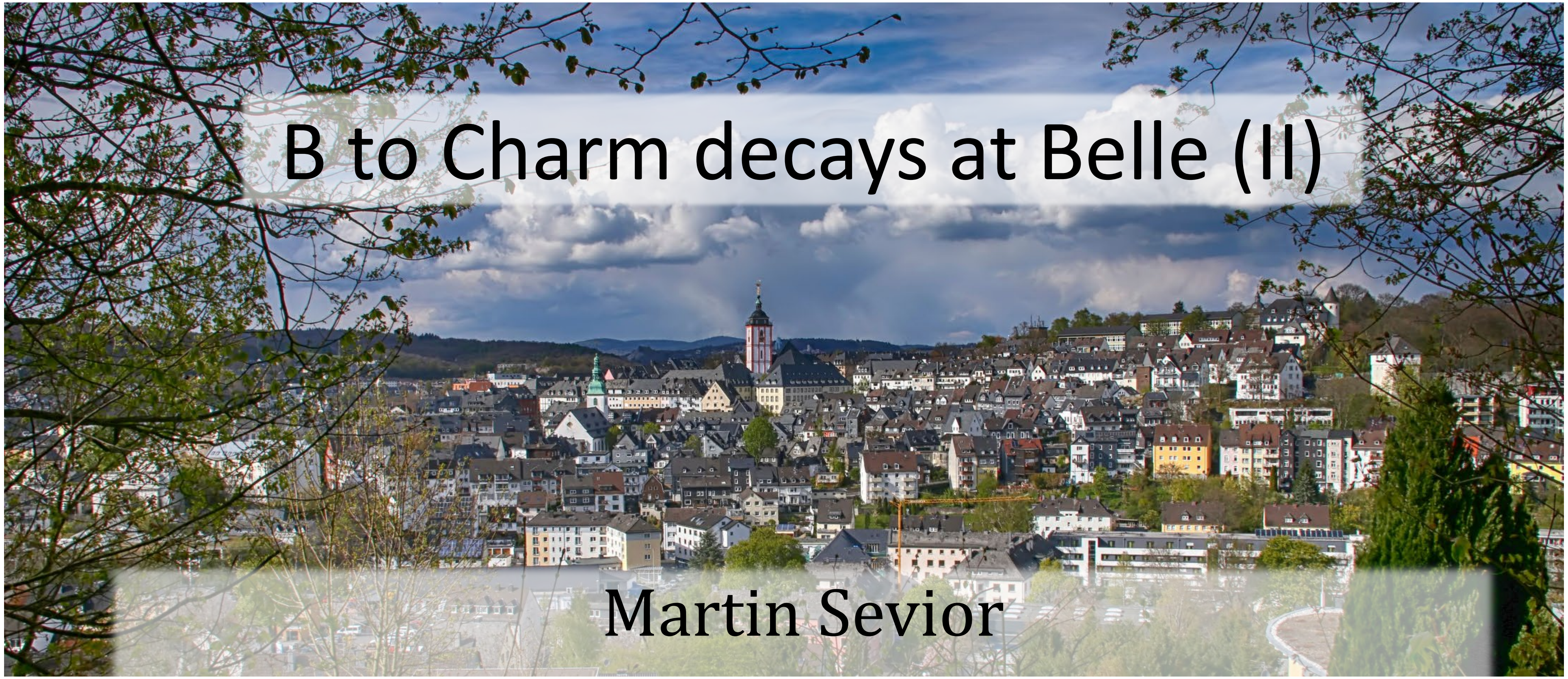
B to Charm decays at Belle (II)



Martin Sevior
University of Melbourne
On Behalf of Belle and Belle II Collaborations

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    T. Bloomfield et al. PRD **105, 072007** (2022) arXiv:2111.12337
  - Combined analysis of Belle and Belle II data to determine the CKM angle Φ_3 using of $B^+ \to D(K_s^0 h^- h^+)\mathrm{h}^+$decays (Belle+ Belle II)
    N. Rout, et al. JHEP 02 **2022**, 063 (2022) arXiv:2110.12125
  - Study of $\overline{B^0} \to D^+ + h^-$ (h=K/π) decays at Belle (Belle)
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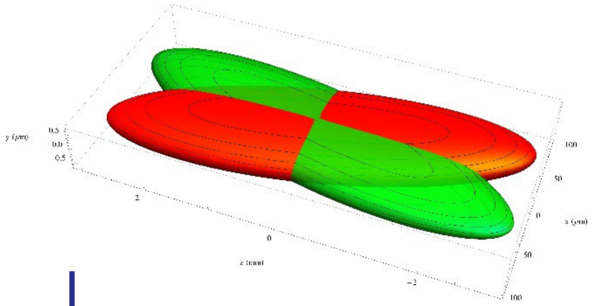
  - Updated B-mixing B-lifetime measurements at Belle II (T. Humair, Moriond EW)
- Summary

Belle/Belle II

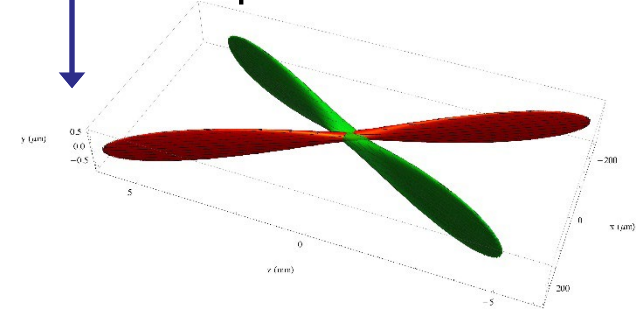
KEK B



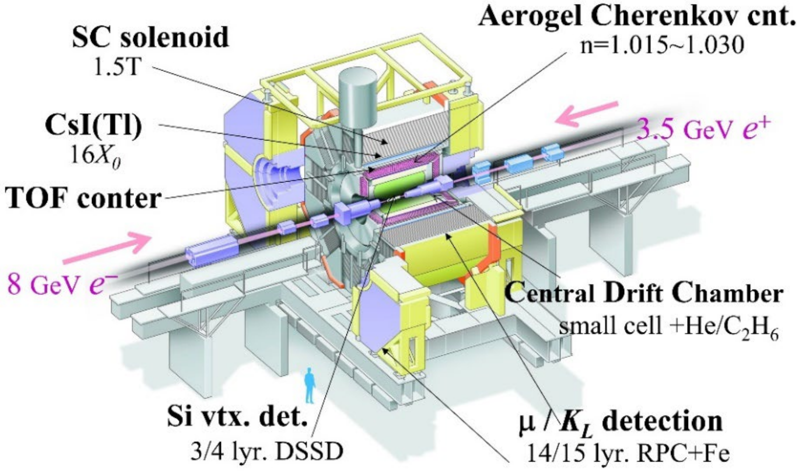
nanobeam

× 30 Luminosity

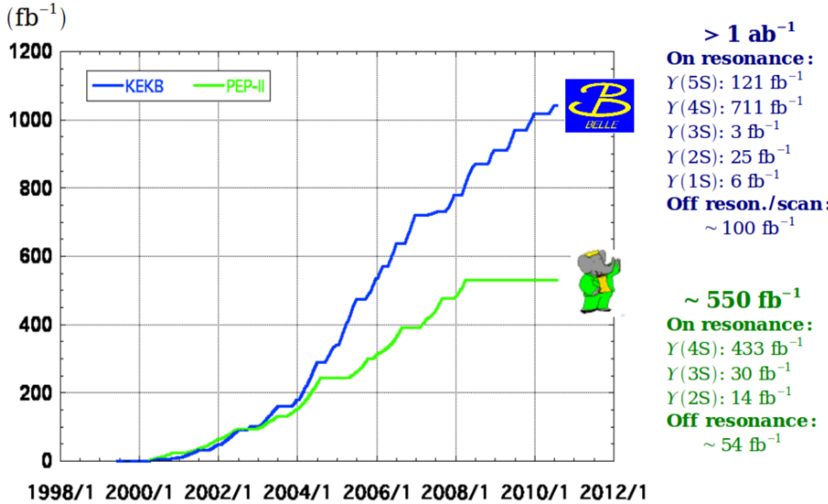
SuperKEK B

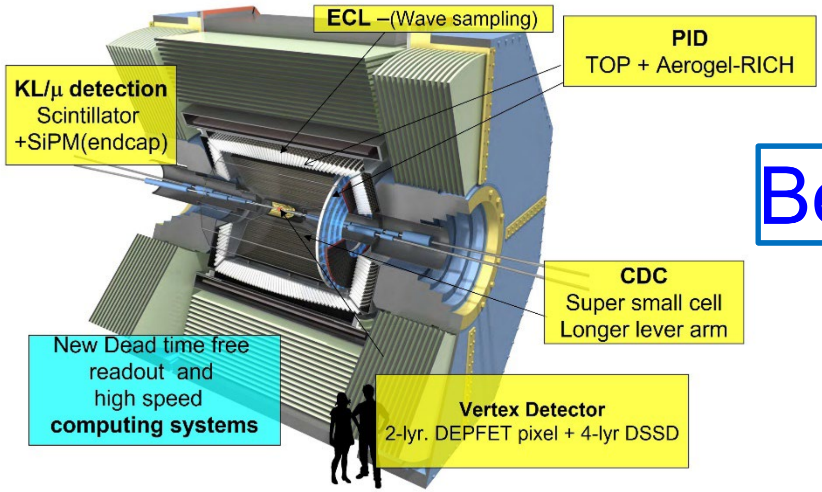


5 mm

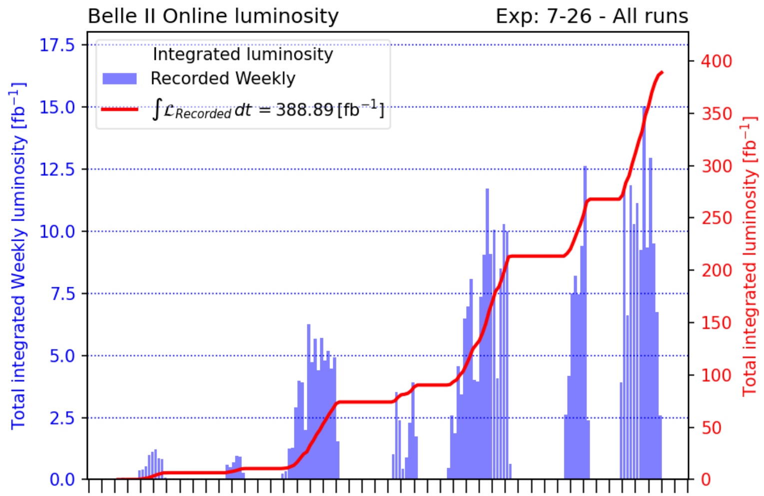


Belle





Belle II



Direct CP Violation

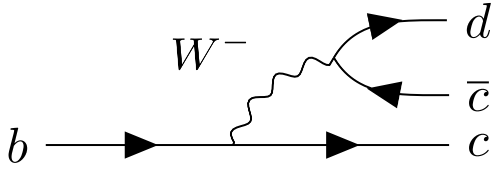
- Direct CP violation when $|A(f)| \neq |\overline{A}(\overline{f})|$

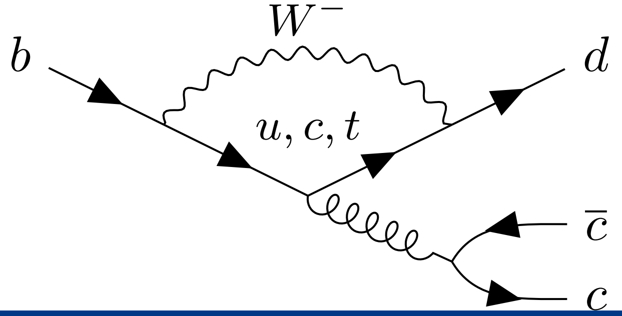
$$A_1 = |a_1| e^{i(\delta_1+\phi_1)} \qquad \overline{A_1} = |a_1| e^{i(\delta_1-\phi_1)}$$

$$\boldsymbol{A} \rightarrow \boldsymbol{f} \quad \xrightarrow{CP} \quad \boldsymbol{\overline{A}} \rightarrow \boldsymbol{\overline{f}}$$

$$A_2 = |a_2| e^{i(\delta_2+\phi_2)} \qquad \overline{A_2} = |a_2| e^{i(\delta_2-\phi_2)}$$

- $\phi_{1,2}$ CP violating weak phase (CKM)
- $\delta_{1,2}$ CP invariant strong phase (differing mechanisms)
- $A_{CP}(P \rightarrow f) \equiv \frac{\Gamma(\mathrm{P}\rightarrow\mathrm{f})-\Gamma(\overline{P}\rightarrow\overline{f})}{\Gamma(\mathrm{P}\rightarrow\mathrm{f})+\Gamma(\overline{P}\rightarrow\overline{f})} \propto \sin(\phi_1-\phi_2)\sin(\delta_1-\delta_2)$
- ∴Need possesses with both strong and weak phase difference.



