Superconductive Positron Stacking Ring

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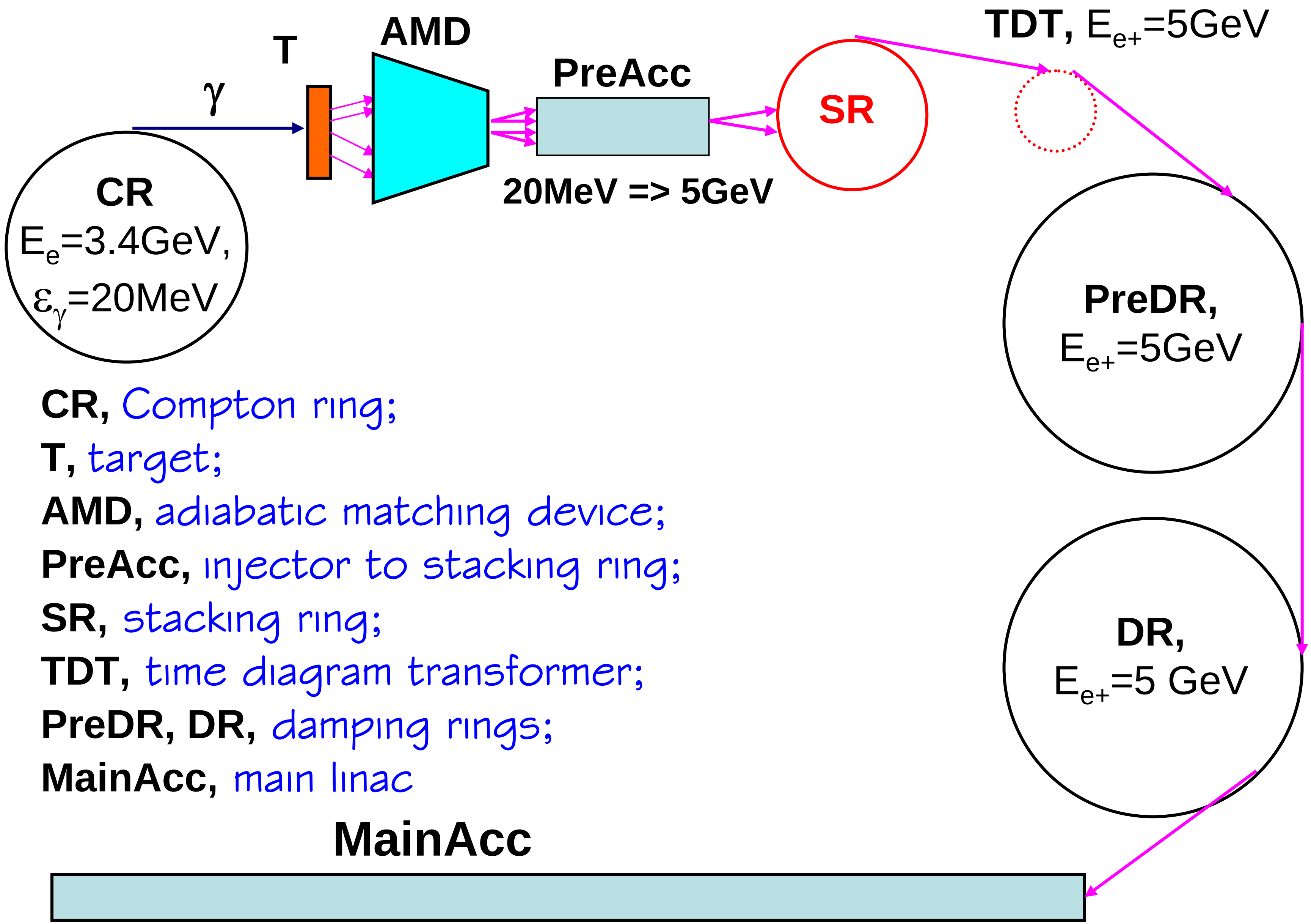
Conclusions:

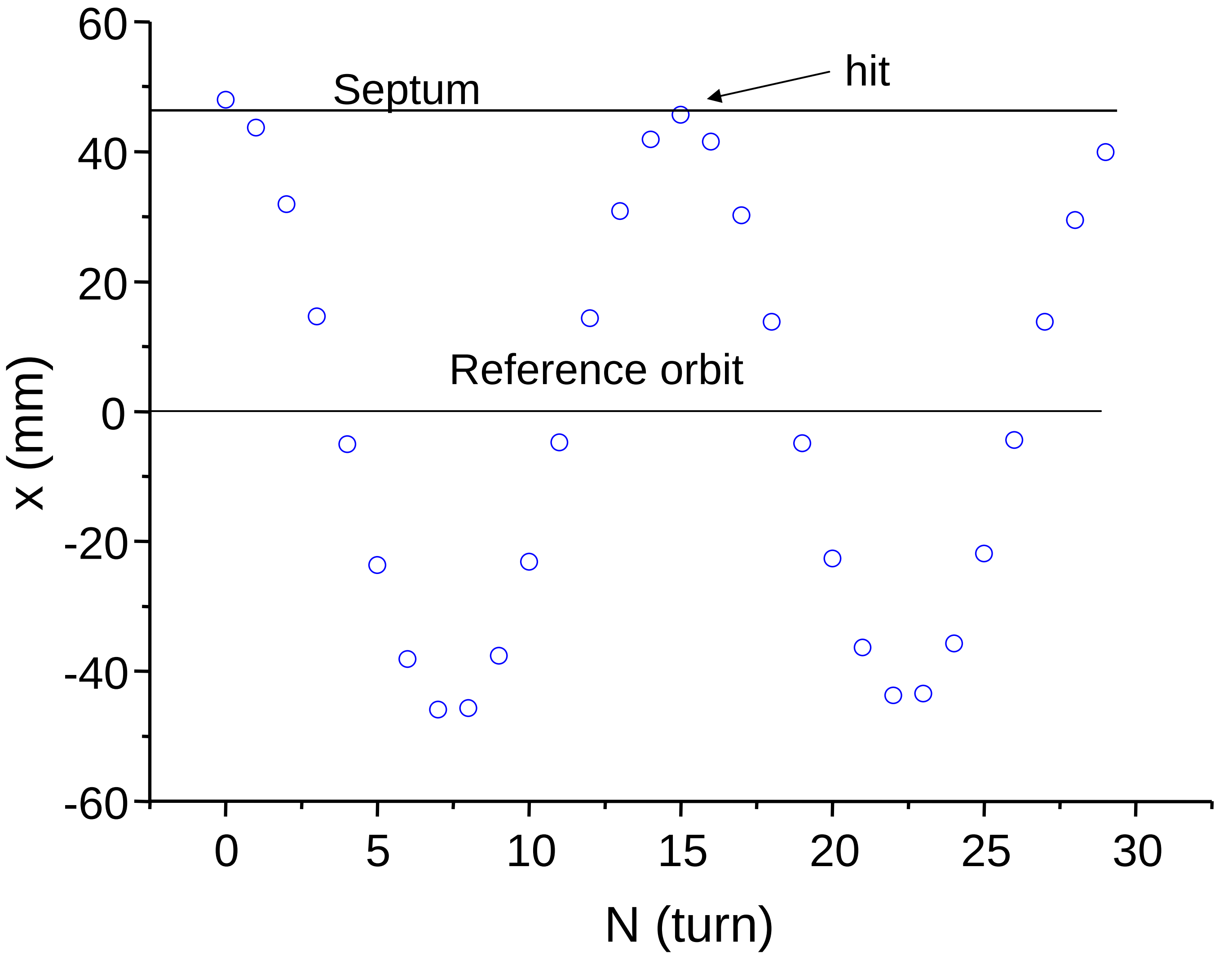
For continuous positron injection
we need SR with damping time of 100 μs

