A Study of Yield calculation for Undulator ILC positron source

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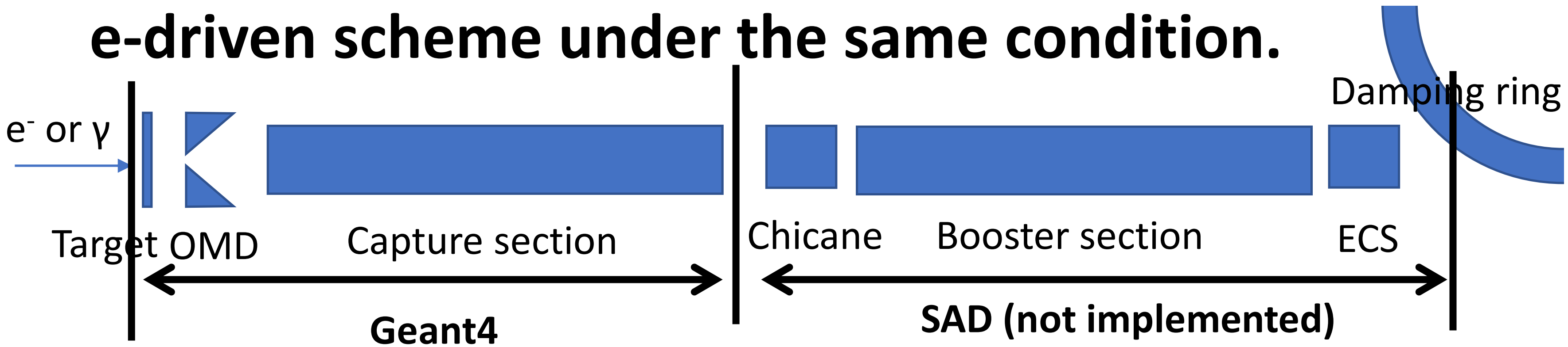
- Purpose of Development of Start-to-End Simulation for ILC positron source
- Simulation test on the undulator scheme using Geant4
- Comparison of simulation results

The purpose of development of simulation for ILC positron source

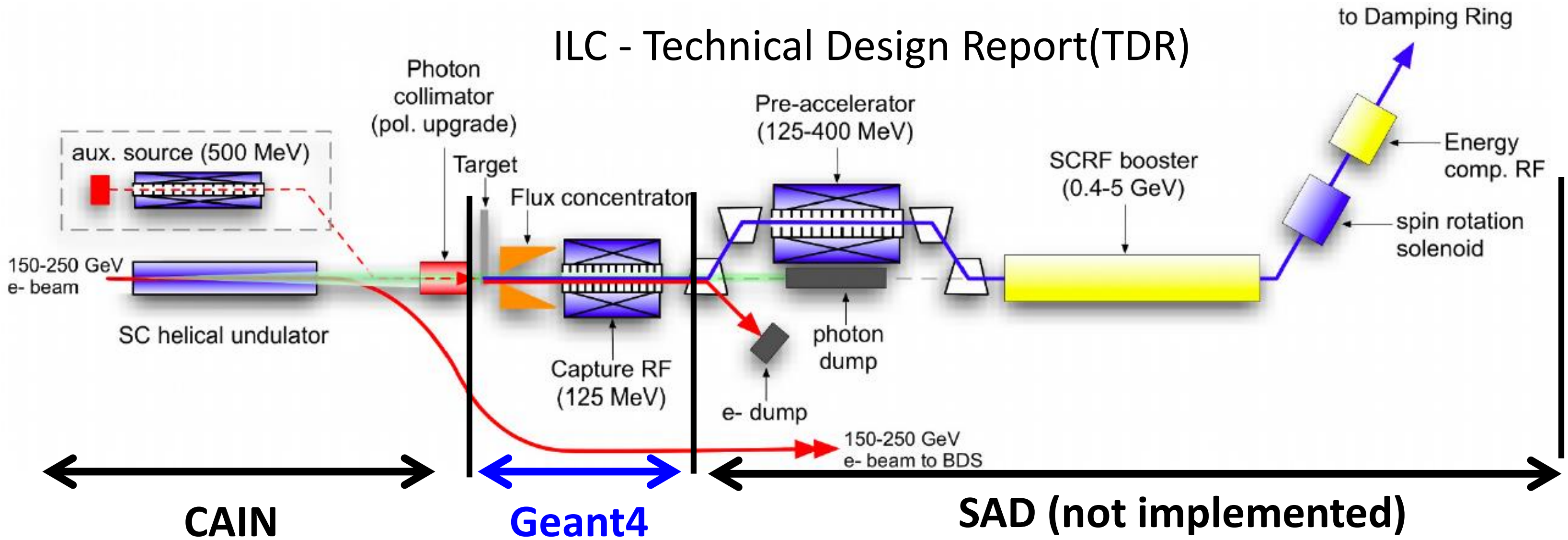
- I am developing start-to-end simulation programs for ILC positron source.
- **The purpose is to compare the yield calculation of positron generation for both undulator scheme and e-driven scheme under the same condition.**



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

Simulation of a positron source for undulator method

The tracking of positrons up to the exit of Capture section (125MeV) can be simulated now.



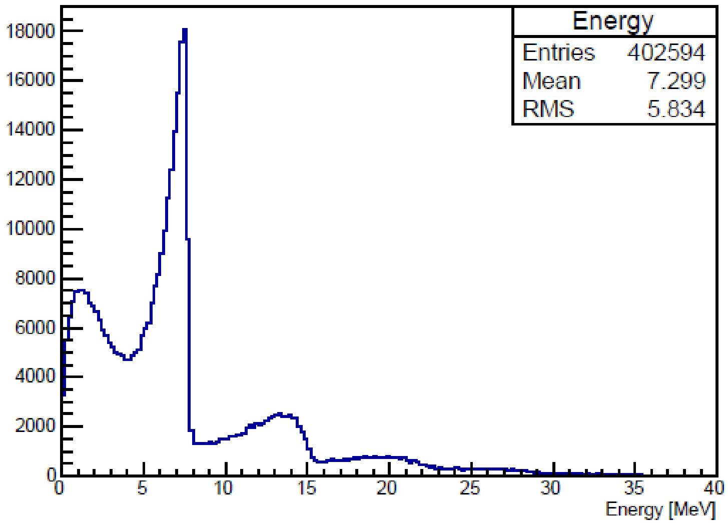
Gamma-ray generation: calculated by K. Yokoya
Positron generation at a target --- Capture section (125MeV): calculated by M. Fukuda
Tracking of positrons after Capture section: T. Okugi
A. Ushakov-san has continued the simulation of Undulator ILC positron source all the time. Now I am trying to reproduce the results of calculations so far.

Positron generation

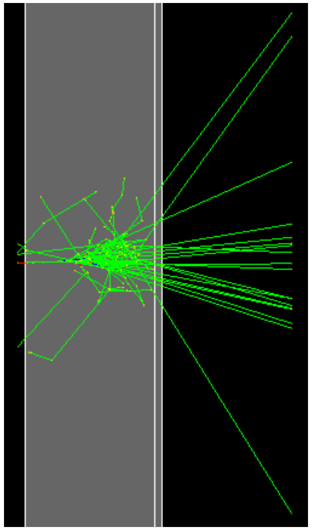
Gamma-rays data from Undulators was calculated by CAIN (Yokoya-san's calculation)
Number of Gamma-rays: 4.03e6 (4,025,930).
There are generated from 10,000 electrons with the energy of 125GeV.

