Prospects of CKM parameter measurements at Belle II

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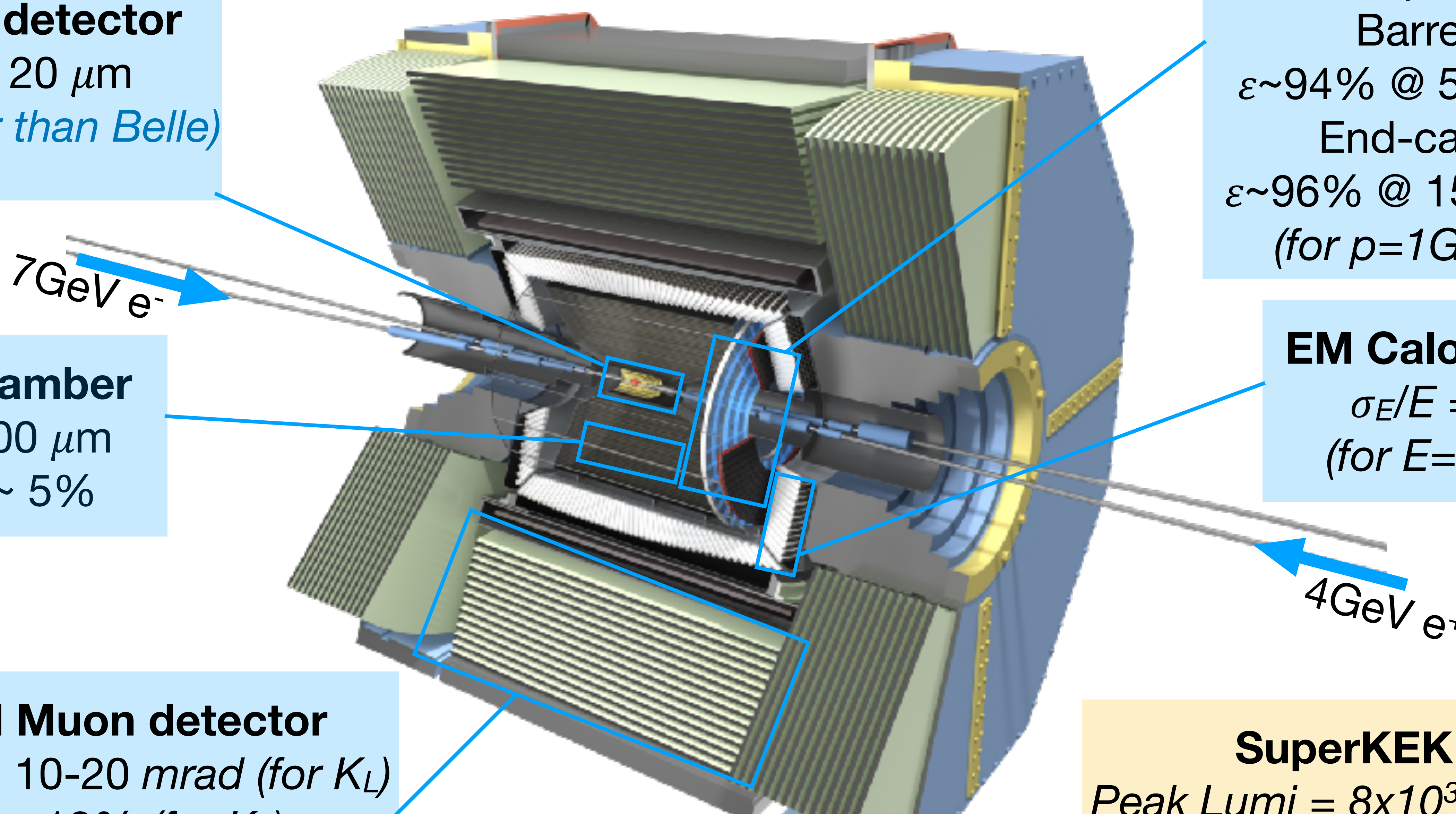
Belle 2 at SuperKEKB

Vertex detector
$\sigma_{z0} \sim 20\ \mu m$
(4x better than Belle)

Drift chamber
$\sigma_{r\phi} \sim 100\ \mu m$
$\sigma_{dE/dx} \sim 5\%$

RICH detectors
K/π separation
Barrel:
$\varepsilon \sim 94\%$ @ 5% fake
End-caps:
$\varepsilon \sim 96\%$ @ 15% fake
(for p=1GeV/c)

EM Calorimeter
$\sigma_E/E = 2\%$
(for E=1GeV)

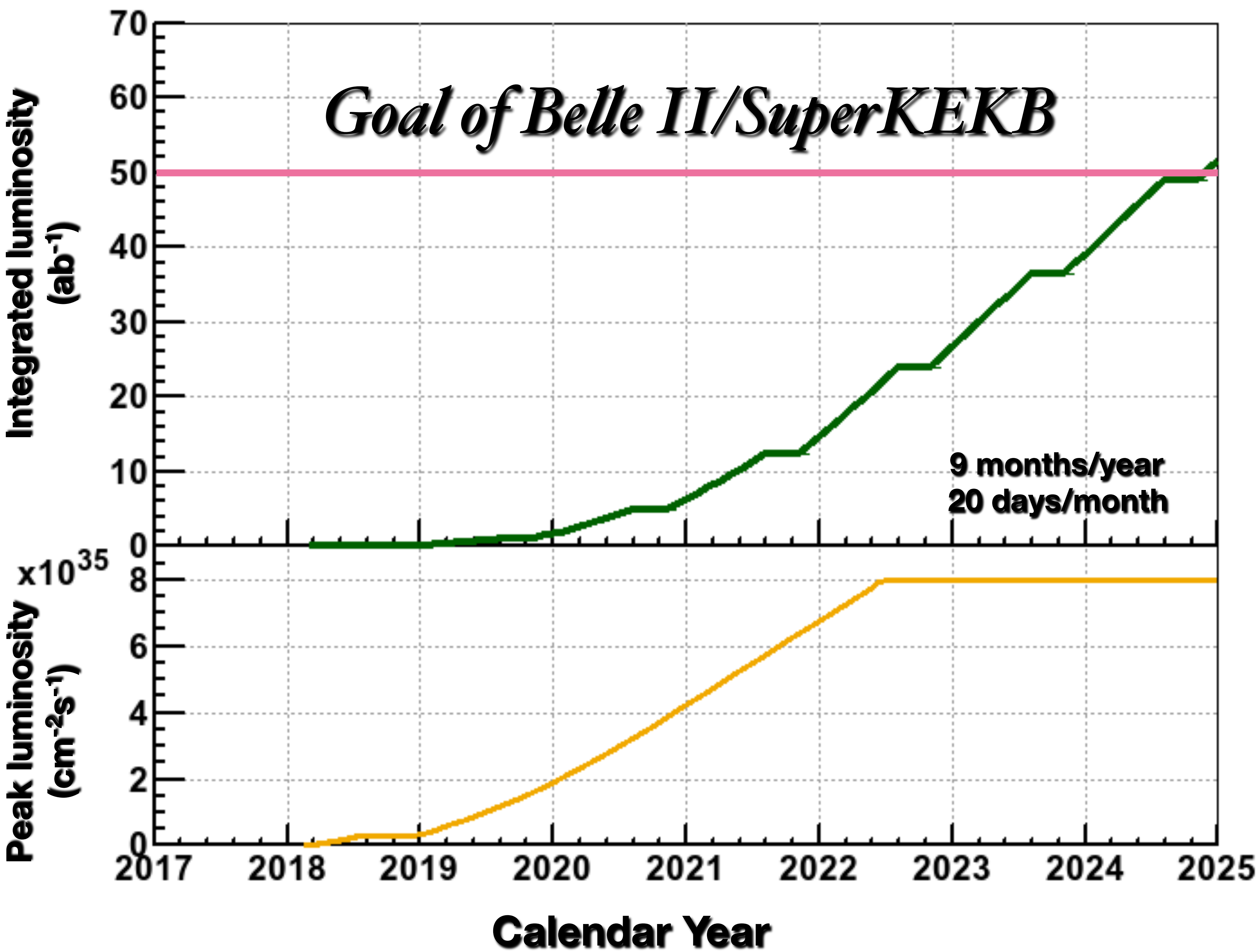


K_L and Muon detector
$\Delta\phi = \Delta\theta \sim 10\text{-}20$ *mrad (for K_L)*
$\sigma_p/P \sim 18\%$ (for K_L)
1% fake μID rate

1000/sec B-mesons stored on disk

SuperKEKB
Peak Lumi = $8 \times 10^{35}\ cm^{-2}s^{-1}$
(40x higher than KEKB)

Schedule



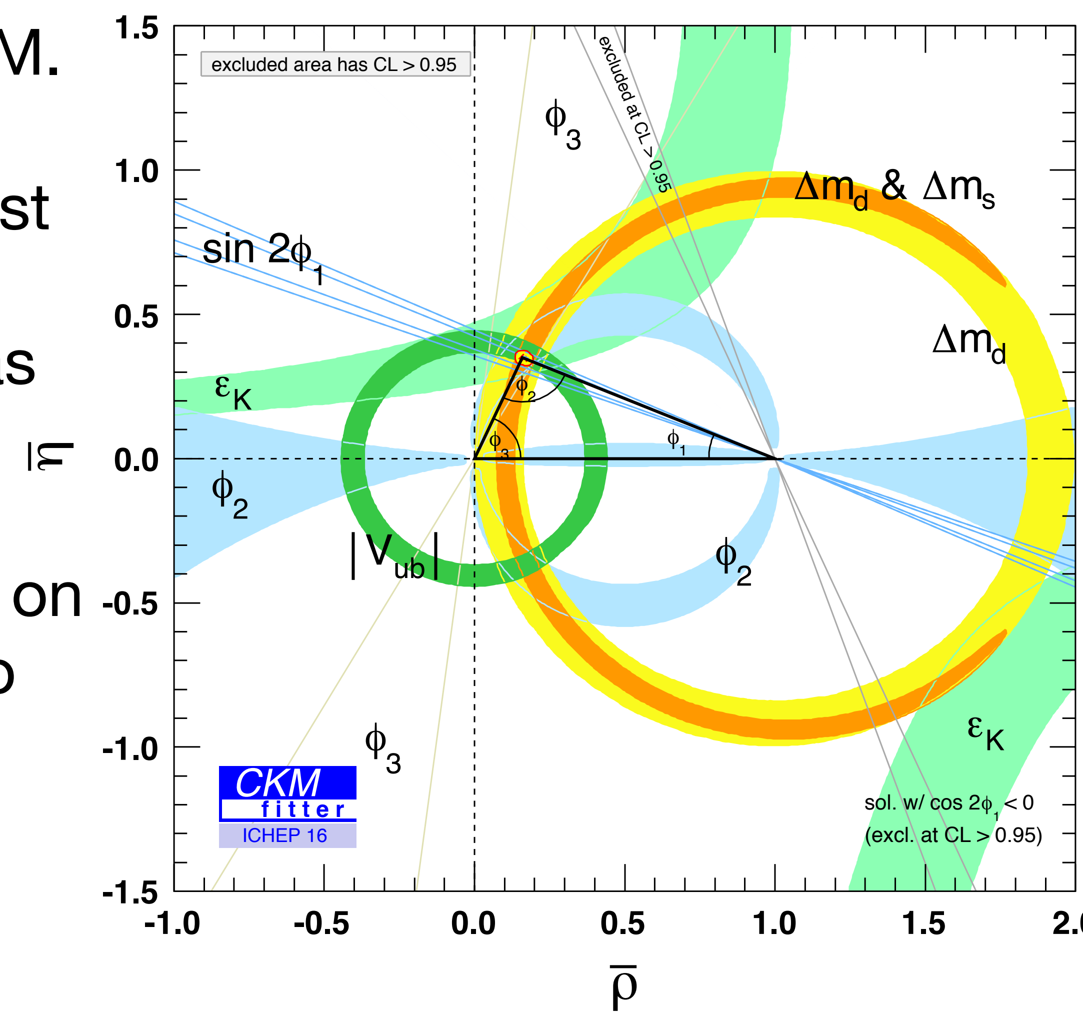
- Collect data w/o vertex detector in 2018, vertex detector is expected in 2019
- Reach B-factories luminosity by 2020
- Collect 5ab^{-1} by 2021
- 50ab^{-1} by 2025

Unitarity triangle status

CKM parameters provide effective null-test of the SM.

