



stacking simulation update

Frank Zimmermann
on behalf of the POSIPOL Collaboration

Particular thanks to:

Tsunehiko Omori and Louis Rinolfi

POSIPOL 2010, 1 June 2010

ILC-CLIC e+ studies, 24 June 2010

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Compton source basics

collide 1.3-1.8 GeV e- beam with laser pulse
stored in optical cavity ($\lambda \sim 1 \mu m$);

yield $\sim 0.2 \gamma/e^-$ for single 600 mJ cavity *

convert Compton scattered photons to e+/e-,
and capture e+

yield $\sim 0.01 e^+/\gamma$ *

stack in accumulation ring

ex.: 6×10^{10} e-/bunch $\rightarrow 10^8$ e+ \rightarrow 40-60 stackings
needed to achieve 4.5×10^9 e+ / bunch for CLIC;
unless several optical cavities are used, as in ILC;
for ERL 10^9 e-/bunch $\rightarrow 2 \times 10^6$ e+ \rightarrow \sim 2000 stack's

*Tsunehiko Omori, 11 October 2008

various scenarios

Compton sources

- Compton ring – CR (“pulsed”), or
- Compton ERL – CERL (“continuous”)

accumulation rings

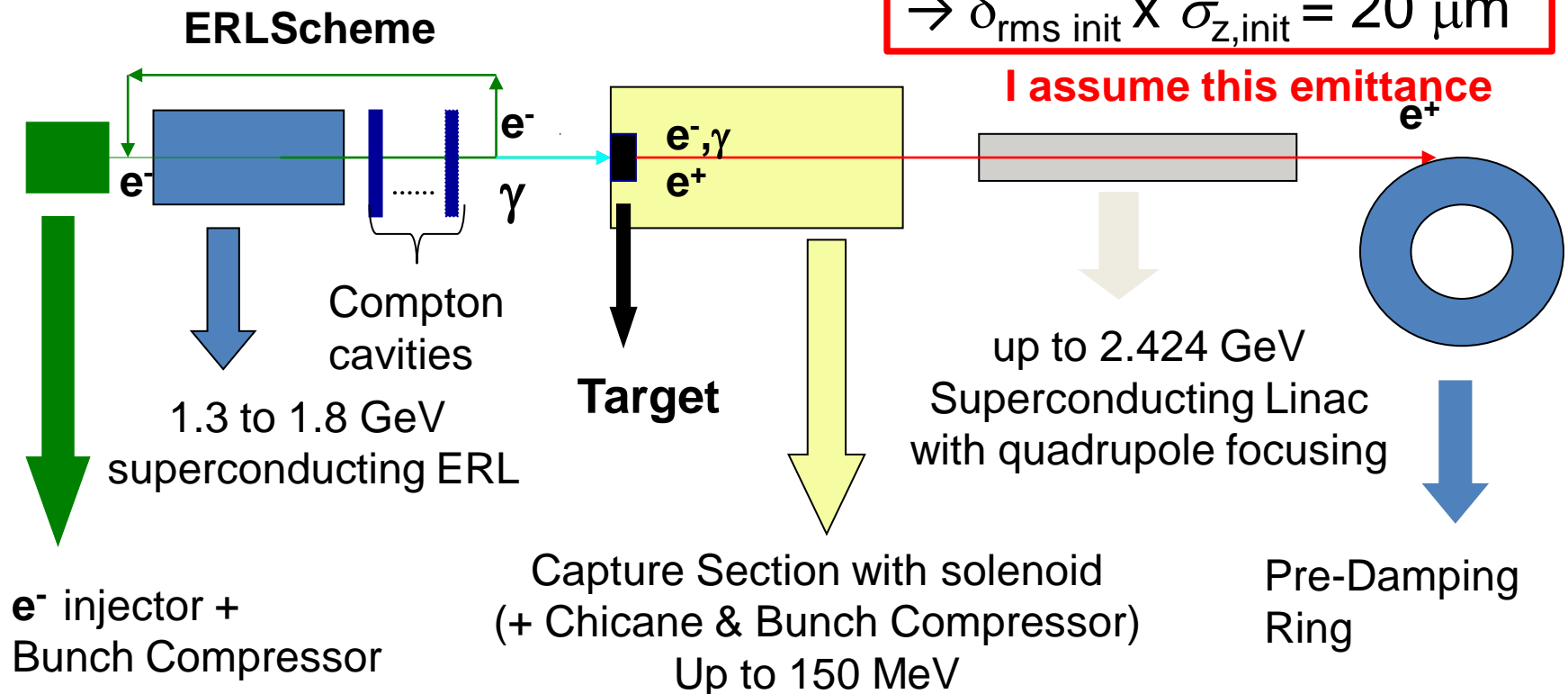
- ILC damping ring
- CLIC pre-damping ring
- two CLIC stacking rings

