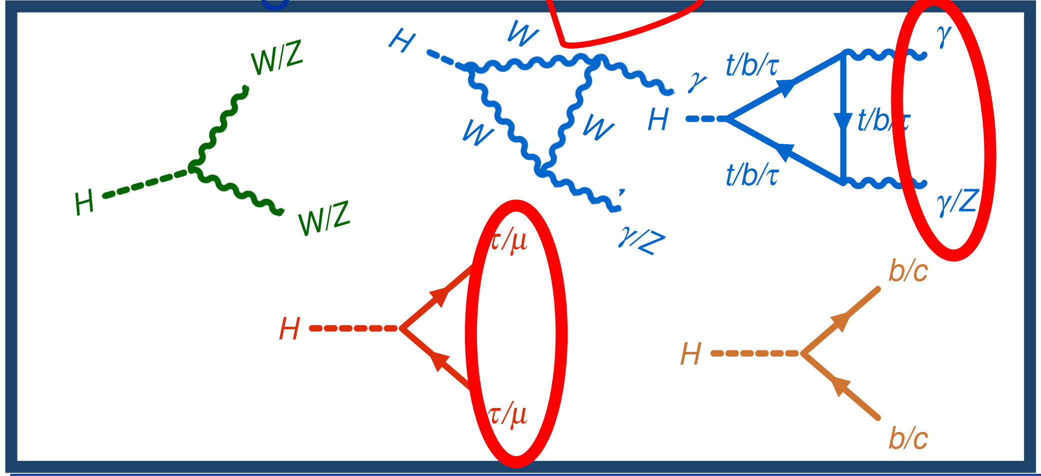


Higgs Mass & Width

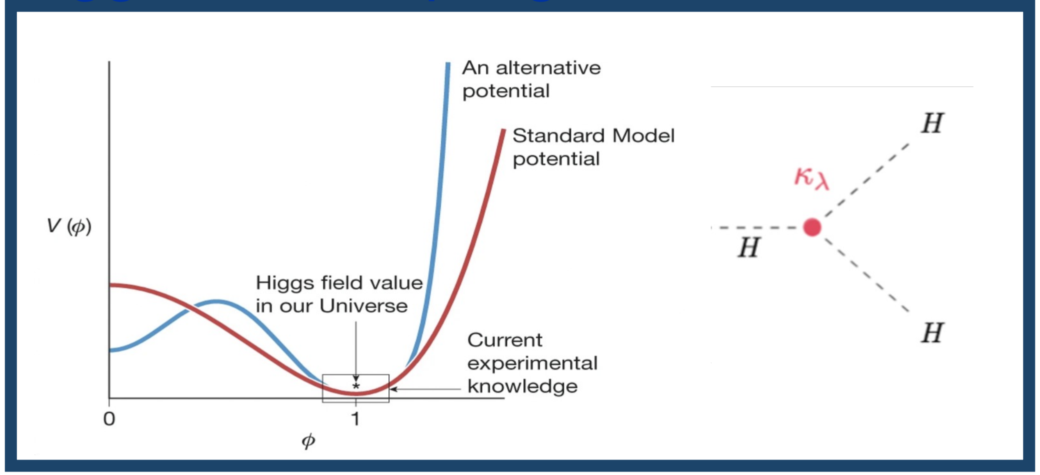


Branching-Ratios

RARE!

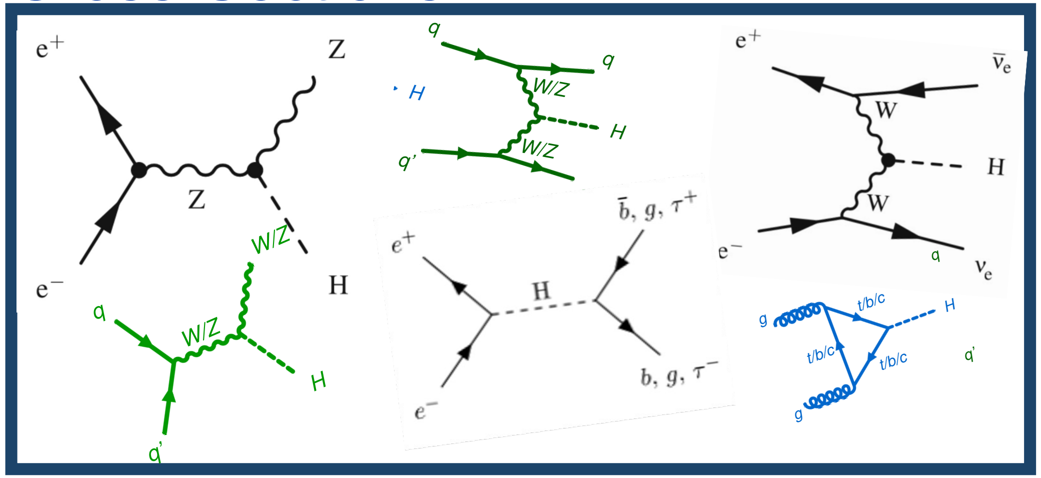


Higgs Self-coupling

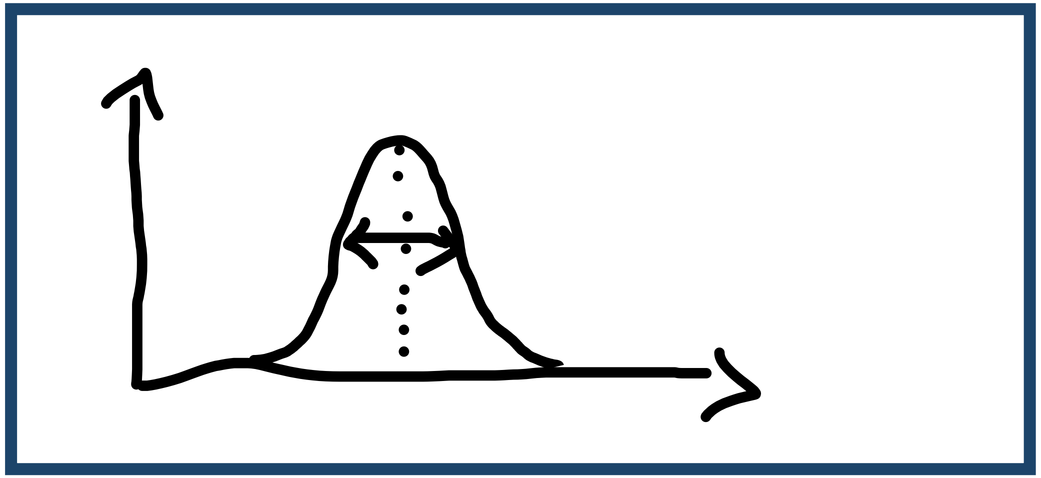


The Higgs Program at unprecedented Precision/Energy

Cross-Sections



Higgs Mass & Width



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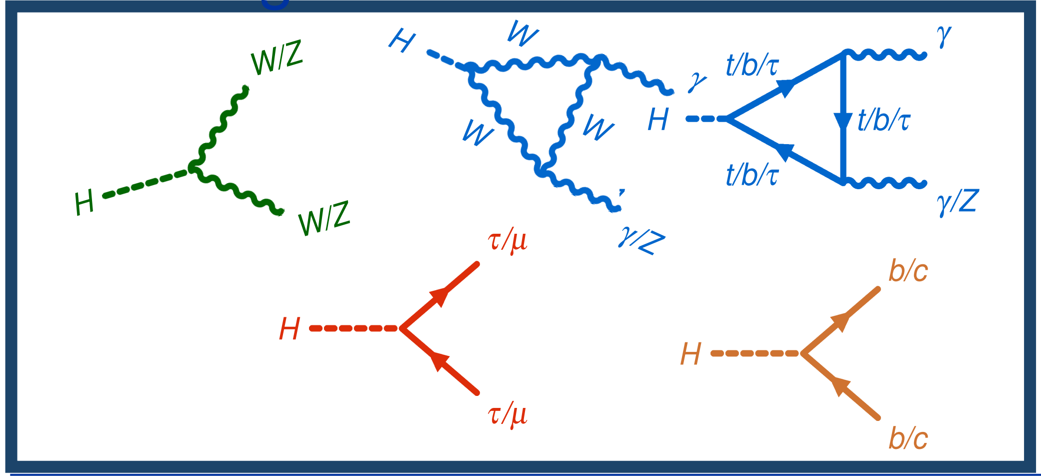

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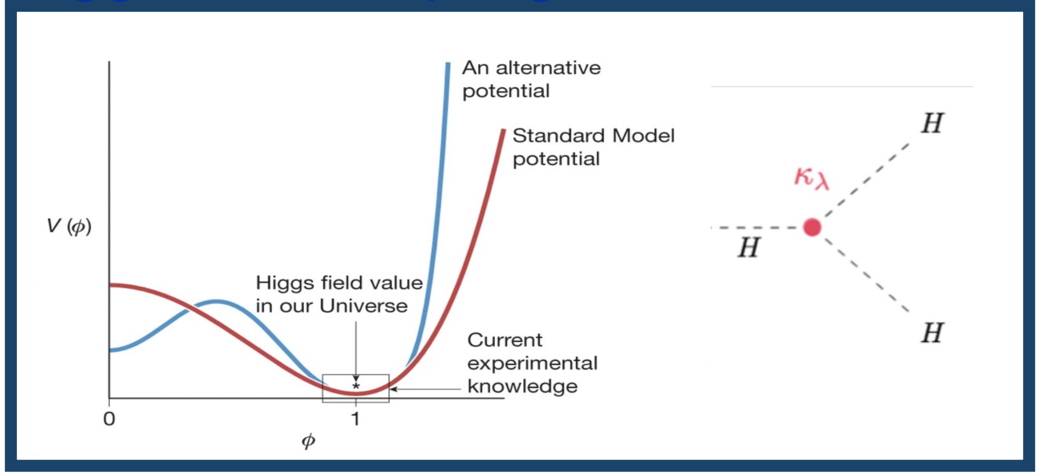
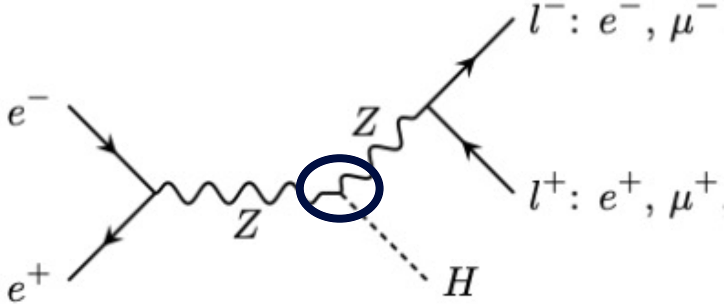


Absolute Normalization for Higgs Couplings and Width

FCC-ee

Selling point for e^+e^- machine



1. Determine inclusive cross-section $\sigma(ZH)$ via recoil mass method: $\sigma(ZH) \propto g_{HZZ}^2$

2. Investigate $H \to ZZ$ decay to extract Higgs width $\Gamma(H)$

$$\sigma(ZH)BR(H \to ZZ) \propto g_{HZZ}^2 \text{ x } \frac{\Gamma(H \to ZZ)}{\Gamma(H)} = \frac{g_{HZZ}^4}{\Gamma(H)}$$

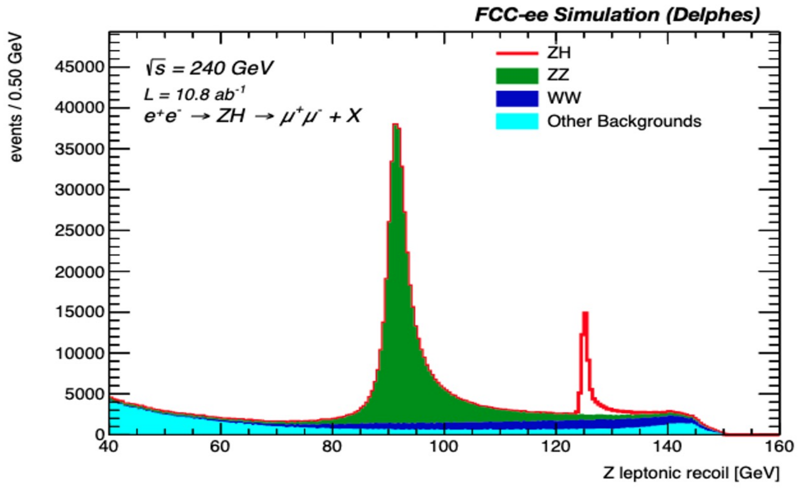
3. Extract absolute couplings of channel H → XX:

$$\sigma(ZH)BR(H \to XX) \propto g_{HZZ}^2 \text{ x } \frac{\Gamma(H \to XX)}{\Gamma(H)} = \frac{g_{HZZ}^4 g_{HXX}^2}{\Gamma(H)}$$

Recoil Mass Method

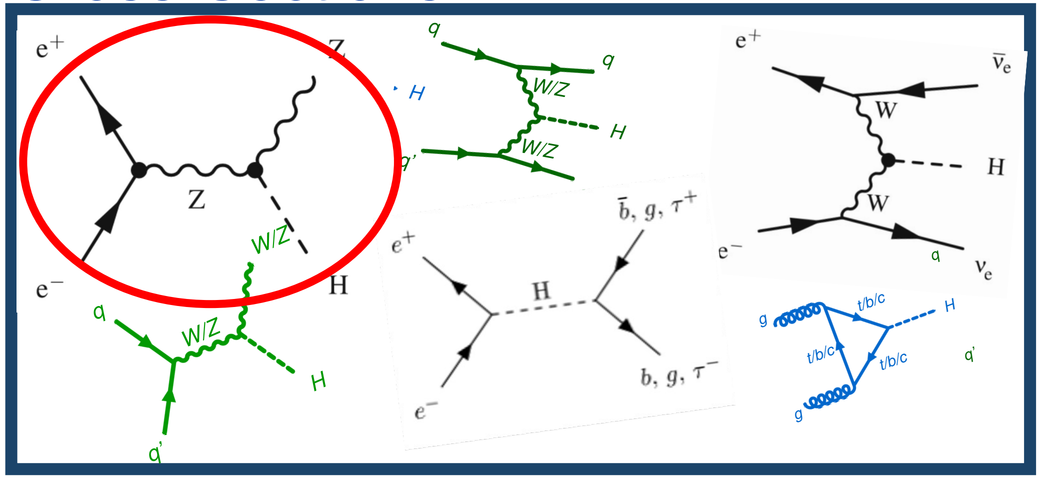
- → Initial state well known
- → Inclusive, model-independent Higgs analysis based on Z-boson kinematics
- → Higgs selection without looking at it's decay products

