

Belle II Status and Prospects @ Moscow International School of Physics 2020

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MATHEMATICS OF THE UNIVERSE



Outline

- 1 Super KEKB and Belle II
- 2 Silicon Vertex Detector
- 3 B Physics
- 4 D Physics
- 5 Dark Sector Physics
- 6 Summary

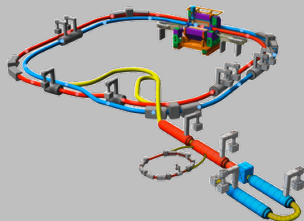
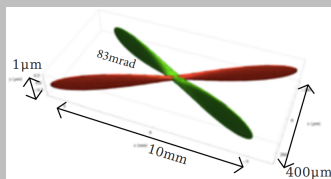
Super KEK B

高エネルギー加速器 ([高] kou [エネルギー] enerugii [加速器] kasokuki) high energy accelerator

$$Y = \sigma \times \mathcal{L} \text{ where } \mathcal{L} \propto \frac{\text{Beam current}}{\text{Beam size}}$$

events cross-section luminosity [s^{-1}] [cm^2] [$cm^{-2}s^{-1}$]

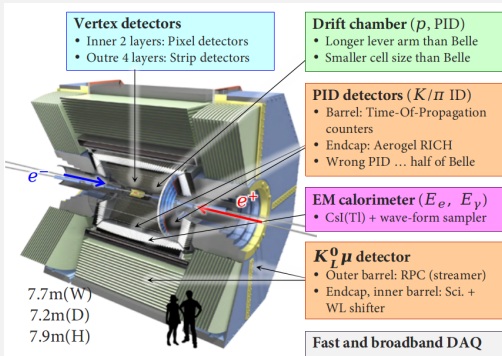
Assymmetric B-factory with e^- at 7 GeV and e^+ at 4 GeV



- Beam current $\times 2$
- Beam size $\div 20$
- $\mathcal{L}_{\text{KEKB}}^{\text{peak}} = 2.1 \times 10^{34} / \text{cm}^2\text{s}$
- $\mathcal{L}_{\text{SKEKB}}^{\text{design}} = 80 \times 10^{34} / \text{cm}^2\text{s}$

B mesons = **e**lectron + **n**ortcele

Belle II subdetectors



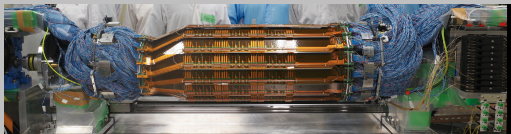
Challenges

- Larger trigger rate 500 Hz \rightarrow 30kHz
- Bigger background, $\times 10 \sim 20$ beam BG
- Performance improvement

Silicon Vertex Detector

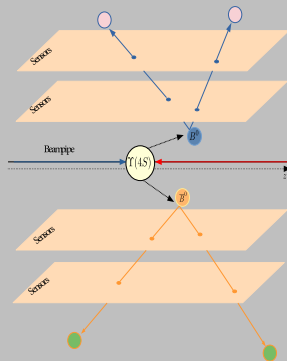
Key concepts

- DSSDs (Double-Sided Strip Detector)
- Chip-on-sensor, minimizes readout path length
- Origami, backside strips connect to readout with flexible circuit

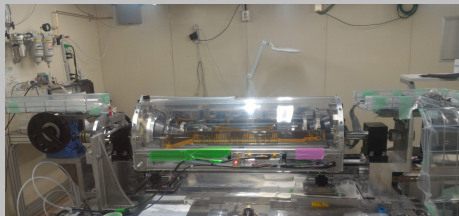


- 1 e^+, e^- collision
- 2 $B^0(\bar{B}^0)$ production at $t = 0$
- 3 B^0 decays at t_1
- 4 \bar{B}^0 decays at t_2

$$\Delta t \equiv t_1 - t_2, \Delta t \sim \frac{z_2 - z_1}{(\beta\gamma)_{B^0} c} \text{ where } (\beta\gamma)_{B^0} = 0.28 \text{ and } \Delta t \sim \mathcal{O}(1)\text{ps}$$

