ILC / CLIC Common issues for Compton

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KEK for CLIC08

Most important common issue is e+ stacking (except Linac scheme).

This is related to short damping time, pre-DR ?, Ne in Compton Ring, beam stability, choice of ERL parameters, energy compression before DR and so on.

optical cavity ⇨ Next talk by Variola-san

high quality and high power laser

Brief review of Compton polarized positron source before today's issues.

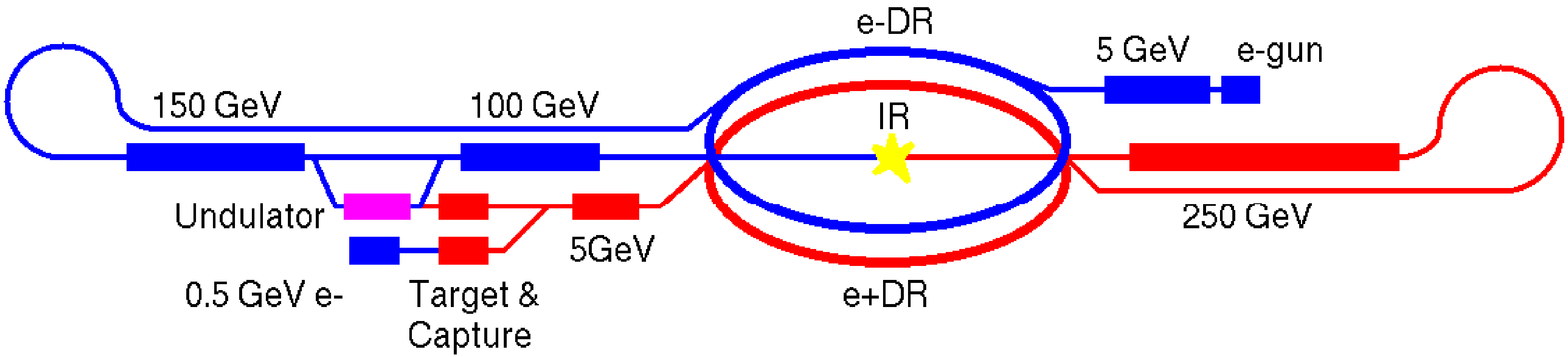
ILC and Positron Source

Parameter	Value
# of positron/bunch	2.00E+10
Bunch spacing	369ns
# of bunch/Pulse	2625
Pulse repetition rate	5Hz

- Undulator is the baseline design.
- Two alternatives:
  - Conventional (electron driven) is a fall back.
  - Laser Compton is an advanced alternative.
- Any schemes are not fully established. Need a certain amount of R&D for ILC positron source.

Baseline Design

- It relies upon gamma rays generated by passing 150 GeV electron through 168m undulator.
- Undulator is "inserted" to part way of ML (150GeV).
- A positron source driven by 0.5 GeV electron is a back up for high availability and machine commissioning.

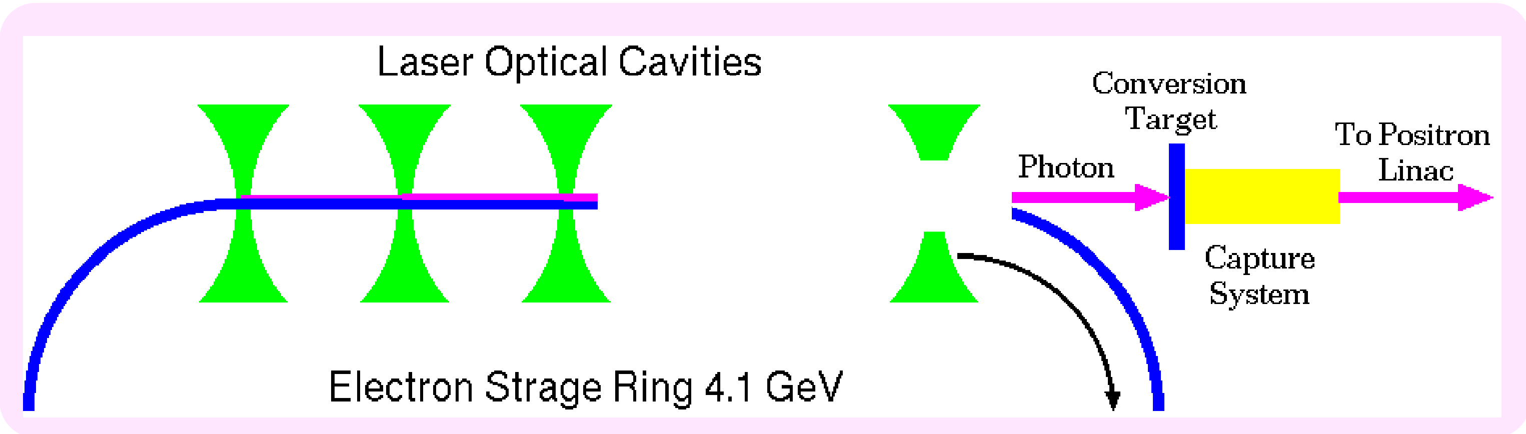


Alternative Design

- e- driven scheme (conventional) and Laser Compton scheme are considered to be alternative schemes.
  - e- driven scheme is a back-up alternative.
  - Laser Compton is an advanced alternative.
- Because the baseline design is a totally new approach, a conservative alternative is very important as a technical backup.
- Laser Compton is attractive, but it is technically immature; It is advanced alternative.

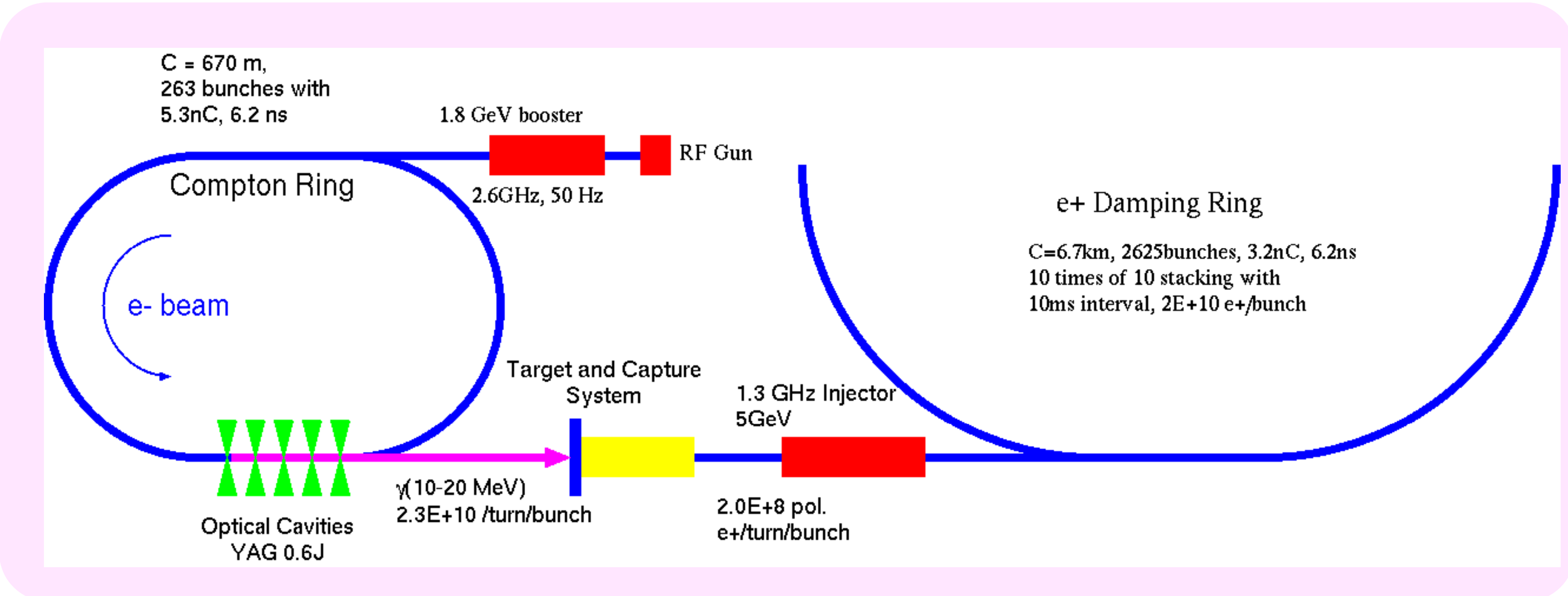
Laser Compton Scheme

- A few GeV (1.8GeV for example) electron bunch collides with 1µm laser photon stored in optical cavity.
- Several 10s MeV gamma impinges in a conversion target.
- A dedicated electron driver is reasonable.
- Obtaining enough positron, is a technical challenge.
  – High intensity electron beam: Linac, Storage ring, ERL
  – High intensity photon beam: High power laser, optical cavity.
  – Stacking scheme: DR stacking, Pre-DR, etc.



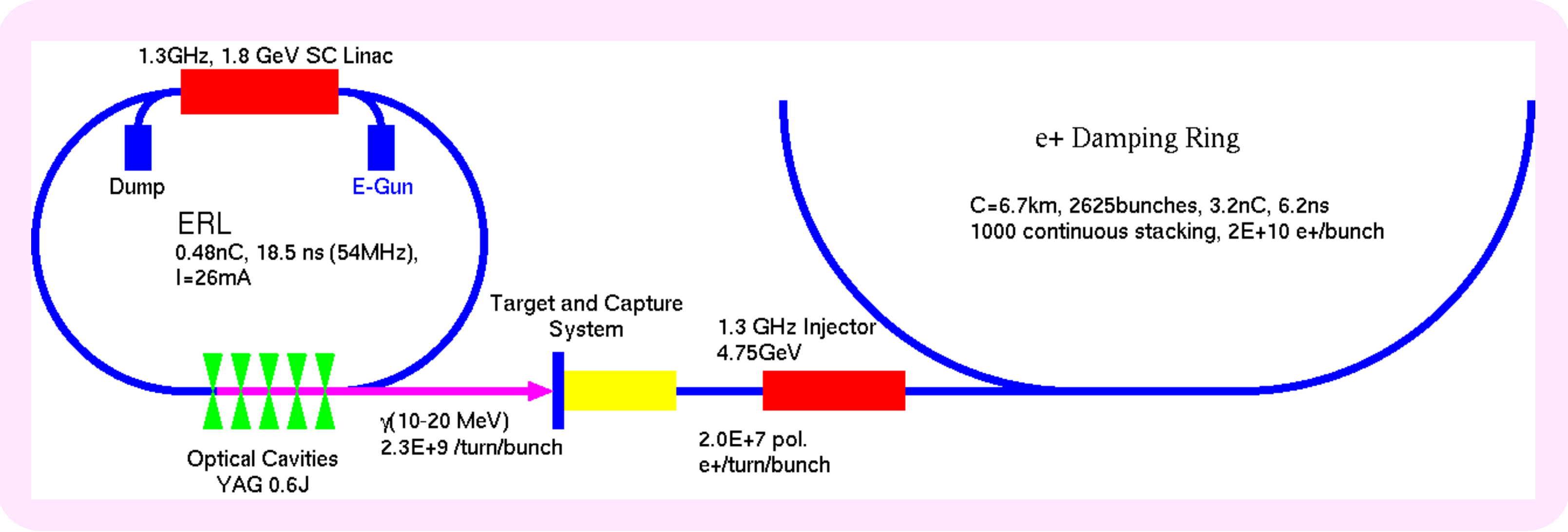
Compton Ring

- A storage ring for electron driver:5.3nC, 6.2ns, 1ps, 1.8GeV, 0.6Jx5CP.
- Positron bunch(Ne+:2.0E+8) is generated.
- 10 bunches are stacked on a same bucket. This process is repeated 10 times with 10ms interval for beam cooling.
- Finally, Ne+:2E+10 is obtained.