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

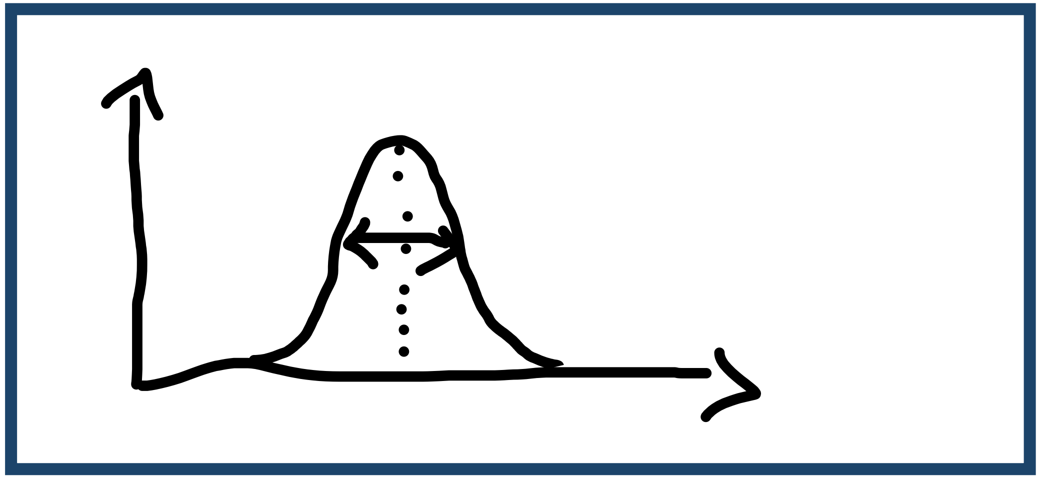


The Higgs Program at unprecedented Precision/Energy

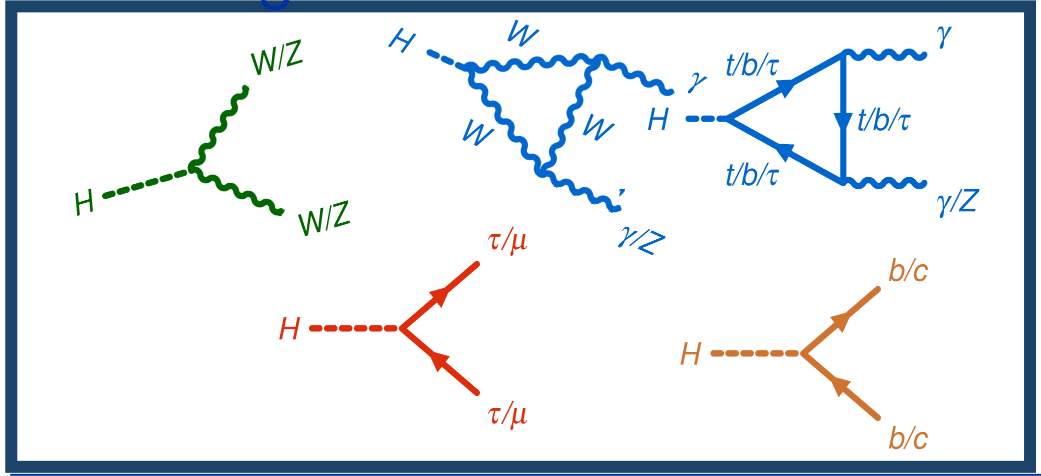
Cross-Sections



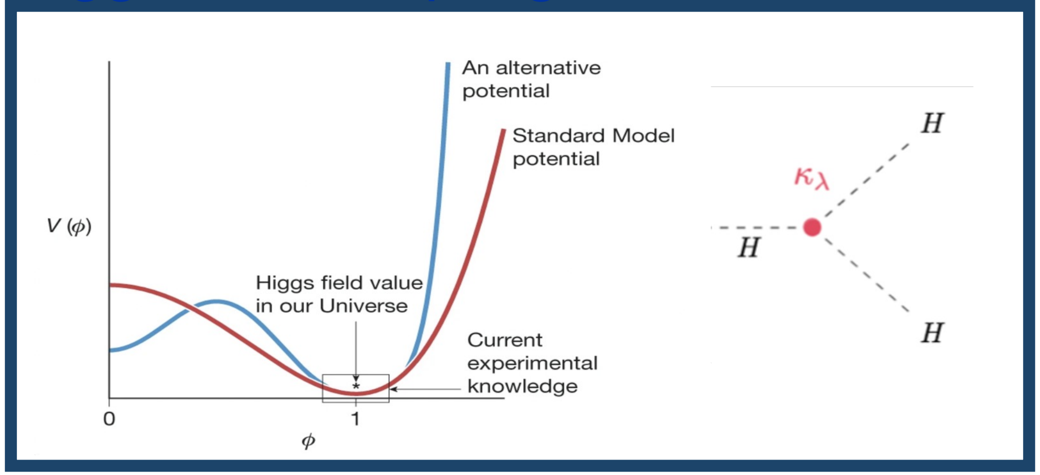
Higgs Mass & Width



Branching-Ratios



Higgs Self-coupling

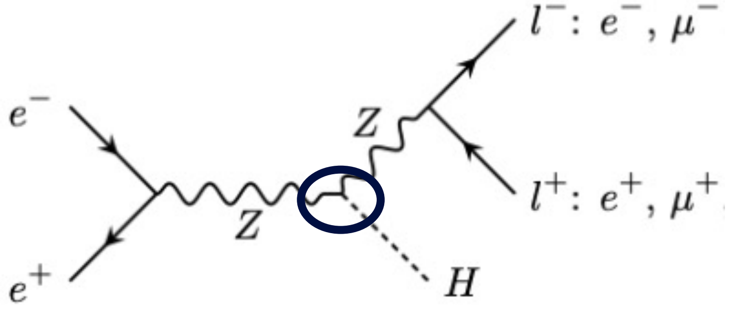


Inclusive ZH Cross-Section

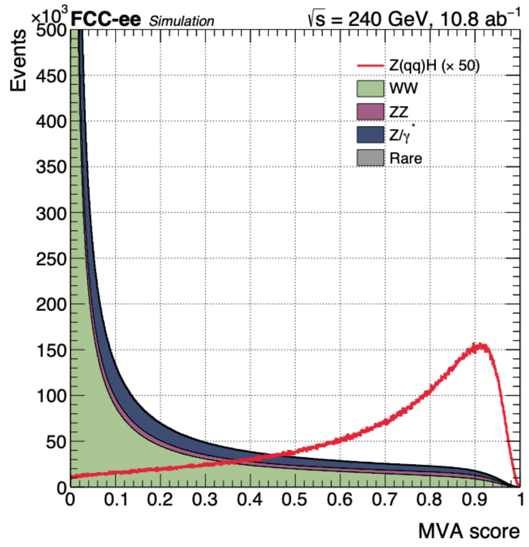
Reference
[arxiv:2512.21290]

FCC-ee

Flagship analysis for e^+e^- machine



Multivariate techniques to improve sensitivity



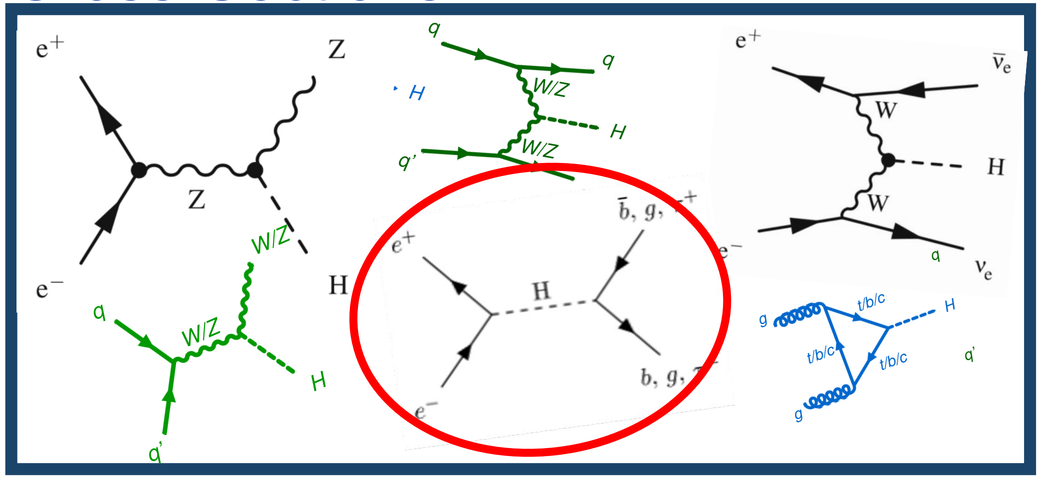
Extract g_{HZZ}^2 via recoil mass method
→ Normalization for FCC-ee but also FCC-hh coupling measurements

- leptonic $Z \rightarrow ll$ $(l = e, \mu)$, as well as hadronic $Z \rightarrow qq$ analysis at 240 and 365 GeV
- Event selection based on Z kinematics
- Likelihood fit on recoil mass distribution
- Model independence shown by statistical tests
  → alter Higgs BR and extract $\sigma(ZH)$

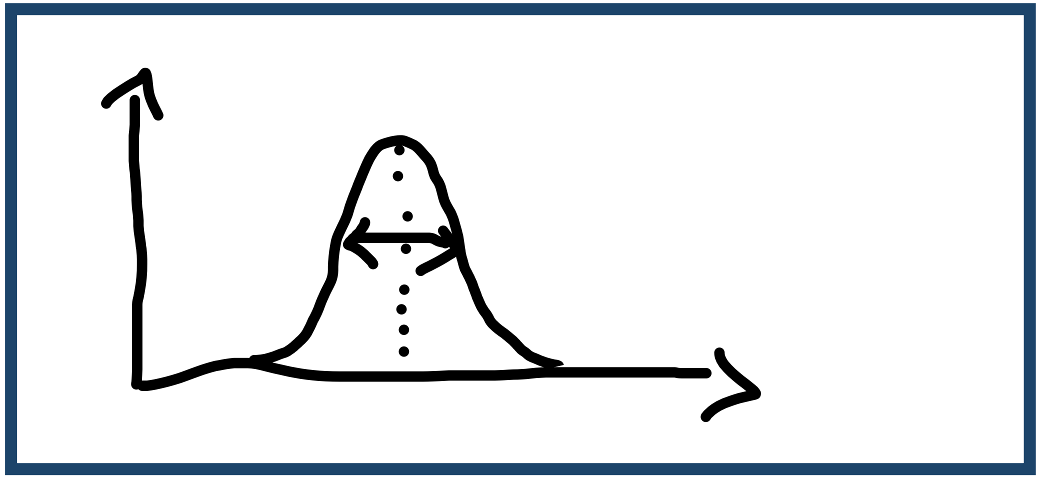
Final state	$\sqrt{s} = 240\,\mathrm{GeV}$	$\sqrt{s} = 365\,\mathrm{GeV}$
Leptonic channels		
$Z(e^+e^-)H$	±0.81	±1.91
$Z(\mu^+\mu^-)H$	±0.68	±1.79
$Z(\ell^+\ell^-)H$	±0.52	±1.32
Hadronic channel		
$Z(q\bar{q})H$	±0.38	±0.56
Combined result		
ZH	±0.31	±0.52

The Higgs Program at unprecedented Precision/Energy

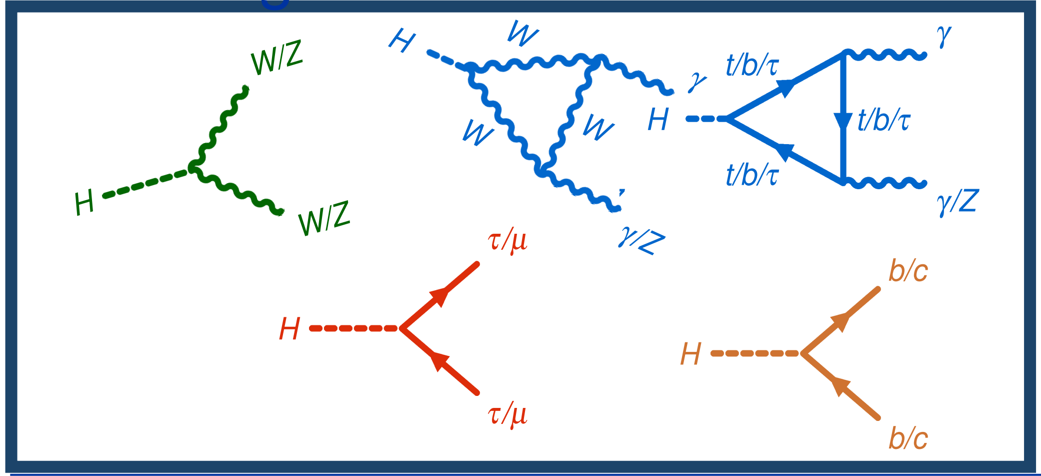
Cross-Sections



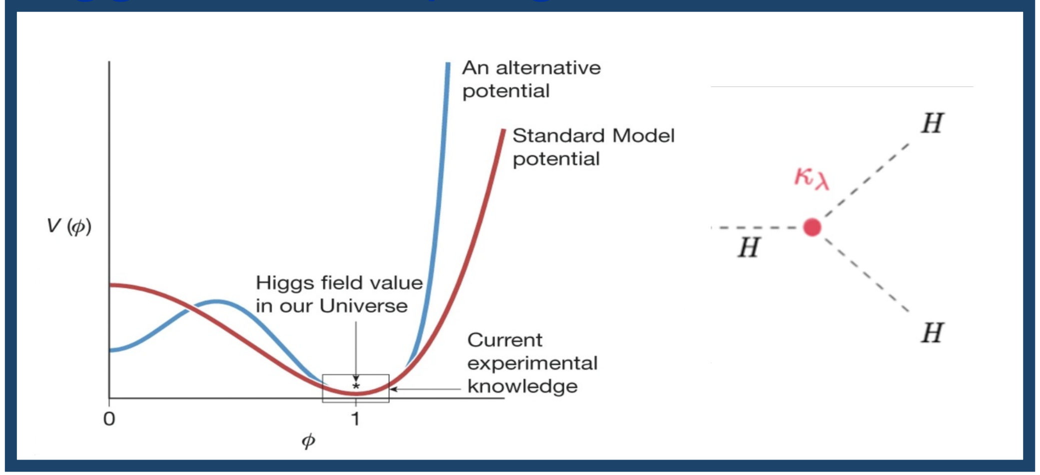
Higgs Mass & Width



Branching-Ratios

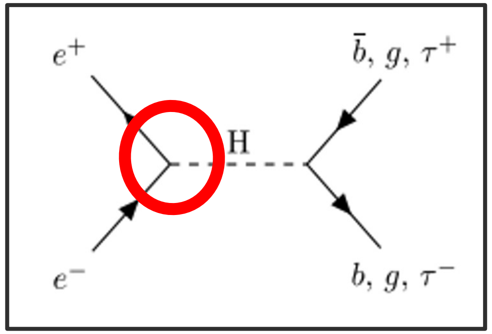


Higgs Self-coupling



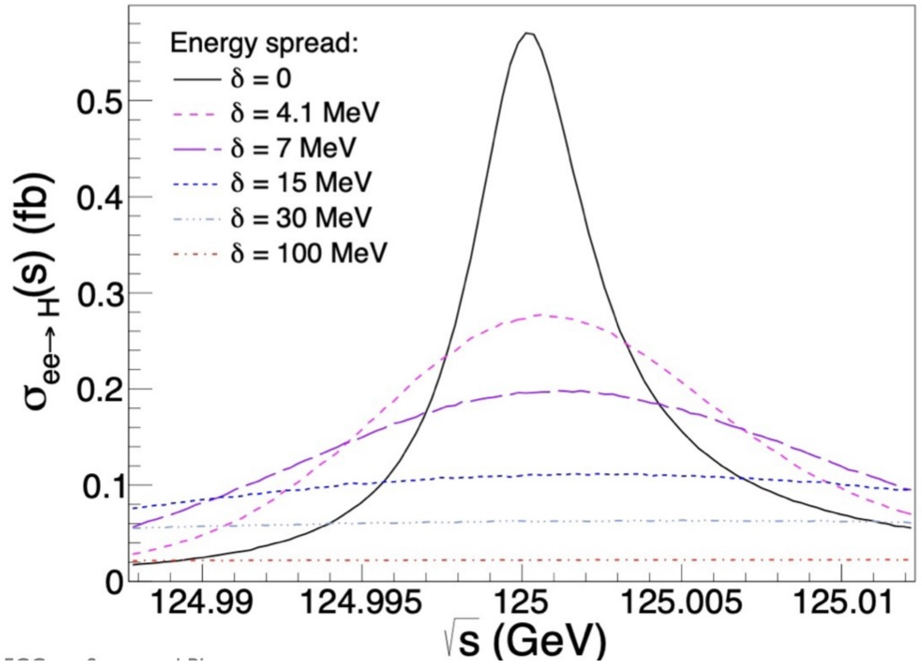
Electron Yukawa

Reference
[arxiv:2107.02686], Arxiv:2604.24152



FCC-ee

First generation Yukawa Study!



dedicated run for resonant s-channel production needed

Strong cross-section dependence on $\sqrt{s}$
→δm_H and BES need to be reduced to level of Higgs width: 4MeV
→BES can be reduced with monochromatisation (current reach 20MeV)

NEW

Leading sensitive channel: $H \rightarrow W$W*→ $l\nu jj$
→ 2.0σ (1Yx1exp)
→ 4Yx4exp ~ 8 σ

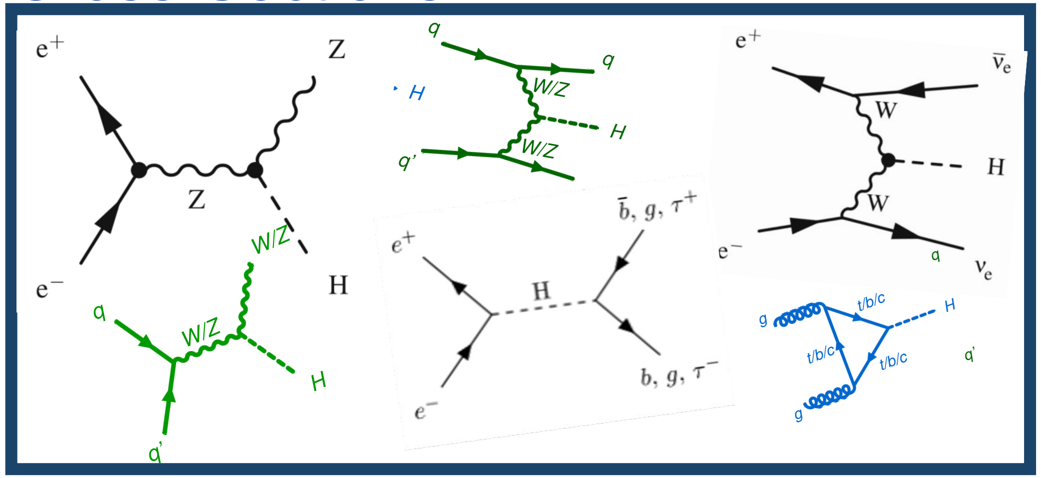
Discovery Potential

Promissing channel: $H \rightarrow gg$:
- High branching ratio
- No background contamination from Z→gg (forbidden), but from mistagged Z→qq

