Status of SuperKEKB and Belle II

Shoji Uno (KEK)

JENNIFER general meeting

2018.10.30

Paris

SuperKEKB

SuperKEKB and Belle II

Belle II

New superconducting final focusing quads near the IP

New IR

Colliding bunches

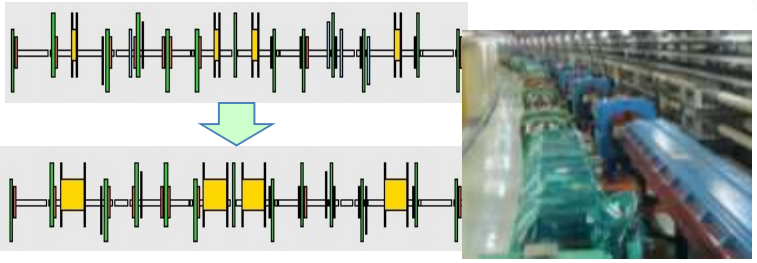
e^+ 4GeV 3.6 A

e^- 7GeV 2.6 A

SuperKEKB

Target: $L = 8 \times 10^{35}/cm^2/s$

Replace short dipoles with longer ones (LER)



Add / modify RF systems for higher beam current

Positron source

New positron target / capture section

Redesign the lattices of HER & LER to squeeze the emittance

Damping ring

Low emittance positrons to inject

TiN-coated beam pipe with antechambers

Low emittance gun

Low emittance electrons to inject

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

Key points for SuperKEKB

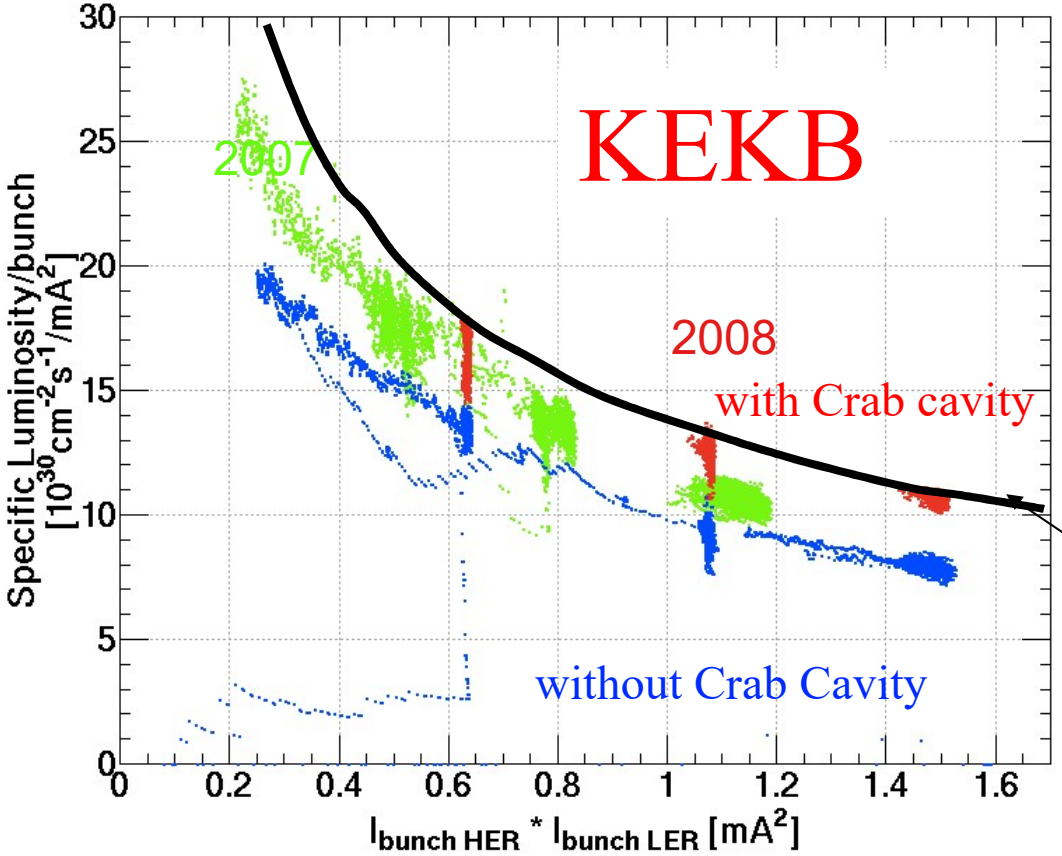
- Smaller beam size with moderate current
  - Nano beam option
    - Very low emittance
    - Stronger final focusing magnet closer to IP
- Complete new LER ring
  - New antechamber to reduce electron cloud
  - New longer and more bending magnets
- Optimized HER parameters (KEKB ring)
- Complete new IR

Why nano beam?

- Bunch luminosity is limited by several reasons.
  - Beam-beam tune shift limit.
  - Bunch lengthening.
  - Higher bunch current → damage hardware component
  - $1.2 \times 10^{31} cm^{-2} sec^{-1}$ at KEKB
    - It is not so high as compared with other machines.
- Higher luminosity means larger number of bunches.
  - Factor 2 at TRISTAN
  - Factor ~50 or more thanks for pretzel scheme at CESR and LEP
  - Factor ~1600 thanks for double rings at KEKB and PEPII (also BEPC II, LHC).
- We only need to improve the number of bunches by factor of three.
  - 5000 (~1600 at KEKB) is real maximum due to RF frequency.

- Super bunch (nano beam) idea improves number of bunches, significantly.

Specific Luminosity

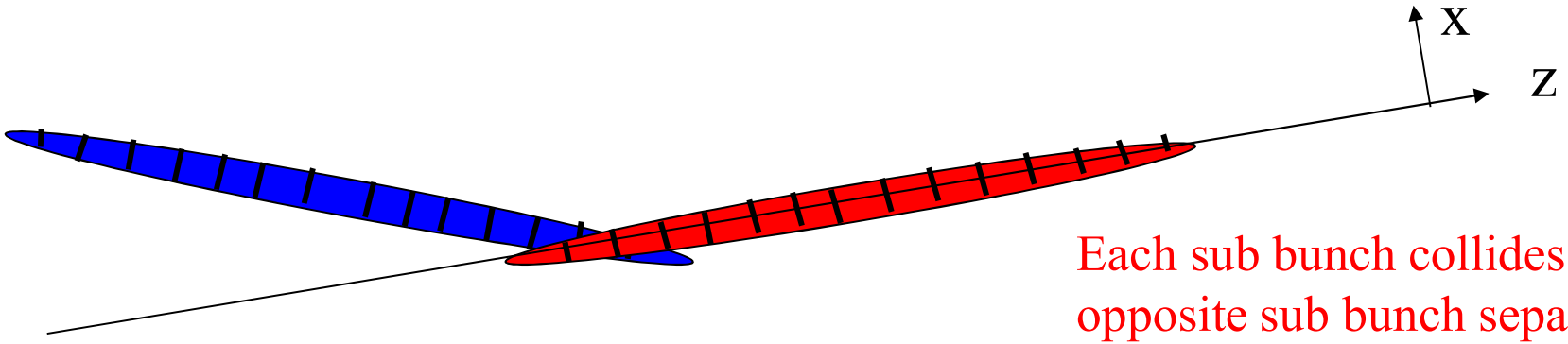


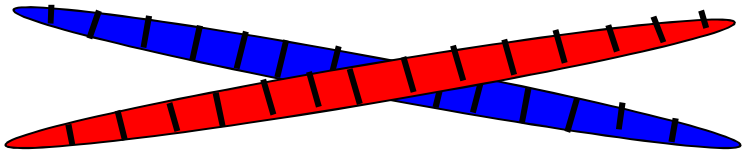
Beam-beam tune shift

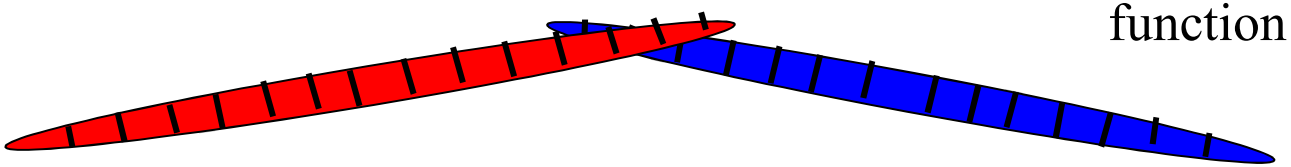
ξ_y**(HER) =0.09**

The beam beam shift could not exceed 0.09 even for higher bunch current and even with the crab cavity.

