ILC Beam Line Changes from TDR

LCWS2024　2024.7.10　K. Kubo

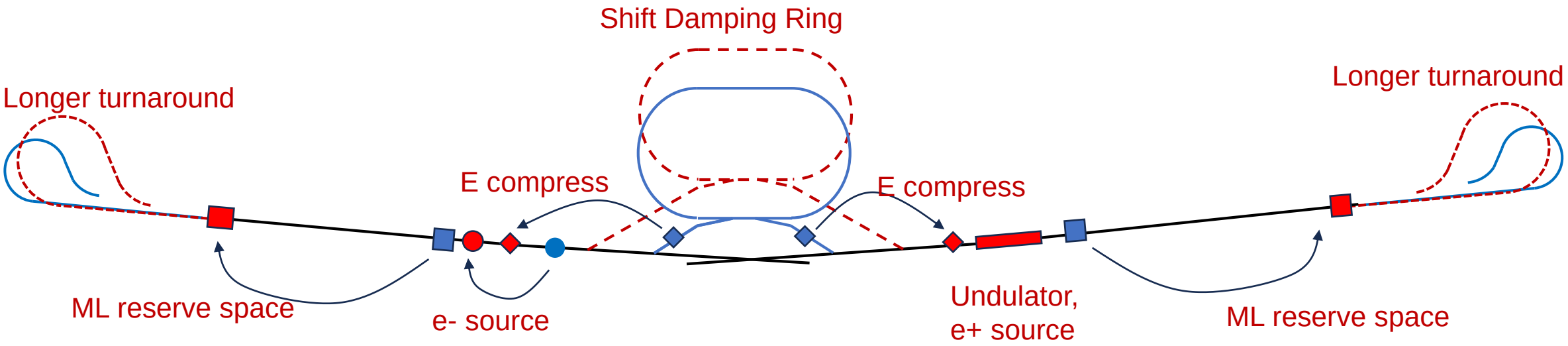
This report is based on activities of the meetings

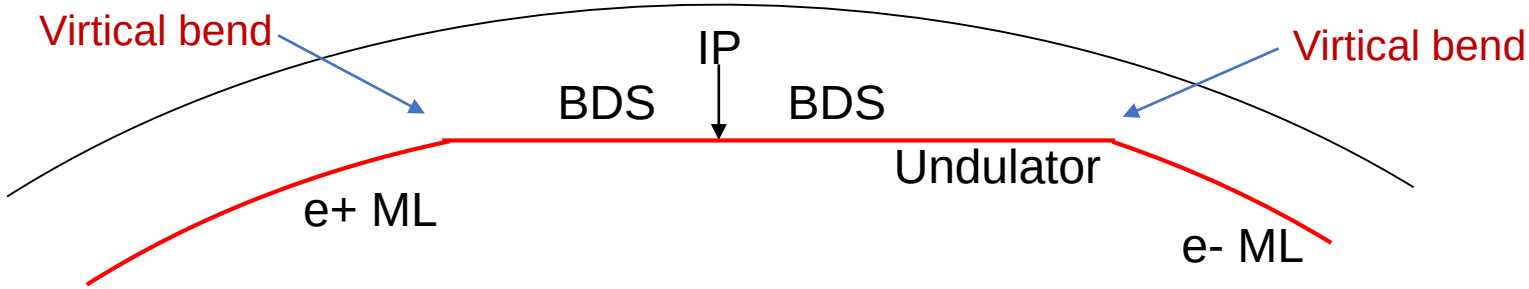
ILC Beamline Related to CFS (2019~)

Members:

Y. Enomoto, H. Hayano, K. Kubo, T. Okugi, T. Sanuki, N. Terunuma, K. Yokoya,

Changes of beamlines from considerations of CFS & beam dynamics



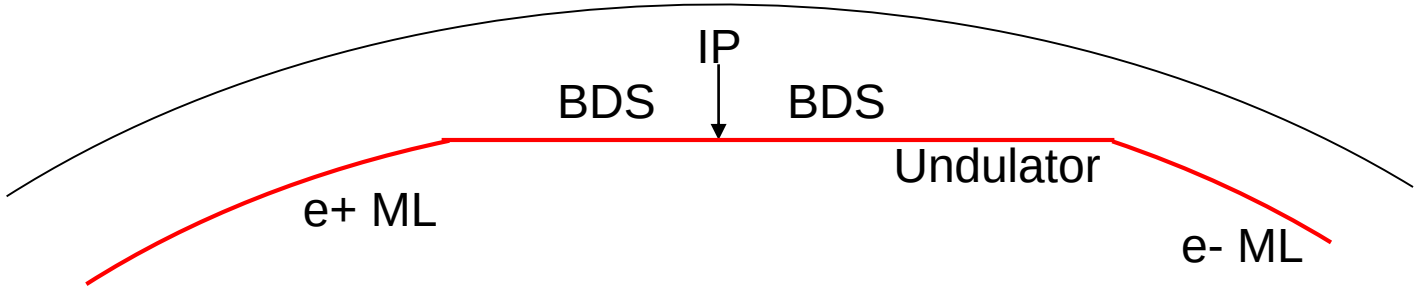


Specify curved and flat regions

(Details are not described in TDR.)

- Between end of e+ ML to end of e- ML, including undulator section for e+ production is in the same plane, which is horizontal at IP.
- MLs are following earth's curvature.
- Insert vertical bends at ML ends and approximately same locations for return lines.

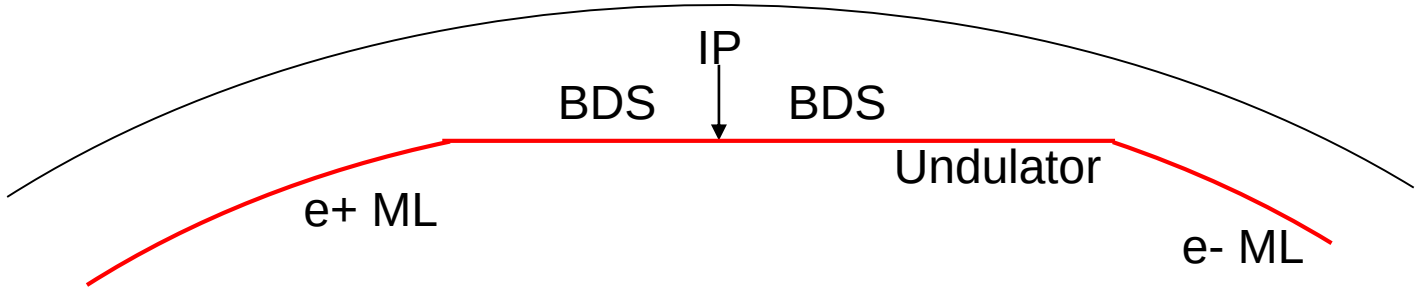
  (0.58 mrad for e- ML and 0.40 mrad for e+ ML)
- Returns lines are straight or curved, following the corresponding beamlines.
- As a result, the elevation of e- ML is less than that of e+ ML by 43 cm.



Specify curved and flat regions (cont'd)

- One alternative was putting the undulator in curved region, before the bending downstream of e- ML. However,
  - Different angles of e+ source beamline and e- BDS. Complicated tunnel configuration.

