22nd edition
PANIC Lisbon Portugal
Particles and Nuclei International Conference

Measurements of Hadronic D and B decays at Belle and Belle II

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Current Status of Hadronic D and B decays at Belle and Belle II

Topics in red are covered in this talk

Hadronic D decays

- **BFs and A_{CP} in $D^0 \to \pi^+\pi^-\eta$, $K^+K^-\eta$ and $\eta\phi$** [Belle] arXiv:2106.04286 accepted by JHEP
- **BFs and A_{CP} in $D_S^+ \to K^+(\pi^0,\eta)$ and $\pi^+(\pi^0,\eta)$** [Belle] PRD 103, 112005 (2021)
- Mixing parameter y_{CP} in $D^0 \to K_S^0\omega$ [Belle] PRD 102, 071102(R) (2020)
- Dalitz-plot analysis of $D^0 \to K^-\pi^+\eta$ [Belle] PRD 102, 012002 (2020)
- CP violation in $D^0 \to K^-K^+\pi^-\pi^+$ [Belle] PRD 99, 011104 (2019)
- Measurement of D^0 and D^+ lifetimes [Belle II] arXiv:2108.03216 submitted to PRL. To be presented in Nisar Nellikunnumel's talk today

Hadronic B decays

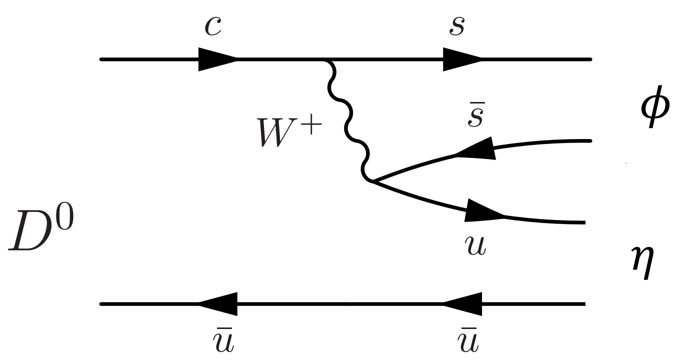
$b \to c$ transition

- **Study of $B \to D^{(*)}h$ at Belle II** [Belle II] arXiv:2104.03628
- **Measurement of Ratio and BFs in $B^0 \to D^-h^+$ decay** [Belle] Preliminary

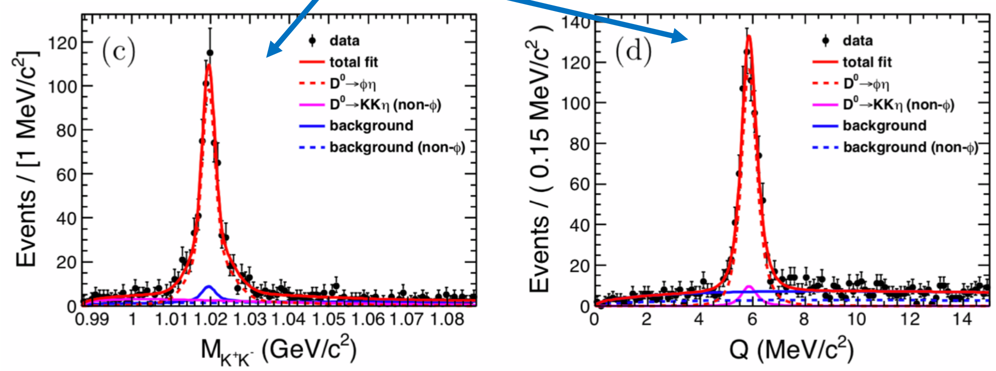
$b \to s, u$ transitions

- **Measurement of time-dependent CP violation parameters in $B^0 \to K_S^0K_S^0K_S^0$** [Belle] PRD 103, 032003 (2021)
- Measurement of branching fraction and Search for CP Violation in $B \to \phi\phi K$ [Belle] arXiv:2101.07753
- **Measurement of the BFs of $B \to \eta' K$ decay** [Belle II] arXiv:2104.06224
- **Search for direct CP-violating asymmetry in $B^0 \to K^0\pi^0$ decays at Belle II** [Belle II] arXiv:2104.14871
- **Measurement of the BFs of $B^0 \to \pi^0\pi^0$ decay** [Belle II] arXiv:2107.02373
- **Study of the $B^+ \to \rho^+\rho^0$ decays [Belle II]** Preliminary
- BFs and direct CP-violating asymmetries in $B^+ \to K^+\pi^0$ and $\pi^+\pi^0$ decays [Belle II] arXiv:2105.04111
- BFs and direct CP asymmetries in $B^0 \to K^+\pi^-$, $B^+ \to K_S^0\pi^+$ and $B^+ \to \pi^+\pi^-$ [Belle II] arXiv:2106.03766

BFs and A_{CP} in $D^0 \to \pi^+\pi^-\eta$, $K^+K^-\eta$ and $\phi\eta$ at Belle



- CP violation in charm physics is observed at LHCb in $D^0 \to \pi^+\pi^-$, K^+K^-
  Phys. Rev. Lett. **122**, 211803 (2019)
- Measure CP asymmetries and BFs with an additional η meson
- Signal extracted with **980 fb^{-1} of Belle data**
  - Fitting the Q-values distributions $Q = M(K^+K^-\eta\pi_s^+) - M(K^+K^-\eta) - m_{\pi_s^+}$
  - The reference mode $\mathcal{B}(D^0 \to K^-\pi^+\eta) = (1.88 \pm 0.05)\%$
  - 2D fit of M_{KK} -Q for $D^0 \to \phi\eta$



- Branching Fractions results:

$$\mathcal{B}(D^0 \to \pi^+\pi^-\eta) = [1.22 \pm 0.02\ (stat.) \pm 0.02(syst.) \pm 0.03(\mathcal{B}_{ref})]\times 10^{-3}$$

$$\mathcal{B}(D^0 \to K^+K^-\eta) = [1.80^{+0.07}_{-0.06}\ (stat.) \pm 0.04(syst.) \pm 0.05(\mathcal{B}_{ref})]\times 10^{-4}$$

$$\mathcal{B}(D^0 \to \phi\eta) = [1.84 \pm 0.09(stat.) \pm 0.06(syst.) \pm 0.05(\mathcal{B}_{ref})]\times 10^{-4}$$

First observation of color-suppressed decay $D^0 \to \phi\eta$

- Asymmetries results:

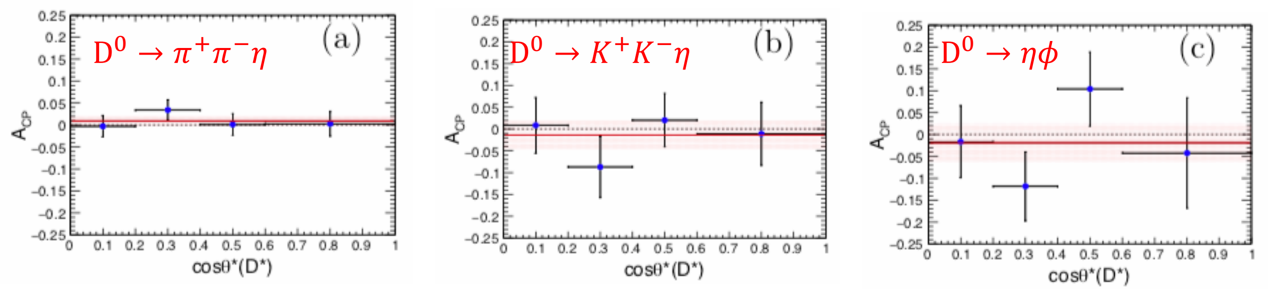
$$A_{CP}(D^0 \to \pi^+\pi^-\eta) = [0.9 \pm 1.2\ (stat.) \pm 0.4(syst.)]\%$$

$$A_{CP}(D^0 \to K^+K^-\eta) = [-1.4 \pm 3.3\ (stat.) \pm 1.0(syst.)]\%$$

$$A_{CP}(D^0 \to \phi\eta) = [-1.9 \pm 4.4\ (stat.) \pm 0.6(syst.)]\%$$

No evidence of CPV found in these decays

- Theory prediction of $A_{CP}(D^0 \to \phi\eta)$ is zero



BFs and A_{CP} in $D_s^+ \to K^+(\pi^0, \eta)$ and $\pi^+(\pi^0, \eta)$ at Belle

PRD 103, 112005 (2021)

- Measure CP asymmetries in charm physics with higher precision to help improve the theoretical predictions
- Neural network(NN) based on input variables $p(D_s^+)$, $|dl_{xy}|$ or dr, $\theta_{heli}(h^+)$, $N(K)$, θ^{thrust} and $\theta(p(D_s^+), \vec{r}_{vtx})$.
- Simultaneously fit for $M_{D_s^+}$ with D_s^{*+}-tagged and untagged D_s^+ samples from **921 fb^{-1} Belle data**
- BF of reference mode $\mathcal{B}(D_s^+ \to \phi[\to K^+K^-]\pi^+)$= (2.24 ±0.08)%

