The Belle II Experiment









Belle II

Belle II experiment



- Aim to collect 50 ab⁻¹ of e⁺e[−] collisions at √s = m_{Y(45)}.
- Wide range of physics: precision CKM measurements, CP violation to new physics searches.



The Belle II Physics Book [arxiv1808.10567]

$\begin{array}{c c c c c c c c c } & exp. uncertainty \\ \hline UT angles & side \\ & \phi_1 \begin{bmatrix} 1 \\ \phi_2 \end{bmatrix} & *** & 0.4 & Belle II \\ \phi_2 \begin{bmatrix} 1 \\ \phi_1 \end{bmatrix} & *** & 0.4 & Belle II \\ \phi_3 \begin{bmatrix} 1 \\ \phi_1 \end{bmatrix} & *** & 0.4 & Belle II \\ \phi_4 \begin{bmatrix} 1 \\ \phi_4 \end{bmatrix} & 1.6 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.02 & Belle II \\ W_{ab} & 1.5\% & 0.005 & Belle II \\ W_{ab} & 1.5\% & Belle II \\ W_{ab} & 1.5\% & 0.035 & B$	Observables	Expected the. accu-	Expected	Facility (2025)
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	\$3 [°]	***	1.0	LHCb/Belle II
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	V _{ch} excl.	***	1.5%	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	V _{ub} incl.	**	3%	Belle II
$ \begin{array}{c} CP \ \mbox{ Volation } \\ CP \ \mbox{ Volation } \\ S(B \to (K^0) \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	V _{ub} excl.	**	2%	Belle II/LHCb
$\begin{split} S(B \to c K^0) & & \bullet \bullet \bullet & 0.02 & \text{Belle II} \\ S(B \to \tau K^0) & \bullet \bullet \bullet & 0.01 & \text{Belle II} \\ A(B \to K^+ \pi^-) 0^{-2} & \bullet \bullet & 0.20 & \text{LifCy,Belle II} \\ (Sem) - popolic & \bullet & 3\% & \text{Belle II} \\ (Sem) - popolic & \bullet & 3\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 7\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 7\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 7\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 7\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 7\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 7\% & \text{Belle II} \\ B(B \to \tau \nu) 10^{-6} & \bullet & 0.5\% & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-2} & \bullet & 0.05 & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-2} & \bullet & 0.03 & \text{Belle II} \\ S(B \to \Lambda \pi^+) 10^{-6} & \bullet & 0.3 & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-6} & \bullet & 0.03 & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-6} & \bullet & 0.03 & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-6} & \bullet & 0.03 & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-6} & \bullet & 0.03 & \text{Belle II} \\ B(B \to \Lambda \pi^+) 10^{-6} & \bullet & 0.03 & \text{Belle II} \\ B(D, \to \eta \nu) & \bullet & 0.9\% & \text{Belle II} \\ B(D, \to \eta \nu) & \bullet & 0.05 & Be$	CP Violation			
$\begin{split} S(B \to \gamma_{1}^{(K_{0}^{(L)})} (1^{K_{0}^{(L)}}) & & & 0.01 & \text{Belle II} \\ A(B \to K^{(K_{0}^{(L)})} (1^{K_{0}^{(L)}}) & & 0.20 & \text{LiCb/Belle II} \\ S(R) \to (p_{0}) (1^{K_{0}^{(L)}}) & & 0.20 & \text{LiCb/Belle II} \\ S(R) \to (p_{0}) (1^{K_{0}^{(L)}}) & & 3\% & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & 3\% & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & 3\% & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & 3\% & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & 3\% & \text{Belle II} \\ B(B \to p_{0}) & & & 2\% & \text{Belle II} \\ B(B \to p_{0}) & & & 0.03 & \text{Belle II} \\ S(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(B \to p_{0}) (1^{K_{0}^{(L)}}) & & & 0.03 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & & & 0.05 & \text{Belle II} \\ B(D_{0} \to p_{0}) & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & & & \\ B(D_{0} \to p_{0}) & & & & & & & & & & & & \\ B(D_{0} \to$	$S(B \rightarrow \phi K^0)$	***	0.02	Belle II
$\begin{array}{ccccc} A(B \rightarrow K^{-a})^{[1]}(D^{-2}] & *** & 4 & \text{Belle II} \\ (Sem l \cdot [loptonic \\ (Sem l \cdot [loptonic \\ B(B \rightarrow \tau \nu) \ [10^{-b}] & ** & 3\% & \text{Belle II} \\ B(B \rightarrow \tau \nu) \ [10^{-b}] & ** & 7\% & \text{Belle II} \\ B(B \rightarrow \tau \nu) & 10^{-b}] & ** & 7\% & \text{Belle II} \\ B(B \rightarrow D \tau \nu) & ** & 2\% & \text{Belle III} \\ B(B \rightarrow D \tau \nu) & ** & 2\% & \text{Belle III} \\ B(B \rightarrow D \tau \nu) & ** & 2\% & \text{Belle III} \\ B(B \rightarrow D \tau \nu) & ** & 0.05 & \text{Belle II} \\ B(B \rightarrow D \tau \nu) & ** & 0.05 & \text{Belle II} \\ B(B \rightarrow D \tau \nu) & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow D \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow K \tau \nu) \ [10^{-b}] & ** & 0.03 & \text{Belle II} \\ B(D \rightarrow \tau \nu) & ** & 0.9\% & \text{Belle II} \\ B(D \rightarrow \tau \nu) & ** & 0.03 & \text{Belle II} \\ B(D \rightarrow \tau \nu) & ** & 0.03 & \text{Belle II} \\ B(D \rightarrow \pi \nu) & ** & 0.03 & \text{Belle II} \\ B(D \rightarrow \pi \nu) & ** & 0.03 & \text{Belle II} \\ B(D \rightarrow \tau \nu) & ** & 0.03 & \text{Belle II} \\ B(D \rightarrow \pi \nu) & ** & 0.$	$S(B \rightarrow \eta' K^0)$	***	0.01	Belle II
$\begin{array}{ccccc} A(B \rightarrow K^+\pi^+) [10^{-2}] & *** & 0.20 & \text{LHCb/Belle II} \\ (Serub) [leptonic & & 3\% & \text{Belle II} \\ B(B \rightarrow \nu \nu) [10^{-6}] & ** & 3\% & \text{Belle II} \\ B(B \rightarrow \nu \nu) [10^{-6}] & ** & 7\% & \text{Belle II} \\ R(B \rightarrow D \tau \nu) & ** & 3\% & \text{Belle II} \\ R(B \rightarrow D \tau \nu) & ** & 2\% & \text{Belle II} \\ R(B \rightarrow D \tau \nu) & ** & 4\% & \text{Belle II} \\ R(B \rightarrow N_{\tau} \nu) & ** & 0.03 & \text{Belle II} \\ S(B \rightarrow N_{\tau}) & ** & 0.03 & \text{Belle II} \\ S(B \rightarrow N_{\tau}) & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow X^+ \nu \nu) [10^{-6}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow Y^+ \nu \nu) [10^{-6}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow Y^+ \nu \nu) [10^{-6}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow Y^+ \nu \nu) [10^{-6}] & ** & 0.03 & \text{Belle II} \\ B(B \rightarrow Y^+ \nu \nu) [10^{-6}] & ** & 0.03 & \text{Belle II} \\ Charm & & & & \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.0\% & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.0\% & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & \text{Belle II} \\ B(D_{\gamma} \rightarrow \gamma \nu) & ** & 0.03 & $	$A(B \rightarrow K^0 \pi^0)[10^{-2}]$	***	4	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$A(B \rightarrow K^{+}\pi^{-})$ [10 ⁻²]	***	0.20	LHCb/Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(Semi-)leptonic			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mathcal{B}(B \rightarrow \tau \nu) [10^{-6}]$	**	3%	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mathcal{B}(B \rightarrow \mu \nu) [10^{-6}]$	**	7%	Belle II
