System Considerations for ILC Positron Source

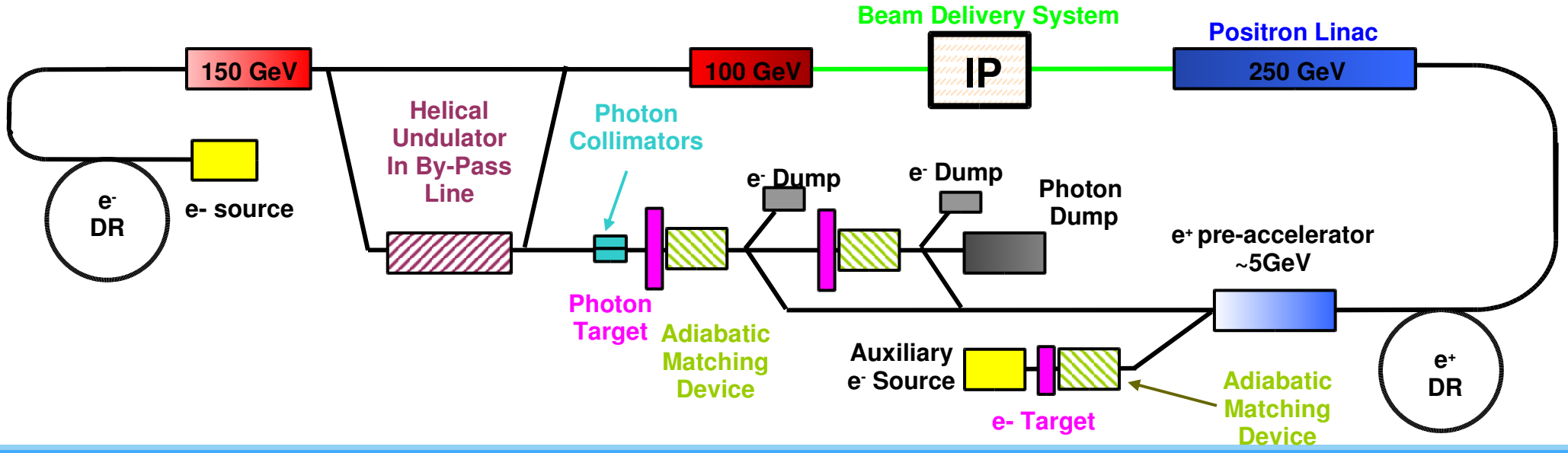
28 April 2006, CERN

KURIKI Masao (KEK)

- Considerations for Baseline ILC Positron Source
- Considerations for Alternative ILC Positron Source
- Summary

Baseline Positron Source

- Baseline positron source is a system, which is tightly coupled with the whole ILC system, rather than a component.
- Addition to the component approach, system oriented approach is important to improve the system reliability.



Construction and Commissioning

- Assuming undulator system, 150 GeV electron is needed to generate e+.
- Positron source commissioning can start only after the e- source and ML commissioning is done.
- Construction and commissioning time could be longer, cost could be higher, and t=0 could be later.

Availability

- When the e- system is in trouble, e+ is not provided. During the recovery time, the e+ is not in operation.
- After the e- system is recovered, the e+ system has to be restarted. An additional time for the e+ recovery is consumed for every e- troubles.
- The availability becomes down to 20% less, compare to 80% without this fact, according to the USLCTOS and ILC-GG3 studies.

Keep Alive Source

- Keep Alive Source, which provides e+ independently from e- system with less intensity or reputation, is considered.
- The e+ commissioning is therefore done without any e- beam.
- The e+ system can be "hot" during the e- downtime. The recovering time for e+ system can be omitted.

Keep Alive Source
Specification

- Defined as 10% of the nominal intensity. 10% means 10% bunch intensity (0.32nC or 0.16nC) with the same bunch structure(2800 or 5600 bunches). This condition is determined so that BPM is working well.
- Placed in the e+ linac to isolate the operation from the e- linac.
- The system components
  - e- driver source and linac.
  - e+ production target.
  - e+ capture and pre-accelerator.