- Branching Fractions

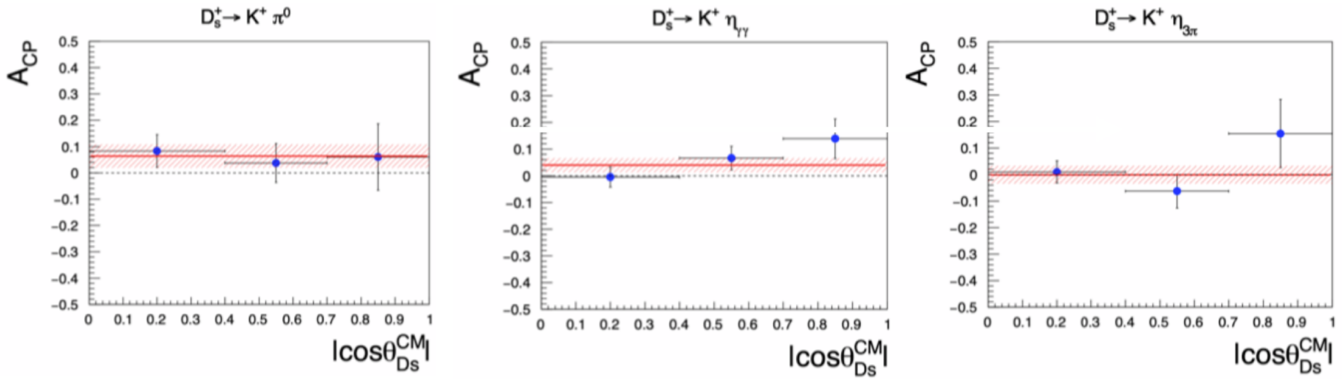
Decay mode	$\mathcal{B}/\mathcal{B}_{\phi\pi^+}$ (%)	$\mathcal{B}$ (10^{-3})
$D_s^+ \to K^+\pi^0$	$3.28 \pm 0.23 \pm 0.13$	$0.735 \pm 0.052 \pm 0.030 \pm 0.026$
$D_s^+ \to K^+\eta_{\gamma\gamma}$	$8.04 \pm 0.32 \pm 0.35$	$1.80 \pm 0.07 \pm 0.08 \pm 0.06$
$D_s^+ \to K^+\eta_{3\pi}$	$7.62 \pm 0.29 \pm 0.33$	$1.71 \pm 0.07 \pm 0.08 \pm 0.06$
$D_s^+ \to K^+\eta$	$7.81 \pm 0.22 \pm 0.24$	$1.75 \pm 0.05 \pm 0.05 \pm 0.06$
$D_s^+ \to \pi^+\pi^0$	$0.16 \pm 0.25 \pm 0.09$	$0.037 \pm 0.055 \pm 0.021 \pm 0.001$
$D_s^+ \to \pi^+\eta_{\gamma\gamma}$	$85.54 \pm 0.64 \pm 3.32$	$19.16 \pm 0.14 \pm 0.74 \pm 0.68$
$D_s^+ \to \pi^+\eta_{3\pi}$	$83.55 \pm 0.64 \pm 4.37$	$18.72 \pm 0.14 \pm 0.98 \pm 0.67$
$D_s^+ \to \pi^+\eta$	$84.80 \pm 0.47 \pm 2.64$	$19.00 \pm 0.10 \pm 0.59 \pm 0.68$
$D_s^+ \to \phi\pi^+$	1	–

- Asymmetries results:

Decay mode	A_{CP}
$D_s^+ \to K^+\pi^0$	$0.064 \pm 0.044 \pm 0.011$
$D_s^+ \to K^+\eta_{\gamma\gamma}$	$0.040 \pm 0.027 \pm 0.005$
$D_s^+ \to K^+\eta_{3\pi}$	$-0.008 \pm 0.034 \pm 0.008$
$D_s^+ \to K^+\eta$	$0.021 \pm 0.021 \pm 0.004$
$D_s^+ \to \pi^+\eta_{\gamma\gamma}$	$0.002 \pm 0.004 \pm 0.003$
$D_s^+ \to \pi^+\eta_{3\pi}$	$0.002 \pm 0.006 \pm 0.003$
$D_s^+ \to \pi^+\eta$	$0.002 \pm 0.003 \pm 0.003$
$D_s^+ \to \phi\pi^+$	–

These results show no evidence of CP violation.

No significant signal of $D_s^+ \to \pi^+\pi^0$ is observed and an upper limit is set to be $\mathcal{B}(D_s^+ \to \pi^+\pi^0) < 1.2\times10^{-4}$

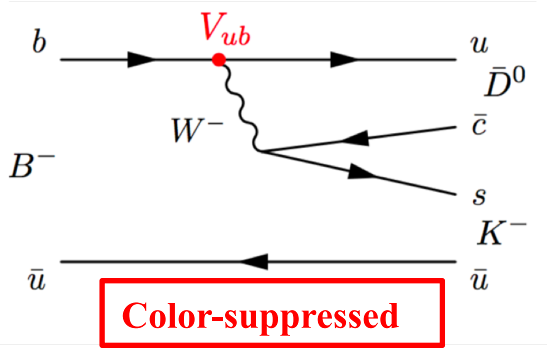


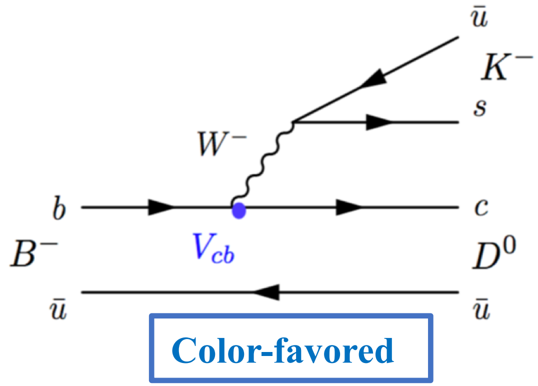
The CKM angle ϕ_3

- Very precise theoretical prediction $\frac{\delta\phi_3}{\phi_3} \sim 10^{-7}$ arxiv:1308.5663
- Test physics beyond SM
- The interference between color-favored and color-suppressed processes can be related :

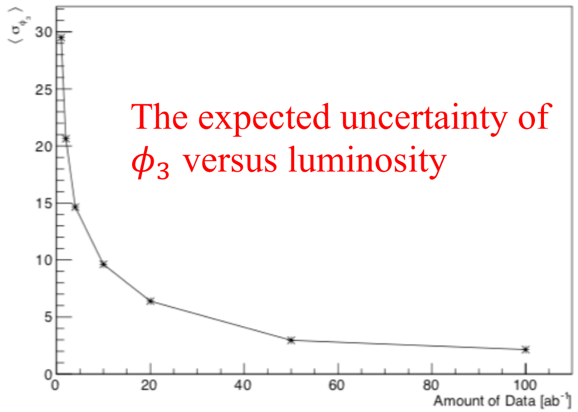
$$\frac{A^{suppr.}[B^- \to \overline{D^0} K^-]}{A^{favor.}[B^- \to D^0 K^-]} = r_B e^{i(\delta_B - \phi_3)}$$

r_B -the magnitude of the ratio of amplitudes ; δ_B -strong-phase difference





- 3 main methods to extract ϕ_3:
  - GLW method: CP eigenstates: K^-K^+, $\pi^-\pi^+$, $K_S^0\pi^0$
  - ADS method: DCS modes: $K^+\pi^-$, $K^+\pi^-\pi^0$
  - BPGGSZ method: self-conjugate multibody final states: $K_S^0\pi^+\pi^-$, $K_S^0K^+K^-$, $K_S^0\pi^+\pi^-\pi^0$



- Foreseen precision of ϕ_3 is expected to be $\mathcal{O}(1°)$ (current world-average $\delta\phi\sim4°$) with the full Belle II dataset of 50 ab^{-1} Belle II Physics book: arXiv:1808.10567

First Belle+Belle II combined results for the ϕ_3 in $B^- \to D^0(K_S^0\pi^+\pi^-)K^-$ will come soon!!!

Study of $B \rightarrow D^{(*)}h$ at Belle II $h = \pi, K$

- The improved measurement of the color-favored hadronic two body decay of B meson helps to a better understanding of QCD effects

- Decay ratio to be extracted:

$$R^{D(*)} = \frac{\Gamma[B \rightarrow D^{(*)}K]}{\Gamma[[B \rightarrow D^{(*)}\pi]} \simeq \tan^2\theta_C \left(\frac{f_K}{f_\pi}\right)^2$$

which will eliminate some systematic uncertainties

- Unbinned 2D simultaneous fit of ΔE versus C' (right plot) for $B^- \rightarrow D^0(K_S^0\pi^+\pi^-)K^-$

$$N^{D^{(*)}\pi}_{kaonID<0.6} = (1 - \kappa_{kaonID>0.6})\ N^{D^{(*)}\pi}_{Total}$$

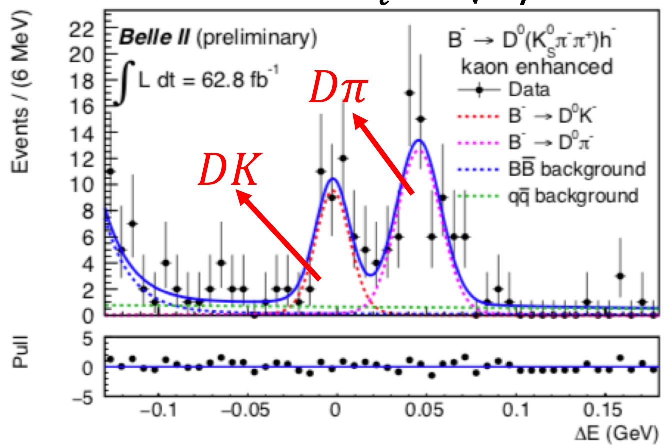
$$N^{D^{(*)}\pi}_{kaonID>0.6} = \kappa_{kaonID<0.6} N^{D^{(*)}\pi}_{Total}$$