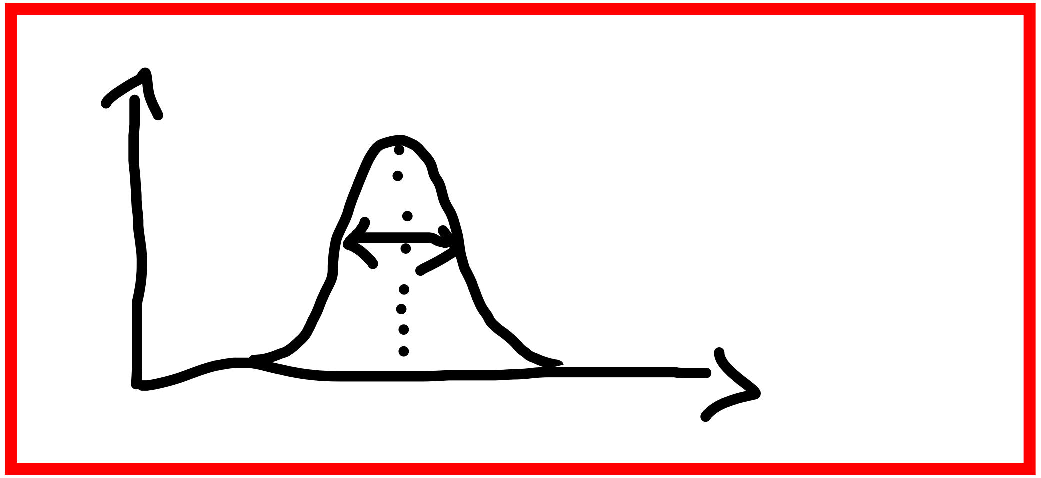
Open Tasks!
- Gluon tagger performance
- Beam monochromatisation

The Higgs Program at unprecedented Precision/Energy

Cross-Sections



Higgs Mass & Width



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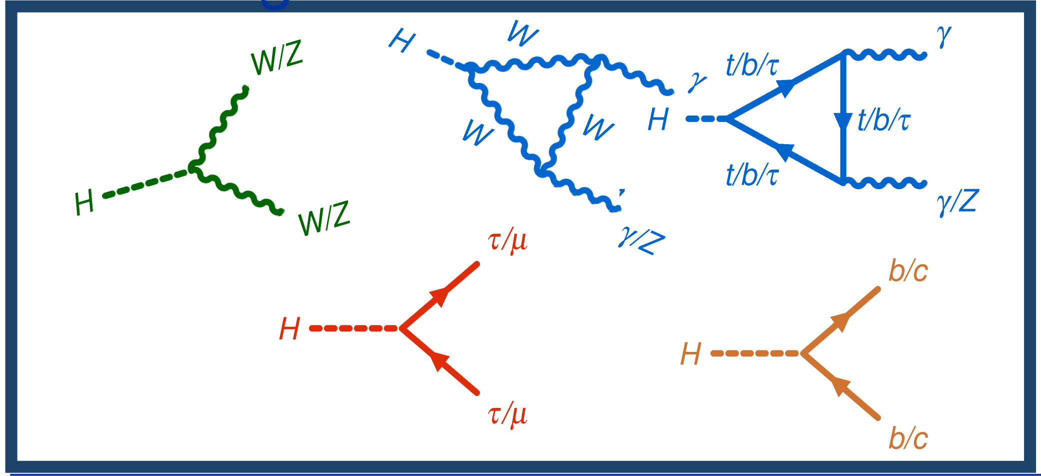
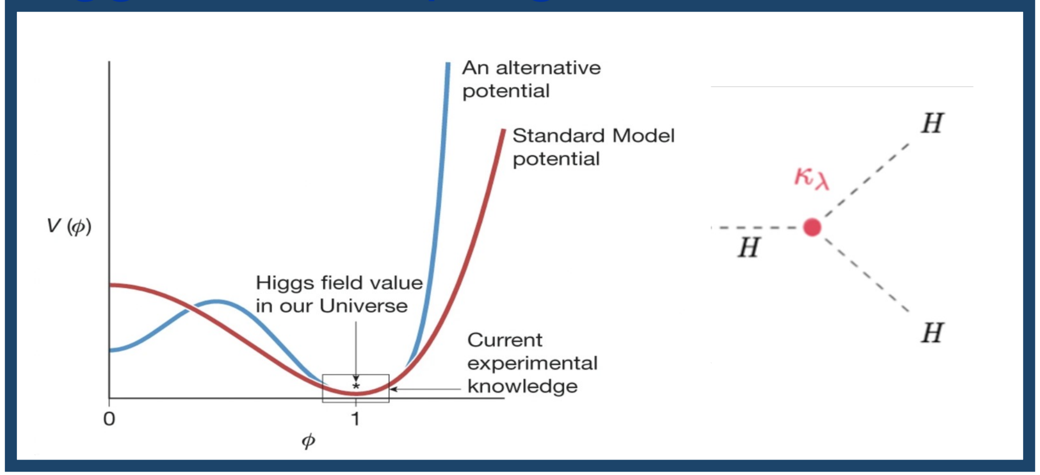
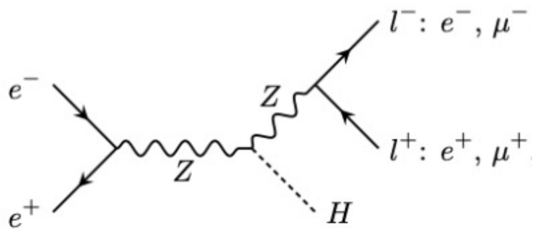


Higgs Self-coupling



Higgs Mass

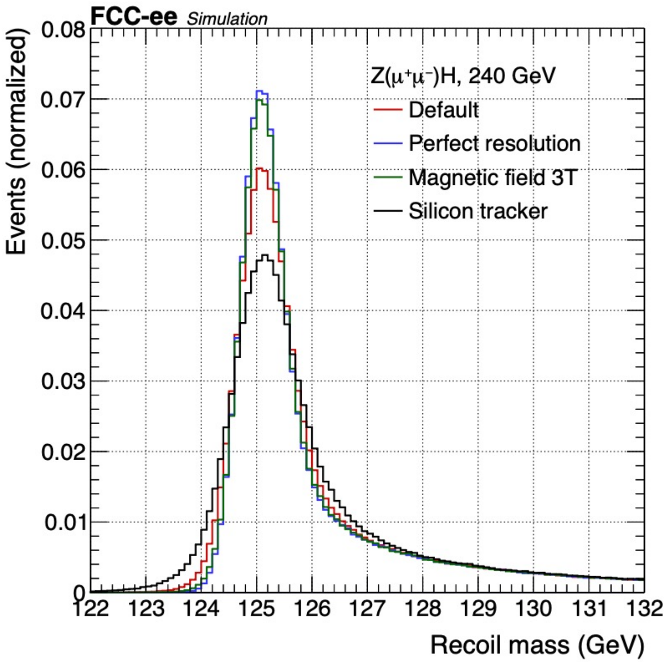


Reference
[DOI: 10.17181/jfb44-s0d81]

FCC-ee

m_H parametric uncertainty in other quantities (BR, σ..)

- Statistics dominated measurement
- Leading sys. uncertainty: beam energy scale calibration



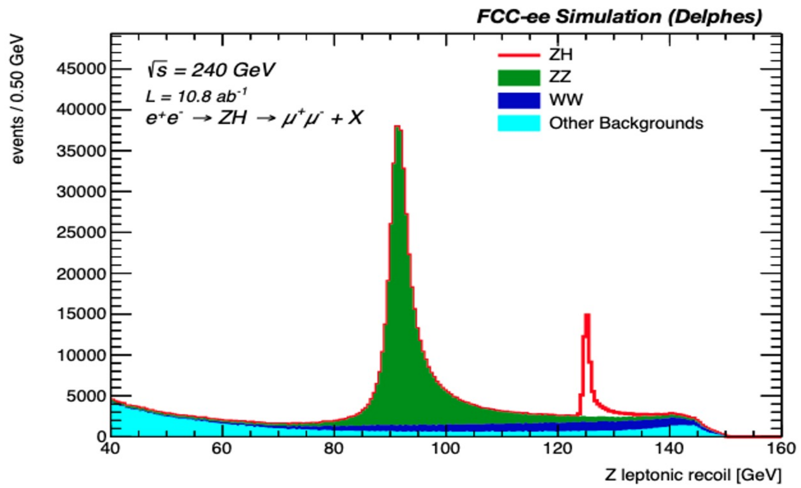
- Simultaneous likelihood-fit in ee and $\mu\mu$ channel at 240 and 365 GeV
- Z($\mu\mu$) dominates sensitivity due to superior momentum resolution

$$\delta(m_H) = 3.97\ MeV$$

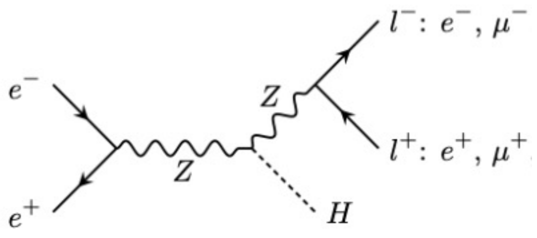
Recoil Mass Method

→ Initial state well known
→ Inclusive, model-independent Higgs analysis based on Z-boson kinematics
→ Higgs selection without looking at it's decay products

$$m^2_{recoil} = s + m_Z^2 - 2\sqrt{s}E_Z$$



Higgs Mass



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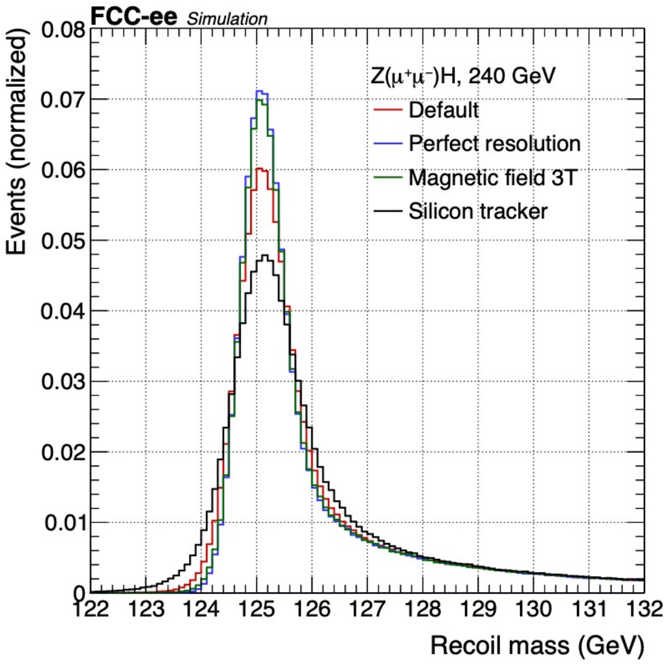
- Statistics dominated measurement
- Leading sys. uncertainty: beam energy scale calibration



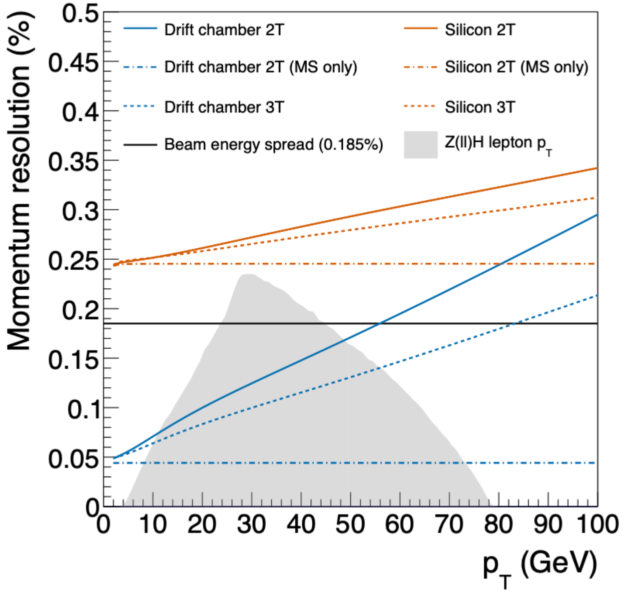
- Simultaneous likelihood-fit in ee and $\mu\mu$ channel at 240 and 365 GeV
- Z($\mu\mu$) dominates sensitivity due to superior momentum resolution

