BELLE status

(Feb.25　10:15-10:35　F.Takasaki)

Belle Status and Plans

February 25, 2002

Fumihiko Takasaki, KEK

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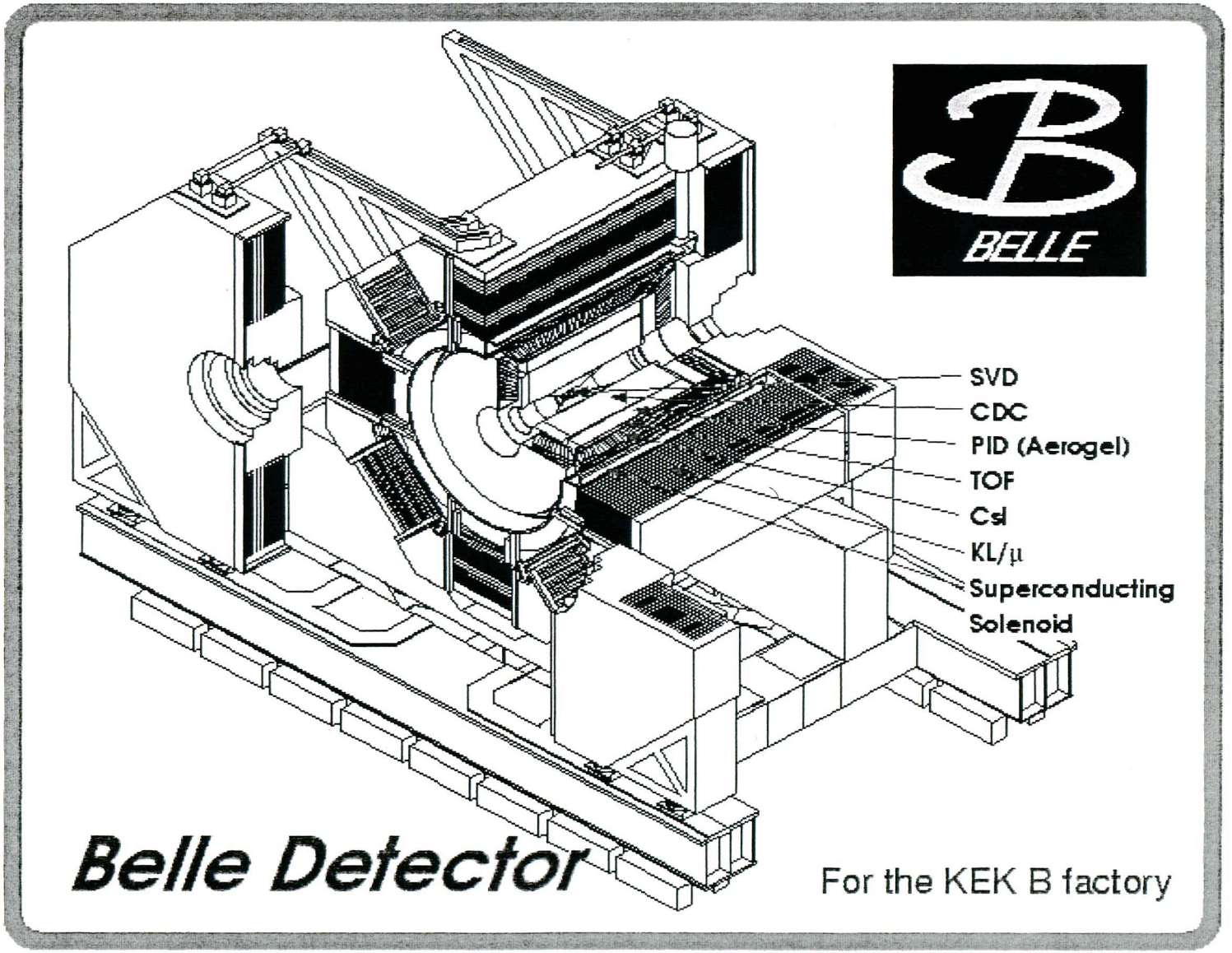
Introduction

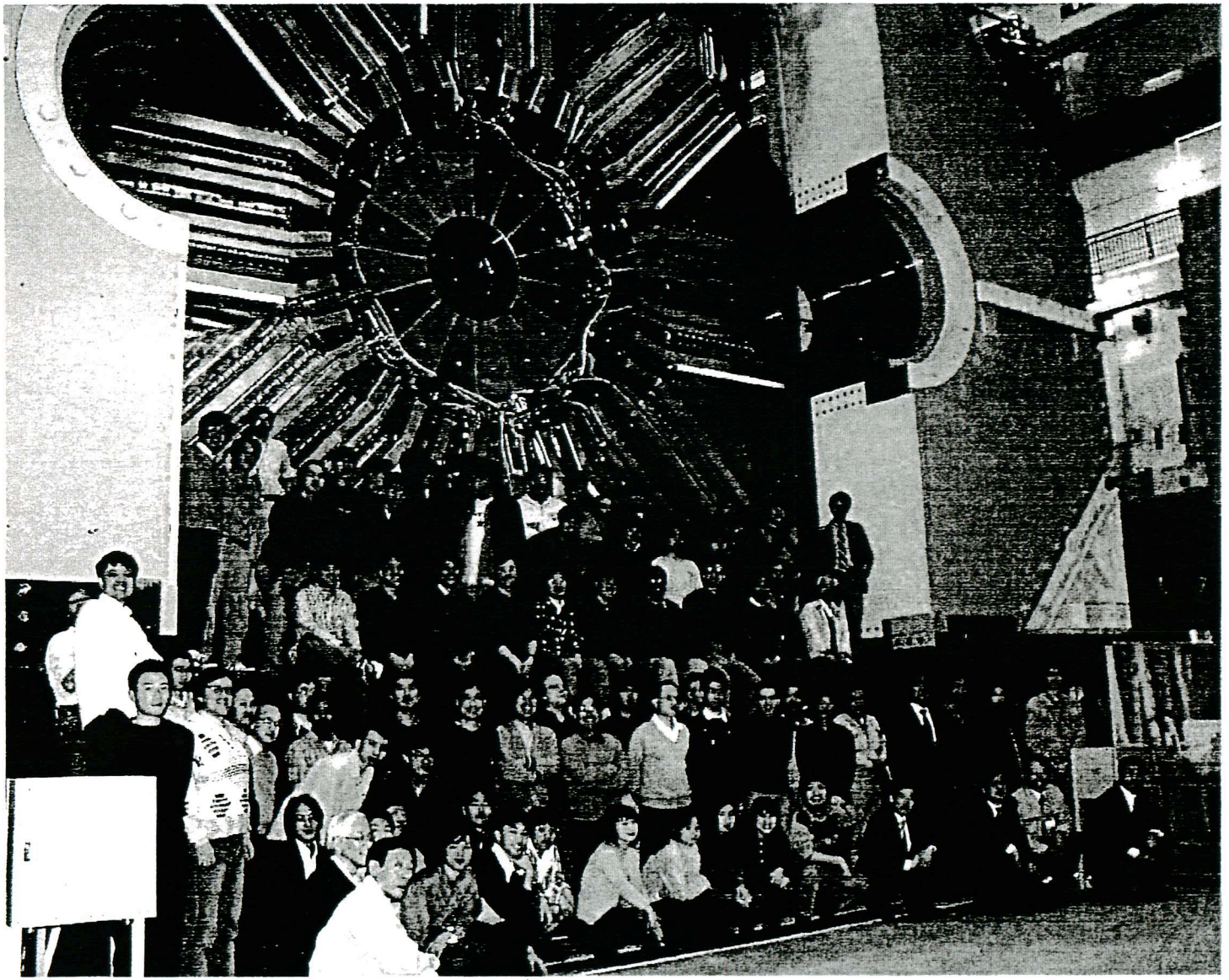
- The KEKB/Belle team did a great job in discovering the CP asymmetry in the B-meson decays. We would like to express our gratitude to the KEKB accel. people for a wonderful performance of the KEKB accelerator.

We also thank the KEKB review team for the careful and timely advice to the operation of the KEKB accelerator.

