Personal notes on the KEK B-factory

Feb. 28, 2020

Fumihiko Takasaki
KEK
Studies on the Quarks / Leptons

KEK

Quarks → B-factory

Leptons → T2K exp

J-PARC to Kamioka
Belle II Collaboration

- 984 active members
- 333 graduate students
- 115 institutes
- 26 countries  (B2MM on June 20, 2019)
T2K Collaboration
12 countries, 69 institutions about 500 people
I could have learned from great people.
Great Stars (I)

Klein-Nishina 1929
On the Nature of Cosmic-Ray Particles

Y. Nishina, M. Takeuchi, and T. Ichimiya
Institute of Physical and Chemical Research, Tokyo
(Received August 23, 1937)

Various authors\(^1\) have taken the view that cosmic-ray particles consist of two or more kinds of corpuscles. According to Compton and Bethe, and Auger,\(^1\) the soft component near sea level is thus composed of electrons and the penetrating one of protons. Assuming the theory of showers by Bhabha and Heitler\(^2\) and by Oppenheimer and Wigner, one ought to be able to observe electrons from protons at high enough levels. We carried out such experiments in high mountainous regions. In one of our experiments, a 1.5 cm thick lead plate was placed in front of a Wilson chamber 40 cm in diameter, which is placed in a magnetic field of about 17,000 oersteds. The operation of the chamber is actually done by Geiger-Müller and the chamber, the Geiger-Müller tube being about 50 cm. The level near Tokyo was about 20 percent of the height being high enough to produce showers nor does it reduce showers nor produce showers nor produce showers nor produce showers.

The initial value of \(H_p\) of the particle was \(7.4 \times 10^5\) gauss-cm and after passing through lead it became \(4.9 \times 10^5\) gauss-cm, showing the loss of about a half of the energy. The loss of energy by ionization and the range in lead calculated from the thickness of the lead bar and the final \(H_p\) are consistent, if we assume the mass in question of the particle to be \(1/7\) to \(1/10\) that of the proton. The above values of \(H_p\) and the
Great Stars (II)

Yukawa 1935
Great stars (III)
Some historical remarks on KEK Accelerators
KEK was established in 1997 in a re-organization of the Institute of Nuclear Study, the University of Tokyo, founded in 1955.

INS 1.2 GeV electron-synchrotron
KEK  Started construction 1971
TRISTAN at KEK (1987-1994)

- Single ring $e^+e^-$ collider < 64GeV
- Peak luminosity $\sim 10^{31}$
- Three general purpose detectors
- Each collected $\sim 400\text{pb}^{-1}$

Fig. 10 TRISTAN accelerator complex.
TRISTAN VENUS Detector

Looked for the Top quark
Electron-Positron Collider

Looked for the Top quark

$\mathbf{m_{top}}$
Very first design of B factory at KEK

K.Oide, Jan. 1988

Straight section of TRISTAN MR

Energy $E = 1\text{GeV}$
Total length $L = 75.45 \text{m} = \frac{L_{\text{mr}}}{40}$
Revolution freq $f_r = 4\text{MHz}$
Betatron tune $V_x = V_y = 3.75, \quad V_{\text{arc}} = 2$
Energy Loss $U_0 = 26.8 \text{keV}$
Bonding Radius $\rho = 3.3 \text{m}$
Momentum Compaction $\alpha = 0.25$
RF Voltage $V_c = 2 \text{MV}$
Synchrotron tune $\beta_5 = 0.1$
Natural bunch length $\sigma_0 = 1.4 \text{cm}$
Clamping time $T_s = 9.3 \text{ms}$
Energy spread $\sigma_0/E = 4.7 \times 10^{-4}$
Harmonic number $n = 128$
Horizontal emittance $\varepsilon_x = 1.1 \times 10^{-9} \text{m}$

Collision Parameters

Crossing angle $20\text{mrad}$
Bunch length $1.4 \text{cm}$
Emittance $1.1 \times 10^{-7} \text{m}$

$\beta_x^* = 1.6 \text{m}$
$\beta_y^* = 0.05 \text{m}$
$\sigma_x^* = 0.42 \text{mm}$
$\sigma_y^* = 0.026 \text{mm}$

Number of bunches $1$
Particle number $3.6 \times 10^{11}$
Current $230 \text{mA}$

