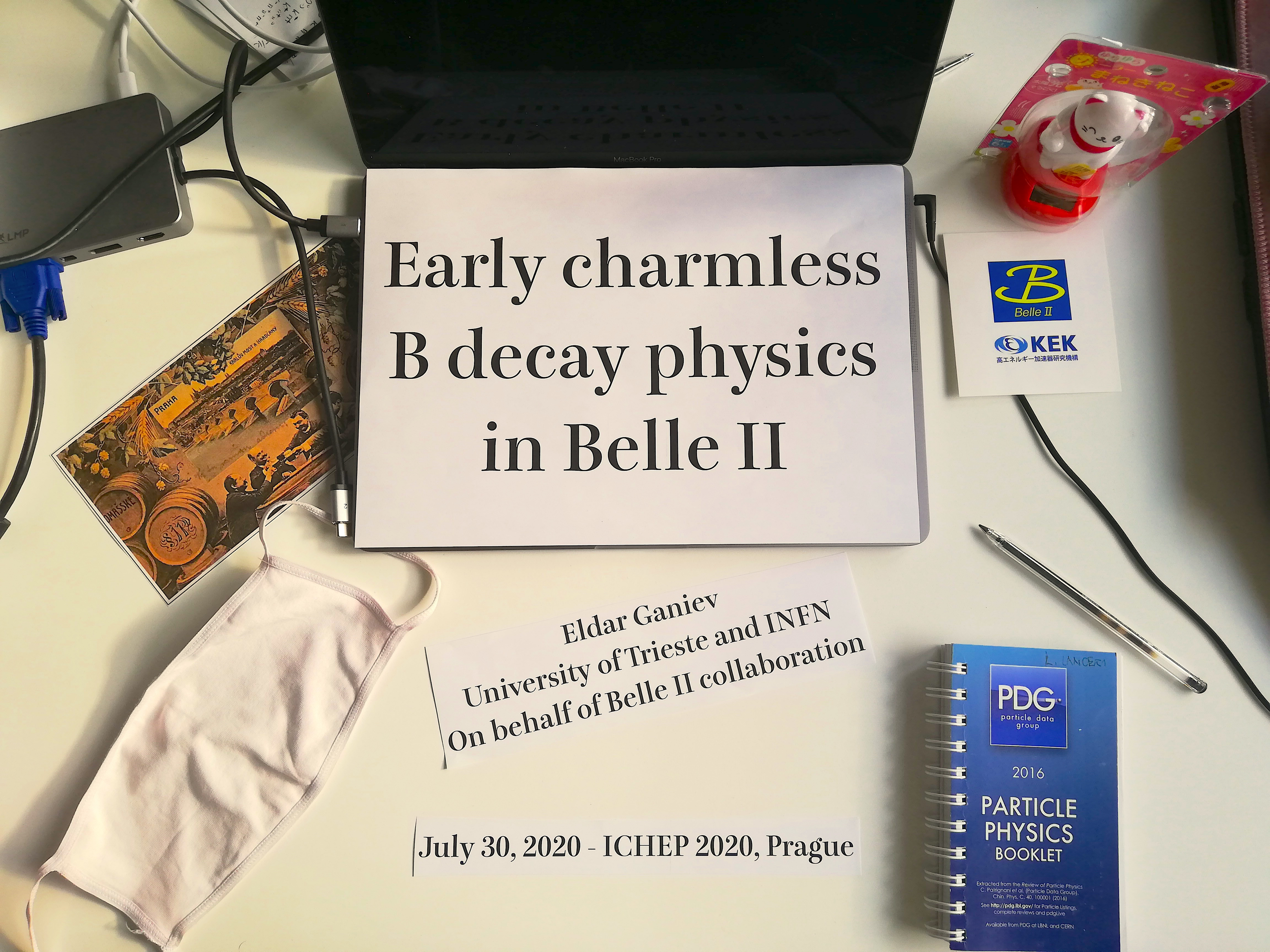

Early charmless
B decay physics
in Belle II
Eldar Ganiev
University of Trieste and INFN
On behalf of Belle II collaboration
July 30, 2020 - ICHEP 2020, Prague
Belle II
KEK
高エネルギー加速器研究機構
PDG
particle data group
2016
PARTICLE PHYSICS BOOKLET
PRAHA

# Hadronic charmless *B* decays

*B* decays without charmed hadrons

Mediated by

Cabibbo-suppressed
$b \to u$

Loop-suppressed
$b \to d$, $b \to s$

Observed 27 years ago by CLEO and grew to account for 15% of experimental flavor-physics papers.

- Highly sensitive to new loop contributions.
- Probe non-SM dynamics in each of the three CKM angles.
- As a byproduct, multiple tests of approaches to deal with QCD factorization, SU(3) symmetries etc.

Challenges:

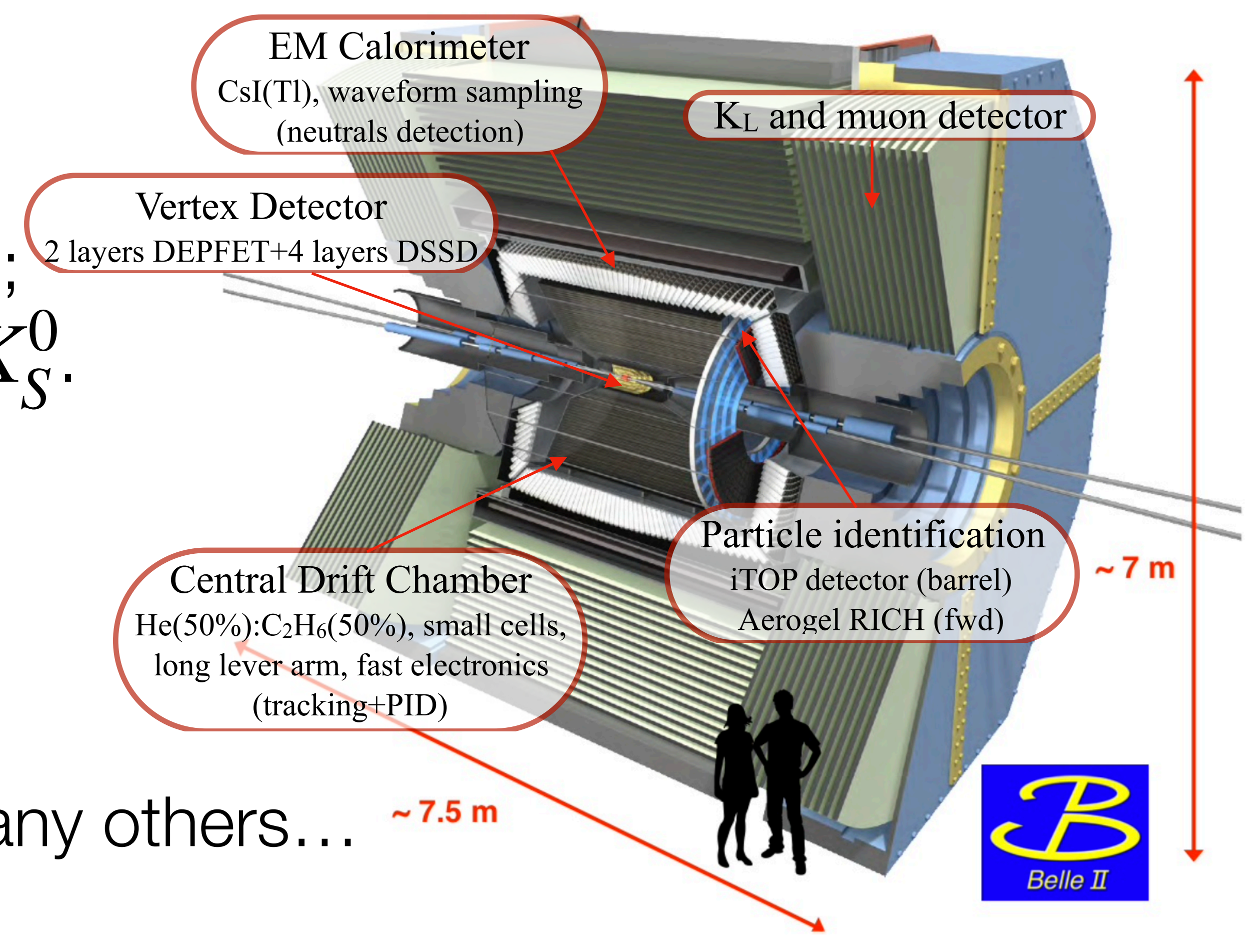
⇒ charmless *B* decays have branching fractions of order $\lesssim 10^{-5}$;

⇒ final states same as prevailing backgrounds.

# Charmless at Belle II

Key role:

- Reach ~1.5° precision on $\alpha/\varphi_2$;
- Test of SM using isospin sum rules;
- Search for local CP asymmetries in $B \to 3h$;
- Time dependent CP violation with $B^0 \to \phi K^0_S$.



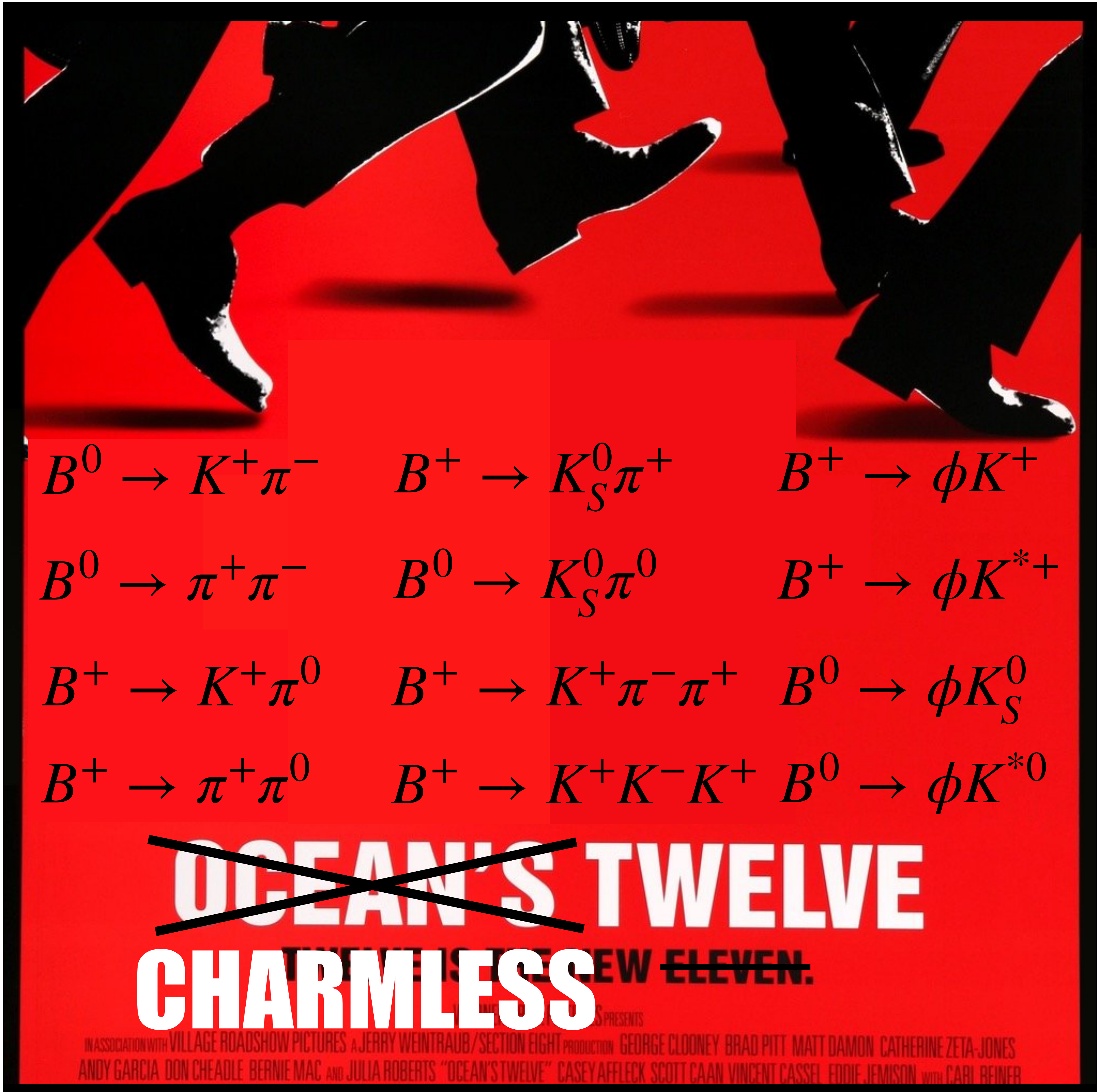

Complementary to LHCb:

- Channels with neutrals as $B^0 \to \pi^0\pi^0$;
- Channels with $K^0_S$ as $B^0 \to K^0_S\pi^0$. And many others…

Belle II in 2019-2020:

- ☑ collected ~75 fb$^{-1}$ of data;
- ☑ World record luminosity by SuperKEKB: $2.4\times10^{34}$cm$^{-2}$s$^{-1}$ (with currents lower than at KEKB);
- ☑ many physics analyses ongoing.

