The Belle II experiment: status and prospects

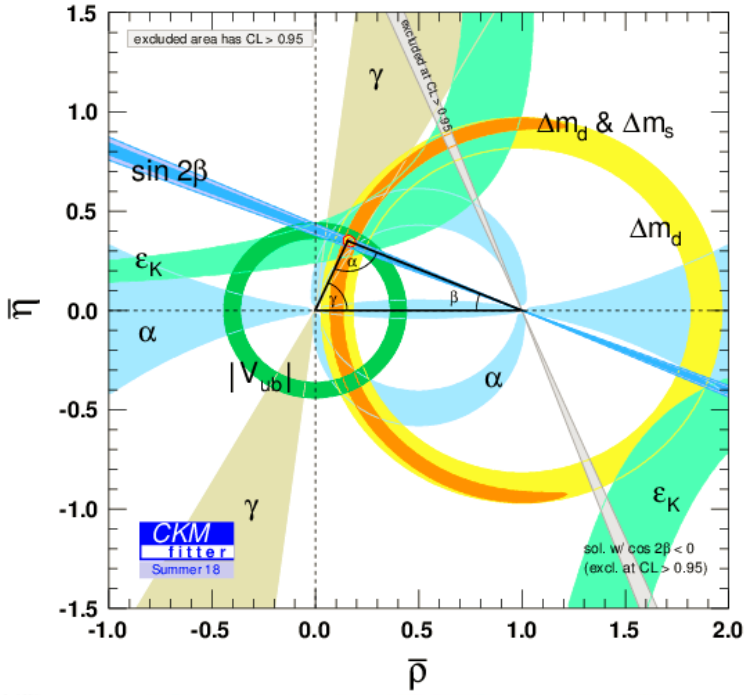
Martin Bessner
University of Hawaii
On behalf of the
Belle II collaboration

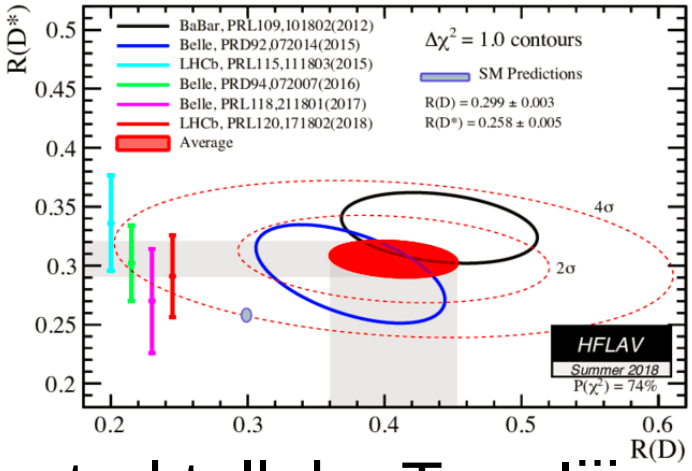
MENU 2019
Pittsburgh,
June 6, 2019

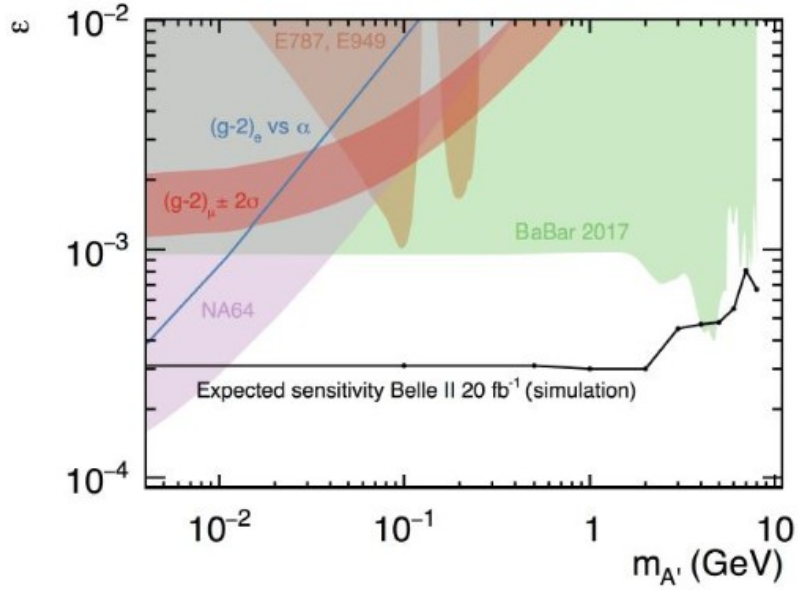
Belle II physics

Electron-positron collisions at 10 GeV
”Intensity frontier”

- CKM matrix elements
- New sources of CP violation
- Lepton flavor violation
- Bottomonium spectroscopy
- Charmonium spectroscopy
- Tetraquarks/pentaquarks
- Dark sector physics
- ...



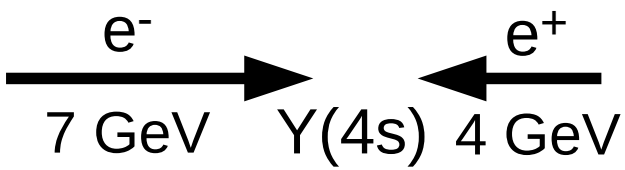




See dedicated talk by Toru Iijima (Tuesday plenary)

B-factories

- B-meson system crucial in flavor physics
- How can we produce them?
  - ➔ In hadron collisions (e.g. LHC)
  - ➔ In electron-positron collisions

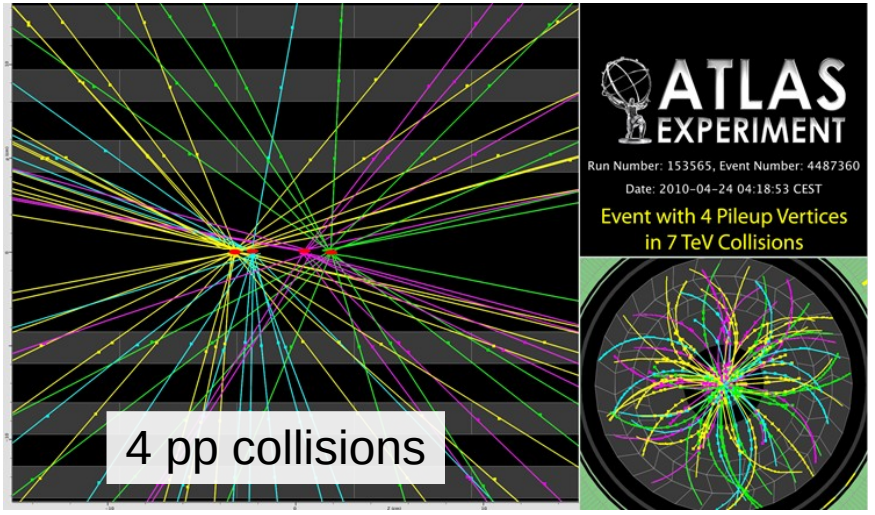


$$\Upsilon(4s) \rightarrow B\bar{B}$$

- Asymmetric energies boost B mesons (→ measure lifetime)
- Energy scan: other Y states, B_s, ...
- Also produced: charmonium, charm, τ, ...

B-factories

- LHC: B mesons at >1 MHz
  Why do we need a B-factory?



- Hadron colliders:
  many B mesons, but large backgrounds
- Electron-positron colliders:
  individual collisions
  no underlying event
  competitive with <0.1% B mesons

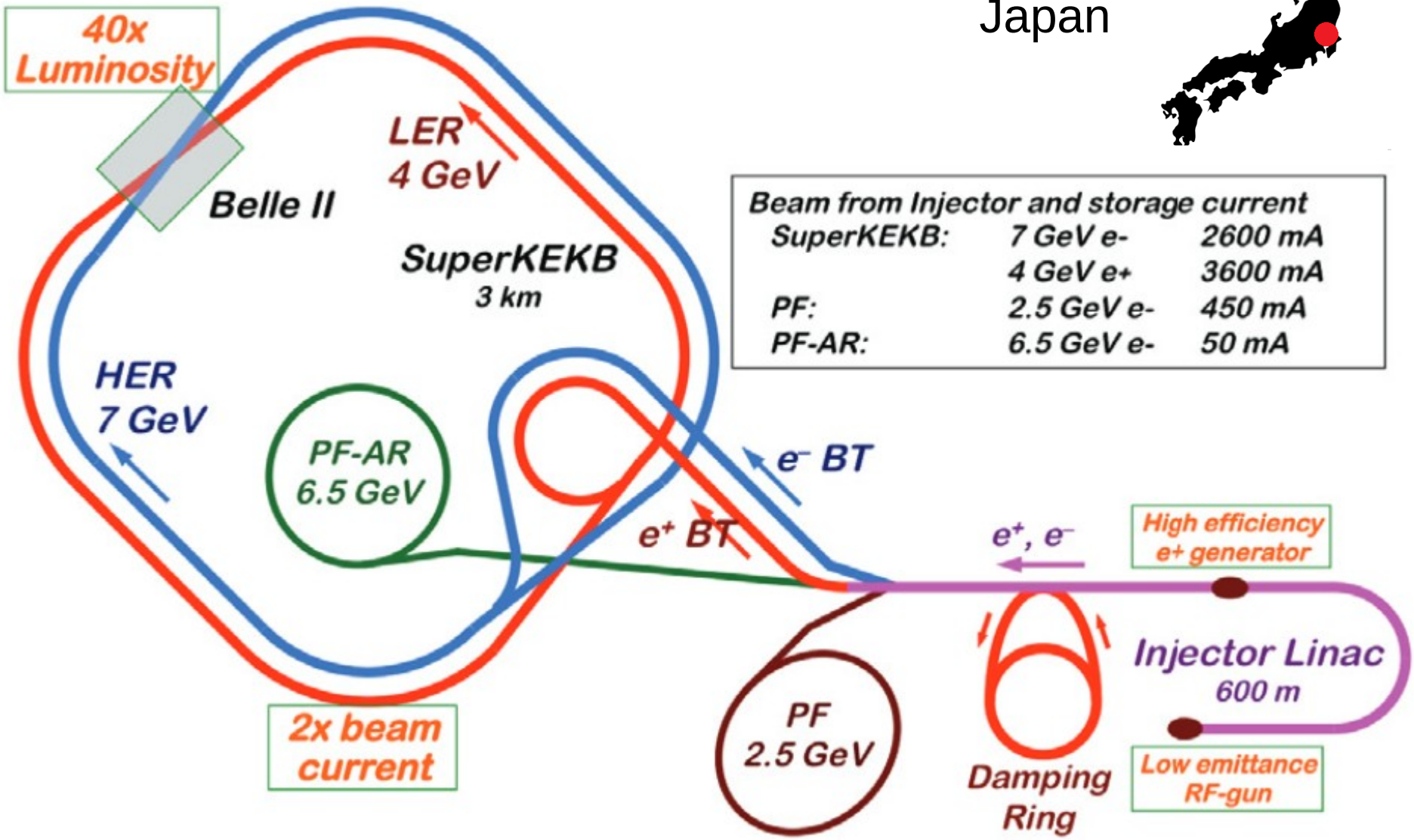
- Belle (1999-2010), BaBar (1999-2008)
- Belle II will go way beyond that

See dedicated talk by Toru Iijima
(Tuesday plenary)

SuperKEKB

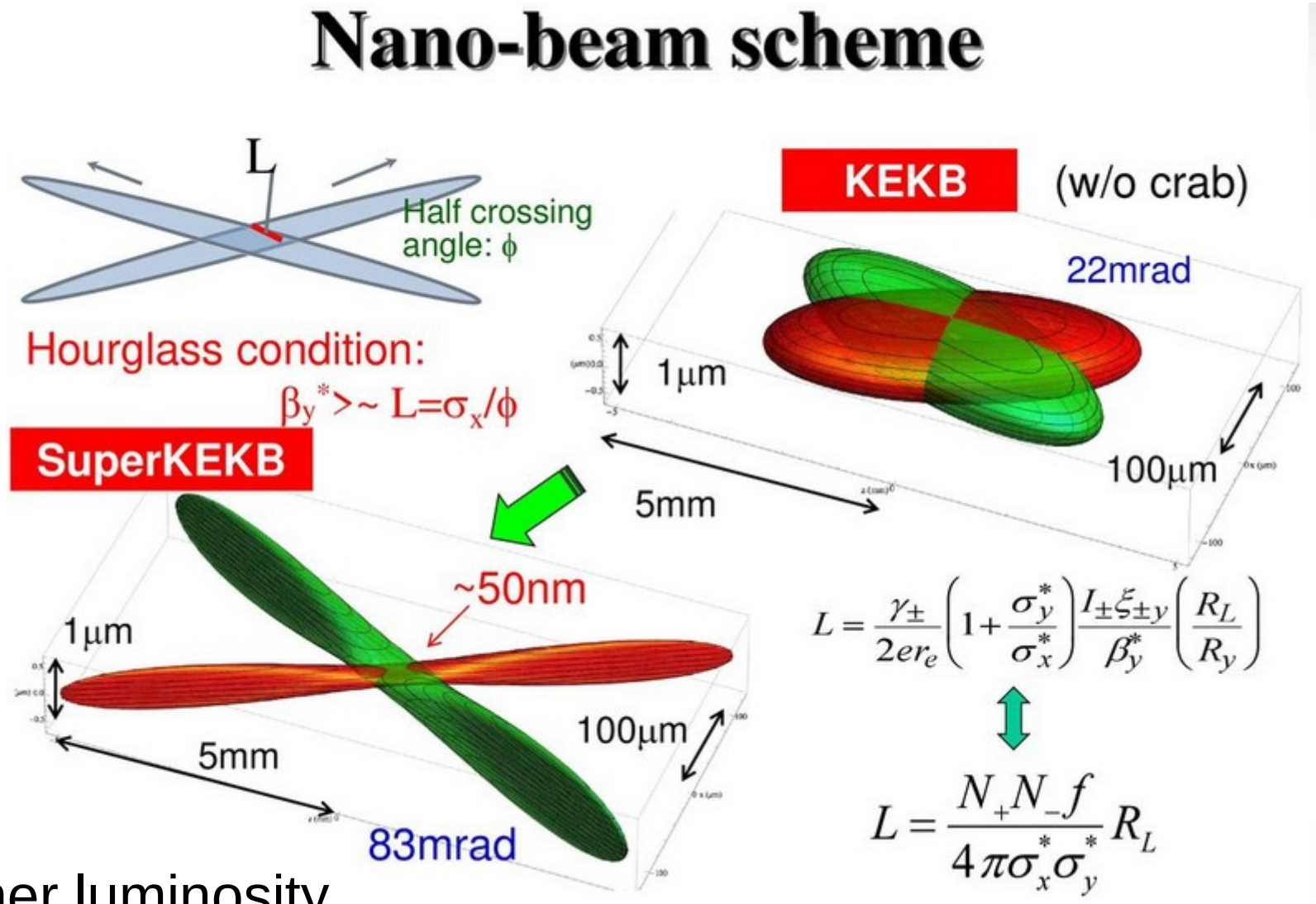
Higher luminosity than KEKB:
8E35/(cm^2 s) and 50/ab

