Ideas for e+ source and e+ polarization

29-May-2013

ECFA LC Workshop at DESY

T. Omori

Assumption

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- If Undulator source is OK, we need no discussions.
- We are worried about the status of the target R/D for undulator. It is challenging target: create 2600 bunches in 1 m sec. Tangential speed of 100 m/s required.
- Backup plan: 300 Hz conventional scheme. No polarization.

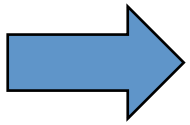
300 Hz scheme

conventional & NOT polarized.

e+ generation in 63 m sec (cf. undulator : in 1 m sec)

How?

- Total Number of bunches: 2640
- Divide into 20 triplets
  (1 Triplet = 3 Mini-Trains)
- Each triplet contains 132 bunches
- 2640 = 20 x 132
- 300 Hz creation of triplets
  triplet to triplet time space = 3.3 m sec
- Create 20 triplets : 63 m sec



Stretching in time

Conventional e+ Source for ILC

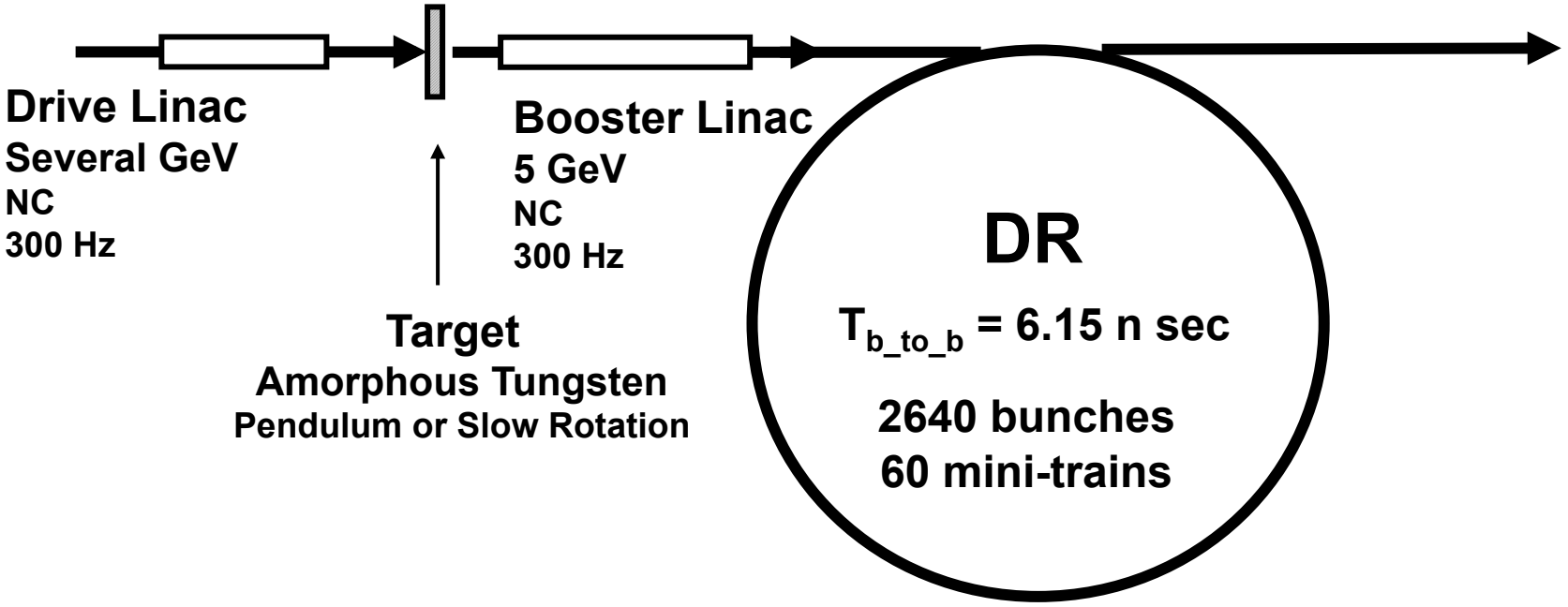
Normal Conducting Drive and Booster Linacs in 300 Hz operation

e+ creation

20 triplets, rep. = 300 Hz
- **triplet = 3 mini-trains with gaps**
- **44 bunches/mini-train, $T_{b\_to\_b}$ = 6.15 n sec**

go to main linac

2640 bunches/train, rep. = 5 Hz
- **$T_{b\_to\_b}$ = 369 n sec**



Time remaining for damping = 137 m sec

We create 2640 bunches in 63 m sec

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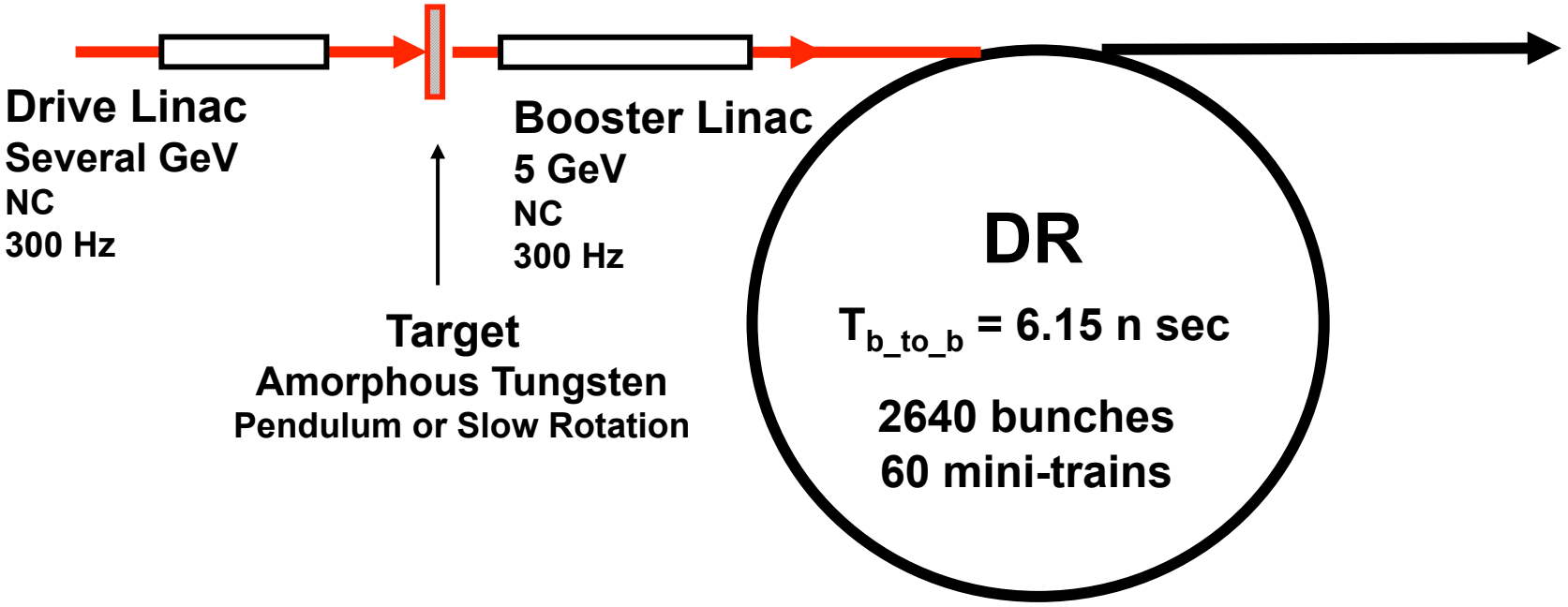

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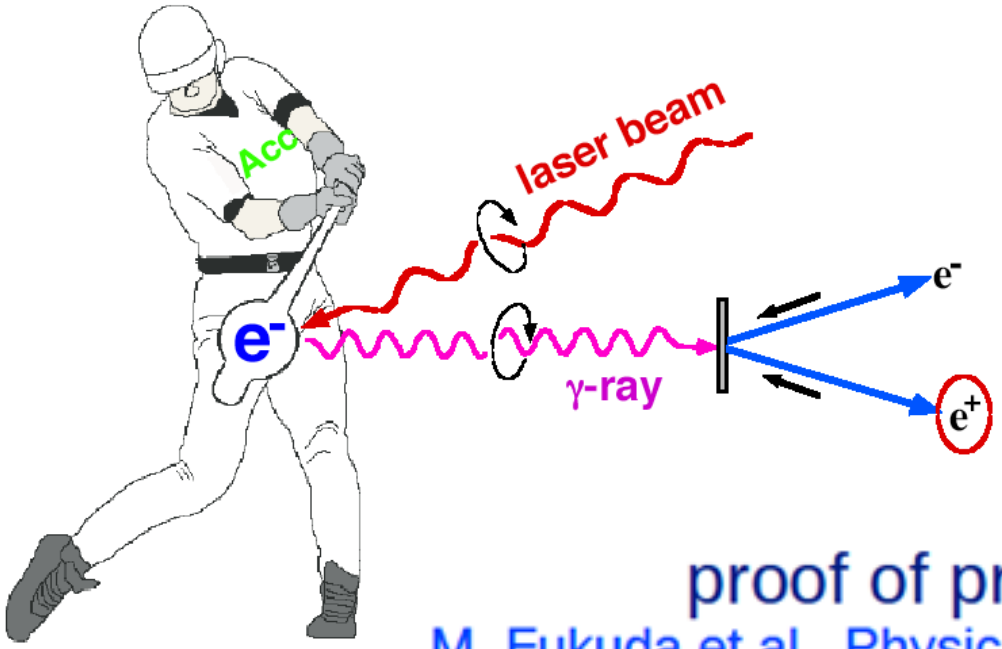
Compton Pol. e+ Source

Upgrade from
300 Hz Conventional e+ source
to
Compton pol. e+ source

Introduction

- Polarized e+ by laser Compton Scheme



Ee~1GeV for 10MeV gammas

easy to control polarization
independent source

proof of principle experiment

M. Fukuda et al., Physical Review Letters 91, 164801 (2003)
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Toward the positron sources

(1) Design Study : upgrade from 300 Hz Conventional

(2) R/D : Optical cavity at ATF

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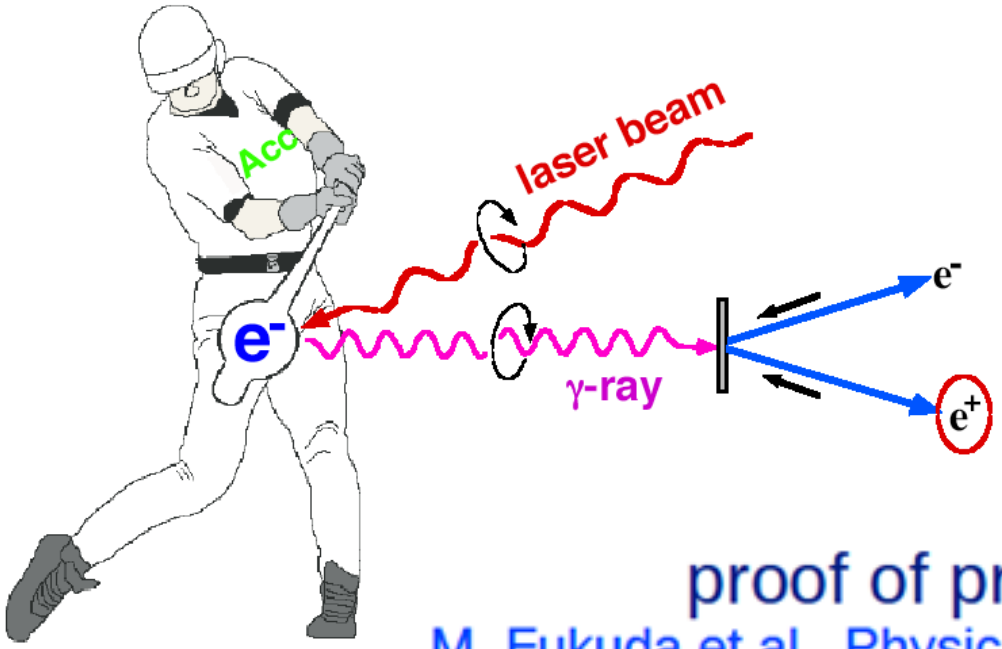

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(1) Design Study : upgrade from 300 Hz Conventional

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Design Study

Upgrade from
300 Hz Conventional e+ source
to
Compton pol e+ source.

Laser Compton e^+ Source for ILC

Reminder: We have 3 schemes.

1. Linac Base Laser Compton

   Linac + non-stacking Laser Cavity (λ=10μm),
   and No stacking in DR

   Proposal V. Yakimenko and I. Pogorersky

   T. Omori et al., Nucl. Instr. and Meth. in Phys. Res., A500 (2003) pp 232-252

2. Ring Base Laser Compton

   Storage Ring + Laser Stacking Cavity (λ=1μm),
   and e+ stacking in DR

   S. Araki et al., physics/0509016

3. ERL Base Laser Compton

   ERL + Laser Stacking Cavity (λ=1μm),
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Laser Compton e^+ Source for ILC

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Conventional e+ Source for ILC

Normal Conducting Drive and Booster Linacs in 300 Hz operation

e+ creation

20 triplets, rep. = 300 Hz, pulse length ~ 1μs
- **triplet = 3 mini-trains with gaps**
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go to main linac

2640 bunches/train, rep. = 5 Hz
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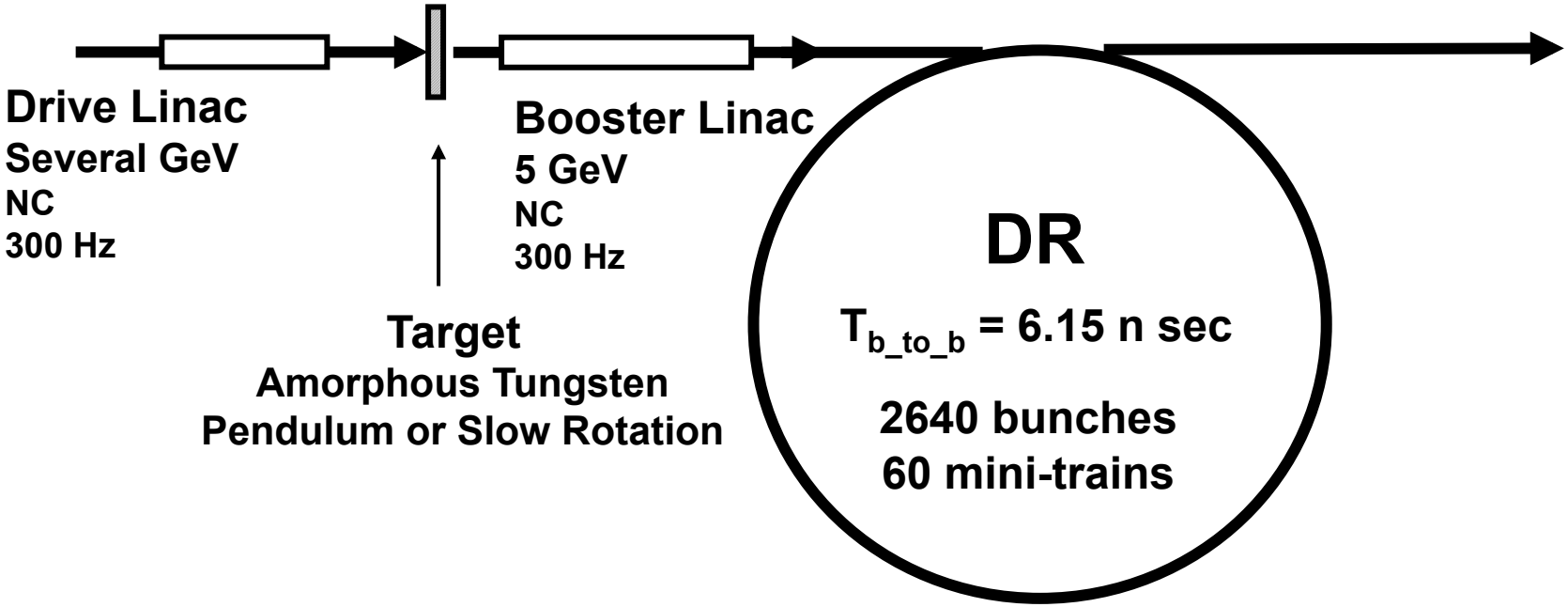