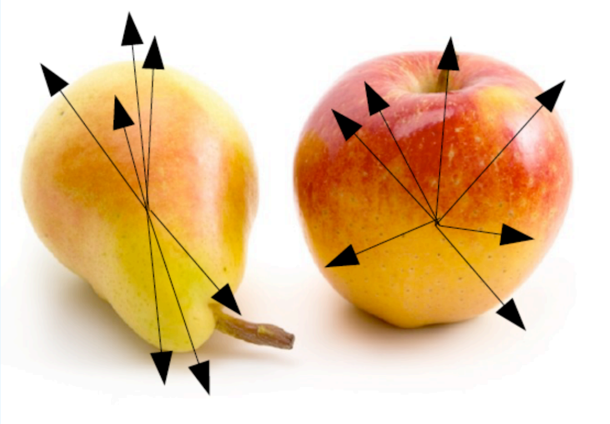
Today: first measurements of branching fraction, CP asymmetry, and polarization for a variety of charmless $B$ decays using 35 fb$^{-1}$ (38M $B\bar{B}$ pairs).


$B^0 \to K^+\pi^-$
$B^+ \to K_S^0\pi^+$
$B^+ \to \phi K^+$
$B^0 \to \pi^+\pi^-$
$B^0 \to K_S^0\pi^0$
$B^+ \to \phi K^{*+}$
$B^+ \to K^+\pi^0$
$B^+ \to K^+\pi^-\pi^+$
$B^0 \to \phi K_S^0$
$B^+ \to \pi^+\pi^0$
$B^+ \to K^+K^-K^+$
$B^0 \to \phi K^{*0}$
~~OCEAN'S~~ TWELVE
CHARMLESS
~~ELEVEN.~~
IN ASSOCIATION WITH VILLAGE ROADSHOW PICTURES A JERRY WEINTRAUB/SECTION EIGHT PRODUCTION GEORGE CLOONEY BRAD PITT MATT DAMON CATHERINE ZETA-JONES
ANDY GARCIA DON CHEADLE BERNIE MAC AND JULIA ROBERTS "OCEAN'S TWELVE" CASEY AFFLECK SCOTT CAAN VINCENT CASSEL EDDIE JEMISON WITH CARL REINER

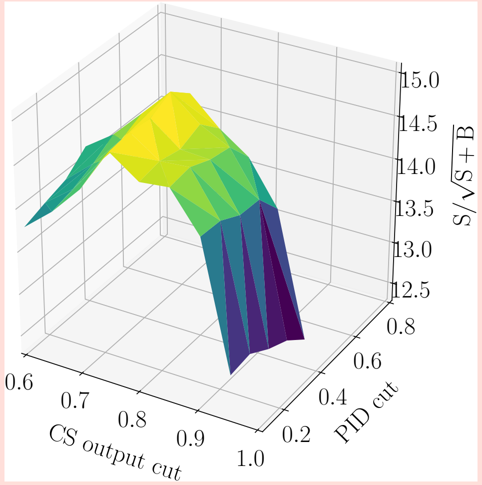
# Analysis ingredients

Goal: measure $\mathscr{B}$, $A_{CP}$ and $f_L$ of two- and three-body charmless $B$ decays.

## Continuum suppression



## Selection optimization

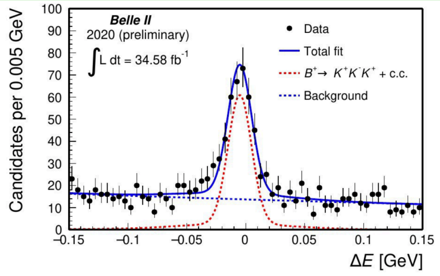



## Efficiency measurement

$$\varepsilon = \frac{N(passed)}{N(generated)}$$

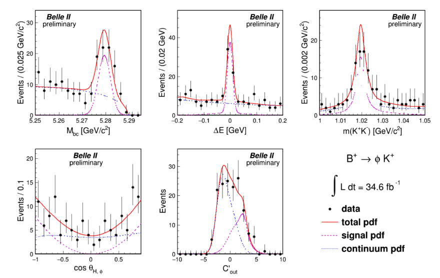
## Signal extraction

1D fit $\Delta E = E_B - E_{beam}$



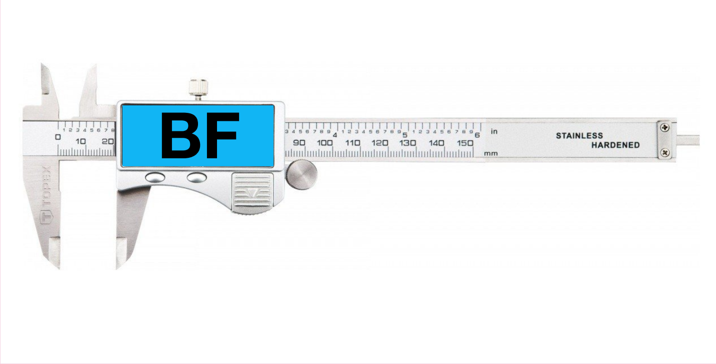

× 8

Multidimensional fit




× 4

## Measurement of branching fraction, CP-asymmetry, and longitudinal polarization.




## Systematics

| Operation | $\varepsilon(B^+ \to K^+K^-K^+)$ | $\varepsilon(B^+ \to K^+\pi^-\pi^+)$ |
|---|---|---|
| Reconstruction | 0.780 | 0.692 |
| Pre-selection | 0.749 | 0.664 |
| $M_{bc}$ and $\Delta E$ requirements | 0.710 | 0.636 |
| PID requirement | 0.435 | 0.507 |
| CS requirement | 0.323 | 0.290 |
| Charm vetoes | 0.290 | 0.250 |

# Selection

Challenge: reject the dominant background from light $q\bar{q}$ pairs (continuum).

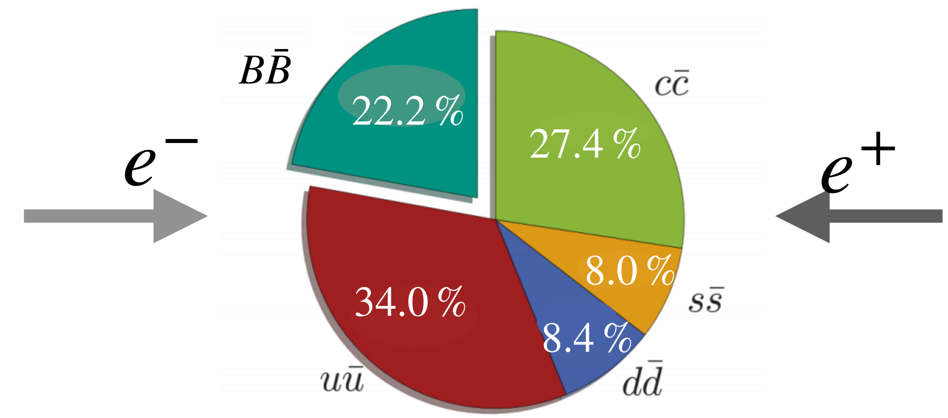
Exploit variables sensitive to topological differences.

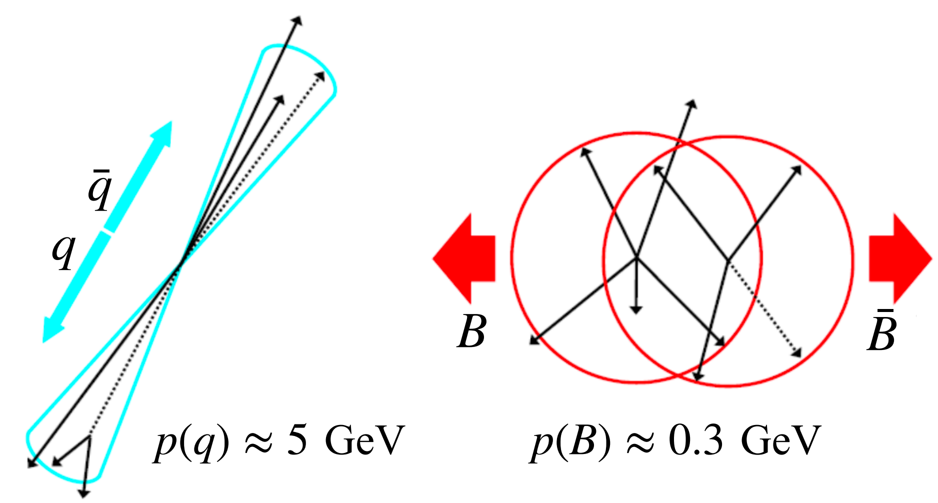
Using multivariate techniques combine 30+ kinematic, decay-time, and topology variables to maximize S/B.

For each channel, we optimize the selection to isolate low-background signal using simulated and control-sample data.