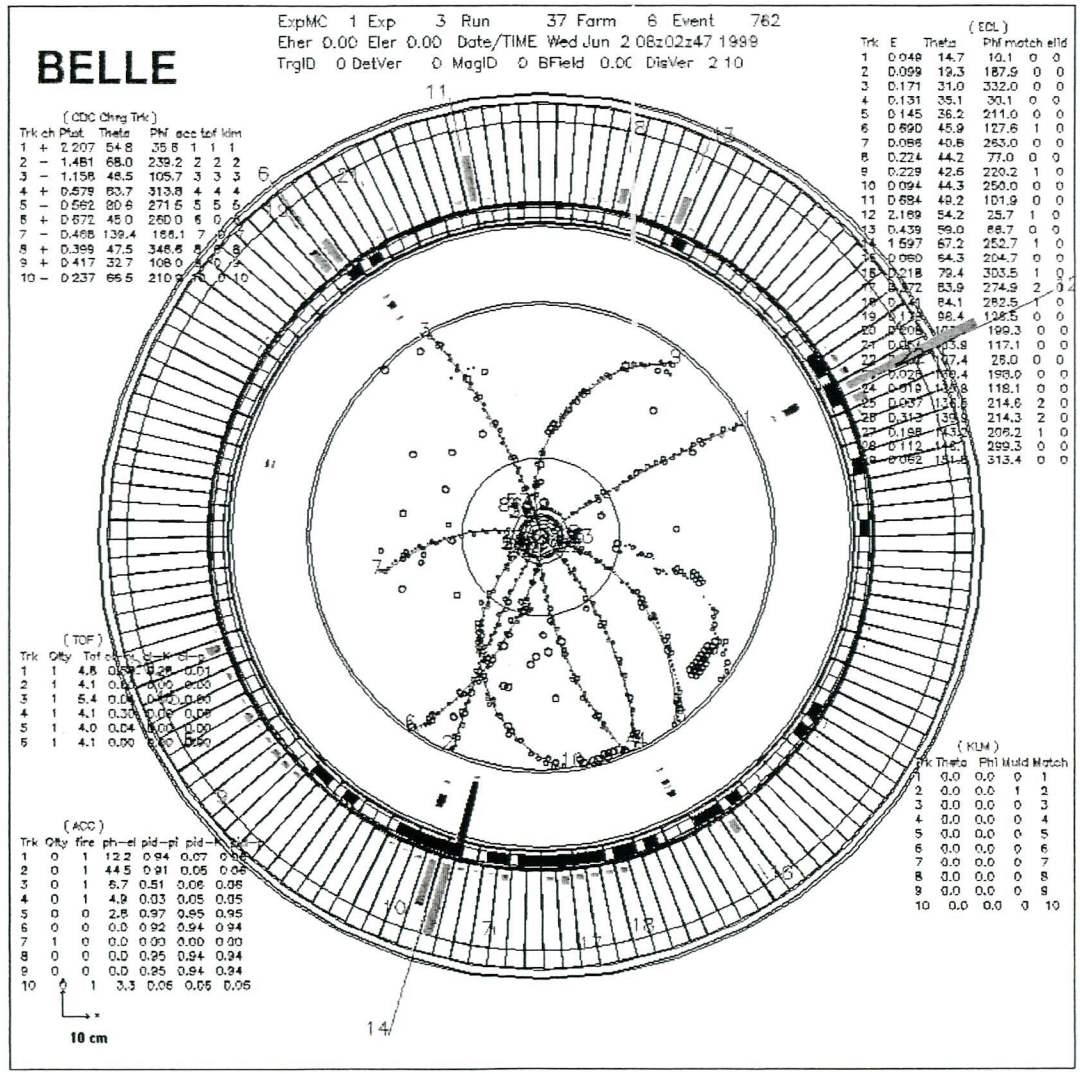
Belle detector



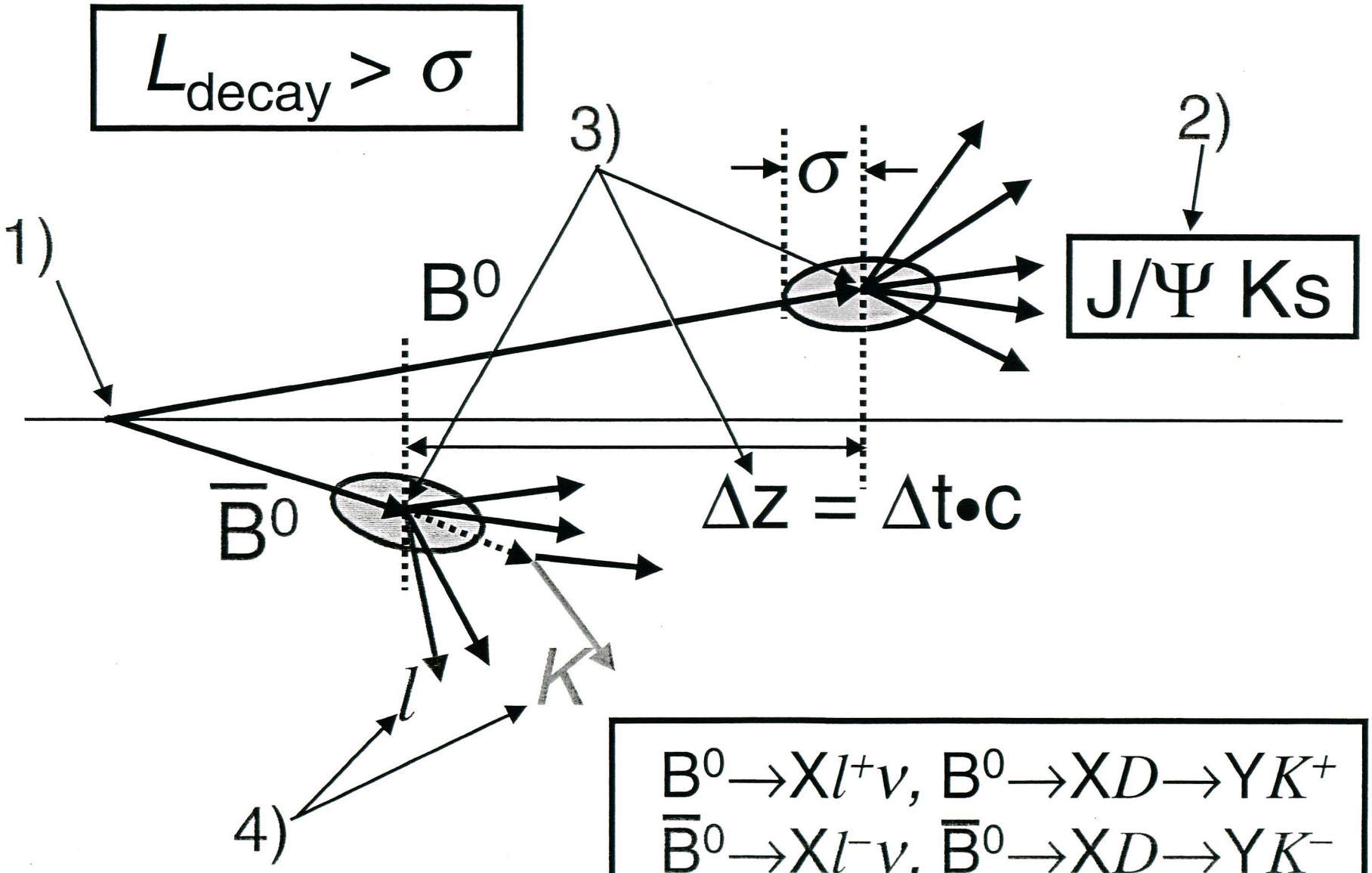
Belle detector



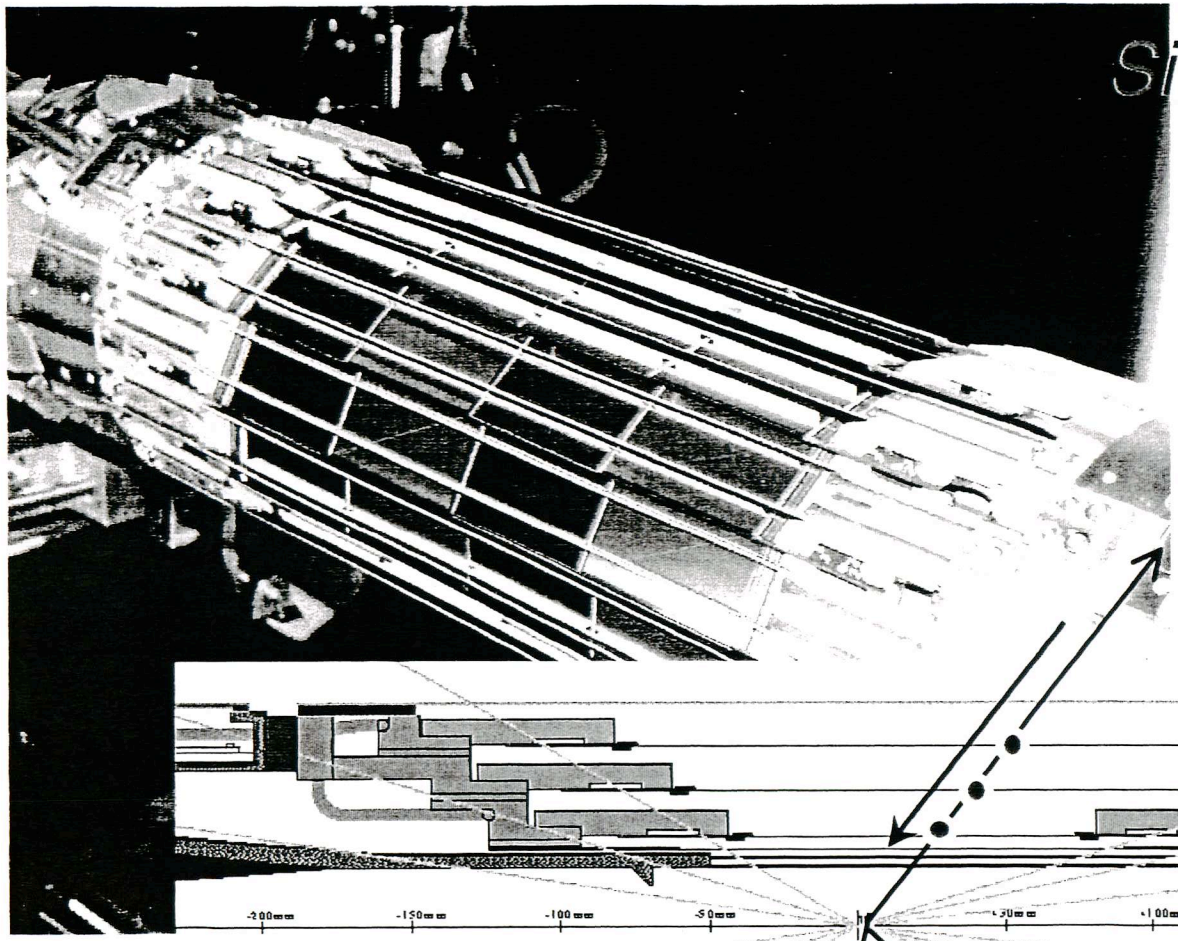
A typical event



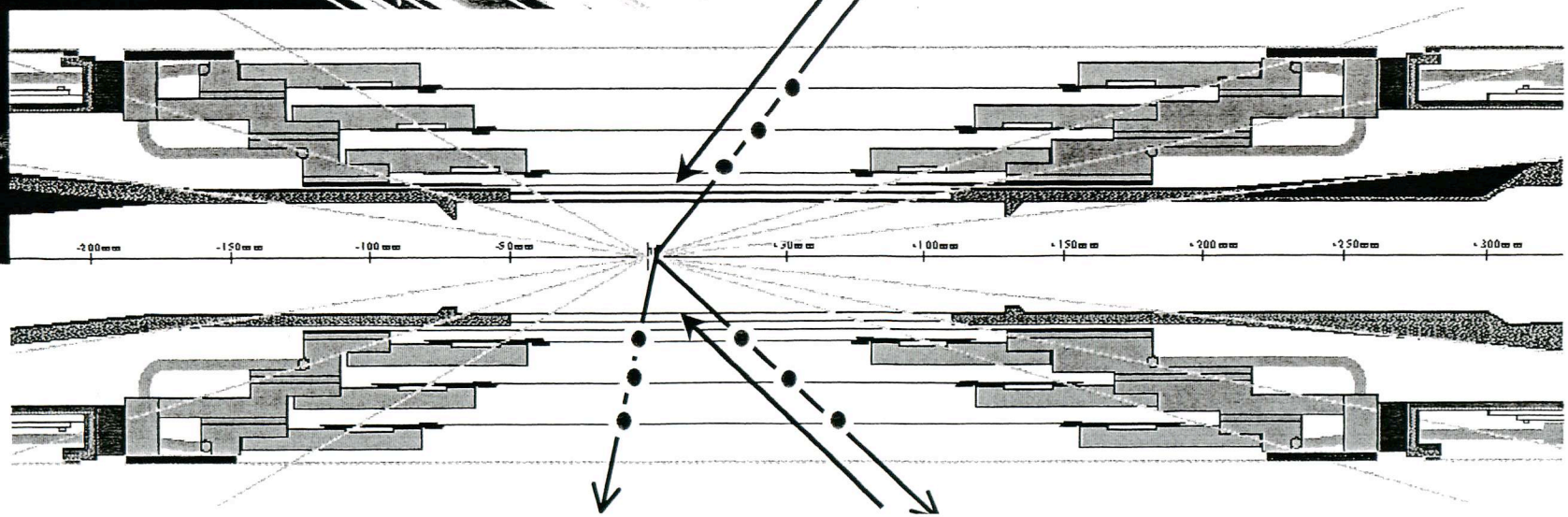
Event finding, Vertexing and Tagging



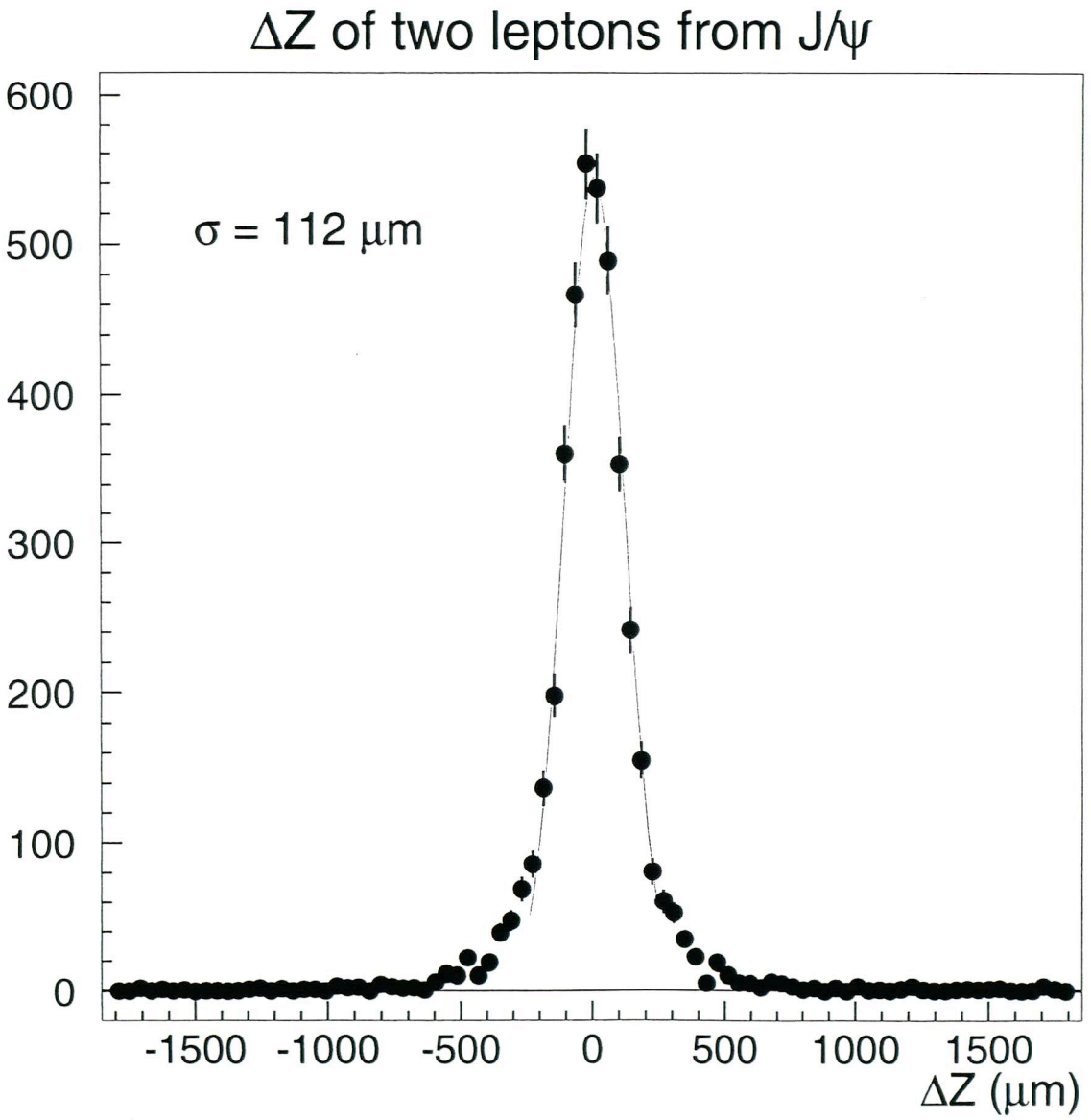
Vertex finding



Silicon Vertex detector



Vertex finding

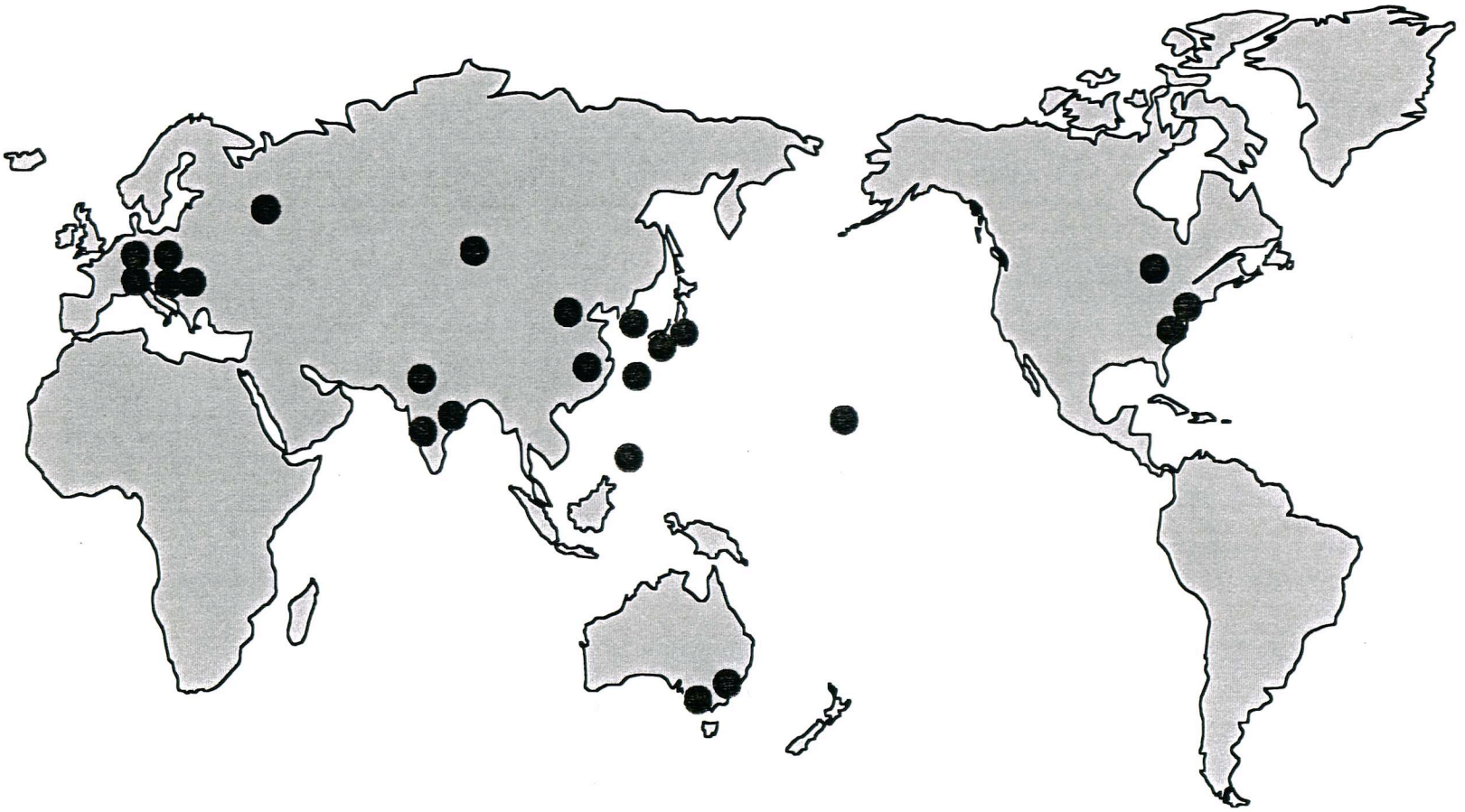


Collaborating Institutions

Japan (Total 183)	KEK	53
	Aomori	2
	Chiba	6
	Chuo	3
	Hiroshima Institute	1
	Kanagawa	1
	Kyoto	6
	Nagoya	16
	Nara women	8
	Niigata	8
	Nihon Dental	1
	Osaka	12
	Osaka City	7
	Saga	3
	Toho	6
	Tohoku	11
	Tohoku Gakuin	7
	Tokyo	11
	Tokyo Metropolitan	1
	TIT	9
	TUAT	4
	Toyama	1
	Tsukuba	5
	Yokkaichi	1
Russia (Total 22)	BINP	13