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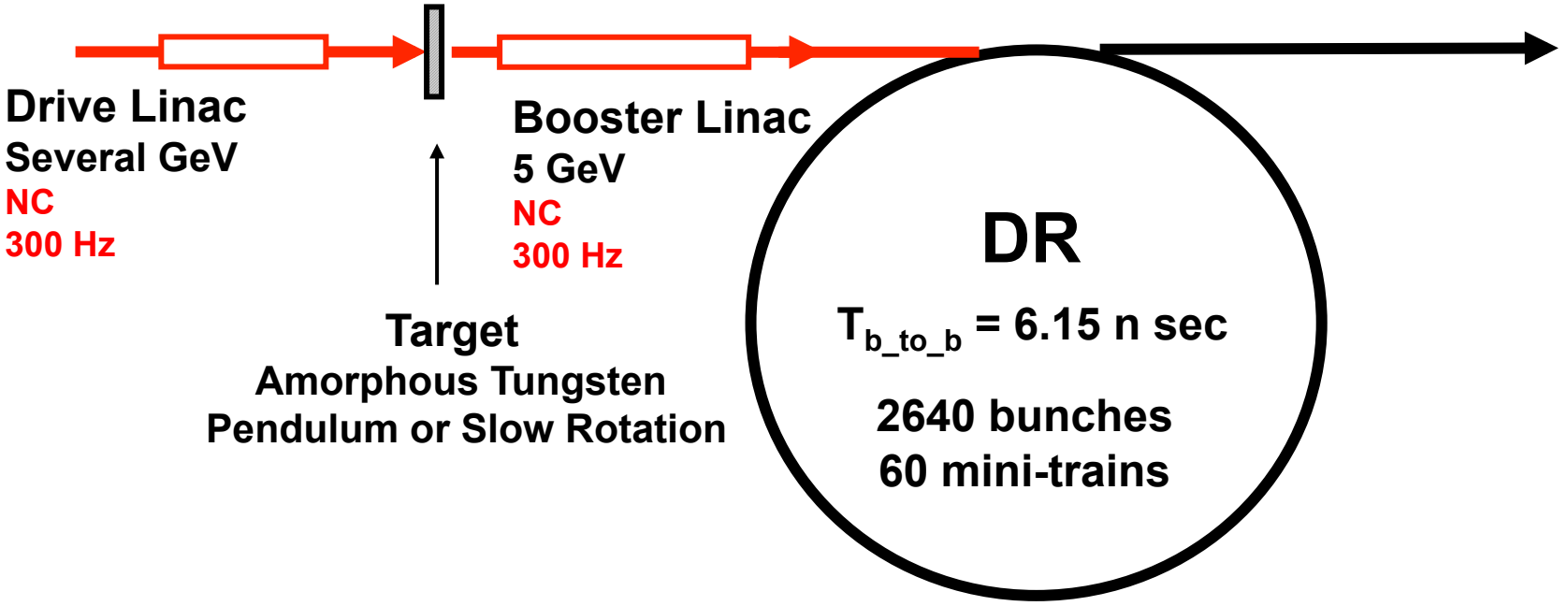
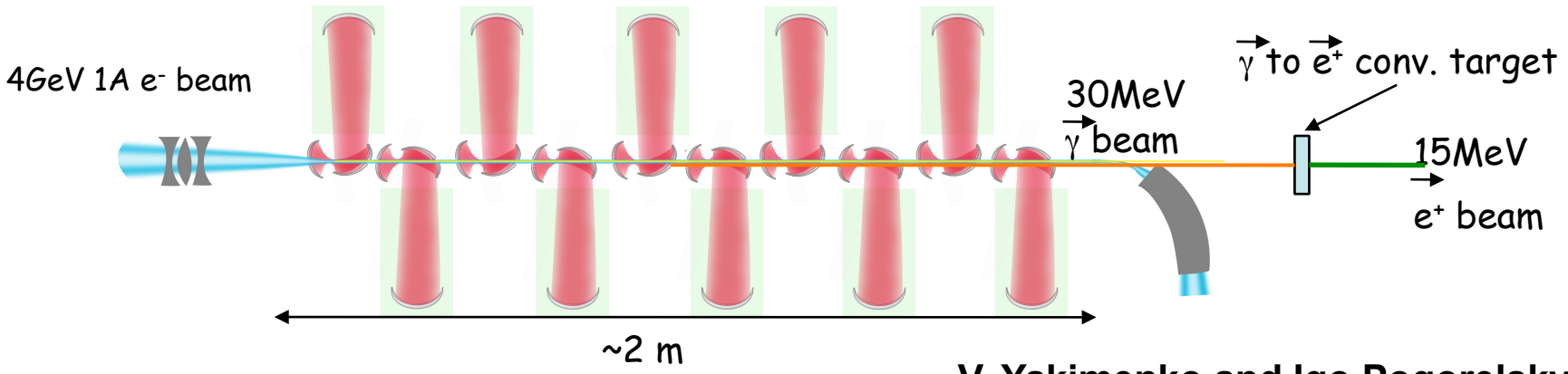


Time remaining for damping = 137 m sec

We create 2640 bunches
in 63 m sec

Linac Scheme

- CO_2 laser beam and 4 GeV e-beam produced by linac.
  - **4GeV 15nC e- beam with 12 ns spacing.**
  - **10 CPs, which stores 10 J CO_2 laser pulse repeated by 83 Mhz cycle.**
- 5E+11 γ-ray -> 2E+10 e+ (2% conversion)
- 1.2μs pulse, which contains 100 bunches, are repeated by 150 Hz to generated 3000 bunches within 200ms.
  - Laser system relies on the commercially available lasers but need R&D for high repetition operation.
  - Ring cavity with laser amplifier realizes the C02 laser pulse train.



V. Yakimenko and Igo Pogorelsky

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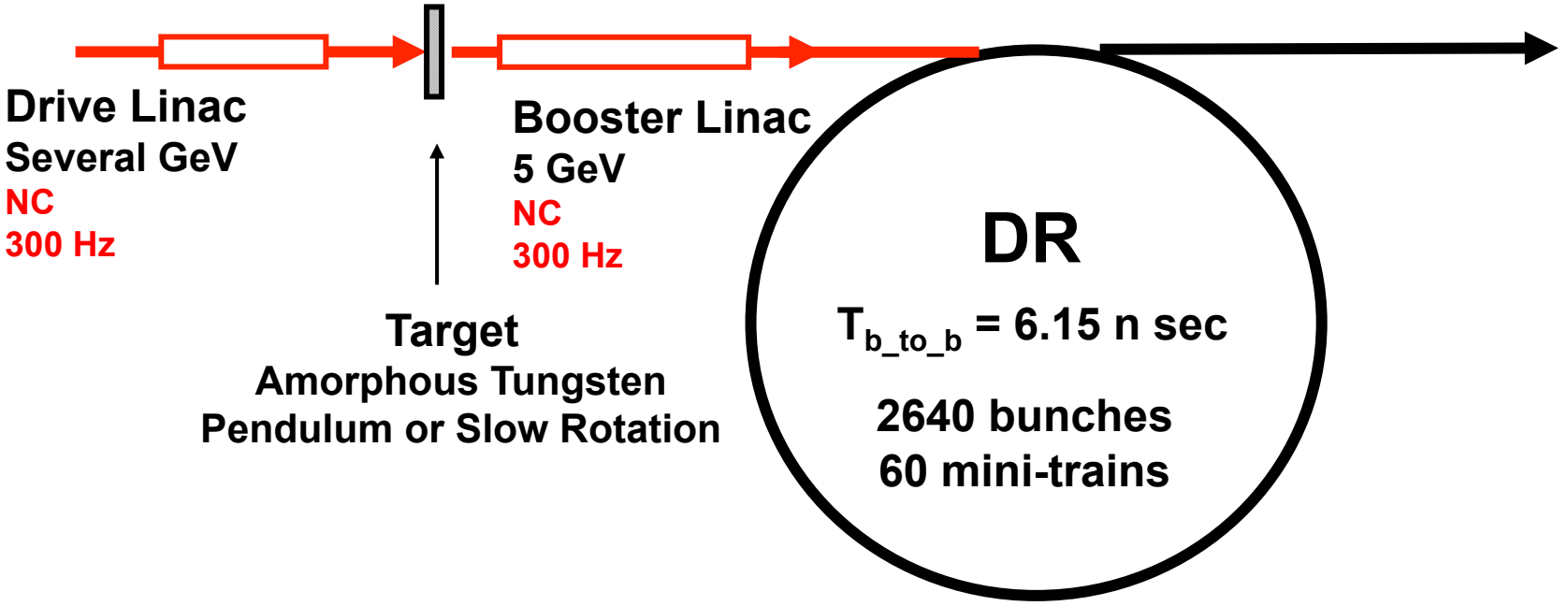

Time remaining for damping = 137 m sec

We create 2640 bunches
in 63 m sec

Linac Compton (NO big change)

Normal Conducting Drive and Booster Linacs <-- Reuse

e+ creation

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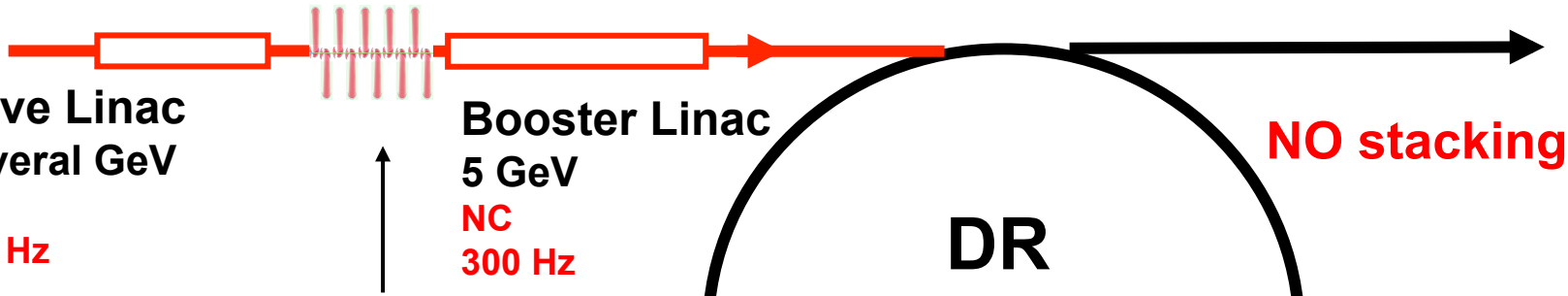


Drive Linac
Several GeV
NC
300 Hz

Booster Linac
5 GeV
NC
300 Hz

Target
CO2 Laser Cavities

Replace target
Single Tungsten Target --> CO2 Laser Cavies

DR
$T_{b\_to\_b}$ = 6.15 n sec
2640 bunches
60 mini-trains

NO stacking in DR

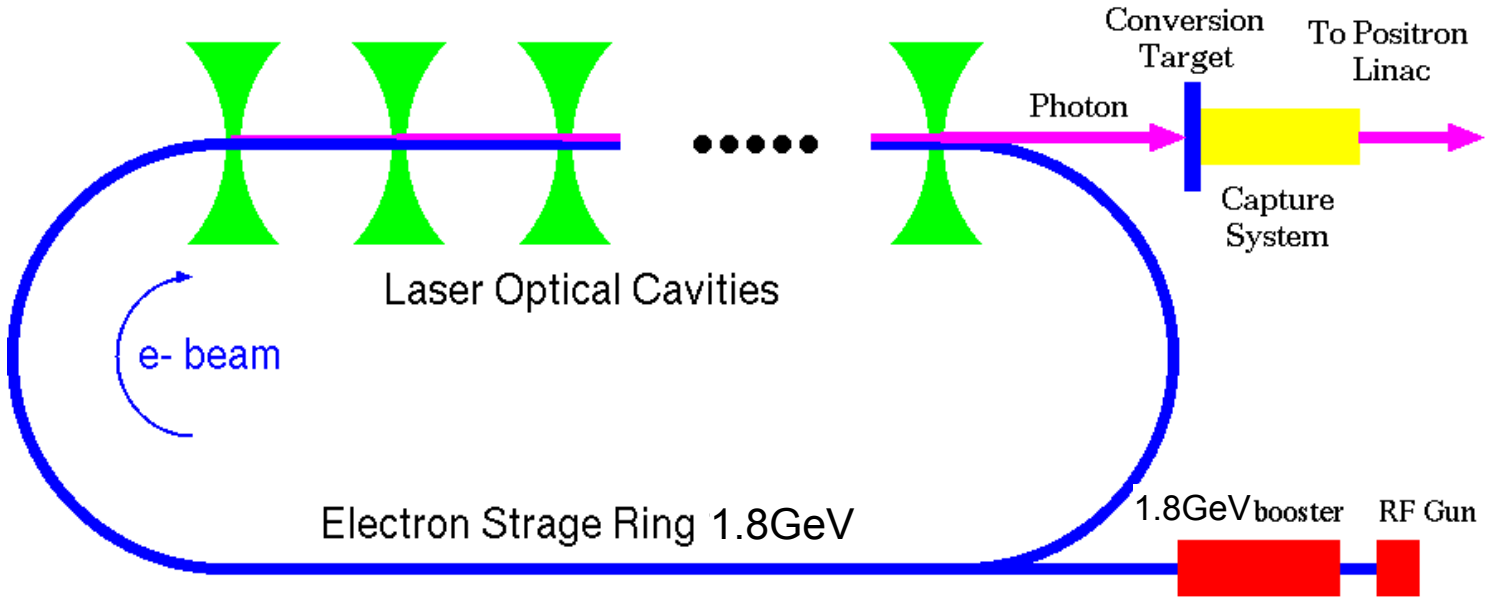
Time remaining for damping = 137 m sec

We create 2640 bunches
in 63 m sec

Compton Ring

- Electron driver:5.3nC, 6.2ns, 1ps, 1.8GeV
- Laser : 0.6Jx5 CP (optical cavities).
- By one collision, positron bunch with Ne+:2.0E+8 is generated.
- 10 bunches are stacked on a same bucket in DR. This process is repeated 10 times with 10ms interval .
- Finally, Ne+:2E+10 is obtained.

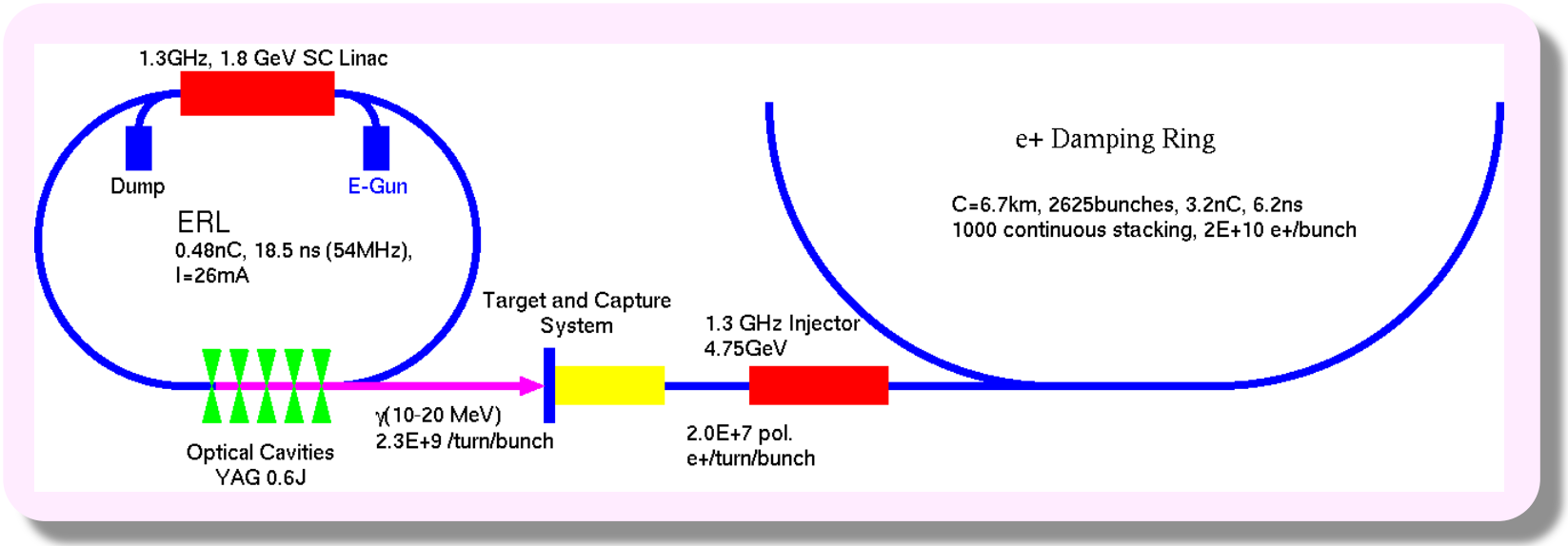
90 ms (10 ms x 9)



ERL scheme

- Electron is provided by ERL (Energy Recovery Linac).
- Both advantages (high yield at Linac and high repetition at CR) are compatible in the ERL solution.
- Continuous stacking the e+ bunches on a same bucket in DR during 100ms, the final intensity is 2E+10 e^+.
- Another 100ms is used for damping.

100 ms



Ring/ERL Compton

Normal Conducting Drive < -- Throw away, Booster Linac <-- Reuse

300 Hz Conventional

e+ creation

20 triplets, rep. = 300 Hz
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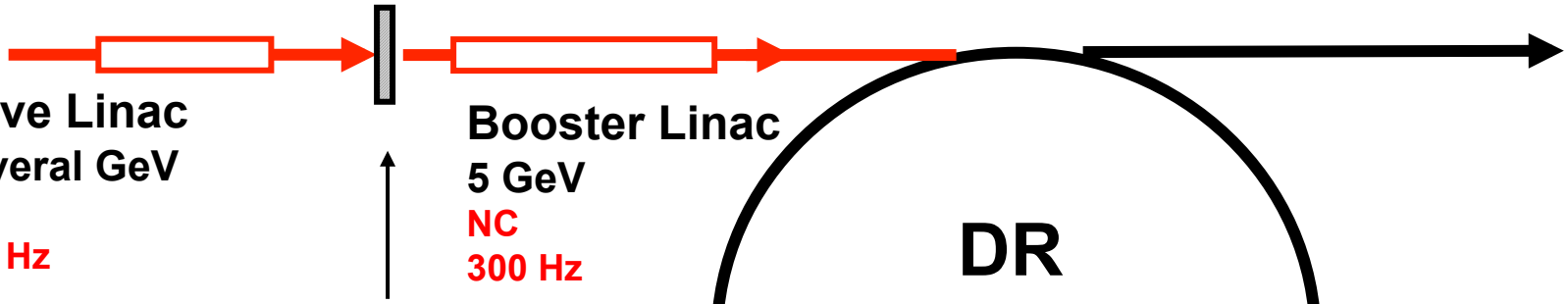


