Study of charmless decay $B \to \eta' K$ at Belle II

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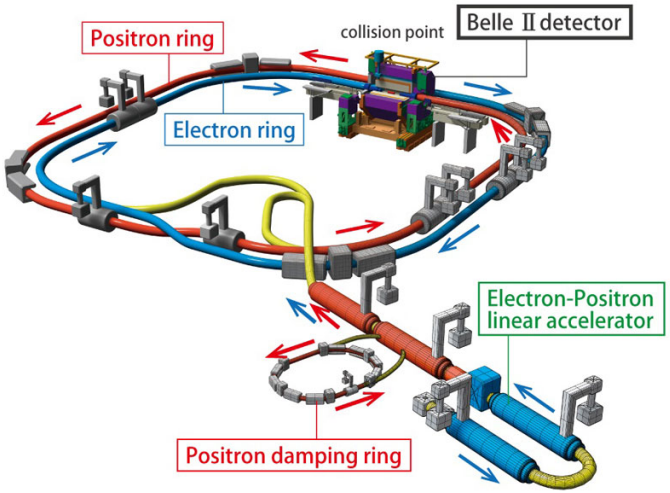
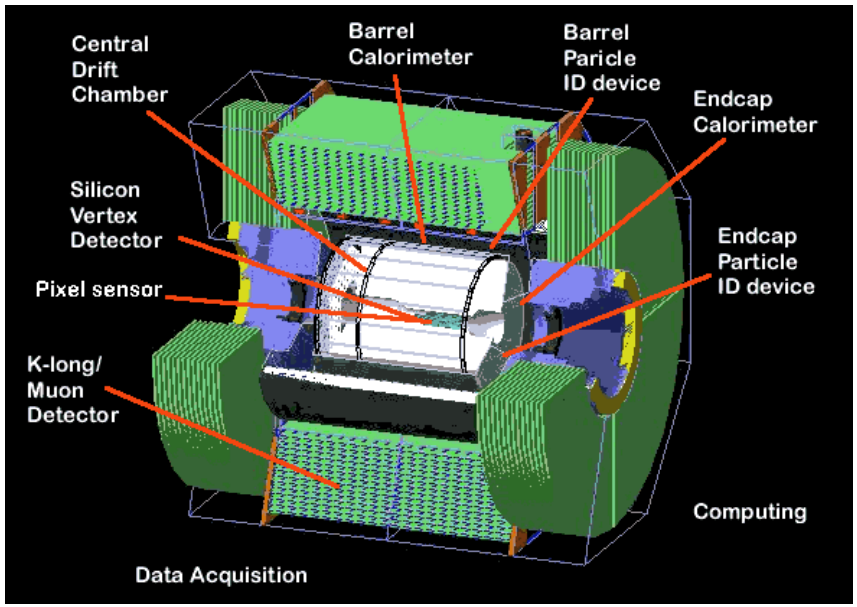


⟵ SuperKEKB:

e^+e^- Flavour Factory

Target luminosity $60 \times 10^{34}\ cm^{-2}\ s^{-1}$

(30 times higher than KEKB record)



Belle II Detector ⟶

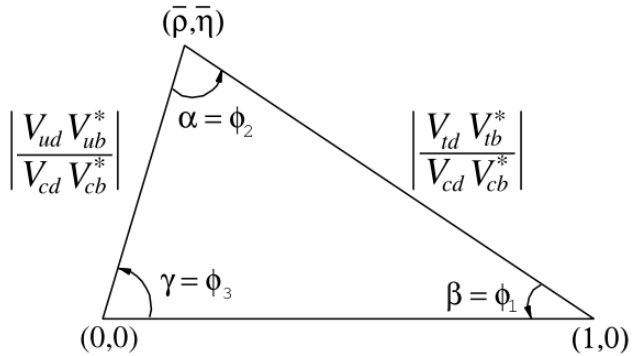
Designed to deal with higher background, higher event rates and reduced CM boost ($\beta\gamma = 0.28$)

Physics program:

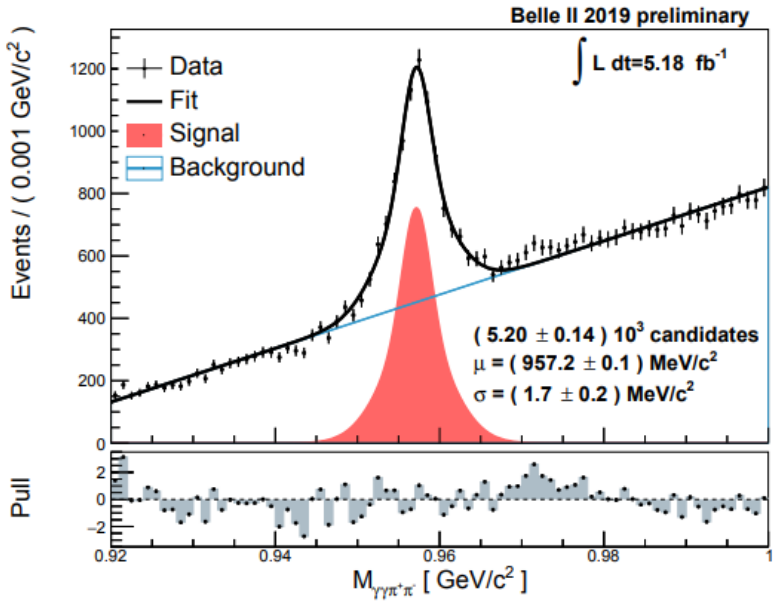
Main goal: search for New Physics in the flavour sector, precisely measuring unitarity triangle

$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} = \begin{bmatrix} 1-\frac{1}{2}\lambda & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{bmatrix}$$

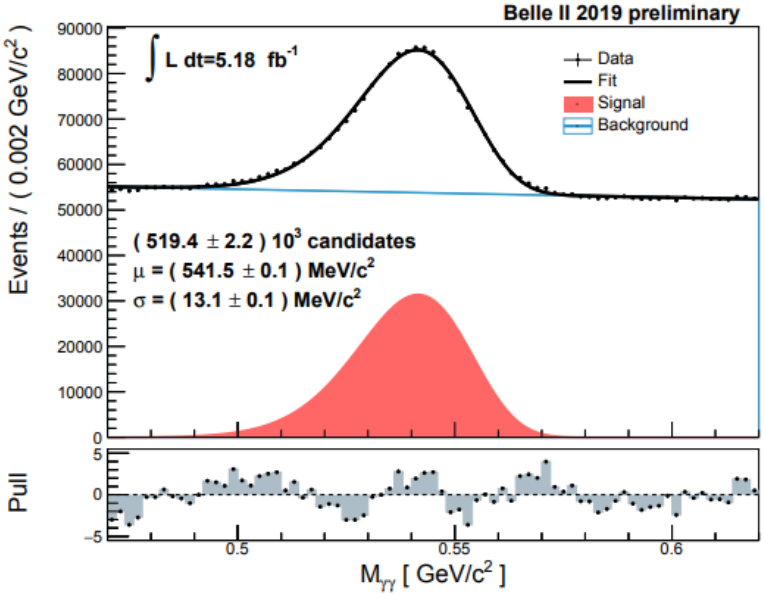
CP violating phase



$\eta' \to \eta(\gamma\gamma)\pi^+\pi^-$



$\eta \to \gamma\gamma$



Successful rediscovery of η and η' [1] in the channels:

- $\eta' \to \eta\pi^+\pi^-$ $(\eta \to \gamma\gamma)$
- $\eta' \to \eta\pi^+\pi^-$ $(\eta \to \pi^+\pi^-\pi^0)$
- $\eta' \to \rho(\pi^+\pi^-)\gamma$

Channel with $\eta \to \pi^+\pi^-\pi^0$ has a lower efficiency than
the one with $\eta \to \gamma\gamma$ $(\epsilon(3\pi/2\gamma) \sim 0.46)$ so it is not included in the following study.

Why $B \to \eta' K$?

