A Yield calculation for E-Driven ILC Positron source

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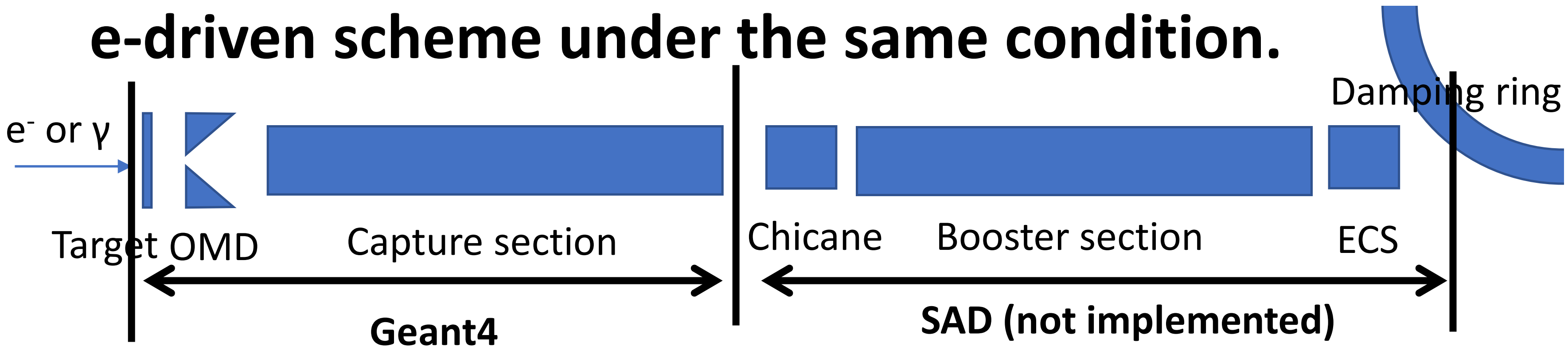
- Purpose of Development of Start-to-End Simulation for ILC positron sources
- Simulation test on the e-driven scheme using Geant4
- Comparison of simulation results

The purpose of development of simulation for ILC positron source

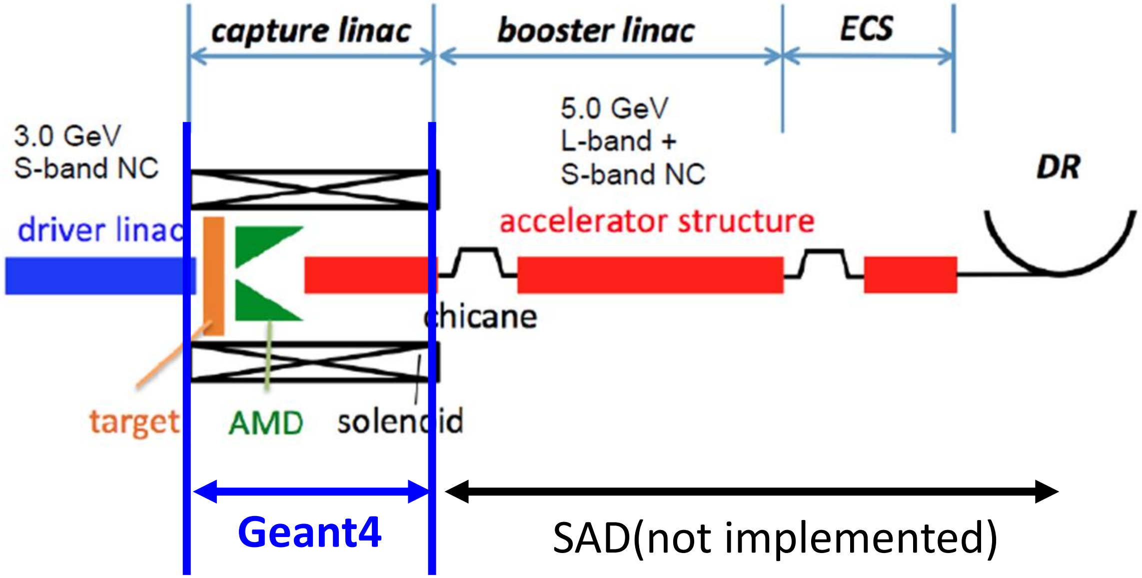
- I am developing start-to-end simulation programs for ILC positron source.
- **The purpose is to compare the yield calculation of positron generation for both undulator scheme and e-driven scheme under the same condition.**



- The positron generation and the tracking up to the capture section end is testing by using Geant4 now.

Simulation of ILC positron source for E-driven scheme

The tracking of positrons up to the exit of Capture section (250MeV) can be simulated now.



ILC-TDR

Kuriki-san and Nagoshi-san have continued the simulation of E-driven ILC positron source all the time. In their simulation,

Positron generation at a target: Geant4

Tracking : Target --- Capture section end(250MeV): General Particle Tracer (GPT)

Tracking: Capture section end --- DR entrance: Strategic Accelerator Design (SAD)

For checking, I would like to compare my calculation result with their calculation result in the end of my talk.

Placement of each components

This placement is almost the same as that of Nagoshi-san's GPT simulation.

Target --- AMD: 5mm

AMD --- Collimator: 114mm

SW tube 1268mm, R: 30mm, Endplate 10mm at both ends

Mask 120mm, R: 30mm

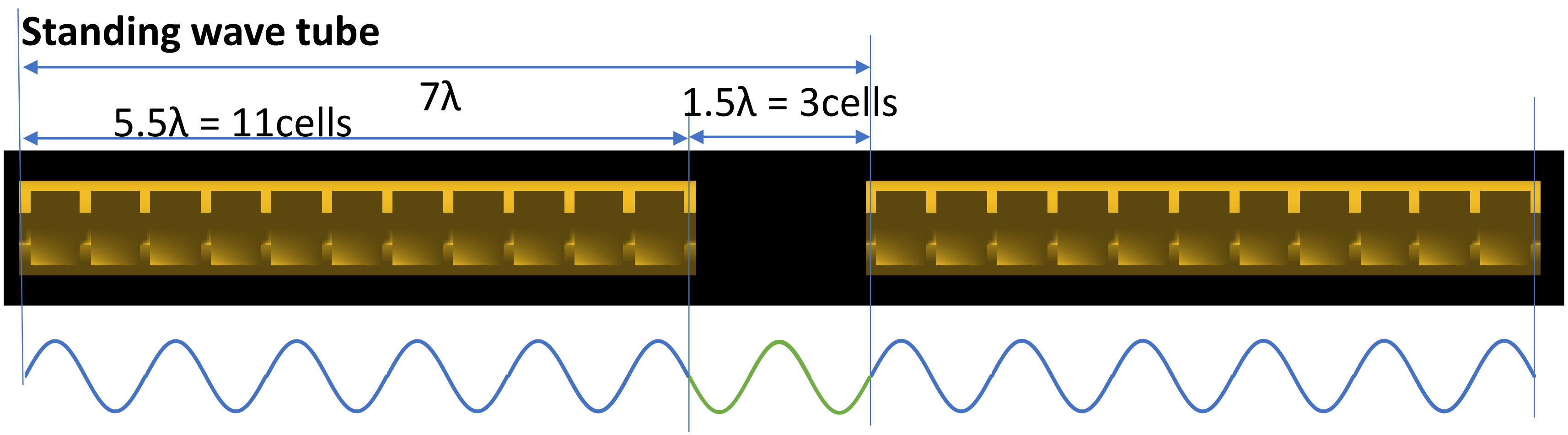
AMD100mm, R_{min}: 8mm, R_{max}: 32mm

Target W26Re 16mm

Total 36 tubes

Arrangement of acceleration tube

I adjusted the gap of accelerating tubes so that particles are accelerated with the same phase in each accelerating tube. To do so, the sum length of accelerating tube and the space should be an integral multiple of the wavelength.



