Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO

Status of the Belle II experiment (and its first results)

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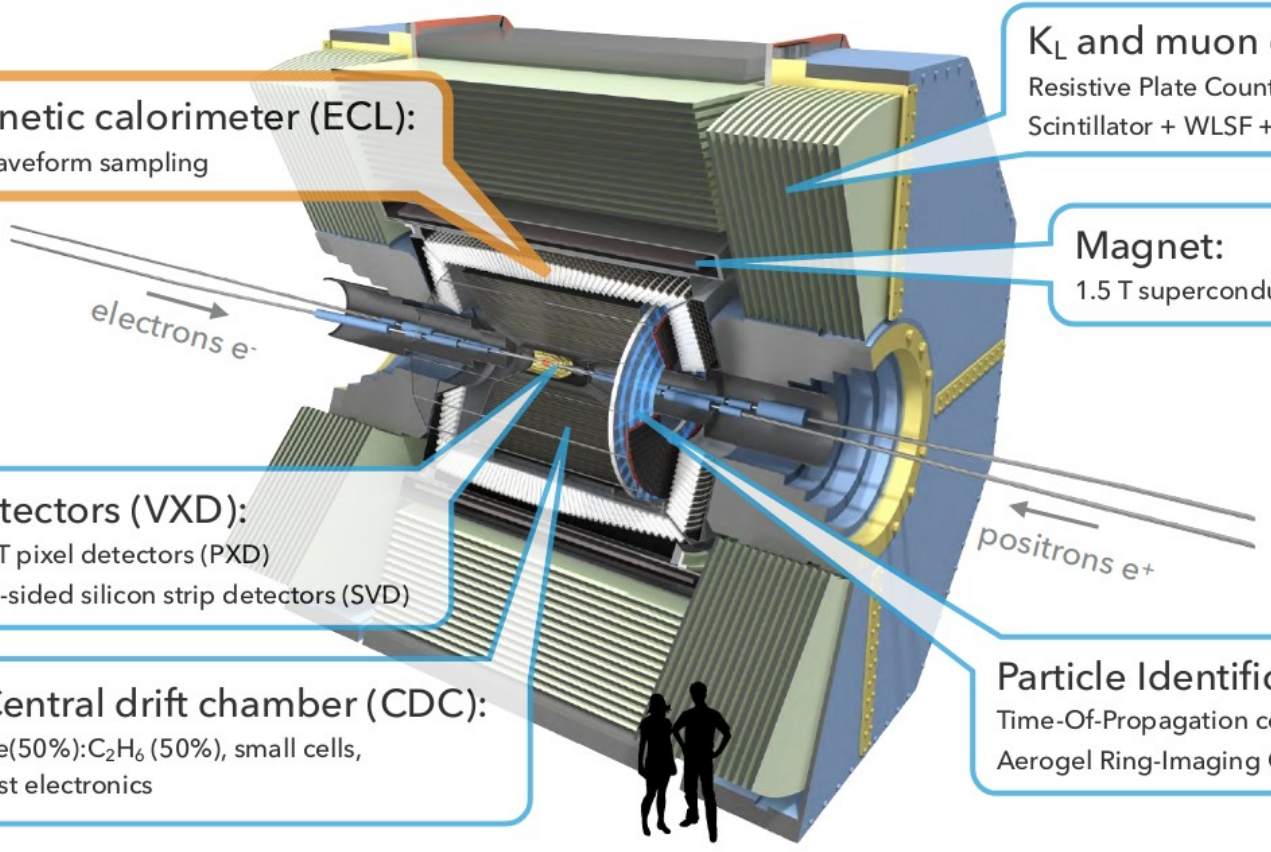
INFN – Sezione di Torino

Rencontres de Moriond 2019 (QCD)
La Thuile, March 25th 2019

The Belle II detector



Electromagnetic calorimeter (ECL):
CsI(Tl) crystals, waveform sampling

K_L and muon detector (KLM):
Resistive Plate Counters (RPC) (outer barrel)
Scintillator + WLSF + MPPC (endcaps, inner barrel)

Magnet:
1.5 T superconducting

Trigger:
Hardware: < 30 kHz
Software: < 10 kHz

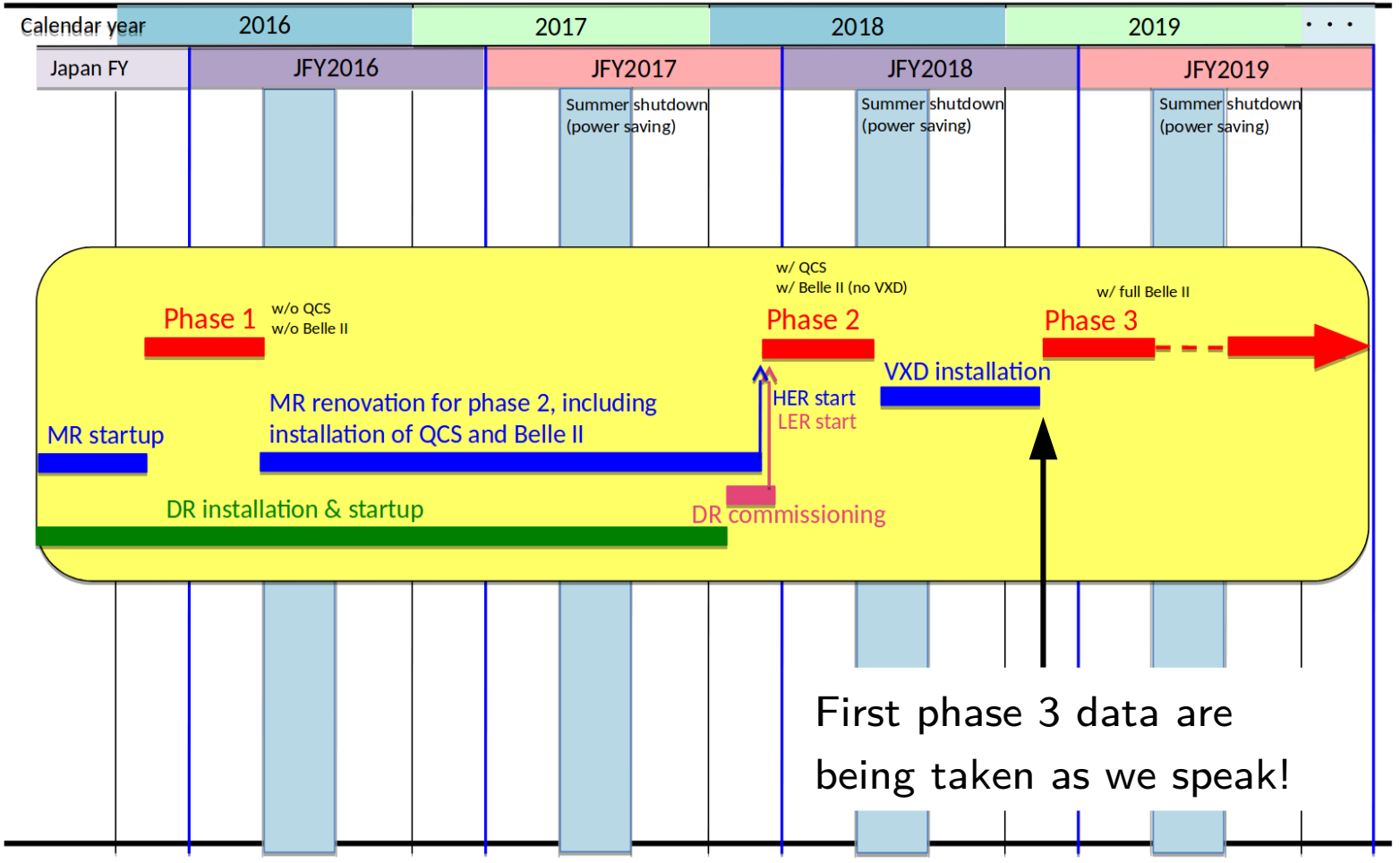
Vertex detectors (VXD):
2 layer DEPFET pixel detectors (PXD)
4 layer double-sided silicon strip detectors (SVD)

Central drift chamber (CDC):
He(50%):C_2H_6 (50%), small cells,
fast electronics

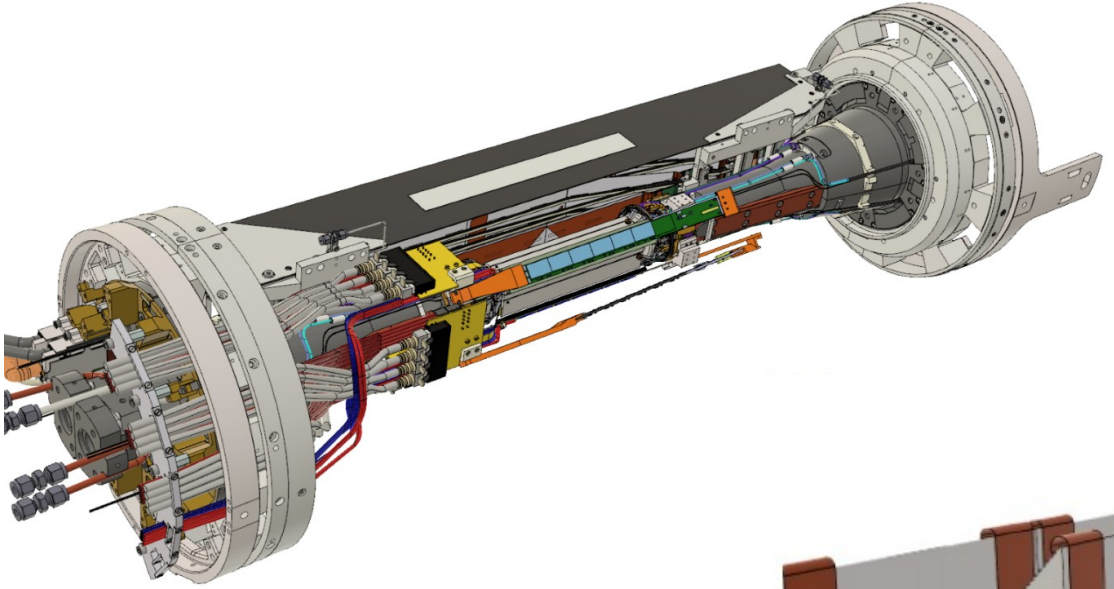
Particle Identification (PID):
Time-Of-Propagation counter (TOP) (barrel)
Aerogel Ring-Imaging Cherenkov Counter (ARICH) (FWD)

DEPFET: depleted p-channel field-effect transistor
WLSF: wavelength-shifting fiber
MPPC: multi-pixel photon counter