- Successful rediscovery of η' and η
- Charmless B decays potentially sensitive to new CP-violating phases from physics beyond the SM

Decay channels and Branching Fractions

Mode	Decay channel	Branching fraction
$B^+ \to \eta' K^+$	inclusive	7.06×10^{-5}
	$\eta' \to \eta(\gamma\gamma)\pi^+\pi^-$	1.19×10^{-5}
	$\eta' \to \rho(\pi^+\pi^-)\gamma$	2.04×10^{-5}
	total	3.23×10^{-5}
$B^0 \to \eta' K$	inclusive	6.6×10^{-5}
	$\eta' \to \eta(\gamma\gamma)\pi^+\pi^-$	5.54×10^{-6}
	$\eta' \to \rho(\pi^+\pi^-)\gamma$	9.54×10^{-6}
	total	1.51×10^{-5}

Only the final state $K^0_s \to \pi^+\pi^-$ is considered for the neutral mode.

Analysis yet to be approved

Study performed on MC samples and data in the side bands (outside the signal region)

Dataset:

Data: $\int Ldt = 34.6$ fb^{-1}

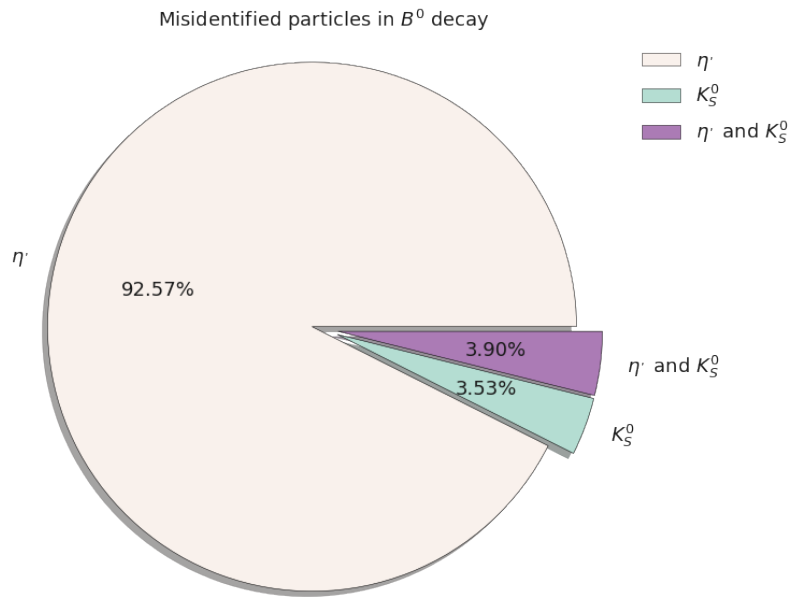
MC simulations:

- **Continuum background ($q\bar{q}$ pairs and τ pairs):** equivalent $\int Ldt = 0.5$ ab^{-1}
- **Peaking background ($B\bar{B}$):** equivalent $\int Ldt = 1$ ab^{-1}

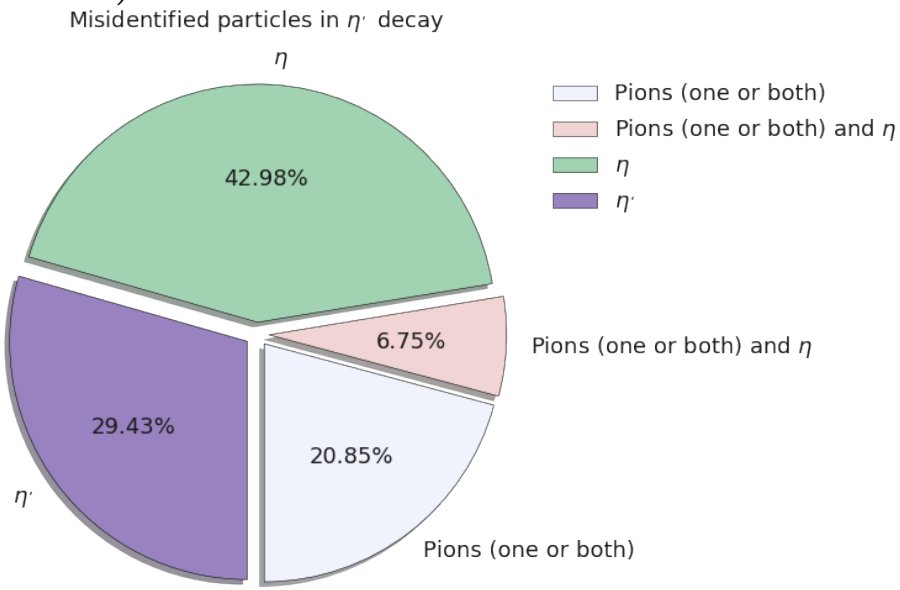
SxF (Signal cross feed):

SxF candidates are misreconstructed signal candidates.

