Hadronic B decays at Belle and Belle II

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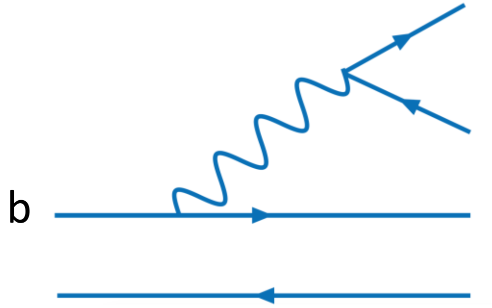
Hadronic Charmed and Charmless B Decays

Charmed decays: B→D(*)h

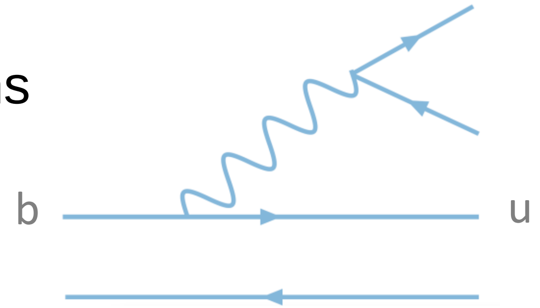
- mediated through Cabibbo-favored **b→c** tree transitions
  - ➢ high branching fractions of ~0.5%
  - ➢ clean channels to test QCD predictions
  - ➢ serve as important control modes



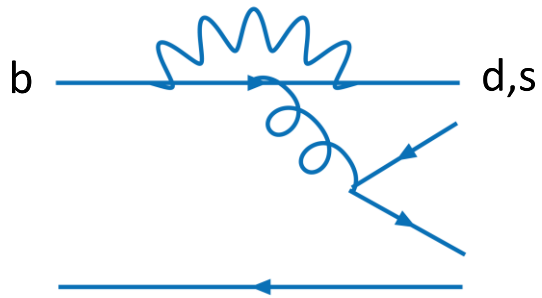
- B→D(*)K modes are theoretically clean modes to precisely determine γ/Φ_3

Charmless decays: B→hh(h)

- mediated through Cabibbo-suppressed **b→u** tree or **b→d, s** loop transitions
  - ➢ sensitive to **non-SM loop contributions**
  - ➢ contribute to determination of **all three CKM angles**

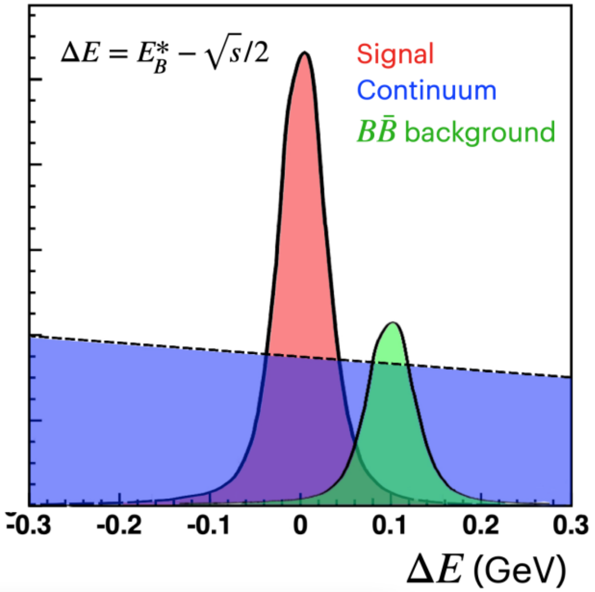


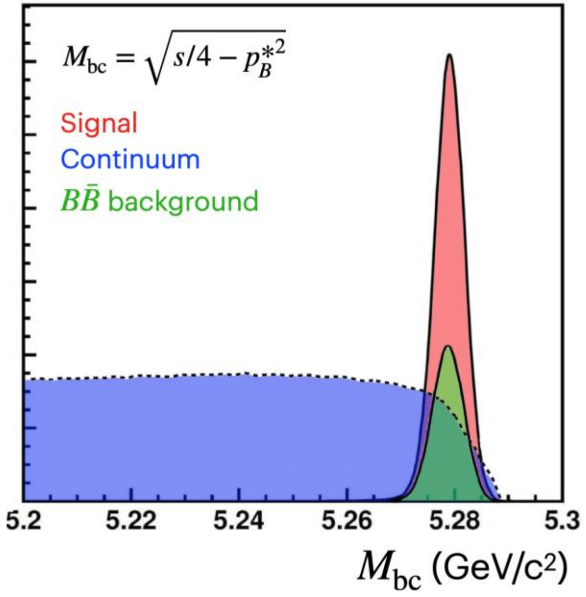
- Challenges:
  - ➢ small branching fractions $\sim\mathcal{O}(10^{-5})$
  - ➢ high backgrounds: $\mathbf{e^+ e^- \rightarrow q\bar{q}}$



Analysis Workflow

1. **Reconstruction**
   - combine final state particles (e.g., pions and kaons) in kinematic fits to form the B decay of interest
2. **Selection**
   - optimized continuum suppression and particle ID criteria
   - vetoes to remove peaking backgrounds (mainly in charmless)
   - determine selection efficiencies for branching fraction calculations
3. **Fit**
   - extract models in ΔE, M_{bc} *(or more)* from simulated data (+ calibrate on data)
   - fit in to data and calculate physics quantities
4. **Systematic Uncertainties**
   - evaluated with control modes and simplified simulations (toy studies)





Belle + Belle II

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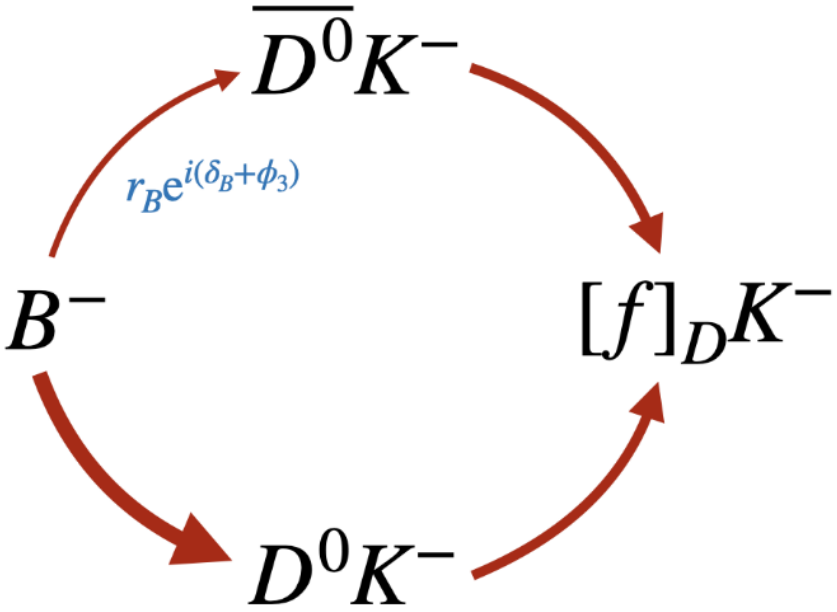
Φ_3 from $B \rightarrow DK$ decays

Φ_3 from $B \to DK$ decays

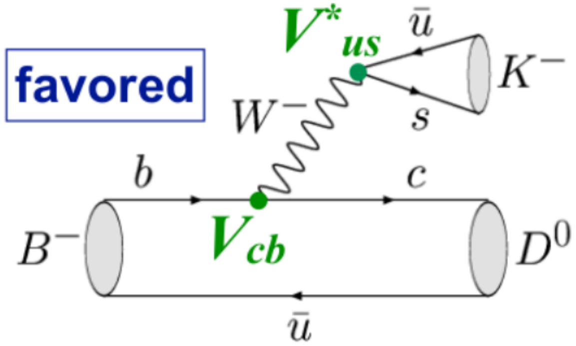
γ, Φ_3 is the phase between $\boldsymbol{b \to c}$ and $\boldsymbol{b \to u}$ transitions: $\boldsymbol{B \to DK}$

