# ECFA Focus Topic: CKMWW

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ILD Meeting "A detector for a Higgs factory and beyond: ILD"
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# Goal

- Use W decays to measure CKM matrix elements $|V_{ij}|$, ~ directly by counting

- Allows for direct, model-independent access to 6 CKM elements (without top)

- Of particular interest: $V_{cb}, V_{cs}, (V_{ub})$

  - test of unitarity of the CKM matrix

  - $V_{cs}$ for comparison with indirect leptonic charmed meson decays

  - $V_{cb}$ to resolve discrepancy between in- & exclusive determinations via semilep. B decays, controls unitarity triangle normalisation $\rightarrow$ already systematically limited at Belle!

  - $V_{ub}$ as test of lattice QCD needed for results from Belle II

- With 100% reconstruction efficiency: $\delta_{V_{ij}}^{th} = \frac{1}{2} N_{ev}^{-1/2}$

for $10^8$ W:

| $W^- \rightarrow$ | $\bar{u}d$ | $\bar{u}s$ | $\bar{u}b$ | $\bar{c}d$ | $\bar{c}s$ | $\bar{c}b$ |
|---|---|---|---|---|---|---|
| BR | 31.8% | 1.7% | $4.5 \times 10^{-6}$ | 1.7% | 31.7% | $5.9 \times 10^{-4}$ |
| $N_{ev}$ | $64 \times 10^6$ | $3.4 \times 10^6$ | 900 | $3.4 \times 10^6$ | $63 \times 10^6$ | $118 \times 10^3$ |
| $\delta_{V_{ij}}^{th}$ | 0.0063 % | 0.027 % | 1.7 % | 0.027 % | 0.0063 % | 0.15 % |

# Necessary Tools

- Identify quark flavours → [flavour tagging tools](#)

  - LCFIPlus is well-established standard

  - a number of new taggers based on neural networks ([1](#), [2](#), [3](#), [4](#)) are being developed, full integration in key4HEP (hopefully) soon

- b, c-tagging need vertexing, well established tools part of reconstruction chains, profit from new tracking algorithms and hardware developments (ALICE ITS3)

- s-tagging needs PID, likely the reason why ILD and IDEA (with dE/dx / dN/dx) in particular are working on s-tagging, new tool ([CPID](#)) being established

DESY.

# Necessary MC Samples

- Center of mass energies

  - theshold scan around 160 GeV interesting for W mass, rather low cross section, no contamination from ZZ

  - 250 GeV is default working point for Higgs factory and has a good WW cross section

  - at higher energies lower cross section, but more boost which is probably helpful for vertex-based tagging, but less so for PID, at some point JER worsens

- Typical expected numbers of WW at 250 GeV at ILC and 160 GeV at FCC-ee: $O(10^8)$

  - ILC profits from ca. factor 2 due to polaristion

  - multiply with number of detectors for FCC-ee

- FCC-ee MC samples are needed

- ILD MC samples with full sim/reco exist, 250 GeV is ca. 12 ab$^{-1}$ (exceeds H-20 by >3 in each pol. channel) and good to go, 500 GeV is ca. 0.5 ab$^{-1}$ and missing some newer reconstruction aspects; might need dedicated samples for $V_{ub}$

# Analysis?

- One analysis being set up by UE

    – use new CPID for particle identification

    – use new neural network tagger (M. Meyer) for flavour tagging

    – use 250 GeV ILD MC production from 2020

    – target: statistical uncertainty on $\left|V_{ij}\right|$ including reconstruction efficiencies and backgrounds

    – focus on $V_{cs}$ (impact of PID on s-tagging)

- FCC-ee (IDEA) analysis desired!

- Given huge statistics, study of systematics are vital and can inform detector design decisions!