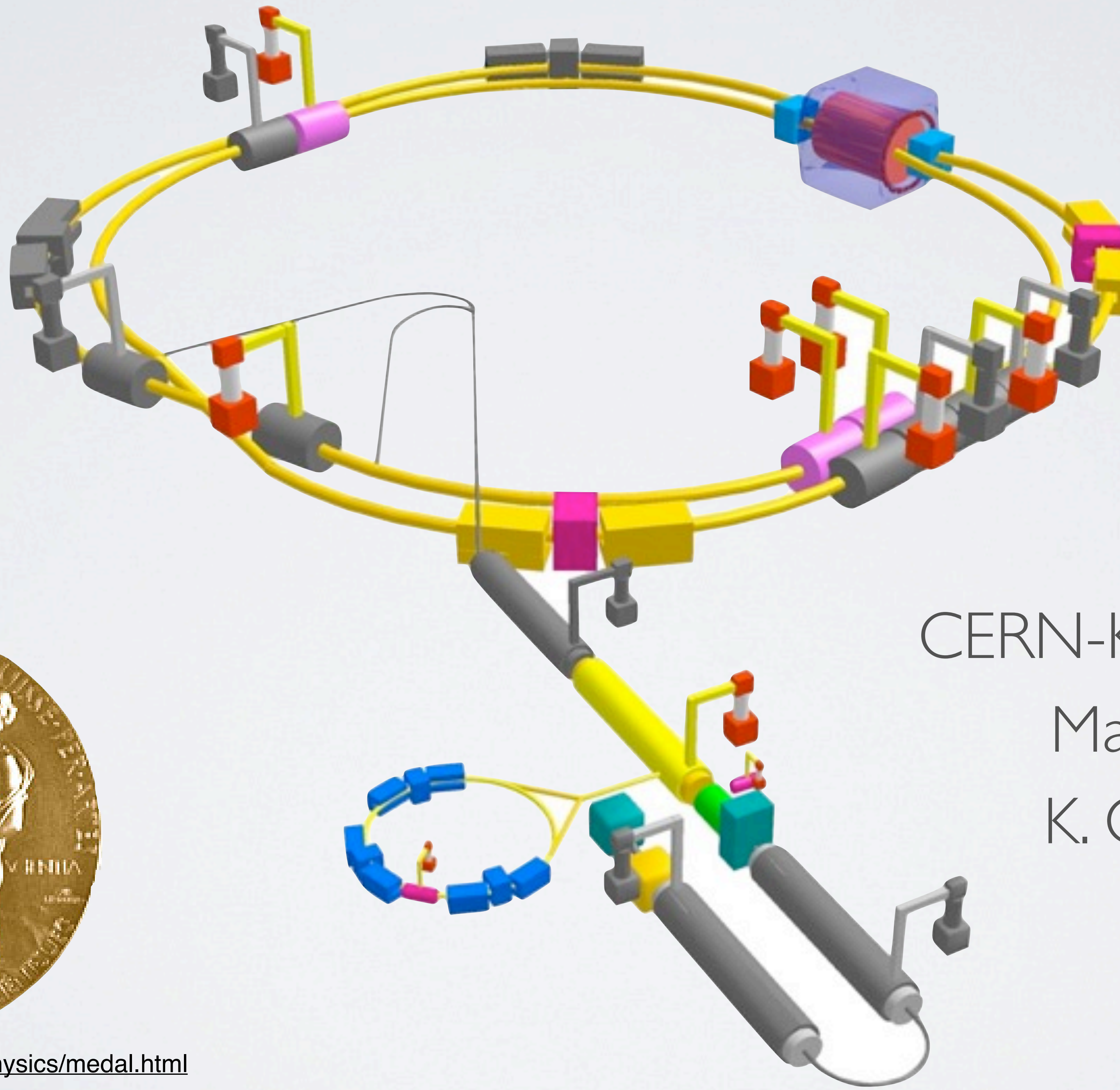
KEKB & SuperKEKB



CERN-KEK Committee
Mar. 29, 2010
K. Oide (KEK)

http://nobelprize.org/nobel_prizes/physics/medal.html

KEKB: Achieved 1,000 fb^{-1}

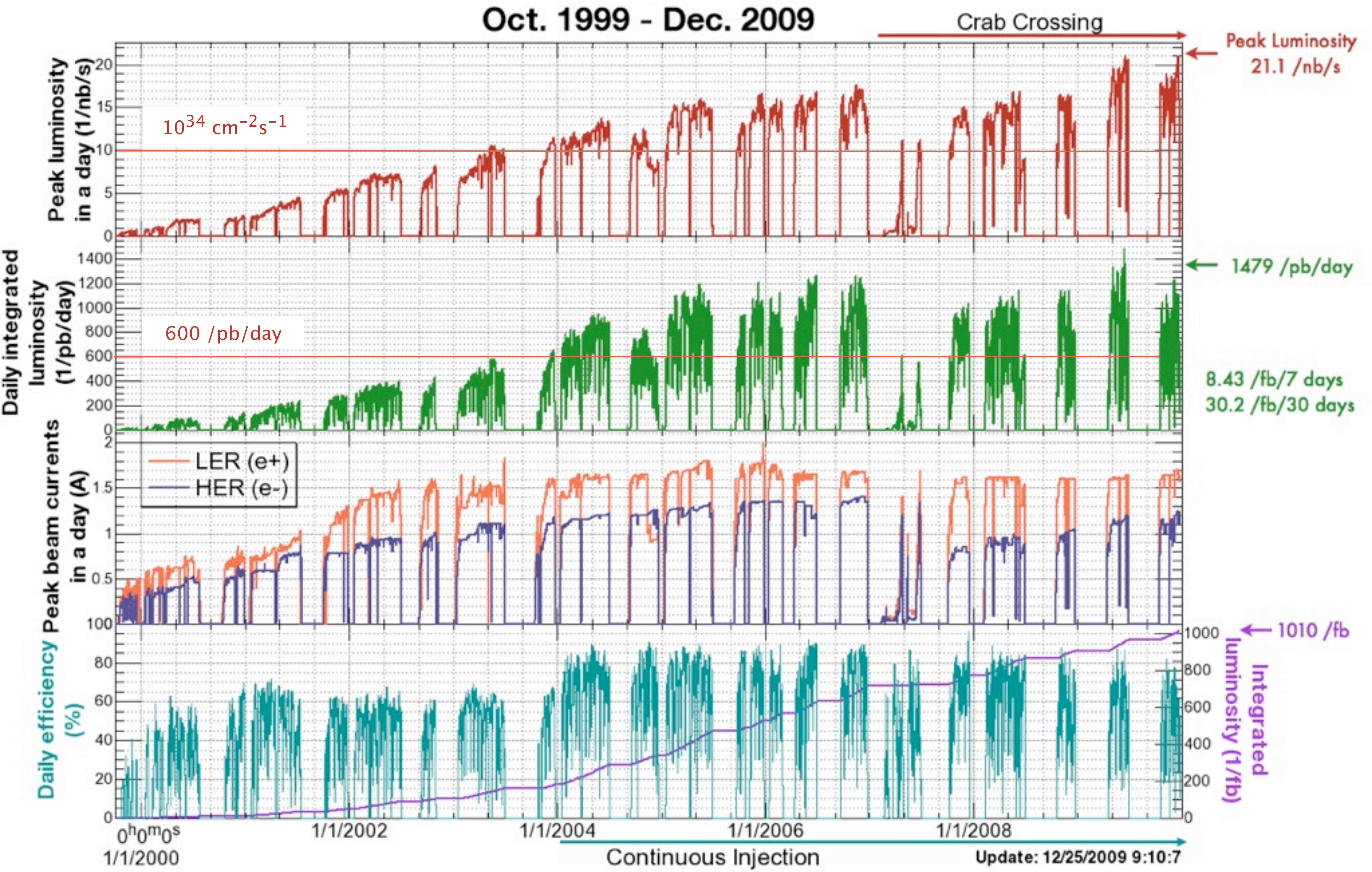
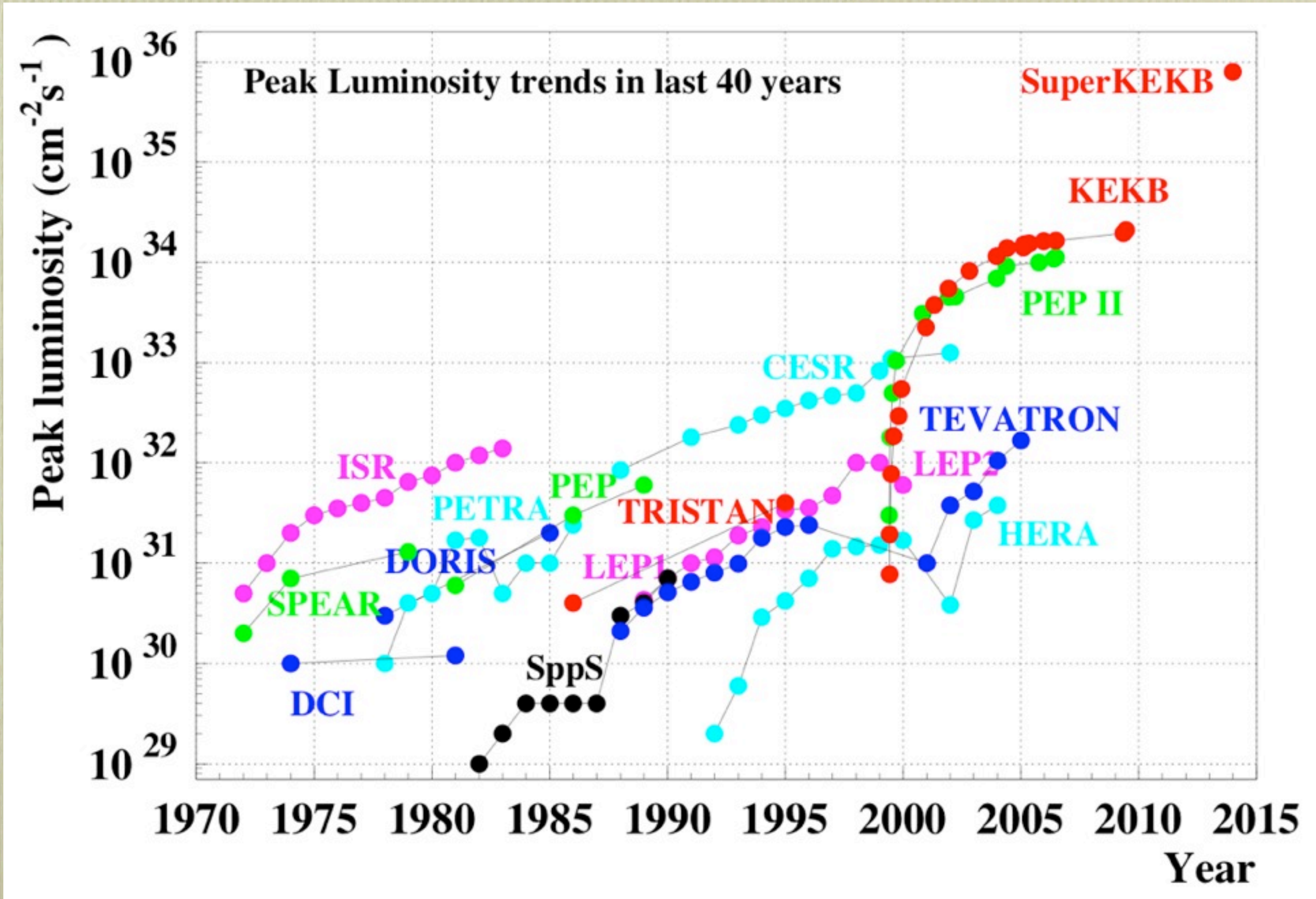