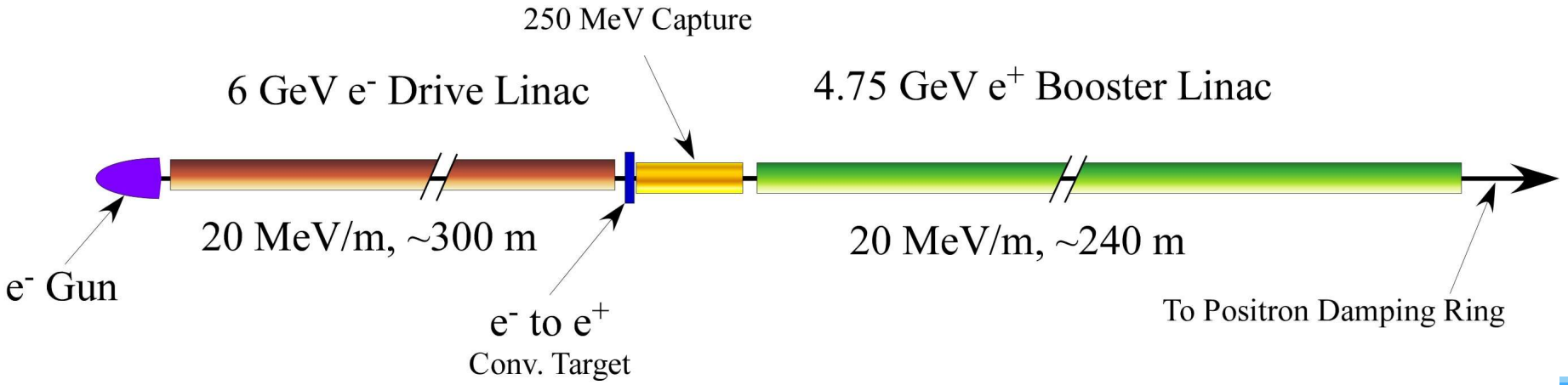
Conventional Scheme

A Prototype of Keep Alive Source

- Conventional scheme, which is a technical backup of ILC main positron source, can be a prototype of the keep alive source.
- Modifications for less intensity:
  - Energy or intensity of drive beam can be scaled.
  - Target thickness should be optimized, when the energy is modified.
  - Target rotation speed can be lower.

ILC Positron Source
Based On Conventional Scheme

Parameter	Value	Units
Positrons per bunch	2.0E+10 (1.0E+10)†	number
Bunches per pulse	2820 (5600) †	number
Pulse Repetition Rate	5	Hz
Electron Drive Beam Energy	6	GeV
Electrons per bunch	2.0E+10 (1.0E+10)†	number
Electron Drive Beam Power	270	kW
Target Material	W-23%Re	-
Target Thickness	4	r.l.
Incident Spot Size on Target	2	mm, rms

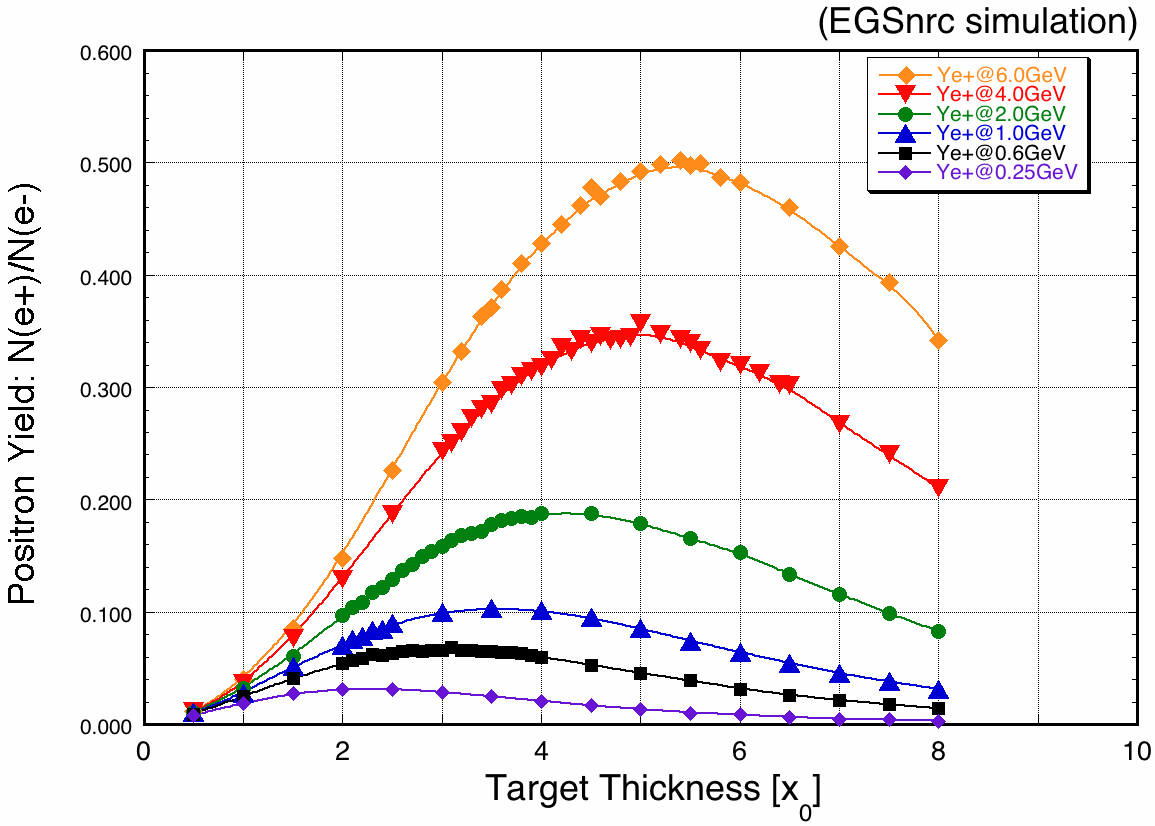


Modifications (1)
Drive Beam

- To generate 10% intensity, drive beam energy or intensity can be scaled.
- By considering the cost, less energy with the same intensity is effective.
- As a first assumption, 0.6 GeV drive beam with 2E+10 electrons is assumed.