	ITEP	9
Poland	Krakow	10

USA (Total 26)	Cincinnati	5
	Hawaii	12
	Princeton	5
	Virginia Tech	4
Germany	Frankfurt	3
Korea (Total 32)	Gyongsang	1
	Korea	4
	Kyungpook	2
	Seoul National	6
	Sungkyunkwan	9
	Yonsei	10
China (Total 16)	IHEP	6
	Peking	4
	USTC	6
Taiwan (Total 21)	National Central	1
	Kaohsiung	2
	NLIT	1
	National Taiwan	17
Switzerland	Lausanne	4
Austria	Vienna	6
Australia (Total 15)	Melbourne	12
	Sydney	3
India (Total 6)	Panjab	2
	Tata	2
	Utkal	2
Slovenia	Ljubljana	5

Belle International Collaboration



Observation of CP asymmetry

- CP asymmetry was observed as Sanda, Carter and Bigi predicted.

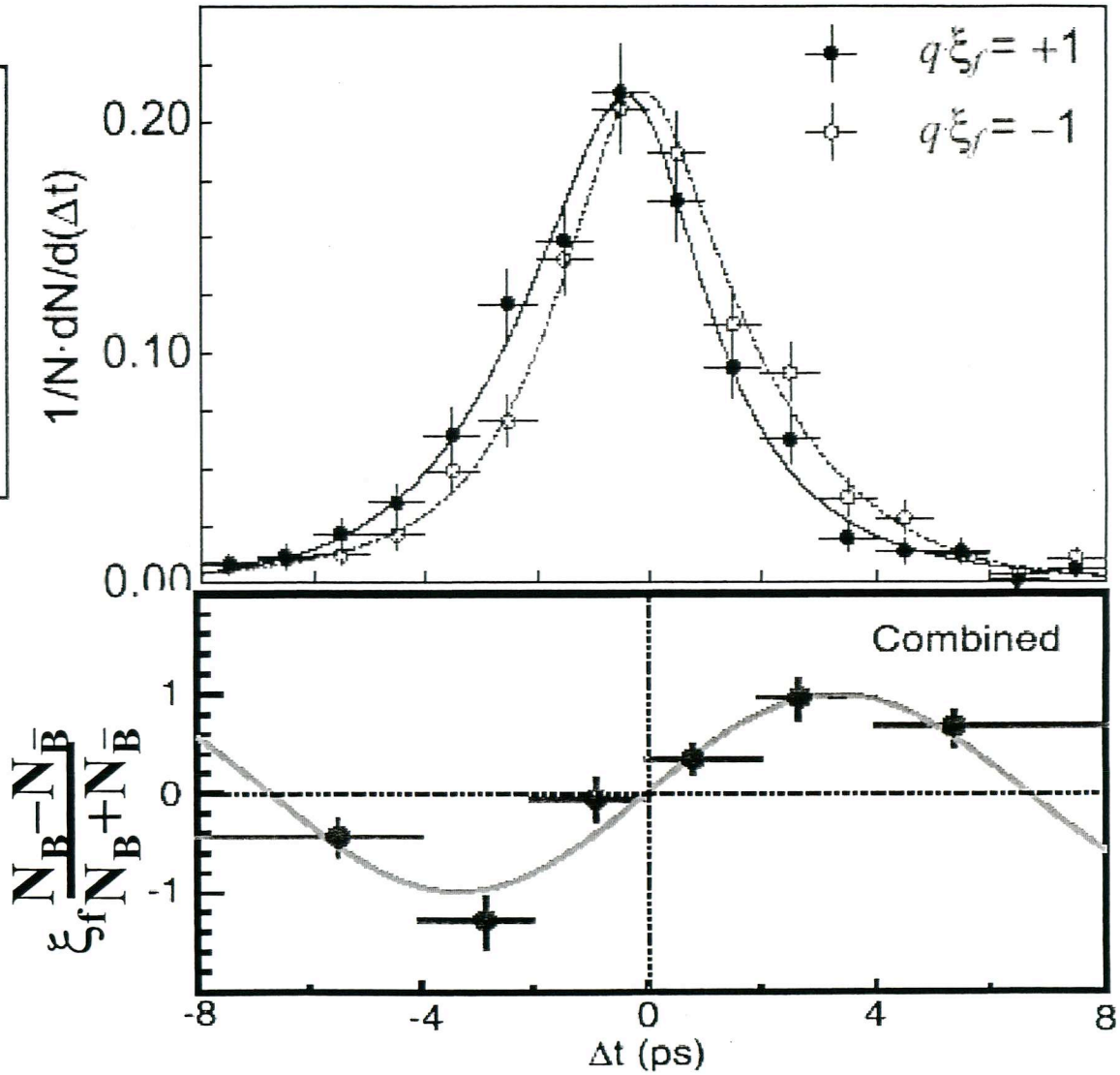
- This is the first clear evidence proving the Kobayashi-Maskawa theory since it was proposed 30 years ago.