***focus of
this talk***

initial e+ parameters (A.Vivoli's ILC simulation,'08)

parameter	value
#e+ / pulse	6.65×10^7
longitudinal edge emittance (10 x rms) at ~200 MeV	0.72 meV-s
transverse normalized edge emittance (10 x rms)	0.063 m-rad

$$\rightarrow \delta_{\text{rms init}} \times \sigma_{z,\text{init}} = 20 \mu\text{m}$$



need simulation for CLIC

improving stacking efficiency (2008)

methods chosen:

- ✓ energy pre-compression [x3] (R. Chehab)
- ✓ addt'l wigglers for faster damping [x2]
- ✓ larger rf voltage [x 1.5 or more!]

→ 2008 ILC DR Compton version

conclusions at LAL meeting Dec. '08

- CLIC & ILC Compton sources w ERL or CR
- e+ emittance preservation after capture
- CLIC PDR & ILC DR parameters adapted for stability and stacking, $\alpha_2 \downarrow \downarrow$, $V_{RF} \uparrow$, $\tau_{||} \downarrow$
- stacking simulation: >90% efficiency with off-momentum off-phase injection
- (P)DR off-momentum dynamic aperture must be adequate (huge! >several %)
- quite some flexibility (# optical cavities vs. e- bunch charge)
- but a few challenges for PDR & DR design

stacking is helped by:

- short damping time
- small longitudinal emittance
- large ring momentum acceptance
(low α , low α_2 , large V_{RF} , higher harmonic rf)
- sufficient store time

simulation results for stacking in DR/pre/-DR:

95% for ILC-CR (300 inj's, $\sigma_\delta=3$ MeV spread)

94% for ILC-CERL (1020 inj's! $\sigma_\delta=0.5$ MeV)

95.5% for CLIC-CR/CERL (80 inj's, $\sigma_\delta=2$ MeV)

last 2 with energy pre-compression - *Compton version of ILC-DR acceptable? #e+ / pulse for CERL schemes?*

2010 simulations for new CLIC scheme (stacking rings)

“Could you please make a e⁺ stacking simulation of the stacking ring (SR) of the "ERL Compton scheme for CLIC", where we will employ SRs which circumferences to be about 48 meters.

Urakawa-san suggested that the SLC damping ring (E~ 1.2 GeV, and circumference ~ 35 meters) will be a good example for the ring lattice.”

Request from T. Omori, October 2009

“... table based on SLC damping ring parameters.

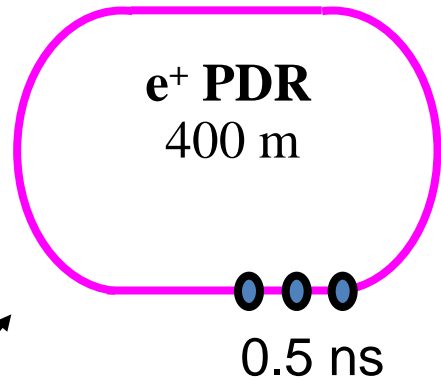
For the CLIC energy, we are rather free to choose between 0.5 to 1 GeV ring. For parameters which are not ... in the Table for the CLIC Storage Ring, you could use those given for the SLC.

For the transverse rms normalized emittance, we can have a value which is bigger than 30 mm.mrad.