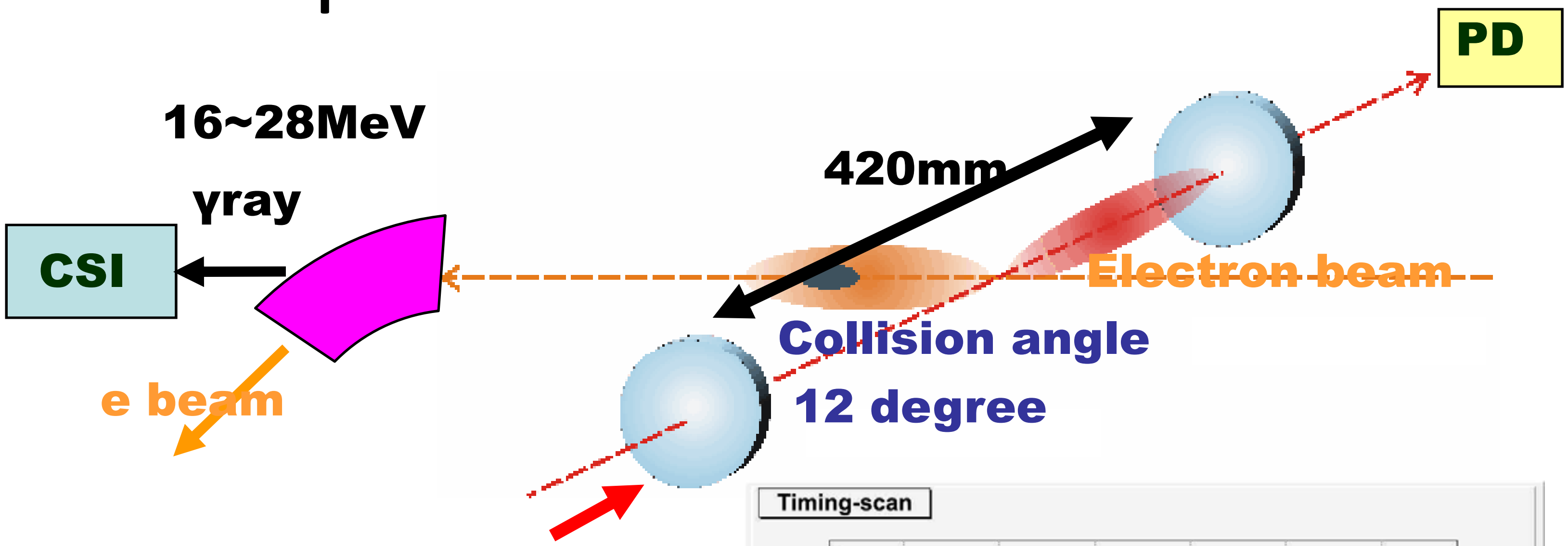


ERL

- ERL(Energy Recovery Linac) is employed as the dedicated electron driver.
  - 0.48nC, 18.5ns (54MHz) ~ 26mA, E=1.8GeV
  - N_{γ}=2.3E+9 by 0.6 Jx5 CP, N_{e+}=2.0E+7
- By a semi-CW operation (50ms), 1000 times stacking in DR is performed and Ne+=2.0E+10 is obtained.



Experiment at KEK-ATF

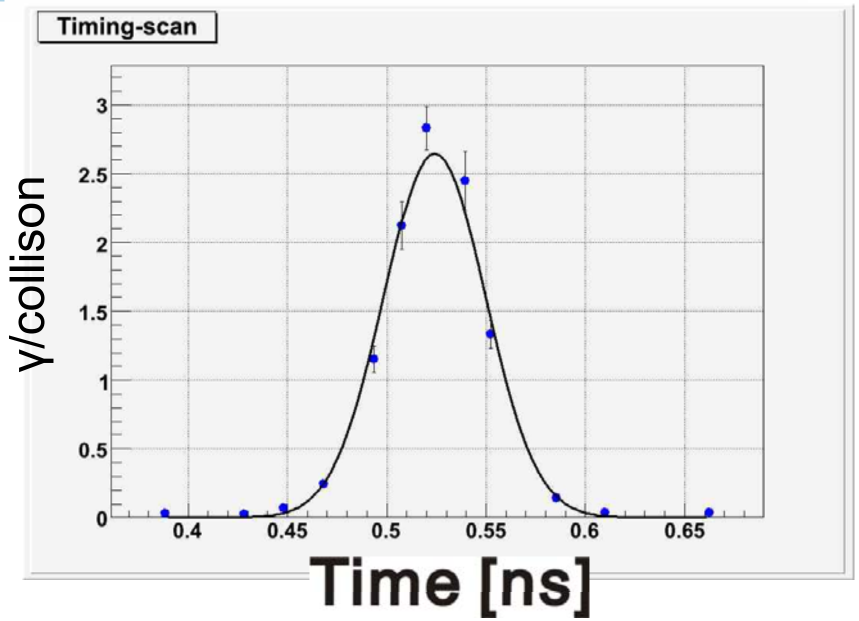


Mode lock laser

λ:1064nm

10W=28nJ , 2.8ns spacing

Pulse length : 7ps

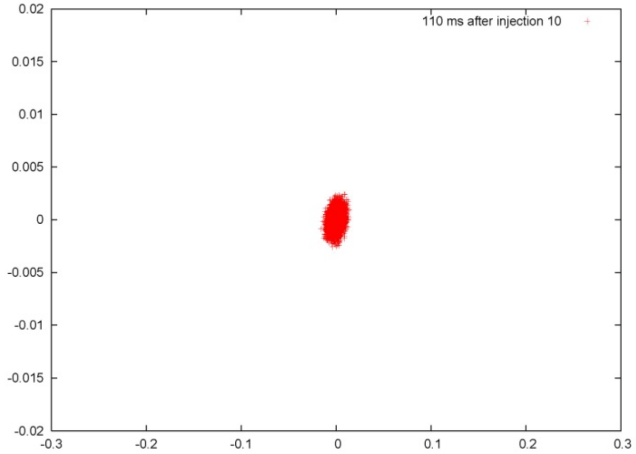


Finess = 780

IP size= 30 μm

Stacking Simulation

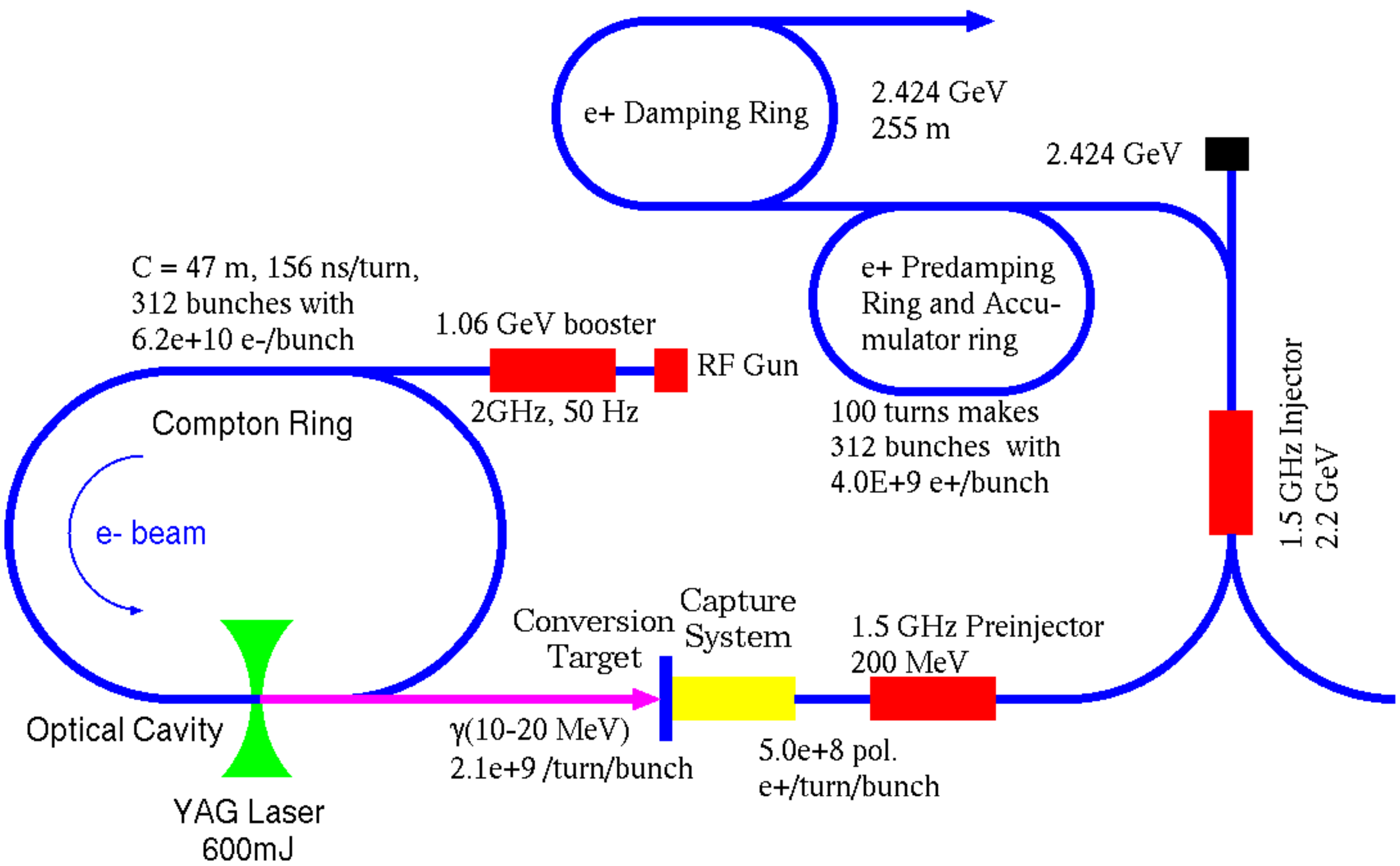
F. Zimmermann



- # of positron by a single collision is not sufficient -> need stacking.
- Stacking simulation in DR (multi-turn injection) shows 10.6% of injected e+ are lost! stacking efficiency ~90%.
- The tolerance of the injection loss would be qualified.

CLIC Compton Scheme

- **Collaboration on Positron Generation strongly supported by CLIC and ILC managements (J.P. Delahaye@PosiPol08)**



PosiPol-Collaboration

- Laser-Compton has a large potential as a future technology.
- Many common efforts can be shared in a context of various applications.
  - X-ray/SR sources for industrial and medical applications,
  - Beam diagnostics with Laser,
  - Polarized Positron Generation for ILC, CLIC, SuperB, ..
- State-of-the-art technologies are quickly evolved with world-wide synergy.
- PosiPol collaboration has been started in 2006.
- The last annual meeting was held at Hiroshima in July 08. The next meeting will be held at near CERN in 2009.

various scenarios

Compton sources

- **Compton ring – CR** ("pulsed"), or
- **Compton ERL – CERL** ("continuous")
- **Compton Linac (Not discussed today)**

accumulation rings

- **ILC damping ring**
- **CLIC pre-damping ring**

Frank Zimmermann (PosiPol 2008) w/slight modification

Basic Parameters

	ILC	CLIC
DR beam energy	5 GeV	2.4 GeV
DR circumference	6700 m	251.6 m
Rep Rate	5 Hz (200 ms)	50 Hz (2 m sec)
# particles/bunch at IP	2×10^{10}	4×10^{9}
pre-DR	Non in default (pre-DR op?)	Yes C=251.6m
#bunches in a train	3000 (50x60)	50
#trains in DR	1	7
$T_{b\text{-}to\text{-}b}$ in DR	6.15 ns	0.5 ns