$\sin 2\phi_1$: Fit Result

$$\sin 2\phi_1 = 0.99 \pm 0.14 \text{ (stat)} \pm 0.06 \text{ (sys)}$$

[PRL 87, 091802 (2001)]

curves from unbinned fit



Belle Results, 2001

Observation of Large *CP* Violation in the Neutral *B* Meson System

K. Abe,[9] K. Abe,[37] R. Abe,[27] I. Adachi,[9] Byoung Sup Ahn,[16] H. Aihara,[39] M. Akatsu,[20] G. Alimonti,[8] K. Asai,[21] M. Asai,[10] Y. Asano,[44] T. Aso,[43] V. Aulchenko,[2] T. Aushev,[14] A. M. Bakich,[35] E. Banas,[25] S. Behari,[9] P. K. Behera,[45] D. Beiline,[2] A. Bondar,[2] A. Bozek,[25] T. E. Browder,[8] B. C. K. Casey,[8] P. Chang,[24] Y. Chao,[24] K.-F. Chen,[24] B. G. Cheon,[34] R. Chistov,[14] S.-K. Choi,[7] Y. Choi,[34] L. Y. Dong,[12] J. Dragic,[19] A. Drutskoy,[14] S. Eidelman,[2] V. Eiges,[14] Y. Enari,[20] R. Enomoto,[9] C. W. Everton,[19] F. Fang,[8] H. Fujii,[9] C. Fukunaga,[41] M. Fukushima,[11] N. Gabyshev,[9] A. Garmash,[2,9] T. J. Gershon,[9] A. Gordon,[19] K. Gotow,[46] H. Guler,[8] R. Guo,[22] J. Haba,[9] H. Hamasaki,[9] K. Hanagaki,[31] F. Handa,[38] K. Hara,[29] T. Hara,[29] N. C. Hastings,[19] H. Hayashii,[21] M. Hazumi,[29] E. M. Heenan,[19] Y. Higasino,[20] I. Higuchi,[38] T. Higuchi,[39] T. Hirai,[40] H. Hirano,[42] T. Hojo,[29] T. Hokuue,[20] Y. Hoshi,[37] K. Hoshina,[42] S. R. Hou,[24] W.-S. Hou,[24] S.-C. Hsu,[24] H.-C. Huang,[24] Y. Igarashi,[9] T. Iijima,[9] H. Ikeda,[9] K. Ikeda,[21] K. Inami,[20] A. Ishikawa,[20] H. Ishino,[40] R. Itoh,[9] G. Iwai,[27] H. Iwasaki,[9] Y. Iwasaki,[9] D. J. Jackson,[29] P. Jalocha,[25] H. K. Jang,[33] M. Jones,[8] R. Kagan,[14] H. Kakuno,[40] J. Kaneko,[40] J. H. Kang,[48] J. S. Kang,[16] P. Kapusta,[25] N. Katayama,[9] H. Kawai,[3] H. Kawai,[39] Y. Kawakami,[20] N. Kawamura,[1] T. Kawasaki,[27] H. Kichimi,[9] D. W. Kim,[34] Heejong Kim,[48] H. J. Kim,[48] Hyunwoo Kim,[16] S. K. Kim,[33] T. H. Kim,[48] K. Kinoshita,[5] S. Kobayashi,[32] S. Koishi,[40] H. Konishi,[42] K. Korotushenko,[31] P. Krokovny,[2] R. Kulasiri,[5] S. Kumar,[30] T. Kuniya,[32] E. Kurihara,[3] A. Kuzmin,[2] Y.-J. Kwon,[48] J. S. Lange,[6] G. Leder,[13] M. H. Lee,[9] S. H. Lee,[33] C. Leonidopoulos,[31] Y.-S. Lin,[24] D. Liventsev,[14] R.-S. Lu,[24] J. MacNaughton,[13] D. Marlow,[31] T. Matsubara,[39] S. Matsui,[20] S. Matsumoto,[4] T. Matsumoto,[20] Y. Mikami,[38] K. Misono,[20] K. Miyabayashi,[21] H. Miyake,[29] H. Miyata,[27] L. C. Moffitt,[19] G. R. Moloney,[19] G. F. Moorhead,[19] S. Mori,[44] T. Mori,[4] A. Murakami,[32] T. Nagamine,[38] Y. Nagasaka,[10] Y. Nagashima,[29] T. Nakadaira,[39] T. Nakamura,[40] E. Nakano,[28] M. Nakao,[9] H. Nakazawa,[4] J. W. Nam,[34] Z. Natkaniec,[25] K. Neichi,[37] S. Nishida,[17] O. Nitoh,[42] S. Noguchi,[21] T. Nozaki,[9] S. Ogawa,[36] T. Ohshima,[20] Y. Ohshima,[40] T. Okabe,[20] T. Okazaki,[21] S. Okuno,[15] S. L. Olsen,[8] H. Ozaki,[9] P. Pakhlov,[14] H. Palka,[25] C. S. Park,[33] C. W. Park,[16] H. Park,[18] L. S. Peak,[35] M. Peters,[8] L. E. Piilonen,[46] E. Prebys,[31] J. L. Rodriguez,[8] N. Root,[2] M. Rozanska,[25] K. Rybicki,[25] J. Ryuko,[29] H. Sagawa,[9] Y. Sakai,[9] H. Sakamoto,[17] M. Satapathy,[45] A. Satpathy,[9,5] S. Schrenk,[5] S. Semenov,[14] K. Senyo,[20] Y. Settai,[4] M. E. Sevior,[19] H. Shibuya,[36] B. Shwartz,[2] A. Sidorov,[2] S. Stanič,[44] A. Sugi,[20] A. Sugiyama,[20] K. Sumisawa,[9] T. Sumiyoshi,[9] J.-I. Suzuki,[9] K. Suzuki,[3] S. Suzuki,[47] S. Y. Suzuki,[9] S. K. Swain,[8] H. Tajima,[39] T. Takahashi,[28] F. Takasaki,[9] M. Takita,[29] K. Tamai,[9] N. Tamura,[27] J. Tanaka,[39] M. Tanaka,[9] G. N. Taylor,[19] Y. Teramoto,[28] M. Tomoto,[9] T. Tomura,[39] S. N. Tovey,[19] K. Trabelsi,[8] T. Tsuboyama,[9] T. Tsukamoto,[9] S. Uehara,[9] K. Ueno,[24] Y. Unno,[3] S. Uno,[9] Y. Ushiroda,[9] S. E. Vahsen,[31] K. E. Varvell,[35] C. C. Wang,[24] C. H. Wang,[23] J. G. Wang,[46] M.-Z. Wang,[24] Y. Watanabe,[40] E. Won,[33] B. D. Yabsley,[9] Y. Yamada,[9] M. Yamaga,[38] A. Yamaguchi,[38] H. Yamamoto,[8] T. Yamanaka,[29] Y. Yamashita,[26] M. Yamauchi,[9] S. Yanaka,[40] J. Yashima,[9] M. Yokoyama,[39] K. Yoshida,[20] Y. Yusa,[38] H. Yuta,[1] C. C. Zhang,[12] J. Zhang,[44] H. W. Zhao,[9] Y. Zheng,[8] V. Zhilich,[2] and D. Žontar[44]

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 0031-9007/01/87(9)/091802(7)$15.00

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We present a measurement of the standard model CP violation parameter $\sin 2\phi_1$ based on a 29.1 fb^{-1} data sample collected at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB asymmetric-energy e^+e^- collider. One neutral B meson is fully reconstructed as a $J/\psi K_S$, $\psi(2S)K_S$, $\chi_{c1}K_S$, $\eta_c K_S$, $J/\psi K_L$, or $J/\psi K^{*0}$ decay and the flavor of the accompanying B meson is identified from its decay products. From the asymmetry in the distribution of the time intervals between the two B meson decay points, we determine $\sin 2\phi_1 = 0.99 \pm 0.14(\text{stat}) \pm 0.06(\text{syst})$. We conclude that we have observed CP violation in the neutral B meson system.

DOI: 10.1103/PhysRevLett.87.091802 PACS numbers: 13.25.Hw, 11.30.Er, 12.15.Hh

Kobayashi and Maskawa (KM) proposed, in 1973, a model where CP violation is incorporated as an irreducible complex phase in the weak-interaction quark mixing matrix [1]. The idea, which was presented at a time when only the u, d, and s quarks were known to exist, was remarkable because it required the existence of six quarks. The subsequent discoveries of the c, b, and t quarks, and the compatibility of the model with the CP violation observed in the neutral K meson system led to the incorporation of the KM mechanism into the standard model, even though it had not been conclusively tested experimentally.

In 1981, Sanda, Bigi, and Carter [2] pointed out that the KM model predicted large CP violation in certain decays of B mesons for a range of quark mixing parameters. Subsequent measurements of the B meson lifetime [3] and the discovery of $B^0\overline{B}^0$ mixing [4] indicated that the parameters lie within such a range. Thus, measurements of CP violation in B meson decays provide important tests of the KM model.