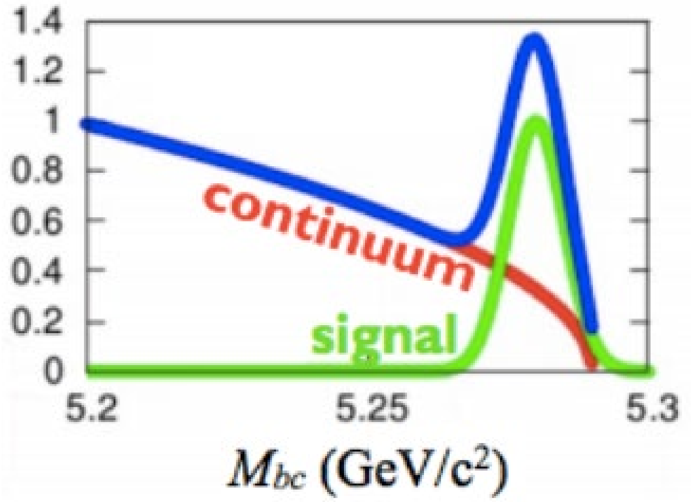


T. Bloomfield

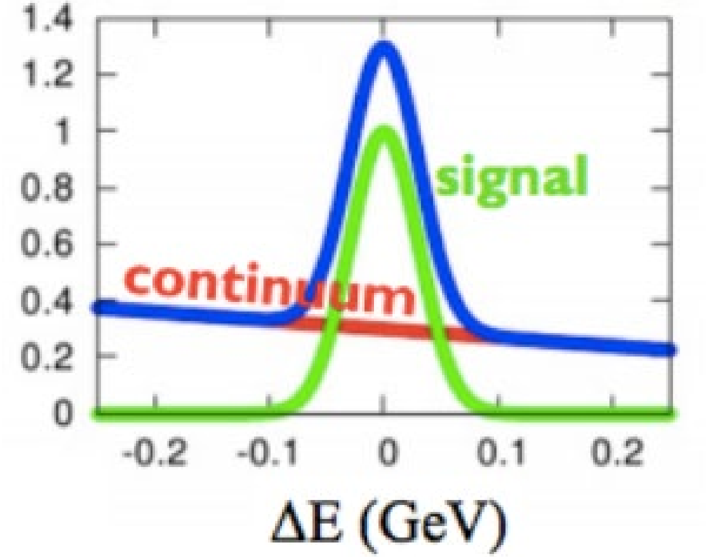
Signal Reconstruction

- Charged particles from hadron ID and tracking.
- Neutral particles from decays:
  - $\pi^0 \rightarrow \gamma\gamma$, pairs in ECL.
  - $K_s \rightarrow \pi^+\pi^-$
- Kinematic variables for fitting: Exploit very well known (e^+e^-)initial state

$$M_{bc} = \sqrt{E_{Beam}^2 - p_B^2}$$



$$\Delta E = E_B - E_{Beam}$$



T. Bloomfield

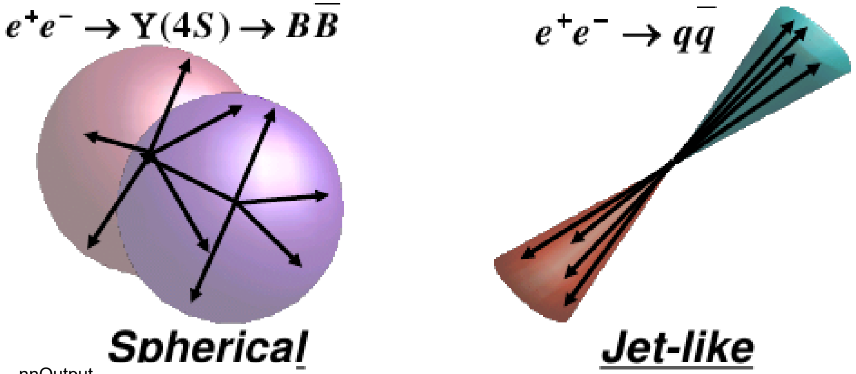
Continuum Suppression

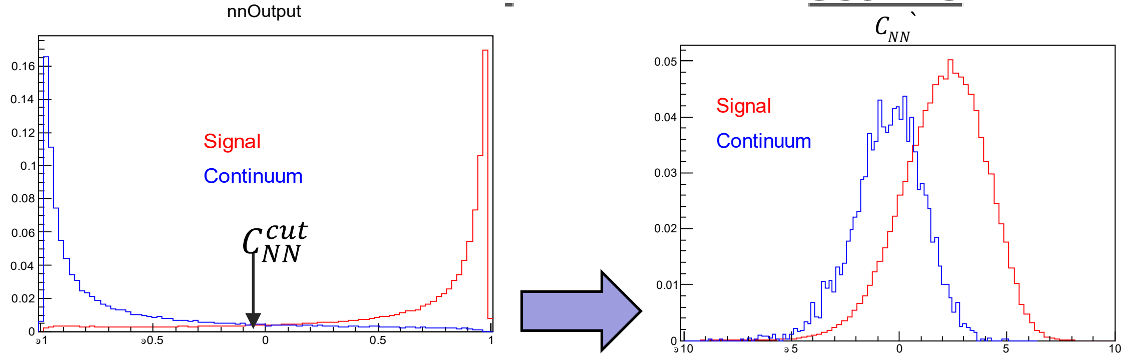
- $e^+e^- \rightarrow q\overline{q}$ $(q \in u, d, s, c)$ dominant background. ~3 times $e^+e^- \rightarrow \Upsilon(4S)$ cross-section.
- Discriminate using event topology.
- Modified Fox-Wolfram moments

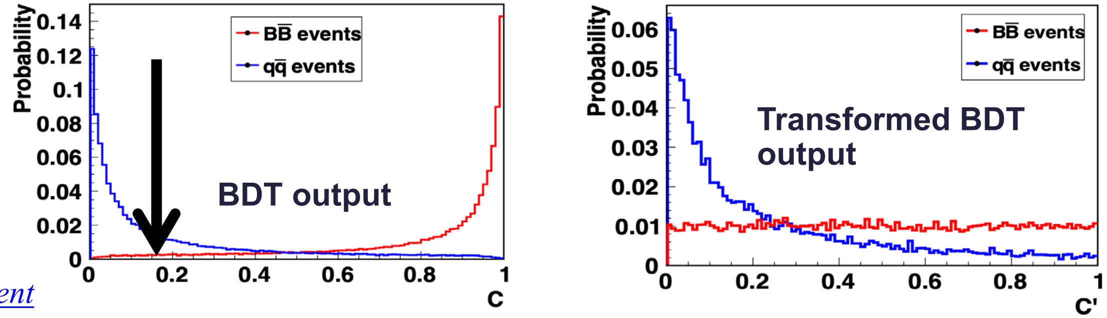
$$R_2 = \frac{\sum_{i,j}|p_i||p_j|P_2(\cos\theta_{i,j})}{\sum_{i,j}|p_i||p_j|}$$

- Combine with other variables using Machine learning (BDT , NN)
- Transform to fit:

$$C'_{NN} = \log\left(\frac{C_{NN} - C_{NN}^{cut}}{C_{NN}^{max} - C_{NN}}\right)$$, μ-transfrom



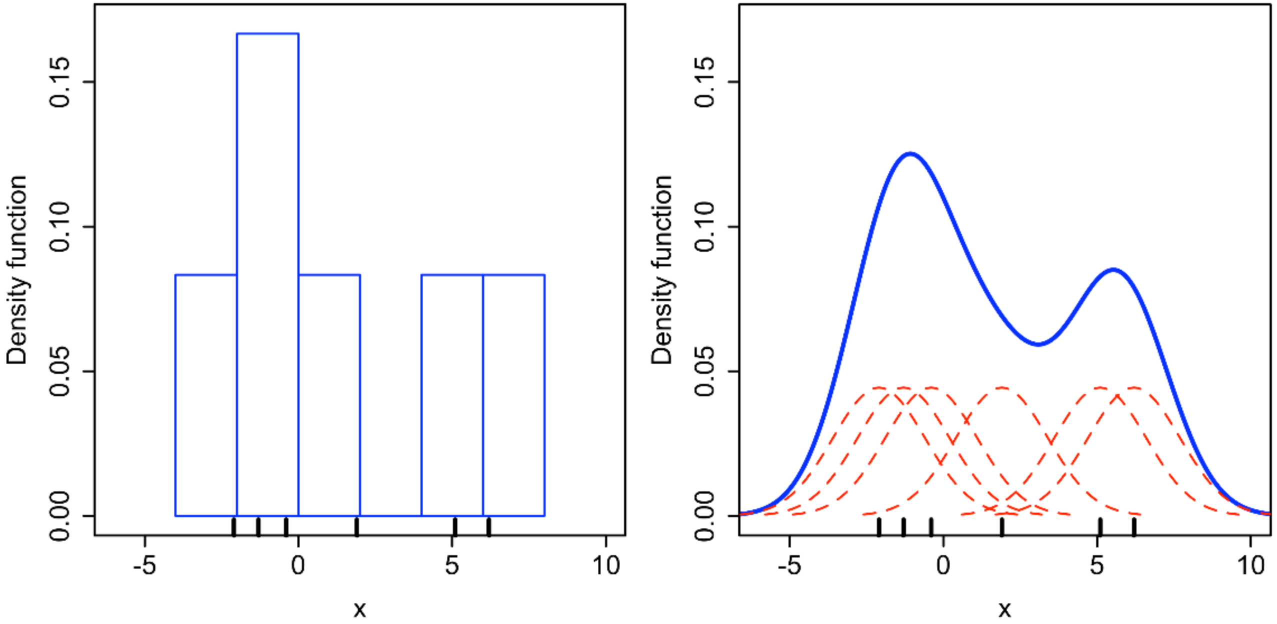




http://tel.archives-ouvertes.fr/tel-00002991/document

KEST PDF for 2D MC based models

- Kernel density estimation models dataset by superposition of kernel function (Gaussian) for each datapoint.
- Use adaptive bandwidth to adjust Gaussian width based on local event density.
- Retains information in high density areas while smoothing low density.



T. Bloomfield

$B^0 \to \overline{D^0}\pi^0$ and $B^+ \to \overline{D^0}\pi^+$ Motivations (Belle)

- Both commonly used control mode in other analysis, allow for high-precision validations of techniques.
  - Important for Belle II precision frontier.

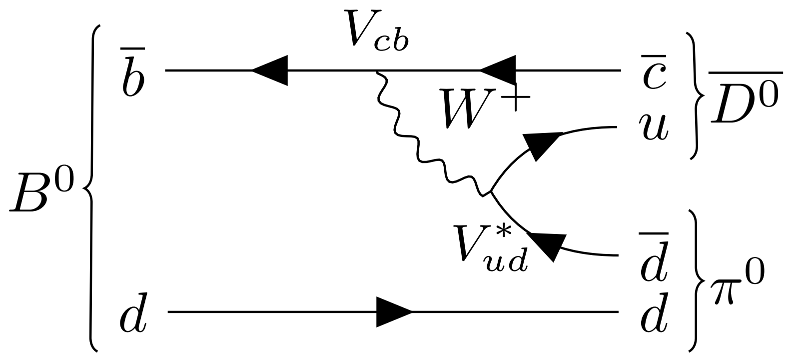
- $\mathrm{B}^0 \to \overline{\mathrm{D}^0}\pi^0$ notably large non-factorisable components.
  - $\mathfrak{B} \gg$ ‘naïve’ factorisation predictions.
  - Constraints for models of final state interactions
  - SCET, pQCD

T. Bloomfield

$B^0 \to \overline{D^0}\pi^0$ and $B^+ \to \overline{D^0}\pi^+$

T. Bloomfield

- $b \to c\bar{u}d$ decay.
- No penguin as final state quark different flavour ⇒ expect no A_{CP}.