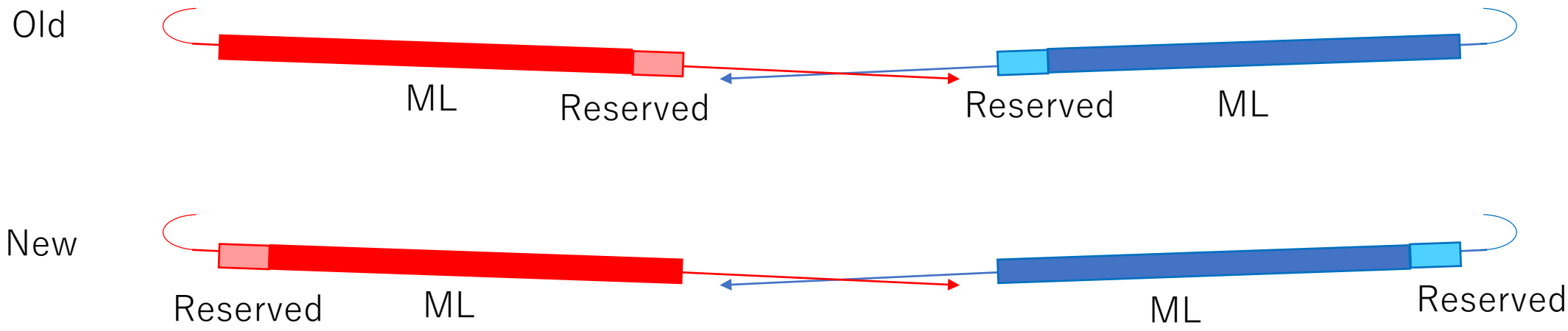
- It is desirable to make IP region horizontal for the physics detectors.
  - Otherwise, if mid point of the straight region is horizontal, the inclination of the detector would be 0.064 mrad.



Main Linac reserved space

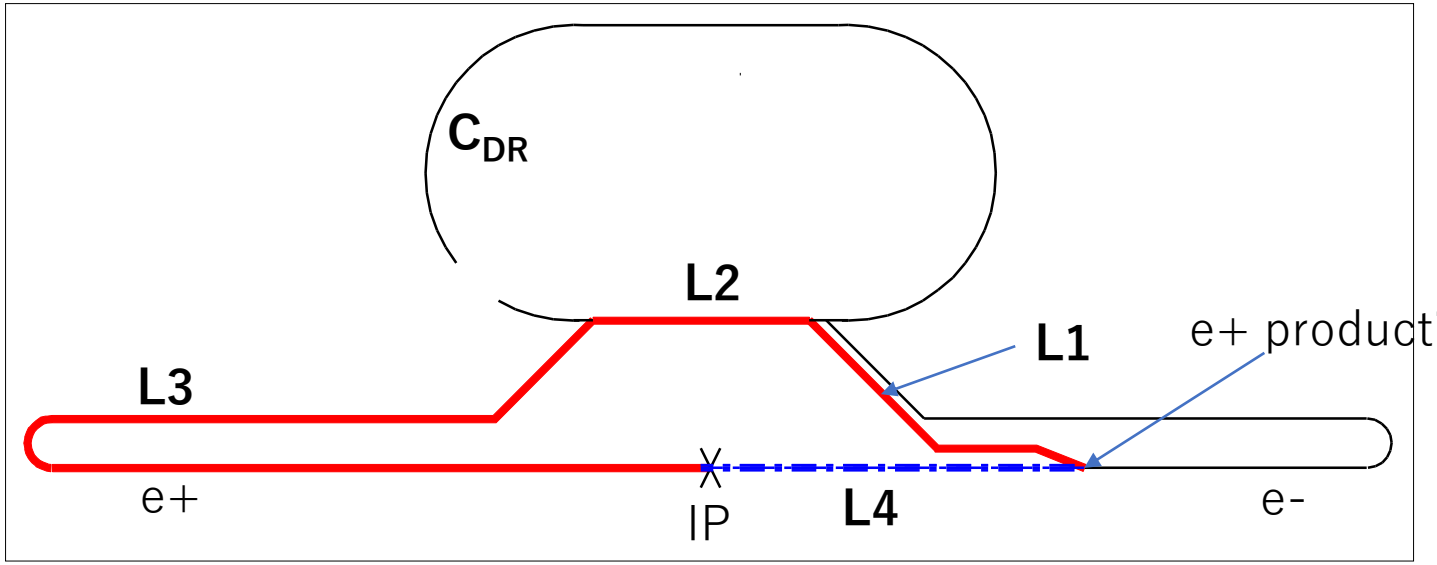
- Downstream -> upstream
- Length is adjusted to satisfy the timing constraint.
- Same reserved length for e- and e+

(Already approved)



Timing constraint

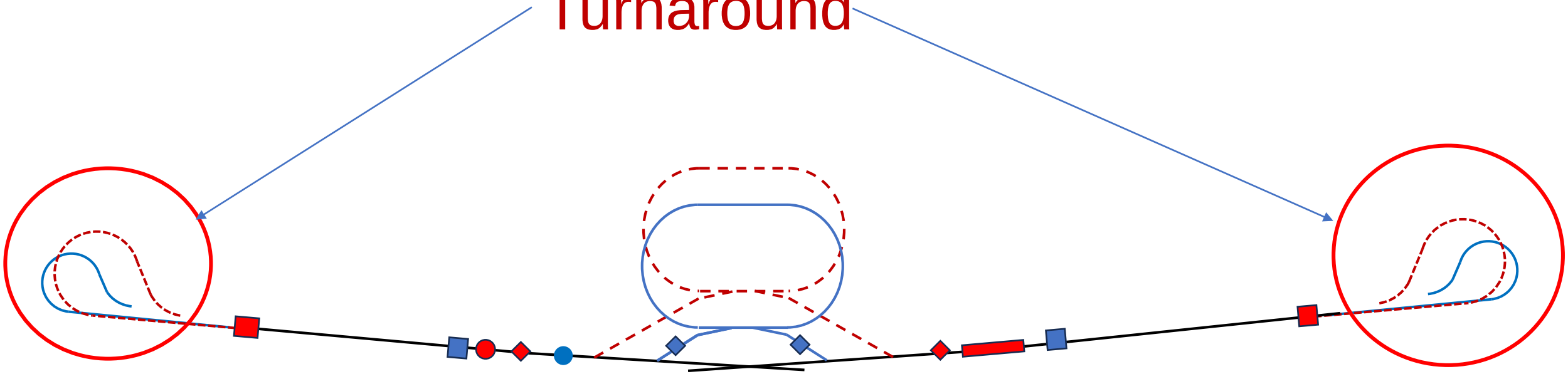
$$(L_1 + L_2 + L_3) - L_4 = n \times C_{DR}$$



Each positron bunch (A) is injected in the same bucket of the bunch (B) which is collided with the electron bunch producing the bunch (A).
Or,
An electron bunch produces positron bunch (A), collides with positron bunch (B).
Then, (A) should be injected in the same bucket of the ring as the bunch (B)

Construction error will be corrected by
“timing adjusting chicane” located at the end of e+ 5 GeV booster linac.