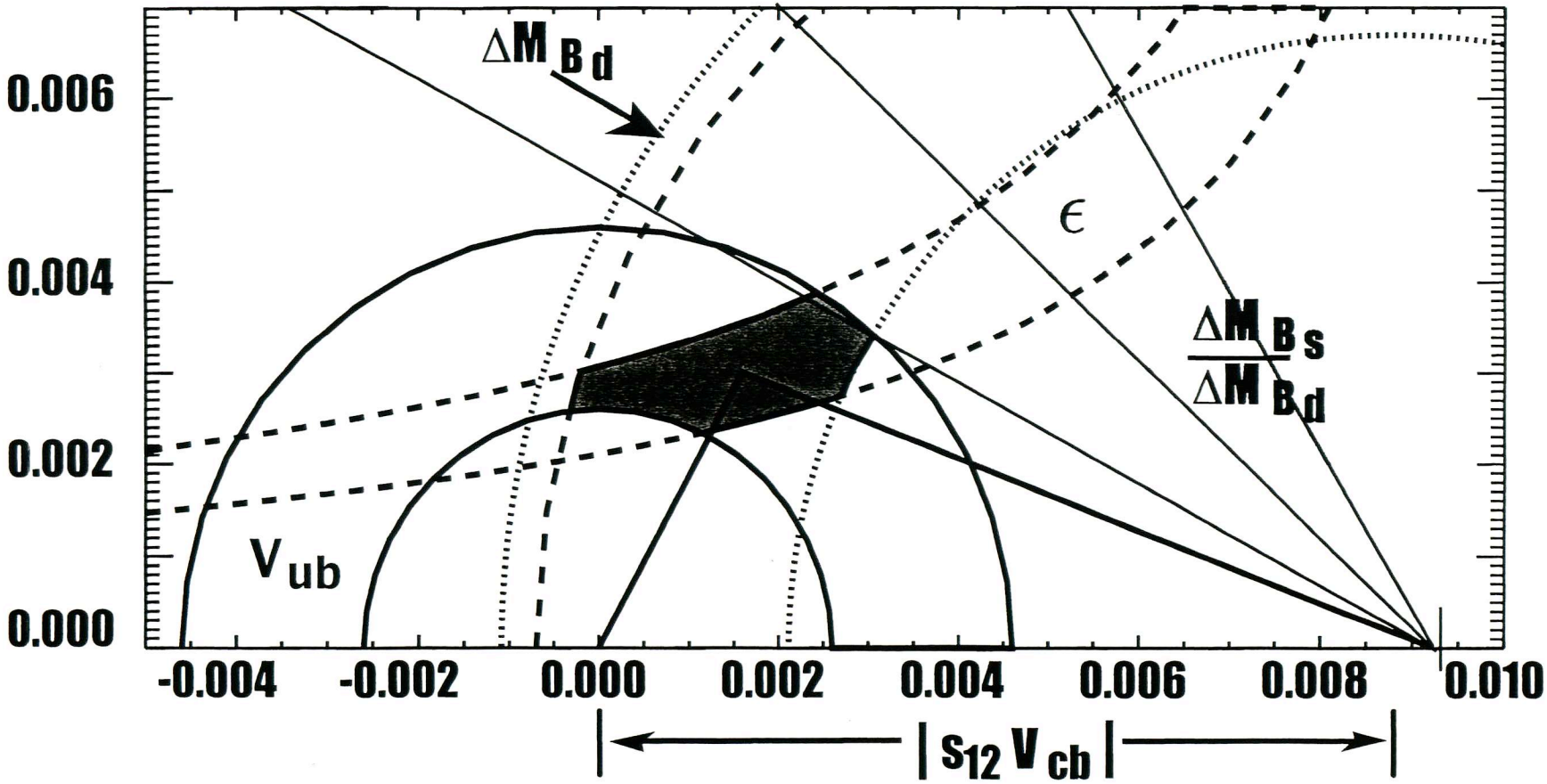
The model predicts a CP violating asymmetry in the time-dependent rates for initial B^0 and $\overline{B}^0$ decays to a common CP eigenstate, f_{CP} [2]. In the case where $f_{CP} = (c\overline{c})K^0$, the asymmetry is given by

$$A(t) \equiv \frac{\Gamma(\overline{B}^0 \to f_{CP}) - \Gamma(B^0 \to f_{CP})}{\Gamma(\overline{B}^0 \to f_{CP}) + \Gamma(B^0 \to f_{CP})} = -\xi_f \sin 2\phi_1 \sin \Delta m_d t ,$$

where $\Gamma[\overline{B}^0(B^0) \to f_{CP}]$ is the decay rate for $\overline{B}^0(B^0)$ to f_{CP} at a proper time t after production, ξ_f is the CP eigenvalue of f_{CP}, Δm_d is the mass difference between the two B^0 mass eigenstates, and ϕ_1 is one of the three internal angles of the unitarity triangle, defined as $\phi_1 \equiv \pi - \arg(\frac{-V_{tb}^* V_{td}}{-V_{cb}^* V_{cd}})$ [5]. For the $(c\overline{c})K^0$ decays, both the ambiguity due to strong interactions and the contribution from direct CP violation are expected to be small [5].

Our previous determination, using a data sample taken in 1999–2000, found $\sin 2\phi_1 = 0.58^{+0.32}_{-0.34}(\text{stat})^{+0.09}_{-0.10}(\text{syst})$

Results of Experiment



Status of Physics Analysis

- Physics analysis covers various topics,
  - CP violation measurements,
  - CKM parameter measurements
  - EW and gluon Penguins
  - B-rare decays
  - Charm physics
  - Tau physics
  - Two photon physics

Status of Physics Analysis *-continued*

- The Belle has already published 19 papers and many will follow.

- The Belle sensitivity reached at the level down to Br(10^{-6}) or smaller.

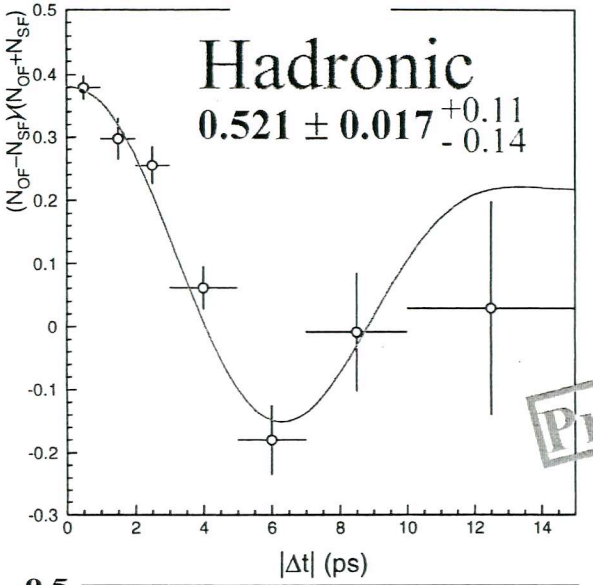
Belle Journal Publications

—— : First Observation

- B Meson lifetimes (τ_{B^0}, $\tau_{B^\pm}$)
- 3-body decays($K^+\pi^+\pi^-$, $K^+K^-K^+$)
- $|V_{cb}|$ by $\overline{B^0} \to D^+ l^- \bar{\nu}$
- $|V_{cb}|$ by $\overline{B^0} \to D^{*+} l^- \bar{\nu}$
- y_{cp} from D^0 lifetime
- $e^+e^- \to J/\psi$ X and $\psi(2S)$ X
- $B^+ \to \chi_{c0} K^+$
- $B \to K l^+ l^-$
- Color suppressed decay,
  $B^0 \to D^0\pi^0$, $D^{*0}\pi^0$, $D^0\eta$ etc.
- $\sin 2\phi_1$, measurement II (>6σ effect), I
- $B \to \eta' K$, $\eta' p$ decay
- Direct CP search in $B^0 \to K\pi$
- $B \to J/\psi\, K_1(1270)$
- $B \to D^{(*)} K^-$ decays
- $B \to \pi\pi$ /$K\pi$ /KK decays
- Inclusive $b \to s\gamma$ decays
- $B^0\,\overline{B^0}$ mixing(Δm) by dilepton

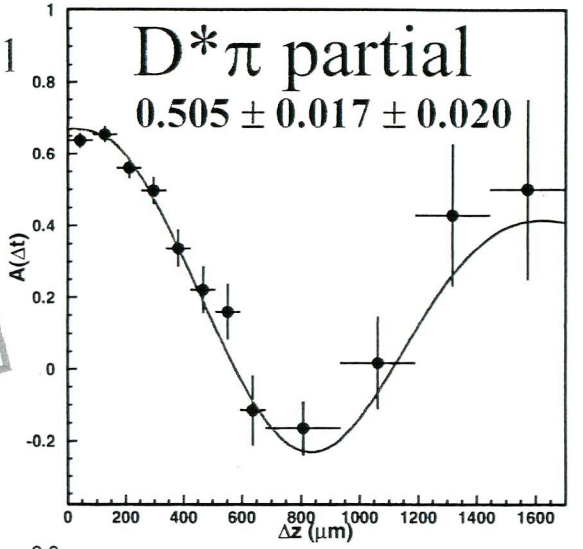
- *Physical Review Letters*
- *Physical Review D*
- *Physics Letters B*

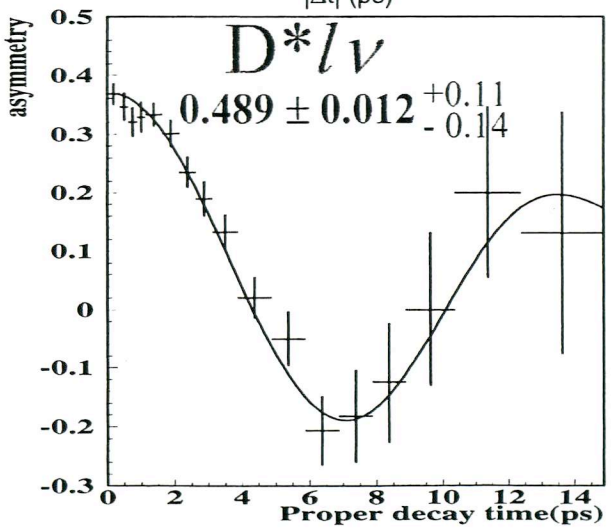
Δm: Asymmetries (4 methods)