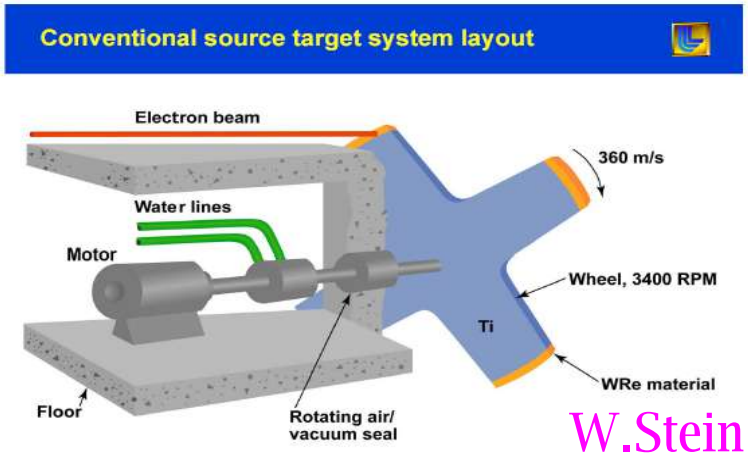
Modifications (2)
Target Thickness

- According to EGS simulation by T. Kamitani, 0.6 GeV drive beam yields more than 10% of that with 6.0GeV.
- For 0.6 GeV, $3X_0$ target thickness is optimum rather than $4.5X_0$.

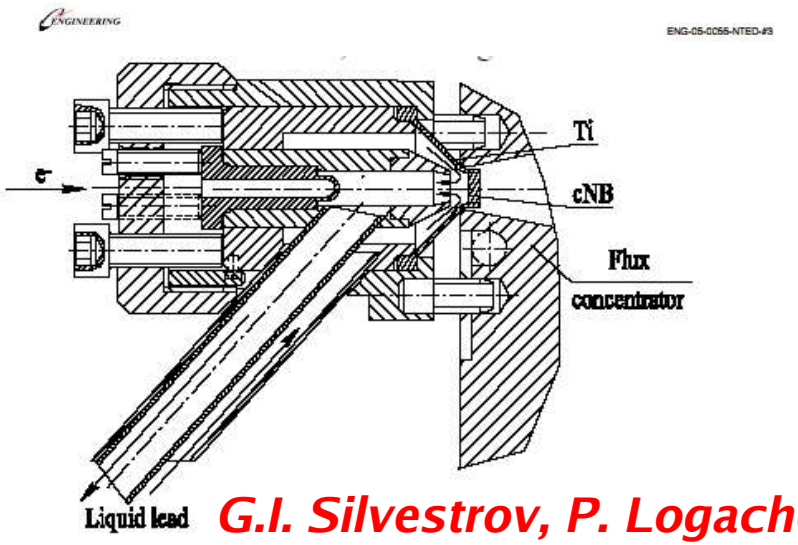


Modifications (3)
Target System

- In the conventional e+ source, 360 m/s tangential speed is required to cure thermal stress and fatigue.
- This limit can be 36 m/s for the keep alive source, but the rotation target is still necessary.
- Liquid lead target can be replacement because of the mechanical simplicity. Be window is an issue.



W.Stein



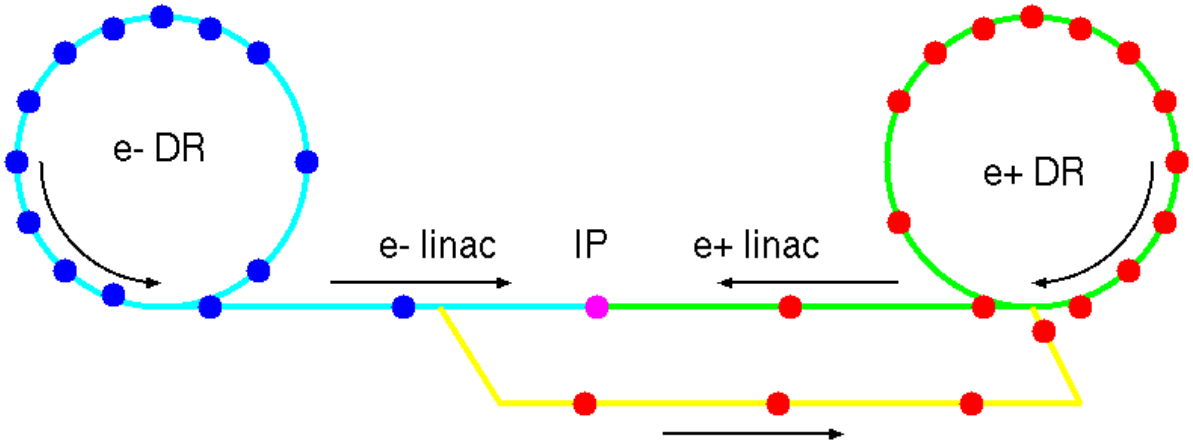
G.I. Silvestrov, P. Logachev

Keep Alive Source
Summary

- Injector: 2.0E+10 (1.0E+10) electrons/bunch, 2800(5600) bunches with 300(150)ns spacing.
- Linac : 0.6 GeV SC (Dead copy of ML module)
- Target: 36 m/s rotation W-Re or Liquid Pb.
- Capture : AMD + L-band NC.
- Pre-accelerator : depends on e+ transport energy from the undulator system.

