From ARGUS to B-Meson Factories

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The writeup of my presentation at the ARGUS Fest consists of three parts: my recollections of the history of B-Meson Factories from 1987 to 1993, the discovery of $D^0\overline{D}^0$ mixing in 2007 at the Factories PEP-II and KEKB, and a short view into the Future.

The Past

1986 and 1988 were the years with the highest luminosities in ARGUS, slightly above 20/pb/month. During the year in between, where the DORIS machine physicists [1] were at the maximum of their possibilities, we had zero because of a long shutdown. This break forced us to fully concentrate on analysis. We published 19 papers in 1987, the top three being those on Full B-Meson Reconstruction [2] with now 151 citations, on $B^0\overline{B}^0$ mixing [3] with 1089, and on $B^0 \to D^{*-}\ell^+\nu$ [4] with 172. These results, together with many others from 1980 to 1987 at CESR and DORIS made widely visible that e^+e^- annihilation is the cleanest and most promising way to discover and to study CP violation in B-meson decays [5]. 1987 was the breakthrough year of the B-Meson Factory idea.

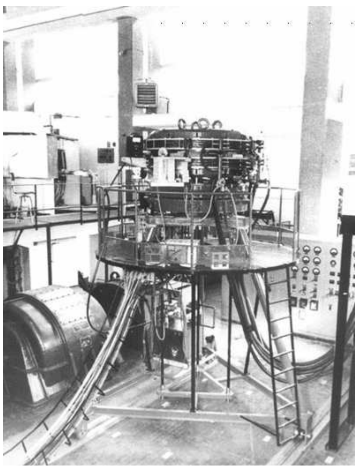

Figure 1: The original e^+e^- storage ring AdA at Frascati.

Storage rings with colliding beams were invented by R. Wideröe around 1942 [6]. After discussions with B. Touschek, he submitted his idea to the German Patentamt in 1943 [7]. The first e^-e^- storage-ring collider was built in 1959 by G. K. O'Neill et al. at Stanford [8], with first experimental results on Moeller scattering in 1965 [9] by W. C. Barber et al. The first e^+e^- collider ring AdA with $2 \cdot 0.25$ GeV was built in 1961 by B. Touschek et al. at Frascati [10]; first collisions were observed mid 1964 at Orsay [11] with a luminosity in the order of $10^{25}/\mathrm{cm}^2/\mathrm{s}$. The original AdA ring, as shown in Fig. 1, is still presented today at Frascati. A list of the e^+e^- rings which have produced important particle physics results and were in operation or planned before 1987 is given in Table 1. All these colliders with the exception of DORIS were single rings with e^+ and e^- in the same vacuum tube. (The double

Table 1: List of e^+e^- storage rings with a selection of their main results.

	location	active	energy	results
ACO, DCI	Orsay	1965-75	$2 \cdot 0.8$ GeV	$\rho,\ \omega,\ \Phi$
VEPP2	Novosibirsk	1965-75	$2 \cdot 0.5$ GeV	multi-π production
ADONE	Frascati	1969-93	$2 \cdot 1.5$ GeV	
SPEAR	SLAC	1972-90	$2 \cdot 4$ GeV	jets, $\psi,\ \psi',\ \mathrm{D},\ \tau$
DORIS	DESY	1973-77	$2 \cdot 3.5$ GeV	
DORIS2	DESY	1978-92	$2 \cdot 5.5$ GeV	$\chi(\mathrm{B}^0),\ V_{\mathrm{ub}}$
VEPP4	Novosibirsk	1975-	$2 \cdot 6$ GeV	$m(\mathrm{c\bar{c}}),\ m(\mathrm{b\bar{b}})$
PETRA	DESY	1978-90	$2 \cdot 17$ GeV	gluon
CESR	Cornell	79-2007	$2 \cdot 6$ GeV	$\Upsilon(4\mathrm{S}),\ \mathrm{B},\ V_{\mathrm{ub}}$
PEP	SLAC	1980-90	$2 \cdot 14$ GeV	$\tau(\mathrm{b})$
TRISTAN	KEK	1987-90	$2 \cdot 32$ GeV	
BEPC	Beijing	1989-	$2 \cdot 2.2$ GeV	$m(\tau)$
LEP	CERN	89-2002	$2 \cdot 90$ GeV	$m(\mathrm{Z}),\ N(\nu),\ m(\mathrm{W})$

ring DORIS operated with a non-zero beam-crossing angle and, therefore, did not reach the planned high luminosity.)