- Some of them (ϕ_3, $|V_{ub}|$, $|V_{cb}|$) are of the key interest since they can be extracted from observables in theoretically clean manner and hence can serve as strong probes of the SM.

- Measurement of others (ϕ_1, ϕ_2) is currently based on phenomenological assumptions which will start to limit precision quite soon, but phenomenological advances of the past decade boost their discriminating power.



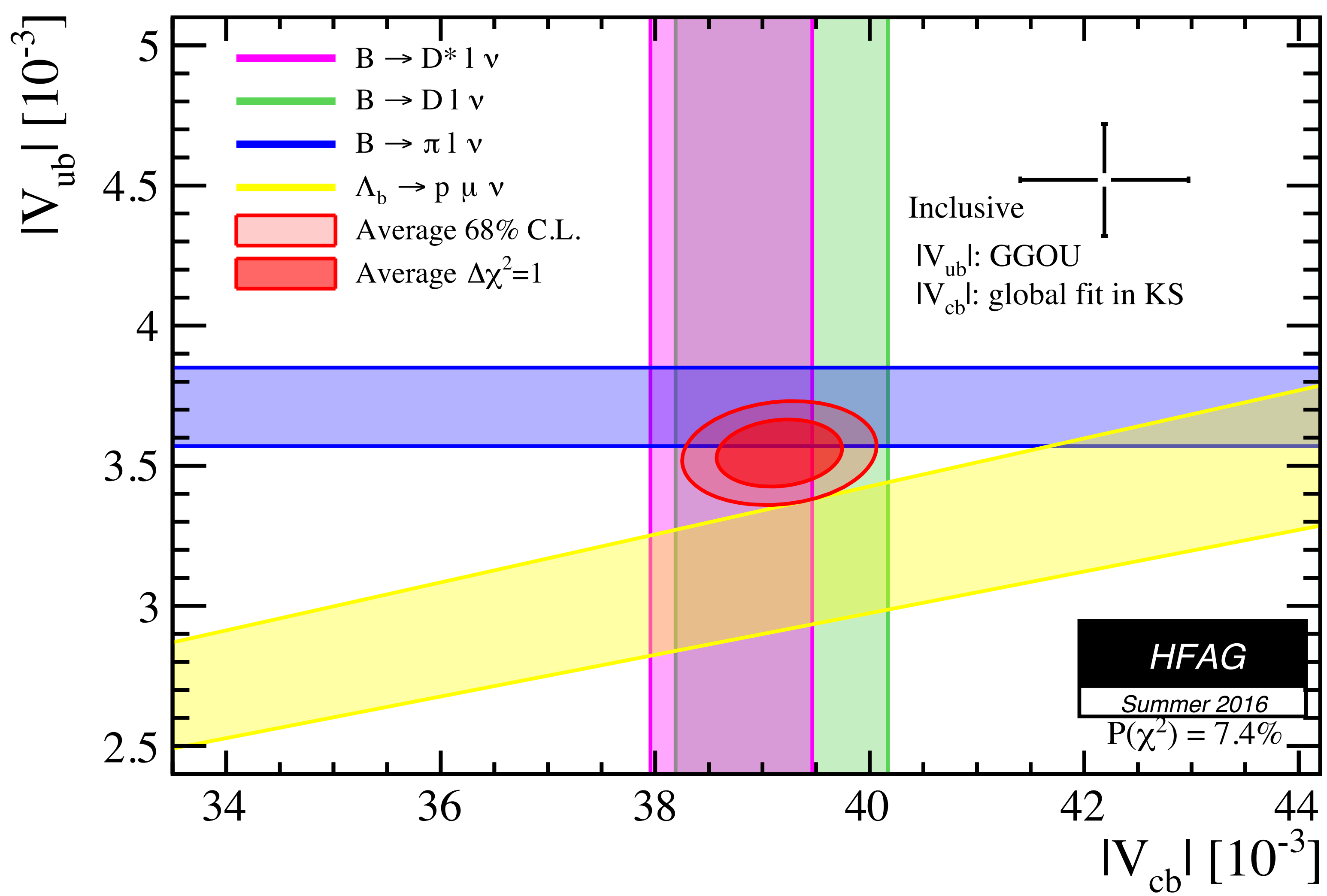
In *B*→*DK* measurements of ϕ_3 Belle II will leverage on accessibility to many different modes and reduced difficulties in Dalitz analysis, which will compensate LHCb's larger sample.
In semileptonic determinations of $|V_{ub}|$ Belle II will benefit from sensitivity to neutrals in final states and full event interpretation.

Semileptonic status

$|Vub|^{incl}=(4.52\ ^{+0.19}_{-0.21})x10^{-3}$ $|Vcb|^{incl}=(42.19 \pm 0.78)x10^{-3}$

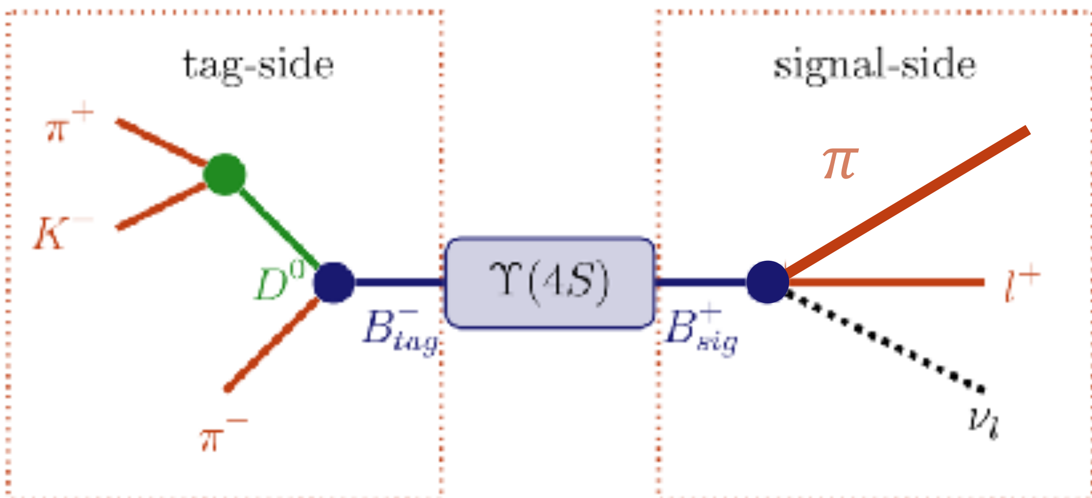
$|Vub|^{excl}=(3.55 \pm 0.12)x10^{-3}$ $|Vcb|^{excl}=(39.16 \pm 0.58)x10^{-3}$

- Currently there is a tension between inclusive and exclusive measurements
- Belle II is expected contribute to both exclusive and inclusive measurements
- LHCb will contribute to exclusive measurements, in particular through Λ_b and B_s decays, where Belle II sensitivity will be very limited



$|V_{ub}|$ in $B \to \pi l \nu$

“Tagged” measurement

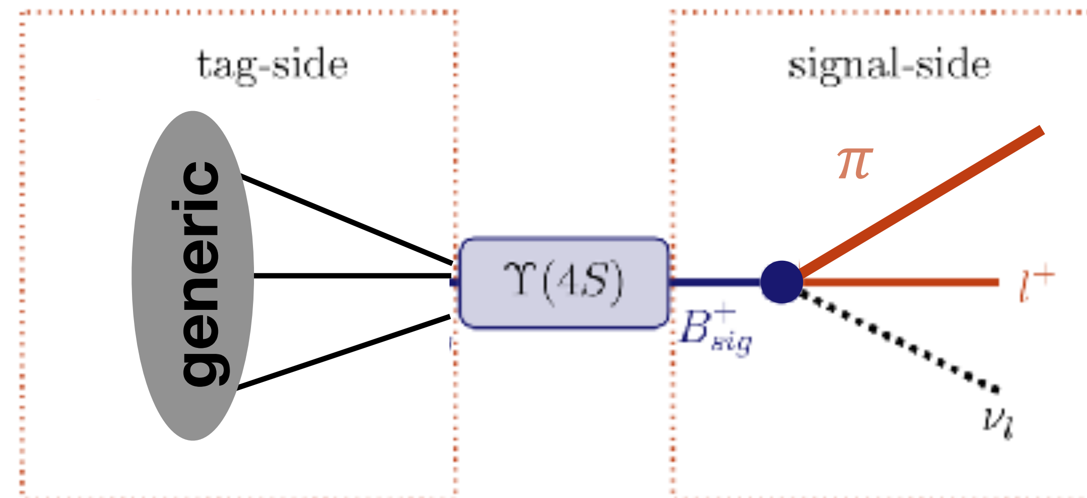


Exact momentum of companion B gives good q^2 resolution.

ϵ = 0.55% (0.3%@Belle)

Improvement w.r.t. Belle is due to the better tagging algorithms

“Untagged” measurement



Indirect determination of companion B momentum spoils q^2 resolution.