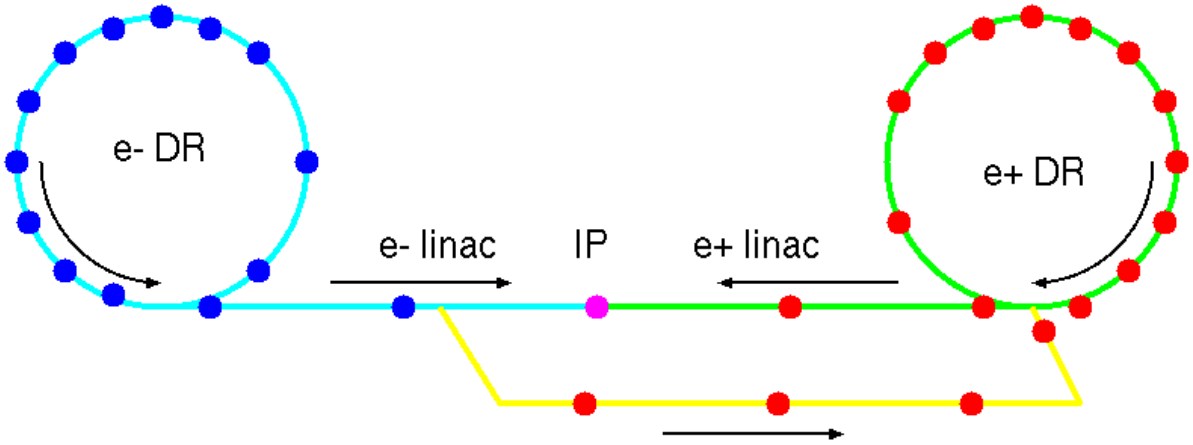
Layout Constraint

- Since ILC Positron is generated from the electron beam, positron bunches are produced during the pulse.
- These positron bunches have to be accepted by DR because there is no other place for waiting.
- In DR, however, there are still positron bunches, which will be extracted, but not extracted yet.



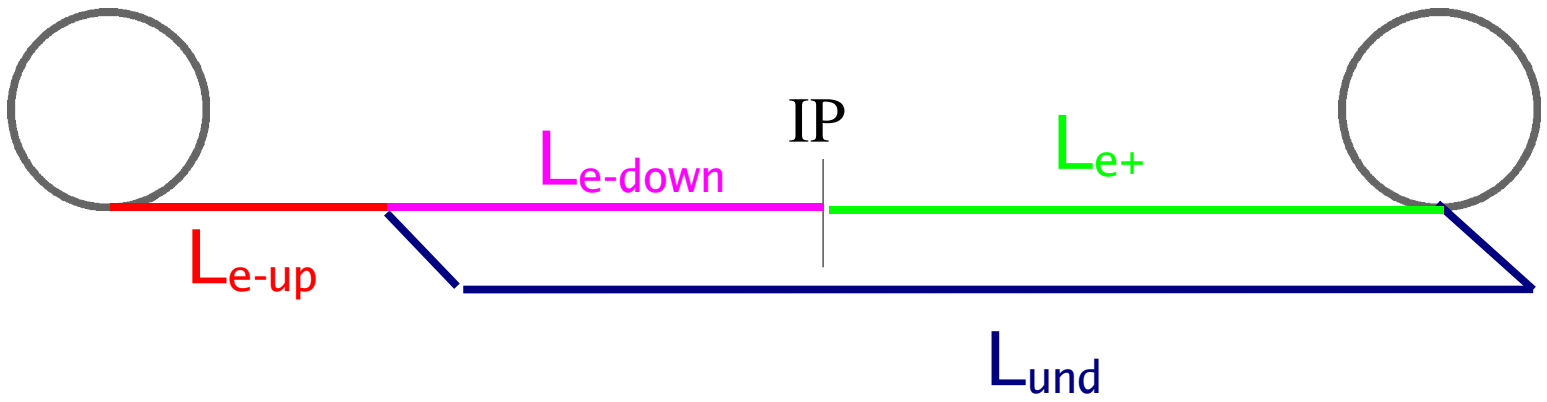
Self Reproduction (1)

- The best solution is self-reproduction; The new e+ bunch is filled in where the associated e+ bunch was.
- The associated e+ bunch is colliding partner of the e- bunch, which generates the new e+ bunch.
- In this scheme, bucket is always vacant for every fill patterns.



Self Reproduction (2)

- The condition for the self-reproduction is
  - $L_{und} + L_{e+} - L_{e\text{-}down} = nC$
- Assuming n=4 or 5 and C=6.5km, $L_{und} + L_{e+} - L_{e\text{-}down} = 26km \text{ or } 32.5km$. Path length adjustment is needed.