Positron generation

Primary e- beam

Energy: 3GeV

Number of electron: $1x10^4$

Beam size on the target: 2mm (1σ)

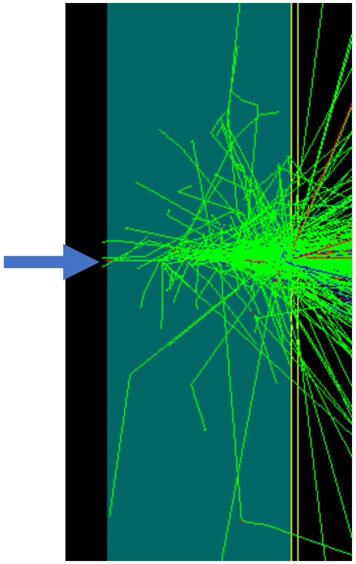
Bunch length: 1mm (1σ)

Target: **W26Re, thickness 16mm**

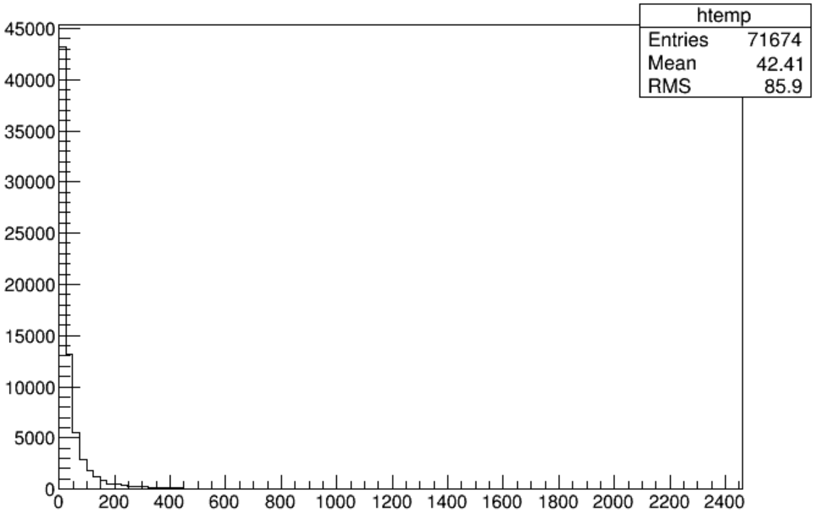
Number of generated positrons: $7.17x10^4$

Electron beam
3GeV
Ne-: $1x10^4$
$\sigma x,y$ = 2mm
σz = 1mm

W26Re 16mm



Generated positrons



Magnetic field of AMD and Solenoid

AMD (Peak 5.0T) + 0.5T (capture section)
After z = 127mm, Bz = const. (~0.5T), Br =0

where

$$B_r^a(r,z) = \sum_{\nu=1}^{\infty} \frac{(-1)^\nu}{\nu!(\nu-1)!} B_{z0}^{(2\nu-1)}(z) \left(\frac{r}{2}\right)^{2\nu-1}$$
$$= -\frac{B'_{z0}(z)}{2} r + \frac{B_{z0}^{(3)}(z)}{16} r^3 - \frac{B_{z0}^{(5)}(z)}{384} r^5 + \frac{B_{z0}^{(7)}(z)}{18432} r^7 - \frac{B_{z0}^{(9)}(z)}{1474560} r^9 + ..$$

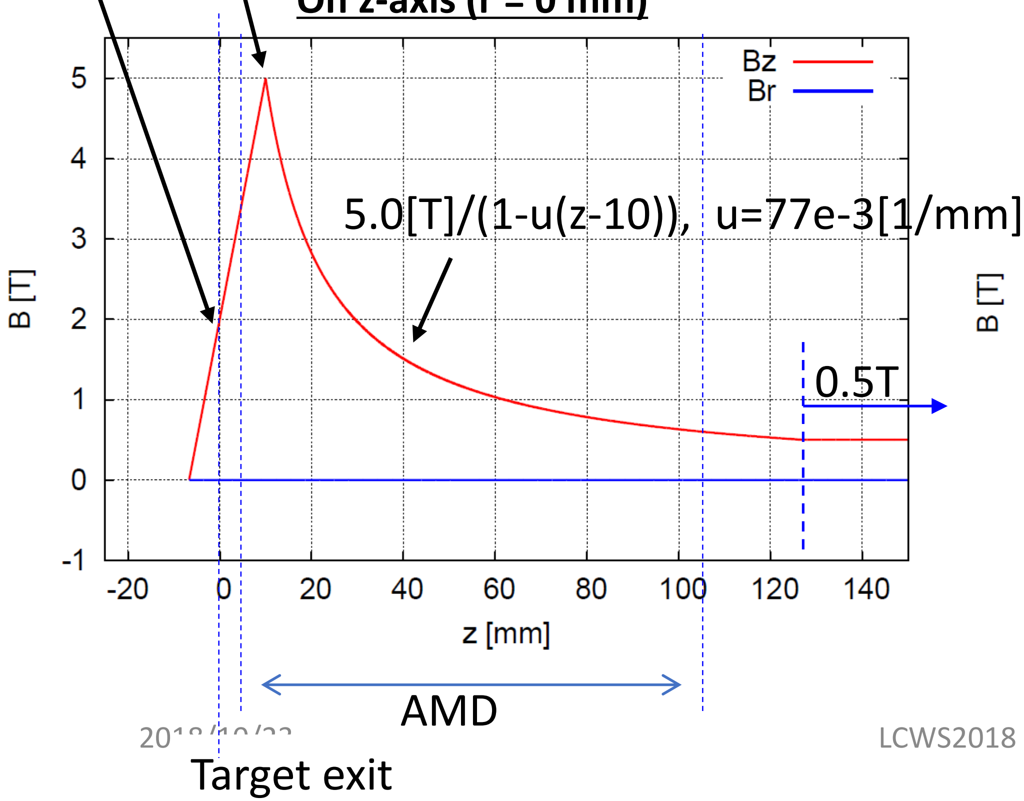
$$B_z^a(r,z) = \sum_{\nu=0}^{\infty} \frac{(-1)^\nu}{(\nu!)^2} B_{z0}^{(2\nu)}(z) \left(\frac{r}{2}\right)^{2\nu}$$
$$= B_{z0}(z) - \frac{B''_{z0}(z)}{4} r^2 + \frac{B_{z0}^{(4)}(z)}{64} r^4 - \frac{B_{z0}^{(6)}(z)}{2304} r^6 + \frac{B_{z0}^{(8)}(z)}{147456} r^8 + \ldots$$

USPAS2015, Steven M. Lund and John J. Barr

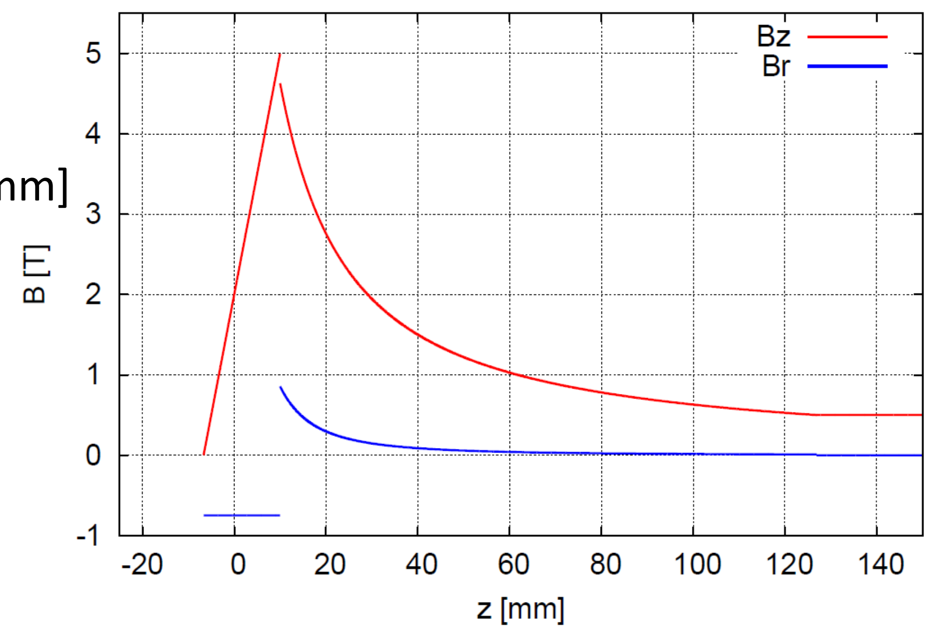
Target rear surface(z=0): 2.0[T]

z=10mm : 5.0[T]

On z-axis (r = 0 mm)

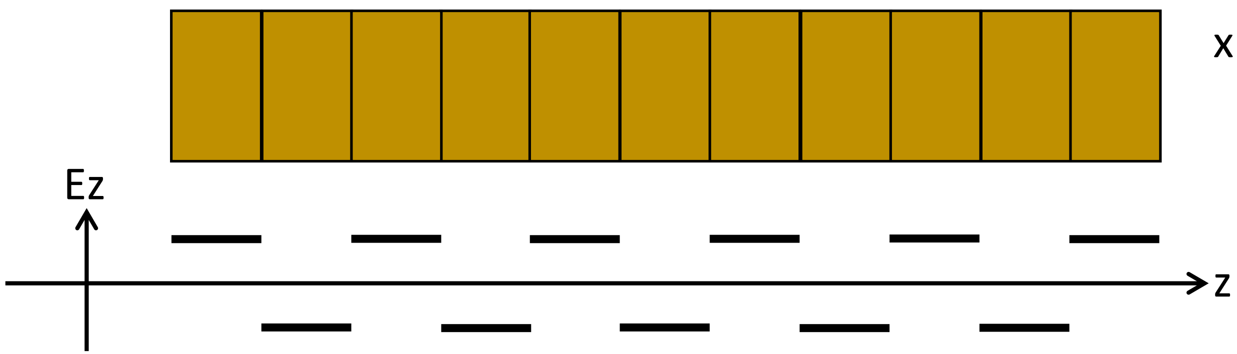


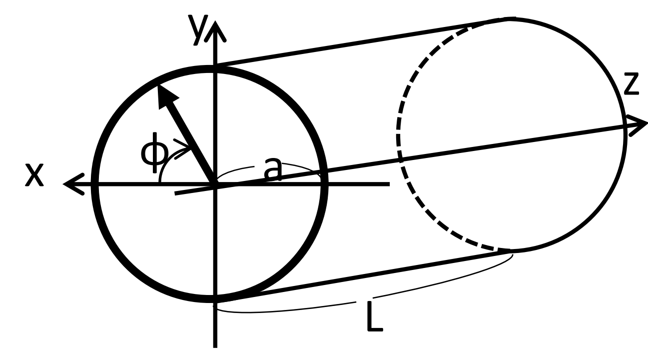
Off axis (r = 5mm)



Accelerating electric field of standing wave tube

A standing wave tube consists of 11 pillboxes(TM010).