ϵ = 20% (11%@Belle)

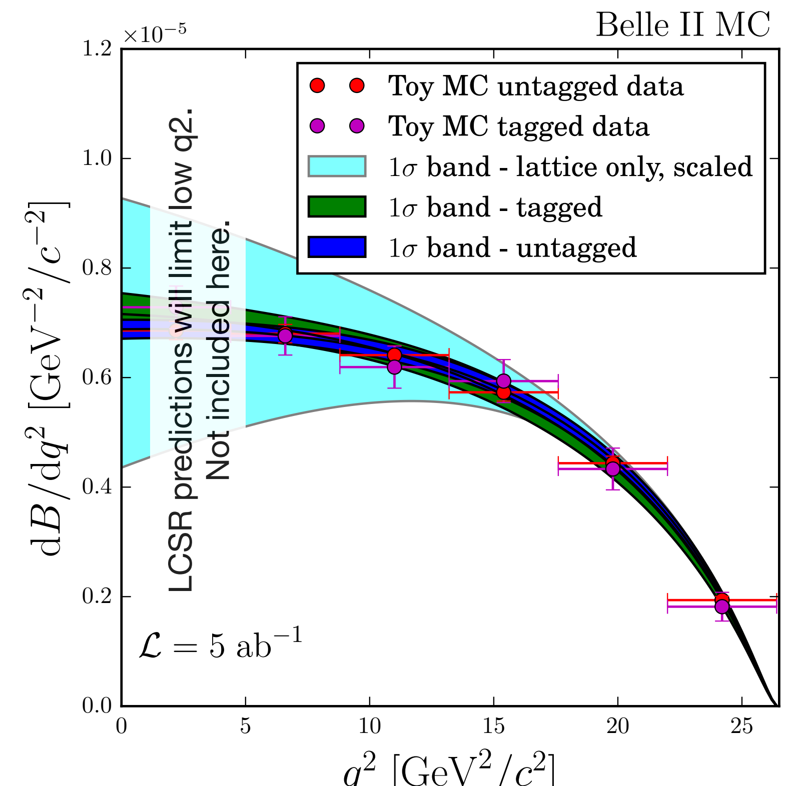
Improvement w.r.t. Belle is due to the better Rest-Of-Event handling

$|V_{ub}|$ from $B \to \pi l \nu$ *(exclusive)*

Currently: δ_{exp}~3.4%, δ_{th}~4.5%

$|V_{ub}|$ is probed directly through combination of QCD-calculated form factors and measured differential branching fraction in bins of transferred from the B meson to leptons ($q^2 \equiv (p_B - p_\pi)^2$).

$$\frac{d\mathcal{B}(B \to \pi l \nu)}{dq^2} = |V_{ub}|^2 \frac{G_F^2 \tau_B}{24\pi^3} p_\pi^3 |f_+^{B\pi}(q^2)|^2$$



Projections of differential branching of $B \to \pi l \nu$ for 5ab^{-1} with theoretical expectations overlaid

Theory uncertainty now dominates.

However, **5x improvements expected** in the next decade will compound with Belle 2 measurements for unprecedented exploratory power

$|V_{ub}|$ from $B \to \pi l \nu$ *(exclusive)*

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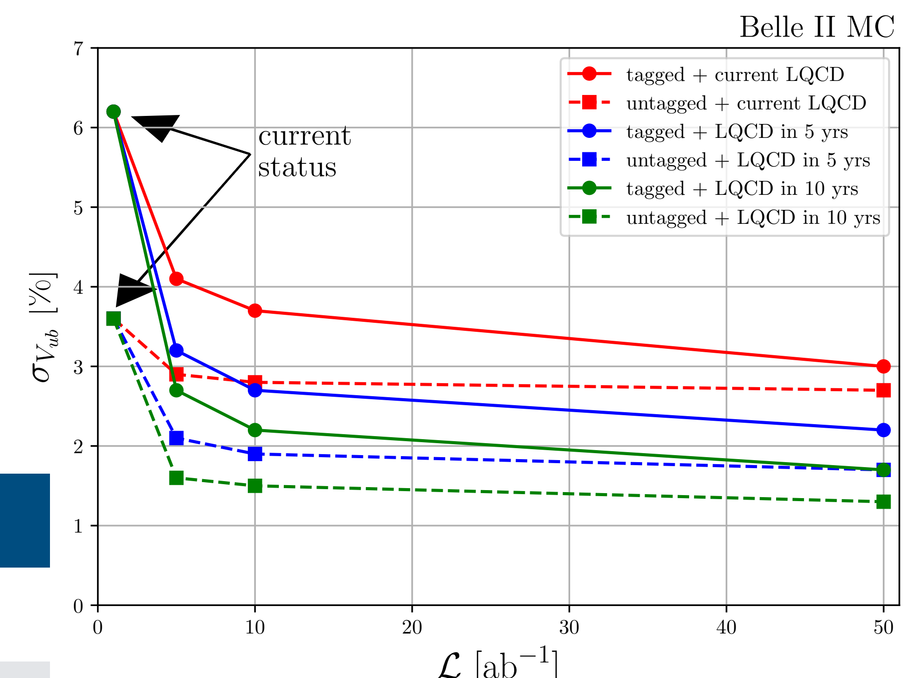
$|V_{ub}|$ is probed directly through combination of QCD-calculated form factors and measured differential branching fraction in bins of transferred from the B meson to leptons ($q^2 \equiv (p_B - p_\pi)^2$).

High precision $|V_{ub}|$ measurements will be available thanks due to the both experimental and theoretical advances



Forecast of $|V_{ub}|$ sensitivity in $B \to \pi l \nu$

	Data	δ^{exp}	δ^{theo}	
$B \to \pi l \nu$	BaBar+Belle	2.4%	3%	HFAG
$B \to \rho l \nu$	BaBar+Belle+CLEO	3.4%	6.8%	JHEP0708(2007) 025
$B \to \omega l \nu$	BaBar+Belle	6.9%	8.3%	
$B \to \eta l \nu$	BaBar+CLEO	$|V_{ub}|$ is not estimated yet		

Summary of channels used for exclusive $|V_{ub}|$ measurements

Expected precision from $B \to \pi l \nu$ (Untagged)

$$\delta^{50\mathrm{ab}^{-1}}_{|V_{ub}|} = 1.3\%$$

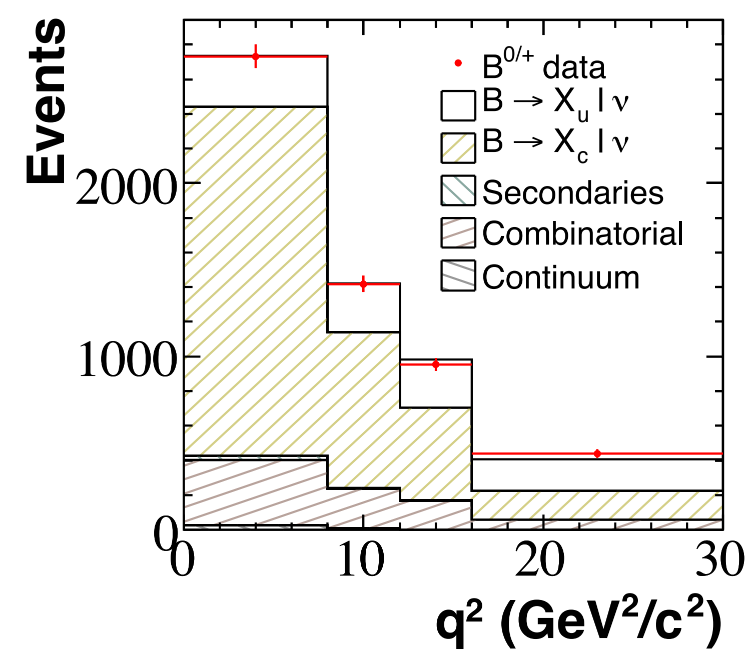
$|V_{ub}|$ from $B \to X_u l\nu$ *(inclusive)*

$|V_{ub}|$ is extracted from combination of triple-differential (in lepton energy and linear combinations of energy and momentum of hadronic system) branching fraction of $B \to X_u l\nu$ decay with perturbative inputs and nonperturbative shape-function.

Phys.Rev.Lett.104:021801,2010

$B \to X_u l\nu$ decays are suppressed respecting background $B \to X_c l\nu$ mode by the factor of 50. However, edges of the phase space are background-free.

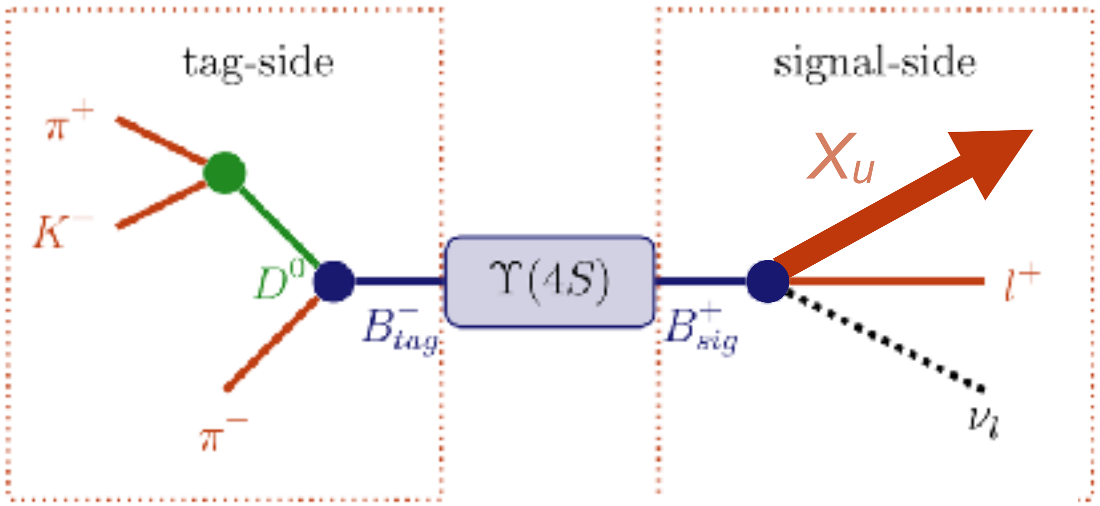
Tradeoff between experimental and theoretical uncertainties: one need to choose between heavier dependence on the shape function model vs more complicated background suppression



Signal and background distributions in bins of the q^2

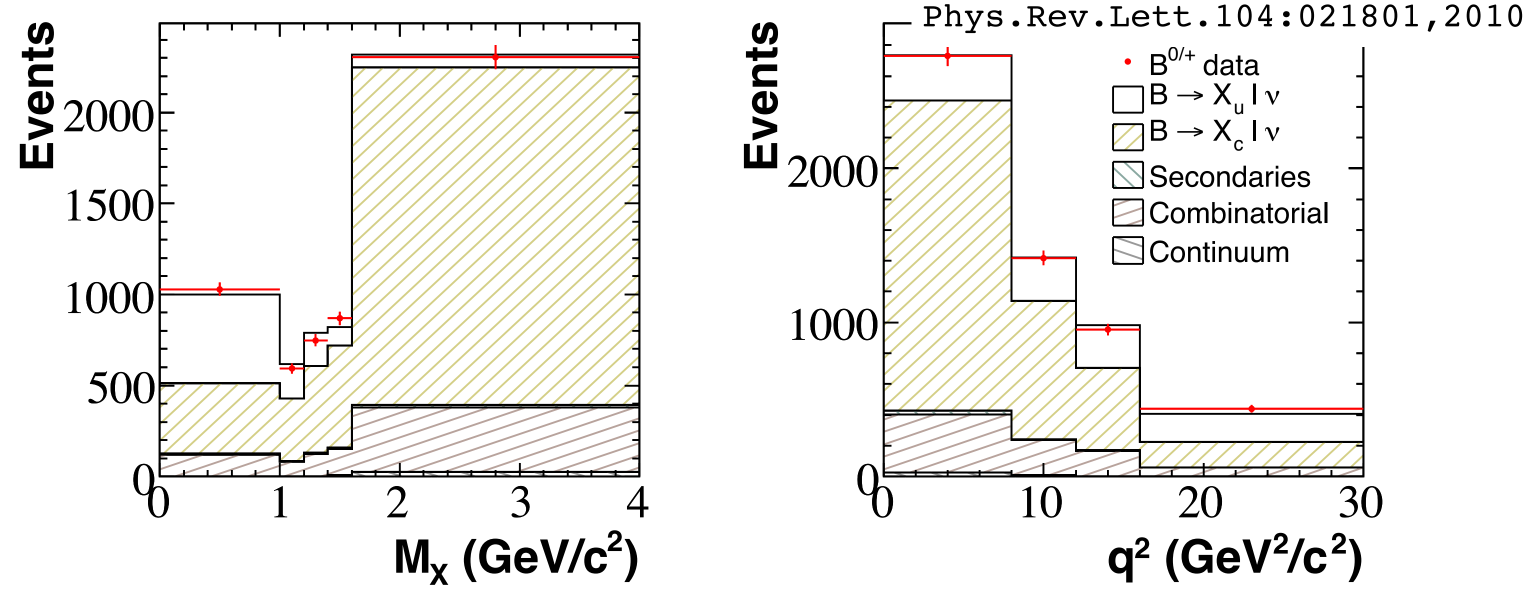
$|V_{ub}|$ from $B \to X_u l \nu$ *(inclusive)*