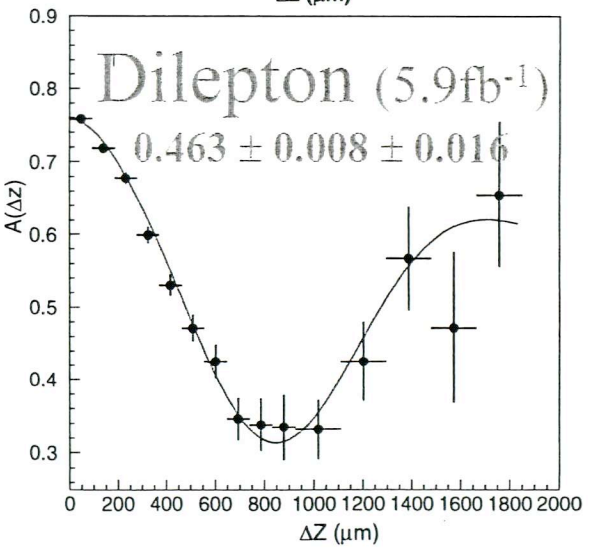


29.1 fb^{-1}

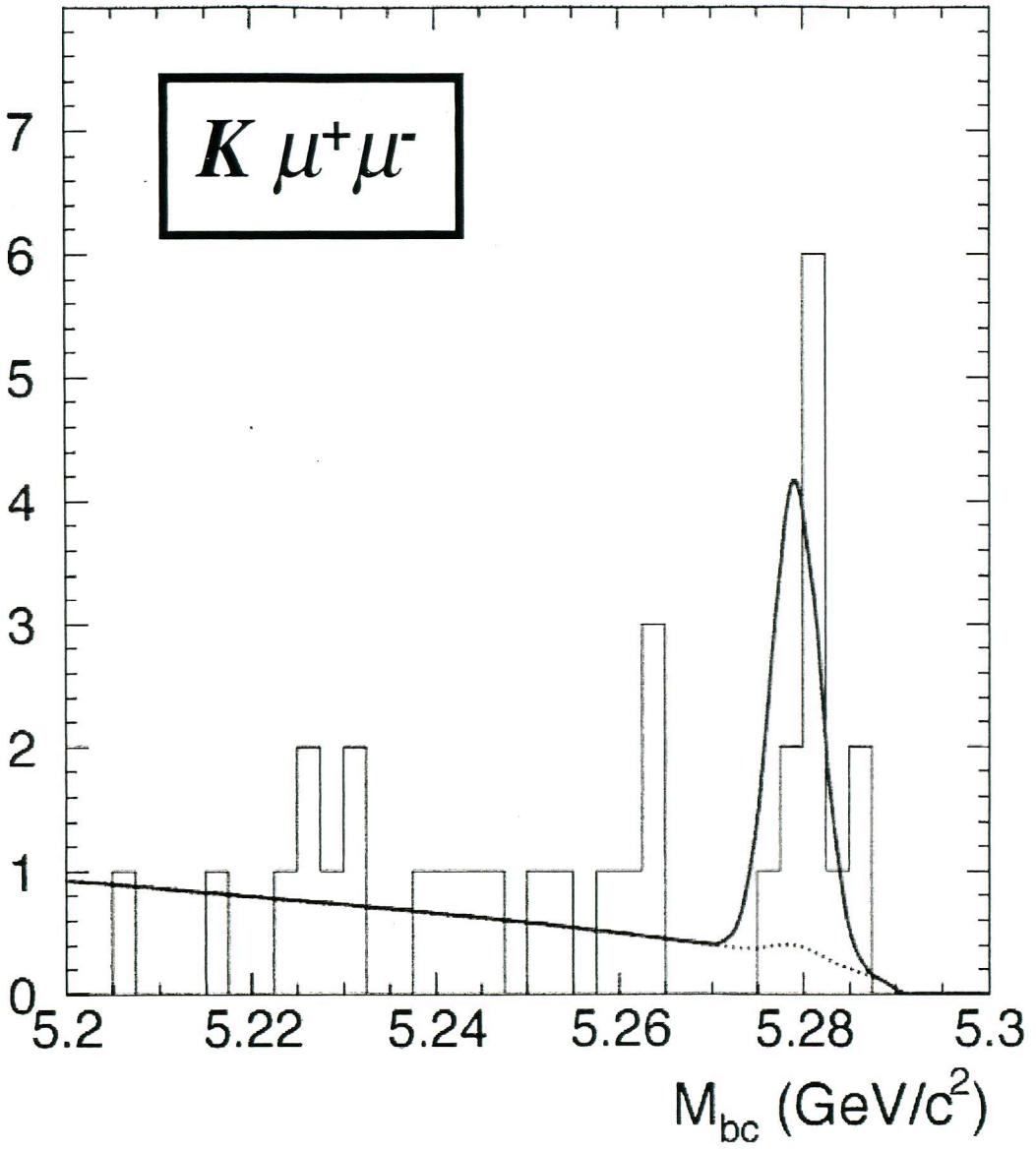
Preliminary







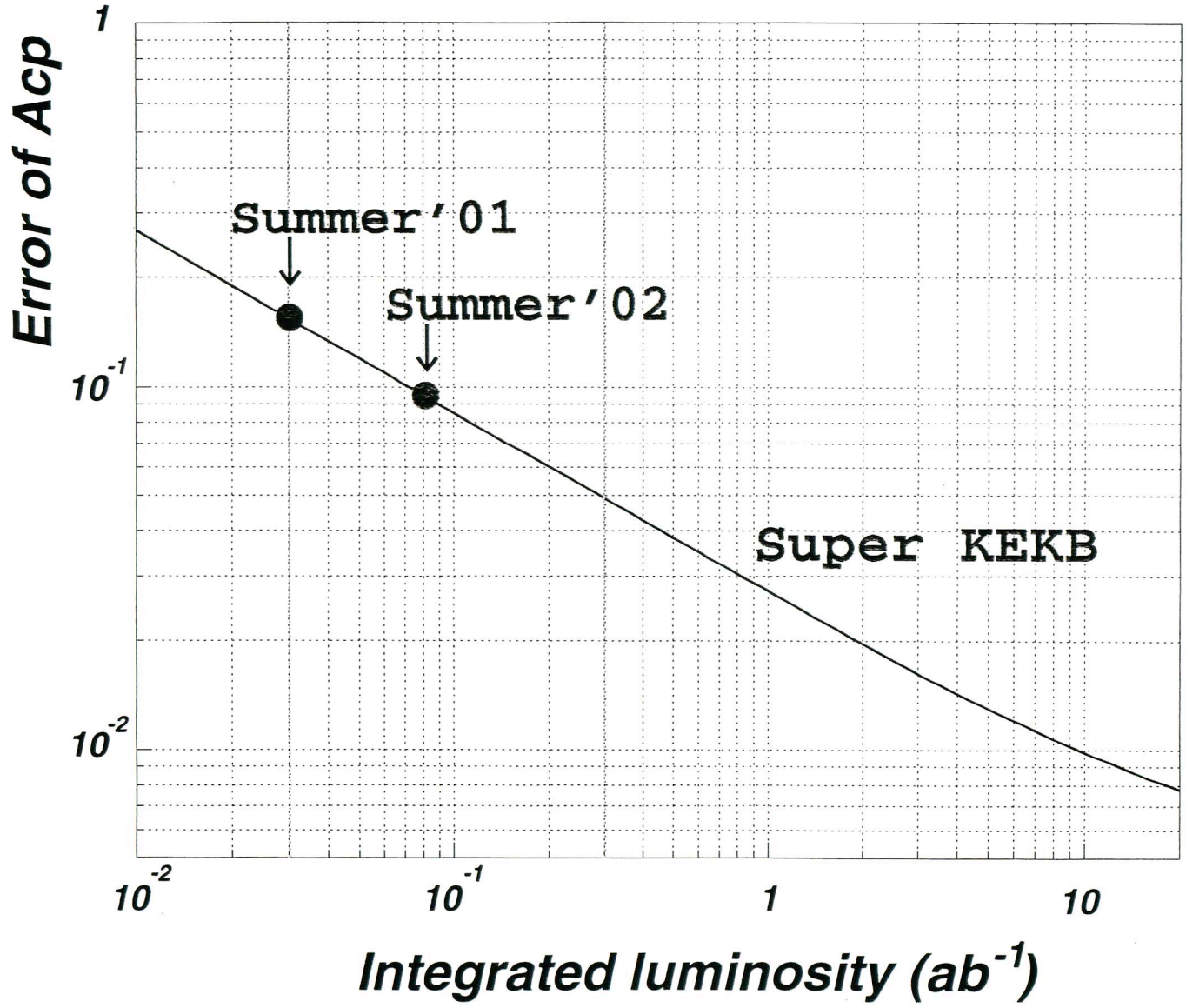
Belle Results, 2001


$K\,\mu^+\mu^-$
7
6
5
4
3
2
1
0
5.2
5.22
5.24
5.26
5.28
5.3
M_{bc} (GeV/c^2)

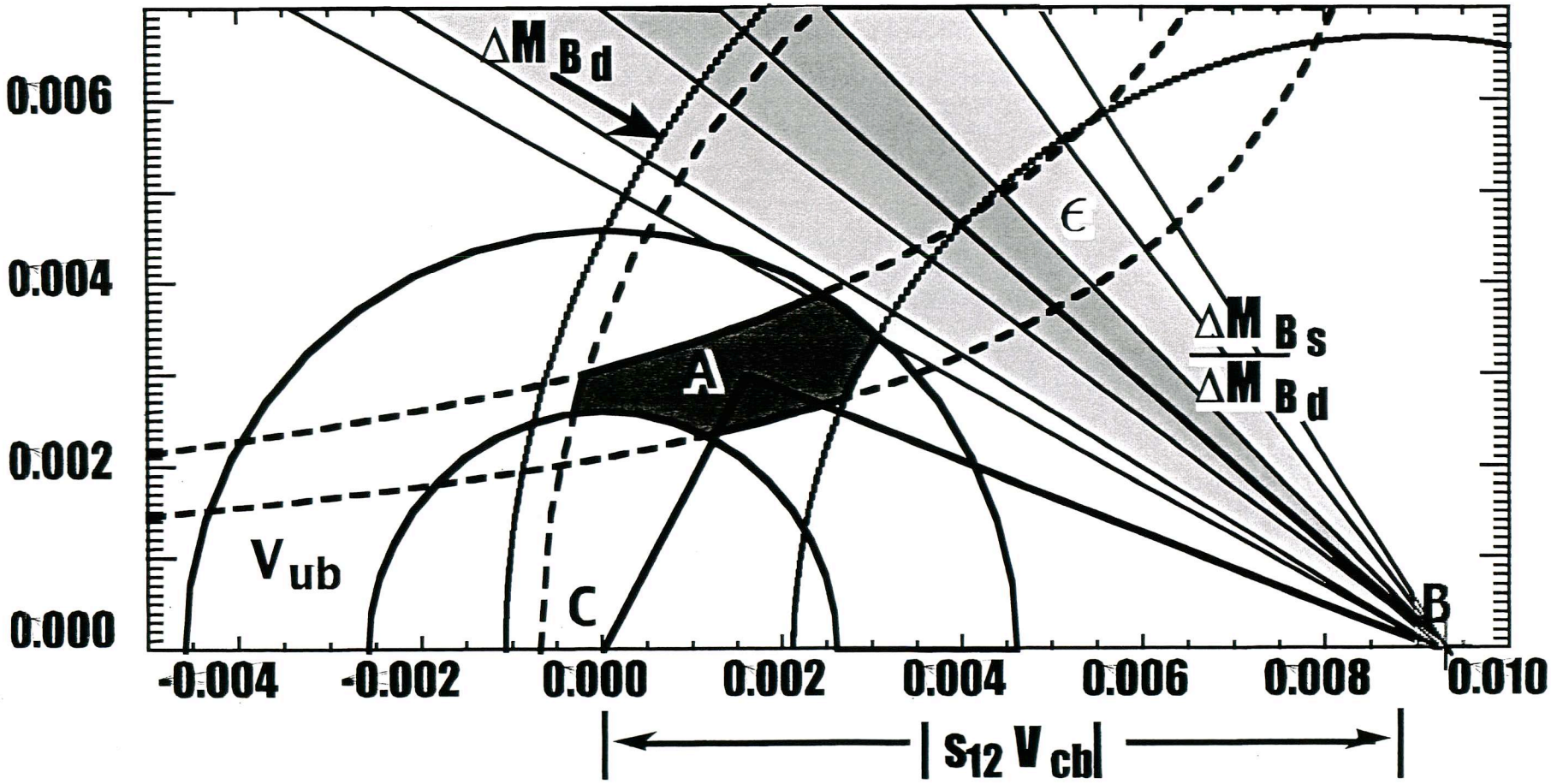
Physics Reach

- The measurement of sin ($2\phi_1$) is rather straightforward. However, extracting other CKM parameters from the data is not easy, because observables are badly polluted by gluons.
- Although we have already more than 50 million events in hand, far much more events are needed to measure CKM parameters and to find possible new effects.