- interference between two decays to same final state gives access to phase

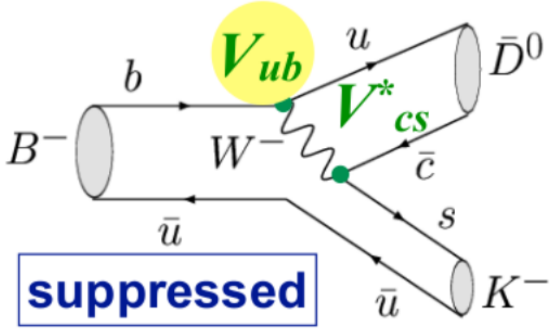


$$\frac{\mathcal{A}^{\text{suppr.}}(B^- \to \overline{D^0} K^-)}{\mathcal{A}^{\text{favor.}}(B^- \to D^0 K^-)} = r_B e^{i(\delta_B+\phi_3)}$$

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



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

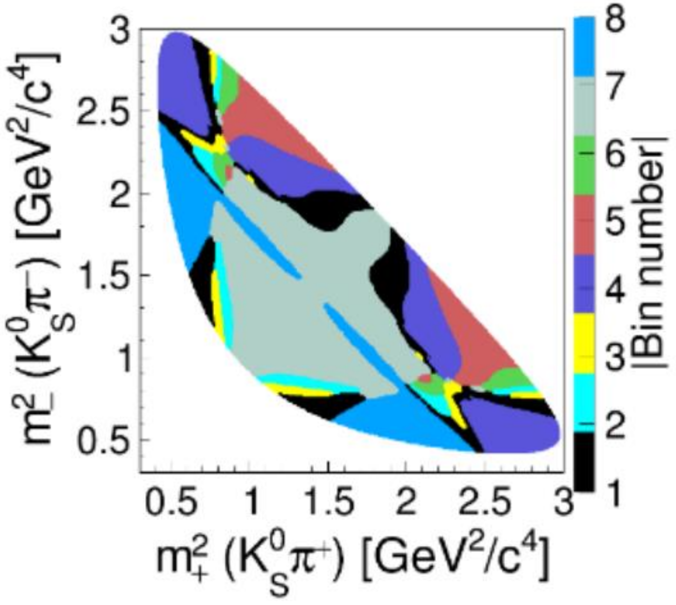


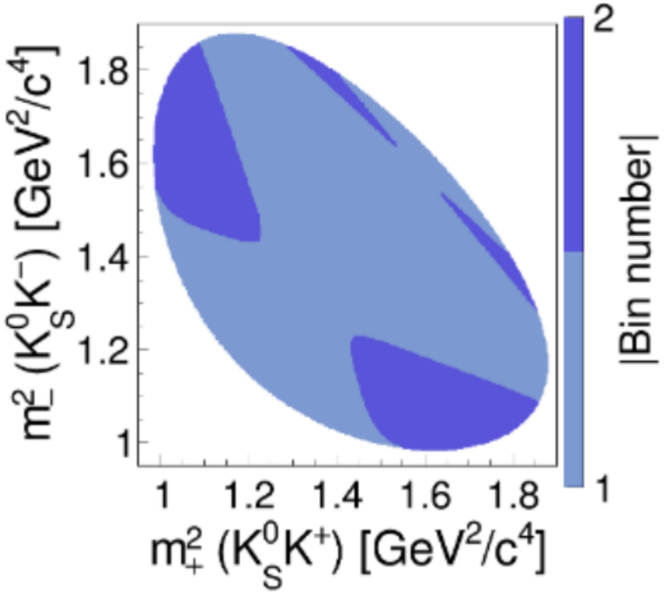
- D's reconstructed from: $K_S^0\pi^+\pi^-$ and $K_S^0 K^+ K^-$
- physics results limited by sample size, due to small branching fractions of involved decays

Φ_3 from $B \to DK$ decays

determination of Φ_3 is dependent on the physics of the D-decay

- could choose a model to describe the Dalitz plot
  - large systematic uncertainties
- **here:** use a binned model independent method
- independently measured D strong-phase parameters in each bin replace model (external input: CLEO & BESIII)
- observed yields per bin can be related to physics quantities of interest (Φ_3, δ_B, r_B)





Φ_3 from $B \to DK$ decays

- 2D (ΔE, C’) simultaneous fit of $B \to DK$ and $B \to D\pi$

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

$$\phi_3(^\circ) = 78.4 \pm 11.4\ (\text{stat.}) \pm 0.5\ (\text{syst.}) \pm 1.0\ (\text{ext. input})$$

previous Belle result: PRD 85, 112014 (2012)

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

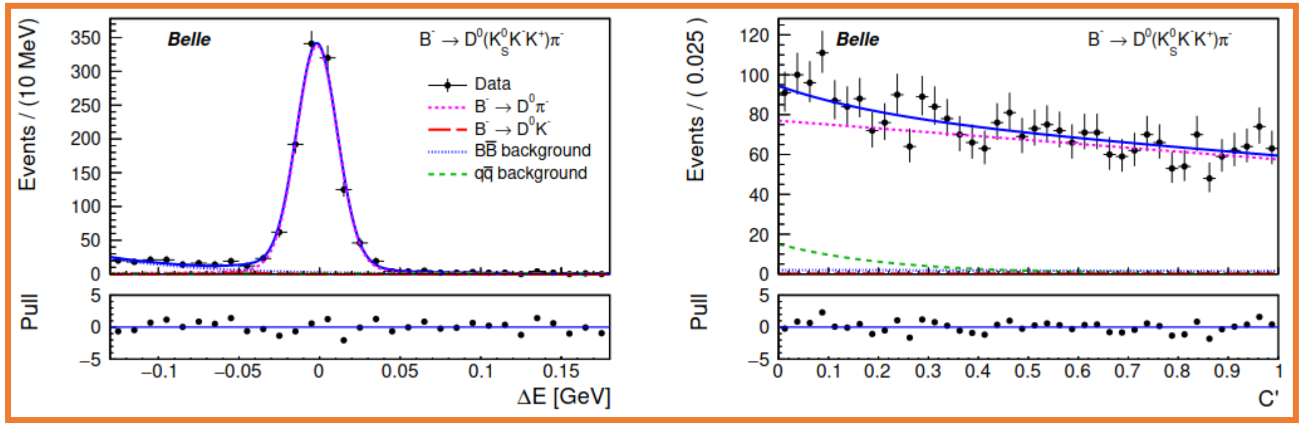
Improvements:

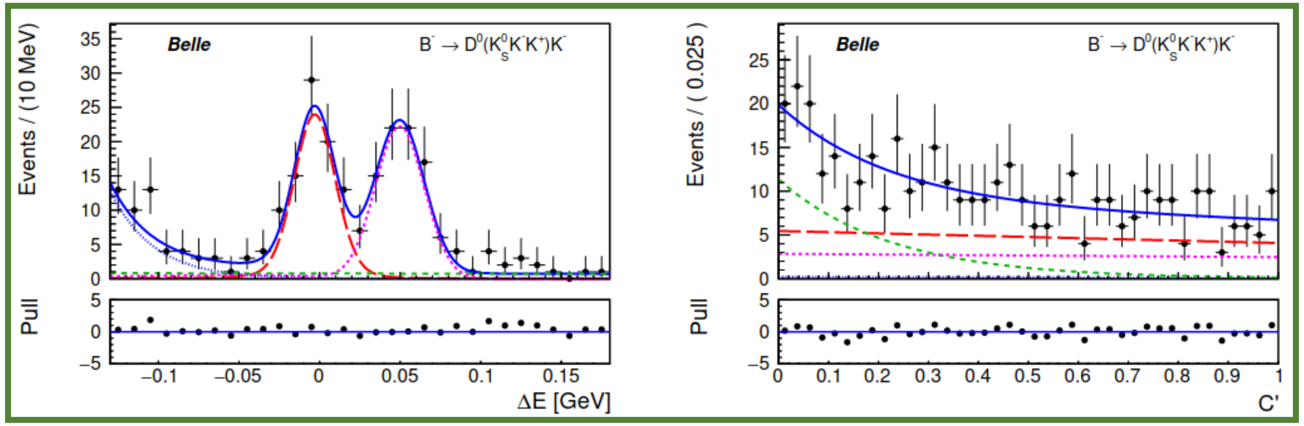
- multivariate K_S^0 selection
- improved background rejection
- new fitting strategy
- new strong phase inputs (BESIII)
- more data (K_S^0KK + Belle II)

