

The Belle II experiment: Early physics and prospect



Manfred Berger

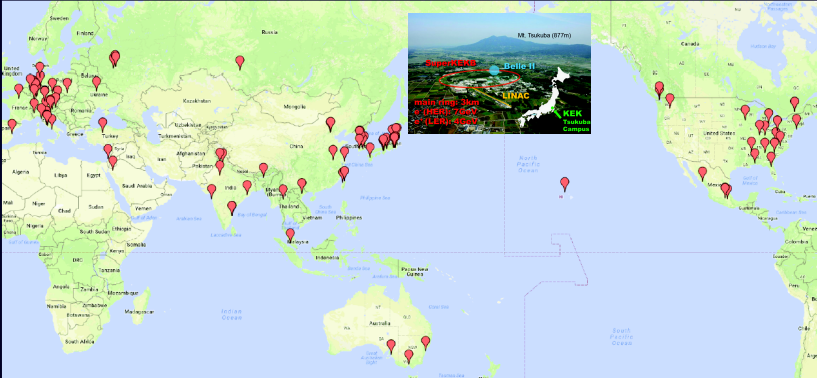


On Behalf of the Belle 2 collaboration

June 4, 2019

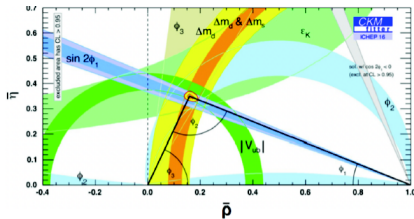
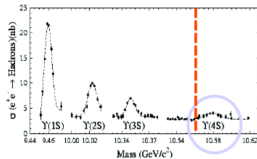
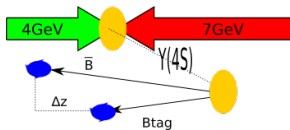
Belle2 Collaboration

Currently about 1000 members around the world.
Growing rapidly in recent years (about twice Belle)
Belle is still active (see Maria's talk on Wednesday)



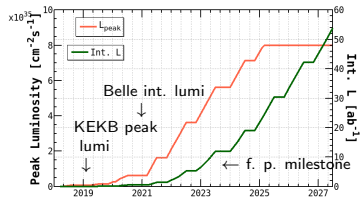
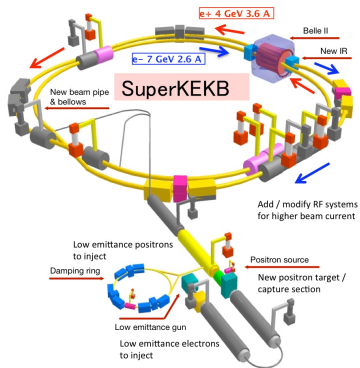
B-factory

- ▶ e^+e^- collision at $E_{cm} \approx m_{\Upsilon(4S)}$
- ▶ Δz between entangled $B\bar{B}$
- ▶ Belle and BaBar confirmed the Kobayashi-Maskawa mechanism
- ▶ Belle II: NP in flavour sector at intensity frontier
- ▶ Rich Physics program (τ , Quarkonium, dark sector)



Process	σ (nb)
$B\bar{B}$	1.1
$q\bar{q}$ (light)	2.1
$c\bar{c}$	1.3
$\tau^+\tau^-$	0.93
e^+e^-	40

SuperKEKB and the Nano beam scheme



Beam current

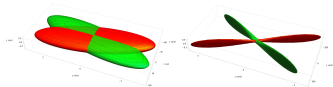
Beam-beam parameter

$$L = \frac{\gamma_{e\pm}}{2er_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \left(\frac{I_{e\pm} \xi_{y}^{\pm}}{\beta_y^*} \right) \left(\frac{R_L}{R_{\xi_y^{\pm}}} \right)$$