Turnaround



Longer Turnaround

Problems of the original design:

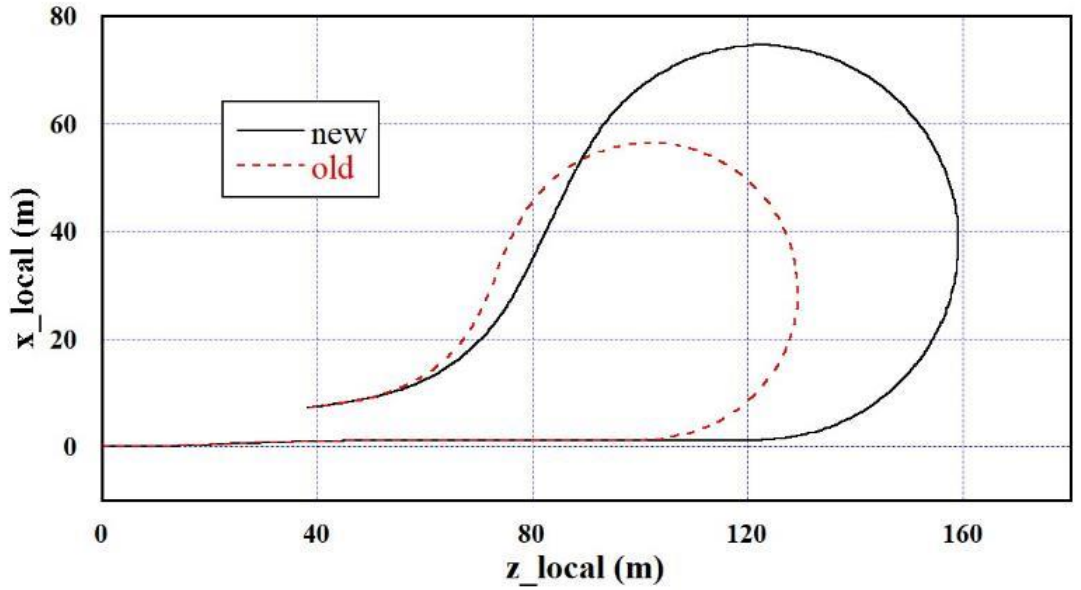
- Horizontal normalized Emittance growth 390nm (even larger number is in TDR, 480nm) is not acceptable for the new (250 GeV) design with lower horizontal emittance at collision.
- Space between bending magnets is too tight. (0.7m)

Old parameters:

- Horizontal normalized Emittance growth 390nm
- Total length 274.9 m

New parameters:

- Horizontal normalized Emittance growth: 175nm
- Total length 353.18 m



Longer Turnaround (cont'd)

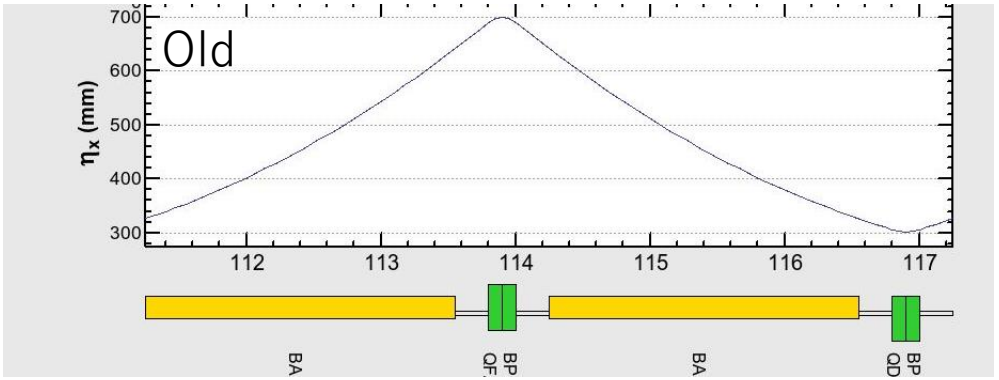
Old parameters:

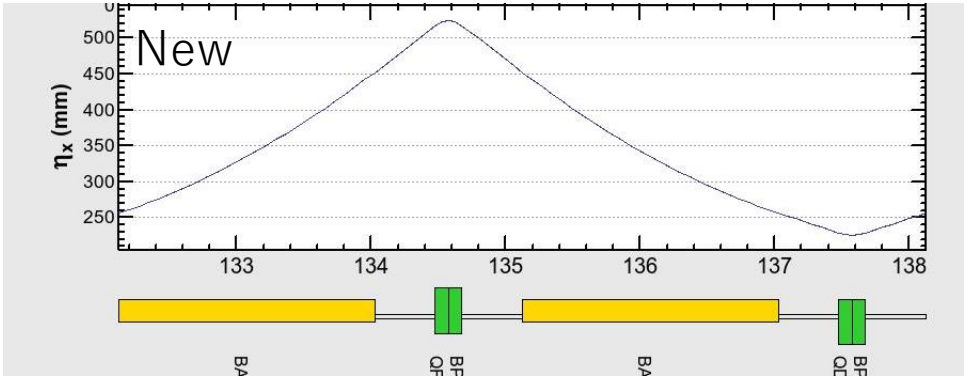
- Bend length 2.3 m, bend angle 0.109 rad
- Bend to bend space 0.7 m

New parameters:

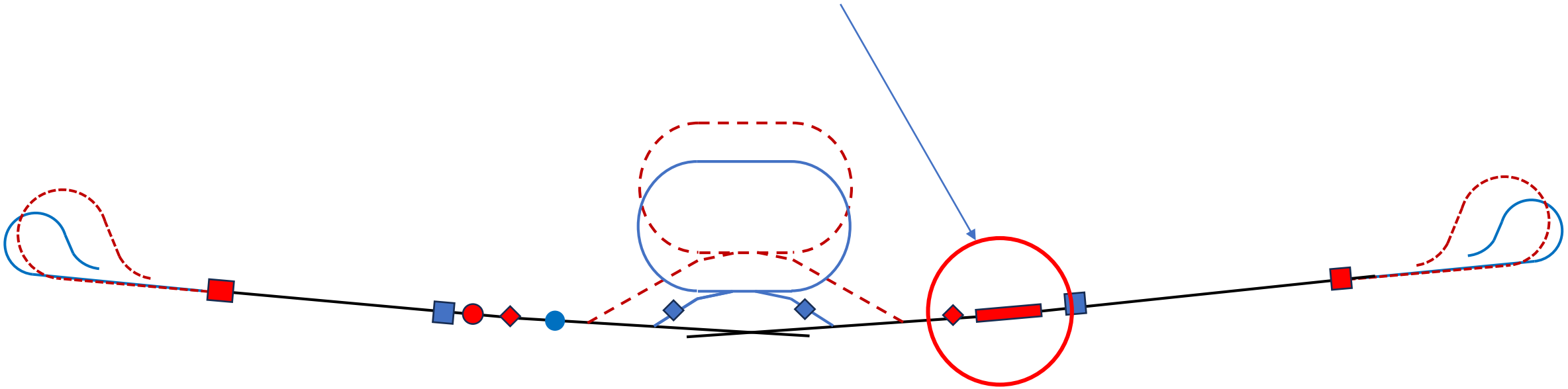
- Bend length 1.9 m, bend angle 0.082 rad.
- Bend to bend space 1.1 m