Possible ways:

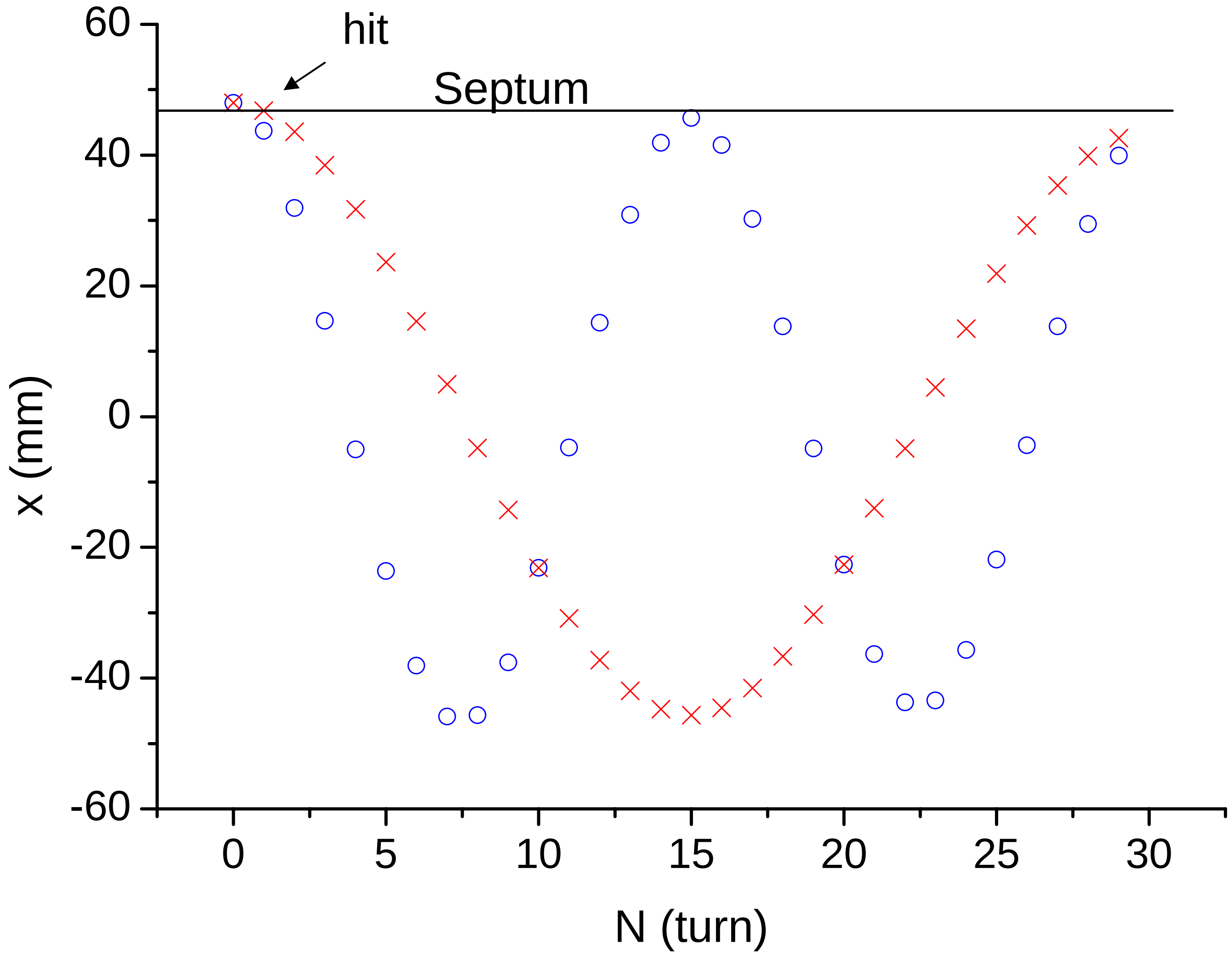
Inection in longitudinal plane;
Fast damping under extremely intensive CS;
Superconductive fields



CR, Compton ring;
T, target;
AMD, adiabatic matching device;
PreAcc, injector to stacking ring;
SR, stacking ring;
TDT, time diagram transformer;
PreDR, DR, damping rings;
MainAcc, main linac



