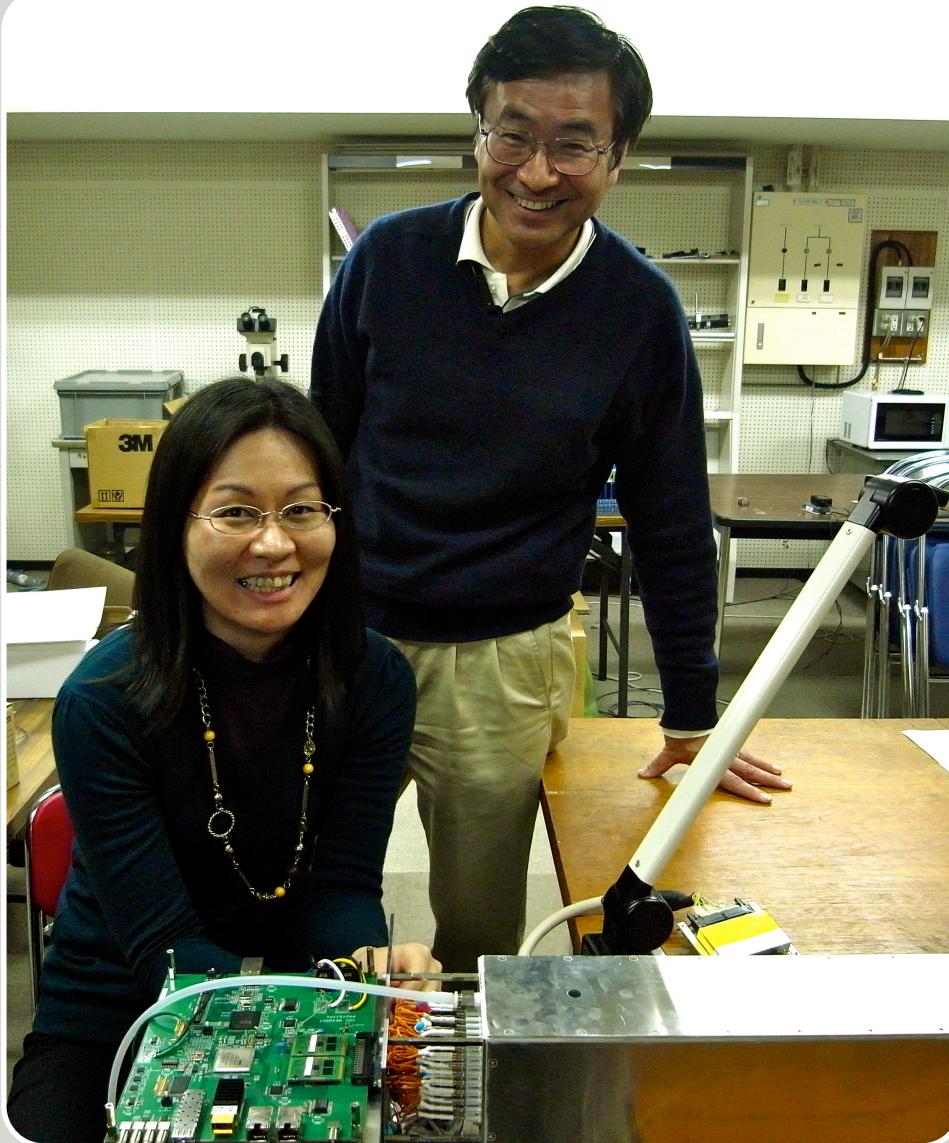


March 23, 2010

The injector machine and the Belle detector have been completed on time. An enormous effort of many people involved in the project.

FEATURE STORY



New electronics tested for Belle II central drift chamber

[Drift Chamber, Belle II]

The final technical design for KEK's Belle detector upgrade, called Belle II, is now being finalized. This week features one of the central components of the Belle II, the central drift chamber (CDC), which tracks charged particles resulting from particle interactions.

Dr. Shoji Uno of KEK (right) and postdoc Dr. Nanae Taniguchi (lower left) work on the central drift chamber (CDC) design for Belle II. Taniguchi successfully demonstrated their new electronics device using the test chamber (silver case).

A drift chamber is the most crucial element of many particle detectors, for without it, none of the data from the other detector components would make any sense. Designing and constructing a drift chamber requires particle physicists with good instincts. The system is complex, and no amount of simulation is sufficient for system optimization.

