

Apertura sigla R&D FCC

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Particle physics in the middle of 2025

- Apart from the Higgs discovery, **all fundamental questions that motivated the LHC still remain open!**
 - DM, matter-antimatter asymmetry, EW-Planck hierarchy, strong CP problem, ν masses, ...
- World priority is a **high-precision Higgs factory** to precisely probe the crucial scalar sector of the SM
- FCC-ee Feasibility Study:
 - Model-independent Higgs couplings down to 0.1%
 - Indirect BSM up to $\Lambda \approx 7$ (70) TeV (+ EW observables)
 - Higgs Yukawa couplings to lightest fermions ($u, d, s, e, \nu?$, DM?)
 - Flavour-violating $H \rightarrow qq'$ decays?
- Followed by energy-frontier **hadron collider (FCC-hh)**: Higgs self-couplings + direct BSM searches up to $\Lambda \approx 100$ TeV

ESPP Open Symposium

3



High-priority future initiatives

A. An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

- *the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors;*

- *Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.*



CERN FCC-ee project

- 80-100 km tunnel in the Geneva area
- e^+e^- operation before pp at $\sqrt{s} = 90, (125), 160, 240$ and 350 GeV

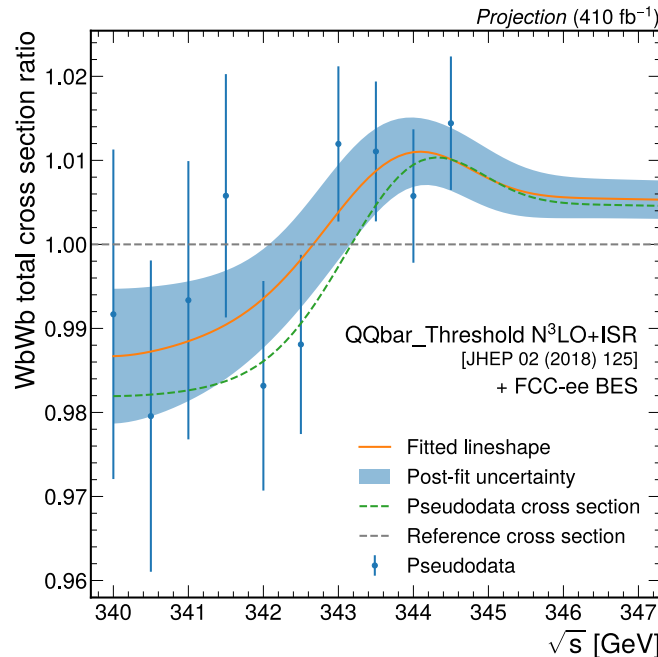
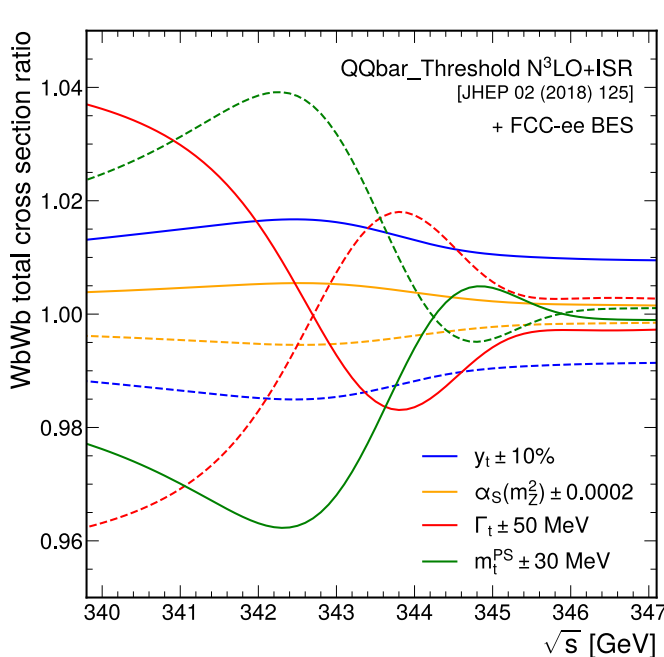


Working point	Z, years 1-2	Z, later	WW	HZ	$t\bar{t}$		(s-channel H)
\sqrt{s} (GeV)	88, 91, 94		157, 163	240	340-350	365	m_H
Lumi/IP ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	115	230	28	8.5	0.95	1.55	(30)
Lumi/year (ab^{-1} , 2 IP)	24	48	6	1.7	0.2	0.34	(7)
Physics Goal (ab^{-1})	150		10	5	0.2	1.5	(20)
Run time (year)	2	2	2	3	1	4	(3)
Number of events	5×10^{12} Z		10^8 WW	10^6 HZ + 25k WW \rightarrow H	$10^6 t\bar{t}$ +200k HZ +50k WW \rightarrow H		(6000)