For the second momentum compaction factor, I did not yet find a value but, may be, you can impose a constraint as you did for the CLIC Pre-Damping Ring.”

L. Rinolfi, October 2009

**new
CLIC
scheme**



312 bunches / train
1 train / ring
50 Hz

0.5 ns

I did not put 9 lost bunches; should I?

312 bunches spaced by 0.5 ns => 156 ns / turn

Stack in the same bucket every 69th turn

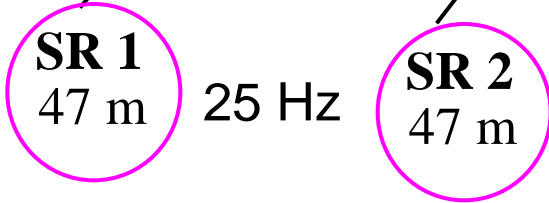
Number of stacking in the same bucket 1864

69 (??) x 1864 = 128 617 turns

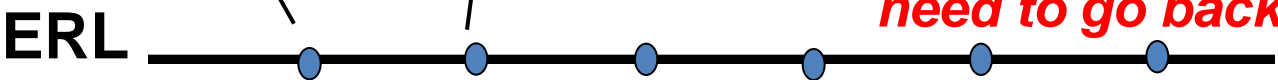
(better 64x2003=128192)

128 617 x 156 ns ~ 20 ms

numbers to be slightly revised; probably I need to go back to original values



25 Hz



32 ns

(321 bunches, every 64th turn)

	Units	SLC Damping Ring	CLIC SR1 and SR2 (for one ring)
Circumference	m	35.28	46.82
Energy	GeV	1.19	1
Charge at injection (1 / bunch)	10^9	50	0.0025
Charge at extraction (1/ bunch)	10^9	50	4.4
Norm. rms equil. emittance (x, y)	mm-mrad	30, 2	30, 2
Transverse damping times	ms	~3.7	0.09
Equilibrium bunch length	mm	6.5	4.0
Equilibrium energy spread	10^{-4}	9	12
Longitudinal damping time (ms)	ms	1.5	0.045
Momentum comp. factor (1 st order)	-	0.0147	0.006
Momentum comp. factor (2 nd order)	-	?	~0.024
RF voltage	MV	0.82	35.0
RF frequency	MHz	714	2000
Harmonic number		84	312
Synchrotron tune		0.012	0.102
Synchronous phase		6.7°	5.7°

conditions for "continuous" stacking scheme :

$$\Delta E_{\text{loss}} \text{ (1 synchrotron period)} \\ > 4 (\sigma_{E0} + E \sigma_{z0} Q_s / (\alpha_c C)) \quad [\text{e.g.} \sim 0.02 E]$$

no septum bump needed if

$$\Delta E_{\text{sync.osc.}} \text{ (1 turn)} \sim 2\pi Q_s \delta E_{\text{inj}} > \\ 4 \sigma_{E0}$$

in our example:

$$\Delta E_{\text{loss/turn}} = 3.5 \text{ MeV}, \sigma_{E0}/E = 0.0028, \\ \sigma_{z0} \sim 7 \text{ mm}, Q_s \sim 0.05, \delta E_{\text{inj}}/E \sim 0.081 \text{ (!)}$$

both conditions fulfilled

treatment of synchrotron radiation

R. Siemann, HEACC 1988

model A

$$z_{new} = z_{old} e^{-T_0/\tau_{\parallel}} + \xi \sqrt{2(1 - e^{-T_0/\tau_{\parallel}})} \sigma_{z,eq}$$

$$\delta_{new} = \delta_{old} e^{-T_0/\tau_{\parallel}} + \xi \sqrt{2(1 - e^{-T_0/\tau_{\parallel}})} \sigma_{\delta,eq}$$

