Injector Upgrade for SuperKEKB

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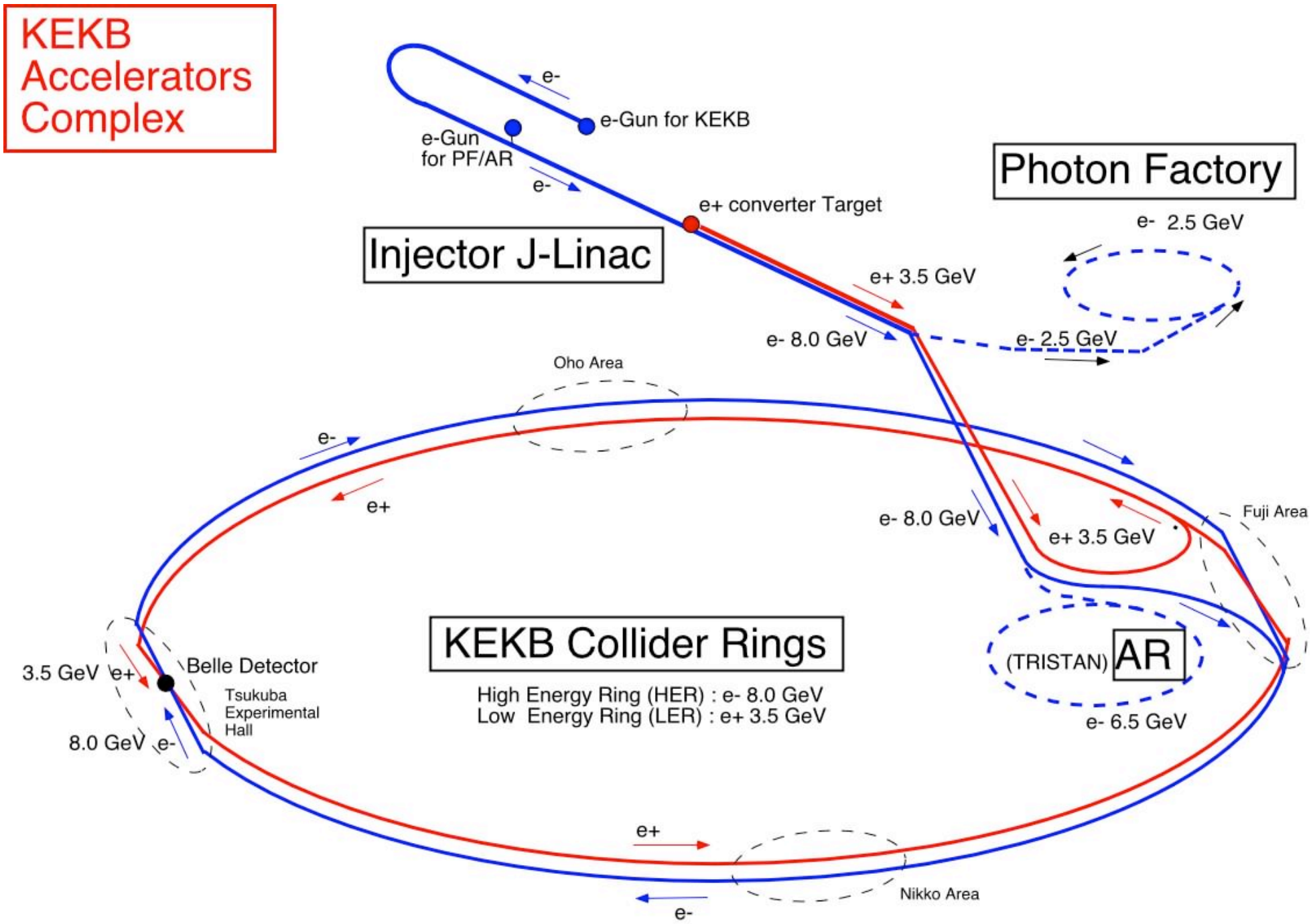
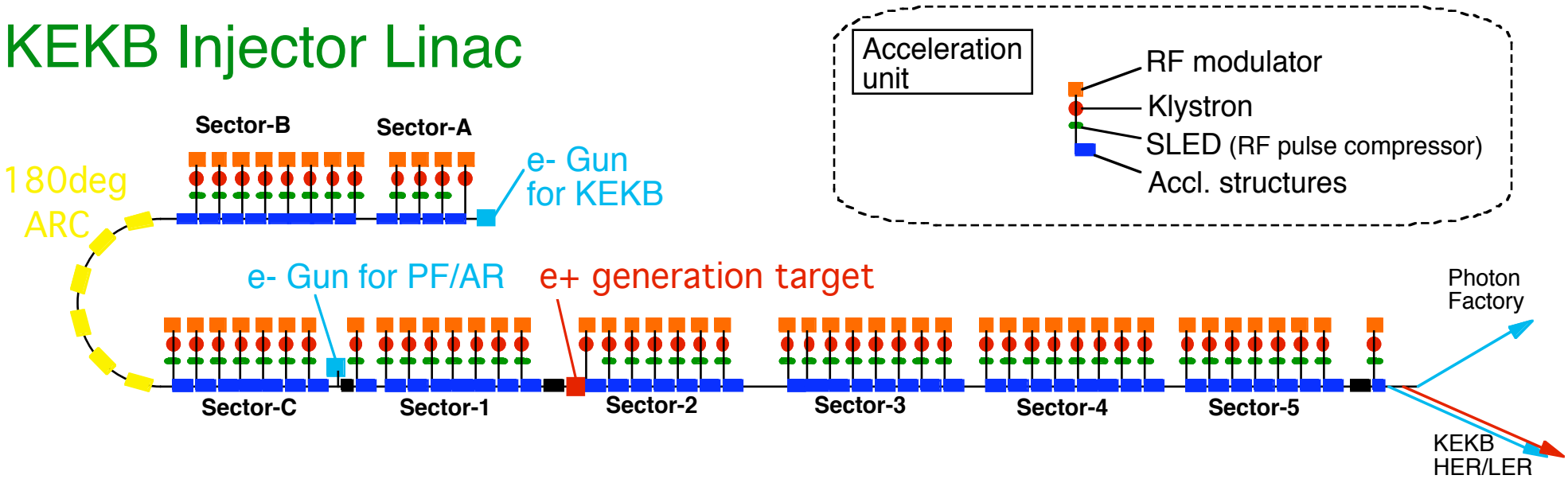

KEKB
Accelerators
Complex
e-
e-Gun for KEKB
e-Gun
for PF/AR
e-
e+ converter Target
Injector J-Linac
Photon Factory
e- 2.5 GeV
e+ 3.5 GeV
e- 8.0 GeV
e- 2.5 GeV
Oho Area
e-
e+
e- 8.0 GeV
e+ 3.5 GeV
Fuji Area
KEKB Collider Rings
High Energy Ring (HER) : e- 8.0 GeV
Low Energy Ring (LER) : e+ 3.5 GeV
(TRISTAN) AR
e- 6.5 GeV
3.5 GeV e+
Belle Detector
Tsukuba
Experimental
Hall
8.0 GeV e-
e+
Nikko Area
e-

KEKB Injector Linac



Energy gain /

Acceleration field	21 MV/m
Accl. structure length	1.928 m
# of Accl. structures	4 /unit

→ 160 MeV/

Total Energy gain potentiality

e- to HER:	(160 MeV/unit)×(55 accl. units) = 8800 MeV
e+ to LER:	(160 MeV/unit)×(29 accl. units) = 4640 MeV
e- to Target:	(160 MeV/unit)×(26 accl. units) = 4160 MeV

KEKB Injector Linac Performance

	Electron (e-)	Positron (e+)
Beam Energy	8.0 GeV	3.5 GeV
Charge	1.0 nC/pulse (single bunch / pulse)	0.64 nC/pulse (single bunch / pulse)
Emittance (normalized)	800 mm.mrad	2500 mm.mrad
Energy spread (full width)	< 0.5%	0.5 %
Injection rate	3.0 mA/sec	1.5 mA/sec

SuperKEKB Requirements to Injector

	KEKB		SuperKEKB
Beam Energy (e-)	8.0 GeV	----->	3.5 GeV
(e+)	3.5 GeV	----->	8.0 GeV !!

NEED Energy upgrade for e+ !

	Feb. 2002	KEKB design	SuperKEKB
Stored current (e-)	0.9 A --->	1.1 A --->	9.4 A !!
(e+)	1.3 A --->	2.6 A --->	4.1 A !!