Positions of equilibrium orbit. Dispersion at injection azimuth η=0.6 m,
momentum deviation $\Delta p/p$=8 %, synchrotron frequency Q_s = 1/15.
Ring circumference C= 100 m, synchrotron damping τ_s= 100 μs (333 turns)



Positions of equilibrium orbit. Dispersion at injection azimuth η=0.6 m, momentum deviation $\Delta p/p$=8 %, synchrotron frequency Q_s = 1/15; 1/30. Ring circumference C=100 m, synchrotron damping τ_s=100 μs (333 turns)

Synchrotron damping time

$$\tau_s \text{ [turn]} \approx E_0 / \Delta E$$

Energy losses

$$\Delta E \text{ [MeV]} = 0.0885\ E^4 \text{ [GeV]} / \rho \text{ [m]}$$

$$E_0 \text{ [GeV]} = 0.3\ B \text{ [T]}\ \rho \text{ [m]}$$

$$B = 10\ T \Rightarrow E_0 \text{ [GeV]} = 3\ \rho \text{ [m]},\ \rho \text{ [m]} = E_0 \text{ [GeV]} / 3$$

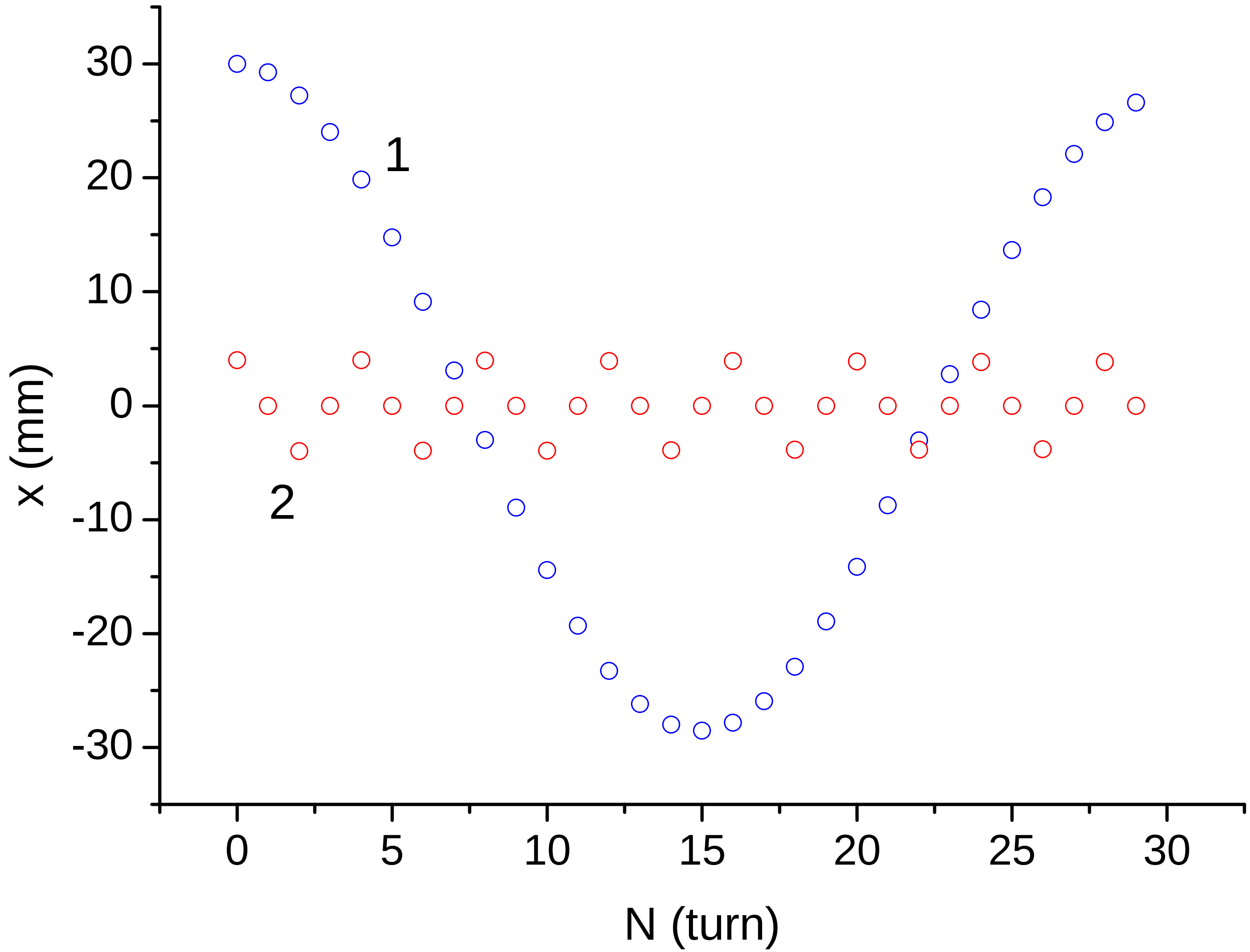
$$\Delta E \text{ [MeV]} = 0.265\ E_0^3 \text{ [GeV]}$$

