Future Plans for B Physics

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1. Hadronic facilities (LHCb, BTeV)
2. Super B factories (Babar/Belle)
3. Linear Collider Giga-Z option.

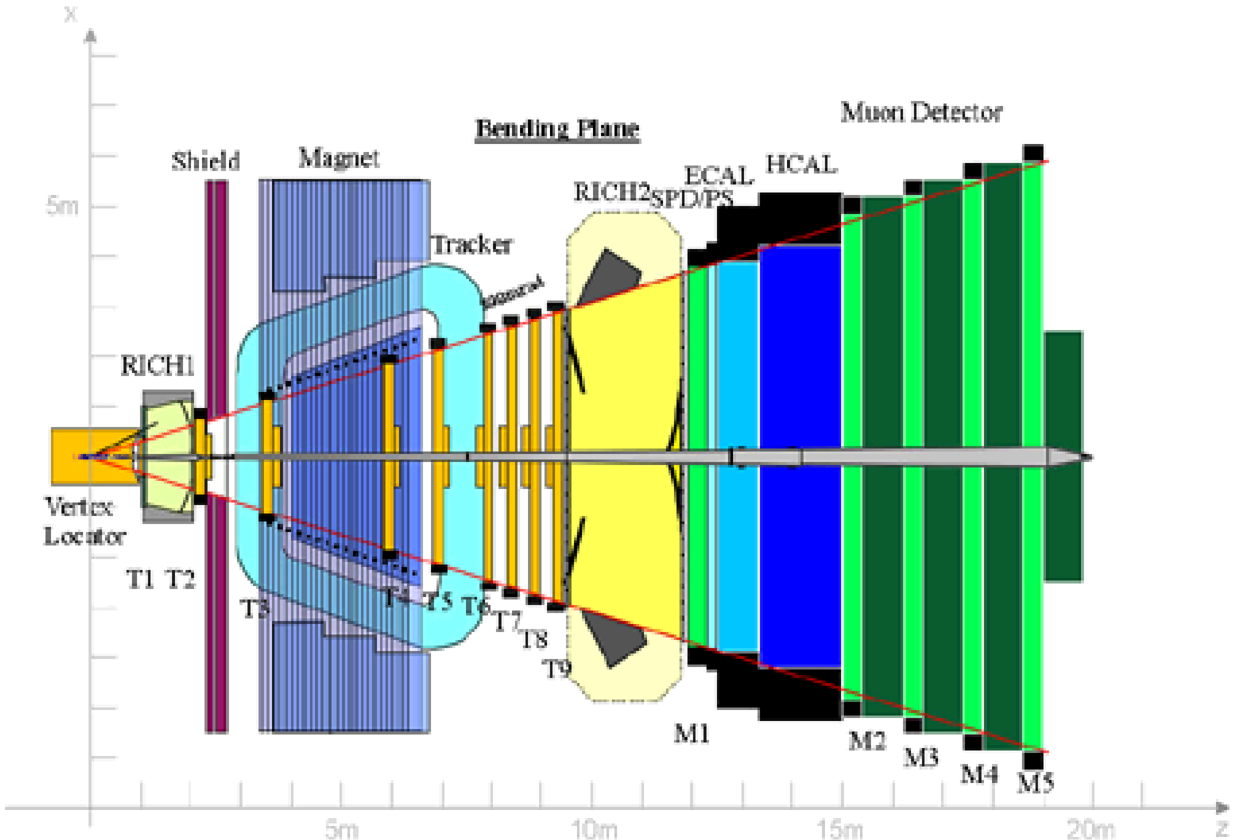
1. Future Hadronic B Facilities

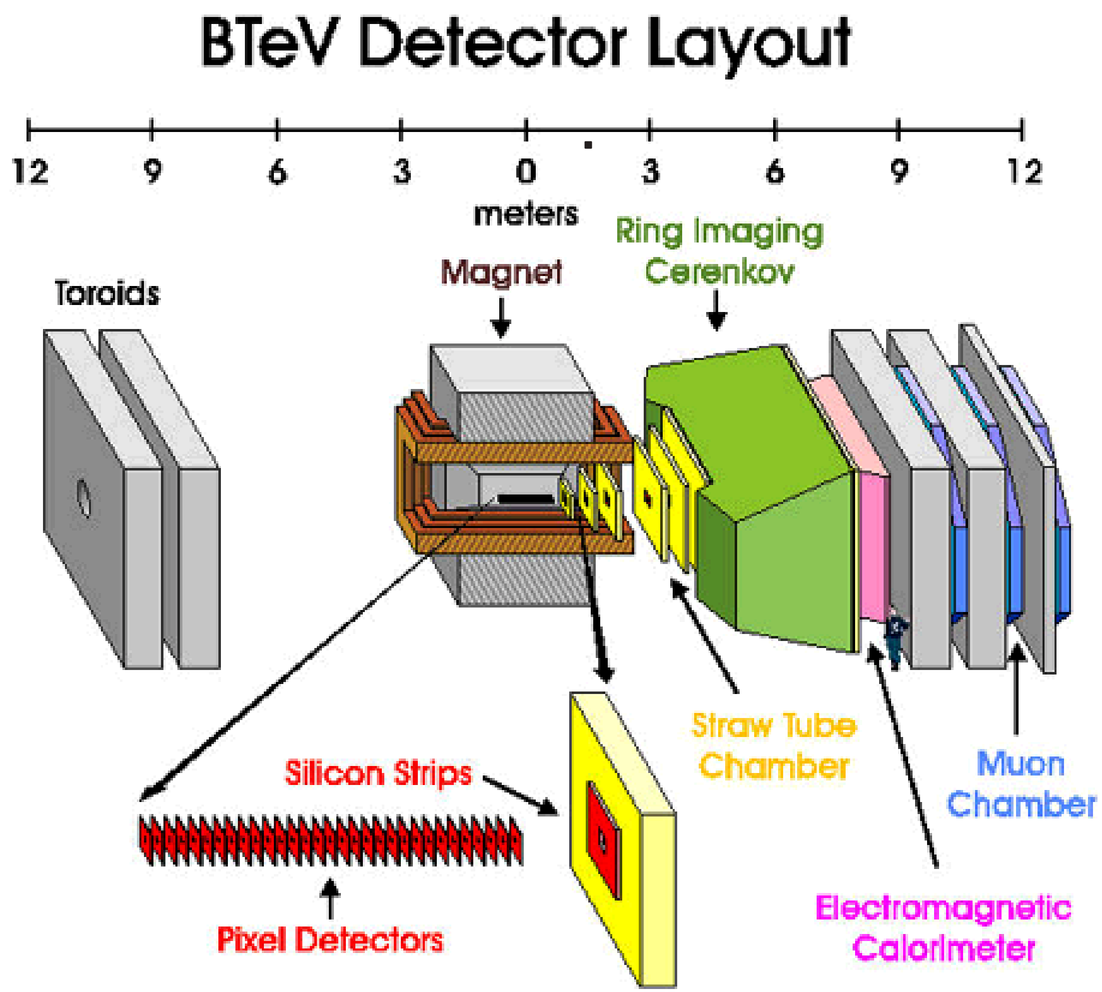
machine	Tevatron	LHC	Super B
detector	*BTeV*	*LHCb* (*ATLAS/CMS*)	(ref.)
$E_{\rm cm}$	2 TeV	14 TeV	10.58 GeV
#bb/yr	2×10^{11}	10^{12}	$10^9 - 10^{10}$
b frac.	0.001	0.005	0.25
$t_{\rm bunch}$	132 ns	25 ns	∼2 ns
#int./xing	2	0.4	–

They all start around 2007-2010.