The Belle II experiment: a timeline



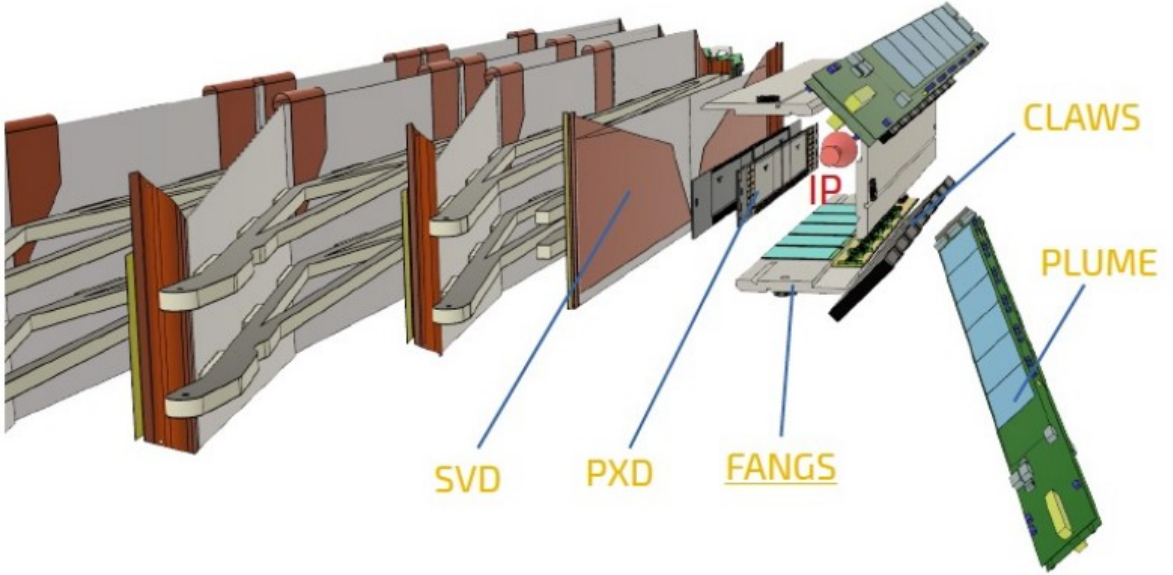
What is "phase 2"?



Pilot run with limited vertexing

→ Background monitor detectors replacing most of the silicon tracker

→ One full octant of PXD+SVD (2 + 4 layers)

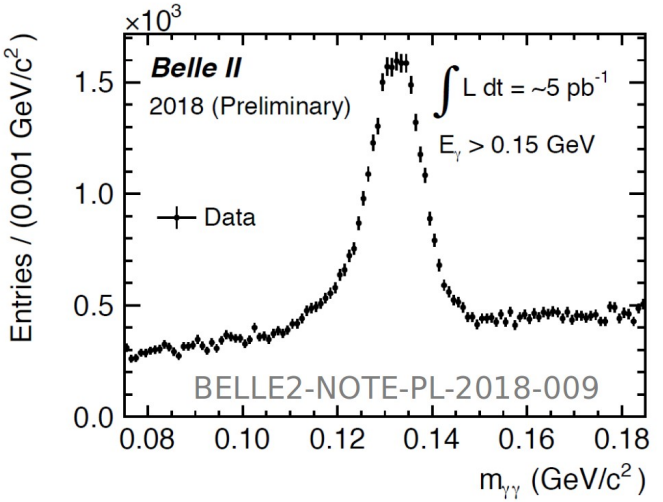


The first Belle II results

Phase 2 lasted from April 26th to July 17th

→ 0.5 fb^{-1} of collisions at Y(4S)

→ 0.55 x 10^{34} $cm^{-2}s^{-1}$ maximum luminosity

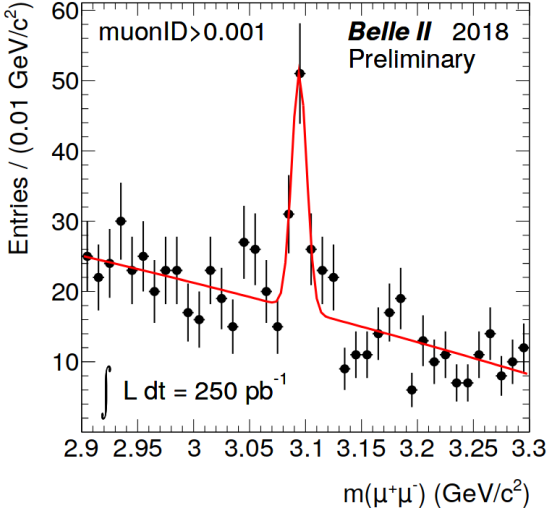


Goals

→ Verify the nano-beam collision scheme

→ Commission the detector

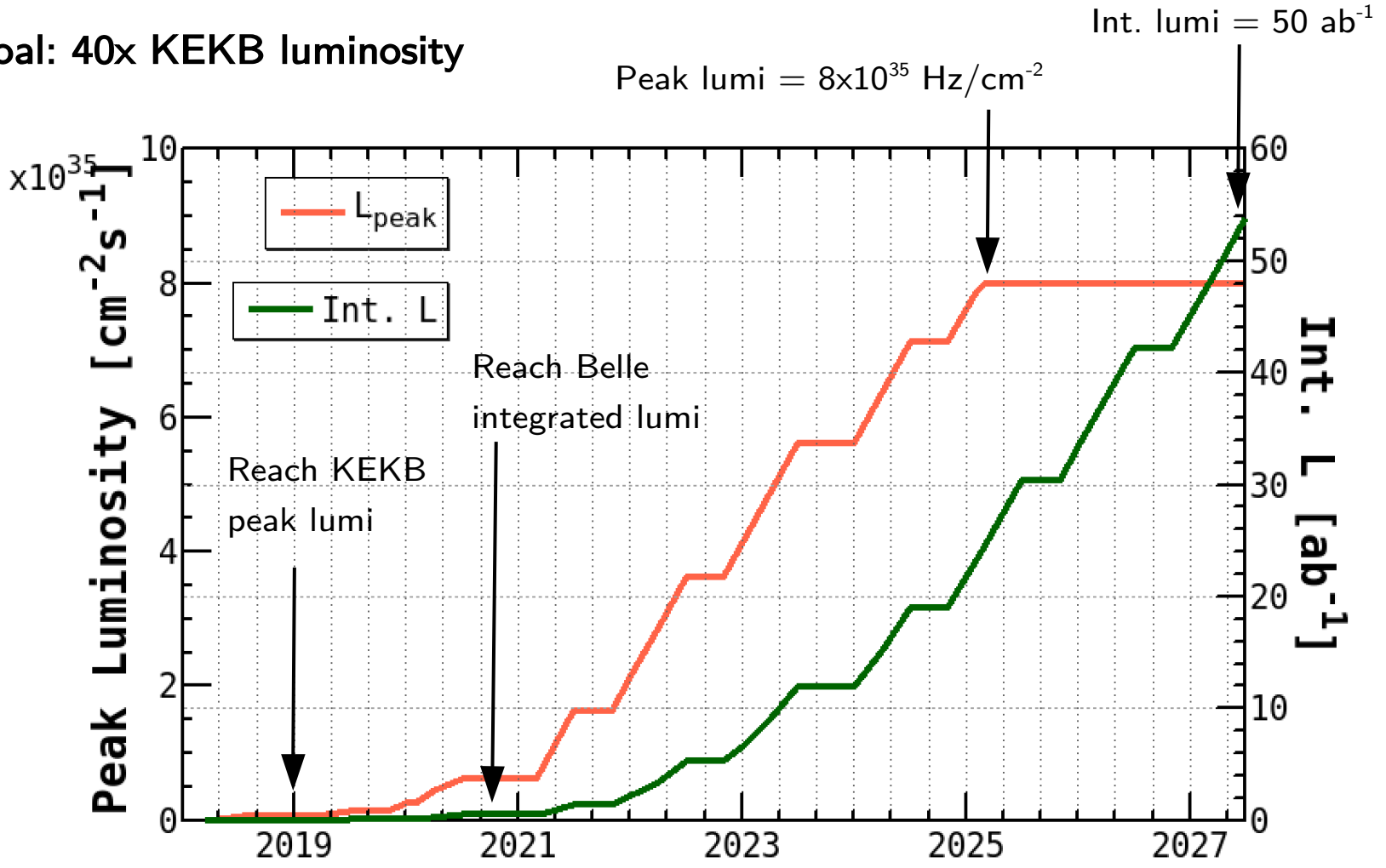
→ Produce some physics result?



The accelerator

Super-KEKB target

Final goal: 40x KEKB luminosity



e^+e^- collision at finite crossing angle

Lorentz factor

Beam current

Beam-beam factor

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

Beam aspect ratio
(flat beam ~ 1-2%)

Vertical beta function at IP

Geometrical corrections
(Hourglass effect...)

Brute force: Increase the current (x2)

Precision: denser beams, smaller β* (x20)

Nano-beam scheme

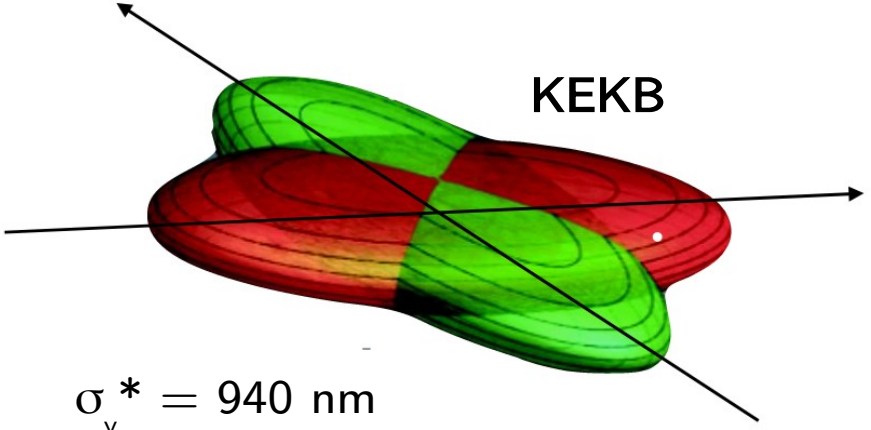
1) Large Piwinski angle by **large θ** and **small σ_x**

$$\phi = \frac{\sigma_z}{\sigma_x} tg\left(\frac{\theta}{2}\right) \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2}$$

2) Very small β

$$\beta_y^* \approx \frac{\sigma_x}{\theta} << \sigma_z$$

3) Non-linear optics (suppress beam-beam resonances)