Dreams, I mean my dreams, that Europe urgently needs a Cornell-like laboratory where B mesons and the search for CP violation in their decays have highest priority started in spring 1985. My first public talk on this subject was given 28 November 1985 at Zurich University. In May 1986, B. Stech and I organized a "Heavy Hadron" Symposium with 130 participants at Heidelberg with the main goal of collecting and spreading arguments for a B-Meson Factory. The proceedings [12] include the presentations of E. Lorenz on a realistic detector and of K. Wille on a double-storage-ring design with 5.3 GeV for both e^+ and e^-, 480 m circumference, 24 bunches in each ring, and a luminosity of $L = 5 \cdot 10^{32}/\mathrm{cm}^2/\mathrm{s}$. DORIS2 had 300 m and $\approx 2 \cdot 10^{31}/\mathrm{cm}^2/\mathrm{s}$.

These ideas resulted in a letter of intent [13] with five authors in November 1986 and a proposal [14] with about 50 authors from Switzerland, Germany, France, and Poland in July 1988. The proposal studies were funded by the Swiss national laboratoy PSI at Villigen (the proposed Factory location), BMBF, and IN2P3. An appendix in the proposal expressed the interest of the Crystal Barrel Collaboration for the 2nd interaction region. The machine proposal included a synchrotron injector and an energy-symmetric double ring of 648 m circumference and 20 bunches in each ring, electrostatic beam separation in the interaction regions, and $L = (1-3) \cdot 10^{33}/\mathrm{cm}^2/\mathrm{s}$. The 1988-state-of-the-art detector was designed to consist of a silicon-strip vertex detector, a precision tracking chamber, a main drift chamber, a Cesium-Iodide calorimeter, a 1.5 Tesla superconducting coil, and an iron return yoke with interleaved muon chambers. In July 1986, KEK presented a “Letter of Intent for Upgrading the TRISTAN Accumulation Ring for B Physics” [15], a storage ring idea with $4 \cdot 10^{32}/\mathrm{cm}^2/\mathrm{s}$. In January 1987, D. Cline organized a “Linear-Collider $\mathrm{B\overline{B}}$-Factory Design Workshop” at UC Los Angeles [16] under the motto “We need a $\mathrm{B\overline{B}}$-Factory in the 1990s with $L \geq 10^{34}$; this can only be done with a new type of machine and we will establish a working group”. In addition to the PSI and KEK intentions, the following three studies were presented at the workshop:

- a Linear Collider with 10^{33} on the $\Upsilon(4\mathrm{S})$ by J. Wurtele and A. Sessler,
- a superconducting Linear Collider with 10^{33} on the $\Upsilon(4\mathrm{S})$ and 10^{34} in the $\mathrm{b\overline{b}}$ continuum by U. Amaldi and G. Coignet, and
- NPEP with two energy-symmetric rings in the PEP tunnel at SLAC with 10^{33} by E. Bloom.

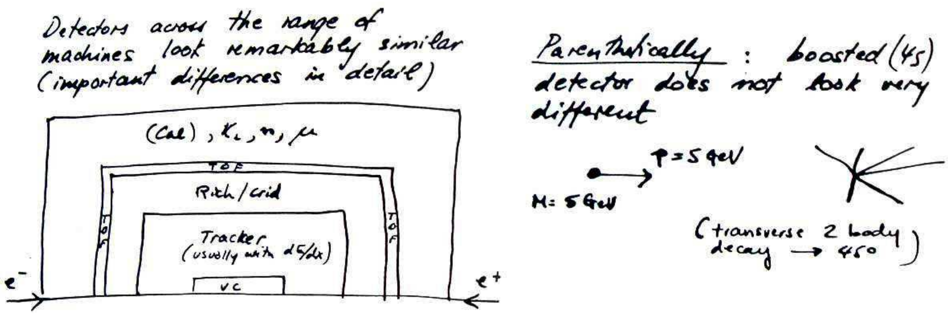

Figure 2: First presentation [17] of the boosted-$\Upsilon(4\mathrm{S})$ idea in 1987.

In the Detector Physics Group summary talk, P. Oddone [17] presented his idea of energy-asymmetric $\mathrm{e^+e^-}$ collisions without elaborating the physics motivation. To my knowledge, and as shown in Fig. 2, this is the first publication of the asymmetry idea.

