Simulation studies for ILC and SKEKB E-Driven positron source

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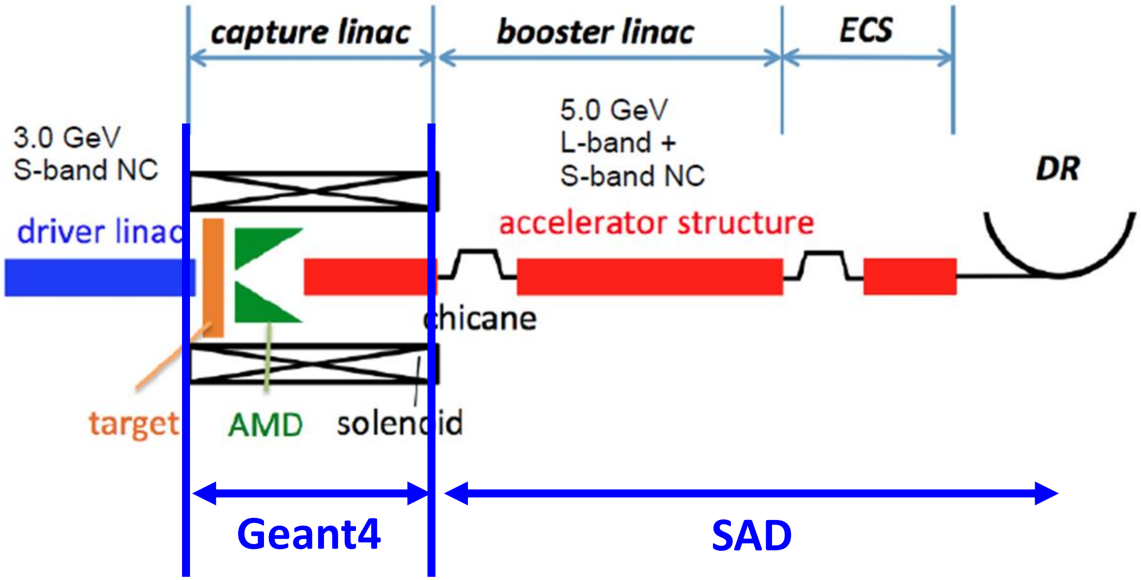
Simulation of ILC positron source for E-driven scheme

Estimations of the yield and the beam loss of the ILC positron source performed by the simulation with Geant4 and SAD.



ILC-TDR

The simulation in the capture linac is performed by the program with Geant4.
The simulation program with Geant4 is my own code. I need check it.

Contents

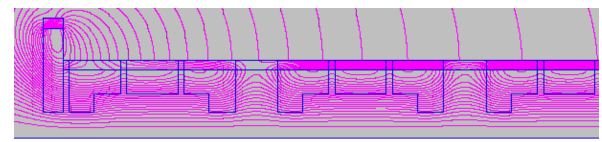
- Comparison with previous simulation by GPT
- Comparison with experimental data in SuperKEKB positron source
- Yield and beam loss for ILC E-driven positron source

Parameters of ILC positron source simulation in capture section

Input ：3GeV e- beam, Ne- $1\text{x}10^4$, σx,y = 2mm on target, σz = 1mm

Target：W26Re, 16mm

Magnetic field: Flux concentrator (Peak 5.0T) +DC solenoid(capture section)



Accelerating tube : 1.3m L-band SW (1300MHz)

