Belle II

2024/10/09
CNRS-JSPS-JST Celebration Event
for the 50th Anniversary of France-Japan Scientific Cooperation @Miraikan

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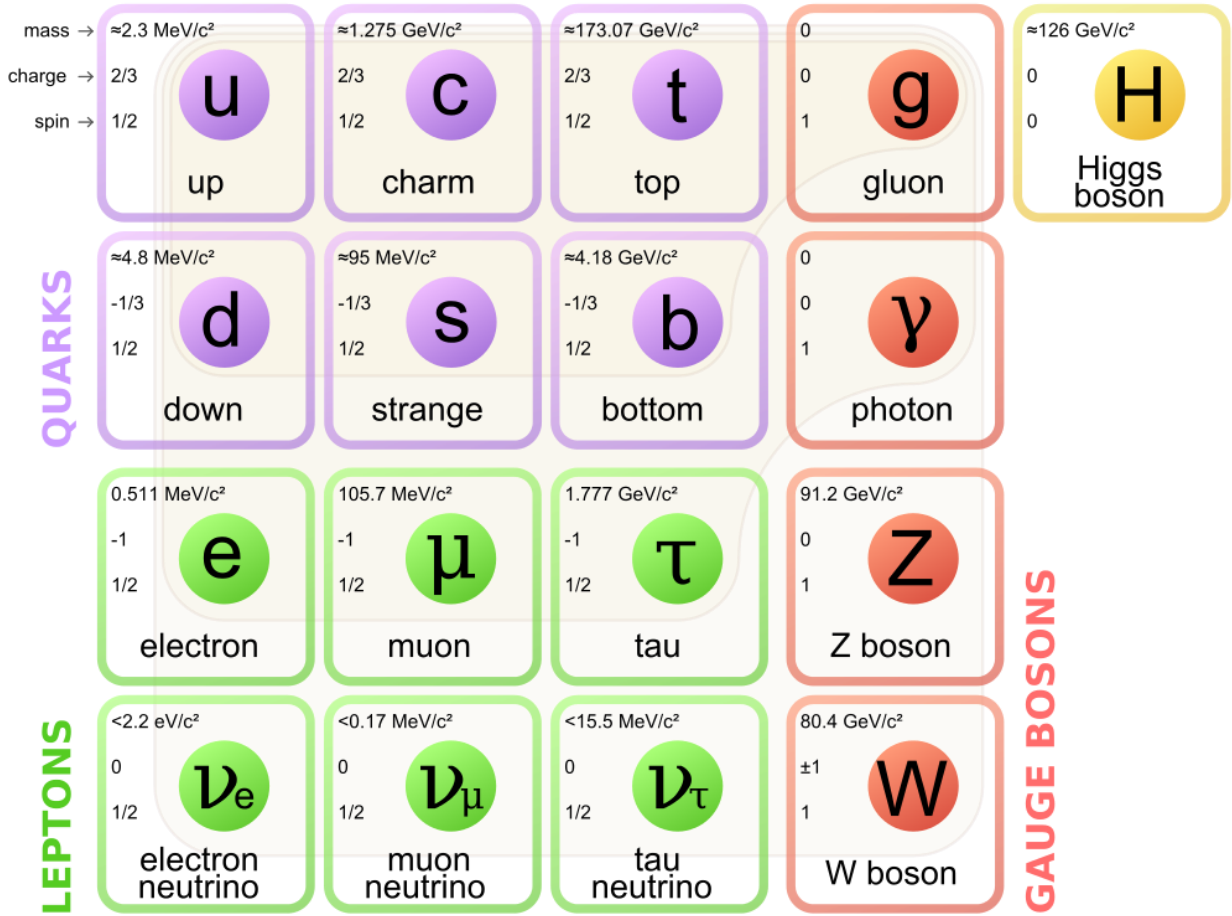
What we know, what we don't know

What we know,

Standard model

- ✓ In particle physics, the Standard Model predicts the behavior of particles.
  Very consistent with experiment results…
- ✓ For every particle, there exists an antiparticle which has an opposite electric charge