$|V_{ub}|$ is extracted from combination of triple-differential (in lepton energy and linear combinations of energy and momentum of hadronic system) branching fraction of $B \to X_u l \nu$ decay with perturbative inputs and nonperturbative shape-function.



Typical analysis flow:

- Full reconstruction of tag-side candidate to fully hadronic state.
- Background suppression.
- Fit of the observed spectra.



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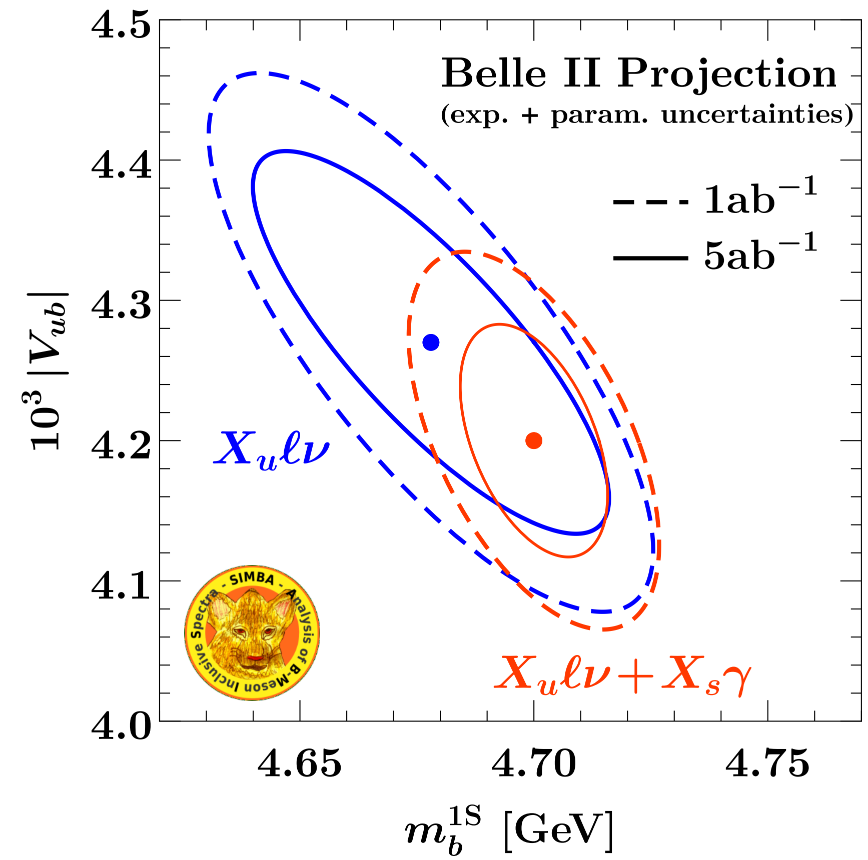
$|V_{ub}|$ from $B\to X_u l\nu$ *(inclusive)*

$|V_{ub}|$ is extracted from combination of triple-differential (in lepton energy and linear combinations of energy and momentum of hadronic system) branching fraction of $B\to X_u l\nu$ decay with perturbative inputs and nonperturbative shape-function.

To improve $|V_{ub}|$ precision Belle II will exploit model-independent parametrisation of shape function. [arXiv:0807.1926]

Such parametrisation use combination of $B\to X_u l\nu$ data with $B\to X_s\gamma$ and constraints (for example on m_b) extracted elsewhere (e.g. from $B\to X_c l\nu$).



Projections of global $|V_{ub}|$ fit at Belle II with 1ab^{-1} and 5ab^{-1} by SIMBA collaboration. Theoretical uncertainties of the same size are not included.

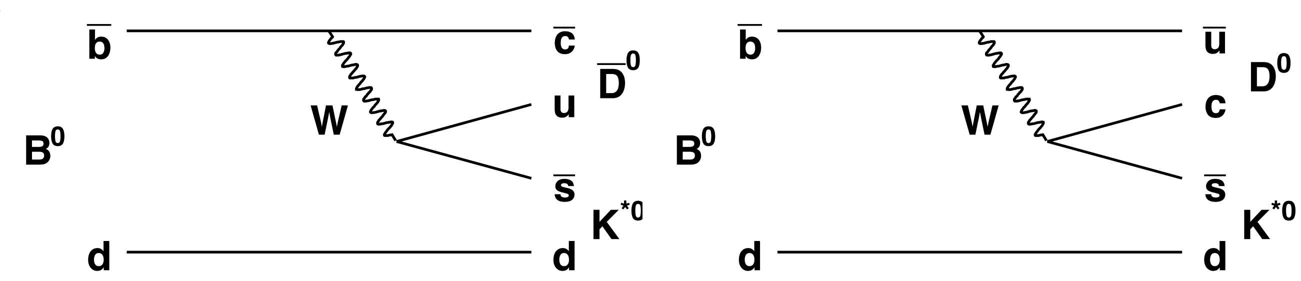
Expected precision of inclusive $|V_{ub}|$ at 5(50)ab^{-1} is 3.4(3)%
With current means $|V_{ub}|^{excl}$ and $|V_{ub}|^{incl}$ measurements will reach 6σ difference

$\phi_3(\gamma)$ from $B \to D^{(*)}K^{(*)}$

Currently: ϕ_3 = (-109.5±5.7)°, (70.5±5.7)°
$\phi_3^{Belle} = (78^{+15}_{-16})°$
$\phi_3^{LHCb} = (72.2^{+6.8}_{-7.3})°$

ϕ_3 is measured through the phase difference between tree amplitudes contributing to $B \to D^{(*)}K^{(*)}$ decays. Due to the absence of penguin amplitudes, theoretical ambiguity in such measurements is much less 1%

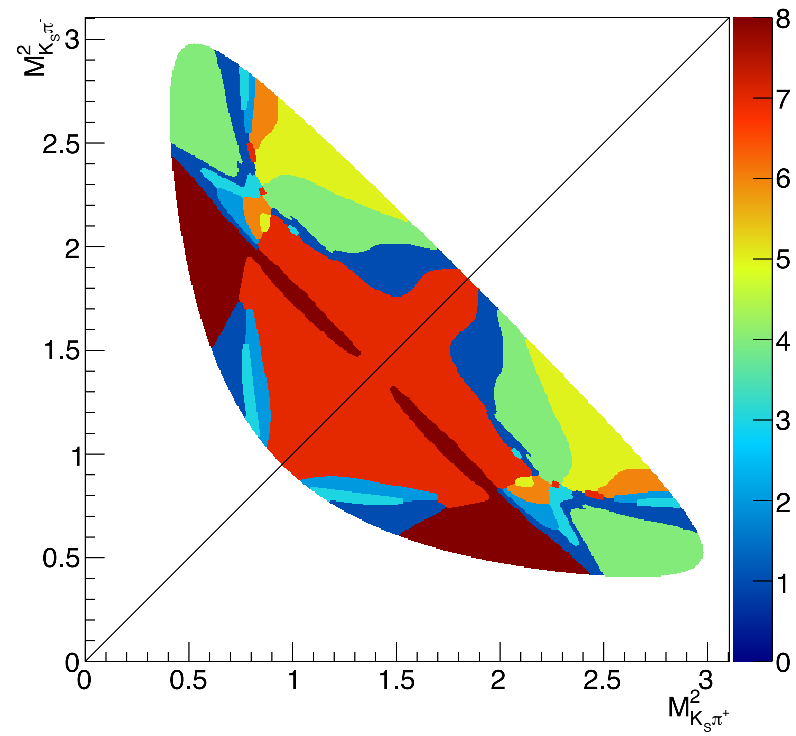
- There is a number of techniques to measure ϕ_3 depending on D final state. Belle II golden mode: Dalitz-plot analysis of self-conjugate D decays (GGSZ) [PRD68, 054018 (2003)]
- Analysis is performed in bins of Dalitz plane, and uses information on phase differences between symmetric bins as an external input (from CLEO [PRD82, 112006 (2010)])



Tree amplitudes contributing to $B \to D^0 K^*$ decays.
Right one is CKM-suppressed.
Relative phase is $\phi_3 \pm$ strong phase, where the sign is defined with initial flavour.