Drive Linac
Several GeV
NC
300 Hz

Booster Linac
5 GeV
NC
300 Hz

Target
Amorphous Tungsten
Pendulum or Slow Rotation

DR

$T_{b\_to\_b}$ = 6.15 n sec

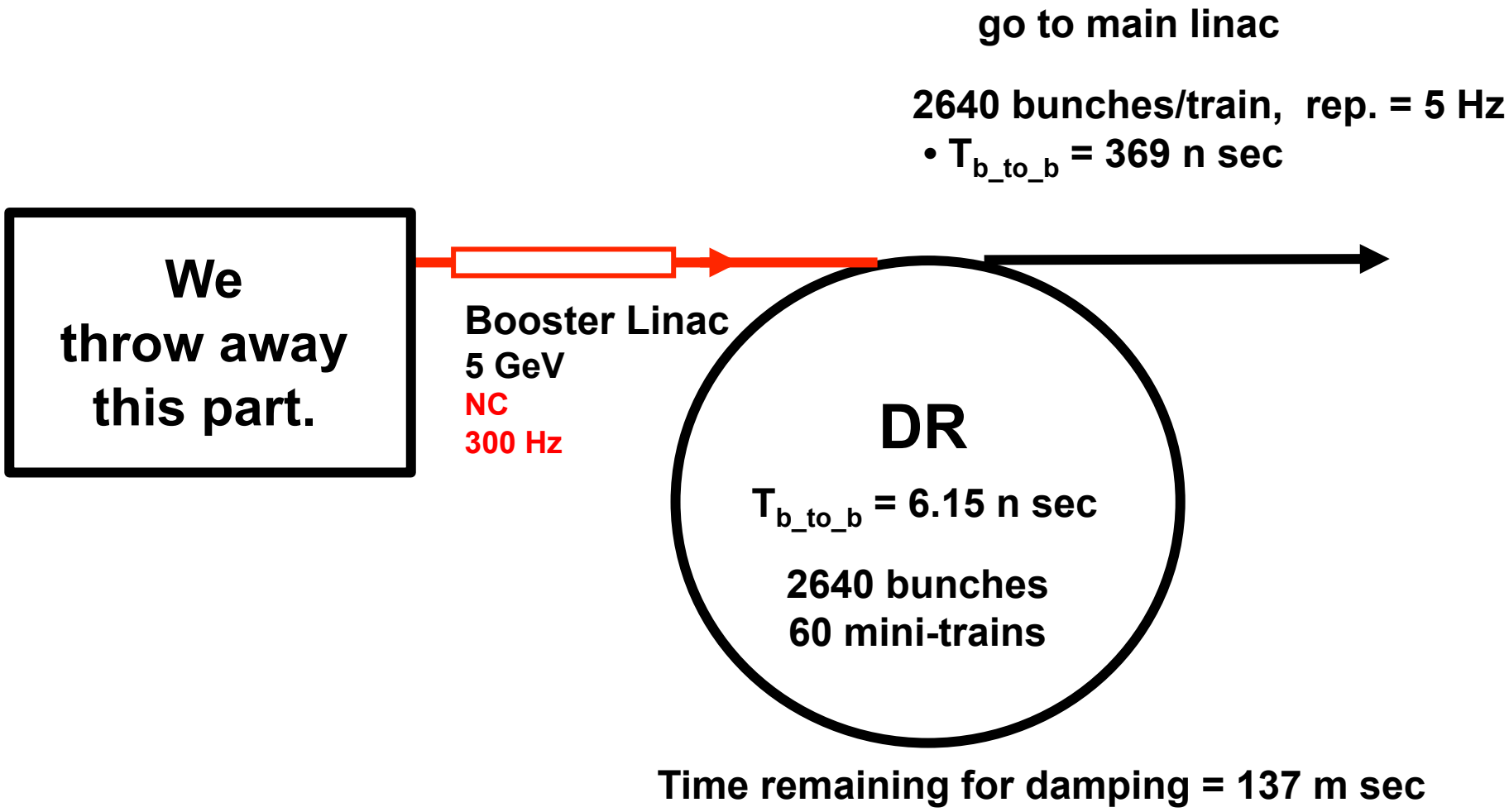
2640 bunches
60 mini-trains

Time remaining for damping = 137 m sec

We create 2640 bunches in 63 m sec

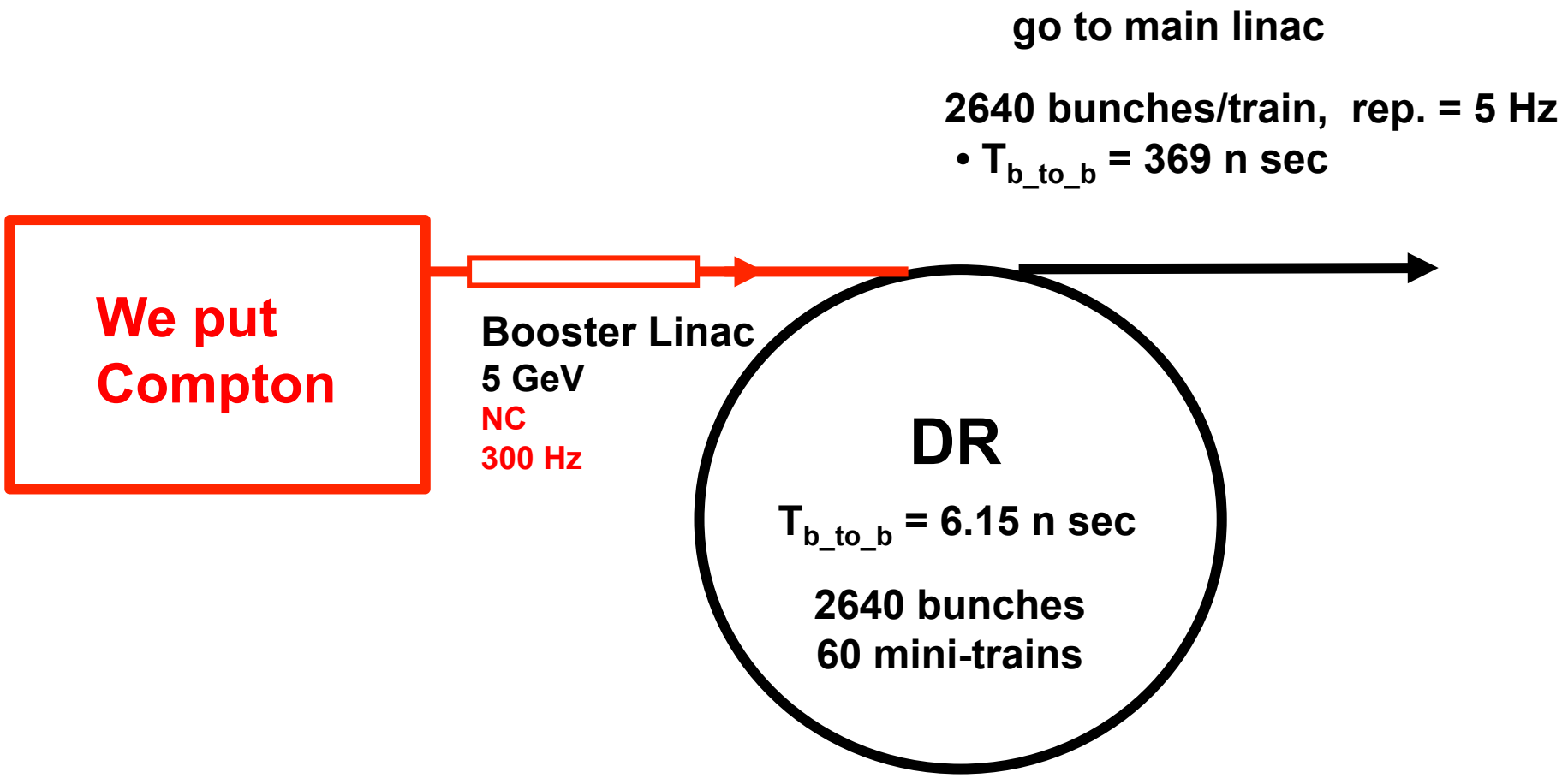
Ring/ERL Compton

Normal Conducting Drive < -- Throw away, Booster Linac <-- Reuse



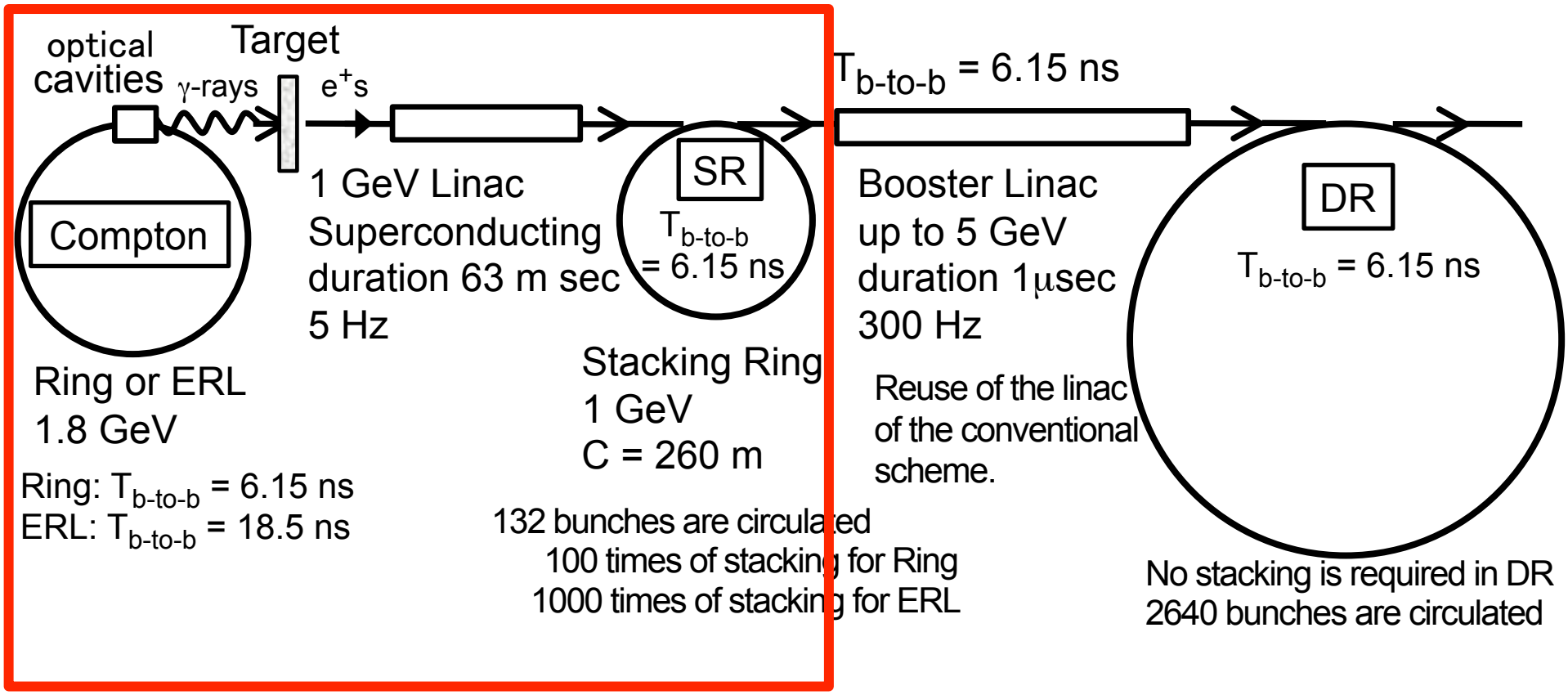
Ring/ERL Compton

Normal Conducting Drive < -- Throw away, Booster Linac <-- Reuse



Ring/ERL Compton (Big Change)

Normal Conducting Drive < -- Throw away, Booster Linac <-- Reuse



Compton

300 Hz Conventional e+
→ Compton pol. e+ source

Ways from 300 Hz conventional e^+ source to Compton pol e^+ source are presented.

(1) Linac Compton :

Small modification. Just replace tungsten target by CO2 laser cavities.

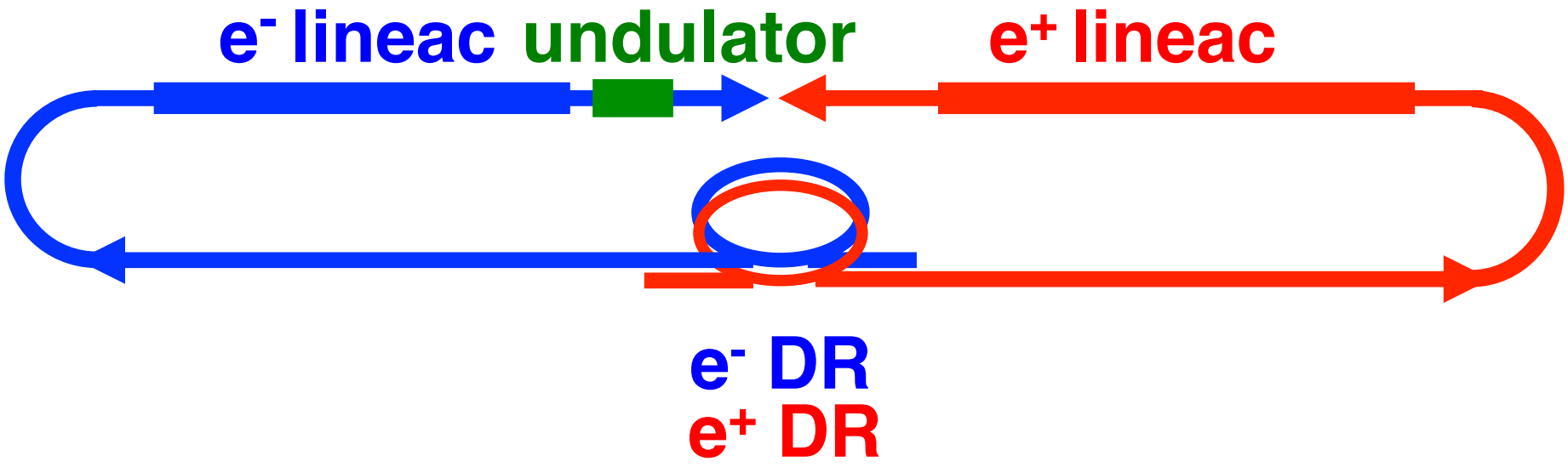
(2) Ring/ERL Compton :

Large modification is required. We add a 1 GeV SC linac (63 ms pulse), a 1 GeV stacking ring, and a Ring/ERL as a driver.

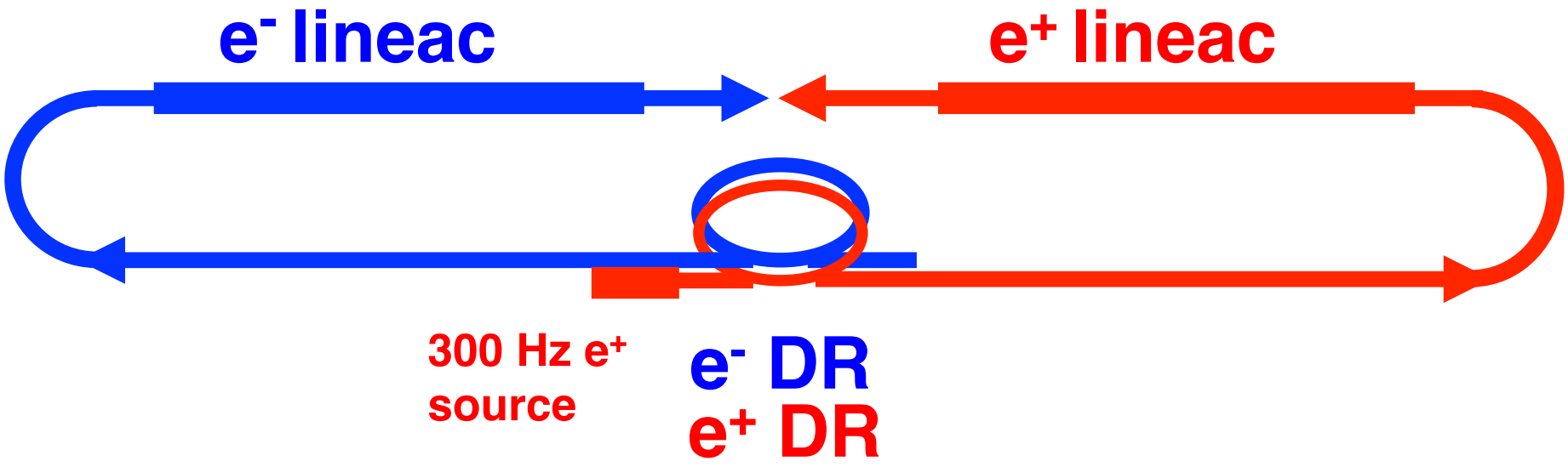
Undulator

Upgrade from
300 Hz Conventional e+ source
to
Undulator pol. e+ source

Undulator e+ source

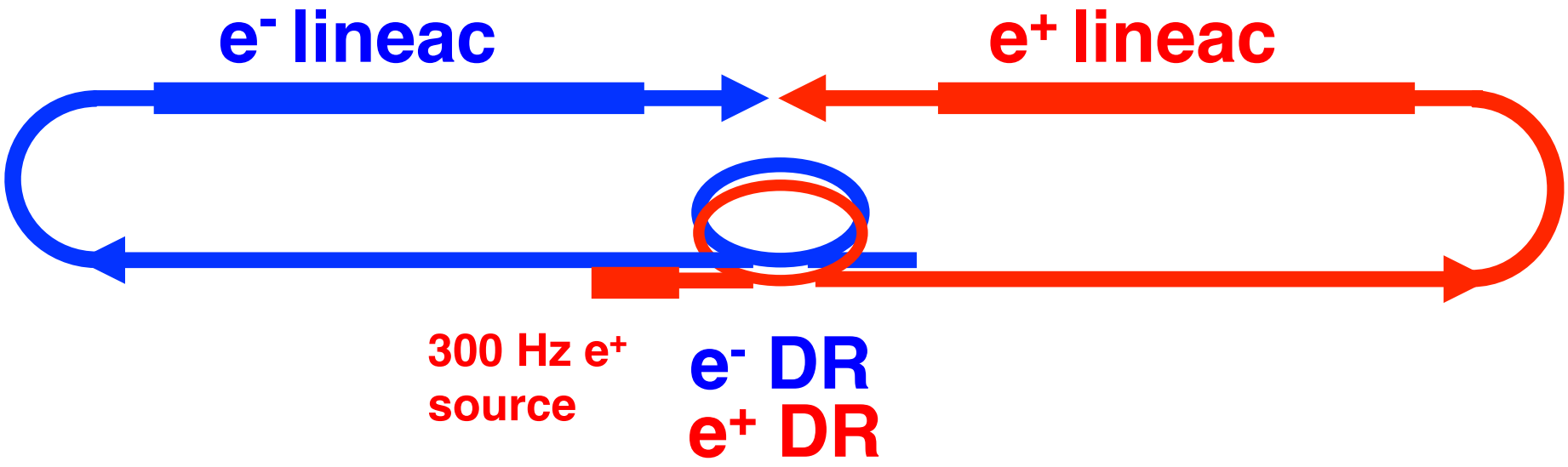


300 Hz Conventional e+



300 Hz Conventional e+

→ Undulator pol. e+ source



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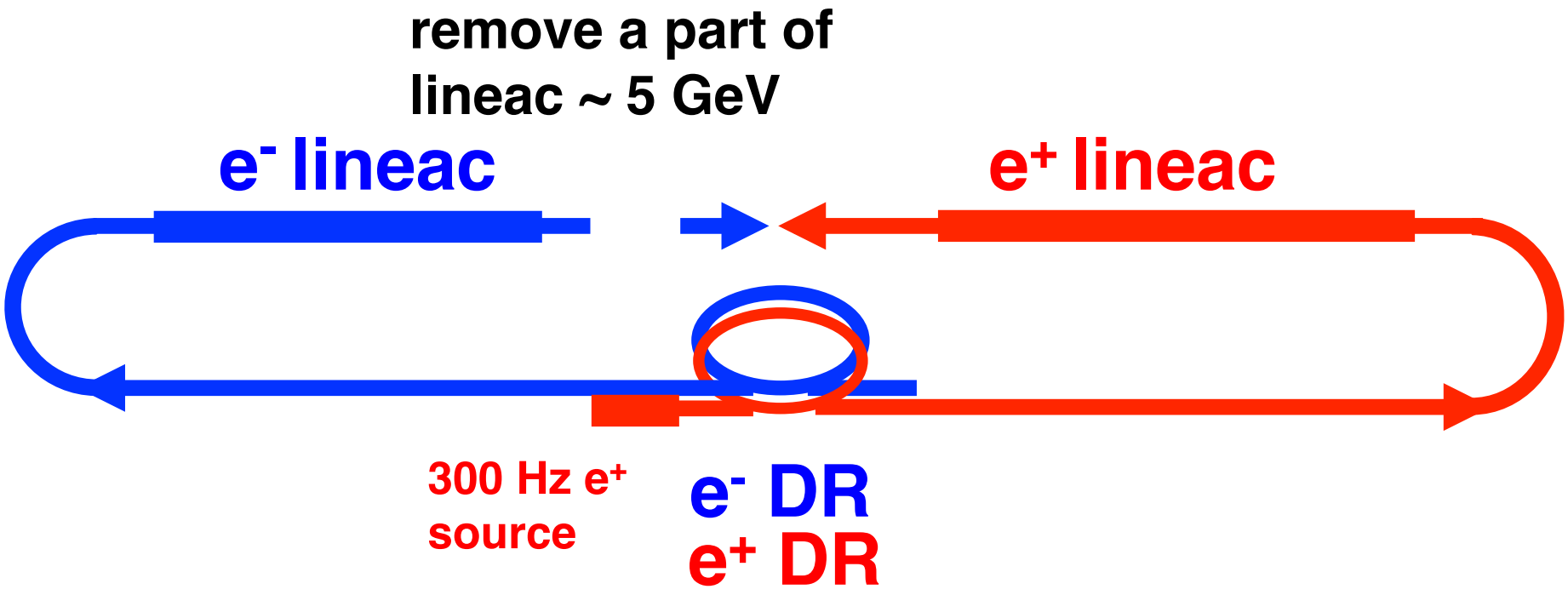