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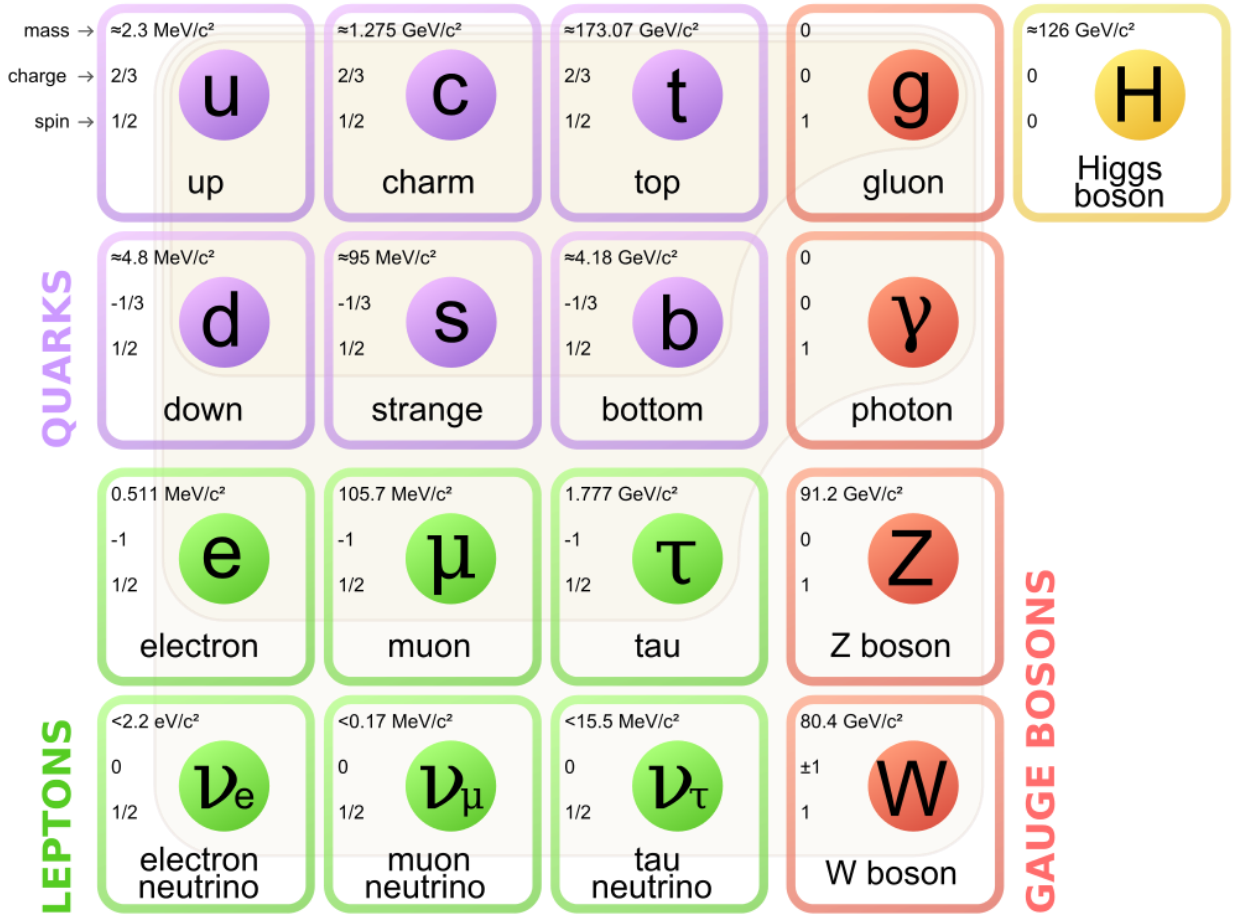
Disappeared anti-matter (antiparticle)

- ✓ In the early universe, it is believed that particles and antiparticles were created in equal amounts, but now particles vastly outnumber antiparticles.
- ✓ CP asymmetry, the physical landscape differs through quarks and antiquarks can be the reason
  - ✓ Belle experiment contributed to the discovery of large CP asymmetry in b-quark
- ☐ However the measured amplitude of CP asymmetry is still insufficient to explain why antimatter disappeared.