NEED Intensity upgrade for e-/e+ !

(1) Energy Upgrade

How to increase e^+ Energy ?

Two schemes under consideration

(A) Higher Acceleration Field scheme

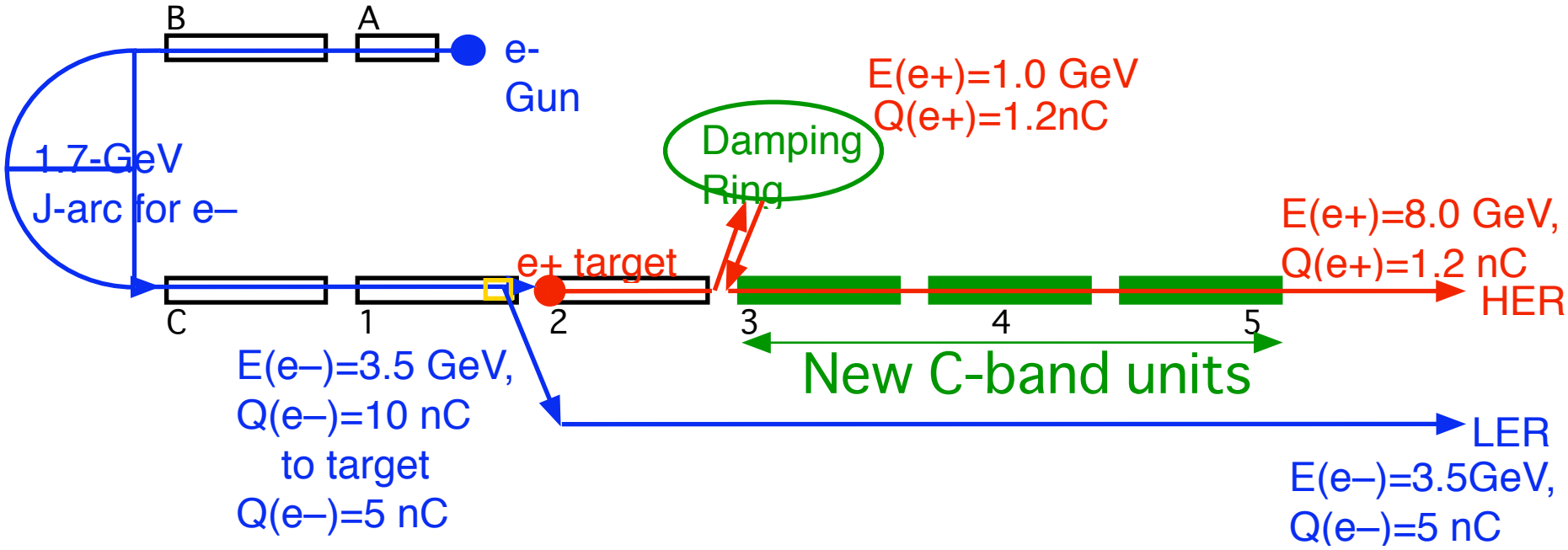
Doubling Acceleration Field (21 -> 42 MV/m)
with C-band system

(B) Beam Recirculation scheme

Recirculate e+ beam
with Damping ring and beam return line
in synchronous to next RF pulse

--> Multi-Beam acceleration in same RF pulse
(primary e- and e+) (high E e+ and low E e+)

(A) Higher Acceleration Field scheme



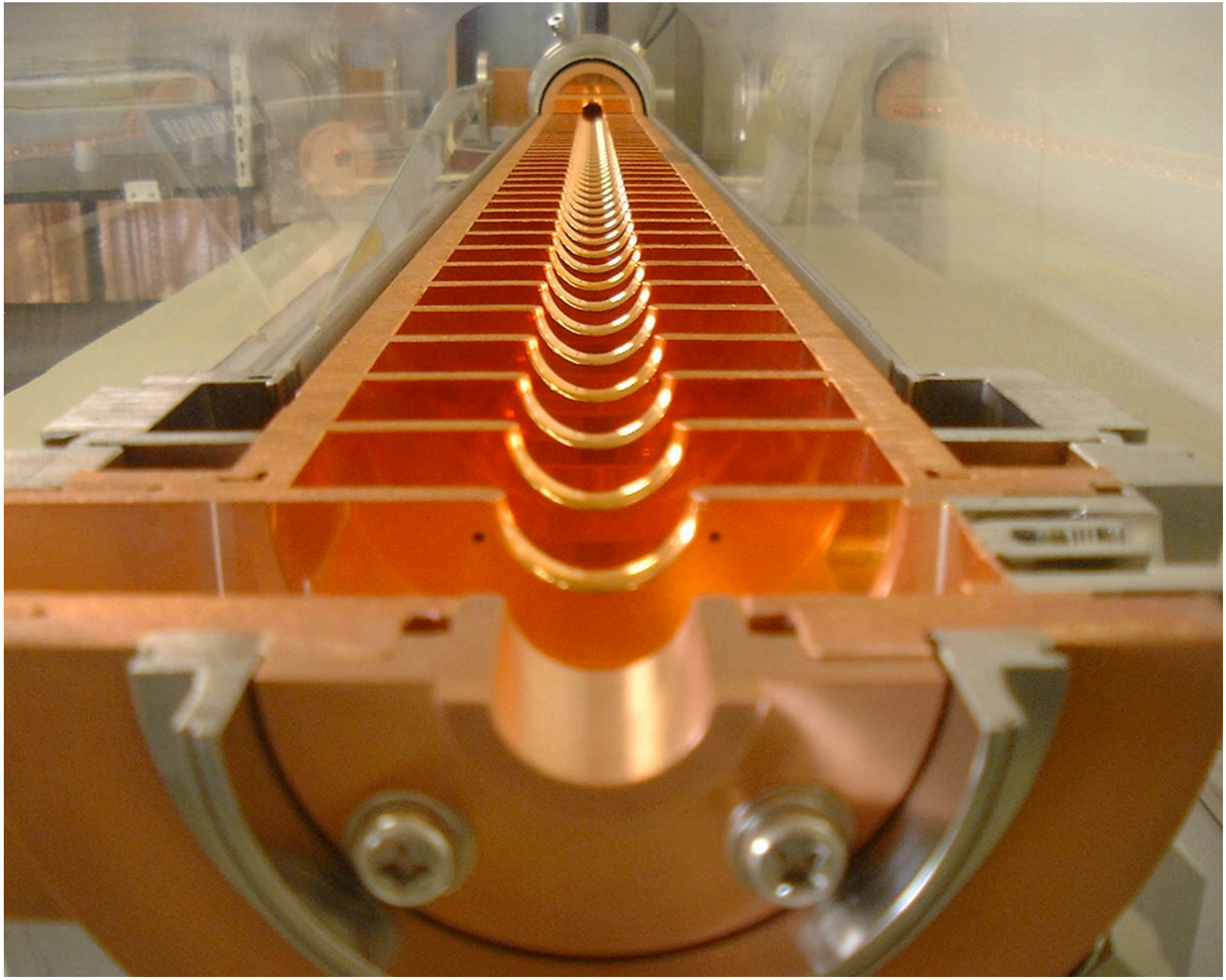
24 accl. units are Replaced to C-band (E_{acc} = 21 -> 42 MV/m)

(E_{gain} = 160 -> 320 MeV/unit)

(max. e+ total E_{gain} = 4640 -> 8640 MeV)