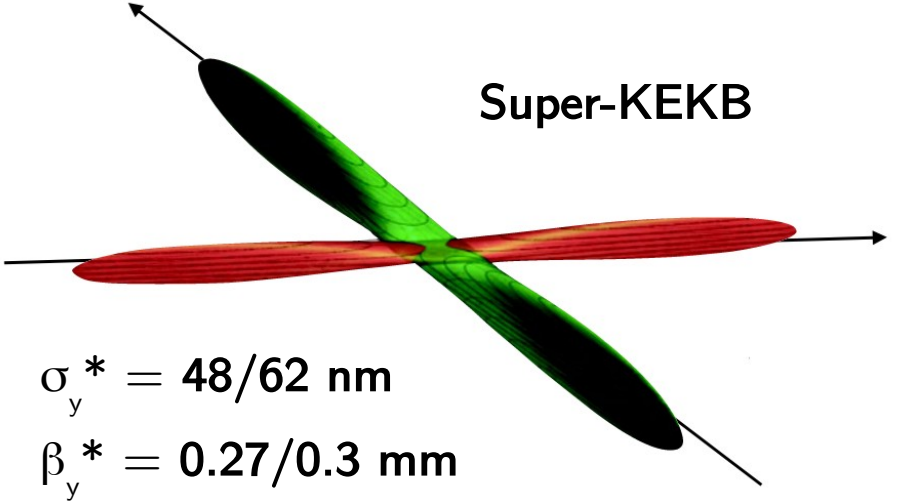


KEKB

$\sigma_y^* = 940$ nm

$\beta_y^* = 5.9$ mm

$\sigma_x^* = 147/170$ μm



Super-KEKB

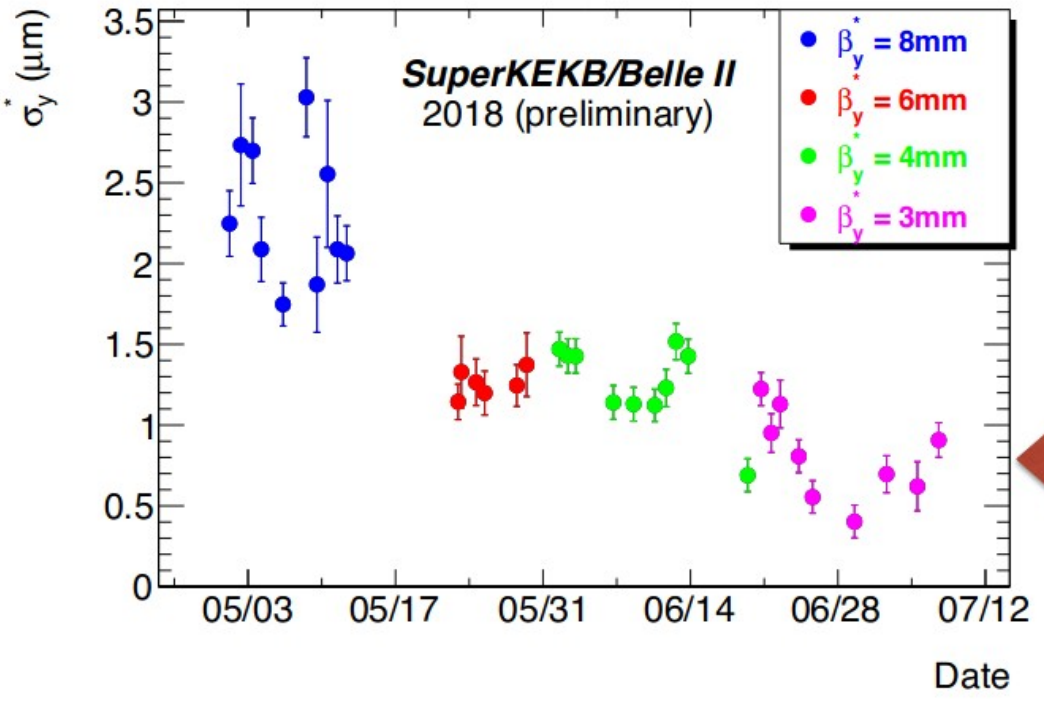
$\sigma_y^* =$ **48/62 nm**

$\beta_y^* =$ **0.27/0.3 mm**

$\sigma_x^* =$ **10.1/10.7 μm**

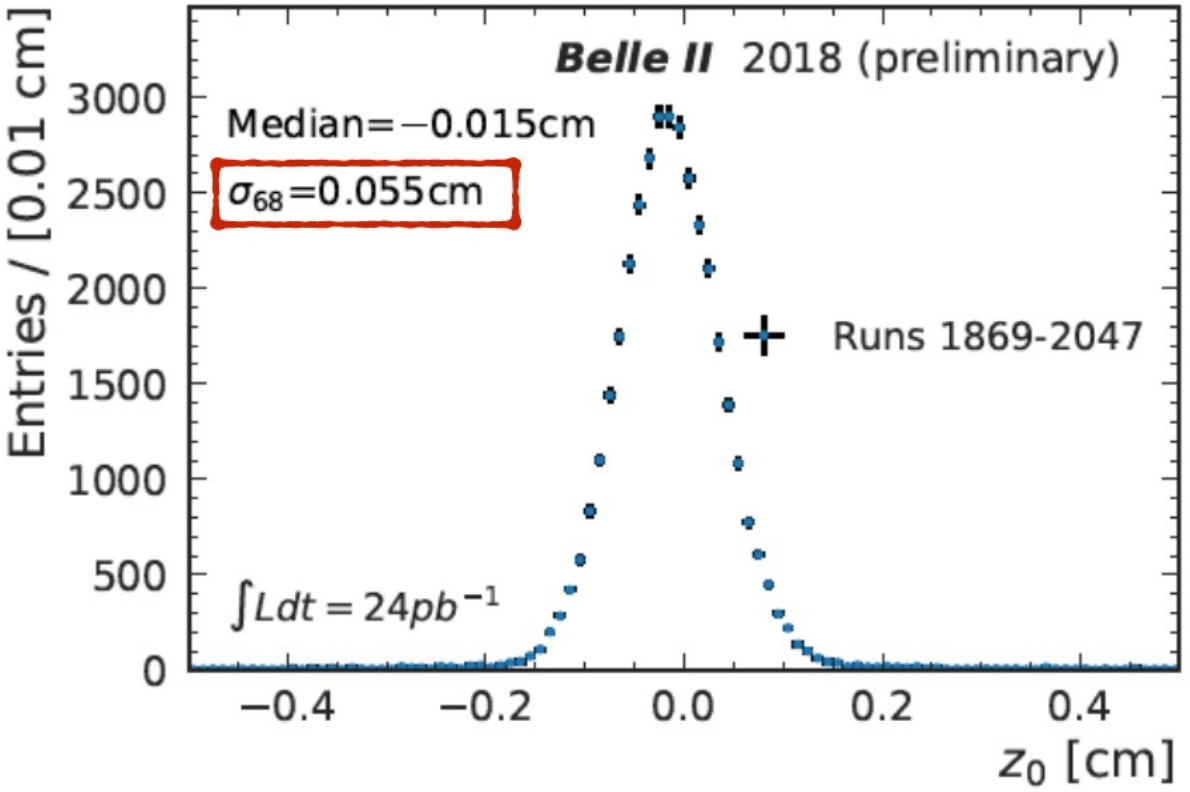
Measuring a nanometric beam

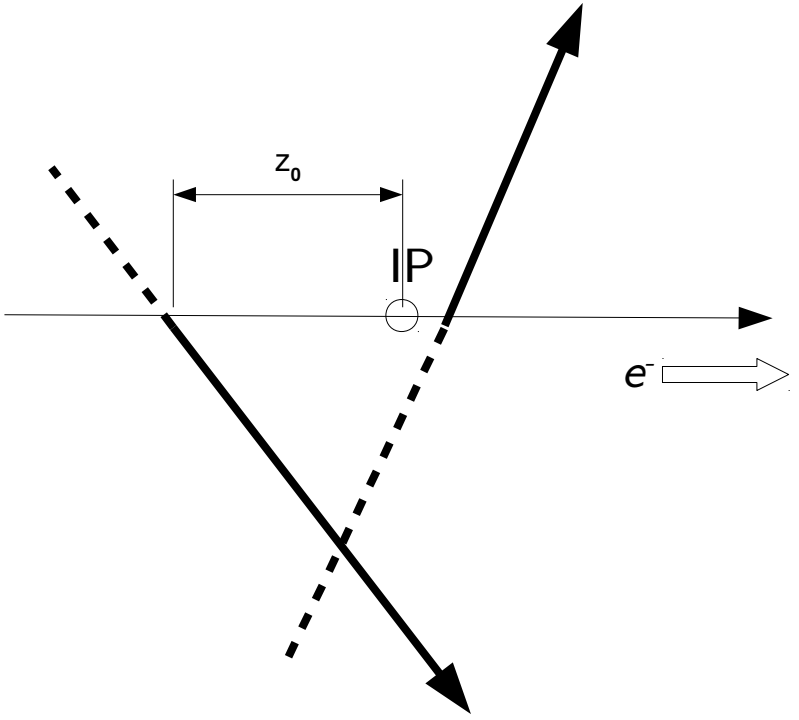
- How to measure the vertical size of the beams?
  - Measure the luminosity with our fast diamond detector while the machine people moves the beam vertically.