LHCb Detector

Single-arm forward detector placed at an Interaction point of a hadron collider (LHC).





Vertexing-tracking-Cerenkov-calorimeter-muon
(similar to LHCb)

	BTeV	LHCb
vertexing	Si pixel	Si strips
spectrometer	10-300 mrad/2.6 Tm	10-300 mrad/3 Tm
Cerenkov	C_5F_{12} (liq.) C_4F_{10}(gas)	Aerogel C_4F_{10}, CF_4(gas)
(π/K)	(3-70 GeV)	(2-150 GeV)
Calorimeter	$PbWO_4$	Shashlik+Fe/tiles
muon	prop. tubes	MWPC/RPC

They are quite similar.

Advantages of dedicated B facilities at hadron machines

- large b statistics
- B_s and Λ_b
- long b decay paths
- good Cerenkov coverage
  ($\longleftarrow$ long track path in Cerenkov devices)

Challenges:

Trigger (hadron trigger, event topology)

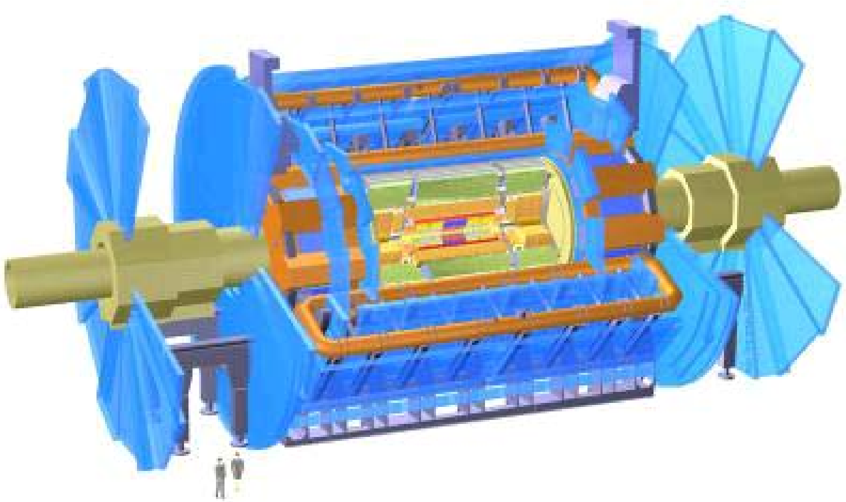
High rates, Radiation damages

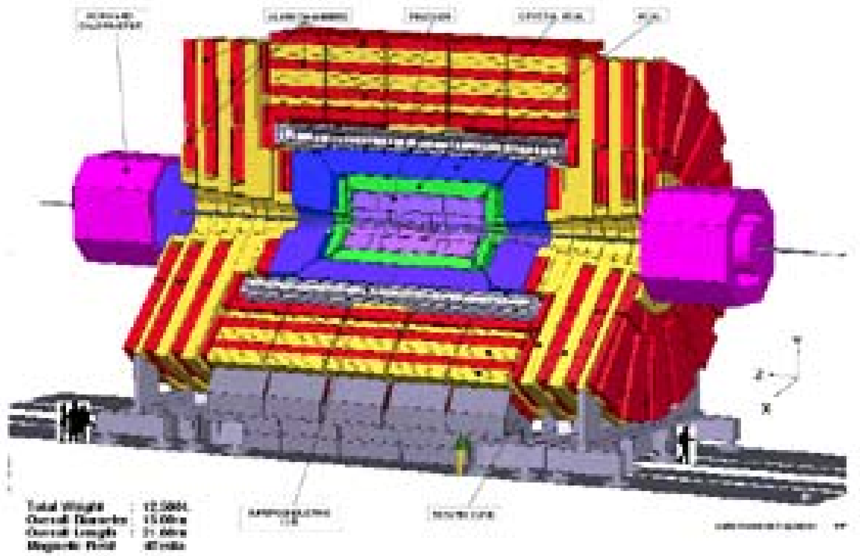
Physics Reach (LHCb)

parameter(mode)	evt/yr	error
$\sin 2\phi_1(B \to J/\Psi K_s)$	100K	0.02
$\phi_3(B \to D^*\pi)$	530K	$\sim 10^\circ$
$\phi_3(B_s \to D_s K)$	2.4K	$\sim 10^\circ$
$\phi_2(B \to \rho\pi)$	1.3K	$2.5 \sim 5^\circ$
$\delta\gamma(B_s \to J/\Psi\phi)$	24K	$\sim 2^\circ$

General-purpose LHC detectors

ATLAS **CMS**





No hadron triggers, but competitive for modes with $\mu^+\mu^-$.
(designed to do B physics while rate is not too high)

	LHCb	BTeV	ATLAS	CMS
$\#(B \to \mu\mu)$	11	7	26	31
$\#(b \to s\mu\mu)$	16K	2.5K	5.4K	2.4 K
$\#(\pi^+\pi^-)$	4.9K	1.5 K	2.3K	0.9K
$x_{s\mathrm{max}}$	71	75	57	42

For simple modes such as these, ATLAS/CMS are competitive.

2. Super B Factories

Current Performances of Asymmetric B Factories

Recorded integrated luminosities (5/27/02)

(fb^{-1})	BaBar	Belle
per 24hrs	0.303	0.395
per 7 days	1.790	2.524
total	87.95	80.29
$\mathcal{L}_{\rm max}$ $(10^{33}/cm^2 s)$	4.602	7.249

$\mathcal{L}_{\rm max}$ approaching $10^{34}/cm^2 s$.
$300 \sim 500$fb^{-1} each by 2006.

Super B Factory Plans

Super BaBar/PEPII	Super KEKB/Belle
$\mathcal{L}_{\rm max} \sim 10^{36}/cm^2s$	$\mathcal{L}_{\rm max} \sim 10^{35}/cm^2s$
$\sim 10ab^{-1}$/yr	$\sim 1ab^{-1}$/yr
$2 \times 10^{10} B$'s/yr	$2 \times 10^{9} B$'s/yr
'new' mchine	KEKB upgrade
'new' detector	Belle upgrade
2010$\longrightarrow$	2007$\longrightarrow$

Advantages of e^+e^- B-factories wrt hadron machines:

1. Cleaner neutral detection.

   $\longrightarrow$ modes with π^0 and multiple γ's.

2. Well defined kinematics.

   $\longrightarrow$ beam-constrained reconstruction.
   $\longrightarrow$ hermiticity and neutrino reconstruction.