Compton Ring Parameters

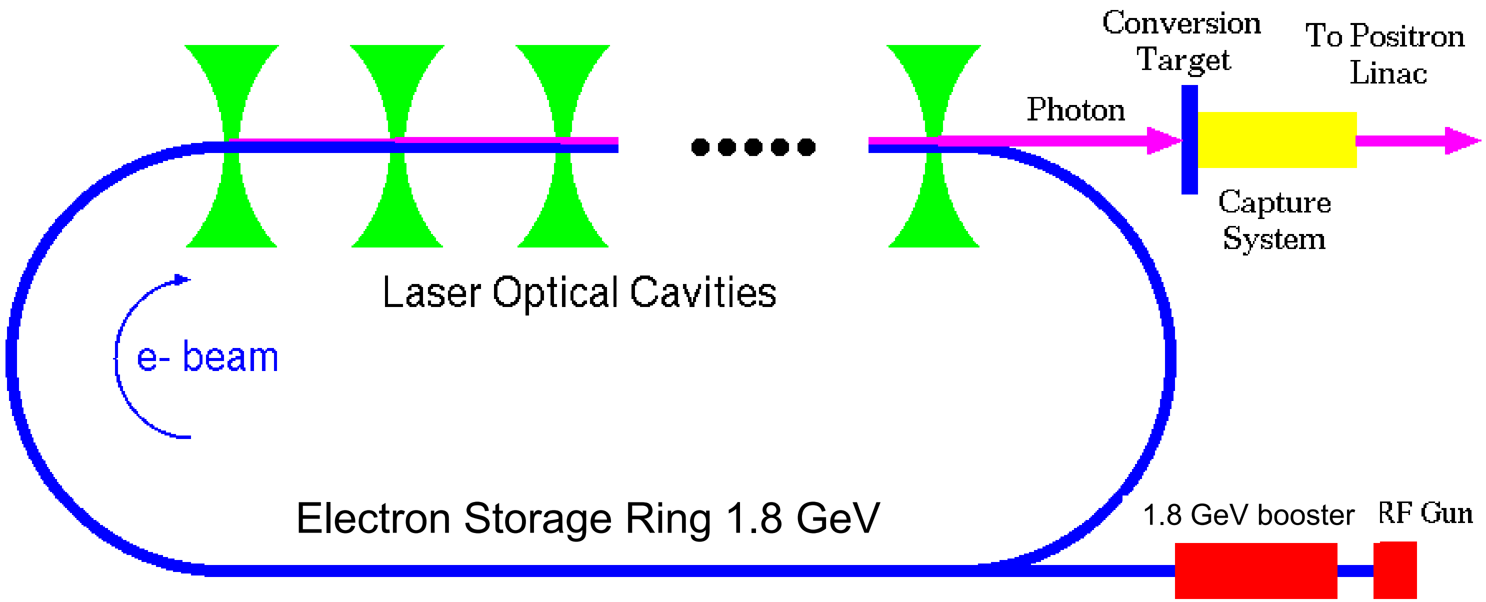
	ILC	CLIC
CR circumference	670 m (small op) 6700 m (large op)	251.6 m
# e-/bunch in CR	3 x 10^{10} (4.8 nC)	6 x 10^{10} (9.6 nC)
CR beam energy	1.8 GeV	1.3 – 1.8 GeV
$T_{b\text{-}to\text{-}b}$ in CR	12.3 ns (80MHz)	?
Laser stacking Cav.	600 mJ x 2	300 mJ x 1?
Ng/Ne$^-$/turn	0.28	0.01
# CR turn /cycle	600(small op) 60(large op)	?
# DR turn/cycle	60	?
Ng/Ne$^-$/cycle	180(small op) 18(large op)	?
# stacking/cycle	30	?
# cycle	10	?
# total stacking	300	?

ERL Parameters

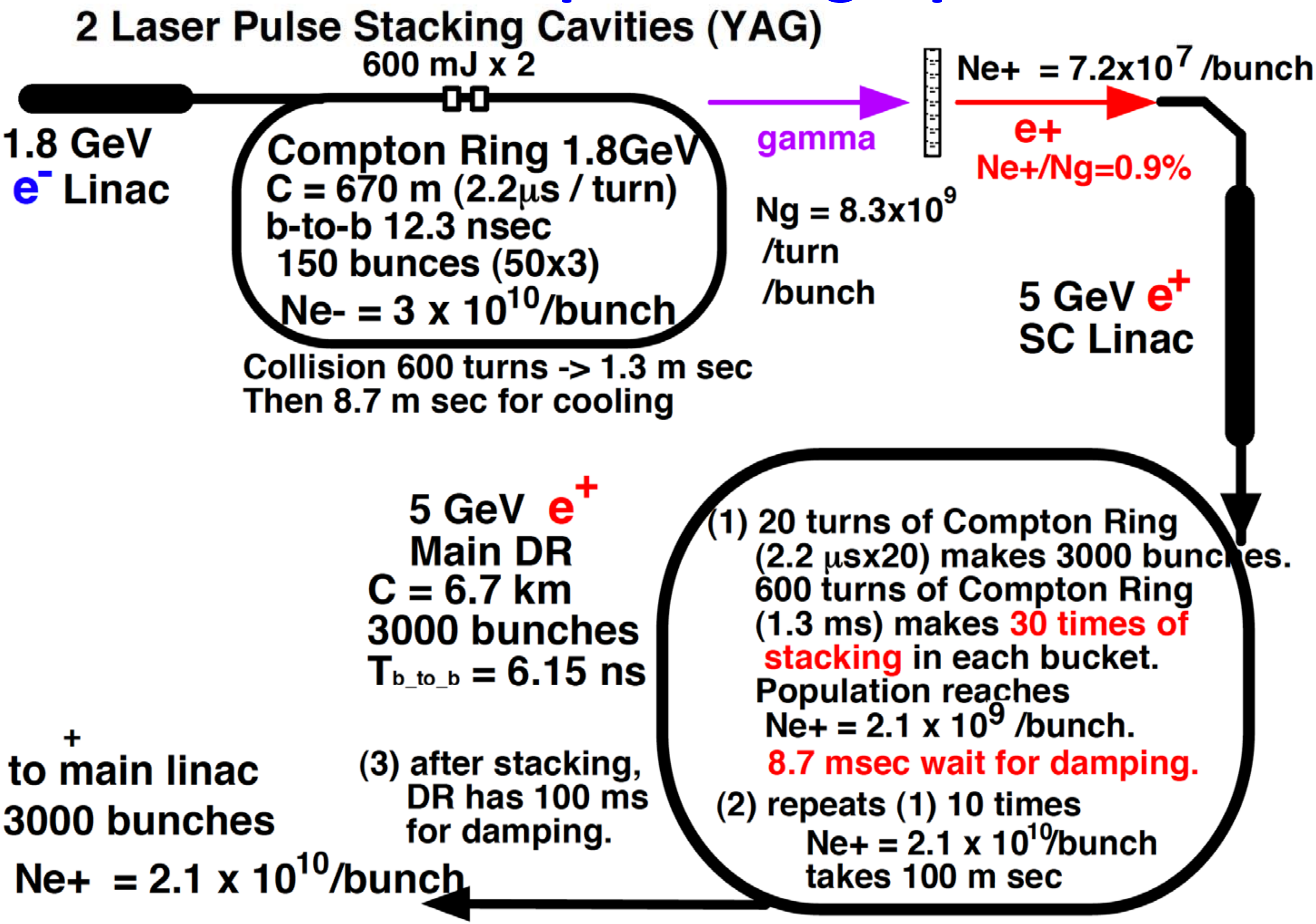
	ILC	CLIC
Frequency	32. 5 MHz ($T_{b\text{-}to\text{-}b}$=30.75ns)	?
# e-/bunch in ERL	3×10^9	?
ERL beam energy	1.8 GeV	1.3 – 1.8 GeV
Laser stacking Cav.	600 mJ x 5	300 mJ x 1?
Ng/Ne-/turn	0.8	?

Compton Ring Scheme for ILC

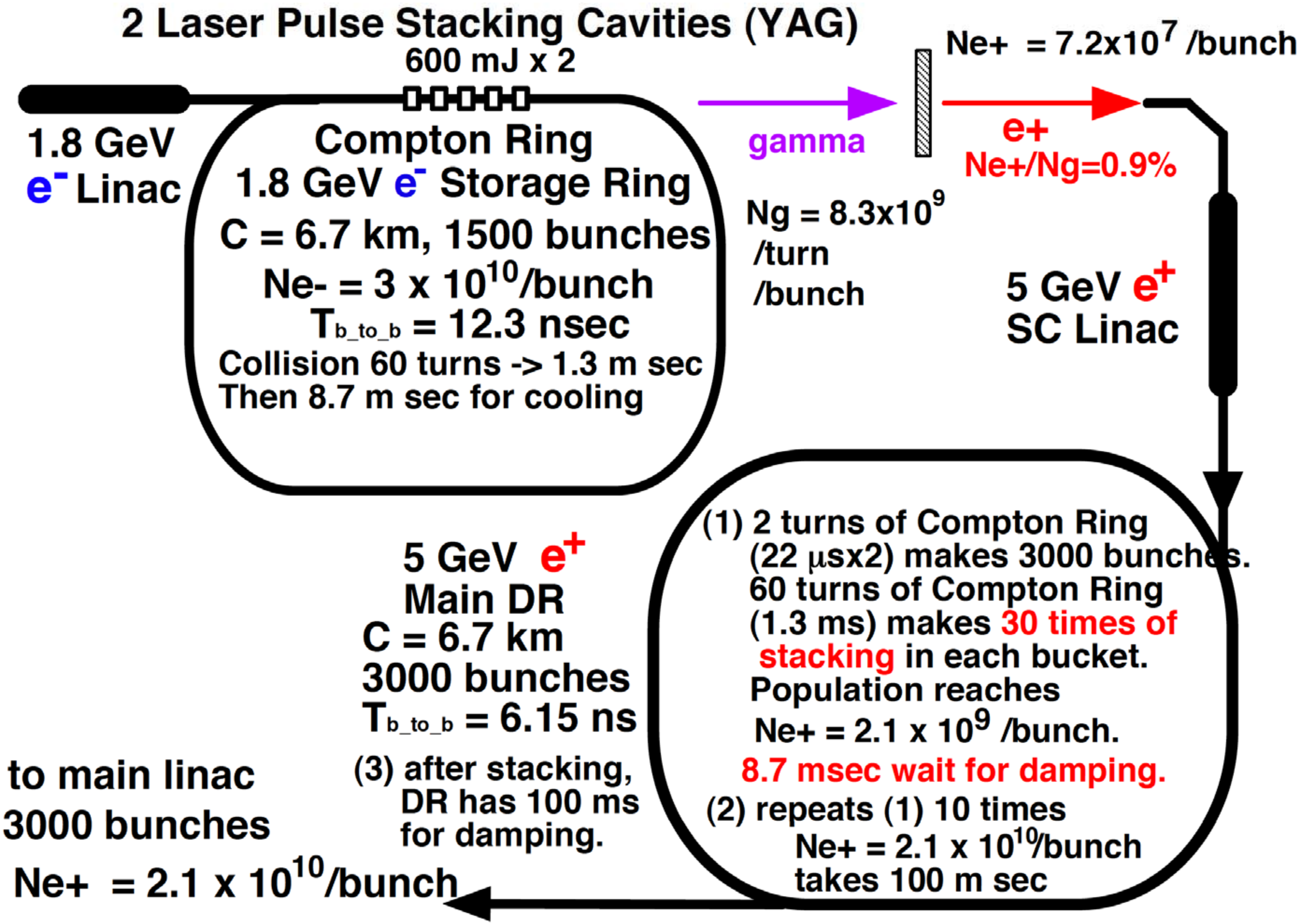
- **Compton scattering of e- beam stored in storage ring off laser stored in Optical Cavity.**
- **4.8 nC 1.8 GeV electron bunches x 2 of 600mJ stored laser -> 8.3E+9 γ rays -> 7.0E+7 e+.**
- **By stacking 300 bunches on a same bucket in DR, 2.0E+10 e+/bunch is obtained.**



