

Commissioning of the KEK B-Factory

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Beauty99 @ Bled, Slovenia

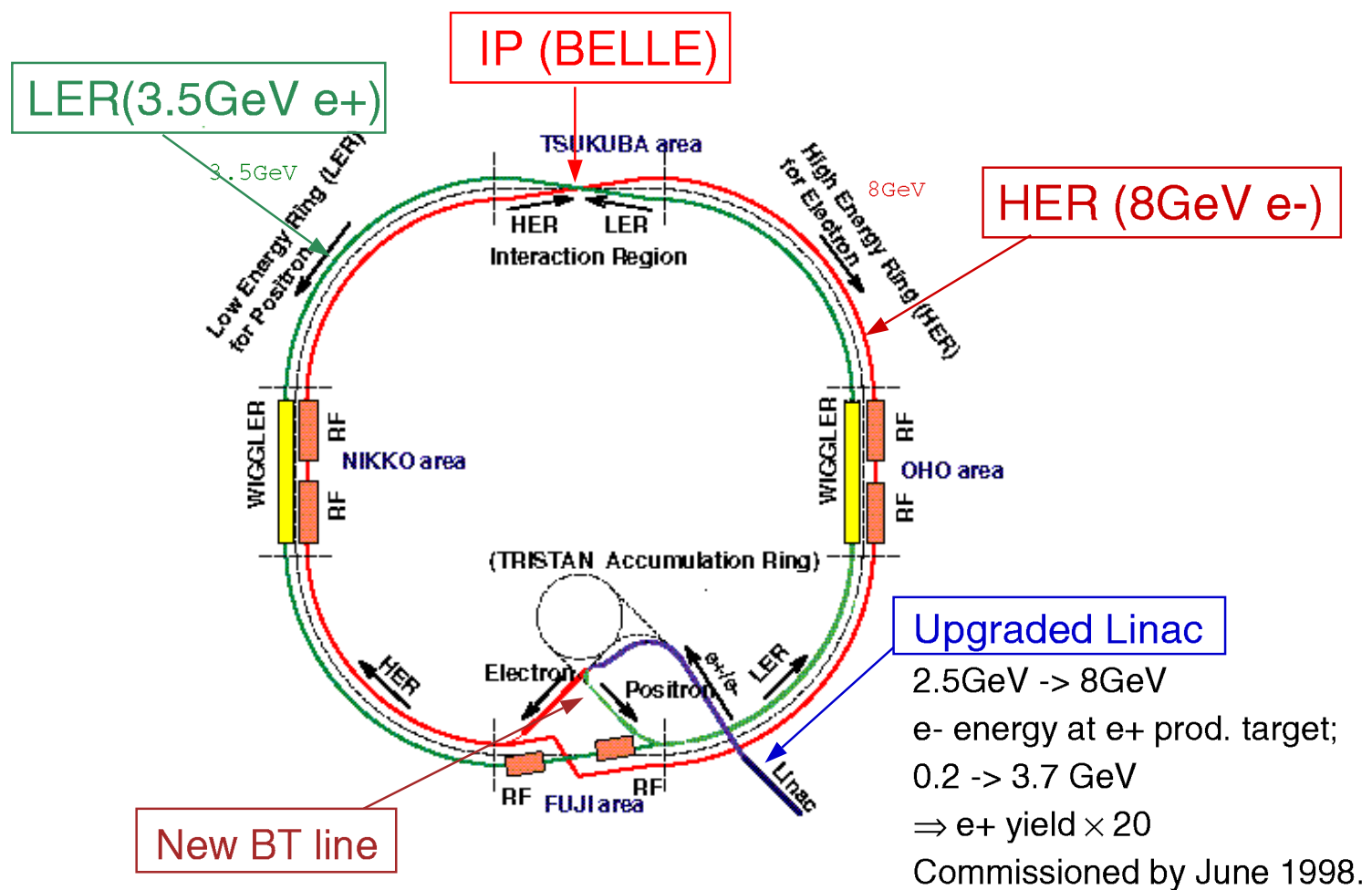
Outline

- **KEKB Overview**
- **Results of 1st stage commissioning**
- **Background issues**
- **Commissioning w/ BELLE**
- **Summary**

