

Belle II status and early physics



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Rencontres de Blois, June 4, 2019

Belle/BaBar era – confirming the Standard model (SM)

- Data collection period: 1999-2020
- The main goal of these experiments was:
 - observation and precise measurements of CP -violation in B -decays
 - $\sin 2\beta$ is still the most precise measurement in the World
- Also many other results were obtained:
 - precise measurements of all CKM parameters
 - study of heavy flavor spectroscopy, including many unexpected results:
 - exotic states observations, starting from $X(3872)$
 - new bottomonium states
 - studies of τ , $\gamma\gamma$ and rare decays
 - etc.
- More than 1000 papers were published by Belle & BaBar

Belle/BaBar era – confirming the Standard model (SM)

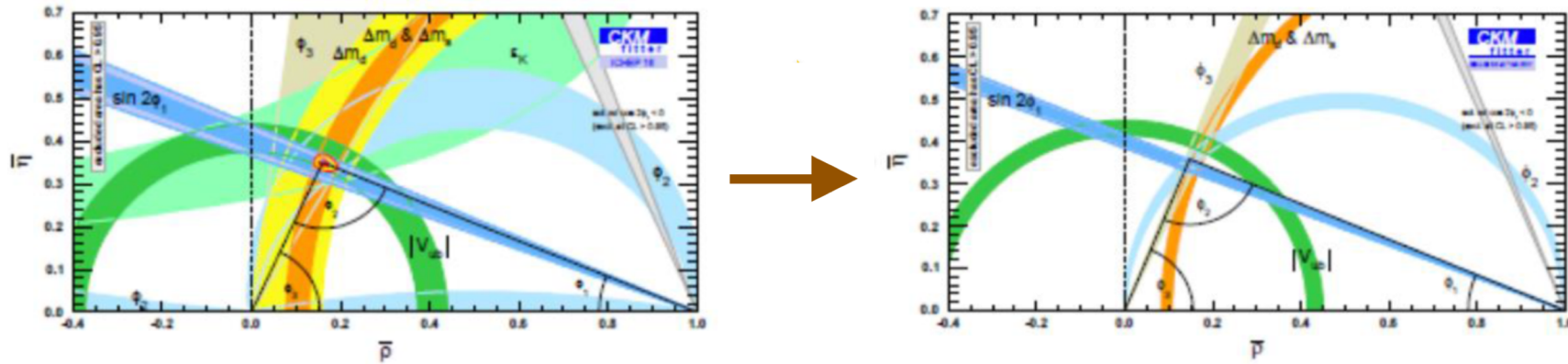
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 - etc.
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The success of these experiments led to the Nobel prize for Kobayashi and Maskawa in 2008



Belle II: new experiment – new goal: search for New Physics

- With total statistics of $\approx 1.5 \text{ ab}^{-1}$ accumulated by Belle & BaBar no significant deviations from Standard model were observed
- Belle II will test SM on the next level using 50 ab^{-1} data (x 50 of Belle data)
 - CP -violation in $b \rightarrow s$ transitions – search for new CP -violating phase to explain a large matter-antimatter asymmetry in the Universe
 - precise measurements of CKM – search for NP in the Unitarity triangle inconsistency



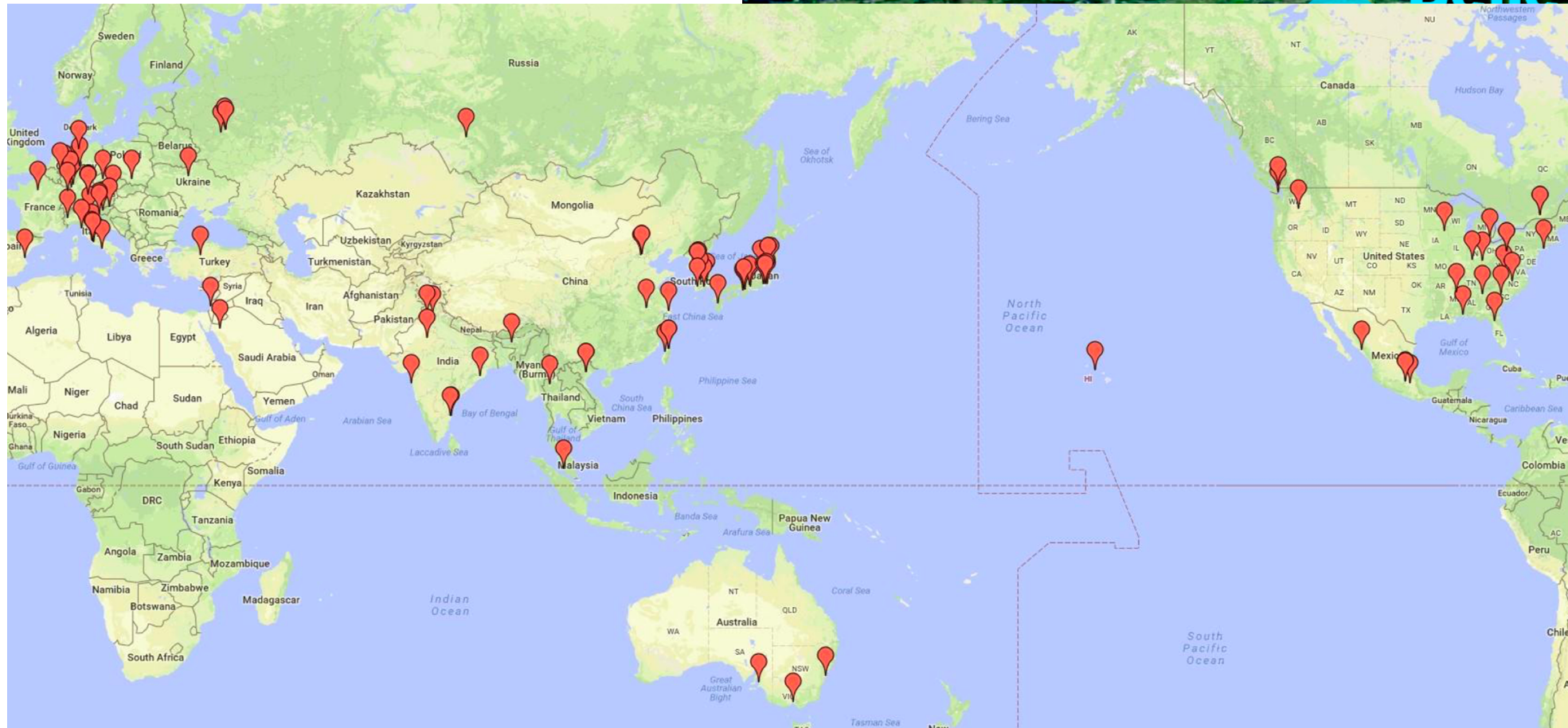
- BR of $B^+ \rightarrow l^+ \nu$ and $B \rightarrow D^{(*)} \tau \nu$ – search for charged Higgs
- CP -violation in $B \rightarrow K^{*0} \gamma$ – search for left-right asymmetry
- $b \rightarrow s l^+ l^-, s \nu \nu$ – search for New Physics (NP) in flavor changing neutral current transitions
- search for exotics states, like tetraquarks, pentaquarks and hybrid QCD states
- study of τ decays – search for lepton flavor violation

Belle II experiment

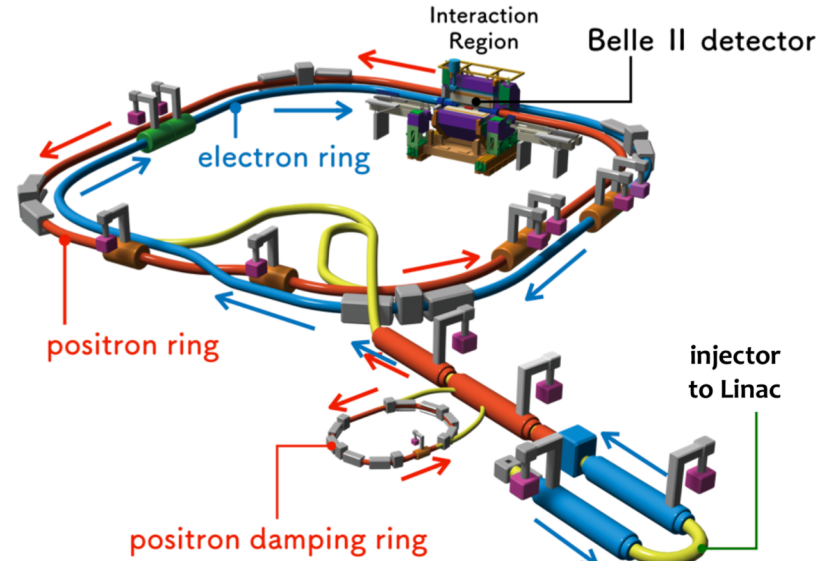
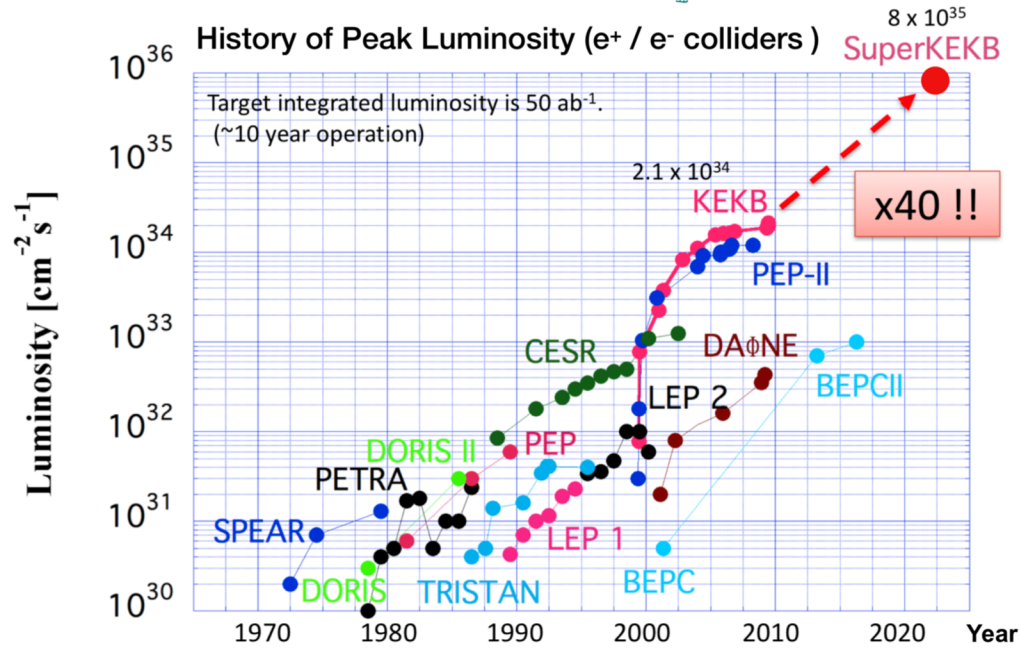


Belle II experiment

Belle II Collaboration contains over 900 members from 26 countries and is actively growing



Upgrade of KEKB accelerator to SuperKEKB

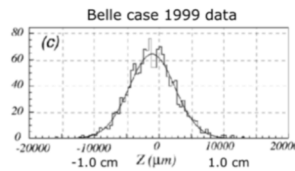


$$e^- \xrightarrow{7 \text{ GeV}} (\star) \xleftarrow{4 \text{ GeV}} e^+$$

Ordinary collision KEKB



Z vertex distribution



$\sigma = 4.5 \text{ mm}$

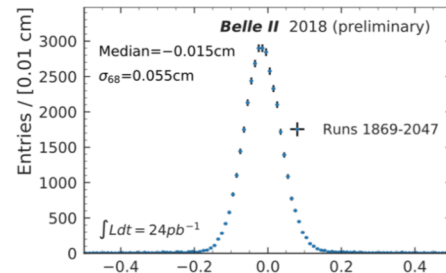
Nano-Beam (SuperKEKB)