- most precise B-factory result

https://arxiv.org/pdf/2110.12125.pdf (accepted by JHEP)

pion-enhanced $\mathfrak{L}(K/\pi) < 0.6$





kaon-enhanced $\mathfrak{L}(K/\pi) > 0.6$

first combined Belle and Belle II analysis

Belle: $\bar{B}^0 \rightarrow D^+ h^-$

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

- theoretically clean modes to test factorization and SU(3) symmetry breaking in QCD

$$\mathcal{R}_{s/d}^{P(V)} \equiv \frac{\mathcal{B}(\bar{B}_s^0 \to D_s^{(*)+}\pi^-)}{\mathcal{B}(\bar{B}^0 \to D^{(*)+}K^-)}$$

  - ➢ cancellation of most systematic effects

- **tensions** in **branching ratio** between theory predictions and measurements, **R-ratios OK**
  https://arxiv.org/pdf/2007.10338.pdf (Bordone et al.)

source	PDG [10^-3]	QCDF prediction [10^-3]	
χ^2/dof	—	—	
$\mathcal{B}(\bar{B}_s^0 \to D_s^+\pi^-)$	3.00 ± 0.23	4.42 ± 0.21	→ 4σ
$\mathcal{B}(\bar{B}^0 \to D^+K^-)$	0.186 ± 0.020	0.326 ± 0.015	→ 5σ
$\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$	2.52 ± 0.13	—	
$\mathcal{B}(\bar{B}_s^0 \to D_s^{*+}\pi^-)$	2.0 ± 0.5	$4.3^{+0.9}_{-0.8}$	→ 2σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$	0.212 ± 0.015	$0.327^{+0.039}_{-0.034}$	→ 3σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	2.74 ± 0.13	—	
$\mathcal{R}_{s/d}^P$	16.1 ± 2.1	$13.5^{+0.6}_{-0.5}$	
$\mathcal{R}_{s/d}^V$	9.4 ± 2.5	$13.1^{+2.3}_{-2.0}$	OK
$\mathcal{R}_s^{V/P}$	0.66 ± 0.16	$0.97^{+0.20}_{-0.17}$	
$\mathcal{R}_d^{V/P}$	1.14 ± 0.15	1.01 ± 0.11	

possible explanations:

1. presence of large non-factorizable contributions of $\mathcal{O}\,(15 - 20\%)$ to amplitudes
2. experimental issue
3. systematic shift in input parameters
4. new physics

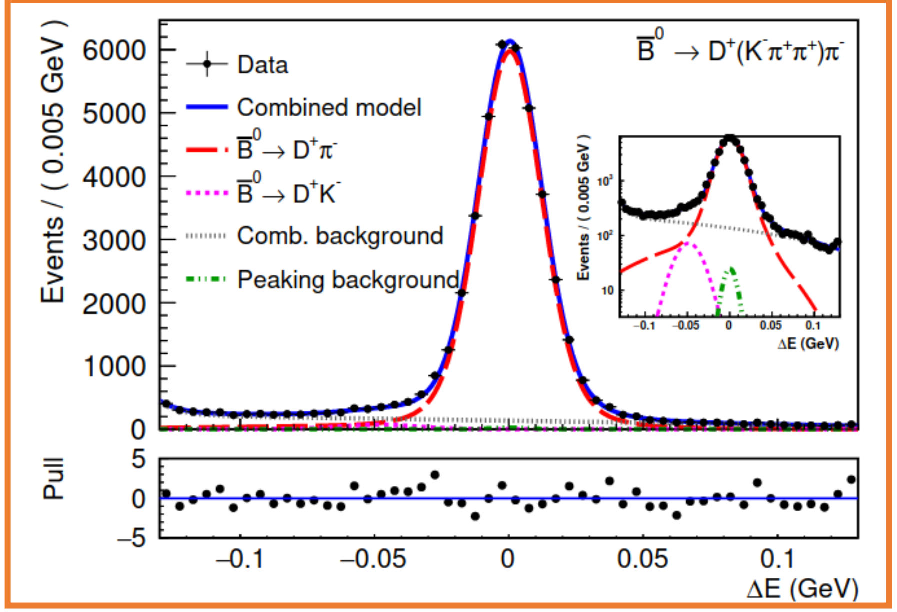
$\bar{B}^0 \to D^+ h^-$

$$R^D \equiv \frac{\mathcal{B}(\overline{B}^0 \to D^+K^-)}{\mathcal{B}(\overline{B}^0 \to D^+\pi^-)}$$

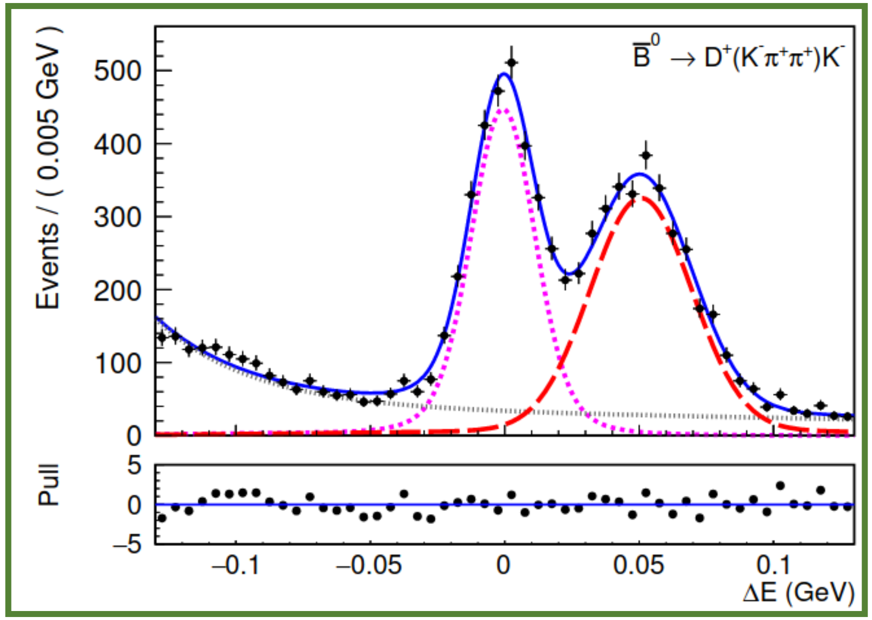
https://arxiv.org/pdf/2111.04978.pdf (accepted by PRD)

- reconstruct $D^+ \to K^-\pi^+\pi^+$
- ΔE simultaneous fit of $\bar{B}^0 \to D^+K^-$ and $\bar{B}^0 \to D^+\pi^-$

pion-enhanced $\mathfrak{L}(K/\pi) < 0.6$



kaon-enhanced $\mathfrak{L}(K/\pi) > 0.6$



$$R^D = 0.0819 \pm 0.0020(\text{stat}) \pm 0.0023(\text{syst})$$
$$\mathcal{B}(\overline{B}^0 \to D^+K^-) = (2.03 \pm 0.05 \pm 0.07 \pm 0.03) \times 10^{-4}$$
$$\mathcal{B}(\overline{B}^0 \to D^+\pi^-) = (2.48 \pm 0.01 \pm 0.09 \pm 0.04) \times 10^{-3}$$

- compatible with world averages

→ 6.6σ from https://arxiv.org/pdf/2007.10338.pdf (Bordone et al.)

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

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(preliminary)

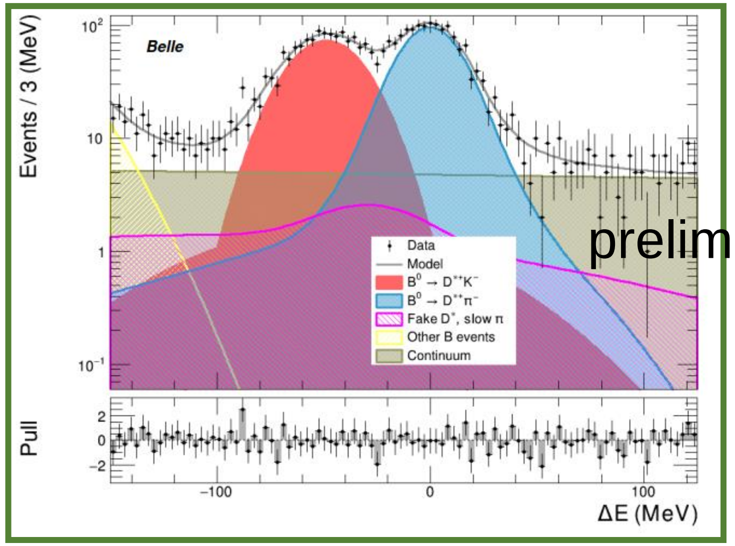
$\bar{B}^0 \to D^{*+}h^-$

- used signal channels:
  - $D^{*+} \to D^0[K^-\pi^+]\pi^+$
  - $D^{*+} \to D^0[K^-\pi^+\pi^+\pi^-]\pi^+$