KEK
Tsukuba,
Japan



Beam from Injector and storage current		
SuperKEKB:	7 GeV e-	2600 mA
	4 GeV e+	3600 mA
PF:	2.5 GeV e-	450 mA
PF-AR:	6.5 GeV e-	50 mA

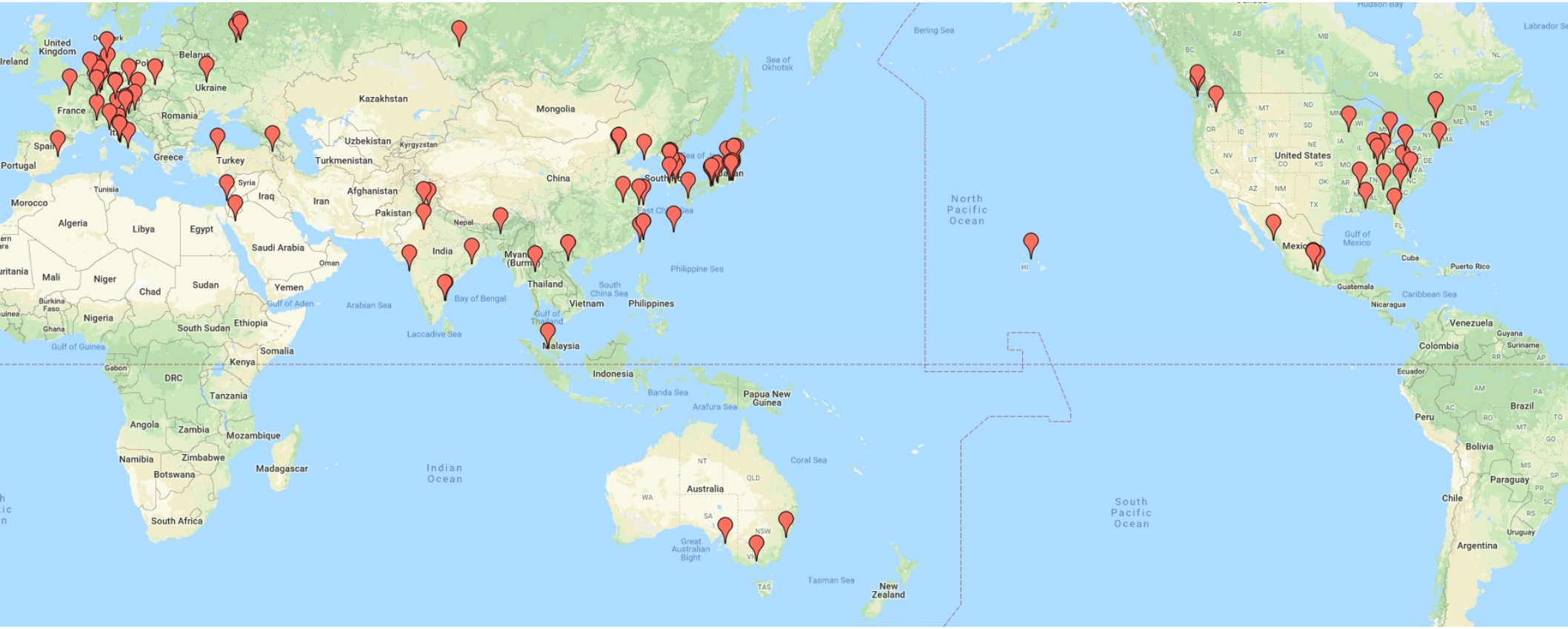
Collision scheme



- Higher luminosity
- Larger crossing angle, narrow collision region
- Leads to new sources of background (discussed later)

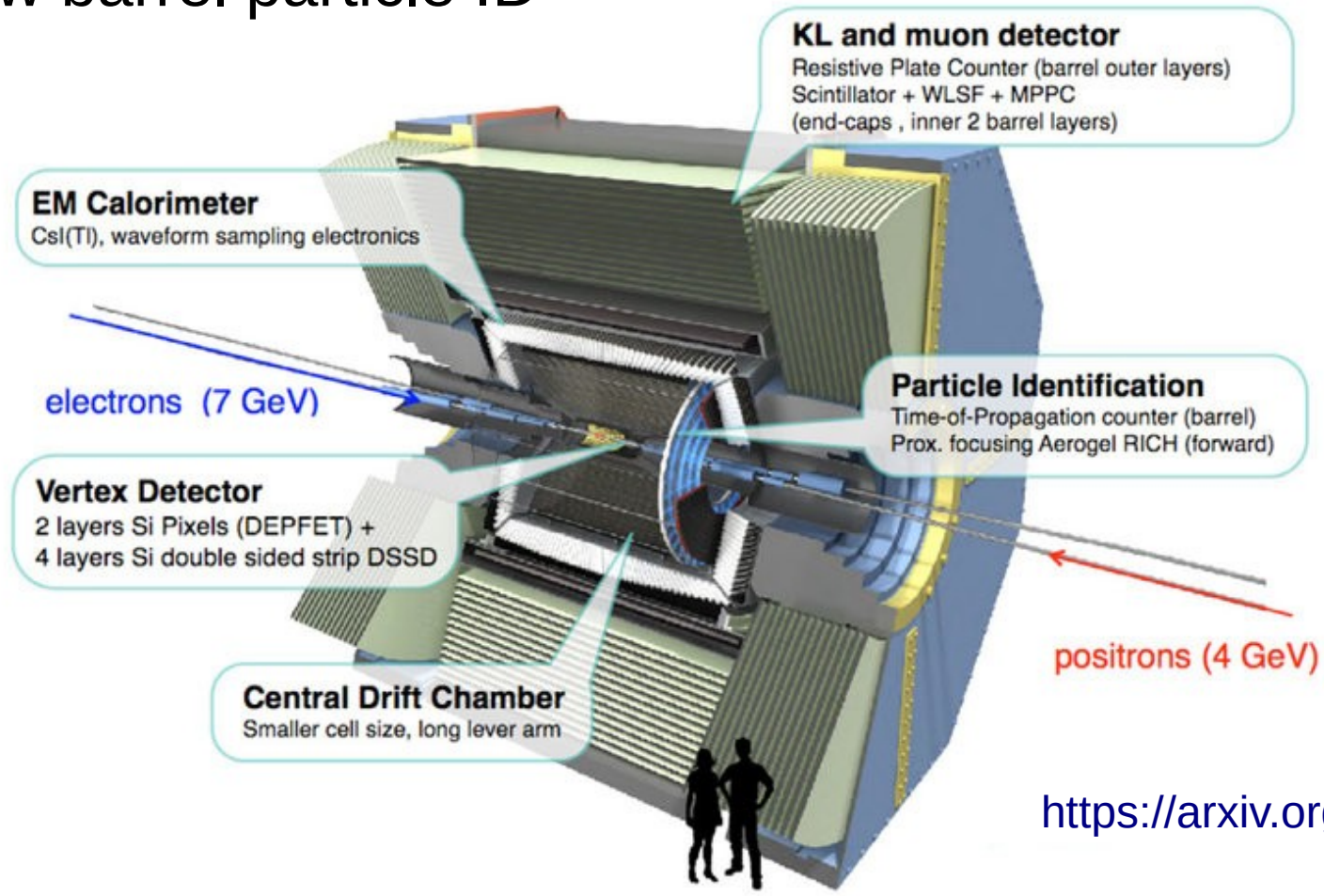
Belle II Collaboration

- Grown a lot in the last years
- ~1000 members in 26 countries
- https://www.belle2.org/



Belle II

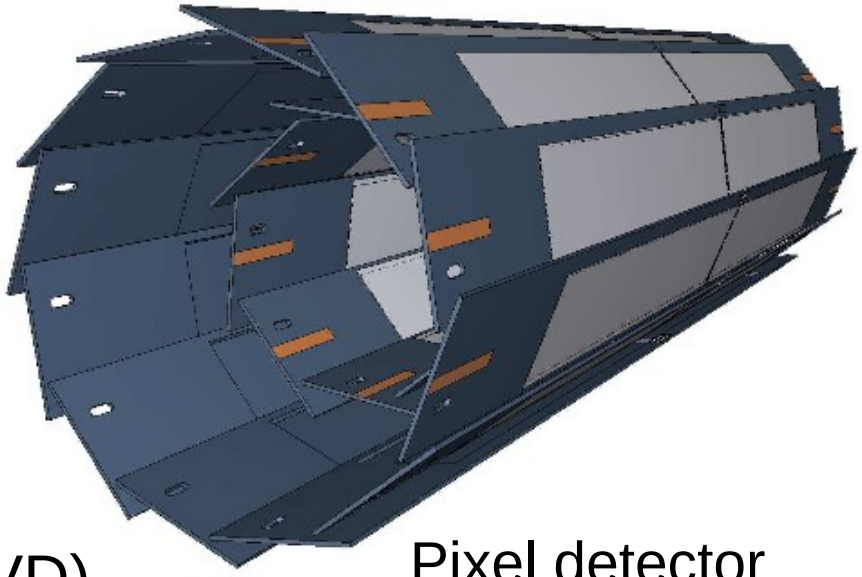
- Detector for SuperKEKB
- Major upgrade from Belle
- More precision, 30 kHz trigger rate, larger tracking detector
- New barrel particle ID



https://arxiv.org/abs/1011.0352

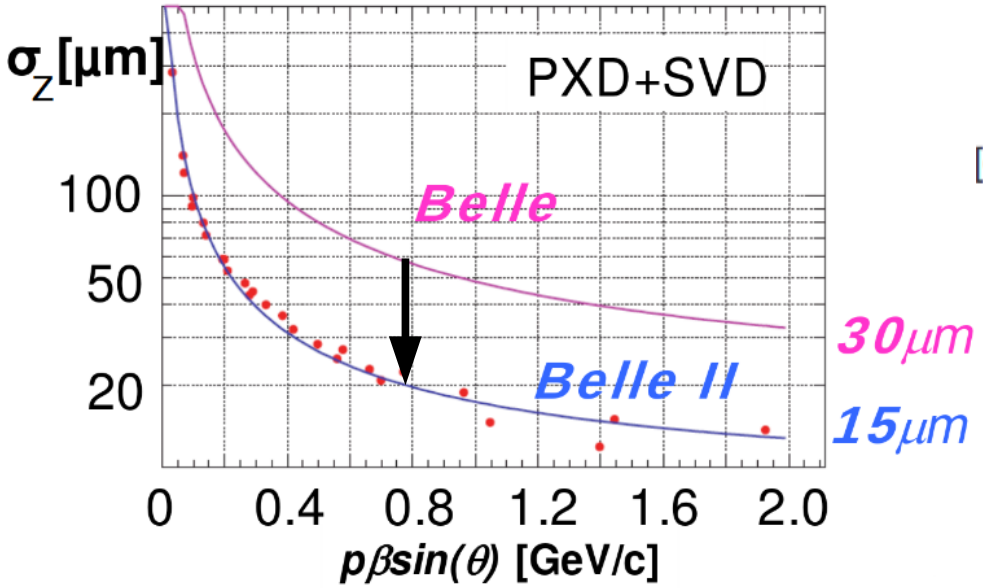
Vertexing

- Bottom/charm hadrons short-living
- Need to reconstruct decay vertices
- Boost reduced from Belle

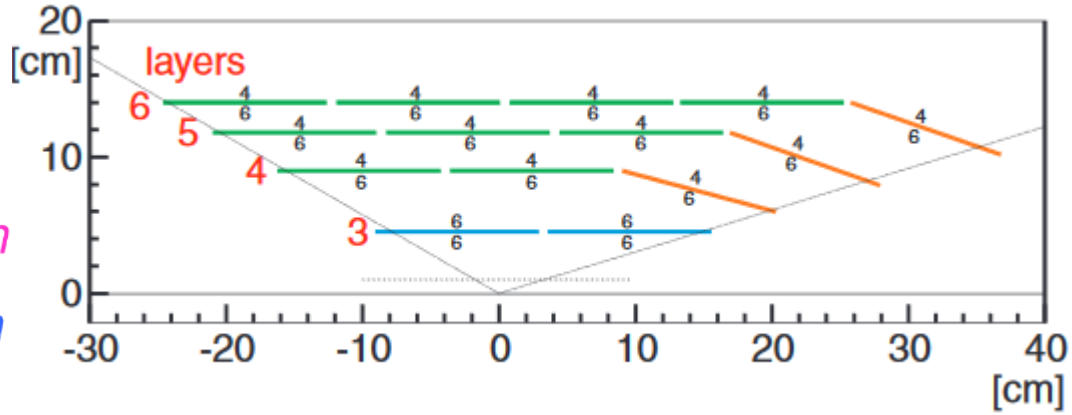


- 2 layers of pixel detector (PXD)
- 4 layers double-sided strip detector (SVD)