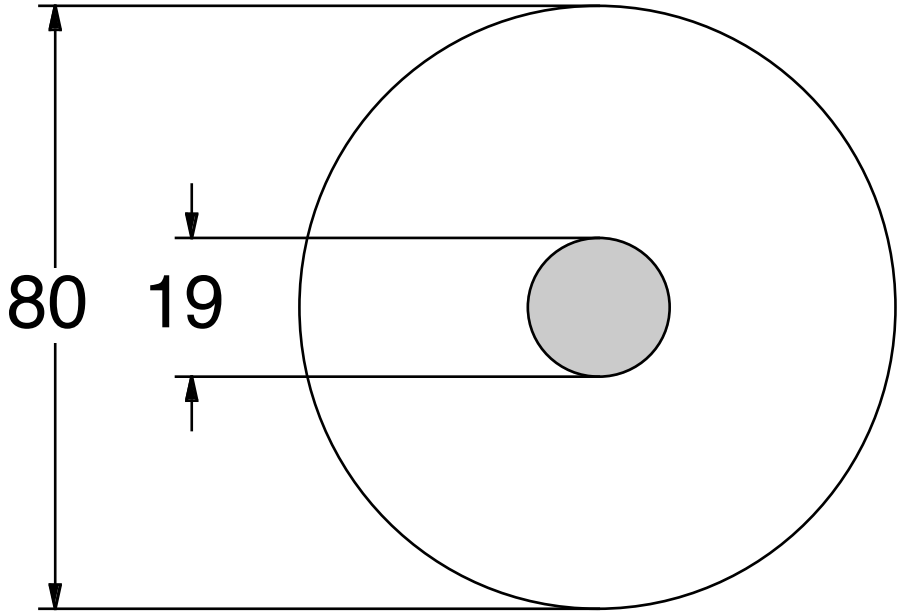
e+ Damping Ring for smaller emittance and beam size to fit for smaller aperture in C-band accl. structures

S-band (2856 MHz) accelerating structure



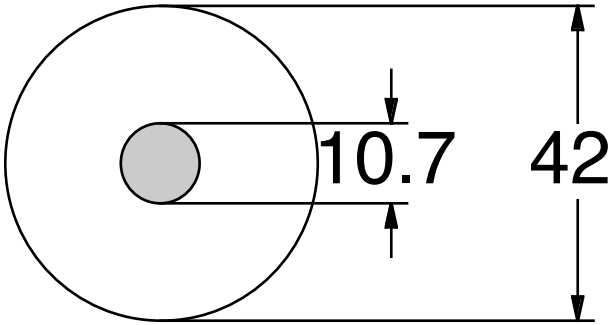
Comparison of accelerating structures

S-band accl. structure



Accl. Field = 21 MV/

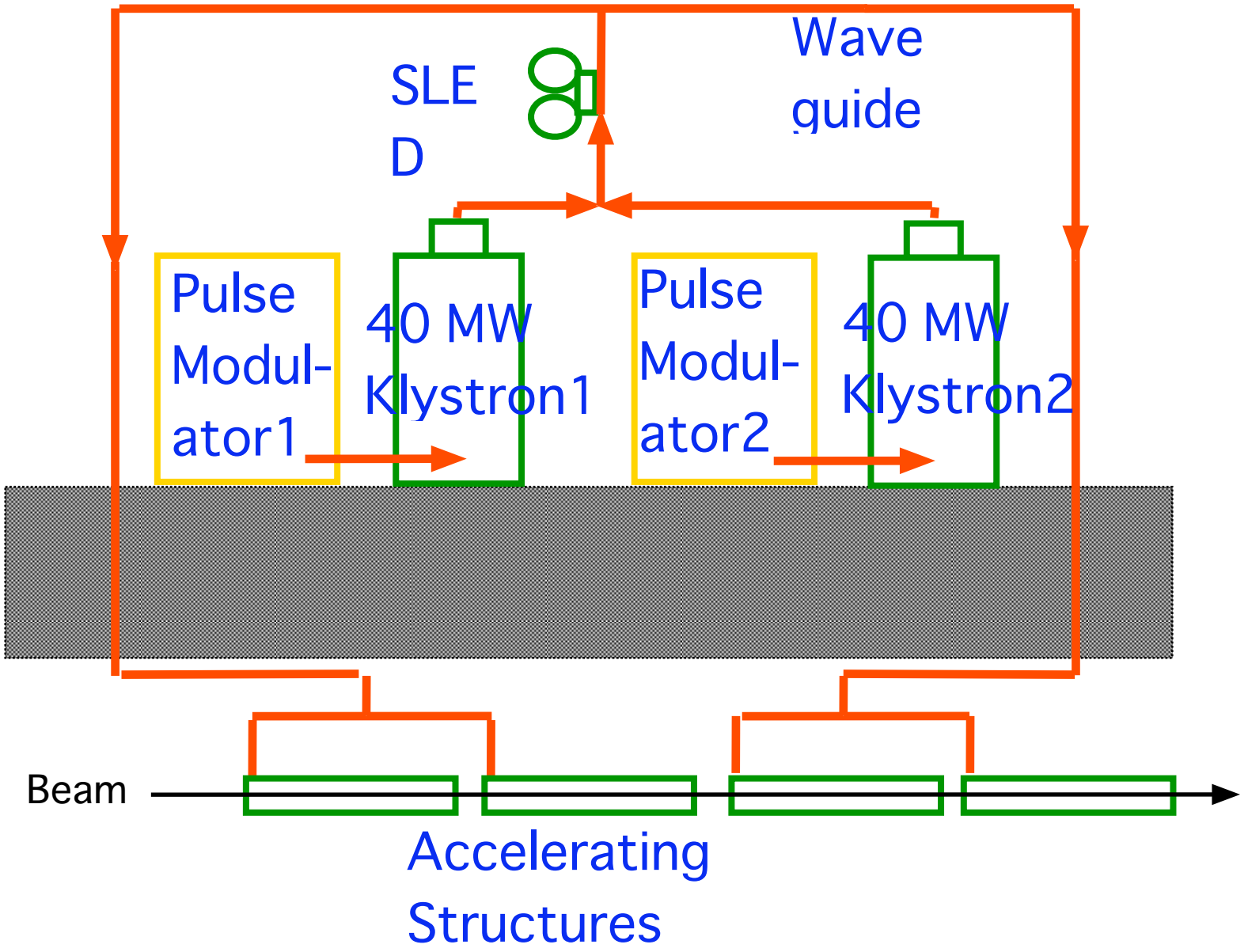
C-band accl. structure (5712 MHz)



(Unit : mm)

Accl. Field = 42 MV/

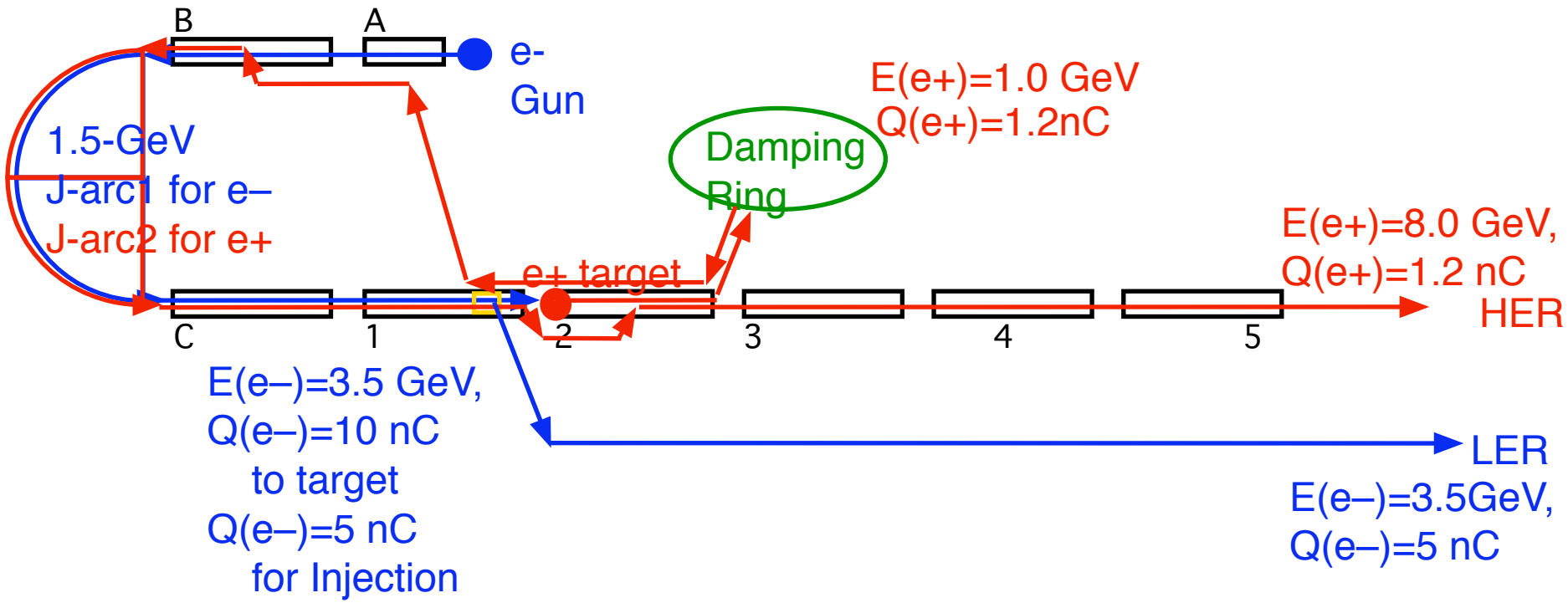
New accelerating unit for C-band structures