- background from misreconstructed D*

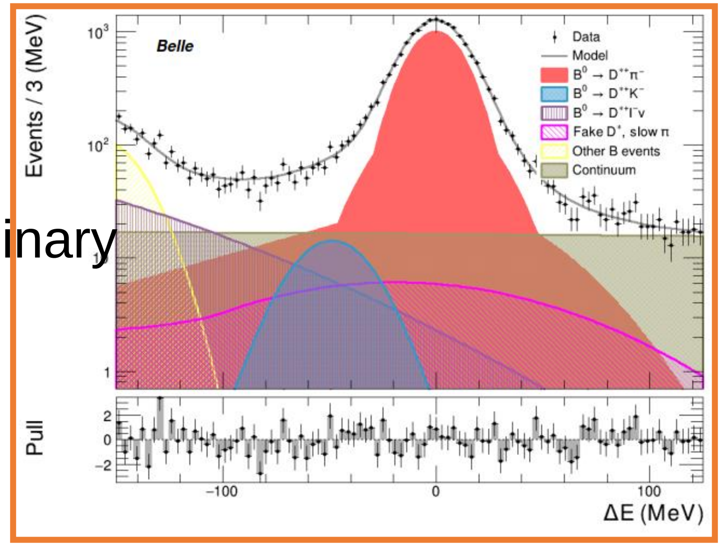
- ΔE simultaneous fit of $\bar{B}^0 \to D^{*+}K^-$ and $\bar{B}^0 \to D^{*+}\pi^-$

kaon-enhanced $\mathfrak{L}(K/\pi) > 0.6$



preliminary

pion-enhanced $\mathfrak{L}(K/\pi) < 0.6$



$D^0 \to K^-\pi^+$	Result	Discrepancy
$\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	$(2.638 \pm 0.023 \pm 0.077) \times 10^{-3}$	1.7σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$	$(2.178 \pm 0.090 \pm 0.078) \times 10^{-4}$	$1.0\sigma(2.7\sigma)$
$D^0 \to K^-2\pi^+\pi^-$		
$\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	$(2.499 \pm 0.021 \pm 0.095) \times 10^{-3}$	2.0σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$	$(2.134 \pm 0.082 \pm 0.086) \times 10^{-4}$	$1.1\sigma(2.8\sigma)$
Combined		
$\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	$(2.569 \pm 0.015 \pm 0.083) \times 10^{-3}$	1.9σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$	$(2.156 \pm 0.061 \pm 0.074) \times 10^{-4}$	$1.1\sigma(2.8\sigma)$

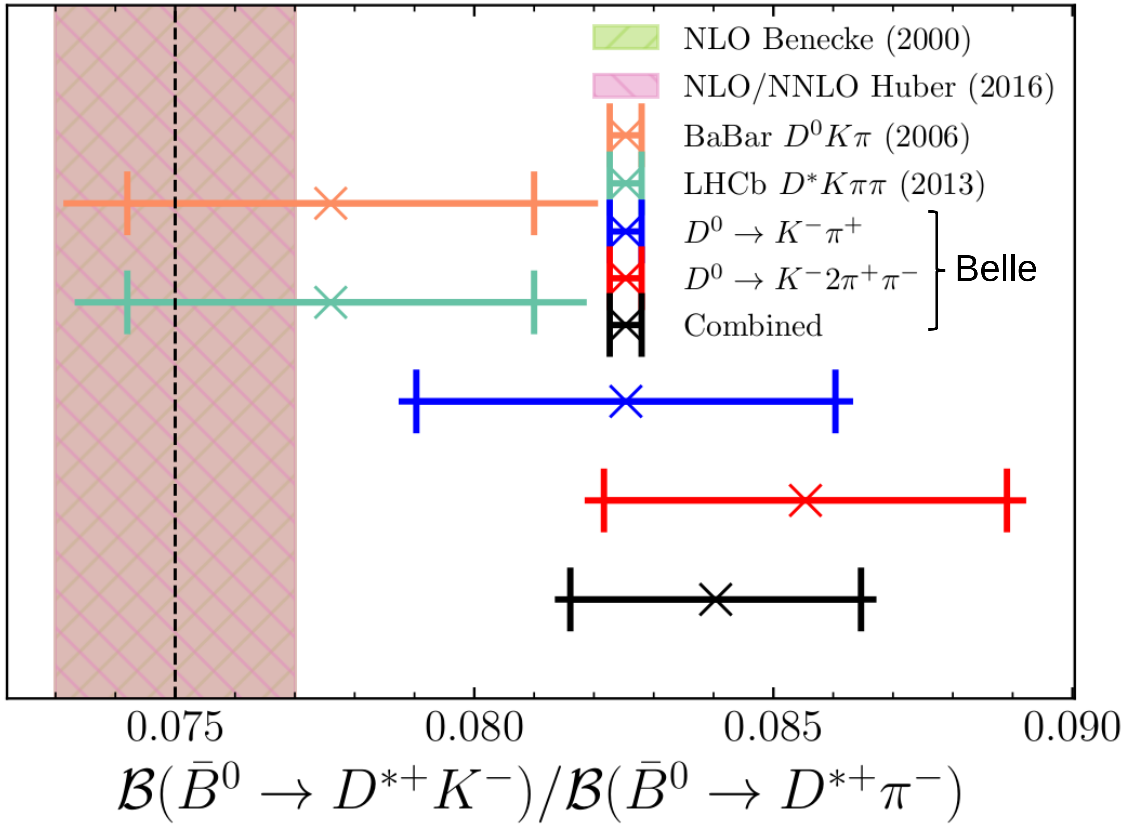
- slight deviations from theory predictions
  w/o brackets: https://arxiv.org/pdf/1606.02888.pdf (Huber et al.)
  w/ bracket: https://arxiv.org/pdf/2007.10338.pdf (Bordone et al.)

- results compatible with earlier Belle measurement
  - ➢ uncertainty improved by a factor of 3.5
  https://arxiv.org/pdf/hep-ex/0104051.pdf

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

$$\mathcal{R}_{K/\pi} = \frac{\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)}{\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)}$$

Channel	Result	Discrepancy
$D^0 \to K^-\pi^+$	$\mathcal{R}_{K/\pi} = (8.254 \pm 0.350 \pm 0.147) \times 10^{-2}$	1.7σ
$D^0 \to K^-2\pi^+\pi^-$	$\mathcal{R}_{K/\pi} = (8.527 \pm 0.336 \pm 0.150) \times 10^{-2}$	2.5σ
Combined	$\mathcal{R}_{K/\pi} = (8.390 \pm 0.243 \pm 0.115) \times 10^{-2}$	2.7σ



total experimental uncertainty reduced to **3.2%**

- LHCb: 5.5% ($\mathcal{R}_{\text{LHCb}} = \mathcal{B}(\bar{B}^0 \to D^{*+}K^-\pi^-\pi^+)/\mathcal{B}(\bar{B}^0 \to D^{*+}2\pi^-\pi^+)$)
  https://journals.aps.org/prd/pdf/10.1103/PhysRevD.87.092001
- BaBar: 5.7% (no simultaneous fit of kaon and pion sample)
  https://arxiv.org/pdf/hep-ex/0509036.pdf