less than 500 nm achieved

Interaction region size



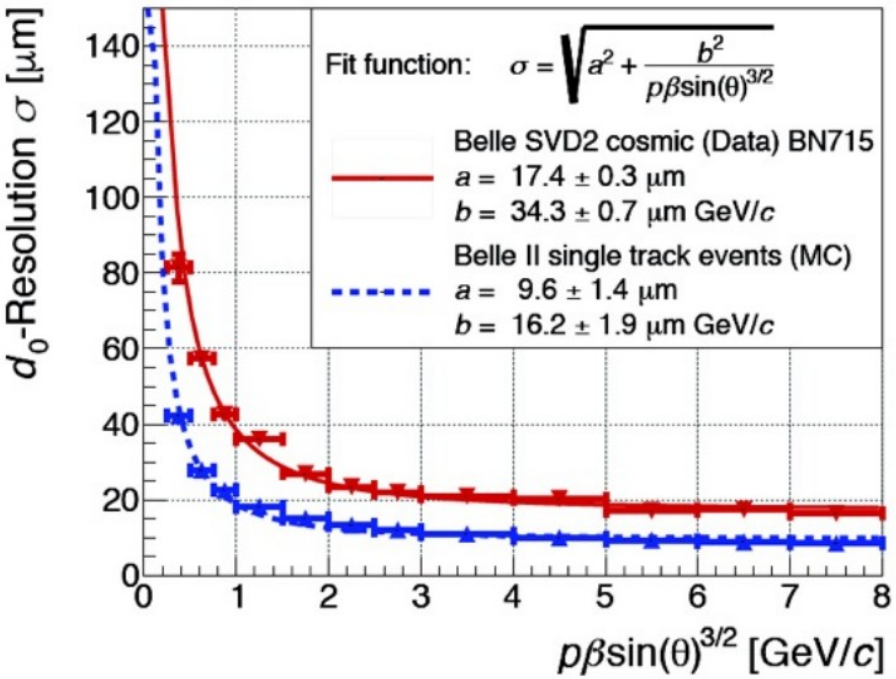


Beam spot ~ 10 times smaller than KEKB

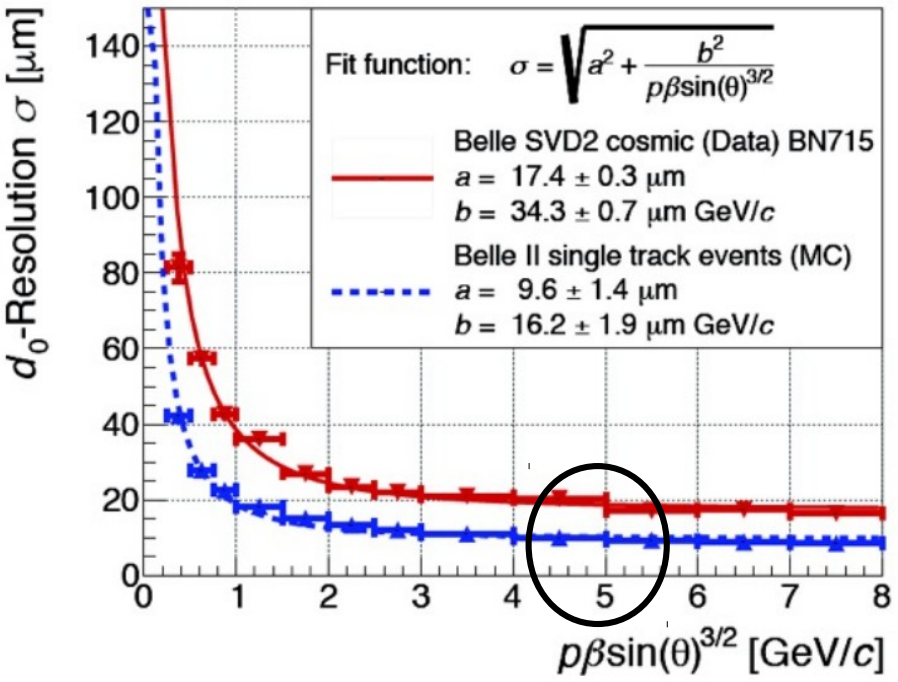
The detector

Vertexing: impact parameter resolution

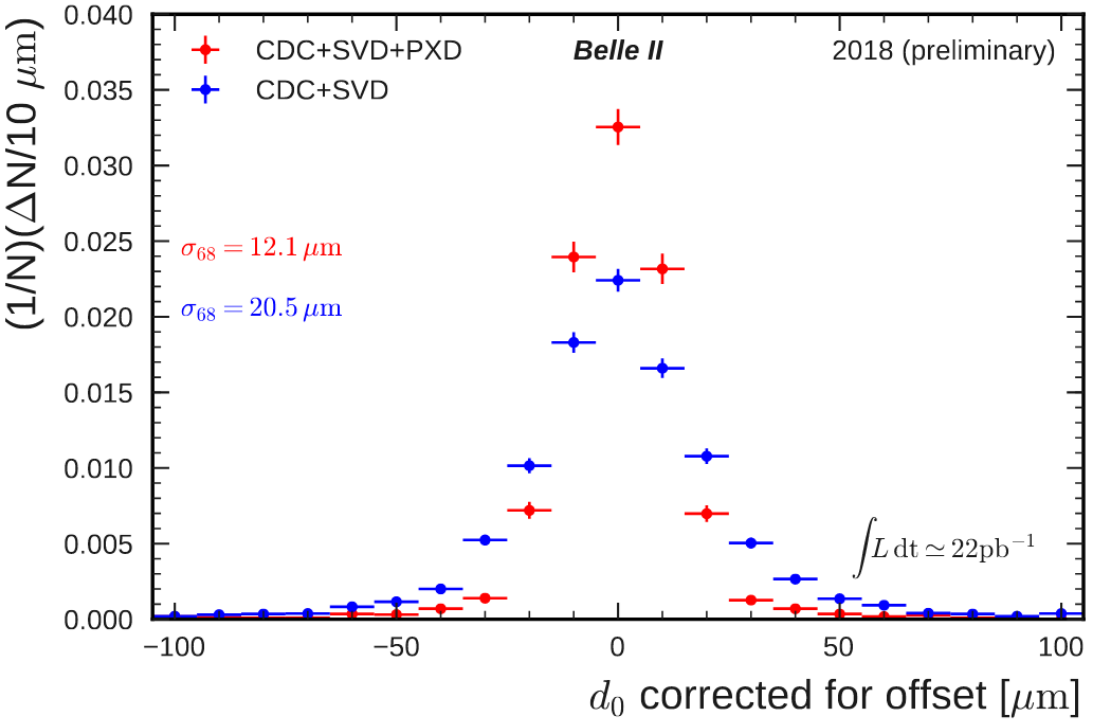
MC (Belle II) and Cosmics (Belle)