Strong motivation for energy asymmetry appeared in the 1987 paper of I. Bigi and A. Sanda [18] with now 333 citations. (Parts of the arguments can be found already in the 1981 paper [19] of the same authors.) The time dependence of a CP-violating B decay into a CP eigenstate at time t_2 after the decay $\Upsilon(4\mathrm{S}) \to \mathrm{B^0\overline{B}{}^0}$ and a flavour-specific decay of the other B at time t_1, which is necessary for distinguishing if the CP-eigenstate decay came from a B or a $\overline{\mathrm{B}}$, is a function of only $t_2 - t_1$. Detectors at a storage ring where the $\Upsilon(4\mathrm{S})$ is produced at rest, and where the $\mathrm{e^+e^-}$ interaction region is much longer than the typical B-decay lengths, can only measure $t_2 + t_1$ and, therefore, cannot detect this type of CP violation. With a sufficiently large boost of the $\Upsilon(4\mathrm{S})$ in the detector frame, the distance between the two B-decay vertices measures $t_2 - t_1$ in very good approximation because of the small Q value of the $\Upsilon(4\mathrm{S}) \to \mathrm{B\overline{B}}$ decay. This consequence of the C- and P-conserving strong $\Upsilon(4\mathrm{S})$ decay, of the Einstein-Podolsky-Rosen paradoxon in two-particle-state quantum mechanics, and of the longitudinal intaction-region size of all realistic e^+e^- colliders requires energy-asymmetric $\Upsilon(4S)$ production for observing CP violation in decays like $B^0 \to J/\psi\ K^0$. With this in mind, with the known value of $\mathrm{Re}(\epsilon)$ in CP-violating K^0 decays, and with the 1987 values of $B^0\overline{B}^0$ mixing and $\mathcal{B}(B \to J/\psi\ K)$, it was clear that a few years with $10^{33}/\mathrm{cm}^2/\mathrm{s}$ are needed for answering the question with $5\,\sigma$ significance if the CP asymmetry in $B^0 \to J/\psi\ K^0_S$ decays has a value around 0.7 as predicted by Standard-Model CP violation or a value near zero .

In September 1987, E. Bloom and A. Fridman held a B-Meson Factory workshop at SLAC, where K. Wille presented the (still energy-symmetric) PSI plan, E. Bloom the transition NPEP $\to$ SBF, a double-ring collider for the three options resting and boosted $\Upsilon(4S)$ and B production in the continuum, D. Cline and U. Amaldi linear colliders, and K. Berkelman a CESR-upgrade plan at Cornell. Starting in the summer of 1988, a series of further workshops at Snowmass, SLAC, and Caltech led to the SLAC proposal of an asymmetric B Factory with 9 GeV e^- on 3.1 GeV e^+ with 40 authors, appearing in October 1989 [20]. The machine paper [21] appeared in October 1989 as well. In the meanwhile, the PSI group had also adopted the boosted-$\Upsilon(4S)$ argument, and the calculations of T. Ruf and T. Nakada for the boost optimization led to K. Wille's energy-asymmetric design [22] with 7 on 4 GeV, published in December 1988.

Asymmetry had a big technical advantage. In symmetric double storage rings, the beam separation in the interaction regions had to be done by electrostatic separators with lengths in the order of 10 m. Energy asymmetry works with magnetic-field separation, e. g. with a tilted detector solenoid, which allows smaller bunch distances and, therefore, larger luminosity.

After the PSI proposal in July 1988 (asymmetry in December 1988) and the SLAC proposal in October 1989, the KEKB proposal [23] for a B-Meson Factory with e^- of 8 GeV, e^+ of 3.5 GeV, and $L \geq 10^{34}/\mathrm{cm}^2/\mathrm{s}$ appeared in

Table 2: The seven high-luminosity e^+e^- storage-ring proposals for B-meson production in 1991. C is the circumference, d_B the bunch distance.

Location	Ref.	E in GeV	L in $\mathrm{cm}^{-2}\mathrm{s}^{-1}$	C in m	d_B in m
PSI	[14]	$7.0 + 4.0$	$(1-3) \cdot 10^{33}$	648	32
SLAC	[21]	$9.0 + 3.1$	$3 \cdot 10^{33}$	2200	1.3
KEK	[23]	$8.0 + 3.5$	$1 \cdot 10^{34}$	3020	0.6
CERN	[24]	$8.0 + 3.5$	$1 \cdot 10^{34}$	963	3.0
Novosibirsk	[25]	$6.5 + 4.3$	$5 \cdot 10^{33}$	714	4.2
DESY	[26]	$9.3 + 3.0$	$3 \cdot 10^{33}$	2300	3.6
Cornell	[27]	$8.0 + 3.5$	$3 \cdot 10^{33}$	765	3.3

March 1991. The PSI proposal did not find approval in Switzerland and was moved into CERN's ISR tunnel [24]. In addition to CERN, also Novosibirsk, DESY, and Cornell proposed B-Meson Factories around the same time. In 1991, we had seven completed proposals for asymmetric e^+e^- double storage rings operating on the $\Upsilon(4S)$; Table 2 lists their main parameters. Only two of them were finally approved, PEP-II at SLAC in October 1993 and KEKB at KEK a few months later in 1994. The machines were ready to collide beams in July 1998 (PEP-II) and in March 1999 (KEKB). The first events were recorded by BABAR in May 1999 and by BELLE some days later in June 1999. The unexpected great successes of the two Factories and the two detectors are summarized by J. Olsen in this Symposium.

The Present

B-Meson Factories do not only produce B mesons. From the very beginning of Factory plans, D-meson, τ-lepton, and other questions have been part of the experimental proposals. This chapter of my presentation deals with D mesons. J. Olsen kindly agreed that I discuss here the "Discovery of the Year", $D^0\overline{D}^0$ mixing. Different aspects of it have been observed by BABAR and BELLE in 2007 with sufficiently large significance. The discovery completes a long history in particle physics; all four meson systems which are allowed to mix have now been observed to mix.