Target: **Ti6Al4V, thickness 7mm**
Number of generated positrons: 4.43e4

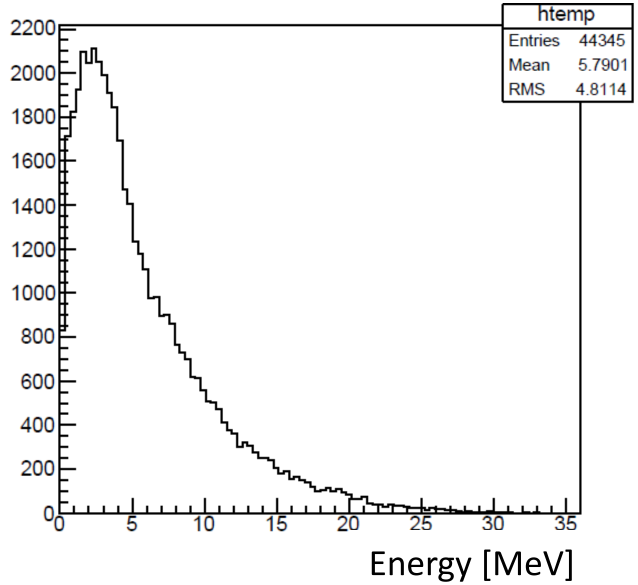
Gamma-rays from Undulator



Ti6Al4V 7mm



Generated positrons



Magnetic field of QWT and Solenoid

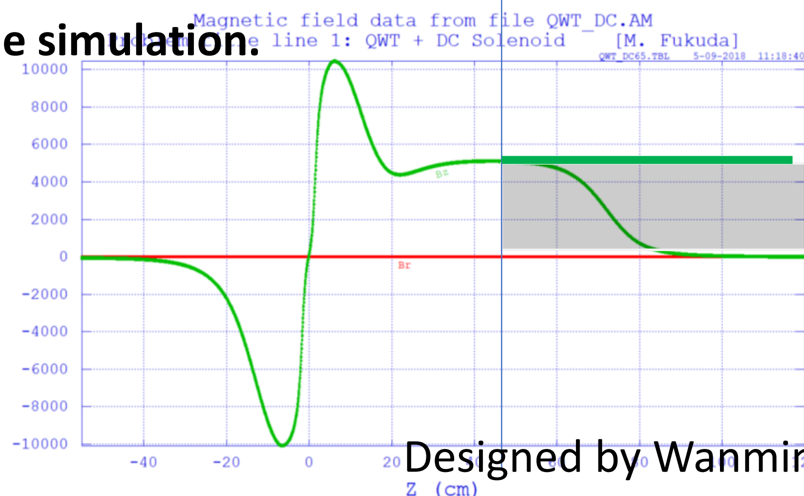
The magnetic field data was calculated by POISSON.

This 2D map data of magnetic field is used in the simulation.

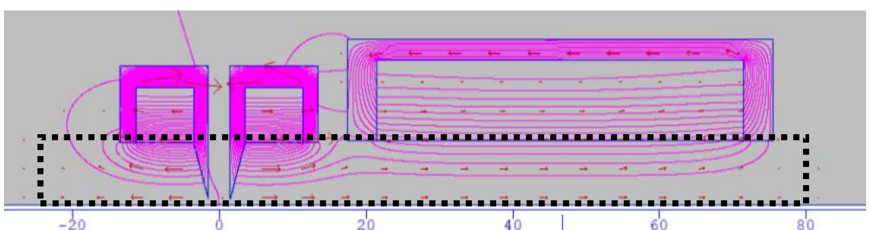
QWT (Peak 1.04T) + 0.5T (capture section)

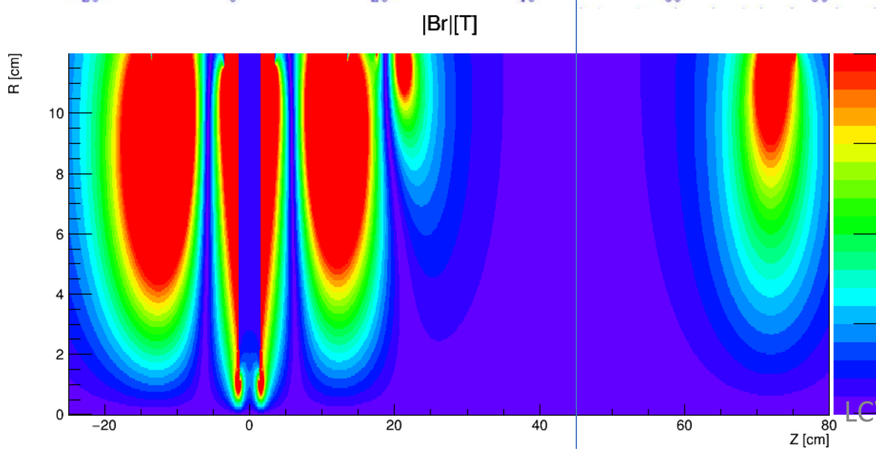
After z = 444.5mm, Bz = const. (~0.51T), Br =0

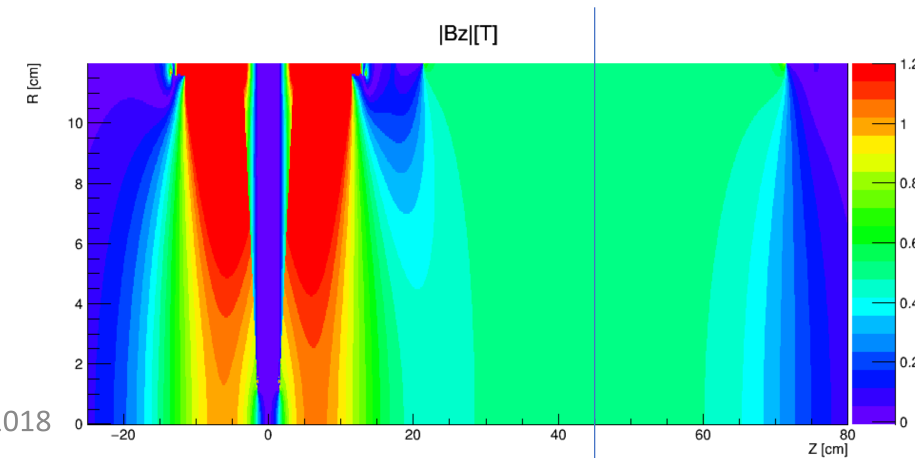
Bz = const. Br=0



Designed by Wanming Liu
Recalculated by Fukuda

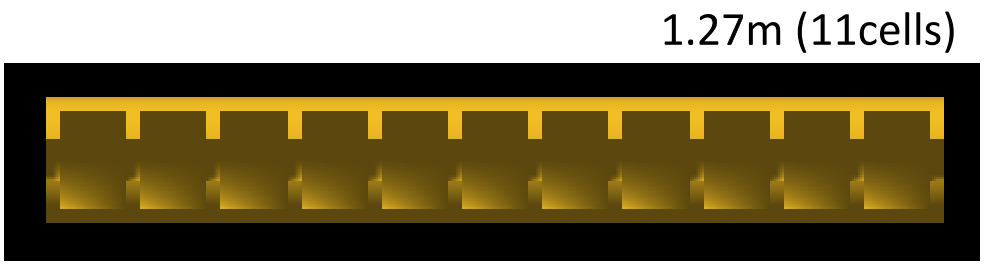






Accelerating electric field of standing wave tube

I consider only the accelerating electric field Ez.