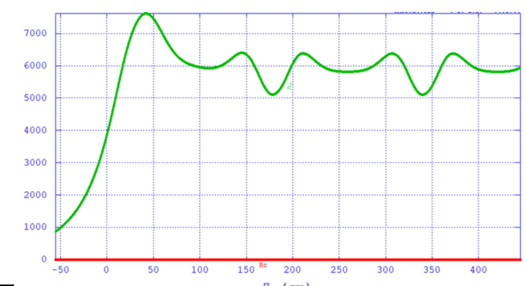
Electric field: 6-11MV/m

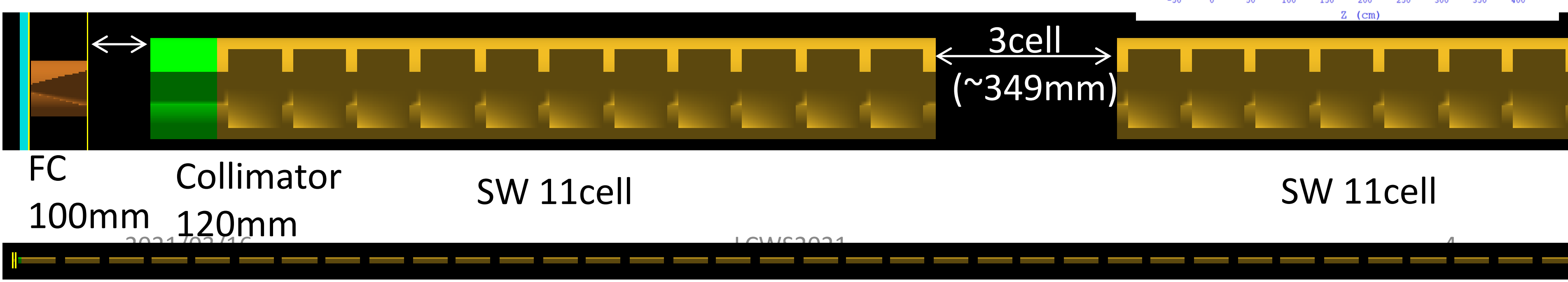
Ez = E0*J0(p01*r/a)*sin(omegatime*t+cavPhase)

Bϕ = E0*J1(p01*r/a)*cos(omegatime*t+cavPhase)/c_light

(Pillbox)

Positron beam is accelerated by 36 accelerating tubes.





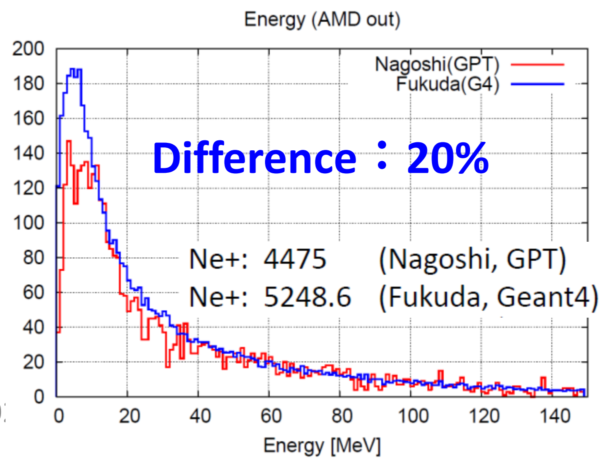
Comparison with previous simulation result

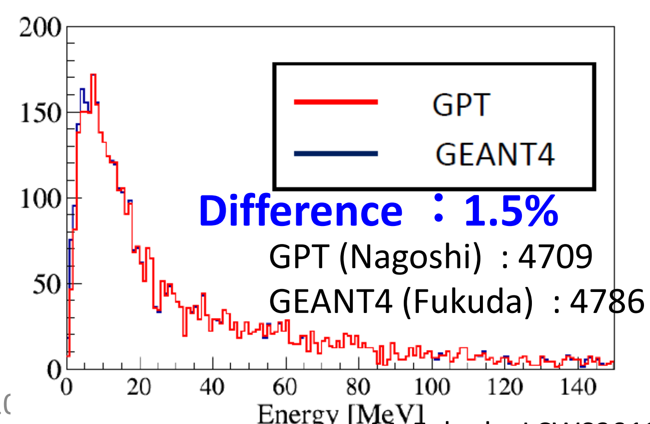
Nagoshi-san simulated the ILC positron beam line to estimate the positron yield by General Particle Tracer (GPT). Firstly, I could not reproduce his result.
The difference is caused by as follow effects:

- Positrons are also generated at the FC by gamma-rays from the target.
- Positrons are scattered at the surface of the FC. A part of them is captured.

The GPT does not include above effects. After removing these effects from my program, I could reproduce the previous simulation result.

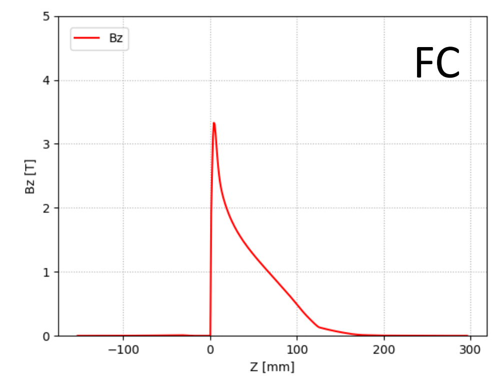
Energy distribution and Number of positrons at FC exit