Arc Cell





Undulator, e+ source



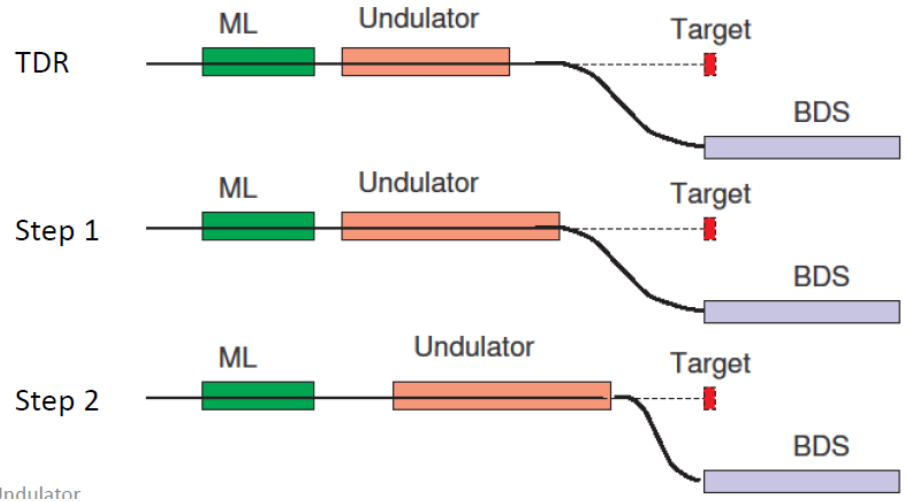
e- beamline for e+ production (undulator, dogleg, e+ production target and photon dump)

- Change total length of undulator from 147 to 231 m.
  - Increase number of undulator magnets from 84 to 132 magnets (each is 175 cm long).
- Move the undulators downstream by 168.8 m. Make the dogleg shorter accordingly.

---- For keeping the positron yield with 125 GeV electron beam energy, lower than TDR,

- Longer undulator is needed.
- Distance to the positron production target cannot be too long because of the increased production angle of photons due to the lower energy of electrons.

Note: Dogleg should be replaced with longer one when the beam energy is increased to 250 GeV



e- beamline for e+ production (cont'd) (undulator, dogleg, e+ production target and photon dump)

- Move photon dump farther from the positron production target.

--- For avoiding destruction of photon dump, transverse size of photon beam should be large, requiring larger distance from the target and the dump.

- Move e+ production target downstream by 6.0 m. The positron capture section and the booster linac are also moved accordingly. (Distance from the undulator center to the target is 407.1 m)

--- For avoiding interference of target room shield and quadrupoles in e- BDS.

.

Comparison of TDR and new length (unit: m)

	TDR	New	Difference
BDS start to IP	2241	2274	33
Undulator center to target	559	401	-158
Undulator end to BDS	464.1	306.1	-158
Dogleg bend to bend	316.0	151.2	-164.8
Undulator start to end	317.9	317.9	0
Space befor undulator	0	165	165
Undulator section start to BDS	802.8	809.8	7.0

Positron Source Beamline

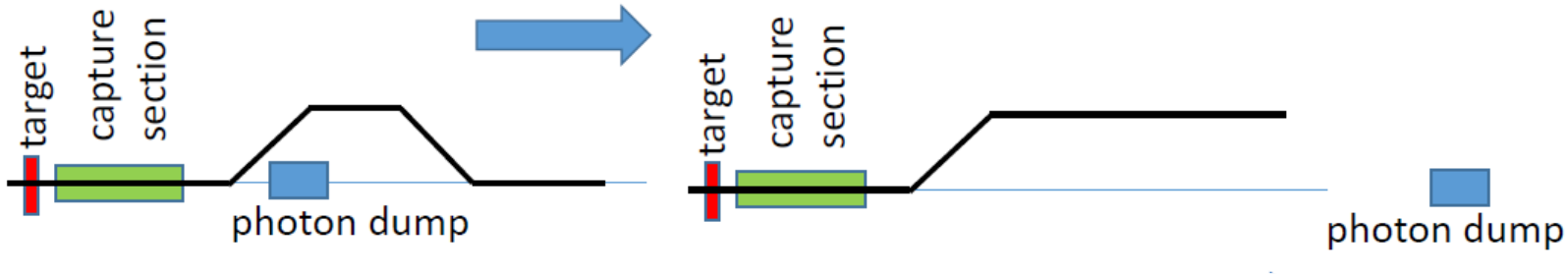
- Replace 125 MeV capture section by 400 MeV capture section

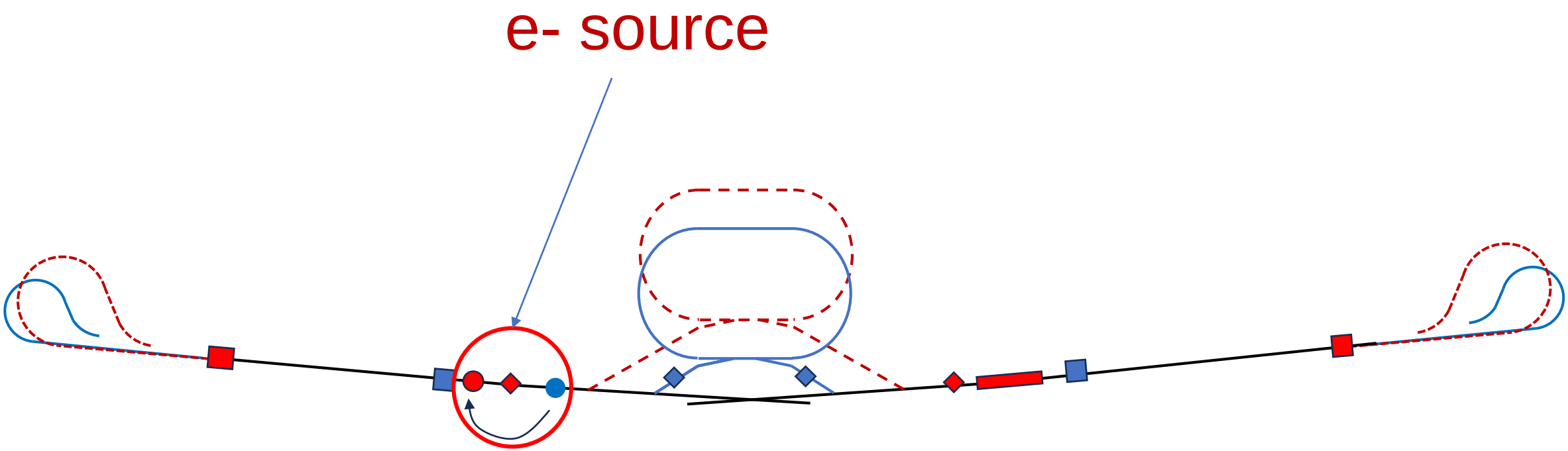
--- For better capture efficiency.

- Shift beamline by 3.6 m, replacing chicane by dogleg

--- 3.6 m for making space of transporting cryomodules.