Pixel detector
diameter: 4.5 cm



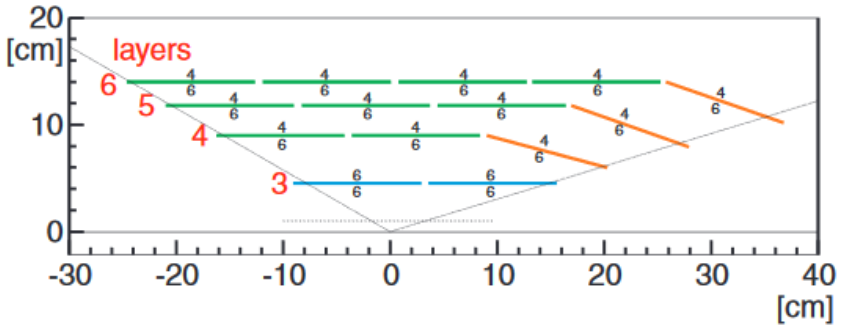
Strip detector

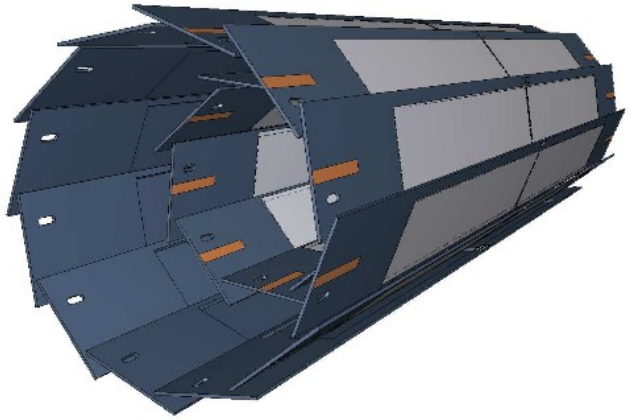


Tracking

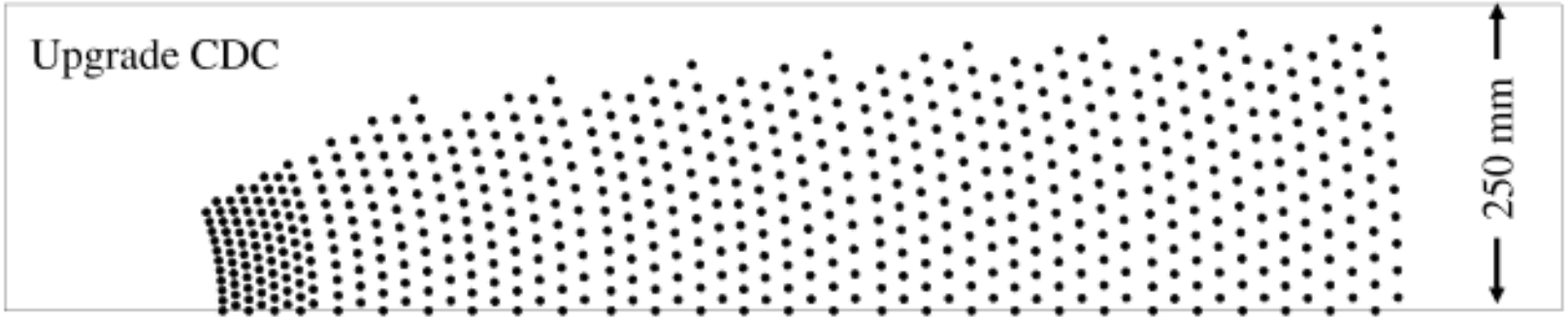
- 2 layers of pixel detector
- 4 layers of double-sided strip detector
- Drift chamber for main tracking (CDC)
  Many hits, long lever arm (1.1 m)

- In 1.5 T magnetic field



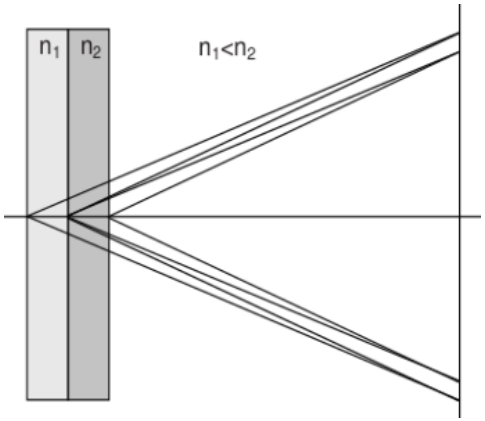


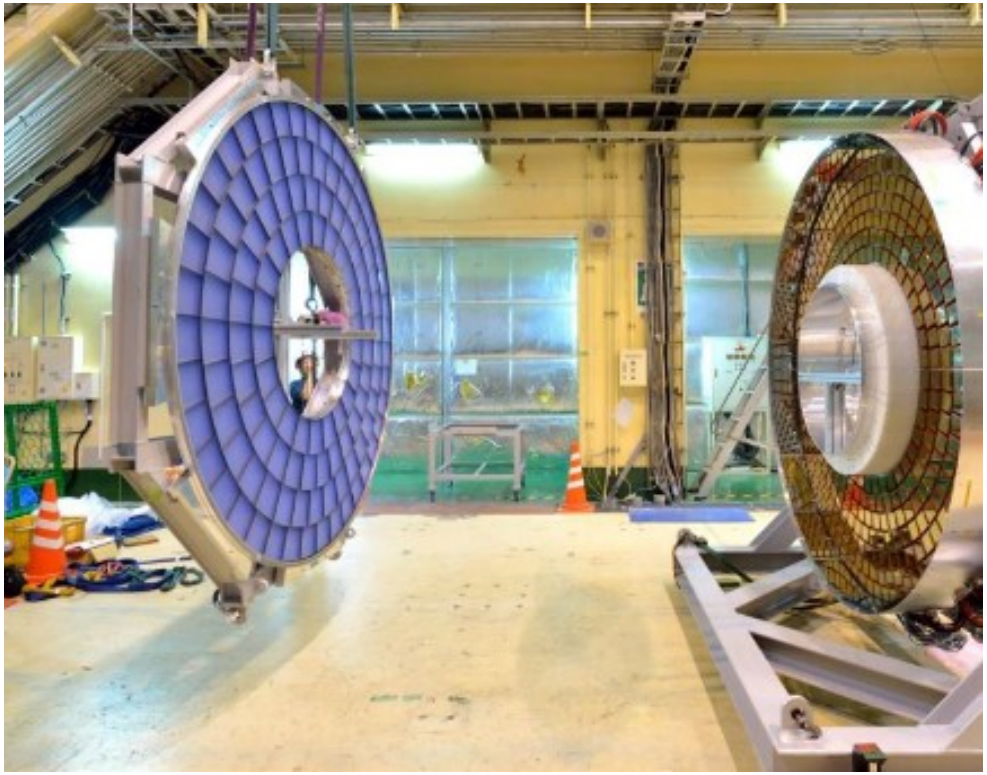
Drift chamber



Charged particle identification

- Aerogel RICH (ARICH) detector in forward side
- Proximity focusing (2 radiators)
- Directly measure Cherenkov angle





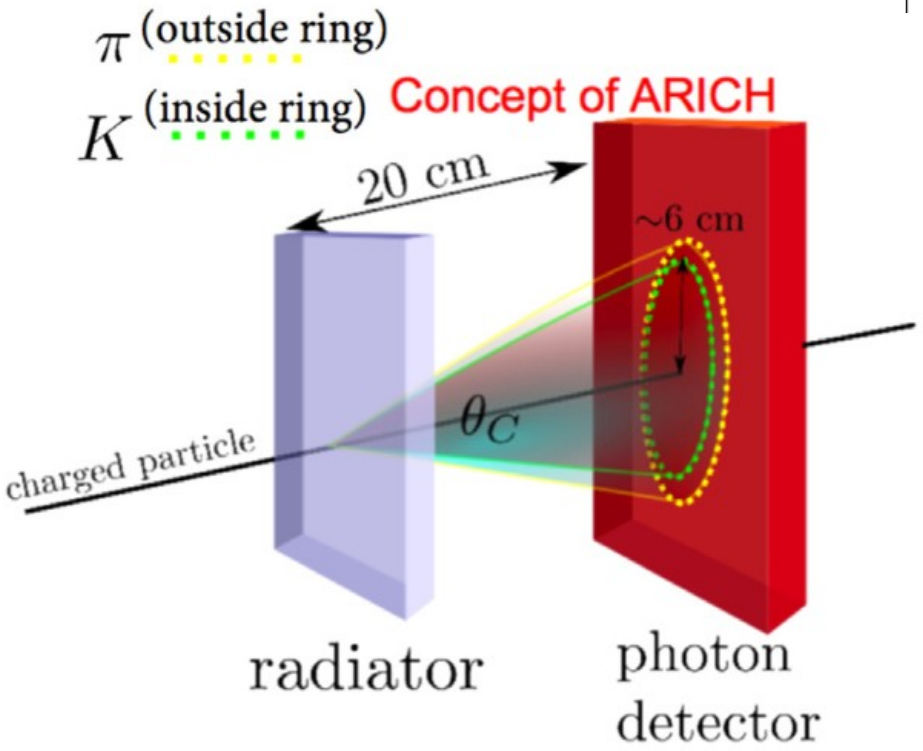
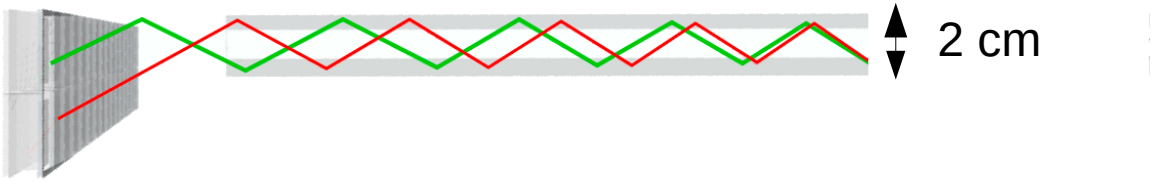
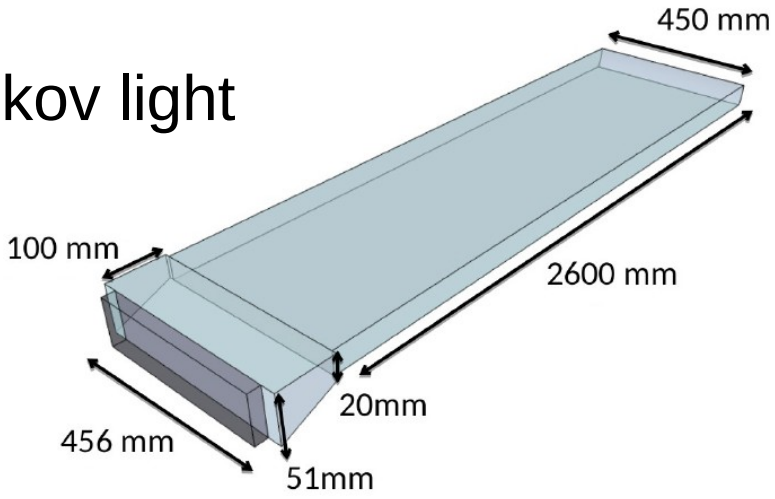


Fig. 7. The concept of the ARICH.

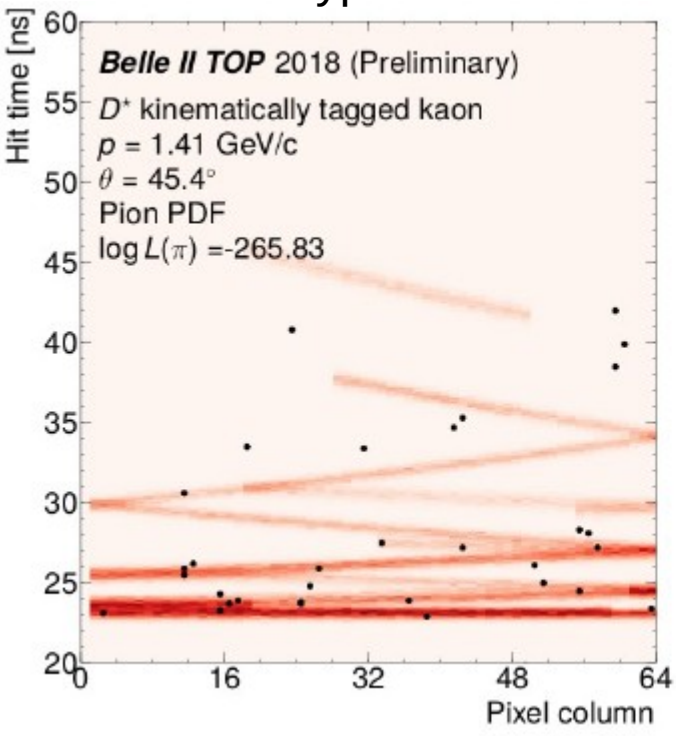
Charged particle identification

- Larger drift chamber →tight space for PID
- Use Time Of Propagation (TOP) of Cherenkov light
- Total internal reflection
- Particle identification in 2 cm