The phenomenology is the same for all four systems. Mesons $M = K^0,\ D^0,\ B^0$ (also called B^0_d), and B_s (also called B^0_s) change with time into superpositions $\psi(t) = a(t)\cdot M + b(t)\cdot \overline{M}$, where a and b, owing to the weakness of the weak interaction, obey a linear differential equation

$$\mathrm{i}\,\partial_t \begin{pmatrix} a \\ b \end{pmatrix} = (m_{ij} - \mathrm{i}\,\Gamma_{ij}/2) \begin{pmatrix} a \\ b \end{pmatrix} \qquad (1)$$

with Hermitean matrices m and Γ. The equation has two eigenstate solutions

$$\begin{aligned} M_h(t) &= (pM + q\overline{M}) \cdot \exp[-\mathrm{i}(m + \Delta m/2)t - (\Gamma/2 + \Delta\Gamma/4)t]\ , \\ M_l(t) &= (pM - q\overline{M}) \cdot \exp[-\mathrm{i}(m - \Delta m/2)t - (\Gamma/2 - \Delta\Gamma/4)t]\ , \end{aligned} \qquad (2)$$

the only states which do not change their flavour compostion with time. The subscript h means "heavy", l means "light", and the mass difference $\Delta m = m(M_h) - m(M_l)$ is positive per definition. The eigenstates have two more properties; they differ in their mean life $1/\Gamma$ (S = short-living, L = long-living) and they are approximate CP eigenstates if $|q/p| \approx 1$, i. e. if CP asymmetry in mixing is small (+ = CP-even, − = CP-odd). CP asymmetry in K^0 mixing is known to be on the 10^{-3} level; in the other three systems it is expected to be of similar order or smaller. Any combination of the three properties (h,l), (S,L), (+, −) is possible [28]. Therefore, in addition to

$$\Delta m/\Gamma = x\ , \quad \Delta\Gamma/2\Gamma = y \qquad (3)$$

phenomenology needs a third parameter. The first one, $x > 0$, is positive per definition. Measurements of the sign of y determine the pairing of mean life and mass, $y > 0$ means $\mathrm{S} = h$. The third parameter $\cos\phi$ determines the pairing of CP eigenvalue and mass. In the D^0 system, it is defined by the amplitude ratio

$$\lambda = \frac{A(\mathrm{D}_h^0 \to \mathrm{K}^+\mathrm{K}^-) - A(\mathrm{D}_l^0 \to \mathrm{K}^+\mathrm{K}^-)}{A(\mathrm{D}_h^0 \to \mathrm{K}^+\mathrm{K}^-) + A(\mathrm{D}_l^0 \to \mathrm{K}^+\mathrm{K}^-)} \, , \tag{4}$$

leading to $\cos\phi = +1$ for the pairing $+ = h$ and $\cos\phi = -1$ for $- = h$ if CP is conserved. (The above definition is more general; it allows CP violation in mixing, in decays, and in mixing-decay interference.)

Table 3: Summary of mixing-eigenstete properties.

	Discovery			
K^0	1958	Long	= CP-odd	= heavy
D^0	2007	Long	= CP-odd (4σ)	= light (2σ)
$\mathrm{B_s}$	Δm in 2006	Long	= CP-odd (1.5σ)	= ?
B^0	1987	Long	= ?	= ?

$\mathrm{K}^0\overline{\mathrm{K}}^0$ mixing was discovered in 1958 [29]; today we know well the CP assignments, Δm, and $\Delta\Gamma$. The mixing probability

$$\chi = \frac{x^2 + y^2}{2 + 2\,x^2} \tag{5}$$

has the value $\chi(\mathrm{K}^0) = 0.498$, i. e. 49.8% of all produced K^0 mesons decay from the $\overline{\mathrm{K}}^0$ state. $\mathrm{B}^0\overline{\mathrm{B}}^0$ mixing is celebrated in this Symposium, we know only Δm, and $\chi(\mathrm{B}^0) = 19\%$ of all produced B^0 mesons decay as a $\overline{\mathrm{B}}^0$. $\mathrm{B_s}\overline{\mathrm{B}}_\mathrm{s}$ mixing has been observed since long time, its Δm value was measured in 2006 [30], $|\Delta\Gamma| \neq 0$ has a significance of only 1.5σ, and $\chi(\mathrm{B_s}) = 49.9\%$ of all produced $\mathrm{B_s}$ mesons decay as a $\overline{\mathrm{B}}_\mathrm{s}$.