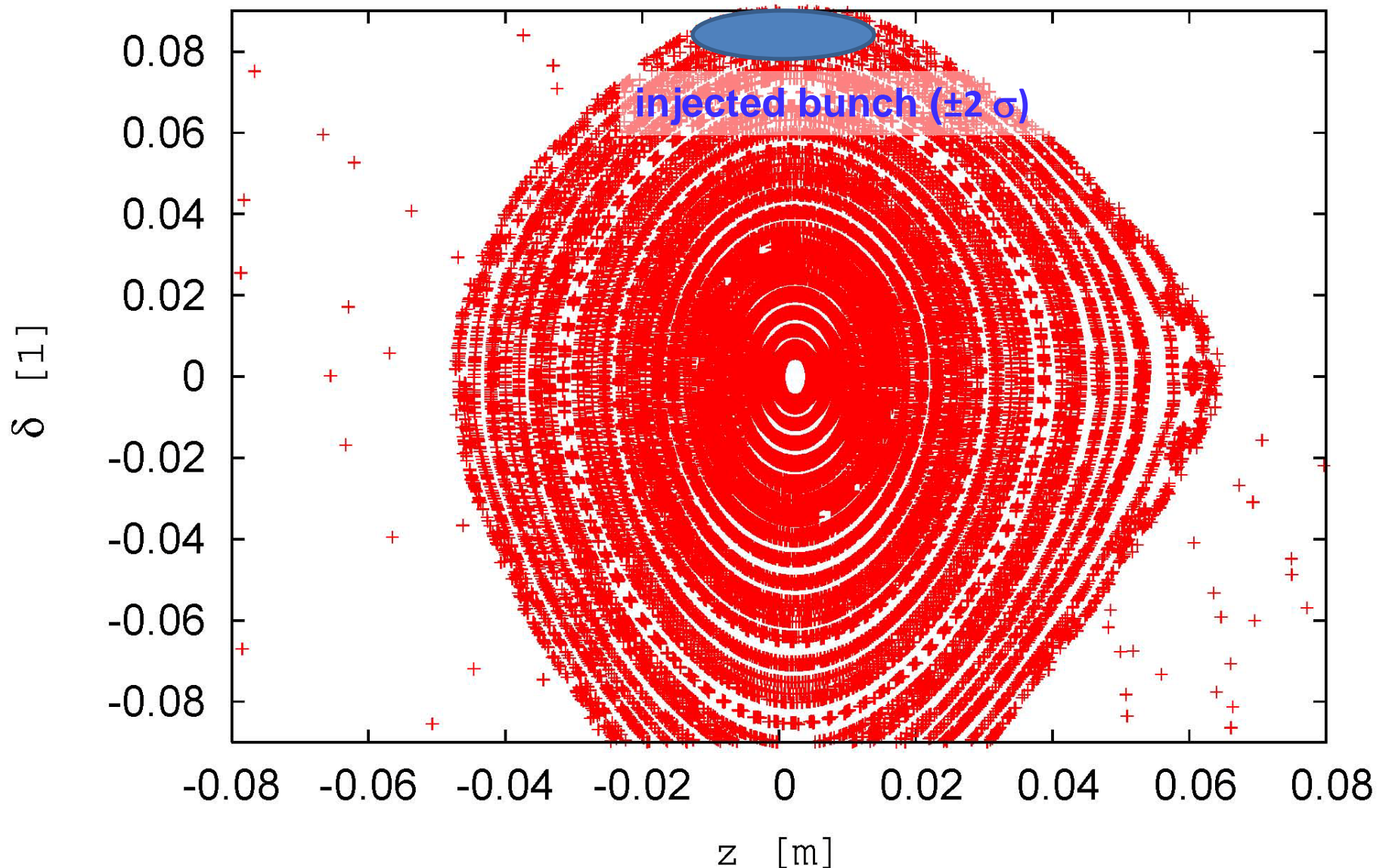
model B (*used in the following*)

$$z_{new} = z_{old}$$

$$\delta_{new} = \delta_{old} e^{-2T_0/\tau_{\parallel}} + \xi \sqrt{2(1 - e^{-2T_0/\tau_{\parallel}})} \sigma_{\delta,eq}$$