$B^0 \to \overline{D^0}\pi^0$

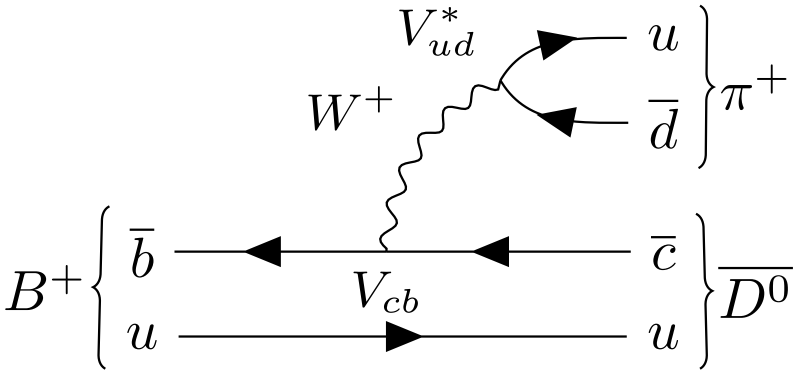
Colour suppressed

Previous results:

Belle: $\mathfrak{B} = (2.25 \pm 0.14 \pm 0.35) \times 10^{-4}$ PRD 74, 092002 (2006)

Babar: $\mathfrak{B} = (2.69 \pm 0.09 \pm 0.13) \times 10^{-4}$ PRD 84(3), 112007 (2011)

A_{CP} is unmeasured.



$B^+ \to \overline{D^0}\pi^+$

Colour allowed, $\mathfrak{B}$ is $\mathcal{O}(10)$ higher.

Previous results:

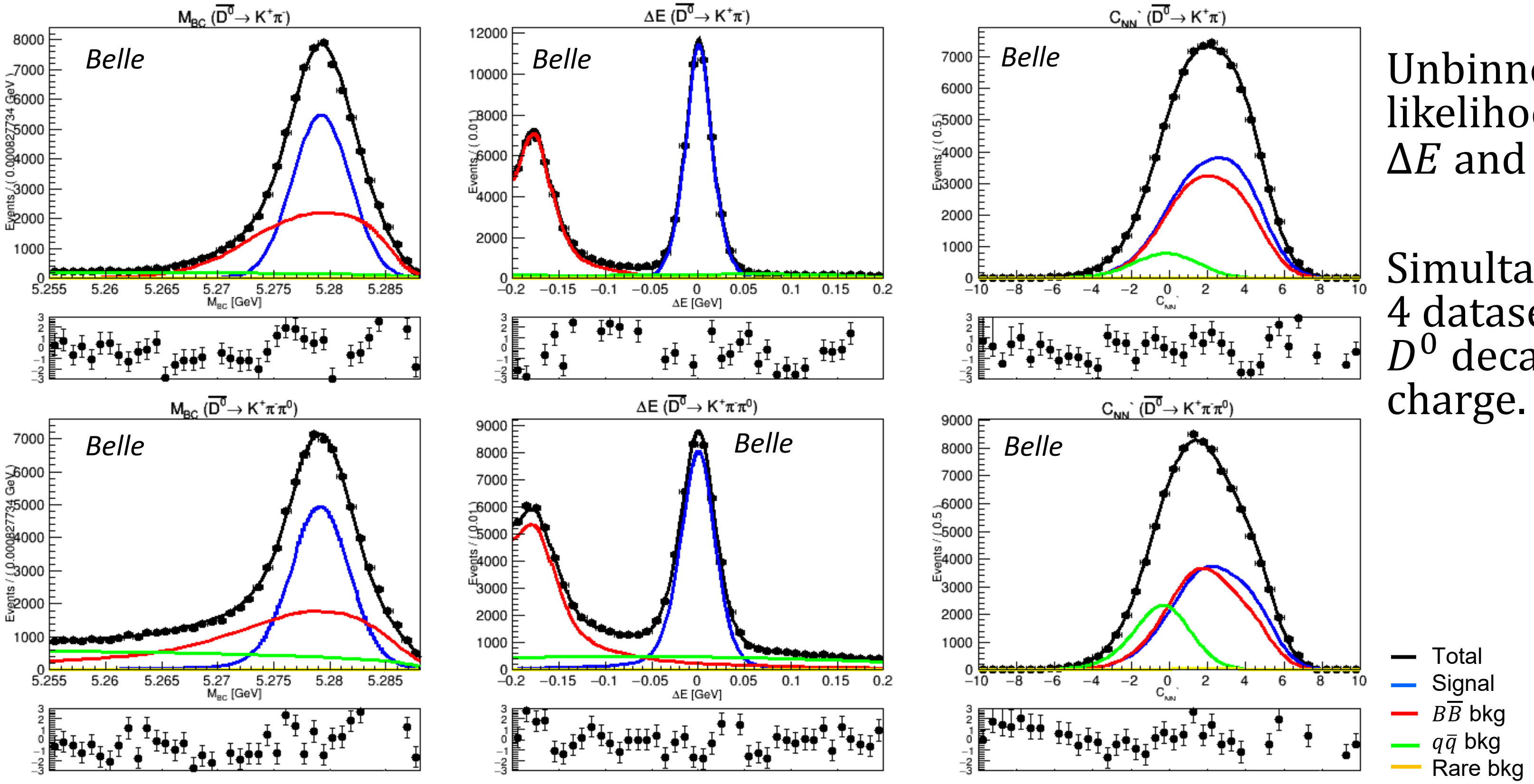
Belle: $\mathfrak{B} = (4.34 \pm 0.10 \pm 0.23) \times 10^{-3}$ PRD 97(1), 012005 (2018)

Babar: $\mathfrak{B} = (4.90 \pm 0.07 \pm 0.22) \times 10^{-3}$ PRD 75, 031101 (2007)

Belle: $A_{CP} = (-0.8 \pm 0.8)\%$ PRD 73, 051106 (2006)

LHCb: $A_{CP} = (-0.6 \pm 0.5 \pm 1.0)\%$ PLB 723, 4453 (2013)

$B^+ \to \overline{D^0}\pi^+$ Result



Unbinned maximum likelihood fit in M_{BC}, ΔE and C'_{NN}

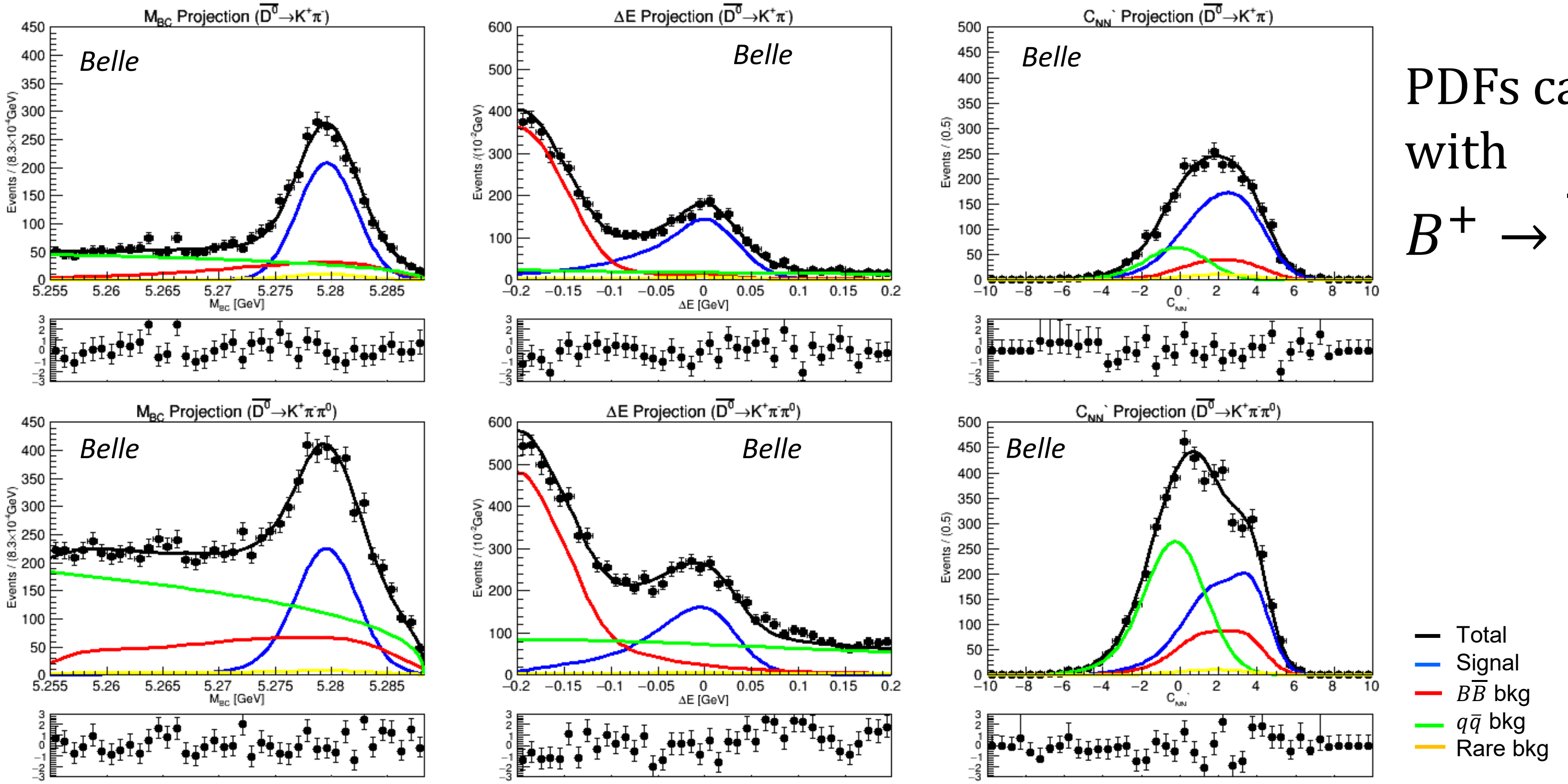
Simultaneous fit over 4 datasets divided by D^0 decay and Kaon charge.

$$\mathfrak{B} = (4.53 \pm 0.02 \pm 0.15) \times 10^{-3}$$
$$A_{CP} = (0.19 \pm 0.36 \pm 0.57)\%$$

~1.7x improvement in precision

T. Bloomfield

$B^0 \to \overline{D^0}\pi^0$ Result



PDFs calibrated with $B^+ \to \overline{D^0}\pi^+$ fit.

$$\mathfrak{B} = (2.70 \pm 0.06 \pm 0.10) \times 10^{-4}$$

Most precise measurement in this channel

$$A_{CP} = (0.42 \pm 2.05 \pm 1.22)\%$$

First measurement in this channel

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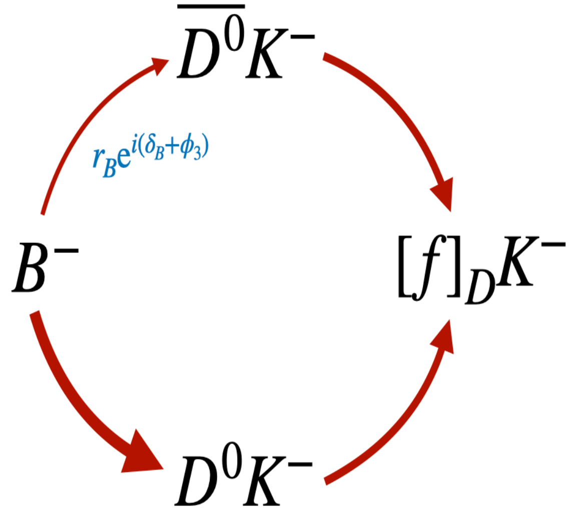
CKM angle ϕ_3 (Belle + Belle II)

ϕ_3 is the phase between $b \to u$ and $b \to c$ quark transitions: $B \to DK$

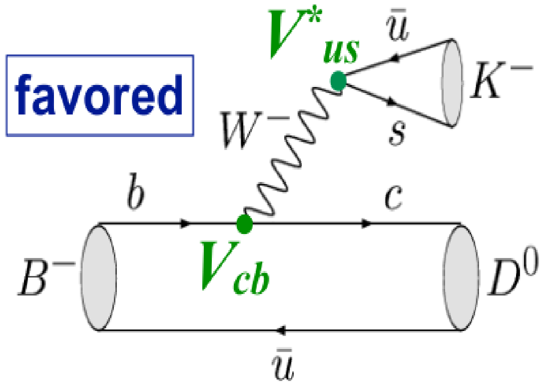


- Common final states allow the interference between the two paths
- Interference gives access to the phase
- The level of interference, and its exact interpretation, depend on the physics of B and D decays