Super bunch (Nano beam)



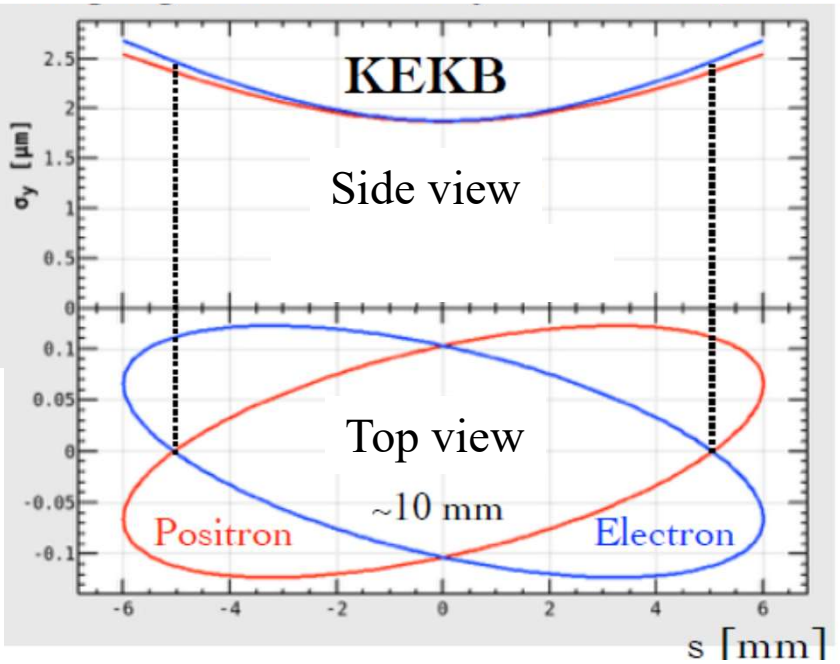


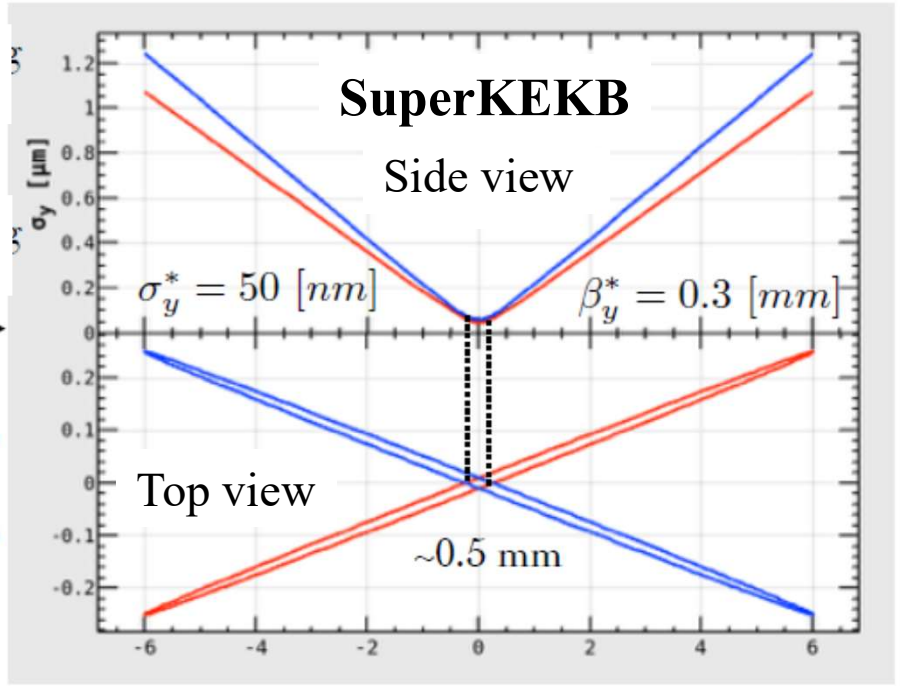


Each sub bunch collides on opposite sub bunch separately.
It means that number of bunches increases significantly.

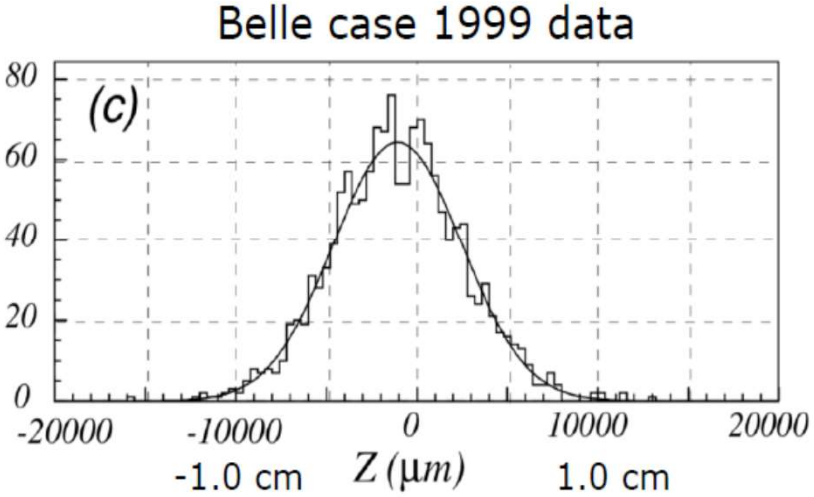
To achieve this scheme, σ_x should be much smaller than σ_z
and rather large crossing angle should be applied.
Lower emittance and lower β function at IP are required.

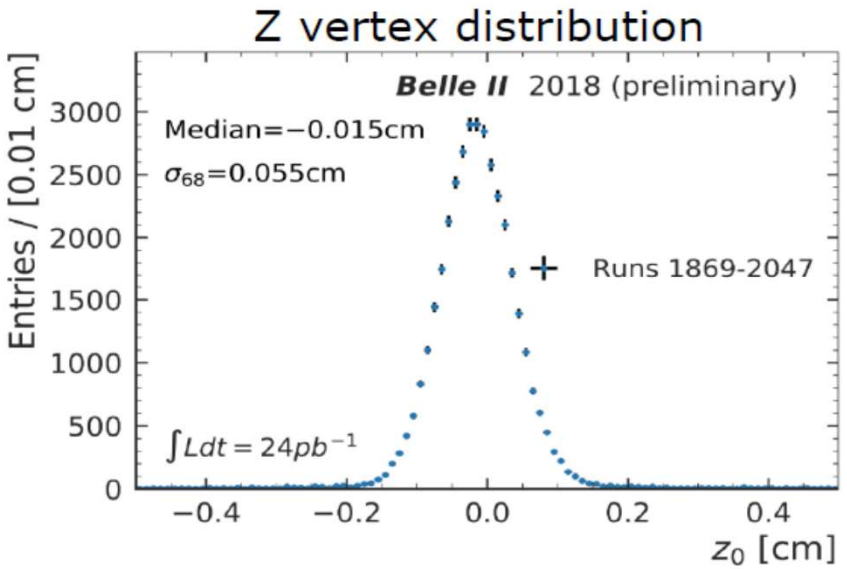
Nano beam collision



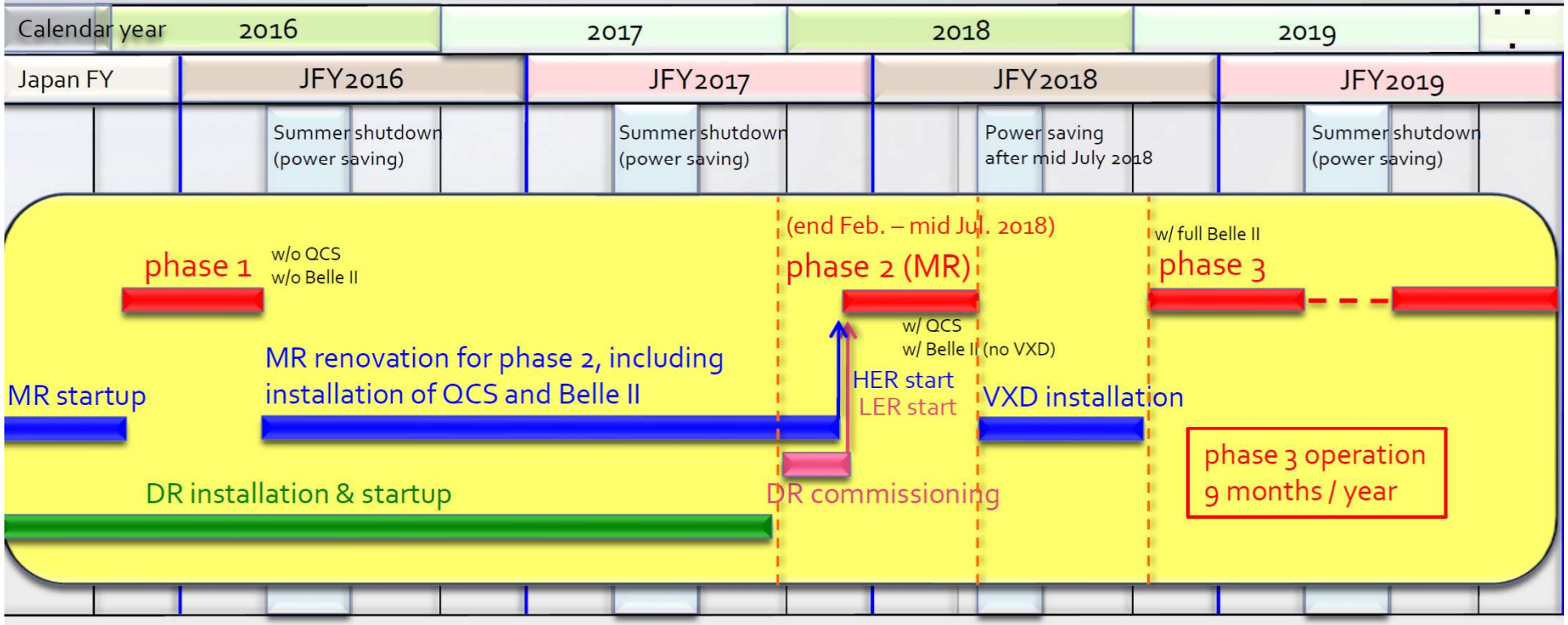


Longitudinal position (mm)