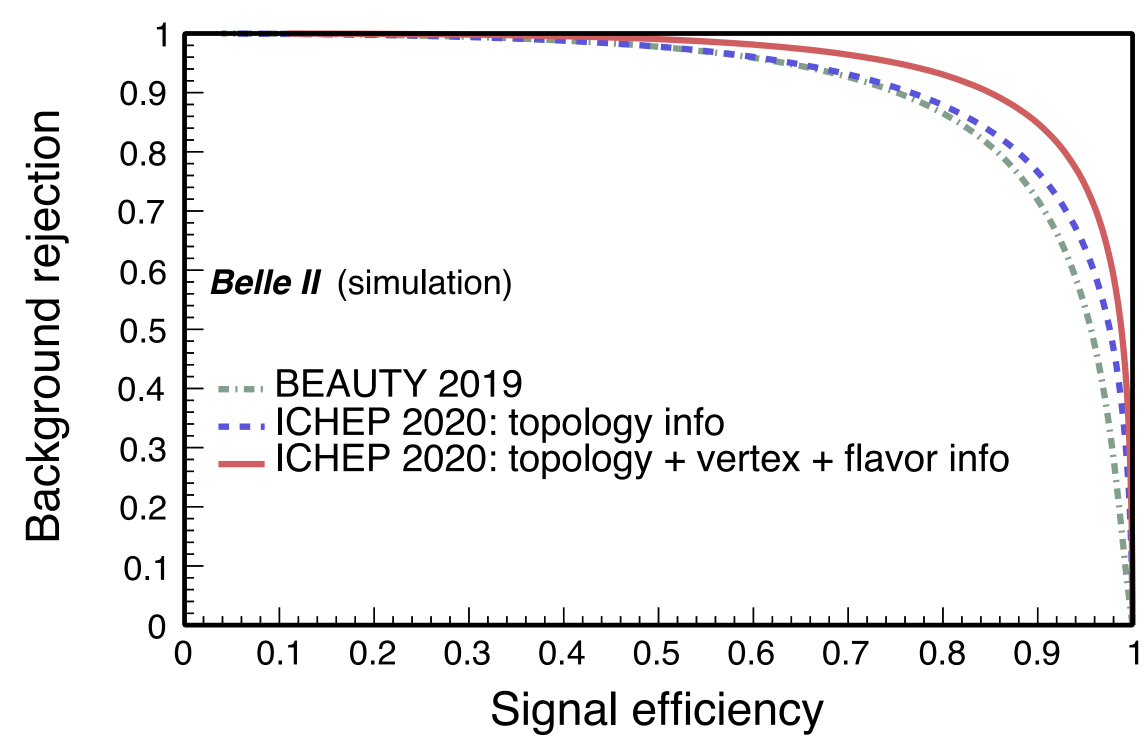
CS selection efficiency: 35 - 79%

$q\bar{q}$ background rejection: 96 - 99%



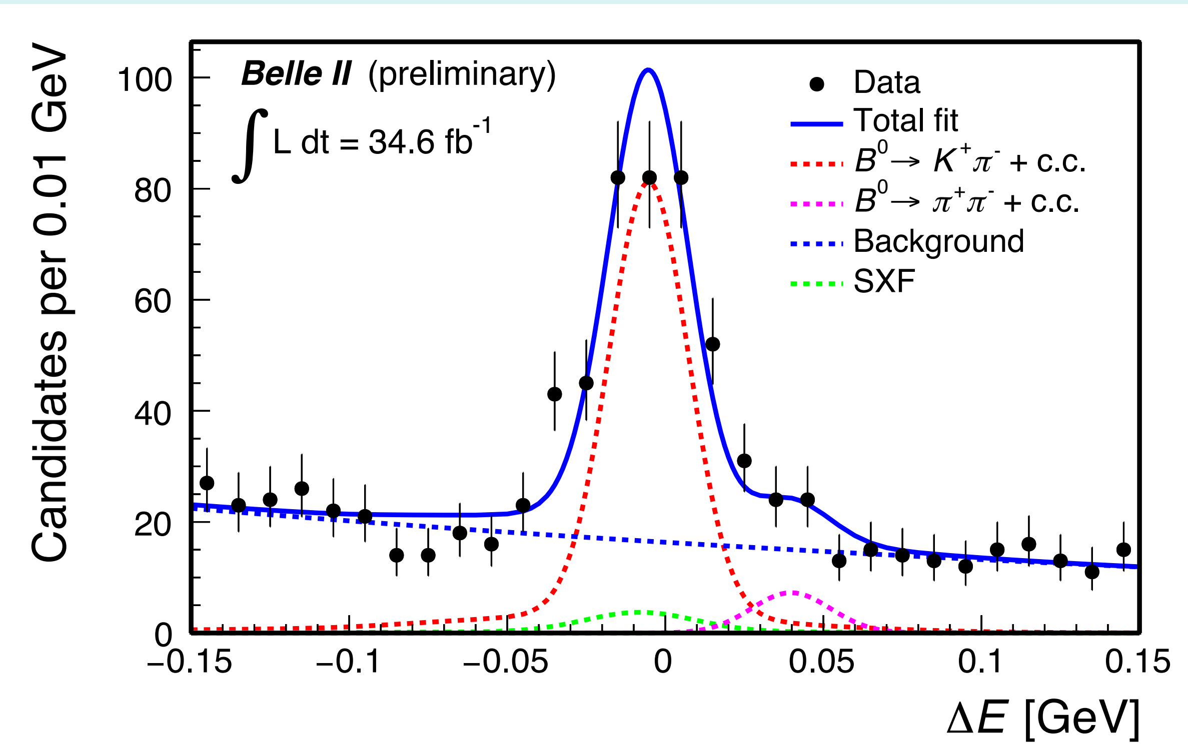




$e^+e^- \to q\bar{q}$ $(q \in \{u, d, s, c\})$ $\qquad$ $e^+e^- \to \Upsilon(4S) \to B\bar{B}$



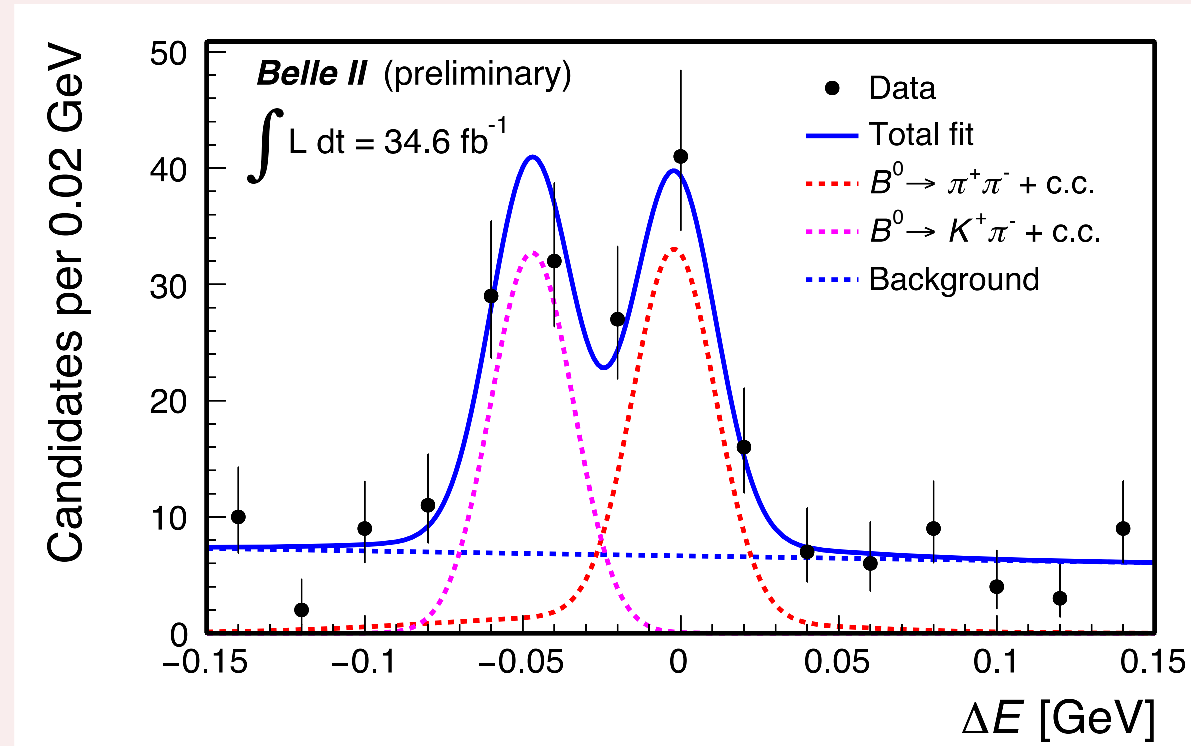
# Two-body: $B^0 \to K^+\pi^-, B^0 \to \pi^+\pi^-$

Two tracks in the final state. Probe of tracking and PID.




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

| | |
|---|---|
| N$_{sig}$ | $289^{+22}_{-21}$ |
| $\mathscr{B}$ [10$^{-6}$] | $18.9 \pm 1.4$(stat.) $\pm$ $1.0$(syst.) |
| **PDG** | |
| $\mathscr{B}$ [10$^{-6}$] | $19.6 \pm 0.5$ |

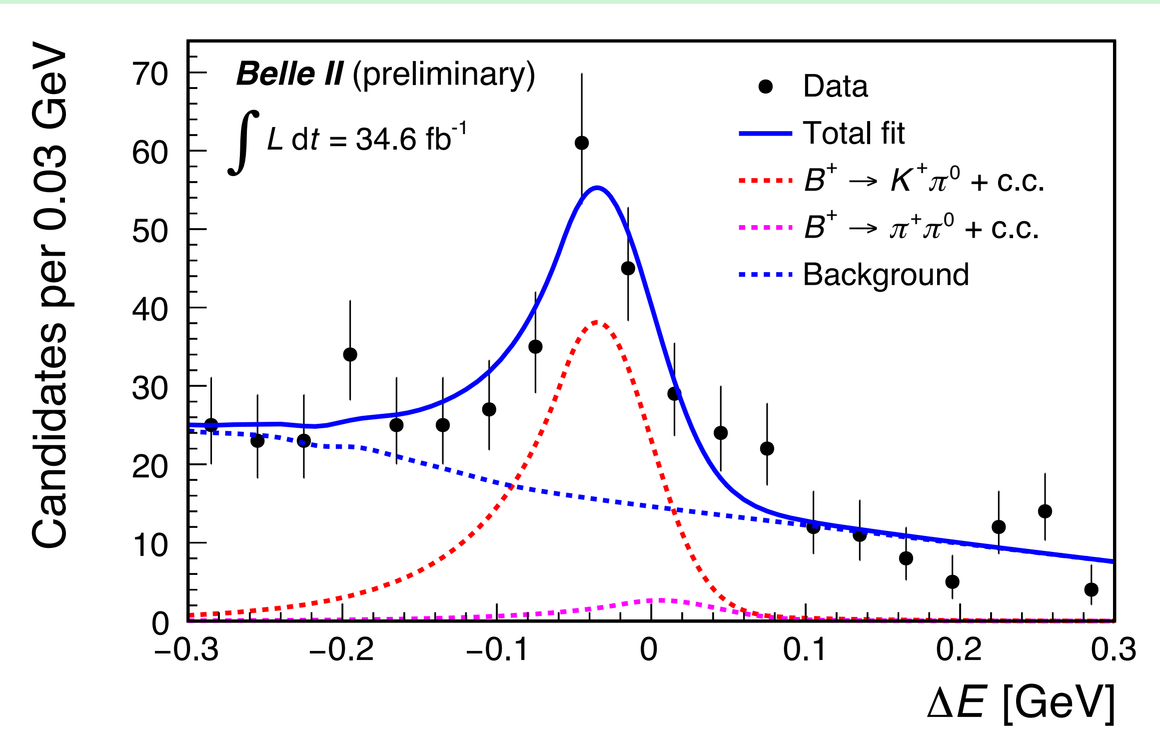



$B^0 \to \pi^+\pi^-$

| | |
|---|---|
| N$_{sig}$ | $61^{+11}_{-10}$ |
| $\mathscr{B}$ [10$^{-6}$] | $5.6^{+1.0}_{-0.9}$(stat.) $\pm$ $0.3$(syst.) |
| **PDG** | |
| $\mathscr{B}$ [10$^{-6}$] | $5.12 \pm 0.19$ |

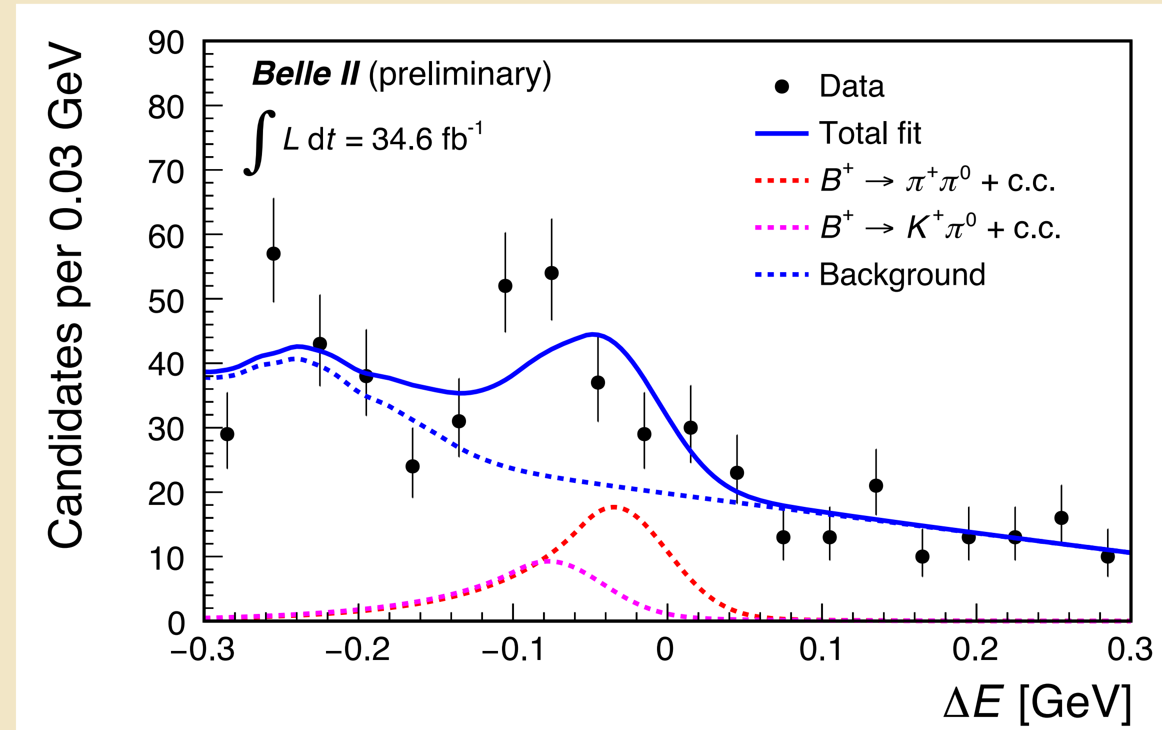
# Two-body: $B^+ \to K^+\pi^0$, $B^+ \to \pi^+\pi^0$

Challenge for $\pi^0$ reconstruction performance. Require good PID.