表 1 世界の主な衝突型加速器

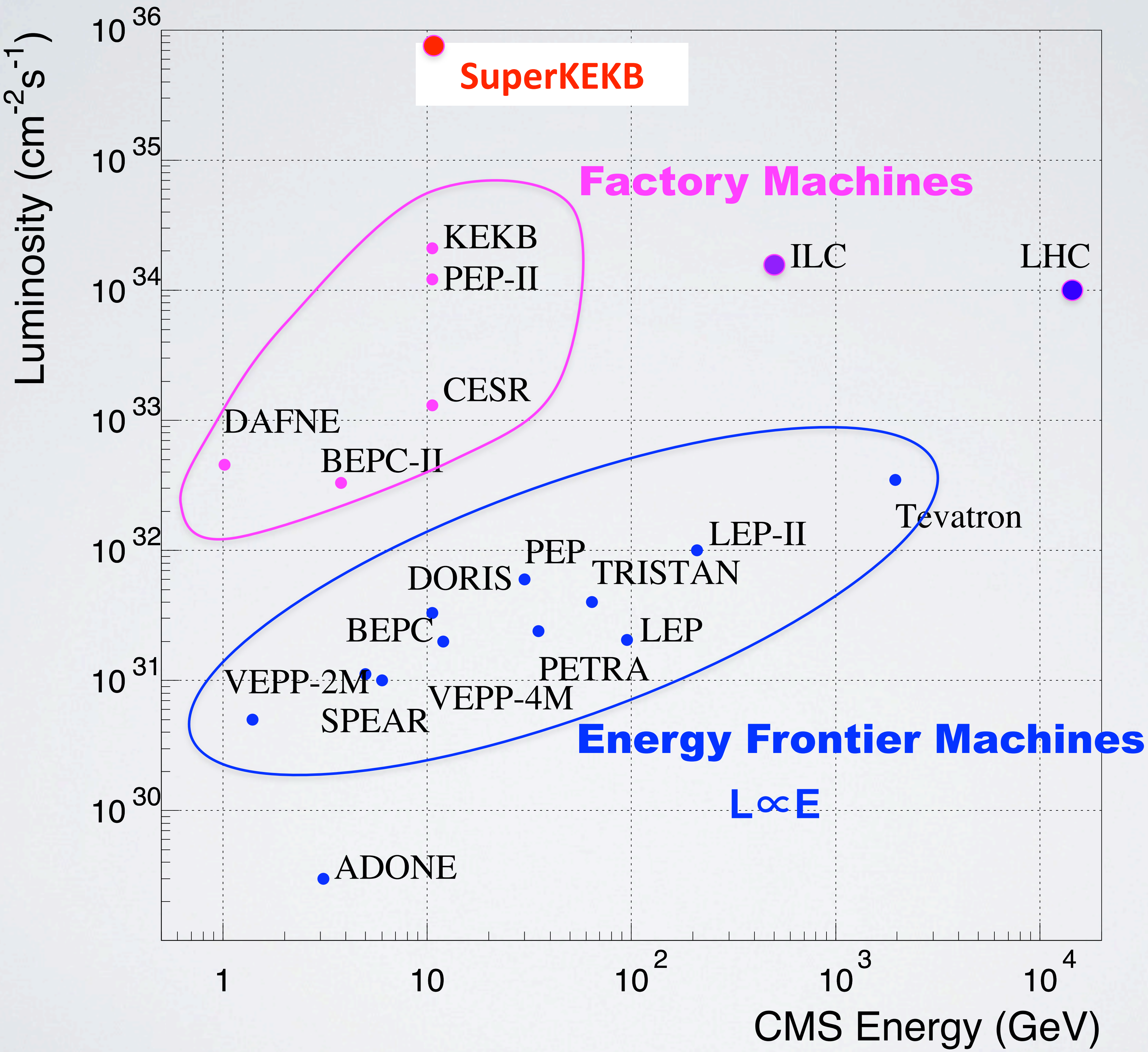
加速器	所在地	粒子	型 ^{a}	ビームエネルギー (GeV)	ルミノシティ ($10^{30}cm^{-2}s^{-1}$)	年 (衝突実験)
AdA	Frascati (伊)	e^+ / e^-	S	0.25	$\sim 10^{-5}$	1962
VEP-I	Novosibirsk (露)	e^- / e^-	D	0.13	$\sim$ 0.001	1963–1965
CBX	SLAC (米)	e^- / e^-	D	0.5		1963–1968
ACO	Orsay (仏)	e^+ / e^-	S	0.5	0.1	1966
Adone	Frascati (伊)	e^+ / e^-	S	1.5	0.6	1969–1993
ISR	CERN (スイス)	p / p	D	3.2	130	1971–1983
SPEAR	SLAC (米)	e^+ / e^-	S	4	12	1972–1990
VEPP-2/2M	Novosibirsk (露)	e^+ / e^-	S	0.7	13	1974–
DORIS	DESY (独)	e^+ / e^-	D	5.6	33	1974–1993
DCI	Orsay (仏)	e^- / e^-	D	1.8	2	1976–2003
PETRA	DESY (独)	e^+ / e^-	S	19	30	1978–1986
VEPP-4M	Novosibirsk (露)	e^+ / e^-	S	7	50	1979–
CESR	Cornell (米)	e^+ / e^-	S	6	1,300	1979–2002
PEP	SLAC (米)	e^+ / e^-	S	15	60	1980–1990
Sp$\bar{p}$S	CERN (スイス)	p / $\bar{p}$	S	315	6	1981–1990
TRISTAN	KEK (日)	e^+ / e^-	S	32	37	1986–1994
Tevatron	Fermilab (米)	p / $\bar{p}$	S	980	350	1987–
BEPC	IHEP (中)	e^+ / e^-	S	2.2	13	1989–2005
LEP	CERN (スイス)	e^+ / e^-	S	46	24	1989–1994
SLC	SLAC (米)	e^+ / e^-	L	46	3	1989–1998
HERA	DESY (独)	$e^\pm$ / p	D	30 / 920	75	1992–
DAΦNE	Frascati (伊)	e^+ / e^-	D	0.7	150	1997–
LEP2	CERN (スイス)	e^+ / e^-	S	105	100	1995–2000
PEP-II	SLAC (米)	e^+ / e^-	D	3.1 / 9	12,000	1999–2008
KEKB	KEK (日)	e^+ / e^-	D	3.5 / 8	21,100	1999–
RHIC	BNL (米)	重イオン	D	$100/n$	0.003 ^{b}	2000–
CESR-c	Cornell (米)	e^+ / e^-	S	1.9	60	2002–2008
VEPP-2000	Novosibirsk (露)	e^+ / e^-	S	1	100	2006–
BEPCII	IHEP (中)	e^+ / e^-	D	2.1	300	2007–
LHC	CERN (スイス)	p / p	D	7,000	10,000 ^{c}	2008–