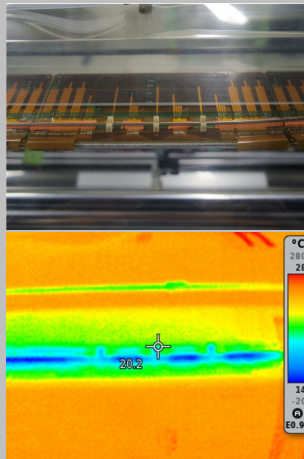


SVD Assembly Dry Volume

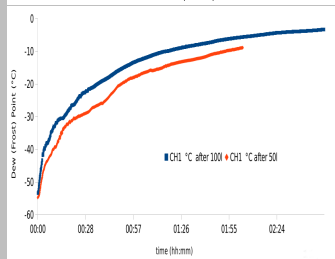
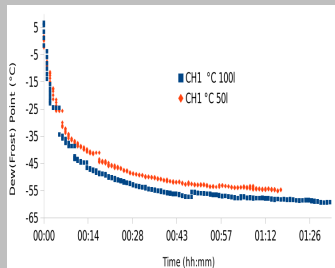


Dry Volume main points

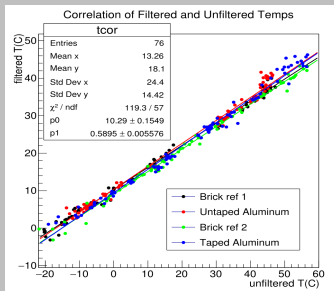
- to isolate SVD from the outside environment
- dry air pumped inside to control dew point
- interlocked (-40°C) dew point sensors with CO_2 cooling system and power supply
- transparent to visible and infrared radiation



SVD Assembly Dry Volume - Achievements

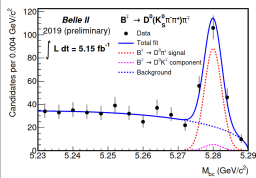
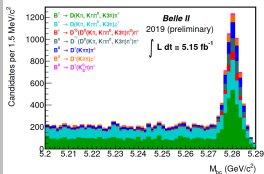
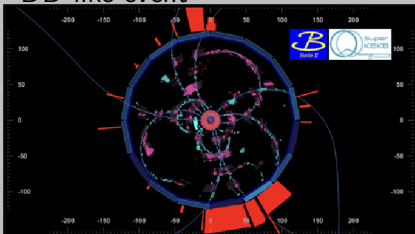


- Overpressure of 1 Pa and reduces humidity
- SVD 10min safety to abort operations (if needed)
- APV monitoring guaranteed



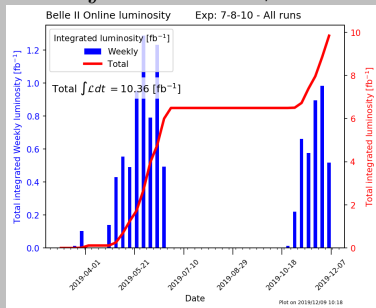
B meson rediscovery at Belle II

$B\bar{B}$ like event



$$\mathcal{L}_{\text{SKEKB}}^{\text{peak}} = 1.2 \times 10^{34} / \text{cm}^2 \text{s}$$

where $\int \mathcal{L} dt = 10.36 / \text{fb}$

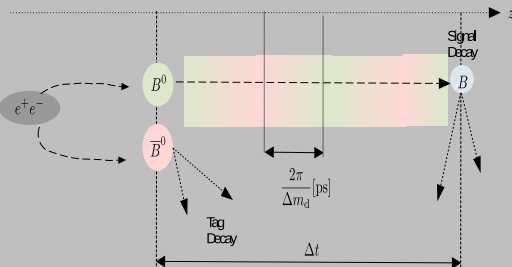


1st Belle II paper on its initial luminosity measurement

Chin.Phys. C41 (2020) 021001

$$M_{bc} = \sqrt{\frac{(s/2 + \mathbf{p}_T \cdot \mathbf{p}_B)^2}{E_T^2} - p_B^2} = \sqrt{E_{\text{beam}}^2 - p_B^{*2}}$$

Rediscovery of $B^0 - \bar{B}^0$ mixing

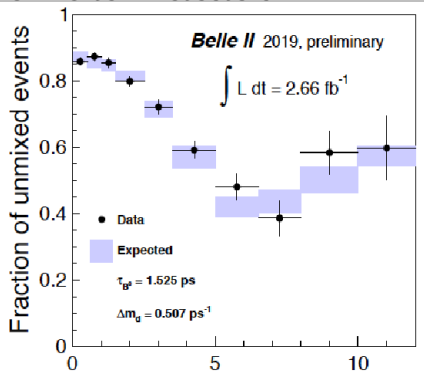


$$P(\Delta t) \propto 1 - \cos \Delta m_d \Delta t$$

$$\Delta m_d \equiv m_{B^0} - m_{\bar{B}^0}$$

$$\Delta t \equiv t_{\text{decay}} - t_{\text{tag}}$$

Validation of effectiveness for Vertex Detectors



Is D the new Beauty?