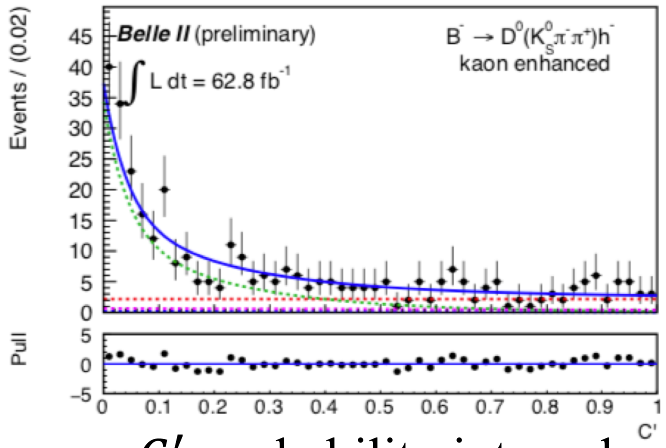
$$N^{D^{(*)}K}_{kaonID<0.6} = (1 - \epsilon_{kaonID>0.6}) R^{D(*)}\ N^{D^{(*)}\pi}_{Total}$$

$$N^{D^{(*)}K}_{kaonID>0.6} = \epsilon_{kaonID>0.6} R^{D(*)}\ N^{D^{(*)}\pi}_{Total}$$

κ- pion fake rate ; ϵ-kaon efficiency

$$\Delta E = \Sigma E_i - \sqrt{s}/2$$





C'-probability integral transformation of FBDT

- Results of 62.8 fb^{-1} :

$$R^D(B^- \rightarrow D^0(K^-\pi^+)h^-) = [7.66 \pm 0.55(stat.)^{+0.11}_{-0.08}(syst.)]\times 10^{-2}$$

$$R^D(B^- \rightarrow D^0(K_S^0\pi^+\pi^-)h^-) = [6.32 \pm 0.81(stat.)^{+0.09}_{-0.11}(syst.)]\times 10^{-2}$$

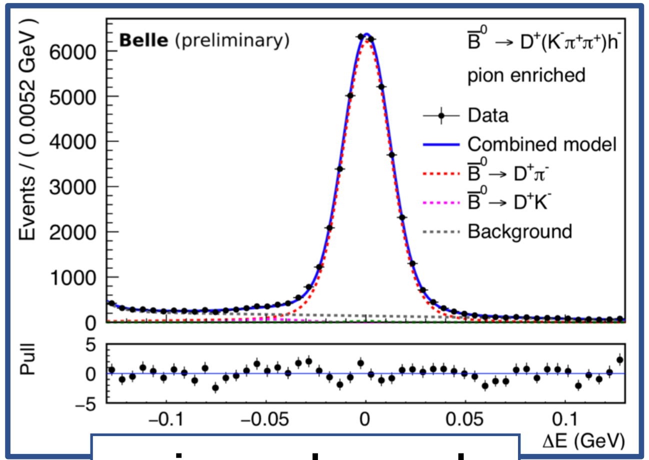
$$R^{D*}(B^- \rightarrow D^{*0}h^-) = [6.80 \pm 1.01(stat.) \pm 0.07\ (syst.)]\times 10^{-2}$$

$$R^D(B^0 \rightarrow D^-h^+) = [9.22 \pm 0.58(stat.) \pm 0.09\ (syst.)]\times 10^{-2}$$

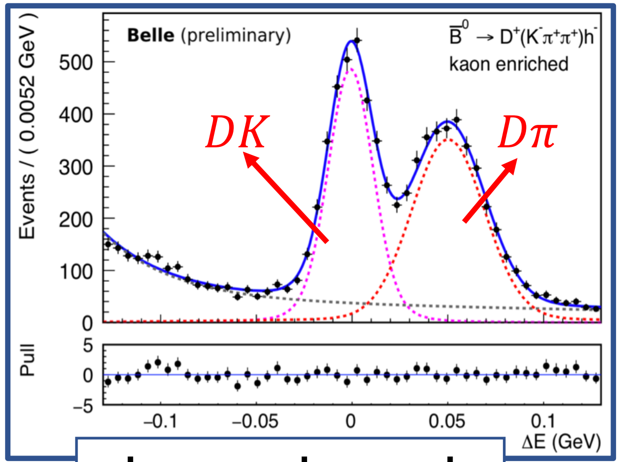
$$R^{D*}(B^0 \rightarrow D^{*-}K^+) = [5.99 \pm 0.82(stat.)^{+0.17}_{-0.08}\ (syst.)]\times 10^{-2}$$

Measurement of Ratio and BFs in $B^0 \to D^-h^+$ decay at Belle $h = \pi, K$

- Similar method refers to Belle II for extracting the signal



pion enhanced



kaon enhanced

$$\Delta E = \Sigma E_i - \sqrt{s}/2$$

- Preliminary Results:

$$R^D = \frac{\Gamma[B^0 \to D^-K^+]}{\Gamma[[B^0 \to D^-\pi^+]} = [8.20 \pm 0.20(stat.) \pm 0.20(syst.)]\times 10^{-2}$$

$$\mathcal{B}(B^0 \to D^-(\to K^+\pi^-\pi^-)\pi^+) = [2.50 \pm 0.01(stat.) \pm 0.10(syst.) \pm 0.04(\mathcal{B}(D \to K^+\pi^-\pi^-))]\times 10^{-3}$$

$$\mathcal{B}(B^0 \to D^-(\to K^+\pi^-\pi^-)K^+) = [2.05 \pm 0.05(stat.) \pm 0.08(syst.) \pm 0.04(\mathcal{B}(D \to K^+\pi^-\pi^-))]\times 10^{-4}$$

These results are consistent with the previous measurement results.

Full Belle dataset result (711 fb^{-1})!!!

- Previous Results:

$$R^D = \frac{\Gamma[B^0 \to D^-K^+]}{\Gamma[[B^0 \to D^-\pi^+]} = [8.22 \pm 0.11(stat.) \pm 0.25(syst.)]\times 10^{-2}$$ LHCb result in JHEP 2013.1(2013)

$$\mathcal{B}(B^0 \to D^-\pi^+) = [2.55 \pm 0.05(stat.) \pm 0.16(syst.)]\times 10^{-3}$$ BaBar result in PRD 75(2007) 031101

$$\mathcal{B}(B^0 \to D^-K^+) = [1.89 \pm 0.19(stat.) \pm 0.10(syst.)]\times 10^{-4}$$ LHCb result in PRL 107(2011) 211801

Measurement of TDCP violation parameters in $B^0 \to K_S^0 K_S^0 K_S^0$ at Belle

PRD 103, 032003 (2021)

- Pure $b \to s q\bar{q}$ penguin transition is sensitive to new physics and provide an opportunity of measurement of $sin2\phi_1$
- In the previous measurement of $sin2\phi_1$, there is 1.6 σ difference between Belle and BaBar result
- Unbinned 3D fit of ΔE – Mbc –T(Transformed NN) to extract signal **with full Belle dataset(711 fb^{-1})**

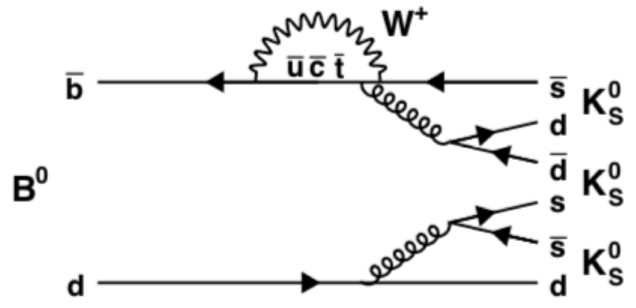
$$M_{bc} = \sqrt{E_{beam}^2 - (\Sigma \vec{p_i})^2} \quad T = log(\frac{NN - NN_{low}}{NN_{high} - NN})$$

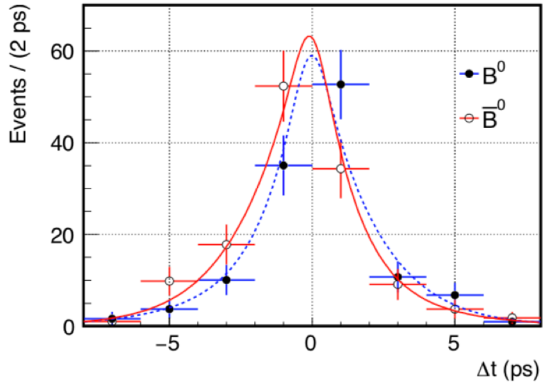
- Time-dependent CP(TDCP) Violation:

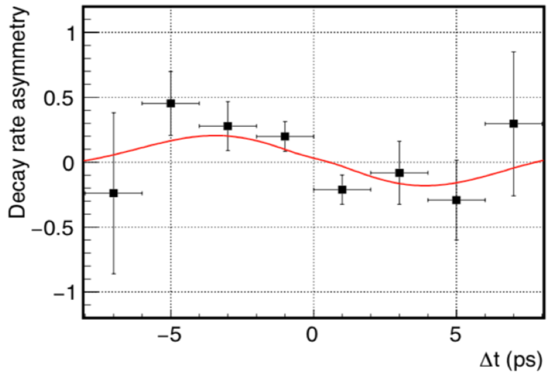
$$\mathcal{A}_{CP} = \frac{P(\bar{B}^0(\Delta t) \to f_{CP}) - P(B^0(\Delta t) \to f_{CP})}{P(\bar{B}^0(\Delta t) \to f_{CP}) + P(B^0(\Delta t) \to f_{CP})} = Ssin(\Delta m \Delta t) + Acos(\Delta m \Delta t)$$

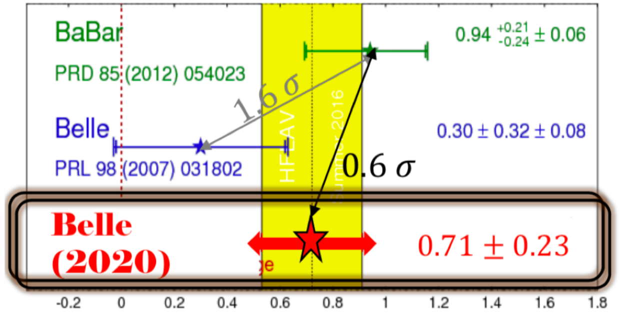
- Results:

$$S = -0.71 \pm 0.23\,(stat.) \pm 0.05(syst.)$$
$$A = 0.12 \pm 0.16\,(stat.) \pm 0.05(syst.)$$

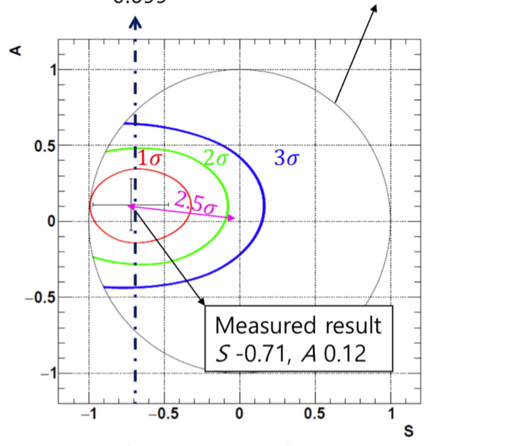








Result improved and 2.5 σ significance of CP violation away from (0,0)



Measurement of the BFs of $B \to \eta' K$ decays at Belle II

arXiv:2104.06224

- $B \to \eta' K$ decays is dominated by penguin transition , measurement of CP violation is sensitive to new physics in the penguin loop
- Belle II detector well suited for neutral final states
- Aimed for early reconstruction and branching fraction measurement
  - ① $B^\pm \to \eta' K^\pm$, with $\eta' \to \eta\pi^+\pi^-$ or $\eta' \to \rho\gamma$
  - ② $B^0 \to \eta' K_S^0$, with $\eta' \to \eta\pi^+\pi^-$ or $\eta' \to \rho\gamma$
- 3D fit of ΔE- M_{bc}- CS_{var}(continuum suppression discriminator)

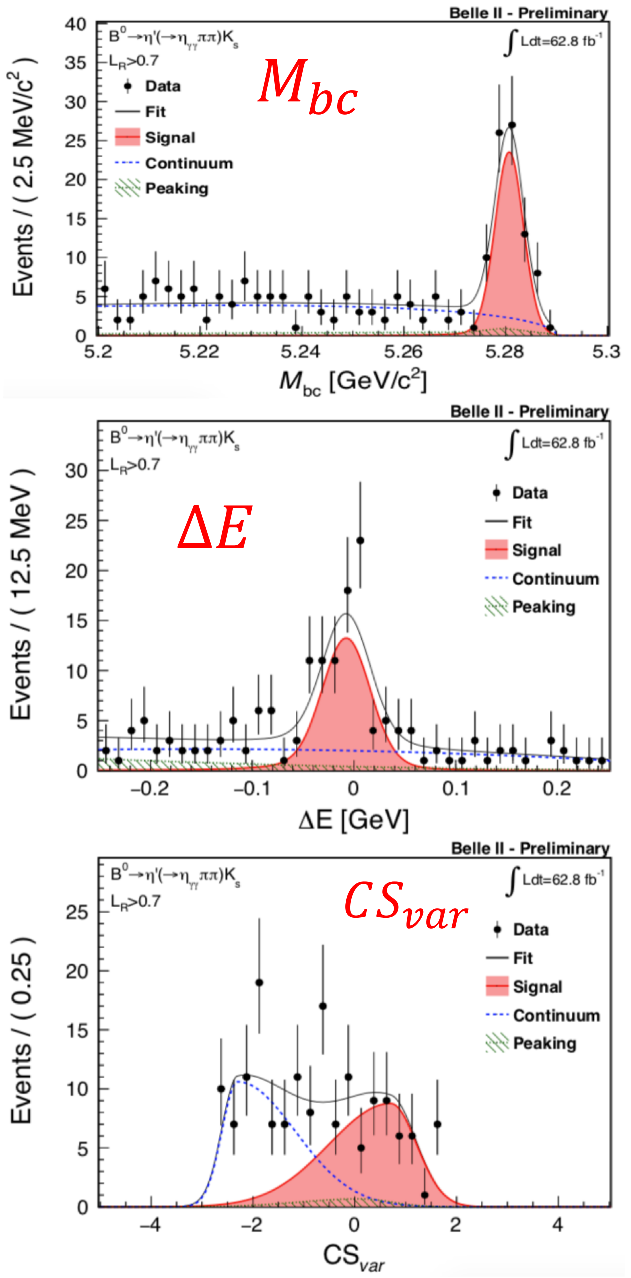
$$CS_{var} = log(\frac{FBDT - FBDT_{low}}{FBDT_{high} - FBDT})$$

- Results with 62.8 fb^{-1}

$$\mathcal{B}(B^\pm \to \eta' K^\pm) = [63.4^{+3.4}_{-3.3}\,(stat.) \pm 3.2(syst.)]\times 10^{-6}$$

$$\mathcal{B}(B^0 \to \eta' K_S^0) = [59.9^{+5.8}_{-5.5}(stat.) \pm 2.9(syst.)]\times 10^{-6}$$

The first measurement of branching fractions at Belle II



First search for direct CP-violating asymmetry in $B^0 \to K^0\pi^0$ decays at Belle II

arXiv:2104.14871

- Isospin sum rule

$$I_{K\pi} = \mathcal{A}_{K^+\pi^-} + \mathcal{A}_{K^0\pi^-}\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^+\pi^0}\frac{\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^0\pi^0}\frac{\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}}$$

  - Stringent null test of standard model(SM)
  - Sensitive to the presence of non-SM physics

- The reconstruction of K_S^0 and π^0 is challenging in this analysis

- Belle II unique access, major limitation in $I_{K\pi}$ determination

- Flavor tagging is required, fit of ΔE- M_{bc}

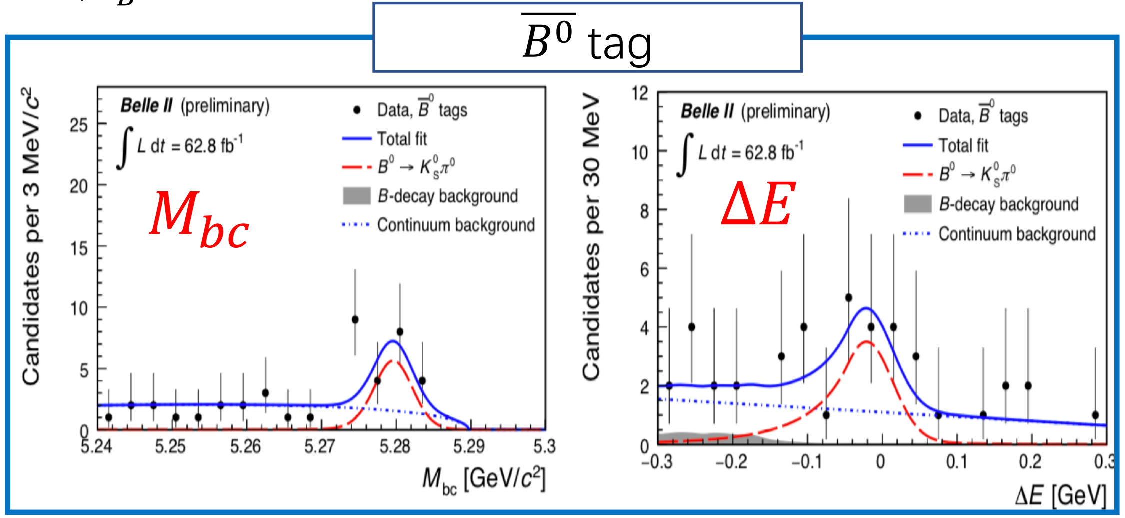
  Flavor-tagging technique in Belle II ➡ arXiv:2008.02707