$$\delta(m_H) = 3.97\ MeV$$

Limitations & Open Tasks

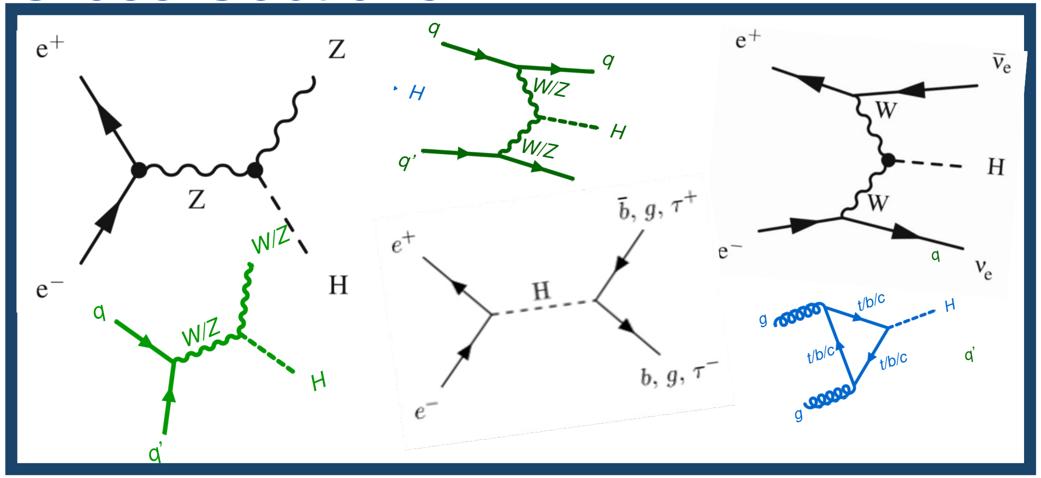
- Transparent tracker is crucial

→ Tracker limits sensitivity if $\frac{\sigma_{pt}}{pt} > BES$

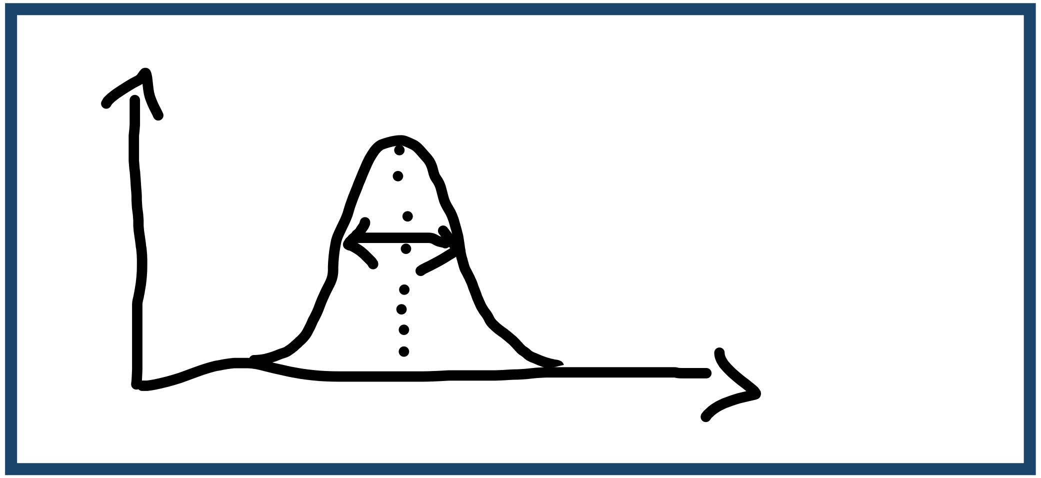


The Higgs Program at unprecedented Precision/Energy

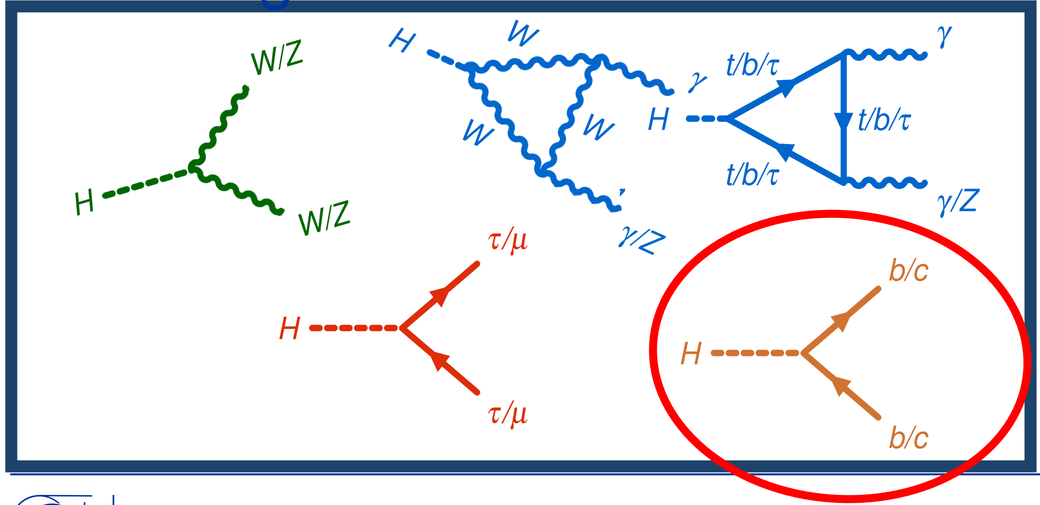
Cross-Sections



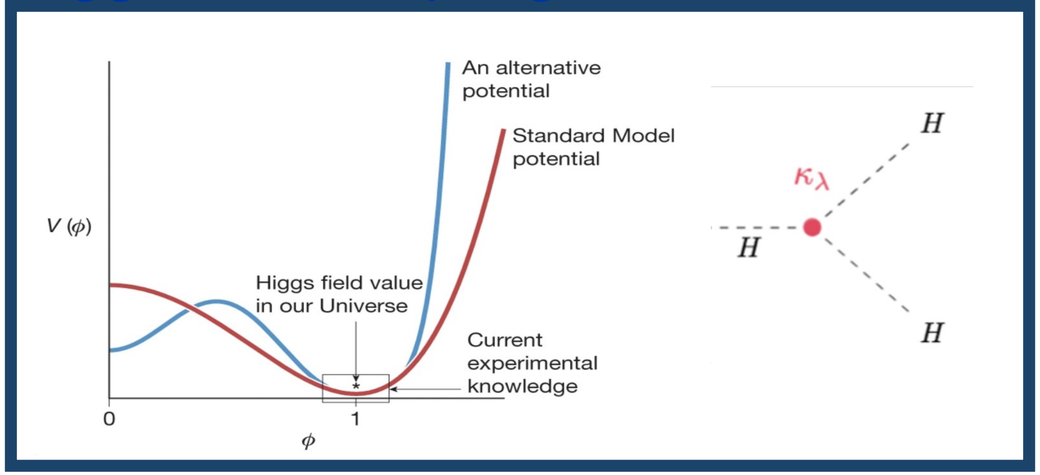
Higgs Mass & Width



Branching-Ratios



Higgs Self-coupling

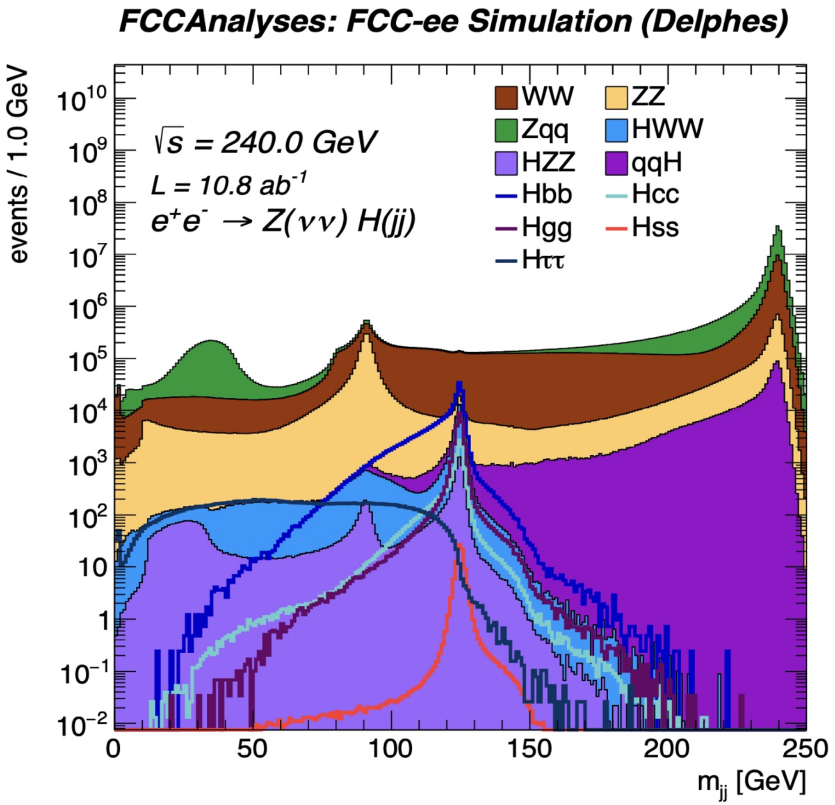


Higgs to hadronic: $H \rightarrow bb, cc, ss$

Reference
[arxiv:2511.23149]

FCC-ee

~80% H decay hadronically



pre-selection stage

- bb/ cc/ gg channels:
  →Clean, large S/B
- ss channel
  →measurable for the first time
- Investigate categories Z($\nu\nu$,jj,ll)H→jj
- **Flavor tagger crucial for signal enhancement**
- Simultaneous fit of σxBRs in VBF and ZH
- Similar analyses for FCNC Higgs decays $H \rightarrow bs, bd, sd, cu$ [1]

Performance Driver!

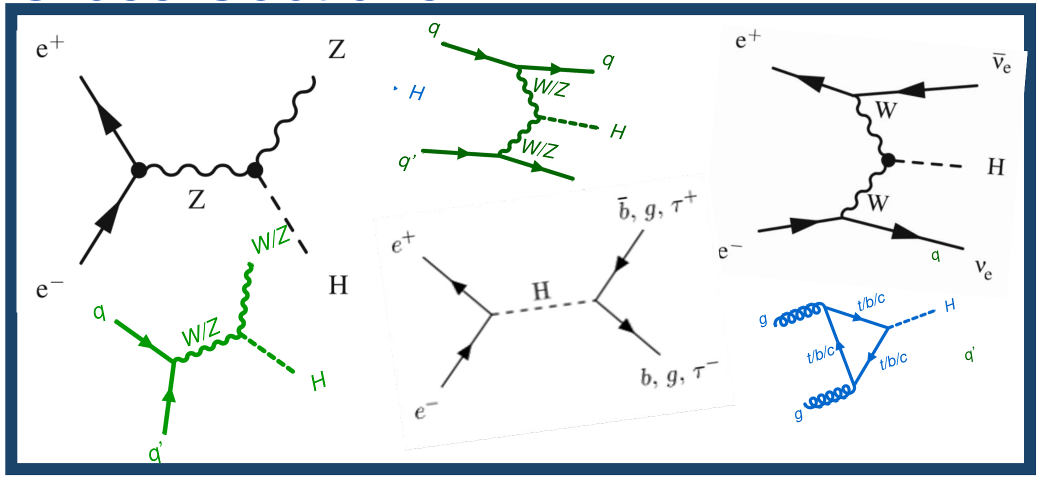
- Jet visible mass resolution
- Jet flavor tagging:

→ Unique opportunities for strange tagging with PID (charged hadron PID missing at LHC) [2]

$\sqrt{s}$	240 GeV		365 GeV	
$\mathcal{L}$	10.8 ab^{-1}		3.12 ab^{-1}	
Channel	ZH	$\nu_e\bar{\nu}_eH$	ZH	$\nu_e\bar{\nu}_eH$
$H \rightarrow b\bar{b}$	±0.21	±1.89	±0.39	±0.64
$H \rightarrow c\bar{c}$	±1.75	±20	±3.01	±3.36
$H \rightarrow s\bar{s}$	±110	±990	±340	±280
$H \rightarrow gg$	±0.85	±5.5	±2.13	±2.56

The Higgs Program at unprecedented Precision/Energy

Cross-Sections



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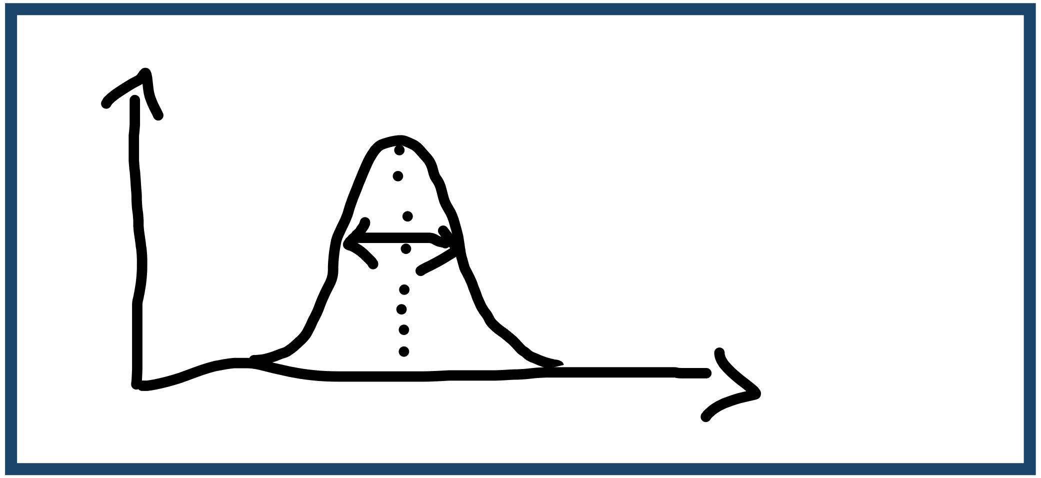

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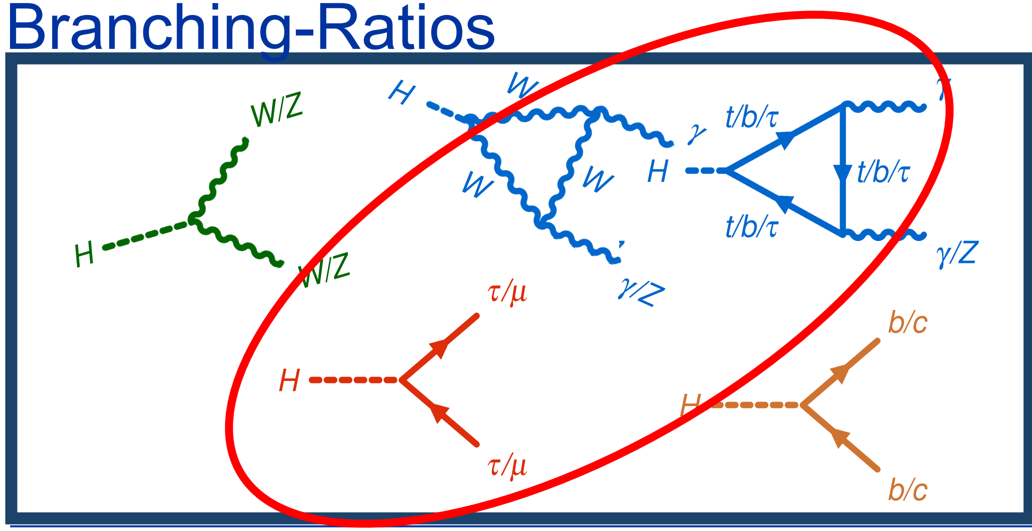
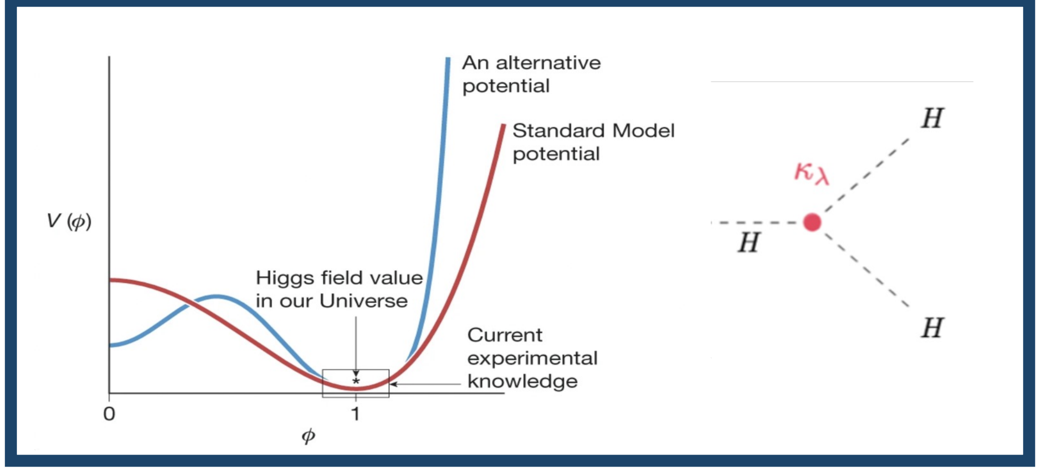
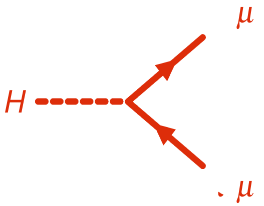


Higgs Self-coupling



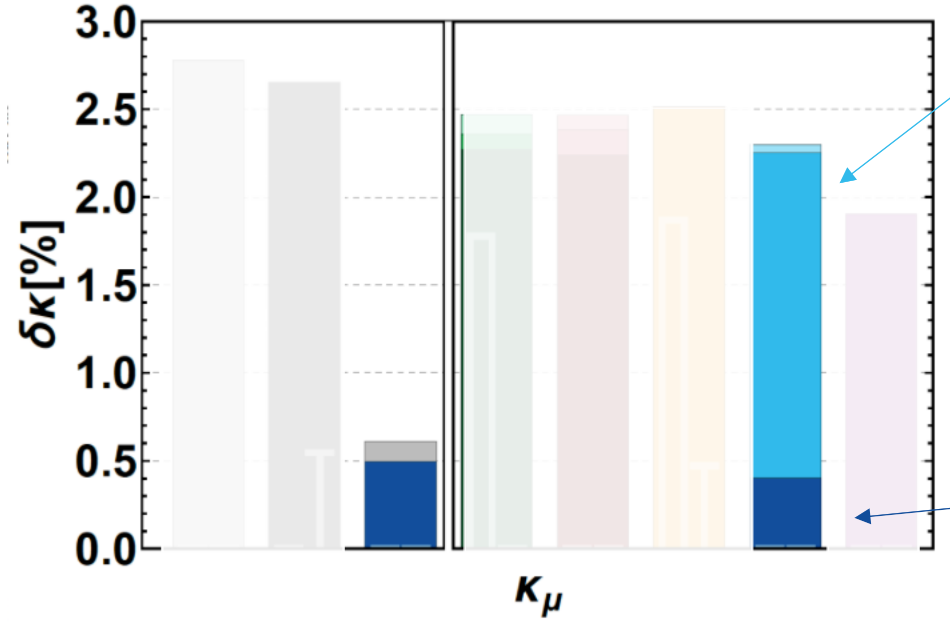
Rare Decays: $H \rightarrow Z\gamma, \gamma\gamma, \mu\mu$



Reference
[cds:2944678]

FCC-hh

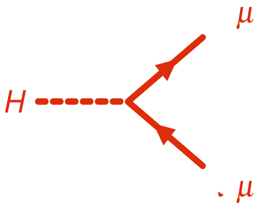
Large Higgs sample at FCC-hh improves precision on/ makes rare decay channels accessible



FCC-ee

FCC-ee + FCC-hh

Rare Decays: $H \to Z\gamma, \gamma\gamma, \mu\mu$



Reference
[cds:2944678]

FCC-hh

Ratio Measuremnet: $H \to \mu\mu$ / $H \to ZZ^* \to \mu\mu\mu\mu$

Strategy

→ Ratios reduce dependence on common systematic assumptions
- Theory unc on production cross-section
- Luminosity
- etc