Misreconstructed particles for $B^0 \to \eta'(\eta(\gamma\gamma)\pi^+\pi^-)K_s$:

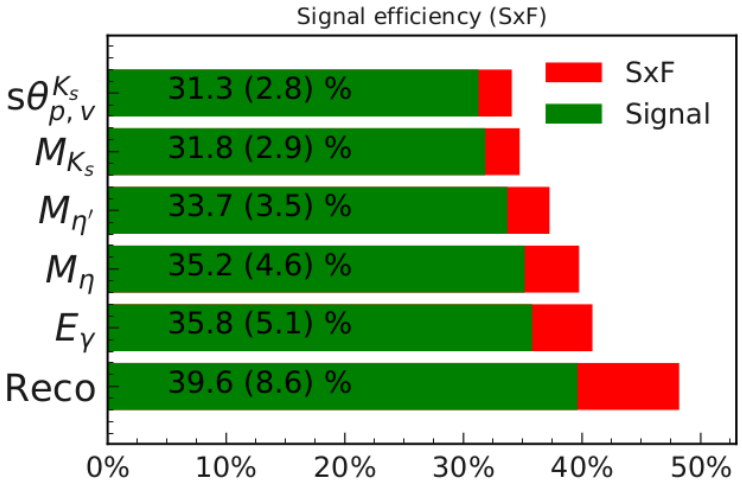


The incorrect reconstruction of B^0 is mainly due to η' reconstruction.



The incorrect reconstruction of the η' particle is mainly due to the η reconstruction ($\sim 50\%$), but also pions are frequently mistaken.

Reconstruction and selection efficiencies



SxF drops significantly after signal selection

$B^{\pm} \to \eta' K^{\pm}$ $\quad$ $B^0 \to \eta' K^0_s$

$\eta' \to \eta\pi^+\pi^-$

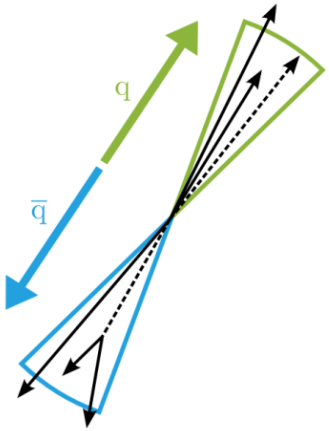
	$\epsilon\%$	SxF %	$\epsilon\%$	SxF %
Reconstruction	40.2 ± 0.11	7.1 ± 0.06	39.6 ± 0.11	8.6 ± 0.06
Selection	31.7 ± 0.10	2.4 ± 0.03	31.3 ± 0.10	2.8 ± 0.04

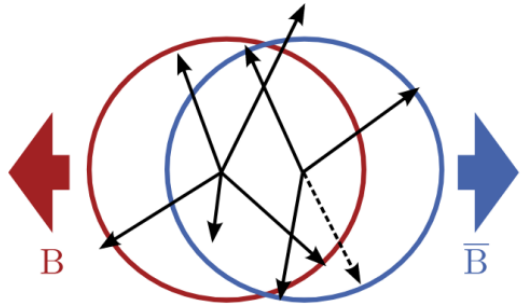
$B^{\pm} \to \eta' K^{\pm}$ $\quad$ $B^0 \to \eta' K^0_s$