$\begin{array}{cccc} R(B \to D^{-}rv) & & & & & 2\% & \text{Belle 11/LHCb} \\ Radiative & EW Penguins \\ \mathcal{B}(B \to N, r_c) & & & & & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & \\ \mathcal{B}(B \to N, r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & & & & \\ \mathcal{B}(D \to r_c) & & \\ \mathcal{B}(D \to r_c) & & & \\ \mathcal{B}(D \to r_c) & & \\ $	$R(B \rightarrow D\tau\nu)$	***	3%	Belle II
$ \begin{array}{cccc} \text{Radiative & EW Penguins} \\ \text{Rel } \rightarrow X_{c}, \gamma) & ** & 4\% & \text{Belle II} \\ A_{CP}(B \rightarrow X_{c}, \gamma) [10^{-2}] & *** & 0.005 & \text{Belle II} \\ S(B \rightarrow \chi) & 0.003 & \text{Belle II} \\ S(B \rightarrow \gamma \gamma) & ** & 0.07 & \text{Belle II} \\ S(B \rightarrow \gamma \gamma) [10^{-6}] & ** & 0.3 & \text{Belle II} \\ B(B \rightarrow \chi + \chi) [10^{-6}] & *** & 15\% & \text{Belle II} \\ B(B \rightarrow \chi + \chi) [10^{-6}] & *** & 0.03 & \text{Belle II} \\ B(B \rightarrow \chi + \chi) & 0.03 & \text{Belle II} \\ B(D \rightarrow \chi + \mu) & *** & 0.0\% & \text{Belle II} \\ B(D \rightarrow \chi + \mu) & *** & 0.0\% & \text{Belle II} \\ B(D \rightarrow \chi + \mu) & *** & 0.0\% & \text{Belle II} \\ B(D \rightarrow \chi + \mu) & *** & 0.03 & \text{Belle II} \\ \end{array} $	$R(B \rightarrow D^* \tau \nu)$	***	2%	Belle II/LHCb
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Radiative & EW Penguins			,
$\begin{array}{cccc} A_{CP}(B \rightarrow X_{q,d'}) \left[10^{-2}\right] & \bullet \bullet \bullet & 0.005 & \text{Belle II} \\ S(B \rightarrow rp) & \bullet & 0.03 & \text{Belle II} \\ S(B \rightarrow rp) & \bullet & 0.07 & \text{Belle II} \\ S(B \rightarrow rp) \left[10^{-6}\right] & \bullet & 0.3 & \text{Belle II} \\ B(B \rightarrow X^{*}rp) \left[10^{-6}\right] & \bullet & 0.3 & \text{Belle II} \\ B(B \rightarrow X^{*}rp) \left[10^{-6}\right] & \bullet & 0.38 & \text{Belle II} \\ B(B \rightarrow X^{*}rp) & \bullet & 0.03 & \text{Belle II} \\ \hline \\ $	$\mathcal{B}(B \rightarrow X_s \gamma)$	**	4%	Belle II
$\begin{split} & S(B \to K_{0}^{2} - K_{0}^{2})^{-1} & & & & & 0.03 & \text{Belle II} \\ & & & 0.07 & \text{Belle II} \\ & B(B \to K^{*} \psi) \left[10^{-6} \right] & & & 0.3 & \text{Belle II} \\ & B(B \to K^{*} \psi) \left[10^{-6} \right] & & & 15\% & \text{Belle II} \\ & R(B \to K^{*} \psi) \left[10^{-6} \right] & & & 0.03 & \text{Belle II} \\ & R(B \to K^{*} \psi) \left[10^{-6} \right] & & & 0.03 & \text{Belle II} \\ & R(D \to \mu \psi) & & & 0.9\% & \text{Belle II} \\ & B(D \to \pi \mu) & & & 0.9\% & \text{Belle II} \\ & B(D \to \pi \mu) & & & 2\% & \text{Belle II} \\ & B(D \to \pi \mu) & & & 2\% & \text{Belle II} \\ & B(D \to \pi \mu) & & & 0.033 & \text{Belle II} \\ \end{split}$	$A_{CP}(B \rightarrow X_{r,d}\gamma) [10^{-2}]$	***	0.005	Belle II
$S(B \to \gamma\gamma)$. ** 0.07 Belle II $B(B \to \gamma\gamma)$ [10 ⁻⁶] ** 0.3 Belle II $B(B \to \gamma\gamma)$ [10 ⁻⁶] ** 0.5 Belle II $B(B \to K^*\mu)$ [10 ⁻⁶] ** 0.03 Belle II/H Cb Charm • $B(D_{\gamma} \to \mu\gamma)$ ** 0.9% Belle II $B(D_{\gamma} \to \mu\gamma)$ ** 0.9% Belle II $B(D_{\gamma} \to \mu\gamma)$ ** 0.03 Belle II	$S(B \rightarrow K_S^0 \pi^0 \gamma)$	***	0.03	Belle II
$\begin{array}{cccc} B(B_{0} \to \gamma\gamma) \left[10^{-6} \right] & ** & 0.3 & \text{Belle II} \\ B(B \to K^{*} \ell \ell) & 15\% & \text{Belle II} \\ R(B \to K^{*} \ell \ell) & *** & 0.03 & \text{Belle II} /LHCb \\ \hline Charm & & & & & \\ B(D_{0} \to \mu \nu) & *** & 0.9\% & \text{Belle II} \\ B(D_{0} \to \tau \mu) & *** & 2\% & \text{Belle II} \\ B(D_{0} \to \tau \mu) & *** & 0.33 & \text{Belle II} \\ \end{array}$	$S(B \rightarrow \rho \gamma)$	**	0.07	Belle II
$B(B \to K^* \phi^0) [10^{-6}]$ *** 15% Belle II $B(B \to K^* \phi^0)$ 0.03 Belle II/LHC Charm *** 0.9% Belle II $B(D_0 \to \mu \mu)$ *** 0.9% Belle II $B(D_0 \to \mu \mu)$ *** 0.038 Belle II	$\mathcal{B}(B_s \rightarrow \gamma \gamma) [10^{-6}]$	**	0.3	Belle II
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mathcal{B}(B \rightarrow K^* \nu \overline{\nu}) [10^{-6}]$	***	15%	Belle II
$ \begin{array}{cccc} \text{Charm} & & & & & \\ \mathcal{B}(D_{\sigma} \to \mu\nu) & & & & \\ \mathcal{B}(D_{\sigma} \to \tau\nu) & & & \\ & & & & \\ \mathcal{B}(D_{\sigma} \to \tau\nu) & & & \\ & & & & \\ \mathcal{B}(D_{\sigma} \to \tau\nu) & & & \\ & & & & \\ \mathcal{B}(D_{\sigma} \to \tau\nu) & & & \\ & & & & \\ \mathcal{B}(D_{\sigma} \to \tau\nu) & & \\ & & & \\ \mathcal{B}(D_{\sigma} \to \tau\nu) & & \\$	$R(B \rightarrow K^* \ell \ell)$	***	0.03	Belle II/LHCb
$B(D_s \to \mu\nu)$ **** 0.9% Belle II $B(D_s \to \tau\nu)$ **** 2% Belle II $B(D_r) \to K_8^{0,0}[10^{-2}]$ *** 0.03 Belle II	Charm			
$\mathcal{B}(D_s \to \tau \nu)$ *** 2% Belle II $A_{CP}(D_0^0 \to K_0^0 \pi^0) [10^{-2}]$ ** 0.03 Belle II	$B(D_s \rightarrow \mu\nu)$	***	0.9%	Belle II
$A_{CP}(D^0 \rightarrow K_S^0 \pi^0) [10^{-2}] ** 0.03$ Belle II	$B(D_s \rightarrow \tau \nu)$	***	2%	Belle II
a line of the second	$A_{CP}(D^0 \to K_S^0 \pi^0)$ [10 ⁻²]	**	0.03	Belle II
$ q/p (D^{\circ} \rightarrow K_{S}^{\circ}\pi^{+}\pi^{-})$ *** 0.03 Belle II	$ q/p (D^0 \to K_S^0 \pi^+ \pi^-)$	***	0.03	Belle II
$A_{CP}(D^+ \rightarrow \pi^+ \pi^0) [10^{-2}]^{**} = 0.17$ Belle II	$A_{CP}(D^+ \rightarrow \pi^+ \pi^0) [10^{-2}]$	**	0.17	Belle II
Tau	Tau			
$\tau \rightarrow \mu \gamma [10^{-10}]$ *** < 50 Belle II	$\tau \rightarrow \mu \gamma [10^{-10}]$	***	< 50	Belle II
$\tau \rightarrow e\gamma [10^{-10}]$ *** < 100 Belle II	$\tau \rightarrow e \gamma \left[10^{-10} \right]$	***	< 100	Belle II
$\tau \rightarrow \mu \mu \mu [10^{-10}]$ *** < 3 Belle II/LHCb	$\tau \rightarrow \mu \mu \mu [10^{-10}]$	***	< 3	Belle II/LHCb