The phase is shifted by π for each cell.

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

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

(Bx= Bphi*(-1.0*y/r) , By = Bphi*(x/r), r = sqrt(x*x+y*y))

Wave length: **λ=230.60958mm (L-band: 1.3GHz)**

Radius of cylindrical cavity: a = p01*λ/2π = 88.263mm

p01 = 2.404825557695772 (when J0(x) = 0, x = p01)

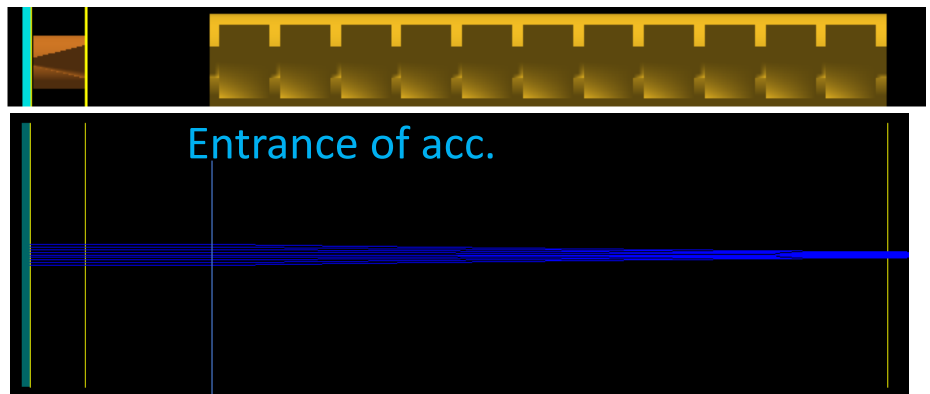
Omegaspace = 2π/λ, omegatime = 2πc/λ 、

E0 = π/2 * Eacc

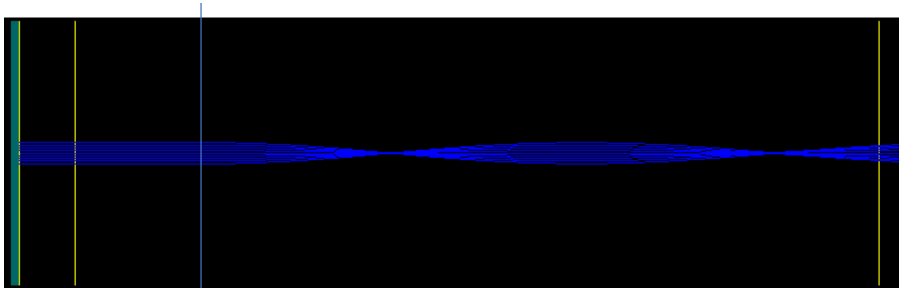
Positron acceleration in the electromagnetic field of the pill box

Input positron energy : 10MeV, Pt = 0

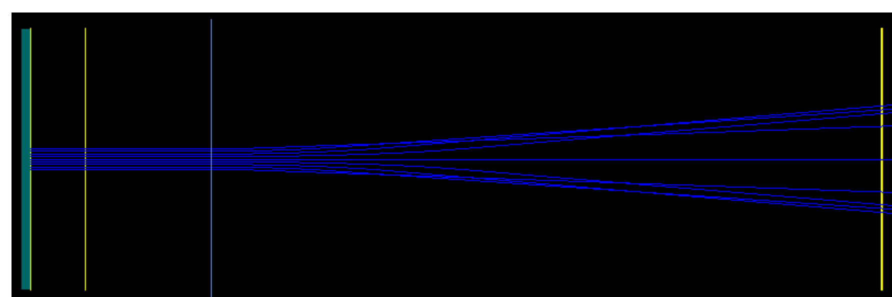
AMD and Solenoid field is zero.



Phase: 172deg (accelerating phase)



Phase from accelerating phase: -90deg (82deg)



Phase from accelerating phase: +90deg (262deg)

Parameters of the simulation up to the capture section for undulator scheme

Input ：3GeV e- beam, Ne- 1x10^4, σx,y = 2mm, σz = 1mm
Target：**W26Re, 16mm**
OMD: **AMD (Peak 5.0T) + 0.5T (capture section)**

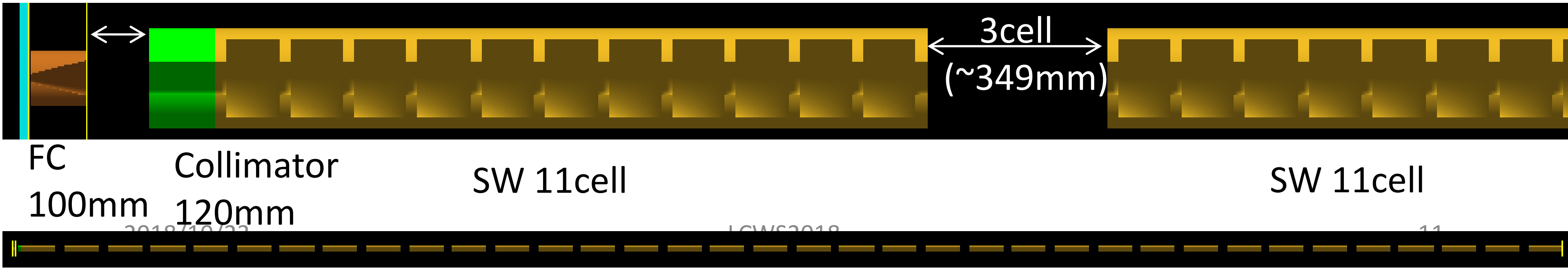
Accelerating tube : SWx36

Electro-magnetic field : <u>**Pillbox (TM010)**</u>

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

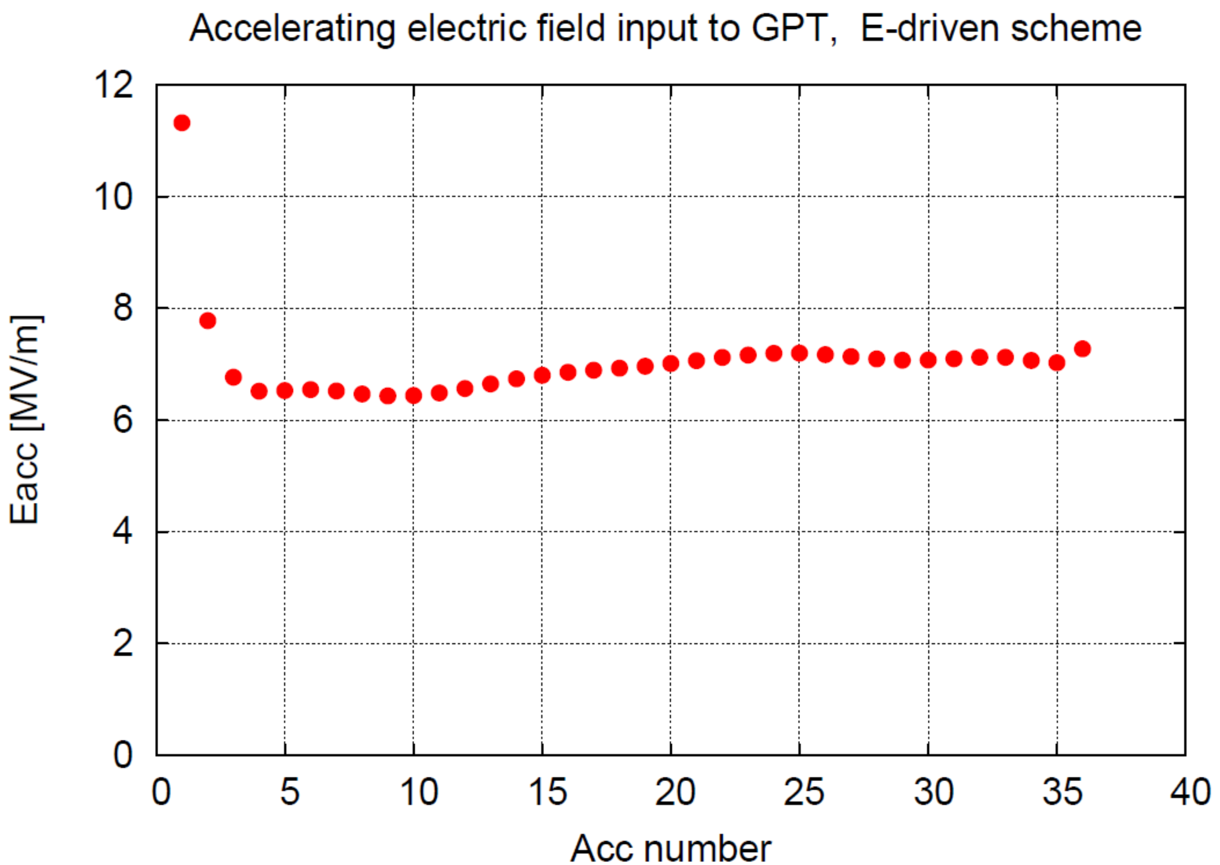
Bϕ = E0*J1(p01*r/a)*cos(omegatime*t+cavPhase)/c_light

→Positrons are accelerated to about 250MeV.