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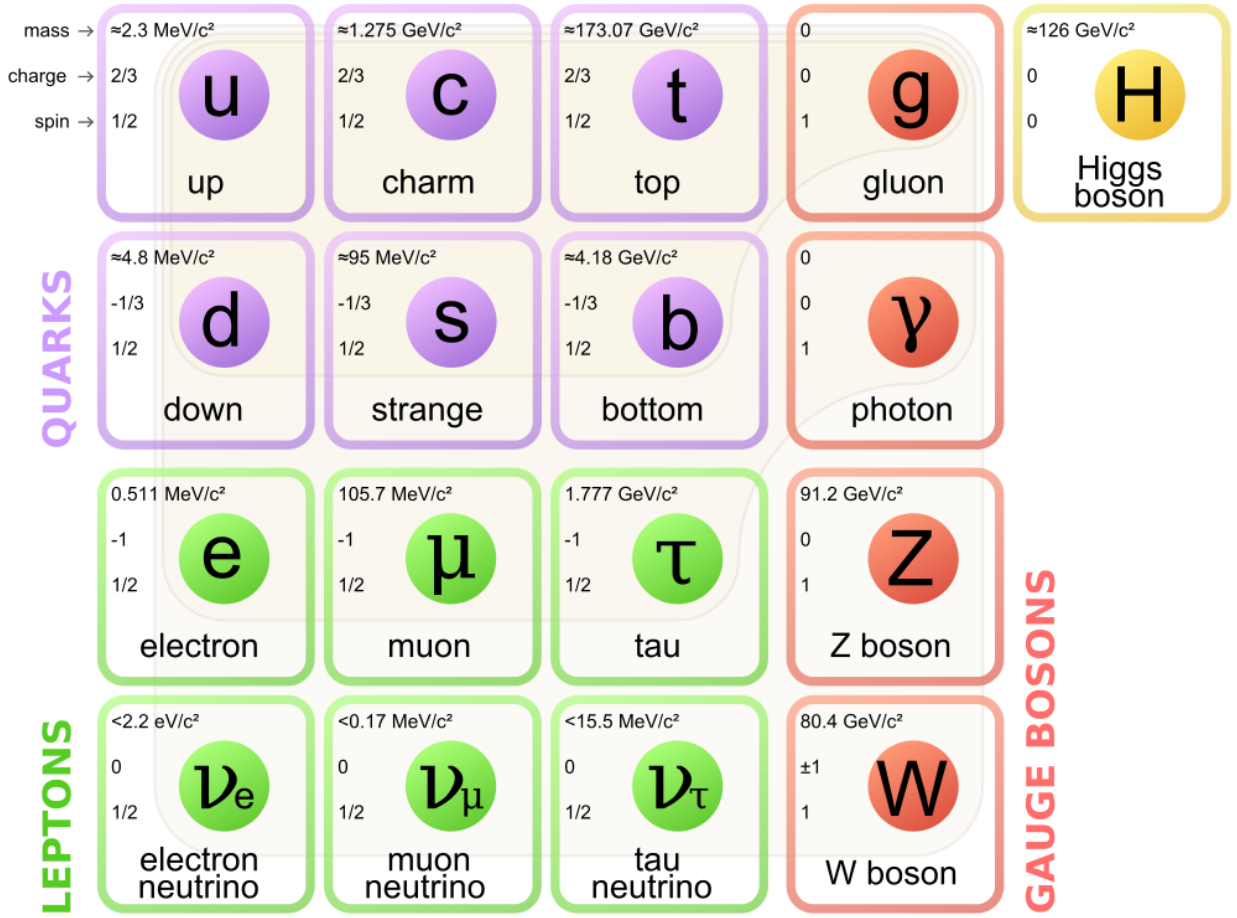


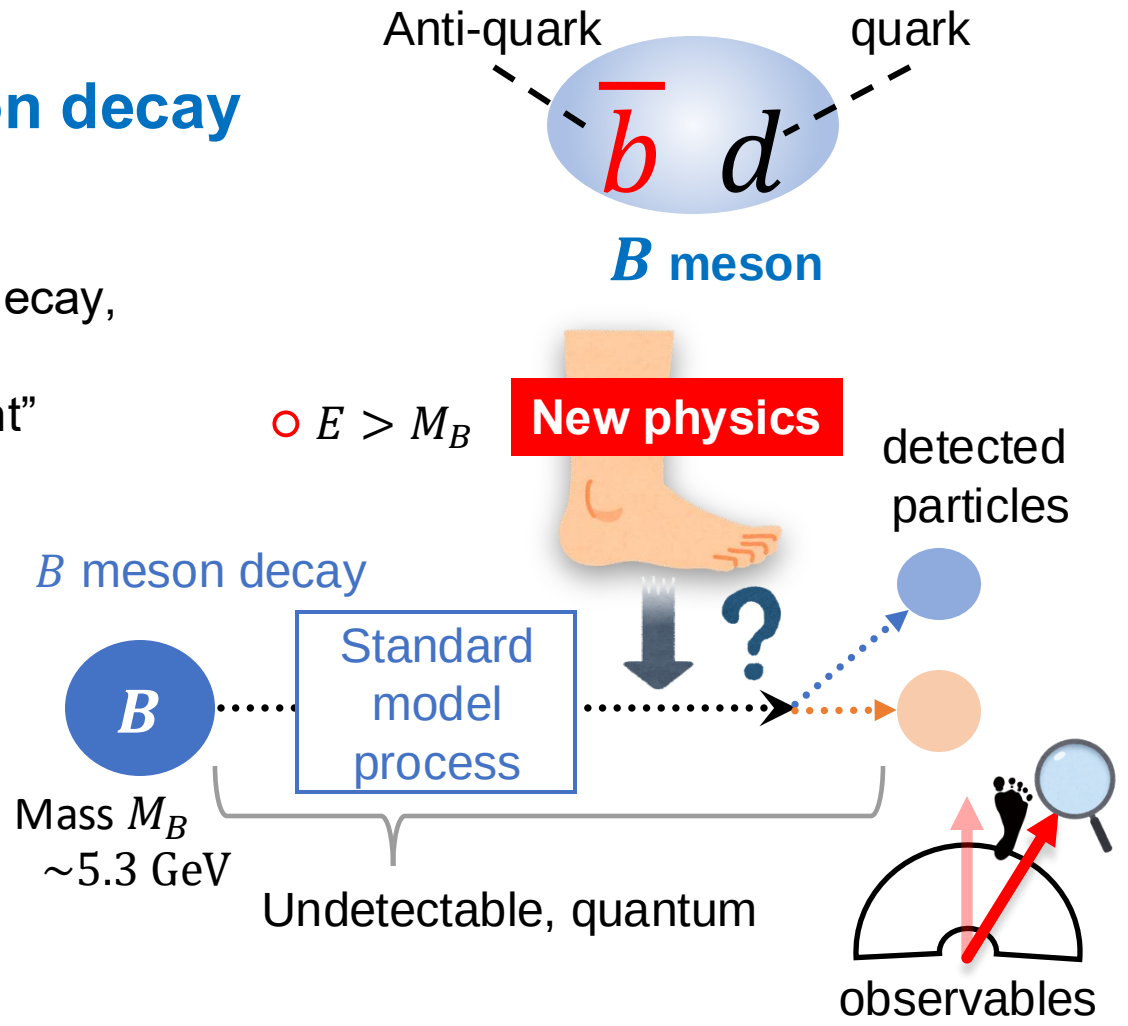
Need a new physics theory beyond the standard model