Aperture(2a): 60mm

Ez = E0*2*sin(omegaspace*(z-zfrontRF)*cos(omegatime*t+Ephase)

omegaspace = k = 2π/λ

omegatime = ω = 2πf = 2πc/λ

λ=230.60958mm (L-band)

Eacc: 15.2MV/m

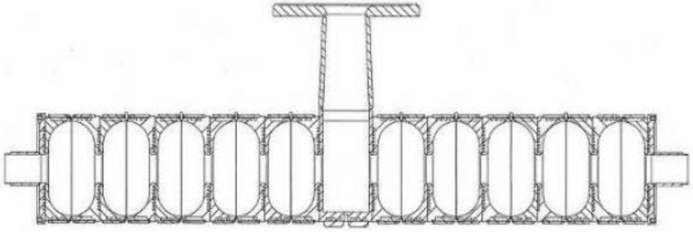


Figure3: 11–cell SW structure.

Table 1: Parameters of SW stricture.

Structure Type	Simple π Mode
Cell Number	11
Aperture 2a	60 mm
Q	29700
Shunt impedance r	34.3 MΩ/m
E_0 (8.6 MW input)	15.2 MV/m

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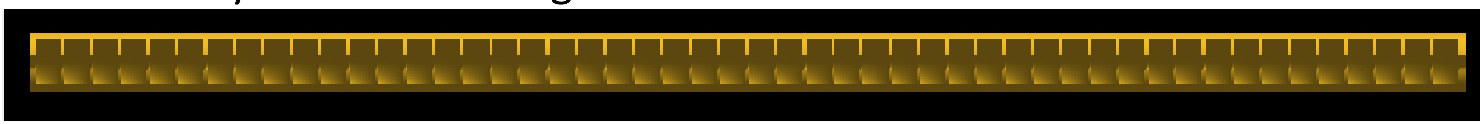
Accelerating electric field of traveling wave tube

Aperture(2a): 46mm

I consider only the accelerating electric field Ez.

4.3m (50cell)



Ez = E0*std::sin(omegaspace*(z-zfrontRF) - omegatime*t -Ephase)

omegaspace = k = 2π/λ

omegatime = ω = 2πf = 2πc/λ

λ=230.60958mm (L-band)

Eacc: 7.2MV/m

Table 2. Parameters of TW structure

Structure Type	TW 3π/4 Mode
Cell Number	50
Aperture 2a	46 mm
Attenuation τ	0.98
Q	24842 - 21676
Group velocity Vg/c	0.62% – 0.14%
Shunt impedance r	48.60 – 39.45 MΩ/m
Filling time T_f	5.3 μs
Power Dissipation	8.2 kW/m
E_0 (8.6 MW input)	8.0 MV/m

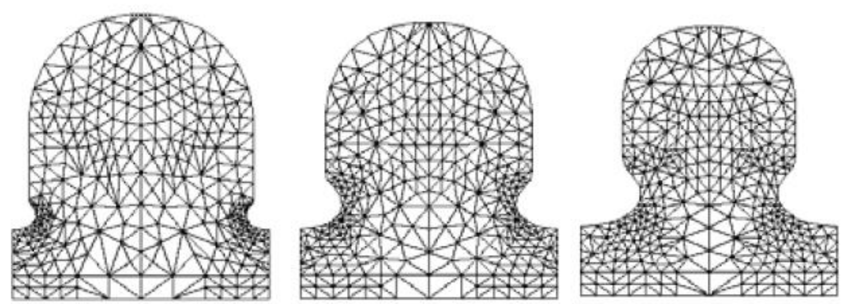


Figure 4. Profiles of the first, middle and last cell for 4.3m 3π/4 Mode TW structures,

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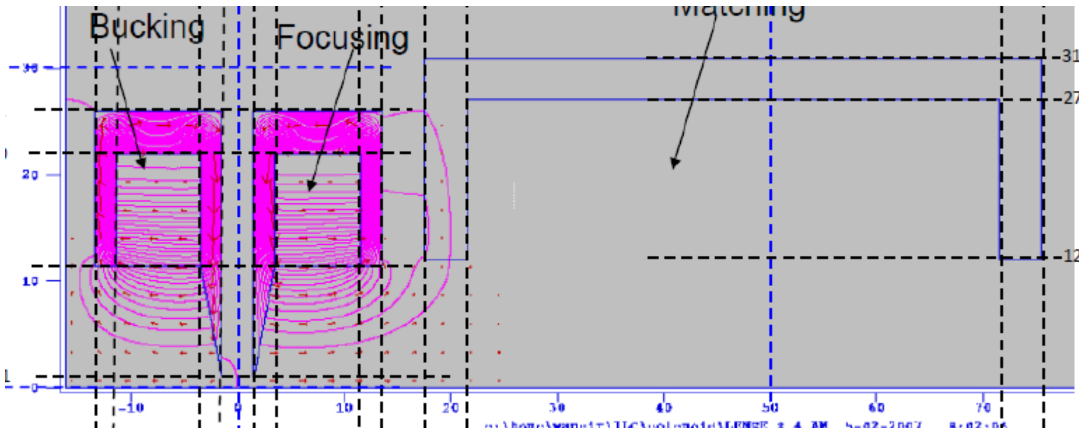
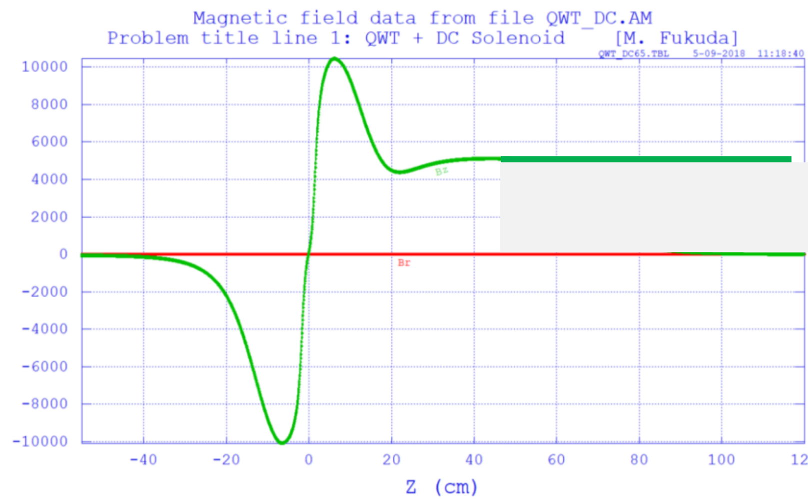
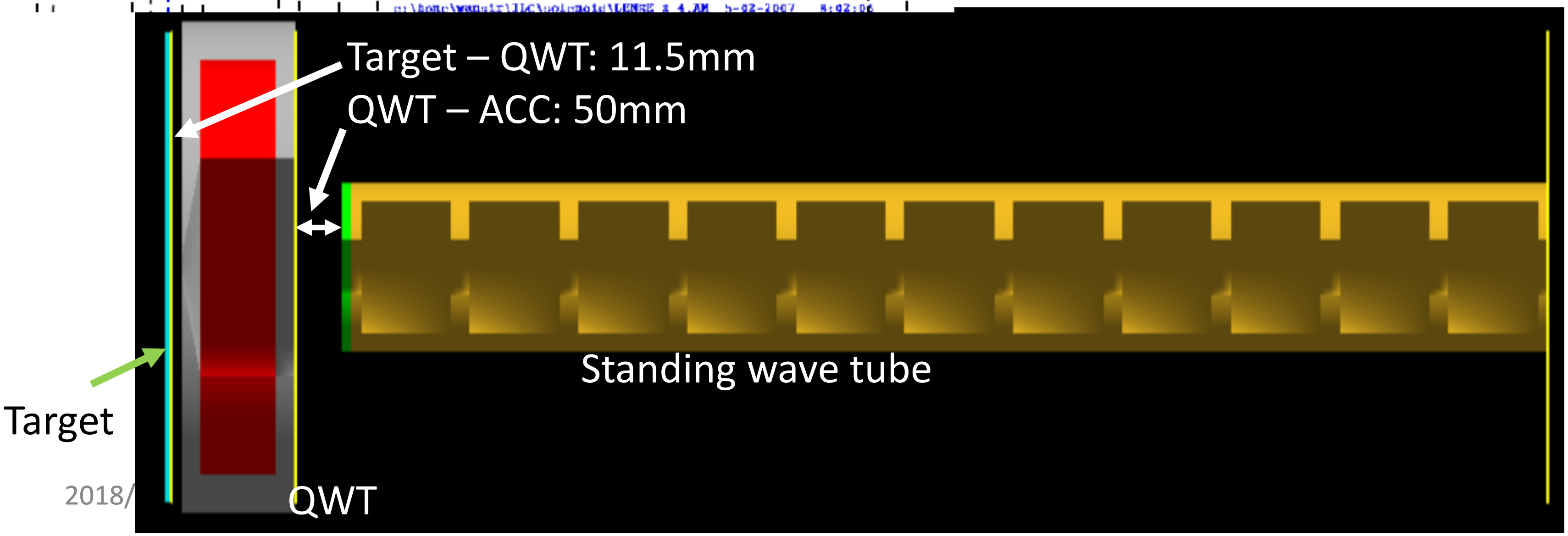
Placement of the QWT and an accelerator