A powerful technique: full-reconstruction tag.
($\sim$0.4% of all B-pairs)

Physics reach of SuperBaBar - CPV angles

angle	mode	BaBar (0.5ab^{-1})	SuperBaBar (10ab^{-1})	BTeV	LHCb
$\sin 2\phi_1$	$J/\Psi K_S$	0.037	0.008	0.025	0.014
$\sin 2\phi_{2\text{eff}}$	$\pi^+\pi^-$	0.14	0.032	0.024	0.056
$\phi_{2\text{eff}} - \phi_2$	$\pi^0\pi^0$	$< 18^\circ$	$< 7^\circ$	$\times$	$\times$
$\sin(2\phi_1 + \phi_3)$	$D^{*+}\pi^-$	0.15	0.03		
ϕ_3	$B \to DK$		$< 2.5^\circ$	$< 10^\circ$	$< 19^\circ$
ϕ_3	$B_s \to D_s K$	$\times$	$< 15^{\circ *}$	$< 7^\circ$	13°

*: 1 ab^{-1} on $\Upsilon 5S$

Physics reach of SuperBaBar(/yr) - rare decays

mode	Br	BaBar * (0.5ab^{-1})	SuperBaBar * (10ab^{-1})	BTeV/LHCb
$B \to X_s\gamma(tag)$	3.3×10^{-4}	$11K(1.7K)$	$220K(34K)$	
$B \to K^*\gamma$	5×10^{-5}	$6K$	$120K$	$25K$
$B \to \rho(\omega)\gamma$	2×10^{-6}	300	$6K$	
$B \to X_s\mu^+\mu^-$	6×10^{-6}	300	$6K$	$3.6K$
$B \to X_s e^+e^-$	6×10^{-6}	350	$7K$	
$B \to X_s\nu\bar{\nu}$	4×10^{-5}	8	160	$\times$
$B \to \tau\nu$	5×10^{-5}	17	350	$\times$
$B \to \mu\nu$	1.5×10^{-7}	8	150	$\times$
$B \to \gamma\gamma$	10^{-8}	0.4	8	$\times$

Physics reach of SuperKEKB

Expected errors on parameters

parameter	mode	KEKB ($0.3ab^{-1}$)	SuperKEKB ($3ab^{-1}$)	$LHCb$
$\sin 2\phi_1$	$J/\Psi K_S etc.$	0.049	0.016	0.014
$\sin 2\phi_{2\text{eff}}$	$\pi^+\pi^-$	0.19	0.060	
$\phi_{2\text{eff}} - \phi_2$	$\pi^0\pi^0$	20°	7°	$\times$
$\sin(2\phi_1 + \phi_3)$	$D^{*+}\pi^-$	0.24	0.077	
$\lvert V_{ub}\rvert$	$\pi(\rho)\ell\nu$	0.043	0.014	$\times$
m_d/m_b	$\rho(\omega)\gamma$	0.42	0.13	$\times$

(Possible) Machine configuration for Super-KEKB (Start 2007)

1. RF: 509 MHz (same as KEKB) $\rightarrow$ 5000 bunches max.

2. $\times$3 increase of design currents
   I_{HER}/I_{LER} = 1.1A/2.6A $\rightarrow$ 3A/10A (luminosity $\sim \times 10$)

3. LER(e^+) electron cloud effect (ECE).
   $\rightarrow$ LER = e^-, HER = e^+ (i.e. energy switch)

4. Use antechambers for vacuum pipes.
   (for SR heating and ECE)

5. Continuous injection (physics run tried with success)

6. Crab crossing optional ($\sim$25% increase in luminosity)

Beam lifetime (SuperKEKB)

1. Residual gas. (dominant now, a few 100 min)
   More current $\longrightarrow$ more gas desorption.
   $\longrightarrow$ need a beefed-up vacuum system.

2. Touschek (LER).
   ($\tau_{\mathrm{Tous}} \sim$ 9 hrs now for 1.2% energy acceptance)
   Touschek rate $\sim$ Bunch current/emittance
   $\longrightarrow$ Increase emittance (reduce $\beta^*_{x,y}$).
   ϵ_x = 18nm $\longrightarrow$ upto 33nm
   (β^*_y/β^*_x = 7/60 mm $\longrightarrow$ 3/15 mm)

3. Collision (radiative Bhabha) (not dominant now)
   Becomes important at Super-KEKB

$$\tau_{\mathrm{tot}} \sim 100 \text{ min.}$$

Machine parameters - KEKB

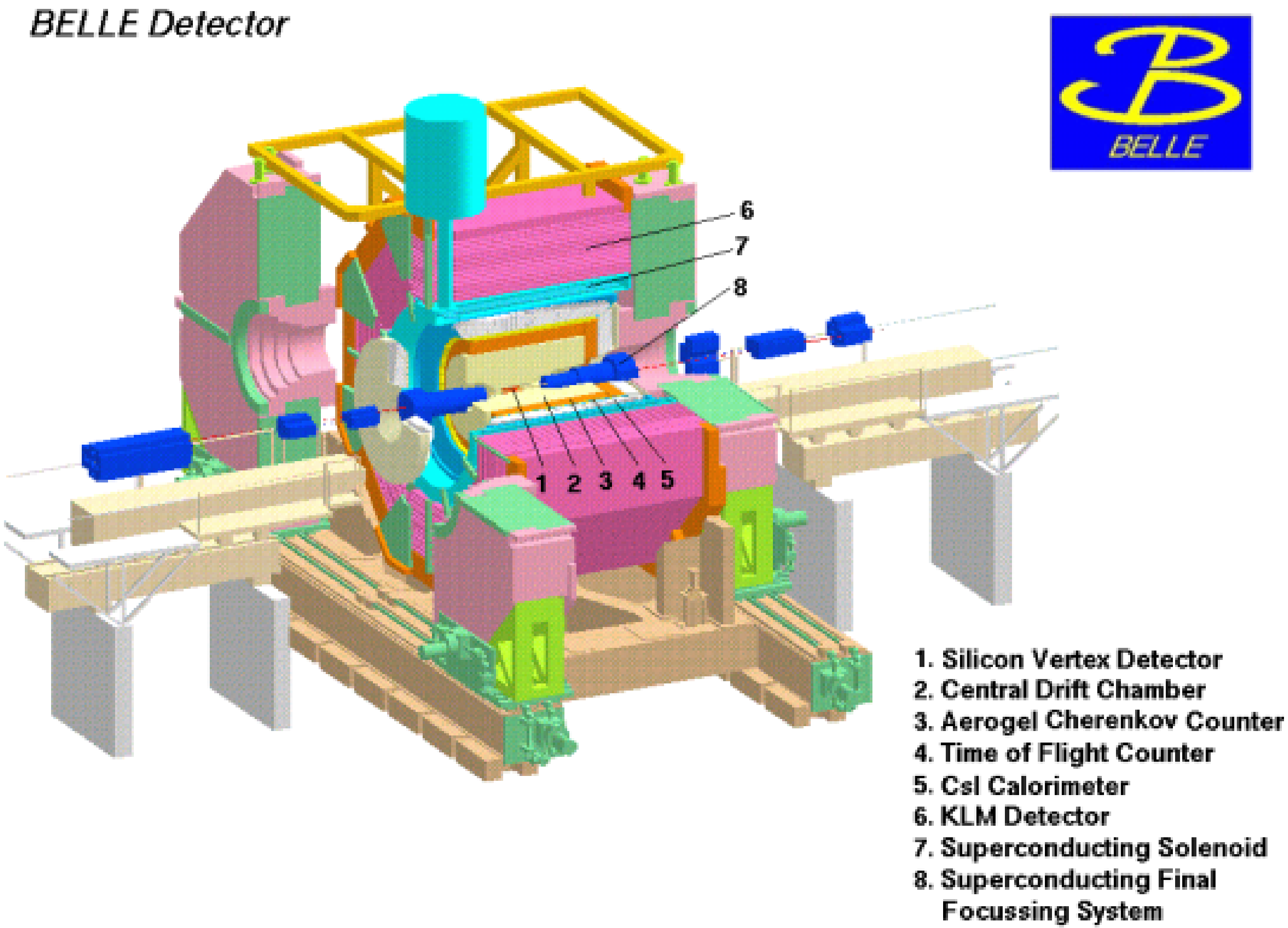
Smaller β_y^* $\longrightarrow$ smaller σ_z (hour-glass effect)
σ_z = 5.6mm $\longrightarrow$ 3mm.