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

| | |
|---|---|
| $N_{sig}$ | $144^{+25}_{-24}$ |
| $\mathscr{B}$ [$10^{-6}$] | $12.7^{+2.2}_{-2.1}(\text{stat.}) \pm 1.1(\text{syst.})$ |
| **PDG** | |
| $\mathscr{B}$ [$10^{-6}$] | $12.9 \pm 0.5$ |

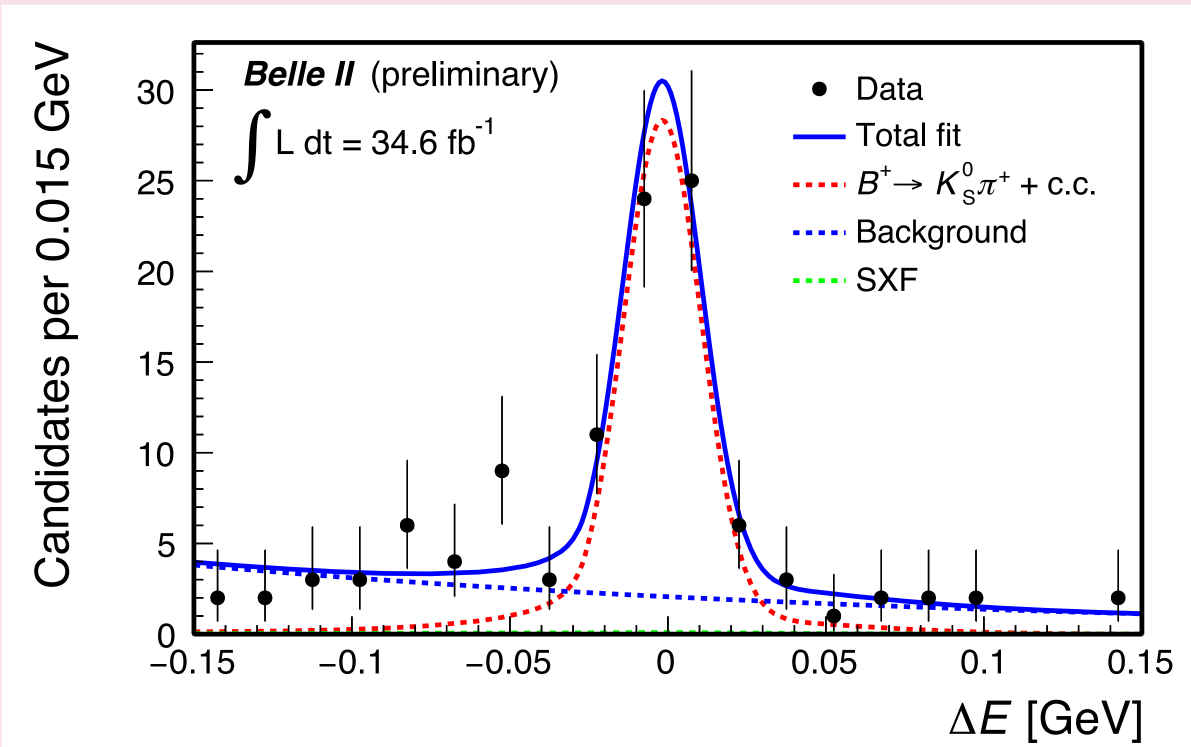



$B^+ \to \pi^+\pi^0$

| | |
|---|---|
| $N_{sig}$ | $68 \pm 27$ |
| **First reconstruction in Belle II data!** | |
| $\mathscr{B}$ [$10^{-6}$] | $5.7 \pm 2.3(\text{stat.}) \pm 0.5(\text{syst.})$ |
| **PDG** | |
| $\mathscr{B}$ [$10^{-6}$] | $5.5 \pm 0.4$ |

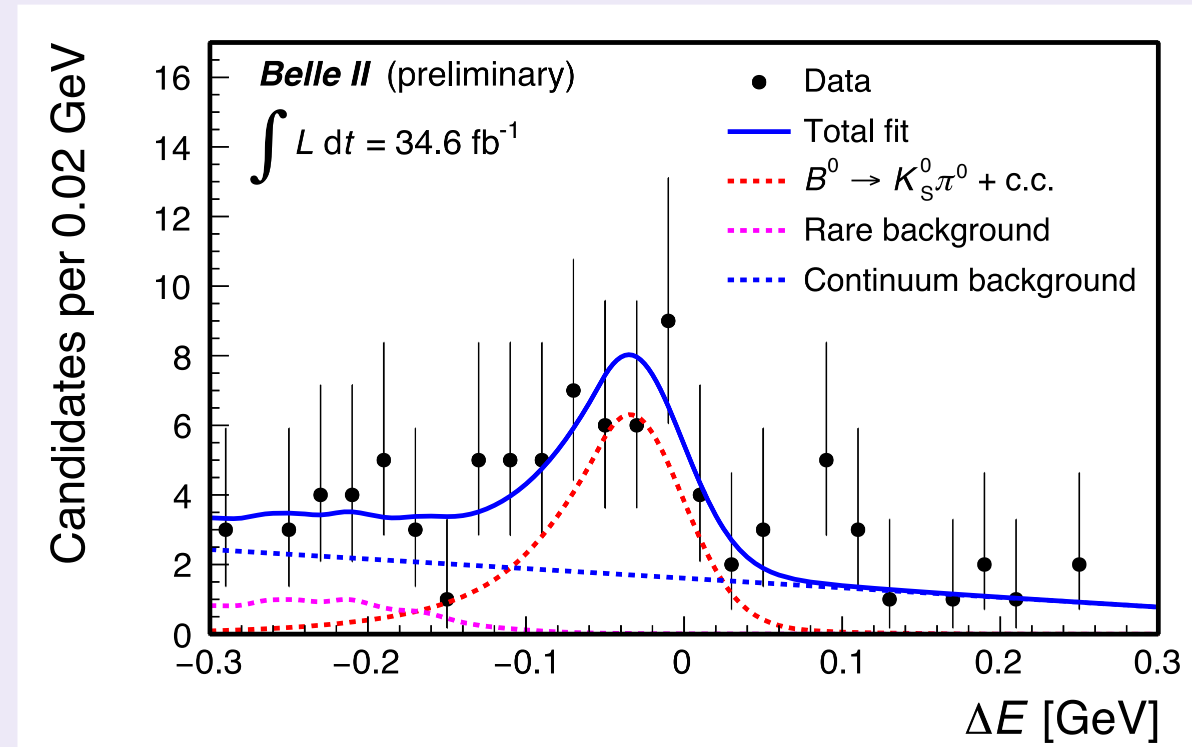
# Two-body: $B^+ \to K^0\pi^+, B^0 \to K^0\pi^0$

Benchmark performance of $K_S^0$ reconstruction.




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

| | |
|---|---|
| N$_{\mathrm{sig}}(B^+ \to K_S^0\pi^+)$ | $65^{+10}_{-9}$ |
| $\mathscr{B}$ [10$^{-6}$] | $21.8^{+3.3}_{-3.0}$(stat.) ± 2.9(syst.) |
| **PDG** | |
| $\mathscr{B}$ [10$^{-6}$] | 23.7 ± 0.8 |

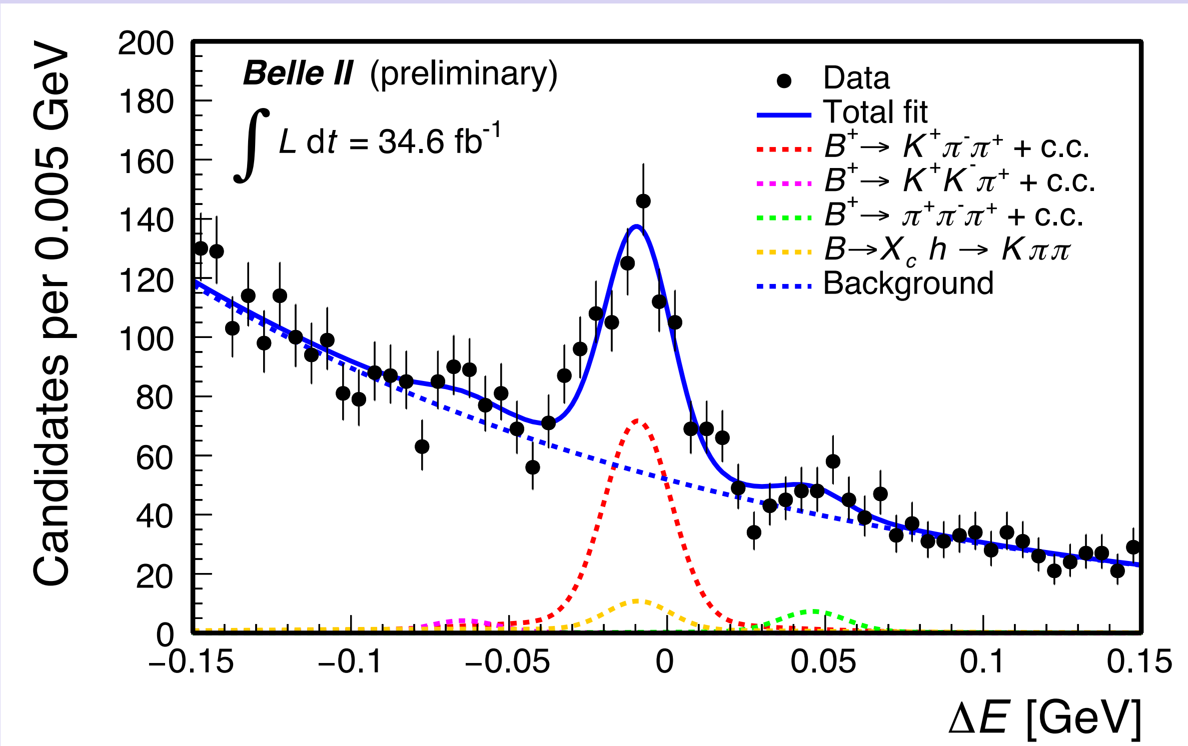



$B^0 \to K^0\pi^0$

| | |
|---|---|
| N$_{\mathrm{sig}}(B^0 \to K_S^0\pi^0)$ | 35 ± 9 |
| **First reconstruction in Belle II data!** | |
| $\mathscr{B}$ [10$^{-6}$] | $10.9^{+2.9}_{-2.6}$(stat.) ± 1.6(syst.) |
| **PDG** | |
| $\mathscr{B}$ [10$^{-6}$] | 9.9 ± 0.5 |