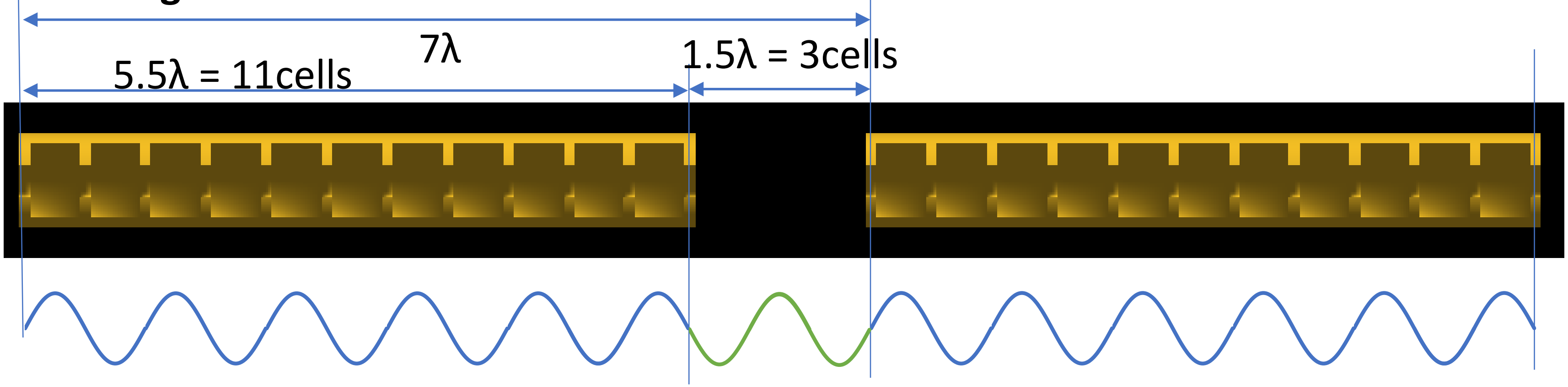




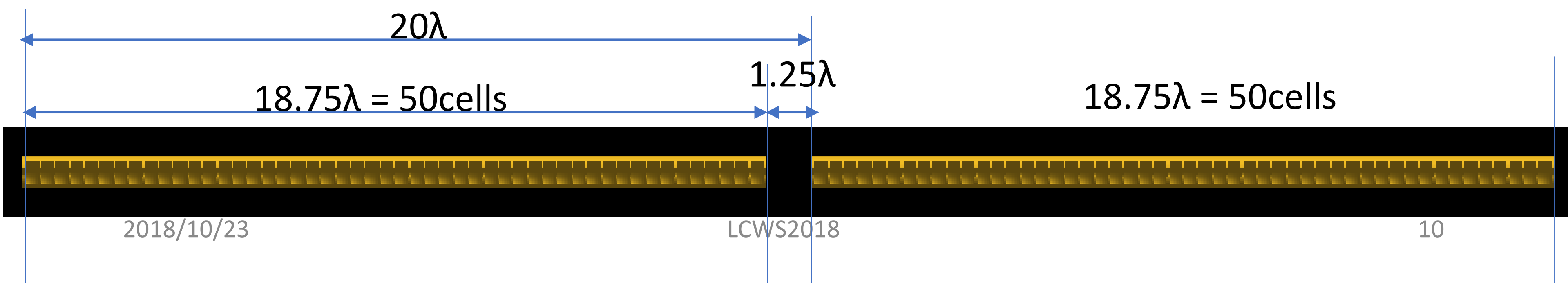
Arrangement of acceleration tube

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.

Standing wave tube



Traveling wave tube:



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

Input ： Gamma-rays from Undulators calculated by CAIN (Yokoya's calculation)
Number of Gamma-rays is 4,025,930 which are generated from 10000 electrons with 125GeV.

Target ： **Ti6Al4V, 7mm**

OMD: **QWT (Peak 1.04T) + 0.5T (capture section)**
The magnetic filed was calculated by POISSON.

Accelerating tube : SWx2 + TWx3

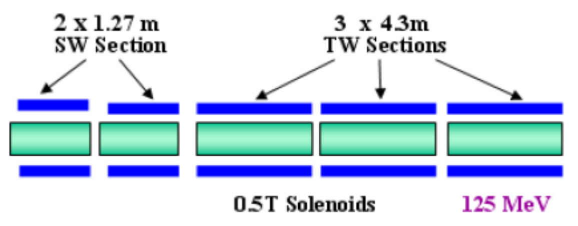


Figure 1. Schematic layout of the capture region.