Small Compton Ring Option



Large Compton Ring Option



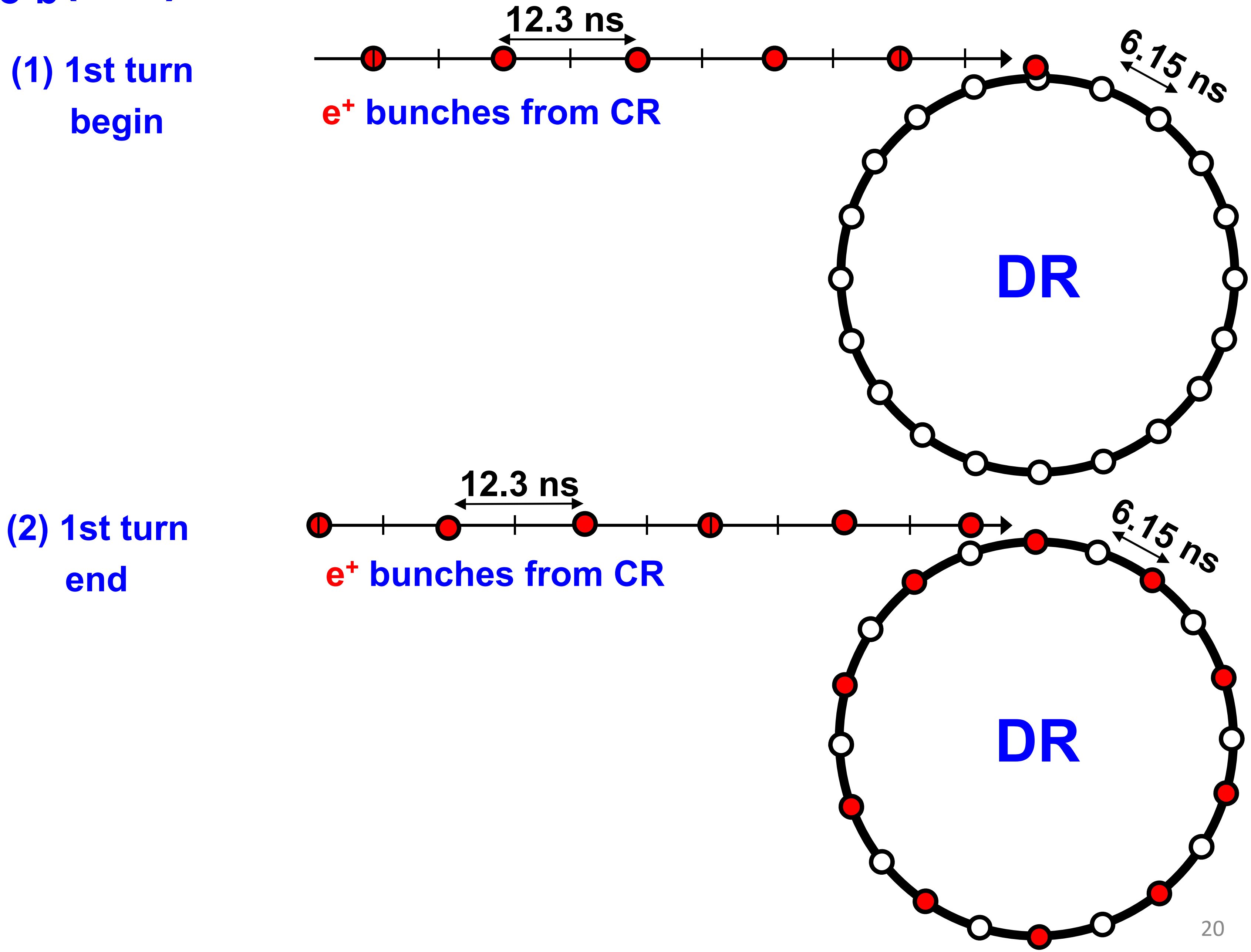
improving ILC-CR stacking efficiency

methods chosen:

✓energy pre-compression [x3] (R. Chehab)
✓ additional DR wigglers for faster damping [x2]
✓ larger rf voltage [x 1.5]