C-band accelerating structure parameters for 42 MV/m

	S-band (present)	C-band unit
RF frequency (f)	2856 MHz	5712 MHz
Mode	2/3 p	2/3 p
shunt impedance (r_0)	57 MW	75 MW
Quality factor (Q)	13700	9700
group velocity (v_g)	0.012 c	0.019 c
RF power from Klystron	41 MW 4 msec	2 x 40 MW 2 msec
Power multiplication	3.4 with SLED	3.4 with SLED/LIPS
Acceleration Field (E_0)	21 MV/m	42 MV/m

(B) Beam recirculation scheme



No significant Upgrade in RF sources & acclerating structures

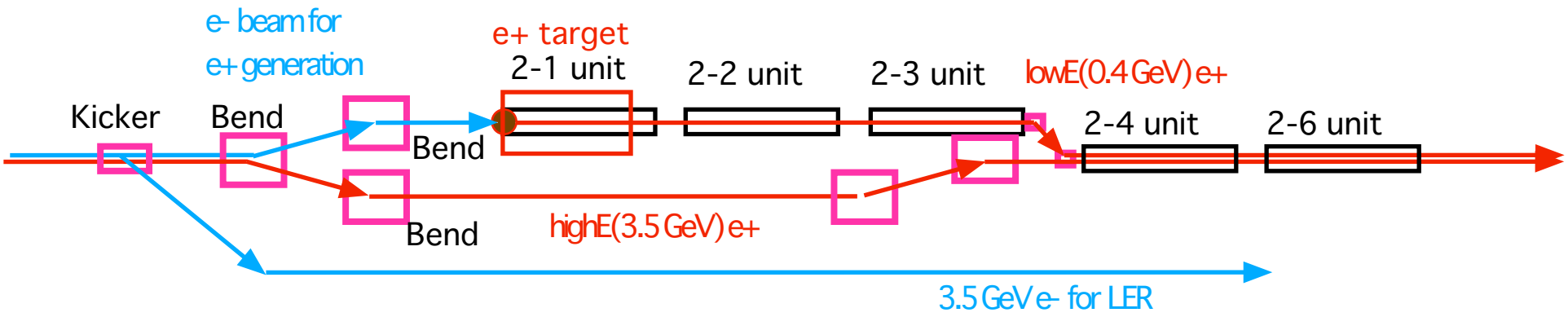
e+ Damping Ring for synchronization to next RF pulse

e+ beam return line, 2nd J-arc for e+, target-bypass beam line

--> Multi-Beam acceleration in same RF pulse

(primary e- and e+) (high E e+ and low E e+)

For the simultaneous acceleration of
e- and e+ beam and
low Energy e+ and high Energy e+ beams
complicated transport line is
necessary.



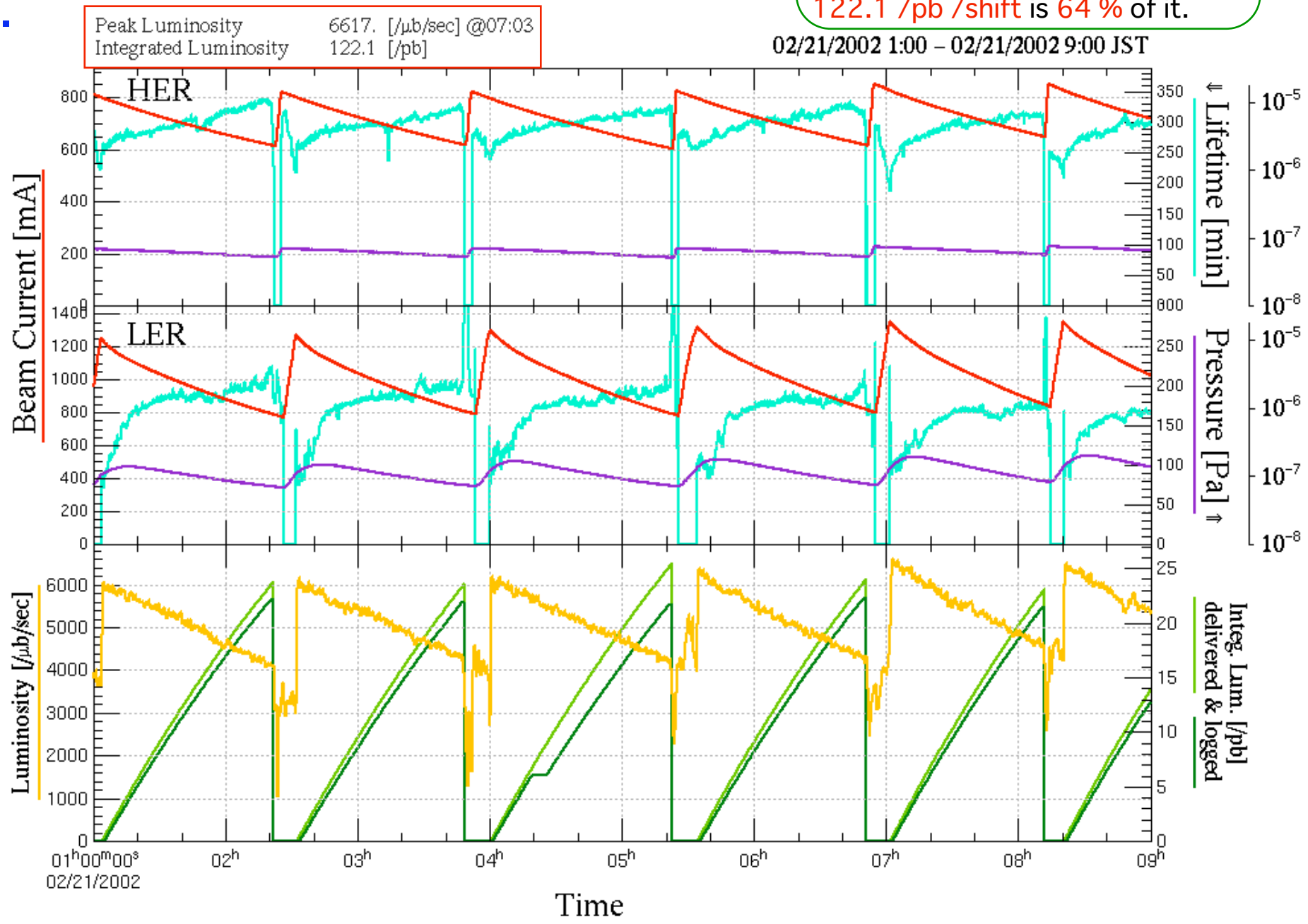
(2) Intensity Upgrade

How much increase ?

How to increase ?