Belle II: $B^0 \to K^0 \pi^0$

$62.8 fb^{-1}$

$B^0 \to K^0\pi^0$

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

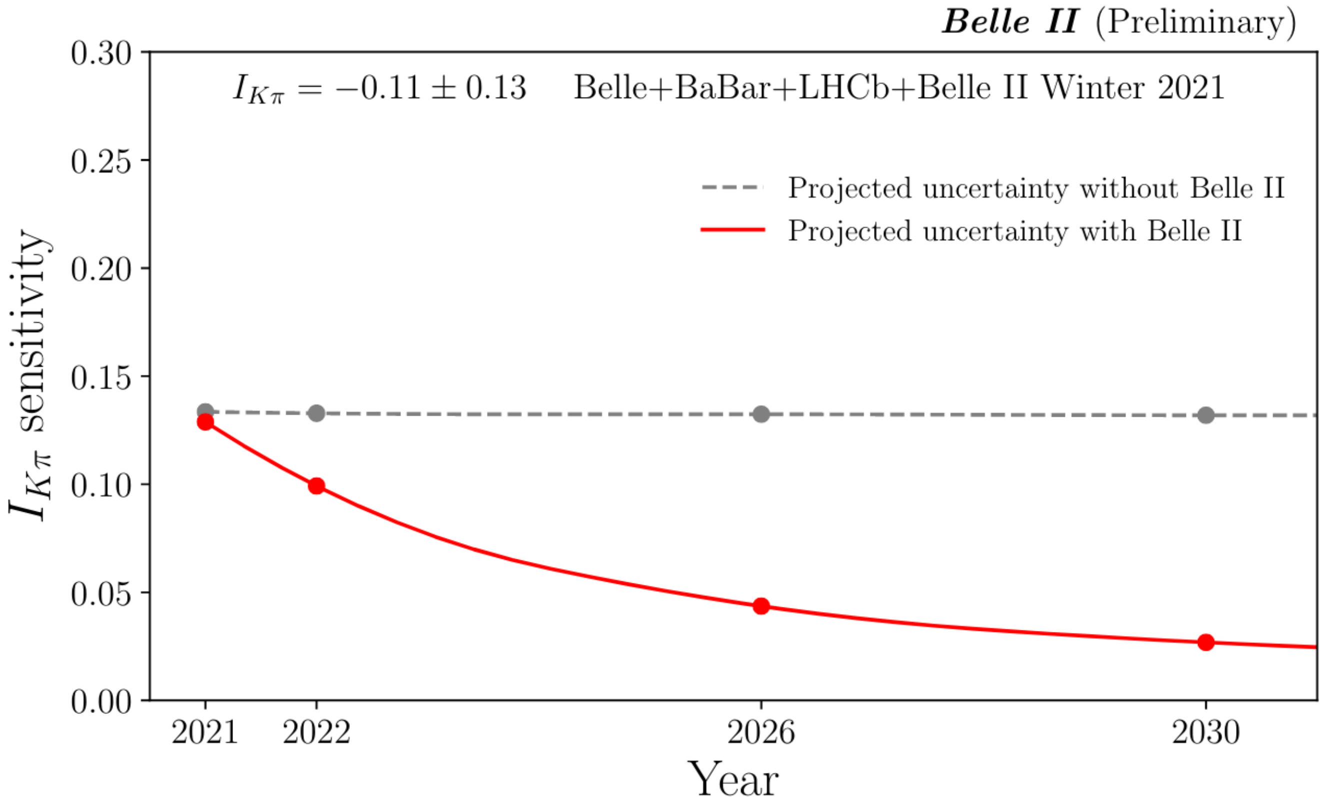
- **limiting** channel in **isospin sum rule**
  - stringent null test of SM

- first **branching fraction** and **A$_{CP}$** measurement shown at Moriond 2021
  https://arxiv.org/pdf/2104.14871.pdf

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

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

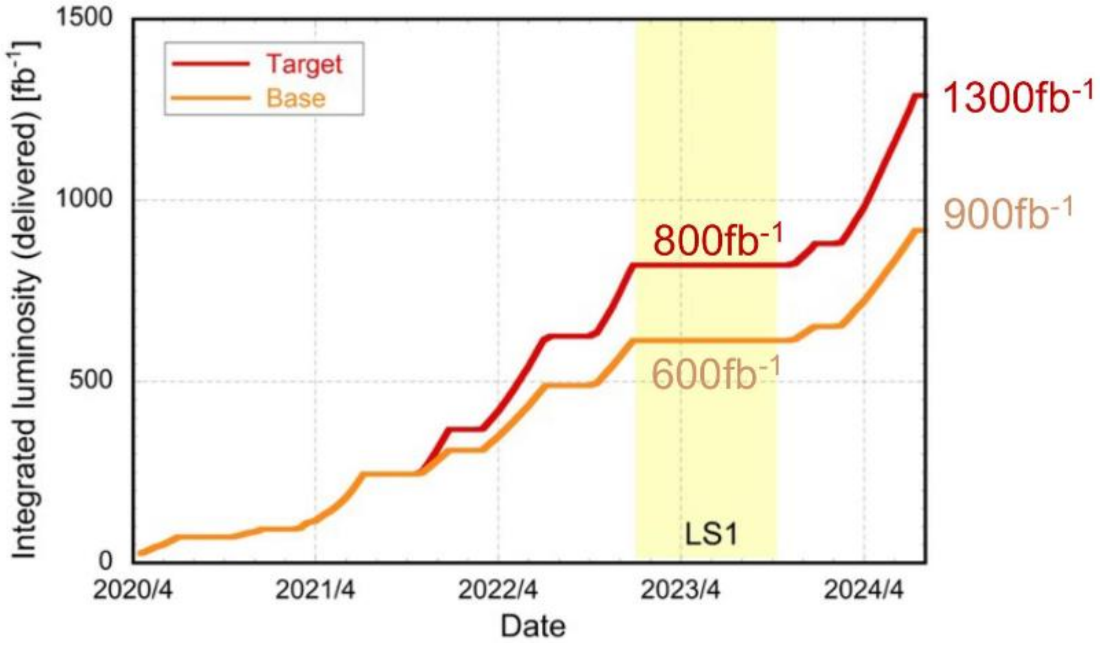
- update on branching fraction and A$_{CP}$
  plus time dependent CP violation



Summary

- Belle still in the game, producing world leading physics results
- Belle II has picked up pace
  - world leading results in charmless sector (i.e., $B^0 \to \pi^0\pi^0$ and $B^0 \to K^0\pi^0$) in ~1year
  - improvements on Φ_3 longer scale
- possibility to combine Belle and Belle II datasets

Belle II luminosity projection



new/updated results to come in the near future
→ stay tuned

Backup

Belle: $B^+ \to K^+K^-\pi^+$

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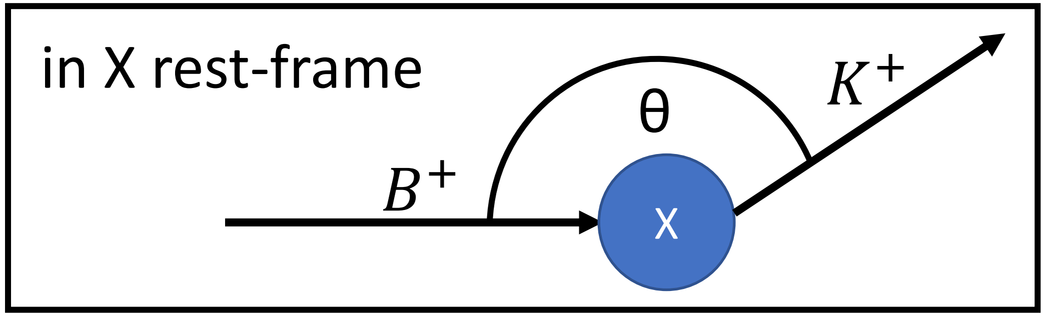
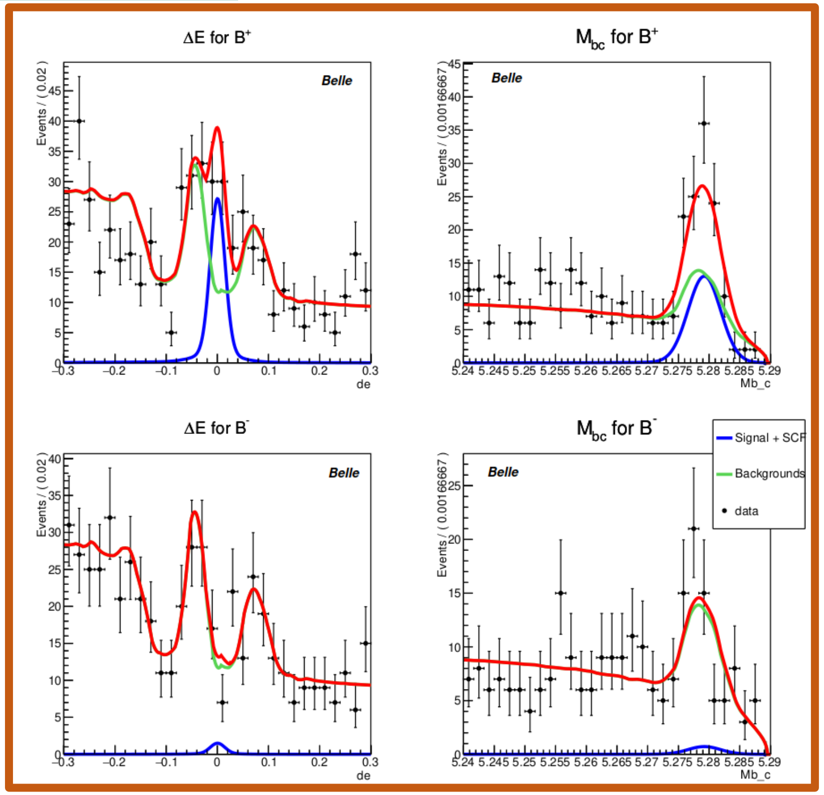
$B^+ \to K^+K^-\pi^+$