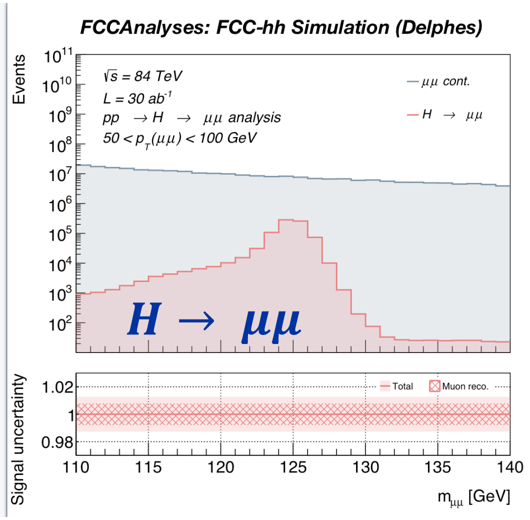
→ Absolute coupling measurement by using FCC-ee

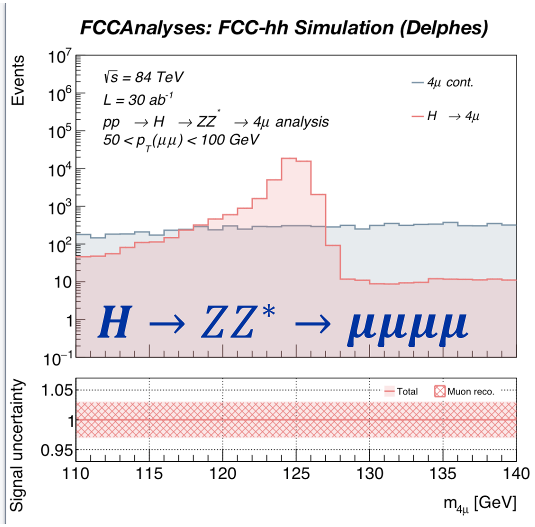
$$\sigma_{prod} BR(H \to XX) = \sigma_{prod} \frac{\Gamma(H \to XX)}{\Gamma(H)}$$

$$\frac{BR(H \to XX)}{BR(H \to ZZ^*)} = \frac{g^2_{HXX}}{g^2_{HZZ}}$$

~ 0.1% precision from FCC-ee

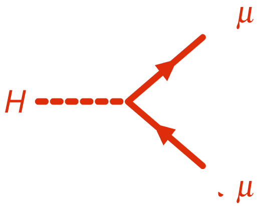
Model-dependent assumptions at hh machines needed





Likelihood Fit to invariant mass distribution in bins of $p_T(H)$ (smaller sys at high $p_T(H)$)

Rare Decays: $H \rightarrow Z\gamma, \gamma\gamma, \mu\mu$



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FCC-hh

Ratio Measuremnet: $H \rightarrow \mu\mu \,/\, H \rightarrow ZZ^* \rightarrow \mu\mu\mu\mu$

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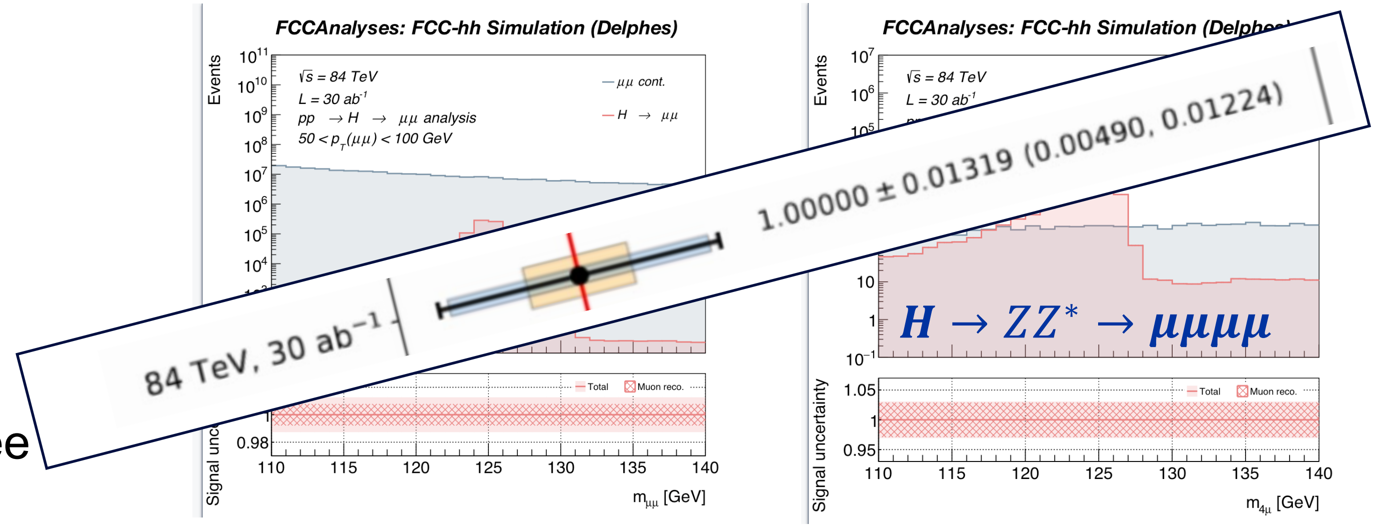

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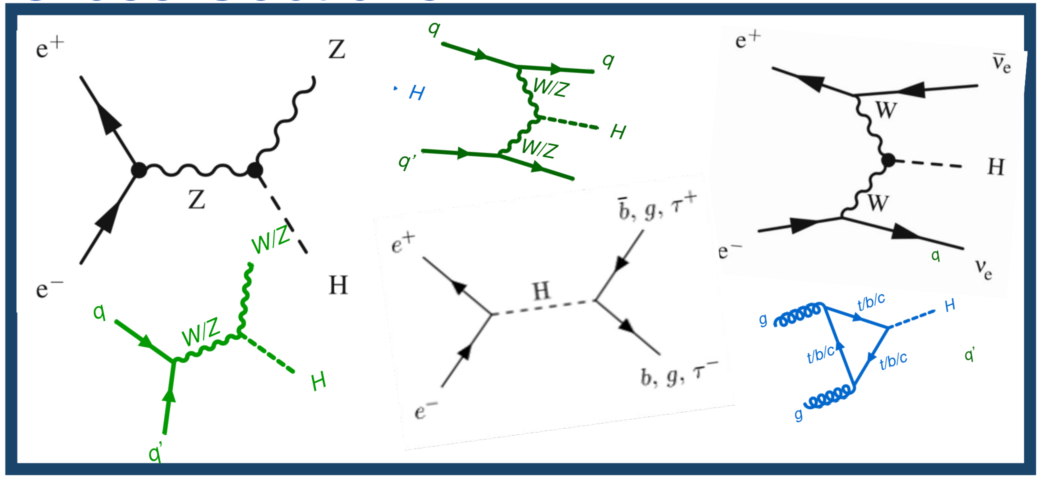
~ 0.1% precision from FCC-ee

Model-dependent assumptions at hh machines needed

$\sqrt{s}$	84 TeV
Scenario	FSR baseline
Int. lumi in ab^{-1}	30
$\delta g_{H\mu\mu}/g_{H\mu\mu}$ in %	0.660

The Higgs Program at unprecedented Precision/Energy

Cross-Sections



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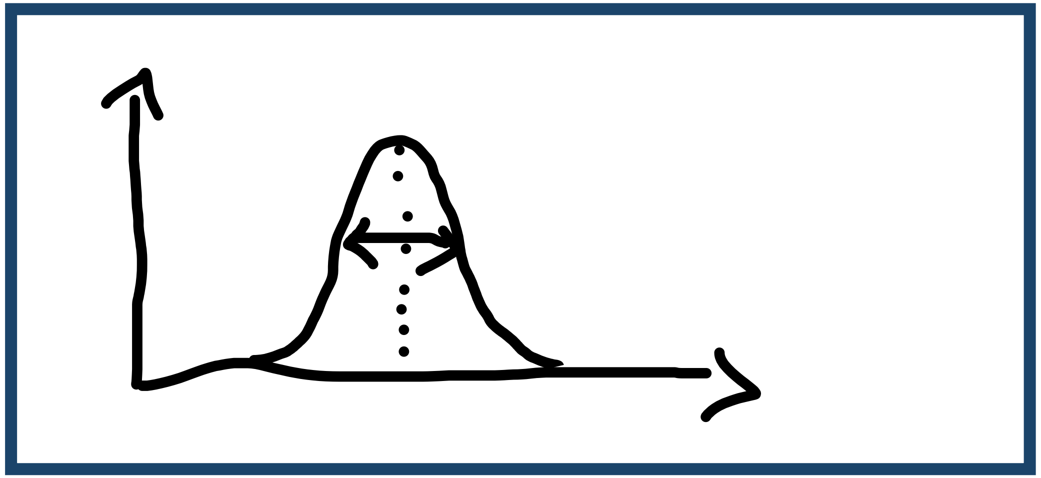

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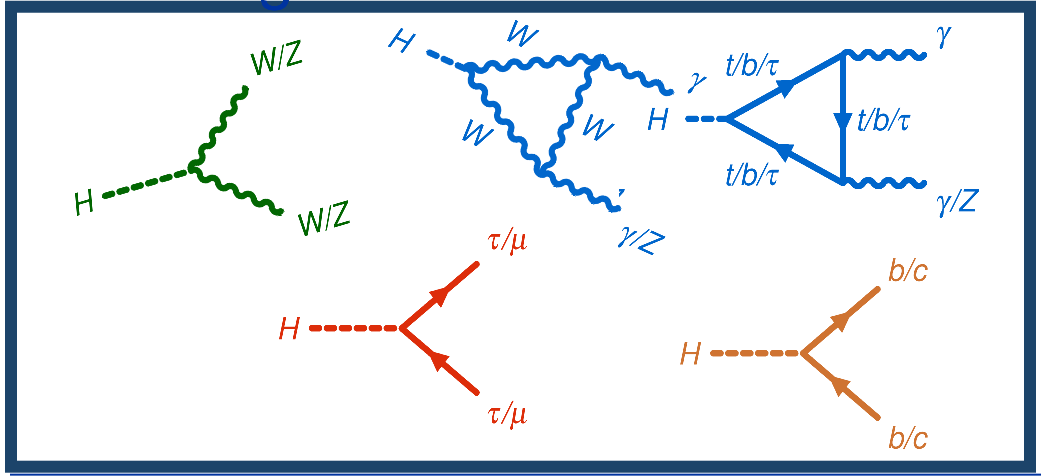
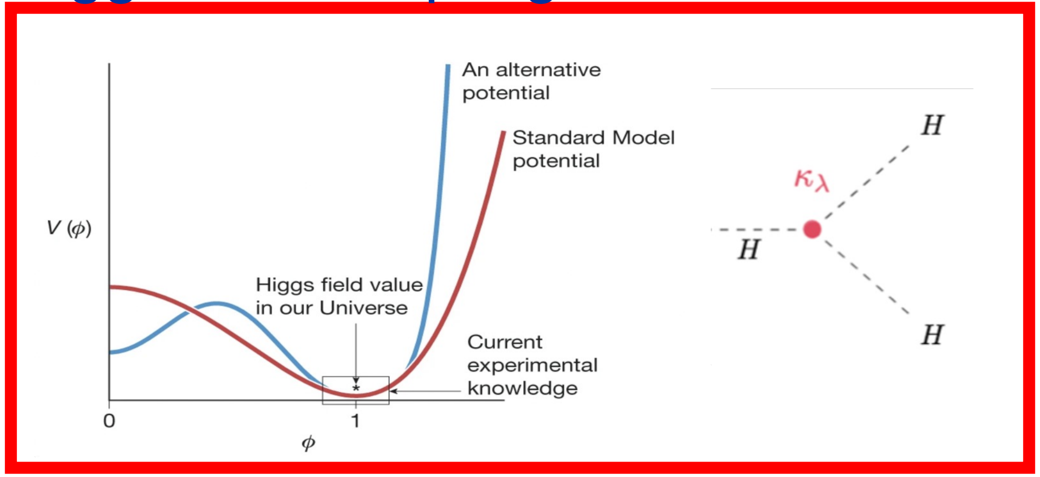


Higgs Self-coupling

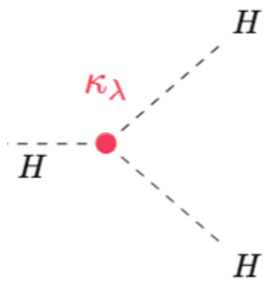


Trilinear Higgs Self-Coupling

Reference
[doi:5mqfv-xnd34], arxiv:2511.03883

FCC-hh

Higgs self-coupling provides insight into
→ Nature of Higgs potential
→ EWK symmetry breaking

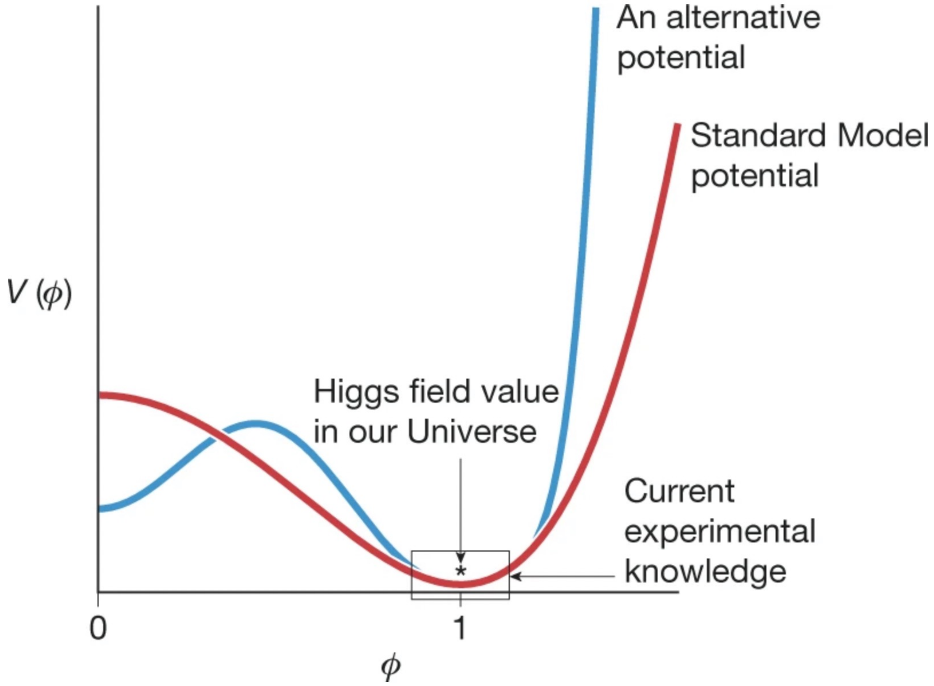


- At FCC-ee: κ_λ accessible indirectly at tree-level ~20-30%
- At FCC-hh: 30 million Higgs pairs expected

Most sensitive channel: $HH \rightarrow bb\gamma\gamma$ (high BR + high selection eff)
- Signal/background discrimination via DNN
- Profile likelihood fit on 2D $m_{\gamma\gamma}m_{bb}$

Channel specific result: $\delta\kappa_\lambda = 3.5(stat.) + 3.8(syst)$

Combination with other channels ($bb\tau\tau, bbbb$) improves precision further



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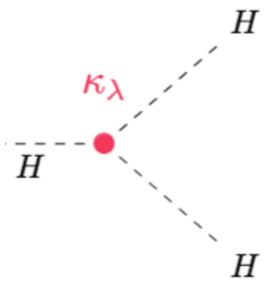

Note

Di-jet resolution has critical impact on analysis

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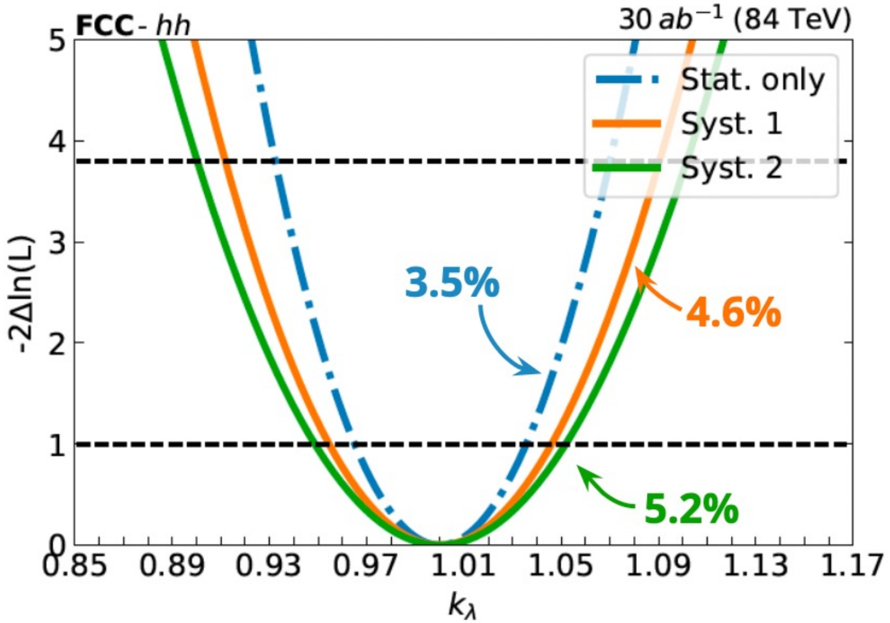