$2\phi = 83 \text{ mrad}$

Z vertex distribution

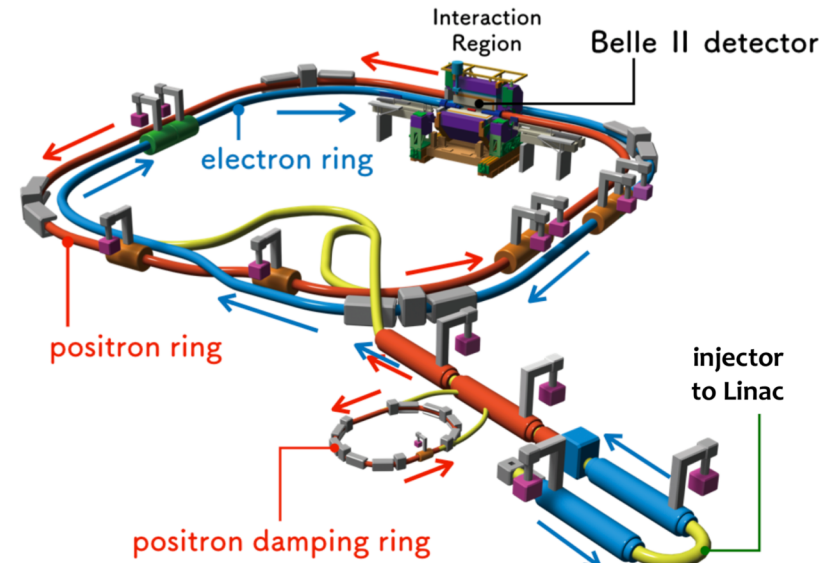
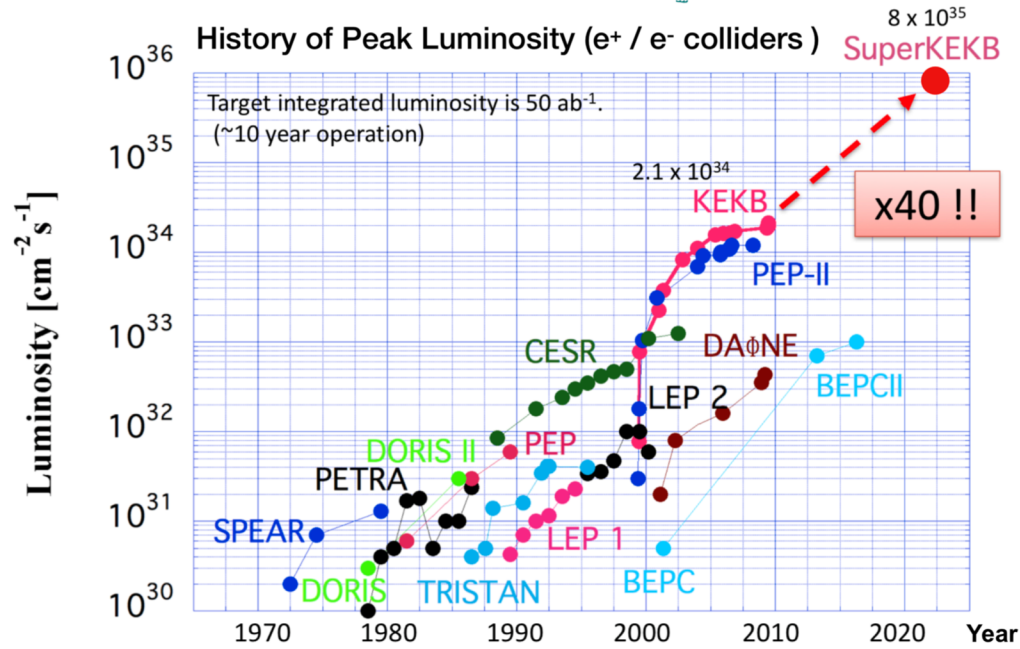
Belle II case 2018 data



$\sigma = 550 \mu\text{m}$

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

Upgrade of KEKB accelerator to SuperKEKB

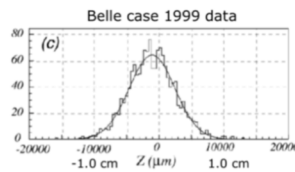


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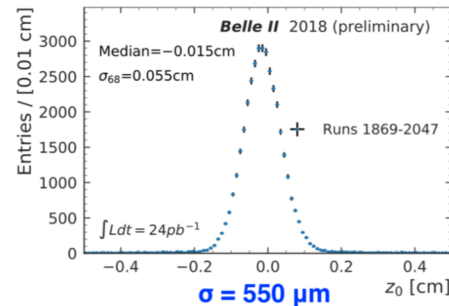
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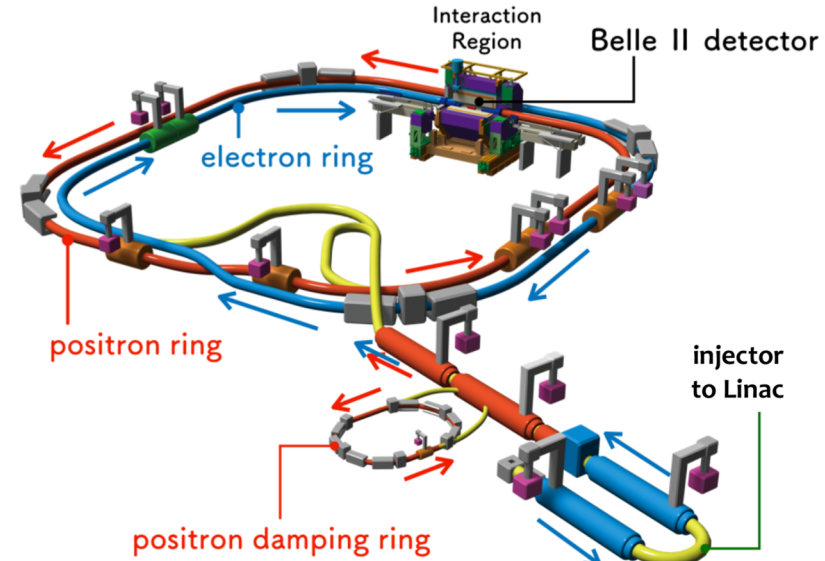
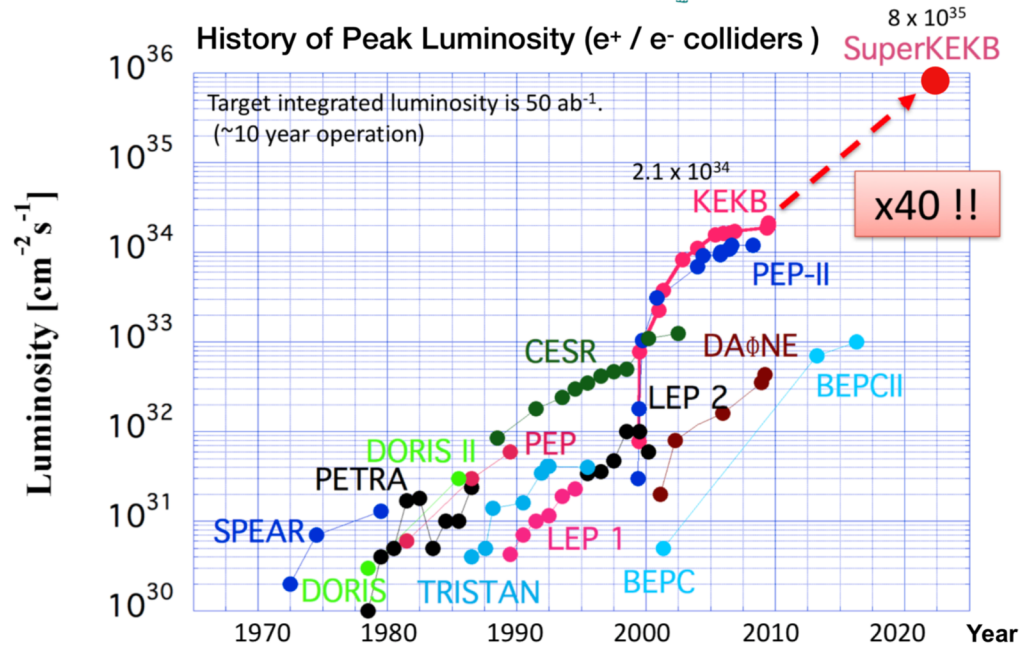
Belle II case 2018 data



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

- Doubling the beam current

Upgrade of KEKB accelerator to SuperKEKB

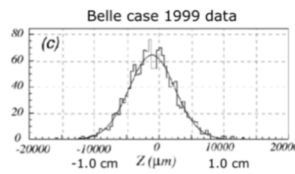


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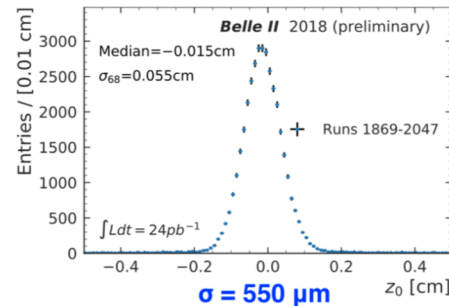
Nano-Beam (SuperKEKB)



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Belle II case 2018 data

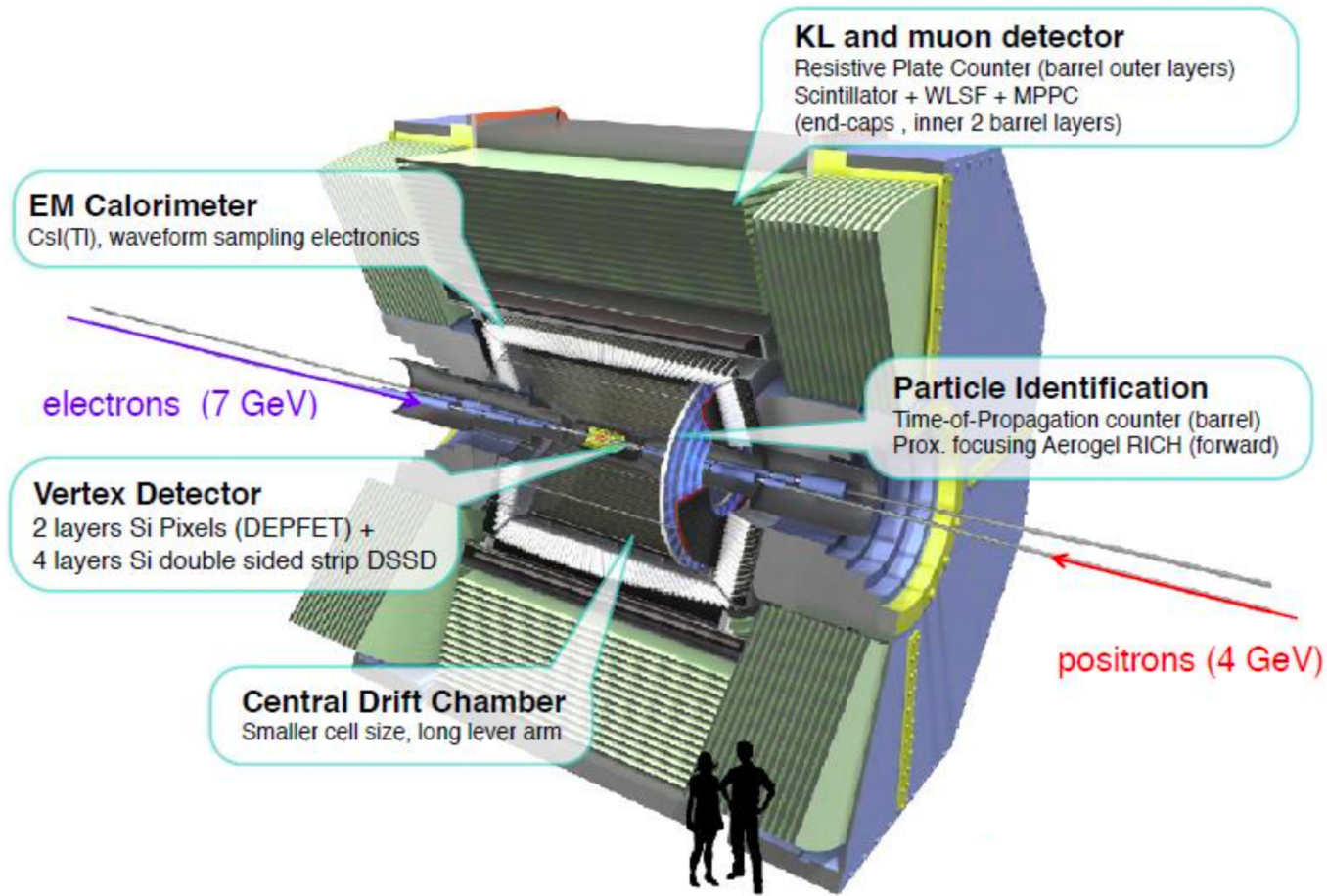


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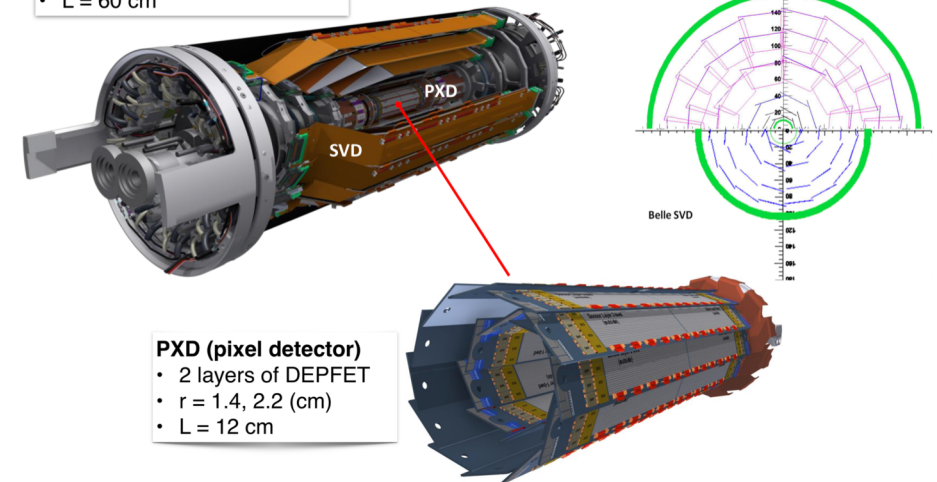
- Doubling the beam current
- Reducing the beam size by factor 20 at IP

