

Search for BSM physics with radiative B decays in Belle II

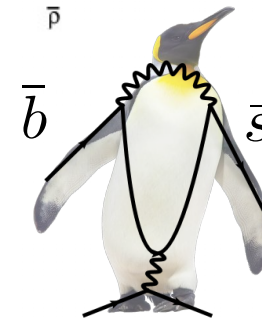
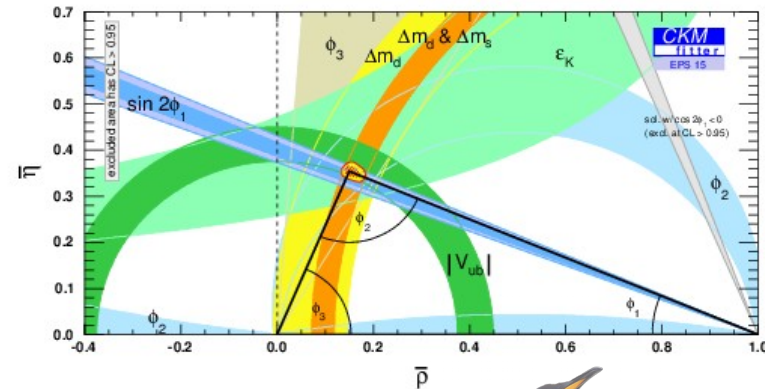
Sviatoslav Bilokin (IPHC Strasbourg)