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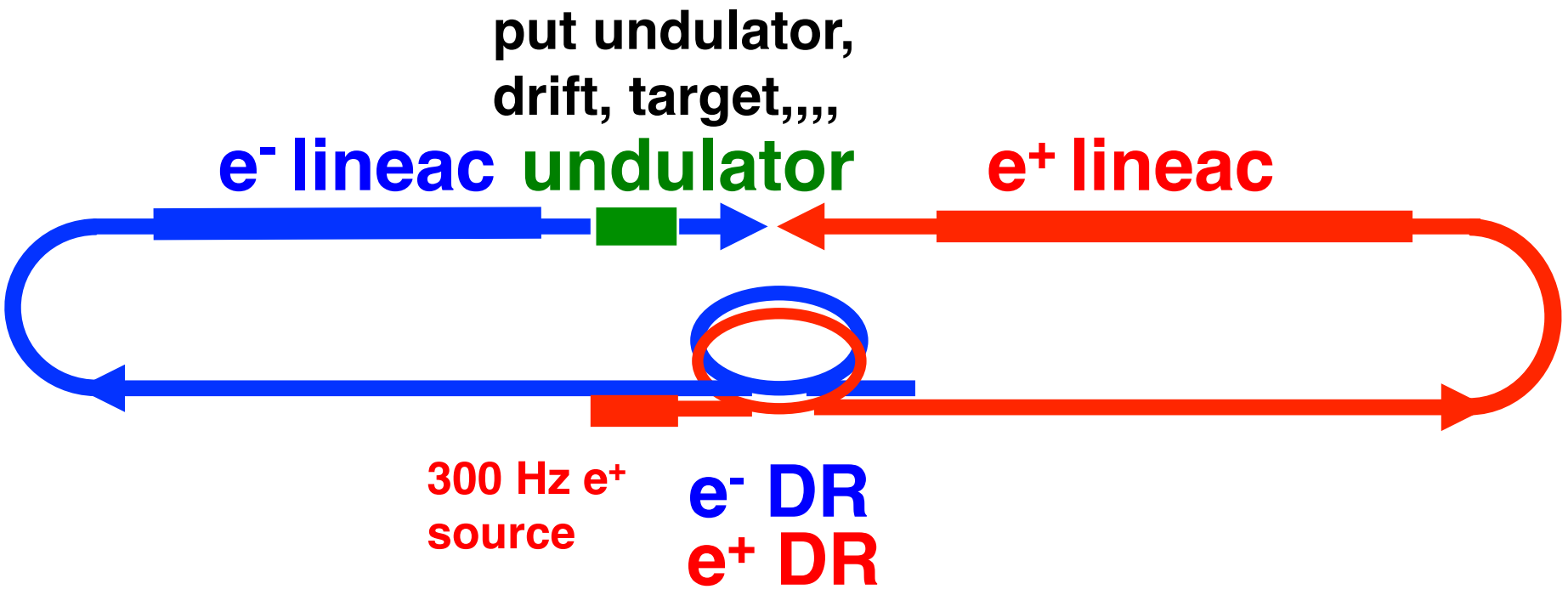

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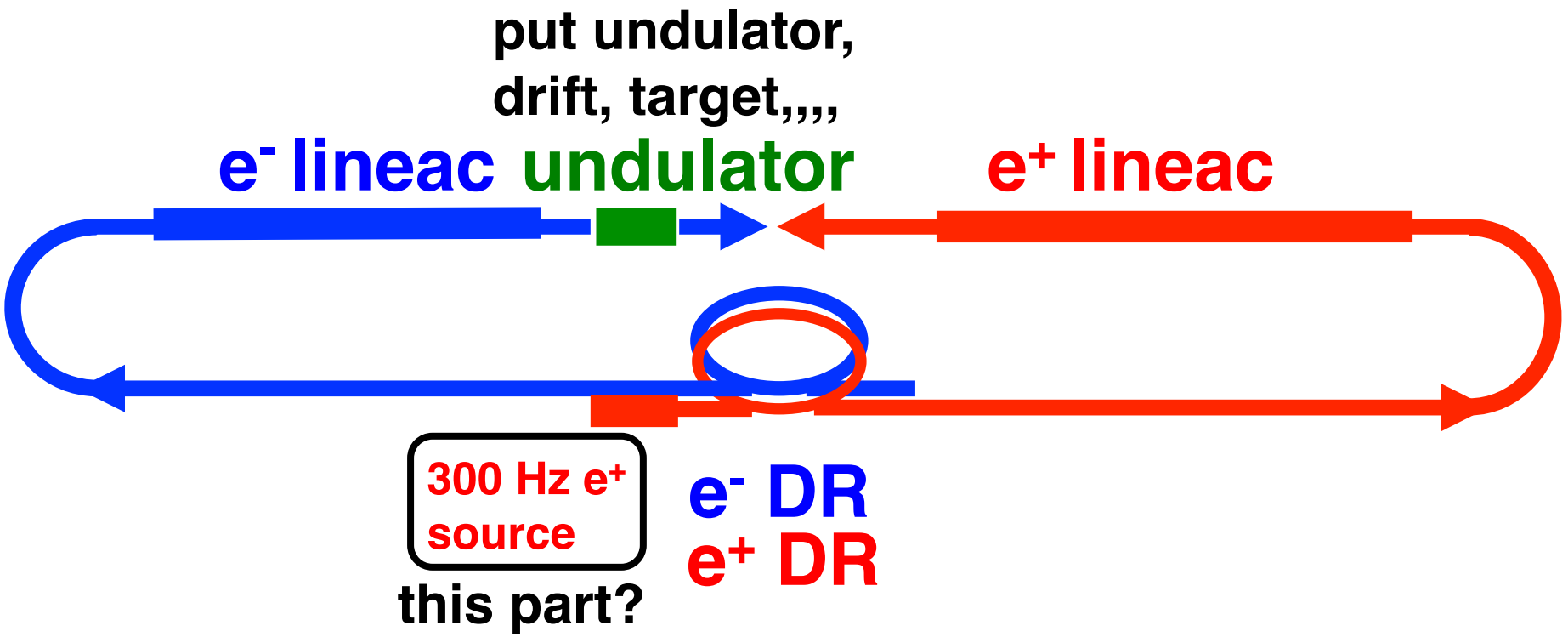
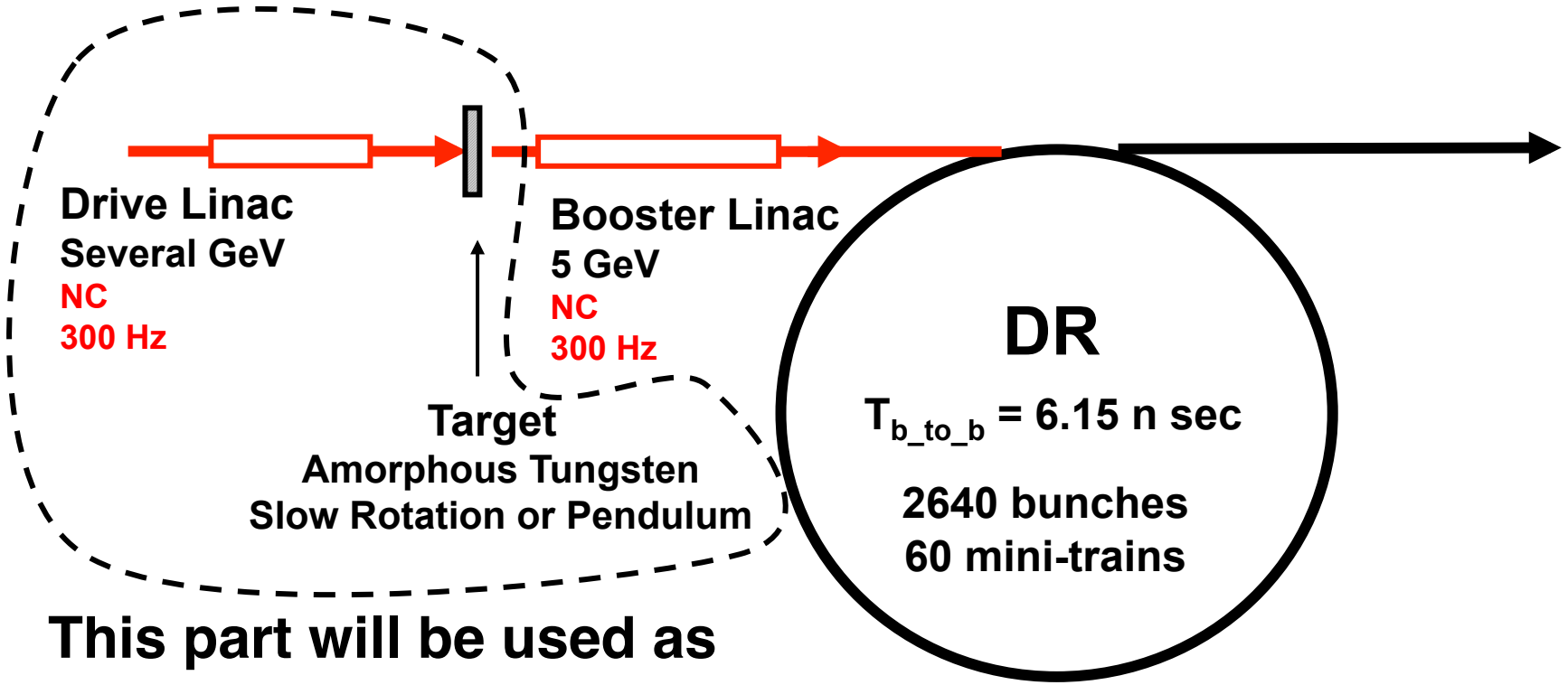


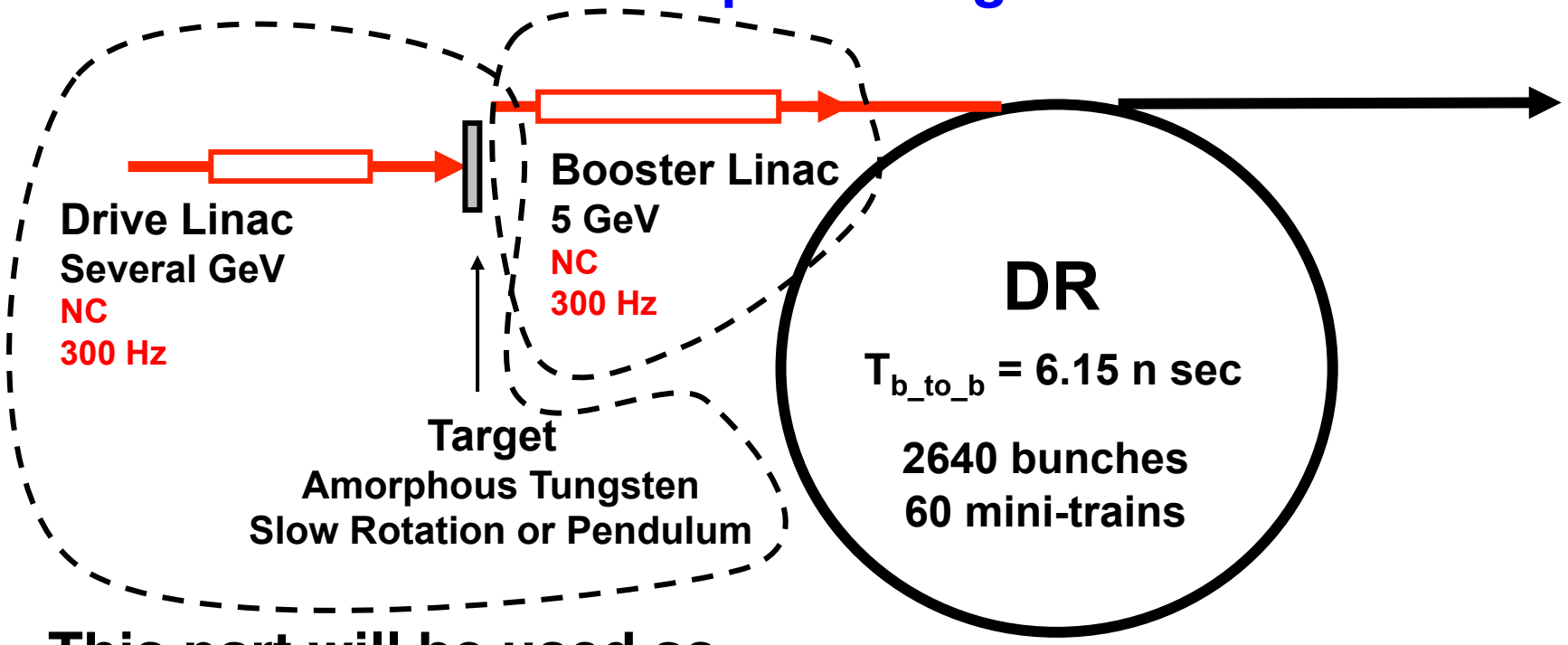
300 Hz Conventional e+
→ Undulator pol. e+ source



This part will be used as a single-bunch full-charge Keep Alive Source

300 Hz Conventional e+
→ Undulator pol. e+ source

We need the booster linac which has 1 ms pulse length. → We need a SC booster linac.



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300 Hz Conventional e+
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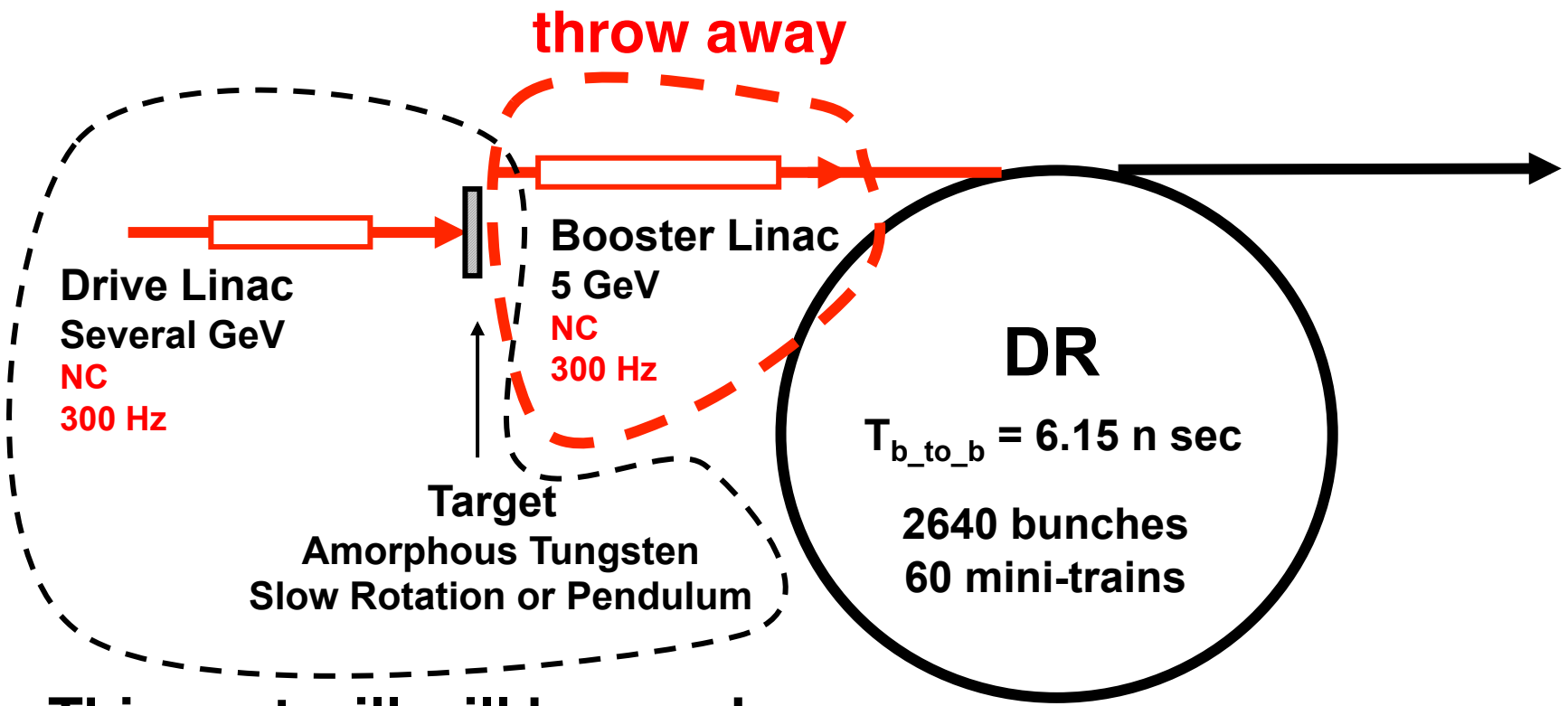