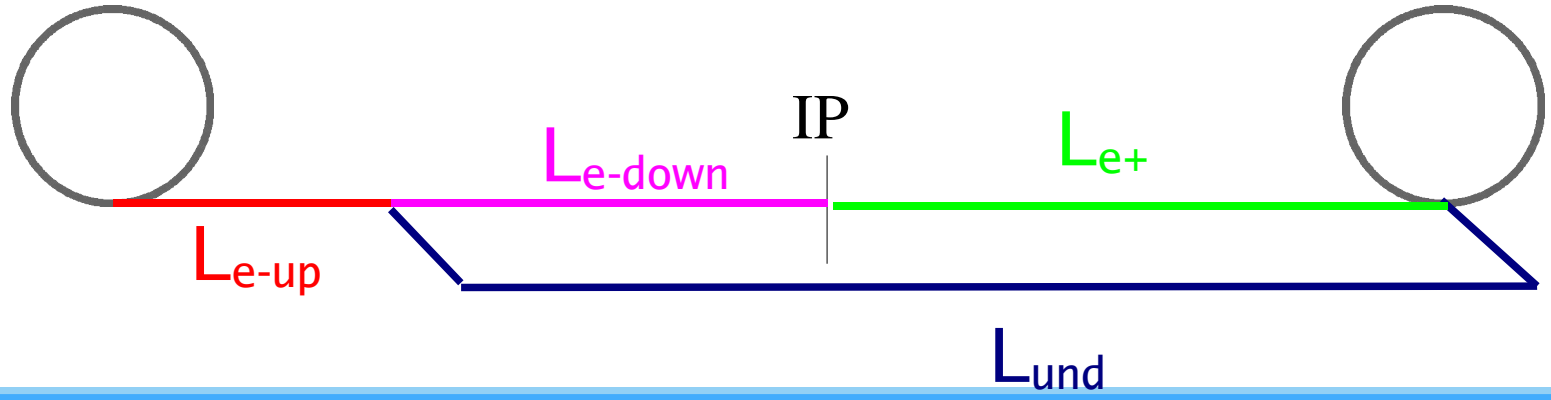


Self Reproduction (3)

- The condition to make the collision at IP is

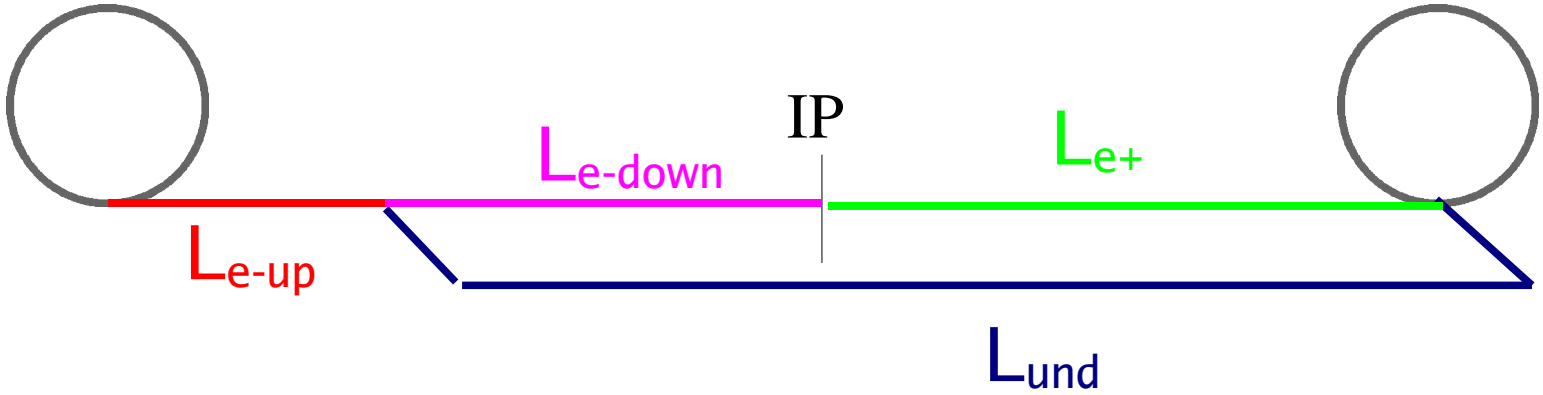
$$L_{e+} - (L_{e\text{-}up} + L_{e\text{-}down}) = -\Delta t\, c - mL_{LNC}$$

  - Δt is relative timing difference e+ and e- systems (DR injection/extraction),
  - m is an integer,
  - L_{LNC} is bunch spacing in ML.