How to explore the new physics? One approach

- **Search for "Quantum imprint" in B meson decay**
  - **Quantum imprint** ⟺ directly search
    - If new physics appears in the process of particle decay, a discrepancy will arise between the theoretical and measured values in some observable. "Imprint"
    - particle decay processes are inherently quantum, so higher-energy scale particles or phenomena that appear to violate the energy conservation can contribute to the decay process.

    ➥ Through finding imprint. We can investigate contributions from new physics at energy scales that we currently cannot directly to produce.

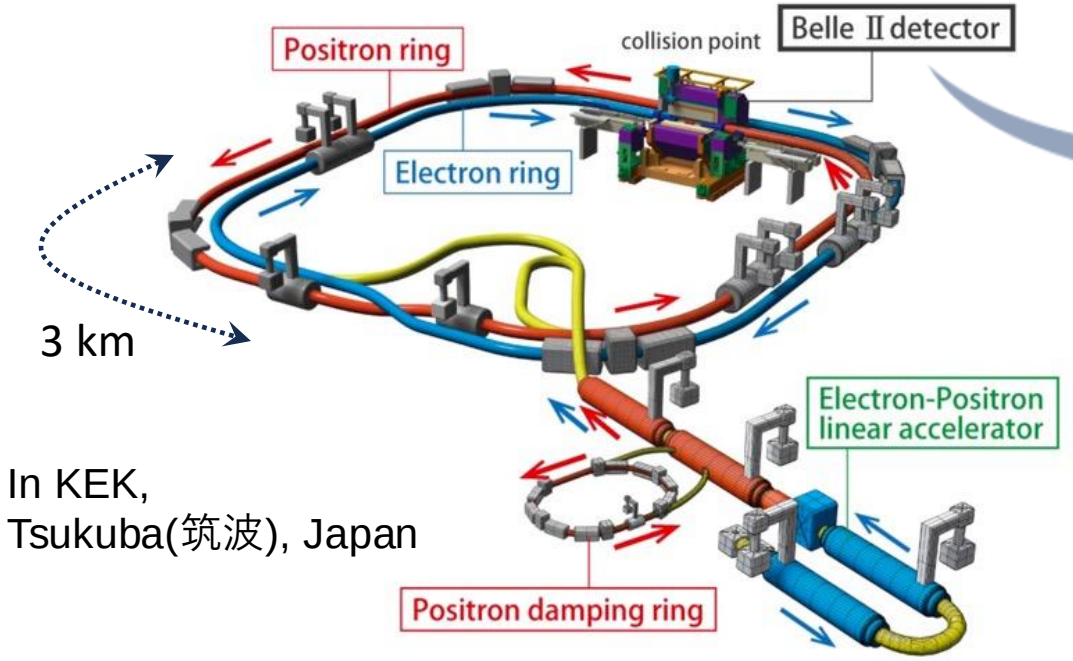
    ➥ Observations to date suggest that the contribution from new physics is small
    → **need a precise measurement with large statistics**