KEKB Overview

- A double ring asymmetric e+e- collider running on $\Upsilon(4S)$
- Target luminosity: $L = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
 - 5000 bunches / c=3016m
 - Beam currents: 1.1A (e-) + 2.6 A (e+)
 - $\Rightarrow 10^8 \text{ BB pairs / year !!}$
- $2 \times 11 \text{ mrad}$ Finite crossing angle
- Construction was finished by Nov. 1998 and commissioning has started since Dec. 1998

KEKB Accelerator



KEKB Parameters

Main Parameters of KEBB

Ring		LER	HER	
Energy	E	3.5	8.0	GeV
Circumference	C	3016.26		m
Luminosity	L	1×10^{34}		cm ⁻² s ⁻¹
Crossing angle	θ_x	± 11		mrad
Tune shifts	ξ_x / ξ_y	0.039 / 0.052		
Beta function @ IP	β_x^* / β_y^*	0.33 / 0.01		m
Bunch size @ IP	σ_x / σ_y	90 / 1.9		μm
Beam current	I	2.6	1.1	A
Natural bunch length	σ_z	0.4		cm
Bunch spacing	sb	0.59		m
Bunch current	Ib	0.51	0.22	mA
Emittance	ϵ_x / ϵ_y	$1.8 \times 10^{-8} / 3.6 \times 10^{-10}$		m
Betatron tune	ν_x / ν_y	45.52 / 45.08	47.52 / 43.08	

RF Cavities

- **KEKB solutions for high beam-loading and coupled bunch instabilities (CBI)**

ARES (normal conducting)

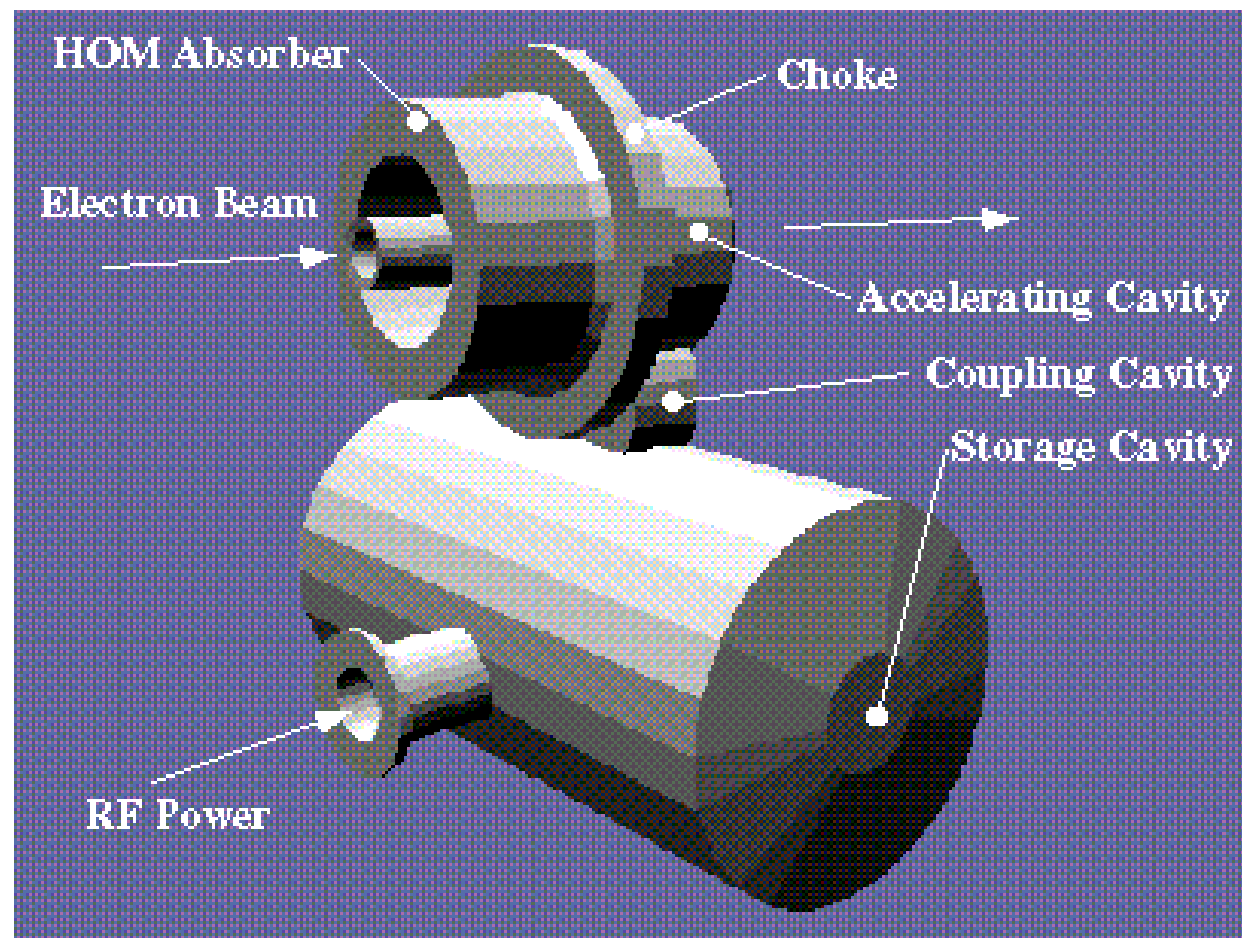
SCC (superconducting cavity)