--- Dogleg for making space for the photon beam to its beam dump




e- source

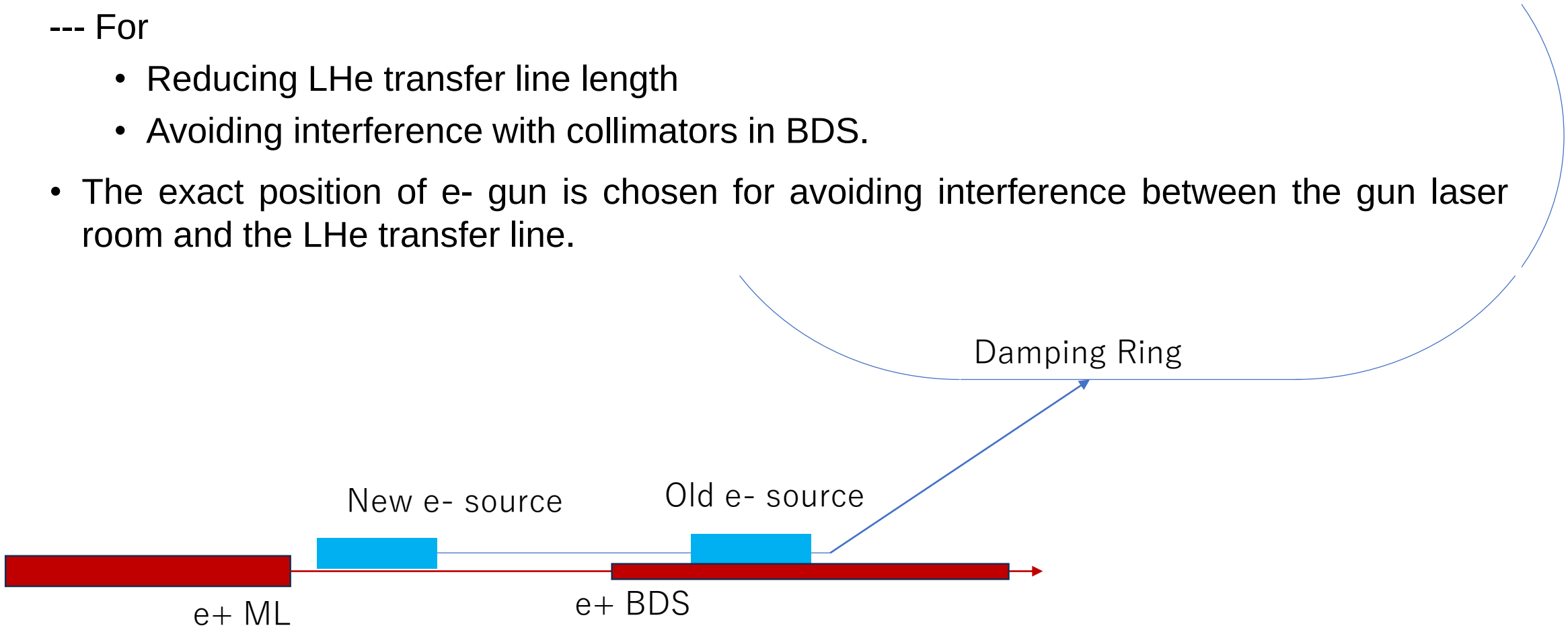
Electron Source Beamline

- Move e- source upstream, close to the end of e+ ML.
- Long beam transfer line is inserted between the booster linac and LTR line.

--- For

  - Reducing LHe transfer line length
  - Avoiding interference with collimators in BDS.

- The exact position of e- gun is chosen for avoiding interference between the gun laser room and the LHe transfer line.



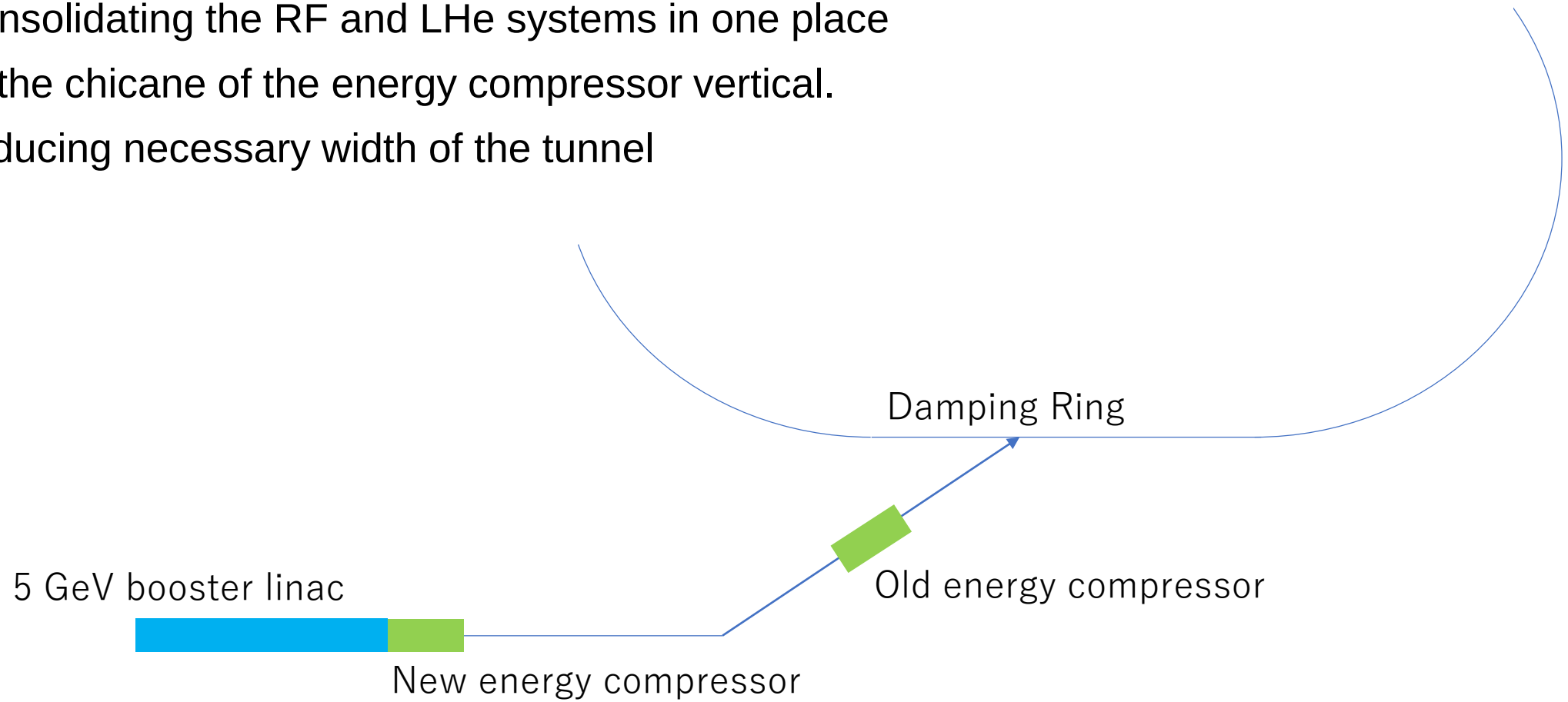
Common changes in e- and e+ source Beamline

- Move energy compressor from LTR to downstream of booster linac.

--- For consolidating the RF and LHe systems in one place

- Make the chicane of the energy compressor vertical.