Accelerating electric field

This data of the accelerating field strength is inputted in the simulation by GPT.
The same field data is inputted in my simulation.

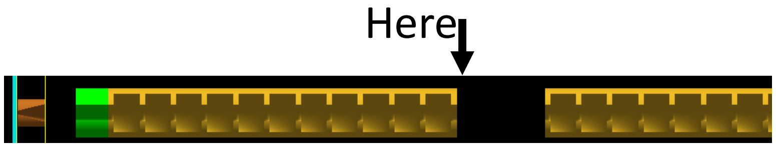


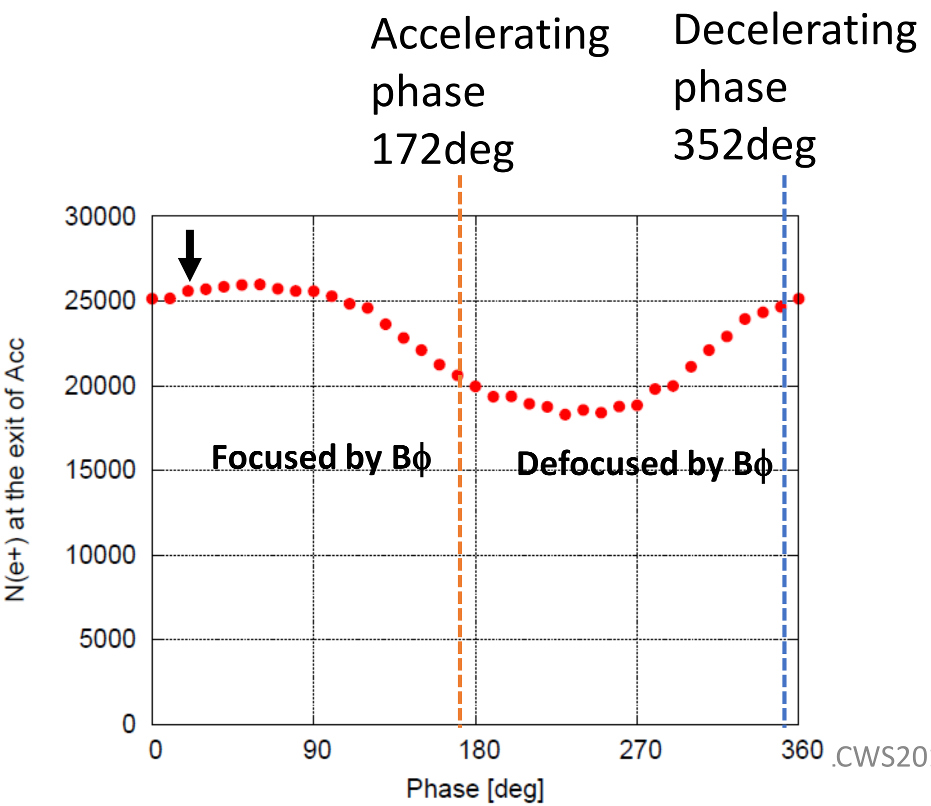
Exit of the first accelerating tube

Firstly, I tracked positrons until the exit of the first accelerating tube to compare the result calculated by GPT.

In GPT simulation, **the phase is set to +30deg from the decelerating phase.**

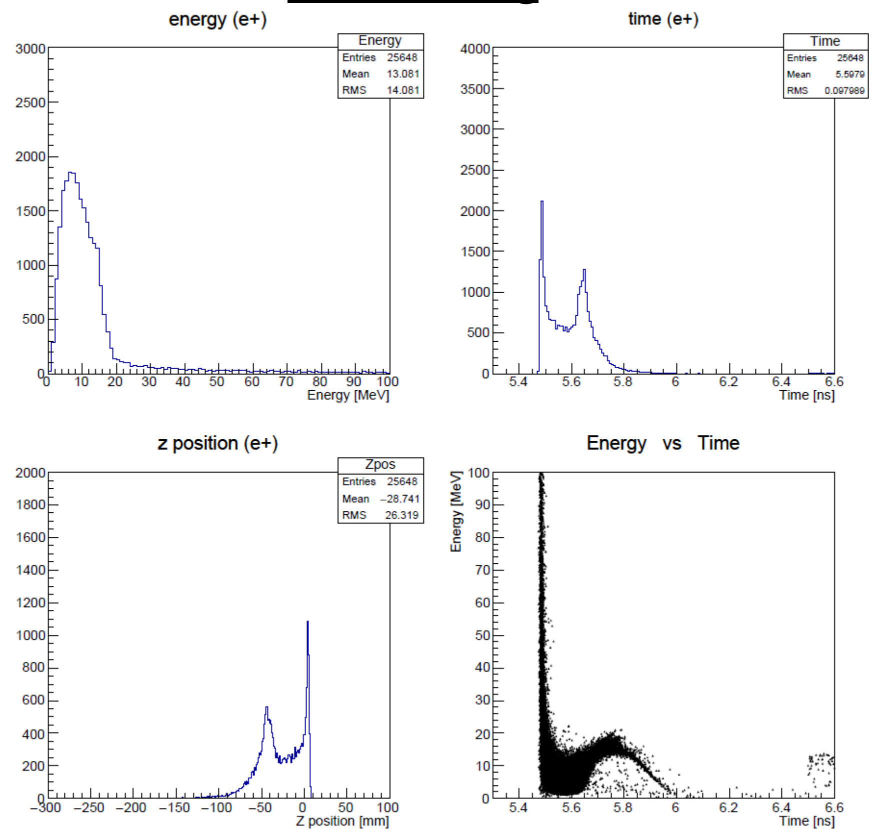
→ 20deg in this graph.





.CWS20:

Phase 20deg

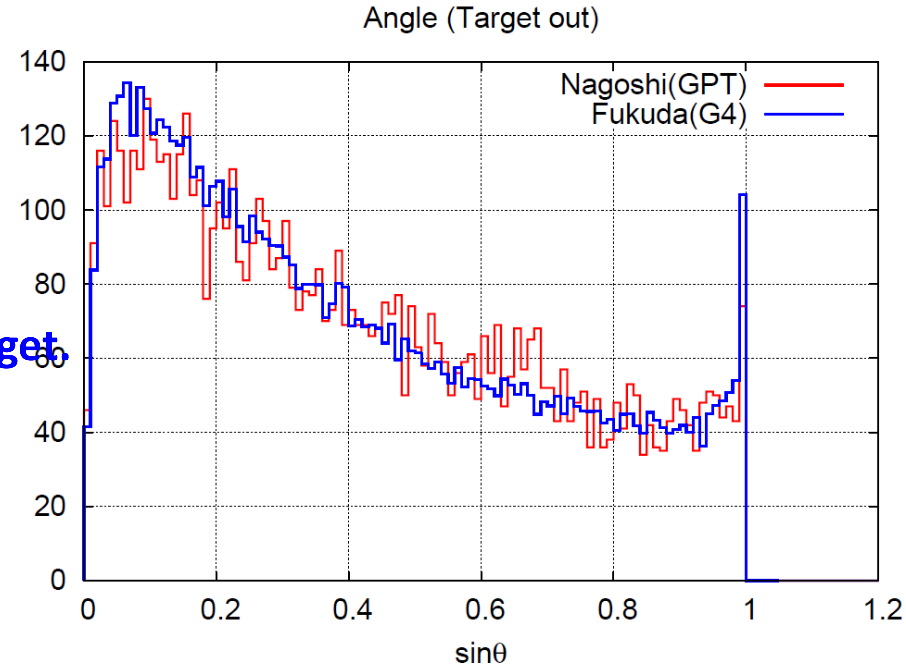


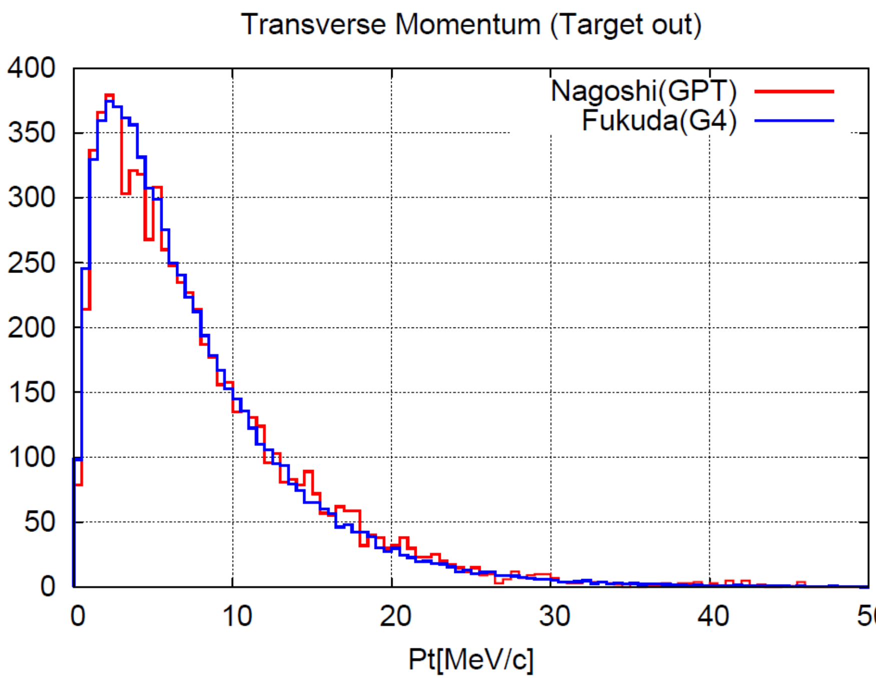
Exit of Target

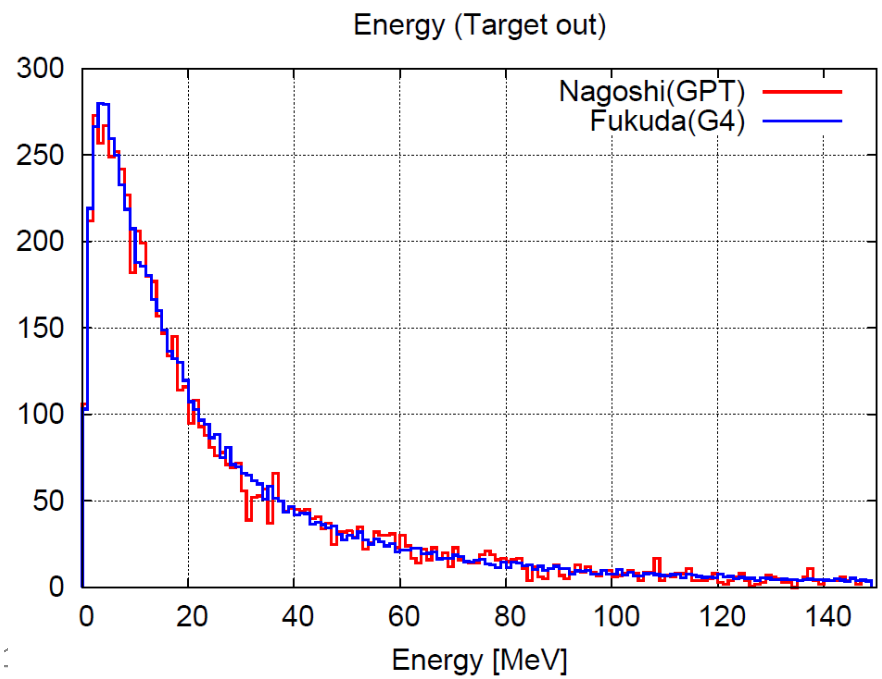
The distributions are same at the exit of a target.

Ne+: 7292 (Nagoshi, GPT, W 16mm)

Ne+: 7167 (Fukuda, Geant4, W26Re 16mm)



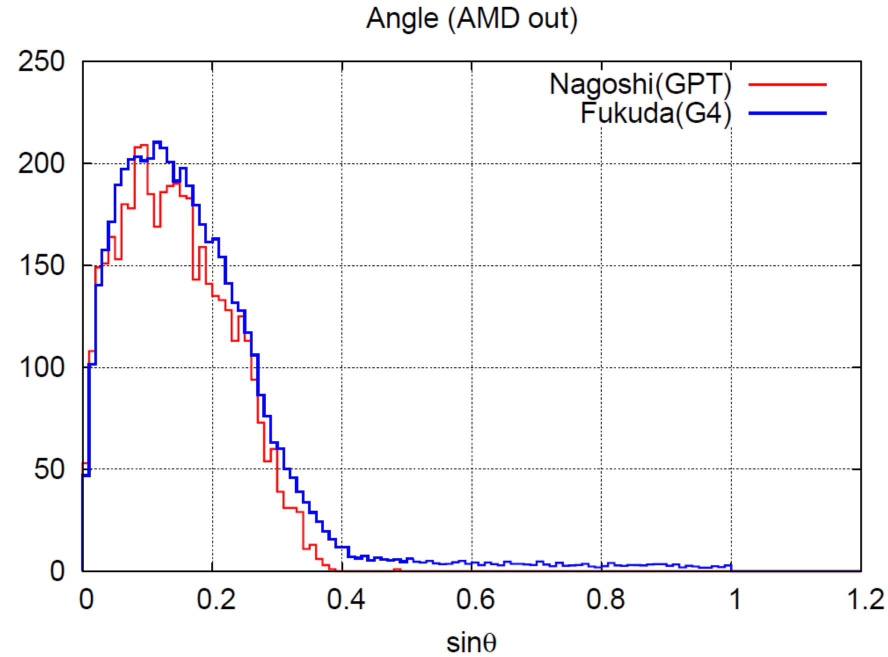


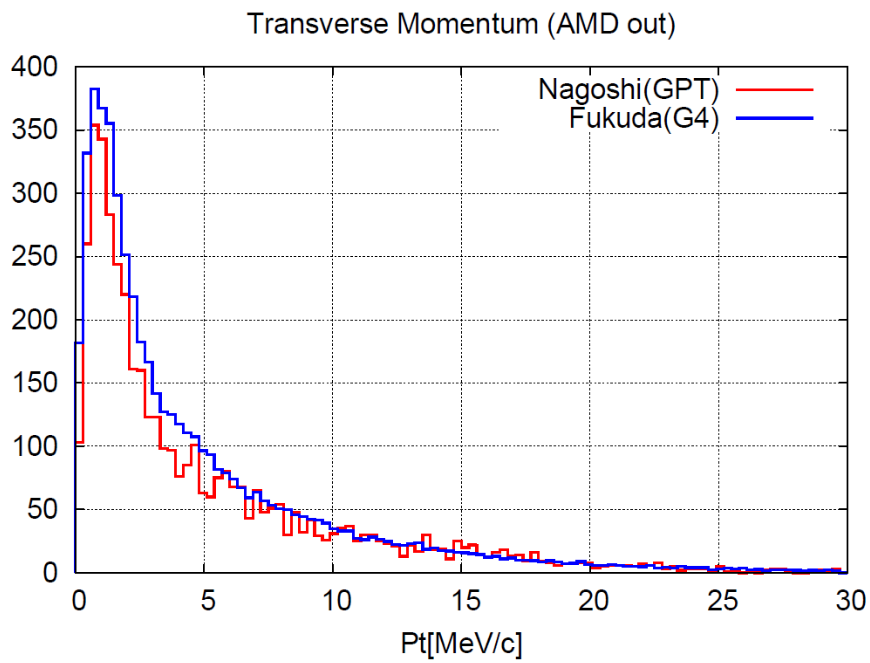


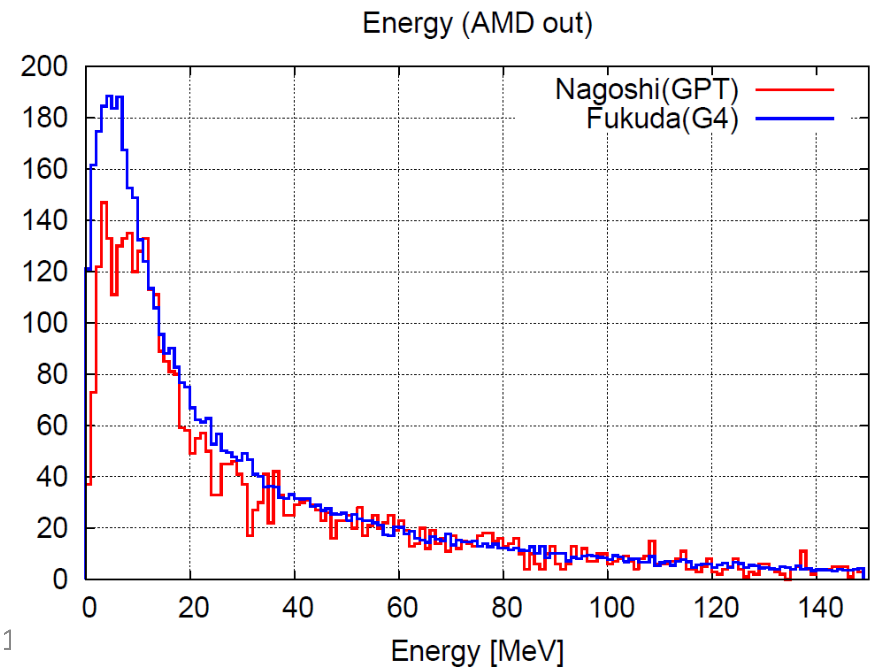
Exit of AMD

In comparison between my result
and Nagoshi-san's result,
The energy distributions is different.