Number of cavities				
Ring	Station	Type	T = 0	Final
LER	Fuji	ARES	12	20
HER	Oho	ARES	6	12
	Nikko	SCC	4	8

+ bunch-by-bunch feedback system

ARES

(Accelerator Resonantly coupled with Energy Storage)

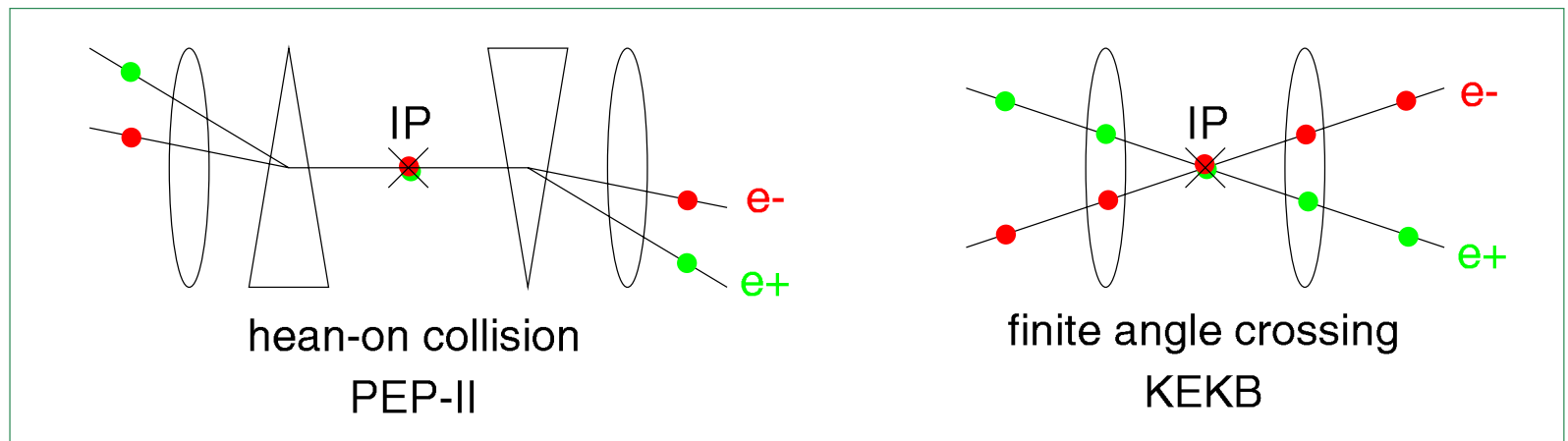


Interaction Region

- 2×11 mrad finite-angle crossing at IP to simplify IR design and fill every bucket with beam
- Superconducting final-focus quad. (QCS) and anti-solenoids inside 1.5 Tesla BELLE solenoid
- + Crab crossing scheme as a fall-back option in case that luminosity loss due to beam-beam kick is serious.

Finite Angle Crossing @ IP

- No strong separation bend at IP
- No synchrotron radiation due to the bend
- No parasitic collisions
- **Shorter bunch spacing**



1st stage commissioning

- Dec.1,1998 ~ Apr.19, 1999
- BELLE at roll out position
- Compensation solenoid at 10% of full excitation
- Maximum stored current
= **514mA (HER)** / **542mA (LER)**

Commissioning Brief History

- **12/1/1998** Start of ring commissioning
- **12/8** HER injection started
- **12/11** HER circulation of 7 turns was observed
- **12/13** HER beam stored with RF
- **12/26** HER 19mA stored with 60 bunches

- **1/12/1999** LER injection started
- **1/13** LER circulation of 3 turns was observed
- **1/14** LER beam stored with RF
- **1/15** LER 1.9mA was stored with 5 bunches
- **1/25** LER 46mA was stored