Upgrade from Belle detector to Belle II

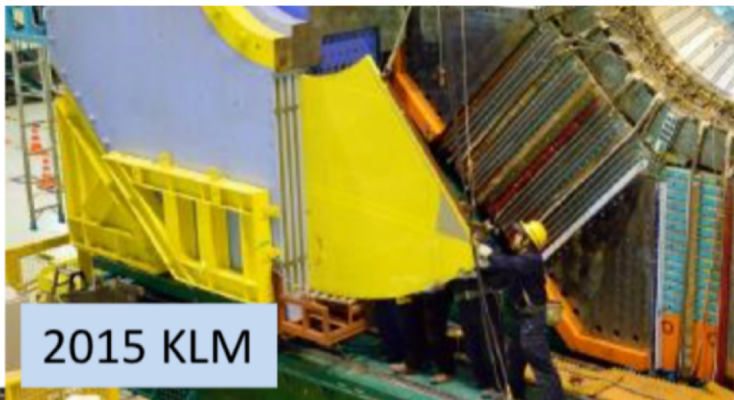
- Higher luminosity → higher occupancy & background level
- Upgrade of all Belle detector subsystems was done



- SVD**
- 4 layers of DSSD
 - $r = 3.8, 8.0, 11.5, 14.0$ (cm)
 - $L = 60$ cm



Belle II detector commissioning



2015 KLM



May 2016: TOP



Oct. 2016: CDC



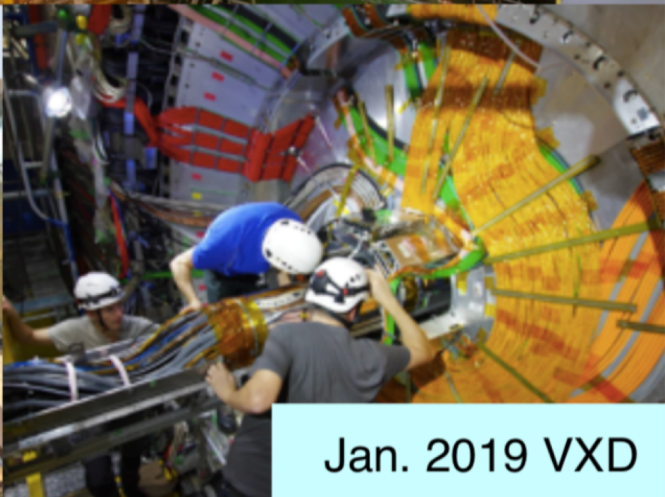
Jan. 2017 BWD ECL



Apr 2017
Belle roll-in

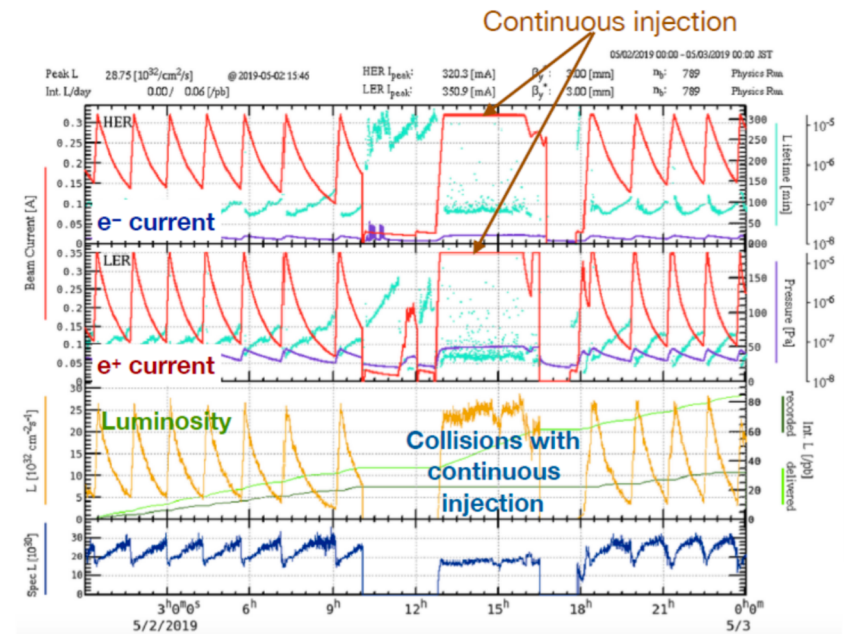
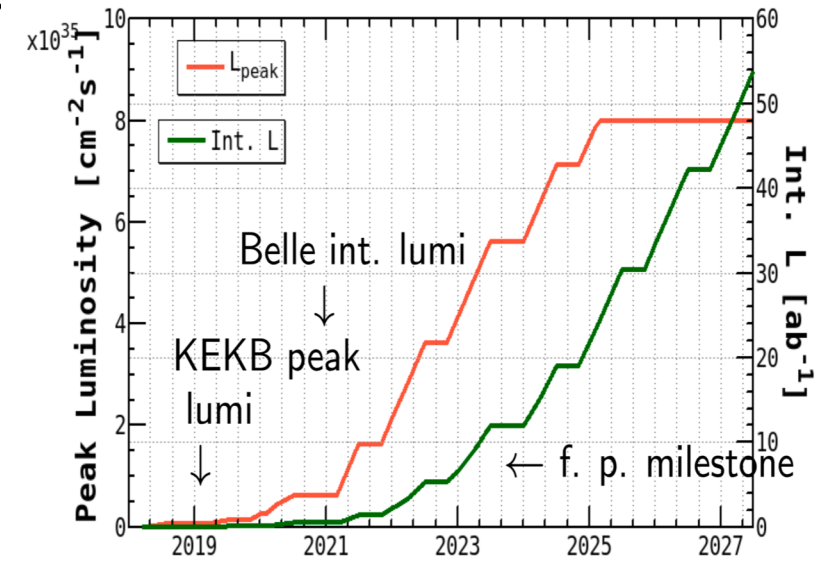
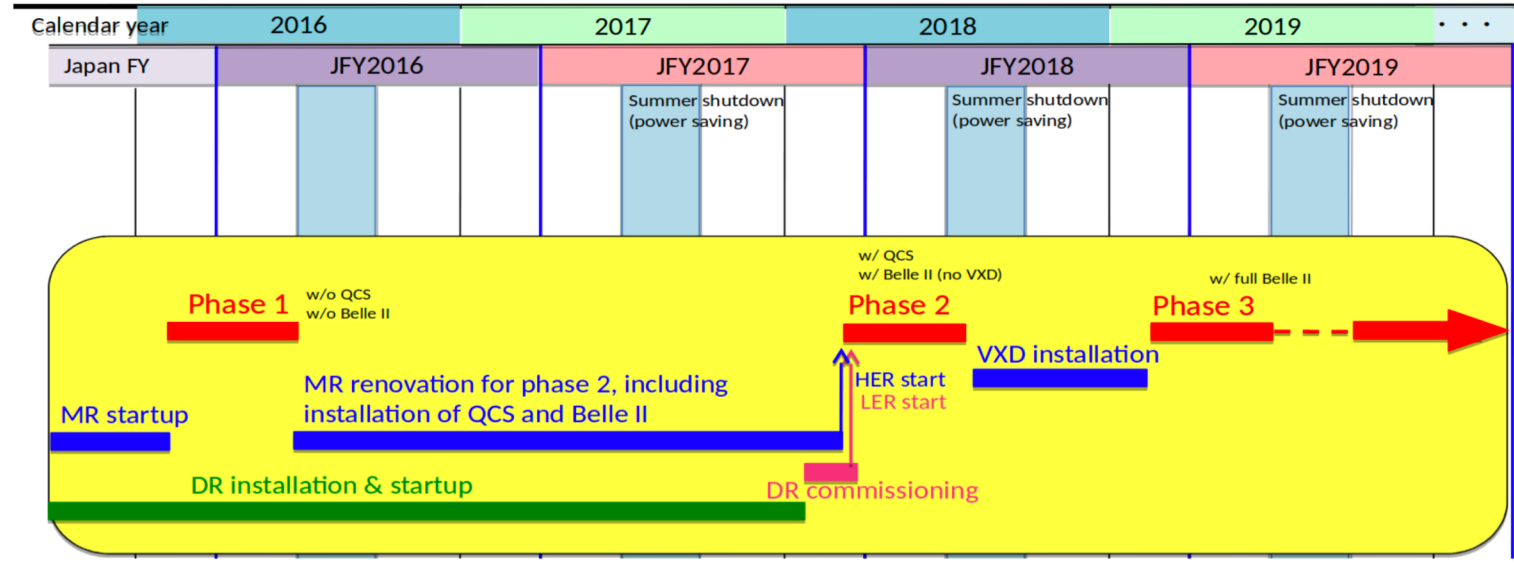


Aug.2017:ARICH

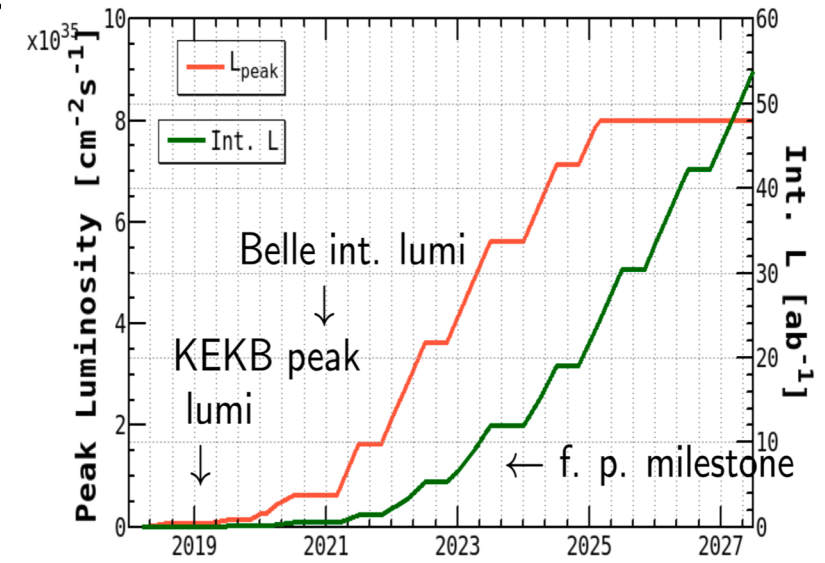
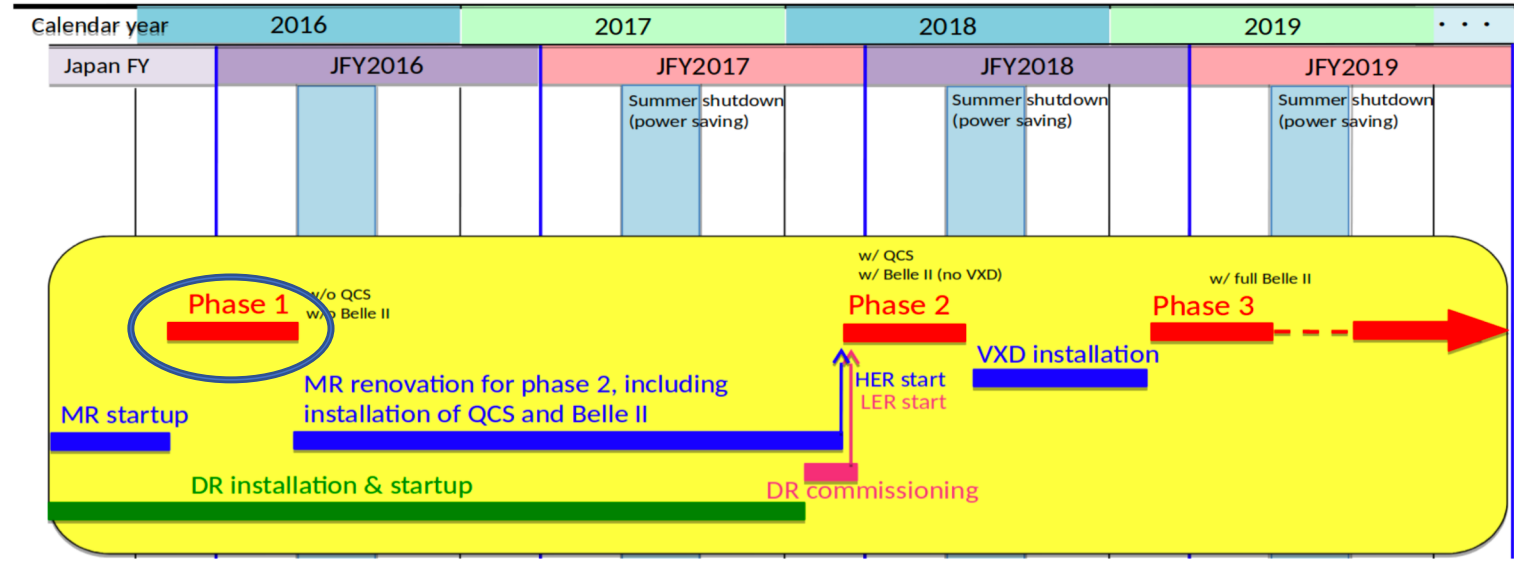