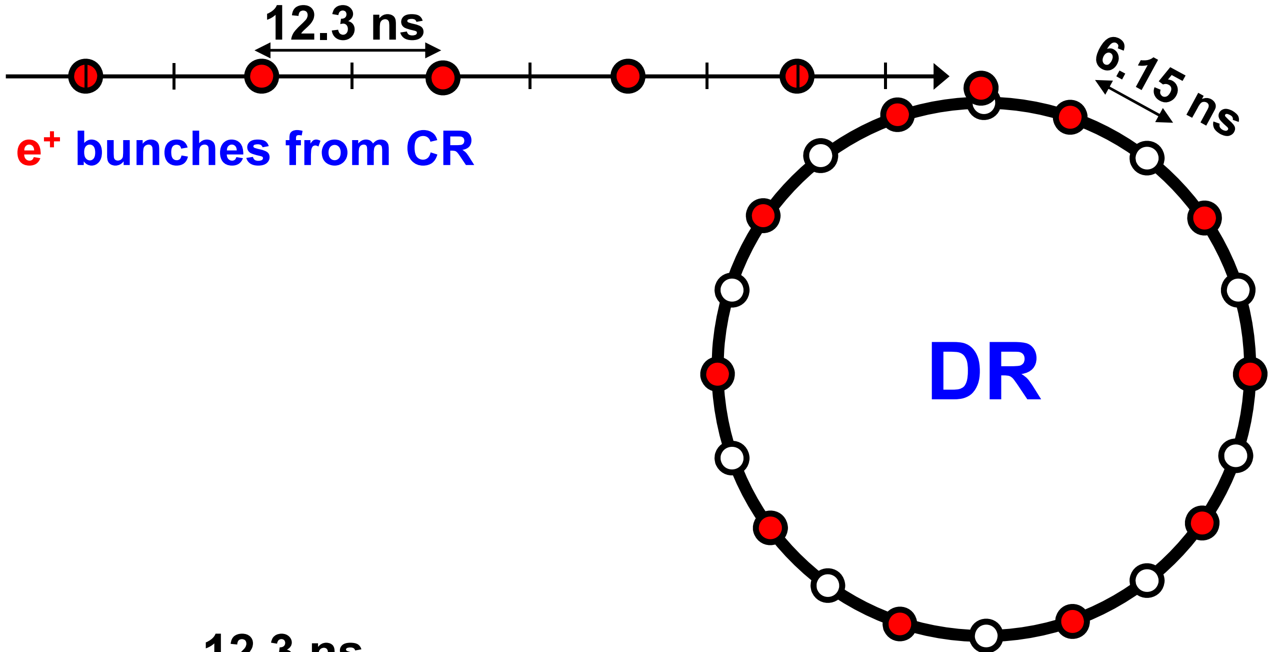
→ 2008 ILC DR Compton version

$T_{b\text{-}to\text{-}b}$(CR)=12.3 ns (80Mhz): 1st turn of DR stacking

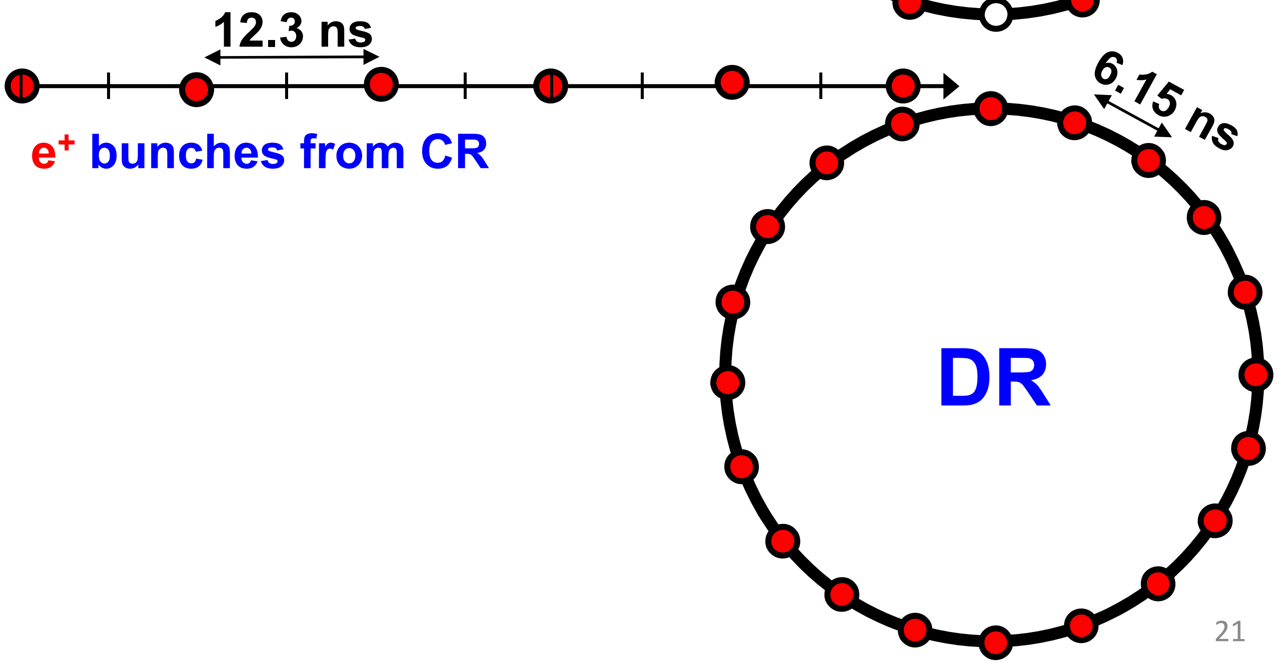


$T_{b\text{-}to\text{-}b}$(CR)=12.3 ns (80Mhz): 2nd turn of DR stacking

(1) 2nd turn begin

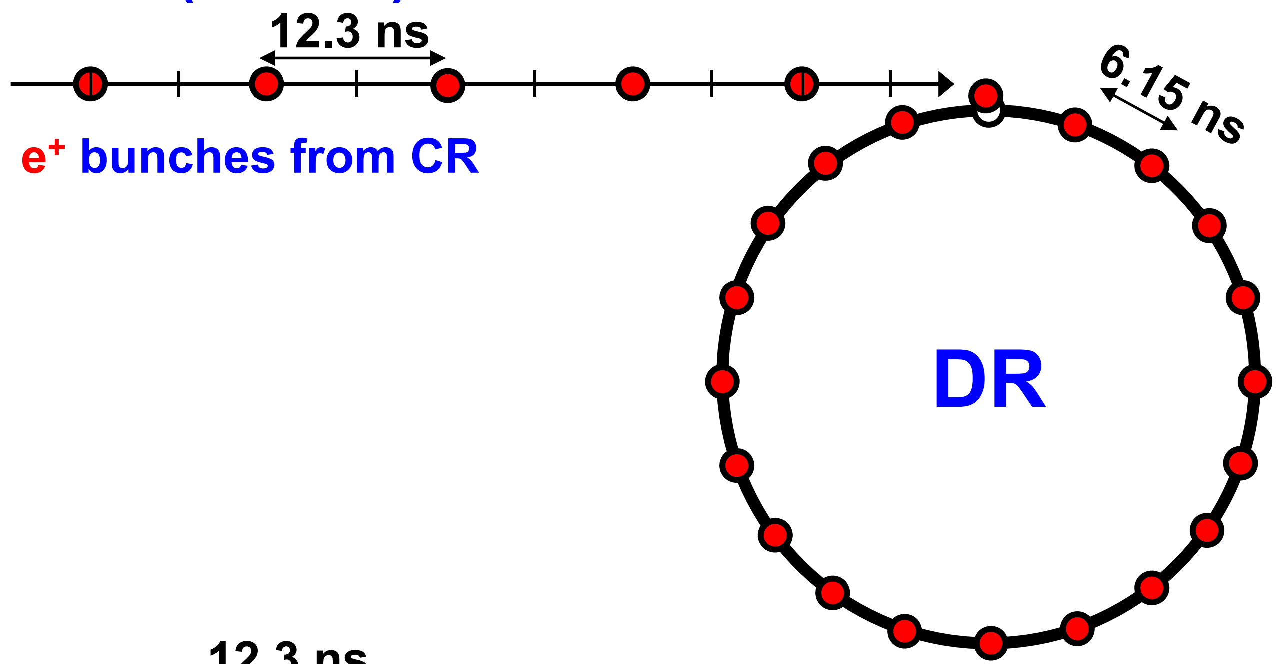


(2) 2nd turn end

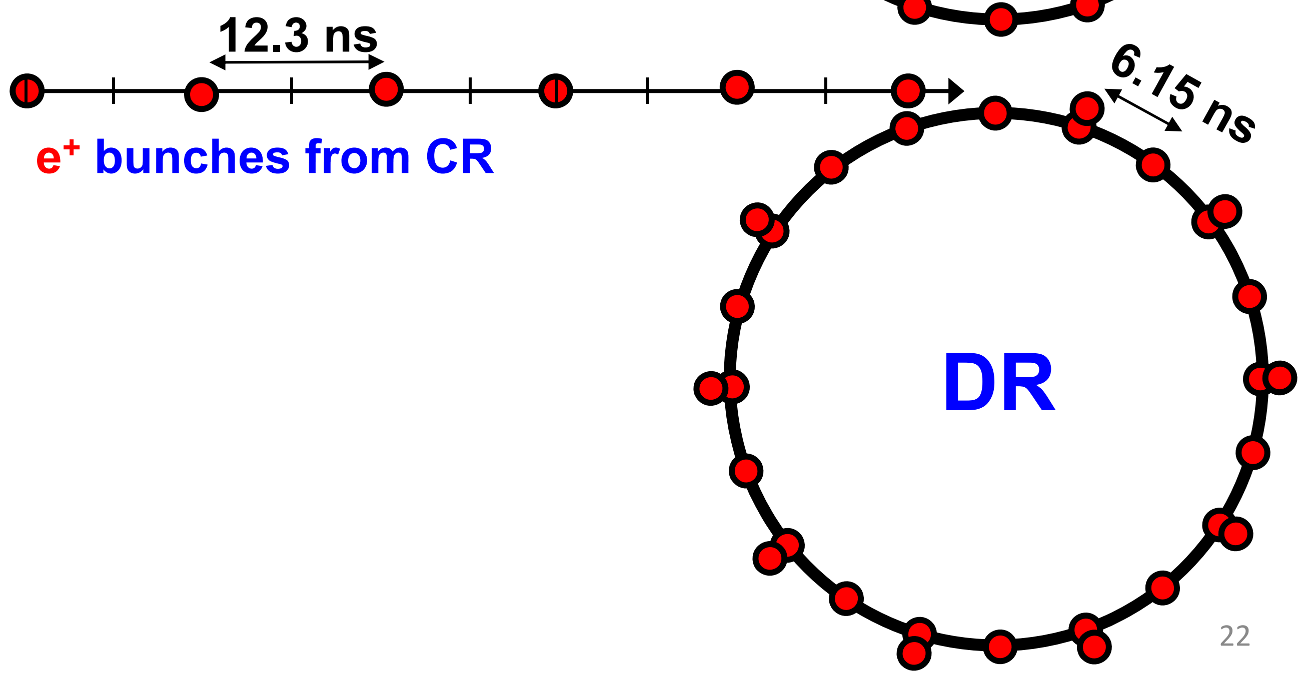


$T_{b\text{-}to\text{-}b}$(CR)=12.3ns (80Mhz): 3rd turn of DR stacking

(1) 3rd turn begin

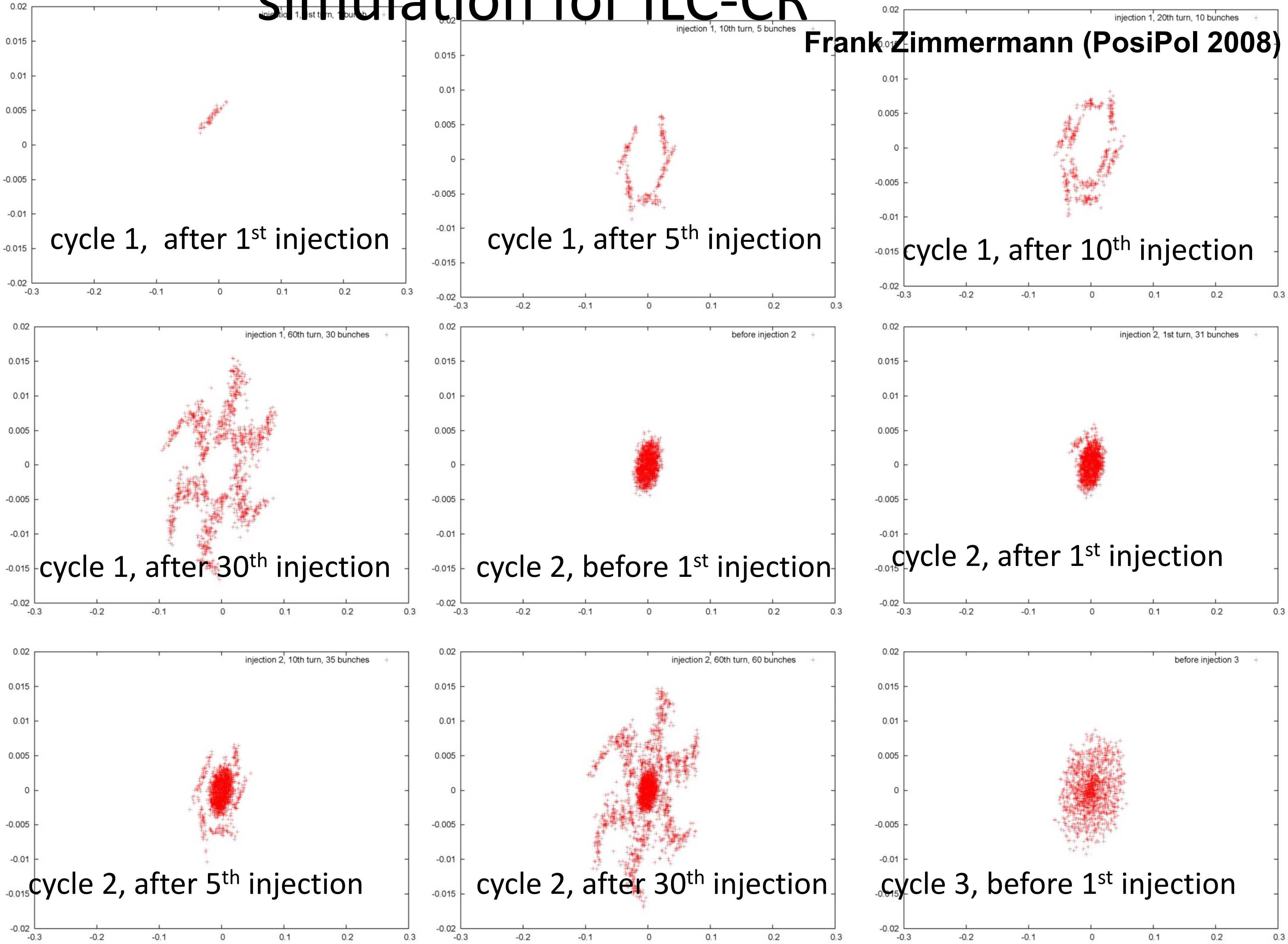


(2) 3rd turn end

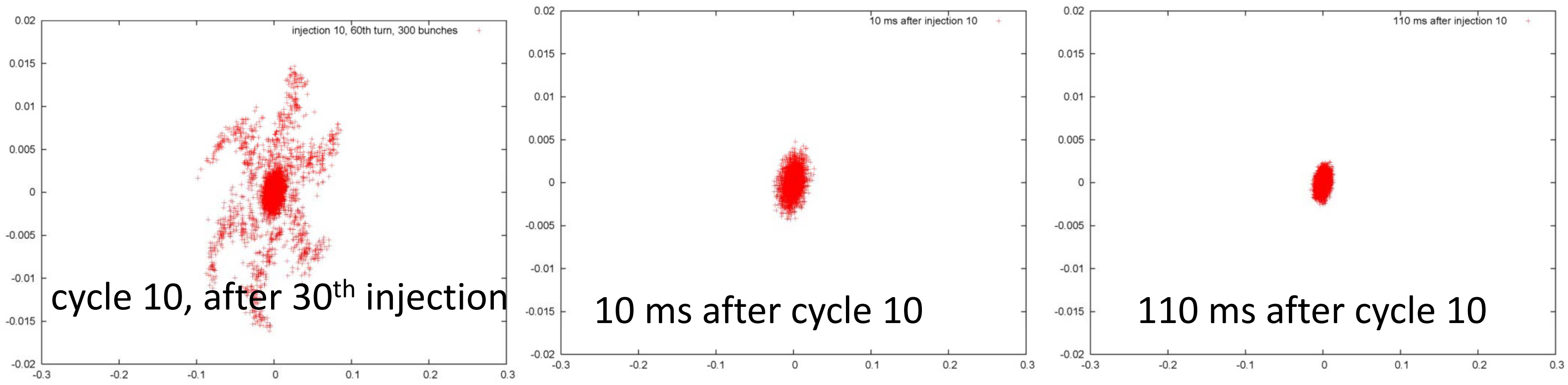


simulation for ILC-CR

Frank Zimmermann (PosiPol 2008)



Frank Zimmermann (PosiPol 2008)



~ 10.6% of injected e+ are lost!

similar loss fraction for single cycle

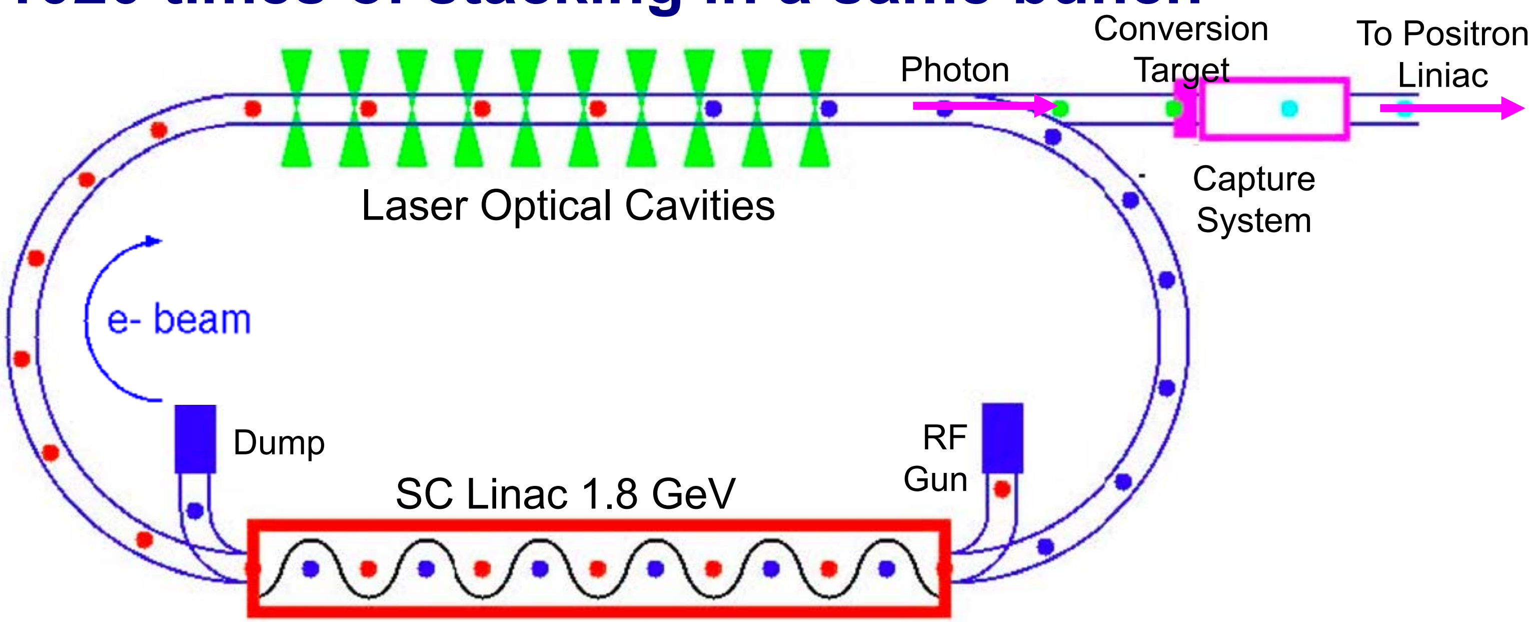
→ stacking efficiency ~90%

for ILC DR Compton version

ERL scheme for ILC

- **High yield + high repetition in ERL solution.**
  - **0.48 nC 1.8 GeV bunches x 5 of 600 mJ laser, repeated by 32 MHz -> 2.5E+9 γ-rays -> 2E+7 e+.**
  - **Continuous stacking the e+ bunches on a same bucket in DR during 100ms, the final intensity is 2E+10 e+.**