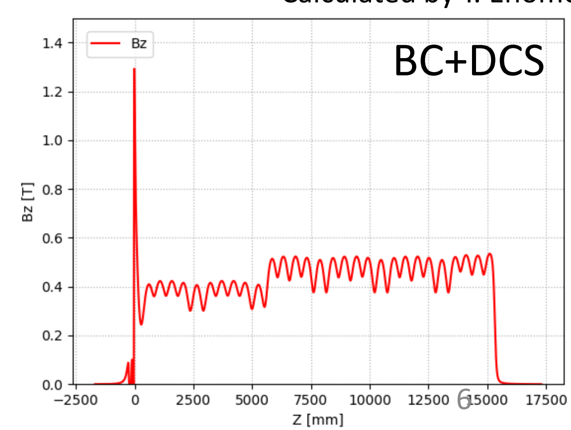


Parameters of SKEKB positron source simulation in capture section

- Target:
  Tungsten, thickness: 14mm ($4X_0$)
- Primary electron beam:
  3.5GeV, $\sigma_{e\text{-beam}}$ on target: 0.5mm x 0.8mm, Ne-: 10000
- Flux concentrator:
  Length 100mm, Inner diameter：7.0mm -- 52.0mm,
  xoffset 2mm
- Distance:
  Target – FC: 2mm, FC – ACC1: 127.6 mm
- Magnetic fields of FC and DC solenoid:
  FC: 3.67 [T], Bridge coil: 1.3 [T], DC Solenoid: 0.4 – 0.5 [T]
  Field data are calculated by CST Studio.
- Electric field of TW accelerating tube (2856MHz(S-band))
  - Length 2m
  - ACC1-ACC2: 7.3MV/m, ACC3-ACC6: 11.0 MV/m
  - **Ez = E0*sin(k(z-z0) - ωt - ϕ)**, $k = 2\pi/\lambda$, $\omega=2\pi c/\lambda$



Calculated by Y. Enomoto

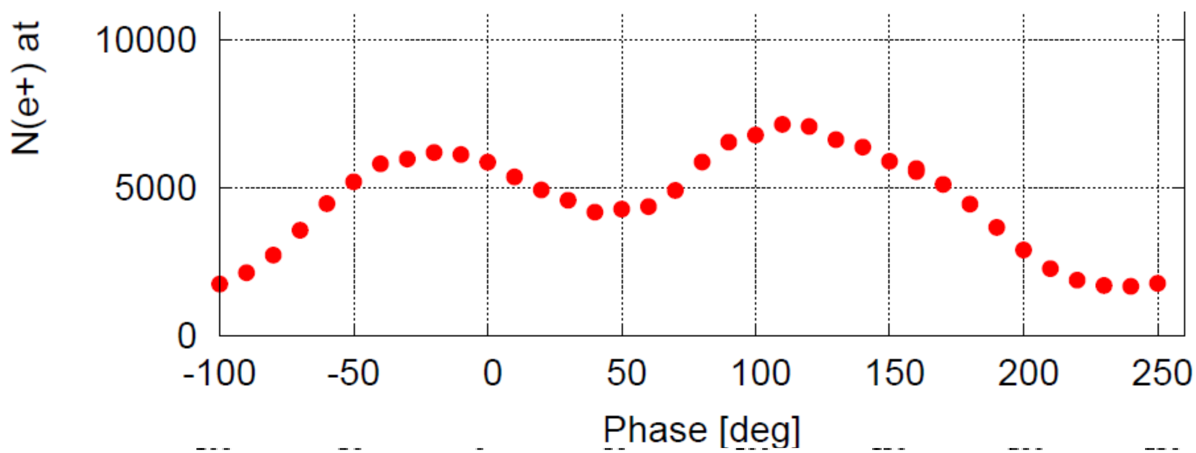


Calculated by Y. Enomoto

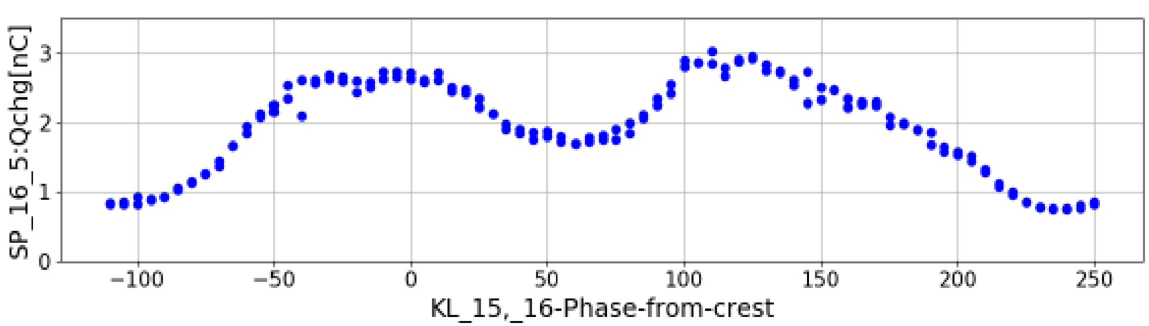
Comparison between measurement and simulation

- The simulation is in good agreement with the measurement in the RF phase scan.

