Journal Club

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Higgs physics at the Future Circular Collider

Open fundamental aspects of the Higgs sector of SM can can be experimentally studied at FCC:

- lightest fermions: uds, e^{+-}, neutrinos
- Higgs potential: λ_3, λ_4 — via pp collision
- new physics coupled to scalar SM sector
- dark matter — via on/off-shell boson invisible decay

Generation of the lightest fermion masses

FCC is a post-LHC project in a new 100-km tunnel under consideration at CERN, designed to deliver pp at $\sqrt{s}$ = 100 TeV with $\mathcal{L}_{int}$ = 0.2-2 ab^{-1}/yr integrated luminosities (FCC-hh), as well as e^+e^- $\sqrt{s}$ = 90-350 GeV with up to 80 ab^{-1}/yr (FCC-ee).

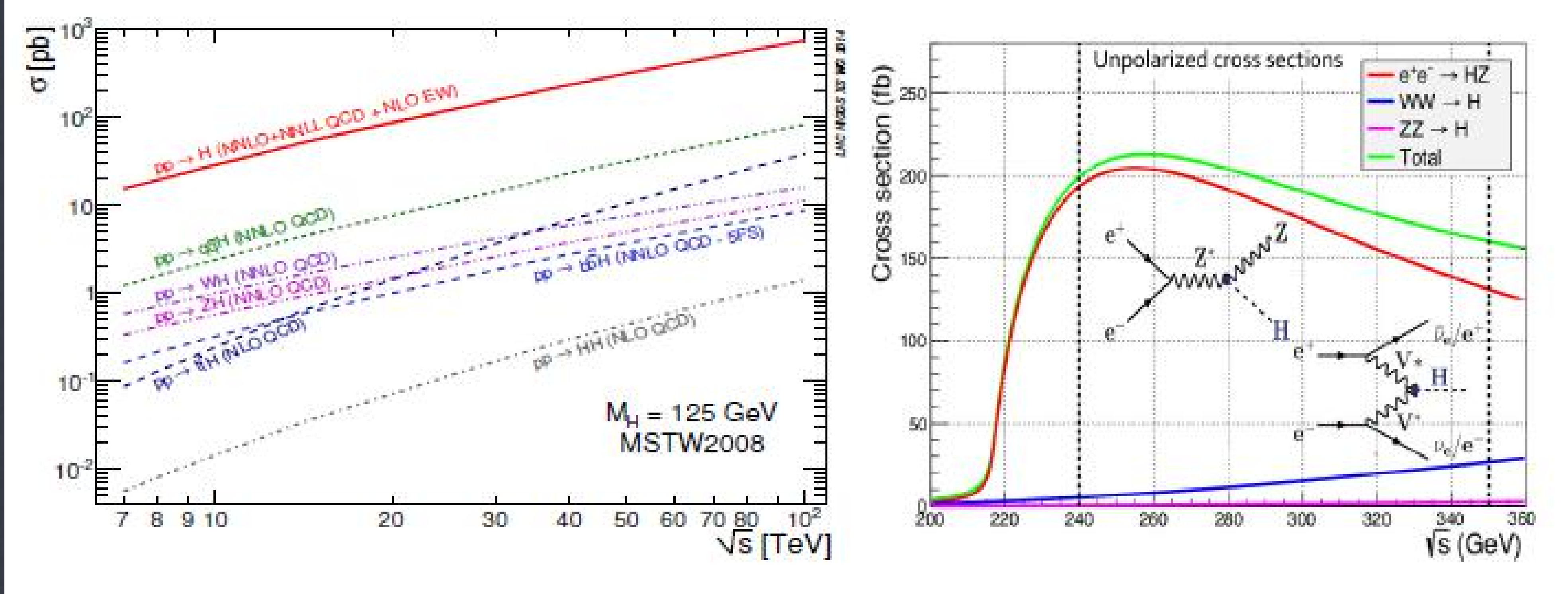


Figure 1: Higgs boson cross sections as a function of c.m. energy (total, and separated for different subprocesses) in pp (left) [6] and e^+e^- (right) [5] collisions.