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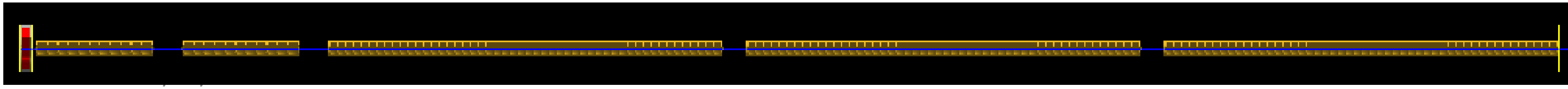
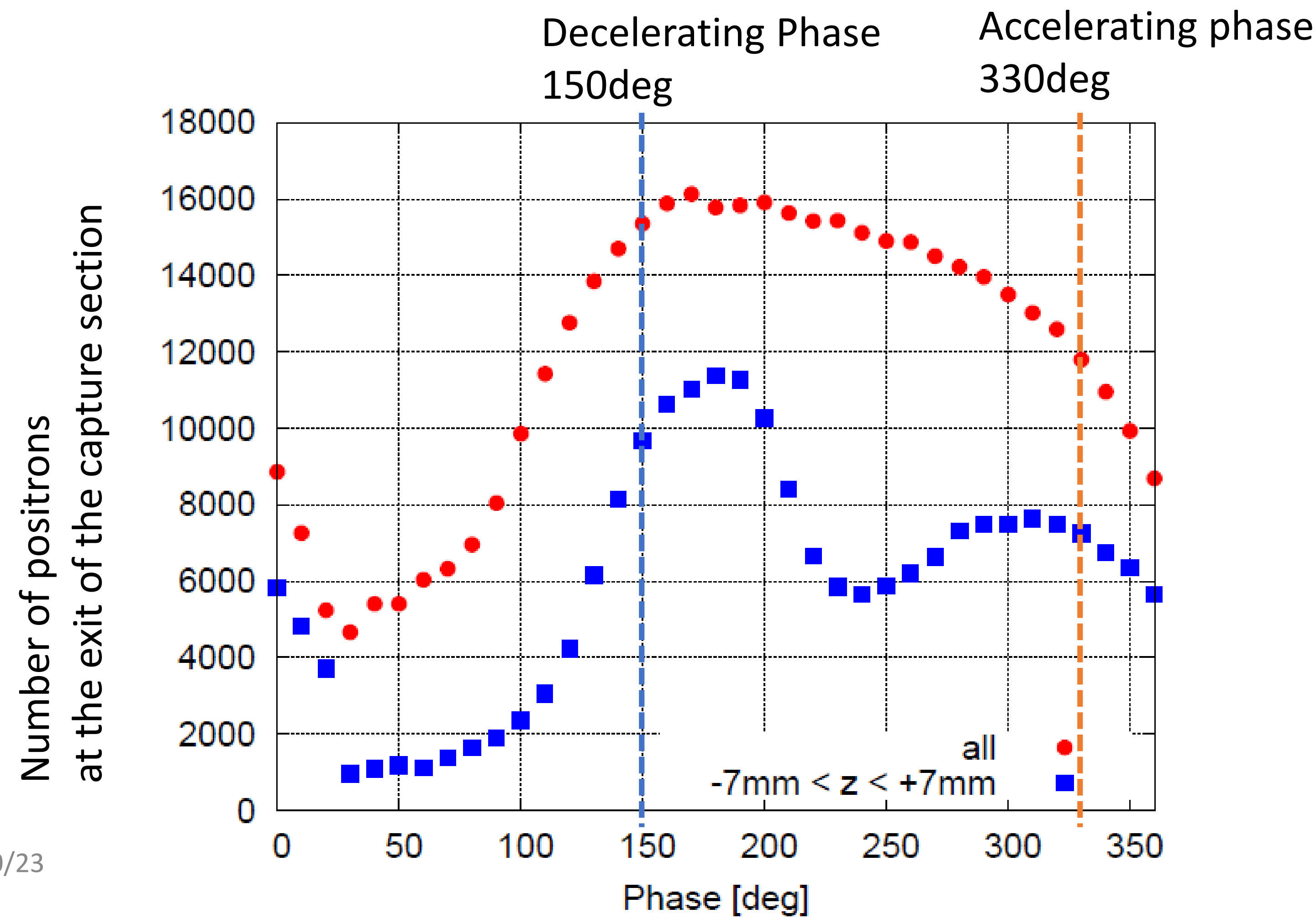
Standing wave tube: Eacc: 15.2MV/m, L-band (1.3GHz) 11cell (1.268m)
Traveling wave tube: Eacc: 7.2MV/m, L-band (1.3GHz) 50cell (4.324m)
→Positrons are accelerated to about 125MeV.



Number of positrons after capture section (125MeV)

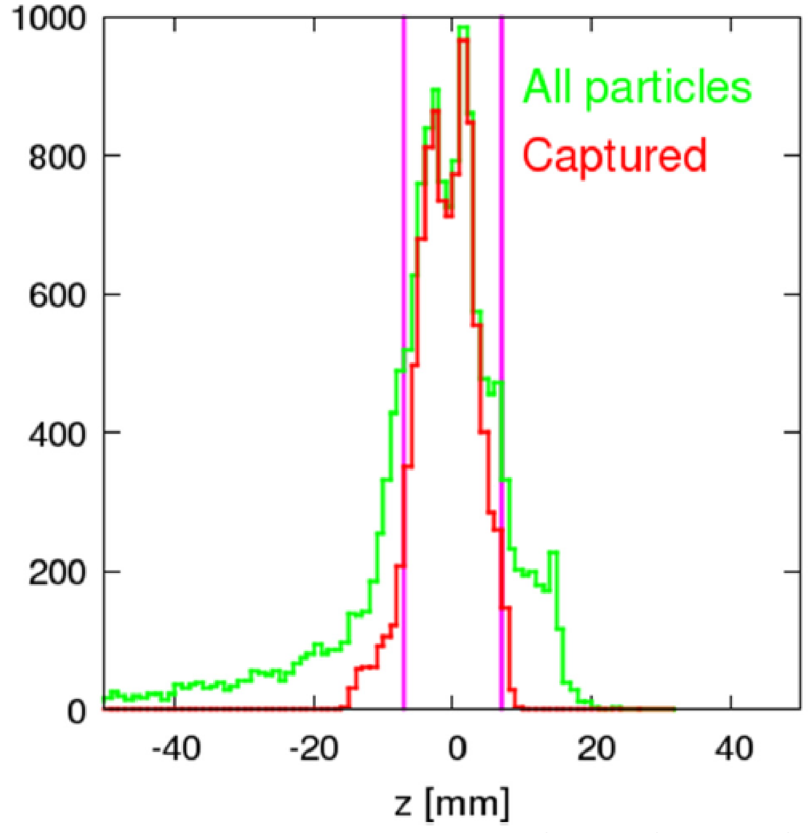
I scanned the phase of accelerating field to find the maximum point of number of positrons.



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.