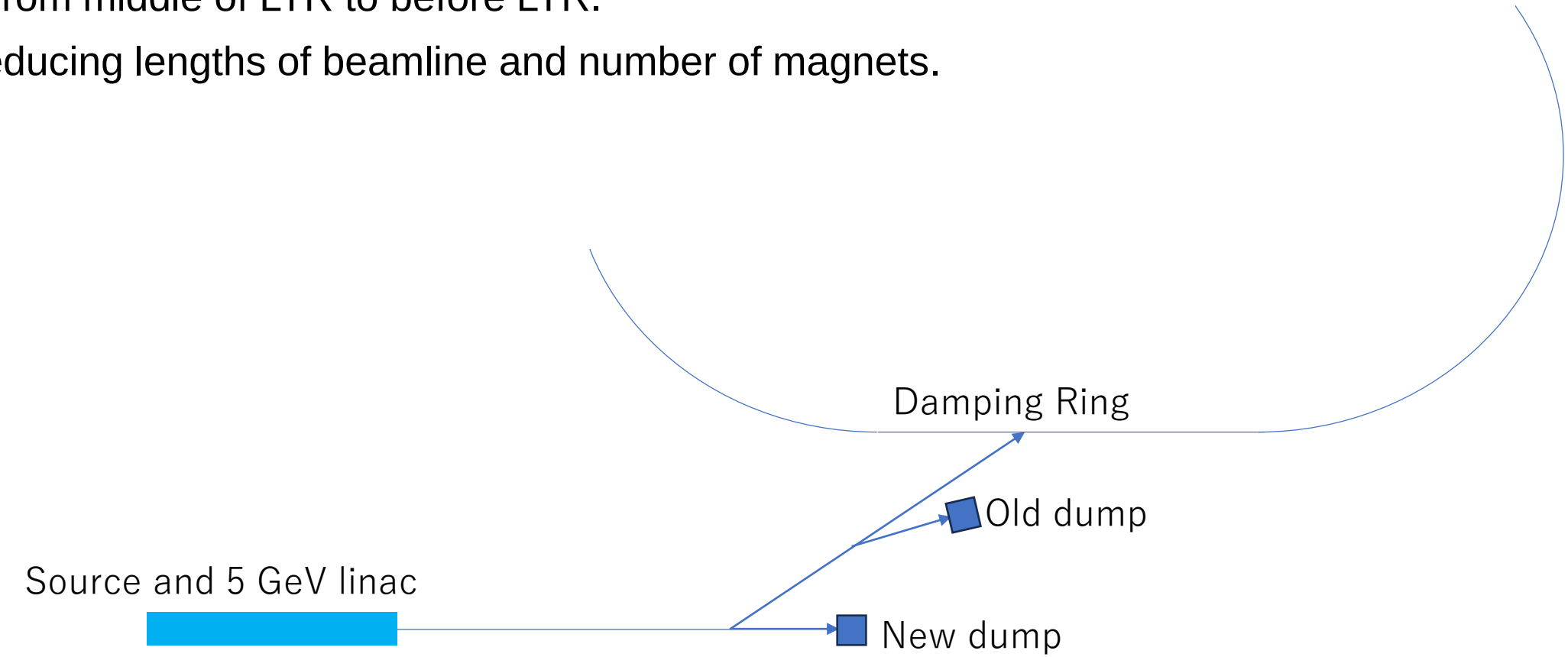
--- For reducing necessary width of the tunnel



e- and e+ source tuning dump (5 GeV) positions

- Move from middle of LTR to before LTR.

--- For reducing lengths of beamline and number of magnets.



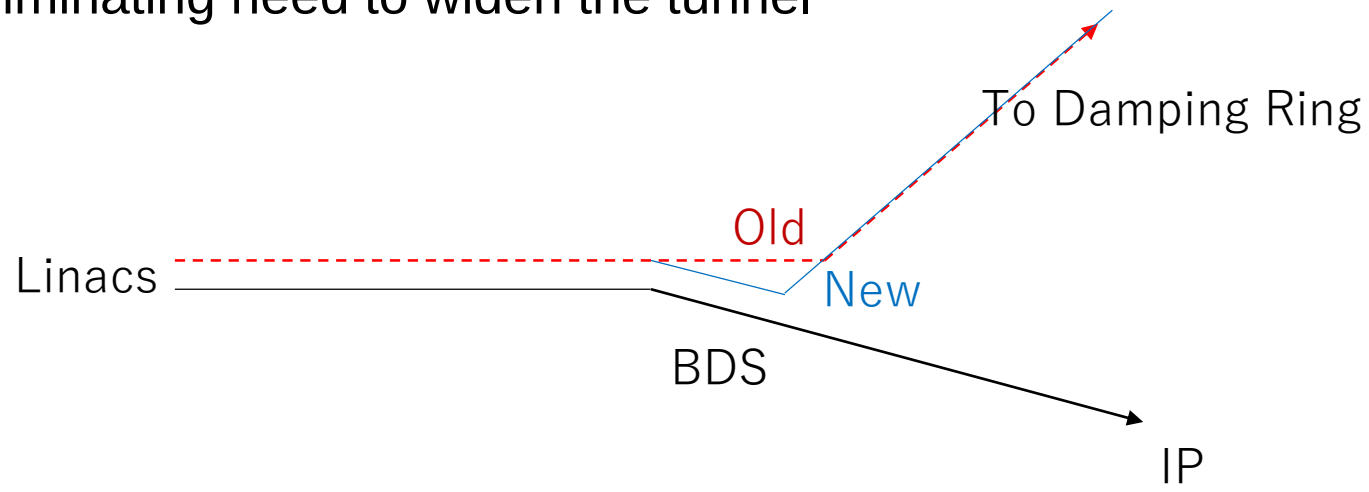
Common changes in e- and e+ source Beamline

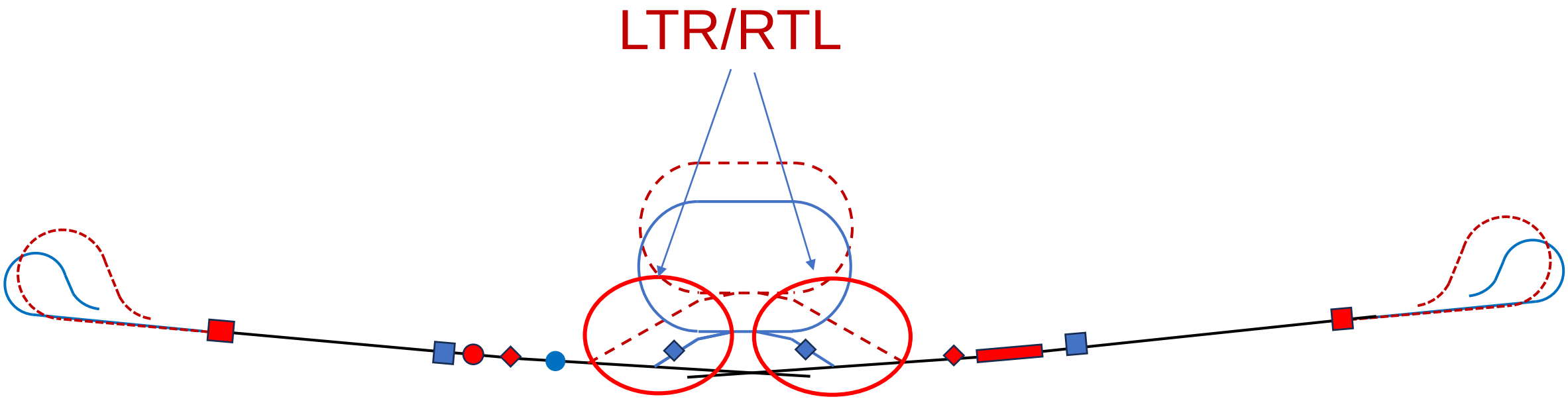
- Make the super conducting booster linac region close to horizontal. (The linac is laser straight, but vertical bend is inserted for making the center of the linac horizontal)

--- For making LHe supply easier

- Bend the beam transport line slightly, before LTR, following the BDS.