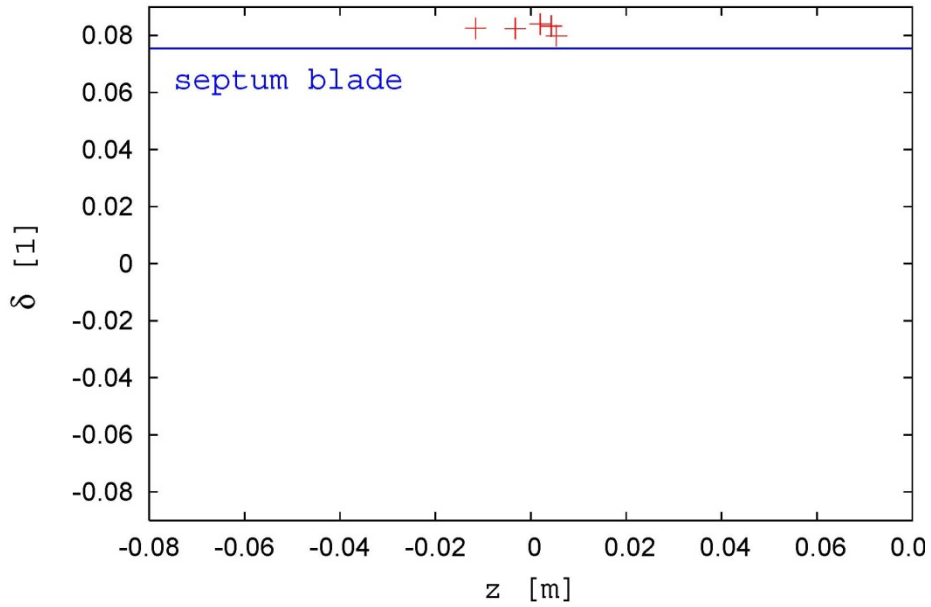
phase space of stacking ring

nominal SR, $V_{rf}=35$ MV, $\alpha_1=0.006$, $\alpha_2=0.024$, $U_0 = 3.5$ MeV

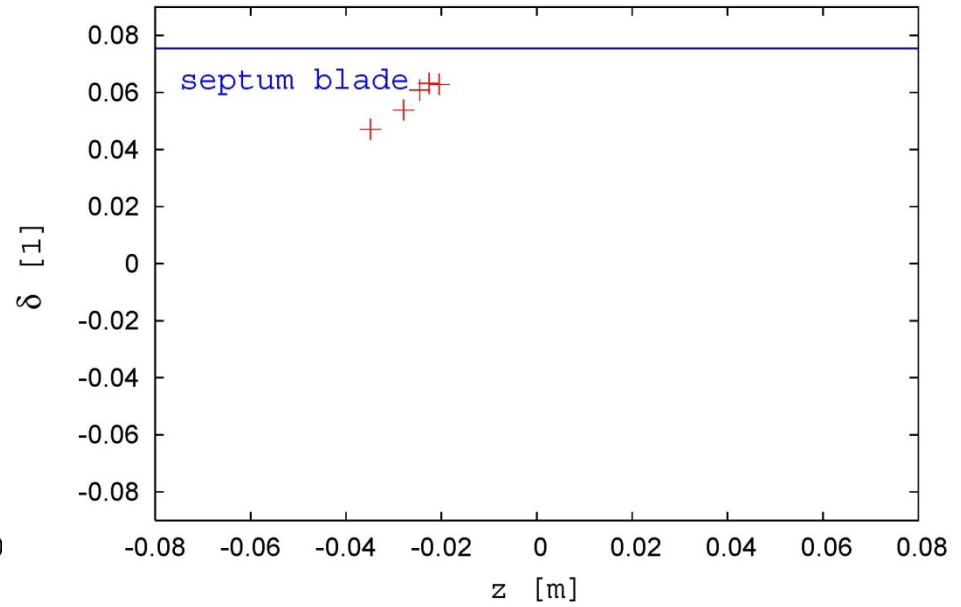


the first few turns after injection bunch #1

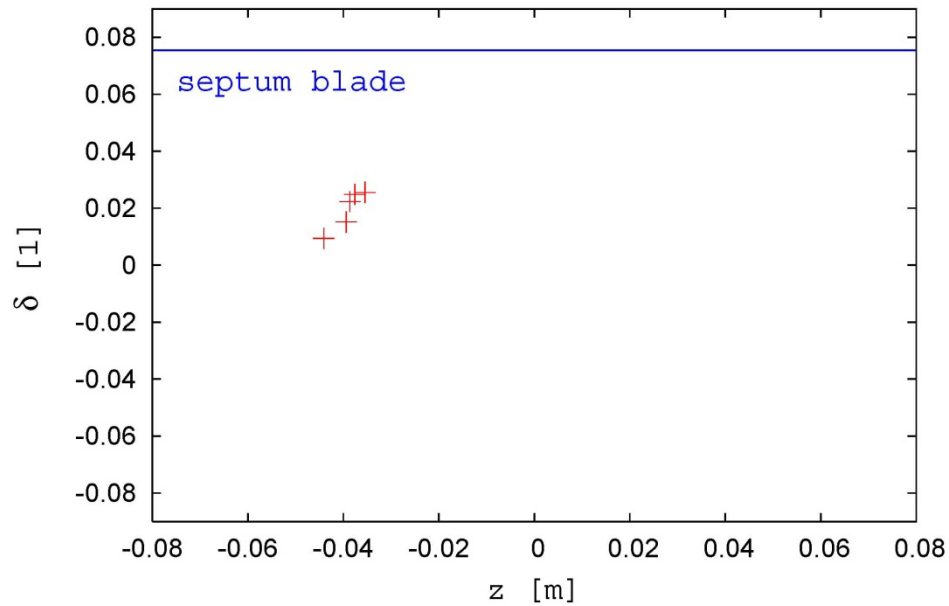
1st turn, 1 bunch



2nd turn, 1 bunch