a S: 単リング, D: 複リング, L: 線形
b 金・金衝突時
c 目標値

KEKB = ルミノシティ・フロンティア



LUMINOSITY OF COLLIDERS

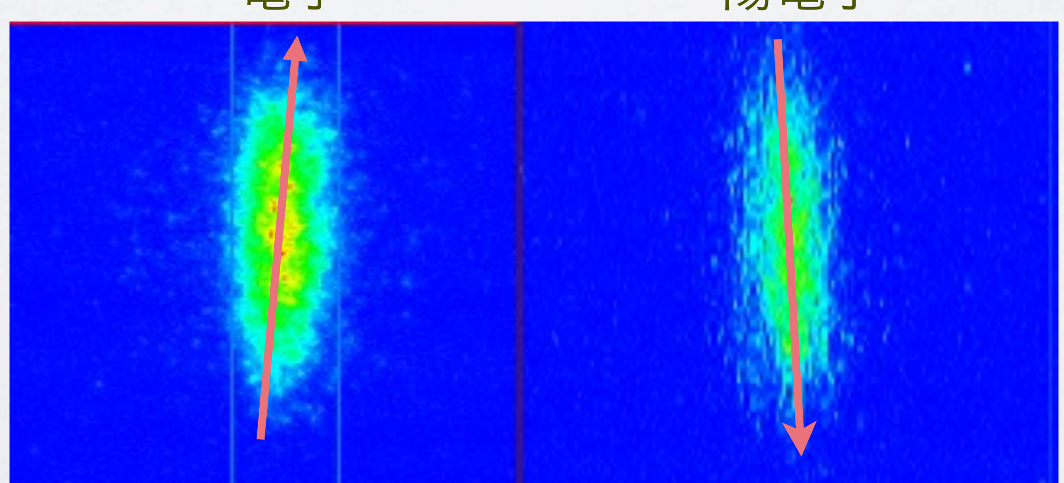


2007年1月、世界初のクラブ空洞がKEKBに各リング1台ずつ装着

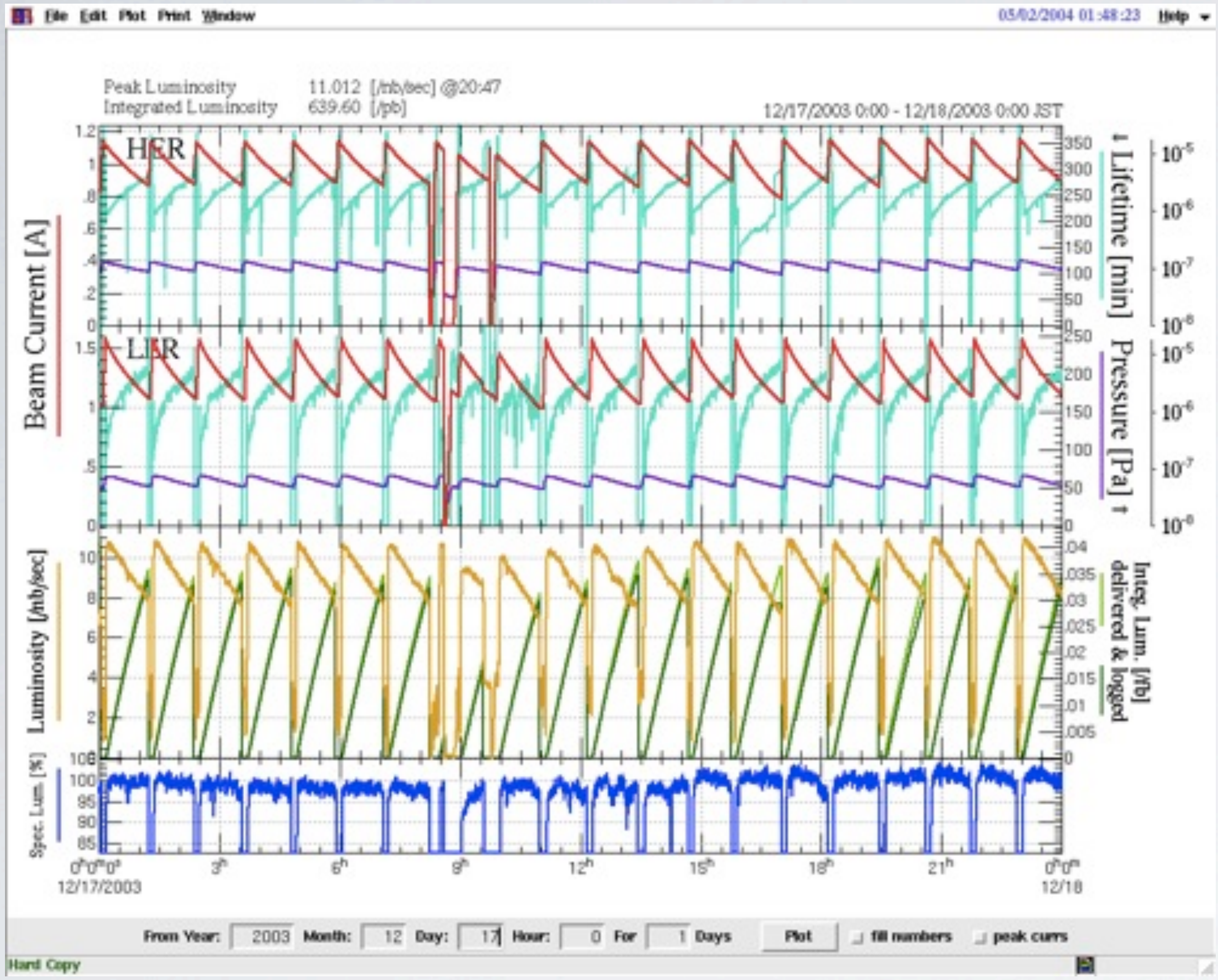
HER (e-, 8 GeV)

LER (e+, 3.5 GeV)