SuperKEKB/Belle II schedule

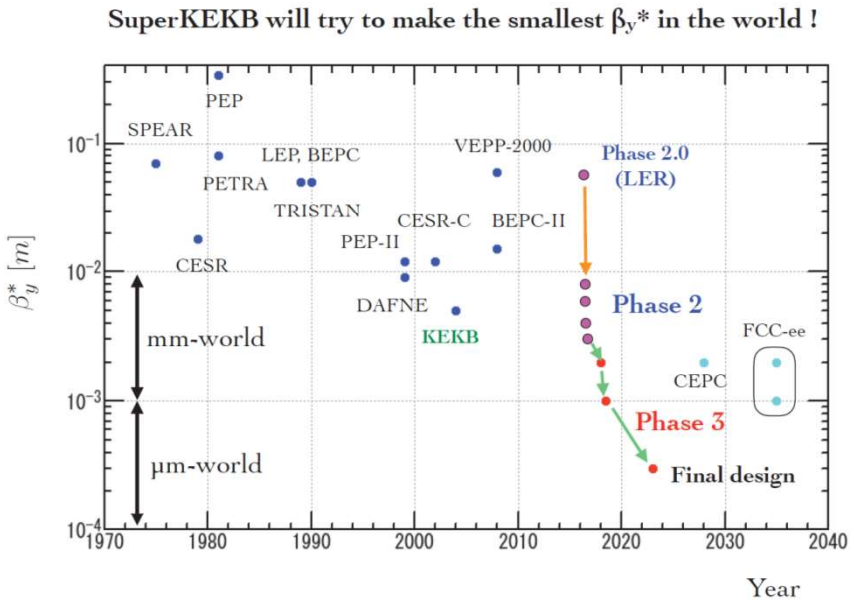


Phase 1 (w/o final focusing Q, w/o Belle II):
- Accelerator system test and basic tuning,
- **Vacuum scrubbing**,
- **Low emittance tuning**, and
- **Beam background studies**

Phase 2 (w/ final focusing Q, w/Belle II but background monitors instead of vertex detectors)
- **Verification of nano-beam scheme**
  target: $L>10^{34}$ $cm^{-2}s^{-1}$
- Understand **beam background** especially in vertex detector volume

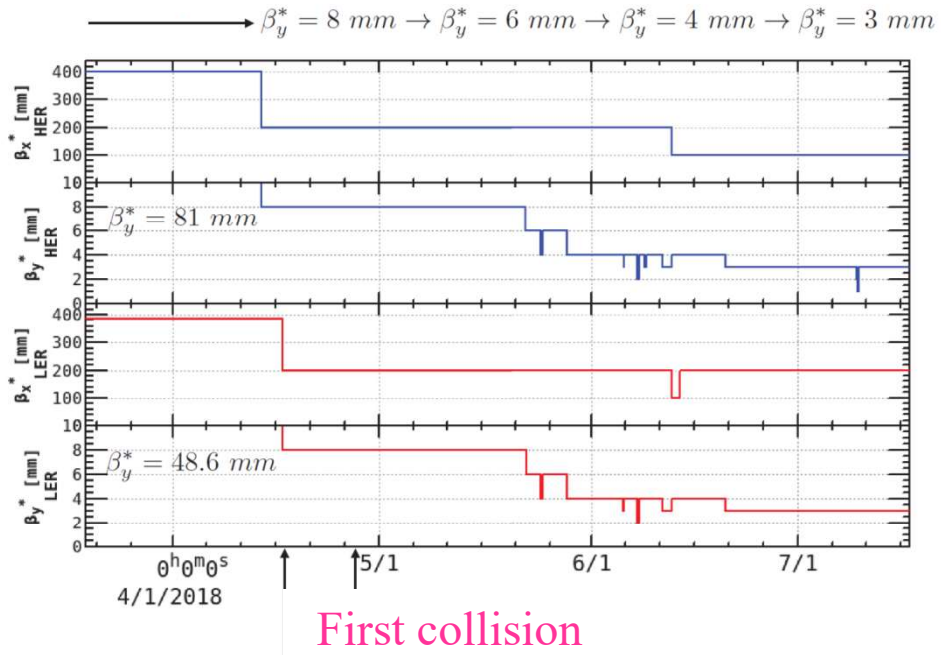
Smaller β^*_y
(vertical focusing length)

