Apertura sigla R&D FCC

Francesco Giuli

CdS Roma Tor Vergata - Preventivi

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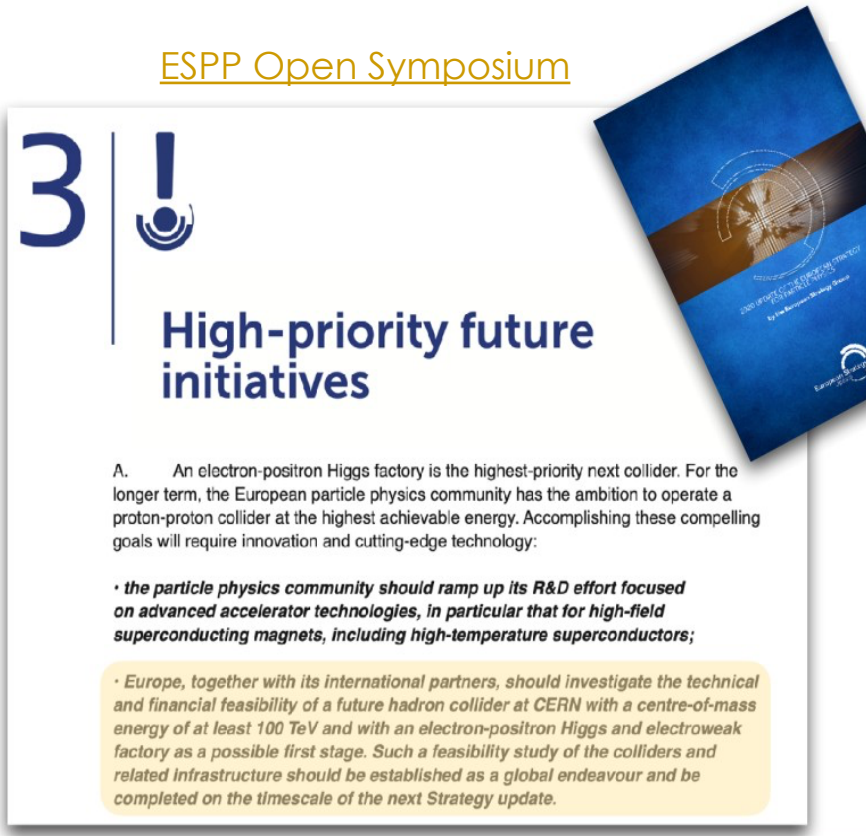
Particle physics in the middle of 2025

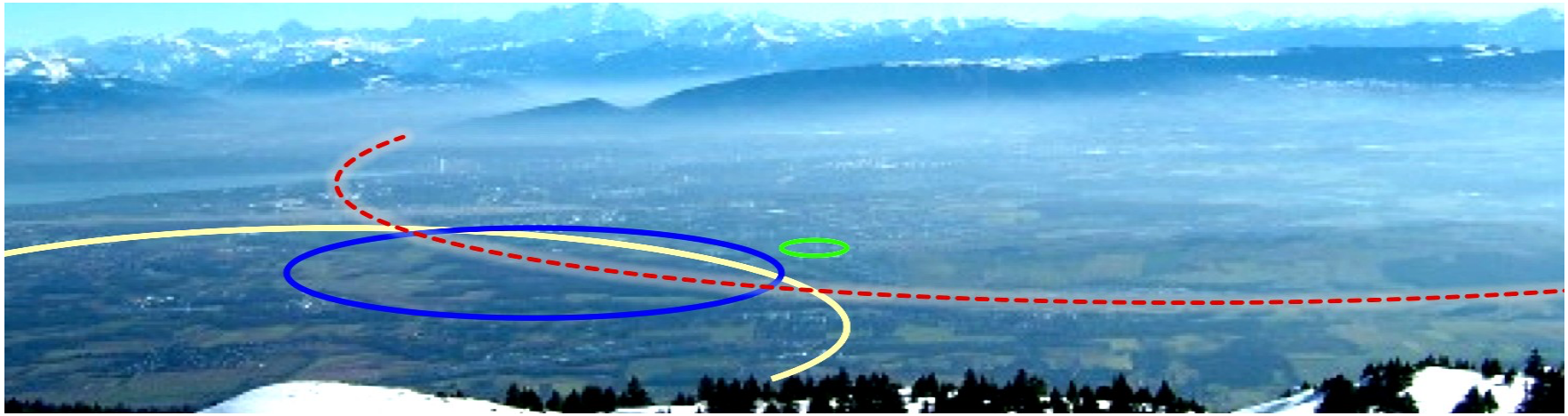
- Apart from the Higgs discovery, all fundamental questions that motivated the LHC still remain open!
  - DM, matter-antimatter asymmetry, EW-Planck hierarchy, strong CP problem, υ masses, …
- World priority is a **high-precision Higgs factory** to precisely probe the crucial scalar sector of the SM
- 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, υ?, DM?)
  - Flavour-violating $H \to qq'$ decays?
- Followed by energy-frontier **hadron collider (FCC-hh)**: Higgs self-couplings + direct BSM searches up to $\Lambda \approx 100$ TeV