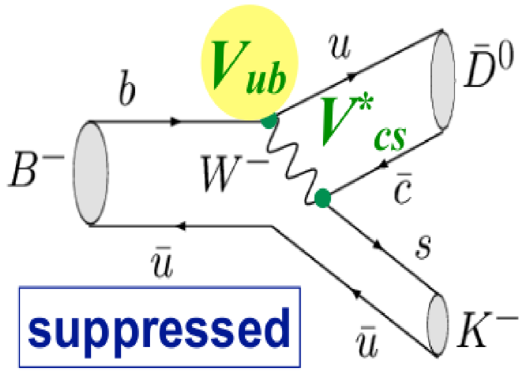
$$\frac{\mathcal{A}^{\text{suppr.}}(B^- \to \overline{D}^0 K^-)}{\mathcal{A}^{\text{favor.}}(B^- \to D^0 K^-)} = r_B e^{i(\delta_B+\phi_3)}$$

Results are limited by the sample size because of the small branching fraction of the decays involved

$B^- \to D^0 K^-$



$B^- \to \overline{D}^0 K^-$



N. Rout

BPGGSZ method *[Phys. Rev. D **68**, 054018]*

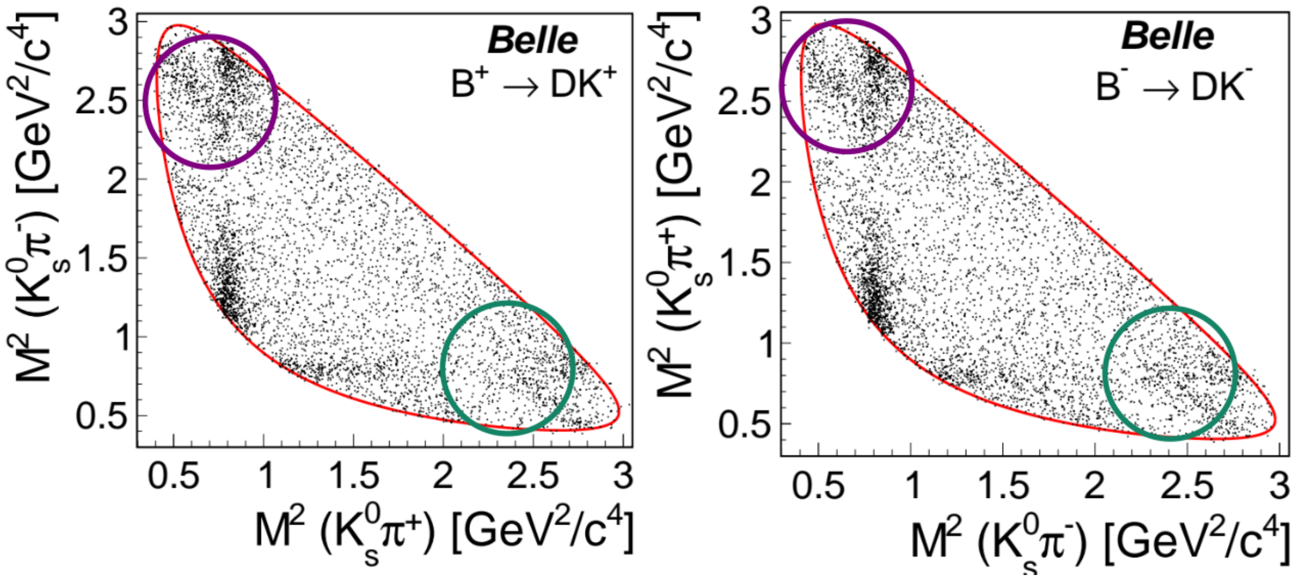
N. Rout

- Uses self-conjugate multi-body $D(K_S^0 hh)$ final states
- Sensitivity to ϕ_3 by comparing D Dalitz plot distributions of B^+ and B^-
- In presence of *CP* violation, differences between B^+ and B^- distributions are expected
- The magnitude and position of the difference is driven by r_B, δ_B, ϕ_3 and the physics of the D decays
- **But, model-dependent analyses have model uncertainty up-to** $3^\circ - 9^\circ$

Fit D Dalitz plot with full Amplitude model

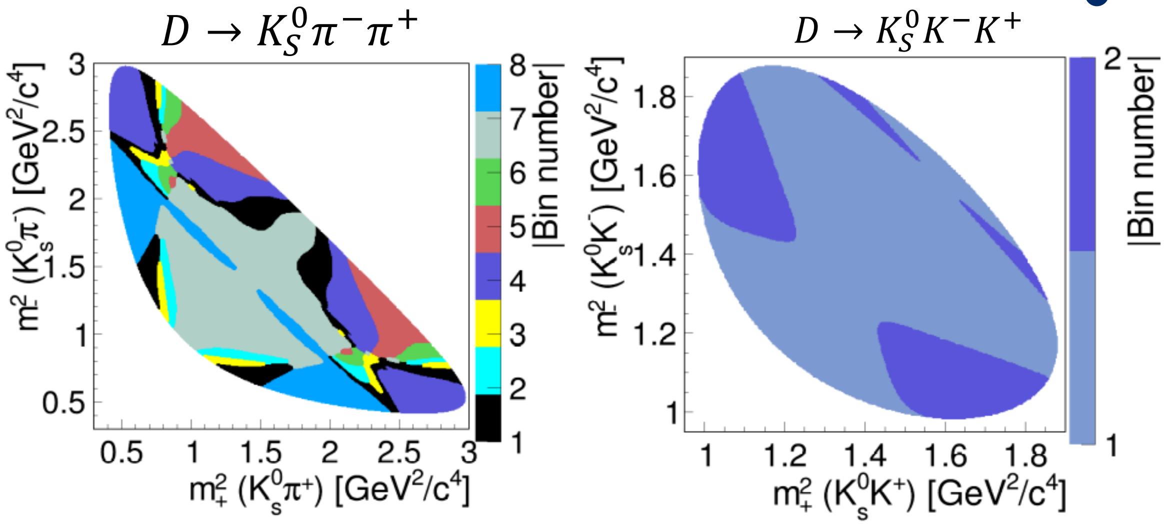
$$A_{B^+} = \overline{A}(m_-^2, m_+^2) + r_B e^{i(\delta_B - \phi_3)} A(m_-^2, m_+^2)$$

$m_\pm^2$ = squared invariant mass of $K_S^0 h^\pm$: D Dalitz plot variable



BPGGSZ: binned model-independent approach

- Optimal (non-uniform) binning of the D Dalitz plot which gives maximum sensitivity to ϕ3
- Observed yields in each bin can be related to physics parameters of interest and *D* decay information



$$N_i^{\pm} = h_{B^\pm}\left[F_i + r_B^2\bar{F}_i + 2\sqrt{F_i\bar{F}_i}(c_i x_\pm + s_i y_\pm)\right].$$

$h_{B^\pm}$: Normalization constant.

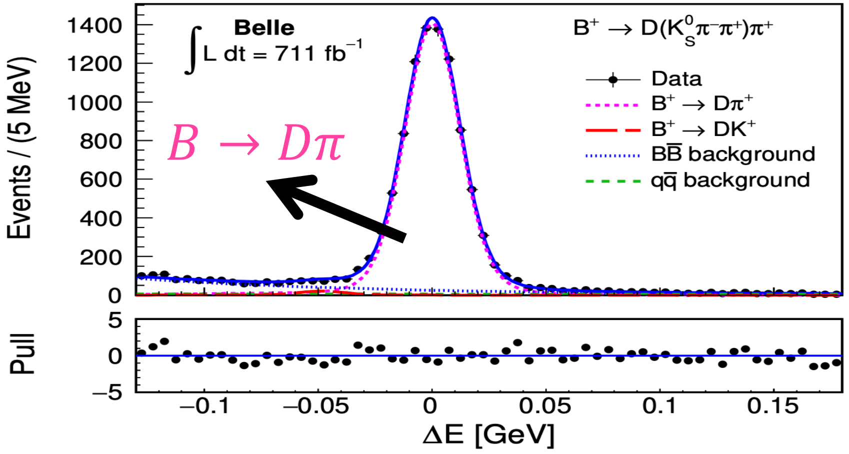
Physics parameters of interest: $(x_\pm, y_\pm) = r_B(\cos(\phi_3 + \delta_B), \sin(\phi_3 + \delta_B))$

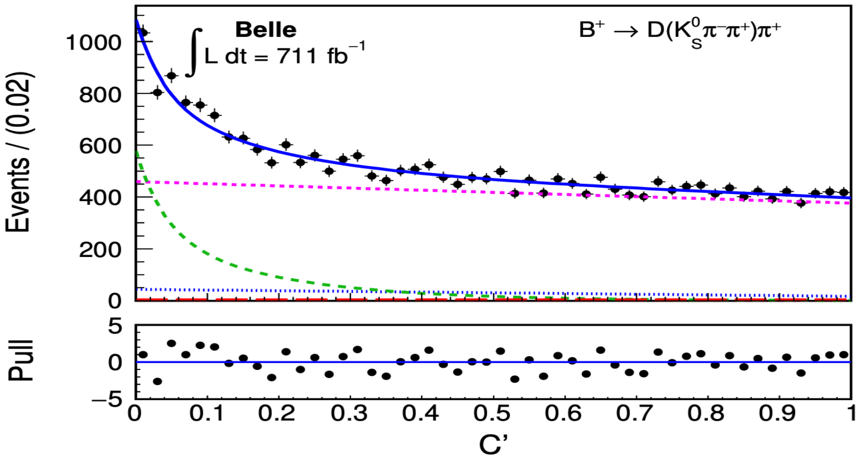
Amplitude-averaged strong phase difference between $\overline{D^0}$ and D^0 over i^{th} bin and are obtained from external charm factories like *CLEO* and *BESIII*.

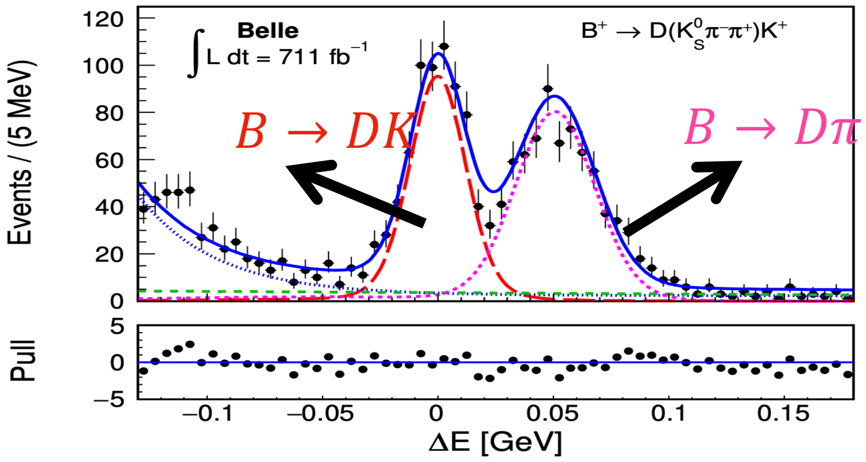
N. Rout

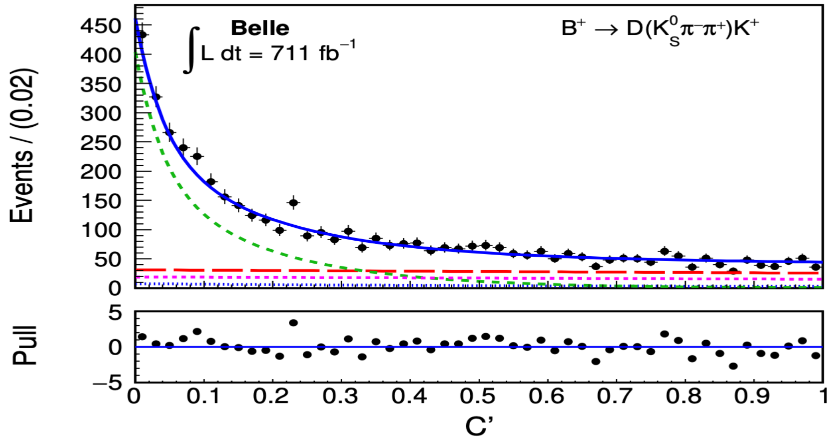
Fraction of pure D^0 decay to bin i taking into account the reconstruction and selection efficiency.