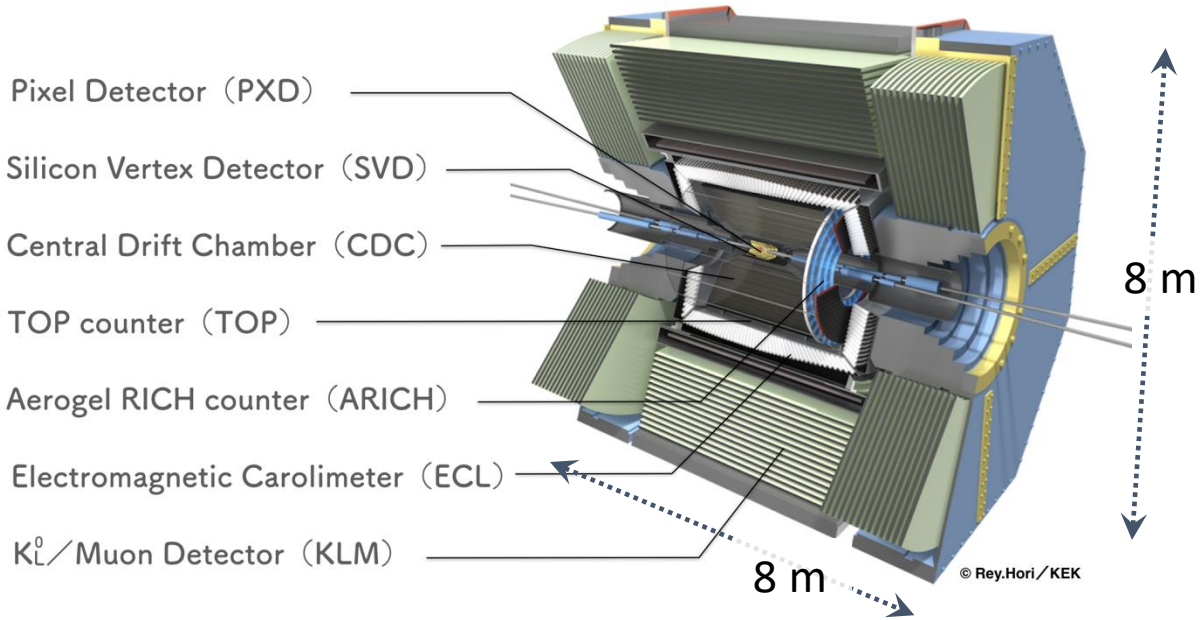
- **Why B meson?** → ✔ Includes b-quark→ accessible CP violation

  ✔ various decay channels ✔ Mass-producible with a collider → **suitable for Quantum imprint**

Belle II experiment = SuperKEKB collider + Belle II detector



In KEK,
Tsukuba(筑波), Japan



SuperKEKB collider

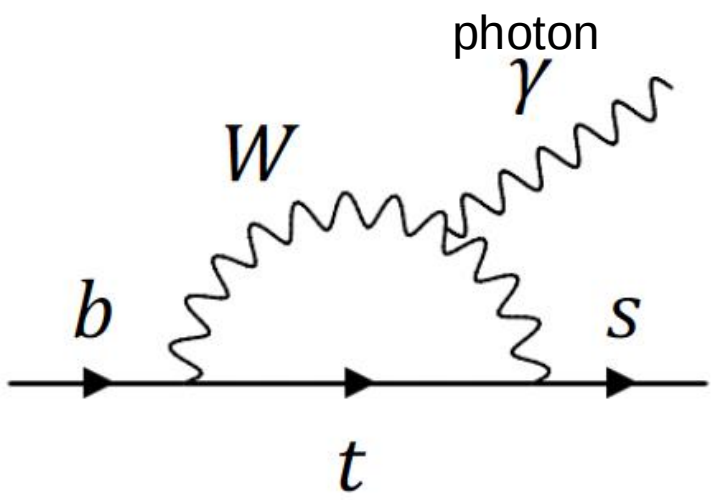
- It collides a 7 GeV electron beam with a 4 GeV positron beam
- The collision rate of beams is increased by squeezing the beam to an ultra-small size. **the world's highest collision performance.**
- Possible to **provide a vast number of B mesons and its anti-particle $\overline{B}$ meson pair**