Beam-beam
Shift

$L = 1.7 \times 10^{31} \text{s}^{-1} \text{cm}^{-2}$

$\rho_x = 0.03$
$\rho_y = 0.03$

$40/\text{m} \quad (\text{m 電流})$
$1.7 \times 10^{10}/\text{m}$
$[0.27 \text{mA} \text{beam/bunch}$

$0.03$
$0.03$
First proposal: Large ring × small ring option

Use TRISTAN tunnel to accommodate 12GeV $e^-$ storage ring

New 2GeV storage ring of ~20 diameter

This option was the least expensive option to realize asymmetric B factory making full use of existing TRISTAN facility.
However, this idea was immediately dismissed by the important paper by Hirata and Keil.

Oide’s email warned that the one of the coherent mode becomes always unstable, if the numbers of bunches in the two rings are much different.
B-Factory : approved for funding
Letter of Intent for a Study of CP Violation in B Meson Decays

The BELLE Collaboration

KEK Report 94-2
April 1994

127 physicists from 31 institutions in 6 countries

<table>
<thead>
<tr>
<th>Detector Component</th>
<th>Responsible Institutions</th>
<th>Number of staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Pipe &amp; Beam Mask</td>
<td>KEK</td>
<td>3</td>
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<tr>
<td>SVD</td>
<td>KEK, Niigata, Osaka, Tokyo MU, KEK</td>
<td>16</td>
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<td>PDC and CDC</td>
<td>Fukushima, KEK, Nagoya, Tokyo A&amp;T</td>
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<td>RICH</td>
<td>Chiba, Chuo, KEK, Saga, Princeton, Taiwan, Toho</td>
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<td>TOF</td>
<td>Hawaii, Hiroshima Tech, KEK, Okayama, Tokyo</td>
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<td>ChI</td>
<td>Beijing, Hefei, KEK, Korea U, Novosibirsk, Nara, SNU, Tokyo Tech</td>
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<tr>
<td>Magnet</td>
<td>KEK</td>
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<td>KLC and MUON</td>
<td>Osaka City U., Tohoku, Tohoku, Onkunin, Tohoku Tech</td>
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<td>Trigger and DA</td>
<td>KEK, Nagoya, Tokyo Tech</td>
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<td>Offline Analysis</td>
<td>Hawaii, KEK, Nagoya, Nara</td>
<td>5</td>
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<tr>
<td>Structure/Assembly</td>
<td>KEK</td>
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Final design of KEKB

<table>
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<tr>
<th>Parameter</th>
<th>KEKB Design</th>
<th>KEKB Achieved with crab</th>
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</thead>
<tbody>
<tr>
<td>Energy (GeV) (LER/HER)</td>
<td>3.5/8.0</td>
<td>3.5/8.0</td>
</tr>
<tr>
<td>$\beta_y^*$ (mm)</td>
<td>10/10</td>
<td>5.9/5.9</td>
</tr>
<tr>
<td>$\varepsilon_x$ (nm)</td>
<td>18/18</td>
<td>18/24</td>
</tr>
<tr>
<td>$\sigma_y$ (\mu m)</td>
<td>1.9</td>
<td>0.94</td>
</tr>
<tr>
<td>$\xi_y$</td>
<td>0.052</td>
<td>0.129/0.090</td>
</tr>
<tr>
<td>$\sigma_z$ (mm)</td>
<td>4</td>
<td>~ 6</td>
</tr>
<tr>
<td>$I_{beam}$ (A)</td>
<td>2.6/1.1</td>
<td>1.64/1.19</td>
</tr>
<tr>
<td>$N_{bunches}$</td>
<td>5000</td>
<td>1584</td>
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<tr>
<td>Luminosity ($10^{34}$ cm$^{-2}$ s$^{-1}$)</td>
<td>1</td>
<td>2.11</td>
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</table>
Many New Ideas
• Continuous beam injection
  – Belle trigger is vetoed for 3.5 msec after injection at 10Hz.
  – Useful to overcome KEKB’s disadvantage of the injection linac compared with the PEP-II’s powerful injector!
  – Started in 2004 almost at the same time as PEP-II.
  – Constant beam current
    → stable temperature of all the machine components
    → stable beam condition
    → easier beam tuning
    → better peak luminosity
Let us work together to disclose mysteries of nature

Feb. 28, 2020

F. Takasaki
KEK