RF Phase scan



Simulation

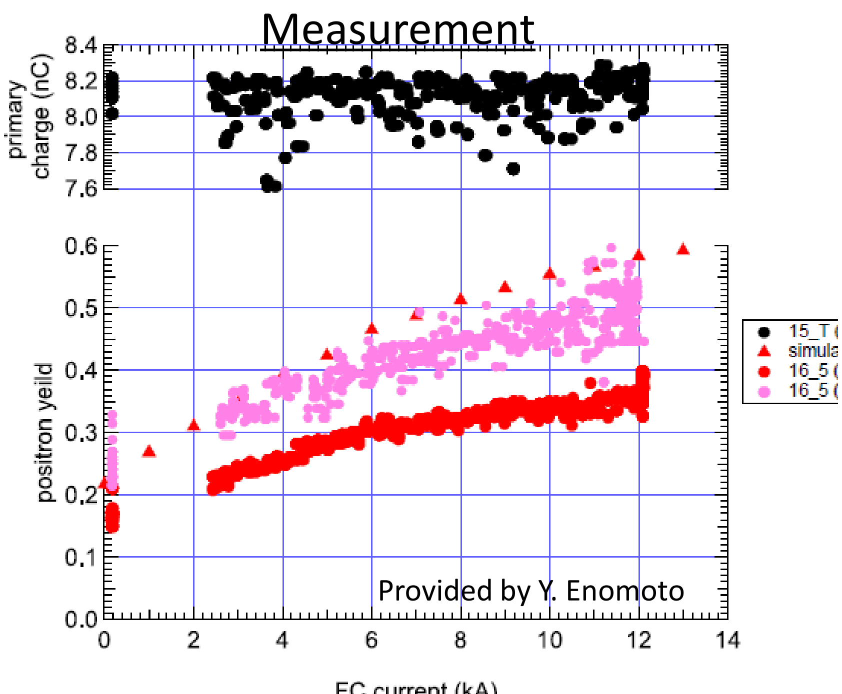


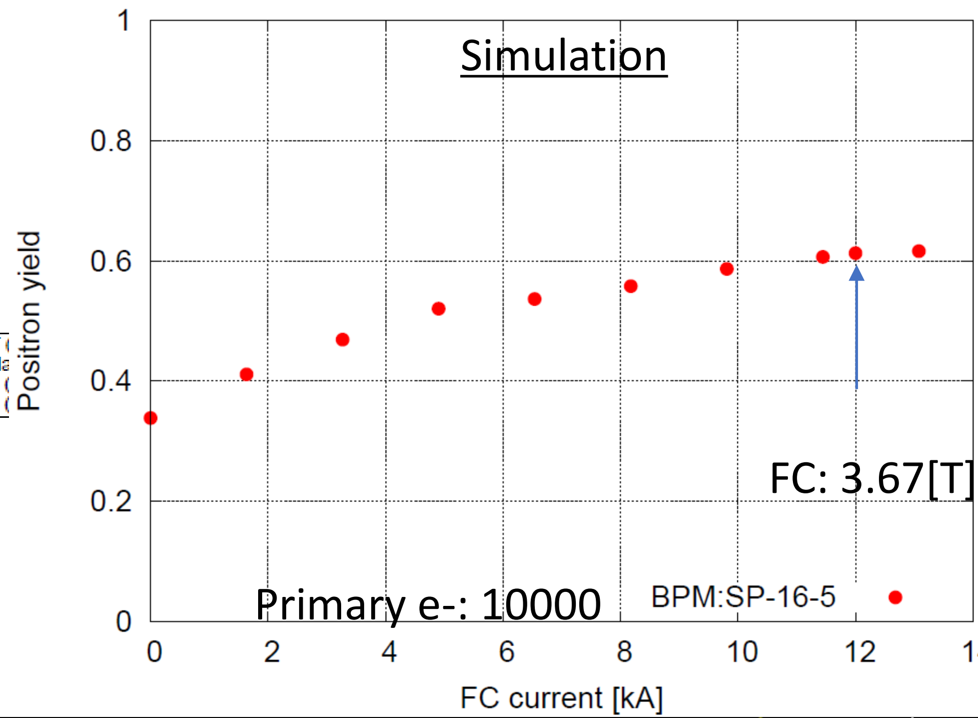
Measurement

Comparison between measurement and simulation

The simulation can almost reproduce the experimental result. The difference is about 20%.
Simulation parameters is set to the parameters of the experiment in 2020. Oct