- BaBar and LHCb reported on an excess at low M_{KK}
- split the sample into five M_{KK} bins

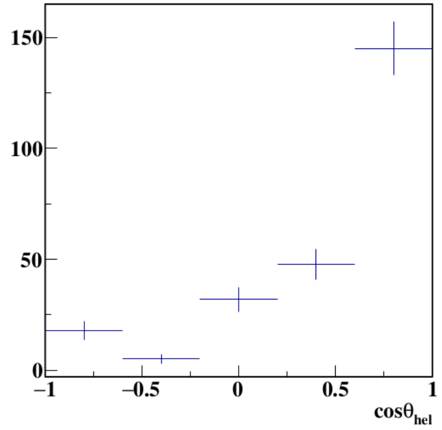
M_{KK}	N_{sig}	$\mathcal{S}(\sigma)$	$\mathcal{A}_{CP}$	$\mathcal{S}(\sigma)$	$d\mathcal{B}/dM\ (\times 10^{-7})$
0.8-1.1	$59.81 \pm 11.38 \pm 2.58$	6.71	$-0.896 \pm 0.166 \pm 0.039$	4.80	$14.0 \pm 2.7 \pm 0.8$
1.1-1.5	$212.35 \pm 21.31 \pm 6.71$	12.49	$-0.157 \pm 0.098 \pm 0.007$	1.58	$37.8 \pm 3.8 \pm 1.9$
1.5-2.5	$113.45 \pm 26.74 \pm 18.59$	3.67	$-0.135 \pm 0.231 \pm 0.030$	0.57	$10.0 \pm 2.3 \pm 1.7$
2.5-3.5	$110.11 \pm 17.56 \pm 4.94$	7.37	$-0.092 \pm 0.158 \pm 0.009$	0.58	$10.0 \pm 1.6 \pm 0.6$
3.5-5.3	$172.64 \pm 25.68 \pm 7.39$	7.43	$-0.053 \pm 0.147 \pm 0.006$	0.36	$8.1 \pm 1.2 \pm 0.5$

- large A_{CP} of -0.896 with stat. significance of $\mathbf{4.8\sigma}$ in first bin
- **helicity angle** gives insight in nature of ‘state’





https://minerva-access.unimelb.edu.au/handle/11343/197534



looks like spin 1

$B^+ \to K^+K^-\pi^+$

tracks
|dr| < 0.2 cm and |dz| < 5cm
binary kaonID > 0.6
or binary pionID < 0.4

veto D^0
1.85 < M_{KK}, $M_{K\pi}$,$M_{K^+\pi^-}$, $M_{\pi^+K^-}$< 1.85 (GeV/c^2)

veto J/ψ
3.06 < M_{ee}, $M_{\mu\mu}$< 3.14 (GeV/c^2)

veto χ_{c0}
3.375 < M_{KK} <3.475(GeV/c^2)

B^-
continuum suppression MVA > 0.88
-0.3 < ΔE < 0.3 GeV
5.24 < M_{bc} < 5.29 GeV/c^2

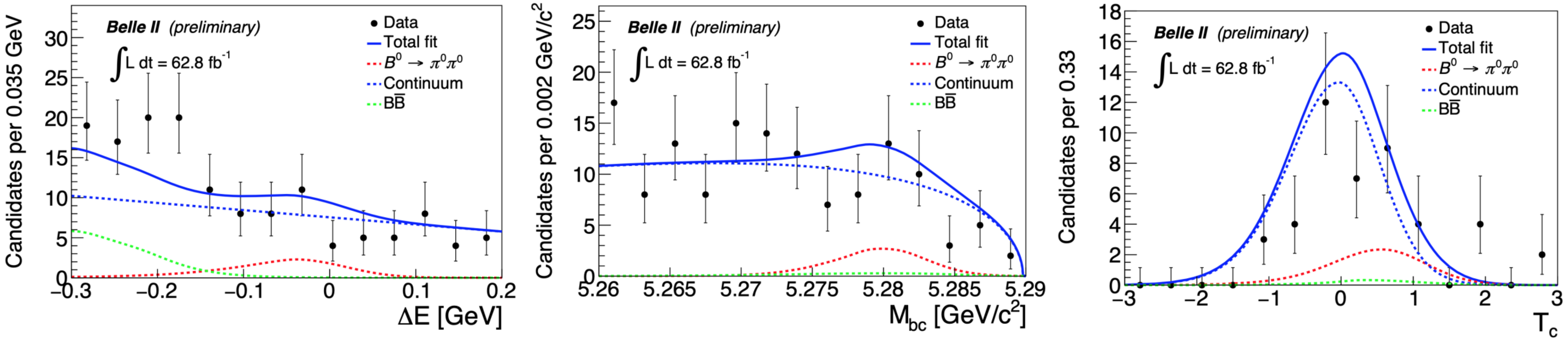
best candidate selection
average multiplicity: 1.344
select candidate with smallest χ^2 of B-vertex fit
→ BCS selects the correct candidate in 92% of the cases

Belle II: $B^0 \to \pi^0\pi^0$

$62.8 fb^{-1}$

$B^0 \to \pi^0\pi^0$

- unique Belle II capability to study **all** $B \to \pi\pi$ channels in consistent manner to extract α/Φ_2
- very **challenging**: two π^0
- first **branching fraction** measurement shown at Moriond 2021 https://arxiv.org/pdf/2107.02373.pdf
  - **3D-fit** in ΔE, M_{bc} and transformed continuum suppression variable T_c



$\mathfrak{B}(B^0 \to \pi^0\pi^0)$ = $[1.09^{+0.50}_{-0.41}$ (stat) ± 0.27 (sys)] x 10^{-6}

➢ update on branching fraction plus direct CP violation

Φ_3 from $B \to DK$ decays

tracks
|dr| < 0.2 cm and |dz| < 1cm
fast kaon (pion) binary ID > 0.6 (<0.6)
fast kaon or pion: cosθ > -0.6 (Belle II)
slow kaons or pions: binary ID

K_S^0
0.487 < InvM < 0.508 GeV/c^2
BDT: 'good' K_S^0
fast kaon or pion: cosθ > -0.6 (Belle II)
slow kaons or pions: binary ID

D^0
1.85 < InvM < 1.88 GeV/c^2
mass constrained fit

veto $e^+e^- \to cc$
$D^{*+} \to D^0\pi^+$: 0.143 < InvM(D^*) – InvM(D^0)< 0.149 GeV/c^2

B^+
-0.13 < ΔE < 0.18 GeV
M_{bc} > 5.27 GeV/c^2

continuum suppression
Belle: C > 0.15
Belle II: C > 0.2

best candidate selection
average multiplicity: 1.02
select candidate with smallest χ^2 of B-vertex fit
→ BCS selects the correct candidate in 65% of the cases

Φ_3 from $B \to DK$ decays

stolen from Niharika Rout's CKM Workshop talk

$$\mathbf{N}_i^{\pm} = \mathbf{h}_{\mathbf{B}^\pm}\left[\mathbf{F}_i + \mathbf{r}_\mathbf{B}^2 \overline{\mathbf{F}}_i + 2\sqrt{\mathbf{F}_i \overline{\mathbf{F}}_i}(\mathbf{c}_i \boldsymbol{x}_\pm + \mathbf{s}_i \boldsymbol{y}_\pm)\right].$$

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

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

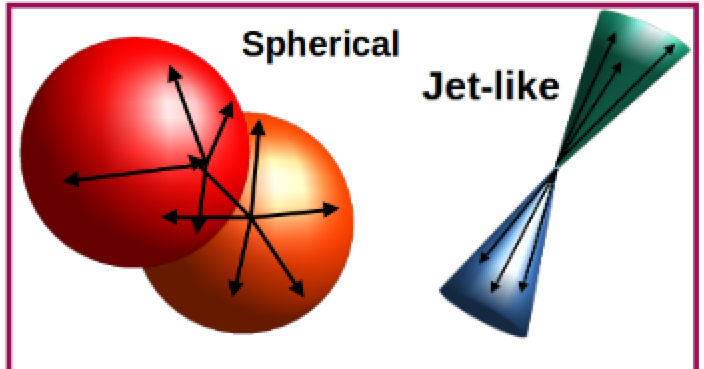
Amplitude-averaged strong phase difference between $\overline{D^0}$ and D^0 over i^{th} bin and are obtained from external charm factories like *CLEO* and *BESIII*.