History of β^*_y



Smallest β^*_y in the colliders

Detuned

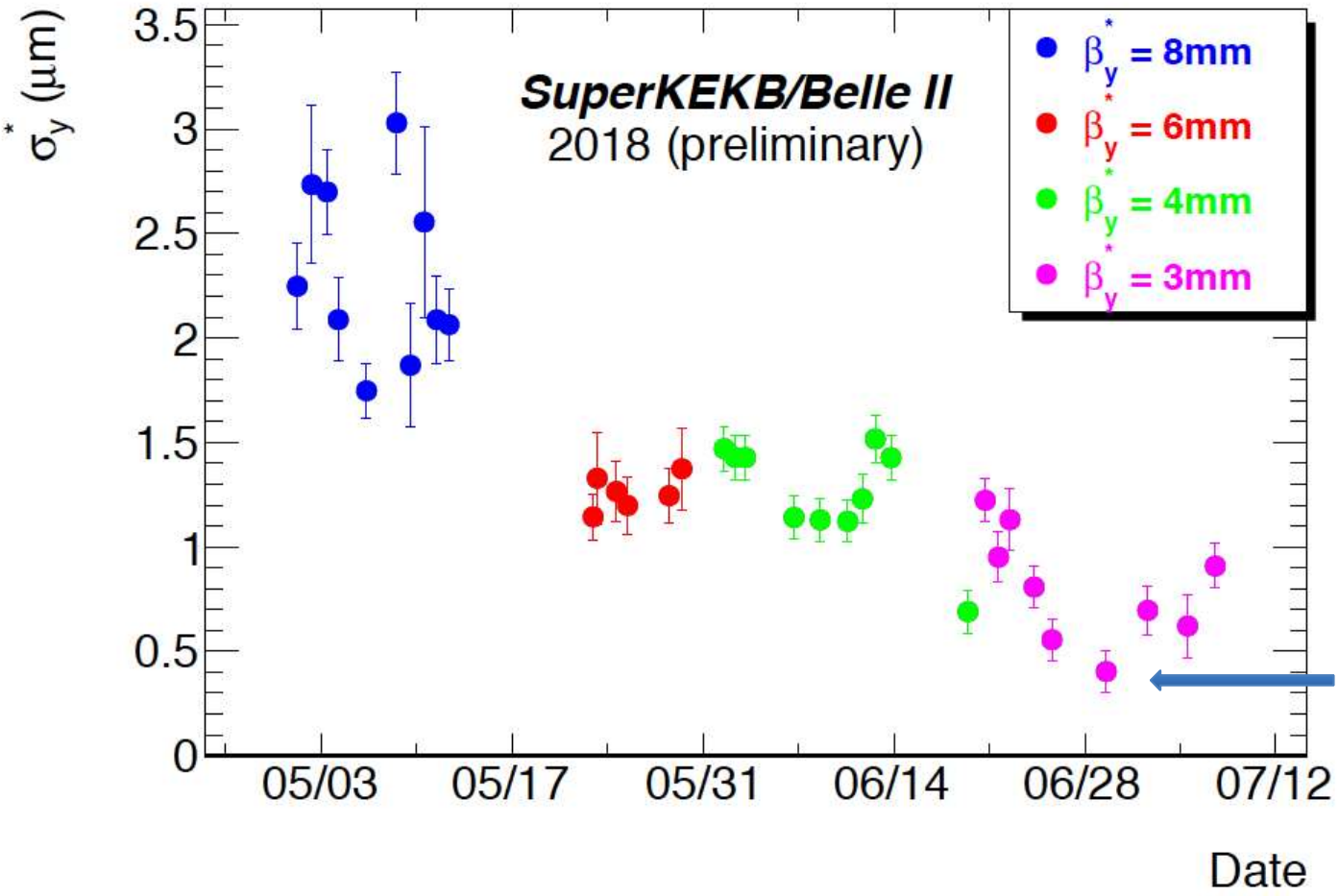


First collision

Start of collision tuning

6

Measured vertical beam size



The record is 400 nm and beam currents of only ~15mA

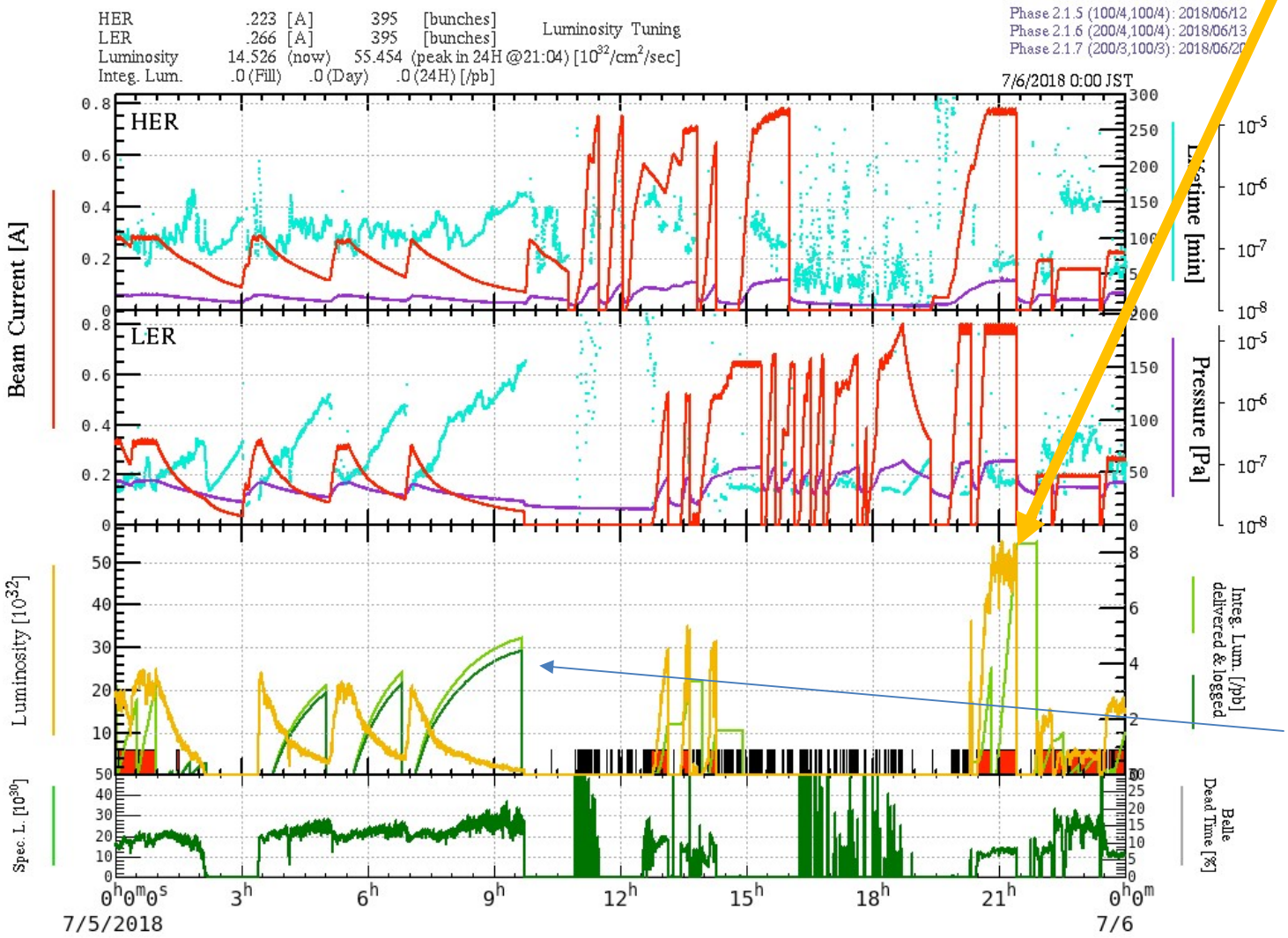
The beam-beam blow-up is most concerned issue for SuperKEKB to obtain high luminosity.

S. Di Carlo et al. (LAL Orsay)

Achievement of Phase 2 operation

$$L_{peak} = 5.5 \times 10^{33} / cm^2 / \text{sec}$$

(Belle II off)



Beam current 0.8A for each beam

Belle II took data (usually owl shift only).
Only able to record ~0.5 fb^{-1} during Phase 2 pilot run.

Belle II

Requirements for Belle II detector

Target luminosity : L= 8 x $10^{35}/cm^2/sec$

Larger beam-related background (×20)

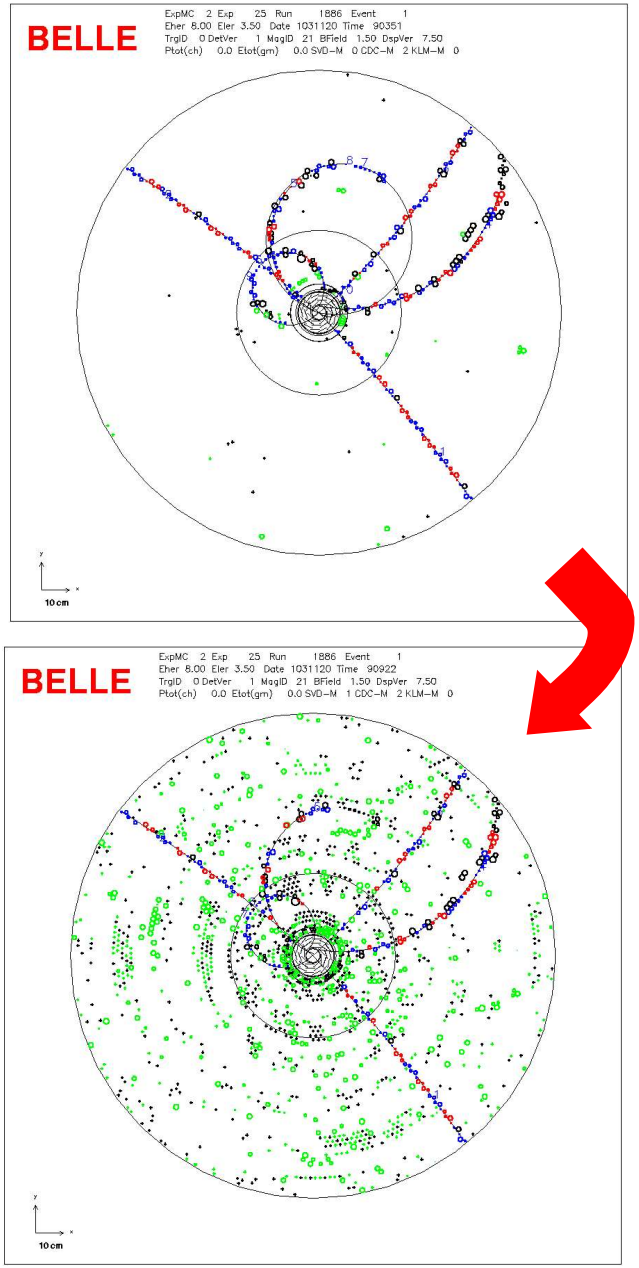
- Finer granularity
- Better timing separation

High trigger rate (×20)

