Flavour at FCC(-ee)

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Scope of Flavour Physics @ FCC(-ee)

- Flavour physics reach with $O(10^{13})$ Z decays (10^8 W, 10^6 Higgs, top)
  - rare decays of c- and b-hadrons and CP violation in the heavy-quark sector
  - rare lepton decays
  - rare Z, (W, h, t?) decays
- In the context of ultimate potential of the LHCb upgrade and Belle II experiments.

FCC CDR

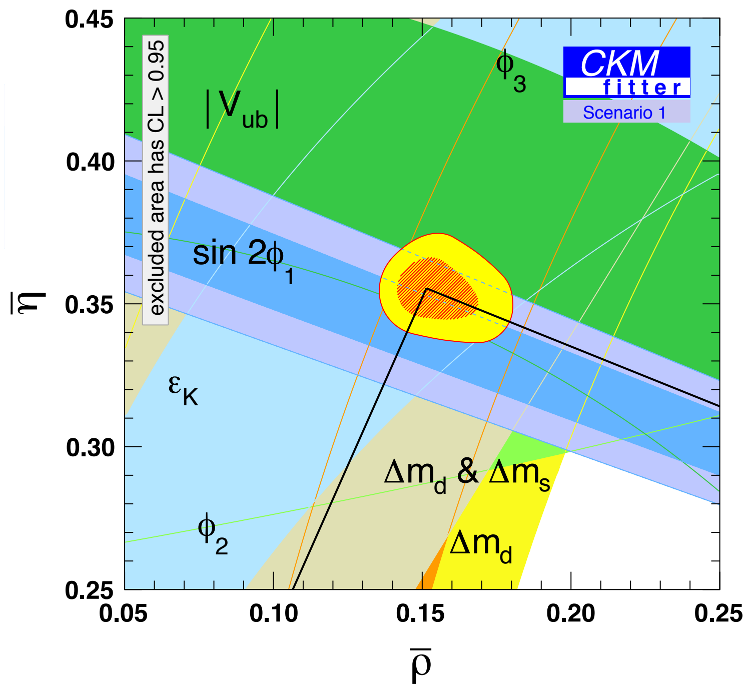
Working point	Lumi. / IP [10^{34} cm^{-2}.s^{-1}]	Total lumi. (2 IPs)	Run time	Physics goal
Z first phase	100	26 ab^{-1} /year	2	
Z second phase	200	52 ab^{-1} /year	2	150 ab^{-1}

Particle production (10^9)	B^0	B^-	B^0_s	Λ_b	$c\bar{c}$	$\tau^-\tau^+$
Belle II	27.5	27.5	n/a	n/a	65	45
FCC-*ee*	400	400	100	100	800	220

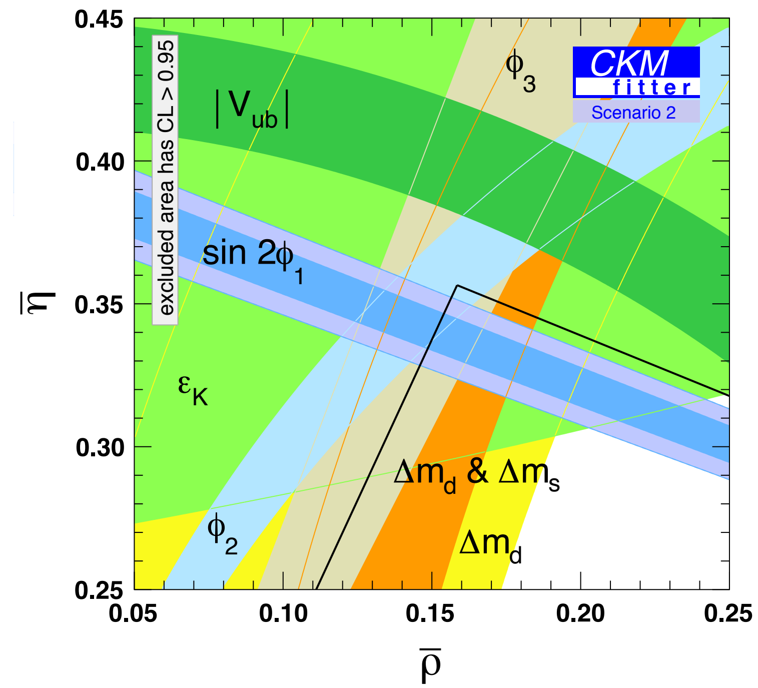
Flavor physics circa 2030: possible scenarios