Model-independent Dalitz in $B \to D^{(*)}K^{(*)}$

- Analysis is performed for self-conjugate D-decays (e.g. $D \to K^0{}_S \pi^+ \pi^-$).
- Dalitz plot is divided to a number symmetrical bins.
- Numbers of events from D flavour eigenstates $K_{\pm i}$ and amplitudes-averaged strong phase differences c_i, s_i between $D^0 \to K^0{}_S \pi^+ \pi^-$ and $\overline{D}^0 \to K^0{}_S \pi^+ \pi^-$ are defined for each bin (the later are defined on charm-factories)
- Number of candidates per each bin depends on amplitudes and relative phases of $B \to DK$ diagrams, $K_{\pm i}$, c_i, and s_i



Dalitz binning used for model-independent analysis

[Belle: Phys. Rev., D85, 112014 (2012)]
[LHCb: JHEP, 10, 097 (2014)]

$\phi_3(\gamma)$ from $B \to D^{(*)}K^{(*)}$

Currently: ϕ_3 = (-109.5±5.7)°, (70.5±5.7)°
$\phi_3^{Belle} = (78^{+15}_{-16})°$
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ϕ_3 is measured through the phase difference between tree amplitudes contributing to $B \to D^{(*)}K^{(*)}$ decays. Due to the absence of penguin amplitudes, theoretical ambiguity in such measurements is much less 1%

Assuming 10fb^{-1} ψ(3770) BESIII dataset, we estimate for GGSZ:

$$\delta\phi_3^{50ab^{-1}} = 3^\circ$$

Combined with other D modes

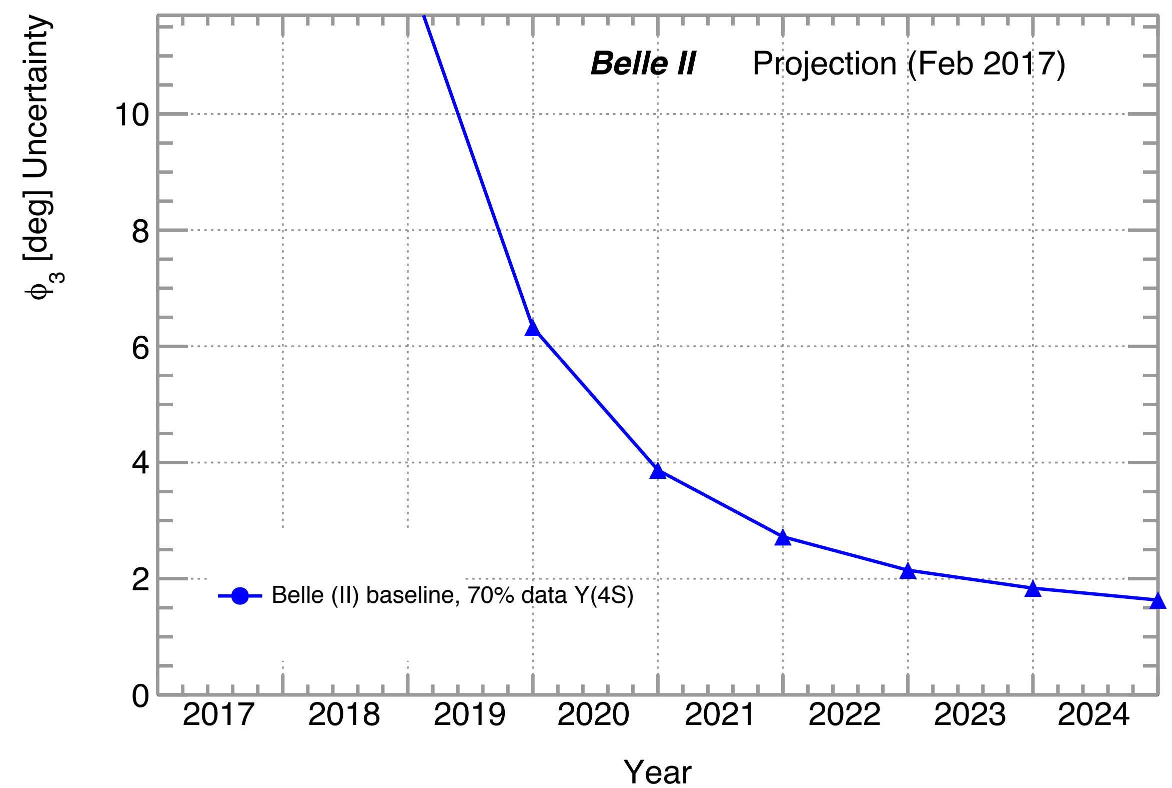
$$\delta\phi_3^{50ab^{-1}} = 1.6^\circ$$

$\phi_3(\gamma)$ from $B \to D^{(*)}K^{(*)}$

Belle II and LHCb will be in tight competition in ϕ_3 sensitivity:

- Due to Belle II unbiased trigger it will be better in Dalitz plot analysis and sensitivity to the neutrals will allow to include more D modes

- LHCb will clearly have more precise results in fully-charged final states



Belle II ϕ_3 sensitivity projection

	D modes	Expected leading sensitivity
CP-even	KK, $\pi\pi$	LHCb
CP-odd	$K^0{}_S\pi^0$	Belle II
Self-conj	$K^0{}_S\pi\pi$, $K^0{}_SKK$	Belle II

Main Belle II modes for ϕ_3 analyses

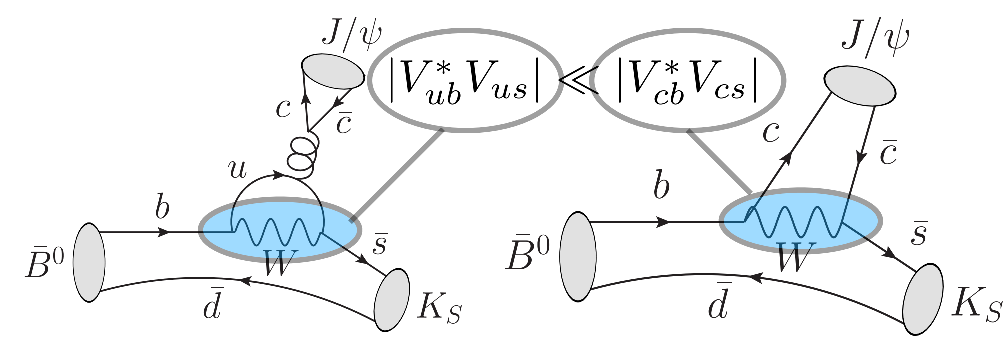
Time-dependent A_{CP}

While the current precision of ϕ_1 and ϕ_2 estimations is experimentally limited, all their measurements suffer from hadronic uncertainties. These uncertainties can be limited through isospin or SU(3) relations.

Currently: $\phi_1 = (21.4 \pm 0.8)^\circ$

b→ccs amplitude is tree-dominated and CP-violation in mixing for these decays is proportional to *sin2ϕ_1* on tree-level. This assumption is valid up to 1% level, which will become dominating at 5ab^{-1}. SU(3) symmetry can be used to control penguin pollution up t 0.1%.

See Alessandro's talk tomorrow



Example of penguin (left) and tree (right) diagrams contributing to *B→J/ψKs* amplitude.

Currently: $\phi_2 = (94.2 \pm 5)^\circ, (166.4 \pm 0.8)^\circ$

The CKM angle ϕ_2 is constrained from A_{CP} observables of *B→hh* (*h* stands for π or ρ) system. Hadronic uncertainties in these systems are controlled through isospin relations, which naturally limits current precision of the method to ~1-2%.

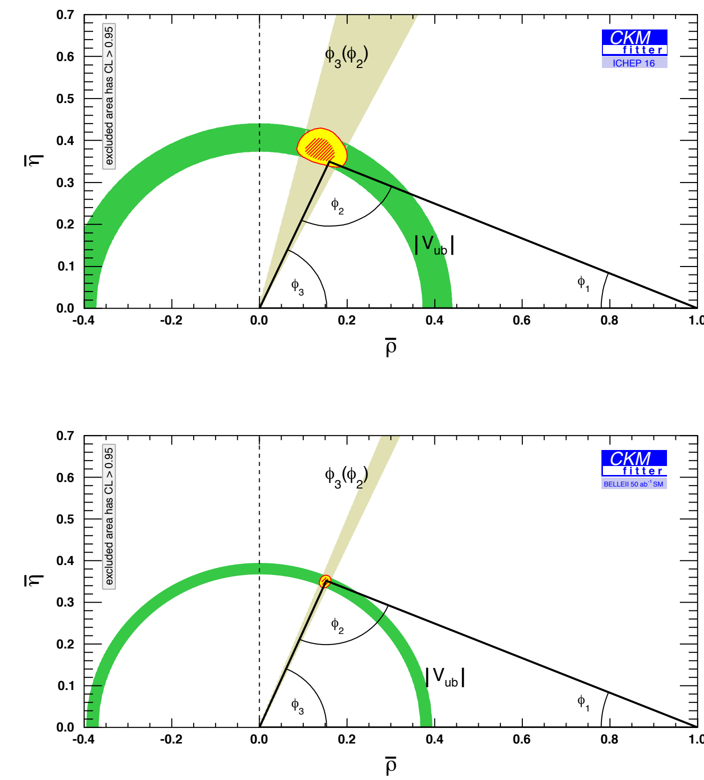
Summary

Measurements of the Belle II will test CKM unitarity with 1% precision.

Most likely, the most relevant contribution to using CKM physics to probe NP offered by Belle II will be a significant improvement in the determination of ϕ_3 and $|V_{ub}|$:

- $|V_{ub}|$ - 1.3%(3%) from exclusive (inclusive) semileptonic measurements.
- ϕ_3 - 1.6° from $B \to DK$ decays

We will also measure with increased precision the ϕ_1 and ϕ_2 parameters, which are less discriminant to BSM physics, but could still contribute to the overall sharpness of the picture, thanks also to theory inputs aimed at reducing the hadronic uncertainties



CKM constraints from tree-dominated decays. Now and at 50ab^{-1}

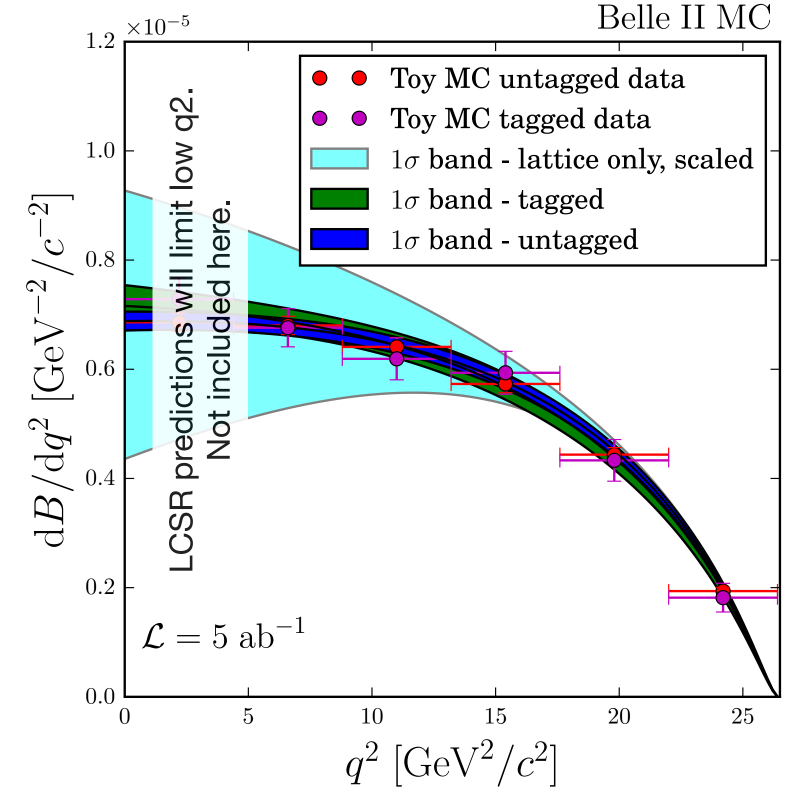
For more see B2TiP report!