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300 Hz Conventional e+
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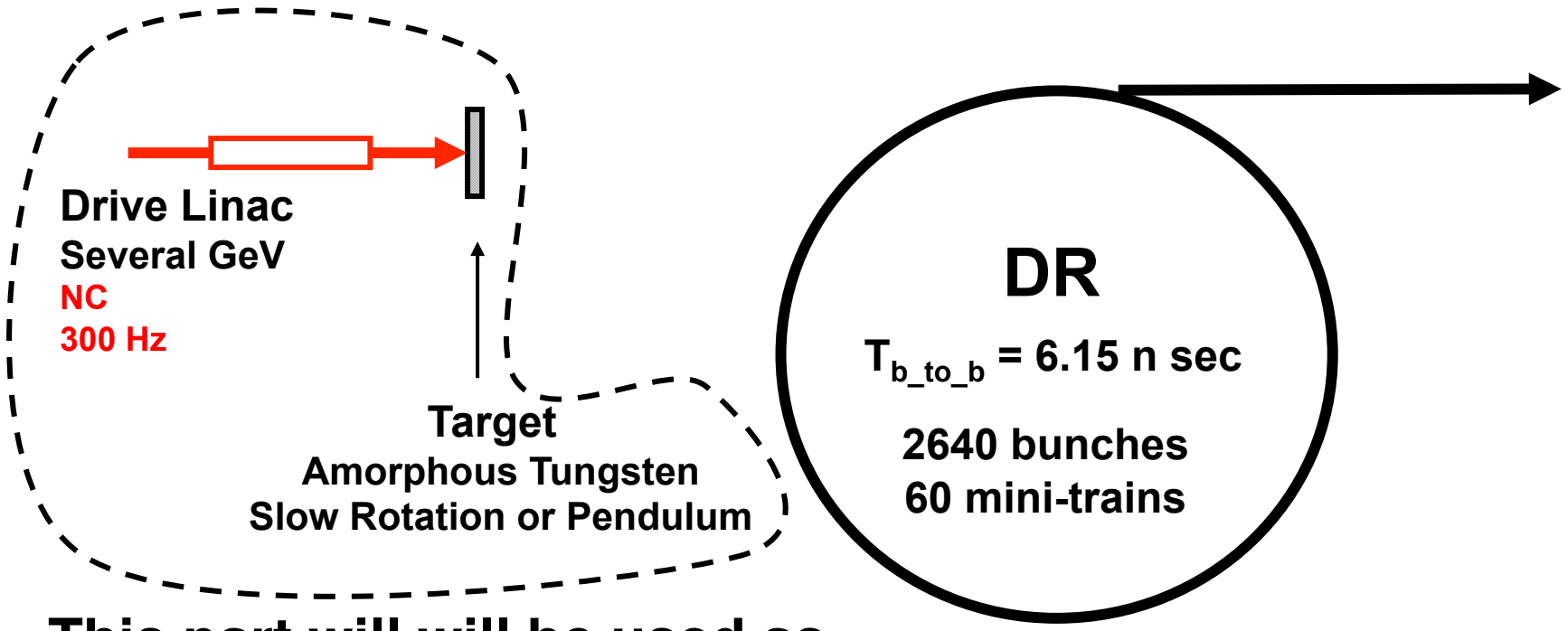

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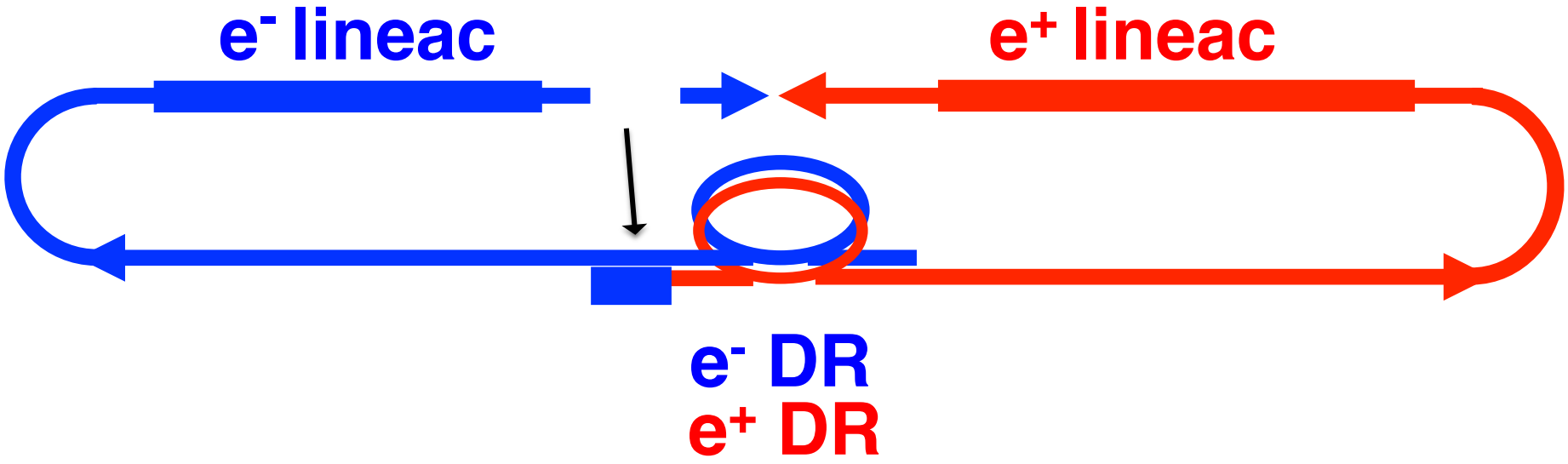
300 Hz Conventional e+

→ Undulator pol. e+ source

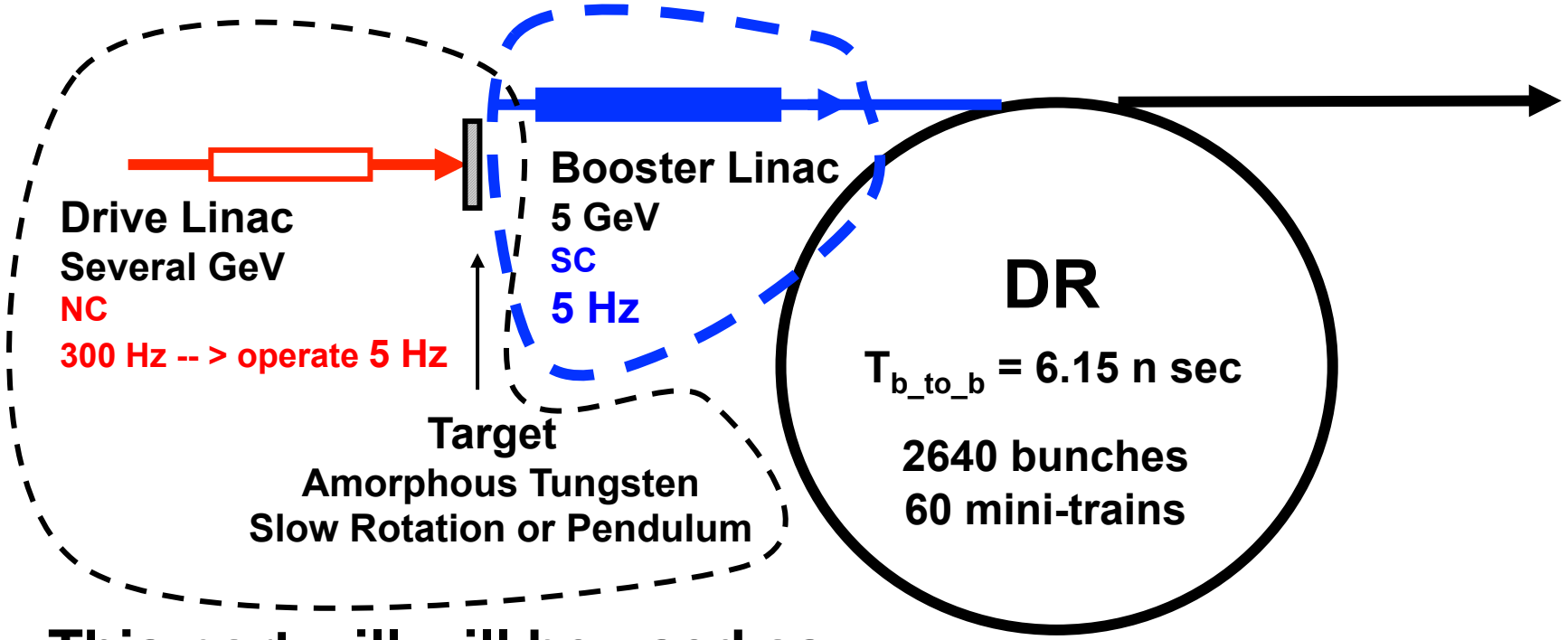
a part of lineac ~5 GeV
becomes the booster



300 Hz Conventional e+

→ Undulator pol. e+ source

put a 5 GeV SC linac which comes from the end of the main linac



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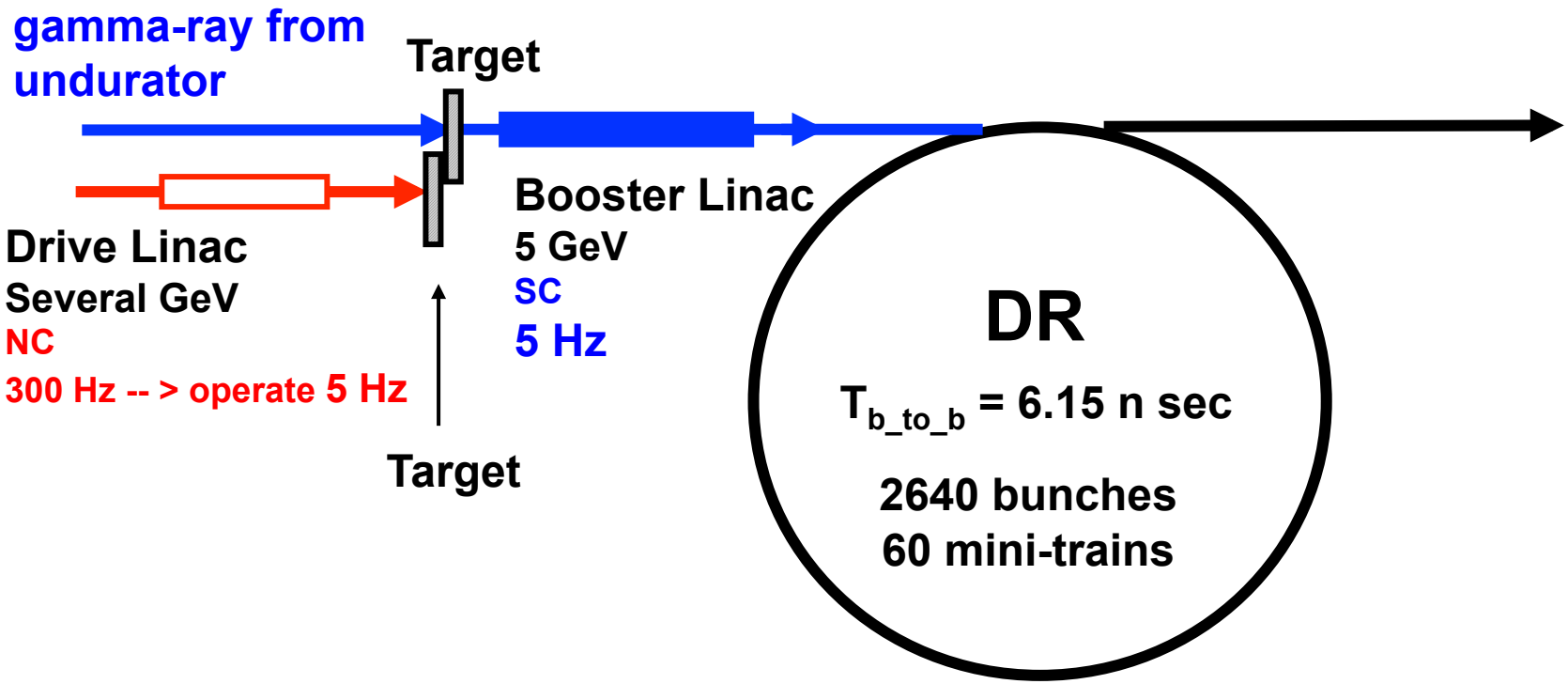
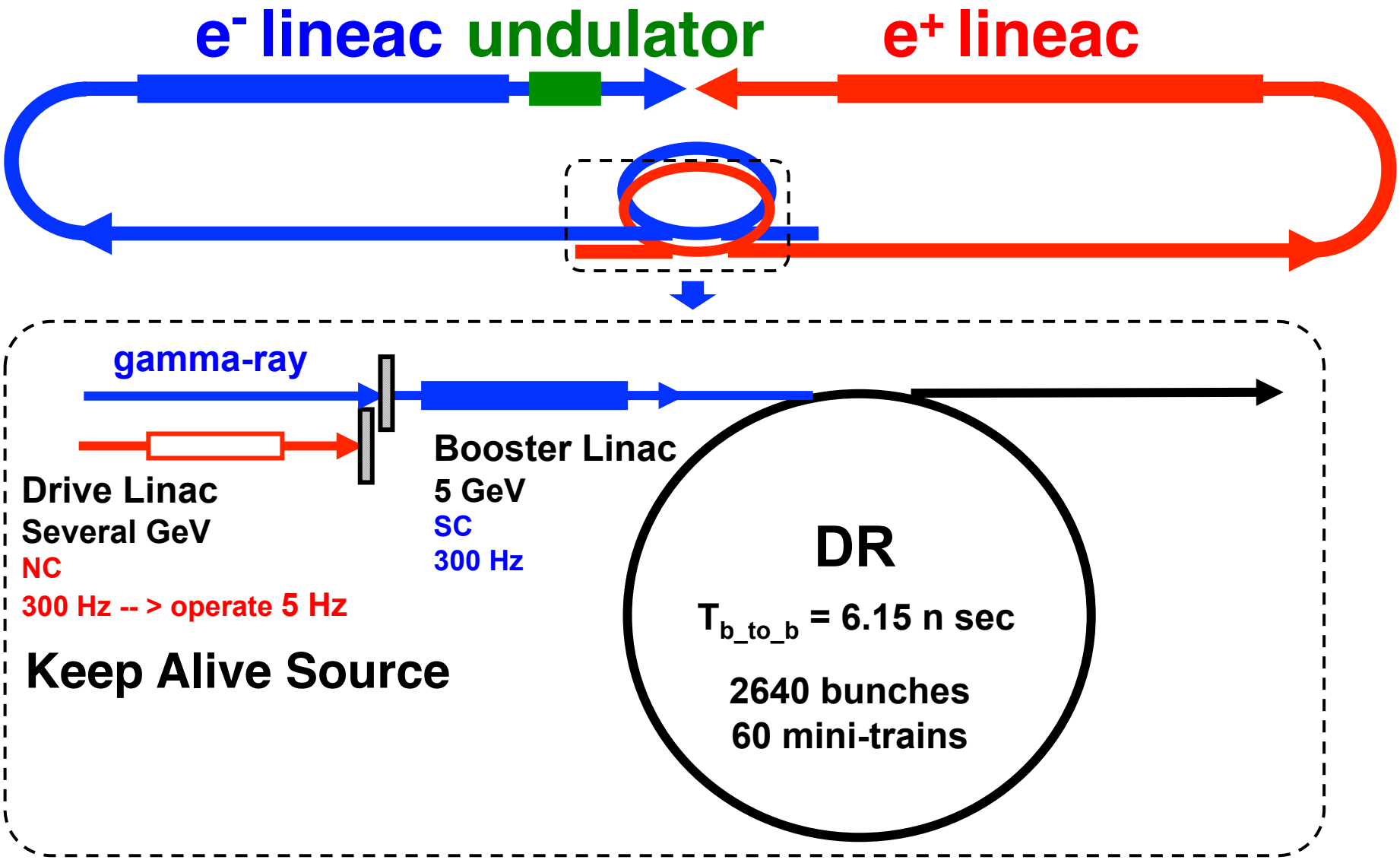
300 Hz Conventional e+
→ Undulator pol. e+ source



300 Hz Conventional e+

→ Undulator pol. e+ source



300 Hz Conventional e+
→ Undulator pol. e+ source

Pros.

No big additional investment.

We can reuse removed e- linac for the e+ booster.

Cons.

Decrease E_{cm}

dE(e-) = - 5 GeV (remove e- linac) - 3 GeV (undulator)

dE_{cm} = - 16 GeV (We don't want asymmetric collision)

Others.

Path length adjustment (e- and e+ interconnection).

We may need to move the turnaround.

Summary

Summary

1. Worry:

We are worried about the status of the target R/D for undulator. Target tangential speed 100 m/s.

2. Backup:

300 Hz conventional scheme. Time stretch.
Target tangential speed 1 m/s.
No polarization.

3. Ways to polarization:

Ways from 300 Hz conventional e^+ source
to Compton pol e^+ source and
to undulator pol e^+ sourceare discussed.