Damping times

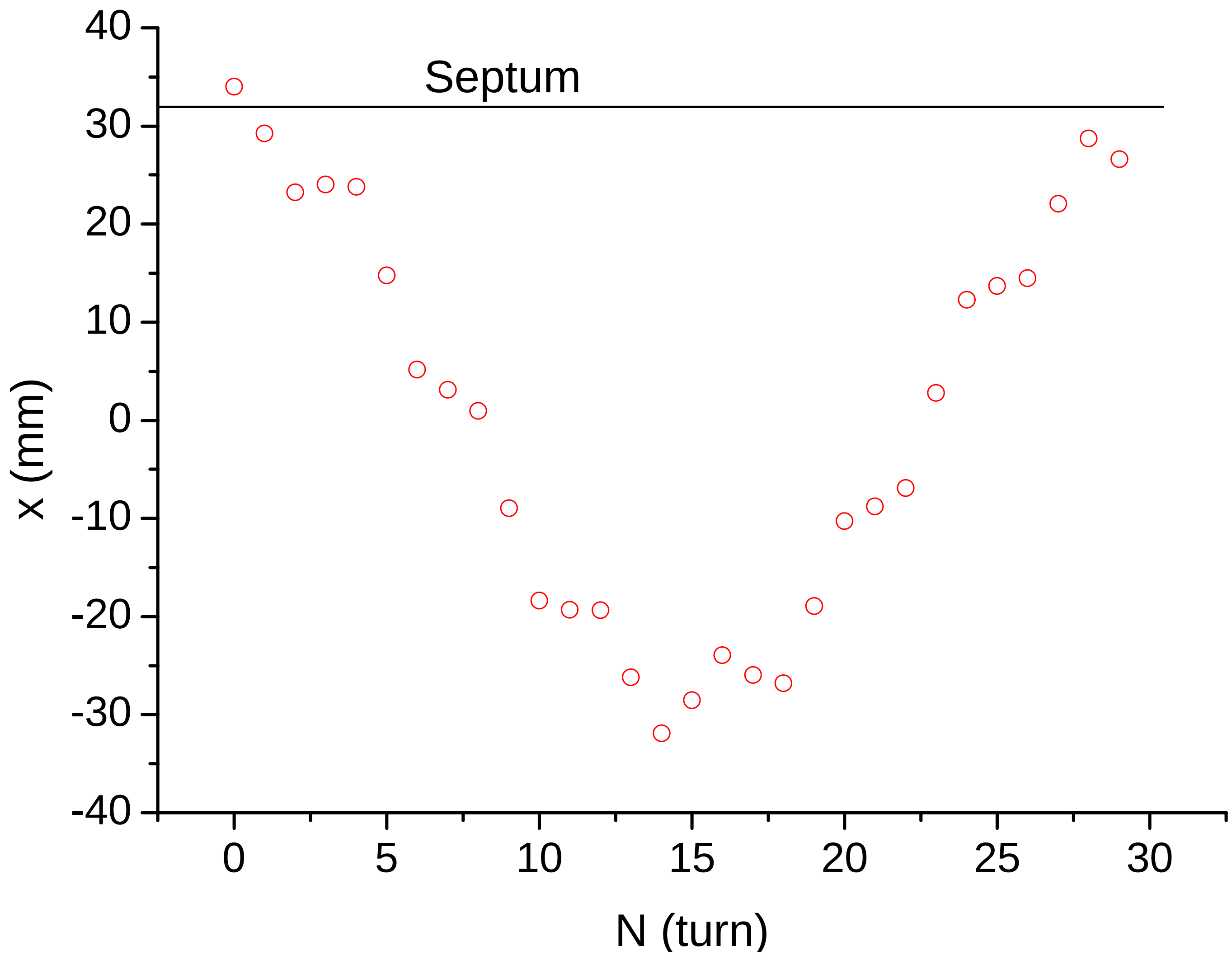
E_0=1 GeV, ΔE=0.265 MeV => 3750 turns **(τ_s=1250 μs)**

E_0=2 GeV, ΔE=2.125 MeV => 940 turns (τ_s=315 μs)

E_0=3 GeV, ΔE=7.170 MeV => 420 turns (τ_s=140 μs)