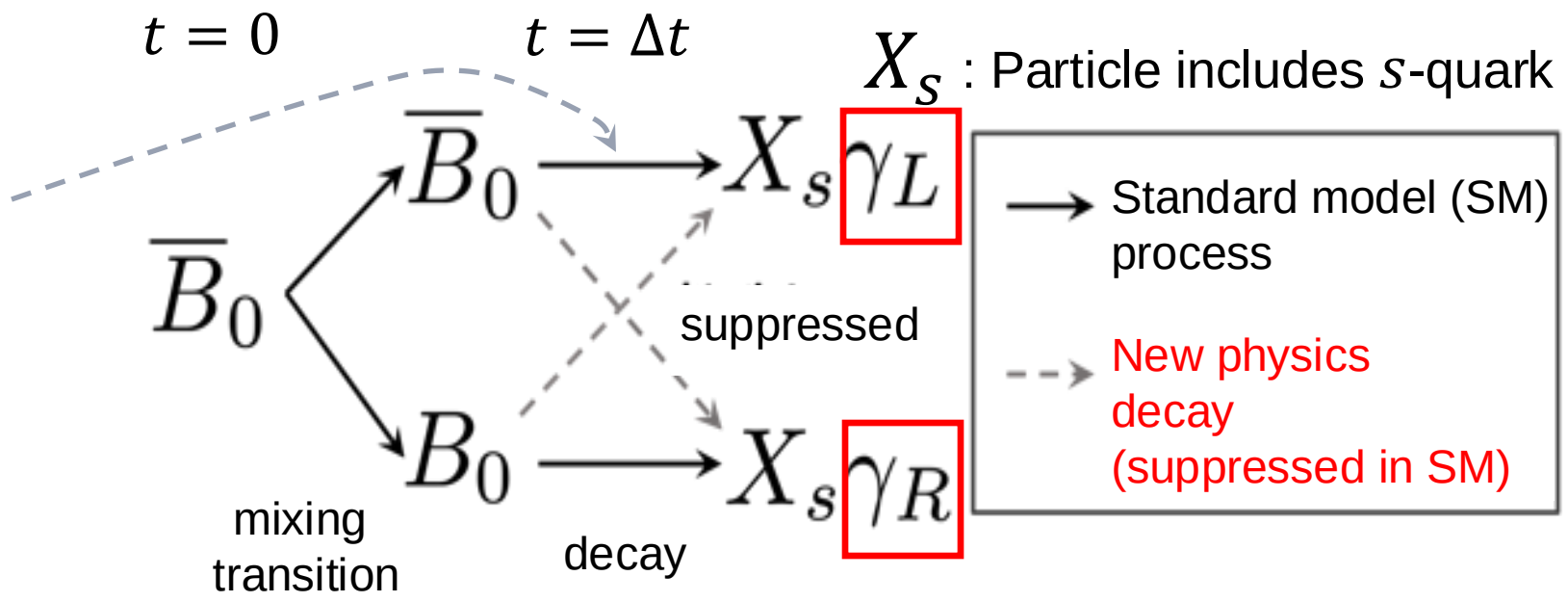
Belle II detector

- The Belle II detector is placed at the collision point of SuperKEKB and measures the particles yielded from the beam collisions
- It is composed of 7 sub-detectors that work together to measure the physical properties of particles
- It can **efficiently and precisely measure the vast number of provided B mesons**

One showcase; $b \to s\gamma$ photon polarization measurement

$b \to s\gamma$ process in standard model





- Photon has a physical property of being left-handed or right-handed
- $\overline{B^0}$-meson decays into X_s with **left**-handed photon
  B^0-meson decays into X_s with **right**-handed photon
- $\overline{B^0} \to X_s\gamma_L$ and $B^0 \to X_s\gamma_R$ are independent
  → no CP violation can be seen
  → measurable CP violation factor $S_{CP} \sim 0$ in the standard model

- If new physics makes photons indifferent to left and right-handedness, CP Violation can be seen
  → $S_{CP} \neq 0$ (become larger)
- Newest result from Belle II *arXiv:2407.09139 (2024)*:
  $B \to K^*(K_S^0\pi^0)\,\gamma$:

$$S_{\mathrm{CP}} = 0.00^{+0.27}_{-0.26} \pm 0.03$$

- Good agreement with the standard model
  still have not see new physics → wait for more data!

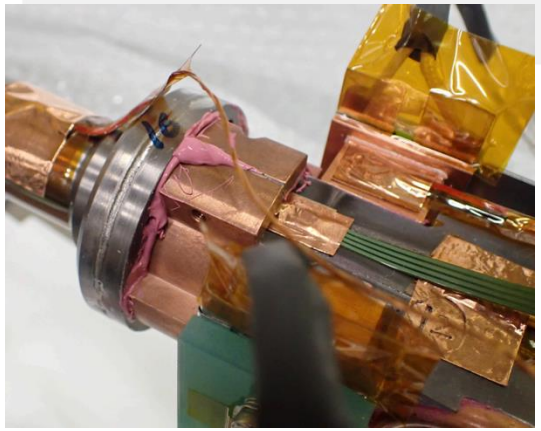
Belle II: The Quest for New Physics is ongoing

2022 June. 2024 Jan. We are here!

Run 1 | Long Shutdown 1 | Run 2

international collaboration with French institutes

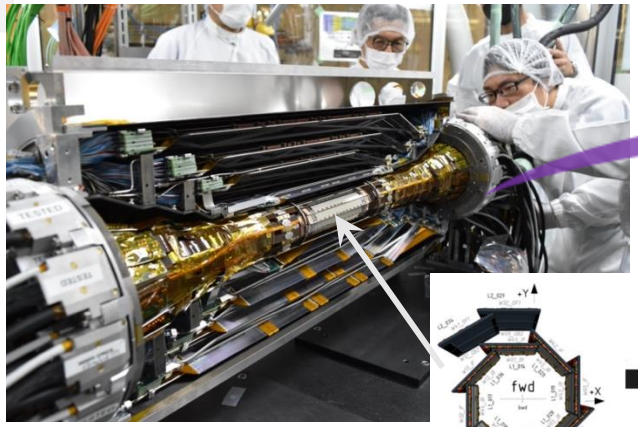
Beam pipe improvement



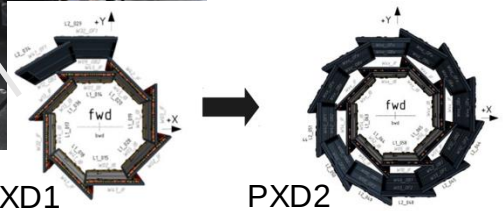
Important works during LS1

- Beam pipe cooling system was updated to prevent heat damage on the vertex detector
- VXD reinstallation works to install full Pixel detector (PXD)