Backup

$|V_{ub}|$ in $B \to \pi l \nu$

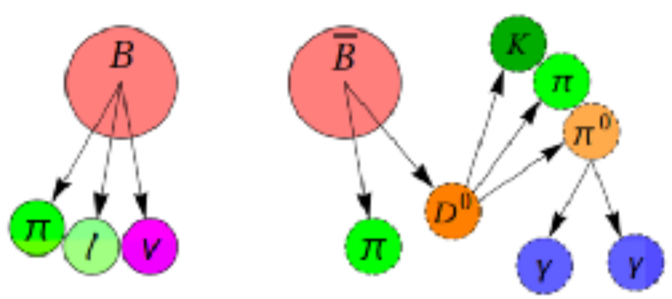
Currently: δ_{exp}~3.4%, δ_{th}~4.5%

$$\frac{d\mathcal{B}(B\to\pi l\nu)}{dq^2} = |V_{ub}|^2 \frac{G_F^2 \tau_B}{24\pi^3} p_\pi^3 |f_+^{B\pi}(q^2)|^2$$



Two methods of B reconstruction:

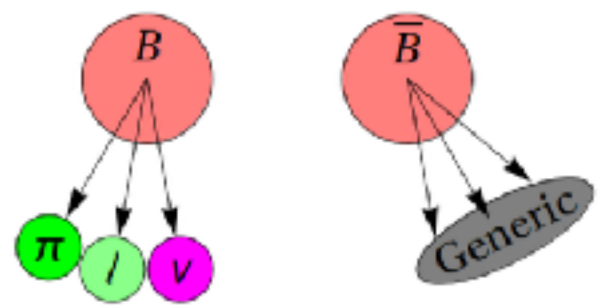
Tagged



Exact momentum of companion B gives good q^2 resolution, for the price of efficiency: ϵ = 0.55% (0.3%@Belle)

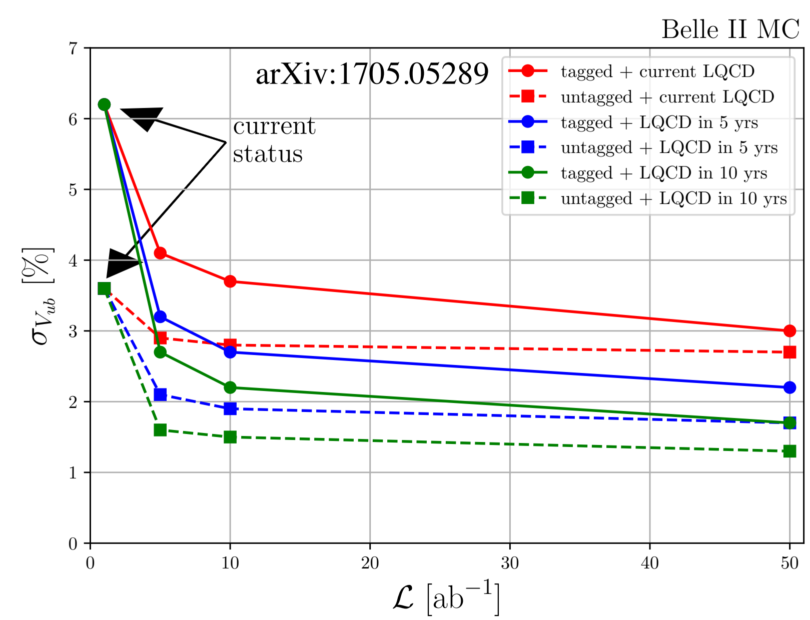
$$\delta_{|V_{ub}|}^{50\mathrm{ab}^{-1}} = 1.7\%^*$$

Untagged



Indirect determination of companion B momentum spoils q^2 resolution, but keeps efficiency high: ϵ = 20% (11%@Belle)

$$\delta_{|V_{ub}|}^{50\mathrm{ab}^{-1}} = 1.3\%^*$$



* assuming x5 reduction of LQCD uncertainty within 10 years

$|V_{ub}|$ in $B \to X_u l \nu$

Currently: δ_{exp}~3.4%, δ_{th}~4.7%

$B \to X_u l\nu$ is suppressed w.r.t. $B \to X_c l\nu$, but has wider phase space. Thus, to measure inclusively $|V_{ub}|$ one selects kinematically clean region and measure triple differential width:

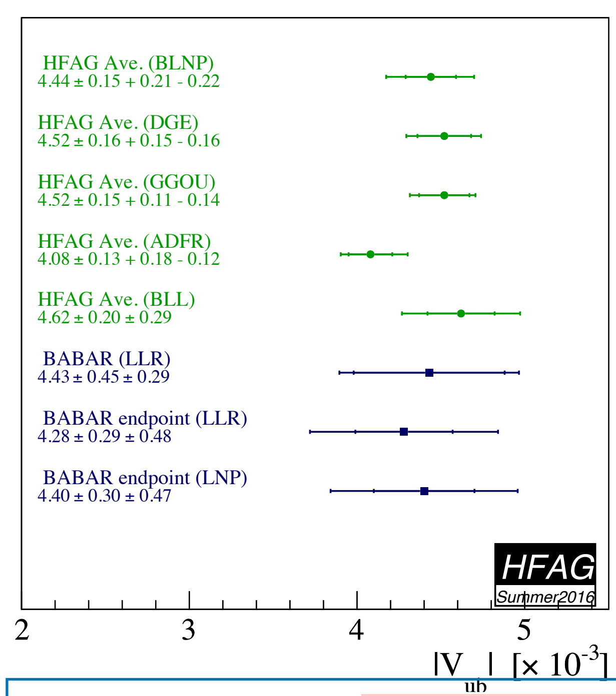
$$\frac{d^3\Gamma}{dp_x^+\, dp_x^-\, dE_l} = \frac{G_F^2 |V_{ub}|^2}{192\pi^3} \int dk\, C(E_l, p_x^+, p_x^-, k) F(k) + \mathcal{O}\left(\frac{\Lambda_{QCD}}{m_b}\right)$$

Experimental input

Describes partonic quark decay, Computed in pQCD up to NNLO

Non-perturbative shape function, source of dominant systematics.

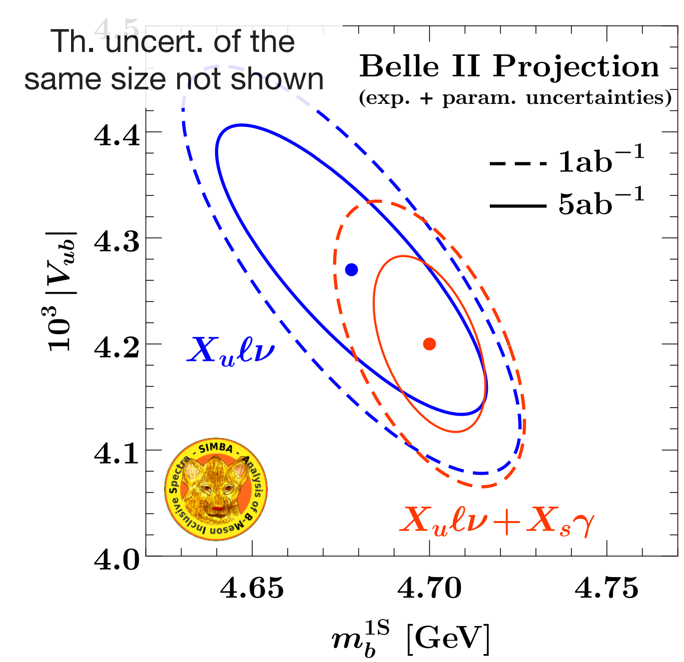
Current results. Note model-dependence



δ_{exp}~3.4%, δ_{th}~4.7%

Belle II approach: **exploit all available theoretical and experimental information.**

- Combination of $B \to X_u l\nu$ data with $B \to X_s\gamma$ and constraints (for example on m_b) extracted elsewhere (e.g. from $B \to X_c l\nu$).
- Model-independent parametrisation of shape function



Expected precision of inclusive $|V_{ub}|$ at 5(50)ab^{-1} is 3.4(3)%

$$|V_{ub}|^{50ab^{-1}}_{excl} = (3.65 \pm 0.04) \times 10^{-3}$$
$$|V_{ub}|^{50ab^{-1}}_{incl} = (4.47 \pm 0.13) \times 10^{-3}$$

$|V_{cb}|$

No sensitivity studies to date, but Belle II is expected to contribute both to exclusive and inclusive measurements

Most recent Belle result:
Phys. Rev. D 93, 032006 (2016)

Exclusive from $B \to D^{(*)} l\nu$

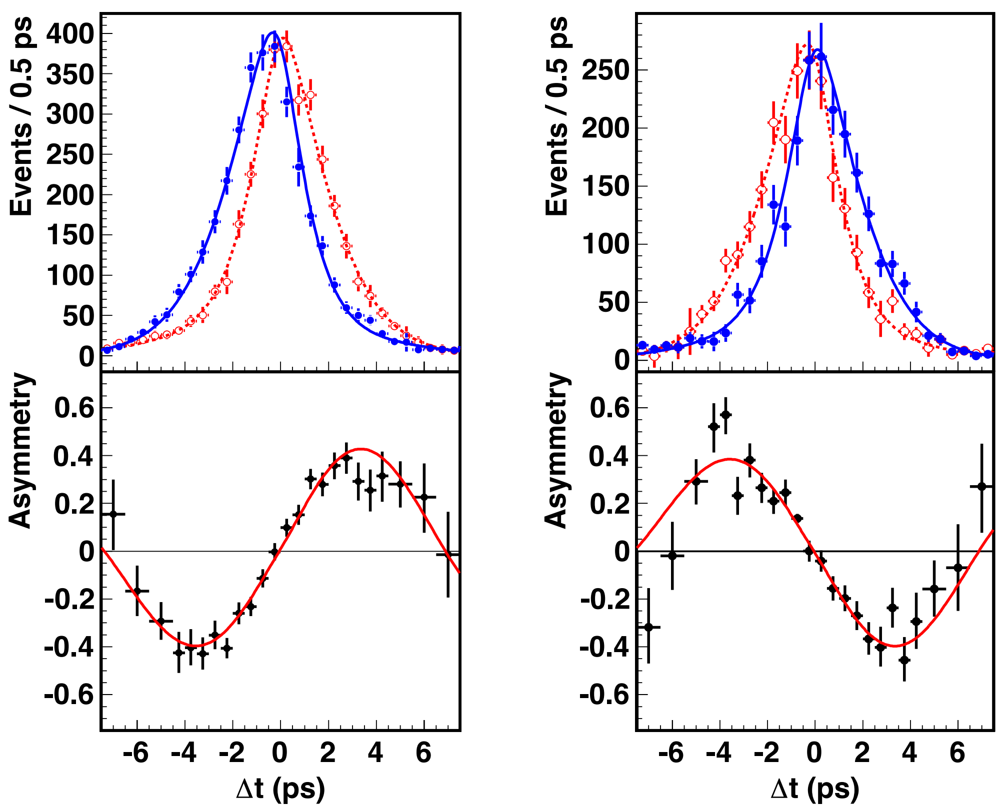
$|V_{cb}|$ is measured from combination of differential decay width in bins of recoil (product of the 4- velocities of the B and D mesons) and phenomenological form-factor (for which many parameterizations exist). Experimentally more challenging than $B \to \pi l\nu$ measurement due to the multiple D final states.