Magnetic field strength scan of the flux concentrator

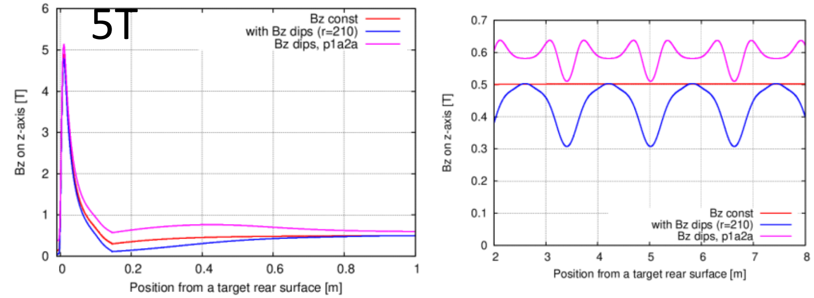


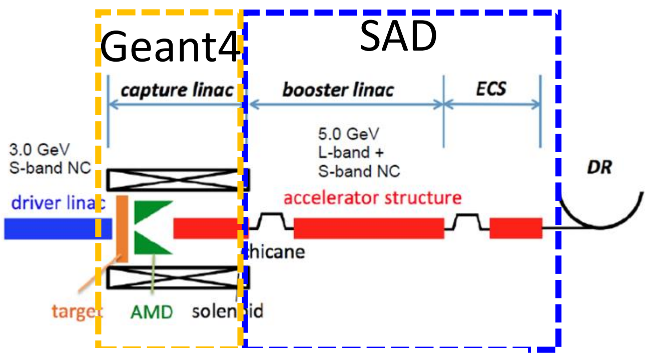


Parameters of simulation for ILC e-driven positron source

capture linac
Target: WRe 16mm
Magnetic field: FC: 5.0T, DC Solenoid: 0.5-0.6T
Accelerating field:
$E_z = E_0 \sin(\omega t + \phi)$ (6-11MV/m)

Solenoid field





Booster linac

Lattice config.	N. of cells	Acc. energy	Energy at the exit	cell length	section length
4Q + 1L	14	243 MeV	493 MeV	3.8 m	53.2 m
4Q + 2L	29	1009 MeV	1502 MeV	6.0 m	174 m
4Q + 4L	18	1252 MeV	2754 MeV	10.4 m	187.2 m
4Q + 4S	26	2345 MeV	5099 MeV	10.4 m	270.4 m

ECS: R56: 1.2m, R65: -0.8m

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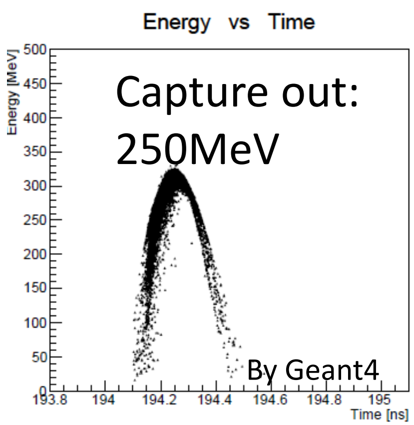
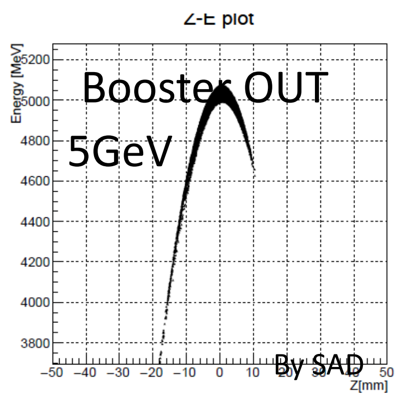
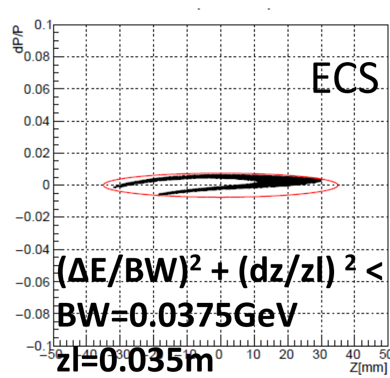
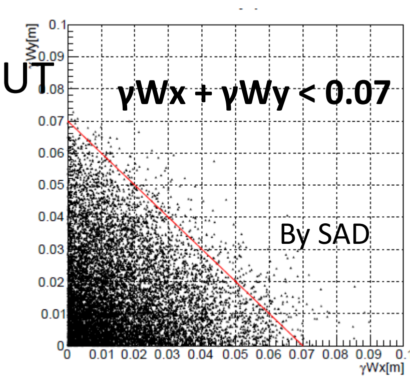