Ne+: 4475 (Nagoshi, GPT)
Ne+: 5249 (Fukuda, Geant4)



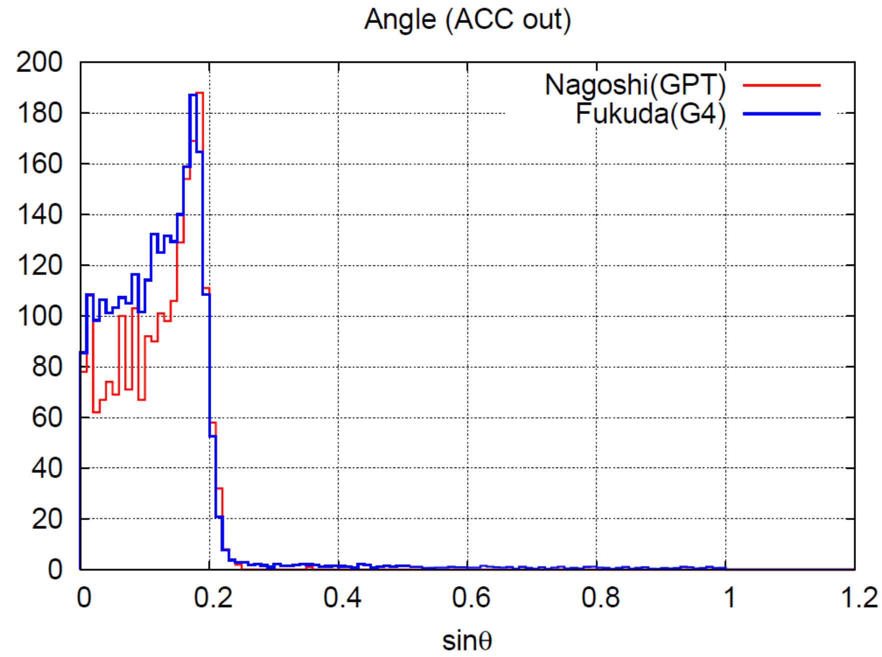


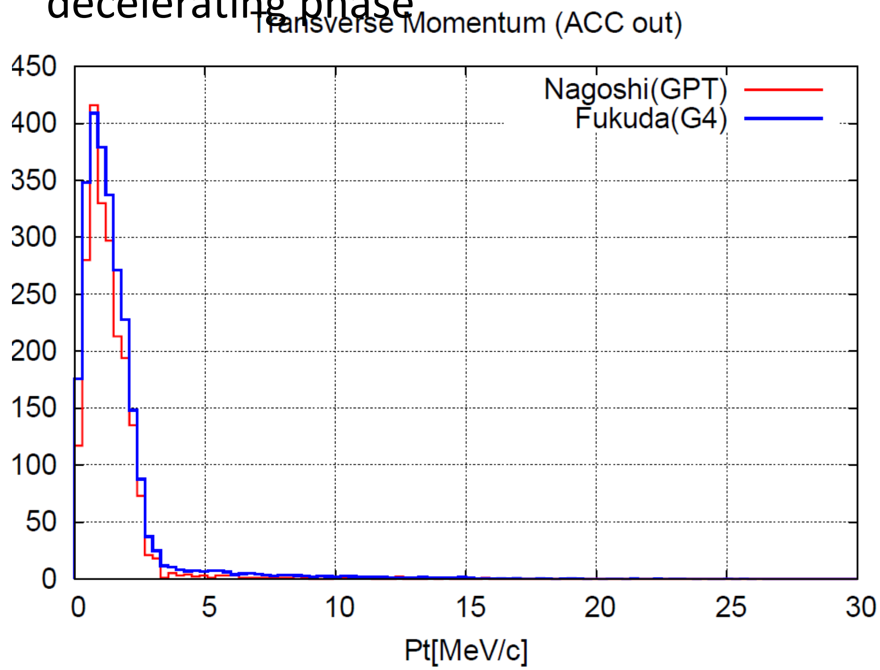


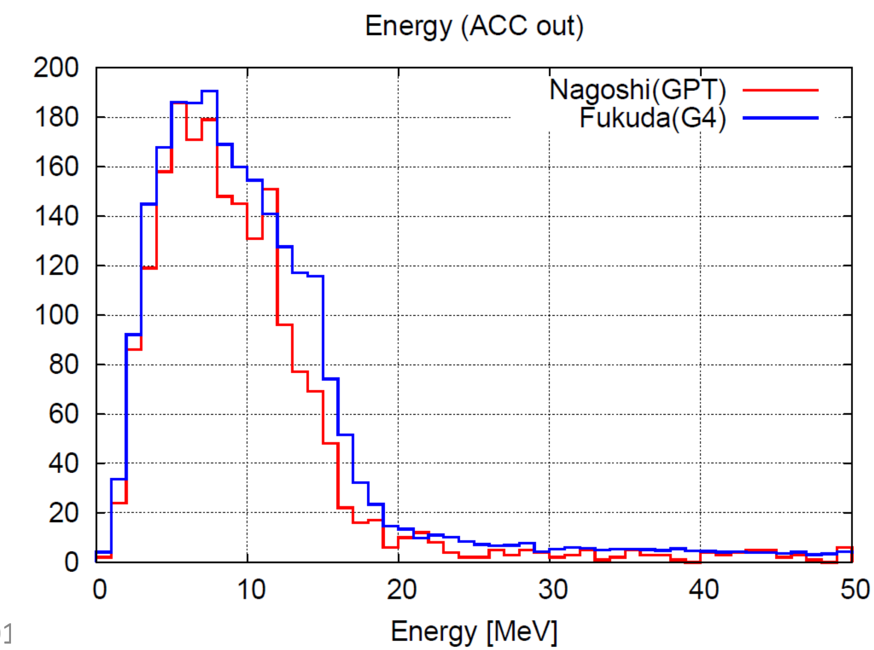
Exit of first Acc.

In comparison between my result and Nagoshi-san's result,
The angle distributions is different.

Ne+: 2142 (Nagoshi, GPT)
Ne+: 2592 (Fukuda, Geant4)
The phase is set to +30deg from the decelerating phase



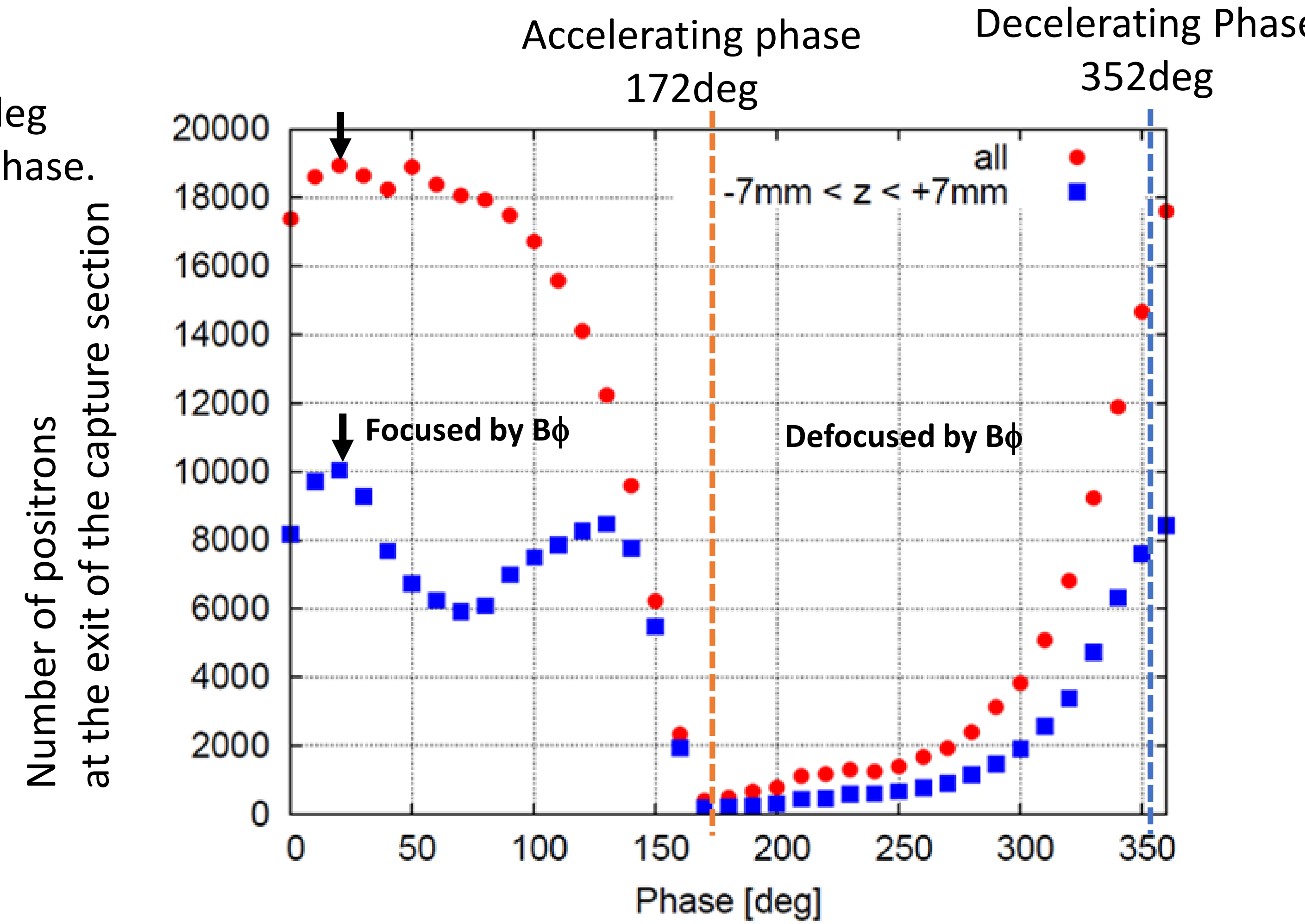




Number of positrons at the end of capture section (250MeV)

