Belle II highlights on first B-physics results

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on behalf of Belle II

FPCP conference
June 8, 2020

1. B^0 lifetime
2. $B \to J/\psi K$
3. Charmless B-decays
4. η and η' mesons

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Flavor in the next decade

The SM: extremely successful but not the full story ...

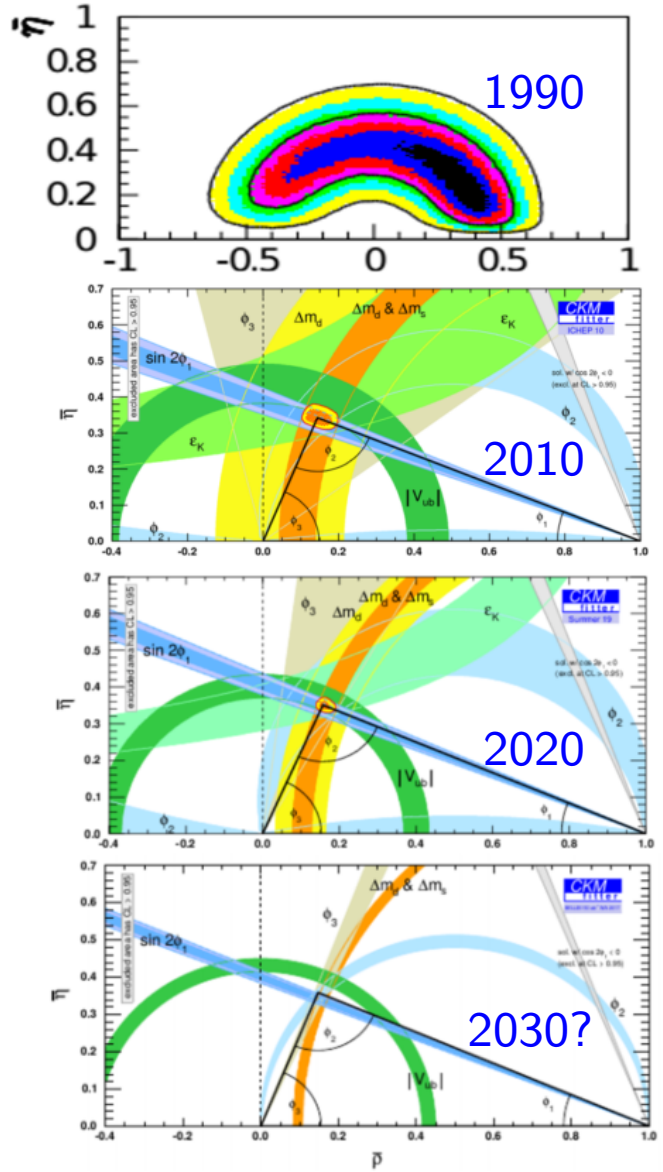
$\Rightarrow$ Flavor might bring us to the next page.

Some of the hot topics on the menu:

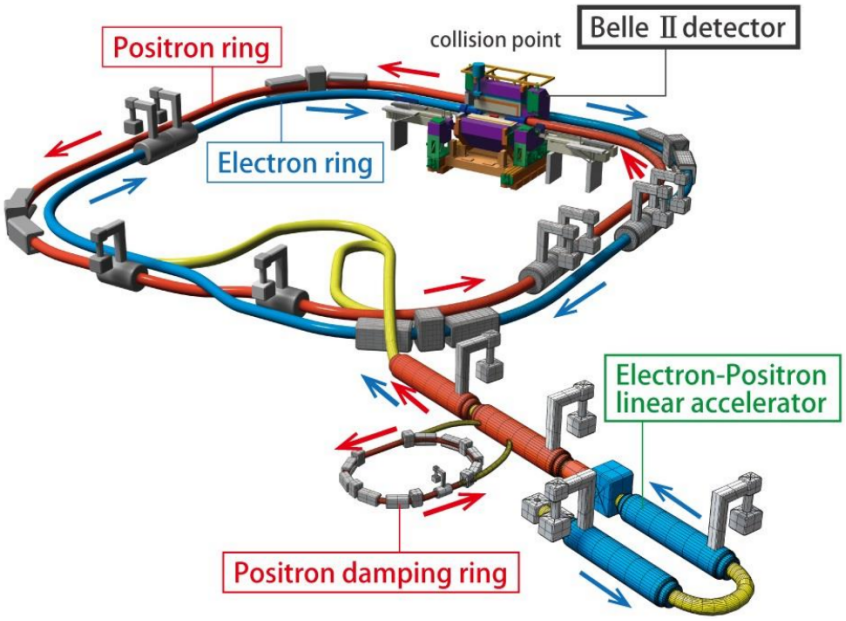
- CKM angles and coefficients — *M. Merola*
- Lepton flavor violation ($\tau \to \mu\gamma$, ...) — *M. Hernandez*
- Charm and charmonium ($X(3872)$, ...), — *R. Briere*
- New physics in penguins ($B \to K^* \nu\bar{\nu}$, ...) — *S. Halder*
- Full event reco. for $B \to X$+missing energy, — *S. Stefkova*

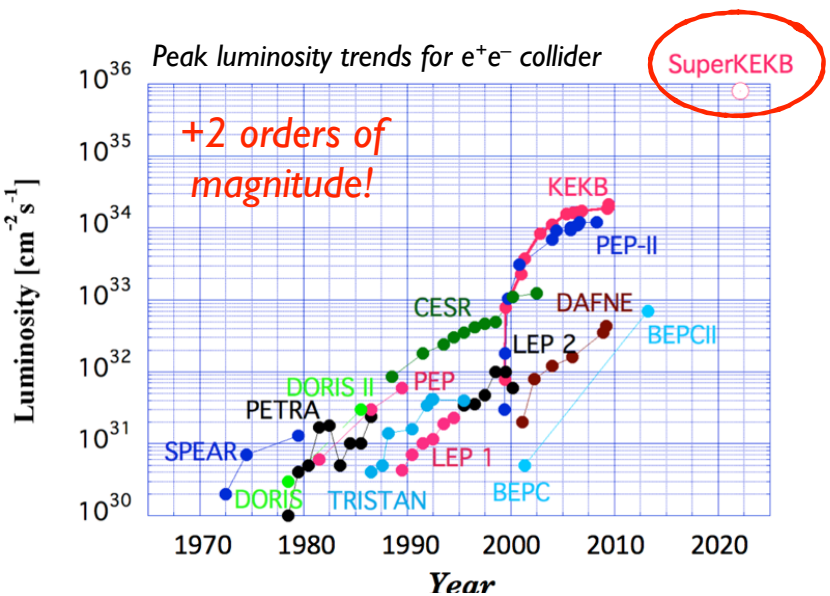
$\Rightarrow$ Belle II expected to lead where precise knowledge on initial state and low backgrounds are key.

Now: *B*-physics highlights of 2019 Belle II data.