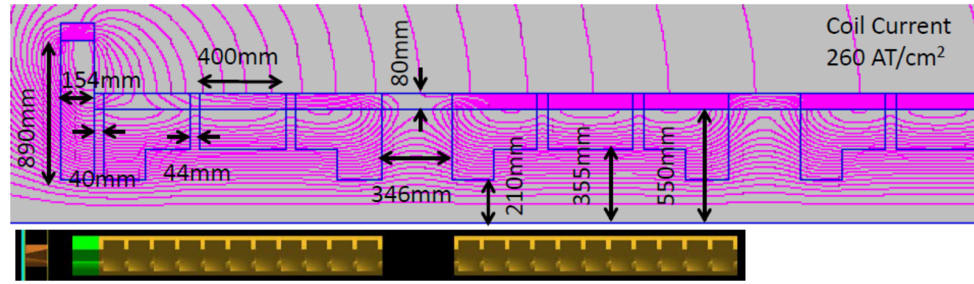


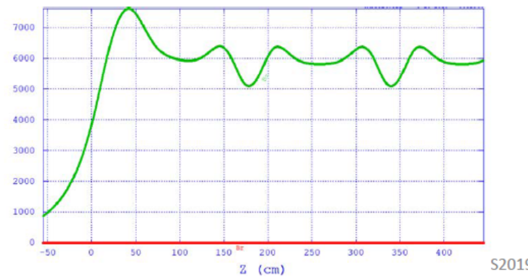


Positron yield

To get higher yield, parameters are optimized.
(RF phase, Solenoid field, distance of target to FC and so on)

Yield(Ne+/Ne-): 1.25
Capture phase: 10deg





current density of coil: 260A/cm2
Coil length: 400mm
Space between coils: 44mm
Yoke thickness: 40mm

Coil shape of both end of accelerating tubes are modified to reduce the drop of the magnetic field at intervals of tubes.

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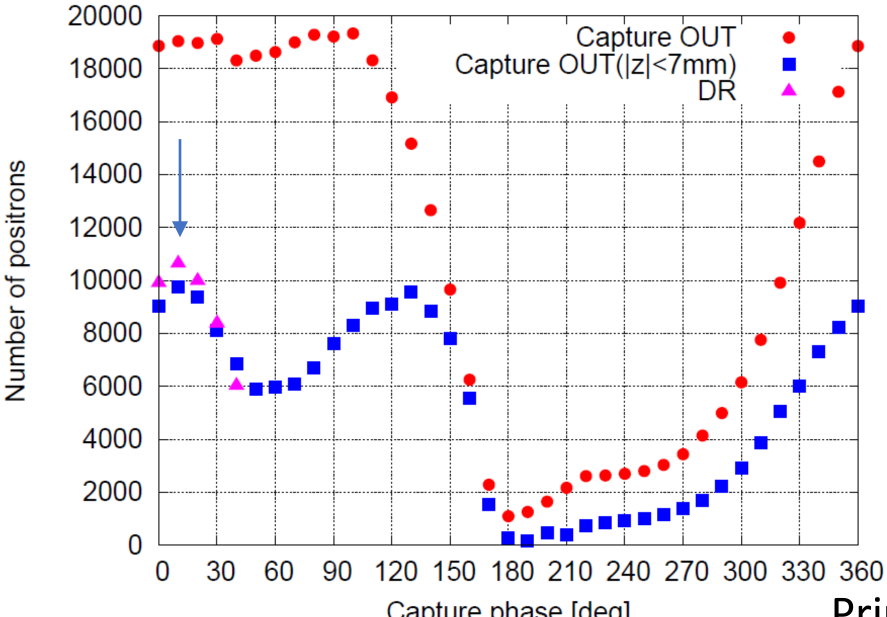
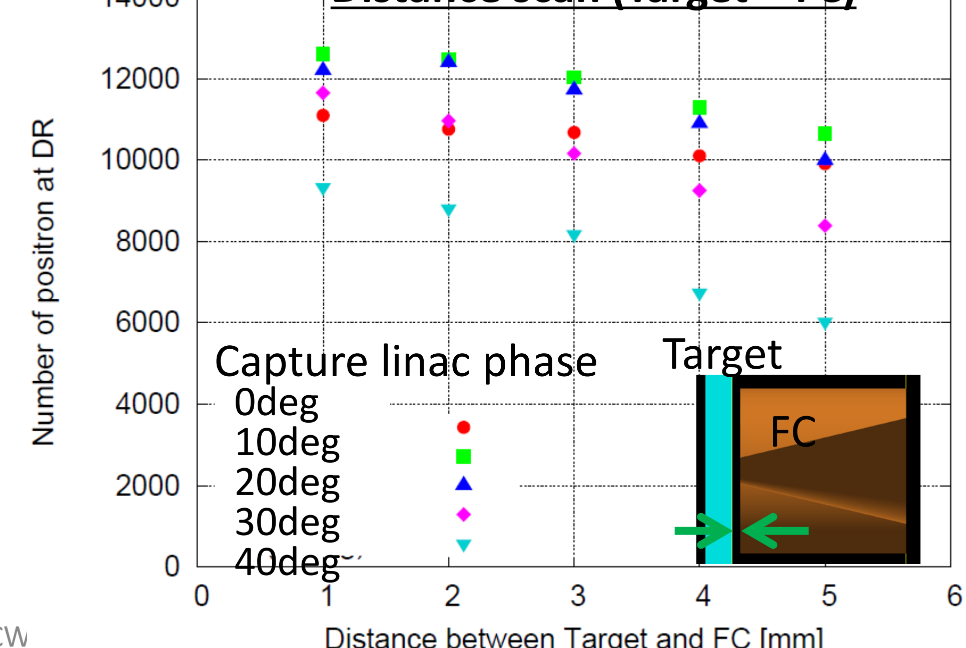
Phase scan