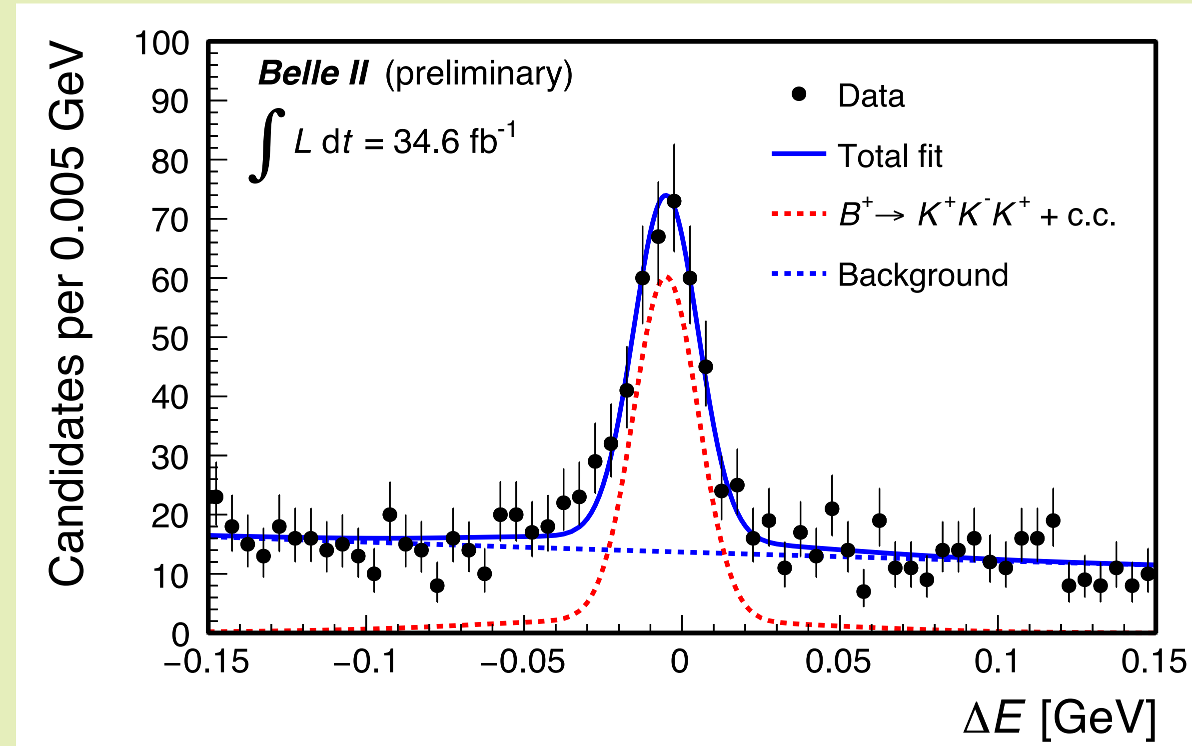
# Three-body: $B^+ \to K^+\pi^-\pi^+, B^+ \to K^+K^-K^+$

Rich Dalitz structure - multitude of peaking backgrounds.




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

| | |
|---|---|
| $N_{sig}$ | 449 ± 37 |
| $\mathscr{B}$ [$10^{-6}$] | 48.0 ± 3.8(stat.) ± 3.3(syst.) |
| **PDG** | |
| $\mathscr{B}$ [$10^{-6}$] | 51.0 ± 2.9 |




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

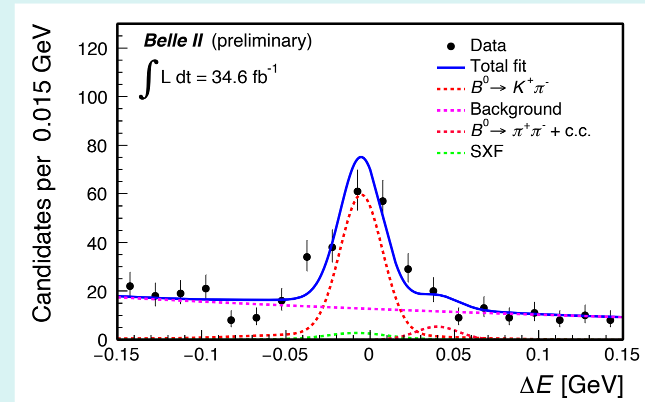
| | |
|---|---|
| $N_{sig}$ | 359 ± 25 |
| $\mathscr{B}$ [$10^{-6}$] | 32.0 ± 2.2(stat.) ± 1.4(syst.) |
| **PDG** | |
| $\mathscr{B}$ [$10^{-6}$] | 34.0 ± 1.4 |