$\eta' \to \rho\gamma$

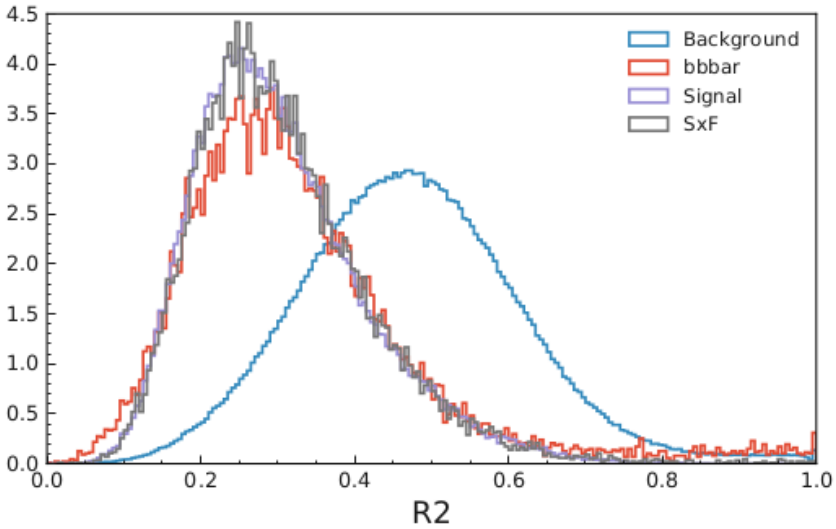
	$\epsilon\%$	SxF %	$\epsilon\%$	SxF %
Reconstruction	31.1 ± 0.10	9.8 ± 0.07	30.5 ± 0.10	11.2 ± 0.07
Selection	24.8 ± 0.10	1.7 ± 0.03	25.2 ± 0.10	2.7 ± 0.04

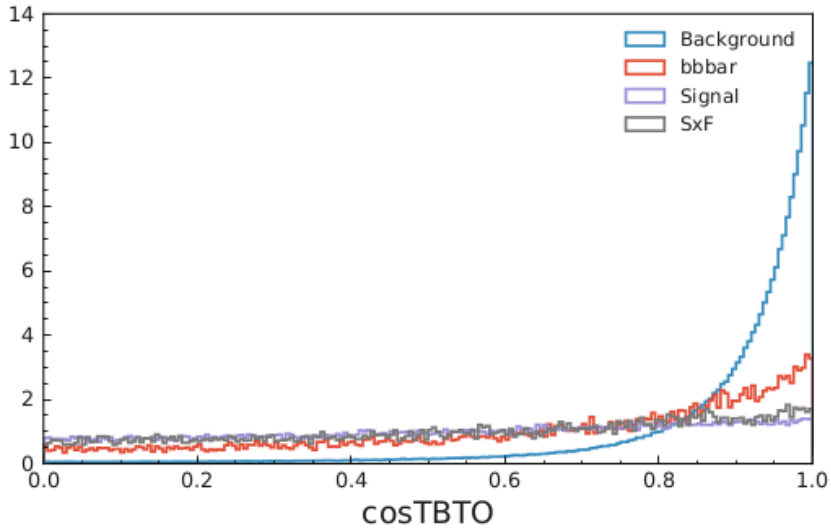
Continuum suppression





- Selection on highly discriminating variables that depend on event shape
- Continuum suppression efficiency for signal $\sim 60\%$.