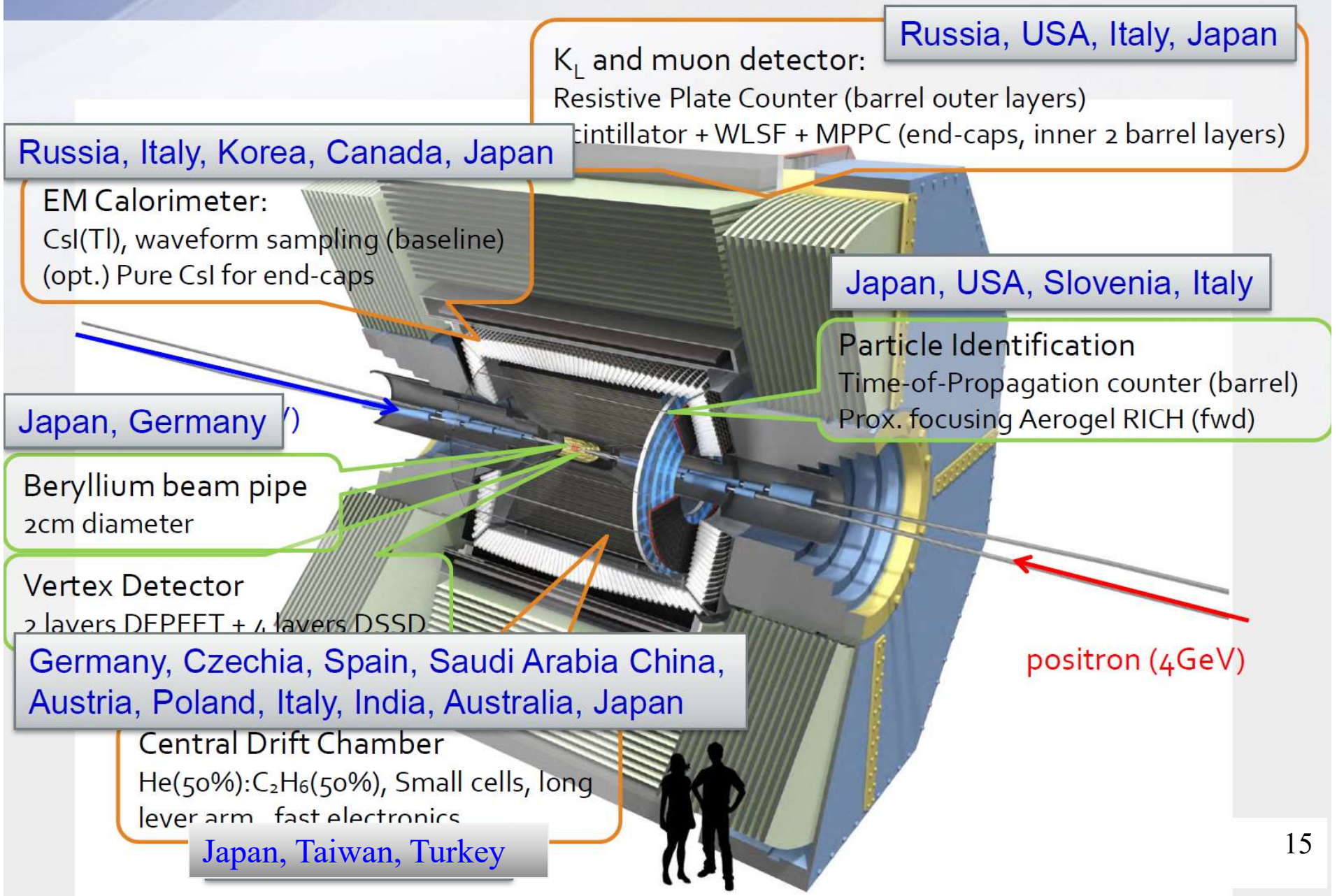
- Pipeline readout

Improvements

- Better particle ID devices
- Better vertex resolution

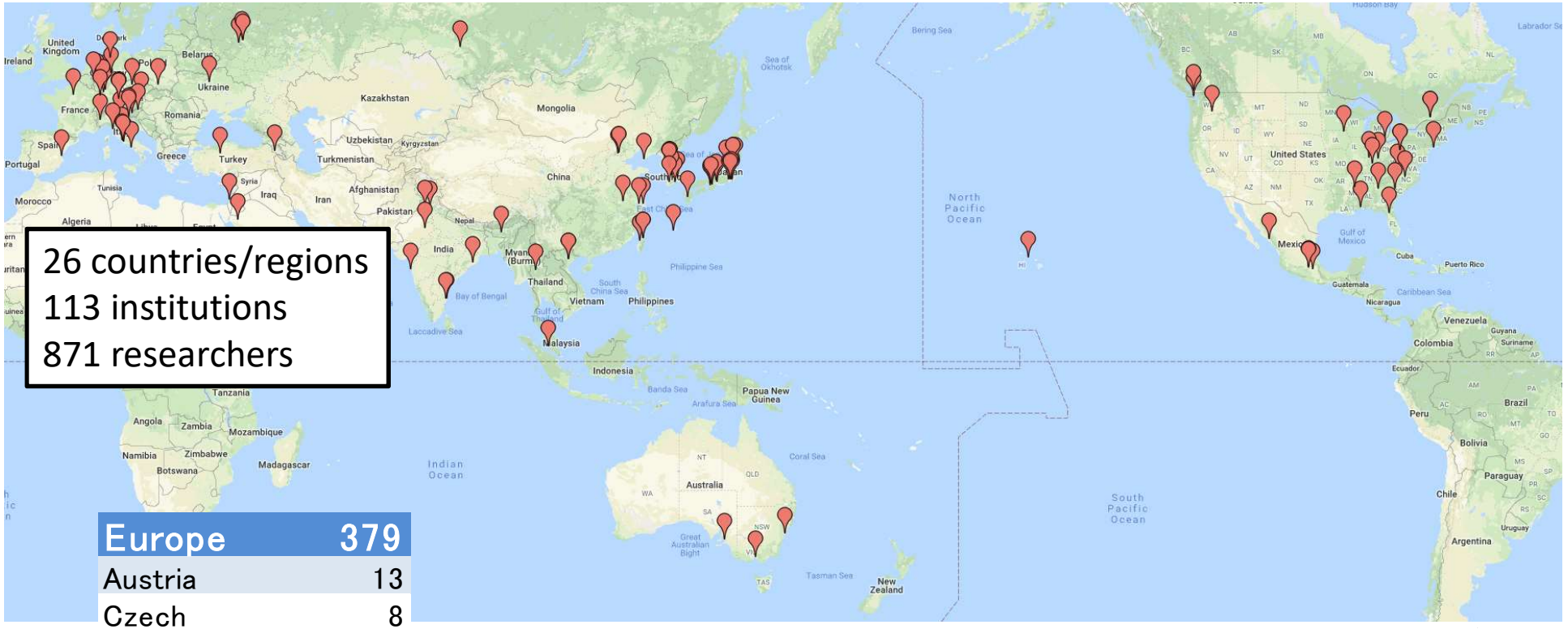


Belle II Detector



Belle II Collaboration

As of Oct. 2018



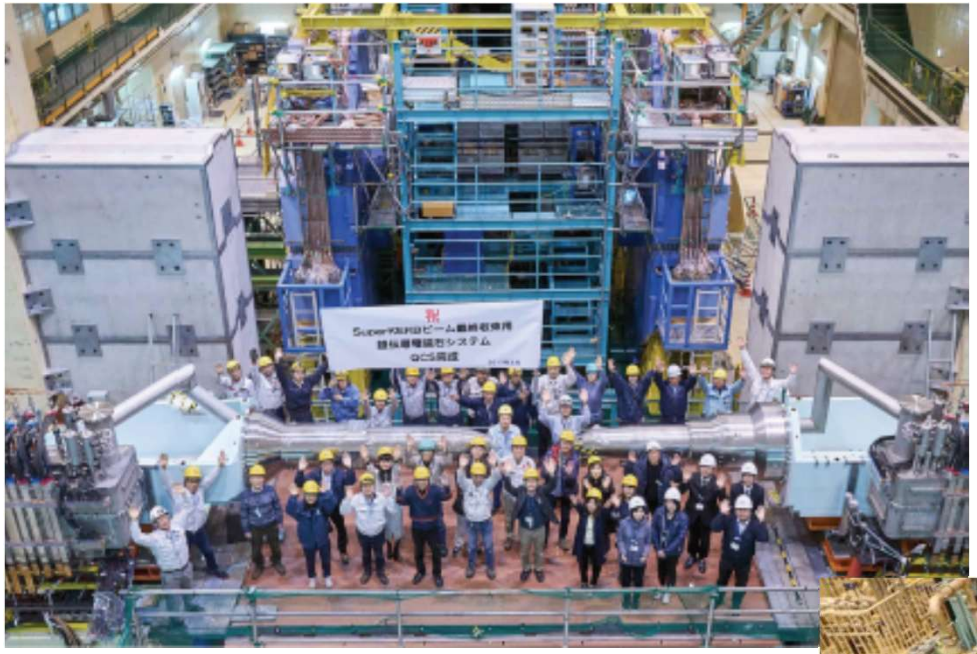
Europe	379
Austria	13
Czech	8
France	25
Germany	175
Israel	7
Italy	74
Poland	13
Russia	39
Slovenia	16
Spain	5
Ukraine	4

Asia	343
Saudi Arabia	5
Armenia	1
Australia	31
China	40
India	37
Japan	148

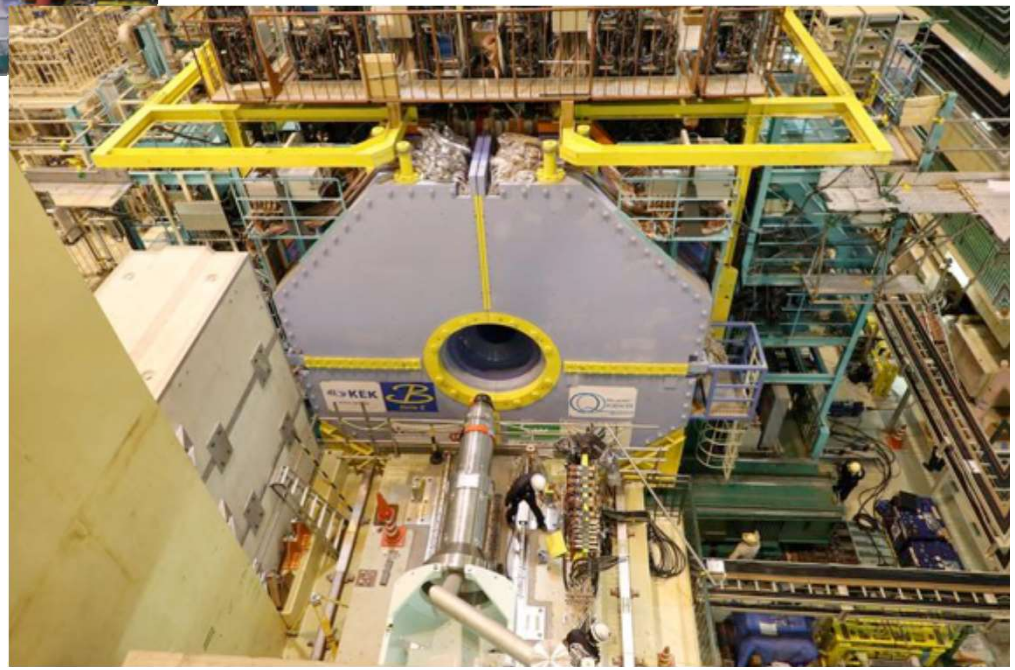
Korea	41
Malaysia	5
Vietnam	2
Taiwan	29
Thailand	1
Turkey	3