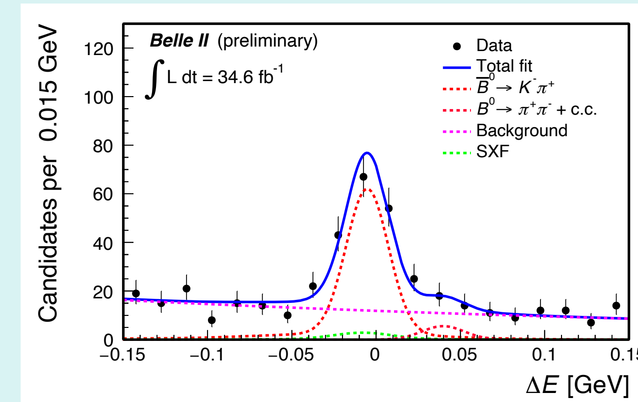
# CP asymmetries in two-body decays

## $B^0 \to K^+\pi^-$

$A_{CP} = 0.030 \pm 0.064(\text{stat.}) \pm 0.008(\text{syst.})$

PDG: $A_{CP} = -0.083 \pm 0.004$

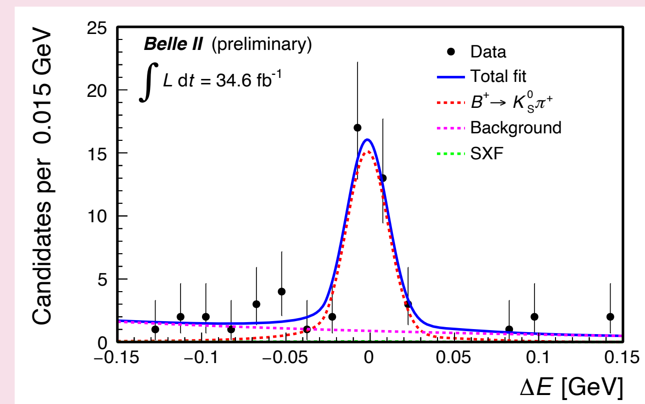


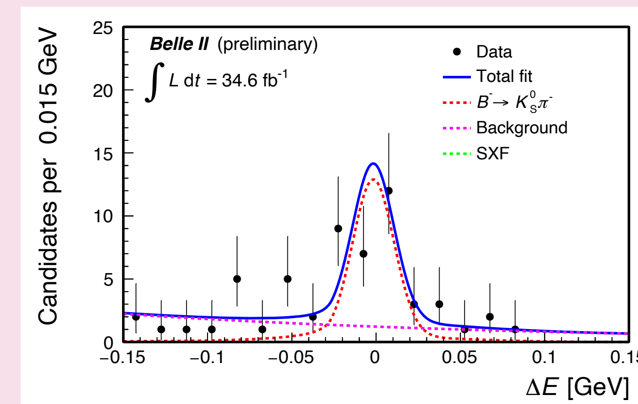




## $B^+ \to K^0_S\pi^+$

$A_{CP} = -0.072^{+0.109}_{-0.114}(\text{stat.}) \pm 0.024(\text{syst.})$

PDG: $A_{CP} = -0.017 \pm 0.016$

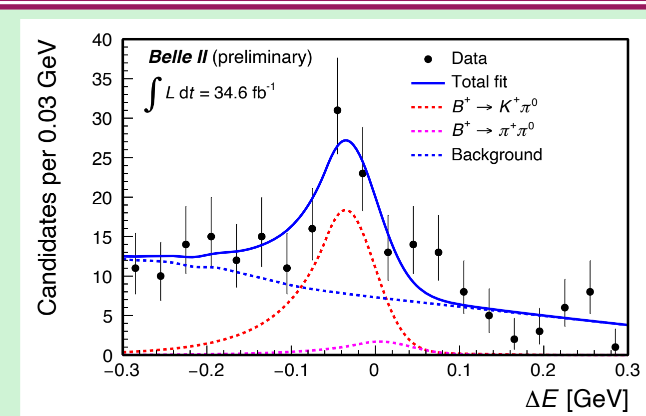


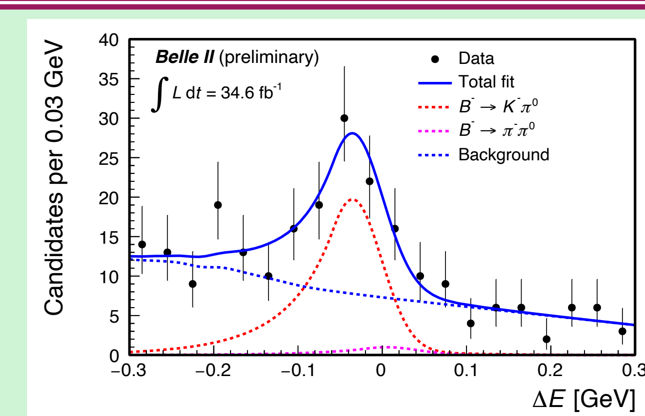




## $B^+ \to K^+\pi^0$

$A_{CP} = 0.052^{+0.121}_{-0.119}(\text{stat.}) \pm 0.022(\text{syst.})$

PDG: $A_{CP} = 0.037 \pm 0.021$

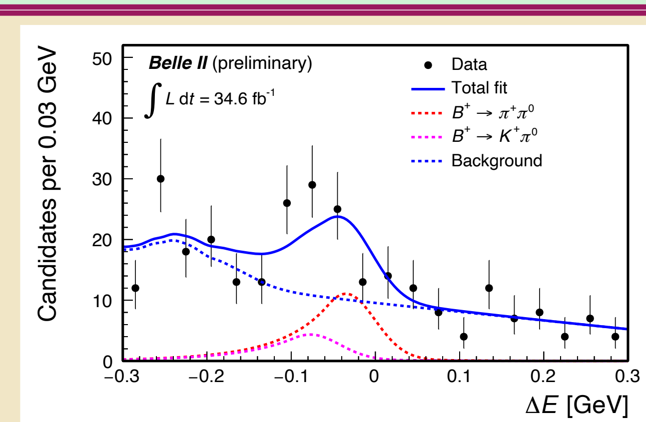


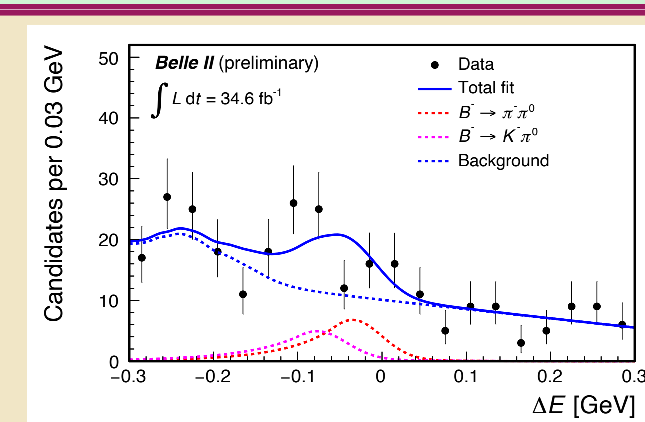




## $B^+ \to \pi^+\pi^0$

$A_{CP} = -0.268^{+0.249}_{-0.322}(\text{stat.}) \pm 0.123(\text{syst.})$

PDG: $A_{CP} = 0.03 \pm 0.04$



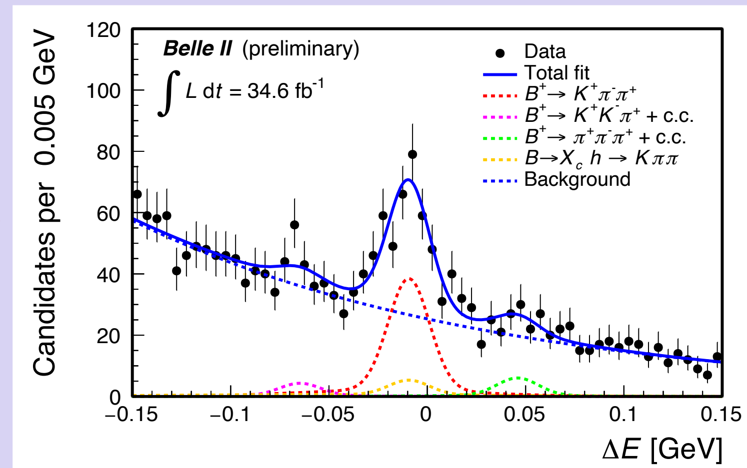



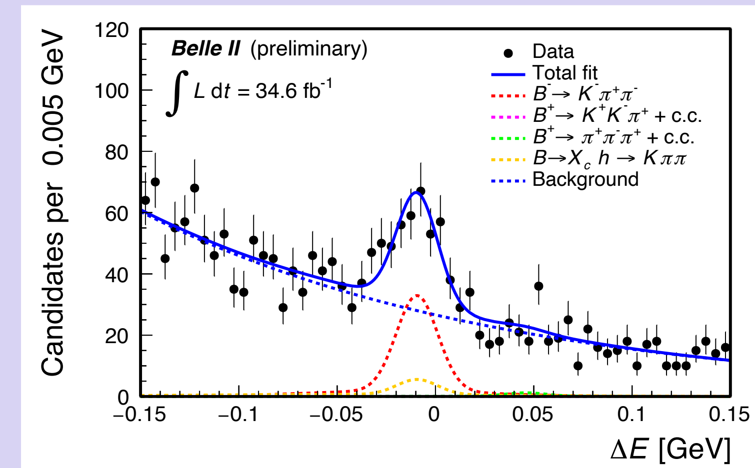
# CP asymmetries in three-body decays

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

$A_{CP} = -0.063 \pm 0.081(\text{stat.}) \pm 0.023(\text{syst.})$

PDG: $A_{CP} = 0.027 \pm 0.008$

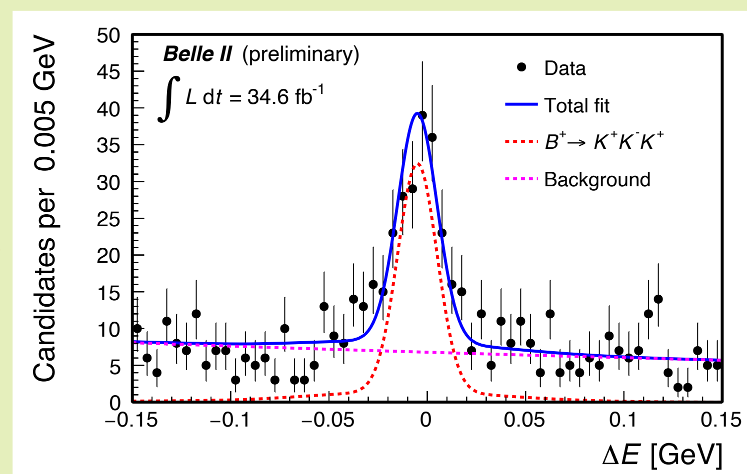


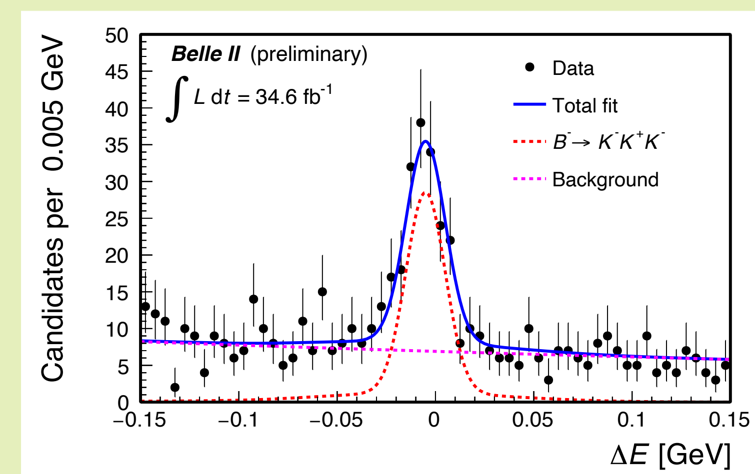




$$B^+ \to K^+K^-K^+$$

$A_{CP} = -0.049 \pm 0.063(\text{stat.}) \pm 0.022(\text{syst.})$

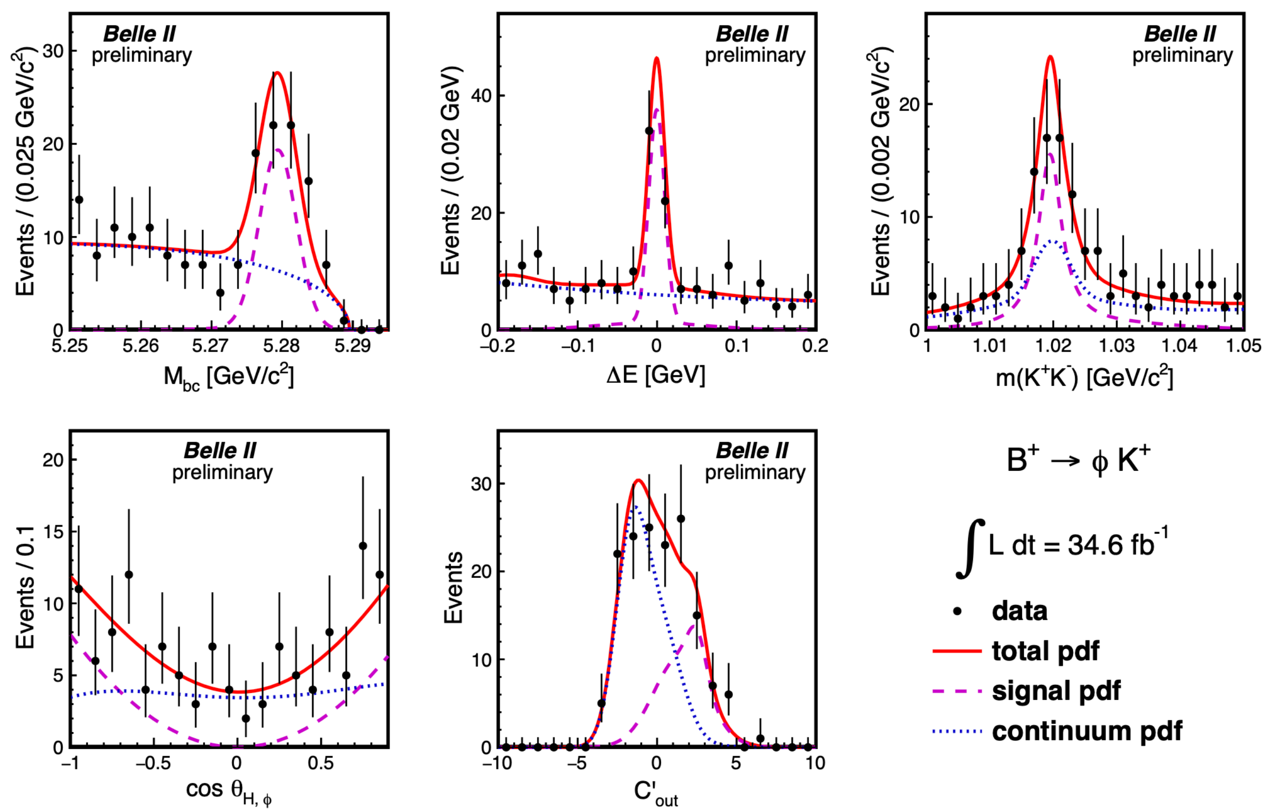
PDG: $A_{CP} = -0.033 \pm 0.008$



# $B \to VP$: $B^+ \to \phi K^+$, $B^0 \to \phi K^0$

Require advanced analysis techniques.




## $B^+ \to \phi K^+$

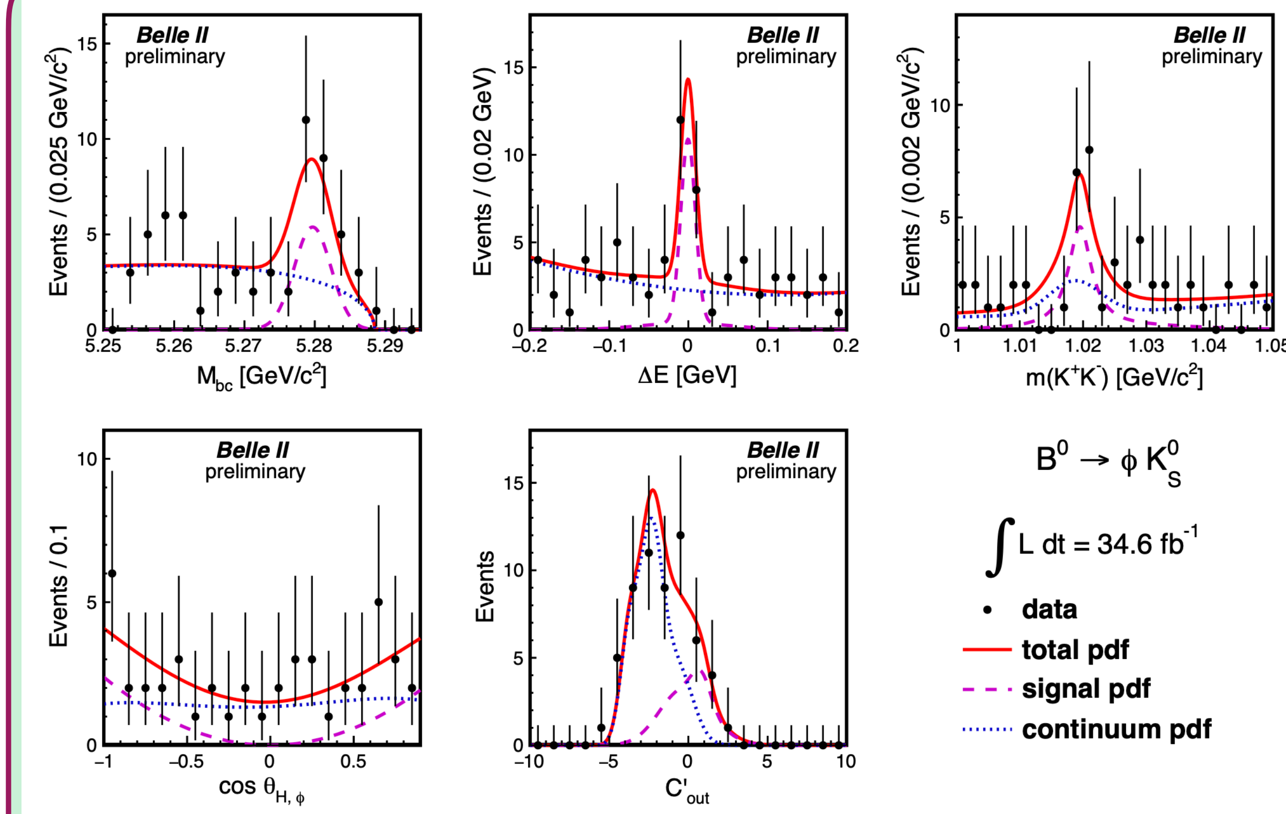
| | |
|---|---|
| $N_{sig}(B^+ \to \phi K^+)$ | $55 \pm 9$ |