1020 times of stacking in a same bunch



ILC-CERL injection scheme - B

Frank Zimmermann (PosiPol 2008)

continuous stacking (ERL option), 32.5 MHz, 1020 injections over 5100 turns (inject every 5th turn), followed by 5155 turns (~100 ms) damping; damping time 6.4 ms; **inject with constant offset δ=0.9%, z=0.01 m**

σ_z=9 mm, **$\sigma_{\delta 0}$=1x10^{-4}** (0.5 MeV, small!!): **36% loss**

offset **d=1.0%, z=0.01 m**: **33% loss**

offset **d=1.2%, z=0.01 m**: **27% loss! 73% efficient**

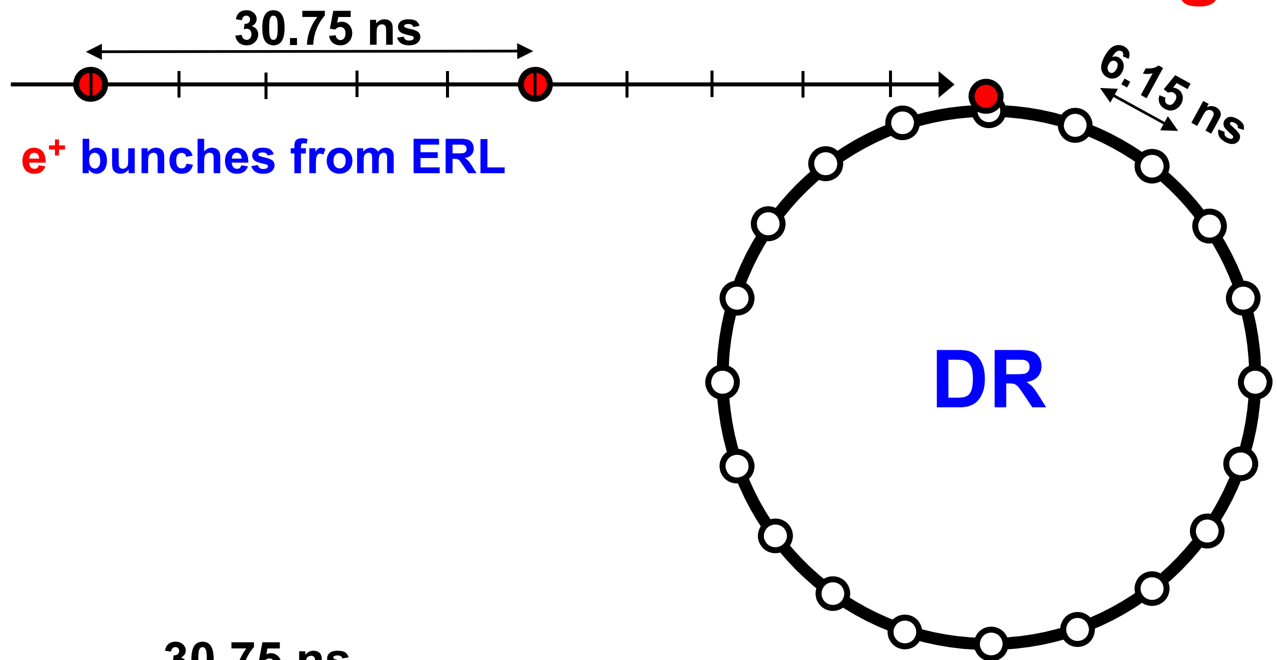
offset **d=1.3%, z=0.01 m**: **23% loss! 77% efficient**

offset **d=1.4%, z=0.01 m**: **16% loss! 84% efficient**

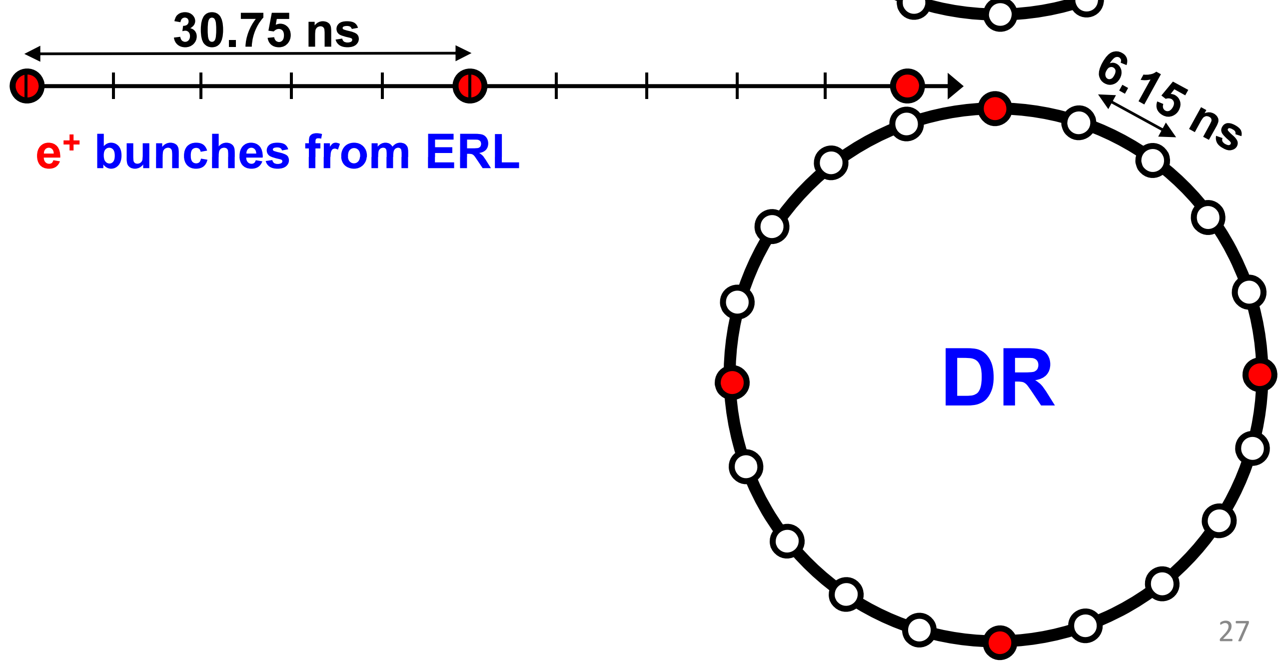
offset **d=1.5%, z=0.01 m**: **9% loss! 91% efficient!**