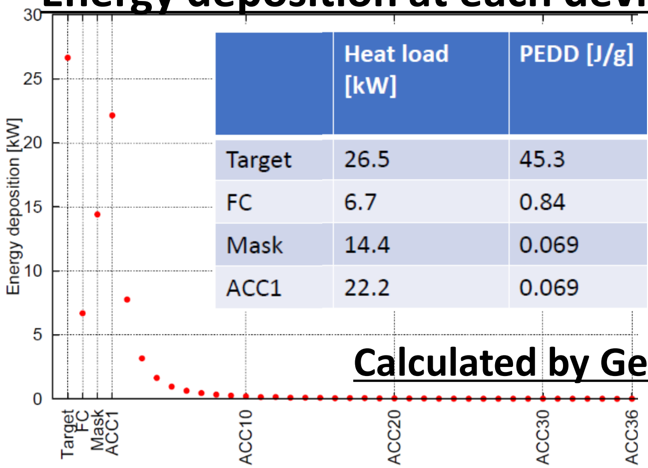
Distance scan (Target – FC)



Primary e-: 10000

Beam loss calculation

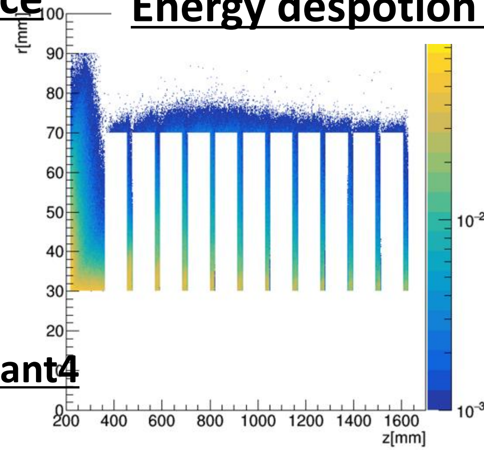
Energy deposition at each device

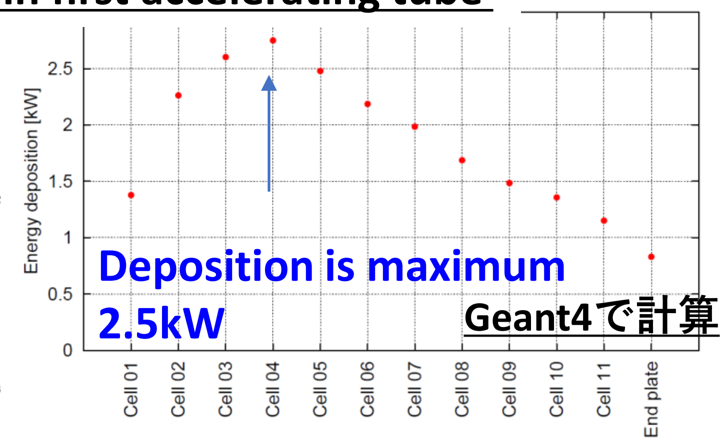


	Heat load [kW]	PEDD [J/g]
Target	26.5	45.3
FC	6.7	0.84
Mask	14.4	0.069
ACC1	22.2	0.069