WA

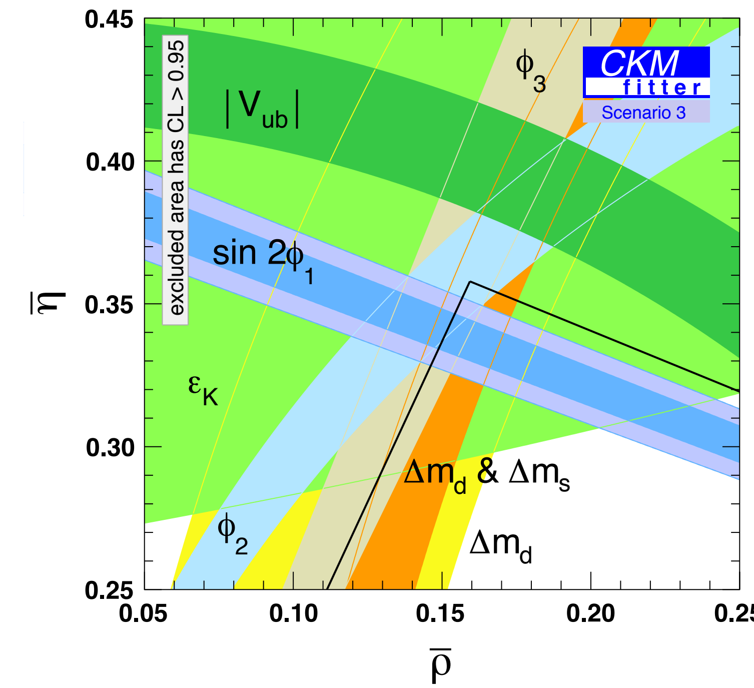
Now



50 ab^{-1} Belle II

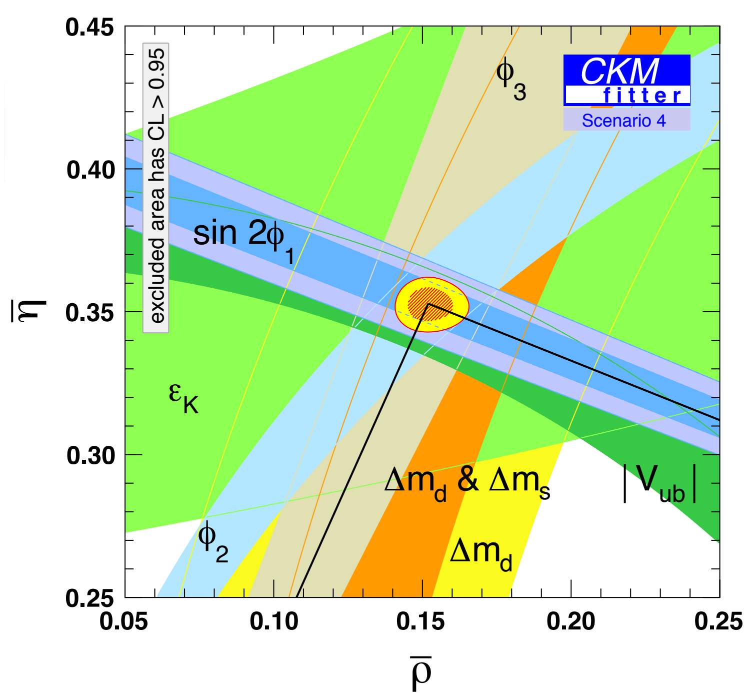


50 ab^{-1} Belle II + LHCb



SM-like

50 ab^{-1} Belle II



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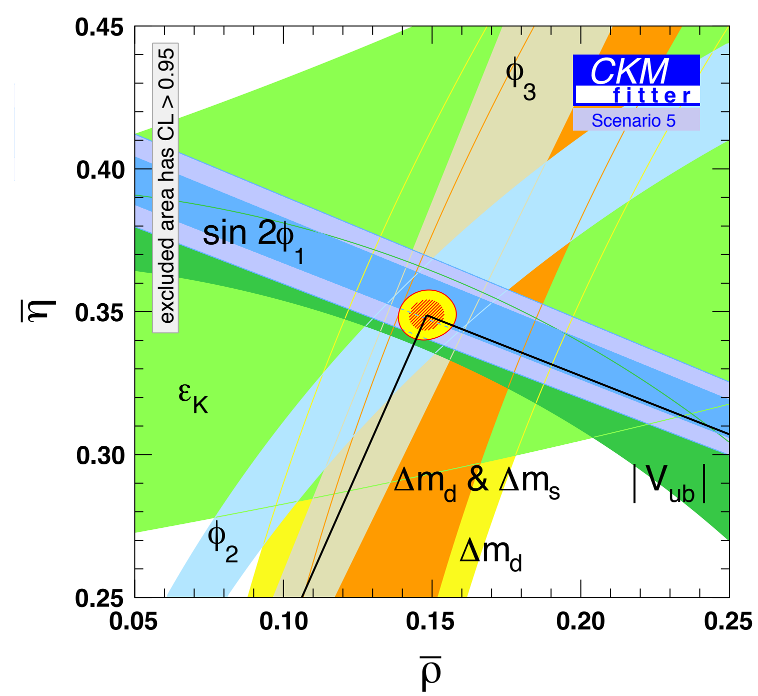

+ discoveries or bounds from high-pT LHC searches

Mandate of Flavour Physics Group

with Gino Isidori

- identify key topics and observables
(extensive and focused primarily on FCC-ee)
- propose new benchmark measurements
(interface with exp. groups - detector requirements, exp. reach)
- project requirements and feasibility of precision calculations
(i.e. EM/EW corrections, lattice QCD)

Interface with other working groups:

- Flavor of Higgs interactions ($h \to \bar{f} f'$, CPV, …)
- top-quark as a probe of flavor (V_{tx}, CPV, LFU)
- Flavor at high p_T (CKM from W decays, FCNC Z decays, …)

Flavour Physics at FCC (in progress)

with Gino Isidori

Contents

1 Leptonic and semileptonic b decays

1.1 $b \to c$

1.1.1 $B_c \to \ell\nu$ and $B_c \to \tau\nu$

Focus on LFU tests.