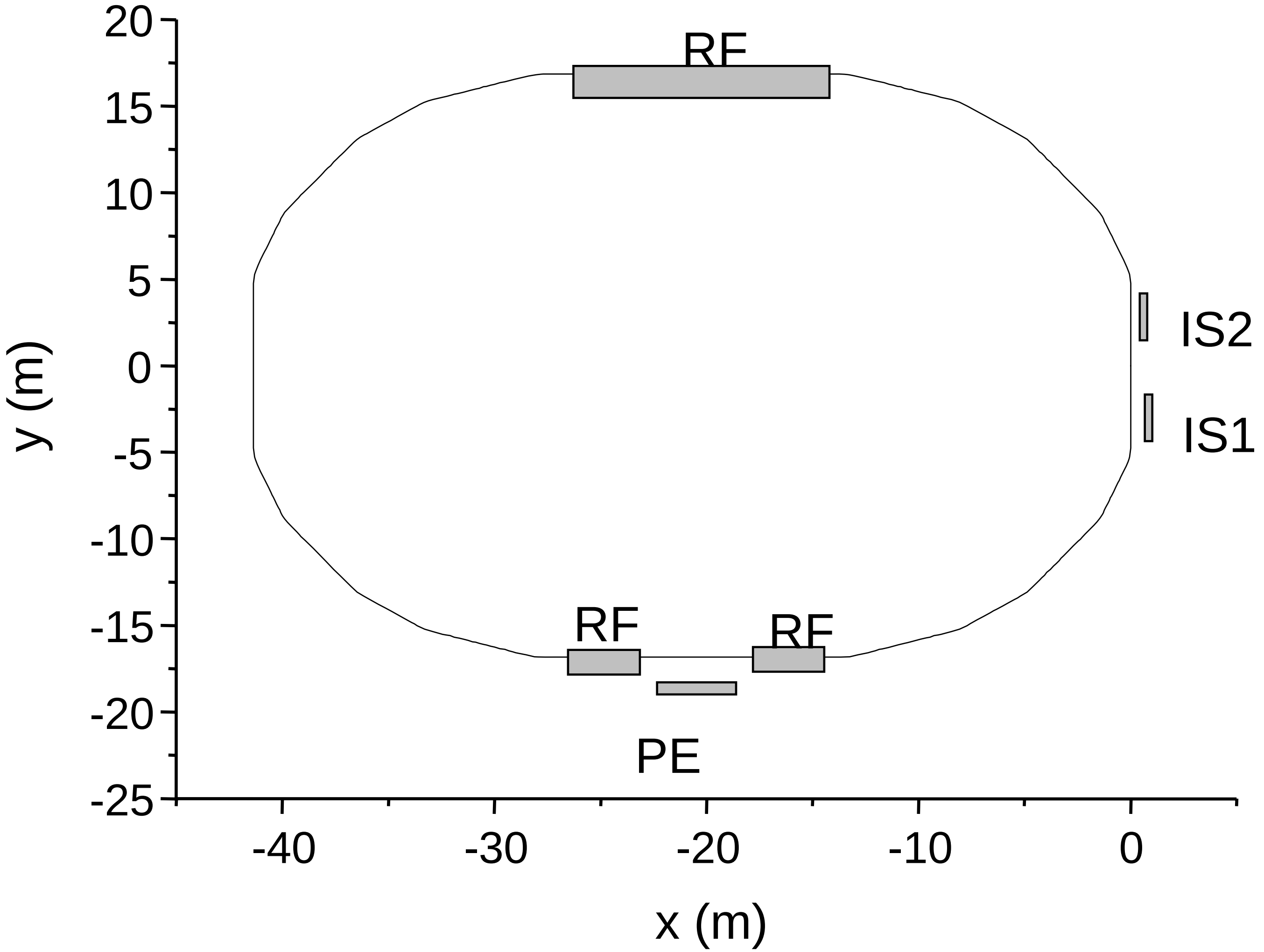


Positions of equilibrium orbit (1) and betatron oscillations (2).
Dispersion at injection azimuth η= 1.0 m,
momentum deviation $\Delta p/p$=3 %, synchrotron frequency Q_s = 1/30.
Ring circumference C= 100 m, synchrotron damping τ_s= 100 μs (333 turns)

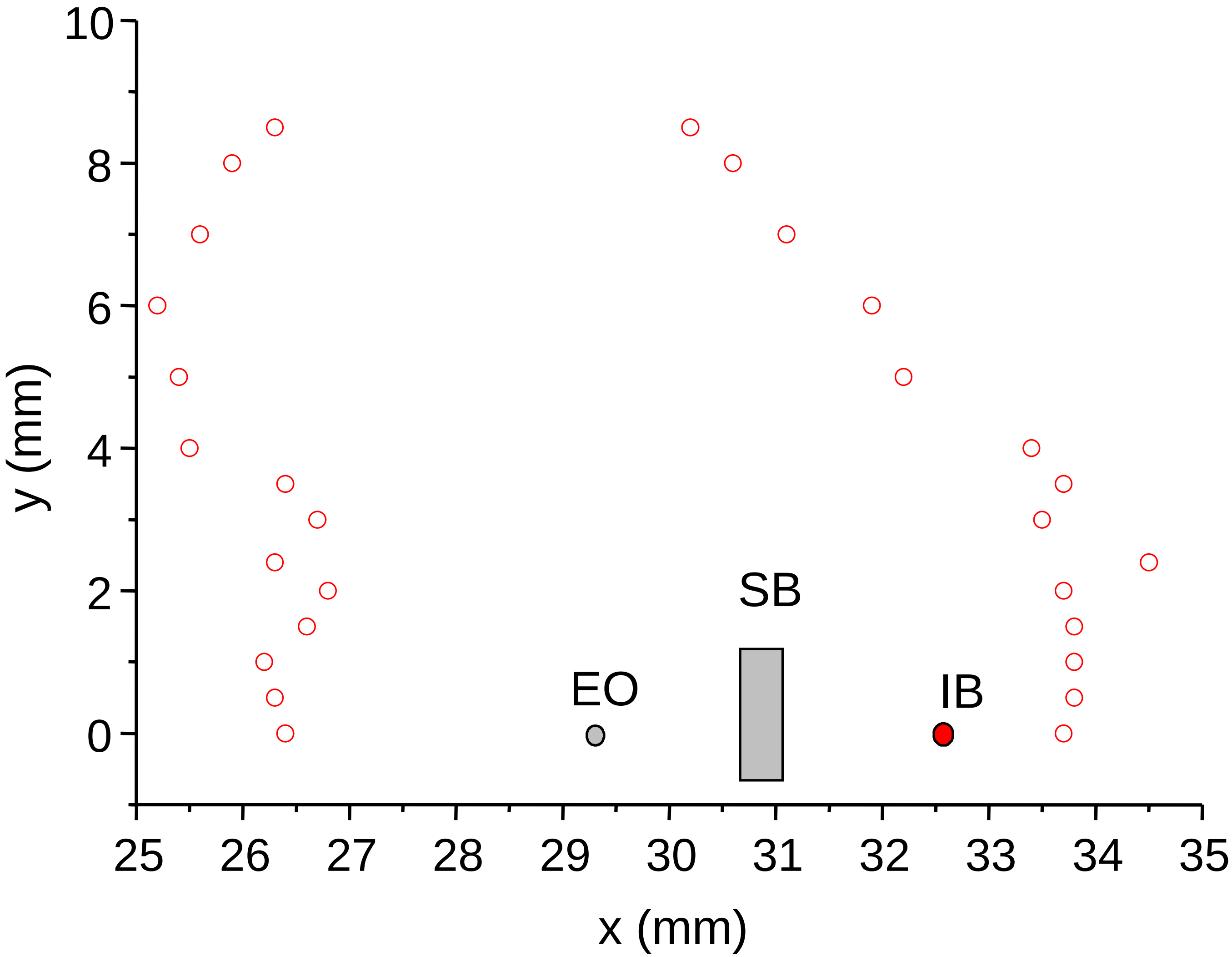


Positions of injected particle. Dispersion at injection azimuth η=1.0 m, betatron amplitude X_b=5 mm, momentum deviation $\Delta p/p$=3 %, synchrotron frequency Q_s =1/30.