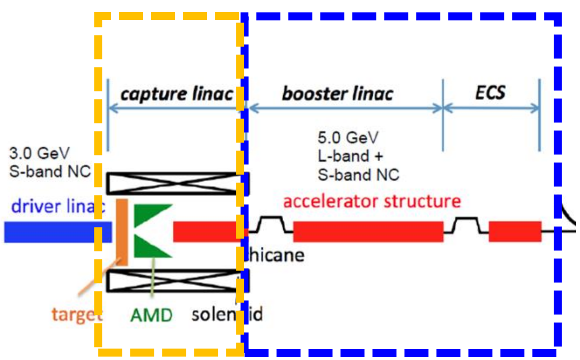
Calculated by Geant4

Energy despotion in first accelerating tube



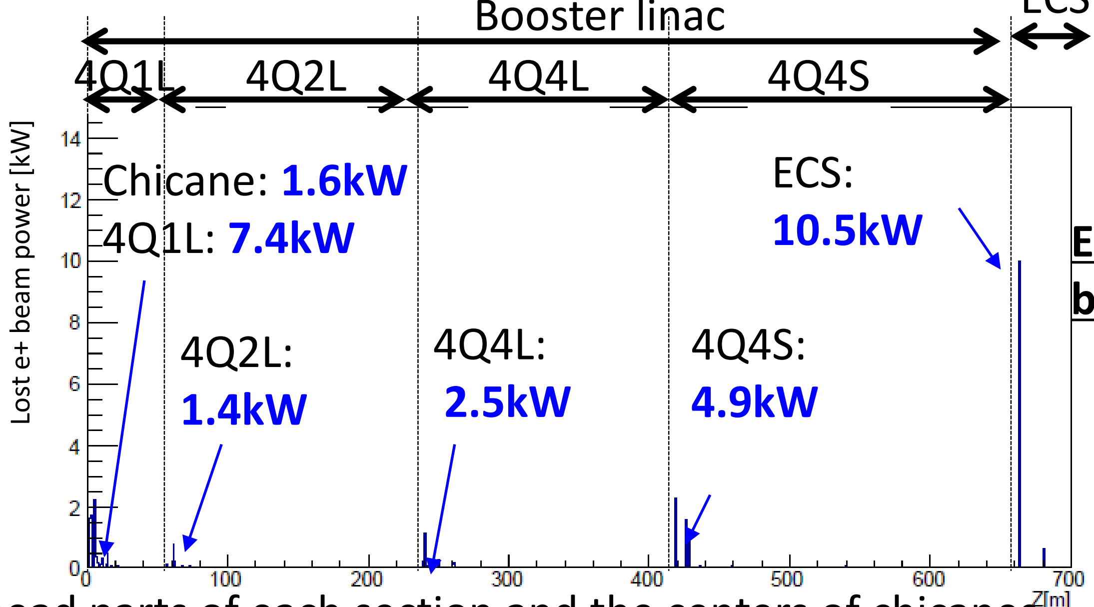


Geant4 SAD



Primary e- beam :
3GeV, 4.8nC/bunch,
1320x5 bunches/sec

Beam loss in Booster linac and ECS



Beam losses occur the head parts of each section and the centers of chicanes.

Summary

- Estimations of the yield and the beam loss of the ILC positron source are performed by simulations with Geant4 and SAD.
- The simulation program with Geant4 is my own code. To check this code, I made the following two comparisons.
  - Comparison with previous simulation in the ILC positron source.
    - I could reproduce the result of Nagoshi-san' simulation within the difference of 1.5%.
  - Comparison with the experimental result of SuperKEKB positron source
    - The simulation is in good agreement with the experimental result in the RF phase scan and FC magnetic field scan.
    - The difference of yield in FC field scan is about 20%.
- Simulation result of ILC positron source
  - Positron yield at DR is 1.25 after the optimization.
  - Beam loss on the ILC positron beam line is also estimated by simulation
    - Beam losse at the ECS chicane is very high. That power is 10.5kW.
    - Beam losses around the entrances of L-band and S-band linac (4Q1L- 4Q4S) are also high, about 1.4-7.4kW.