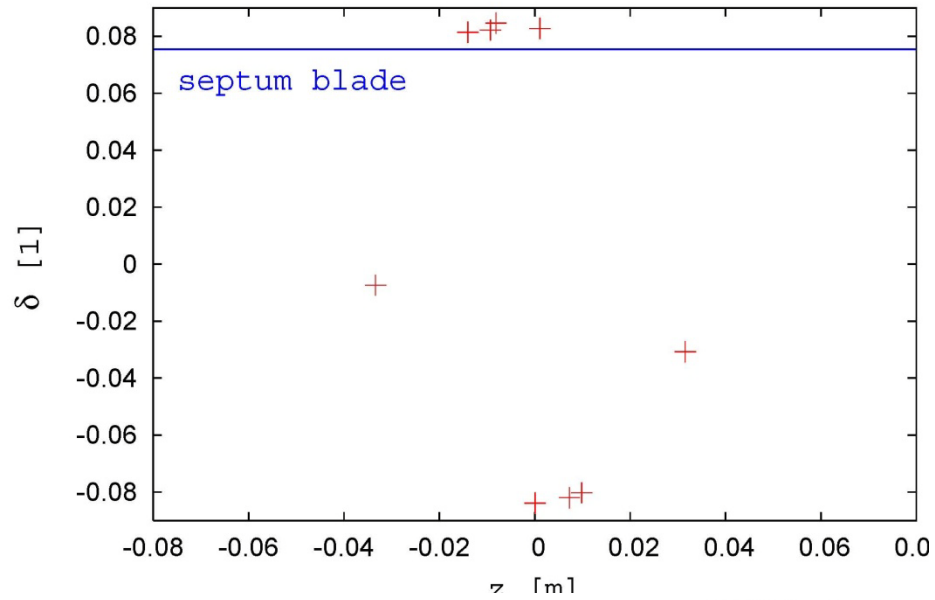


3rd turn, 1 bunch

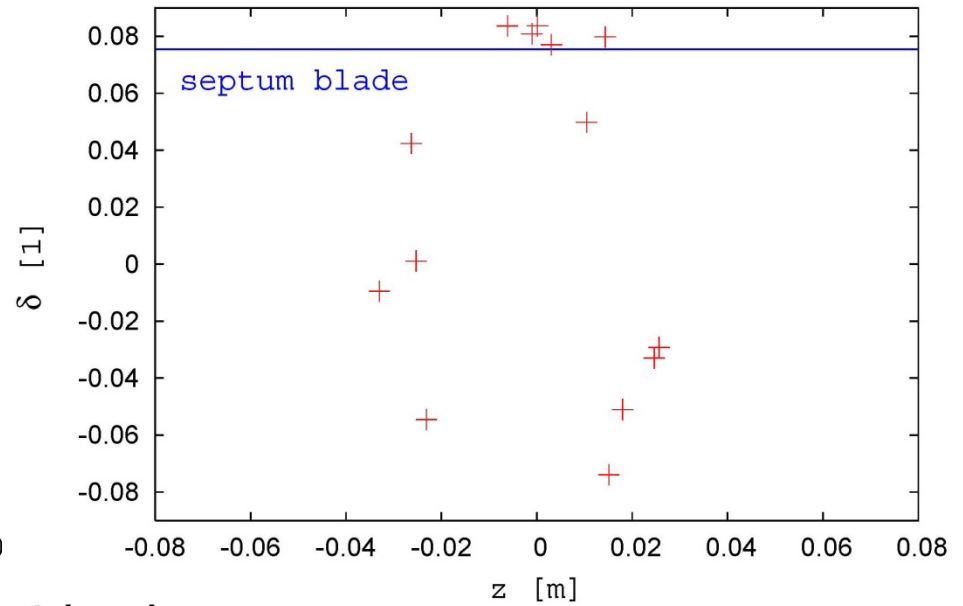


injecting bunches # 2, 3 and 6

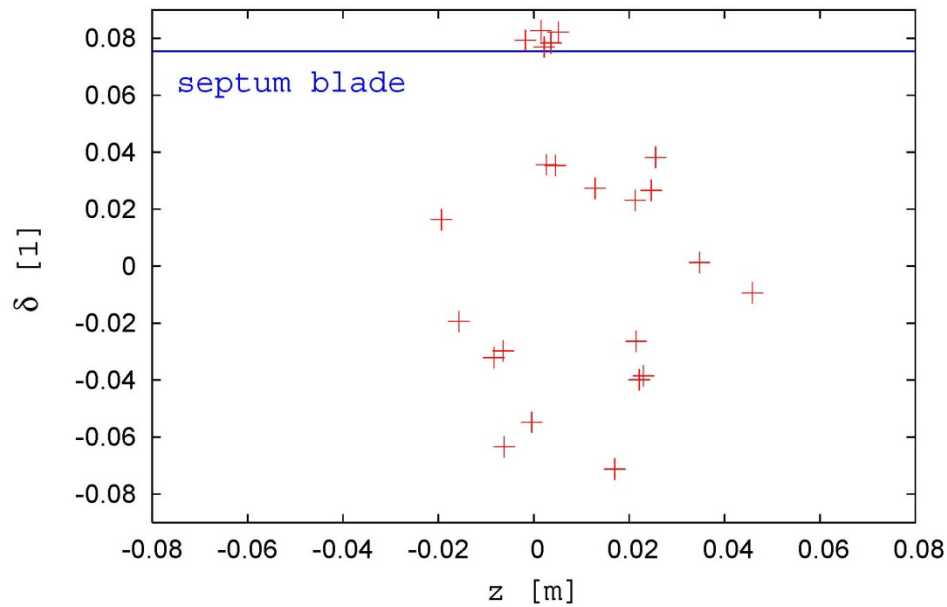
69th turn, 2 bunches



138th turn, 3 bunches

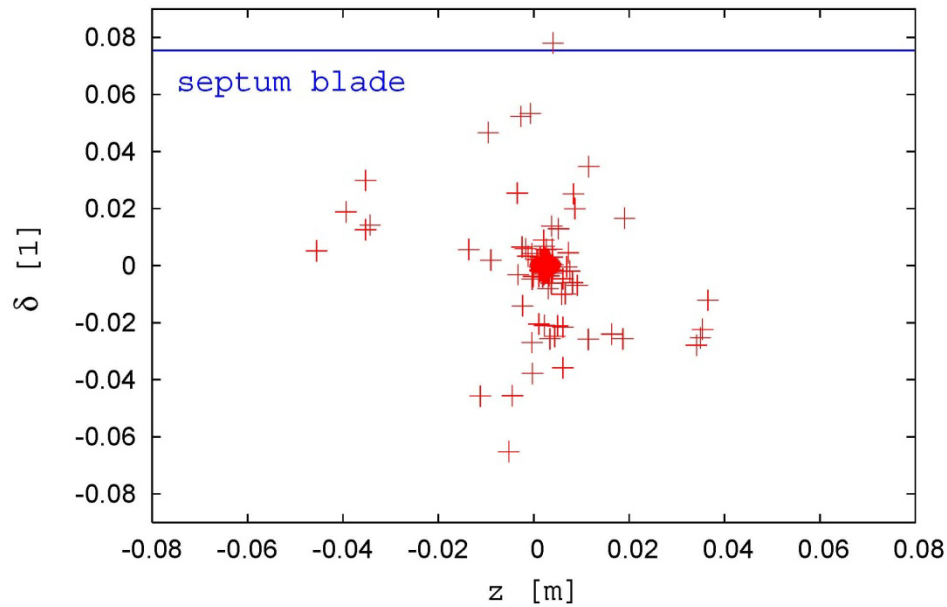


276th turn, 6 bunches

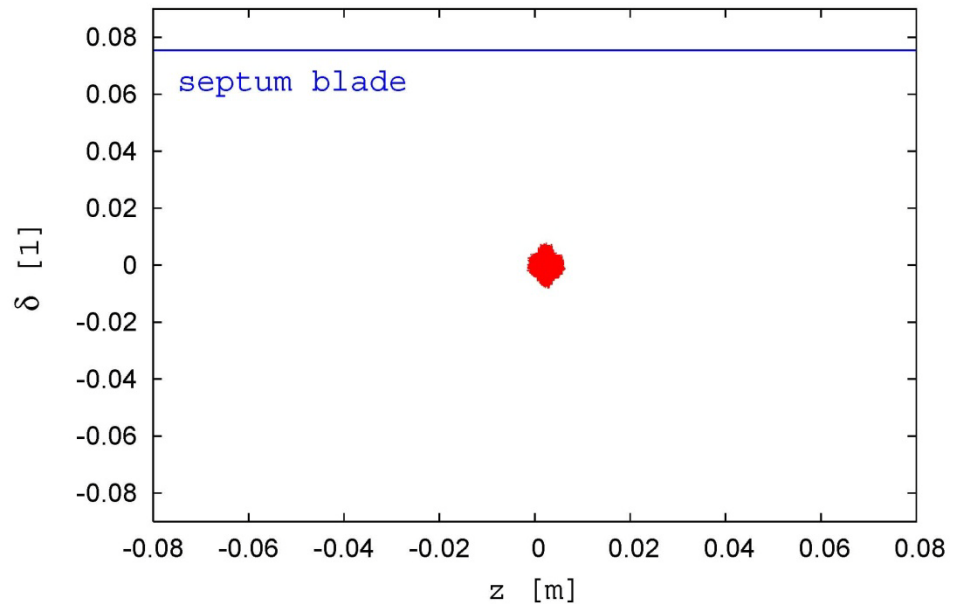


after injecting the last bunch (# 1864)

128618th turn (20 ms), 1864 bunches, after last inj



20 ms after last injection



conclusions

CLIC stacking rings must have much shorter damping times $\sim 50 \mu\text{s}$ and higher RF voltage (35 MV) than SLC damping rings

large off-momentum dynamic aperture up to $\delta_{inj} \sim 9\%$ (!) is also required

preliminary simulations with semi-optimized parameters indicate $>95\%$ stacking efficiency

numbers need to be slightly refined

open questions

lattice design for stacking ring

wiggler and RF for stacking ring

**impedance & stability for 35 MV RF
(Kaoru Yokoya)**

**nonlinear wigglers to damp large amplitude
particles more efficiently?**