Belle II Collaboration: 1050 members, 120 institutes, 26 countries

William Sutcliffe

Belle II experiment



- Aim to collect 50 ab⁻¹ of e⁺e⁻ collisions at √s = m_{Υ(45)}.
- Wide range of physics: precision CKM measurements, CP violation to new physics searches.



The Belle II Physics Book [arxiv1808.10567]

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Observables	Expected the. accu-	Expected	Facility (2025)
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		racy	exp. uncertainty	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	UT angles & sides			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	φ ₁ [°]	***	0.4	Belle II
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	\$\$2 P	**	1.0	Belle II
$ \begin{split} & \chi_{ab}^{*} \text{incl.} & & & & & & & & & & & & & & & & & & &$	\$ [°]	***	1.0	LHCb/Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	V _{cb} incl.	***	1%	Belle II
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	V _{cb} excl.	***	1.5%	Belle II
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	V _{ub} incl.	**	3%	Belle II
$\begin{array}{c} CP \mbox{ Violation } \\ CP \mbox{ Violation } \\ S(B \to q R^{0}) & *** & 0.02 & \mbox{ Belle II } \\ S(B \to q R^{0})[10^{-2}] & *** & 0.01 & \mbox{ Belle II } \\ A(B \to R^{0} \times \gamma)[10^{-2}] & *** & 0.20 & LiCh/Selle II \\ S(B \to q \gamma)[10^{-2}] & *** & 0.20 & LiCh/Selle II \\ B(B \to \mu \nu) 10^{-0}] & ** & 5\% & Belle II \\ B(B \to \mu \nu) 10^{-0}] & ** & 5\% & Belle II \\ B(B \to \mu \nu) 10^{-0}] & ** & 5\% & Belle II \\ B(B \to \mu \nu) 10^{-2}] & ** & 4\% & Belle II \\ B(A \to \chi \gamma) & ** & 4\% & Belle II \\ S(B \to \chi \gamma) 10^{-2}] & ** & 0.05 & Belle II \\ S(B \to \chi \gamma) 0.07 & Belle II \\ S(B \to \chi \gamma) 0.07 & Belle II \\ B(B \to \chi \gamma \nu) 10^{-0}] & ** & 0.3 & Belle II \\ B(B \to \chi \gamma \nu) 10^{-0}] & ** & 0.3 & Belle II \\ B(B \to \chi \gamma \nu) 10^{-0}] & ** & 0.3 & Belle II \\ B(B \to \chi \gamma \nu) 10^{-0}] & ** & 0.3 & Belle II \\ B(B \to \chi \gamma \nu) 10^{-0}] & ** & 0.3 & Belle II \\ B(B \to \chi \gamma \nu) 10^{-0}] & ** & 0.3 & Belle II \\ B(D \to \eta \gamma) 10^{-0}] & ** & 0.3 & Belle II \\ B(D \to \eta \gamma) 10^{-0}] & ** & 0.3 & Belle II \\ B(D \to \eta \gamma) 10^{-0}] & ** & 0.3 & Belle II \\ B(D \to \eta \gamma) 10^{-0}] & ** & 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 10^{-1}] & 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 10^{-1}] & 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 0.3 & Belle II \\ A_{CP}(D^{0} \to \kappa \frac{9}{2} \pi^{0}) 0.3 & 0.3 & 0.4 \\ Belle II$	$ V_{ub} $ excl.	**	2%	Belle II/LHCb
$\begin{split} S(B \to \phi K^0) & & & & & 0.02 & \text{Belle II} \\ S(B \to \phi K^0) & & & 0.01 & \text{Belle II} \\ A(B \to K^+ \gamma^0) [10^{-2}] & & & 4 & \text{Belle II} \\ (\text{Semi-leptonic} & & & & \\ B(B \to \tau \nu) [10^{-6}] & & & & \\ B(B \to \tau \nu) [10^{-6}] & & & & \\ B(B \to \tau \nu) [10^{-6}] & & & & & \\ R(B \to D^- \nu) & & & & 3\% & \text{Belle II} \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to D^- \nu) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & & & & \\ R(B \to X_{\gamma}) & & \\ R(B \to X_{\gamma}) & & \\ R(B \to X_{\gamma}) & & & \\ R(B \to X_{\gamma})$	CP Violation			
$\begin{split} S(B \to q^0 K^0) & \longrightarrow \\ S(B \to q^0 K^0) & \longrightarrow \\ A(B \to K^0 \pi^0) [10^{-2}] & & & 0.01 & \text{Belle II} \\ A(B \to K^0 \pi^0) [10^{-2}] & & 0.20 & \text{LICO/Palle II} \\ (\text{Semi-leptonic} & & & \\ B(B \to \mu \mu) [10^{-6}] & & & 3\% & \text{Belle II} \\ B(B \to \mu \mu) [10^{-6}] & & & 3\% & \text{Belle II} \\ B(B \to \mu \mu) [10^{-6}] & & & 3\% & \text{Belle II} \\ B(B \to \mu \mu) [10^{-6}] & & & 3\% & \text{Belle II} \\ B(B \to L^0) & & & & 3\% & \text{Belle II} \\ B(B \to L^0) & & & & & 3\% & \text{Belle II} \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & & & \\ B(B \to L^0) & & & \\ B(B \to L^0) & & & \\ B(B \to L^0) & & & \\ B(B \to L^0) $	$S(B \rightarrow \phi K^0)$	***	0.02	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$S(B \rightarrow \eta' K^0)$	***	0.01	Belle II
$\begin{array}{cccc} \mathcal{A}(B \to \mathcal{K}^+\pi^-) \left[0^{-2} \right] & & & & 0.20 & \text{LICO/Belle II} \\ \hline & & & \\ \mathcal{B}(B \to \mu\nu) \left[10^{-6} \right] & & & & 3\% & \text{Belle II} \\ \mathcal{B}(B \to \mu\nu) \left[10^{-6} \right] & & & & 3\% & \text{Belle II} \\ \mathcal{R}(B \to D^{+}\nu) & & & & 3\% & \text{Belle II} \\ \mathcal{R}(B \to D^{+}\nu) & & & & & 3\% & \text{Belle II} \\ \mathcal{R}(B \to D^{+}\nu) & & & & & & & & \\ \mathcal{R}(B \to D^{+}\nu) & & & & & & & & \\ \mathcal{R}(B \to D^{+}\nu) & & & & & & & & & \\ \mathcal{R}(B \to D^{+}\nu) & & & & & & & & & \\ \mathcal{R}(B \to D^{+}\nu) & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & & \\ \mathcal{R}(B \to \mathcal{R}^{+}\nu) & & & & & & & & & & \\ \mathcal{R}(D \to \tau \nu) & & & & & & & & & \\ \mathcal{R}(D \to \tau \nu) & & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & & & & \\ \mathcal{R}(D \to \tau \mu) & & $	$A(B \rightarrow K^0 \pi^0)[10^{-2}]$	***	4	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mathcal{A}(B \rightarrow K^+\pi^-)$ [10 ⁻²]	***	0.20	LHCb/Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(Semi-)leptonic			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mathcal{B}(B \rightarrow \tau \nu) [10^{-6}]$	**	3%	Belle II