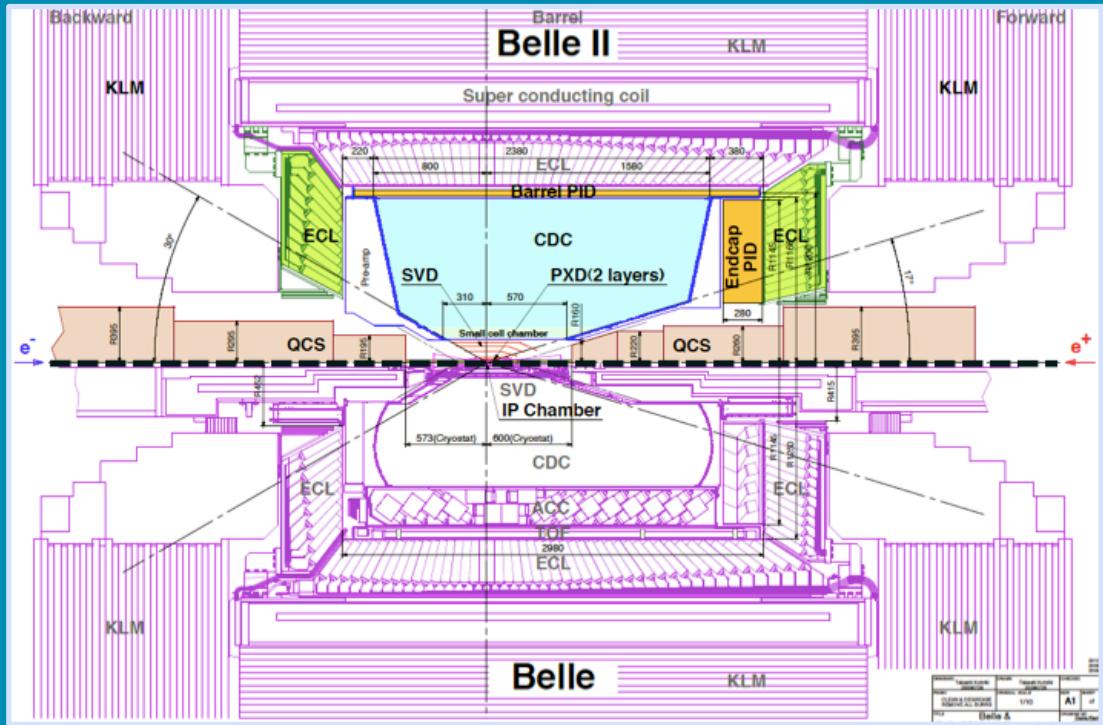
Dr. Shoji Uno of KEK has been working on drift chambers ever since he joined the Belle collaboration in 1990. Now joined by a

postdoc, Dr. Nanae Taniguchi, the team of two is finalizing the design for the new central drift chamber (CDC) of the B Factory's upgrade, the Belle II.

The current detector, Belle, is located in the KEKB accelerator ring, at the point where the electron and positron beams intersect. The new Belle II detector will sit at the exact same position on the upgraded version of KEKB, the SuperKEKB. The CDC tracks the pathways of the charged particles that result

from the interaction of the two high energy beams.

The CDC detects charged particles using wires. When particles pass through a helium based gas mixture inside the chamber, they ionize the gas molecules, knocking out electrons. An electric field is created by applying high voltage on 'sense wires' strung across the chamber. The field causes electrons to accelerate towards the wires. These electrons knock out additional electrons from the gas as they travel. A



The current Belle detector (bottom) and the upgraded Belle II detector (top) viewed from the top. The CDC tracks charged particles with horizontally arranged wires and a helium based mixture of gases. Note that the endplates on the new CDC (blue) have a different shape so as to increase their physical strength.

number of electrons and ions produced move speedily near the sense wire. The sense wire senses the motion and creates a pulse signal. The signal is then sent to the data acquisition (DAQ) system.

Same concept, robust structure

"The design of the new CDC does not change much from the original, because Belle's CDC has worked very well throughout the past decade," says Uno. "However, SuperKEKB will

produce collisions at 40 times higher luminosity, so the new CDC must be able to work in conditions with 20 times higher background noise." By adding more sense wires, Uno and Taniguchi can improve the signal-to-noise ratio.