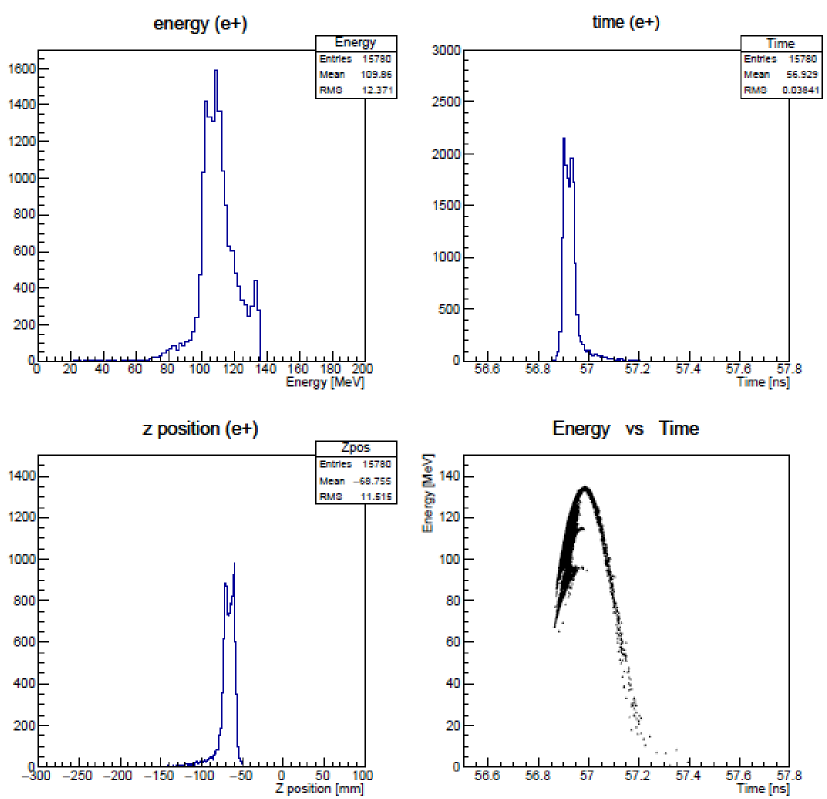


The phases of all the accelerating tubes were simultaneously moved.

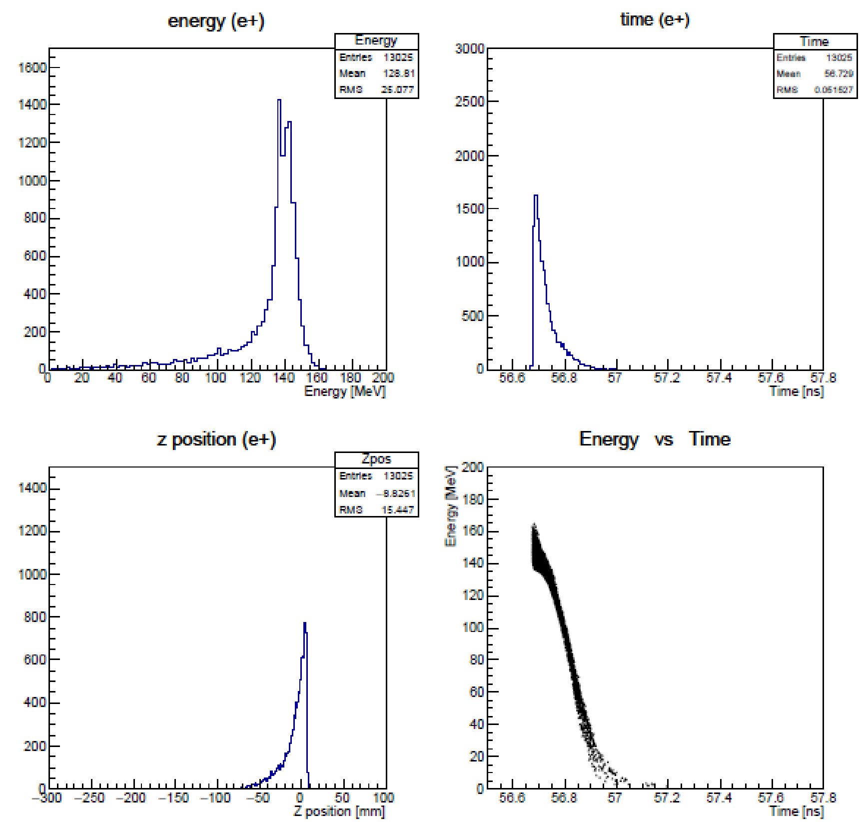
Analyzed by T. Okugi

Energy, z position and time distribution of positrons

Phase 180deg
(near decelerating phase)



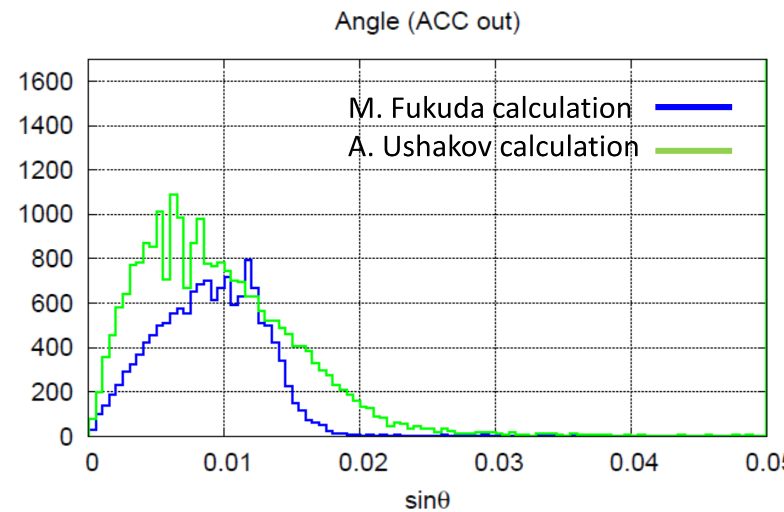
Phase 310deg
(near accelerating phase)

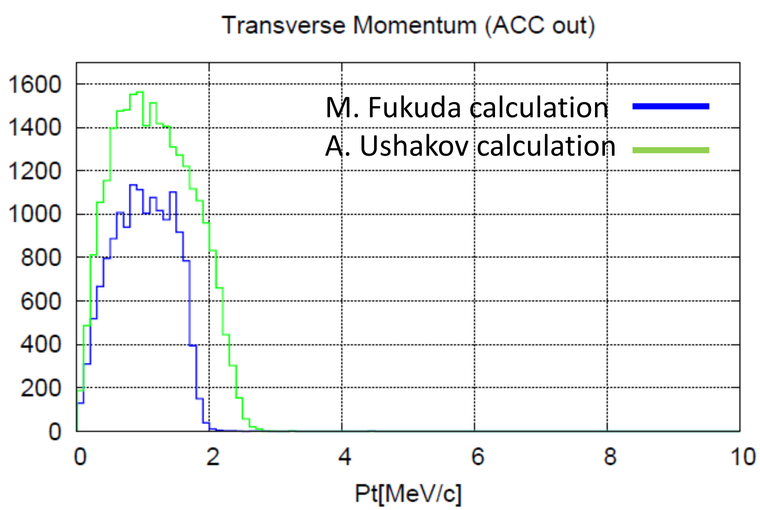


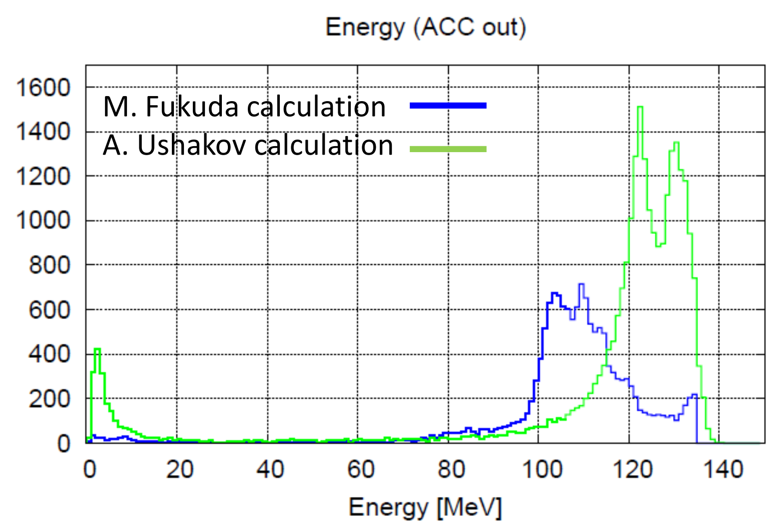
Positron distributions at the end of the capture section

In comparison between my result and Ushakov-san's result,
The distributions are different.