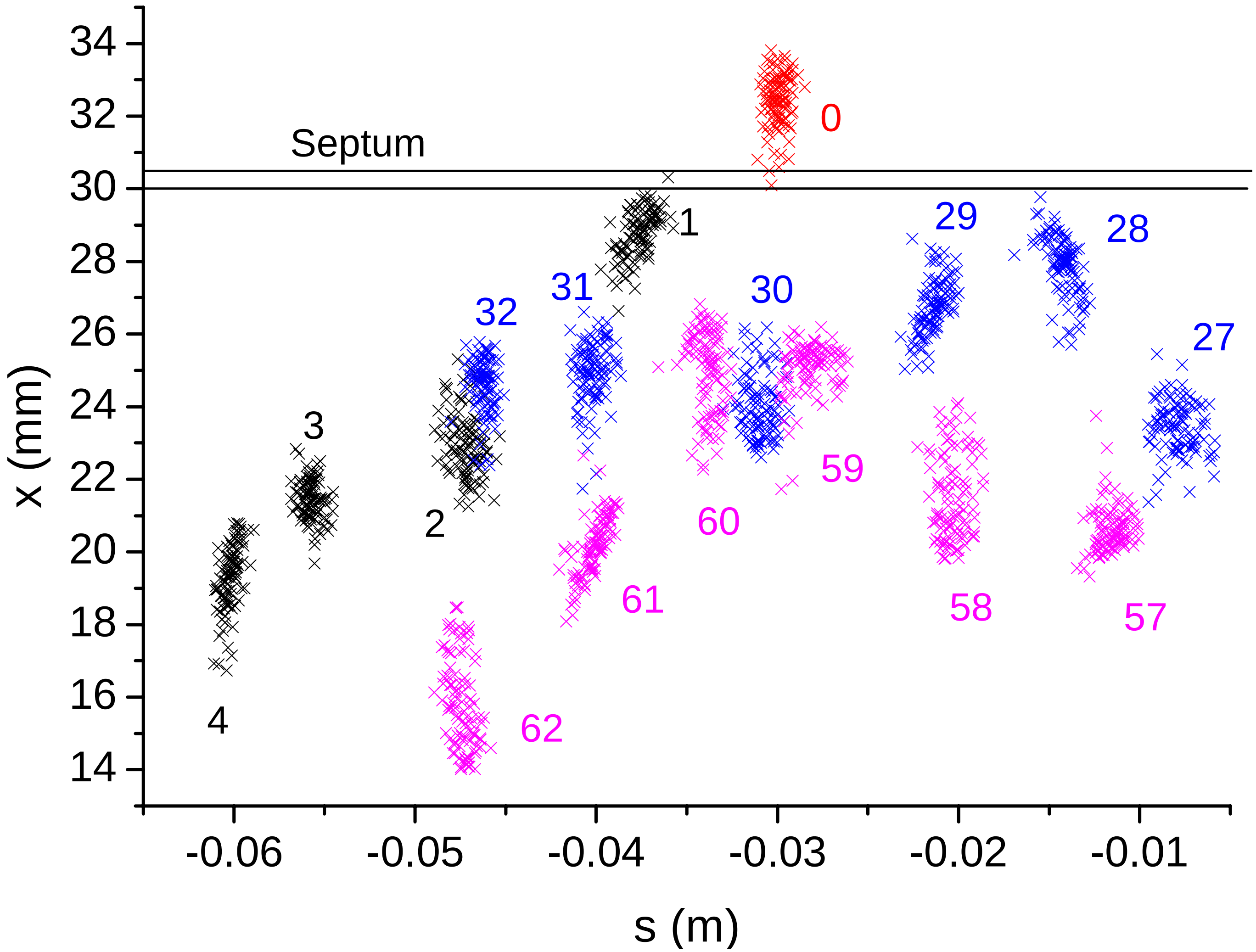
Ring circumference C=100 m, synchrotron damping τ_s=100 μs (333 turns)



Ring layout. Energy E_0=5 GeV, circumference C≈125 m, bend.field B=6 T, energy losses ΔE≈20 MeV / turn, synchrotron damping time τ_s=104 μs. IS1,IS2, injection septums; RF, rf-sections; PE, positron extraction.



Dynamic aperture at injection azimuth. IB, injected beam; EO, equilibrium orbit; SB, septum blade. Momentum deviation $\Delta p/p_0 = 3$ %, dispersion at injection azimuth $\eta = 1$ m.