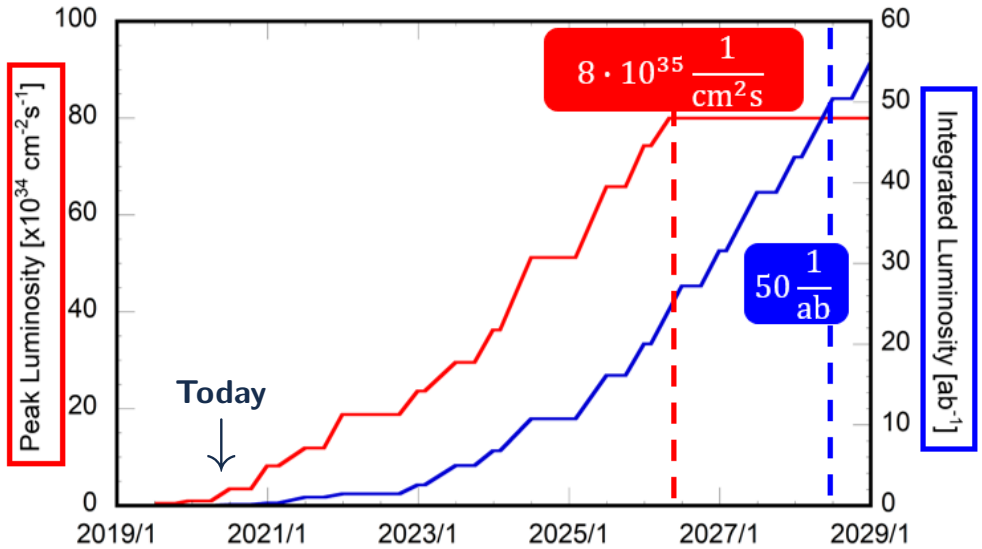


SuperKEKB





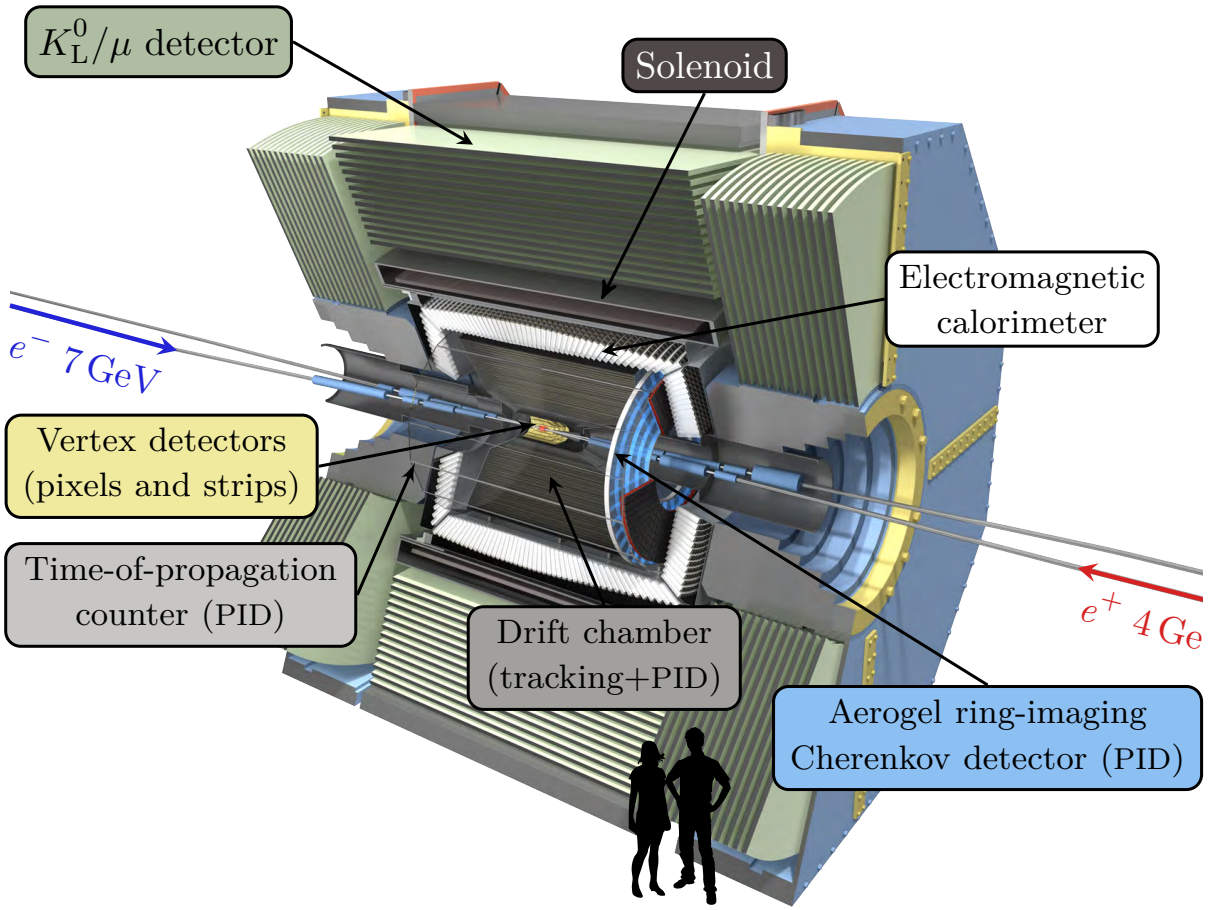
Goal: $2 \times \text{Current}, \ \frac{\text{Beamsize}}{20} \Rightarrow 40 \times \text{Lumi.}$

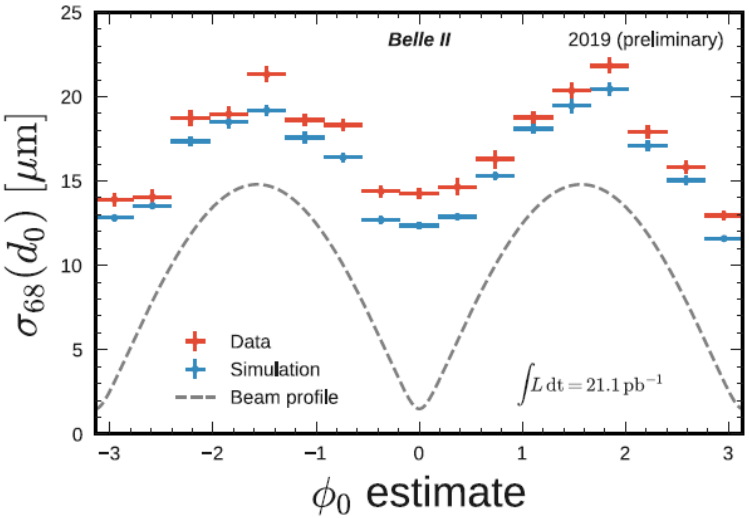


Today: $\mathcal{L} = 1.8 \cdot 10^{34} \ \frac{1}{\text{cm}^2\,\text{s}} \approx \text{KEKB Lumi.}$

$\Rightarrow$ with half of KEKB current.

Belle II



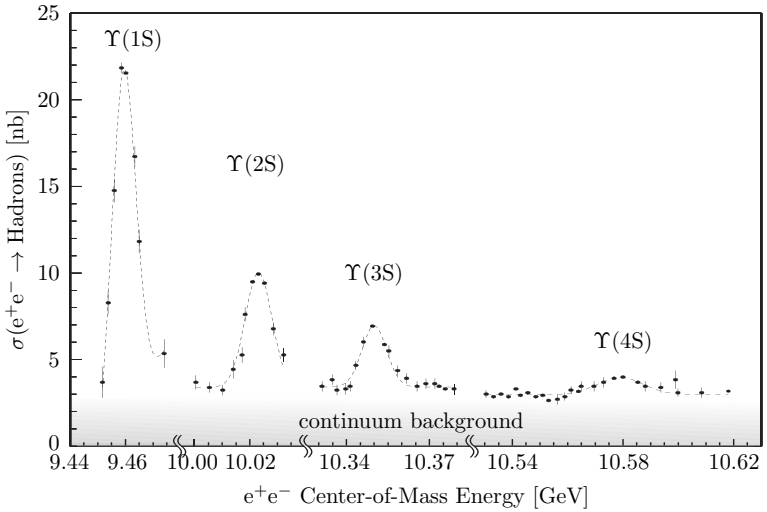


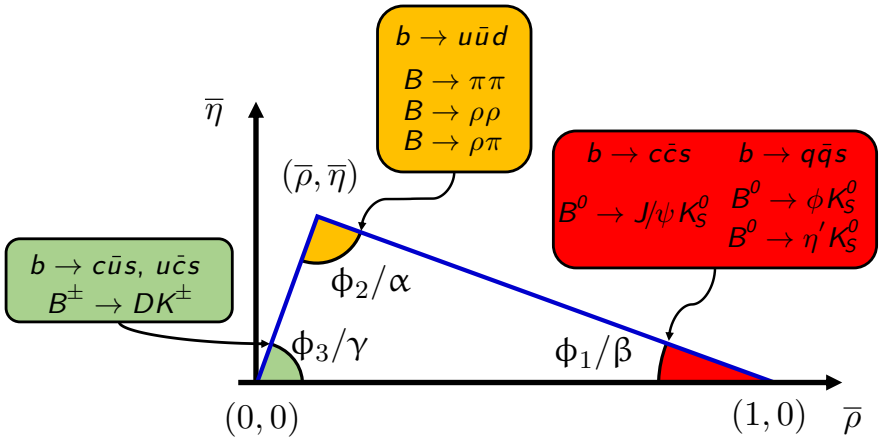
$\sigma(d_0) \approx 2\times$better than Belle.

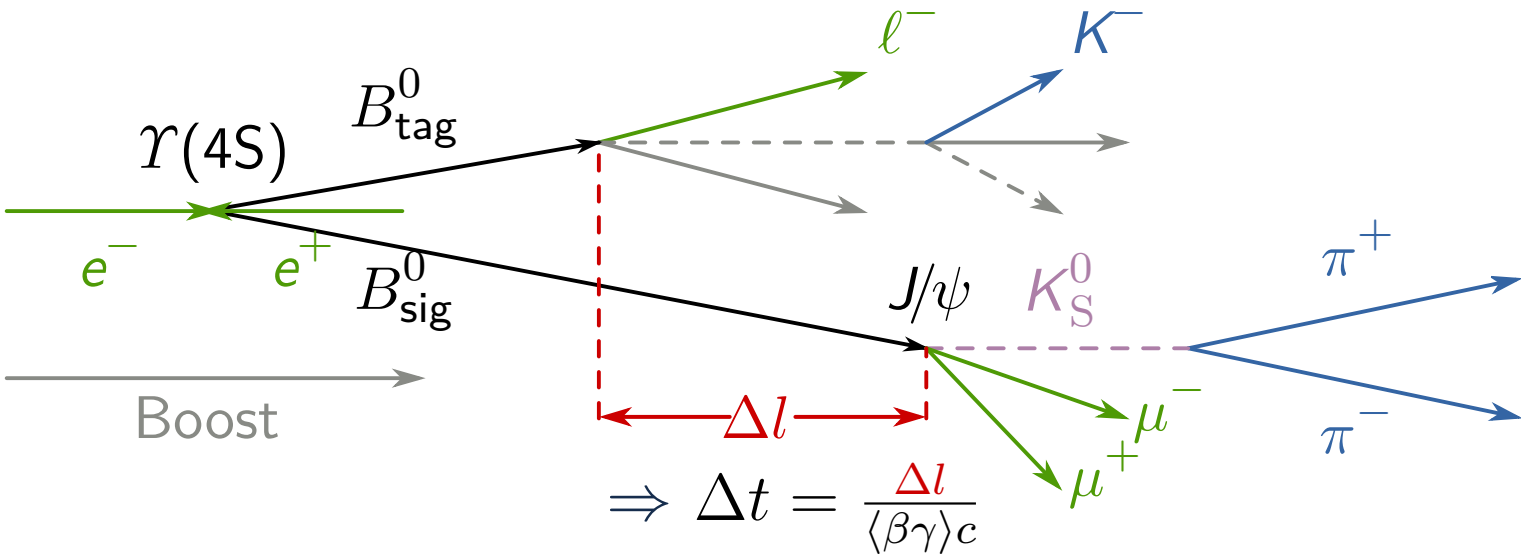
Improved vertexing, tracking and particle-identification (PID) detectors.