Phase: 180deg





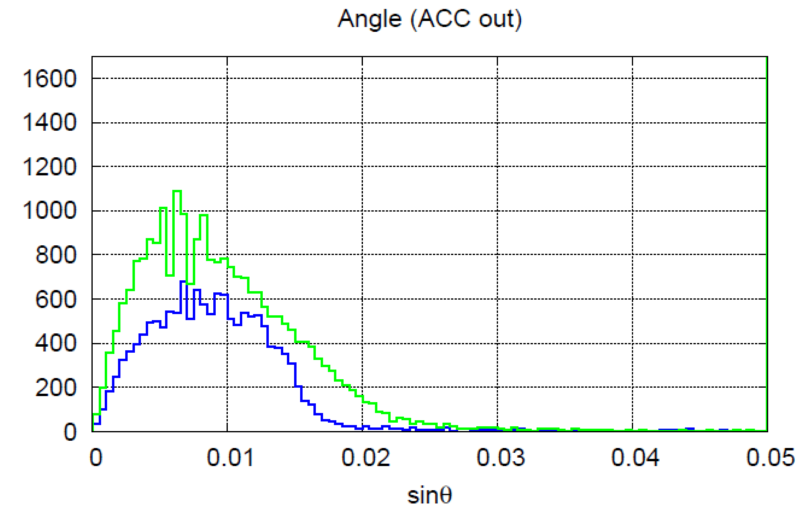


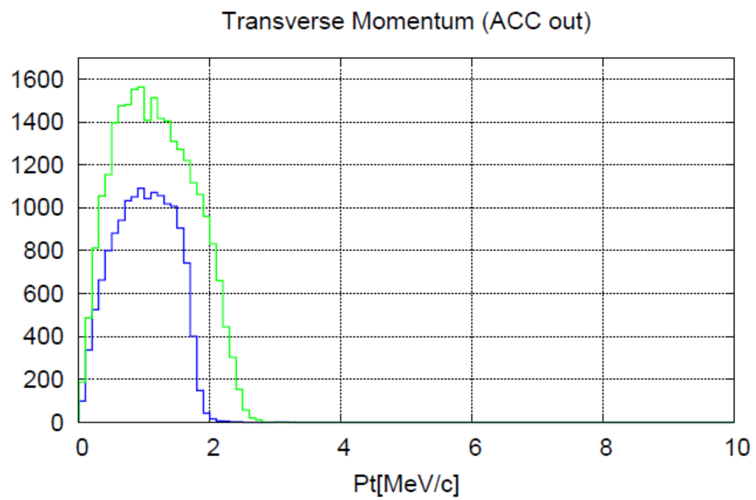
I thank Ushakov-san for sending me the data of positron

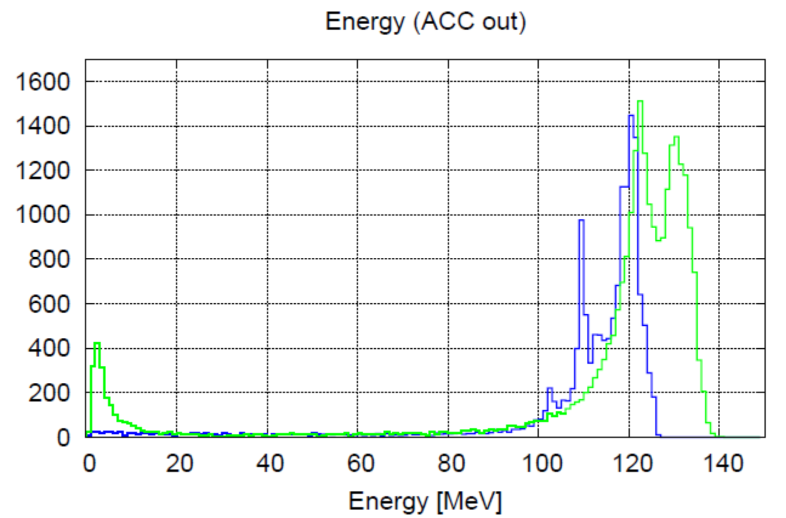
Positron distributions at the end of the capture section

I tried to change the phases of TW accelerating tubes.
SW: 180deg, TW: 220deg

The distributions are still different.
But the difference becomes less.