	KEKB (now)		Super-KEKB	
	LER(e^+)	HER(e^-)	LER(e^-)	HER(e^+)
energy(GeV)	3.5	8	3.5	8
nbunch	1223	1223	5018	5018
I_{beam}(A)	1.33	0.82	9.4	4.1
I_{bunch}(mA)	1.09	0.67	1.87	0.82
ϵ_x(nm)	18	24	33	33
ϵ_y/ϵ_x	0.055	0.041	0.064	0.064
β_x^*(cm)	59	63	15	15
β_y^*(mm)	7	7	3	3
σ_z(mm)	5.6	5.6	3	3
crossing(mRad)	22		30	
L(10^{33}/cm^{2}s)	6.6		100	

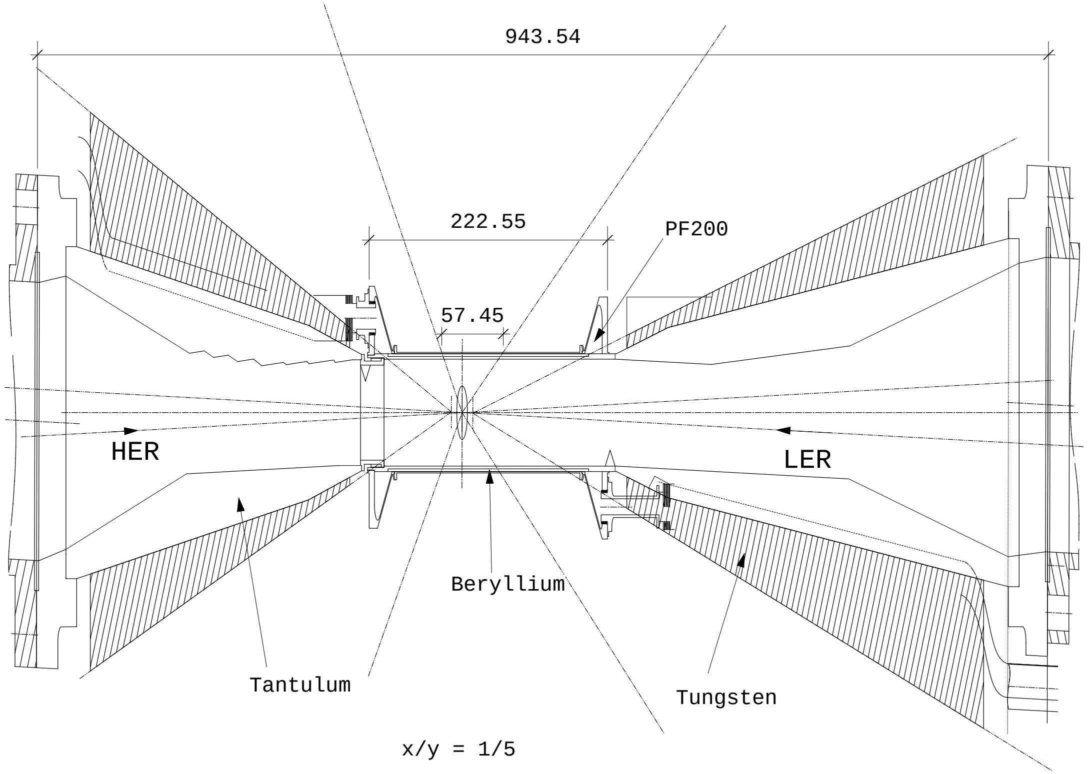
Super PEPII Parameters

	v.1	v.2
particle	e^+/e^-	e^+/e^-
E_{beam} (GeV)	9.1/3	8/3.5
$I_{\rm beam}$	8.4/24.5	9.6/22
f_{RF} (MHz)	476	714
circumference(m)	2200	2425
nbunch	3400	5700
σ_z (mm)	1.8	1.8
β^*_x/β^*_y (mm)	15/1.5	1.5/1.5
$\mathcal{L}(/cm^2s)$	10^{36}	10^{36}
lifetime(min)	5	5

SuperKEKB detector: upgrades to current Belle



IR Design and Beam Background



Possible r=1cm IP beampipe design
(r=2cm→1.5cm in 2003 upgrade)

Particle Background MC (Karim Trabelsi)

Silicon Lyr1 doses (2002 upgarde study)

(kRad/yr=10^7s) for (1nTorr CO, 1.1A/2.6A)				
Version	Data	MC(now)	MC(2002)	MC(2002)
r(b.p.)	2cm	2cm	1cm	1.5cm
r(lyr1)	3cm	3cm	1.5cm	2.2cm
HER Brem		6	28	13
HER Coul		35	35	13
HER sum	24	41	63	26
LER Brem		20(9)	67(63)	13(9)
LER Coul		15	52	14
LER Touschek		57(7)	474(464)	29(9)
LER sum	82	92(31)	593(579)	56(32)
Total	106	133(72)	655(641)	82(58)

Extrapolation to Super-KEKB

Beam current $\sim \times 4$, Lifetime $\sim \times 1/3$, Same vacuum (true?).

Lyr1 doses

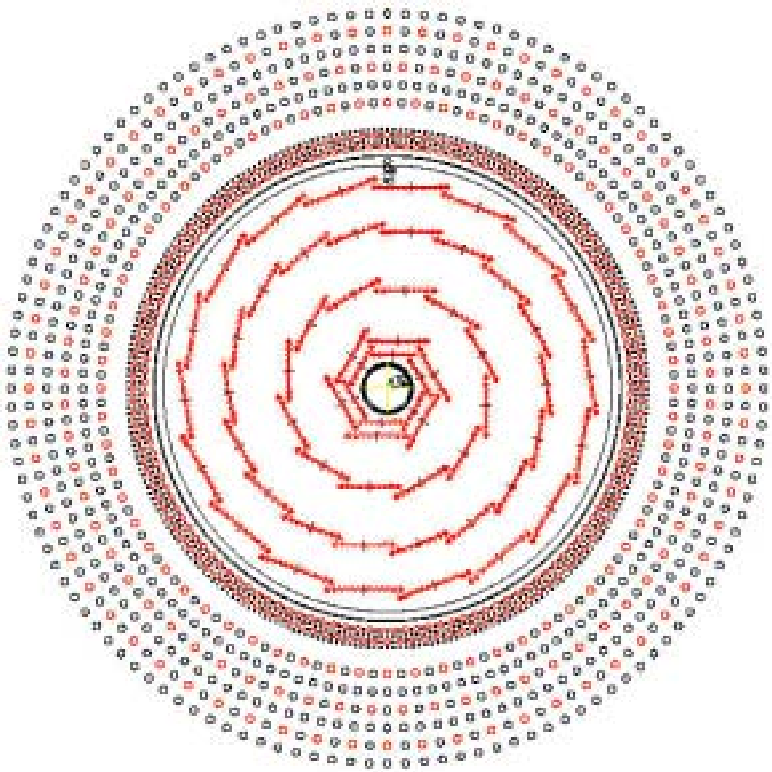
(MRad/yr=10^7s) for (1nTorr CO, 3A/10A)				
	Conservative		Optimistic	
r(b.p.)	1cm	1.5cm	1cm	1.5cm
HER sum	0.5	0.2	0.2	0.1
LER sum	6.8	0.6	2.3	0.2
Total	7.3	0.8	2.5	0.3

Conservative: scales with (beam current)/(lifetime).
Optimistic: scales with (beam current).