America	149
Canada	29
Mexico	16
U.S.A.	104

After Phase 1



Roll-in on April 11th , 2017

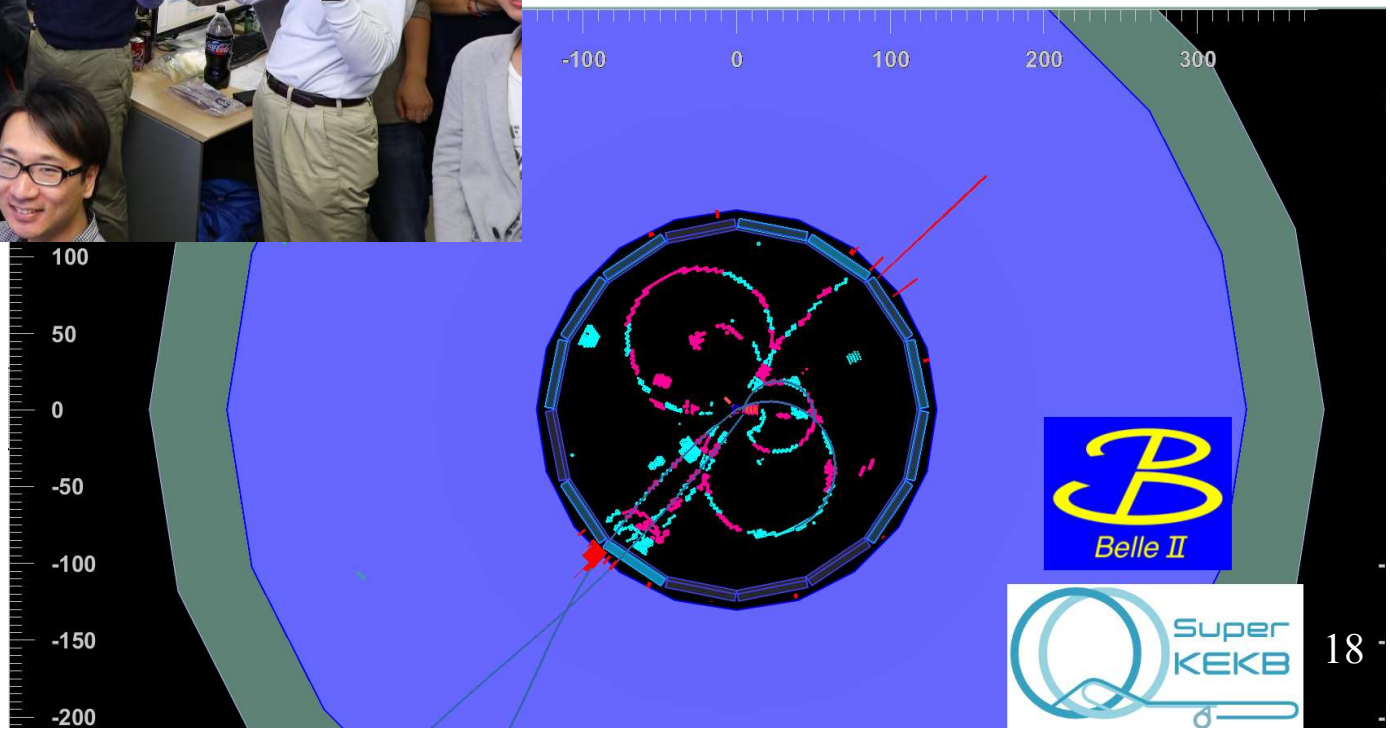


Construction and installation
of the final focusing magnets (QCS)
were done.

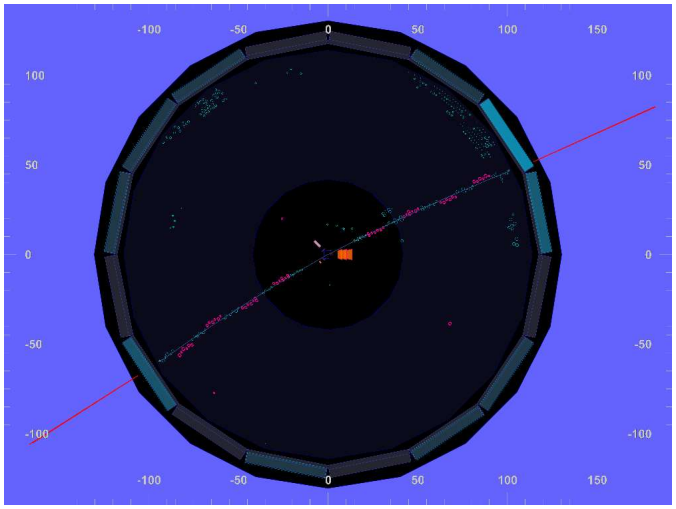
Damping ring construction
and commissioning
were performed, also.