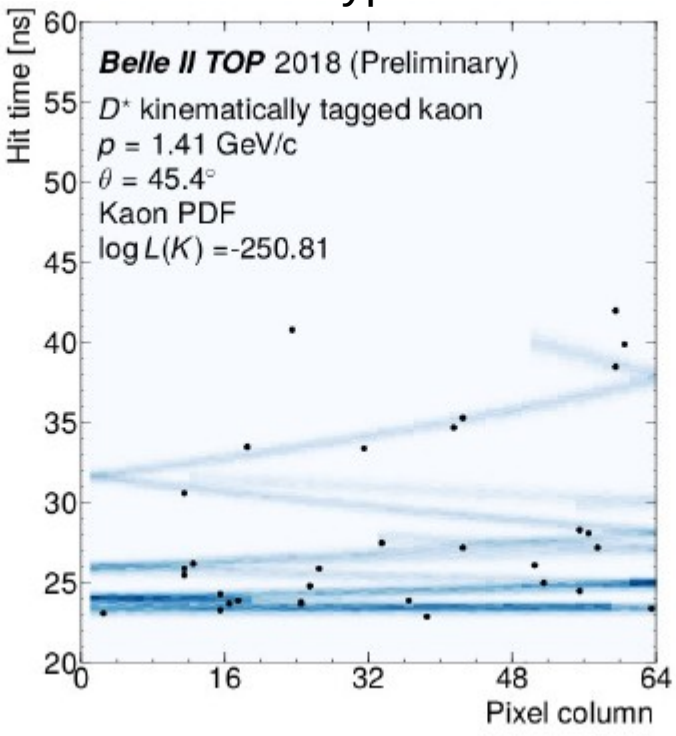




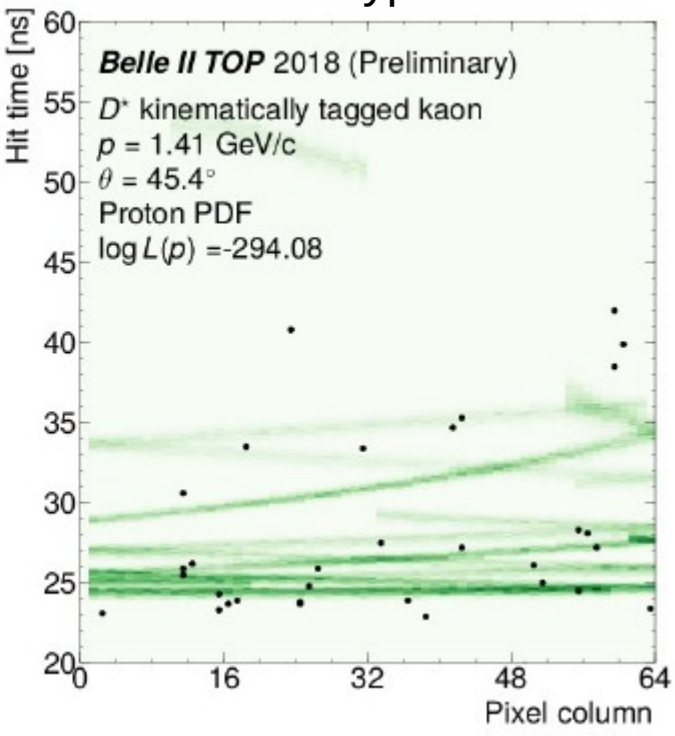
Pion hypothesis



Kaon hypothesis

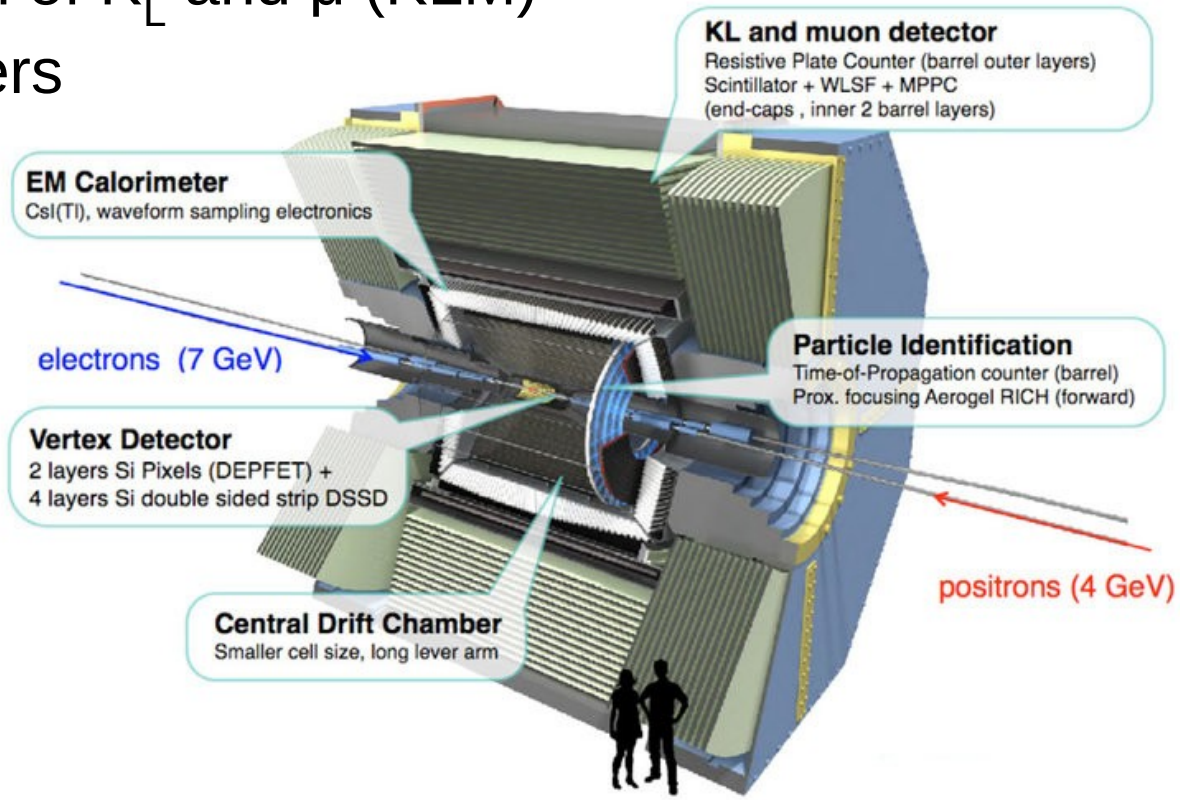


Proton hypothesis



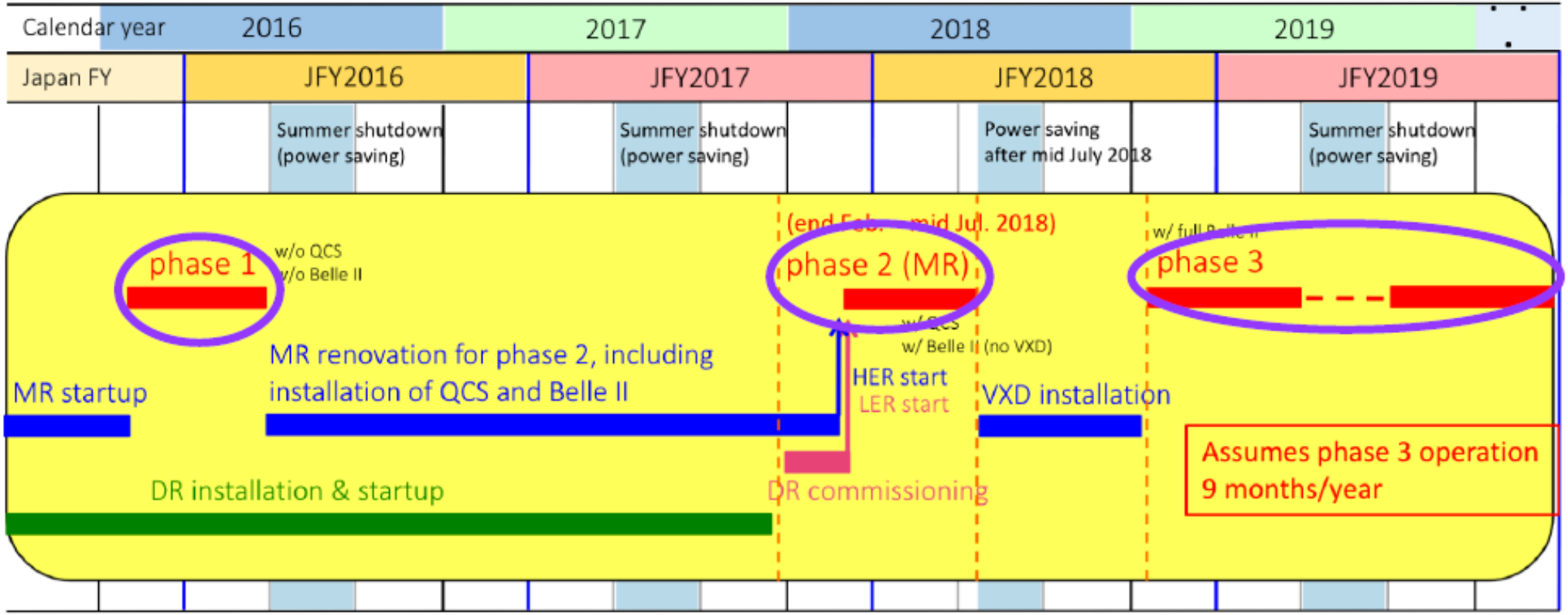
Outer detectors

- Electromagnetic calorimeter (ECL) taken from Belle
  - Scintillators
  - New readout electronics
  - For direct photons, π^0, e
- 1.5 T superconducting solenoid
- Flux return and detection of K_L and μ (KLM)
  - Resistive plate chambers
  - Scintillators



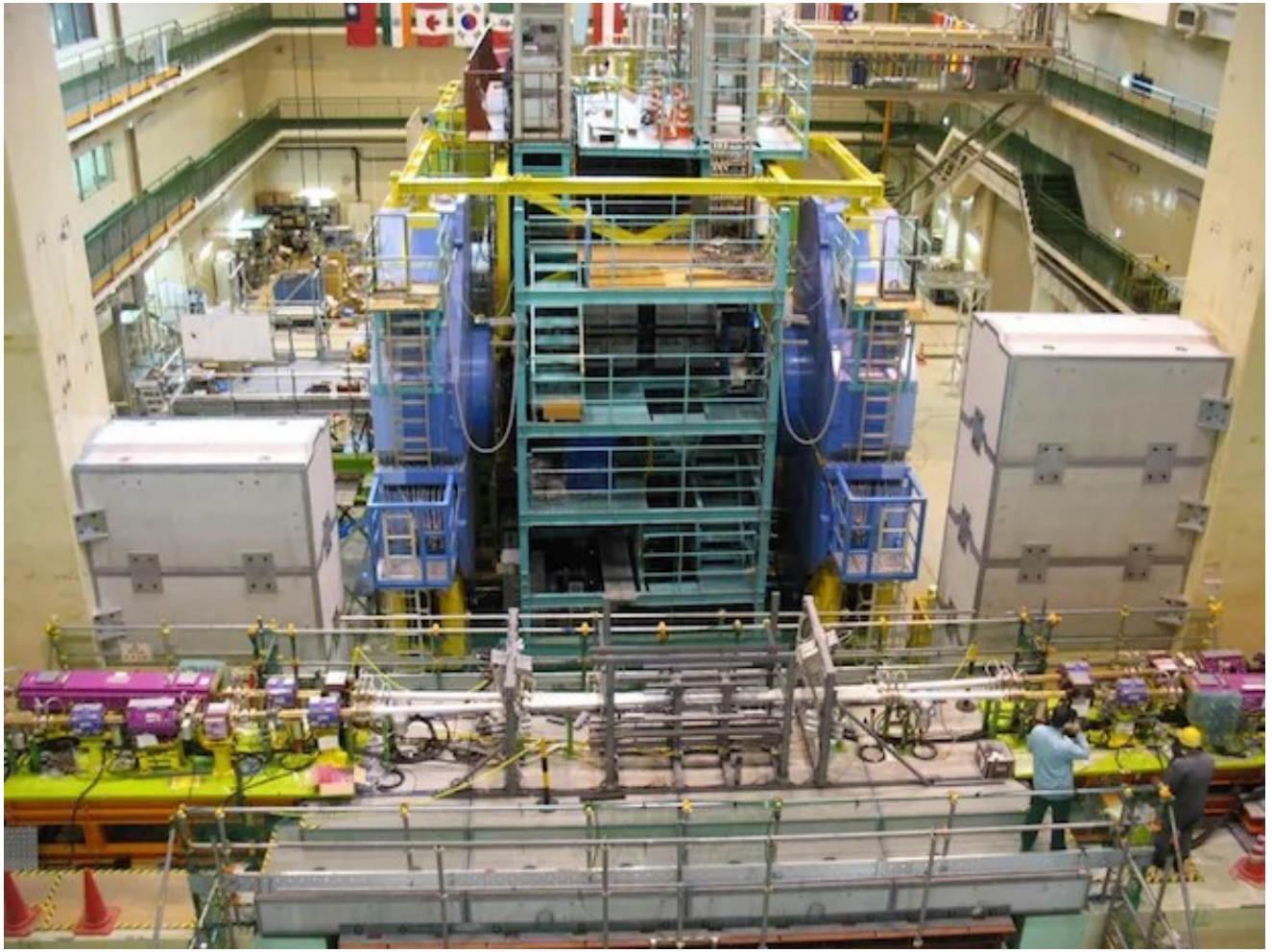
Timeline

- Phase 1: Accelerator commissioning
- Roll-in of detector
- Phase 2: Detector commissioning
- Installation of VXD
- Phase 3: Physics data-taking



Phase 1: accelerator

- Accelerator commissioning (no collisions)
- Beast II measured backgrounds
- Seven detector types:
  injection backgrounds, ionizing radiation, fast/thermal neutrons, ...