$\mathrm{D}^0\overline{\mathrm{D}}^0$ mixing has been searched by many groups. In the celebrated year 1987, ARGUS [31] published a search for $\mathrm{D}^{*+} \to \pi^+(\mathrm{D}^0 \to \overline{\mathrm{D}}^0 \to \mathrm{K}^+\pi^-)$ decays and obtained $\chi(\mathrm{D}^0) < 0.014$ (90% CL), one of the best limits at that time. From the results of BABAR and BELLE we have now obtained $\chi(\mathrm{D}^0) \approx 1 \cdot 10^{-4}$ with 5σ from zero. Table 3 summarizes the relations between the three eigenstate properties in the sequence of decreasing knowledge level. Our bithday child is the rear-end light in the Table. The three major indications for $\mathrm{D}^0\overline{\mathrm{D}}^0$ mixing are presented in the following where all formulae are ony valid in the limit of no CP violation:

1.) BELLE [32] has studied the lifetime distributions of 1.2 M $\mathrm{D}^0 \to \mathrm{K}^-\pi^+$, 110 k $\mathrm{D}^0 \to \mathrm{K}^-\mathrm{K}^+$, and 50 k $\mathrm{D}^0 \to \pi^-\pi^+$ decays and found a difference as shown in Fig. 3. A fit to the data points gives the ratio

$$\tau(\mathrm{D}^0 \to \mathrm{K}^-\pi^+)/\tau(\mathrm{D}^0 \to \mathrm{K}^-\mathrm{K}^+) = y \cdot \cos\phi = (1.31 \pm 0.32 \pm 0.25)\, 10^{-2} \quad (6)$$

which is $3.2\,\sigma$ from zero. BABAR has presented a preliminary result for the lifetime difference [33] and finds $y \cdot \cos\phi = (1.24 \pm 0.39 \pm 0.13)\, 10^{-2}$ by combining $\mathrm{K}^+\mathrm{K}^-$ and $\pi^+\pi^-$ dacays. My average of the two results is $y \cdot \cos\phi = (1.28 \pm 0.29)\, 10^{-2}$ which is different from zero with $4.4\,\sigma$. The sign of the measurement fixes the pairing S = +.

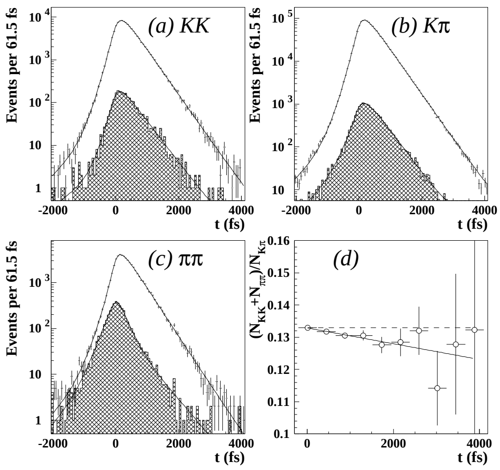

Figure 3: BELLE results [32] for the time dependence of $\mathrm{D}^0 \to \mathrm{KK}$, $\mathrm{K}\pi$, $\pi\pi$. Part (d) shows the ratio $(\mathrm{KK}+\pi\pi)/\mathrm{K}\pi$.

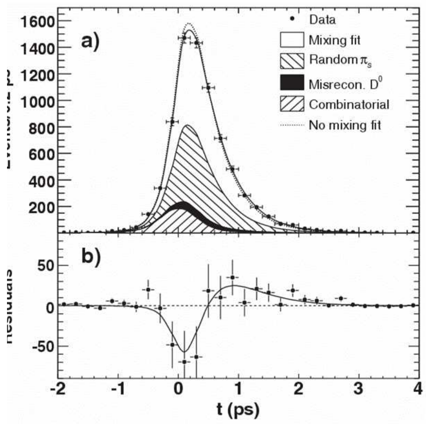

Figure 4: BABAR results [34] for (a) the time dependence of $\mathrm{D}^0 \to \mathrm{K}^+\pi^-$ decays. In part (b), the points show the differences between data and the no-mixing fit, the line shows the difference between the best fit and the no-mixing fit.

2.) BABAR has reported direct evidence [34] for the transition $\mathrm{D}^0 \to \overline{\mathrm{D}}{}^0$ by observing $\mathrm{D}^{*+} \to \pi^+\mathrm{D}^0$ decays with time-dependent sequential decays $\mathrm{D}^0 \to a(t)\mathrm{D}^0 + b(t)\overline{\mathrm{D}}{}^0 \to \mathrm{K}^+\pi^-$. The observed time dependence is shown in Fig. 4(a). It is described by the expression

$$N_{+-}(t) = N_{-+}(0)\cdot \mathrm{e}^{-\Gamma t}\cdot \left[R_D + \sqrt{R_D}\, y' \cos\phi\, \Gamma t + (x'^2 + y'^2)(\Gamma t)^2/4\right]\ , \quad (7)$$

where N_{+-} and N_{-+} are the numbers of $\mathrm{K}^+\pi^-$ and $\mathrm{K}^-\pi^+$ decays.

$$R_D = \Gamma(\mathrm{D}^0 \to \mathrm{K}^+\pi^-)/\Gamma(\mathrm{D}^0 \to \mathrm{K}^-\pi^+) \quad (8)$$

is the Double-Cabibbo-suppressed decay ratio, and x', y' are related [35] to x, y through

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\delta & \sin\delta \\ -\sin\delta & \cos\delta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \quad (9)$$

with the difference δ of final-state-interaction phase shifts between $D^0 \to K^+\pi^-$ and $D^0 \to K^-\pi^+$.