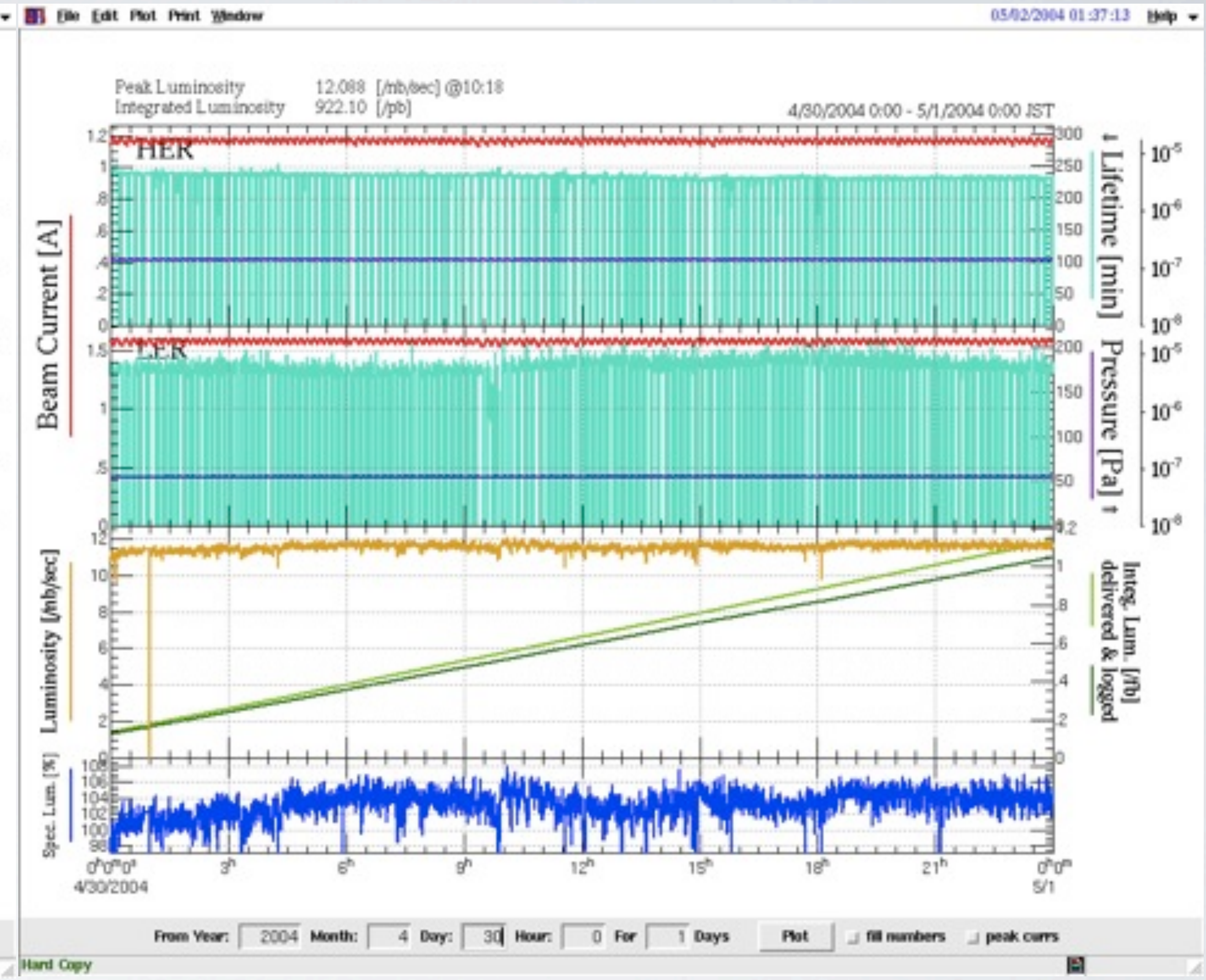
電子　　陽電子



CONTINUOUS INJECTION(TOP-UP)



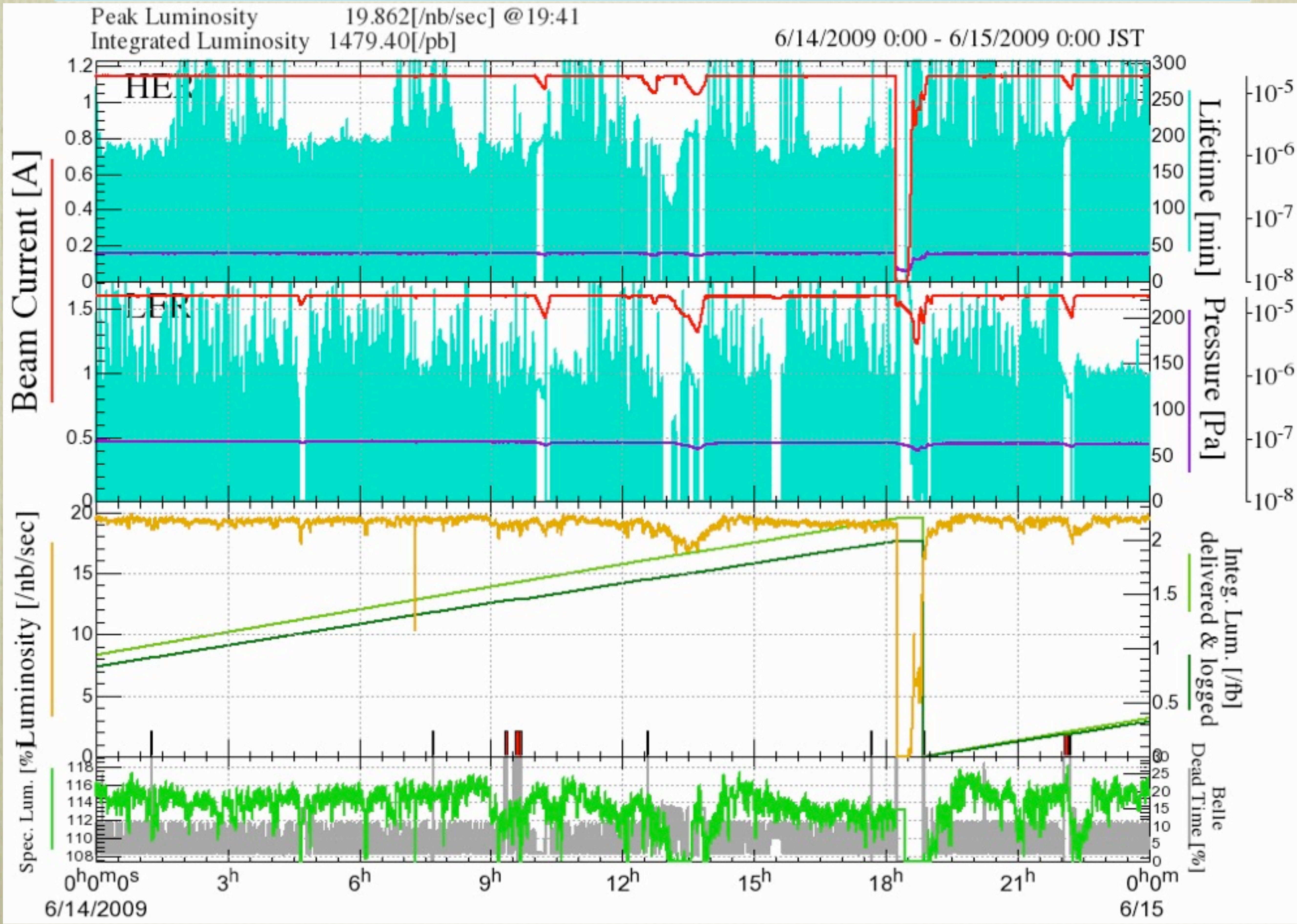
before



after

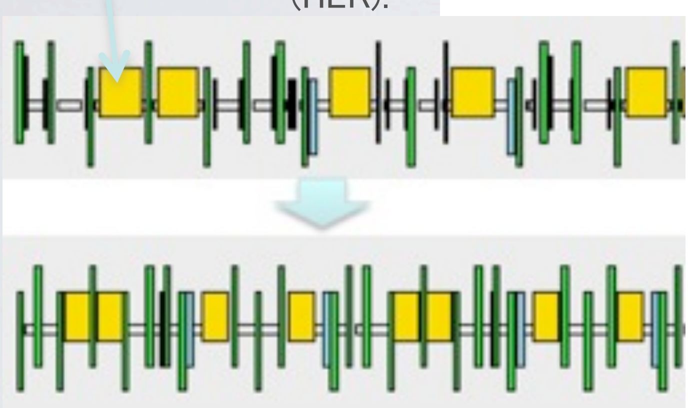
- Belle continues data taking except for 2-4% of the instance of injection.
- Average luminosity was improved by 30%.
- The nearly constant beam current improved the machine stability for further tuning of luminosity.