$\begin{array}{cccc} R(B \rightarrow D^{+} p) & & & & & 3\% & \text{Belle II} \\ R(B \rightarrow D^{+} p) & & & & & & & & \\ Radiative & EW Penguins & & & & & & \\ R(B \rightarrow X, r) & & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & \\ R(B \rightarrow X, r) & & & & & & & \\ R(B \rightarrow X, r) & & & & & & \\ R(B \rightarrow X, r) & & & & & & \\ R(B \rightarrow X, r) & & & & & \\ R(B \rightarrow X, r) & & & & & \\ R(B \rightarrow X, r) & & & & & \\ R(B \rightarrow X, r) & & & & & \\ R(B \rightarrow X, r) & & & & \\ R(B \rightarrow X, r) & & & & \\ R(B \rightarrow X, r) & & & & \\ R(B \rightarrow X, r) & & & & \\ R(B \rightarrow X, r) & & & & \\ R(B \rightarrow X, r) & \\ R(B \rightarrow X, r)$	$\mathcal{B}(B \rightarrow \mu \nu)$ [10 ⁻⁶]	**	7%	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$R(B \rightarrow D\tau\nu)$	***	3%	Belle II
$ \begin{array}{cccc} \text{Radiative k EW Penguins} \\ \text{R(}B \rightarrow X_r, r) & ** & 4\% & \text{Belle II} \\ A_{CP}(B \rightarrow X_r, r') & 10^{-2} & ** & 0.005 & \text{Belle II} \\ \text{S}(B \rightarrow K_r) & 0.03 & \text{Belle II} \\ \text{S}(B \rightarrow K_r) & 0.07 & \text{Belle II} \\ \text{S}(B \rightarrow K_r) & 0.07 & \text{Belle II} \\ \text{B}(B \rightarrow K^* c) & 0.07 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.07 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.07 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.08 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.03 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.03 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.03 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.03 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.03 & \text{Belle II} \\ \text{R}(B \rightarrow K^* c) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 10^{-2} \\ \text{R}(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* (P)(D^* \rightarrow K^* c^*) & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* (P)(P) & 0.03 & 0.03 & \text{Belle II} \\ \text{R}(P)(D^* (P)(P) & 0.03 & 0.03 & 0.03 & 0.03 \\ \text{R}(P)(P)(D^* (P)(P) & 0.03 & 0.03 & 0.03 & 0.03 \\ \text{R}(P)(D^* (P)$	$R(B \rightarrow D^* \tau \nu)$	***	2%	Belle II/LHCb
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Radiative & EW Penguins			
$\begin{array}{ccccc} A_{CP}(B \rightarrow X_{pd} \sigma) [10^{-2}] & & & 0.005 & \text{Belle II} \\ S(B \rightarrow X_{pd} \sigma) & & 0.03 & \text{Belle II} \\ S(B \rightarrow \rho \sigma) & & 0.07 & \text{Belle II} \\ S(B \rightarrow \rho \sigma) & & 0.3 & \text{Belle II} \\ B(B \rightarrow X^* \nu \sigma) [10^{-6}] & & 0.3 & \text{Belle II} \\ B(B \rightarrow X^* \nu \sigma) & 0.03 & \text{Belle II} \\ B(B \rightarrow K^* \nu \sigma) & & 0.03 & \text{Belle II} \\ Charm & & & \\ B(D \rightarrow \tau \sigma) & & & 2\% & \text{Belle II} \\ B(D \rightarrow \tau \sigma) & & & 2\% & \text{Belle II} \\ B(D \rightarrow \tau \sigma) & & & & 2\% & \text{Belle II} \\ B(D \rightarrow \tau \sigma) & & & & & 2\% & \text{Belle II} \\ Tau & & & & & & \\ Tau & & & & & & & & \\ Tau & & & & & & & & \\ Tau & & & & & & & & & \\ \tau \rightarrow \sigma \gamma [10^{-10}] & & & & & & & & & \\ \tau \rightarrow \sigma \sigma [10^{-10}] & & & & & & & & & \\ \end{array}$	$B(B \rightarrow X_s \gamma)$	**	4%	Belle II
$S(B \rightarrow K_{2}^{0}a^{2}\gamma)^{-1}$ **** 0.03 Belle II $S(B \rightarrow \rho\gamma)$ 0.07 Belle II $B(B \rightarrow \Gamma\gamma\gamma)$ [10 ⁻⁶] *** 0.3 Belle II $B(B \rightarrow K^{+}\nu\rho)$ [10 ⁻⁶] *** 0.3 Belle II $R(B \rightarrow K^{+}\nu\rho)$ [10 ⁻⁶] *** 0.03 Belle II $B(D, \rightarrow \tau\gamma)$ = 0.05 Belle II $B(D, \rightarrow \tau\gamma)$ = 0.03 Belle II $A_{CP}(D^{-} \rightarrow \pi^{+}\pi^{0})$ [10 ⁻²] ** 0.03 Belle II $A_{CP}(D^{-} \rightarrow \pi^{+}\pi^{0})$ [10 ⁻²] ** 0.17 Belle II $\tau \rightarrow \sigma\gamma$ [10 ⁻¹⁰] ** < 00 Belle II $\tau \rightarrow \sigma\gamma$ [10 ⁻¹⁰] ** < 00 Belle II $\tau \rightarrow \sigma\gamma$ [10 ⁻¹⁰] ** < 0 Belle II	$A_{CP}(B \rightarrow X_{s,d}\gamma) [10^{-2}]$	***	0.005	Belle II
$S(B \rightarrow \gamma \gamma)^{-1}$ ** 0.07 Belle II $B(B \rightarrow \gamma \gamma)$ [10 ⁻⁶] ** 0.3 Belle II $B(B \rightarrow K^* \nu \rho)$ [10 ⁻⁶] *** 0.03 Belle II $B(B \rightarrow K^* \nu \rho)$ [10 ⁻⁶] *** 0.03 Belle II $B(D \rightarrow \mu \rho)$ *** 0.9% Belle II $B(D \rightarrow \tau \rho)$ *** 2% Belle II $B(D \rightarrow \tau \rho)$ *** 2% Belle II $A_{CP}(D^{0} \rightarrow K_{S}^{0}\pi^{+}\pi^{-})$ *** 0.03 Belle II $I_{P}(P(D^{0} \rightarrow K_{S}^{0}\pi^{+}\pi^{-})$ *** 0.03 Belle II T_{AU} **** $\sigma^{-1}(p^{-1})$ *** 0.03 Belle II T_{AU} **** $\sigma^{-1}(p^{-1})$ *** <50 Belle II $\tau \rightarrow \sigma_{\gamma}[10^{-10}]$ *** <50 Belle II $\tau \rightarrow \sigma_{\gamma}[10^{-10}]$ *** <50 Belle II $\tau \rightarrow \sigma_{\gamma}[10^{-10}]$ *** <50 Belle II	$S(B \rightarrow K_S^0 \pi^0 \gamma)$	***	0.03	Belle II