Signal extraction: Belle data









2D $(\Delta E, C')$ simultaneous fit of $B \to D\pi$ and $B \to DK$

$K - \pi$ misidentification rate is directly extracted from data

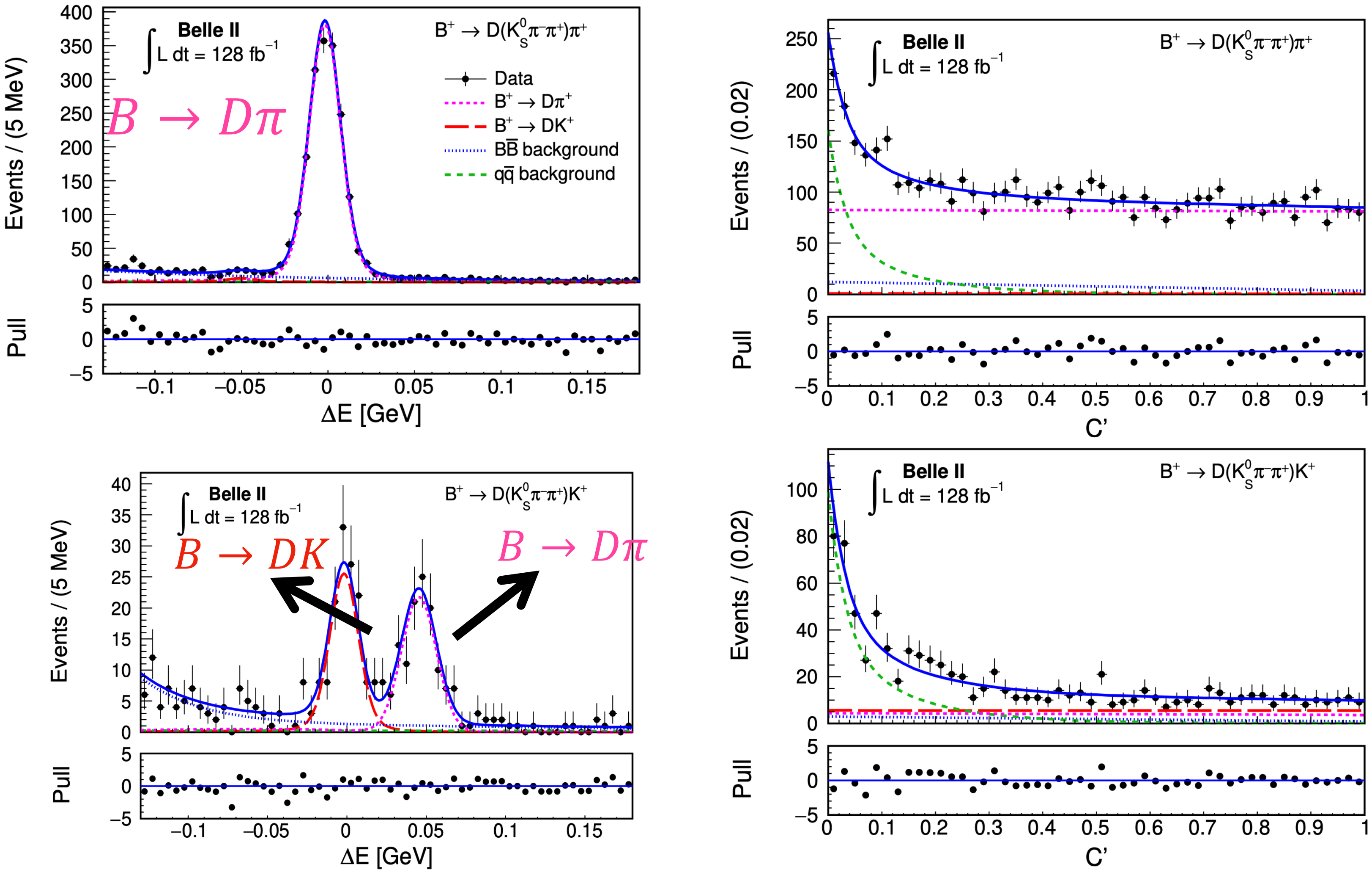
N_{signal}: Belle

$$K_S^0\pi\pi = 1467 \pm 53$$
$$K_S^0 KK = 194 \pm 17$$

40% increase in signal yield as compared to previous best result of Belle

N. Rout

Signal extraction: Belle II data



- 2D $(\Delta E, C')$ simultaneous fit of $B \to D\pi$ and $B \to DK$
- $K - \pi$ misidentification rate is directly extracted from data

N$_{signal}$: Belle II

$$K_S^0\pi\pi = 280 \pm 21$$

$$K_S^0 KK = 34 \pm 7$$

Additional 17%

N. Rout

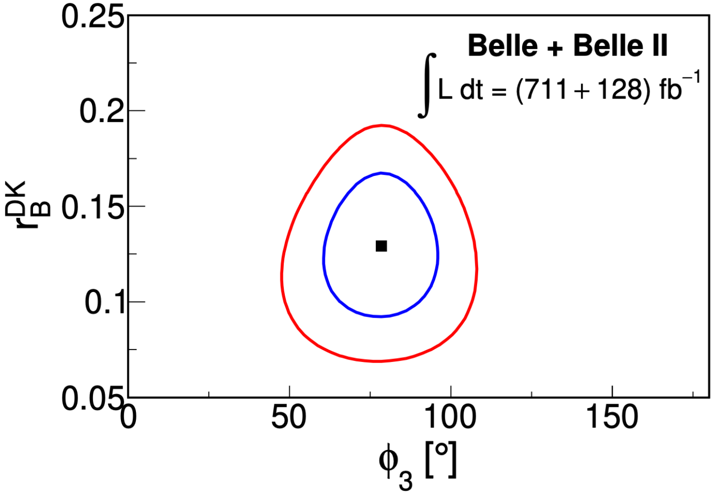
Results

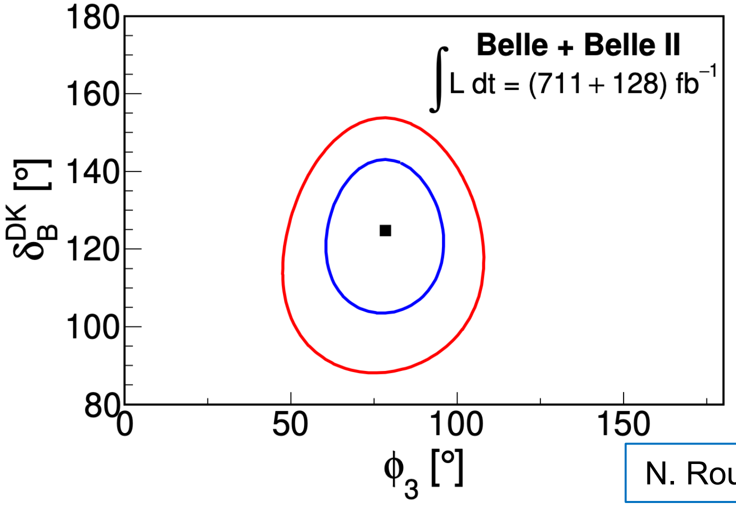
$\delta_B(°)$	124.8 ± 12.9 (stat.) ± 0.5 (syst.) ± 1.7 (ext. input)
r_B^{DK}	0.129 ± 0.024 (stat.) ± 0.001 (syst.) ± 0.002 (ext. input)
$\phi_3(°)$	78.4 ± 11.4 (stat.) ± 0.5 (syst.) ± 1.0 (ext. input)

Belle previous results: *PRD **85**, 112014 (2012)*

$$\phi_3(°) = 77.3^{+15.1}_{-14.9} \pm 4.1 \pm 4.3$$

- This result is most precise to date from the *B*-factory experiments
- New inputs from BESIII on strong-phase has significant impact on systematic uncertainty
- Use of $B \to Dh$ decay mode to incorporate efficiency effects reduces the experimental systematic uncertainty





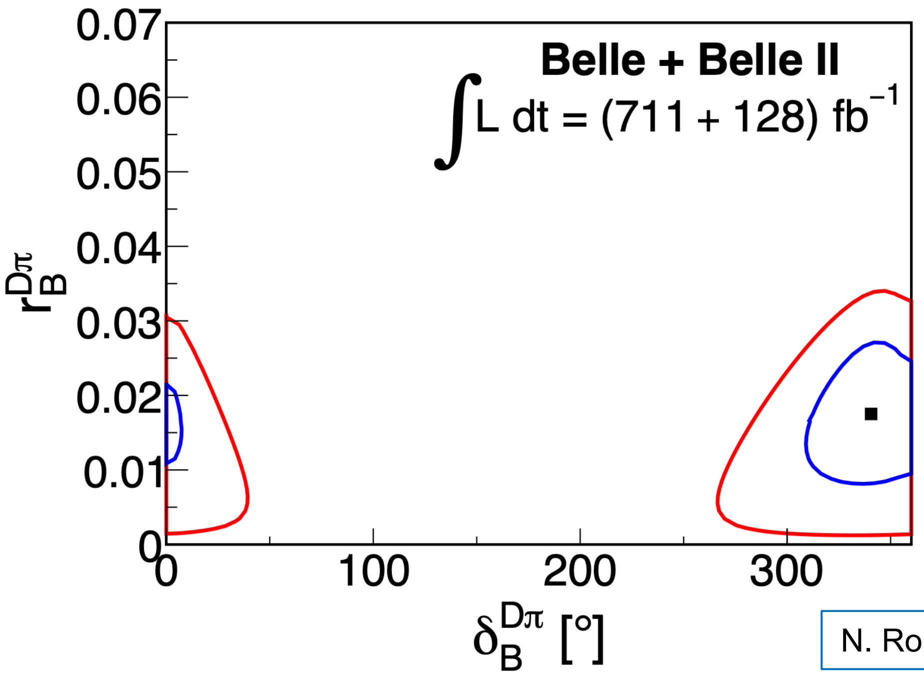
N. Rout

Results

$$r_B^{D\pi} = 0.017 \pm 0.006(\text{stat.}) \pm 0.001(\text{syst.}) \pm 0.001(\text{extinput})$$

$$\delta_B^{D\pi}(°) = 341.0 \pm 17.0(\text{stat.}) \pm 1.2(\text{syst.}) \pm 2.6(\text{extinput.})$$

- Results of $B \to D\pi$ provided for the first time from the B-factory experiments
- Consistent with the world average value



N. Rout

$\bar{B}^0 \to D^{*+}h^-$ (Belle)

- Decay widths of $B \to D^{(*)}h$ can be estimated from their semileptonic counterpart

$$\Gamma(\bar{B}^0 \to D^{*+}h^-) = 6\pi^2 \tau_B |V_{uq}|^2 f_h^2 X_h |a_1(q^2)|^2 \times d\Gamma(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu})/dq^2|_{q^2=m_h^2}$$

- Beneke et al: $|a_1| = 1.05$ (10.1016/S0550-3213(00)00559-9)
- Huber et al: $|a_1(\pi)| = 1.071 \pm 0.014$, $|a_1(K)| = 1.069 \pm 0.013$ (10.48550/JHEP09(2016)112)
- Previous studies (Fleischer et al. 10.1103/PhysRevD.83.014017) of $|a_1|$ have not been performed within a single experiment which would cancel many systematic uncertainties
- $SU(3)$ symmetry implies that $|a_1|$ should be consistent for $h = \{\pi, K\}$

D. Ferlewicz

THE UNIVERSITY OF MELBOURNE

Belle II

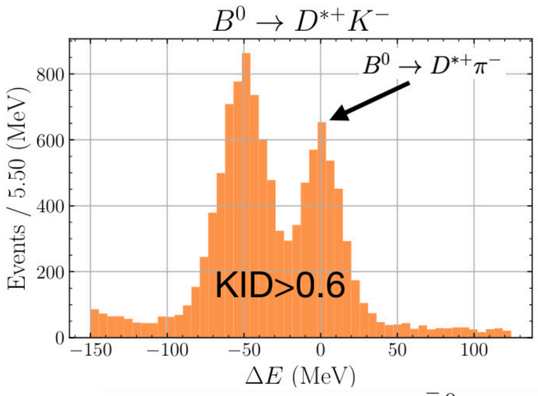
$\bar{B}^0 \to D^{*+}h^-$ measurement

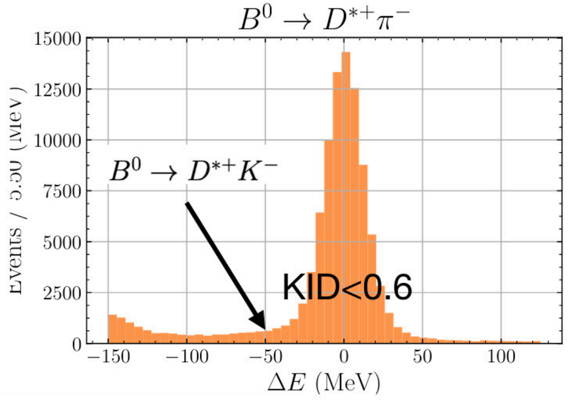
J.F. Krohn, D. Felewicz et al. (Belle, 2022)