**First reconstruction in Belle II data!**

| | |
|---|---|
| $\mathcal{B}$ [$10^{-6}$] | $6.7 \pm 1.1(\text{stat.}) \pm 0.5(\text{syst.})$ |

**PDG**

| | |
|---|---|
| $\mathcal{B}$ [$10^{-6}$] | $8.8^{+0.7}_{-0.6}$ |




## $B^0 \to \phi K^0$

| | |
|---|---|
| $N_{sig}(B^0 \to \phi K^0_S)$ | $16 \pm 5$ |

**First reconstruction in Belle II data!**

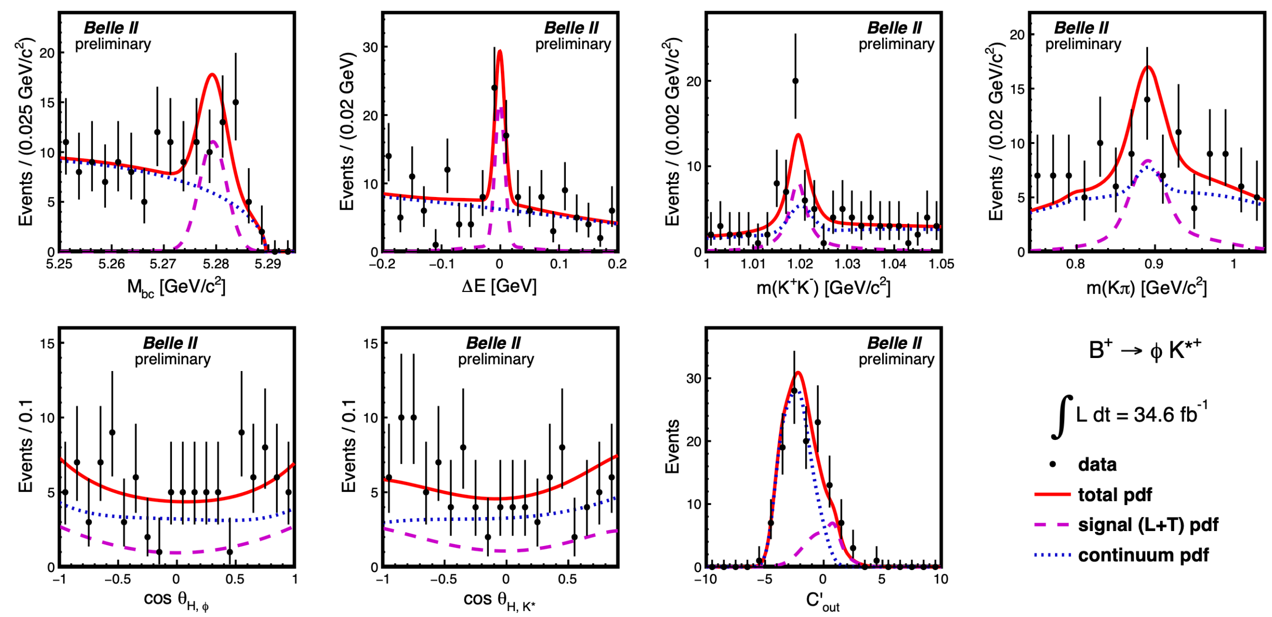
| | |
|---|---|
| $\mathcal{B}$ [$10^{-6}$] | $5.9 \pm 1.8(\text{stat.}) \pm 0.7(\text{syst.})$ |

**PDG**

| | |
|---|---|
| $\mathcal{B}$ [$10^{-6}$] | $7.3 \pm 0.7$ |

# $B \to VV$: $B^+ \to \phi K^{*+}$, $B^0 \to \phi K^{*0}$

Require full angular analysis.



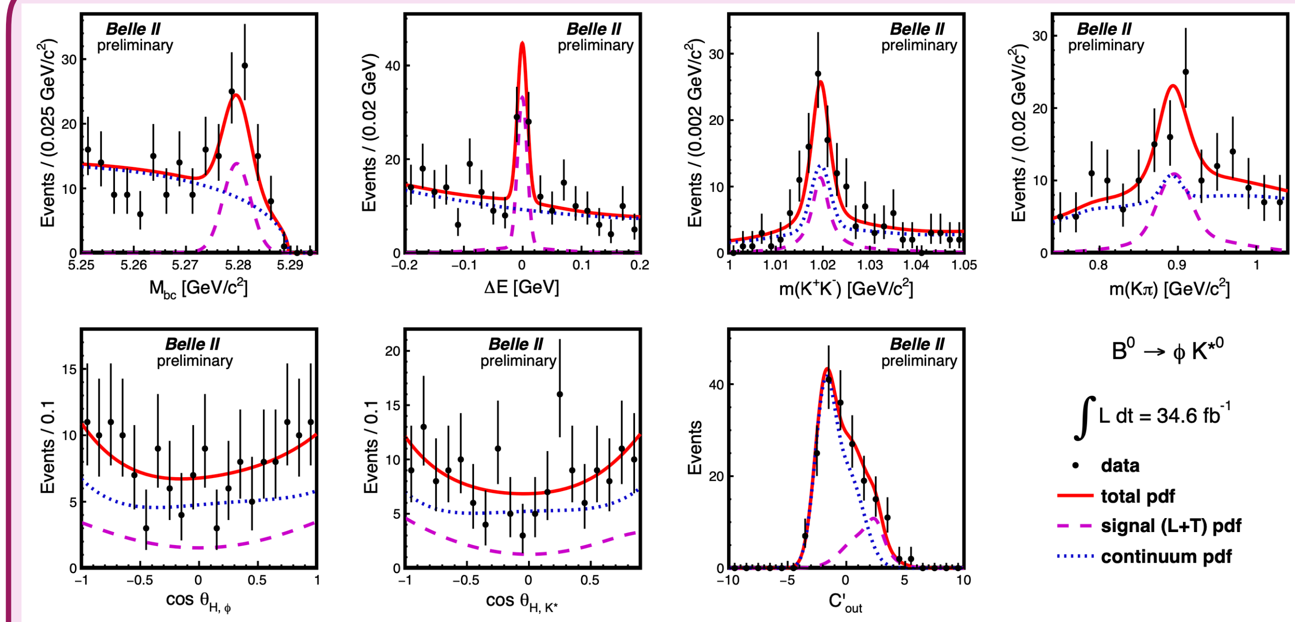

## $B^+ \to \phi K^{*+}$

| | |
|---|---|
| $N_{sig}$ | $33 \pm 8$ |
| $\mathscr{B}$ [$10^{-6}$] | $21.7 \pm 4.6$(stat.) $\pm 1.9$(syst.) |
| $f_L$ | $0.58 \pm 0.23$(stat.) $\pm 0.02$(syst.) |

**First reconstruction in Belle II data!**

**PDG**

| | |
|---|---|
| $\mathscr{B}$ [$10^{-6}$] | $10 \pm 2$ |
| $f_L$ | $0.50 \pm 0.05$ |




## $B^0 \to \phi K^{*0}$

| | |
|---|---|
| $N_{sig}$ | $48 \pm 10$ |
| $\mathscr{B}$ [$10^{-6}$] | $11.0 \pm 2.1$(stat.) $\pm 1.1$(syst.) |
| $f_L$ | $0.57 \pm 0.20$(stat.) $\pm 0.04$(syst.) |

**First reconstruction in Belle II data!**

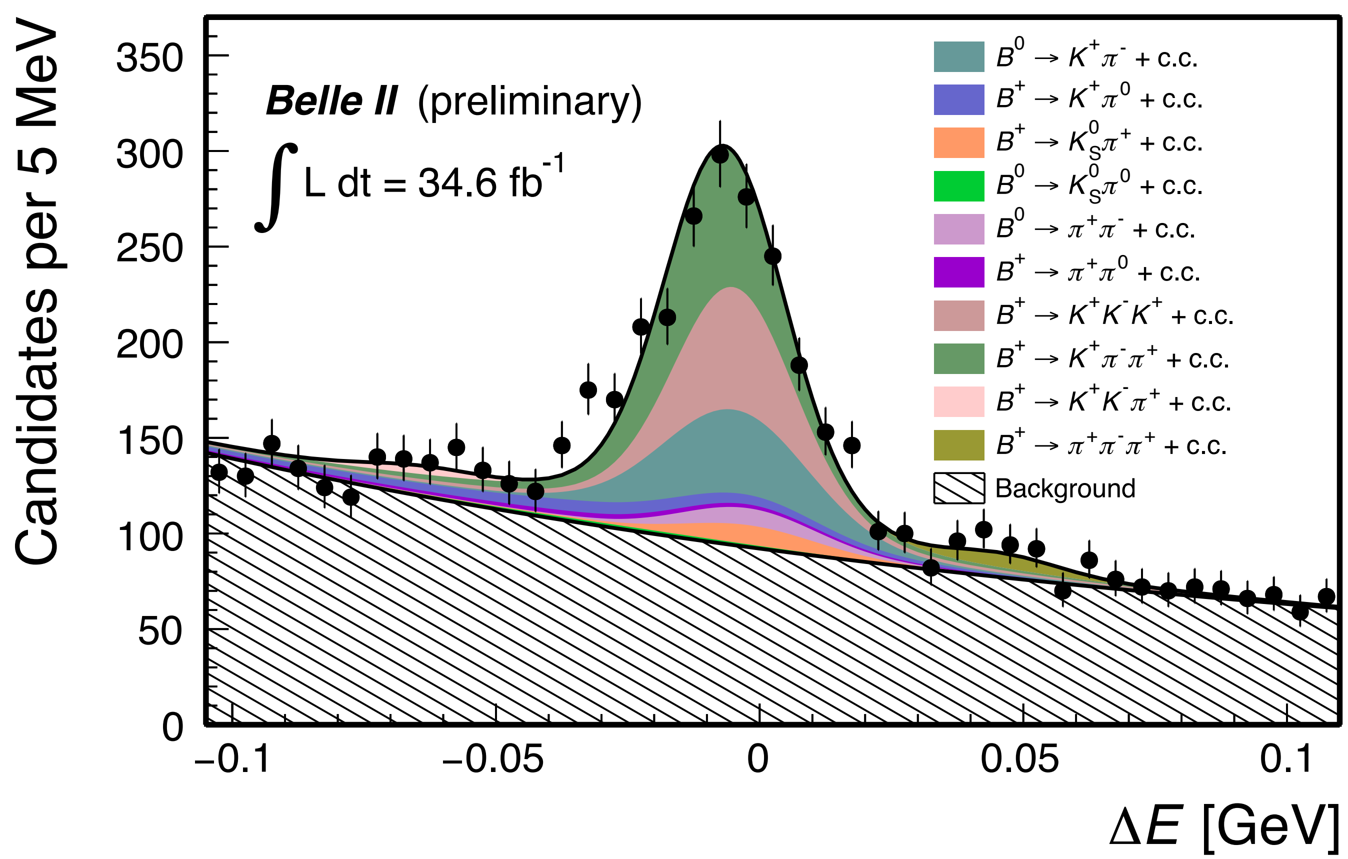
**PDG**

| | |
|---|---|
| $\mathscr{B}$ [$10^{-6}$] | $10.0 \pm 0.5$ |
| $f_L$ | $0.497 \pm 0.017$ |

# Summary

- First measurements of branching fraction and CP-asymmetries of charmless $B$ decays with 35 fb$^{-1}$ of $\Upsilon$(4S) data.

- Results are in good agreement with known values, and performance is comparable with Belle's best. It proves good understanding of detector and tools.




Belle II is on track to lead searches of non-SM indications in quark dynamics.