Vertex detector reinstallation



Vertex detector



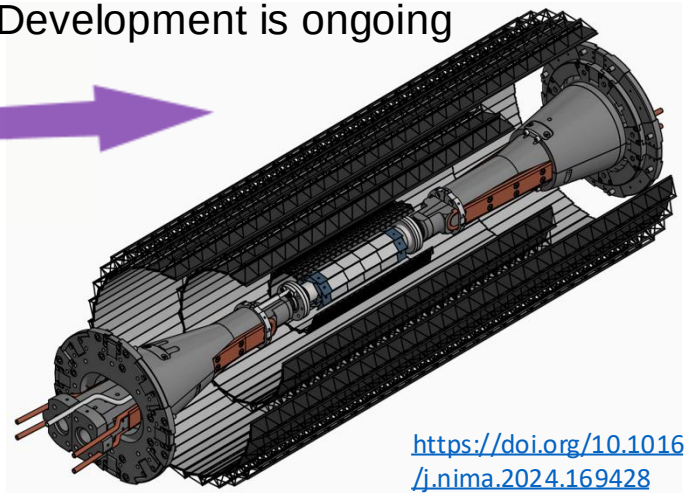
PXD1 PXD2

Future: Long Shutdown 2

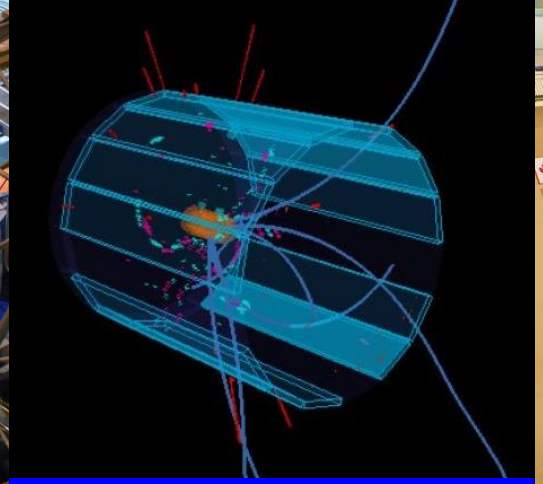
SuperKEKB beam collision rate ↗
→ physics events ↗
→ background radiation dose ↗

NEW vertex detector
data processing performance ↗
radiation tolerance ↗

Development is ongoing



https://doi.org/10.1016/j.nima.2024.169428



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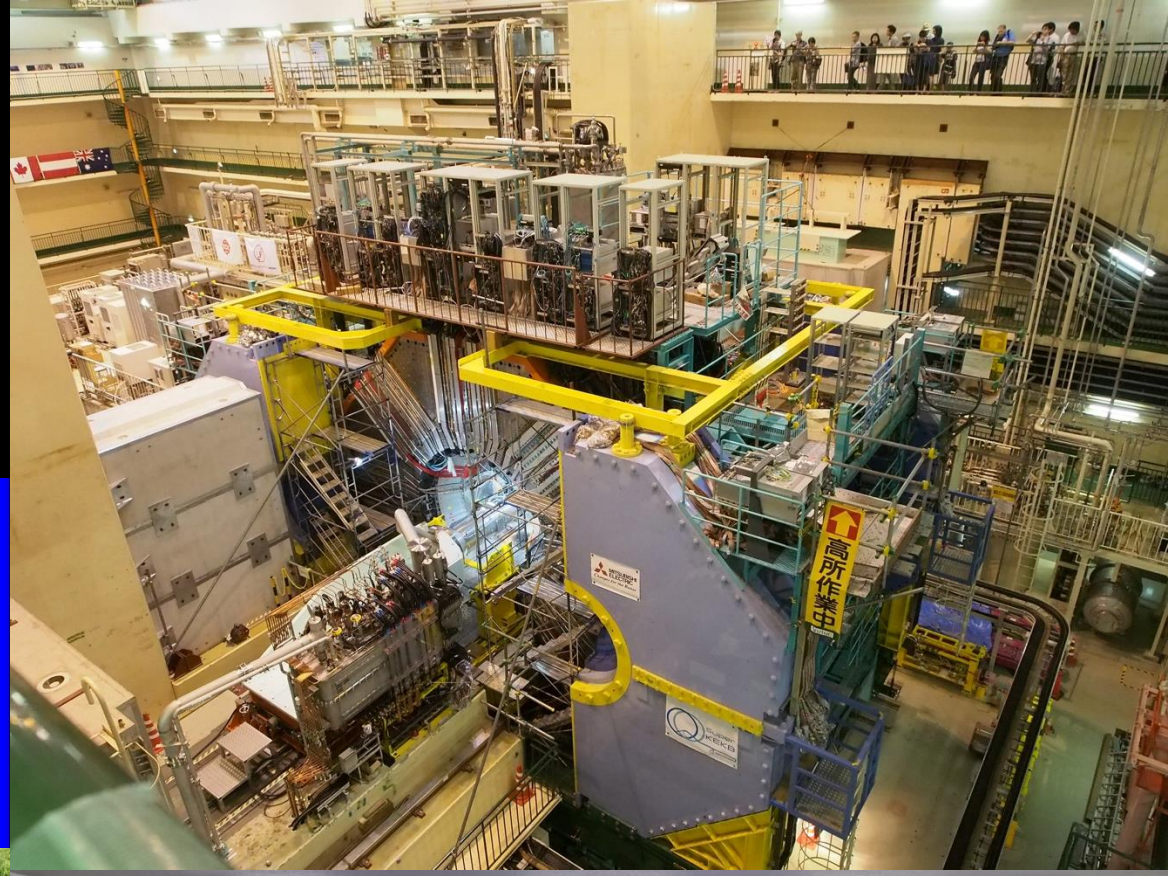