$\begin{array}{cccc} \mathcal{B}(B, \to \gamma\gamma) \left[0^{-6} \right] & & & 0.3 & \text{Bele II} \\ \mathcal{B}(B \to K^* \nu \ell) \left(0^{-6} \right) & & & 15\% & \text{Bele II} \\ \mathcal{R}(B \to K^* \ell \ell) \left(0^{-6} \right) & & & 0.3 & \text{Bele II} / LRCb \\ \hline Charm & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & 0.9\% & \text{Belle II} \\ \mathcal{B}(D, \to \tau \mu) & & & & 2\% & \text{Belle II} \\ \mathcal{B}(D, \to \tau \mu) & & & & & 0.9\% & \text{Belle II} \\ \mathcal{B}(D, \to \tau \mu) & & & & & 0.9\% & \text{Belle II} \\ \mathcal{B}(D, \to \tau \mu) & & & & & & 0.9\% & \text{Belle II} \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & 0.9\% & \text{Belle II} \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & & & & & & \\ \mathcal{B}(D, \to \tau \mu) & & & & & & & & & & & & & & & & & & $	$S(B \rightarrow \rho \gamma)$	**	0.07	Belle II
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mathcal{B}(B_s \rightarrow \gamma \gamma) [10^{-6}]$	**	0.3	Belle II
$\begin{array}{cccc} R(B \to K^+(\ell_0^{-1}) & \overset{***}{& & & 0.03 & \text{Bele II/LRCb} \\ \hline Charm & & & & \\ S(D_+ \to \mu) & & & 0.9\% & \text{Belle II} \\ S(D_+ \to \mu) & & & & 0.9\% & \text{Belle II} \\ S(D_+ \to \mu) & & & & 0.03 & \text{Belle II} \\ S(D_+ \to K_{2}^{0} + \mu) & & & 0.03 & \text{Belle II} \\ S(D_+ \to K_{2}^{0} + \mu) & & & 0.03 & \text{Belle II} \\ S(D_+ \to K_{2}^{0} + \mu) & & & 0.03 & \text{Belle II} \\ S(D_+ \to K_{2}^{0} + \mu) & & & 0.17 & \text{Belle II} \\ S(D_+ \to K_{2}^{0} + \mu) & & & \\ S(D_+ \to K_{2}^{0} + \mu) & & & \\ S(D_+ \to K_{2}^{0} + \mu) & & & \\ S(D_+ \to K_{2}^{0} + \mu) & & & \\ S(D_+ \to K_{2}^{0} + \mu) & & & \\ S(D_+ \to K_{2}^{0} + \mu) & & & \\ S(D_+ \to K_{2}^{0} + \mu) & \\ S(D$	$\mathcal{B}(B \rightarrow K^* \nu \overline{\nu}) [10^{-6}]$	***	15%	Belle II
$ \begin{array}{c} \text{Charm} & & & & & \\ \text{Charm} & & & & & 0.9\% & \text{Belle II} \\ \mathcal{B}(D_s \to \mu\nu) & & & & & 2\% & \text{Belle II} \\ \mathcal{B}(D_s \to \tau\nu) & & & & 2\% & \text{Belle II} \\ \mathcal{B}_{cr}(D^0 \to K_S^0\pi^0) [10^{-2}] & & & & 0.03 & \text{Belle II} \\ \mathcal{I}_{arr}(D^0 \to K_S^0\pi^+\pi^-) & & & & 0.03 & \text{Belle II} \\ \overline{Tau} & & & & & & \\ \overline{Tau} & & & & & & & \\ \overline{Tau} & & & & & & & \\ \overline{Tau} & & & & & & & & \\ \tau \to \sigma\tau [10^{-10}] & & & & & & & & \\ \tau \to \sigma\tau [10^{-10}] & & & & & & & & \\ \tau \to \sigma\tau [10^{-10}] & & & & & & & & \\ \end{array} $	$R(B \rightarrow K^*\ell\ell)$	***	0.03	Belle II/LHCb
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Charm			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$B(D_s \rightarrow \mu\nu)$	***	0.9%	Belle II
$A_{CP}(D^0 \rightarrow K_2^{0,0})[0^{-2}]$ ** 0.03 Belle II $ q/p (D^0 \rightarrow K_2^{0,0}\pi^+\pi^-)$ *** 0.03 Belle II $T_{AU} \rightarrow \rho_1[10^{-10}]$ ** 0.17 Belle II $T_{AU} \rightarrow \rho_1[10^{-10}]$ *** < 50 Belle II $\tau \rightarrow o_1[10^{-10}]$ *** < 50 Belle II $\tau \rightarrow o_1[10^{-10}]$ *** < 3 Belle II/LICb	$B(D_s \rightarrow \tau \nu)$	***	2%	Belle II
$ q'_{P}(D^{0} \rightarrow K_{2}^{0}\pi^{+}\pi^{-})$ *** 0.03 Belle II $\Delta_{CP}(D^{+} \rightarrow \pi^{+}\pi^{0})[10^{-2}]$ *0.17 Belle II Tau $\tau \rightarrow q\tau_{1}[10^{-10}]$ *** <50 Belle II $\tau \rightarrow q\tau_{1}[10^{-10}]$ *** <100 Belle II $\tau \rightarrow q\tau_{1}[10^{-10}]$ *** <108 Belle II/LICb	$A_{CP}(D^0 \rightarrow K_S^0 \pi^0) [10^{-2}]$	**	0.03	Belle II
$\frac{A_{CP}(D^+ \to \pi^+ \pi^0) [10^{-2}]}{\text{Tau}}$ ** 0.17 Belle II $\overline{\text{Tau}}$ $ au$ $\tau \to i \gamma [10^{-10}]$ *** < 50 Belle II $\tau \to i \gamma [10^{-10}]$ *** < 100 Belle II $\tau \to i \alpha [10^{-10}]$ *** < 3 Belle II/LRCb	$ q/p (D^0 \rightarrow K_S^0 \pi^+ \pi^-)$	***	0.03	Belle II
Tau $τ \rightarrow μγ [10^{-10}]$ **** < 50 Belle II $τ \rightarrow eγ [10^{-10}]$ **** < 100 Belle II $τ \rightarrow equ [10^{-10}]$ **** < 3 Belle II/LHCb	$A_{CP}(D^+ \rightarrow \pi^+ \pi^0) [10^{-2}]$	**	0.17	Belle II
$\tau \rightarrow \mu \gamma [10^{-10}]$ *** < 50 Belle II $\tau \rightarrow e \gamma [10^{-10}]$ *** < 100 Belle II $\tau \rightarrow u \alpha 1 [10^{-10}]$ *** < 3 Belle II/LHCb	Tau			
$\tau \rightarrow e\gamma [10^{-10}]$ *** < 100 Belle II $\tau \rightarrow \mu\mu\mu [10^{-10}]$ *** < 3 Belle II/LHCb	$\tau \rightarrow \mu \gamma [10^{-10}]$	***	< 50	Belle II
$\tau \rightarrow \mu \mu \mu [10^{-10}]$ *** < 3 Belle II/LHCb	$\tau \rightarrow e\gamma [10^{-10}]$	***	< 100	Belle II
	$\tau \rightarrow \mu \mu \mu [10^{-10}]$	***	< 3	Belle II/LHCb