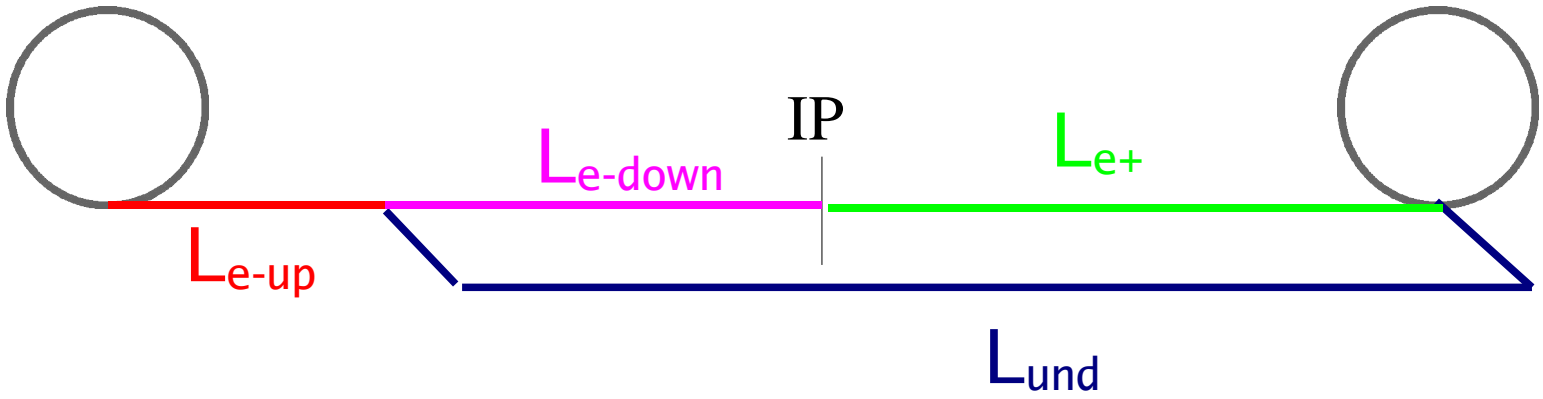
Self Reproduction (4)

- When a e+ bunch is just extracted, colliding partner e- bunch is at (from e- DR)
  - $L_{e\text{-}up} + L_{e\text{-}down} - L_{e+} = \Delta tc + mL_{LNC}$
- For the e- bunch, the distance to e+ DR through e+ production line is
  - $L_{e\text{-}up} + L_{und} - (\Delta tc + mL_{LNC}) = L_{und} - L_{e\text{-}down} + L_{e+}$



Self Reproduction (5)

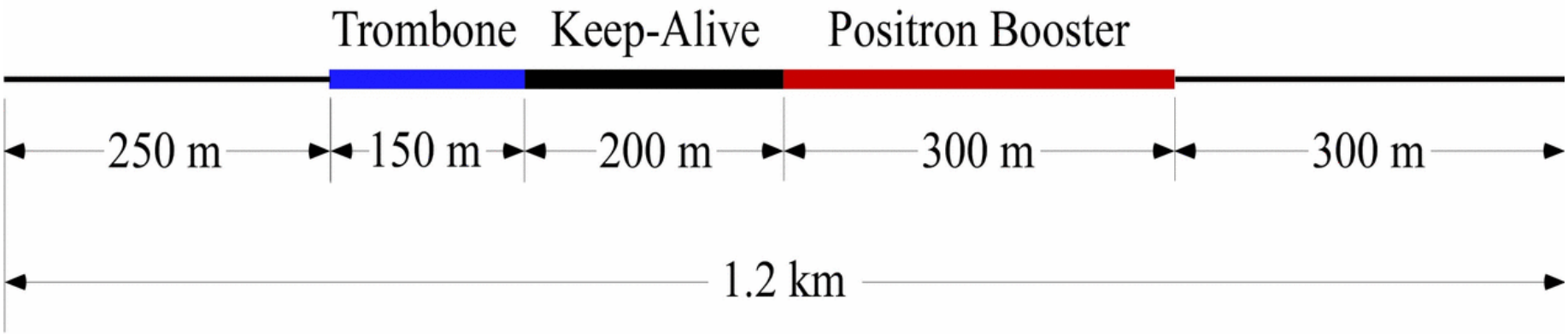
- The distance to e+ DR through e+ production line has to be an integer of the DR circumference *C*,
  - $L_{e\text{-}up} + L_{und} - (\Delta tc + mL_{LNC}) = L_{und} - L_{e\text{-}down} + L_{e+} = nC$

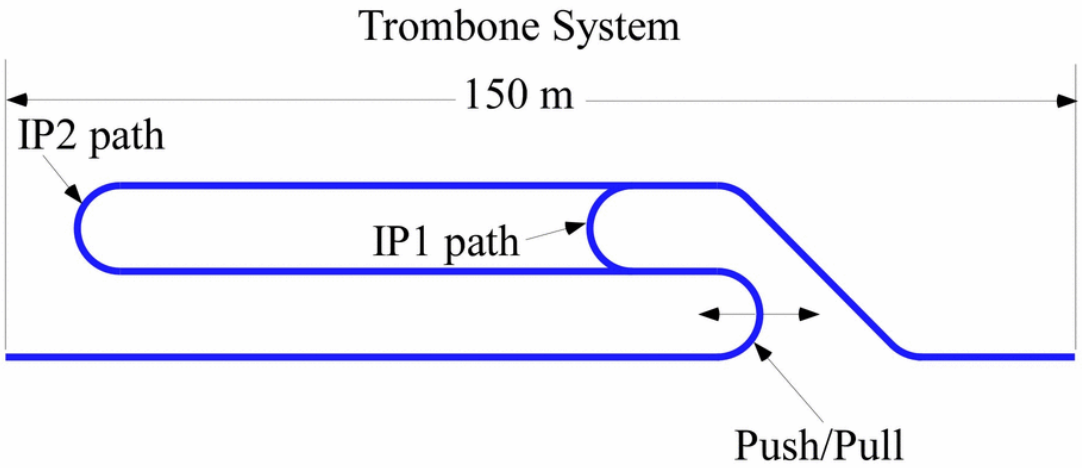


Path Length Adjustment

- Path length has to be adjusted for the self-reproduction.
- Size and accuracy of the adjustment could be
  - Large adjustment : several kms to quantize the path length in unit of C, DR circumference. Accuracy for the adjustment could be in m.
  - Small adjustment : several ms to quantize the path length in unit of DR RF wave length. Accuracy could be in mm.