Challenges: increased backgrounds, higher trigger rates.

B production and CP-V







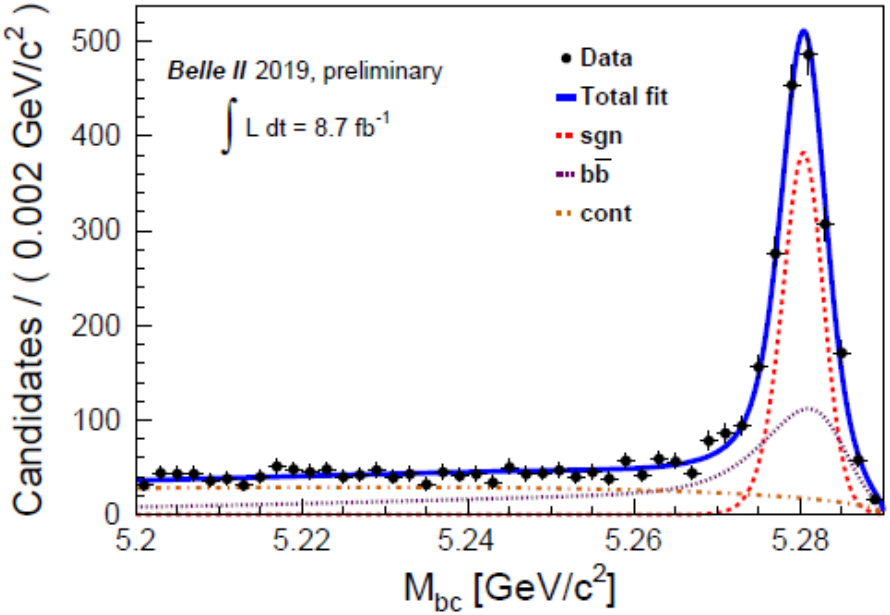
High-performance in signal B-decay and vertex reconstruction are **key**.

B^0 lifetime

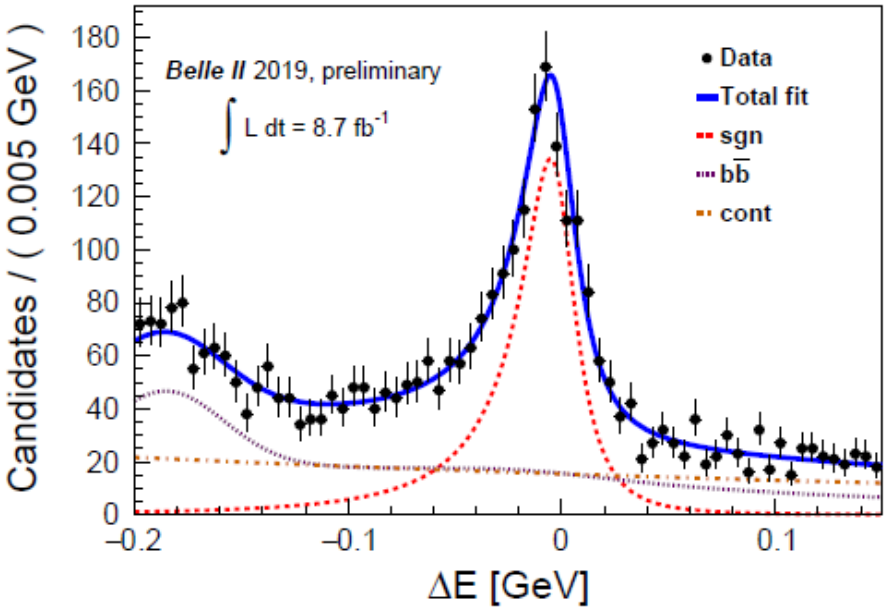
Benchmarks vertex reconstruction and time-resolution models.

- Reconstruct $B^0 \to D^{(*)-}\pi^+(\rho^+)$ decays.
- Separate **signal** from $B\bar{B}$ and continuum backgrounds performing a 2D fit to the ΔE and $M_{\rm bc}$ distributions.

$$M_{\rm bc} \equiv \sqrt{s/(4c^4) - (p_B^*/c)^2}$$



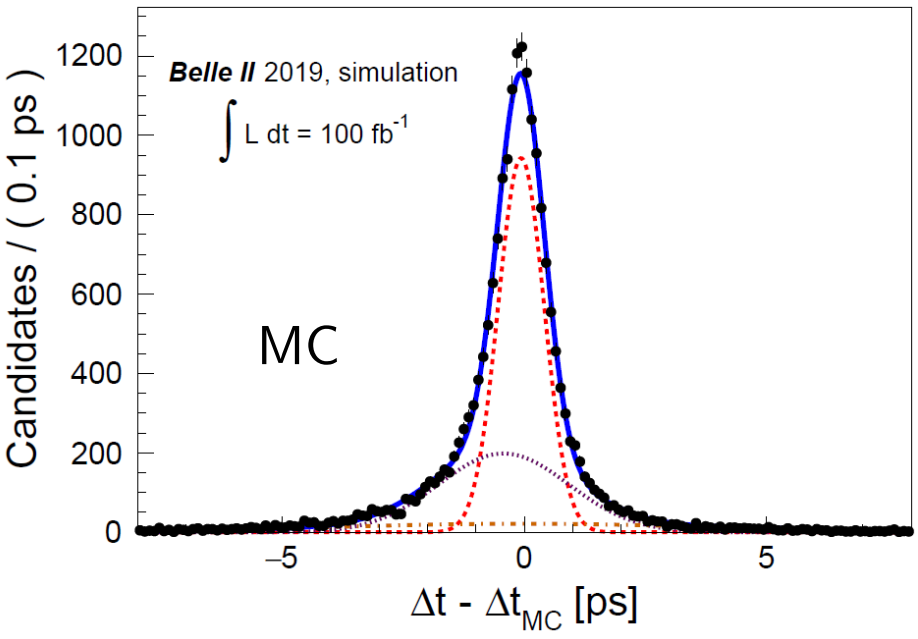
$$\Delta E \equiv \frac{\sqrt{s}}{2} - E_B^*$$



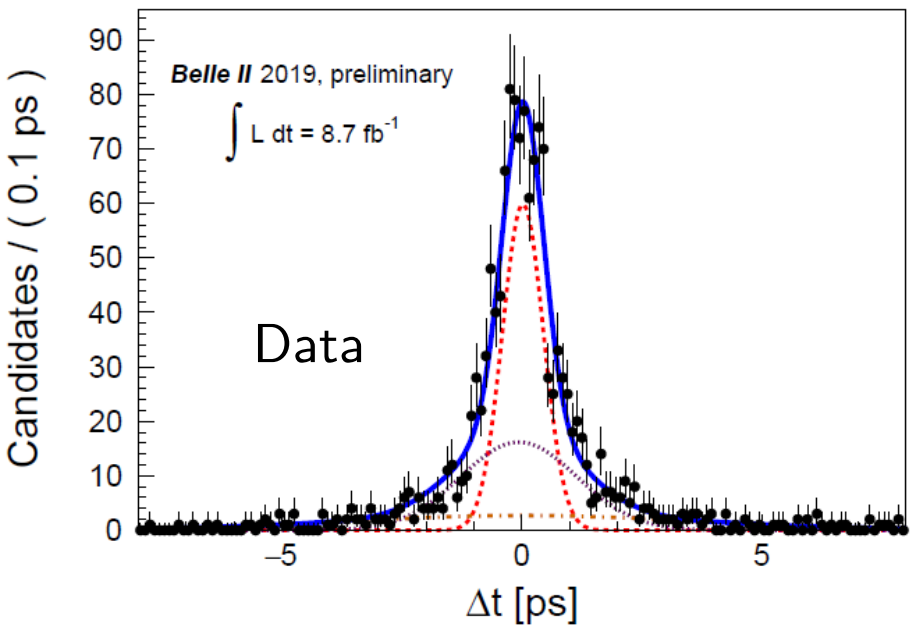
Resolution and Δt pdf.

$\mathcal{R}(\Delta t - \Delta t_{\rm true})$ modeled with 3 Gaussian functions:
$\Rightarrow$ Relative fractions, shifts and width scaling factors from simulation.
$\Rightarrow$ Global shift $\mu_{\Delta t}$ and width $\sigma_{\Delta t}$ from data.

Signal: fit to MC.



$q\bar{q}$: fit to sideband.