The power of continuous injection: =1.5 fb^{-1}/day

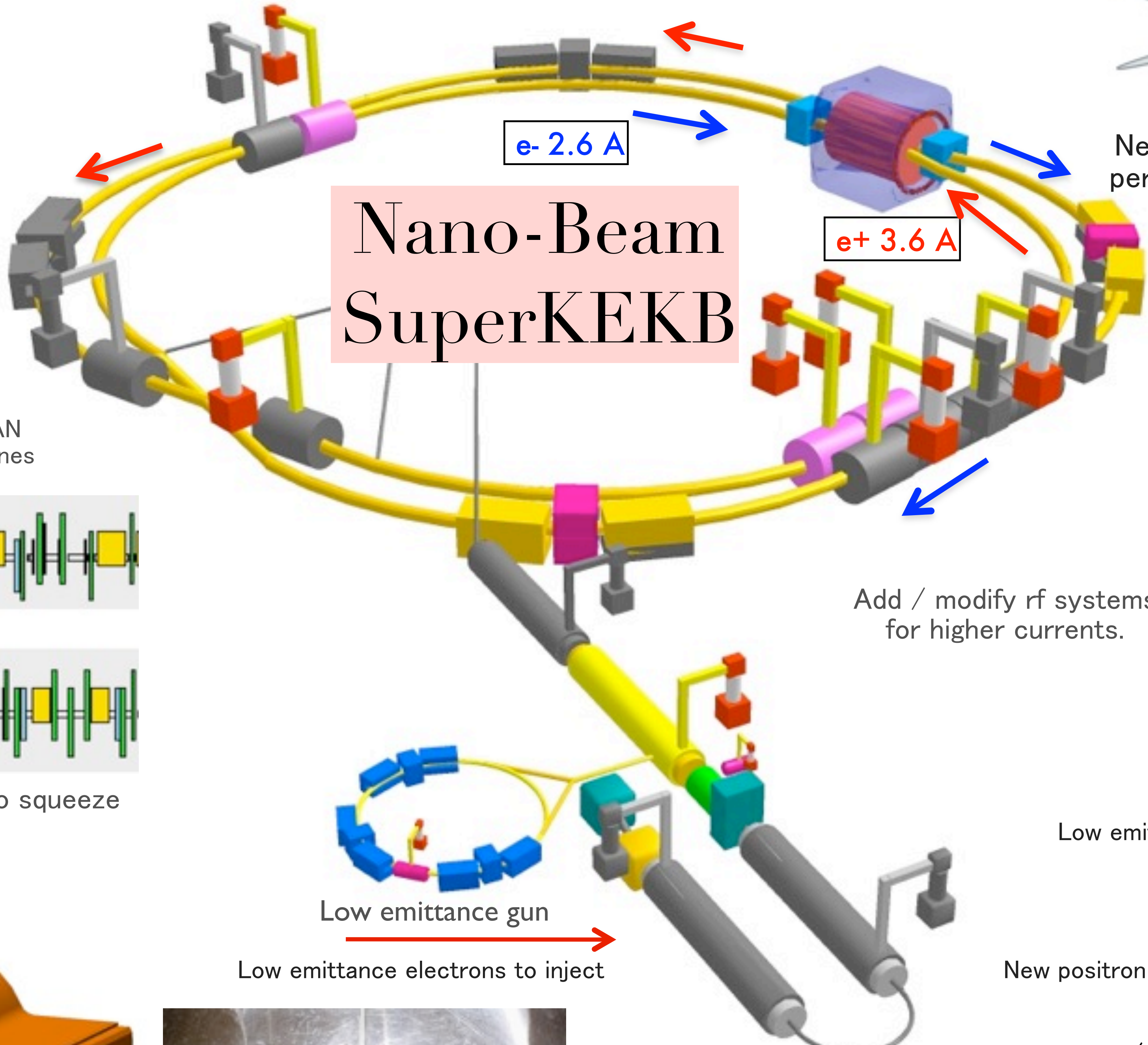


Nano-Beam SuperKEKB

Replace long TRISTAN dipoles with shorter ones (HER).



Redesign the HER arcs to squeeze the emitance.



Low emittance gun

Low emittance electrons to inject

Colliding bunches

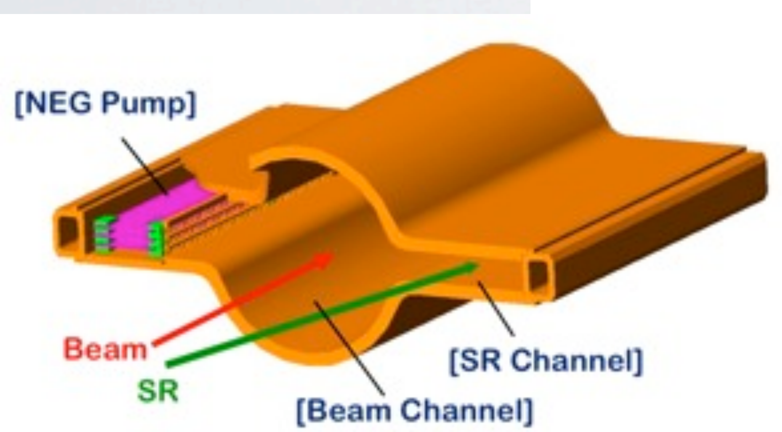
New Superconducting / permanent final focusing quads near the IP

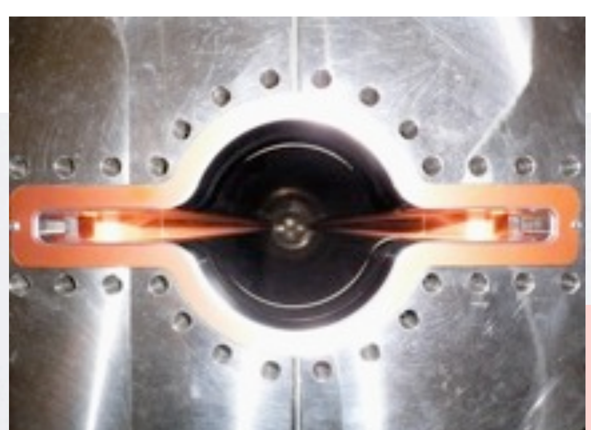
Add / modify rf systems for higher currents.

Low emittance positrons to inject

New positron target / capture section

$$L = \frac{\gamma_\pm}{2 e r_e}\left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$





TiN coated beam pipe with antechambers

x40 Gain in Luminosity

Stored Current:

1.7 / 1.4 A (e^+/ e^- KEKB)

→ 3.6 / 2.6 A (SuperKEKB)

Beam-Beam Parameter:

0.09 (KEKB)

→ 0.09 (SuperKEKB)

Lorentz factor

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

classical elec. radius

beam size ratio

Correction factors due to hour-glass / crossing angle

Luminosity:

0.21×10^{35} $cm^{-2}s^{-1}$ (KEKB)

8×10^{35} $cm^{-2}s^{-1}$ (SuperKEKB)

Vertical β at the IP:

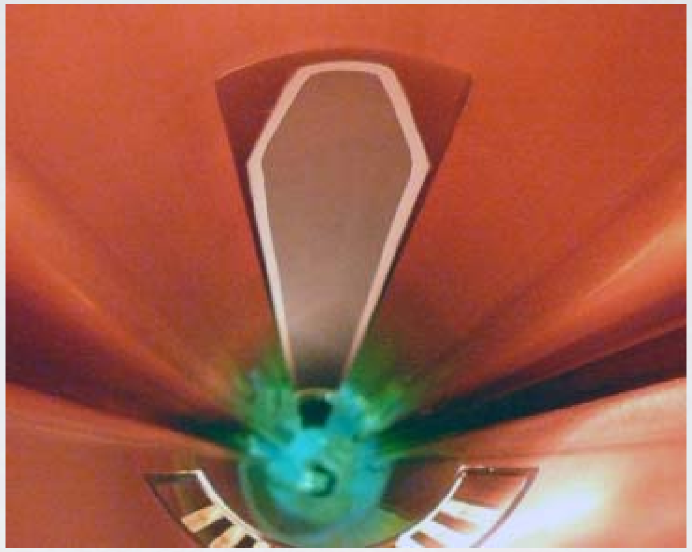
6.5/5.9 mm (KEKB)

→ 0.24/0.42 mm (SuperKEKB)

Major Items to Upgrade

- Beam pipes for both rings: 6 km in total.
  - Al/Cu for LER/HER.
  - Mitigation techniques for suppression of electron cloud.
- New superconducting / permanent magnets around the IP.
- Additional normal magnets to reduce emittance:
  - New longer dipoles / wiggler dipoles for LER.
  - New arc lattice for HER.
  - New IR optics.
  - Precise power supplies.
- Rearrangement of existing ARES cavities with additional power sources.
- Positron damping ring and new positron target.
  - C-band and L-band rf will be utilized.
- New rf gun for electrons with reduced emittance.
- Upgrade of beam diagnostics for better precision and speed.