on behalf of the Belle II collaboration

ALPS 2018

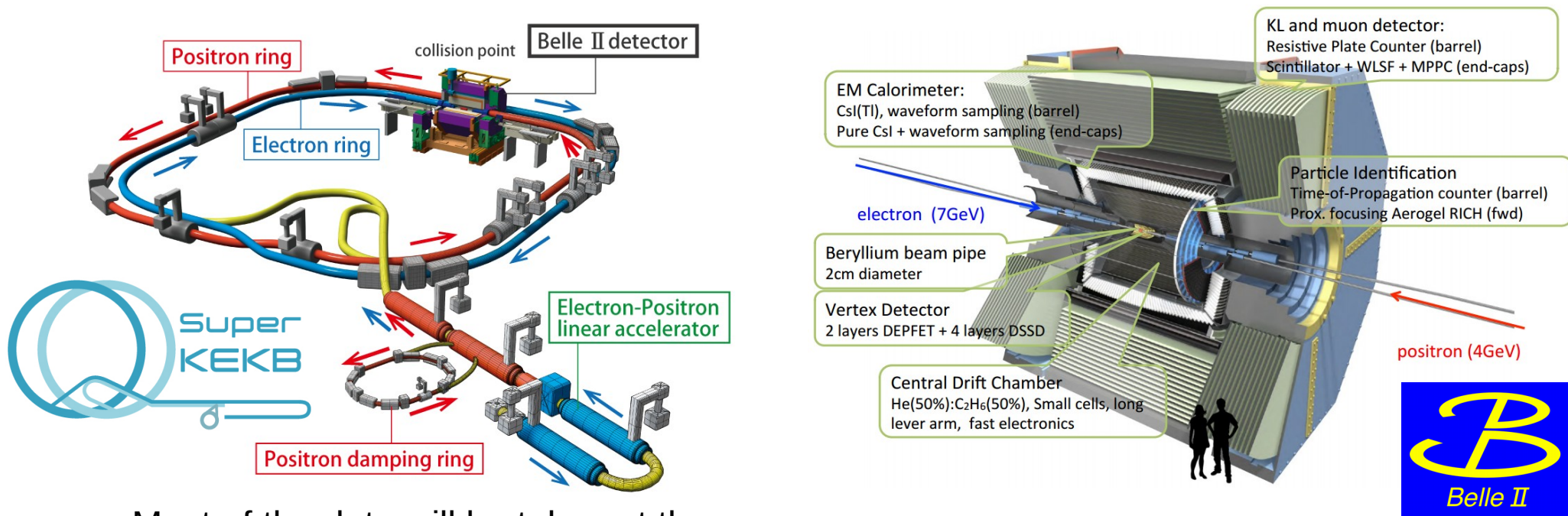
Scientific motivation

- Belle II @ SuperKEKB is the new e^+e^- facility at intensity frontier, which studies properties of rare B meson decays – **b-factory**
 - Successor of **Belle @ KEKB**
and **BaBar @ PEP II**
 - Rich physics program
 - Direct searches of BSM
 - Dark matter, axions, exotics ...
 - Indirect searches
 - **B physics (CKM, EW penguins, radiative decays)**
 - Charm physics
 - Tau physics
 - Quarkonium and QCD studies
 - No New Physics (NP) particles have been discovered at the LHC yet
 - Importance of the indirect searches is rising
 - Belle II can reach beyond the energy frontier sensitivity
 - Constructive complementarity & competition with LHC



See talk by Peter Krizan

Belle II at SuperKEKB



- Most of the data will be taken at the Y(4S) resonance
 - $E(e^-) = 7\text{ GeV}$, $E(e^+) = 4\text{ GeV}$
- Nano-beam scheme and doubling the beam current
 - Vertical beam size is 50nm
 - Higher beam background

- Improved vertex resolution, PID, tracking, etc...
- High detection efficiency $\gamma, \pi^0, K_{S,L}^0$
- **Detector commissioning has started and full Belle II will be next year**

Plan to collect 50 ab⁻¹ by 2025

$$\mathcal{L} = 8 \cdot 10^{35} \text{ cm}^{-2} \text{ s}^{-1} (\text{KEKB} \times 40)$$

Belle II TDR - arXiv:1011.0352

See talk by Peter Krizan

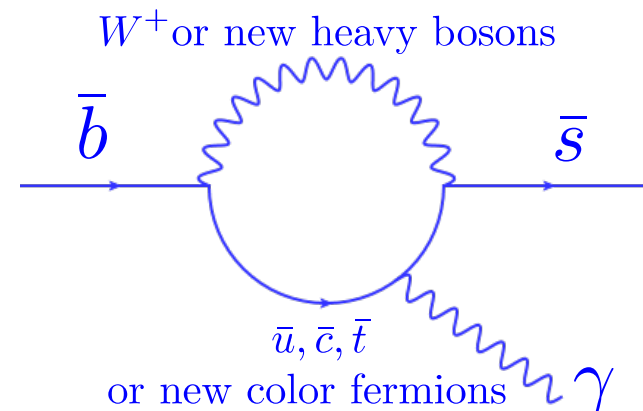
Radiative decays

- Indirect New Physics searches in $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$ channel

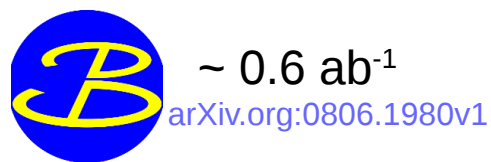
- Underlying process is $b \rightarrow s \gamma$
- In Standard Model no time-dependent CP violation (TDCPV) is expected due to its V-A structure and photon polarization

- Sensitive to New Physics effects

- $BR(B^0 \rightarrow K^0 \pi^+ \pi^- \gamma) = (1.95 \pm 0.22) \cdot 10^{-5}$
(PDG 2016)

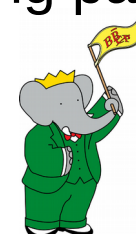


- Results of the previous experiments on CP violating parameters:



$$\mathcal{S}_{K_S^0 \pi^+ \pi^- \gamma} = 0.09 \pm 0.27^{+0.04}_{-0.07}$$

$$\mathcal{A}_{K_S^0 \pi^+ \pi^- \gamma} = 0.05 \pm 0.18 \pm 0.06$$



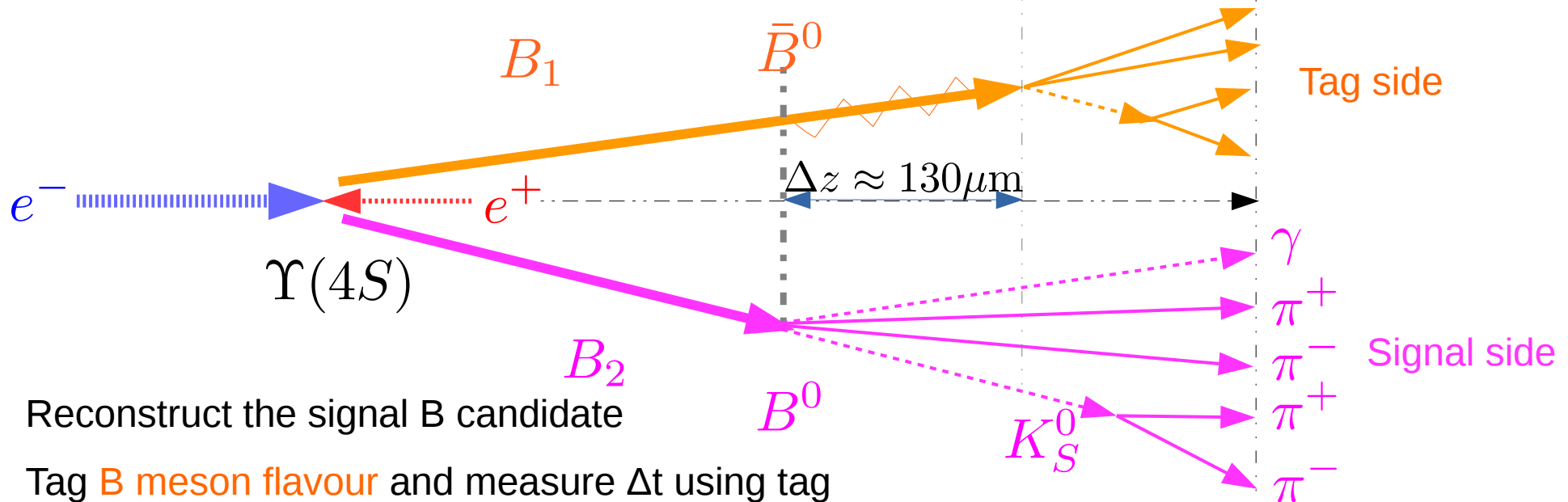
$\sim 0.43 \text{ ab}^{-1}$
[arXiv.org:1512.03579](https://arxiv.org/1512.03579)

$$\mathcal{S}_{K_S^0 \pi^+ \pi^- \gamma} = 0.14 \pm 0.25 \pm 0.03,$$

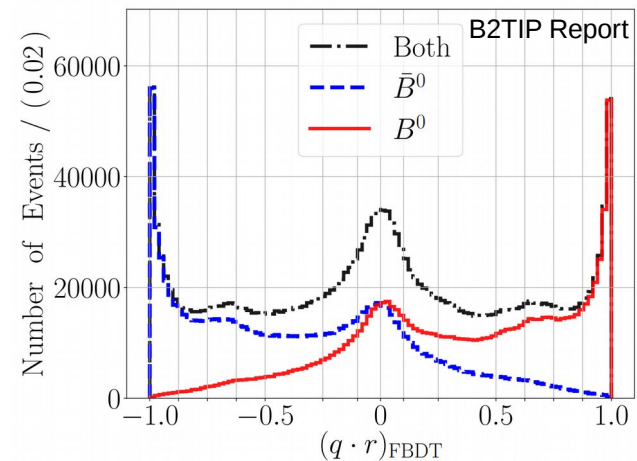
$$\mathcal{C}_{K_S^0 \pi^+ \pi^- \gamma} = -0.39 \pm 0.20^{+0.03}_{-0.02}.$$

- **The results of the previous b-factories, Belle and BaBar are statistically limited → increase sensitivity x10 with Belle II**