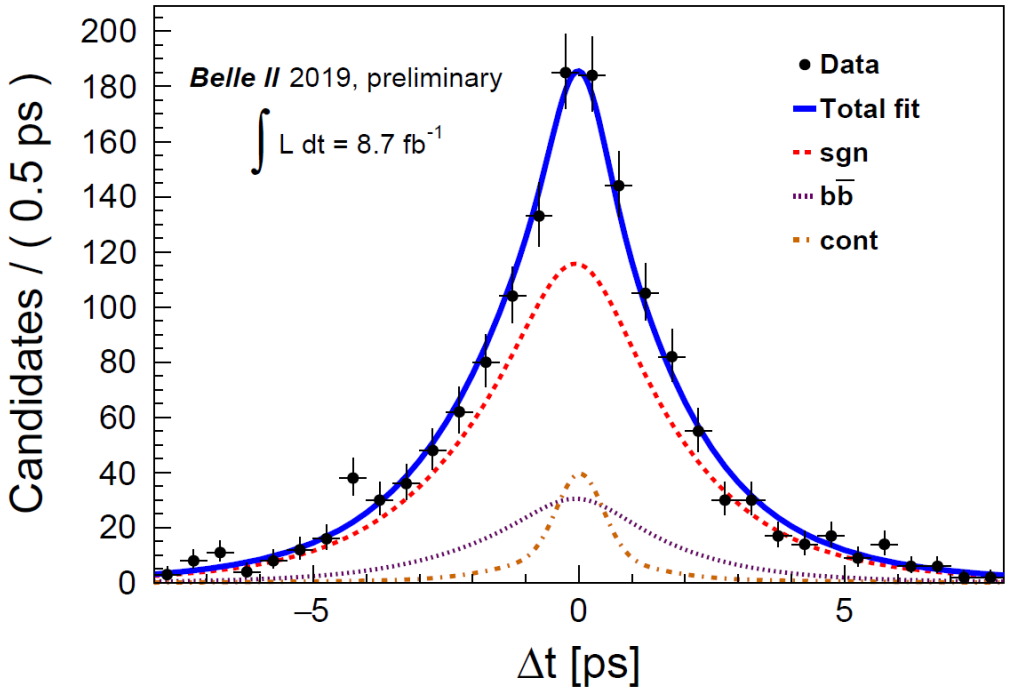


	Data	MC
$\mu_{\Delta t}$ [ps]	-0.03 ± 0.06	-0.09 ± 0.02
$\sigma_{\Delta t}$ [ps]	0.56 ± 0.18	0.44 ± 0.09

$B\bar{B}$: $\tau_{\rm eff}$ from fit to MC, same resolution as **signal**.

Full fit to Δt

$$\mathcal{P}^{\text{Obs}}(\Delta t, \tau_{B^0}) \propto e^{\frac{-|\Delta t|}{\tau_{B^0}}} \otimes \mathcal{R}(\Delta t - \Delta t_{\text{true}})$$



Systematic uncties. [ps]	
Fit bias	0.05
τ_{eff}	0.01
Calibration	0.03

$\Rightarrow$ $\tau_{B^0} = 1.48 \pm 0.28 \pm 0.06$ ps

$\Rightarrow$ compatible with world average 1.519 ± 0.004 ps.

BELLE2-CONF-PH-2020-003 [arXiv:2005.07507]

$\Rightarrow$ Preliminary resolution-model explored.

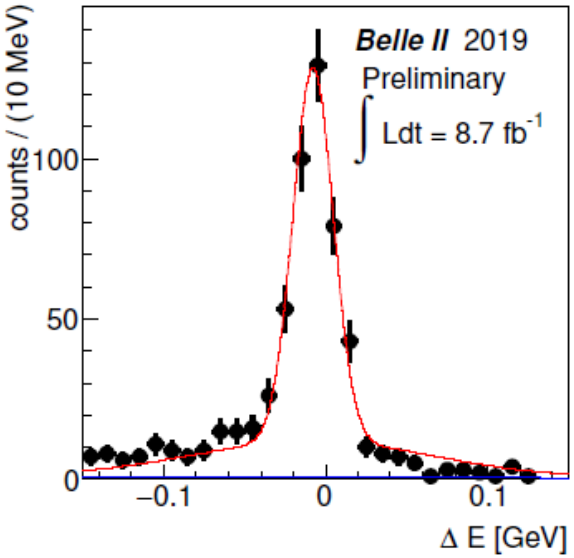
$\Rightarrow$ Good understanding of basic ingredients for Δt-dep. analyses.

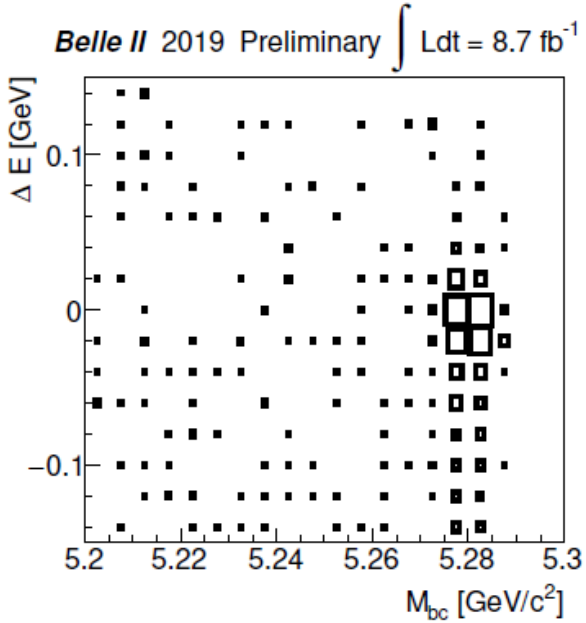
$B^+ \to J/\psi K^+$

Key to validate $J/\psi K^0_S$ analysis.

Useful to study flavor symmetries.

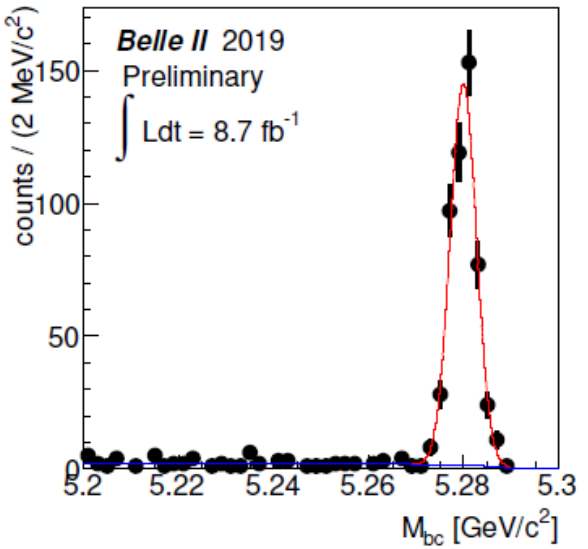
BELLE2-NOTE-PL-2020-004





Signal yield

B-decay mode	Data	MC
$J/\psi(\to e^+e^-)K^+$	176 ± 13	190.0 ± 10
$J/\psi(\to \mu^+\mu^-)K^+$	322 ± 17	290.3 ± 18
$J/\psi(\to \ell^+\ell^-)K^+$	496 ± 22	480.3 ± 21

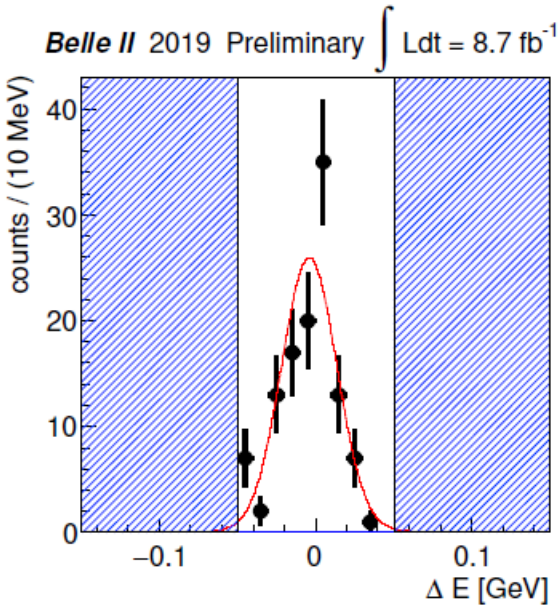


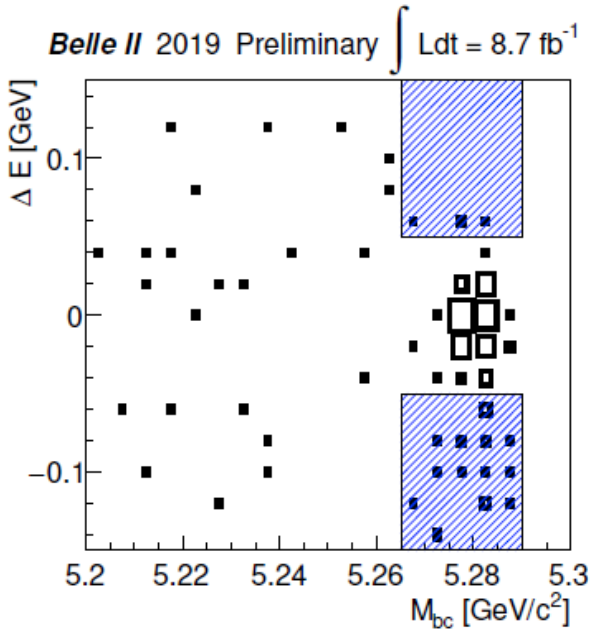
$\Rightarrow$ Good data/MC agreement.

$B^0 \to J/\psi K^0_S$

Golden mode for $\sin(2\phi_1)$.