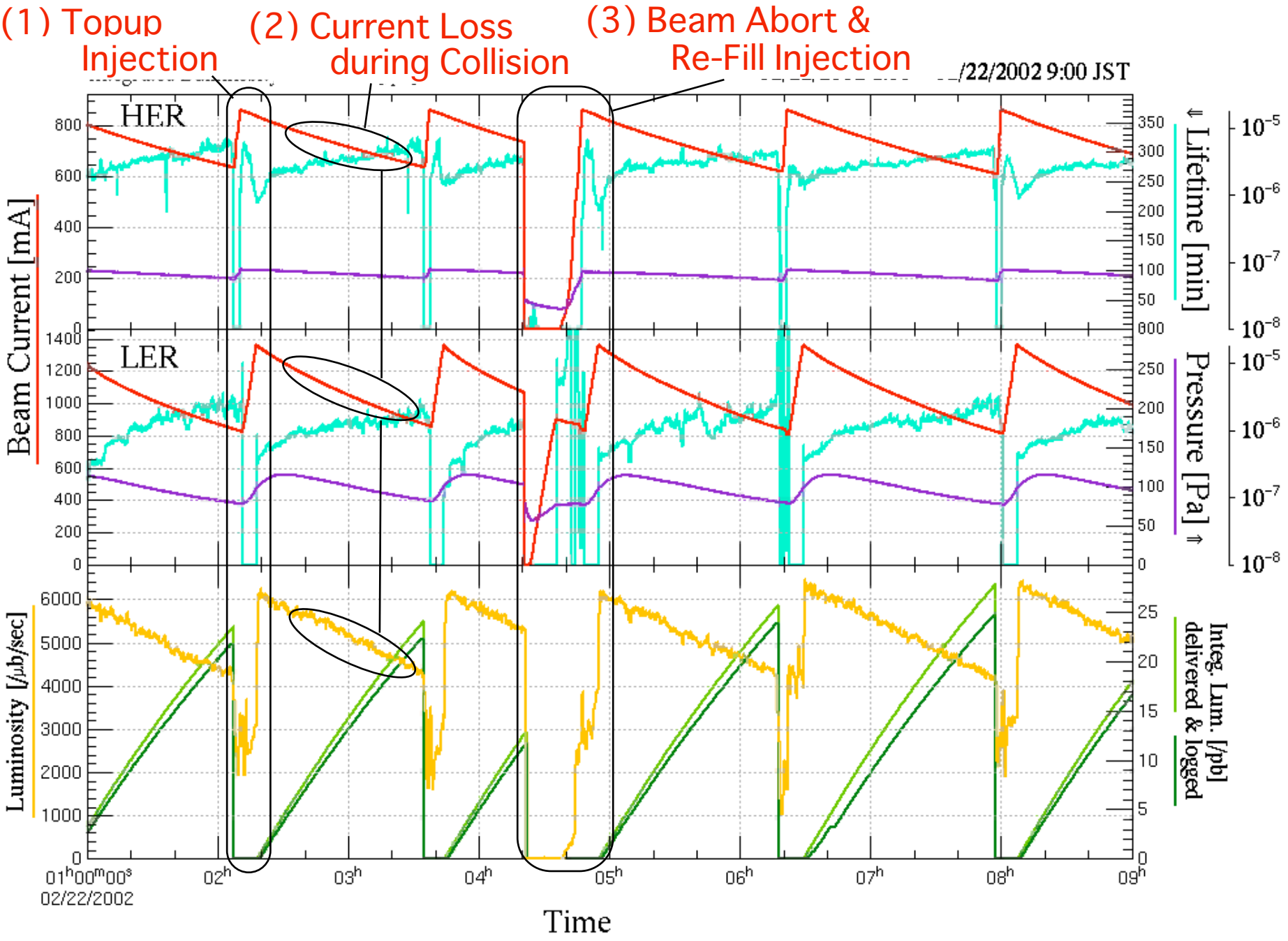
Best Shift (8hours) 2002 Feb.

If L_{Peak} continues for 8 Hours
=> 190 /pb /shift
122.1 /pb /shift is 64 % of it.