• Belle II Collaboration: 1050 members, 120 institutes, 26 countries

Belle II

SuperKEKB

• Upgrade of KEKB with original aim $\times 40\mathcal{L}$



- beam current, $I_{e^{+/-}} \times 1.5$
- Reduction in beam size, β_v , by factor 20





• New aim $x30\mathcal{L}$

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β*_y [mm] 1.0 0.6

CERNCOURIER



We can spare no words in thanking KER for their pioneering work in achieving results that push forward both the accelerator frontier and the related physics frontier *Posidie lawsed*





14 September 2020 - FSP 3 / 25

0.3

Belle II

The Belle II Detector







- Inner vertex detector:
 - PXD: 2 layers of DEPFET pixels
 - SVD: 4 layers of DSSD
- Central Drift Chamber for tracking.
- 1.5 T Superconducting solenoid
- Excellent tracking and vertexing down to $p_{\rm T}{\sim}100~{\rm MeV}$
- Impact parameter resolution in z \sim 20 μ m
- PID provided by Time of propagation (TOP) counter and a aerogel RICH
- Outer muon and $K_{\rm L}$ detector

Belle II and LHCb



- Event topology:
 - $e^+e^- \rightarrow \Upsilon(4S) \rightarrow B^+B^-, B^0\overline{B}^0$
 - $\sigma(e^+e^- \rightarrow \Upsilon(4S))$ small
 - Clean environment ⇒ great for missing energy
- Detector:
 - Fully hermetic
 - Great performance for electrons, γs and neutrals





- Event topology:
 - $pp \rightarrow b\bar{b}$
 - $\sigma(pp \rightarrow b\bar{b})$ much larger
 - Events less clean and less constraints as partons interact
 - Λ_b , B_s through fragmentation
- Detector:
 - Forward spectrometer
 - Electrons and \(\pi^0s\) challenging due to ECAL

Hidden sector searches

Hidden sector searches - the first Belle II papers





- Search for a $e^+e^- \rightarrow \ell^+\ell^-(Z^{'} \rightarrow \text{invisible})$
- Limit in the plane of $M_{Z'}$ and g'
- Published in PhysRevLett.124.141801



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• More searches to follow (e.g dark photon via $e^+e^- \rightarrow \gamma_{\rm ISR}(A' \rightarrow \chi \bar{\chi}))$

Bele II simulation

- Search for a $e^+e^-
 ightarrow (A
 ightarrow \gamma \gamma) \gamma$
- Bump hunt in the diphoton mass
- Submitted to PRL arXiv:2007.13071



The Belle II Experiment

Semileptonic B decays motivation



• $|V_{ub}|/|V_{cb}|$ constrains UT length opposite ϕ_1



• Potentially new physics in $B \rightarrow D^{(*)} \tau \nu$.

$$R\left(D^{(*)}\right) = \frac{\mathcal{B}(B \to D^{(*)}\tau^-\bar{\nu}_{\tau})}{\mathcal{B}(B \to D^{(*)}\mu^-\bar{\nu}_{\mu})}$$



• Collide e^+e^- to make $\Upsilon(4S)$ particles.

$$\xrightarrow[e^-]{} \Upsilon(4S) \xleftarrow[e^+]{} e^+$$

• FEI: employs over 200 BDTs to reconstruct 10000 *B* decay chains.

Comput Softw Big Sci (2019) 3: 6.



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- Study remaining B as signal (B_{sig}) .

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• Collide e^+e^- to make $\Upsilon(4S)$ particles.



- Reconstruct tag-side (B_{tag}) . ۲
- Study remaining *B* as signal (B_{sig}) . ۲
- Flavour constraints: $B_{tag}^+ \implies B_{sig}^-$ Kinematic constraints:

$$p_{\nu} = p_{e^+e^-} - p_{\ell^-} - p_{B^+}$$

۰ FEI: employs over 200 BDTs to reconstruct 10000 B decay chains.



$B \to X \ell \nu$ decays

- Crucial for inclusive $|V_{ub}|$ and $|V_{cb}|$
- Large branching fraction ($\sim 20\%$).
- FEI calibrated by measuring Xℓν [arxiv2008.06096]



• Measurement of the *M_X* moments [arxiv2009.04493]

• Calibration factor,
$$\epsilon_{cal} = N_{Data}^{\chi\ell\nu} / N_{MC}^{\chi\ell\nu}$$



• Fit *M_X* functional form after a background subtraction.



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 $* \implies B$ Rest Frame

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Rollo II

 $\langle M_X \rangle$

BaBar (2007)

1.8

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Semileptonic B decays

Rediscovering $B \to \pi \ell \nu$ and $B \to D^* \ell \nu$ with tagging



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The Belle II Experiment

Semileptonic B decays

Untagged $B \to D^{(*)} \ell \nu$

• Key modes for exclusive $|V_{cb}|$.



Starting from

$$0=p_{
u}^2=(p_B^*-p_Y^*)^2$$

one can derive:

$$\cos \theta_{BY} = \frac{2E_B^* E_Y^* - m_B^2 - m_Y^2}{2|\vec{p}_B^*||\vec{p}_Y^*|}$$

Differential measurements allow a determination of the form factors, f(q²); [arxiv2008.07198]

 ${\cal B}(B^0 o D^{*+} \ell
u) =$



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The Belle II Experiment

Time dependent CP violation

$\sin 2\phi_1$ from $B^0 \to J/\psi K_s^0$





$$\begin{split} \theta_{CP}(t) &= \frac{\mathcal{B}(\overline{B}^0 \to K_s^0 J/\psi) - \mathcal{B}(\overline{B}^0 \to K_s^0 J/\psi)}{\mathcal{B}(\overline{B}^0 \to K_s^0 J/\psi) + \mathcal{B}(\overline{B}^0 \to K_s^0 J/\psi)} \\ &= \mathcal{S}_{CP}^{K_s^0 J/\psi} \sin(\Delta m_d t) + \mathcal{A}_{CP}^{K_s^0 J/\psi} \cos(\Delta m_d t) \\ &\sim \sin(2\phi_1)\sin(\Delta m_d t) \cos\mathcal{A}_{CP}^{K_s^0 J/\psi} \sim 0 \end{split}$$