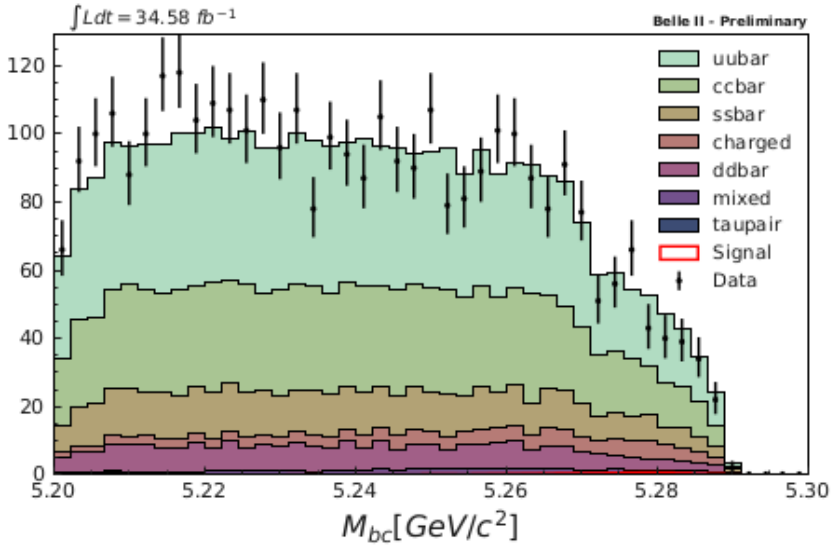


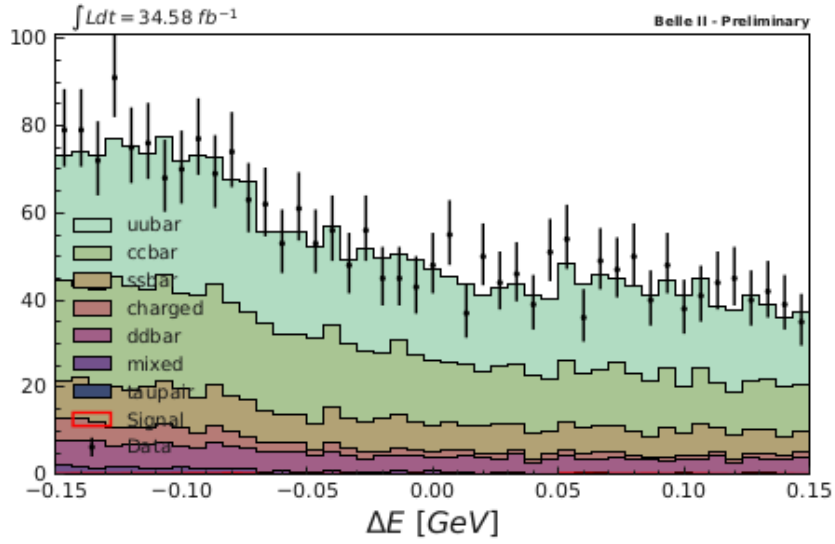
cosTBT0: cosine of angle between thrust axis of the signal B and thrust axis of Rest Of Event
R2: Reduced Fox-Wolfram moment

Fit variables:

- $M_{bc} = \sqrt{E^2_{beam} - P^2_B}$
- $\Delta E = E_B - E_{beam}$
- $M_{\eta'}$

Signal region (SR) and side band (SB)





SR: $M_{bc} > 5.27\ \mathrm{GeV/c^2}$ and $-0.07 < \Delta E < 0.05$ GeV

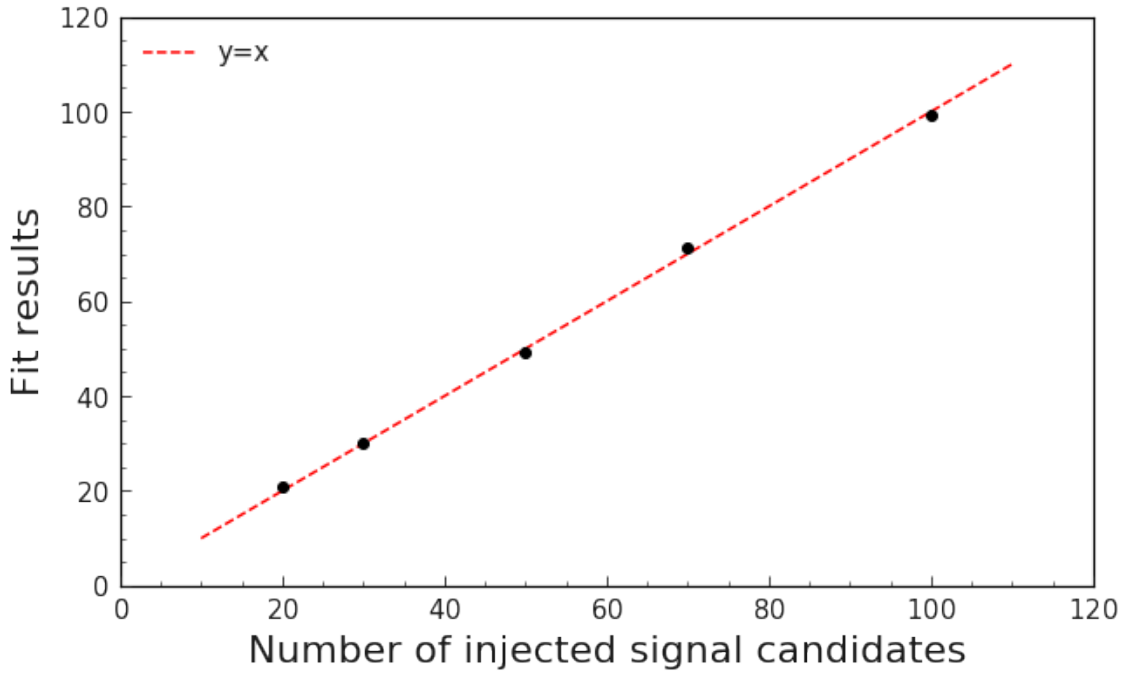
SB: complementary region up to $M_{bc} > 5.2\ \mathrm{GeV/c^2}$ and $|\Delta E| < 0.200$ GeV