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

Φ_3 from $B \to DK$ decays

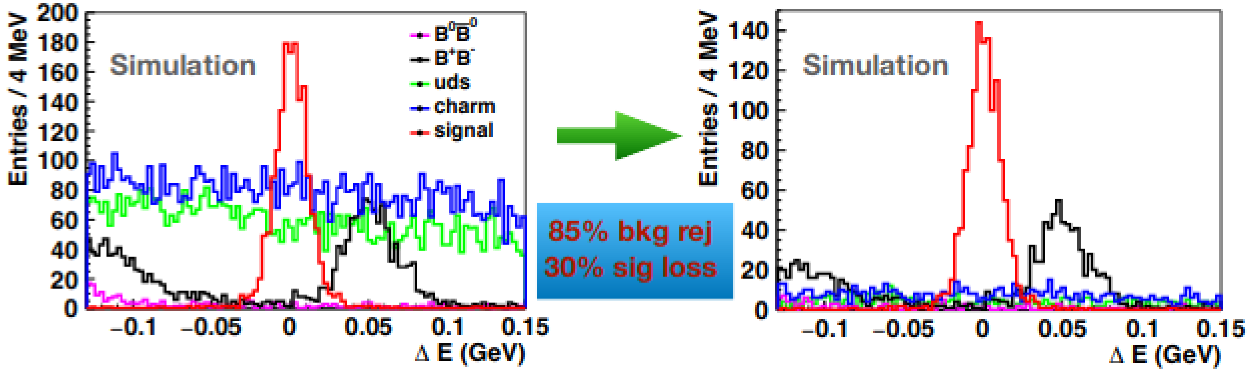
stolen from Niharika Rout's CKM Workshop talk

Background suppression



$e^+e^- \to \Upsilon(4S) \to B\bar{B}$ $e^+e^- \to q\bar{q}$

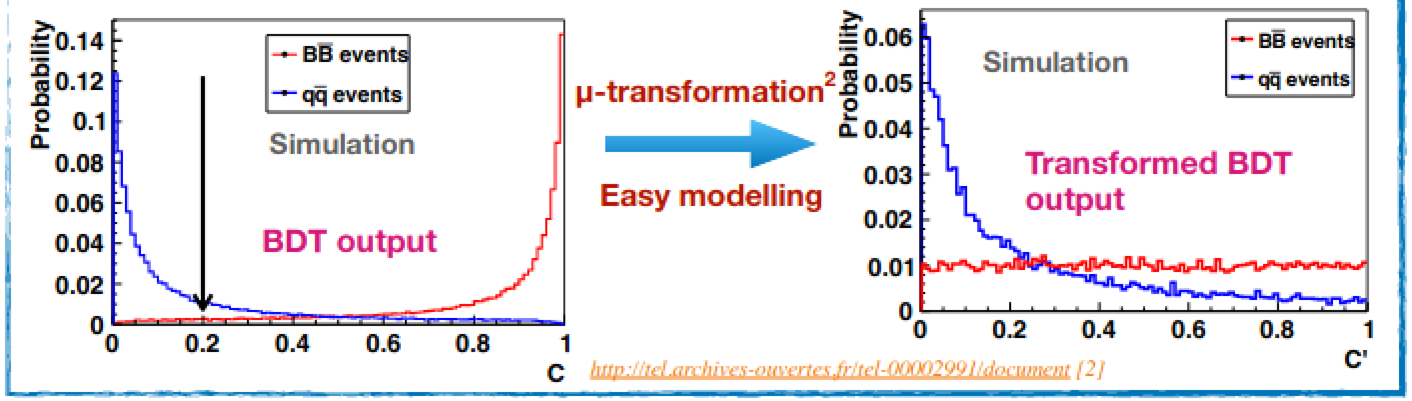
Dominant background from $e^+e^- \to q\bar{q}$ processes



Inputs to boosted-decision-tree (BDT)

⬇️

- Event shape variables
- Angular variables
- Vertex variables
- Flavour tag variables



http://tel.archives-ouvertes.fr/tel-00002991/document [2]

Φ_3 from $B \to DK$ decays

Source	$\sigma_{x_+^{DK}}$	$\sigma_{y_+^{DK}}$	$\sigma_{x_-^{DK}}$	$\sigma_{y_-^{DK}}$	$\sigma_{x_\xi^{D\pi}}$	$\sigma_{y_\xi^{D\pi}}$
Input c_i, s_i	0.22	0.55	0.23	0.67	0.73	0.82
PDF parametrisation	0.07	0.08	0.12	0.16	0.12	0.12
PID	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
Peaking background	0.03	0.05	0.03	0.04	0.02	0.10
Fit bias	0.16	0.06	0.12	0.16	0.49	0.10
Bin migration	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03
Total	0.18	0.11	0.17	0.23	0.51	0.19
Statistical	3.15	4.20	3.27	4.20	4.75	5.44

Table 3. Systematic uncertainty summary. All values are quoted in units of 10^{-2}.

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

tracks
|dr| < 0.2 cm and |dz| < 1.5cm
binary kaonID > 0.6
or binary pionID < 0.6

D^+
mass within ±2.5σ of nominal D^+ mass
mass constrained fit

$\bar{B}^0$
continuum suppression MVA > 0.88
-0.13 < ΔE < 0.13 GeV
5.27 < M_{bc} < 5.29 GeV/c^2

veto $B^0 \rightarrow K^{*0}[K^+\pi^-]J/\psi[l^+l^-]$
$M_{\pi\pi}$ within ±3σ of nominal J/ψ mass

best candidate selection
average multiplicity: 1.007
select candidate with smallest $\|M_{bc} - m_{\bar{B}^0}\|$
→ BCS selects the correct candidate in 92% of the cases

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

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%
Tracking	–	1.40%	1.40%
$N_{B\overline{B}}$	–	1.37%	1.37%
f^{00}/f^{+-}	–	1.92%	1.92%
$D^+ \to K^-\pi^+\pi^+$ model	–	0.69%	0.69%
PDF parameterization	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%

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

Particle candidate	Requirement
all tracks	$\|dz\| < 2$ cm, $\|dr\| < 4$ cm
fast π^-	$\mathcal{L}_{K/\pi} < 0.6$
slow π^-	no requirements
K^-	$\mathcal{L}_{K/\pi} > 0.6$
D^0	$M - 3\sigma_M < M < M + 3\sigma_M$
D^{*+}	$\Delta M - 3\sigma_{\Delta M} < \Delta M < \Delta M + 3\sigma_{\Delta M}$
B^0	$M_{\text{bc}} > 5.27$ GeV
B^0	-150 MeV $< \Delta E <$ 125 MeV

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

$D^0 \to K^-\pi^+$		
type	$\bar{B} \to D^{*+}\pi^-$	$\bar{B} \to D^{*+}K^-$
π-ID stat.	0.78%(0.72%†)	0.54%
π-ID sys.	0.60%(0.44%†)	0.27%
K-ID stat.	0.76%	1.05%(0.72%†)
K-ID sys.	0.53%	1.15%(0.61%†)
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%
3 tracks tracking sys.	1.05%	1.05%
MC stat.	0.39%†	1.4%†
fixed yields bkg. PDF	0.10%†	0.10%†
fixed shapes bkg. PDF	0.10%†	0.10%†
fit bias	0.15%†	0.15%†
N-B^0-mesons	1.84%	1.84%
$\mathcal{B}(D^{*+} \to D^0\pi^+)$	0.74%	0.74%
$\mathcal{B}(D^0 \to K^-\pi^+)$	0.78%	0.78%
total (Br.)	3.20%	3.60%
total (ratio)	1.93%	1.93%
fit stat. err.	0.84%	4.00%