Generation of the lightest fermion masses

Higgs boson $\xrightarrow{\text{couple}}$ fundamental fermions $\xrightarrow{\text{decay}}$ stable visible matter

formed by 1st generation fermions($u\bar{u}$, dd, ss, $e^{\pm}$)

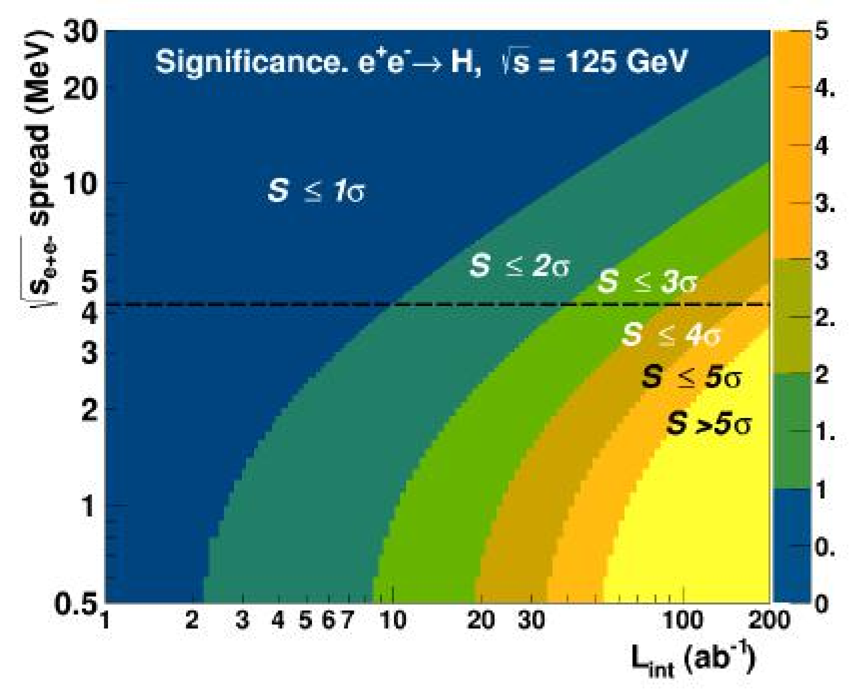


Figure 2: Significance contours for the $e^+e^- \to$H observation at $\sqrt{s} = 125$ GeV (combining 10 Higgs boson decays) in the $\sqrt{s}$-spread vs. $\mathscr{L}_{int}$ plane at FCC-ee [9]. The dashed line shows the natural H boson width.

Sterile neutrinos Ni produced at FCC-ee, observed via Ni → H + v

Determination of the Higgs potential

process	(statistical) precision on σ_{SM}	68% CL interval on Higgs self-couplings
$HH \to b\bar{b}\gamma\gamma$	3%	$\lambda_3 \in [0.97, 1.03]$
$HH \to b\bar{b}b\bar{b}$	5%	$\lambda_3 \in [0.9, 1.5]$
$HH \to b\bar{b}4\ell$	$O(25\%)$	$\lambda_3 \in [0.6, 1.4]$
$HH \to b\bar{b}\ell^+\ell^-$	$O(15\%)$	$\lambda_3 \in [0.8, 1.2]$
$HH \to b\bar{b}\ell^+\ell^-\gamma$	–	–
$HHH \to b\bar{b}b\bar{b}\gamma\gamma$	$O(100\%)$	$\lambda_4 \in [-4, +16]$

Table 1: Expected precision on SM cross sections for double and triple Higgs final-states reachable at FCC-hh (pp at 100 TeV, 30 ab^{-1}), and associated 68% CL ranges on λ_3 and λ_4 Higgs self-couplings. Details are provided in [6].

λ3, λ4 self-coupling interaction,
Higgs determination

↓

confirm the shape of the Higgs potential and the mechanism of electroweak symmetry breaking