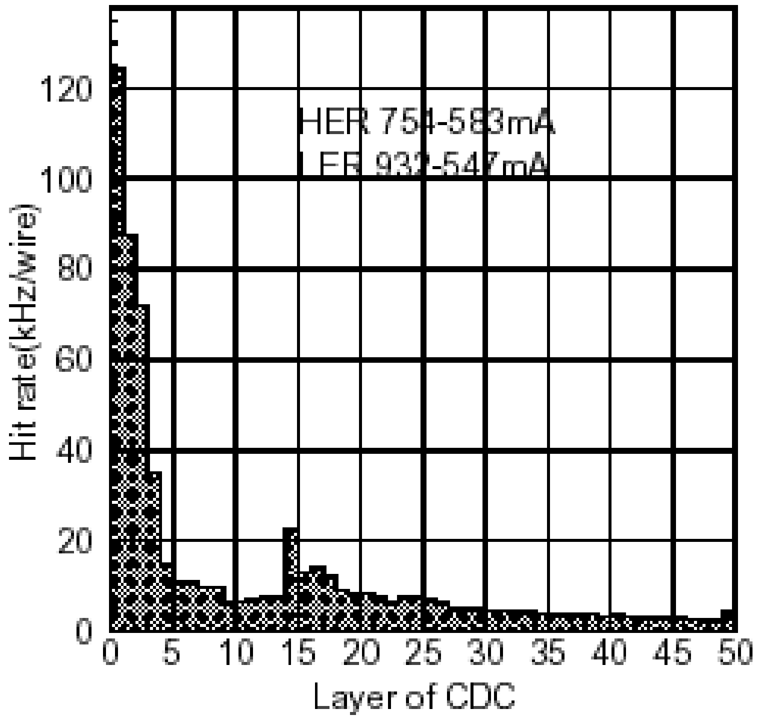
Vertexing

- Radiation dose.
  7.3 MRad/yr expected.
  2002 upgrade FE chip:
  OK at 20 MRad.
  Radhardness is OK.

- Occupancy.
  Silicon strip detector
  occupancy ~ 1.
  $\longrightarrow$ pixel device:
  hybrid, CMOS monolithic,
  or CCD.
  (CMS type as fallback)



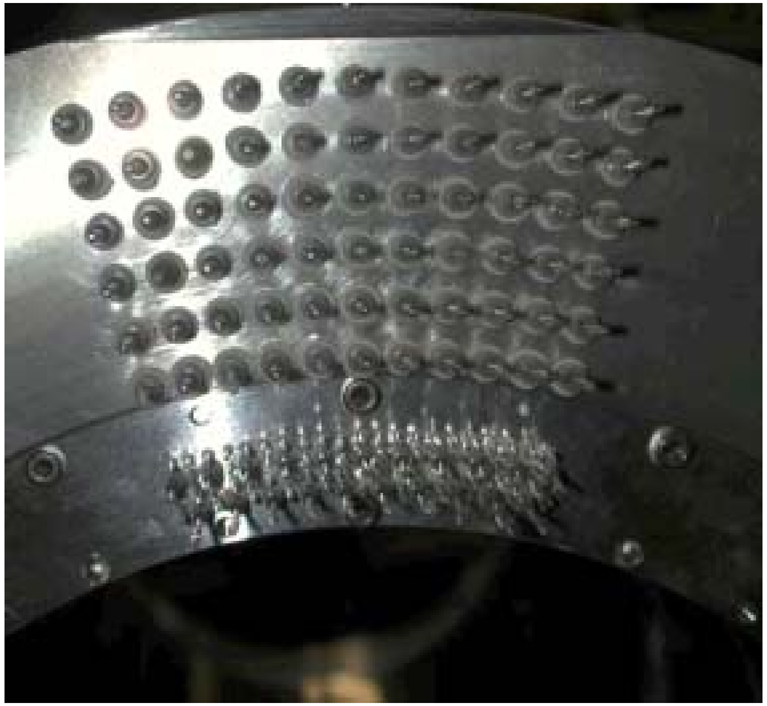
Central Trackers



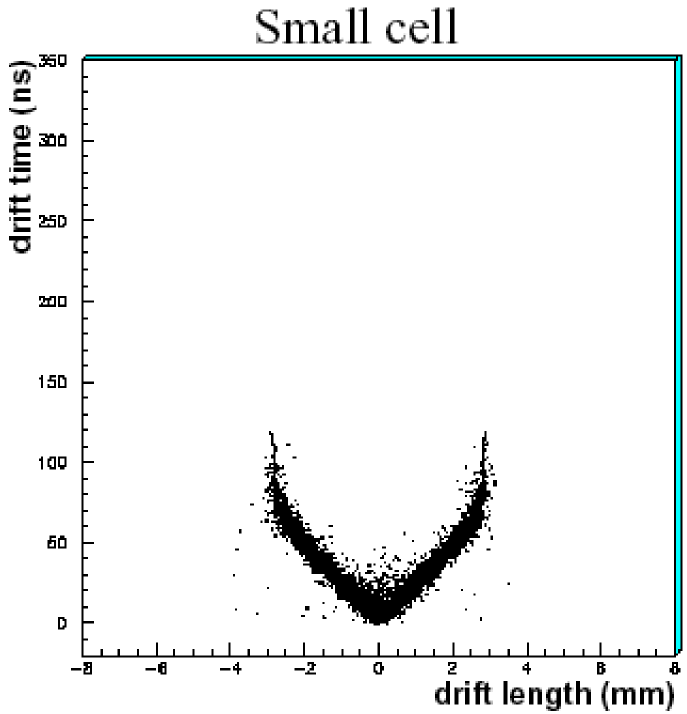
- Innermost CDC: ∼100 kHz now. (∼10% inefficiency)
- Inner layers (upto r=15cm) to be replaced by SVD.
- Rest of the CDC:
  A small-cell chamber (5mm cell) with a faster gas (e.g. CH_4).
  Super-B deadtime → a few %.