- **1/26** Horizontal beam-beam interaction was first observed
- **2/5** First beam collision was observed.

Commissioning summary (Linac)

e- Linac / BT			
	Design	Achieved	
Beam Energy	8	8.5	GeV
Charge/bunch @ BT end	1.2	< 0.8	nC
Transmission	100	80 ~ 100	%
Repetition	50	50	Hz
Emittance	< 0.1	0.06	μm

e+ Linac / BT			
	Design	Achieved	
Beam Energy	3.5	4	GeV
Charge/bunch @ e+ targt	10	8	nC
Charge/bunch @ BT end	0.64	< 0.4	nC
Transmission	100	70	%
Repetition	50	50	Hz
Emittance	< 0.25	0.4	μm

Commissioning summary (HER)

HER			
	Design	Achieved	
Beam Energy	8	8	GeV
Beam Current	1100	514	mA
Single bunch current	0.22	4	mA
Number of bunches	5000	800	
β_x^* / β_y^* @ IP	33 / 1	100 / 1.0	cm
v_x / v_y	44.53 / 42.20	44.65 / 42.14	
Rf voltage	max. 20	9	MV
v_z @ 8MV	0.0119	0.0114	
Bunch length @0mA, 8MV	5.6	5.6	mm
Injection rate @50Hz	6	< 1.5	mA / s
Injection eff. @50Hz	100	< 60	%
Average pressure @ 100mA	< 1	45	nTorr
Life time @ 100mA		60	min.

Commissioning summary (LER)

LER			
	Design	Achieved	
Beam Energy	3.5	3.5	GeV
Beam Current	2600	542	mA
Single bunch current	0.52	2.3	mA
Number of bunches	5000	1024	
β_x^* / β_y^* @ IP	33 / 1	100 / 1.0	cm
v_x / v_y	45.35 / 44.41	45.27 / 44.18	
Rf voltage	max. 8	4.8	MV
v_z @ 8MV	0.0118	0.0110	
Bunch length @0mA, 4MV			
Injection rate @50Hz	3.2	< 1.4	mA / s
Injection eff. @50Hz	100	< 80	%
Average pressure @350mA	< 1	40	nTorr
Life time @350mA		50	min.