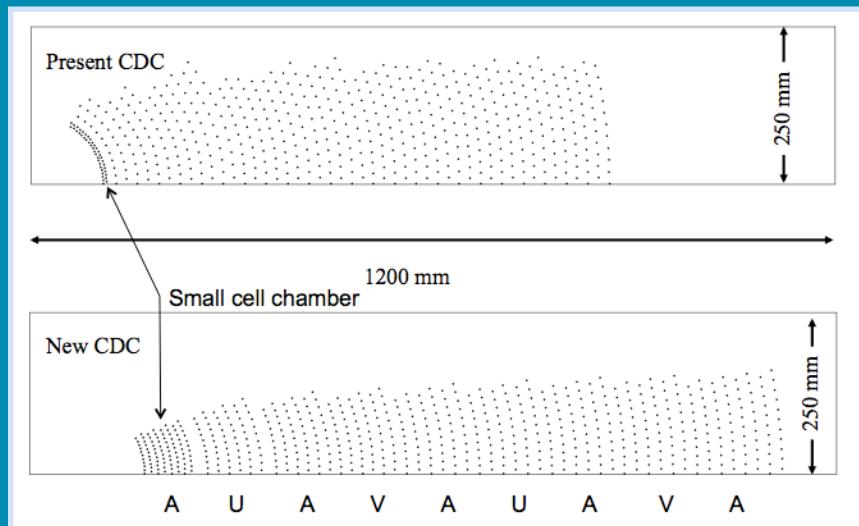
The CDC is a barrel structure around the beam pipes, and sits just outside a cylinder of the inner detector called silicon vertex detector (SVD). One big change in the baseline design is

that the outer detector to the CDC, the particle identification detector (PID), will shrink in size by a factor of 3, owing to the new technology called time of propagation counter. Due to this and in order to maintain the current level of performance in a high luminosity environment, the number of wires in the CDC will be doubled. The current CDC has 8,464 sense wires and 25,392 field wires. The upgraded CDC will have 14,336 sense wires and 42,240 field wires.

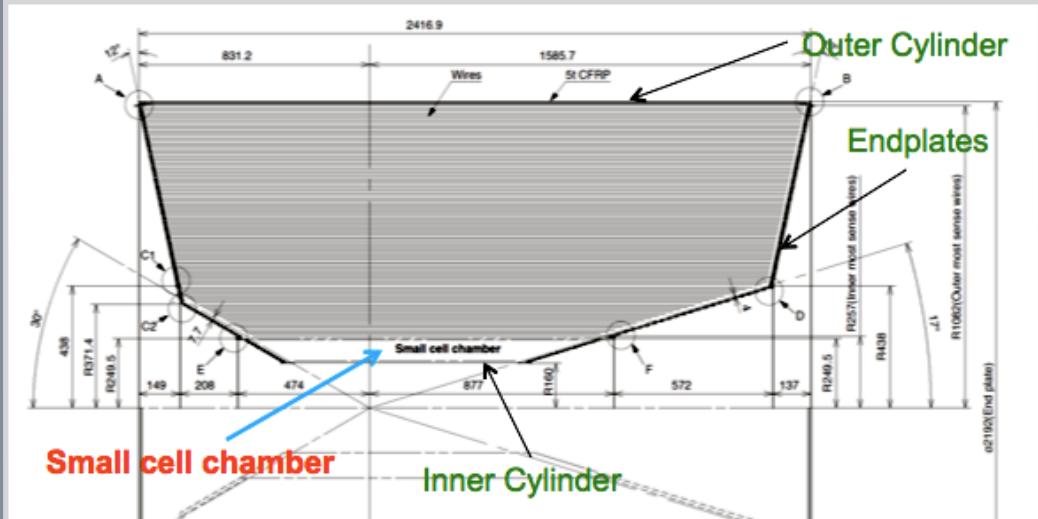
"The key is to balance weight of the wires, the wire tension, and the performance deterioration due to gravitational sag of the wires," explains Taniguchi. Since wires are strung horizontally, gravity makes the sense wires sag at the middle. The sagging can affect measurements. Taniguchi calculated the sag due to gravitation for a range of tensions, and simulated the effect on the performance. "If the influence of sagging on the performance of the detector is smaller than the influence of the detector's inherent mechanical resolution, then we are good."

The biggest concern, however, is the tension on the end plates due to the wires. Currently, the CDC's thirty thousands wires produce 3 tons of force, displacing the location of the endplates as much as 3 millimeters. "The current endplates are shaped so that particles entering the CDC have to go through minimum distance of material," explains Uno. The cross sectional view of the endplates are therefore curved so that particles from the interaction point would fly through no more than one centimeter of the endplate thickness in radial direction.