- State-of-the-art detectors + exquisite control of the beam energy \rightarrow **tiny systematic uncertainties (10^{-5})**

Top quark mass at FCC-ee

- e^+e^- collisions from threshold scan around $\sqrt{s} = 340\text{-}345$ GeV
- $\Delta m_{top} \approx 7$ MeV (exp.) thanks to very good \sqrt{s} control



Assumed
parametric
uncertainty:
 $\Delta\alpha_s \approx 0.1\%$
 $\Delta m_{top} \approx \pm 2$ MeV

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- QCD theory for $\sigma(e^+e^- \rightarrow t\bar{t})$ vs. \sqrt{s} at threshold: $\Delta m_{top} \approx \pm 35$ MeV from N³LO scale uncertainties

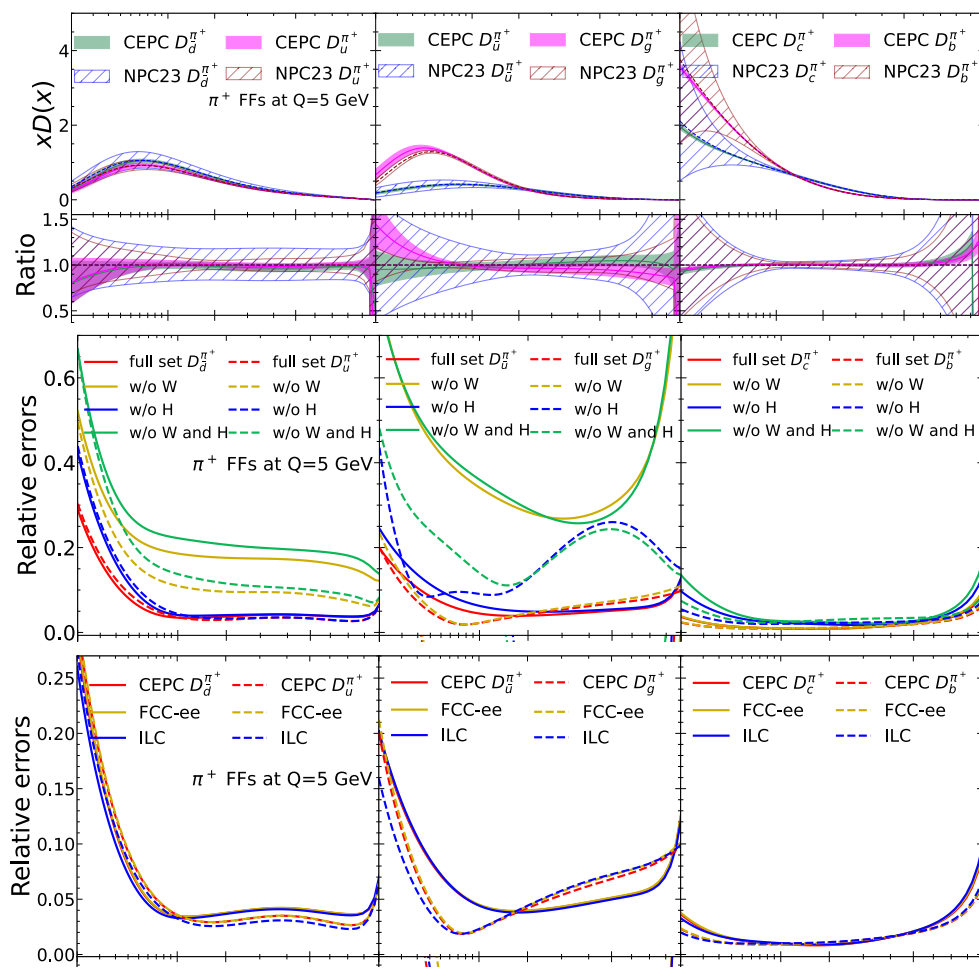
PNRQCD predictions known to N³LO (also including EW+non-resonant effects @ NNLO)

$$R \sim v \sum_k \left(\frac{\alpha_s}{v} \right)^k \cdot \left\{ \underbrace{1}_{\text{(LO)}} ; \underbrace{\alpha_s, v}_{\text{(NLO)}}; \underbrace{\alpha_s^2, \alpha_s v, v^2}_{\text{(NNLO)}}; \underbrace{\alpha_s^3, \alpha_s^2 v, \alpha_s v^2, v^3}_{\text{(N3LO)}}; \dots \right\}$$