Jan. 2019 VXD

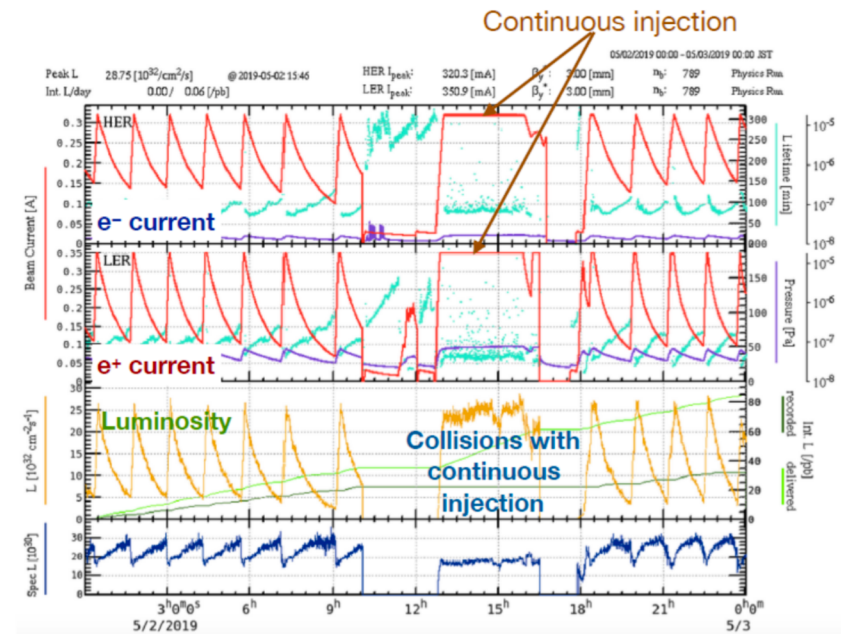
SuperKEKB & Belle II schedule



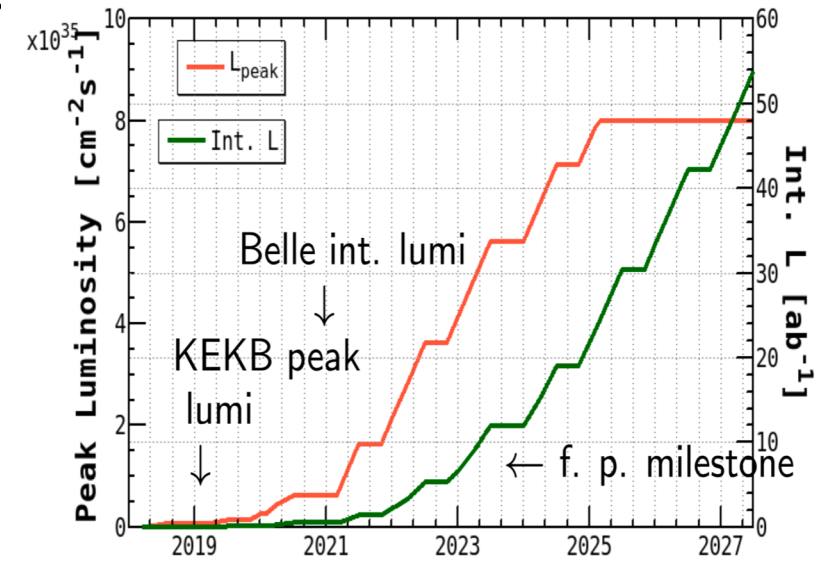
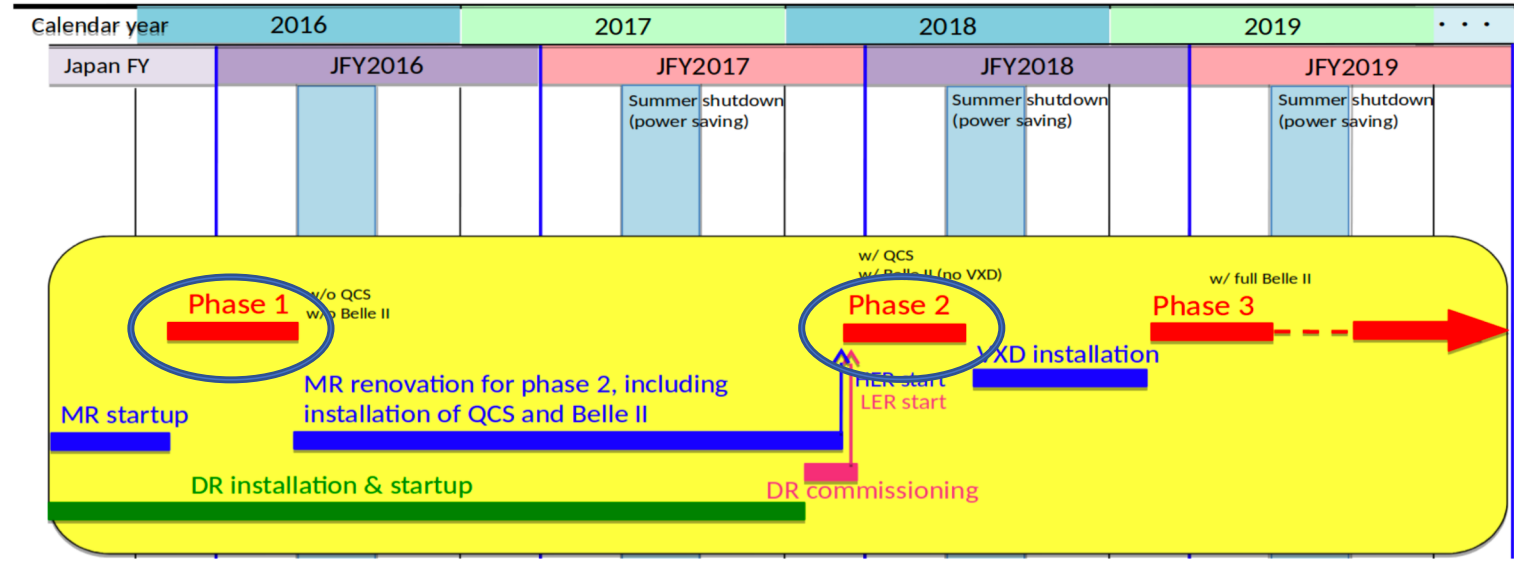
SuperKEKB & Belle II schedule



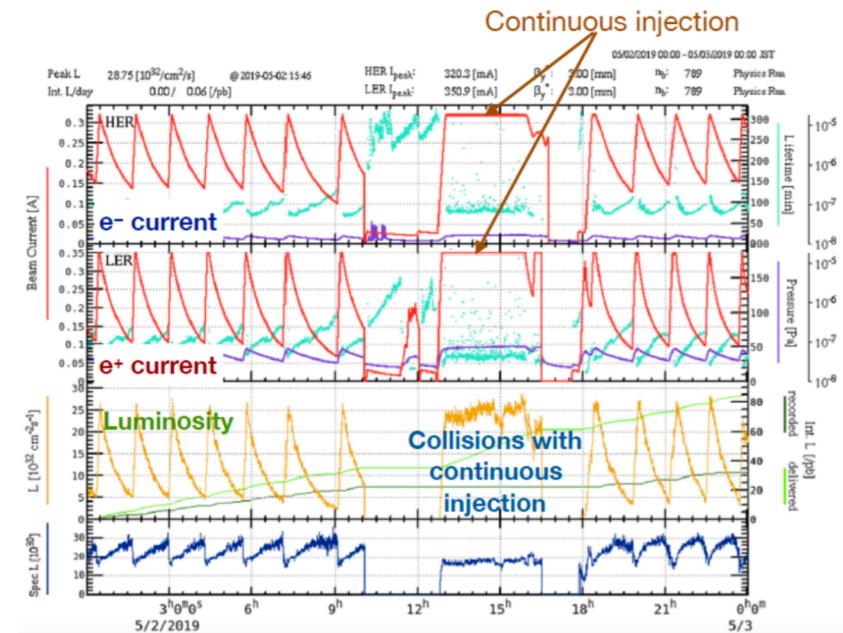
- Phase 1: SuperKEKB commissioning w/o final focus w/o Belle II



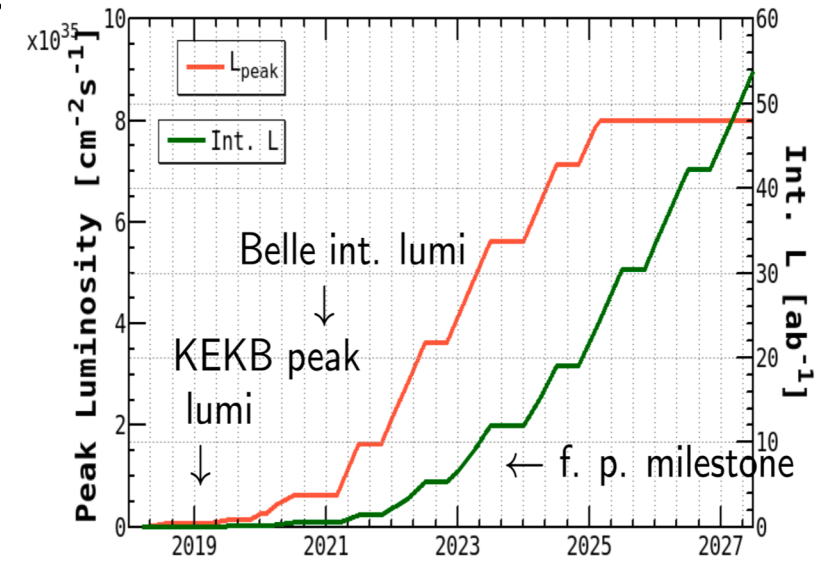
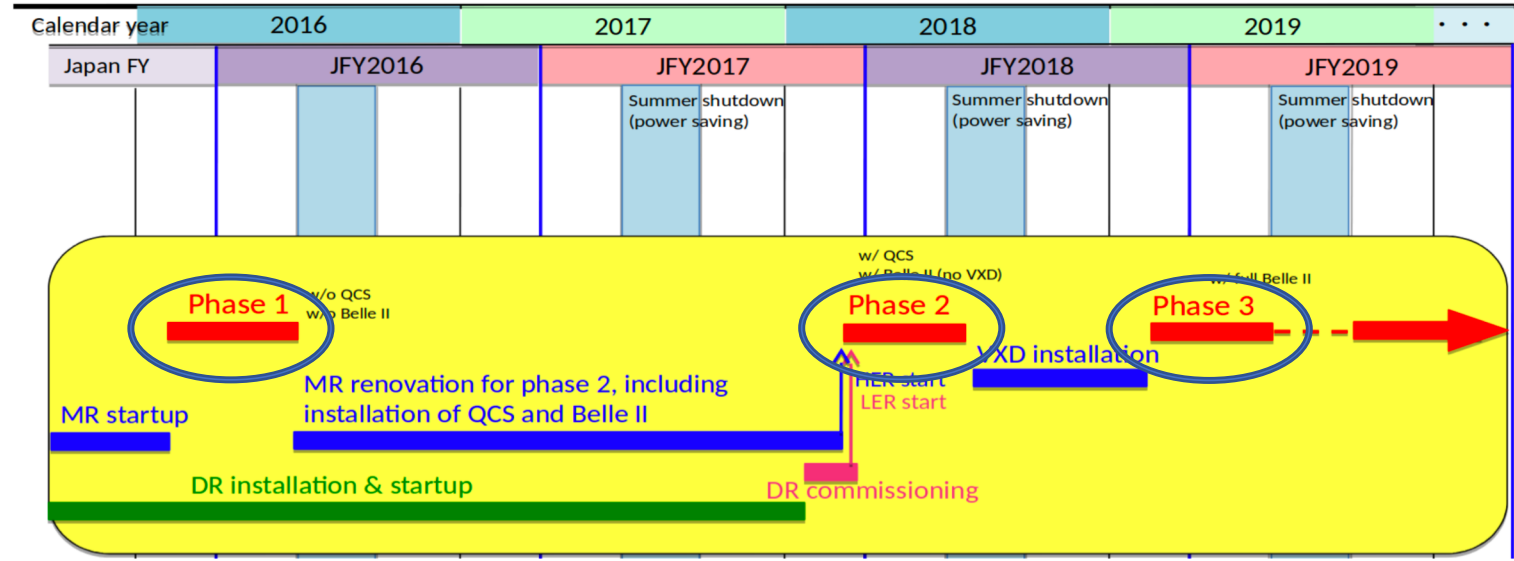
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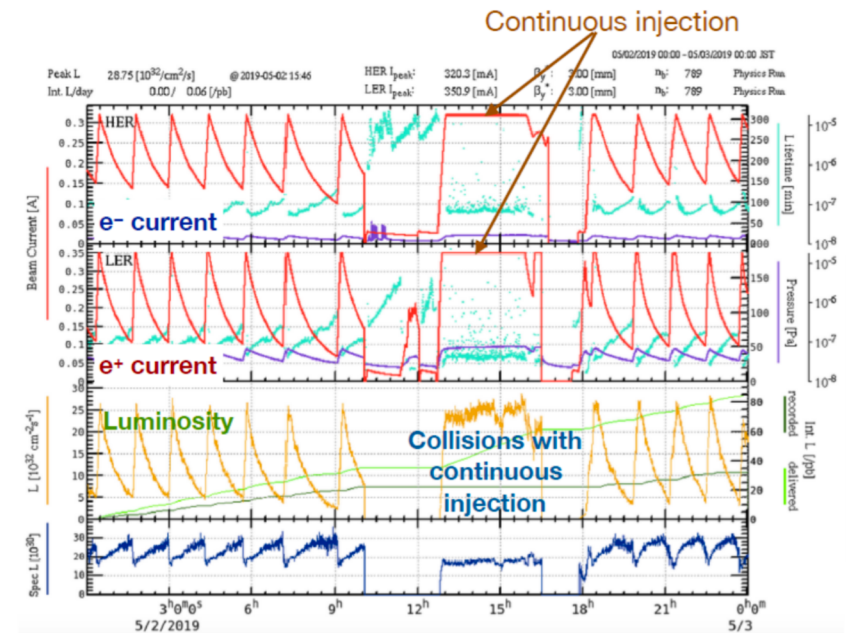
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- Phase 2: collision w/ final focus w/ Belle II w/o VXD (**500 pb⁻¹ recorded**)