The two fits with free parameters x', $y'\cos\phi$ and with no mixing ($x' = y' = 0$) differ by $3.9\,\sigma$ as shown in Fig. 4(b). The best-fit parameters are

$$R_D = (3.03 \pm 0.16 \pm 0.10)\,10^{-3}\ ,$$
$$x'^2 = (-0.22 \pm 0.30 \pm 0.21)\,10^{-3}\ ,\quad y'\cos\phi = (9.7 \pm 4.4 \pm 3.1)\,10^{-3}\ . \tag{10}$$

Fig. 5 shows the pertinent likelihood contours. BELLE [36] had an earlier evidence for mixing of this type, but with a significance of only $2.0\,\sigma$.

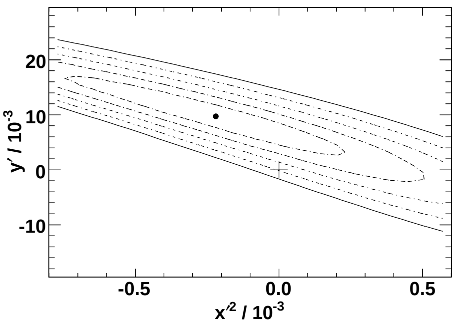

Figure 5: Fit results for $y'\cos\phi$ and x'^2 from the BABAR observation [34] of $D^0 \to K^+\pi^-$ decays. The dot shows the best fit, the five contours represent one to five standard deviations, and the cross shows the no-mixing point.

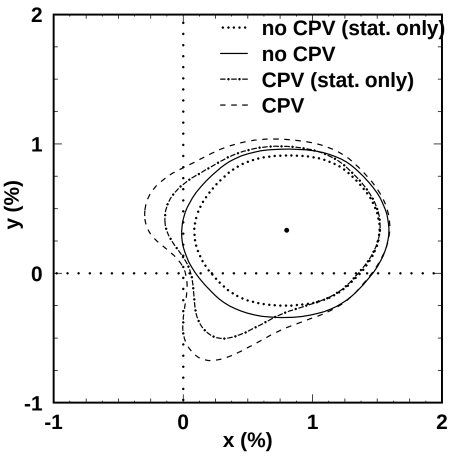

Figure 6: Fit results for x and y from the Dalitz analysis of BELLE [37] in D decays to $K^0_S\pi^+\pi^-$ The four contours correspond to two standard deviations.

3.) A time-dependent Dalitz-plot analysis of the three-body decays $a(t)D^0 + b(t)\overline{D}^0 \to K^0_S\,\pi^+\,\pi^-$ by BELLE [37] in 2007 led to the third evidence for mixing. The analysis is sensitive to x and y if a model for the Dalitz-plot population is used. With their expertise for such a population model, as used for determining the angle γ of the CKM-matrix unitarity triangle [38], BELLE finds

$$x = \left(0.80 \pm 0.29 \begin{matrix}+0.13\\-0.16\end{matrix}\right)10^{-2}\ ,\quad y = \left(0.33 \pm 0.24 \begin{matrix}+0.10\\-0.14\end{matrix}\right)10^{-2} \tag{11}$$

with the $2\,\sigma$ likelihood contours in Fig. 6. The central point is $2\,\sigma$ away from the no-mixing point $x = y = 0$, but there may be an additional systematic uncertainty from the Dalitz-plot model.

A final HFAG fit [39] to all observations in Summer 2007, including also less significant results on $x^2 + y^2$ leads to the likelihood contours for x

and y in Fig. 7. They are very close to ellipses for one and two standard deviations. The pronounded non-Gaussian shapes for 4 and $5\,\sigma$ have their origin in the non-linear transformation of (y', x'^2) from the $D^0 \to \overline{D}^0 \to K^+\pi^-$ measurement to (x, y). The central point of the fit is

$$x = (8.8 \pm 3.3)\,10^{-3}\ ,\quad y = (6.8 \pm 2.1)\,10^{-3}\ ,\quad \chi(D^0) = (0.7 \pm 0.3)\,10^{-4}\ . \quad (12)$$

The fit result for the mixing probability $\chi(D^0)$ is different from zero with a significance of five standard deviations. The fit result for x and y without the restriction of CP conservation in mixing looks nearly identical.