The endplates for the new CDC will have to endure 4 tons of force. "The cross section of the new endplates will be a straight line



This cross-sectional view shows the arrangement of sense wires for the Belle CDC (top) and Belle II CDC (bottom). Owing to the compactness of the outer detector (the particle identification detector or PID), the new CDC will be able to accommodate twice as many wires as the current one. It has a structure called super-layer, consisting of a combination of wires arranged in axial direction parallel to one another (A), and of wires arranged in varying angles (U). Six layers of axial wires make one group and six layers of stereo wires make another.



design for Belle. Now that we have this technology, KEK can develop custom chips for various projects," says Uno. By using the technologies made available by KEK's Electronic System Group, Uno and his team can create compact, high-speed, and low power readout electronics.

rather than round." The team calculated that this would be a balanced shape, providing a physically robust framework without having undue influence on the performance.

The super-layer scheme and small cells Drift chambers are extremely complex systems, with many parameters to consider when designing. Using the accumulated expertise of chamber scientists, as well as past experimental data, the KEK team developed an optimal design. One widely accepted design, and the one used for the current Belle CDC, is called the super-layer structure. It consists of a combination of wires arranged in axial direction parallel to one another, and of wires arranged in varying angles—called stereo wires. Six layers of axial wires make one group and six layers of stereo wires make another. The Belle II's CDC has nine groups of these.

In addition, there will be eight layers of tightly spaced axial wires at the inner part of the CDC. This group is called a small cell. Past experience has shown that the introduction of a small cell in a chamber helps separate signals from noise by tracking particles freshly coming out of the interaction point. "In 2003, we installed two layers of small cell to test the concept," says Uno.

New compact readout electronics

The CDC readout electronics will be completely replaced, owing to advancements in technology over the last two decades. The new CDC will employ an all-in-one technology that amplifies the signal, applies a pulse shaping, and then converts the analog signal into a digital signal.

The current Belle CDC sends signals all the way from the detector to an electronics hut 30 meters away via 30-meter cables to interpret the signals for data analysis. In the new CDC, all the electronics will be inside the Belle II detector, right beside the

chamber itself. Digitalized data will be readily available through fiber optic connections, to be collected in the DAQ system.

Signals from wire chamber is very small, so they are amplified by preamplifier component of the electronics. Amplified signals are shortened to make sure sensitivity to higher frequency signals in Belle II. The electronics also need the ability to separate noise from signal. These functions, called shaping and discrimination, will be built into the new electronics. The electronics will use an application-specific integrated circuit (ASIC). An ASIC is a chip specially designed for a particular use. The new ASIC will process eight channels on a 4-millimeter by 4-millimeter chip for Belle II, whereas the previous chip processed one channel on a 1-centimeter by 3-centimeter chip for Belle.

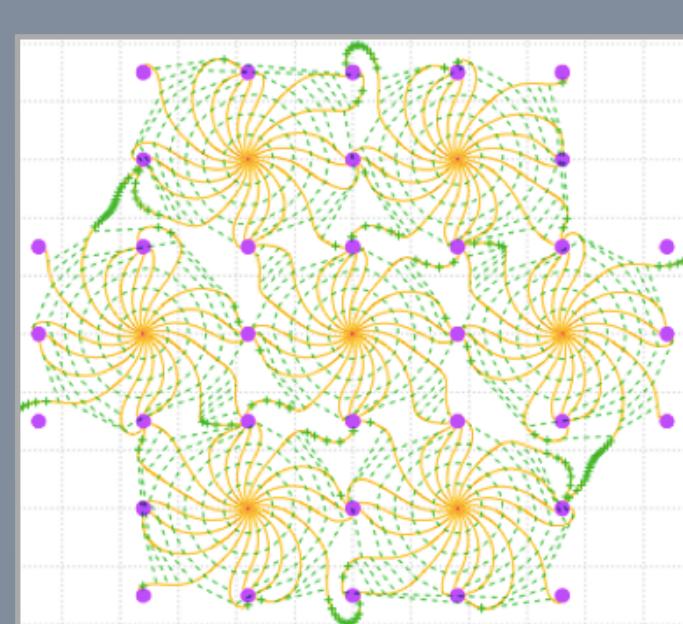
"ASIC technology was uncommon in Japan 20 years ago when we were starting the

In November of last year, Taniguchi successfully demonstrated the newly designed electronic device. She investigated optimal values for such parameters as gain, noise cancellation, and time resolution, using a hybrid board that contained all necessary parts.

"The new readout electronics with ASIC are the result of many people's efforts and many advanced technologies developed at KEK," says Taniguchi. Their readout electronics with ASIC will be ready by this summer.