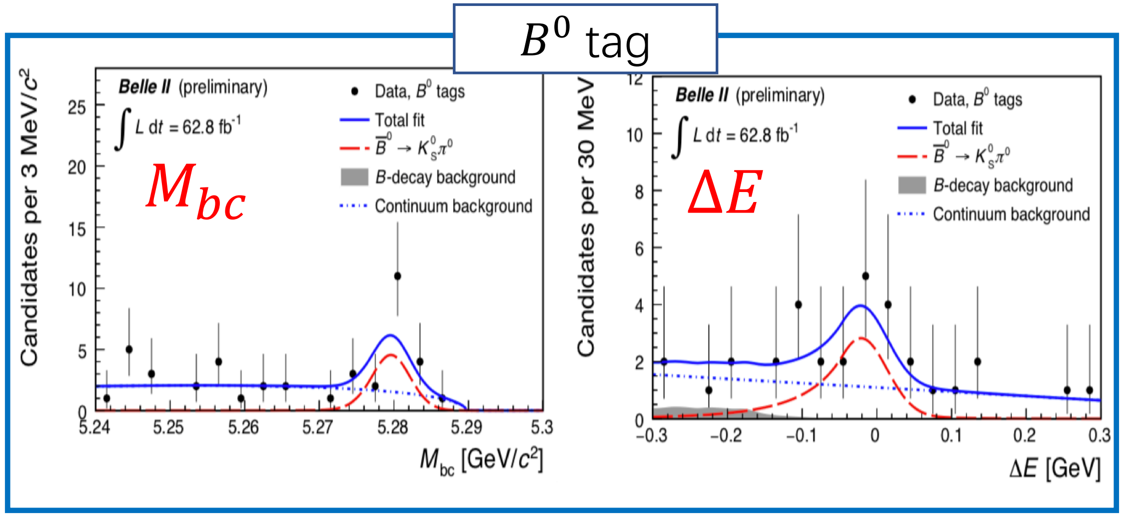
- Results with 62.8 fb^{-1}:

$$\mathcal{B}(B^0 \to K^0\pi^0) = [8.5^{+1.7}_{-1.6}(stat.) \pm 1.2(syst.)]\times 10^{-6}$$

$$\mathcal{A}(B^0 \to K^0\pi^0) = -0.40^{+0.46}_{-0.44}(stat.) \pm 0.04(syst.)$$

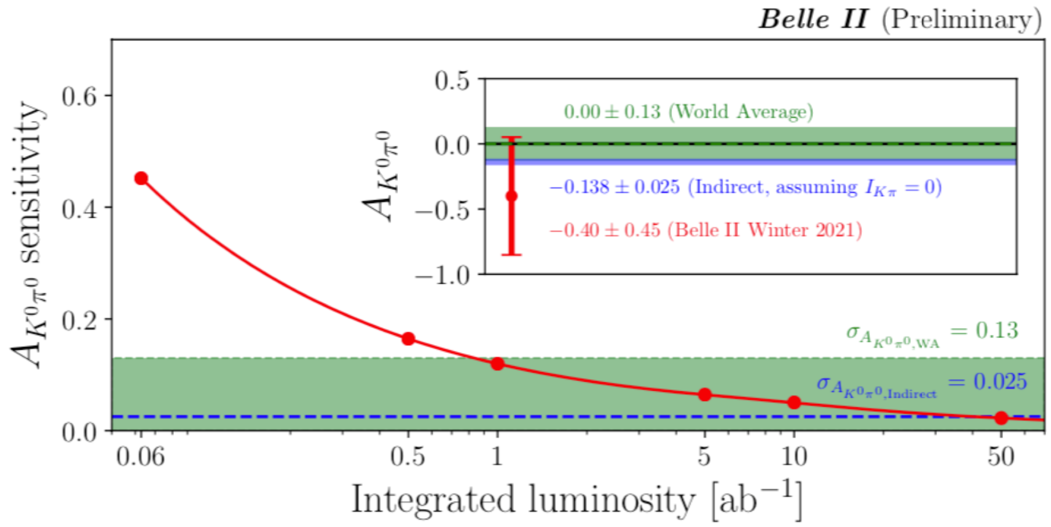
First Belle II measurement of the $B^0 \to K^0\pi^0$ decay

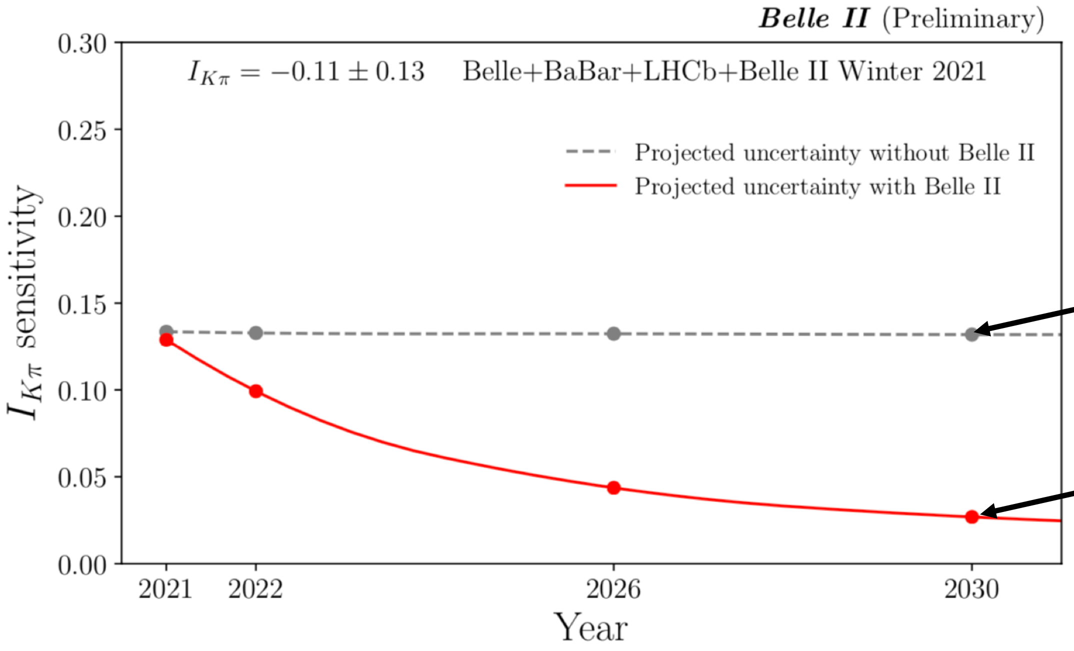




Isospin sum rule Uncertainty projection

- Extrapolate the uncertainty on $I_{K\pi}$ in the next decade
- Future projections with Belle II and LHCb expected luminosities
- Dominant uncertainty coming from $A_{K^0\pi^0}$
- Belle II will play a crucial role in pinning down the $I_{K\pi}$





Grey dashed curve is the case if only $A_{K^+\pi^-}$, $A_{K^+\pi^0}$ and $A_{K^0\pi^+}$ are updated

Red curve is the projection when updates on $I_{K\pi}$ measurements including $A_{K^0\pi^0}$

Measurement of the BFs of $B^0 \to \pi^0\pi^0$ decay at Belle II

PANIC 2021 Conference
arXiv:2107.02373

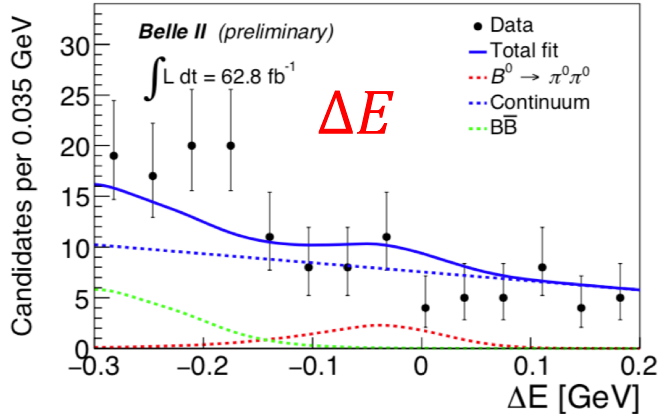
- Unique Belle II capability to this kind of final states to extract CKM angle ϕ_2
- Very challenging :
  - Only neutral final states of two π^0s (only photons to reconstruct)
  - Branching fraction is of $\mathcal{O}(10^{-6})$
- A fast boosted decision-tree(FBDT) training of 20 combined ECL variables is performed to suppress the background photons
- 3D fit of $(\Delta E, M_{bc}, T_c)$ to extract signal

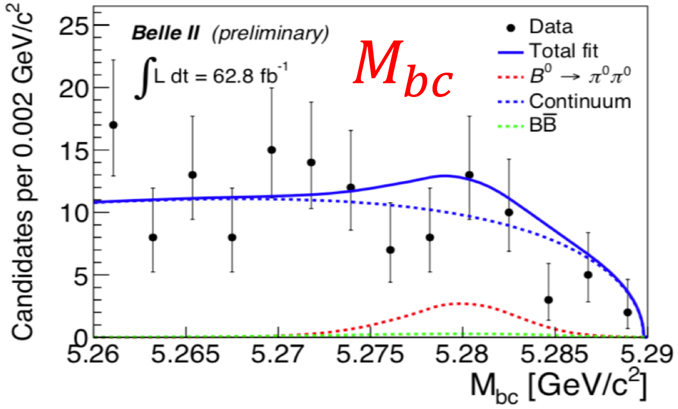
  T_c with 28 input training variables associated with event topology
- Right plots are the signal enhanced projections
- Results with 62.8 fb^{-1} :