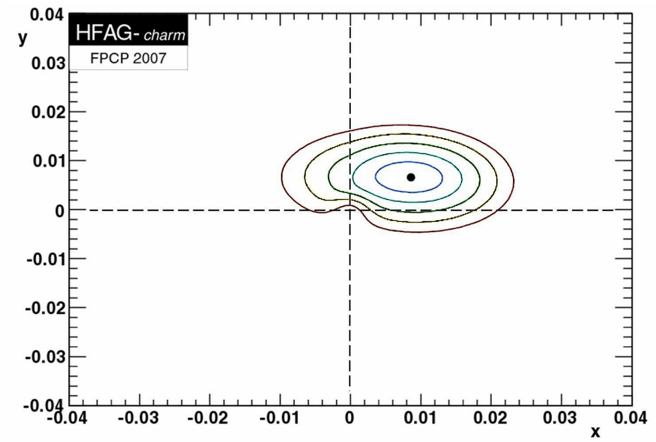

Figure 7: Combined fit to all $D^0\overline{D}^0$ mixing results with contours corresponding to 1 to 5 standard deviations [39]. The dashed lines correspond to $x = y = 0$.

One final comment on $\cos\phi$: There is strong evidence for $\Delta\Gamma\cos\phi > 0$, weak evidence for $\Delta\Gamma > 0$, and consequently for $\cos\phi = +1$. Until we have stronger evidence, the parameter $\cos\phi$ should be kept in the mixing phenomenology. We can completely forget it when the signs of both $\Delta\Gamma$ and $\Delta\Gamma\cos\phi$ will be well measured.

The Future

BABAR will finish data taking in September 2008[1], BELLE around half a year later. There are at present two major activities for a continuation of the B-Meson-Factory successes.

The present KEK roadmap [40] foresees a three-year KEKB shutdown after the end of BELLE's present data taking in the spring of 2009. During this shutdown, KEKB shall be upgraded to a luminosity of some $10^{35}/\mathrm{cm}^2/\mathrm{s}$

[1] when writing these lines, there is already sad evidence for an earlier end in March.

and BELLE shall be replaced by an upgraded detector, to be built by a new international Collaboration.

The SuperB initiative [41] was started around 2002 by BABAR phsicists, mainly from the US, Italy, France, and UK. At the end of 2005, INFN in Italy promoted the formation of an international study group on a Conceptual Design Report (CDR) for an e^+e^- double storage ring, a "Super Flavour Factory" containing

- the physics case in the era of LHC,
- a machine and detector design able to integrate $(15-65)$/ab/year on the $\Upsilon(4S)$,
- the possibility of running at $\sqrt{s} = 4$ GeV with a peak luminosity of $10^{35}/\mathrm{cm}^2/\mathrm{s}$, and
- at least one polarized beam for τ-lepton physics.

The CDR was published in April 2007 [42] by 320 authors (experimenalists, theorists, and accelerator physicists) from 85 institutions in 15 countries, including 65 non-BABAR experimentalists. The luminosity goal is $1\cdot10^{36}/\mathrm{cm}^2/\mathrm{s}$ [with an option for doubling this goal]. The main luminosity gain comes from the bunch size in the interaction region with $\sigma_y^* = 35\,\mathrm{nm}$, $\sigma_x^* = 5\,\mu\mathrm{m}$, $\sigma_z^* = 6\,\mathrm{mm}$ and from a crab-crossing-like beam-crossing scheme called "crab-waist". The main other machine parameters are 2000 m circumference, $E(\mathrm{e}^-) = 7$ GeV, $E(\mathrm{e}^+) = 4$ GeV, 30 mrad beam-crossing angle, 1.3 m [0.65 m] bunch distance, $I(\mathrm{e}^-) = 1.3$ A [2.2 A], $I(\mathrm{e}^+) = 2.3$ A [4.0 A], and $P = 17$ MW [35 MW], where the values in brackets are for the double-luminosity option. The smaller boost than in PEP-II requires better vertex resolution. This shall be achieved with an interaction-region beam tube radius of 1 cm and a pixel Silicon vertex detector with the first layer having the diameter of a one-Euro coin. The detector could be based on BABAR but needs new components for at least the calorimeter endcap, the vertex detector, the drift chamber, the DIRC readout and in the areas of trigger, data acquisition, and computing.

An International Review Committee has been appointed by INFN earlier this year. The members are: J. Dainton (Daresbury, chair), J. Lefrançois (Orsay), A. Masiero (Padova), R. Heuer (DESY), D. Schulte (CERN), A. Seiden (UC Santa Cruz), Y.-K. Kim (FNAL), and H. Aihara (Tokyo). The review is scheduled for November 2007 in Frascati. The report of the Committee is expected in spring 2008, after results from the DAΦNE test of the "crab-waist" scheme. Later in 2008, a presentation to the CERN strategy group is foreseen.