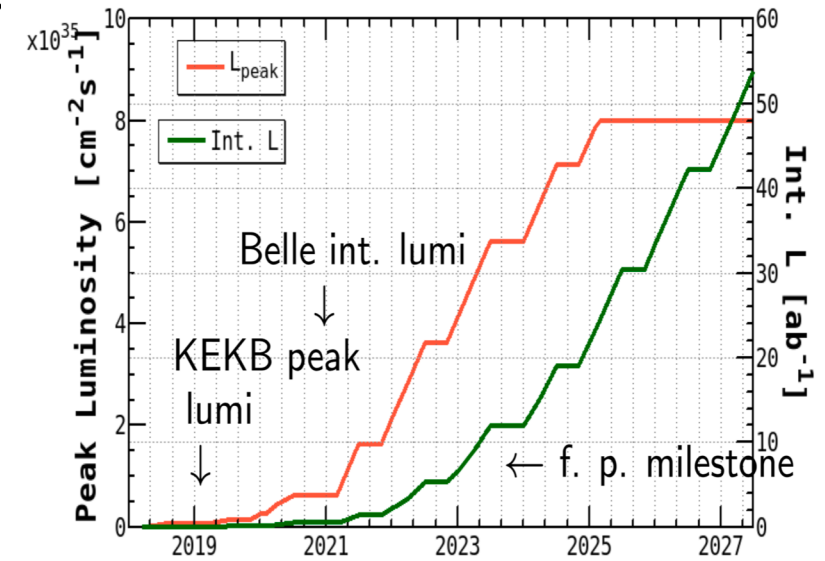
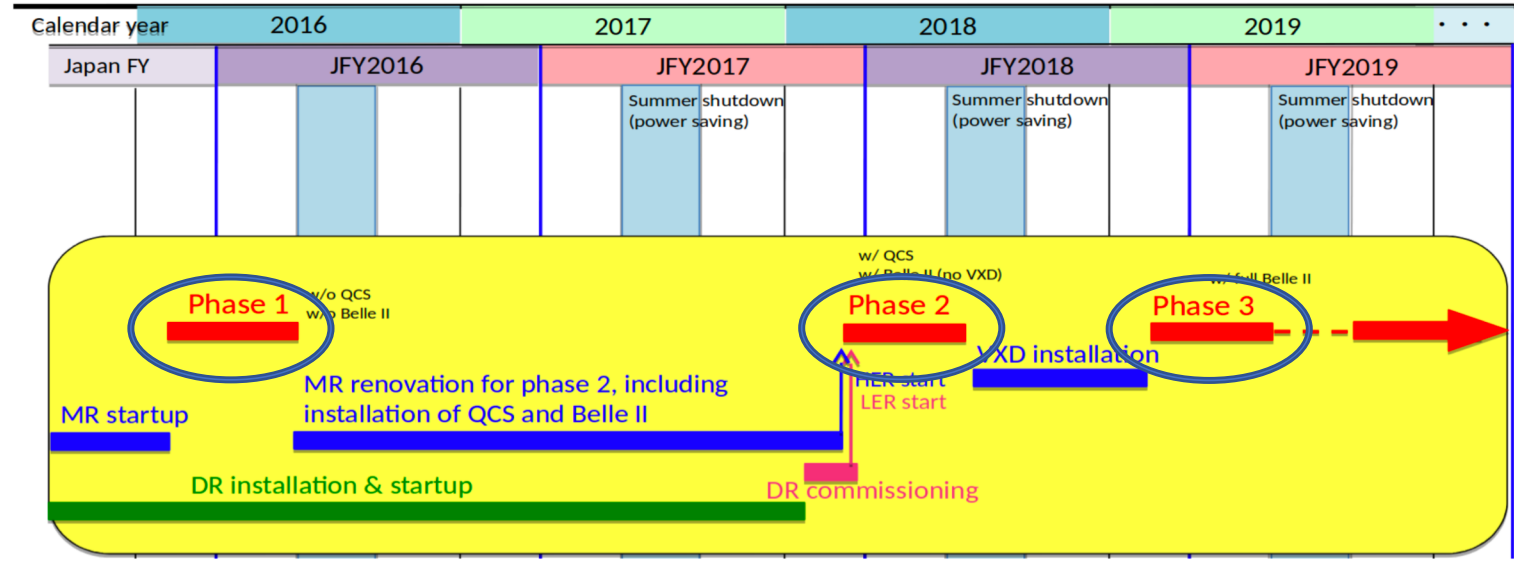
SuperKEKB & Belle II schedule



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- Phase 3: collision w/ full Belle II (since March 25, 2019)

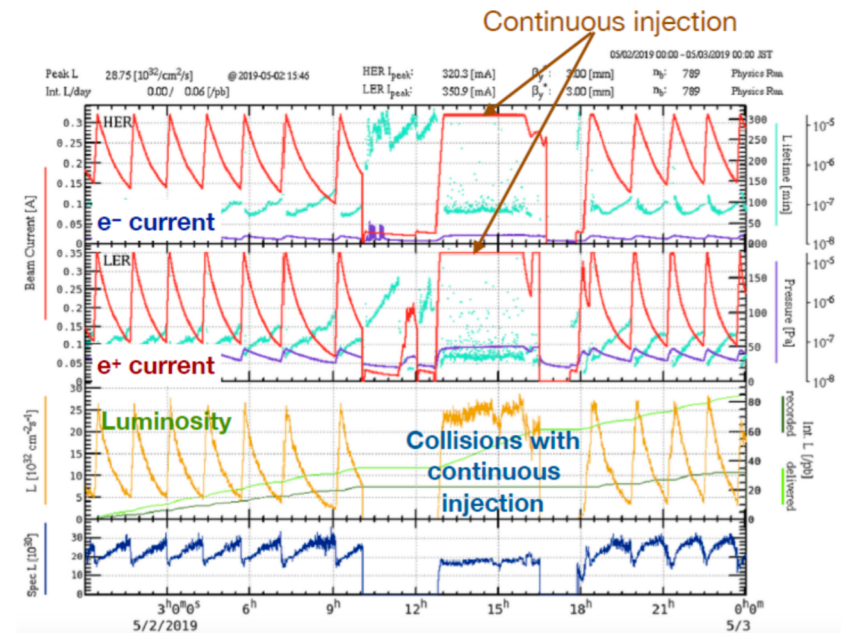


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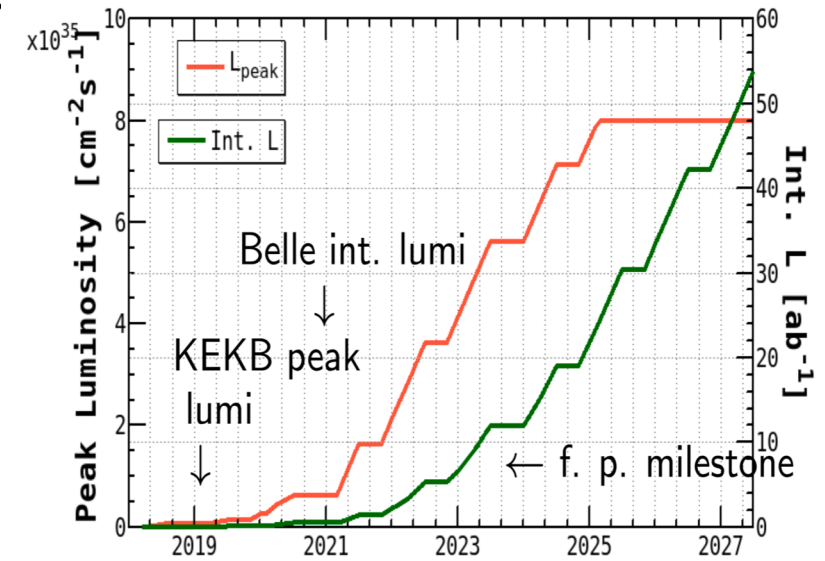
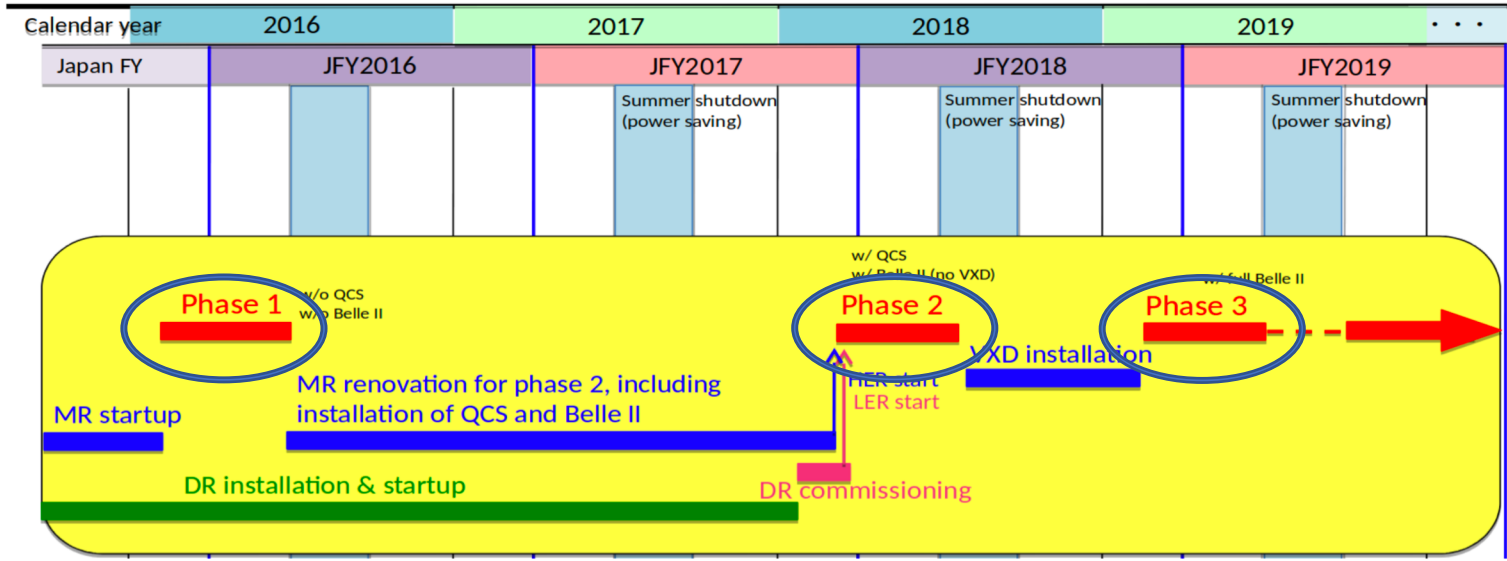