Inclusive from $B \to X_c l\nu$

$|V_{cb}|$ is measured from fit to moments of lepton energy and hadronic mass. 2% uncertainty is limited theoretically, but it will improved by inclusion of high-order ($O(\alpha_s/m_b^3)$ and $O(\alpha_s^3)$) corrections. Fit precision might be also increased by inclusion of additional constraints, such as $B \to X_c\gamma$ data or the mass of c-quark

Time-dependent A_{CP}

Time-dependent CP asymmetry is constructed from difference in decay-time between decay rates of B^0 and anti-B^0 mesons to the same final state. A_{CP} depends on direct and mixing CP violating decay amplitudes.



Δt and A_{cp} distributions for CP-odd (left) and CP-even (right) *B→(cc)K⁰* modes. Red (blue) data points correspond to B^0 ($\bar{B}^0$) initial state. `[Phys. Rev. Lett. 108 171802]`

- Most of the systematic uncertainties can be reduced with increased statistics of data or simulations sample
- Two remained “irreducible” systematics:
  - **Vertex resolution** - constrained both by hardware and software performance
  - **Tag side interference** - for hadron tag, chance of mistagging due to interference of tag-side decay amplitude.

Reducing irreducibles

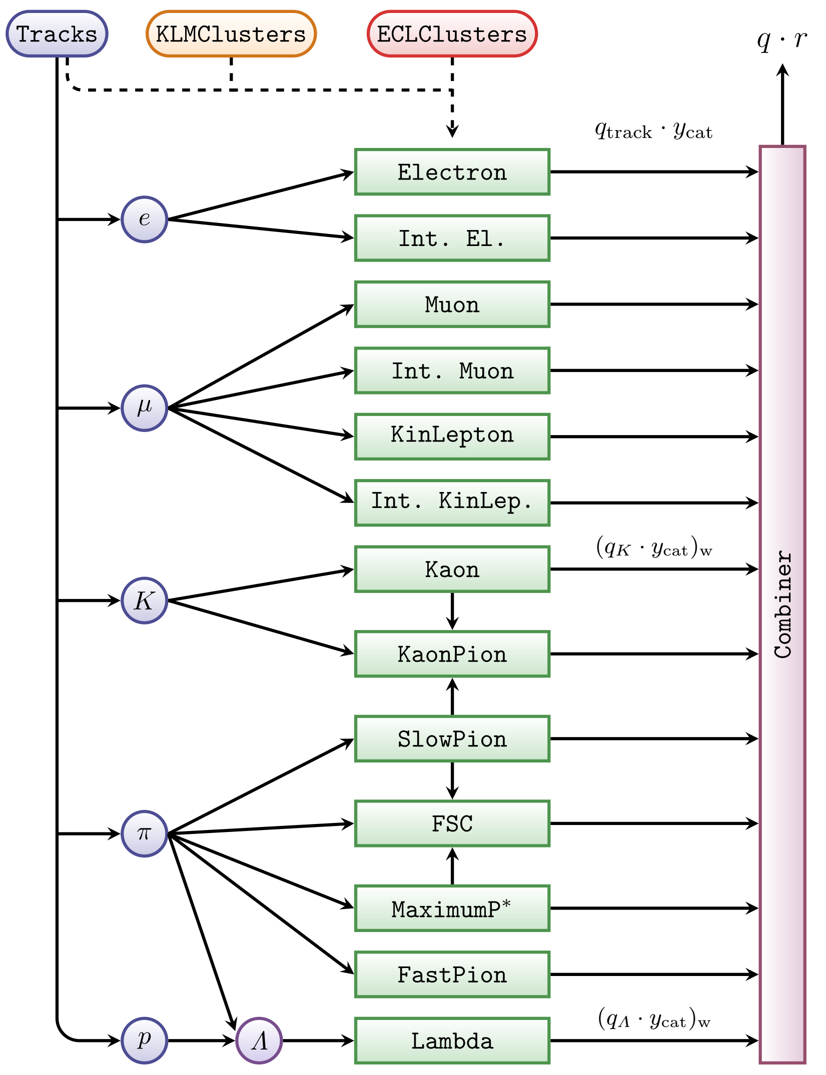
Novel hardware and software approaches will significantly improve **vertex and Δt resolution**, which will reduce vertex-related systematics.

For instance, vertex resolution is expected to be 4x times better than at Belle, where both hardware and software advances improve Belle resolution twice.

Advanced tagging algorithm is expected to provide high **tagging efficiency**

$\varepsilon_{EFF} = 35.84\%$ ($\varepsilon_{EFF}^{BELLE} = 30.04\%$)

Multiple tagging categories will allow to benefit from high statistics by flexible **trade off between statistical and systematic uncertainties.**



Belle II tagging categories

$\phi_1(\beta)$ in $b \to ccs$

Currently: $\phi_1 = (21.4 \pm 0.8)^\circ$

In $b \to ccs$ decays amplitude is composed from tree and doubly CKM-suppressed penguin contributions.

$$A_f = \lambda_c^s T_f + \lambda_u^s P_f, \;\; \lambda_i^q \equiv V_{ib}^* V iq$$

Since tree contribution is dominant and CP-even:

$$\mathcal{S}_f \;\; = -\eta_f \sin 2\phi_1 + \mathcal{O}(\lambda_u^s/\lambda_c^s) \equiv -\eta_f \sin(2\phi_1 + \delta\phi_1)$$

$$\Delta\mathcal{S}_{J/\psi K_s^0} = 2\bar{\lambda}^2 Re(\frac{P_f}{T_f}) \sin\phi_3 \cos 2\phi_1 + \mathcal{O}(\bar{\lambda}^4), \;\; \bar{\lambda}^2 \sim 0.05$$

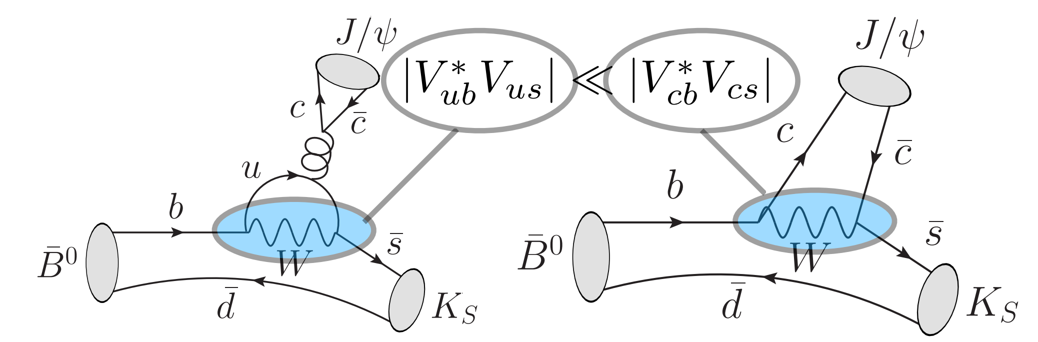
P_f/T_f can be constrained phenomenologically:
$\delta\phi$~0.1°(QCDF/pQCD), $|\delta\phi|$<0.68°(OPE)

SU(3) symmetry - alternative way to control penguins

$$(1+\bar{\lambda}^2)\sin(2\phi_1) = \mathcal{S}_{J/\psi K_S^0} - \bar{\lambda}^2 \mathcal{S}_{J/\psi\pi^0} - 2(\Delta_K + \bar{\lambda}^2\Delta_\pi)\cos 2\phi_1 \tan\phi_3$$

(Δ are splittings of the charged and neutral rates)

Study of b→ccd decays required



Example of penguin (left) and tree (right) diagrams contributing to $B \to J/\psi Ks$ amplitude.

Results of sensitivity study:

	stat	syst	
$\mathcal{S}_{b\to c\bar{c}s} = 0.667$	± 0.023	± 0.012	Belle
$\mathcal{A}_{b\to c\bar{c}s} = 0.006$	± 0.016	± 0.012	Belle
$\mathcal{S}_{b\to c\bar{c}s} = xxx$	± 0.0027	± 0.0044	50ab^{-1}
$\mathcal{A}_{b\to c\bar{c}s} = xxx$	± 0.0019	± 0.0088	50ab^{-1}
$\mathcal{S}_{J/\psi\pi^0} = -0.65$	± 0.21	± 0.05	Belle
$\mathcal{A}_{J/\psi\pi^0} = -0.08$	± 0.16	± 0.05	Belle
$\mathcal{S}_{J/\psi\pi^0} = xxx$	± 0.027	± 0.027	50ab^{-1}
$\mathcal{A}_{J/\psi\pi^0} = xxx$	± 0.020	± 0.042	50ab^{-1}

$$\delta\phi_1^{50ab^{-1}} \sim 0.1^\circ$$

With SU(3)-constrained ΔS

$\phi_1(\beta)$ in charmless decays

Currently: $\phi_1 = (21.4 \pm 0.8)^\circ$

In $b \to qqs$ decays amplitude is penguin-dominated (hence it is also sensitive to non-SM contributions):

$$A_f = \lambda_c^s P_f + \lambda_u^s T_f + A_f^{NP}$$

Penguin amplitudes have the same phase as $b \to ccs$ trees, hence:

$$-\eta_f^{CP} \mathcal{S}_f = \sin 2\phi_1 + \Delta\mathcal{S}_f$$

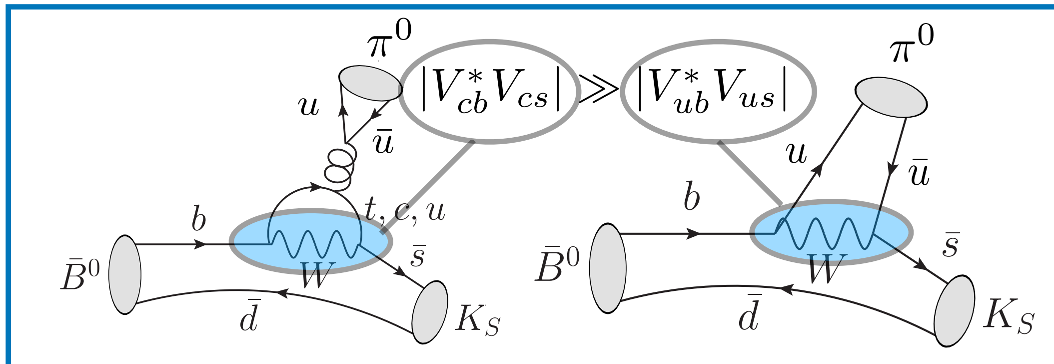
$$\Delta\mathcal{S}_f = 2\cos 2\phi_1 \sin\phi_3 \left|\frac{\lambda_u^s}{\lambda_c^s}\right| Re\left(\frac{T_f}{P_f}\right) + \Delta\mathcal{S}_f^{NP}$$

Again, tree pollution can be controlled by QCDF or by SU(3) symmetry which requires $b \to qqd$ study.