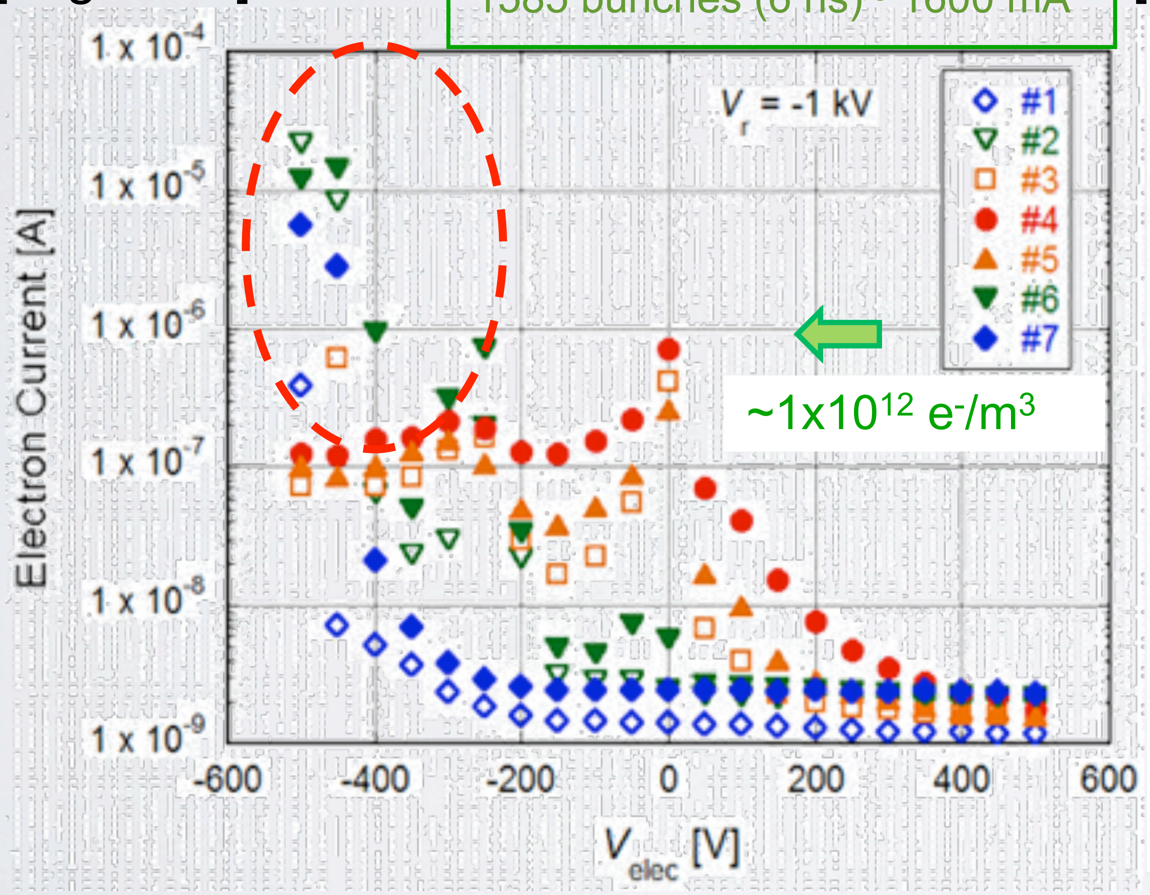
Suppression of Electron Cloud



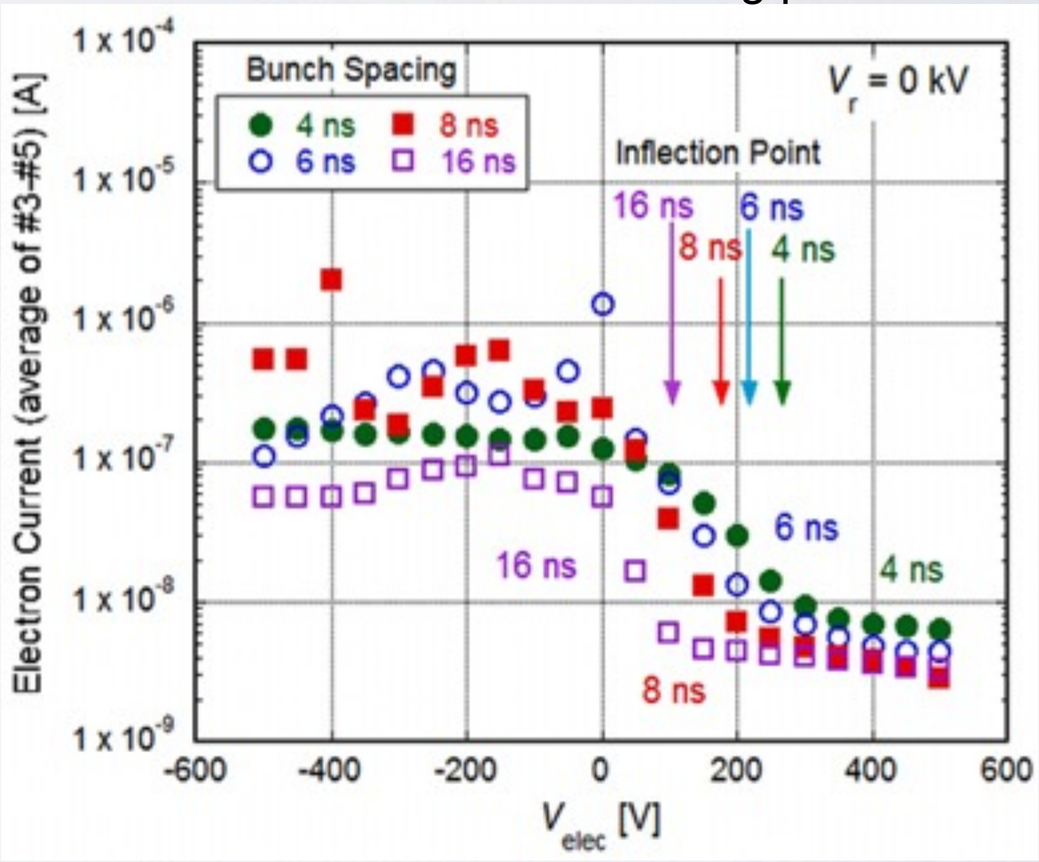
An antechamber with electron-cloud suppression electrodes.

[Log scale]

1585 bunches (6 ns)~ 1600 mA



[Log scale] Different bunch filling patterns

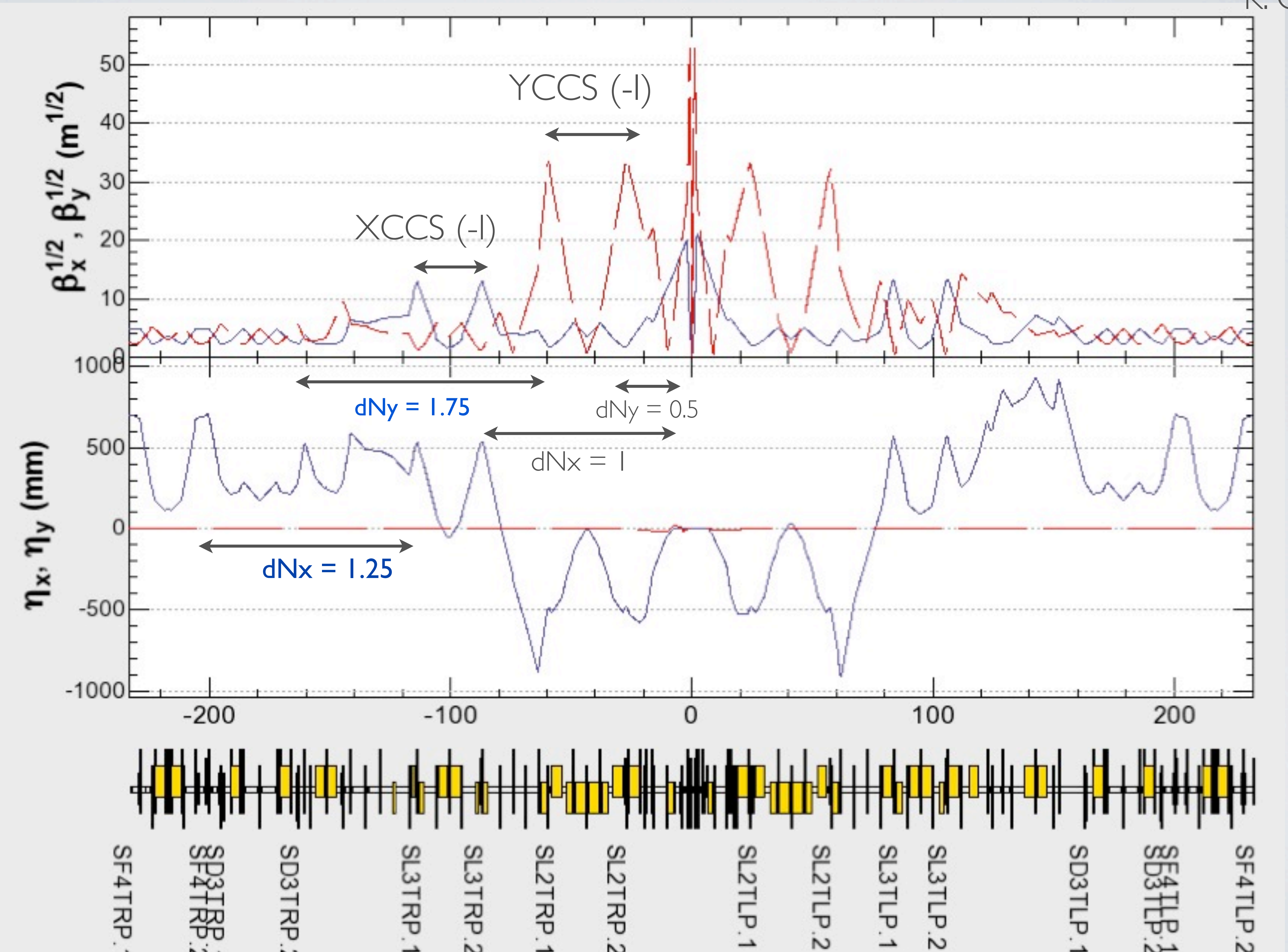


Electron cloud density decreased to 1/10 at V = +200 V, 1/100 at V = +500 V.