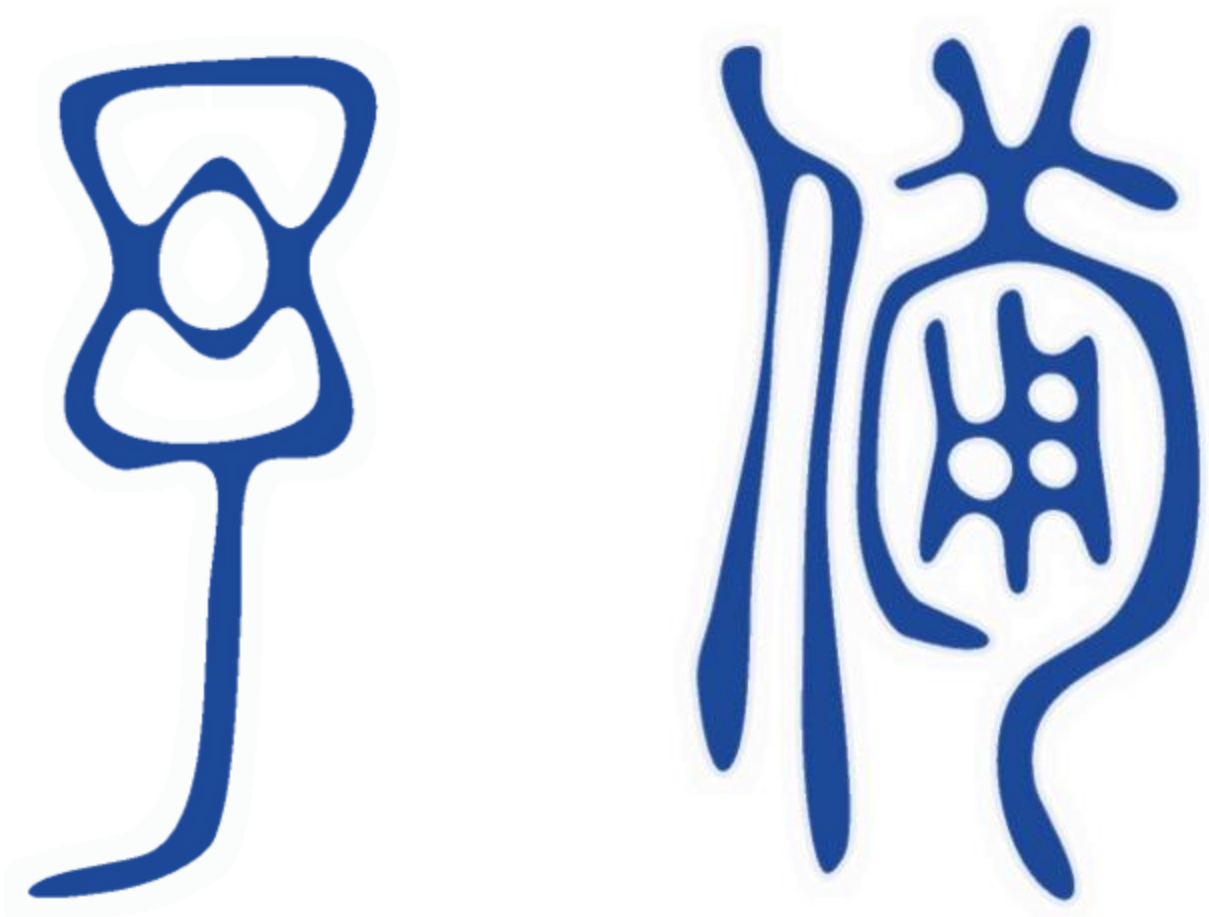

- Back up -

Belle II mind map