ESPP Open Symposium



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

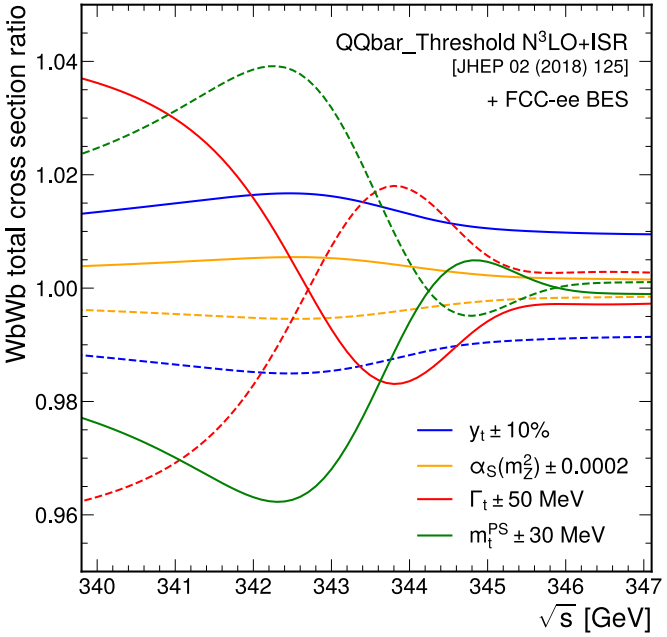


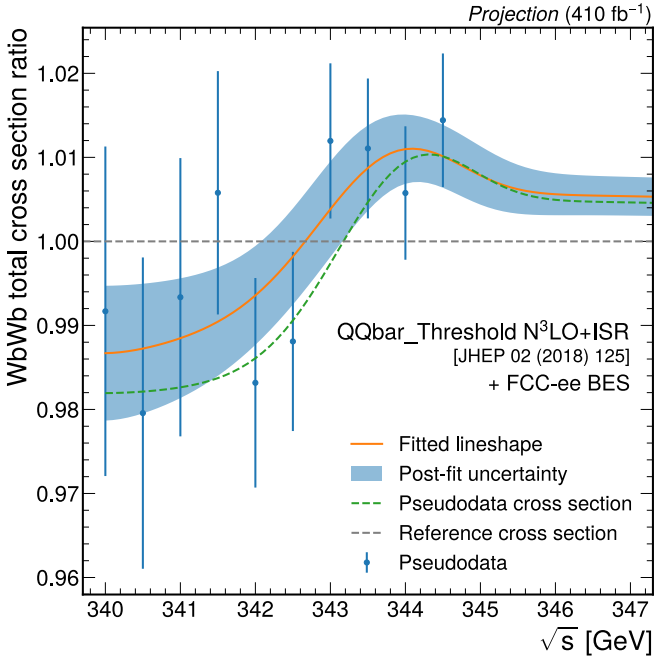
Working point	Z, years 1-2	Z, later	WW	HZ	$t\bar{t}$		(s-channel H)
$\sqrt{s}$ (GeV)	88, 91, 94		157, 163	240	340-350	365	m_H
Lumi/IP ($10^{34}\,cm^{-2}s^{-1}$)	115	230	28	8.5	0.95	1.55	(30)
Lumi/year (ab^{-1}, 2 IP)	24	48	6	1.7	0.2	0.34	(7)
Physics Goal (ab^{-1})	150		10	5	0.2	1.5	(20)
Run time (year)	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 → **tiny systematic uncertainties (10^{-5})**

Top quark mass at FCC-ee

- e^+e^- collisions from threshold scan around $\sqrt{s}$ = 340-345 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

2503.18713

- QCD theory for $\sigma(e^+e^- \to t\bar{t})$ vs. $\sqrt{s}$ at threshold:

$\Delta m_{top} \approx \pm 35$ MeV from N³LO scale uncertainties

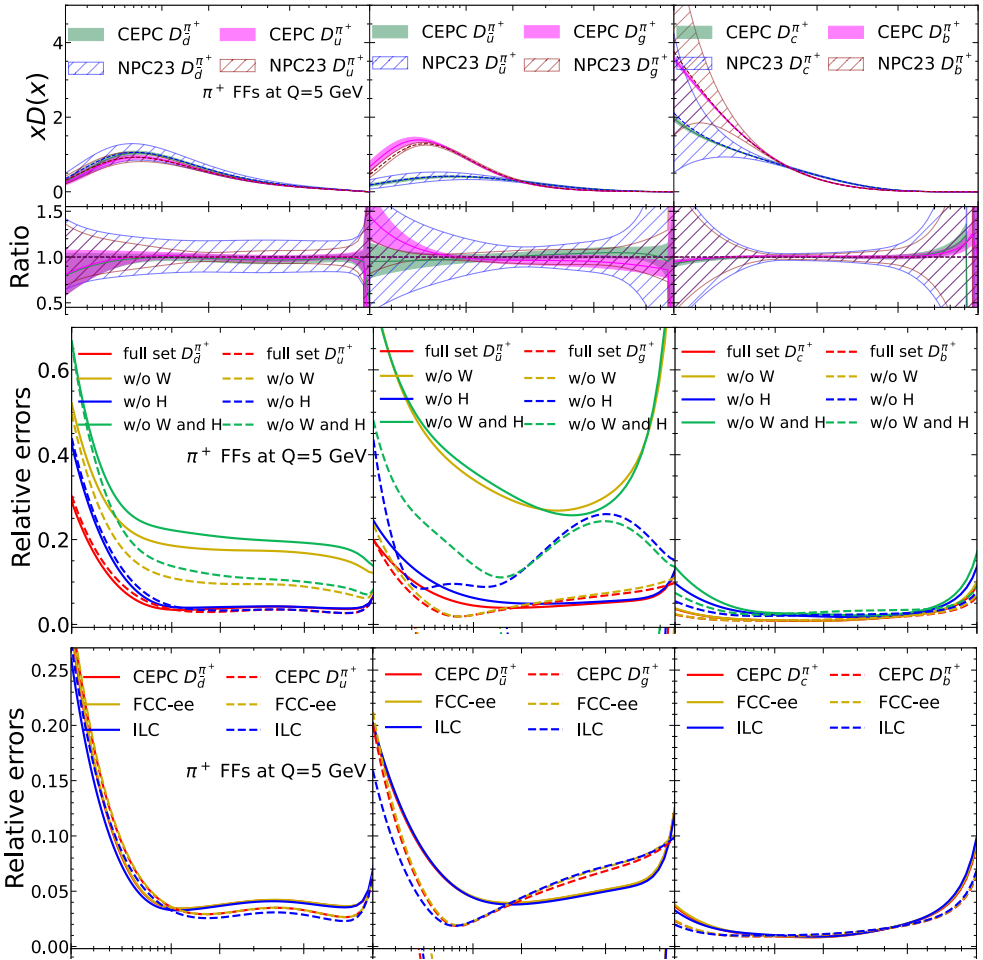
PNRQCD predictions known to N³LO (also including EW+non-resonant effects @ NNLO)

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

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

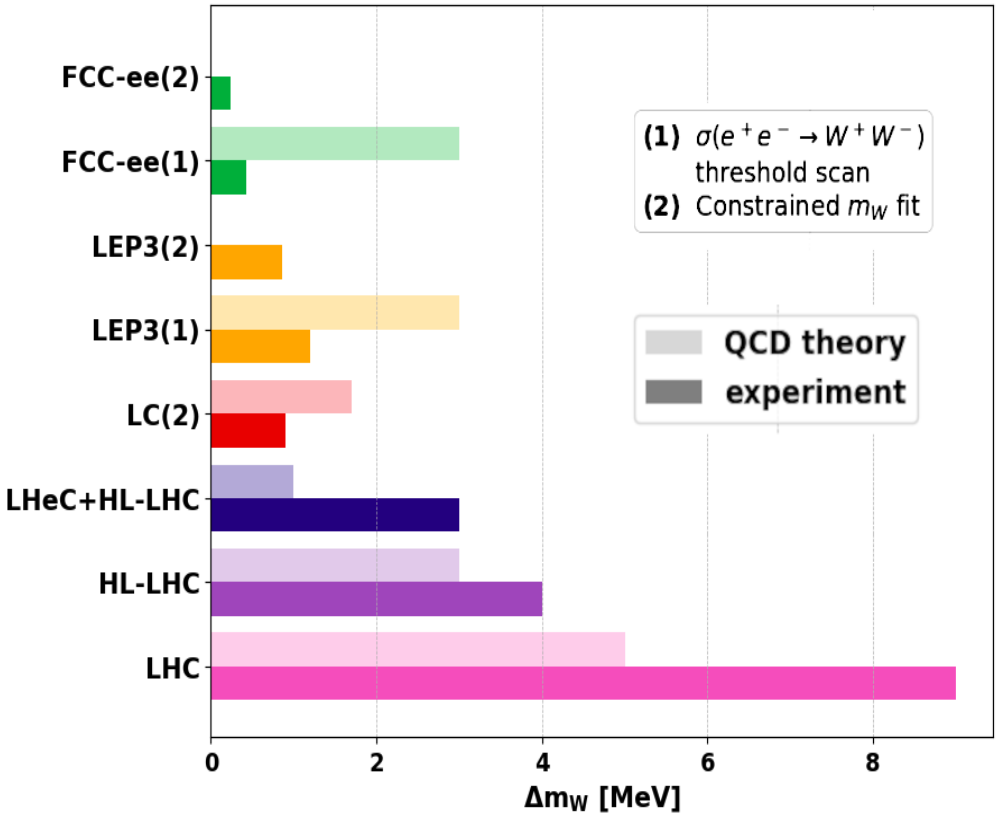
Parton FFs at FCC-ee

- High luminosity and high energies of future lepton colliders open new opportunities for precision determination of FFs - 2407.10059
- 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 constarining **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⊗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%

0.7 FTE in total

- 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