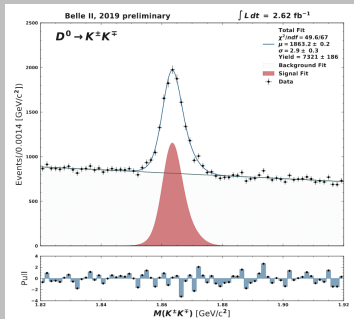
CPV in D – LHCb

- $D^0 \rightarrow \pi^+ \pi^-$
- $D^0 \rightarrow K^+ K^-$
- $\int \mathcal{L} dt = 5.9 \text{fb}^{-1}$
- $\Delta A_{\text{CP}} = (-15.4 \pm 2.9) \times 10^{-4}$

CPV in D – Belle II

- same decays
- $\int \mathcal{L} dt = 1.0 \text{ab}^{-1}$
hopefully by next year

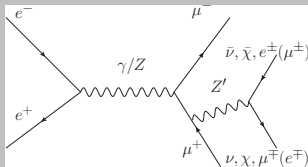
$$A_{\text{CP}}(f; t) \equiv \frac{\Gamma(D^0(t) \rightarrow f) - \Gamma(\bar{D}^0(t) \rightarrow f)}{\Gamma(D^0(t) \rightarrow f) + \Gamma(\bar{D}^0(t) \rightarrow f)}$$
$$\Delta A_{\text{CP}} \equiv A_{\text{CP}}(K^- K^+) - A_{\text{CP}}(\pi^- \pi^+)$$



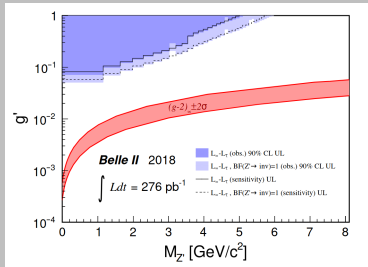
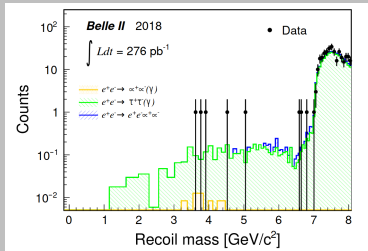
Dark Sector Prospects

$L_\mu - L_\tau$ $U(1)$ gauge boson (Z')

- Only coupled to heavy leptons by g'
- Searched in $e^+e^- \rightarrow [Z' \rightarrow \mu^+\mu^-]\mu^+\mu^-$ by **BABAR in 2016**
- The 1st new physics search from Belle II was in $e^+e^- \rightarrow [Z' \rightarrow e^\pm\mu^\mp]\mu^+\mu^-$

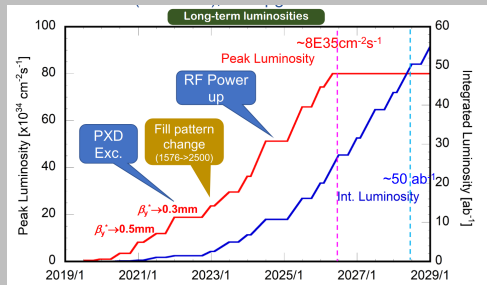


1912.11276 (accepted in PRL!)



Summary

- Belle II data-taking is ongoing, subdetectors performance have been confirmed
- Vertex Detectors cooling system working without any problem (yet)
- B physics traditional channels such as $B \rightarrow J/\psi K_S^0$ already should have a complete analysis result with 100fb^{-1} by ICHEP 2020
- $B \rightarrow \pi^+\pi^-$ hopefully soon after
- Dark sector analysis: dark photon, X_{17} and others will take longer



For more: [Belle II physics book](#)