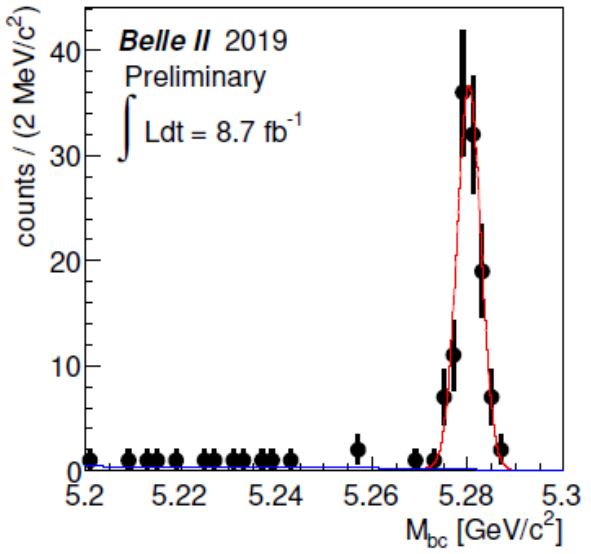
BELLE2-NOTE-PL-2020-004





Signal yield

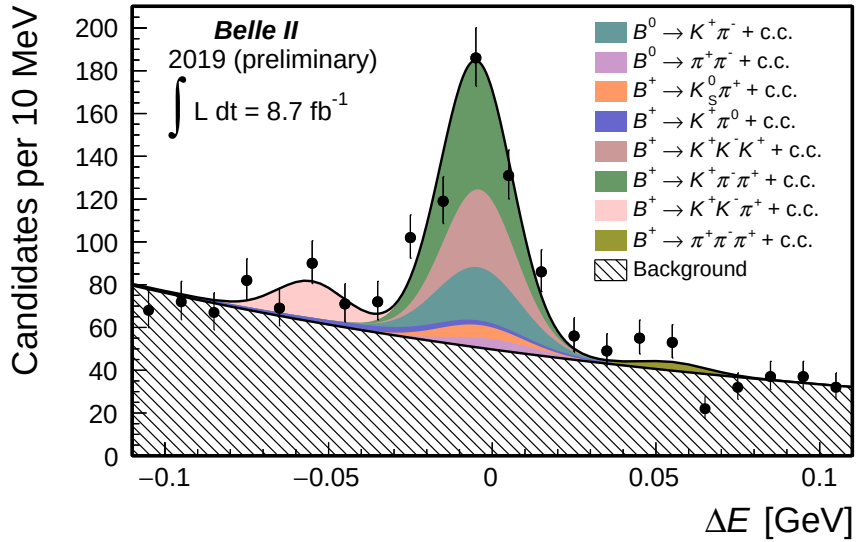
B-decay mode	Data	MC
$J/\psi(\to e^+e^-)K^0_S$	38 ± 6.3	39 ± 3
$J/\psi(\to \mu^+\mu^-)K^0_S$	75 ± 8.5	65 ± 5
$J/\psi(\to \ell^+\ell^-)K^0_S$	114 ± 11	103 ± 6



$\Rightarrow$ Good data/MC agreement.

Charmless B decays

- **Key** for ϕ_2 and isospin sum rules.
- Sensitive to new loop contributions.
- Suppressed with $\mathcal{B} \lesssim 10^{-5}$.



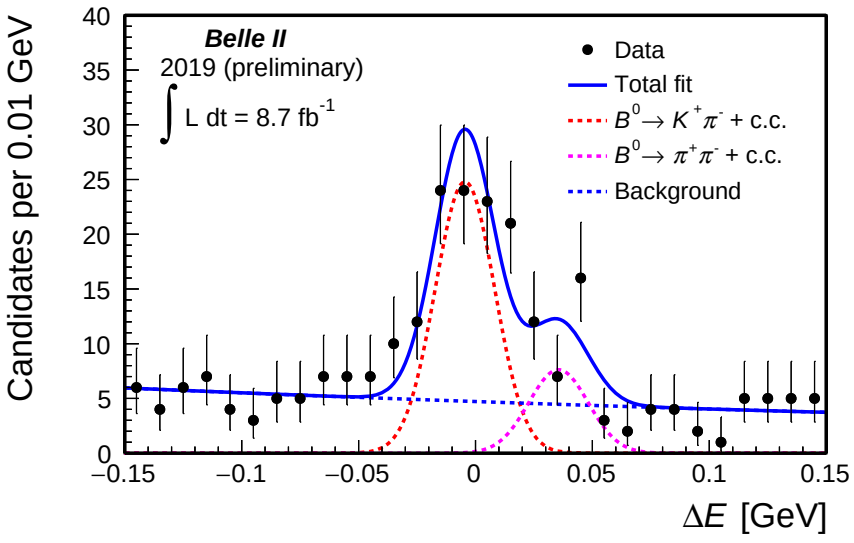
Belle II has reconstructed 400 charmless B decays.

⇒ **Impose challenges on:**
particle identification,
reconstruction of neutral particles,
and suppression of large backgrounds.

BELLE2-CONF-PH-2020-001 [arXiv:2005.13559]

Charmless 2-body decays

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



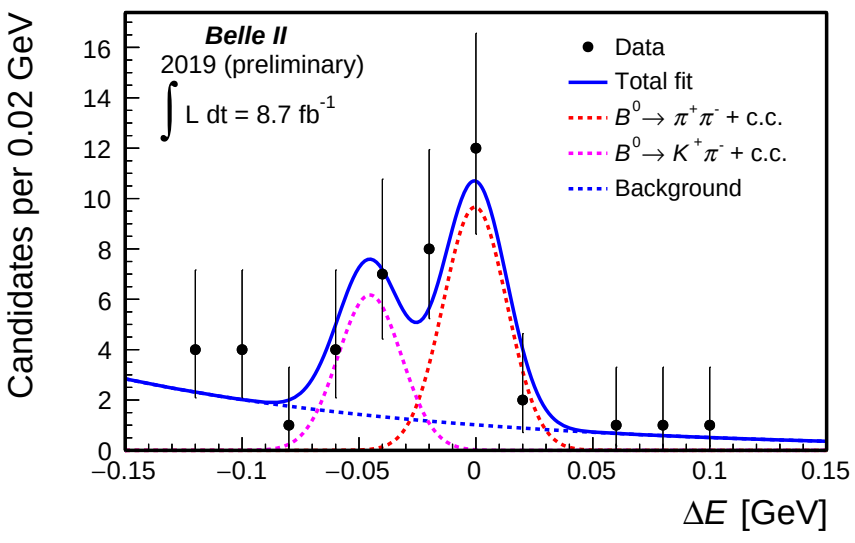
Signal yield	79 ± 11

Signal yield/fb^{-1}

Data	9.1 ± 1.3
MC	7.4 ± 0.5

$\Rightarrow$ $\approx 2\times$ yield/fb wrt. BEAUTY 2019.

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



Signal yield	16 ± 5

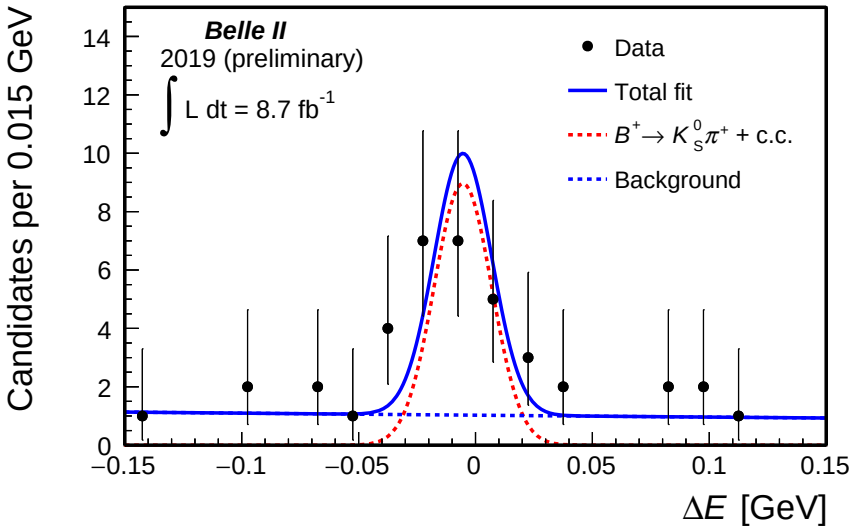
Signal yield/fb^{-1}

Data	1.8 ± 0.6
MC	1.6 ± 0.2

$\Rightarrow$ Proved PID capabilities.