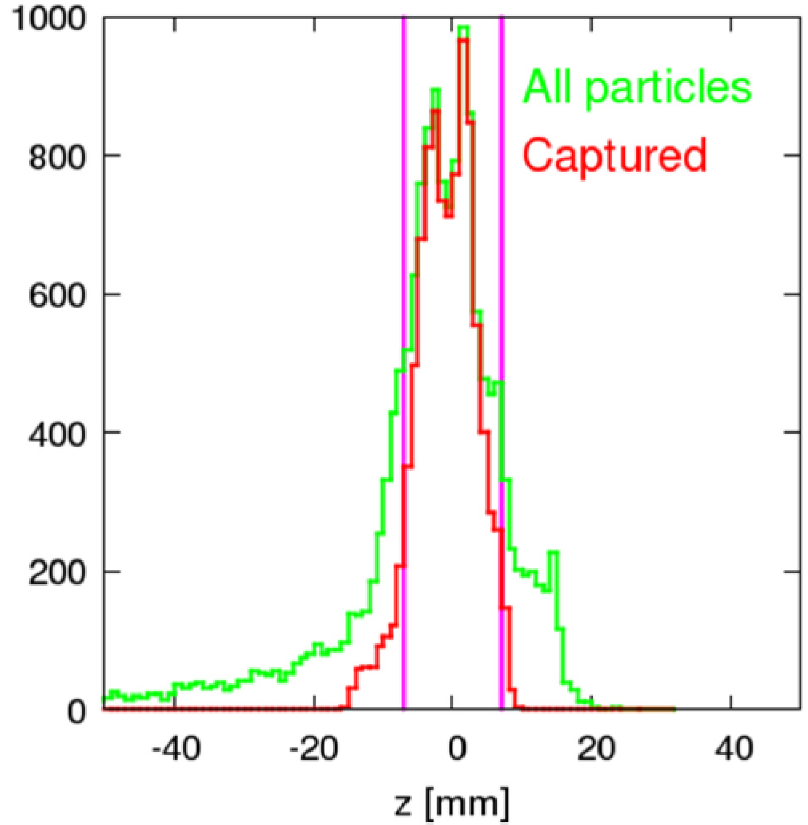
I scanned the phase of accelerating field to find the maximum point of number of positrons.

In GPT simulation,
the phase is set to +30deg
from the decelerating phase.
→ 20deg in this graph.



Phase scan of accelerators

The phase of the accelerator was optimized so that the number of positrons within +/- 7 mm in the longitudinal position distribution was maximized.



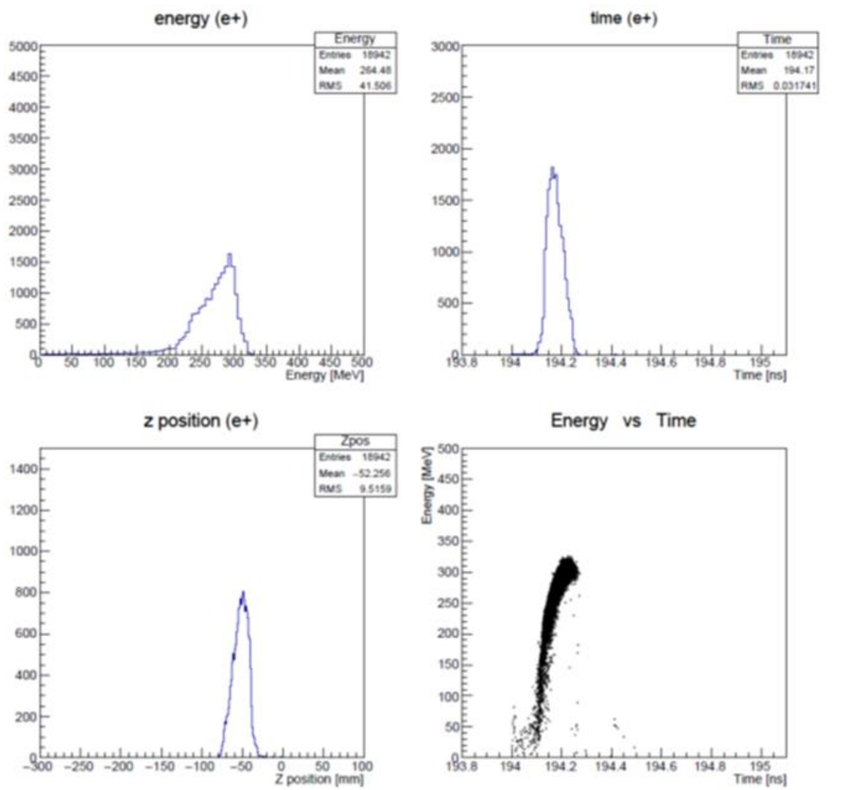
Positrons within +/-7mm from the peak of longitudinal position distribution are captured in DR.
(in case of undulator scheme)

The phases of all the accelerating tubes were simultaneously moved.

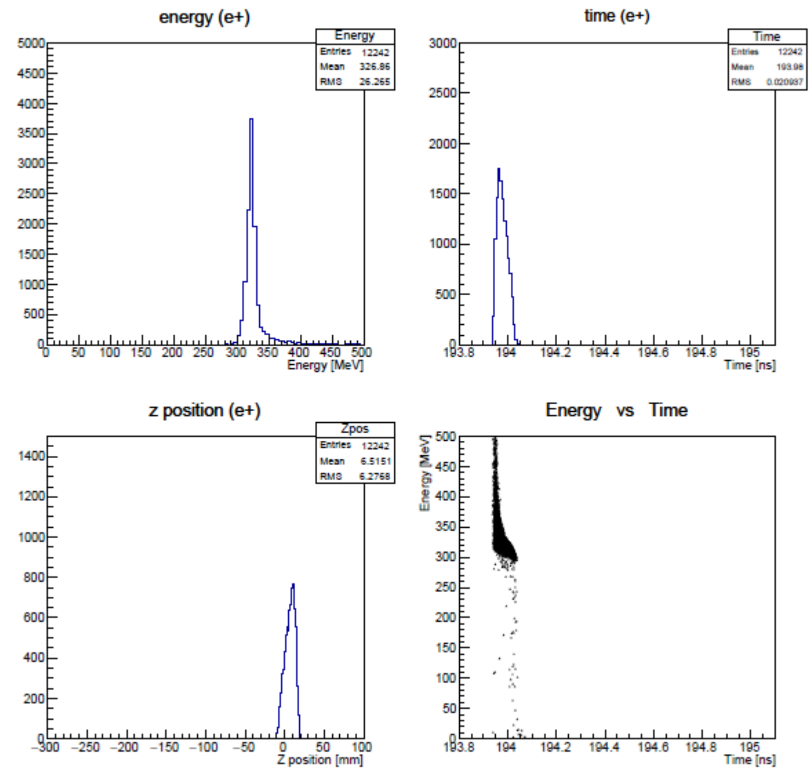
Analyzed by T. Okugi

Energy, z position and time distribution of positrons

Phase 20deg
(near decelerating phase)



Phase 130deg
(near accelerating phase)