• Measure
$$a(\Delta t = \Delta z_{
m boost}/(\gamma eta_{
m boost} c))$$

• One requires:

- excellent Δz resolution
- a good flavour tagging performance
- stats $\mathcal{B}(B^0 \to J/\psi(\ell\ell)K_s^0(\pi^+\pi^-)) \sim 3.6 \times 10^{-5}$



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Flavour tagging at Belle II



- Performance characterised by:
 - w wrong tag fraction
 - $\epsilon_{\rm eff} = \epsilon_{\rm tag} (1 2w)^2$
- Quantified performance with $B^0 \rightarrow D^{(*)-}\pi^+$ [arxiv2008.02707]
- Belle $\epsilon_{eff} = 30.1 \pm 0.4\%$, Belle II $\epsilon_{eff} = 33.8 \pm 3.9\%$, LHCb $\epsilon_{eff} {\sim} 5\%$

Categories	Targets for \overline{B}^0	Underlying decay mod
Electron	e ⁻	enderlying decay mod
Intermediate Electron	e^+	$\overline{B}{}^0 \rightarrow D^{*+} \overline{\nu}_{\ell} \ell^-$
Muon	μ^{-}	$\square D^0 \pi^+$
Intermediate Muon	μ^+	× K-
Kinetic Lepton	l ⁻	- A A
Intermediate Kinetic Leptor	n 🧨	$\overline{B}{}^0 \rightarrow D^+ \pi^- (K^-)$
Kaon	K^{-}	
Kaon-Pion	K^-, π^+	$\hookrightarrow K^{\circ} \nu_{\ell} \ell^{+}$
Slow Pion	π^+	
Maximum p^*	ℓ^-, π^-	$\overline{B}^0 \rightarrow \Lambda_c^+ X^-$
Fast-Slow-Correlated (FSC)	ℓ^-, π^+	$ A \pi^+ $
Fast Hadron	π^{-}, K^{-}	L n 7-
Lambda	Α	· P #

 Flavour tagger ouput: *q* · *r* where *q* = [−1, 1] flavour estimate, *r* = dilution factor=1 − 2w



A first time dependent CP measurement at Belle II

Experimentally measure

$$egin{aligned} \mathsf{a}_{CP}(t) =& rac{\mathsf{N}(B^0_{ ext{tag}}) - \mathsf{N}(\overline{B}^0_{ ext{tag}})}{\mathsf{N}(B^0_{ ext{tag}}) + \mathsf{N}(\overline{B}^0_{ ext{tag}})}(\Delta t) \ &= \sin(2\phi_1)\sin(\Delta m_d\Delta t) imes \ &(1-2w)\mathcal{R}(\Delta t) \end{aligned}$$

- $\mathcal{R}(\Delta t)$ resolution function.
- w is determined from a time dependent measurement of mixing in $B^0 \to D^- \pi^+$.
- First 2.7 σ evidence of TDCP violation at Belle III



$b ightarrow s \ell \ell$ anomalies

 A wide range of anomalies observed: exclusive Bs, angular distribution of B → K^{*}ℓℓ, R_K^(*)





$b \rightarrow s \ell \ell$ anomalies

A wide range of anomalies observed: exclusive \mathcal{B} s, angular distribution of $B \to K^* \ell \ell, R_{\kappa^{(*)}}$





EWP decays

Belle II's orthogonal and complementory role



• Soon rediscovery of $B \to X_s \ell \ell$ which has orthogonal OPE theory inputs to $B \to K^{(*)} \ell \ell$

Observables	Belle $0.71 \mathrm{ab^{-1}}$	Belle II $5 ab^{-1}$	Belle II 50 ab^{-1}
$Br(B \rightarrow X_{s}\ell^{+}\ell^{-})$ ([1.0, 3.5] GeV ²)	29%	13%	6.6%
$Br(B \rightarrow X_{s}\ell^{+}\ell^{-})$ ([3.5, 6.0] GeV ²)	24%	11%	6.4%
$Br(B \rightarrow X_s \ell^+ \ell^-)$ (> 14.4 GeV ²)	23%	10%	4.7%
$A_{FB}(B \rightarrow X_s \ell^+ \ell^-)$ ([1.0, 3.5] GeV ²)	26%	9.7%	3.1%
$A_{FB}(B \rightarrow X_{s}\ell^{+}\ell^{-})$ ([3.5, 6.0] GeV ²)	21%	7.9%	2.6%
$A_{\rm FB}(B\to X_s\ell^+\ell^-)~(>14.4~{\rm GeV^2})$	19%	7.3%	2.4%

• Good performance for both e and μ reconstruction.



• $b \rightarrow s \nu \bar{\nu}$ orthogonal probe without $c \bar{c}$ contributions





i	\bar{u}, \bar{d}	
Belle	Be	lle II
(2017)	5 ab^{-1}	50 ab^{-1}
$< 40 \times 10^{-6}$	25%	9%
$< 19 \times 10^{-6}$	30%	11%
	$\begin{tabular}{ c c c c c } \hline & & & & & & & & & & & & & & & & & & $	$\begin{tabular}{ c c c c c c } \hline & \bar{u}, \bar{d} \\ \hline & $Belle$ & $Belle$ \\ (2017) & 5 ab^{-1}$ \\ < 40 \times 10^{-6}$ & 25% \\ < 19 \times 10^{-6}$ & 30% \\ \hline \end{tabular}$

EWP decays

Belle II's orthogonal and complementory role



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a, a		u, u		
Observables	Belle	Bel	lle II	
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$B(B \rightarrow K^+ \nu \overline{\nu})$	$<19\times10^{-6}$	30%	11%	

Charmless physics





• Bs and $A_{\rm CP}$ s for several modes in [arxiv2009.09452]



au physics using $e^+e^- o au^+ au^-$

τ physics using $e^+e^- \rightarrow \tau^+\tau^-$

 clean e⁺e⁻ enviroment excellent for τ physics



τ mass recently measured [arxiv2008.04665]

$$M_{\min} = \sqrt{M_{3\pi}^2 + 2(E_{\text{beam}} - E_{3\pi})(E_{3\pi} - P_{3\pi})} \le m_{\tau},$$



- Precision τ physics (e.g. m_{τ} , \mathcal{B} s)
- Can search for LFV in τ s at $\mathcal{O}(10^{-9})$
- $\tau\tau$ events also used to study tracking and PID performance.



• $m_{ au} = 1777.28 \pm 0.75(stat.) \pm 0.33(sys.)$ MeV

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Future prospects

• A joint effort from Belle II and LHCb will be instrumental in resolving the *B* anomalies and finding any inconsistencies in the CKM picture.



Conclusion

- Belle II will provide precision determinations of the CKM parameters
 - Differential measurement of untagged $D^*\ell\nu$ already $\implies |V_{cb}|$ soon
 - First measurement of sin $2\phi_1$ with $B^0 \rightarrow J/\psi K_s$
 - Observation of $B
 ightarrow \pi \ell \nu \implies |V_{ub}|$ soon
 - \blacktriangleright Measurements of key charmless modes for ϕ_2 and ϕ_3
- Belle II will play a crucial role in the B anomalies
 - $B \to D^* \ell \nu$ observed with tagging in preparation for $R(D^{(*)})$
 - ▶ Belle II will provide orthogonal probes of the $b \rightarrow s \ell \ell$ anomalies
- While being a *B* factory Belle II has a diverse physics program.
 - au mass measurement
 - First papers dark sector searches

m_{τ} systematics

Systematic uncertainty	${\rm MeV}\!/c^2$
Momentum shift due to the B-field map	0.29
Estimator bias	0.12
Choice of p.d.f.	0.08
Fit window	0.04
Beam energy shifts	0.03
Mass dependence of bias	0.02
Trigger efficiency	≤ 0.01
Initial parameters	≤ 0.01
Background processes	≤ 0.01
Tracking efficiency	≤ 0.01

Table I. Summary of systematic uncertainties.