Charmless 2-body decays

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



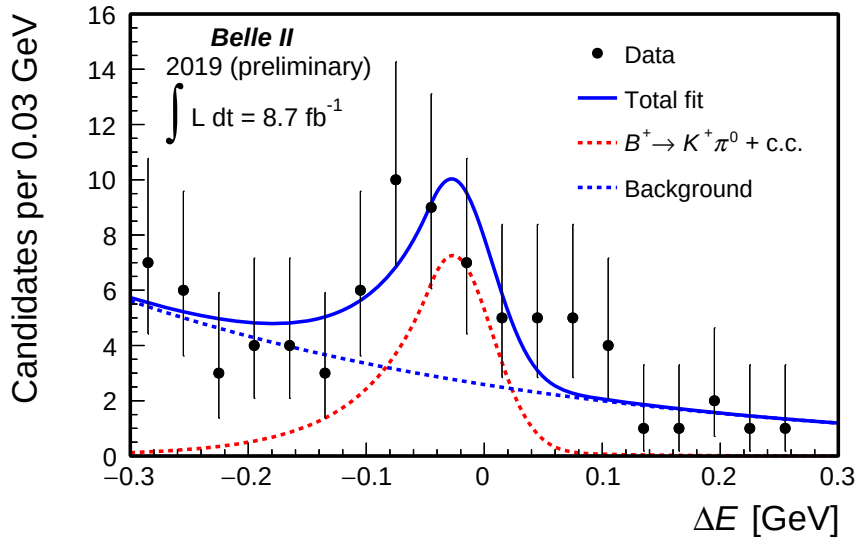
Signal yield	18 ± 5

Signal yield/fb^{-1}

Data	2.1 ± 0.6
MC	1.7 ± 0.2

$\Rightarrow$ Clean K^0_S reconstruction.

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



Signal yield	27 ± 8

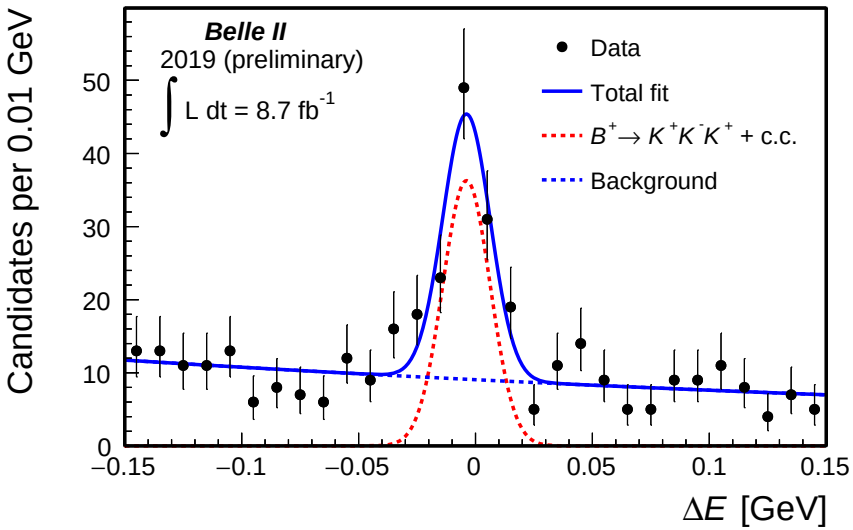
Signal yield/fb^{-1}

Data	3.1 ± 0.9
MC	3.8 ± 0.4

$\Rightarrow$ Good perf. on π^0 reco.

Charmless 3-body decays

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

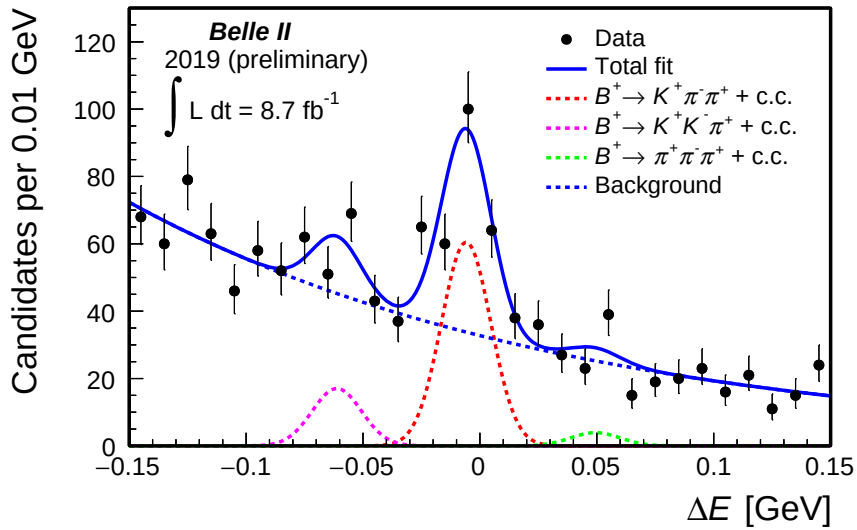


Signal yield	92 ± 12

Signal yield/fb^{-1}

Data	10.6 ± 1.4
MC	11.2 ± 0.6

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



Signal yield	160 ± 19

Signal yield/fb^{-1}

Data	18.4 ± 2.2
MC	20.2 ± 0.9

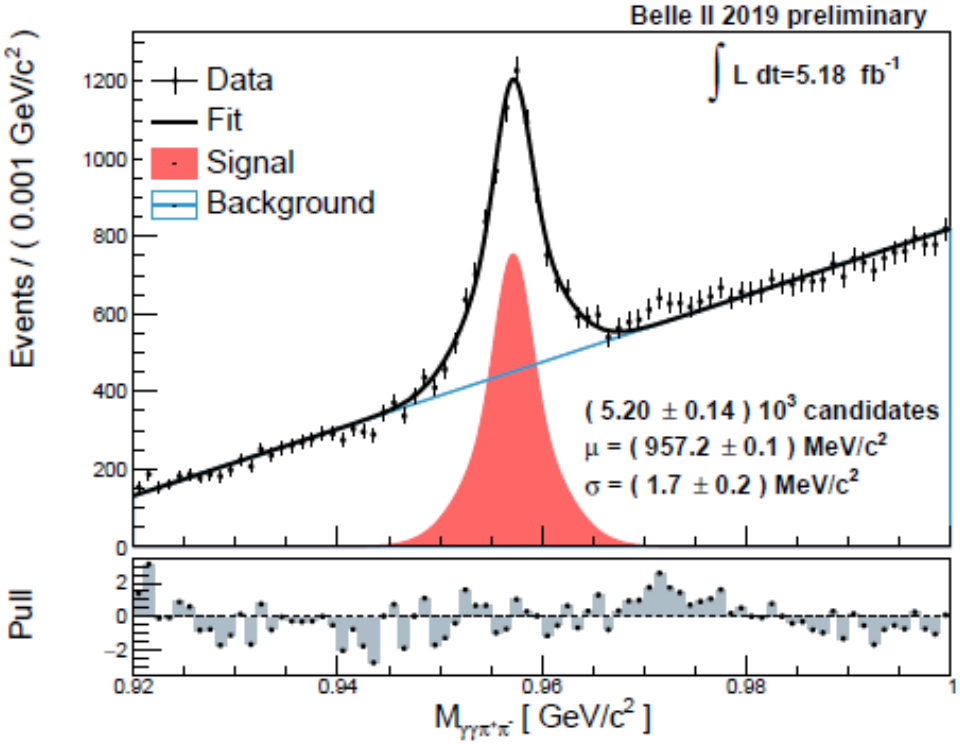
$\Rightarrow$ Good agreement between data and simulation.

Rediscovery of η and η'

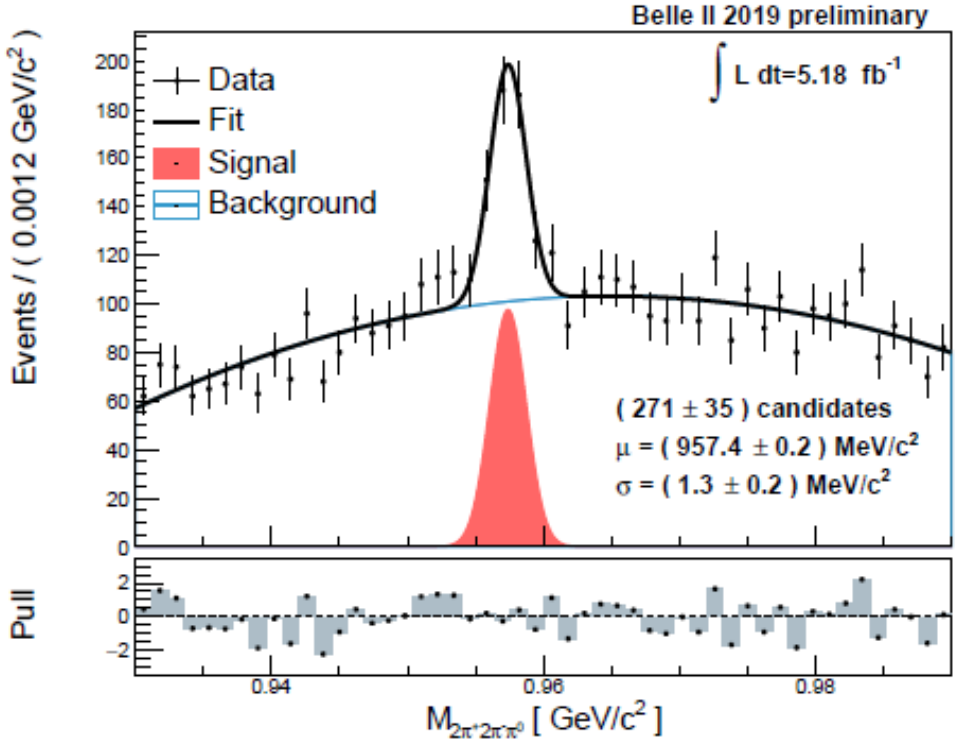
$B^0 \to \eta' K^{(*)0}$, $\eta K^{(*)0}$: highly sensitive to new $b \to q\bar{q}s$ loops.