TDCPV measurement



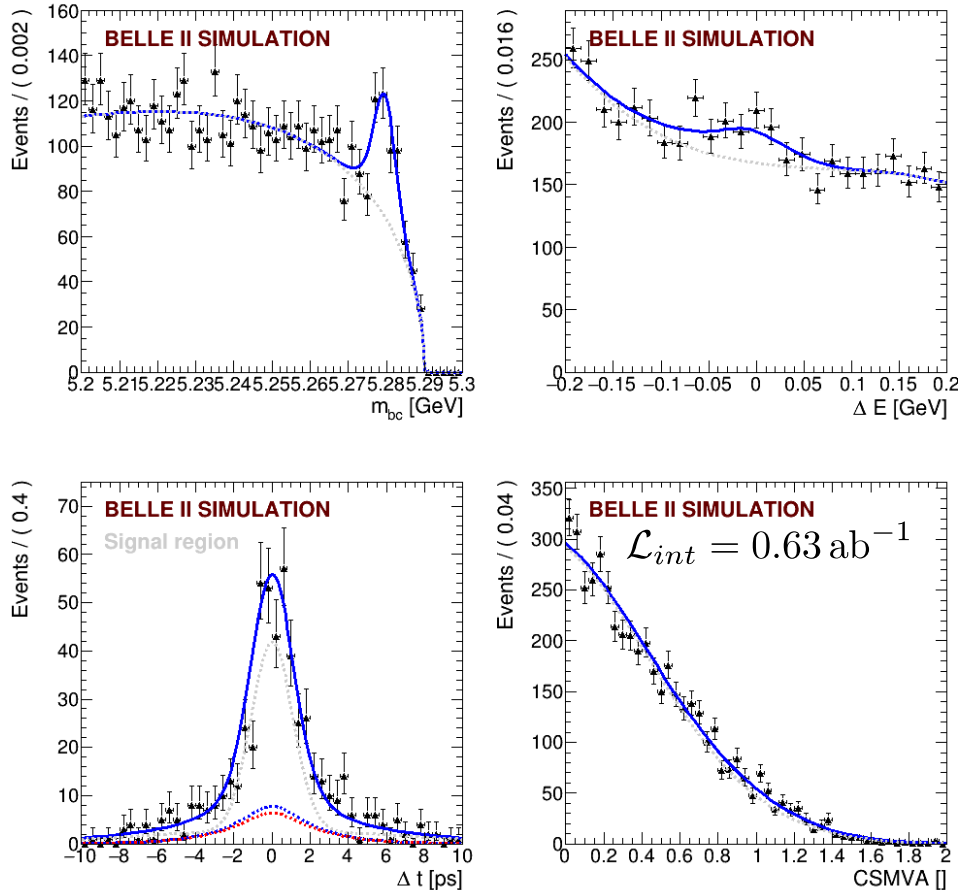
- Reconstruct the signal B candidate
- Tag **B meson flavour** and measure Δt using tag side and signal side B candidate vertices
 - **Effective flavour tagging efficiency is 33.6%**
 - **Detector improvement: +3%**
 - **Algorithm improvement: +3%**
- Compute discriminating observables
- Build signal and background probability density functions (PDFs) models and extract **S** and **A** TDCPV parameters



$$\mathcal{P}(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau} [1 + q(S \sin(\Delta m \Delta t) + A \cos(\Delta m \Delta t))]$$

Full simulation extended likelihood fit

- Multidimensional fit of the full simulation:



- Main observables:

- M_{bc} – beam-constrained mass

$$m_{bc} = \sqrt{(E_{beam}^{c.m.s.})^2 - (p_B^{c.m.s.})^2}$$

- ΔE – energy difference

$$\Delta E = E_B^{c.m.s.} - E_{beam}^{c.m.s.}$$

- Δt – proper decay time difference

- Continuum Suppression MVA against the $e^+e^- \rightarrow q\bar{q}$ processes

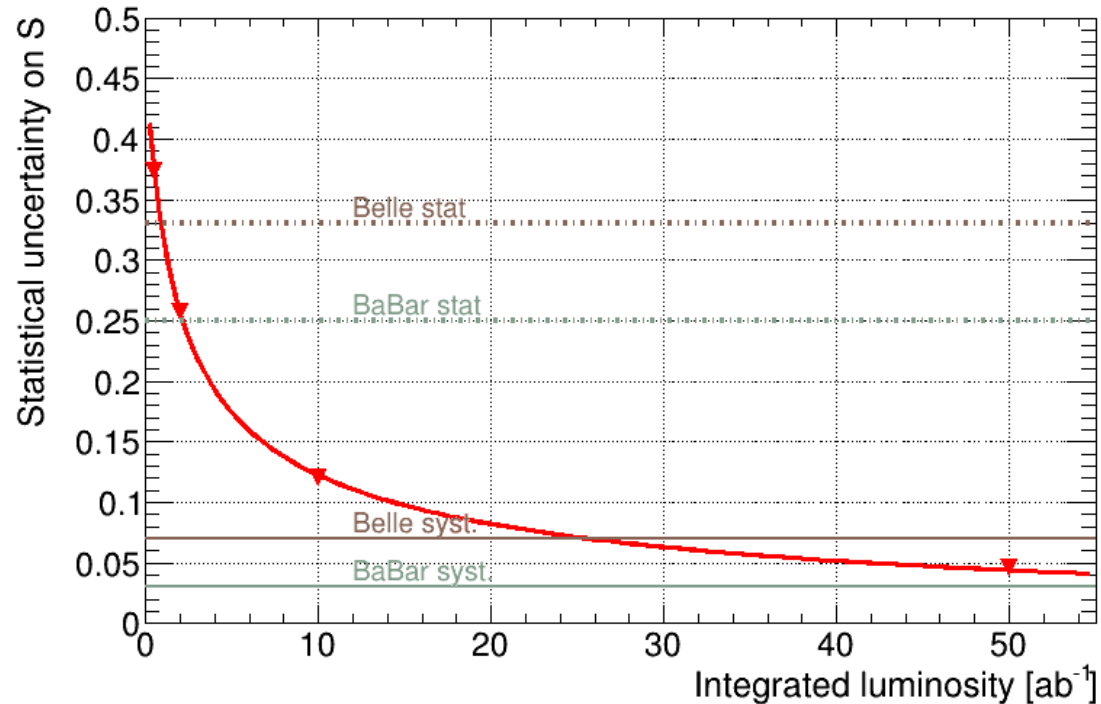
$$A = -0.2 \pm 0.26$$

$$S = 0.01 \pm 0.37$$

Full analysis on simulation has a precision close to the one obtained at Belle and there is a room for improvement

Sensitivity study

- The Toy MC studies will provide statistical and systematics prospects
- Results of 1000 Toy MC experiments:



- The expected statistical uncertainty at full Belle II luminosity will be comparable to the BaBar systematics