Prototype small-cell chamber

Inner layers: 5mm cell
Outer layers: 'normal' cell

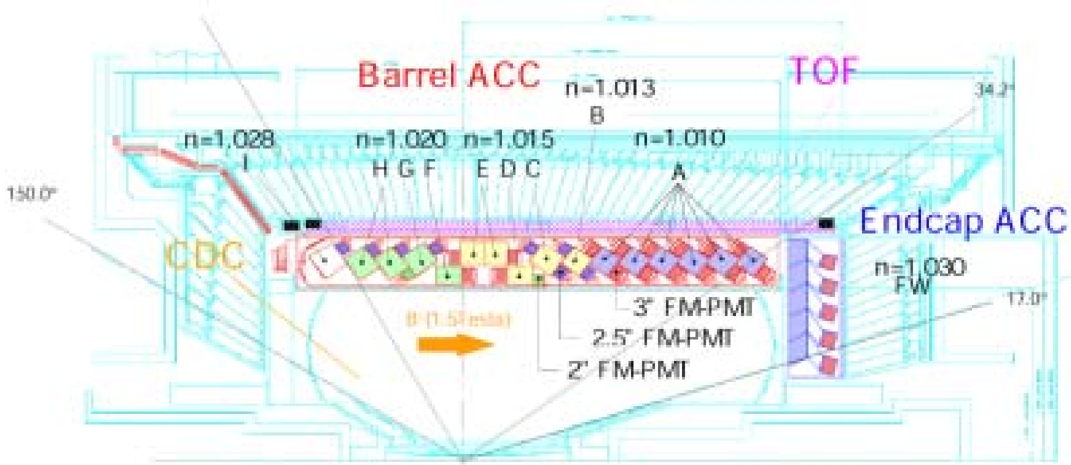


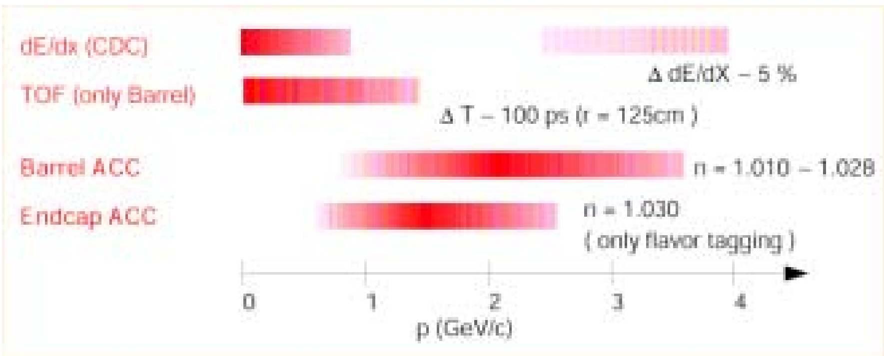
Drift time vs distance



Particle Identification

Belle PID π/K separation



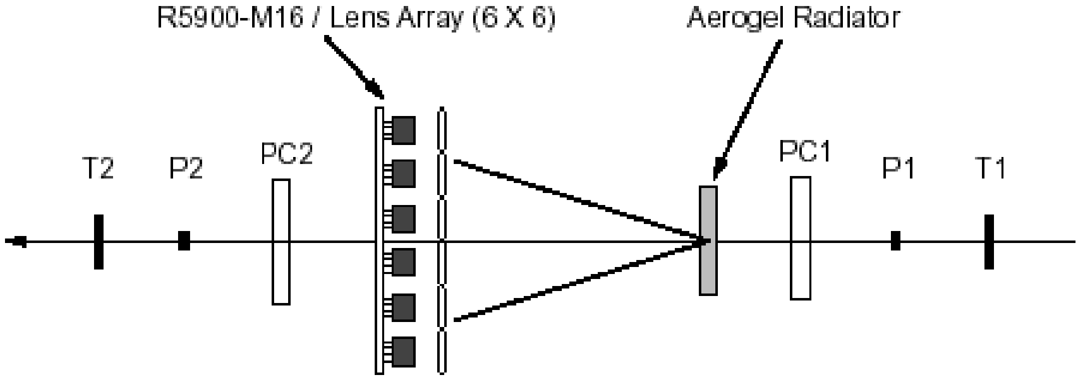


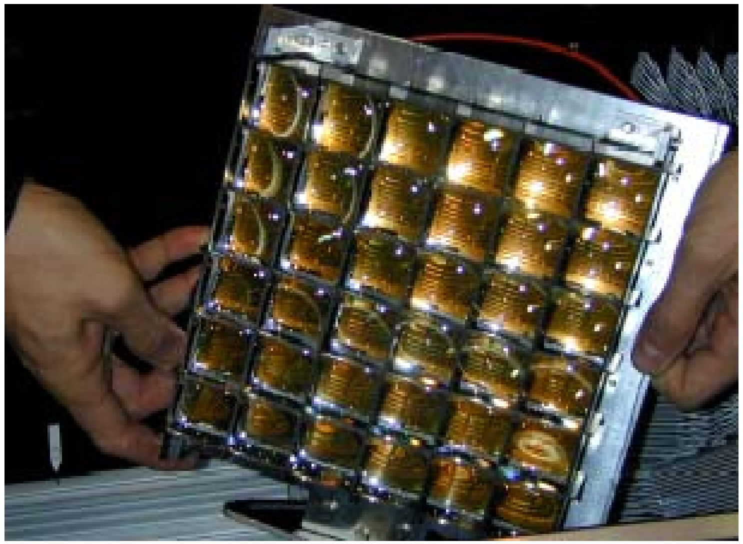
Better π/K separation.
More noise hits
at higher luminosity.
$\longrightarrow$ Ring-Imaging

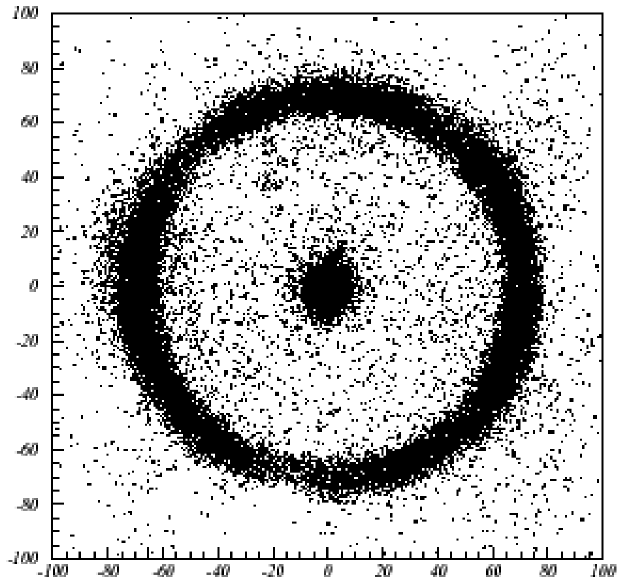
2 candidates:

- Ring-imaging aerogel. (End Cap)
- TOP counter. (Barrel)

Beam test of Aerogel-RICH







RING (run0074)