[Beneke, Kiyo, Marquard, Penin, Piclum, Steinhauser '15]

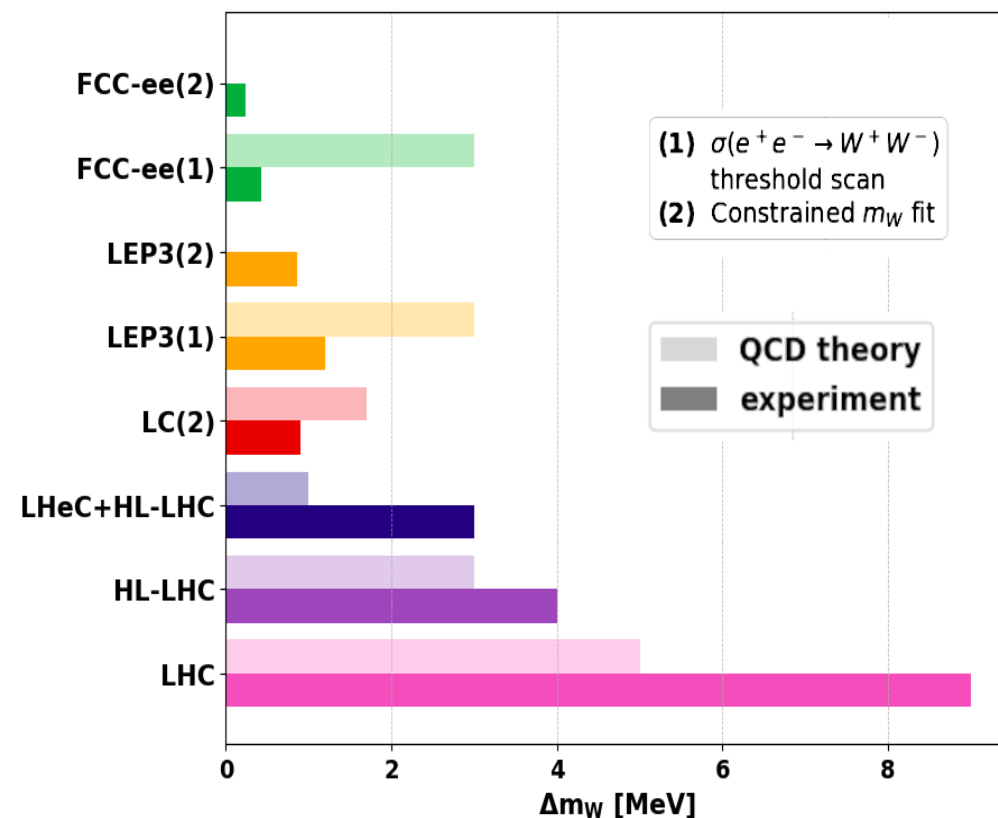
Parton FFs at FCC-ee

- High luminosity and high energies of future lepton colliders open new opportunities for precision determination of FFs - [2407.10059](https://arxiv.org/abs/2407.10059)
- Fits to FFs at NLO in QCD carried out with data solely from future e^+e^- colliders



- Assuming same (un-)correlated systematic uncertainties as SLD measurements
- Statistical errors calculated based on prescribed luminosities
- W boson data essential for **quark flavour separation**
- Similarly Higgs boson data for constraining **gluon FFs**
- **ILC, FCC-ee and CEPC give quite similar results** except in regions limited by statistics

W boson mass at FCC-ee



- $\sigma_{WW}(\sqrt{s})$ scan in leptonic decays: $\Delta m_W \approx \pm 0.4$ MeV (exp.)
- Theory uncertainties (including mixed EW \otimes QCD): $\Delta m_W \approx 3$ -5 MeV
- Constrained m_W fit: $\Delta m_W \approx \pm 0.25$ MeV
- HL-LHC+LHeC: $\Delta m_W \approx \pm 3$ MeV (± 1 MeV from PDFs)

- Different high-precision m_W extractions require parallel QCD processes
- m_W measurements help us understand non-pQCD i.e. color reconnection effects

People involved

 Cognome 	 Nome 	%
Camarri	Paolo	10%
Cerrito	Lucio	10%
De Sanctis	Umberto	10%
Di Ciaccio	Anna	10%
Giuli	Francesco	20%
Vanadia	Marco	10%

- Since < 2 FTE, we are under Dotazioni Gruppo 1
- ~1.2 k€ metabolismo
- ~4.5 k€ conferences and workshops
- Missions to be opened under RD FCC Bologna
- For the time being just analyses-oriented contribution
- Detector-oriented contribution in the future **if able** to increment FTE/people

0.7 FTE in total