- New Belle (711 fb^{-1}) $\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$ and $\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$ measurement, with $D^{*+} \to D^0\pi^+$ and $D^0 \to K^-\pi^+$ or $D^0 \to K^-2\pi^+\pi^-$ (previous 10.4 fb^{-1})

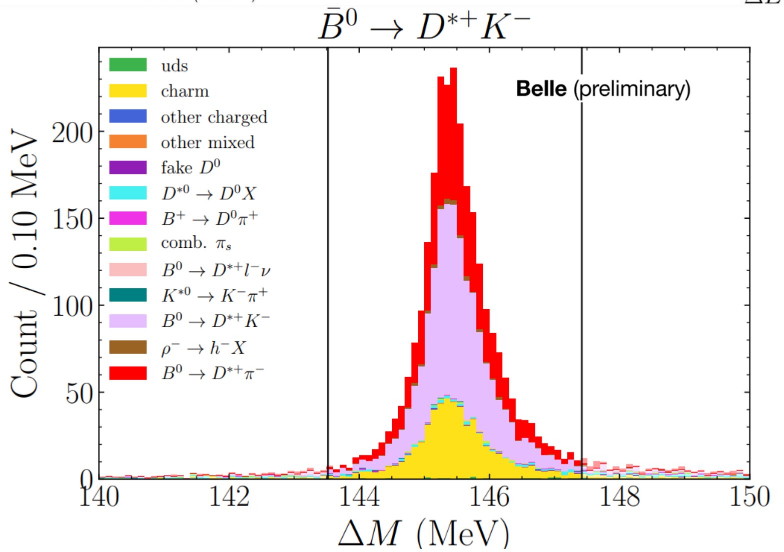
<u>Selection criteria:</u>

- Pion $\mathcal{L}_{K/\pi} < 0.6$ (except slow pions)
- Kaon $\mathcal{L}_{K/\pi} > 0.6$
- D^* candidates have ΔM_{D^*-D} within ≈ 2.1MeV/c² of mean
- $M_{bc} > 5.27$ GeV/c²
- $-150 < \Delta E\ (MeV) < 125$





- Signal yields from simultaneous unbinned maximum-likelihood fit of $\Delta E = E_B - E_{beam}$
  - π signal PDF = double Gaussian + Crystal Ball
  - K signal PDF = Gaussian + Crystal Ball
  - Common resolution factor for widths is used for fits to data: $\sigma_i^{data} = \beta\sigma_i^{width}$



J.F. Krohn

D. Ferlewicz

$\bar{B}^0 \to D^{*+}h^-$ measurement

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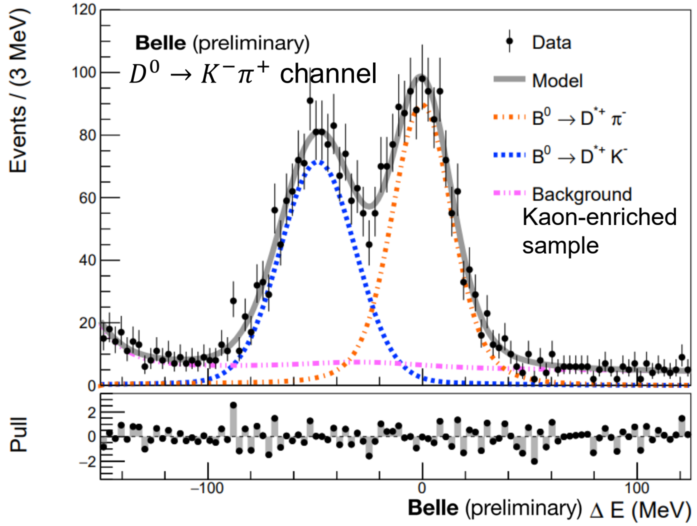
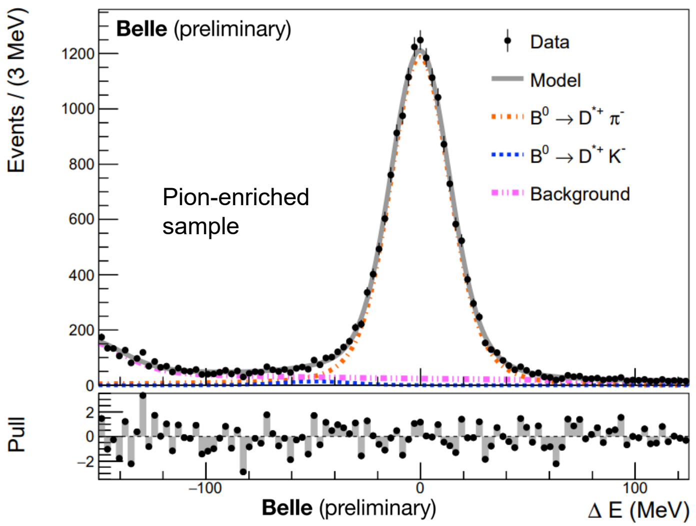
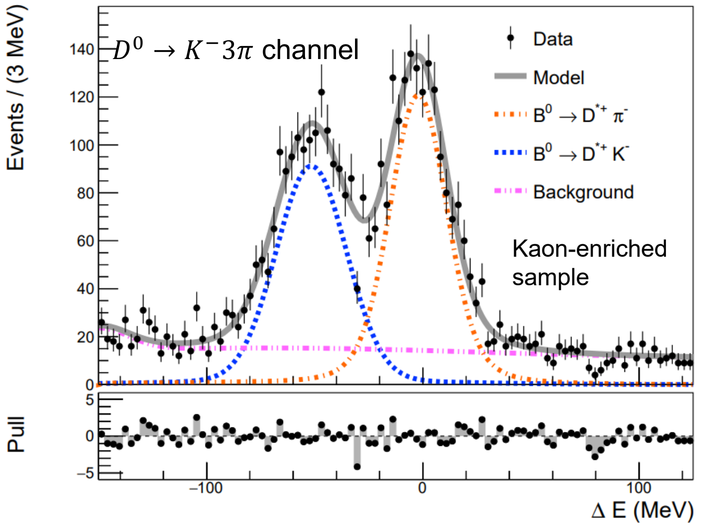
Belle II

J.F. Krohn

D. Ferlewicz







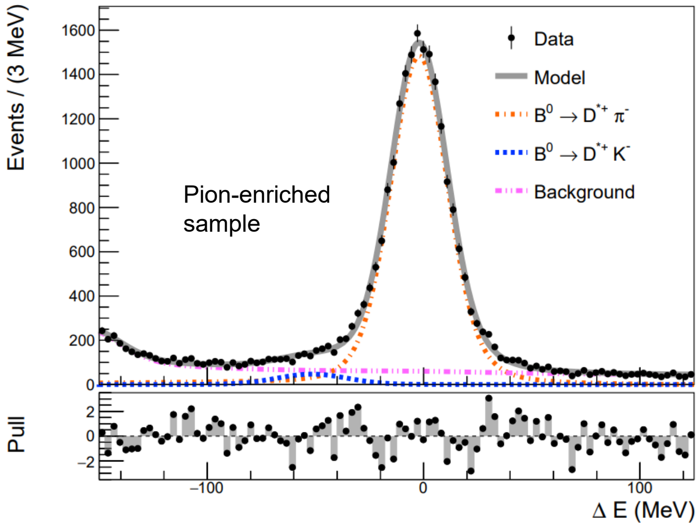
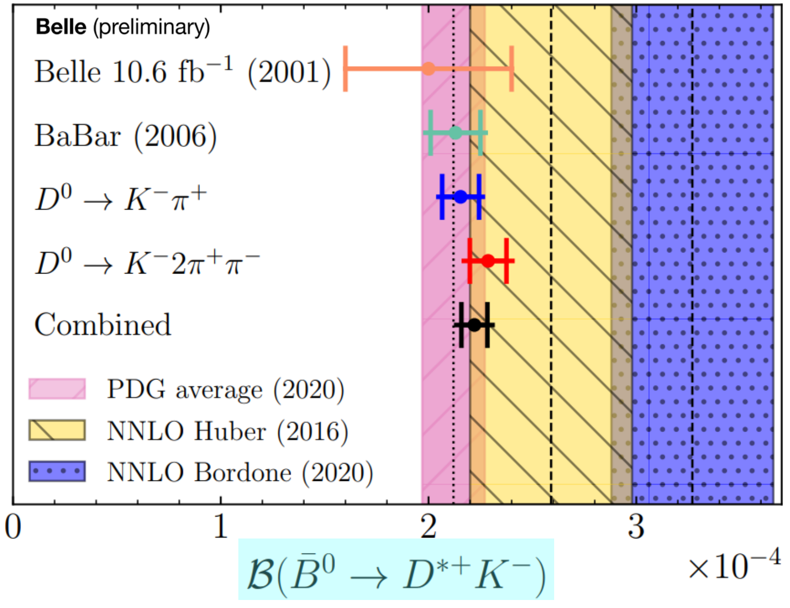


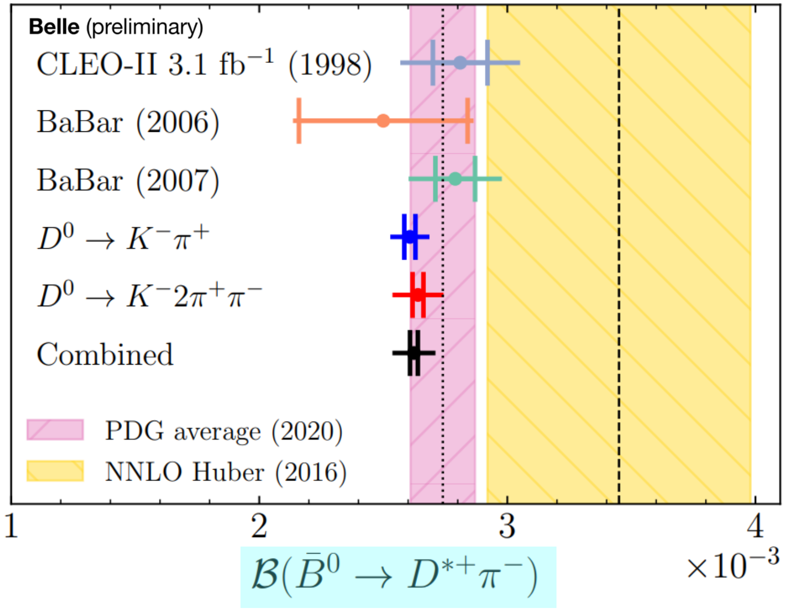
Table of uncertainties for B.F.
Values with † are propagated to R^D,
otherwise are cancelled

type	$\bar{B} \to D^{*+}\pi^-$	$\bar{B} \to D^{*+}K^-$
π-ID stat.	0.75% 0.58%†	0.32%
π-ID sys.	0.49% 0.41%†	0.19%
K-ID stat.	0.74%	1.04% 0.64%†
K-ID sys.	0.55%	0.89% 0.55%†
K-ID run dep. sys.	0.30%	0.30%
π_{slow} stat.	0.79%	0.79%
π_{slow} sys.	0.01%	0.01%
π_{slow} corr.	1.33%	1.33%
Tracking sys.	1.26%	1.26%
Fixed yields bkg. PDF	0.07%†	0.07%†
Fixed shapes bkg. PDF	0.07%†	0.07%†
Fit bias	0.09%†	0.37%†
$N_{\bar{B}^0 B^0}$	1.84%	1.84%
$\mathcal{B}(D^{*+} \to D^0\pi^+)$	0.74%	0.74%
$\mathcal{B}(D^0)$	0.94%	0.94%
MC stat.	0.26%†	0.99%†
Total sys. ($\mathcal{B}$)	3.26%	3.47%
Total sys. (ratio)	1.50%	1.50%
Total stat. err.	0.57%	2.74%