Aerogel-RICH beam test results

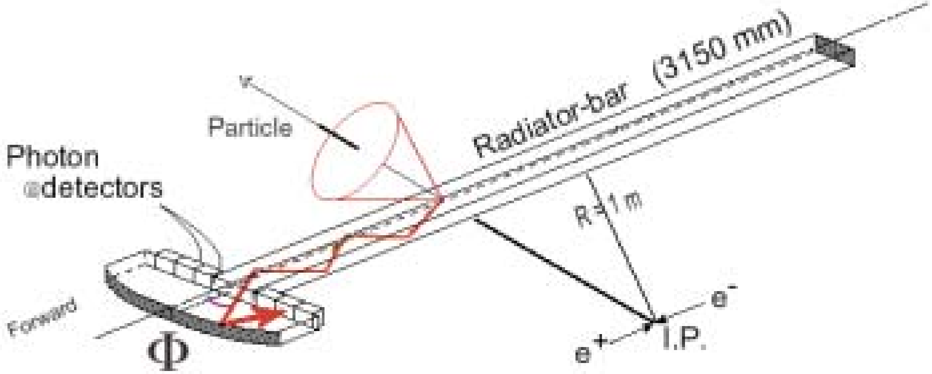
n	$N_{p.e.}$ w/o lens	$N_{p.e.}$ w/ lens	$\delta\theta_c$
1.029	2.21 (3.78)	3.90	12.8
1.050	2.25 (4.06)	3.34	15.9

( ): MC expectation

1. Finer-grain PMT readout (16 outputs/PMT): 10-20% improvement of $\delta\theta_c$.
2. Novosibirsk aerogel: 80% increase of $N_{p.e.}$
3. Flat-pannel Hybrid (Avalanche) Photodiode (H(A)PD) under study.

Time of Propagation (TOP) counter

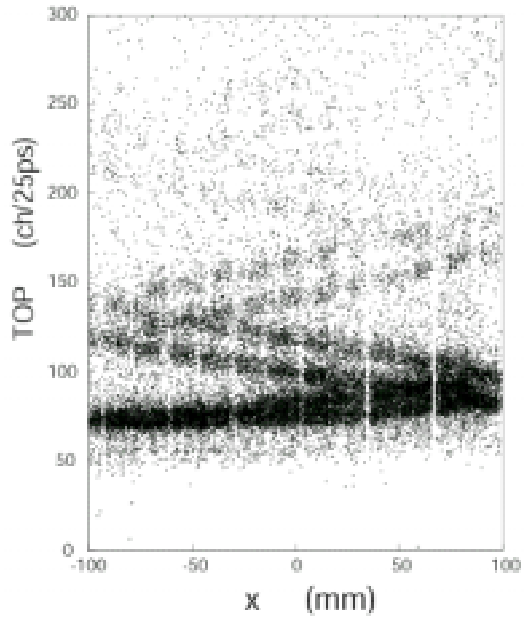
Top counter concept



- Fused silica radiator.
- 2D position of p.e.:
  x (horizontal hit pos.)
  t (time of propagarion)
- Discrete ambiquity in x.
- $\delta t \sim 100$ps photon detector in 1.5T field.

TOP counter prototype

Beam test with 2.5 GeV/c pions (KEK).

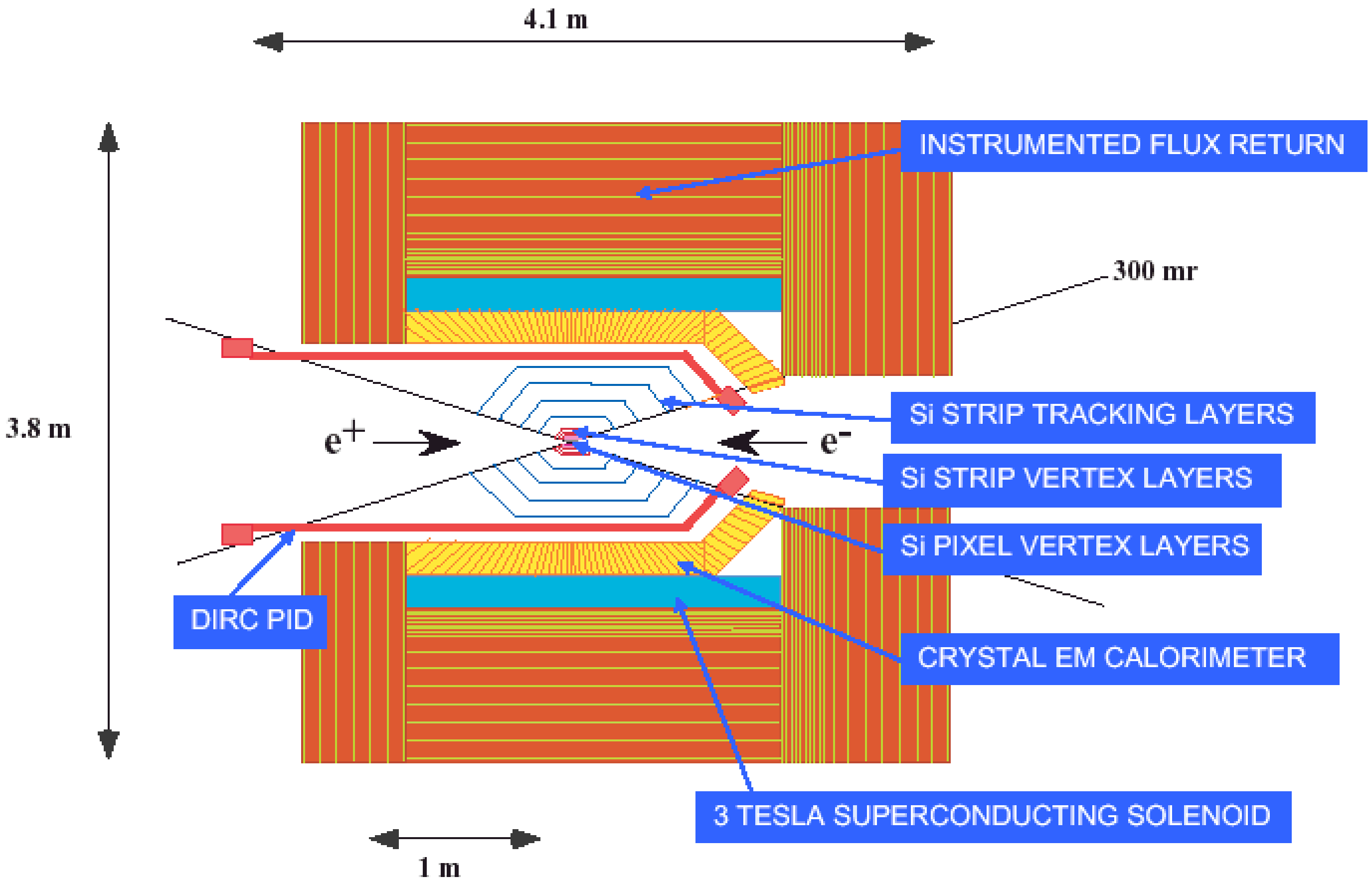


- $N_{p.e.} \sim 30$.
- Fused silica polish is critical.
- Multi-anode PMT used. But not in 1.5T field.

EM Calorimeter

- Current system: 8376 CsI(Tl) blocks.
- Barrel: 1kRad/3ab^{-1} expected. 5-10% light loss. ($\sim$ OK)
- Endcap: Pure CsI ($\times 100$ faster decay time, $\times 10$ rad.hard). R&D at BINP (with photo triode/tetrode) Noise~ 1MeV$\rightarrow$0.2MeV expected.
- Wave-form samp. and shorter shaping time. $\rightarrow \sigma_{\rm pileup} \times 0.5$. Installing FADC in Belle for a study.