1.1.2 $b \to X_c\ell\nu$ and $b \to X_c\tau\nu$

Angular analysis and LFU ratio.

1.2 $b \to u$

1.2.1 $B \to \pi\ell\nu$ and $B \to \pi\tau\nu$

Absolute BR (measurement of $|V_{ub}|$), angular analysis and LFU ratio. Closely related with similar goals: $B_s \to K\ell\nu$.

1.2.2 $B_u \to \ell\nu$ and $B_u \to \tau\nu$

Focus on LFU tests. Estimate of ultimate precision, since it determines theoretical limits.

2 Rare leptonic and semileptonic b decays

2.1 $b \to s$

2.1.1 $B \to K^{(*)}\tau\tau$

Sensitivity study of angular analysis including tau polarization observables. Suggestion: using $B \to K^{(*)}\mu\mu$ as normalization at the differential level.

J. F. K., S. Monteil, A. Semkiv and L. V. Silva,1705.11106
L. Li and T. Liu, 2012.00665

2.1.2 $B_s \to \tau\tau$

BR, time dependent study, tau polarization.

see also R. Fleisher et al., 1709.04735, 1303.3820

2.1.3 $B \to X_s\ell\ell$

How close the experimental approach can get to the fully inclusive observables. Possible search for (long-lived/displaced) resonances in di-lepton spectrum.

2.1.4 $B \to K^{(*)}\nu\nu$

BR, time dependent studies (theoretical proposal in progress).

see also S. Descotes-Genon, M. Novoa-Brunet, K. Vos, 2008.08000

2 Rare leptonic and semileptonic b decays

2.1.5 $B \to \pi\ell\ell$, $B \to \rho\ell\ell$, $B_s \to K^{(*)}\ell\ell$

Study of backgrounds (even from rare processes).

2.1.6 $B_d \to \tau\tau$

Separation from $B_s \to \tau\tau$.

2.2 $B_{d,s} \to \ell\ell'$ and $B_{d,s} \to h\ell\ell'$

Lepton flavor and lepton number violating modes. Strongest theoretical interest in $\ell = \tau$, need experimental sensitivity study.

3 CPV in b decays and mixing

3.1 γ

Ultimate experimental precision (theory study in ref. [1]).

J. Brod and J. Zupan, 1308.5663

3.2 ϕ_s

3.2.1 $B_s \to \phi\psi$ and $B_s \to \phi\phi$

Potential to challenge theory. Need theoretical ideas to improve predictions.

3.3 $\gamma + \phi_s$ and $B_s \to D_s K$

Checks on the theory side. Experimental prospects (i.e. ref. [2, 3]).

R. Aleksan, L. Oliver and E. Perez,
2107.05311, 2107.02002

3.4 Mixing induced semileptonic charge assymmetries

Ultimate experimental precision. Can one reach SM theory predictions?

4 Tau physics

4.1 $\tau \to \ell\nu\bar{\nu}$

Ultimate exp. precision on LFU ratios (dominated by statistics or systematics). Need theoretical work to go beyond 10^{-3} relative precision.

4.2 $\tau \to 3\mu$ and $\tau \to \mu ee$

Ultimate experimental sensitivity.

4.3 $\tau \to \ell h$

Experimental sensitivity to $\tau \to \phi\ell$ (see e.g. ref. [4] theoretical motivation). Other benchmark modes ($h = \pi, \eta$).

L. Allwicher, G. Isidori and N. Selimovic, 2109.03833

4.4 $\tau \to \ell\gamma$

Competitive experimental reach to Belle-II?

4.5 $\tau \to X_h\nu$

Study of hadronic moments. How close the experimental approach can get to the fully inclusive observables.

5 Charm physics

5.1 CPV in radiative charm decays

See e.g. ref. [5] for theoretical considerations and connections to ΔA_{CP}.

G. Isidori and J. F. K., 1205.3164

5.2 $D \to h\nu\bar{\nu}$

Can it be done (especially for the neutral mode $D^0 \to \pi^0\nu\bar{\nu}$ or $D^0 \to \rho^0\nu\bar{\nu}$)?

5.3 $\mathbf{D^0} \to \gamma\gamma$

Needed for SM prediction of $D^0 \to \mu\mu$. Can the experimental precision be competitive to Belle-II?