positrons →

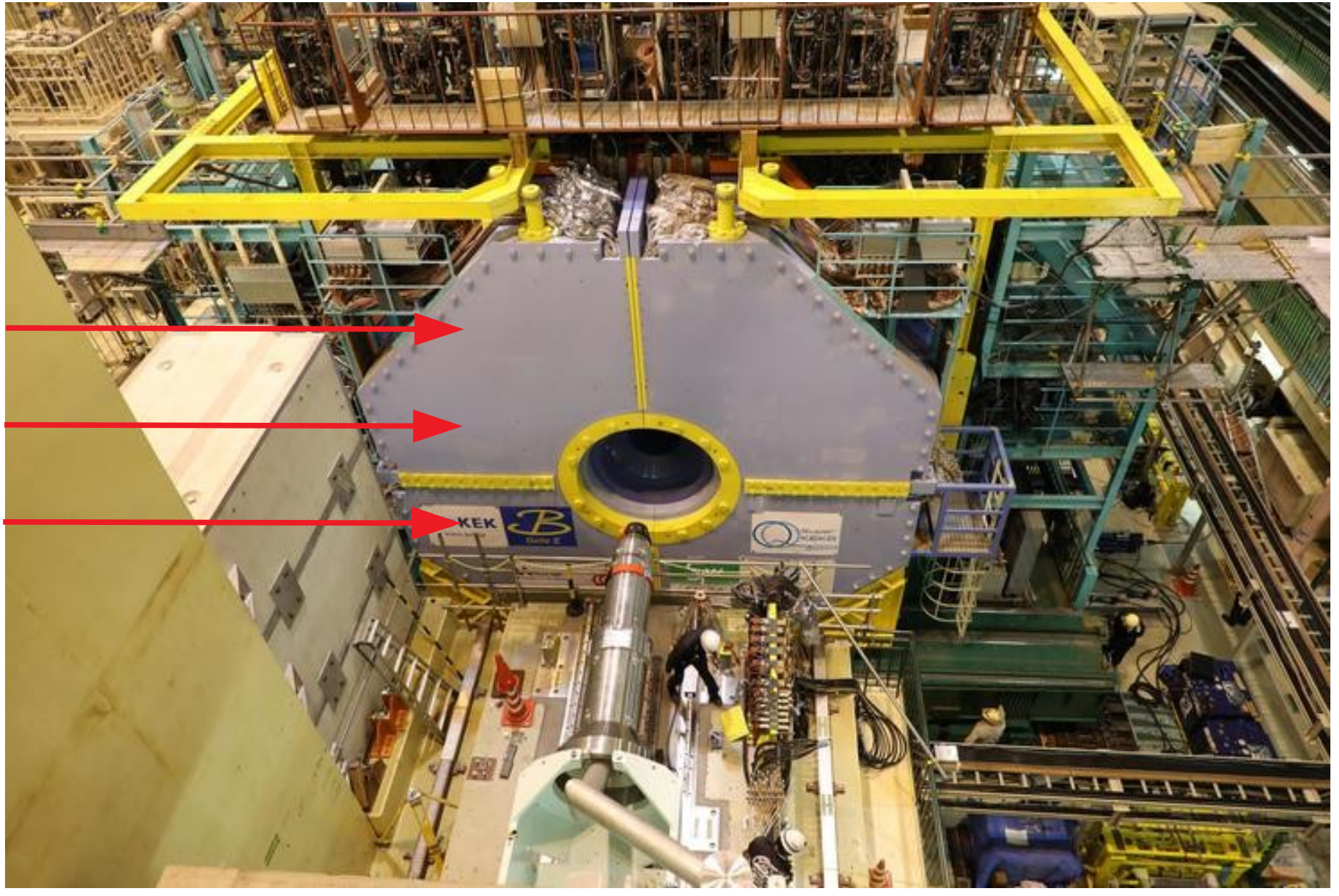
← electrons

Phase 1: detector assembly

Here: TOP installation

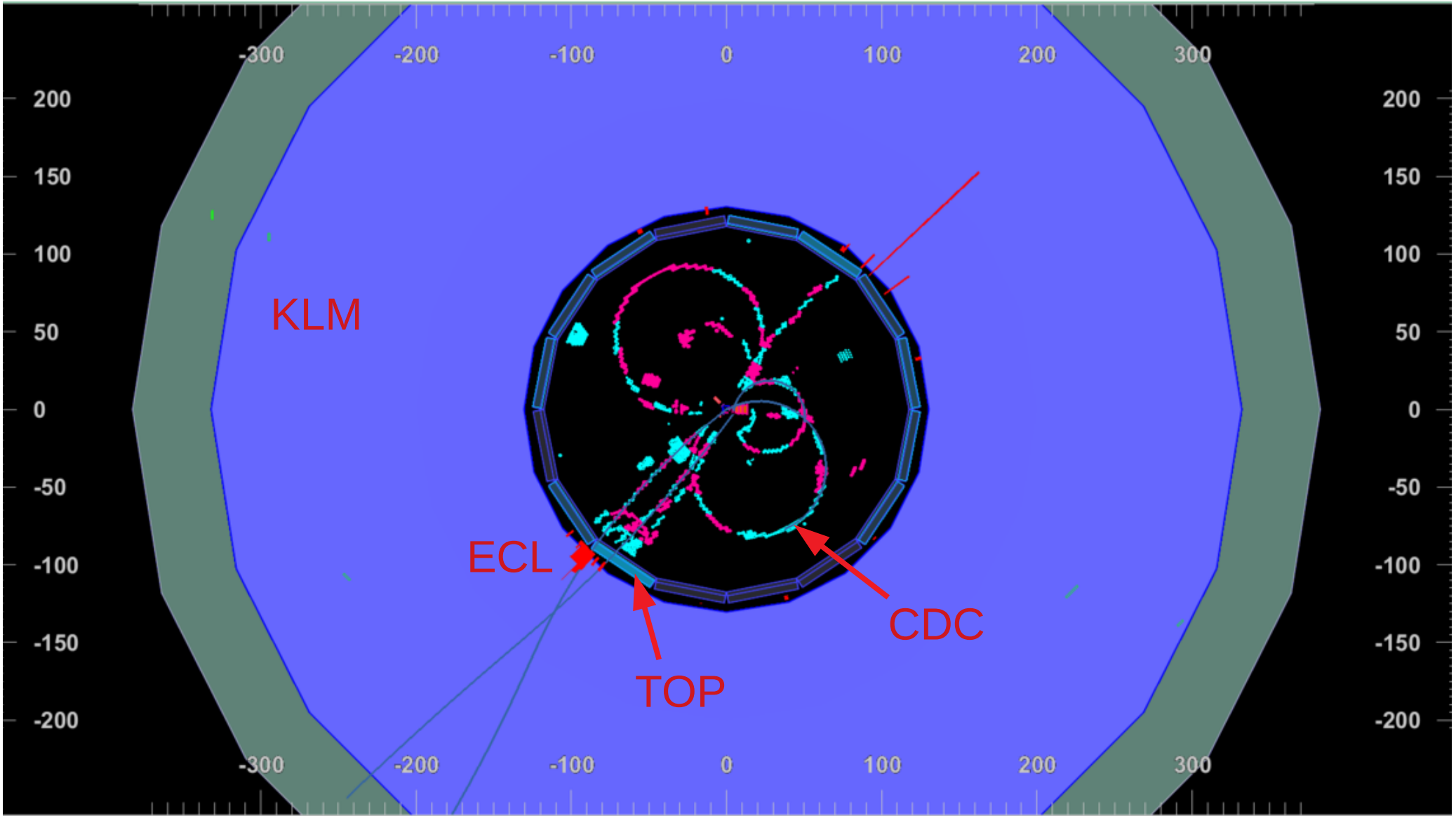
Detector roll-in

April 11, 2017

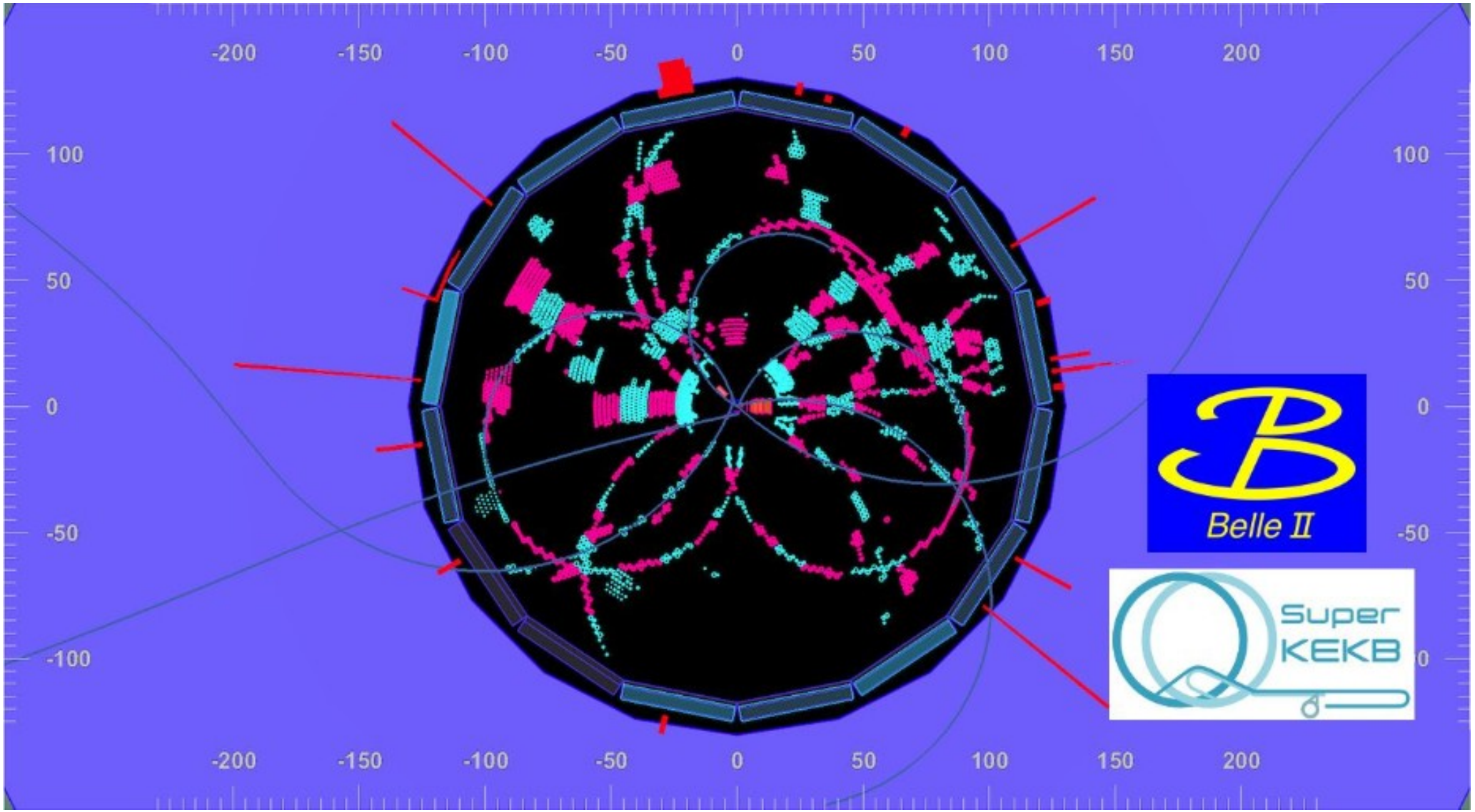


Phase 2: First collisions

April 26, 2018



$B\bar{B}$ event candidate

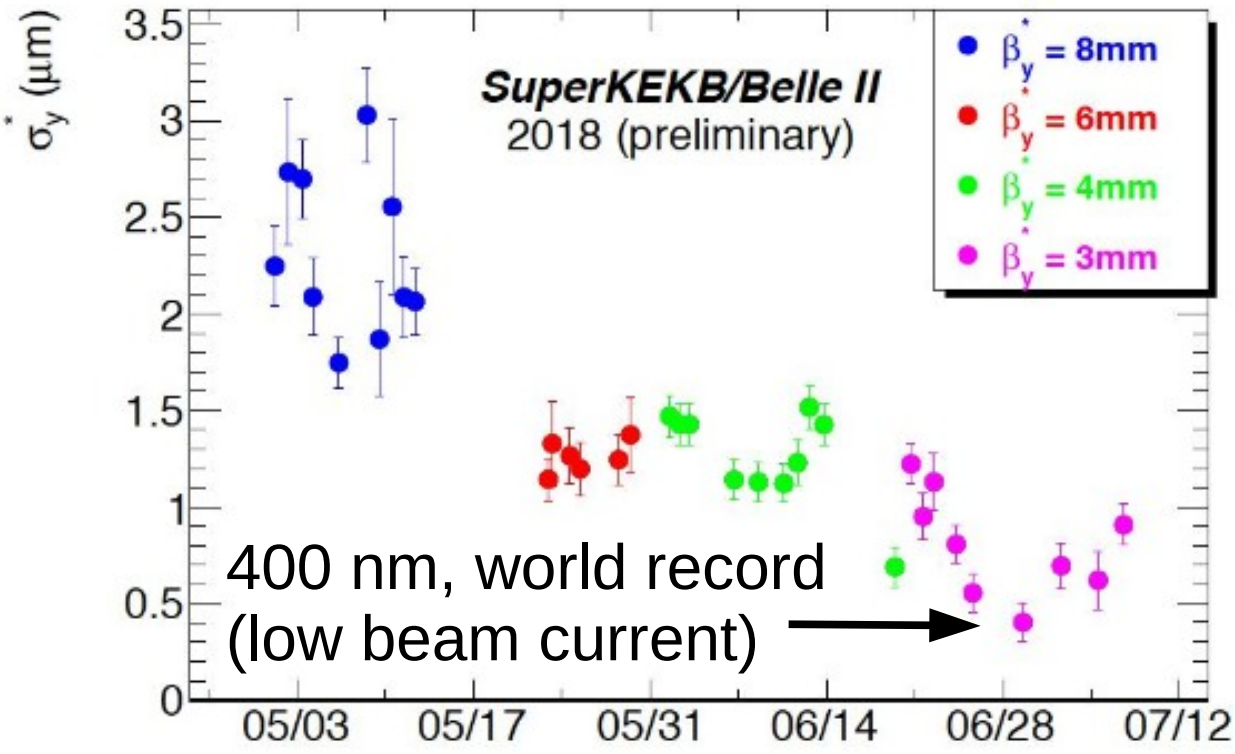


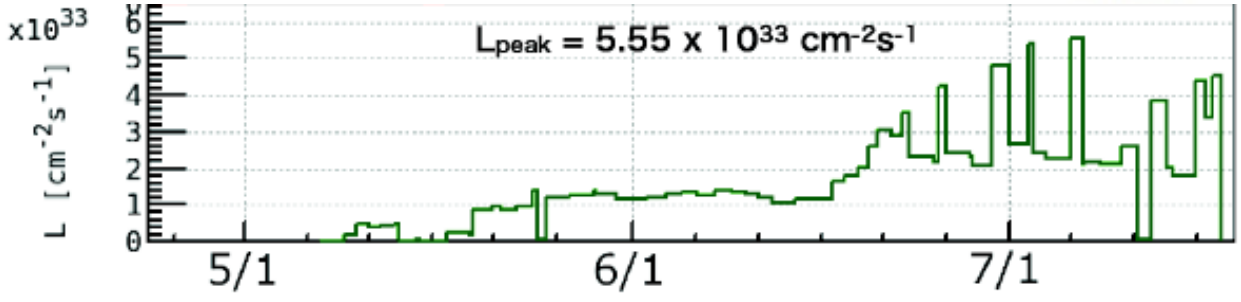
Control room

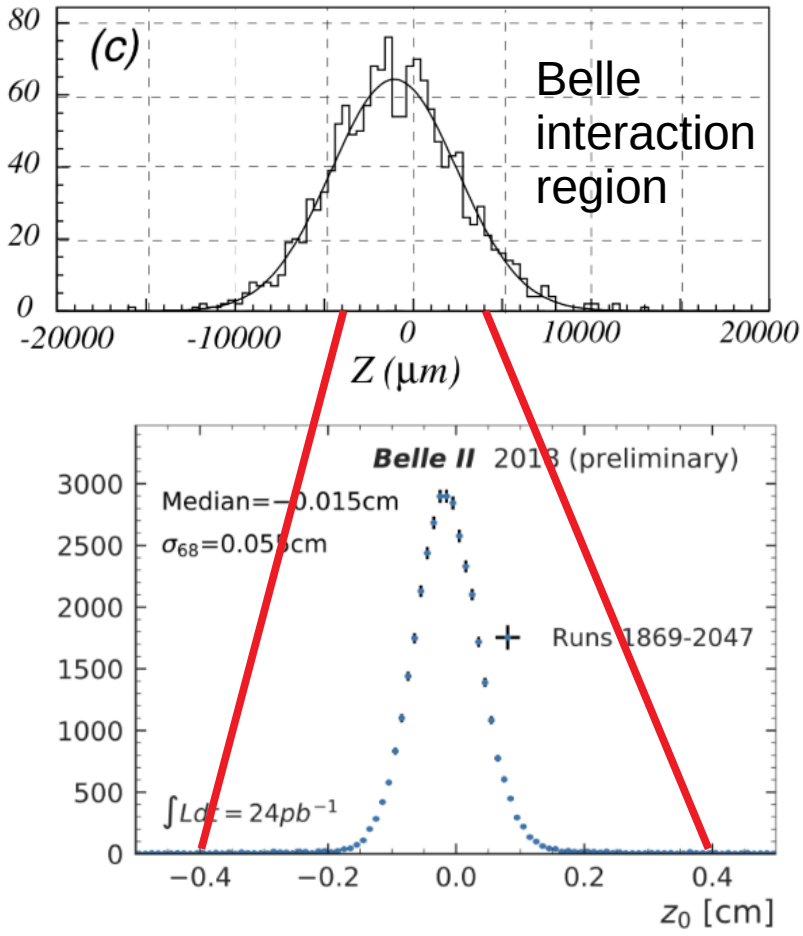
Accelerator tuning

Nano-beam scheme
in operation

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

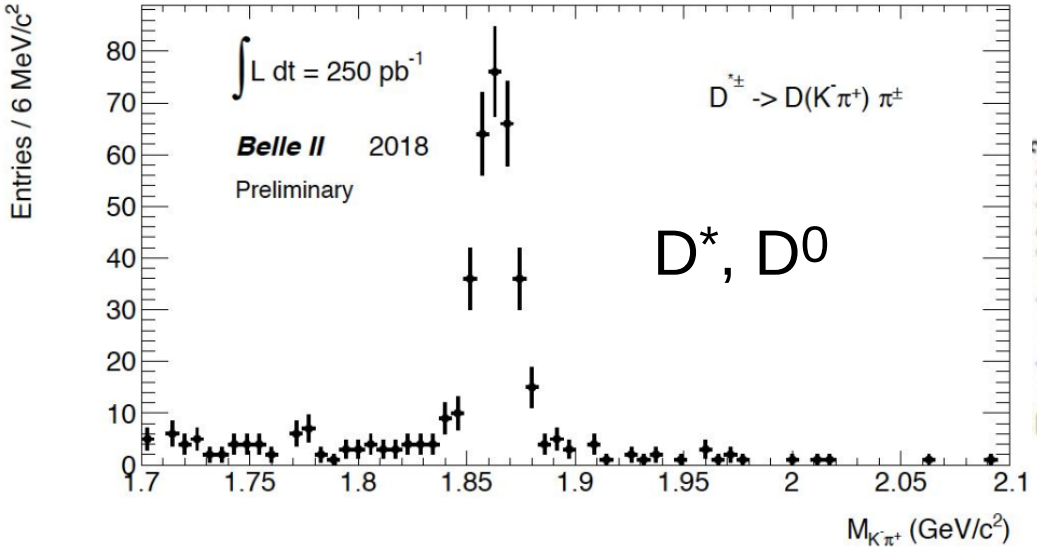


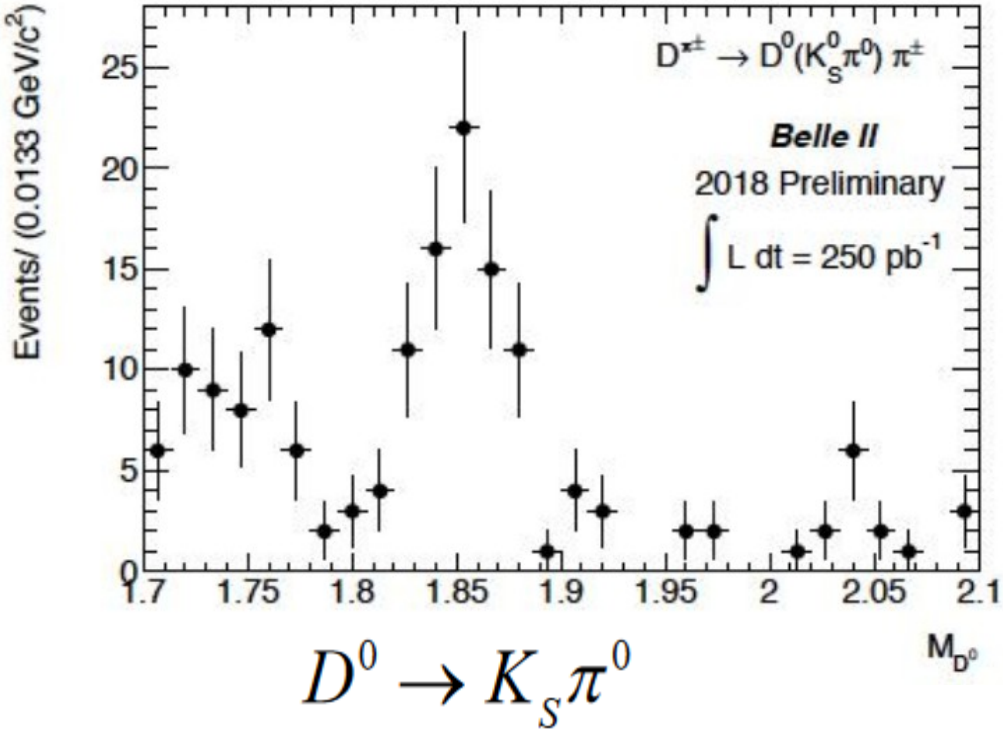


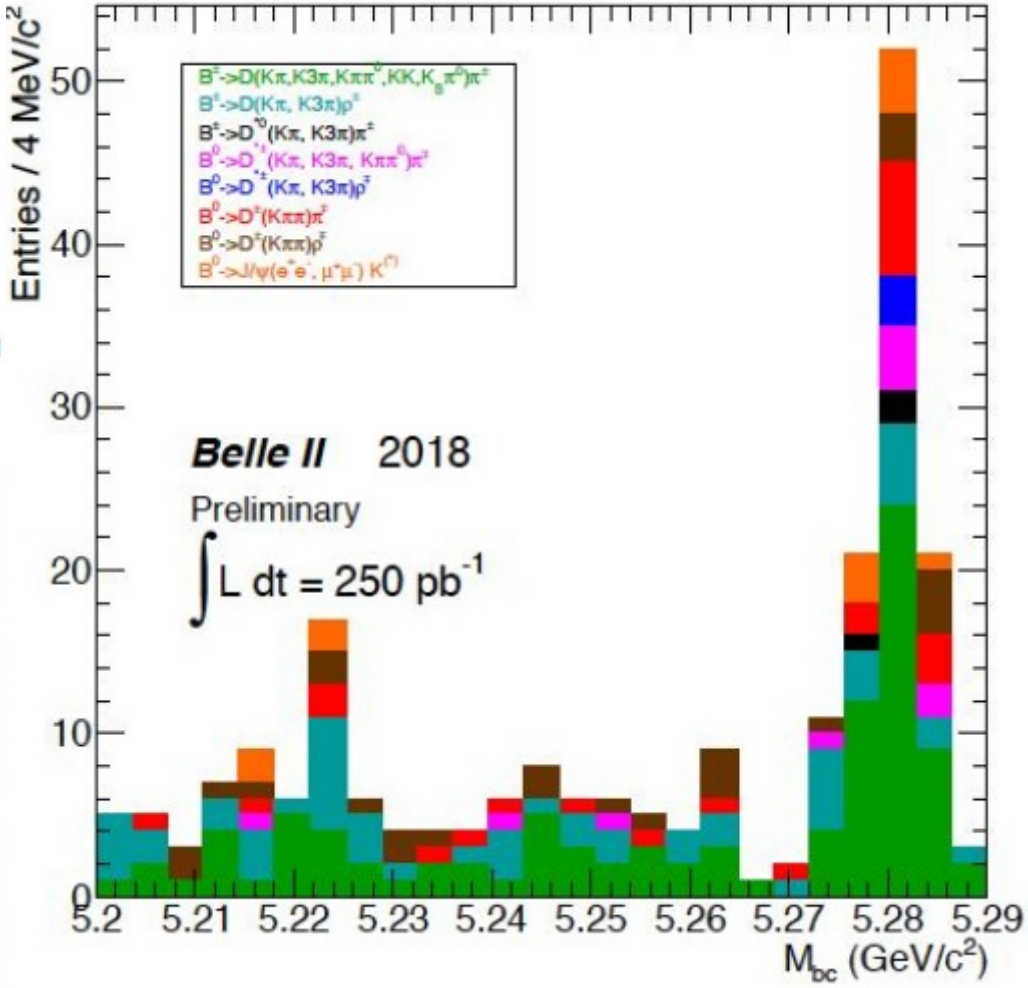