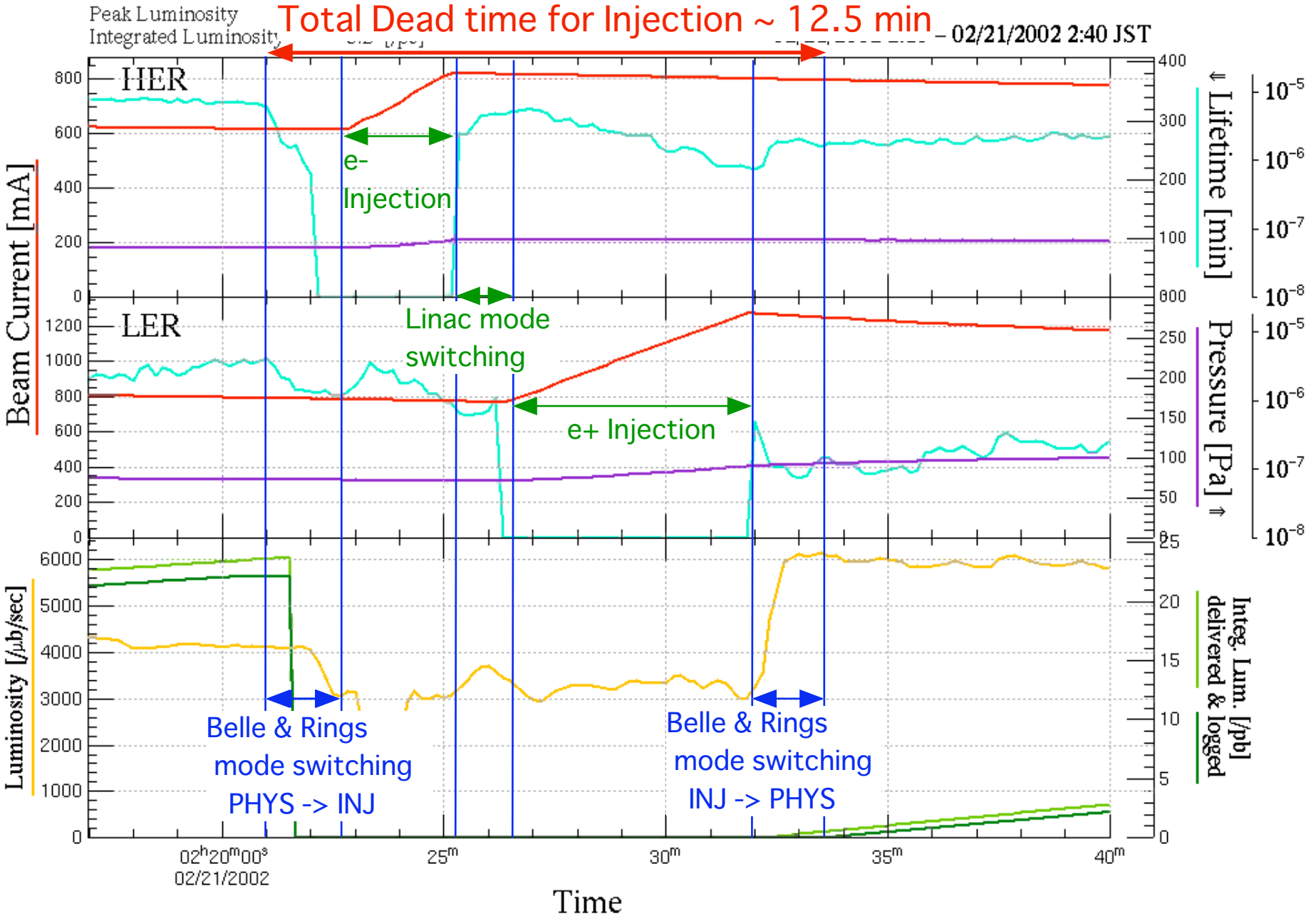
Inefficiency

Fac

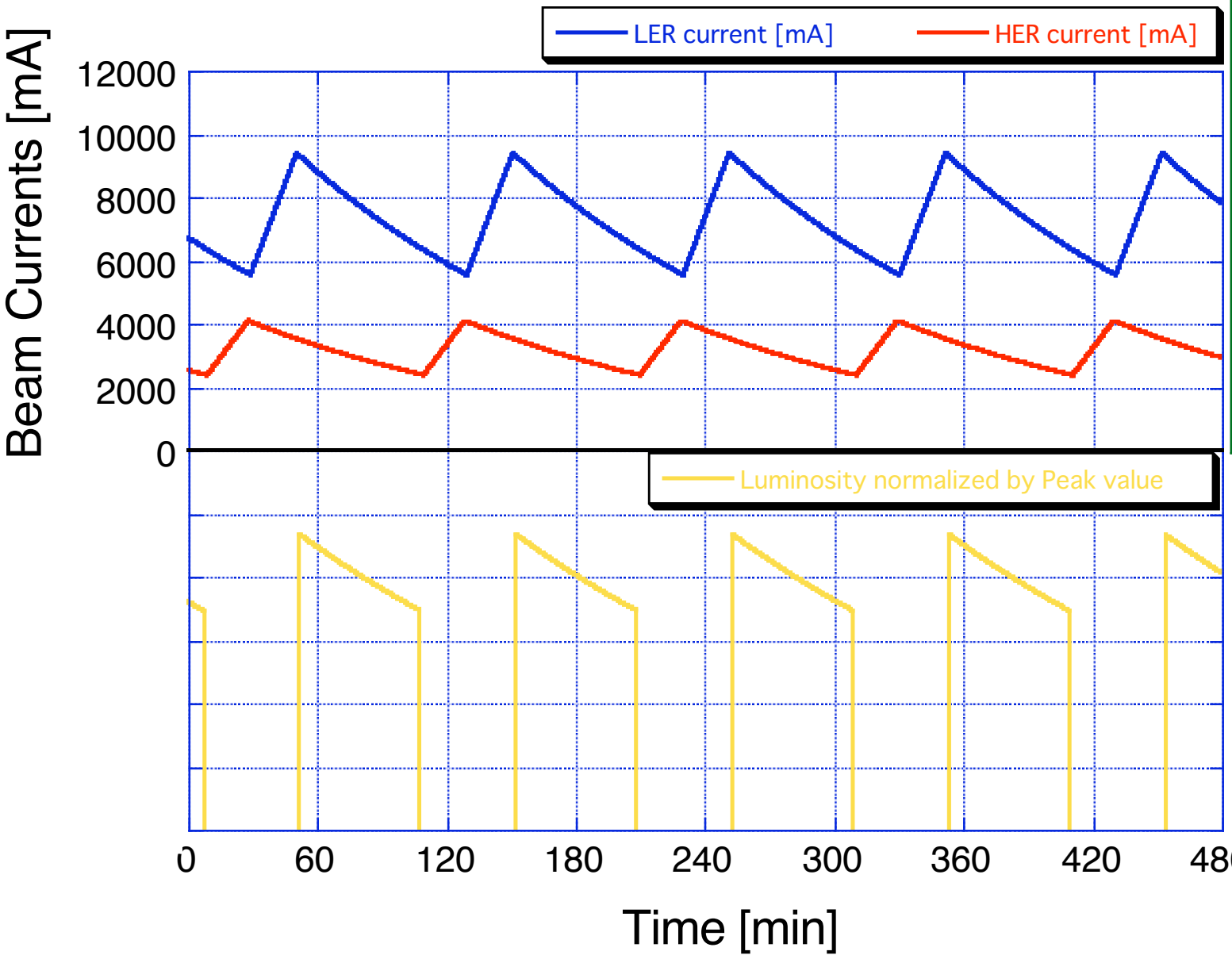


Topup Injection time

Injection interval ~ 86 min



Simulated Run status



SuperKEKB
(present INJ rate)

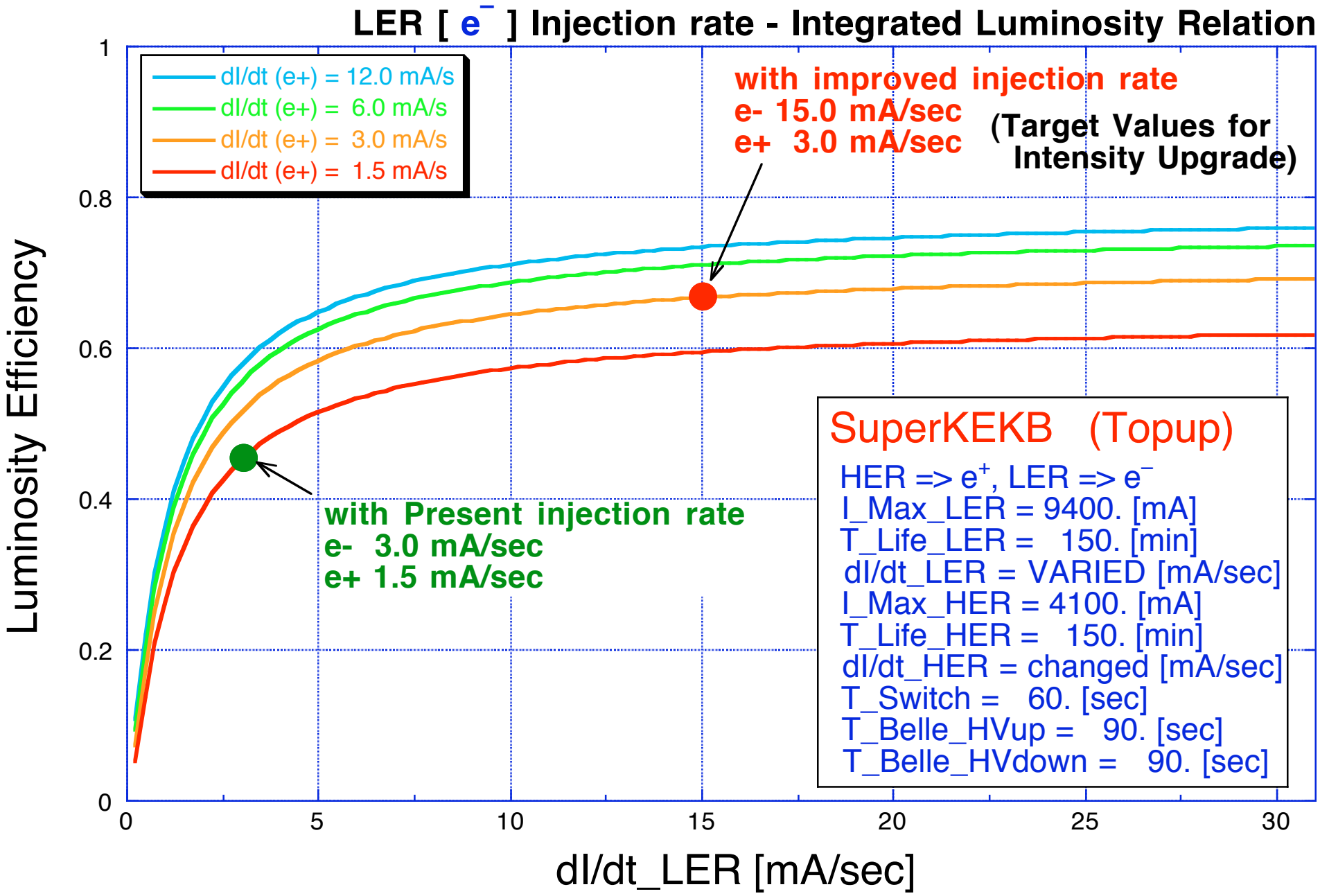
[HER e+]
dI/dt = 1.5 mA/sec
max current = 4100 mA
lifetime = 150 min

[LER e–]
dI/dt = 3.0 mA/sec
max current = 9400 mA
lifetime = 150 min

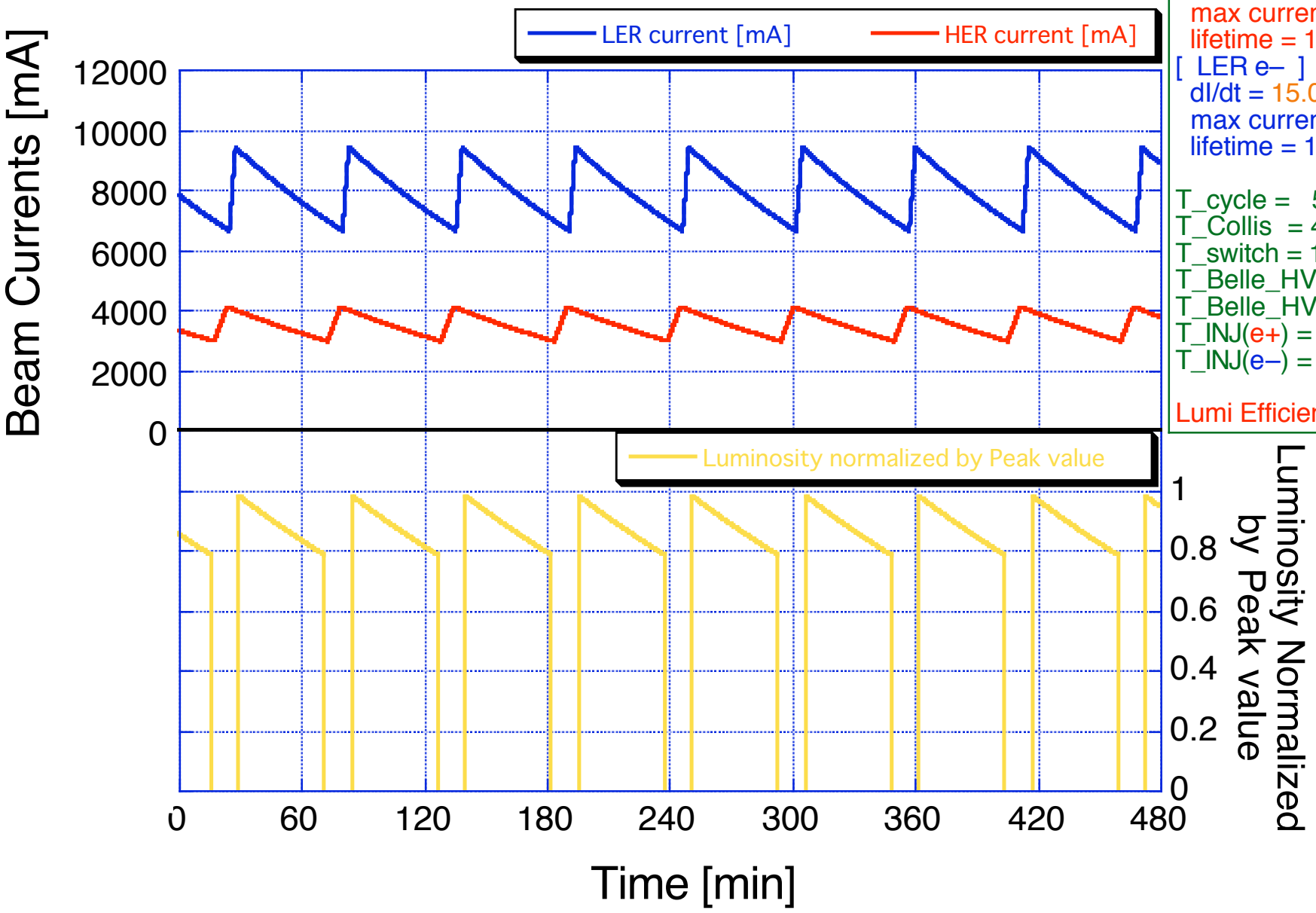
T_cycle = 100 min
T_Collis = 59 min
T_switch = 1.0 min
T_Belle_HVup = 1.5 min
T_Belle_HVdw = 1.5 min
T_INJ(e+) = 19.1 min
T_INJ(e–) = 21.4 min