Backup Slides

Lessons Learned

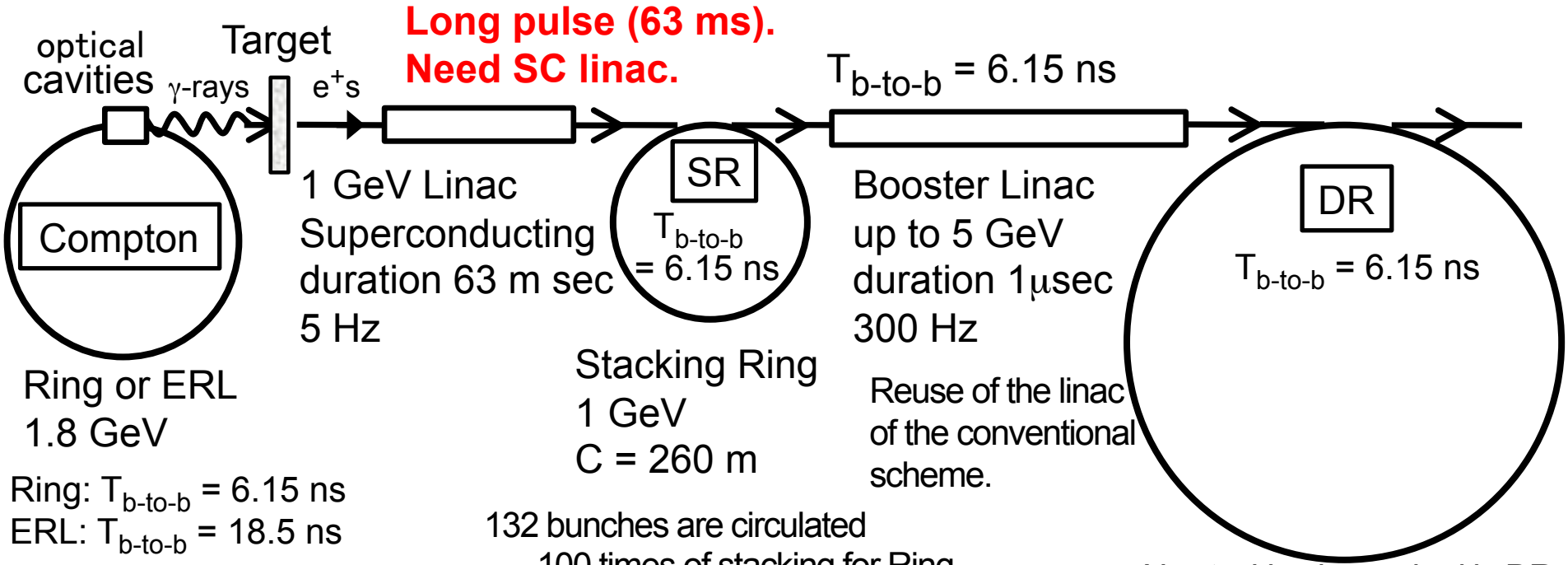
- Ferrofluidic seals are not boring, each one has its own individual personality
  - We would prefer them to be anonymously interchangeable and predictable
- They all have outgassing spikes
  - A differential pumping region just after the seal would be a useful modification
- We are pushing them to speeds at which there is significant heat dissipation
  - Off-the-shelf models do not seem to be well designed for this.
  - Improved cooling design is a must for any future system

Future Work

- As long as the current seal is working properly it will be allowed to run and collect data if we can understand the vibration spikes
- Any future development of the Ferrofluidic seal concept will need to be in partnership with manufacturers to create a device optimized for our needs.
  - Improve cooling channel routing in the stationary section to dissipate heat from the ferrofluid and the bearings
  - Replace the inner rotating section with one designed to be the outer sleeve of the shaft.
    - This will eliminate the O-rings
    - This will improve contact with the shaft cooling water for additional cooling

Ring/ERL Compton

Normal Conducting Drive < -- Throw away, Booster Linac <-- Reuse



We create 2640 bunches in 63 m sec.
We make stacking in the SR.

NO stacking in DR.

Ring/ERL Compton

Details (All parameters are tentative and still premature)

Ring/ERL Common Details

Positrons produced by the polarized gamma-rays are accelerated upto 1 GeV by the superconducting linac then injected into the 1 GeV stacking ring. The linac operates at 5 Hz and has a long duration of 63 m sec. Then the 1 GeV stacking ring with about 260m circumference is employed. In the stacking ring, 132 bunchs are stored with 6.15 ns bunch spacing. The 132 bunches are sent to the booster linac at once by a kicker which pulse length is 1 micro seconds. The booster linac is normal conducting. It has heavy beam loading ($3x10^{10}$ positrons/bunch) and operated with about 1 μ sec pulse duration at 300 Hz. 20 times beam extraction from the stacking.

Ring-Compton Details

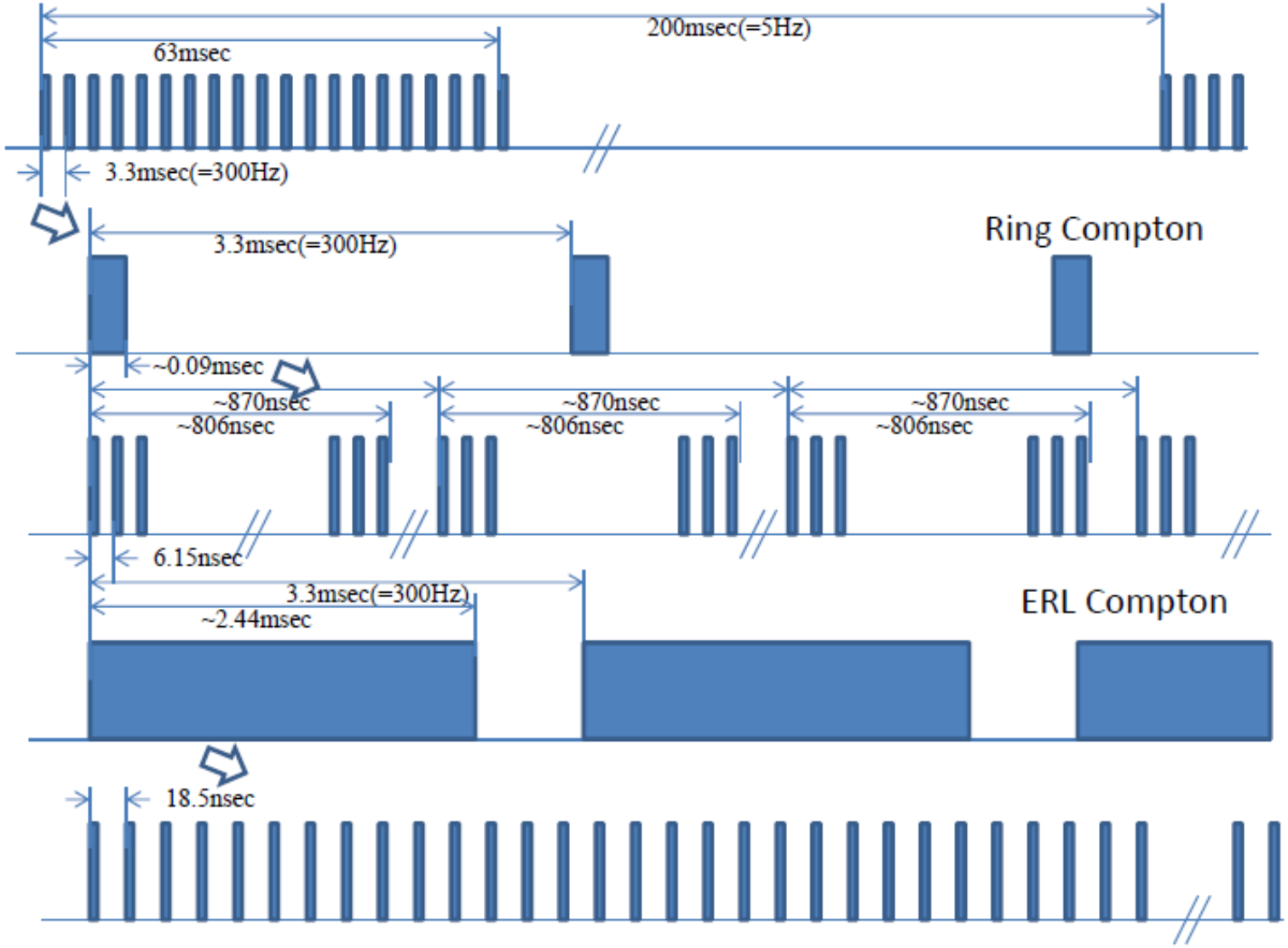
We need 100 times positron bunch stacking in the same bunch in the staking ring. Since the bunch spacing in the Compton ring and in the staking ring is the same, 100 times of stacking need 100 turns in the sacking ring. It takes about 87μs, because the circumference of the ring is 260 m. We take cooling period of 3.2ms after stacking for stable operation of the Compton ring and the stacking ring. Total period of one cycle is 3.3 m sec (300 Hz). 20 times beam extraction takes 63ms.

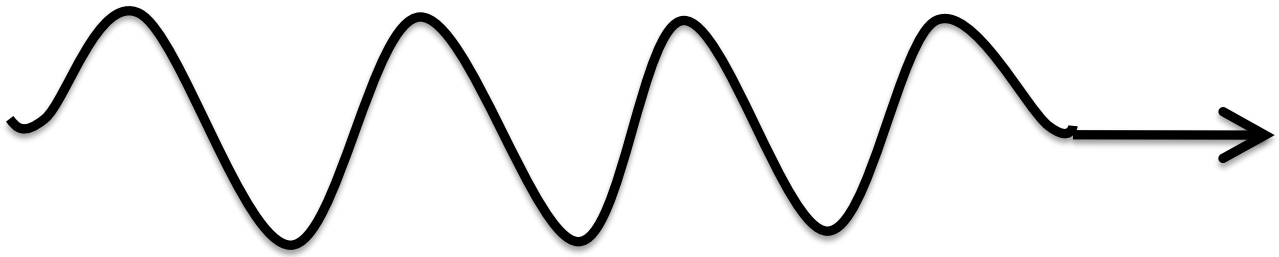
ERL-Compton Details

We need 1000 times of the stacking in the same bunch in the stacking ring. The bunch separation in ERL is 18.5 n sec. Therefore, the period of 1000 times positron bunch stacking is about 2.4ms. In a turn of the stacking ring, stacking is performed with three bunch intervals. In the next turn, stacking is not performed in the same bunch, but it is performed in the adjacent bunch which has 6.15-n-sec separation. This means stacking on the same bunch is performed with three turn intervals. The interval makes the stacking easier. Also through the process of the stacking, bunch spacing is changed from 18.5 ns to 6.15 ns. Since stacking takes long time, 2.4 m sec, cooling in the stacking ring is on going simultaneously. Remaining 0.9 m sec is used for additional cooling.

Ring/ERL Compton

Timing Chart (All parameters are tentative and still premature)





(For ERL, in each turn stacking are performed with three bunch intervals. This makes the stacking easier and changes bunch spacing from 18.5 ns to 6.15 ns.)

Laser Compton e^+ Source for ILC

We have 3 schemes.

1. **Ring Base Laser Compton**

   Storage Ring + Laser Stacking Cavity (λ=1μm), and e+ stacking in DR

   S. Araki et al., physics/0509016

2. **ERL Base Laser Compton**

   ERL + Laser Stacking Cavity (λ=1μm), and e+ stacking in DR

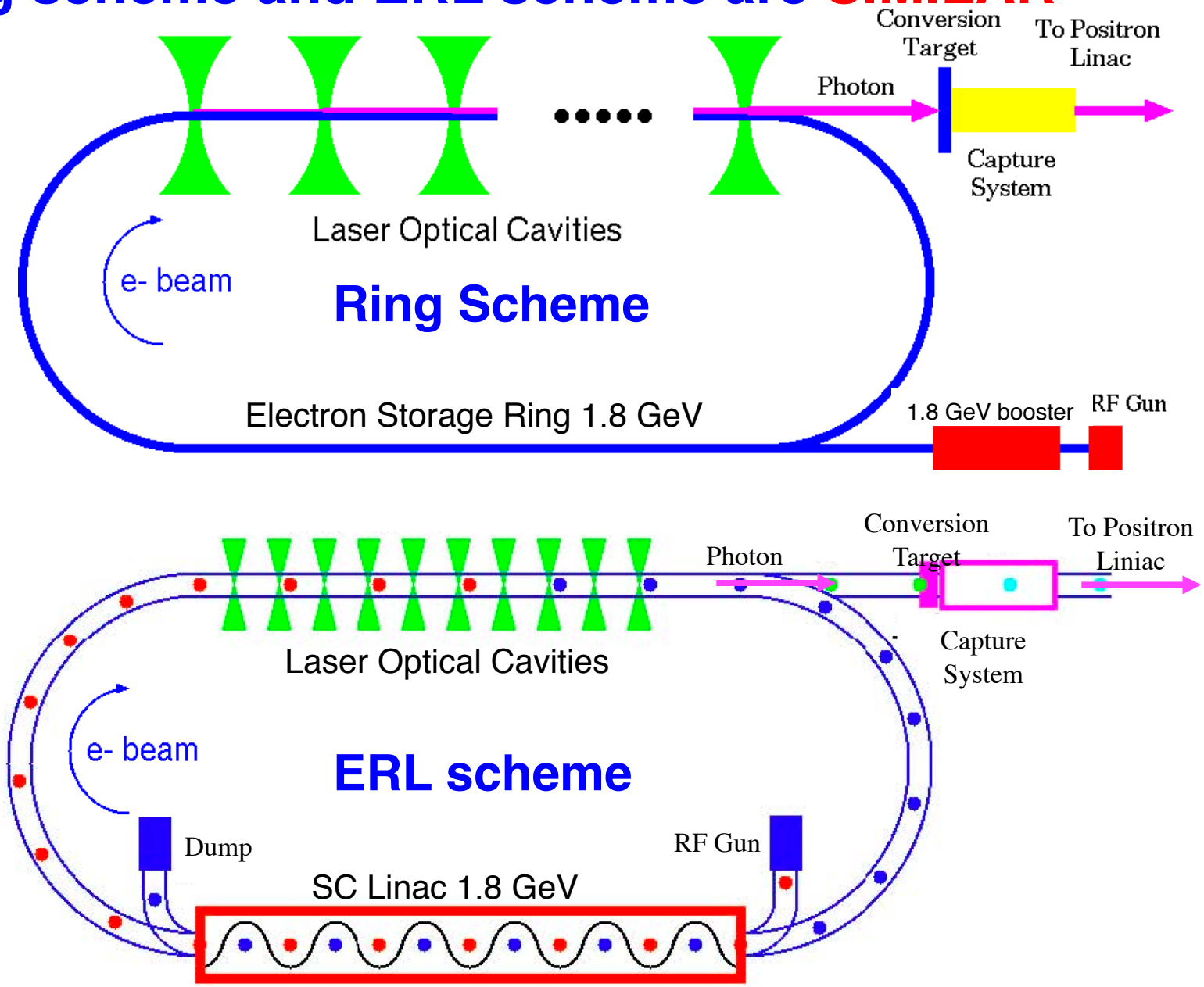
3. **Linac Base Laser Compton**

   Linac + non-stacking Laser Cavity (λ=10μm), and No stacking in DR

   Proposal V. Yakimenko and I. Pogorersky

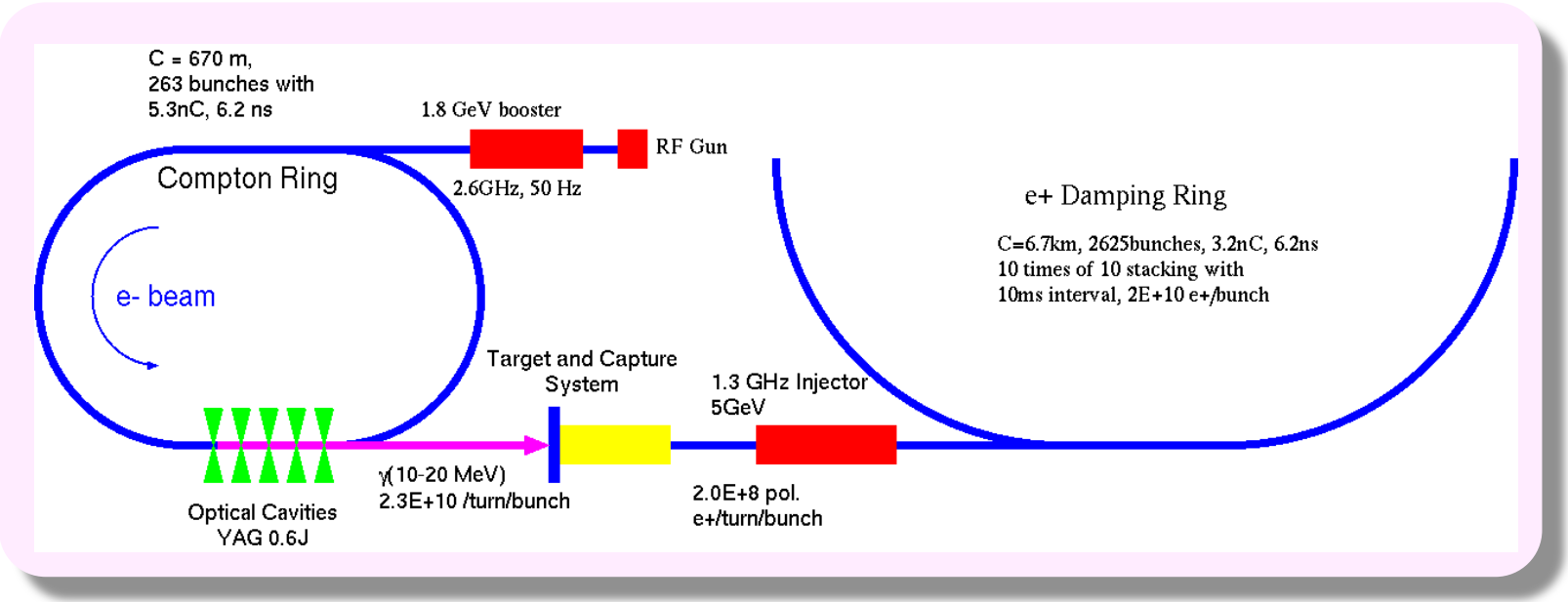
   T. Omori et al., Nucl. Instr. and Meth. in Phys. Res., A500 (2003) pp 232-252

Ring scheme and ERL scheme are SIMILAR

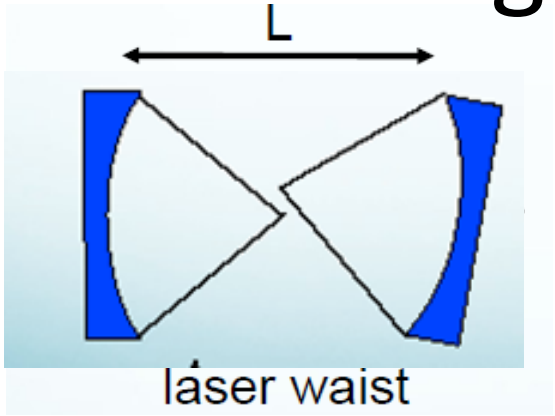


Compton Ring (1)

- Inverse Compton scattering between electron stored in a ring (CR) and laser light stored in optical cavities.
- Energy spread of the electron beam is increased by the scattering. 10 ms interval for the beam cooling.
- 100 times stacking in a same bucket of DR makes the required bunch intensity.