Events for first collision on April 26, 2018

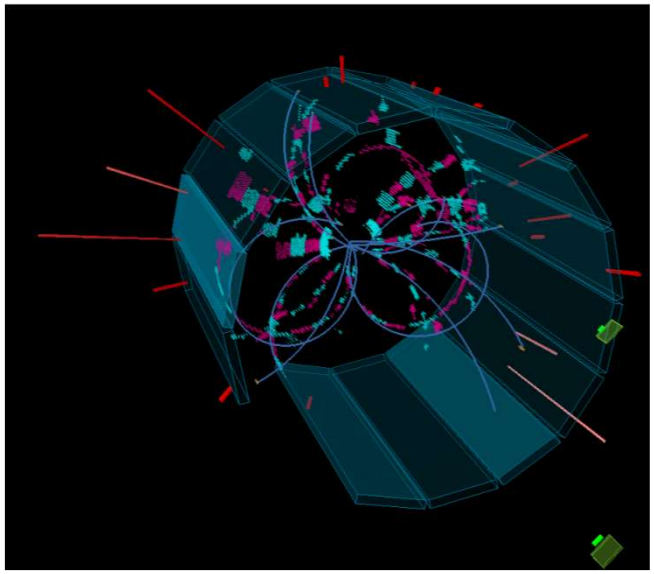
First hadronic event



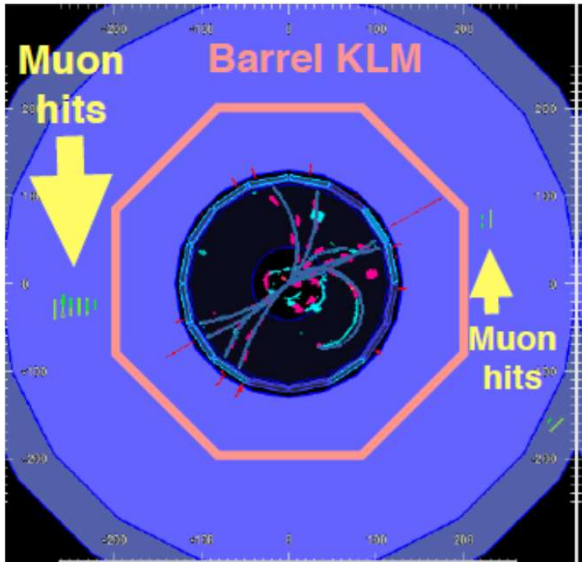
More Events



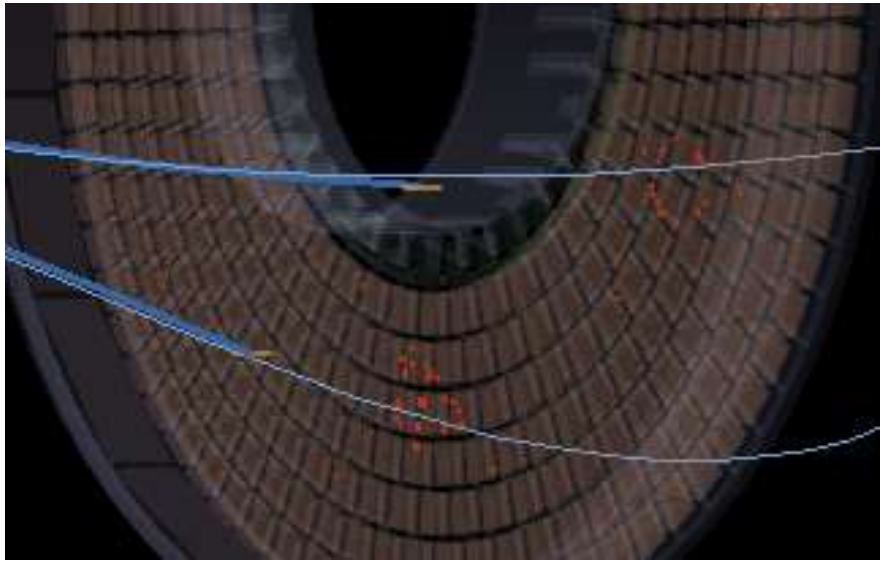
Bhabha event



$B\bar{B}$ like event

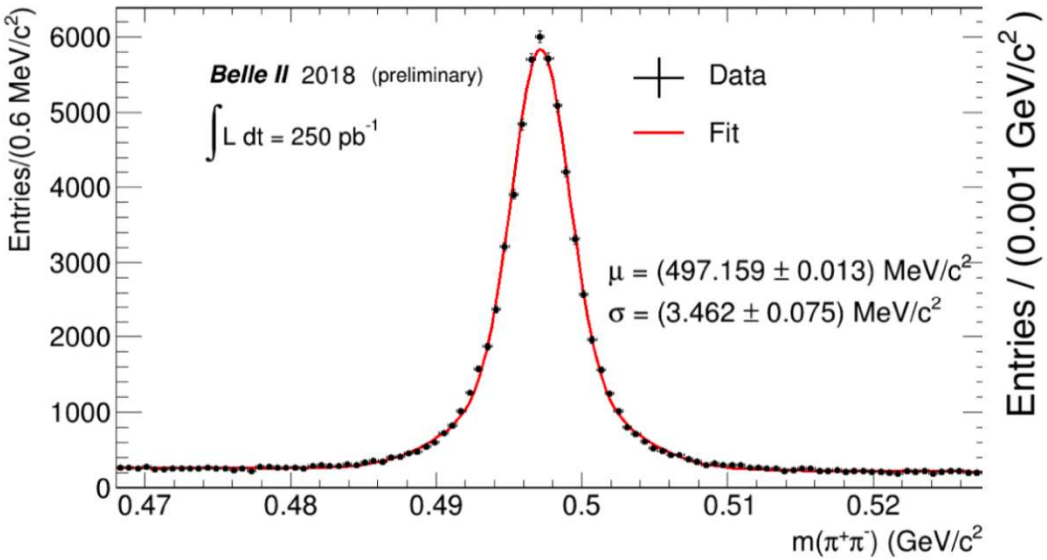


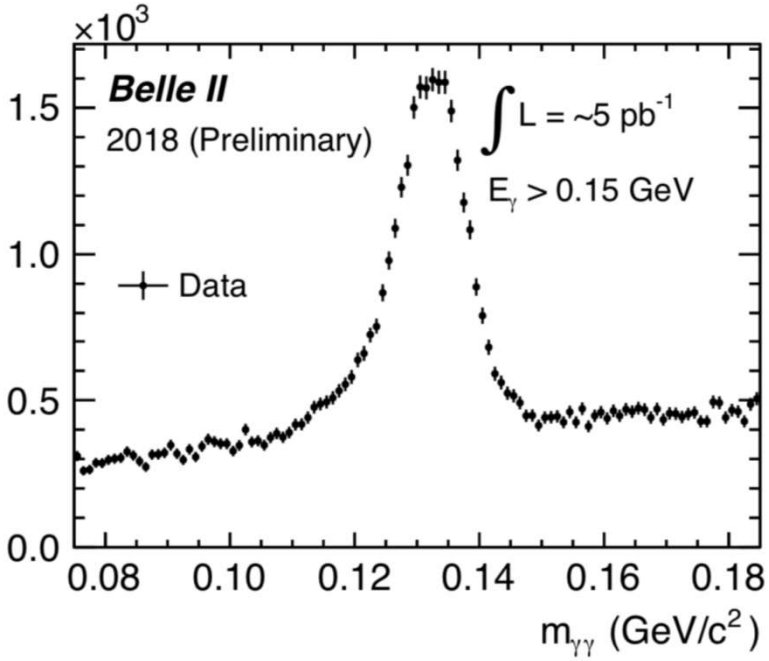
KLM is working.



ARICH is working.