$\Rightarrow$ First milestone reached by reconstructing η and η' mesons.

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



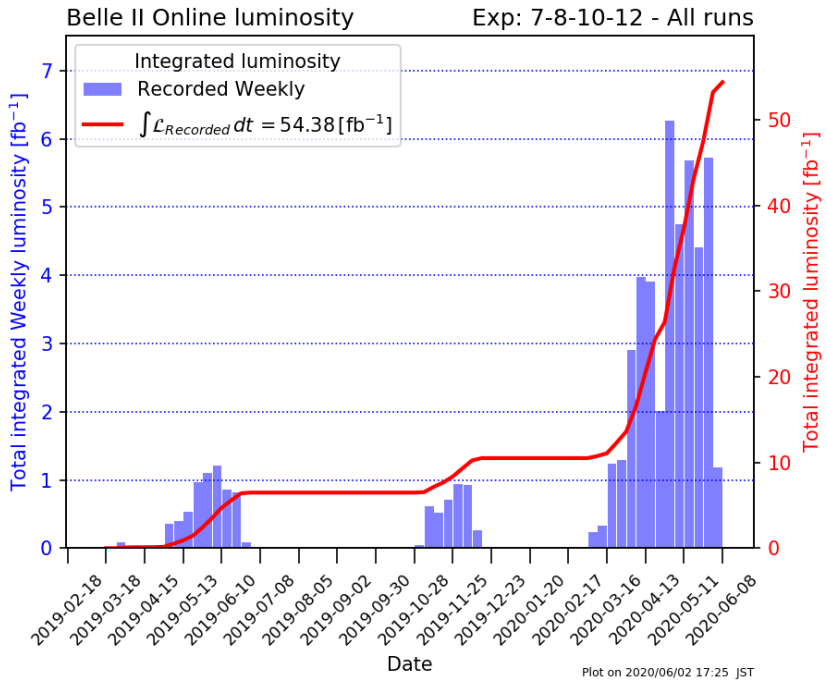
$\eta' \to \pi^+\pi^-\eta(\pi^+\pi^-\pi^0)$



BELLE2-NOTE-PL-2020-003

Summary and outlook

- Good performance confirmed by benchmarking to well-known physics.
- Overall good agreement between data and simulation proves good understanding of detector and tools.
- Performance already comparable with Belle.



$\Rightarrow$ Updates in progress.

$\Rightarrow$ Stay tuned!

$\Rightarrow$ Belle II on track to probe non-standard model physics in B dynamics.

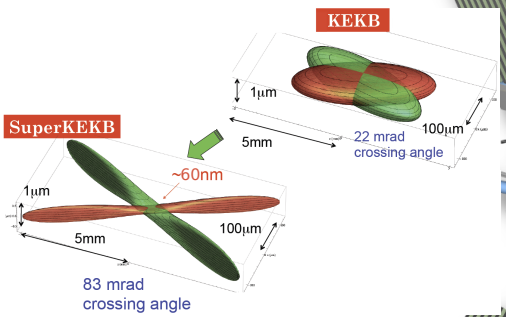
Backup:

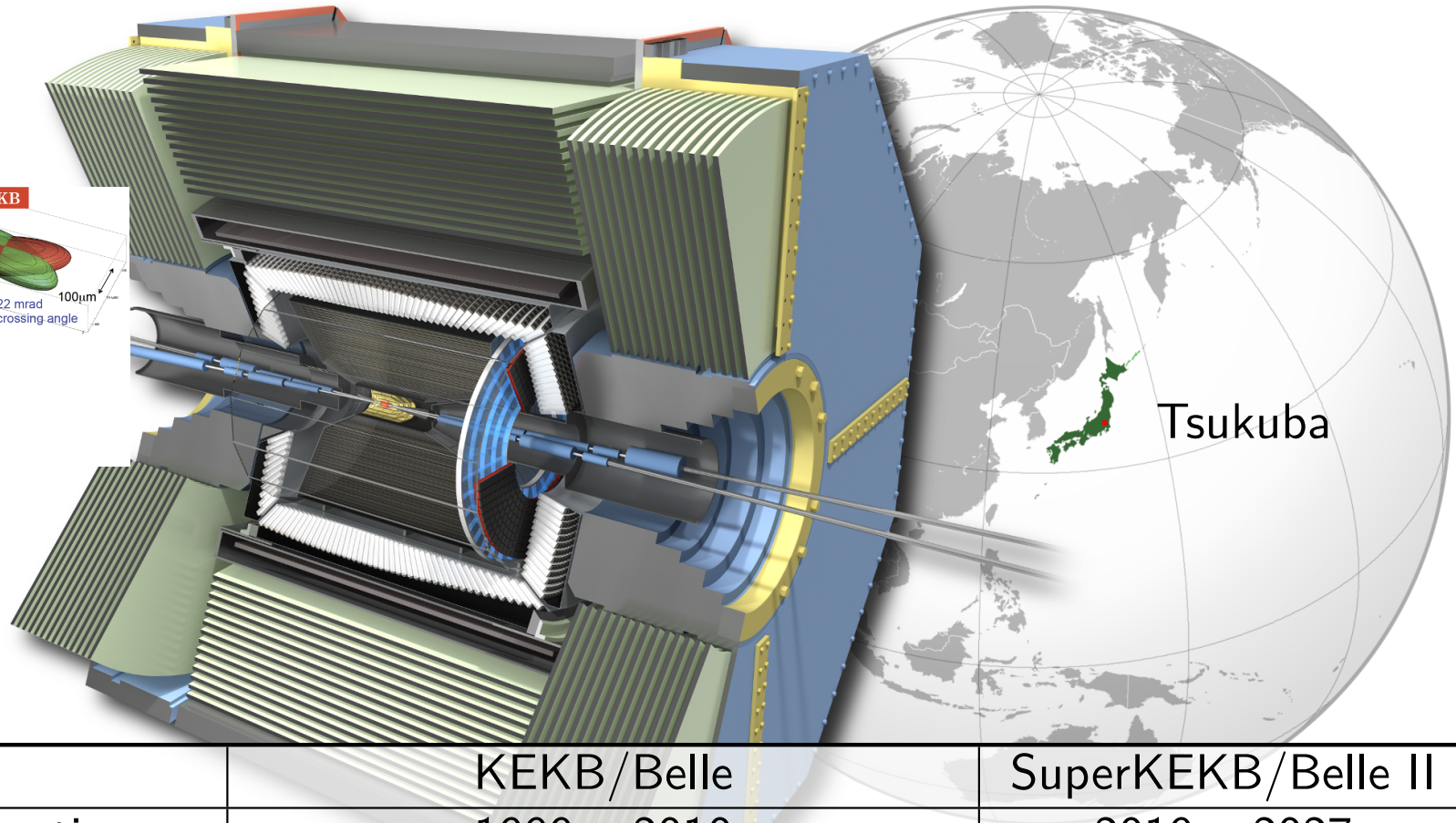
Comparison with Belle

	Belle II		Belle PRD.87.031103	
Decay	Yield/fb^{-1}	Purity	Yield/fb^{-1}	Purity
$B^0 \to K^+ \pi^-$	9.1 ± 1.3	≈ 10	10.6 ± 0.18	≈ 5
$B^0 \to \pi^+ \pi^-$	1.8 ± 0.6	≈ 5.5	2.96 ± 0.12	≈ 2.4
$B^+ \to K^0_S \pi^+$	2.1 ± 0.6	≈ 10	4.5 ± 0.1	≈ 12
$B^+ \to K^+ \pi^0$	3.1 ± 0.9	≈ 3.6	5.2 ± 0.13	≈ 3.5

$\Rightarrow$ Performance qualitatively comparable with Belle.