Lumi Efficiency = 0.450

Improvement By Intensity Upgrade



Simulated Run status



SuperKEKB
(improved INJ rate)

[HER e+]
dI/dt = 3.0 mA/sec
max current = 4100 mA
lifetime = 150 min

[LER e–]
dI/dt = 15.0 mA/sec
max current = 9400 mA
lifetime = 150 min

T_cycle = 56 min
T_Collis = 45 min
T_switch = 1.0 min
T_Belle_HVup = 1.5 min
T_Belle_HVdw = 1.5 min
T_INJ(e+) = 6.4 min
T_INJ(e–) = 3.1 min

Lumi Efficiency = 0.667

New Ideas

(1) By Continuous Injection,

--> No gradual Current Loss (e+, e-)
--> No dead time of Beam injection
except Belle data acquisition VETO (2 ms)
--> No dead time of Belle Detector HV Up/Down
--> Less injection current (to make up only gradual loss)

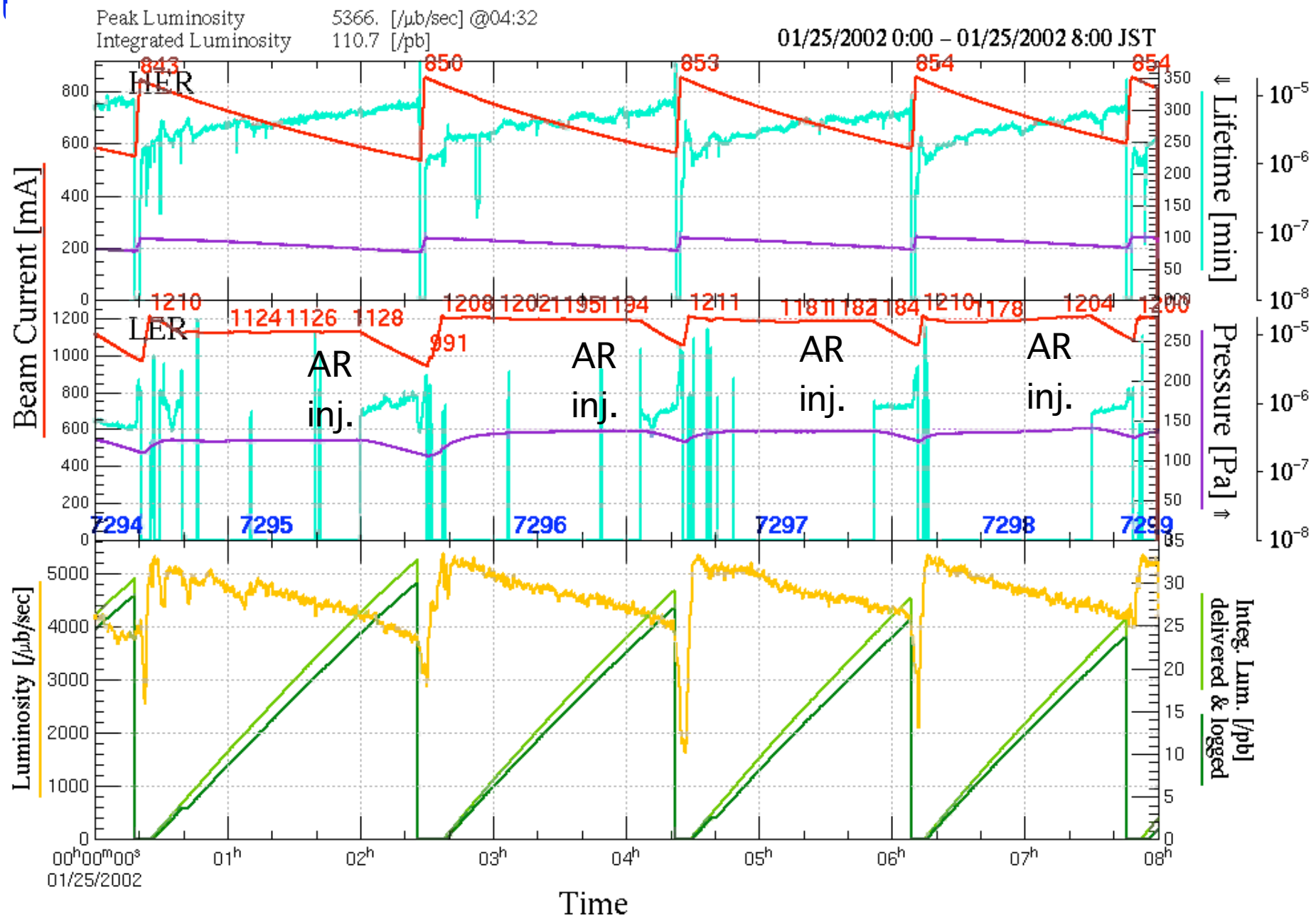
		present
dI/dt (e- Inj.) = 1.01 mA/s	<<	3.0 mA/s
dI/dt (e+ Inj.) = 0.46 mA/s	<<	1.5 mA/s

(assuming LER e- 9.4A, HER e+ 4.1A, lifetime 150min)

(GOOD NEWS !!)