σ : beam size

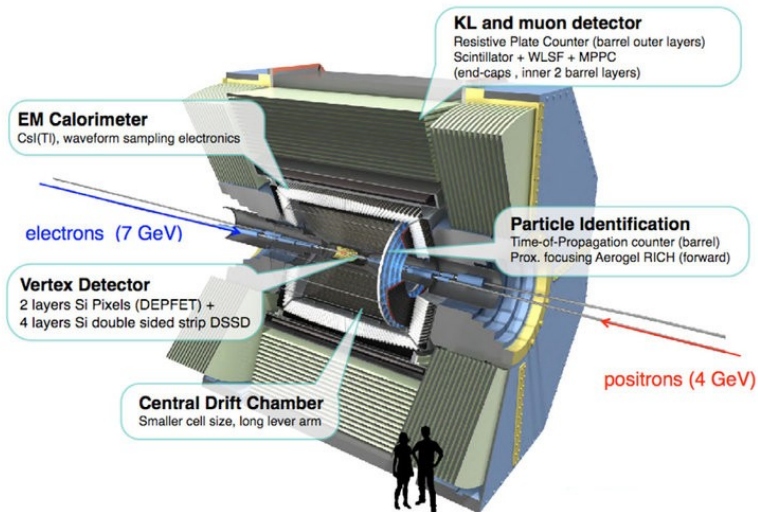
β function

- ▶ $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$, 40 times the luminosity of KEKB
- ▶ 2 times the beam Current
- ▶ 20 times smaller beam spot
- ▶ Slight decrease to boost



Belle II Detector

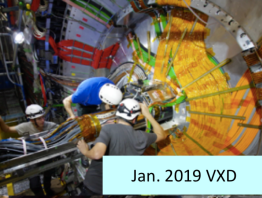
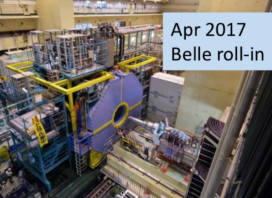
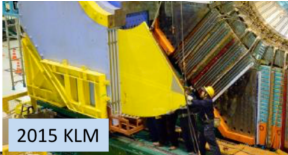
- ▶ Major upgrade from Belle
- ▶ 30 kHz trigger rate, more precision, larger tracking detector



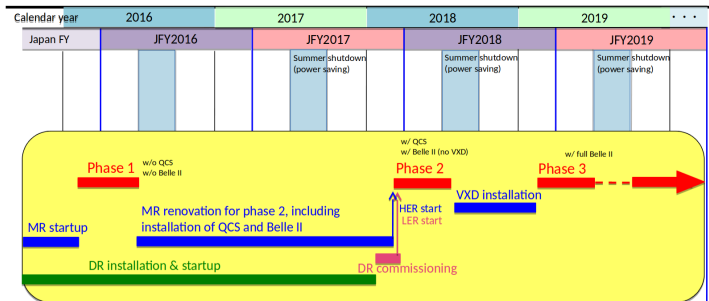
Belle II in pictures

- 2010, Belle and KEKB operation completed
- Started upgrade to Belle II and SuperKEKB

Sub-detector installation



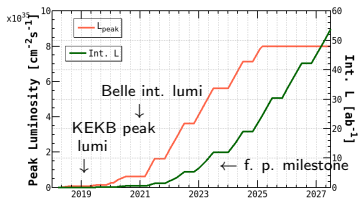
Timeline



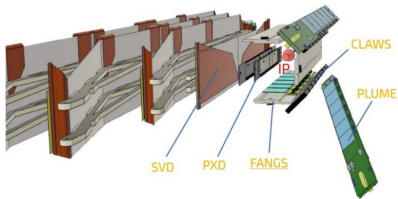
Phase 2 completed.

- ▶ 500 pb^{-1} integrated luminosity taken
- ▶ $5.5 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ luminosity achieved
- ▶ No VXD

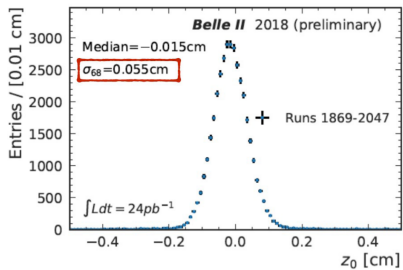
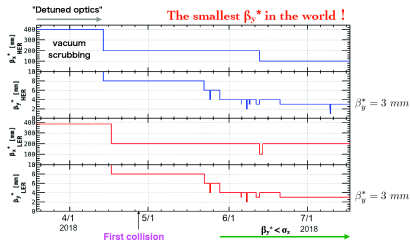
Started Phase 3