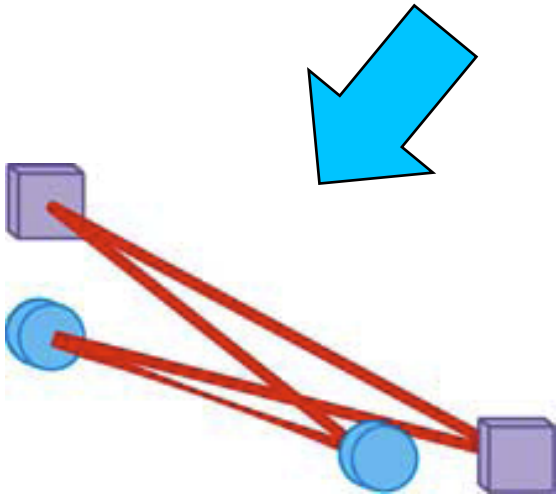


We should go to 3D 4 mirror ring cavity to get small sport size



2 mirrors is not stable
for small spot size

2d 4M has astigmatism

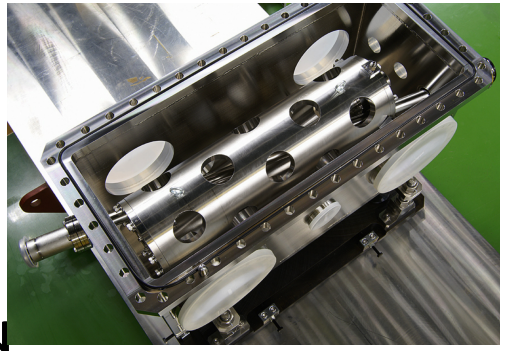


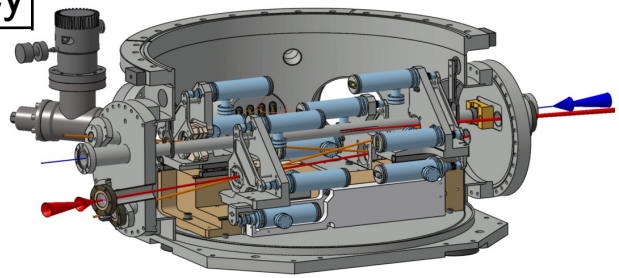
3D (or twisted)
4M ring cavity

Brief History

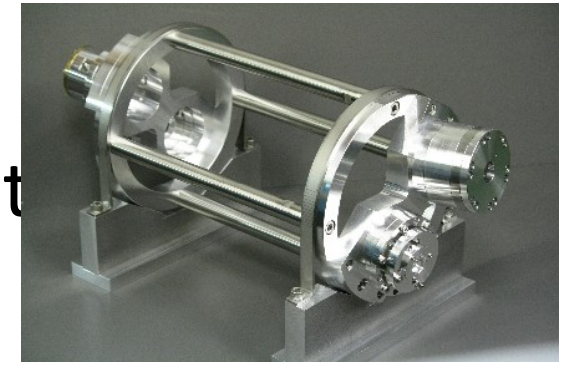
- 2007　2 Mirror cavities installed
  - 2.5kW　γ rays generate
- 2010 French 4 Mirror cavity installed

Reported FJPPL2010 Annecy

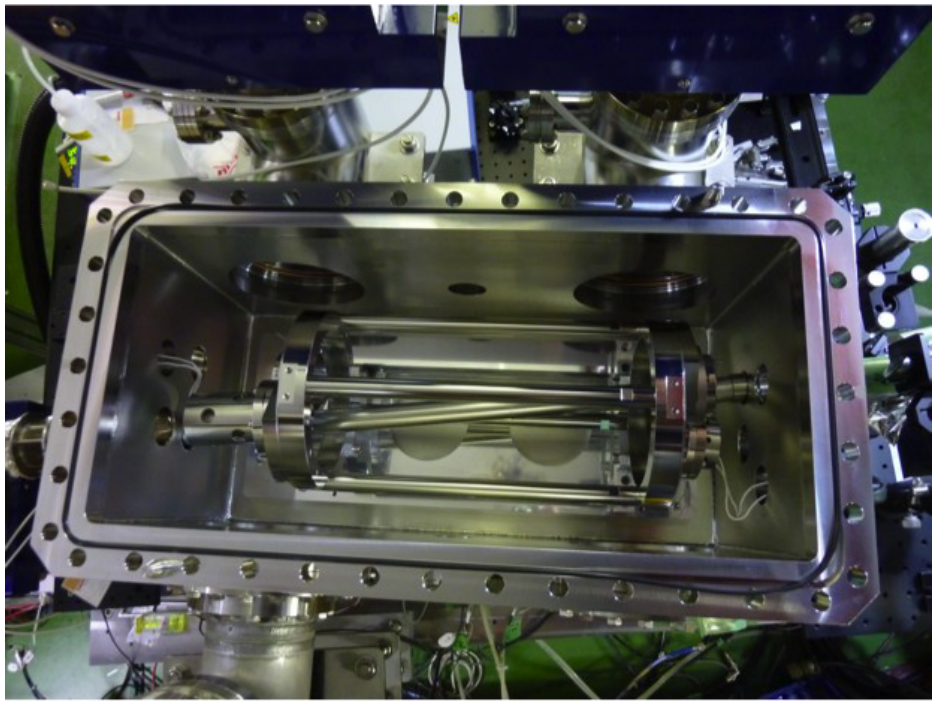




  - γ rays confirmed
- 2011　earthquake
  - No major damage to our equipment.
  - beam back in June 2011
- 2011　KEK-Hiroshima 4 mirror cavit installed
  - γ rays confirmed

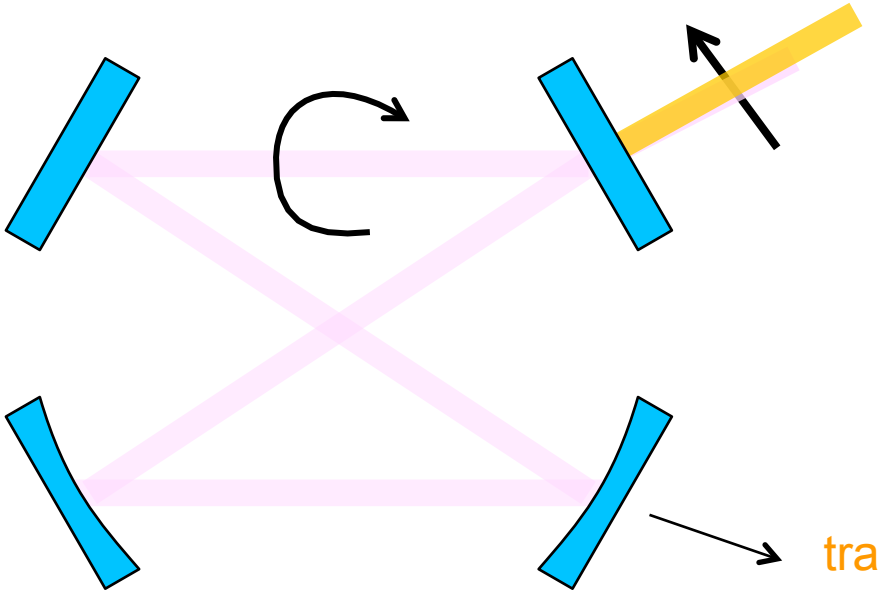


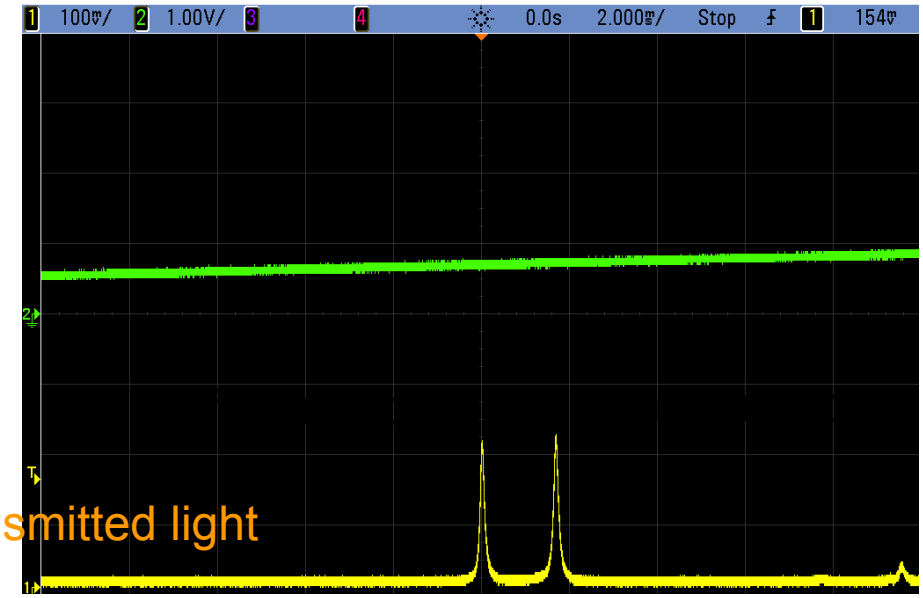
Installation of KEK-Hiroshima 4M-cavity



3 Dimensional 4 Mirror Cavity

- Resonates only for circular polarization
  - geometric phase due to twisted pass
  - cavity only resonates with circular polarization
  - usable for pol. switching

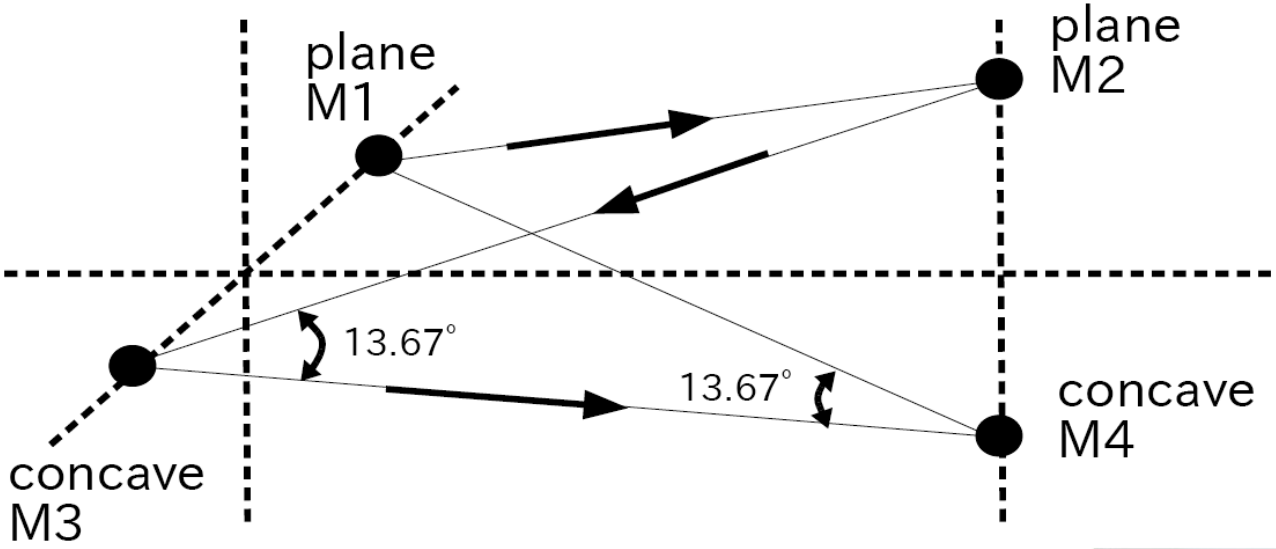




transmitted light

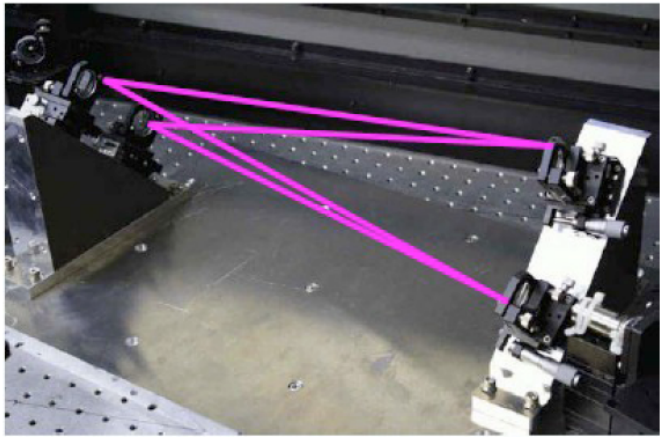
circumference of the cavity

Configration of test bed

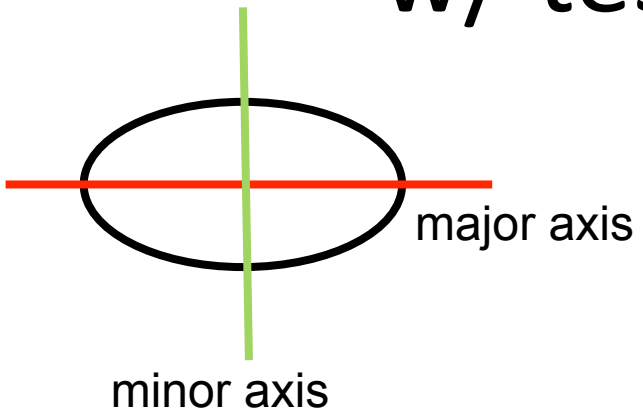


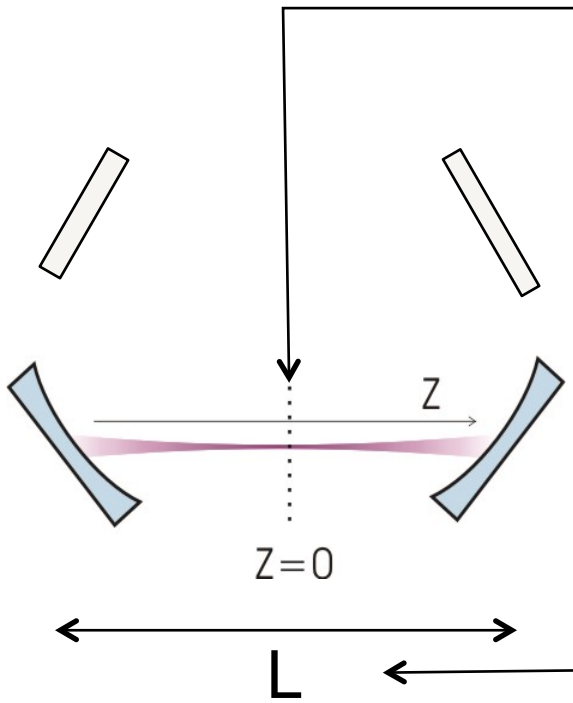
L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