		Current		5 ab^{-1}
ϕK^0	$-\eta\mathcal{S}$	0.74	$^{+0.11}_{-0.13}$	±0.048
	$\mathcal{A}$	-0.01	±0.14	±0.035
$\eta' K^0$	$-\eta\mathcal{S}$	0.59	±0.07	±0.027
	$\mathcal{A}$	0.05	±0.05	±0.02
ωK^0_S	$-\eta\mathcal{S}$	0.45	±0.24	±0.08
	$\mathcal{A}$	0.32	±0.17	±0.06

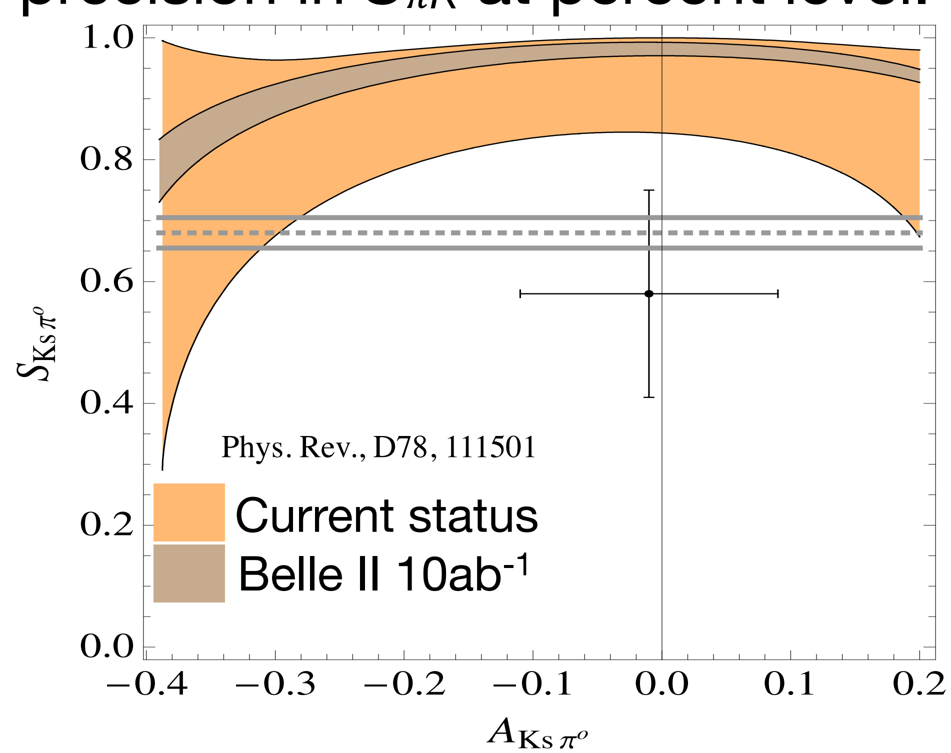
For many modes: $\delta\phi_1^{5ab^{-1}} \sim 1^\circ$

Combined, might be competitive to *b→ccs precision*



Example of penguin (left) and tree (right) diagrams contributing to $B \to \pi^0 Ks$ amplitude.

Special case: $B \to \pi K$ system. Isospin relations allow to obtain precision in $S_{\pi K}$ at percent level.

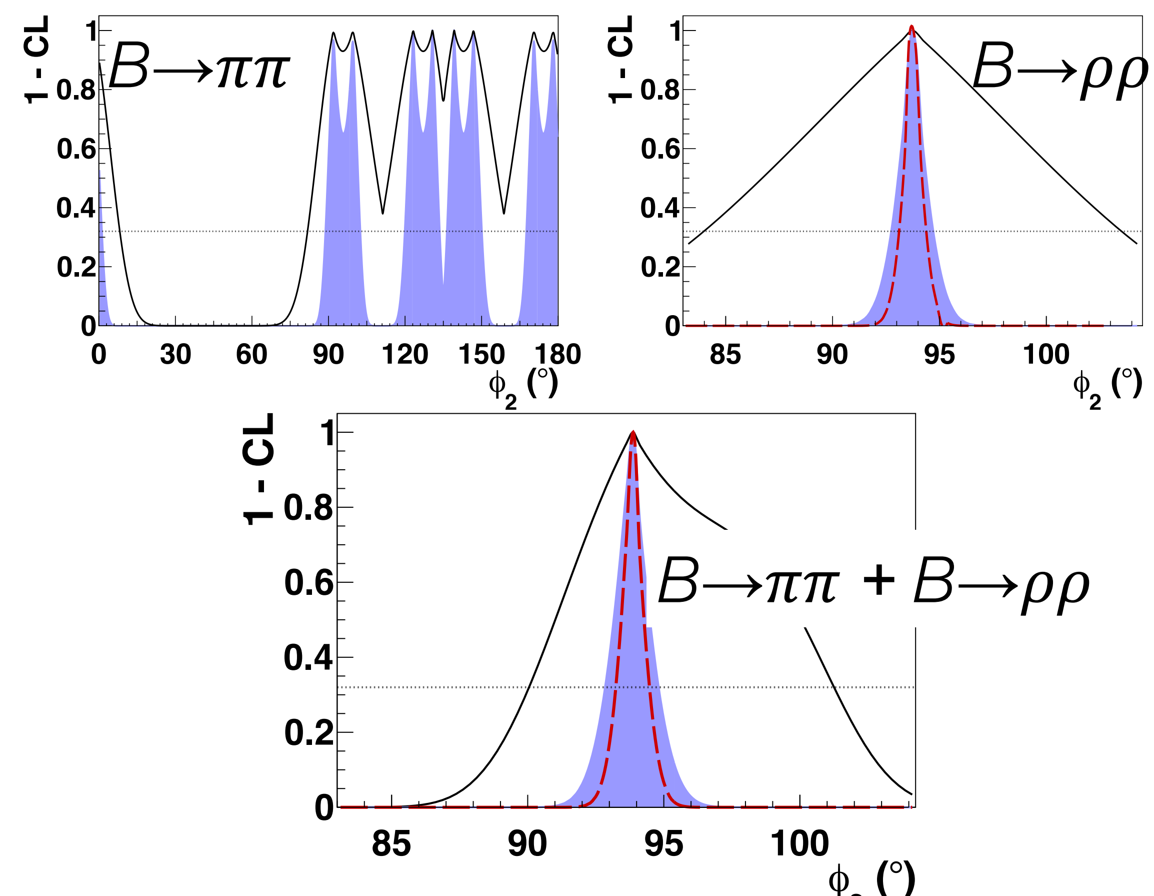


$\phi_2(\alpha)$ in $B\to\pi\pi$ and $B\to\rho\rho$

Currently: $\phi_2 = (94.2 \pm 5)^\circ, (166.4 \pm 0.8)^\circ$

The CKM angle ϕ_2 is constrained from A_{CP} observables of *B→hh (h stands for π or ρ)* system. Hadronic uncertainties in these systems are controlled through isospin relations.

- Theoretical precision is limited by the size of isospin breaking effects, which is estimated as $\Delta\phi_2=\pm1.5^\circ$, which is still more precise than experimental results
- Belle II is expected to significantly (factor of 5) improve existing results by redoing previous measurements.
- Full Belle II dataset will also allow to perform time-dependent CP analysis of $B\to\pi^0\pi^0$ decay using converted photons ($\gamma\to e^+e^-$) and Dalitz decays ($\pi^0\to e^+e^-\gamma$). This will add another factor of 2 improvement.



Current (black) and expected @50ab^{-1} (blue) sensitivities to ϕ_2 through isospin analysis of $B\to hh$ system. Red line shows effect of inclusion of $B\to\pi^0\pi^0$ results

$\phi_3(\gamma)$ in $B \to D^{(*)}K^{(*)}$

ϕ_3 is defined as a phase difference between contributing tree amplitudes:

$$\frac{A(B^- \to \bar{D}^0 K^-)}{A(B^- \to D^0 K^-)} = r_B e^{i(\delta_B - \phi_3)}$$

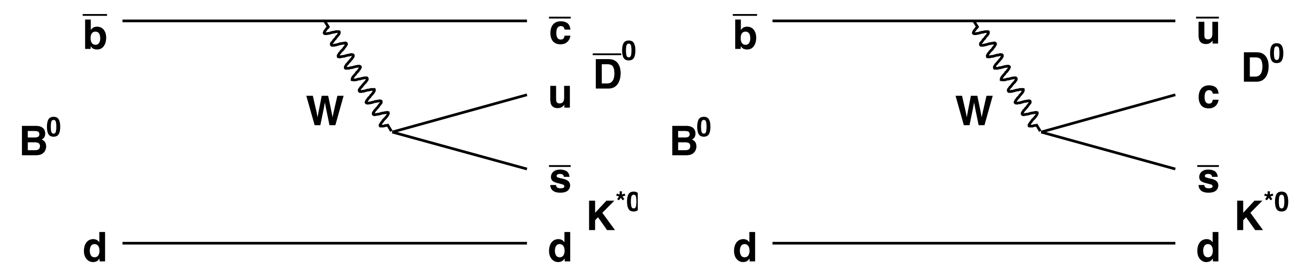
There is a number of techniques depending on D final state. Belle II golden mode: Dalitz-plot analysis of self-conjugate D-decays (GGSZ)

$$\frac{d\Gamma_{B^-}(m_+^2, m_-^2)}{dp} \propto |A_+|^2 + r_B^2 |A_-|^2 + \\ +2r_B|A_+||A_-|\cos(\delta_D + \delta_B + \phi_3)$$

$m_\pm$ - invariant $K^0{}_S\pi^\pm$ mass, $A_{+(-)}$ - $D(\overline{D})$ amplitudes (functions of $m_\pm$), δ_D - their phase difference

Amplitude models can be fit to the flavour samples of $D^{*+} \to D\pi^+$ and used as an input for $B \to DK$ fit. Results into the big systematic uncertainty: $\delta\phi_3^{syst}$=8.9°

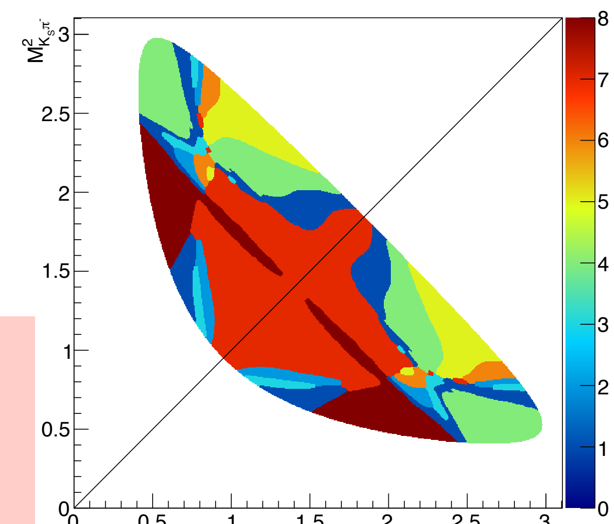
Currently: $\phi_3 = (-109.5 \pm 5.7)^\circ, (70.5 \pm 5.7)^\circ$



Tree amplitudes contributing to $B \to D^0 K^*$ decays

Phys. Rev. D 82, 112006(2010)

Model-independent approach:
Measure averages over the CLEO bins



Dalitz binning used for model-independent analysis

Expected sensitivity for this method only:

$$\delta\phi_3^{50ab^{-1}} = 3^{\circ *}$$

Combined with others:

$$\delta\phi_3^{50ab^{-1}} = 1.6^{\circ *}$$

*Assuming 10fb^{-1} ψ(3770) BESIII dataset