Phase 2



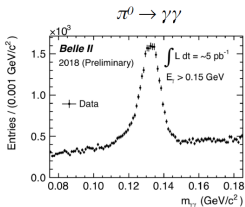
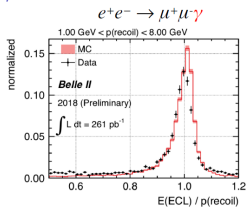
- ▶ Verifying the nano-beam scheme.
- ▶ Study backgrounds
- ▶ $\beta_y^* = 3\text{mm}$ reached. (Final goal: 300 nm)
- ▶ $\sigma_y = 400\text{nm}$ reached. (Final goal: 50 nm)
- ▶ Beamspot already ≈ 0.1 Belle



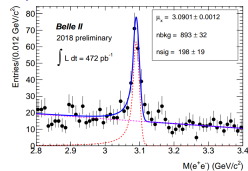
Phase 2

Physics rediscoversies

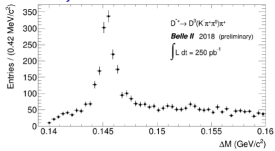
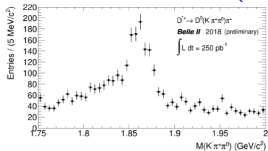
γ, π^0 reconstruction



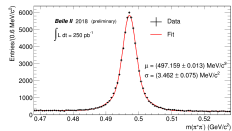
$J/\psi \rightarrow e^+e^- \gamma$



Charm: $D^* \rightarrow D^0(K^-\pi^+\pi^0)\pi^+$



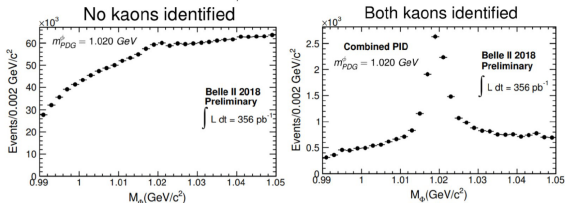
$K_S \rightarrow \pi^+\pi^-$



Performance during phase 2

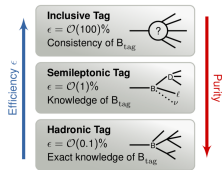
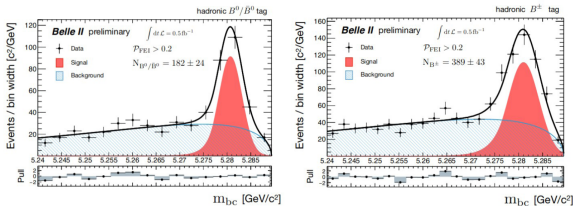
Kaon ID

$$\phi \rightarrow K^+ K^-$$



- ▶ Only TOP and drift chamber

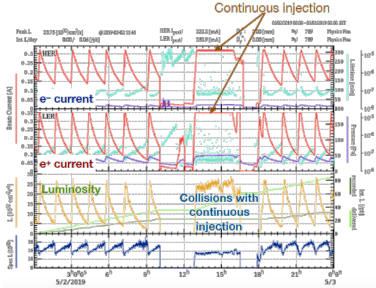
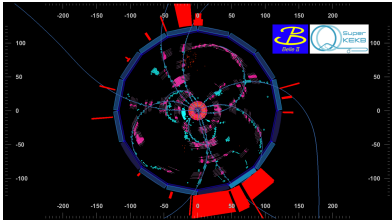
Hadronic tag



- ▶ More than 5000 modes to reconstruct B^{\pm} and B^0

Phase 3

- ▶ Full Belle II coverage
- ▶ Started March 2019
- ▶ Current focus on beam background remediation
- ▶ Plan to collect $\pm 5 \text{ fb}^{-1}$ by July



Downtime for most of April
Unrelated fire incident near LinAc

Performance studies

Semileptonic B decays

See talk by Antonio later in this session.