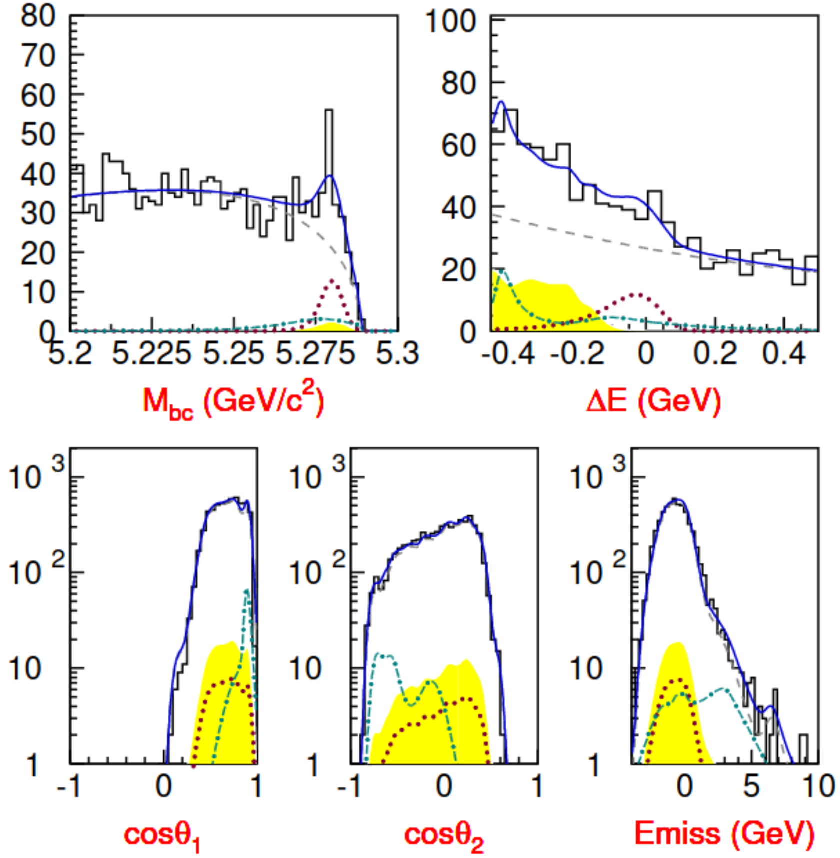
$D^0 \to K^-2\pi^+\pi^-$		
type	$\bar{B} \to D^{*+}\pi^-$	$\bar{B} \to D^{*+}K^-$
π-ID stat.	0.95%(0.65%†)	0.20%
π-ID sys.	0.52%(0.46%†)	0.20%
K-ID stat.	0.72%	1.03%(0.72%†)
K-ID sys.	0.57%	0.62%(0.62%†)
K-ID run dep. sys.	0.30%	0.30%
π_{slow} stat.	0.79%	0.79%
π_{slow} sys.	0.01%	0.01%
π_{slow} corr.	1.33%	1.33%
5 tracks tracking sys.	1.75%	1.75%
MC stat.	0.35%†	1.39%†
fixed yields bkg. PDF	0.10%†	0.10%†
fixed shapes bkg. PDF	0.10%†	0.10%†
fit bias	0.08%†	0.74%†
N-B^0-mesons	1.84%	1.84%
$\mathcal{B}(D^{*+} \to D^0\pi^+)$	0.74%	0.74%
$\mathcal{B}(D^0 \to K^-2\pi^+\pi^-)$	1.70%	1.70%
total (Br.)	3.81%	4.05%
total (ratio)	1.89%	1.89%
fit stat. err. (Br.)	0.78%	3.70%

Combined			
Type	$\bar{B} \to D^{*+}\pi^-$	$\bar{B} \to D^{*+}K^-$	Corr. coeff.
π-ID stat.	0.77%(0.58%†)	0.34%	3/5
π-ID sys.	0.50%(0.41%†)	0.21%	3/5
K-ID stat.	0.66%	0.93%(0.64%†)	3/5
K-ID sys.	0.49%	0.80%(0.55%†)	3/5
K-ID run dep. sys.	0.27%	0.27%	3/5
π_{slow} stat.	0.79%	0.79%	1
π_{slow} sys.	0.01%	0.01%	1
π_{slow} corr.	1.33%	1.33%	1
tracking sys.	1.26%	1.26%	3/5
MC stat.	0.26%†	0.99%†	0
fixed yields bkg. PDF	0.07%†	0.07%†	0
fixed shapes bkg. PDF	0.07%†	0.07%†	0
fit bias	0.09%†	0.37%†	0
N-B^0-mesons	1.60%	1.60%	1
$\mathcal{B}(D^{*+} \to D^0\pi^+)$	0.74%	0.74%	1
$\mathcal{B}(D^0)$	0.94%	0.94%	0
total (Br.)	3.25%	3.42%	
total (ratio)	1.50%	1.50%	
fit stat. err. (Br.)	0.57%	2.74%	

Belle: $B^0 \to \pi^0\pi^0$ and $B^0 \to K^0\pi^0$

$B^0 \to \pi^0\pi^0$ (535×10^6 $B\bar{B}$ pairs)

https://arxiv.org/pdf/hep-ex/0610065.pdf



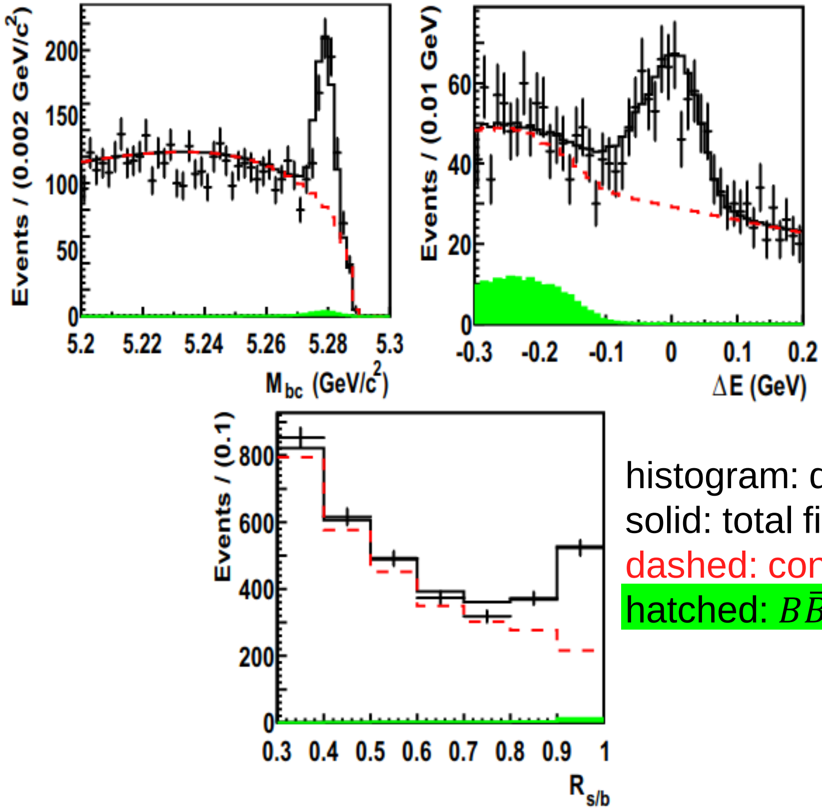
histogram: data
solid: total fit
dotted: signal
dashed: continuum
dot-dashed: off-time
hatched: $B^+ \to \rho^+\pi^0$

$$\mathcal{B}(B^0 \to \pi^0\pi^0) = (1.1 \pm 0.3(\text{stat.}) \pm 0.1(\text{syst.})) \times 10^{-6}$$

$$\mathcal{A}_{CP}(B^0 \to \pi^0\pi^0) = 0.44\,^{+0.73}_{-0.62}(\text{stat.})^{+0.04}_{-0.06}(\text{syst.})$$

$B^0 \to K^0\pi^0$ (657×10^6 $B\bar{B}$ pairs)

https://arxiv.org/pdf/0809.4366.pdf



histogram: data
solid: total fit
dashed: continuum + $B\bar{B}$
hatched: $B\bar{B}$

$$\mathcal{B}(B^0 \to K^0\pi^0) = (8.7 \pm 0.5 \pm 0.6) \times 10^{-6}$$

$$\mathcal{A}_{K^0\pi^0} = +0.14 \pm 0.13 \pm 0.06$$