Projected Error of $\sin 2\phi_1$



Projection of ϕ_1 measurement



Detector upgrade

- This is for the better vertex resolution and better tracking efficiency for low energy particles and to live with the higher beam current operation, we replace the inner part of the Belle tracking system. The new system will have 1) smaller beam pipe radius (2cm » 1.5 cm), 2) 4 silicon layers and 3) small cell drift chamber. The system will be ready for installation this summer.

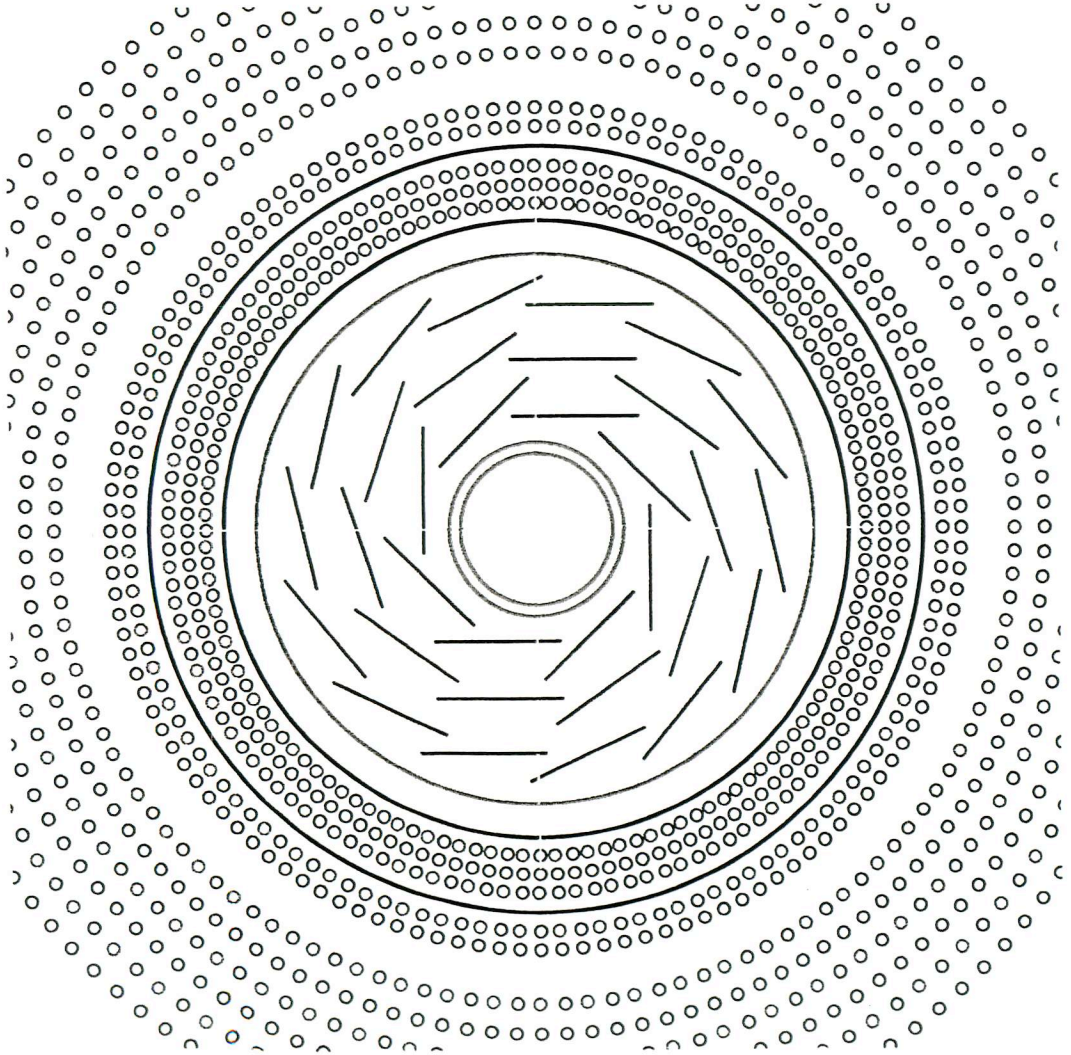
- We also plan to increase CPU power and to develop pipe-line TDC system.

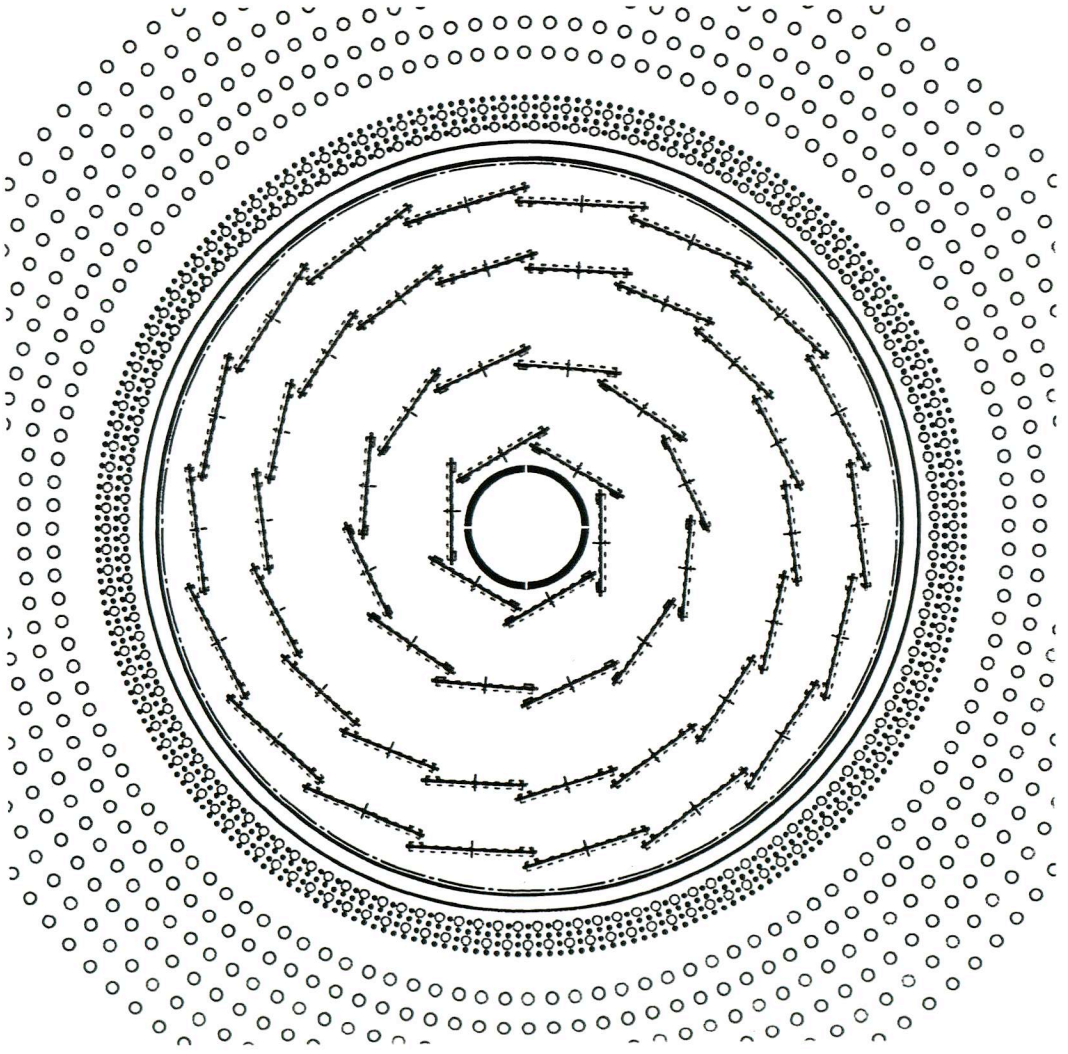
Design modification

Beam pipe : R_{in} = 2.0 cm
SVD1 : R = 3.0, 4.5, 6.0 cm
CDC : 3 layers of Cathode part