Still a long way to go

Particle re-discovery







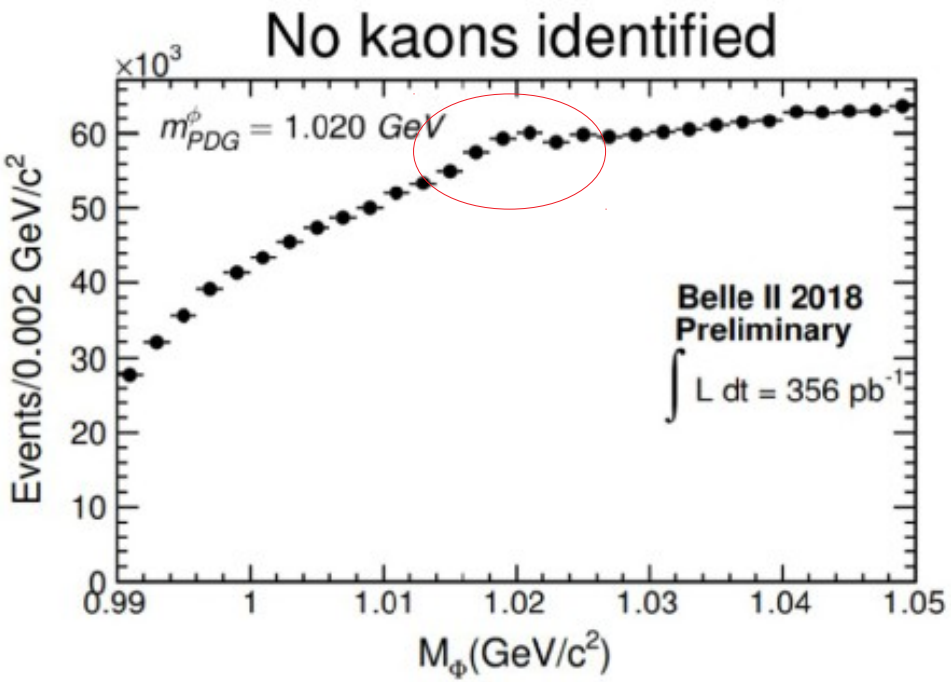
B mesons

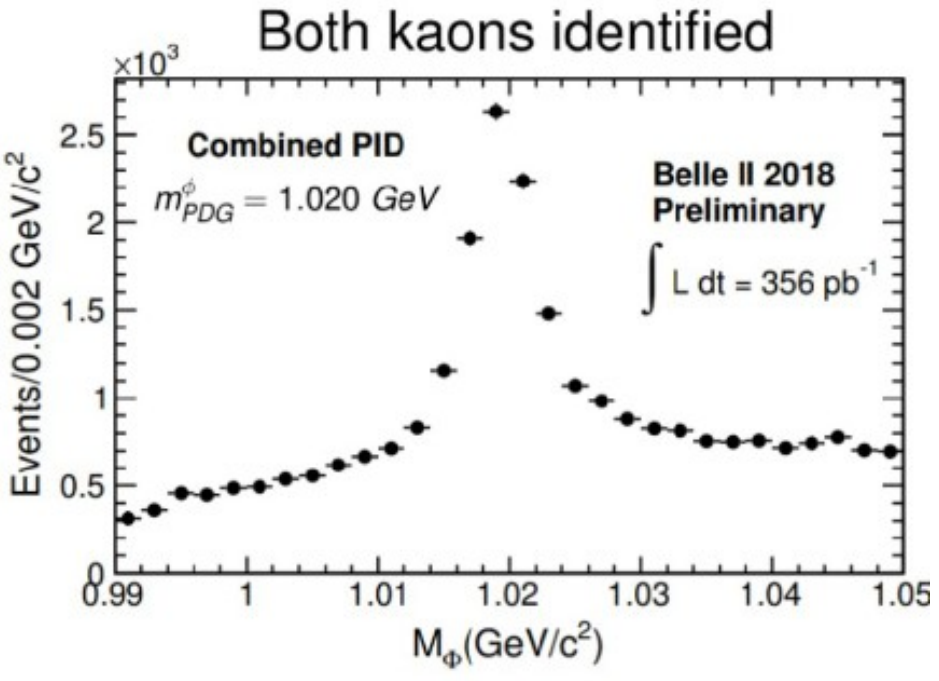
Particle re-discovery

Particle identification from tracking dE/dx, ARICH and TOP

Calibration still ongoing

$$\phi \to K^+K^-$$





VXD installation

VXD installed 2018/2019
Only 1 pixel layer completed in time
Second layer to be installed later

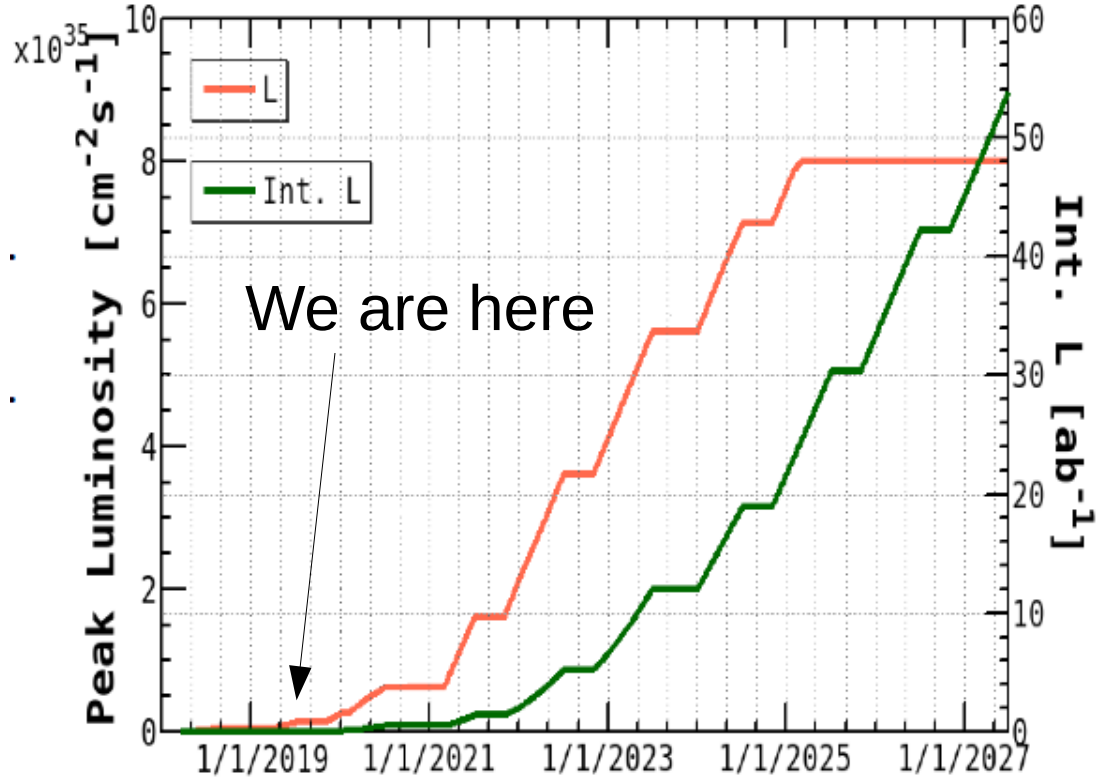
1/2 of VXD

Phase 3

March 24, 2019

Phase 3 schedule

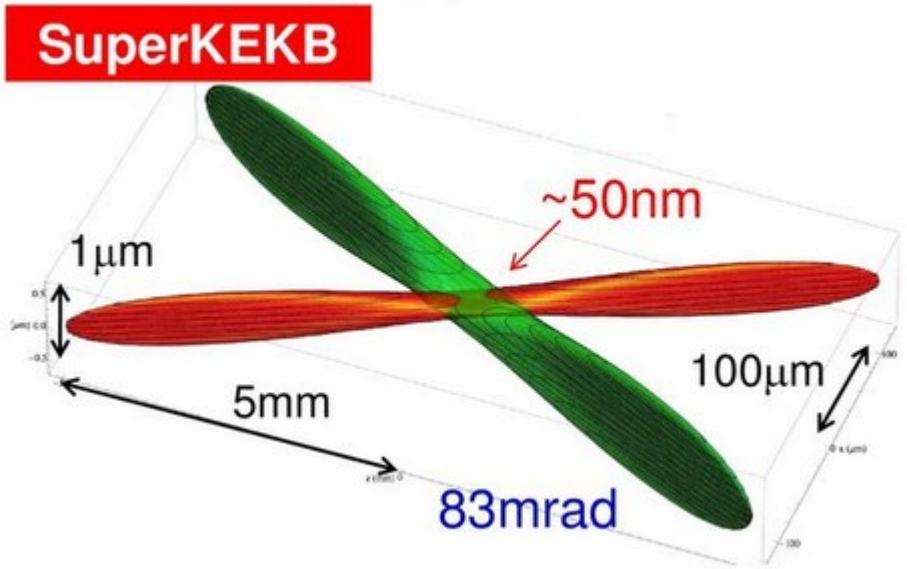
- First collisions in March
- April: Soot in accelerator (from unrelated fire), no beam
- Collecting data May-June
- Plan: Running 7-9 months/year with summer shutdowns