Mass peaks for charged tracks and photons



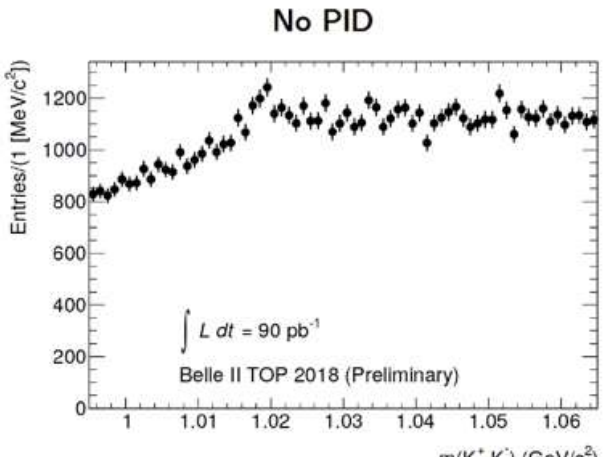


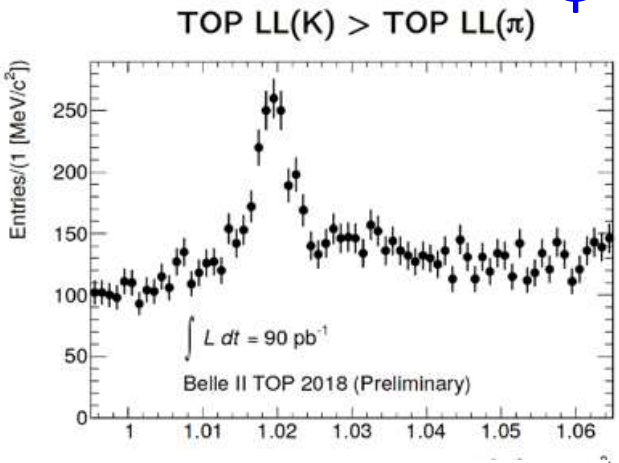
Particle Identification

The phase 2 data demonstrates that the TOP principle is working

$\phi \rightarrow K^+K^-$ with both the tracks in the TOP acceptance

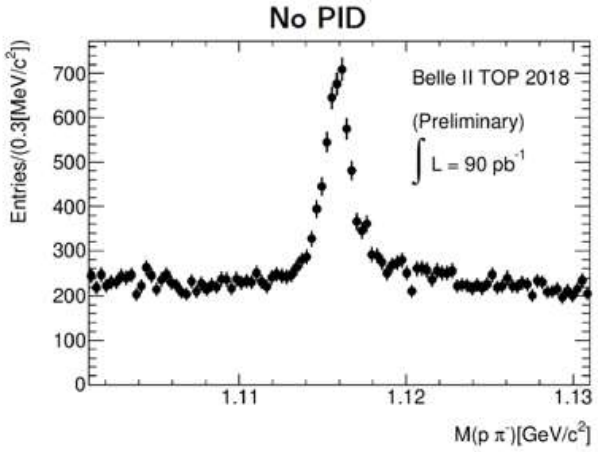
$\phi \rightarrow KK$

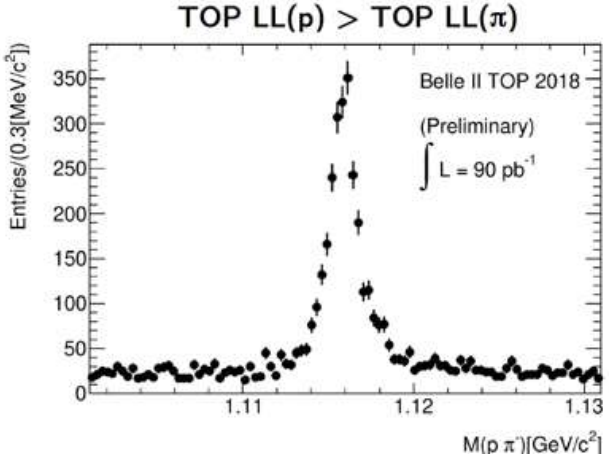




$\Lambda \rightarrow p\pi$ with the **proton candidate** in the TOP acceptance

$\Lambda \rightarrow p\pi$

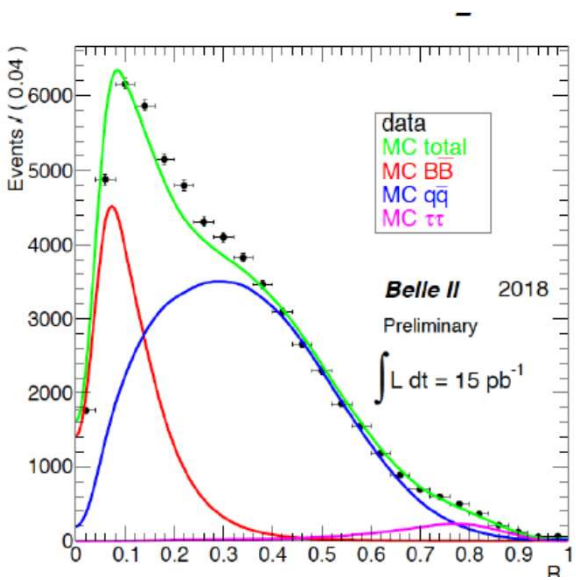




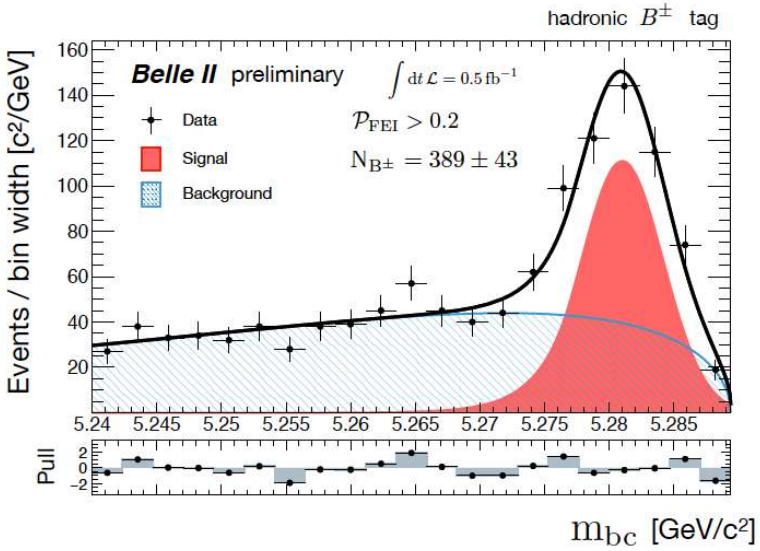
T. Iijima, G. Varner, K. Nishimura et al.

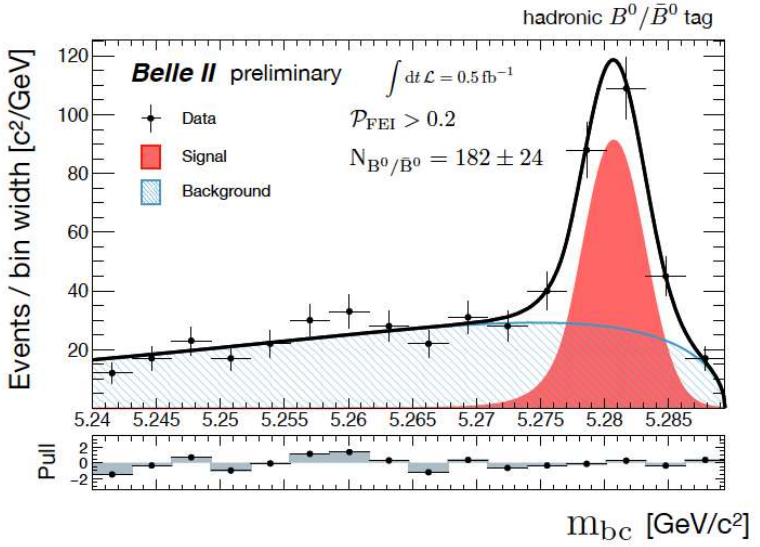
Reconstruction of *B* mesons

R2 distribution



New method (Boosted Decision Trees) shows better efficiency by factor 3.6.

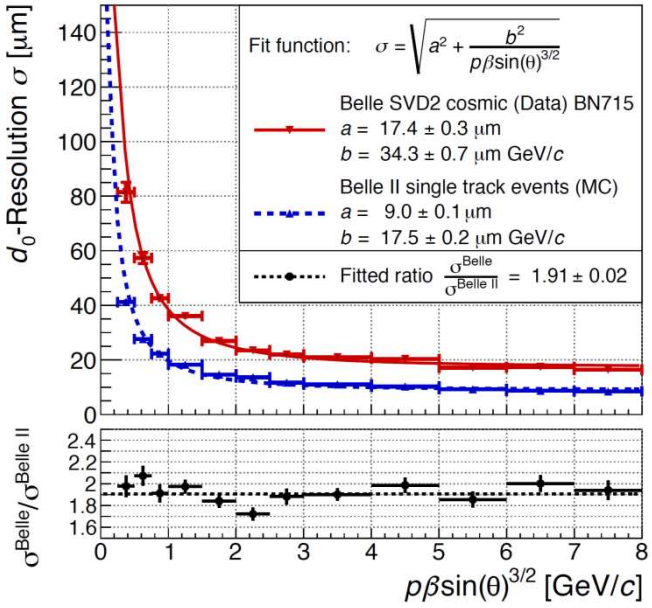




B2NOTE-2018-031-1, W. Sutcliffe, F. Bernlochner

Preparation for Phase 3 operation

- Phase 2 operation ended at July 17th.
- The vertex detector will be installed, soon.
  - The construction was done.
  - The commissioning is underway just before the installation.

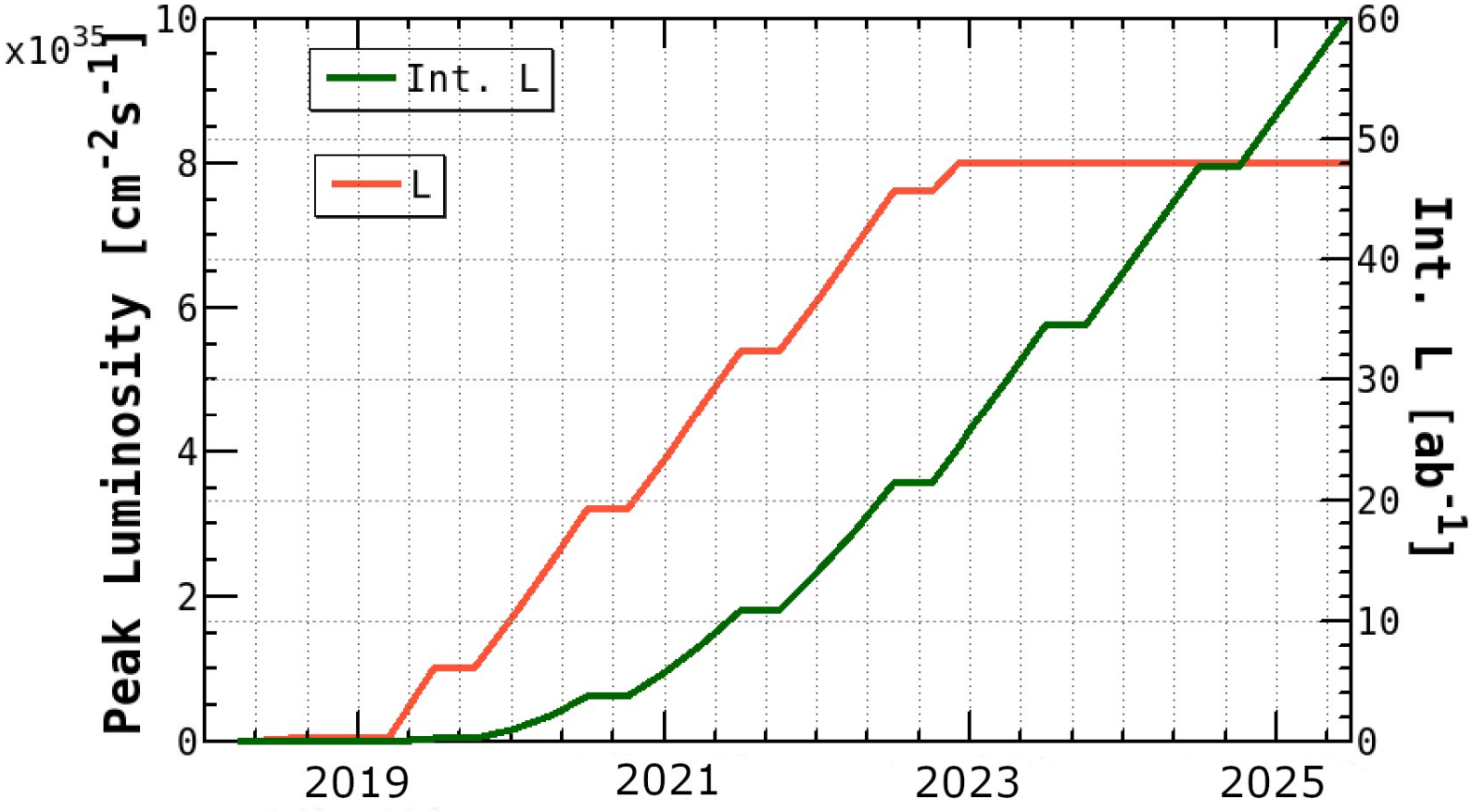


Belle

Belle II

SuperKEKB Luminosity Projection

Updated luminosity profile



Summary

- After several years construction, Belle II successfully observed first collision events from the SuperKEKB machine on April 26th, 2018.
  - Belle II detector was basically working.
    - Still, we need more calibration and tuning.
  - It is just the starting point of a long experiment.
- The vertex detector will be installed soon.
  - The phase 3 operation will start in March, 2019.
- Fruitful physics will come soon.
  - Belle II collaboration is still growing.
  - Please come to KEK more frequently and stay longer.