f_{rep}(ERL) = 32.5 MHz : 1st turn of DR stacking

(1) 1st turn
begin

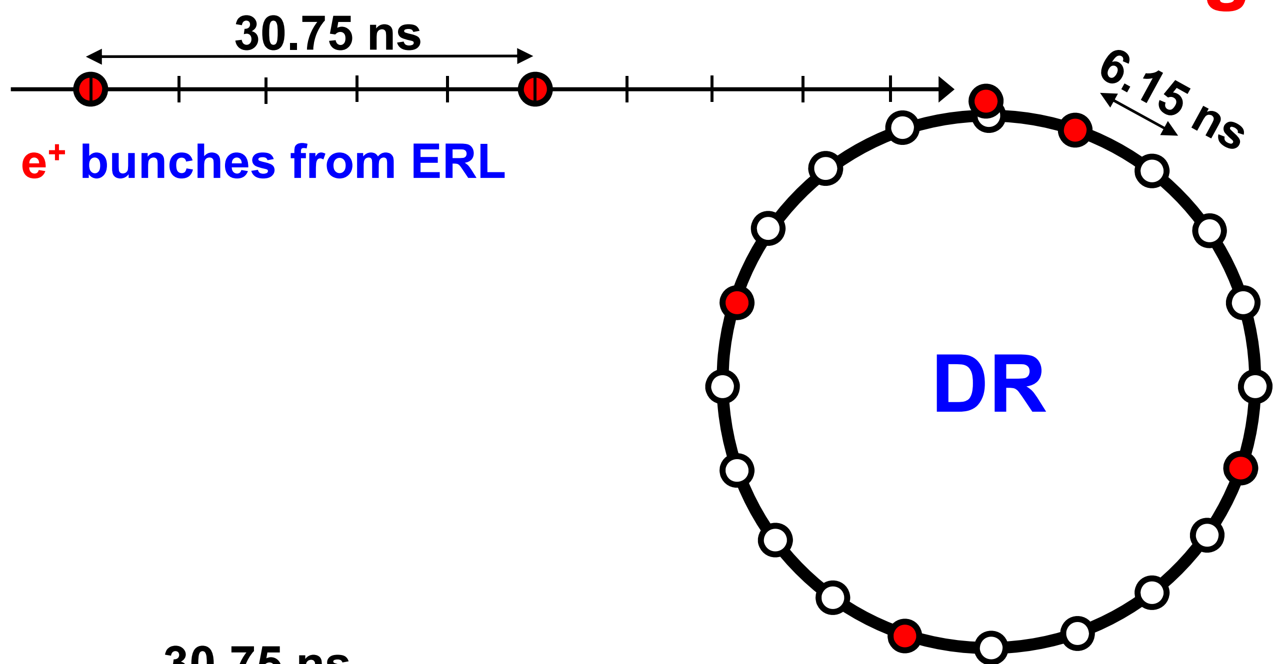


(2) 1st turn
end

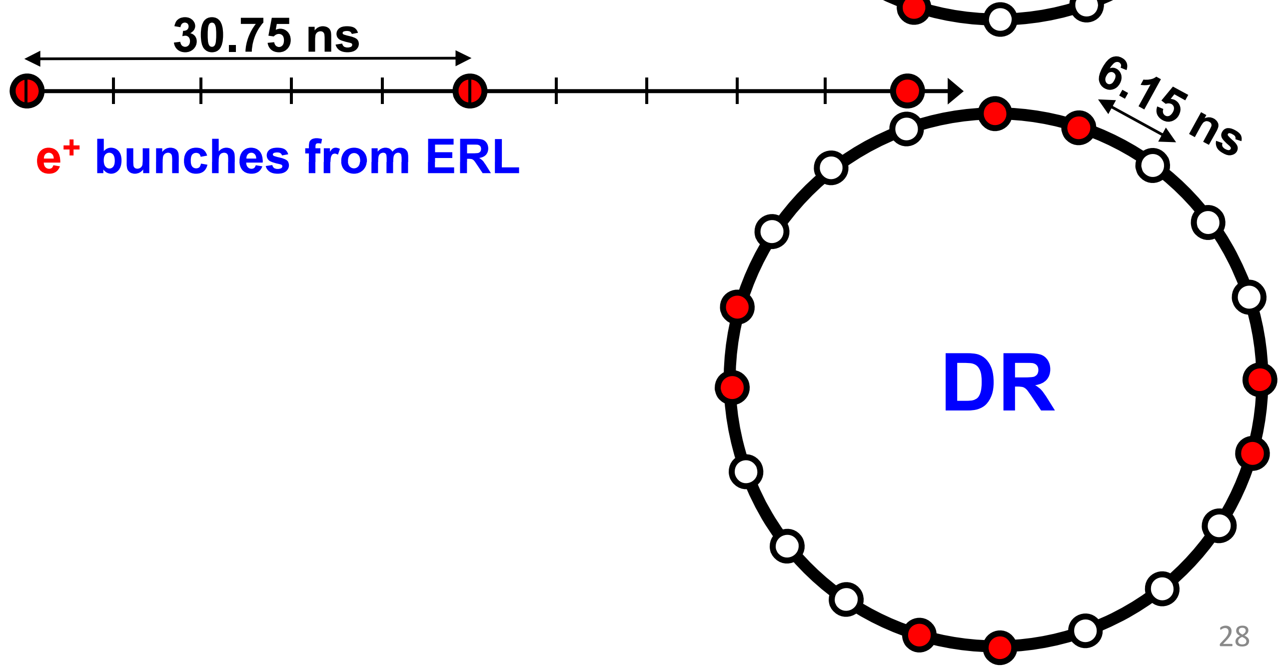


f_{rep}(ERL) = 32.5 MHz : 2nd turn of DR stacking

(1) 2nd turn begin

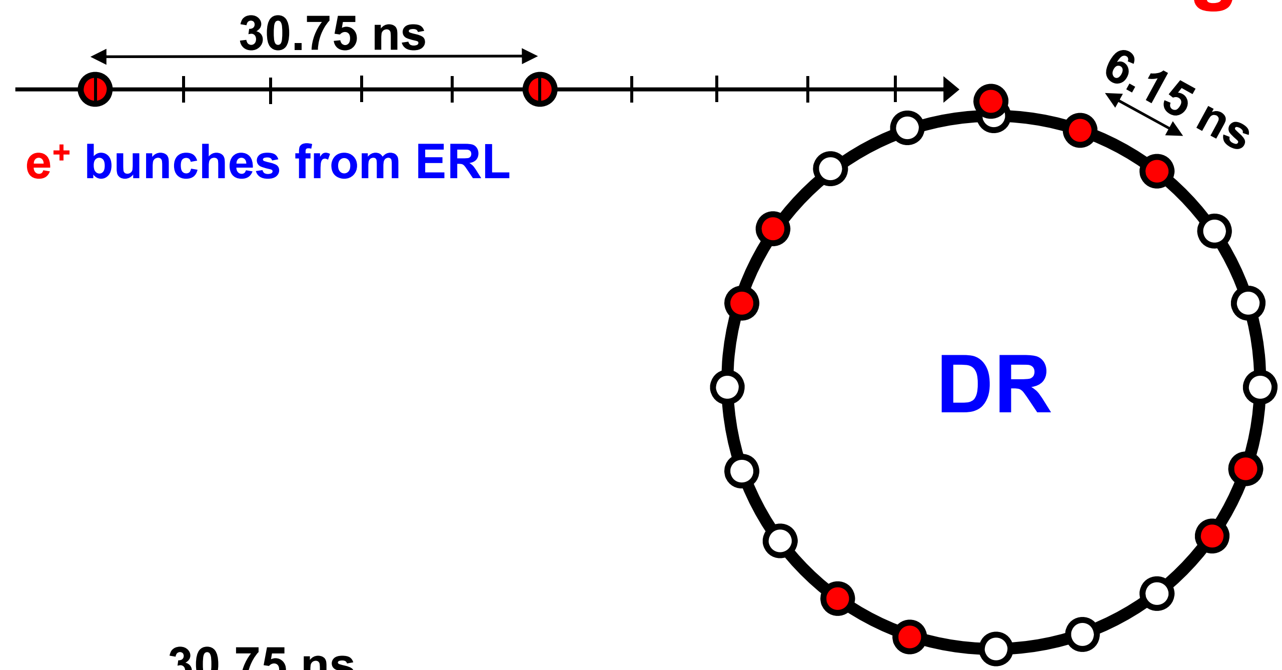


(2) 2nd turn end

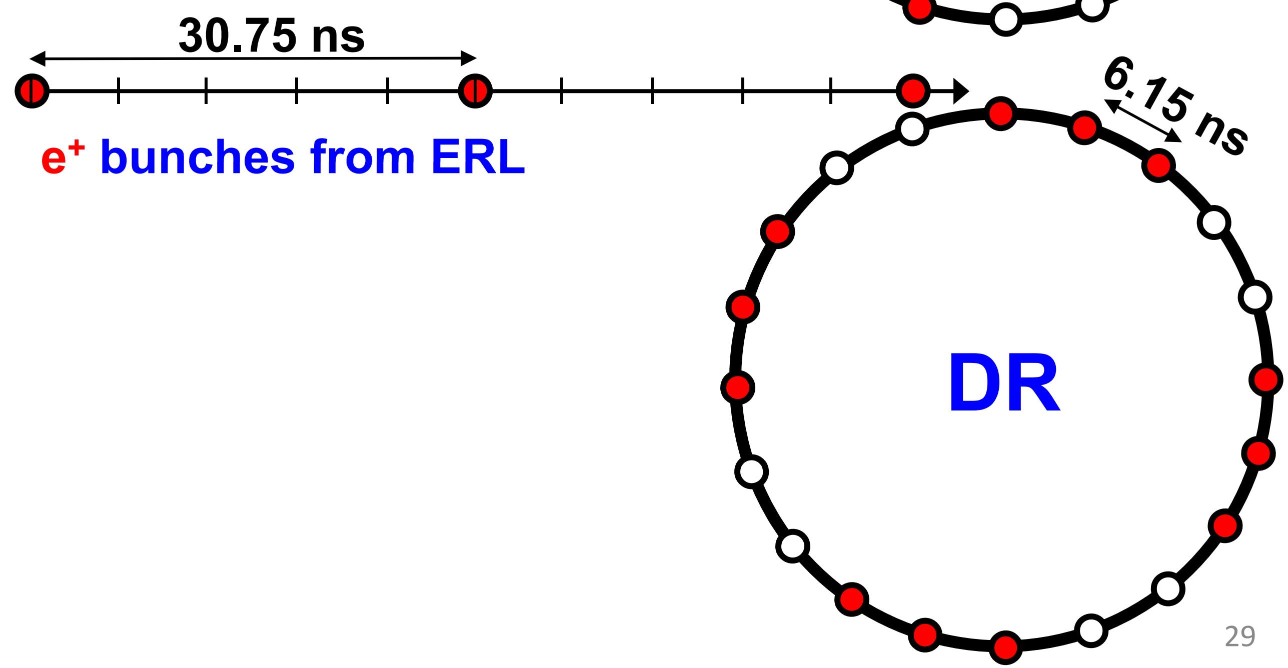


f_{rep}(ERL) = 32.5 MHz : 3rd turn of DR stacking

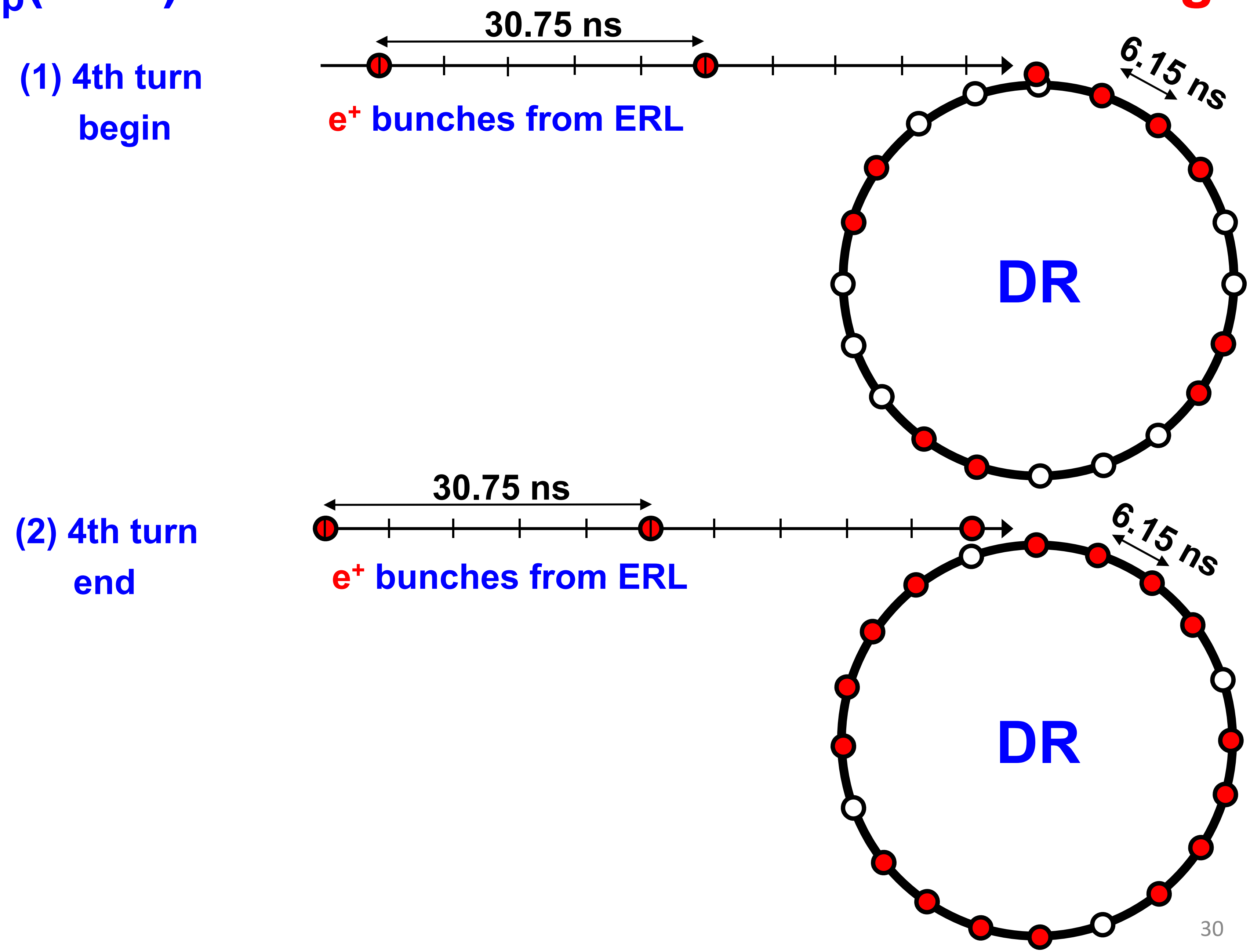
(1) 3rd turn
begin



(2) 3rd turn
end

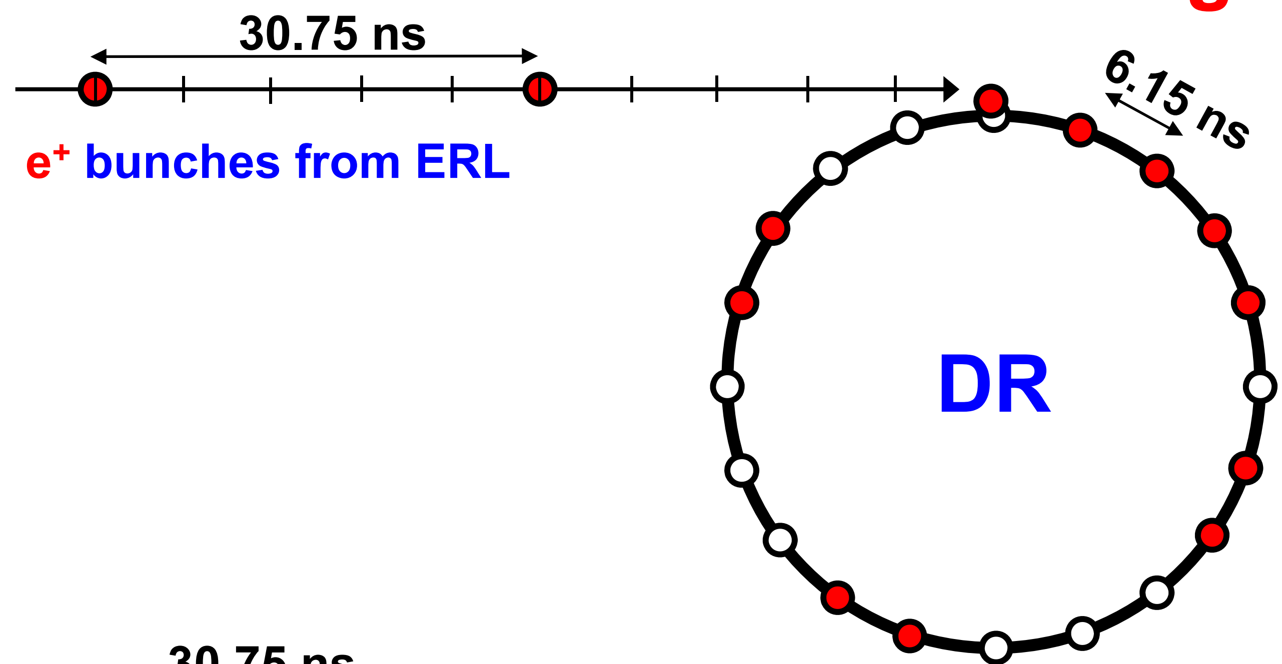


f_{rep}(ERL) = 32.5 MHz : 4th turn of DR stacking