Tentative Goal

Tentative Goal (K.Oide)			
	LER	HER	
Current	520	220	mA
No. of bunches	1000	1000	
β_y^* / β_x^* @ IP	0.01 / 1	0.01 / 1	m
Emittance ϵ_x	18	18	nm
Emittance ratio ϵ_y / ϵ_x	1	1	%
Beam-beam ξ_y / ξ_x	0.05 / 0.05	0.05 / 0.05	
Luminosity	2×10^{33}		$\text{cm}^{-2} \text{s}^{-1}$

Detector background study (I)

- Detector background has been studied with the "BEAST" commissioning detector.
 - Dose @ injection = $\sim 5\text{rad}/100\text{mA}$ for "Good" injection
 - Dose @ storage mode:
 - LER: 10mrad/sec @ 350mA with $dP/dI = 40\text{nTorr/Amp}$
 $\rightarrow 20\text{mrad/sec}$ @ 500mA
 - HER: 13mrad/sec @ 250mA with $dP/dI = 15\text{nTorr/Amp}$
 $\rightarrow 13\text{mrad/sec}$ @ 250mA
- $\Rightarrow 330\text{ krad/year}$ at $L = 2 \times 10^{33}\text{ cm}^{-2}\text{ s}^{-1}$
(no extrapolation, the worst case)

Detector background study (II)

- Current dependence

$$\text{LER: } \propto I^2$$

\Rightarrow will be decreased as vacuum improved.

$$\text{HER: } \propto I$$

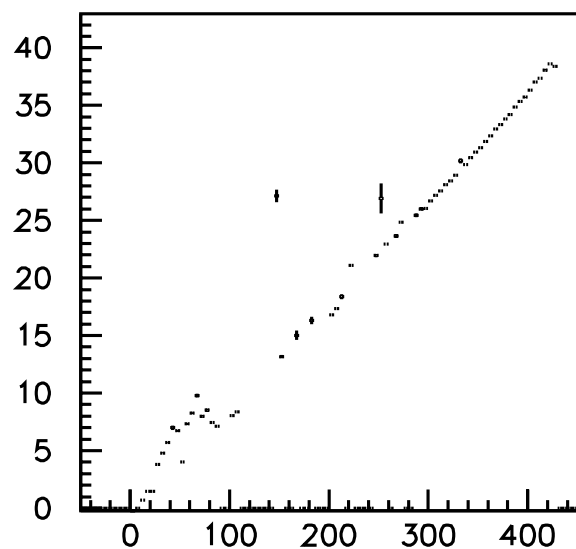
\Rightarrow Beam Halo or Synchrotron radiation ?

- Present background situation is marginal and more improvement is needed.
- The goal is to achieve $< 200\text{krad/year}$
 $=$ " maximum tolerance of SVD-1.0"

Dose vs Current

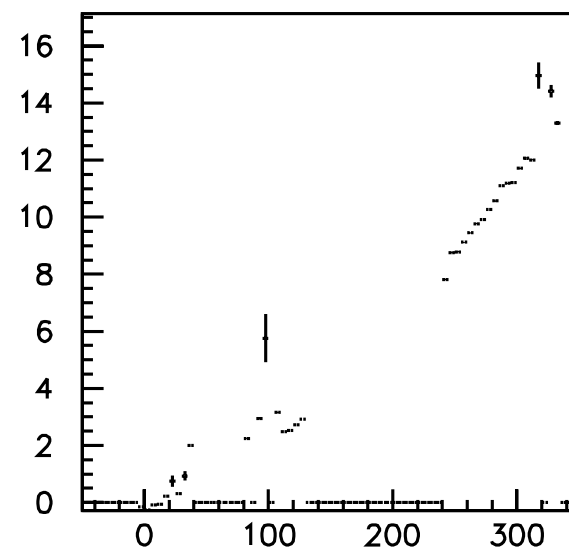
Dose (mrad/sec)