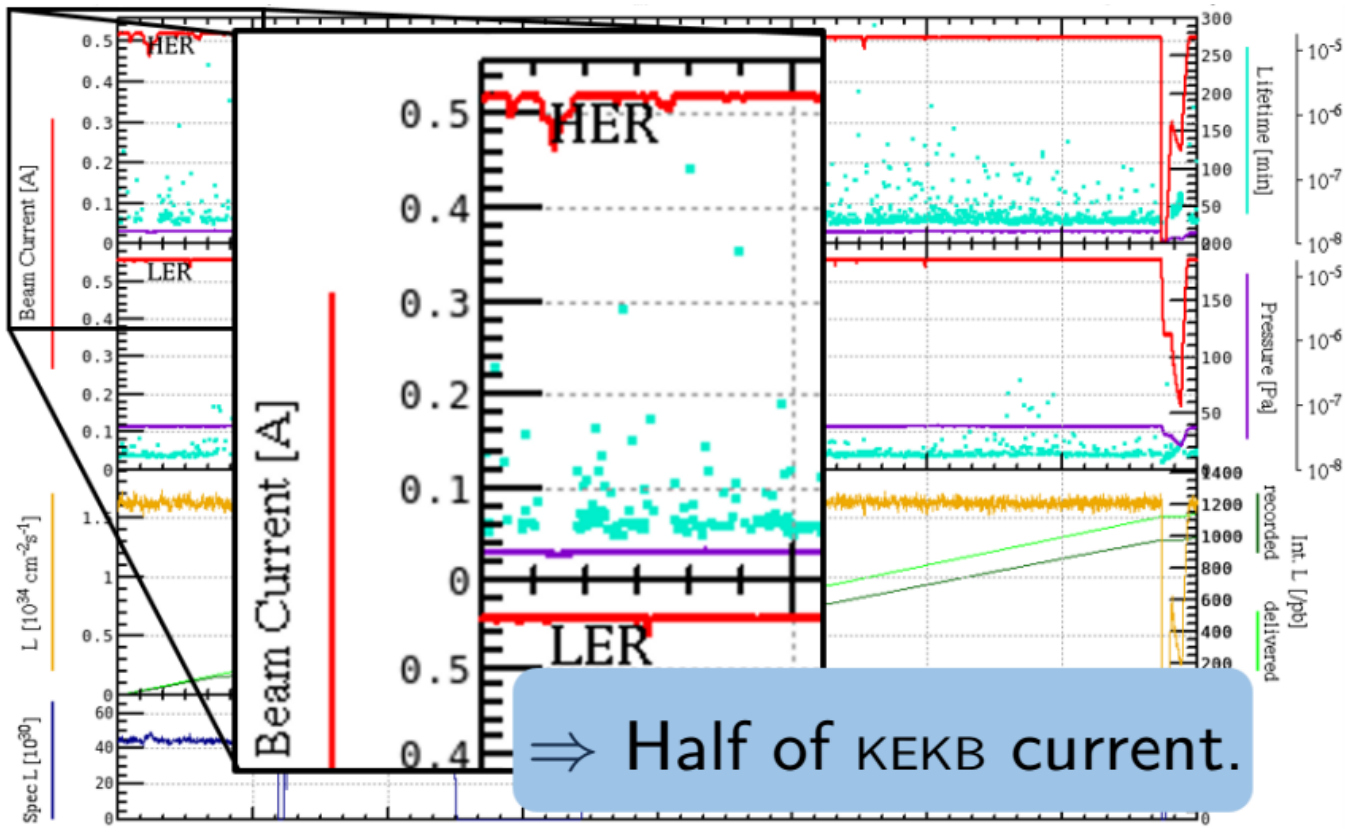
Belle ⇒ Belle II





	KEKB/Belle	SuperKEKB/Belle II
operation	1999 – 2010	2019 – 2027
e^-/e^+ beam E	$8/3.5$ GeV	$7/4$ GeV
e^-/e^+ beam I	$1.2/1.6$ A	$2.6/3.6$ A
Inst. Lumi. $\mathcal{L}$	$2.11 \cdot 10^{34}\text{cm}^{-2}\text{s}^{-1}$	$8 \cdot 10^{35}\text{cm}^{-2}\text{s}^{-1}$
$\int \mathcal{L} \cdot dt$	$\sim 0.8\,\text{ab}^{-1}$ ($772 \cdot 10^6$ $B\,\bar{B}$ pairs)	$50\,\text{ab}^{-1}$

SuperKEKB operation



Rediscovery of η and η'

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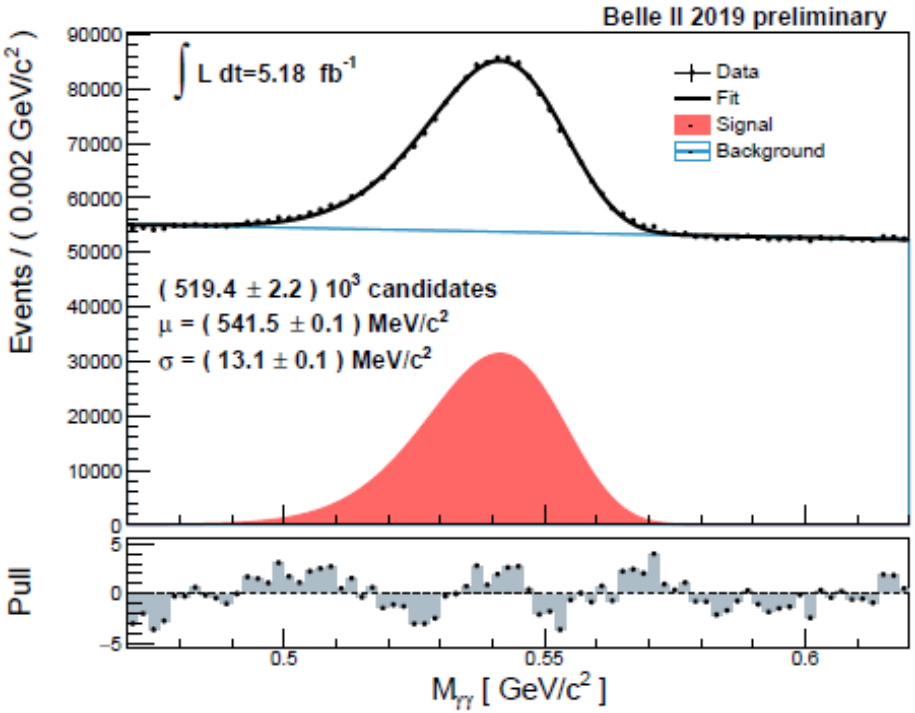
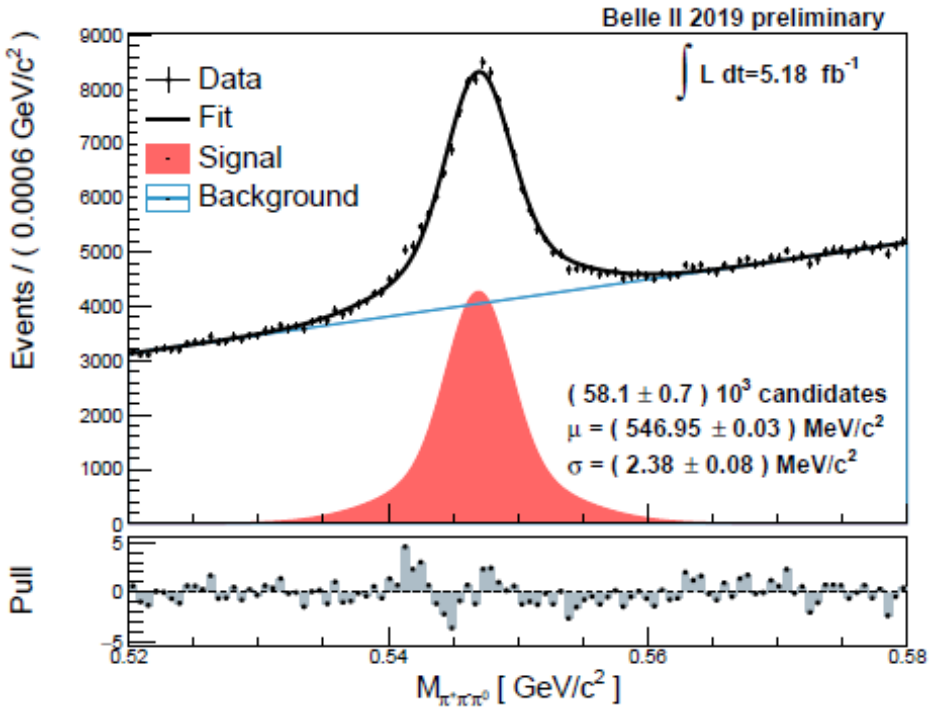
$\eta \to \gamma\gamma$



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



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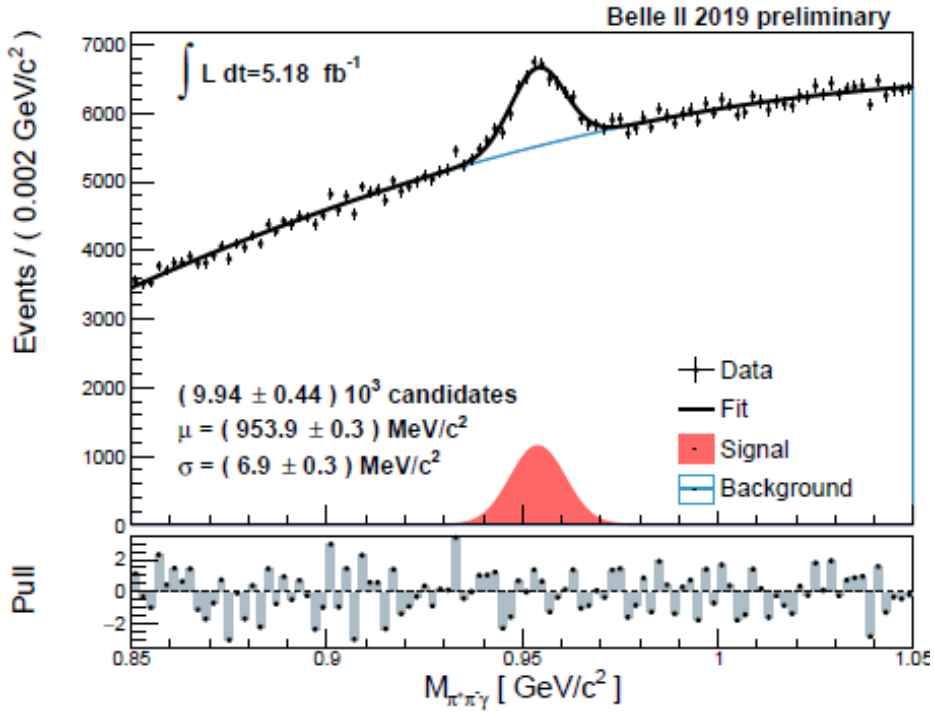
$\eta' \to \rho\gamma$



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