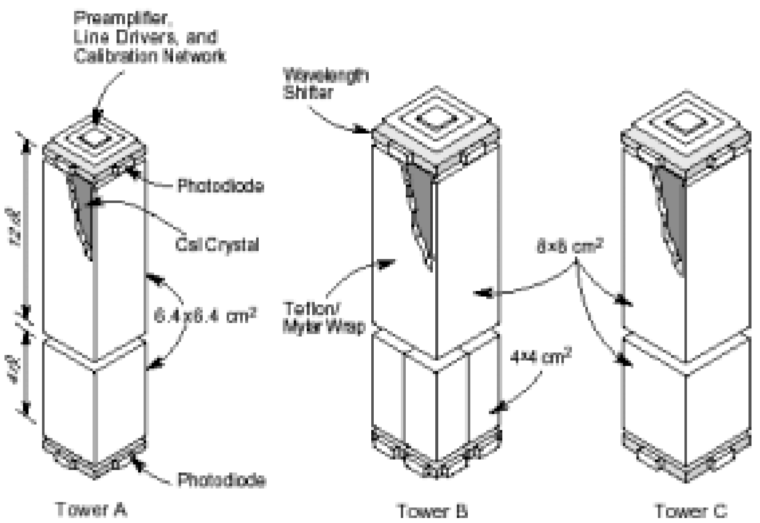
SuperBaBar Strawman Design



Compact design: dictated by EMcal (3Tesla field)

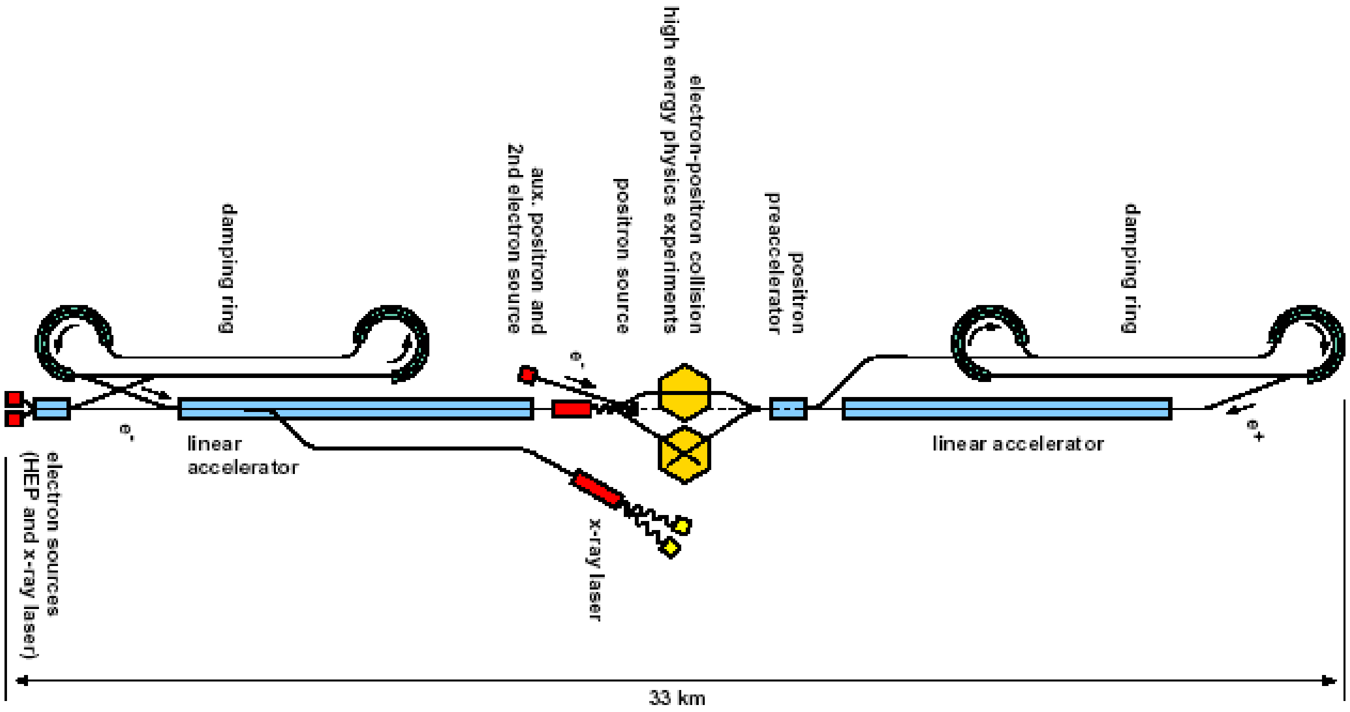
EM Cal Options (SuperBaBar)

	CsI(Tl)	CsI	LSO	YAP
$\tau_{\rm dcay}$ (ns)	>680	16	47	27
X_0 (cm)	1.86	1.86	1.14	2.63
$R_{\rm Mol}$ (cm)	3.8	3.8	2.3	2.8
$\#^{\gamma}$/keV	56	2.5	27	16.2
rad. (MRad)	0.01	0.01-0.1	100	100
cost ($/cc)	3.2	4	>7	>15



3. Linear Collider Giga-Z Option

Run Tesla on Z^0 (>2010)



Collect 1 Giga Z^0's in 50-100 days.

Giga-Z main goal: precision EW

	LEP/SLC/Tevatron	Giga-Z
$\sin^2\theta_{\rm eff}(A_{LR})$	0.23146 ± 0.00017	± 0.000013
M_z	$91.1875 \pm 0.0021 GeV$	$\pm 0.0021 GeV$
$\alpha_s(M_Z^2)$	0.1183 ± 0.0027	± 0.0009
$\Delta\rho$	$(0.55 \pm 0.10) \times 10^{-2}$	$\pm 0.005 \times 10^{-2}$
N_ν	2.984 ± 0.008	± 0.004
A_b	0.898 ± 0.015	± 0.001
R_b	0.21653 ± 0.00069	± 0.00014

Beam polorization $\to A_{LR}$.

Excellent b-tagging $\to$ advantage in modes with b.

Giga-Z generates 400M b-hadrons
($200 fb^{-1}$ B-factory equivalent)

	$\sin 2\phi_1$	$\sin 2\phi_{2\text{eff}}$
BaBar/Belle (now)	0.12	0.26
CDF(Run2)	0.08	0.10
ATLAS	0.01	0.09
LHCb	0.01	0.05
Giga-Z	0.04	0.07

Not very competitive with Super B-factories.
Run longer (∼1yr instead of 50-100 days)?

Giga-Z: some interesting modes

- $b \to s\nu\bar{\nu}$
  (Z-penguins $\to$ many new phys)

  ~ 1000 expected events.
  (separation of $2B$'s by hemispheres)

- $\Lambda_b \to \Lambda\gamma$ helicity structure
  ($R_{LR} = \Gamma(b_L \to s_R\gamma)/\Gamma(b_R \to s_L\gamma) \ll 1$ in SM)

  Use the polarized b from $Z \to$ polarized Λ_b. (60% pol)

  ~750 $\Lambda_b \to \Lambda\gamma$ will be seen

Summary

- An exciting era of flavor physics has just started with the measurement of $\sin 2\beta$.

- Challenges awaits us to confront the standard model in the CPV and rare decays of heavy quarks.

- Facilities to meet the challenges are being planned and intense works are going on.