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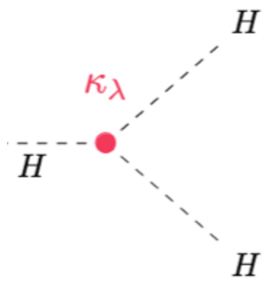

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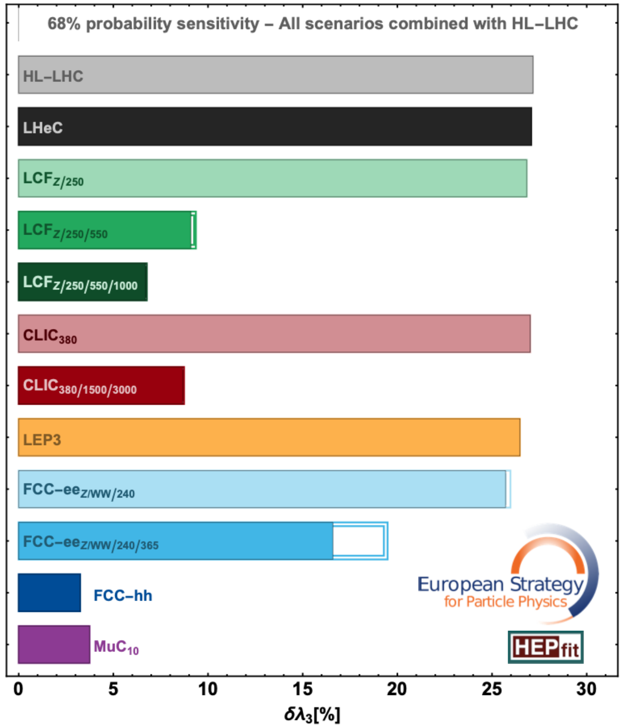

Couplings and Branching Ratios

Coupling	HL-LHC	FCC-ee	FCC-ee + FCC-hh
κ_Z (%)	1.3*	0.10	0.10
κ_W (%)	1.5*	0.29	0.25
κ_b (%)	2.5*	0.38 / 0.49	0.33 / 0.45
κ_g (%)	2*	0.49 / 0.54	0.41 / 0.44
κ_τ (%)	1.6*	0.46	0.40
κ_c (%)	–	0.70 / 0.87	0.68 / 0.85
κ_γ (%)	1.6*	1.1	0.30
$\kappa_{Z\gamma}$ (%)	10*	4.3	0.67
κ_t (%)	3.2*	3.1	0.75
κ_μ (%)	4.4*	3.3	0.42
$\lvert\kappa_s\rvert$ (%)	–	$^{+29}_{-67}$	$^{+29}_{-67}$
Γ_H (%)	–	0.78	0.69
$\mathcal{B}_{inv}$ (<, 95% CL)	1.9×10^{-2} *	5×10^{-4}	2.3×10^{-4}
$\mathcal{B}_{unt}$ (<, 95% CL)	4×10^{-2} *	6.8×10^{-3}	6.7×10^{-3}

$\sqrt{s}$	240 GeV		365 GeV	
channel	**ZH**	**WW → H**	**ZH**	**WW → H**
ZH → any	±0.31		±0.52	
γH → any	±150			
H → bb	±0.21	±1.9	±0.38	±0.66
H → cc	±1.6	±19	±2.9	±3.4
H → ss	±120	±990	±350	±280
H → gg	±0.80	±5.5	±2.1	±2.6
H → $\tau\tau$	±0.58		±1.2	±5.6 (*)
H → $\mu\mu$	±11		±25	
H → WW*	±0.80		±1.8 (*)	±2.1 (*)
H → ZZ*	±2.5		±8.3 (*)	±4.6 (*)
H → $\gamma\gamma$	±3.6		±13	±15
H → Zγ	±11.8		±22	±23
H → $\nu\nu\nu\nu$	±25		±77	
H → inv.	$< 5.5 \times 10^{-4}$		$< 1.6 \times 10^{-3}$	
H → dd	$< 1.2 \times 10^{-3}$			
H → uu	$< 1.2 \times 10^{-3}$			
H → bs	$< 3.1 \times 10^{-4}$			
H → bu	$< 2.2 \times 10^{-4}$			
H → sd	$< 2.0 \times 10^{-4}$			
H → cu	$< 6.5 \times 10^{-4}$			

observable	**param**	**stat.**	**stat. + syst.**	
$\mu = \sigma(H) \times \mathcal{B}(H \to \gamma\gamma)$	$\delta\mu$	0.1%	1.4%	(*)
$\mu = \sigma(H) \times \mathcal{B}(H \to \mu\mu)$	$\delta\mu$	0.4%	1.2%	
$\mu = \sigma(H) \times \mathcal{B}(H \to \ell\ell\ell\ell)$	$\delta\mu$	0.2%	1.8%	(*)
$\mu = \sigma(H) \times \mathcal{B}(H \to \gamma\ell\ell)$	$\delta\mu$	1.1%	1.7%	(*)
$\mu = \sigma(ttH)\, \mathcal{B}(H \to \gamma\gamma)$	$\delta\mu$	0.4%	2.2%	
$R = \mathcal{B}(H \to \mu\mu)/\mathcal{B}(H \to \mu\mu\mu\mu)$	$\delta R/R$	0.5%	1.3%	
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$R = \sigma(ttH)\, \mathcal{B}(H \to b\bar{b})/\sigma(ttZ)\, \mathcal{B}(Z \to b\bar{b})$	$\delta R/R$	1.2%	2.0%	(*)
$R = \sigma(VBF - H))\, \mathcal{B}(H \to e\mu\nu\nu)/\sigma(VBS - WW))\, \mathcal{B}(WW \to e\mu\nu\nu)$	$\delta R/R$	1.9%	2.0%	
$\mathcal{B}(H \to \text{invisible})$	$\mathcal{B}$@95%CL	1.2×10^{-4}	2.6×10^{-4}	(*)
$\sigma(HH)$	$\delta\kappa_\lambda$	3.5%	5.2%	

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Coupling	HL-LHC	FCC-ee	FCC-ee + FCC-hh
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$\kappa_{Z\gamma}$ (%)	10*	4.3	0.67
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κ_μ (%)	4.4*	3.3	0.42
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H → ZZ*	±2.5		±8.3 (*)	±4.6 (*)
H → $\gamma\gamma$	±3.6		±13	±15
H → Zγ	±11.8		±22	±23
H → $\nu\nu\nu\nu$	±25		±77	
H → inv.	$< 5.5 \times 10^{-4}$		$< 1.6 \times 10^{-3}$	
H → dd	$< 1.2 \times 10^{-3}$			
H → uu	$< 1.2 \times 10^{-3}$			
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$\mu = \sigma(H) \times \mathcal{B}(H \to \gamma\ell\ell)$	$\delta\mu$	1.1%	1.7%	(*)
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$\sigma(HH)$	$\delta\kappa_\lambda$	3.5%	5.2%	

- One order of magnitude improvement compared to HL-LHC
- FCC-ee/hh complementary
- Absolute Higgs width measurement of 0.78!

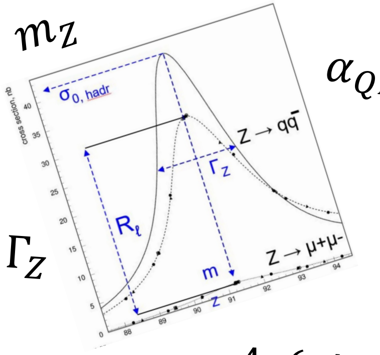
So much more beyond the Higgs

The Electroweak and Top – Program at FCC-ee

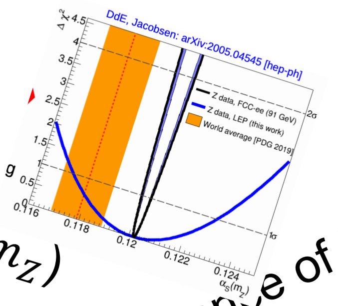
FCC-ee

Z pole run

m_Z



$\alpha_{QED}(m_Z^2)$



Γ_Z

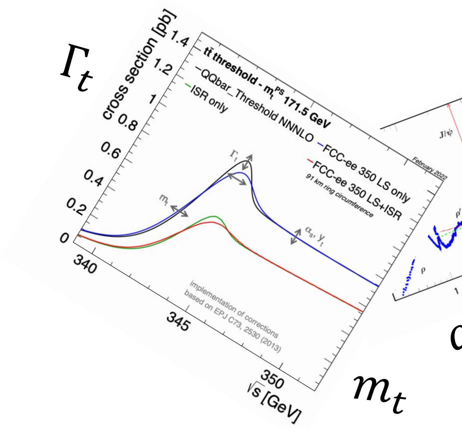
$\alpha_S(m_Z)$

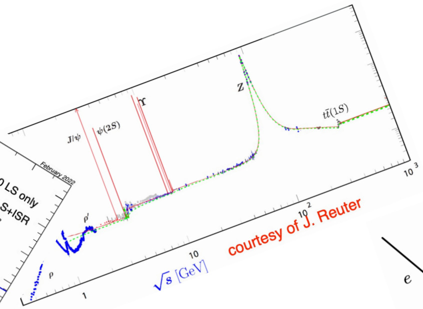
$A_f(sin\vartheta_W^{eff})$

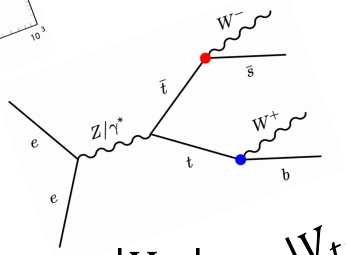
Abundance of B,D

Top

Γ_t



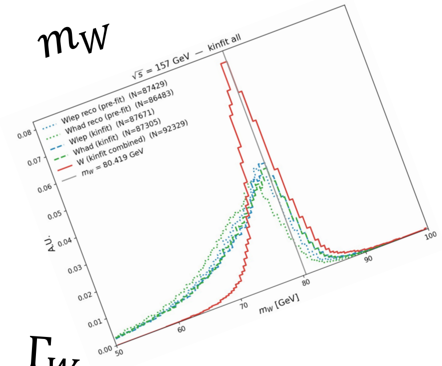




m_t α_S ψt $|V_{tb}|$ $|V_{ts}|$

WW run

m_W



Γ_W

$\alpha_S(m_Z^2)$

$|V_{cb}|$

$|V_{cs}|$

BR(W→lυ)

CHALLENGES

EWPOs parametric inputs i.e. $m_W(m_t, \alpha_S(m_Z), ..)$

Observed Deviation = new physics effect + uncertainty from input parameters

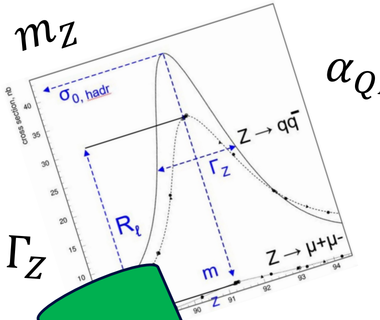
→ Bring systematics down to stat level
→ Precise knowledge of luminosity, $\sqrt{s}$, BES, .. crucial

The Electroweak and Top – Program at FCC-ee

FCC-ee

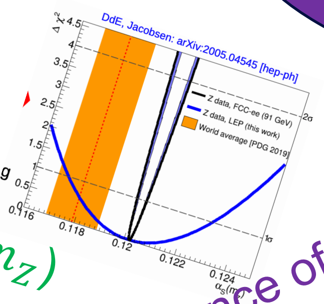
Z pole run

m_Z



Γ_Z

$\alpha_{QED}(m_Z^2)$



$\alpha_S(m_Z)$

$A_f(sin\vartheta_W^{eff})$

Abundance of B,D

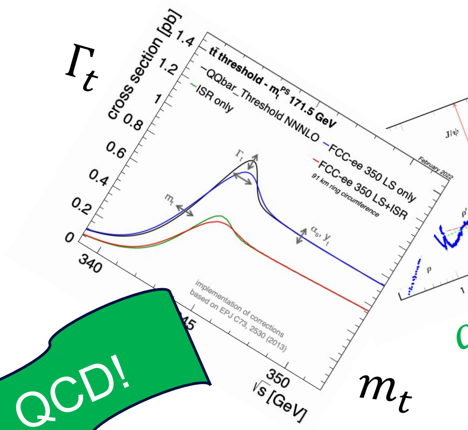
Flavor!

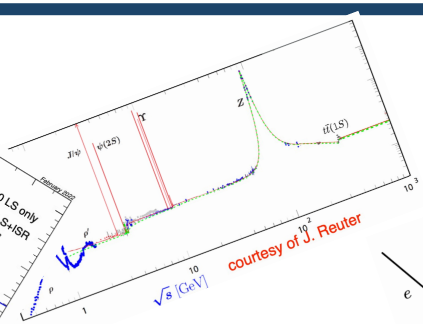
QCD!

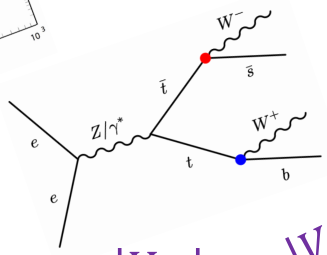
BSM!

Top

Γ_t







m_t

α_S

ψt

$|V_{tb}|$

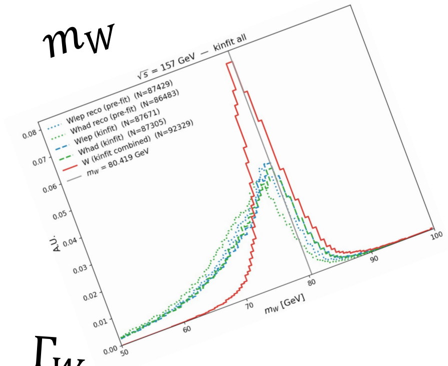
$|V_{ts}|$

Flavor!

QCD!

WW run

m_W



Γ_W

$\alpha_S(m_Z^2)$

BR(W→lυ)

$|V_{cb}|$

$|V_{cs}|$

Flavor!