  second pixel layer, replace aging parts, ...
- Challenge: Accelerator backgrounds

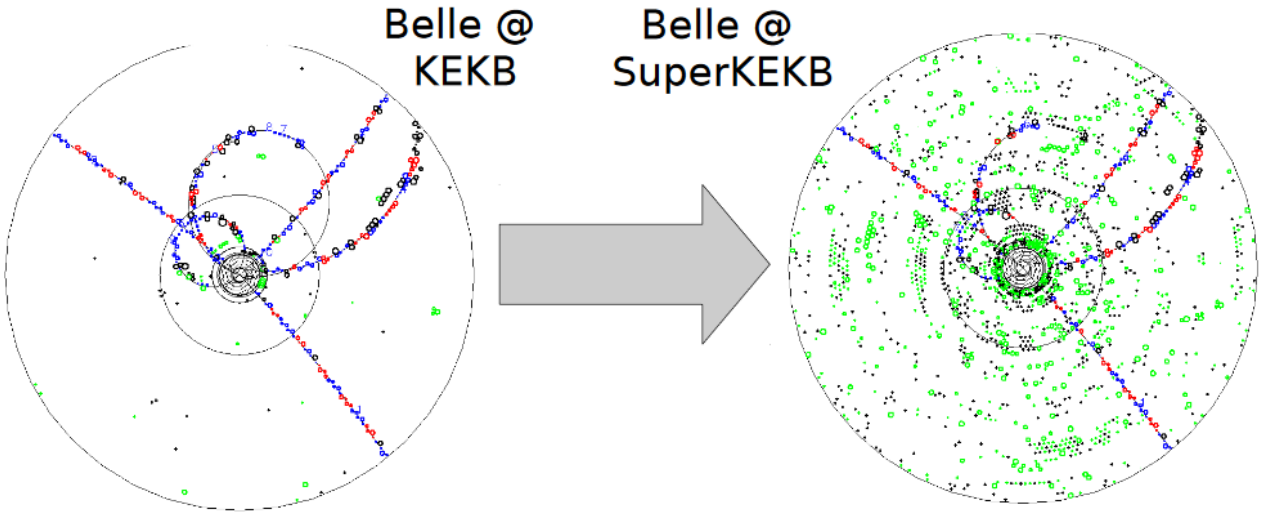


Accelerator backgrounds

Collisions are clean, but...

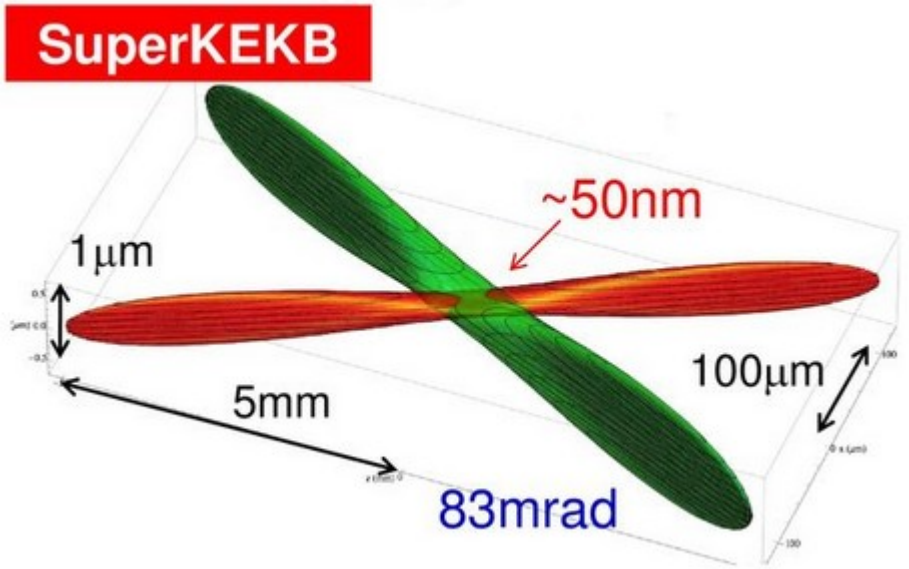
- Intra-beam scattering
  (Touschek effect)
  scales with 1/emittance
- Beam-gas scattering
- Beam/beam interaction
- Synchrotron radiation

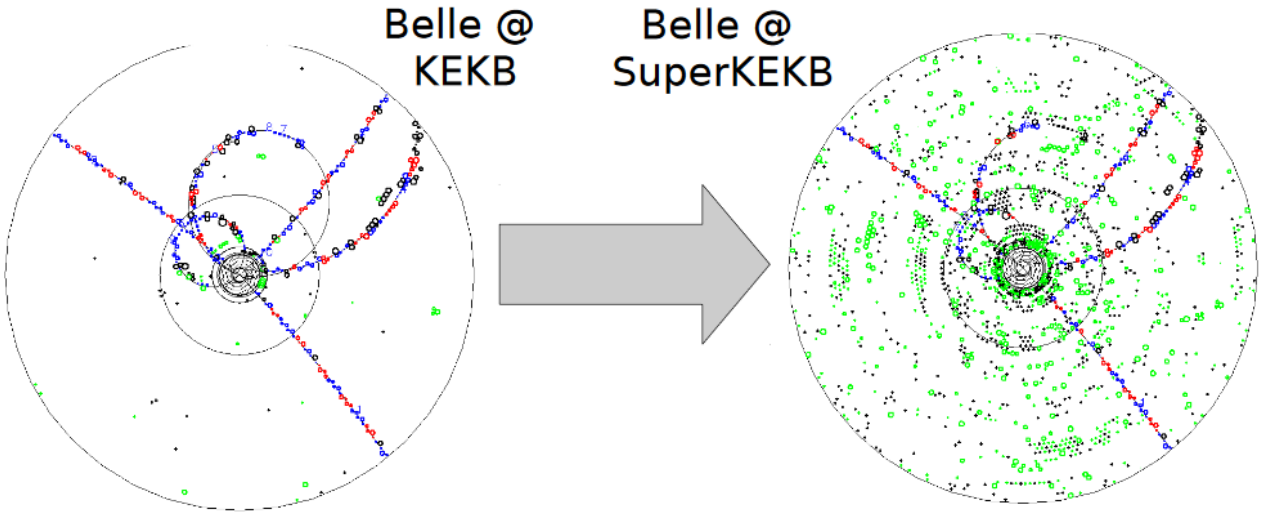




Accelerator backgrounds

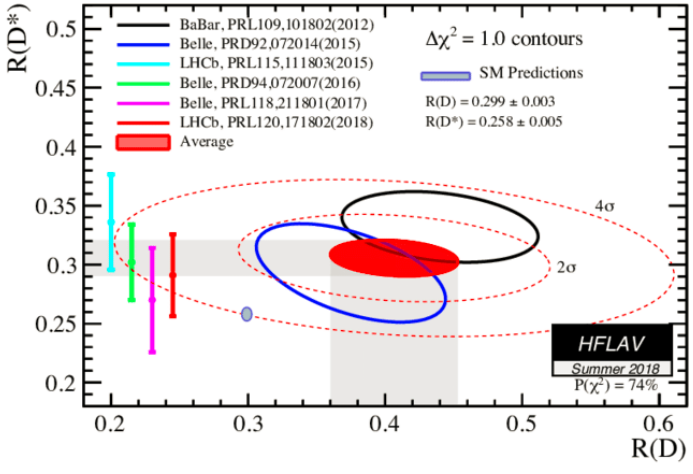
- Much higher than in Belle
- Challenge for:
  - Trigger
  - Readout
  - Tracking
  - CDC HV
  - TOP PMT lifetime
- Mitigation:
  - higher e^+ energy
  - vacuum scrubbing
  - collimator tuning