Component	$D^0 \to K^-\pi^+$		$D^0 \to K^-2\pi^+\pi^-$	
	$\bar{B}^0 \to D^{*+}\pi^-$	$\bar{B}^0 \to D^{*+}K^-$	$\bar{B}^0 \to D^{*+}\pi^-$	$\bar{B}^0 \to D^{*+}K^-$
$\bar{B}^0 \to D^{*+}\pi^-$	16494 ± 142	1247 ± 46	19500 ± 162	1587 ± 52
$\bar{B}^0 \to D^{*+}K^-$	225 ± 53	1182 ± 49	731 ± 71	1414 ± 55
Background	3390 ± 115	658 ± 61	7067 ± 185	1448 ± 97

$\bar{B}^0 \to D^{*+}h^-$ measurement





Belle (preliminary)

$\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$		
$D^0 \to K^-\pi^+$	$(2.154 \pm 0.089 \pm 0.078) \times 10^{-4}$	1.1
$D^0 \to K^-2\pi^+\pi^-$	$(2.287 \pm 0.088 \pm 0.092) \times 10^{-4}$	0.7
Combined	$(2.221 \pm 0.063 \pm 0.077) \times 10^{-4}$	0.9

$\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	Result	$n\sigma$ meas.$-$theo.
$D^0 \to K^-\pi^+$	$(2.607 \pm 0.023 \pm 0.083) \times 10^{-3}$	1.8
$D^0 \to K^-2\pi^+\pi^-$	$(2.640 \pm 0.022 \pm 0.101) \times 10^{-3}$	1.7
Combined	$(2.623 \pm 0.016 \pm 0.086) \times 10^{-3}$	1.7

$\mathcal{R}_{K/\pi}$		
$D^0 \to K^-\pi^+$	$(8.26 \pm 0.35 \pm 0.16) \times 10^{-2}$	1.8
$D^0 \to K^-2\pi^+\pi^-$	$(8.56 \pm 0.34 \pm 0.16) \times 10^{-2}$	2.5
Combined	$(8.41 \pm 0.24 \pm 0.13) \times 10^{-2}$	2.7

Belle (preliminary)

J.F. Krohn

D. Ferlewicz

$\bar{B}^0 \to D^+ h^-$

$$R_D = \frac{\mathfrak{B}(\bar{B}^0 \to D^+ K^-)}{\mathfrak{B}(\bar{B}^0 \to D^+ \pi^-)} \approx \tan^2(\theta_C)\left(\frac{f_K}{f_\pi}\right)^2$$

- Important input for determining ϕ_3
- Important control mode for determining ϕ_1
- Test of factorization and SU(3)
- Complete measurement using all Belle Data

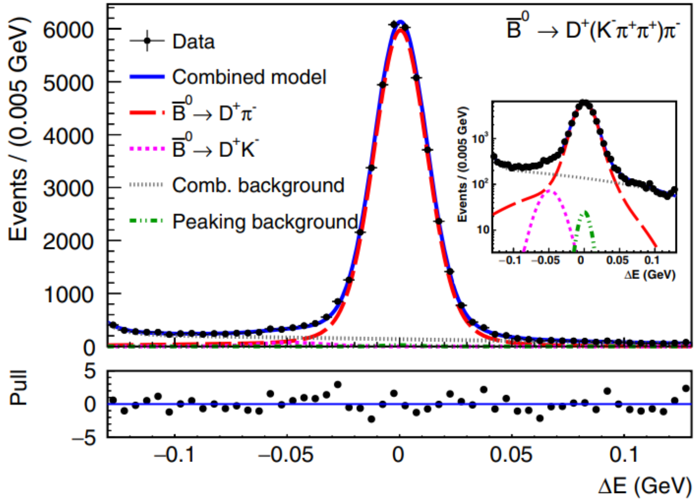
$\bar{B}^0 \to D^+ h^-$ measurement

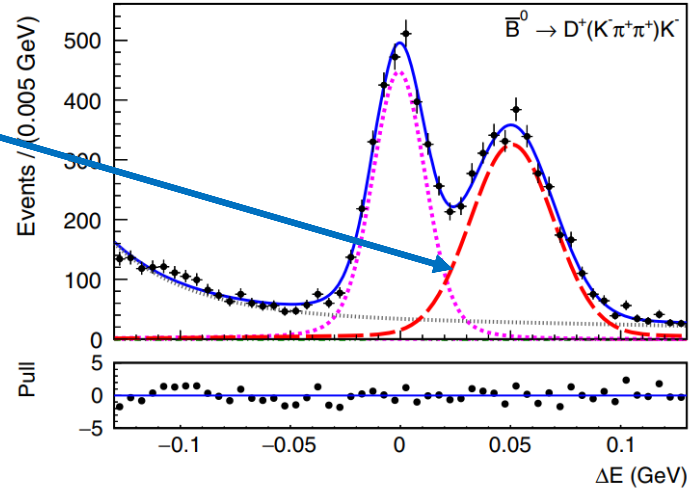
E. Waheed et al. (Belle, 2022)
10.1103/PhysRevD.105.012003

- New Belle (711 fb^{-1}) $\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$ and $\mathcal{B}(\bar{B}^0 \to D^+K^-)$ measurement, with $D^+ \to K^-\pi^+\pi^-$, updating the 2001 (10.4 fb^{-1}) result
- Similar selection criteria to $\bar{B}^0 \to D^{*+}h^-$, but with D meson mass selected with $\approx$ 13 MeV/c^2 of known M_{D^+}
- Simultaneous fit to pion- and kaon-enriched samples

Source	R^D	$\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$	$\mathcal{B}(\bar{B}^0 \to D^+K^-)$
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$	…	1.71%	1.71%
Tracking	…	1.40%	1.40%
$N_{B\bar{B}}$	…	1.37%	1.37%
f^{00}/f^{+-}	…	1.92%	1.92%
$D^+ \to K^-\pi^+\pi^+$ model	…	0.69%	0.69%
PDF parametrization	2.71%	1.63%	1.79%
PID efficiency of K/π	0.88%	0.68%	0.73%
D^+ mass selection window	0.05%	0.56%	0.64%
J/ψ veto selection	0.12%	0.004%	0.15%
Peaking background yield	0.07%	0.04%	0.00%
MC statistics	< 0.01	0.04%	0.04%
Fit bias	…	0.58%	0.61%
Total	2.85%	3.43%	3.54%

Signal PDFs are double Gaussians with floated resolution factor





E. Waheed

D. Ferlewicz

$\bar{B}^0 \to D^+h^-$ results

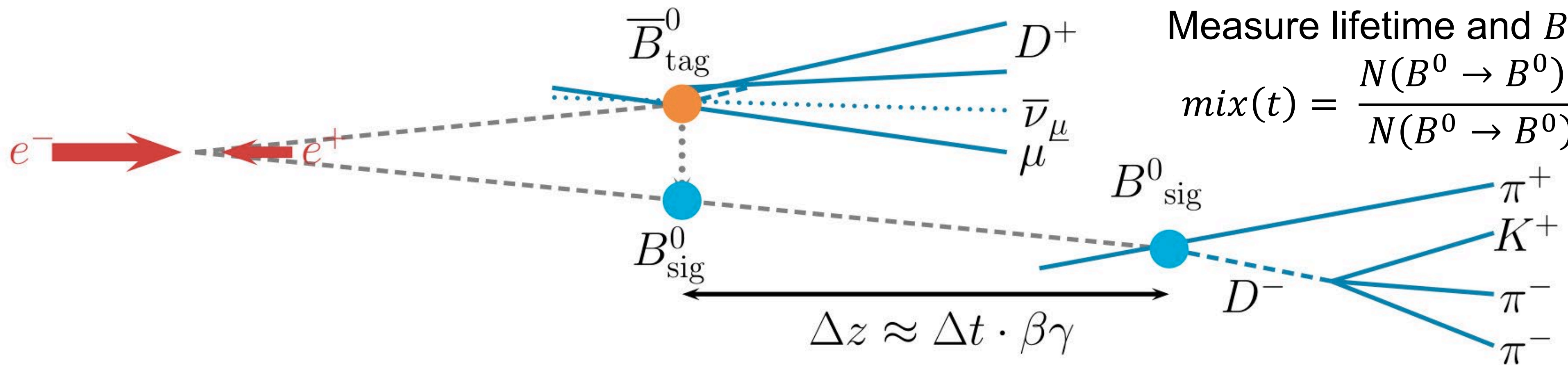
Measurement	Result ($\pm$ *stat.* $\pm$ *sys.* [$\pm$ D branching fraction sys.]*)	Theory prediction (Huber 2016)
$\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$	$(2.48 \pm 0.01 \pm 0.09 \pm 0.04^*) \times 10^{-3}$	$(3.93 \pm 0.43) \times 10^{-3}$
$\mathcal{B}(\bar{B}^0 \to D^+K^-)$	$(2.03 \pm 0.05 \pm 0.07 \pm 0.03^*) \times 10^{-4}$	$(3.01 \pm 0.32) \times 10^{-4}$
$R^D \approx \tan^2\theta_C \left(\frac{f_K}{f_\pi}\right)^2$	$0.0819 \pm 0.0020 \pm 0.0023$	0.077 ± 0.002

- World's most precise measurements
- Branching fractions and ratio consistent with previous measurements
- This channel is often used in control samples for *CP*-violation and ϕ_3 measurements
- Can be used with Belle $B^0 \to D^-\ell^+\nu$ study to check consistency in $|a_1|$ measurements with reduced systematic uncertainties

E. Waheed

D. Ferlewicz

B-mixing and Lifetime (Belle II)



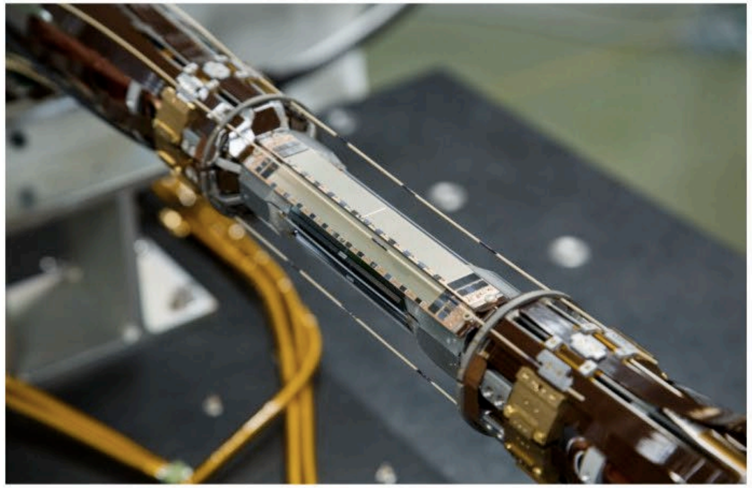
Measure lifetime and $B^0 - \bar{B}^0$ mixing

$$mix(t) = \frac{N(B^0 \to B^0)(t) - N(B^0 \to \bar{B}^0)(t)}{N(B^0 \to B^0)(t) + N(B^0 \to \bar{B}^0)(t)}$$

New beam scheme means reduced boost wrt Belle:

$$\beta\gamma = 0.43 \longrightarrow \beta\gamma = 0.29$$
$$\Delta z \approx 200\ \mu\text{m} \longrightarrow \Delta z \approx 130\ \mu\text{m}$$

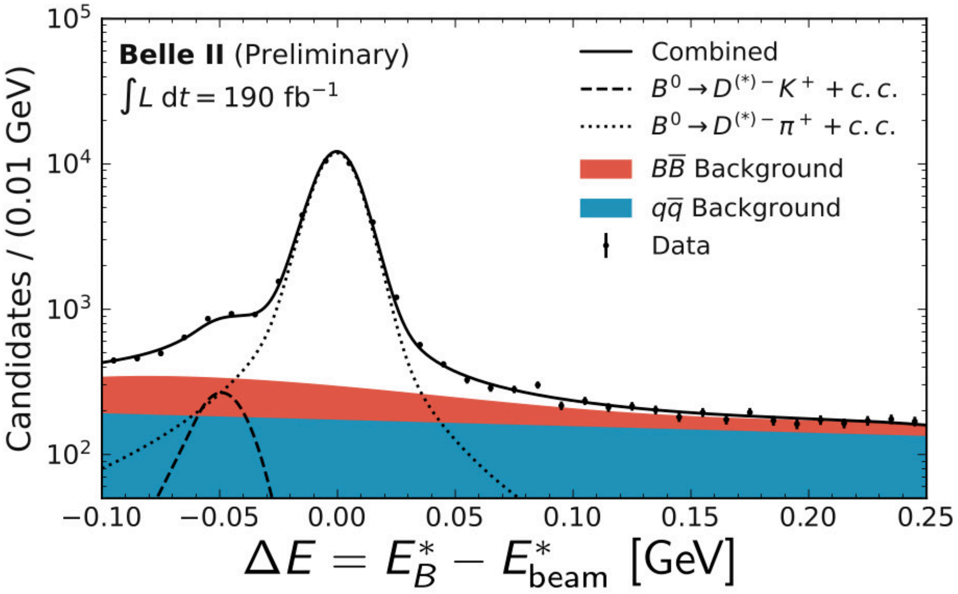
$\Rightarrow$ added a pixel detector directly around the beam pipe (radius $\approx$ 1.4 cm) to recover precision on Δt.