Positron Insertion
(Submitted to CCB)





Lower Energy Operation

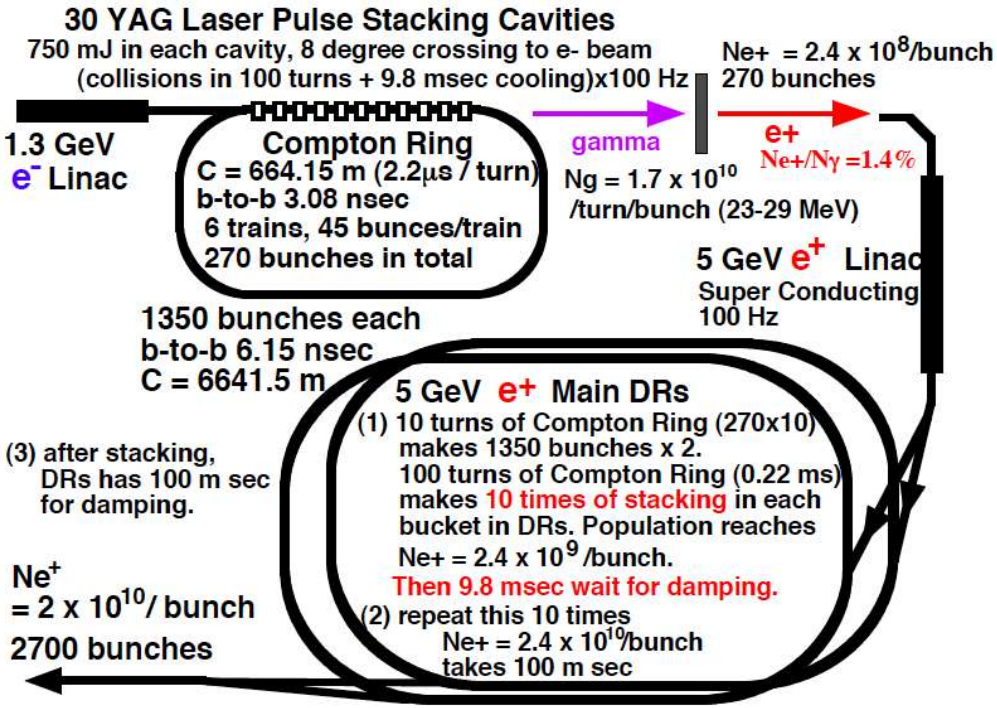
- 150 GeV beam energy is required to generate positron.
- For lower energy operation than 150 GeV, the latter part of ML is operated in deceleration phase.
- There is no fundamental difficulty on this operation mode, but the energy spread becomes larger (0.1% -> 0.3% or more). It could be an issue for giga-Z option.

System Consideration for the ILC Alternative

- ILC e+ source based on Compton scheme is considered as an advanced alternative.
- The positron generation is isolated from the e- system. The system wide complexity is relieved.
- On the other hand, due to the less gamma yield, 10 turns of CR makes 1 turn of DR with less e+ intensity and the positrons are stacked 100 times. It means e+ source is tightly coupled with DR.

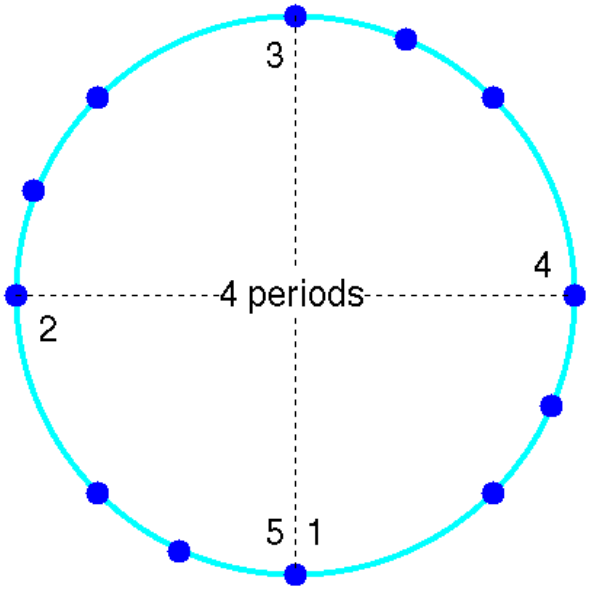
Compton and DR

- In the current configuration, CR, Compton Ring, has exactly 1/10 smaller circumference. Harmonic number of DR must have 10 as a divisor.
- Bunch fill pattern must have 10 super-periods.
- These are tight constraints on DR and fill pattern.