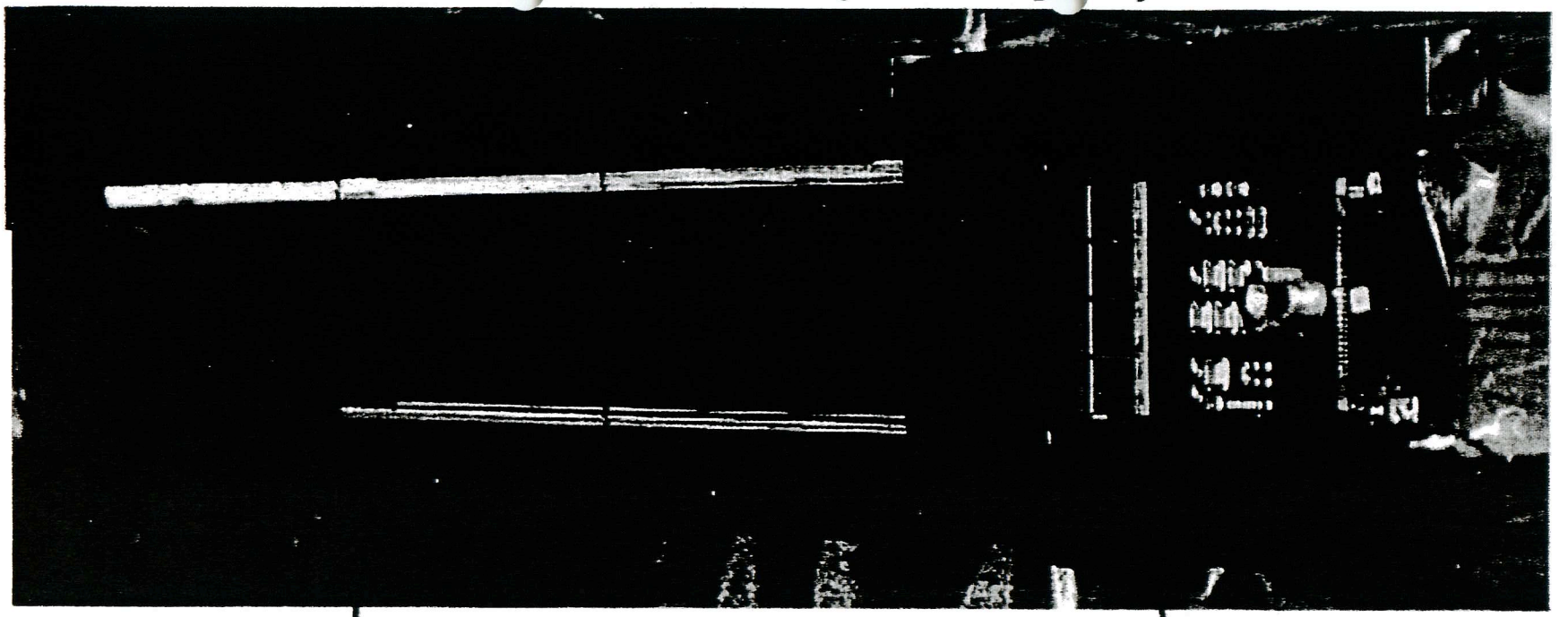
→

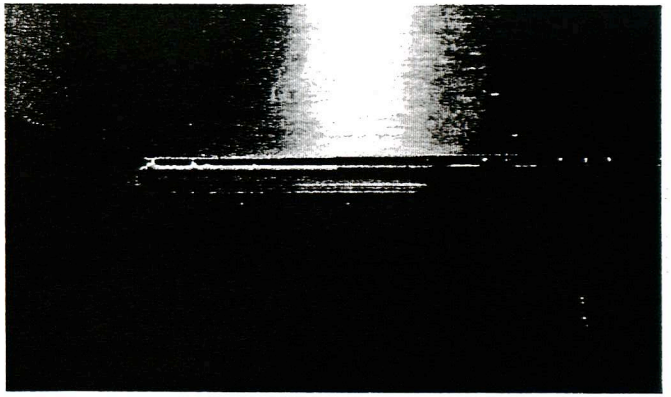
Beam pipe : R_{in} = 1.5 cm
SVD2 : R = 2.0, 4.35, 7.0, 8.8 cm
CDC : 2 layers of small cell chamber



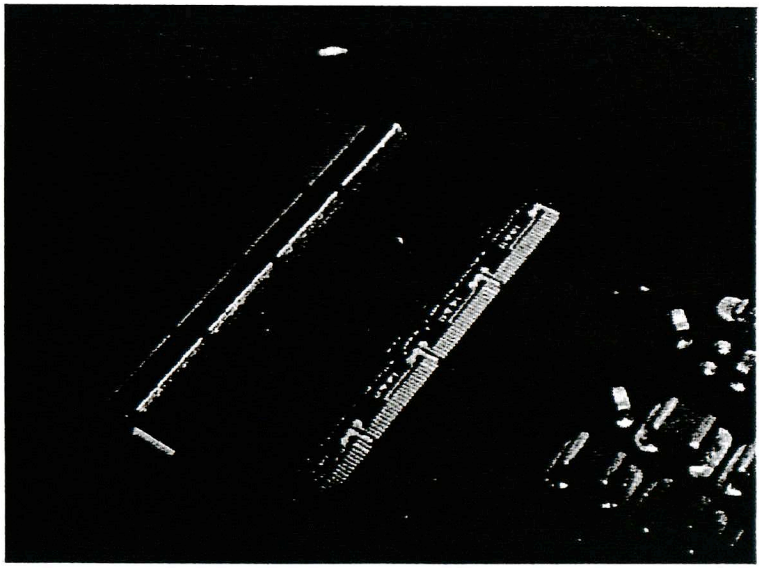


First Half ladder (4th layer)



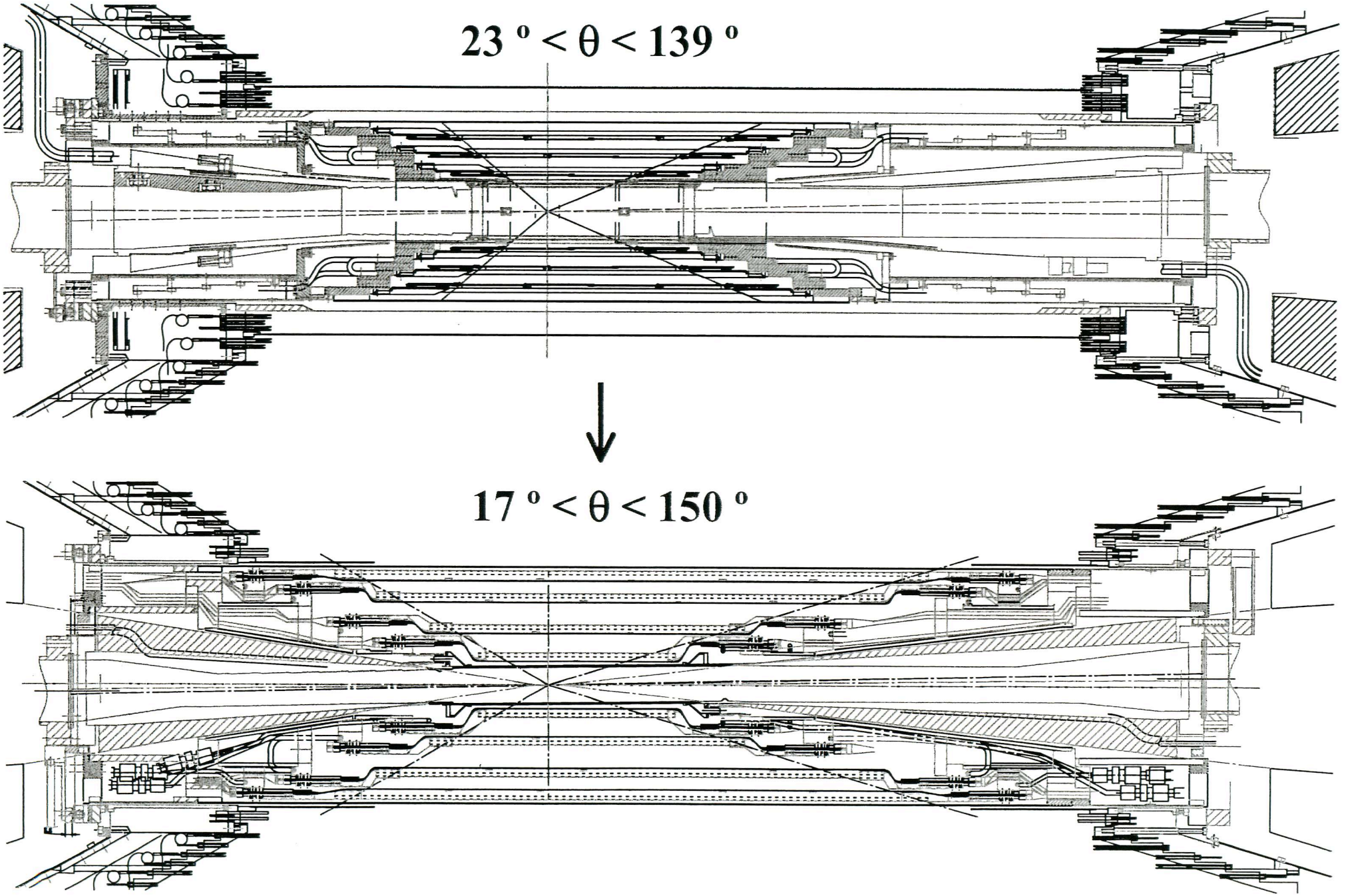


Z-pad closeup

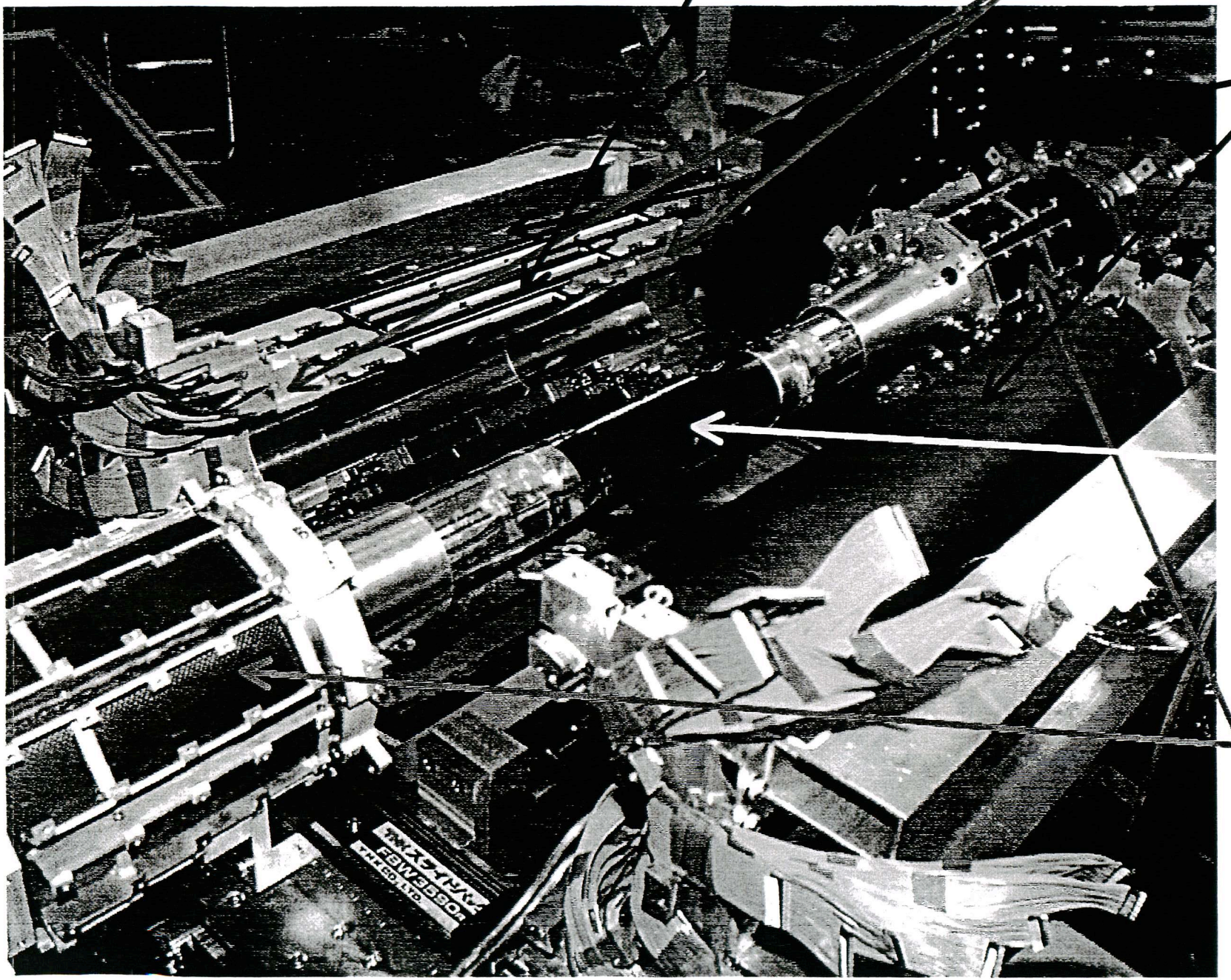


Hvbrid/VA1TA

Acceptance



Structure of SVD1



Summary

- The KEKB/belle made a very good start of the project.

- However, there are many questions to be clarified which can be best studied at the KEKB/Belle. To do so, we need much more events. We would like to ask you to give us good advice for the substantial upgrade of the luminosity.