Searches for new scalar-coupled physics

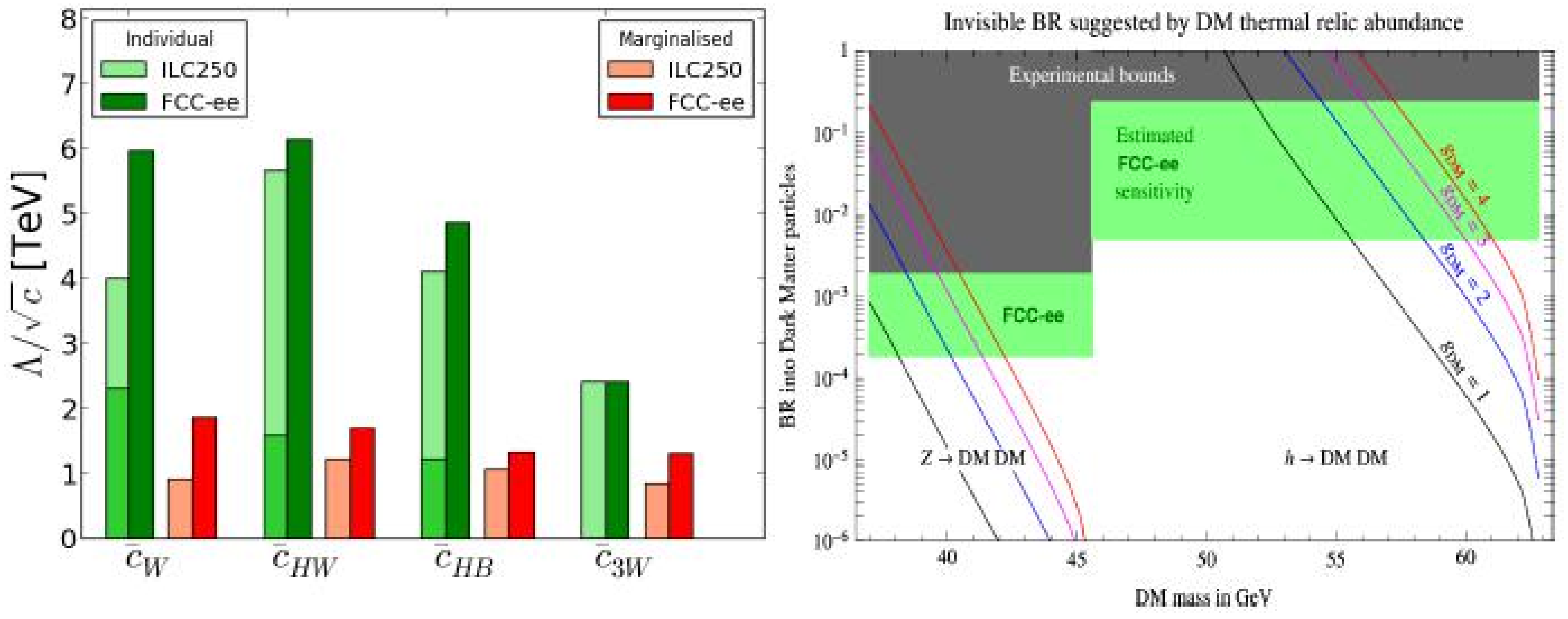
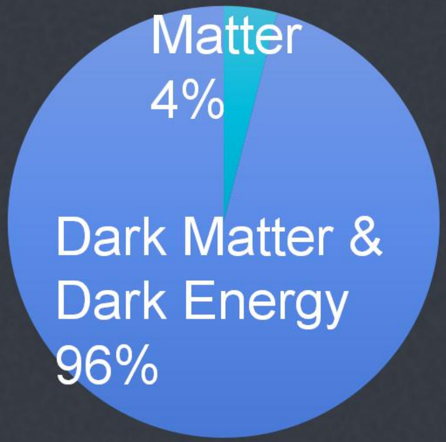


Figure 3: Left: Sensitivity reach to new physics scales ($\Lambda/\sqrt{c_i}$), encoded in four dim-6 operator c_i coefficients, of precision Higgs (and triple gauge boson couplings) measurements at FCC-ee and ILC [17]. Right: FCC-ee sensitivity for rare H (and Z) decays into DM pairs in the $\mathrm{BR}_{\mathrm{H,Z}\to\phi\phi}$ vs. m_ϕ plane [23].

Dark Matter



In Higgs-portal models, the H boson acts as a mediator between the SM and DM particles, playing a central role in the evolution of the early universe. Attractive scenarios exist for DM candidates (Φ) lighter than mH;Z/2, consistent with the measured DM thermal relic abundance in the universe, with DM freezing out through resonant H (or Z) exchanges. In such cases, the measurements of the invisible H and Z widths provide the best collider options to test such scenarios.

Theoretical studies indicate that the FCC-hh can place strong constraints on Higgs-portal couplings.

THANK YOU