HER



(ptzlc43+0.016)*300. VS. currzem

LER

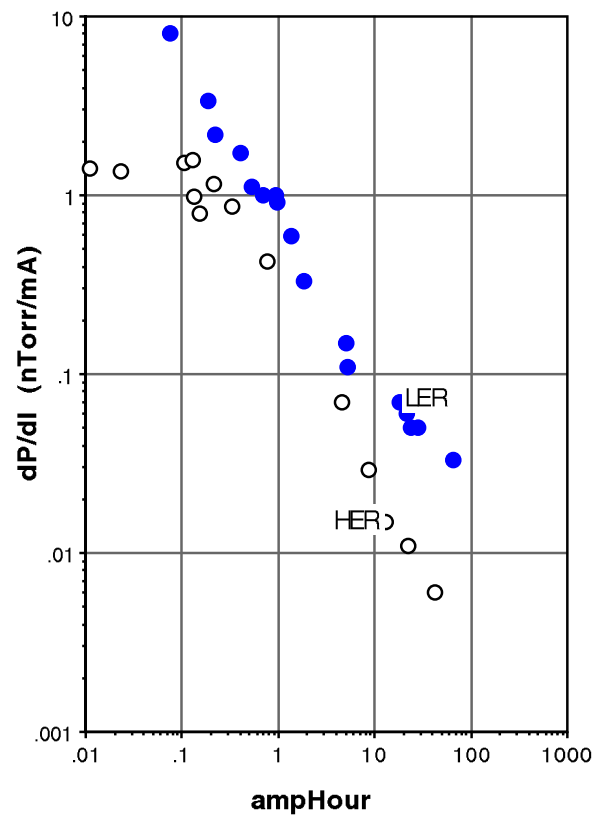


(ptzlc43+0.016)*300. VS. currzep

Current (mA)

Vacuum Improvement

Vacuum improvement (4/19)



Commissioning with BELLE

- **First Beam Collision (May 31~June 1)**
 - Beam life time was short with designed bunch current
 - Physics run (June 1)
 - 9mA(HER) + 25mA(LER)
 - $\sigma_y \sim (7-10)\mu\text{m}$
 - $\langle L \rangle \sim 1.5 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$
 - First observation of collision events by BELLE.
- **Second Beam Collision (June 6~June 9)**
 - Found a tune giving enough beam life time with designed bunch current
 - Physics run (June 9 ~ 10)
 - 19mA(HER) + 45mA(LER)
 - $\sigma_y \sim (4-6)\mu\text{m}$
 - $\langle L \rangle \sim 1 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$ (consistent with BELLE measurement)
 - ~1250 hadronic events by BELLE

Accident on June 11

- In the evening of June 11, serious vacuum leak was found around IP
- An iron plate ($20 \times 10 \times 0.1 \text{ cm}^3$), probably left in the gap between QCS and beam pipe, hit three electrodes of an 8-electrode BPM ("Octapos")
- Recovery schedule
 - June 19 New QCS chamber restored and connected to the BELLE IP chamber.
QCS pushed into BELLE
 - June 20~24 QCS cryogenics restoration
 - June 25 BELLE endyoke closed.
Linac/KEKB BT operation start
 - June 25~27 QCS cooled down
 - June 27 or 28 Beam will be back in KEKB ring.

Plan

- **June 10~11 LER wigglers installed.**
- **June 28 Resume main ring operation**
 - Background study
 - Energy scan
 - Continuous physics run
- **Summer shutdown**
 - Originally scheduled from Jul.25~, but now under discussion.
 - Addition of 12-14 ARES cavities in LER(6-8) and HER(6).
(exact number is not determined yet)
- **Oct./beg.~ long run with BELLE**

Summary

- **KEKB construction has been finished by Nov/end, 1998**
- **KEKB has been commissioned since Dec.1, 1999**
- **The achieved maximum current is 514mA(HER) and 542mA (LER)**
- **No major serious problem**
- **KEKB has delivered beam for two physics run periods in June, and 1st collision events have been acquired by BELLE**
- **Reduction of detector background level is the present key issue to achieve the tentative goal ($2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$).**

A lot of trouble..., but lots of progress, achievement and fun !