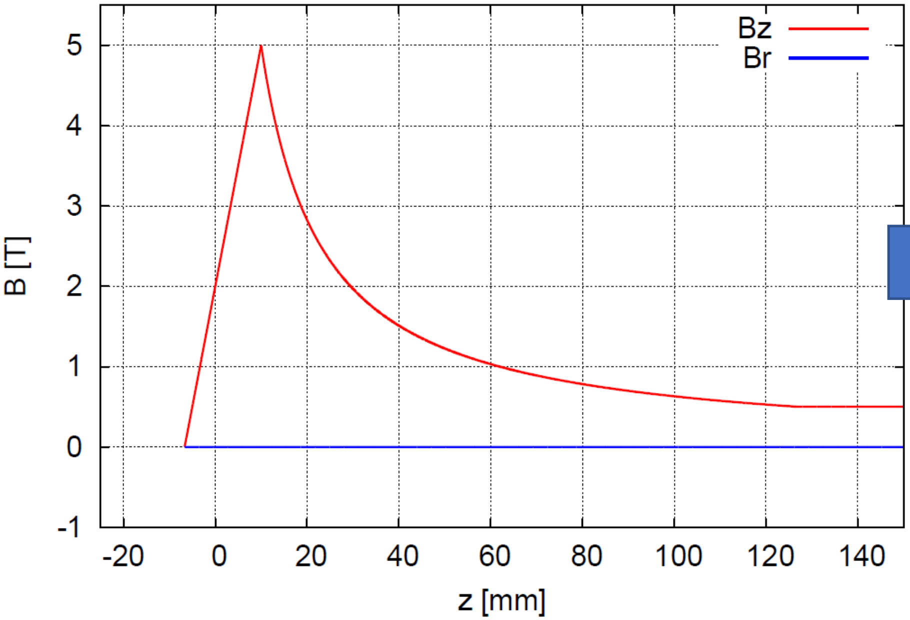


Summary

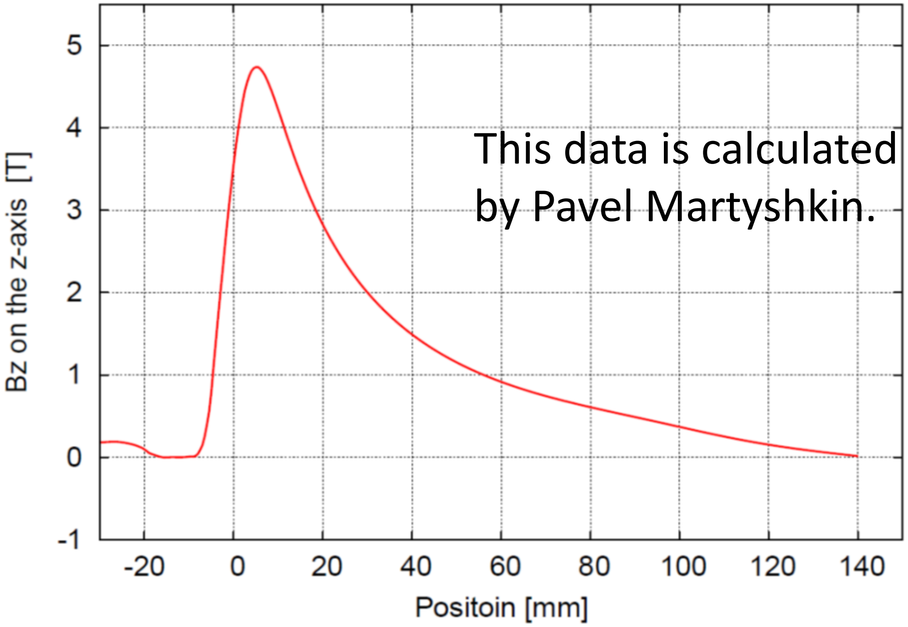
- The positron generation and the tracking up to the capture section end is testing by using Geant4 now.
- I compared the result of simulation at the exit of the target , the AMD and the first accelerating tube.
  - At the target exit, the number of positrons and the distributions of positron are consistent.
  - However, the energy distribution at the AMD exit and the angle distribution at the first acc. exit are different. The number of positrons is also about 20% different.
  - It has not been clarified why the difference is occurring now.
- After this,
  - Use the magnetic field data of AMD calculated by Dr. Pavel Martyshkin.

AMD magnetic field

On z-axis (r = 0 mm)



On z-axis (r = 0 mm)



This data is calculated by Pavel Martyshkin.

The purpose of development of simulation for ILC positron source

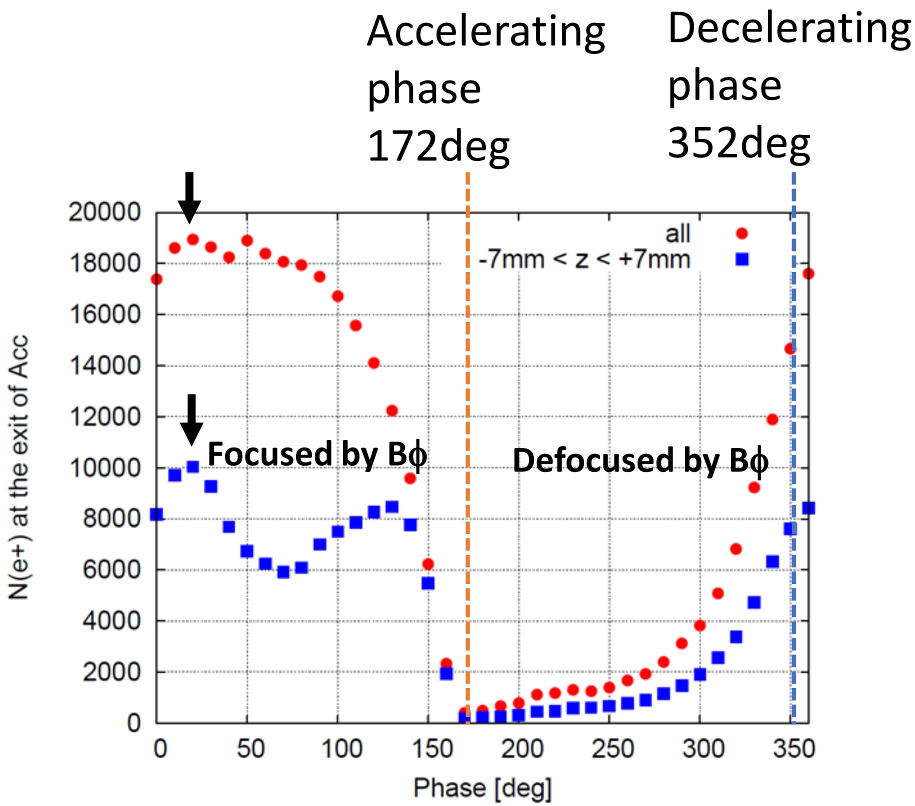
- I will develop start-to-end simulation codes for ILC positron source.
    - Positron generation of target: Geant4
    - Target to Capture section: Geant4
    - Booster section to DR: SAD (not implemented)
- **The purpose is to compare the yield calculation of positron generation for both undulator scheme and e-driven scheme under the same condition.**
- **I am developing the simulation program from the positron generation to the end of the capture section.**
    - Code: Geant4.10
    - The program is based on the example program of B4.

Summary

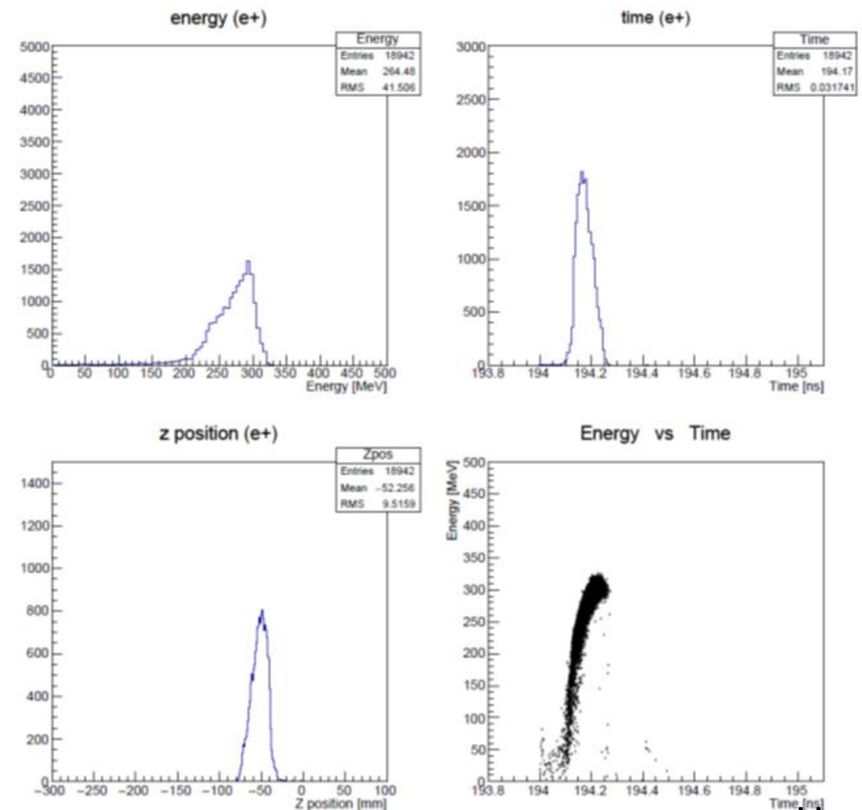
- The tracking simulation up to the exit of Capture section (250MeV)
  - I compared the result of simulation at the exit of the target , the AMD and the first accelerating tube.
  - At the target exit, the number of positrons and the distributions of positron are consistent.
  - However, the energy distribution at the AMD exit and the angle distribution at the first acc. exit are different. The number of positrons is also about 20% different.
  - It has not been clarified why the difference is occurring now.
  - At the exit of the capture section, the number of positrons is 1.9e4. Among them, 1.0e4 positrons are within +/-7mm from the peak of longitudinal position distribution.
- After this,
  - Use the magnetic field data of AMD calculated by Dr. Pavel Martyshkin.
  - The simulation of positron source for e-driven scheme (ILC and SuperKEKB)

The end of capture section

In GPT simulation, the phase is set to +30deg from the decelerating phase.
→ 20deg in this graph.



Phase 20deg



Here