--- For eliminating need to widen the tunnel




LTR/RTL

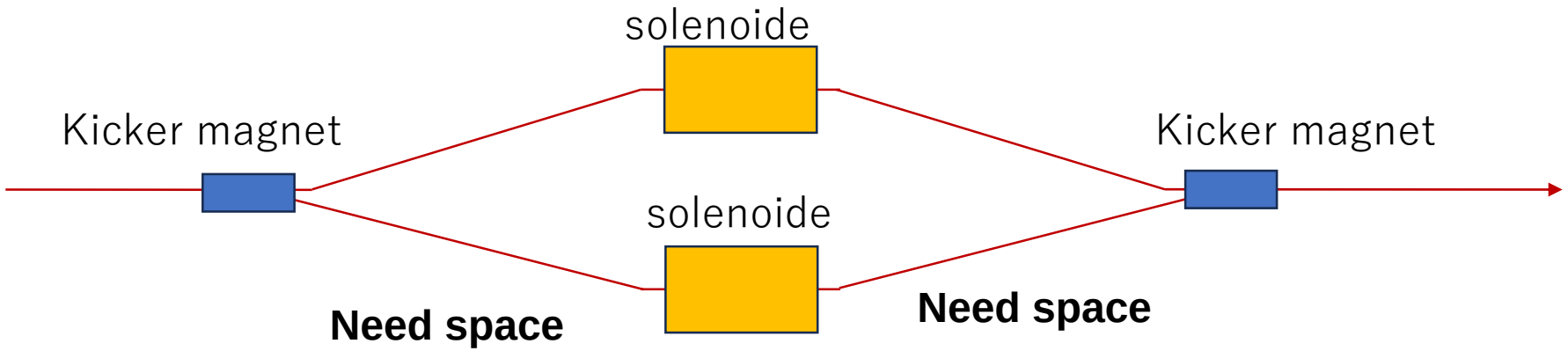
LTR/RTL Geometry

- Change e+ LTR, e- RTL line geometry
  - Longer straight regions at both sides of the e+ spin rotator solenoids
  - e- RTL is changed accordingly.
  - e+ side and e- side become asymmetric.

--- For keeping long enough regions for switching two spin rotators

(Details are not described in TDR)

Two solenoides with opposite fields for switching polarization of e+ beam



e+ Damping Ring injection line

Damping Ring is 0.35 m higher than the LTR.

2nd e+ Damping Ring will be 2.5 m higher than the 1st Ring (if constructed).

- Make a simple vertical dogleg for 0.35 m elevation

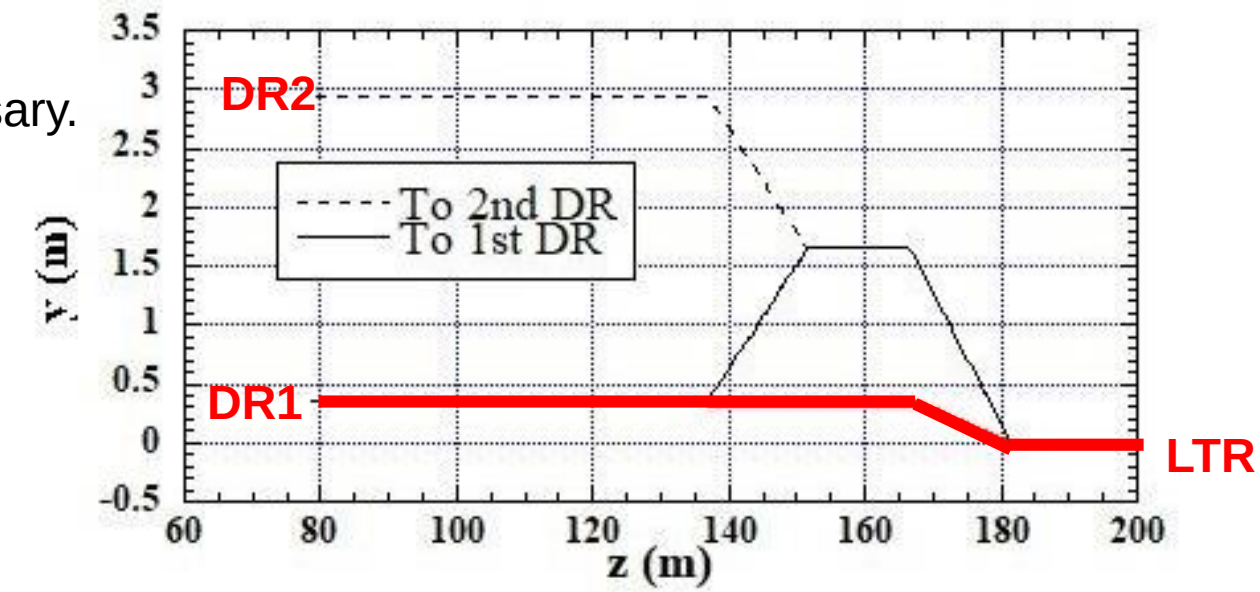
If two e+ rings are needed, reconstruct beamline as:

- Raise 1.6 m first, then, branch into two lines, up and down by 1.25 m
  (two beamlines the same length)
- e+ beamline length 0.14 m increase. Timing adjusting chicane is designed to address this change.

--- This design is simple at the beginning.

The second damping ring may not be necessary.

(Details not in TDR)



Position of Damping Rings, LTR/RTL

Change in 2022:

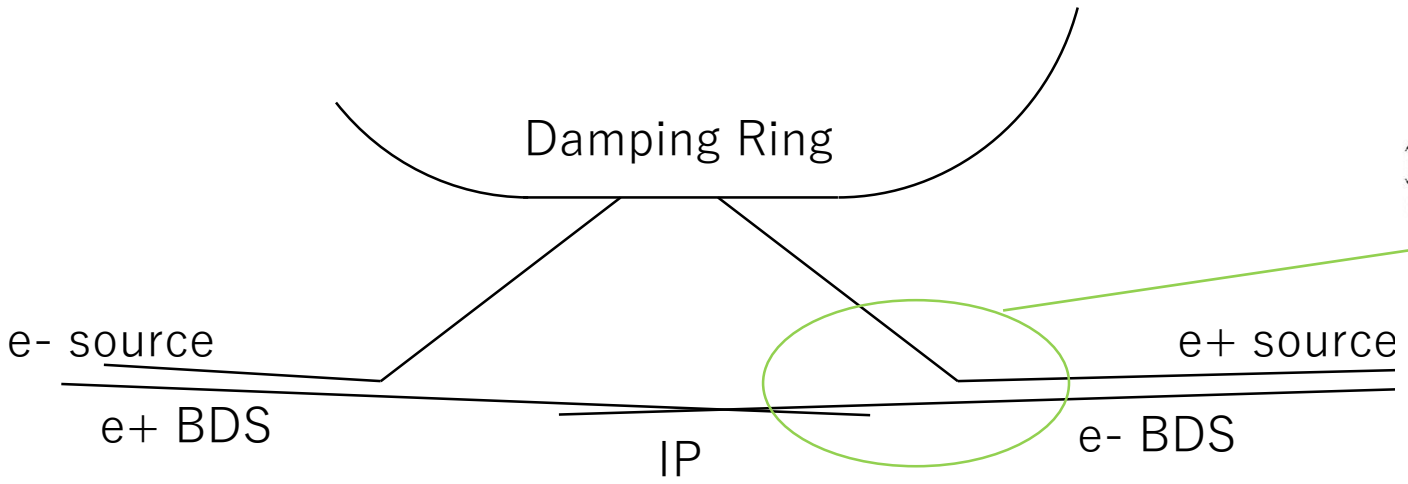
- Shift Damping Ring 2.1 m farther from Linac and IP