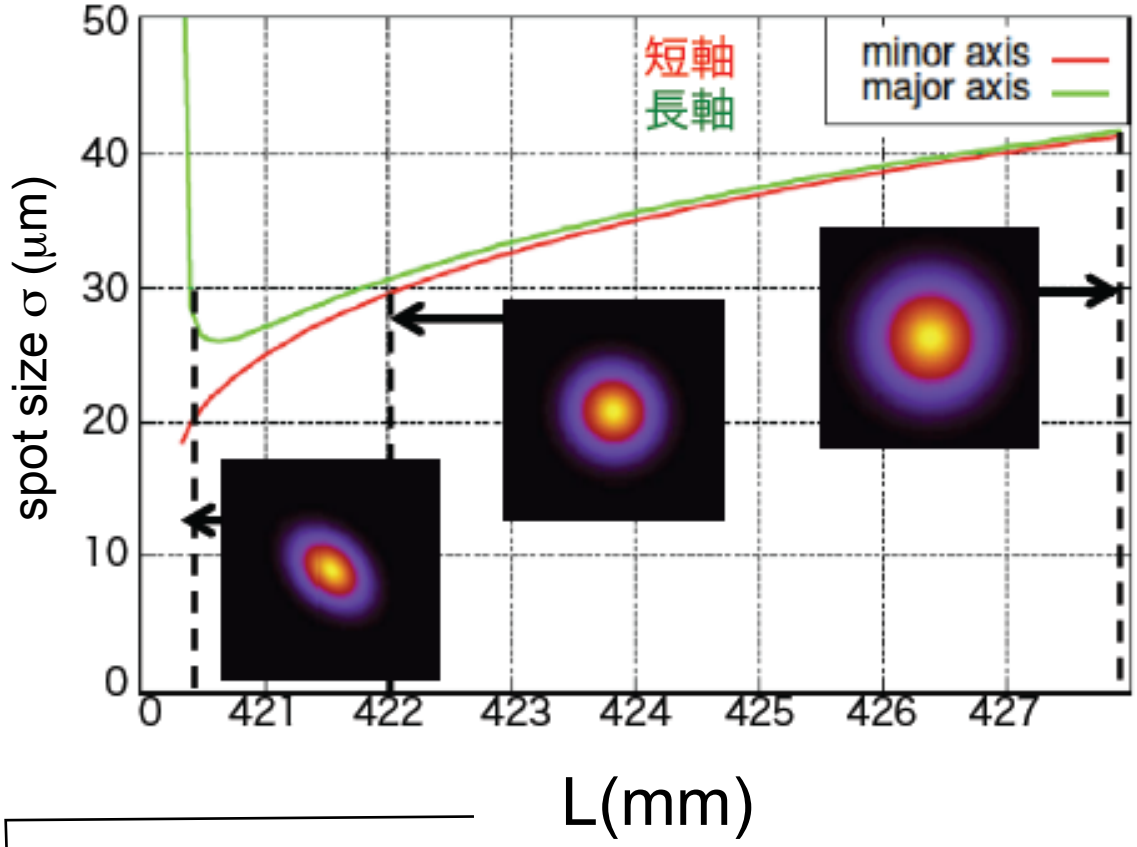
M2-M4=100mm
M1-M3=100mm



calculation of spot size w/ test bench geometry

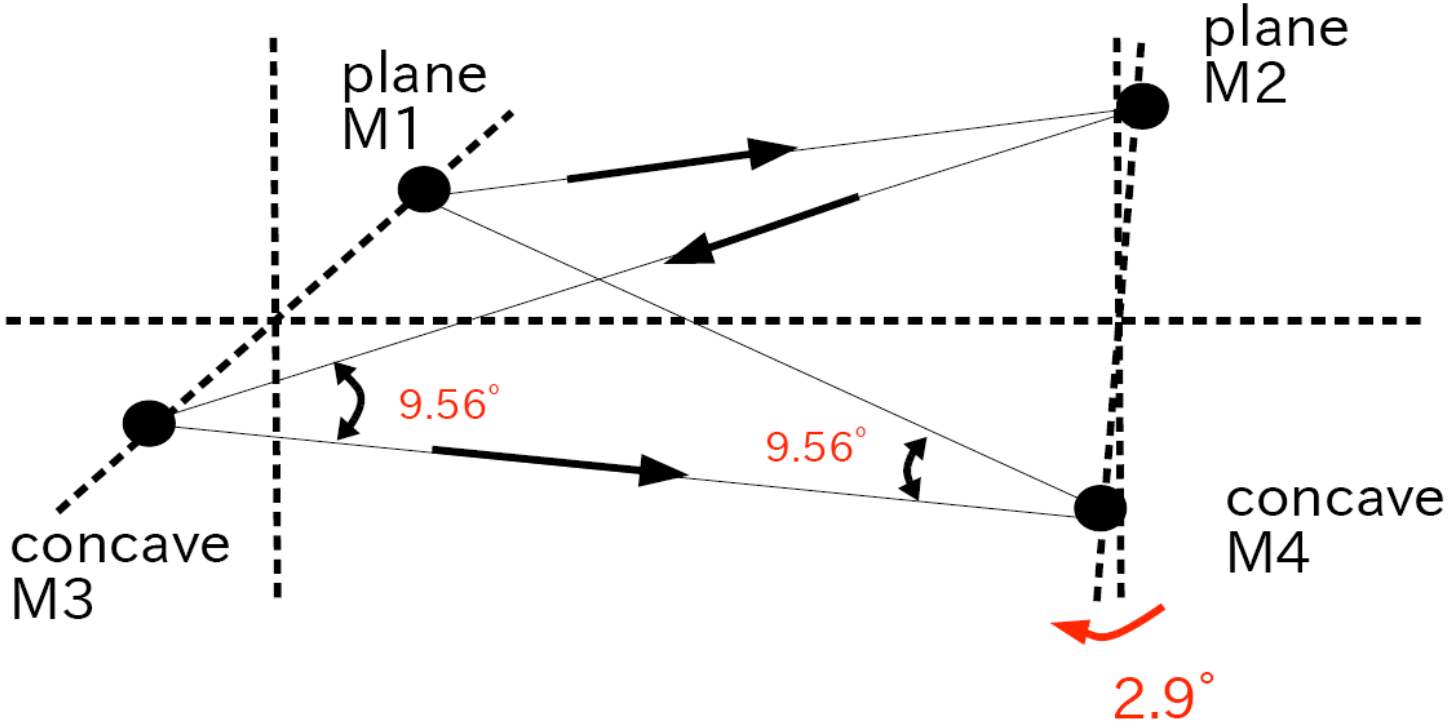






spot size is not sufficiently small with test bench geometry

new geometry

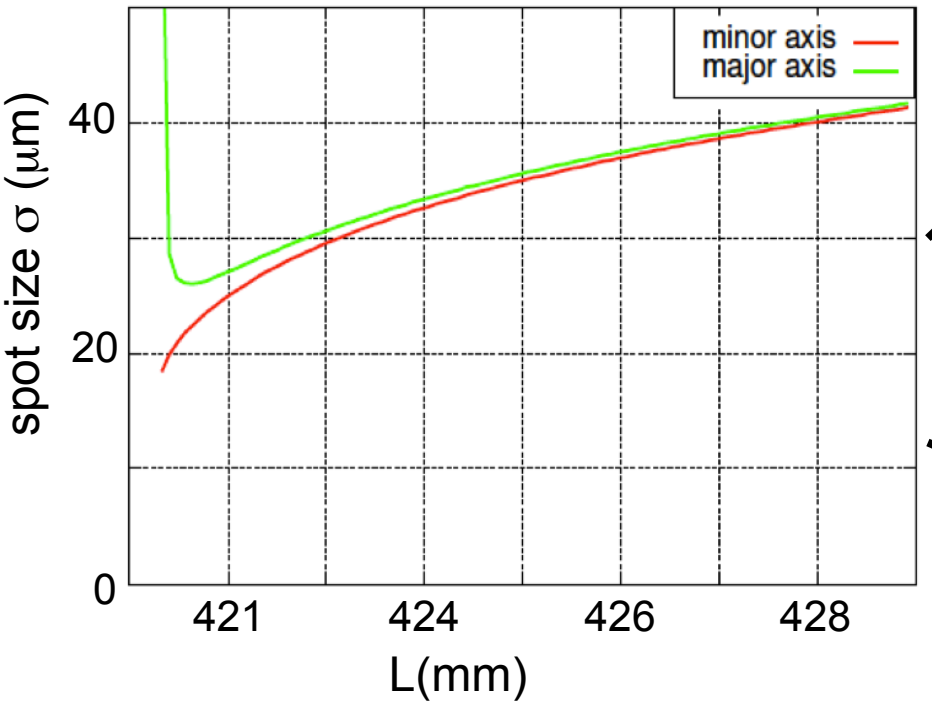


L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

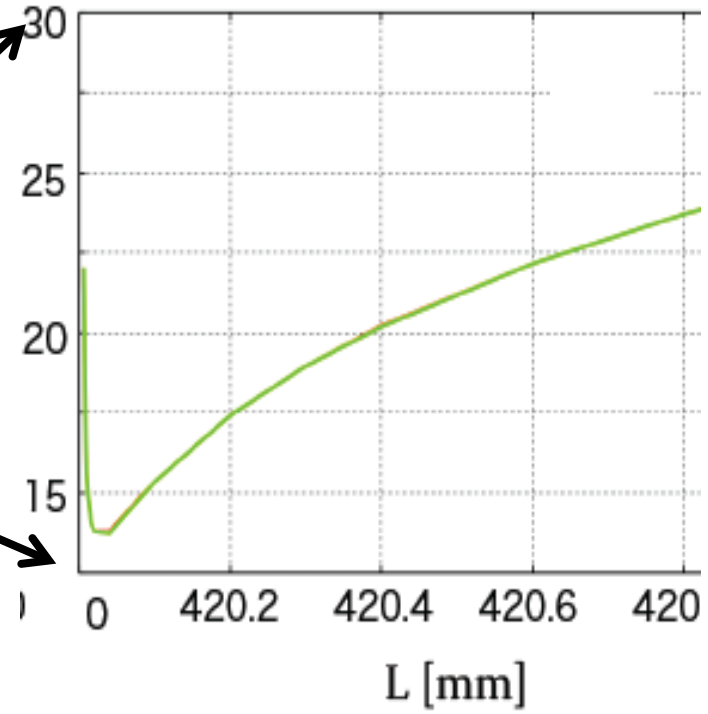
M2-M4=70mm
M1-M3=70mm

expected spot size w/ new geometry

Before optimization



After optimization



laser spot size of 15 μm is expected with new geometry

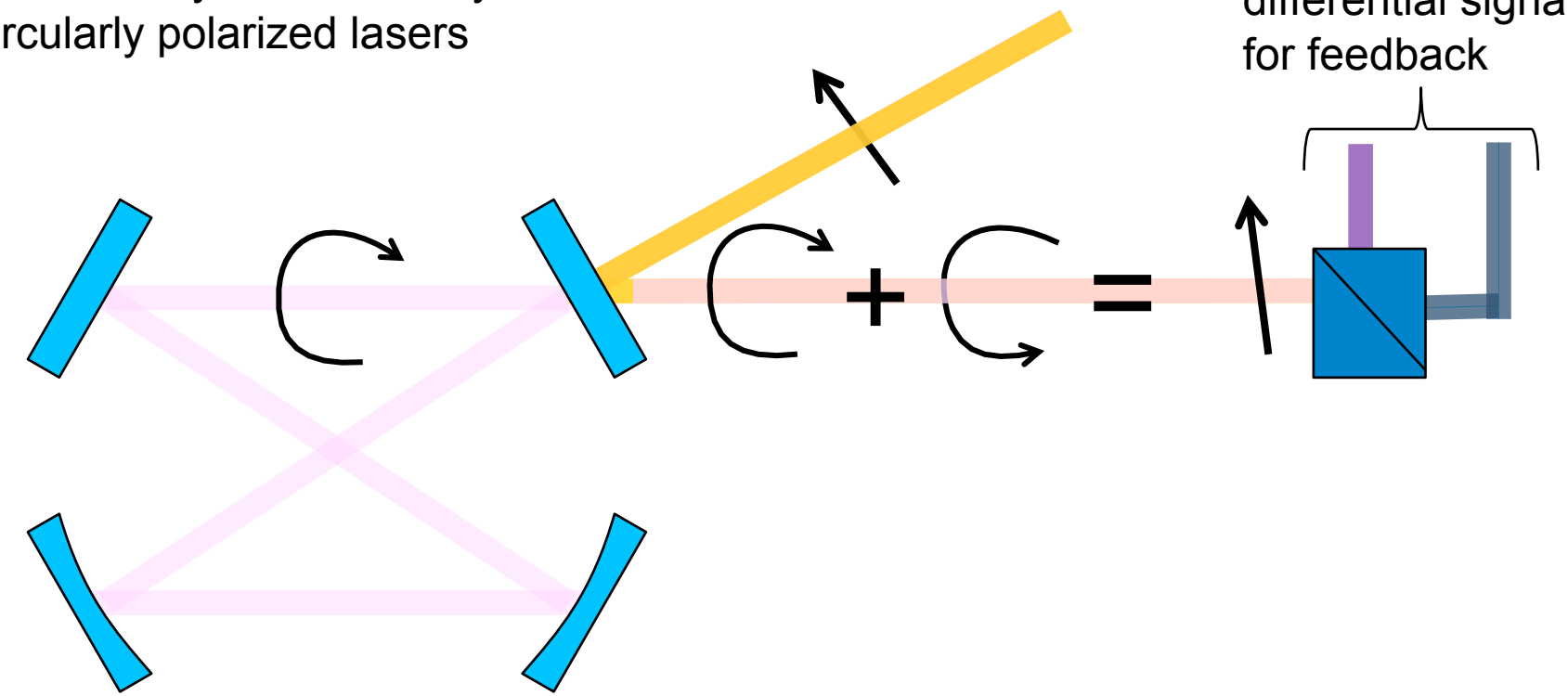
Cavity length feedback with 3D feature

cavity length must be L = nλ/2 with very high precision

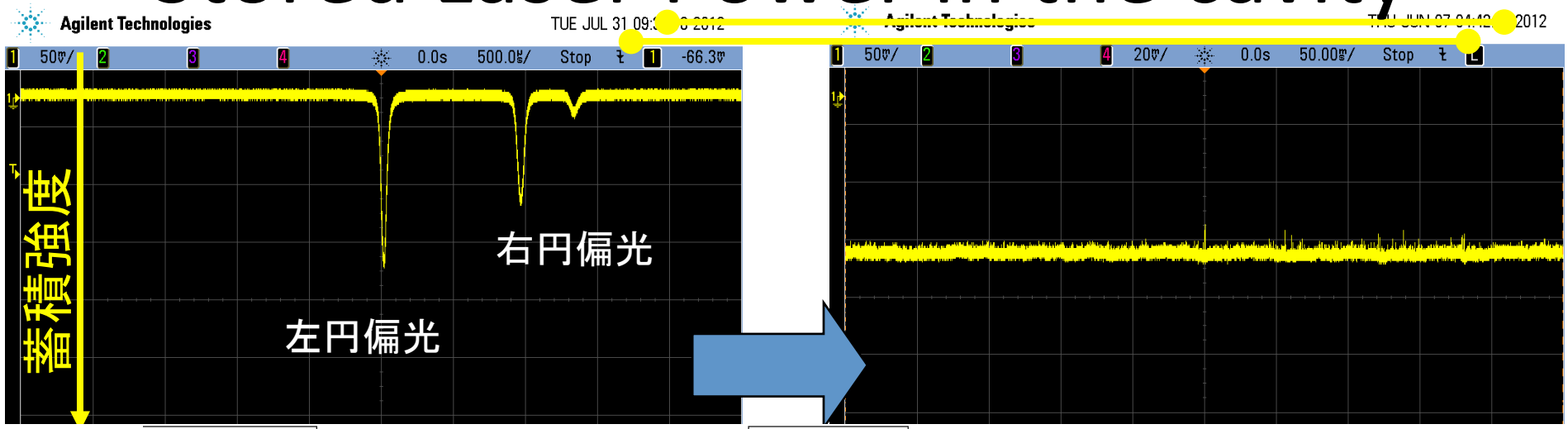
(for enhancement of 1900 dL<< 87pm while L = 1.64m)

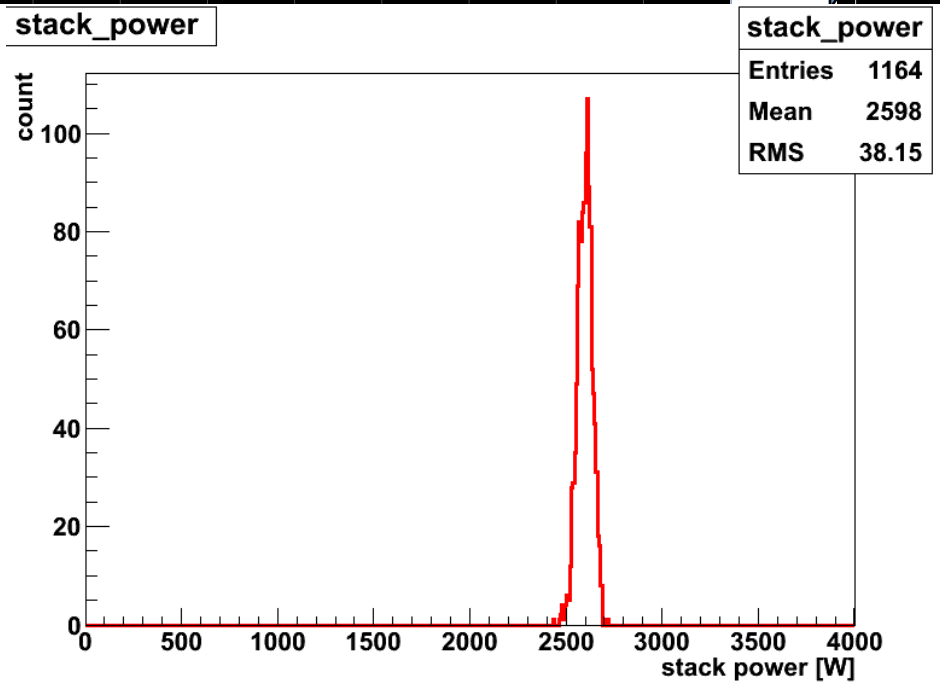
3D4M cavity resonate only with circularly polarized lasers

differential signal for feedback



Stored Laser Power in the cavity

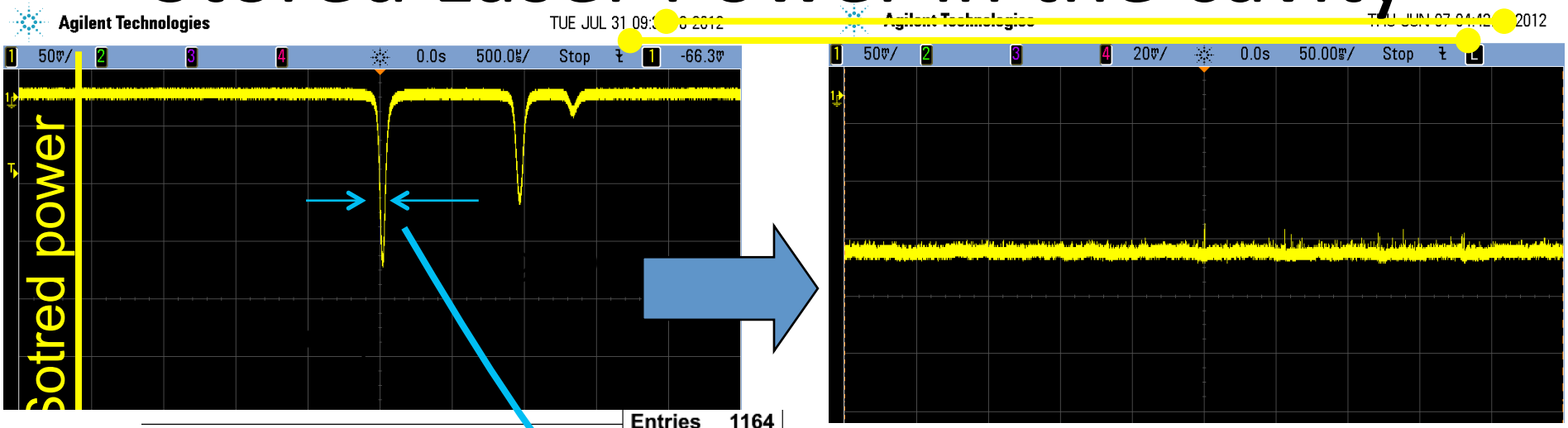


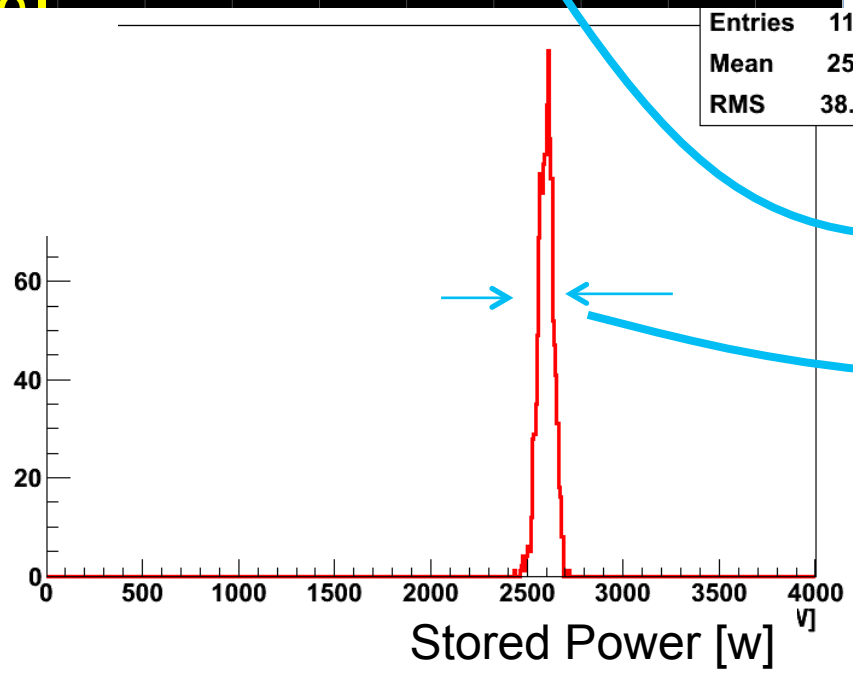


stack_power	
Entries	1164
Mean	2598
RMS	38.15

Laser Power 2.6kW
Time Jitter＝8.0ps

Stored Laser Power in the cavity





FWHM: 110pm

4pm

Laser Power 2.6kW
(1850 enhancement)
Time Jitter＝8.0ps