A possible site for the international SuperB project is on the campus of the Tor Vergata University south-east of Rome in 3 km distance from the LNF laboratory at Frascati, the place where the first e^+e^- storage ring had been built by B. Touschek and his collaborators.

References

[1] I gratefully remember the collaboration with H. Nesemann and K. Wille.

[2] H. Albrecht et al. (ARGUS), Phys. Lett. B 185, 218 (1987)

[3] H. Albrecht et al. (ARGUS), Phys. Lett. B 192, 245 (1987)

[4] H. Albrecht et al. (ARGUS), Phys. Lett. B 197, 452 (1987)

[5] I learnt the exciting CP-violation prospects after the Υ discovery 1977 from M. K. Gaillard.

[6] R. Wideröe's autobiographic notes, in "The Infancy of Particle Accelerators", ed. by P. Waloschek, DESY report 94-039 (1994)

[7] R. Wideröe, Deutsches Patentamt, Patentschrift Nr. 876279, submitted September 1943, published 1953

[8] W. C. Barber, B. Gittelman, G. K. O'Neill, W. K. H. Panofsky, and B. Richter, Stanford University Report HEPL 170 (June 1959)

[9] W. C. Barber, B. Gittelman, G. K. O'Neill, and B. Richter, Phys. Rev. Lett. 16, 1127 (1966)

[10] C. Bernardini, G. F. Corazza, G. Ghigo, and B. Touschek, Nuovo Cimento 18, 1293 (1960)

[11] C. Bernardini, G. F. Corazza, G. Di Giugno, J. Haïssinski, P. Marin, R. Querzoli, and B. Touschek, Nuovo Cimento 34, 1473 (1964)

[12] Proc. Int. Symp. on Production and Decay of Heavy Hadrons, Heidelberg 1987, ed. by K. R. Schubert and R. Waldi

[13] R. Eichler, T. Nakada, K. R. Schubert, S. Weseler, and K. Wille, SIN report PR-86-13 (1986)

[14] Paul Scherrer Institute (formerly SIN), PSI Report PR-88-09 (1988)

[15] H. Aihara et al., KEK internal, July 1986, presented in ref. [16]

[16] Proc. Linear Collider $\mathrm{B\overline{B}}$ Factory Conceptual Design Workshop, UC Los Angeles 1987, ed. by D. Stork

[17] P. Oddone, in ref. [16]

[18] I. I. Bigi and A. I. Sanda, Nucl. Phys. B 281, 41 (1987)

[19] I. I. Bigi and A. I. Sanda, Nucl. Phys. B 193, 85 (1981)

[20] A. Eisner et al., SLAC-353 (1989), ed. by D. Hitlin

[21] D. Hitlin et al., SLAC-352 (1989)

[22] R. Eichler et al., PSI Report PR-88-22 (1988)

[23] S. Kurokawa et al., KEK Report 90-24 (March 1991).

[24] G. Coignet et al., CERN 90-02 (March 1990), ed. by T. Nakada

[25] A. N. Dubrovin et al. (Budker Inst. Novosibirsk), submitted paper to the EPAC Accelerator Conf., Rome, 1988

[26] H. Nesemann et al., DESY Report 89-080 (1989)

[27] J. Alexander et al., Cornell Report CLNS 89/962 (1989)

[28] I acknowledge discussions with Z. Ligeti on this subject.

[29] M. Baldo-Ceolin et al., Nuovo Cimento 6, 130 (1957)
E. Boldt, D. O. Caldwell, and Y. Pal, Phys. Rev. Lett. 1, 150 (1958)
F. S. Crawford et al., Phys. Rev. 113, 1601 (1959)

[30] A. Abulencia et al. (CDF), Phys. Rev. Lett. 97, 242003 (2006)

[31] H. Albrecht et al. (ARGUS), Phys. Lett. B 199, 447 (1987)

[32] M. Starič et al. (BELLE), Phys. Rev. Lett. 98, 211803 (2007)

[33] W. Lockman (BABAR), presented at the Lepton-Photon Conference, Daegu, 2007

[34] B. Aubert et al. (BABAR), Phys. Rev. Lett. 98, 211802 (2007)

[35] K. R. Schubert, Progress in Particle and Nuclear Physics 21, 3 (1988)

[36] L. M. Zhang et al. (BELLE), Phys. Rev. Lett. 96, 151801 (2006)

[37] L. M. Zhang et al. (BELLE), Phys. Rev. Lett. 99, 131803 (2007)

[38] A. Poluektov et al. (BELLE), Phys. Rev. D 73, 112009 (2006)

[39] Heavy Flavour Averaging Group, FPCP07 part of http://www.slac.stanford.edu/xorg/hfag/charm, 2007

[40] M. Yamauchi and K. Oide, private communication

[41] I thank M. Giorgi and F. Forti for their up-to-date informations on SuperB.

[42] Report INFN/AE-07/02, SLAC-R-856, LAL 07-15, arXiv.org/abs/0709.0451