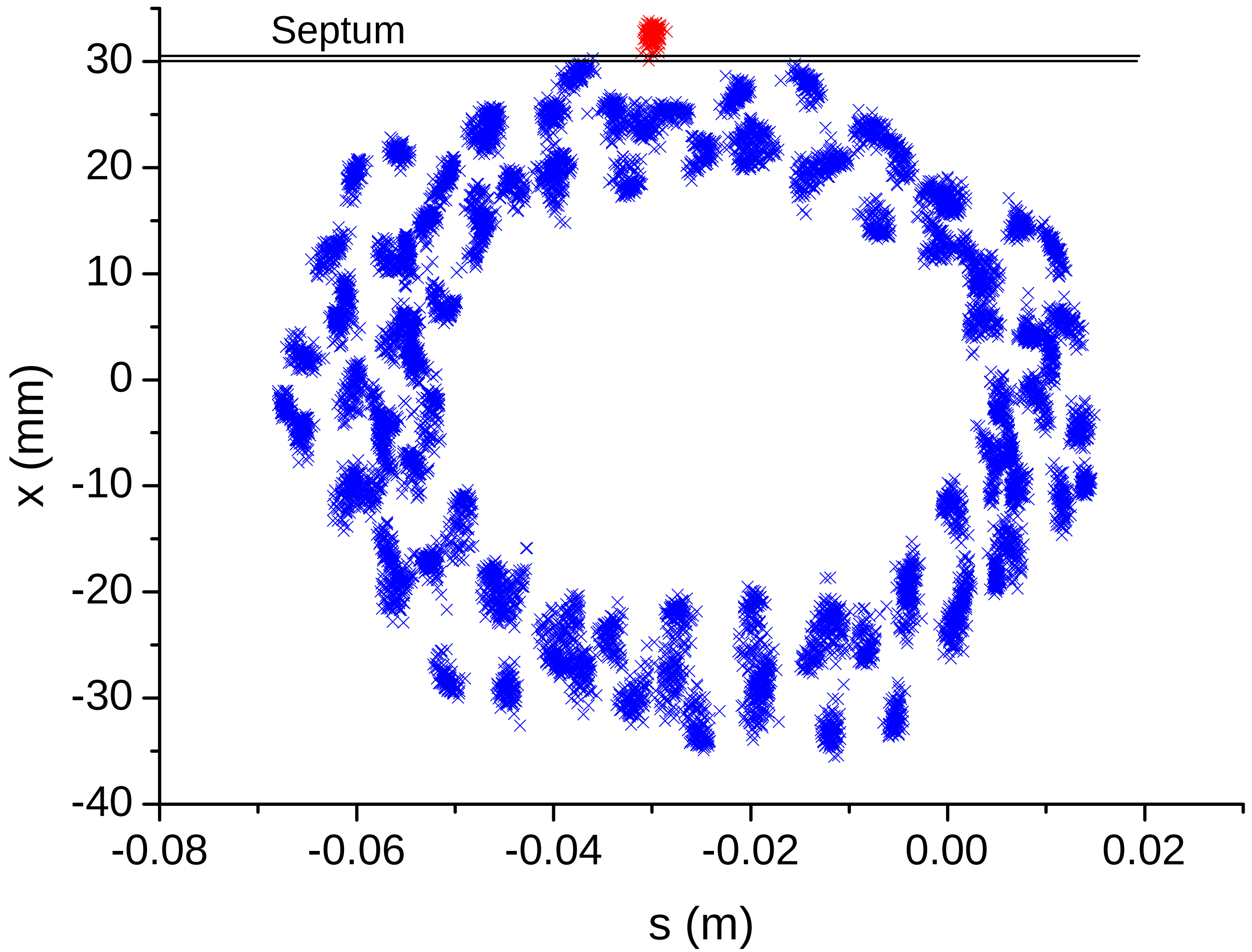
Injection simulation. Numbers near bunch position indicate turn number (0 labels injected bunch)

Simulation parameters&results:

Injected particles number 100;
Transversal beam emittance $2000*10^{-6}$ m*rad (normalized);
Energy distribution is Gaussian $\Delta p/p_0=0.2$ % > (20-15)/5000;
Septum thickness 0.5 mm;
Dispersion at injection azimuth $\eta=1$ m;
Pulse deviation of injected beam from reference $(p_{inj}-p_o)/p_o=3$ %.

Two particles are out of the dynamic aperture and are lost during the injection;
One particle of the injected bunch is lost on septum;
Two particles are lost on septum blade after the first turn;
In the sequel particles are not lost.

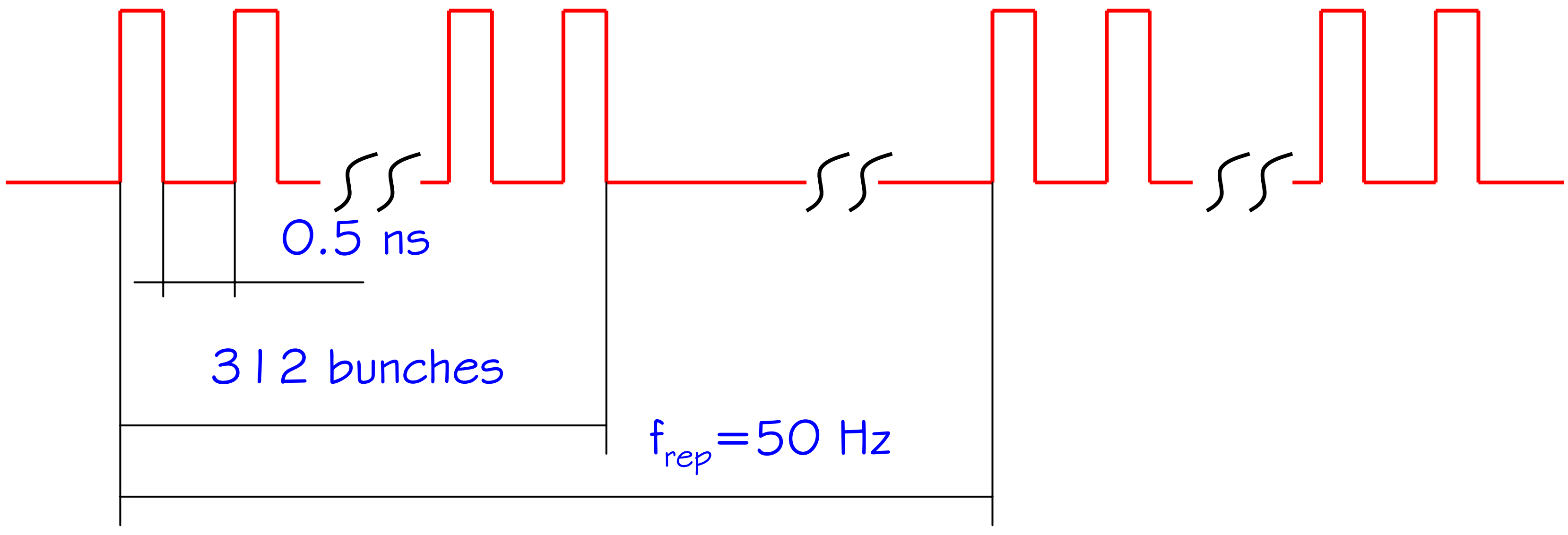
Thus, 95 particles are successfully injected, i.e. the injection efficiency is equal to 95 %.