# Belle II hot charmless summer

$$\mathcal{B}(B^0 \to K^+\pi^-) = [18.9 \pm 1.4(\text{stat}) \pm 1.0(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^+\pi^0) = [12.7^{+2.2}_{-2.1}(\text{stat}) \pm 1.1(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^0\pi^+) = [21.8^{+3.3}_{-3.0}(\text{stat}) \pm 2.9(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^0 \to K^0\pi^0) = [10.9^{+2.9}_{-2.6}(\text{stat}) \pm 1.6(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^0 \to \pi^+\pi^-) = [5.6^{+1.0}_{-0.9}(\text{stat}) \pm 0.3(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to \pi^+\pi^0) = [5.7 \pm 2.3(\text{stat}) \pm 0.5(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^+K^-K^+) = [32.0 \pm 2.2(\text{stat.}) \pm 1.4(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^+\pi^-\pi^+) = [48.0 \pm 3.8(\text{stat}) \pm 3.3(\text{syst})] \times 10^{-6},$$

$$\mathcal{A}(B^0 \to K^+\pi^-) = 0.030^{+0.064}_{-0.064}(\text{stat}) \pm 0.008(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^+\pi^0) = 0.052^{+0.121}_{-0.119}(\text{stat}) \pm 0.022(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^0_S\pi^+) = -0.072^{+0.109}_{-0.114}(\text{stat}) \pm 0.024(\text{syst}),$$

$$\mathcal{A}(B^+ \to \pi^+\pi^0) = -0.268^{+0.249}_{-0.322}(\text{stat}) \pm 0.123(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^+K^-K^+) = -0.049 \pm 0.063(\text{stat}) \pm 0.022(\text{syst}), \text{ and}$$

$$\mathcal{A}(B^+ \to K^+\pi^-\pi^+) = -0.063 \pm 0.081(\text{stat}) \pm 0.023(\text{syst}).$$

| $\mathcal{B}(\times 10^{-6})$ | |
|---|---|
| $\phi K^+$ | $6.7 \pm 1.1 \pm 0.5$ |
| $\phi K^0$ | $5.9 \pm 1.8 \pm 0.7$ |
| $I_{\phi K}$ | $1.1 \pm 0.4 \pm 0.2$ |
| $\phi K^{*+}$ | $21.7 \pm 4.6 \pm 1.9$ |
| $\phi K^{*0}$ | $11.0 \pm 2.1 \pm 1.1$ |
| $I_{\phi K^*}$ | $2.0 \pm 0.6 \pm 0.3$ |
| $f_L$ | |
| $\phi K^{*+}$ | $0.58 \pm 0.23 \pm 0.02$ |
| $\phi K^{*0}$ | $0.57 \pm 0.20 \pm 0.04$ |

# Backup

# Systematic uncertainties

| 1. Tracking efficiency | 2. $K_S^0$ reco. efficiency | 3. $\pi^0$ reco. efficiency |
|---|---|---|
| A lower tracking efficiency in data wrt. MC.<br><br>For each final-state track $0.91\,\%$ | A small decrease in $K_S^0$ reconstruction efficiency.<br>$1\,\%$ for each cm of flight length.<br><br>$\sim 12\,\%$ | Data/MC discrepancy.<br><br>$\sim 6\,\%$ |
| **4. PID and CS efficiencies** | **5. Number of $B\bar{B}$ pairs** | **6. Signal modelling** |
| Data/MC discrepancy.<br>Selection-depending.<br><br>$\sim 2-4\,\%$ | Uncertainty on cross-section, integrated luminosity, potential beam energy shift.<br><br>$\sim 2.7\,\%$ | Data/MC discrepancy for CDC hits distribution.<br>Signal model choice.<br><br>$\sim 2\,\%$ |
| **7. Background modelling** | **8. Peaking and $B\bar{B}$ bkg bias** | **9. Instrumental asymmetries** |
| Background model choice.<br><br>$\sim 3\,\%$ | Modeling of peaking and $B\bar{B}$ bkg.<br><br>$\sim 0.3\,\%$ | $\mathscr{A}_{\text{det}}(K^+\pi^-) = -0.010 \pm 0.003$<br>$\mathscr{A}_{\text{det}}(K^+) = -0.015 \pm 0.022$<br>The uncertainty on the $\mathscr{A}_{\text{det}}$ is considered as systematic. |

# Systematic uncertainties

| Source | $B^+ \to \phi K^+$ | $B^+ \to \phi K^{*+}$ | $B^0 \to \phi K_S^0$ | $B^0 \to \phi K^{*0}$ |
|---|---|---|---|---|
| Tracking efficiency (M) | 2.7 | 4.6 | 3.6 | 3.6 |
| $K_S^0$ reconstruction efficiency (M) | – | 6.3 | 10.8 | – |
| Kaon ID efficiency (M) | 6.4 | 1.1 | 1.0 | 4.7 |
| Number of $B\overline{B}$ events (M) | 2.7 | 2.7 | 2.7 | 2.7 |
| Modeling of $C_{\mathrm{out}'}$ (A) | 1.3 | 1.2 | 1.0 | 5.9 |
| $B\overline{B}$ background yield (A) | 0.3 | 1.2 | 1.4 | 2.3 |
| Nonresonant yield (A) | 3.1 | 1.8 | 4.5 | 3.2 |
| SXF fraction (A) | – | 0.6 | – | 1.0 |
| Total multiplicative | 7.5 | 8.3 | 11.7 | 6.5 |
| Total additive | 3.4 | 2.5 | 4.8 | 7.1 |
| Total | 8.2 | 8.7 | 12.7 | 9.7 |

Table 4: Summary of the systematic uncertainties (expressed in absolute values) affecting the measurement of $f_L$ in the $B \to \phi K^*$ modes.

| Source | $B^+ \to \phi K^{*+}$ | $B^0 \to \phi K^{*0}$ |
|---|---|---|
| Acceptance function | 0.014 | 0.007 |
| Modeling of $C_{\mathrm{out}'}$ | 0.001 | 0.035 |
| $B\overline{B}$ background yield | 0.002 | 0.009 |
| Nonresonant yield | 0.006 | 0.008 |
| SXF fraction | 0.001 | 0.003 |
| Total | 0.015 | 0.038 |

# Systematic uncertainties

TABLE IV. Summary of the (fractional) systematic uncertainties of the branching-fraction measurements.

| Source | $K^+\pi^-$ | $K^+\pi^0$ | $K^0_S\pi^+$ | $K^0\pi^0$ | $\pi^+\pi^-$ | $\pi^+\pi^0$ | $K^+K^-K^+$ | $K^+\pi^-\pi^+$ |
|---|---|---|---|---|---|---|---|---|
| Tracking | 1.8% | 0.9% | 2.7% | 1.8% | 1.8% | 0.9% | 2.7% | 2.7% |
| $K^0_S$ efficiency | - | - | 12.5% | 11.6% | - | - | - | - |
| $\pi^0$ efficiency | - | 6.5% | - | 6.5% | - | 6.5% | - | - |
| PID and continuum-supp. eff. | 1.1% | 2.6% | 0.9% | 1.4% | 1.3% | 2.7% | 2.3% | 1.0% |
| $N_{B\bar{B}}$ | 2.7 % | 2.7% | 2.7% | 2.7% | 2.7% | 2.7% | 2.7% | 2.7% |
| Signal model | 1.1% | 2.3% | $< 0.1\%$ | $< 0.1\%$ | 4.5% | 0.5% | 0.6% | 3.5% |
| Continuum bkg. model | 4.2% | 3.1% | 1.5% | 4.8% | $< 0.1\%$ | 3.6% | 0.3% | 5.0% |
| $B\overline{B}$ bkg. model | 0.4% | $< 0.1\%$ | - | - | 1.6% | 0.4% | - | 0.2% |
| Total | 5.5% | 8.5% | 13.2% | 14.6% | 5.9% | 8.4% | 4.4% | 7.2% |

TABLE V. Summary of (absolute) systematic uncertainties in the $\mathcal{A}_{CP}$ measurements.

| Source | $K^+\pi^-$ | $K^+\pi^0$ | $K^0_S\pi^+$ | $\pi^+\pi^0$ | $K^+K^-K^+$ | $K^+\pi^-\pi^+$ |
|---|---|---|---|---|---|---|
| Signal model | 0.005 | 0.001 | 0.007 | 0.005 | 0.001 | 0.003 |
| Pkg./$B\overline{B}$/s×f background model | 0.005 | - | 0.006 | 0.120 | - | 0.004 |
| Instrumental asymmetry corrections | 0.003 | 0.022 | 0.022 | - | 0.022 | 0.022 |
| Total | 0.008 | 0.022 | 0.024 | 0.121 | 0.022 | 0.023 |

# Highlights of Belle II charmless program

PTEP 2019, 123C01 (654 pages)
DOI: 10.1093/ptep/ptz106

**The Belle II Physics Book**

| Process | Observable | Theory | Sys. dom. (Discovery) [$\mathrm{ab}^{-1}$] | vs LHCb | vs Belle | Anomaly | NP |
|---|---|---|---|---|---|---|---|
| $B \to \pi^0 K^0$ | $A_{\mathrm{CP}}, I_{K\pi}$ | $\star\star$ | $>50$ | $\star\star\star$ | $\star\star\star$ | $\star\star\star$ | $\star\star$ |
| $B \to \rho K$ | $A_{\mathrm{CP}}, I_{K\rho}$ | $\star$ | $>50$ | $\star\star$ | $\star\star\star$ | - | $\star\star$ |
| $B \to \rho K^*$ | $f_L$ | $\star\star$ | $>50$ | $\star\star$ | $\star\star$ | - | $\star\star\star$ |
| $B \to K^+K^-/\pi^+\pi^-$ | $Br., A_{CP}$ | $\star\star$ | $>50$ | $\star$ | $\star\star\star$ | $\star\star$ | $\star\star$ |
| $B \to K\pi\pi, KKK$ | $A_{CP}$ | $\star\star$ | $>50$ | $\star\star$ | $\star$ | $\star\star\star$ | $\star$ |
| $B_s \to K^0\overline{K}^0$ | Lifetime | $\star$ | $>5$ | $\star\star$ | $\star\star\star$ | - | $\star\star$ |
| $B \to \rho^\pm\rho^0$ | $\phi_2$ | $\star\star\star$ | $>50$ | $\star$ | $\star\star\star$ | $\star$ | $\star$ |
| $B \to \pi^0\pi^0$ | $\phi_2$ | $\star\star$ | $>50$ | $\star\star\star$ | $\star\star\star$ | $\star\star$ | $\star\star$ |
| $B \to \pi^0 K_S^0$ | $S_{\mathrm{CP}}$ | $\star\star$ | $>50$ | $\star\star\star$ | $\star\star\star$ | $\star\star$ | $\star\star$ |

# Towards BSM using isospin

**A precise sum rule among four $B \to K\pi$ CP asymmetries** [1]

Michael Gronau August 2005

A sum rule relation is proposed for direct CP asymmetries in $B \to K\pi$ decays. Leading terms are identical in the isospin symmetry limit, while subleading terms are equal in the flavor SU(3) and heavy quark limits. The sum rule predicts $A_{\rm CP}(B^0 \to K^0\pi^0) = -0.17 \pm 0.06$ using current asymmetry measurements for the other three $B \to K\pi$ decays. A violation of the sum rule would be evidence for New Physics in $b \to s\bar{q}q$ transitions.

$$I_{K\pi} = A_{CP}^{K^+\pi^-} + A_{CP}^{K^0\pi^+} \frac{Br(K^0\pi^+)}{Br(K^+\pi^-)} \frac{\tau_{B^0}}{\tau_{B^+}} - 2A_{CP}^{K^+\pi^0} \frac{Br(K^+\pi^0)}{Br(K^+\pi^-)} \frac{\tau_{B^0}}{\tau_{B^+}} - 2A_{CP}^{K^0\pi^0} \frac{Br(K^0\pi^0)}{Br(K^+\pi^-)}$$