DR Constraint

- Assuming super-periods, bunches are extracted from DR not successfully, as long as the extraction reputation ~ bunch spacing in Linac is a constant.
- We have to make "a step" to extract next bunches. ("Step solution" in DR jargon)
- It does not means that the collision is lost, as long as e+ and e- are synchronized. Therefore, this is not a strong constraint, but the system flexibility is slightly decreased.



DR Fill Pattern

- "Step" solution : Bunch spacing in Linac is not a constant, t_{LNC}, or $t_{LNC} \pm m t_{DRRF}$; 300 ± 3.1 ns.
- Solutions without any "step" is generally possible("filled solution" in DR jargon).
- Step solution has more DR fill pattern flexibility than that of filled solution.
- The energy variation due to the step is quite small, less than 1E-4.

DR Fill Pattern Summary

	Step solution	Filled solution
Baseline	Yes	Yes
Alternative	Yes	No
Flex	Large	Small
Bunch spacing in Linac	Not constant	Constant

Cavity Availability (1)

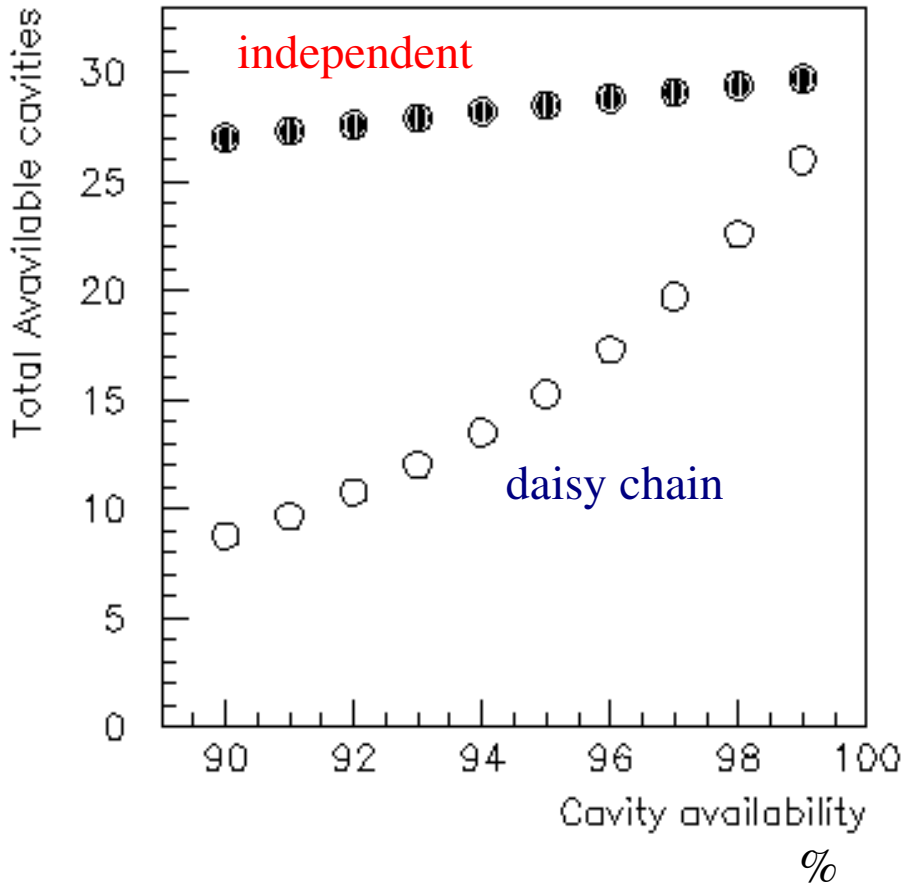
- # of available cavity depends on the cavity operation scheme : daisy chain or ind. cavities.
- Average available cavity is considered with the following assumptions;
  - 30 independent and chained cavities.
  - Same availability for all cavities.
  - In daisy chain, no laser for downstream cavities when some cavity is in trouble.
  - Laser availability is not considered.

Cavity Availability (2)

$$Ndsy = 30 \prod_{i=1}^{30} P_i + \sum_{m=2}^{30} \left[\left(\prod_{i=1}^{m-1} P_i \right) (1 - P_m)(m-1) \right]$$

$$Nind = \sum_{i=1}^{30} P_i$$

- Independent cavity is preferred in the view of availability.
- In the independent scheme, total high availability is easily obtained with some spares.



Summary
- Baseline -

- Baseline ILC e+ source has system-wide dependencies.
  - Keep Alive source is required for effective initial commissioning, construction, and high availability. It means the baseline is a hybrid system of undulator and conventional schemes.
  - Layout is also constrained to realize the self-reproduction. Large and small path length adjustments are required.
  - For the lower energy operation, energy spread becomes larger.

Summary
- Alternative -

- Alternative ILC e+ source has also a constraint on DR, but it is not a system wide and less limitation.
  - DR must have a divisor (~10) on the harmonic number and super-periods on the fill pattern.
  - Only "Step" solution is possible, but there is no fundamental difficulties on this solution.
- Total availability of cavity is studied. Independent cavity system is proffered; by assuming some spares, availability is not an issue at all.