Flavour tagging: miss tag fraction

Given a total number of events N, the efficiency ε is defined as the fraction of events to which the flavor tagging algorithm can assign a flavor tag, i.e.

$$\varepsilon = \frac{N^{\text{tag}}}{N}$$

where N^{tag} is the number of tagged events. The fraction of wrong identifications over the number of tagged events is denoted by w. Thus, the number of tagged B and \overline{B} events is given by

$$N_{B^0}^{\text{tag}} = \varepsilon (1 - w) N_{B^0} + \varepsilon w N_{\overline{B}^0}$$

 $N_{\overline{B}0}^{\text{tag}} = \varepsilon (1 - w) N_{\overline{B}^0} + \varepsilon w N_{B^0}$,

where N_{B^0} and $N_{\overline{B}0}$ are the true number of B^0 and \overline{B}^0 mesons on the tag side. The asymmetry observed in CP-violation analysis is then

$$a_{CP}^{\text{obs}} = \frac{N_{B^0}^{\text{tag}} - N_{\overline{B}^0}^{\text{tag}}}{N_{B^0}^{\text{tag}} + N_{\overline{B}^0}^{\text{tag}}} = (1 - 2w) \cdot \frac{N_{B^0} - N_{\overline{B}^0}}{N_{B^0} + N_{\overline{B}^0}} = (1 - 2w) \cdot a_{CP},$$

where a_{CP} corresponds to the CP asymmetry in CP analyses, i.e. to eq. (2.32) for timedependent measurements or to eq. (2.36) for time-integrated (see Sect. 2.7.3). Thus, in order to minimize systematic uncertainties, the value of w has to be precisely measured. The strength of the observed CP asymmetry is proportional to |1 - 2w|, i.e. the CP asymmetry becomes "diluted" because of the wrong-tag fraction. The so-called dilution factor is defined as

$$r \equiv |1 - 2w|$$
, (4.1)

Effective tagging efficiency

tag (w = 0, 1). The statistical uncertainty of a_{CP} is

$$\delta a_{CP} = \frac{\delta a_{CP}^{obs}}{1 - 2w}$$

Assuming that a_{CP}^{obs} is small, i.e. $N_{B^0}^{tag} \approx N_{\overline{B}0}^{tag}$, one obtains for the statistical uncertainty of a_{CP}^{obs}

$$\delta a_{CP}^{\text{obs}} \stackrel{N_{B^0}^{\text{tog}} \approx N_{B^0}^{\text{tog}}}{=} \frac{1}{\sqrt{N^{\text{tag}}}}.$$

Thus, one finds that

$$\delta a_{CP} = \frac{1}{\sqrt{N^{log}(1 - 2w)}}$$
(4.2)

The effective tagging efficiency ε_{eff} of a flavor tagging algorithm is defined such that the statistical uncertainty on the measured asymmetry a_{CF} is related to the effective number of tagged events N^{eff} by

$$\delta a_{CP} = \frac{1}{\sqrt{N^{\text{eff}}}} = \frac{1}{\sqrt{\varepsilon_{\text{eff}} \cdot N}}.$$
 (4.3)

So, the statistical uncertainty on a_{CP} would be the same if one would have $N^{\rm eff}$ perfectly tagged events instead of N events tagged with an effective efficiency $\varepsilon_{\rm eff}$. Comparing eq. (4.2) with eq. (4.3), one obtains

$$\varepsilon_{\text{eff}} = \frac{N^{\text{rag}}}{N} \cdot (1 - 2w)^2 = \varepsilon \cdot r^2.$$
 (4.4)

Backup

Belle II $b \rightarrow sll$ and LFV prospects





 Complementory constraints on C₉ and C₁₀.



• P'_5 projections for $B \to K^* \ell \ell$

Observables	Belle $0.71 \mathrm{ab^{-1}}$	Belle II $5 \mathrm{ab}^{-1}$	Belle II ab^{-1}
P_5' ([1.0, 2.5] GeV ²)	0.47	0.17	0.054
$P_5'~([2.5, 4.0]{ m GeV^2})$	0.42	0.15	0.049
P'_5 ([4.0, 6.0] GeV ²)	0.34	0.12	0.040
$P_5' \ (> 14.2 {\rm GeV^2})$	0.23	0.088	0.027

• Clean environment and possibility of tagging essential will allow competive searches for $B \rightarrow K^* \tau \tau$ and $B \rightarrow K^* \ell \tau$

Observables	Belle $0.71 \text{ ab}^{-1} (0.12 \text{ ab}^{-1})$	Belle II 5 ab ⁻¹	Belle II 50ab^{-1}
$Br(B^+ \rightarrow K^+ \tau^+ \tau^-) \cdot 10^5$	< 32	< 6.5	< 2.0
$Br(B^0 \rightarrow \tau^+ \tau^-) \cdot 10^5$	< 140	< 30	< 9.6
${\rm Br}(B^0_s\to\tau^+\tau^-)\cdot 10^4$	< 70	< 8.1	-
$Br(B^+ \rightarrow K^+ \tau^{\pm} e^{\mp}) \cdot 10^6$			< 2.1
$Br(B^+ \rightarrow K^+ \tau^{\pm} \mu^{\mp}) \cdot 10^6$	_	-	< 3.3
$Br(B^0 \rightarrow \tau^{\pm}e^{\mp}) \cdot 10^5$	_	-	< 1.6
$\text{Br}(B^0 \rightarrow \tau^{\pm} \mu^{\mp}) \cdot 10^5$			< 1.3

William Sutcliffe

$|V_{xb}|$ and $R(D^*)$ prospects

 Eventually systematically limited by tagging calibration

	5 ab^{-1}	$50 {\rm ~ab^{-1}}$
R_D	$(\pm 6.0 \pm 3.9)\%$	$(\pm 2.0 \pm 2.5)\%$
R_{D^*}	$(\pm 3.0 \pm 2.5)\%$	$(\pm 1.0 \pm 2.0)\%$

stat. sys.

• LHCb and Belle II will resolve $R(D^*)$ anomaly.



• Will achieve 1-2% uncertainty on $|V_{ub}|$ and $|V_{cb}|$

Observables	Belle	В	elle II
	(2017)	5 ab^{-1}	50 ab^{-1}
$ V_{cb} $ incl.	$42.2 \cdot 10^{-3} \cdot (1 \pm 1.8\%)$	1.2%	-
$ V_{cb} $ excl.	$39.0 \cdot 10^{-3} \cdot (1 \pm 3.0\%_{ex.} \pm 1.4\%_{th.})$	1.8%	1.4%
$ V_{ub} $ incl.	$4.47 \cdot 10^{-3} \cdot (1 \pm 6.0\%_{ex.} \pm 2.5\%_{th.})$	3.4%	3.0%
$ V_{ub} $ excl. (WA)	$3.65 \cdot 10^{-3} \cdot (1 \pm 2.5\%_{ex.} \pm 3.0\%_{th.})$	2.4%	1.2%

 ⇒ high precision tree level determination of the UT apex