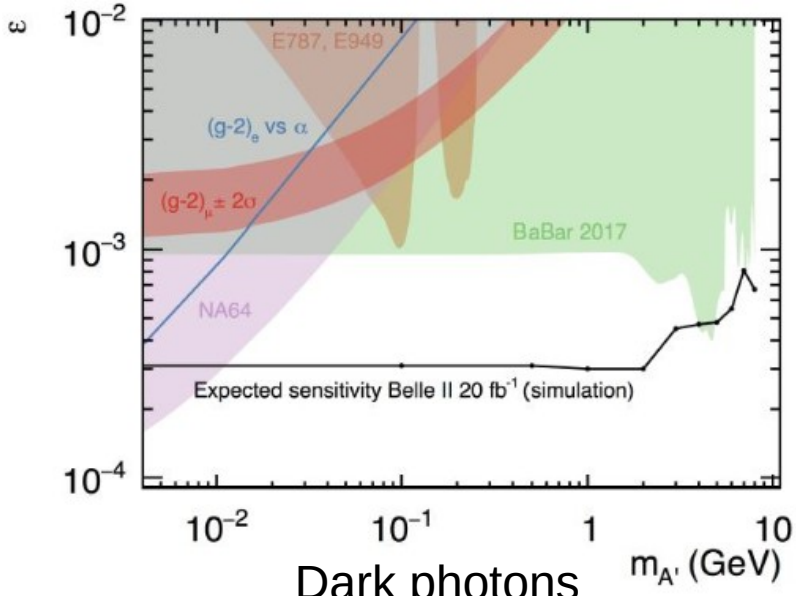


Outlook

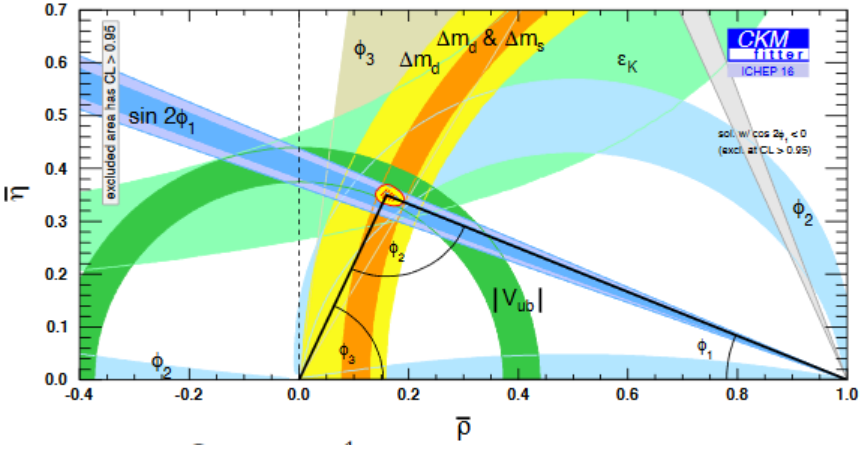
- First few fb^{-1} collected
- ~20 fb^{-1} enough for competitive results
- Long-term goal: 50 ab^{-1}.
- Mainly Y(4s) but also other energies



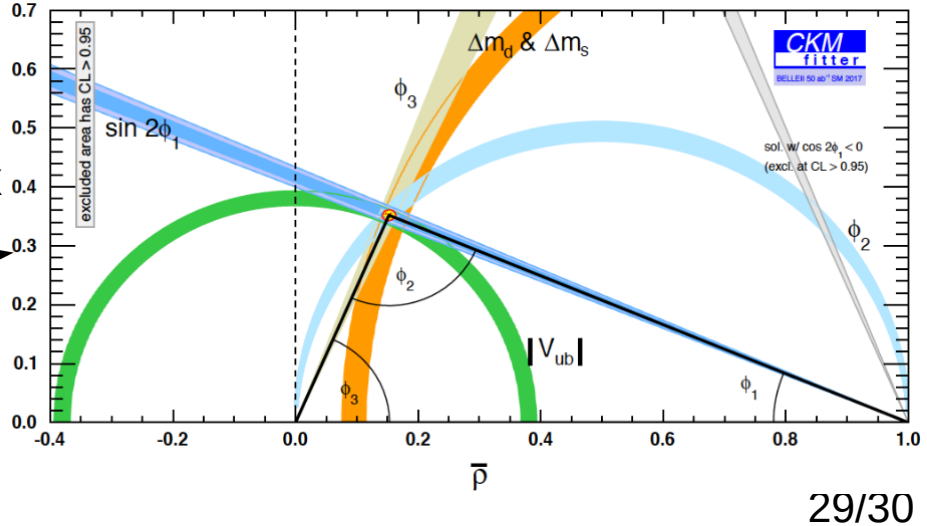
R(D*)
~1/ab



Dark photons
20/fb

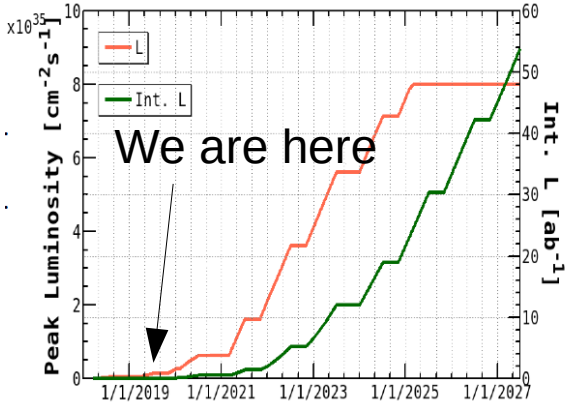


CKM matrix
50/ab



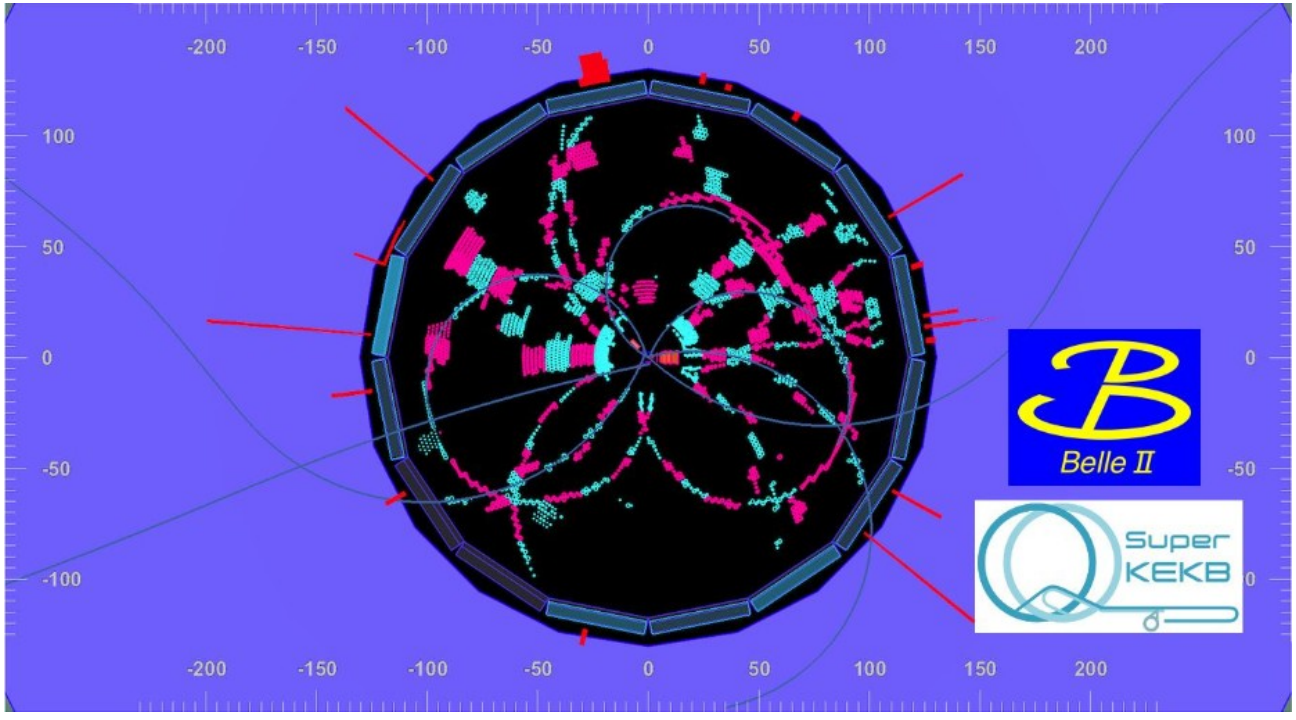
Summary

- B-factories: Tools for flavor/hadron physics, dark sector searches
- Belle II: More data than Belle, improved detector
- Commissioning run in 2018
- Regular data-taking since March 2019
- Major challenge: Backgrounds



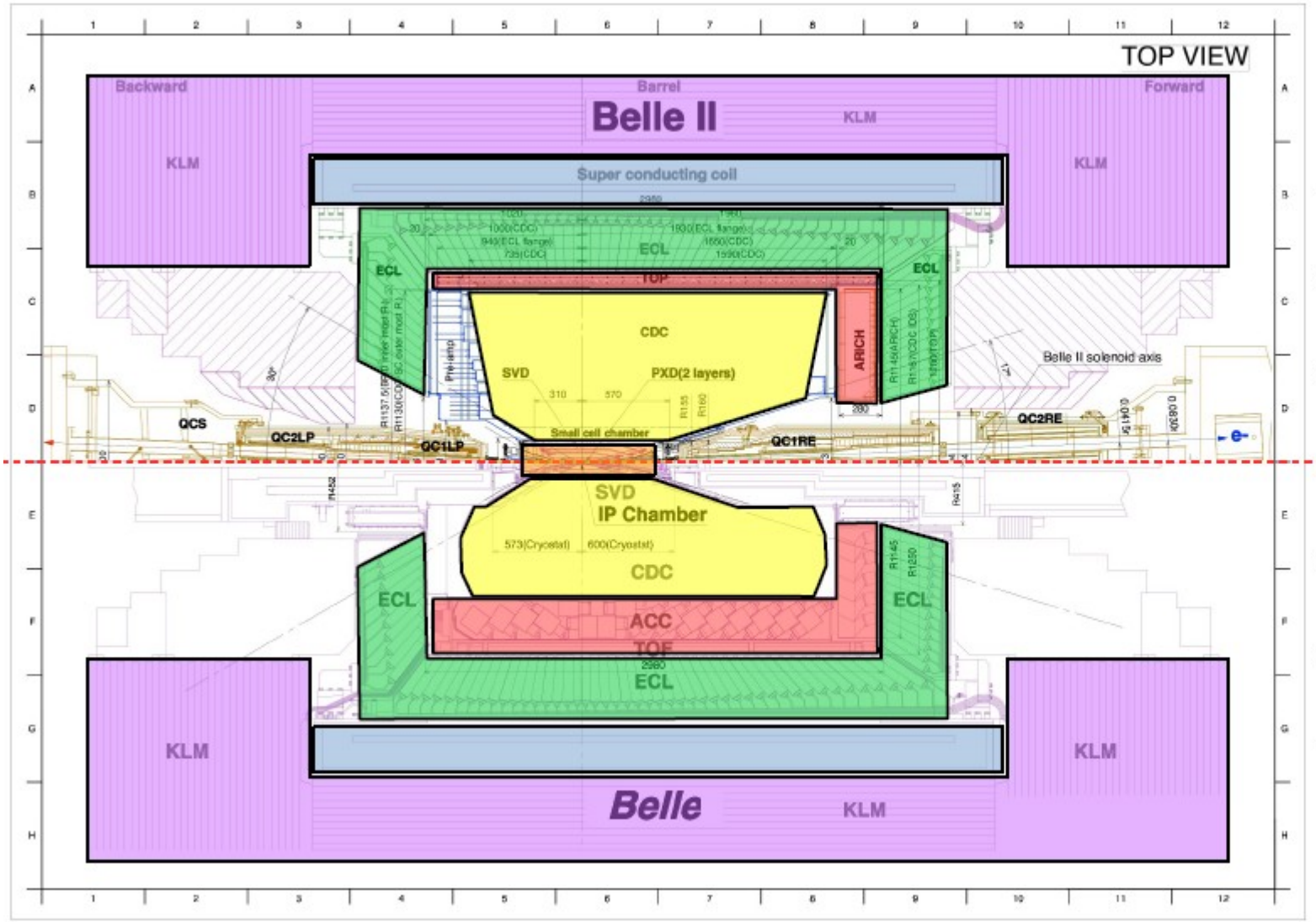
- 50 ab^{-1}
- ~50 billion $B\bar{B}$ pairs
- Improved precision over Belle
- Many new measurements

Stay tuned!



Backup slides

Belle II vs. Belle



- K_L/Muon System
- Magnet Coil
- EM Calorimeter
- π/K Identification
- Drift Chamber
- Silicon Tracking

Comparison: Belle timeline

Hua YE, “Belle & Belle II Activities”, 2016