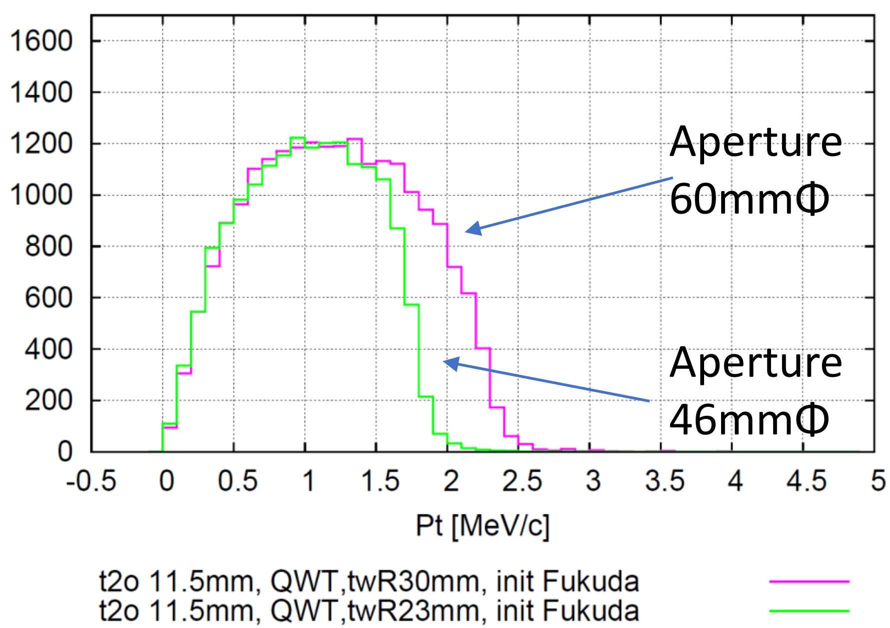


I thank Ushakov-san for sending me the data of positron

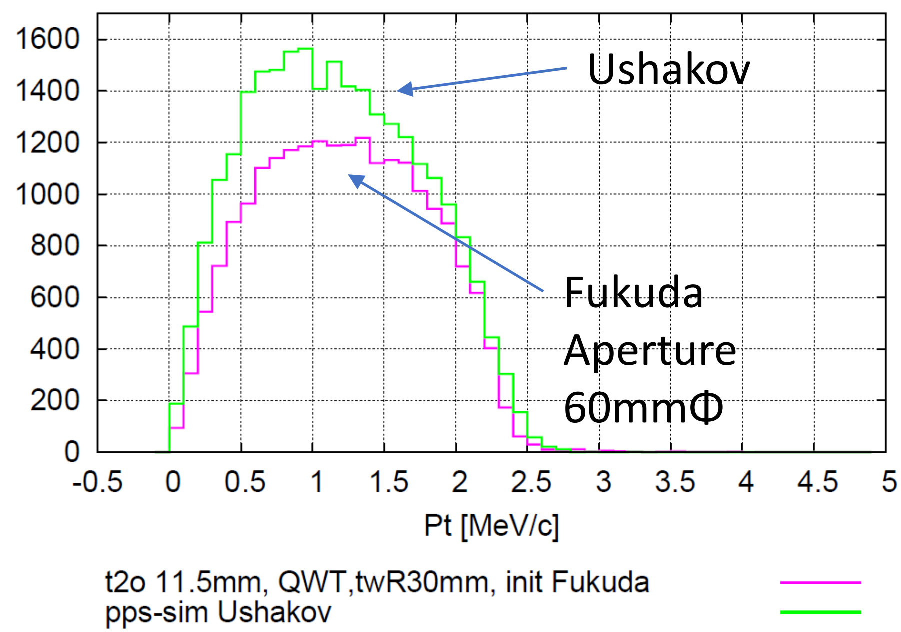
Transverse momentum when the aperture(2a) of TW is 60mm

I calculated positrons distribution after capture section when the aperture(2a) of TW tube was changed from 46mm to 60mm.
In this case, the maximum of Pt became 2.5 MeV/c. However, the distribution around 1MeV/c is different yet.

Transverse momentum (Pt)



Transverse momentum (Pt)

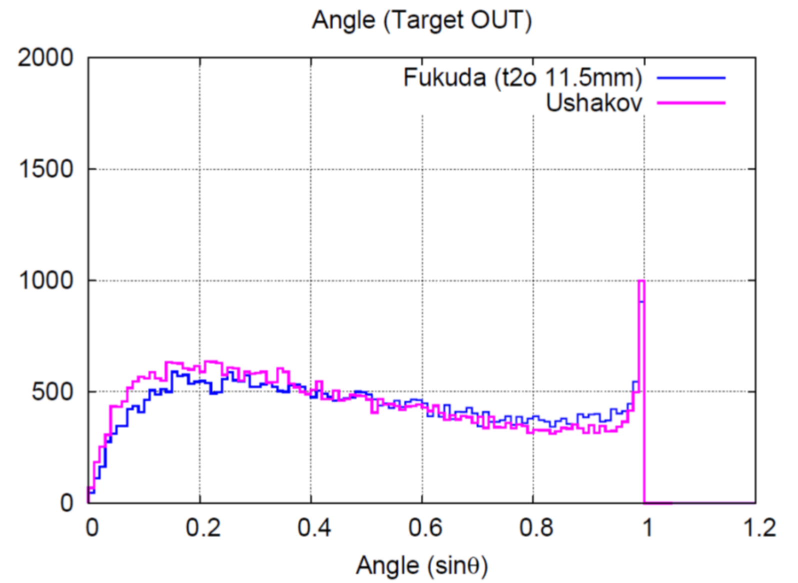


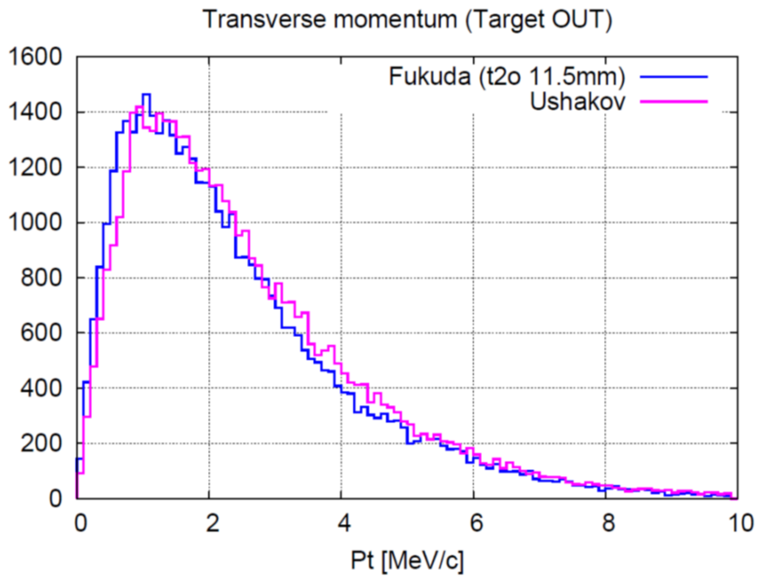
Aperture(2a) of TW tube: 46 → 60mm

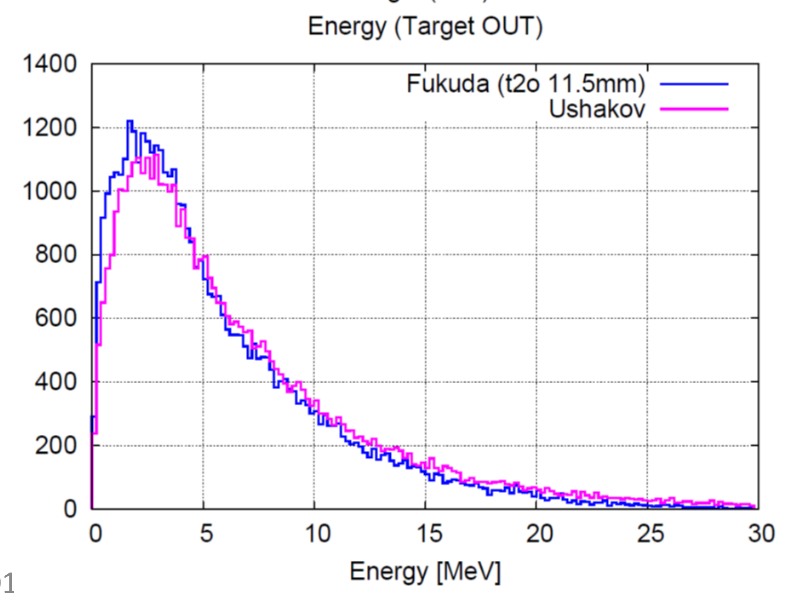
Positron distributions at the exit of a target

The distributions are almost same at the exit of a target.

Number of e+ at the exit of a target
4.5e4 (M.Fukuda)
4.7e4 (A.Ushakov)
Target：**Ti6Al4V, 7mm**







I thank Ushakov-san for sending me the data of positron

Summary

- The positron generation and the tracking up to the capture section end is testing by using geant4 now.
- In comparison between my result and Ushakov-san's result, the yield and the distributions of positron at the end of the capture section are not consistent.
- I think the optimization of the phase is not enough in my simulation.
- After this,
  - Optimization of phase in Geant4 simulation.
  - Calculation from the end of the capture section to DR entrance by SAD code.