Vertexing: impact parameter resolution



Belle II **data**: bhabha events

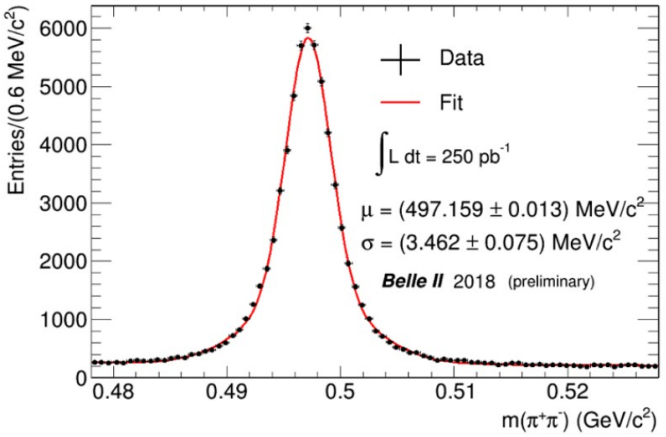


→ measured 12.1 μm, expected ~10 μm

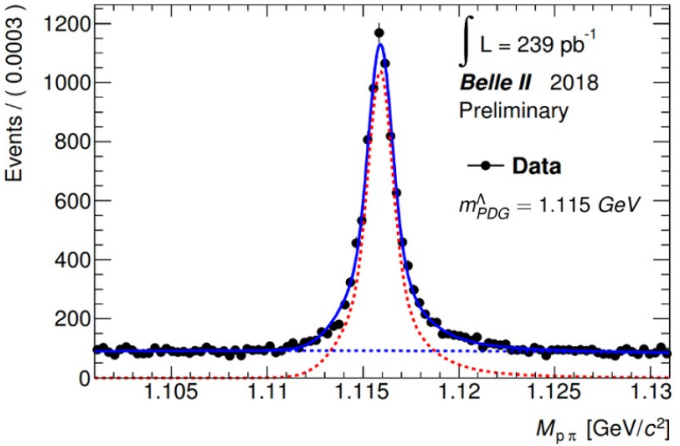
→ PXD contribution is crucial

Tracking

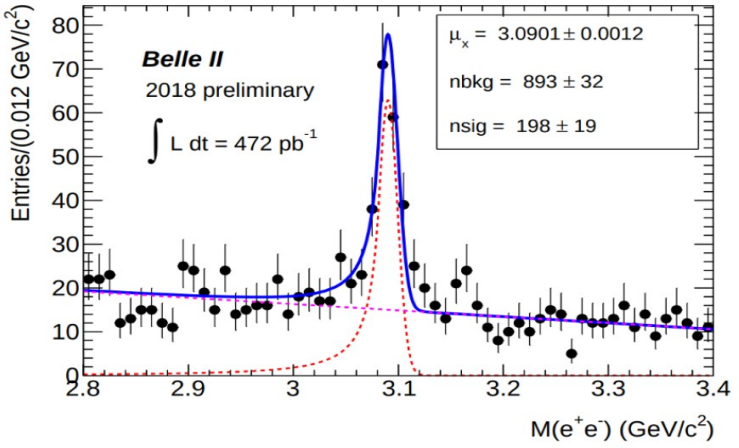
$K_s \to \pi^+\pi^-$



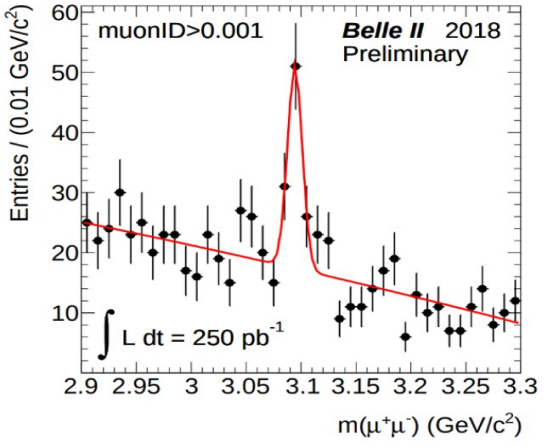
$\Lambda \to p\pi^-$



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

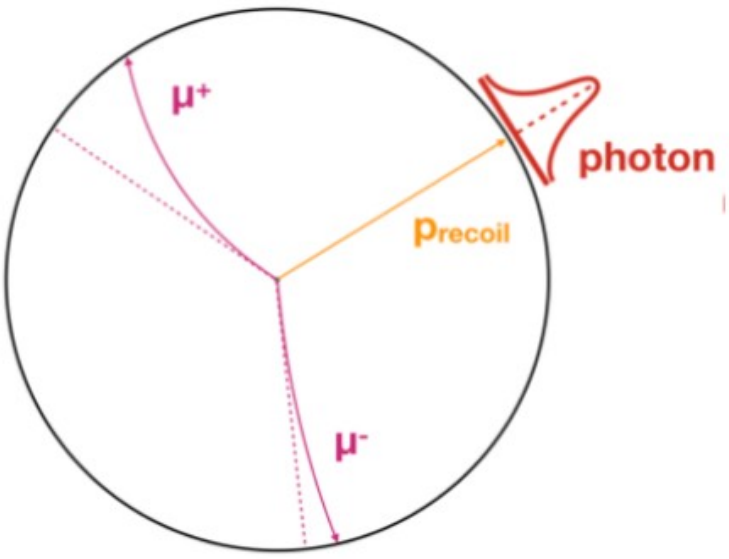


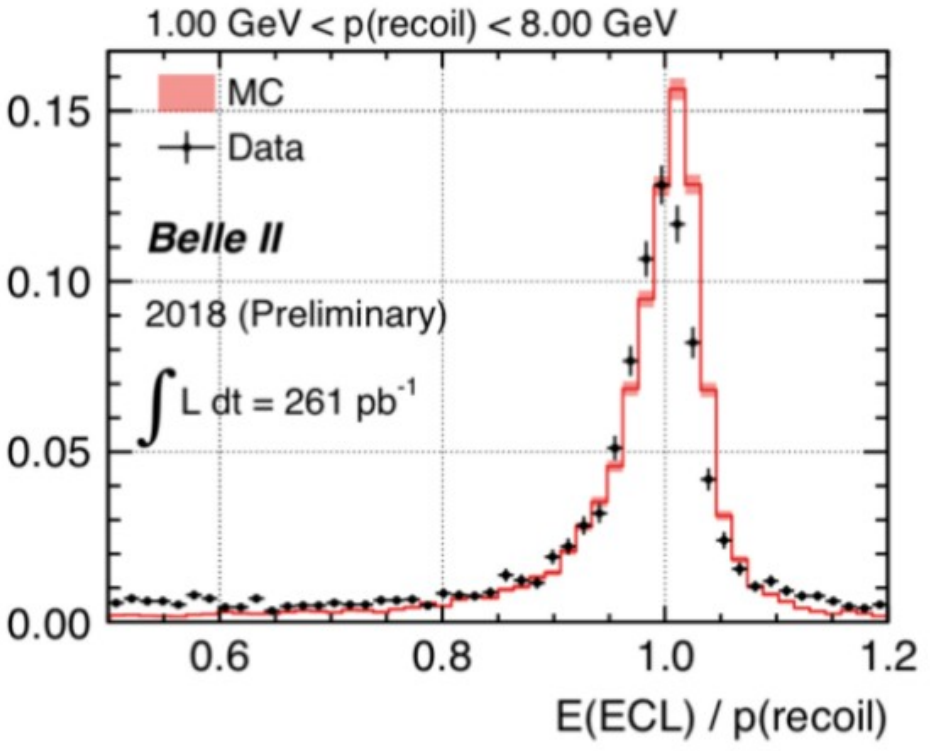
$J/\psi \to \mu^+\mu^-$



Calorimetry

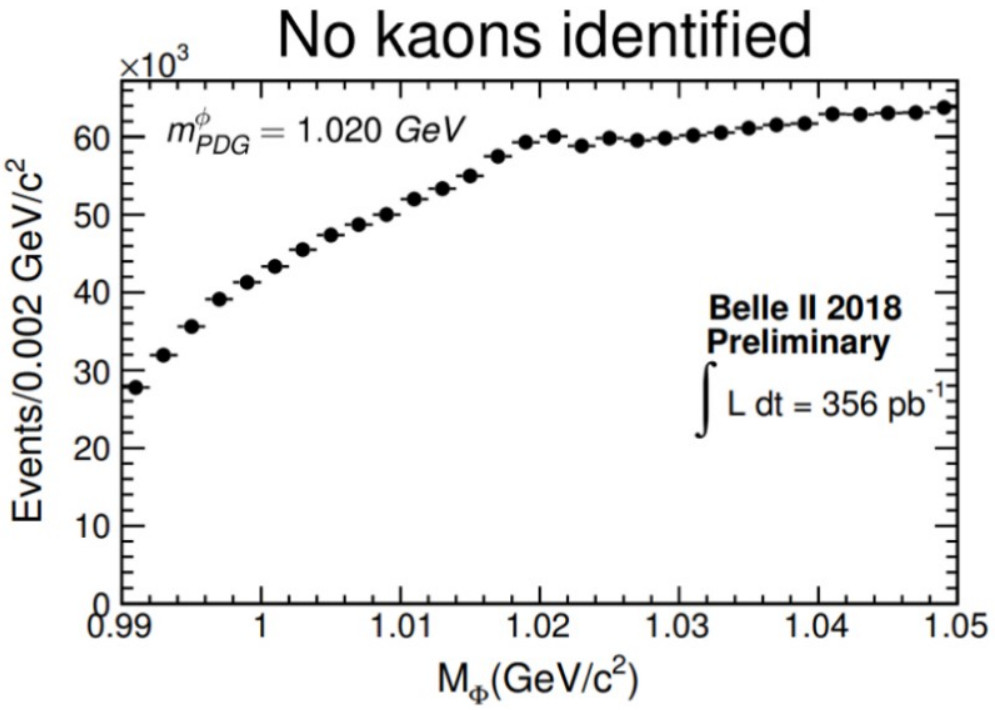
$$e^+e^- \rightarrow \mu^+\mu^-\gamma$$

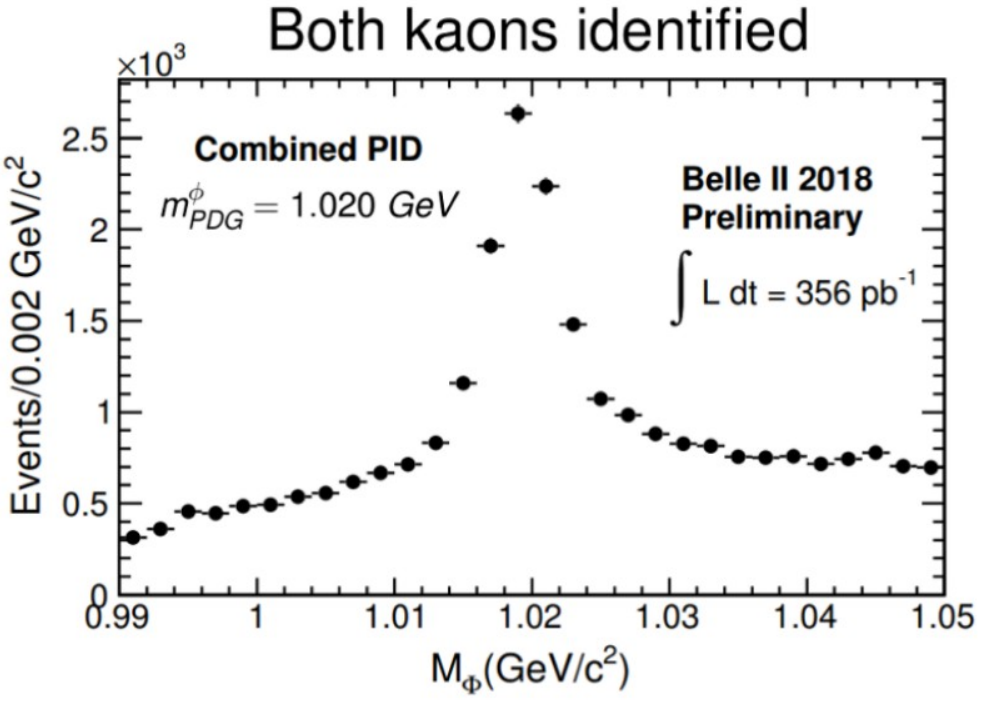




An example of combined Particle ID

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

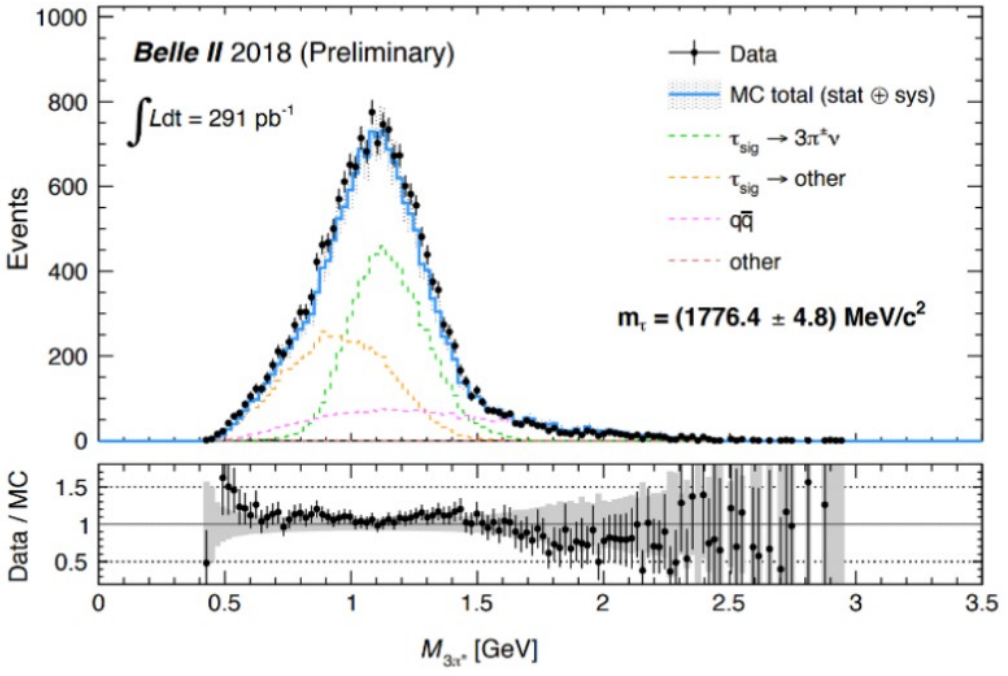




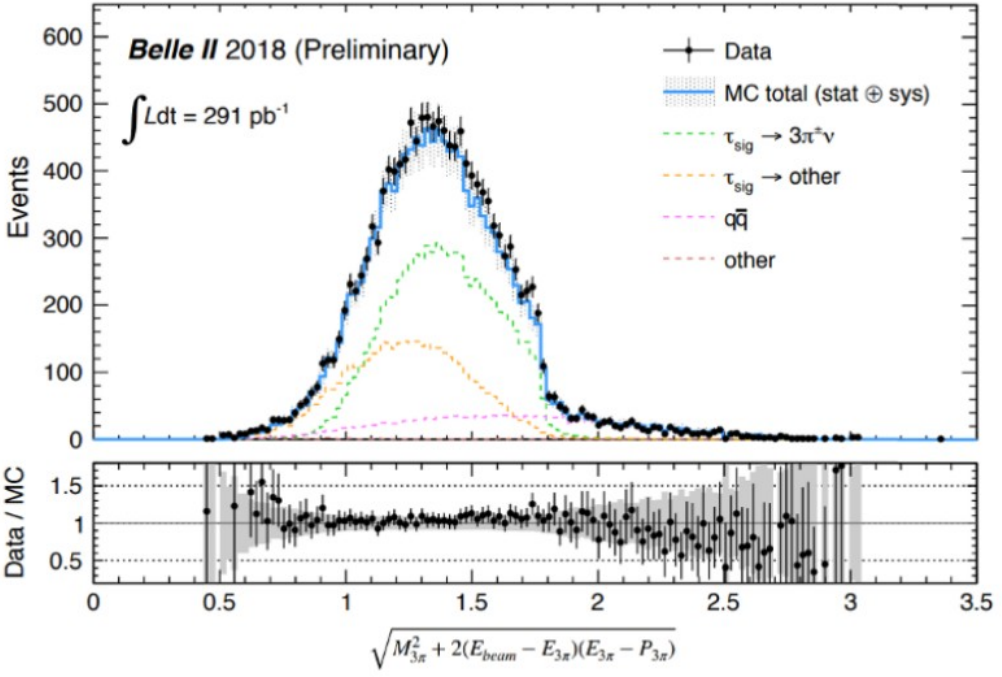