CHALLENGES

EWPOs parametric inputs i.e. $m_W(m_t, \alpha_S(m_Z), ..)$

Observed Deviation = new physics effect + uncertainty from input parameters

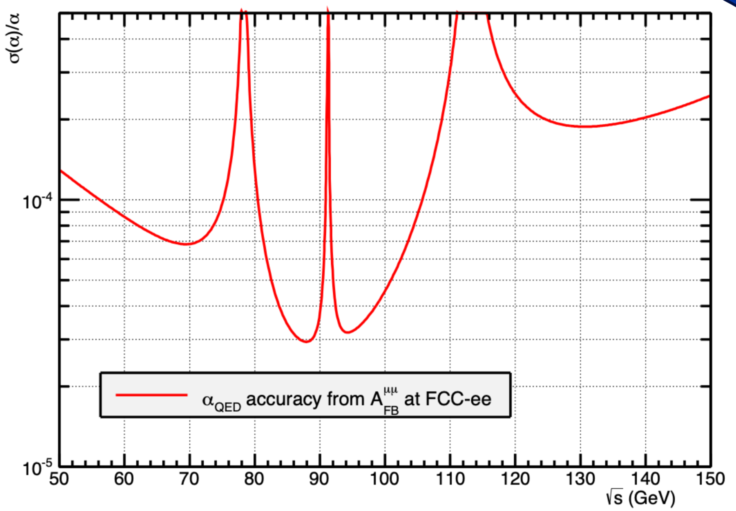
→ Bring systematics down to stat level
→ Precise knowledge of luminosity, $\sqrt{s}$, BES, .. crucial

$\alpha_{QED}(m_Z)$ on/off Z-peak

Reference
[arxiv:1512.05544], [slides: J. Eysermans], [arxiv:2501.05508]

FCC-ee

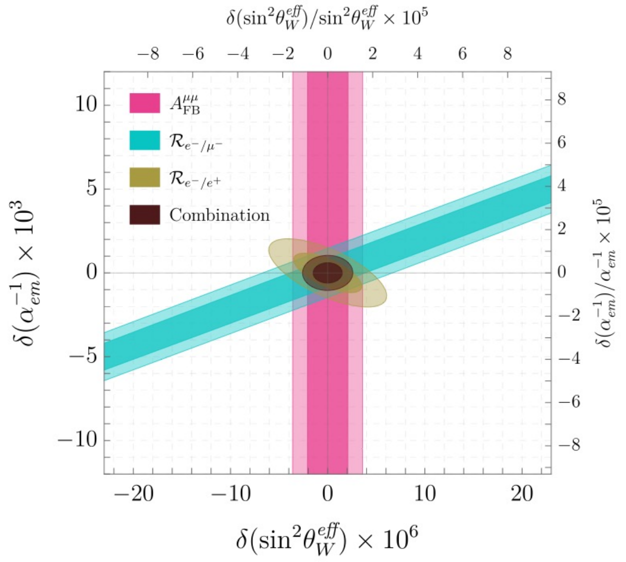
Dominant parametric uncertainty in EW precision fit ($\sin(\theta_W, m_W)$):
→ Avoid QCD-loop uncertainties from $\alpha(0) \rightarrow \alpha(\mathrm{m_Z})$ extrapolation
→ Measure at the Z-pole
→ Current uncertainty needs to be reduced by one order of magnitude to $\sim 10^{-5}$

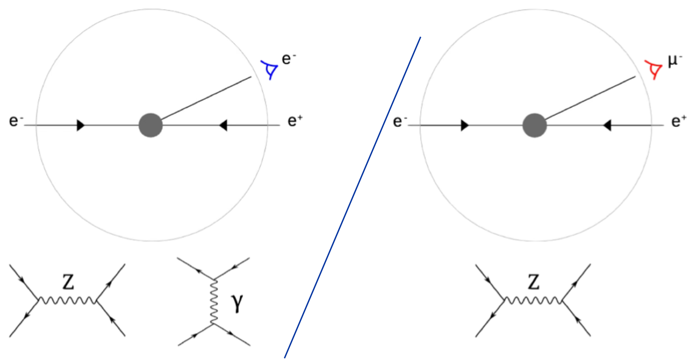


Approach 1): $A_{FB}^{\mu\mu}$ off peak measurements, on peak constraints $\sin(\theta_W)^{eff}$ $\quad \dfrac{\delta\alpha}{\alpha} = 3x10^{-5}$

Approach 2): Lepton Ratios in Forward Region $\quad \dfrac{\delta\alpha}{\alpha} = 6x10^{-6}$

→ Compare differential distributions of R_{e^-/e^+} , R_{e^-/μ^-} in forward region





Challenge:

e/μ identification in forward region

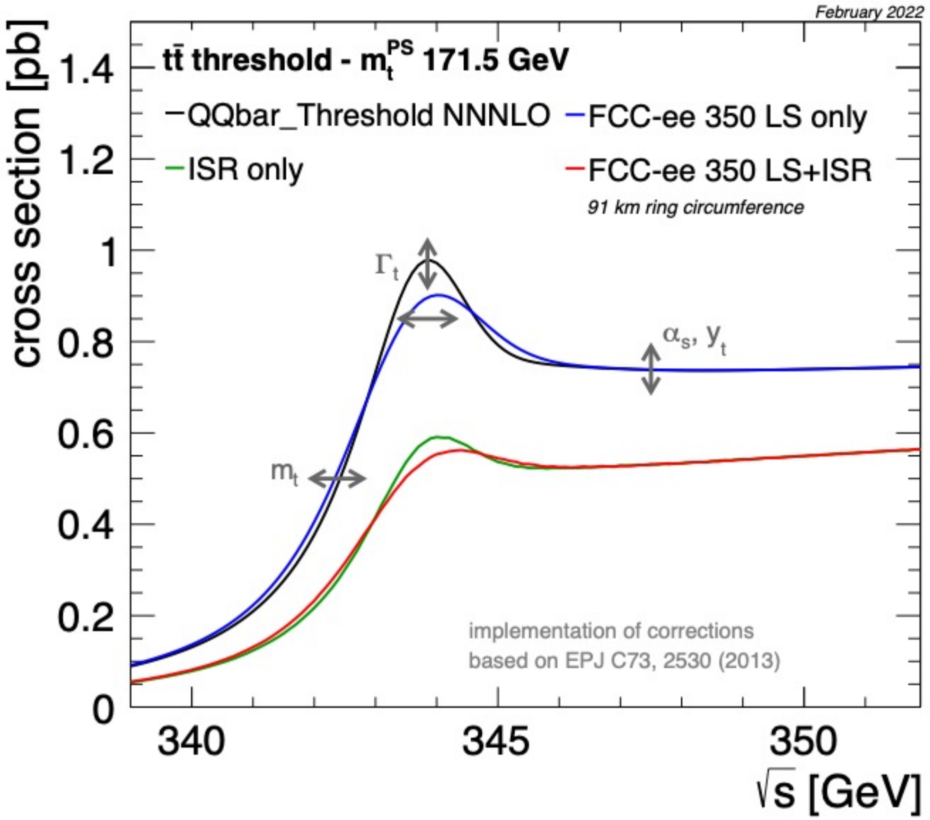
Top Threshold Scan

Reference
[arxiv:2203.06520], [arxiv:2503.18713]

FCC-ee

Scan $\sqrt{s}$ around tt production and measure ee→WbWb

Curve encodes top quark properties as $m_t, \Gamma_t, y_t, (\alpha_S)$



Challenge

Near threshold tt behaves like a short-lived QCD bound state, requiring high-order non-relativistic QCD
→N4LO needed from theory side

Theoretical precision dominates

Uncertainty source	m_t^{PS} [MeV]	Γ_t [MeV]
Experimental (stat. ×1.2)	4.3	10.4
Parametric y_t	4.2	3.6
Parametric α_S	2.2	1.7
Luminosity calibration (uncorr.)	0.5	1.0
Luminosity calibration (corr.)	0.4	0.4
Beam energy calibration (uncorr.)	1.2	1.8
Beam energy calibration (corr.)	1.2	0.1
Beam energy spread (uncorr.)	0.3	0.8
Beam energy spread (corr.)	0.1	1.1
Total profiled	6.8	11.5
Theory, unprofiled (scale)	35	25

Flavor at the Z-pole

Reference
[https://pos.sissa.it/443/060/pdf]

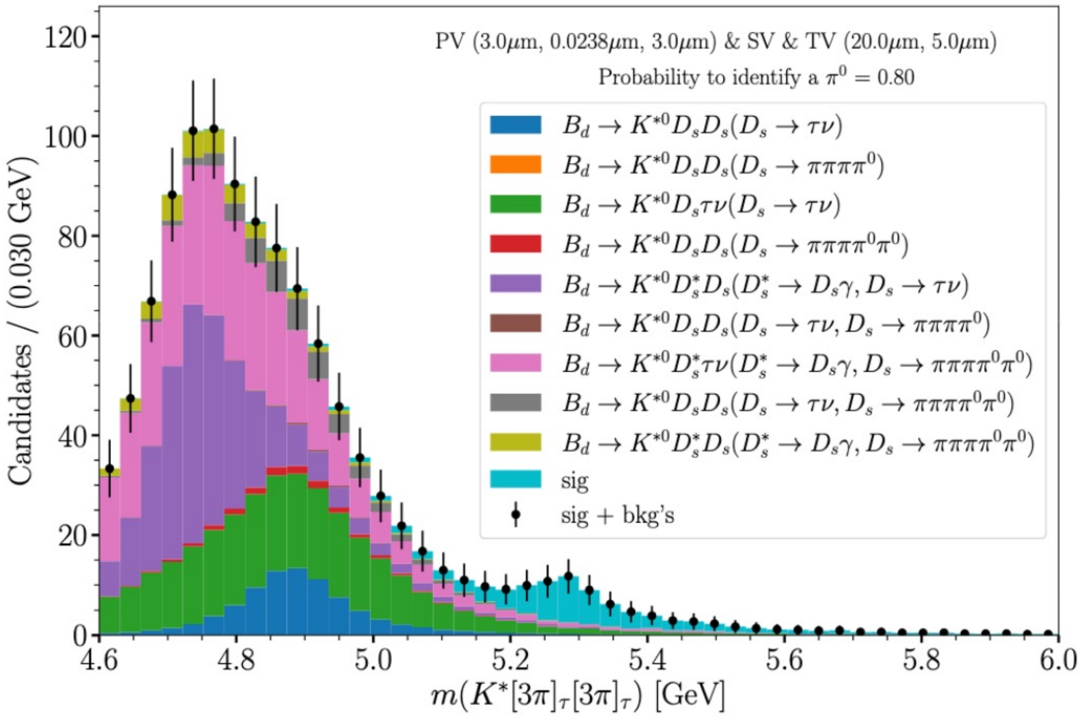
FCC-ee

Attribute	$\Upsilon(4S)$	pp	Z
All hadron species		✓	✓
High boost		✓	✓
Enormous production cross-section		✓	
Negligible trigger losses	✓		✓
High geometrical acceptance	✓		✓
Low backgrounds	✓		✓
Flavour-tagging power	✓		✓
Initial-energy constraint	✓		(✓)

Z-pole combines many attributes in terms of flavour physics

$B \to K^*\tau\tau$ analysis

- Not observed to date
- Requires 2-3μm impact parameter resolution
- Requires excellent PID capabilities

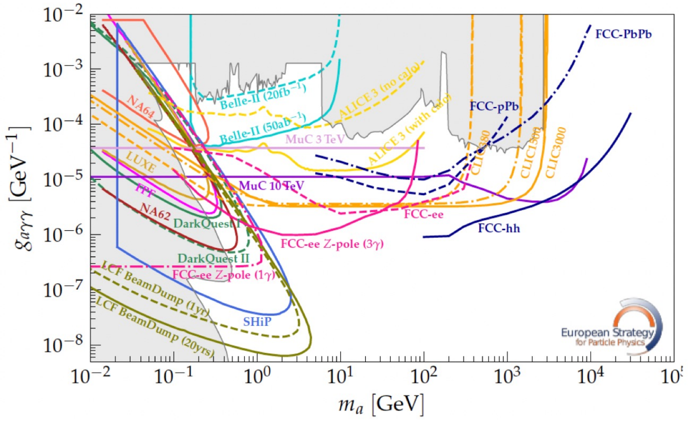


Let‘s not forget FCC-hh

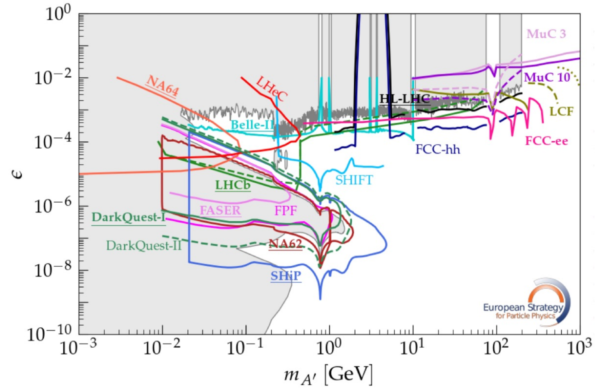
The BSM- Program – A Selection

FCC-hh

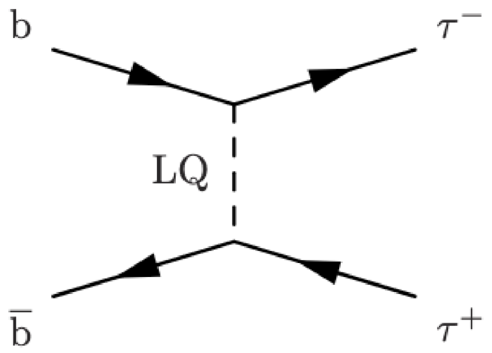
ALPs



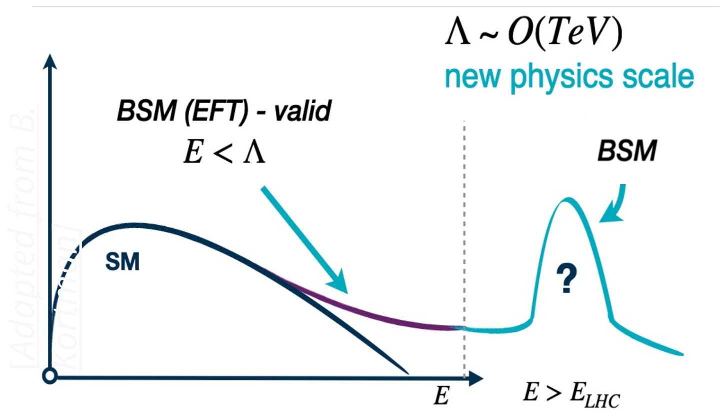
Dark Sector



Leptoquarks



New Resonances



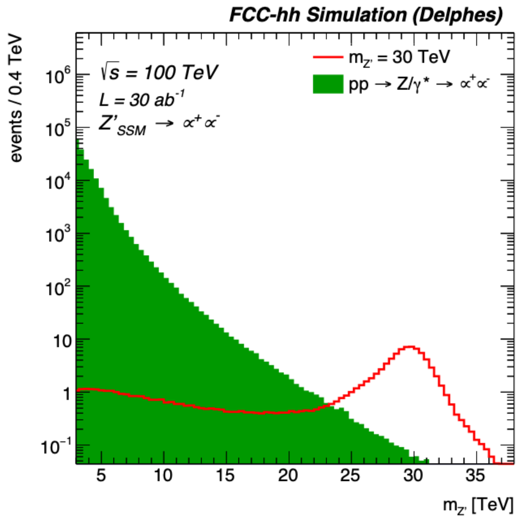
New Resonances

Reference
[ESPPU input]

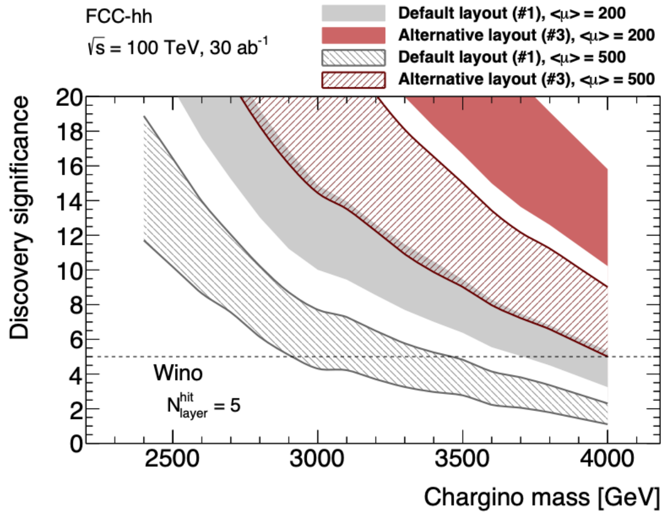
FCC-hh

BSM object (%)	100 TeV CDR baseline	84 TeV FSR baseline
$Z'_{SSM} \to \ell\ell$	43	37
$Z'_{SSM} \to \tau\tau$, tt	18	16
$Z'_{TC} \to$ tt	23	20
$G_{RS} \to$ WW	22	19
$Q^* \to$jj	40	35
$\tilde{W}^0$	4.4	4.0
$\tilde{h}^0$	1.2	1.1