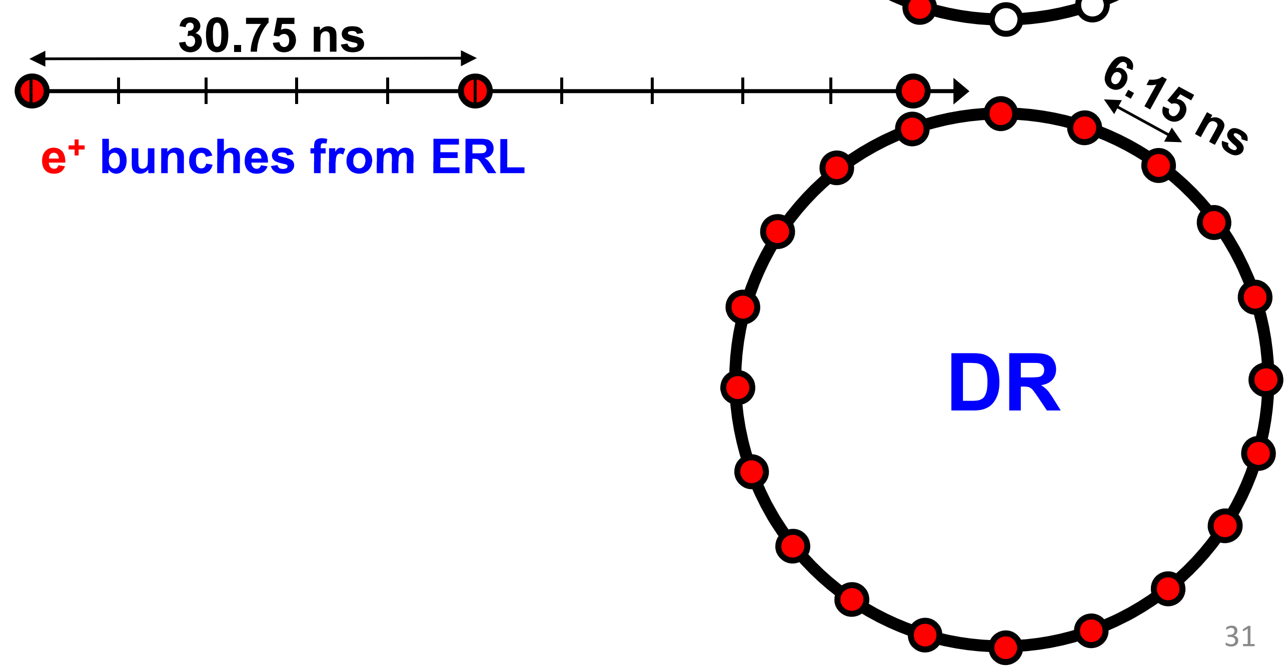


f_{rep}(ERL) = 32.5 MHz : 5th turn of DR stacking

(1) 5th turn begin

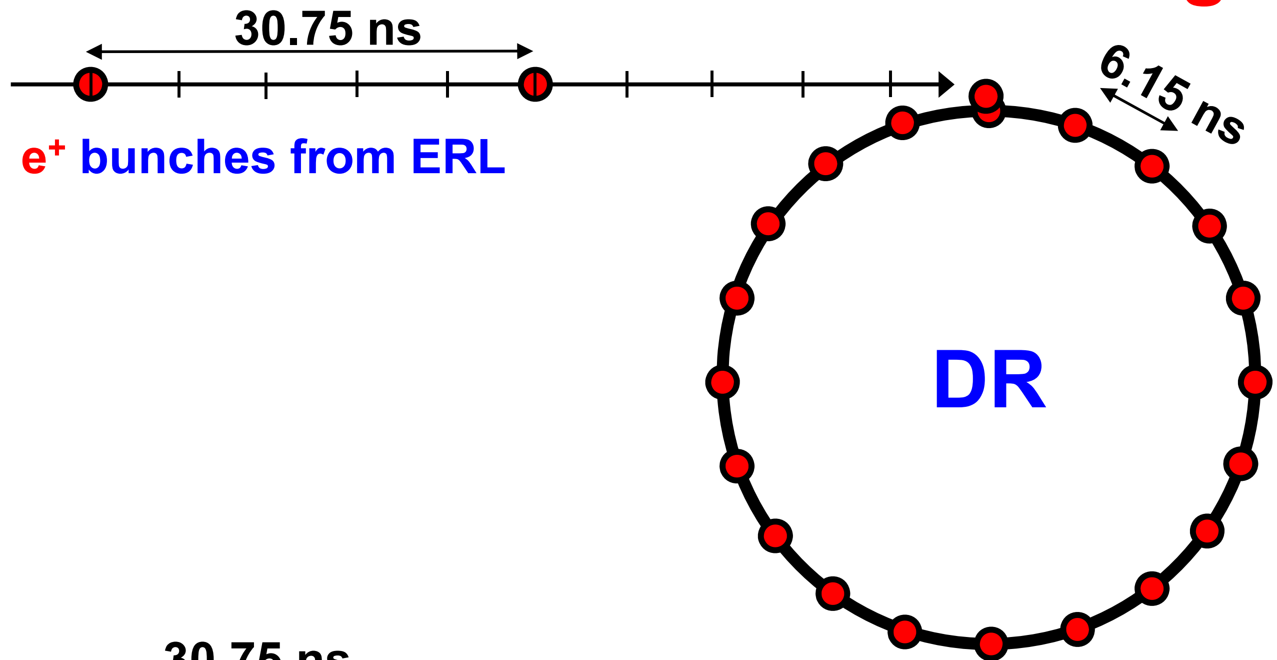


(2) 5th turn end

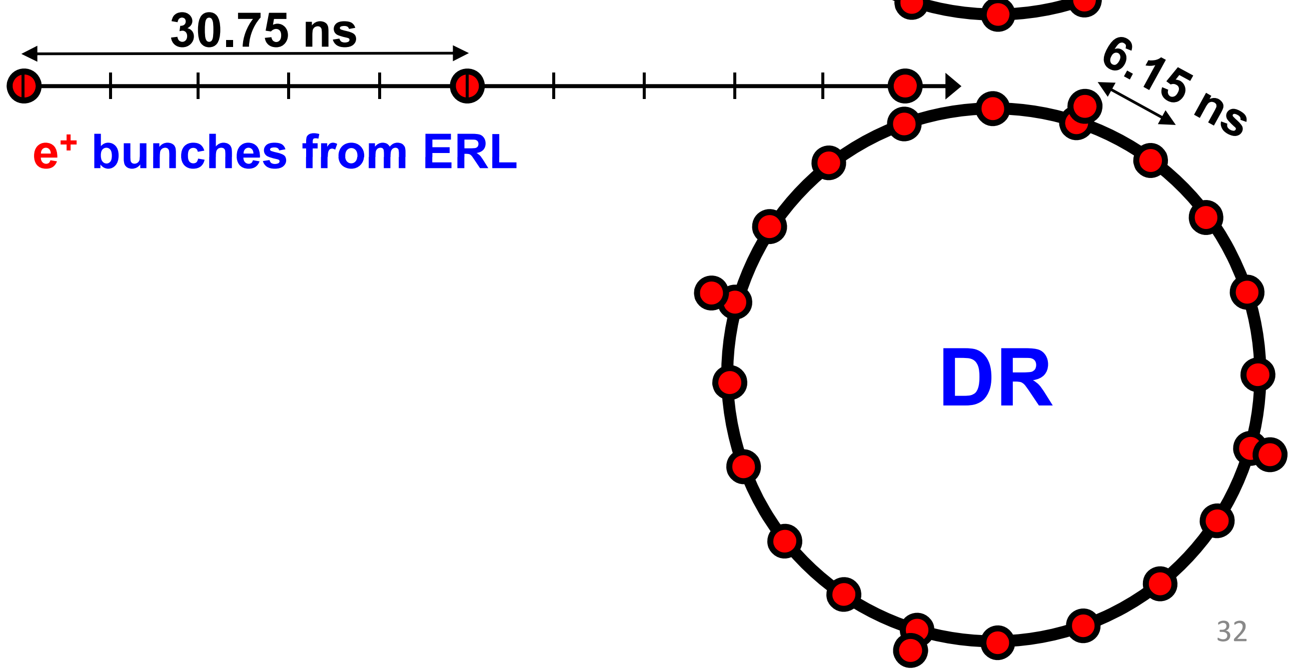


f_{rep}(ERL) = 32.5 MHz : 6th turn of DR stacking

(1) 6th turn
begin

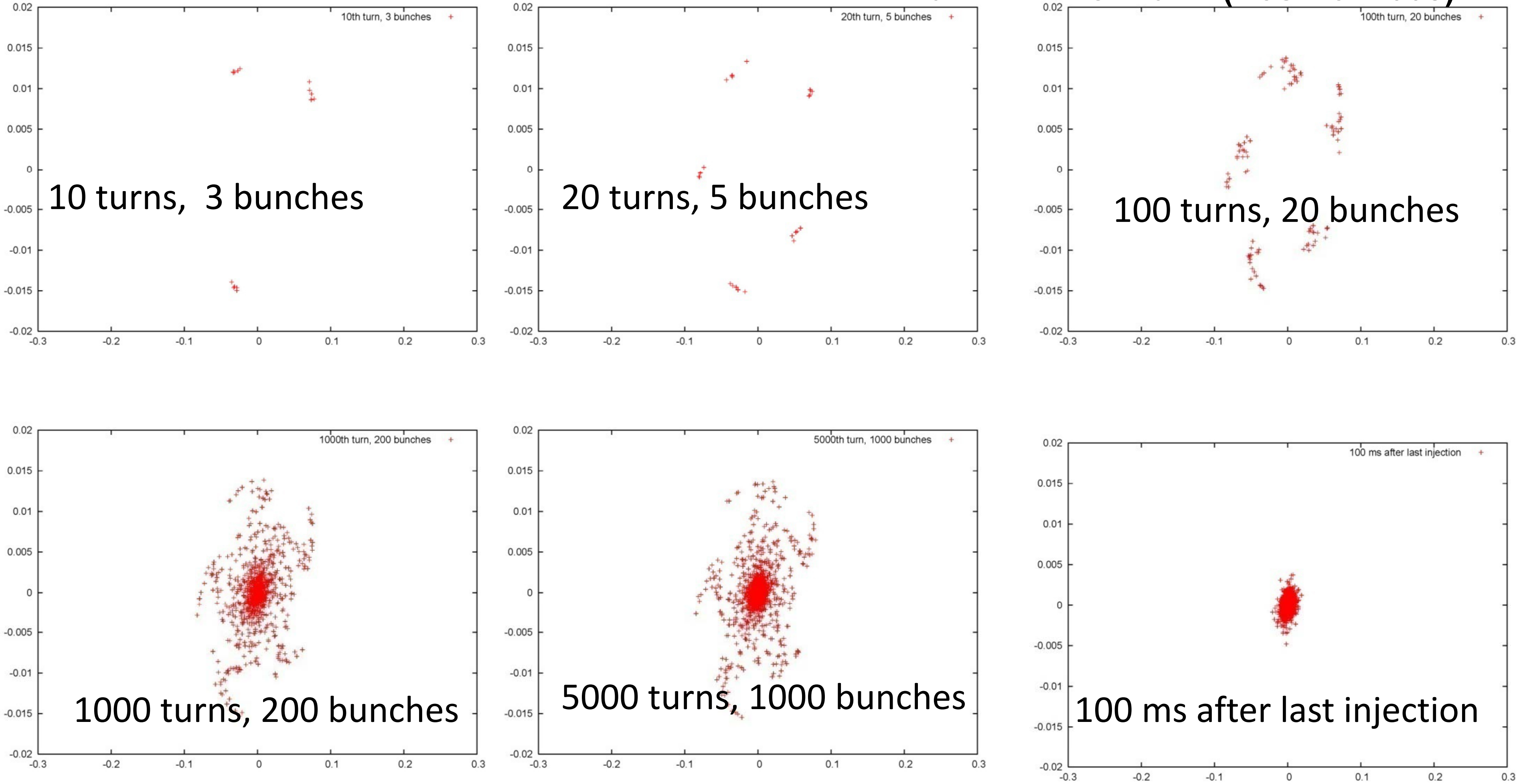


(2) 6th turn
end



simulation for ILC-CERL

Frank Zimmermann (PosiPol 2008)



→ stacking efficiency ~91%
for ILC DR Compton version

Acknowledgement

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