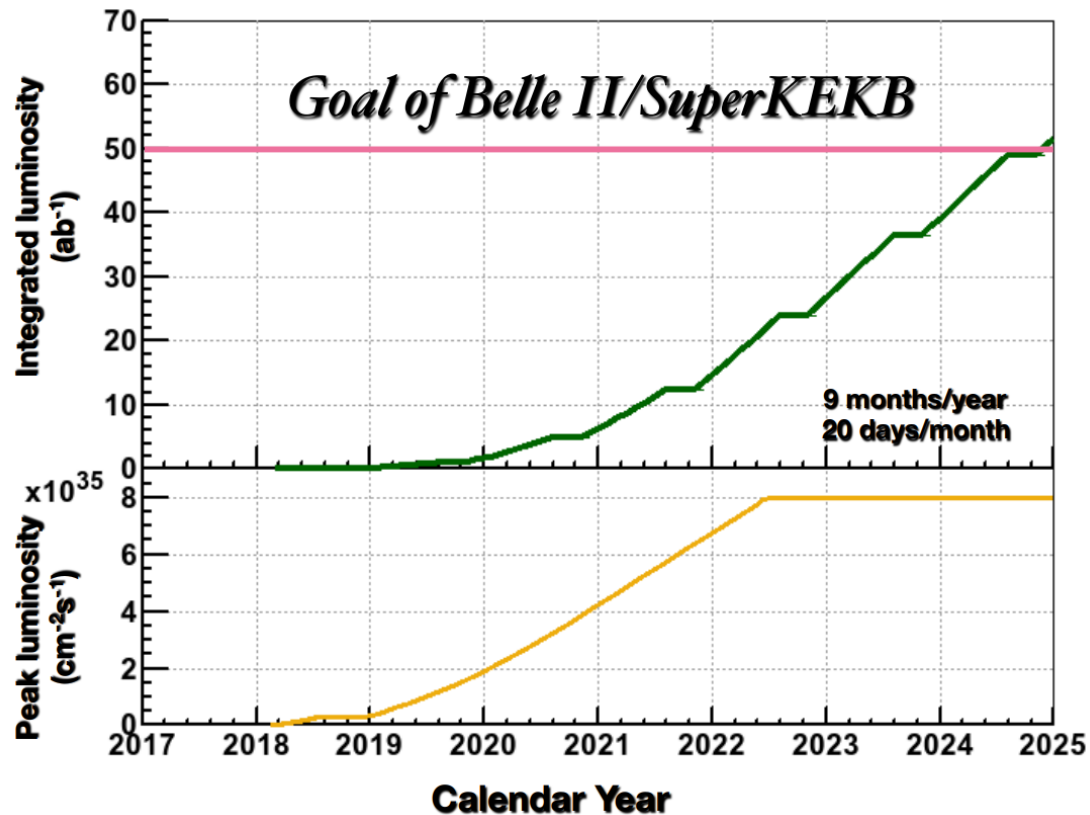
Summary

- Radiative processes, like $b \rightarrow s\gamma$, are sensitive probes for New Physics
 - The e+e- collisions at Belle II is an excellent environment to study radiative processes
- For $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$ statistical uncertainty on $\delta S \sim 0.04$ is reachable, despite the small branching ratio
- Another channel $B^0 \rightarrow K_S^0 \pi^0 \gamma$ gives $\delta S \sim 0.03$, it has a larger cross section and easier interpretation, which will provide even more precise results!
- **Belle II will provide enough data to have statistical uncertainties comparable to the systematic ones for the radiative TDCPV studies**

Thank you!

SuperKEKB planning

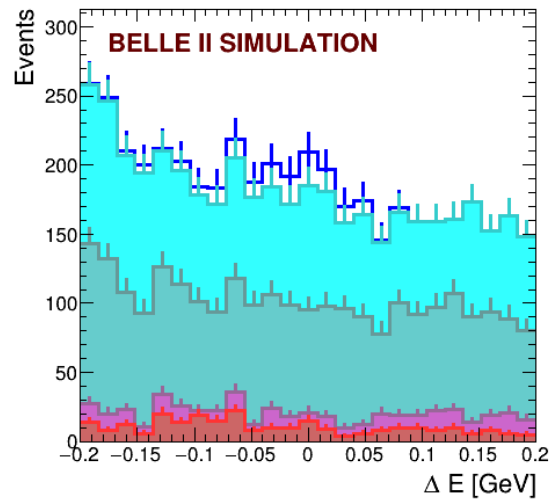
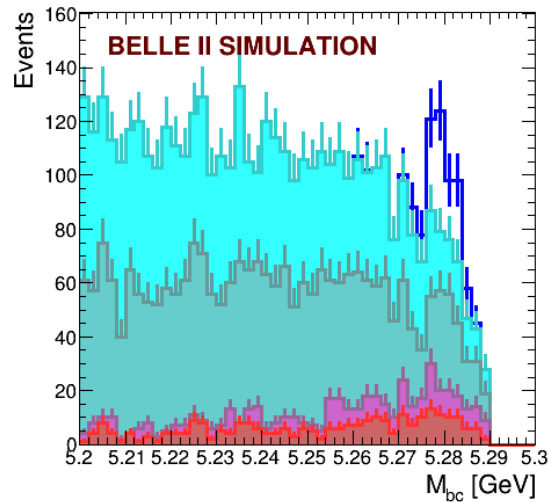
- One has the following plot from KEK webpage:



- Final goal is **50 ab⁻¹**
- In 2020 we will have **2 ab⁻¹**, which is already ~4 times full Belle dataset

Current progress

- Most of the reconstruction and background rejection procedures have been applied:



- We compute 4 main discriminative observables:
 - M_{bc} – beam-constrained mass
 - ΔE – energy difference
 - Δt – temporal distance
 - Continuum Suppression MVA against the $e^+e^- \rightarrow q\bar{q}$ processes