Direct mass reach of up to 40TeV
→linear scaling: ~7xreach LHC



Heavy Resonances



Supersymmetry Studies

Precision Measurements from FCC-ee could lead the way

.. And so much more I did not cover

Conclusion

Exciting physics program with many possibilities to contribute

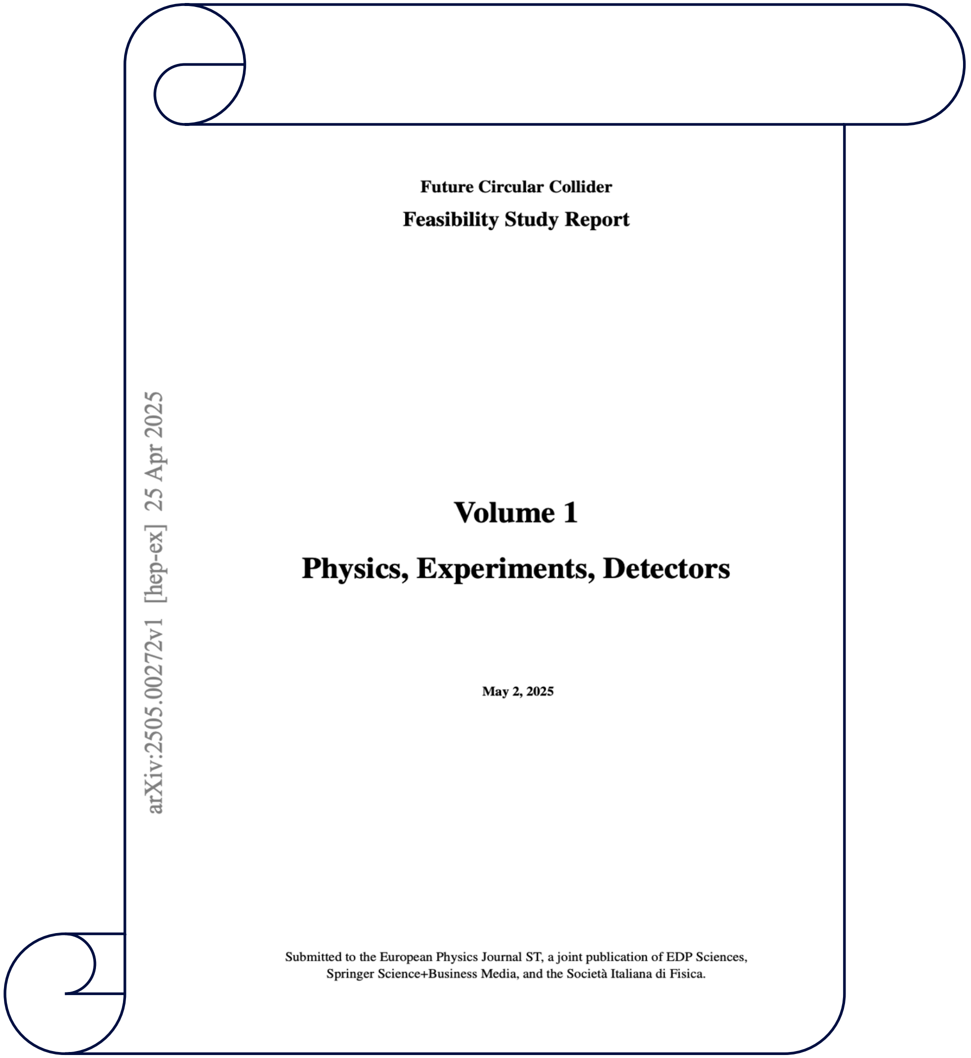
- Full simulation: studies, testing, reporting
- Many analyses to explore:
  →Various physics channels
  →Beam induced background studies
  →..
- Reconstruction Techniques to be improved
  →Handling of pile-up at FCC-hh
  →Flavor tagging
  →..
- Detector/ accelerator studies
  → control of beam parameters
  → detectors fulfilling physics needs
  →etc

Join the Effort

Subscribe to corresponding mailing lists:
https://groups-portal.web.cern.ch/

- > **FCC-PED-Physics**
  - FCC-PED-PhysicsCoordinationGroup
  - FCC-PED-PhysicsGroup-BSM
  - FCC-PED-PhysicsGroup-EWPrecision
  - FCC-PED-PhysicsGroup-Flavours
    - FCC-PED-PhysicsGroup-Flavours-Coordination
    - FCC-PED-PhysicsGroup-Flavours-CPC
    - FCC-PED-PhysicsGroup-Flavours-Charm
    - FCC-PED-PhysicsGroup-Flavours-CPV
    - FCC-PED-PhysicsGroup-Flavours-Rare
    - FCC-PED-PhysicsGroup-Flavours-TauEW
  - FCC-PED-PhysicsGroup-GlobalFits
  - FCC-PED-PhysicsGroup-hh
  - FCC-PED-PhysicsGroup-Higgs
  - FCC-PED-PhysicsGroup-HighLevelReco
  - FCC-PED-PhysicsGroup-MCgenerators
  - FCC-PED-PhysicsGroup-PrecisionCalculations
  - FCC-PED-PhysicsGroup-QCD
  - FCC-PED-PhysicsGroup-Top
- > **FCC-PED-SoftwareAndComputing**
  - FCC-PED-SoftwareAndComputing-Coordination
  - FCC-PED-SoftwareAndComputing-Analysis
  - FCC-PED-SoftwareAndComputing-Core
  - FCC-PED-SoftwareAndComputing-DB

Feasibility Study Report & Other Resources


Future Circular Collider
Feasibility Study Report

arXiv:2505.00272v1 [hep-ex] 25 Apr 2025

Volume 1
Physics, Experiments, Detectors

May 2, 2025

Submitted to the European Physics Journal ST, a joint publication of EDP Sciences, Springer Science+Business Media, and the Società Italiana di Fisica.

Feasibility Study Report: Volume 1
[arXiv:2505.00272v1]

EW, Higgs, Top
[cds:n78xk-qcv56]

QCD
[cds:2fxav-m4p30]

Flavour
[cds:jnzpp-1fw39]

BSM
[cds:69m03-zzb95]

FCC-hh
[cds:bzhc2-mem17]

Manifesto
[cds:3kaxg-ejn91]

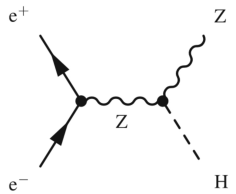
home.cern

The Importance of the Two Stages

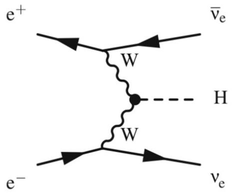
FCC-ee

Clean, model-independent precision baseline

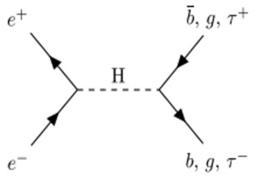
- Different production modes covered at various $\sqrt{s}$ scenarios



Higgsstrahlung @ 240GeV



VBF Fusion @365



S-channel Higgs production @125

- Model-independent determination of Higgs properties (cross-section, width)
- Unique access to hadronic decays, electron Yukawa, invisible

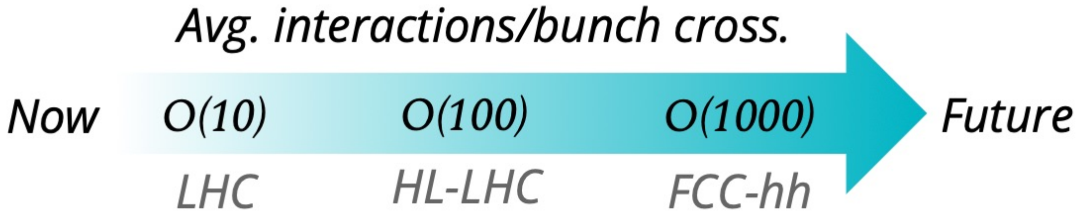
FCC-hh

High Statistics/ high energy Higgs frontier

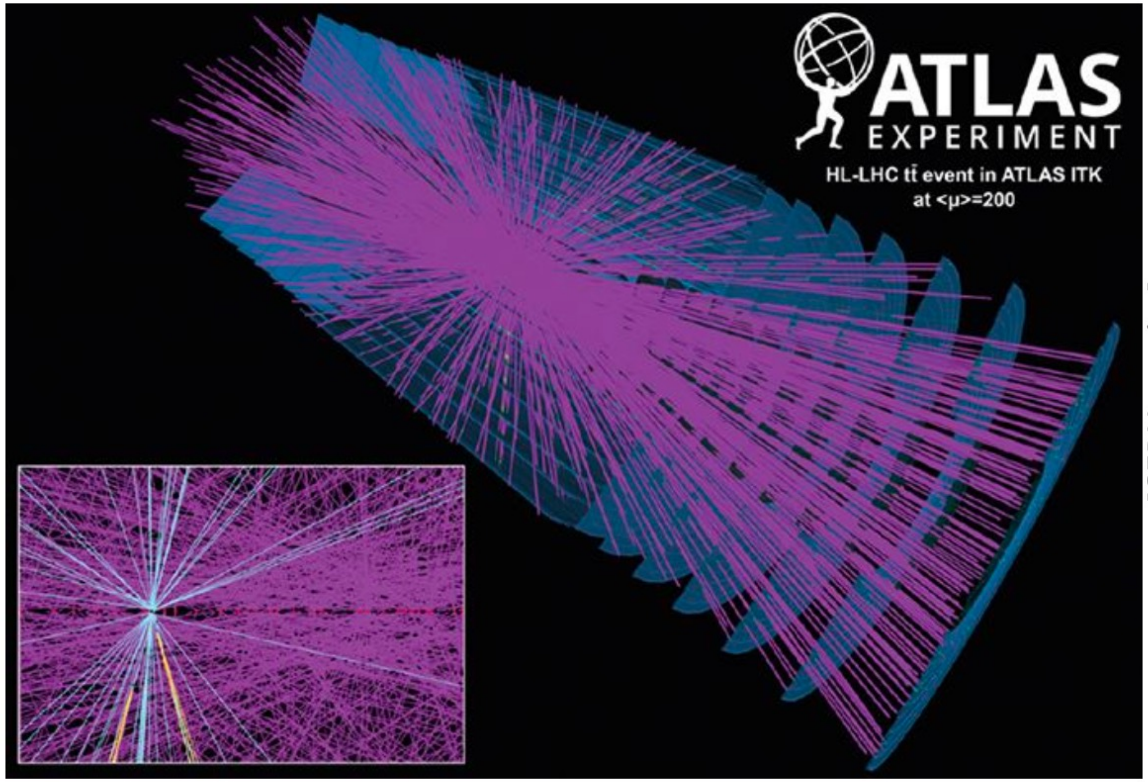
- study of rare decays:
  $H\gamma\gamma$, $H\mu\mu$, $HZ\gamma$
- Higgs self coupling at percent-level
  → Constraints on Higgs potential
- constraints on high scale new physics

What about pile-up?

- Huge pile-up make future hadron collider measurements increasingly difficult
- Hard to quantify the impact exactly
  - Powerful pile-up suppression techniques through e.g. high precision timing detectors
  - LHC performance better than expected at higher pile-up !
- No direct pile-up overlay, assume LHC levels in the Delphes parametrizations

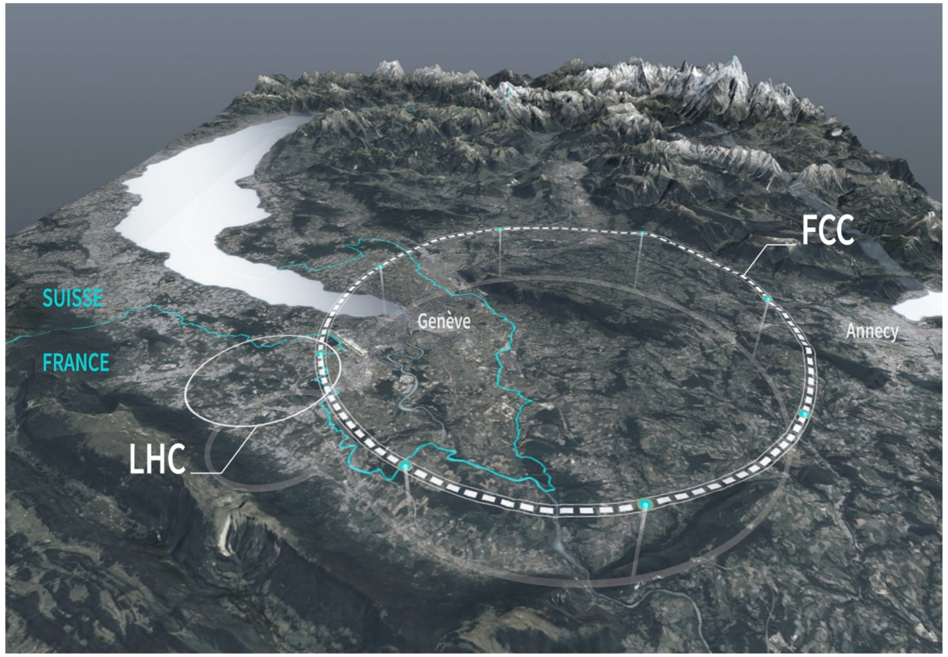


$\langle\mu\rangle = 200$



[CERN courier]

The FCC Integrated Program



- Proposed Future Circular Collider
- 91 km ring, built at CERN
- Two stages: → FCC-ee on luminosity frontier
  → FCC-hh on energy frontier
- Physics cases tested and found to be complementary (cite feasability):
  →FCC-ee: not only Higgs but also EW, QCD, flavour top factory; explore light physics frontier
  →FCC-hh: new energy frontier
- Project extends several decades
- Common infrastructure of two stages→ cost effective

FCC-ee Operartion

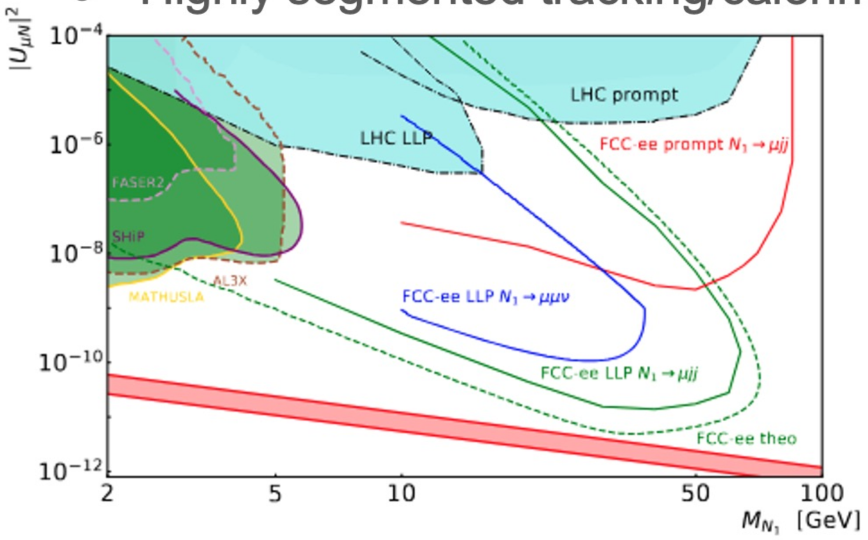
Working point	Z pole	WW thresh.	ZH	$t\bar{t}$	
$\sqrt{s}$ (GeV)	88, 91, 94	157, 163	240	340–350	365
Lumi/IP ($10^{34}\,cm^{-2}s^{-1}$)	140	20	7.5	1.8	1.4
Lumi/year (ab^{-1})	68	9.6	3.6	0.83	0.67
Run time (year)	4	2	3	1	4
Integrated lumi. (ab^{-1})	205	19.2	10.8	0.42	2.70
Number of events	6×10^{12} Z	2.4×10^{8} WW	2.2×10^{6} ZH + 65k WW $\rightarrow$ H	2×10^{6} $t\bar{t}$ + 370k ZH + 92k WW $\rightarrow$ H	

High Precision requires large data samples and thus high luminosity machines

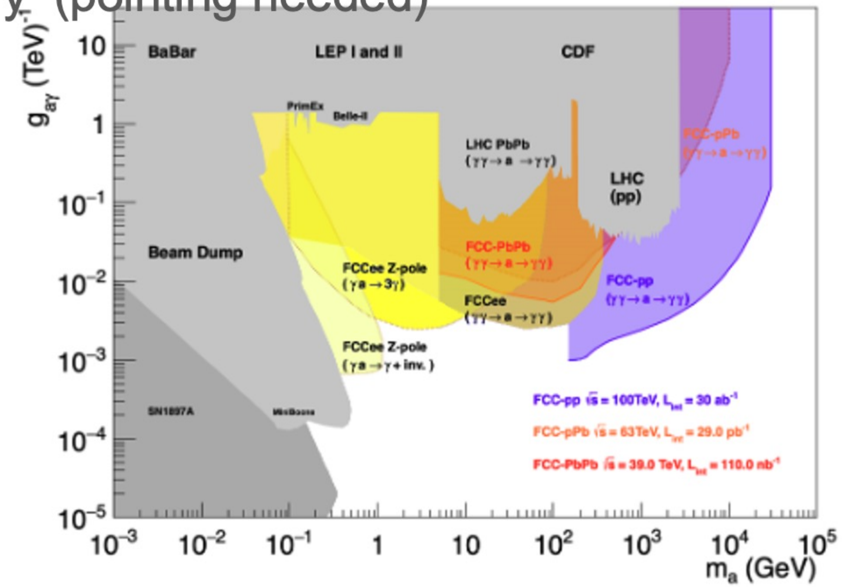
BSM at FCC-ee

At the Tera Z can discover light states (possibly feebly coupled and long-lived)

- Highly segmented tracking/calorimetry (pointing needed)



Heavy Neutral leptons (HNL)



Axion-like particles (ALPs)

[M. Selvaggi, ecole de GIF]