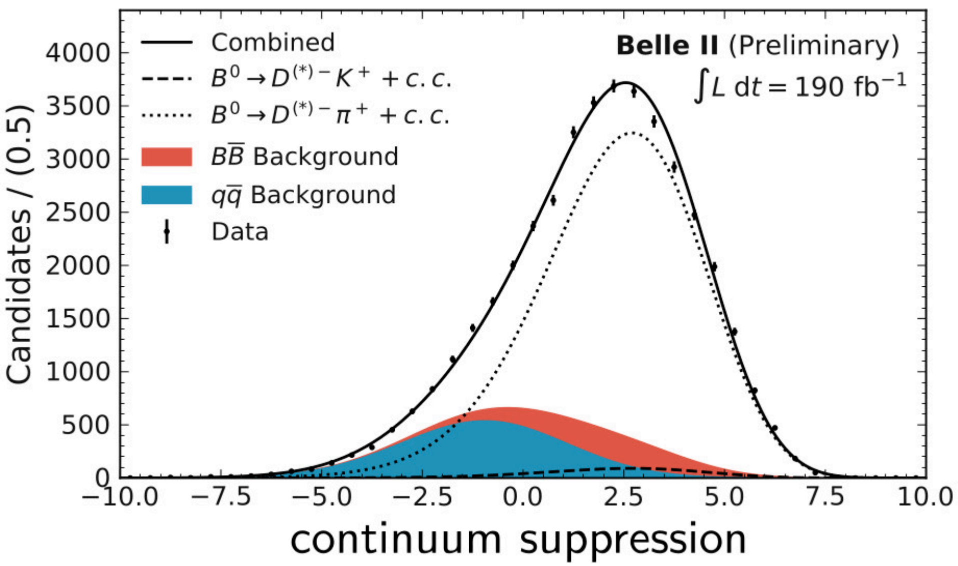


T. Humair

Use beam spot profile to increase precision on vertex fit
⇒ new beam scheme means smaller beam spot and stronger constraint

B reconstruction





Use $\sim 40k$ decays reconstructed from hadronic $B^0 \to D^{(*)-}\pi^+/K^+$ modes.

2 backgrounds: $e^+e^- \to q\overline{q}$ and misreconstructed $e^+e^- \to B\overline{B}$
Discriminate signal and backgrounds using ΔE and event-shape multivariate classifier.

1. Subtract backgrounds from sidebands (sWeights) to obtain background-free signal sample.
2. Fit background-subtracted Δt distribution, with a model taking into account wrong-tag fraction and finite vertex resolution

T. Humair

Belle II Mixing and lifetime results (190 fb^{-1})

Measure lifetime and $B^0 - \bar{B}^0$ mixing

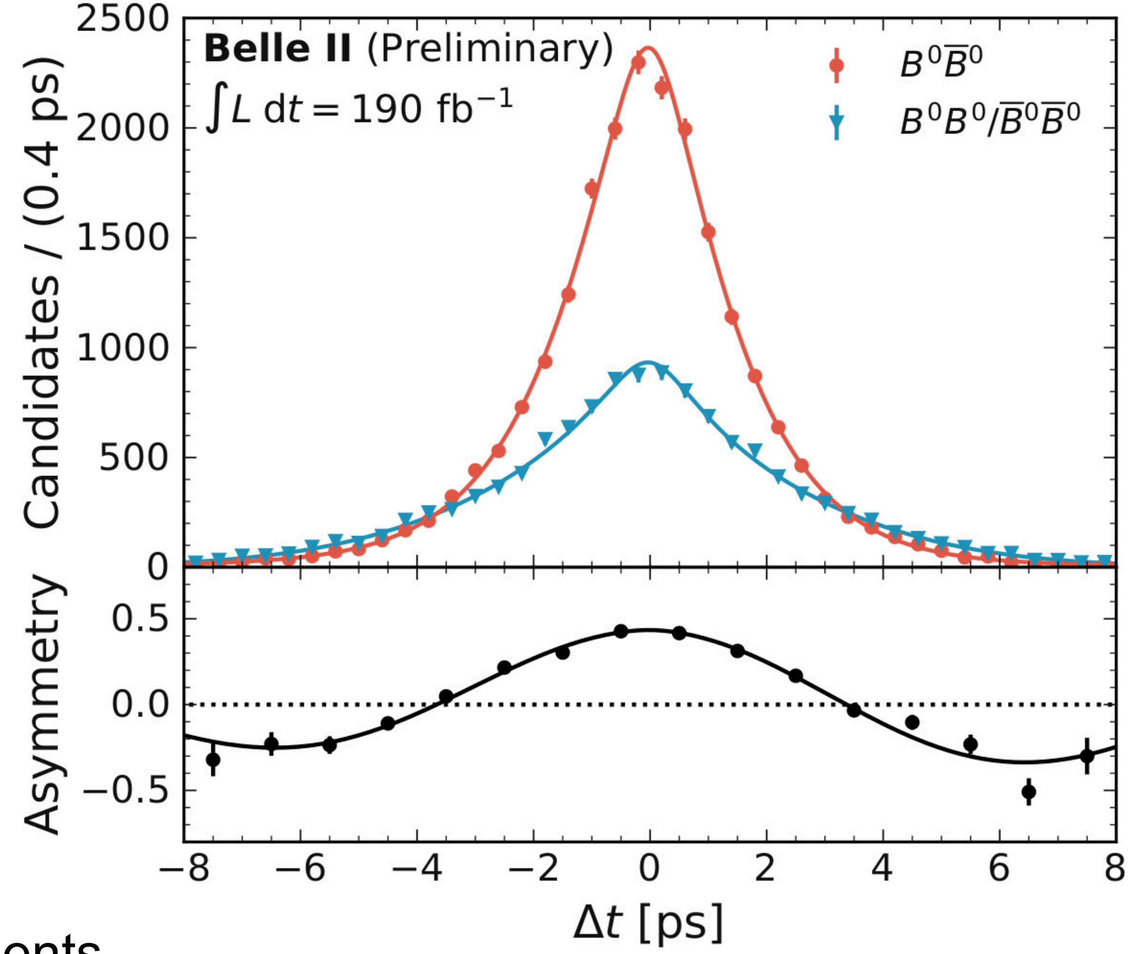
$$mix(t) = \frac{N(B^0 \to B^0)(t) - N(B^0 \to \bar{B}^0)(t)}{N(B^0 \to B^0)(t) + N(B^0 \to \bar{B}^0)(t)} = \cos(\Delta m t)$$

Δm is the Oscillation frequency

Preliminary Results:

$$\tau_{B^0} = 1.499 \pm 0.013\,(stat.) \pm 0.008\,(syst.)\,ps$$
$$\Delta m_d = 0.516 \pm 0.008\,(stat.) \pm 0.005\,(sys.) ps^{-1}$$

- Compatible with World-Average
- Compared to Belle and BaBar's best measurement:
  - better alignment and background systematics.
  - comparable resolution modelling systematics.
  - Need to add $B^0 \to D^{(*)} l \nu$ modes
  - Ready for Time-Dependent CP-violation measurements



Conclusion

Belle II

Summary	Result	Reference
First measurement of A_{CP} Highest precision $\mathfrak{B}$.	$B^0 \to \overline{D^0}\pi^0$: $\mathfrak{B} = (2.69 \pm 0.06 \pm 0.09) \times 10^{-4}$, $A_{CP} = (0.10 \pm 2.05 \pm 1.22)\%$	T. Bloomfield et al. (Belle) PRD **105, 072007** (2022)
Most precise measurement by almost 2x.	$B^+ \to \overline{D^0}\pi^+$: $\mathfrak{B} = (4.53 \pm 0.02 \pm 0.14) \times 10^{-3}$, $A_{CP} = (0.19 \pm 0.36 \pm 0.57)\%$	
Most precise measurement of ϕ_3 by B-factories	$B^+ \to D(K_s^0 h^- h^+)$: $\delta_B(°) = 124.8 \pm 12.9 \pm 0.5 \pm 1.7$ $r_B^{DK} = 0.129 \pm 0.024 \pm 0.001 \pm 0.002$ $\phi_3(°) = 78.4 \pm 11.4 \pm 0.5 \pm 1.0$ $\delta_B^{D\pi}(°) = 341.0 \pm 1.2 \pm 2.6$ $r_B^{D\pi} = 0.017 \pm 0.006 \pm 0.001 \pm 0.001$	N. Rout, et al. (Belle, Belle II) JHEP 02 **2022**, 063 (2022)
Most precise measurements Important test of Factorization Needed for ϕ_3	$\overline{B^0} \to D^+ + h^-$: $\mathfrak{B}(\overline{B^0} \to D^+\pi^-) = (2.48 \pm 0.01 \pm 0.09 \pm 0.04) \times 10^{-3}$ $\mathfrak{B}(\overline{B^0} \to D^+K^-) = (2.03 \pm 0.05 \pm 0.07 \pm 0.03) \times 10^{-4}$ $\mathrm{R^D} = 0.0819 \pm 0.0020 \pm 0.0023 \pm 0.03$	E. Waheed et al. (Belle) PRD **105, 012003** (2022)
Most precise measurements $R_{K/\pi}$ is 2.7 σ from Theory	$\overline{B}^0 \to D^{*+}h^-$: **Preliminary** $\mathfrak{B}(\overline{B^0} \to D^{*+}\pi^-) = (2.623 \pm 0.016 \pm 0.086) \times 10^{-3}$ $\mathfrak{B}(\overline{B^0} \to D^{*+}K^-) = (2.221 \pm 0.063 \pm 0.077) \times 10^{-4}$ $R_{K/\pi} = 0.0841 \pm 0.0024 \pm 0.013$	J.F. Krohn, D. Ferlewicz et al. (Belle, 2022) to be submitted to PRD
Validation of Belle II for Time-Dependent Analyses	**Preliminary** τ_{B^0}: $1.499 \pm 0.013 \pm 0.008\ ps$ Δm_d: $0.516 \pm 0.008\ \pm 0.005\ ps^{-1}$	(Belle II) Moriond EW (2022)

Thank You

Backup

$\bar{B}^0 \to D^{*+}h^-$ systematics

Table of uncertainties for B.F. Values with † are propagated to R^D, otherwise are cancelled

type	$\bar{B} \to D^{*+}\pi^-$	$\bar{B} \to D^{*+}K^-$
π-ID stat.	0.75% 0.58%†	0.32%
π-ID sys.	0.49% 0.41%†	0.19%
K-ID stat.	0.74%	1.04% 0.64%†
K-ID sys.	0.55%	0.89% 0.55%†
K-ID run dep. sys.	0.30%	0.30%
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π_{slow} corr.	1.33%	1.33%
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$\mathcal{B}(D^{*+} \to D^0\pi^+)$	0.74%	0.74%
$\mathcal{B}(D^0)$	0.94%	0.94%
MC stat.	0.26%†	0.99%†
Total sys. ($\mathcal{B}$)	3.26%	3.47%
Total sys. (ratio)	1.50%	1.50%
Total stat. err.	0.57%	2.74%

$\bar{B}^0 \to D^+h^-$ Systematics

Source	R^D	$\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$	$\mathcal{B}(\bar{B}^0 \to D^+K^-)$
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$	...	1.71%	1.71%
Tracking	...	1.40%	1.40%
$N_{B\bar{B}}$	...	1.37%	1.37%
f^{00}/f^{+-}	...	1.92%	1.92%
$D^+ \to K^-\pi^+\pi^+$ model	...	0.69%	0.69%
PDF parametrization	2.71%	1.63%	1.79%
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