TOP + dE/dx from the drift chamber

Some physics: τ rediscovery

τ → 3 π ν Mass

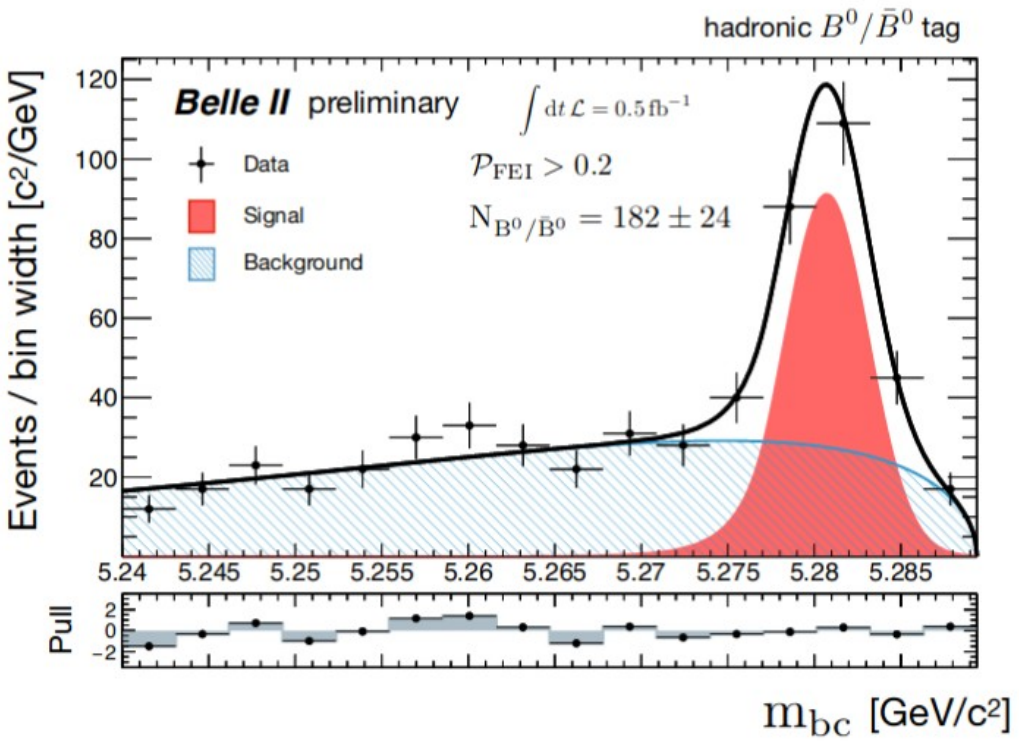


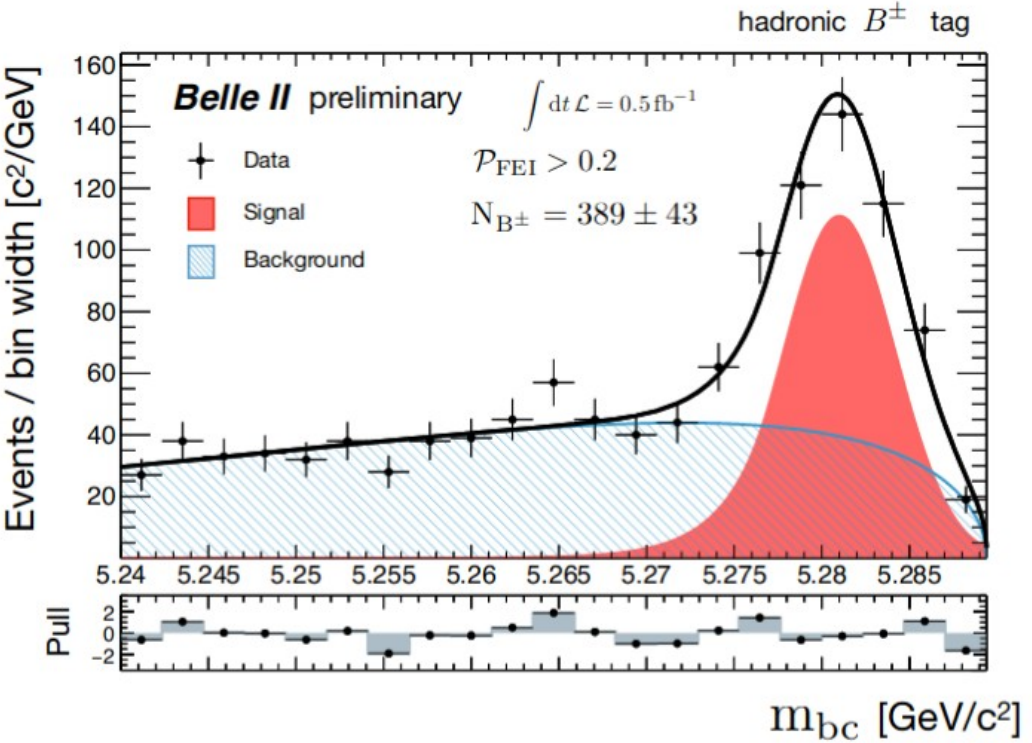
τ → 3 π ν Pseudo-Mass



First re-measurement of the tau mass

Some physics: Full reconstruction





Recursive reconstruction algorithm:

→ Reconstruct B^0 or B^+ in 5000+ modes (*tag* B)

→ Essential reconstruct events with missing energy

Conclusions

The Belle II experiment has successfully concluded the phase 2 pilot run:

→ Basic detector performance is satisfactory

→ Nano-beam scheme has been realized

Phase 3 is starting

→ Full physics run

→ 20 fb^{-1} by the summer 2019

Any physics out of phase 2?

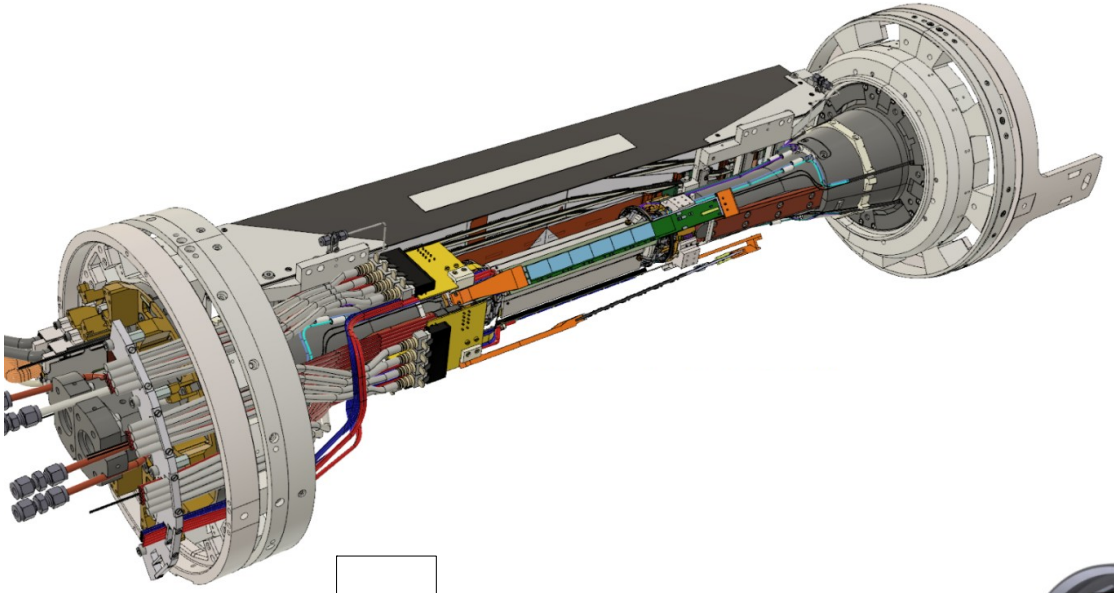
→ Yes!

→ Search for **axion-like particles** in ee → $\gamma\gamma\gamma$

→ Search for **Z'** in ee → 4l

Backup

What is "phase 3"?