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Continuous injection was tested on May 2, 2019

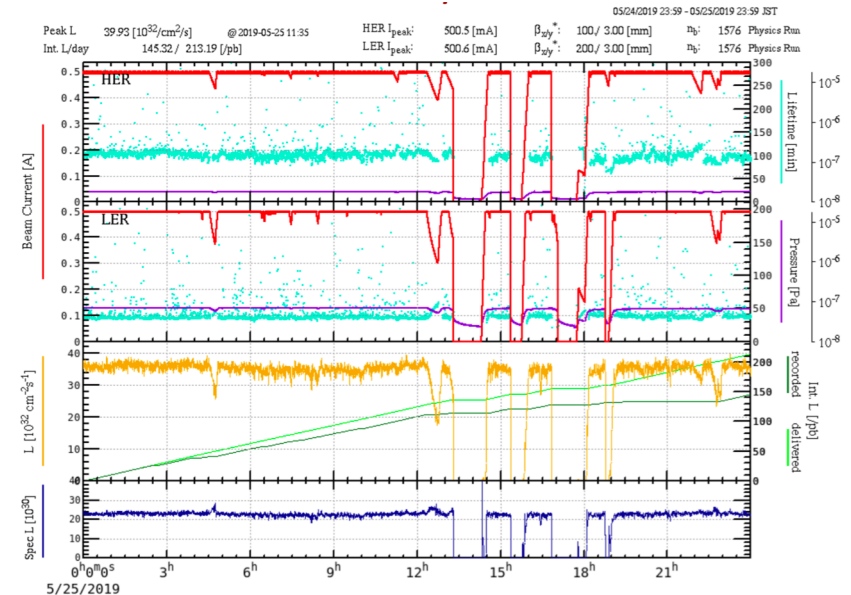


SuperKEKB & Belle II schedule

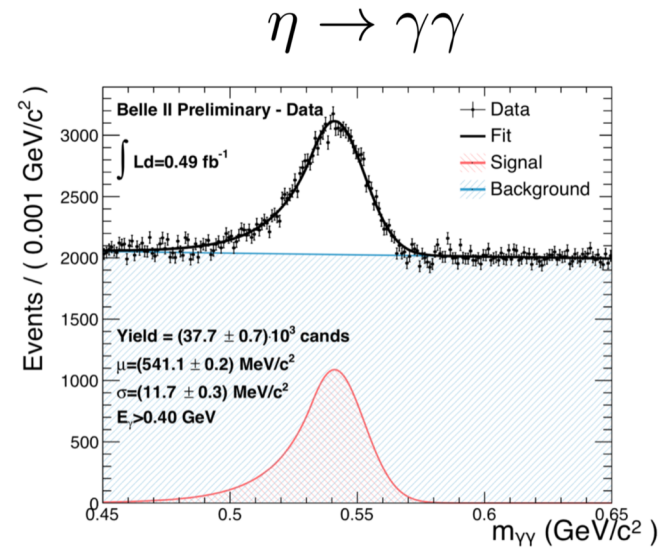
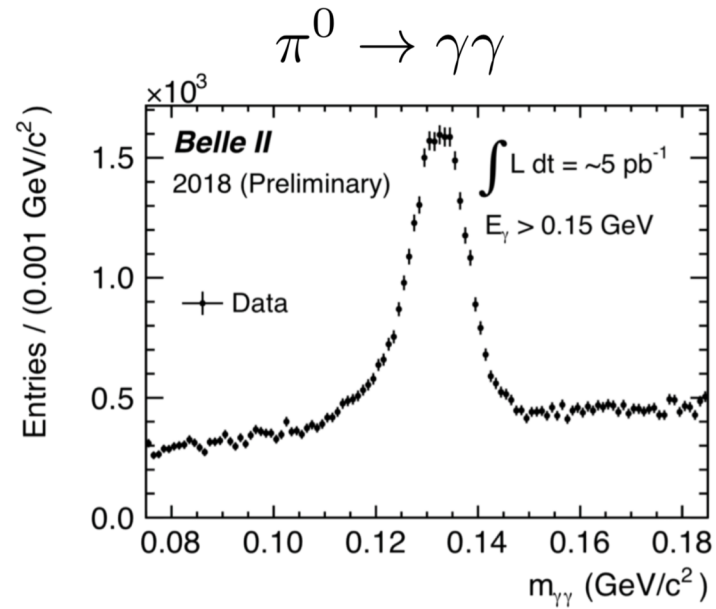


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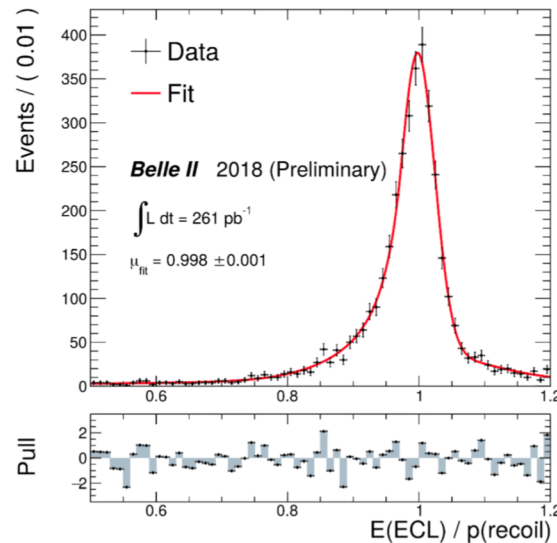
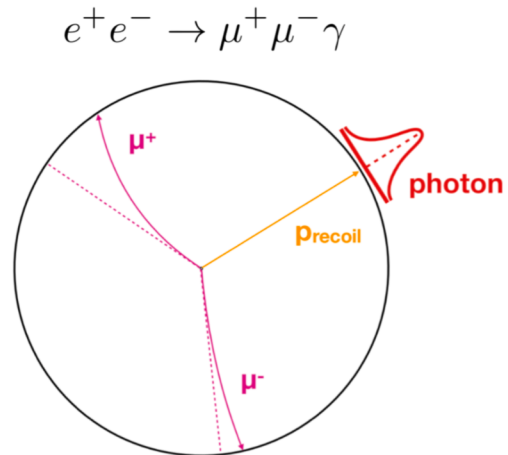
Continuous injection is operating (May 25, 2019)



Phase 2 – checking performance: calorimeter



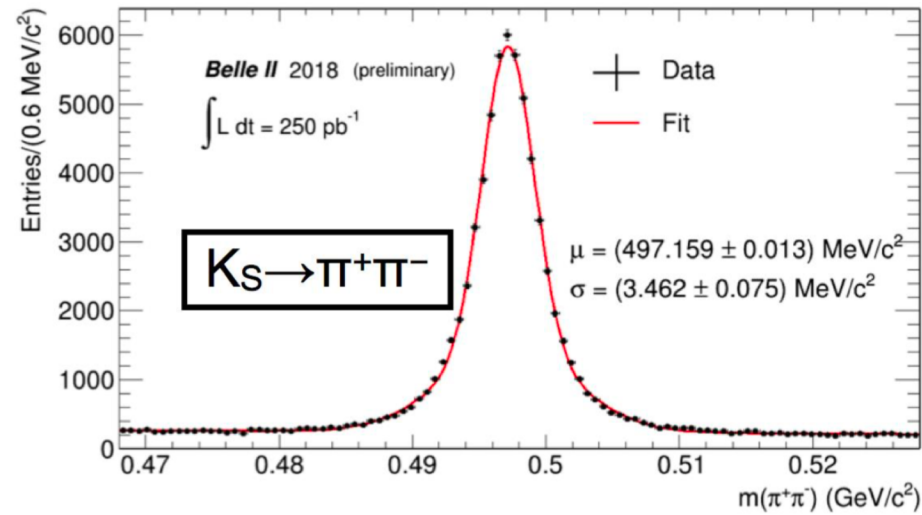
Proper π^0 & η masses –
good EM calorimeter calibration



Important for dark matter
search with single / triple
photon triggers:
 $e^+e^- \rightarrow \gamma X$
 $e^+e^- \rightarrow \gamma (\gamma \gamma)$

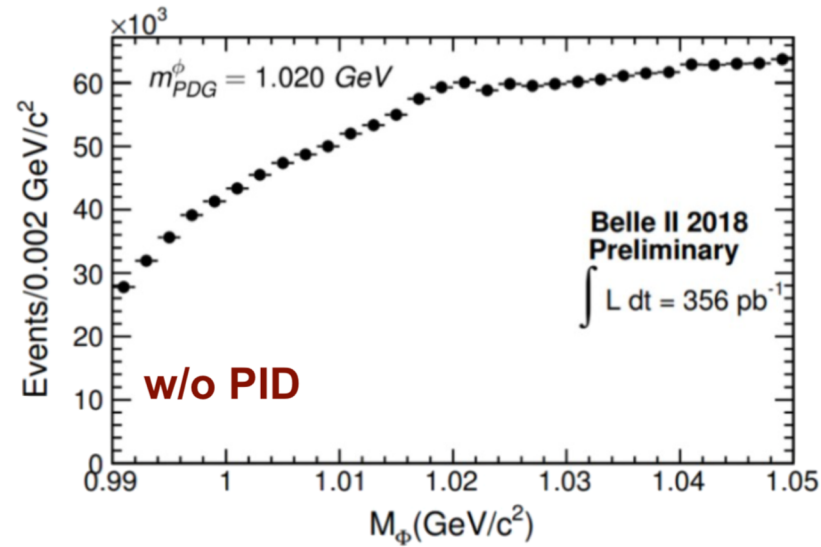
Phase 2 – checking performance: tracking

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

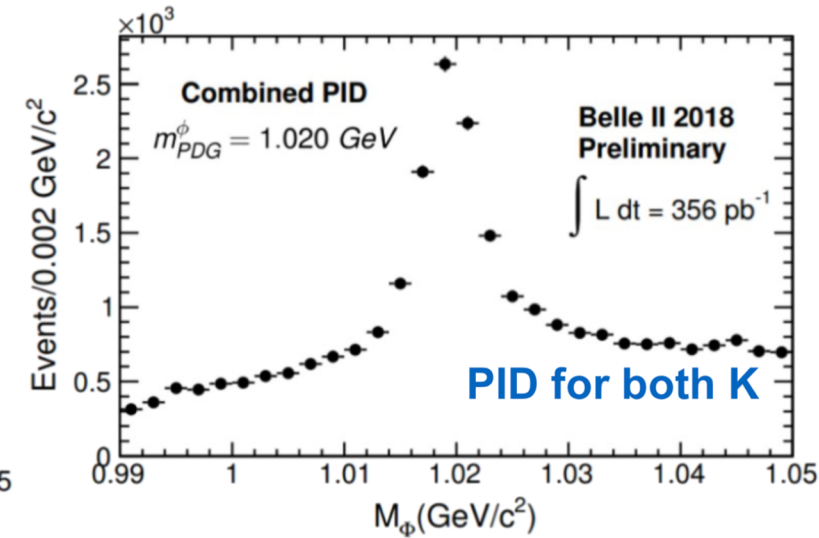


Good charged track's
momentum resolution

$$\phi \rightarrow K^+ K^- \text{ w/o PID}$$



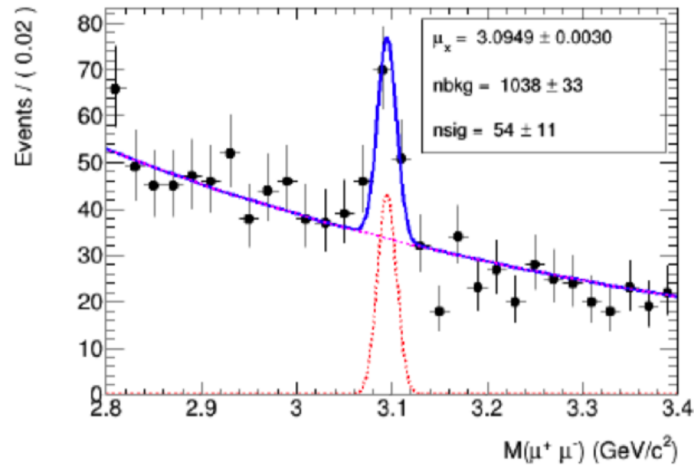
$$\phi \rightarrow K^+ K^- \text{ w/ PID}$$