Positions of injected bunch during
3 synchrotron cycles

Disadnantage #1

Crazy SR (RF) power

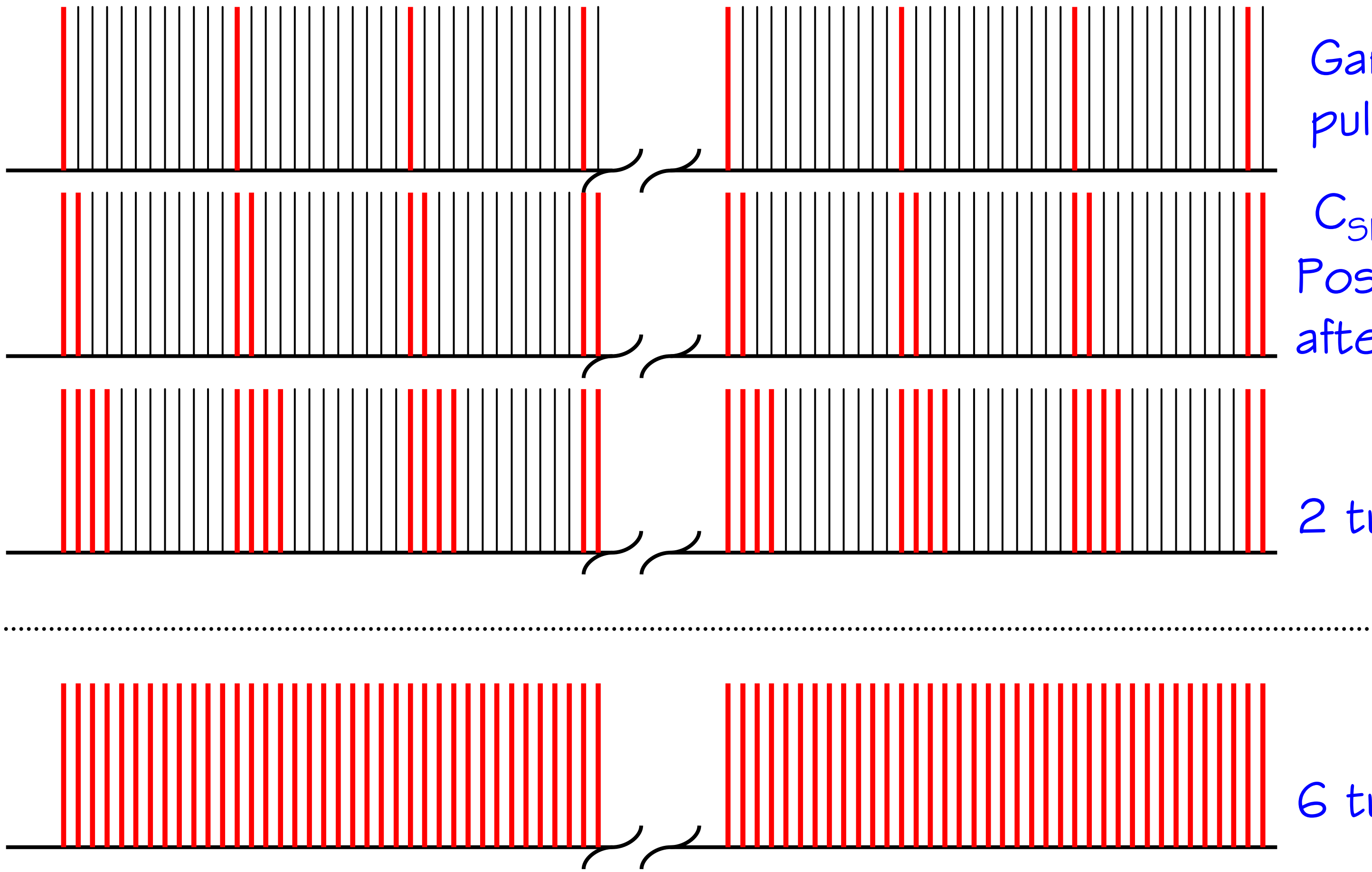


$N_{eb}=7*10^9$ => $Q_b \approx 1.125$ nC => $I_{stor}=2.25$ A,

$\Delta E=20$ MeV, $P_{SR}=45$ MW !!!

Operation mode

CR: circumference C_{CR} ~300 m, bunch spacing 6 ns ;
SR: circumference C_{SR} ~ 150 m, bunch spacing 0.5 ns, bunch number N_b ~ 960;



Gamma-beam pulses from CR

$C_{SR}=C_{CR}/2-\lambda_{RF}$
Pos.beam in SR after 1 turn in CR

2 turns in CR

6 turns in CR

Operation mode

TDT: C_{TDT} ~ 50 m, bunch number N_b ~ 320, bunch spacing 0.5 ns.

CR: repetition rate f_{rep}=2.5 kHz (T_{rep}=400 μs => 400 turns =
100 turns (gamma generation) + 300 turns (beam damping);
SR: 200 turns (positron injection) + 600 turns (beam damping),
after that quick positron beam extraction (3 turns in TDT) to TDT and
just after that to pre-damping ring from TDT.

As a result: stored current in SR 2.25 A/150=15 mA=>P_{SR}=300 kW

At positron energy E_0 ~ 3.5 GeV P_{SR} ~ 200 kW, but larger
beam emittance, larger required DA. Pulse deviation ~ 3.5-4 %

Disadvantage #2

Large loss power.

$I_{e+} = 15\ \mu A$, $k = 90\ \%$ => $P_{loss} = 8\ kW$

Disadvantage #3

Large RF voltage $V_{rf} = 50\ MV$

Disadvantage #4

Superconductive linac with positron energy $E_0 = 5\ GeV$

Main parameters of stacking ring

Parameter	Value
Positron energy, GeV	5
Ring circumference, m	125.012
Bending field, T	6
RF frequency, GHz	2
RF voltage, MV	50
Harmonics number	834
Bunch spacing, ns	0.5
Beam energy losses, Mev/turn	19.8
Synchrotron damping time, μs	104
Normalized emittance of injected beam, m*rad	$2000*10^{-6}$
Dispersion at injection azimuth, m	1
Pulse deviation of injected beam, %	3
Injection efficiency, %	>90

Summary

Stacking ring with the superconductive bendings for the continuous positron injection is proposed .

The injection efficiency into proposed stacking ring is greater than 90 %

The proposed ring can be used as the base for the further R&D