Good agreement between MC and data outside the signal region

Fit procedure

Unbinned Maximum Likelihood fit of M_{bc}, ΔE and $M_{\eta'}$

Fit procedure tested with toy MC samples generated using pdfs for background and sampling signal from large signal dataset.



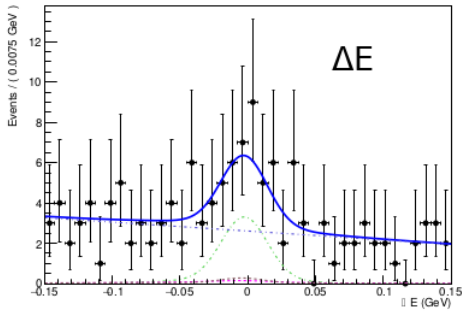
The fit is stable. No significant bias has been found.

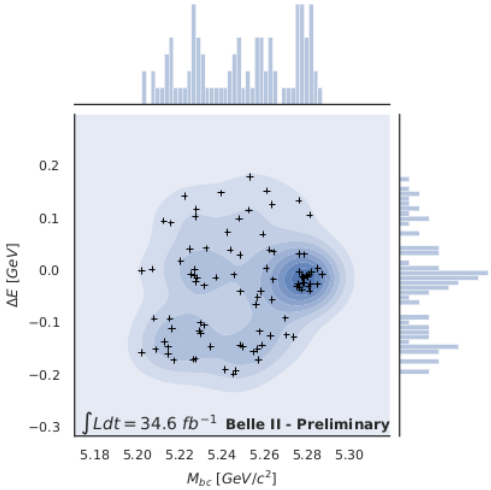
Fit results

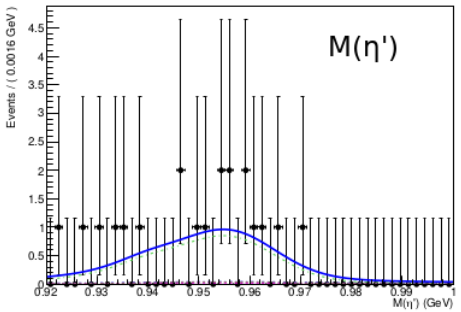
Results on simulated datasets built from MC using as input the expected number of events in each category (backgrounds,SxF, signal).

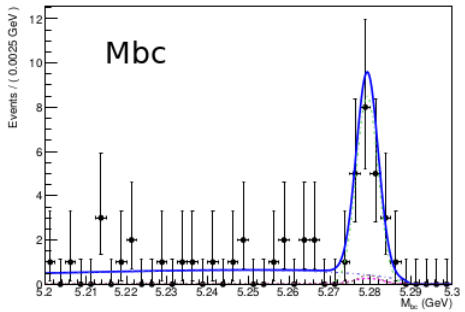
Signal enriched region for $M_{bc}, \Delta E, M_{\eta'}$, with a cut on likelihood ratio signal over background of 0.7.

The 2d plots of M_{bc} and ΔE are shown for all events









Conclusions and outlook

- Charmless B decays potentially sensitive to the presence of new CP-violating phases
- Promising analysis on charmless $B \to \eta' K$ decay
  - successful signal extraction on MC
  - good agreement between MC and data outside the signal region

Outlook:

- Signal extraction on Belle II data
- Extend to Time Dependent CP Violation measurement

Bibliography


Stefano Lacaprara, *Rediscovery of η and η' mesons in early phase 3 Belle II data*, BELLE2-NOTE-PL-2020-003