Y. Suetsugu

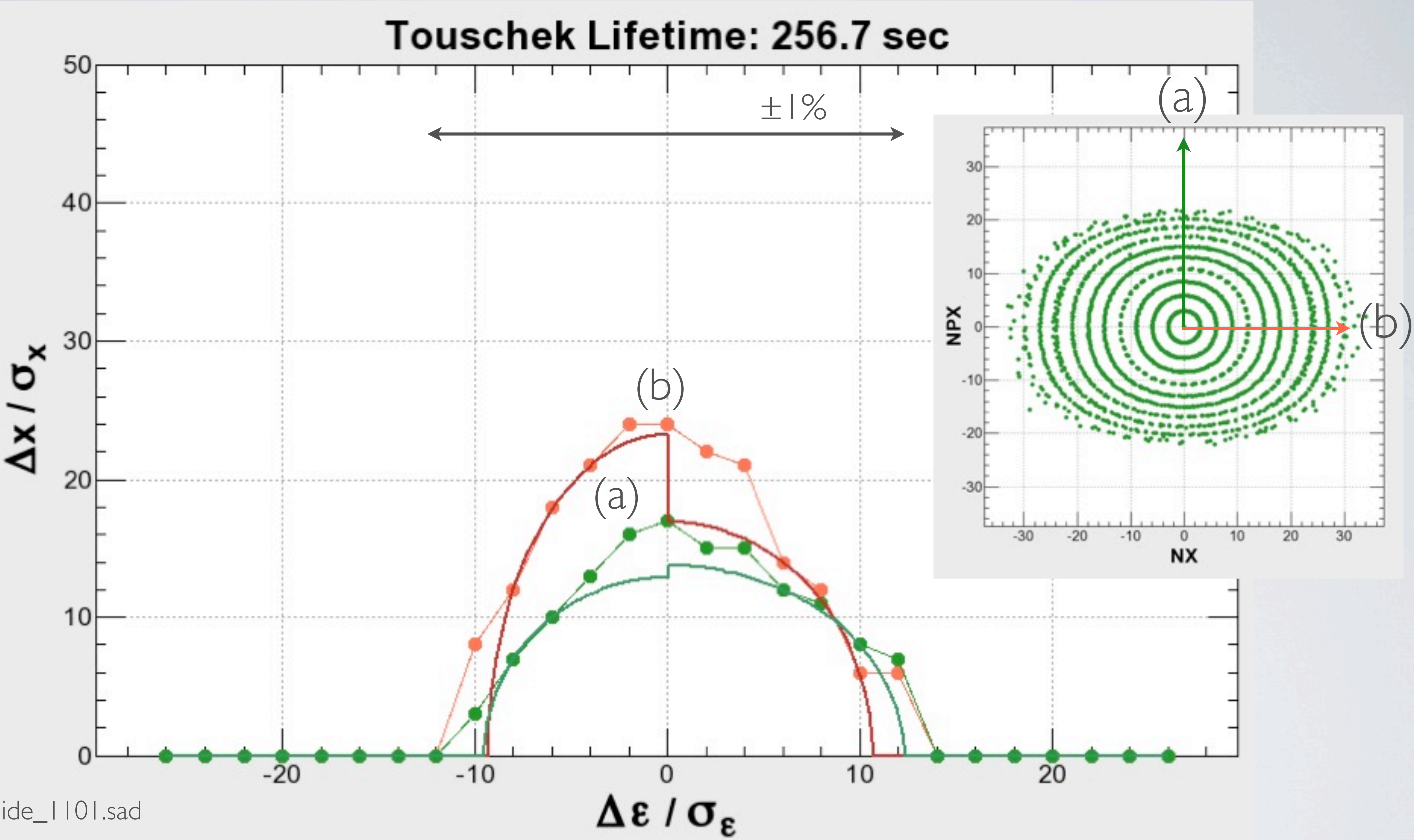
LER 2 Family Local Chromaticity Correction