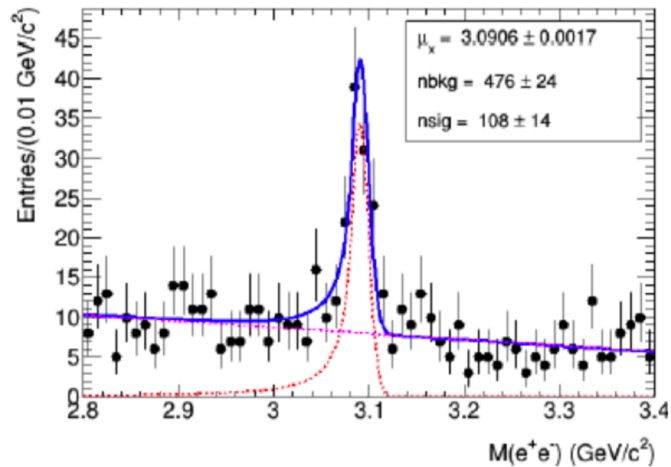
High PID performance

Phase 2 – checking performance: heavier particles

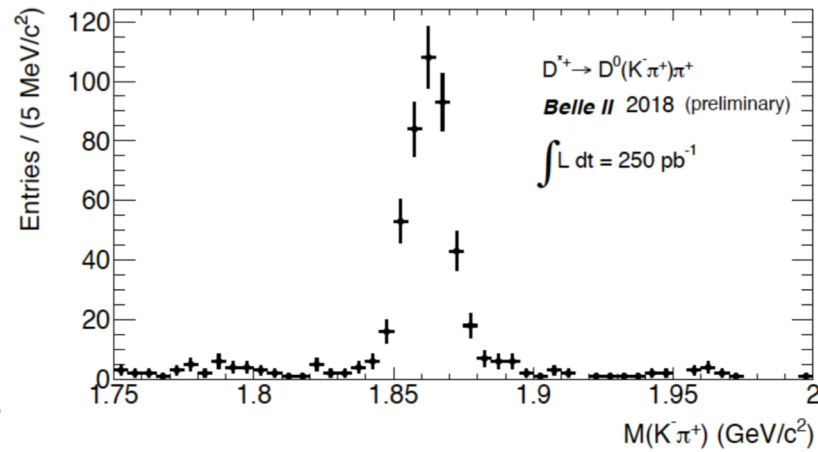
$J/\psi \rightarrow \mu^+\mu^-$



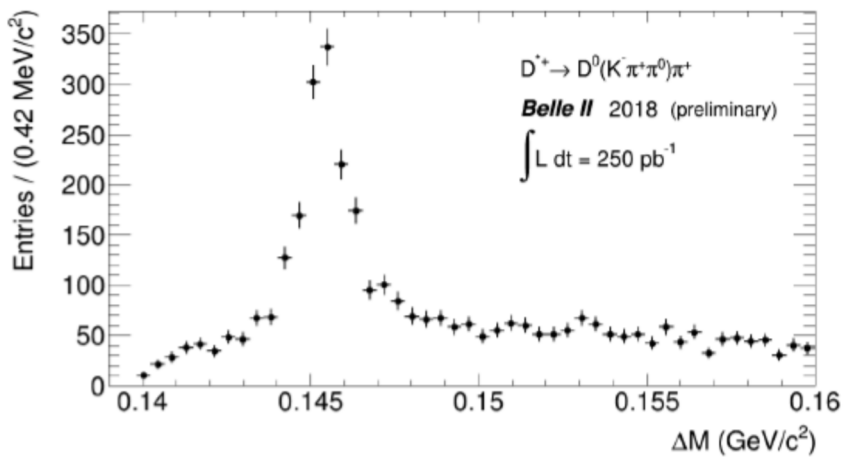
$J/\psi \rightarrow e^+e^-$



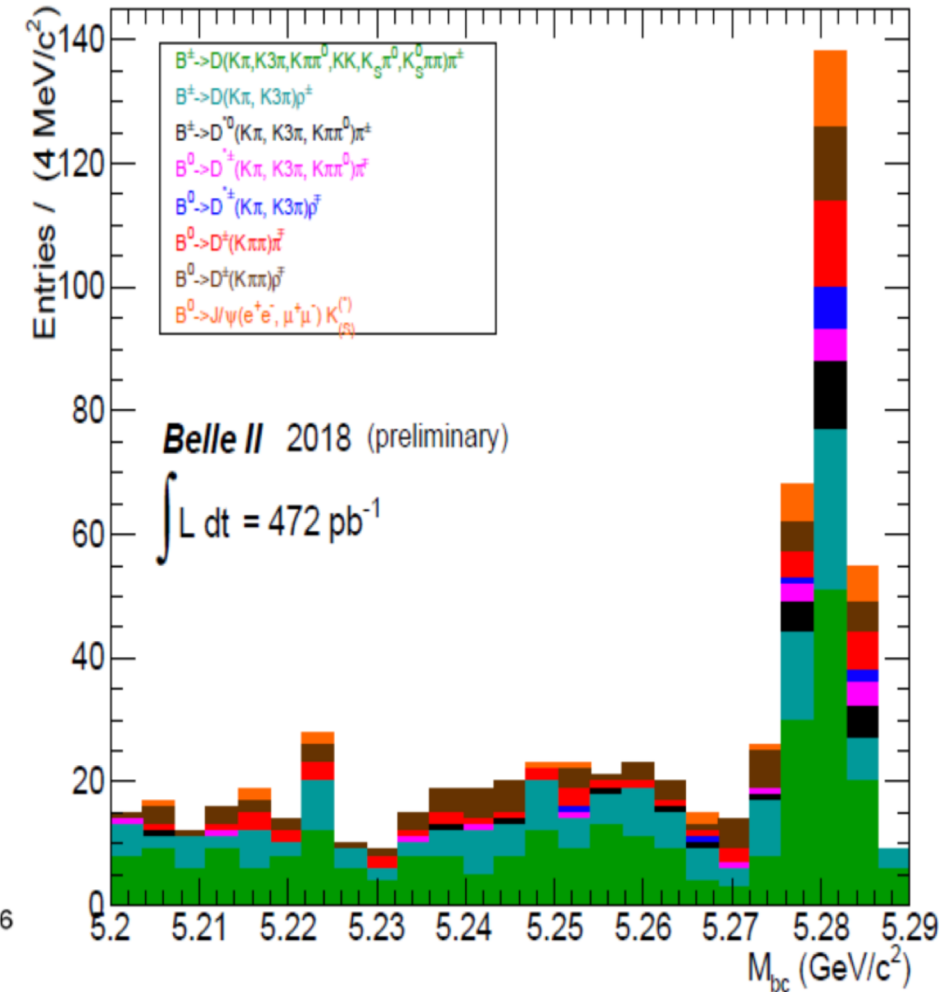
$D^0 \rightarrow K^-\pi^+$



$D^{*+} \rightarrow D^0(K^-\pi^+)\pi^+$

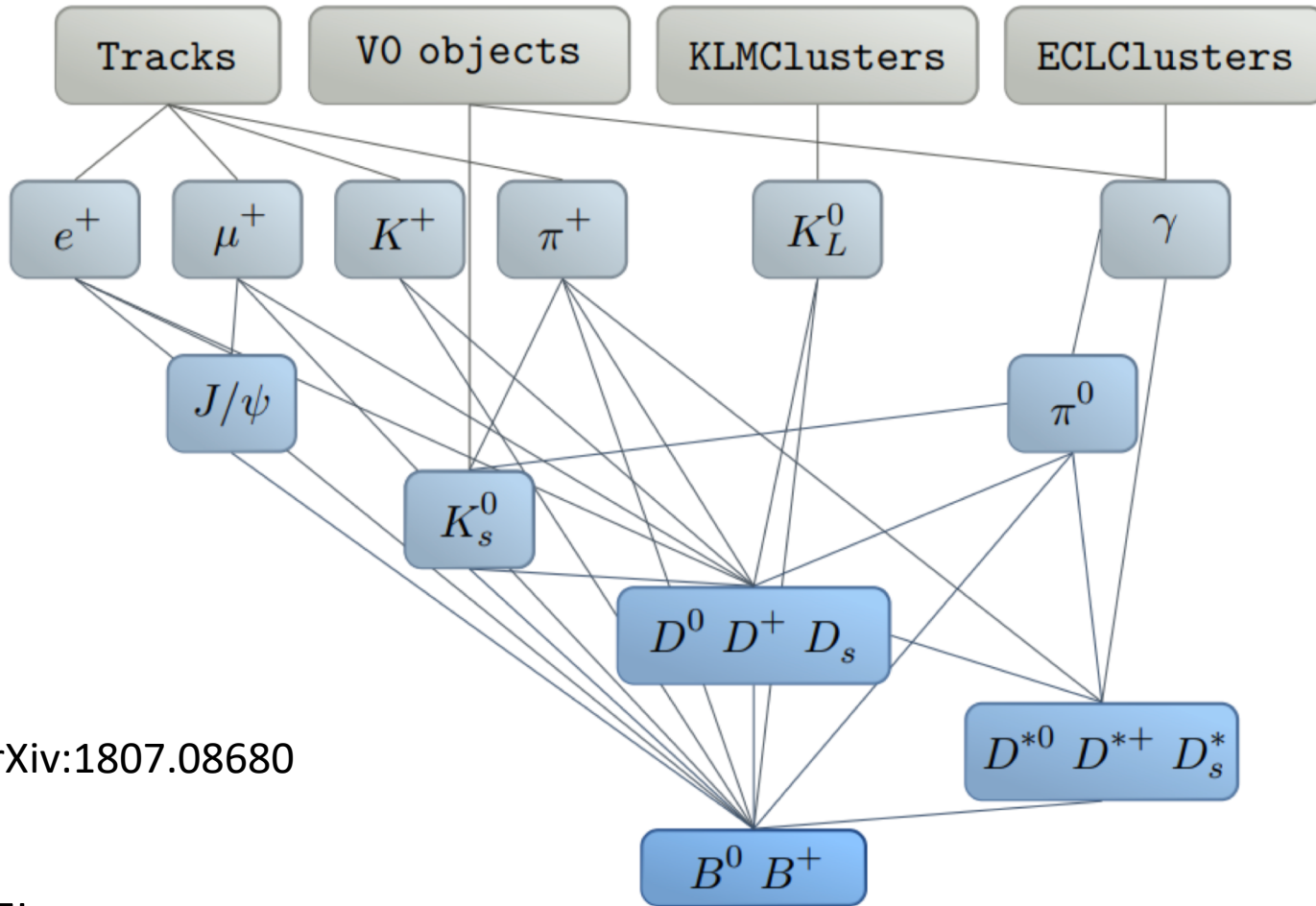


$$M_{bc} = \sqrt{(E_{CM}/2)^2 - p_B^2}$$



All masses on the proper places – good magnetic field calibration

Phase 2: full event interpretation (FEI)

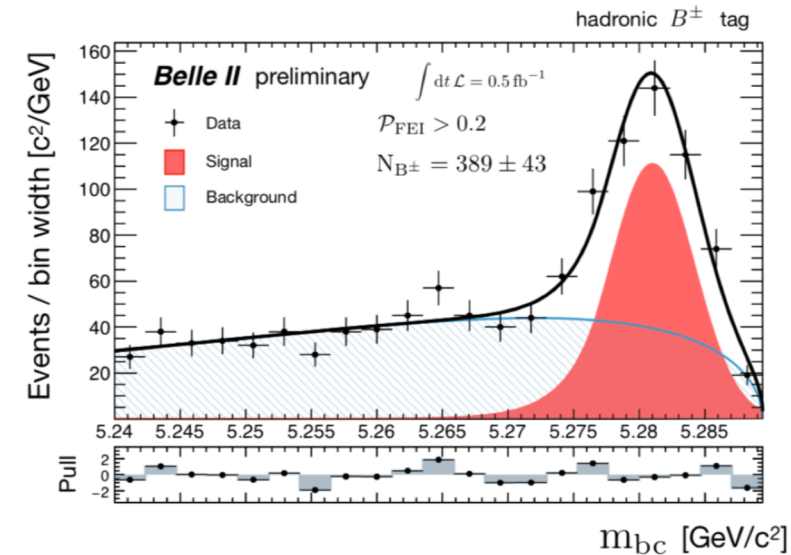
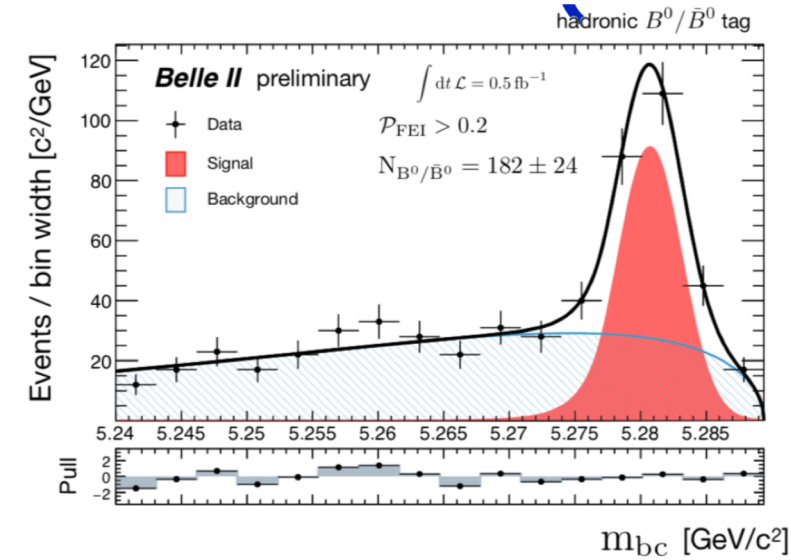


arXiv:1807.08680

FEI:

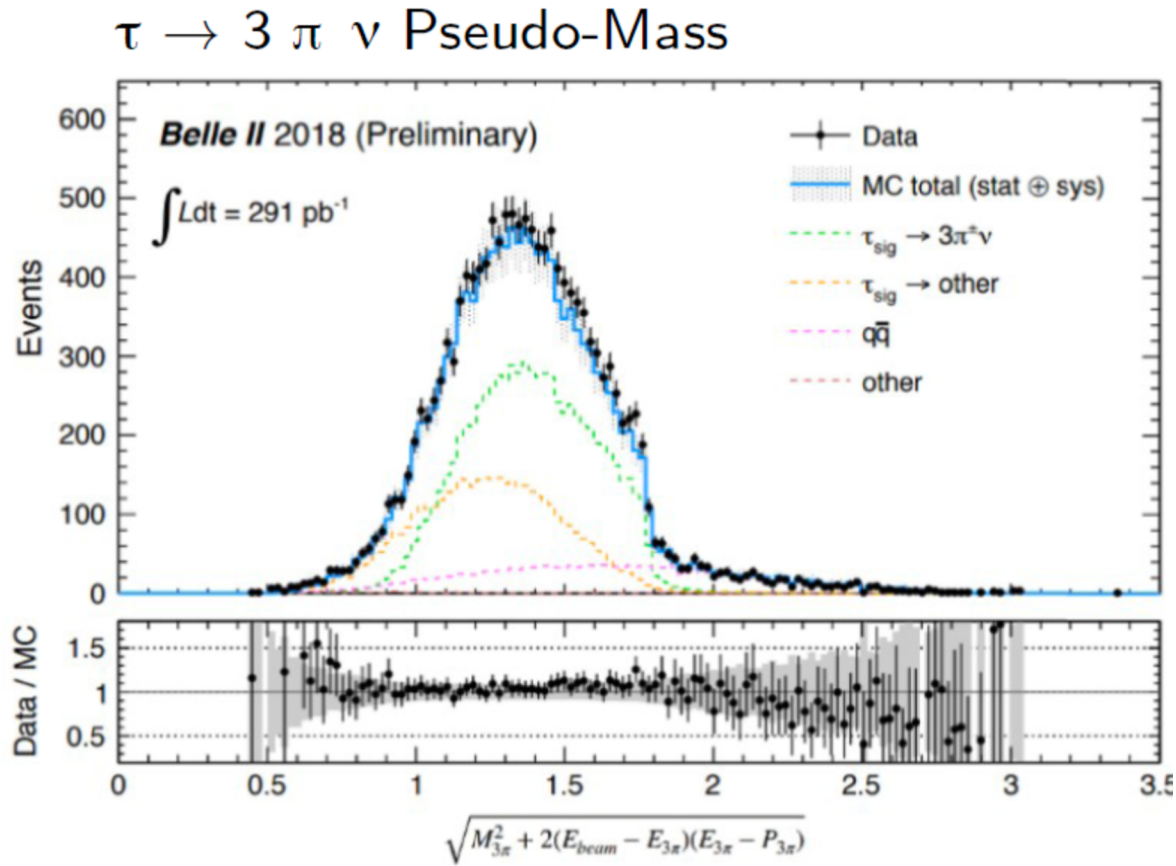
- enhances by a factor of 2 the event tagging efficiency
- important tool for the analyses with neutrino, like $B^+ \rightarrow l^+ \nu$, $D^{(*)}l\nu$, $K^{(*)}l\nu$, ect.

Data Particles
Intermediate Stages



Almost 600 fully rec. B events

Phase 2: first physics results

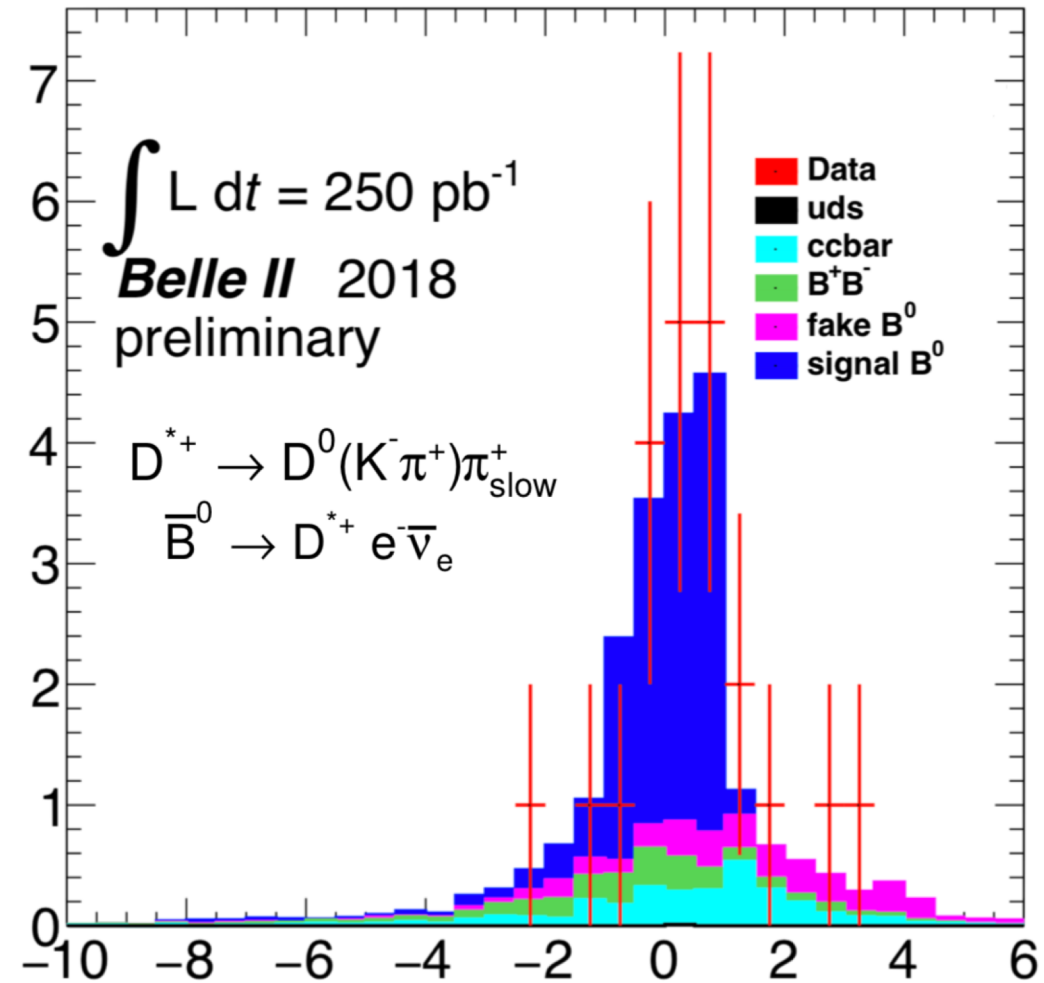


Preliminary τ mass measurement:

$$m_\tau = (1776.4 \pm 4.8(\text{stat})) \text{ MeV}/c^2$$

consistent with previous results

Events/0.5



$$\cos \theta_{BY} = \frac{2E_B^* E_Y^* - M_B^2 - M_Y^2}{2p_B^* p_Y^*}$$

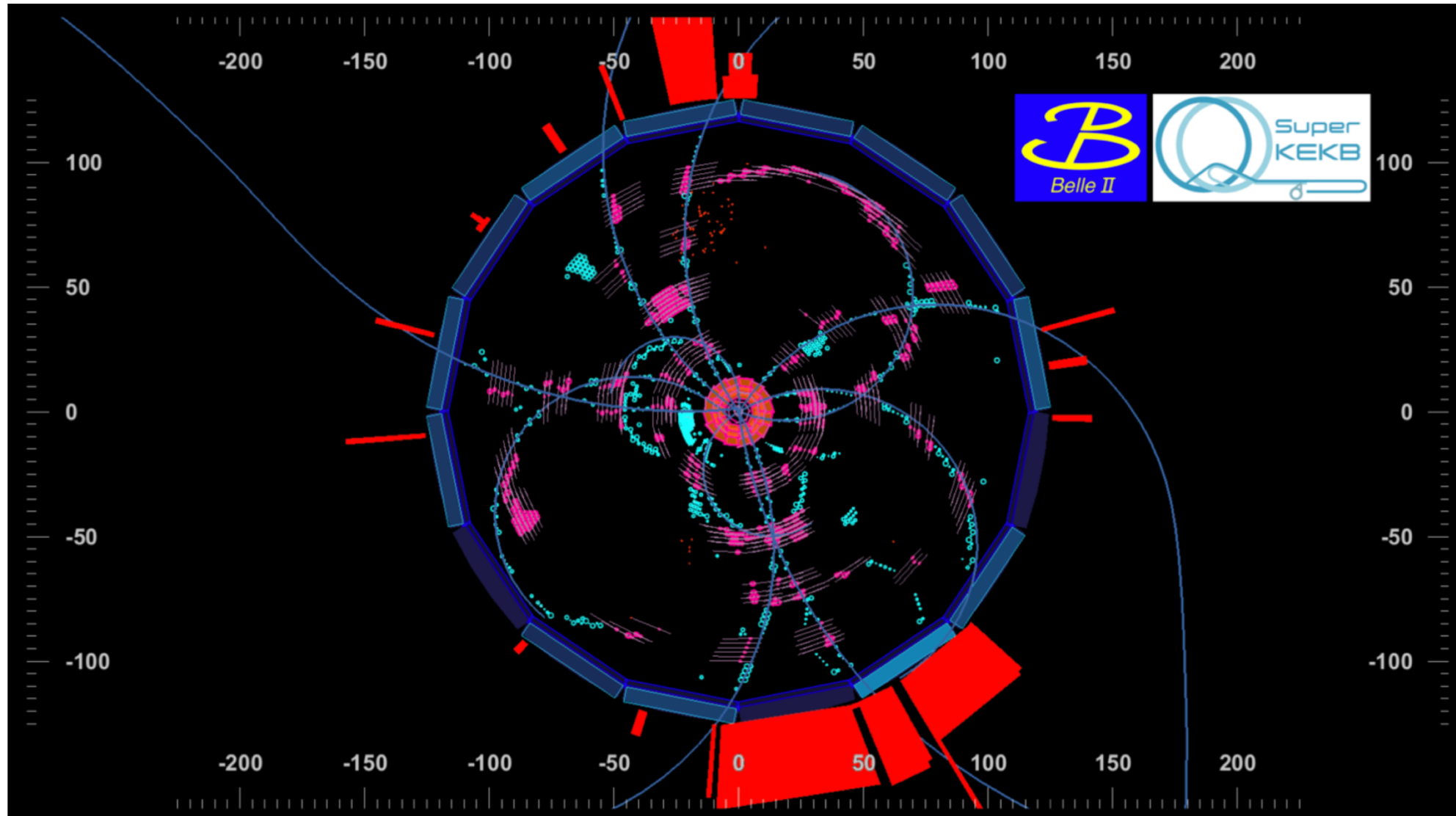
22 events reconstructed

15 events in the signal region

Phase 3 started on March 25, 2019



First B-like event in the Belle II Phase 3 run



5 fb⁻¹ will be collected by this Summer

Conclusion

- SuperKEKB accelerator has been commissioned
- First 500 pb⁻¹ data were collected during Phase 2 Belle II commissioning w/o vertex detector
- First physics analyses with Phase 2 data are ongoing
- Phase 3 is started with fully installed Belle II detector on March 25, 2019

Thank you!