Thinking outside the box

Belle's CDC is already an elaborate system that demonstrates superb craftsmanship. While the development of silicon detectors has become common and straightforward, drift chambers remain notorious for the



Simulation result of gravitational sag effect. Sense wires (orange) are surrounded by field wires (purple) which create an accelerating electric field (field lines are orange).



Two layers of small cell were installed in 2003.

incredibly large number of variables to be considered during design. "Because the system is too complex to be amenable to any meaningful computer optimization studies, a lot of the design choices are made based on our past experiences," says Uno. "However,

needed light wires. So he used aluminum wires without the gold coating. Since aluminum cannot be soldered to the endplates, the new CDC's wires are fixed by crimping pins. As to oxidation, Uno has found that "aluminum oxidization does not affect the performance of

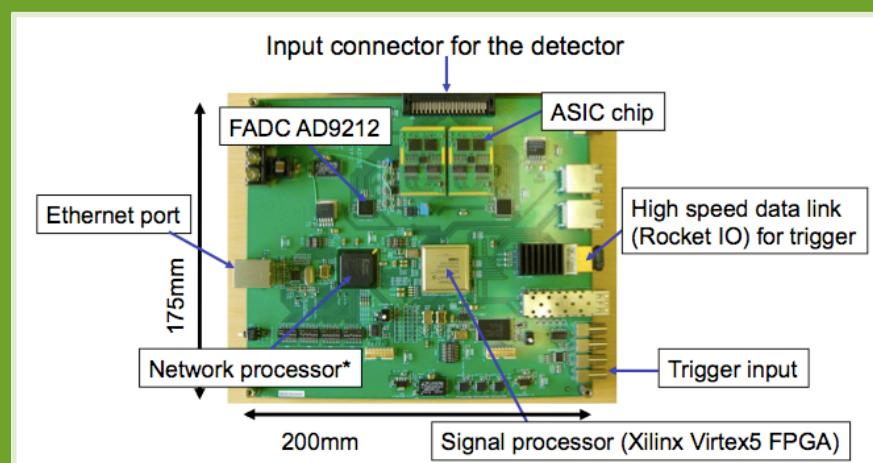
sometimes it's necessary to go beyond experience and make educated guesses in chamber science."

The current Belle CDC uses bare aluminum for the field wires. Because aluminum cannot be soldered and is easily oxidized, no drift chamber had previously used bare aluminum. Other similar chambers have used gold-coated aluminum. For the B Factory upgrade, however, Uno

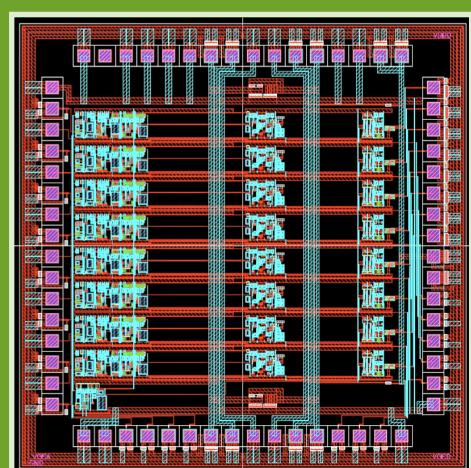
the detector a bit," Uno grins, "It was simply a superstition that oxidation affects the performance." KEK's Belle CDC remains to be the sole chamber that uses bare aluminum wires. He says that people are still uncomfortable with this design for unfounded reasons.

Before the B Factory experiment, most drift chambers were filled with an argon-based gas mixture. This was because argon is inexpensive, and also sensitive to X-rays. For initial testing of drift chambers, experimenters often used X-rays with an energy similar to the energy lost by the charged particles produced at the collider. For the B Factory, however, X-rays are considered background noise. In addition, because argon is so heavy, it can destruct the momentum measurement of particles. To solve this problem, the team developed an X-ray insensitive, light gas mixture consisting of helium and ethane. This was the first time a high energy experiment had used a helium based mixture.

Drift chambers are packed with the very basics of particle physics experiment, and cultivate creativity and good intuitions. This is why many particle physicists think it profiting to work on them once in the course of their career. "CDC is such an important and profoundly elaborate detector component, which excites me greatly," says Taniguchi. "There also is much work to be done in the future." The team welcomes new collaborators to work with them towards the goal of the next generation B Factory detector.



Prototype of the new readout electronics for the Belle II CDC.



The new ASIC preamplifier will host 8 channels on a 4-millimeter by 4-millimeter chip.

Related Link:
[Belle II](#)

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