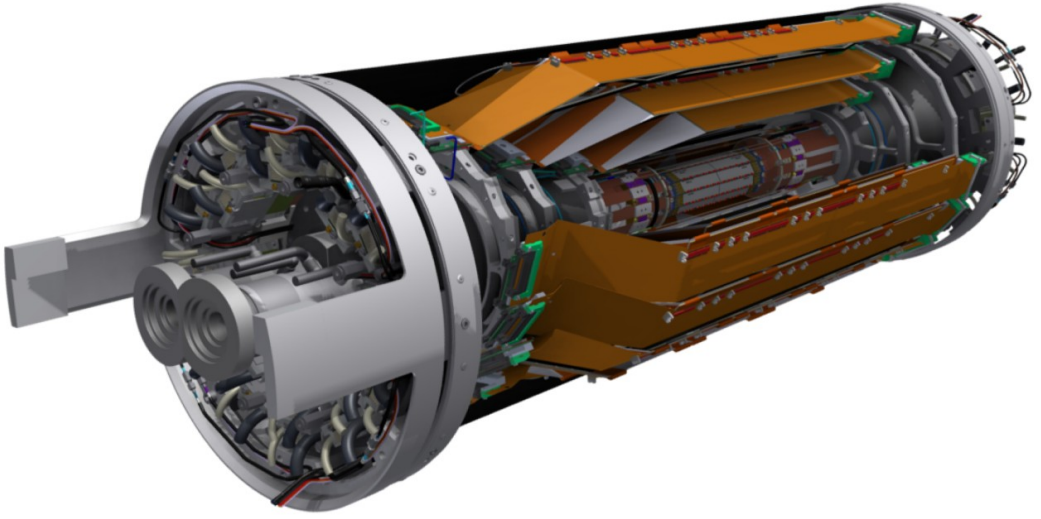


Phase 3 = (almost) final setup for physics

→ 4 full layers of silicon strips

→ 1 + 1/6 full layers of pixel

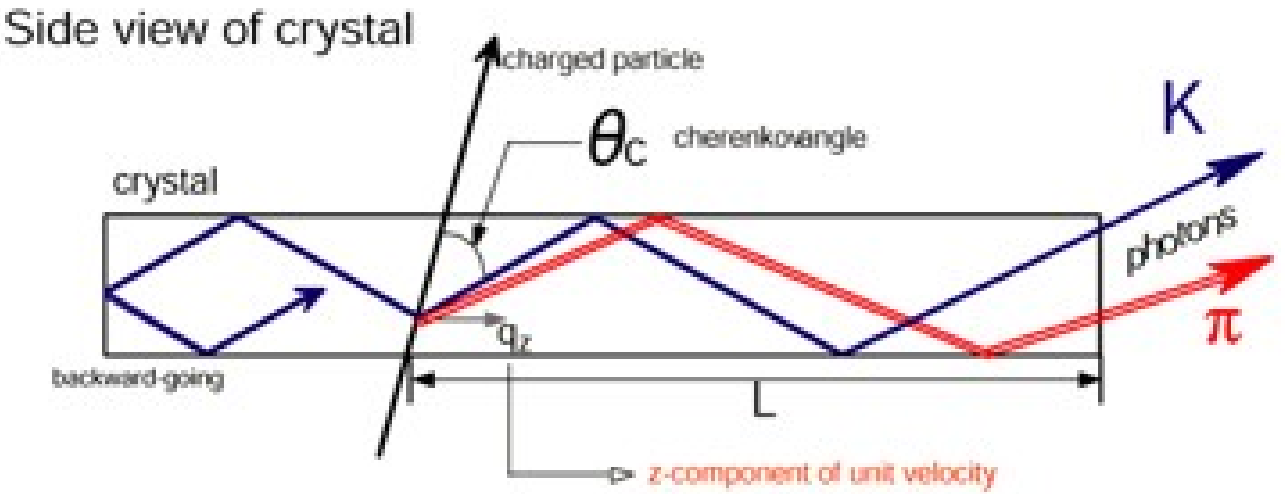
→ full installation approx in 2020



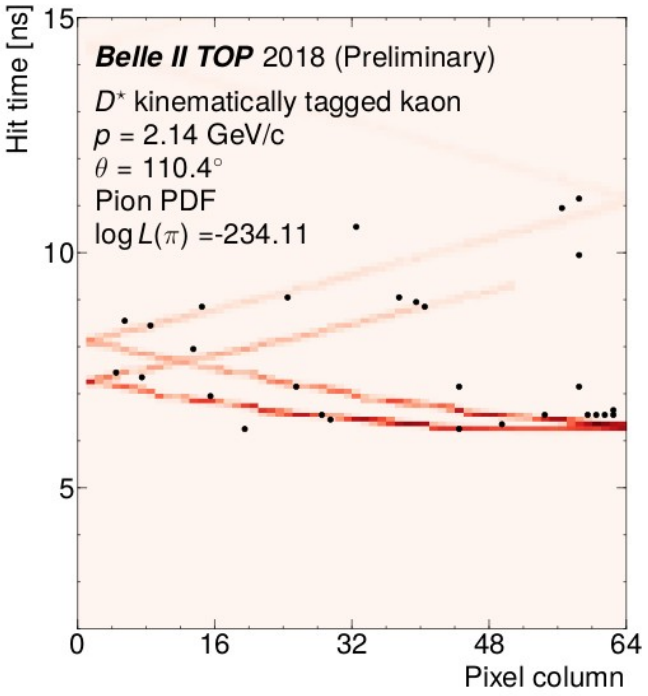
The TOP is a "*DIRC in the time domain*"

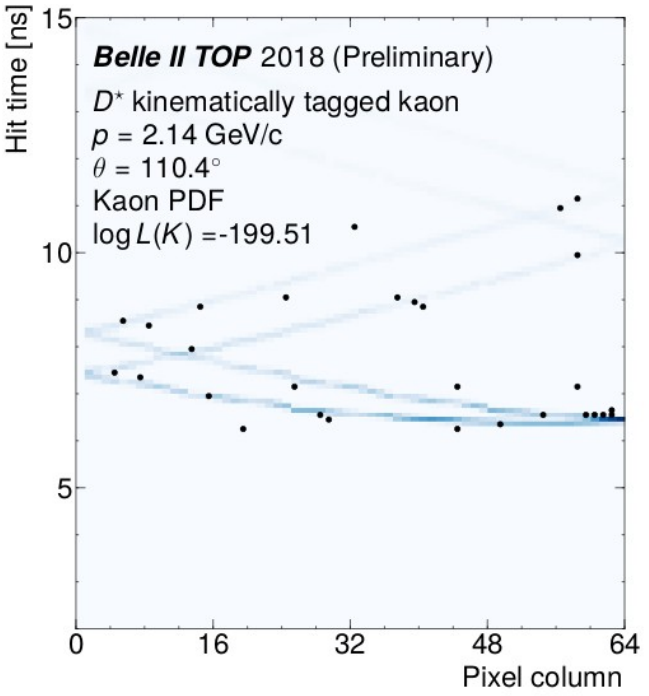
→ Cherenkov light trapped and propagated to the readout in a wide bar of fused silica

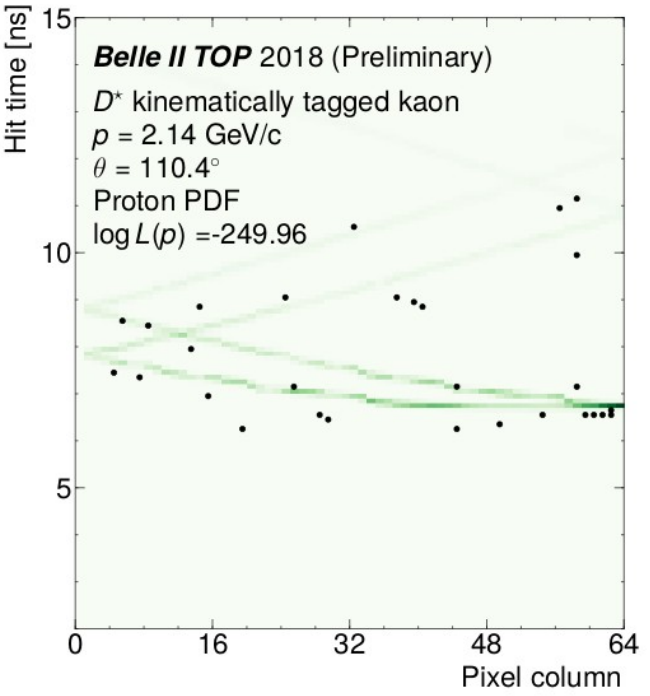
→ The Cherenkov angle is measured by the **time of propagation** rather than the ring image on the PMT surface



Visualizing the Cherenkov rings



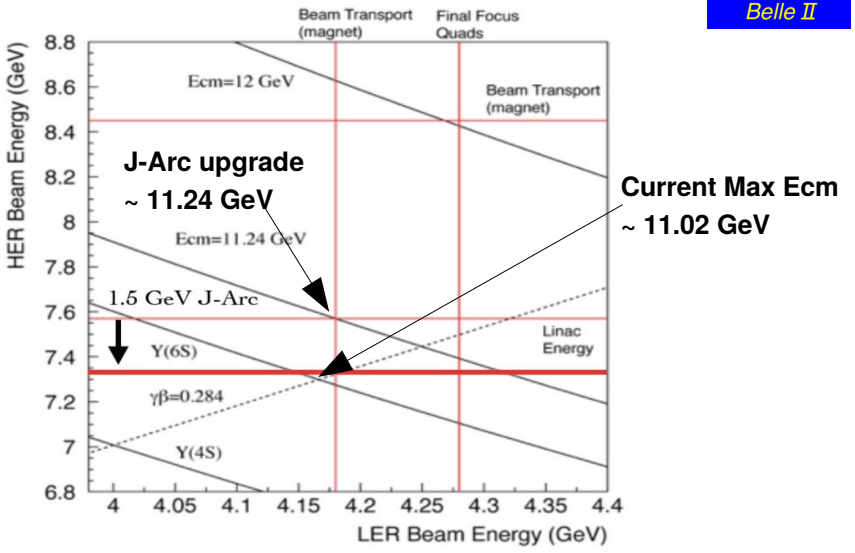


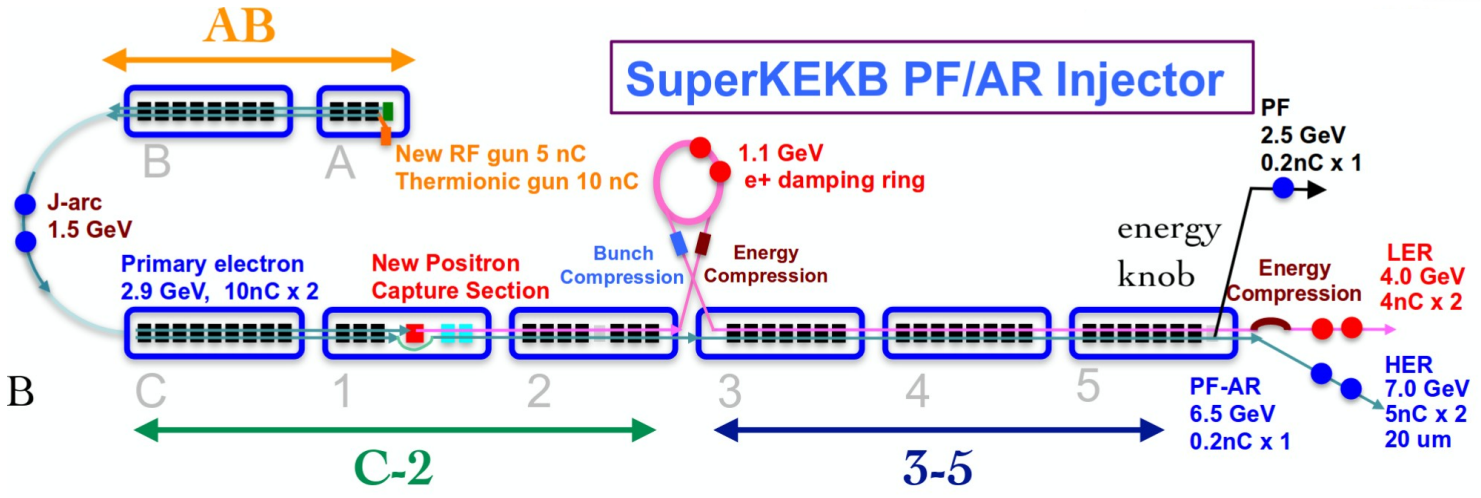


Super-KEKB: energy and limitations

Super-KEKB is technically an accumulation ring
→ All the acceleration phase is done in the LINAC
→ RF only to sustain the beams (continuous injection!)

Current max Ecm = ~ 11.02 GeV, a bit above Y(6S)
Achievable max Ecm = ~ 11.24 GeV, at $\Lambda_b\overline{\Lambda}_b$ threshold





The TOP counter at Belle II

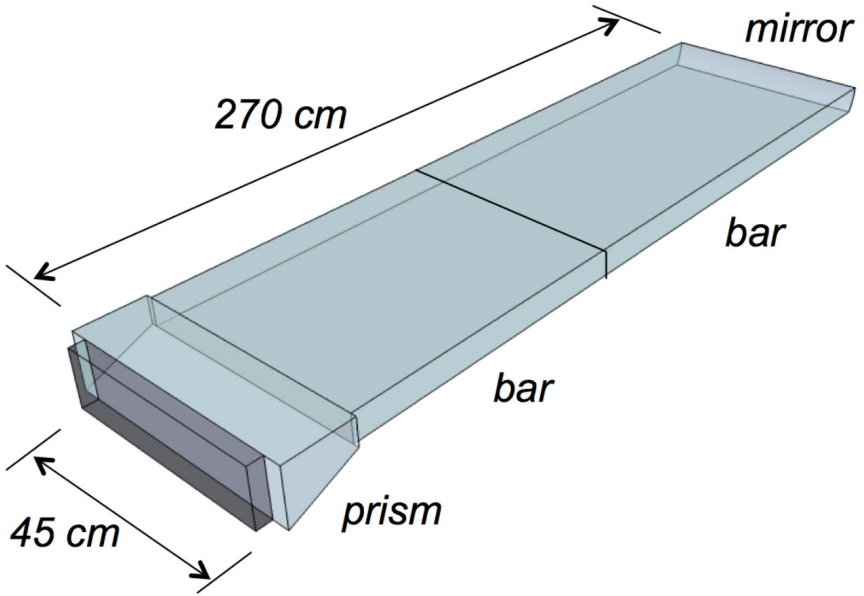
TOP implementation in Belle II:

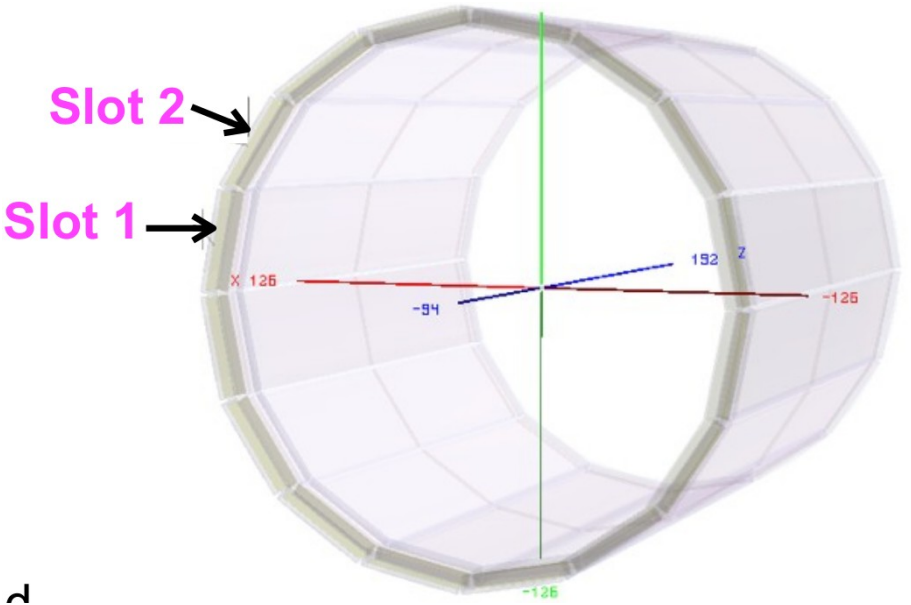
→ 16 modules (or slots) arranged around the interaction point

→ Each module is made of two identical bars of fused silica glued together

→ Backward side: expansion prism, PMTs and readout

→ Forward side: spherical mirror



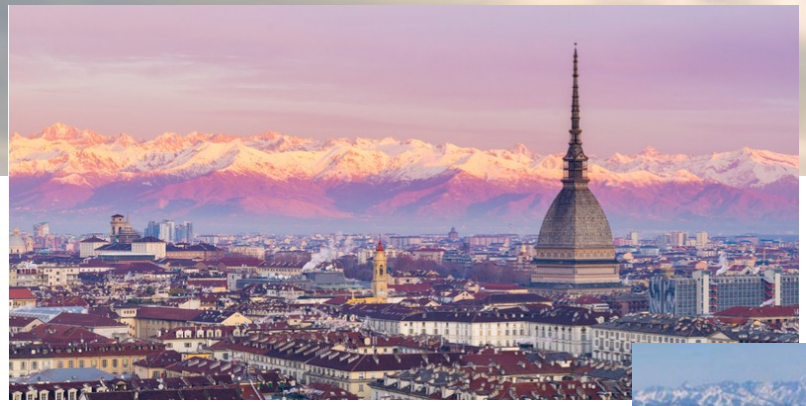


QWG 2019! May 13-17 Torino

QWG 2019 - The 13th International Workshop on Heavy Quarkonium

13-17 May 2019 Torino

Europe/Rome timezone



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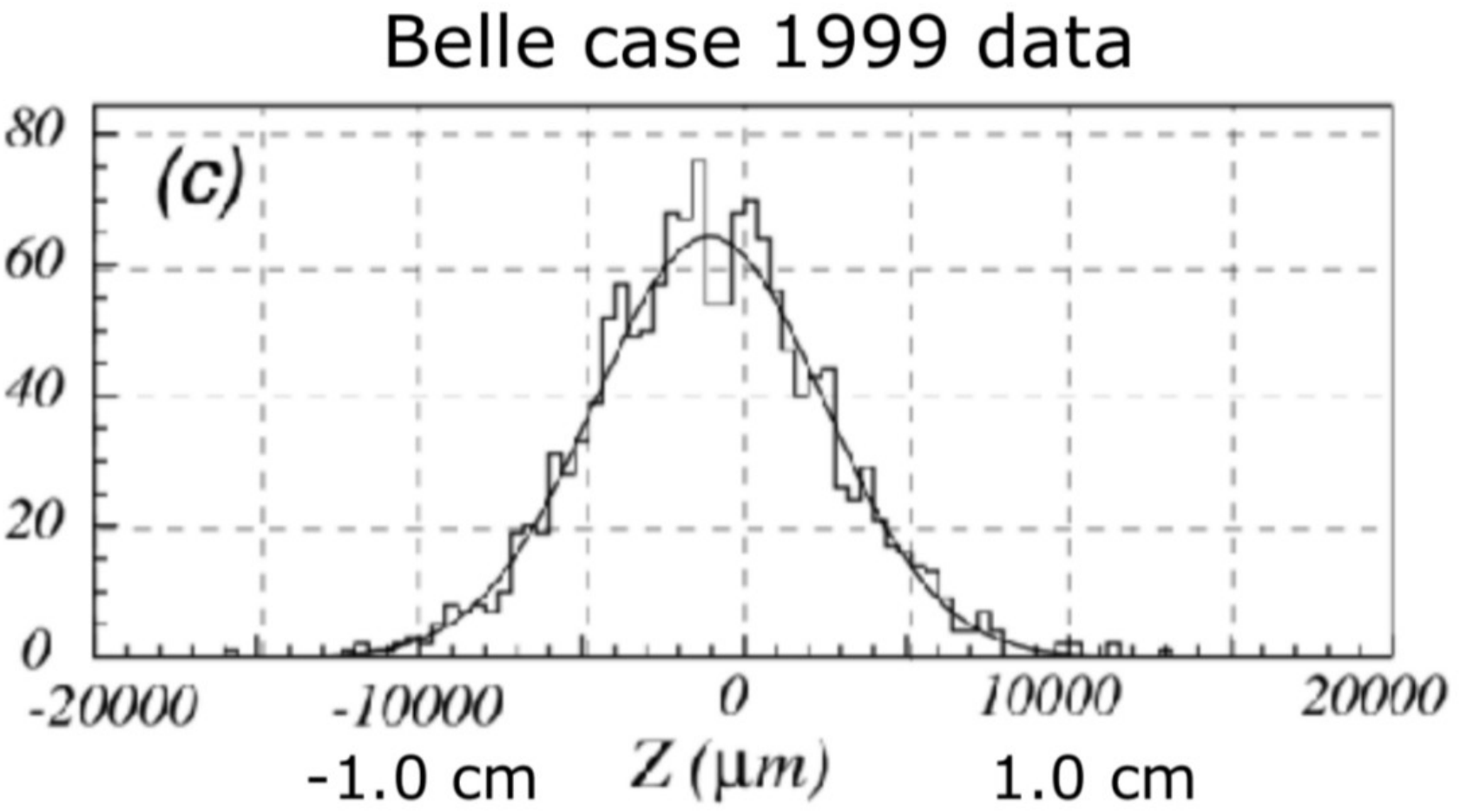
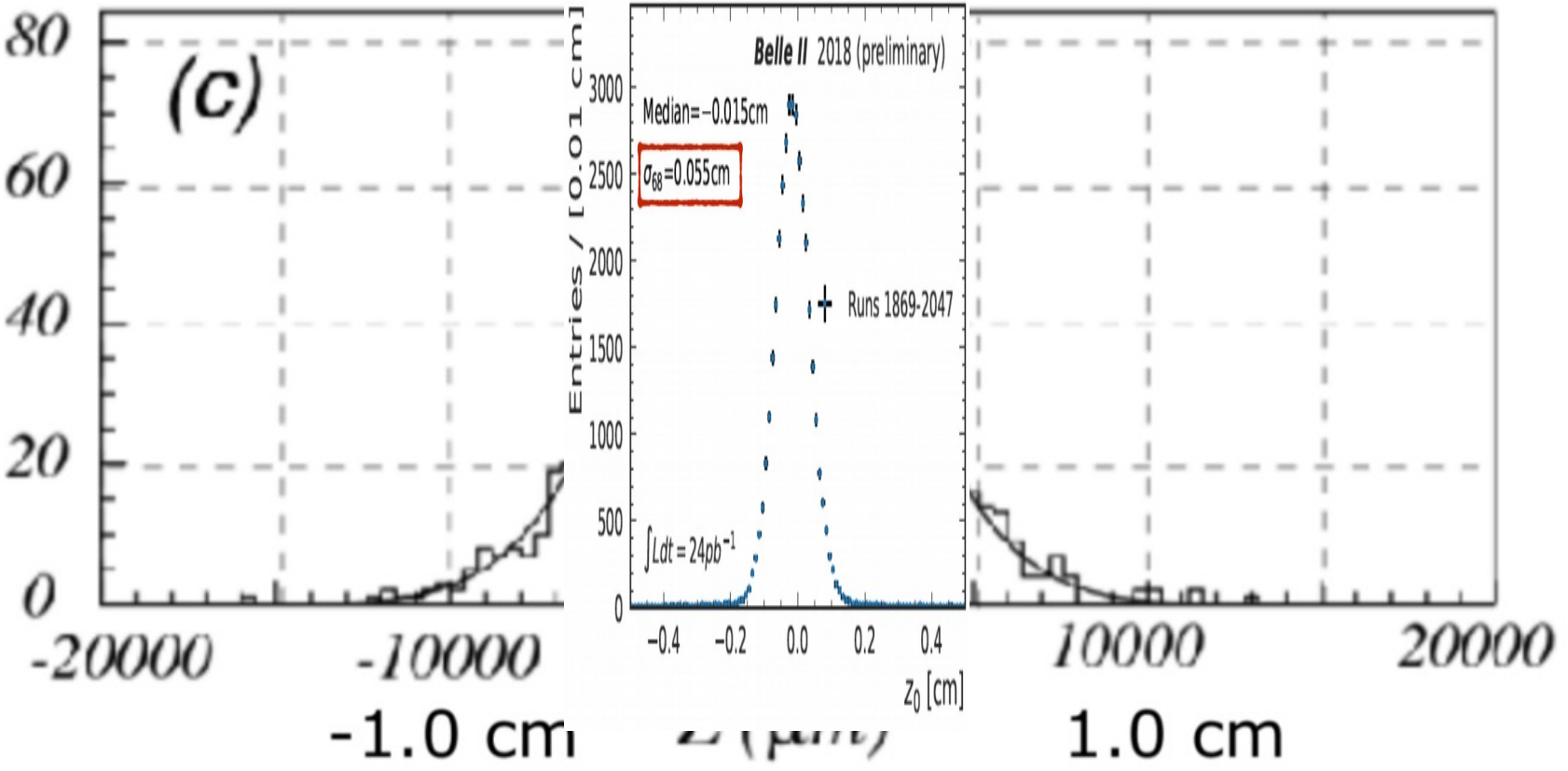
IP size


Belle case 1999 data
(c)
80
60
40
20
0
-20000
-10000
0
10000
20000
-1.0 cm
Z (μm)
1.0 cm

IP size

Belle case 1999 data