Radiative EW Penguins

$$B \rightarrow K^* \gamma \quad (2 \text{ fb}^{-1})$$

$$B \rightarrow X_s \gamma \quad (10 \text{ fb}^{-1})$$

Charm

D lifetime (2 fb^{-1})

$$D^0 \rightarrow K^+ \pi^- \quad (10 \text{ fb}^{-1})$$

$$D^0 \rightarrow K^+ \pi^- \pi^0 \quad (10 \text{ fb}^{-1})$$

Hadronic B decays

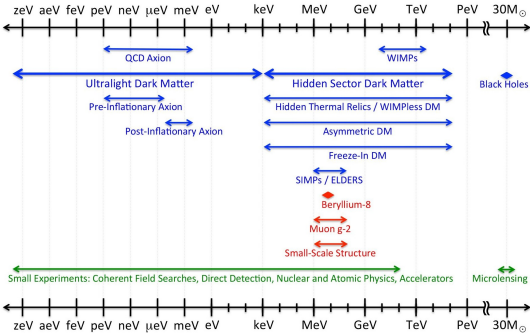
$$B \rightarrow K \pi \quad (10 \text{ fb}^{-1})$$

$$B \rightarrow \phi K \quad (10 \text{ fb}^{-1}) \quad B \rightarrow J/\psi K \quad (2\text{-}10 \text{ fb}^{-1})$$

Probably first publications: Dark Sector

Dark Sector at Belle II

Dark Sector Candidates, Anomalies, and Search Techniques



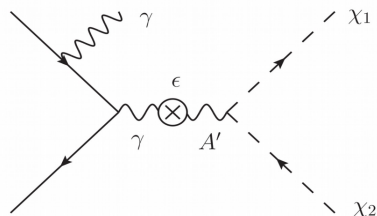
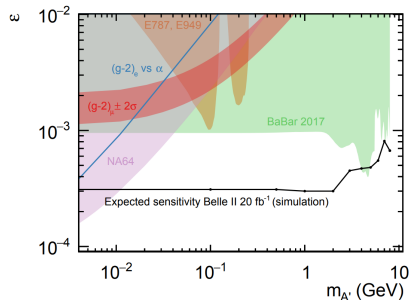
Belle II can reach

- ▶ Below GeV scale
- ▶ Missing energy
- ▶ Dark forces
- ▶ Multiple photons



Probably first publications: Dark Sector

Dark γ sensitivity



Single γ trigger

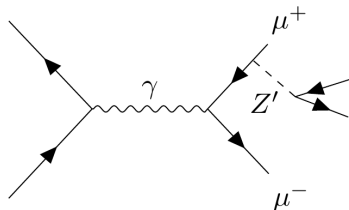
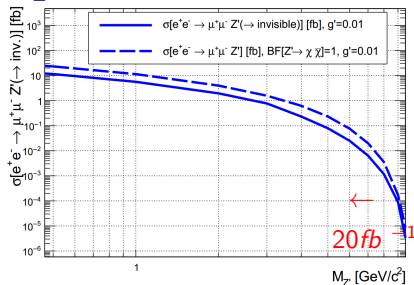
- ▶ $E < 1$ GeV and 2nd cluster
 $E < 300$ MeV
- ▶ $E > 2$ GeV and Bhabha veto
and $e^-e^+ \rightarrow \gamma\gamma$ veto

Phase 2

- ▶ Vector: Dark photon A' ,
Dark Z'
- ▶ Pseudo Scalar: ALPs, axion

Probably first publications: Dark Sector

$M_{Z'}$ sensitivity



Z' signal

- ▶ Z' only couples to 2nd and 3rd gen leptons
- ▶ Recoil mass against $\mu^+\mu^-$ pair

Phase 2

- ▶ Vector: Dark photon A' , Dark Z'
- ▶ Pseudo Scalar: ALPs, axion

Summary and outlook

- ▶ Phase 2 run has been successfully concluded.
- ▶ Phase 3 started in March 2019
 - ▶ Physics run with the full Belle II detector
 - ▶ 5 fb^{-1} by July.
 - ▶ 100 fb^{-1} by end of the year.
- ▶ Already competitive results at 10 fb^{-1} .
- ▶ 50 ab^{-1} after 8 years.