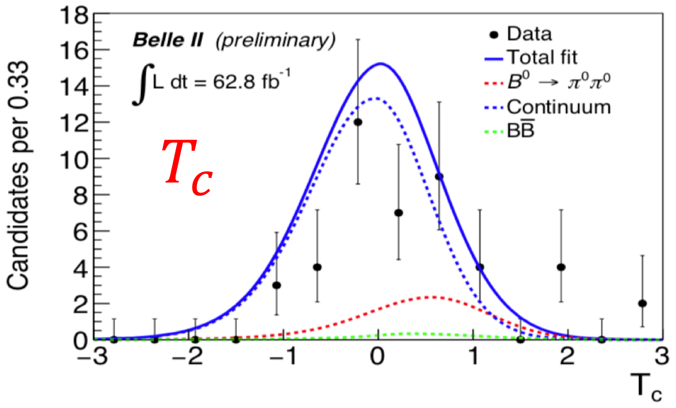
  $N(B^0 \to \pi^0\pi^0) = (14^{+6.8}_{-5.6})$ Signal significance of 3.4 σ

  $\mathcal{B}(B^0 \to \pi^0\pi^0) = (0.98^{+0.48}_{-0.39}(stat.) \pm 0.27(syst.))\times 10^{-6}$

First measurement in Belle II data.
Much improved than Belle report of evidence of 3.4 σ using 140 fb^{-1}







Study of the $\boldsymbol{B^+ \to \rho^+\rho^0}$ decay at Belle II

preliminary

PANIC 2021 Conference

- $\boldsymbol{B \to \rho\rho}$ decays to determine the $\boldsymbol{\phi_2}$
- Pion-only final state and broad $\boldsymbol{\rho}$ peak leads to large background
- Spin-0 decays to spin +1 and spin -1, requires angular analysis
- 6D fit including **ΔE**, T_c and $\boldsymbol{\rho}$ mass to extract the signal; helicity angles to measure fraction f_L of decays with longitudinal polarization
- Results with 62.8 fb^{-1} :

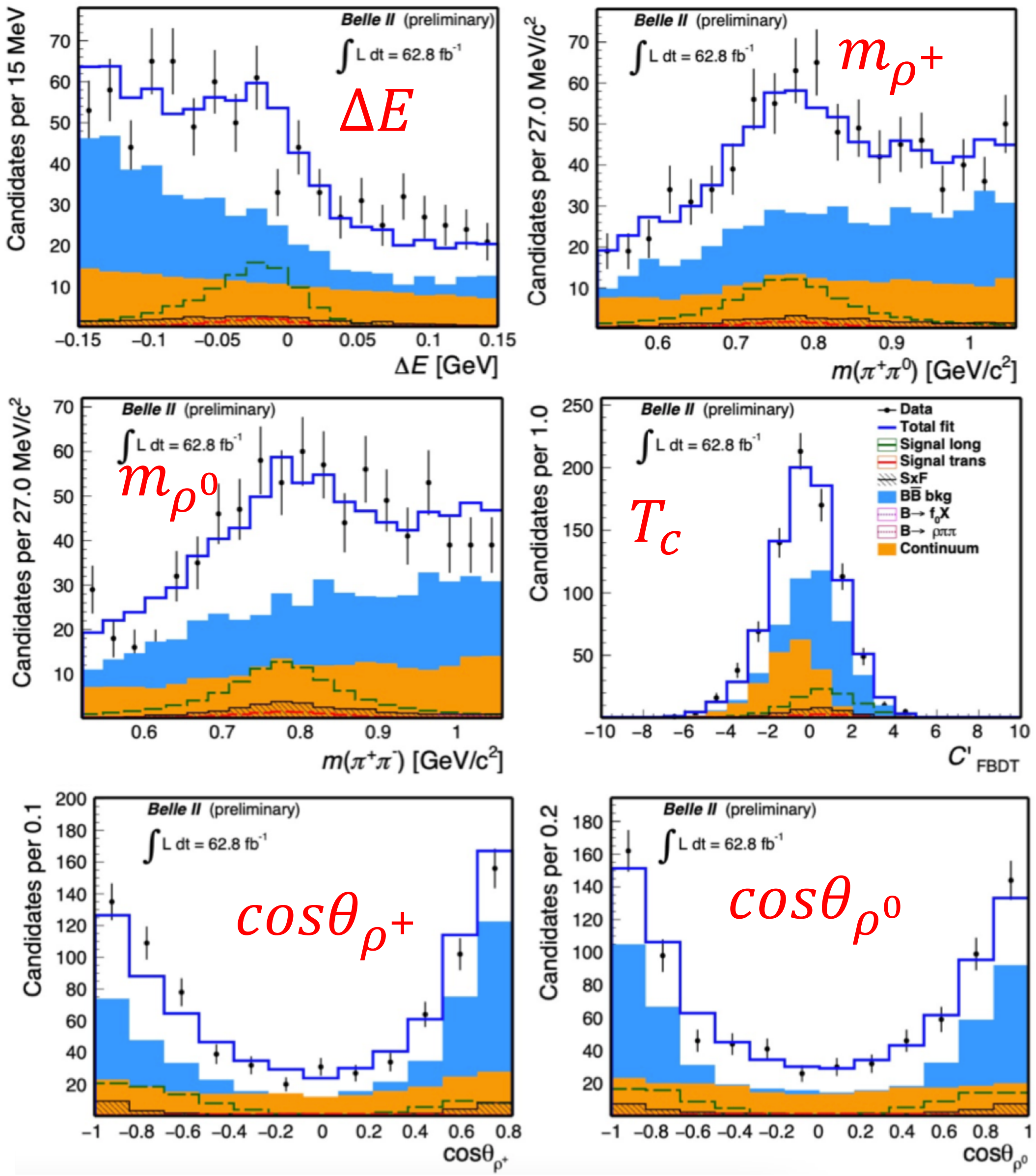
$$\text{N}(B^+ \to \rho^+\rho^0) = 104 \pm 16$$

$$\mathcal{B}(B^+ \to \rho^+\rho^0) = (20.6 \pm 3.2\,(stat.) \pm 4.0(syst.))\times 10^{-6}$$

$$f_L = 0.936^{+0.049}_{-0.041}(stat.) \pm 0.021(syst.)$$

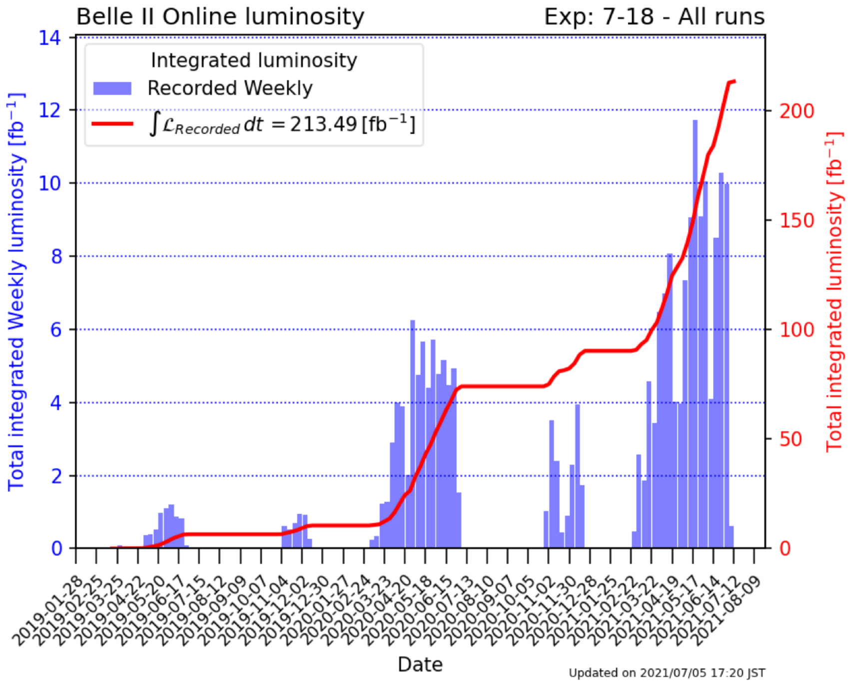
First measurement in Belle II data.

20% better precision than Belle on 78 fb^{-1} PRL 91, 221801 (2003)



Summary

- First observation of color suppressed $D^0 \to \eta\phi$ with high statistical significance with Belle data is reported.
- Studies of precise determination of ϕ_3 are ongoing with the brand new Belle II data. Especially the combined result of Belle + Belle II of $B^- \to D^0(K_S^0\pi^+\pi^-)K^-$ will come soon.
- Belle updated the measurement result of the CPV parameters in $B^0 \to K_S^0 K_S^0 K_S^0$ analysis.
- We measure the decay of $B \to \eta' K$ at Belle II .
- The measurements of isospin sum rule related ingredients are measured with Belle II data.
- Belle II is preparing for a leading role in ϕ_2 measurement.