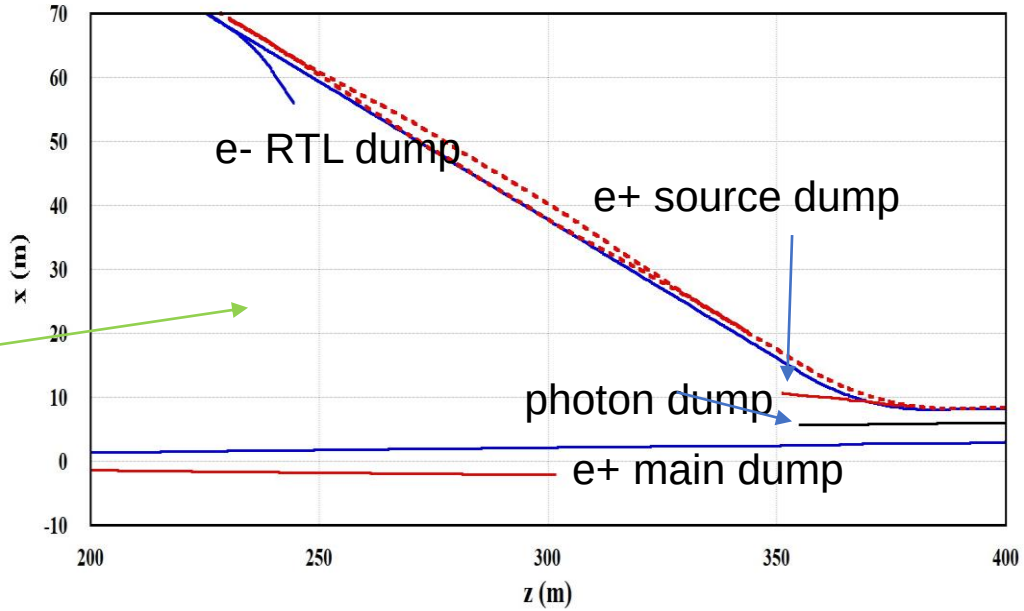
--- Result of e+ source dogleg change (from 1.5 m to 3.6 m), for keeping straight-line lengths in e+ LTR line.

Change in 2023:

- Additional shift of Damping Ring, 100 m farther from Linac and IP

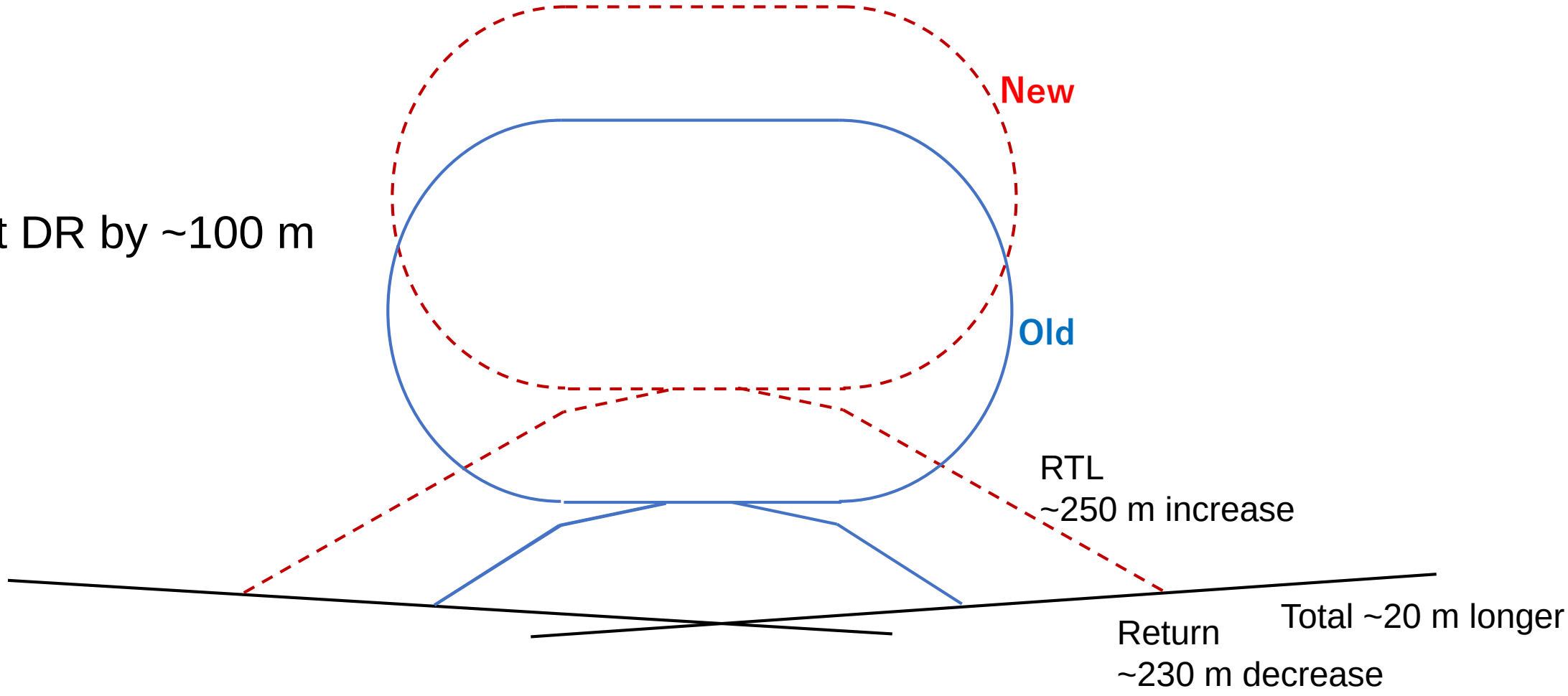
--- For making enough space around IP and Linac-RTL/LTR branches for beam dumps.





Position of Damping Rings, LTR/RTL (cnt'd)

Shift DR by ~100 m



Damping Ring – lower horizontal emittance

2017

- Longer bending magnet, 3 m -> 5 m
  - For reducing horizontal emittance

  → Presentation in ALCW2018 (https://agenda.linearcollider.org/event/7826/sessions/4644/#20180531), etc.

2023

- Divide bending magnet, 5 m -> 2.4 m x 2
  - For easier construction and transfer, etc.
- Add space between magnets.
  - For realistic design

→ Will be reported in DR session of this workshop

Main linac reference points (PM-8, PM+8)

- Move the reference point, PM-8 and PM+8, upstream (farther from IP) by 2 m.
  (The reference points are the centers of the LHe domes)

--- For avoiding interference between the LHe transfer line and quadrupole magnets.

Changes of beamlines Summary