K. Oide



lerfqlc_Oide_1101.sad

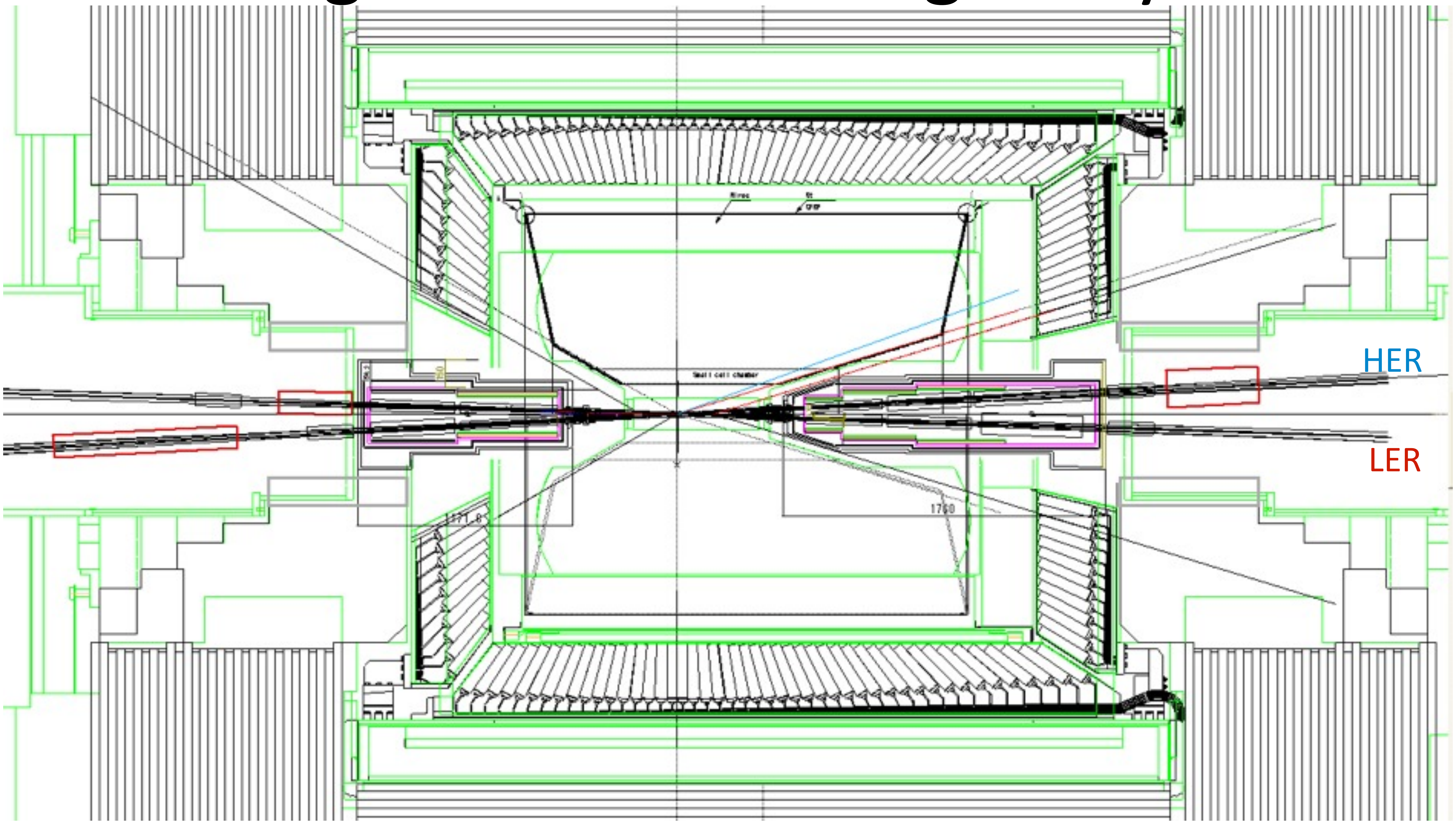
Dynamic Aperture with LER 2-family LCCS



lerfqlc_Oide_1101.sad

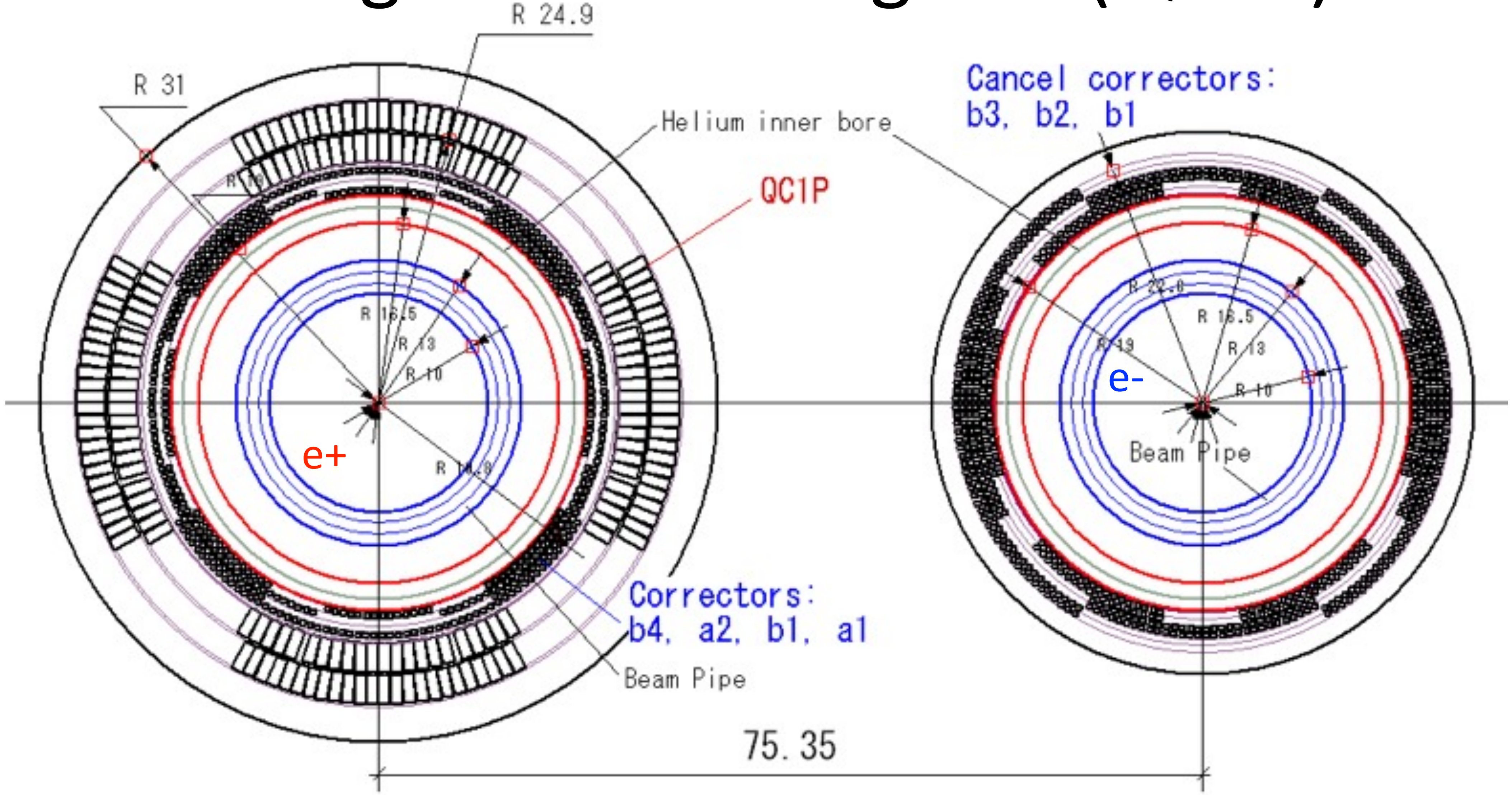
- Emittances: Hor.: 3.0 nm with intrabeam (4 GeV, 3.6 A, 2500 bunches, 0.4% coupling). Ver: 4.2 pm @ 0 current, with SOL F1. βx = 32 mm, βy = 0.27 mm.
- Solenoid V3 in the IR.   Skew sexts at SL2,SL3,SD3T,SF4T
- Sextupoles are optimized by downhill simplex method looking at the lifetime.

Configuration of IR magnet system



5 SC main qadrupoles (QC1RP, QC1RE, QC2RP, QC1LP, QC1LE)
3 permanent quadrupoles (QC2RE, QC2LP, QC2LE)
2 SC compensation solenoids
32 SC correction coils

Design of IR SC magnets (QC1P)



Magnet design (QC1RP and QC1LP)

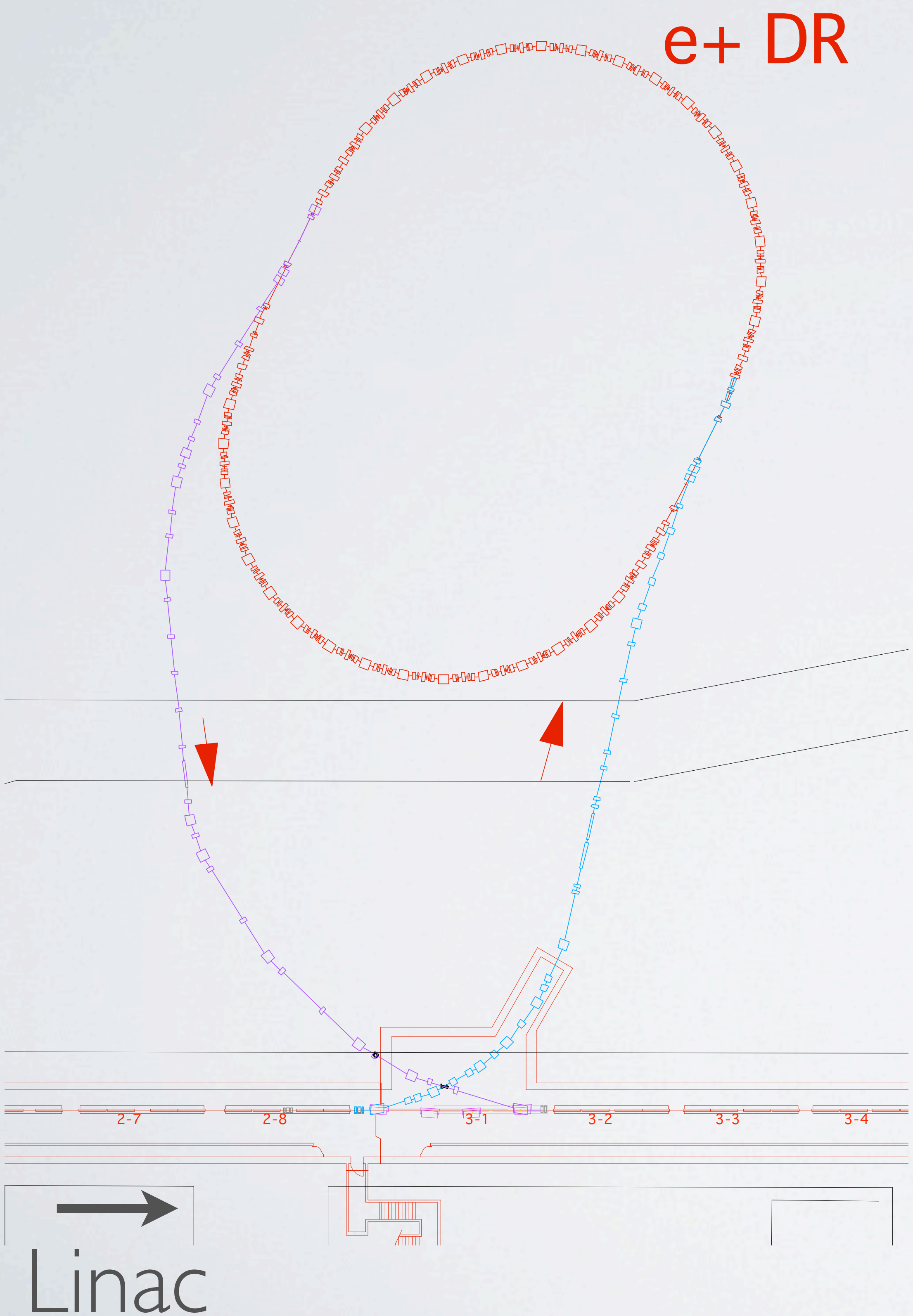
- Same design of the cross section for QC1RP and QC1LP
- 2 layer coils [double pancake type]
- Designed SC cable [under development]
  - Cable size : 2.5 mm in height, and 0.93 mm in width
  - SC strand cable : ϕ 0.5 mm, 10 wires in the cable
- SC correctors inside of the magnet bore
  - b_4, a_2, b_1, a_1 from the inside
  - Single layer coil
- Beam pipe : warm tube, inner radius=10 mm

SC cancel correctors against the leak field from QC1P

- b_3, b_2, b_1 from the inside

Beam pipe : warm tube , inner radius=10 mm

Positron Damping Ring



- 1 GeV, C ≈ 136 m.
- 50Hz, up to 8 nC / bunch, 2 bunches / pulse, 4 bunches / ring.
- Energy / bunch compression at injection / extraction.
- Electron cloud will be mitigated by TiN coating and solenoid windings.
- Components have been funded.

Table 2: Parameters of the Damping Ring

Energy	1.0	GeV
Number of bunch trains	2	
Number of bunches/train	2	
Circumference	135.50207	m
Maximum stored current	70.8	mA
Energy loss per turn	0.0714	MV
Horizontal damping time	12.66	ms
Injected-beam emittance	2100	nm
Equilibrium emittance	12.6	nm
Emittance at extraction	16.3	nm
Energy band-width of injected beam	$\pm$ 1.5	%
Bunch length of injected beam	6.05	mm
Energy spread	5.25×10^{-4}	
Bunch length	5.03	mm
Bend-angle ratio	0.35	
Phase advance/cell	1.903/.480	rad
Momentum compaction factor	0.0019	
Number of normal-cells	40	
Cavity voltage for 1.5% bucket-height	0.261	MV
RF frequency	509	MHz
Chamber diameter(normal cell)	32	mm

Plan of Luminosity Upgrade