All the measurements done with Belle II data agree with the known results within uncertainties. With the data-taking carried on, Belle II will lead to more interesting results.

Meanwhile, Belle is still providing fruitful studies and result as well

Thank you for listening !
感谢聆听！

Belle II

Backup

More info. of $D^0 \to \pi^+\pi^-\eta$, $K^+K^-\eta$ and $\eta\phi$

- Detail of A_{raw}

$$A_{raw} = A_{CP}^{D^0\to f} + A_{FB}^{D^{*+}} + A_{\epsilon}^{\pi_s}$$

The first term is what we want; the second term is the forward-backward asymmetry due to $\gamma - Z^0$ interference and higher-order QED effects in $e^+e^- \to c\bar{c}$ collision; the third term is asymmetry resulting from a difference in reconstruction efficiencies between π_S^- and π_S^+.

- The corrected asymmetry is :

$$A_{corr}(cos\theta) = A_{CP}^{D^0\to f} + A_{FB}^{D^{*+}}(cos\theta)$$

The third term cancel with the weights for $\pi_{soft}(p_T, cos\theta)$

- The observable to extract:

$$A_{CP}(cos\theta) = \frac{A_{corr}(cos\theta)+A_{corr}(-cos\theta)}{2}$$

$$A_{FB}(cos\theta) = \frac{A_{corr}(cos\theta)-A_{corr}(-cos\theta)}{2}$$

- Systematic uncertainties

Systematic sources	$\frac{\mathcal{B}(D^0\to\pi^+\pi^-\eta)}{\mathcal{B}(D^0\to K^-\pi^+\eta)}$	$\frac{\mathcal{B}(D^0\to K^+K^-\eta)}{\mathcal{B}(D^0\to K^-\pi^+\eta)}$	$\frac{\mathcal{B}(D^0\to(\phi\to K^+K^-)\eta)}{\mathcal{B}(D^0\to K^-\pi^+\eta)}$
PID efficiency correction	1.8%	1.9%	1.9%
Signal PDF	0.3%	0.5%	0.9%
Background PDF	0.0%	0.0%	0.1%
Mass resolution calibration	0.1%	0.3%	0.0%
Yield correction with efficiency map	0.3%	0.7%	–
MC statistics	0.3%	0.4%	0.4%
K_S^0 veto	0.1%	–	–
Interference in M_{KK}	–	–	2.5%
Total syst. error	1.9%	2.1%	3.3%

Sources	$\sigma_{A_{CP}}(D^0\to\pi^+\pi^-\eta)$	$\sigma_{A_{CP}}(D^0\to K^+K^-\eta)$	$\sigma_{A_{CP}}(D^0\to\phi\eta)$
Signal and bkg	0.004	0.010	0.006
$\cos\theta^*$ binning	0.002	0.004	0.002
$A_\varepsilon(\pi_s)$ map	0.001	0.001	0.001
Total syst. error	0.005	0.011	0.006

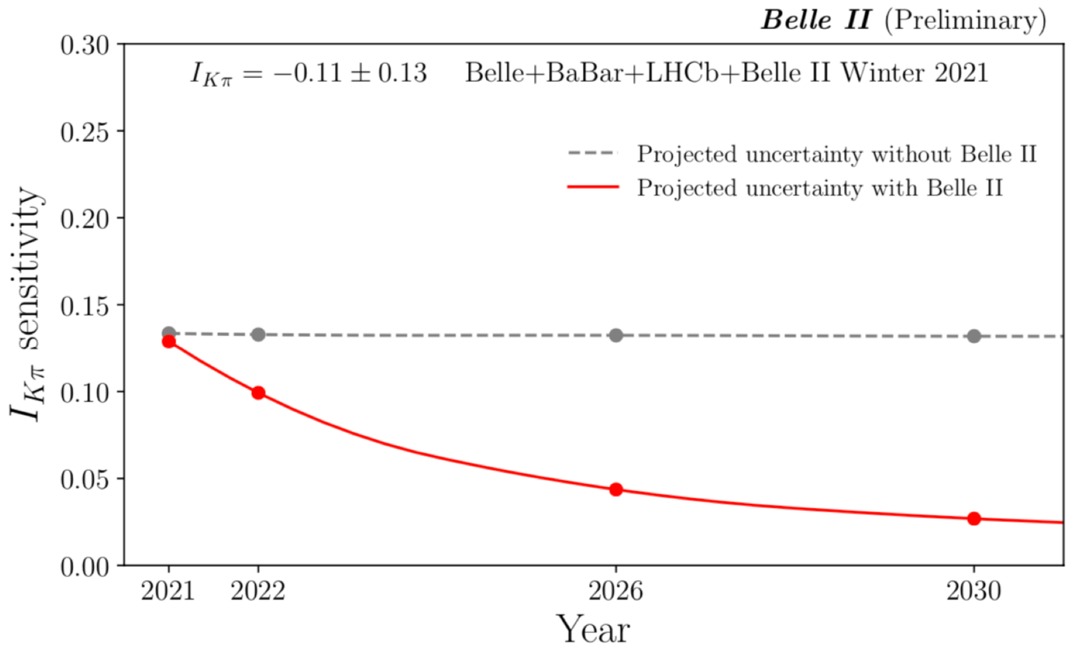
More info. Of Ratio and branching fraction in $B^0 \to D^- h^+$ decay

- Most of the systematic effects cancel in the ratio of the BF due to the kinematical similarity of the two decay modes $B^0 \to D^- K^+$ and $B^0 \to D^- \pi^+$
- The main source of systematic uncertainty is from the K/π identification.
- We assumed all the systematic uncertainties to be independent.
- Total uncertainty is the sum in quadrature of the contribution from individual sources.

Source	R^D	$\mathcal{B}(\overline{B}^0 \to D^+\pi^-)$	$\mathcal{B}(\overline{B}^0 \to D^+K^-)$
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$	–	1.71%	1.71%
Multiplicative uncertainties			
Tracking	–	1.40%	1.40%
MC statistics	–	0.04%	0.04%
$\Delta N_{B\bar{B}}$	–	1.37%	1.37%
f_{00}	–	1.23%	1.23%
PID efficiency of K/π (stat.)	0.01%	0.00%	0.31%
PID efficiency of K/π (syst.)	0.01%	0.04%	0.64%
Total multiplicative	0.01%	2.31%	2.42 %
Additive uncertainties			
PDF parameterisation	0.199×10^{-2}	0.040×10^{-3}	0.028×10^{-4}
D^+ mass selection window	0.002×10^{-2}	0.058×10^{-3}	0.047×10^{-4}
J/ψ veto selection	0.003×10^{-2}	0.001×10^{-3}	0.000×10^{-4}
Fit bias	–	0.030×10^{-3}	0.020×10^{-4}
Total additive	0.199×10^{-2}	0.077×10^{-3}	0.058×10^{-4}

More info. of isospin sum rule

- Uncertainty projection



Red curve is the projection when updates on the complete set of $K\pi$ measurements

Grey dashed curve is the case if only $A_{K^+\pi^-}$, $A_{K^+\pi^0}$ and $A_{K^0\pi^+}$ are updated

Belle II will play a crucial role in pinning down the $I_{K\pi}$

- Systematic uncertainties of $B^0 \to K^0\pi^0$ measurement

Source	$\delta\mathcal{B}(\%)$
Tracking efficiency	1.8
K_S^0 reconstruction efficiency	3.8
π^0 reconstruction efficiency	13.0
Continuum-suppression efficiency	2.4
N($B\bar{B}$) (as written in Eq. 3)	1.4
Signal model	<0.1
Continuum background model	1.4
Total	14.0

Source	$\delta\mathcal{A}_{K^0\pi^0}$
Flavor tagging modelling	0.03
B^0 mixing parameter χ_d	<0.01
B-decay background asymmetry	0.03
Continuum background asymmetry	0.01
Total	0.04

BF and direct CP-violation in $B^+ \to K^+\pi^0$ and $\pi^+\pi^0$ decays @Belle II

- Isospin sum rule

$$I_{K\pi} = \mathcal{A}_{K^+\pi^-} + \mathcal{A}_{K^0\pi^+}\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^+\pi^0}\frac{\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^0\pi^0}\frac{\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