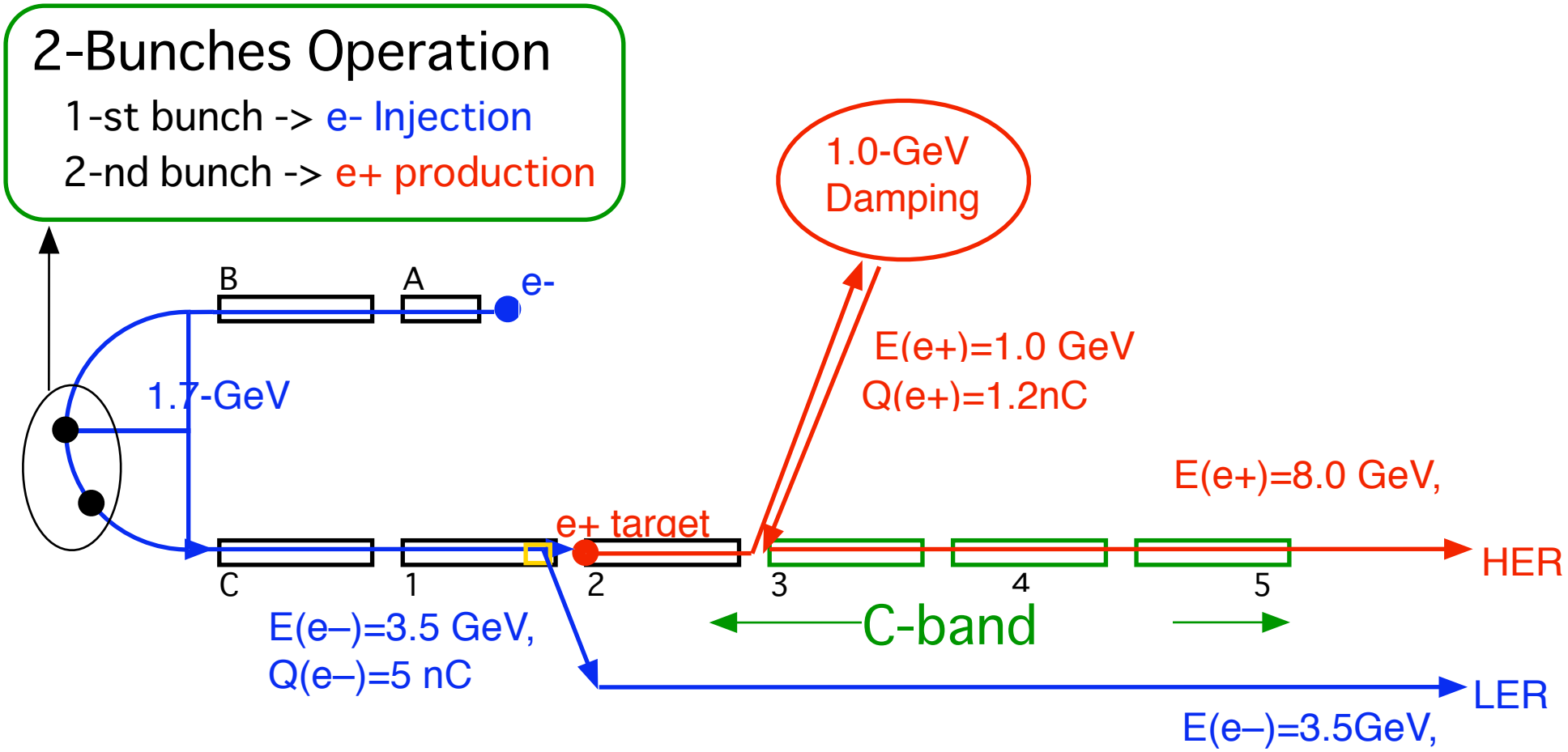
Test KEKB operation with Continuous Injection (e+ only) was successful in 2001 Dec. and 2002 Jan.

Continuous Injection Test

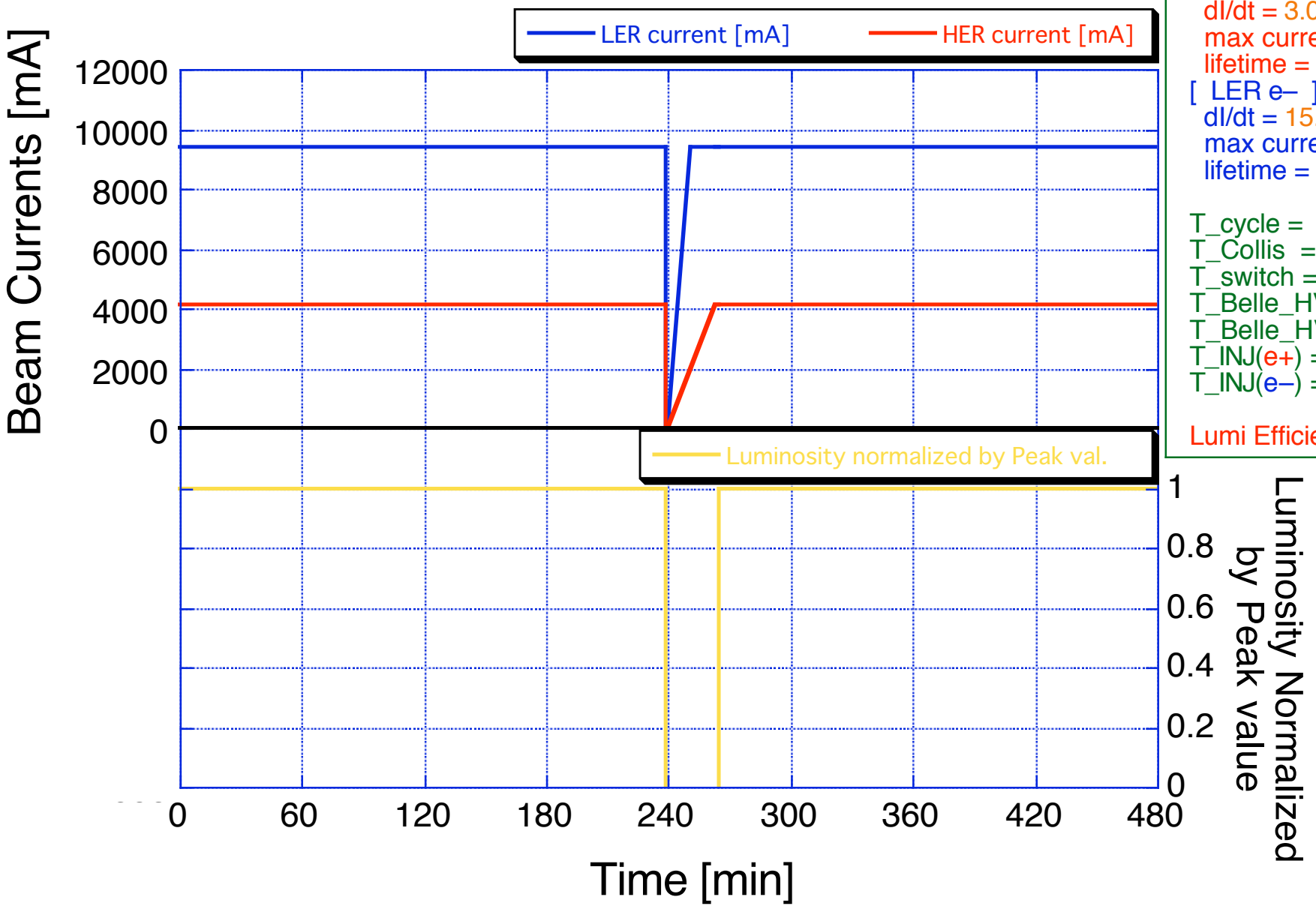


(2) By Simultaneous Injection of e+/e-

--> No dead time of Linac Mode change (e+ <-> e-)
--> Perfect constant stored current for e+ and e-



Simulated Run status



SuperKEKB
(Continuous & Simultaneous INJ)

[HER e+]
dI/dt = 3.0 mA/sec
max current = 4100 mA
lifetime = 150 min

[LER e–]
dI/dt = 15.0 mA/sec
max current = 9400 mA
lifetime = 150 min

T_cycle = till Abort
T_Collis = till Abort
T_switch = none
T_Belle_HVup = 1.5 min
T_Belle_HVdw = 1.5 min
T_INJ(e+) = 22.8 min
T_INJ(e–) = 10.4 min

Lumi Efficiency = 0.946

How to achieve e- Intensity increase

3.0 mA/sec --> 15.0 mA/sec

(1 nC/pulse) (5 nC/pulse)

already 10 nC e- beam is accelerated
to the e+ generation target

No problem on Generation of 5 nC e- beam

* Wake field issue
* Beam quality issue for the Injection

(5 nC beam has larger emittance and energy spread !)

--> IF it is essential, e- Damping Ring ?

How to achieve e+ Intensity increase

1.5 mA/sec --> 3.0 mA/sec

(0.6 nC/pulse) (1.2 nC/pulse)

e+ capture section upgrade

With stronger focusing solenoid (flux concentrator?)

* Beam quality issue for the Injection

if No Damping Ring

Summary1 Energy upgrade for e+ 8.0 GeV injection

(1) Higher accelerating field with C-band structures

Simple Beamline Layout and Operation
Need C-band components R & D
-> Challenge for High acceleration Field
Higher Cost

(2) Beam recirculation with damping ring

Complicated Beamline Layout and Operation
No need for accl. unit upgrade
Lower Cost

Summary2 Intensity upgrade

(1) e- (x 5 increase) By 5 nC e- beam injection
5 nC beam generation OK
Wake effects -> Beam quality OK ?

(2) e+ (x 2 increase) By Adiabatic Matching system
Need Flux concentrator

(3) Continuous Injection --> already OK for Linac

(4) e+/e- simultaneous Injection By 2 bunches operation
Need Fast Kicker