  I. Stringent null test of standard model(SM)
  II. Sensitive to the presence of non-SM physics

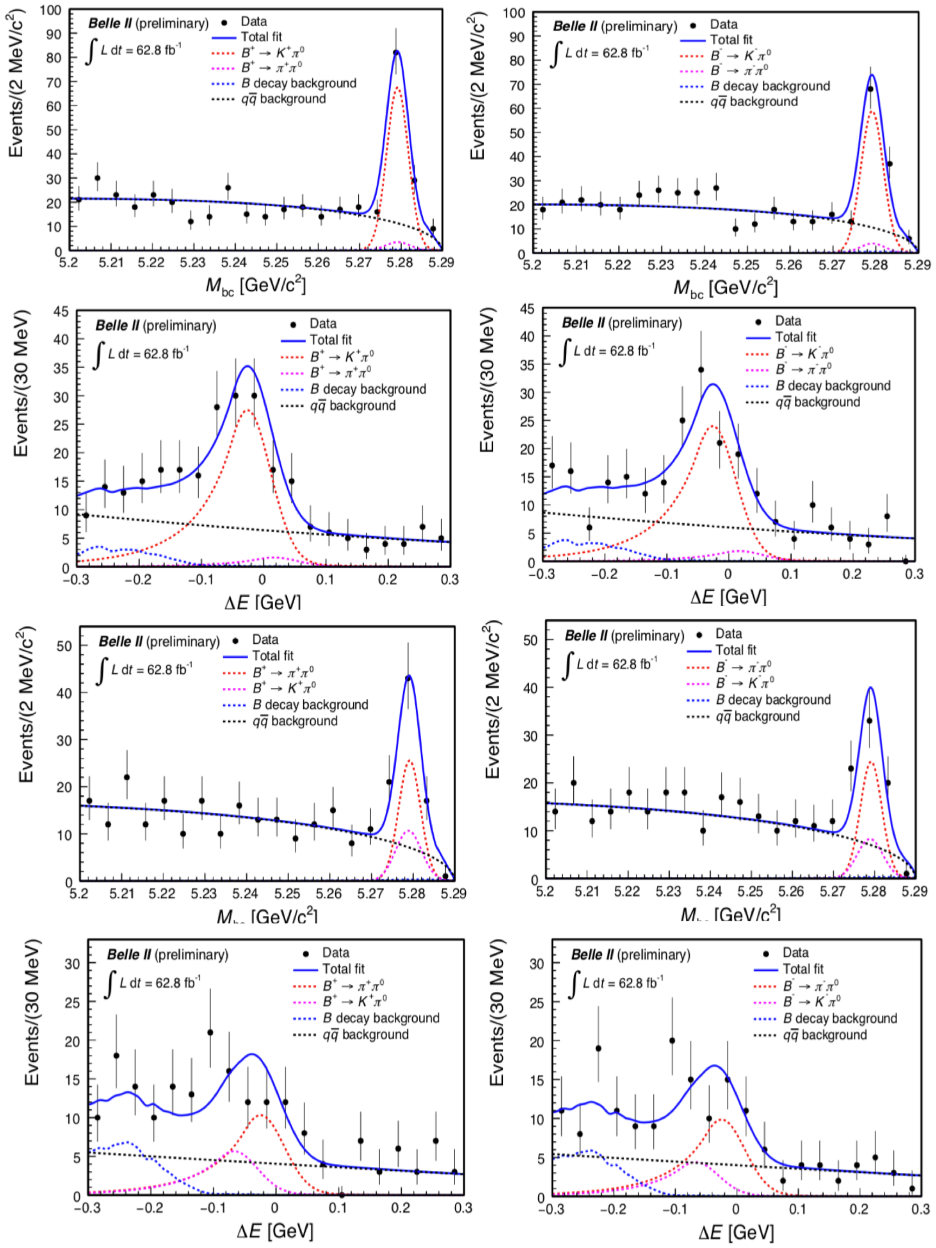
- $\mathcal{B}(B^+ \to \pi^+\pi^0)$ is an ingredient for an isospin-based determination of ϕ_2 based on $B \to \pi\pi$
- One track + one π^0 can probe π^0 reconstruction and PID separation
- 2D fit of $(\Delta E, M_{bc})$
- Results:

$$\mathcal{B}(B^+ \to K^+\pi^0) = [11.9^{+1.1}_{-1.0}(stat.) \pm 1.6(syst.)]\times 10^{-6}$$

$$\mathcal{B}(B^+ \to \pi^+\pi^0) = [5.5^{+1.0}_{-0.9}(stat.) \pm 0.7(syst.)]\times 10^{-6}$$

$$\mathcal{A}(B^0 \to K^+\pi^0) = -0.09 \pm 0.09\ (stat.) \pm 0.03(syst.)$$

$$\mathcal{A}(B^0 \to \pi^+\pi^0) = -0.04 \pm 0.17\ (stat.) \pm 0.06(syst.)$$



BF and direct CP-violation in $B^0 \to K^+\pi^-$, $B^+ \to K_S^0\pi^+$,$\pi^+\pi^-$ decays @Belle II

- Isospin sum rule

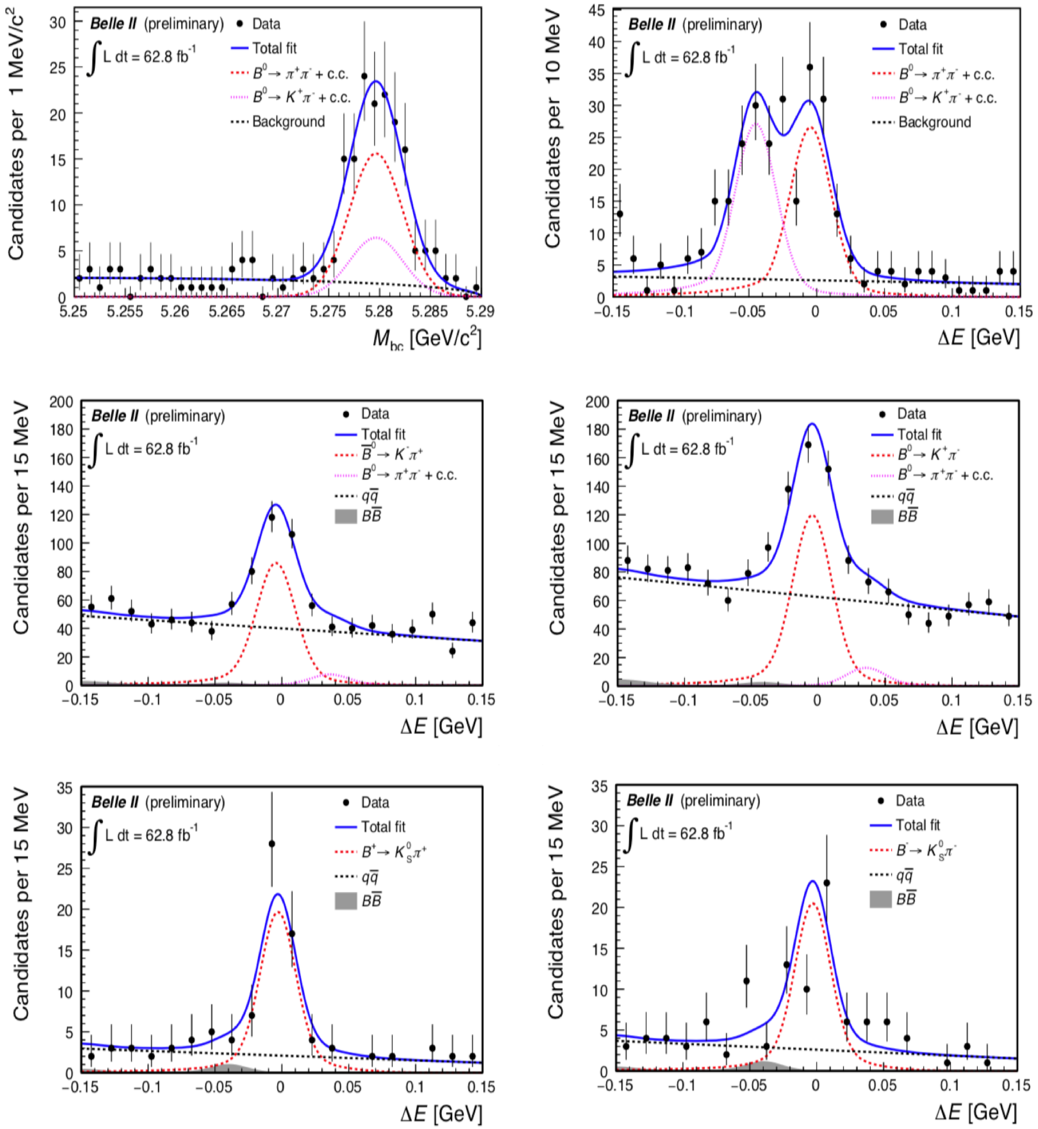
$$I_{K\pi} = \mathcal{A}_{K^+\pi^-} + \mathcal{A}_{K^0\pi^+}\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^+\pi^0}\frac{\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^0\pi^0}\frac{\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

  I. Stringent null test of standard model(SM)
  II. Sensitive to the presence of non-SM physics

- Two tracks final states can probe PID separation
- One K_S^0 and one track final state can valid the reconstruction of K_S^0
- 2D fit of (ΔE, M_{bc})
- Results:

$$\mathcal{B}(B^0 \to K^+\pi^-) = [18.0 \pm 0.9\,(stat.) \pm 0.9(syst.)]\times 10^{-6}$$
$$\mathcal{B}(B^+ \to K^0\pi^+) = [21.4^{+2.3}_{-2.2}(stat.) \pm 1.6(syst.)]\times 10^{-6}$$
$$\mathcal{B}(B^0 \to \pi^+\pi^-) = [5.8 \pm 0.7\,(stat.) \pm 0.3(syst.)]\times 10^{-6}$$

$$\mathcal{A}(B^0 \to K^+\pi^-) = -0.16 \pm 0.05\,(stat.) \pm 0.01(syst.)$$
$$\mathcal{A}(B^0 \to K^0\pi^+) = -0.01 \pm 0.08\,(stat.) \pm 0.05(syst.)$$



First Belle II measurement of the $B^- \to K^0\pi^0$